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FORMAL REPORT

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RHIC Spin Collaboration Meeting VI

October 1, 2001

Organizers:

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Preface to the Series

The RIKEN BNL Research Center (RBRC) was established in April 1997 at Brookhaven National Laboratory. It is funded by the "Rikagaku Kenkyusho" (RIKEN, The Institute of Physical and Chemical Research) of Japan. The Center is dedicated to the study of strong interactions, including spin physics, lattice QCD, and RHIC physics through the nurturing of a new generation of young physicists.

During the first year, the Center had only a Theory Group. In the second year, an Experimental Group was also established at the Center. At present, there are seven Fellows and eight Research Associates in these two groups. During the third year, we started a new Tenure Track Strong Interaction Theory RHIC Physics Fellow Program, with six positions in the first academic year, 1999-2000. This program has increased to include ten theorists and one experimentalist in the current academic year, 2001-2002. Beginning this year there is a new RIKEN Spin Program at RBRC with four Researchers and three Research Associates.

In addition, the Center has an active workshop program on strong interaction physics with each workshop focused on a specific physics problem. Each workshop speaker is encouraged to select a few of the most important transparencies from his or her presentation, accompanied by a page of explanation. This material is collected at the end of the workshop by the organizer to form proceedings, which can therefore be available within a short time. To date there are thirty-four proceeding volumes available.

The construction of a 0.6 teraflops parallel processor, dedicated to lattice QCD, begun at the Center on February 19, 1998, was completed on August 28, 1998.

T. D. Lee
August 2, 2001

*Work performed under the auspices of U.S.D.O.E. Contract No. DE-AC02-98CH10886.

CONTENTS

Introduction

The sixth meeting of the RHIC Spin Collaboration (RSC) took place on October 1, 2001 at Brookhaven National Laboratory. RHIC is now in its second year of operation for physics production and the first polarized proton collision run at $\sqrt{s}$=200 GeV is expected to start in eight weeks. The RSC has developed a plan for this coming run through two previous meetings, RHIC Spin Physics III (August 3, 2000) and IV (October 13-14, 2000). We requested the following:

- two weeks of polarized proton studies in AGS
- three weeks of polarized collider commissioning, and
- five weeks of polarized proton physics run.

As a result, we have obtained all we asked and the above plans are implemented in the current opearation schedule.

The focus of the present meeting was to bring all involved in the RHIC Spin activities up-to-date on the progress of machine development, theory issues, and experimental issues. This meeting was right after the Program Advisory Committee (PAC) meeting and it started with the comments on the PAC discussion by Gerry Bunce, who was informed about the PAC deliberations by Tom Kirk. The PAC was fully supportive to complete the proposed spin program within the currently available budget for RHIC run 2 operations. Gerry further explained the expected luminosity to be $\int \mathcal{L}dt$ =0.5 pb^{-1} per week, reflecting the current machine status. The introductory session also had a talk from Werner Vogelsang that reviewed the progress in perturbative QCD theory focused on spin effects.

Following the introduction, the meeting had three sessions to present and discuss the detailed status of the acceleration complex required for the spin program, the polarimeters that will be used to measure the beam polarization, and the experiments that will make measurements to obtain physics results from the first polarized proton collisions. All of the talks were extremely stimulating and indicated a good state of readiness for the upcoming collision program with polarized protons. Because the information content was so high, this volume contains complete copies of the transparencies from all of the talks.

There were many highlights from the meeting. This summary selects only a few that are particularly encouraging.

- The optically pumped polarized ion source is achieving its goals of delivering 200 μA of polarized beam with polarization in excess of 75%.

- The AC dipole for RHIC, that will be used to induce rapid polarization reversal of the beam stored in RHIC, is ready for installation. A plan for completing its installation and its commissioning was presented. When completed, the AC dipole will allow independent polarization reversal of the RHIC beams, thereby playing a pivotal role in controlling systematic errors in spin asymmetry measurements.

- Polarimeters are in place in both the Blue and Yellow rings. The polarimeters will measure recoil carbon ions from proton+carbon elastic scattering at very small $|t|$ in the vicinity of the Coulomb-nuclear interference (CNI) maximum in the analyzing power.

These encouraging developments suggest that the goals of the first polarized proton run can be accomplished.

Several issues regarding the longer term goals of the RHIC spin collaboration remain to be resolved. A primary concern is the calibration of the CNI polarimeters, to achieve accurate measurements of the beam polarization magnitude. At the end of the meeting, it was discussed that a one day meeting of the RSC will be organized for a date in November to discuss methods of calibrating the RHIC beam polarization. Furthermore, bi-weekly meetings of the RSC will be held to review progress and to discuss outstanding issues in the remaining time before the start of the first polarized proton run.

We are grateful to Ms. Tammy Heinz and Ms. Pam Esposito for their extremely efficient help throughout the meeting, and in preparation of these proceedings. Without their help it would not have been possible to hold this meeting, especially because both of us were taking shift during most of the preparation time. We thank RIKEN BNL Research Center for generous support for this meeting and Department of Energy for the supporting facility.

L.C. Bland and Naohito Saito
8 October 2001

RHIC Spin Plan

Gerry Bunce, RBRC and BNL

RHIC Spin Collaboration Meeting, Oct. 1, 2001

This presentation was an introduction to an excellent meeting, discussing the plans for the spin program, set to start next month.

The running plan starts with tuning the AGS for polarization, where we have a dedicated 2 weeks scheduled from the beginning of November. This work will occur during heavy ion fills in RHIC, and the goal is to reach 50% polarization at the RHIC injection energy. The heavy ion to pp changeover is scheduled for Nov. 19-23, and we discussed the work and required time during the presentations. The pp and polarized commissioning is scheduled for the 3 following weeks. Then the first polarized proton collision physics will start. Five weeks are scheduled for polarized collisions at 100 GeV x 100 Gev, P_{beam}=50%, luminosity 4 x 10^{30} $cm^{-2}s^{-1}$, 1.5 pb^{-1} per week. The agreed split is 1 week/1.5 pb^{-1} transverse spin, 4 weeks/6 pb^{-1} longitudinal spin.

The second transparency addresses the likely luminosity, listing a number of "real world" factors, compared to "design". The conclusion is that 0.5 pb^{-1}/week would be a more achievable (but perhaps still difficult) goal. The split transverse to longitudinal will need to be decided depending on success and circumstances.

The third transparency lists issues. Many of these items were addressed very positively at the meeting. The last item, preparations and plans for the future, will need to be the focus of a future meeting.

G. Bunce
1 Oct. 2001
RSC Meeting

RHIC Spin Plan

- AGS tuning for polarization
  - dedicated 2 weeks ~~Oct~~/Nov.
- Heavy ion → pp changeover
  - 4-5 days Nov. ~~12-16~~? 19-23
- pp commissioning
  - 2 weeks
- p⇑p⇑ commissioning
  - 1 week
- p⇑p⇑ physics at 100 GeV × 100 GeV, $P_{beam} \gtrsim 50\%$, $L = 4 \times 10^{30}$, 1.5 pb^{-1}/wk*

* { - 1 week / 1.5 pb^{-1} transverse pol.
  - 4 weeks / 6 pb^{-1} longitudinal pol.

5 weeks physics for p⇑p⇑ and pp

Notes / Remarks

* on the 1.5 pb^{-1} / week

$L = 4\times10^{30}\ (8\times10^{31}/20) \times 1$ week

$\times 100\%$ availability $= 2.4\ pb^{-1}$

– if average $\bar{L}$ / fill $= 2\times10^{30}$

RHIC up 40% ⇒ **0.5 pb^{-1}/week**

$$\frac{\text{Bunches}}{\text{Design}} \times \left(\frac{N_{bunch}^{(protons)}}{N_{spin\ design}}\right)^2 \times \frac{\epsilon_{2001}}{\epsilon_{design}} \times \left(\frac{\beta^*_{2001}}{\beta^*_{design}}\right)^{-1} \times \frac{L_{avg}}{L_{max}}$$

× vertex cut

$$\frac{1}{4} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$$

× ?

↑ Can be 1 if we use 120 bunches

⇒ lower than spin design by at least factor 32

→ above a factor 40 is assumed

---

* on split between longitudinal / transverse pol.

– not set in stone

– actual split depends on amount of beam delivered and success in maintaining polarization while turning off one snake at 100 GeV

More to discuss — today and beyond

- prospects for P ≳ 50% at RHIC injection
  - AGS, AGS to RHIC (+ source!)
- control of tune/orbit in RHIC
  - **prospect to reach requirement?**
- prospects/plan for decellerating to carry polarimeter A_N to 100 GeV? **— A_N at injection?**
- prospects/plan for spin flipping?
- experiments — readiness?
  - relative L_{++}/L_{+-}
  - redundancy, ability to measure **polarization sign** L(P)?
  - local deadtimes; **bunch pattern**?
  - rate/trigger capabilities
  - planned measurements
- theory for planned measurements!
- local polarimeters
- running conditions
  - Ø-polarization bunches?
  - some radial polarization running?
  - pp2pp test with lower N_p?
  - any limit on N_p from silicon?
- future — beyond 2001/2
  - rotators; CNI for AGS (2003); jet ⇑ (2004)

Theory topics

in year-1 and beyond

Werner Vogelsang

RIKEN-BNL Research Center
and Nuclear Theory, BNL

RSC meeting VI, BNL
October 1, 2001

Outline :

I. Introduction : "Basic theory"

II. $A^{\pi}_{\rm LL}$ at RHIC

III. "Global analysis"

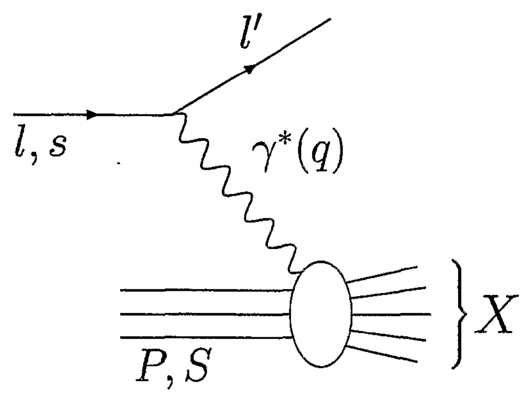
IV. Towards high orders

V. Transverse *two*-spin asymmetries

VI. $A^{\pi}_{\rm N}$ at RHIC

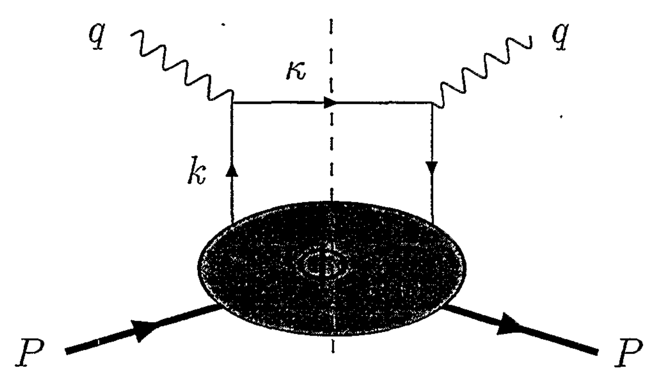
I. Introduction : "Basic theory"

polarized DIS :



$$\mathcal{W}_A^{\mu\nu}(P,q,S) \;=\; i\,M\,\varepsilon^{\mu\nu\rho\sigma} q_\rho \left[\frac{S_\sigma}{P\,q}\, g_1(x,Q^2) + \frac{S_\sigma(P\,q) - P_\sigma(S\,q)}{(P\,q)^2}\, g_2(x,Q^2) \right]$$

Parton model :



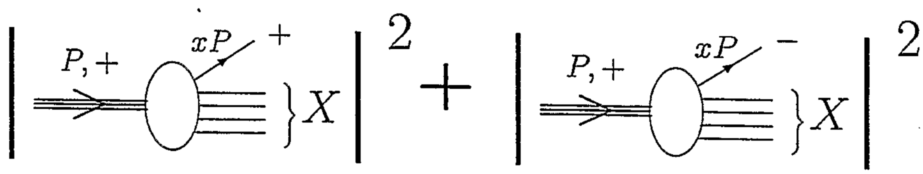
$$\mathcal{W}^{\mu\nu} \;=\; e^2 \int \frac{\mathrm{d}^4 k}{(2\pi)^4}\, \delta\Big((k+q)^2\Big)\, \mathrm{Tr}\left[\Phi\, \gamma^\mu (\not{k} + \not{q}) \gamma^\nu\right]$$

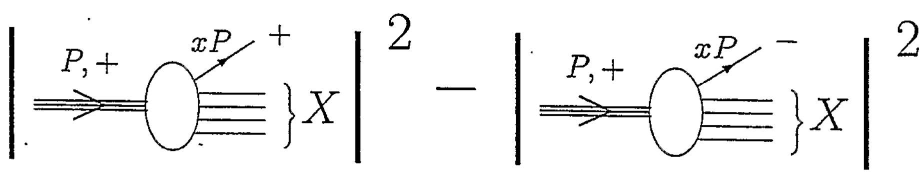
$$\Phi_{ij}(k,P,S) = \int \mathrm{d}^4\xi \; \mathrm{e}^{ik\cdot\xi} \, \langle PS|\bar{\psi}_j(0)\psi_i(\xi)|PS\rangle$$

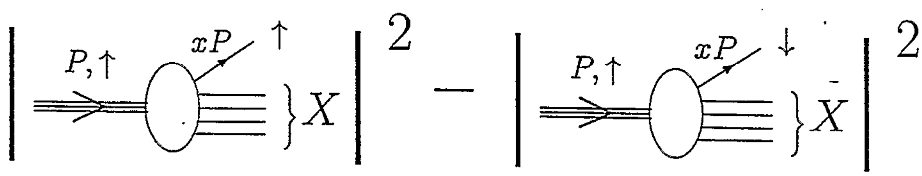
leading contributions, $k^\mu \sim x\,P^\mu$

$$\Phi = \frac{1}{2}\left[q(x)\,\not{P} + \lambda\,\Delta q(x)\,\gamma_5\,\not{P} + \delta q(x)\,\not{P}\,\gamma_5\,\not{S}_\perp \right]$$

where

$q(x) =$ 

$\Delta q(x) =$ 

$\delta q(x) =$ 

Probabilities –
map of nucleon spin structure at leading power !

These can be expressed as

$$q(x) = \frac{1}{4\pi}\int d\xi^- \, e^{i\xi^- xP^+} \langle P,S|\bar{\psi}(0)\,\gamma^+\,\psi\left(0,\xi^-,\mathbf{0}_\perp\right)|P,S\rangle$$

$$\Delta q(x) = \frac{1}{4\pi}\int d\xi^- \, e^{i\xi^- xP^+} \langle P,S|\bar{\psi}(0)\,\gamma^+\,\gamma_5\,\psi\left(0,\xi^-,\mathbf{0}_\perp\right)|P,S\rangle$$

$$\delta q(x) = \frac{1}{4\pi}\int d\xi^- \, e^{i\xi^- xP^+} \langle P,S|\bar{\psi}(0)\,\gamma^+\,\gamma_\perp\,\gamma_5\,\psi\left(0,\xi^-,\mathbf{0}_\perp\right)|P,S\rangle$$

In full QCD :

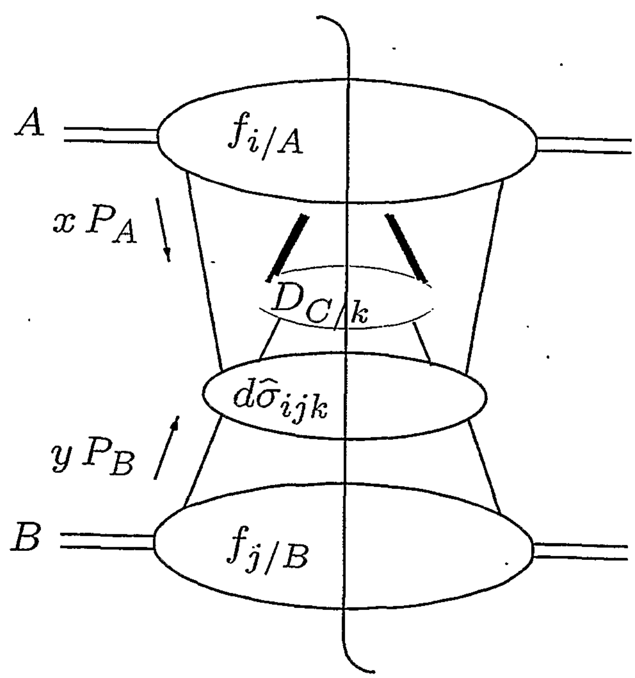
- definitions of pdf's (essentially) same
- gluon distributions $\sim$ F.T.$(G^{+j}\,G_{+j})$ etc.
- in $A^+ = 0$ gauge; to be made gauge-invariant
- "moments" $\rightsquigarrow$ local operators,
  e.g. $\int_0^1 dx\,\Delta q(x) \;\propto\; \langle P,S\,|\bar{q}\,\gamma^\mu\,\gamma^5\,q|\,P,S\rangle$
- operators involved require renormalization
  $\Rightarrow$ scale-dependent $q(x,\mu),\ldots$: "evolution"
- definitions vital in proofs of factorization theorems
- a measure of nucleon structure !

Collinear factorization :

(Sterman,Libby; Ellis et al.; Amati et al.;
Curci et al.; Collins,Soper,Sterman; Collins)

Hard scale ($M = Q,\ p_T,\ m_{\rm HQ},\ \ldots$)

$$d\sigma_{AB\to C(M)X} = \sum_{ijk}\int dx\,dy\,dz\; f_{i/A}(x,\mu)\; f_{j/B}(y,\mu) \times d\hat{\sigma}_{ijk}(xP_A, yP_B, P_C/z, \mu, \alpha_s(\mu))\; D_{C/k}(z,\mu)$$



... up to inverse powers in hard scale M

- partonic cross sections $d\hat{\sigma}_{ijk}$ are perturbative, and predicted by QCD

$$d\hat{\sigma}_{ijk} = d\hat{\sigma}^{(0)}_{ijk} + \frac{\alpha_s}{2\pi} d\hat{\sigma}^{(1)}_{ijk} + \dots$$

- pdfs are *universal* : same in all reactions (holds separately for unpolarized, longitudinally pol., transversity)

- $\Rightarrow$ notion of "nucleon structure" meaningful

- allows tests of QCD

- enables us to look for / study new things
  - fragmentation (spin) effects
  - polarized photon structure
  - physics beyond the Standard Model

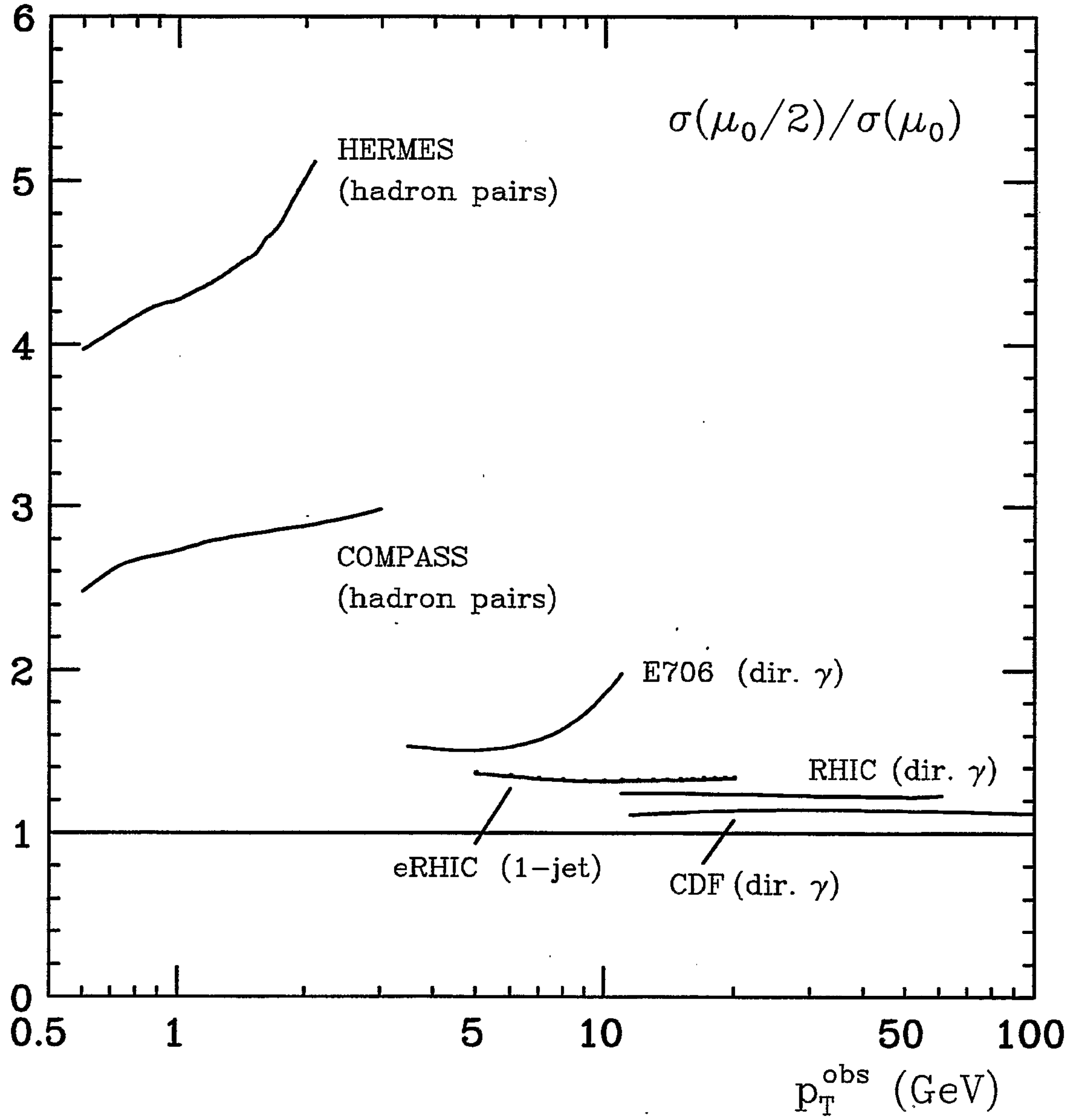
- scale μ is arbitrary; should be $\sim M$

$$\mu \frac{\mathrm{d}}{\mathrm{d}\mu} d\sigma_{AB} = 0$$

at *finite* order, residual scale dependence; to decrease with each new order of PT

Example :

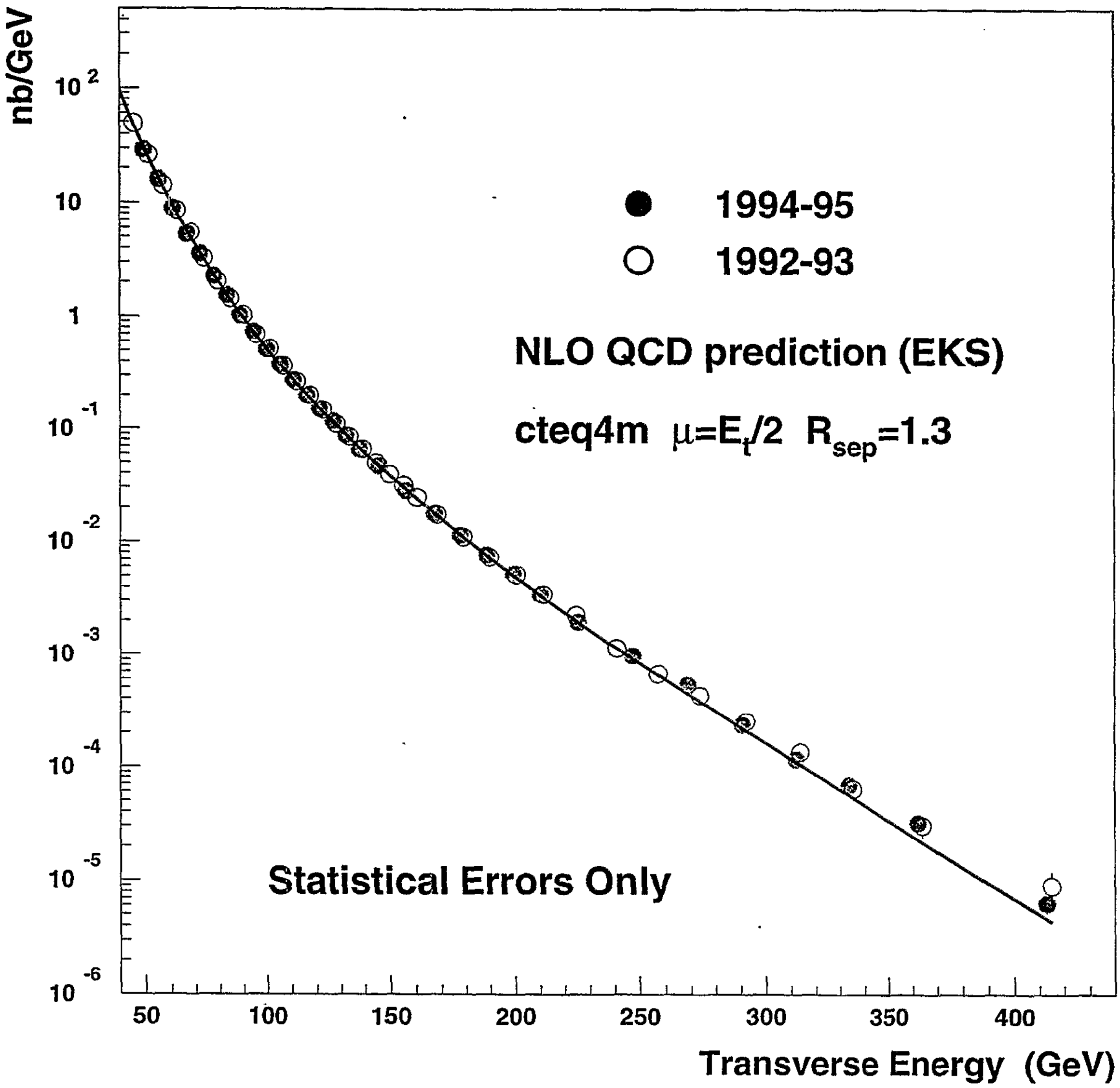
scale dependence of unpolarized cross sections relevant for measurements of gluon density



(de Florian, Stratmann, WV)

II. A_{LL}^{π} at RHIC

High-p_T jets at the Tevatron :



(among other things)

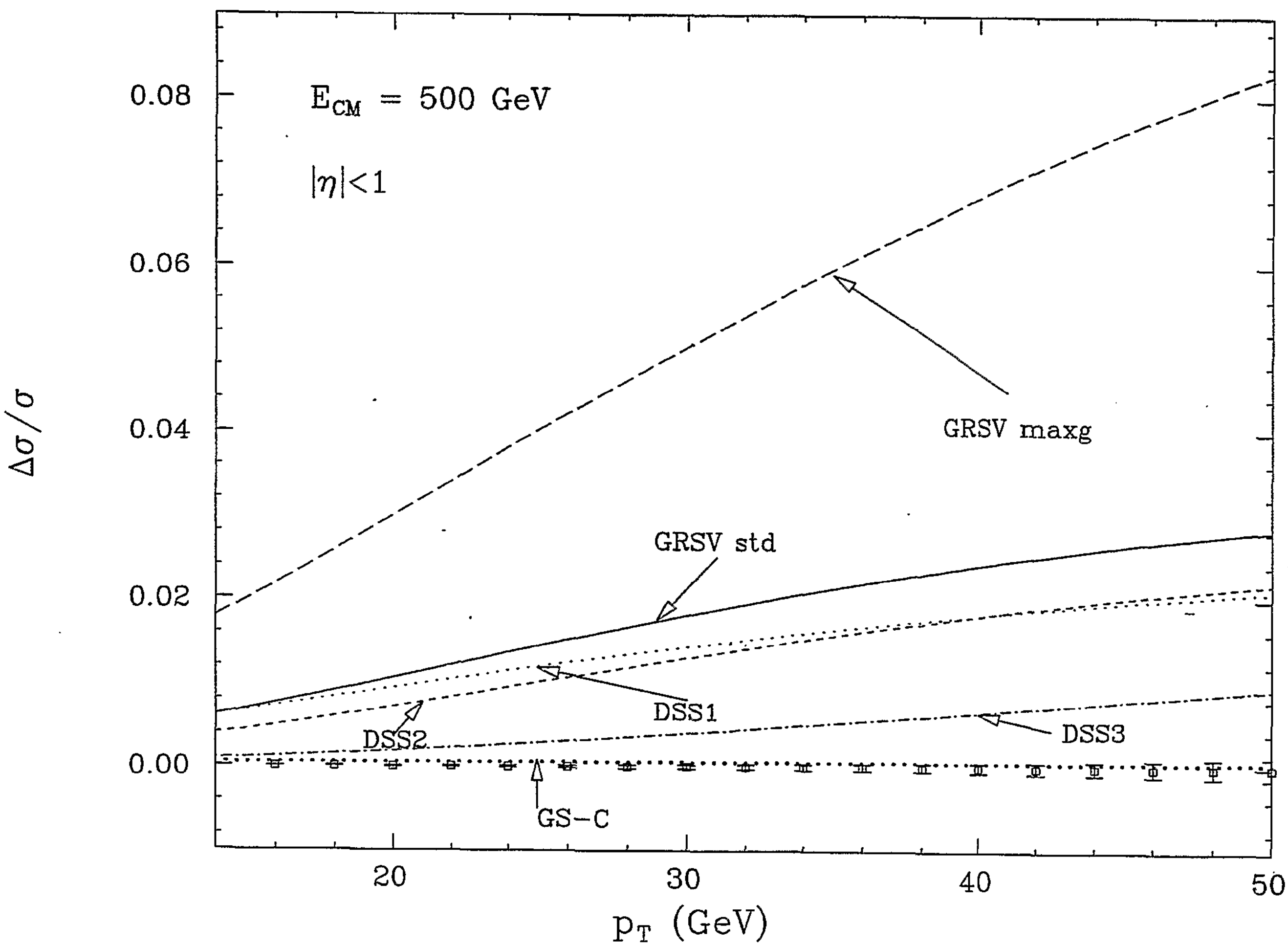
- source of information on gluon density

Jet production at RHIC :

Spin asymmetry

$$A_{LL}^{\rm jet} = \frac{d\sigma_{++} - d\sigma_{+-}}{d\sigma_{++} + d\sigma_{+-}} \equiv \frac{d\Delta\sigma}{d\sigma}$$

gives access to Δg :

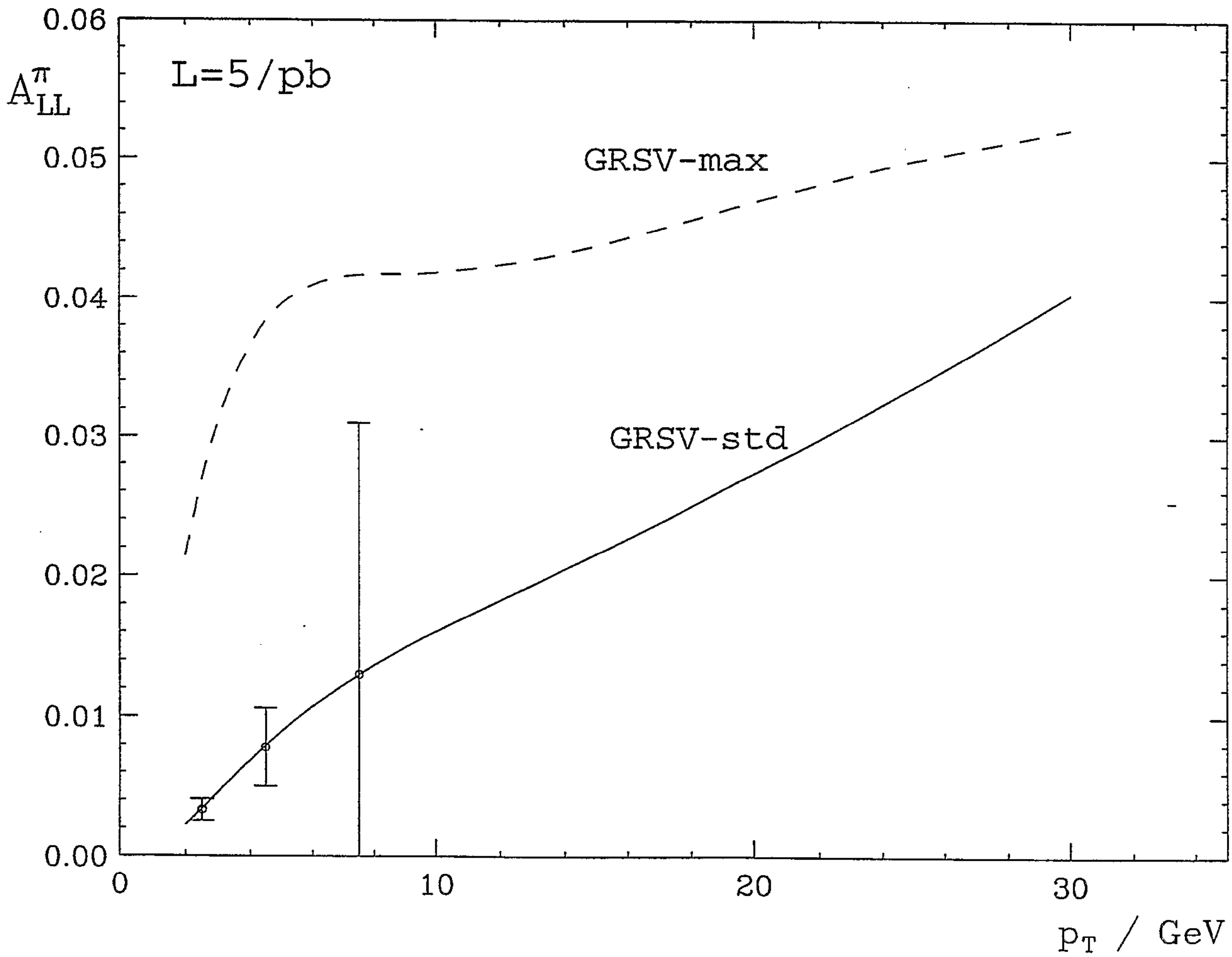


NLO (de Florian, Frixione, Signer, W.V.)

leading pions as jet surrogates :

- useful at lower energies
- can go to lower p_T ($\sim$ few GeV)
- do not require "4π" angular coverage

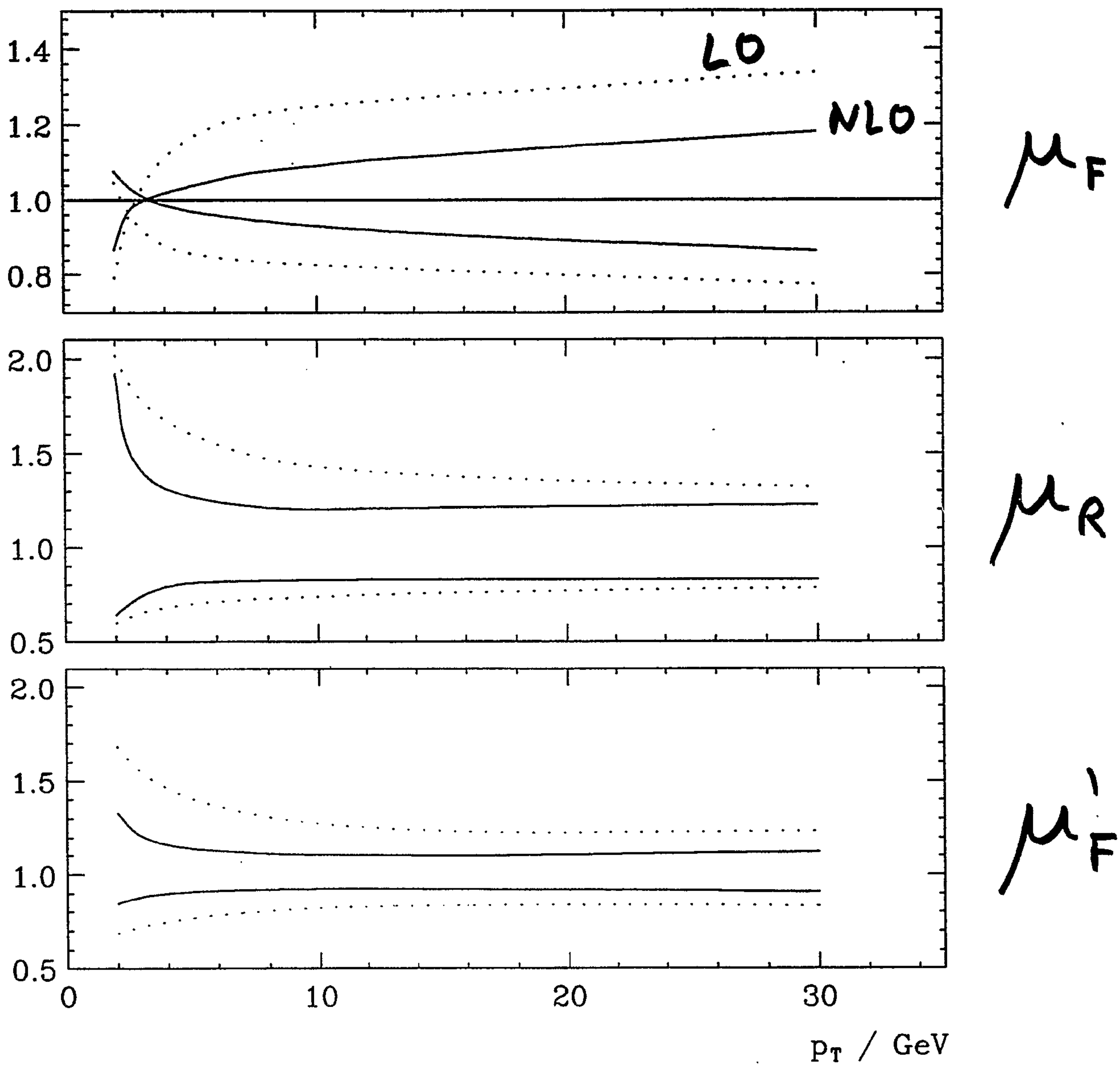
Pion production at RHIC
spin asymmetry sensitive to Δg :



$p_T/2$, $2p_T$

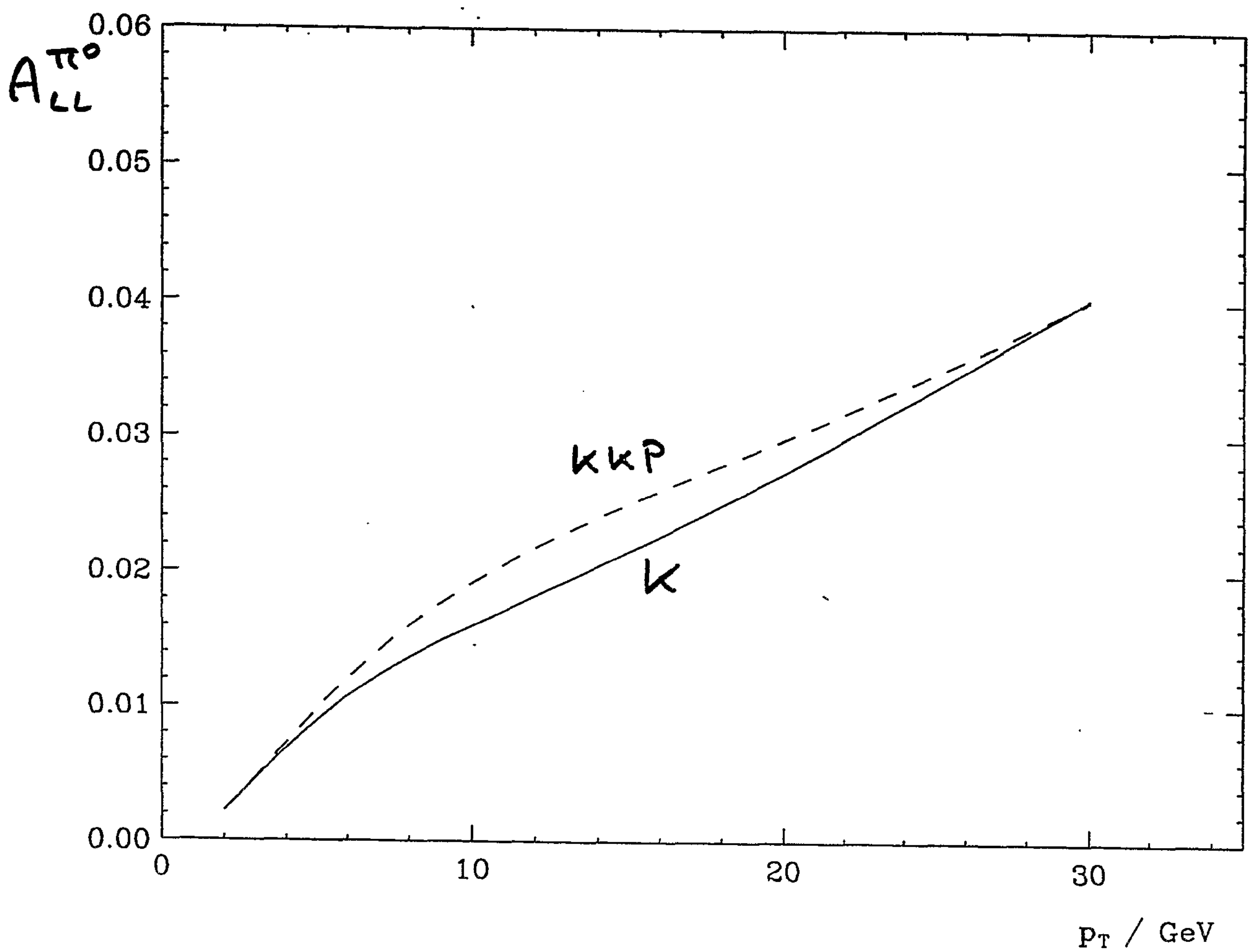
$\sigma(\mu) / \sigma(\text{all } \mu = p_T)$

Scale dependence

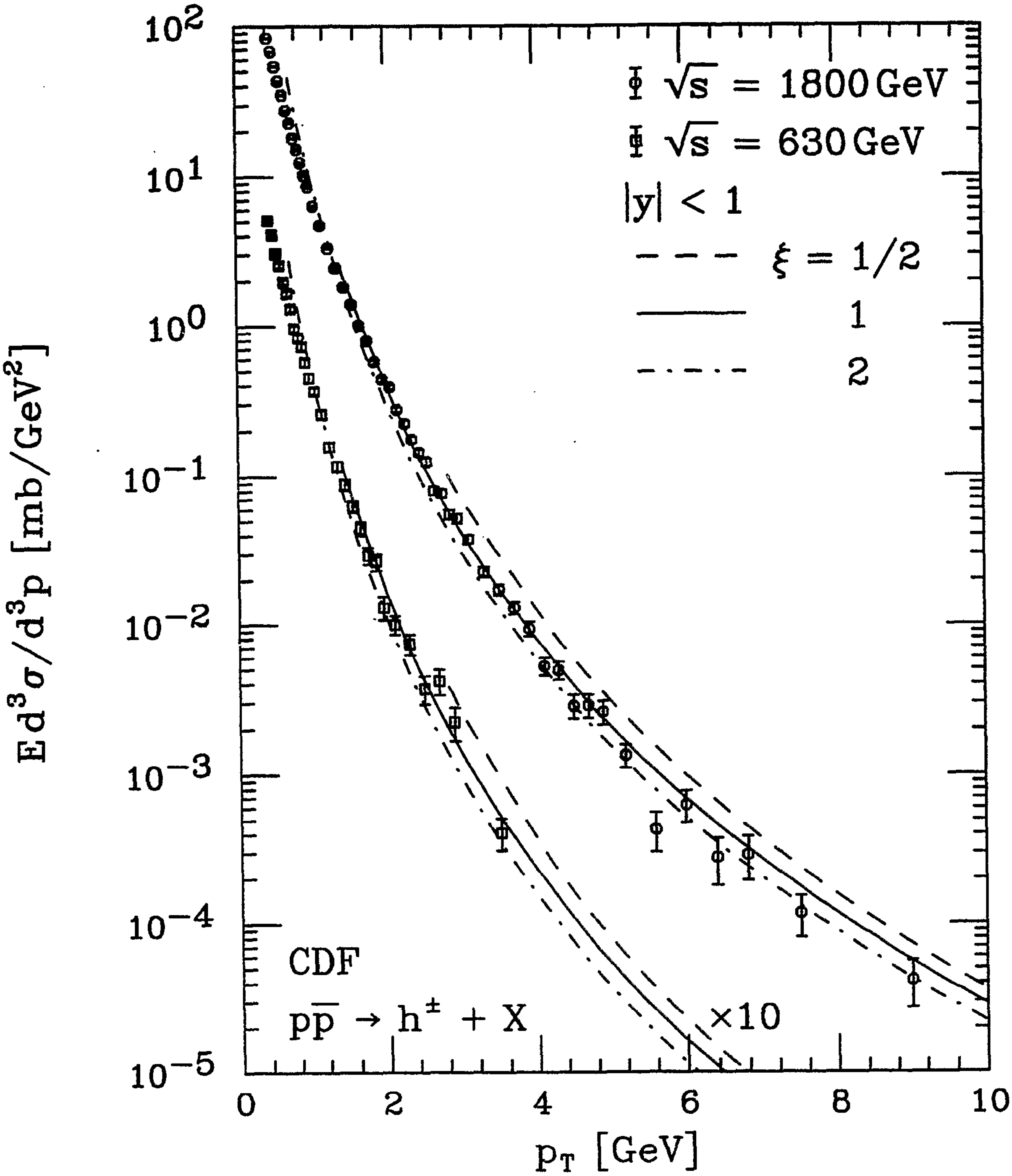


- same in polarized case ?

Spin asymmetry and fragmentation fcts. :



Comparison to data from unpol. colliders :
Kniehl,Kramer,Pötter



III. "Global analysis"

To learn from data need to efficiently evaluate

$$\sigma = \sum_{ijk} f_i \otimes f_j \otimes \hat{\sigma}_{ijk} \otimes D_k$$

- a lesson from unpolarized case
- need "global analysis"
  - input pdfs at scale μ_0 in terms of ansatz with free parameters
  - evolve to scale μ relevant to a data point
  - compare to data and assign χ^2 value
  - vary parameters and minimize χ^2
- requires typically 1000's of evaluations of the cross section
- want $\hat{\sigma}_{ijk}$ at order "as high as possible"
  - theoretical uncertainties decrease
  - but already NLO often numerically involved and time-consuming
- *very* hard to reconcile

unpolarized case :

- gross features of pdfs known
- often ok to use LO $\to$ NLO 'K' factors
- even here, not always the case
  (gluon distribution at large x)

polarized case :

- pdfs known with *much less* accuracy
- pdfs and partonic cross sections
  may have zeros !
  $\Rightarrow$ locally large NLO corrections possible
  (bad convergence of fits based on K fact.)
- want fast and practical way of using exact
  higher-order cross sections in global fits

$\to$ recent work with Marco Stratmann

(similar efforts : AAC, M. Hirai et al.)

"Mellin technique"

(earlier ideas : Berger, Graudenz, Hampel, Vogt; Kosower)

Moments of a function $f(x)$:

$$f^{\,n} \;\equiv\; \int_0^1 dx\, x^{n-1}\, f(x)$$

Consider general cross sec. for producing final state H with observed variable O

$$\frac{d\sigma^H}{dO} \;=\; \sum_{a,b,c} \int_{\text{exp-bin}} dT \int_{x_a^{\text{min}}}^1 dx_a \int_{x_b^{\text{min}}}^1 dx_b \int_{z_c^{\text{min}}}^1 dz_c$$

$$\times\, f_a(x_a,\mu_F)\; f_b(x_b,\mu_F)\; D_c^H(z_c,\mu_F')$$

$$\times\, \frac{d\hat{\sigma}^c_{ab}}{dOdT}(x_aP_A, x_bP_B, P_H/z_c, T, \mu_R, \mu_F, \mu_F')\ ,$$

Express pdfs by their Mellin inverses :

$$f_a(x_a,\mu_F) \;=\; \frac{1}{2\pi i}\int_{\mathcal{C}_n} dn\; x_a^{-n}\, f_a^{\,n}(\mu_F)$$

$$f_b(x_b,\mu_F) \;=\; \frac{1}{2\pi i}\int_{\mathcal{C}_m} dm\; x_b^{-m}\, f_b^{\,m}(\mu_F)$$

Find :

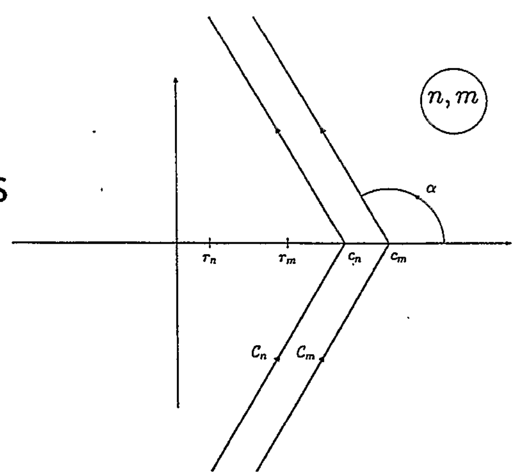
$$\frac{d\sigma^H}{dO} = \frac{1}{(2\pi i)^2}\sum_{a,b,c}\int_{\mathcal{C}_n} dn \int_{\mathcal{C}_m} dm\, f_a^n(\mu_F)\, f_b^m(\mu_F)$$

$$\times \int_{\text{exp-bin}} dT \int_{x_a^{\min}}^1 dx_a \int_{x_b^{\min}}^1 dx_b \int_{z_c^{\min}}^1 dz_c\, x_a^{-n} x_b^{-m}\, D_c^H(z_c,\mu_F')$$

$$\times \frac{d\hat{\sigma}_{ab}^c}{dOdT}(x_a P_A,\, x_b P_B\,, P_H/z_c, T,\, \mu_R, \mu_F, \mu_F')$$

$$\equiv \sum_{a,b}\int_{\mathcal{C}_n} dn \int_{\mathcal{C}_m} dm\, f_a^n(\mu_F)\, f_b^m(\mu_F)\, \tilde{\sigma}_{ab}^H(n,m,O,\mu_R,\mu_F)$$

- $\tilde{\sigma}_{ab}^H(n,m,O,\mu_R,\mu_F)$ is cross section for "dummy" pdfs $x_a^{-n} \times x_a^{-m}$
- contains all tedious integrations
- can be pre-calculated on a suitable grid in n, m
- for optimal contours, *exponential decrease* of x_a^{-n}, x_a^{-m} along contours
- pdfs fall off at least as fast as $1/|n|^4$, $1/|m|^4$



Finally, n, m integrations are all that's left !

