Proton Polarimetry at the Relativistic Heavy Ion Collider

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For

The RHIC Polarimetry Group

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* Graduate Students (SUNY SB, Shandong U) data analyses

** Honorary Member

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PST2009

September 7-11, 2009

Outline

- Requirements for the physics program and machine development
- Upgrades to the p-Carbon CNI polarimeters and Jet
  - Tandem Tests
- The experience in Run 9
  - The p-C polarimeters
  - The Polarized Jet target
  - Problems we faced this year
- The path forward
- Towards future efforts

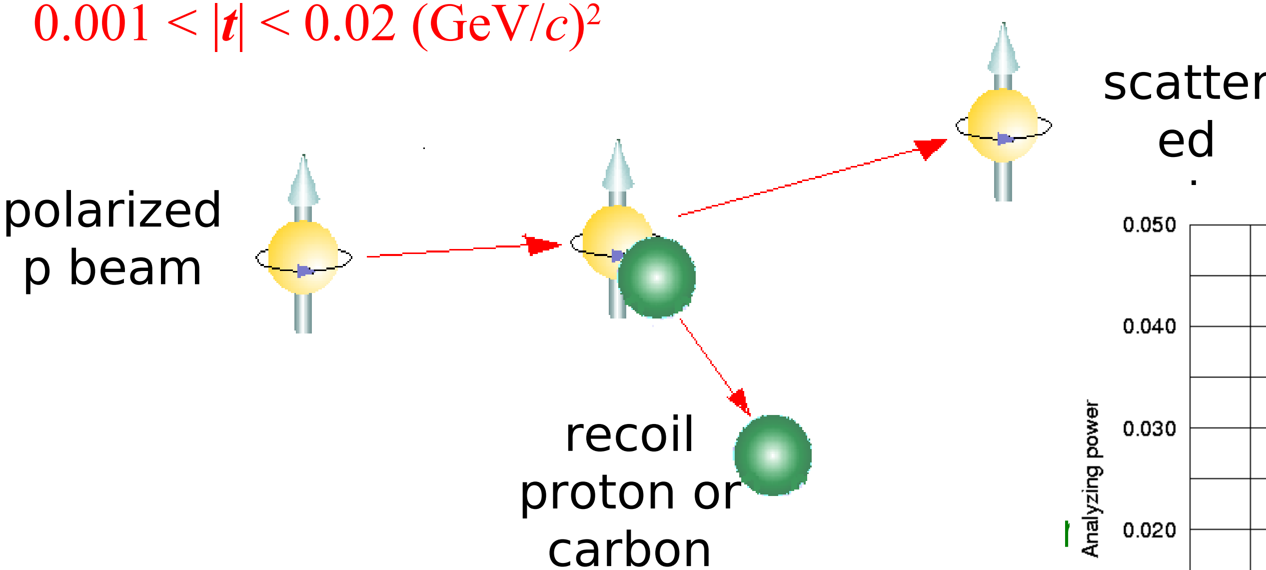
The Polarimetry Requirements for RHIC

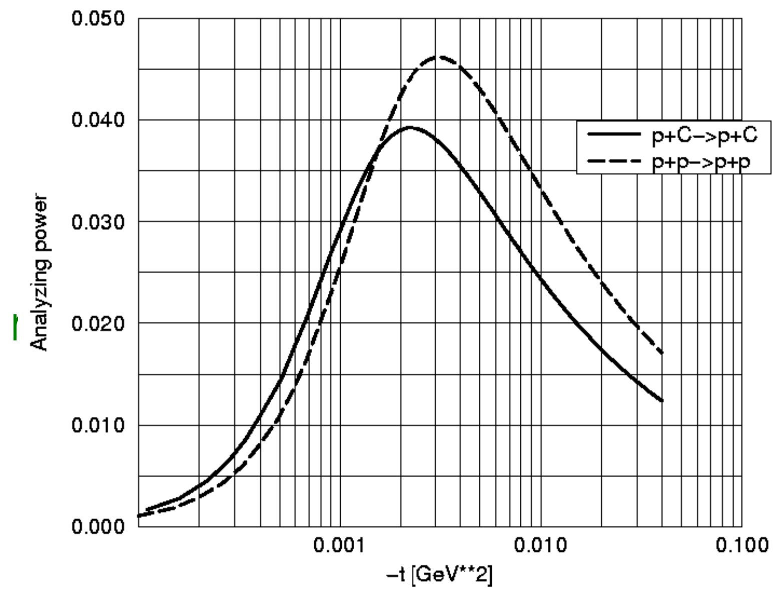
- The polarimeters should operate over a very wide range, The beam energy ranging from injection at 24 to 250 GeV
- The physics program requires precision polarimetry < 5%
- Polarimeter calibration is required at each energy
- Beam polarization profile
- Polarization lifetime or decay during a store
- Polarization measurement on the ramp
- Bunch to bunch emittance measurements

pp and p-Carbon Elastic Scattering

elastic kinematics are fully constrained by the recoils only !

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





For p-p elastic scattering only:

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

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

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

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

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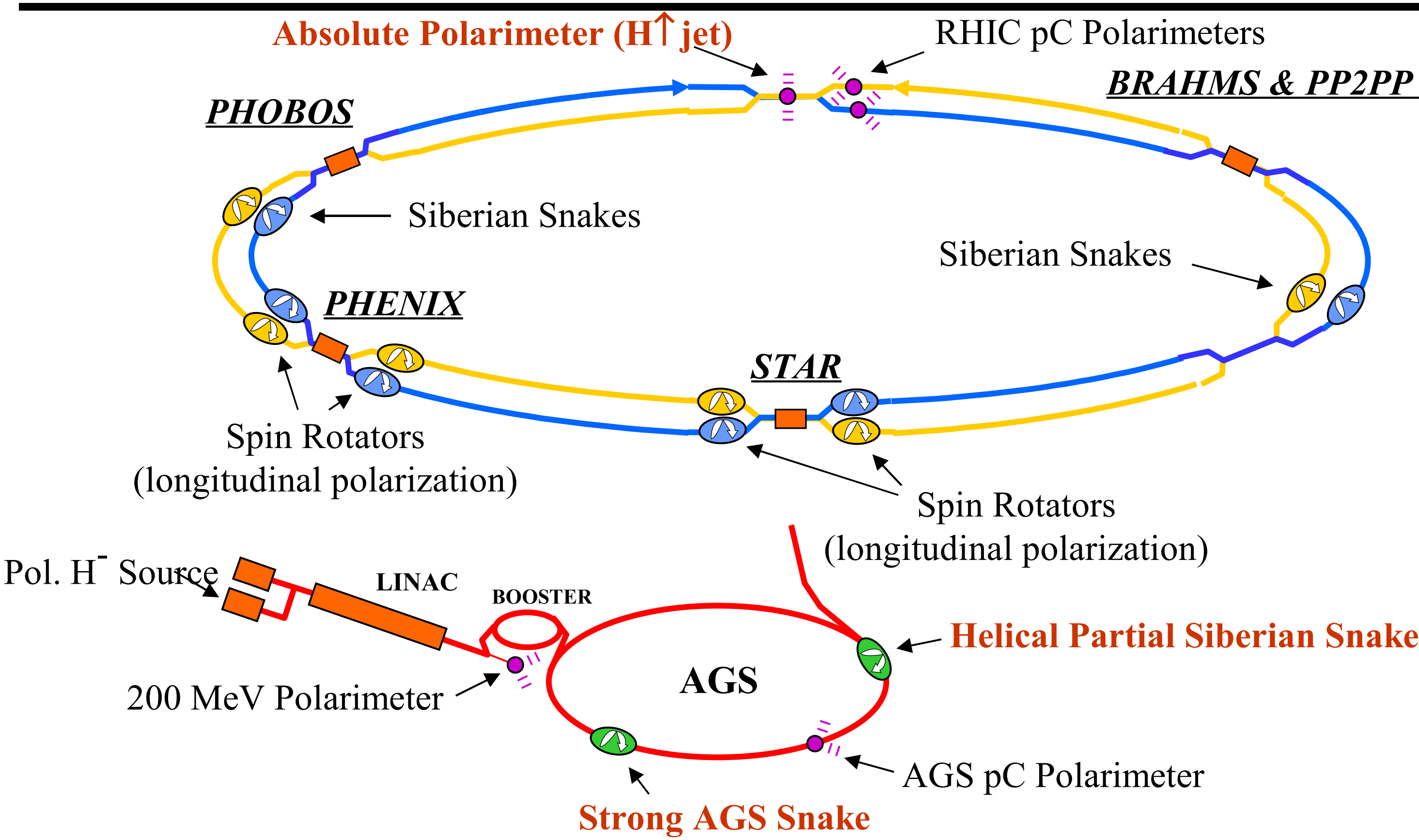
The RHIC Polarimeters At A Glance

	H-Jet polarimeter	*p*-C polarimeter
Target	Polarized atomic hydrogen gas jet target	Ultra thin carbon ribbon
Event rate	~20 Hz 10% statistics in a 6-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 for experimental groups

The RHIC Polarized Collider



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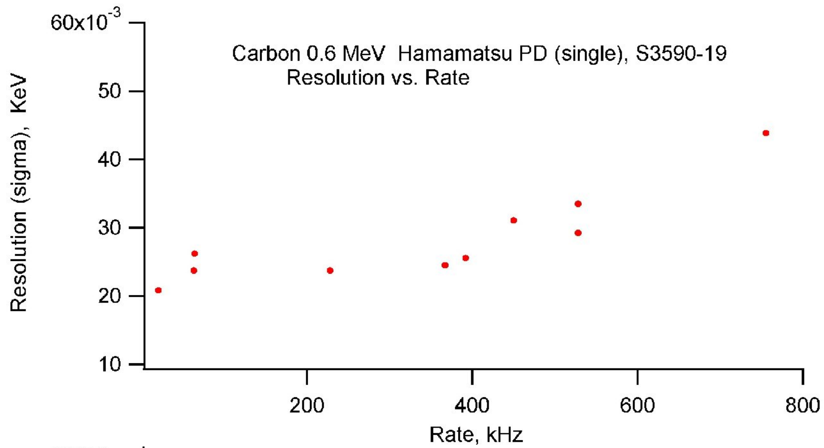
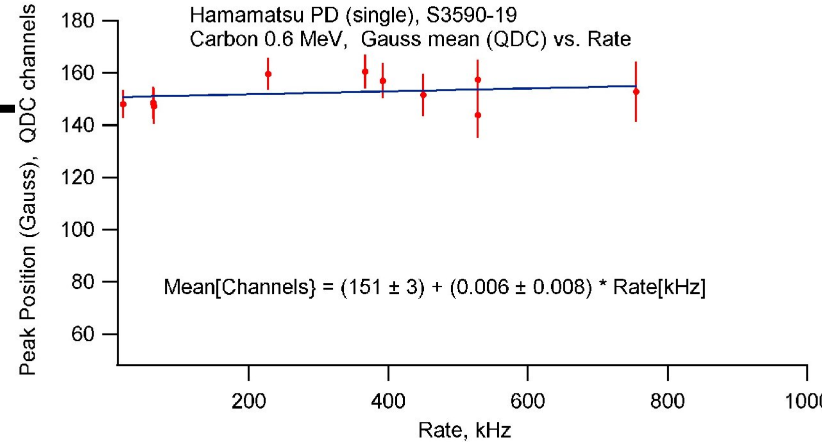
R&D At The BNL Tandem

