19 July 2007
RHIC S&T Review

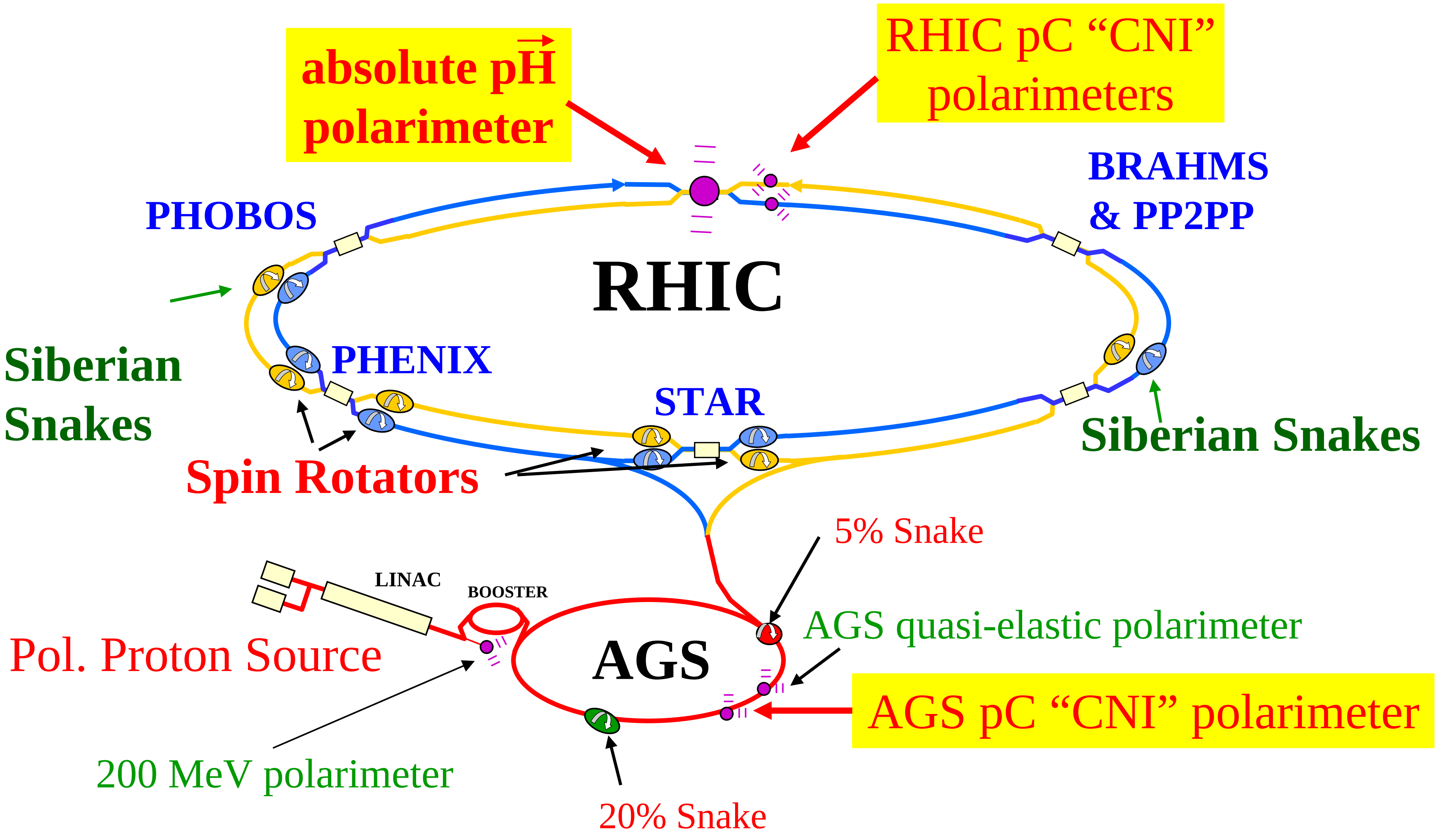
Polarimetry at RHIC

Presented by G. Bunce

---done by a collaboration of BNL Physics, BNL CAD, RBRC/Riken, Wisconsin, ITEP (Moscow), BNL Instrumentation, Indiana, UC Riverside, Stony Brook, Los Alamos, MIT

---supported by DOE and Riken

RHIC *pp* accelerator complex



Polarimetry at RHIC

---use anomalous magnetic moment of proton

--- E-M spin flip amplitude, analyzing power at RHIC energies (Coulomb-Nuclear Interference region—CNI)

---polarized atomic hydrogen jet target in RHIC

--- absolute polarization of jet from Breit-Rabi polarimeter

--- for elastic scattering obtain RHIC beam polarization directly from the jet polarization

---use carbon micro-ribbon target polarimeters to monitor polarization every 2 hours, including polarization profile

---calibrated with jet at same time; interpolate between jet measurements

---obtain luminosity-weighted polarization

---quick feed-back on beam polarization for monitoring and accelerator development, including measurements on the acceleration ramp

---achieved goal of 5% $\Delta P/P$ for absolute polarization at 100 GeV

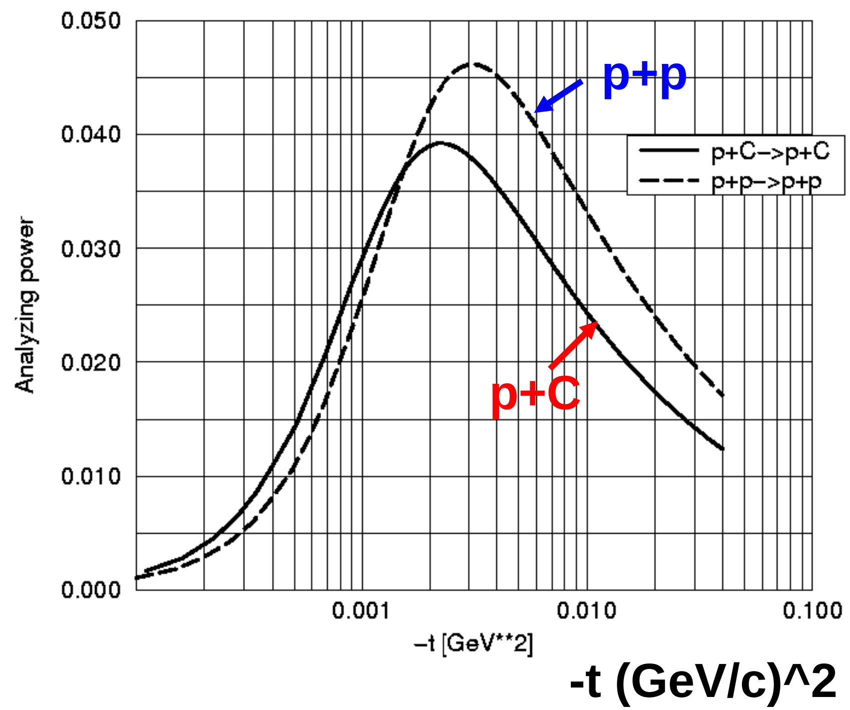
A_N & Coulomb Nuclear Interference

the left – right scattering asymmetry A_N arises from the interference of the spin non-flip amplitude with the spin flip amplitude (Schwinger)

$$A_N = C_1 \phi_{flip}^{em\,*} \phi_{non-flip}^{had} + C_2 \phi_{flip}^{had\,*} \phi_{non-flip}^{had}$$

$\propto(\mu-1)_p$ $\propto\sigma^{pp}_{had}$ unknown

$A_N\,(t)$



---EM spin flip calculable
---A_N significant
---also over RHIC energy range
---for both proton and carbon targets
---hadronic spin flip unknown

PHYSICAL REVIEW VOLUME 73, NUMBER 4 FEBRUARY 15, 1948

On the Polarization of Fast Neutrons

can be traced back to

JULIAN SCHWINGER
Harvard University, Cambridge, Massachusetts

(Received January 8, 1948)

