Results of RHIC *pC* CNI Polarimeter Run-03

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Xth workshop on high energy spin physics

(NATO ADVANCED RESEARCH WORKSHOP)

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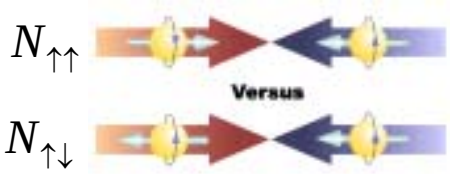
pC CNI Polarimeter : Impact on the RHIC Spin project

Single Spin

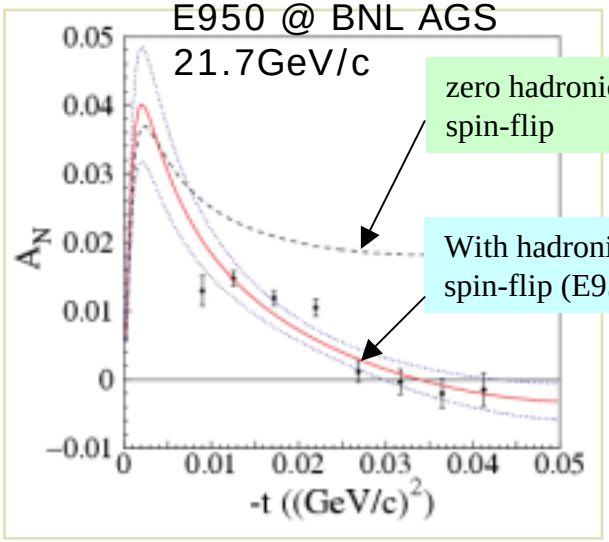
Physics Asymmetry

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

Double Spin

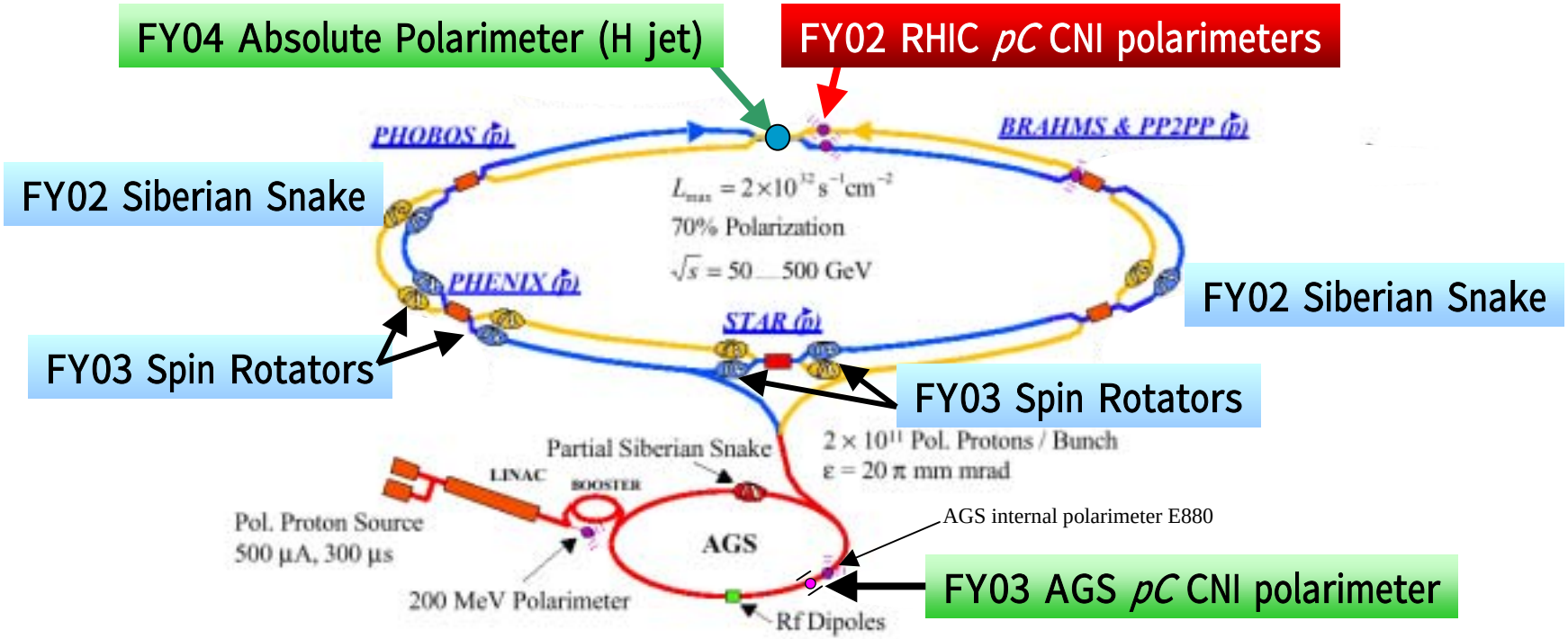


$$A_{LL} = \frac{1}{P_B^{\,2}}\left(\frac{N_{\uparrow\uparrow} - N_{\uparrow\downarrow}}{N_{\uparrow\uparrow} + N_{\uparrow\downarrow}}\right) = \varepsilon_{LL}$$



