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FORMAL REPORT

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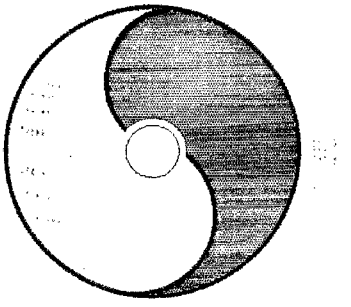
# RHIC Spin Collaboration Meetings XXI, XXII, & XXIII

January 22, 2004
February 27, 2004
March 19, 2004



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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 four 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 had increased to include ten theorists and one experimentalist in academic year, 2001-2002. With five fellows having already graduated, the program presently has eleven theorists and three experimentalists. Of these eleven RHIC Physics Fellows, five have been awarded/offered tenured positions, and this will be their final year in the program.

Beginning in 2001 a new RIKEN Spin Program (RSP) category was implemented at RBRC. These appointments are joint positions of RBRC and RIKEN and include the following positions in theory and experiment: RSP Researchers, RSP Research Associates, and Young Researchers, who are mentored by senior RBRC Scientists. A number of RIKEN Jr. Research Associates and Visiting Scientists also contribute to the physics program at the Center.

RBRC 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 59 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. A 10 teraflops QCDOC computer in under development and expected to be completed this year.

N. P. Samios, Director
April 1, 2004

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

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Contact Information

# RHIC Machine Status

Wolfram Fischer
— Run Coordinator for Run-4 Gold-Gold Operation —

BROOKHAVEN
NATIONAL LABORATORY

RHIC Spin Collaboration Meeting
22 January 2004

Content

1. Run-4 start-up and ramp-up
2. Run-4 Luminosity development
3. Current typical running conditions
4. Luminosity limitations
5. Important improvements relevant to polarized proton operation
6. Summary

- 12/01/03 2 weeks of start-up begin
  (24h/day machine development)
- 12/15/03 2 weeks of ramp-up begin
  (owl shift for experiments)
- 12/31/03 Physics Run started

Comments:
- Ramp-up period 1 week shorter than planned
- Total of 8 days with larger problems during start-up/ramp-up
- Started Physics Run with
  - stores above design luminosity
  - ~40(μb)$^{-1}$/week (last week in Run-2 had 24(μb)$^{-1}$)

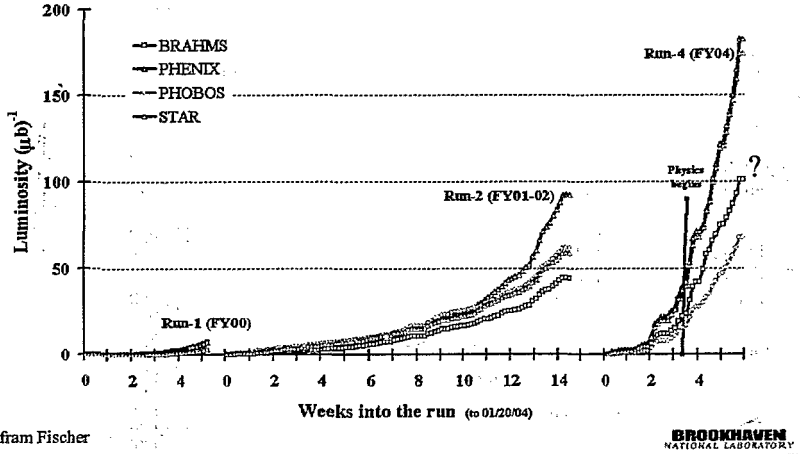
[luminosity numbers denote delivery to Phenix/Star]





Delivered 182.5 (μb)$^{-1}$ to Phenix [109.8]
72.7 (μb)$^{-1}$ last week [ 42.4]
**Target 330 (μb)$^{-1}$**

Star ×0.9
Phobos ×0.3
Brahms ×0.5?








2

Sat, 01/17/04 Current typical running conditions (under consideration at all times):

| Quantitiy | Unit | Value | Comment |
|---|---|---|---|
| Bunch intensity | $10^9$ Au ions | 1.0 / 0.7 | Blue / Yellow, injected |
| Number of bunches | ... | 61 | per ring |
| Initial ZDC rates | kHz | 8.0 | at Phenix and Star, 1/3 at Brahms and Phobos |
| Initial luminosity | $10^{26}cm^{-2}s^{-1}$ | 8.0 | at Phenix and Star, 1/3 at Brahms and Phobos |
| Luminosity lifetime | hrs | 2.5 | for first 3 hours of store, larger thereafter |
| Time between fills | hrs | 5.0 | for uninterupted production |
| Optimum store length | hrs | 3.8 | to maximize average luminosity, for uninterupted production |

Comments:
- initial luminosity is 8x design
- average store luminosity is ~2x design (good stores)
- luminosity lifetime is dominated by IBS and beam-beam (no collision beam lifetime about 20 hours)
- time between fills has large variations (0.5 to 12 hours)





- Vacuum
  - Yellow stochastic cooling kicker yo4, now baked
  - Blue collimators bi8
  - Blue instrumentation section bo2
- Intrabeam scattering
  - At injection:
    - Longitudinal emittance increase
    - Debunching
  - At store:
    - Debunching
    - Transverse emittance increase
- Beam-beam interaction
- Background

**Luminosity lifetime: ~2.5hrs**
**Beam lifetime without collisions: ~20 hrs**





3

- Better optics model (Johannes)
- Orbit correction after each ramp (Vadim)
- Flexible bunch patterns
  (almost all bunch numbers between 3 and 111, arbitrarily distributed)
- Better instrumentation (Pete, ...)
  (IPM, Schottky, PLL tune meter, BPMs)
- Low order nonlinear IR correction finished (Fulvia)
- Better background reduction
  - Shielding for Phenix and Brahms (Kin, Dana, Charlie Pearson)
  - Horizontal 2-stage collimation in both rings (Angelika, ...)
- Faster beginning-of-store activities
  - Automatic steering for all experiments ~5min (Ted, Angelika)
  - Automatic collimator settings ~30min (Angelika, Wenge)





- More efficient operation
  - Faster down ramps (George)
  - Faster quench recovery (cryo)
  - Higher loss limits on ramp (fewer ramps aborted)
  - Fast access from home (more analysis power available)
  - Data base driven electronic logbook (Todd, Ila)
  - Phobos magnet controlled by Sequencer (Johannes)
- Increased reliability
  - AtR, starved microbes in cooling water (Al Pendzick)
  - Much reduced ice ball maintenance (George, ...)
  - Corrector power supplies (Don)





4

- Run-4 start-up and ramp-up period one week shorter than planned
- Current gold-gold luminosity is about 2x higher than at end of last gold-gold run (instantaneous, per store and per week)
- Most improvements for gold-gold operation will also benefit polarized proton operation

# AGS pp Commissioning Plan

H. Huang, BNL

for
RHIC Spin Collaboration Meeting XXI
January 22, 2004
RIKEN BNL Research Center

## FY03 AGS pp Operation

| | 2003 | 2004 |
|---|---|---|
| Intensity: | 0.6*10^11 | >10^11 |
| Pol. at ext.: | 45% | 55% |

It is not conclusive that AGS extraction polarization is inversely proportional to intensity. The beam scrape done in Booster last year limited intensity.

In the long run, the CNI polarimeter needs to handle 2*10^11/bunch intensity.

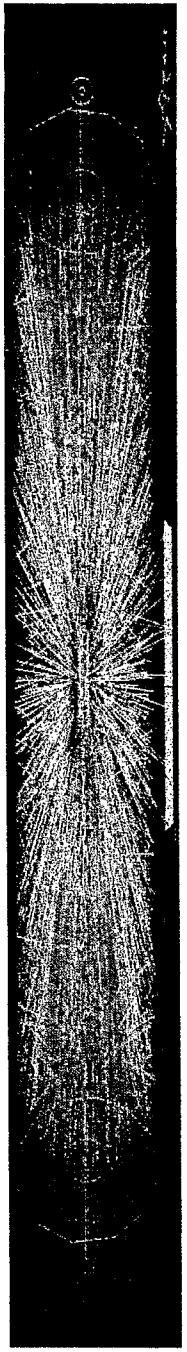
The ramp polarization measurement did not show expected ~10% polarization loss at 48-ν (with large statistical error).

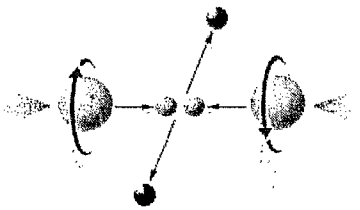


## FY04 AGS pp Preparation

Warm snake will be ready in early March and CNI polarimeter upgrade won't be earlier. The starting time of AGS pp setup will be around March 1st.

- Commission the new warm snake.
- Commission the upgraded CNI polarimeter.
- Continue ramp measurement with faster polarimeter to get better statistics.
- Measure beta function and look for possible explanation of ramp measurements.

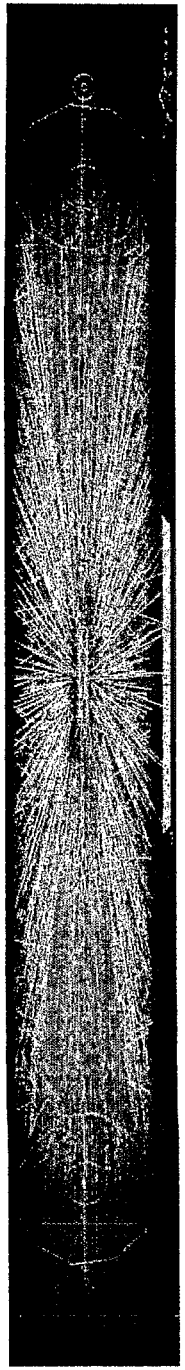




# RHIC Polarized Proton Run 2004

**M. Bai**

**C-A Department, BNL**



# PP FY04 Run Goal

- 55 bunches with $1x10^{11}$ per bunch, emittance: 15 $\pi$ mm-mrad
- Average current/ring: 70mA
- Peak luminosity: $11x10^{30}$ $cm^{-2}s^{-1}$
- Average luminosity: $6.0x10^{30}$ $cm^{-2}s^{-1}$
- B* = 1m at STAR and PHENIX
- Polarization at store >=0.40
- Ultimate goal for PP FY2004:
  - 55 bunches w. $2x10^{11}$ per bunch
  - 112 bunches w. $1x10^{11}$ per bunch

**Achieved in PP FY03**

55 bunches w. $0.7x10^{11}$ per bunch, emittnace: 15 $\pi$ mm-mrad

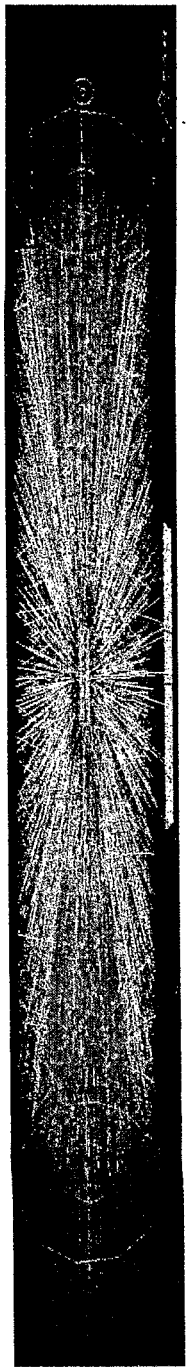
Average current/ring: 48mA

Peak luminosity: $6.0x10^{30}$ $cm^{-2}s^{-1}$

Average luminosity: $3.0x10^{30}$ $cm^{-2}s^{-1}$

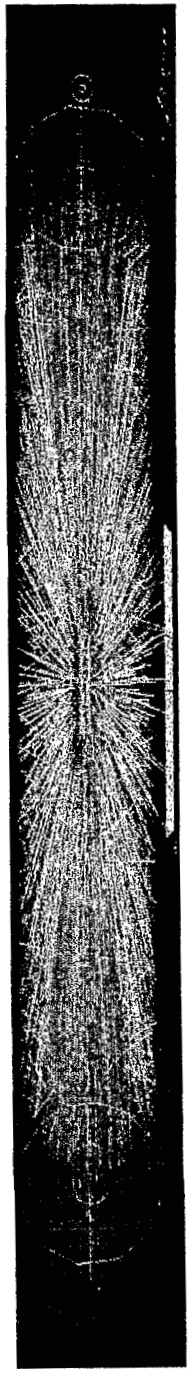
B* = 1m at STAR and PHENIX

Polarization at store: 0.30



# Strategies to achieve the goal

- Ameliorate beam-beam effect
  - New working point
  - Reducing beam-beam driven resonances by adjusting phase advance between IRs
- IR non-linearity correction
- Pushing and learning the limit of the achievable proton intensity
  - NEG coating
  - beam scrubbing
- Beta squeeze along the ramp
  - Avoid hysteresis effect when beta squeeze at flattop, so the machine is more reproducible
- Better model engine
  - Ironing the tune & chromaticity along the ramp(Johannes)
- PLL: feedforward
- Smaller emittance to gain luminosity
- Multi-bunch injection
  - Gain the average luminosity

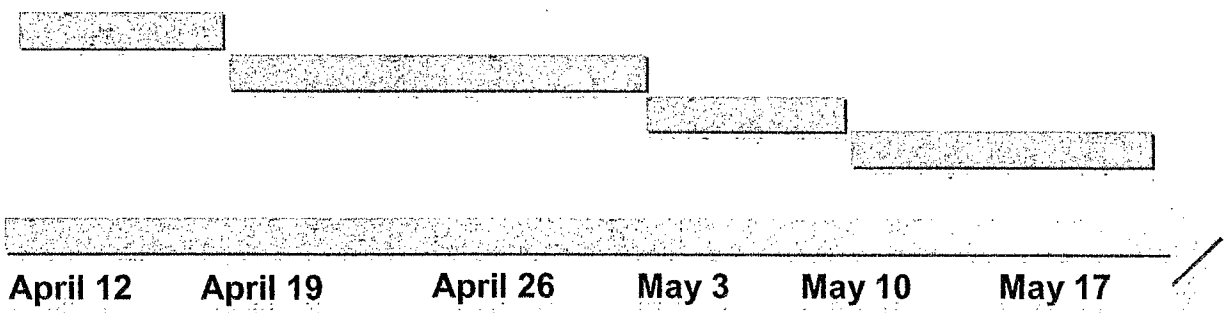


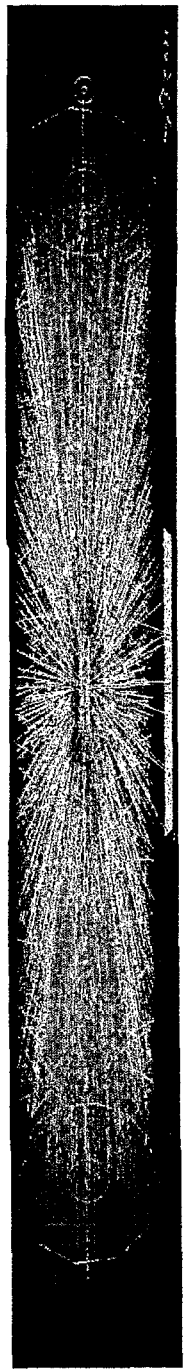
# Lattice for PP FY04 Run

- **Lattice**
  - **Injection: 10 10 10 10 10 10**
  - **Store: 1 1 3 10 3 10**
- **Injection energy**
  - **gamma=25.937(Ggamma=46.5)**
- **golden orbit**
  - **Same as FY03 RUN except an additional 10mm H separation bump at IP 12 for Jet Target**
  - **The separation bump should remain the same from injection to flattop.**
- **Snakes on DC, spin rotators off for calibration**
  - **Local orbit bump at injection to compensate the orbit excursion at snakes**
  - **Rotator on for testing if time permits**
- **Question:**
  - **for the future, how often experiments will need to change the rotator configuration?**

# Time Table

- **Total 5 weeks**
- **April 12 – May 17, 2003**
  - **Phase 1: week 0 – 1**
  - **Phase 2: week 1 – 2**
  - **Phase 3: week 2 – 4**
  - **Phase 4: week 4 – 5**

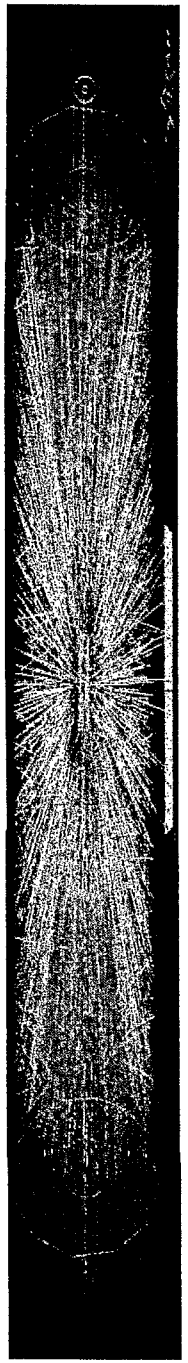




# Phase 1 – week 0 – 1

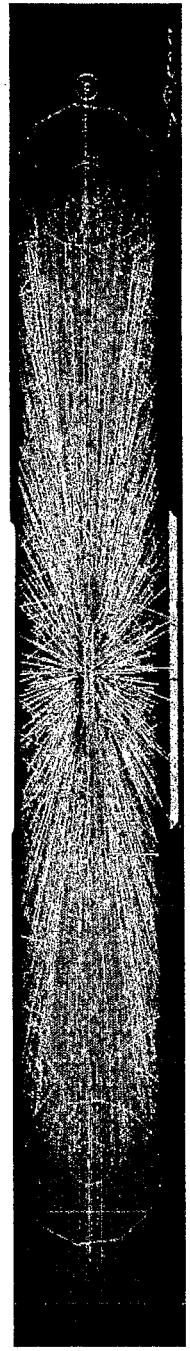
- Ring access: 3 days + 1 day contingency
  - Jet Target installation
  - RF common cavity shortout
  - Magnet test ramp to 100 GeV (ps crew + Johannes)
  - Exercise snake magnet and spin rotator (ps crew + Waldo + Johannes
  - Others if there's any

- Injection setup: 3 days
  - Establish circulating beam in B&Y
    - AtR setup: Nick Tsoupas
    - RF work and Injection kicker timing: Wolfram and RF crew
    - Multi-bunch injection
  - Instrumentation setup
    - Bpm(esp. The bpms at snakes), IPM, PLL, Schottky, WCM: Todd, Pete, ...
    - Injection damper: R. Michnoff
    - E-detector: P. He, Ulbado, S. Y. Zhang, ...
    - CNI polarimeter: CNI experts
  - Machine tunning(at one of the working point candidates)
    - Orbit correcton: Vadim, ...
    - Decoupling: Joanne, Fulvia, Wolfram, Todd, Mei
    - optics measurement & correction: Todd, Mei, Johannes, Rama, ...
  - Jet target tunning: parasitic, Yousef, Sandro, ...



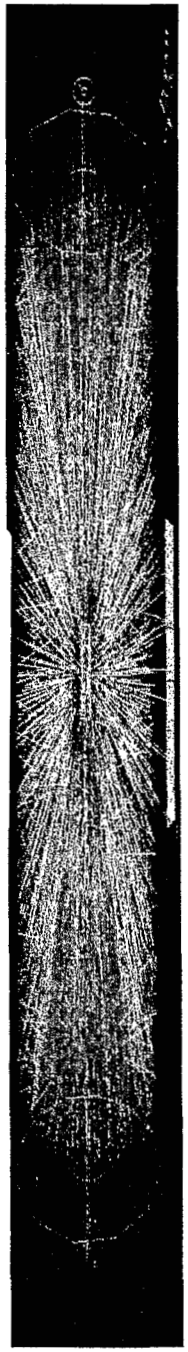
# Phase 2 – week 1 – 3

- New working point development
  - New working point scan at injection (Rogelio, Wolfram, Haixin, Vadim, Waldo, Mei and others)
    - Beam in collision
    - Lifetime vs. working point
    - Backgrounds vs. working point (56 bunches)
    - Polarization vs. working point (56 bunches)
  - Ramp development with the new working point
    - Good transmission efficiency
    - Good polarization
  - Store activity
    - Good lifetime at flattop
    - Good luminosity lifetime
    - IR non-linear resonance measurement and correction:
      - IR non-linear work force
    - Orbit bump closure: Vadim, Fulvia
- Polarization development (Haixin, Vadim, Waldo, Mei and others)
  - Polarization vs. Different orbit rms at one of the strong resonances location
  - Polarization vs. Different tunes at one of the strong resonances location
- Jet Target tunning: parasitic to the machine development (Yousef, Sandro, and others)
  - Check whether there is any depolarization resonances with 55 bunches
  - Check any dependence on beam intensity
  - Parasitic to the machine development



# Phase 3 – week 3 – 4.5

- Calibration of CNI against Jet target
  - Dedicated beam with stable polarization to get 10% measurement
  - Steady injector performance
    - Intensity, polarizatio
  - Reliable RHIC performance
    - Orbit control, procedures to avoid slow deteriorations of the orbit and etc.



# Phase 4 – week 4.5 – 5

- Spin tune measurement
  - Mei, Waldo, Haixin, Vadim, CNI polarimeter crew
  - Measure polarization vs. ac dipole frequency
- Spin flipping
  - Mei, Waldo, CNI experts
  - Measure the spin flipping efficiency vs. different spin tune (different snake configuration)
  - Measure the spin flipping efficiency vs. different sweeping frequency
  - Measure the spin flipping efficiency vs. different spin flipper strength.
- Beam scrubbing
  - Still under evaluation on its resulted radiation impact on the beam instrumentations, esp. bpm electronics.

# Short Update on RHIC Snake Quench Protection Plan

W. MacKay, BNL

*(no transparencies shown at this time)*

for
RHIC Spin Collaboration Meeting XXI
January 22, 2004
RIKEN BNL Research Center

# Contents

- Status of the model
- Results from experiments at injection:
  - RHIC design tunes
  - LHC tunes
  - SPS tunes and beyond
  - ISR inverse tunes

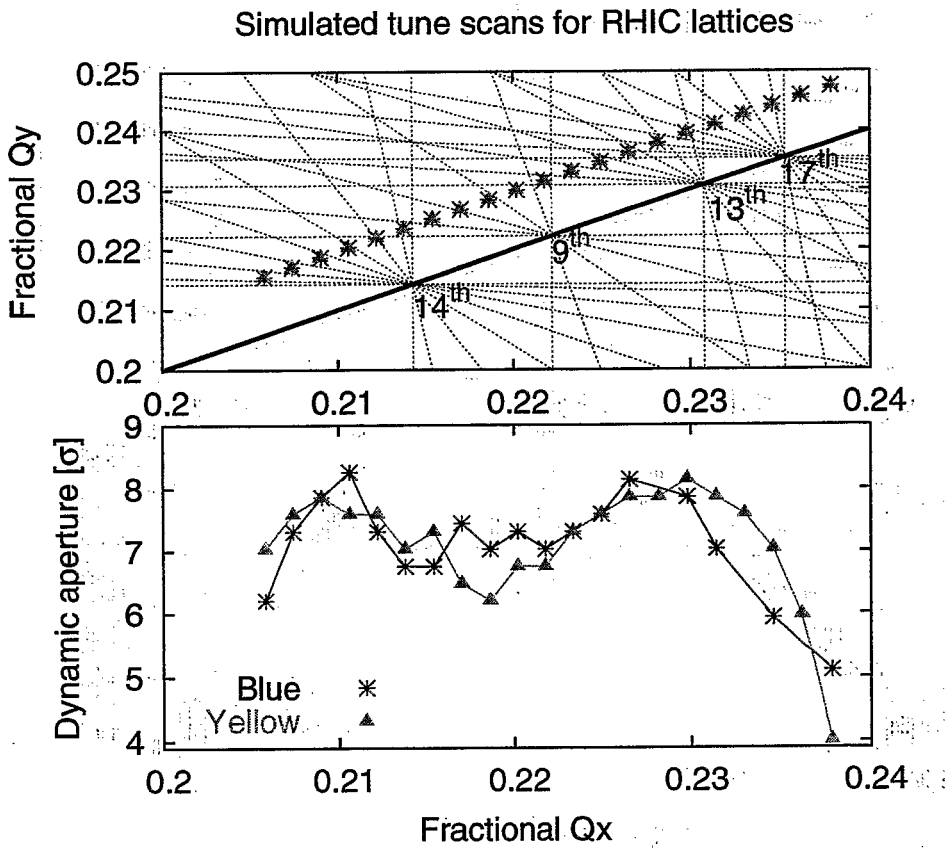
(Experimenters: Fulvia, Mei, Vadim, La Pena, Greg, Rama, Wolfram, Rogelio...)

## Status of the model I

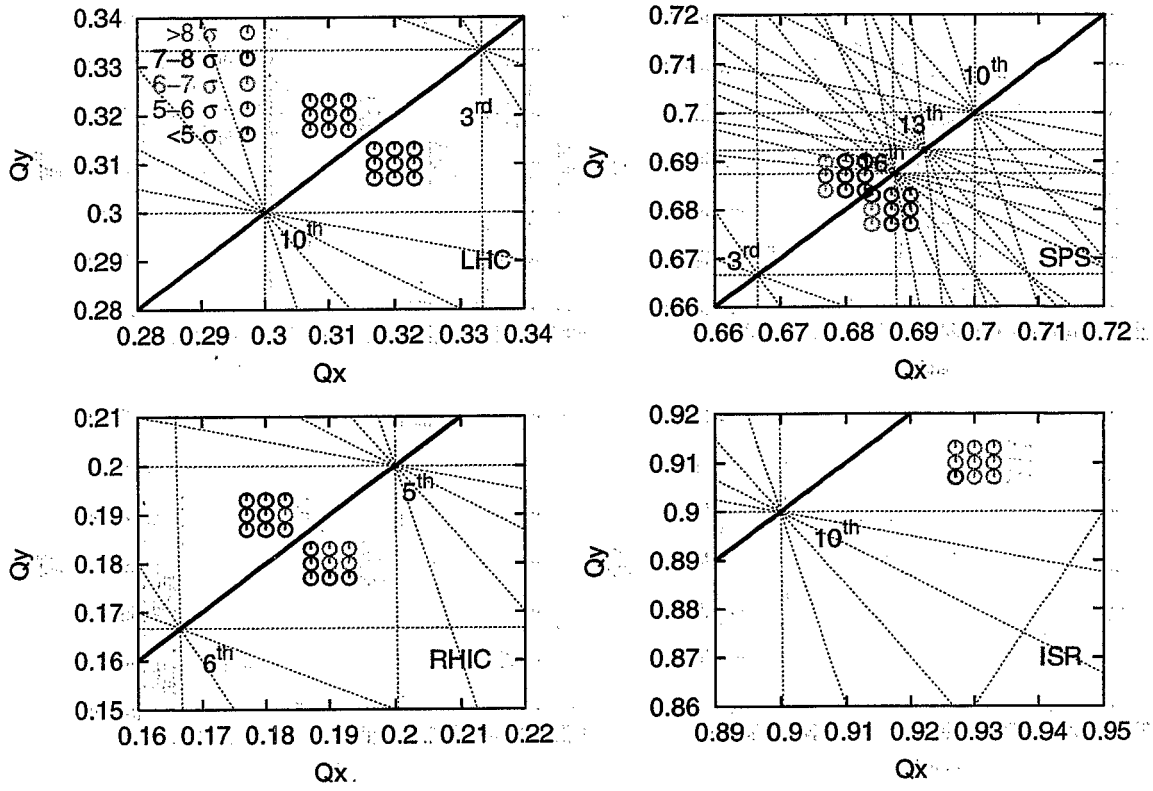
-Magnets in the IR regions have been splitted into 8 slices