ALTHOUGH the production of polarized thermal neutrons has long been an accomplished fact, no such success has been forthcoming with fast neutrons. Only one method for the polarization of fast neutrons has thus far been suggested,[1] of which the essential mechanism is the large, effective nuclear spin-orbit interaction present when neutrons are resonance scattered by helium and similar nuclei. It is the purpose of this note to suggest a second mechanism for polarizing fast neutrons—the spin-orbit interaction arising from the motion of the neutron magnetic moment in the nuclear Coulomb field. Despite the apparent small magnitude of this interaction, the long-range nature of the Coulomb field is such that the use of small scattering angles will produce almost complete polarization under ideal conditions. A closely related phenomenon produced by this electromagnetic interaction is an additional scattering of unpolarized neutrons which increases rapidly with decreasing

where $k=p/\hbar$ is the neutron wave number. Hence, the unscreened Coulomb field of a point nucleus will be effective for scattering in the angular range:

$$1/ka \ll 2\sin\vartheta/2 \ll 1/kR. \tag{3}$$

If the nuclear radius and atomic screening radius are taken to be

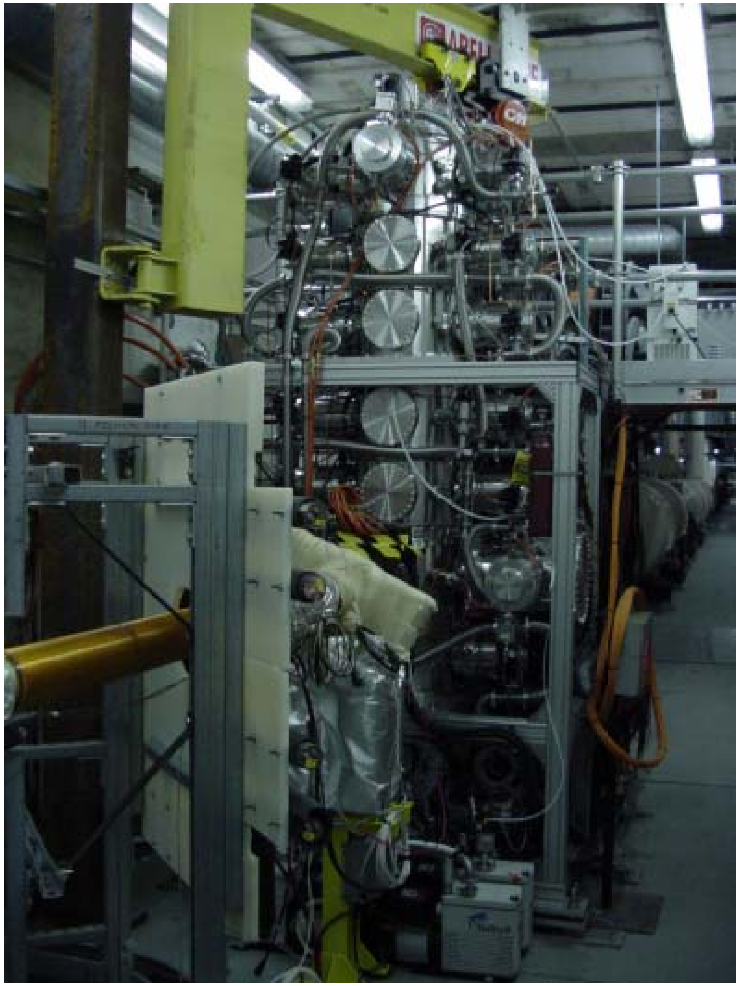
$$R=1.5\cdot10^{-13}A^{\frac{1}{3}}\text{ cm} \quad \text{and} \quad a=0.53\cdot10^{-8}Z^{-\frac{1}{3}}\text{ cm},$$

the angle restrictions for a 1-Mev neutron scattered in Pb, for example, are

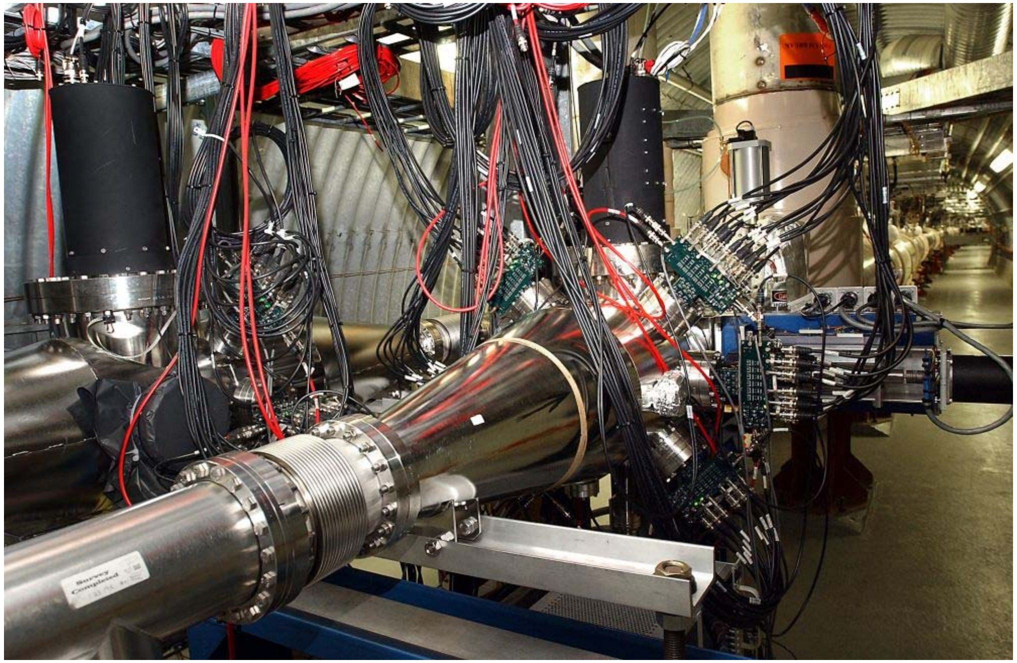
$$4\cdot10^{-4} \ll 2\sin\vartheta/2 \ll \tfrac{1}{2}. \tag{4}$$

The electromagnetic scattering of a neutron under these conditions can be calculated with the plane wave Born approximation, for the nuclear scattered wave is negligible compared with the incident wave at the significant scattering distances. We denote the incident plane wave by

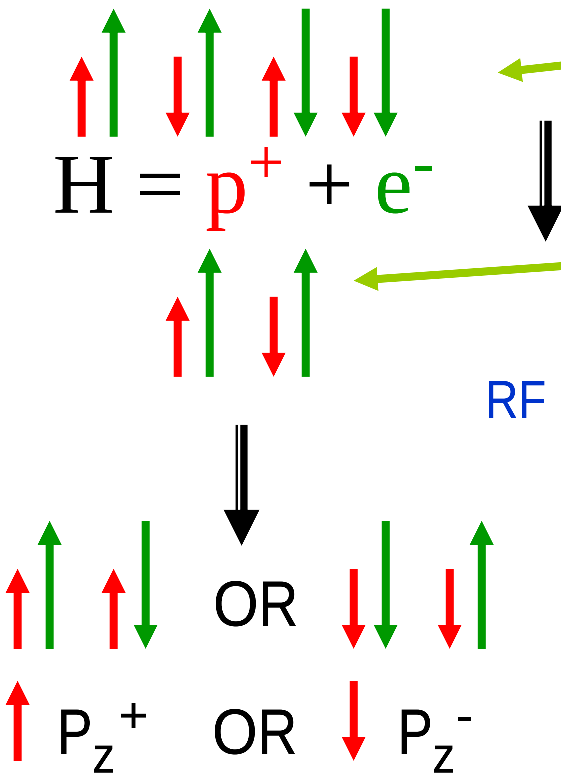
Polarized H jet at IP12

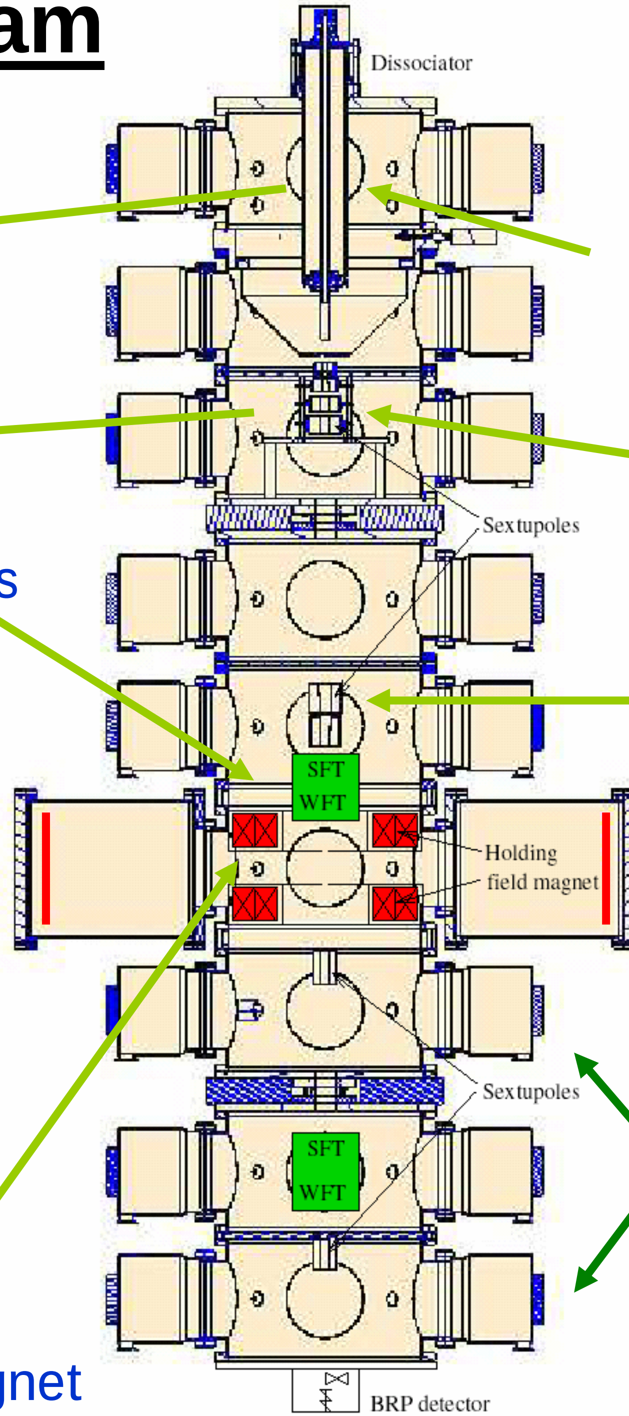


Carbon target polarimeters near IP12



The Atomic H↑ Beam Source





H_2 dissociator

separation magnets (sextupoles)

