BNL-52658
Formal Report

RIKEN BNL Research Center

SCIENTIFIC PRESENTATIONS

8th MEETING OF THE MANAGEMENT STEERING COMMITTEE OF THE RIKEN BNL COLLABORATION

RIKEN, Wako, Japan

March 11-12, 2002

RBRC Scientific Articles

Volume 5

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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 hard QCD/spin physics, lattice QCD and RHIC (Relativistic Heavy Ion Collider) physics through nurturing of a new generation of young physicists. The Director of RBRC is Professor T. D. Lee.

The first years were dedicated to the establishment of a theory group. This has essentially been completed consisting of Fellows, Postdocs, and RHIC Physics/University Fellows, with an active group of consultants. The center also organizes an extensive series of workshops on specific topics in strong interactions with an accompanying series of published proceedings. In addition, a 0.6 teraflops parallel processor computer has been constructed and operational since August 1998. It was awarded the Supercomputer 1998 Gordon Bell Prize for price performance. An active experimental group centered around the spin physics program at RHIC has subsequently also been established at RBRC.

Members and participants of RBRC on occasion will develop articles such as this one, in the nature of a status report or a general review.

N. P. Samios

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

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RIKEN BNL SPIN PHYSICS PROJECT AT RHIC

Satoshi Ozaki

RHIC

RIKEN BNL Spin Physics Project at RHIC

Satoshi Ozaki

RIKEN/BNL Spin Physics Collaboration
Management Steering Committee Meeting

March 11-12, 2002
At RIKEN, Wako, Saitama, Japan

RHIC

The Spin Physics Project

Equipment Construction to Enable Collisions of Polarized Protons at RHIC

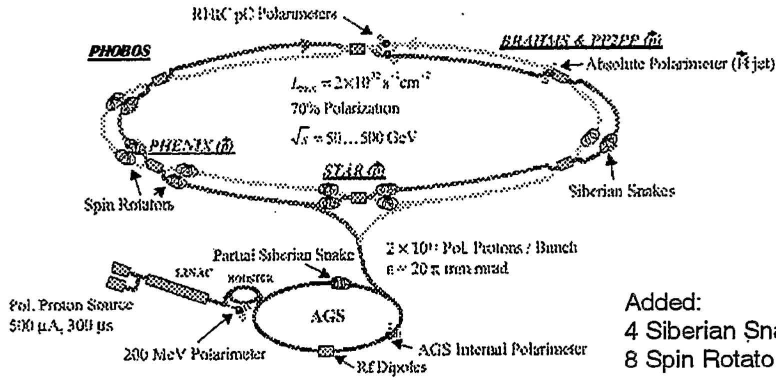
- Experimental Apparatus, 11/95 – 9/01
  Muon Magnet and Muon ID Steel,
  Muon Tracking and Muon ID Detectors
  Muon ID In-panel Preamplifier
  FEM for PHENIX EMCal, etc.

- Accelerator Hardware, 3/97 – 12/01
  Superconducting Helical Dipole Development
  4 Siberian Snakes and 4 Spin Rotators
  Polarimeters
  Measurement Probe
  16 Helical Dipoles for Spin Rotators No. 5 – 8, etc.

Total Spent at BNL $ 16.93 M
Total Spent in Japan ¥ 350.0 M

RHIC Layout for SPIN Physics

RIKEN-BNL Collaboration in Spin Physics:



Added:
4 Siberian Snakes
8 Spin Rotators

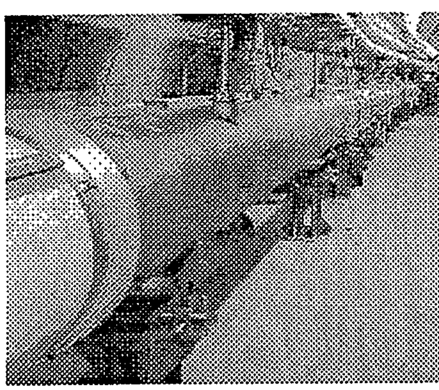
Brookhaven Science Associates
U.S. Department of Energy

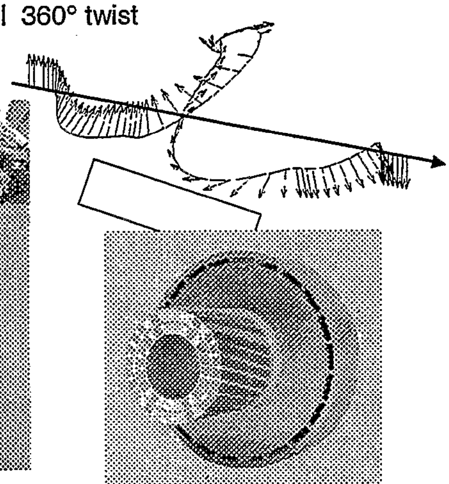
BROOKHAVEN NATIONAL LABORATORY

First Siberian Snake in RHIC Tunnel

Siberian Snake: 4 superconducting helical dipoles, 4Tesla,
2.4 m long with full 360° twist

All 4 Snakes in the Tunnel





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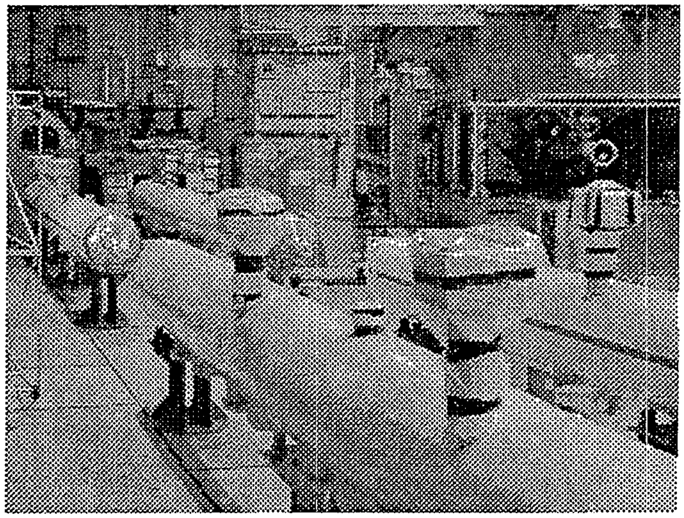
RHIC

Spin Rotators #1-4 in Storage



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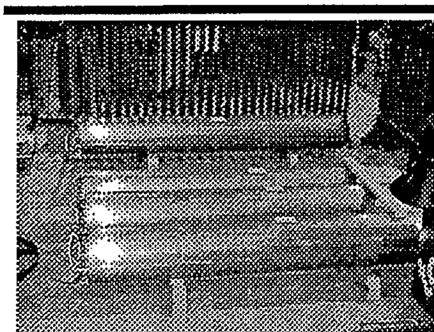
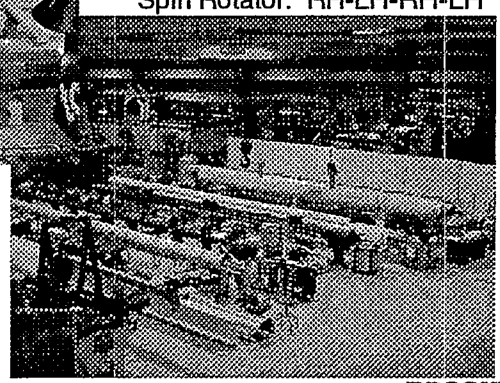
RHIC

Helical Superconducting Dipoles



Snake and Spin Rotator look alike:
Both made of 4 helical dipoles
Helicity configuration
Snake: RH-RH-RH-RH
Spin Rotator: RH-LH-RH-LH



16 helical dipoles fabricated

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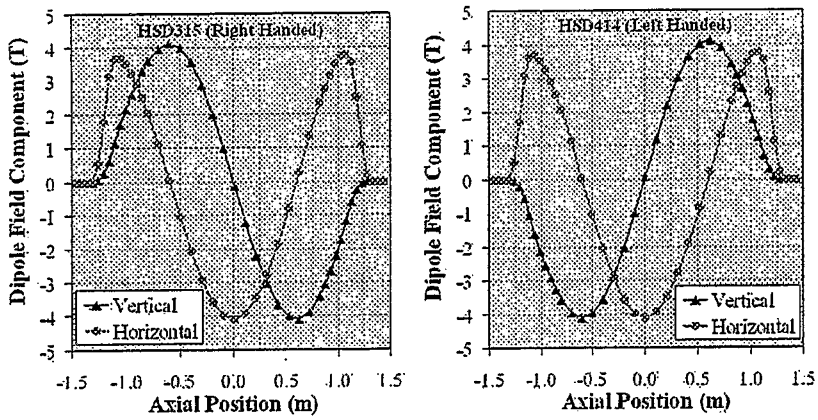
RHIC

Helical Dipole Fields



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RHIC

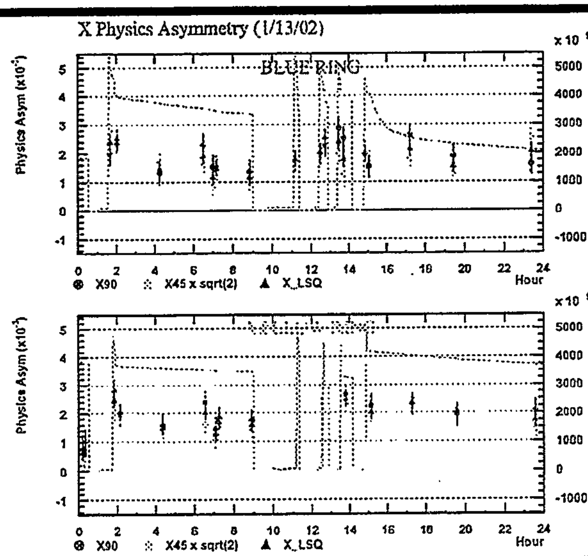
Polarization During Ramp and Store

The asymmetry remains almost fixed during acceleration and store

Asymmetry:

A measure of the polarization

This plot made by Osamu Jinnouchi



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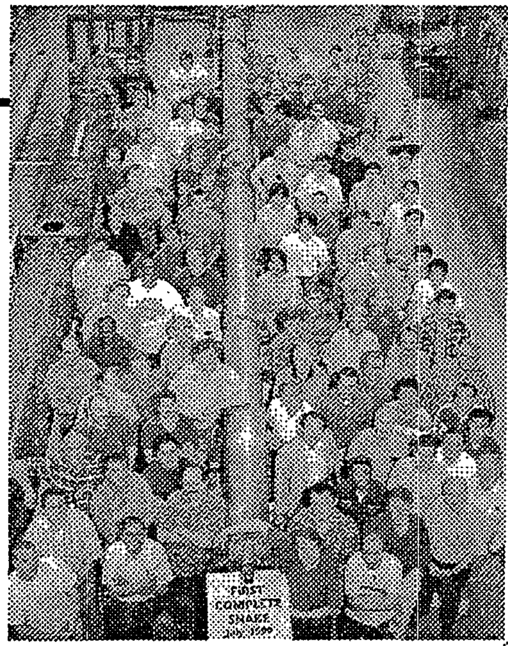
RHIC

The First Complete
Siberian Snake

July 1999



Four Helical dipoles:
4T, 2 m long,
& 360° Twist

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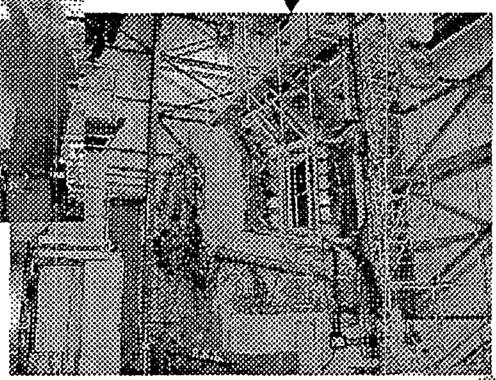
NATIONAL LABORATORY

RHIC

PHENIX South Muon ID and Tracker

South Muon Magnet and Tracking Detector



South Muon ID Panels

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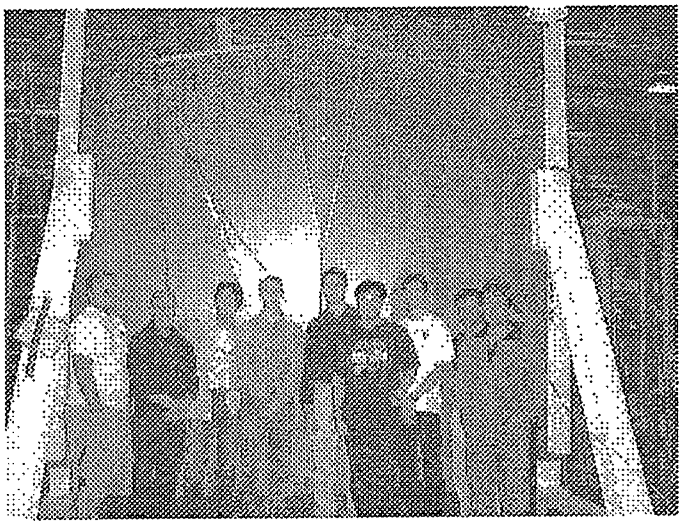
Muon Tracking Detector Panel



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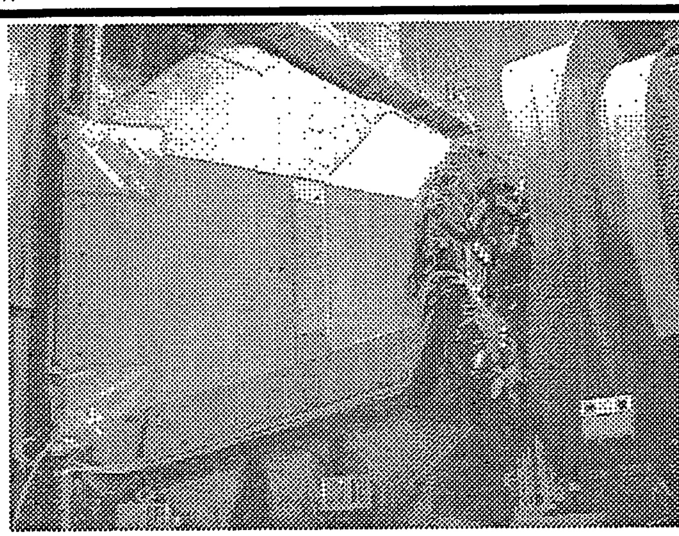
Completed PHENIX South Muon Arm



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RHIC FACILITY OPERATIONS REPORT

Thomas B. W. Kirk

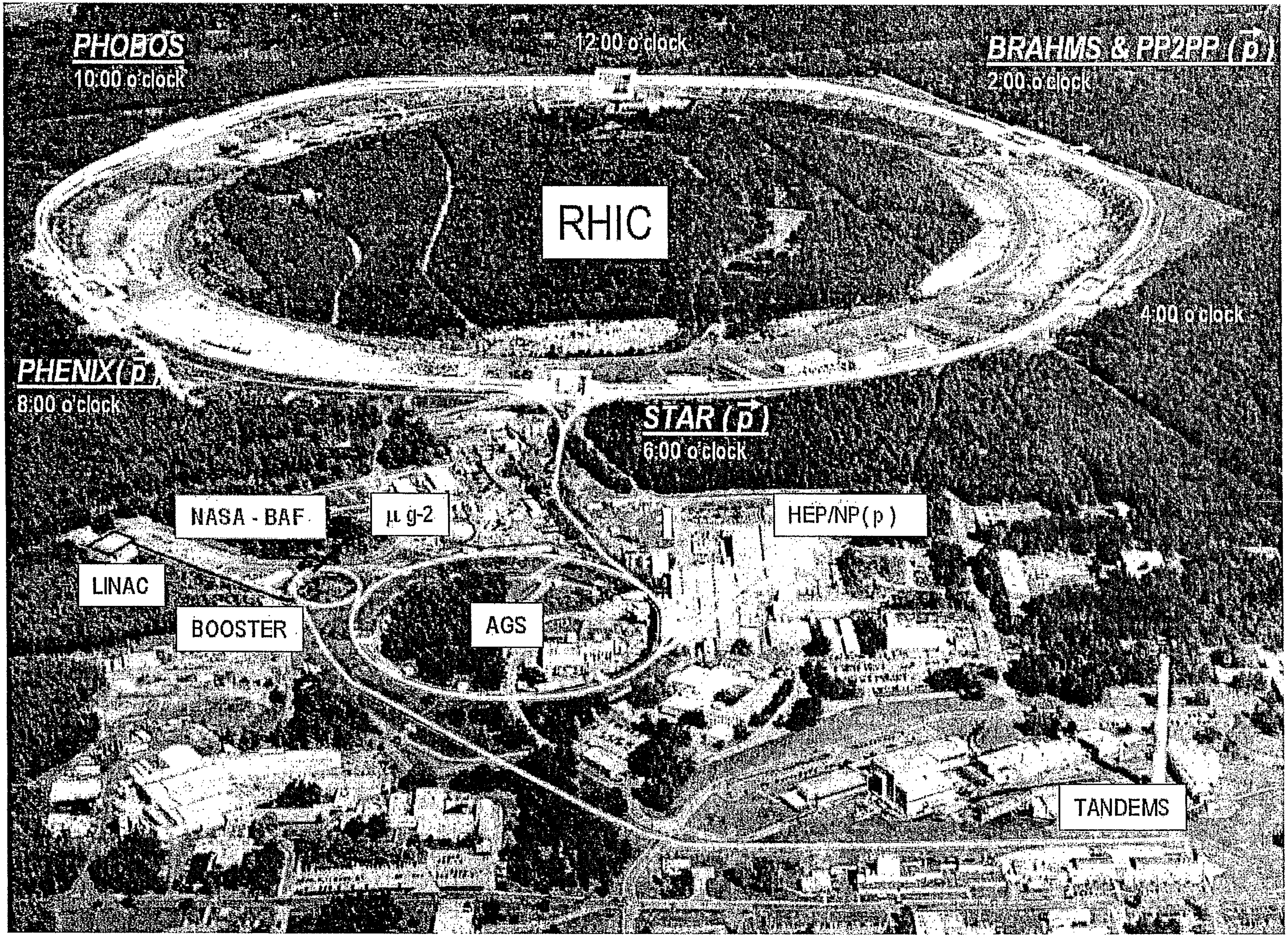
RHIC Facility Operations Report

Presented to the
Management Steering Committee
of the
Riken - BNL Collaboration

11

by
Thomas B.W. Kirk
Associate Laboratory Director
HENP

Wako, Japan
March 11, 2002


PHOBOS
10:00 o'clock
12:00 o'clock
BRAHMS & PP2PP ($\vec{p}$)
2:00 o'clock
RHIC
4:00 o'clock
PHENIX($\vec{p}$)
8:00 o'clock
STAR ($\vec{p}$)
6:00 o'clock
NASA - BAF
μ g-2
HEP/NP (p)
LINAC
BOOSTER
AGS
TANDEMS

BNL's Current Status and Operations

- **BNL commissioned Au x Au and pol. p x p beams in FY2001-2002**
  - full energy and luminosity were achieved with Au running
  - polarized proton beams were accelerated to 100 GeV without loss of pol.
  - the need for a stronger, SC AGS snake magnet for pol. was demonstrated

- **Data was taken by all RHIC experiments in Au x Au and pp beams**
  - 14 weeks of Au x Au at 100 GeV/amu was taken by 4 RHIC experiments
  - 3 weeks of polarized proton data were taken by 5 experiments
  - mean polarizations in the proton beam averaged <30%

- **R&D has been started to improve the RHIC polarized proton ops.**
  - the solenoidal AGS partial snake magnet inhibits high polarization
  - the backup Westinghouse AGS main power supply held down pol in AGS
  - the Siemans power supply is being repaired; it will be ready for FY 2003

- **RHIC operations has been raised by $16M in the FY03 PB**
  - the number of RHIC running weeks will rise from 19 to 29 cryo weeks
  - the number of data weeks will rise from 9 to 22 weeks in FY2003

Current RHIC-related Research Programs

The following RHIC-related research programs are currently active at BNL:

- **RHIC Experiments using Au x Au and polarized proton collisions**
  - **BRAHMS** Experiment (2-arm spectrometer with tracking & particle ID)
  - **PHOBOS** Experiment (all Si detector with 4π acceptance and magnetic tracking)
  - **STAR** Experiment (large TPC in 0.5T B-field with EM calorimetry + partial TOF/particle ID)
  - **PHENIX** Experiment (large, multi-function magnetic detector with extensive particle ID)
  - **pp2pp** elastic scattering experiment with polarized protons
  - integration of RHIC spin physics with **RIKEN BNL Research Center** experimenters

- **Theoretical Nuclear Physics**
  - a growing and active nuclear theory group emphasizing HI and spin physics
  - close collaboration of BNL NP theorists with the RIKEN BNL Research Center at BNL
  - a sponsor and partner in many workshops and topical conferences on theory subjects

- **Accelerator and Detector R&D Program**
  - continuing upgrades, improvements and evolution studies in the RHIC-AGS complex
  - continuing detector R&D in BNL's Physics and Instrumentation Divisions

RHIC makes news, and physics....

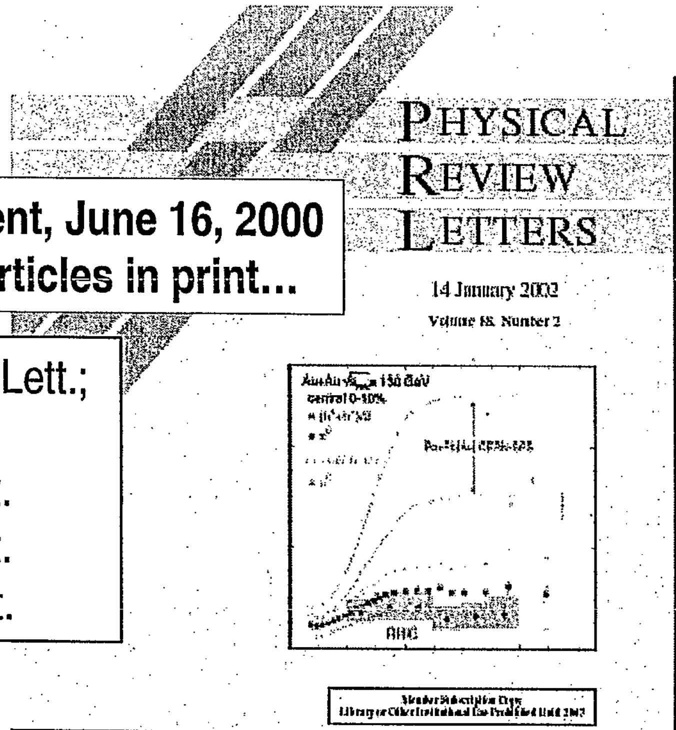
N.Y. Times covers QuarkMatter 2001

THE NEW YORK TIMES, TUESDAY, JANUARY 23, 2001

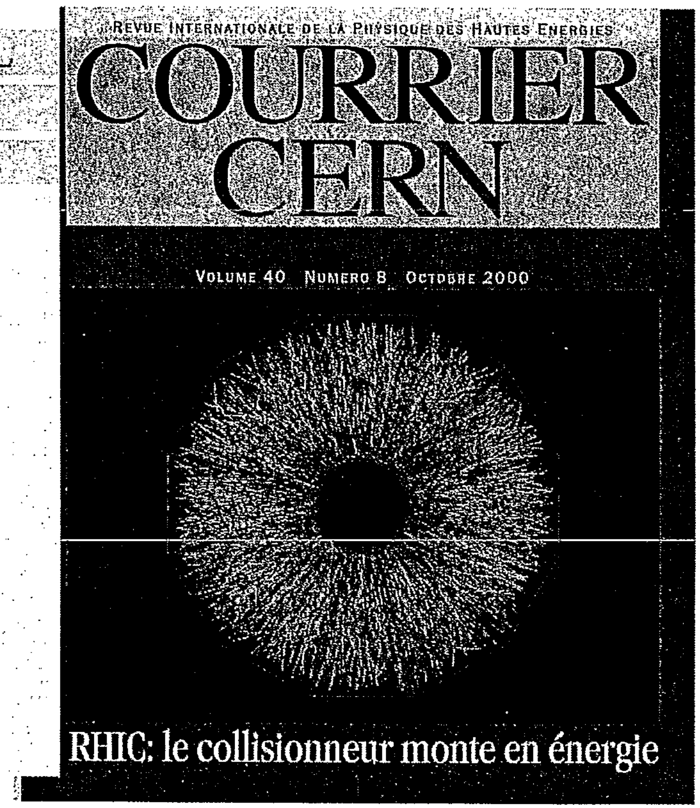
Trying to Cook a Soup of Free-Range Quarks

Since the first collision event, June 16, 2000
15 Letter-Journal physics articles in print...

BRAHMS: 2 [1 Phys. Rev. Lett.;
1 Phys. Lett.]
PHOBOS: 4 Phys. Rev. Lett.
PHENIX: 3 Phys. Rev. Lett.
STAR: 6 Phys. Rev. Lett.