-Blue and Yellow lattices are now available

-Bug in the Beam-Beam module under investigation

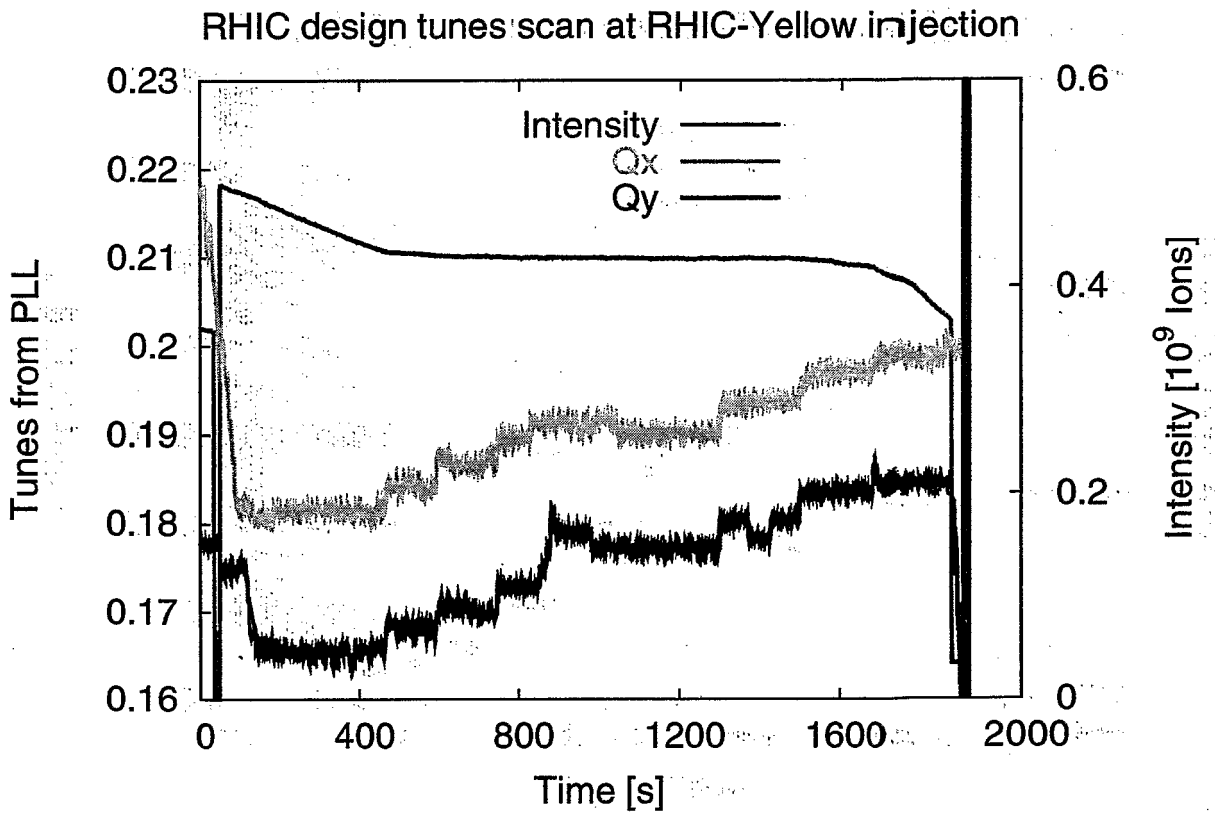


## Status of the model II

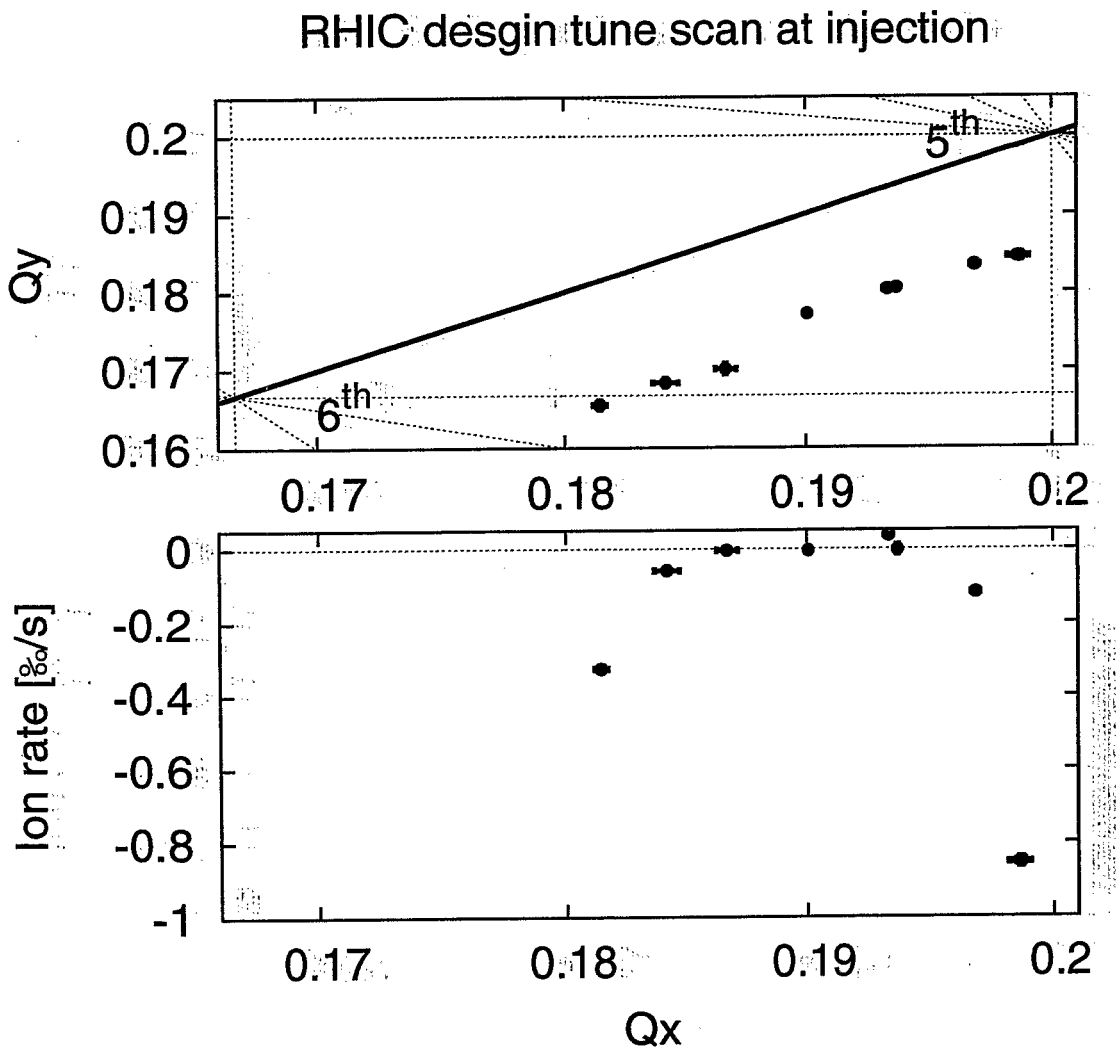



# These plots contain no Beam-Beam!!!!

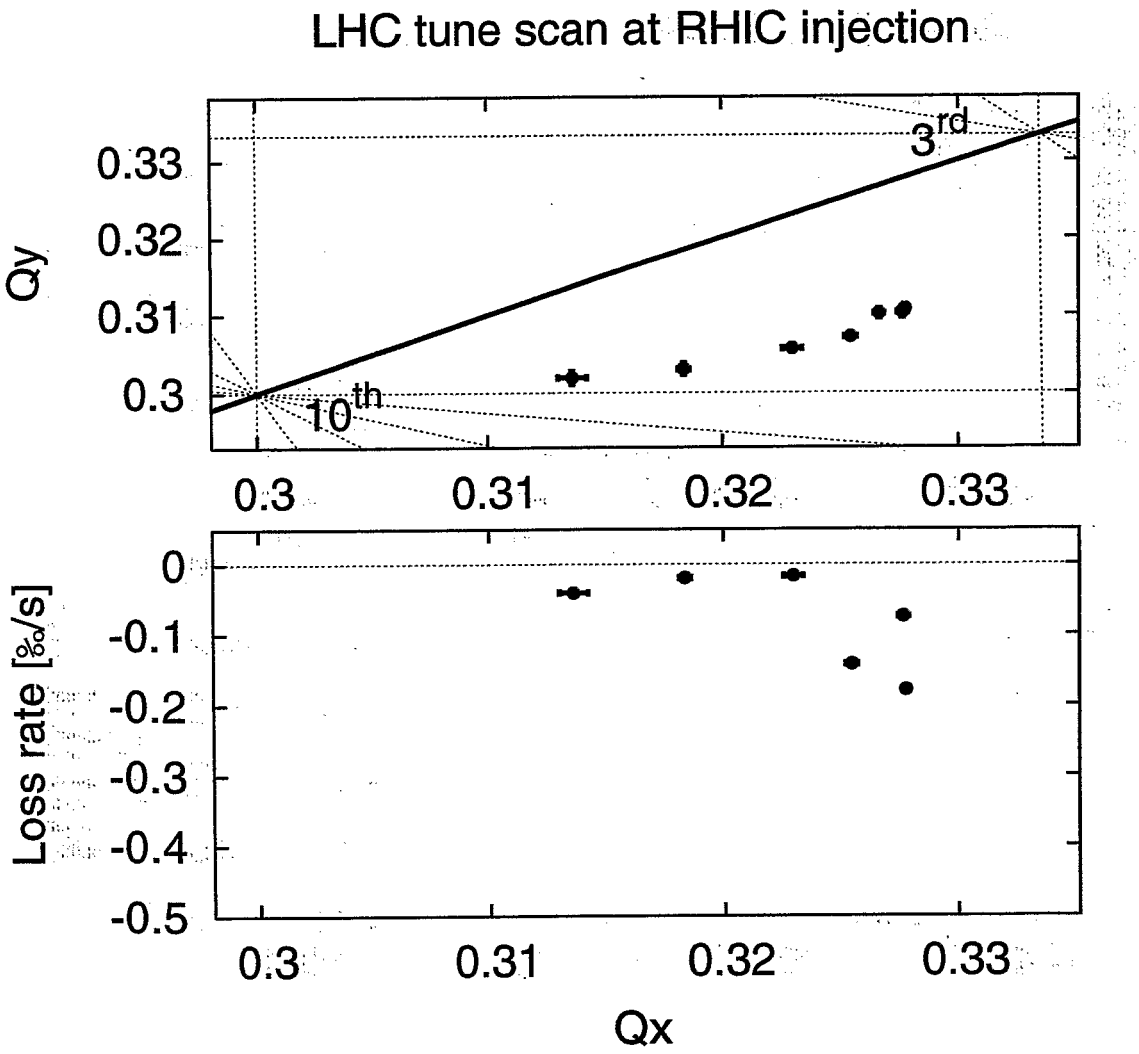
# Experiments: RHIC design I



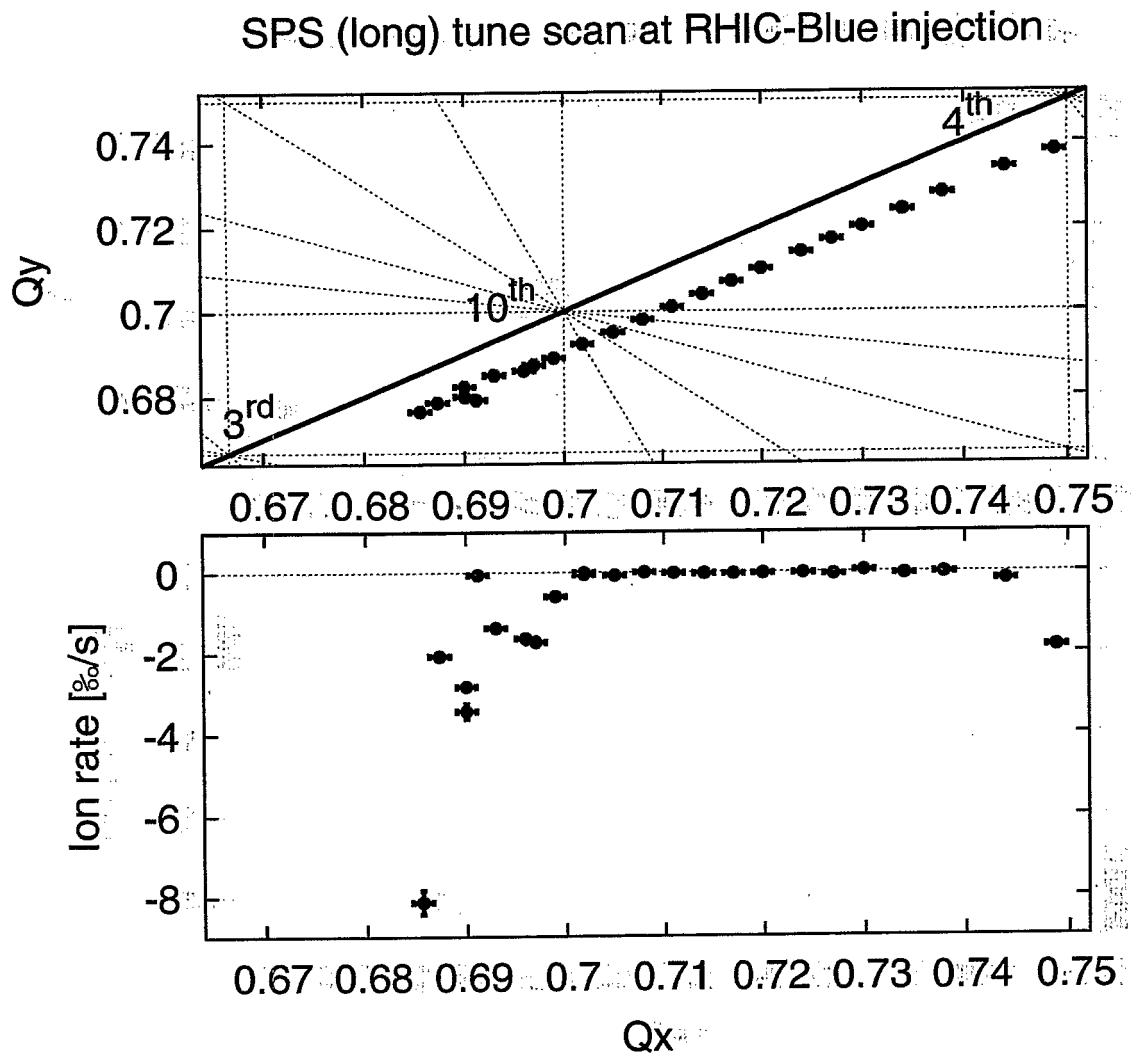
# Experiments: RHIC design II



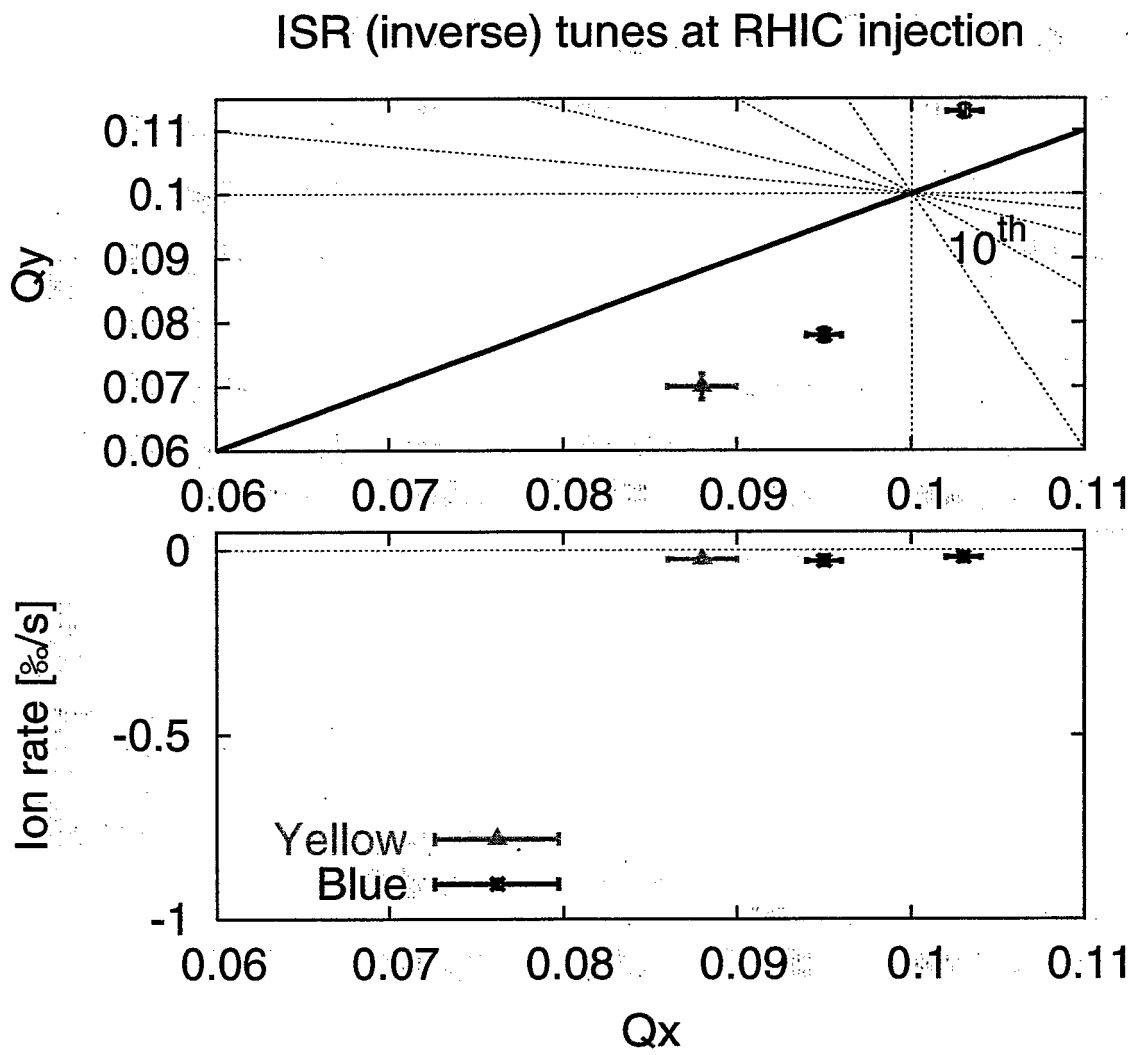
# Experiments: LHC



# Experiments: SPS tunes and beyond



# Experiments: ISR inverse tunes

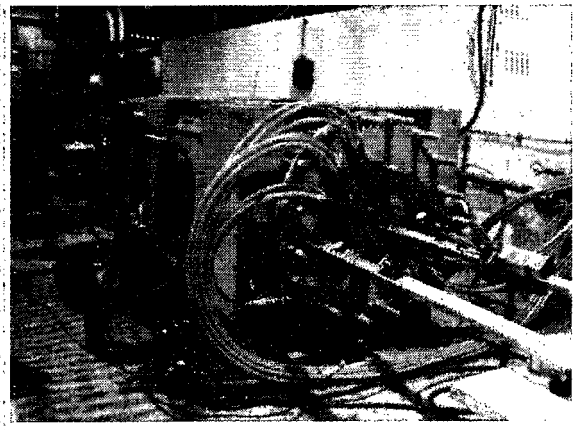


## Conclusions & outlook

- Tracking model is improving
- Discarded tunes from experiments:
  - SPS ($\approx$0.68)
  - ISR ($\approx$0.92)
- New tunes to investigate:
  - up from SPS ($\approx$0.73)
  - ISR inverse ($\approx$0.1)
- Experiments with collisions will be performed at injection

# AGS warm snake status and field mapping

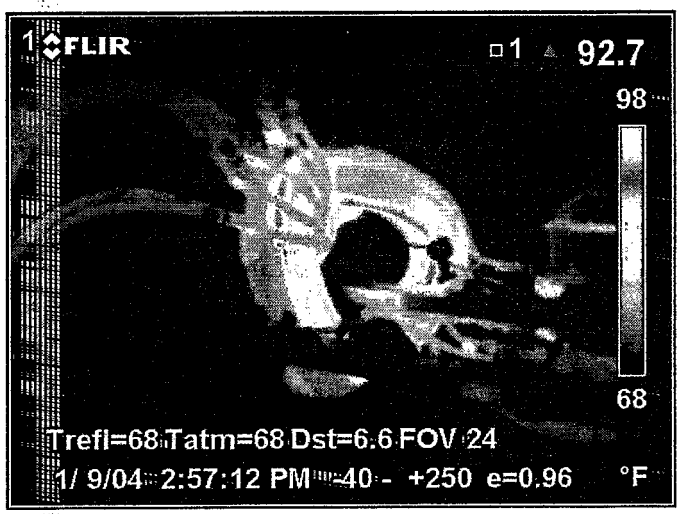
Junpei Takano



The warm snake is under measurement in bldg.902.

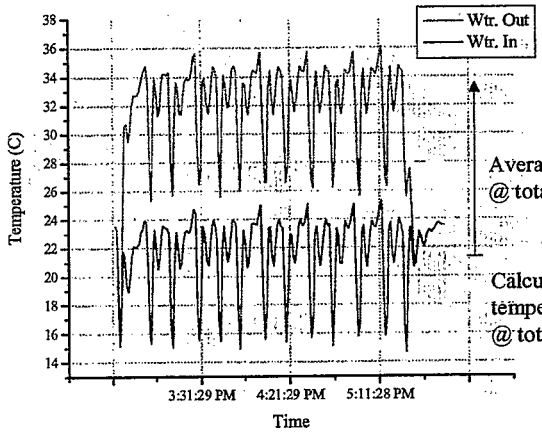
RIKEN BROOKHAVEN NATIONAL LABORATORY

## Temperature rise




**Thermo graphic data @ 2700Amp.**

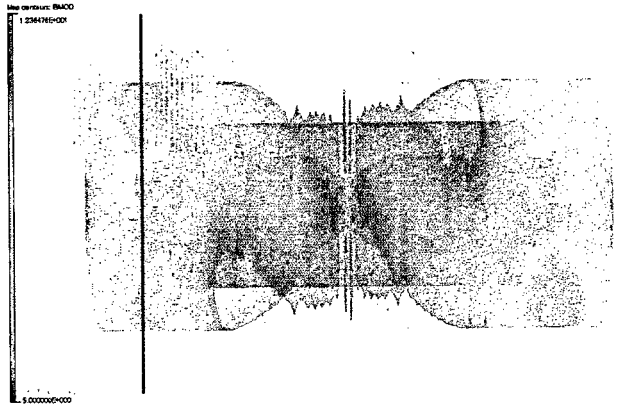
## Temperature rise at full current




Average temperature rise = 10.5 ℃
@ total water flow rate = 185 gal/min

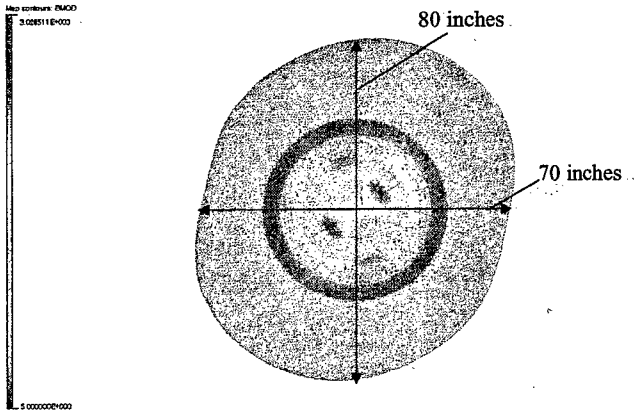
Calculated data:
temperature rise = 14.8 ℃
@ total water flow rate = 162 gal/min

## Magnetic field around the warm snake



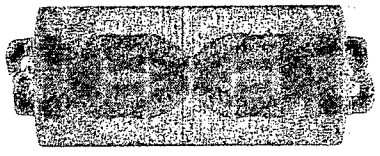
This field map shows the magnetic field over 5 gauss at radius = 30 inches.
Under 5 gauss is the security area for persons who has the pace maker.

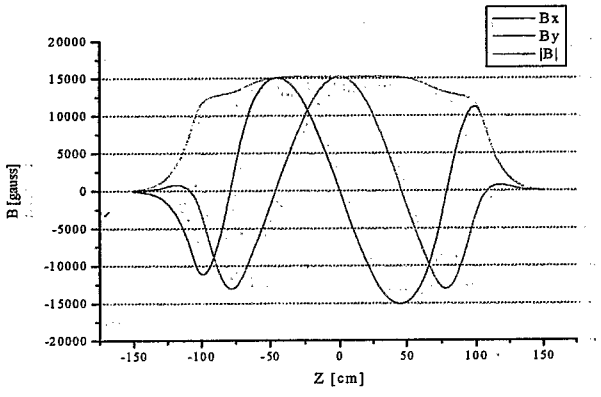
## Magnetic field around the warm snake




This field map shows the magnetic field over 5 gauss at z = 50 inches.

## Magnetic field on the z-axis

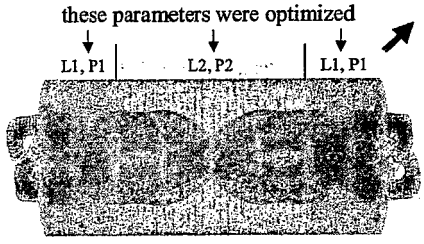


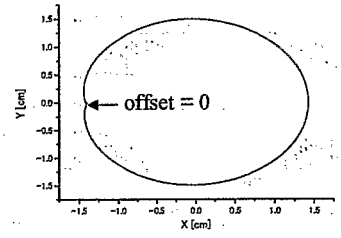


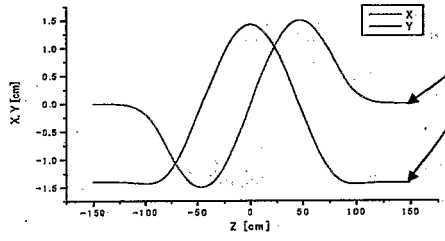
## Simulated beam trajectory

L1 = 39 [cm], L2 = 132 [cm]
P1 = 90 [cm/rev] , P2 = 184 [cm/rev]

these parameters were optimized



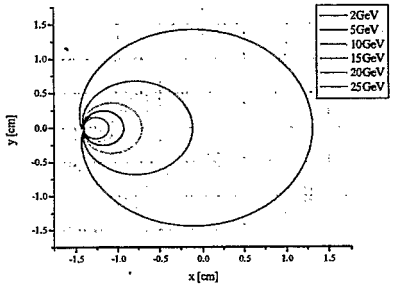

offset = 0

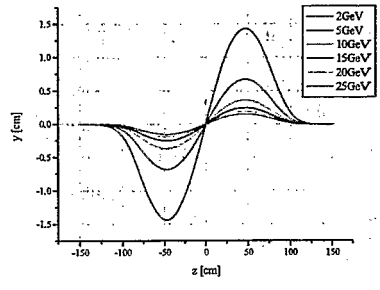
deflection angle = 0

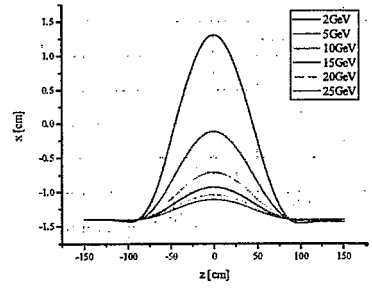
This beam trajectory is perfect !

## Beam trajectory

~ depending on the energy ~



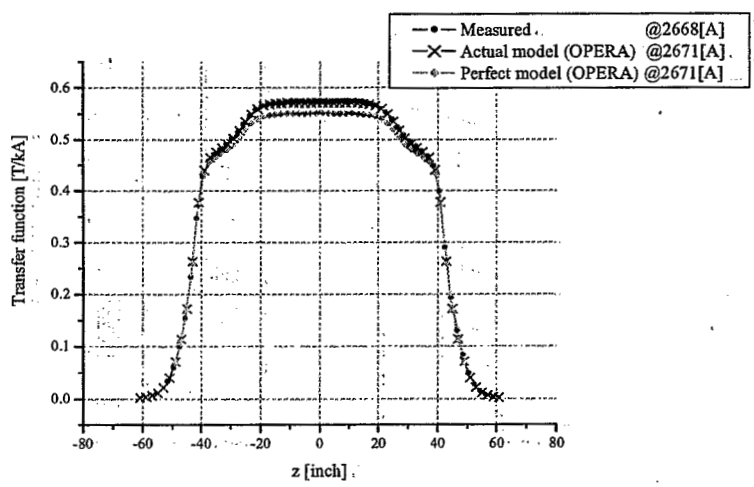
## Error study

However these beam trajectories are the result of the ideal simulated model.
The actual magnet has some errors.
The main errors which should be considered are:

- B-H curve of the steel
- Packing factor of the laminations
- Coil position error
- Dimensional errors of the yoke and laminations because of the lamination pressing.

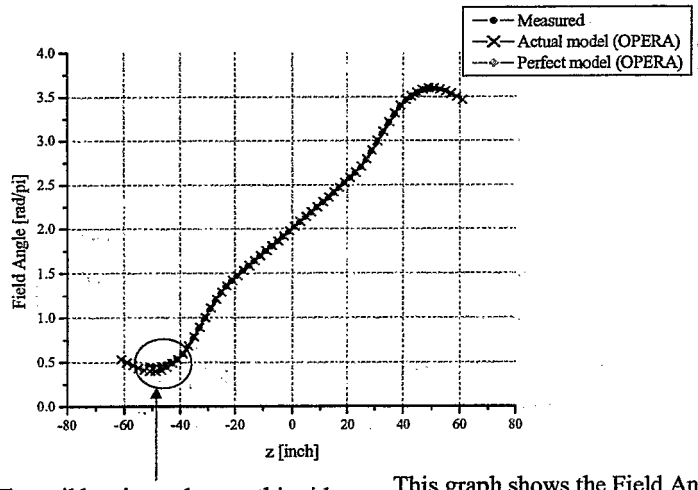
→ The model which is completely like the actual magnet must be simulated.

## Measured magnetic field




This graph shows the difference of the magnetic field between the Measured and Perfect which is caused by the saturation of the steel in rapid pitch region.

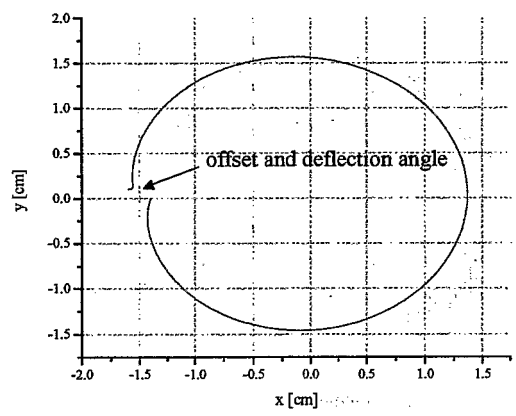
## Measured magnetic field




The coil has its outlets on this side.

This graph shows the Field Angle.

## Beam trajectory

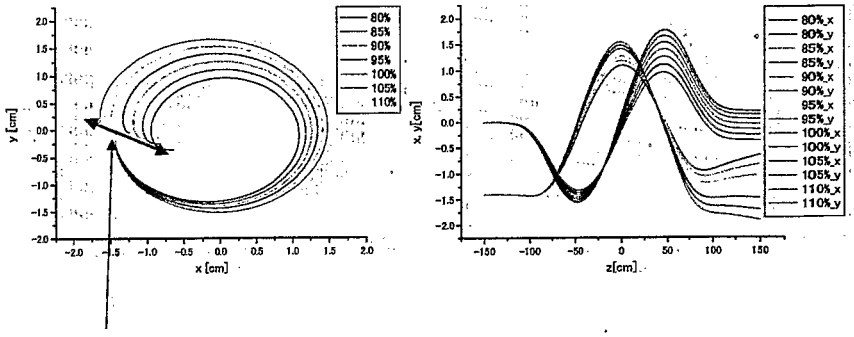



This is the beam trajectory of the actual model.
The output beam has offset and deflection angle.
Magnetic flux at the center of the magnet is 1.53 Tesla.

## Beam trajectory

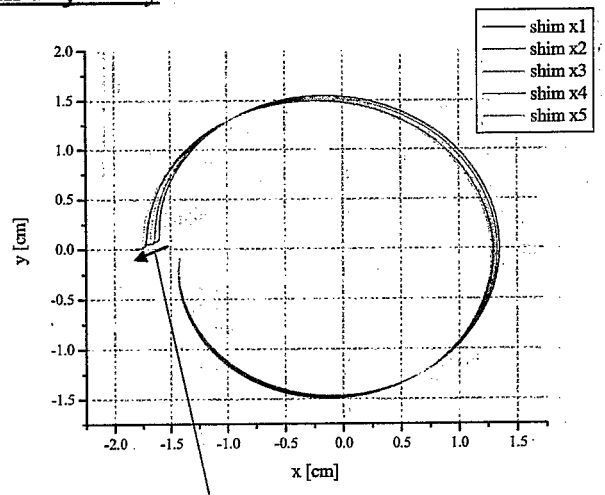
~ depending on the current ~

Current = 80% to 110%




The operation current is one of the method for correcting the beam trajectory.

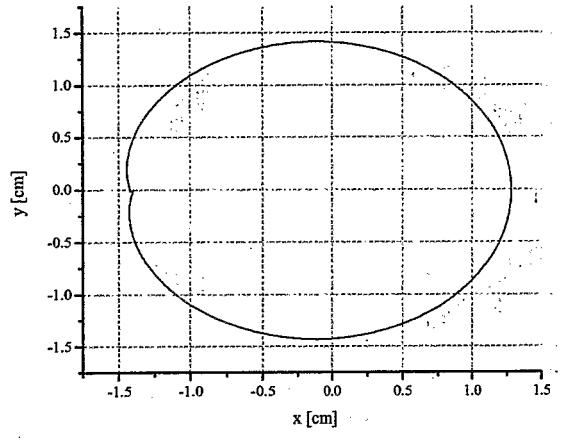
## Beam trajectory




The Beam output position will be varied on this way, if the shims are put on the pole piece.

## Beam trajectory

The result of the matrix about the current and shims are:
current : 94.5%
shims : x0.7
This trajectory is the output with 95% current and a shim.




Magnetic flux at the center of the magnet is 1.46 Tesla.

## Summary

The measured data being compared to the simulated data.
We know the way to correct the beam trajectory with shims and operating current.

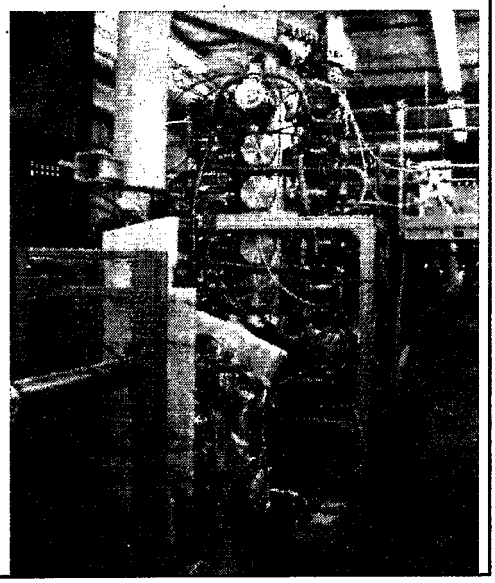
## Measurement plan

1. Measuring the 3 patterns of the current, 100%(done), 95%, 90%.
2. Analyzing the effect of the shims, it is also 3 patterns – shims x0(done), x3, x5.
3. Transfer function at the center of the slow and rapid region.
4. The field quality of the magnetic field where the beam threw will be surveyed.

# COMMISSIONING THE *pp* POLARIMETER

Alessandro Bravar
et al.

