Polarimetry of RHIC and AGS

H. Huang

- **Scheme of Polarimetry**
- **Performance**
- **Upgrade**

BROOKHAVEN NATIONAL LABORATORY

Collaborators (Polarimeter + Jet)

I.G.Alekseev[A] A.Bravar[B] G.Bunce[B*] S.Dhawan[D] R.Gill[B]
H.Huang[B] W.Haeberli[E] G.Igo[F] O. Jinnouchi*
V.P.Kanavets[A] K.Kurita[H] A.Khodinov[M] A.Kponou[B] Z.Li[B]
W.Lozowski[I] W.W.MacKay[B] Y.Makdisi[B] A.Nass[B] H.Okada[G]
S.Rescia[B] T.Roser[B] N. Saito[G] H.Spinka[L] E.J.Stephenson[J]
D.N.Svirida[A] D.Underwood[L] C.Witten[F] T.Wise[I] J.Wood[F]
A.Zelenski[B]

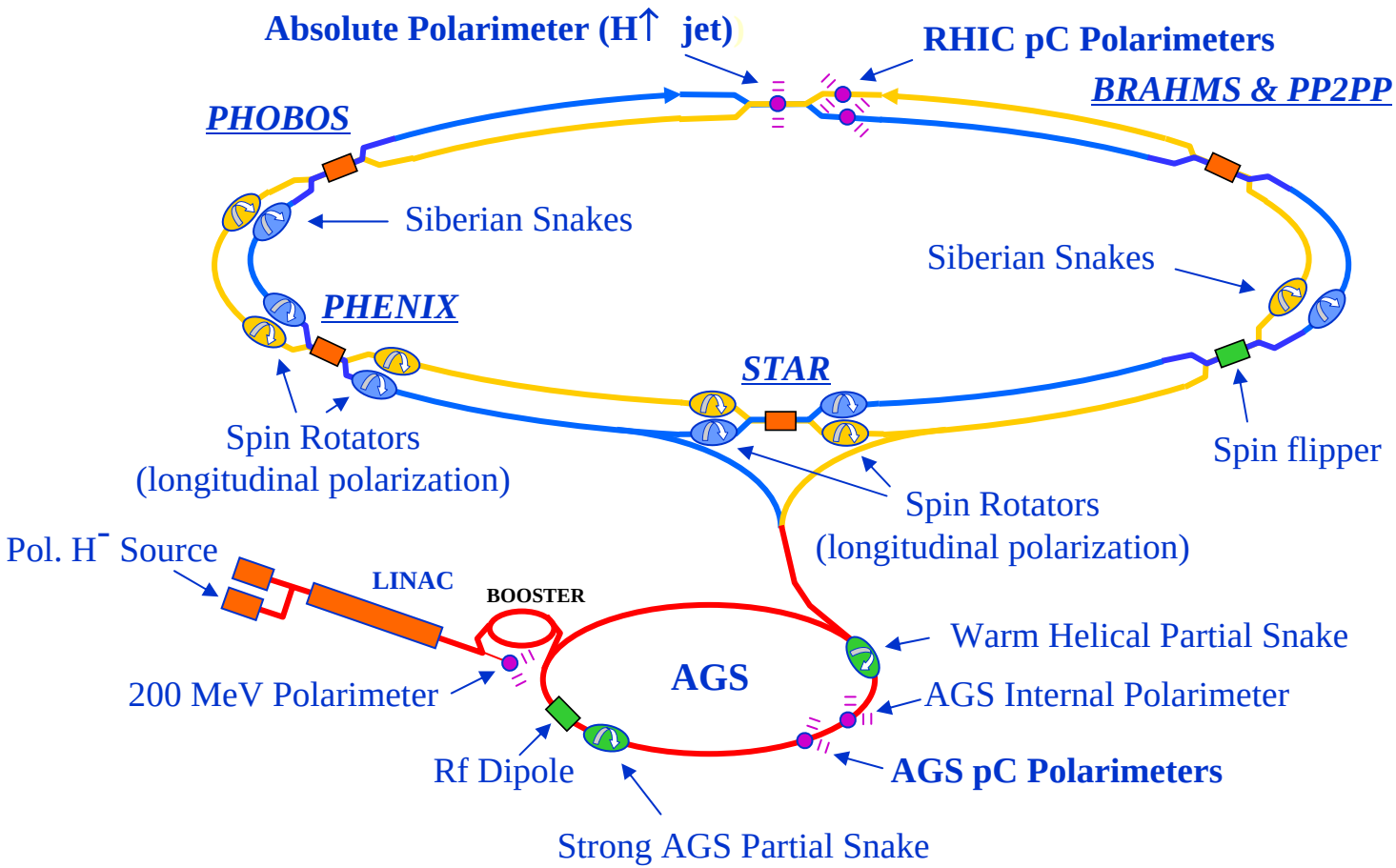
RBRC* ITEP[A] BNL[B] ANL[C] Yale U[D] Wisconsin U[E] UCLA[F]
Kyoto U[G] Rikkyo U[H] Indiana U[I] Indiana U[J] IUCF[K] Argonne U[L] StonyBrook U[M]

we are moving more operational parts to CAD, and continued collaboration with physics group is needed and planned

RHIC Polarimeter Requirements

- Must provide fast (minutes) and reliable measurements
- Tool to tune snakes and possibly spin rotators at various energies, from injection @ 24 GeV to 250 GeV
- Device must fit in Q3 to Q4 (~35 m) warm straight of RHIC
- Disturbance to the RHIC beam must be minimal
- Provide absolute polarization measurement for experiments
- RHIC Spin Program requires $\Delta P_{beam} / P_{beam} < 0.05$

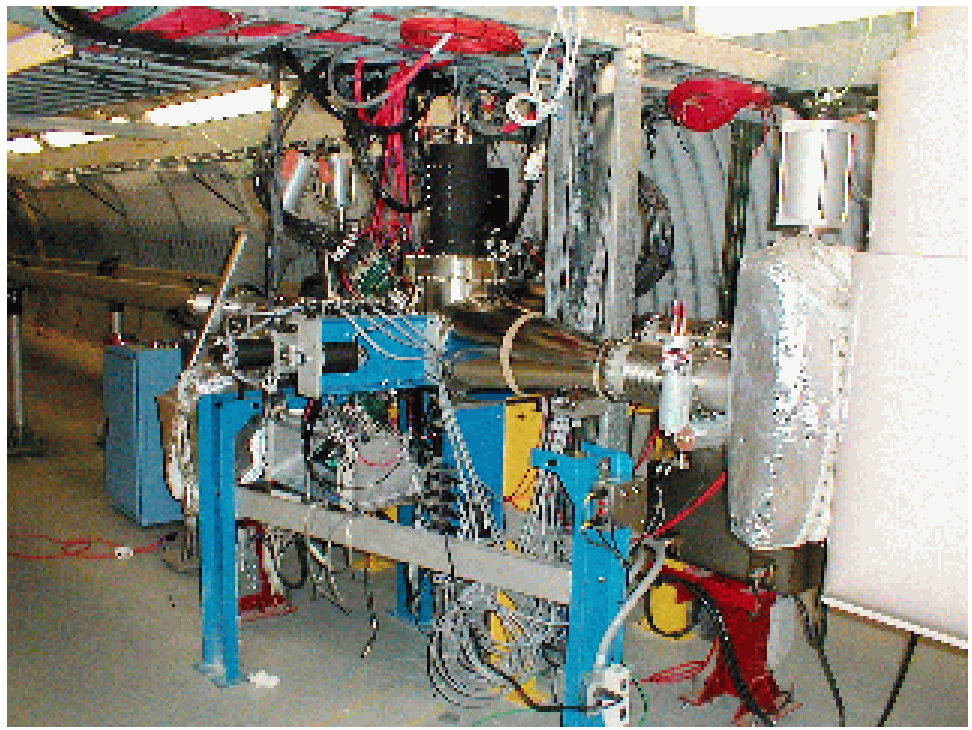
RHIC polarized proton accelerator complex