RF transitions

focusing magnets (sextupoles)

recoil detectors

Breit-Rabi polarimeter

holding field magnet

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

JET target polarization & performance

2004, 05, 06

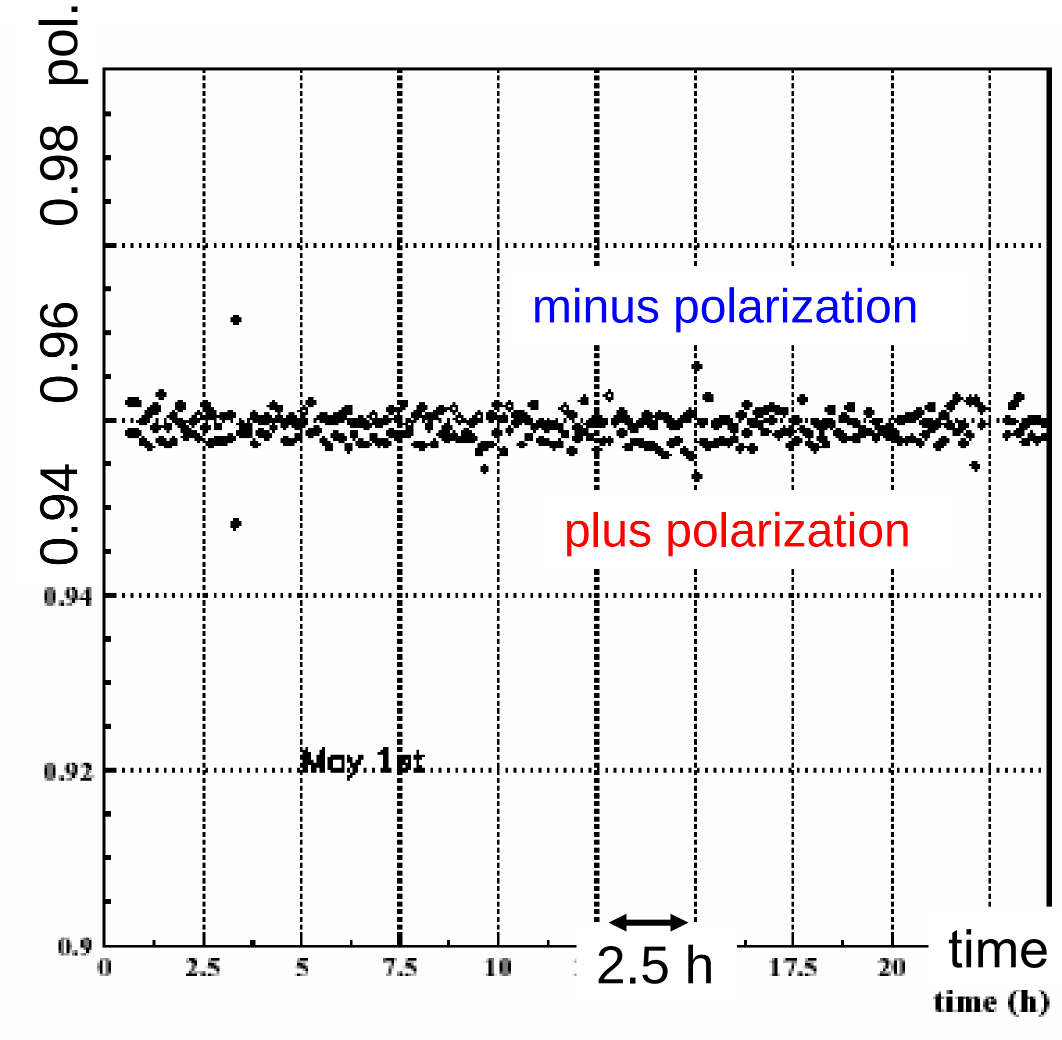
the JET ran with an average intensity of 1×10^{17} atoms / sec

the JET thickness of 1×10^{12} atoms/cm^2 record intensity

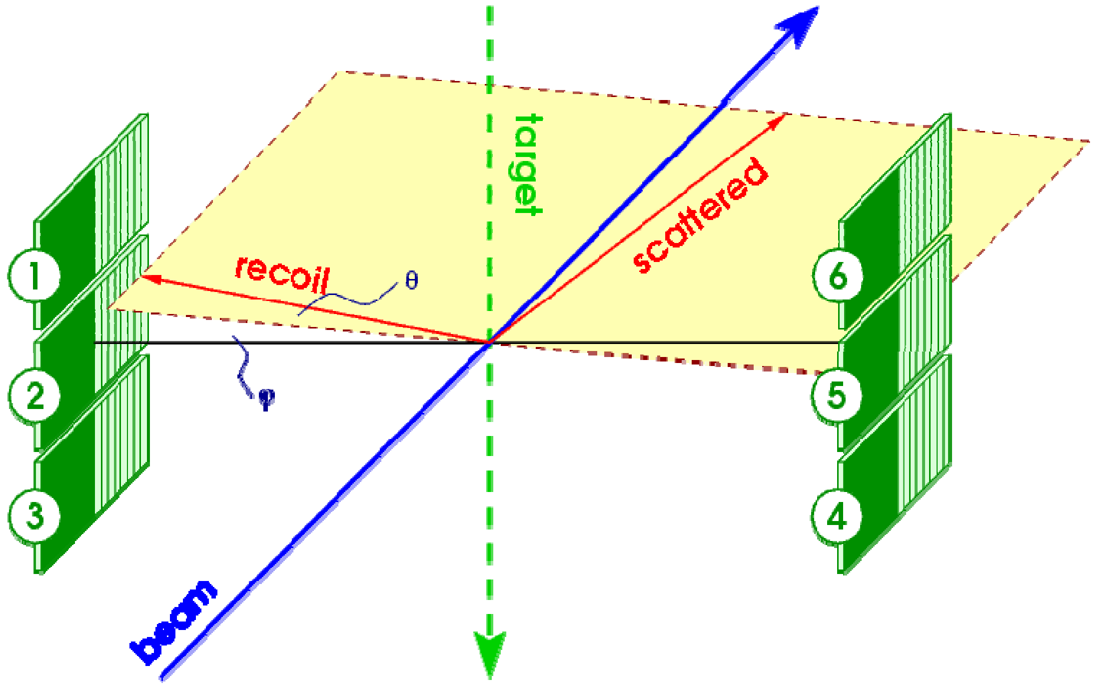
target polarization cycle
+/0/- ~ 500 / 50 / 500 sec

polarization to be scaled down due to a ~3% H_2 background:

$P_{target} = 0.924 \pm 0.018$



Recoil Silicon Strip Spectrometer



For p-p elastic scattering only:

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

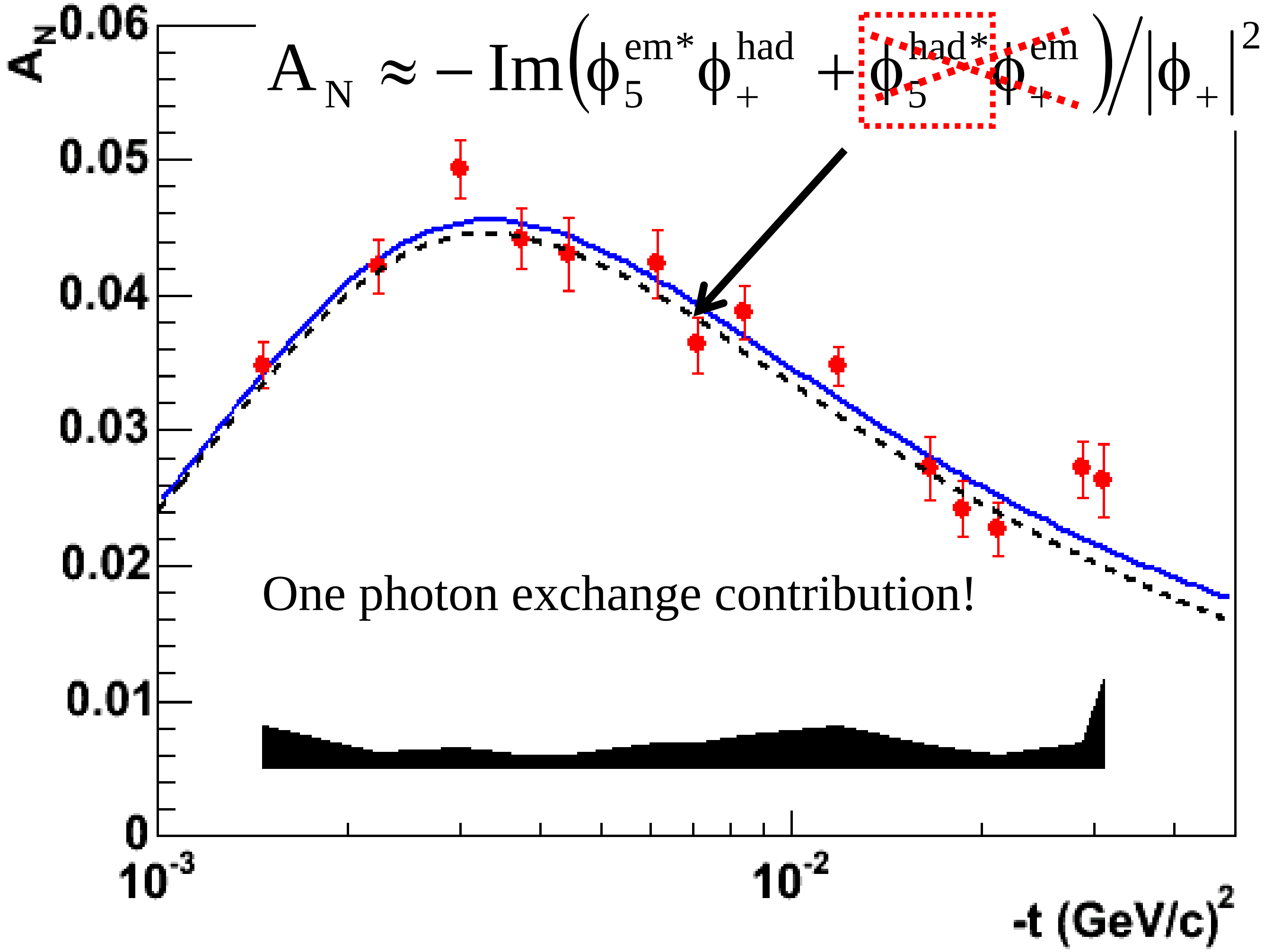
$$\varepsilon_{beam} = A_N \cdot P_{beam}$$

