RHIC pC CNI Polarimeter performance from Run-03

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At the 4th CPanP (SPIN 2003) at Seattle

Low-energy hadron physics

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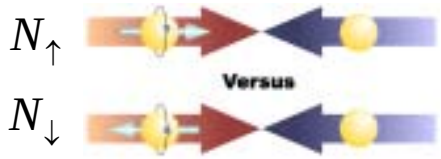
pC CNI Polarimeter : Impact on the RHIC Spin project

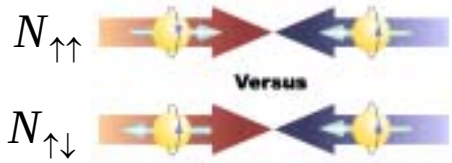
Single Spin



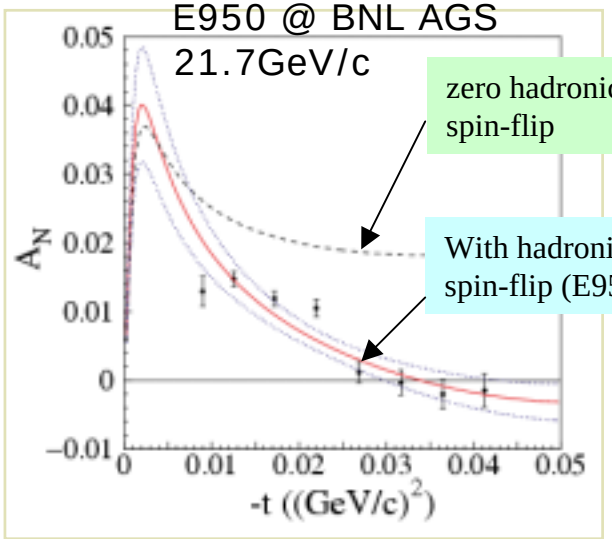
Physics Asymmetry

$$A_L = \frac{1}{P_B}\left(\frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow}\right) = \varepsilon_L$$

Double Spin



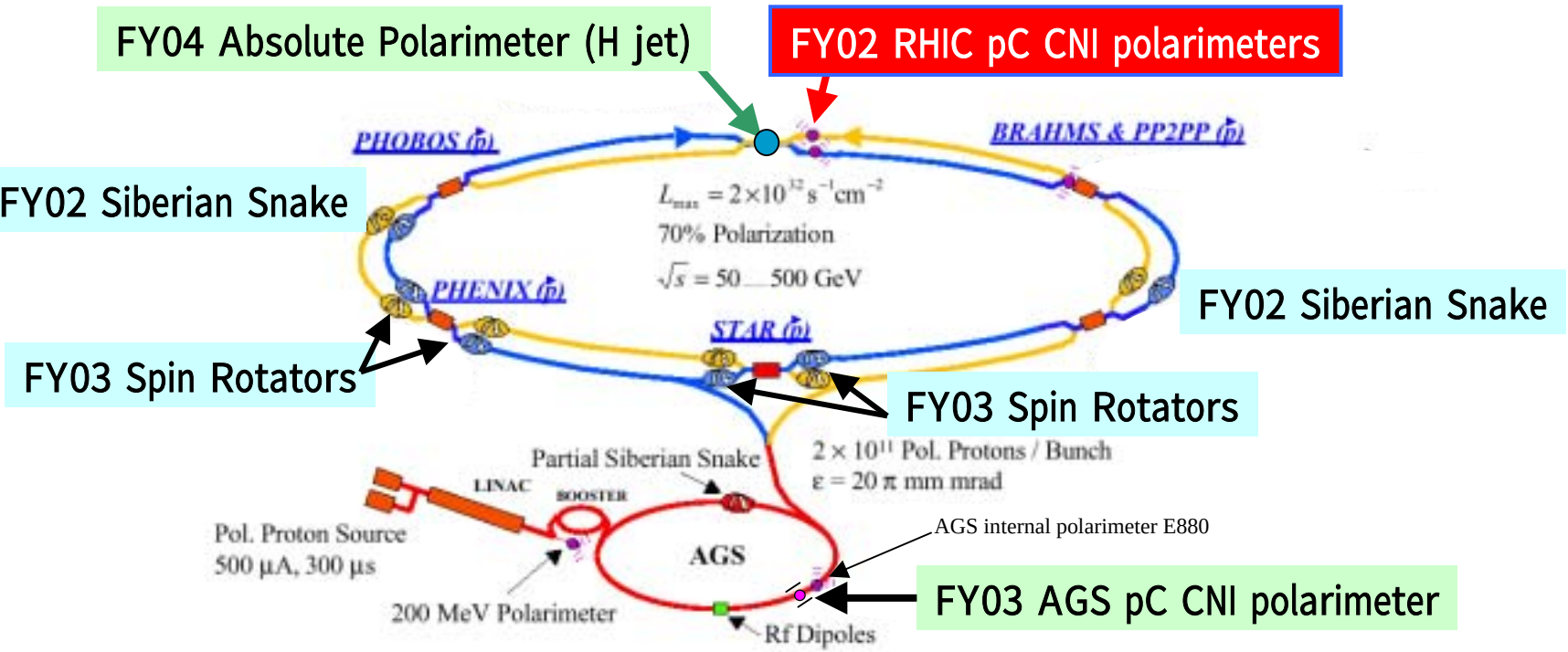
$$A_{LL} = \frac{1}{P_B^{\,2}}\left(\frac{N_{\uparrow\uparrow} - N_{\uparrow\downarrow}}{N_{\uparrow\uparrow} + N_{\uparrow\downarrow}}\right) = \varepsilon_{LL}$$



- The raw asymmetry (=ε) has to be normalized with beam polarization to get analyzing powers of the process (A_L, A_{LL})
- The impact is quadratic on double spin asymmetry (i.e.gluon polarization)
- Adopt pC CNI (coulomb Nuclear Interference) polarimeter for its fast and reliable measurement performance

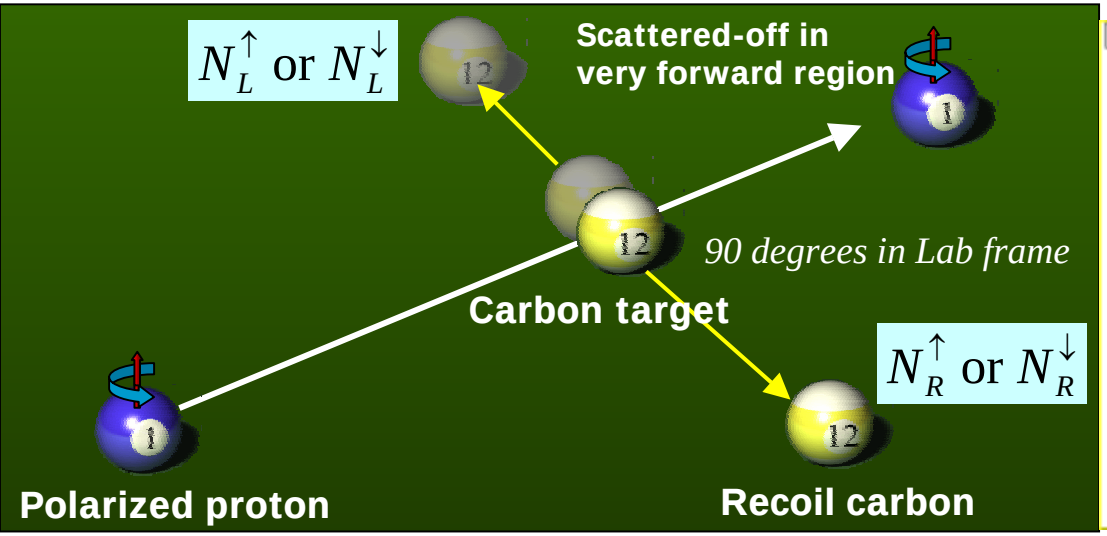
- A_N of pC CNI is known from QED calculation (size ~1% in our detection range), except the contribution from hadronic spin flip term which requires direct measurement (E950 @BNL AGS)

