A. Poblaguev
C-AD

Polarization Profile: from Source to RHIC

The RHIC/AGS Polarimetry Group:
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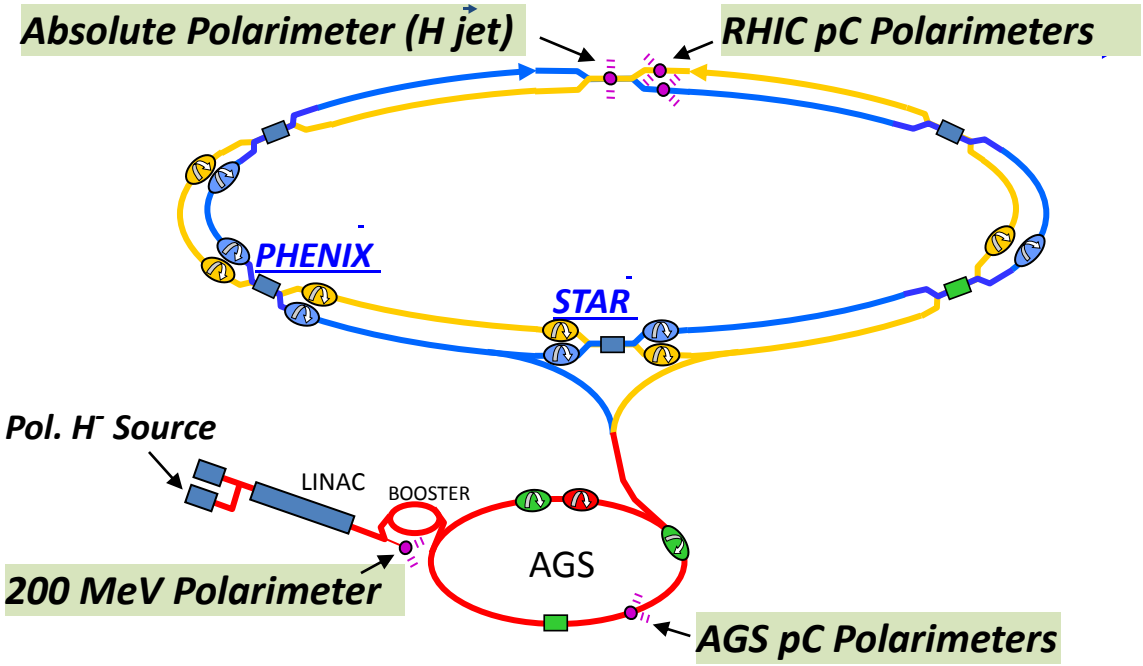
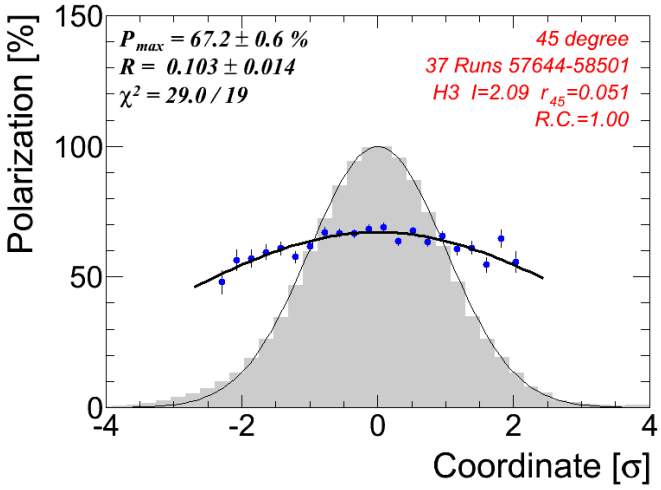
Polarized Proton Beams



- **200 MeV Polarimeter:** - monitors source polarization (well calibrated)
- **AGS pCarbon polarimeter** (96 channels)
  - is used for beam development at AGS
  - monitors polarization delivered to RHIC
- **RHIC pCarbon Polarimeters** (two 72 channel polarimeters per each beam)
  - polarization profile
  - polarization vs time in a fill
  - bunch by buch polarization
  - fill-by –fill polarizations
- **H-Jet polarimeter:** (96 channels)
  - measure average (absolute) polarization