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

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

A_N in the CNI region @ $\sqrt{s}$=13.7 GeV

2004 Data



H. Okada et al., PLB 638 (2006), 450-454

Obtaining the beam polarization

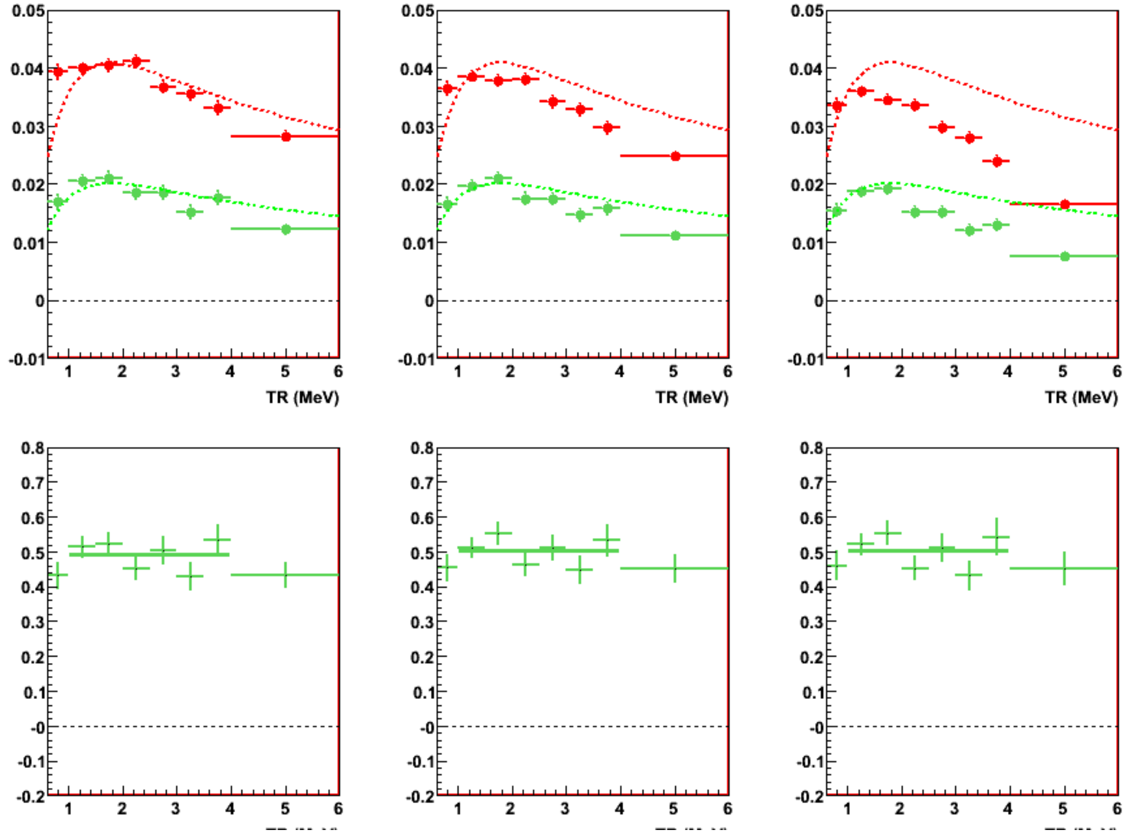
2005 Data

background: 1x 2x 4x

ε(target)

ε(beam)

ε(beam)/ ε(target)