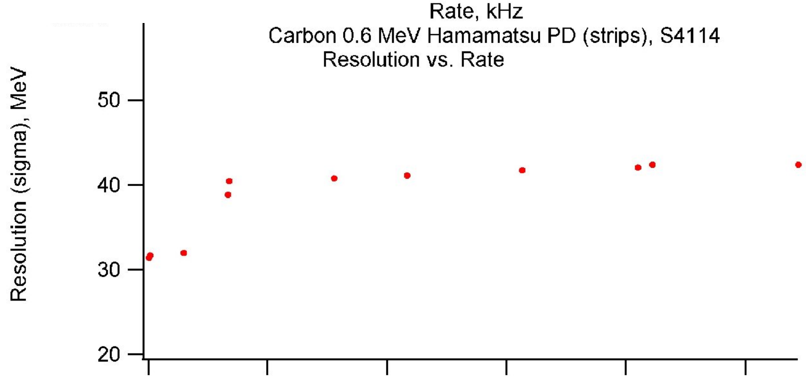
Atoian, Gill, Morozov

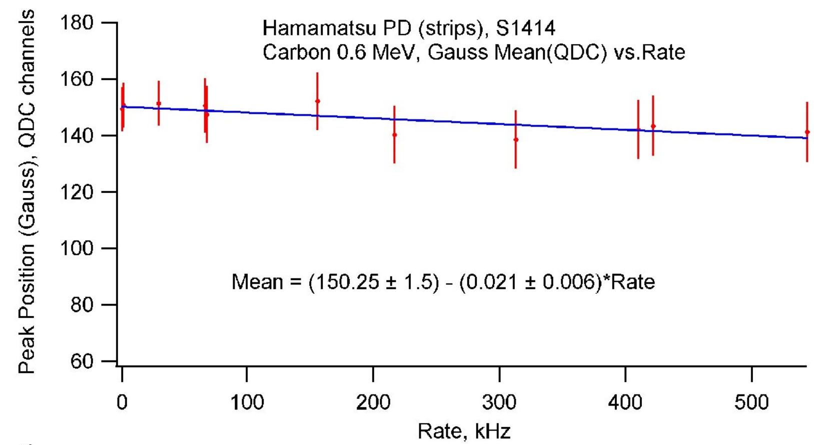
- Carbon beams to scan energies of interest with varying intensities up to $4.10^6/cm^2$ and test BNL and Hamamatsu detectors.
  - 0.3 – 10 MeV (wider than the current range to reach the Alpha energy from the Am source)
  - Carbon charge of +1 and +2
  - Provide a good energy calibration, and energy resolution
  - Decouple the time and energy dependences
  - Use a foil to simulate the polarimeter carbon target
  - Use alpha sources impinging forward and backward to determine the effective silicon thickness

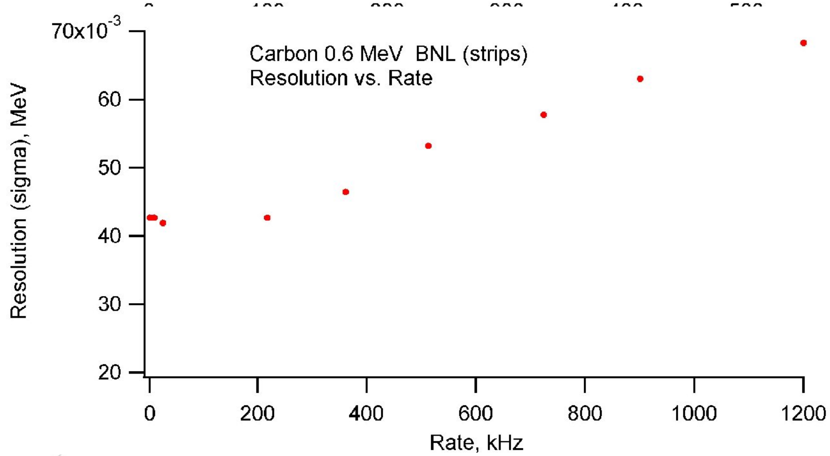
Rate dependence for 0.6 MeV C: For comparison rate at RHIC 50-100 kHz/ strip

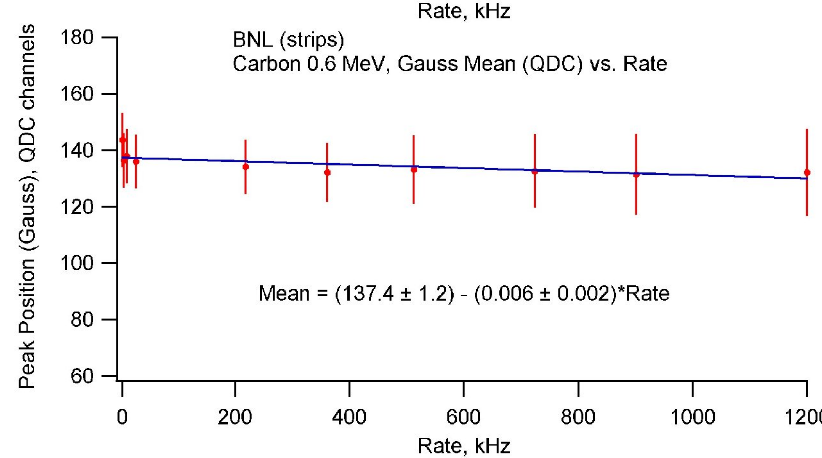








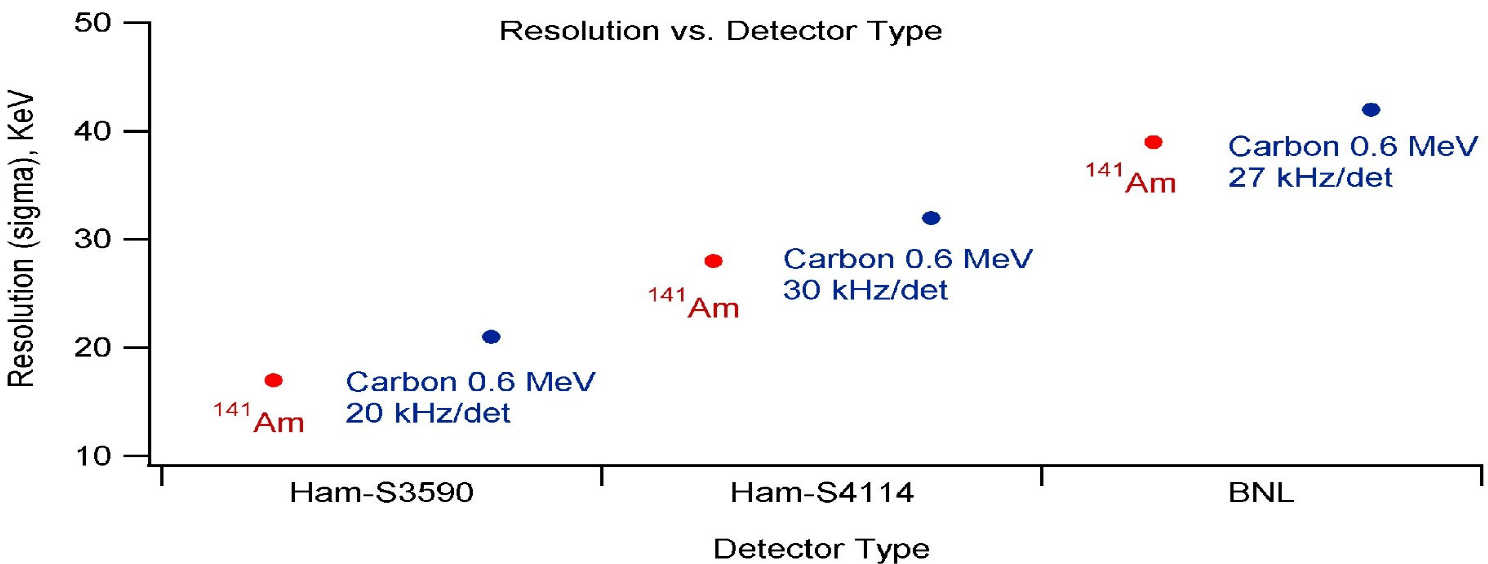




New Detector Tests

Atoian, Gill, Morozov

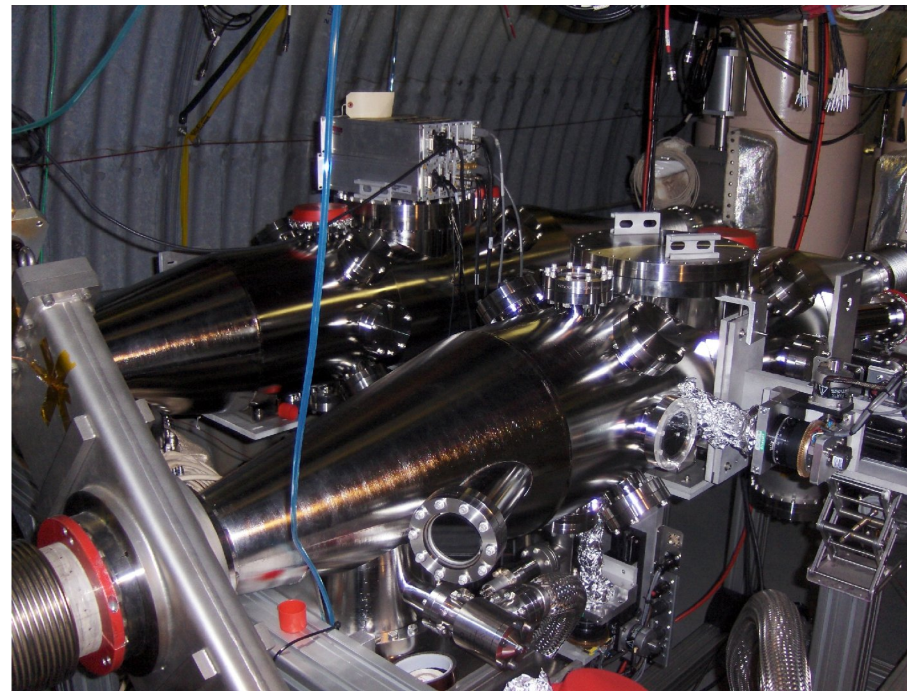
- Compare BNL and Hamamatsu large area (1cm x 1cm) Si and strip PIN photodiode detectors. Results show a several advantages to use these devices instead of the strip detectors
- A factor of ~2 better resolution (21 KeV vs. 43 KeV) which allows us to measure elastic carbons at ~ t=-0.005 GeV/c^2 at higher analyzing power
- ~ 20 times less bias current after 4 months working on the RHIC beam (0.23µA vs. 4 µ A)
- Simplify the readout electronics as well as DAQ



RHIC Polarimeters Upgrade (May 2008- Feb 2009)

A. Bazilevsky, S. Bugros, T. Curcio, D. Gassner, R. Gill, H. Huang, D. Lehn, G. Mahler, M. Mapes, B. Morozov, T. Russo, M. Sivertz, D. Steski, R. Todd, A. Zelenski, Y. M.