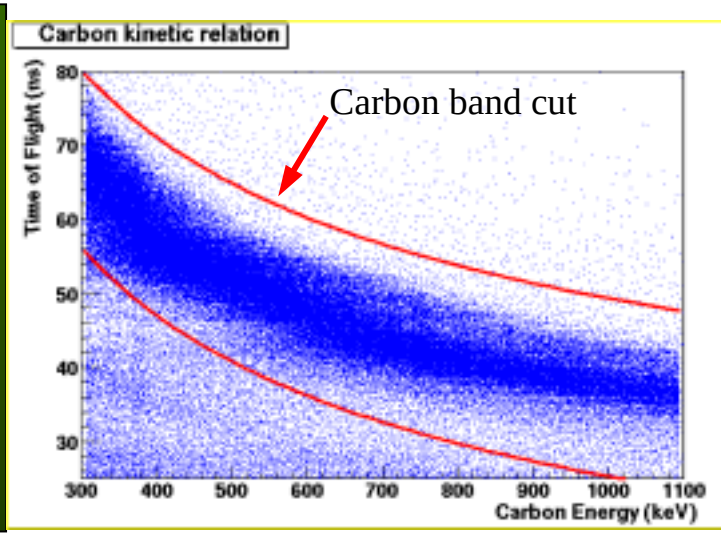
RHIC varieties of components for pp-mode



- Final goal is to know absolute beam polarization up to ±5%
- Achieve this precision with, pC CNI polarimeter (relative measurement) + Polarized H gas jet target polarimeter (absolute calibration from ‘04)
- Challenges to the unexplored experimental conditions (high energy beam, large bunch intensity, etc)

pC CNI : Asymmetry and Kinematics





- A_N is known from E950 experiment to be small ~ 1% and it requires large statistics > 10^7
- Measure left-right asymmetry of recoil carbons
- Very small momentum transfer region $0.006 < -t(GeV/c)^2 < 0.03$

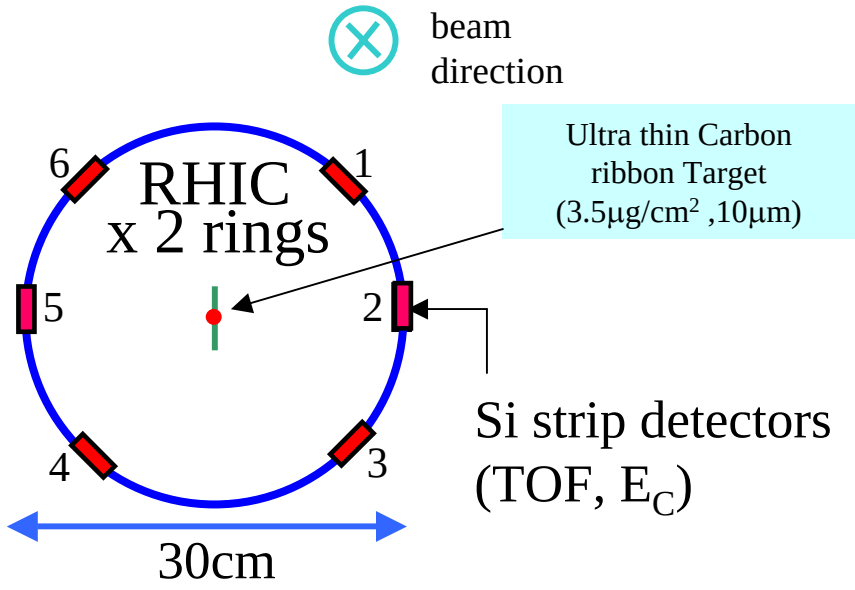
- 250< Carbon energy(keV)<1200
- 30< Time of flight (ns) < 80

the recoil detection

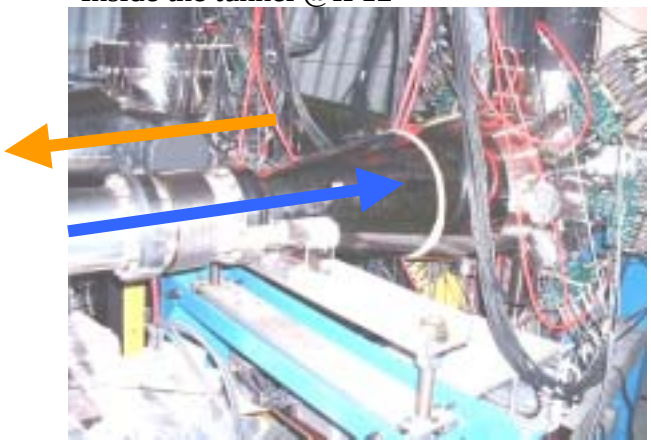
$$P_{beam} = -\frac{1}{A_N}\frac{\sqrt{N_L^{\uparrow}N_R^{\downarrow}} - \sqrt{N_R^{\uparrow}N_L^{\downarrow}}}{\sqrt{N_L^{\uparrow}N_R^{\downarrow}} + \sqrt{N_R^{\uparrow}N_L^{\downarrow}}}$$

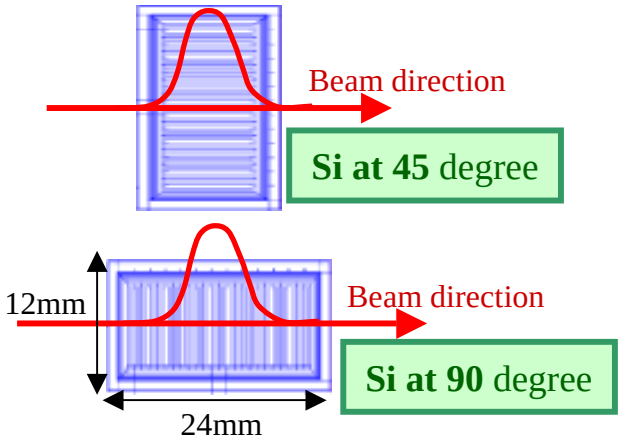
Square root formula

Detector/Target layout



Inside the tunnel @IP12





- Detectors are 15cm away from target → slowest carbons can reach Si during one bunch crossing (106 nsec = 120 bunch mode)
- Si at 45 degree : sensitive to vertical and radial components of asymmetry
- Si at 90 degree : sensitive to longitudinal target position
- Independent measurements by two detector sets (45 and 90 degree Si's)

Data acquisition with WFD (Wave Form Digitizer)

Demand for a fast readout system to satisfy the huge statistics (20M) and high event rate condition (400k events/sec, ~30sec)

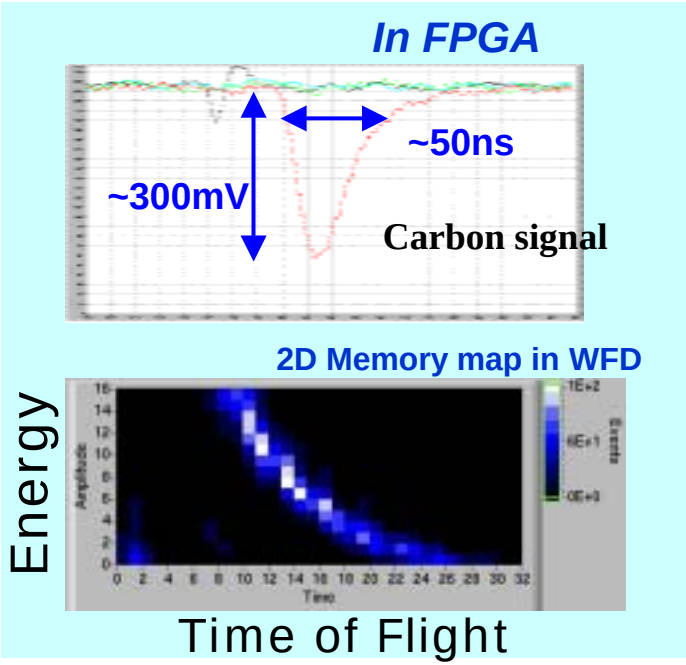
→ WFD system !