Example : Prompt γ at RHIC

$$\frac{d\Delta\sigma^{\gamma}}{dp_T} = \sum_{a,b} \int_{\eta-\text{bin}} d\eta \int_{x_a^{\min}}^{1} dx_a \int_{x_b^{\min}}^{1} dx_b \, \Delta f_a(x_a, \mu_F)\, \Delta f_b(x_b, \mu_F)$$

$$\times \frac{d\Delta\widehat{\sigma}^{\gamma}_{ab}}{dp_T d\eta}(x_a P_A,\, x_b P_B\,, p_T, \eta,\, \mu_R, \mu_F)$$

$$d\Delta\widehat{\sigma}^{\gamma}_{ab} = \underbrace{d\Delta\widehat{\sigma}^{\gamma,(0)}_{ab}}_{\text{LO}} + \left(\frac{\alpha_s}{\pi}\right) \underbrace{d\Delta\widehat{\sigma}^{\gamma,(1)}_{ab}}_{\text{NLO}} + \ldots$$

Toy analysis :

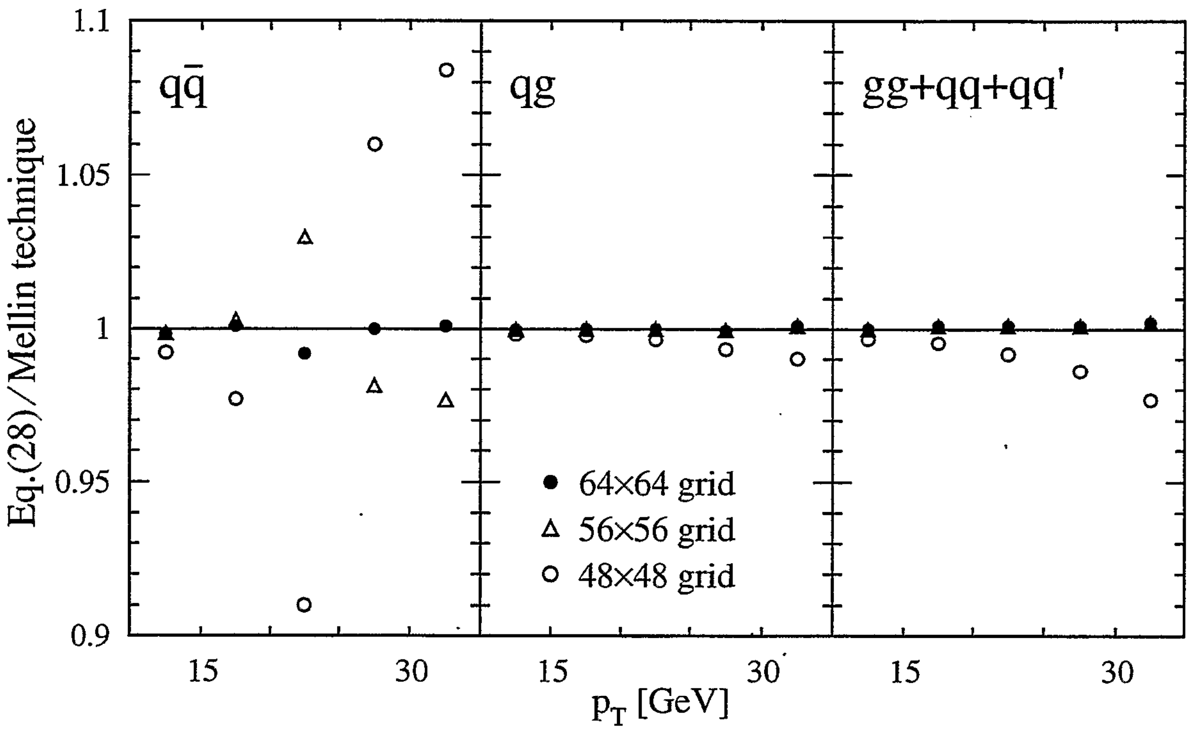
- NLO, scales $\mu_F = \mu_R = p_T$
- $\sqrt{S} = 200$ GeV, $|\eta| < 0.35$, isolated cr. sec.
- "ficticious" data points at
  $p_T = 12.5, 17.5, 22.5, 27.5, 32.5$ GeV
  calc. with GRSV $\oplus$ random Gaussian 1σ shift
- fit to DIS *and* prompt photon "data"
  ansatz for gluon density :

  $$\Delta g(x, \mu_0) = N\, x^{\alpha}\, (1-x)^{\beta}\, (1+\gamma\, x)\; g(x, \mu_0)$$

- perform large number of fits;
  allow for $\Delta\chi^2 = 4$ to obtain "error band"

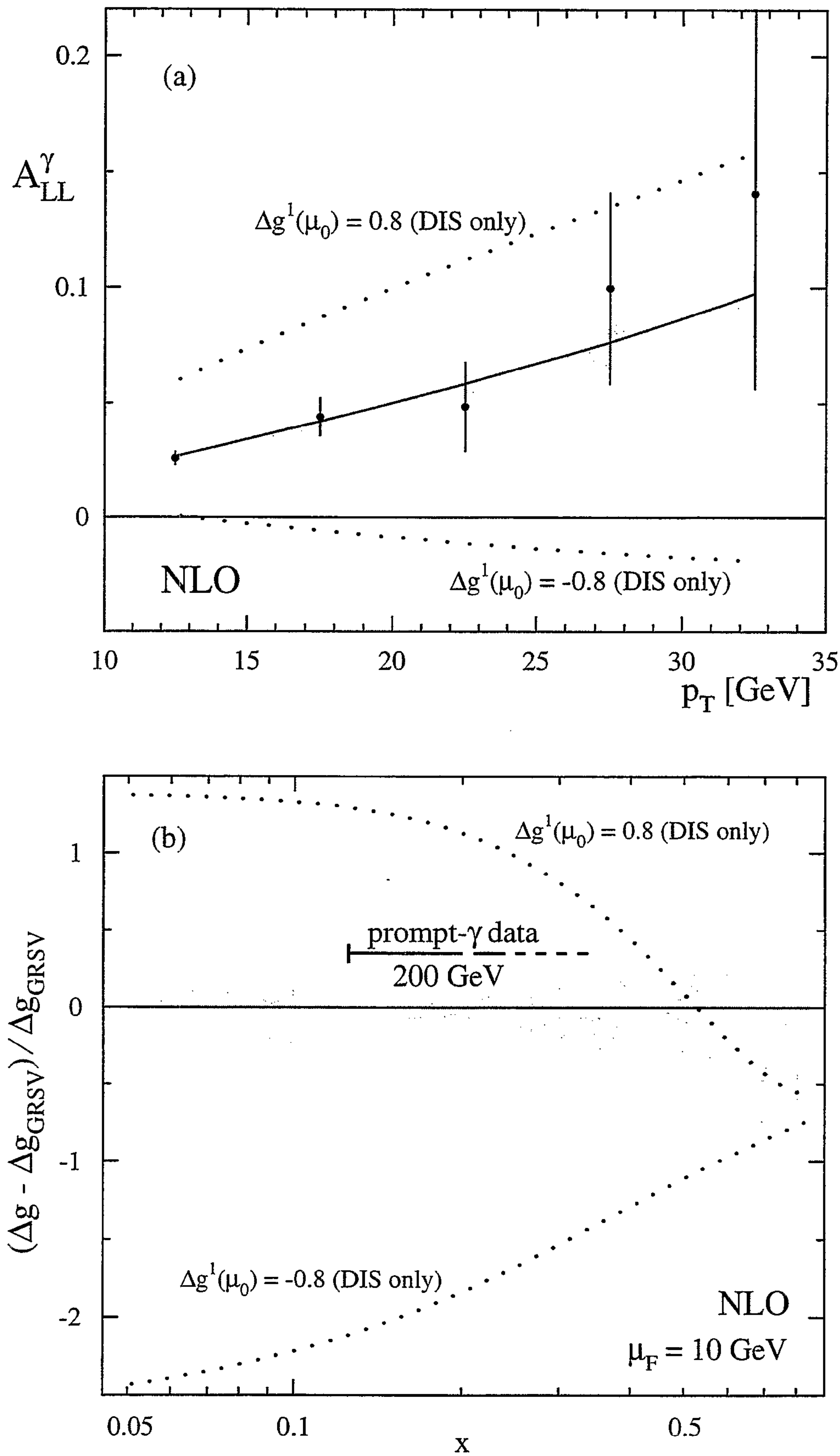
Accuracy of method :

(Stratmann,WV)



Evaluation of cross section extremely fast :

- generation of grids in n, m takes $\sim$ 5 hrs.
- after that :
  1000 evaluations of cr. sec. in $\sim$ 10 sec.



(further constraints by data at $\sqrt{S} = 500$ GeV)

V. Transverse *two*-spin asymmetries

Factorization formalism valid for cross sections with two transversely polarized beams (Collins)

- involves transversity densities
- probably not preferred way of measuring δq; promising : "interference fragmentation fcts." (Jaffe,Jin,Tang; Grosse-Perdekamp et al.)

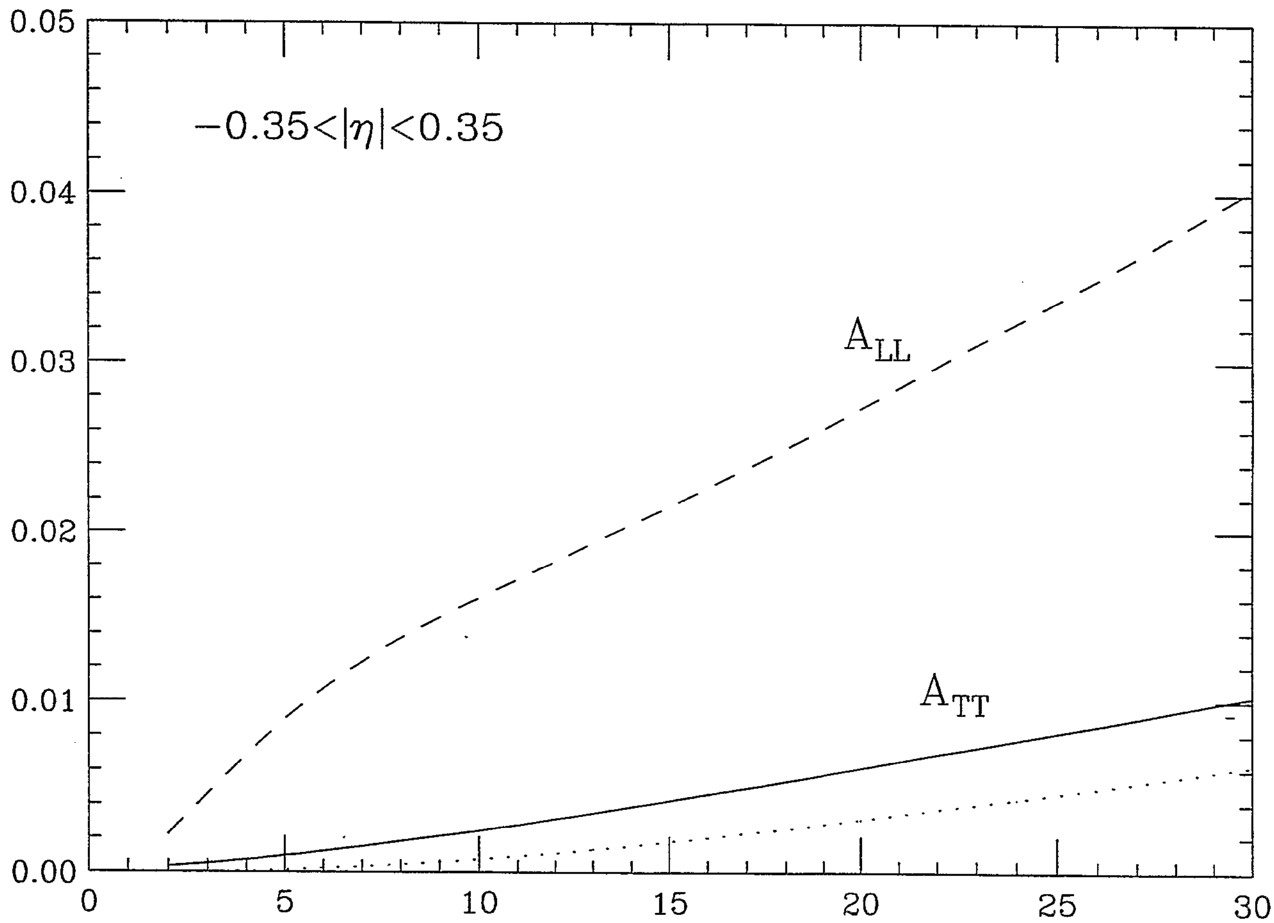
Re-emphasize : A_{TT} is expected small, "$A_{TT} \ll A_{LL}$" (Jaffe,Saito)

- Drell-Yan process in $\vec{p}\vec{p}$:
  - presumably $\delta\bar{q}(x)$ small
  - in addition, low rates
- dir. photons, jets, inclusive hadrons,... :
  - no gluon transversity, however, gluon contribution to unpolarized cross section!
  - relevant hard scattering cross sections typically color-suppressed
  - Soffer's inequality limits size of δq

  \+ rates can be substantial

  ⇒ small asymmetries *may* be measurable

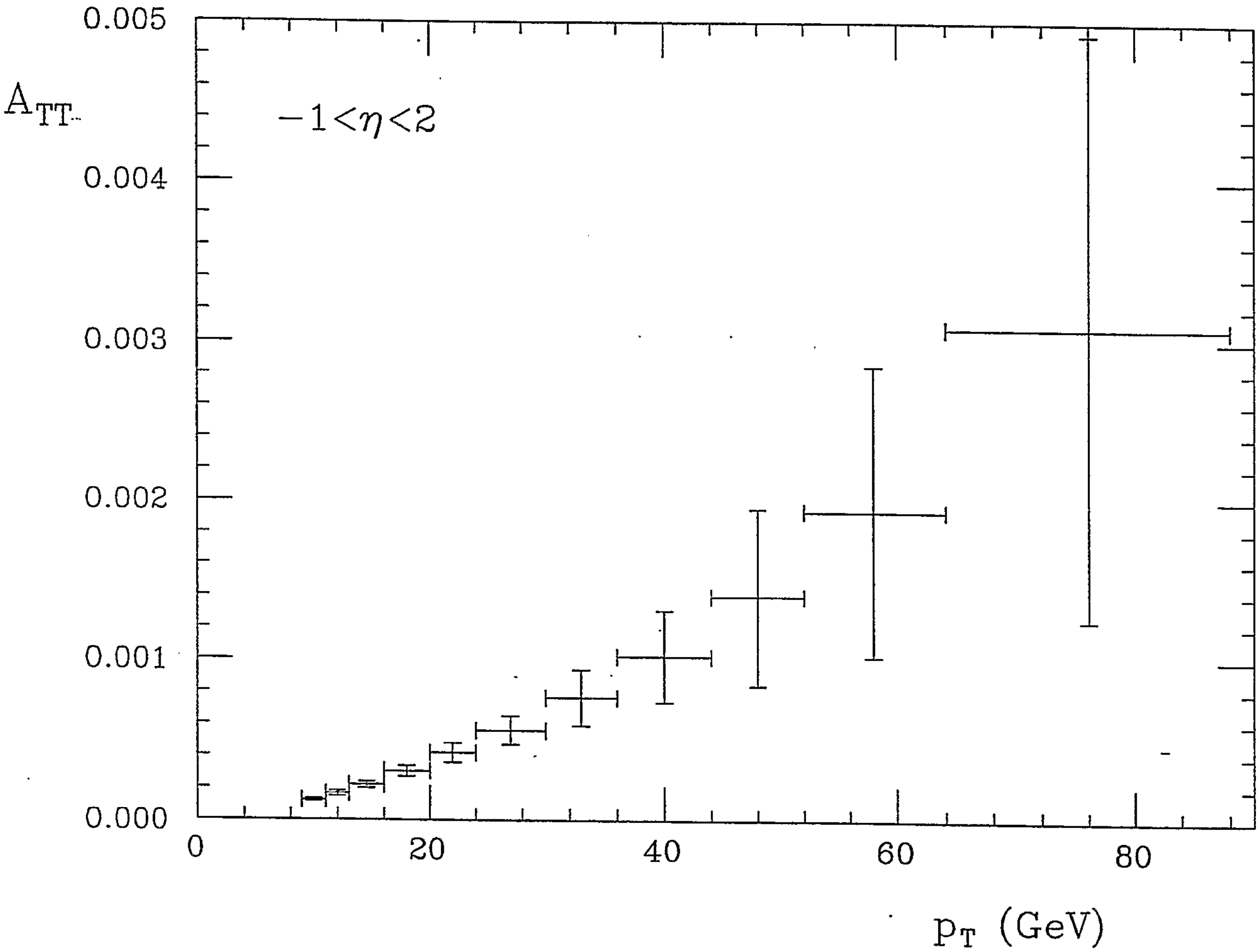
Estimate "maximal" A^{π}_{TT}, based on Soffer's inequality :



(dotted : $\delta q(x, \mu_0) = \Delta q(x, \mu_0)$)

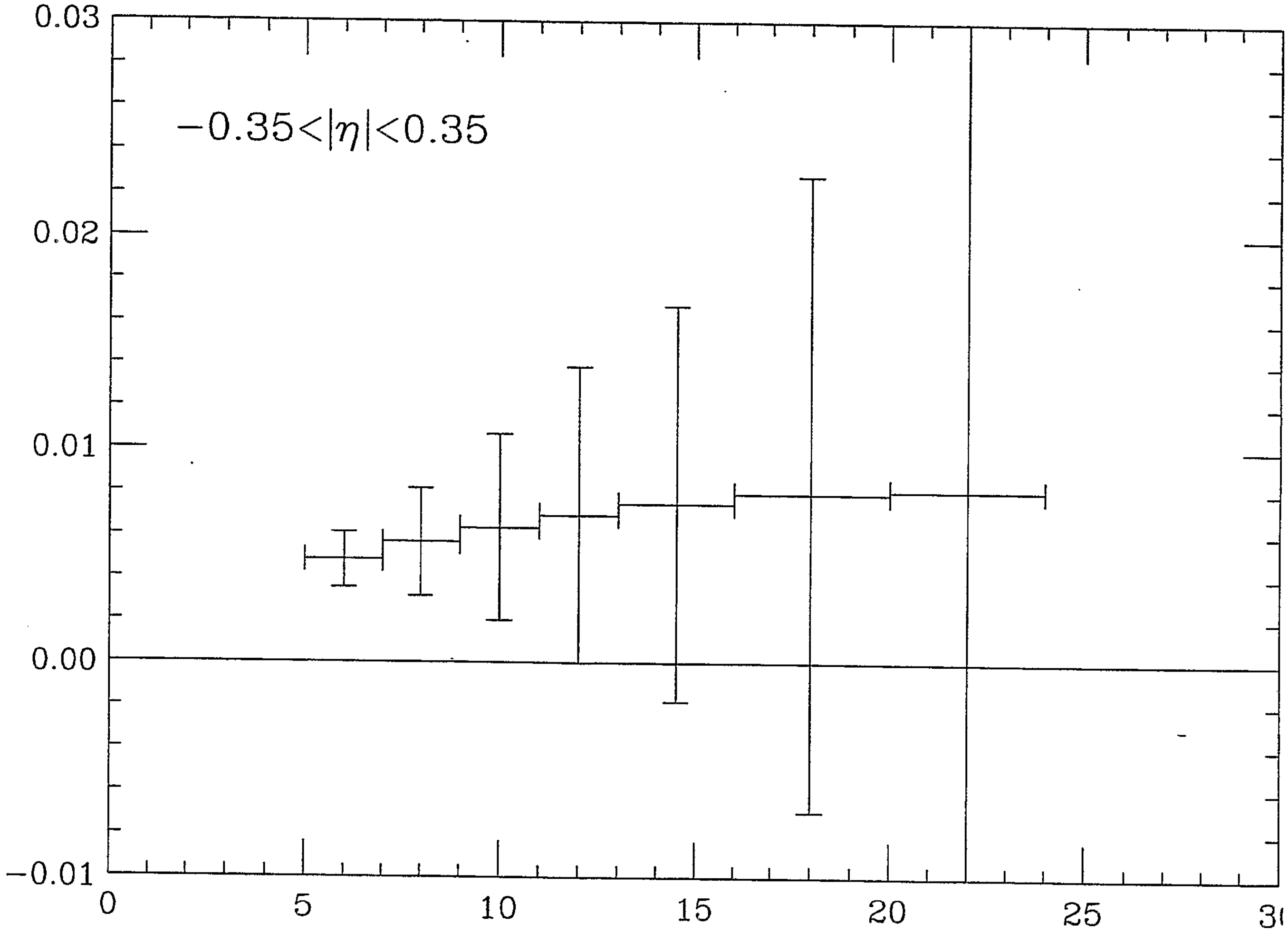
A_{TT} in single-inclusive jet production :

($\sqrt{S} = 500$ GeV)



(de Florian, Stratmann, WV)

A_{TT} for prompt photon production :
($\sqrt{S} = 200$ GeV)



(Soffer, Stratmann, WV)

VI. A_N^π at RHIC

- sizable A_N seen in fixed-target expts.
  E581/704...
- pQCD : A_N to vanish at leading power
  (Kane,Pumplin,Repko)

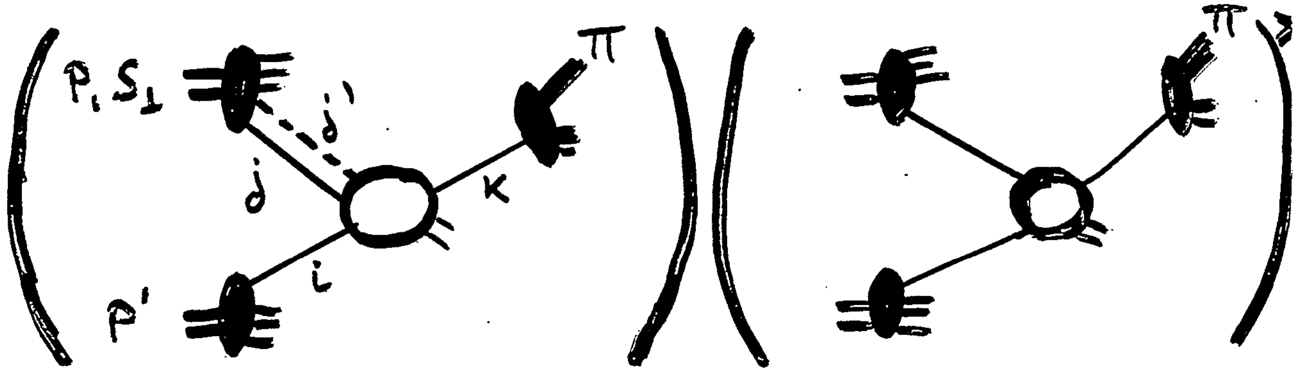
Qiu & Sterman : can A_N be understood as a nonleading-power effect in pQCD ?

- prove factorization to first non-leading power in unpol. / pol. hadron-hadron collisions
  (earlier work in DIS : Vainshtein,Shuryak; Ellis,Furmanski,Petronzio; Jaffe,Soldate; Qiu)
- typical structure for A_N is :

$$\Delta\sigma_{A+B\to\pi}(\vec{s}_T)$$

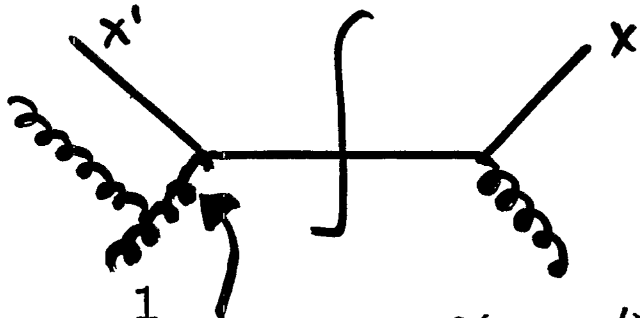
$$= \sum_{i(jj')k} \phi^{(3)}_{jj'/A}(x,x',\vec{s}_T) \otimes \phi_{i/B}(y) \otimes H_{i(jj')\to k}(\vec{s}_T) \otimes D_{k\to\pi}(z)$$

$+$ other terms $+$ higher power corrections



- $T_F(x,x') = \text{F.T.}\langle P,S|\bar{\psi}(0)\,\gamma^+ F_\alpha^+(\xi_2^-)\psi\left(\xi_1^-\right)|P,S\rangle$
- factorization $\Rightarrow$ universality
- interference $\Rightarrow$ interpretation not easy

- gluon propagator :



$$\frac{1}{x - x' + i\epsilon} \longrightarrow i\pi\delta(x - x') + \text{real}$$

$$\Rightarrow \text{need } T_F(x,x) \text{ , and } \frac{d}{dx}T_F(x,x)$$

- argue

$$\frac{d}{dx}T_F(x,x) \gg T_F(x,x) \quad (\text{large-}x)$$

- calculable short-distance cross sections :

$$\hat{\sigma} \sim \sigma_{\text{born}} \times \left(A\frac{p_T}{-\hat{u}} + B\frac{p_T}{-\hat{t}} \right)$$

$\sim \frac{\lambda p_T}{S}$ $\quad$ $\sim \lambda/p_T$

- no evolution yet

- other approaches :
  - Sivers, Anselmino et al.; Boer et al.; Leader...

  $k_\perp$-dependent distribution/fragmentation fcts.
  - Boros et al.

FY2001 Polarized Proton Commissioning

W. Mackay

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

FY2001 Polarized Proton Commissioning

- Layout of Accelerator Complex.
- Goals for FY2001 Run.
- Setup for Snake Charming.
- How the snakes work.
- 2 $\Rightarrow$ 1 snake ramp for longitudinal polarization.
- Schedule

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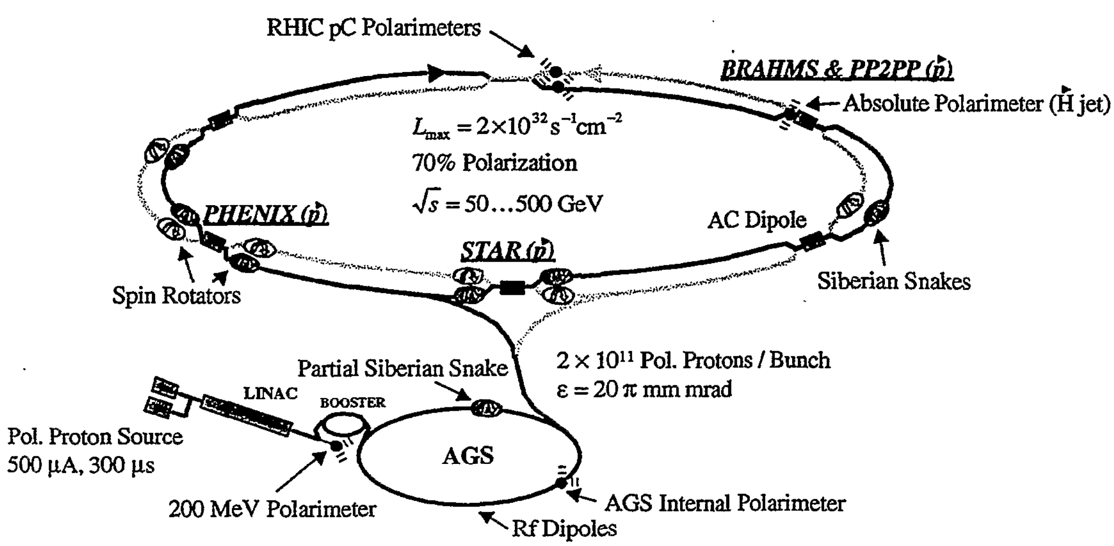
1

Polarized Protons in RHIC



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Goals for FY2001 Run

- 2 pC-CNI polarimeters (1 per ring) installed.✓
- 4 snakes (2 per ring) installed.✓
- 8 power supplies (2 per snake).
  - installed.✓
  - not yet operational.

- Provide 100 GeV × 100 GeV collisions with long. pol. at all IR's.
  - Hope to achieve at least 50% polarization per beam.
- Accelerate polarized protons to 250 GeV.

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Injection and Storage Energies

	Injection	Nominal Store	Top Energy
$G\gamma$	46.5	192	477.6991
γ	25.9364	107.0922	266.4472
U (total energy)	24.3354 GeV	100.4817 GeV	250 GeV
p/q	81.1138 Tm	335.1561 Tm	833.9044 Tm
I_{dipole}	473.923 A	1954.18 A	5067.303 A

$$(G = 1.7928474 \quad mc^2 = 0.93827231 \text{ GeV} \quad c = 299792458\text{m/s})$$

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Setup for Snake Charming

Systems to commission:
1. 2 polarimeters (yellow, and new electronics for blue).
2. ac dipole (spin flipper)
3. 4 snakes (8 power supplies): orbit; spin
4. phase-locked loops for betatron-tune control
5. polarization info transfer to experiments (CDEV)
6. injection pattern program (new version)

New ramps ($\beta^* = 10$ m):
1. acceleration $G\gamma : 46.5 \Rightarrow 192$ (all snakes on)
2. deceleration $G\gamma : 192 \Rightarrow 46.5$ (all snakes on)
3. at fixed field $2 \Rightarrow 1$ snakes at fixed energy
4. possible commissioning of β-squeeze at 100 GeV

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Considerations

Orbit correction:
- Locally correct the orbit at snakes.
- Flatten vertical orbit in ring ($\sigma_v \lesssim 0.2$ mm).
- Keep orbit flattened during the ramps.

Energy ramps:
- May have to ramp snakes slightly with energy (~6 A).
- Ramp local corrections to snake orbits?
  (First snake required 0.18 mr vertical correction at injection.)
- First try with constant currents in snakes.
- Decelerate beam back to injection energy.

Polarimeters:
- Vert polarization with both snakes at injection.
- Horiz polarization with single snake at storage
- Measure polarization during certain intervals during energy ramps.

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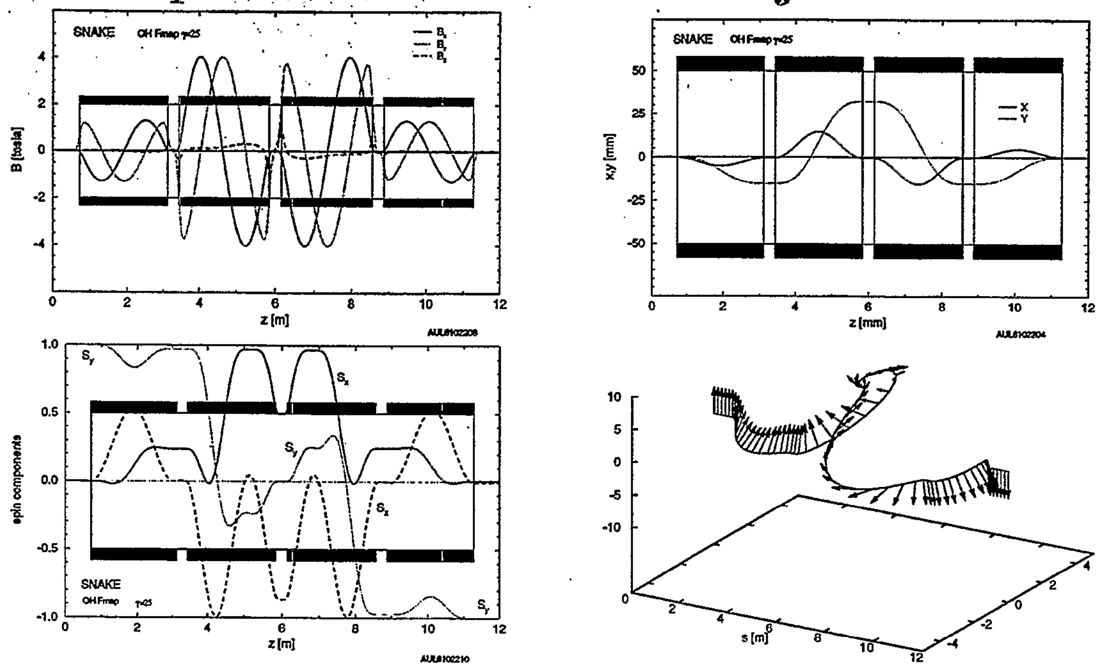
Operation of Snake at Injection



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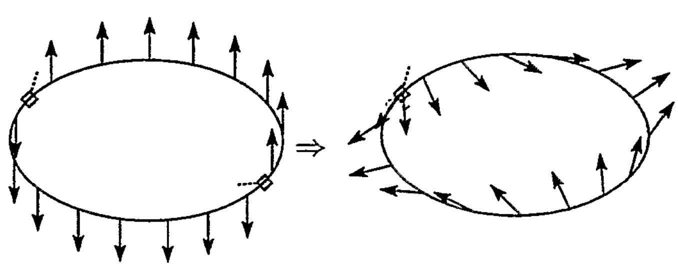
Longitudinal Polarization in RHIC

- Inject vertically polarized protons with both snakes on.
  $E \sim 24.3$ GeV ($G\gamma \sim 46.5$)
- Accelerate beams to 100.48 GeV ($G\gamma = 192$)
- Turn off one snake in each ring: polarization $\Rightarrow$ horizontal plane.
  (Long. Pol. at IR's.)



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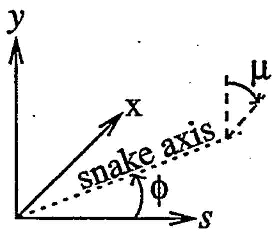
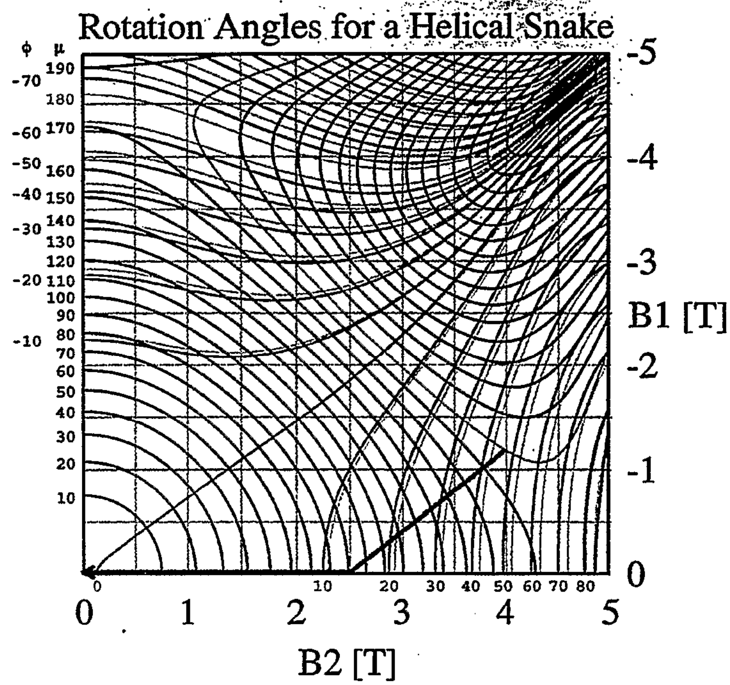


The rotation axis of the snake is ϕ, and μ is the rotation angle.

Note that the ϕ contours shift slightly from injection (red) at 25 GeV to storage (pink) at 250 GeV.



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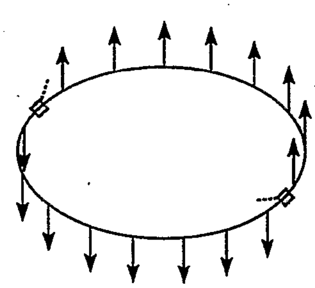
Spin tune with two snakes $[\mu_1, \phi_1]$ and $[\mu_2, \phi_2]$ on opposite sides of ring: $\nu_{\rm sp} = \delta/2\pi$ where



$$\cos\frac{\delta}{2} = \cos\frac{\mu_2}{2}\cos\frac{\mu_1}{2}\cos G\gamma\pi - \sin\frac{\mu_2}{2}\sin\frac{\mu_1}{2}\cos(\phi_2 - \phi_1).$$

and $G = \frac{g-2}{g} = 1.7928$ for protons.

For $\mu_1 = \pi$,

$$\cos\frac{\delta}{2} = -\sin\frac{\mu_2}{2}\cos(\phi_2 - \phi_1),$$

$\nu_{\rm sp} = 0.5$ for either $\mu_2 = 0°$ or $\phi_2 - \phi_1 = 90°$.

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Calibration of Snakes

Two snakes:

- Set two snakes in one ring for best guess at $\mu_{1,2} = 180°$ and $\phi_{1,2} = \pm 45°$.
- Adjust currents to move along $\mu = 180°$ contour to have $\Delta\phi = 90°$ ($\nu_{sp} = 0.5$).
  We can assume equal but opposite currents for the 2 snakes.

2 ⇒ 1 snake ramp:

- Ramp down one snake and measure horizontal polarization.
- Do energy scan through at least one full unit of $\Delta(G\gamma)$.
  This should give a calibration of energy vs current.

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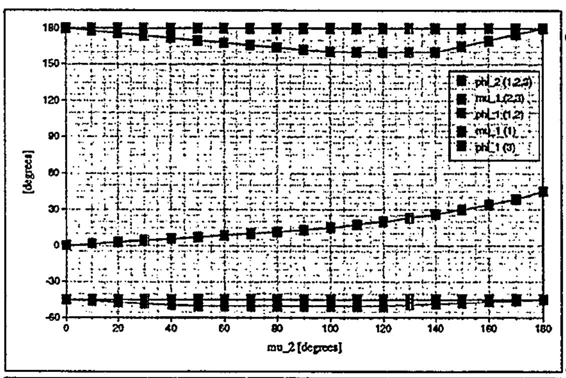

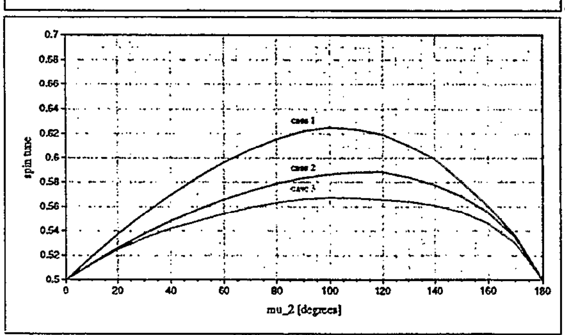

	Snake one		Snake two					
G*gamma	mu1	phi1	mu2	phi2	cos(pi*nu)	nu	1-nu	case 2
192	180	-45	180	45	0.0000	0.5000	0.5000	
192	175	-45	170	38.5	-0.1089	0.5347	0.4653	
192	170	-45	160	34	-0.1721	0.5550	0.4450	
192	165	-45	150	30	-0.2141	0.5687	0.4313	
192	160	-45	140	26	-0.2419	0.5778	0.4222	
192	160	-45	130	23	-0.2610	0.5840	0.4160	
192	160	-45	120	20	-0.2736	0.5882	0.4118	
192	160	-45	110	17.5	-0.2729	0.5880	0.4120	
192	160.5	-45	100	15	-0.2686	0.5866	0.4134	
192	162	-45	90	13	-0.2595	0.5836	0.4164	
192	164	-45	80	11.5	-0.2447	0.5787	0.4213	
192	166	-45	70	10	-0.2267	0.5728	0.4272	
192	168	-45	60	8.5	-0.2053	0.5658	0.4342	
192	170	-45	50	7.1	-0.1796	0.5575	0.4425	
192	172	-45	40	5.7	-0.1506	0.5481	0.4519	
192	174	-45	30	4.4	-0.1176	0.5375	0.4625	
192	176	-45	20	3	-0.0818	0.5261	0.4739	
192	178	-45	10	1.5	-0.0426	0.5136	0.4864	
192	180	-45	0	0	-0.0000	0.5000	0.5000	
G*gamma	mu1	phi1	mu2	phi2	cos(pi*nu)	nu	1-nu	case 3
192	180	-45.0	180	45	0.0000	0.5000	0.5000	
192	175	-45.8	170	38.5	-0.0945	0.5301	0.4699	
192	170	-46.7	160	34	-0.1440	0.5460	0.4540	
192	165	-47.5	150	30	-0.1735	0.5555	0.4445	
192	160	-48.3	140	26	-0.1905	0.5610	0.4390	
192	160	-49.2	130	23	-0.2000	0.5641	0.4359	
192	160	-50.0	120	20	-0.2049	0.5657	0.4343	
192	160	-50.0	110	17.5	-0.2091	0.5671	0.4329	
192	160.5	-50.0	100	15	-0.2102	0.5674	0.4326	
192	162	-50.0	90	13	-0.2065	0.5662	0.4338	
192	164	-50.0	80	11.5	-0.1971	0.5632	0.4368	
192	166	-50.0	70	10	-0.1848	0.5592	0.4408	
192	168	-50.0	60	8.5	-0.1693	0.5541	0.4459	
192	170	-50.0	50	7.1	-0.1497	0.5478	0.4522	
192	172	-49.0	40	5.7	-0.1316	0.5420	0.4580	
192	174	-48.0	30	4.4	-0.1071	0.5342	0.4658	
192	176	-47.0	20	3	-0.0772	0.5246	0.4754	
192	178	-46.0	10	1.5	-0.0415	0.5132	0.4868	
192	180	-45.0	0	0	-0.0000	0.5000	0.5000	

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Polarization with a Single Snake On

At $E = 100.48$ GeV:

$G\gamma = 192 = 3 \times 64$

Pol. at IR's may be 7° from long.

$\cos(7°) \simeq 0.999998.$

For $\frac{\Delta p}{p} = \pm 0.001$

STAR/BRAHMS: σ_θ $[\cos\sigma_\theta]$

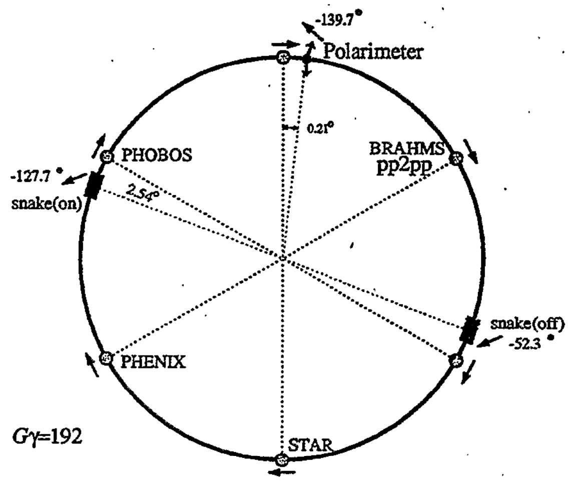
$32 \times \frac{\Delta p}{p} \times 360° = \pm 12°$ [0.98]

PHENIX:

$64 \times \frac{\Delta p}{p} \times 360° = \pm 23°$ [0.92]

PHOBOS:

$96 \times \frac{\Delta p}{p} \times 360° = \pm 35°$ [0.82]



Polarization in Blue Ring with One Snake On

Note: Effect of momentum spread degrades polarization by a few percent.

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(Ambitious) Schedule

- ~3 weeks before end of Gold run:
  tune up injectors with pol. protons.
- ~3 weeks of commissioning pol. protons in RHIC.
- ~5 weeks of collisions with pol. protons.

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Comments on Luminosity

$$L = f_{\mathrm{rev}} \frac{N_1 N_2 N_b}{4\pi \sigma_x \sigma_y} = f_{\mathrm{rev}} \frac{N_1 N_2 N_b}{4\pi \frac{\epsilon^N_{95\%}}{6\beta\gamma} \beta^*}$$

$$\simeq 78 \text{ kHz} \times \frac{10^{11} \times 10^{11} \times 55}{2 \times \frac{2\times 10^{-5}\text{ m}}{100} \times 10 \text{ m}} \quad \text{(Here } \beta^* = 10 \text{ m for scaling.)}$$

$$\simeq 1 \times 10^{30} \text{ cm}^{-2}\text{s}^{-1}$$

- For the energy ramps we, want equal and constant β^* at all IR's.
  - We plan injection studies to see if β^* =3 m works at PHOBOS.
- Can we accelerate 55×10^{11} protons per ring?
  - So far with gold, we have reached only $\sim$ 30% of design intensity.

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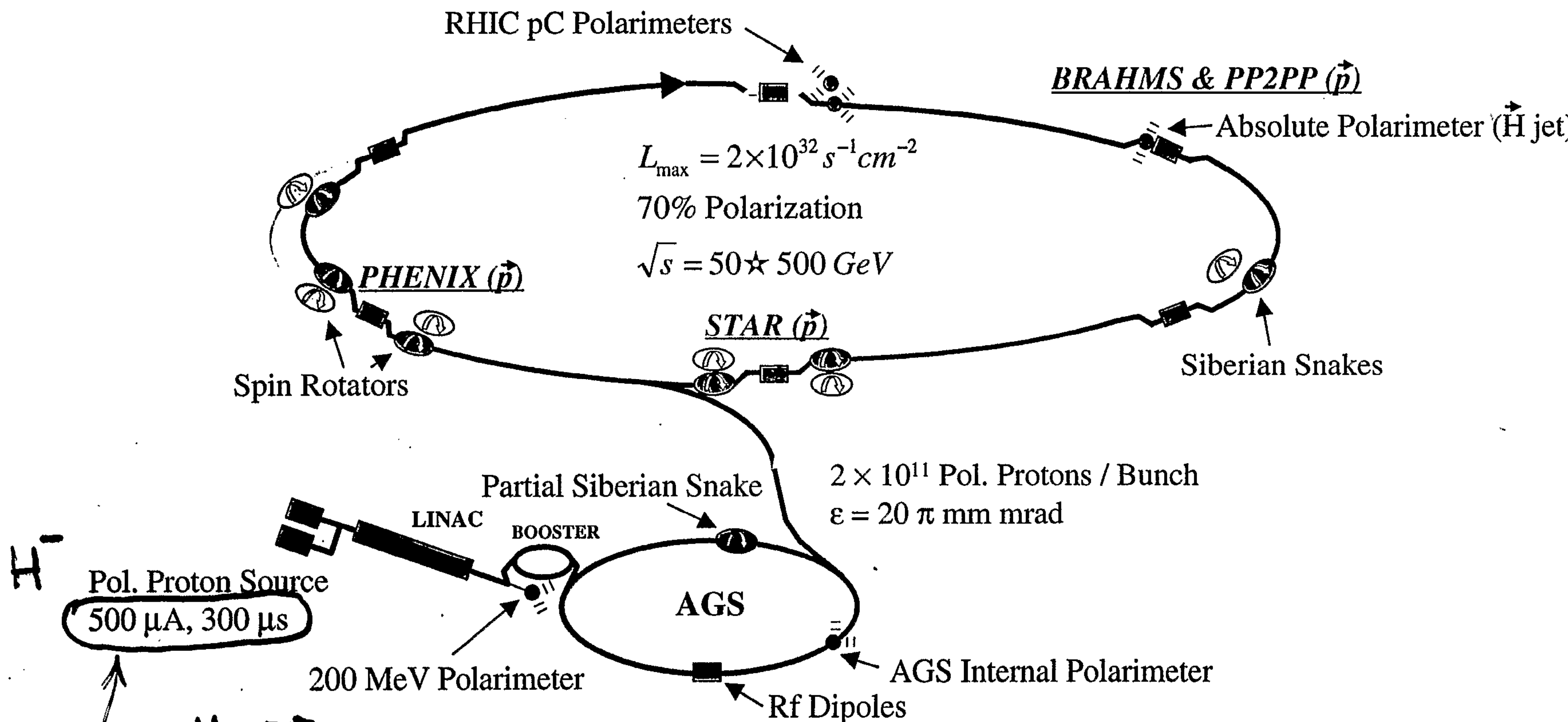
Optically-Pumped Polarized H^- Ion Source for RHIC Spin Physics

A.Zelenski[1,2], J.Alessi[1], B.Briscoe[1], G.Dutto[3], H.Huang[1], A.Kponou[1], S.Kokhanovski[2], V.Klenov[2], A.Lehrach[1], P.Levy[3], V.LoDestro[1], Y.Mori[4], M.Okamura[5], D.Raparia[1], J.Ritter[1], T.Takeuchi[5], G.Wight[3], V.Zoubets[2]

1 - Brookhaven National Laboratory, USA
2 - INR, Moscow, Russia
3 - TRIUMF, Canada
4 - KEK, Japan
5 - RIKEN, Japan

PST 2001

Polarized proton collisions in RHIC



$9 \cdot 10^{11}$ $\vec{H}^-$ / OPPIS pulse

→ $4 \cdot 10^{11}$ out of LINAC → ~ 200 μA × 300 μs

→ $2 \cdot 10^{11}$ in RHIC

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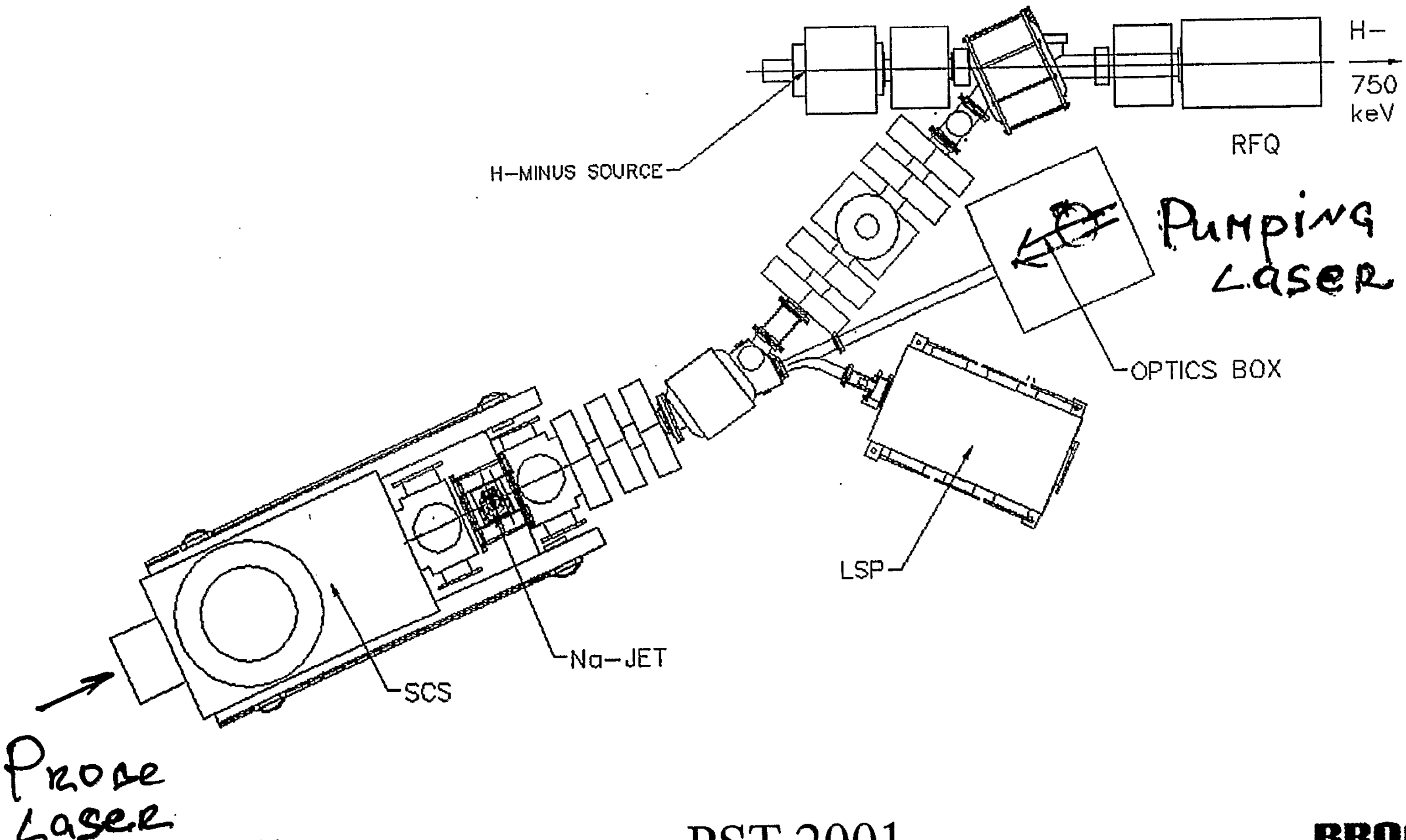
The polarized RHIC injector layout



OPPIS INJECTOR

1. **Reliability.**
   Maintenance. Downtime. 80%
   Backup.