Polarization in Collision Experiments



Intensity and Polarizations profiles, *I(x,y)* and *P(x,y)*, are needed for the analysis

Gaussian Approximation:

$$I_x(x) = I^{(x)}_{\max} e^{-x^2/2\sigma^2} \qquad P_x(x) = P^{(x)}_{\max} e^{-R_x x^2/2\sigma^2}$$

$$R = \sigma_I^2/\sigma_P^2$$ *(similar for y coordinate).*

Average Beam Polarization *(measured by polarimeter):*

$$\langle P \rangle = P^{(x)}_{\max}/\sqrt{1+R_x} = P^{(y)}_{\max}/\sqrt{1+R_y}$$

- **In the *pCarbon* polarimeters, x- and y-profiles may be mesured using moving target (vertical and horizontal, respectively). In a fixed target run, the Pmax is measured.**
- **In the *H-Jet* polarimeter, average beam polarization is measured.**

Average Polarization in experiment:

$$\langle P_{coll} \rangle = \langle P \rangle \sqrt{\frac{(1+R_x)(1+R_y)}{(1+\frac{1}{2}R_x)(1+\frac{1}{2}R_y)}} \approx 1 + \frac{R_x + R_y}{4}$$ *(single spin)*

A model dependence between *<P>* and *R:*

(W. Fischer and A. Bazilevsky, Phys.Rev.ST Accel.Beams 15 (2012) 041001)

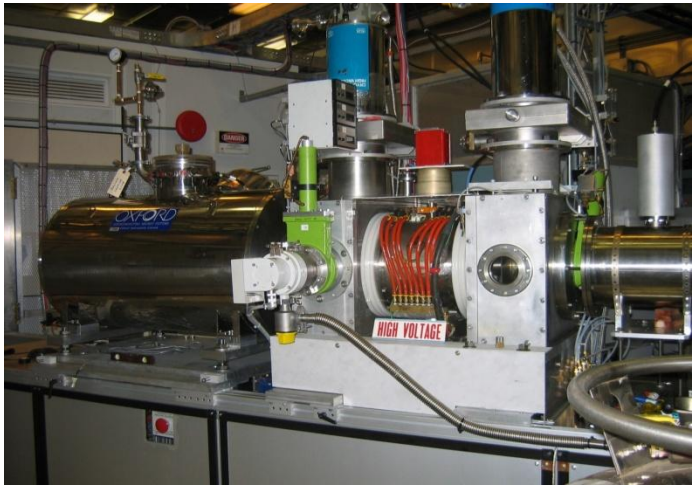
If the development of polarization profiles it the primary reason for the reduction of the average polarization :

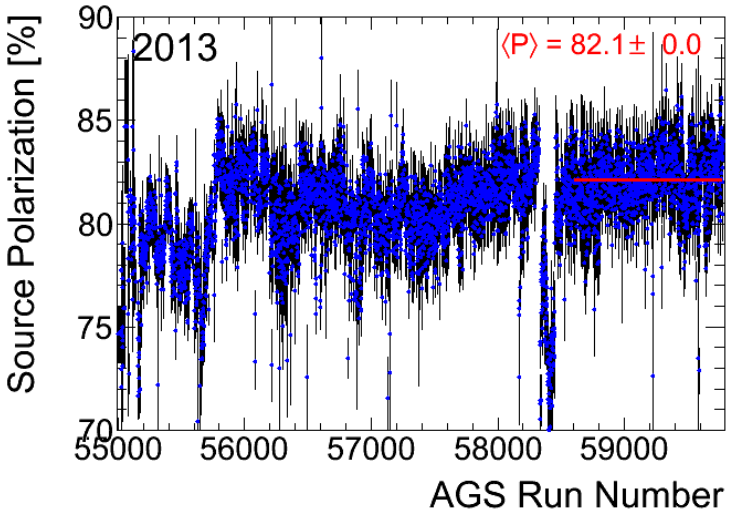
$$\langle P \rangle = \frac{P_0}{(1+R_x)(1+R_y)}$$