Short-shaped Si signals are digitized and characterized in the FPGA

- Max pulse height (peak)
- Time of flight
- Pulse integral (charge)
- Bunch #

Store them in on-board memory.

Read out data after measurement (nominal 20M events)



Constant Fraction Timing (Tof)
Max pulse Height (Energy)

Dead time less DAQ system can minimizes the measurement time

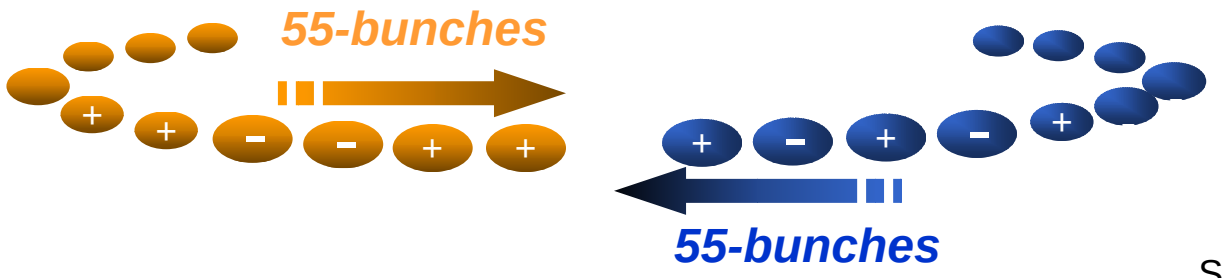
- Minimize the disturbing beam → longer beam lifetime
- Minimize the radiation damage on Si detectors

RHIC Spin polarized proton run-03

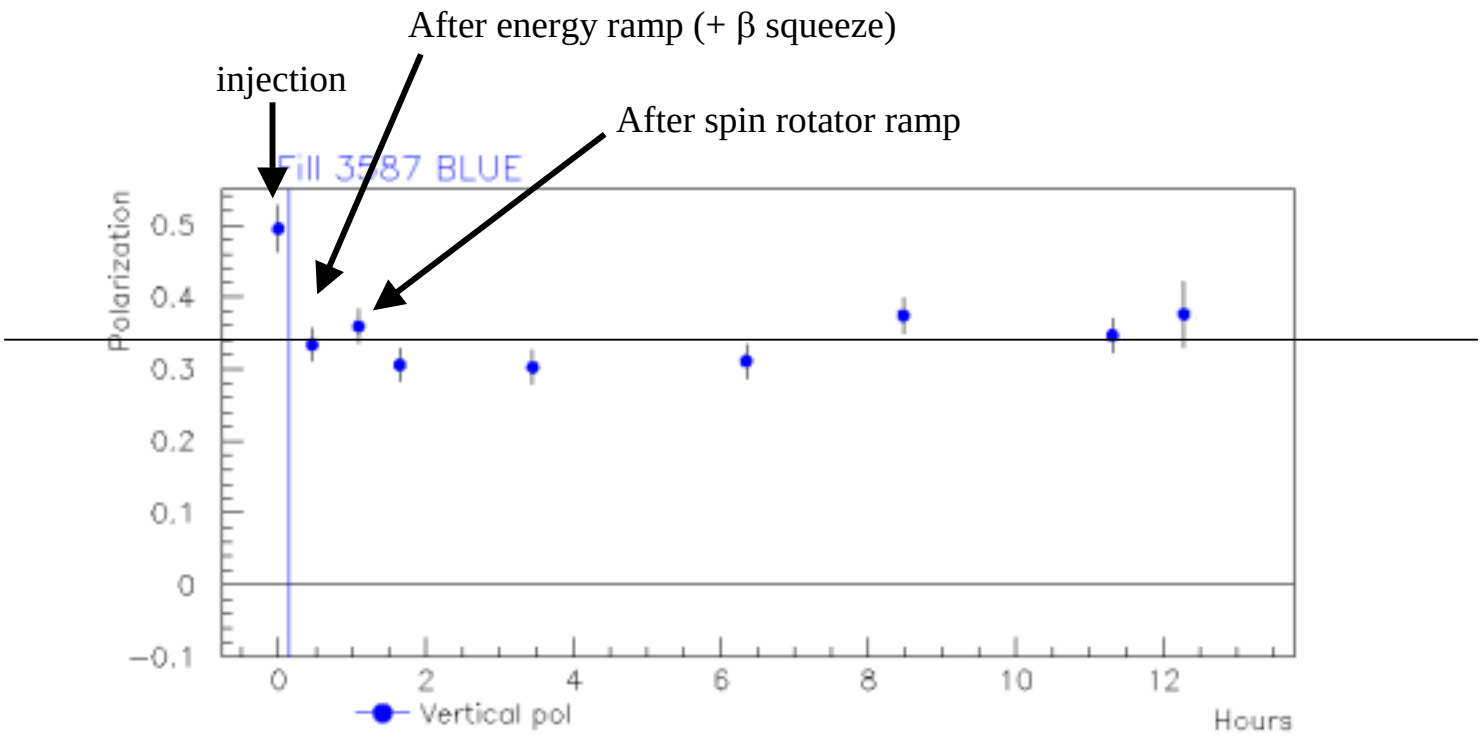
- Run periods
  - Mar 26th – May 3rd 2003 (5weeks)/ pp commissioning
  - May 3rd – May 30th 2003 (4weeks)/ physics run
- New device
  - Spin rotators started commission and operation
  - ✧ From Apr 22nd IR8 (Phenix)
  - ✧ From May 15th IR6 (Star)
- 55 bunches per ring with 0.65 x 10^{11} p↑/ bunch
- Major 3 spin sign patterns

Pattern 1 (195runs)	Pattern 2 (488runs)	Pattern 3(254runs)
BLUE + + - - + + ,,,	BLUE + - + - + - ,,,	BLUE + - + - + - ,,,
YELL + - + - + - ,,,	YELL + + - - + + ,,,	YELL + - + - + - ,,,

Last 50 runs were taken with 3 un-polarized bunches



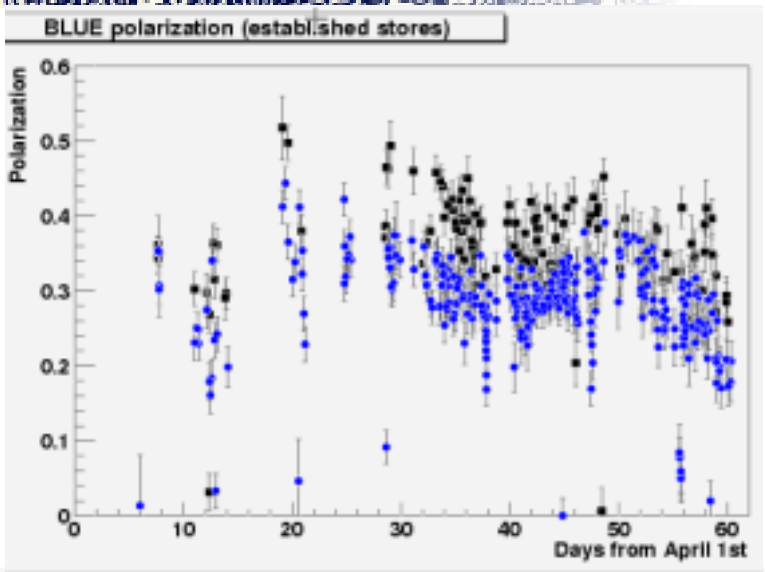
Polarization measurements at fill with rotator ramp