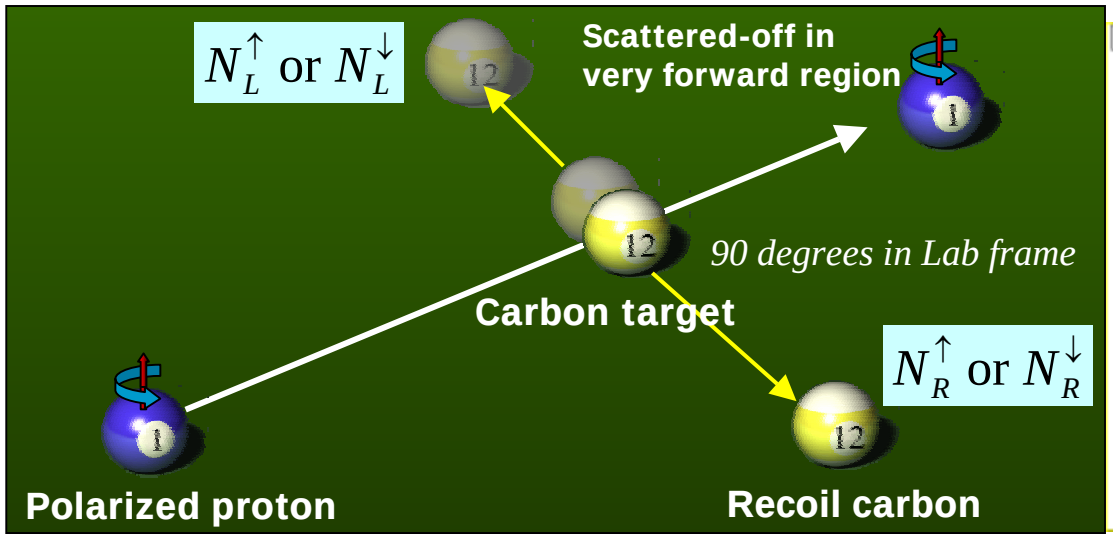
- RHIC-Spin is the first Polarized-Proton collider
- The raw asymmetry (=ε) needs to be **normalized with beam polarization** to obtain analyzing powers of the process (A_L, A_{LL})
- The impact is quadratic on double spin asymmetry (i.e.gluon polarization)
- *pC* CNI polarimeter (elastic proton-Carbon scattering Coulomb Nuclear Interference) is used for polarization measurements (fast, reliable)
- A_N of *pC* CNI is mainly known from QED calculation (size ~1% in our detection range), except the contribution from hadronic spin flip amplitude which requires direct measurement (22GeV/c E950 @BNL AGS)

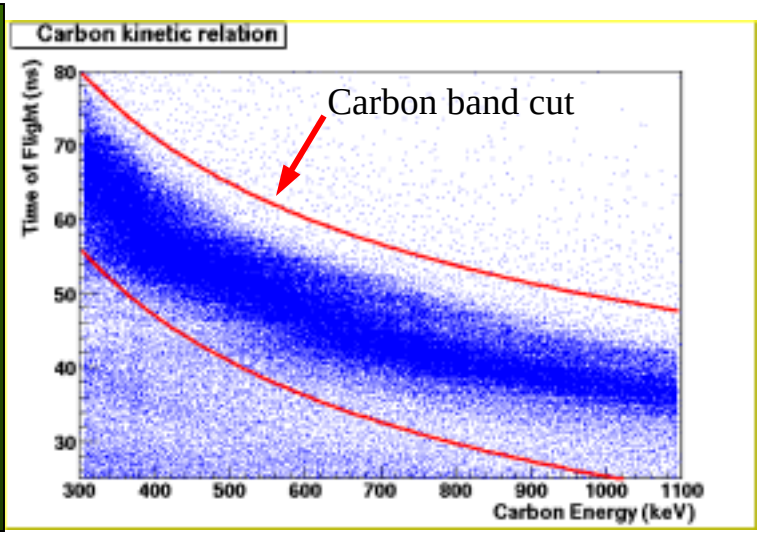
RHIC varieties of components for pp-mode



- Final goal is to know absolute beam polarization 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)

Elastic pC CNI : Asymmetry and Kinematics





$(g\text{-}2)_p$ σ_{total}

$$A_N = c_1 \phi^{em}_{\text{flip}} \times \phi^{had}_{\text{non-flip}} + c_2 \phi^{em}_{\text{non-flip}} \times \phi^{had}_{\text{flip}}$$

Calculable — Require direct measurement

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

- A_N~ 1% requires large statistics > 10^7
- Measure left-right asymmetry of recoil carbons
- Very small momentum transfer