Basic Designs

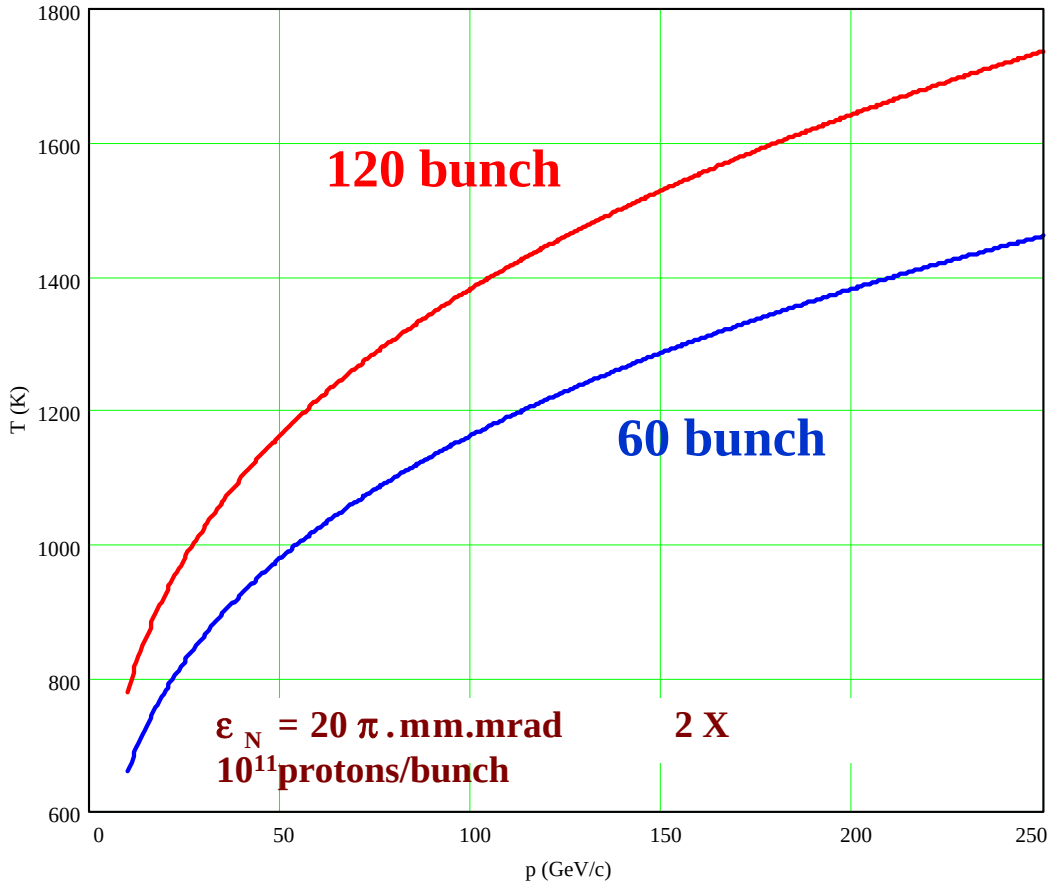
Strategy: A fast relative polarimeter calibrated with a polarized jet target

- Four target holders to provide redundancy in the case of ribbon breakage.
- Two axes for polarization profile measurement in both plane; also more targets to use
- 45 degree detectors to measure both vertical and radial components of polarization.
- Taping structure to reduce impedance impact.



Carbon Target

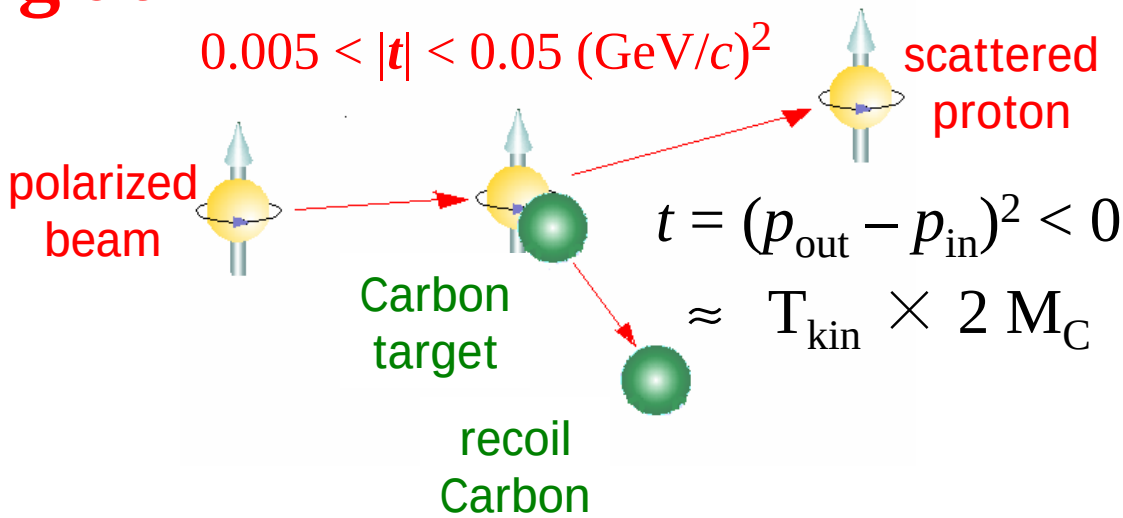
- Thickness ~5 μg/cm^2 (25 nm, only ~100 atomic layers)
- Width 5—15 μm with 25 mm length
- Dimension ratio is 1 : 200 : 2000000
- The target can survive the bright RHIC proton beams.
- Small effect on the stored beam lifetime, allows tens of measurements in a single store
- Advanced technique developed at Indiana University and transferred to BNL now



Elastic pC Scattering at Low *t*

$$A_N = -\frac{1}{P_B} \cdot \frac{N_{left} - N_{right}}{N_{left} + N_{right}}$$

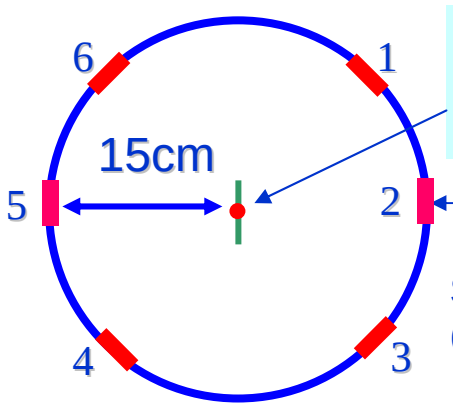
recoil



1. A_N from interference of spin non-flip and spin flip amplitudes
   ⇒ spin dependence is from em spin-flip amplitude
   ⇒ hadronic spin flip is possible, so A_N must be calibrated by experiment (jet)

2. Polarimetry
   - almost "calculable"
   - small $A_N \sim 1 - 2$ % ⇒requires large statistics > 10^7
   - large cross section
   - weak beam momentum dependence (p > 20 GeV/*c*) if any