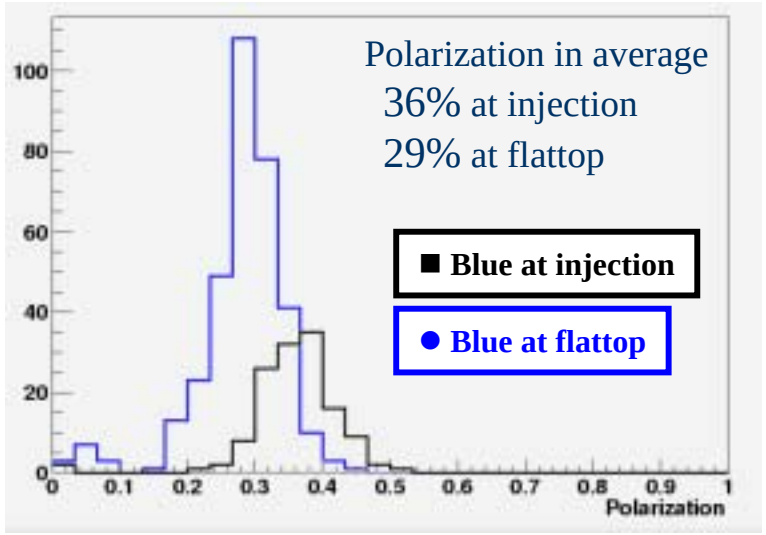


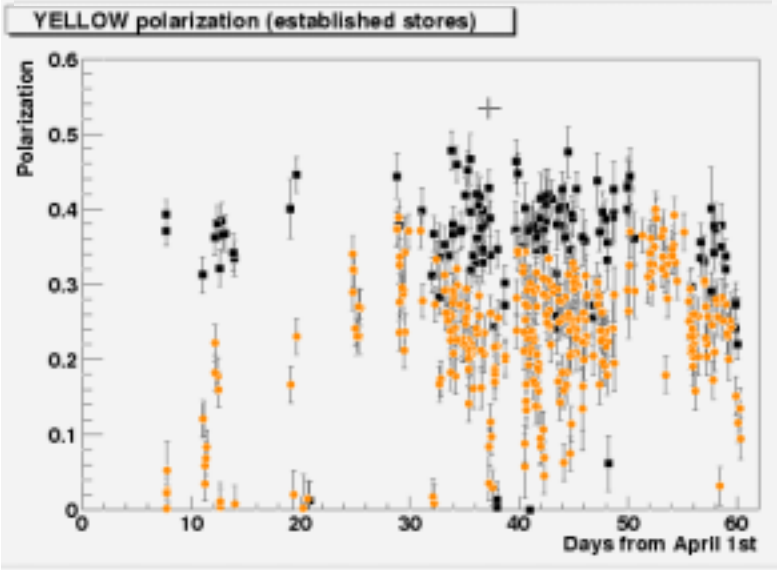
- Measurement procedure
  - Injection (24GeV) → After acceleration (100GeV) → After spin rotator ramp → every 2 hours
- Fills tend to lose polarization at the first ramp and stay constant during the long fill