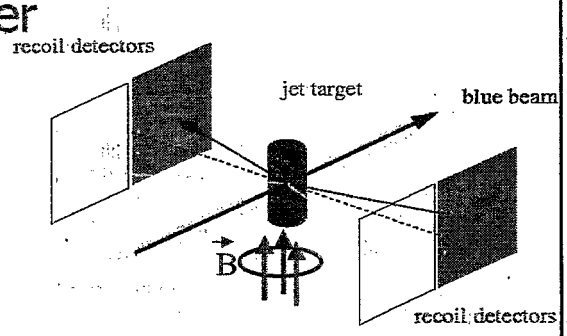
JET in the IR

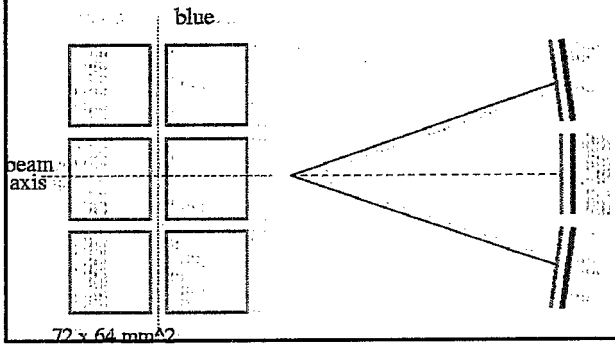


**RHIC SPIN Coll. Meeting**
**January 21, 2004**

## Recoil spectrometer

2004 RUN
WILL INSTALL
6 DETECTORS
ON BLUE BEAM
ONLY




will have "design" azimuthal coverage

one Si layer only
⇒ smaller energy range
⇒ reduced bkg rejection power

1

# The road to $P_{beam}$

Requires several independent measurements

0 target polarization $P_{target}$ (Breit-Rabi polarimeter)

1 $A_N$ for elastic *pp* in CNI region: $A_N = 1 / P_{target}\, \varepsilon_N'$

2 $P_{beam} = 1 / A_N\, \varepsilon_N''$

1 & 2 can be combined in a single measurement: $P_{beam} / P_{target} = - \varepsilon_N' / \varepsilon_N''$

3 *CALIBRATION*: $A_N^{pC}$ for *pC* CNI polarimeter in detector kinematical range:

$A_N^{pC} = 1 / P_{beam}\, \varepsilon_N'''$

(1 +) 2 + 3 measured almost simultaneously alternating *p* and *C* CNI polarimeters

4 BEAM POLARIZATION: $P_{beam} = 1 / A_N^{pC}\, \varepsilon_N''''$ to experiments

at each step pick-up some measurement errors:

$$\frac{\Delta P_{beam}}{P_{beam}} = \left(\frac{\Delta P_{target}}{P_{target}}\right) \oplus \left(\frac{\Delta A_N}{A_N}\right)_{pp} \oplus \left(\frac{\Delta A_N}{A_N}\right)_{pC} \oplus \left(\frac{\Delta \varepsilon}{\varepsilon}\right)_{pC} < 10\%$$

transfer calibration measurement

requires $< 10^7$ *pp* CNI events

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# Rates for *pp* CNI events (old estimates)

| beam intensity | target density |
|---|---|
| 1 ~~2~~·10^11 p / bunch<br>55 ~~112~~ bunches<br>78 kHz | ~~5·10^11~~ 2·10^12 atoms / cm² |

acceptance ~ 1/12 of azimuth (~30°)

| | |
|---|---|
| \|t\| range (GeV²) | 1·10⁻³ — 2·10⁻² |
| ⟨σ⟩ (cm²) | 3 · 10⁻²⁷ |
| ⟨$A_N$⟩ | 0.03 |
| F. o. M. | 2.7·10⁻³⁰ |

$$\mathbf{L} = 2\cdot10^{11} \times 112 \times 78\cdot10^{3} \times 5\cdot10^{11} \sim 10^{30}\ \mathrm{cm^{-2}s^{-1}}\ (1\mu b^{-1}s^{-1})$$

$$\sim 10^{28}\ \mathrm{cm^{-2}s^{-1}}\ /\ \mathrm{bunch}$$

$$\mathbf{N} = \mathbf{L} \times \langle\sigma\rangle \times acc\,(\Delta\varphi = 30^0/2\pi) \times eff\,(50\%) \sim 125\ \mathrm{Hz}$$

$$\sim 1\ \mathrm{Hz}\ /\ \mathrm{bunch}$$

in 12 hours (i.e. 1 machine fill)

can collect $\sim 5 \times 10^6$ *pp* CNI events

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2

## Bring the JET to full operational status

- **3 - 4 days JET installation in tunnel (IP12)**
- **1/2-1 week to fine tune the jet beam parameters and attain a stable running condition. This could be done parasitically with RHIC beam tuning.**
- **Tune the dissociator for maximum intensity**
- **Measure the intensity in chamber 7 by pressure rise**
- **Turn on the holding field magnet, RF systems, and BRP gauge and measure the jet polarization without beam.**
  - Measurements in November indicated the jet beam polarization to be 99% of the theoretical maximum (this depends on the holding field magnet setting)
- **Repeat the Jet polarization measurement with beam** (dedicated)
  - Assess if we suffer any beam depolarization from the bunched beam (and intensity). Our expectation is no effect if running with 56 bunches. This has to do with the uniformity of the holding field magnet.
- **It does not matter if the beam is at injection or at store. However, it is of interest to do the same with the 200 Mhz system on.**
- **The two RHIC beams should be separated by at least 1 cm horizontally; one beam centered [vertically] in the JET chamber (BPMs and profile measurements)**

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## Commissioning *pp* polarimeter steps

1 Energy calibration with α source (Am) and time calibration of Si detectors

2A Identification of elastic *pp* events
- energy – position correlations
- inelastic backgrounds
- energy and time resolution (200 MHz system on)
- $M_X$ resolution

2B FE & receiving electronics and DAQ setup / debugging
- online waveform analysis
- self-triggering
- synchronization with RHIC clocks
- event building

first 2 – 3 weeks "parasitic mode"

3 RUNNING ⇒ $A_N$ *pp* and $A_N$ *pC* in CNI region
- different running conditions (one beam vs both beams, etc.)
- polarized and unpolarized beams and target
- ⇒ collect > $10^7$ events at 100 GeV
- ⇒ collect a sizable sample also at 24 GeV

week 4 dedicated

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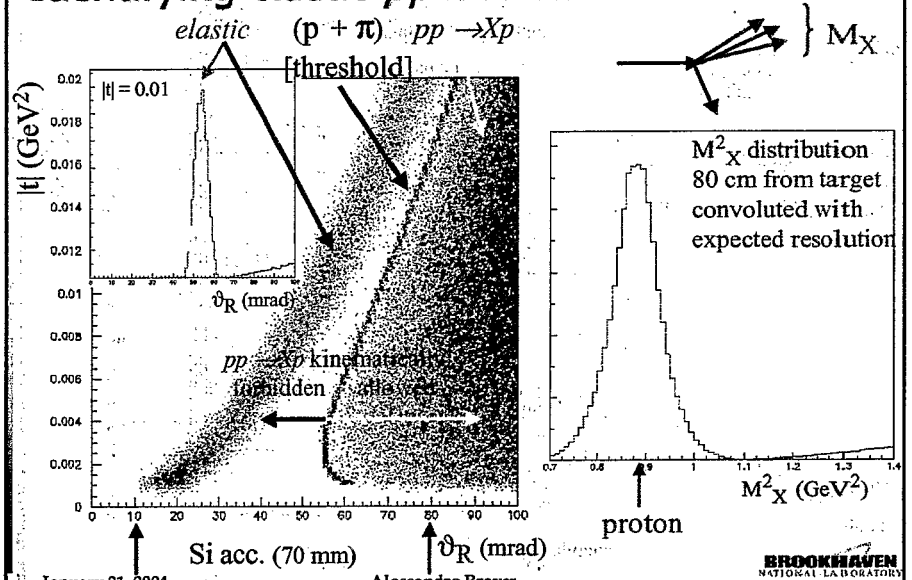
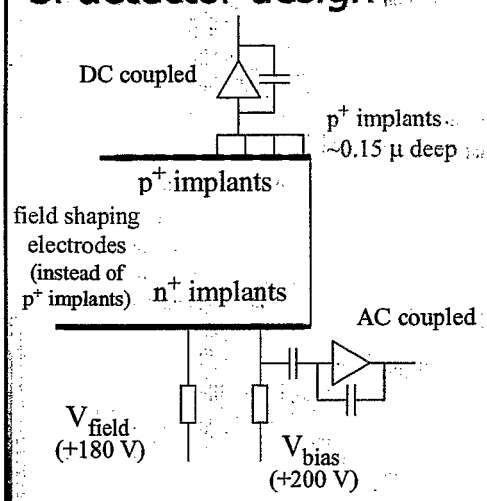
3

## Identifying elastic *pp* events






## Si detector design



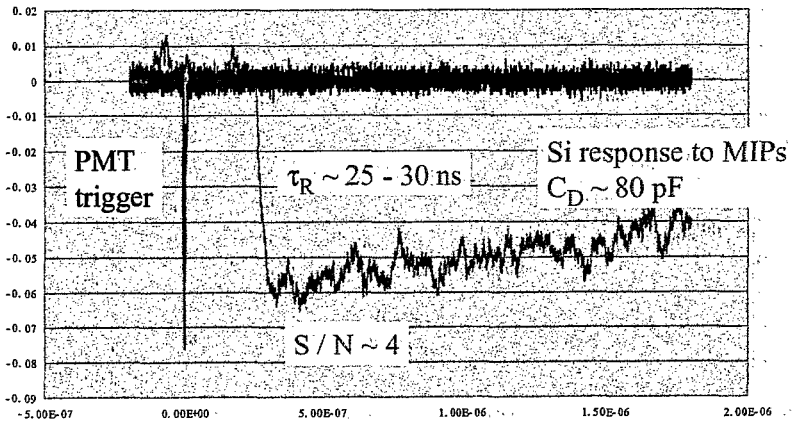

to minimize entrance window:
1. no $SiO_2$
2. replaced Al electrode with thin wires
3. shallow implants

dead layer < 200 nm (cfr. 3 μm!)
almost no energy loss for recoil protons in CNI range

double sided readout (opt.)
72 × 64 mm²
thickness 500 microns
$p^+$ side pitch 1 mm
readout pitch 4 mm
$n^+$ side pitch 4 mm
C ≈ 80 pF/readout ch.

## Si performance

MIP signals before shaping (full bandwidth)
NB slowest recoil protons > 3 MIPs



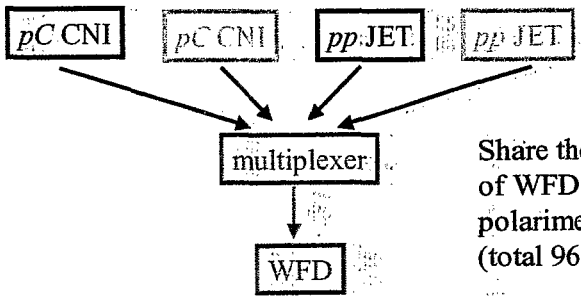

final detectors will have lower leakage currents => expect better S / N



## Running scheme

alternate measurements with *pp* CNI (JET) and pC CNI polarimeters about each hour

*pp* measurement: only fraction of whole statistics
pC measurement: > 2 $10^7$ events (full measurement)




Share the same set of WFD for all RHIC polarimeters (total 96 ch.)

Same WFD code for pC CNI and JET polarimeters

# RHIC CNI polarimeter Run-03 *(Nearly)* final results

Osamu Jinnouchi (RIKEN BNL Research Center)

*RHIC-Spin-Collaboration Meeting*

*Jan. 22, 2004*

## *Calibrations/Corrections in offline analysis*

- Constrained and unconstrained variables of Carbon events
  - Time
    - Scale (fixed) – WFD clock
    - Time zero – Unconstrained
  - Energy
    - Scale (fixed) – Am calibration (a few % uncertainty)
    - Shift by Si dead layer – Unconstrained
- T0, d-layer can be determined by the fit to Carbon locus
- d-layer correction needs to be implemented in non-linear function of deposit energy (was linear at online analysis)
- d-layer estimation is very important, it directly couples to $-t$, hence it changes the $A_N$
- These parameters are different by strip to strip, and time to time

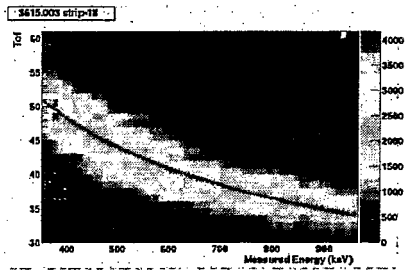
## *Fit to Carbon locus*

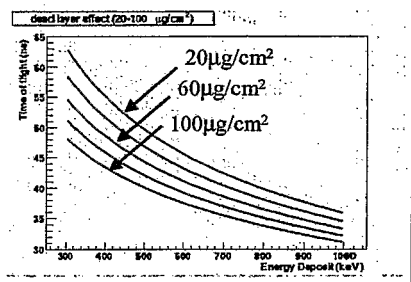
- Fits with non-relative kinematics

$$t.o.f.(ns) = \frac{1181.6}{\sqrt{E_{kin}}} + t0$$

$$E_{kin} = f(E_{deposit}, D_{width})$$

- With the factor 1181.6, the fit is forced to the Carbon mass (11.17GeV/c²)
- t0 and d-layer are strongly correlated. Thus, it would be useful to see run-by-run stability, even though they can be simultaneously determined from fit.

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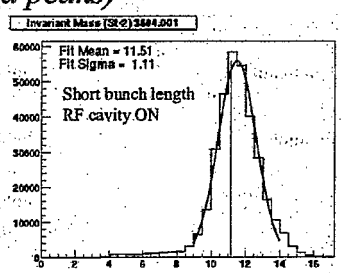
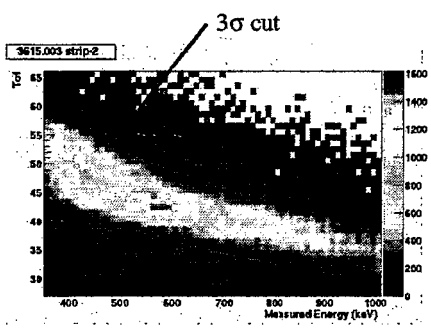
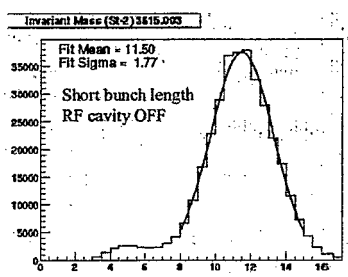
Jan. 22, 2004

## *Invariant mass (Carbon & alpha peaks)*

- Carbon events are selected with the cut defined by invariant mass
- Back ground contribution can be estimated by changing the cut criteria (2σ, 3σ,...)
- Better separation is obtained than the fixed time window which was used in online




4

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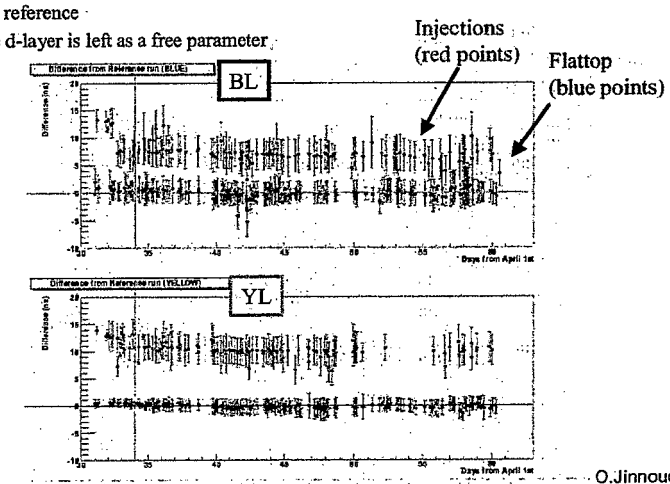
## *Run by run fluctuations (RF timing, beam position)*

- Timing (arriving time) of the carbon banana is stable (as long as the RF and beam position are stable)
- However there were fluctuations when scanned through the whole run
- Once determined the T0 and D-layer at reference run, T0 could be fixed for any run as the deviation from the reference
- Only the d-layer is left as a free parameter

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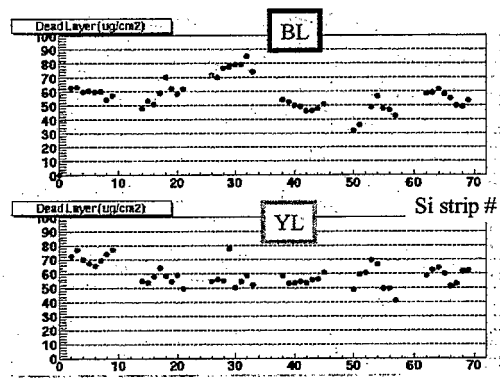
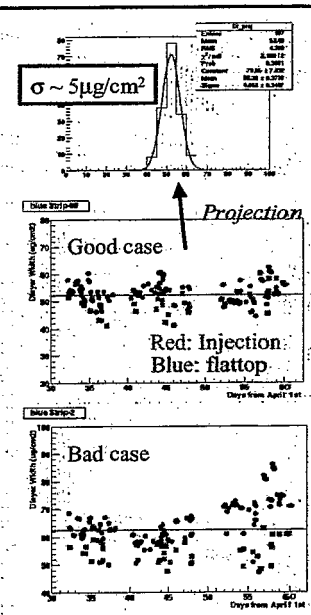
## *Si dead-layer corrections*

- Widths are 50-80ug/cm² in average
- Size of the fluctuations is ±5μg/cm² which is about the same uncertainty of Run-02
- Averaged value during the runs is determined for each silicon (not each strip)




6

Si strip #

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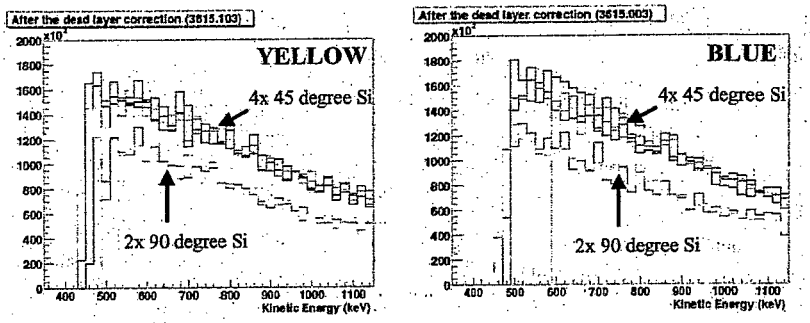
## *Energy spectrums after the energy corrections*




- The spectrums are shifted to higher energies due to the large dead layer correction
- The asymmetries (=ε) got almost nothing or small change, while the analyzing power (=AN) became smaller → indicating larger polarization with about 10% (relatively) increase



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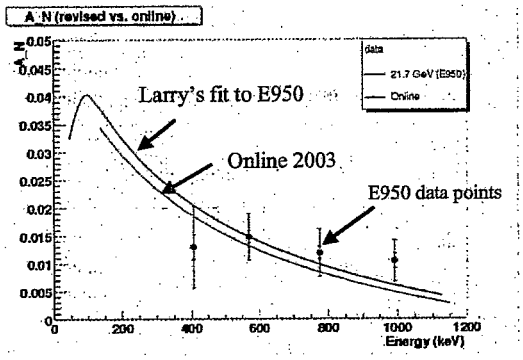
## *Revised analyzing power*




- Online results were based on the wrong AN(red curve)
- AN for the given run is calculated with weighted sum of this curve
- Increasing by about 10% in AN implies the reduction of polarization result by 10%



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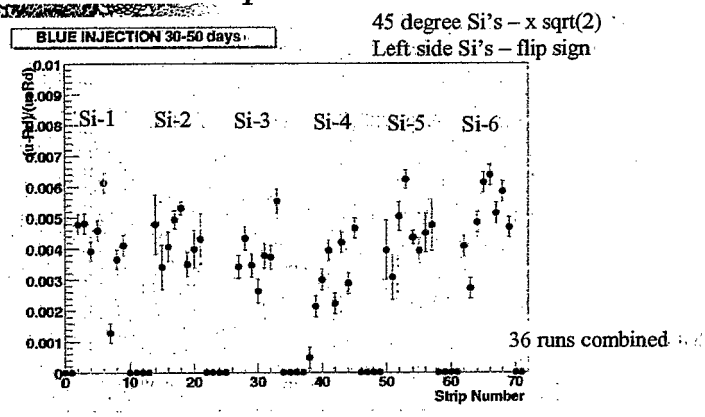
## $A_N$ for individual strips




- $A_N$ for each strips could be determined by (ui-dRi)/(ui+dRi) where R=U/D (luminosity ratio)
- The polarization could be determined as an average of the valid strips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## Outlook

- From the first glance, the new numbers are more or less the same with the online values (-10% from AN, +10% from d-layer correction)
- New polarization values are ready to be released when the systematic errors become available
- Things to be done
  - Understand the fluctuations in d-layer fit result
  - Compare the d-layer size with Kyoto tandem test result
  - Bunch by bunch study has not been done – new polarization values should include (customized) to each experiment


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## *Appendix slides ...*

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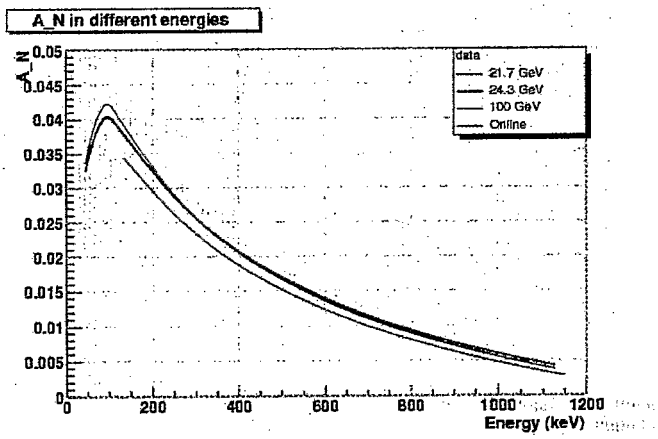
## *AN for different energies*




- L.Trueman's prediction based on pomeron model
- Assuming the 100GeV, 24GeV shape (Run-02 data points) as inputs

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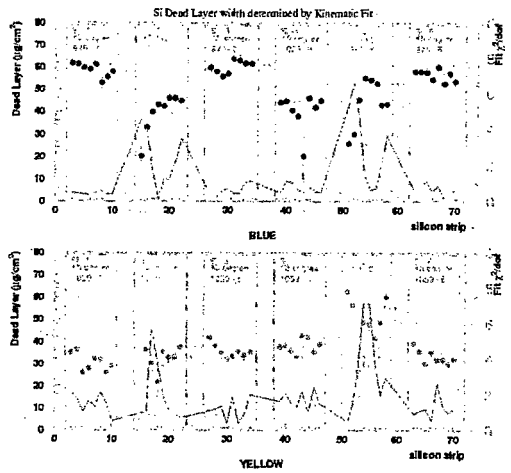
Jan. 22, 2004

## *Dead layer distribution at Run-02*




- Silicons from the same wafer showed quite similar values
- Known within ±5µg/cm²

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O.Jinnouchi @ RSC
Jan. 22, 2004

**RHIC Spin Collaboration Meeting XXI**
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**RIKEN BNL Research Center**

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# RHIC Spin Collaboration Meeting XXI
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**RHIC Spin Collaboration Meeting XXI**
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RIKEN BNL Research Center
**RHIC Spin Collaboration Meeting XXI**
January 22, 2004
Bldg. 1005, Third Floor Conference Room
Brookhaven National Laboratory

*******AGENDA*******

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| | | |
|---|---|---|
| 9:00 – 9:25 | Machine Status & Update | W. Fischer |
| 9:25 – 9:50 | AGS pp Commissioning Plan | H. Huang |
| 9:50 – 10:15 | RHIC pp Commissioning Plan | M. Bai |
| 10:15 – 10:25 | Short Update on RHIC Snake Quench Protection Plan | W. MacKay |
| 10:25 – 10:45 | Coffee Break | |
| 10:45 – 11:10 | New Working Points & Beam Beam Tune Shift/Spread | R. Tomas |
| 11:10 – 11:35 | AGS Warm Snake Status and Field Mapping | J. Takano |
| 11:35 – 12:00 | pp CNI (gas jet) Polarimeter Commissioning Plan | A. Bravar |
| 12:00 – 12:25 | RHIC pC CNI Polarimeter "FY03 Final Results" | O. Jinnouchi |
| 12:25 - | Updates from Experiments *(if any since last meeting)* | |

# RHIC Machine Status

Wolfram Fischer

— Run Coordinator for Run-4 Gold-Gold Operation —

For the C-A RHIC Team

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration Meeting
27 February 2004

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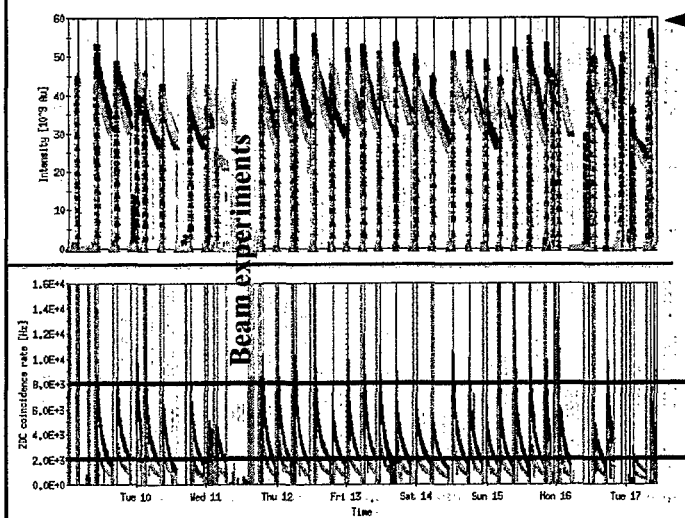
Content

1. Run-4 Au-Au luminosity development
2. Peak luminosities and best performance
3. Time in store
4. Luminosity limitations
5. Luminosity estimates for pp operation
6. Summary

RHIC Run-4 Physics stores

Best week (9 Feb to 17 Feb)




60e9 Au intensity

enhanced luminosity

design luminosity

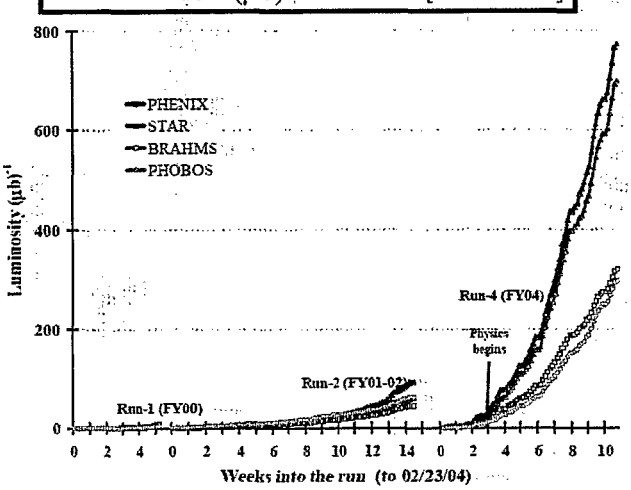
Wolfram Fischer

BROOKHAVEN NATIONAL LABORATORY 3

RHIC Run-4 Luminosity evolution

Delivered 766 $(\mu b)^{-1}$ to Phenix [week ago : 480]
132 $(\mu b)^{-1}$ last week [best week: 153]

As of 02/22/04 24:00
Star ×0.9
Phobos ×0.3
Brahms ×0.4




maximum projection

physics target

minimum projection

Wolfram Fischer

BROOKHAVEN NATIONAL LABORATORY 4

RHIC Run-4 — Peak luminosity and best week performance

| Mode | No of bunches | Ions/bunch [$10^9$] | β* [m] | Emittance [μm] | $L_{peak}$ [$cm^{-2}s^{-1}$] | $L_{store\ ave}$ [$cm^{-2}s^{-1}$] | $L_{week}$ [$\mu b^{-1}$] |
|---|---|---|---|---|---|---|---|
| Run-4 achieved | 56 | 0.9 | 1 | 15-40 | $15 \times 10^{26}$ | $4 \times 10^{26}$ | 153 |
| Run-4 goal* | 56 | 0.9 | 1 | 15-40 | $12 \times 10^{26}$ | $3 \times 10^{26}$ | 70 |
| Design | 56 | 1.0 | 2 | 15-40 | $9 \times 10^{26}$ | $2 \times 10^{26}$ | 50 |

[* Run-4 goal: basis for maximum projection]

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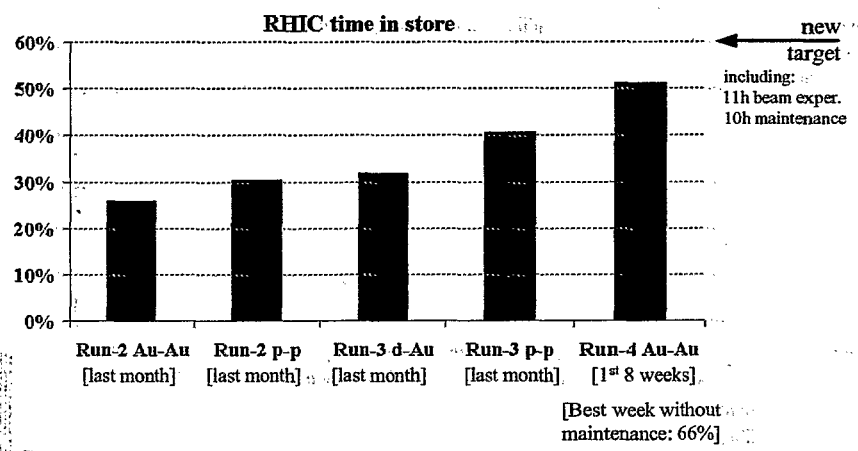
RHIC — Time in store




Comments:
- Not all store time used by experiments (initial background, detector turn-on, etc.)
- Usable store time differs from experiment to experiment

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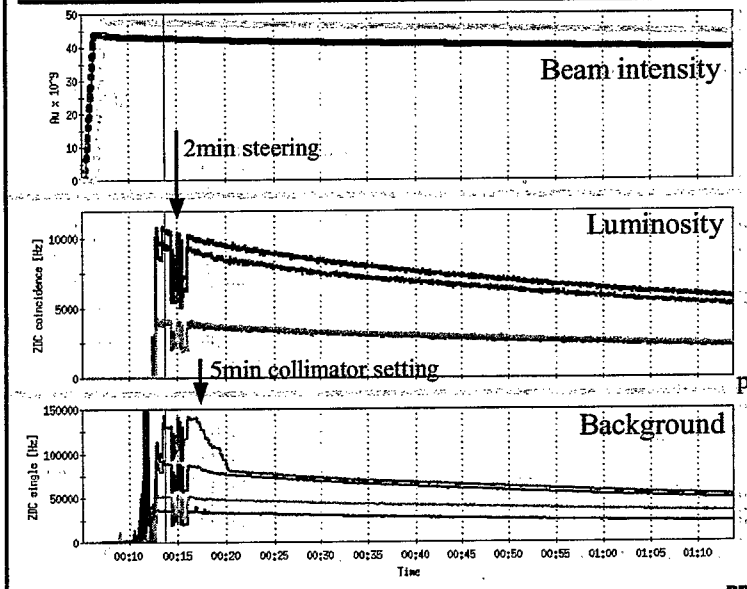
RHIC Run-4 — Beginning of store activities




Steering and collimator setting within ~10min

[up to 1hr in previous Runs]

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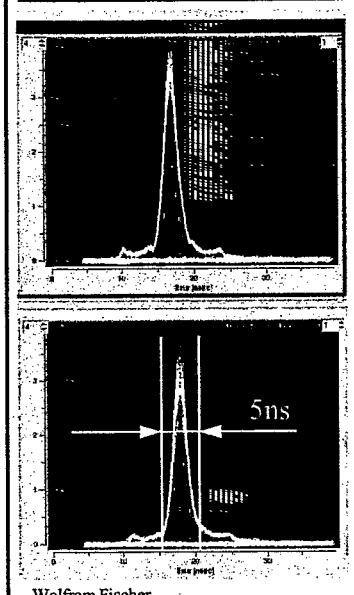
RHIC Run-4 — Rebucketing and vertex distribution




Improved rebucketing

- fully automatic at end of energy ramp
- only small amount of beam in adjacent buckets

→ Almost no further improvement possible

(Widening of longitudinal distributions are from intra-beam scattering. This limit can only be overcome by beam cooling at full energy.)

