RHIC Polarimetry, Current Status and Future Plans

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Outline

- The Mission
- The chosen physics process
- What has been achieved
  - The polarized hydrogen Jet target
  - The RHIC p-Carbon polarimeters
- The proposed paths forward
- Summary

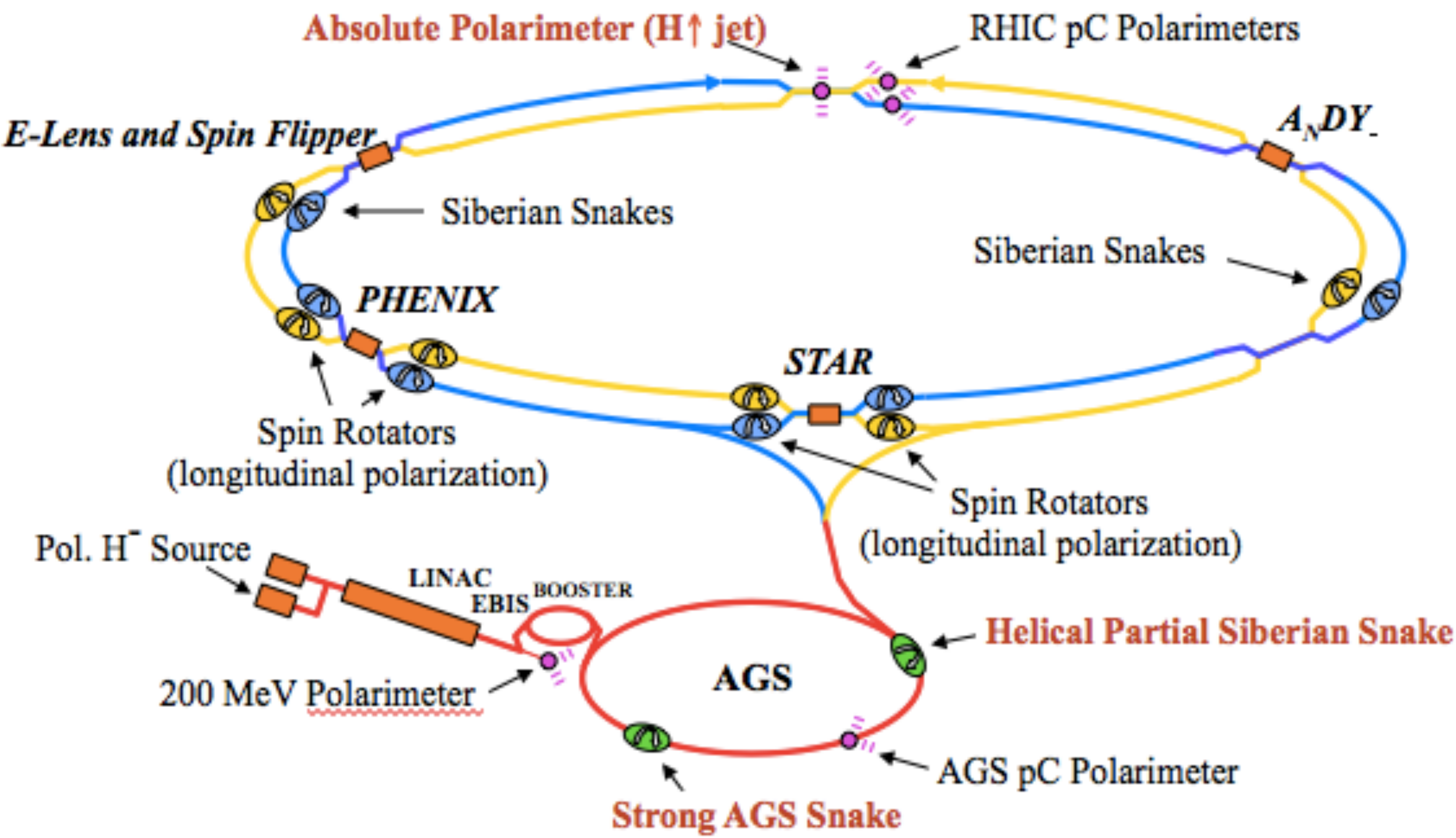
The Mission

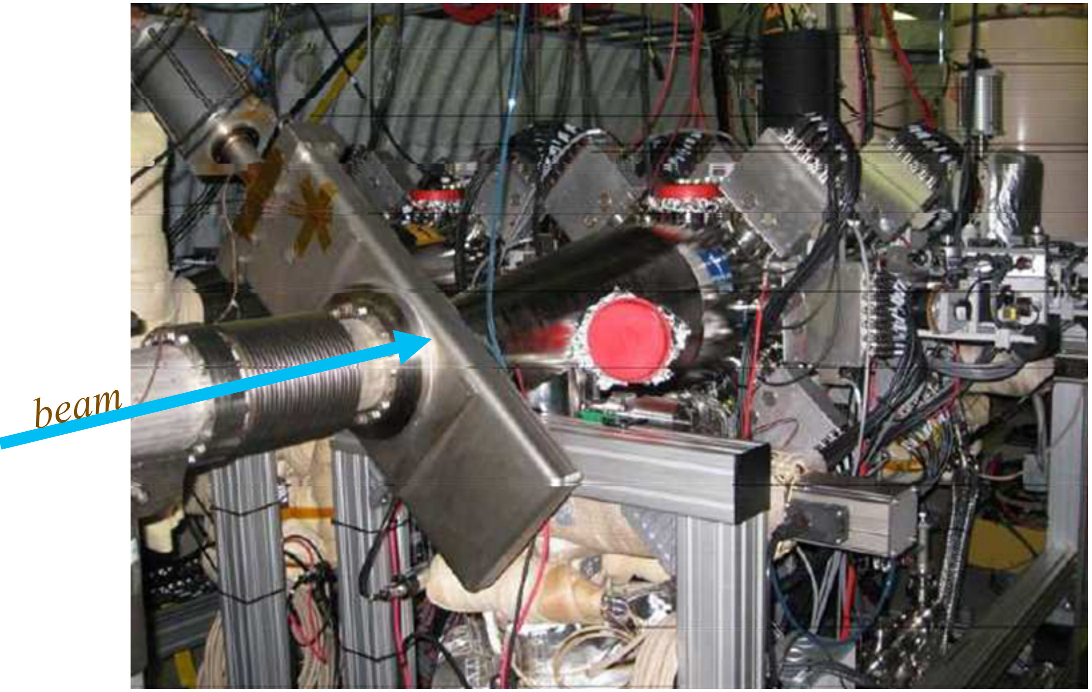
- RHIC: a wide range, from injection at 24 to 255 GeV
- The physics program required polarimetry < 5%

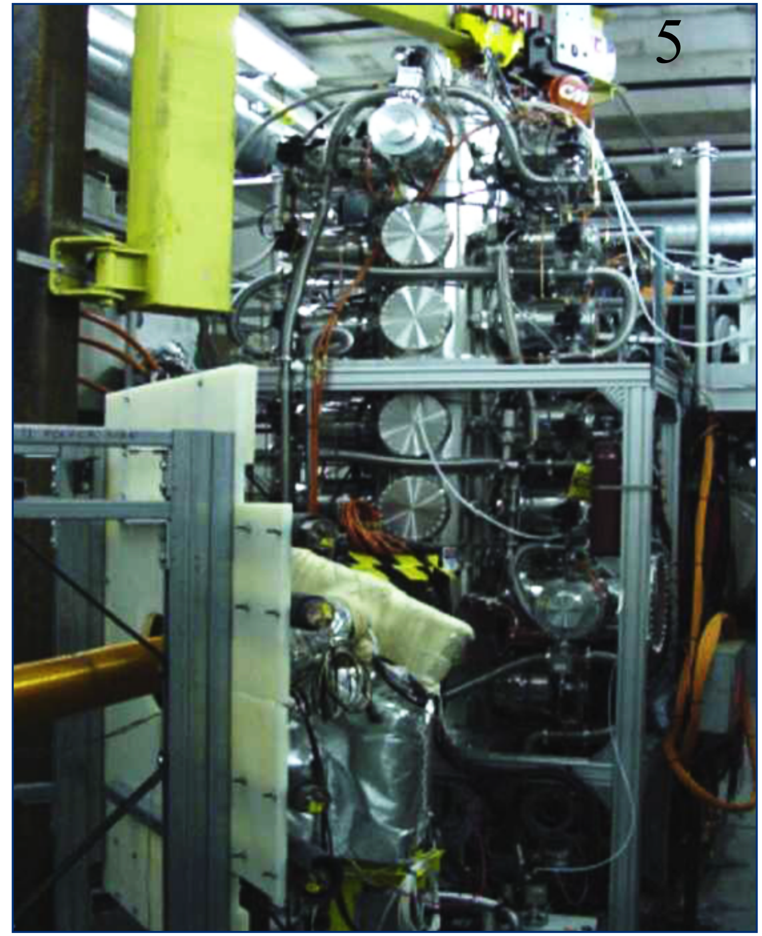
$$\frac{\Delta P_{beam}}{P_{beam}} \approx \frac{\Delta P_{target}}{P_{target}} \oplus \frac{\Delta \varepsilon_{target}}{\varepsilon_{target}} \oplus \frac{\Delta \varepsilon_{beam}}{\varepsilon_{beam}}$$