2. **Stability.**
   Current fluctuations, drift. | need some
   Sparking. | more work
   Constant polarization.

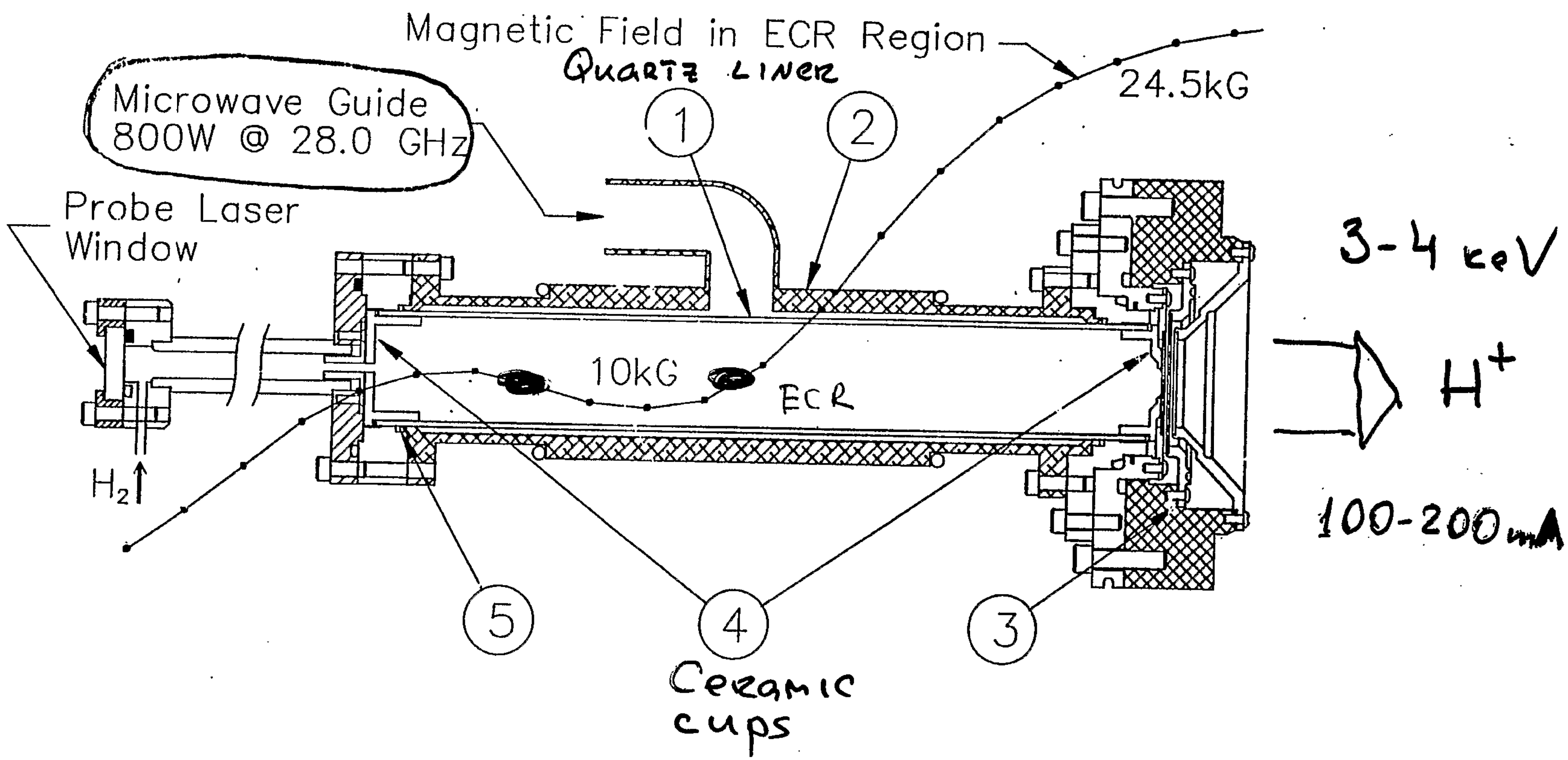
3. **Performance.**
   Current 200 uA at 200 MeV. good
   Polarization > 75% at 200 MeV. good

4. **Control and monitoring.**
   Polarization direction. good
   On-line polarization monitoring. good

18 GHz → 28 GHz ECR H^+ ECRFIGUR.PS .DWG .DSK

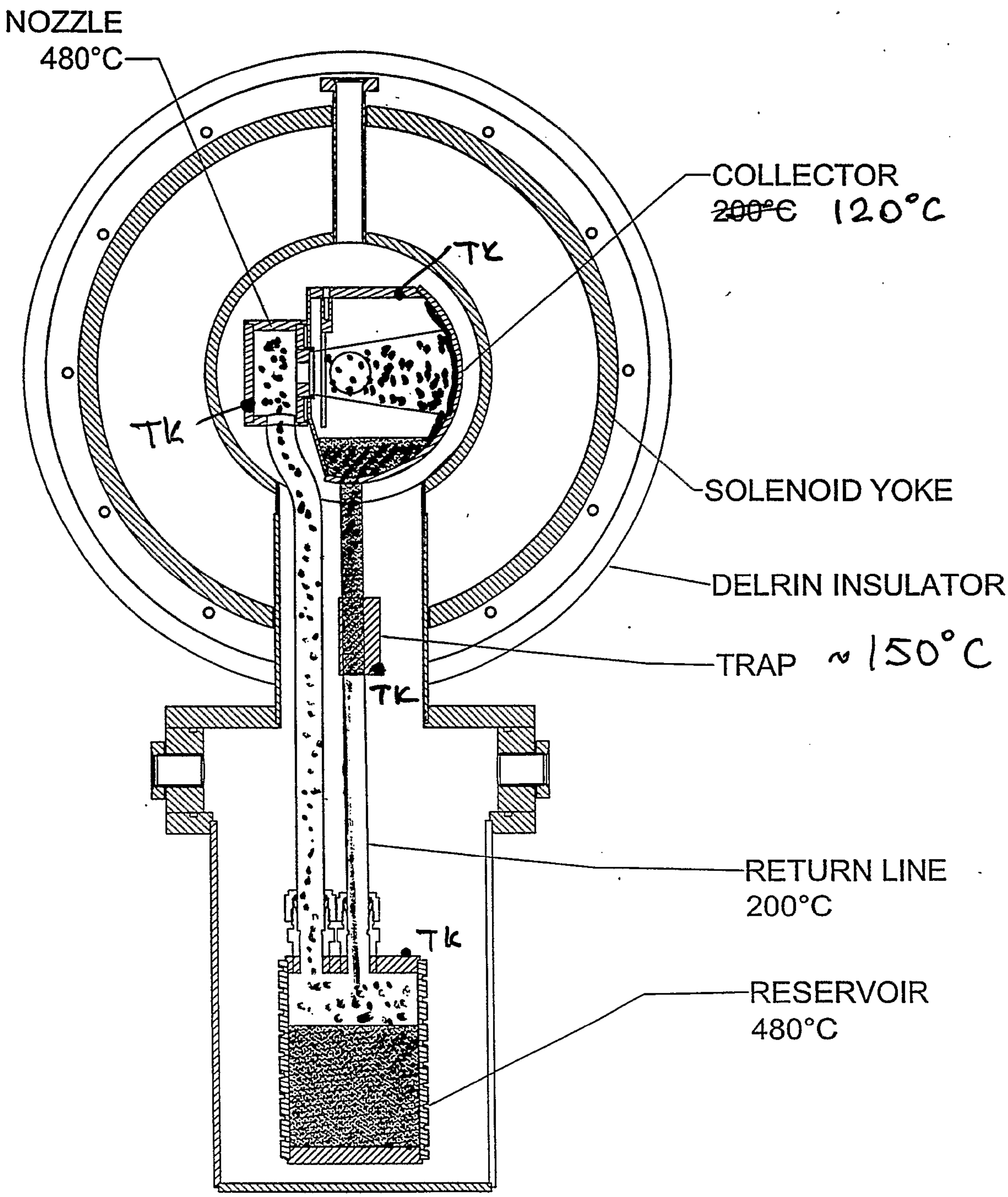
A new CPI tube EIK - VKQ2453

29.2 GHz - 1.2 kW cw



The TRIUMF OPPIS ECR primary proton source

BNL OPPIS SODIUM JET IONIZER CELL



SODIUM – JET IONIZER CELL FEATURES

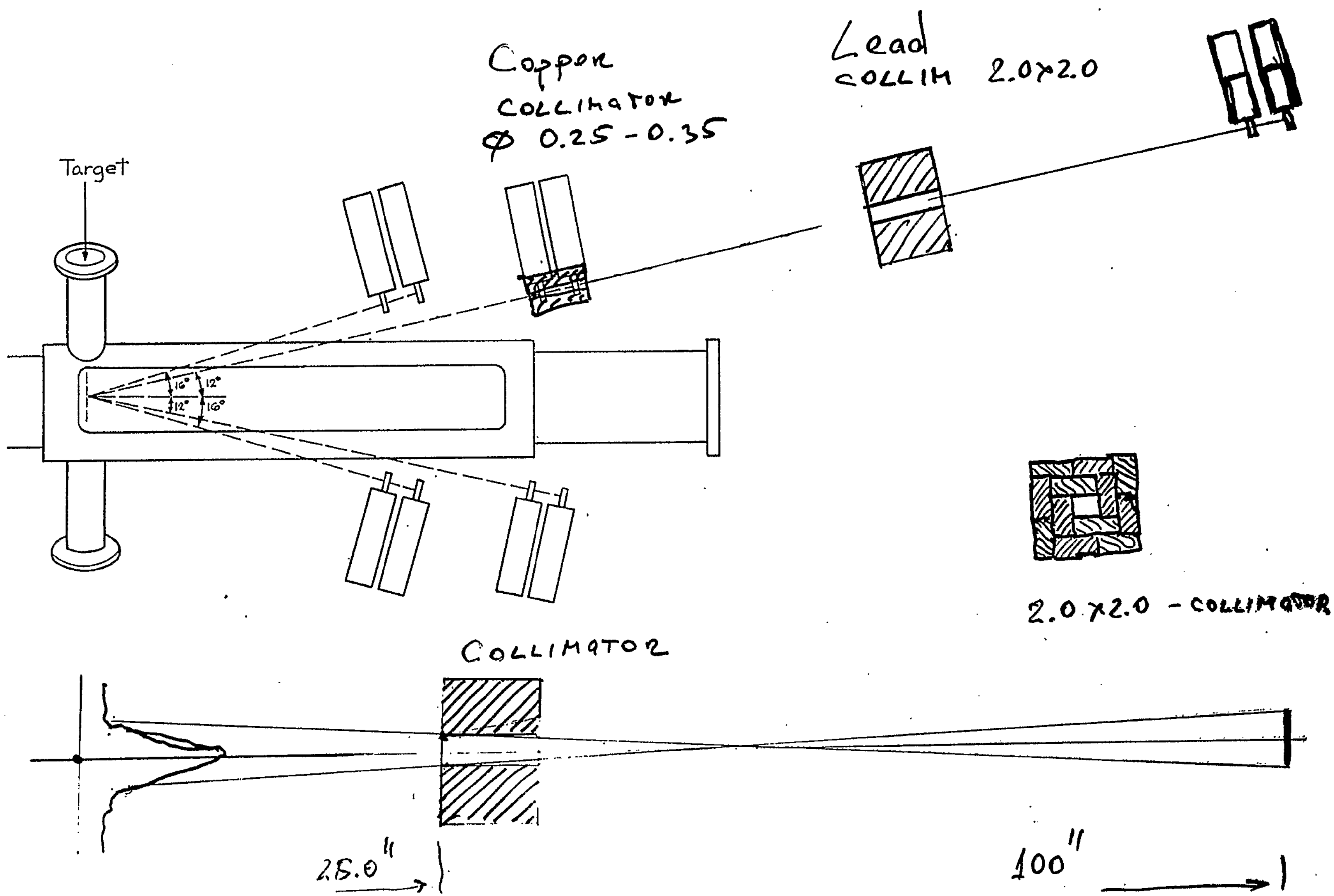
1. Low sodium losses for a large (3.0 cm) cell aperture diameter

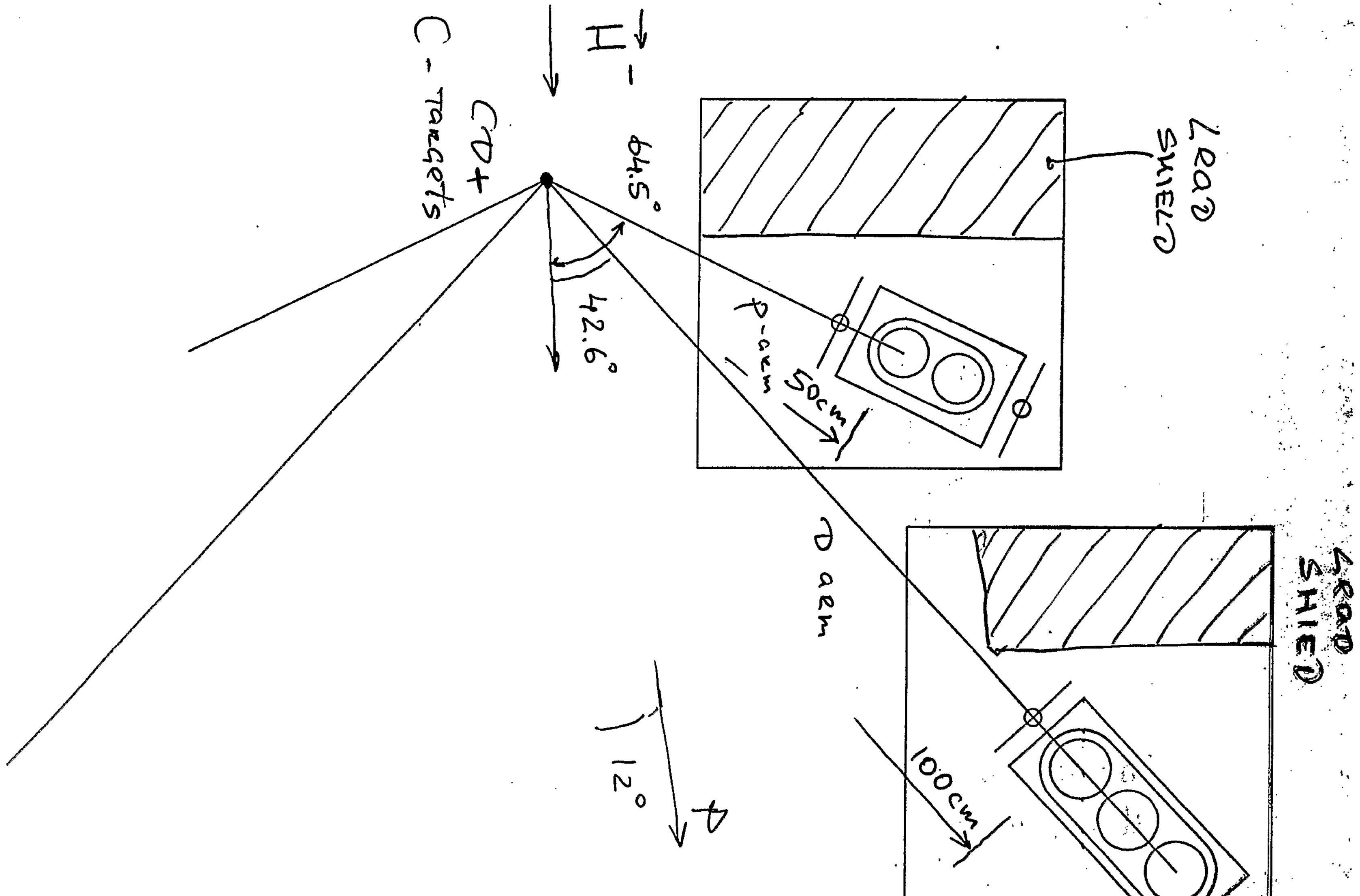
2. The ionizer cell can be biased to - 32.0 kV, for producing of a 35.0 keV H^- ion beam ready for injection to RFQ

3. The H^- polarization is higher due to:

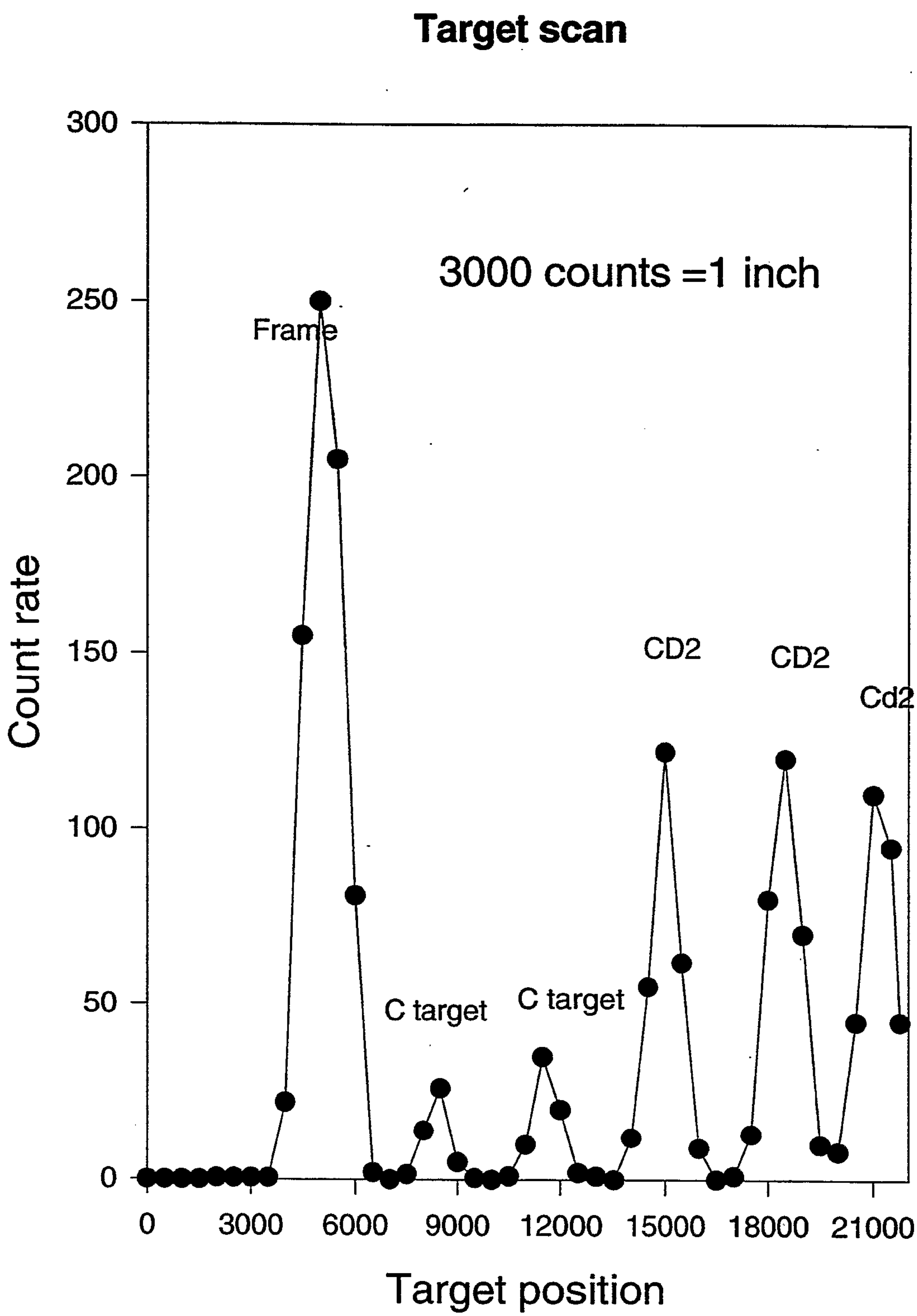
a). Na vapor is completely confined within 1.4 kG ionizer magnetic field
b). Na vapor density in the Rb neutralization cell is reduced
c). energy separation of the ions produced outside the ionizer cell
d). energy for the spin-transfer collisions can be set optimal for efficient polarization (about 3.0 keV) transfer and ionization without the current losses

200 MeV polarimeter upgrade

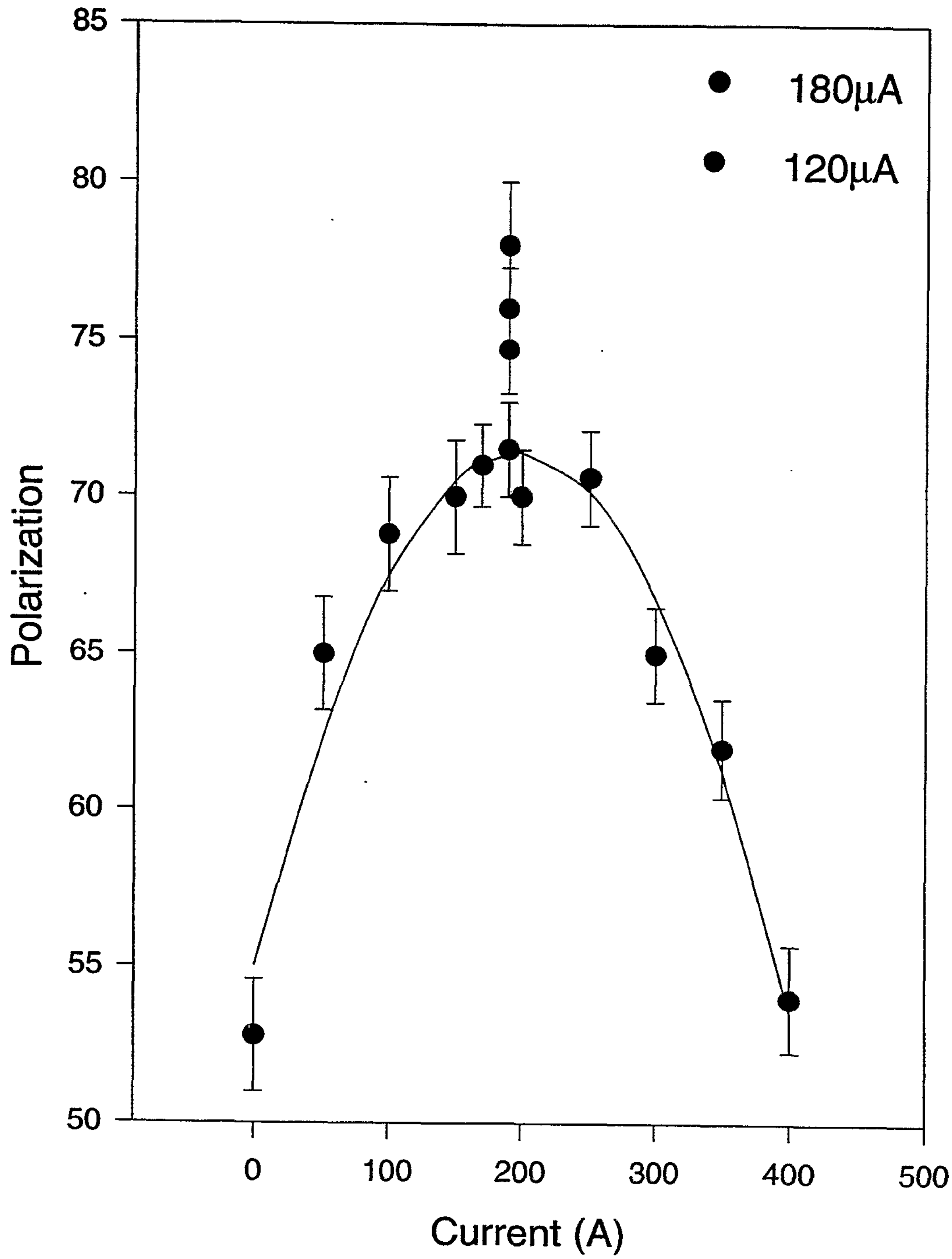




Lead shield
H-
CD + C - targets
64.5°
42.6°
p-arm
50cm
D arm
Lead shield
100cm
12°
P


Target scan
3000 counts =1 inch
Frame
C target
C target
CD2
CD2
Cd2
Count rate
300
250
200
150
100
50
0
0
3000
6000
9000
12000
15000
18000
21000
Target position

Spin-rotator **Solenoid Field Scan**



200 MeV POLARIMETER(12 degree-accidental)

STATUS:

199

PROCESSING

START | STOP | SAVE | EXIT

READING

PULSE	LEFT	RIGHT	CLK+	CLK-	POL.	ACC_L	ACC_R
57	139.0	31.0	1336.0	0.0	-0.8253833	0.0	2.0
58	49.0	97.0	0.0	1339.0		0.0	1.0
59	137.0	34.0	1336.0	0.0	-0.7592347	3.0	0.0
60	36.0	94.0	0.0	1344.0		1.0	0.0
61	136.0	40.0	1336.0	0.0	-0.8227953	0.0	1.0
62	35.0	91.0	0.0	1338.0		0.0	1.0
63	124.0	29.0	1336.0	0.0	-0.8755044	0.0	1.0
64	53.0	81.0	0.0	1341.0		1.0	0.0
65	127.0	40.0	1336.0	0.0	-0.6210239	0.0	1.0
66	41.0	92.0	0.0	1337.0		4.0	0.0
67	127.0	26.0	1336.0	0.0	-0.9273443	0.0	3.0
68	41.0	112.0	0.0	1338.0		0.0	0.0
69	108.0	40.0	1336.0	0.0	-0.7447725	0.0	0.0
70	46.0	113.0	0.0	1339.0		1.0	0.0
71	119.0	29.0	1336.0	0.0	-0.8442137	1.0	0.0
72	53.0	100.0	0.0	1338.0		1.0	1.0
73	150.0	37.0	1336.0	0.0	-0.7743603	1.0	2.0
74	57.0	109.0	0.0	1340.0		1.0	1.0
75	103.0	28.0	1336.0	0.0	-0.7323845	0.0	0.0
76	39.0	85.0	0.0	1339.0		1.0	0.0
77	113.0	37.0	1336.0	0.0	-0.735234	1.0	2.0

Left arm events (+,-): 4978.0-31.0 1844.0-38.0

Right arm events(+,-): 1340.0-44.0 3665.0-26.0

POLARIZATION (P,dP): -0.7580054 0.01333734

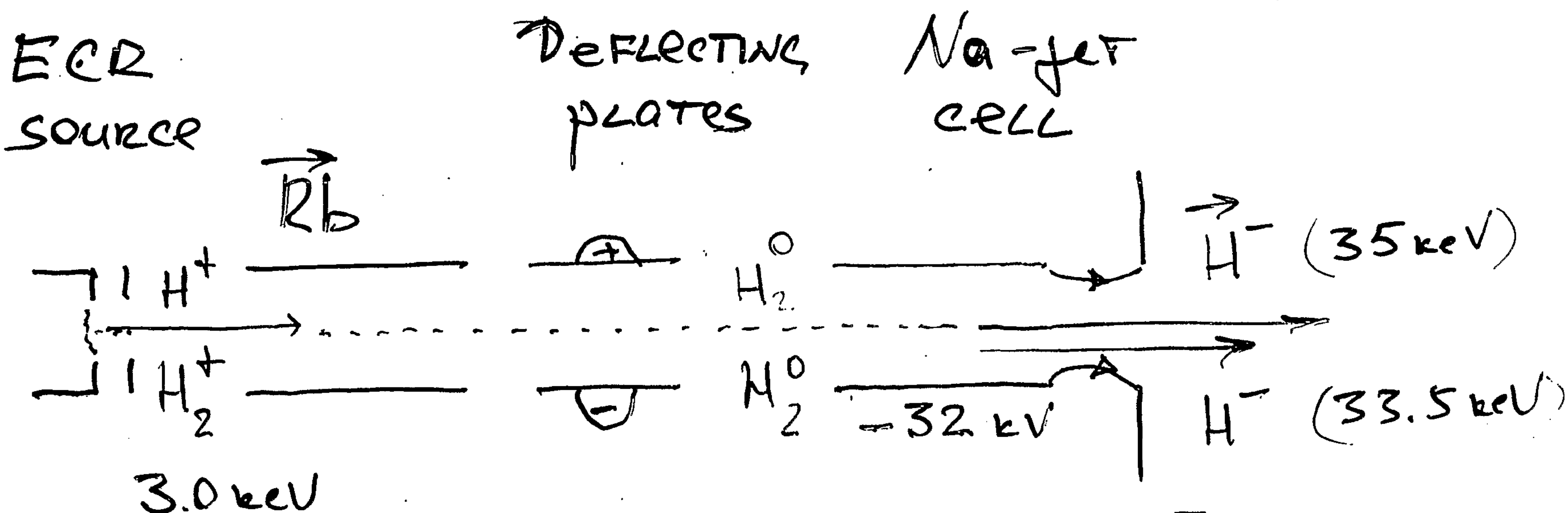
-75.8 ± 1.3

CORRECTED -82 %

RESTART

Wed Sep 26 13:56:07 EDT 2001

Polarization dilution due to molecular H_2^+ ions from the ECR source

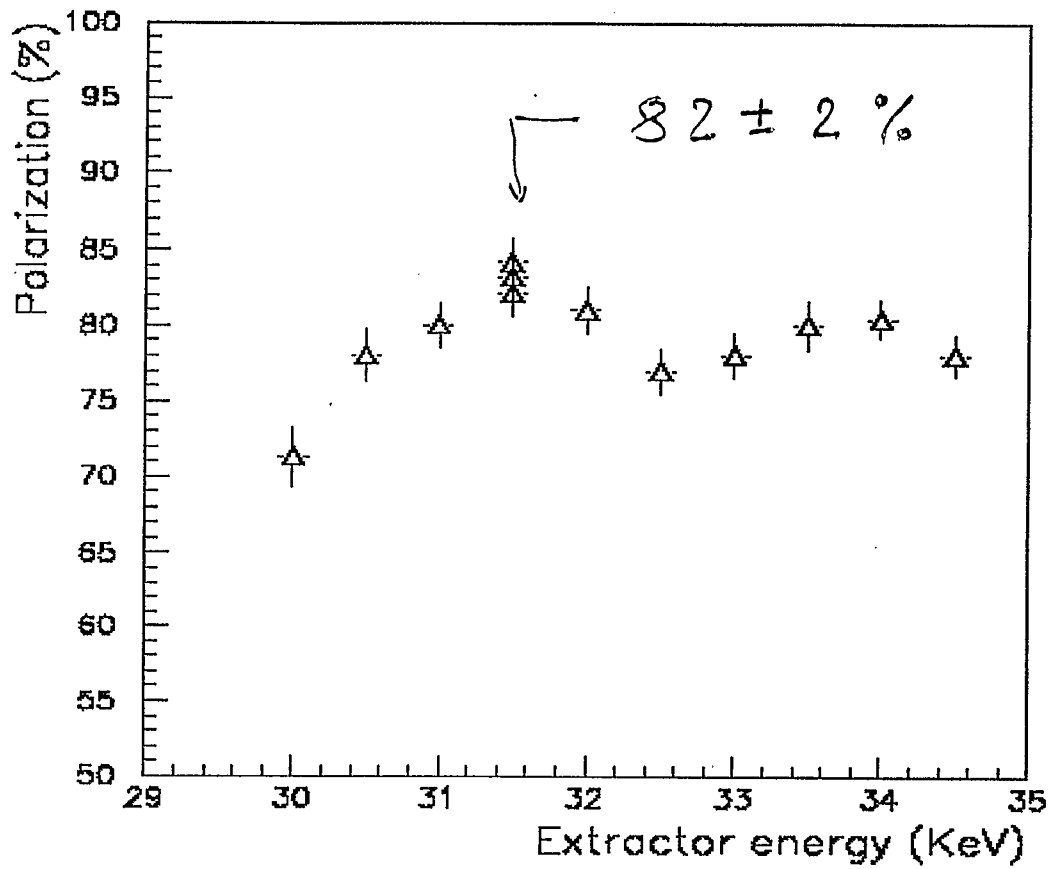


$H^0 + Na \rightarrow H^-$ (3 keV)

$H_2^0 + Na \rightarrow H^- + H^0$

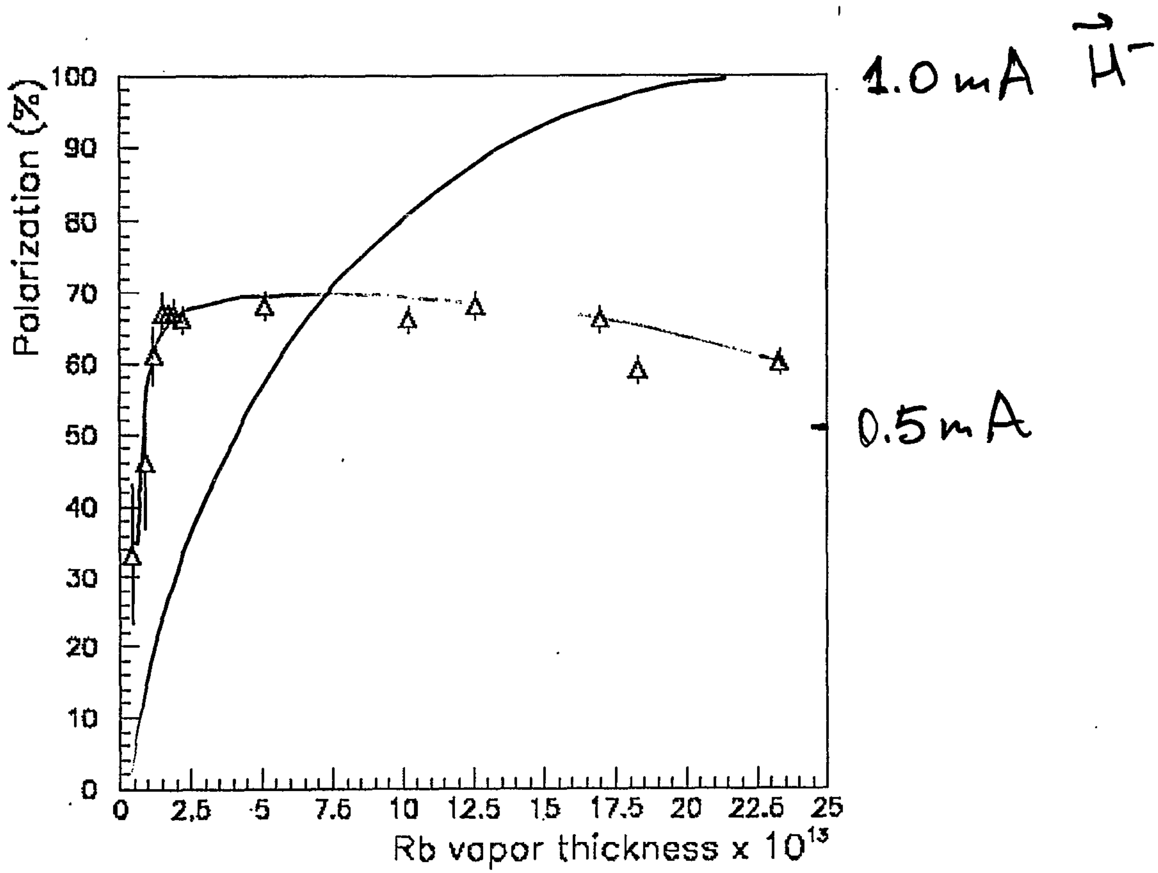
1.5 keV

$\rightarrow H^-$ 1.5 keV

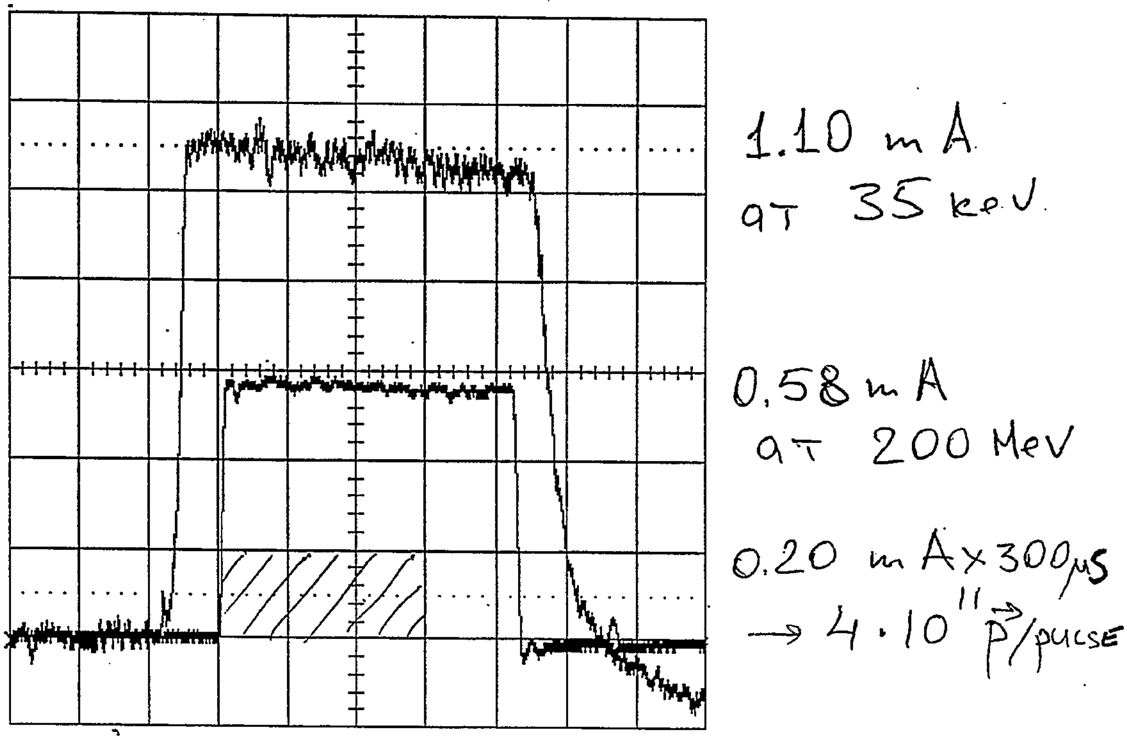


H- beam polarization at 200 MeV vs RFQ injection energy

$P_{raw} \times 1.08$



The proton beam polarization in Lamb-shift polarimeter vs the optically- pumped Rb vapor thickness



The polarized H – ion current pulse: top trace-the OPPIS beam at 35 keV energy; bottom trace – the 200 MeV beam current. A vertical scale is 0.2 mA/div, a horizontal scale is 100 us/div.

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PROPOSAL INFORMATION QUESTONAIRE

LABORATORY DIRECTED RESEARCH AND DEVELOPMENT PROGRAM

PRINCIPAL INVESTIGATOR : A. ZELENSKI PHONE : 334-8387

DEPARTAMENT : **CAD** DATE :March 22, 2001

OTHER INVESTIGATORS: J.Alessi, M.Anerella, S.Kokhanovski, A.Kponou ,
V. LoDestro, H.Huang (BNL),
V.Klenov, V. Zoubets (INR, Moscow), V. Davydenko (BINP, Novosibirsk) - collaborators

TITLE OF PROPOSAL : FEASIBILITY STUDY OF A 20-50 mA

POLARIZED H^- ION SOURCE FOR HIGH-ENERGY COLLIDERS

PROPOSAL TERM : OCTOBER 2001 TO : OCTOBER 2003

SUMMARY OF PROPOSAL

The objective of this LDRD project is a proof of principle of a very high intensity polarized $H^-(D^-)$ ion sources, based on spin-transfer collisions between atomic hydrogen beam (of a 1.0 – 5.0 keV energy) and optically-pumped alkali –metal vapors. The advantage of this technique is that atomic beam intensity is not space-charge limited, therefore an atomic H beam intensity of about 500 mA equivalent current through the polarizing cells was already demonstrated. With a 10-16 % ionization efficiency in the sodium or rubidium ionizer cell a polarized H- ion current of about 20-50 mA can be achieved (some beam losses occur in the intermediate helium gaseous ionizer and optically pumped Rb cells). Favorable results in obtaining a high (in excess of 80%) nuclear polarization in the spin-transfer collisions would finally solve the problem of a polarized beam injectors for high-energy accelerators and colliders. The first application will be the polarized beam intensity increase for future polarized RHIC luminosity upgrade and also for eRHIC proposal .

PROPOSAL FOR 20-50 mA
POLARIZED H⁻ ION SOURCE

Calibration of the 200-MeV Linac Polarimeter

E. Stephenson

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

Calibration of the 200-MeV Linac Polarimeter

E.J. Stephenson, and R.M. Toole, *Indiana University Cyclotron Facility*
H. Huang, K. Kurita, and A. Zelenski, *Brookhaven National Laboratory*

In response to concerns about the calibration of the p+Carbon scattering used routinely to measure the polarization of the 200-MeV proton beam at the BNL linac, we undertook a recalibration based on the precise analyzing powers for p+d scattering determined at IUCF. When the recoil deuteron is observed at θ=42.6E, the analyzing power is known to be A=0.507K0.002. The objective at BNL was to make a setup for the linac that would generate a clean sample of p+d elastic events. IUCF provided the target material and the deuteron arm detectors. The proton arm detectors were taken from the 16E-detectors from the p+C polarimeter.

Several modifications were made to the setup used at IUCF to handle the large instantaneous rates from the pulsed beam at BNL. Each arm (p and d) had two scintillators required to be in coincidence (4 total). In front of these scintillators, aluminum absorbers removed lower energy protons. The thickness was chosen so that the deuterons stopped in the second scintillator on that arm. Behind this scintillator, a veto scintillator was installed to remove higher energy protons. The coincidence timing between the arms was 15 ns. Thresholds were adjusted to be just under the pulse heights of the p+d events. In this configuration, a 20 μA linac beam gave a random coincident rate in this system that was 10-20% of the real p+d rate.

Figure 2 shows a cross section of the original IUCF polarimeter with only single detectors on each arm. The target was a CD_2 polyethylene foil. An absolute polarization standard was provided by double scattering using the K600 magnetic spectrometer and its focal plane detector. The resulting calibration between 80 and 200 MeV is shown also.

Figure 3 contains a scale drawing of the proton and deuteron arm layout. CD_2 foils were mounted on the target ladder drive along with a pure a pure carbon target. The calibration involved making measurements with this new setup for p+d scattering interspersed with p+C scattering at 12E. Sample data is shown in Fig. 4. Note cuts on energy. Peak sums were taken from the time spectra.

Figure 5 shows a plot of the p+C analyzing powers as a function of the laboratory angle. The solid curve is the angular distribution reported by McNaughton at 200 MeV for proton inclusive scattering. The two open points are the original calibration, completed at IUCF in 1982. At that time, mounting difficulties required that a sideways polarized beam be used, and this made an accurate transfer of the calibration from lower energy scattering from ^{4}He difficult. The errors on the original calibration are statistical only. The new calibration value for p+C scattering (A=0.576K0.013 at 12E) is shown by the solid point. This value is 8% below the old calibration, a change that will be reflected in linac beam polarizations that are higher than before. The beam current during the calibration was limited to 20 μA because of random pileup in the p+d scattering detectors. The error bar reflects the statistics obtained for p+d scattering and at present is not limited by our knowledge of the reference analyzing power.

Further improvements are possible with additional running time. This may become available during the upcoming RHIC polarized proton running period. For this, pulses from the linac could be shared with this polarimeter and the calibration taken during normal proton production running.

<u>Recalibration of 200-MeV Linac Polarimeter</u>

H. Huang, K. Kurita, and A. Zelenski -- *BNL*
R. Toole (REU student) and E.J. Stephenson -- *IUCF*

<u>Objective</u>:
Recalibrate 12☜-detector system on p+C linac polarimeter

Use p+d scattering as analyzing power standard.
(A = 0.507 ☺ 0.002 for deuteron recoil at θ_{lab} = 42.6☜.

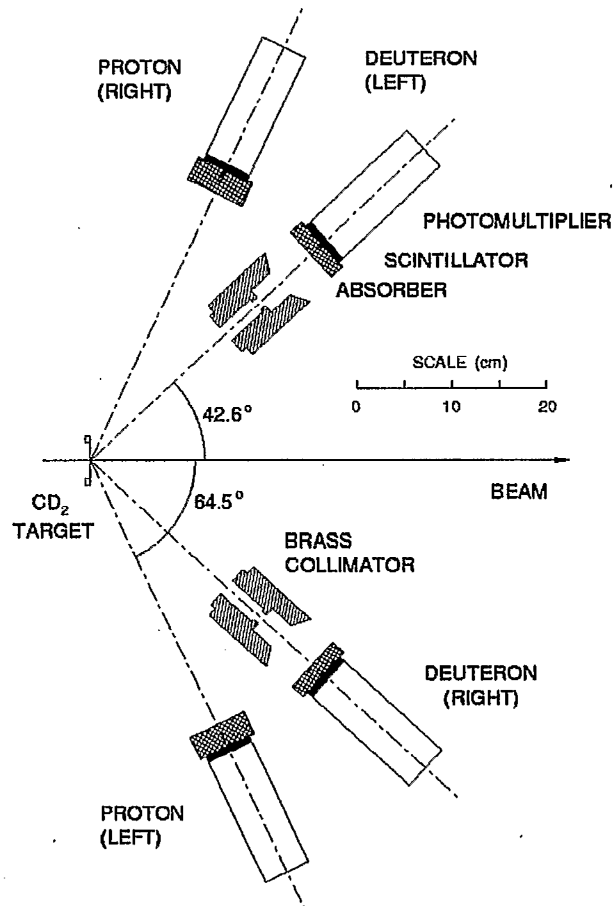
IUCF provides CD_2 target material and deuteron arm detectors.
BNL provides stands and alignment help, electronics, data acquisition.