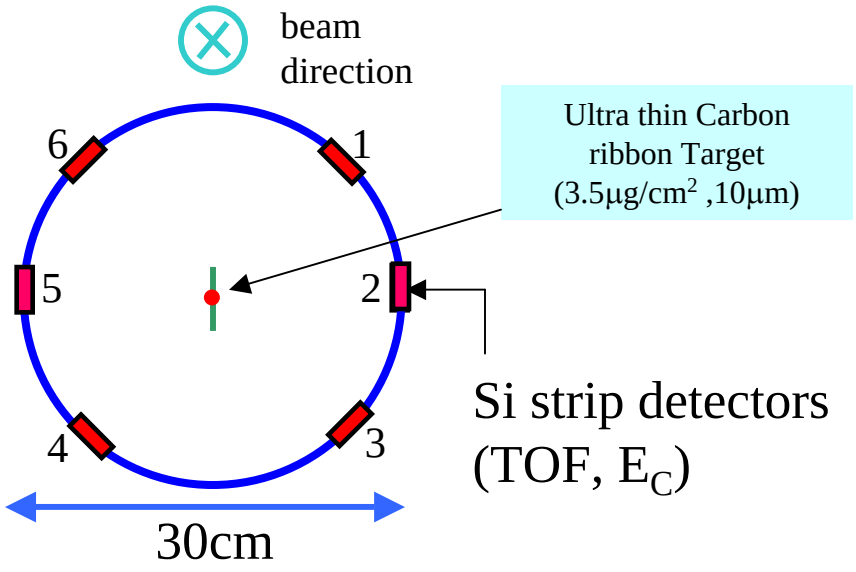
  0.006 < $-t$(GeV/c)^2 < 0.03

Square root formula

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

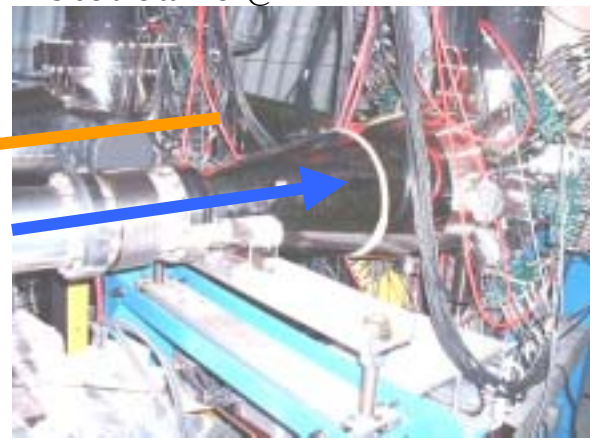
the recoil detection

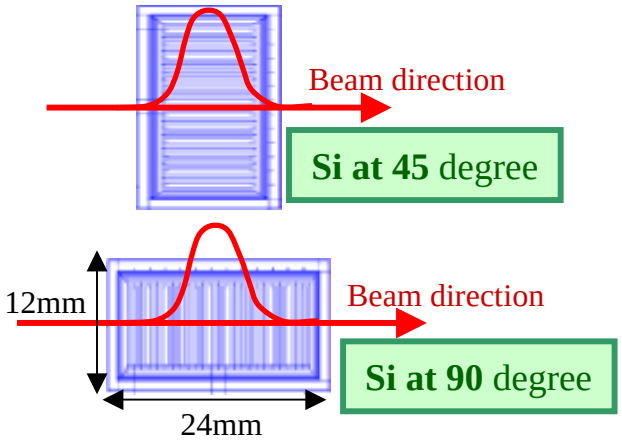
Detector/Target layout



RHIC x 2 rings

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)

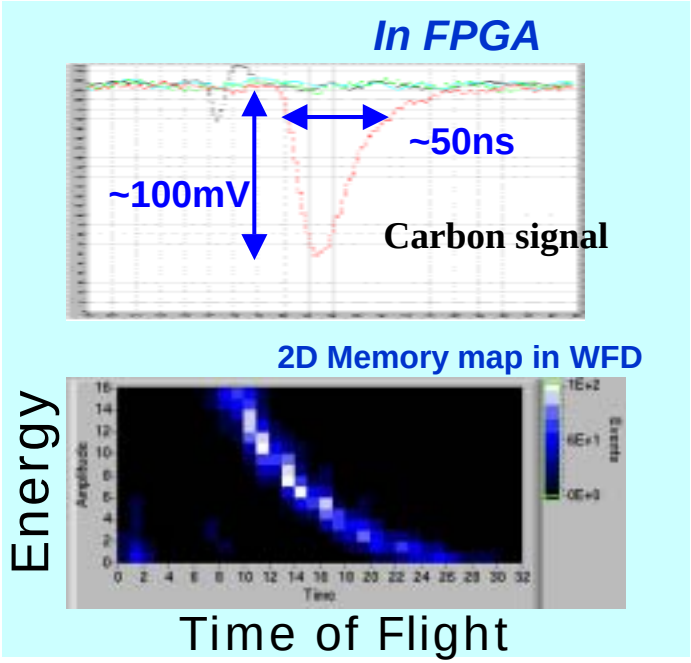
→ WFD system !

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

- Max pulse height (peak)
- Time of flight (CFD)
- 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

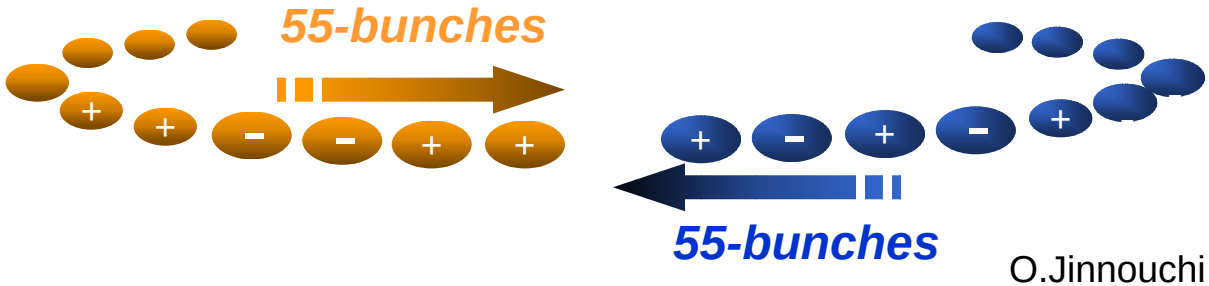
- Minimize the disturbing beam → longer beam lifetime
- Minimize the radiation damage on Si detectors