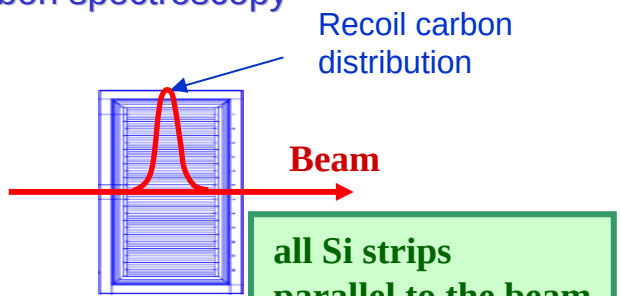
Detector Setup + DAQ



Ultra thin Carbon ribbon Target ($5\mu g/cm^2$)

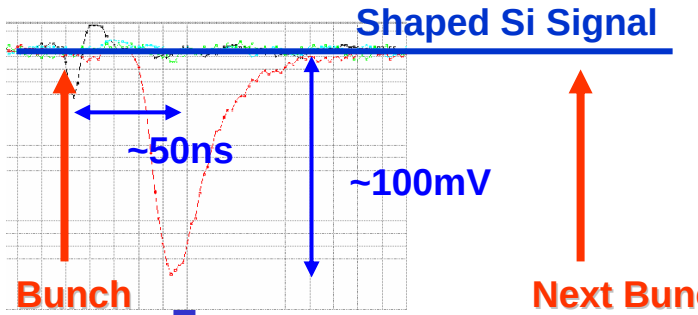
Si strip detectors (TOF, E_C)

Thin dead layer for low energy carbon spectroscopy



all Si strips parallel to the beam

12 x 6 strips (10mm x 2mm pitch)



Wave Form Digitizer (WFD)

20M events / 20sec

- Pulse Height
- TOF
- Bunch ID
- Integral (Q)

online

Select carbons at on-board LUT

- Scaler data
- Asymmetry calculation
- Online results (to experiments)

offline

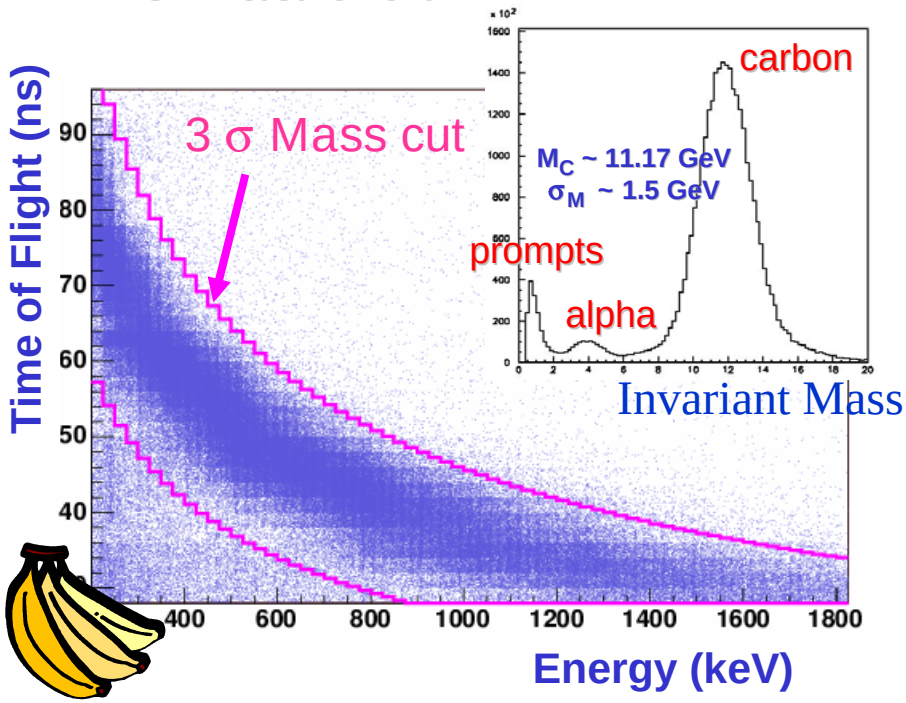
Event by event data

- Stored in on-board memory
- Used for offline detailed study

Recoil carbon PID à Asymmetry calculation

Particle ID (banana cut)

- Clear separation from backgrounds using TOF measurement



non-relativistic kinematics

$$tof = \sqrt{\frac{M_C}{2T_{kin}}}L$$

Asymmetry calculation

$$\varepsilon_N^{\uparrow} = -\frac{N_L^{\uparrow} - N_R^{\uparrow}}{N_L^{\uparrow} + N_R^{\uparrow}} \quad \text{for up spin}$$

$$\varepsilon_N^{\downarrow} = -\frac{N_R^{\downarrow} - N_L^{\downarrow}}{N_R^{\downarrow} + N_L^{\downarrow}} \quad \text{for down spin}$$

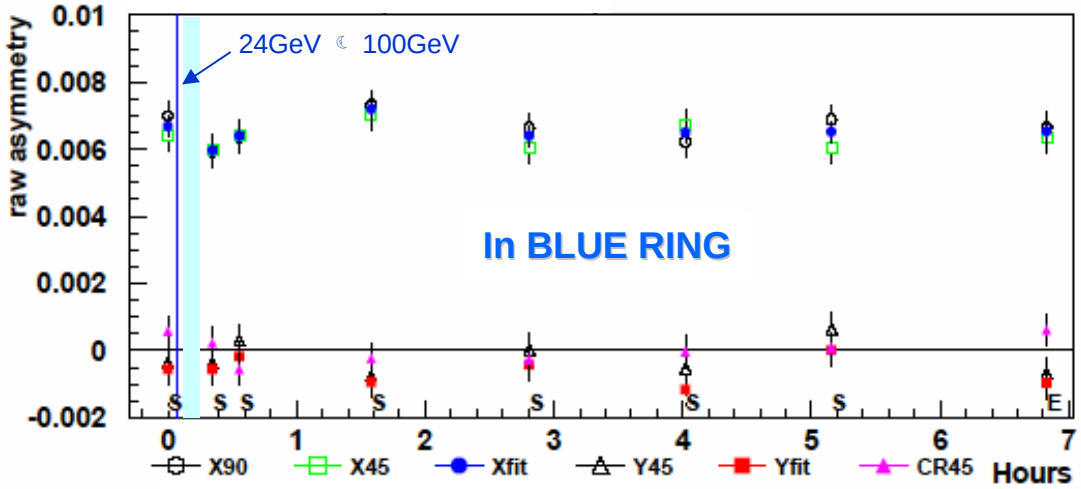
With alternating spin pattern (+,-,+,-) square-root formula

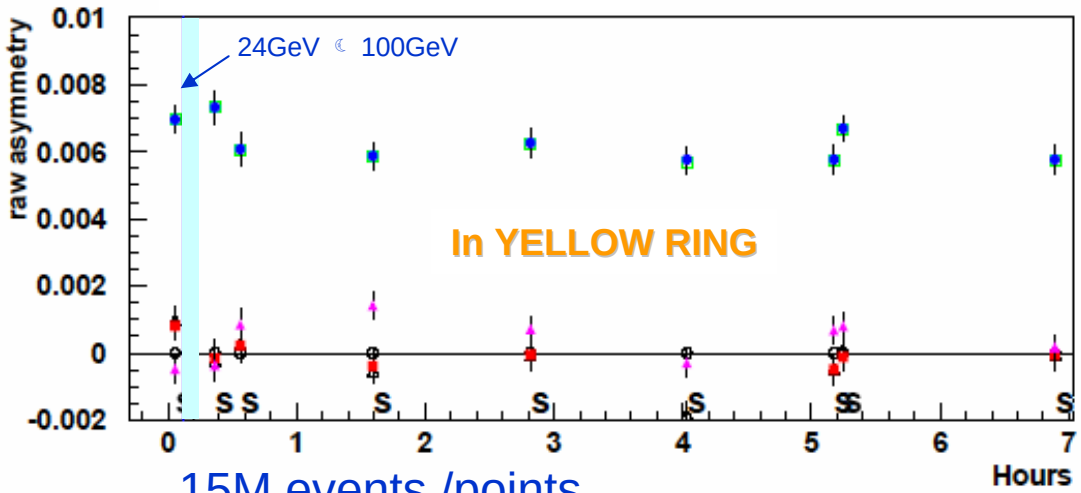
$$\varepsilon_N = -\frac{\sqrt{N_L^{\uparrow} N_R^{\downarrow}} - \sqrt{N_R^{\uparrow} N_L^{\downarrow}}}{\sqrt{N_L^{\uparrow} N_R^{\downarrow}} + \sqrt{N_R^{\uparrow} N_L^{\downarrow}}}$$