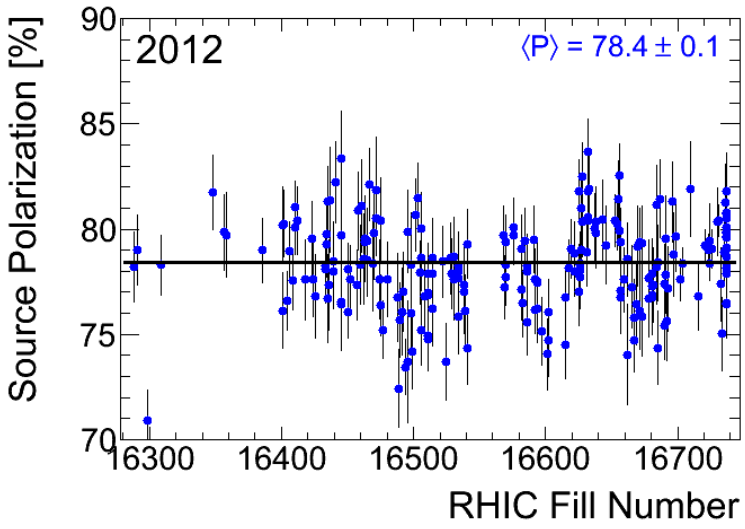
$P_0 = P_{source}$ **is "zero-emittance polarization".**

