Polarization measurement of proton beams at RHIC

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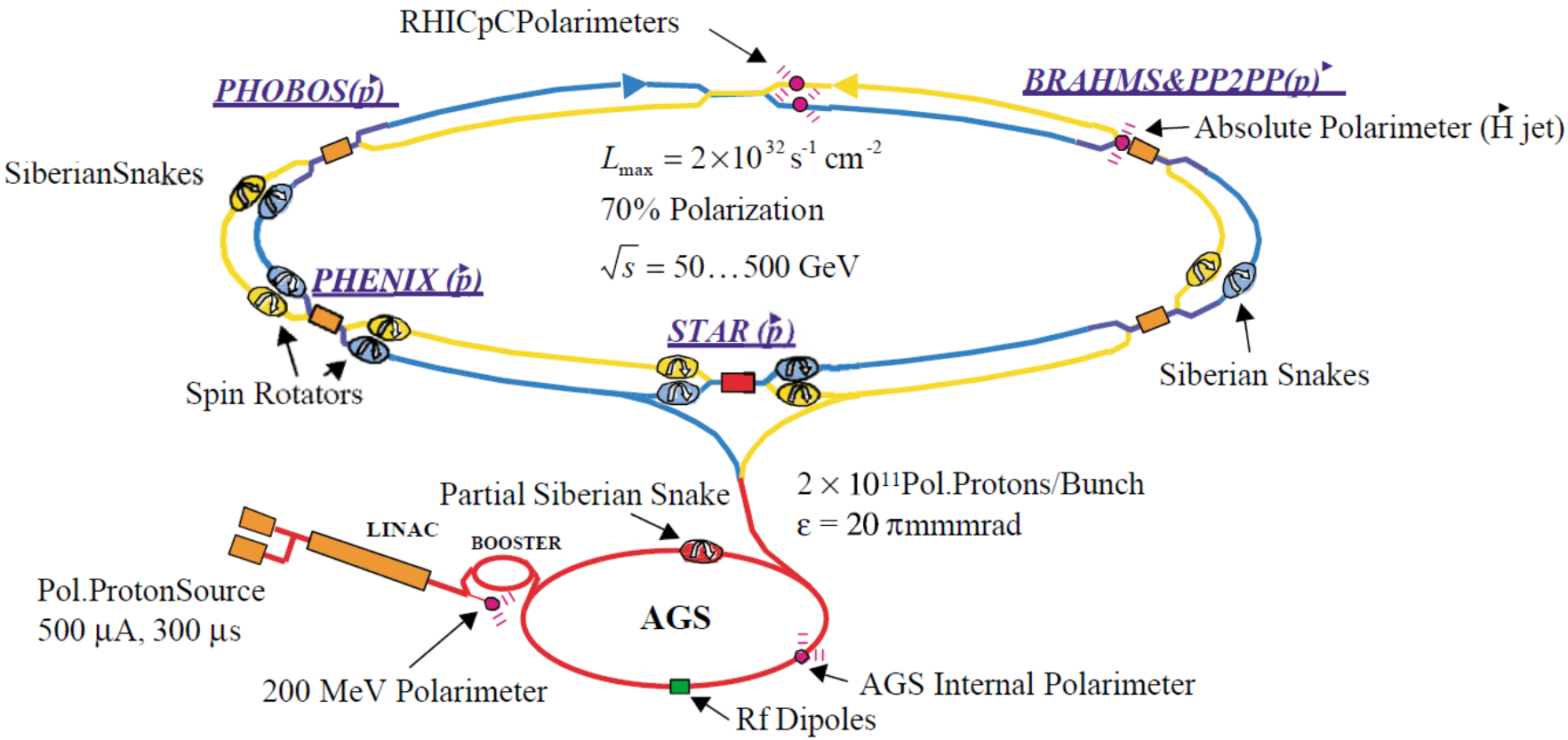
Outline

- Motivation
- Polarization measurements
  - pC polarimeters
  - $H-$jet polarimeter
- Results and overview
- Possibilities at higher energy (LHC...)

Spin physics motivations

1. Measure Δg
2. Polarized quark PDFs
   (through W production and Drell-Yann)
3. Quark transversity distributions
   (through transverse single-spin asymmetries)
4. Physics beyond the SM
   (through new PV asymmetries, if observed)

Polarized proton collisions at BNL



Measuring beam polarization at RHIC

Beam polarization:

$$P_B = \frac{1}{A_p} \frac{N_L - N_R}{N_L + N_R}$$

A_p : known (theory or experiment) analyzing power of the reaction

At RHIC:

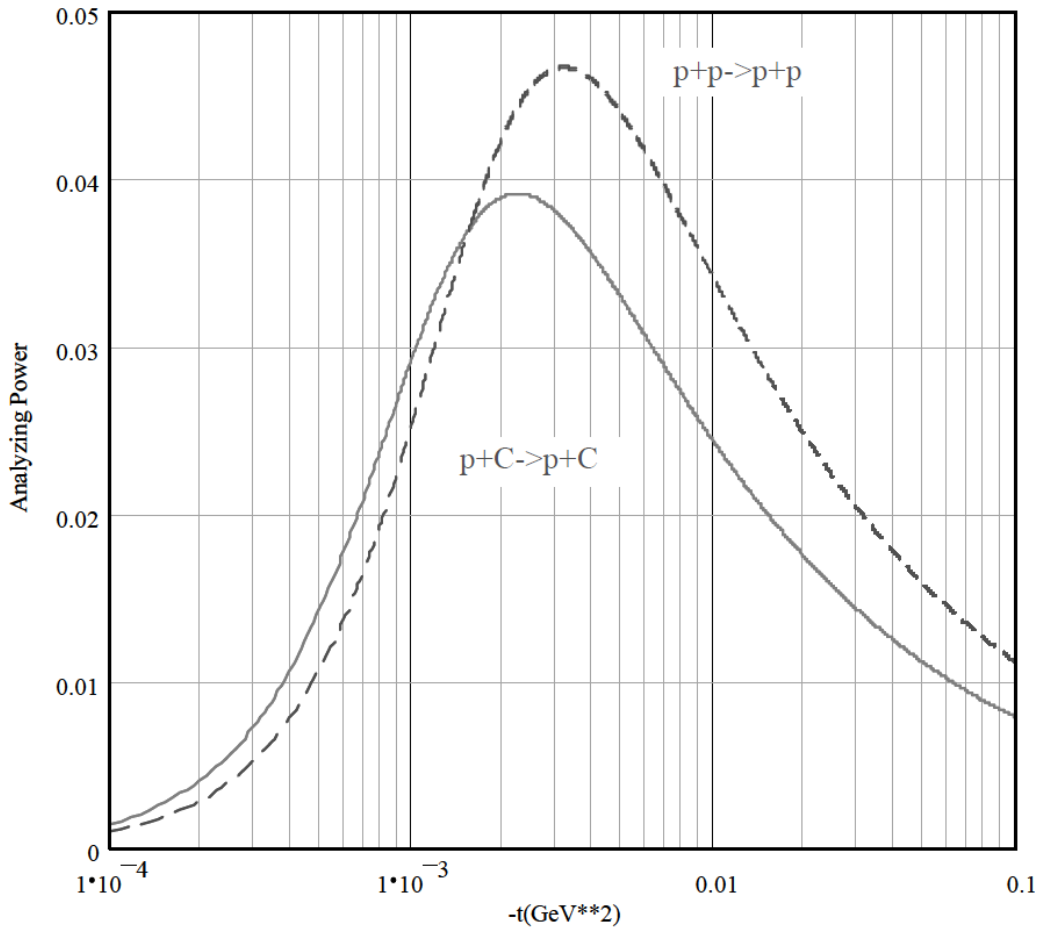
- $eC \rightarrow eC$
- $ep \rightarrow ep$

in the CNI (Coulomb-Nuclear Interference) region:

$$0.001 < t < 0.01 \text{ (GeV/c)}^2$$

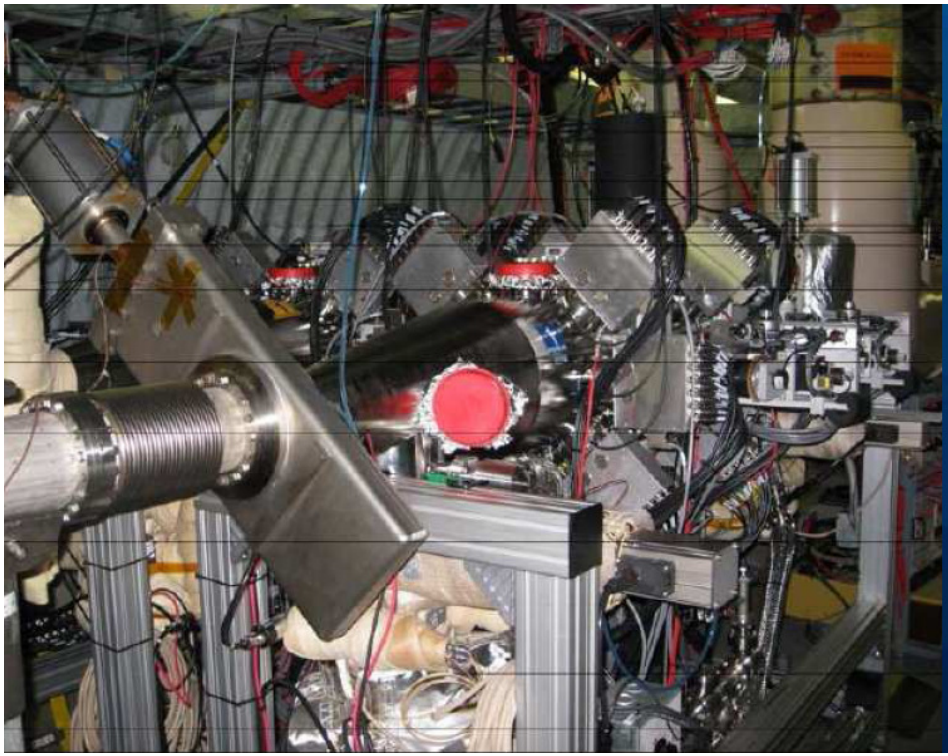
where $t = (p_{in} - p_{out})^2 = -2ME_{kin}$ is the momentum transfer