$$\mathbf{P_{beam} = \varepsilon_N / A_N}$$

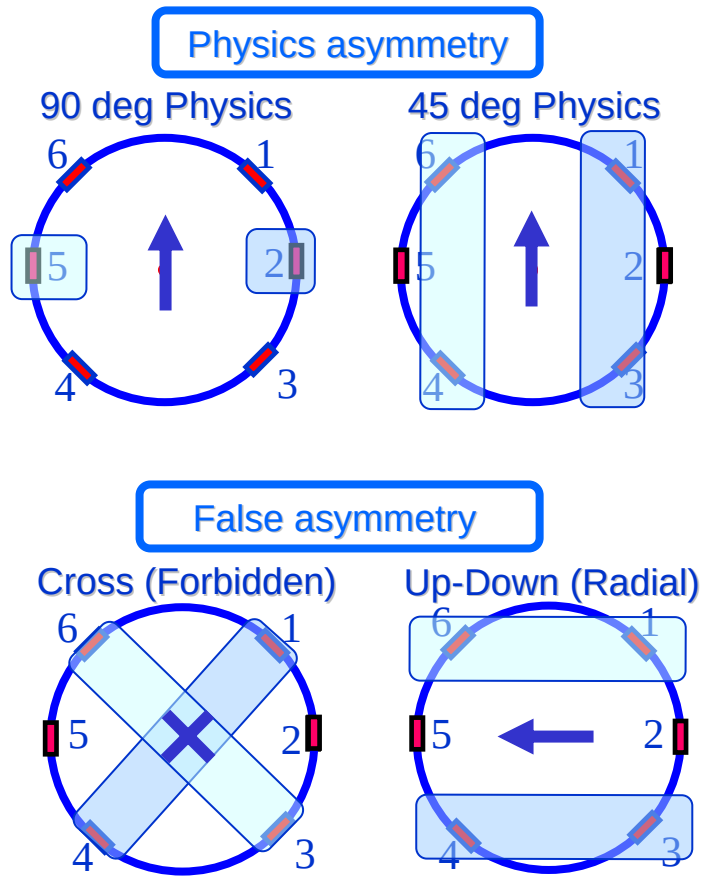
Polarization Measurements during RHIC Fill