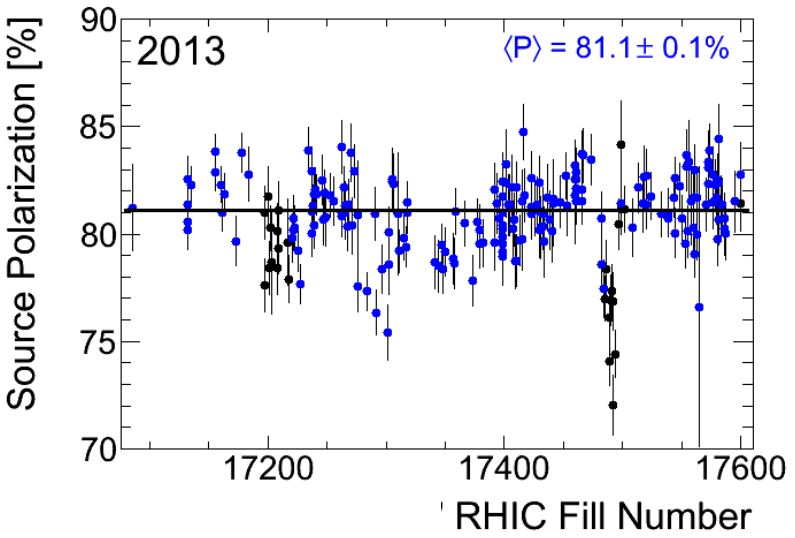
Source Polarization

New Polarized Source in Run 13

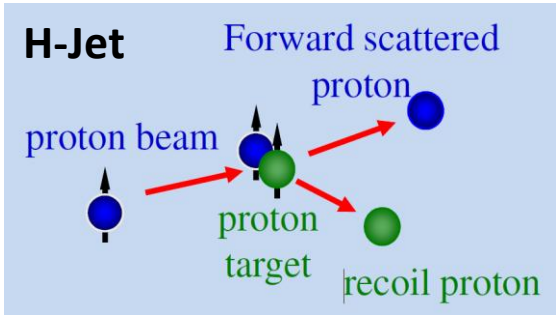


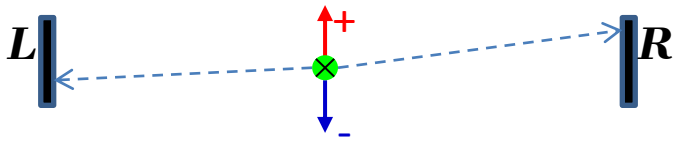


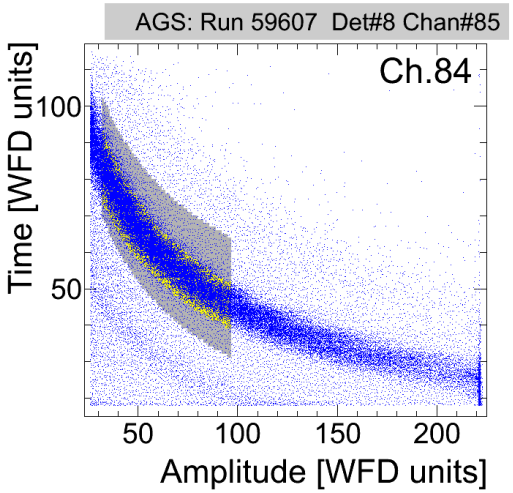




Polarization Measurements in pCarbon and H-Jet







- ***Nonrelativistic recoiled proton (carbon for the pCarbon) is detected at 90˚ in Silicon detectors.***
- ***Detection asymmetry depends on the beam polarization***

$$a_{LR} = \frac{N_R - N_L}{N_R + N_L} = A_N P + \delta_{LR}$$ *(left-right asymmetry)*

$$a_{+-} = \frac{N_+ - N_-}{N_+ + N_-} = A_N P + \delta_{+-}$$ *(up-down asymmetry)*

- ***Systematic errors δ_{LR} and δ_{+-} may be eliminating in the combined method:***

$$a_{phys} = A_N P = \frac{\sqrt{N_R^+ N_L^-} - \sqrt{N_R^+ N_L^-}}{\sqrt{N_R^+ N_L^-} - \sqrt{N_R^+ N_L^-}}$$

- ***In pCarbon we use predefine analyzing power $A_N(E)$.***
- ***In H-Jet, A_N may be internally measured***

$$a_{beam} = A_N P_{beam}, \quad a_{jet} = A_N P_{jet}$$

$$P_{beam} = P_{jet} \times (a_{beam}/a_{jet})$$

Event selection: $$E_{\mathrm{kin}} = \frac{ML^2}{2(t-t_0)^2} = \alpha A + E_{\mathrm{loss}}(\alpha A, x_{DL})$$

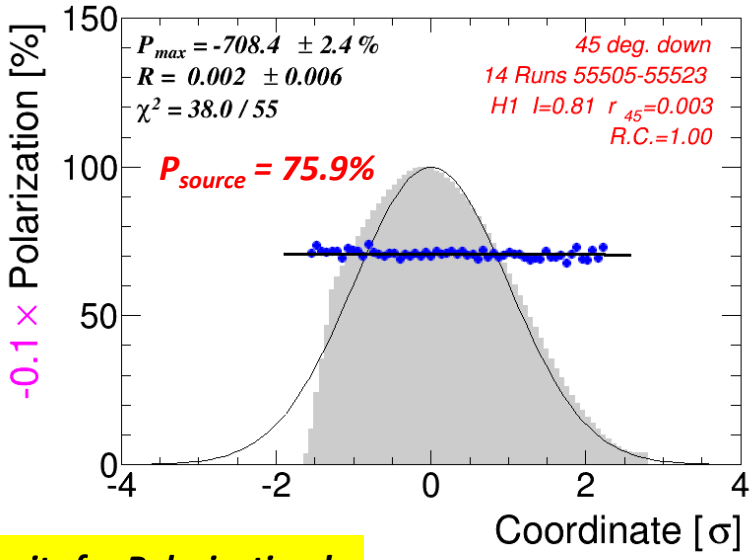
A, t are mesured signal amplitude and time