- Polarimeter calibration is required at each energy
- Beam polarization profile
- Polarization lifetime or decay during a store
- Polarization measurement on the ramp
- Bunch to bunch emittance measurements

The Accelator Complex







Carbon polarimeters

Two per ring

Fast measurement

$\sigma \approx 4\%$

Beam polarization profile

Polarization decay (time dependence)

← normalization

Hydrogen jet polarimeter

Polarized target

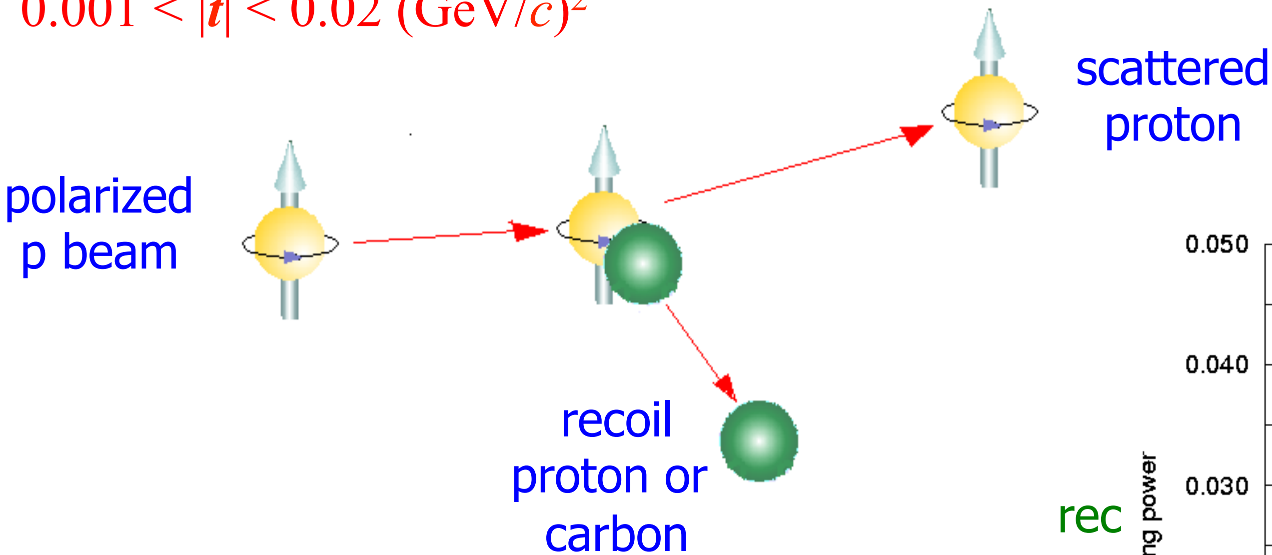
Continuous operation

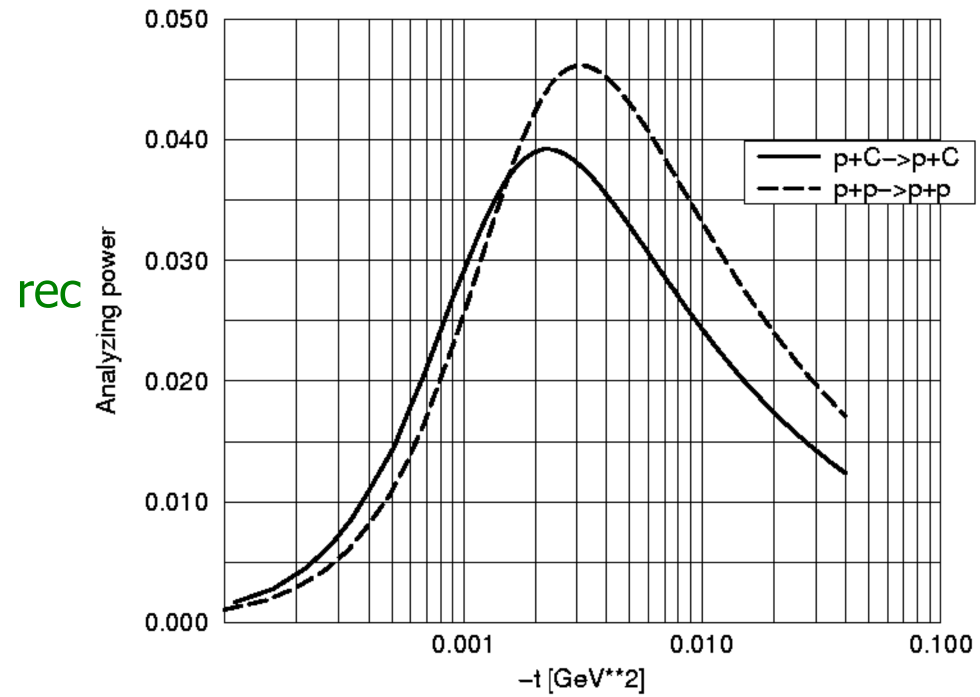
$\sigma \approx 5-8\%$ per fill

pp and p-Carbon Elastic Scattering in the Coulomb Nuclear Interference region

elastic kinematics are fully constrained by the recoils only !

$0.001 < |t| < 0.02\ (\mathrm{GeV}/c)^2$





For p-p elastic scattering (identical particles):

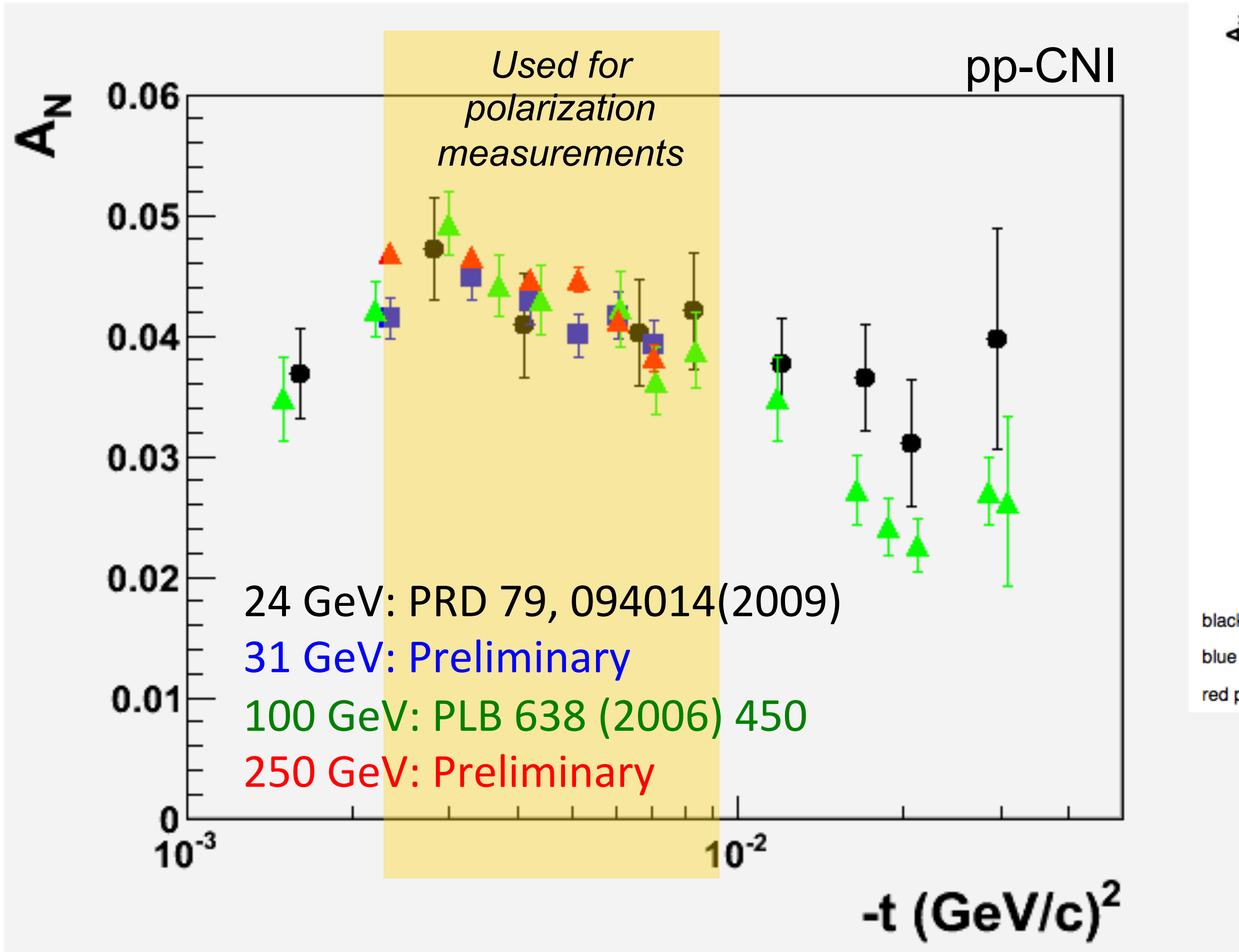
$$\varepsilon = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow}$$