- New vacuum chambers
- Two polarimeters in each beam
- New target drive mechanisms
- New target holders 6 (V) 6 (H) ea.
- Simultaneous H and V pol. profiles
- New vacuum isolation valves
- Multiplexing to reduce cost
- In situ test of new detectors



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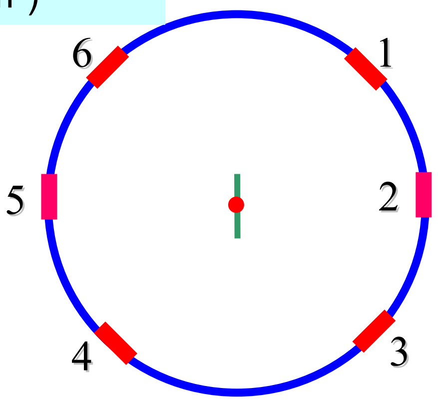
Controls group programming for Fixed and scanning mode operations

S. Nemesure, J. Jamilkowski

p-Carbon Polarimeters Energy Calibration

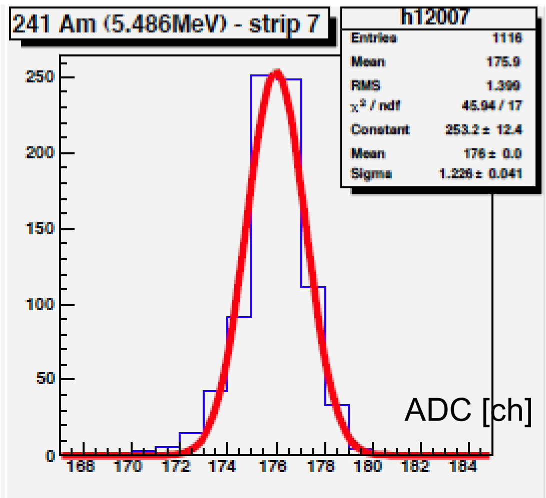
Ultra thin Carbon ribbon Target (5μ g/cm²)



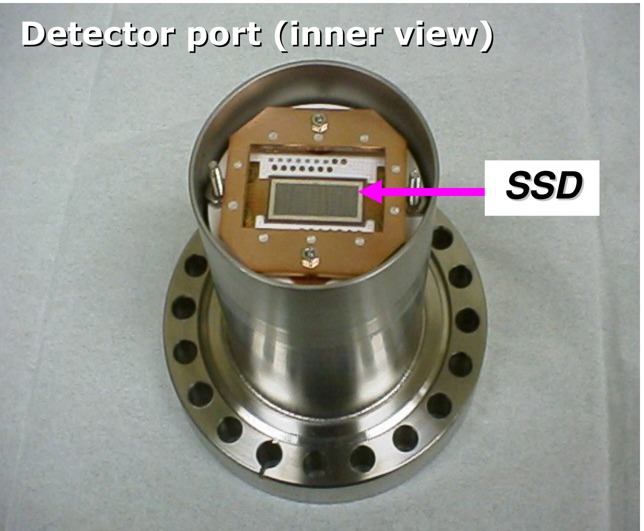
Alpha source
5.486 MeV (85%)
5.443 MeV (12%)

E_α

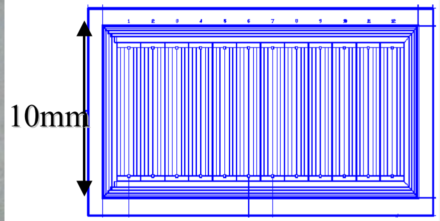
Fitting Error < 0.01%

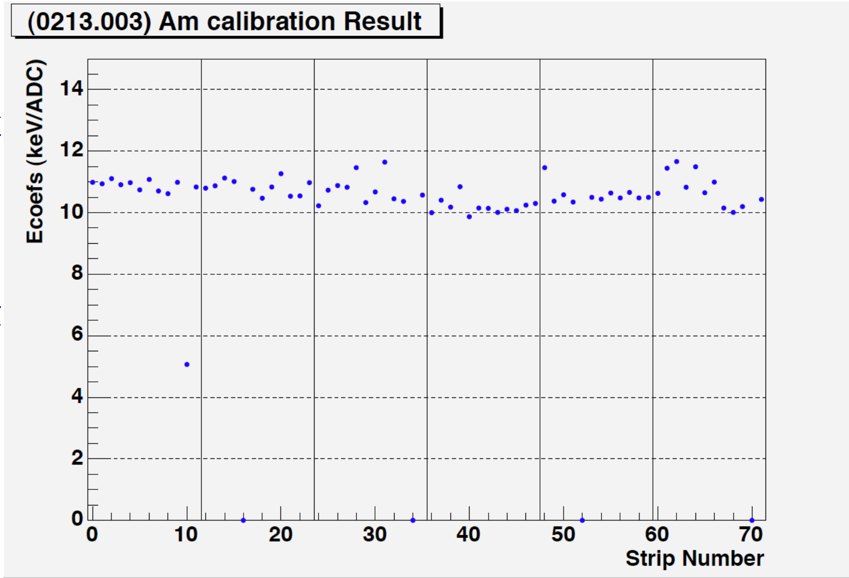


~50keV/ch

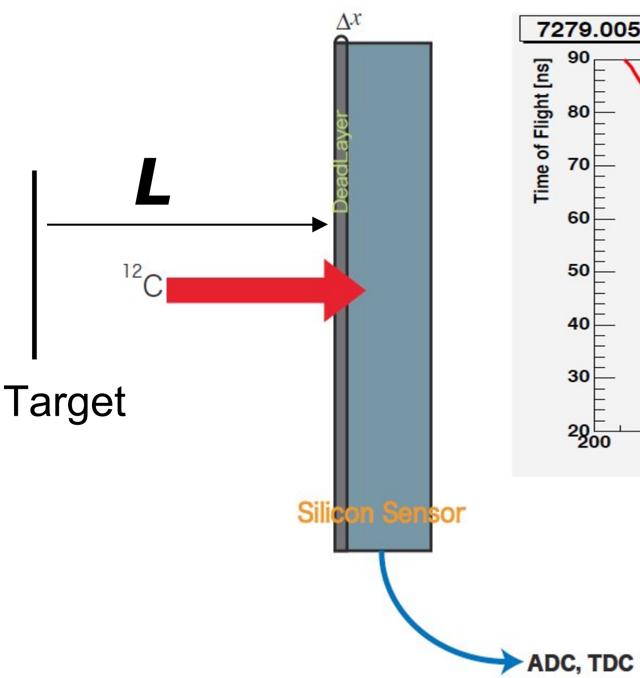


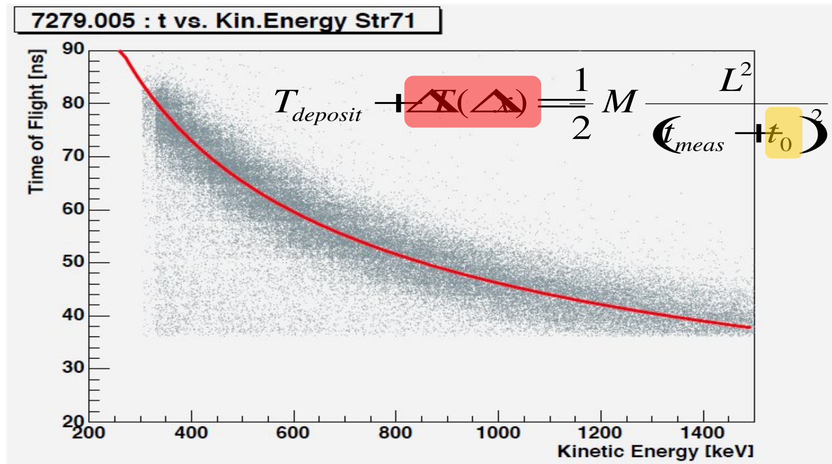
2mm pitch 12 strips





Energy Correction





$(t_0, \Delta x)$ ➔ Kinematic Fit

$$T = T_{deposit} + \Delta T(\Delta x)$$

(adc× C_α) (effective deadlayer)