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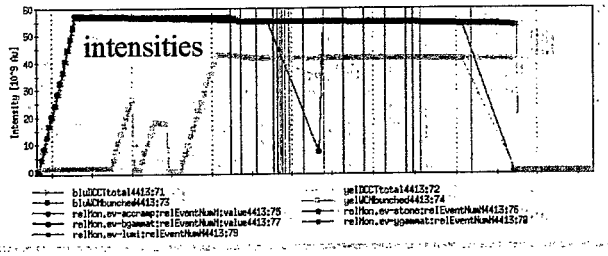
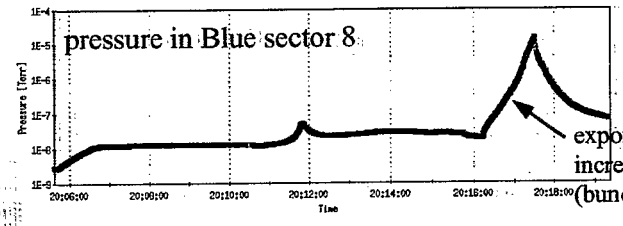
- Beam intensities in both rings are limited by vacuum instabilities
- Machine operates as closely as possible at these limits



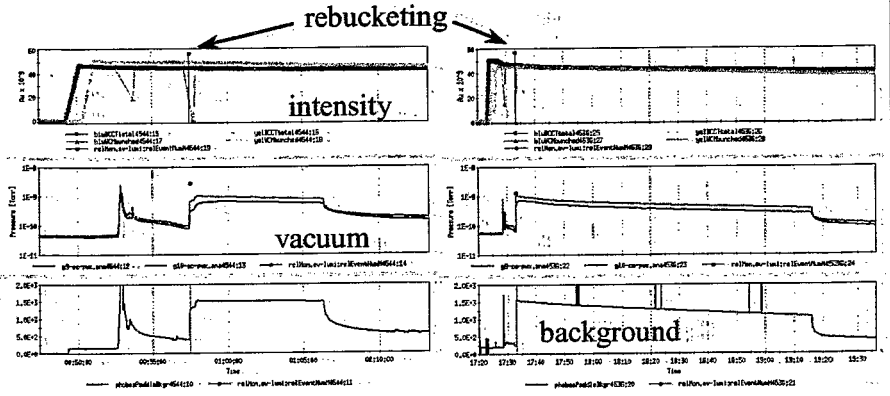

exponential pressure increase after rebucketing (bunch length shortened)





PHOBOS background increase after rebucketing, drops after minutes to 2 hours

→ under investigation




4544: drop after 8min

4536: drop after 1:43hrs

- Assume
  - Same charge can be stored for p and Au beams (45x45, 1.1e9/bunch – not yet the vacuum limit)
  - pp luminosity lifetime of 7h (2h for Au beams)
  - 20mm·mrad transverse normalize emittance
  - 5h store length, 2h refill (optimum store length 4.7h)
  - 50% of calendar time in store
- Luminosity is
  - $7\times10^{30}cm^{-2}s^{-1}$ peak
  - $3.5\times10^{30}cm^{-2}s^{-1}$ average per store
  - 1.1 $pb^{-1}$/week





- Delivered Au-Au luminosity exceed most optimistic assumptions: delivered $800(\mu b)^{-1}$ to PHENIX in 8 weeks (almost the same to STAR, 1/3 to BRAHMS and PHOBOS)
- Calendar time in store increased to 50%
- Smaller vertex distribution, fast steering and collimator setting than in Run-3
- Vacuum limits beam intensity, and severely affects PHOBOS background

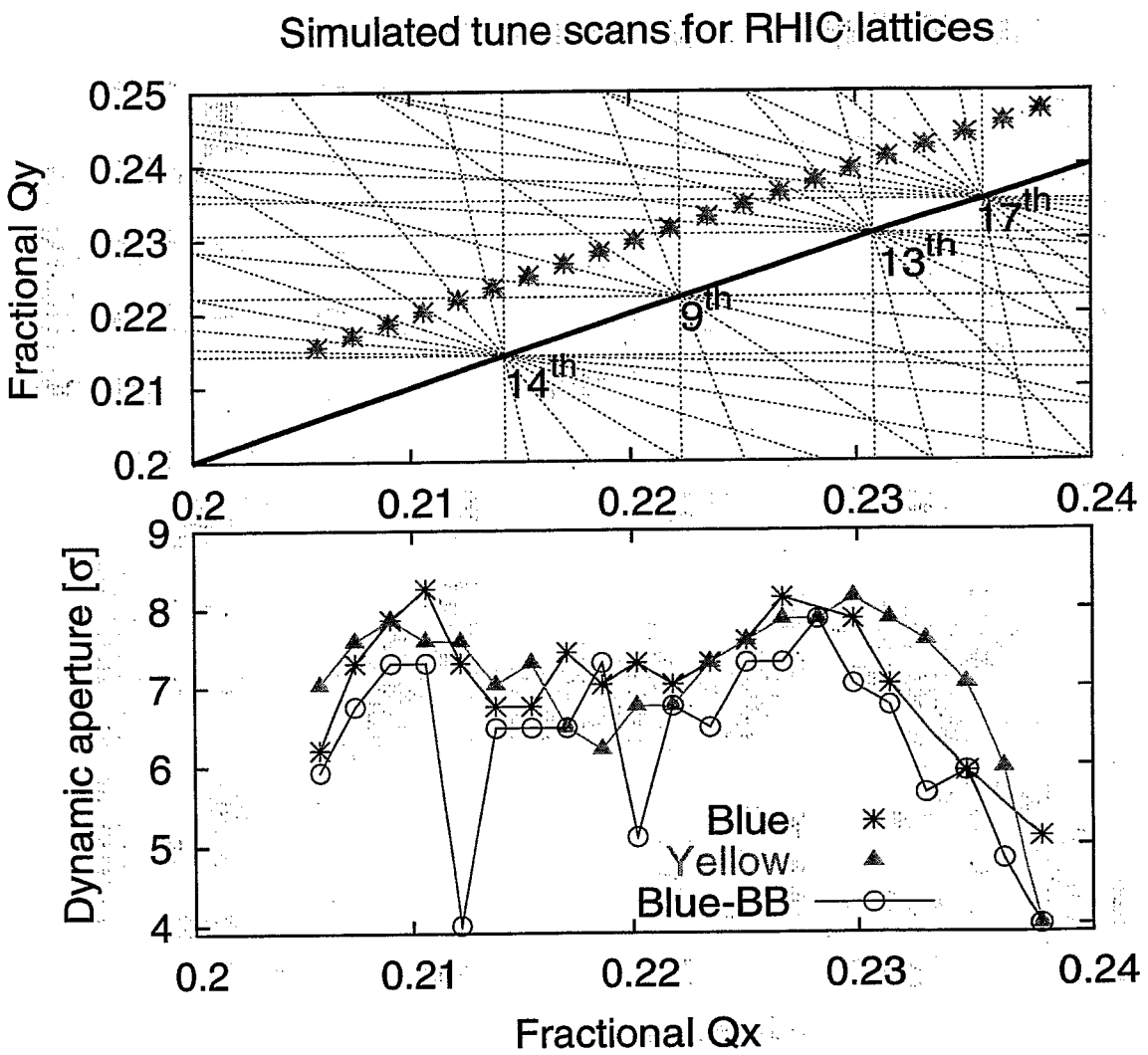
# Contents

- Ongoing simulations
- Experiments at injection with collisions:
  - RHIC operation tunes
  - RHIC design tunes
  - SPS tunes and beyond

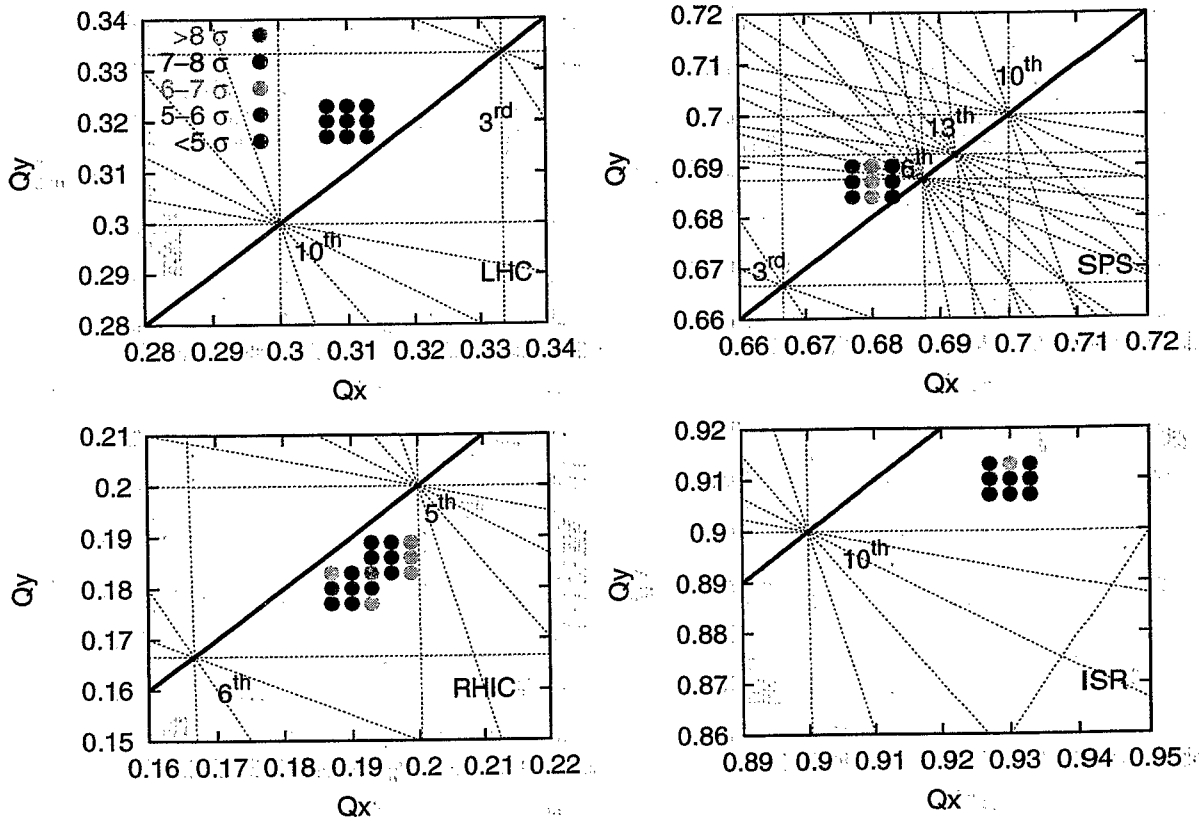
(Experimenters: Vadim, Wolfram, Giovanni, Rogelio...)

## Ongoing simulations I

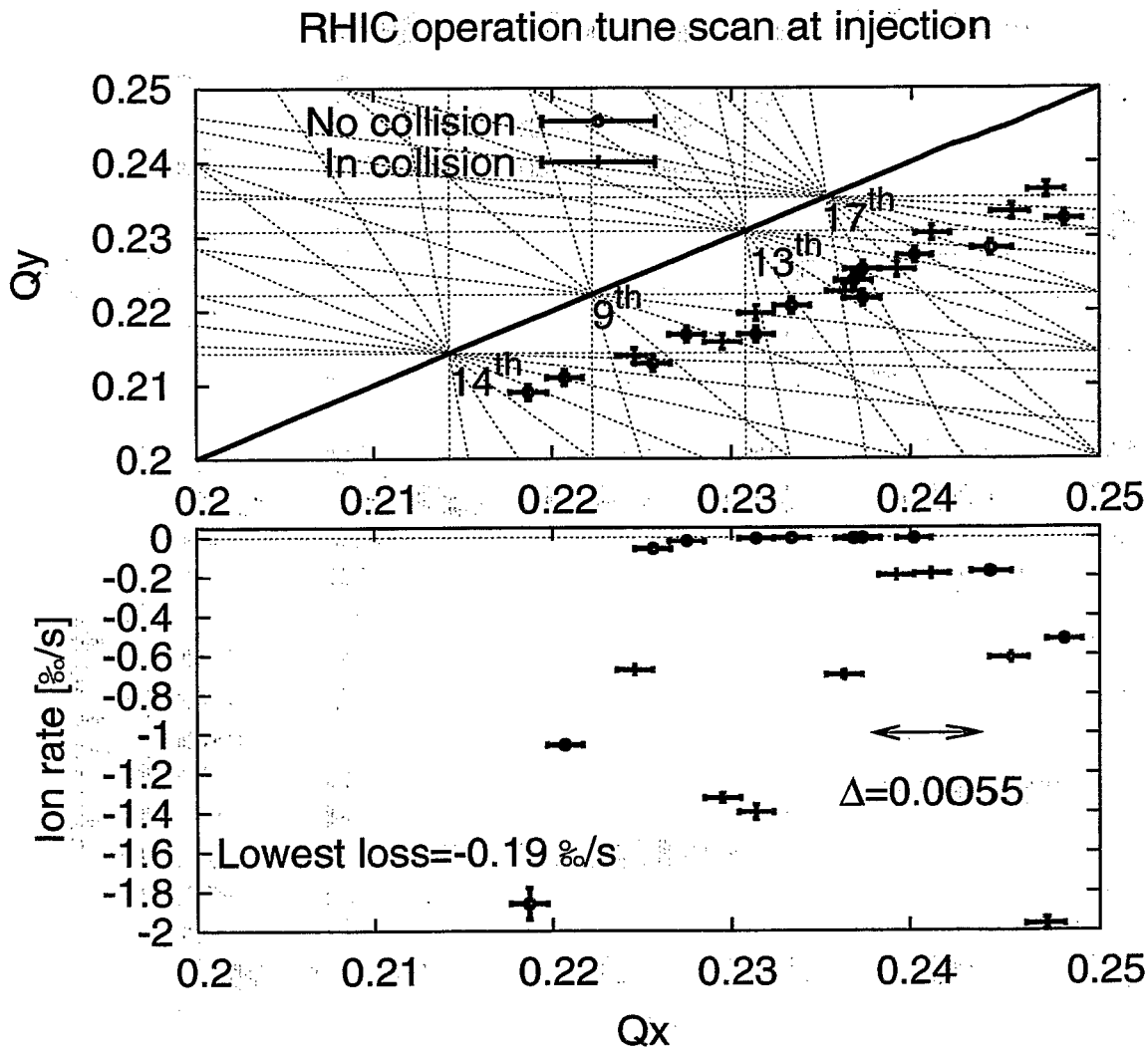
### Beam Beam has been included



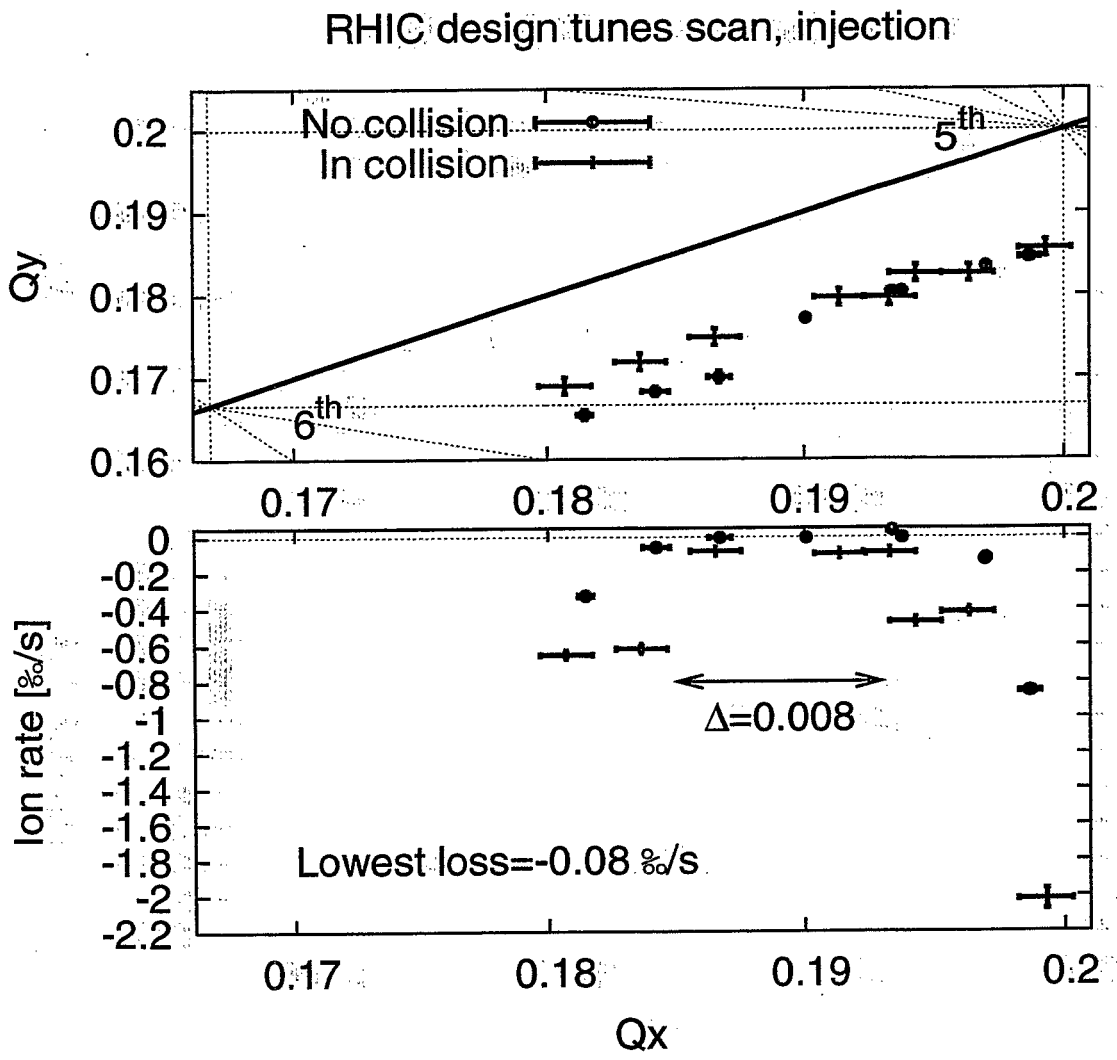
# Ongoing simulations II



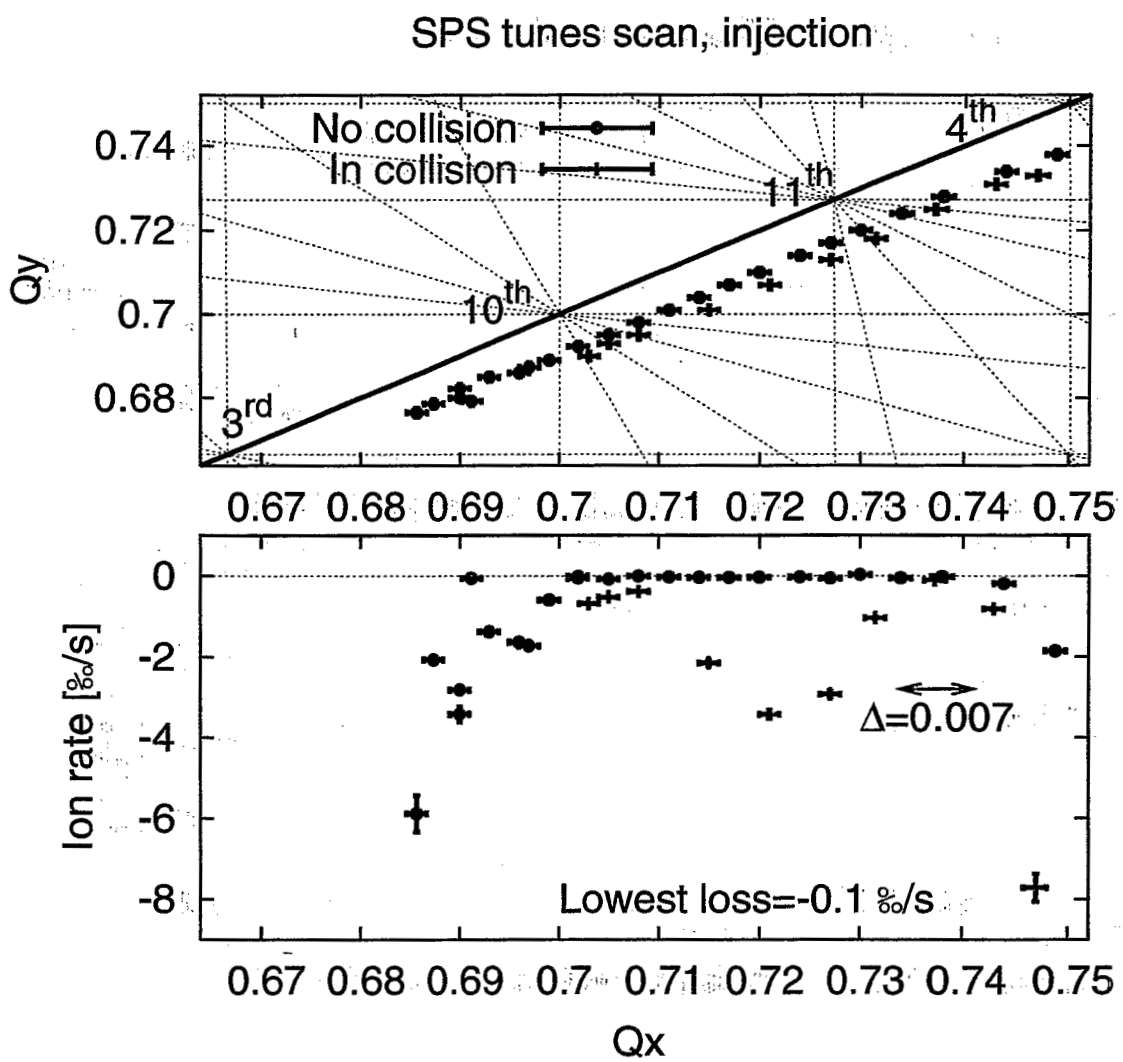
# Experiments: RHIC operation



# Experiments: RHIC design



# Experiments: SPS tunes and beyond



## Conclusions & outlook

- Best candidate so far is RHIC design tunes
- No experimental data for ISR ($\approx 0.1$) and LHC ($\approx 0.32$)
- More simulations still needed at store and at injection

# Source Update and Plan

A. Zelenski, BNL

for
RHIC Spin Collaboration Meeting XXII
February 27, 2004
RIKEN BNL Research Center

## OPPIS status and plans.

- **OPPIS status. Preparation for the run.**
- **Polarization studies. Polarization losses in the Sona-transition.**
- **Plans.**

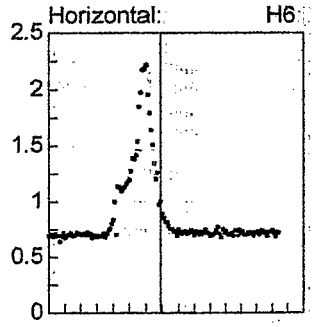
**RSC meeting Febr.27, 2004**

## OPPIS status.

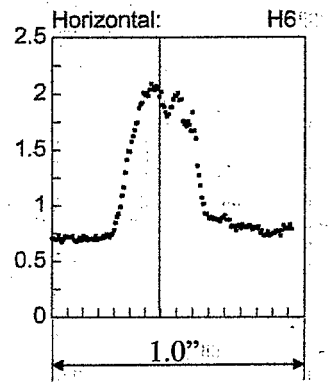
- The 29 GHz tube has been repaired and a new spare tube was purchased.
- One of the original KEK Ar-laser is dead, a spare was installed and woks fine, but at this moment there is no spare for this essential equipment.
- A new diagnostics box was built for the 35 keV beamline. Some beam optics upgrade and better diagnostics resulted in the transport efficiency improvement to 55% from the OPPIS to 200 MeV.

1

## Beam energy spread measurements at 200 MeV.



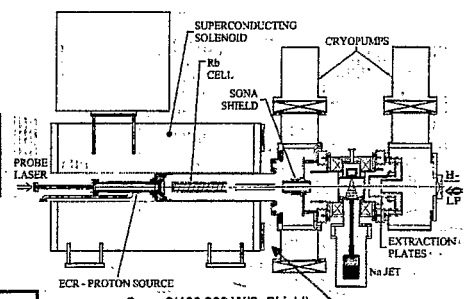

After linac tune

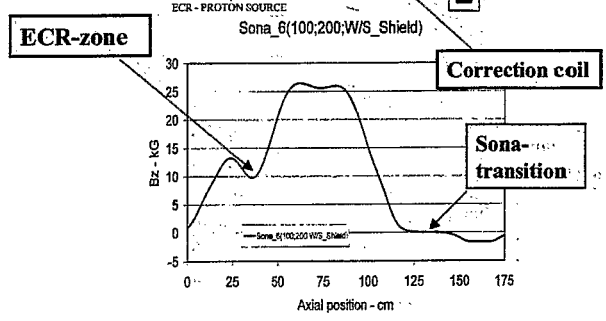



- **Left profile corresponds to ΔP/P~0.07%(FWHM) – energy spread.**

## SONA-TRANSITION.

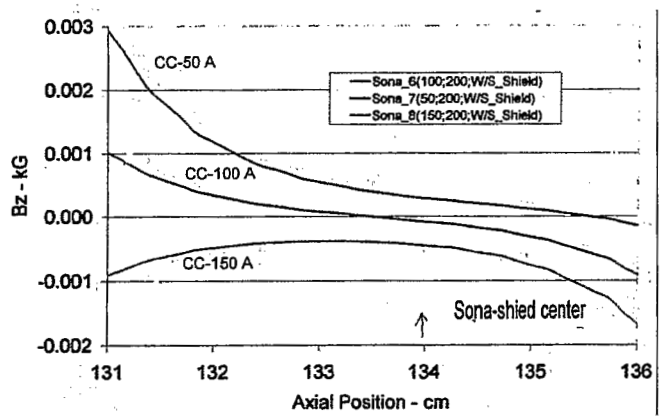
**Polarization transfer from electron to proton.**




2

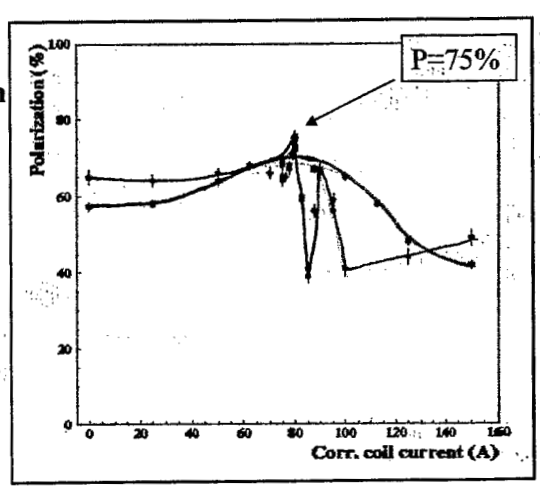
## Magnetic field gradient in the Sona-region.



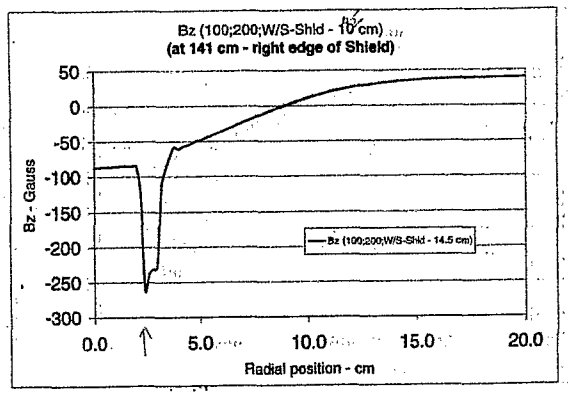

**Longitudinal Bz field in the Sona region at different correction coil current settings.**

## Depolarization in the Sona-transition.

- **Red line –polarization vs. correction coil current without magnetic shield.**
- **Blue line- measurements with the magnetic shield.**



## Magnetic field in the Sona-region.




- **Radial dependence of the Bz field at the Sona-shield entrance.**

## PLANS.

**Present superconducting solenoid produces too strong transverse field in the Sona-region.**

- We need another superconducting solenoid with the cold yoke to produce reliably 80-85% polarization.
- There is a plan to build a new solenoid at BNL for 2007 run. The design work is in progress.
- There is a possibility to borrow solenoid from the TRIUMF OPPIS for the 2005-06 runs.