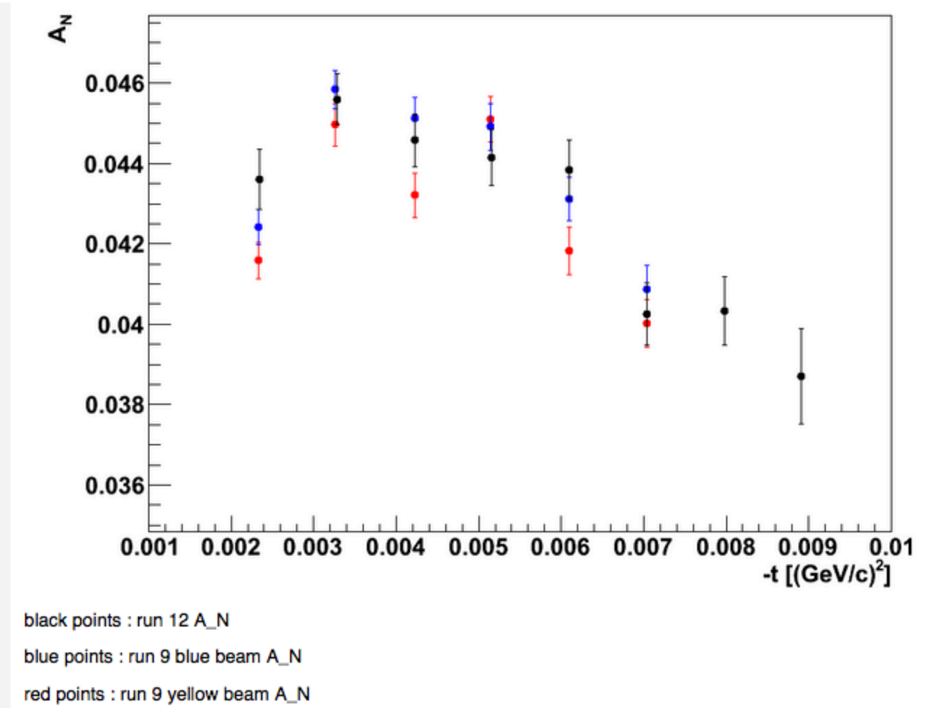
$$\varepsilon_{beam} = A_N \cdot P_{beam}$$

$$\varepsilon_{target} = A_N \cdot P_{target}$$

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

Polarized Hjet: Analyzing power Vs. Energy

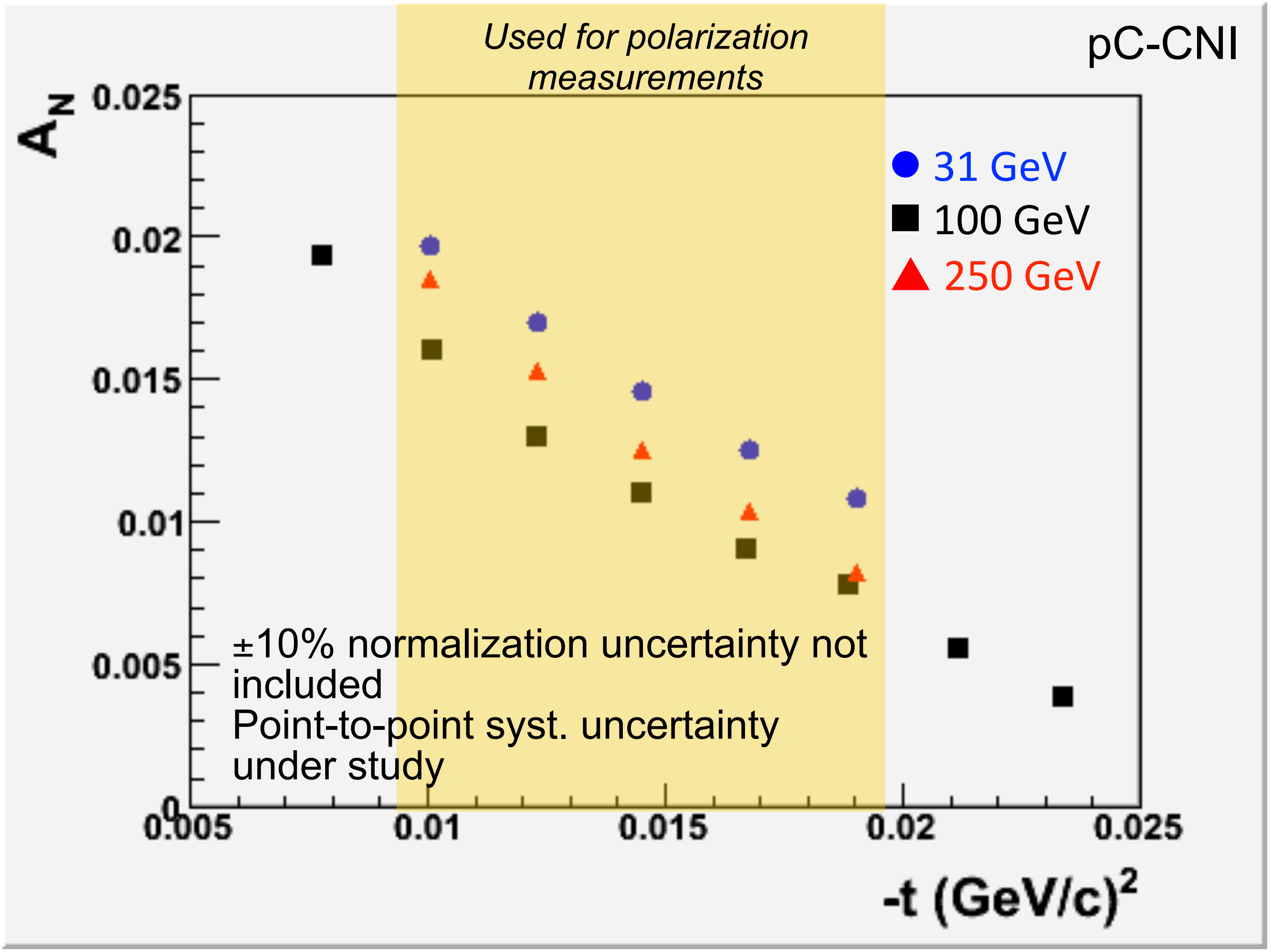




A_N over several 100 GeV runs
Good consistency

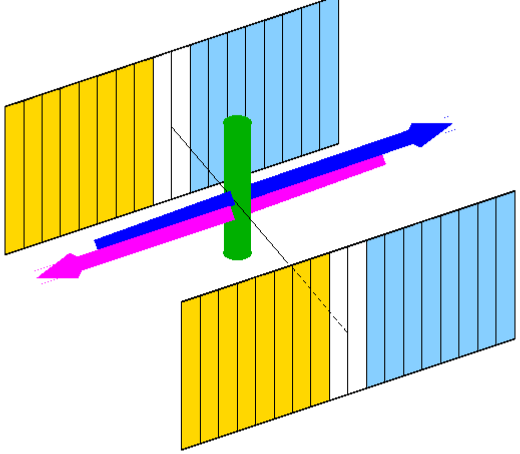
Weak energy dependence ideal for a wide energy range 24 to 250 GeV

p-Carbon: A_N



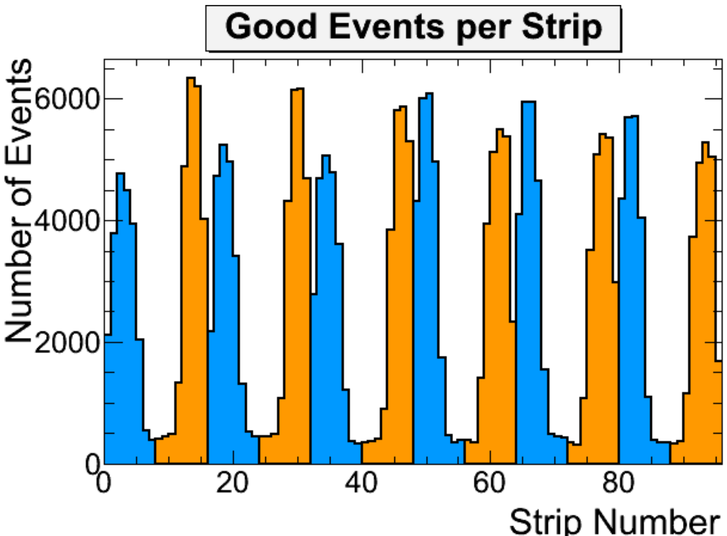
Weak energy dependence ⇒ *pC* elastic scattering in CNI region is good for polarimetry in wide beam energy range

Running Conditions



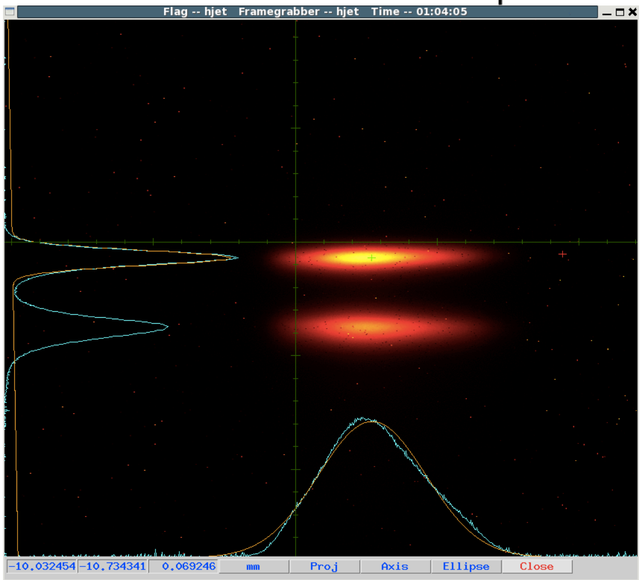
Run with two beams vertically by 2.5-3 mm dictated by the Machine beam-beam requirements

Backgrounds are measured independently



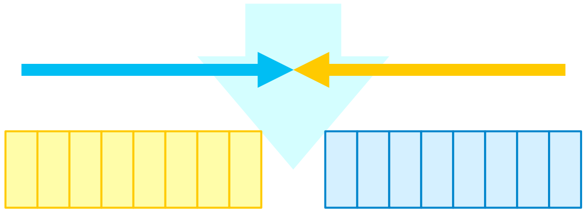
Simultaneously measure A_N in pp elastic Scattering and beam polarization

The Jet Luminescence monitor shows the two beams, also measures vertical emittances.



p-Carbon polarimeters (2 per beam) take data when needed at ~ 4 hour intervals.