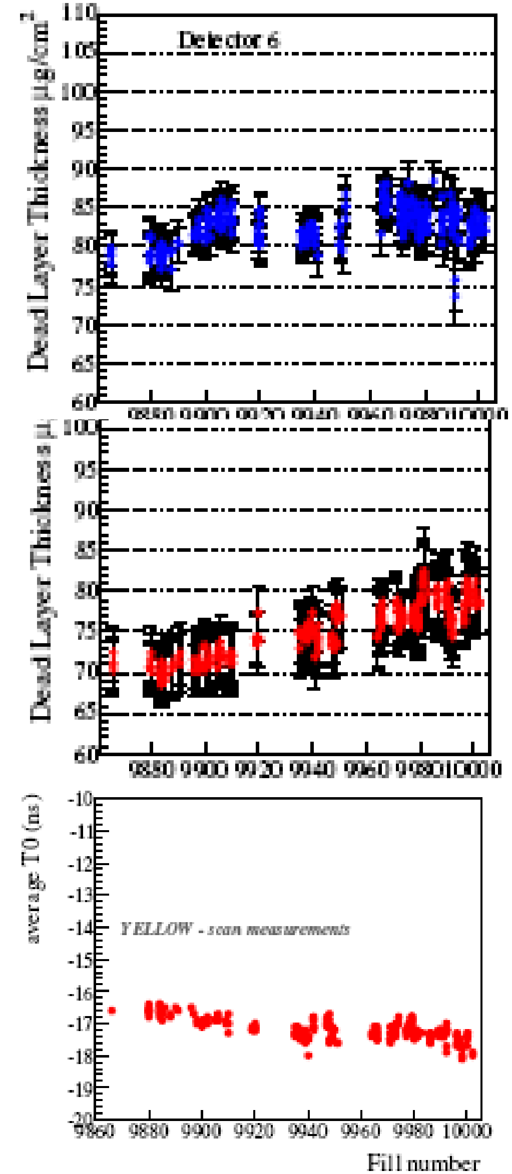
Run5: 40-55 μg/cm²

Run6: 70-80 μg/cm²

Run8: 75-90 μg/cm²

Run9: 50-80 μg/cm²

10 μg/cm$_2$ >> 6% in ΔA_N



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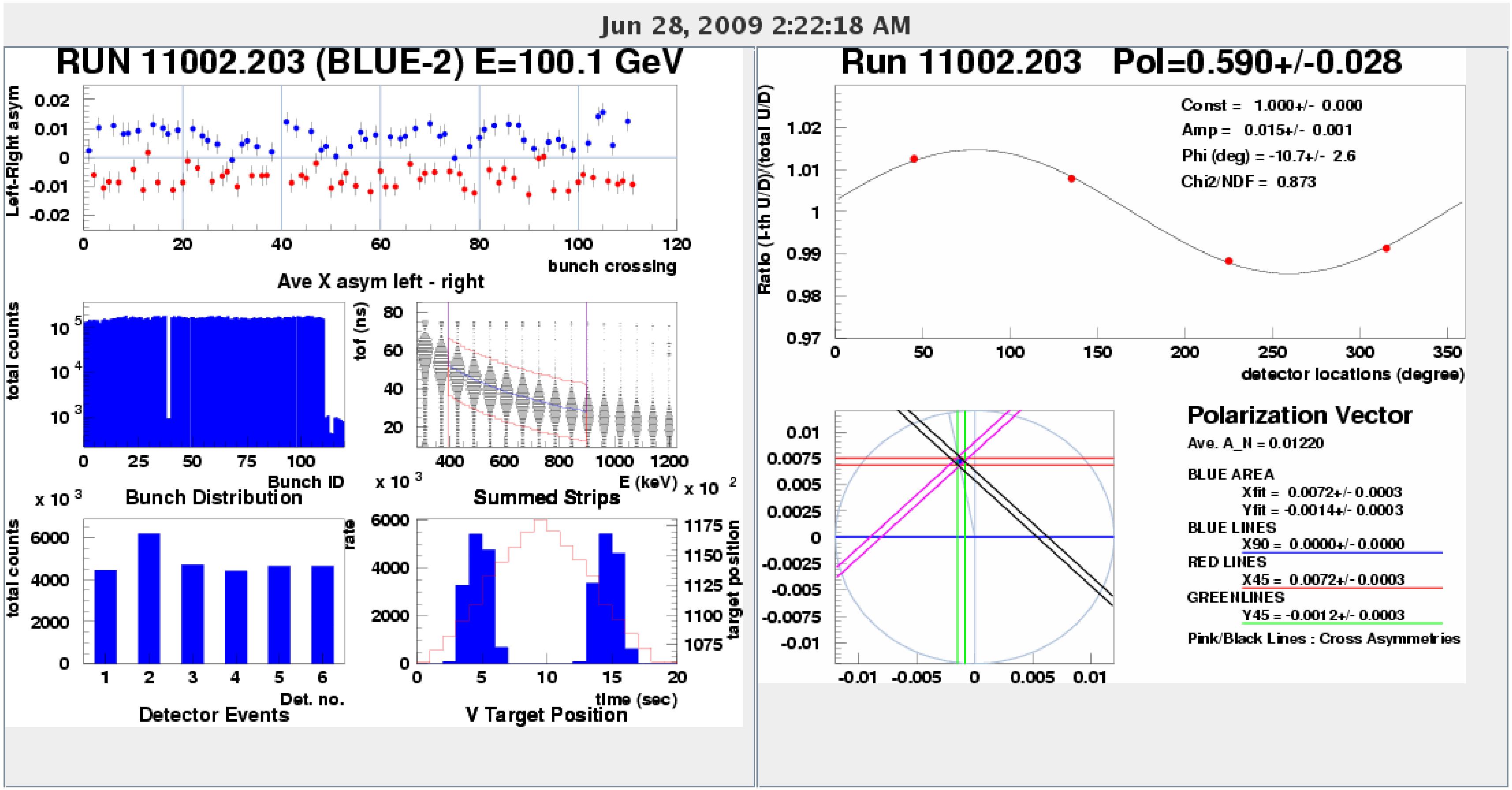
Online Polarimeter display



Carbon rate 50 - 100 kHz/ strip

Prompts background to signal ~ 1/1 with an energy threshold cut at 125 keV.

Shaper pulse rise time 20 nsec and fall time 50 nsec

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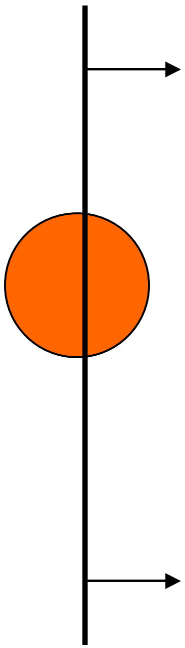
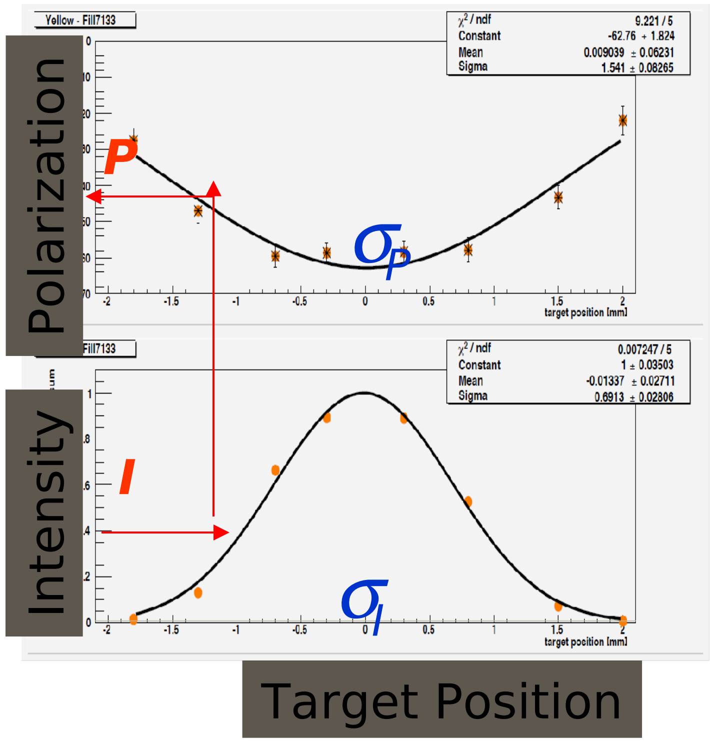
pC: Polarization Profile

Bazilevsky

pC



Scan the Carbon target over the beam:



1. Directly measure σ_I and σ_P:

$$R = \frac{\sigma_I^2}{\sigma_P^2}$$

2. Obtain R directly from the $P(I)$ fit:

$$\left.\begin{array}{l} P(x) = P_{\max} \cdot \exp\left(-\dfrac{x^2}{2\sigma_P^2}\right) \\ \\ I(x) = I_{\max} \cdot \exp\left(-\dfrac{x^2}{2\sigma_I^2}\right) \end{array}\right\} \quad P = P_{\max} \cdot \left(\frac{L}{L_{\max}}\right)^R$$

Precise target positioning is NOT necessary

R ~ 0.1–0.3 ⇒ 5–15% difference in lower polarization seen by HJet compared to that observed by experiments

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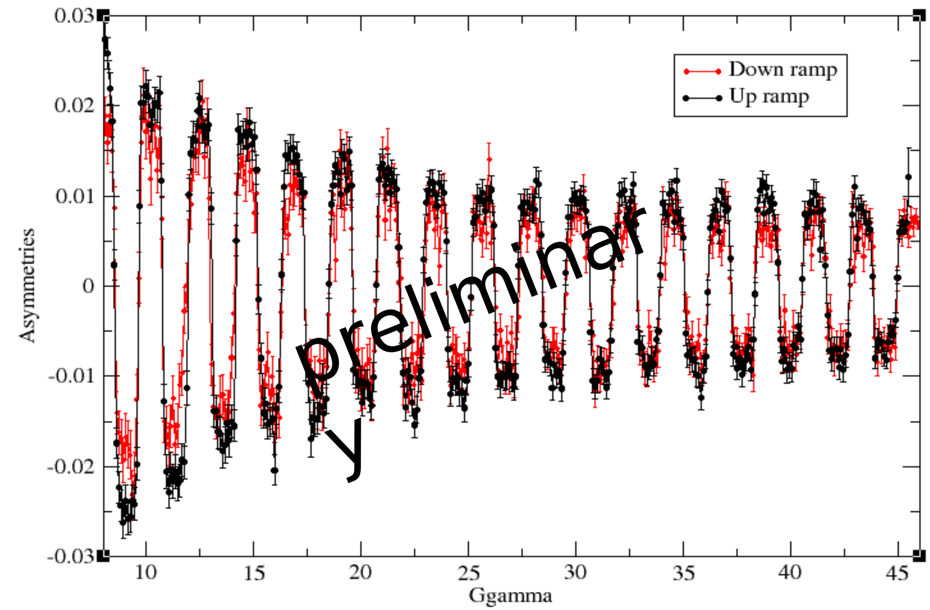
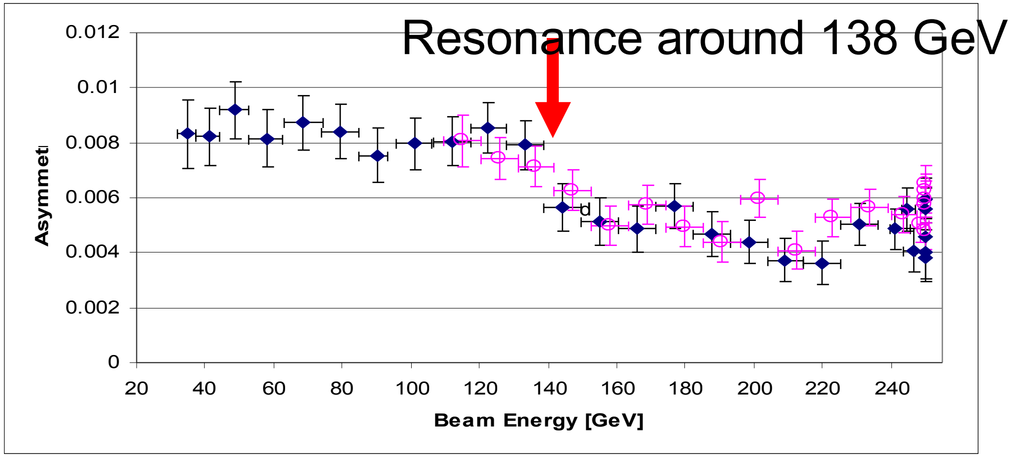
Polarization On The Ramp

Two such examples:



For the AGS where we sum over
Many passes to accumulate
statistics
In this case ramped up and down



For RHIC @ 250 GeV ramp were
each is a single pass limited by the
onboard local memory