# The Jet Target for RUN 4

Yousef Makdisi
On behalf of the Polarized Jet collaboration
RSC meeting Feb 27, 2004
Commissioning exercise

- Status
- Impact on the machine
- Installation
- Bring to operational status
- Polarization Measurements and Timelines

# Status

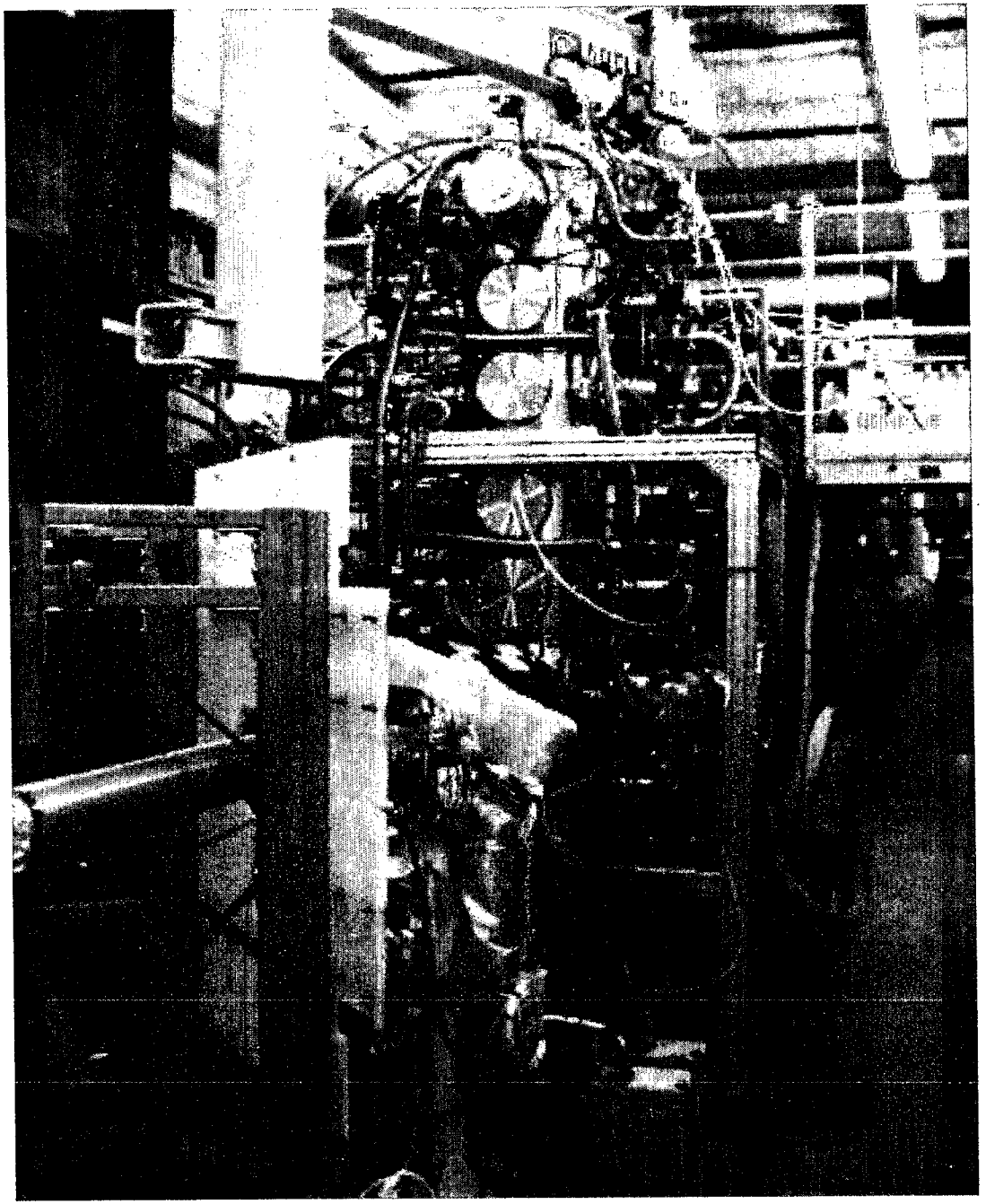
- Major construction on the jet was completed by mid October 2003.
- The Jet was moved to RHIC and installed on its tracks in October 2003.
- Operated remotely for a period of 3 weeks with all systems running.
- Returned the Jet to the lab during the third week in November.
- Some alignment efforts ensued (December 03)
- Measurements of the H /$H_2$ /$H_2O$ were carried out. (January 04)
- Improved the nozzle cooling. (February 04)
- Connected supplies to VME for computer control (Jan and Feb 04)
- Installed Test silicon detectors to assess H effects on leakage current / performance as was experienced at IUCF.
- WFDs for p-Carbon and Jet delivered to BNL. (February 04)
- Completed detector electronics design. (Feb 04) Fabrication (ongoing)
- Remaining items:
  - Recoil collimators (within a week)
  - RF shield (within a week)
  - Software for automatic tuning & polarization measurements
  - Final silicon detectors and electronics (2nd week in March)

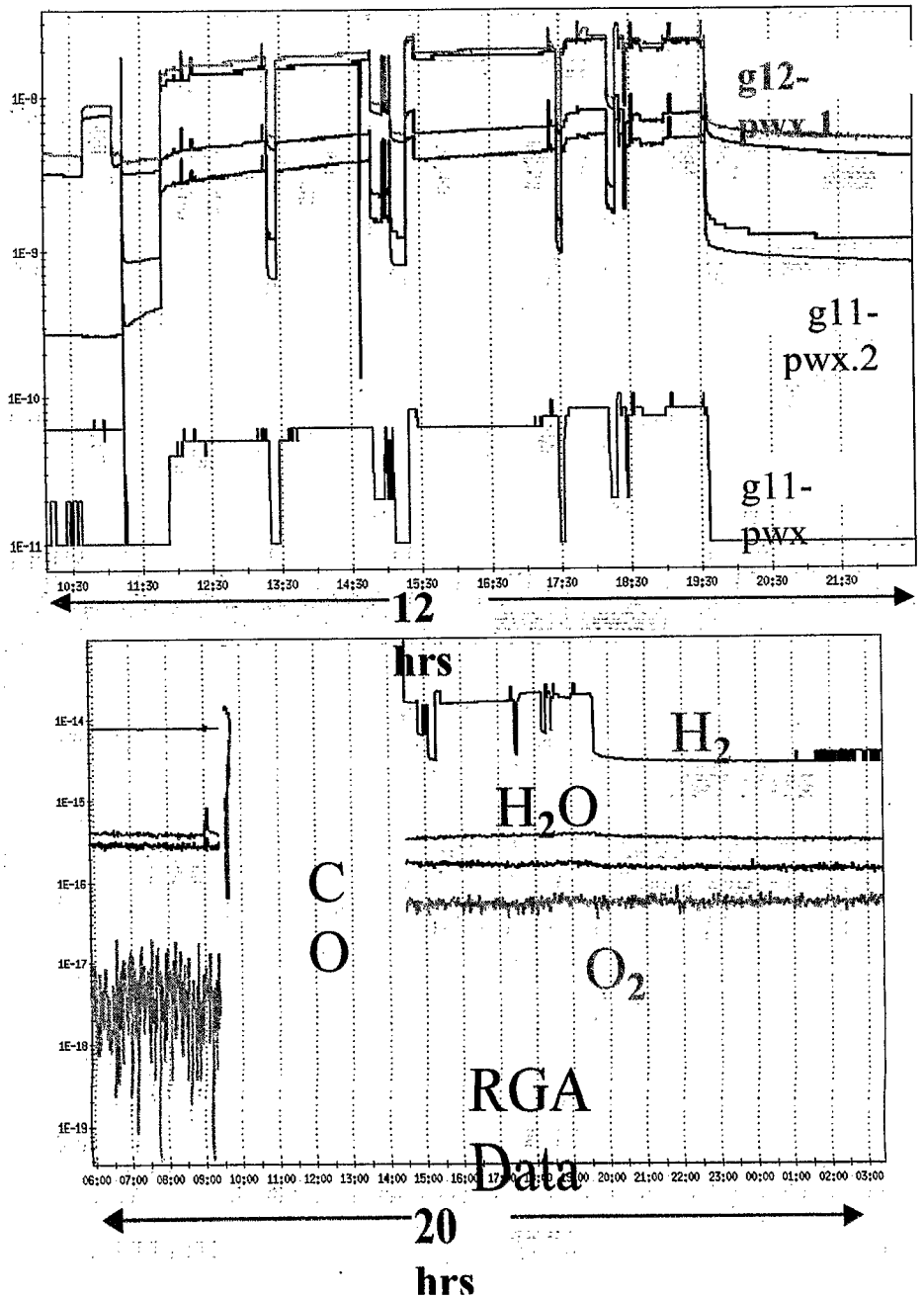
# Jet parameters

- The jet is running quite reliably with about $1.2 \times 10^{17}$ atoms/ sec measured in the collision chamber.
- The Jet beam profile is about 5.5 mm.
- The Jet thickness as seen by the RHIC beam is $10^{12}$ atoms/cm$^2$.
- The molecular hydrogen background was measured at 3% nuclear.
- The jet vacuum in the scattering chamber is $1 \times 10^{-8}$ Torr with beam off and $2 \times 10^{-8}$ Torr with jet beam on.
- The RF transitions in both the ABS and BRP stages are operating at 99% efficiency.
- Silicon detectors will be installed to measure one beam only.

# Jet in the IR

- Three flanges to button up which will speed the leak checking process.
- Two valves on either side
- Beam pipe profile reduced from 5" diameter to a 6x6 $cm^2$
- Copper RF shield across the jet to minimize RF impedance
- Vacuum at 2-5 x $10^{-9}$ Torr on either side of the jet allows a continuous operation.






# The impact of H-Jet to IP12 vacuum (Hseuh)

Vacuum @ 1.3m

- low e-10 Torr w/ valves closed
- ~ 1e-9 Torr with Jet off
- ~ 5e-9 Torr with Jet on

Vacuum @ 7.5m

- ~ 1e-11 Torr with Jet off
- ~ 5e-11 Torr with Jet on

$\Delta P$ is mostly hydrogen @ 7.5m

No observable increase in heavier species

# Install the Jet in the tunnel (March 24??)

Estimate a 3-day shutdown on restricted access

- Move the racks a day or two earlier to the 12 o'clock service building
  - Electrical and water systems will be connected.
- Load the on a truck a day earlier and park overnight in building 912 awaiting the opening of the tunnel.
- Rig the jet into the tunnel (1/2 day) (The clock starts !!)
- Install the jet on the tracks and survey (1 shift)
- Connect services electrical, cabling, air, water cooling (parasitic)
- Turn on the vacuum system and leak check (2 shifts)
- Run the jet and get to a state where we are controlling it remotely (1day)
- We will have continuous shift coverage to manage this stage
- An additional day of contingency when we enter under Controlled access.

# Bring the Jet to full operational status

**Estimate another 1/2-1 weeks to fine tune the jet beam parameters and attain a stable running condition. (Parasitic with RHIC beam tuning.)**

- **Tune the dissociator for maximum intensity**
- **Measure the intensity in chamber 7 by pressure rise**
- **Turn on the holding field magnet, RF systems, and BRP gage and measure the jet polarization <u>without beam</u>.**
  - Measurements in November indicated the jet beam polarization to be 99% of the theoretical maximum (this depends on the holding field magnet setting)
- **Repeat the Jet polarization measurement <u>with beam</u>** (dedicated - 1 shift?)
  - Assess if we suffer any beam depolarization from the bunched beam (and intensity). Our expectation is no effect if running with 56 bunches. This has to do with the uniformity of the holding field magnet.
  - It does not matter if the beam is at injection or at store. However, it is of interest to do the same with the 200 Mhz system on.
  - The two RHIC beams should be separated by at least 1 cm horizontally.

# Silicon detectors

Estimate 1-2 weeks to fine tune the silicon detectors and readout. This partially overlaps with the jet tuning.

- Adjust grounding to assure maximal signal to noise ratio (this may require entry to the IR)
- Parasitically with beam on tune the silicon detectors to the elastic scattering process (timing and energy).
  - This can be done with a stored proton beam regardless of polarization or energy at injection or 100 GeV. The recoil proton energy and timing do not change drastically with energy.
- At this point we will be in a position to start using the jet polarization and a polarized beam to measure the Analyzing power of pp elastic scattering in the CNI region.
- We need a reliable mechanism to assure the beam is centered on the jet (BPMs and profile measurements)

# Beam Polarization measurements

- We estimate 1 week of dedicated running with one "stable" polarized beam (Blue Ring) to gather the necessary statistics for a 10% measurement of the beam polarization.

  - We would like to collect 10M elastic events.
  - $\delta\varepsilon = 3.10^{-4}$ and $A_N = 0.03 \Rightarrow \delta\varepsilon/A_N = .01$ Using $1x10^{11}$ per bunch, Jet density $2x10^{12}$ atoms per $cm^2$, this should take 24 hours. Assuming 50% accelerator up time and 50% detector efficiency, we are up to 4 days.
  - We will have target empty runs to assess the beam gas interactions.
  - Additional runs with different collimation.
  - Of course, the data will be collected with different jet polarization conditions.

- Because of the common WFDs, data will be collected alternately with the respective p-Carbon CNI polarimeter in order to calibrate that polarimeter. Several variations on this theme will be tried.

# Banking on Success

- We will move to the Yellow RHIC beam. In this case the recoil silicon detectors are positioned in the backward region, thus another background type measurement.
  - We need to remotely translate the jet from one beam line to the other.
- We would like to measure the effect of the bunched beam on the jet polarization with a 112-bunch fill. This impacts the uniformity of the holding field magnet. (about 1 shift)
- This is likely to overlap with plans to see what intensity per bunch and luminosity the collider can achieve with such a fill.

An advertisement:

A C-AD seminar on the Polarized Jet Target : Friday March 5th at 4 pm.
By Alexander Nass

# First Results on Polarization Dilution Measurements in the Polarized H-jet

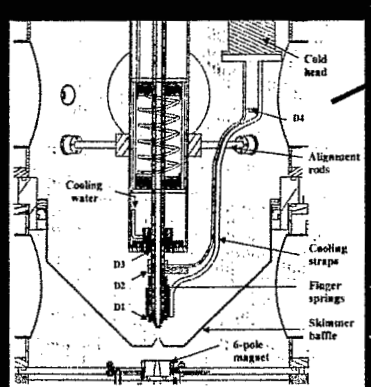
A. Zelenski, BNL

for
RHIC Spin Collaboration Meeting XXII
February 27, 2004
RIKEN BNL Research Center

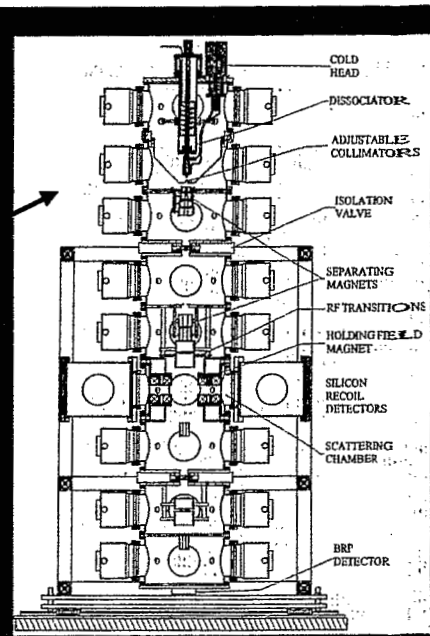
## H-jet beam studies.

- H-jet operation. Dissociator.
- QMA-quadrupole mass analyzer upgrade.
- Atomic beam velocity measurements.
- $H_2$/ H – ratio measurements at the collision point.
- QMA calibration.
- H-jet polarization.

## H - jet polarimeter.

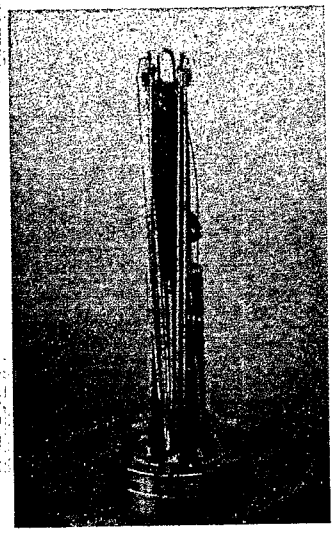


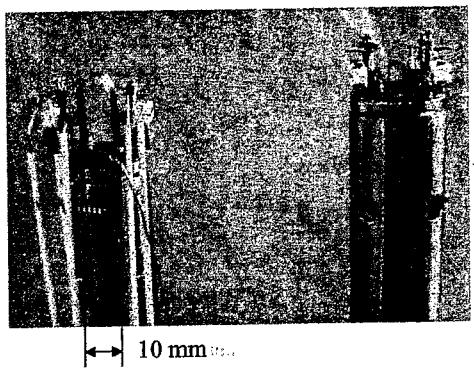

Dissociator




1

## QMA upgrade for H-jet measurements.

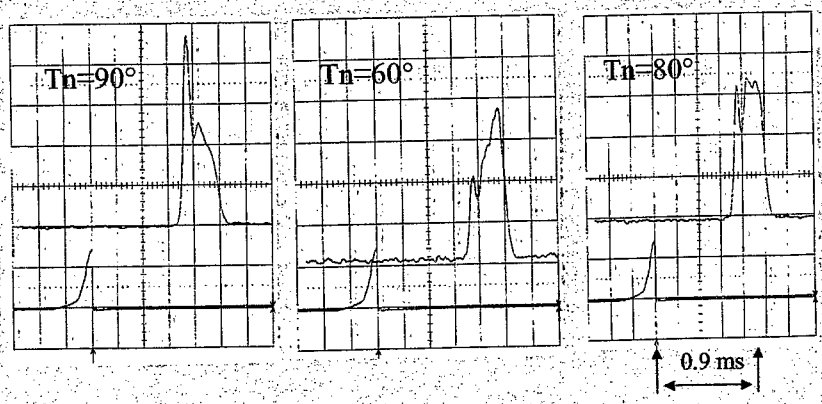





Original QMA geometry (right)
Expanded QMA sensitive volume (left)

## QMA atomic beam velocity measurements.

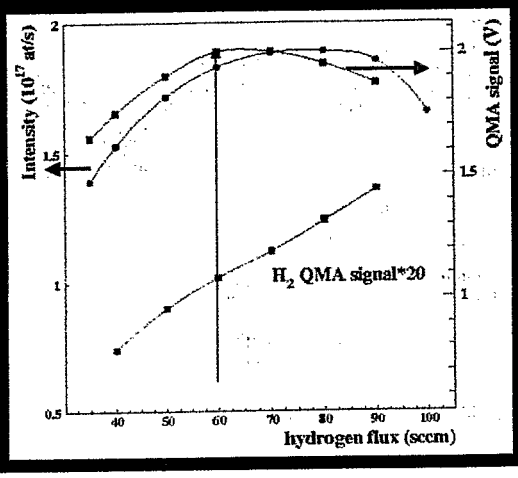
**L=135 cm- drift length.**




**Vb ~1500-1800 m/s**

2

## Atomic beam intensity and density measurements in the collision region




- H-beam intensity and density vs. H2 flow in dissociator.

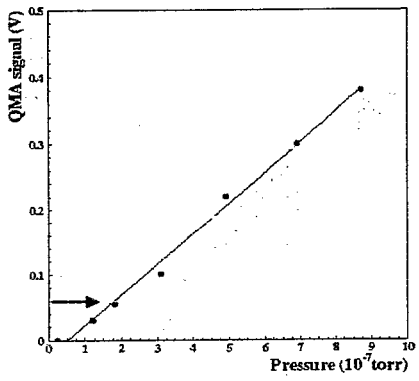
## QMA calibration.

$10^{-7}$ torr.$H_2$ ⇔

0.98· $10^{10}$ $H_2$/cm3

Measured H2 / H density ratio:

~1.5%× 2 → 3%- polarization dilution.




- QMA atomic beam signal vs. H2 partial gas pressure in the collision chamber.

## RESULTS.

- H-jet works continuously for two months.
- The beam intensity is very stable at best performance.
- The first beam velocity measurements gives:
  $V \sim (1.6\text{-}1.9)\cdot 10^5$ cm/s.
- The total H-jet thickness is about $1.5\cdot 10^{12}$ atoms/cm$^2$.
- The RF-transitions efficiencies were measured with BRP polarimeter at ~ 99.8%.
- $H_2/H \sim 1.5\%$ -ratio was measured in the collision region with the QMA, which gives about 3% polarization dilution.
- It gives 92±2% effective proton polarization at 1.0 kG holding field and 94 ±2% polarization at 1.4 kG field.

4

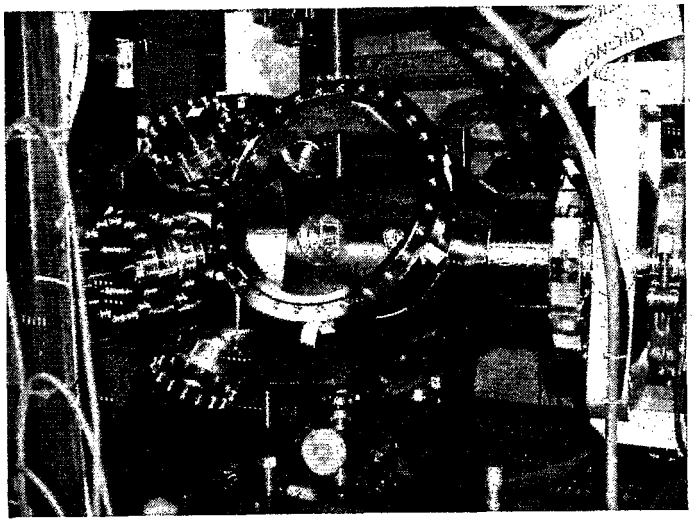
# AGS Polarized Proton Status

H. Huang

Haixin Huang
Feb. 26, 2004

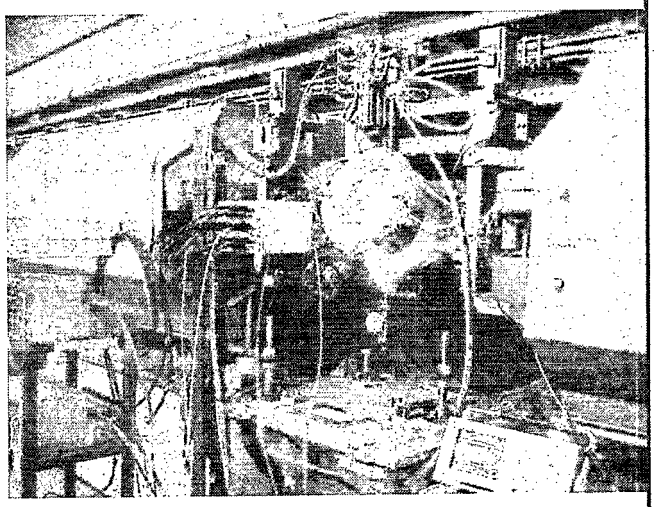
BROOKHAVEN NATIONAL LABORATORY

## AGS CNI Polarimeter (1)



## AGS CNI Polarimeter (2)

- Move the detectors away from beam by 3 inches.
- Installed targets and detectors on Feb. 18.
- Installed electronics on Feb. 26.



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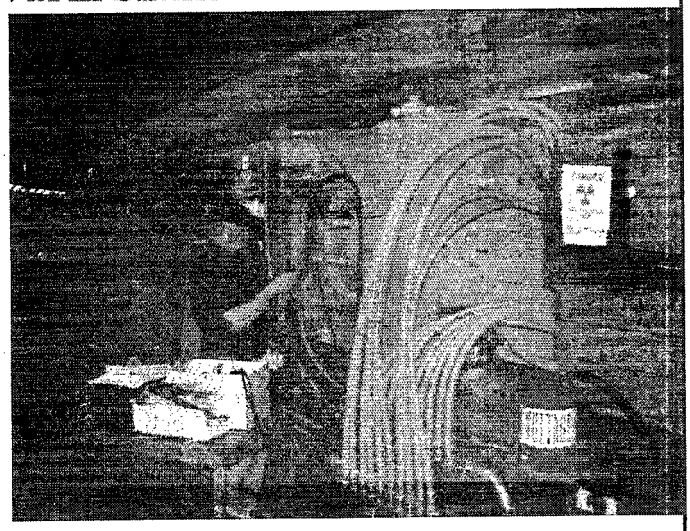
## AGS Helical Warm Snake

- All measured data are well predicted by 3d calculation. Integral field can be adjusted within about 100 Gauss-m, this means no orbit deflection.
- Magnet has been tested in the ring upto 2750A.
- Ready by March 3.



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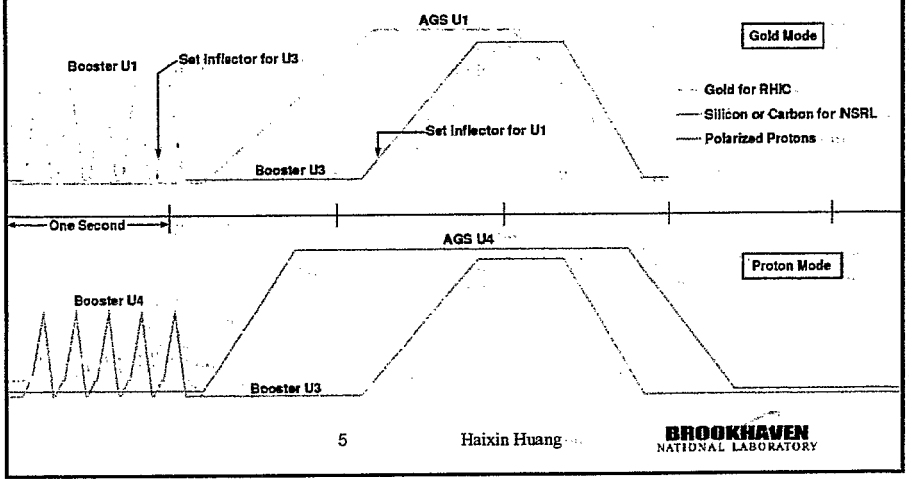
## Supercycles for RHIC, NSRL, and PP Operation.

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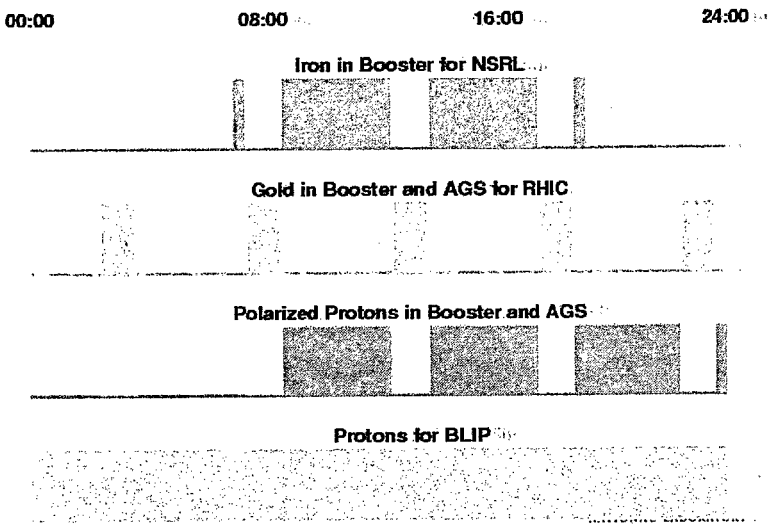
## Time Sharing of AGS and Booster



## Goal for Next a Few Days

- Establish beam in Booster extraction.
- Establish beam in AGS extraction (or some lower energy flattop, should be higher than transition so CNI polarimeter commissioning can be easier).
- Firing AC dipole pulses (to make sure any problem can be fixed on next maintenance day).
- Commissioning CNI polarimeter.
- Tuning E880 polarimeter.
- Booster harmonic scan.

# More Detailed RHIC Commissioning Plan

M. Bai, BNL

for
RHIC Spin Collaboration Meeting XXII
February 27, 2004
RIKEN BNL Research Center

# RHIC Polarized Proton FY04 Run Schedule

### *Content*

- Goal for FY04 Run
- Setup & configuration
- Strategies
- Run Plan

### *Goal for FY04 Run*

- 55 bunches with $1x10^{11}$ per bunch
- average current/ring: 70mA
- peak luminosity: $11x10^{30}$ cm-2s-1
- average luminosity
- explore the intensity limit

### *Setup & Configuration*

- Lattice (IP 6 8 10 12 2 4)
  - ❖ ❖ Injection: 10 10 10 10 10 10
  - ❖ ❖ Store: 1 1 3 10 3 10
- Beam energy
  - ❖ ❖ Injection: $G\gamma$=46.5
  - ❖ ❖ Store: $G\gamma$=191.5
- Working point:
  - ❖ ❖ Qx=28.73, Qy=29.72
- Golden orbit
  - ❖ ❖ Same as Run FY03 with additional 10mm H separation at IP 12
- snakes & spin rotators
  - ❖ ❖ snakes: on at DC from injection to flattop
  - ❖ ❖ spin rotator: on at DC from injection to flattop to allow experiments to take advantage of every store
- experiment magnets:
  - ❖ ❖ STAR: On at full field from injection to flattop
  - ❖ ❖ Phenix: On at full field from injection to flattop

### *Strategies*

- Ameliorate beam-beam effect
- IR non-linearity correction
- Beta squeeze along the ramp
- Better model engine
- PLL: feed-forward

*Run Plan*

- **April 2 – 2**
  - High current test of Snakes: George, Don Bruno, … 6 hours
  - Establish beam in Blue and Yellow at injection
    1. Injection lattice: Johannes
    2. AGS extraction and AtR tuning: Nick Tsoupas and RHIC shift crew
    3. Injection kicker timing fine adjustment: Fischer
    4. Snake turning on: Waldo
    5. RF work: M. Brennan
       - Capturing
       - Adjust the rf frequency to match the additional path length due to snakes: Johannes, Joe Delong
    6. time in bpms, esp. bpms at snakes: Todd
  - Machine tuning
    1. Orbit correction: Vadim
    2. Decoupling: Fulvia, Joanne, Wolfram, Todd, Yun, Mei
    3. chromaticity correction: Steve T.
    4. Optics measurement and correction: Rama, Todd, Steve T., Johannes, Mei
  - Instrumentation Setup
    1. Tunemeter(Artus): Angelika
    2. Schottky & PLL: Pete
    3. IPM: Roger, Steve
    4. WCM: Roger Lee
    5. CNI polarimeter: Osamu, Sandro, Haixin
  - Check the spin pattern request against the measured: Olsen, Haixin, Omar

- **April 3 -- 4**
  - Start ramp development with 6x6 bunches
    1. parameter:
       - working point: 28.73, 29.72
       - bunch intensity: reasonable
    2. fig. of merit:
       - good transmission efficiency
       - good polarization transmission efficiency
    3. strategy:
       - tune control along the ramp:
         - ⇒ model: Johannes
         - ⇒ PLL feed-forward: Pete Cameron
       - Orbit correction along the ramp: Vadim
         - ⇒ Goal: < 0.5mm rms orbit distortion, esp. at the three intrinsic spin resonances
           1. $G\gamma=64$
           2. $G\gamma=104$
           3. $G\gamma=179$

- Decoupling along the ramp: Fulvia, Todd, Wolfram, Yun, Mei
  - ⇒ ⇒ Empirical feed-forward skew quadrupole tuning
  - ⇒ ⇒ Skew quadrupole modulation: Yun
- Chromaticity along the ramp: Steve Tepikian
  - ⇒ ⇒ Both H & V chromaticity > 0.0

❖ ❖ Continue CNI Setup

❖ ❖ Polarization vs. working point at injection B&Y at injection: 2hours

1 1 after CNI polarimeter is ready

2 2 Scan vertical tune from 29.67 to 29.75, with the H tune stay > 0.01 away from vertical tune.

3 3 Keep the vertical tune fixed at the value which gives the best polarization, scan the H tune around the V tune to exam the coupling effect.

❖ ❖ tripplet vibration test(just before turning off RHIC for the shutdown): Christoph

1 1 stop the helium flow with beam at store 5-10minutes

2 2 take million turn by turn bpm data

- **April 5 – 7**

❖ ❖ Jet Target installation

❖ ❖ RF area

1 1 common cavity short-out

2 2 one of the yellow cavity(3.3) windows

❖ ❖ Experiments

1 1 STAR

2 2 Phoenix

❖ ❖ RHIC BPM work

1 1 move the BPM electronics out of the 7c alcove

❖ ❖ Spin rotator quench protection system work

- **April 8 – 12**

❖ ❖ Measure the path length change due to the snakes and rotators at injection

1 1 Measure rf frequency at injection with rf, snake and rotator off

2 2 Turn on the snakes and measure rf frequency with rf and rotator off

3 2 Turn on the rotators, measure rf frequency with rf off

❖ ❖ Retune the injection with the spin rotator on:

1 1 RF work

- Match the new path length with the rotator on

2 2 working point tuning, orbit correction, decoupling....