Oleg Eyser



$$P_Y = -\varepsilon_Y / \varepsilon_T \; P_T$$

$$P_B = -\varepsilon_B / \varepsilon_T \; P_T$$

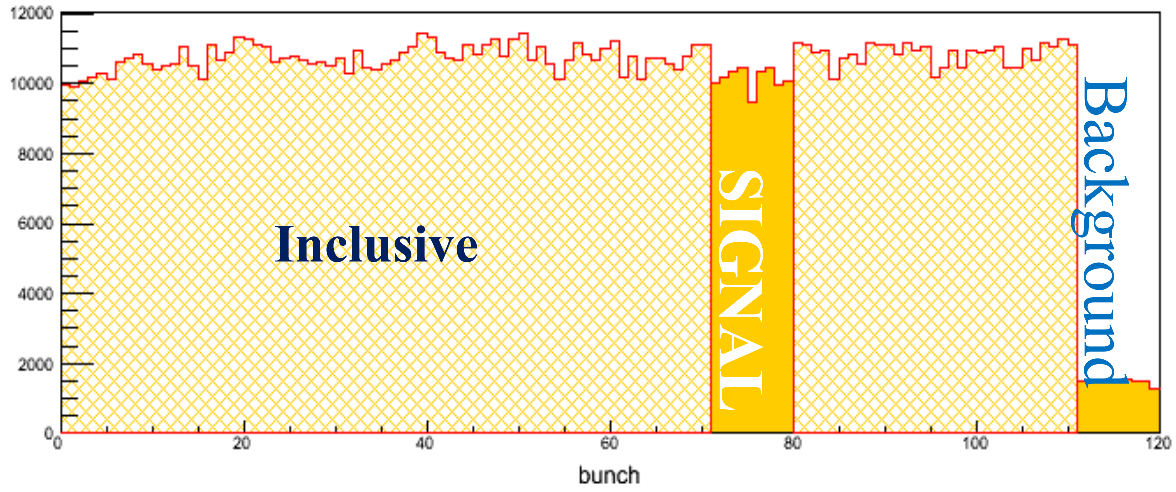
$$\varepsilon_S = \varepsilon - r \cdot \varepsilon_B / 1 - r$$

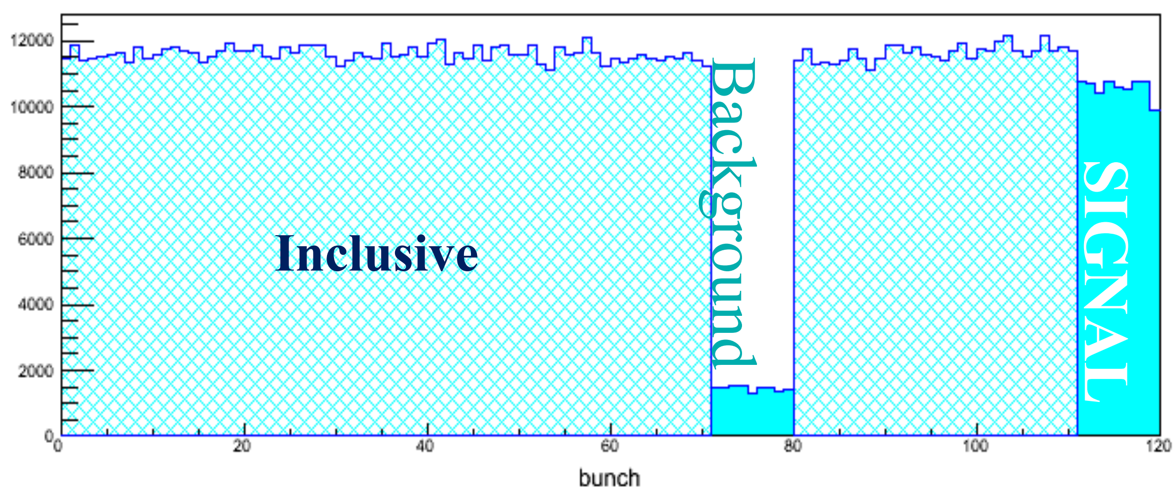
signal: ε_S

background: ε_B

inclusive: ε

background fraction: r

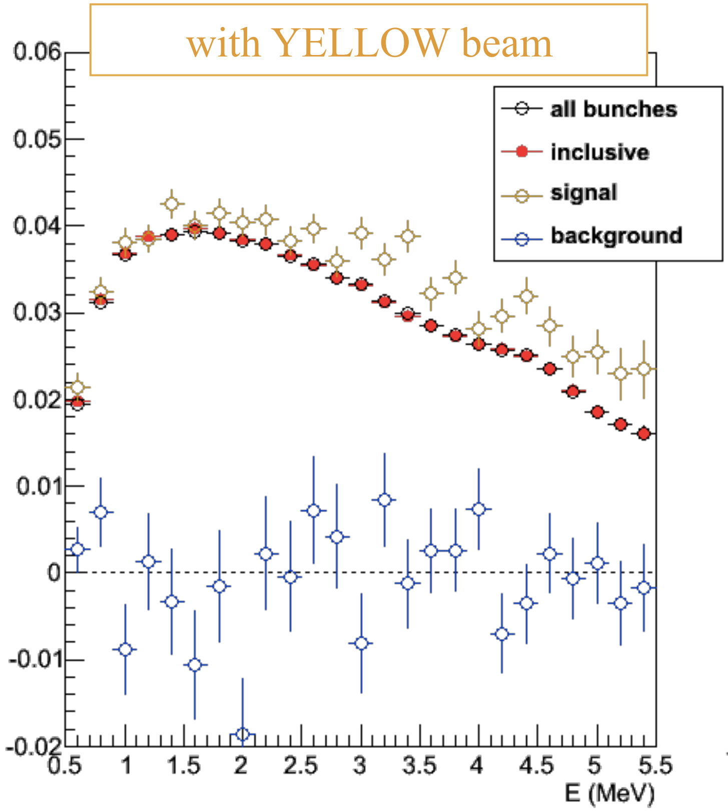


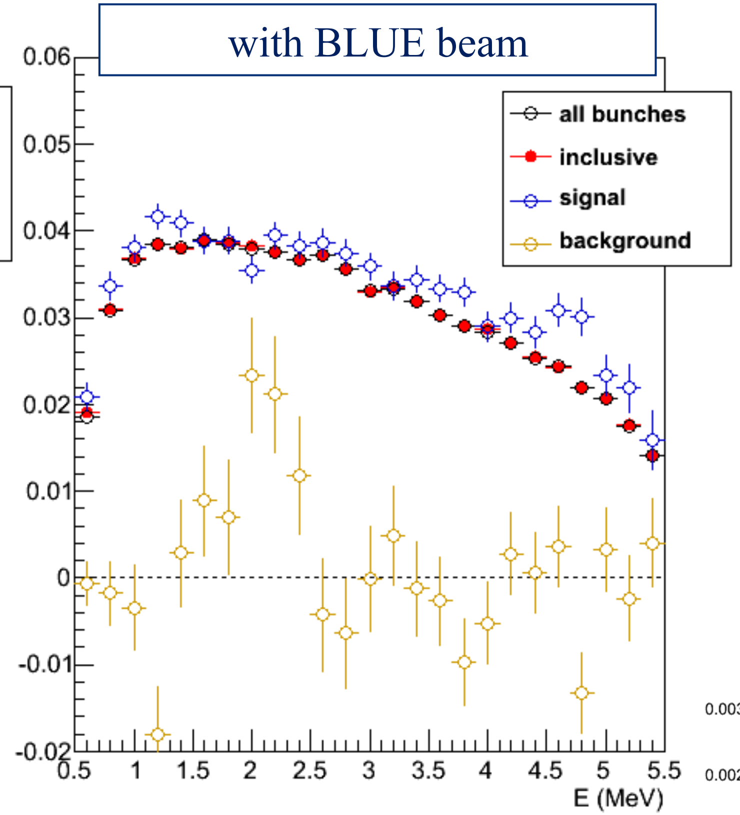


RHIC bunch

Oleg Eyser

Target Asymmetries



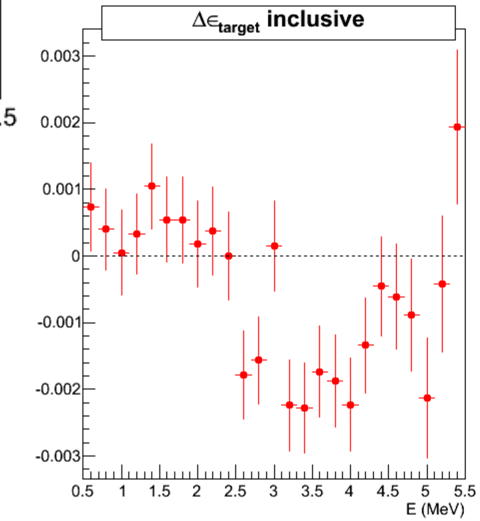


120 bunches

102 bunches

9 bunches

9 bunches



Full 2013 statistics!