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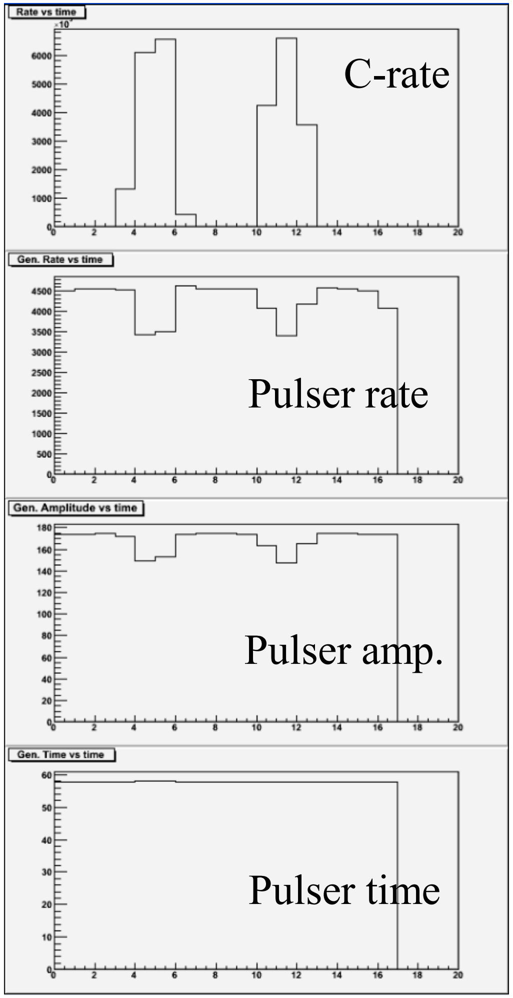
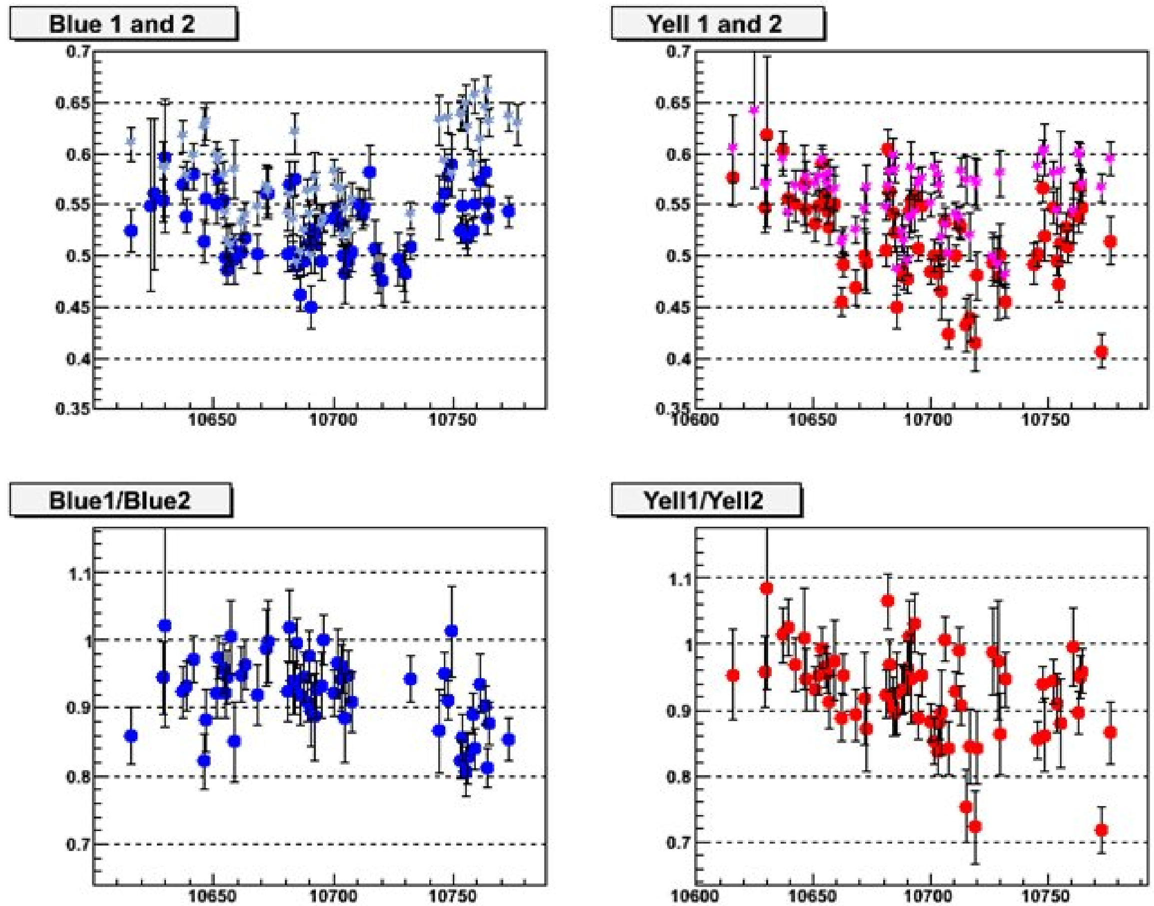
Polarimeters rate problems





Blue1/Blue2: dropped from 0.94 to ~0.85 after target change in Blue2

Yell1/Yell2: shows more variations above stat. uncertainties (rate effect?)

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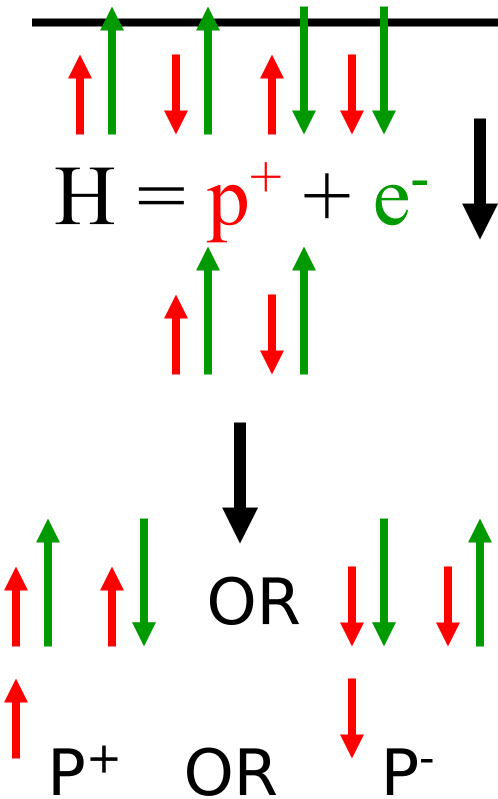
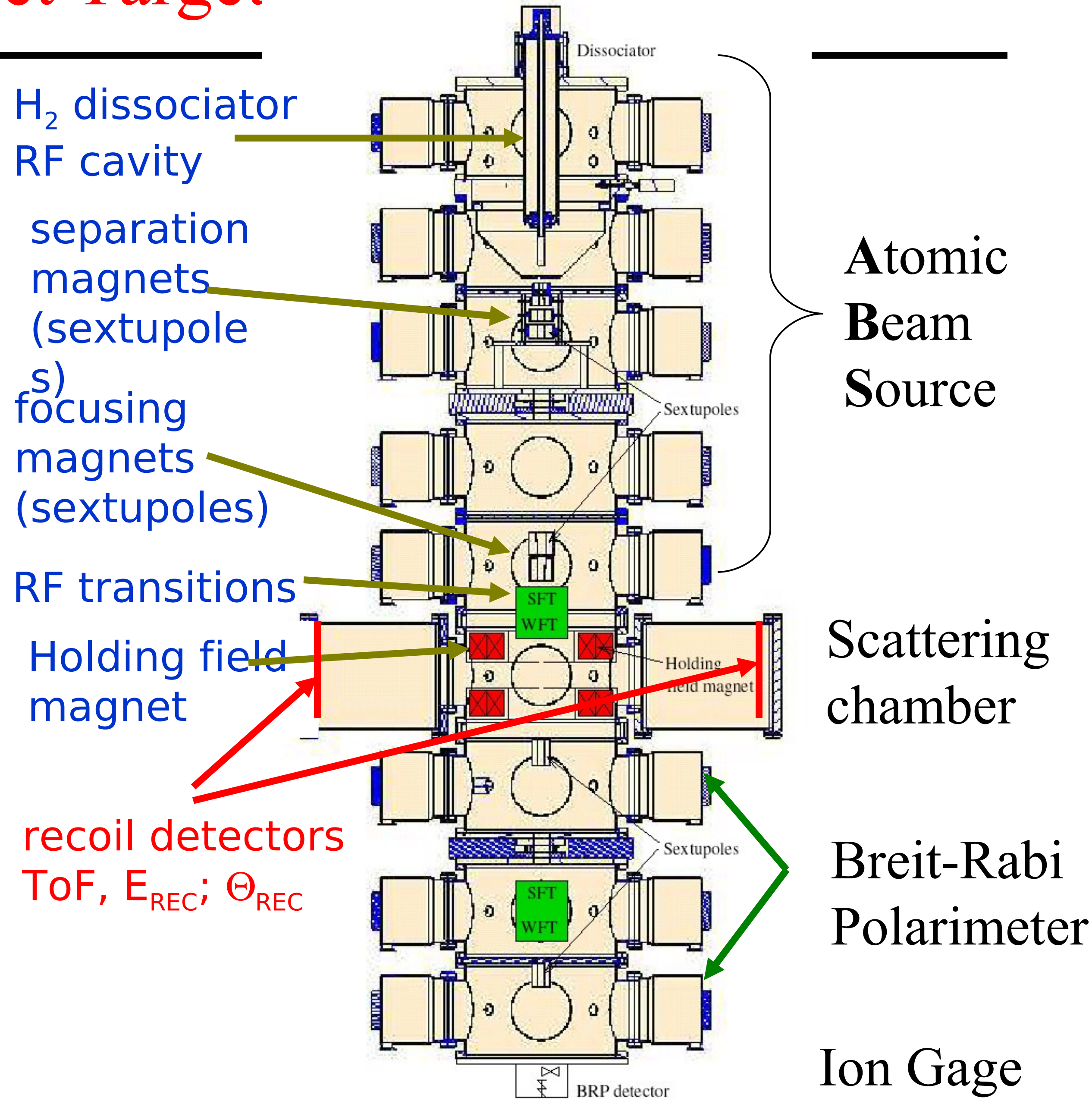
Rate Studies

Atoian, Bazilevsky, Gill, Morozov, Rescia

- We have in hand several data runs with high rate and the nominal WFD readout
- We have taken special measurements to study rate problems varying:
  - The beam intensity and number of bunches
  - The polarimeter target thickness
- With help from the Instrumentation Division also used a fast scope (20 G samples/sec) to study the pulse height and baseline variation versus rate at the output of various stages:
  - The preamplifier
  - The shaper
  - With BNL and Hamamatsu detectors
  - With the Yale WFD readout in a full waveform mode to study baseline shifts
  - With a separate ADC and TDC readout
- Analyses are ongoing but seem to indicate that both the BNL and Hamamtsu detectors can handle the high rates through the shaper stage.