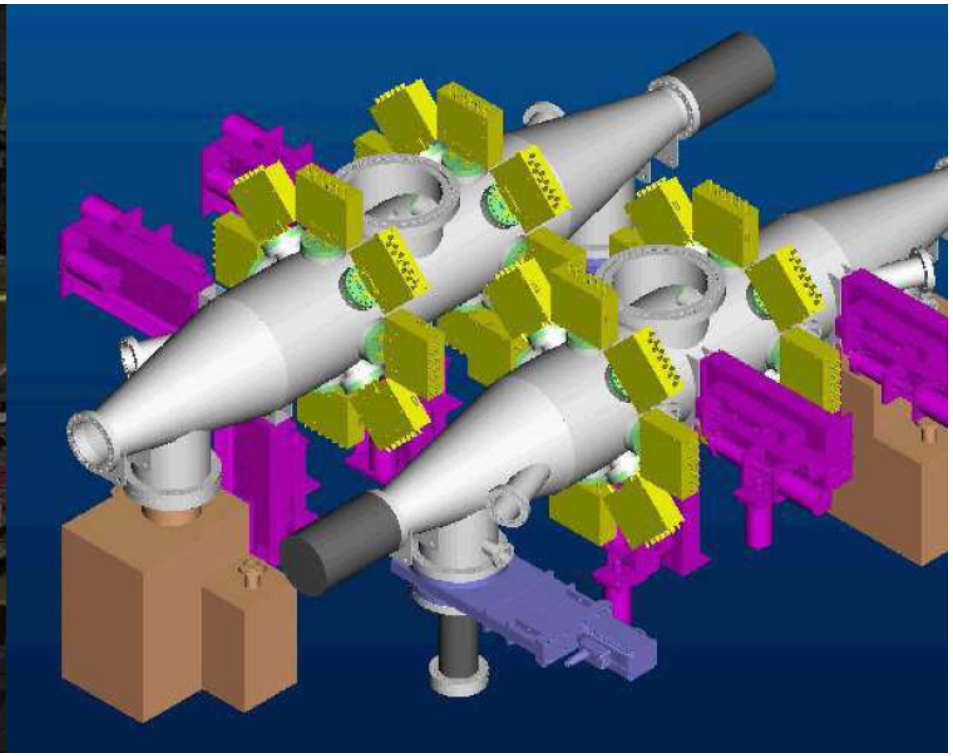
CNI region



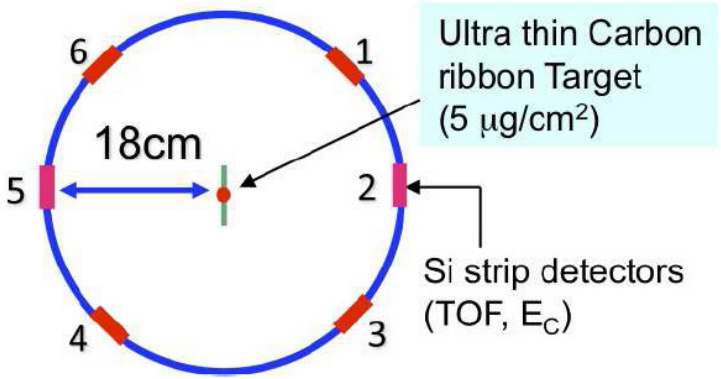
High analyzing power, high cross-section, roughly independent of energy