RHIC Spin polarized proton run-03

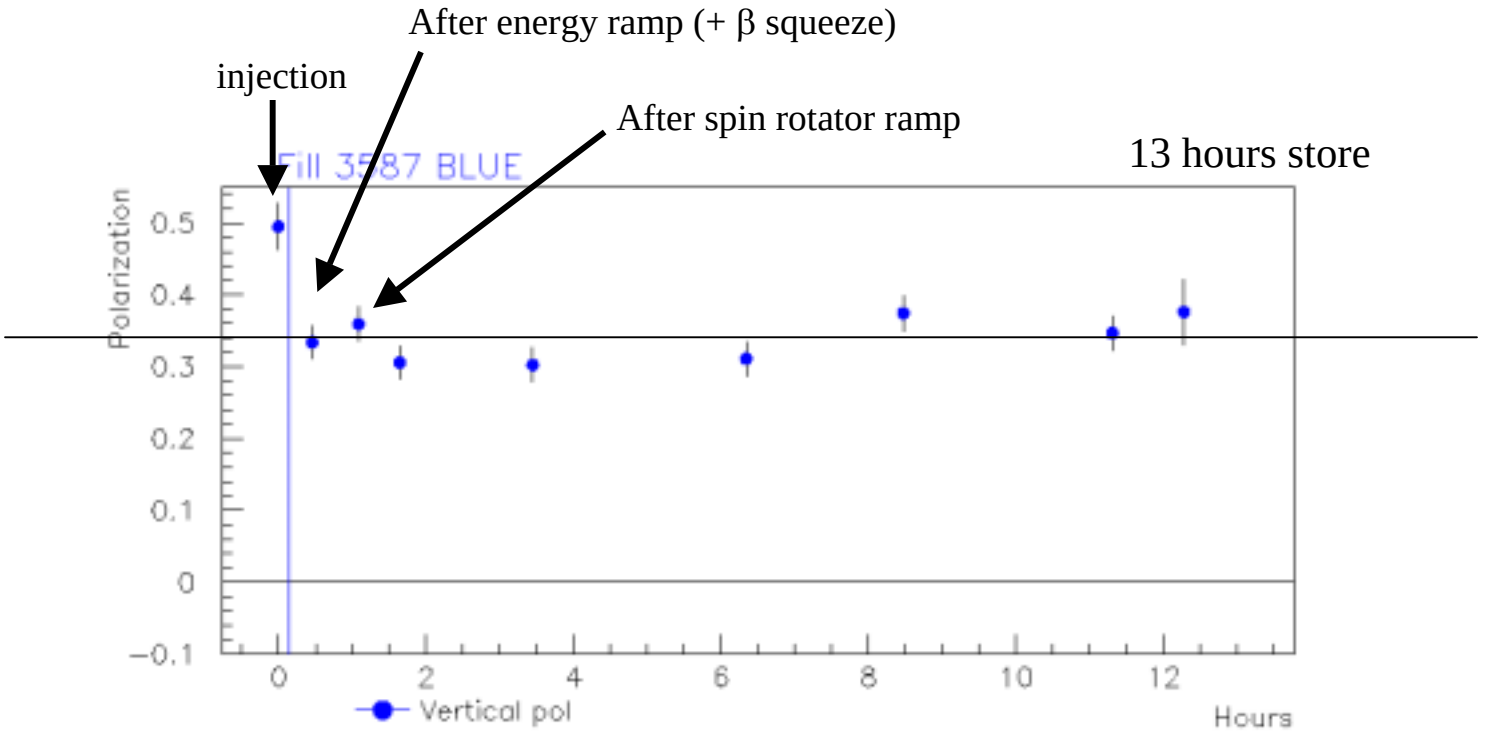
- Run periods
  - Mar 26th – May 3rd 2003 (5weeks)/ pp commissioning
  - May 3rd – May 30th 2003 (4weeks)/ physics run
- New device
  - Spin rotators started commission and operation
    - From Apr 22nd IR8 (Phenix)
    - From May 15th IR6 (Star)
- 55 bunches per ring with 0.65 x 10^{11} p↑/ bunch
-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



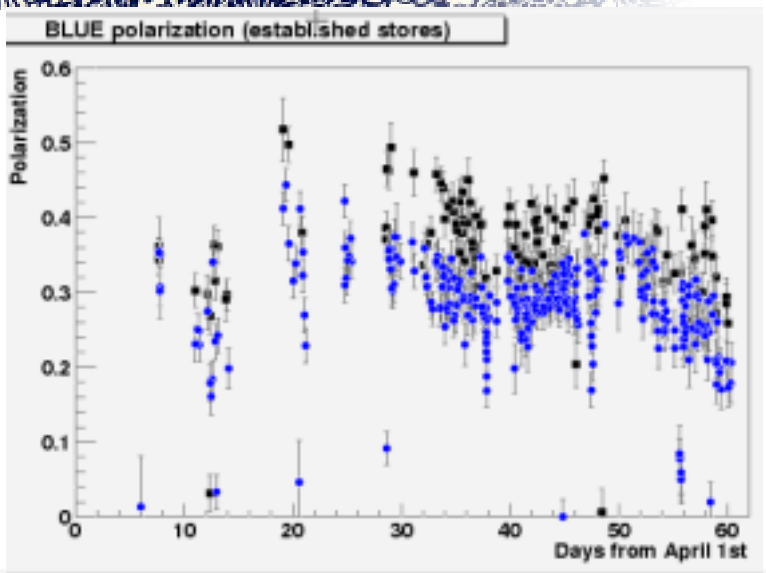
Polarization measurements at fill with rotator ramp