Normalize with known target polarization

Issues for the Jet

- Background (beam gas interactions, or from the other beam): Run13 we dedicated some running with single beam and displaced beam running outside the jet detector acceptance to understand backgrounds and systematics. The analysis is in progress

- Background estimation using the beam abort gap during normal running yields ~12% with zero polarization and 1% dilution

- Better determination of the Si strip dead layer as well as the t0 which impact the recoil proton energy measurement.

- The molecular hydrogen background (unpolarized) was measured off line at 1.5% implying a 3% dilution, will re-do this to assess any changes with running conditions.

  A must if one is to aim for better than 5% accuracies

The Path forward for the Jet

- We started a Jet DAQ upgrade utilizing new JLab Hall D VME based WFD system. Will test in RHIC Run15 (polarized pp and pA runs) (A. Poblaguev et. al)
    - A 256 MHz system which should be adequate for the Jet
    - Will test it for the p-Carbon polarimeters
- Purchased new 500 um Hamamatsu silicon detectors, to replace the current 300 um (Thanks to RBRC and C-AD) (G. Atoian et. al)
    - Maximize the vertical acceptance coverage
    - Increased recoil proton coverage from: 1- 4.5 >> 0.5 – 9 MeV
    - Overall a factor of 1.5 – 2 gain in statistical accuracy
- With Belov (INR) we plan to install a new electron beam gun and TOF detector for a molecular hydrogen component measurement.

Inelastic contamination (single pion production)

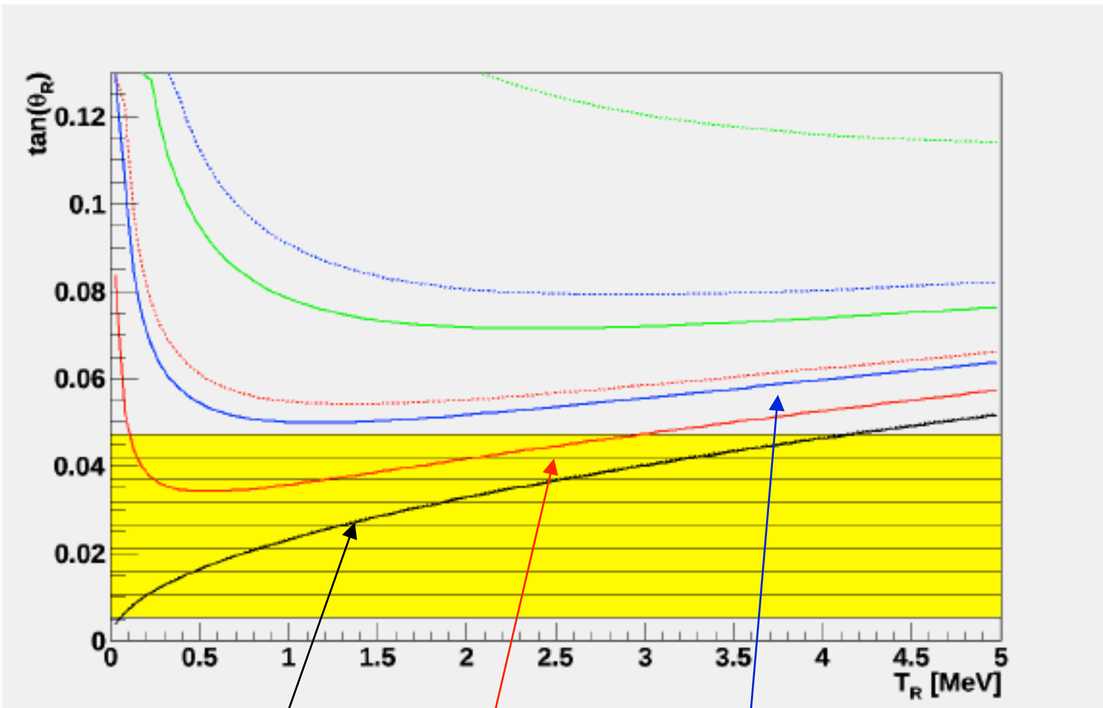


Figure 3: Recoil angle dependence on kinetic energy. Solid lines are for 250 GeV beam and dashed lines are for 100 GeV. Black lines are for elastic scattering, red for $\delta m = m_\pi$, blue for $\delta m = 2m_\pi$, and gree for $\delta m = m_{N(1440)}$. Yellow background indicates the silicon detector acceptance (with no correction on magnetic field).

pp elastic | pp, $+m_\pi$ | pp, $+2m_\pi$

A Recoil Energy Cut to test for pion contamination or dilution:

At 5 MeV (nominal)

Blue : 0.480 +/- .0053
Yellow: 0.479 +/- 0053

At 4 MeV

Blue : 0.484 +/- .0056
Yellow : 0.482 +/- .0057

At 3 MeV

Blue: 0.486 +/- .0064
Yellow : 0.476 +/- .0066

New silicon detectors will allow us to extend the range and study the inelastic contribution at higher t ranges.

Calibration methods used in Hjet *(Poblaguev)*

- **α-particles from ^{241}Am and ^{148}Gd (α, x_{DL})**

$$E_\alpha = \alpha A + E_{\text{loss}}^{(\alpha)}(E_\alpha, x_{\text{DL}})$$

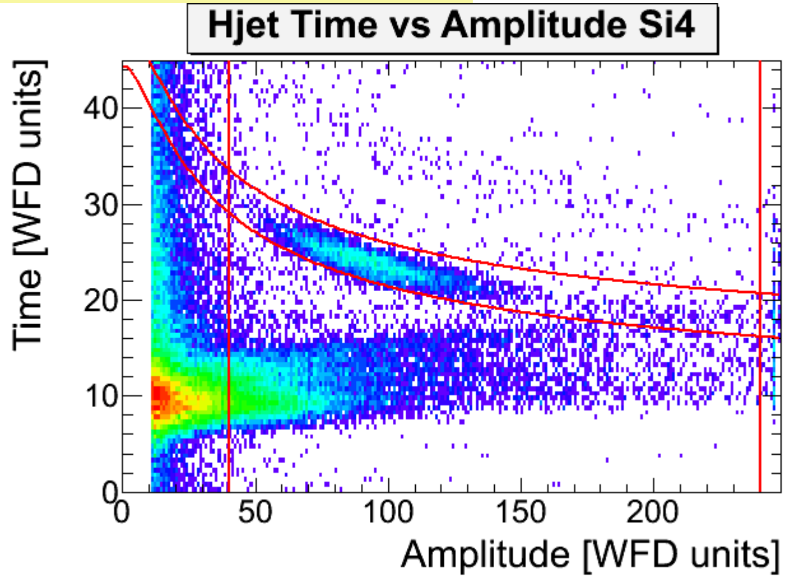
- **high energy (low amplitude) prompt particles (t_0)**

$$t_0 = \langle t_{\text{prompt}} \rangle + \text{tof}_{\text{prompt}}$$

- **geometry based calibration (t_0 and α^*)**

measured $A_{\text{geom}} \Leftrightarrow$ known E_{geom}

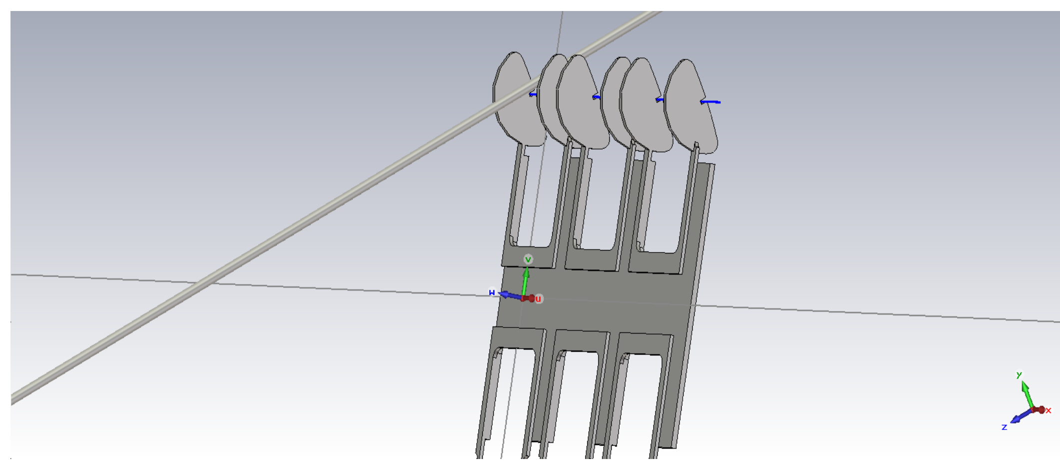
$$t_0 = \langle t(A_{\text{geom}}) \rangle - \text{tof}(E_{\text{geom}})$$