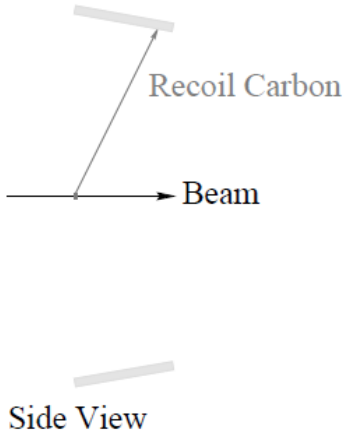
pC polarimeters



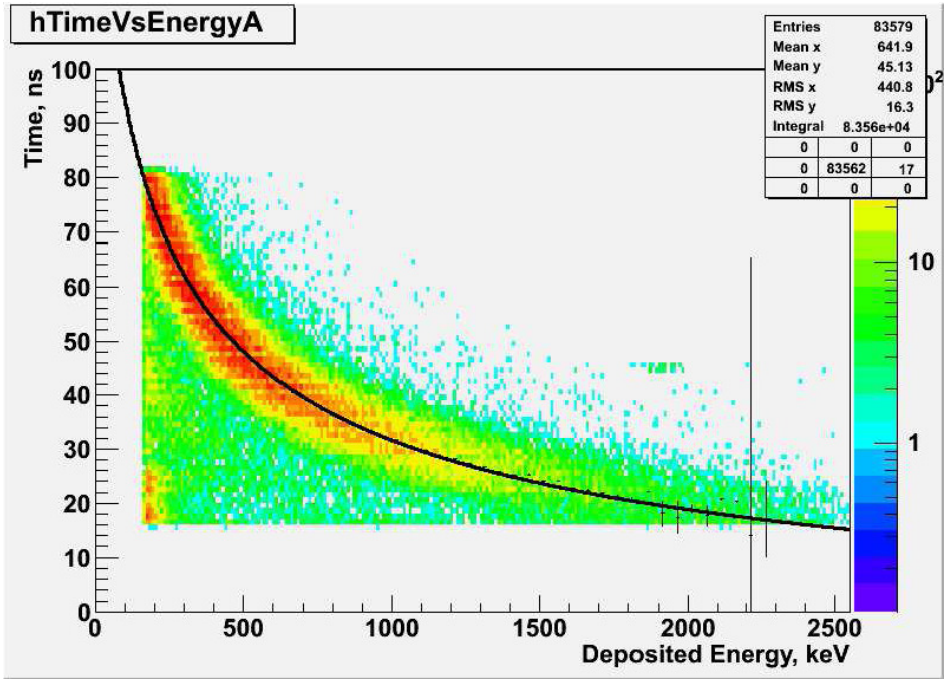


- 2 polarimeters in each ring
- 6 horizontal and 6 vertical ultra-thin (~ 30 nm!) C targets each





pC polarimeters: kinematics

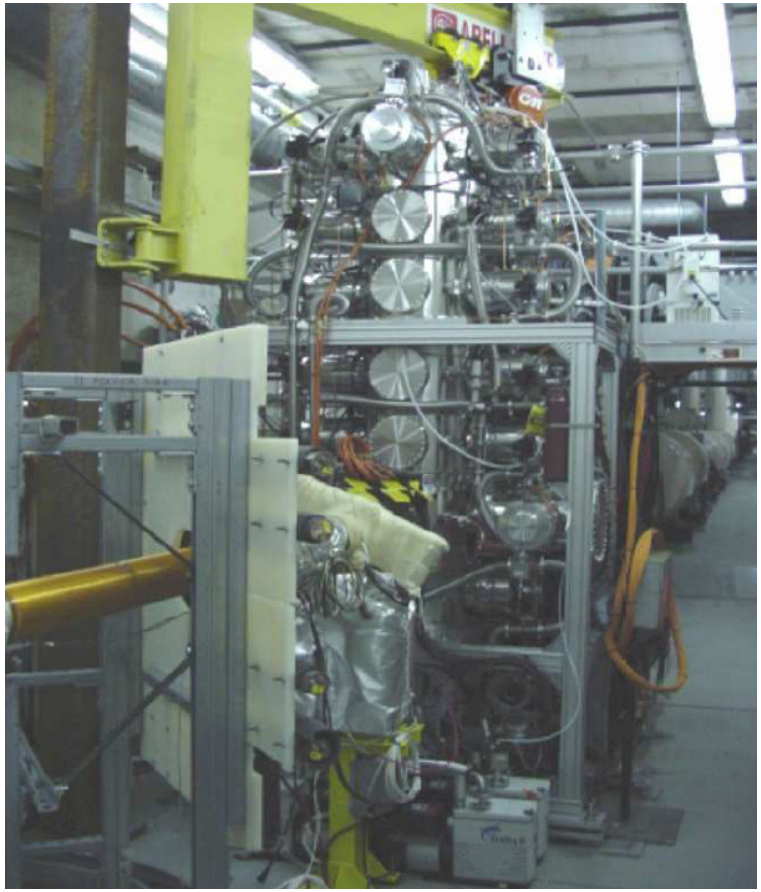


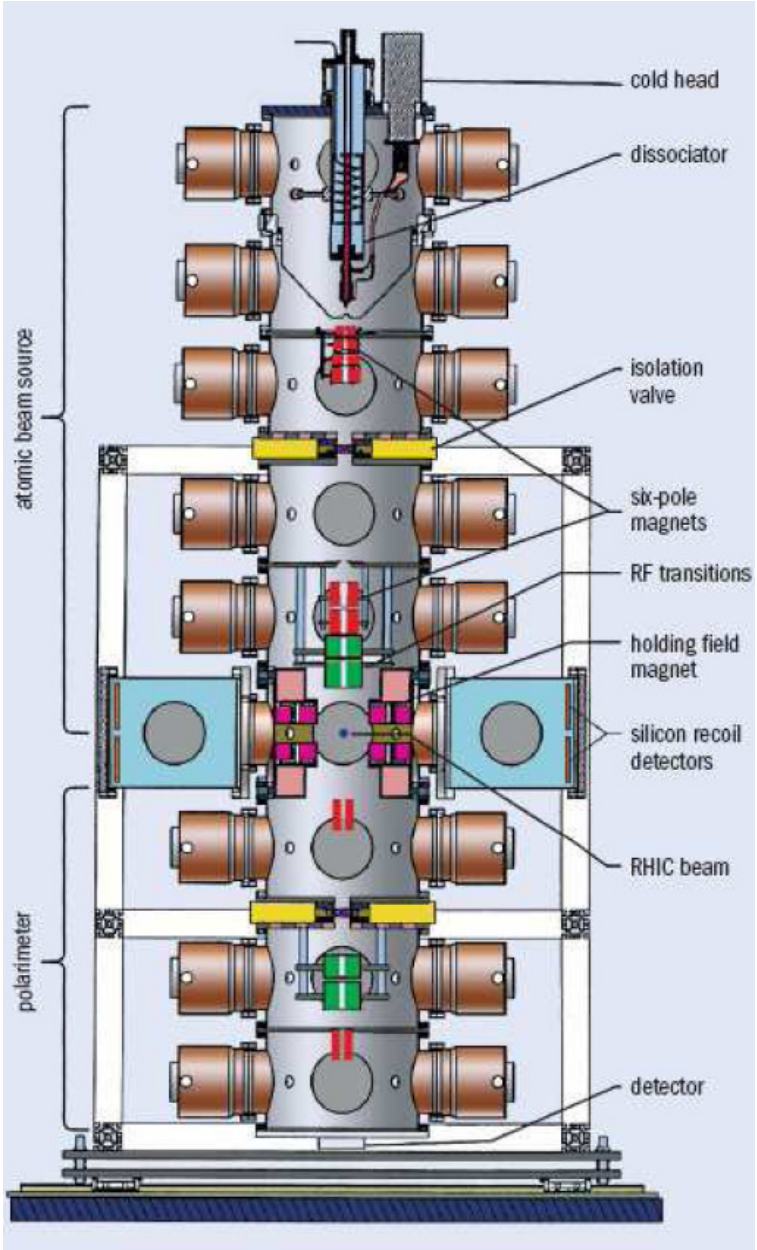
Calibration param. : time offset t_0 and effective dead layer thickness x_{DL}:

$$E_{meas} + E_{loss} = \frac{M_C}{2} \frac{L^2}{(t_{meas} + t_0)^2}$$

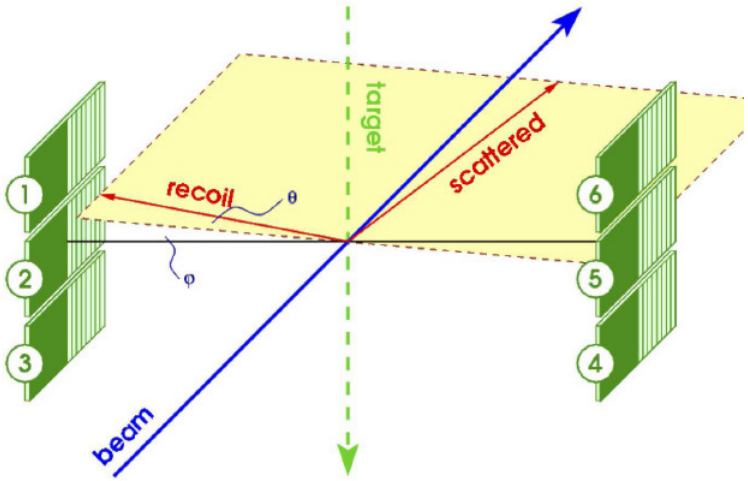
with $E_{loss}(E_{meas}, x_{DL})$ an enerly loss parameterization for carbon

Hydrogen Jet polarimeter





Hydrogen Jet: kinematics



- Both beams intercept the H-jet (separated by $\sim 4\,\text{mm}$)
- Beam and target are both protons:

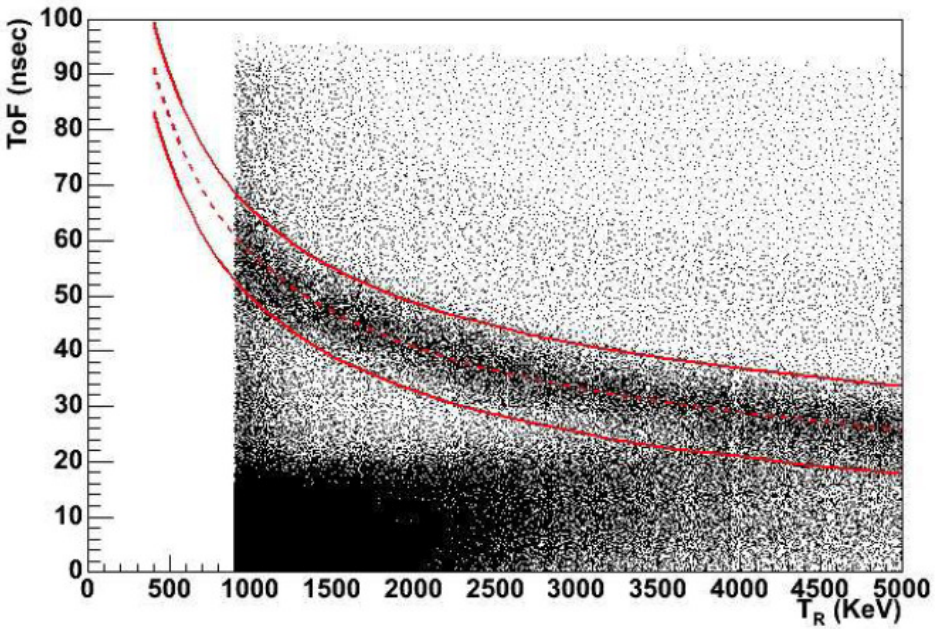
$$P_{\text{beam}} = -\frac{\epsilon_{\text{beam}}}{\epsilon_{\text{target}}} P_{\text{target}}$$