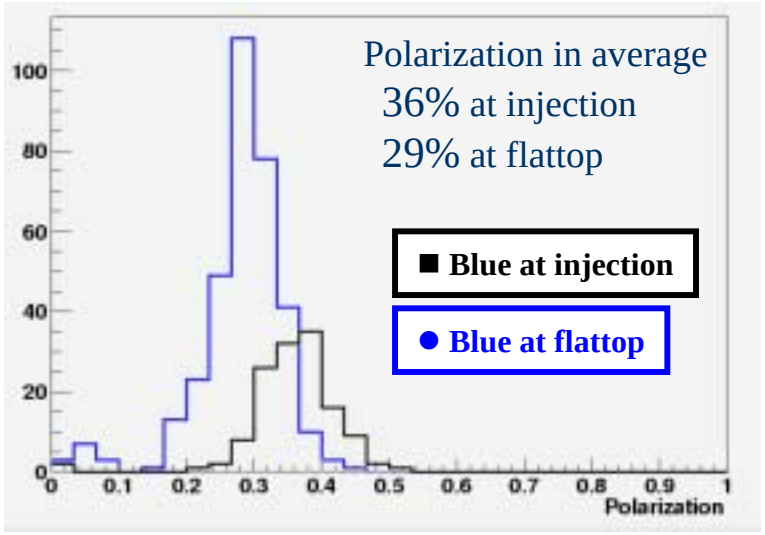


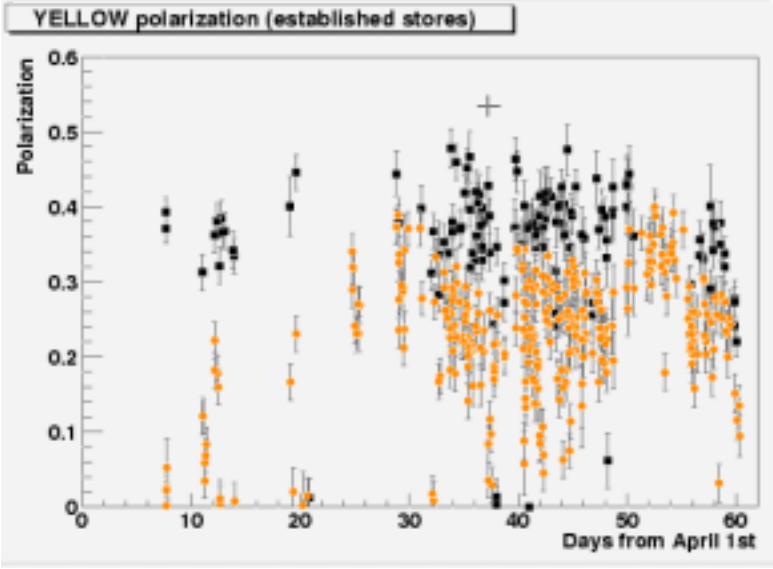
- Measurement procedure
  - Injection (24GeV) → After acceleration (100GeV) → After spin rotator ramp → every 2 hours
- Fills tend to lose polarization at the first ramp and stay constant during the long fill