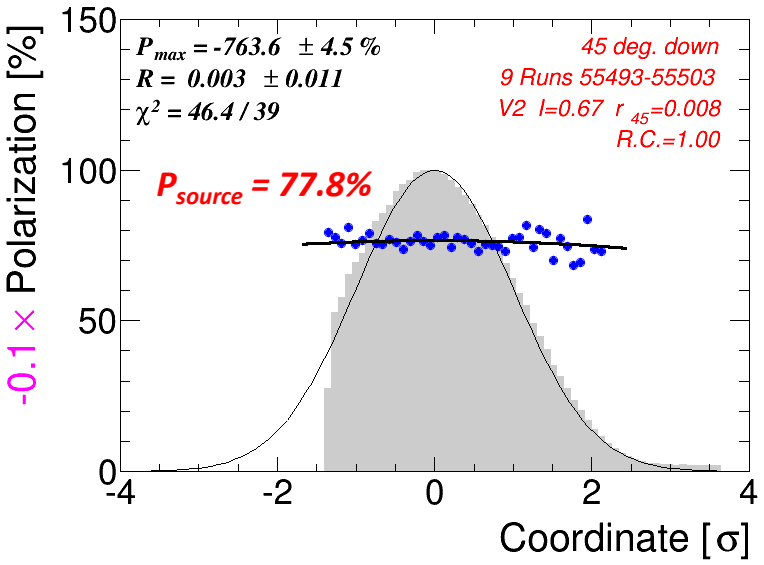
t_0, α , and x_{DL} are calibration parameters.

Energy range *1.0 – 5.0 MeV* (Hjet)

***0.4 – 0.9 MeV* (pCarbon)**

AGS p-Carbon: Polarization at Injection (2.4 GeV)

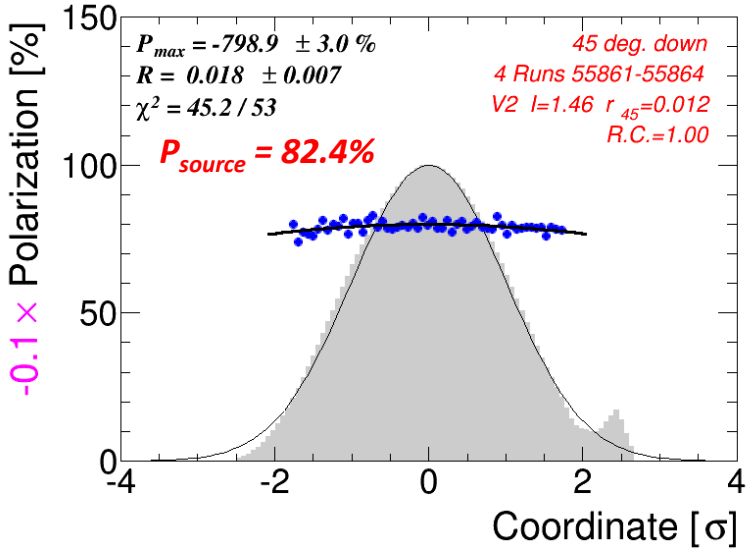




Arbitrary units for Polarization !

In AGS, polarization profile at injection was measured for the first time:

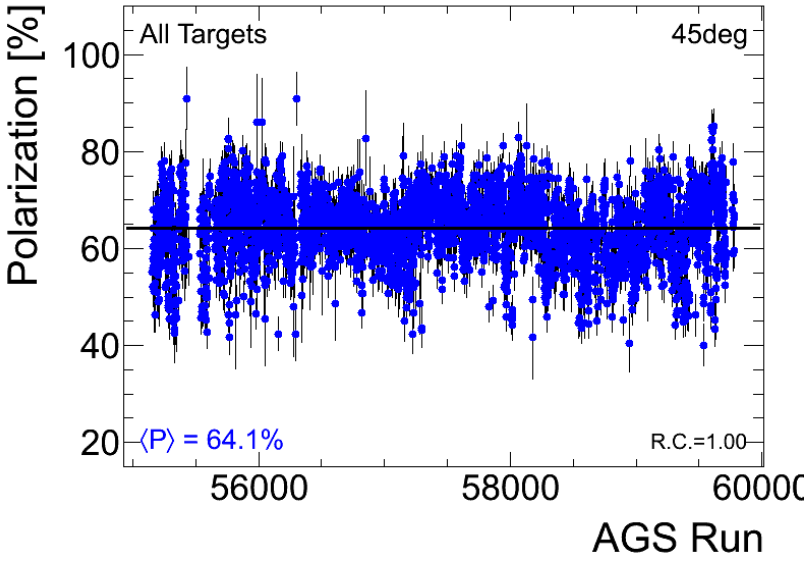
- No polarization profile was observed at low intensity.
- *R≈ 0.02* at higher intensity
- Analyzing power was not calibrated for the injection energy (24 GeV A_N was used instead)