PHENIX High Pt suppression
Data: PRL 88, 022301(2001)
Featured on PRL cover



RHIC Facility Evolution - R&D Program

- **RHIC will operate unchallenged until LHC begins research in FY07/08**
  - there exist no other **Heavy Ion** facilities in the world in the QGP energy regime
  - the RHIC **Polarized Proton** capability is unique for frontier spin physics
- **Continuing upgrades are needed to keep RHIC at the research frontier**
  - AIP funding is expected to provide continuing accelerator complex improvements
  - Facilities Cap. Eqp. Funds will enable continuous improvement of RHIC & RCF
  - Research Cap. Eqp. Funding will enable detector improvements to continue
- **RHIC R&D was supported in the NSAC 'FY 2001 Long Range Plan' Report**
  - RHIC luminosity upgrades of a factor 40 can be foreseen - **'RHIC II'**
  - detector/trigger upgrades can match the increased luminosity capability of RHIC II
  - new detector capabilities to respond to new physics discoveries will be pursued
  - **R&D funding** is essential for success of the long term RHIC Program
  - ***RHIC will be superior for phase-transition studies even after LHC starts***
- **The long-term evolution of RHIC was studied during the LRP process**
  - new or transformed RHIC detectors will be studied as the physics unfolds
  - **'eRHIC'** physics is an attractive direction for future facility evolution

SPIN PHYSICS AT RHIC

Naohito Saito

PHYSICS of RHIC SPIN
– RIKEN and RBRC Activities-

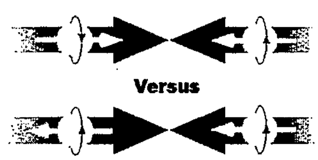
BNL RIKEN Management Steering Committee Meeting
March 11-12, 2002

Naohito Saito
RIKEN / RIKEN BNL Research Center

RIKEN

Spin Physics at RHIC

- Measure Spin Asymmetries in *pp* collision to pin down
  - Spin Structure of the Nucleon
    - Proton Spin Sum Rule
    - Transversity Distributions

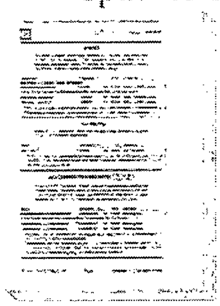


  - Spin Dependence of Fundamental Interactions
    - Parity Violating Interaction
    - CP Violation in Quark Sector and Higgs Sector
  - Spin Dependence of Fragmentation
    - E.g. Lambda fragmentation function
  - Spin Dependence in *pp* elastic scattering

RIKEN Naohito Saito (RIKEN/ RBRC)

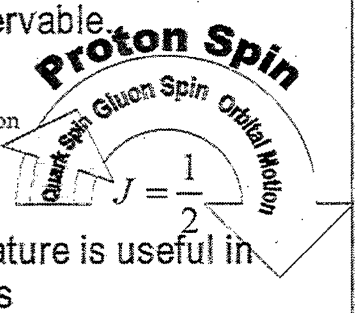
Why Spin Physics?

- "Spin" is a fundamental observable.

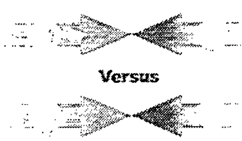


$$\Delta\Sigma = 0.1 \sim 0.2$$

Total fraction of the proton spin carried by the quark spin: Scheme dependent.



- *Axial vector* nature is useful in symmetry tests
  - Parity
  - Time Reversal



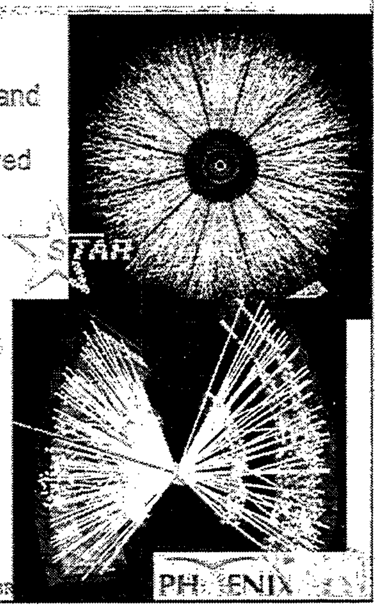
		$\mathcal{P}$	$\mathcal{T}$
position	x	$-x$	x
momentum	p	$-p$	$-p$
spin	σ	σ	$-\sigma$

RIKEN

Naohito Saito (RIKEN/RBRC)

RHIC Achievements

- Year-1
  - First Collision of Gold beams at 56 and 130 GeV/A last year
  - 10% of Designed Luminosity achieved
  - Successful Physics Run
  - Successful Spin Commissioning!
- Year-2
  - First Collision of Gold beams at 200 GeV/A !!!
    - 42 μb^{-1} delivered & 24 μb^{-1} recorded
    - 170 M events processed
  - First Collision of Polarized Proton Beams at 200 GeV!!!
    - 3.7 G events processed
    - 0.15 pb^{-1} recorded



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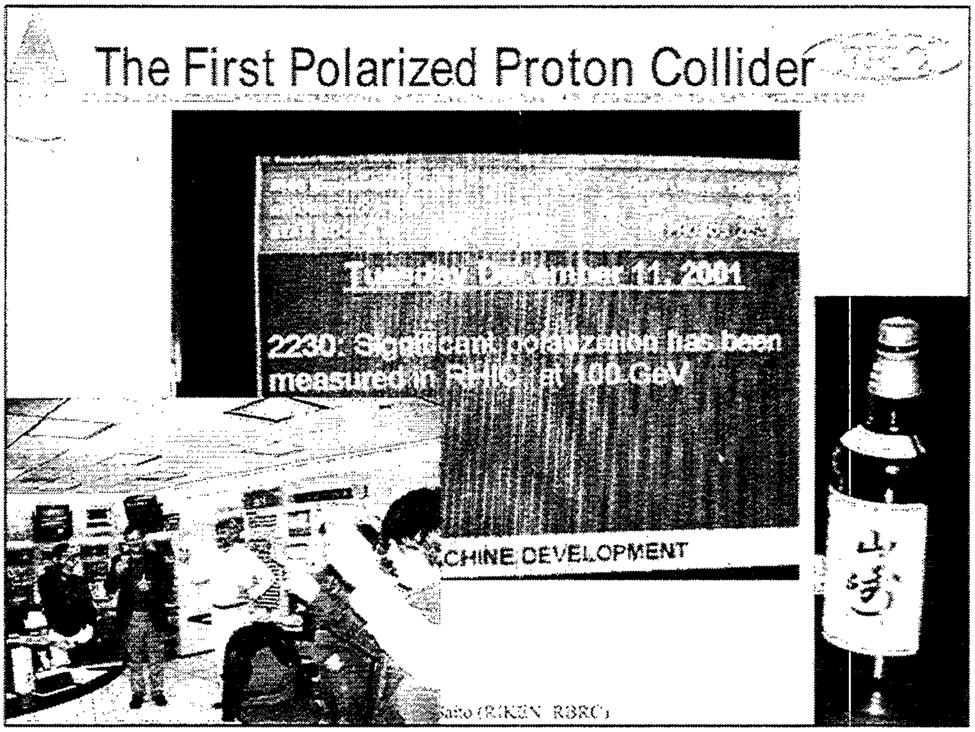
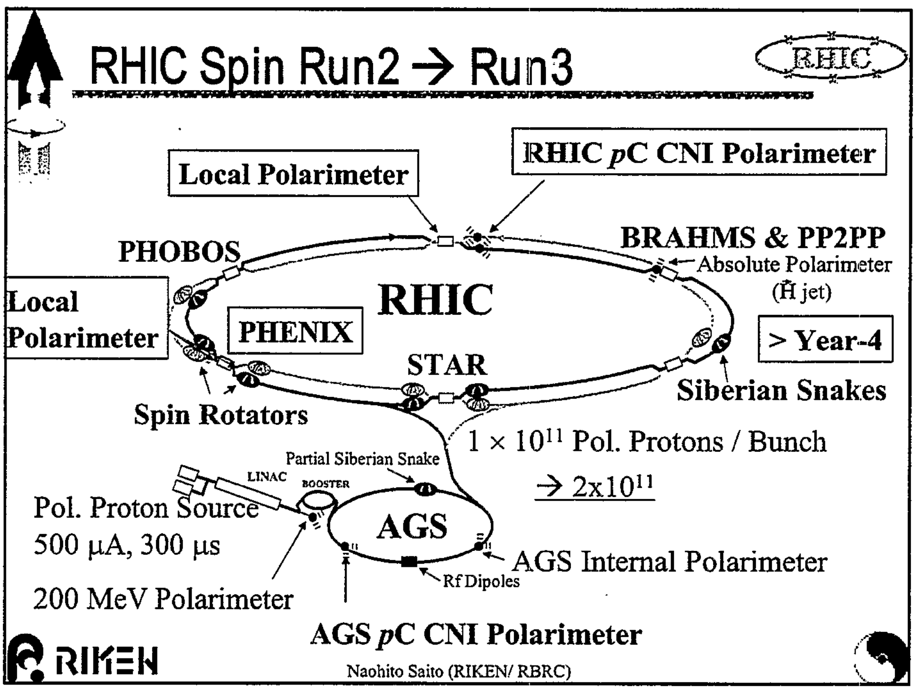
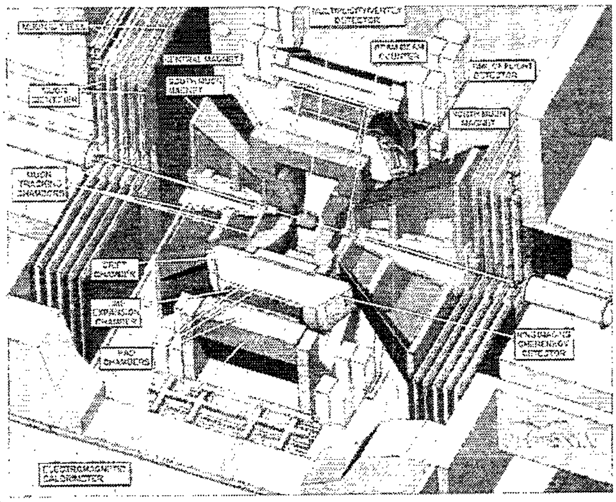
Naohito Saito (RIKEN/RBRC)


The First Polarized Proton Collider
2230: Significant polarization has been measured in RHIC at 100 GeV
CHINE DEVELOPMENT


RHIC Spin Run2 → Run3
RHIC
Local Polarimeter
RHIC pC CNI Polarimeter
PHOBOS
BRAHMS & PP2PP
Absolute Polarimeter (H jet)
Local Polarimeter
RHIC
PHENIX
> Year-4
STAR
Siberian Snakes
Spin Rotators
1 × 10^11 Pol. Protons / Bunch
→ 2x10^11
Partial Siberian Snake
LINAC
BOOSTER
Pol. Proton Source
500 μA, 300 μs
AGS
AGS Internal Polarimeter
Rf Dipoles
200 MeV Polarimeter
AGS pC CNI Polarimeter
RIKEN
Naohito Saito (RIKEN/ RBRC)

PHENIX Detector System

- Inner Detectors:
  - BBC
  - MVD
  - NTC
- Central Arms
  - EMCal
  - Tracking
  - PID
    - RHIC
    - TOF
- Muon Arms
  - South Completed
  - North in construction



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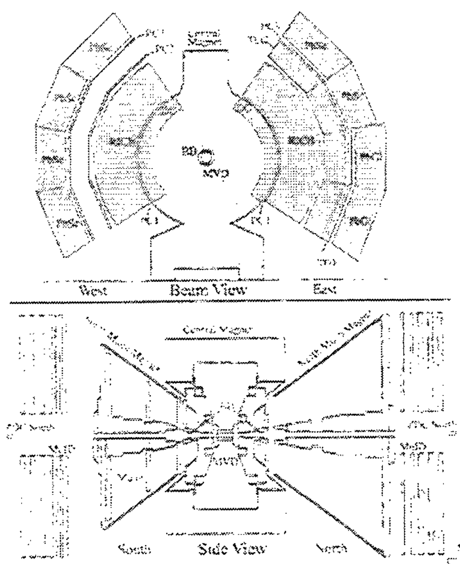
Naohito Saito (RIKEN/ RBRC)

PHENIX Run2 Configuration

- Fully equipped Central Arms
  - EMCal
  - Trk Chambers
  - RICH
- Newly installed Muon Arm
  - Muon Tracker
  - Muon Identifier
- New Counter
  - NTC
- EMC-RICH Trigger



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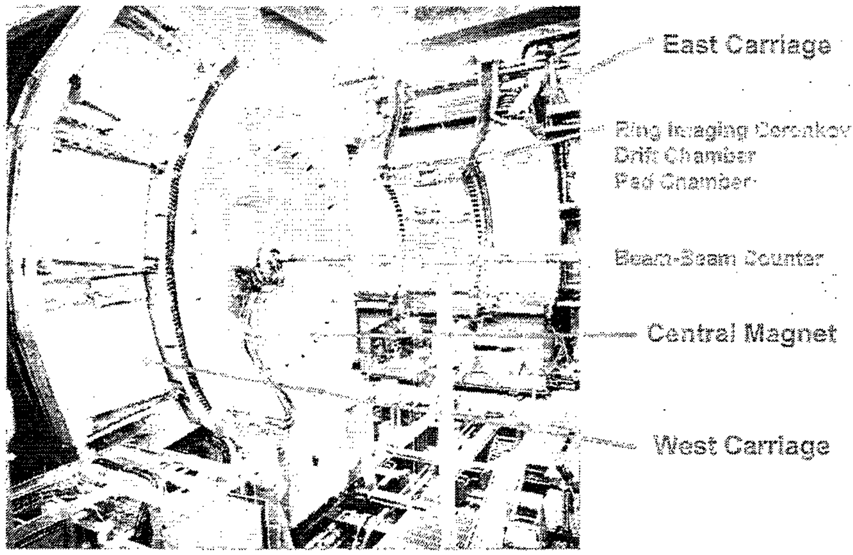
PHENIX Central Spectrometer



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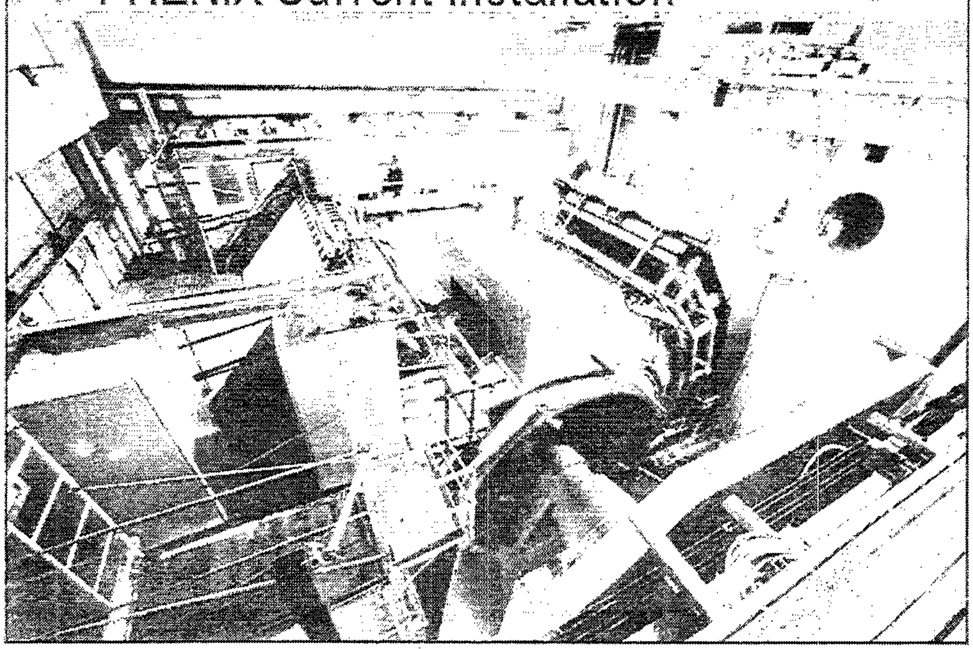
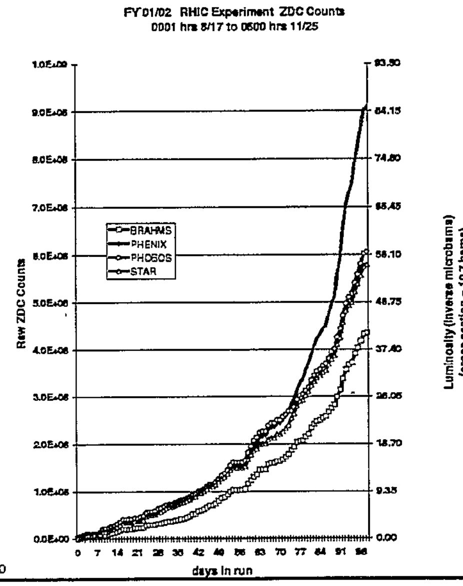
PHENIX Current Installation



RHIC Au-Au Luminosity

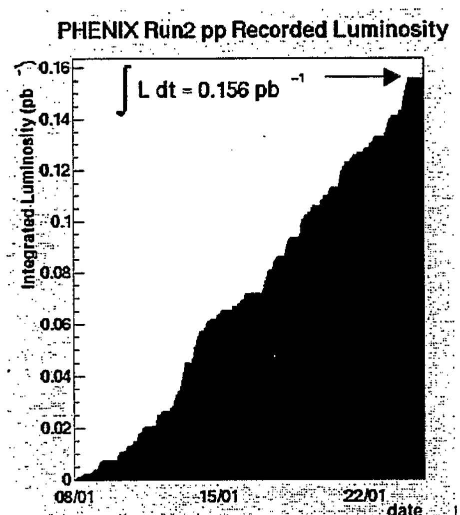
- Last Two weeks were most productive
- PHENIX has received 42 μb-1 within useful vertex region and 24 μb-1 has been recorded



RIKEN Naohito

PHENIX Run2 pp

- Delivered peak luminosity ~ $1 \times 10^{30} cm^{-2} s^{-1}$
- Data Band Width ~ 60 MB/s = 6 CD's/min



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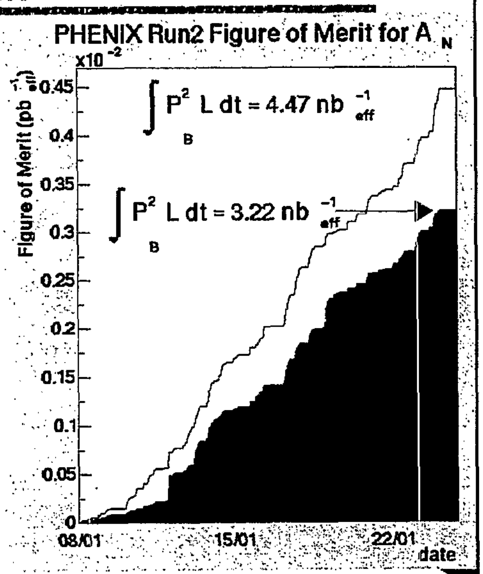
PHENIX Run 2 Spin

RHIC

- Beam Polarized Transversely
- Yellow > Blue
  - $<P_{yellow}>=17\%$
  - $<P_{blue}>=14\%$
    - Assumption: Analyzing Power is E-indep.
- Enough Statistics for first A_N physics



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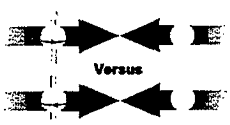
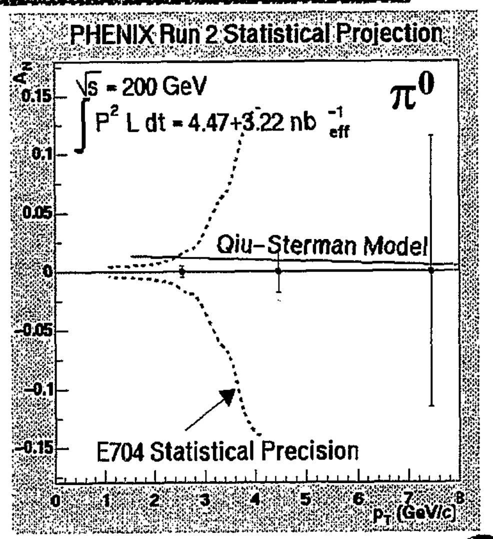
Run2 PHENIX Spin A_N Expectation

RHIC

- Single Transverse Spin Asymmetry for Neutral pion



- Statistical Significance of A_N ~ 10x E704



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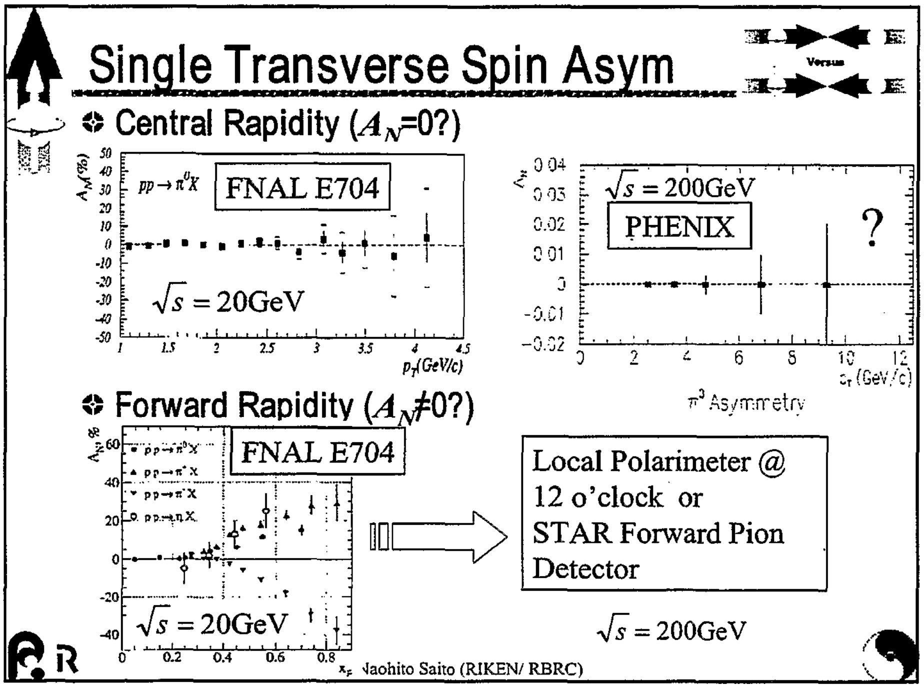
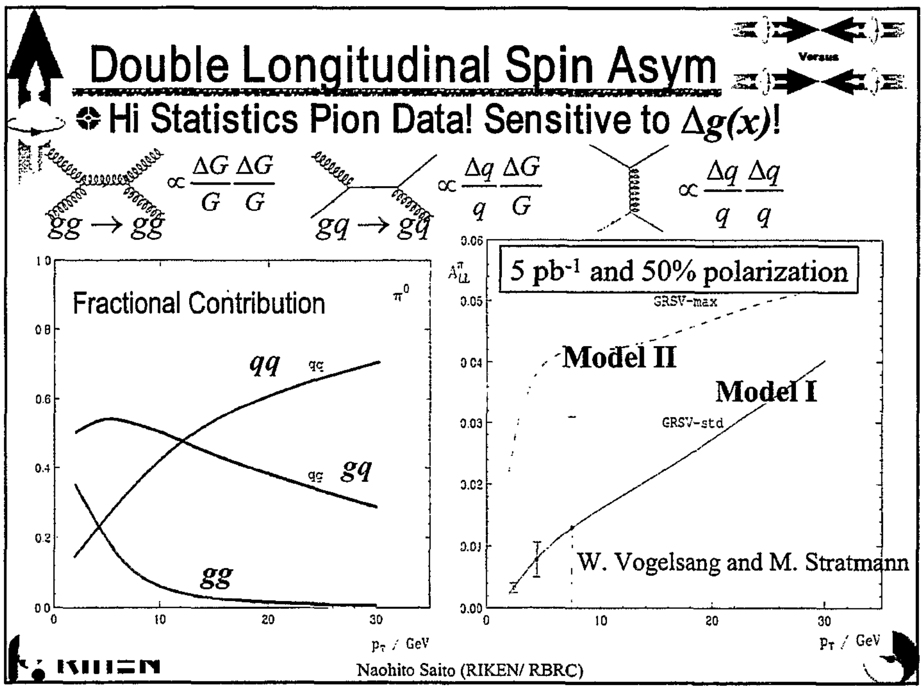

Single Transverse Spin Asym
Versus
Central Rapidity (A_N=0?)
FNAL E704
$pp \to \pi^0 X$
$\sqrt{s} = 20$GeV
p_T(GeV/c)
$\sqrt{s} = 200$GeV
PHENIX
?
π^0 Asymmetry
Forward Rapidity ($A_N \neq 0$?)
FNAL E704
$\sqrt{s} = 20$GeV
Local Polarimeter @
12 o'clock or
STAR Forward Pion
Detector
$\sqrt{s} = 200$GeV
Naohito Saito (RIKEN/ RBRC)


Double Longitudinal Spin Asym
Versus
Hi Statistics Pion Data! Sensitive to $\Delta g(x)$!
$gg \to gg$ $\propto \frac{\Delta G}{G}\frac{\Delta G}{G}$
$gq \to gq$ $\propto \frac{\Delta q}{q}\frac{\Delta G}{G}$
$\propto \frac{\Delta q}{q}\frac{\Delta q}{q}$
Fractional Contribution
qq
gq
gg
p_T / GeV
5 pb^{-1} and 50% polarization
GRSV-max
Model II
Model I
GRSV-std
W. Vogelsang and M. Stratmann
p_T / GeV
RIKEN
Naohito Saito (RIKEN/ RBRC)

RHIC Spin Plan (PHENIX and STAR)

Year	CM Energy	Weeks	Int. Lum.	Remarks
2001	200 GeV	5	7 pb^{-1}	Gluon pol. with pions / TT*
2002	200 GeV	8	160 pb^{-1}	Gluon pol. with direct γ, jets/ TT
	500 GeV	2	90 pb^{-1}	PV W production, u-quark pol.
2003	200 GeV	8	160 pb^{-1}	Gluon pol. with γ + jet/ TT
	500 GeV	2	120 pb^{-1}	First ubar,dbar pol. meas..
2004	500 GeV	8	480 pb^{-1}	Gluon pol. with γ+jet, γ,jet+jet, heavy flavor, ubar, dbar pol.
	200 GeV	2	48 pb^{-1}	Gluon pol. with γ, γ+jet, heavy flavor/TT
2005	500 GeV	5	300 pb^{-1}	More statistics
	200 GeV	5	120 pb^{-1}	
2006	200 GeV	10	210 pb^{-1}	