E(recoil) MeV

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

P(target)=92.4% +/- 1.8%

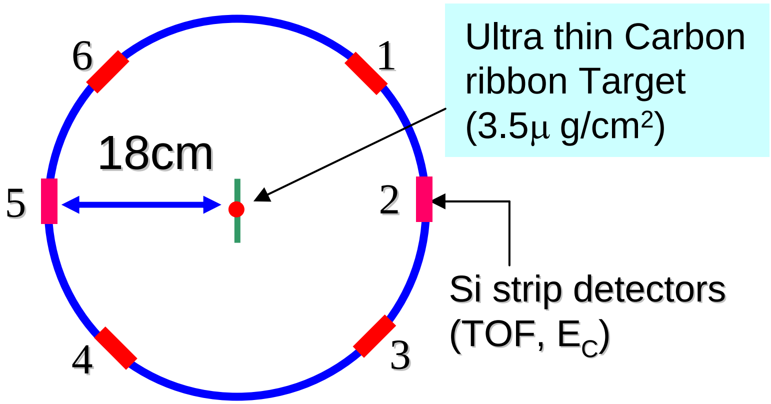
P(blue beam)=49.3% +/- 1.5% +/- 1.4%

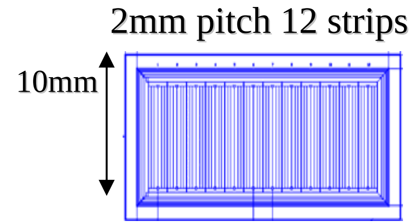
P(yellow beam)=44.3% +/- 1.3% +/- 1.3%

Delta P/P = 4.2%

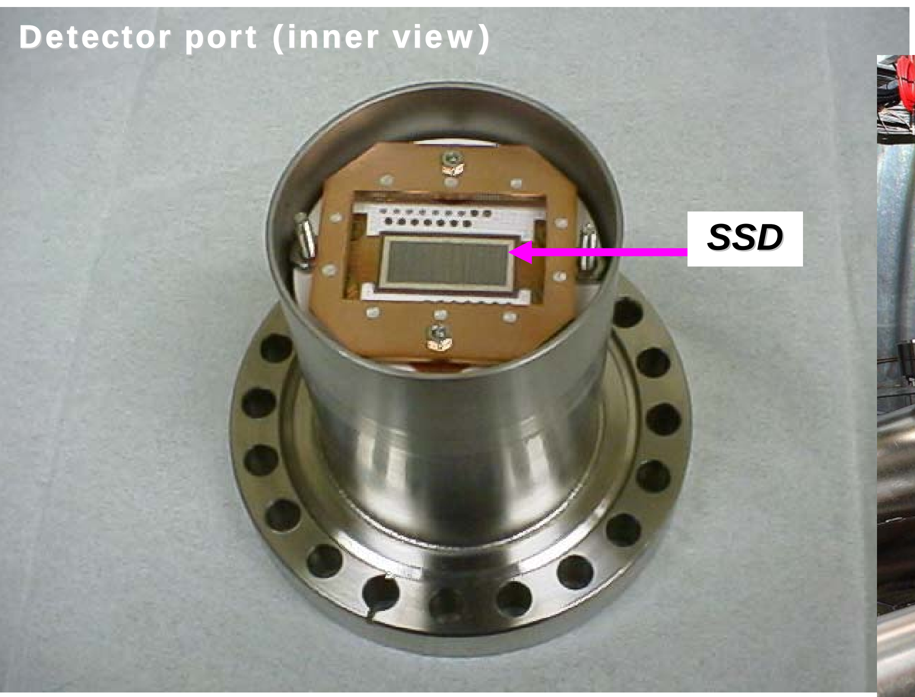
Goal: 5%

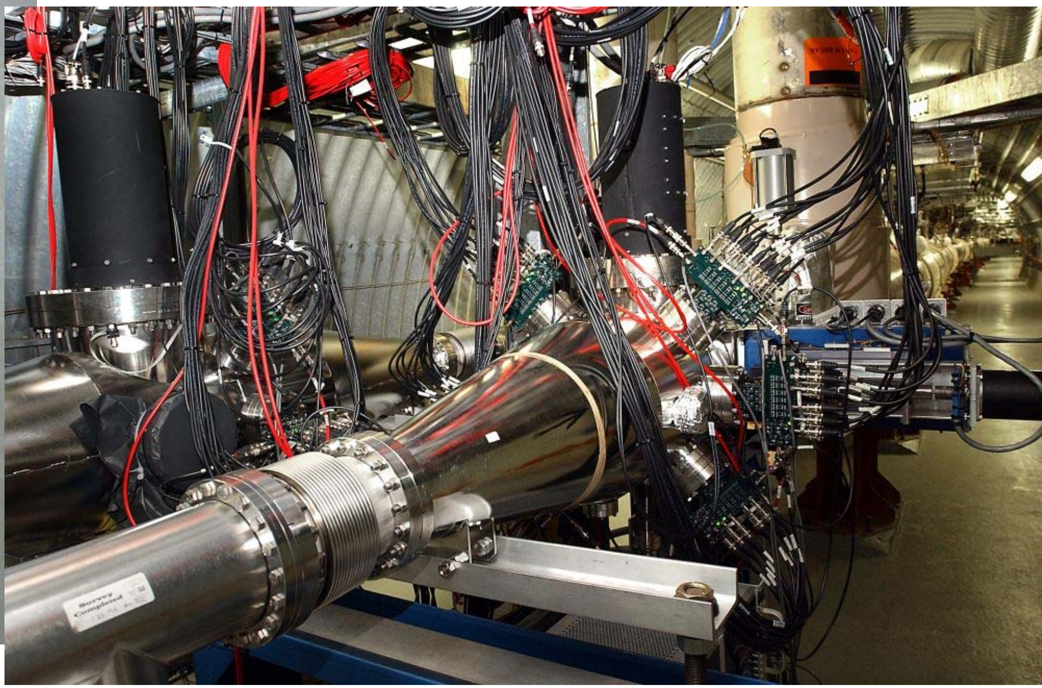
pC Polarimeter Setup



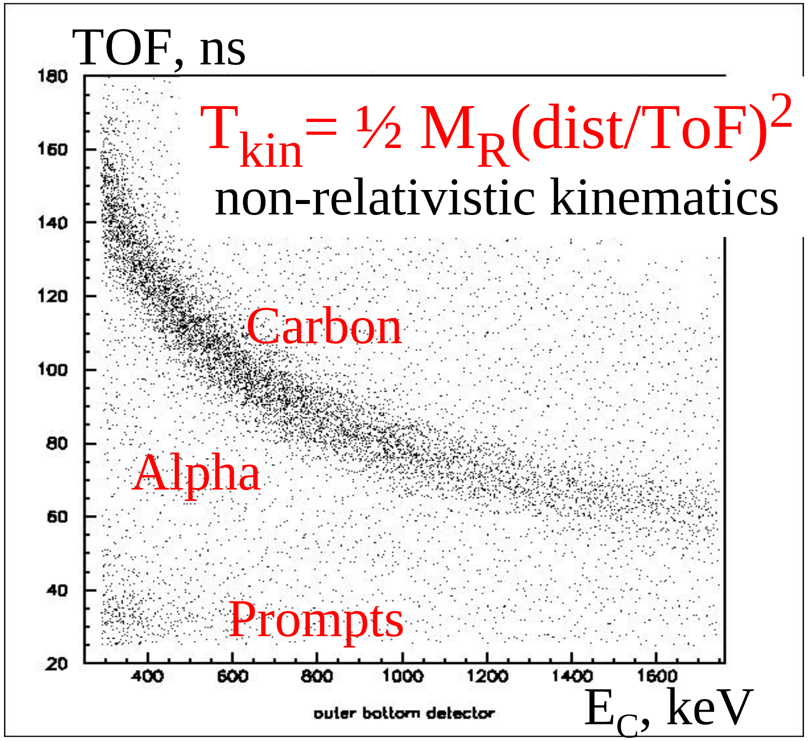


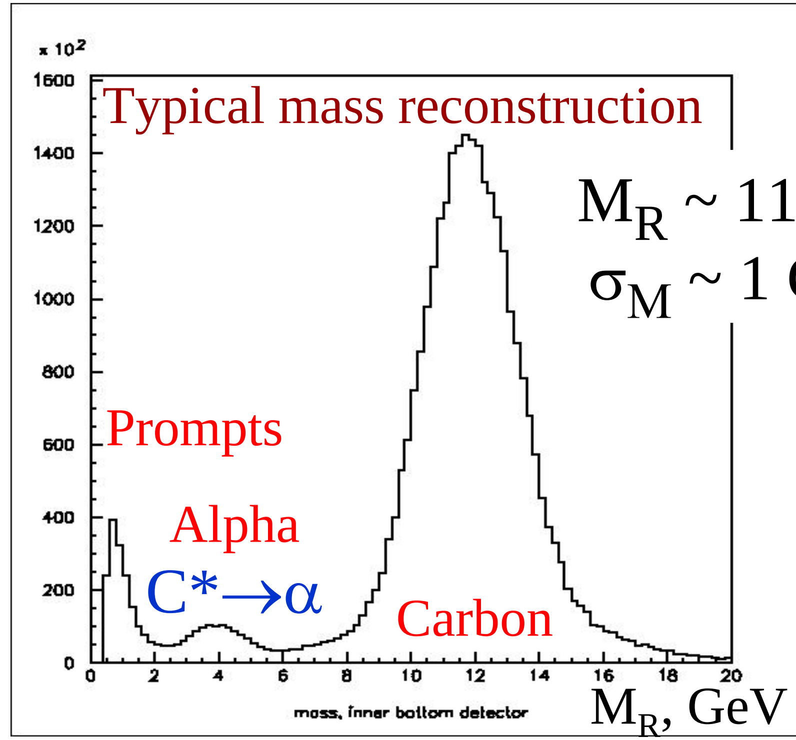
72 strips in total





Event Selection & Performance

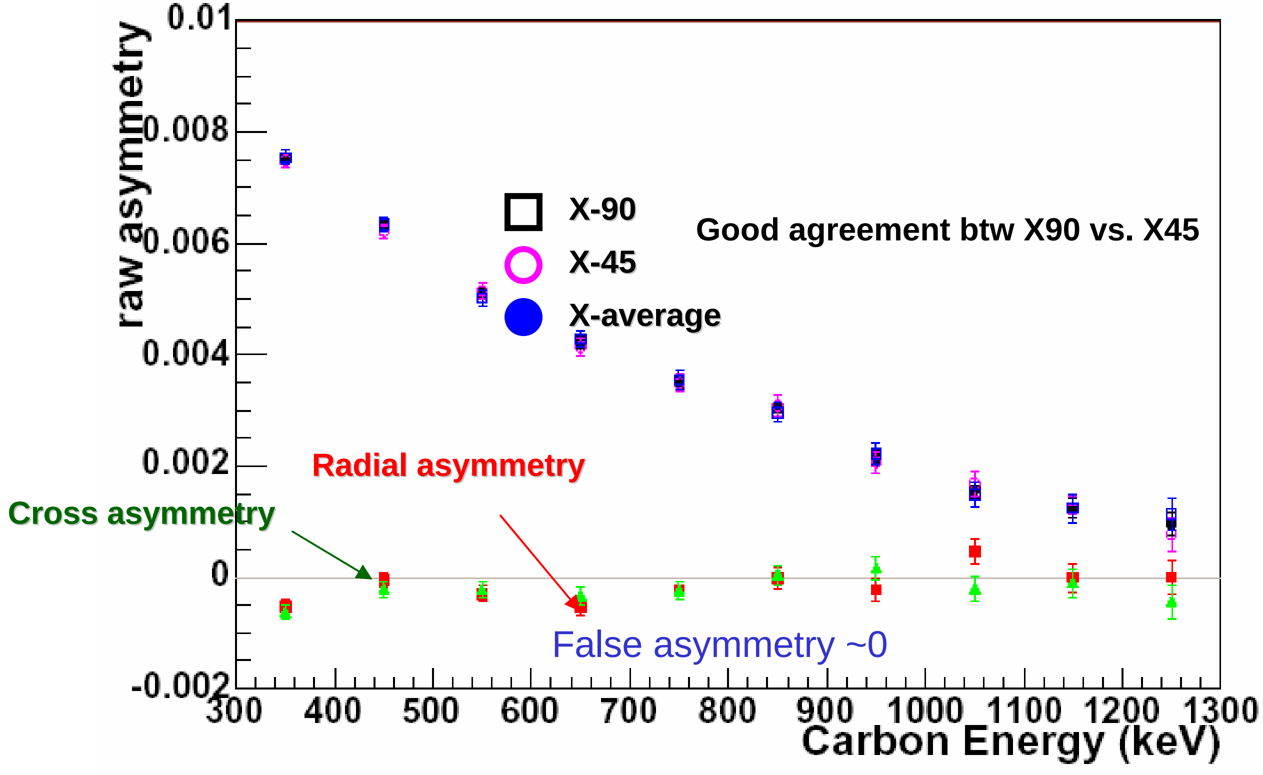




- very clean data, background < 1 % within “banana” cut
- good separation of recoil carbon from α ($C^* \to \alpha + X$) and prompts

  may allow going to very high $|t|$ values
- Δ (Tof) < ± 10 ns ($\Rightarrow \sigma_M \sim 1$ GeV)
- very high rate: 10^5 ev / ch / sec

Raw asymmetry @ 100 GeV



Regular polarimeter runs (every 2 hours)