The Polarized H-Jet Target



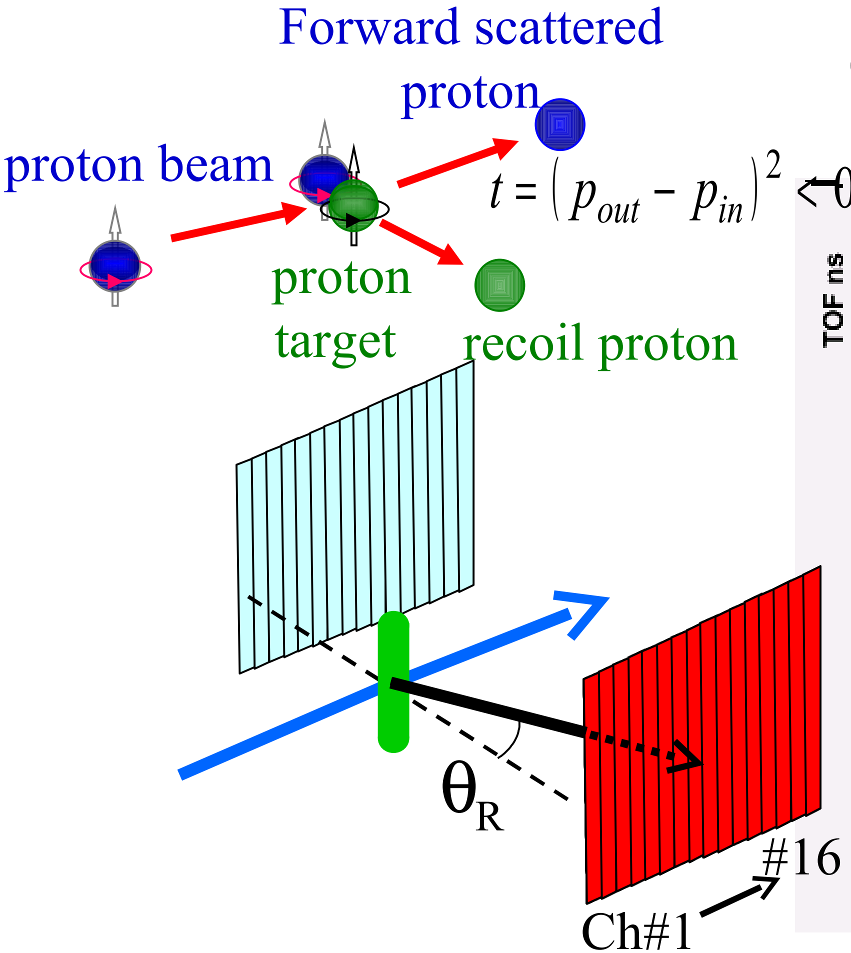


record beam intensity
100% eff. RF transitions
focusing high intensity
B-R polarimeter

$P_{target} \sim 0.924 \pm 0.018$

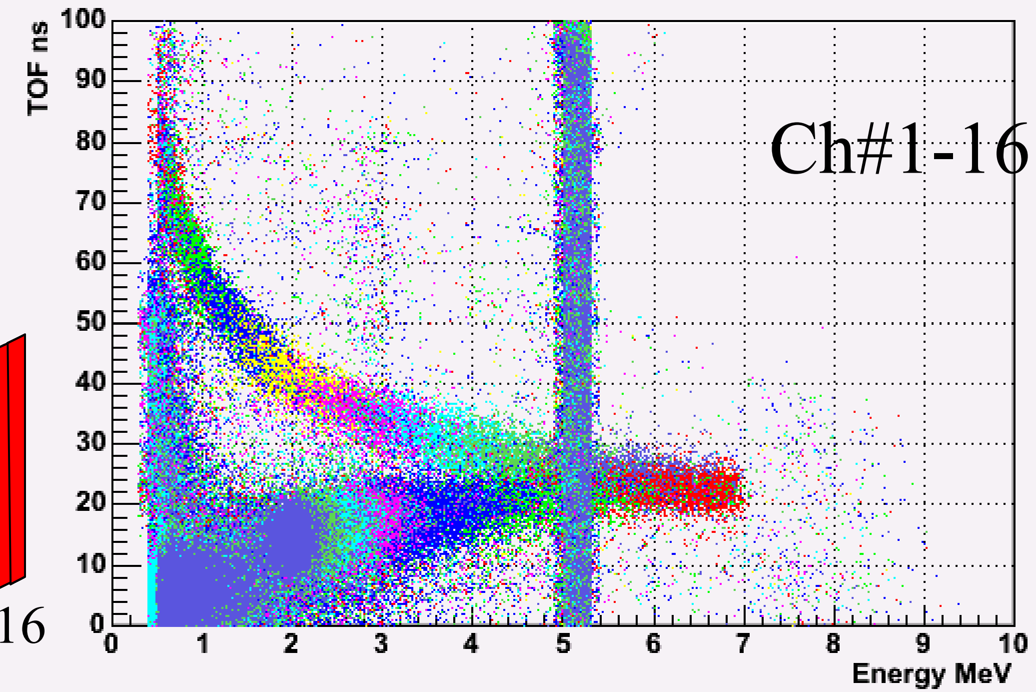
Recoil Spectrometer Measurement

H. Okada



$ch\# \propto \theta_R$, θ_R big $\Rightarrow T_R$ big

$\Rightarrow$ fast protons

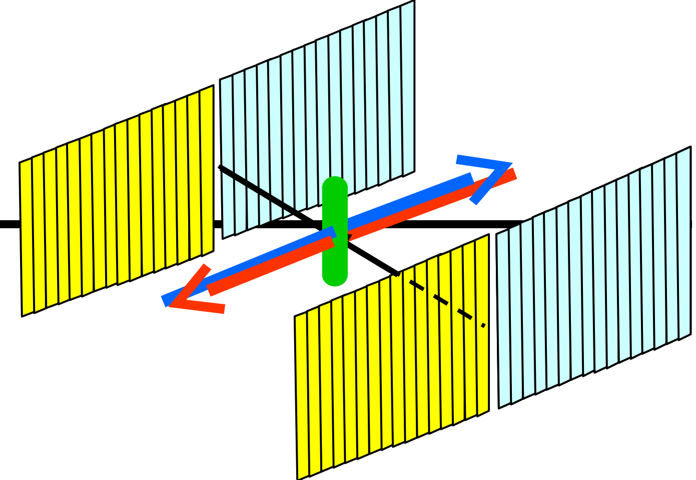


Array of Si detectors measures $\mathbf{T_R}$ **& tof** of recoil particles.

Channel # corresponds to recoil angle $\boldsymbol{\theta_R}$.

2 correlations (T_R & tof) and (T_R & θ_R) → the elastic process

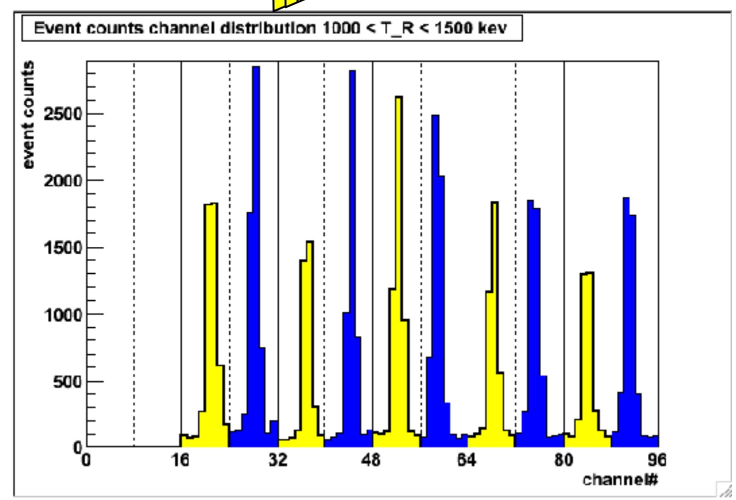
Running conditions Run9

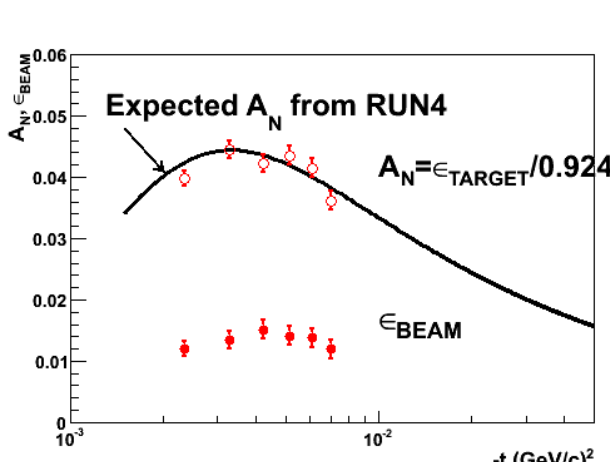


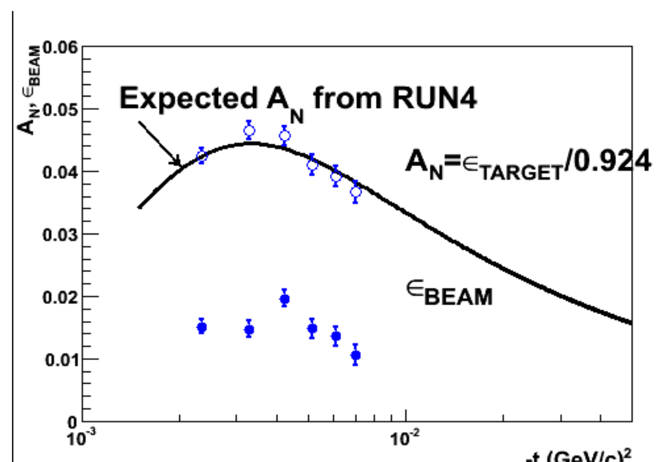
- Ran with two beam simultaneously separated vertically by 3-4 mm dictated by the machine Beam-beam requirements