Attempt to observe <u>clean</u> sample of p+d elastic events:
(plastic scintillation detectors)
- observe both deuteron and proton
- use multiple detectors on both arms (IUCF had only one)
  - proton arms are actually old 16☜ p+C detectors
- use one detector on deuteron as a veto
- make timing coincidence tight
- use absorbers on both arms to reduce lower energy rate
- set high thresholds on scintillators

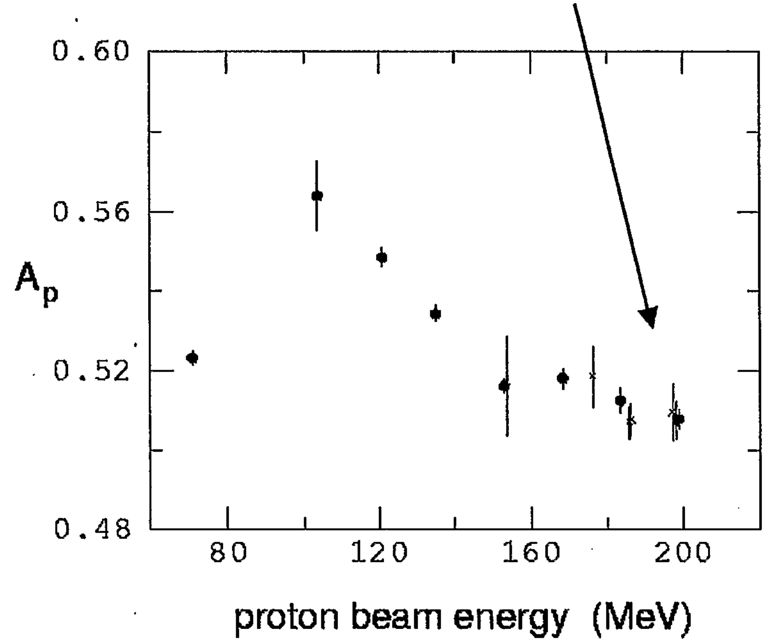
(if clean enough, count events in scalers)

Calibration of beam line polarimeter at IUCF

Polarimeter used CD_2 target and p+d elastic scattering.



The calibration made use of double scattering in the K600 spectrometer and focal plane polarimeter as the absolute reference standard. At 200 MeV, the p+d analyzing power is known to better than 0.5% absolute.

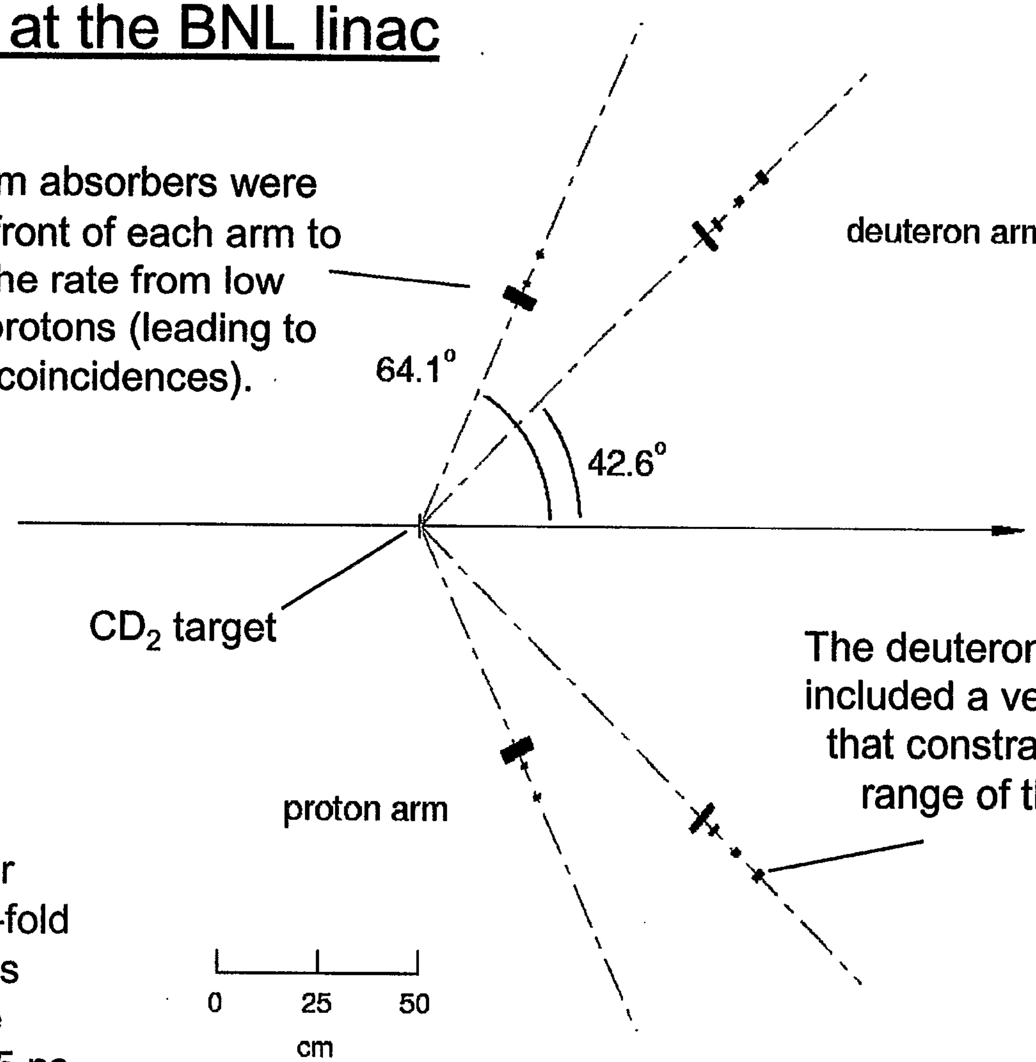


A = 0.507 ☺0.002

PLAN: Duplicate the critical geometry at the BNL linac, then set up a system to extract only p+d elastic events.

Setup at the BNL linac

Aluminum absorbers were used in front of each arm to reduce the rate from low energy protons (leading to random coincidences).

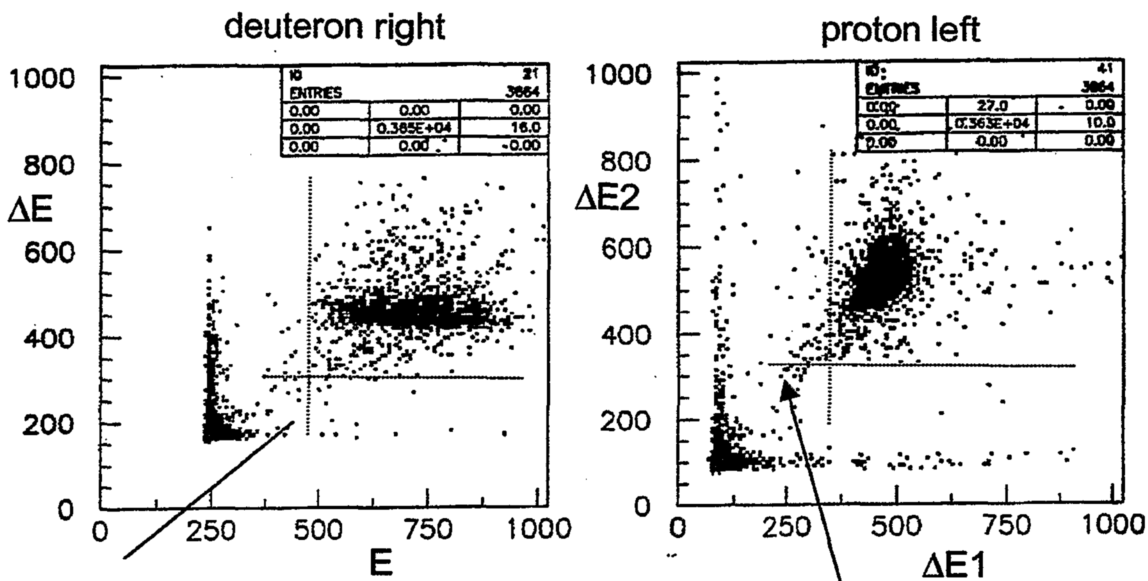


The deuteron telescope included a veto detector that constrained the range of the particles.

The event trigger consisted of a 4-fold coincidence (plus veto) with a time acceptance of 15 ns.

SAMPLE DATA

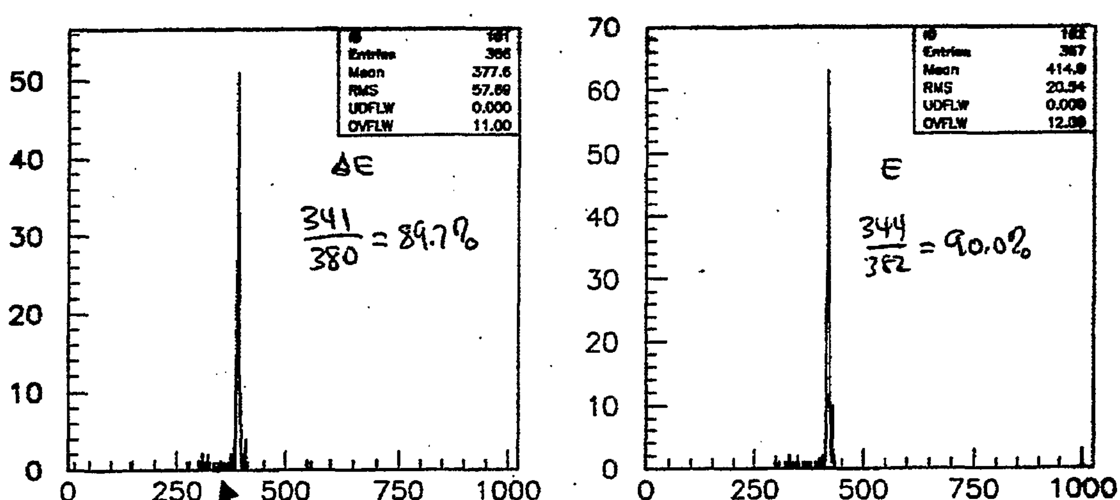
scintillator pulse heights



ADC thresholds (events at lower pulse height come from triggers on the other arms)

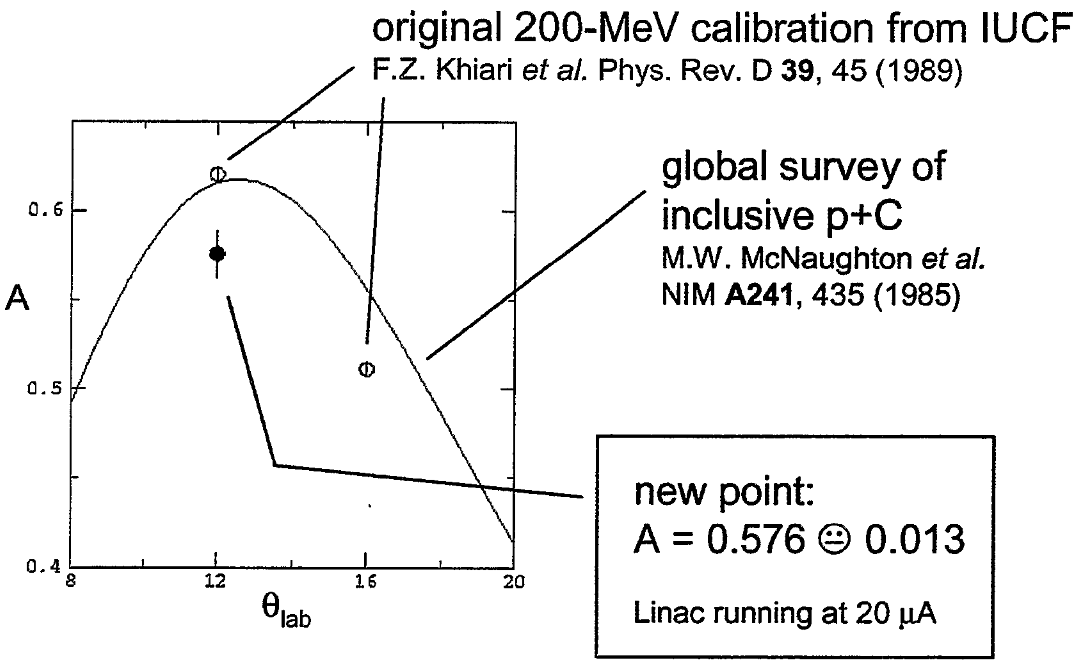
Endpoint (200 MeV) of proton locus

timing peaks for deuteron arm



random events show as tail (10%) below the peaks

Results



Other analyzing powers:

$p + CD_2$ at 12☜ 0.534 ☺ 0.012

p+d scalers 0.456 ☺ 0.010
(value depends on random rate)

Other Issues:

Improving 12☜-detector reliability: increase detector separation to remove sensitivity to nearby sources of events.

Making system operate better for larger beam currents: opens possibility to use p+d scattering during RHIC polarized running.

AGS Commissioning Plan

H. Huang

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

AGS Commissioning Plan

Status of last run:

LINAC 200MeV polarimeter: 60~70%
before extraction from AGS: 30~50%
average extracted from AGS: 33%
average injected into RHIC: 19%

New Development since last run

Source polarization reached 60~70% last year. 75% polarization has been measured at LINAC end with 180μA. See no problem to reach 75% with 200μA for the coming run.

AGS will use less powerful Westinghouse for next run. The acceleration rate will be about half of Siemens. This will have direct impact on beam polarization.

Polarization in the AGS

Problems during last run:
1. Tune setting is critical for AC dipole operation. A hardware problem prevented us from monitoring the betatron tunes constantly. (fixed).
2. Beam emittance not stable. Horizontal emittance reduced to 15π, but still have room to go further down.
3. Total of >10% depolarization at weak resonances $24+\nu_y$ and $48-\nu_y$ not touched.
4. Polarization measured at end of LINAC disagreed with measured at AGS injection.

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Update on AGS polarimeter

Install forward arms to detect inclusive p-p scattering for several low energies: $G\gamma$=4.7, 7.5, 13.5. Combined with the recoil arms, we can select elastic scattering. The hope is to solve the puzzle of injection beam polarization. The installation will be done soon.

To standardize the polarized proton operation, the E880 polarimeter will be controlled by VME modules for normal operation. The system we currently use should still be used as testing and debugging tool. The hardware has been installed.

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Spin Tracking for the AGS

Resonance	$\|P_f/P_i\|$ 5% snake, Siemens	$\|P_f/P_i\|$ 3% snake, Westinghouse
0+ν	0.9640	0.9460
24-ν	0.9864*	0.9729
12+ν	0.9863	0.9907
36-ν	0.9718	0.9870
24+ν	0.9692*	0.9357
48-ν	0.9051*	0.8294
36+ν	0.9142	0.9452
Total	73.1%	66.0%
75% LINAC	54.8%	49.5%
AtR 96%	52.6%	47.5%

* (no correction)

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Attacking the weak resonances

1.Change the quads setting around $24+\nu_y$ and $48-\nu_y$ to reduce the weak depolarizing resonance strength. The optimum setting requires move vertical tune from 8.70 to 8.83(need to confirm beam is happy with this tune setting). The consequence is that the AC dipole frequency will have to be moved. The improvement factor is 1.06. More simulation is underway. (Vahid Ranjbar)

2.Use polarized proton tune quads to correct the resonances. With 2 quads, the resonance crossing speed can be increased by a factor 2. The improvement factor is 1.04. Beam test will be done with gold beam. (Mei Bai).

3. Reduce horizontal emittance to 10π. The improvement factor is 1.04.

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AGS Performance

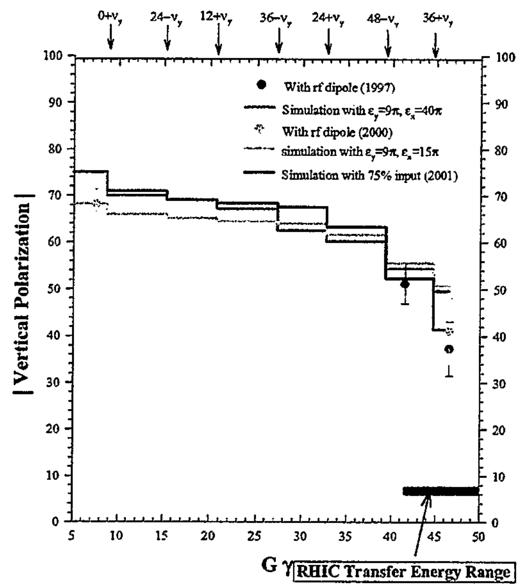
Green line: Simulation with 2000 commissioning conditions, 68% as input from LINAC.

The two expt. points:

68 +-3% at $G\gamma$=7.5;
(taken at the end of the run)

41+-7% at $G\gamma$=46.5
(averaged over 6 consecutive runs in 2 hours) .

Blue line: same beam condition except higher input from LINAC: 75% and Westinghouse.



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Polarization expectation

Machine chains	$\lvert P_f/P_i \rvert$
LINAC to AGS	100%
AGS	66.0%
AtR	96%
RHIC	100%
Total	63.4%

LINAC input 75% ------>47.5%

If better efficiency at 24+ν_y and 48-ν_y and coupling resonances achieved, the output will be higher: 50% to 55%.

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RHIC Spin Flipper Status

M. Bai

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

RHIC Spin Flipper Status

Mei Bai

Collider Accelerator Department

- RHIC Spin flipper
  - a dipole magnet with horizontally oriented oscillating magnetic field.
  - maximum magnetic field:
    100 Gauss-m, spin resonance strength:
  - oscillating frequency: 37.5 kHz
  - time for getting a full spin flip: 2seconds
  - capable of independantly achieve spin flipping in each ring.

- project status
  - Magnet:
    - DC magnetic field measurement:
      - transfer function:
        106.8 Gauss-m/kAmp
      - multipole components: < 1%
      - integral field angle: 6 mrad
    - AC magnetic field measurement:
      - 2nd & 3rd harmonic distortion: -60 dB
    - ready for installation.
    - Location : IP4

- project status
  - Electric system:
    - magnet inductance:
      - 104.96 μH @ 37.5 kHz
      - 26.362 μH @ 64.0 kHz
    - Q factor:
      - 320 @ 37.5 kHz
      - 309 @ 64.0 kHz
    - 6 kwatt power supply testing done
    - cap-bank assembly done
    - vertical testing

- project status
  - Control system:
    - Front end computer installed
    - PA remote control PLC in progress.
    - Programing the Lecroy scope for digitizing magnet current readback done.
    - Application ready for integrated testing.

- schedule
  - magnet installation:
    - estimated time for installation: 2 -3 shifts
    - between Oct. 1 and Oct. 15
  - system review:
    - before Oct. 15
  - system testing:
    - second week of Oct.
  - Power supply and cap-bank installation:
    - estimated time for installation: 1-2 shifts
    - after Oct. 15

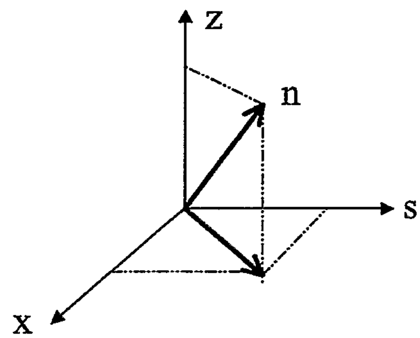
- commission the RHIC spin flipper
  - at injection
    - with both snakes
    - move the spin tune away from half integer by tunning the two snakes' axis slightly away from being perpendicular.
    - Slowly ramp the spin flipper frequency across the spin tune and measure the beam polarization after the frequency ramping.
  - At storage:
    - with both snakes
    - with one snake

- application of the RHIC spin flipper
  - flip the spin direction for reducing the systematic error.
  - measure the spin tune:
    - slowly move the spin flipper frequency towards the spin tune and then let the induced spin resonance be on top of the spin tune.
    - measure the beam polarization
    - the spin tune=

• in the frame which rotates at the same frequency as the spin flipper's frequency, the stable spin direction is

$$\hat{n} = \frac{\delta}{\lambda}\vec{e}_z + \frac{\varepsilon_1}{\lambda}\vec{e}_x + \frac{\varepsilon_2}{\lambda}\vec{e}_s$$

$$\lambda = \sqrt{\delta^2 + \varepsilon_1^2 + \varepsilon_2^2} \qquad \delta = \gamma_m - \gamma_s$$



RHIC Spin Collaboration Meeting
Oct. 1, 2001

Spin Tracking for Spin Run2001

(Spin RHIC Collaboration Meeting VI, BNL Oct 1,2001) *

A.U. Luccio, Brookhaven National Laboratory, Upton, NY

October 3, 2001

1 General Strategy. RHIC with errors

During Run2001 we plan to inject polarized protons in both rings of RHIC, accelerate them to an energy of approximatively 100 GeV and make beams collide. We want to produce a polarization state either transverse or longitudinal in all interaction regions.

Since in each ring we have installed two Siberian Snakes but there will be no spin rotators yet, to produce longitudinal polarization at the IR's a possible strategy is to gradually turn off one snake in each ring, as shown by Waldo MacKay in a contribution to this meeting. With this, the spin orientation rotates adiabatically from the vertical to the longitudinal at all IR's if the proton spin tune $G\gamma$ is kept constant to a value multiple of 3. For this exercise we have chosen a value $G\gamma = 192$ that corresponds to a proton energy close to 100 GeV. A possible (optimized) path to produce this effect is shown in Fig.1, where the spin rotation angle μ and the axis of spin precession angle ϕ in both snakes are shown as a function of turn number. Along this path the currents in the two pairs of helices that constitute each snake are kept within allowed limits.

In the following we show results of spin tracking with the code *Spink*. The used RHIC configuration is the closest to the actual machine, that includes position errors in all elements. To create an input file for *Spink*, *MAD* reads the database containing the measured values of the displacements of all elements, using the *Doom* protocol. The machine is shown in Fig.2.

For non polarized beams a good orbit correction in a lattice affected by errors is normally obtained when the orbit is forced to pass as close as possible through the centers of the machine quadrupoles. For polarized particles, that behave as gyroscopes, it is instead more effective to correct the orbit on the absolute horizontal plane, as shown in the figure. The correction within 0.2 mm is being calculated by *MAD* using the *Micado* algorithm.

*Work performed under the auspices of the U.S.Department of Energy.

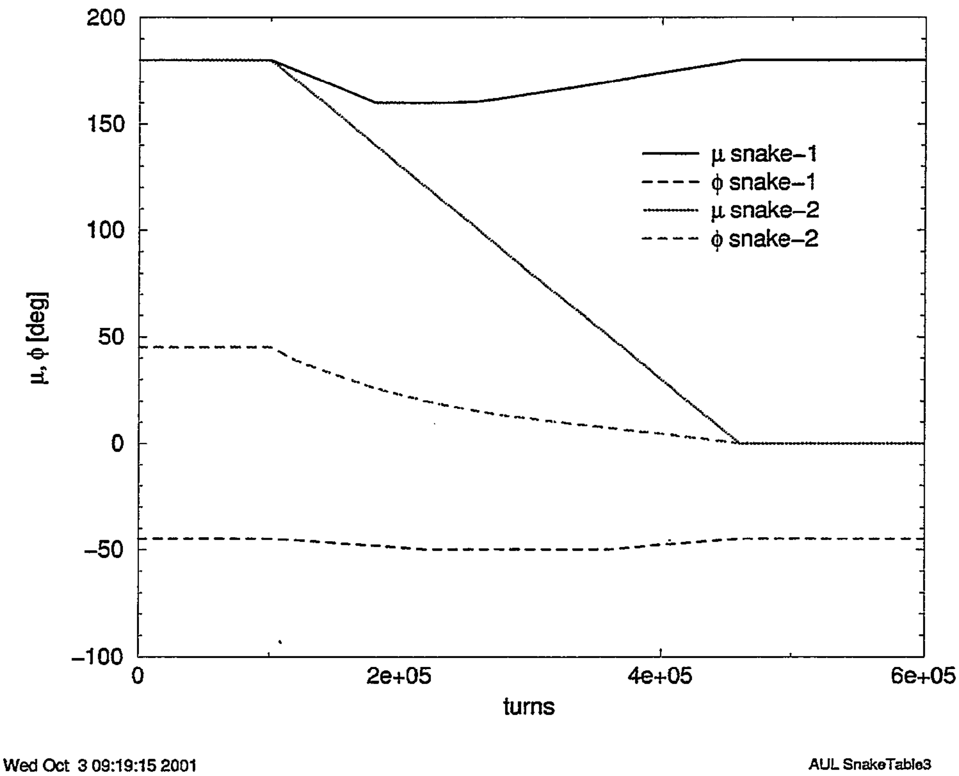


Figure 1: Snake Table 3. Spin precession angle μ and axis angle ϕ for Run2001

2 Scanning the tune space

An example of successful Spin tracking in shown in Fig.3. The figure shows the three components of the spin S_x (radial), S_y (vertical) and S_z (longitudinal) at the IR's CLOCK6 (STAR) and CLOCK8 (PHENIX). For this tracking one particle has been brought and then stored for 60,000 turns at an energy equivalent to $G\gamma = 192$. The initial particle spin was oriented along the stable spin direction (sensibly vertical). During storage Snake 2 is turned gradually off and Snake 1 is maintained close to its initial setting of $\mu = 180^0$ and $\phi = -45^0$.

As shown, the spin rotates from the initial vertical orientation to the final longitudinal orientation. The noise of the spin curves are due to the imperfections of the lattice.

The polarization will be continuously measured at POLAR, a location close to CLOCK12 (within 2% of the ring circumference). When the spin is oriented longitudinally at the IR (CLOCK) locations, its radial component S_x, measured at POLAR, reaches a value of ≈ 0.55. Fig.4 shows the result at POLAR for the "good" case of Fig.3.

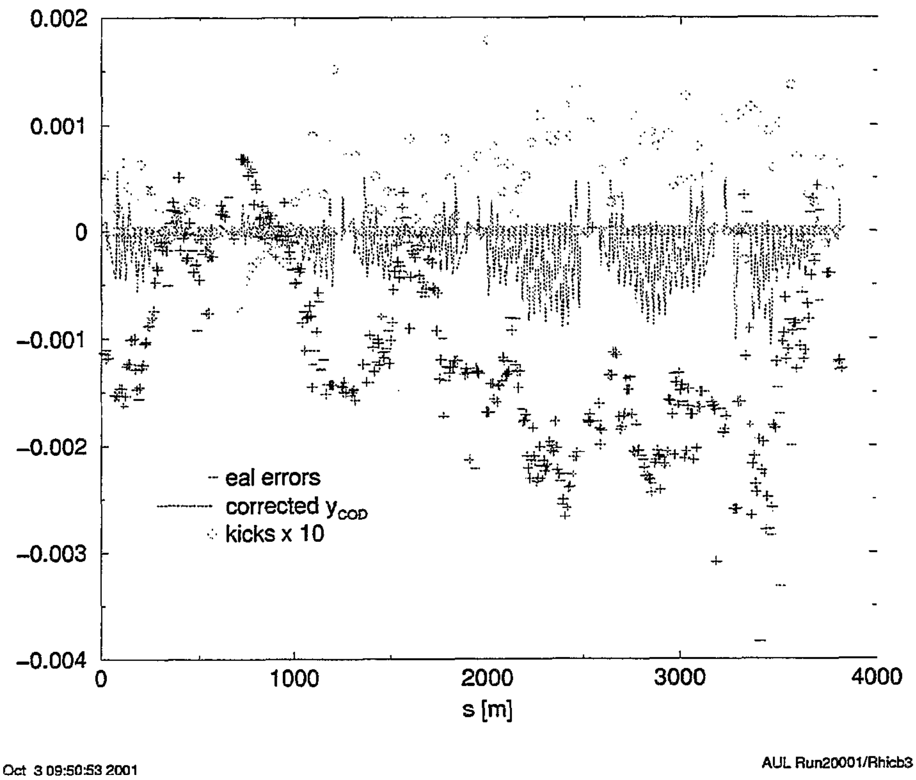


Figure 2: RHIC with errors. Measured vertical displacement errors are shown with crosses. The orbit has been corrected by *MAD* with *Micado* to the absolute horizontal. Corrected orbit and corrector strengths are also shown

In the same figure we show the spin tune of the particle under the action of the snakes. The value of the spin tune, calculated from the trace of the spin matrix for one complete spin turn (i.e when the particle returns to its starting position in the orbital phase space), is 0.5 with two snakes at the beginning of the tracking and returns to 0.5 with only one snake at the end of the tracking. In-between, the spin tune reaches lower values, ≈ 0.45 for the present energy equivalent to $G\gamma = 192$. When the spin tune is not constant at 0.5, i.e. when we temporarily operate with a full snake and a partial snake, combinations of the spin tune with the betatron tunes of the particle in its orbital motion may create spin instabilities. It is then imperative to explore the betatron tune space to find where conditions are adequate to preserve spin polarization.

Fig.5 shows a few results of spin tracking at POLAR for different values of the betatron tunes. In the figure, case #402, corresponding to the example of Fig.4 above is one of the good ones, while case #338 and #408 are bad. The former seem to show a spin depolarizing resonance when the sum of the betatron

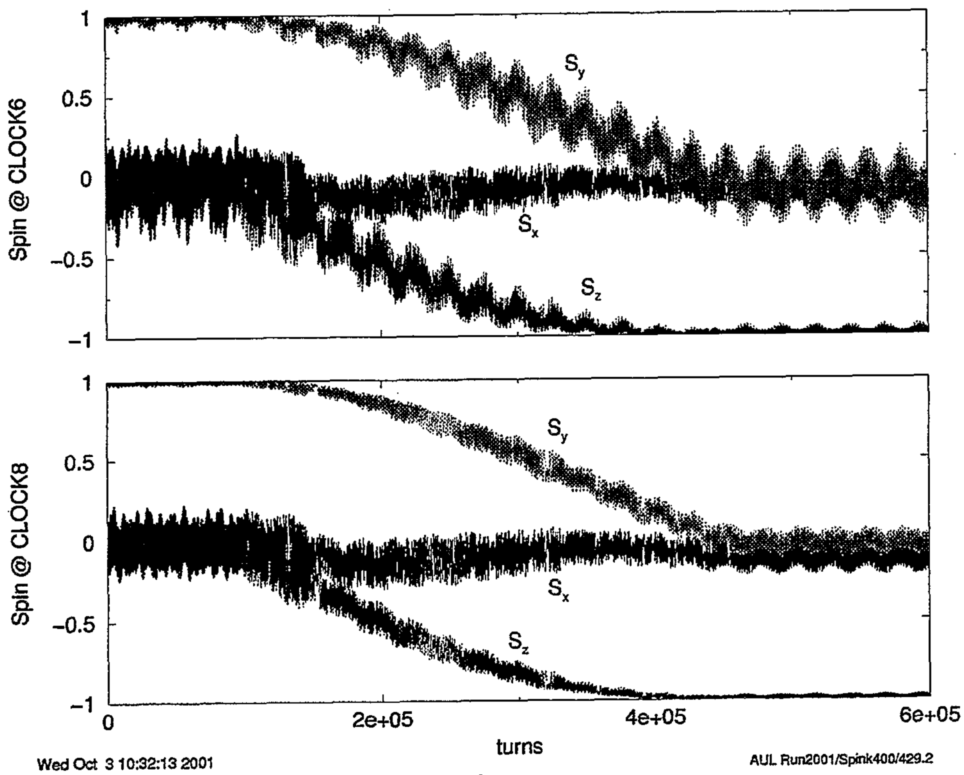


Figure 3: Components of the spin at two IR's. Track one particle on a phase contour of 10π mm-mrad for 60,000 turns at $G\gamma = 192$. Use Snake Table 3

tunes is equal to the lower average value of the spin tune and the latter when the sum of the two tunes crosses the spin tune curve twice.

Fig.6 shows a betatron tune landscape with good and bad cases. Full dots represent bad cases. Empty circles represent good cases. Three lines delimit regions. For points above the upper horizontal line the vertical tune alone interferes with the spin tune curve of Fig.4. The diagonal curve represent the sum of betatron tunes $\nu_x + \nu_y = const$, where the constant is the deepest point reached by the spin tune curve. Tune values in the region in the right upper corner of the chart above this line are unstable. The lower horizontal line represent $\nu_y = 1/6$ a notoriously unstable band for spin for a machine with periodicity 6.

Fig.7 shows a zoomed-in area of Fig.6, around tunes that best seem to suit RHIC. The "good" case described at the beginning in Figs.3 and following is labeled as case #402 on this plot.

All tracking examples so far assumed that the snake gymnastics at $G\gamma = 192$ could be done in 60,000 turns. This is hardly realistic for the ramping

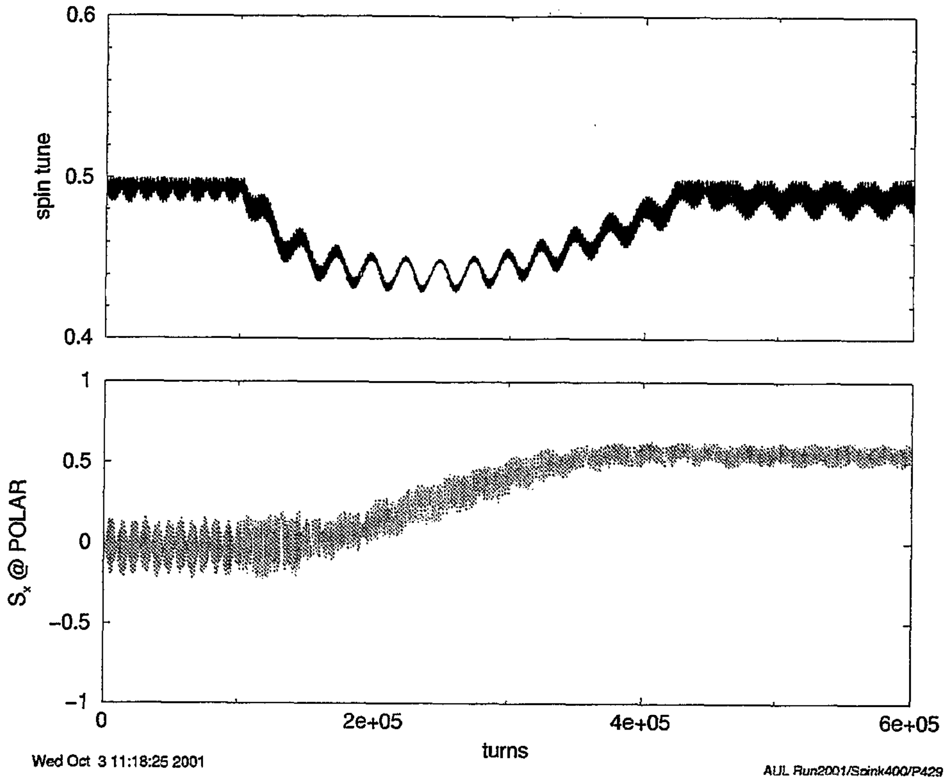


Figure 4: Spin Tune and radial component of the spin at POLAR for the conditions of Fig.3

capabilities of the present snakes and power supplies. If spin resonances are present, the growth rate of the resulting instabilities and the final value of the polarization depend on the speed of resonance crossing. It is then important to examine in deeper detail and with a slower tracking rate some of the good candidates. Fig.8 shows the same tracking of case #402(at POLAR) in 60,000 turns compared with tracking at 6.10^5 and 6.10^6 turns. *Spink* is symplectic enough to deal with a few million turns in RHIC without showing any non physical growth of emittance. The latter number, 6 million of turns is of the same order of what can be realistically achieved, and shows clearly the onset of some instability in the polarization (this tracking took about 32 hours on a 1.5 GHz Linux Box).

More systematic work is in progress.

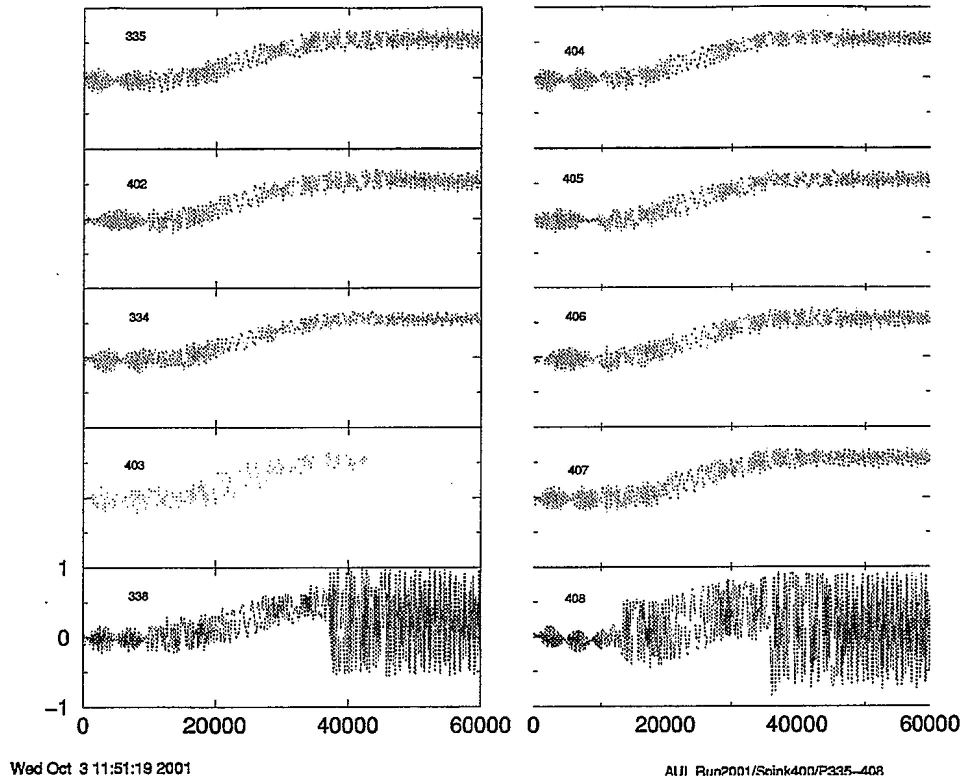


Figure 5: Radial component of the spin at POLAR for various betatron tunes

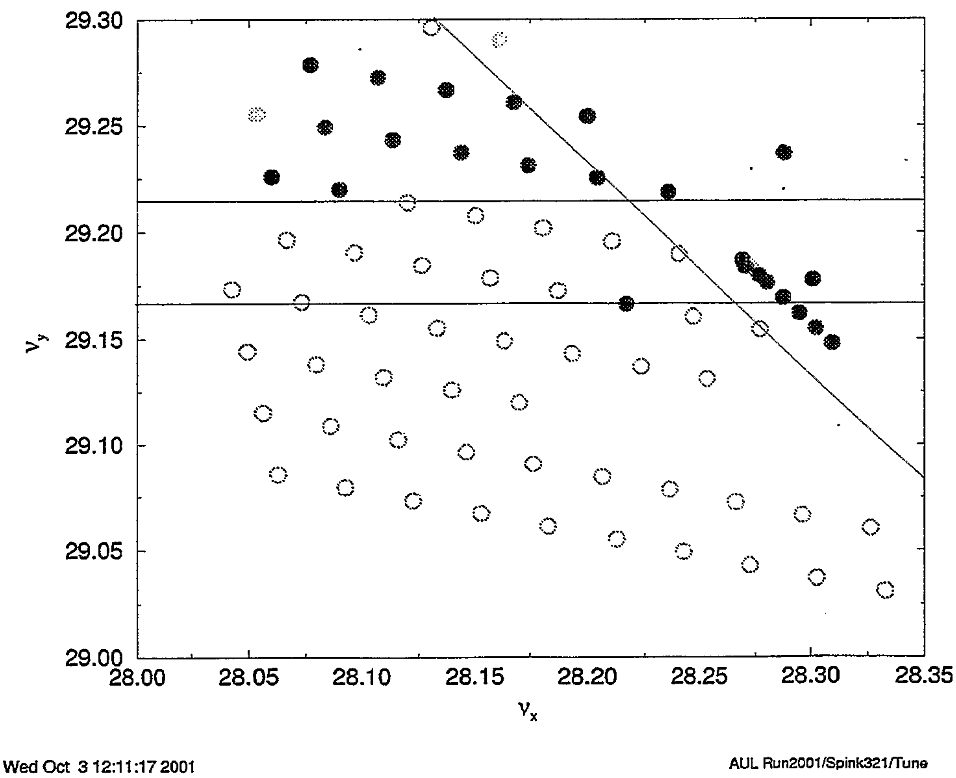


Figure 6: Chart of the betatron tune for spin stability in Run2001. Full dots are unstable cases, empty circles are good cases

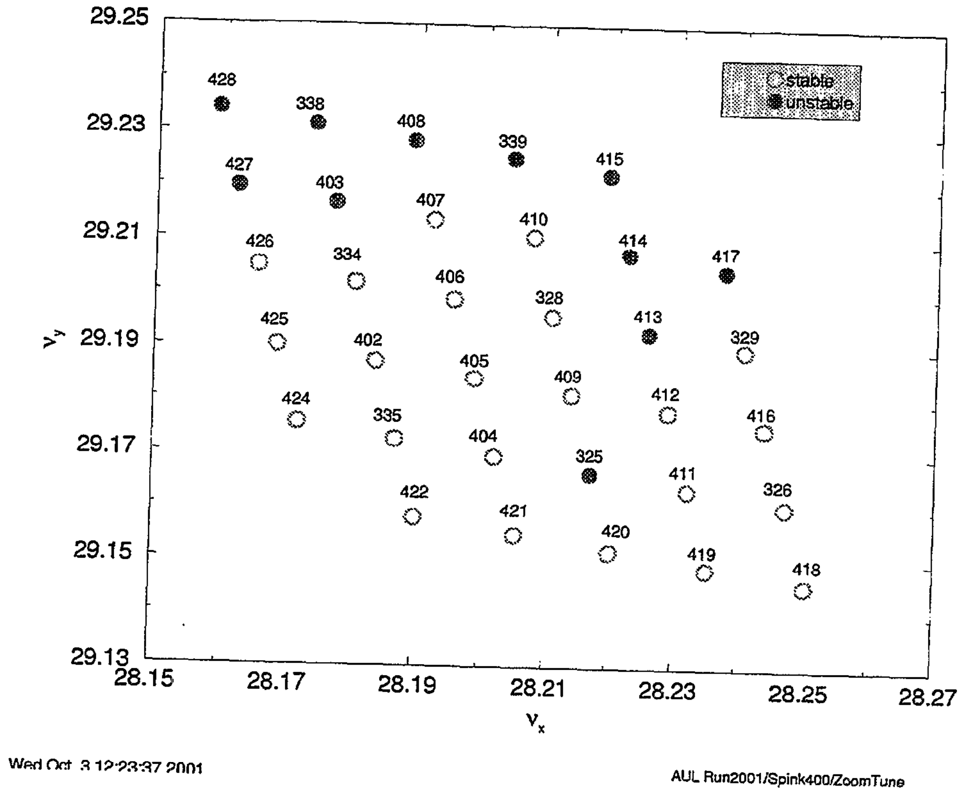


Figure 7: Zoomed-in Chart of the betatron tune for spin stability in Run2001

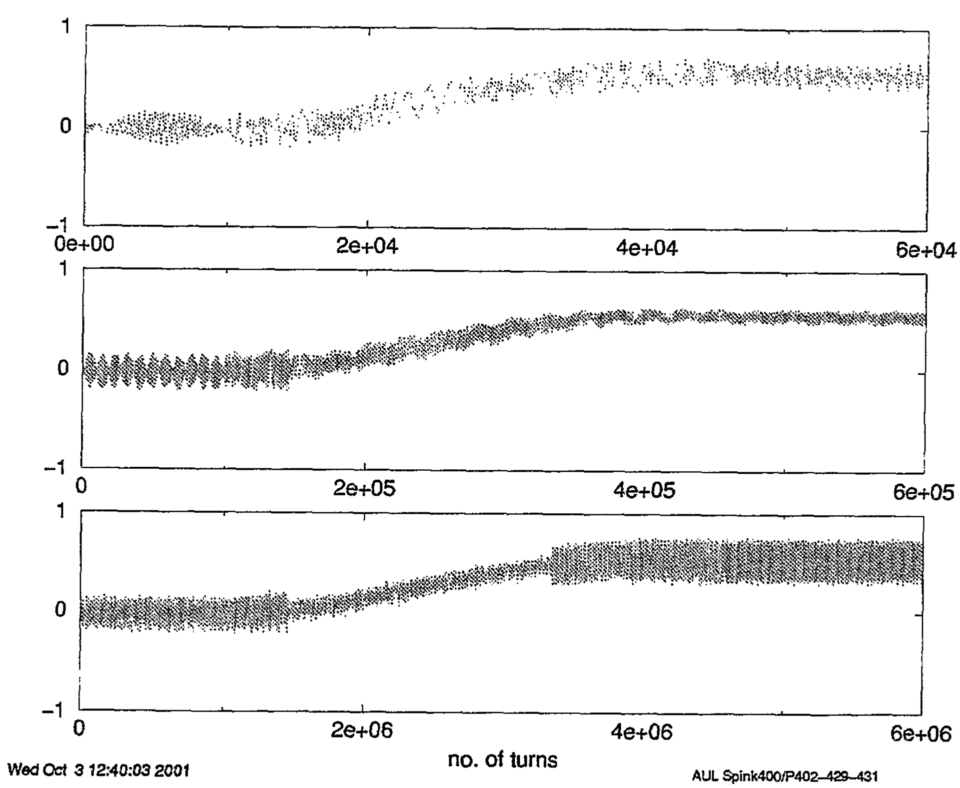


Figure 8: S_x at POLAR for Case #402 with snakes being ramped at different rates

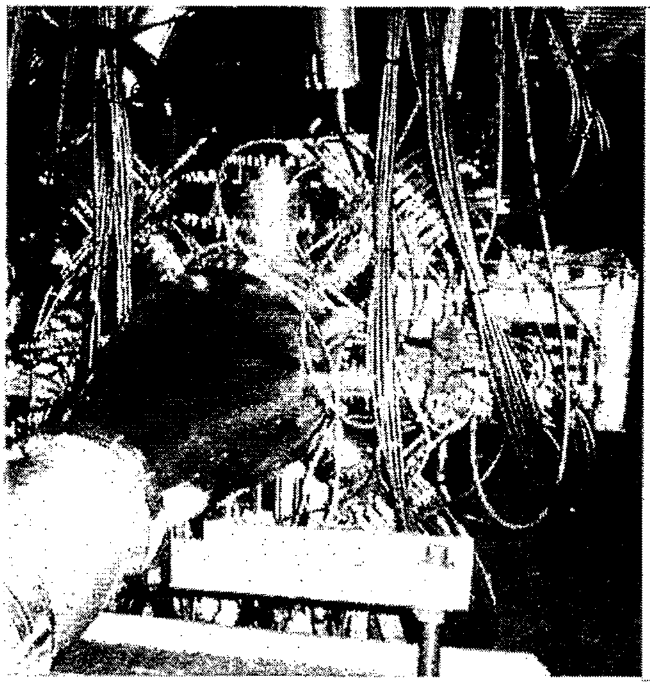
RHIC Polarimeter Updates

D. Svirida

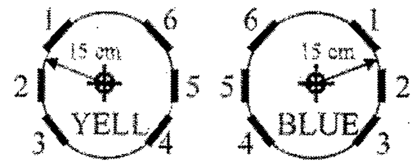
RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

Current Status

RSC Meeting VI



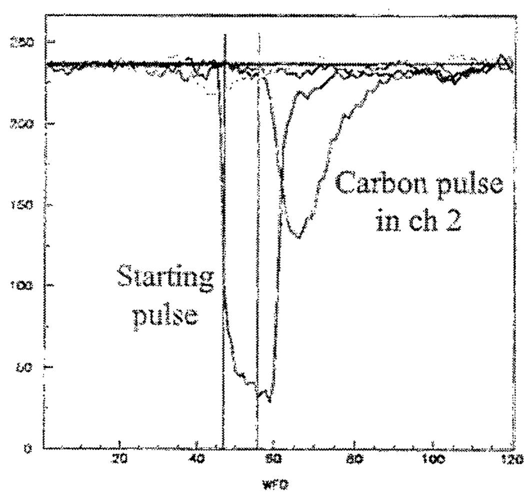
- WFD idea proved working during 2000 fall run (V1)
- 12 Si detectors mounted in the tunnel in both rings Apr 2001

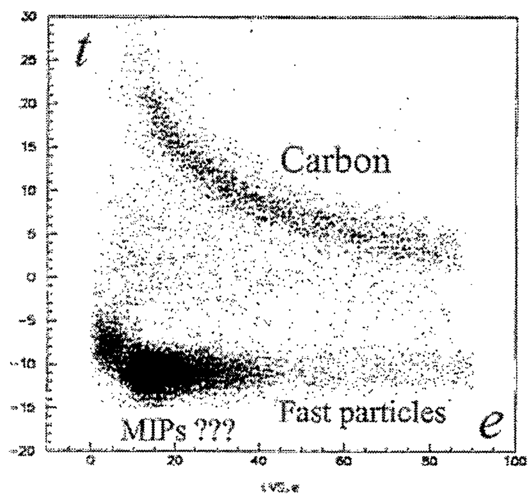


- Cabling and preamps tested along with WFD V2 Apr 2001
- WFD configuration V5 developed and tested with pulser
- 6 WFD modules working, 2 assembled, 4 expect next week (new PCB version)
- Expect to have 48 channels this year