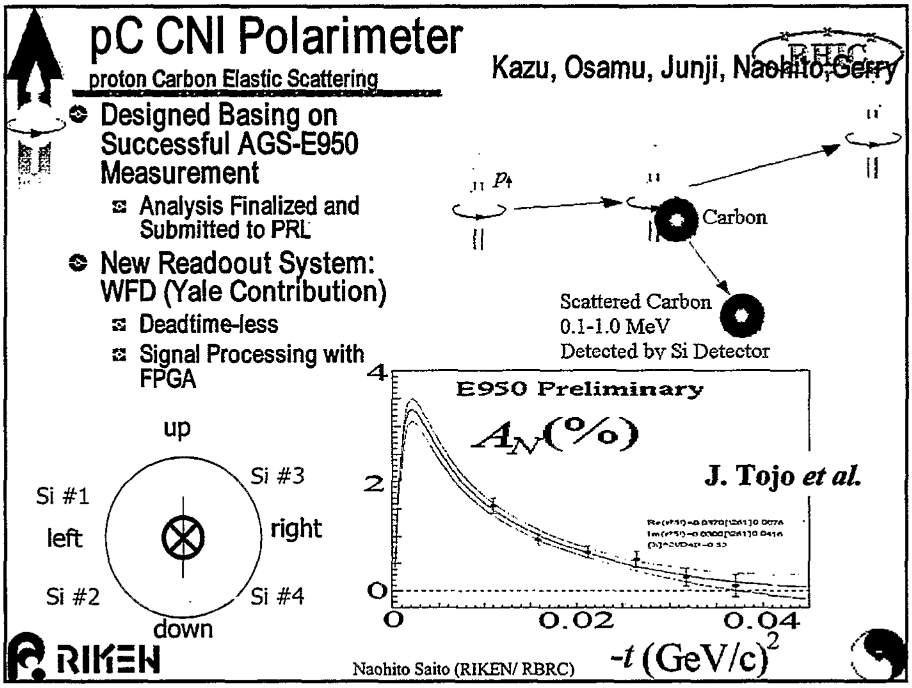
* TT Transverse Spin Physics

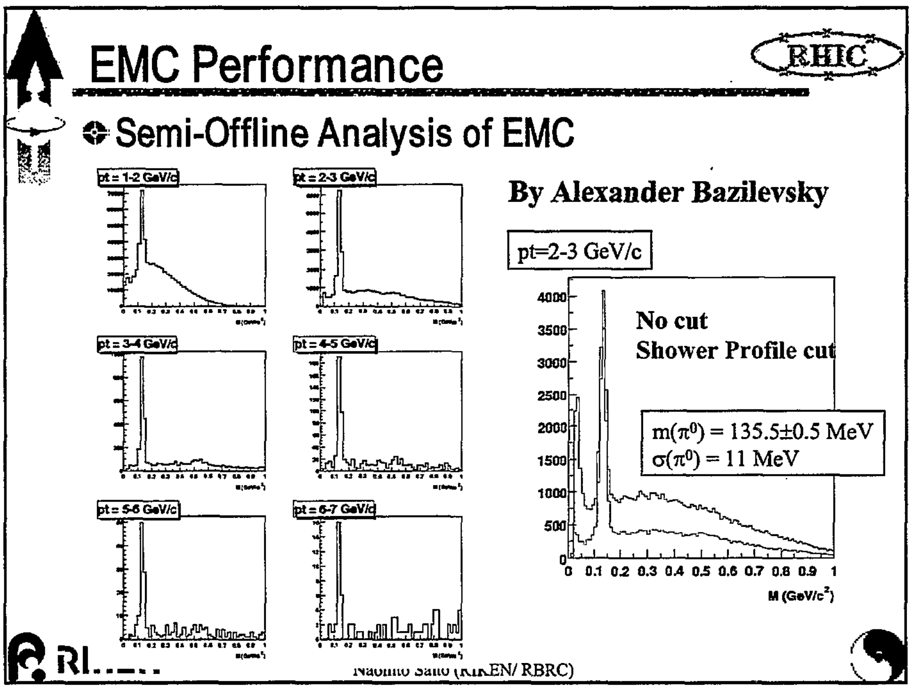
RIKEN Naohito Saito (RIKEN/ RBRC)

RIKEN and RBRC Activities

- PHENIX Muon Arm Doug, Atsushi, Jiro, Hiroki, Mao, Hideyuki, Nobuyuki
- PHENIX EMCal
  - Analysis of Au-Au Data Sasha, Hisa
  - FEE QA Hisa, Yuji
  - High Energy Beam Test Yuji, Hisa and Naohito
- PHENIX Trigger
  - EMCal + RICH Matthias, Kensuke
  - Charged Hadron Trigger Yuji and Kensuke
  - MuID Hiroki
- PHENIX NTC Brendan, Abhay
- PHENIX CC-J Takashi, Yasushi, Yuji, Satoshi, Osamu
- PHENIX Spin Monitor Yuji, Hiroki
- Polarimeter
  - RHIC Polarimeter Kazu, Osamu, Junji, Doug, Gerry and Naohito
  - Local Polarimeter Brendan, Abhay,Yuji, Manabu, Yoshi, Yasushi, Kiyoshi, Gerry, Ken and Naohito
- Global Analysis of Polarized Data Masanori, Yuji, Naohito, Hideyuki
- Fragmentation Functions Matthias, Akio

RIKEN Naohito Saito (RIKEN/ RBRC)

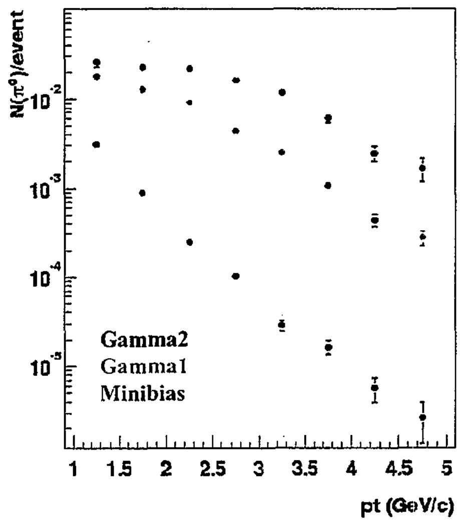

pC CNI Polarimeter
proton Carbon Elastic Scattering
Kazu, Osamu, Junji, Naohito, Gerry
RHIC
Designed Basing on Successful AGS-E950 Measurement
Analysis Finalized and Submitted to PRL
New Readoout System: WFD (Yale Contribution)
Deadtime-less
Signal Processing with FPGA
Carbon
Scattered Carbon
0.1-1.0 MeV
Detected by Si Detector
up
Si #1
left
Si #2
down
Si #3
right
Si #4
E950 Preliminary
A_N(%)
J. Tojo et al.
4
2
0
0
0.02
0.04
$-t$ (GeV/c)^2
RIKEN
Naohito Saito (RIKEN/ RBRC)


EMC Performance
RHIC
Semi-Offline Analysis of EMC
pt = 1-2 GeV/c
pt = 2-3 GeV/c
pt = 3-4 GeV/c
pt = 4-5 GeV/c
pt = 5-6 GeV/c
pt = 6-7 GeV/c
By Alexander Bazilevsky
pt=2-3 GeV/c
No cut
Shower Profile cut
m(π^0) = 135.5±0.5 MeV
σ(π^0) = 11 MeV
4000
3500
3000
2500
2000
1500
1000
500
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
M (GeV/c^2)
RIKEN/ RBRC)

EMC Trigger Performance

RHIC

- Our brand new trigger system just work fine!!!
- Hi-p_T sample enhanced by factor 20-200!
- Trigger team led by Matthias Perdekamp



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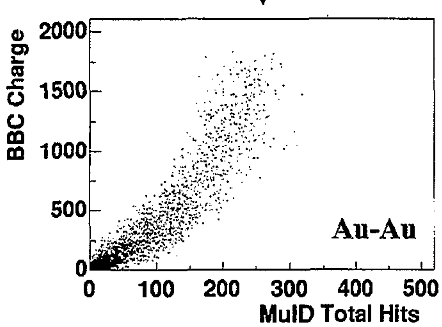
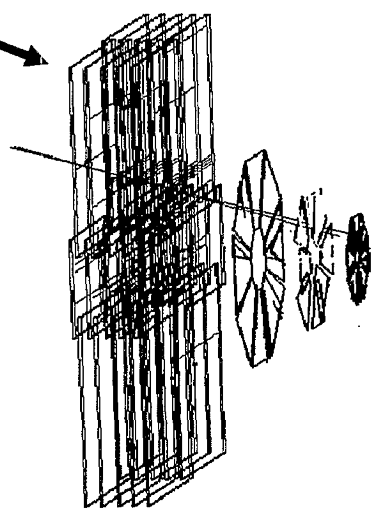
Muon Arm Performance

RHIC

- Muon Track Candidate
- MuID Hits Correlated with BBC



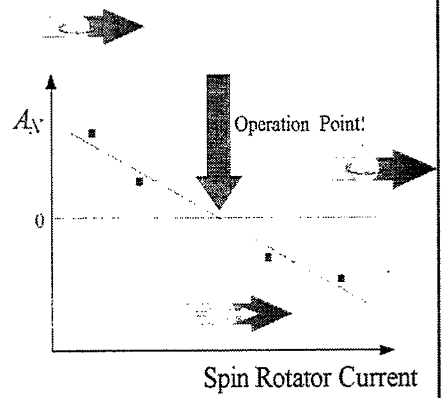


RIKEN

Naohito Saito (RIKEN/ RBRC)

Motivation of Local Polarimeter

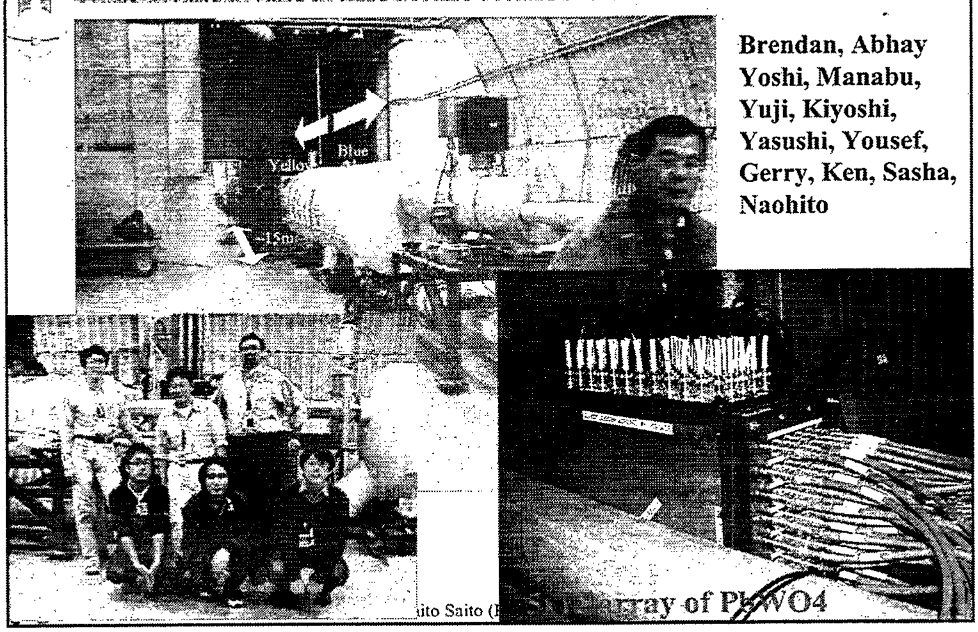
- Confirm Spin Dynamics in RHIC Ring
  - Especially for the operation with *SPIN ROTATORS*
    - Spin Dynamics between Spin Rotators is completely transparent to the rest of accelerator "by design"
  - Very important to be ready for Run3, where we use Spin Rotators



RIKEN Naohito Saito (RIKEN/ RBRC)

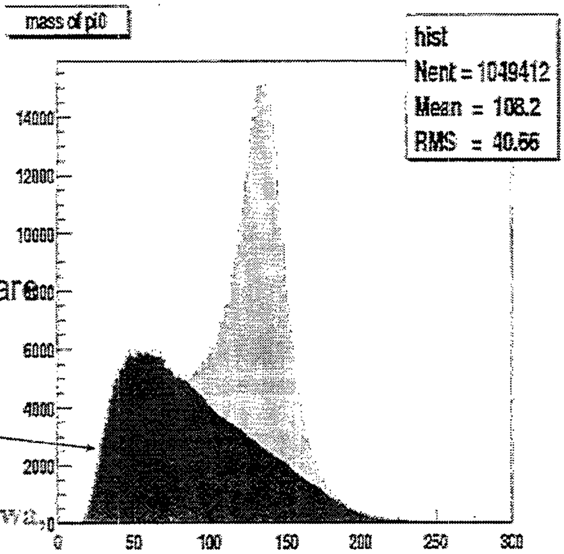
Local Polarimeter Test at IP12

Brendan, Abhay
Yoshi, Manabu,
Yuji, Kiyoshi,
Yasushi, Yousef,
Gerry, Ken, Sasha,
Naohito



Local Polarimeter Offline Plot

- Invariant mass distribution of two photon candidates
- Calibration is being refined
- Systematic studies are underway



Yoshi Fukao, Manabu Togawa,
Alexander Bazilevsky

RIKEN

Naohito Saito (RIKEN/ RBRC)

Summary

- First Spin Physics Run was SUCCESSFUL
  - Many accomplishments by RIKEN, RBRC, and BNL
- Polarization at AGS has to be improved!!
- Thanks:
  - Advisory Group:
    - T.D. Lee, N. Samios
    - T. Roser, Y. Makdisi, M. Tannenbaum and R.L. Jaffe
  - Strong Supports from Japan
    - RIKEN I. Tanihata and M. Ishihara
    - Kyoto University K. Imai
    - Tokyo Institute of Technology T.-A. Shibata
  - Super Secretaries
    - R. Greenberg, P. Esposito, T. Heinz, and T. Ito
    - N. Kiyama and Y. Kishino
  - Strong Support from ICO
    - H. Horie → C. Shimoyamada
    - T. Noda, M. Yokota, E. Nagahama, M. Funami->S. Asaka
  - Special Support from BNL
    - B. Kirk

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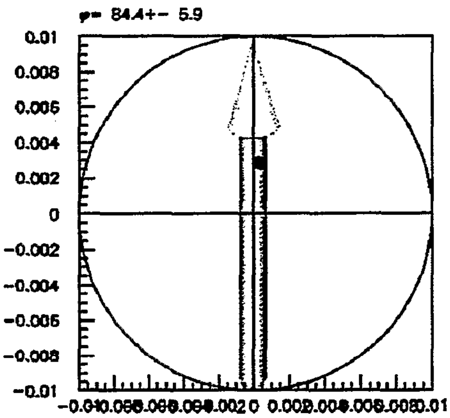
Naohito Saito (RIKEN/ RBRC)

Successful Spin Commissioning

RHIC

- September 13, 2000 : The Exciting Day
- The First Polarized Proton Beam Stored at RHIC
  - $G\gamma$=46.5 (24.3 GeV/c)
- Then Accelerated up to ~30GeV/c with Snake on
  - Spin Orientation Rotated as Expected



Participating Groups:
BNL
RIKEN, Japan
RBRC
ANL
Indiana
Kyoto
ITEP Moscow

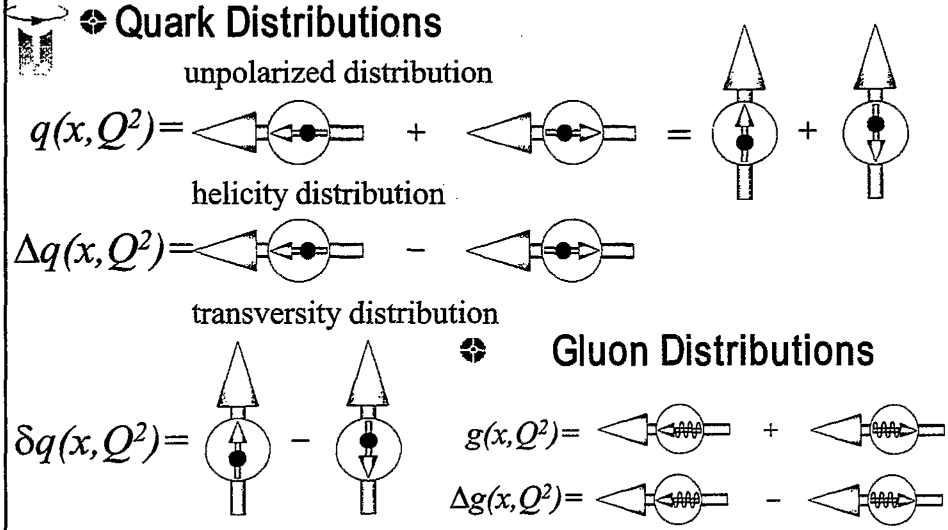
RIKEN

Naohito Saito (RIKEN/ RBRC)

Parton Distribution Functions

RHIC

- Quark Distributions



No Transverse Gluon Distribution

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RHIC Spin Structure Studies at a Glance

Δg measurements

process	measure	PHENIX	STAR
A_{LL} (pp--> □(jet)X)	□g ×A_1^p	yes	yes
A_{LL} (pp--> □X)	□g ×(□g +□□)	yes	yes
A_{LL} (pp-->jet X)	□g ×(□g +□□)	no	yes
A_{LL} (pp-->QQbar X)	□g ×□g	yes	no
A_{LL} (pp-->J/□ X)	□g ×□g	yes	no
A_{LL} (pp--> $□_2$ X) ✸	□g ×□g	yes?	no

- •Lepton, Photon, and Hadron
- •Rare Process → Trigger

Δq measurements

process	measure	PHENIX	STAR
A_L (pp-->W^+ X)	□u , □dbar	yes	yes
A_L (pp-->W^- X)	□d , □ubar	yes	yes
A_{LL} (pp-->$l^+ l^-$ X)	□q x □qbar	yes	yes?
A_L (pp-->WcX) ✸	□s, □sbar	yes	yes

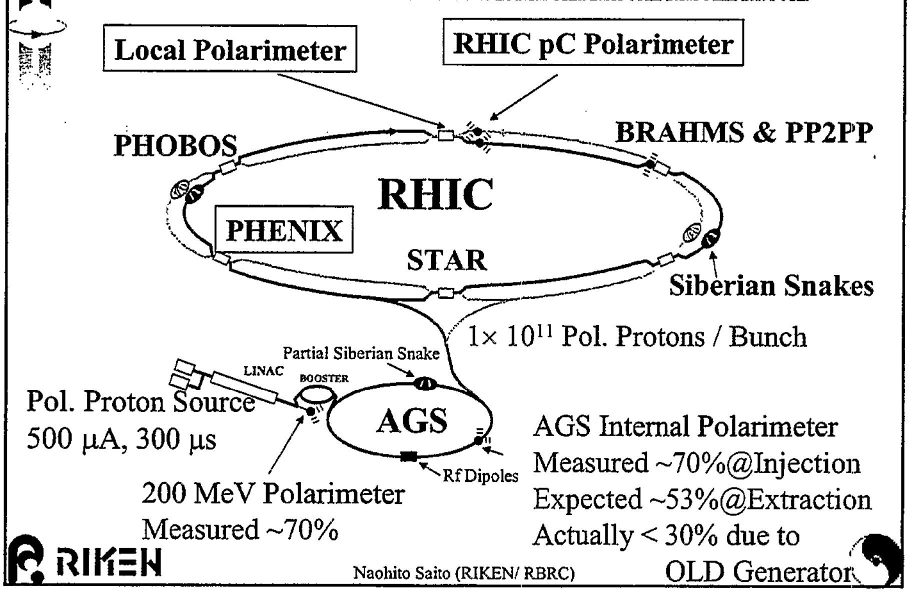
δq measurements

process	measure	PHENIX	STAR
A_T(pp-->($□^+ □^-$)X)	□q x D	yes	yes
A_{TT}(pp-->$l^+ l^-$ X)	□q x □qbar	yes	yes?
✸ A_T(pp--> □($□^+ □^-$)X)	□q x D	yes	yes

✸*L/E* Upgrade desirable

RIKEN Naohito Saito (RIKEN/ RBRC)

RHIC: The Polarized Collider Run 2



BNL RHIC SPIN GROUP

Gerry Bunce

11 March 2002
RBRC Management Steering Committee
G. Bunce

BNL RHIC Spin Group

1. **Mission: Develop and lead the spin program at RHIC**

   ---Core group at Brookhaven for the spin program
   Develop permanent staff of spin physicists at BNL to lead, develop and participate in the spin program, in collaboration with the RIKEN BNL Research Center (RBRC) and RIKEN staff at Brookhaven.
   Members of STAR, PHENIX, PP2PP experiments

2. **Proposed to DOE Medium Energy Symons Committee in 1998, received strong support.**

3. **Group formed starting in 2001:**

   STAR: Les Bland (from Indiana U.), Sandro Bravar (from COMPASS), Bernd Surrow (from ZEUS, Goldhaber Fellow)

   PHENIX: Gerry Bunce (Group Leader)

   PP2PP: Wlodek Guryn (Spokesman, PP2PP), Ron Gill, Stephan Bueltmann (from SMC and JLab)

4. **Immediate contributions:**

   Forward pi0 detectors and beam-beam counters for STAR—major contribution to broaden STAR spin program—important measurements this year.

   PP2PP experiment installed roman pots, silicon detectors, took data for elastic scattering---major success.

   Contributions in collaboration with RBRC on PHENIX and 12 o'clock test, organize and help lead the RHIC spin run.

5. **Future:**

   Expect the group to grow to 4-5 physicists for STAR and PHENIX.

   Major responsibilities, in collaboration with RBRC and other groups for

   ---new AGS CNI polarimeter

   ---detectors for and polarization measurements with polarized jet target

   ---spin and heavy ion physics with forward pi0 detectors and STAR TPC

   ---develop jet detector for PHENIX muon arms with RBRC

   ---set up local polarimeters for STAR and PHENIX based on forward n

   ---continue PP2PP measurements with Roman pots

   ---continue to serve as coordinator/leader of RHIC spin program

6. **Collaboration with BNL and RBRC Theorists**

   We are fortunate to have Werner Vogelsang as a member of RBRC/BNL.

   ---we have frequent visitor and workshop programs bringing in many important spin theorists who provide many ideas for the program

   ---it is very important to add one (and later more) spin theorists to the staff at RBRC/BNL to work with Werner and us!

Remarks: **the BNL RHIC Spin Group is underway, it already provides new ideas, leadership, and new physics potential to the RHIC spin program. It is modeled after and works in close collaboration with the RIKEN BNL Research Center. And, the first spin run was a great success!**

RIKEN CCJ

Takashi Ichihara

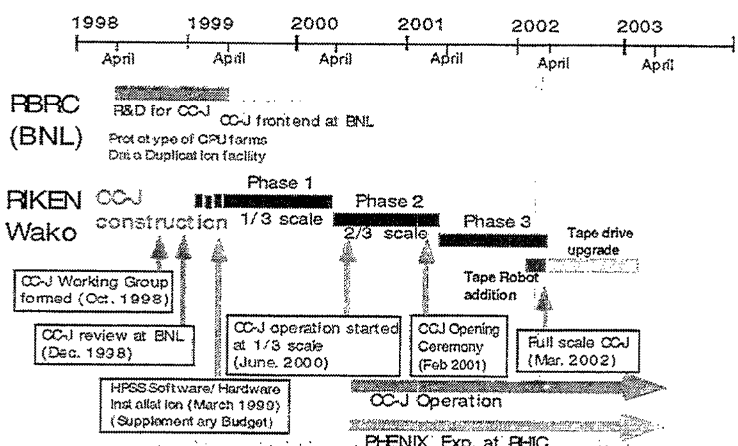
RIKEN CCJ

Computing Center in Japan for spin physics at RHIC

T. Ichihara
RIKEN, RBRC

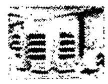
Presented on 11 March 2002
at RIKEN-BNL MSC at RIKEN

Plan and Current Status of RIKEN CCJ



System upgrade in JFY2001

- Hardware upgrade in JFY 2001
  - CPU : 192 ⇒ 330 (total clock 168 GHz -> 374 GHz)
  - Disk : 9.2 TB ⇒ 25.2 TB
  - HPSS Tape Library : 100 TB ⇒ 350 TB (addition of a new silo)



New silo will be installed in the end of March 2002

  - Hardware (CPU, Disk, HPSS library etc.) reaches to the designed requirement in the end of March 2002, except for HPSS tape drives.