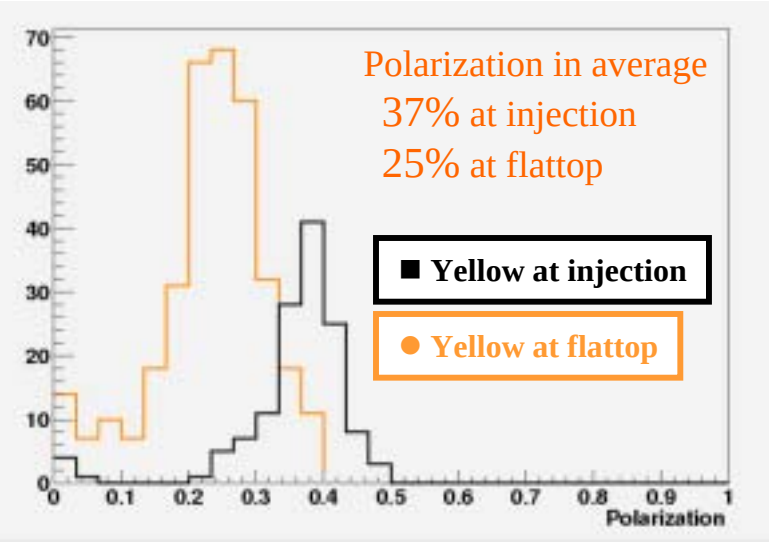
Polarization results in average

- The same A_N is used for 100GeV

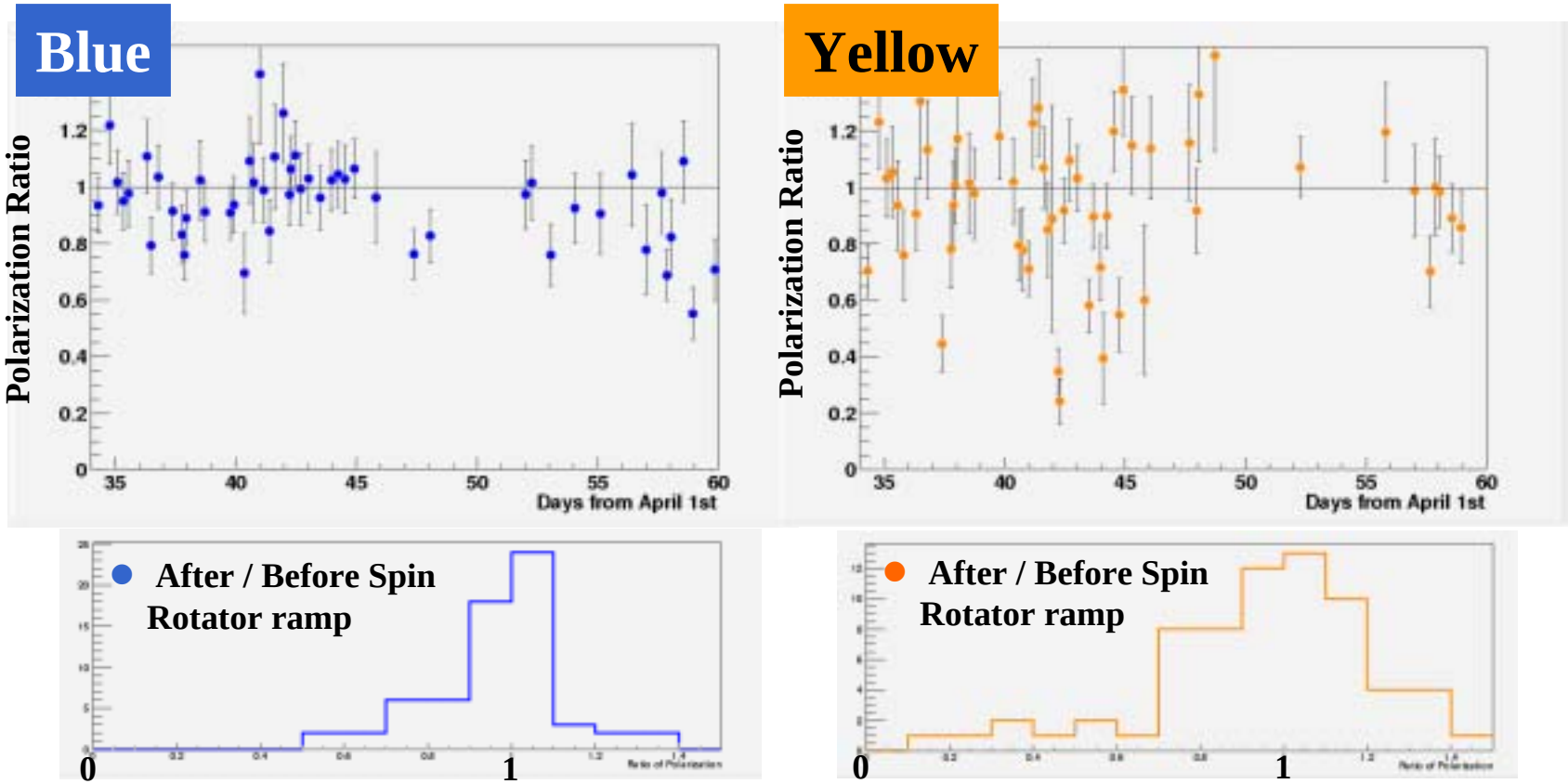






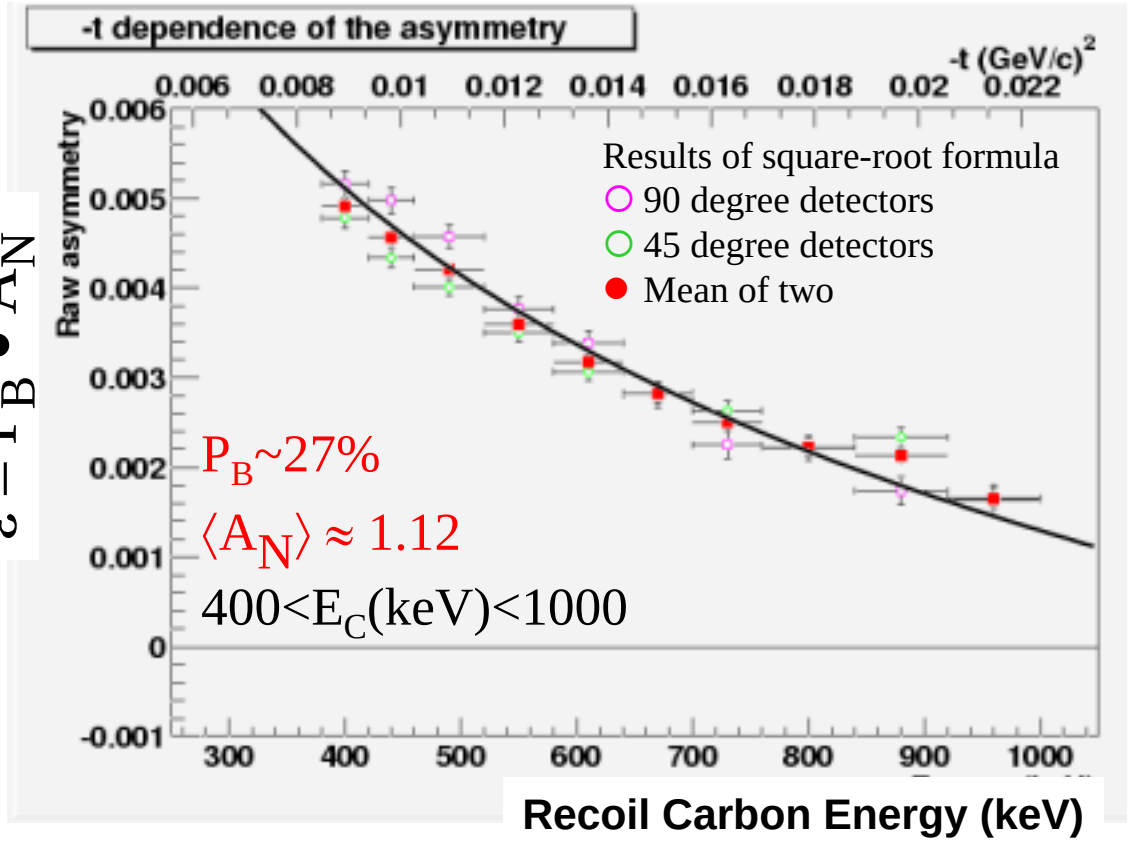


Polarization after/before spin rotator ramp



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

Raw asymmetry → Polarization



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