- Elastic events easily identified by

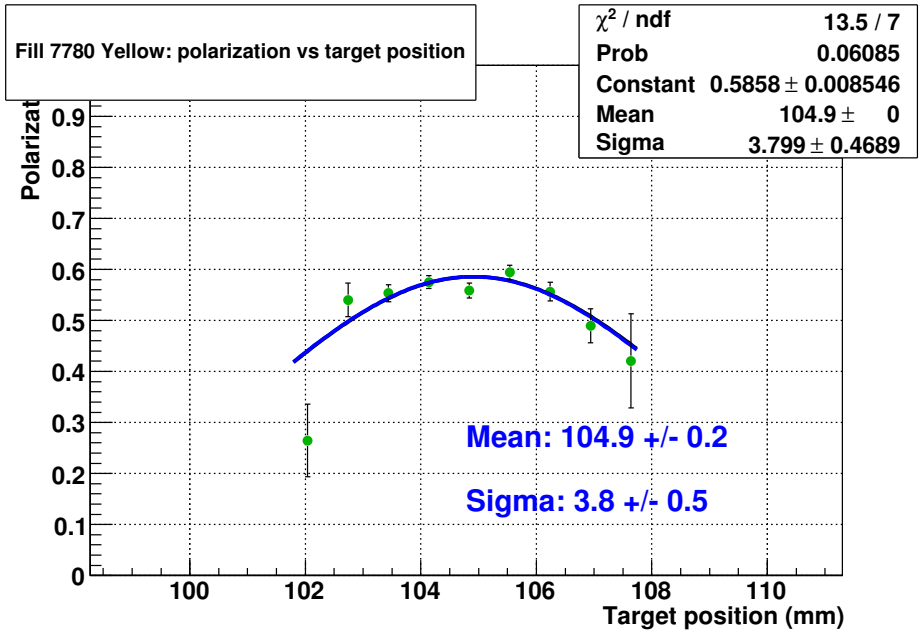
$$t_{\text{TOF}} = L\sqrt{\frac{m_p}{2E_{\text{kin}}}}$$

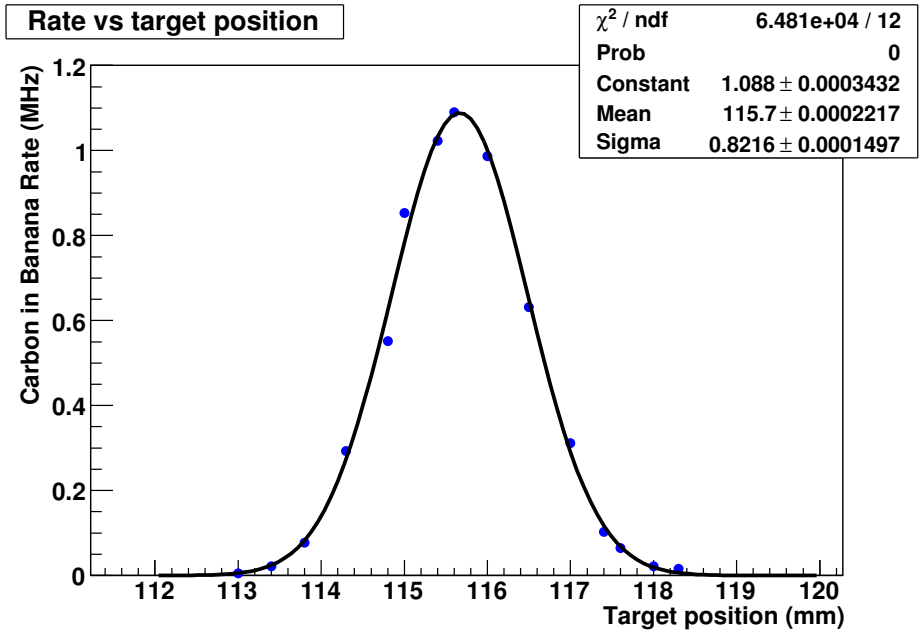
- Asymmetry:

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



Polarization profile



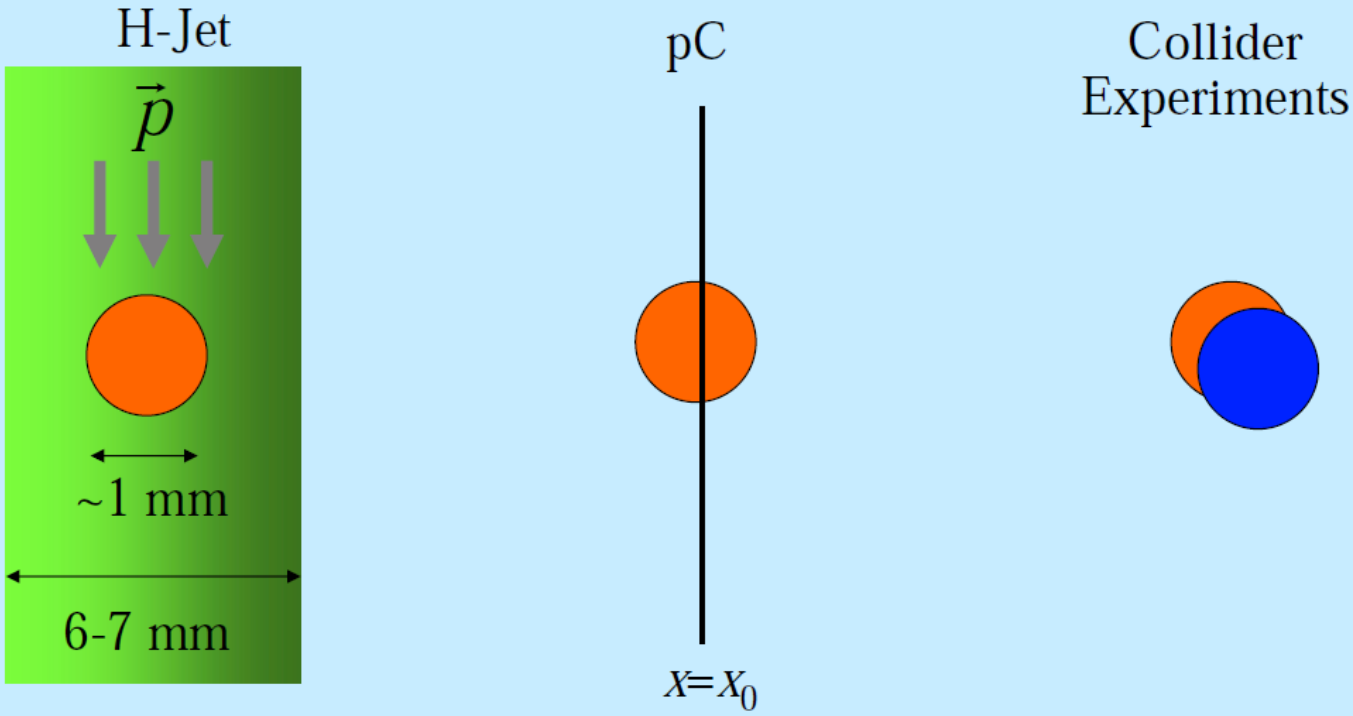


$$\left.\begin{aligned} L &= L_{max} \cdot e^{\frac{-x^2}{2\sigma_L^2}} \\ P &= P_{max} \cdot e^{\frac{-x^2}{2\sigma_P^2}} \end{aligned}\right\} \Rightarrow P = P_{max} \cdot (L/L_{max})^{(\frac{\sigma_L}{\sigma_P})^2}$$

- Fit of P vs L/L_{max}
- P_{max} and $r = (\sigma_L/\sigma_P)^2$ are the 2 free parameters of the fit