- Hardware update plan in JFY 2002
  - Tape dive : RedWood drive (4 units) ⇒ 9940B (10 units)
    - Current : RedWood 11.2 MB/s 50 GB/volume : Prod. discontinued
    - [illegible] 30 MB/s 200 GB/volume:
  - HPSS server :

System Requirement and Achievement of CCJ

Annual Data amount

- DST 150 TB
- micro-DST 45 TB
- Simulated Data 30 TB
- Total 225 TB ([illegible])

Hierarchical Storage System

- Handle data amount of 225 TB/year
- Tape I/O bandwidth: 112 MB/s (44 MB/s)
- HPSS system

CPU (SPECint95)

Simulation	**8200**
Sim. Reconst	1300
Sim. ana.	170
Theor. Mode	800
Data Analysis	2000
Total	12470 SPECint95 (295 GHz)
	15800 SPECint95 (374 GHz)

Disk storage system

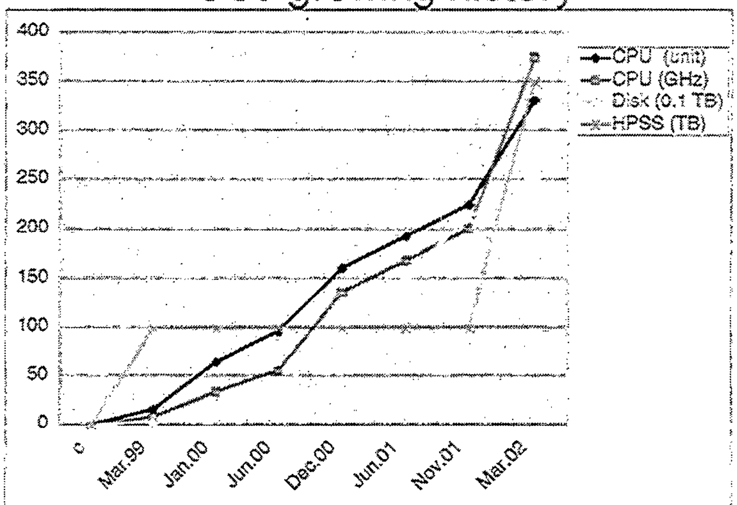
- 20 TB capacity (25 TB+48TB)
- All RAID system
- I/O bandwidth: 520 MB/s (620 MB/s)

- Data Accessibility
  - Data Duplication Facility (tape cartridge)
  - Wide Area Network (IMnet/APAN/ESnet)
- Software Environment
  - AFS, Objectivity/DB, Batch Queuing System

System requirement

[illegible] in the end of March 2002

CCJ growing history



	c	Mar.99	Jan.00	Jun.00	Dec.00	Jun.01	Nov.01	Mar.02
CPU (unit)	0	16	64	96	160	192	224	330
CPU (GHz)	0	8	34	56	136	168	200	374
Disk (0.1 TB)	0	3	19	35	92	152	212	252
HPSS (TB)	0	100	100	100	100	100	100	350

Components of RIKEN CCJ

proposals/plans in CCJ

Simulation

submitted	title	contact	status	resource	webpage
2000/07/11	[illegible]	T. Sakaguchi	finished		
2000/08/01	[illegible]	N. Hayashi	finished(pisa)	/ccj/w/tmp01	[illegible]
2000/09/13	[illegible]	N. Hayashi	finished(pisa/DST)	/ccj/w/tmp01	[illegible]
2000/11/10	[illegible]	N. Hayashi	finished(pisa/DST)	/ccj/w/tmp01	[illegible]
2001/05/10	[illegible]	T. Thomas / H.D.Sato	finished	/ccj/w/data06 (650GB)	

Research Plan

submitted	title	contact	status	resource	expiration date
2000/11/14	[illegible]	T. Matsumoto	finished	/ccj/w/tmp02(100GB)	2001/03/31
2001/01/03	[illegible]	T. Hachiya	finished	/ccj/w/tmp05(100GB)	2001/03/31
2001/02/09	[illegible]	A. Kiyomichi	finished (2001/03/05)	/ccj/w/tmp04(100GB)	2001/03/31
2001/03/26	[illegible]	H. Torii	finished	/ccj/w/data06(100GB)	2001/04/30
2001/08/23	[illegible]	H. Kobayashi/ N. Kamihara	finished	/ccj/w/data04(100GB)	2001/09/30
2001/11/16	[illegible]	K. Oyama	in progress	/ccj/w/tmp02(100GB)	2001/11/30
2001/11/21	[illegible]	K. Homma	in progress	/ccj/w/data07(300GB)	2001/12/05
2001/11/21	[illegible]	Y. Goto	in progress	/ccj/w/data08,12(2TB) (for pp raw data)	2002/01/31
2001/12/22	[illegible]	H. Ohnishi	in progress	/ccj/w/data14 (500GB)	2002/01/31
2002/01/09	[illegible]	H. Sato	in progress	/ccj/w/data09,10,15(3TB) (for pp raw data)	2002/03/31
2002/01/09	[illegible]	T. Sakaguchi	in progress	/ccj/w/data17(400GB) (for uDST production)	2002/07/31
2002/01/11	[illegible]	K. Katou	finished	/ccj/w/data17(50GB)	2002/01/31
2002/01/17	[illegible]	M. Tamai	in progress		2002/02/15
2002/01/18	[illegible]	Y. Goto	in progress	/ccj/w/data04(200GB)	2002/01/31
2002/01/29	[illegible]	H. Masui	in progress	/ccj/w/data01(600GB)	2002/03/31
2002/02/20	[illegible]	K. Katou	in progress	/ccj/w/data12(500GB)	2002/07/31
2002/02/27	[illegible]	K. Tanida	in progress	/ccj/w/data04(50GB)	2002/09/31

- 11 research plans were finished and 12 research plans are now in progress
- Several simulations and calibration for RUN 2 is now in progress
- Data transfer of RUN 2 in now in progress

CCJ Operation

- Operation, maintenance and development of CC-J are carried out under the charge of the CCJ Planning and Coordinate Office (PCO).

CCJ Director (Chief Scientist of the Radiation Lab.)
H. En'yo

Planning and Coordination Office

manager	T. Ichihara	(RIKEN and RBRC)
technical manager	Y. Watanabe	(RIKEN and RBRC)
scientific programming coordinator		
	H. En'yo	(RIKEN and RBRC, PHENIX-EC)
	H. Hamagaki	(CNS-U-Tokyo, PHENIX-EC)
PHENIX Liaison	N. Saito	(RIKEN and RBRC)
computer scientists	S. Yokkaichi	(RIKEN)
	O. Jinnouchi	(RIKEN)
	Y. Goto	(RBRC)
	S. Sawada	(KEK)

Technical Management Office

Manager, Data duplication	Y. Watanabe	(RIKEN and RBRC)
System engineer	N. Otaki (IBM Japan)	
Tape duplication operator	(TBD)	

Maintenance and Operation cost

in k Yen

- HPSS Operation and Maintenance
  - HPSS software 29,600
  - HPSS Hardware maint. 11,200
  - HPSS System Engineer 25,200

  HPSS subtotal 66,000
- Data Server Maintenance
  - Sun Hardware E450x6 4,000
  - Sun Software (Solaris) 2,000
  - RAID Hardware (24TB) 9,000
  - Network switch 2,000
  - UPS maintenance 1,800

  Data Servers subtotal 18,800
- CPU farm Maintenance
  - Alta cluster (256 CPU) 9,600
  - 1u CPU (72 CPU) 1,400
  - LSF software (328 CPU) 4,500

  CPU farm subtotal 15,500
- Data Duplication at BNL
  - Hardware maint (sun&ibm) 2,600
  - Operator for tape duplication 11,000

  Data Duplication subtotal 13,600
- Tape cartridge
  - 2000 volumes (100TB) 24,000

  Tape cartridge subtotal 24,000

Maintenance and Operation cost
Total 137,900

Upgrade cost in 2002 53,000
(tape drives, HPSS server)

Grand total in JFY2002
190,900

RBRC OPERATION-THEORY GROUP

T. D. Lee

RBRC Theory Group

(February 2001 – March 2002)

T. D. Lee

Presentation
8th Meeting of The Management Steering Committee of RIKEN BNL Collaboration

RIKEN, Wako, Saitama, Japan
March 11-12, 2002

T. D. Lee, RBRC Director
N. P. Samios, RBRC Deputy Director
Hideto En'yo, RBRC Associate Director
* * * *

RBRC Research Scientists (2001 – 2002)
Theory Group
T.D. Lee, Group Leader
Anthony Baltz, Deputy Group Leader

<u>Research Associates (Post Docs)</u>
Aoki, Y.
Itakura, K.
Nara, Y.
Nemoto, Y.
Noaki, J.
Orginos, K.
Ikeda, Takashi (4/1/02)

<u>Advisory Committee</u>
Baltz, A.
Creutz, M.
Gyulassy, M.
McLerran, L.
Pisarski, R.

<u>Fellows</u>
Blum, T.
Dawson, C.
Vogelsang, W.

<u>Consultants/ Visiting Scientists</u>
Gyulassy, M.
Jaffe, R.
Ohta, S.
Shuryak, E.

<u>Tenure Track/RHIC Fellows</u>

Bass, S.	(Duke)
Kusenko, A.	(UCLA)
Jeon. S.	(McGill)
Schaefer, T.	(SUNY, SB)
Stephanov, M.	(U. of IL, Chicago)
van Kolck, U.	(Arizona)
Venugopalan, R.	(BNL)
Wettig, T.	(Yale)

<u>Collaborators/ Associates</u>
Mawhinney, R.

<u>Computer Scientist</u>
Dong, Z.

Boer, D. (Post Doc—left 6/27/01)
Schaffner-Bielich, J. (Post Doc—10/31/01)
Bödeker, D. (RHIC Physics Fellow, BNL—12/31/01)
Son, D. T. (RHIC Physics Fellow, Columbia—3/31/02)

RHIC Physics Fellow (established in '99)

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RBRC Graduates

Name	Dates at RBRC	RBRC Position	New Position Title	New Position Institution
Bödeker, Dietrich	12/2000 to 12/2001	RHIC Physics Fellow, BNL	Professorship, C-4	U. of Bielefeld, Germany
Boer, Daniêl	10/1998 to 06/2001	Research Associate	Academy Researcher, Tenure Track	Dutch Royal Academy of Sciences, Free University, Amsterdam
Fujii, Hirotsugu	09/1997 to 09/1999	Research Associate	Assistant Professor	U. of Tokyo, Komaba, Inst. of Physics
Kharzeev, Dmitri	08/1997 to 09/1999 10/1999 to 03/2000	RIKEN BNL Fellow RHIC Physics Fellow, BNL	Physicist, Tenured Staff	BNL
Kurita, Kazuyoshi	[04/1997 to 09/1997 10/1997 to 03/2000] 04/2000 to 03/2002	[Postdoc. Res. RIKEN Special Postdoc Res., RIKEN] RIKEN BNL Fellow	Associate Professor	Rikkyo University, Tokyo
Nara, Yasushi	10/1999 to 09/2002	Research Associate	Research Associate	U. of Arizona, Tucson
Rischke, Dirk	09/1997 to 09/2000 10/2000 to 01/2001	RIKEN BNL Fellow RHIC Physics Fellow, BNL	Professorship, C-4	Inst. f. Theor. Phys. J.W. Goethe-Univ. Frankfurt, Germany
Saito, Naohito	[04/1995 to 03/1996] 04/1996 to 03/2001 04/2001 to 03/2002	[RIKEN Special Postdoc. Fellow] RIKEN/RBRC Res. RIKEN Spin Prog. Res.	Associate Professor	Kyoto U., Japan
Sasaki, Shoichi	09/1998 to 09/2000	Research Associate	Assistant Professor	U. of Tokyo, Japan
Schaffner-Bielich, Jürgen	09/1998 to 10/2001	Research Associate	Research Associate	Columbia University
Son, Dam Thanh	10/1999 to 03/2002	RHIC Physics Fellow, Columbia U.	Tenured Position	U. of Washington, Seattle, Natl. Inst. for Nuclear Theory
Wingate, Matthew	09/1997 to 09/2000	Research Associate	Assistant Professor	Ohio State U., Columbus
Yasui, Yoshiaki	09/1997 to 09/2000	Research Associate	Appointment Title?	Radiation Lab, RIKEN, KEK, Theory Group, Japan

publication list (Theory)

RBRC 1 — RBRC 31

at the first Anniversary Celebration

October 16, 1998

RBRC 32 — RBRC 54

at the 4th Management Steering Committee Meeting, February 28, 1999

RBRC 55 — RBRC 81

at the 5th Management Steering Committee Meeting, January 27, 2000

RBRC 82 — RBRC 174

at the 7th Management Steering Committee Meeting, February 13, 2001

RBRC 175 — RBRC 246

at the 8th Management Steering Committee Meeting, March 11

Since the RBRC Scientific Review Committee Meeting November 29-30, 2001

RBRC/#

232. Ania Kulesza, George Sterman, Werner Vogelsang, "Joint Resummation in Electroweak Boson Production," [hep-ph/0202251] Phys. Rev. D (submitted).

233. Y. Aoki, T. Blum, N. Christ, C. Cristian, C. Dawson, T. Izubuchi, R. Mawhinney, G. Liu, S. Ohta, K. Orginos, A. Soni, and L. Wu [RBC Collaboration], "Chiral Properties of Domain Wall Fermions with Improved Gauge Actions," Phys. Rev. D (to be submitted).

234. Thomas Schaefer, "Instanton Effects in QCD at High Baryon Density,"[hep-ph/0201189] SUNY-NG-02-01, 26 pp., January 2002.

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246. Se-yong Kim, Shigemi Ohta, "Zero Temperature Phase Structure of Multiflavor QCD," [hep-lat/0111040], Presented at *19th International Symposium on Lattice Field Theory (LATTICE 2001),* Berlin, Germany, 19-24 August 2001; Nucl. Phys. Proc. Suppl. 106, 873-875 (2002); Berlin 2001, Lattice Field Theory, 873-875 (2002).

Weekly Seminars

Spin Physics *(Theory & Exp)*	Tuesdays (10:00 a.m.)	Organized by Y. Goto and W. Vogelsang
Nuclear Physics	Tuesdays (11:00 a.m.)	Organized jointly with BNL Staff
High Energy-RIKEN Theory	Wednesdays (1:30 p.m.)	Organized jointly with BNL Theorists
QCD and RHIC Physics *(Theory & Exp)*	Thursdays (12:30 p.m.)	Organized by C. Dawson
High Energy Theory Lunch Talks	Fridays (12:00 Noon)	Organized by S. Dawson
Nuclear Physics-RIKEN Theory	Fridays (2:00 p.m.)	Organized jointly with BNL Staff

Volume 32	RHIC Spin Physics V (BNL 52628) February 21, 2001 Organizing Committee: Gerry Bunce, Naohito Saito, Steve Vigdor, Thomas Roser, Hal Spinka, Hideto En'yo, Leslie C. Bland, Wlodek Guryn
Volume 33	Spin Physics At RHIC in Year-1 and Beyond (BNL-52635) May 14-18, 2001 Organizing Committee: Leslie Bland, Daniël Boer, Naohito Saito, Werner Vogelsang
Volume 34	High Energy QCD: Beyond the Pomeron (BNL-52641) May 21-25, 2001 Organizing Committee: John Dainton, Wlodek Guryn, Dmitri Kharzeev, and Yuri Kovchegov
Volume 35	RIKEN Winter School, Quarks, Hadrons and Nuclei-QCD Hard Processes and the Nucleon Spin (BNL 52643) December 1-5, 2000, RIKEN, Japan Organizers: N. Saito, T.-A. Shibata, and K. Yazaki
Volume 36	RHIC Spin Collaboration Meeting VI (BNL-52642) October 1, 2001 Organizers: Les Bland and Naohito Saito

Volume 37	RHIC Spin Collaboration Meeting VI (Part 2) (In preparation) November 15, 2001 Organizers: Les Bland and Naohito Saito
Volume 38	RBRC Scientific Review Committee Meeting (BNL-52649) November 29-30, 2001 Organizers: T. D. Lee and N. P. Samios

RBRC Workshops in 2002

Date: January 13 to April 19, 2002
Title: RBRC Workshop on Theory Studies for RHIC-Spin
Organizer: Werner Vogelsang

The aim of this workshop is to attract several spin theorists to the Center for longer stays of about 4 weeks (to promote closer collaborations between theorists and experimentalists for RHIC spin).

Participants include: Jianwei Qiu (Iowa State U)
Mauro Anselmino (University and INFN, Torino, Italy)
Umberto d'Alesio (INFN, Torino)
Jiro Kodaira (Hiroshima U.)
Students: Michhiro Hori (Hiroshima U.)
Hiroshi Yokoya (Hiroshima U.)
Marco Stratmann (U. of Regensburg, Germany)

Date: February 22, 2002
Title: RHIC Spin Collaboration Meeting VII
Organizer(s): Brendan Fox

Date: March 18-22, 2002
Title RBRC Workshop on Hadron Structure from Lattice QCD
Organizers: Thomas Blum, Daniël Boer, Michael Creutz, Shigemi Ohta, Kostas Orginos

Date: March 28-30, 2002
Title: Baryon Dynamics at RHIC
Organizers: Nu Yu (LBL), Miklos Gyulassy (Columbia), Dmitri Kharzeev (BNL)

Other RBRC Scientific Articles Proceedings Volumes:

Volume 1 Prospects for Spin Physics at RHIC
Gerry Bunce, Naohito Saito, Jacques Soffer, Werner Vogelsang
July 2000

Volume 2 Status Report on the Calculation of ε'/ε
RBRC-Brookhaven-Columbia Collaboration
November 2000

Volume 3 Scientific Presentations: 7th Meeting of the Management Steering Committee of the RIKEN BNL Collaboration, RIKEN, Wako, Japan, February 13-14, 2001.

Volume 4-CP Violation in K Decay From Lattice QCD
Thomas Blum and Robert Mawhinney
RBRC-Brookhaven-Columbia QCDSP Collaboration
July 26, 2001

- Outstanding Junior Investigator Award In Nuclear Theory - 2001, the two OJI selected by U.S. DOE are both RBRC members:

  M. Stephanov

  U. van Kolck

- Both Stephanov and Van Kolck are also awarded the prestigious Alfred Sloan Fellowship in 2002.

- Institute for Nuclear Theory, U. of Wash.
Lattice QCD and Hadron Phenomenology
9/24 – 12/7/2001
RBRC invitees: Y. Aoki, C. Dawson, K. Itakura, J. Noaki + K. Orginos

- Institute for Theoretical Physics, Santa Barbara
QCD and Gauge Theory Dynamics in the RHIC Era
4/1/02 – 6/28/02
RBRC invitees: S. Bass, T. Blum, T. Schaefer, D. Son, M. Stephanov, R. Venugopalan

D. Kharzeev, formerly a RBRC Fellow is one of the organizers

Outstanding Theory Contributions

I. Cold dense quark matter :

1. Dam Son, Misha Stephanov + Dirk Rischke on color superconductivity & confinement

2. T. Schaefer on color-flavor-locked condensate

II RHIC process :

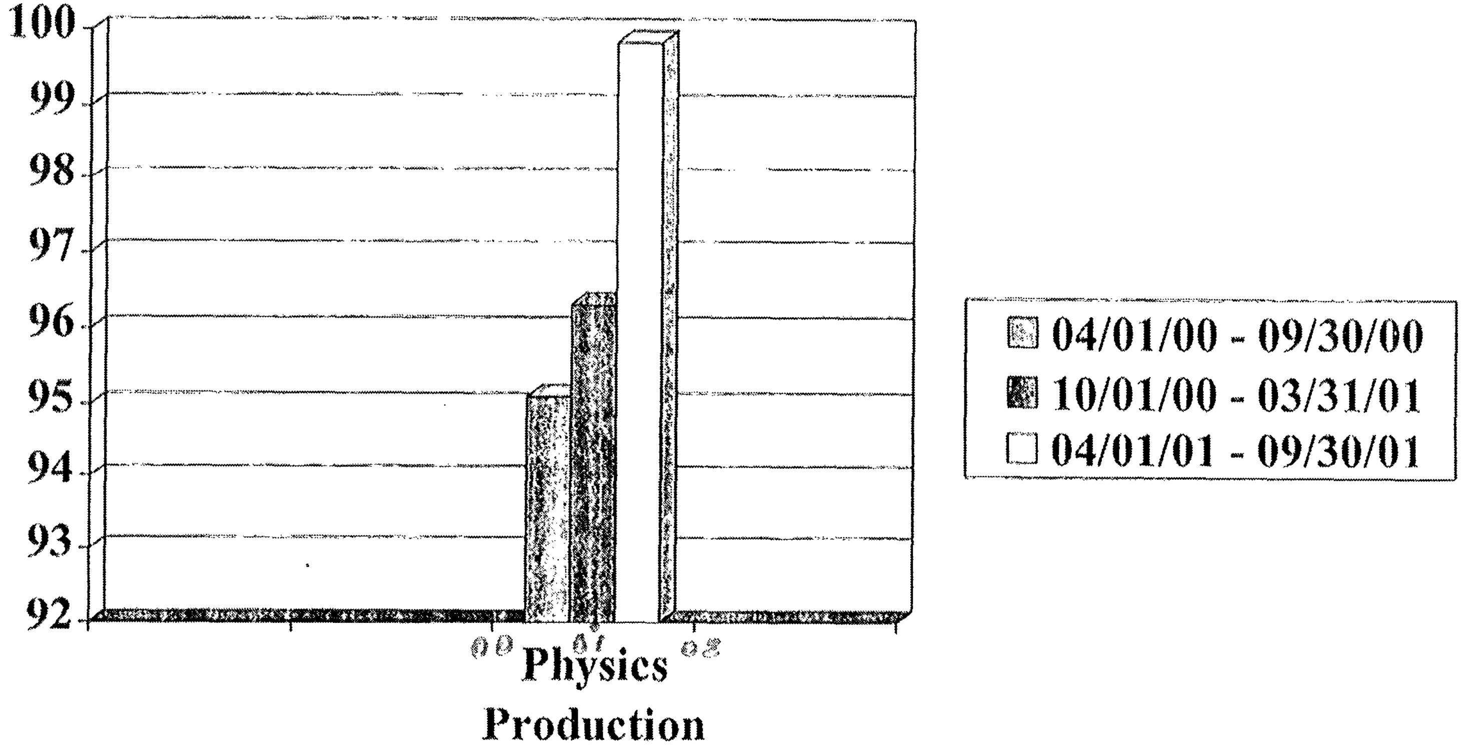
1. Raju Venugopalan, Yasushi Nara (with L. McLerran) on Color glass condensate

2. QCD plasma by Dietrich Bodecker

III Spin structure fn analysis by Werner Vogelsang

IV. Dark matter analysis by Alexander Kusenko, ... etc.

RBRC – QCDSP
Percent of Uptime



RBRC-BNL-CU (RBC) Collaboration

February 2002

- <u>RIKEN-BNL Research Center:</u>

  Visiting Faculty: Shigemi Ohta (KEK)

  Fellows: Tom Blum, Chris Dawson

  Postdoc: Yasumichi Aoki, Jun-Ichi Noaki, Yukio Nemoto, Kostas Orginos,

  Former Postdoc: Shoichi Sasaki, Matt Wingate

- <u>BNL:</u>

  Faculty: Mike Creutz, Amarjit Soni

  Visiting Faculty: Taku Izubuchi (Kanazawa)

  Postdoc: Saša Prelovšek

- <u>Columbia:</u>

  Faculty: Norman Christ, Robert Mawhinney

  Postdoc: Thomas Manke, Azusa Yamaguchi

  Student: Calin Cristian, Changhoan Kim, Xiaodong Liao, Ludmila Levkova, Guofeng Liu

- <u>Columbia/BNL:</u>

  Postdoc: Chulwoo Jung (SciDAC)

02-20-02:1

Major Achievements from QCDSP
(2001 – 2002)

1. Massive Domain Wall Fermion Lattice Calculations (to maintain chiral sym.) *

2. Completion of the First Calculation on $\Delta I = \frac{1}{2}$ rule and ϵ'/ϵ in Kaon Decay (in the quenched approx.) *

3. Discovery of the Highly Effective DBW II Lattice Action

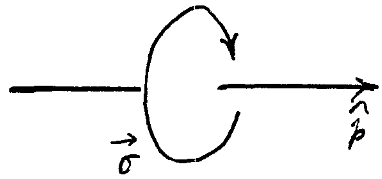
4. Testing G_A/G_V in β- decay (Gateway to First Principle Calculations on Spin Structure Functions)

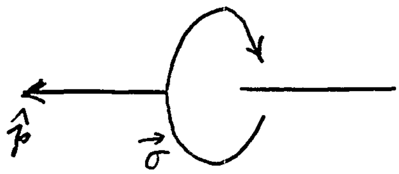
5. First Anisotropic Lattice Calculation on QCD Phase Transition Diagram

* Also by CP-PAC

chiral symmetry

chirality $= \vec{\sigma} \cdot \hat{p}$ (or Γ_5)

-1  left hand

$+1$  right hand

Chirality is a good (exact) quantum no. only for a zero mass particle

The Goldstone - Nambu boson of a chiral sym. vacuum = a zero mass pion

•

(quark)

• Chirality can be an approx. quantum no. for a theory with nonzero, but small, mass particles (quarks)

$\because \quad E = \sqrt{p^2 + m^2} \cong p \quad$ if $\quad p \gg m$

$$\therefore \quad \boxed{m^2_{pion} = 0 \quad \text{if} \quad m_{quark} = 0}$$

BNL-52634
Formal Report

RIKEN BNL Research Center

CP VIOLATION IN K DECAY FROM LATTICE QCD

Thomas Blum and Robert Mawhinney
RBRC-Brookhaven-Columbia QCDSP Collaboration

July 26, 2001

RBRC Scientific Articles

Volume 4

Building 510A, Brookhaven National Laboratory, Upton, N.Y 11973-5000, USA

Comparison with Experimental Results

Quantity	Experiment	This calculation
Re A_0(GeV)	3.33 $\times 10^{-7}$	3.26(19) $\times 10^{-7}$
Re A_2(GeV)	1.50 $\times 10^{-8}$	1.279(57) $\times 10^{-8}$
ω	22.2	25.5(57)
Re (ϵ'/ϵ)	15.3(26) $\times 10^{-4}$ (NA48)	−4.4(24) $\times 10^{-4}$
	20.7(28) $\times 10^{-4}$ (KTev)	

$$\frac{\mathrm{Amp}(K \to 2\pi)_{I=0}}{\mathrm{Amp}(K \to 2\pi)_{I=2}} \equiv \omega$$

$$\frac{\dfrac{\mathrm{Rate}(K_L^0 \to \pi^+\pi^-)}{\mathrm{Rate}(K_S^0 \to \pi^+\pi^-)}}{\dfrac{\mathrm{Rate}(K_L^0 \to \pi^0\pi^0)}{\mathrm{Rate}(K_S^0 \to \pi^0\pi^0)}} = \left| \frac{\epsilon + \epsilon'}{\epsilon - 2\epsilon'} \right|^2 \cong 1 + 6\, \mathrm{Re}(\epsilon'/\epsilon)$$

70

Nucleon Matrix Element

- confirming $G_V = 1$ and $Z_A = Z_V$

- testing $G_A/G_V = 1.26$?