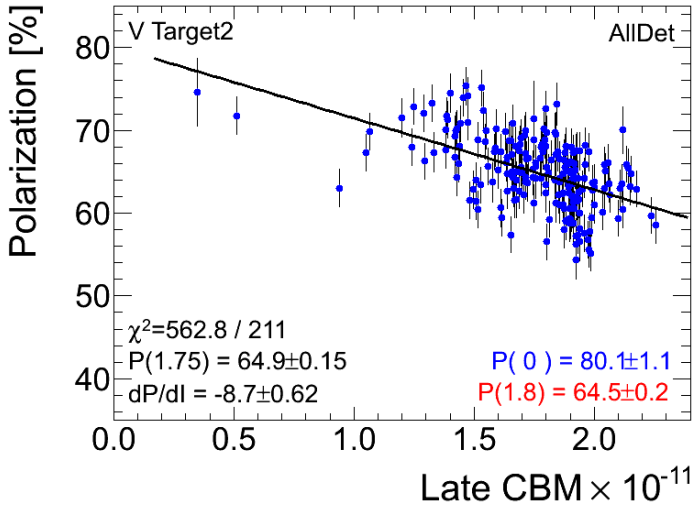
AGS pCarbon: Polarization at Flattop (24 GeV)

- **3800 Polarization measurements at flattop in Run 2013**
- **200 Measurements for RHIC Fill monitoring**

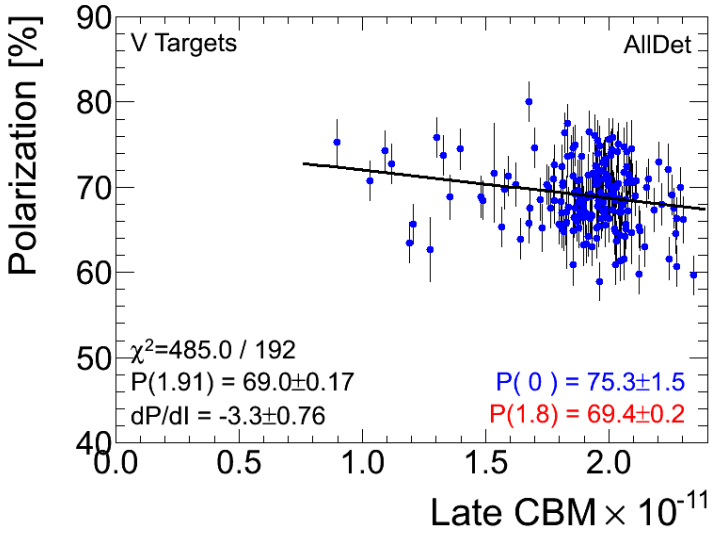
Polarization results are consistent with Run 12 with a possible few percent improvement.