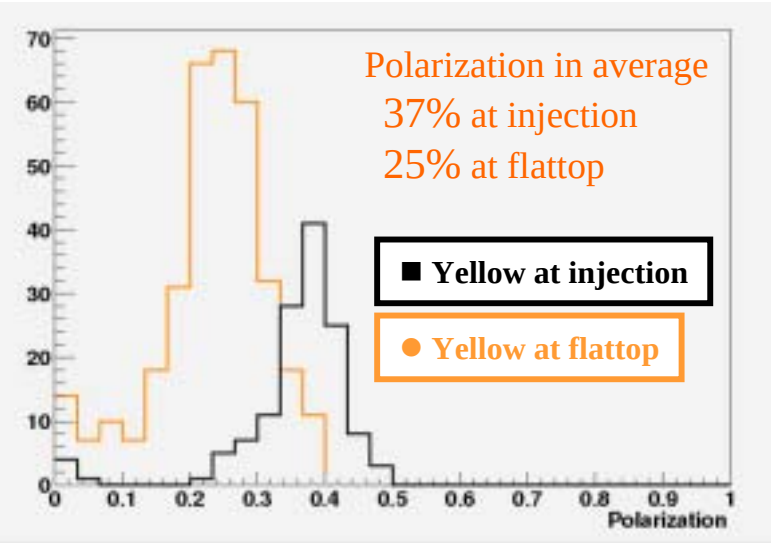
Polarization results in average

- The same A_N is used for 100GeV

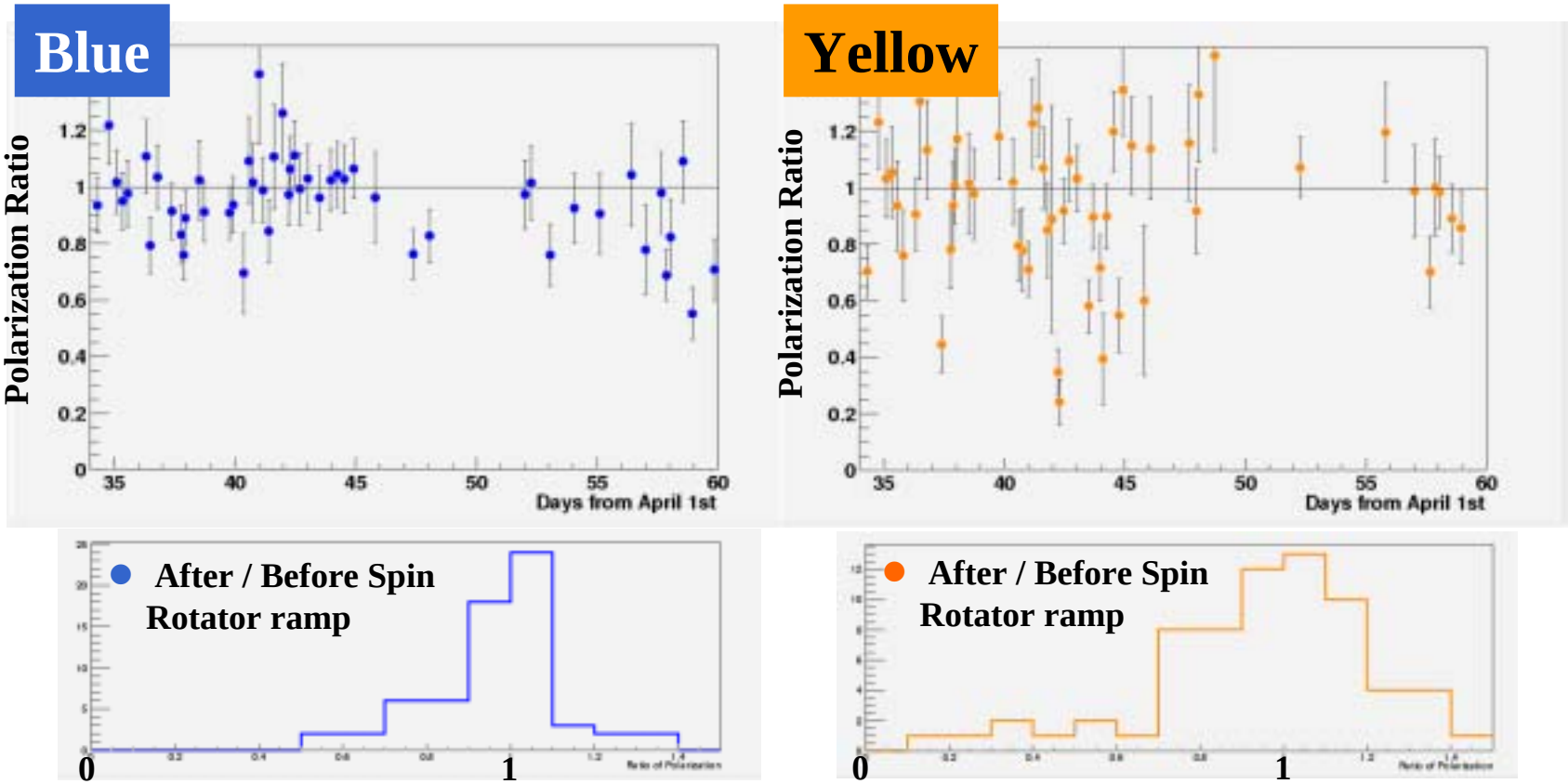






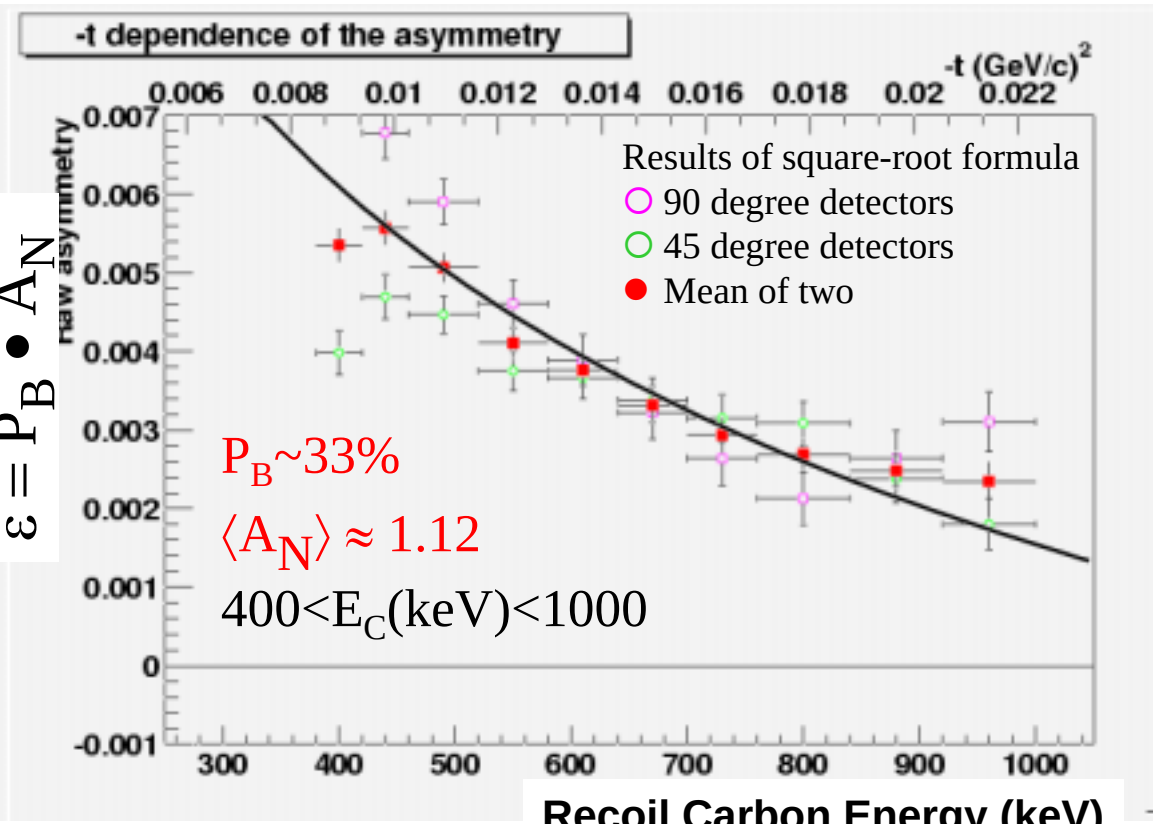


Polarization after/before rotator ramp



- Longitudinal spin direction was confirmed by local polarimeters at PHENIX and STAR
- Mostly **Rotator ramp could keep the polarization**

Raw asymmetry → Polarization



$$P_{beam} = \frac{1}{\langle A_N \rangle} \cdot \varepsilon_N$$

$$\langle A_N \rangle = \frac{\sum N(t_i) A_N^{th}(t_i)}{\sum N(t_i)}$$

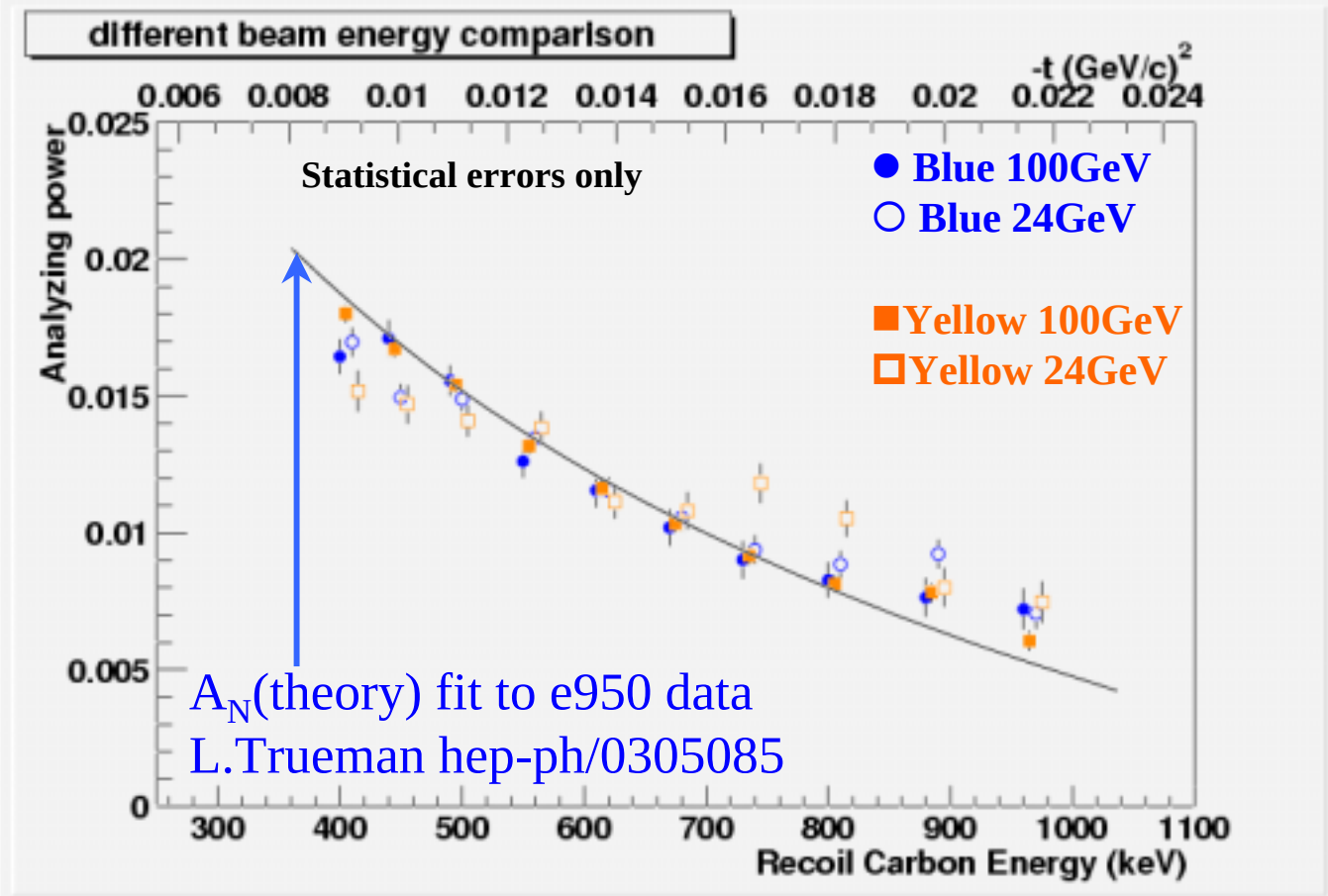
$A_N^{th}(t)$: Theoretical function fi
to E950 data