goal

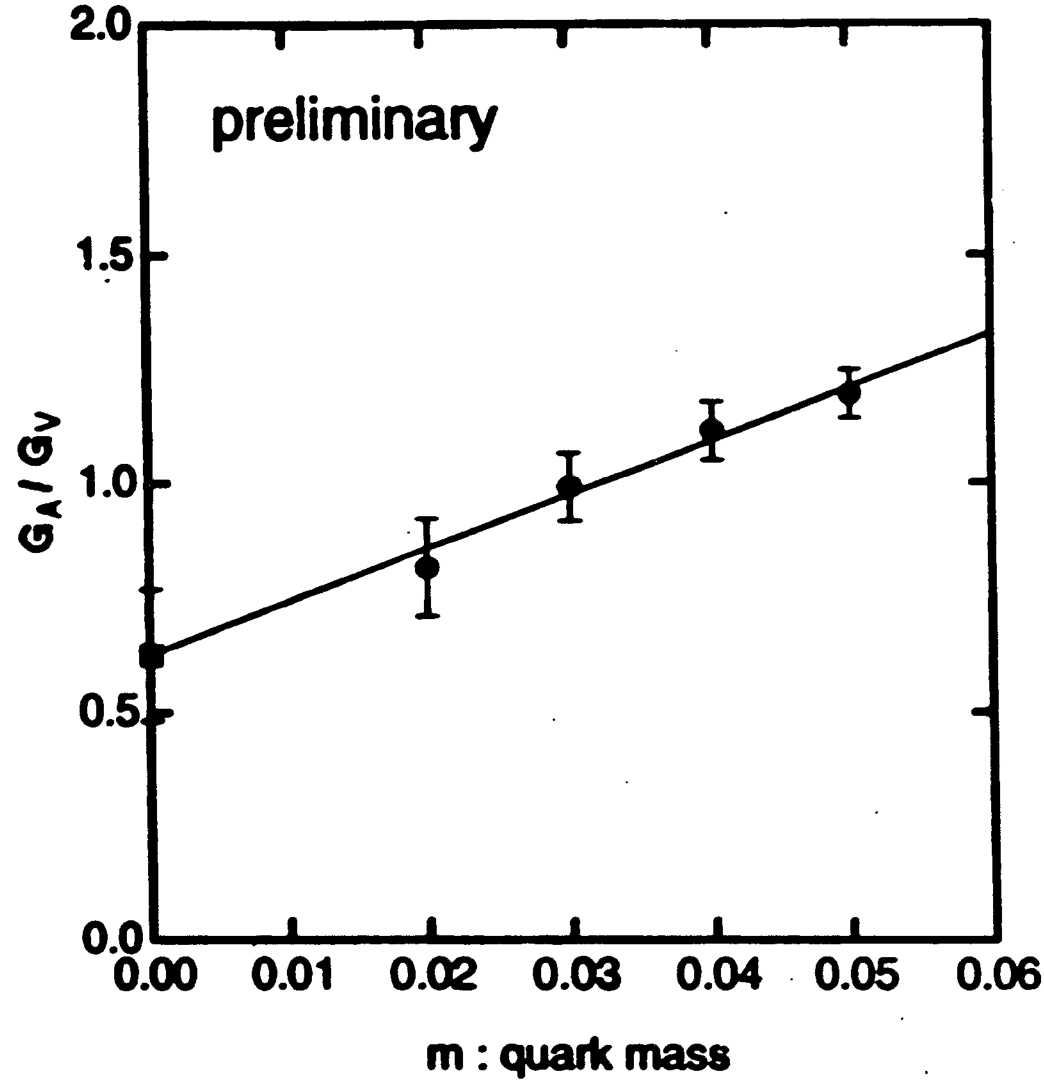
evaluating all spin structure

functions from lattice QCD

β - decay

Nucleon axial vector coupling

(Feb. 2001)



$(G_A/G_V)_{exp.} = 1.26$

charged weak current $V_\mu - A_\mu$

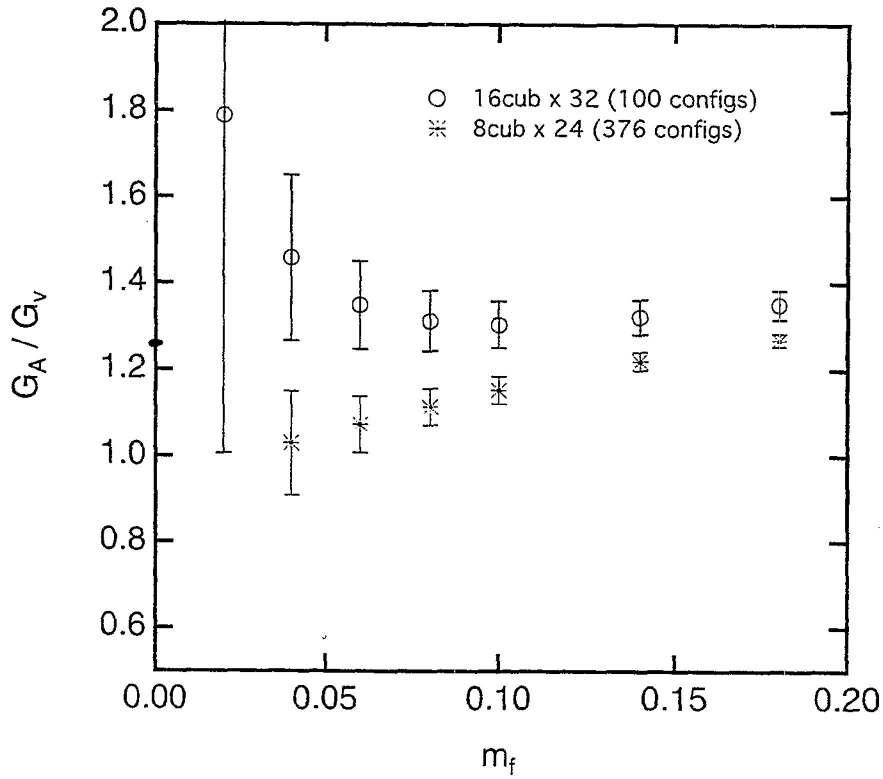
- $G_A/G_V = 0.63(14)$ by linear extrapolation to m=0
- Also get $\Delta u/G_V = 0.50(14)$ and $\Delta d/G_V = -0.15(7)$

(RBRC) S. Sasaki

Nucleon g_A

- Measured with DBW2 gauge actions with $a^{-1} \sim 1.3$ GeV.
- Two volumes: $8^3 \times 24$ and $16^3 \times 32$.
- Blum, Sasaki, Ohta

Evidence for finite volume effects, but better statistics required.



02-20-02:3

Objective

Minimize Chiral Symmetry breaking in the space of Gauge Actions.

Actions Tested:

- Wilson: $S_g = \frac{\beta}{3}\mathrm{Re\,Tr}\left\langle 1 - \Box \right\rangle$

- One loop Symanzik:

$$S_g = \frac{\beta}{3}\mathrm{Re\,Tr}\left[c_0 \left\langle 1 - \Box \right\rangle + 2c_1 \left\langle 1 - \Box\!\Box \right\rangle + \frac{4}{3} c_2 \left\langle 1 - \mathrm{\Large ⧉} \right\rangle \right]$$

c_i computed by 1-loop tadpole improved perturbation theory.

[Lüscher & Weisz Phys.Lett. B158 (1985)]

[Alford *et.al.* Phys.Lett. B361 (1995)]

- Iwasaki:

$$S_g = \frac{\beta}{3}\mathrm{Re\,Tr}\left[(1 - 8c_1) \left\langle 1 - \Box \right\rangle + 2c_1 \left\langle 1 - \Box\!\Box \right\rangle \right]$$

With $c_1 = -0.331$ computed by perturbative RG blocking.

[Iwasaki (1983)]

- DBW2: Same as Iwasaki but $c_1 = -1.4067$ computed non-pertrubatively by RG blocking.

[Takaishi Phys.Rev. D54 (1996)]

K. Orginos, Y. Aoki
(2001)

domain wall fermion

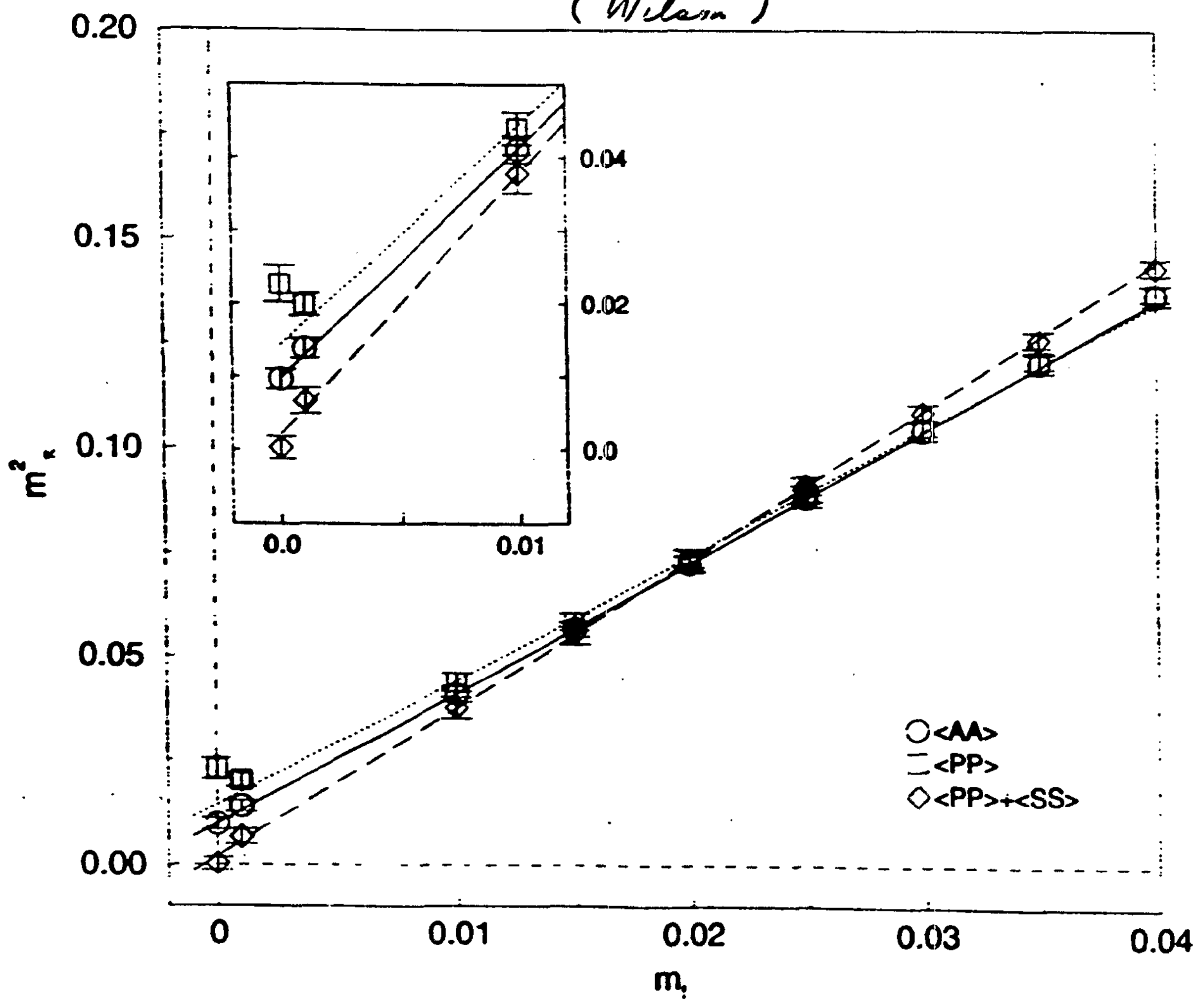
(full chiral symmetry if with dynamic fermion and $L_s \to \infty$)

In quenched approx. $m_\pi^2 = 0$ if $m_f + m_{res} = 0$

fluctuations in m_{res} are due (largely) to zero-modes & near zero modes

$16^3 \times 32$ $\beta = 6.0$ $L_s = 16$

(Wilson)

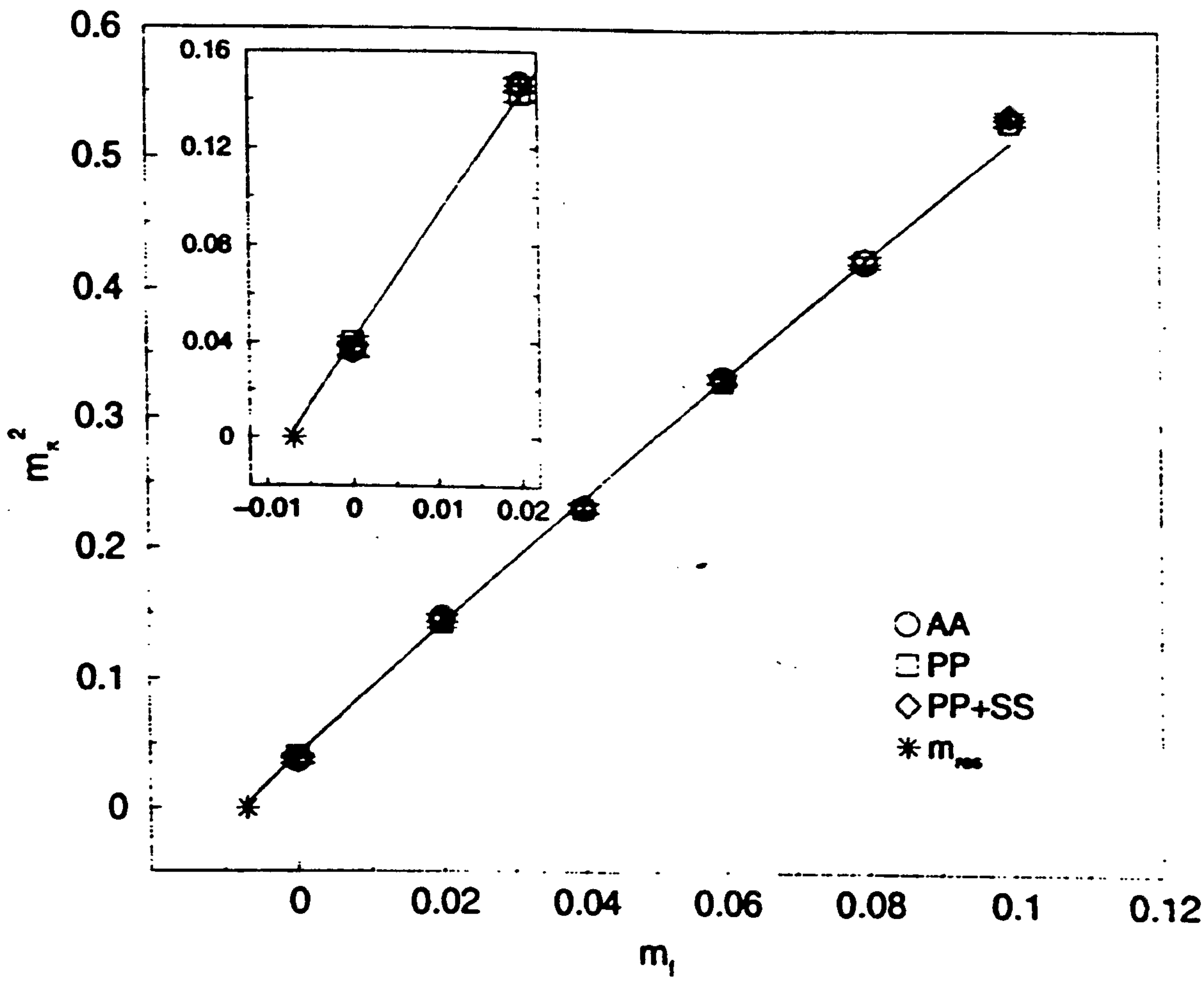


RBRC — QCDSP

Domain Wall Fermion

$m_{res} \simeq +8$ MeV

$16^3 \times 32$ $\beta = 6.0$ $L_s = 48$ (Wilson)



RBRC – QCDSP
(2001)

used in ϵ'/ϵ calculation

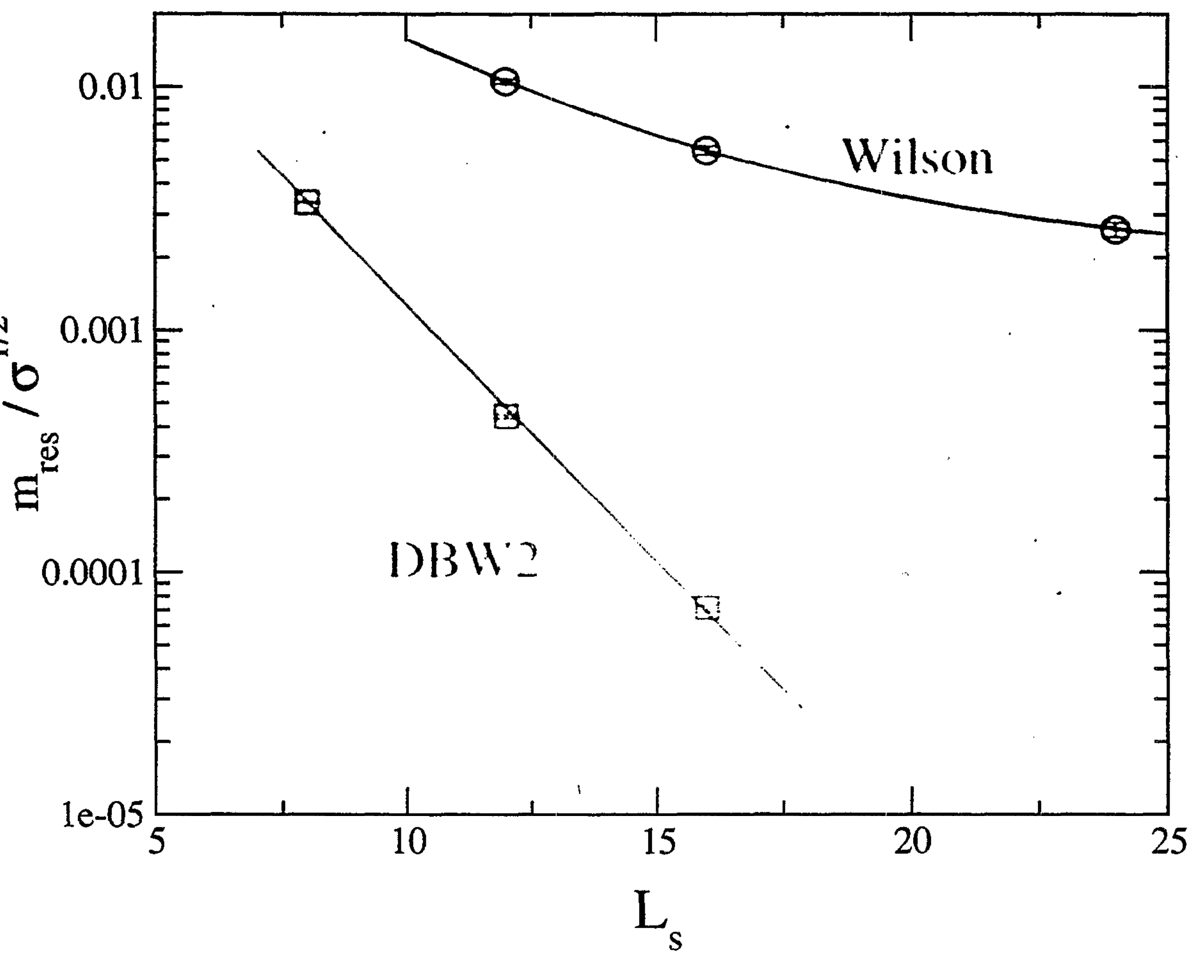
Residual Mass for Quenched QCD

Which gauge action gives the smallest m_{res}?

Compare Wilson and DBW2 gauge actions for lattice spacing $a \sim 0.1$ fermi. (K. Orginos, Y. Aoki)

DBW2 shows marked improvement

For $L_s = 16$, DBW2 m_{res} is 100 times smaller.



02-20-02:4

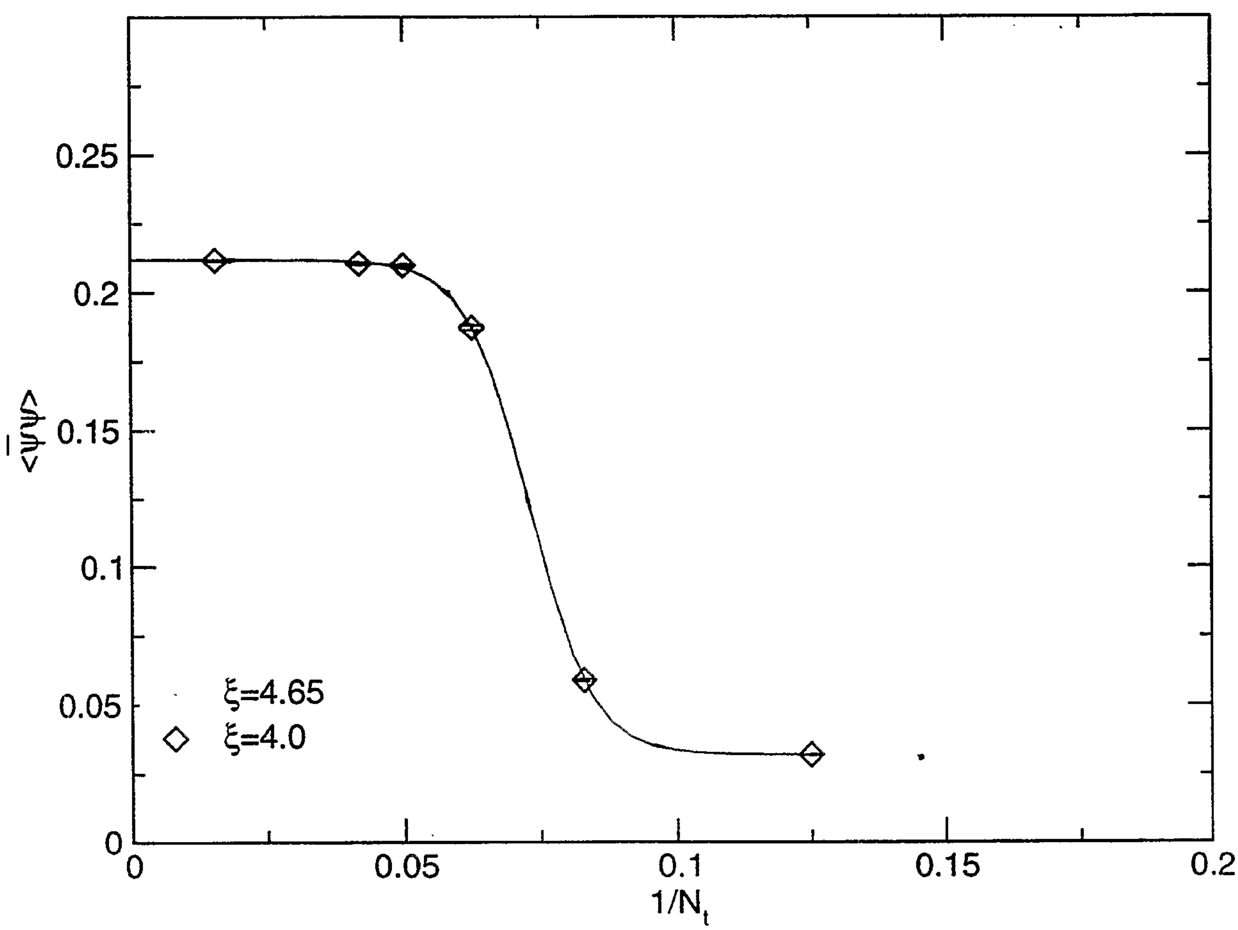
Anisotropic Staggered Thermodynamics

1. Keep a_s fixed and a_t fixed. Vary N_t to vary temperature. Levkova, Manke

2. $N_t = 4, 8, 12, 16, 24, 28$ and 64.

Only temperature varies through transition, nothing else.

The phase transition



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ξ = anisotropy = a_s / a_T

Progress in Lattice Gauge Theory

Staggered and Wilson fermions

- $T = 0$ and $T \neq 0$ lattice QCD being investigated
- Large scale simulations by CP-PACS, CU, JLQCD, MILC, RBC, UKQCD, APE/ROME, QCDSF, ...
- Formulation breaks chiral and/or flavor symmetry

Domain wall fermions

- Full flavor and chiral symmetry ($L_s \to \infty$)

	Quenched QCD	QCD
$T = 0$	Chiral limit (RBC) (CP-PACS) NPR (RBC) Spectrum, B_K, ϵ'/ϵ (RBC) (CP-PACS)	Spectrum (RBC) Residual mass (RBC) Improved algorithms (RBC)
$T \neq 0$		T_c (RBC) $U_A(1)$ breaking (RBC)

02-20-02:3

Future Projects

With Domain Wall Fermions

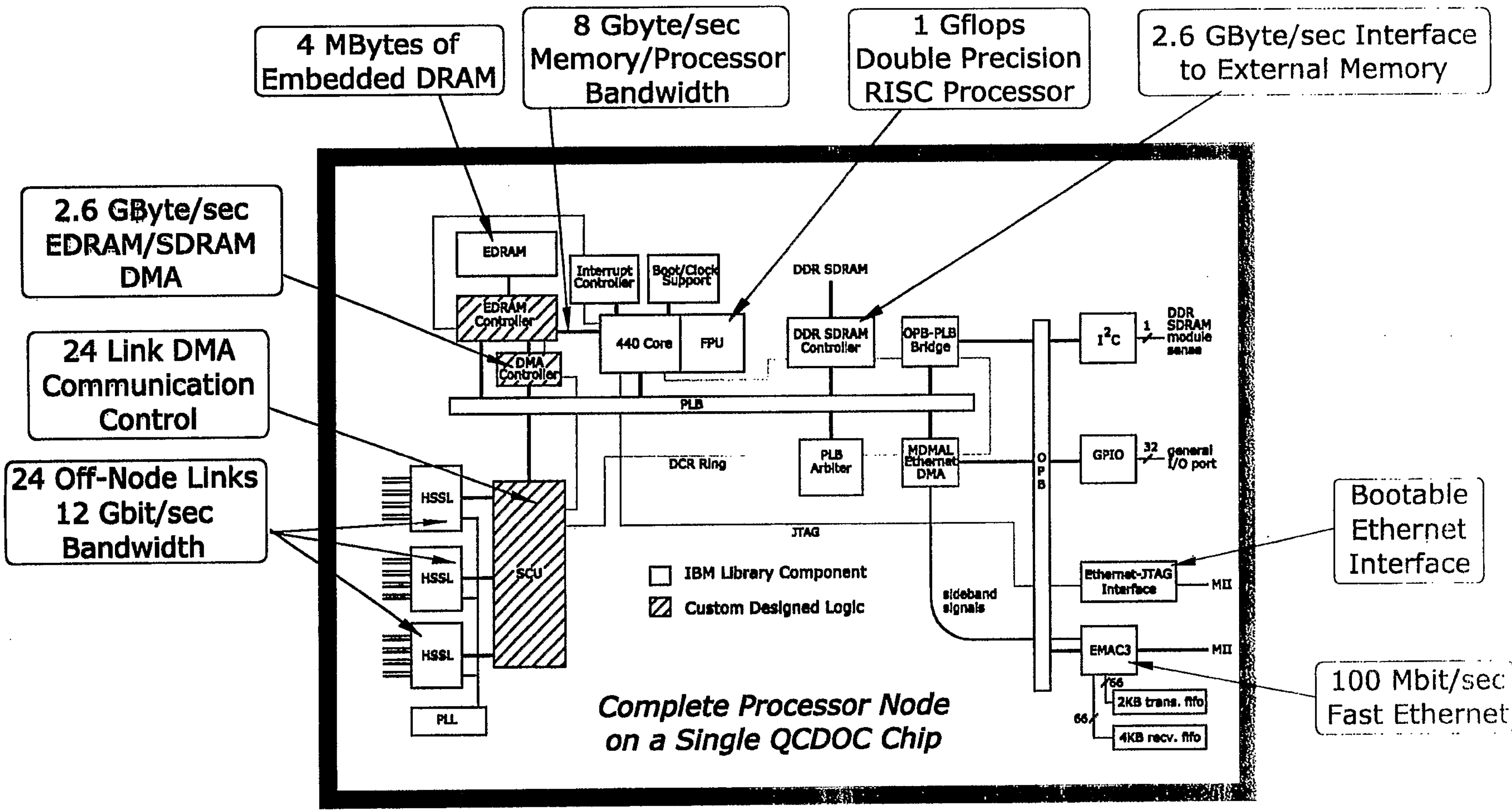
1. Full QCD with DWF
   - Improve action, allowing smaller L_s
   - Lay groundwork for 10 Teraflops QCDOC.
2. Quenched studies of $K \to \pi\pi$ physics
   - Use DBW2 and smaller lattice spacing.
   - Check systematic effects in calculations
3. g_A and nucleon spin matrix elements with DBW2.