Test of WFD idea

RSC Meeting VI



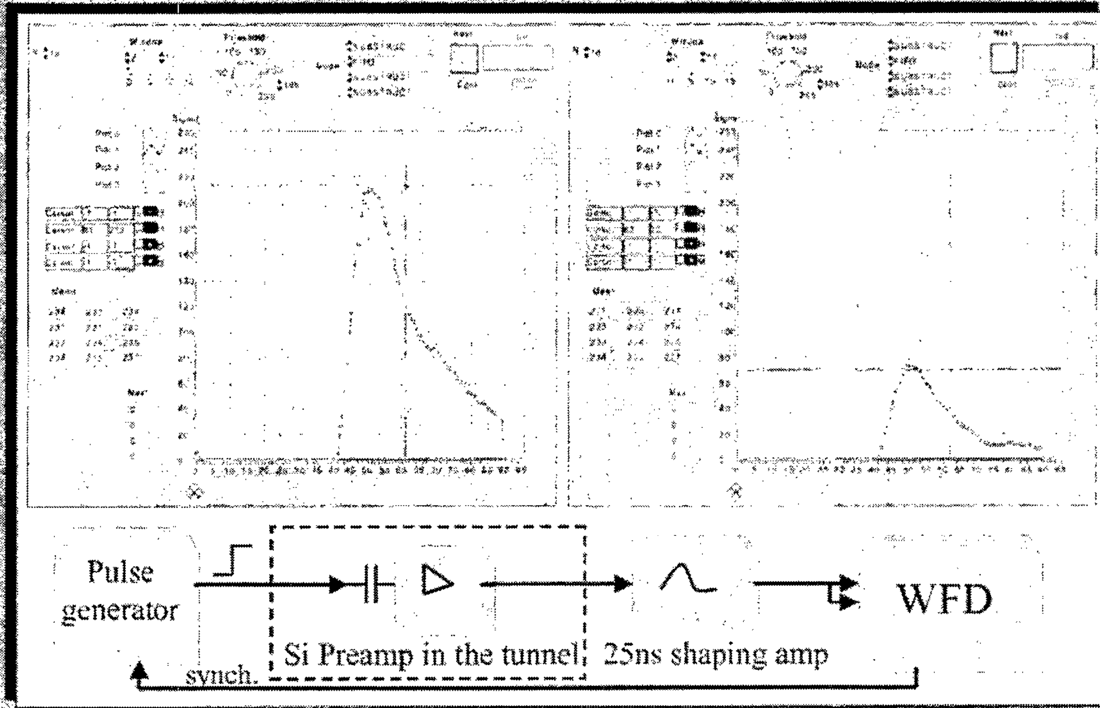


- 1 WFD module V1, 4 channels
- Common external trigger, 3 chans relative to reference pulse on ch. 4
- Waveforms read to PC

- Off-line event reconstruction

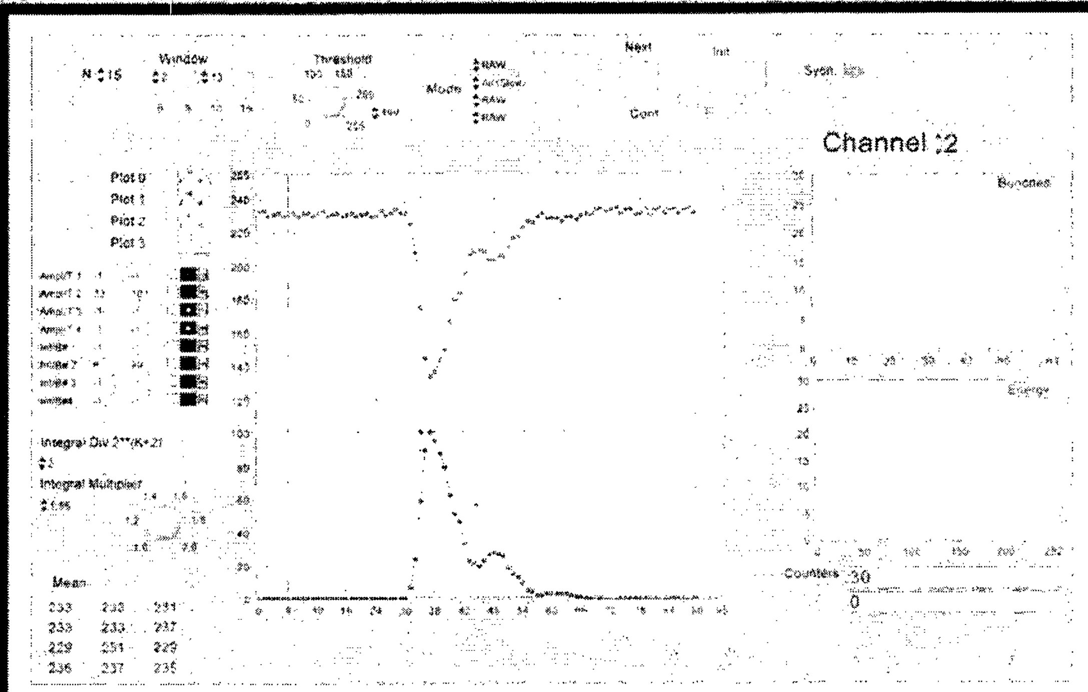
Detector and WFD V2 test

RSC Meeting VI



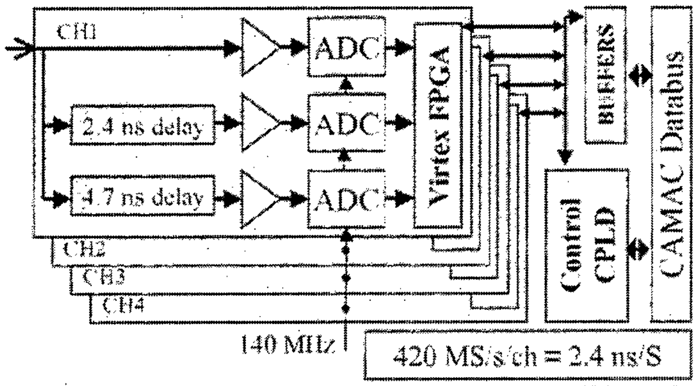
WFD V5 test

RSC Meeting VI



WFD Block Diagram

RSC Meeting VI



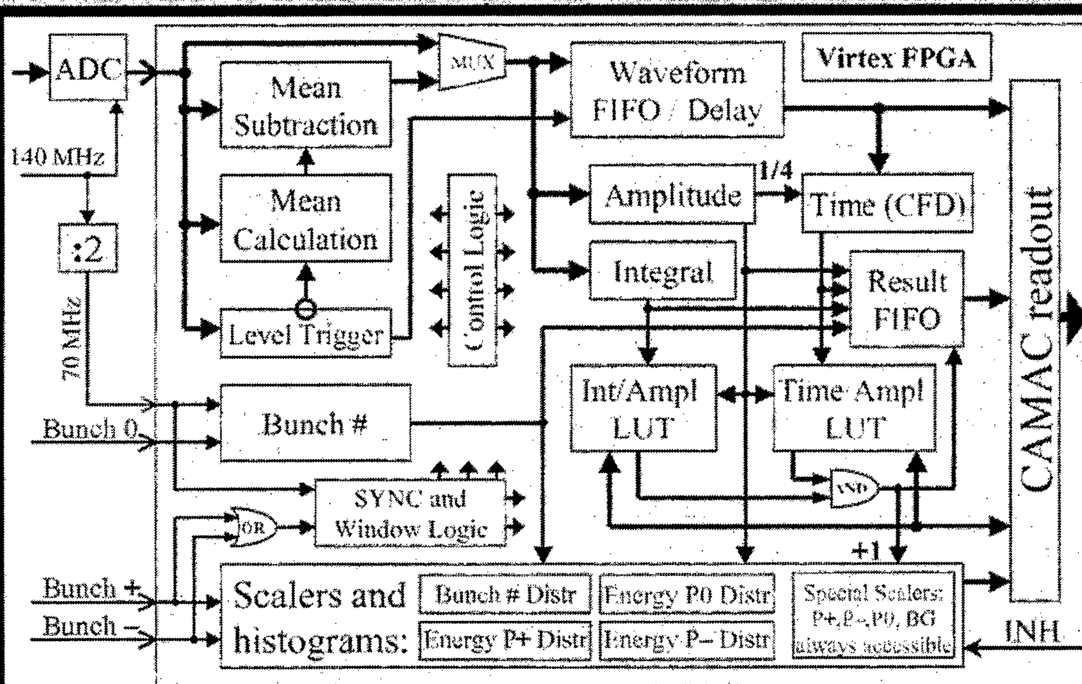
Mode	FIFO, ev	Bytes/ev	Max ev/s	Note
RAW	16	90	3*10⁴	Debug
WAVEFORM	16	90	3*10⁴	Debug
RESULT	256	4	7*10⁵	Test/Run
BOTH	1	92	3*10⁴	Test
SCALERS	–	0	:	Run

Expecting rate: 10^7

- ✓8-bit amplitude and integral
- ✓ 2.4 ns time resolution
- ✓ Bunch # information
- ✓ Windowed sensitivity
- ✓ Noise reduction
- ✓ Time/amplitude LUT
- ✓ Integral/ampl LUT
- ✓ LUTs programmable trough CAMAC
- ✓ 5 always accessible scalers (P+,P–,P0, 2*BG)
- ✓ 60 ch bunch distribution
- ✓ 3*64 ch amplitude distributions for P+,P–,P0
- ✓Crate INH stops scaling
- ✓ Zero deadtime
- ✓ Flexible FPGA configuration

FPGA Block Diagram

RSC Meeting VI



Commissioning and Run

RSC Meeting VI

Commissioning

- With real carbon signals compare parameters calculated ON-BOARD with those calculated by various OFF-LINE methods using the waveforms ("BOTH" mode)
- Energy calibration

Run

- EITHER: Get some events with LUTs fully open to determine carbon cuts ("RESULT"), then program LUTs
- OR: Get some events with wide LUTs to get the luminosity information = "figure of quality" ("SCALERS")
- Get main statistics ON-BOARD ("SCALERS")
- Read out scalers/histograms.
- Calculate average and bunch by bunch polarization:

$$\min S^2 = \min \sum_{\substack{i=1,M \\ j=1,L}} \left(N_{ij} - \sigma_0 \cdot I_i \cdot C_j \cdot \left(1 + A_{pC} \cdot P_i \cdot \sin(\alpha_j - \varphi)\right)\right)^2,$$ where:

N_{ij} – count of j-th strip in i-th bunch;
I_i, P_i – i-th bunch intensity and polarization;
C_j, α_j – j-th strip acceptance and angle;
φ – polarization vector angle.

$2 \cdot M + N$ parameters
$M \cdot N$ measurements

To Do List

- Transfer the FPGA design to the new version of the PC board and test new modules
- Finish with *5 frequency multiplier and V124 signal fanouts
- Develop and debug the software for commissioning and running

E950 Results

J. Tojo

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

E950 Results

Junji Tojo
Kyoto University / RIKEN

RHIC Spin Collaboration Meeting
October 1st, 2001

BNL-AGS E950 Collaboration

I.G. Alekseev[4], M. Bai[2], B. Bassalleck[8], G. Bunce[2,7], A. Deshpande[7], J. Doskow[3], S. Eilerts[8], D.E. Fields[8], Y. Goto[7], H. Huang[2], V. Hughes[9], K. Imai[5], M. Ishihara[7], V.P. Kanavets[4], K. Kurita[7], K. Kwiatkowski[3], B. Lewis[8], B. Lozowski[3], Y. Makdisi[2], H.O. Meyer[3], B.V. Morozov[4], M. Nakamura[5], B.V. Przewoski[3], T. Rinckel[3], T.Roser[2], A. Rusek[2], N. Saito[6,7], B. Smith[8], D.N. Svirida[4], M. Syphers[2], A. Taketani[6], T.L. Thomas[8], J. Tojo[5,6], K. Yamamoto[5], L. Zhu[5], D. Wolfe[8], D. Underwood[1]

[1]Argonne National Laboratory
[2]Brookhaven National Laboratory
[3]Indiana University Cyclotron Facility
[4]Institute for Theoretical and Experimental Physics, Russia
[5]Kyoto University, Japan
[6]RIKEN, Japan
[7]RIKEN BNL Research Center
[8]University of New Mexico
[9]Yale University

Two Aspects of E950 results

- **Analyzing power A_N for RHIC CNI Polarimeter**
  The only calibration point at 21.7 GeV/c ($G\gamma$=41.5)
  up to the operation of the polarized gas jet target
  (RHIC injection energy: 24.3 GeV/c ($G\gamma$=46.5))

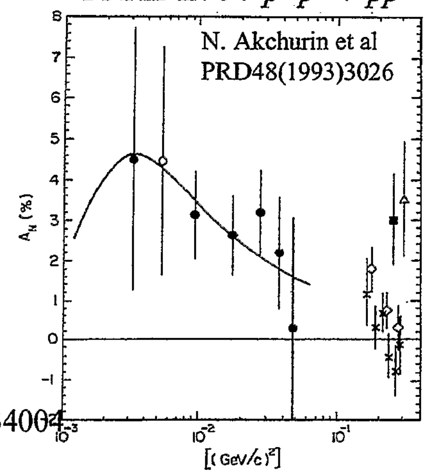
- **Physics interest**
  Hadronic spin-flip r_5 at high energy

$$r_5 \equiv \frac{m_N}{q} \frac{F_s(q)}{\operatorname{Im} F_o(q)}$$

$F_s(q)$:spin-flip amp., $F_o(q)$:spin-nonflip amp.

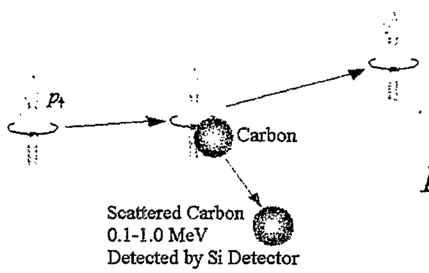
Recent theoretical developments
on pA elastic scattering including r_5
B.Z. Kopeliovich and T.L. Trueman, PRD64(2001)034004

FNAL-E704 $p^{\uparrow}p \to pp$



Kinematics / Detector configuration

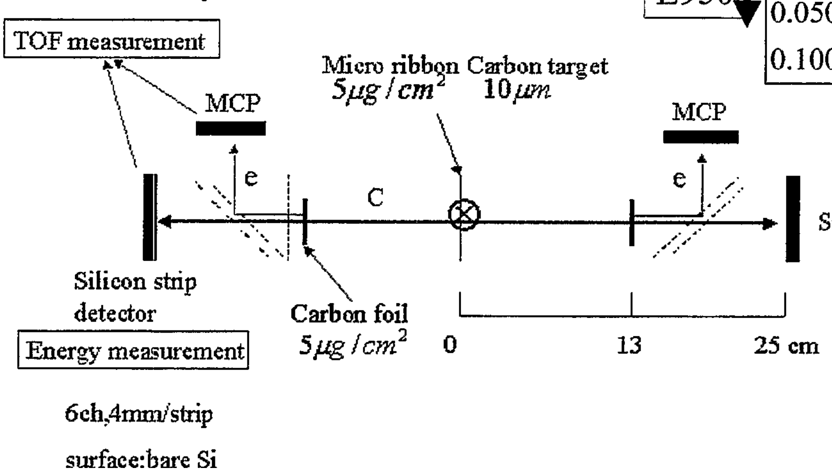
CNI region: $10^{-3} < -t < 10^{-2}$ $(GeV/c)^2$



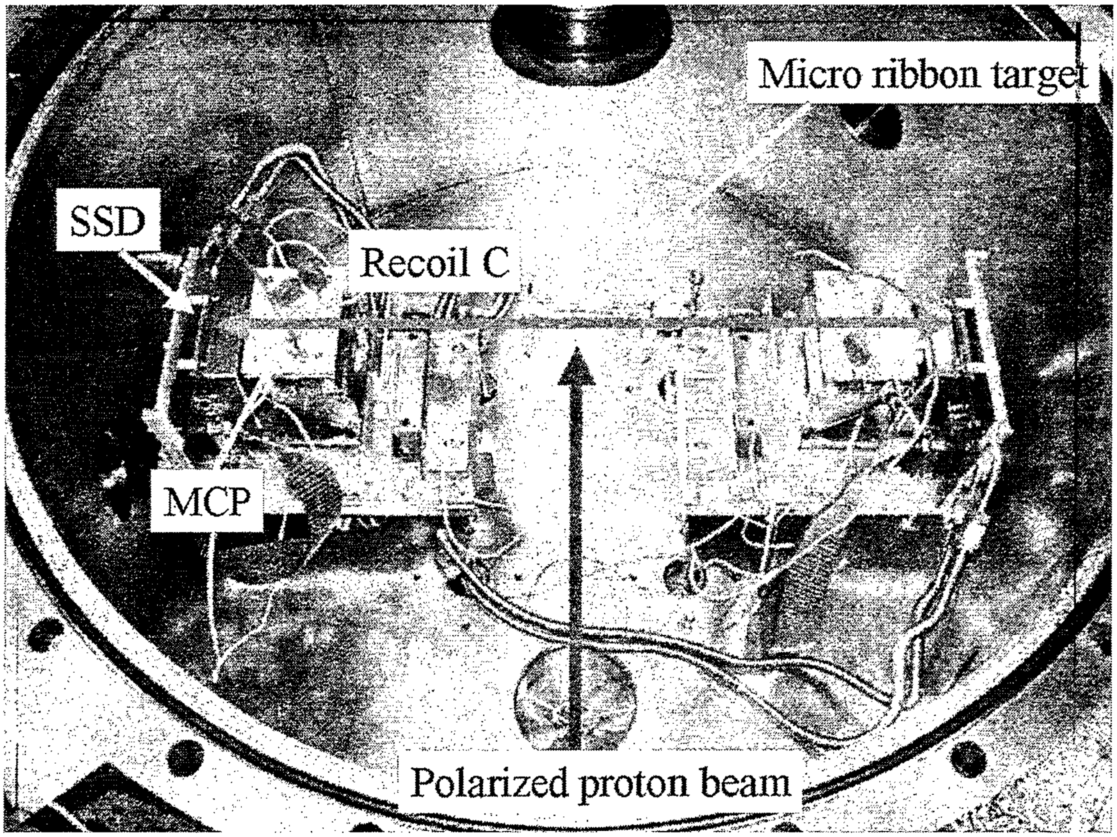
$$E_C = \frac{-t}{2M_C}$$

$-t$ (GeV/c)^2	E_C (keV)
0.001	45
0.005	224
0.010	450
0.050	2236
0.100	4473

E950 (range 0.010–0.050)



6ch,4mm/strip
surface:bare Si



Experimental Run Condition

- **Bunched polarized proton beam in the AGS ring**
  Momentum : 21.7 GeV/c
  Polarization : ~40% (from the AGS-internal/E925 polarimeter)
  Polarization sign : Up and Down alternated every spill (↑↓↑↓↑↓)
  1 bunch/ring, 5×10^9 protons/bunch
  Bunch length : 25 ns ($\sigma \approx 6ns$), Bunch crossing freq. : 370 kHz

- **Trigger**
  $(\sum_{All} \oplus Si) \otimes RF$, Trigger rate : $2\times10^3 / spill$

- **Data**
  ADC/TDC for all Si's and MCP's
  Beam Polarization, its sign and beam intensity from the AGS

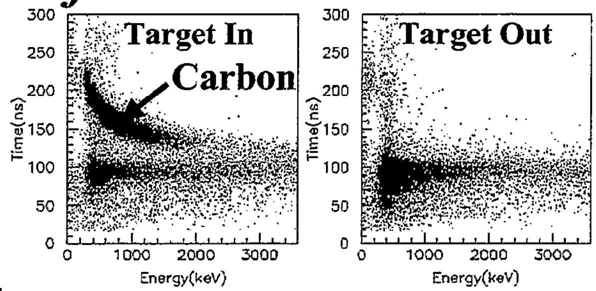
Detector Performance

- **Si strip detector**

Recoil carbon detection w/ Si

Clearly seen in T-vs-E corr.

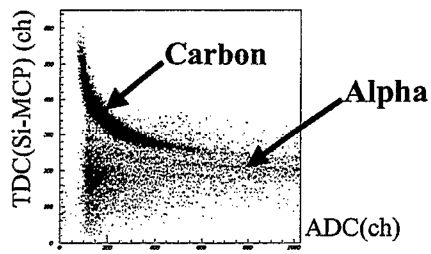
Successfully detected inside the ring.



Energy resolution

from low energy exp. and E950 data

$$\frac{\Delta E}{E} = \frac{0.05}{\sqrt{E}} \oplus (0.05 - 0.12)$$



Time resolution

dominated by bunch length

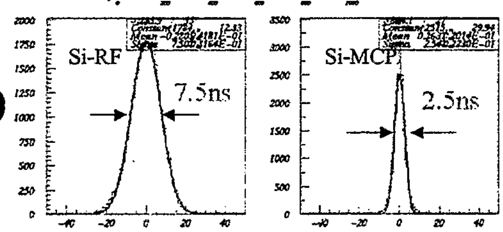
ΔT ; $7\,ns$

- **Micro Channel Plate(MCP)**

Improved Time resolution

Intrinsic Time resolution of Si

: $2.5\,ns$



Analysis Procedure

- **Calibration of detectors**
- **Event selection**
- **Study of detector resolution**
- **Definition of Momentum transfer**
- **Backgrounds estimation**
- **Beam polarization from E925 Polarimeter**
- **Analyzing power**
- **Systematic errors**

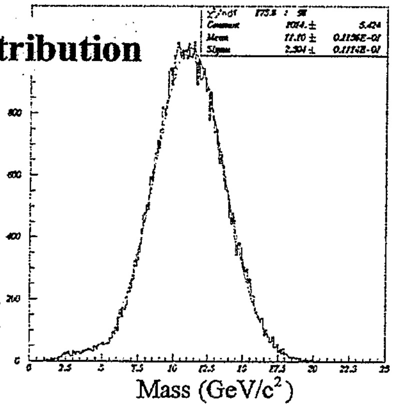
Event Selection

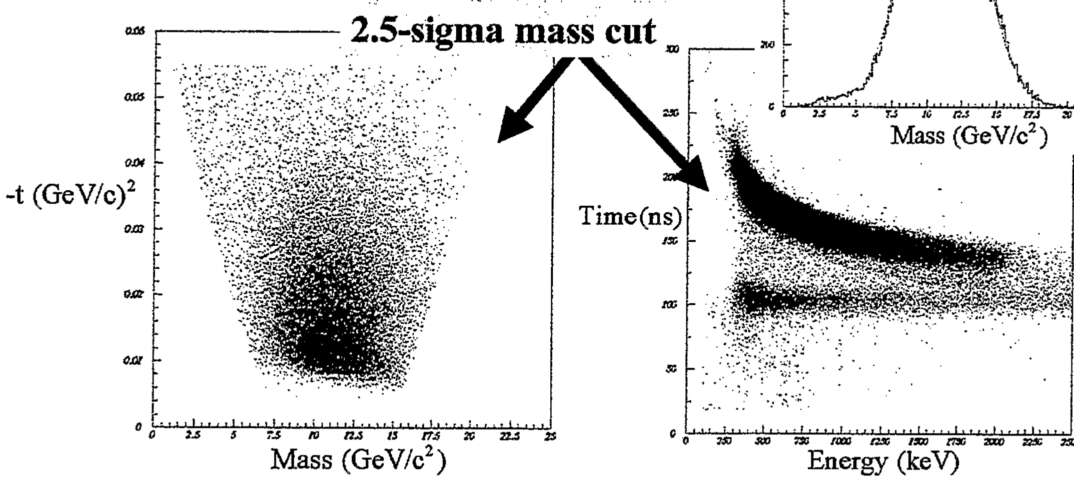
- **Selection on –t-vs-Mass**

(-t was defined from Time and Energy)

- **Cut using Mass**

Based on –t-dependent mass resolution





Study on Detector Resolution

- **Strip-by-strip resolutions for Energy, Time and Mass**

Important to define cut and momentum transfer

Mass resolution from Kinematics

$$\left(\frac{\Delta M}{M}\right)^2 = \left(\frac{\Delta E}{E}\right)^2 + 4\left(\frac{\Delta T}{T}\right)^2$$

Energy resolution

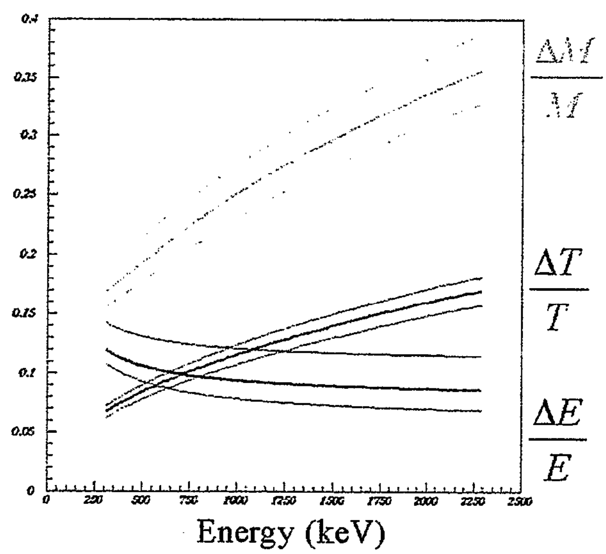
From Low E test exp. and E950 data

$$\frac{\Delta E}{E} = \frac{0.05}{\sqrt{E(MeV)}} \oplus (0.05 - 0.12)$$

Time resolution

Dominated by bunch length

$$\frac{\Delta T}{T} = \frac{(7.0 \pm 0.5)ns}{T}, \quad T = \frac{L}{c}\sqrt{\frac{M_C}{2E}}$$



Momentum Transfer

- **Determine from both Energy and Time: t_E and t_T**

$$t_E = 2M_C E_{Tgt-Foil}(E_{Si})$$

$$E_{Foil-Si} = E_{Si} + \Delta E_{Dead}(E_{Si})$$

$$E_{Tgt-Foil}(E_{Si}) = E_{Foil-Si} + \Delta E_{Foil}(E_{Foil-Si}) = E_{Si} + \Delta E_{Dead}(E_{Si}) + \Delta E_{Foil}(E_{Si})$$

$$t_T = 2M_C E_T(T_{Tgt-Si})$$

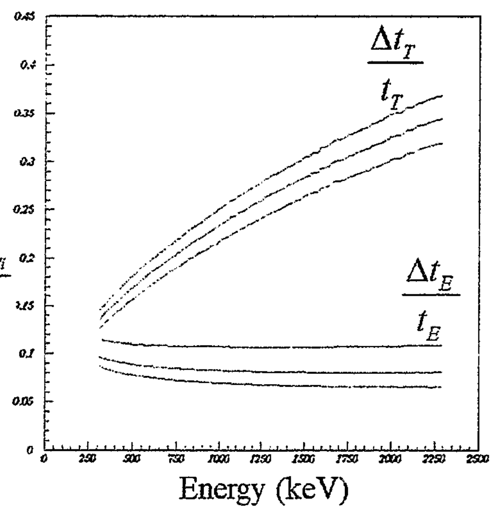
$$T_{Tgt-Si} = \frac{L_{Tgt-Foil}}{c}\sqrt{\frac{M_C}{2E_T}} + \frac{L_{Foil-Si}}{c}\sqrt{\frac{M_C}{2E_{Foil-Si}(E_T)}}$$

- **Define w/ weighted mean in terms of resolutions**

$$\frac{\Delta t_E}{t_E} = \frac{\partial E_{Tgt-foil}}{\partial E_{Si}}\frac{E_{Si}}{E_{Tgt-Foil}}\frac{\Delta E_{Si}}{E_{Si}} \quad \frac{\Delta t_T}{t_T} = \frac{\partial E_T}{\partial T_{Tgt-Si}}\frac{T_{Tgt-Si}}{E_T}\frac{\Delta T_{Tgt-Si}}{T_{Tgt-Si}}$$

$$-t = \frac{w_E t_E + w_T t_T}{w_E + w_T}$$

$$w_E = \left(\Delta t_E / t_E\right)^{-2},\ w_T = \left(\Delta t_T / t_T\right)^{-2}$$



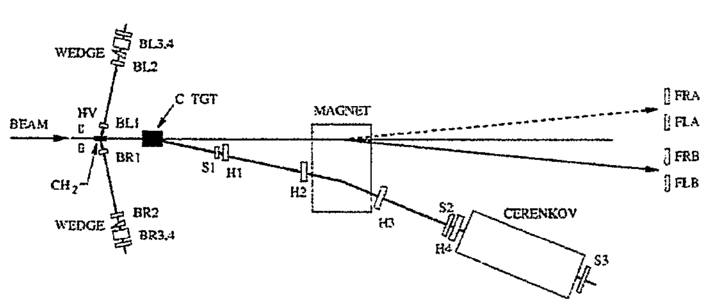
Beam Polarization Measurement

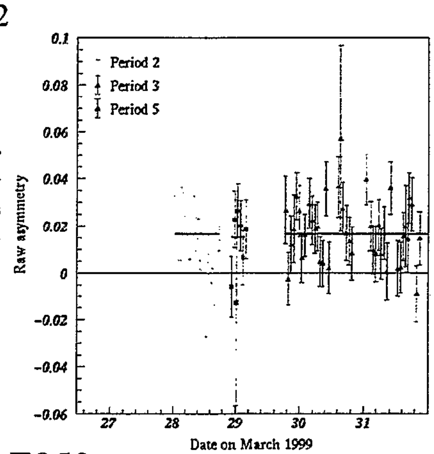
- **E925 polarimeter: pp elastic scattering at** $-t = 0.15\ (GeV/c)^2$

Analyzing Power: $A_N = 0.040 \pm 0.0048$ from global analysis

Target: CH_2, (Carbon for BG study), Two Forward/Recoil detector arms

Setup figure from K. Krueger et al., PLB459(1999)412





Beam was extracted to E925 beam line.

Beam Polarization had been measured during E950 run.

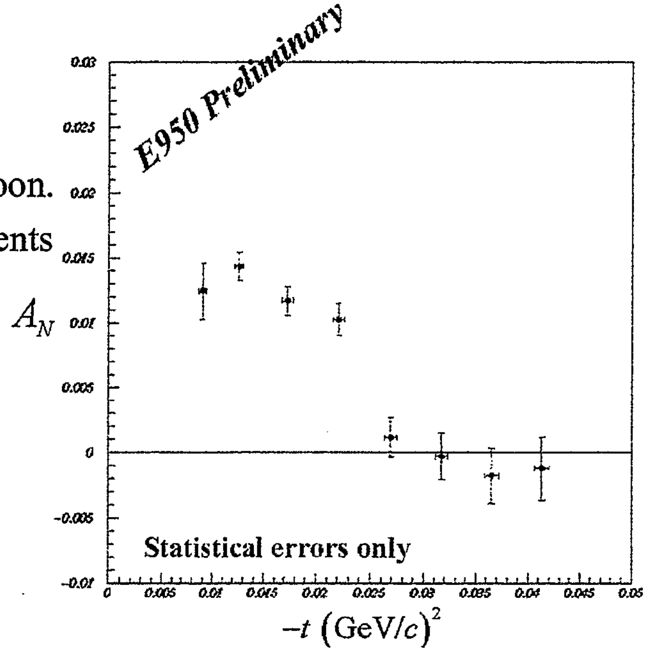
P_B ; 40%

Analyzing Power

- **Combine raw asymmetry from E950 and polarization from E925 polarimeter**

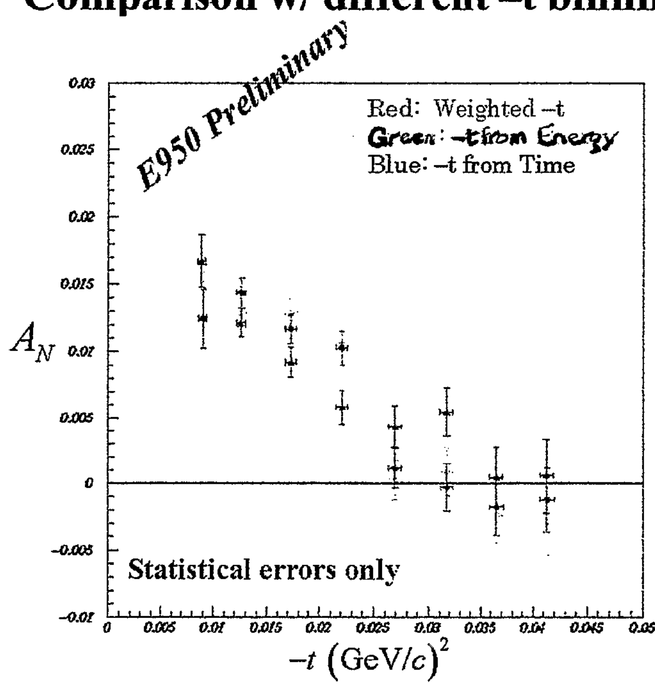
BGs are contained.
BGs subtraction will be done soon.
At most ~20% from Prompt events and Alpha fragments.

Systematic error estimation are on going (almost done).



Possible Size of Systematic Error

Comparison w/ different –t binning



Summary

- Analyzing power $A_N(t)$ of pC elastic scattering in the CNI region was measured for the first time at 21.7 GeV/c.

- Preliminary result of $A_N(t)$ are shown.

- Background and systematic error estimations are on going. The final result are coming soon!

Analysis of RHIC Polarimeter-2000

Osamu Jinnouchi*

The current status of the data analysis on RHIC commissioning run 2000 is reported. Detailed analysis based on the mass identification is firstly applied for this data set. The quality of the analysis procedure is confirmed by several aspects. Those are t-dependence of the cross-section, angle-dependences, and mass distributions. It is also shown that RHIC polarimeter is expected to have very low background, and little contamination of α particles. Carbon events are well separated from that of the α's, owing to the good time and energy resolutions of the detectors.

*e-mail:josamu@bnl.gov

Analysis of RHIC Polarimeter-2000 Commissioning Run

Osamu Jinnouchi (RIKEN)

Oct. 1, 2001 RHIC Spin Collaboration Meeting VI

Reminder of the RUN

Detecting the recoiled Carbon (CNI region) with Si detectors installed obliquely by 45°

Measurement with CNI polarimeter

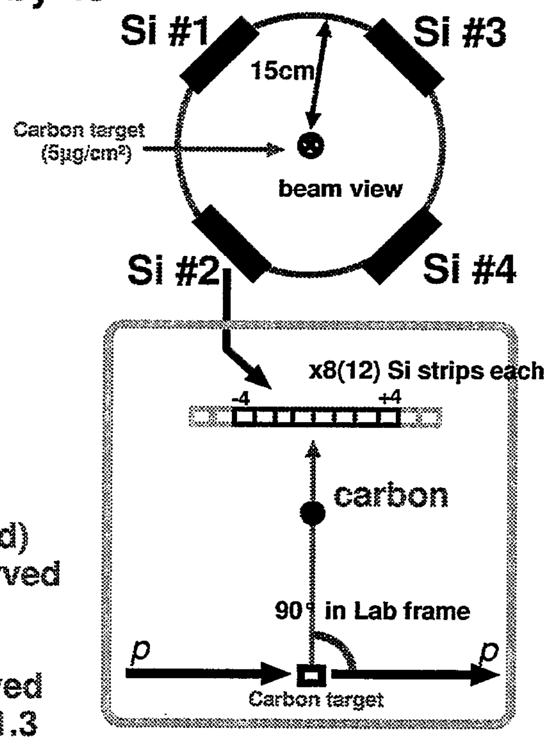
Energy & TOF

→ Identify Carbon

→ Calculate Asymmetry

What had been already understood from the fast analysis

- up and down polarization with
  - significant asymmetry size
  - clear direction
- siberian snake on (1 snake was installed)
  - horizontal spin direction was observed
- ramping up energy
  - horizontal spin rotation was observed
  - observed no asymmetry over $G\gamma \geq 61.3$



Analysis Procedure

Kinematical fit is performed with

$$T = \sqrt{\frac{M L^2}{2}} \frac{1}{\sqrt{E}}$$

Simultaneously applied for α and C

Fitting Constraints

Mc : Carbon mass 11.18GeV/c²

Mα: Alpha mass 3.73GeV/c²

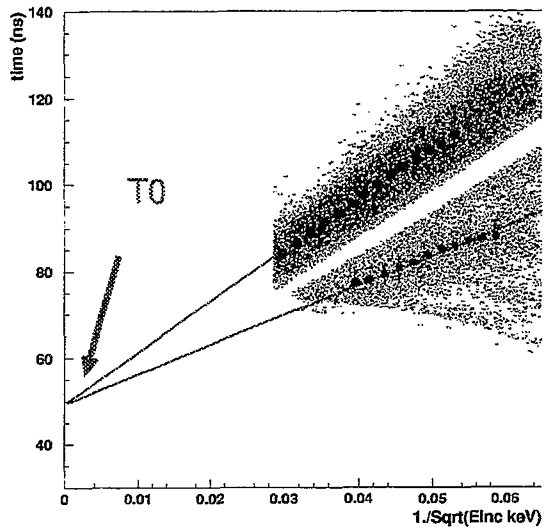
T0 : common to α and Carbon

Known parameters

Time scale, Slewing, Distance(L) ,,,

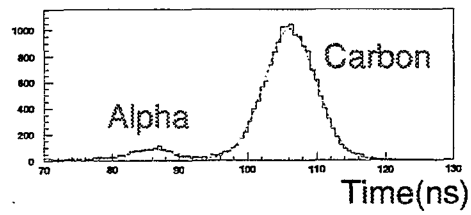
Fitting Assumptions

Dead layer width on Si surface
= 74μg/cm² (from Tandem test)



→ **Mass Reconstruction (i.e. particle ID)**

→ **Extract Energy Scale (no direct calibration has performed)**



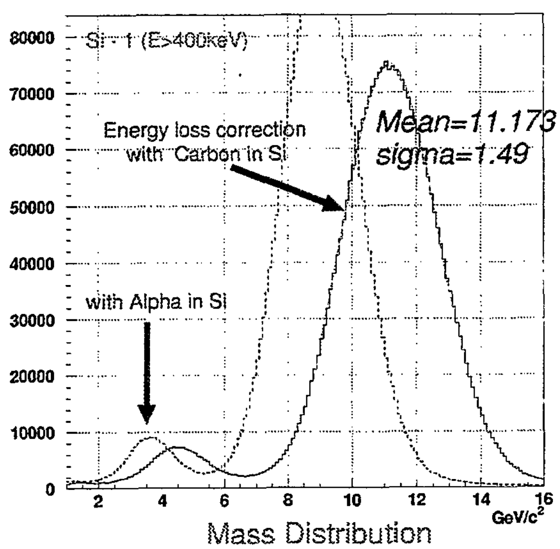
Mass Reconstruction

Alpha and Carbon mass peaks are Clearly separated

Carbon ID can be defined by Mass

flat mass cut is performed so far,

→ Should be improved as a t-dependent cut (coming soon)



Max Alpha/Carbon ratio is ~10%

Alpha Contamination within Carbon peak is estimated to be extremely small

Mass Reconstruction

Alpha and Carbon mass peaks are Clearly separated

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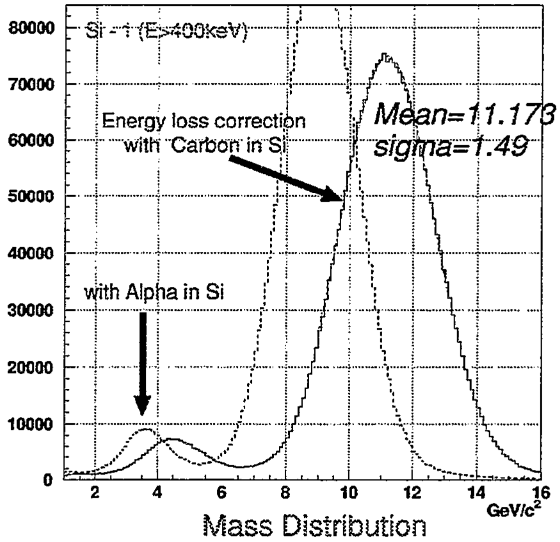


Max Alpha/Carbon ratio is ~10%

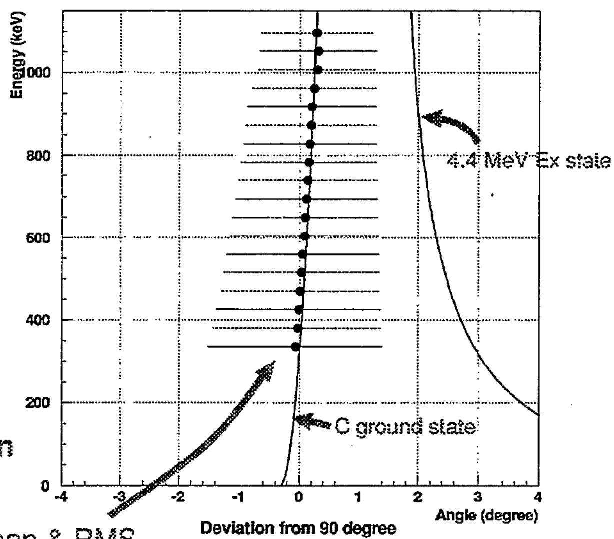
Alpha Contamination within Carbon peak is estimated to be extremely small

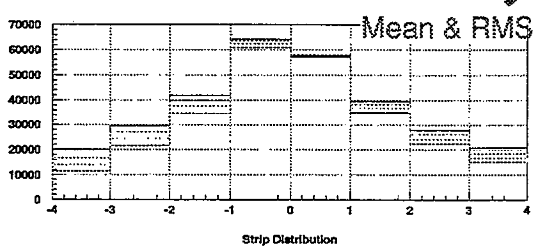
Recoil Angle Dependence

Scattering angle is estimated from strip distributions

Scattered angle distribution fits well with kinematical curve

- Deviation is -0.3°~ -0.5° (corresponds to -1.3~-0.8mm for Si geometry)
- All four Si shows same distribution





These histograms show strip distributions for different energy
The lower the wider

Asymmetry → Polarization

Raw asymmetry is calculated with square-root formula, with 6-bunches (⇑⇓⇑⇓⇑⇓)

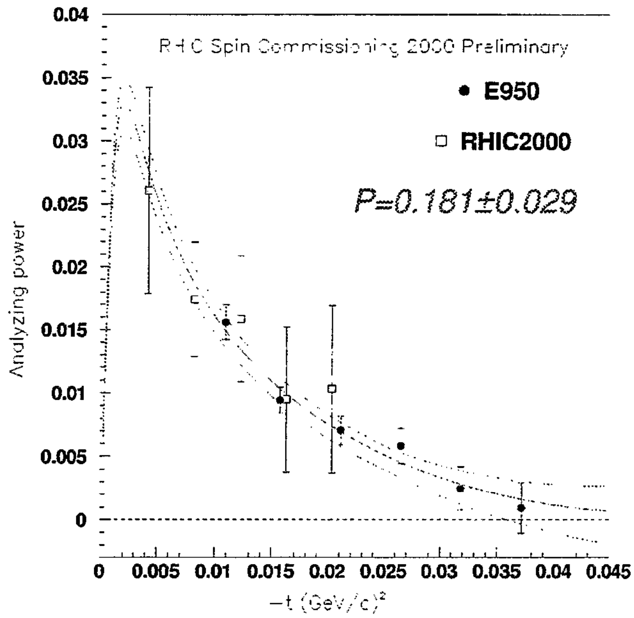
$$A = \frac{\sqrt{L(\Uparrow)}\sqrt{R(\Downarrow)} - \sqrt{L(\Downarrow)}\sqrt{R(\Uparrow)}}{\sqrt{L(\Uparrow)}\sqrt{R(\Downarrow)} + \sqrt{L(\Downarrow)}\sqrt{R(\Uparrow)}}$$

Extract Polarization by fitting to E950's result,

$$P = A(t) / A_N(t)$$
$$= 0.181 \pm 0.029$$

This result is obtained with typical run set

⇨ need much more statistics



Summary & Outlook

summary

- Detailed analysis has been carried out using Mass ID
- Several features of analysis indicate that the procedure of analysis works well
  - Firstly confirmed t-dependence of cross-section
  - Angle dependence
  - Mass distribution

outlook

- Need to precisely study run depedence of
  - the spin direction during Snake runs
  - the energy dependencies of the polarization
- To extract asymmetry with Alpha (from physical interest)

  these are under progressing now

- The energy scale will be confimed by direct calibration measurement

Determination of RHIC Beam Polarization

D. Fields

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

Determination of RHIC Beam Polarization

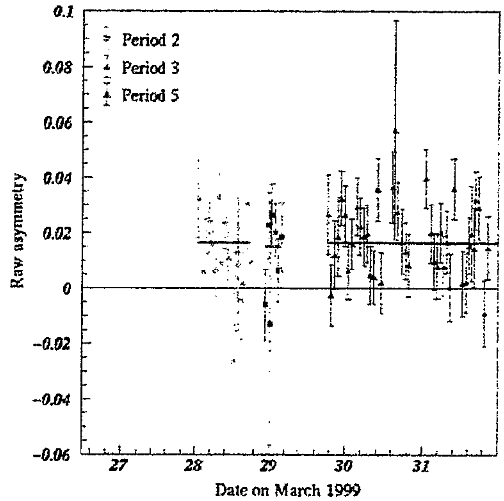
- Results from E950 – Junji Tojo.
  - Determination of A_N using $\mathbf{P}_B$ from E925.
- Results from RHIC Polarimeter – Osamu Jinnouchi.
  - Expected uncertainties from RHIC polarimeter.
- How do we use these to determine beam polarization at full energy?
  - How to determine polarization at injection energy without an absolute polarimeter.
  - How to determine polarization after acceleration.

General Process at Injection Energy

- Use RHIC p+C CNI polarimeters to measure beam polarization at injection energy. Need physics analyzing power.
- Get physics analyzing power from E950 asymmetry measurement. E950 needs beam polarization from E925.
- E925 determines the beam polarization from pp elastic measurement. Needs pp elastic analyzing power from fits to previous calibrated data. Weak link.

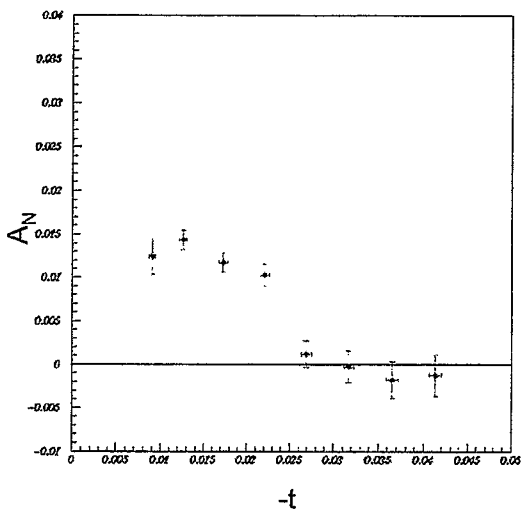
Results from E925

- E925 determines beam polarization to be 0.407±0.035(stat) ±0.048 (syst) during E950 running (total uncertainty ~15%).
- The systematic uncertainty (12%) is dominated by the determination of the analyzing power calculated from other measurements (at different energies) to be A_N=0.0400±0.0048.



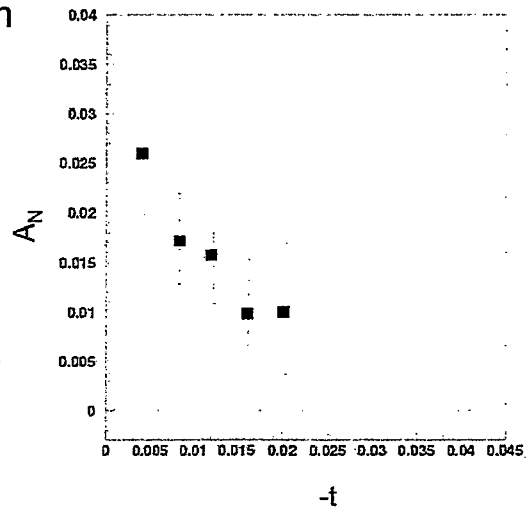
Results from E950

- E950 has very small statistical uncertainties (~10% in low –t region).
- The value of the asymmetry at low –t is very stable with even gross changes in the analyzing procedure, and therefore has small systematic uncertainty (~5%).



Results from RHIC Polarimeter

- Needs extrapolation from E950 energy to RHIC injection energy.
- Statistical uncertainties expected to be ~1% during upcoming run.
- Well understood systematic uncertainties.
- Match to E950 shape in very good agreement.



Calibrating the RHIC Polarimeter at Injection Energy Using E950

- Energy differences.
  - E950 was at $\sqrt{s} = 24.7 GeV$
  - RHIC injection is at $\sqrt{s} = 25.9 GeV$
  - AGS internal polarimeter during RHIC polarimeter run has large systematic uncertainties.
  - Uncertainty in the theoretical energy dependence of asymmetry ~5% (from fits to E950 data using range of real part of μ_P extrapolated to injection energy).
- No shape differences, only scale uncertainty.

Theoretical Determination of Energy-Dependence of Analyzing Power

- E950 does not fix the determination of the hadronic spin-flip amplitude to a high enough degree to be able to say the even what sign of the energy dependence of the asymmetry will be at full energy.

Method of Accelerating and Decelerating Beam

- E950 Energy is too low for injection (~transition).
- Injection energy at $G\gamma$=46.6, E = 24.3GeV.
- Plan to make asymmetry measurements at "stepping stones" along the way, or also possibly during the ramp (ramp time vs. measurement time!).
- Then plan to decelerate and make measurements, although beam loss back at injection energy may *require* measurements during ramp down.
- Scenario #1: Asymmetry is the same at low and high energies and is the same upon return to low energy.
- Scenario #2: Asymmetry is different at low and high energies, but is the same upon return to low energy.
- Scenario #3: Asymmetry is different at low and high energies, and is also different upon return to low energy.