Online Results

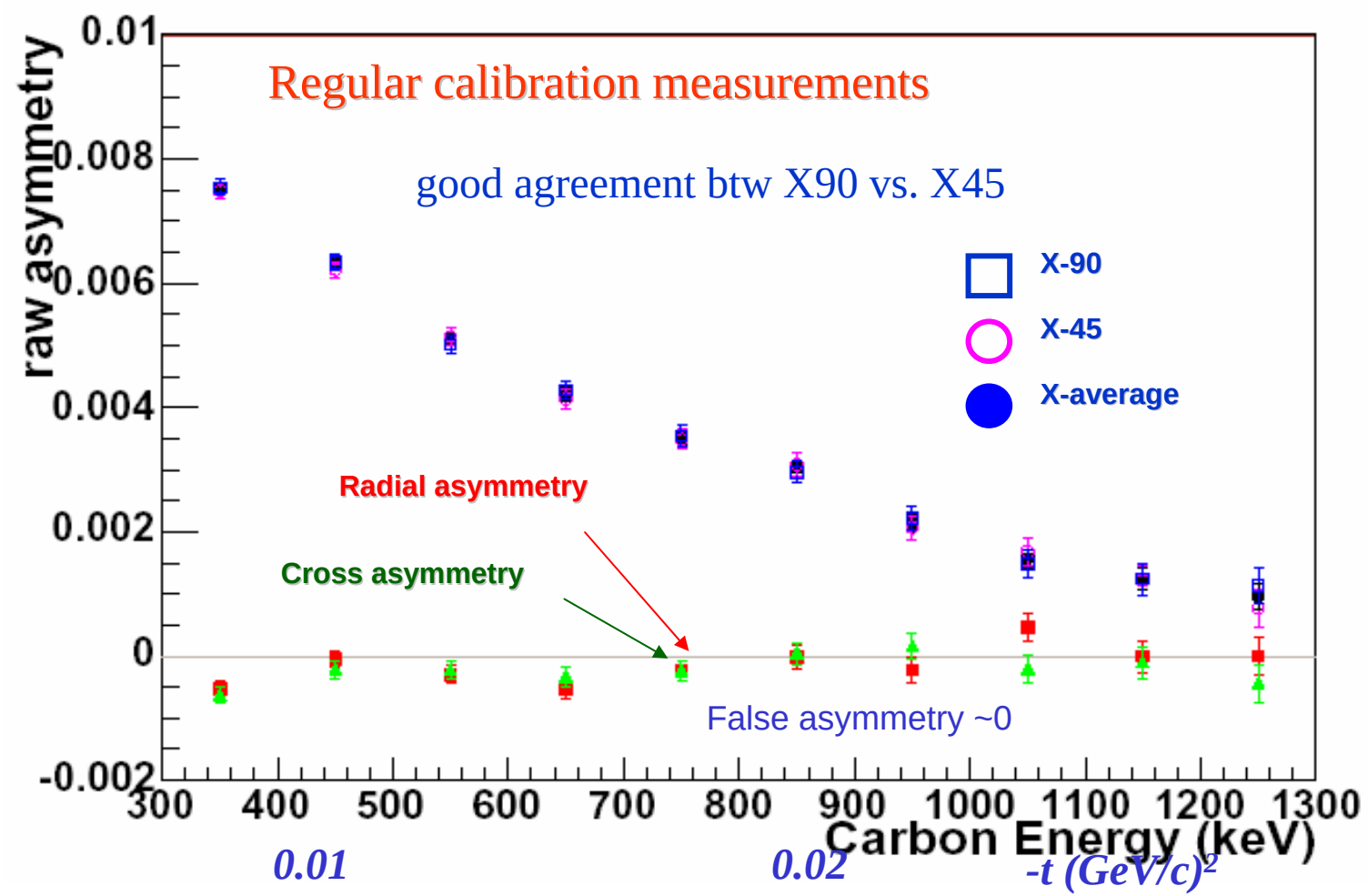




15M events /points

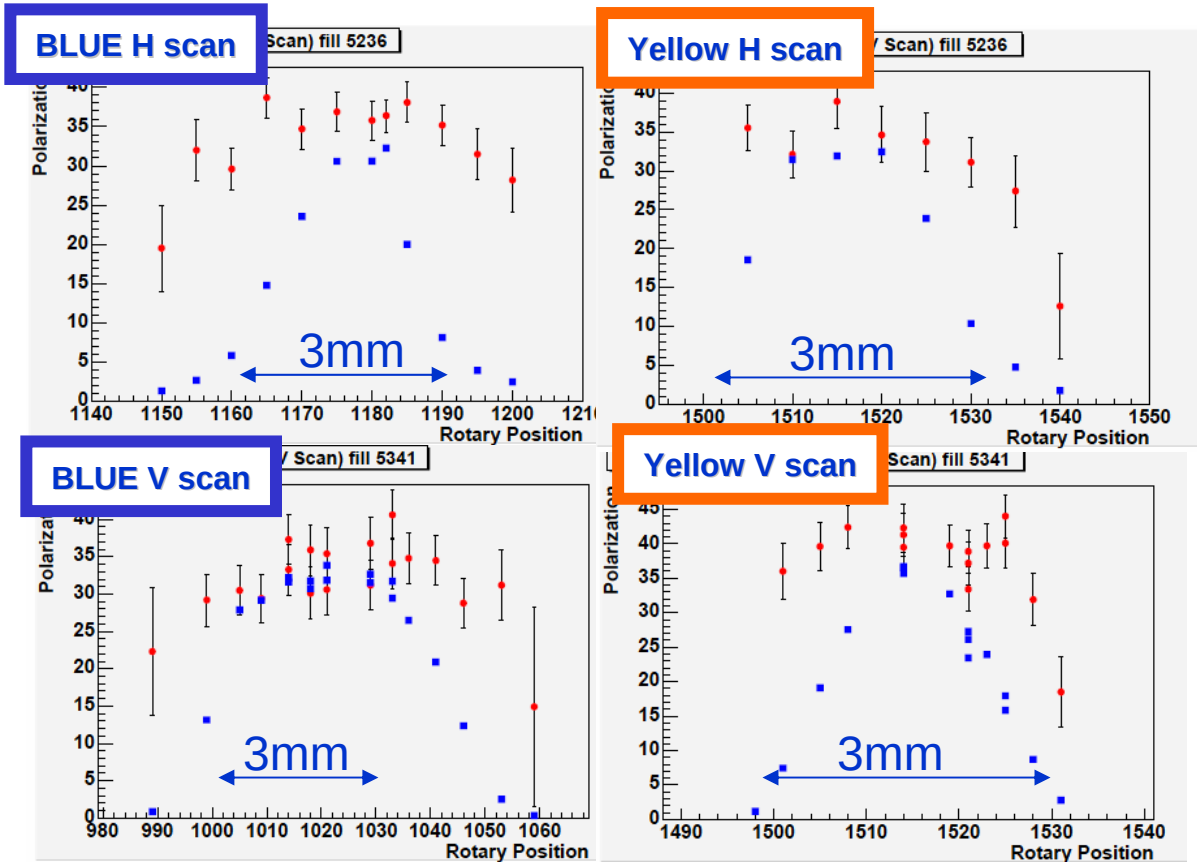


Raw Asymmetry vs. *t*



- Measurements taken with running Jet-target in parallel
- very clean asymmetry values

Beam Polarization Profiles



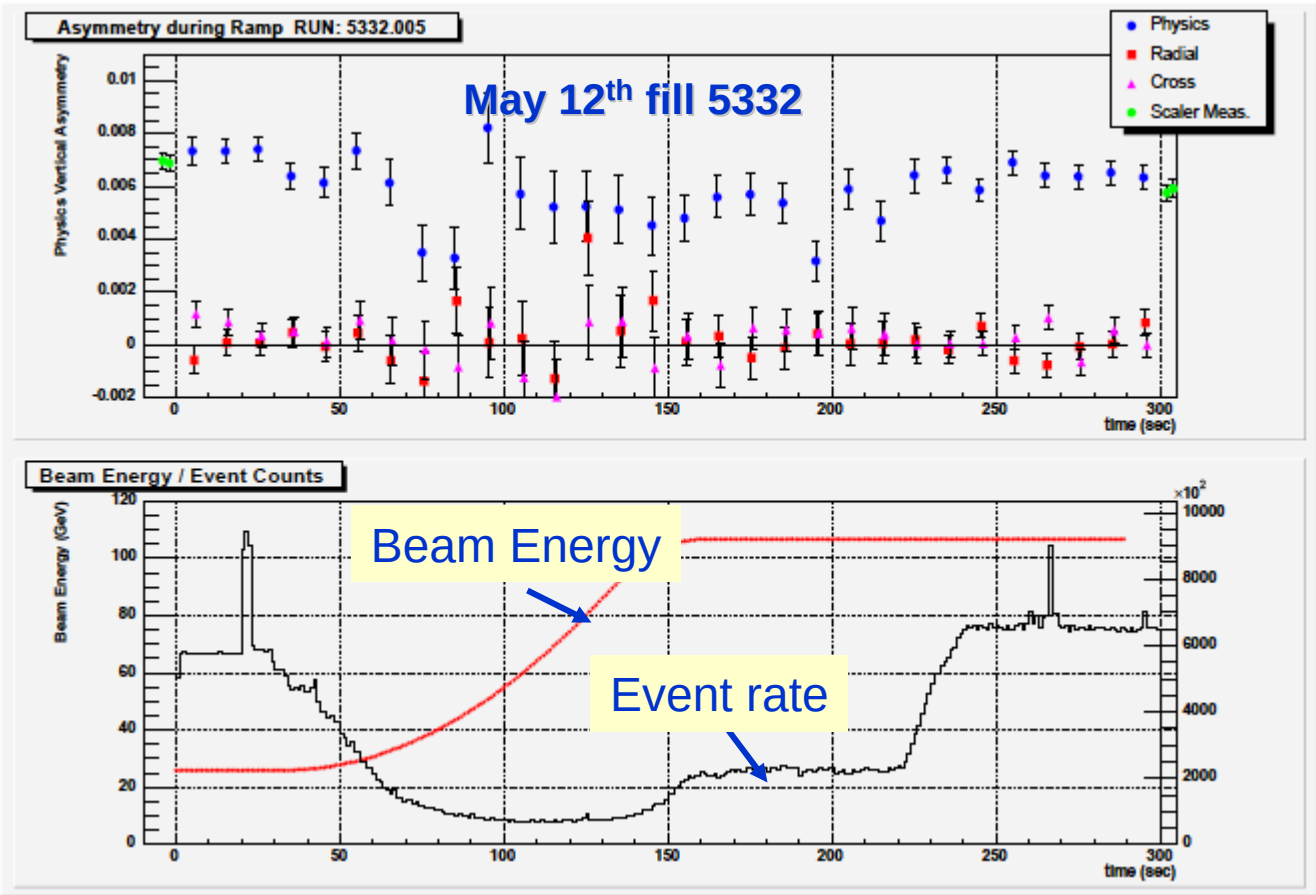
- Polarization
- Beam Intensity

H Scan --horizontal scan with vertical target

V Scan – vertical scan with horizontal target

- Capability of polarization profile measurement was demonstrated.
- Polarization profiles are flat in the middle part of the beam profiles, which is most important to experimenters.
- The polarization drop at the edges of beam could have two possible sources: inherited from AGS due to the way we correct intrinsic resonances (AC dipole); large amplitude particles have stronger resonance strength. Every polarization measurement will have this profile info (target scan through beam)

Ramp measurements

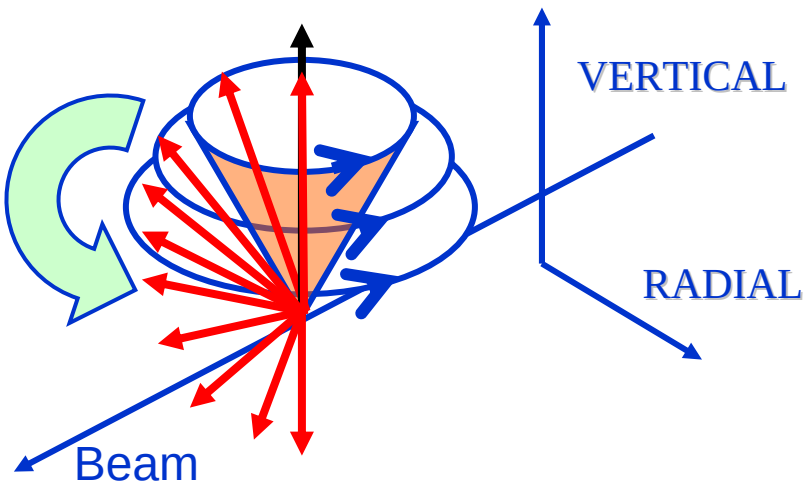


- As demonstrated, the polarimeters can measure polarization along the ramp.
- Ramp measurement can provide location of possible polarization loss along the ramp. It is a very important tool in machine tuning, especially when exploring 250GeV acceleration.
- It is important to have better orbit control on the ramp or target tracking the beam to separate polarization loss from polarization profile issues.