L. Trueman hep-ph/0305085

- Once the polarization is determined, A_N for each $-t$ bin can be calculated

$$A_N(t_i) = \varepsilon_N(t_i) \Big/ P_{beam}$$

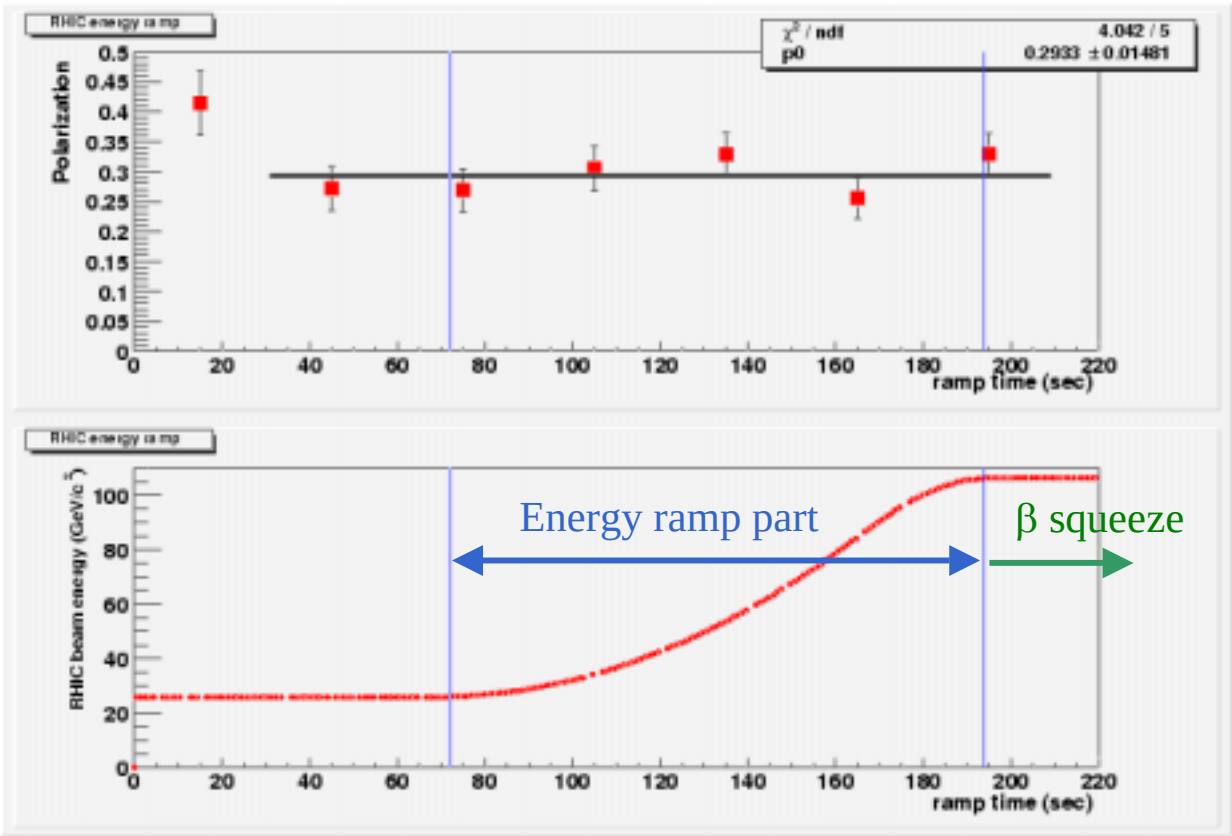
-t dependence of A_N at different energies at RHIC



- Data points are normalized with polarization
- A_N shape has small dependence on beam energy in this energy scale → hadronic spin-flip contribution is still large at 100GeV

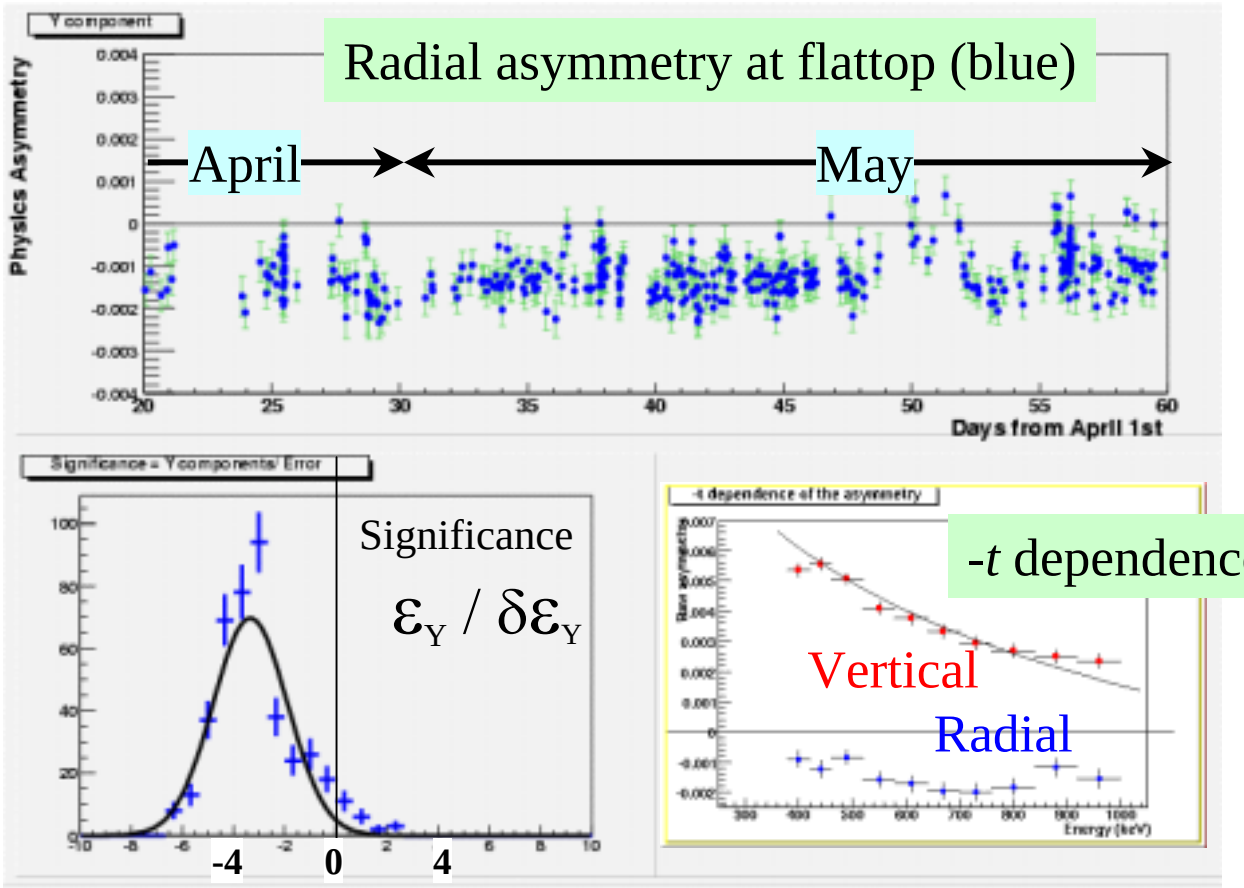
Polarization measurement along the ramp

Yellow Ring (fill: 3516, 3652 combined)



- Continuously measure polarization along the energy ramp + β squeeze
- Statistics was not enough, limited by size of memory on WFD

Systematic errors



- False asymmetry (radial component) was consistently observed throughout the run
- -*t* dependence for the radial component is not CNI shape
  → Not physics!