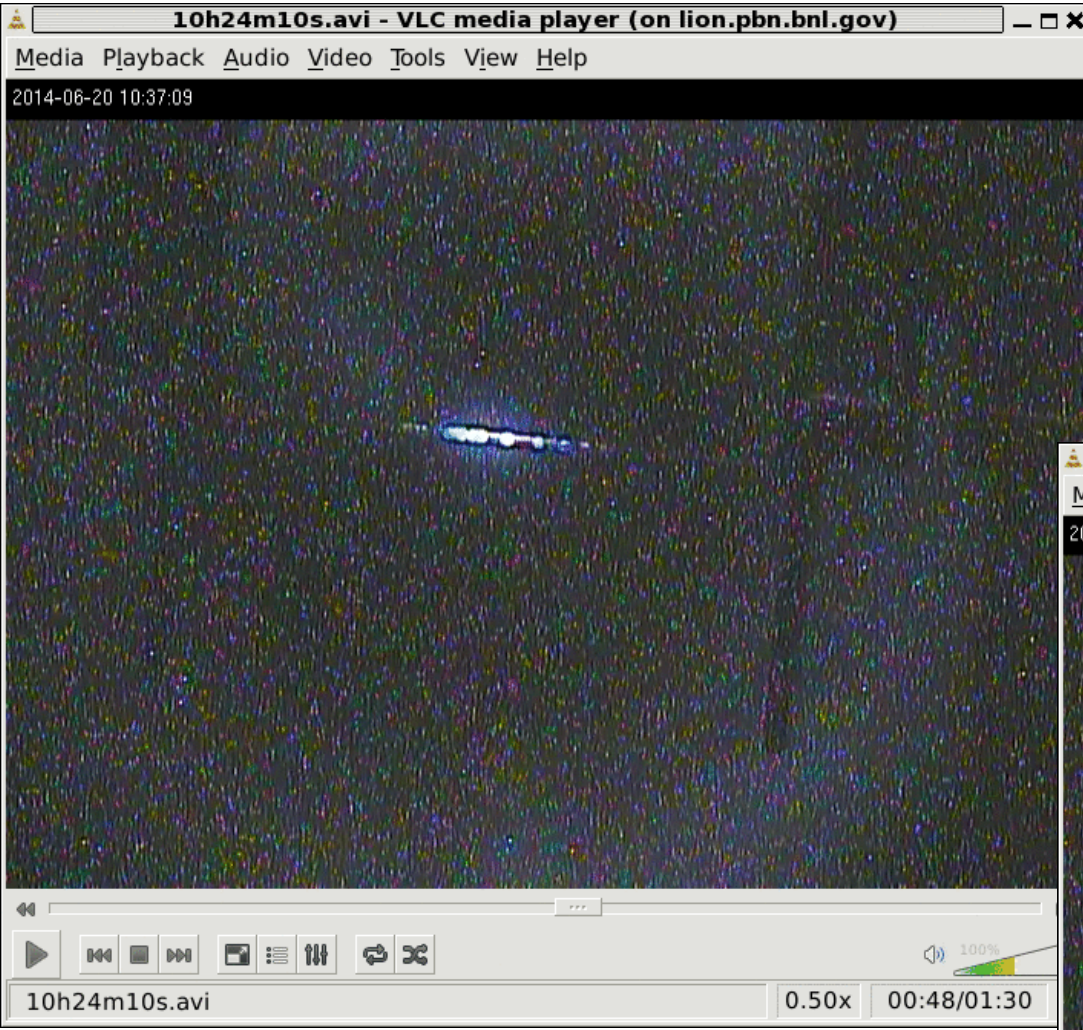
- **All three methods use essentially different experimental data**
- **Neither method allows to determine all calibration parameters α, t_0, x_{DL}**
- **Every method combined with experimentally measured dependence $t = t(A)$ allows us to determine all calibration parameters α, t_0, x_{DL}.**

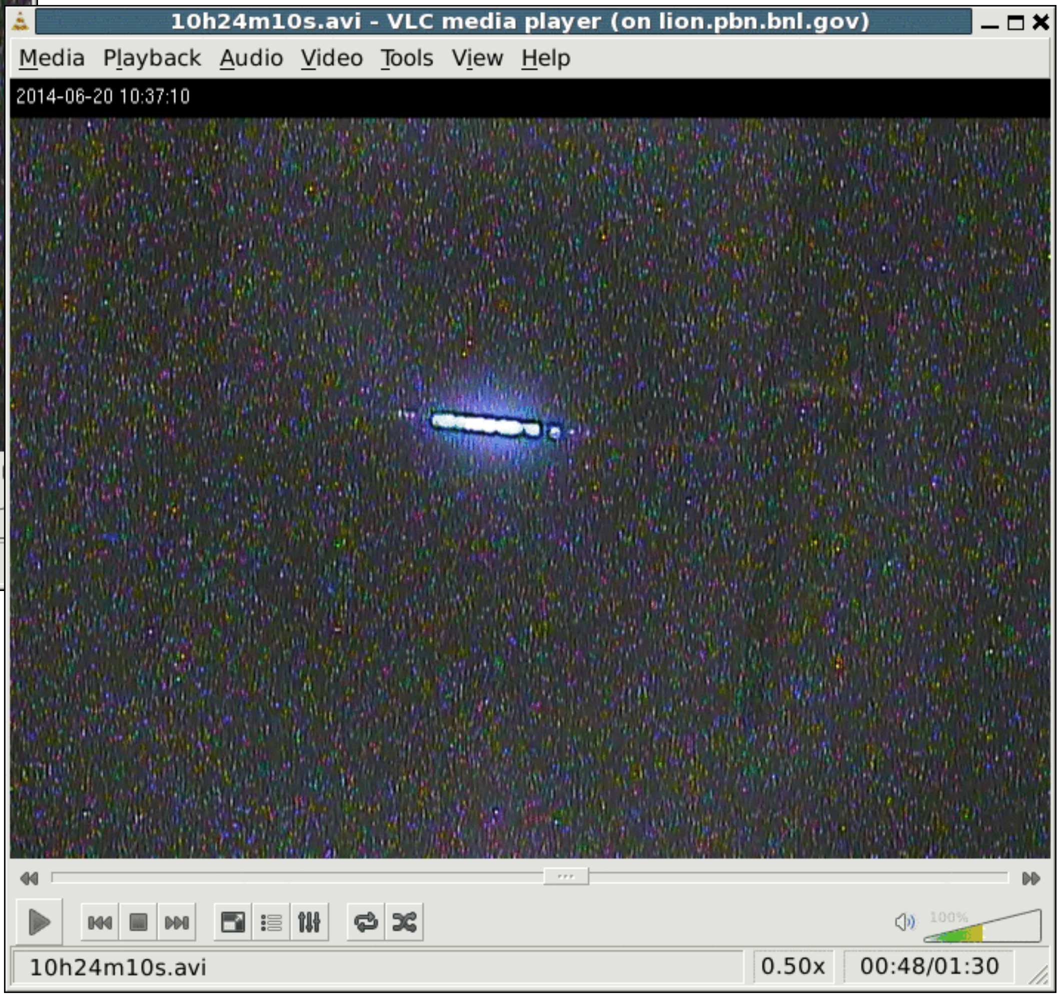
p-Carbon polarimeters:Target issues Huang/ Kewisch

- Target life time was poor in run13 with higher bunch intensity (1.6-2*10^{11}) at 255GeV. We had to replace targets twice.
- Simulations with micro-studio showed that the electric-magnetic fields at the edges can be greatly reduced with added flips (fins).
- It is assumed that the high frequency fields induce electrons moving back and forth, which in term heats the target tails and makes them glowing.
- About 2/3 targets are broken near the ends, which supports the idea that the EM fields (and heating)
- Built targets with and w/o fins
- Tested with 3He beams in Run14