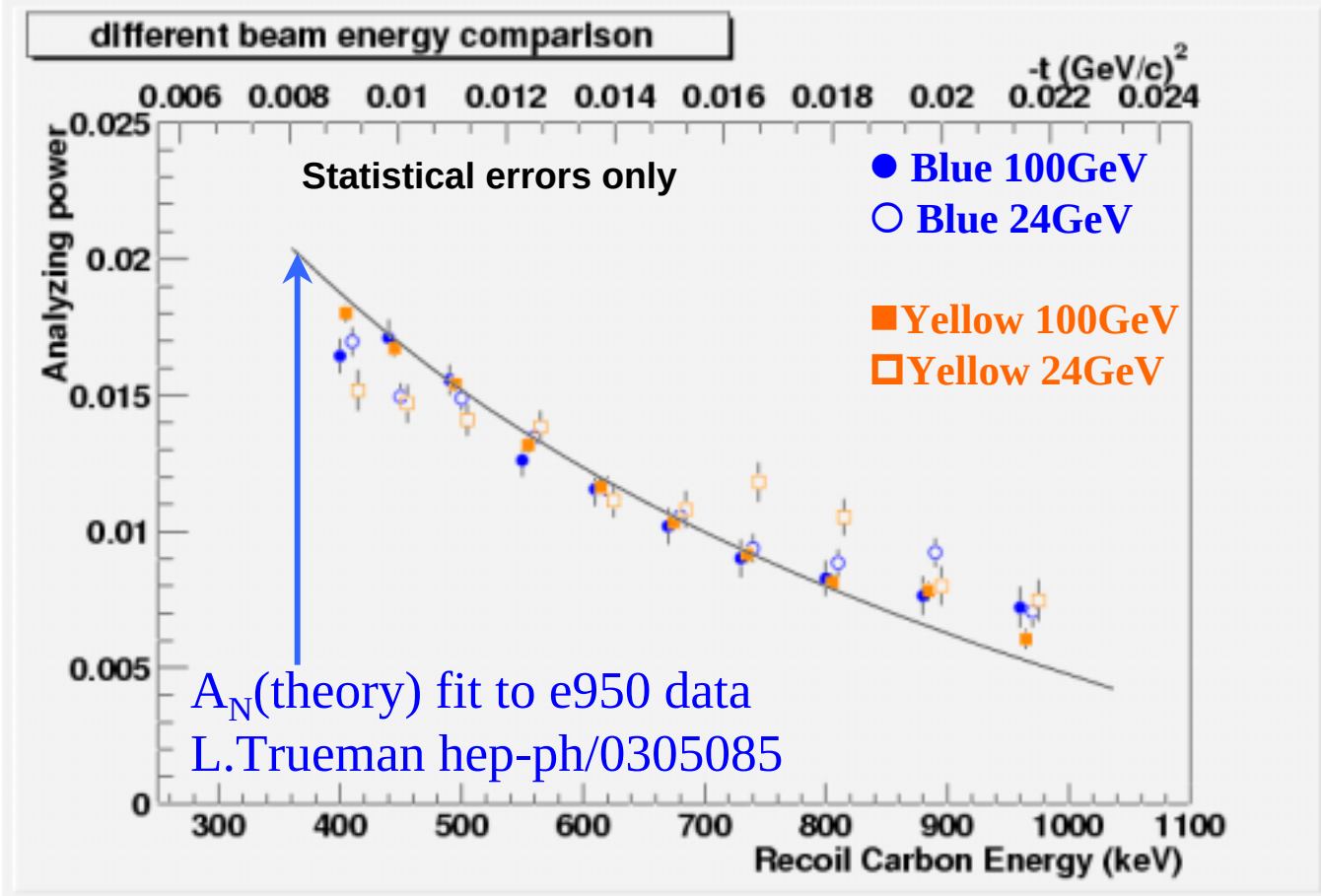
$$\langle A_N \rangle = \frac{\sum N(t_i) A_N^{th}(t_i)}{\sum N(t_i)}$$

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

L. Trueman hep-ph/0305085

- Once the polarization is determined, A_N for each $-t$ bin can be calculated as, $A_N(t_i) = \varepsilon_N(t_i) / P_{beam}$

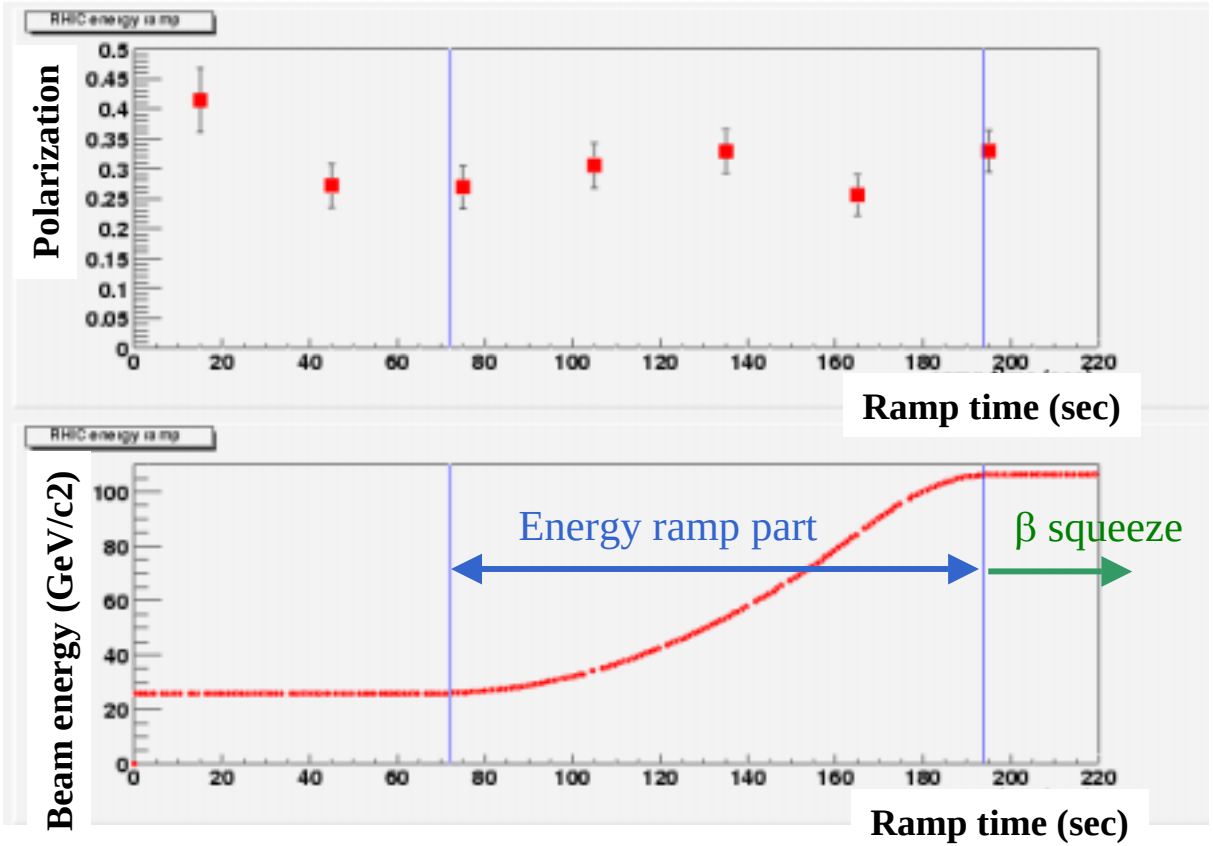
-t dependence of A_N at different energies at RHIC