Plan towards the next run

- Improve the ability to gain event statistics for ramp measurement
  - Increase the memory & readout speed of WFD
- Understand, fix/improve or estimate systematic errors
  - Study is under progress

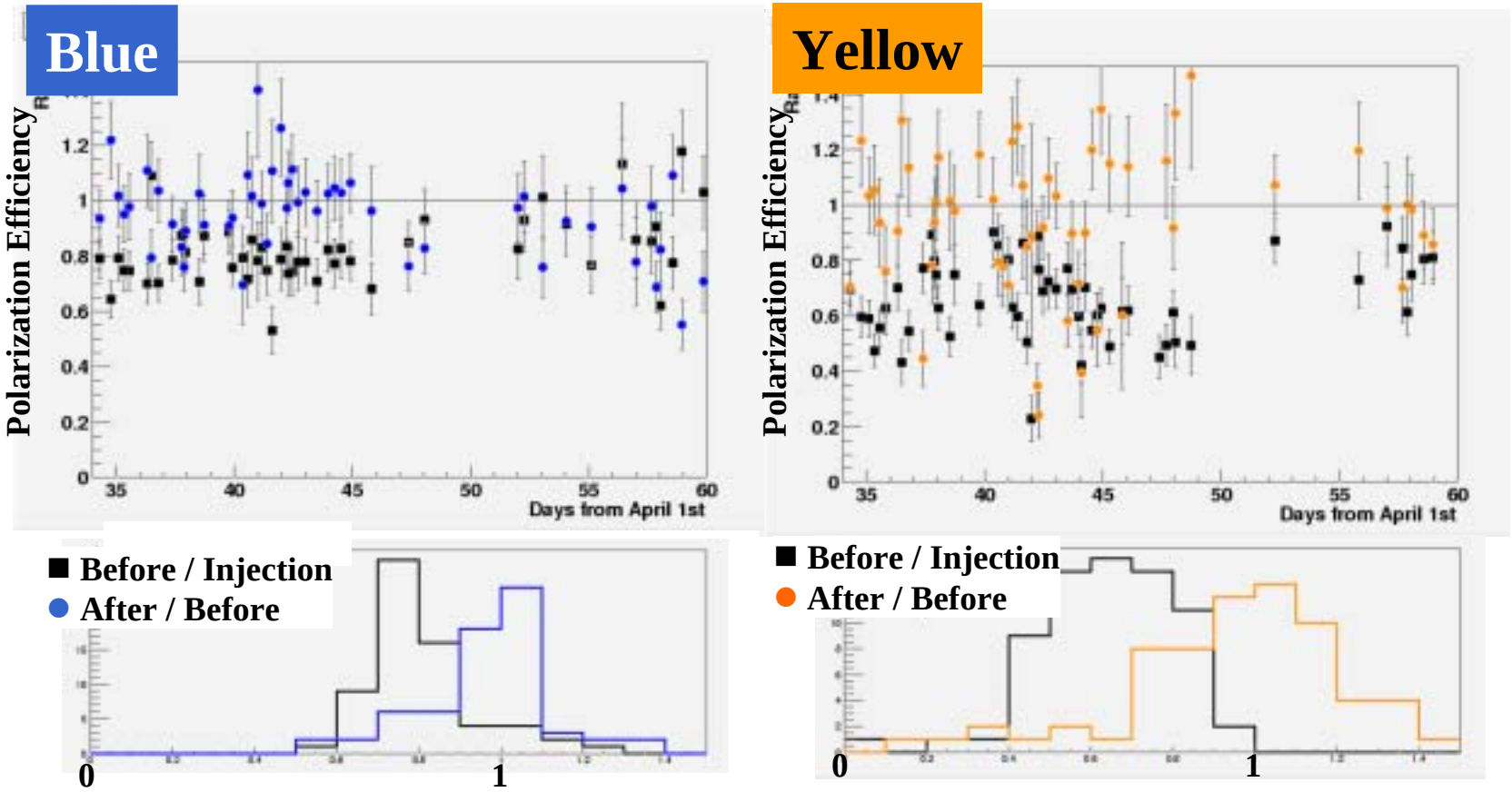
- Associated work with absolute jet polarimeter
  - Polarized gas jet target will be installed during this summer shutdown for pC CNI calibration

Summary

- RHIC pC CNI polarimeter stably worked through Run-03 period
- The polarization in average at store energy was improved from the last run (run-02)
  - BLUE (11%)→ 29%
  - Yellow (16%)→ 25%
- The spin rotators worked
- The first ramp measurement was attempted
- Observed non-negligible false asymmetries
- Polarized gas-jet target will be commissioned in Run-04