With Anisotropic Lattices

1. Extend anisotropic thermodynamics to DWF
2. Heavy quark physics
   - Heavy-heavy spectrum calculated
   - Extended to other heavy quark physics

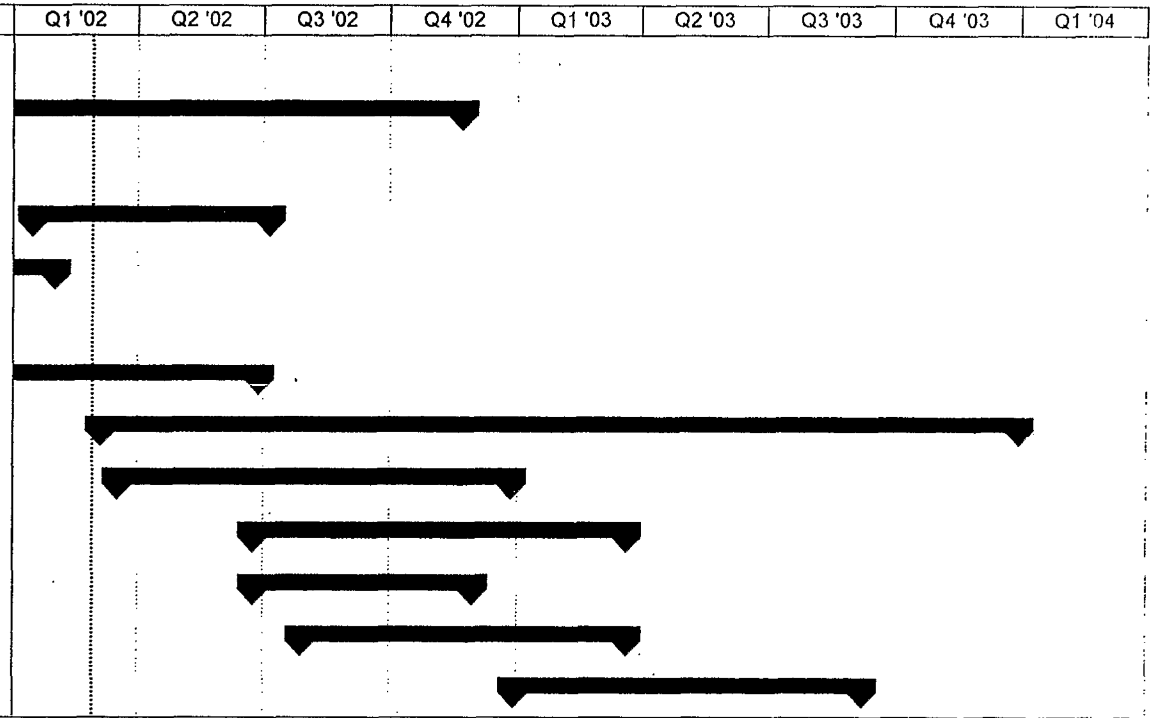
QCDOC status

- ASIC Design:
  - All major components complete
  - Large scale simulation using QCD code with communications ongoing
  - Physical chip layout underway at chip vendor
- Prototype chips delivered this summer
- Board and cabinet design started
- 2 Teraflops machine available toward end of JFY02
- 10 Teraflops machine in JFY03


4 MBytes of Embedded DRAM
8 Gbyte/sec Memory/Processor Bandwidth
1 Gflops Double Precision RISC Processor
2.6 GByte/sec Interface to External Memory
2.6 GByte/sec EDRAM/SDRAM DMA
24 Link DMA Communication Control
24 Off-Node Links 12 Gbit/sec Bandwidth
Bootable Ethernet Interface
100 Mbit/sec Fast Ethernet
EDRAM
EDRAM Controller
DMA Controller
Interrupt Controller
Boot/Clock Support
440 Core
FPU
DDR SDRAM
DDR SDRAM Controller
OPB-PLB Bridge
PLB
PLB Arbiter
MDMAL Ethernet DMA
DCR Ring
JTAG
HSSL
HSSL
HSSL
SCU
PLL
OPB
I²C
1
DDR SDRAM module sense
GPIO
32
general I/O port
Ethernet-JTAG Interface
MII
EMAC3
MII
sideband signals
66
2KB trans. fifo
66
4KB recv. fifo
IBM Library Component
Custom Designed Logic
Complete Processor Node on a Single QCDOC Chip

Schedule for QCDOC Design and Construction

ID	Task Name
1	**Develop Architecture**
4	**Design ASIC chip**
18	**IBM ASIC Support**
26	**Design printed circuit boards**
33	**QCD ASIC Evaluation/Test Software**
36	**OS Software, Level I**
39	**OS Software, Level II**
42	**Physics Applications Software**
43	**Construction of Prototype**
58	**Phase I Construction (Columbia)**
59	**Construction of 8-MBD Machine**
66	**Construction of 32-MBD Machine**
75	**Phase II Construction (RBRC)**



RBRC OPERATION-EXPERIMENT

Hideto En'yo

RBRC Experimental Group

Activity Summary from
organizational point of view.

Hideto En'yo

Executive summary of the run2

- Excellent achievement as the 1st year of polarized proton collision
- Still need significant progress in Polarization and Luminosity. *Important addition will be the AGS snake.*

- RBRC/RIKEN personnel exhibited great jobs

Member of RBRC experiment '01

RBRC

Group Leaders:

- Hideto Enyo (Wako)
- Gerry Bunce(deputy)

Fellows/Postdoc

- Matthias Grosse Perdekamp
- Abhay L Deshpande
- Brendan Fox
- Yuji Goto
- Kazuyoshi Kurita
- Douglas Fields (New Mexico)
- Alexander Bazilevsky

22 active members

RIKEN Spin Program

Tenure researcher

•Naohito Saito
•Atsushi Taketani
•Takashi Ichihara (WakoCCJ)
•Yasushi Watanabe(WakoCCJ)

Postdoc

•Satoshi Yokkaichi(WakoCCJ)
•Hideyuki Kobayashi
•Jiro Murata (Wako)
•Kensuke Okada (June)
•Osamu Jin-nouchi (April)

Students

•Hisa Torii
•Junji Tojo
•Hiroki Sato

Graduations from RBRC/RIKEN

- Naohito Saito; to Kyoto Univ. Asc. Prof. 1st April '02
- Kazu Kurita; to Rikkyo Univ. Asc. Prof. 1st April '02
- Yuji Goto; becomes RIKEN tenure, 1st April '02
- Jiro Murata; became RIKEN tenure, July '01
- Matthias Perdekamp; RBRC joint appointment with Illinois Univ. Mid of 2002.
  - **Results of good performance of this project.**
  - **We miss them, but we will be paid back more in a few years of scale.**
  - **Extending our Empire.**

Polarimetry

one of the important area charged for RBRC personnel

- ✧ CNI-pol: served excellently well through the runs.
  - ✧started with Junji Tojo's pioneering work
  - ✧built in RHIC by Kazu Kurita
  - ✧Osamu Jinnouchi (new RIKEN postdoc) takes it over.
- ✧ Local Polarimeter (12O'clock) gave us a surprising gift
  - ✧Started with Yuji Goto's initiative
  - ✧Abhay, Brendan for detector construction and setup
  - ✧New Kyoto students will finalize the result

Central Arm(electrons and photons)

- Trigger for spin: excellent achievement
  - ✧Yuji Goto's initiative
  - ✧Matthias G. Perdekamp realized the trigger
  - ✧Kensuke Okada (new RIKEN postdoc) takes it over
- Analysis
  - ✧Sasha Bazilevsky readings the analysis efforts
  - ✧Hisa Torii will finish his thesis in 2002

Muon Arm

South Muon Arm: well commissioned,

- Doug E. Fields + Hideyuki Kobayashi in Tracking
- Atsushi Taketani + Hiroki Sato in Identifier

- Hiroki Sato will finish his thesis in 2002. This will be the first thesis from PHENIX-SPIN
- New Student from T.I.Tech expected

Belle Activity initiated (Electron Positoron Collider in KEK)

Belle can provide us vital input for the transversity study in *RHIC spin experiment.*

RBRC is now the member of Belle Collaboration

- Matthias Perdekamp leading the project
- Akio Ogawa and Soeren Lange (both are not in PHENIX) have joined with newly established "RBRC visiting scientist" scheme
- New postdoc to be assigned
- New student from Heidelberg is expected.

Wako activity

- CCJ: almost reached to the full scale. Spin analysis is about to start.
  - ➢Akio Kiyomichi will join us as a RIKEN postdoc
- PHENIX detector Upgrade (silicon tracker):
  - ➢New tenure Researcher in Radiation Lab, Kiyoshi Tanida started from October 1st to be charged for the electronics development and the support structure
  - ➢Silicon pixel detector developments with CERN ALICE/NA60
    - ➢Hiroaki Ohnishi (BNL) 1st Jan. '02
    - ➢Johann Heuser (SUNY) 1st April '02
    - ➢Rykov Vladimir (Wayn State U) 1st May '02
  - ➢Si-Strip R&D with BNL instrumentation division (Z. Li); Yuji Goto is in charge in RBRC side.

Major events

- RBRC Visiting Researcher (unpaid) is established
  - Analysis Proposal to Belle in KEK (Spin in Fragmentation)
    - M.G.Perdekamp (RBRC, Contact person for BELLE)
    - Soeren Lange (Frankfurt, STAR)
    - Akio Ogawa (Penn State U, STAR)
    - New postdoc for Belle (seeking)
  - Si tracker development (will soon be established in RBRC with the BNL instrumentation division)
  - This is also a contract of RIKEN (trip etc can be supported)
  - RBRC Theory is also using this framework

Major events

- Special Doctoral Fellow Ship of RIKEN (For Japanese only) is open through RBRC and Radiation Lab in Wako.
  - From April 1st. Takahiro. Kawabata (Kyoto-U) and Junji.Tojo (Kyoto-U , currently RBRC student) will start with RBRC experimental group. Takashi Ikeda (U-Tokyo) will start with RBRC theory group
- Junior Research Associate of RIKEN is called through RBRC exp+theory and Radiation Lab.(for Japanese only)
  - Yoshitaka Hatta will join the RBRC theory Group
- Scheme for wider student support (also for non-Japanese) is under development.

Experiment G. Organization JFY02

BELLE
Soeren Lange (Visitor)
Akio Ogawa (Visitor)
New postdoc

RBRC STUDENT
Hisa Torii
Hiroki Sato
Nobuyuki Kamihara
Manabu Togawa
+more ?

RBRC
Hideto Enyo (@Wako)
Gerry Bunce
Matthias Grosse Perdekamp
Abhay L Deshpande
Brendan Fox
Douglas E. Field
Alexander Bazilevsky

New appointments; selection on going

~30 active member +~3 active visitors

UPGRADE
Kiyoshi Tanida
Hiroaki Ohnishi
Johann Hauser
Rykov Vladimir

RIKEN/RBRC
Naohito Saito(Visitor)
Yuji Goto
Atsushi Taketani
Hideyuki Kobayashi
Kensuke Okada
Osamu Jin-nouchi
T. Kawabata
J. Tojo

WAKO/CCJ
Takashi Ichihara
Yasushi Watanabe
Satoshi Yokkaichi
Akio Kiyomichi

3rd RIKEN Winter School on QCD

'Quark-Gluon Structure of the Nucleon and QCD'

➢ will be held at the end of this month at Wako Campus for 3 days

- Lectures by
  - Soper 'Basics of QCD Perturbation Theory',
  - Oka 'Properties of Hadrons in Non-Perturbative QCD'
  - Hatsuda 'Introduction to Hot and Dense QCD'
  - + 6 short lectures
- More than 50 (Japanese) students !
  - Our future relays on the young generation

Special Thanks to Administrative Staffs in BNL and Wako

Especially to M.Yokota and H.Horie

RBRC OPERATION-EXPERIMENT

Gerry Bunce

11 March 2002
RBRC Management Steering Committee
G. Bunce

RBRC Experimental Group---a few remarks

<u>Much</u> to be proud of !

RBRC Workshops led to coordinated plan between experiments and accelerator which resulted in the September 2000 commissioning and the December 2001-January 2002 first spin run.

RBRC, with important collaborators, led the new RHIC polarimeter development and realization. These devices were invented for RHIC and work beautifully, measuring the polarization to 2% in one minute.

RBRC initiated and led design and realization of high rate event selection for spin for PHENIX. These triggers worked beautifully, increasing the number of events by x100 over min-bias.

RBRC designed and built additional beam-beam counters for pp for PHENIX. These worked well.

RBRC designed special electronics to keep track of luminosity for each crossing for PHENIX. This is necessary for spin and worked.

RBRC designed, built, calibrated (at Stanford), installed a photon detector for very forward polarization measurements. This worked and we observed very large online spin asymmetry for neutrons.

RBRC and collaborators led triggering for the PHENIX muon arm, and we expect to have cross sections and spin asymmetries for forward muons and pions. This was very successful.

RIKEN funded the Siberian Snakes for RHIC. This was a great success—the first time Snakes were used at high energy.

We took the first data ever at root(s)=200 GeV with colliding polarized protons, providing our first look at the spin structure of the proton using quark and gluon probes. We have beautiful data, and our sensitivity to transverse spin effects is 10x better than previous experiments, and at 10x the energy.

And, we should be very proud of our graduating class:

Naohito Saito, Kazu Kurita, Matthias Perdekamp, Yuji Goto

as well as our present members.

FUTURE PERSPECTIVES—RHIC LONG RANGE PERSPECTIVES

Thomas B. W. Kirk

RHIC Long Range Perspectives

Presented to the
Management Steering Committee
of the
Riken - BNL Collaboration

by
Thomas B.W. Kirk
Associate Laboratory Director
HENP

Wako, Japan
March 11, 2002

Major New Accelerator Initiatives

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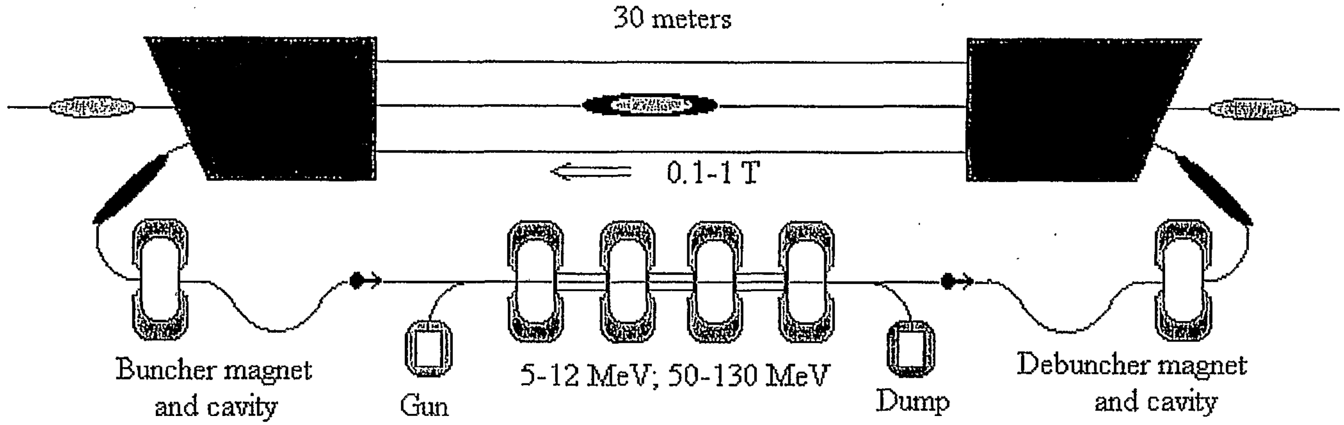
- **RHIC Luminosity Upgrade (RHIC II) [NP]**
  - RHIC luminosity upgrade 'White Paper' for NP LRP completed
  - RHIC beam cooling at colliding energy
- **Electron-(Heavy Ion, Pol. Proton) Collider (EIC) [NP]**
  - 'White paper' for NP LRP completed
  - RHIC beam cooling R&D
- **Neutrino factory or superbeam [HEP]**
  - Design for 1- 4 MW AGS upgrade completed (MC study II):
    - 1.2-1.5 GeV Superconducting Proton Linac
    - 2.5 - 5 Hz AGS Repetition Rate
  - CAP study for neutrino superbeam from AGS underway

Laboratory Initiative - RHIC II

- **Motivation**
  - collider programs require **periodic upgrades to stay at the frontier**
  - 'rare' processes will enhance physics reach with more luminosity
  - RHIC collider has already identified clear luminosity upgrade paths
  - DOE and BNL mutually plan on this evolution path for RHIC
- **Scope & Timing**
  - accelerator project scope is x40 luminosity increase
  - detector upgrades meet higher luminosity & address rare processes
  - planning for the RHIC upgrades began with **'01 NP Long Range Study**
  - RHIC II Construction Project transpires over the period FY 05 - 11
- **Cost**
  - accelerator upgrades \$54M; detector upgrades \$80M; TEC = \$134M
  - no *new* detectors included but may be needed (cost scale >\$50M)
- **Scientific Benefits**
  - **expansion of physics** in the RHIC facility <=> **rare processes**
  - extend detector capabilities <=> **explore new phenomena in HI events**

The RHIC Electron Beam Cooler

Courtesy Thomas Roser, BNL C-A Dept.



<u>R&D issues:</u>

High intensity photocathode electron gun

High efficiency energy recovering SC linac with magnetized electron beam

Efficient electron beam transport and debunching/bunching

High precision (10 ppm) solenoid for 30 m cooling section.

Laboratory Initiative - eRHIC

- **Motivation**
  - extends and leverages an existing major NP facility for new physics
  - exploits existing BNL research capabilities for **new science reach**
  - multi-program future facility benefits (NP + BES)

- **Scope & Timing**
  - 10 GeV electron beam plus one new **e-A Detector** in RHIC ring
  - physics & conceptual design thru Fy06; constr. project FY09-15
  - key to success is starting **PERL R&D** next year for **electron ion cooling**

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- **Cost**
  - R&D funding at ~$200K/year
  - eRHIC Construction Project estimated at $295M

- **Scientific Benefits**
  - opens a new field of NP - **high energy probes of cold nuclear matter**
  - investigates a wholly new phenomenon, the **'color spin glass'**
  - could be leveraged to provide new FEL photon capability at BNL

OVERALL AND FUTURE PERSPECTIVES
RIKEN BNL RESEARCH CENTER

T. D. Lee

RIKEN BNL Research Center

Overall and Future Perspectives

T. D. Lee

Presentation
8th Meeting of The Management Steering Committee of
RIKEN BNL Collaboration

RIKEN, Wako, Saitama, Japan
March 11-12, 2002

- RBRC aims to be the intellectual leader in the new field of High Energy Nuclear Physics

- Through RHIC and Spin Physics, RBRC will explore

1. the Relativistic Nature of Nucleon and Nuclear Structure,

2. the Complex Intrinsic Structure of the Physical Vacuum,

3. New Form of Nuclear Matter

Importance of Spin

- All elementary particles have non-zero spin

lepton (e , ν , μ , ..)	Spin $\frac{1}{2}$
quark (u, d, s, ..)	" $\frac{1}{2}$
photon (γ)	" 1
gluon (g)	" 1
graviton (G)	" 2

- Vacuum has spin 0 (with parity + or ∵ parity non conservation)

- All zero spin (0+ / 0-) are related to excitations of Vacuum

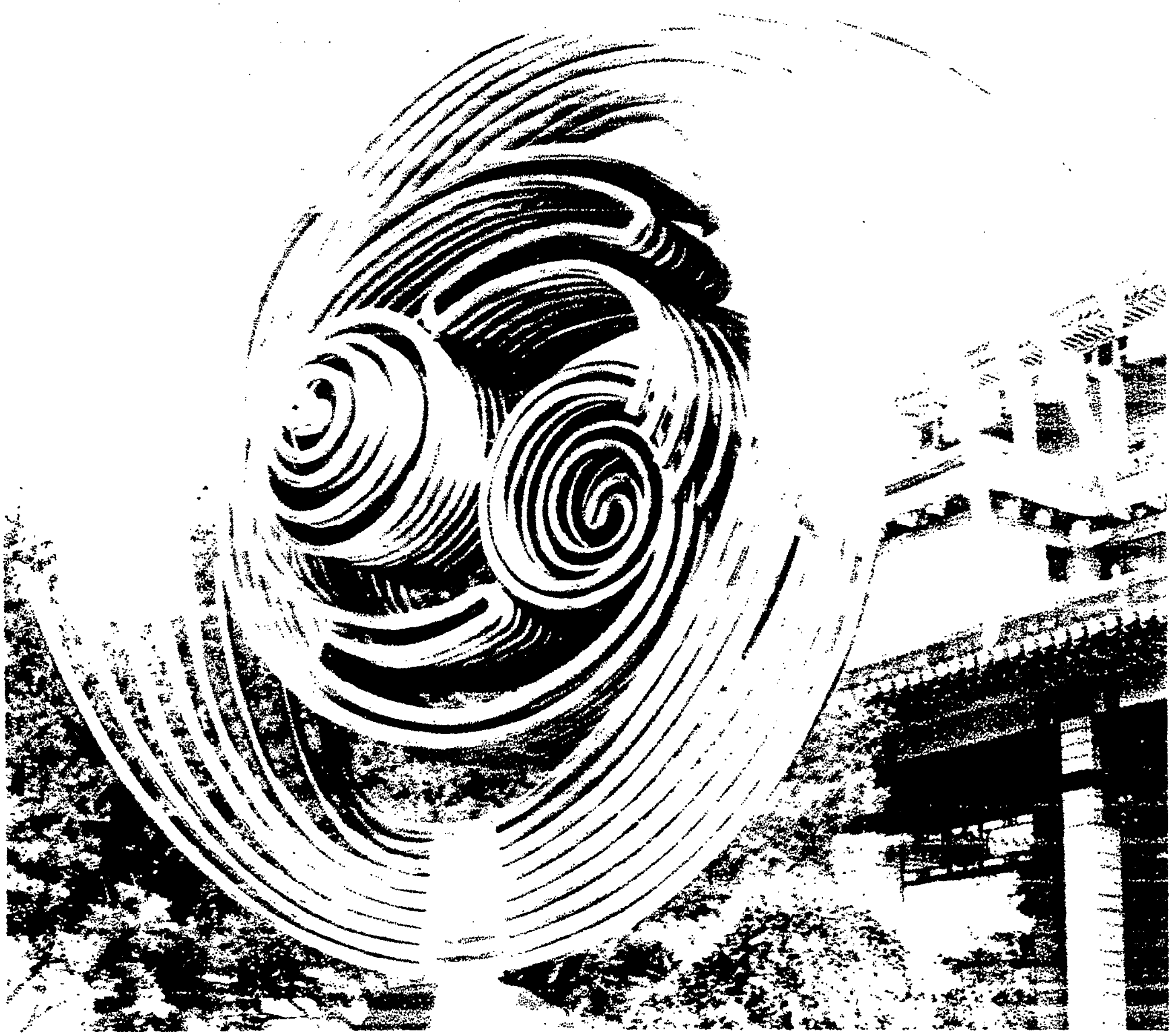
pion (0-) : Nambu - Goldstone excitation

Higgs (0±) : Vacuum excitation

Therefore non-elementary !