Polarization profile corrections

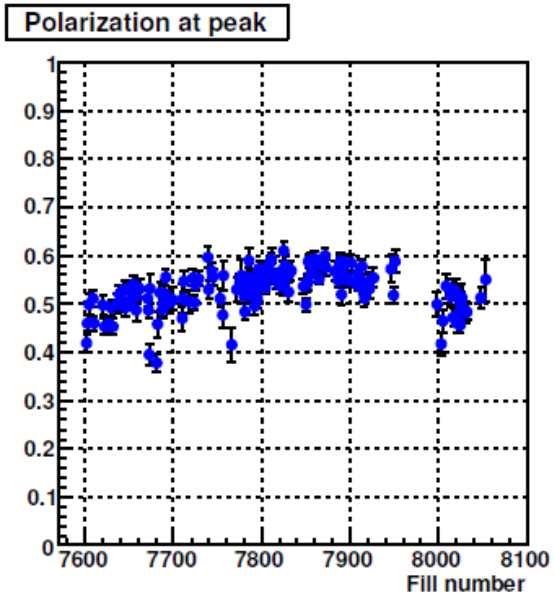
Average Polarization

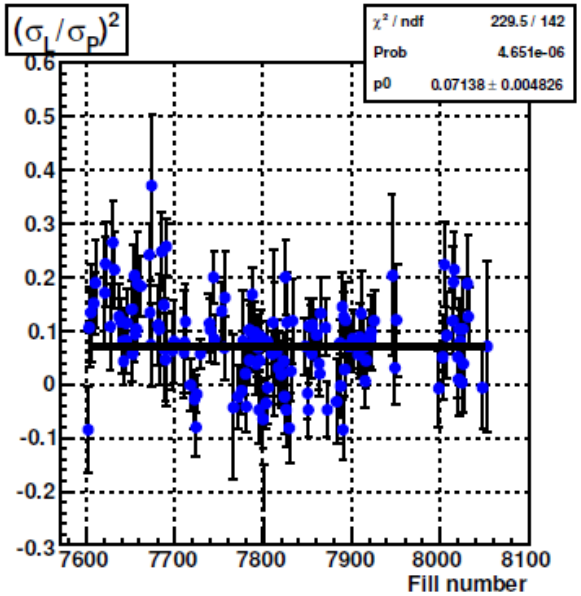


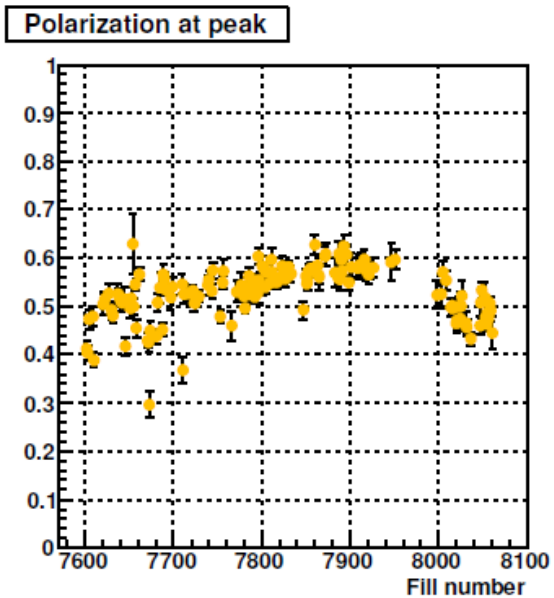
$$\langle P\rangle = \frac{\int P(x,y)\, I(x,y)\, dxdy}{\int I(x,y)\, dxdy} \qquad \langle P\rangle = \frac{\int P(x0,y)\, I(x0,y)\, dy}{\int I(x0,y)\, dy} \qquad \langle P\rangle = \frac{\int P(x,y)\, I_1(x,y)\, I_2(x,y)\, dxdy}{\int I_1(x,y)\, I_2(x,y)\, dxdy}$$

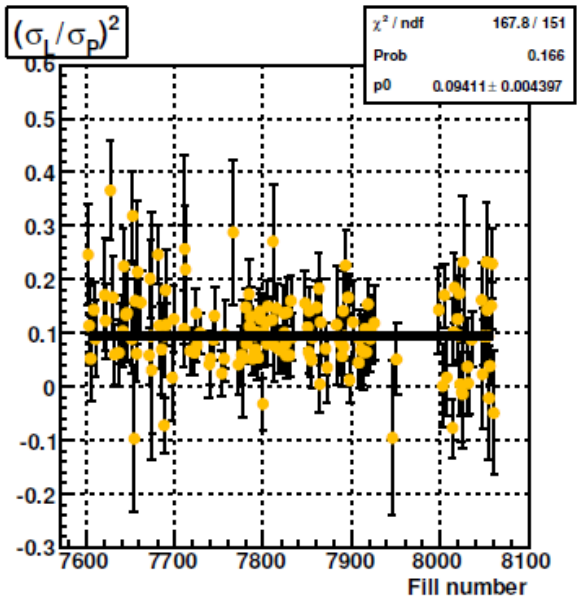
$P(x,y)$ – polarization profile, $I(x,y)$ – intensity profile

Results for Run-6 (2006)









Overview of RHIC polarimeters

	H-jet polarimeter	**pC polarimeters**
Target :	Polarized atomic H gas jet	Ultra thin C ribbon
Calibration :	Self-calibrating (known target pol.)	Normalized to H-jet
Event rate :	$\sim$ 20 Hz $\sim$8% stat. error in 6–8 h fill	$\sim$ 2 MHz $\sim$2% stat. error
Operation :	Continuous	Few min. every few hours
Role :	- Average beam pol. - Calibration for pC	- Fast online feedback - Beam profile - Bunch by bunch & store by store pol. for exp.

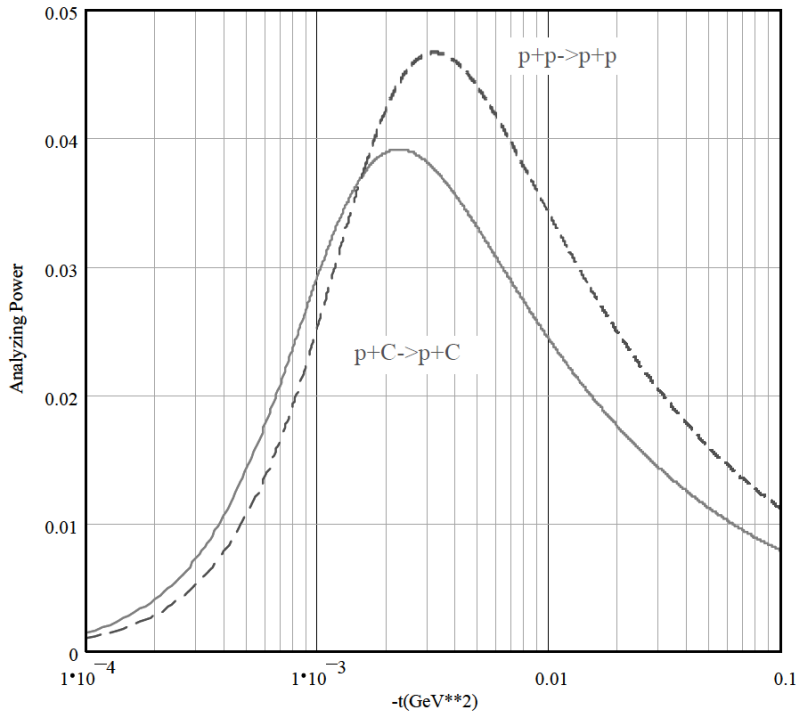
Summary

- pp and pC elastic scattering in the CNI region well suited for polarimetry at RHIC energies
- 3–5% stat and 4–6% syst. uncertainties in polarization measurements
- Non-destructive measurements
- pC and pp complement to each other
- Normalization (abs. measurement) rely only on $H-$jet

Applicability at LHC ?

- At LHC, CNI region (probably) inaccessible. For fixed t:
  - Scattering angle $\sim 1/p_{\text{beam}}$
  - Beam size $\sim 1/\sqrt{p_{\text{beam}}}$

Higher $-t$ needed to get out of the beam



- Higher recoil energy $-t = 2ME_{kin}$
- Counting rates at higher energy ??