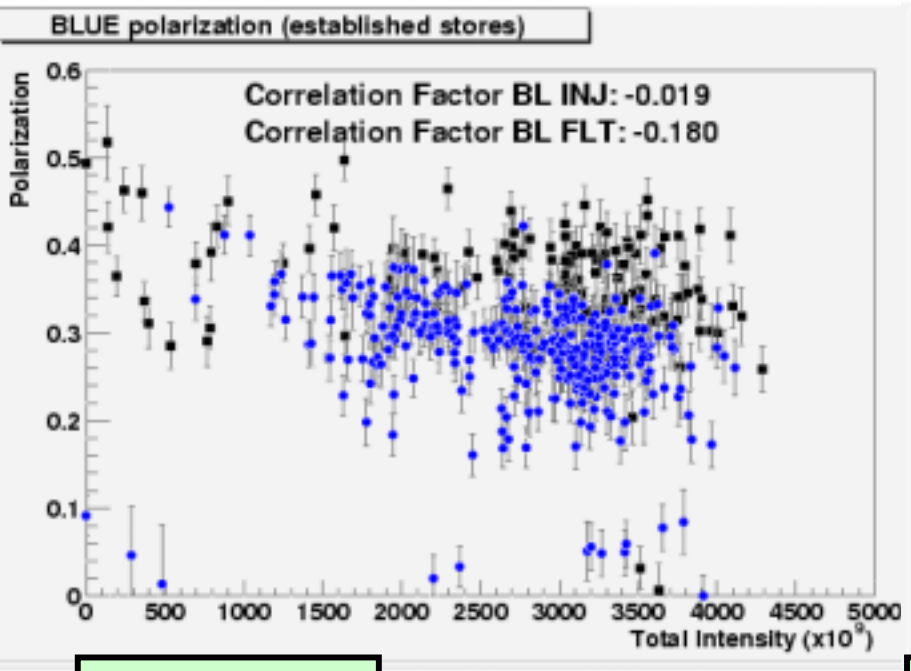
Back Up Slides

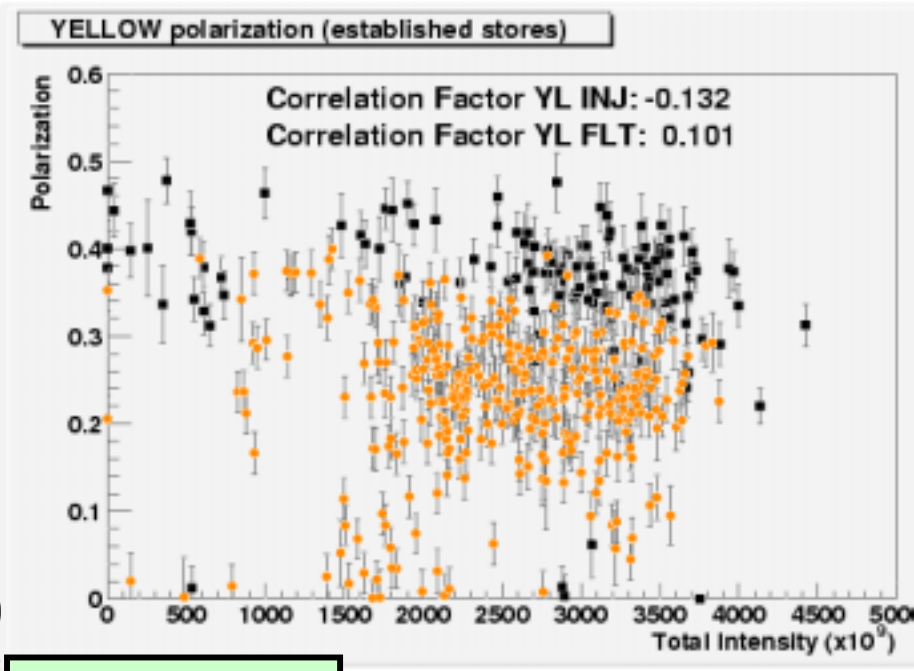
Polarization after/before rotator ramp



- Significant polarization drop was systematically observed after energy ramp (A_N at 100GeV is not known)
- Longitudinal spin direction was confirmed by polarimeters at PHENIX and STAR
- Mostly **Rotator ramp could keep the polarization**

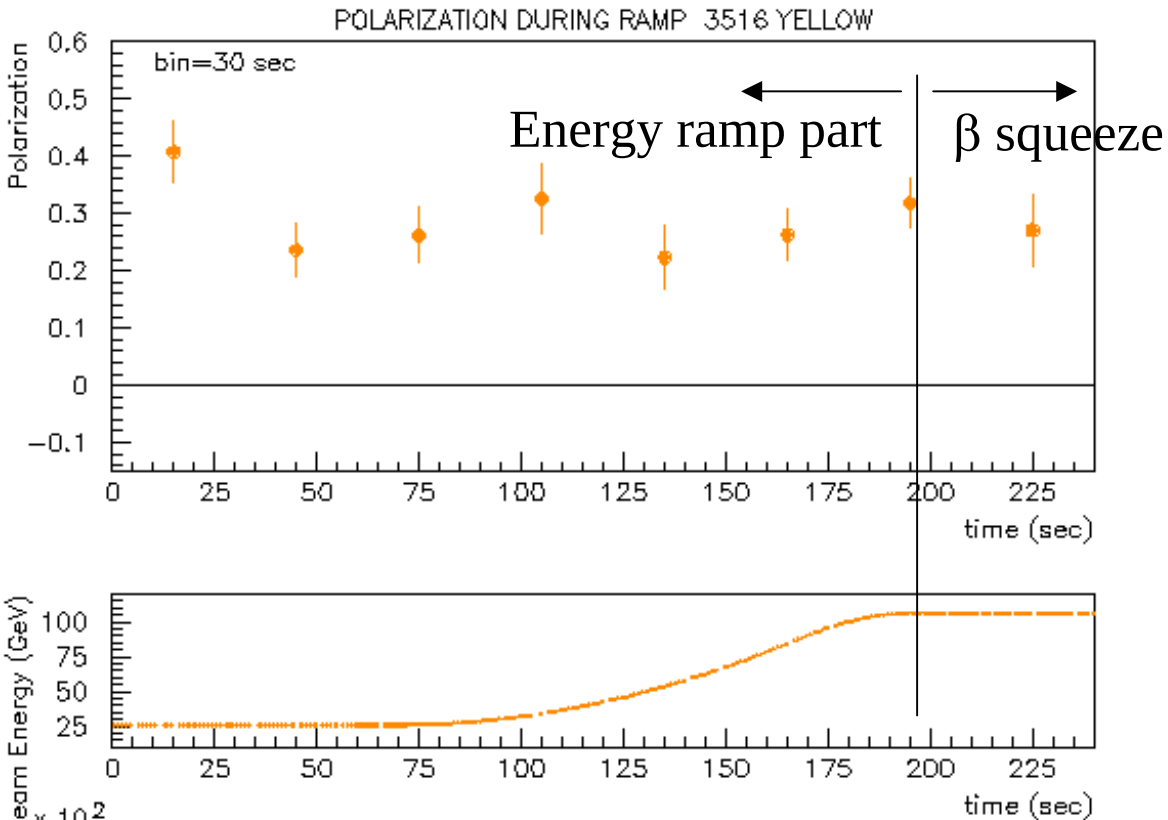
Beam intensity dependence





- There is small correlation btw intensity and polarization at both energies and both rings

Polarization measurement along the ramp



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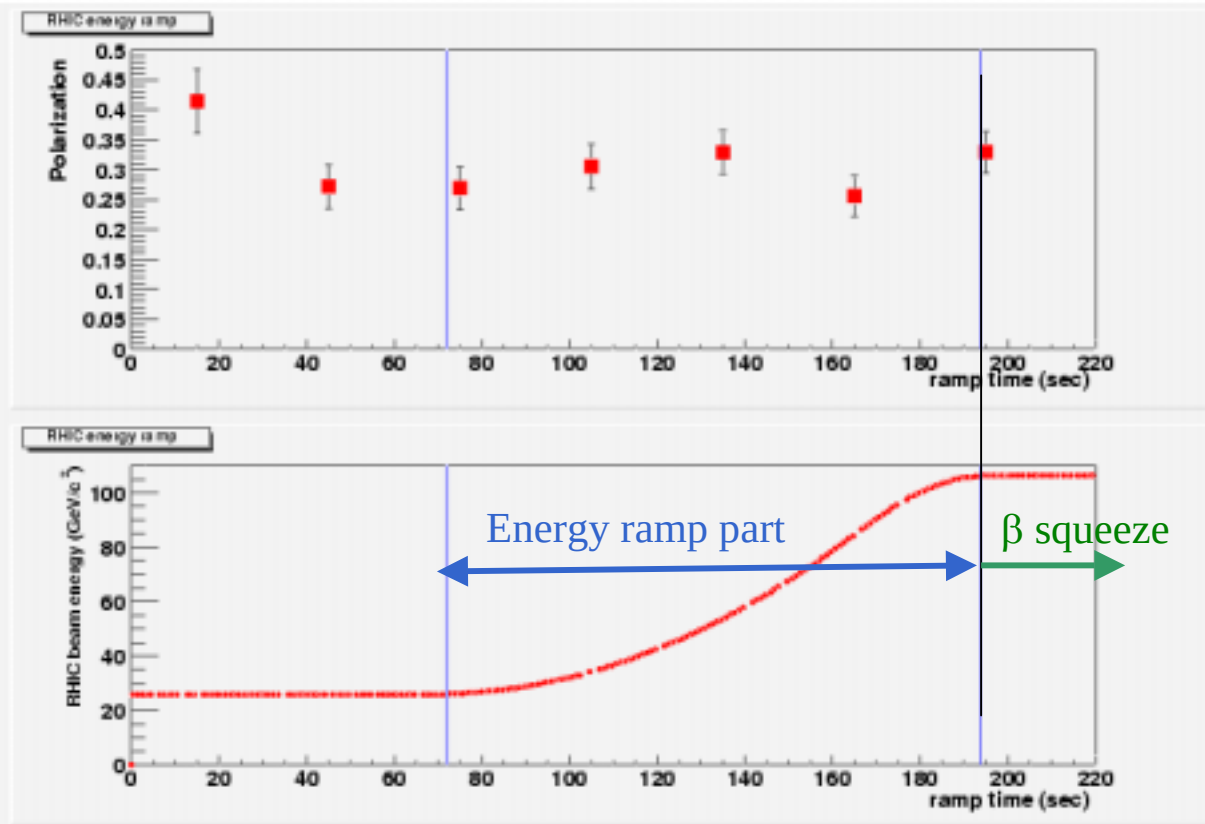

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