❖ ❖ Continue 6x6 ramp development with rotators on

1 1 RF radial loop on, master blue, slave yellow

2 2 Good transmission efficiency

3 3 Good polarization transmission efficiency

4 4 Establish collisions at store: Vadim, M. Brennan,

❖ ❖ Re-bucketing at store (without common cavities)

❖ ❖ Jet target tuning

1 1 may need a few hours of beam at injection for their tuning

- Store activity
  1. orbit correction
  2. decoupling
  3. IP steering
  4. IR non-linear correction
     - At IP6 &IP8
     - Measure DA without zero IR correction(10 minutes)
     - Set the sectupoles at IP6&8 with last year's operational settings, check the DA, and fine adjustments of the sextupole setting if necessary
     - Use the IR bump application to find the best skew sextupole setting as well as the octupole setting
     - Correct the higher order multiple predicted by the simulation(simulation with PP lattice, TBD)
     - Check the DA(1 hr)
       - ⇒ w/wo the correction to confirm
       - ⇒ w/wo collision to see the effect of beam-beam on DA

- **April 13 – 15**
  - Ramp development with 56 bunches
    1. Good transmission efficiency
    2. Good polarization transmission efficiency
       - tune control along the ramp
       - orbit correction along the ramp
       - chromaticity correction along the ramp
    3. orbit correction
    4. decoupling
    5. IP steering
    6. IR non-linear correction
    7. collimation setup
  - Jet target tuning
    1. will need about 0.5 hour with beam in collision at store

- **April 16 – 16**
  - Luminosity improvement
    1. Working point scan at store
       - Beam polarization vs. tune
       - Beam lifetime vs. tune
         - ⇒ beam in collision at all 4 IPs and measure the following figures for individual bunch which total has 2 collisions, 3 collisions and 4 collisions over one revolution, respective
         - ⇒ betatron tunes
         - ⇒ transverse emittances
         - ⇒ bunch length
         - ⇒ luminosity (TBD)

- ❖ ❖ push the bunch intensity limit at injection
  - 1 1 6 bunches with 2 x$10^{11}$ bunch intensity
  - 2 2 23 bunches with 2 x$10^{11}$ bunch intensity
  - 3 3 37 bunches with 1.5 x$10^{11}$ bunch intensity
  - 4 4 45 bunches with 1.2 x$10^{11}$ bunch intensity
  - 5 5 56 bunches with 1.0 x$10^{11}$ bunch intensity
  - 6 6 56 bunches with 2.0 x$10^{11}$ bunch intensity
  - 7 7 112 bunches with 1.0x$10^{11}$ bunch intensity
  - ⇒ ⇒ watch the vacuum pressure rise at various places as well as the experiment backgrounds
- ❖ ❖ OWL shift: Store for
  - 1 1 Jet target tuning: owl shift
    - ▪ ▪ measure the polarization with 56 bunches(blue) to see if there's any impact (1 shift is required)
  - 2 2 experiment data taking

- **April 17 – 20**
  - ❖ ❖ Polarization development: Waldo, Vadim, Johannes, Haixin, Mei
    - 1 1 Polarization ramp development
      - ▪ ▪ Polarization efficiency vs. orbit distortion at Gγ=104
      - ▪ ▪ Polarization efficiency vs. vertical betatron tune at Gγ=104
      - ▪ ▪ Polarization efficiency vs. horizontal betatron tune at Gγ=104
      - ▪ ▪ 56 bunch ramp with 1x$10^{11}$ bunch intensity
    - 2 2 store energy scan: Waldo, Johannes, Mike Brennan
      - ▪ ▪ both radial polarization and vertical polarization vs. slightly different store energy
    - 3 3 polarization profile scan
      - ▪ ▪ injection and store
      - ▪ ▪ Horizontal and vertical
  - ❖ ❖ OWL shift: store for
    - 1 1 Jet target tuning
    - 2 2 Experimental data taking

- **April 21 – April 28**
  - ❖ ❖ Jet target measurement
    - **1 1** 56 bunches with 1x$10^{11}$ bunch intensity at store
    - **2 2** CNI measurement for calibration
    - **3 3** Steady reliable and reproducible machine operation
  - ❖ ❖ STAR and PHENIX data taking
  - ❖ ❖ 112 bunch at store to see the effect on jet target (1 shift)

- **April 29 – May 2**
  - ❖ ❖ CNI polarimeter calibration using Jet target at injection (TBD)

- **May 3 – 6**
  - ❖ ❖ Spin tune measurement
  - ❖ ❖ Spin flipper commissioning

- **May 6 – 7 (last shift)**
  - ❖ ❖ Intensity limit exploration
    1. 56 bunches with 2e11 bunch intensity at injection
    2. 112 bunches with >1d11 bunch intensity at injection
    3. different fill pattern with high intensity bunch against the vacuum pressure rise
    4. beam scrubbing

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# Update from STAR

S. Trentalange, UCLA/BNL

*(see web site www.physics.ucla.edu/~trent/ for various talks and presentations)*

for
RHIC Spin Collaboration Meeting XXII
February 27, 2004
RIKEN BNL Research Center

# PHENIX Run 4 Preparation

2/27/2004
RHIC Spin Collaboration Meeting

Abhay Deshpande
Stony Brook University
RIKEN BNL Research Center

# PHENIX Aspirations

- An improved A_{LL} measurement for pi^{0} production
- Tests of new detector concepts for future spin runs
  - Relative Luminosity scintillator "telescope"
    - R&D Future relative luminosity monitor
  - Forward muon background measurement
    - R&D future muon trigger upgrade
  - (STAR) Scalar board tests and commissioning
    - R&D future relative luminosity monitor & detector correlations
- In Run 4 PHENIX should be ready for all of the above to have realistic chance of using this in Run 5 & later
- Allow enough time for Jet Target to be commissioned
  - *Unlikely: absolute scale for polarization from this run?*

## Summary: CAD run plan (Mei Bai)

- **Goals:**
  - 55 bunches with 1 x 10^{11} per bunch
  - Average current/ring: 70 mA
  - Peak luminosity: 11 x 10^{30} cm^{-2} sec^{-1}
  - Average luminosity (?)
  - Snakes (ON) and **spin rotators (OFF) --> We would like to have them ON!**



## Run 4 pp CAD Plan (Mei Bai)

- **Run Plan for 5 weeks (35 days)**
- **Week 1 (March 26-April 1, 2004)**
  - Jet target installation
  - RF common cavity work
  - Establish circulating beam in blue and yellow
  - Instrumentation setup
  - Machine tuning (orbit, working point,decoupling,optics)
  - Begin jet target tuning
- **Week 2 (April 2-9, 2004)**
  - New working point development at injection
  - Jet target tuning
  - Ramp development (6 bunches,transmission, polarization)
  - Ramp development (56 bunches, 1 x 10^{11} bunch intensity)

## Run 4 pp plan (Mei Bai)

- Week 3 (April 9-15, 2004)
  - Jet target tuning
  - Store activity: *beam lifetime, luminosity, background, polarization*
- Week 4 (April 16-22, 2004)
  - Polarization development
  - Store energy scan (radial and vertical polarization vs. slightly different store energies)
  - Jet target Measurement (56 bunches, CNI measurements)
  - Steady reliable reproducible machine operation
- Week 5 (April 23-30, 2004)
  - 112 bunches with 1 x 10^{11} per bunch
  - Different fill patterns
  - 56 bunches with 2 x 10^{11} per bunch
  - Spin tune measurement (1/2 day)
  - Spin flipper commissioning (1/2 day)

2/27/04 Abhay Deshpande 5

## What? Who? When?

- **Possibly ~45% polarization & ~1-2 pb^{-1} data (minimum)**
  - Longitudinal polarization: **A_{LL} pi^{0} production**
  - Try: improve up on the Run3 result by factors of ~3 in δA_{LL}
  - Ramps development with Spin Rotators ON **WEEK 2**
  - Needs Local polarimetry readiness **WEEK 2**
- **Detector tests for future runs:**
  - Luminosity telescope (X. Wei et al.)
    - **WEEK 1 INSTALL & DEBUG**
  - Forward muon arm upgrade (X. Wei et al.)
    - Installation time for hardware (2-3 days) and testing
    - **WEEK 1 INSTALL & DEBUG**

  } Fig->
  - STAR Scalar boards (Marcus W.,Robert B. et al.)
    - Intermediate board: GL1 board <--> Star scalars
    - Couple with Spin Sorting: **COMMISSION: WEEK 2 or 4**

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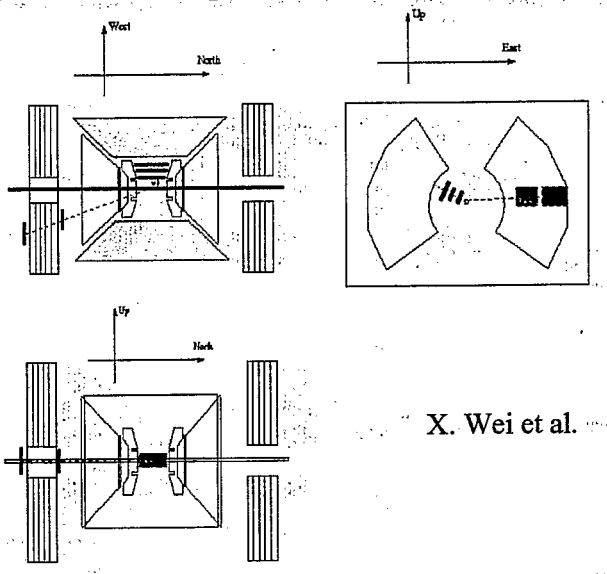
## Telescope & RPC locations




X. Wei et al.



## What? Who? When?

- PHENIX Other General readiness:
  - Spin sorting (Goto et al.) **Week 2**
  - Trigger **Weeks 1,2**
    - GL1P trigger board spin sorting (John L., Belikove, Yuji)
    - LVL1: mulDLL1 (John L. et al.)
    - LVL1: EMCal-RICH Trigger (ERT) (Kensuke, Frank et al.)
    - For future use: LVL2 trigger (Tony F. et al.)
      - tests planned in weeks 1-3
  - DAQ (EVB-Group)
    - For future use: Multi-event buffer
      - tests and development planned in weeks 1-3
  - Online Monitoring (Chris P. et al.)
  - We are encouraging all system specialists to be delay their vacations after a long Au-Au run
    - Especially after the possible 2 extra weeks at 63 GeV CM

## 1008 Activities Week-by-Week

- **Week 1 in parallel with jet installation (~ 3 days)**
  - Install luminosity telescope and RPC in MuID gaps
  - Fix ERT ROC & start tests
  - Install & check STAR scalar boards
  - DAQ/EvB development for future runs
- **Week 2**
  - Local polarimeter ready to function
  - DAQ/EvB development for future runs
- **Week 3**
  - DAQ/EvB development
- **Week 4**
  - Local polarimeter operational
  - Triggers setup (perhaps earlier)
  - DAQ needs to be ready for us
- **Week 5**
  - **Take data when possible**



## Optimist's view....

- If the polarization in Week 5 is ~(45-50)%
- We intend to ask for extra ~2 weeks of runs
  - This intent has already been expressed to the BNL management
- What can 2 times luminosity and 50% polarization do?
  - Figure of merit:
    - Sqrt[P_{y}^{2} * P_{b}^{2} * L dt]
    - *Assuming Run 3 luminosity:*
      *Sqrt[(50/27)^{2}] --> 3.7 improvement in the stat error*

**RHIC Spin Collaboration Meeting XXII**
**February 27, 2004**
**RIKEN BNL Research Center**

**LIST OF REGISTERED PARTICIPANTS**

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**RHIC Spin Collaboration Meeting XXII**
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RIKEN BNL Research Center
**RHIC Spin Collaboration Meeting XXII**
February 27, 2004
Bldg. 1005, Third Floor Conference Room
Brookhaven National Laboratory

*******AGENDA*******

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| | |
|---|---|
| 9:00 – 9:15 | Welcome & Coffee |
| 9:15 – 9:45 | Machine Status & Update.....W. Fischer |
| 9:45 – 10:15 | Updates on New Working Points & Beam Beam Tune Shift/Spread.....R. Tomas |
| 10:15 – 10:45 | Source Update and Plan.....A. Zelenski |
| 10:45 – 11:00 | Coffee Break |
| 11:00 – 11:30 | Jet Commissioning Scenarios.....Y. Makdisi |
| 11:30 – 12:00 | First Results on Polarization Dilution Measurements in the Polarized H-jet.....A. Zelenski |
| 12:00 – 14:00 | Lunch |
| 14:00 – 14:30 | Revised AGS Commissioning Plan.....H. Huang |
| 14:30 – 15:00 | More Detailed RHIC Commissioning Plan.....M. Bai |
| 15:00 – 15:15 | Coffee Break |
| 15:15 – 16:15 | Updates from Experiments<br>STAR.....S. Trentalange<br>PHENIX.....A. Deshpande |
| 16:15 – 17:00 | Discussions on FY04 Physics Data Taking within 5 Weeks and Beyond, and AOB |

*Next RSC Meeting ~ Friday, March 19, 2004 (to be confirmed)*
*See webpage http://www.bnl.gov/riken/RSC-meetings.htm for tentative agenda*

# RHIC Machine Status

Wolfram Fischer

**— Run Coordinator for Run-4 Gold-Gold Operation —**

**For the C-A RHIC Team**

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration Meeting
19 March 2004

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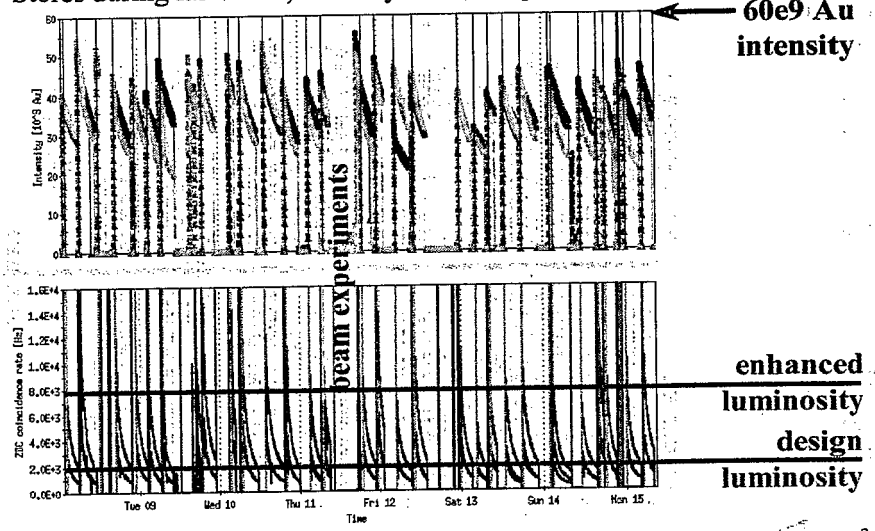
Content

1. Run-4 Au-Au luminosity development
2. Low energy run preparation
3. Summary

RHIC Run-4 17 March 2003

## Stores during last week, Monday to Monday

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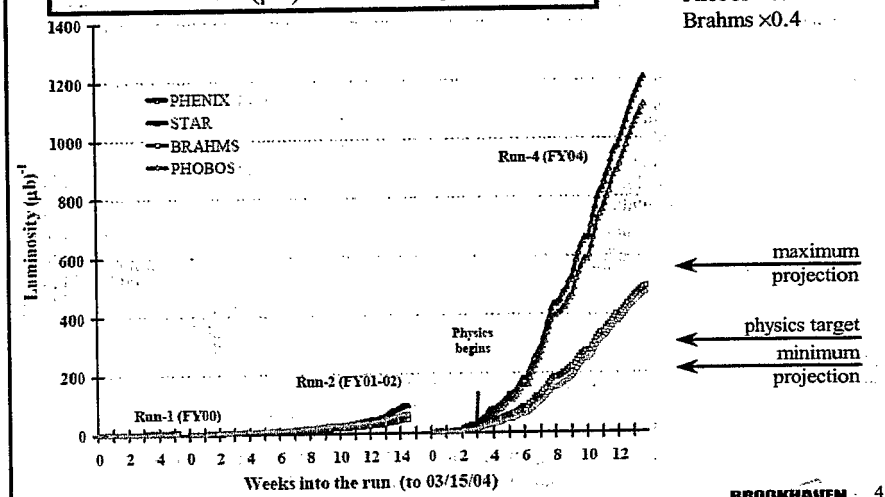
RHIC Run-4 17 March 2003

Delivered 1196 $(\mu b)^{-1}$ to Phenix [week ago : 1060]
136 $(\mu b)^{-1}$ last week [best week: 158]

As of 03/14/04 24:00
Star ×0.9
Phobos ×0.3
Brahms ×0.4

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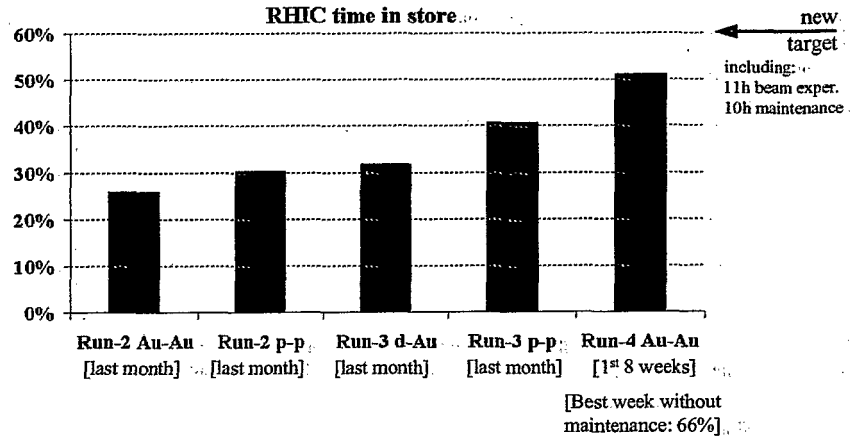
2



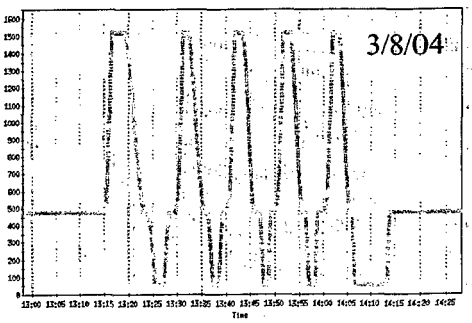

Comments:
- Not all store time used by experiments (initial background, detector turn-on, etc.)
- Usable store time differs from experiment to experiment





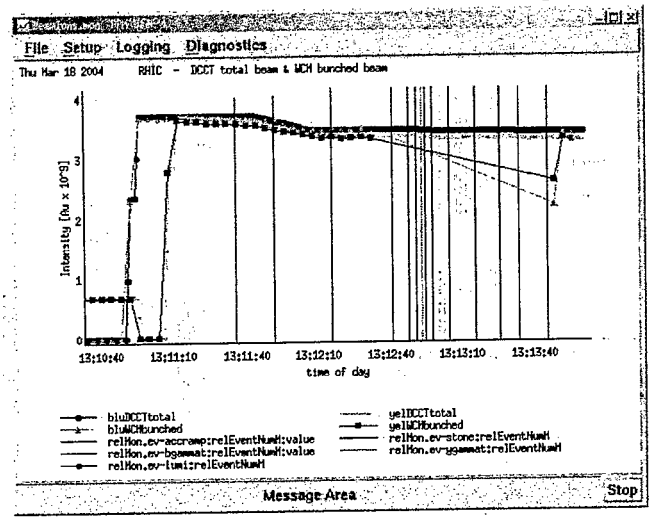
# Low energy run: 31.2GeV/u total beam energy

- Tested ramp without beam (Al, George, Johannes)
- Thursday: test ramp with beam (10 hrs)
  → Accelerated and stored beam, started rf re-commissioning
- Wednesday 24-March, 8am: switch to low energy
  → Need to reach production fast, only small changes after setup
  - 24h shifts scheduled for 3 days
  - Finish ramp development
  - Re-commission rf storage system
  - Other systems (ZDC, BLM gap cleaning, collimation)



RHIC Run-4 Set-up for 62.4GeV/u cm energy

## 1st ramp to 31.2GeV/u successful




M. Bai
J. van Zeijts
G. Ganetis
A. Marusic

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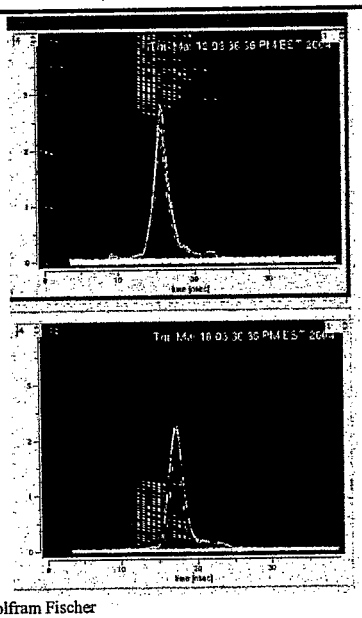
RHIC Run-4 Set-up for 62.4GeV/u cm energy



## Beam rebucketed at lower energy

M. Brennan
M. Blaskiewicz

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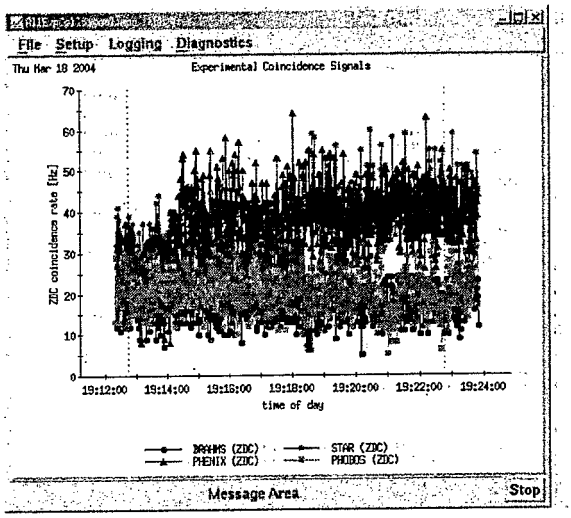
About 50Hz ZDC rates (gains not adjusted, 23 bunches/ring)




T. Satogata
J. van Zeijts





- Delivered Au-Au luminosity exceed most optimistic assumptions: delivered >1200(μb)$^{-1}$ to PHENIX in 11 weeks (almost the same to STAR, 1/3 to BRAHMS and PHOBOS)
- Calendar time in store increased to 50%
- Low energy run setup on track

# News from AGS Polarized Protons Run

H. Huang

Haixin Huang
Mar. 19, 2004

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# Depolarizing Resonances in the AGS

**Imperfection Resonances**

arising from sampling of error fields, fields due to closed orbit errors, etc.

$G\gamma=n$ (integer) $G\gamma=5,6,\ldots 46$ partial snake

**Intrinsic Resonances**

arise from sampling of focusing fields due to finite beam emittance.

$G\gamma=kP\pm\nu_y$

Strong ones: $G\gamma=0+\nu_y, 12+\nu_y, 36\pm\nu_y$; AC dipole

Weak ones: $G\gamma=24\pm\nu_y, 48-\nu_y$ crossing speed as fast as possible

horizontal betatron motion coupled to the vertical betatron motion by some coupling elements: solenoid

$G\gamma=kP\pm\nu_x$ $G\gamma=0+\nu_x, 12+\nu_x, 36\pm\nu_x$ Crossing speed as fast as possible

Polarization after passing an isolated resonance with strength $\varepsilon$ and crossing speed $\alpha=Gd\gamma/d\theta$ is given by Froissart-Stora Formula:

$P_f/P_i=2\exp[-\pi|\varepsilon|^2/(2\alpha)]-1$

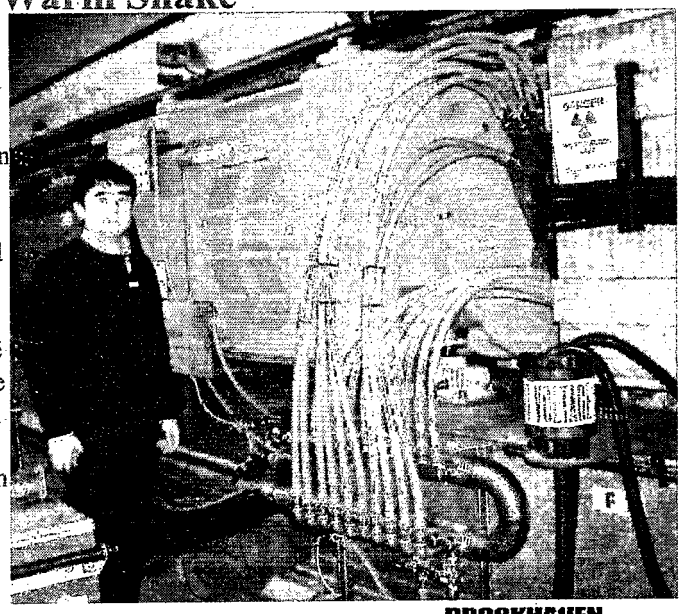
$\pi|\varepsilon|^2/(2\alpha)<<1$, $P_f/P_i\rightarrow 1$;

$\pi|\varepsilon|^2/(2\alpha)>>1$, $P_f/P_i\rightarrow -1$.

2 Haixin Huang BROOKHAVEN NATIONAL LABORATORY

# AGS Helical Warm Snake

- Funded by RIKEN.
- With the new warm snake, coupling between the two transverse motions are greatly reduced. We don't need to compromise snake strength anymore.
- The commission of the new warm helical snake started March 5 with proton beam.
- Magnet has been run in the ring at 2700A.



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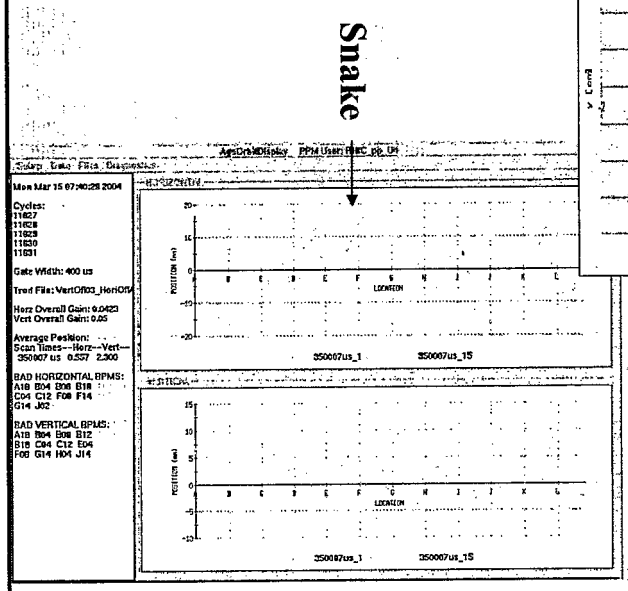
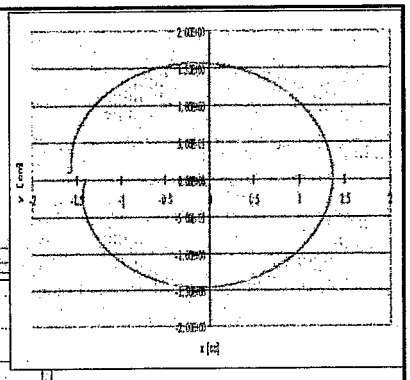
# AGS closed orbit with snake on



**Orbit in the snake With full current (from Junpei)**

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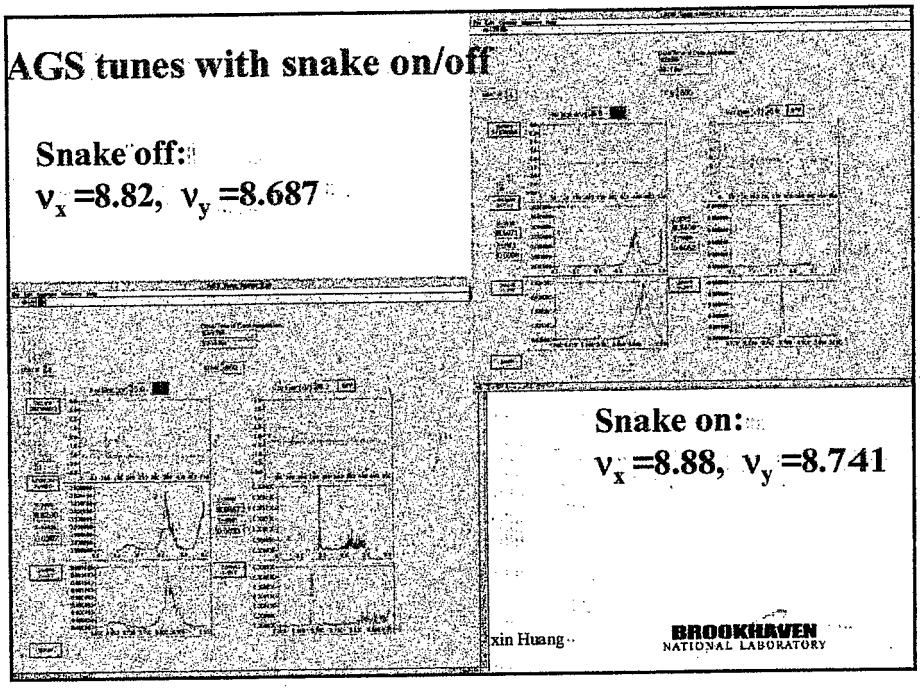
## AGS tunes with snake on/off

**Snake off:**

$\nu_x = 8.82$, $\nu_y = 8.687$



**Snake on:**

$\nu_x = 8.88$, $\nu_y = 8.741$

xin Huang

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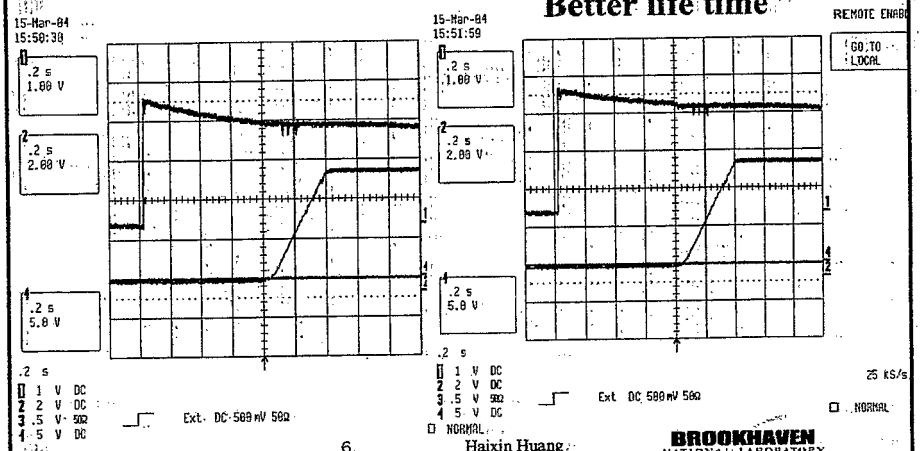
## AGS intensity with snake on/off

**Snake off**

**Snake on**

**Better life time**

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Haixin Huang

BROOKHAVEN NATIONAL LABORATORY

## Job List

- Establish beam in AGS extraction with good intensity. ✓
- Calibrate the Gauss Clock Counts for the new main magnet function to set the timing of AC dipole pulses. ✓
- Careful tune optics to give healthy AC dipole pulses to overcome four strong intrinsic resonances, which include vertical and horizontal tunes, vertical and horizontal chromaticities. ✓
- Adjust the driving tunes for all four ac dipole pulses to maximize the ac dipole driving field. ✓
- Correct orbit with the helical snake on and minimize the coupling with skew quads. ✓
- Booster harmonic scan to eliminate polarization loss in the Booster. ✓
- AC dipole pulse timing scan at various resonances.
- Fine tune the ac dipole pulses to eliminate emittance growth if any.
- Correct 8th and 9th harmonics along the ramp.



## Polarization at Gγ=7.5

- Polarization at Gγ=7.5 was measured as 77+-1.8(stat)+-4.7(sysm)% with E880 polarimeter. The sign is flipped from injection as expected. If assuming the analyzing power is proportional to 1/p, the polarization at injection can also be estimated.
- Gγ=4.5 is better than Gγ=4.7 or better polarization from the source?

| Energy | Polarization | 200MeV Polarization | Pol. Last year |
|---|---|---|---|
| 7.5 | (77.0+-1.8+-4.7)% | (71.4+-0.6)% | (73.6+-0.4+-4.5)% |
| 4.5/4.7 | (-74.1+-1.4+-4.5)% | (72.3+-0.7)% | (-71.5+-1.9+-4.5)% |

## Difference this year

- Of course the new warm snake. Much less coupling from this snake. There are several benefits:

1. We can run the snake as strong as we want without concerning the coupling resonances.
2. The effect from horizontal dimension is small, so less parameters to worry about (horizontal emittance, horizontal tunes).

- Faster Bdot (faster resonance crossing rate).
- No scraping in the Booster (higher intensity easily)
- CNI polarimeter perform well with the higher intensity.

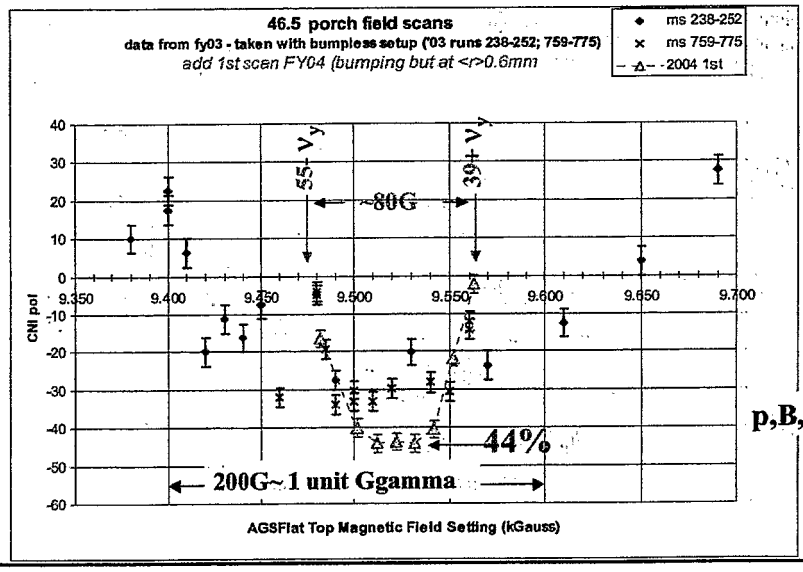


## Polarization at Gγ=46.5

- 0.1+-2.5% with snake off, ac dipole on.
- 0.4+-2.5% with snake on, ac dipole off.
- One single comparison between CNI and E880: 32.3+-2.3% vs. 32+-5%.
- With each of the ac dipole on/off measurement(before reaching 44% in AGS, about 30% at the time), the vertical emittance can be estimated.
- It suggests that there is no effect from 36+ $\nu_y$: timing is off, driving tune is off, emittance too large.

| Resonance | Flip Efficiency | Emittance | |
|---|---|---|---|
| $0+\nu_y$ | -0.600 | $16.2\pi$ | Not well corrected? |
| $12+\nu_y$ | 0.633 | $7\pi$ | |
| $36-\nu_y$ | -0.198 | $7.5\pi$ | |
| $36+\nu_y$ | -0.96 | $58\pi$ | Not well corrected |

# Polarization at AGS extraction vs. B field




p,B,r,f

# Comment

- A_N has been raised by 10% from last year.
- The polarization seems more stable comparing to last year.
- The relative shift of plateau between last year and this year is understandable, since the energy is determined by both B field and radius.
- Spin sign should flip every unit of Gγ, or about 200G. In between, when the beam energy stays at weak resonance at 46.3 (55-$\nu_y$) and 46.7 (39+ $\nu_y$), beam can be depolarized. This distance should be about 80G. Since this is an incomplete field scan, the full structure is not seen in this plot.
- The plateau of high polarization is smaller this year. This may indicates that the strength of all resonances are enhanced by the new warm snake.