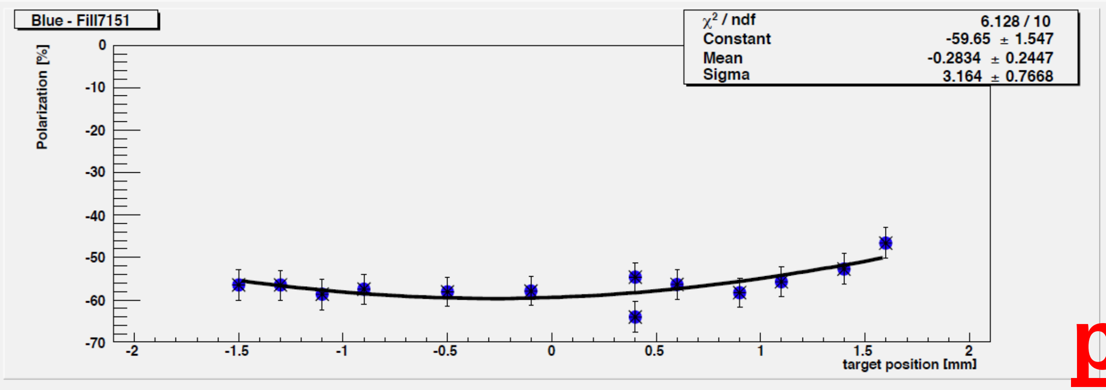
--measurements taken simultaneously with Jet -target

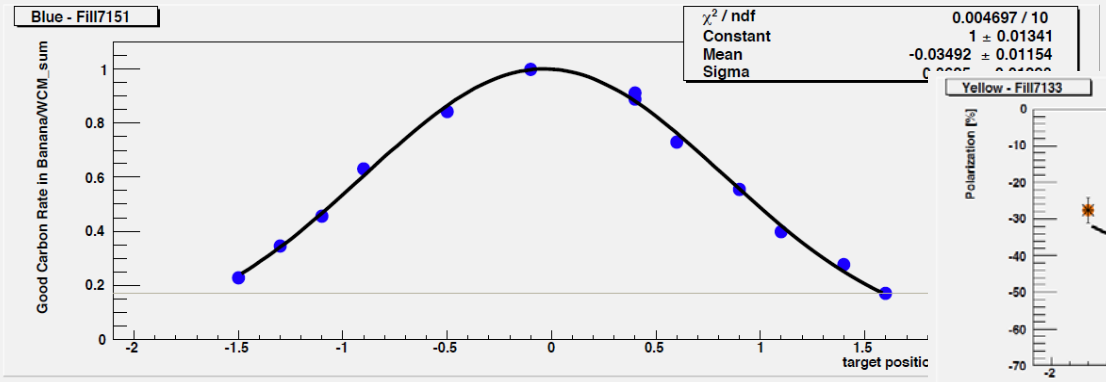
--very stable behavior of measured asymmetries

--ΔP = 3% per measurement (20 M events, 30 s)

Blue beam polarization profile

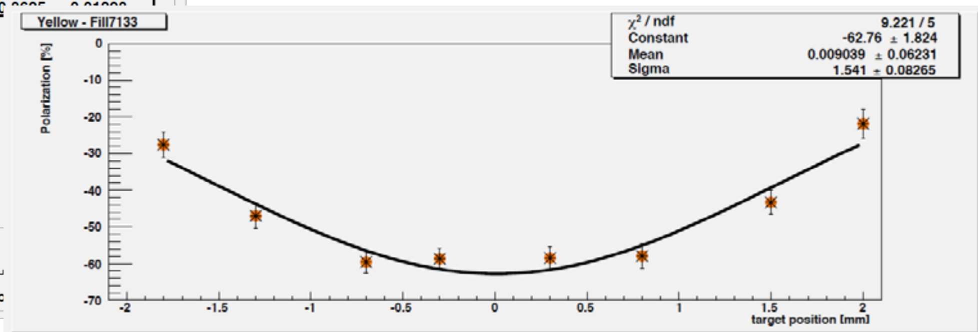
P(jet avg)=P(peak) x 1.00

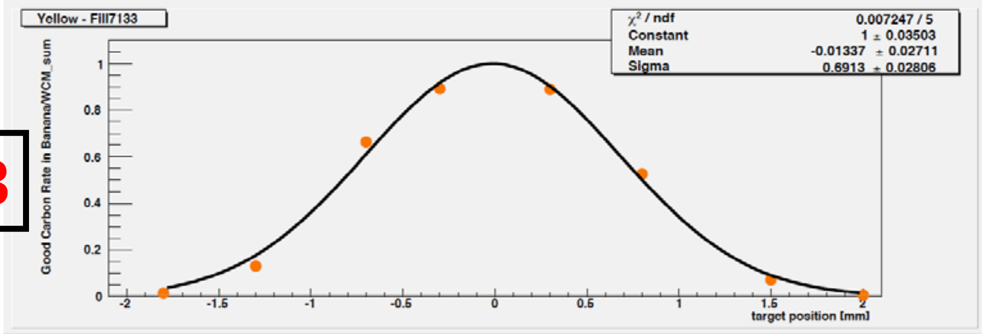




2005 Data

Yellow beam polarization profile

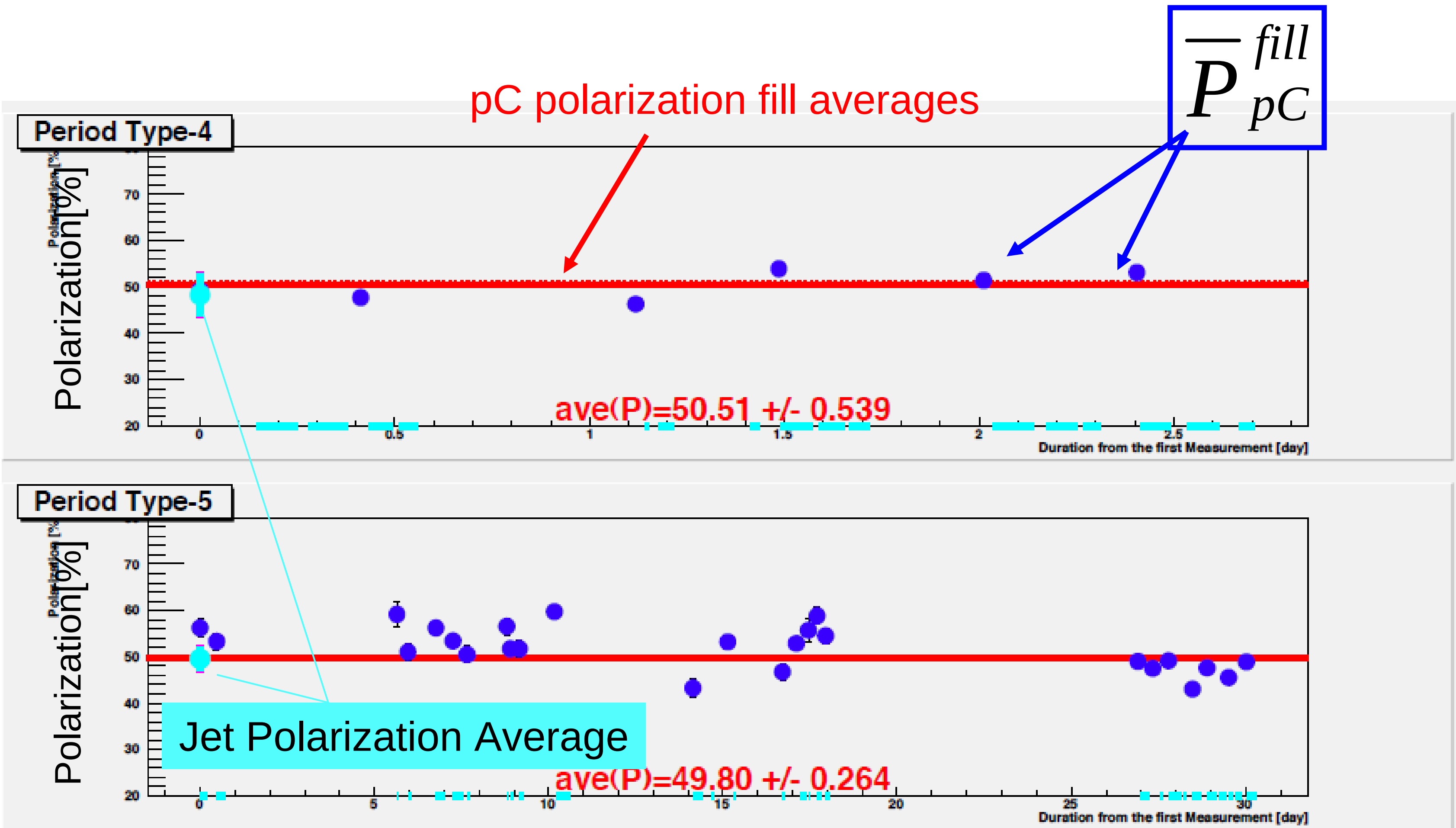




P(jet avg)=P(peak) x .93

Comparison between pC vs. Jet (Blue)

2005 Data



Duration from the first measurement[days]