Method of Accelerating and Decelerating Beam

- Scenario #1:
  - Analyzing power is the same at injection and full energy, and there is no polarization loss.
- Scenario #2:
  - Analyzing power is different at injection and full energy, and there is no polarization loss.
- Scenario #3:
  - Difference upon return to injection energy is due to polarization loss, equally distributed between ramp up and ramp down (?).
  - Difference between injection and full energy due to energy dependence of analyzing power.
    - Consistency check with E950 hadron spin-flip measurement.

Estimate of Beam Polarization Uncertainty

- Injection Energy:
  - From E950. (~19%)
- Full energy:
  - From Acceleration/Deceleration. (Statistics dominated, ~1.4%)
- From Theory:
- Overall double spin asymmetry scale uncertainty from beam polarization <50%

RHIC Polarimeter Data Format

K. Kurita

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

RHIC Polarimeter Data Format

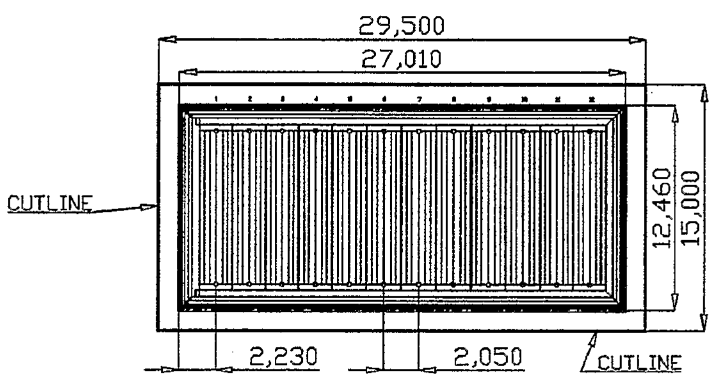
RSC collaboration meeting
Oct. 1, 2001
Kazu Kurita (RBRC)

Outline

- 1, Polarimeter geometry
- 2, Configuration of run2001
- 3, Proposed data format for distribution

Si design

- Boron(front) and Phosphor(back) implantation
- Bare Si surface
- 2mmx10mm x 12 strips
- small capacitance + thin dead layer

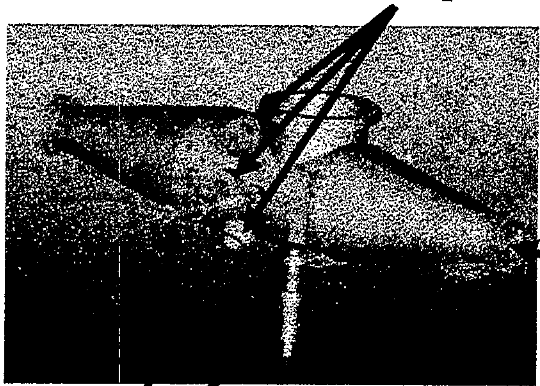


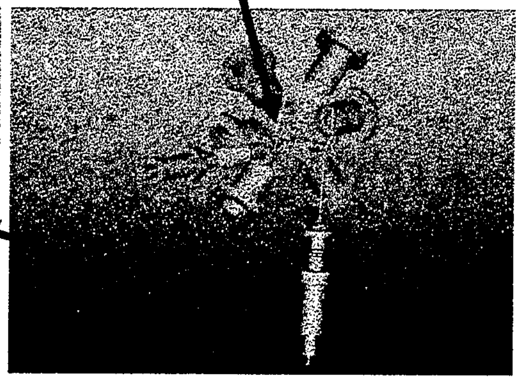
Chamber Design

(George Mahler)

Detector ports

Micro ribbon C target(5um/cm2 thick)



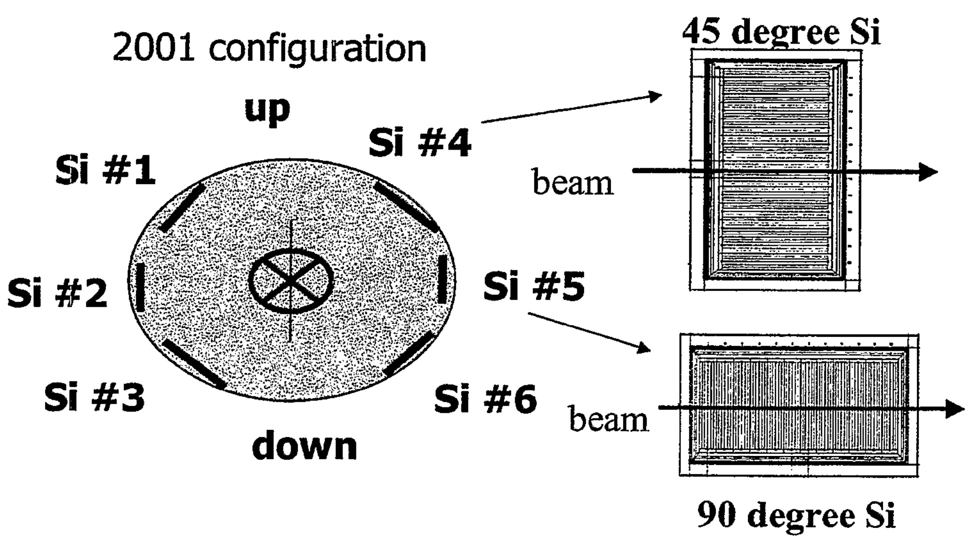


Target control

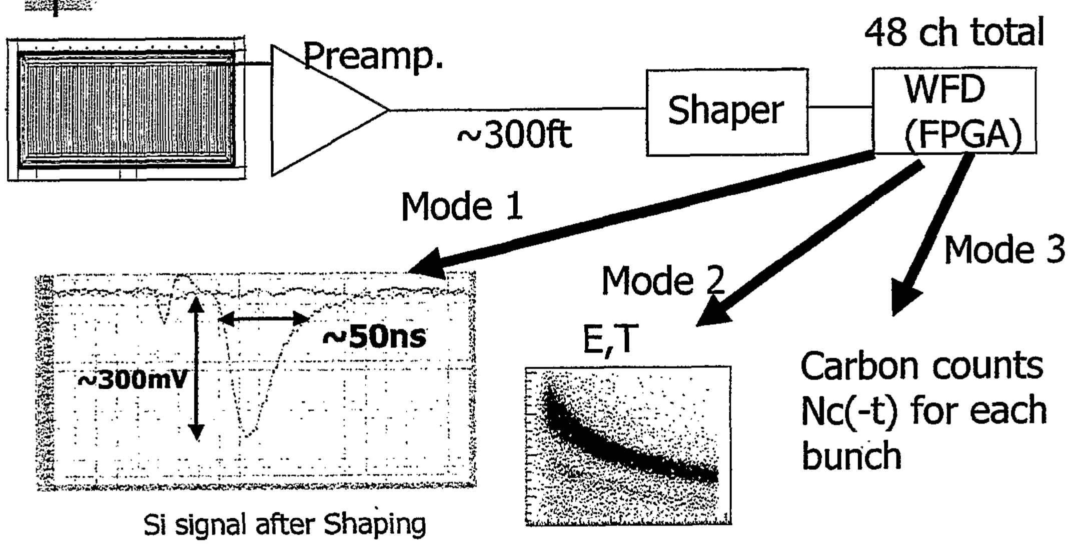
Detector ports and targets arrangement

Si Detector Orientation

2001 configuration

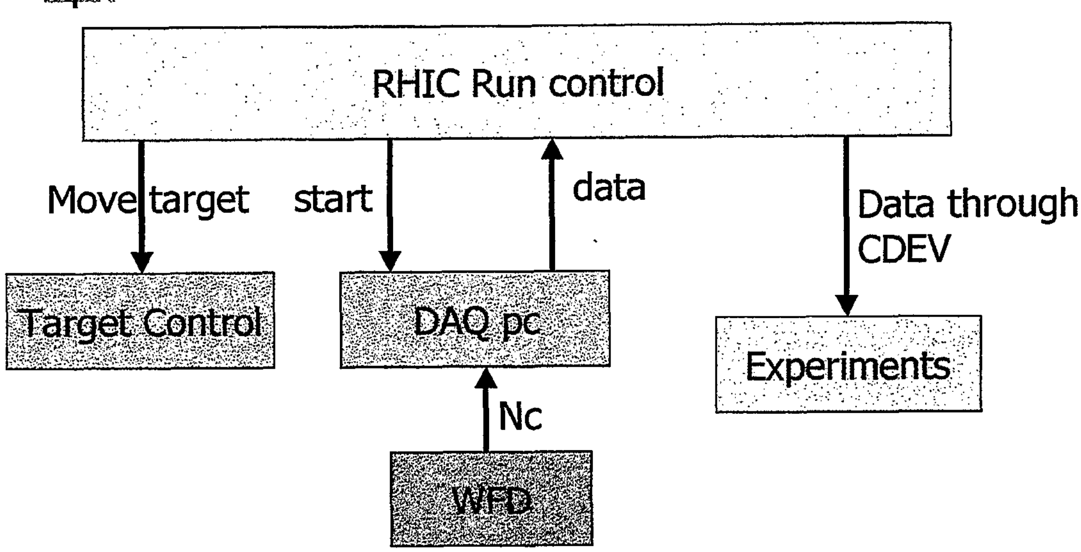


Si Detector Read Out



Si signal after Shaping

RHIC Run Control



Data Collection and Distribution Procedure

- 1, Command in PET page initiate a run
- 2, Move the target in
- 3, Send command to the DAQ pc to take data (or diagnosis mode)
- 4, DAQ pc collects carbon counts and process them and ships out all info to the controller
- 5, Controller distribute the data to experiments through CDEV
- 6, Move the target out

Criteria of the data format

- 1, Provides sufficient information for all experiments.
- 2, Detail enough to spot problems by many people.
- 3, Do not allow different results from the same data set. (everybody has to use the same formula agreed upon)
- 4, Ready to use.
- 5, Upgrade should be transparent

Proposed Information for distribution

- 1, run ID ; Fill ID+ y/b+ seq.#
- 2, time stamp ; begin and end time
- 3, version #'s ; DAQ version +cut id
- 4, Beam Energy ; dipole current
- 5, target ; target ID + position
- 6, Quality bit(s) ; O.K. or not

Continued

- 7, Total, up,down and unpol carbon counts
- 8, Carbon counts per Si per bucket
  6x360 integers
  (-t integration range by polarimeter crew)
- 9, average asymmetry
  asymmetry size ±error, ang.±error
- 10, bunch by bunch asymmetry
  2x2x360 floats
  (taking pair with unpol. bunch or non-square root method?)

Bunch by bunch polarization

- 1, Using one un-polarized bunch
  - In case of pol. Bunch pair

$$N_{LU} = \sigma_0(1+P\,A_N)A_L L_U$$
$$N_{LD} = \sigma_0(1-P\,A_N)A_L L_D$$
$$N_{RU} = \sigma_0(1-P\,A_N)A_R L_U$$
$$N_{RD} = \sigma_0(1+P\,A_N)A_R L_D$$
$$A = \frac{\sqrt{LU}\sqrt{RD}-\sqrt{LD}\sqrt{RU}}{\sqrt{LU}\sqrt{RD}+\sqrt{LD}\sqrt{RU}} = PA_N$$

Continued...

- In case of one un-pol. bunch

$$N_{LU} = \sigma_0(1+P\,A_N)A_L L_U$$
$$N_{LD} = \sigma_0 A_L L_D$$
$$N_{RU} = \sigma_0(1-P\,A_N)A_R L_U$$
$$N_{RD} = \sigma_0 A_R L_D$$
$$A = \frac{\sqrt{LU}\sqrt{RD}-\sqrt{LD}\sqrt{RU}}{\sqrt{LU}\sqrt{RD}+\sqrt{LD}\sqrt{RU}} = \frac{\sqrt{1+P\,A_N}-\sqrt{1-P\,A_N}}{\sqrt{1+P\,A_N}+\sqrt{1-P\,A_N}}$$

$\approx \frac{1}{2}PA_N$ (when PAn is small)

Continued…

- 2, after knowing stability of A and L, calculate left right asymmetry with corrections.

Issues

- What diagnosis mode and quality check should be used?
- Stable bunch by bunch asymmetry determination method is to be determined.
- What is the procedure to update the data already distributed?

Status of Phenix "Local" Polarimeter

B. Fox

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

Status of Phenix "Local" Polarimeter

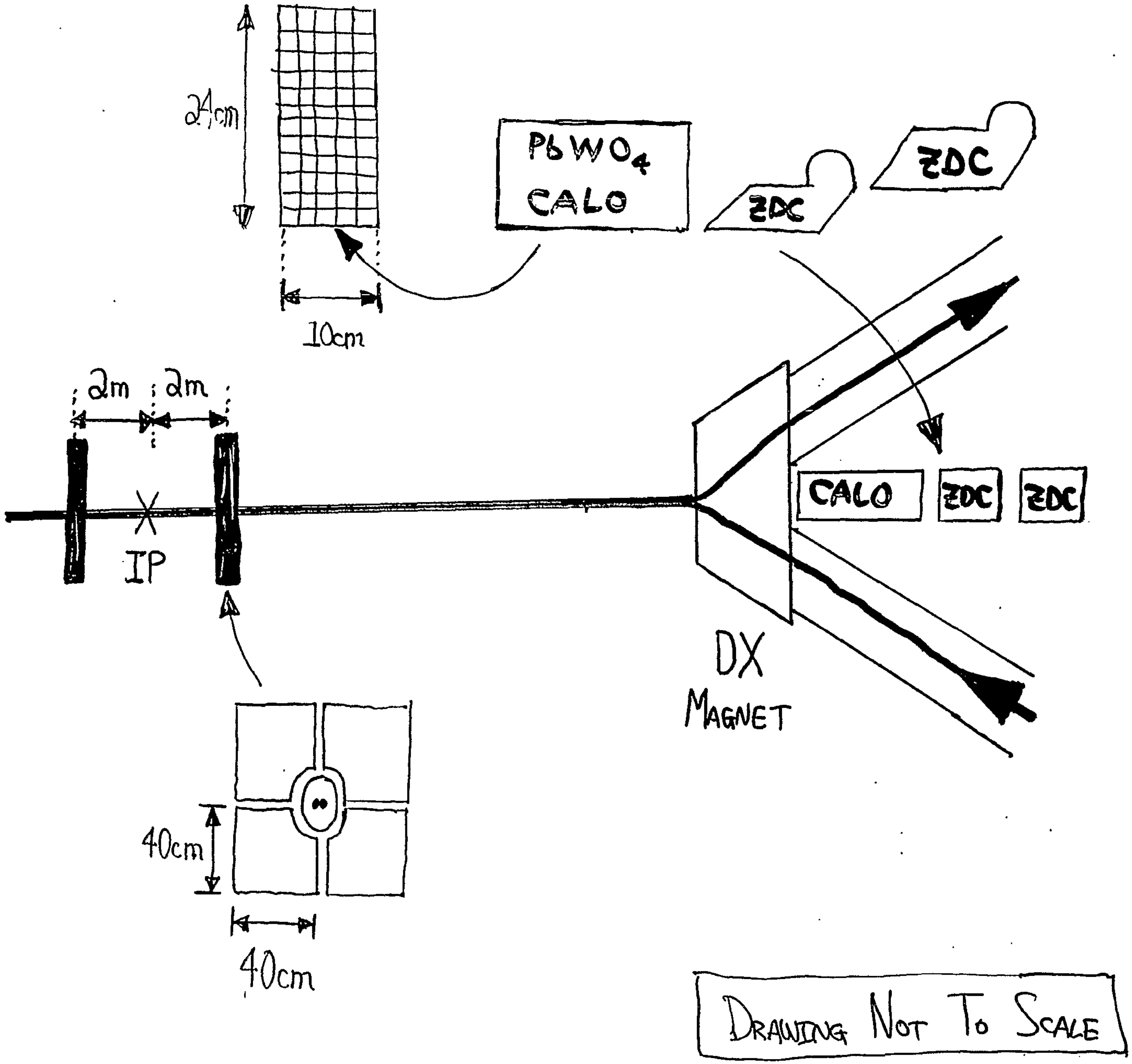
B. Fox

For

L. Bland, G. Bunce, A. Deshpande, Y. Fukao, Y. Goto, K. Imai, R. Muto, E. Pascuzzi, N. Saito, F. Sakuma, M. Togawa, J. Tojo

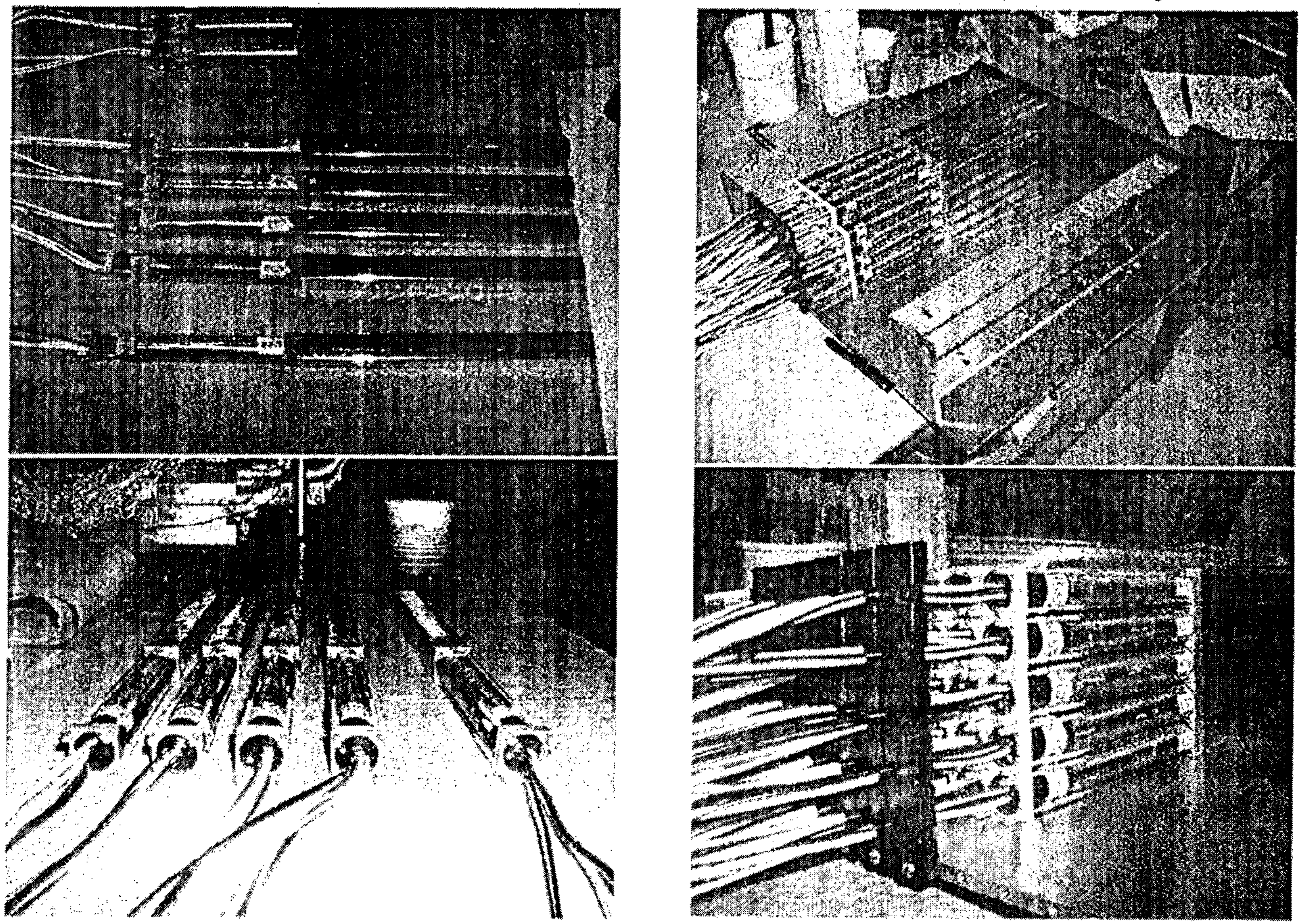
W. Dalton, W. Lenz, D. von Lintig

R. Alforque, Aron K., G. McIntyre, T. Curcio


24cm
10cm
PbWO4 CALO
ZDC
ZDC
2m
2m
IP
DX
MAGNET
CALO
ZDC
ZDC
40cm
40cm
DRAWING NOT TO SCALE

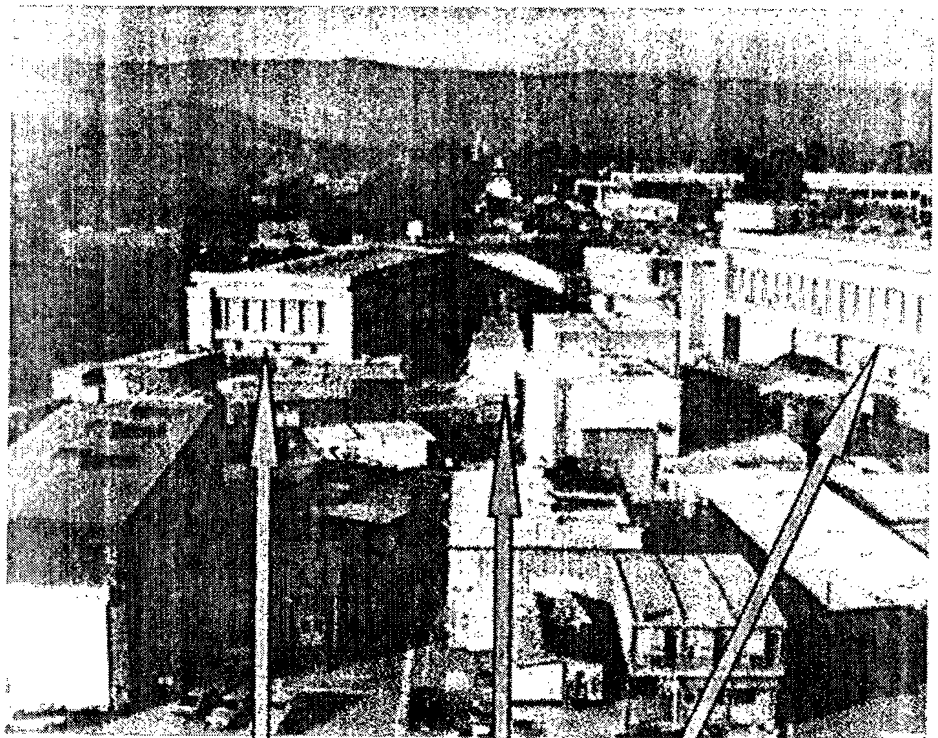
The Towers & The Calorimeter

Don V. L.
Bill D., Bill L.
Rudy A., Aron K.



Final Focus Test Beam

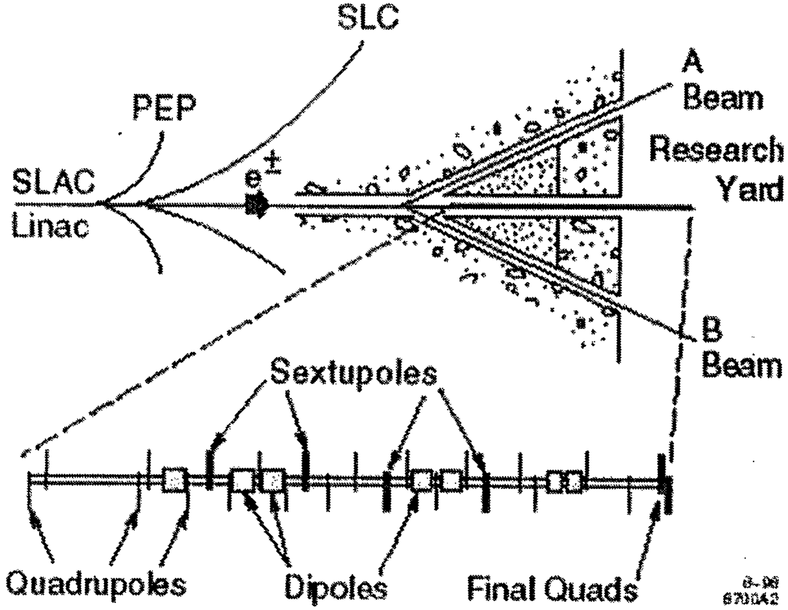
FFTB



End Station B

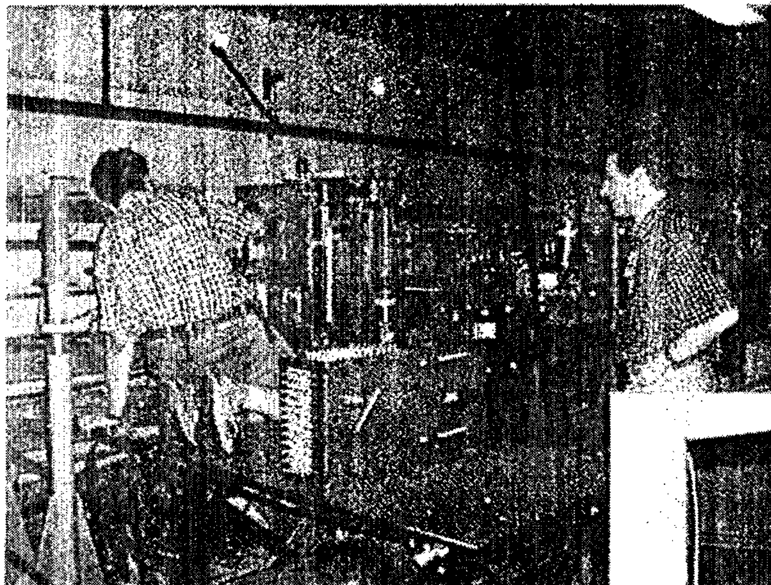
FFTB

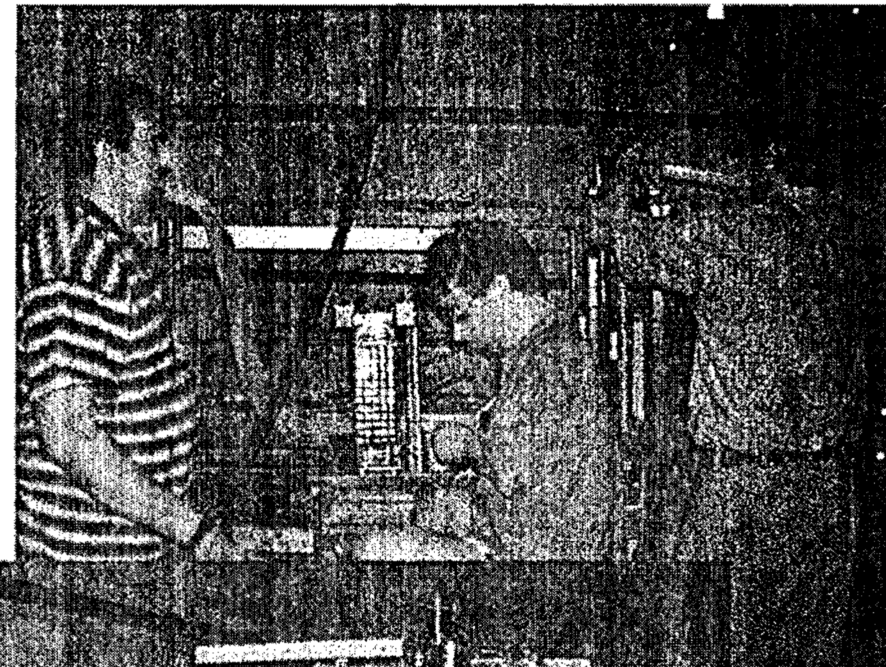
End Station A

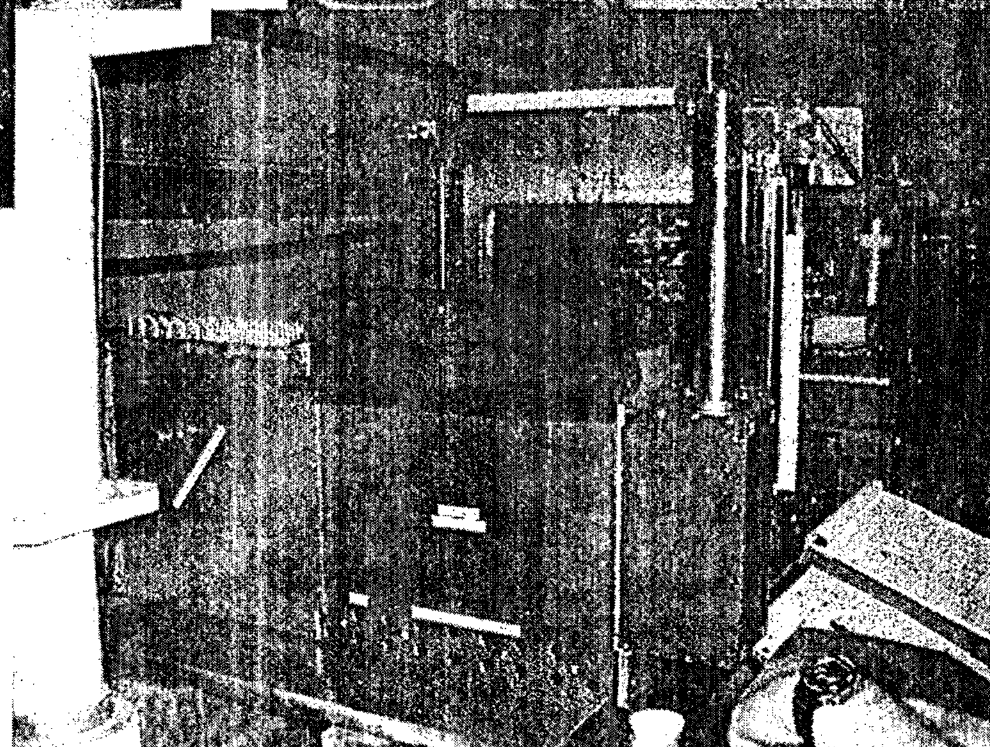


Built by an international collaboration
to work on achieving minute beam spots
For work on NLC:
1998: 1micron(wide) by 0.06 micron(height)

Inside FFTB… Setup 1

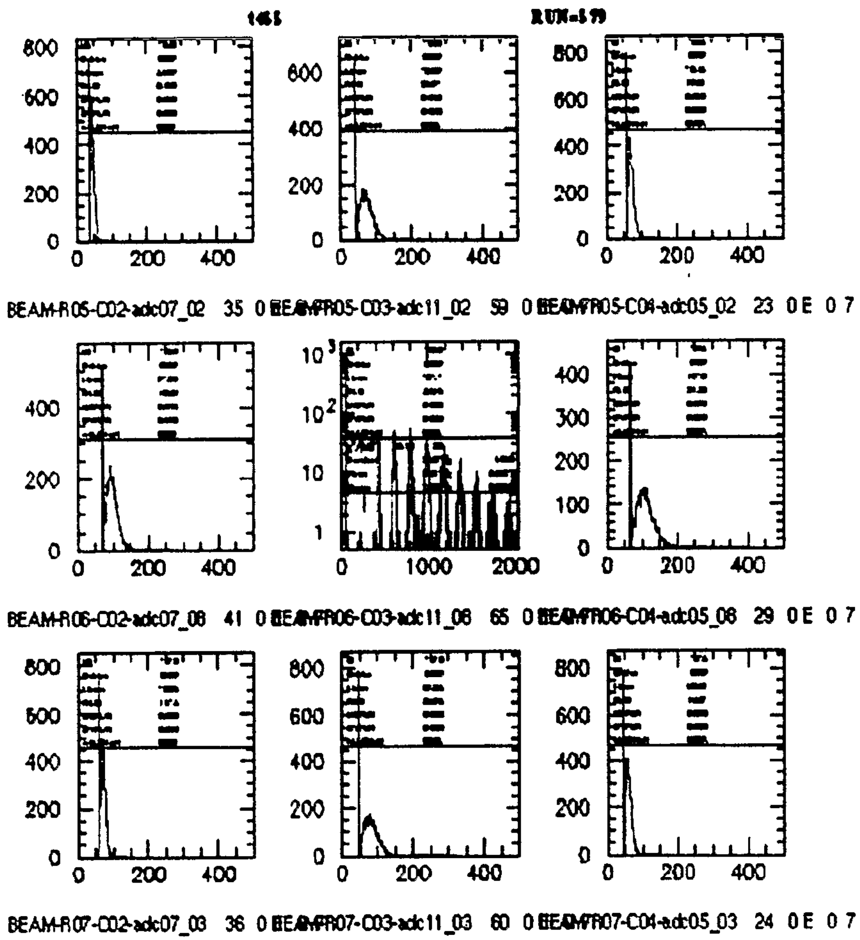




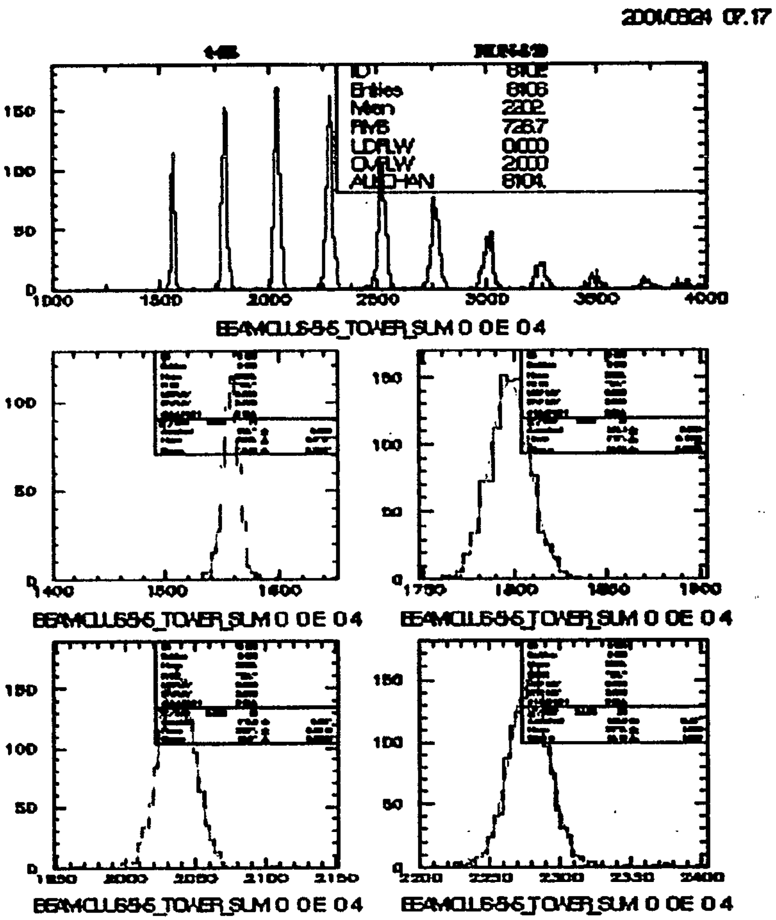


Calorimeter arrives
At SLAC

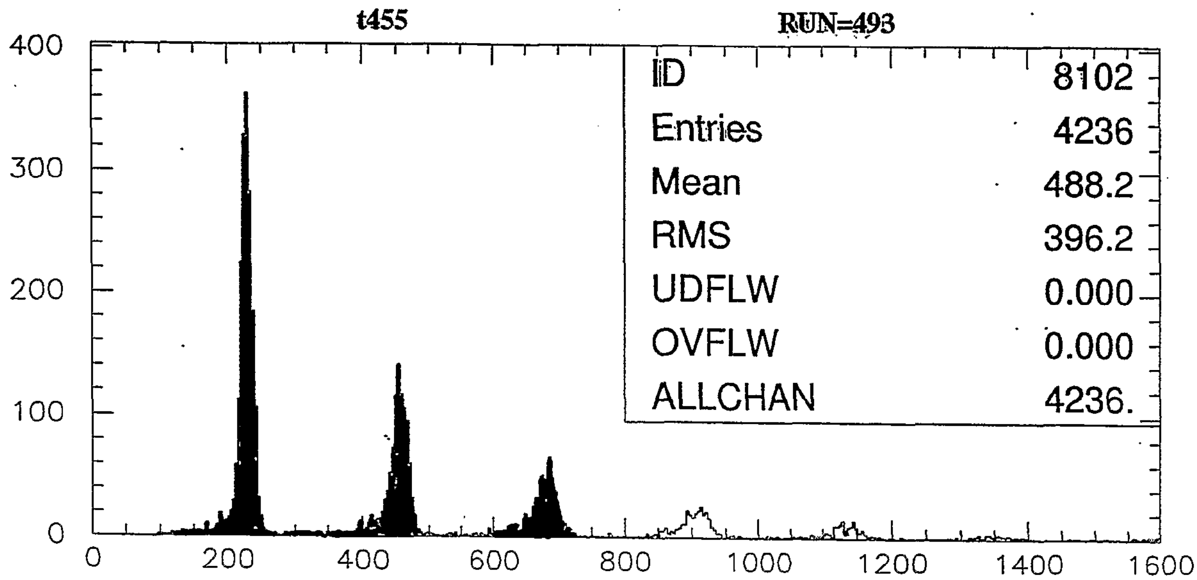
1st Look at what we had…



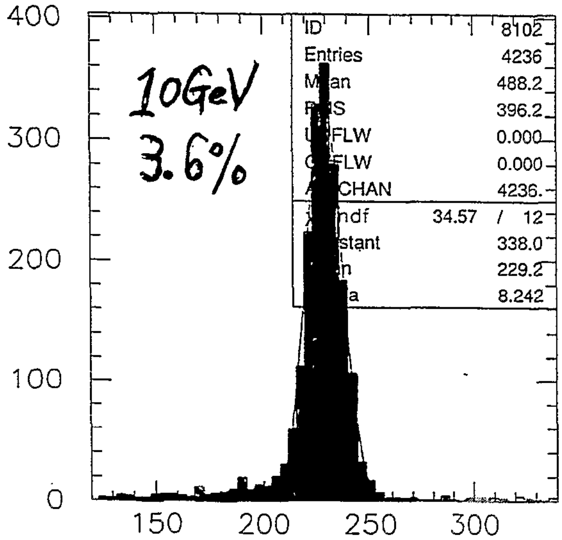
Center block: Column 3, Row 6

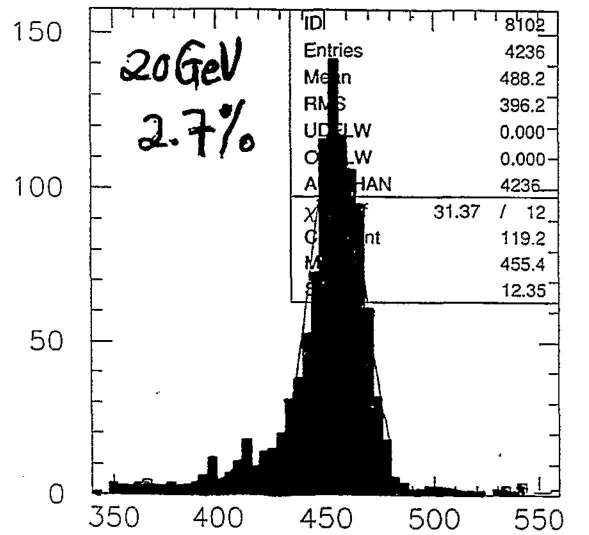


1,2,3,4… electron peaks



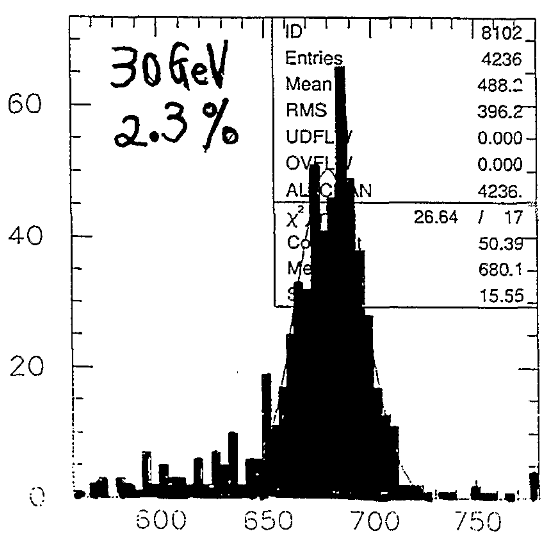
BEAM-CLUS-5x5_TOWER_SUM 0 0E 0 4

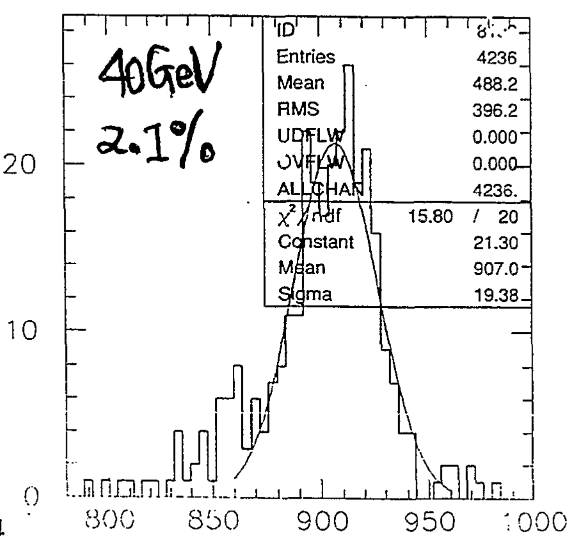




BEAM-CLUS-5x5_TOWER_SUM 0 0E 0 4

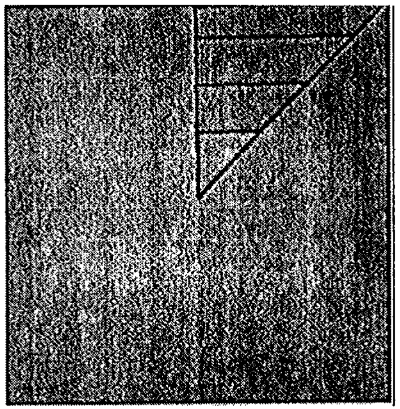
BEAM-CLUS-5x5_TOWER_SUM 0 0E 0 4





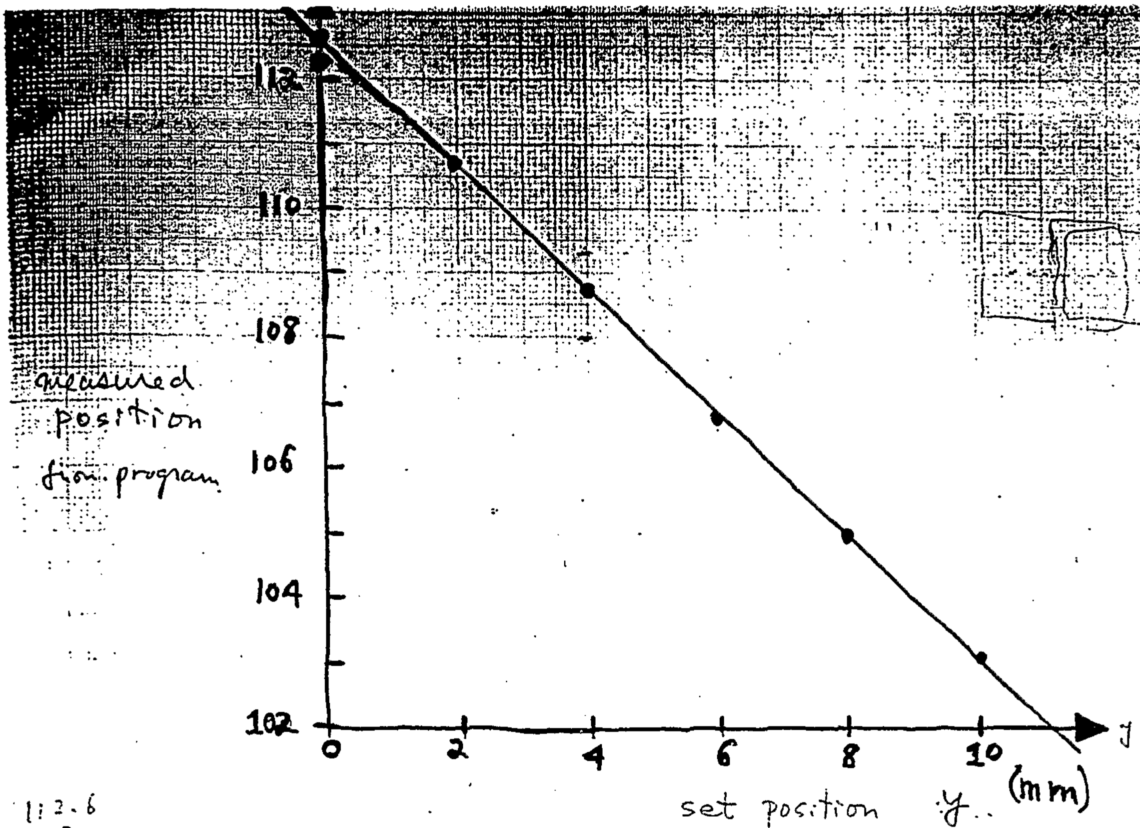
Shower Profile

- Scan the entire calorimeter: all towers at their centers
- Row 3, block 6 (approx. center of the calorimeter)



On diagonals, edges and in-between
With 2 mm steps

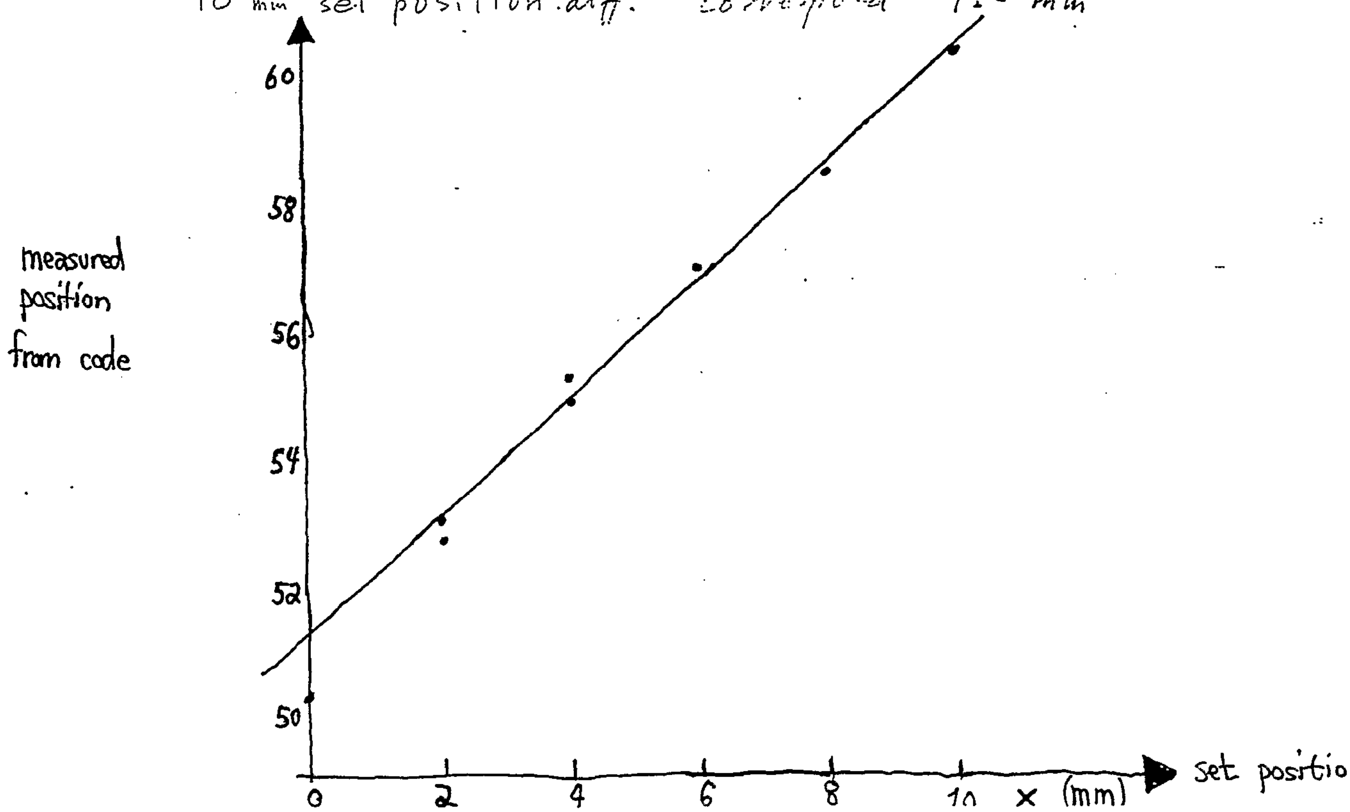
- Edge block (has crystals on 3 sides) and corner blocks (has crystals on two sides only) → See how showers look there
- Ask for 5,10,15 & 20 GeV electrons: 1 electron/bunch, 2,3,4,5 electrons/bunch
- 10 GeV data with pre-shower counter in front of the calorimeter to see what happens to the energy/position resolution by adding material in front of the calorimeter
- Steel plate to simulate the wall of the DX magnet (10 GeV data)



112.6
103.1

It comes from. Run# 623 to Run#628.