Spin Precession Measurements

- Use AC dipole to excite spin precession
- Measure vertical polarization component
- Measure radial component using complete time stamp from each event
  - revolution number
  - bunch crossing number
- Ratio of vertical over radial component measures difference of drive tune and spin tune
- Some data were taken in last run and are under analysis

spin flip ~ a few sec.



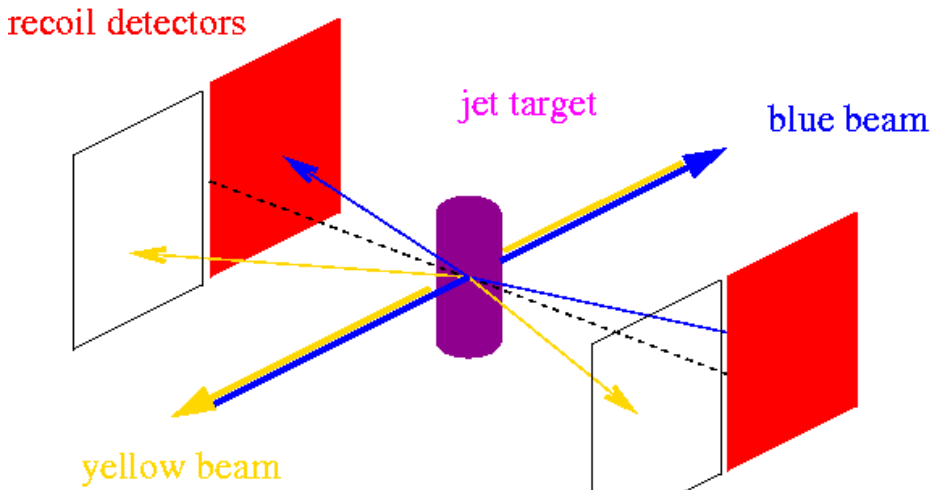
Polarized Jet

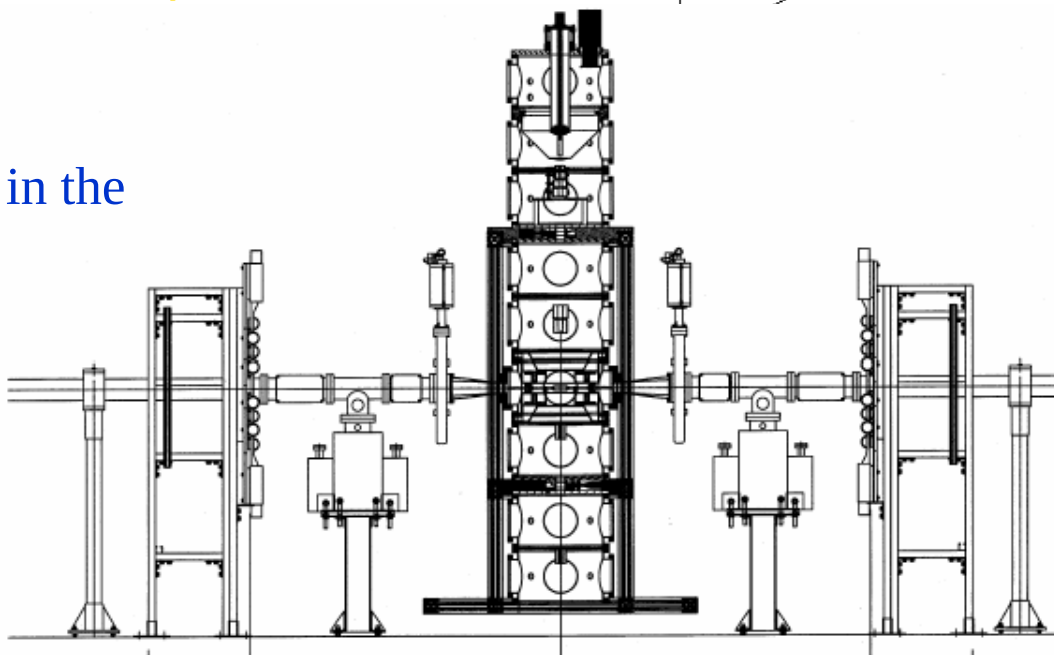
- RHIC absolute polarimeter
  to calibrate pC polarimeters to < 5%

- Polarized Hydrogen Gas Jet Target
  - thickness $1.3*10^{12}$ p/cm^2
  - polarization $92.4 \pm 1.8\%$
  - FWHM 6 mm

- Silicon recoil detectors

- Measure A_N^{pp} in *pp* elastic scattering in the CNI region to $\Delta A_N < 10^{-3}$ accuracy