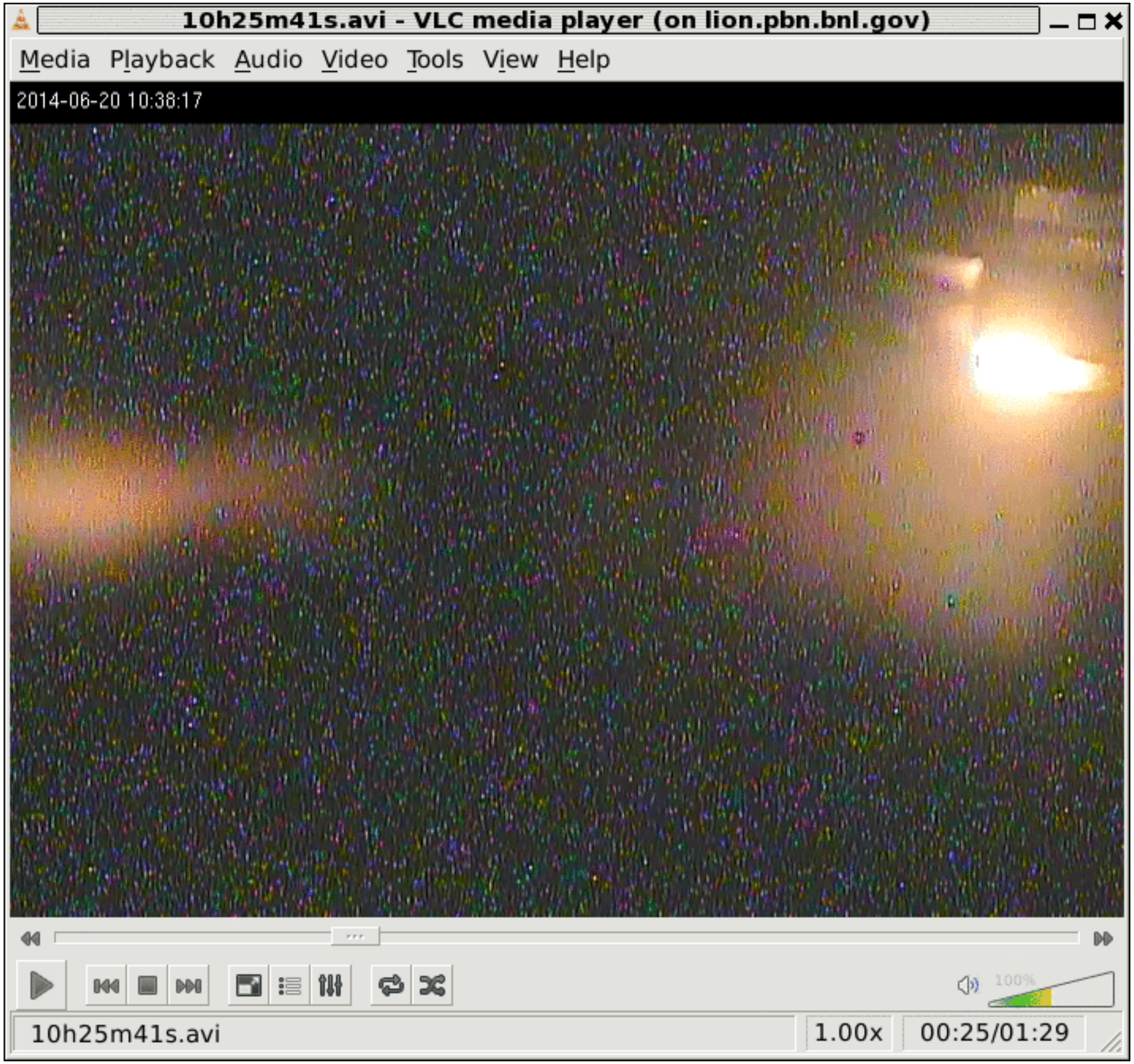


Target (with Fins) Crossing ^{3}He Beam (Huang et. al)





Big Flash When Switching to No-fin Targets



Summary

- The RHIC complex polarimeter systems continue to evolve in an effort to improve operational and statistical precision.
  - pp elastic scattering in the CNI region is a preferred tool as the analyzing power is constant with energy
  - A polarized hydrogen jet target, a calibration tool, and polarization measurements and lifetime during a store
  - Polarization accuracy of better than 5% is at hand with plans for improvement underway
    - ✓ A new VME based DAQ for the Jet target
    - ✓ A larger acceptance Jet Si detectors
    - ✓ New p-Carbon polarimeter targets for better longevity

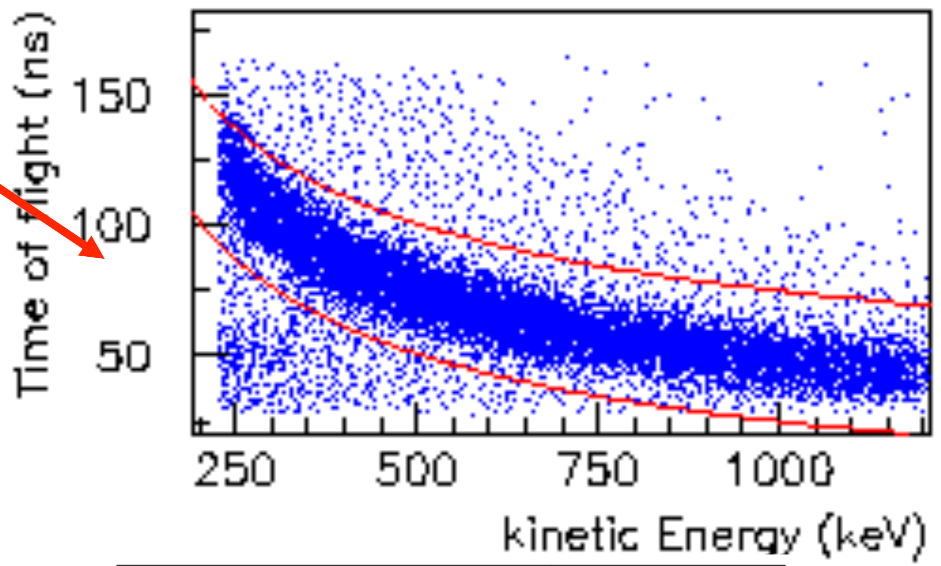
Back up

CNI Polarimeter Principle

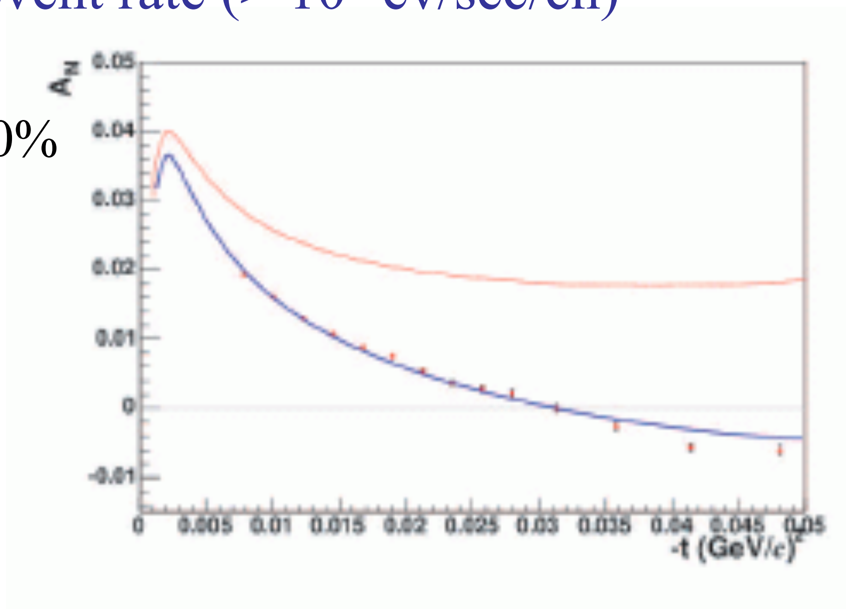
- Recoil carbons detected with Si detectors
- Identified via ToF vs T_{kin} correlation ⇒ inv. mass recoil =>gives only "particle ID"
- Position vs energy correlation spoiled by multiple scattering in target
- Background from beam dissociation very small for this kinematics
- Background events < few % within the "banana" cut
- very high event rate (> 10^5 ev/sec/ch)

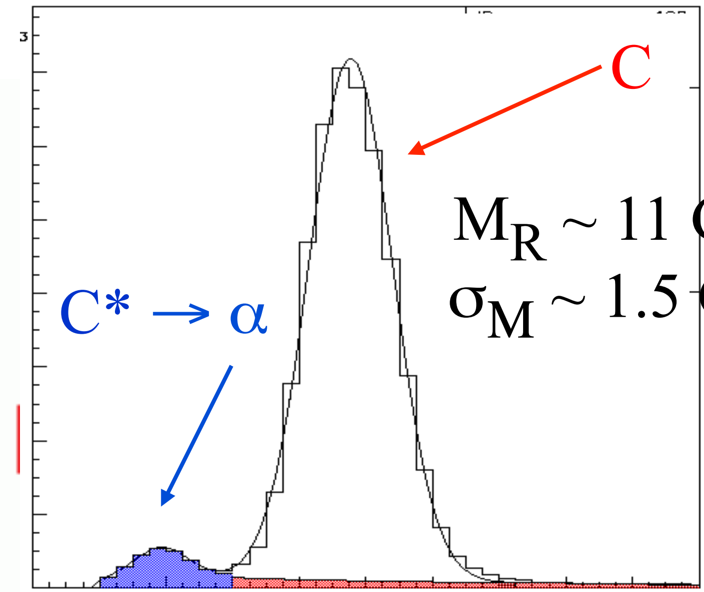
$T_{kin} = \frac{1}{2} M_R\,(\text{dist} / \text{ToF})^2$