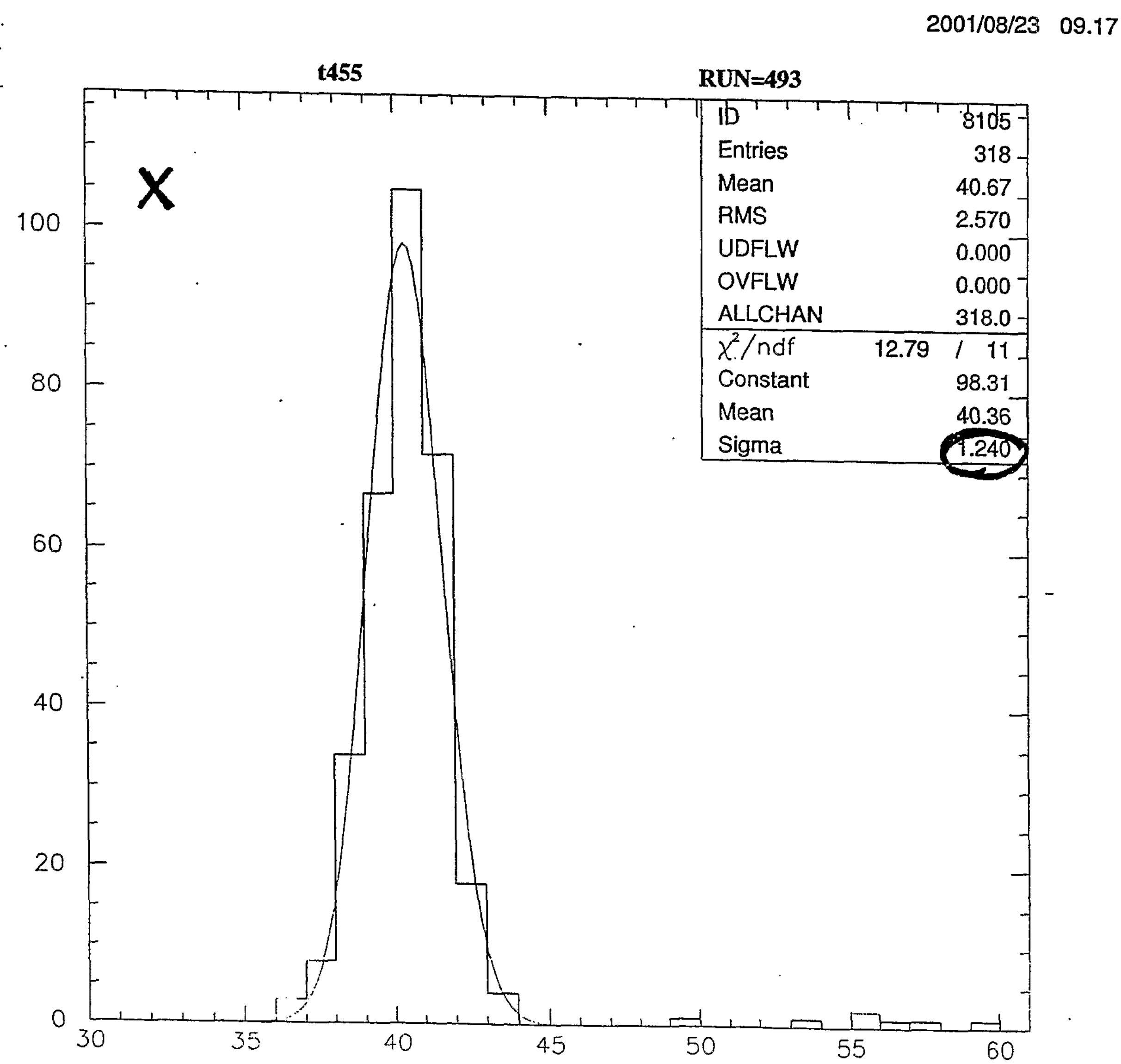
10 mm set position diff. correspond 9.5 mm



Area work to install 10cm high stage is on-going

☆ splitter on R07 C03 / R08 C03 were removed

→ pulse hight in DAQ should be twice larger

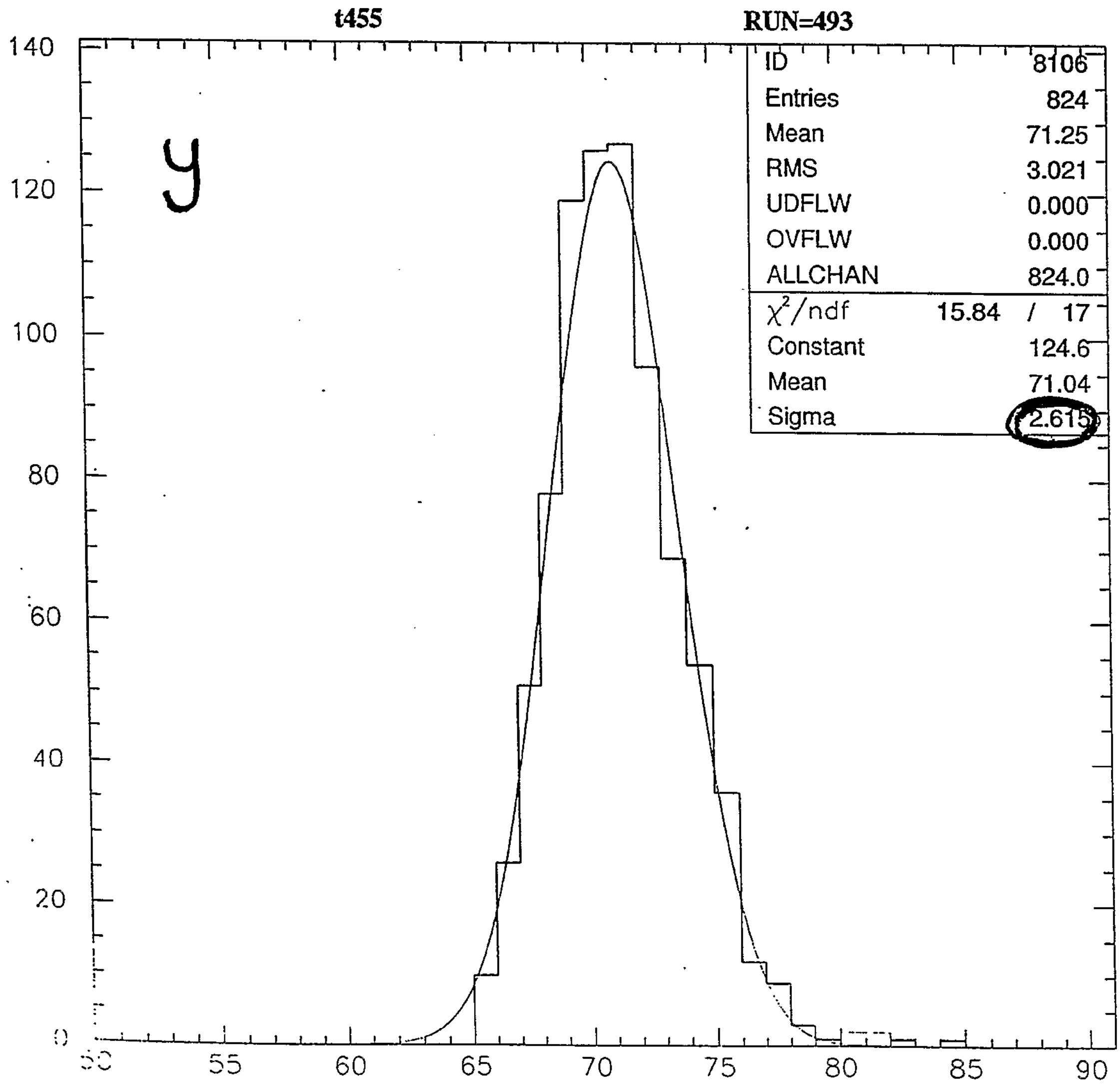


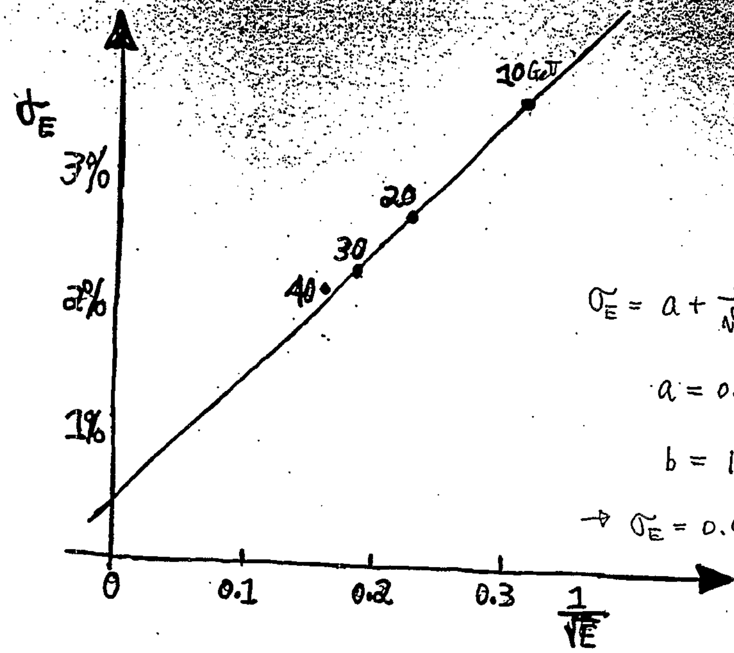
Results from cluster-fitting program using lnE weights on p. 136-137. The widths are
$\sigma_x = 1.2$ mm, $\sigma_y = 2.6$ mm.

This is consistent with a beam width for $x \lesssim 1$ mm, and $\sigma_y \approx 3$ mm. The actual resolution is smaller.

Note that $\chi^2/DF \approx 1$ => using lnE as weight seems to be a good estimate. Check by comparing with linear fit.

2001/08/23 09.17





$\sigma_E = a + \frac{b}{\sqrt{E}}$

$a = 0.45\%$

$b = 10\%$

$\rightarrow \sigma_E = 0.45 + \frac{10.0}{\sqrt{E}}$ (%) where E is in GeV

E = 10 GeV $\quad \sigma_E^S$ (statistics) = 3.16% $\rightarrow n_{p.e} = 1000$! at 10 GeV

nominal value of p.e. 8~10 / MeV for 5" tube. (Russian data sheet)

5" → 3/4" (15mm$^\phi$) × 0.44

1/10 filter × 0.1

→ 80000 p.e at 10 GeV

⇒ 3520 p.e.

why 1000 p.e instead of 3520 (expected) ?

- index of cookie
- filtering factor < 1/10 due to not perpendicular light.
- ?

cosmic dE/dx → 26 MeV / 2cm PbWO → if 1000 p.e / 10 GeV → 2.6 p.e. for cosmic ray.

Outlook

- Deign and Safety Review
- Analysis of SLAC test beam data
- Check calibrations at LEGS using ~1 GeV photons
- Temperature Control and Monitoring
- GMS Upgrade
- Bunch bits V124 module
- ZDCs from CAD
- Redesign of the “back” box
- Monte Carlo
- Stand Alone Trigger for the calorimeter
- Trigger counters for IP12
- DAQ

An ep-Polarimeter for RHIC

F. Meissner

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

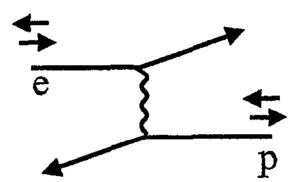
An ep-Polarimeter for RHIC

F. Meissner, LBNL   G. Igo, UCLA

Use longitudinal spin asymmetry in elastic electron-proton scattering for an absolute polarization measurement at RHIC.

Elastic e-p scattering:

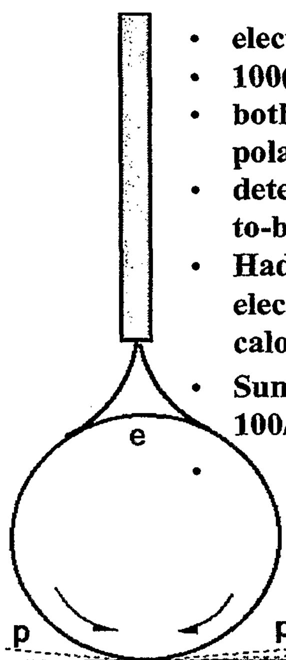
- **Known large analyzing power**
- **Calculable**
- **Many data** (Alguard et.al, etc.)



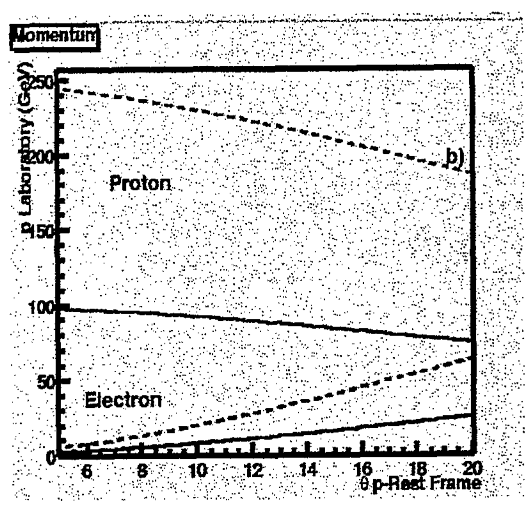
Scatter a longitudinally polarized electron beam off the longitudinally polarized proton beam

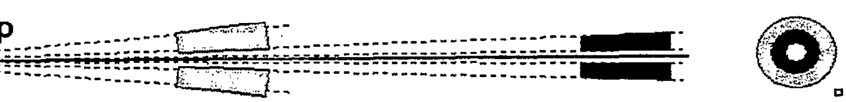
Ee 25 MeV (10 MeV) ⟶ ⟵ Ep 100 GeV (250GeV)

Setup



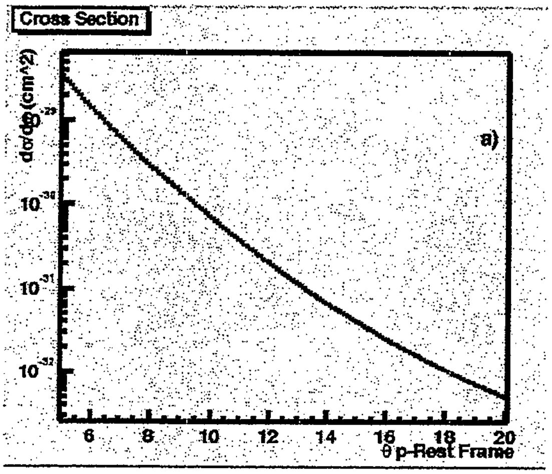
- **electron -Linac/Ring ?**
- **100(250) GeV proton RHIC**
- **both longitudinally polarized**
- **detect both particles back-to-back in coincidence**
- **Hadronic and electromagnetic 2π calorimeters (Φ–resolution)**
- **Sum of momenta: 100/250GeV**
- **Clean trigger, no background.**

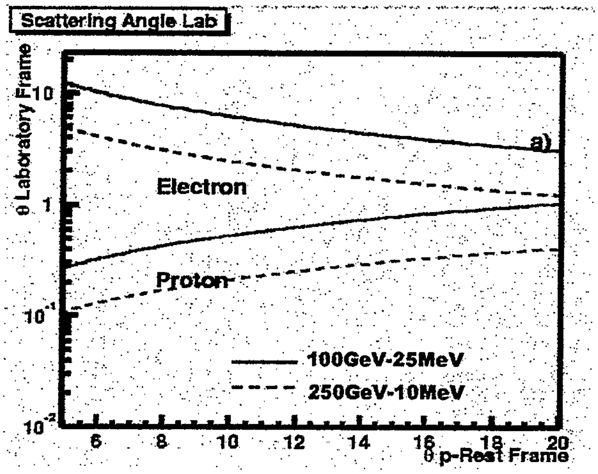




Kinematics

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega}_{Mott} \times \left[\frac{G_E^2 + bG_M^2}{1+b} + 2bG_M^2 \tan^2\left(\frac{\theta}{2}\right)\right]$$





- 25 MeV-100 GeV and 10MeV –250 GeV same c.m.s energy
- Scattering angles in lab: 0.1< θp< 1 deg.; 1< θe <10

Longitudinal Asymmetry

$$A_{\|} = \frac{\frac{\tau G_M}{G_E}\left\{\frac{2M}{E} + \frac{G_M}{G_E}\left[\frac{2\tau M}{E} + 2(1+\tau)\tan^2\frac{\theta}{2}\right]\right\}}{1+\tau\left(\frac{G_M}{G_E}\right)^2\left[1+2(1+\tau)\tan^2\frac{\theta}{2}\right]}$$

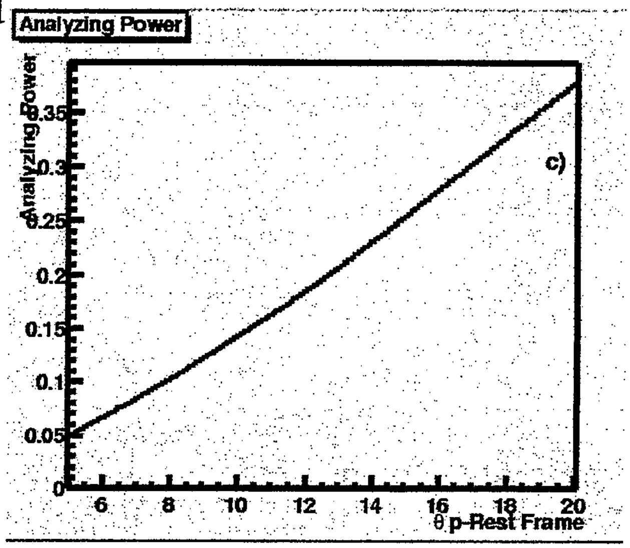
Form factors well measured

$$\frac{G_M}{G_E} = \frac{\mu^p}{\mu^n} = 2.79;$$

$$G_M(Q^2) = \frac{\frac{\mu^p}{\mu^n}}{\left(1+\frac{Q^2}{0.71}\right)^2}.$$

Asymmetry measured as

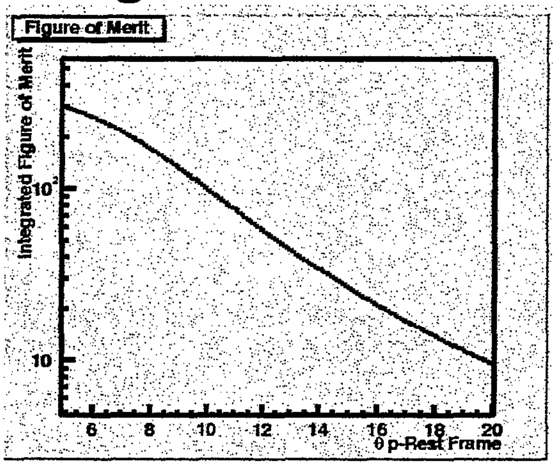
$$A_{\|} \equiv \frac{\sigma^{\rightleftarrows} - \sigma^{\rightrightarrows}}{\sigma^{\rightleftarrows} + \sigma^{\rightrightarrows}}. \approx \frac{1}{P_e\, P_p}\frac{N^{\rightleftarrows} - N^{\rightrightarrows}}{N^{\rightleftarrows} + N^{\rightrightarrows}}.$$



Estimated Signal

Assume:

- Acceptance: 2π x 0.1-10 deg
- Luminosity: 2*10^31 $cm^{-2}s^{-1}$
  1% EIC, 10% pp
  ~50mA (15mA) e-current
- Counting rate: 10Hz
  (0.2< Θp < 1: 0.6 Hz @250GeV)
- Polarizations: P_B=0.5,P_e=1



Average asymmetry 0.04 measurable with
4% statistical uncertainty within a 10hr fill
Systematic uncertainty determined by the electron beam polarization measurement.

(With EIC luminosity 1.5% within 1hr !)

Summary

Feasibility?

- Detector/Calorimeters standard technology
  (Distance of detectors to beam pipe and interaction region)
- Polarized source and accelerator:
  R&D for EIC ?
- Reuse equipment ?
  Jefferson, Bates, SLAC, Tesla, Lep……
- Needs expert input … Needs to mature …

At Luminosity $2*10^{31}$ $cm^{-2}s^{-1}$ (1% EIC, 10% pp) a signal asymmetry of A=0.04 could be measured with 4% statistical uncertainty within 10 hours.

Previous e-p Proposals

- Deep-inelastic scattering (Igo et.al, 96)

  x-section and asymmetries small w.r.t. elastic ep
- Elastic e-p on transverse p-beam (Glavanakov et.al 1996)

  A_{LL} A_{NN} A_{LS} , anti-collider, small (<5mrad) scattering angles, only e or p detected, magnet to bend out from beam.
- Elastic e-p from atomic H gas target (Nikolenko et.al 1996)

  target as for pp, background , fixed target kinematics, detect p-and e in coincidence, deflector magnets

Elastic muon-electron scattering successful used for beam polarization measurements by SMC

RHIC Spin ~ Brahms

F. Videbaek

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

RHIC SPIN
Brahms
presented by F.Videbaek

RHIC SPIN meeting

October 1, 2001

Earlier discussions

•FV "RHIC spin physics, Apr 27-29,98, Riken Vol 7

•A.Bravar "Future transversity measurements"

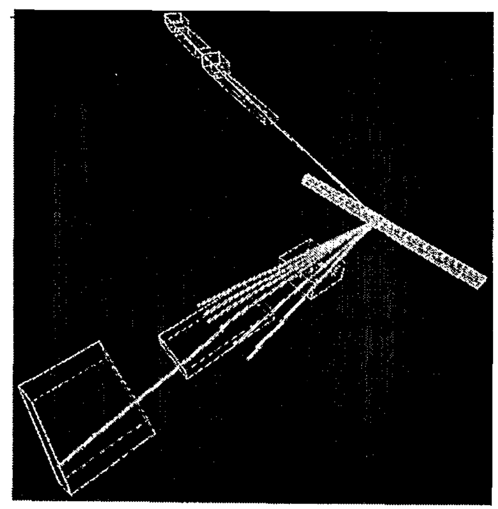
Transverse Asymmetries

Experimental issues

Acceptances

Rates

Resources.



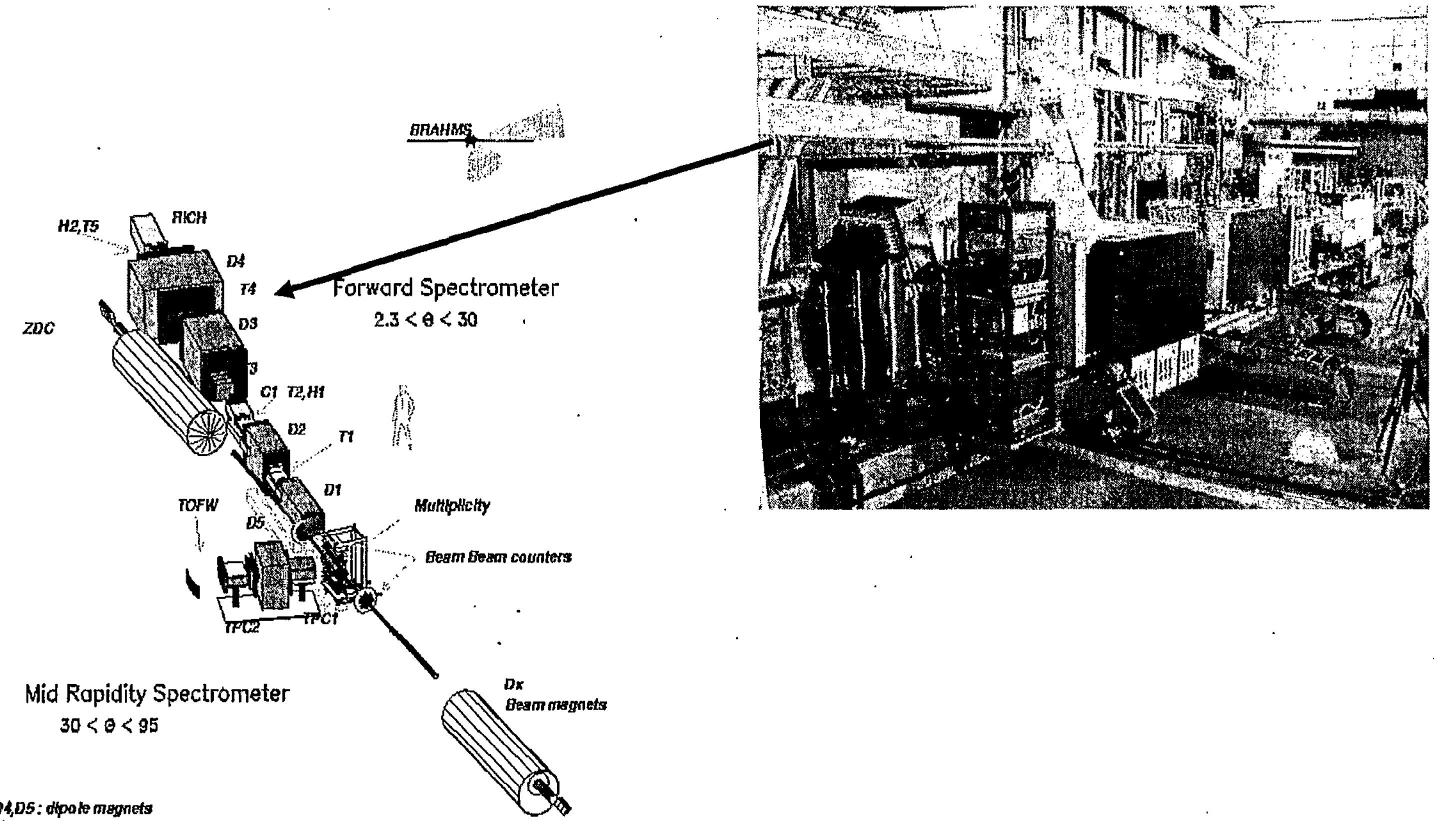
pp Running in Run-2

- Commissioning of detector system
  - Comparison to pp as a reference for AA will be useful.
  - Implement the common in-elasticity detectors shared with pp2pp.
  - Spectrometers need time-start counter for spectrometers for TOF PID. Resource limited for implementing this, but could be achieved for FS, certainly not for MRS.
- Exploring possibilities for a spin program (high x_F, transverse polarization) for transversity measurements with the RHIC spin group. This could be initiated in Run-2 with the one week of ~ 1.5 pb^{-1},but will require a longer period for high statistics later.

Transverse asymmetries

- Inclusive meson measurements mainly at large xF (.3-.7) and small pt (1-4 GeV/c)
- Most existing data at lower energy.
- A_{nn} = N(++)-N(+-)/(N(++)-N(--))
- A_{nn} (pi+) >0 (pi-)< 0, ~5-20% depending pt, xf.
- A pi- measurements will complement the STAR pi0 measurement. In fact important to map out pi0/ pi- for range of xF, pt – not a single shot measurement.
- Theoretical understanding has emerged.

Perspective View of BRAHMS Spectrometer



D1,D2,D3,D4,D5 : dipole magnets
T1,T2,T3,T4,T5, TPC1 TPC2: tracking detectors
H1,H2,TOFW : Time-of-flight detectors
RICH, GASC : Cherenkov detectors

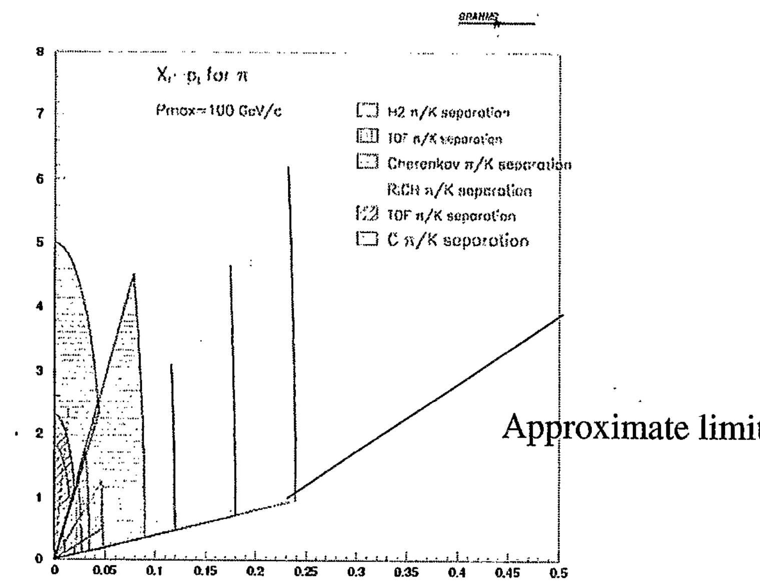
Experimental issues

- Coverage xF-Pt
- Solid angle, rates
  - BFS ~ .6 msr; P-theta acceptance.
  - At xf~.25 pt~1
- DAQ is event driven
  - Effective data-rate will depend on trigger setup (using sets of hodo-scope in FS
  - Background issues (already present in AA)
  - ~500/sec with DC, RICH,Hodoscopes and no TPCs.
- Polarization counting, scalers,...

Acceptance & rate

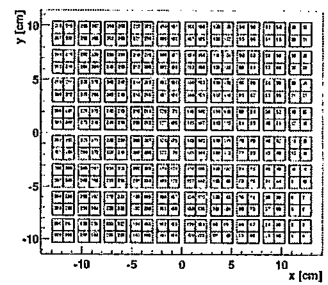
- The acceptance is comes from the lowest angle at 2.3 degrees, and at xf~.25 the pt is ~ 1.0 GeV/c
- At higher Xf the pt gets relative higher since the magnets is at fixed field.

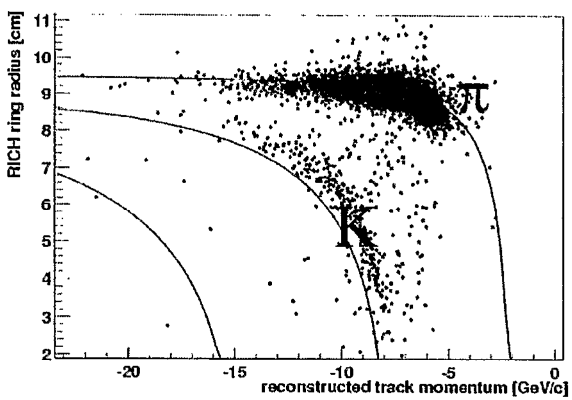
- At the lum of ~5% the rate at xf~.20 is 1-2 pion per sec. At xf~.5 it is lower by at least 1/1000.

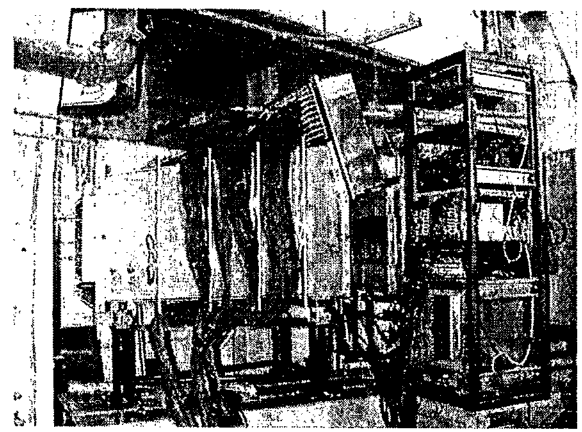


Particle Identification in current setup

- The High momentum PID is exclusively from the RICH situated at ~20 m.
- C_4F_{10}-C_5F_{12} mixture at 1-1.25 atm.
- Could be replaced in future runs with different gas for lower index, that could give pi/K/p sep at higher p.
- Designed for few tracks. 2*2 segmented focal plane.
- 150cm Focal length
- - Entrance window ~ 45*35 cm at 20m







Issues for pp running

- Implement the polarization counting (scalers, bunch information)
- Setup of triggering.
- Determine optimum angles, field setting for short run
- Add FS hodoscope (both tof+triggering)
- Include pp2pp (inelasticity counters in setup)
- Resources for, preparing setup, running exp and analyzing data.
- Aim if sufficient interest to have a feasibility run, and first look at data in the ~ 1 wk of transverse polarization.

Status of the PP2PP Experiment

S. Bültmann (Brookhaven National Laboratory)

Summary

The PP2PP experiment at RHIC is going to measure elastic and total cross-sections in (un-)polarized proton-proton scattering. The experiment is located at the 2 o'clock interaction region (IR) of the RHIC complex. Elastic scattering at the RHIC energies, $\sqrt{s} = 200$ GeV/c and possibly 500 GeV/c during the first year, requires detection of the scattered protons at very small angles. At 57 m from the IR, where *parallel to point focusing* is satisfied, the scattering angle is directly proportional to the measured distance between the scattered proton and the beam axist, $\Theta = y_{Det}/L_{eff}$. With $L_{eff} = 20$ m the four-momentum transfer range is 0.003 to 0.100 $(\text{GeV}/c)^2$ at $\sqrt{s} = 200$ GeV/c.

Elastic scattering requires the detection of the two collinearly scattered protons in coincidence. To measure their positions, we are installing Roman Pot stations in the two outgoing beam pipes, about 57 m on either side of the interaction region. Each station consists of two Roman Pots mounted above and below the beam centre, containing a detector package of four silicon microstrip detectors and one scintillation counter. The active area is about 80 mm $\times$ 50 mm, the position resolution better than 0.1 mm.

During the initial setup and commissioning phase, the detectors will be located 31 mm above and below the beam centre, making only a higher $|t_{min}|$ of 0.018 accessible. During a special run with reduced luminosity of $1.5{\cdot}10^{28}\,\text{cm}^{-2}\,\text{sec}^{-1}$ and probably 6 bunches in each ring, the position will be at a distance of 15 mm from the beam centre. For the 6 bunches we would like to have radially polarized protons colliding in this pattern: $\uparrow\downarrow, \downarrow\uparrow, \uparrow\uparrow, \downarrow\downarrow, \uparrow 0, 00$. For further systematic studies the polarizations can be reversed via the spin flipper.

The setup will feature additional scintillation counters close to the interaction region to tag non-elastic scattering events. These counters will measure single- and double-diffractive scattering events, in the pseudo-rapidity range of $2.6 < \eta < 5.6$.

During the Year-2001 engineering run of PP2PP the main focus of the measurements will be on the total cross-section, σ_{tot}, its difference between the two transverse helicity states of the beam, $\Delta\sigma_T$, the single and double transverse spin asymmetries, A_N and A_{NN}, and the energy dependence of the nuclear slope, b. This should allow to distinguish between different exchange models brought forward for example in[1].

Assuming a cross section of about 40 mb would lead to an expected physics event rate of about 600 Hz, the trigger rate being probably higher at around 1 kHz. For the above mentioned bunch fill pattern we would collect about 300,000 events per hour and pattern. Hence, a store of about 10 hours would be sufficient for our measurements. If also 250 GeV/c become available, we would like to have additional beam time with reduced luminosity at that energy.

At present the production, assembly, and testing of the detectors measuring the vertical position of the scattered protons is underway. The assembly of the horizontal detectors is going to start in a few weeks. The Roman Pots will be available by November 26 at the switch-over time to proton running, as will be the inelastic detectors, which had been previously mounted and tested.

[1] N. Buttimore et al, PRD 59:114010 (1999) and E. Leader and T. Trueman, PRD 61:077504 (2000)

Measurements for Engineering Run in Year-1

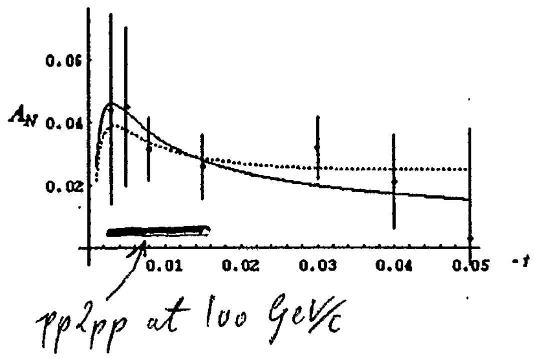
Kinematic coverage:

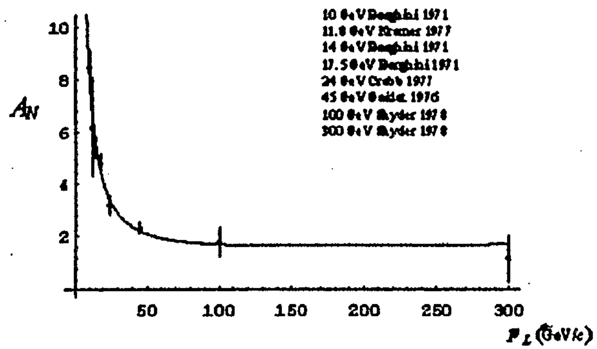
- at 100 GeV/c: $0.003 < -t < 0.015\ (\text{GeV}/c)^2$
- at 250 GeV/c: $0.006 < -t < 0.100\ (\text{GeV}/c)^2$

- Study CNI region, σ_{tot}, A_N, A_{NN}
- s and t dependence of the nuclear slope, B
- Measurement of A_N over large $-t$ range to find suitable kinematic region for polarimetry

Analyzing Power A_N

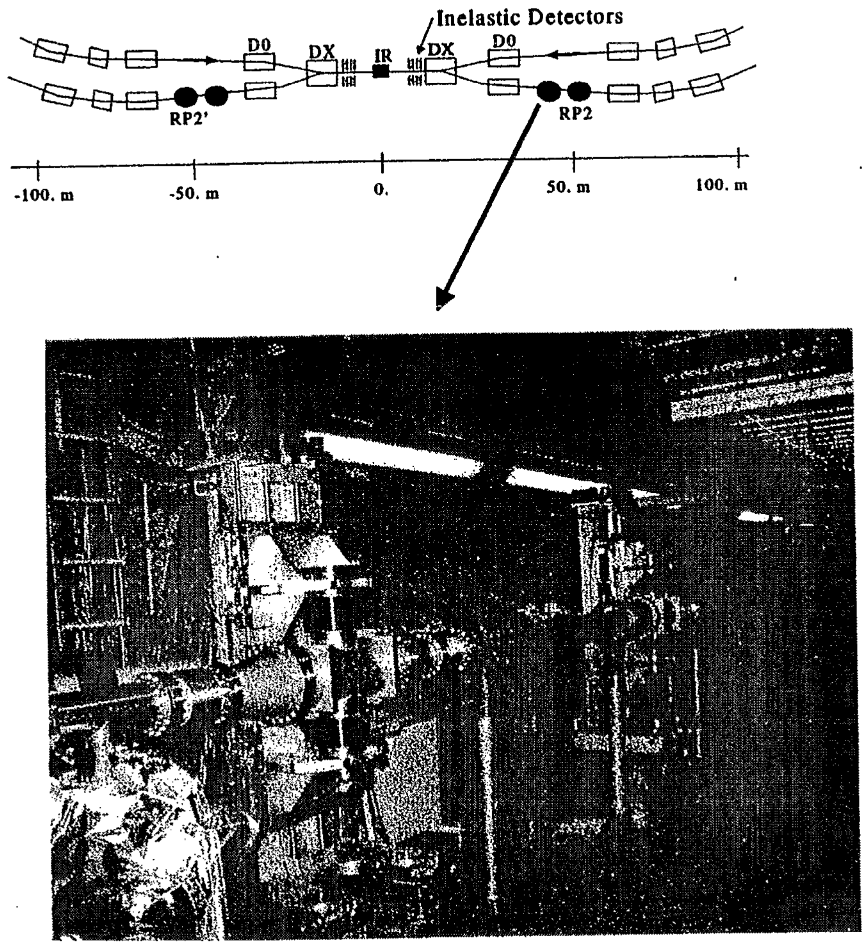
THE SPIN DEPENDENCE OF HIGH-ENERGY PROTON SCATTERING.
N.H. Buttimore, B.Z. Kopeliovich, E. Leader, J. Soffer, T.L. Trueman
Phys.Rev.D59:14010,1999





Layout of the Experiment

Roman pot location is determined by parallel to point focusing.



Expected Run Plan

- Set up and commissioning concurrent with other experiments at a 'safe' distance (3.1 cm from beam centre)

- **Special low intensity run for pp2pp** (1.5 cm from beam centre)

  - Total proton intensity ≈ $1.5 \cdot 10^{11}$ (6 bunches)
    ➔ $L \approx 1.5 \cdot 10^{28}$ $\mathrm{cm^{-2} sec^{-1}}$

  - Radial polarization direction

  - 600 Hz physics rate for ~40 mb cross-section (2 million events per hour)

  - Assume 6 bunches with fill pattern

    ↑↓ ↓↑ ↑↑ ↓↓ 0↑ 00

    ➔ 300,000 events per hour and pattern

  - Need 1 beam store of about 10 hours (for each beam energy?)

  - Would like 2 hours during commission early

Status of Experiment

- Vacuum parts for all four Roman Pot stations installed (Roman Pots to be installed during switch-over time)
- Infrastructure mostly on place
- Production of silicon detector assemblies started (first Y-detector assembled and aligned last week)
- Testing of detectors to begin this week
- Silicon detector wafers being manufactured at InstDiv (new batch available beginning 3 weeks from now)
- DAQ work underway (Dima and Igor arrived)
- Inelastic detectors installed, tested, and dismantled again for Au-Au running
- Plan to install Roman Pots in November

Outlook

2003

- Extend measurements to $0.1 < -t < 1.3$ (GeV/c)^2

Beyond 2003

- Measure in CNI region, requiring special tune $0.0004 < -t < 0.12$ (GeV/c)^2
- Measure in large -t region $1.3 < -t < 5$ (GeV/c)^2
- Elastic scattering of proton-deuteron, deuteron-deuteron, and proton-^{4}He also possible

Stephen Bültmann RHIC Spin Collaboration Meeting BNL October 1, 2001

STAR readiness for $\vec{p}-\vec{p}$ running

G. Rakness
Indiana University Cyclotron Facility
Representing the STAR Spin Collaboration

The status of the STAR experiment concerning its readiness for polarized proton collisions is presented. The goals of STAR Spin for the first year of $\vec{p}-\vec{p}$ running include: to commission the accelerator and detectors for $\vec{p}-\vec{p}$ collisions, to measure spin asymmetries for the first time in a $\vec{p}-\vec{p}$ collider, to understand the limiting systematic uncertainties for the measurement of A_{LL}, and to collect 'minimum-bias' $p-p$ events for the use of the STAR heavy ion physics program. The primary focus of STAR Spin for this year is to measure single-spin transverse asymmetries, in particular one which is expected to be non-zero, namely, the inclusive production of π^0 mesons at low-p_T and moderate x_F, concurrent with a single-spin asymmetry which is expected to be small, that is, the production of leading $h^\pm$ at high-p_T and mid-rapidity.

One of the major efforts in recent months has been the installation and commissioning of the Forward Pion Detector (FPD), which detects daughter photons from the decay of π^0 mesons. The commissioning of the FPD with $Au-Au$ collisions so far has met with reasonable success. With cuts on the timing information from the STAR ZDC's, the data suggest that a significant fraction of the events seen at the FPD come from collisions at the STAR interaction region. This conclusion is further bolstered by the changes in the scaler rates observed in the detector during a van der Meer scan of the beams. A portion of these events exhibit features in the detector which, from simulation, are expected from highly energetic π^0 mesons.

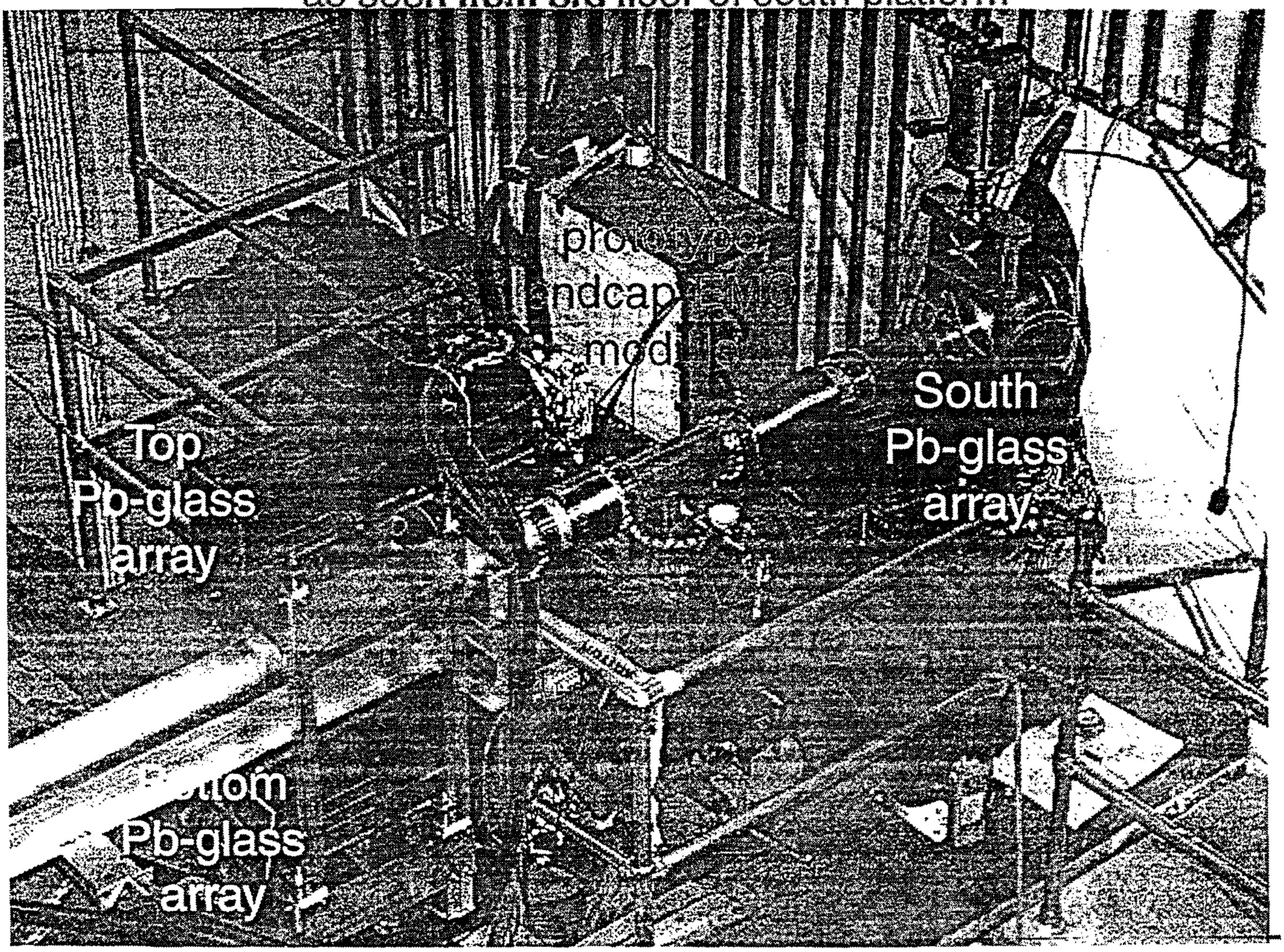
The Beam-Beam Counters (BBC) are currently under construction, and are expected to be installed during the shutdown just prior to the $\vec{p}-\vec{p}$ run. The BBC's will measure the rate of double-diffractive scattering events by detecting multiple MIP's coincident east and west of the STAR interaction region, and will be used to measure the relative luminosity between beam-crossings with different orientations of the polarization vectors.

The Barrel Electromagnetic Calorimeter (EMC) is currently being commissioned with $Au-Au$ collisions. The Barrel EMC will be used, amongst other things, for calorimetry in the measurement of inclusive $h^\pm$ at high-p_T and mid-rapidity.

In addition to these detector subsystems, there has been work in development of the triggers that will be used for $\vec{p}-\vec{p}$ running. The largest open question is the bandwidth which will be devoted to each trigger type, and is currently under discussion within STAR. There has also been software development on the STAR spin-sorting database, which contains beam and detector information necessary for asymmetry analyses.

Forward Pi0 Detector

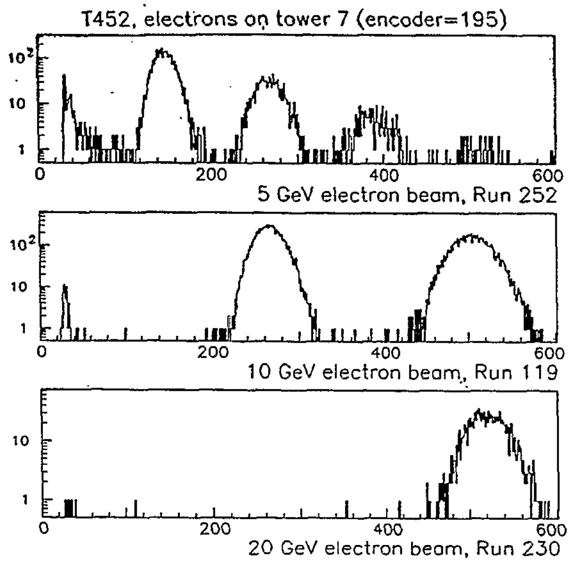
as seen from 3rd floor of south platform



East tunnel platform extension

- All components of the FPD are in position.
- Control, triggering and DAQ electronics are functional in 'stand-alone' mode.
- Detector commissioning during Au-Au collision run is underway.
- Hardware link to STAR level-0 trigger and software link to STAR DAQ is planned to be completed prior to the start of polarized proton running.

Results with the prototype endcap EMC

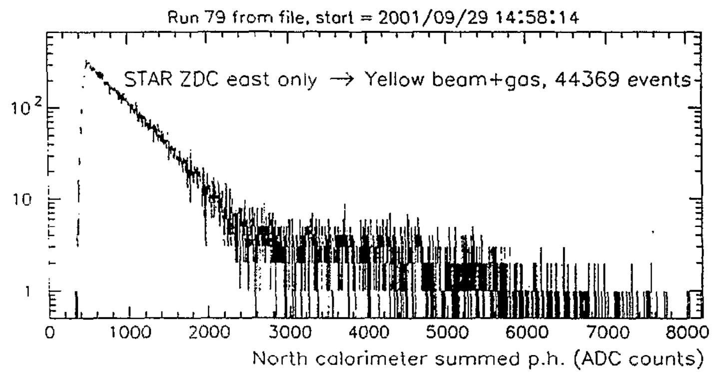


The prototype endcap EMC was calibrated at SLAC in January, 2001 during test-beam experiment T-452 using beams of 5, 10 and 20 GeV.