Jet Analysis by Oleg Eyser

2005 Jet Normalization Summary

A_N(2005) = A_N(2004) x (S +/- ΔA(jet stat)/A +/- ΔA(jet syst)/A +/- ΔA(pC syst)/A)

- Blue

A_N(05)=A_N(04)x(1.01 +/- .031 +/- .029 +/- .005)

ΔP/P(profile)=4.0%

ΔP(blue)/P(blue) = 5.9%

- Yellow

A_N(05)=A_N(04)x(1.02 +/- .028 +/- .029 +/- .022)

ΔP/P(profile)=4.1%

ΔP(yellow)/P(yellow) = 6.2%

Δ[P(blue) x P(yellow)]/[P_b x P_y] = 9.4% ← **Goal: 10%**

Polarimetry plans for 2007-2010

- 2006 run—horizontal pC target scans normal proceedure
- 2007---formed new polarimetry team (after departure of Bravar to U. Geneva); collaboration with CAD in place.
- 2007— completed 2005 polarimetry analysis (ΔP/P=6% each beam, ΔP^2/P^2=9.4%);
- complete polarization analysis for 2006, 200 GeV and 62 GeV;
- study detectors with <1 MeV carbon beam in Tandem (July 2007)
- 2008—new pC target drives; plan H and V scans each fill
- 2008-2010---continue leading RHIC polarimetry analysis; possible development of new detectors and electronics (radiation hardness, dead layer correction in carbon tgt. polarimeters, pile-up concerns for higher intensities); possible development of unpolarized jet polarimeter

Discussion: importance of maintaining strong collaboration with experiments: use of “detailees” for data monitoring and data analysis each year

RHIC Polarimetry

BNL Physics: A. Bazilevsky (Analysis Leader), B. Morozov (Hardware, R&D), R. Gill (0.5 FTE), G. Bunce (0.5 FTE) + Post Doc (2008)

--A. Bravar led group through Aug. 2006 (now at U. Geneva)

BNL CAD: Y. Makdisi (Jet Leader), A. Zelinski (Jet and carbon tgt), H. Huang, A. Nass (2003-5), M. Sivertz, Kin Yip, Support Group for jet and for p-carbon polarimeter hardware

RBRC and RIKEN: I. Nakagawa (1 FTE for 2005-7), H. Okada (2003-6)

ITEP: I. Alekseev, D. Svirida (1-2 months during run)

Wisconsin: W. Haeberli, T. Wise

BNL Instrumentation: S. Rescia, Zheng Li, V. Radeka

Also: S. Dhawan (Yale), E. Stephenson (Indiana), J. Wood (UCLA)

Experiment Detailees:

2004 jet analysis: H. Okada (Kyoto)

2005 jet data: K.O. Eyser (UC Riverside)—jet analysis

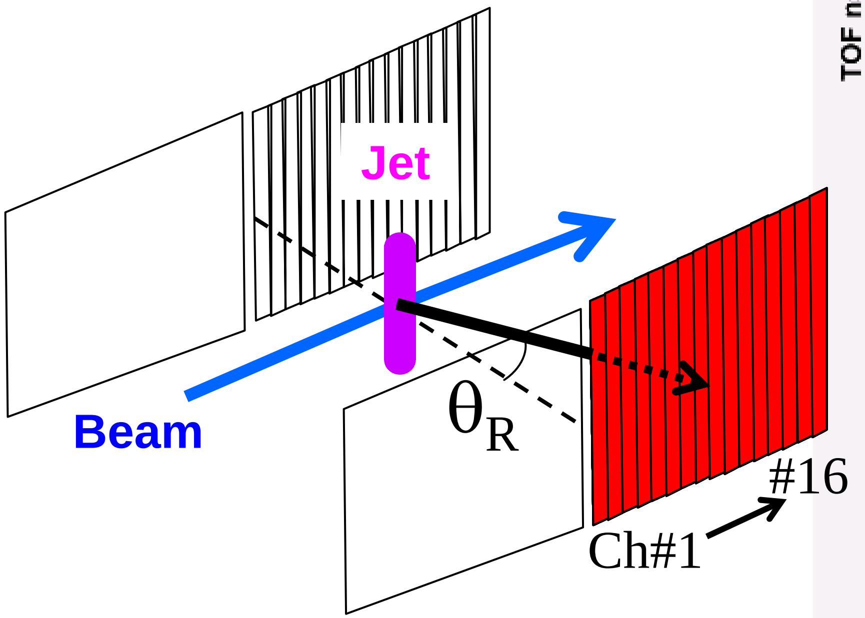
2006 data: A. Hoffman (MIT) and A. Dion (Stony Brook)—online monitoring;

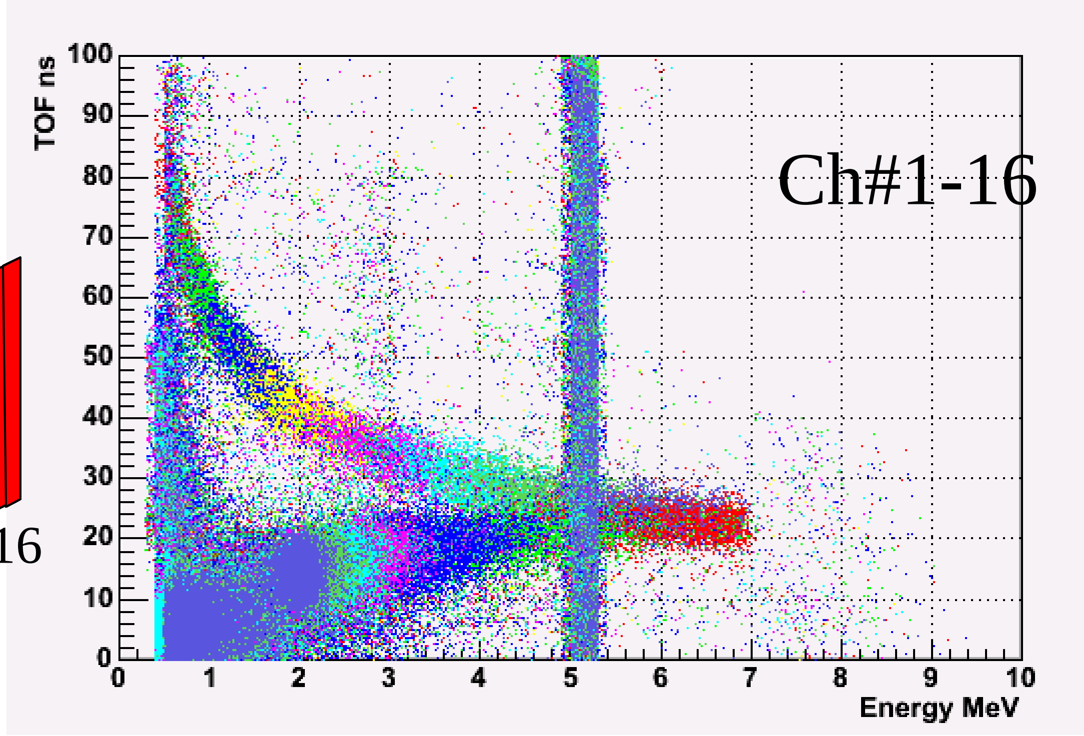
C. Camacho and H. Liu (Los Alamos)—pC analysis;

K. Boyle (Stony Brook)—jet analysis

Some Details:

- jet elastic signal identification and background
- pC systematic studies (examples)
- pC and jet comparison for yellow beam in 2005 (blue part of presentation)

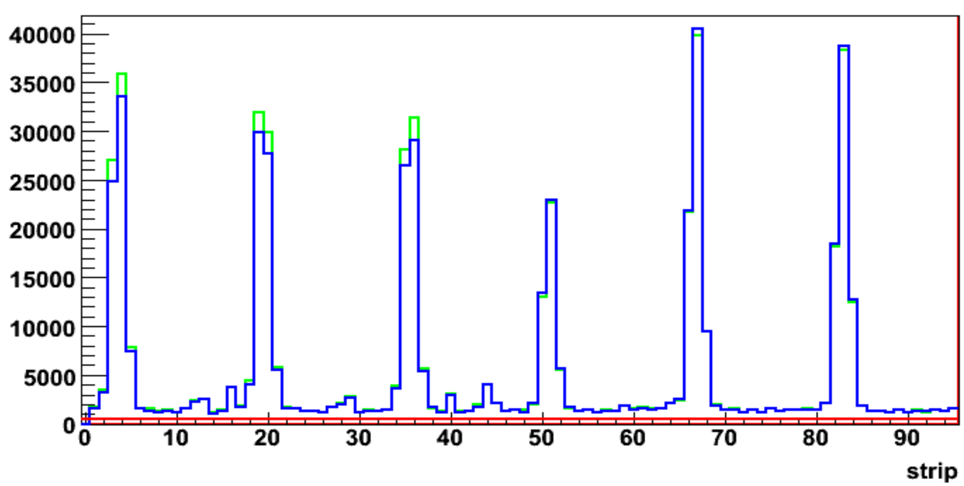




Example of background for one recoil energy slice:

Yield
(up / down)