non-relativistic kinematics



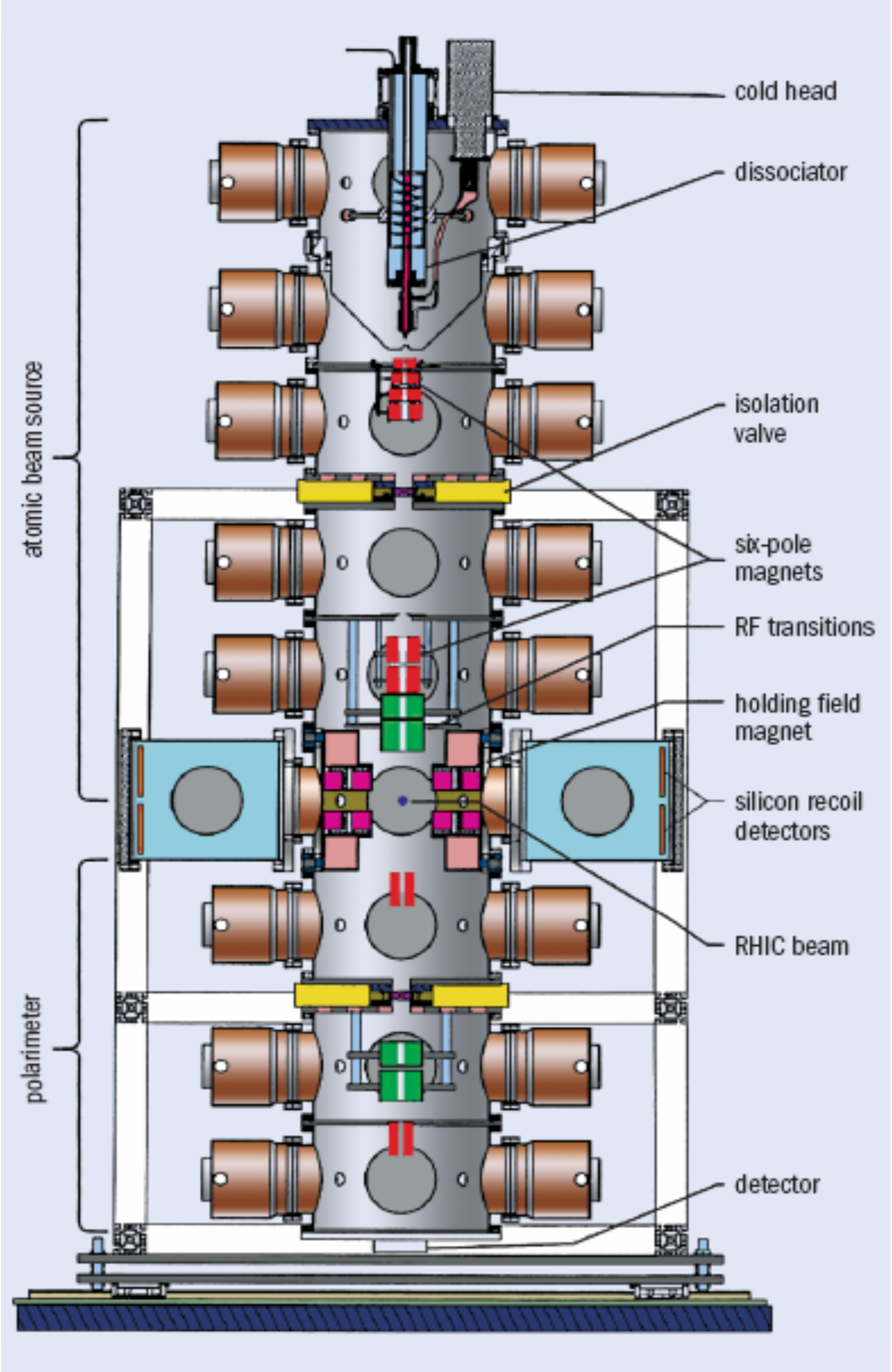
A_N ~1%: for 100% polarization





H-jet polarimeter.

- The H-jet polarimeter includes three major parts: polarized Atomic Beam source (ABS), scattering chamber, and Breit-Rabi polarimeter.
- The polarimeter axis is vertical and the recoil protons are detected in the horizontal plane.
- The common vacuum system is assembled from nine identical vacuum chambers 50 cm diameter, which provide nine stages of differential pumping each at 1000 l/s
- Flip jet polarization every 300 sec
- The Jet beam is focused to 6 mm FWHM so it sees the full beam polarization profile
- Thickness: 1.2 x10^{12} atoms / cm^2
- Jet polarization ~ 92%

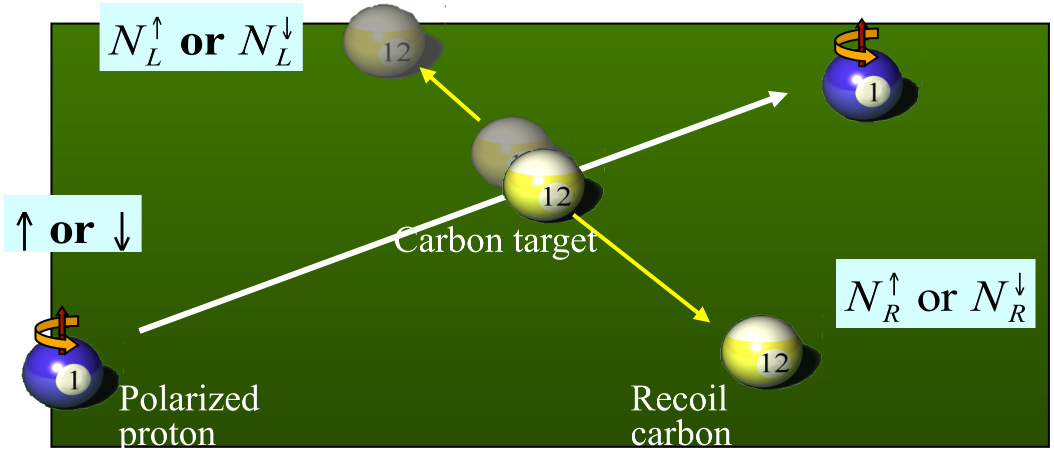


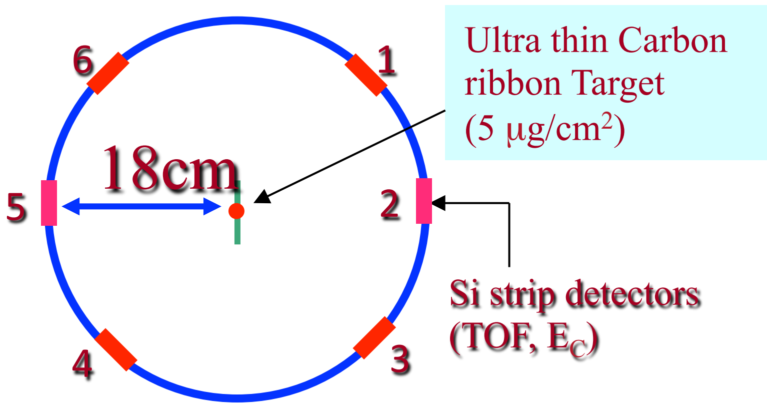
P-Carbon CNI polarimeter.

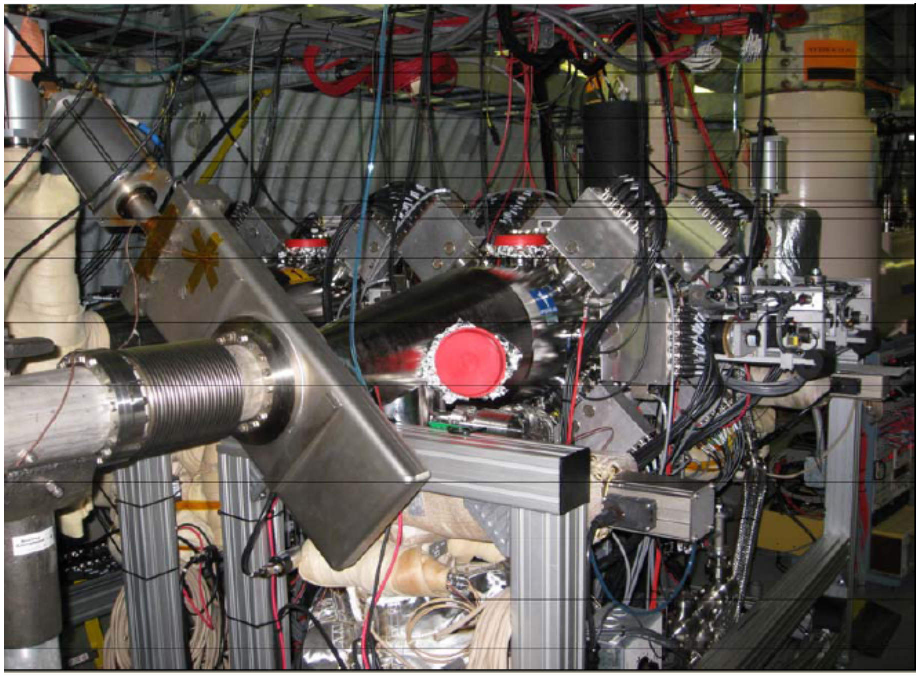
Elastic scattering: interference between electromagnetic and hadronic amplitudes in the Coulumb-Nuclear Interference (CNI) region.

$$P_{beam} = -\frac{\varepsilon_N}{A_N^{pC}}$$

$$\varepsilon_N = \frac{N_L - N_R}{N_L + N_R}$$







The RHIC Polarimeters At A Glance

	H-Jet polarimeter	*p*-C polarimeter
Target	Polarized atomic hydrogen gas jet target	Ultra thin carbon ribbon
Event rate	~20 Hz 3% statistics in a 8-hr fill	~2M Hz 2-3% per measurement
operation	continuously	1 minutes every few hours
A_N	Measured precisely BRP gives self-calibration	Requires calibration from the Jet data
Role	Absolute beam pol. measurement, Calibration for RHIC *p*C polarimeter	ONLINE monitor, Fill by Fill beam polarization Polarization Profiles Beam Emittance measurements