- Backgrounds were minimal no grater than one Beam condition

- Measured A_N in pp elastic scattering At 250 GeV Below show 4 stores combined







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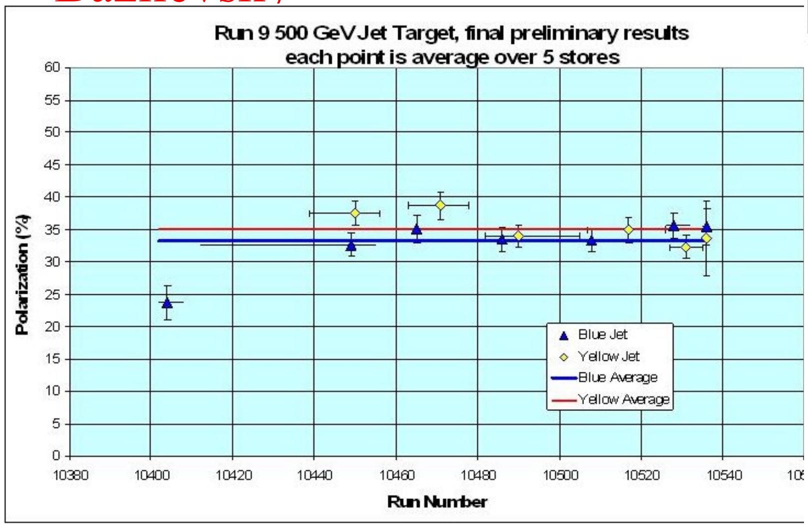
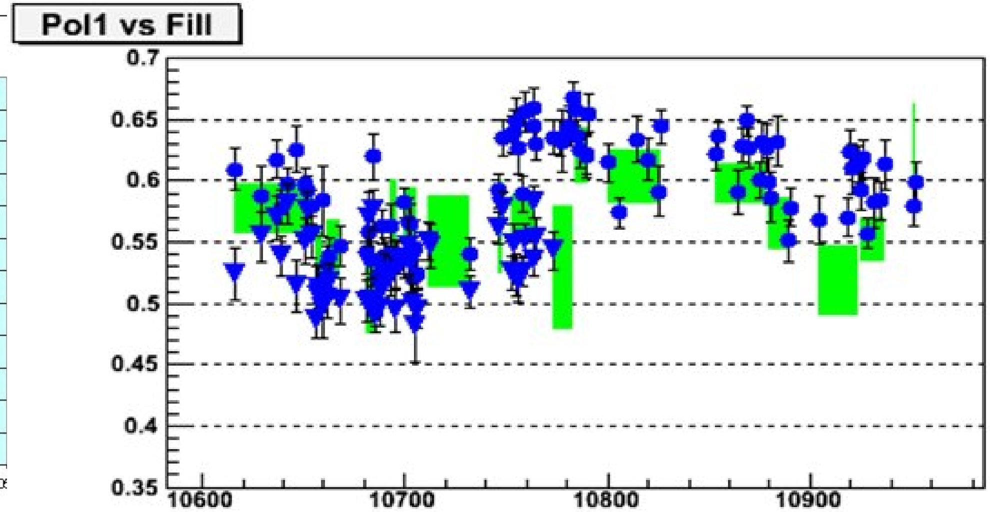
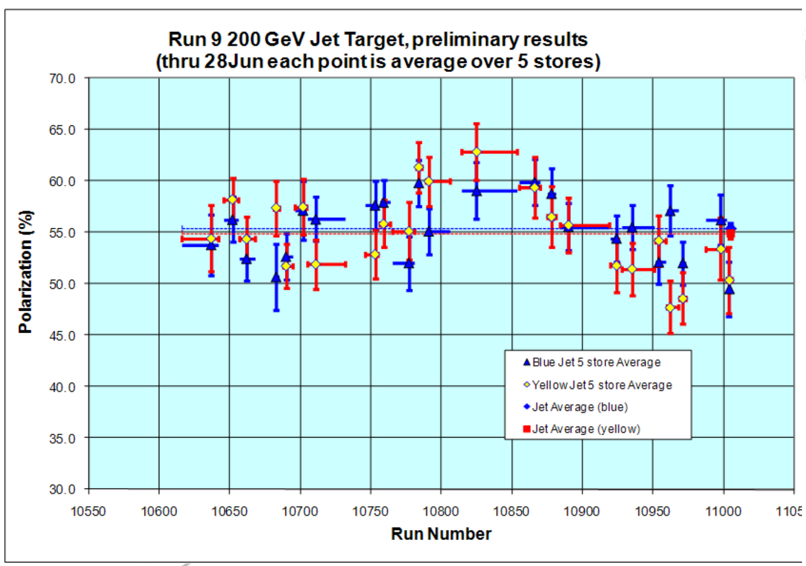
Results Run9

Analysis By S.K. Lee and X. Li

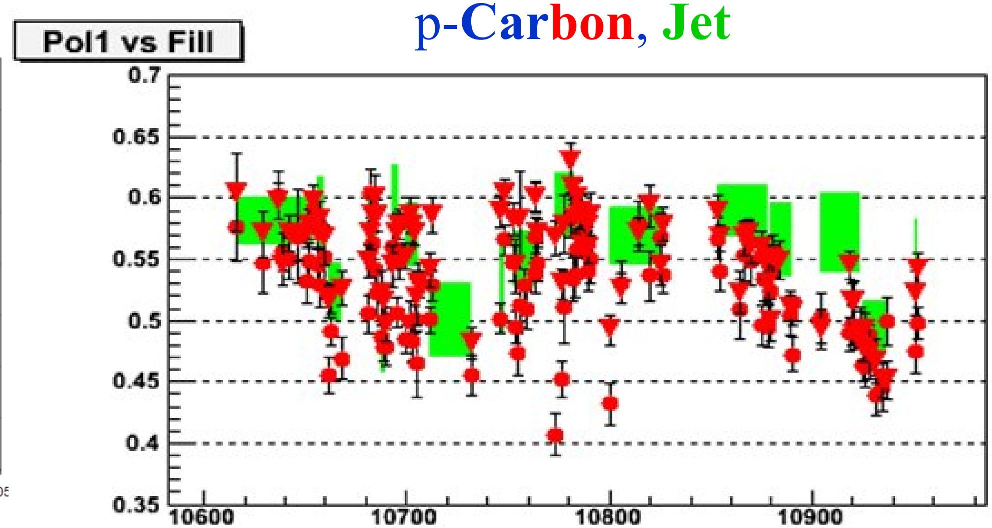
Compiled by P. Pile and A. Bazilevsky





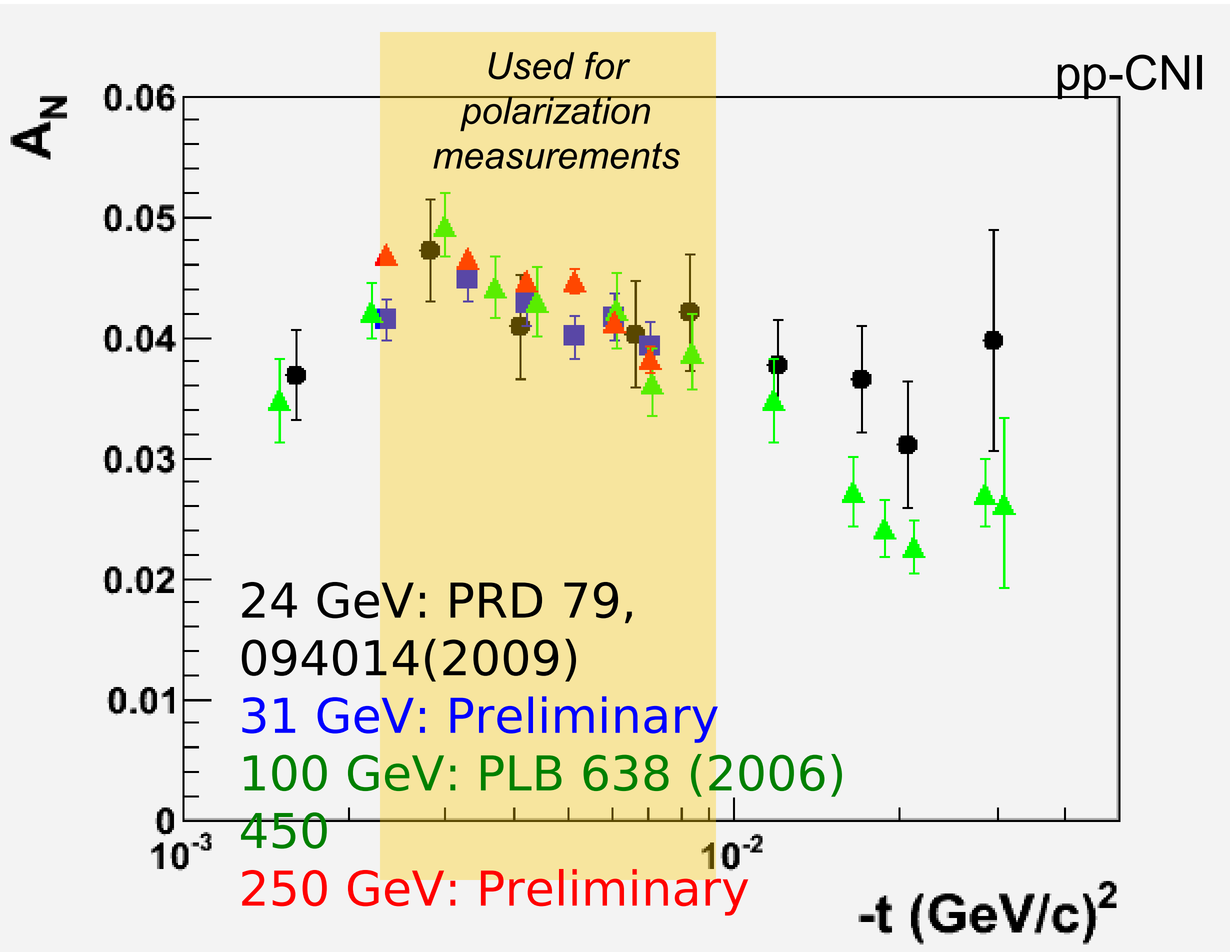


p-Carbon, Jet



Jet periods defined by target changes

Polarized Hjet: A_N



Weak (if any) energy dependence ⇒ *pp* elastic scattering in CNI region is ideal for polarimetry in wide beam energy range

Possibly an unpolarized hydrogen Jet for higher intensity?

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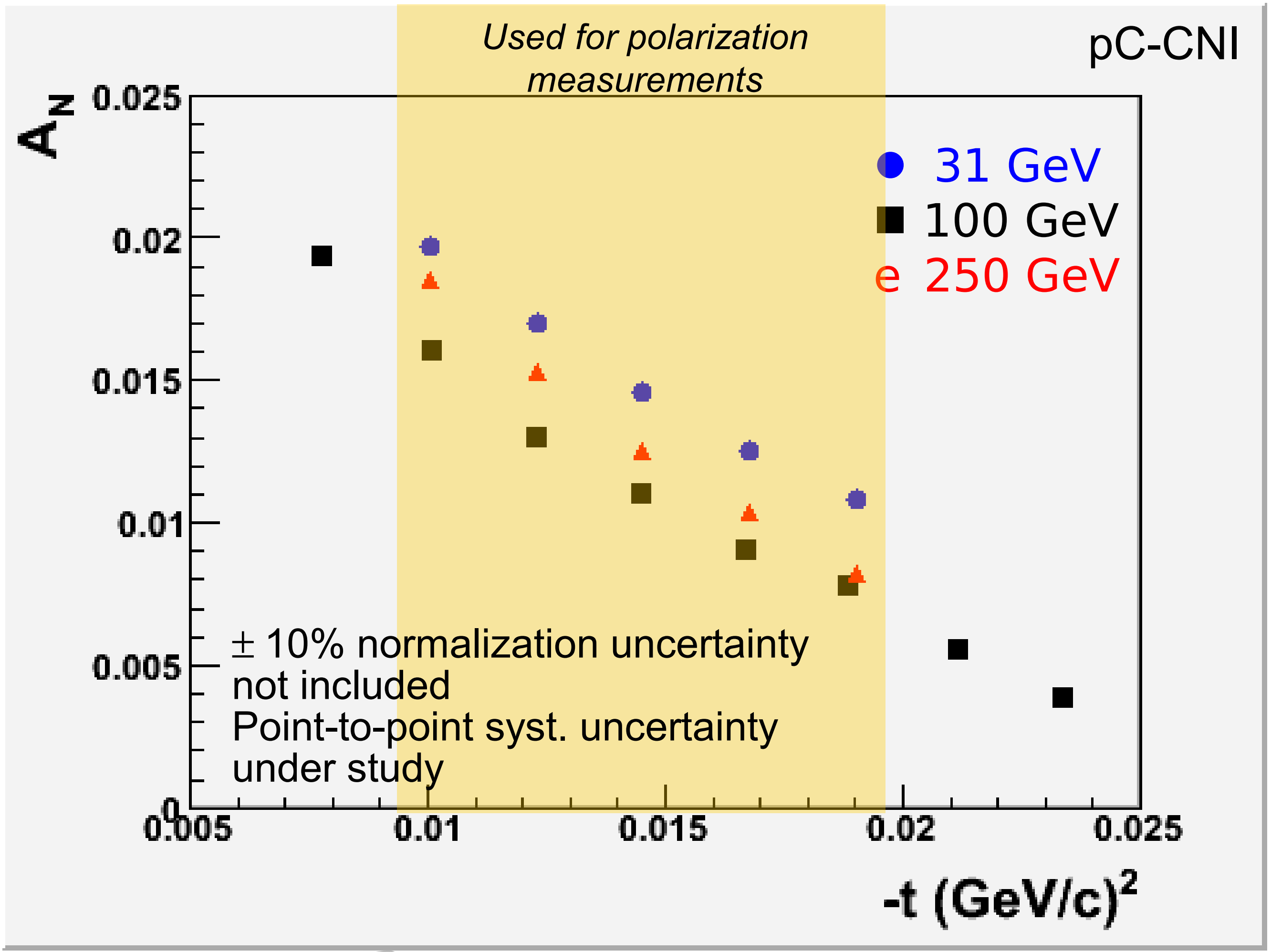
p-Carbon: A_N