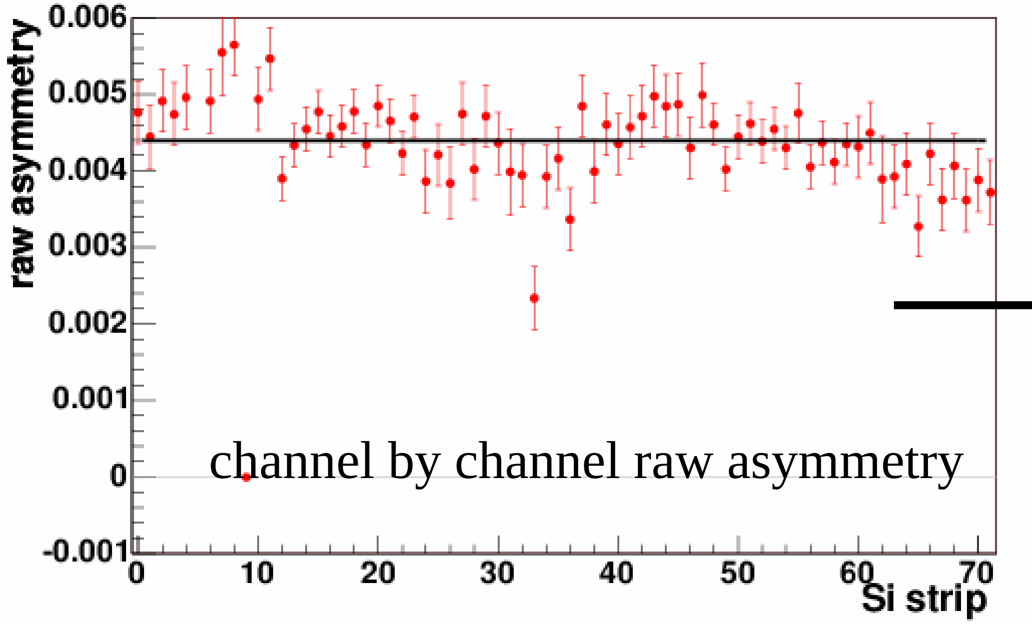
E= 1.0–1.5 MeV

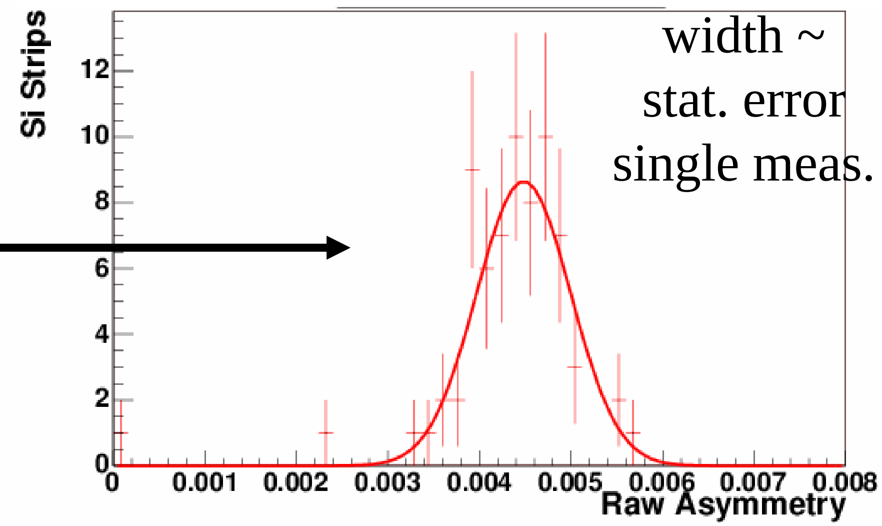


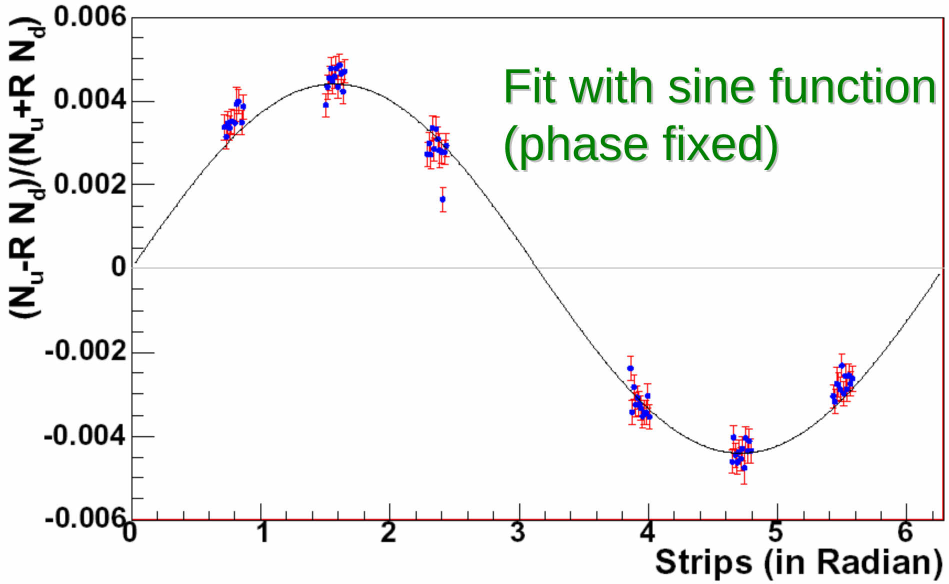
Strip number (6 detectors)

*p*C Systematics:

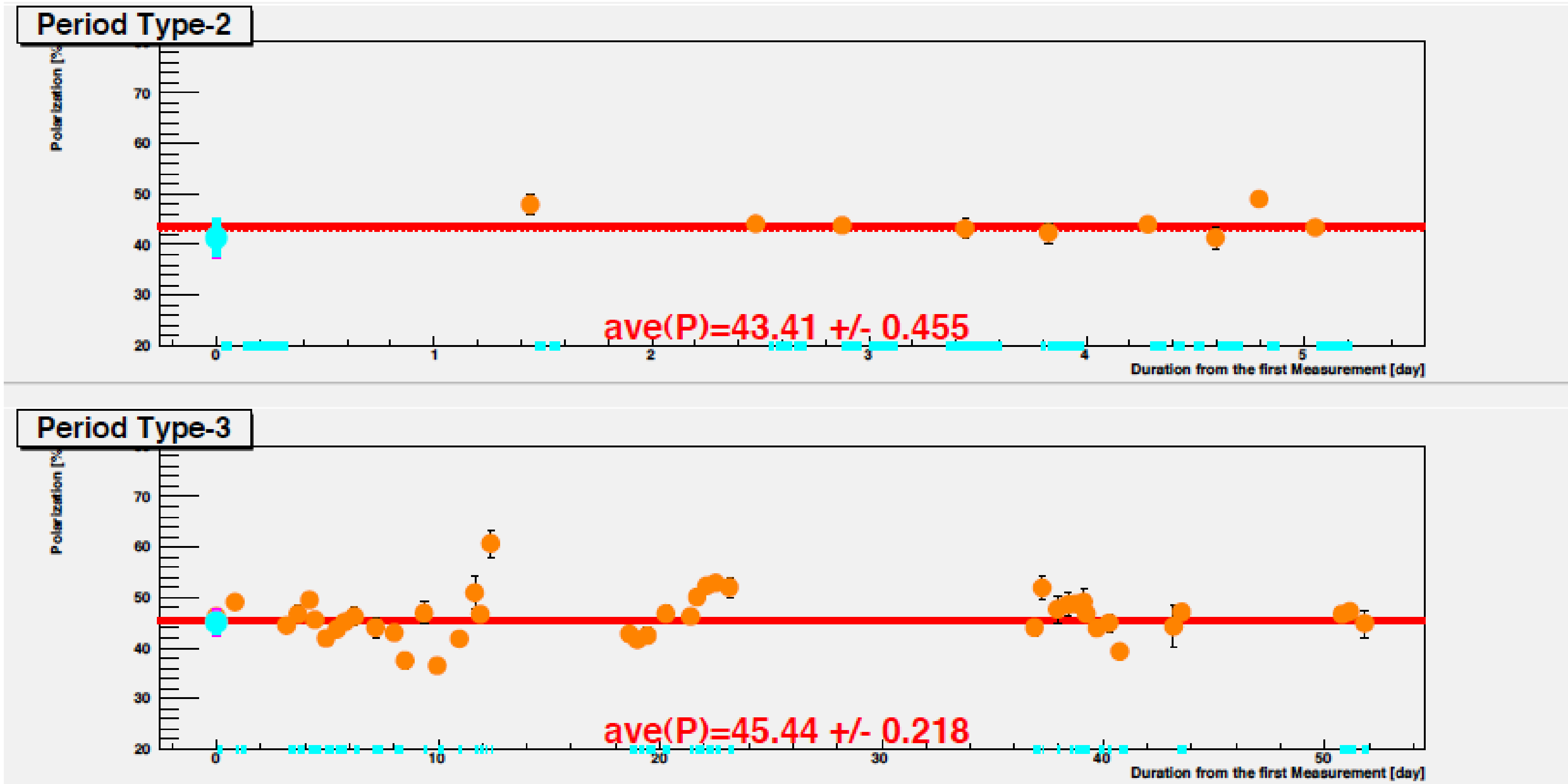
each detector channel covers same ***t*** range
→ 72 independent measurements of A_N







pC vs. Jet (Yellow)



2005 Data