RBRC

RIKEN BNL Research Center



物之道

道生物

物生道

道为物之规

物为道之成

天地之艺物之道

李政道 二00一

The Tao of Matter

Tao Creates Matter

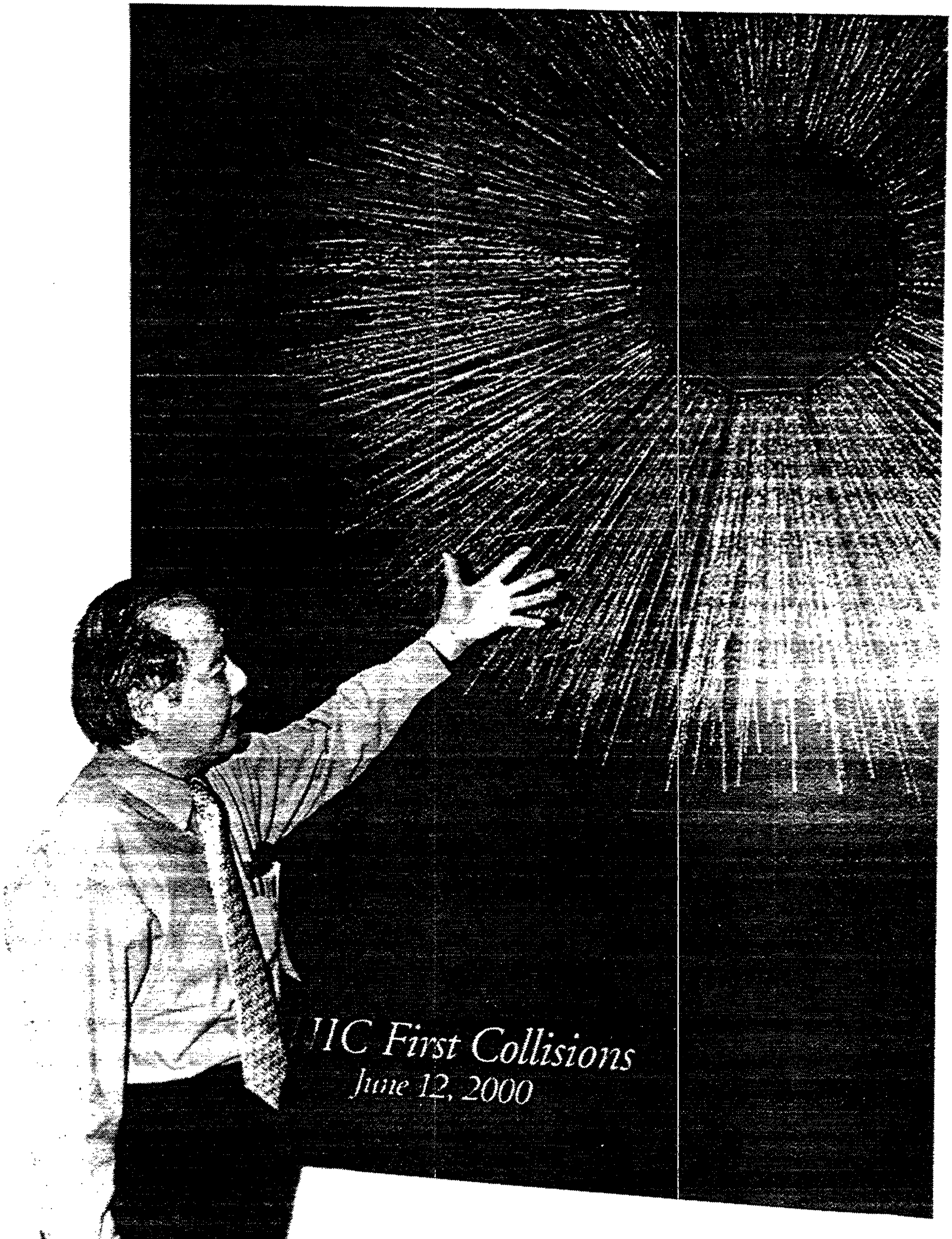
Matter Generates Tao

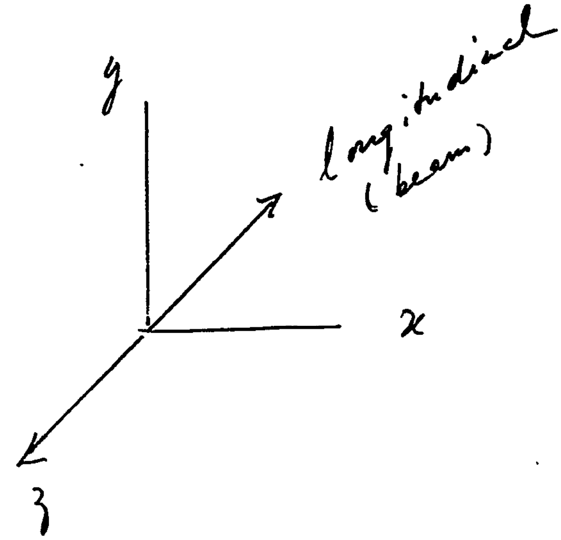
Tao Shapes the Action of Matter

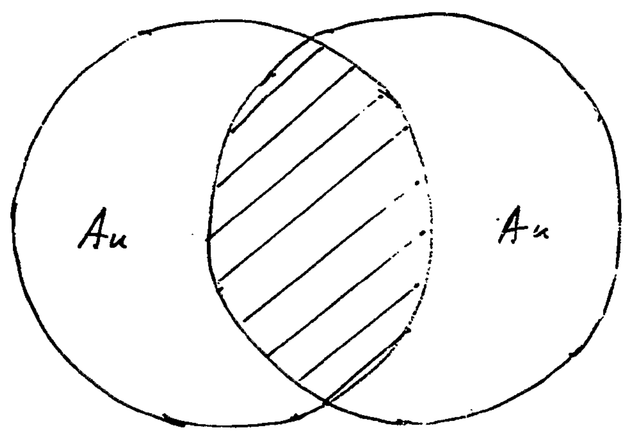
Matter Forms the Completion of Tao

The Art of the Universe is the Tao of All Matter

T.D.L., 2001


IC First Collisions
June 12, 2000


y
longitudinal
(beam)
x
z


Au
Au

Azimuthal asymmetry of high p_t particles

* Finite dE/dx $\Longrightarrow v_2(p_t) \longrightarrow 0$ for $p_t \longrightarrow \infty$ *

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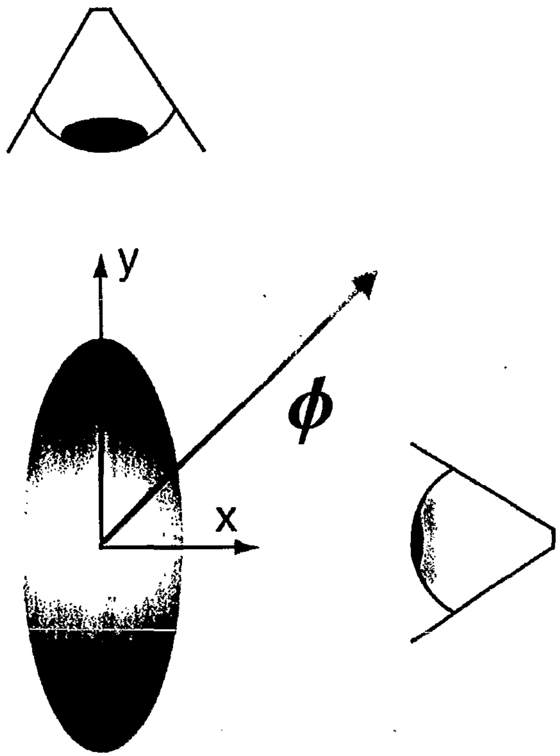
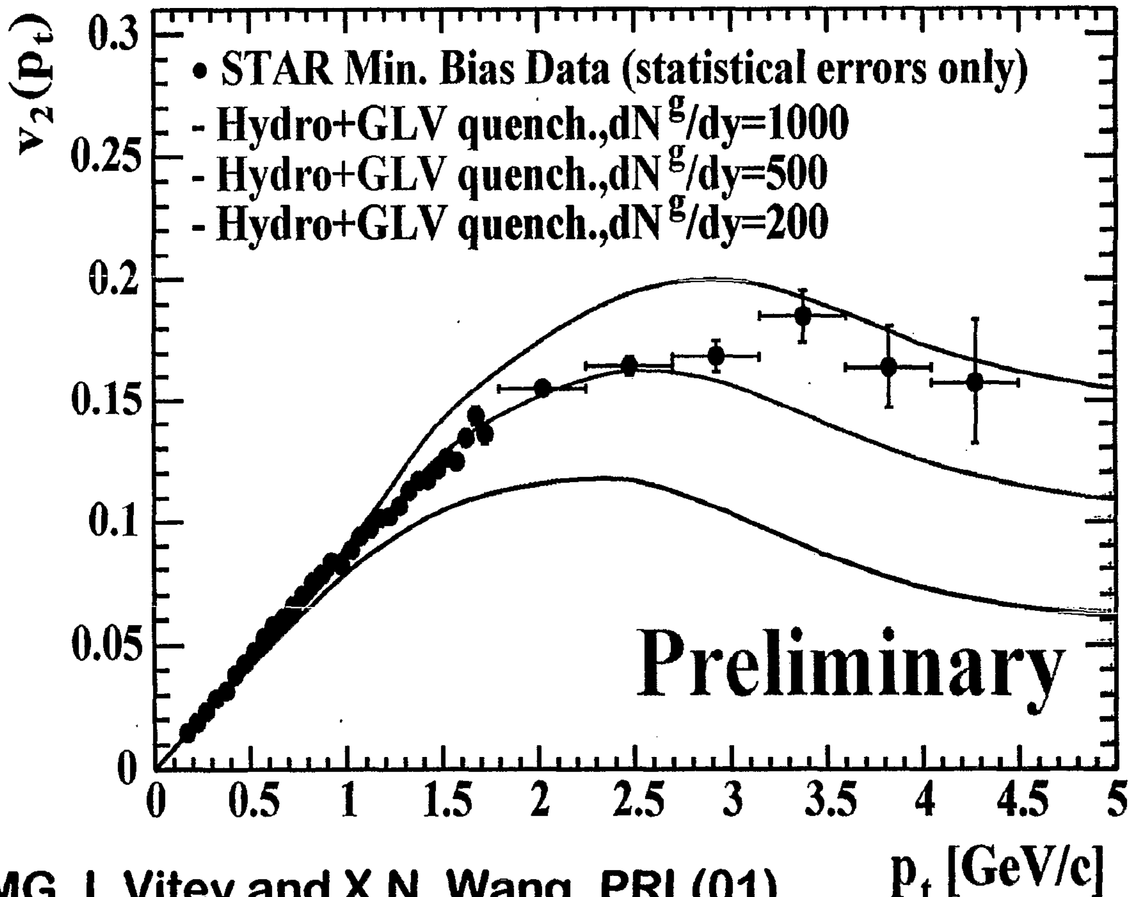


Raimond Snellings

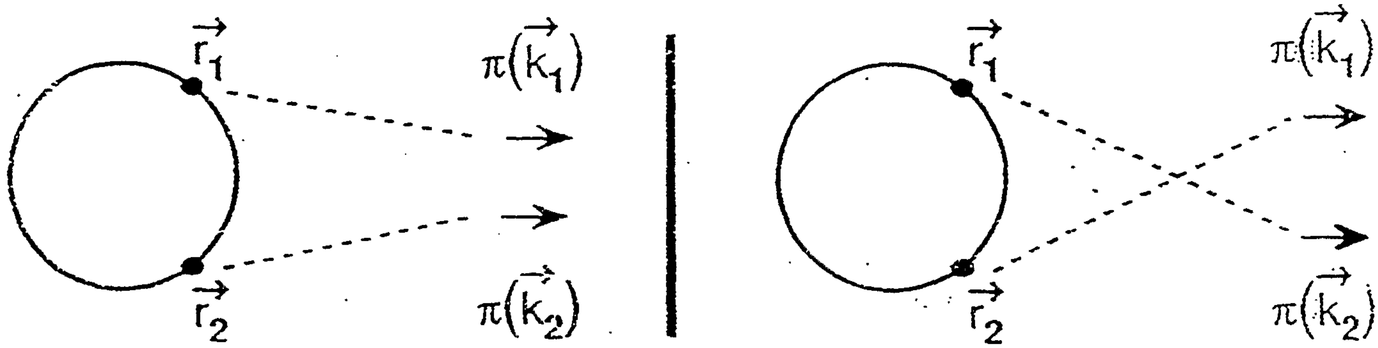
$$dN/dydp_T^2d\phi \propto 1 + 2v_2(p_T)\cos(2\phi)$$



MG, I. Vitev and X.N. Wang, PRL(01)

Conversion of particle signals to volume measurements (Hanbury-Brown/Twiss)

Special case $t_1 = t_2$ (originally for stars)



$$|\text{Amp}|^2 \propto |e^{i\vec{k}_1\cdot\vec{r}_1 + i\vec{k}_2\cdot\vec{r}_2} + e^{i\vec{k}_2\cdot\vec{r}_1 + i\vec{k}_1\cdot\vec{r}_2}|^2$$

$$\text{''} \quad = 1 + \cos \vec{q}\cdot\vec{r}\,. \quad \text{(varies from 1 to 2)}$$

$$\vec{q} = \vec{k}_1 - \vec{k}_2 \qquad \& \qquad \vec{r} = \vec{r}_1 - \vec{r}_2$$

Here, π can be any bosonic channel.

For fermionic channel:

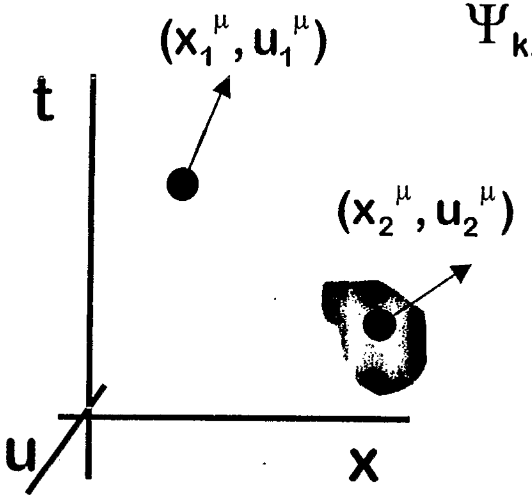
$$|\text{Amp}|^2 \propto 1 - \cos \vec{q}\cdot\vec{r}$$

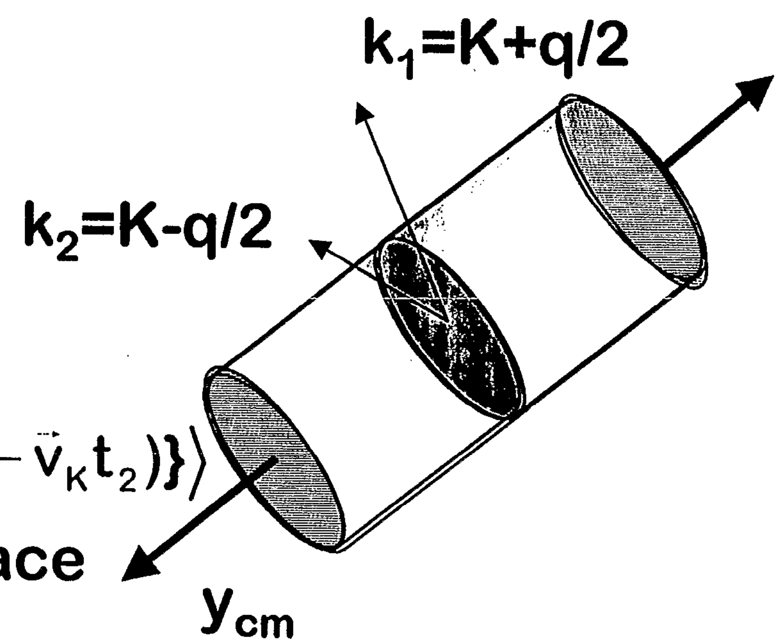
Hanbury-Brown, Twiss (1954) Intensity Interferometry $\langle I(t_1) I(t_2) \rangle$

Goldhaber, Goldhaber, Lee, Pais (1960) $pp \rightarrow \pi^- \pi^- X \quad C_{\pi\pi}(k_1, k_2)$

Kopylov & Podgoretsky, Shuryak, Coconni (1973)
Yano & Koonin (1978)
Gyulassy, Kauffmann, Wilson (1979)
Zajc, Two Pion Correl in Heavy Ion Collisions, PhD 1982

$$\Psi_{k_1,k_2} = \frac{1}{\sqrt{2}} \left(e^{-ik_1x_1} e^{-ik_2x_2} + e^{-ik_1x_2} e^{-ik_2x_1} \right)$$

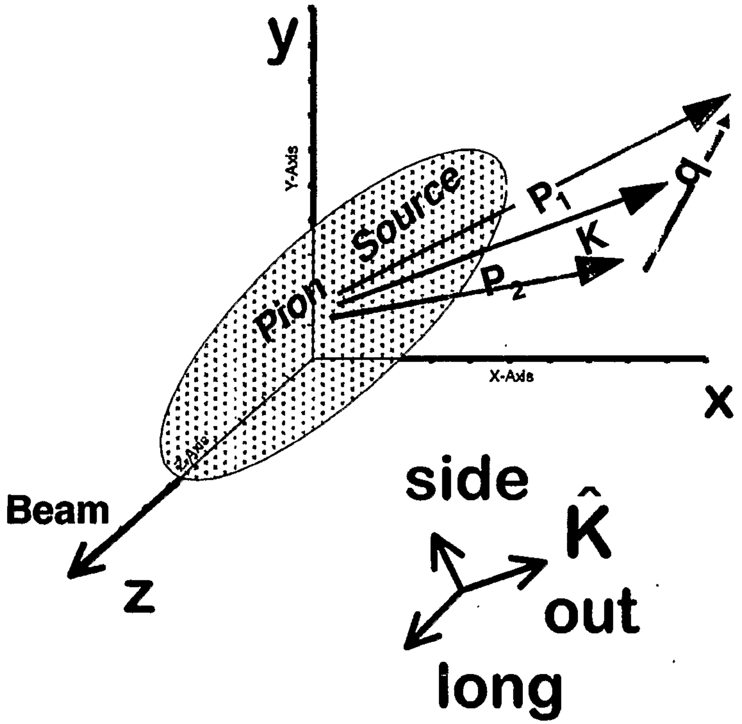


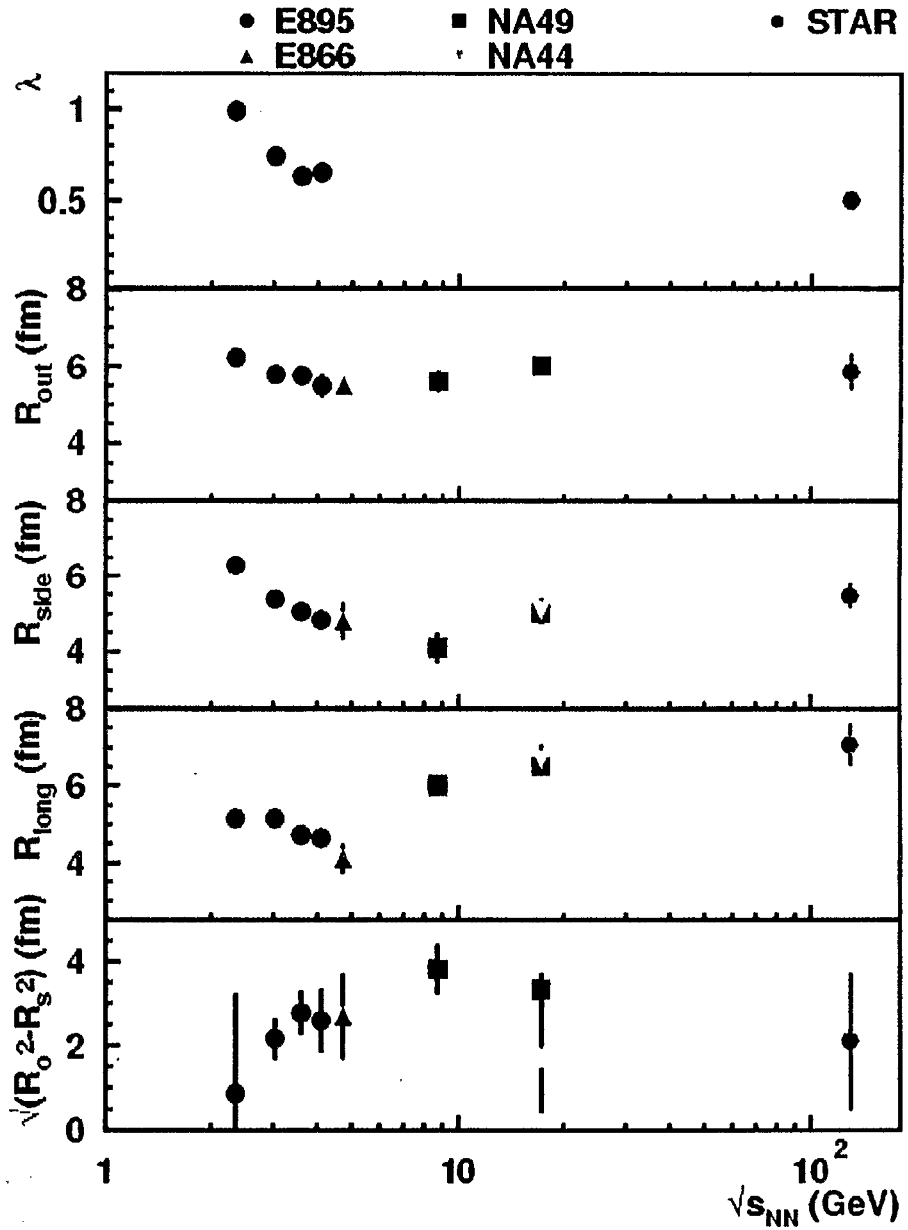


$$C_{\pi\pi}(\vec{q}, \vec{K}) \sim 1 + \langle Cos(\vec{q} \cdot \{(\vec{x}_1 - \vec{v}_K t_1) - (\vec{x}_2 - \vec{v}_K t_2)\}) \rangle$$

6D "Snapshot" of 7D Phase Space

AGS-SPS-RHIC
Pion Interferometry

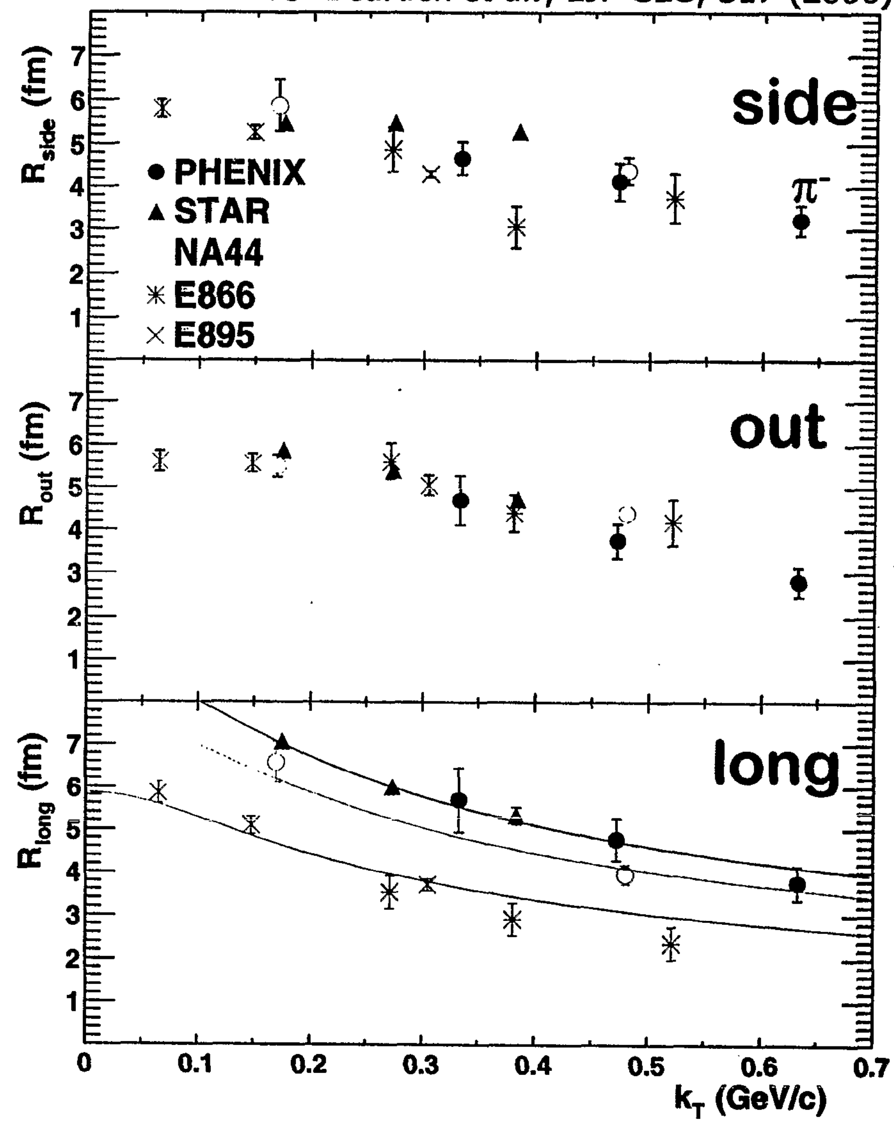




- Central AuAu (PbPb)
- R_{out}~R_{side}~R_{long}~6fm at any s??

Surprising *Weak* Energy dependence!