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

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A Path Forward

- Complete data analyses to discern the bottle neck in the current polarimeters
  - Look into using new Hamamatsu detectors
    - lower leakage current vs Rad exposure
    - Better energy resolution > lower t reach and higher analyzing power
    - Smaller acceptance and thus rate per strip
  - Look for a viable hardware solution (ADC / TDC system?)
  - Provide better control on our target production
  - Investigate new target technology
    - Laser ablation techniques (TRIUMF)
    - Carbon nano tubes (SUNY SBU research)
- Better Slow Controls, calibration, and monitoring

A Path Forward Near Term

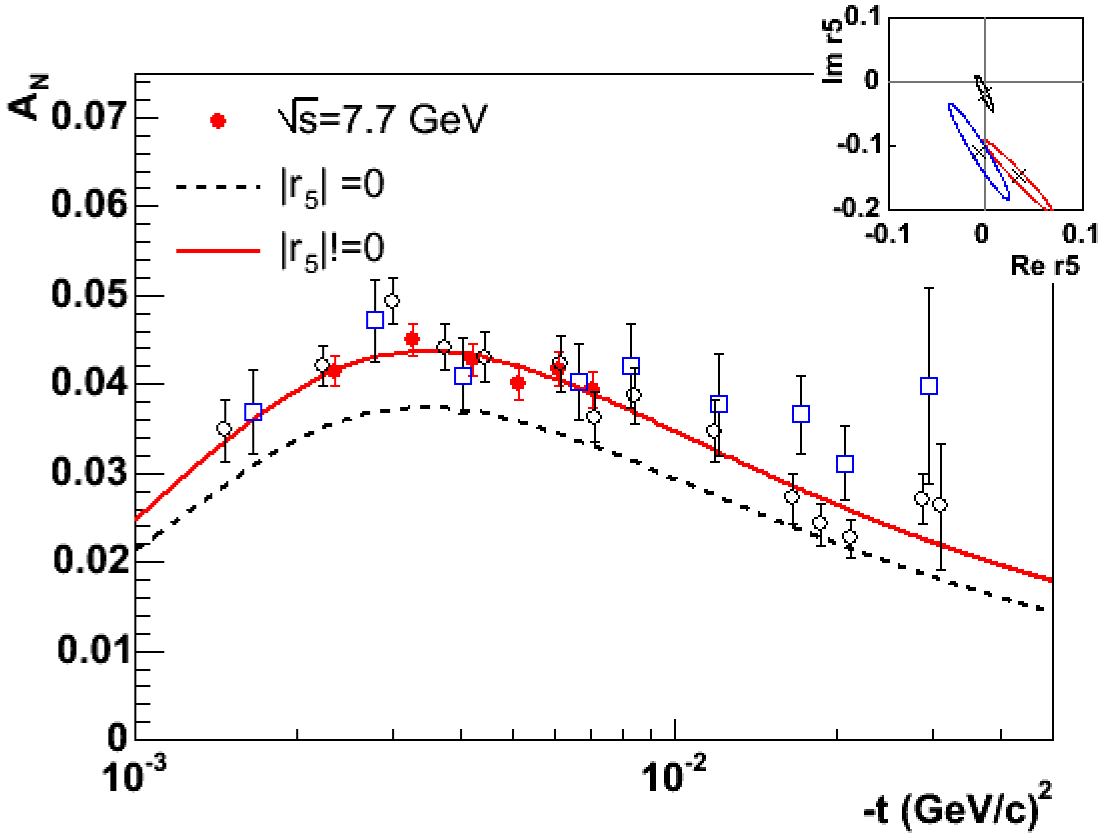
- Install Hamamatsu 300μ Silicon Photodiode PIN detectors on two of the six Jet detectors
  - Use the same amplifier / shaper and WFD readout
  - In situ comparison of:
    - Energy resolution and thus lower t reach
    - Susceptibility to beam induced background
- Install similar detectors at 45 degrees in the AGS p-C polarimeter
  - Equip with new amplifier / shaper electronics and a separate ADC / TDC
  - Allows in situ comparison of the two systems
    - Rate issues
    - Susceptibility to radiation damage
    - Energy resolution

Summary

- The RHIC polarimetry group had a busy year
- Installed new polarimeter systems and the polarized Jet target
- Observed significant rate issues
- Initiated studies to understand these issues and analyses
- Received significant help from PHENIX and STAR graduate students for Jet and p-Carbon data analyses
- Had a Polarimetry Workshop (July 31st) to chart a future course
- Looking to this Workshop for ideas to increase the Jet intensity

Backup

pp analyzing power



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2005 Jet Normalization Summary

$$A\_N(2005) = A\_N(2004) \times (S \pm \Delta A(\text{jet stat})/A \pm \Delta A(\text{jet syst})/A \pm \Delta A(\text{pC syst})/A)$$

- Blue

$$A\_N(05)=A\_N(04)\times(1.01 \pm .031 \pm .029 \pm .005)$$

$\Delta P/P(\text{profile})=4.0\%$

$\Delta P(\text{blue})/P(\text{blue}) = 5.9\%$

- Yellow

$$A\_N(05)=A\_N(04)\times(1.02 \pm .028 \pm .029 \pm .022)$$

$\Delta P/P(\text{profile})=4.1\%$

$\Delta P(\text{yellow})/P(\text{yellow}) = 6.2\%$

$\Delta[P(\text{blue}) \times P(\text{yellow})]/[P\_b \times P\_y] = 9.4\%$ ← **Goal: 10%**

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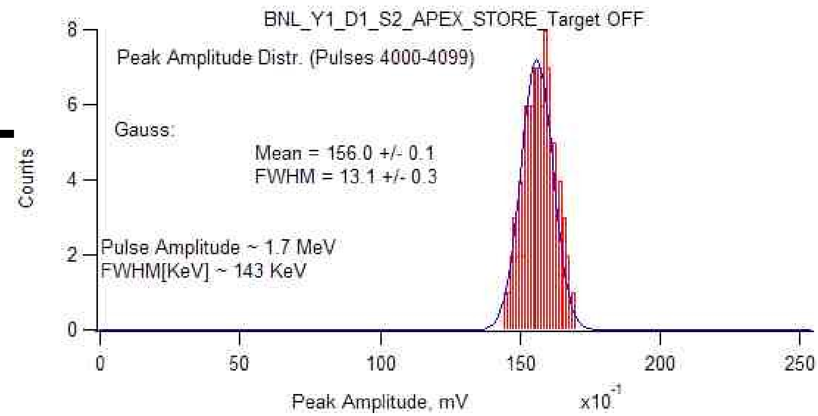
Polarimeter Operational Issues

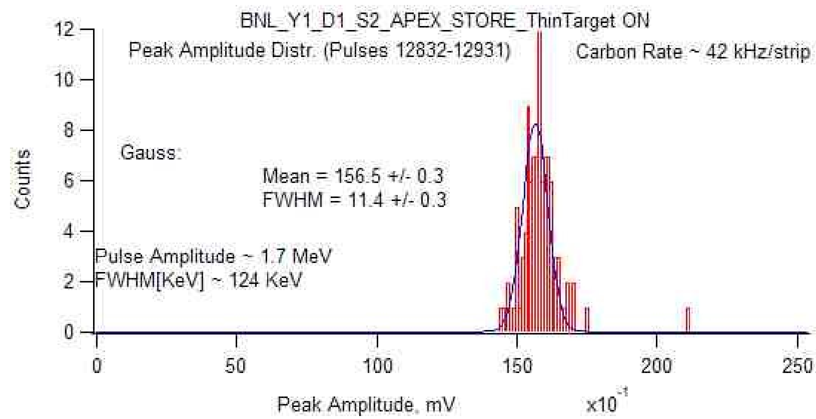
- A slow start, new hardware, double the polarimeters and control software.
- Polarimeter measurements were successfully carried by MCR operators.
  - A simplified application rarely caused problems. Having a second polarimeter as backup helped. If both were down, we still had the jet. The applications occasionally picked up the wrong start and end target scan positions.
- Online results provided the first information for accelerator tuning. A quick offline analysis came soon after. Final offline analysis and Jet calibration will then be given to the experiments. (Start with the 100 GeV)
- Ramp measurements were attempted but the online analysis did not work properly also the target position feedback loop proved hard to implement. Reverted to measurements at distinct locations on the ramp which proved quite useful.
- One AC unit failure in the counting house but the building AC and the weather came to our rescue. We need to install high temp alarms

APEX Rate Studies

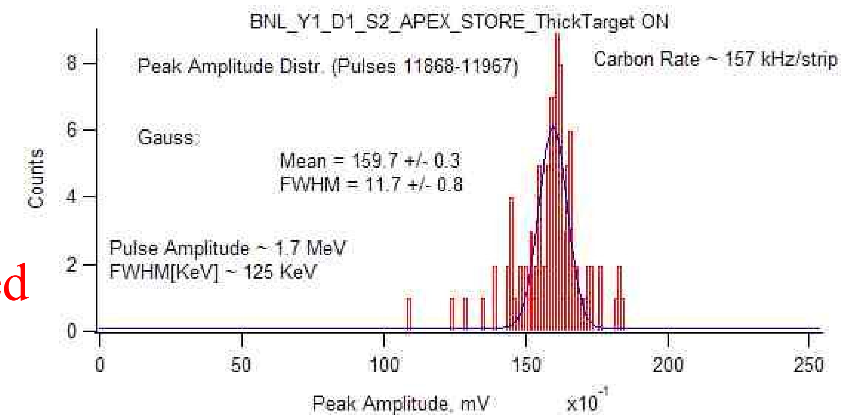
Injected Generator pulse
No target



With a thin Carbon target
Carbon rate 42 kHz/ strip



With a thick target
Carbon rate 157 kHz/strip



No appreciable change observed

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