# AGS Parameters

| | Last Year | So Far This Year |
|---|---|---|
| Polarization | 45+-2.6% | 44+-2.3% (10% higher $A_N$) |
| Intensity | $0.6*10^{11}$ | $1.1*10^{11}$ |
| Vertical Emittance | 6 π | 7 π? |
| Horizontal Emittance | 12 π | 30 π |
| Coherence at 0+ | 9.8mm | 10mm |
| Coherence at 12+ | 8mm | 7mm (weaker and shouldn't) |
| Coherence at 36- | 5.3mm | 5.5mm |
| Coherence at 36+ | 5.5mm | 6mm |
| Snake Strength | 4% early 5% later | 8% injection, 6% top |



# What Else Will We Do?

- Timing scan for each resonance.
- Optimize the coherence at each intrinsic resonance, the coherence monitor just available on Tuesday.
- Avoid emittance blow up if any ( no vertical profile measurement before today); minimize vertical emittance.
- Higher extraction energy? (to increase resonance crossing rate at 36+ν; but it is less an issue if no coupling resonance around)
- Correct orbit along the ramp. (less important with 6% snake and little coupling)
- Ramp measurement to make sure there is no drop of polarization at 36+ν and find out where we lose polarization.
- Use the new foil in LTB to reduce the emittances.
- Explore relation between polarization and both horizontal and vertical emittances.
- Explore relation between polarization and beam intensity.
- Explore multiple bunch injection scheme.

# RHIC Snake Quence Protection Update

G. Ganetis, BNL

*(talk unavailable at time of publication)*

for
RHIC Spin Collaboration Meeting XXIII
March 19, 2004
RIKEN BNL Research Center

# Updates on RHIC Commissioning Plan

M. Bai, BNL

*(see http://www.agsrhichome.bnl.gov/AP/Spin2004)*

for
RHIC Spin Collaboration Meeting XXIII
March 19, 2004
RIKEN BNL Research Center

# "Final" Result from RHIC pC CNI

Osamu Jinnouchi (RIKEN BNL Research Center)

*RHIC-Spin-Collaboration Meeting*

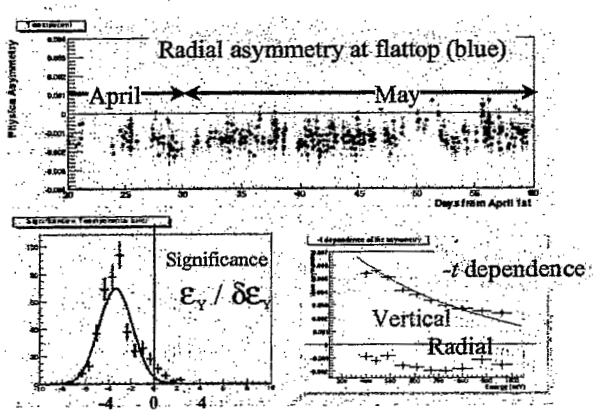
*Mar. 19, 2004*

## *Towards the final result*

- Goal/Aim of this work
  - Provide the stable, reliable polarization info with properly estimated systematic errors
  - Understand the origin of the systematic errors, correct them if possible
- Advances of Run-03 data from Run-02
  - In Run-02, Systematic error was estimated with run-by-run fluctuations and bunch shuffling because of the limited info (scaler data – phenomenological approach)
  - In Run-03, event-by-event data enables further detailed study

## *Issues known during the Run-03 (radial component)*

- Radial polarization component was observed throughout the run
- The shape of $-t$ dependence indicated a non-CNI origin
  (Similar flat $-t$ dependence was also seen in yellow flattop)

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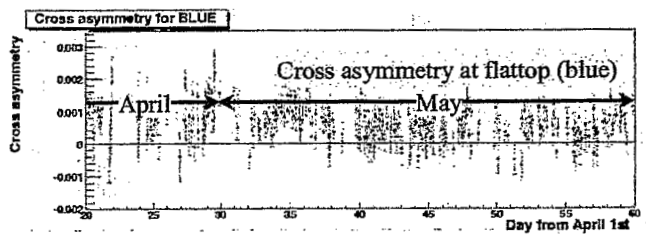
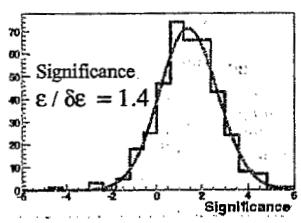
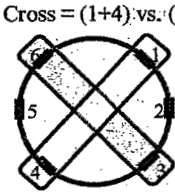
## *Issues known during the Run-03 (Cross asymmetry)*

- Cross asymmetries were constantly observed throughout the run
- It meant that $A_N$ for the detectors were not balanced




Cross = (1+4) vs. (3+6)

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## *Consider each Si strip as an Individual Polarimeter*

- Square-root-formula (X,Y,Cross,etc), $\chi^2$-fit ($\phi$-fit) always require a set of detectors to calculate asymmetry, and it is not easy to directly specify which detectors (strips) are bad and how much they are

- New diagnostic method is to use each Si-strip as an individual polarimeter, but still keep the cancellation mechanism on acceptance and luminosity asymmetry

- $P_i = (U(i) - R*D(i)) / (U(i) + R*D(i)) / A_N(i)$

  U(i), D(i) : i-strip carbon counts

  $R = \Sigma U(i) / \Sigma D(i)$ : luminosity ratio

  $A_N(i)$ : Analyzing power of i-strip

- Some results with Scaler data were shown last year, the following results were based on Event-mode data (with new calibration)



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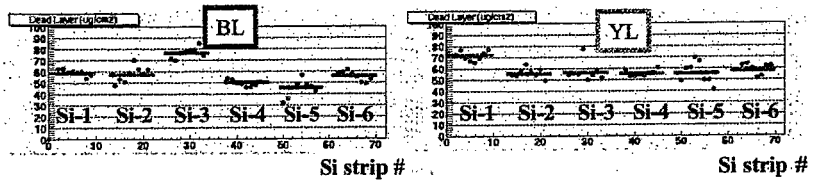
## *Si dead-layer corrections*

- (Off-line procedures how to determine d-layer were shown in Jan.)
- Widths are distributed 50-80ug/cm$^2$.
- Size of the fluctuations is ±5μg/cm$^2$ which is about the same uncertainty of Run-02
- Averaged values for each Si (not each strip) were fixed and used for all the analysis
- Shifted energy spectrum by ~100keV, make $A_N$ smaller (~10%)




- Time zero is adjusted for each run, each strip, and the kinematical function is always on the Carbon mass peak
- $A_N$ fit E950 was revised → $A_N$ became larger (~10%)



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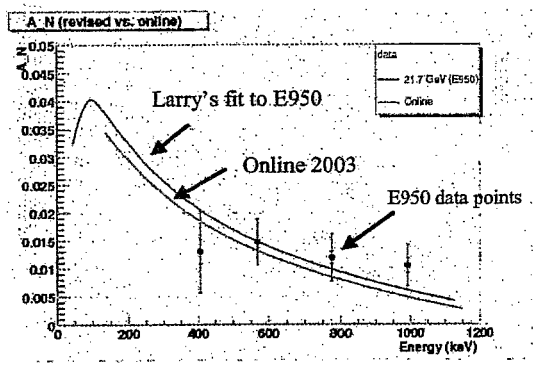
## *Revised analyzing power*




- Online results were based on the wrong AN(red curve)
- AN for the given run is calculated with weighted sum of this curve
- Increasing by about 10% in AN implies the reduction of polarization result by 10%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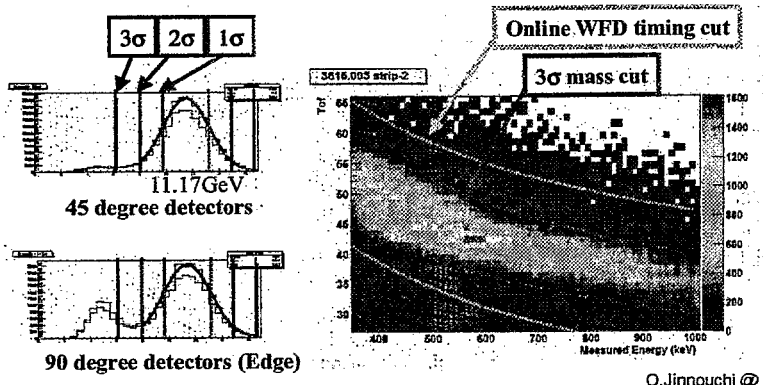
## *Event selection with Carbon mass*

- Online event selection was defined by time window (±12nsec)
- By using the mass for event cut criteria, signal/noise ratio could be improved
- Mass resolution differs run by run, and also depending on the Carbon energy. These effects are taken into account





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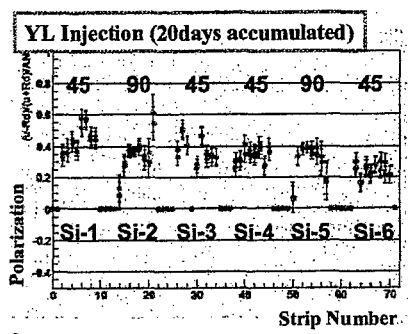
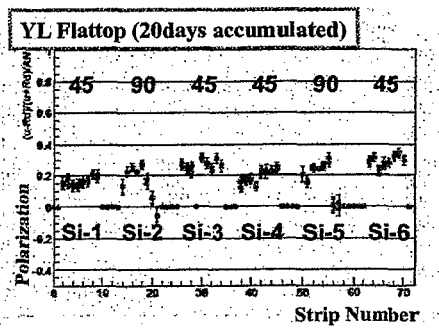
## *Strip-by-Strip polarization (YELLOW)*

- P(i) is calculated for each strip for different mass cut
- With the normalization, the flat distribution is expected
  - For 45 degree detectors $A_N$ is reduced by $\sqrt{2}$
  - Sign is flipped for left side detectors (Si4-6)
- The values are rather stable for different cuts

● 1.5σ cut
● 3.0σ cut

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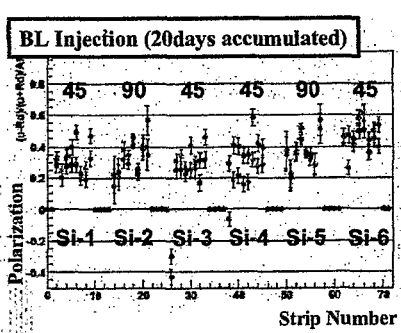
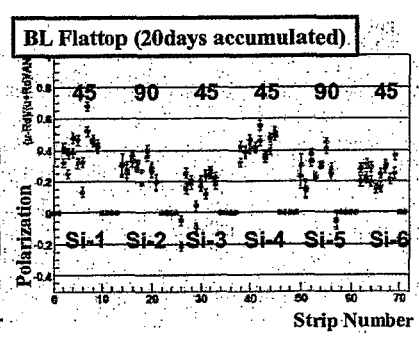
## *Strip-by-Strip polarization (Blue)*

- The results are very unstable and there is strong correlation to the mass cut
- The values looks unreasonable for several detectors far beyond statistical uncertainty

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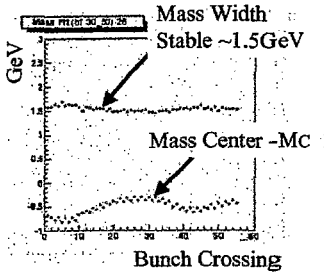
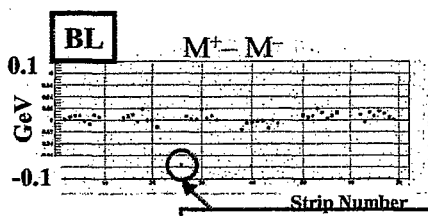
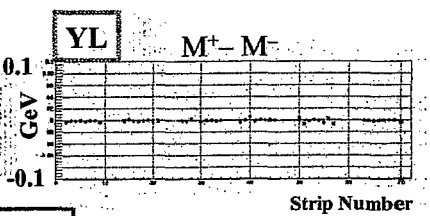
## *Bunch (Spin) dependence of the carbon mass*

- One particular strip in blue CNI sees extremely large difference btw plus/minus bunches (→ will be eliminated from all the analysis)
- Some strips (in blue CNI) see small but the same effect
- Obviously there is large fluctuation in regards to Carbon mass value (either T.o.f. or Energy is moving)




(see next page for zoomed plots)




Should be excluded from analysis

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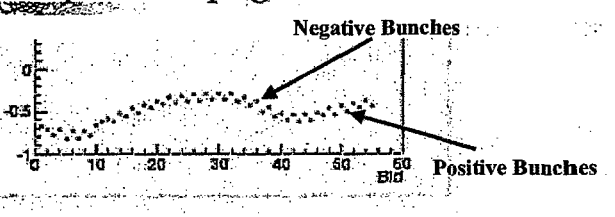
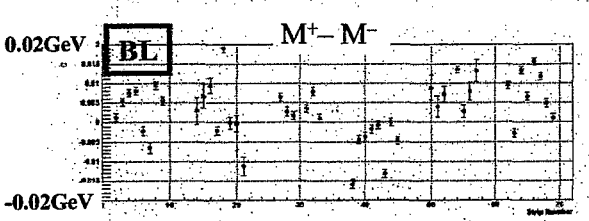
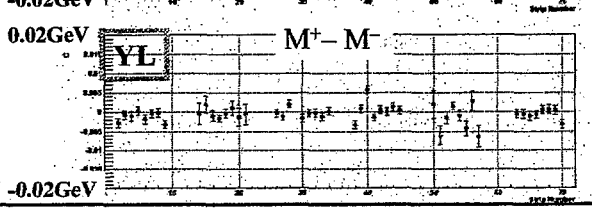
## *Zoom up of the previous page*

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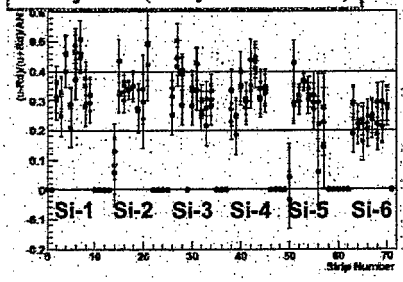
## *Comparison btw different mass cut (Yellow)*

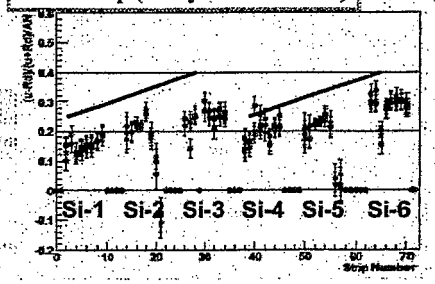
- Corrections on the mass peak improves the cut dependence
- There is small structures in the case of flattop which indicates the radial asymmetry component
- The edge strips (2 strips in both edge) in 90 degree detectors always behave differently, we decided to exclude them from polarization analysis

- **1.0σ cut**
- **2.0σ cut**
- **3.0σ cut**

**YL Injection (20days accumulated)**




**YL Flattop (20days accumulated)**

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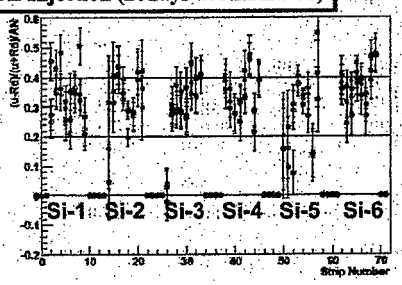
## *Comparison btw different mass cut (Blue)*

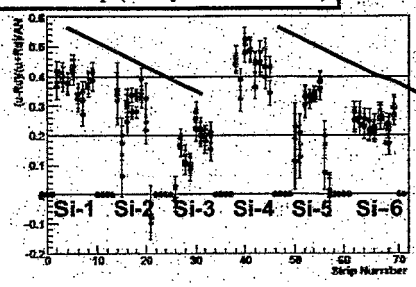
- In case of blue CNI, the improvements are much clear
- There are repetitive structures in flattop
- Two edge strips in 90° and the 1st strip of Si-3 should be neglected

- **1.0σ cut**
- **2.0σ cut**
- **3.0σ cut**

**BL Injection (20days accumulated)**




**BL Flattop (20days accumulated)**

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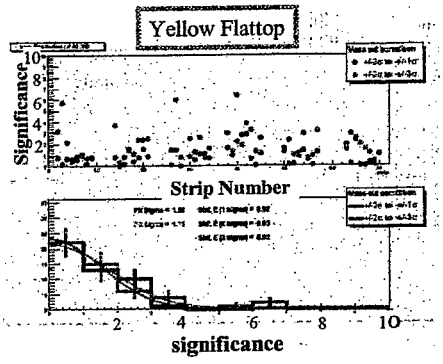
## *Statistical significance from different cut*

- With the following formula, the statistical significance can be assessed (for the case, one data set is the subset of the other)
- Sig. = $|\varepsilon 1 - \varepsilon 2| / \sqrt{(\sigma_{\varepsilon 1}^2 - \sigma_{\varepsilon 2}^2)}$
- $\sigma_{gauss}=1$ is expected for stat. only
- Excess could be considered as systematic errors
  $\sigma_{sys} = \sqrt{\sigma^2 - 1} \times \sigma_{stat}$
- Yellow --- 0.5% (FL) 1.5% (IJ)
- BLUE --- 1.1% (FL) 1.3% (IJ)
  in polarization

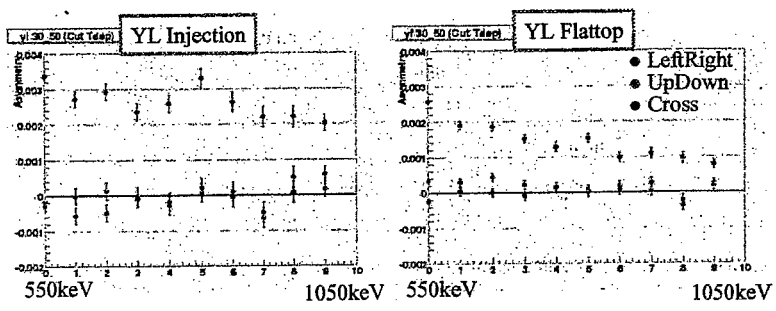



Red – +/-2σ to +/-3σ
Black – +/-2σ to +/-3σ



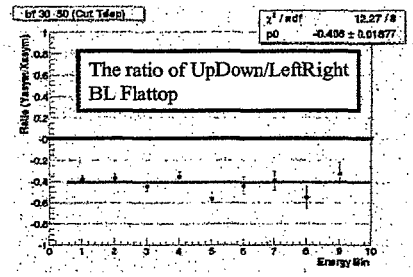
## *-t dependence of the X/Y asymmetry (Yellow)*

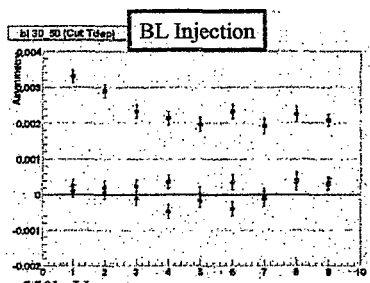
- In yellow flattop, radial component is observed
- Cross asymmetry is around zero

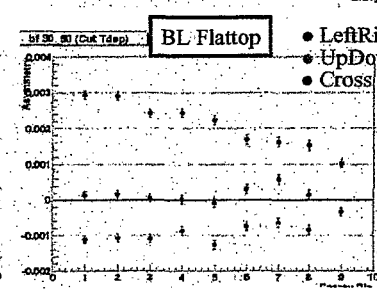


## *-t dependence of the X/Y asymmetry (Blue)*

- The radial component has $-t$ dependence and the shape is similar to the vertical component
- The cross asymmetry is around zero



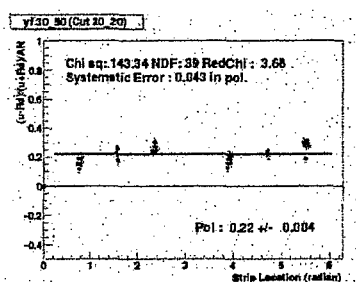




- LeftRight
- UpDown
- Cross

17 550keV 1050keV 550keV 1050keV RSC Mar. 19, 2004

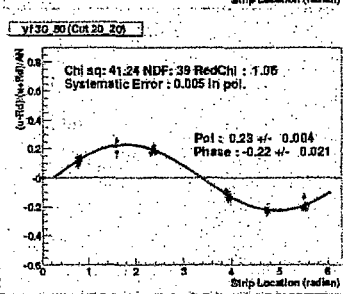
## *Systematic error estimations from two scenarios (Yellow Flattop)*




- Try to fit with two assumptions
- Systematic error is estimated with $\sigma = \sqrt{(\chi_{fit}^2 - 1)} \times \sigma_{stat}$
- Two edge strips are removed

Vertical Pol. Only

+/- 4% polarization error (out of 22%)




Allow radial components

+/- 1% polarization error (out of 23%)
12° toward inside of the ring

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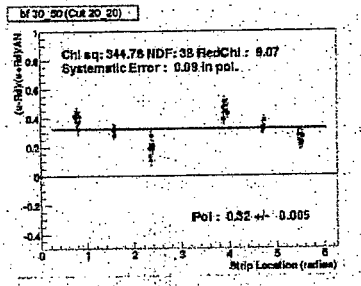
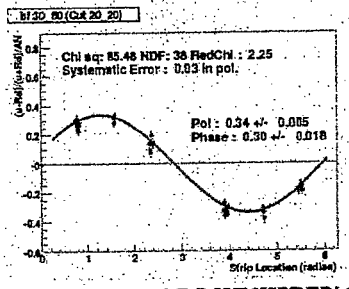
## *Systematic error estimations from two scenarios (Blue Flattop)*




- The systematic errors largely differ depending on the assumptions

**Vertical Pol. Only**

+/- 9% polarization error (out of 32%)




**Allow radial components**

+/- 3% polarization error (out of 34%)
17° toward inside of the ring

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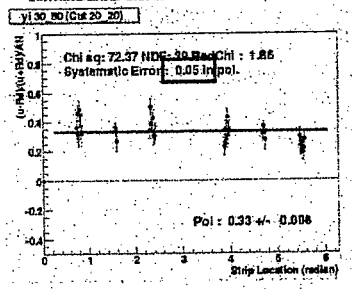
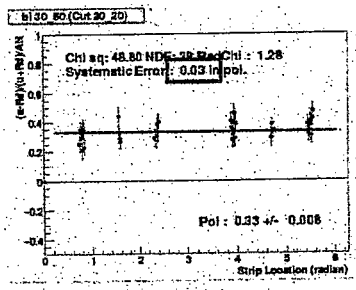
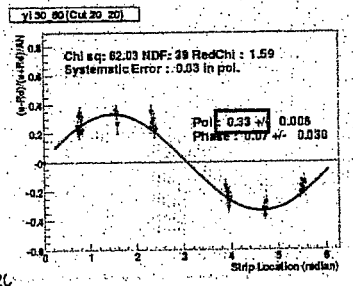
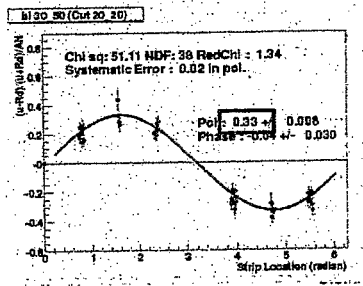
## *Cases for injections*




20

...chi @ RSC
Mar. 19, 2004

## *Summary*

- Procedure has been established to stabilize the CNI measurements
- The major systematic error components are estimated
  - Vertical only (Flattop)
    - BL – 9% (out of 32%)
    - YL – 4% (out of 22%)
  - Allow radial (Flattop)
    - BL – 3% (out of 34%)
    - YL – 1% (out of 23%)
- Event selection dependence is small
- Applying the procedure is rather straightforward
- The run-by-run (fill by fill) results for experiments will be done soon (including the bunch selection)



O.Jinnouchi @ RSC
Mar. 19, 2004

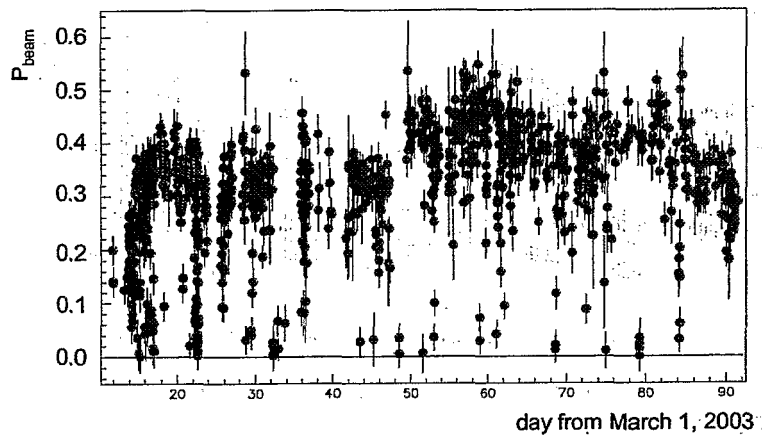
# AGS CNI Polarimeter FY03 Results

Jeff Wood, UCLA

## Outline

- Overview of 2003 data
  - Polarization history in AGS
  - A at various beam energies
  - Polarization during AGS ramp
  - AGS-RHIC Comparison
- Finalizing data
  - Background Studies
  - Energy Calibration

# 2003 AGS Polarization vs. Day




- Provided feedback ⇒ tune many machine parameters
- Polarization generally increased throughout the run

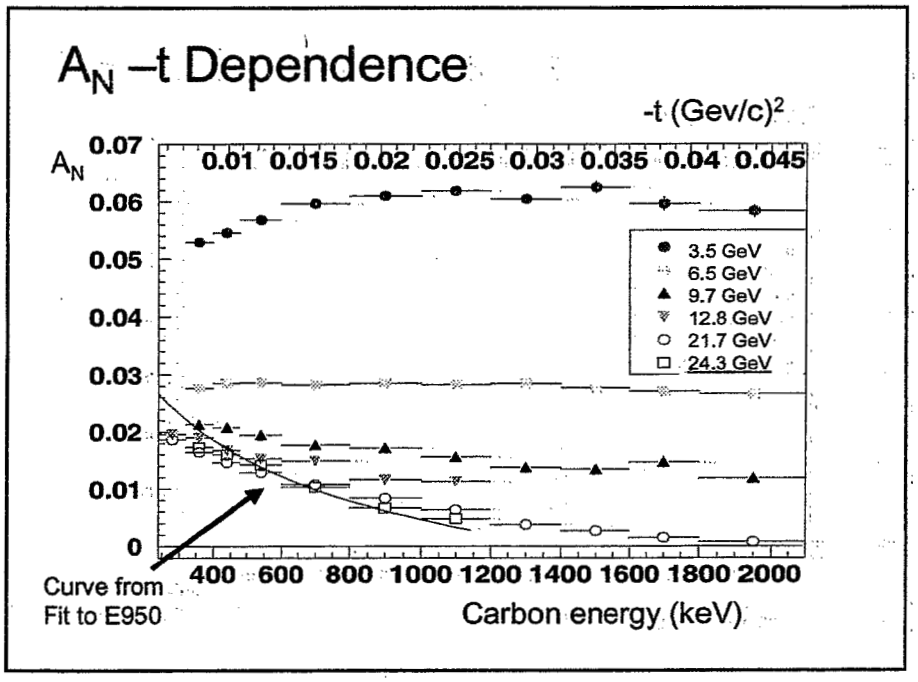
# CNI $A_N$ Calibration with E880

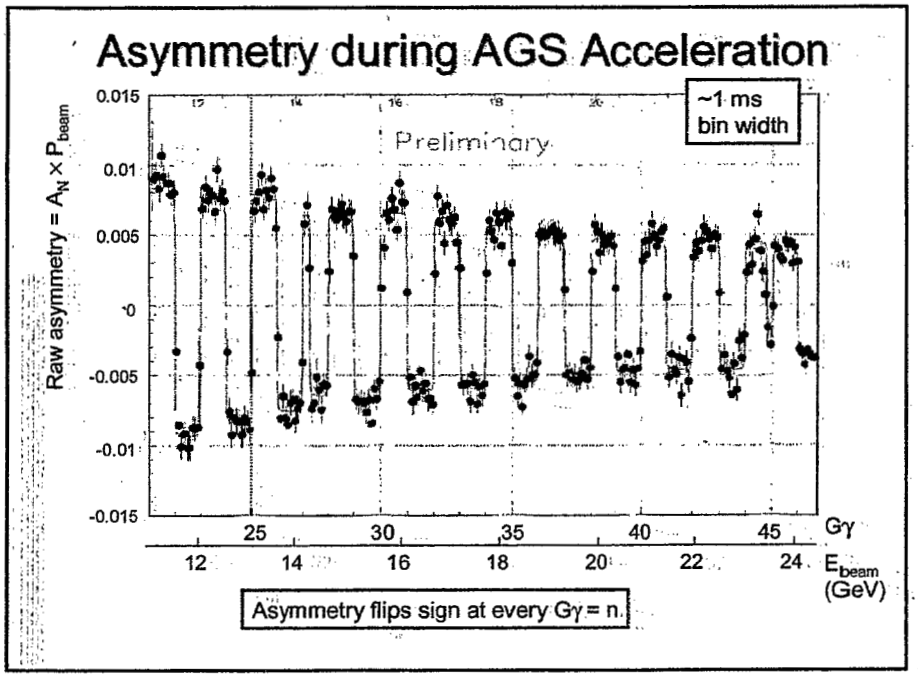
* Uncertainty from E880 $A_N$ not included

For $-t = 0.009 - 0.022\ (\mathrm{GeV}/c)^2$

| $G\gamma$ | date | E880 P* | CNI $A_N$ (%) |
|---|---|---|---|
| 7.5 | May 15 | 73.6 ± 0.29 | 5.87 ± 0.02 |
| 12.5 | May 17, 21 | 67.7 ± 0.9 | 3.05 ± 0.04 |
| 18.5 | May 28 | 64.6 ± 1.4 | 1.83 ± 0.04 |
| 24.5 | May 30 | 64.1 ± 2.1 | 1.43 ± 0.05 |
| 41.5 | May 27, 28 | 48.8 ± 1.9 | 1.06 ± 0.04 |

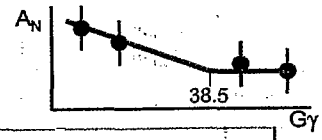
$A_N$ at 46.5: fit to E950 data (L. Trueman hep-ph/0305085)
$\langle A_N \rangle = 1.16\%$

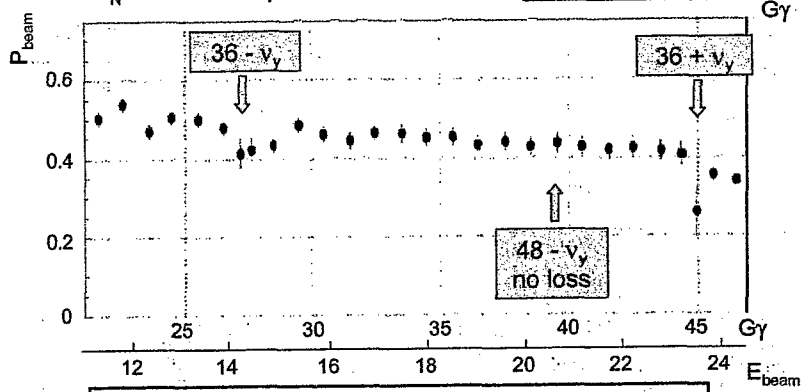

$A_N$ –t Dependence
-t (Gev/c)$^2$
$A_N$
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.01 0.015 0.02 0.025 0.03 0.035 0.04 0.045
3.5 GeV
6.5 GeV
9.7 GeV
12.8 GeV
21.7 GeV
24.3 GeV
400 600 800 1000 1200 1400 1600 1800 2000
Curve from
Fit to E950
Carbon energy (keV)


Asymmetry during AGS Acceleration
~1 ms
bin width
Preliminary
Raw asymmetry = $A_N \times P_{beam}$
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
25 30 35 40 45
Gγ
12 14 16 18 20 22 24
$E_{beam}$
(GeV)
Asymmetry flips sign at every Gγ = n.