M. Lisa *et al.*, PRL **84**, 2798 (2000)
R. Soltz *et al.*, to be sub PRC
C. Adler *et al.*, PRL **87**, 082301
I.G. Bearden *et al.*, EJP **C18**, 317 (2000)



- R_{out} and R_{side} are energy independent within error bars.
- Weak energy dependence of R_{long}
- No indication of different physics from AGS to RHIC
- Fit R_{long} to: $\frac{A}{\sqrt{m_T}}$
- AGS: A = 2.19 +/- .05
- SPS: A = 2.90 +/- .10
- RHIC: A = 3.32 +/- .03

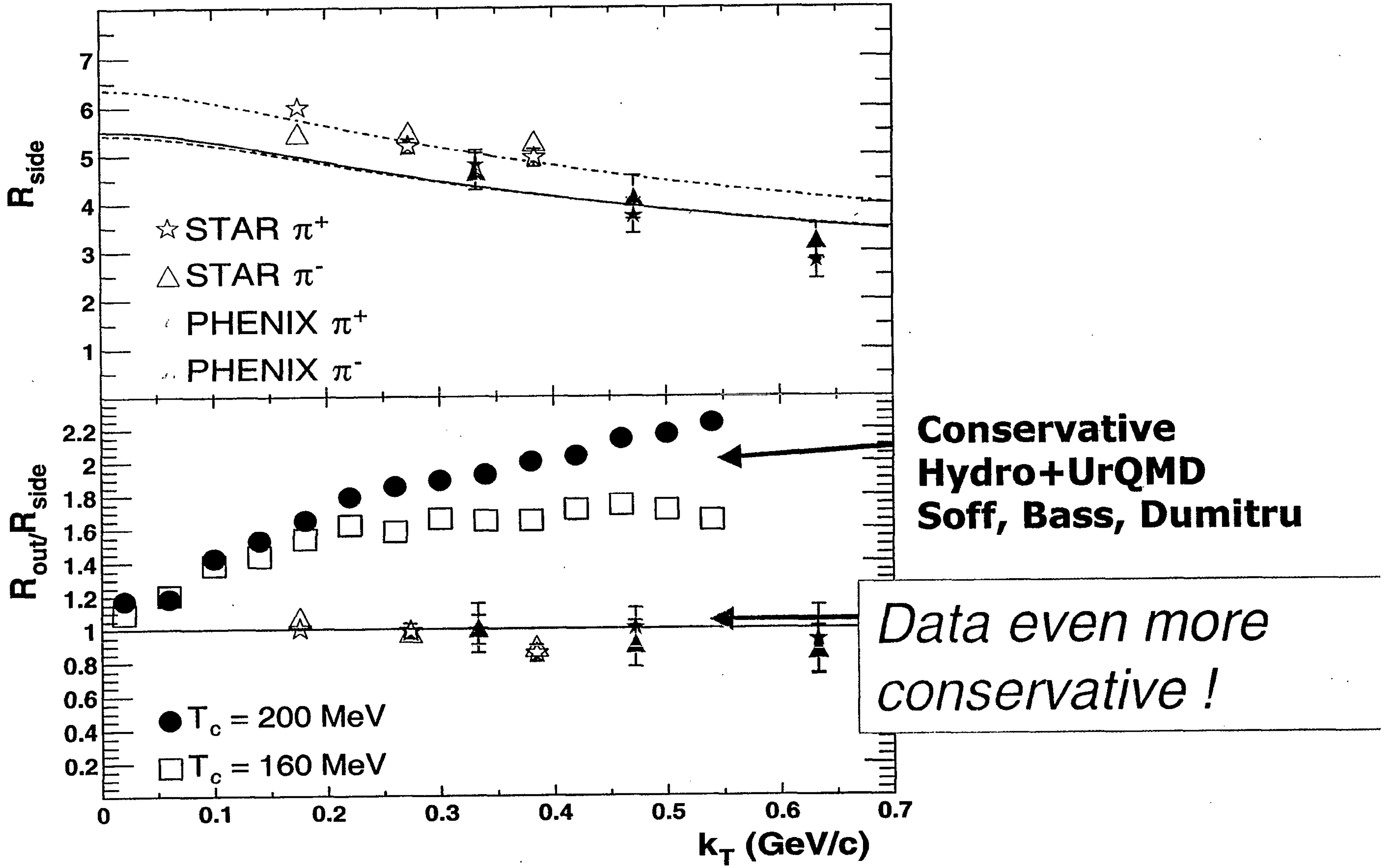
The Pion Interferometry Problem at RHIC

The Space-Time Puzzle

- Instead of slowly burning QGP $\Delta\tau \sim R/v_{def} >> R$
- Evidence for Sudden freezeout $\Delta\tau << R$!
- $R_{out} \sim R_{side} \sim R_{long} \sim 6$fm indep of $1 < KE_{cm} < 100$ AGeV?
- Yet huge $v_2 \sim 0.15$ out to 6 GeV, transverse flow , hadro equilibration, pbar > pi-, ...

RBRC Seminar 2/7/02 M. Gyulassy

PHENIX and STAR at RHIC



HBT correlation projects

$$\vec{q} \cdot (\vec{x}_1 - \vec{v}_K t_1) - (\vec{x}_2 - \vec{v}_K t_2)$$

to

$$\vec{q} \quad \& \quad \vec{K}$$

Since $\Delta \vec{q} \cdot \Delta \vec{x} \geq \frac{\hbar}{2}$,

perhaps quantum correlation is important in RHIC

The present quasi-classical description of QGP is inadequate!

A New Method to Derive N-dim. Quantum Wave Functions by Integrations Along a Single Trajectory

RBRC # 89, 151, 152

Annals of physics 288 (2001) 52 - 102

A New Convergent Formulation of Quantum Field Theory

RBRC # 176

Annals of physics 294 (2001) 67 - 133

TDL, R. Friedberg, W. C. Zhao

RBRC / Columbia / CCAST

The New Method

1. Reduce any N-dim. eigenvalue problem in Quantum Mechanics (2nd order partial differential equation) to a <u>series</u> of First Order One-Dimensional Differential Equations, which can be readily integrated along a single trajectory.

2. Recast the usual divergent perturbative series into a new series based on integrals along a single trajectory. <u>The new series is convergent</u>!

Stark Effect

$$H = -\frac{1}{2}\nabla^2 - \frac{Ze^2}{r} + \epsilon r \cos\theta$$

discovered by Stark (1913)

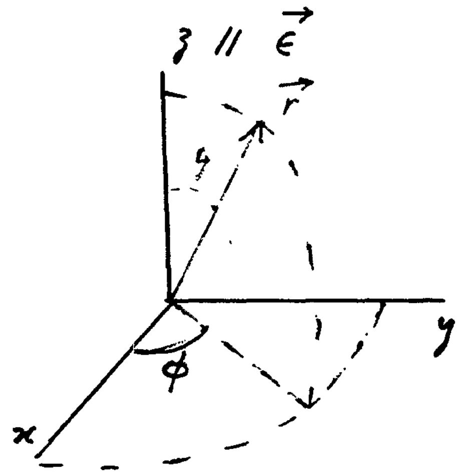
studied by Bohr (1915)

Schwarzschild (1916)

Kramers (1920)

Schroedinger (1926)

Epstein (1926), ...



Only until 1954, Foley et. al found

$$E = -\frac{1}{2}Z^2e^4 - \frac{9}{4}\frac{\epsilon^2}{Z^4e^8} + O(\epsilon^4)$$

The new method (RBRC #89) gives exact result in closed form to <u>any</u> order in ϵ^2

$H\psi = E\psi$. Write $\psi = e^{-S}$

$$S = Ze^2r + \frac{\epsilon r}{Z^2e^4}\cos\theta \cdot \left(1 + \frac{1}{2}Ze^2r\right)$$

$$- \frac{\epsilon^2 r^2}{Z^4e^8}\left\{\frac{7}{16}(1+\cos^2\theta) + \frac{1}{24}Ze^2r(1+3\cos^2\theta)\right\}$$

$$+ \frac{\epsilon^3 r}{Z^8e^{16}}\cos\theta\left\{\frac{53}{8}\left(1+\frac{1}{2}Ze^2r\right) + \frac{13}{48}(Ze^2r)^2(3+\cos^2\theta) + \frac{1}{16}(Ze^2r)^3(1+\cos^2\theta)\right\} + \cdots$$

$$E = -\frac{1}{2}Z^2e^4 - \frac{9}{4}\frac{\epsilon^2}{Z^4e^8} - \frac{3555}{64}\frac{\epsilon^4}{Z^{10}e^{20}} + \cdots$$

(divergent, as it should)

other examples of asymptotic expansions:

1. $$\int_x^\infty e^{-gy^2}\,dy = \frac{e^{-gx^2}}{2gx}\left(1 - \frac{1}{2gx^2} + \frac{1\cdot 3}{(2gx^2)^2} - \cdots\right)$$

↑ finite for any $g > 0$ ↑ divergent always

2. $$\left(\frac{g-2}{2}\right)_\mu = \frac{1}{2}\frac{\alpha}{\pi} + 0.765\ 857\ 376(27)\left(\frac{\alpha}{\pi}\right)^2$$
$$+ 24.050\ 508\ 98\ (44)\left(\frac{\alpha}{\pi}\right)^3$$
$$+ 126.07(41)\left(\frac{\alpha}{\pi}\right)^4 + 930\ (170)\left(\frac{\alpha}{\pi}\right)^5$$
$$+ \cdots$$

This is Spin physics at its most fundamental; yet the theoretical formula is <u>divergent</u>!

FUTURE PERSPECTIVES EXPERIMENTAL GROUP

Hideto En'yo

Future Perspectives

Experimental Group

For 5 Years under the New MoU

- RHIC Spin Experiment is in *FULL SWING*
- Need 5 years to accomplish the measurements described in the proposal (200GeV/500GeV, with longitudinal spin and transverse spin).

Experiment G. Organization JFY02

BELLE
Soeren Lange (Visitor)
Akio Ogawa (Visitor)
New postdoc

RBRC
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New appointments:
selection on going

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T. Kawabata
J. Tojo

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Hisa Torii
Hiroki Sato
Nobuyuki Kamihara
Manabu Togawa
+more ?

~30 active member
+~3 active visitors

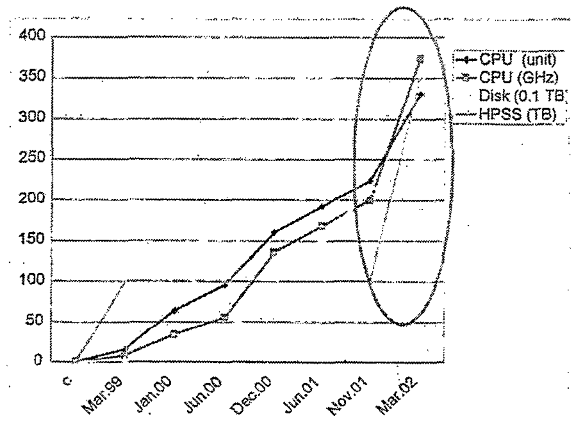
WAKO/CCJ
Takashi Ichihara
Yasushi Watanabe
Satoshi Yokkaichi
Akio Kiyomichi

RBRC in 2002

- **Core of the project**
  - Physics analysis of the data (using CCJ)
  - Preparation for the next run (Muon North etc.) and maintain the spin data taking
  - Build up the future beam time strategy with other spin experiments and accelerator
  - AGS polarimeter
- New fellows/postdocs will be appointed.

CCJ in JFY2002

- We got budget approved along the line of the last MSC:
  - Tape Dive :
    4 x redwood drive
    10 x 9940B
  - HPSS server
- Can store 3-year data from PHENIX



•Current : redwood 11.2 MB/s 50 GB/volume
•2002Q4: 9940B 30 MB/s 200 GB/volume

BELLE

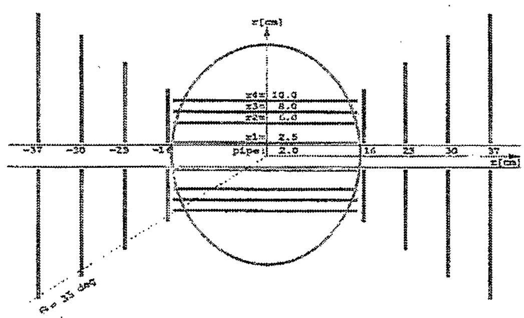
- To study the spin in the quark fragmentation
  - Very important for the RHIC spin program
  - Belle provides the best data to be looked into.
  - 1 Fellow + 2 Visiting Scientists from RBRC + 1 postdoc from Wako.
  - Will be responsible for the fragmentation *analysis* and related *Monte Carlo studies*
- Will use CCJ (100GHz-year scale)

PHENIX Upgrade (Silicon Tracker)

- Will enhance the physics capabilities of PHENIX spin program.
  - gluon polarization
    - photon + jet
    - heavy flavor via b-tagging
  - anti-quark polarization
    - $W^{\pm}/Z^0$/Drell-Yan via isolation cut

Straw man design

- PHENIX will submit a design report in a few months from now.
  - Typical silicon strip detectors are enough for the p-p runs. But in the Heavy Ion runs, occupancy will be 25%,10%,7%,5% for the 1st to the 4th layer.
  - ⇒ Pixcel detecrot for the 1st layer at least.

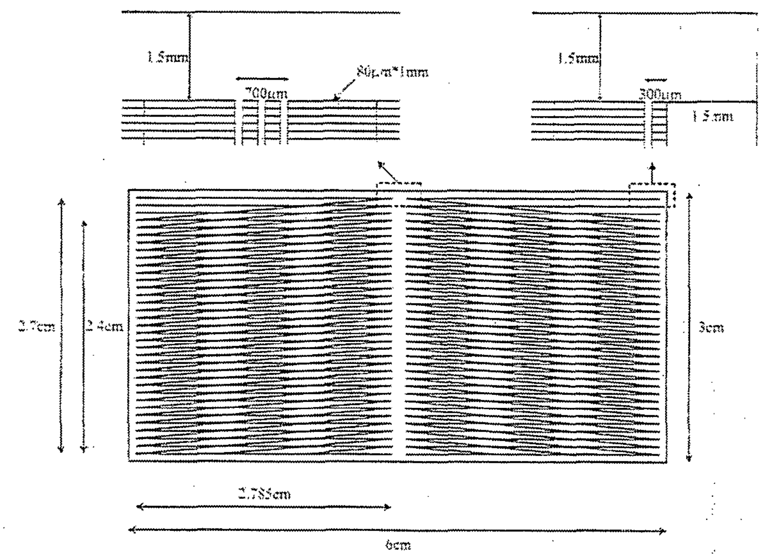


RIKEN・RBRC silicon project

- Microstrip layers
  - first prototype sensor at BNL
    - by Zheng Li (BNL instrumentation)
    - single-side two-direction readout strip
  - Will be tested as a telescope.
- Pixel layers (well advanced at CERN)
  - *"RIKEN-CERN silicon pixel project"*
    - H. Ohnishi, J. Heuser ➔ NA60
    - K. Tanida, J. Tojo – α ➔ ALICE
- Mechanical structure design started at RIKEN
    - to study cooling, cabling, ...
    - HYTEC inc. with ISU, LANL, ...

Prototype sensor (Strip)

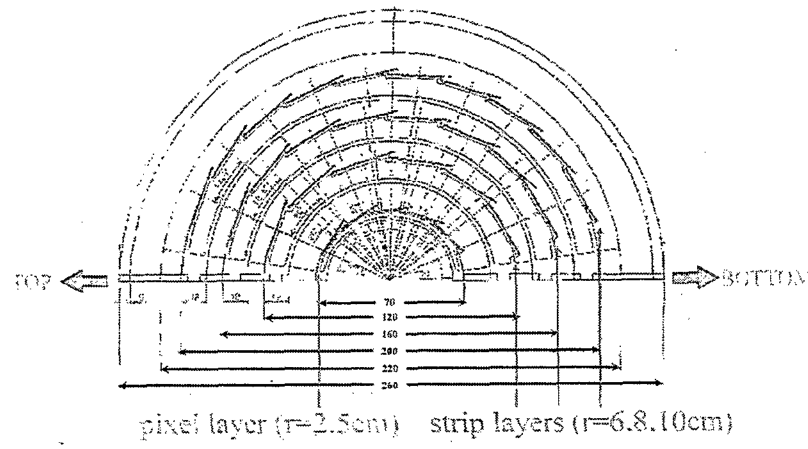
- First prototype sensor by Zheng Li (BNL instrumentation)



Mechanical structure Study

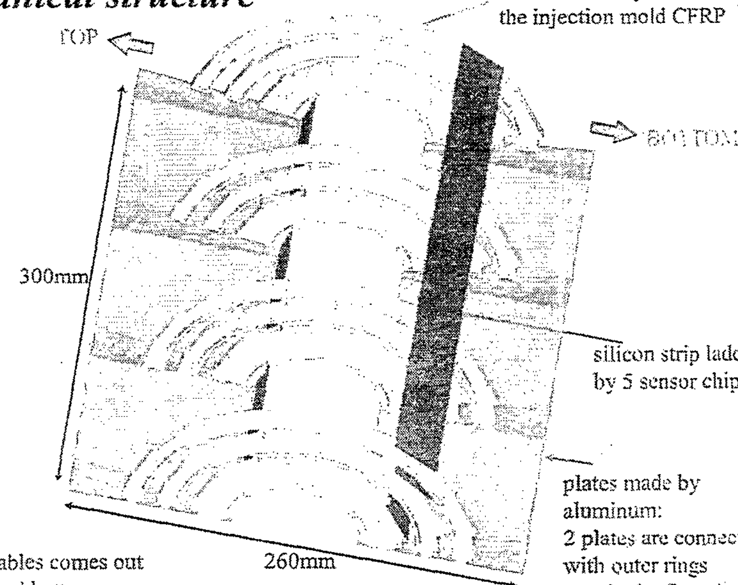
sensor chip: 3cm × 6cm
sensor strip: 80μm(pitch) × 3cm(length)
(1chip = 375 × 2strips × 2direction)
readout chips on top of the sensor
(12 readout chips for 1 sensor)

Half shell of the silicon detector



Mechanical structure

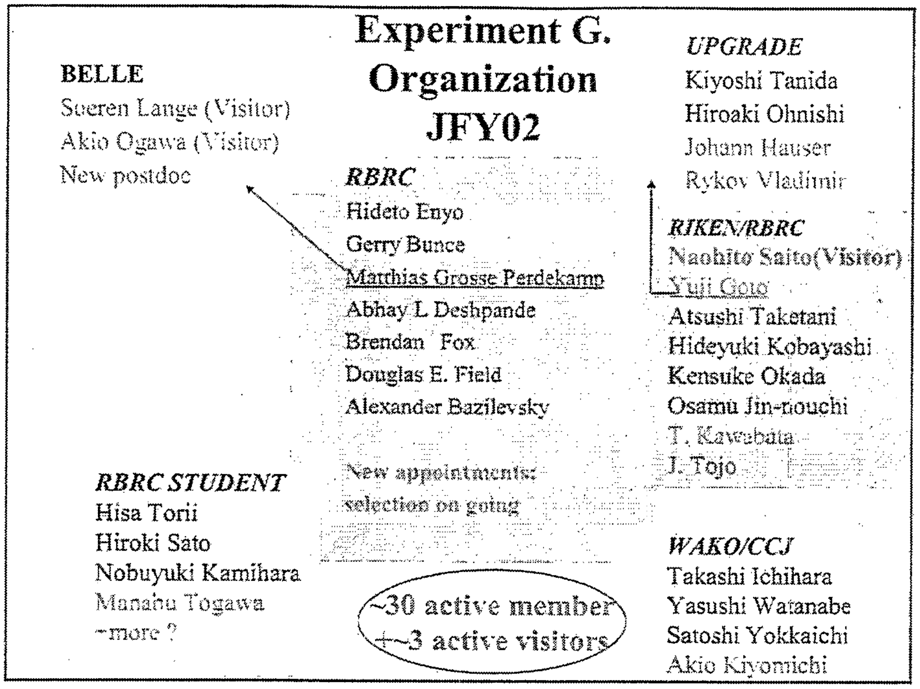
wheel: made by the injection mold CFRP



silicon strip ladder by 5 sensor chips

plates made by aluminum:
2 plates are connected with outer rings
(not in the figure)

services/cables comes out from top and bottom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RBRC STUDENT
Hisa Torii
Hiroki Sato
Nobuyuki Kamihara
Manabu Togawa
~more ?
~30 active member
+~3 active visitors
WAKO/CCJ
Takashi Ichihara
Yasushi Watanabe
Satoshi Yokkaichi
Akio Kiyomichi

FUTURE PERSPECTIVES IMPROVEMENT AND MANTENANCE OF ACCELERATOR

Satoshi Ozaki

RHIC

How to Achieve High Polarization in the AGS

Satoshi Ozaki

RIKEN/BNL Spin Physics Collaboration
Management Steering Committee Meeting

March 11-12, 2002
At RIKEN, Wako, Saitama, Japan

Brookhaven Science Associates
U.S. Department of Energy

BROOKHAVEN NATIONAL LABORATORY

RHIC

The First RHIC Polarized Proton Run

55 bunches per ring with 0.8×10^{11} p↑/bunch

- Charge/bunch and total charge higher than with gold beams
- Lattice with constant β* of 3 m during ramp
- Peak luminosity at beginning of store: 1.5×10^{30} cm^{-2} s^{-1}
- Energy/beam: 100 GeV
- Beam polarization ~ 25 %
  RHIC polarimeters work reliably
- Little if any depolarization in RHIC during acceleration and store
  Siberian Snakes work
- ~ 60 % polarization loss in AGS; aggravated by lower ramp-rate from Westinghouse motor-generator
- **Strong Siberian snake in AGS (~ 30 % of full snake) could avoid all depolarization in the AGS**

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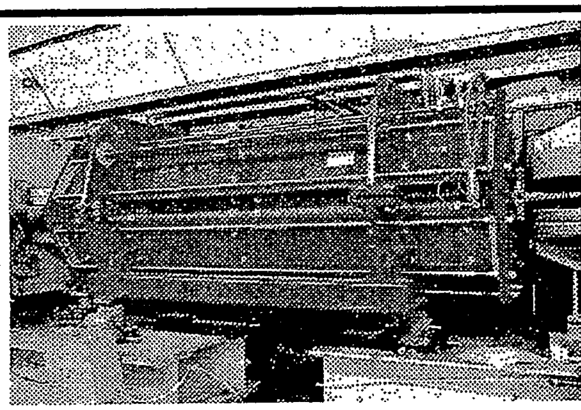
Present AGS Partial Snake



A room temperature solenoid: a conservative approach.

Needed superconducting helical dipole for a stronger snake

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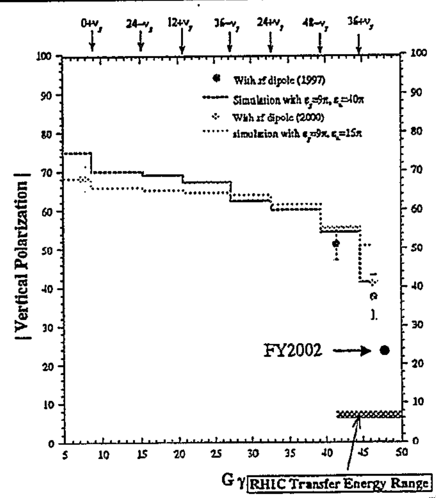
Proton Polarization at the AGS

- Full spin flip at all imperfection resonances using partial (5%) Siberian snake
- Full spin flip at strong intrinsic resonances using rf dipole
- Remaining polarization loss from coupling and weak intrinsic resonances
- Larger polarization loss in FY2002 due to lower ramp-rate of WH motor-generator and higher bunch intensity (?)



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RHIC

Helical Partial Snake for the AGS

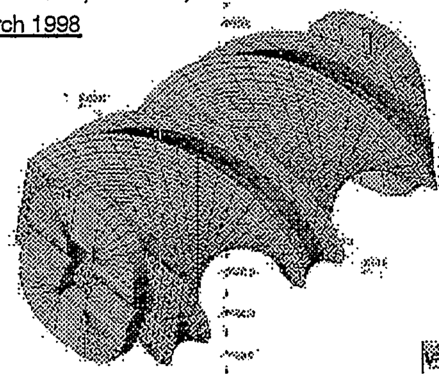
Normal Conducting HELICAL Dipole MAGNET FOR AGS PARTIAL SNAKE

M. Okamura, T. Tominaka and T. Katayama, RIKEN, Japan,

N. Tsoupas, BNL; EPAC 2000

T. Roser, M. Syphers, E. Courant, L. Latner, BNL

M Okamura; RIKEN; March 1998



RHIC

AGS 30% Snake

- Present AGS Partial Snake (5%)
- Room Temperature Solenoid: conservative approach

- Proposed AGS Partial Snake (30%)
- Use the superconducting helical dipole technology which was developed in the RIKEN collaboration for the RHIC snake and spin rotators.
- Rough parameter of the snake

  one 360° superconducting helical dipole:

  20 cm ID, 1.8 m long, 3.5T

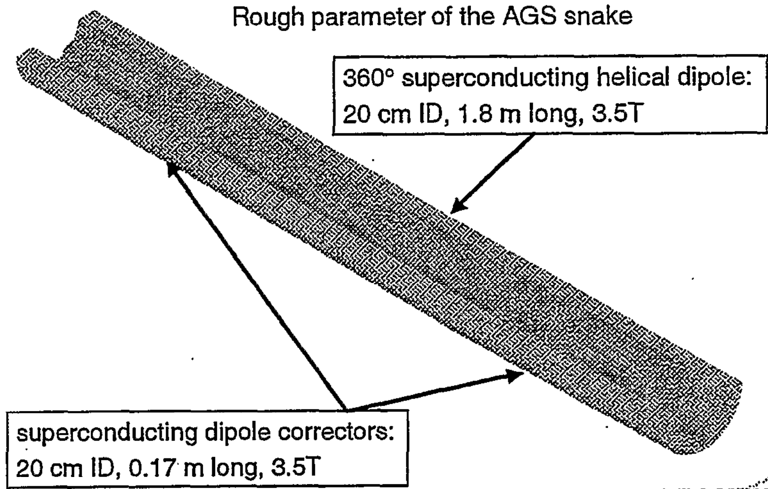
  two normal superconducting dipole correctors:

  20 cm ID, 0.17 m long, 3.5T
- Detailed design work in progress

RHIC

AGS Superconducting Helical Snake

Rough parameter of the AGS snake



RHIC

AGS Partial Snake Cost Estimate

Use superconducting helical dipole technology developed for RHIC snakes

- 1 superconducting helical dipole:20 cm ID, 1.8 m long, 3.5T
- 2 normal superconducting dipole correctors:20 cm ID, 0.17 m long, 3.5T
- Sextupole corrector winding on the cold bore

Costs in $1,000

Item	Helical Coils	Dipole Corrector Coils	Assemble Storage Unit	Sextupole Coils	Assemble Cold Mass	Cryostat Assembly	Total Cost
Design	$140	$140	$86	$18	$74	$108	$566
Production	$396	$229	$225	$95	$197	$267	$1,409
Material	$186	$39	$187	$54	$136	$248	$850
Labor	$210	$190	$38	$41	$61	$19	$559
Warm/Cold Test	$0	$0	$53	$0	$0	$62	$115
Total	$536	$369	$364	$113	$271	$437	$2,090

Estimate includes normal Laboratory overhead and 20% contingency

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RHIC

Estimated Cost of Spare Helical Dipole Magnets

Satoshi Ozaki

RIKEN/BNL Spin Physics Collaboration
Management Steering Committee Meeting

March 11-12, 2002
At RIKEN, Wako, Saitama, Japan

RHIC

Cost of 3 Spare Helical Dipoles

Cost in $1,000,

Item	Cost, FY02$	JFY02	JFY03
Production			
Material	$110.0	$110.0	
Labor	$223.0	$54.0	$169.0
Cold Test			
Material	$15.9		$15.9
Labor	$20.5		$20.5
Total	$369.4	$164.0	$205.4

Estimated costs include normal Laboratory overhead and 15% contingency.

PUBLICATION LIST
RBRC THEORY GROUP

March 02

RIKEN BNL Research Center
Theory Group
Publication List

RBRC/#

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