- Data points are normalized with polarization
- A_N shapes are quite similar → hadronic spin-flip contribution is the same magnitude at 100GeV (as 24GeV)

Polarization measurement along the ramp

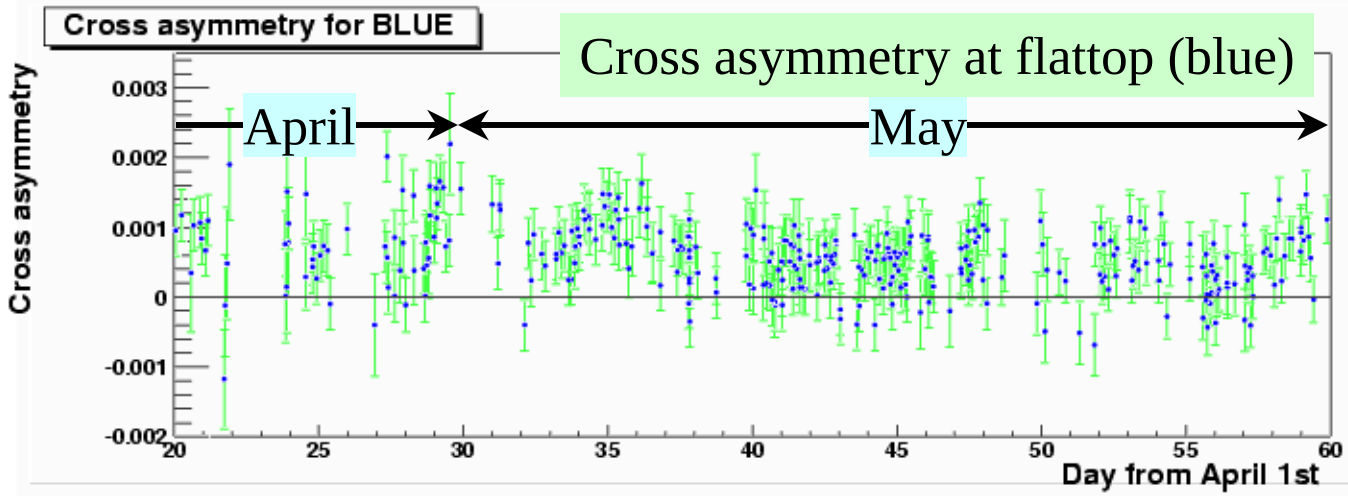
Yellow Ring (fill: 3516, 3652 combined)

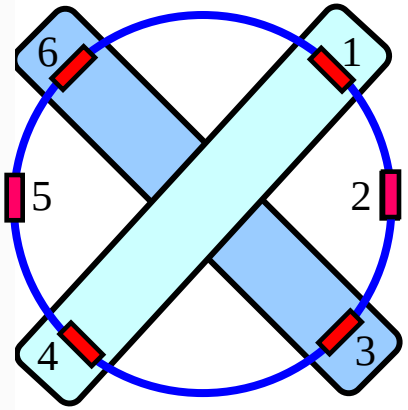


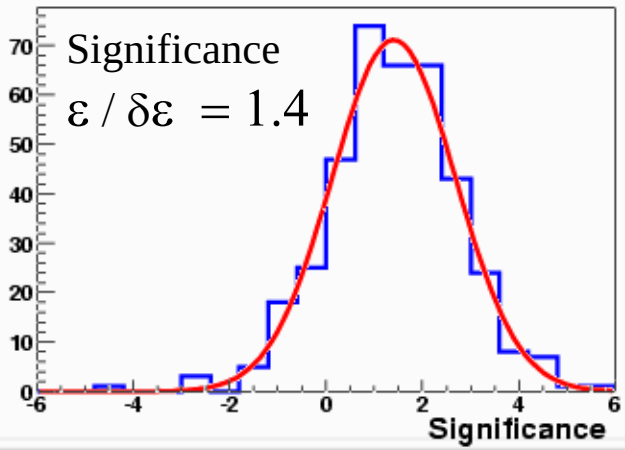
- Same AN is assumed at any energy
- Continuously measure polarization along the energy ramp + β squeeze
- Statistics was not enough, limited by size of memory on WFD

Systematic errors

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







- In Blue flattop, false asymmetry (cross) was consistently observed throughout the run
- Other check with radial component showed a similar systematic error
- Size and mechanism are being studied

Summary & Outlook

- RHIC *pC* CNI polarimeter **stably worked** through Run-03 period
- The polarization in average at store energy **was improved** from previous run (Run-02)
  - **BLUE (11%)→ 29%**
  - **Yellow (16%)→ 25%**
- The spin rotators worked and **kept polarization**
- **The first ramp measurement** was completed but with low statistics
- Observed non-negligible false asymmetries, the study is in progress
- Observed **small beam energy dependence** of A_N from 24 to 100 GeV

- Increase the on-board memory for WFDs and readout speed. Improve the event statistics, especially for ramp measurements study
- Polarized gas-jet target will be commissioned in Run-04