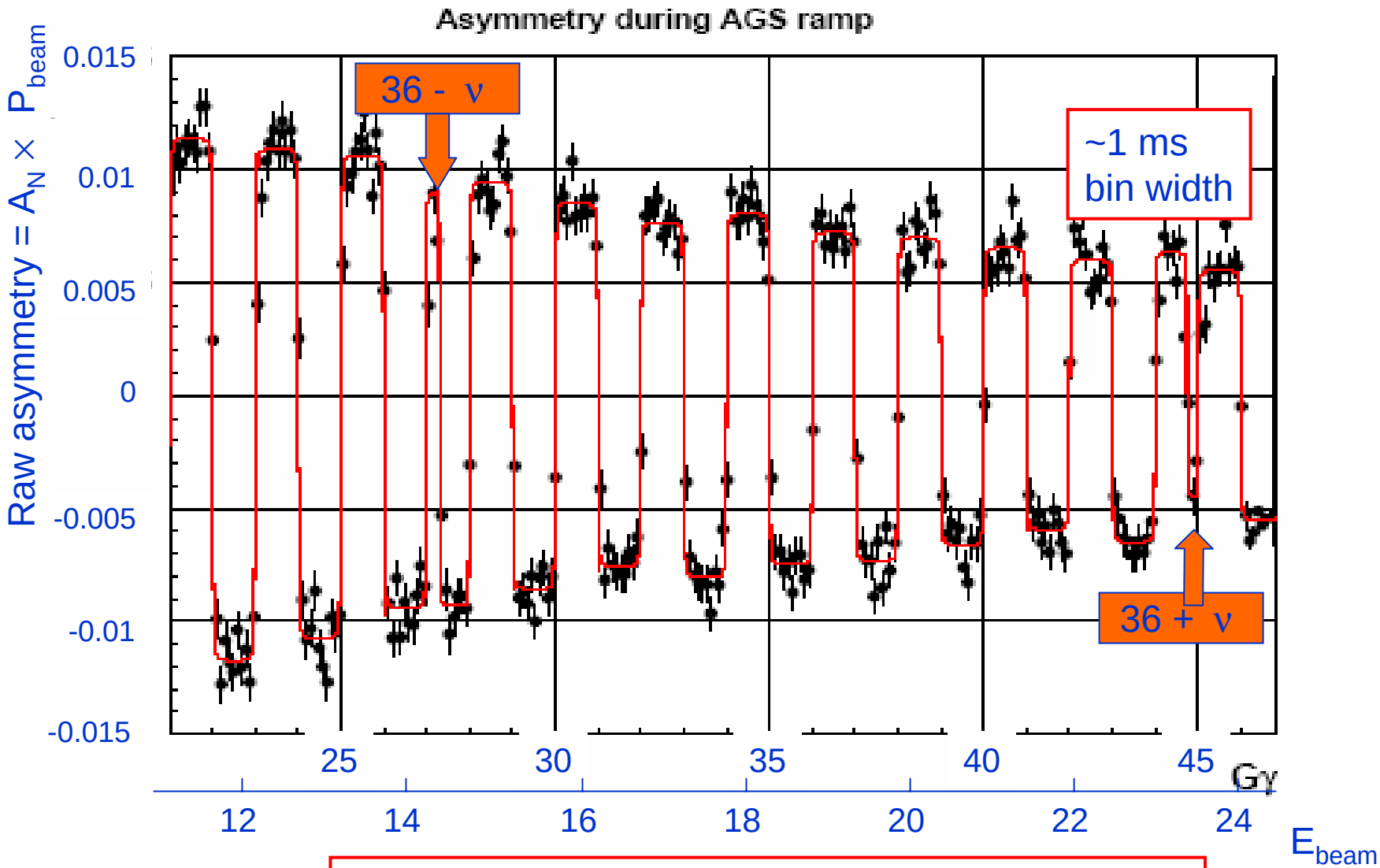




Success of Polarized Jet Commissioning Run

- In RUN 4 the jet was installed and took data with beam energies of 100 and 24 GeV respectively.
- At 100 GeV, the analyzing power A_N in pp elastic scattering in the Coulomb Nuclear Interference region was measured. The average analyzing power over *t* interval of 10^{-3} and 10^{-2} $(GeV/c)^2$ was measured to 2% statistical accuracy.
- From the jet online data the beam polarization over the same period was measured to be 0.37 +/- 0.02. Over the same period the Blue beam p-Carbon polarimeter reported a beam polarization of 0.38. No systematic error included.

AGS Ramp Measurement



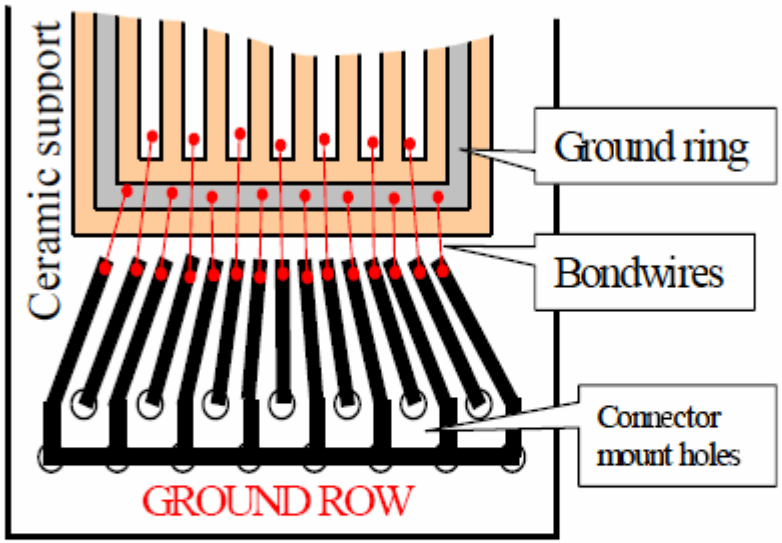
Asymmetry flips sign at every G γ = N and intrinsic res.

Improvements to RHIC Polarimeters

- Add more electronics to separate the readout of polarimeter in two rings: capable of ramp measurement for the two rings the same time
- New application to control the polarimeter (for non experts)
- Measure polarization with target scanning through beam: get polarization profile in the same run
- Fast DAQ readout (ramp/event mode)
- Install coolers for Si detectors (extend Si detector life time)
- Expand Si detector distance from beam by 3-5cm
- New FE boards and new preamp chips, new shaper boards and attenuator boards
- Computer controllable Power Supply/ Bias Supply
- More detectors to increase acceptance (to compensate for limited target and Si detector life time)?

Induced current free silicon design

No More Beam Induced Pickups…



NO BEAM CHARGE INDUCED SIGNAL !!!

(Up to $2 \cdot 10^{11}$ p/bunch)

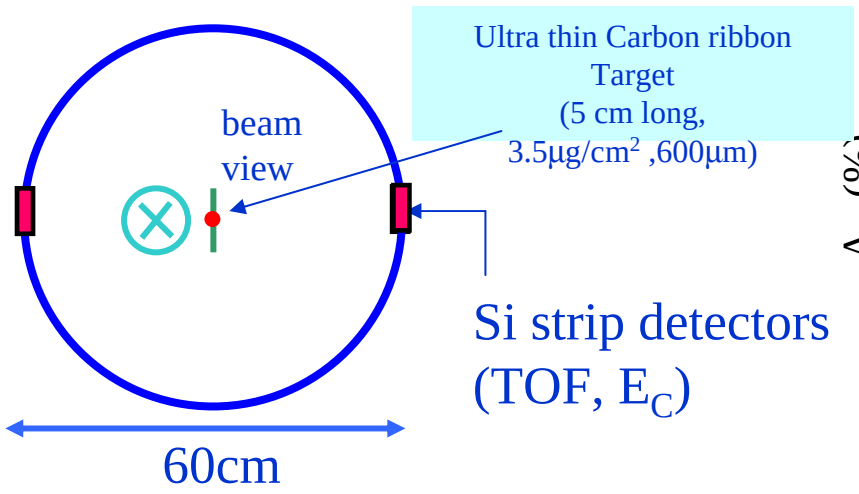
- The improvement in AGS CNI was a great success
  - Every second wire is ground line, from edge to edge.
  - Wide range of $-t$ is available
  - Able to open the time window to very close to the beam crossing
- To apply this to RHIC
  - new vacuum feedthroughs
  - new detector mounts (ceramics)
  - R&D on the glue for the vacuum
  - new RF shields
  - add coolers