# Polarization during AGS Acceleration

Model for Gγ dependence of $A_N$
- Interpolate $A_N$ from measurements at Gγ = 18.5, 24.5, 41.5 and 46.5
- $A_N$ constant for Gγ = 38.5 – 46.5

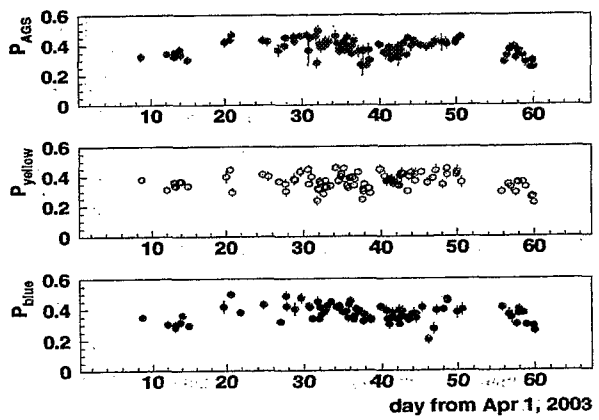



- Consistent with smooth polarization loss from 11 to 23 GeV
- ~15% relative loss at strong intrinsic resonance 36 + ν

# AGS - RHIC Comparison

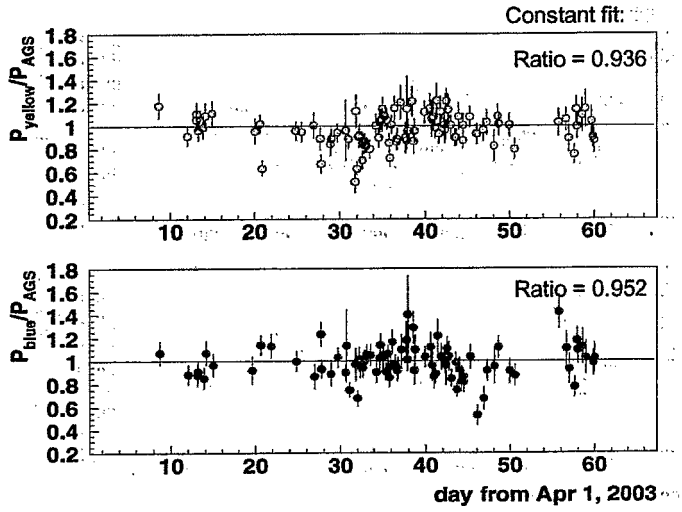
- AGS measurements occuring near RHIC fill
- average RHIC injection measurements for each fill




All polarimeters see drop in P at end of run

4

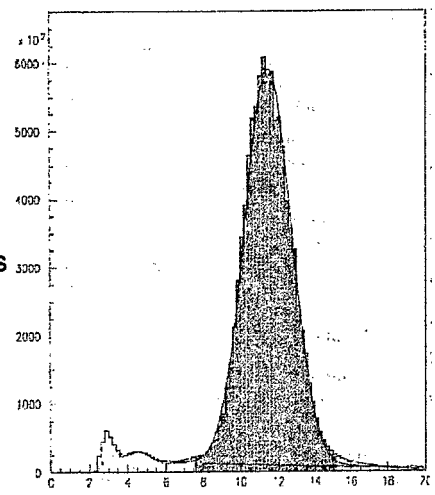
## Ratio $P_{RHIC}/P_{AGS}$



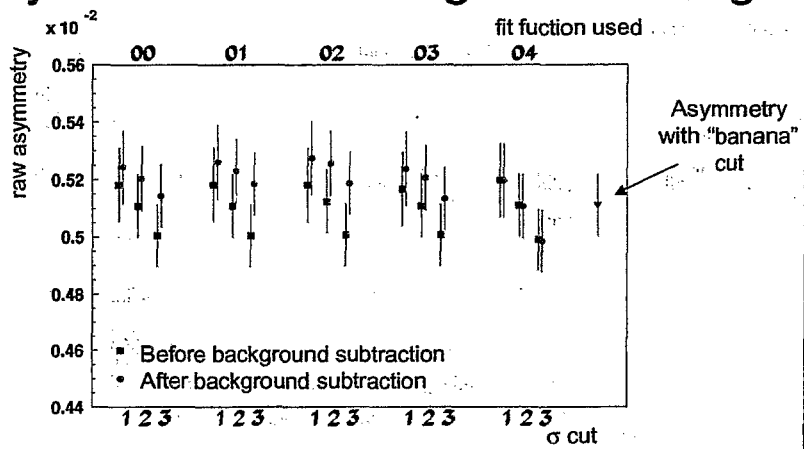

## Systematic Studies

Background subtraction:

- Fit mass with
  $G_1 + G_2 + a + b/x$
- Try other functions for background
- Use 1σ, 2σ and 3σ cuts
- Compare how asymmetry changes



# Asymmetries w/ Background Fitting




Mean difference After – Before

1σ: 1.2% shift 2σ: 1.7% shift 3σ: 2.5% shift

# Conclusions and Outlook

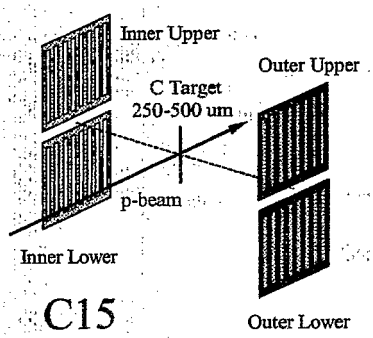
- FY03 AGS CNI Data
  - P generally increased or stable during run
  - $A_N$ (w/ –t dependence) studied at various beam energies
  - AGS Ramp: no losses at $G\gamma = 48 - \nu$
  - P loss < ~7% AGS to RHIC
- Systematic Studies
  - Asymmetry stable with different cuts
  - Background effect < 3% on asymmetry
  - Energy calibration to be studied

# FY04 AGS CNI Polarimeter Updates

D. Svirida, ITEP/BNL

for
RHIC Spin Collaboration Meeting XXIII
March 19, 2004
RIKEN BNL Research Center

## New Features




C15

New in FY2004

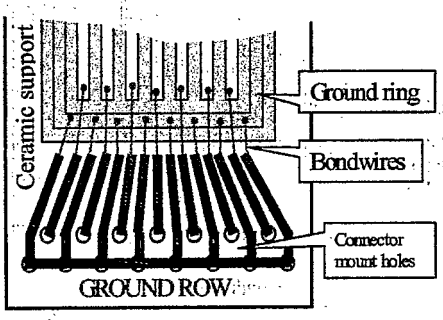
- 4 90-degree detectors 12 strip each
- Total 48 channels – 12 WFD modules with 4x onboard memory
- Enlarged TOF distance 32 cm
- New preamp boards with higher amplification – 2 stages (12 ch/board)
- Improved grounding/shielding and stability – no oscillations
- Scaler (histogram) readout mode for the flattop measurements – fast readout – no intensity limit from the readout side (needs debugging)

Minor problems

- Inadequate preamp board design by BNL instrumentation: a) sufficient bias current leakage on the boards; b) lack of ground planes -- had to slow down the preamps to get reasonable stability
- Strange WFD behavior – need fine tuning of clocking signals

Dima Svirida (ITEP/BNL) "FY04 AGS Polarimeter Updates"

## Admirable Breakthrough

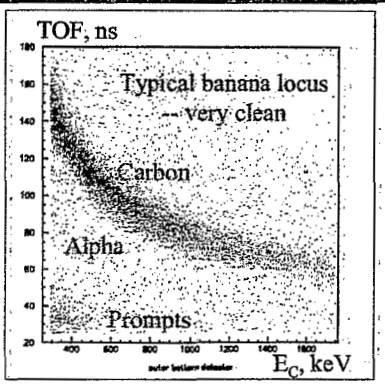


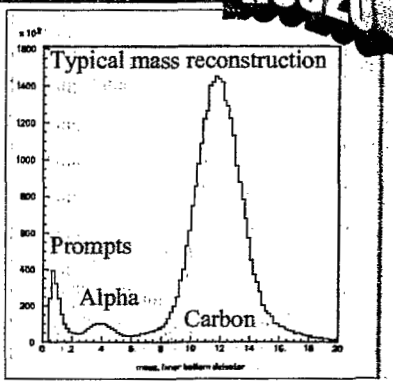

**NO BEAM CHARGE INDUCED SIGNAL !!!**
**(Up to $1.5 \cdot 10^{11}$ p/bunch)**

- Top secret: every second line IS GROUND the whole way down to the very strip
- No pileup in the preamp
- Lower limit in $-t$ is only by the detector noise
- No upper limit on $-t$
- Can see real relativistic (fast) particles from the target – good $T_0$ definition (the rate is of the same order as carbons or higher)

Dima Svirida (ITEP/BNL) "FY04 AGS Polarimeter Updates"

## Performance




- Very clean data
- Good separation of carbon from prompts may allow going to very high $-t$ values
- Low $\chi^2$ of sequential measurements – stable operation



## To Do

- Fine tune clock signals
- Debug scaler/histogram mode for regular flattop measurements
- Develop broadcasting of the results through the CDEV/ADO system
- Mount attenuator boards for faster attenuation switch (under production)
- Switch to the new USB CAMAC controller for 10 times faster readout in 'event' mode (also need WFD firmware upgrade)
- Ramp measurements before changing detectors (April 5)
- Mount Peltie coolers when changing detectors for lower noise and higher radiation tolerance
- pC physics behind RHIC stores (need dedicated time):
  - Go to the lowest and highest possible $-t$ values (?? 100 kEv – – ?? 10 MeV)
  - Measure $A_N$ at several flattop energies, smaller energy step, go as low with beam energy as possible

# Status of Run 2003 Analysis of pp2pp Experiment

Włodek Guryn
for pp2pp collaboration
*Brookhaven National Laboratory, Upton, NY, USA*

**OUTLINE of the TALK**

- Where we left off?
- What is different in Run 2003?
- How analysis is done?
- Where do we stand?
- What are the questions?
- Where do we go from here?

# Where we left off: Forward slope B measurement (SB)

Fit $|t|$-distribution with

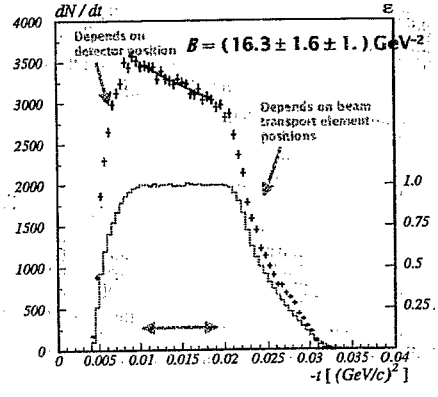
$$\frac{dN}{dt} = C\left[\frac{4\pi(\alpha G_E^2)^2}{t^2} + \frac{(1+\rho^2)\sigma_{tot}^2 e^{+Bt}}{16\pi} + \frac{(\rho+\Delta\Phi)\alpha G_E^2 \sigma_{tot} e^{+\frac{1}{2}Bt}}{t}\right]$$

Using fits to world data of $\sigma_{tot} = 51.6$ mb and $\rho = 0.13$

Fit $B$ for $0.010\ \mathrm{GeV}^2 \le |t| \le 0.019\ \mathrm{GeV}^2$

$B = (16.3 \pm 1.6 \pm 1.)\ \mathrm{GeV}^{-2}$

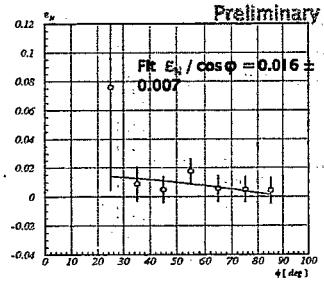
Phys. Lett. B 579 (2004) 245-250



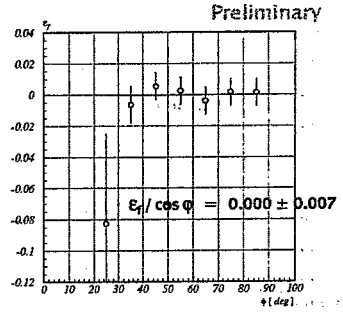
## Where we left off: $A_N$ (SB)

Single spin asymmetry $A_N$ arises in CNI region mainly from interference of hadronic non-flip amplitude with electromagnetic spin-flip amplitude

$$A_N(t) = \frac{1}{P_{beam} \cdot \cos\varphi} \frac{N_{\uparrow\uparrow}(t) + N_{\uparrow\downarrow}(t) - N_{\downarrow\downarrow}(t) - N_{\downarrow\uparrow}(t)}{N_{\uparrow\uparrow}(t) + N_{\uparrow\downarrow}(t) + N_{\downarrow\downarrow}(t) + N_{\downarrow\uparrow}(t)} \propto \frac{\mathrm{Im}\,[\,\Phi_5^{\,*}\,\Phi_+\,]}{d\sigma/dt} \quad \text{for small } t$$

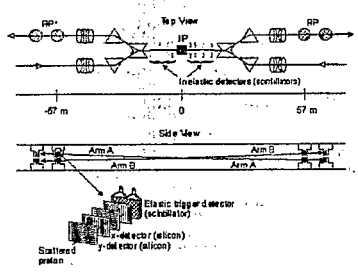



Raw Asymmetry




False Asymmetry

## Principle of the Measurement




- Elastically scattered protons have very small scattering angle $\theta^*$, hence beam transport magnets determine trajectory scattered protons
- The optimal position for the detectors is where scattered protons are well separated from beam protons
- Need Roman Pot to measure scattered protons close to the beam without breaking accelerator vacuum

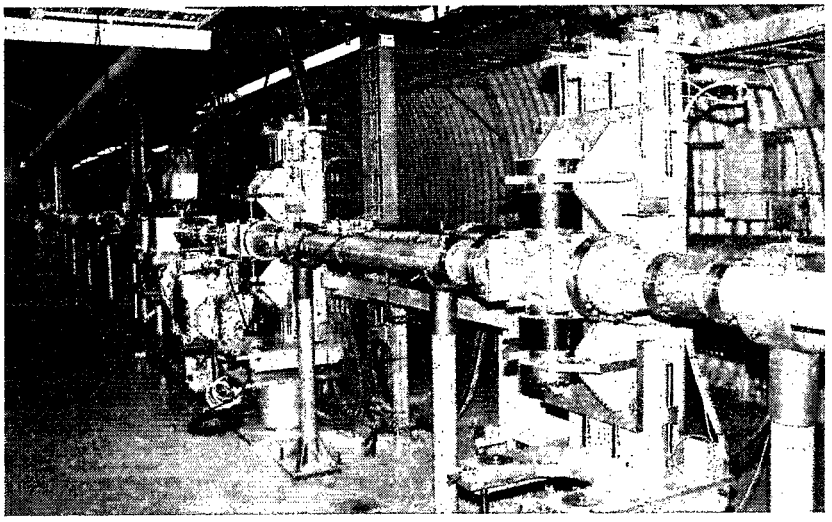
Beam transport equations relate measured position at the detector to scattering angle

$$\begin{pmatrix} x_D \\ \Theta_D^x \\ y_D \\ \Theta_D^y \end{pmatrix} = \begin{pmatrix} a_{11} & L_{eff}^x & a_{12} & a_{14} \\ a_{12} & a_{22} & a_{23} & a_{24} \\ a_{13} & a_{23} & a_{33} & L_{eff}^y \\ a_{14} & a_{24} & a_{34} & a_{44} \end{pmatrix} \begin{pmatrix} x_0 \\ \Theta_x^* \\ y_0 \\ \Theta_y^* \end{pmatrix}$$

$x_0, y_0$: Position at Interaction Point
$\Theta^*_x, \Theta^*_y$: Scattering Angle at IP
$x_D, y_D$ : Position at Detector
$\Theta^x_D, \Theta^y_D$ : Angle at Detector

2

## The pp2pp Experimental Setup



## What's new in Run 2003

| | Engineering 2002 | 2003 |
|---|---|---|
| Number of RP stations | 2 | 4 |
| Number of Si planes | 16 | 32 |
| Number of elastic events | $3 \cdot 10^5$ | $3 \cdot 10^6$ |
| Beam momentum | 100 GeV | |
| Number of bunches | 55 | |
| $\beta^*$ | 10 m | |
| Beam emittence $\varepsilon$ [mm mrad] | 12 | 16, 18 |
| $\lvert t \rvert$-range | 0.004-0.035 $(GeV/c)^2$ | |
| Proton intensity | $5 \cdot 10^{11}$ | $19 \cdot 10^{11}$ |
| Proton beam polarization (estimate) | 0.24 | 0.37 |

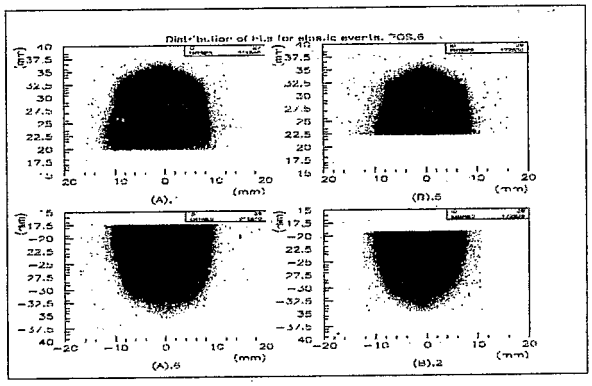
## Elastic event analysis ITEP Moscow and Krakow/BNL

**ANALYSIS FOSCUS of ANALYSIS IS NOW ON UNDERSTANDING SYSTEMATIC EFFECTS**

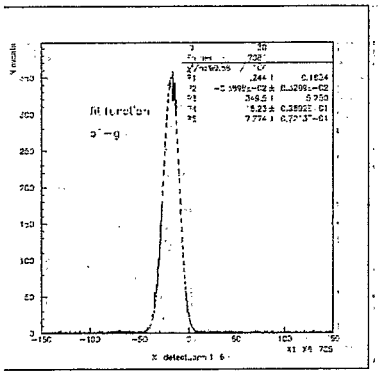
1. Pedestal value, pedestal width ($\sigma$) and dead channels are determined.
2. Valid hit is dE/dx with $4\sigma$ above pedestal;
3. Cluster size is $\leq 6$ consecutive strips above pedestal cut;
4. Elastic events are reconstructed using correlations of hits and track reconstruction (ITEP;)
5. Clean events, one hit per plane in four RPs are used for full reconstruction, offsets calculation, (x0,y0) (Krakow/BNL);
6. Clean events with one hit per plane in RP1 and RP3 for dN/dt distributions, to get large statistics.

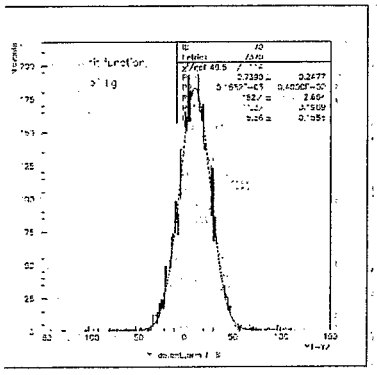
**Show 1/3 of the data**

## Elastic Events Hit Distribution ITEP



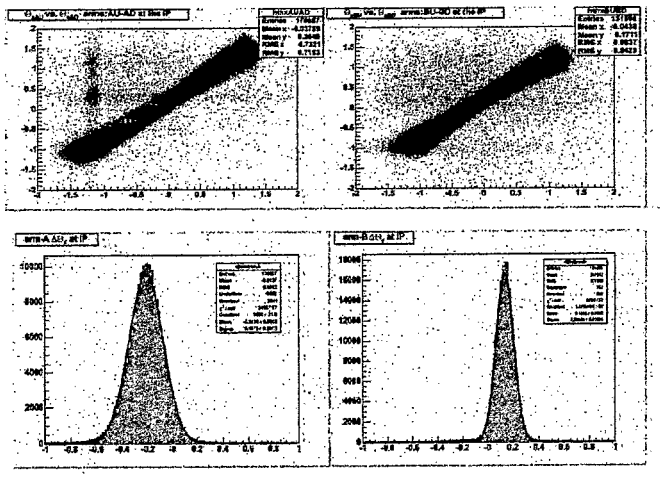
## Elastic Events x-x, y-y corerlations (ITEP)



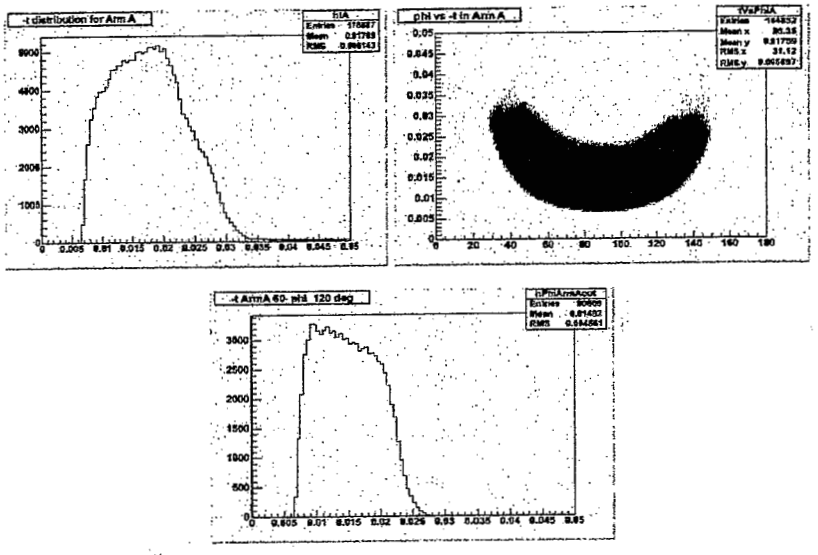


## Elastic Events: Krakow/BNL

Angular correlation



## Elastic Events: Krakow/BNL

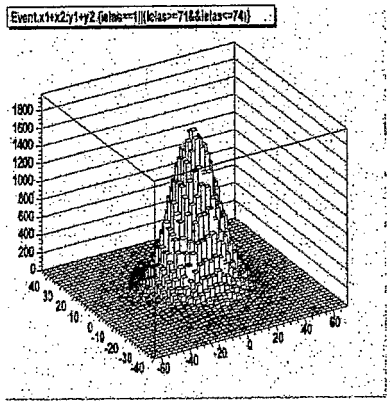



## Elastic event analysis Krakow/BNL (cut effects on 1/3 data)

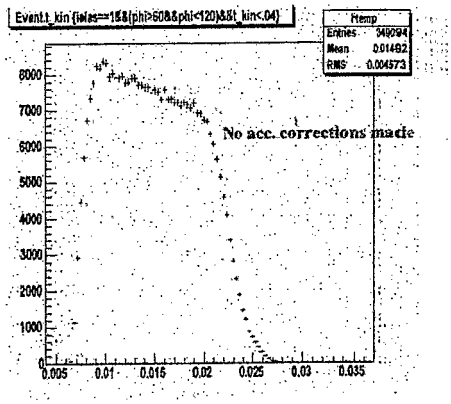
| CUT DESCRIPTION | # Events |
|---|---|
| All Events | 931k |
| Elastic trigger (idtrig=1) | 901k |
| Clean elastic trigger arm A | 339k |
| Clean elastic trigger arm B | 315k |
| Gold events arm A | 177k |
| Gold events arm B | 152k |
| Colinearity $3\sigma(\Delta\theta_x,\Delta\theta_y)$ arm A | 165k |
| Colinearity $3\sigma(\Delta\theta_x,\Delta\theta_y)$ arm B | 134k |
| $0.01 < -t < 0.02$ (Gev/c)$^2$ arm A (dN/dt fit region) | 91k |
| $0.01 < -t < 0.02$ (Gev/c)$^2$ arm B (dN/dt fit region) | 91k |

## Status of run 2003 analysis (SB)

x-y correlations

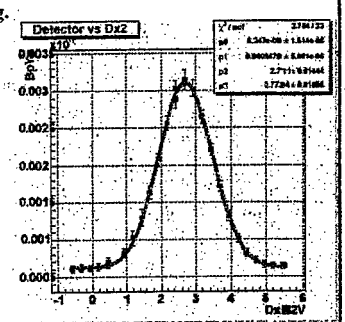



dN/dt (not corrected)




## Summary

1. We have a very clean data set, very few dead or noisy channels:
   - Excellent silicon detection efficiency;
   - Measurement of local angles with new RPs allows reconstruction of $(x_0, y_0)$.
2. Because of less scraping $-t_{min}$ is not as small as in the Engineering Run, it is not a problem for B or $A_N$.
3. Given good data sample we have, the systematic errors are very important to determine.
4. We need more information from the accelerator about the transport, non-linear transport is being calculated, to do off-axis tracking.
5. We will use data to cross check the transport.
6. Van der Meer scans will be used to determine luminosity.



## Summary continued

| Estimate of statistical error | | |
|---|---|---|
| Nuclear slope $\Delta B$ | 1.6 $(GeV/c)^{-2}$ | 0.35 $(GeV/c)^{-2}$ |
| Raw asymmetry $\Delta\varepsilon_N$ | 0.007 | 0.001 |
| Total cross section $\Delta\sigma_{Tot}$ | | 2-3 mb |

**Knowledge of beam transport, including off-axis, is crucial to improve systematic error**

Yellow

$$\begin{pmatrix} a_{11} & L^x_{eff} & a_{12} & a_{14} \\ a_{12} & a_{22} & a_{23} & a_{24} \\ a_{13} & a_{23} & a_{33} & L^y_{eff} \\ a_{14} & a_{24} & a_{34} & a_{44} \end{pmatrix}$$

Blue

$$\begin{pmatrix} a_{11} & L^x_{eff} & a_{12} & a_{14} \\ a_{12} & a_{22} & a_{23} & a_{24} \\ a_{13} & a_{23} & a_{33} & L^y_{eff} \\ a_{14} & a_{24} & a_{34} & a_{44} \end{pmatrix}$$

**Stay tuned for the next RSC meeting and the RHIC/AGS users meeting**

# RHIC Spin Collaboration Meeting XXIII
**March 19, 2004**
**RIKEN BNL Research Center**

## LIST OF REGISTERED PARTICIPANTS

# *RIKEN PARTICIPANTS*

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# RHIC Spin Collaboration Meeting XXIII
**March 19, 2004**
**RIKEN BNL Research Center**

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# RHIC Spin Collaboration Meeting XXIII
**March 19, 2004**
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**RHIC Spin Collaboration Meeting XXIII**
**March 19, 2004**
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RIKEN BNL Research Center
**RHIC Spin Collaboration Meeting XXIII**
March 19, 2004
Bldg. 1005, Third Floor Conference Room
Brookhaven National Laboratory

*******AGENDA*******

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| | |
|---|---|
| 9:00 | Welcome & Coffee |
| 9:10 | Machine Status & Update.....W. Fischer |
| 9:30 | News for AGS pp Run.....H. Huang |
| 10:30 | Coffee Break |
| 10:45 | RHIC Snake Quence Protection Update.....G. Ganetis |
| 11:00 | Updates on RHIC Commissioning Plan.....M. Bai |
| 11:45 | Some Discussions on FY05 Run.....ALL |
| 12:00 | Lunch |
| 13:30 | "Final" Result from RHIC pC CNI.....O. Jinnouchi |
| 14:30 | FY03 AGS CNI Polarimeter Results.....J. Wood |
| 15:00 | Coffee Break |
| 15:20 | FY04 AGS CNI Polarimeter Updates.....D. Svirida |
| 15:50 | Update from pp2pp.....W. Guryn |
| 16:45 | AOB and next meeting date |
| 17:00 | Beer & Food |

*See webpage http://www.bnl.gov/riken/RSCXXIII.htm for posted talks.*

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## Additional RIKEN BNL Research Center Proceedings:

Volume 59 – RHIC Spin Collaboration Meeting XXI (January 22, 2004), XXII (February 27, 2004), XXIII (March 19, 2004) – BNL-

Volume 58 – RHIC Spin Collaboration Meeting XX – BNL-71900-2004

Volume 57 – High pt Physics at RHIC, December 2-6, 2003 – BNL-72069-2004

Volume 56 – RBRC Scientific Review Committee Meeting – BNL-71899-2003

Volume 55 – Collective Flow and QGP Properties – BNL-71898-2003

Volume 54 – RHIC Spin Collaboration Meetings XVII, XVIII, XIX – BNL-71751-2003

Volume 53 – Theory Studies for Polarized *pp* Scattering – BNL-71747-2003

Volume 52 – RIKEN School on QCD "Topics on the Proton" – BNL-71694-2003

Volume 51 – RHIC Spin Collaboration Meetings XV, XVI – BNL-71539-2003

Volume 50 – High Performance Computing with QCDOC and BlueGene – BNL-71147-2003

Volume 49 – RBRC Scientific Review Committee Meeting – BNL-52679

Volume 48 – RHIC Spin Collaboration Meeting XIV – BNL-71300-2003

Volume 47 – RHIC Spin Collaboration Meetings XII, XIII – BNL-71118-2003

Volume 46 – Large-Scale Computations in Nuclear Physics using the QCDOC – BNL-52678

Volume 45 – Summer Program: Current and Future Directions at RHIC – BNL-71035

Volume 44 – RHIC Spin Collaboration Meetings VIII, IX, X, XI – BNL-71117-2003

Volume 43 – RIKEN Winter School – Quark-Gluon Structure of the Nucleon and QCD – BNL-52672

Volume 42 – Baryon Dynamics at RHIC – BNL-52669

Volume 41 – Hadron Structure from Lattice QCD – BNL-52674

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Volume 39 – RHIC Spin Collaboration Meeting VII – BNL-52659

Volume 38 – RBRC Scientific Review Committee Meeting – BNL-52649

Volume 37 – RHIC Spin Collaboration Meeting VI (Part 2) – BNL-52660

Volume 36 – RHIC Spin Collaboration Meeting VI – BNL-52642

Volume 35 – RIKEN Winter School – Quarks, Hadrons and Nuclei – QCD Hard Processes and the Nucleon Spin – BNL-52643

Volume 34 – High Energy QCD: Beyond the Pomeron – BNL-52641

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

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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

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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
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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
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Volume 11 – Event Generator for RHIC Spin Physics – BNL-66116
Volume 10 – Physics of Polarimetry at RHIC – BNL-65926
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Volume 6 – Quarks and Gluons in the Nucleon – BNL-65234
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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 Meetings XXI, XXII, & XXIII

January 22, 2004 * February 27, 2004 * March 19, 2004

Li Keran

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

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Speakers:

| | | | |
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| G. Ganetis | W. Guryn | H. Huang | O. Jinnouchi |
| W. MacKay | Y. Makdisi | D. Svirida | J. Takano |
| R. Tomas | S. Trentalange | J. Wood | A. Zelenski |

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