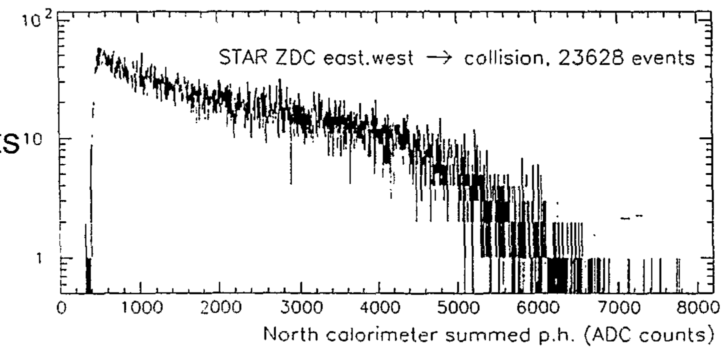
Shown in the figure are events with 0, 1, 2 and more high-energy electrons per beam pulse.

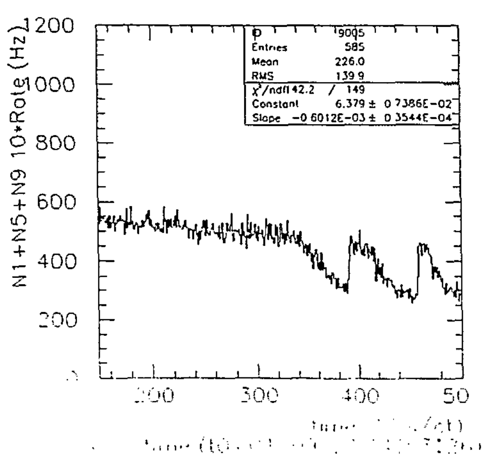
Data at RHIC for Au beams with E = 100 GeV/nucleon

The summed energy in the prototype endcap EMC is very different for Yellow ring beam-gas events versus collision events, as determined by conditions on the STAR ZDC's.



For Au-Au collisions, we see events with up to ~230 GeV electron-equivalent energy.



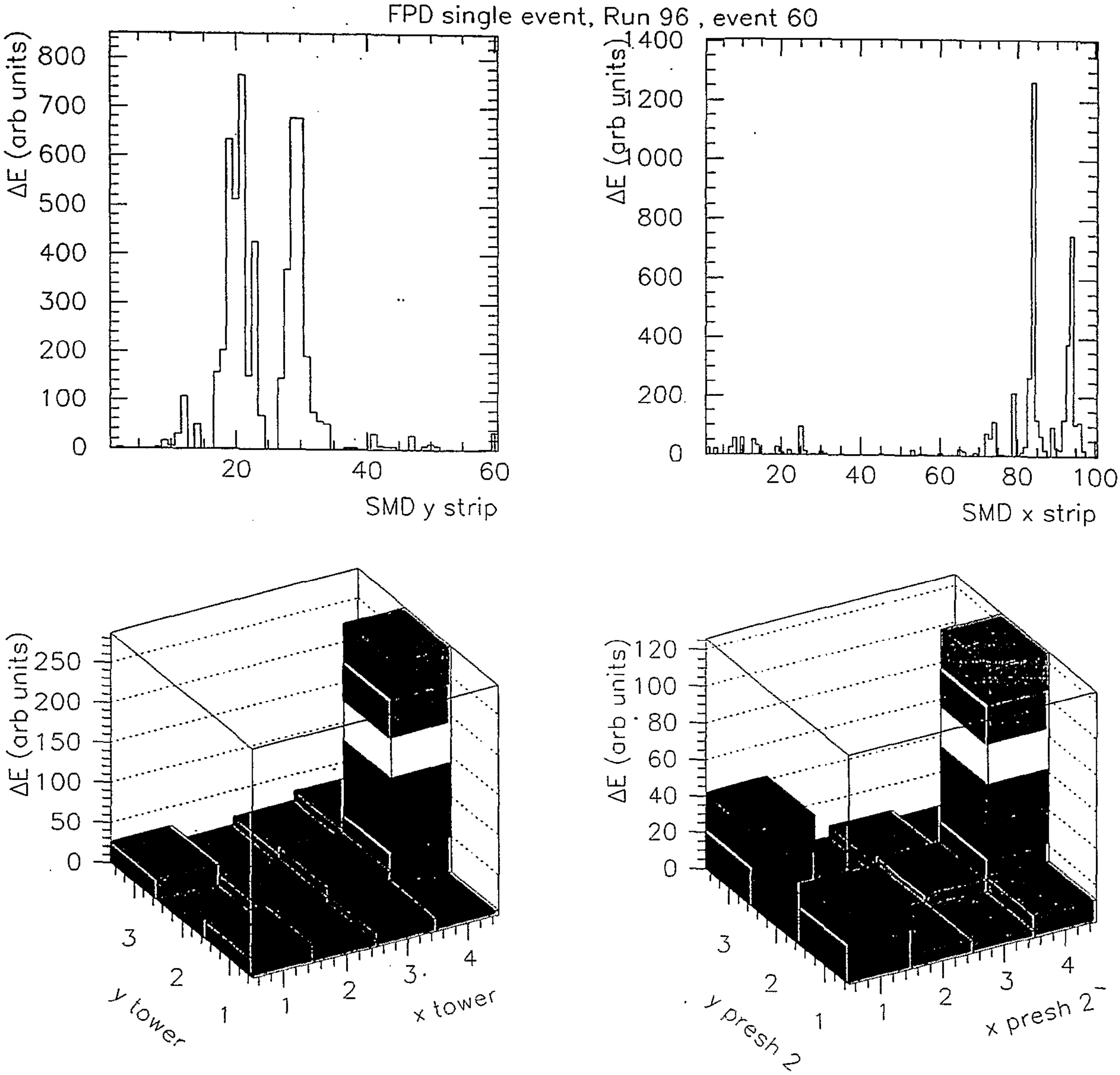


The count rate of pulses with electron equivalent energy >20 GeV is sensitive to collisions, as evidenced by measurements during a van der Meer scan at the STAR interaction region.

STAR spin

Prototype endcap EMC event

STAR spin

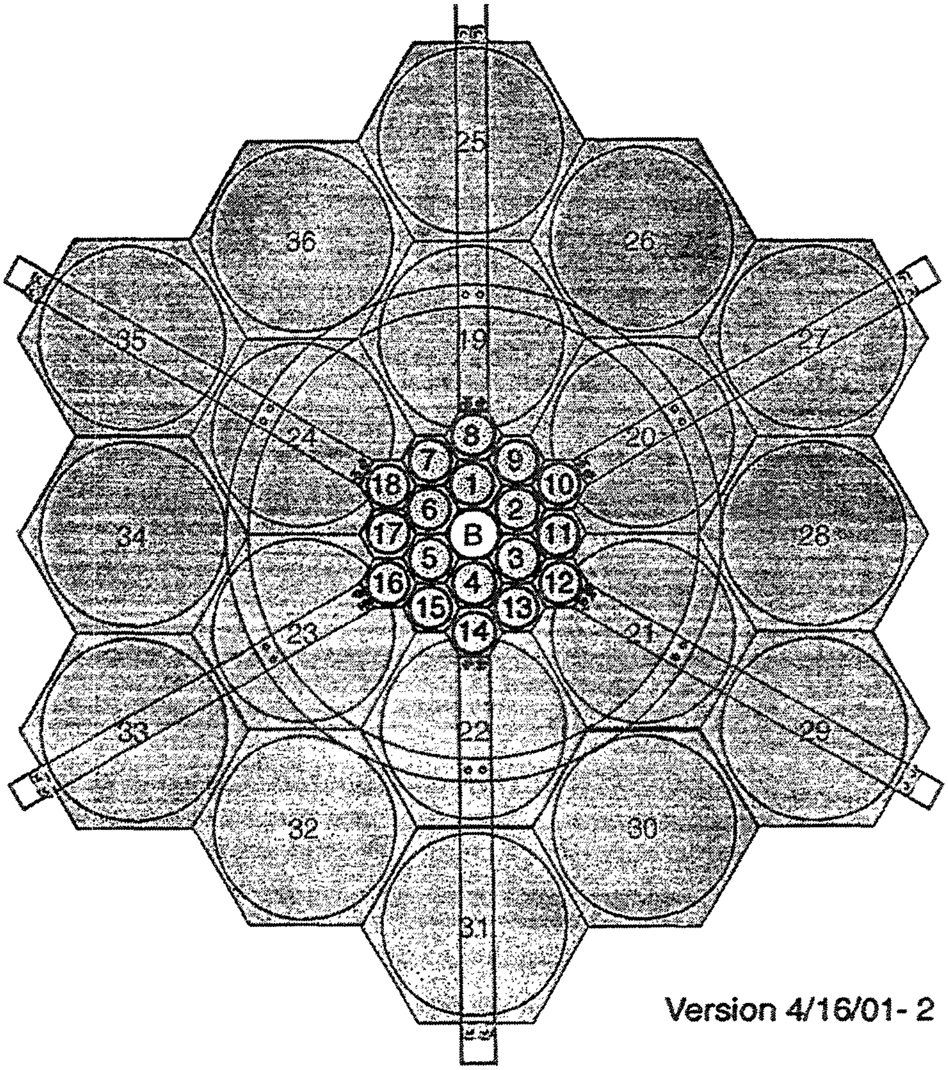


We observe single evidence that are similar to those expected for $\pi^0 \rightarrow \gamma\gamma$ decay for Au-Au collision events. These events are rare, but have the expected signatures:

- a significant fraction of the energy deposited into a single calorimeter tower.
- two peaks in both the x,y shower-maximum detector planes.
- large energy deposition (~5 MIP's) in the preshower tile of the high tower.

STAR Beam-Beam Counter

Front View



Version 4/16/01- 2

STATUS

- Mechanical support frame manufacturing complete.
- Photomultiplier tubes and magnetic shields on hand.
- PMT light-tight box manufacturing completed by ~10/15
- Scintillator machining completed by ~10/18.
- Tests of triggering electronics underway.

High-p_T, mid-rapidity

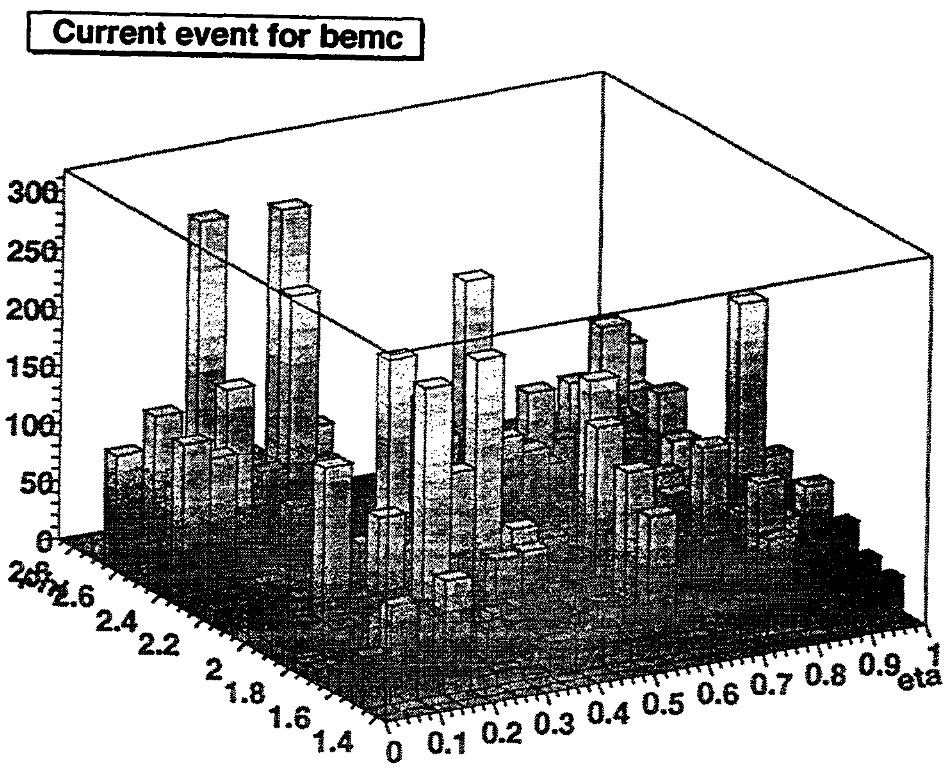
Primary detectors:

- Time-Projection Chamber
- Barrel Electromagnetic Calorimeter (EMC) patch

Currently commissioning Barrel EMC....

Coverage: $0 < \eta < 1$: $1.4 < \varphi < 2.8$ rad (12 modules)

Typical $Au-Au$ 'central event' from Sept. 2001: 25-50% tower occupancy



PHENIX Status and Plans

M. Grosse Perdekamp

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

PHENIX Status and Plans

Subsystem Readiness

- Tracking
- Calorimetry
- Luminosity Monitor
- DAQ/Level 2 Trigger
- Level 1 Trigger
- Slow Control
- Monitoring
- PRDF

Trigger Mix and Goals

RHIC Spin Collaboration Meeting, October 1, 2001. Matthias Grosse Perdekamp, RBRC

Detector Configuration for pp

Central Arm Tracking
- Drift Chamber
- Pad Chambers
- Time Expansion Chamber

Muon Arm Tracking
- Muon Tracker

Calorimetry
- PbGl and PbSc (gain balance, level 1)

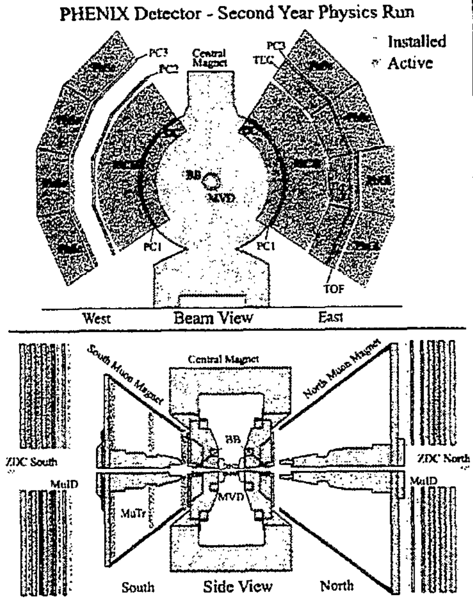
Particle Id
- Muon Identifier (level 1)
- RICH
- TOF
- TEC

Luminosity Counters/Vertex Detectors
- BBC
- ZDC
- NTC
- MVD

DAQ
- Bandwidth upgrade, event size/data volume

Trigger
- Level 2 (Bandwidth upgrade)
- Level 1 (GL1P,muld, EMC/RICH)

PHENIX Detector - Second Year Physics Run



PHENIX Status and Plans 2 RHIC Spin Collaboration Meeting, October 1, 2001

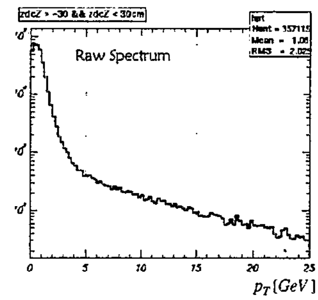
Central Arm Tracking

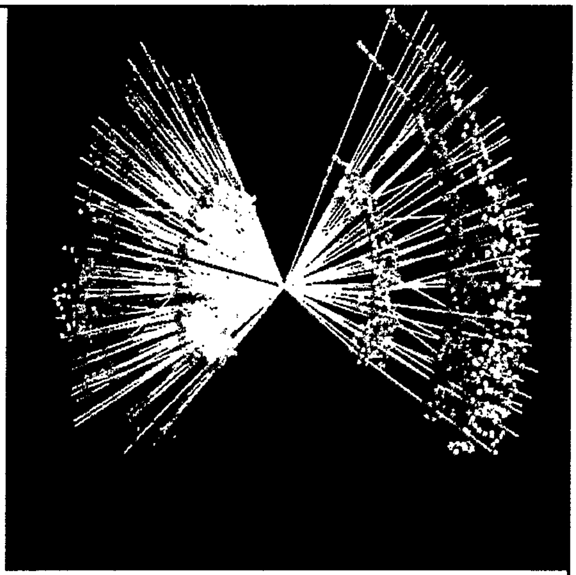
DC: West chamber re-build, gas additive, new high voltage configuration:

$\varepsilon = 0.85 \rightarrow 0.97$ (single wire)
$\sigma = 120\ \mu m$ (design: $150\mu m$)

PC: PC2 + PC3 inserted in west arm

TEC: Instrumented 2 additional sectors



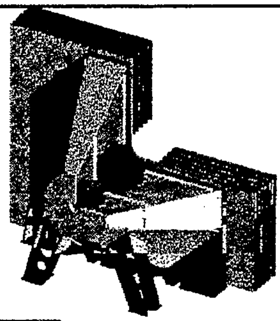


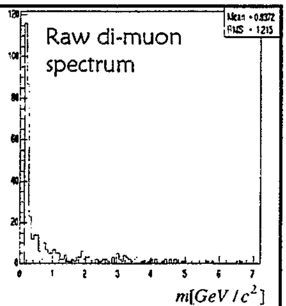
West Arm: DC+ PC1 + PC2 + PC3
East Arm : DC+ PC1 + PC3 +TEC

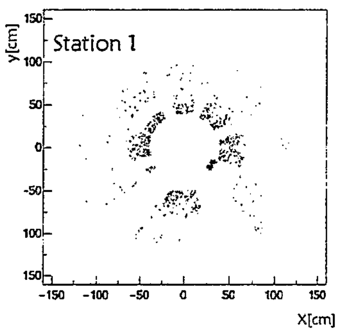
Muon Arm

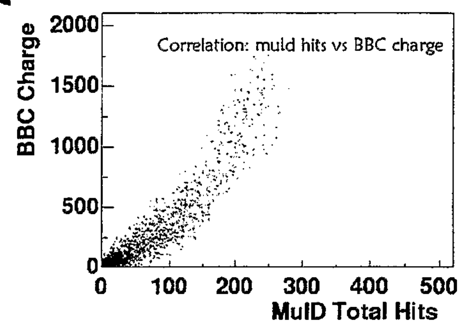
South Muon Tracker Installed

muId trigger



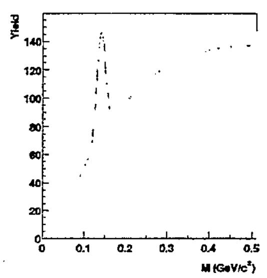


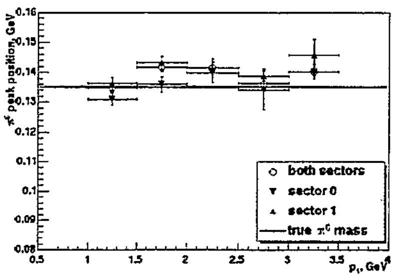




EMC

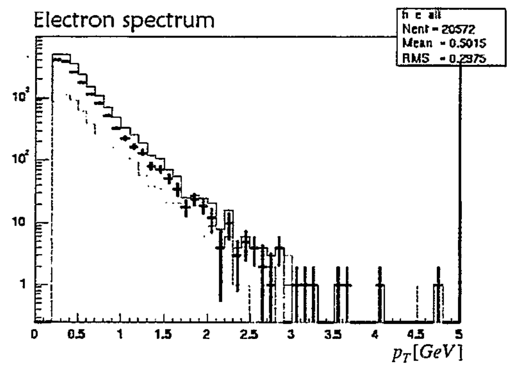
- Added 1 PbGl (E0) and 3 PbSC sectors (E2,E3,W2,W3)
- Trigger cards to be installed (5 days)
- All sectors calibrated and operational
- Level 1 trigger requires raw gain calibration





RICH

- Fully operational
- Trigger cards to be installed (1 day)



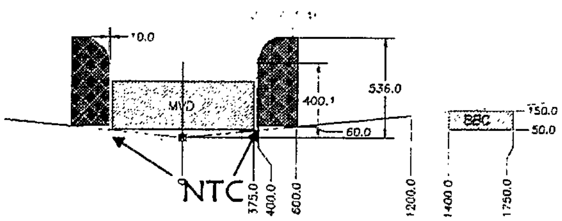
Luminosity Monitor

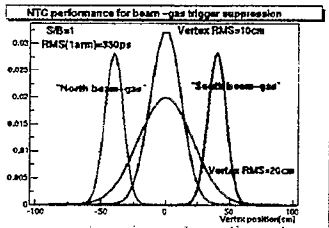
Monitor	$x \cdot \sigma_{tot}$
ZDC	1%
BBC	66%
NTC	85%
BBC||NTC	90%

Strategy:

GIIP: 4 event scalers/bunch crossing (inhibit from DAQ busy).

A large acceptance normalization trigger (BBC||NTC) will be used in low intensity runs to calibrate the ZDC and BBC coincidences as luminosity monitors.





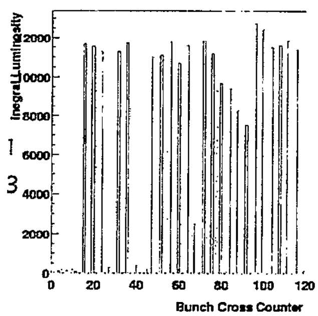
Asymmetries from HI-data

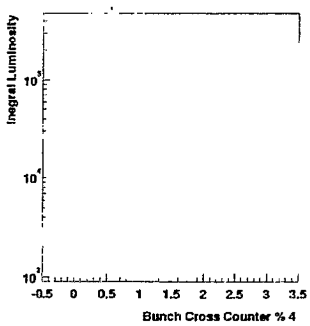
Sasha Bazilevsky, Basanta Nandi

$L \approx$ number of triggers (BBC or ZDC)

BCC % 4 = 1

BCC % 4 = 3



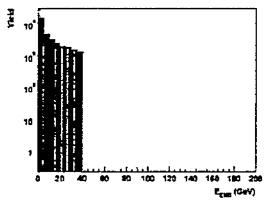


A = (red-black) / (red+black) = (1.86±0.14)%

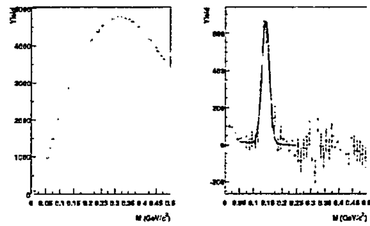
π^0 Asymmetries in Au + Au

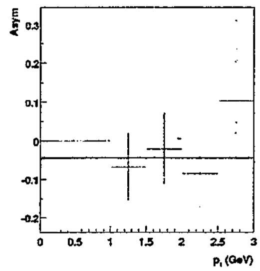
Sasha Bazilevsky

Select peripheral events



π^0s from event mixing technique



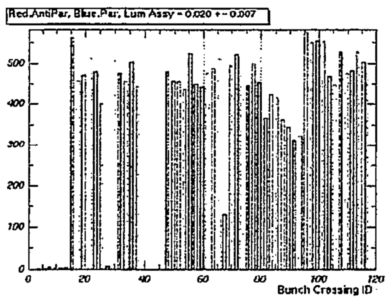


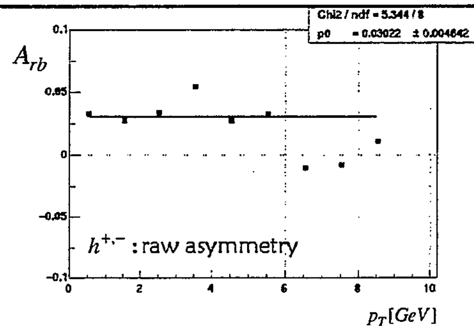
Runs 26180 and 26183
with 0.5Mevents:

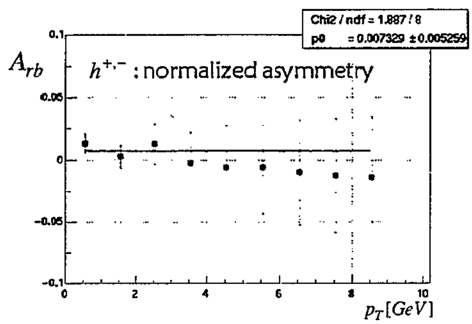
$A = (-4.3 \pm 5.5)\%$

$h^{+,-}$ Asymmetries in Au + Au

Basanta Nandi





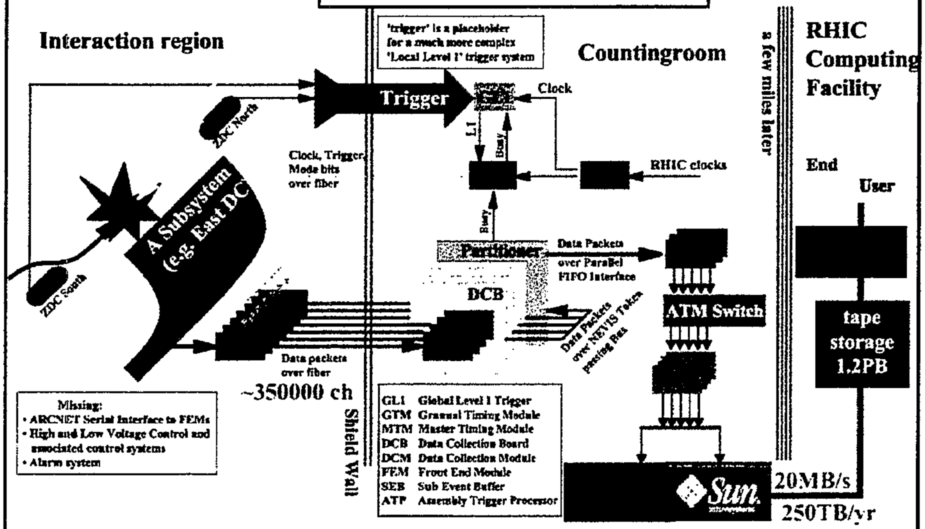


Run 26180 (no centrality selection)
with 0.1Mevents:

$A = (0.7 \pm 0.5)\%$

DAQ/Level 2

Current projection for pp 2kHz into SEB
600Hz to tape (event size limitation)
⇒ level 2 rejection is required



Level 1 trigger

Muon Arm:
- a) Custom FPGA board (muID-LL1) which finds horizontal and vertical roads pointing to the vertex in the muon identifier.
- b) CAMAC based coincidence of muon identifier gaps. Resolution limited to quadrants, no vertex pointing, vulnerable to cosmics-> requires NTC.

Central Arm:
- a) Custom LL1 which analyses and correlates threshold information from 172 trigger tiles in the EMC (4 thresholds) and 256 trigger tiles in the RICH (1 threshold).
- b) CAMAC based trigger using coarse trigger tiles. 16 trigger tiles in the EMC (3 thresholds) and 16 triger tiles in the RICH.

Minimum Bias:
- a) NTC||BBC
- b) Clock

Slow Control/PRDF/Monitoring

Item	Objectivity	PRDF	Monitor
bunch pattern	yes	yes(header)	yes
beam currents	yes	yes(header)	yes
polarization pattern	yes	yes(header)	yes
polarimeter information	yes	yes(header)	yes
GL1 scalers vs bunch configuration	no	yes(event)	yes
GL1P scalers	no	yes(event)	yes
level 1 configuration, pre-scale factors	yes	yes(header)	yes
level 1 rates and rejection	no	no	yes
level 1 trigger bit information	no	yes	yes
level 2 configuration, pre-scale factors	yes	yes(header)	yes
level 2 rates and rejection	no	no	yes
level 2 scalers	no	yes(event)	yes
level 2 monitoring	yes	yes(header)	yes
detector performance vs bunch configuration	no	no	yes
NTC	yes	yes	yes

Assumptions

NTC and T0 detector installation time does not come out of the 8 weeks time.

3 weeks of polarized p-p beam setup.

Luminosity of 5×10^{30} cm^{-2} sec^{-1} (raw interaction rate of 250 Khz).

Greater than 50% beam polarization.

1 week of running with transverse spin polarization to get about 1 pb^{-1}.

4 weeks of running with longitudinal spin polarization to get about 4 pb^{-1}.

PHENIX Physics Goals

I) Obtain p-p reference data for comparison with the data from the HI runs.

II) Place first constraints on the gluon polarization in the proton through pion production in the central arms.

III) Establish the first measurement of spin asymmetries in J/Psi production in the muon arm.

IV) Search for any transverse spin effects.

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Level 1: Trigger Mix

	Spin	HI - comparison	trigger	rate
Central arm	$A_{LL}^{\pi^0}$	$\pi^0 - p_t$ -spectrum	EMC 4x4 tiles > 2 and 3 GeV	0.2kHz
Central arm	$A_{LL}^{h^{+,-}}$	$h^{+,-} - p_t$ -spectrum	EMC 2x2 tiles > 0.9 GeV	1.4kHz
Central arm	$A_{LL}^{e^{+,-}}$, $A_{LL}^{\pi^{+,-}}$	single $e^{+,-}$, J/ψ	EMC 2x2 tiles > 0.9 GeV ⊗ RICH	0.1kHz
Central arm	NA	ϕ	2xRICH÷30	0.1kHz
Muon arm	$A_{LL}^{J/\psi}$	J/ψ	1 deep muon (last muid gap)	0.2kHz
	Clock	min bias		0.5kHz
	NTC||BBC	min bias		0.5kHz

Total 3.0kHz?

➡ Need charged hadron level 2 trigger

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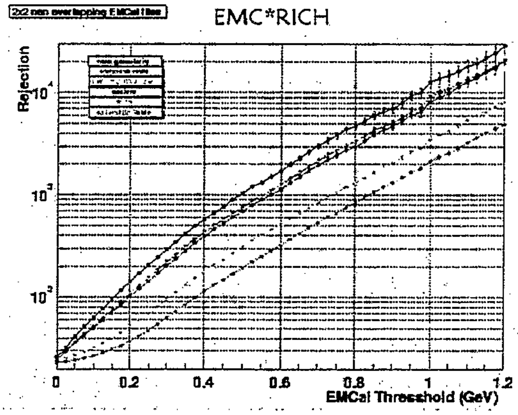
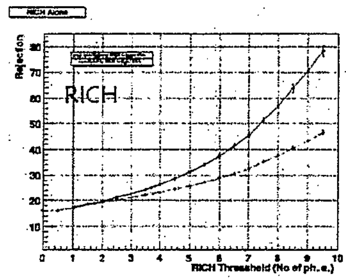
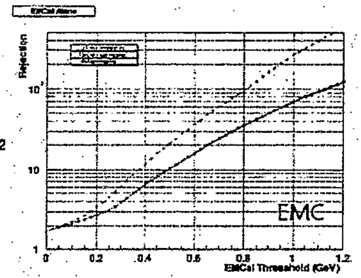
Trigger Rejection (EMC-RICH)



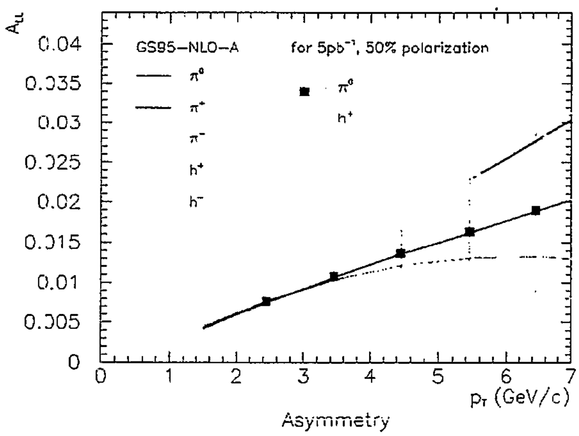




Trigger Bandwidth allocation
will be finalized from data

Sensitivities

Yuji Goto



Conclusion

Balance between HI comparison running and spin is possible.

NTC, trigger, DAQ and spin specific data+monitoring need to be finalized.

Requires 1 week of access between Au and p run.

Luminosity Monitoring and Bunch Current

H. Sato

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

Luminosity Monitoring and Bunch Current

Hiroki Sato, Kyoto Univ./RIKEN
RHIC Spin Collaboration Meeting VI
October 1, 2001

- Introduction
- Features of bunch-by-bunch current
- Comparison of bunch-current product and event rate at PHENIX

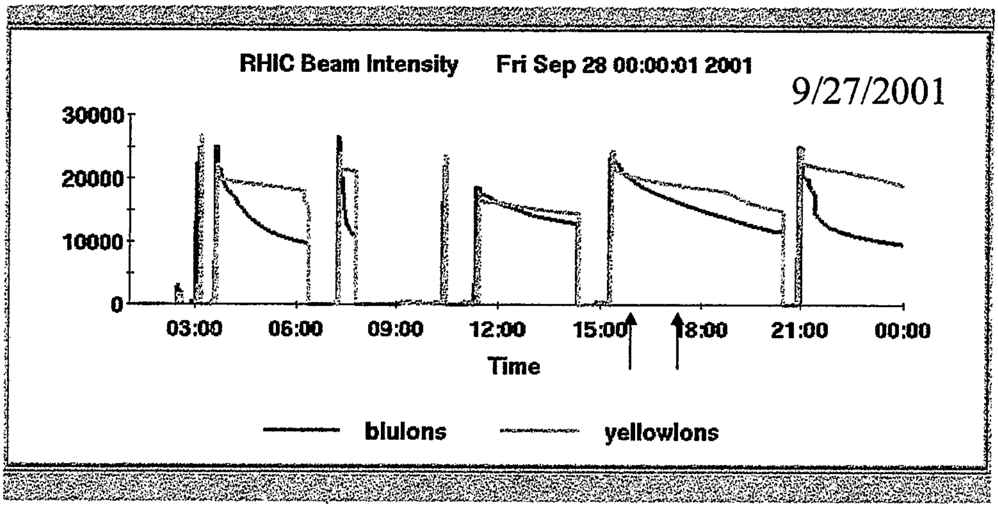
Needs for luminosity measurement for spin physics

$$A_{LL} = \frac{1}{P_{B1}P_{B2}} \frac{N_{++}/L_{++} - N_{+-}/L_{+-}}{N_{++}/L_{++} + N_{+-}/L_{+-}}$$

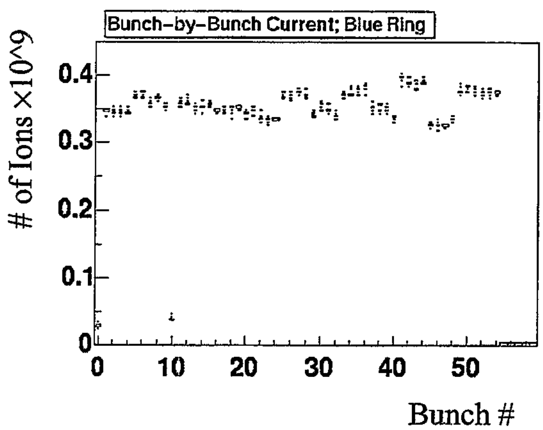
- Need to measure crossing-by-crossing luminosity to obtain physics asymmetry
- Our goal is $\delta(L_{++}/L_{+-}) \sim 10^{-4}$
- How to measure luminosity?
  1, Use bunch-current product (from CDEV)
  2. Use scaler values from experiment (BBC,ZDC,NTC,...)

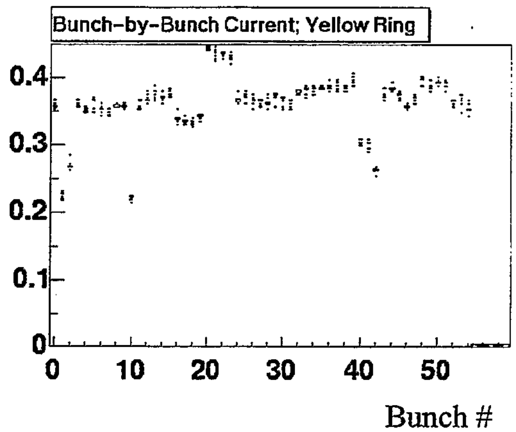
* Actually we need both since 2 can be spin-dependent

Features of Bunch Current…



Bunch Current
Bunch-by-Bunch Dependence

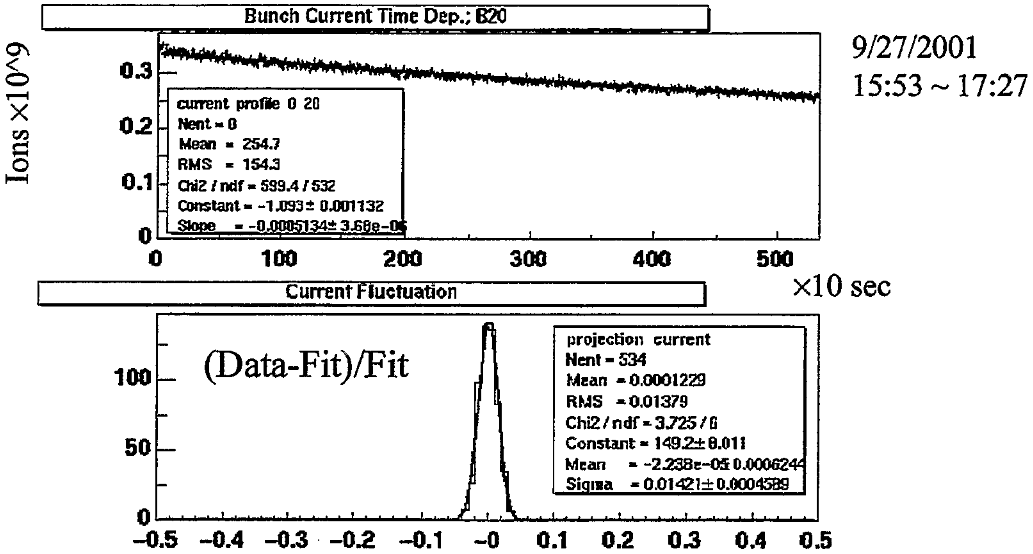




9/27/2001,15:53
1 min.
(6 data points)

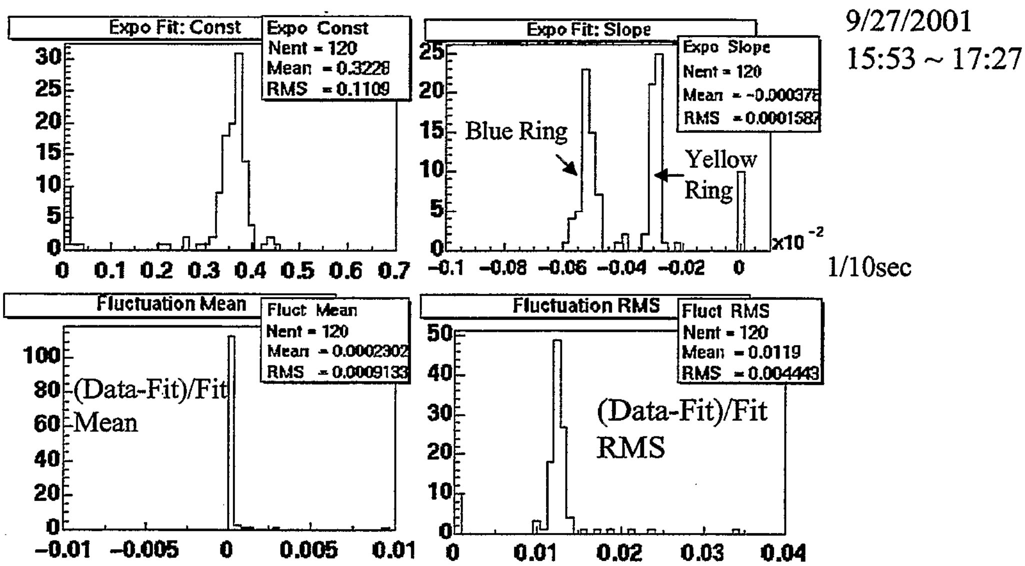
- Maximum difference ~20%

Bunch Current; Time Dependence



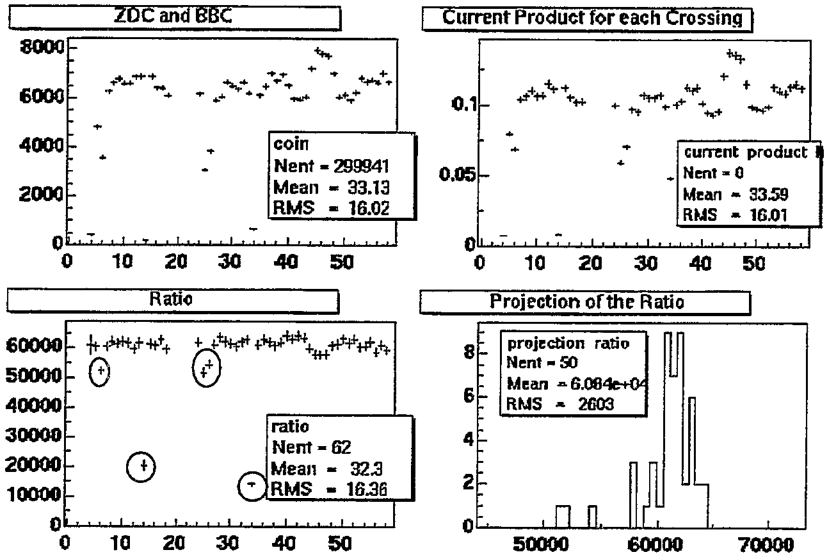
- Bunch current attenuation ~ 0.3%/min.
- Time fluctuation ~ 1.3%

Bunch Current Fit Parameters



- Bunch current and decay slope are different bunch by bunch as well as ring by ring

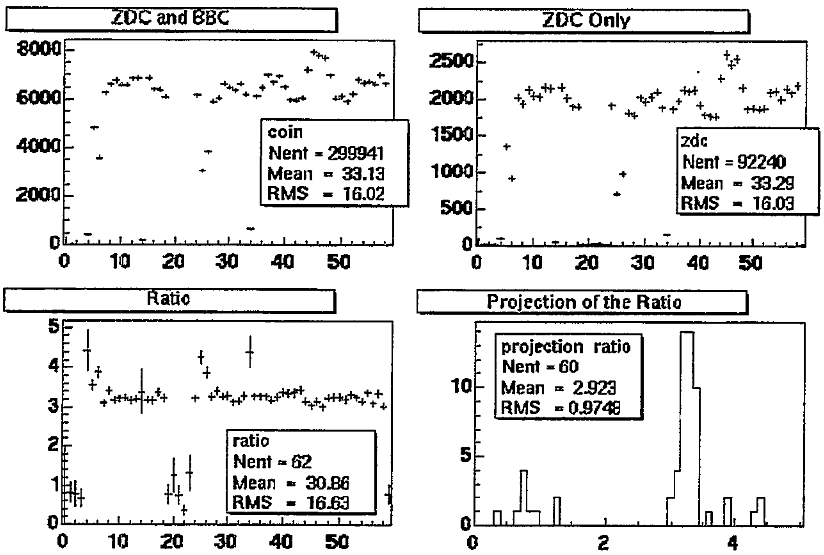
Event Rate vs. Bunch Current Product



9/27/2001
15:53 ~ 17:27

- Fluctuation found on some bunches

Coincidence vs. ZDC only



9/27/2001
15:53 ~ 17:27

Fake Asymmetries

Spin cofiguration	+-+-...	++--++--...	++++---- ++++----...
Event rate (BBCxZDC)	-0.0025	0.0076	-0.035
Event rate/current product	-0.0002	0.0040	0.0077

Stat. Error ~ 0.003
"bad" crossings are removed

Summary

- We need to get crossing-by-crossing luminosity to obtain physics asymmetry.
- Bunch current differs bunch by bunch (~20%).
- Current decay rate also differs bunch by bunch.
- There is 1~2% time fluctuation of bunch current
- Fluctuation of the ratio of the bunch-current product to trigger rate at PHENIX was found for some bunches.
- Fake asymmetry < 0.003 is achieved

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October 1, 2001
RIKEN BNL Research Center

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RHIC Spin Collaboration Meeting VI

October 1, 2001

Small Seminar Room, Physics Dept., Brookhaven National Laboratory

*****AGENDA*****

Opening Session *Chair: Tim Hallman*

09:00 - 09:10	Welcome	N. Samios
09:10 - 09:25	Comments on PAC ~ *Presented by Gerry Bunce*	T. Kirk
09:25 - 09:40	RHIC Spin Plan	G. Bunce
09:40 - 10:20	Theory Topics in Year-1 and Beyond	W. Vogelsang

10:20 - 10:40 Coffee Break

Accelerator Session *Chair: Les Bland*

10:40 - 11:10	Overall Commissioning Plan	W. Mackay
11:10 - 11:25	OPPIS Status	A. Zelenski
11:25 - 11:40	200 MeV Polarimeter	E. Stephenson
11:40 - 12:00	AGS Commissioning	H. Huang
12:00 - 12:15	Spin Flipper Status	M. Bai
12:15 – 12:30	Spin K Status	A. Luccio

****Room must be cleared by 12:30. Thanks.**

12:30 - 13:30 Lunch

Polarimeter Session *Chair: Naohito Saito*

13:30 - 13:50	RHIC Polarimeter Updates	D. Svirida
13:50 - 14:05	E950 Results	J. Tojo
14:05 - 14:20	Analysis of RHIC Polarimeter - 2000	O. Jinnouchi
14:20 - 14:35	How We Combine E950 & RHIC Polarimeter Results.	D. Fields
14:35 - 14:50	Data Format for RHIC Polarimeter	K. Kurita
14:50 - 15:05	Local Polarimeter Status	B. Fox
15:05 - 15:20	Polarimeter for Longitudinal Polarization	F. Meissner

15:20 - 15:50 Coffee Break

Experiment Session *Chair: Gerry Bunce*

15:50 - 16:15	BRAHMS	F. Videbaek
16:15 - 16:40	pp2pp	S. Bueltmann
16:40 - 17:05	STAR	G. Rakness
17:05 - 17:30	PHENIX	M. Grosse Perdekamp
17:30 - 17:45	Luminosity Monitoring & Bunch Current	H. Sato

Pictures

RHIC Spin Collaboration Meeting VI
October 1, 2001
RIKEN BNL Research Center
Brookhaven National Laboratory

Additional RIKEN BNL Research Center Proceedings:

Volume 36 – RHIC Spin Collaboration Meeting VI – BNL-
Volume 35 – RIKEN Winter School – Quarks, Hadrons and Nuclei – QCD Hard Processes and the Nucleon Spin – BNL-
Volume 34 – High Energy QCD: Beyond the Pomeron – BNL-
Volume 33 – Spin Physics at RHIC in Year-1 and Beyond – BNL-52635
Volume 32 – RHIC Spin Physics V – BNL-52628
Volume 31 – RHIC Spin Physics III & IV Polarized Partons at High Q^2 Region – BNL-52617
Volume 30 – RBRC Scientific Review Committee Meeting – BNL-52603
Volume 29 – Future Transversity Measurements – BNL-52612
Volume 28 – Equilibrium & Non-Equilibrium Aspects of Hot, Dense QCD – BNL-52613
Volume 27 – Predictions and Uncertainties for RHIC Spin Physics & Event Generator for RHIC Spin Physics III – Towards Precision Spin Physics at RHIC – BNL-52596
Volume 26 – Circum-Pan-Pacific RIKEN Symposium on High Energy Spin Physics – BNL-52588
Volume 25 – RHIC Spin – BNL-52581
Volume 24 – Physics Society of Japan Biannual Meeting Symposium on QCD Physics at RIKEN BNL Research Center – BNL-52578
Volume 23 – Coulomb and Pion-Asymmetry Polarimetry and Hadronic Spin Dependence at RHIC Energies – BNL-52589
Volume 22 – OSCAR II: Predictions for RHIC – BNL-52591
Volume 21 – RBRC Scientific Review Committee Meeting – BNL-52568
Volume 20 – Gauge-Invariant Variables in Gauge Theories – BNL-52590
Volume 19 – Numerical Algorithms at Non-Zero Chemical Potential – BNL-52573
Volume 18 – Event Generator for RHIC Spin Physics – BNL-52571
Volume 17 – Hard Parton Physics in High-Energy Nuclear Collisions – BNL-52574
Volume 16 – RIKEN Winter School - Structure of Hadrons - Introduction to QCD Hard Processes – BNL-52569
Volume 15 – QCD Phase Transitions – BNL-52561
Volume 14 – Quantum Fields In and Out of Equilibrium – BNL-52560
Volume 13 – Physics of the 1 Teraflop RIKEN-BNL-Columbia QCD Project First Anniversary Celebration – BNL-66299
Volume 12 – Quarkonium Production in Relativistic Nuclear Collisions – BNL-52559
Volume 11 – Event Generator for RHIC Spin Physics – BNL-66116
Volume 10 – Physics of Polarimetry at RHIC – BNL-65926
Volume 9 – High Density Matter in AGS, SPS and RHIC Collisions – BNL-65762
Volume 8 – Fermion Frontiers in Vector Lattice Gauge Theories – BNL-65634
Volume 7 – RHIC Spin Physics – BNL-65615

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Volume 5 – Color Superconductivity, Instantons and Parity (Non?)-Conservation at High Baryon Density – BNL-65105

Volume 4 – Inauguration Ceremony, September 22 and Non -Equilibrium Many Body Dynamics – BNL-64912

Volume 3 – Hadron Spin-Flip at RHIC Energies – BNL-64724

Volume 2 – Perturbative QCD as a Probe of Hadron Structure – BNL-64723

Volume 1 – Open Standards for Cascade Models for RHIC – BNL-64722

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RIKEN BNL RESEARCH CENTER

RHIC Spin Collaboration Meeting VI

October 1, 2001

Li Keran

Nuclei as heavy as bulls
Through collision
Generate new states of matter.
T.D. Lee

Speakers:

M. Bai	S. Bültmann	G. Bunce	D. Fields
B. Fox	M. Grosse Perdekamp	H. Huang	O. Jinnouchi
T. Kirk	K. Kurita	A. Luccio	W. Mackay
F. Meissner	G. Rakness	N. Samios	H. Sato
E. Stephenson	D. Svirida	J. Tojo	F. Videbaek
W. Vogelsang	A. Zelenski		

Organizers: Les Bland & Naohito Saito