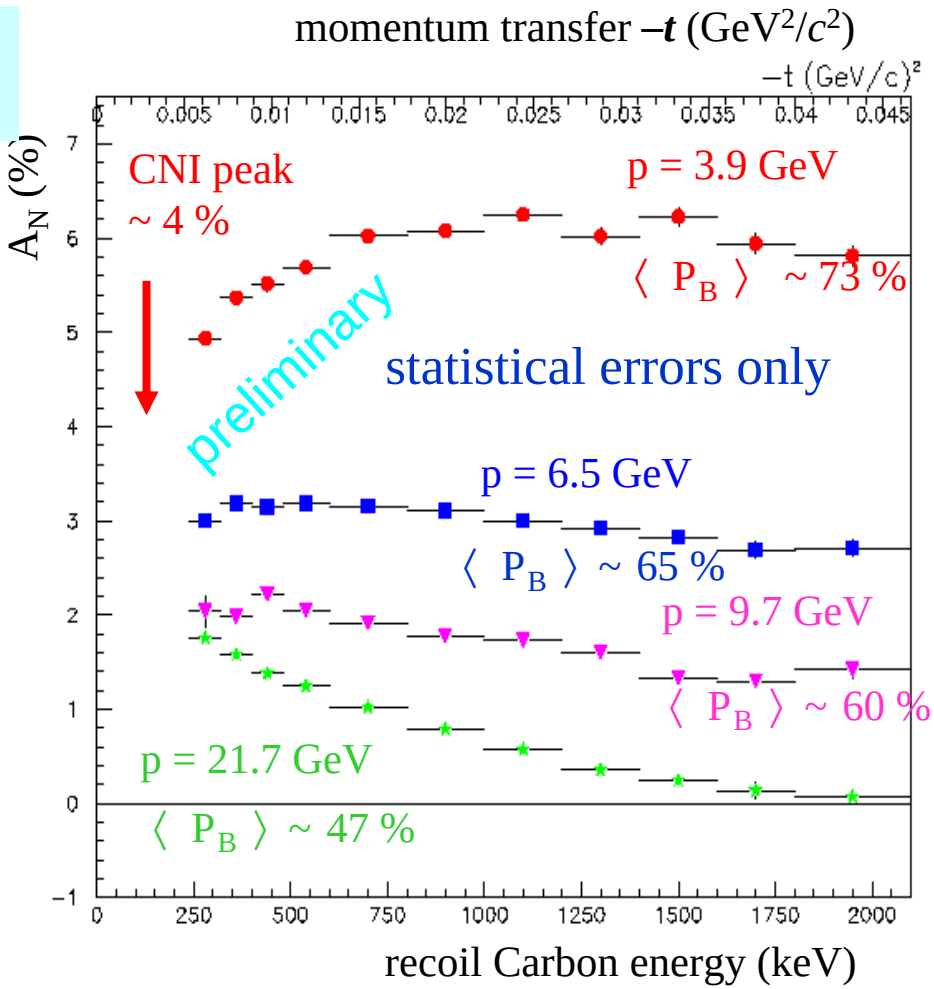
Summary

- RHIC CNI polarimeters are reliable and stable.
- Absolute calibration (of $p+C$) with the jet data at 24 and 100 GeV has started. Online (without considering systematic errors) results show that the A_N we have used is about correct.
- Separate readout of the polarimeters in two rings will enhance the performance of the polarimeters (ramp measurement in two rings at the same time)
- Various changes in the detector front end electronics and vacuum feed-through will address the induced current issue and the lifetime of the Si detector.
- New application is essential for the smooth operation of the polarimeter.
- The separated readout will be ready by the start of next run while the new front-end electronics and fast readout will be ready in the middle of the run.

Backup Slides

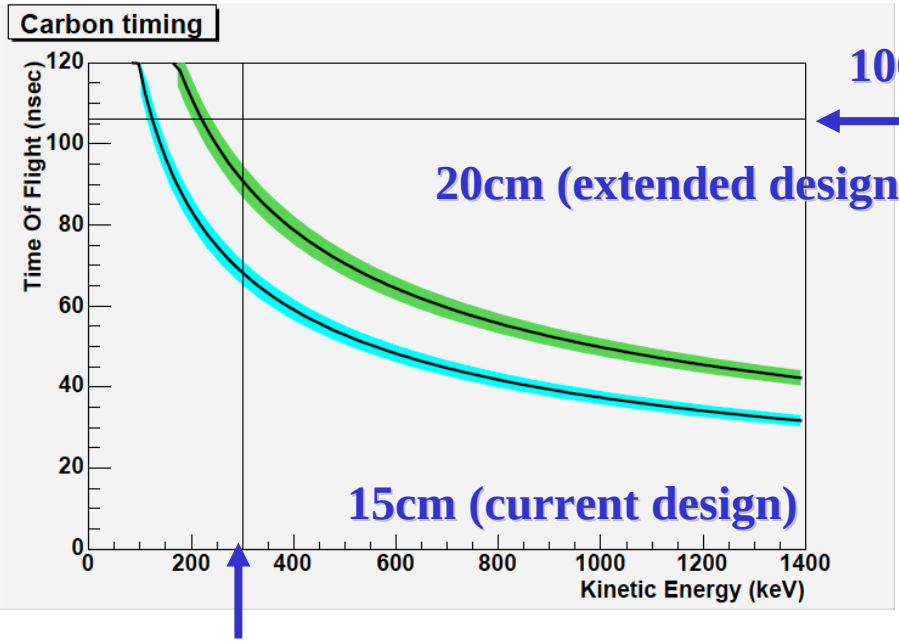
AGS CNI Polarimeter





- Only 90 degree detectors installed.
- pC $A_N(-t)$ dependence are different at different AGS beam energies.

Detector Distance Extension



- Extends 3-5cm from target
  - No induced currents assumed
  - Increase timing resolution
  - Reduce RF noise in the shaper boards
- Faster signals
  - faster preamps, shaping

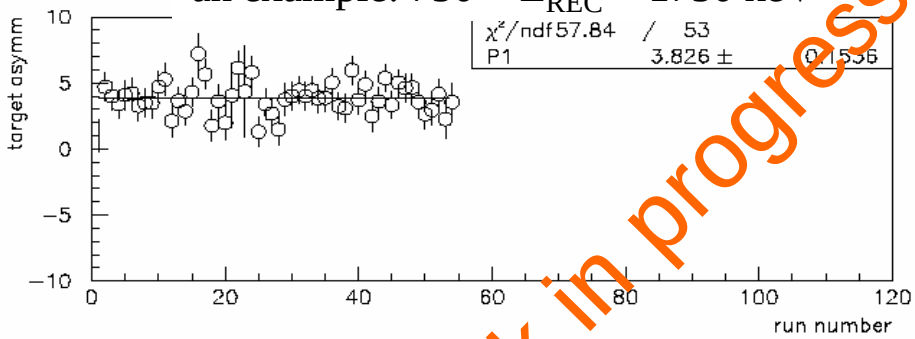
“ONLINE” measured asymmetries

ONLINE ≡ statistical errors only
no background corrections
no dead layer corrections
no systematic studies
no false asymmetries studies
no run selection

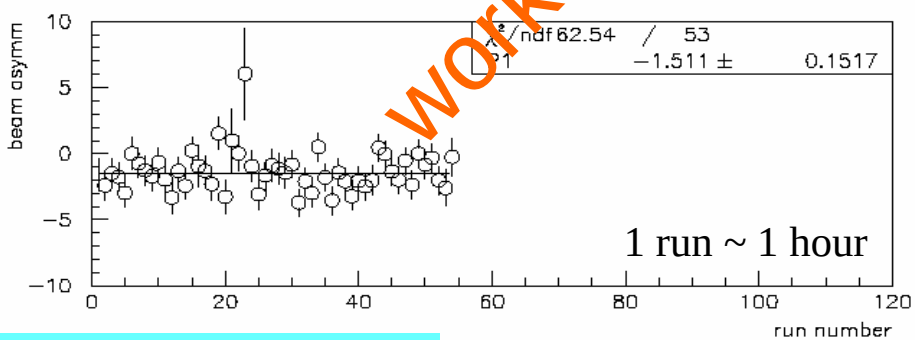
data divided into 3 *p* energy energy bins

an example: $750 < E_{REC} < 1750$ keV

“Target”: average over beam polarization



“Beam”: average over target polarization



work in progress !

blue beam with alternating bunch polarizations: ↑ ↓ ↑ ↓ ↑ ↓ …

good uniformity from run to run (stable JET polarization)
JET polarization reversed each ~ 5 min.

$$P_{beam} = -P_{target} \cdot \frac{\varepsilon_{beam}}{\varepsilon_{target}}$$

$\langle P_{beam} \rangle = 37\,\% \pm 2\,\%$

$\langle P_{beam}\ (pC\ \mathrm{CNI}) \rangle = 38\,\%$

No major surprises ?
(statistical errors only !)