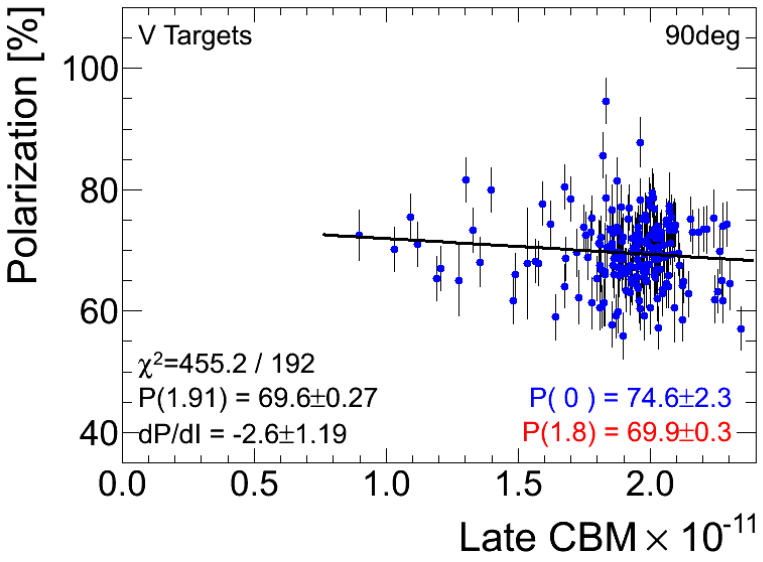
Run12 RHIC ref measurements

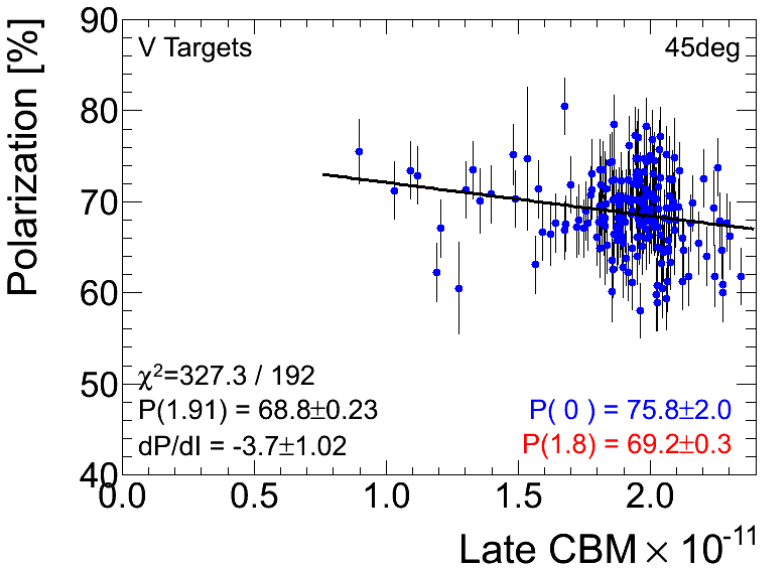


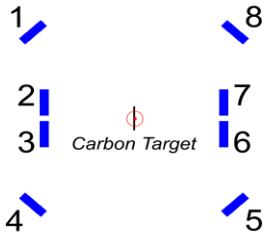
Run13 RHIC ref measurements

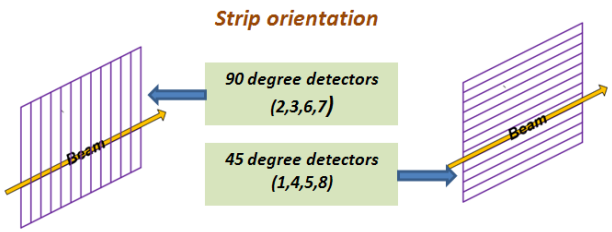


AGS p-Carbon Detectors: 90 degree vs. 45 Degree







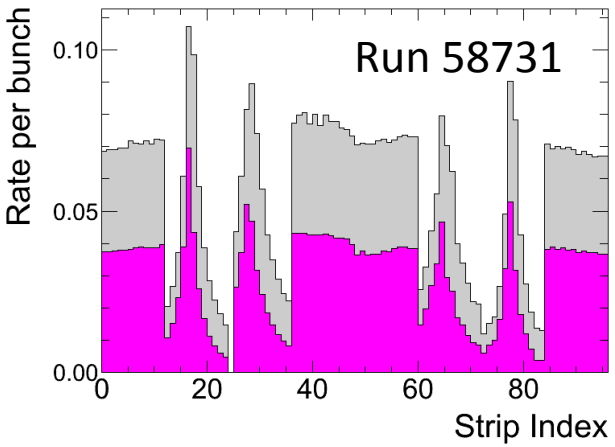


AGS pCarbon Polarimeter:

3 different detector types:

- **1,8** - Hamamatsu, **slow** preamplifiers, L = 51 cm
- **2,7** - BNL 2mm, **slow** preamplifiers, L = 30 cm
- **3,6** - BNL 1 mm, **slow** preamplifiers, L = 30 cm
- **4,5** - Hamamatsu, **slow** preamplifiers, L = 51 cm

AGS p-Carbon Detectors: Rate Corrections

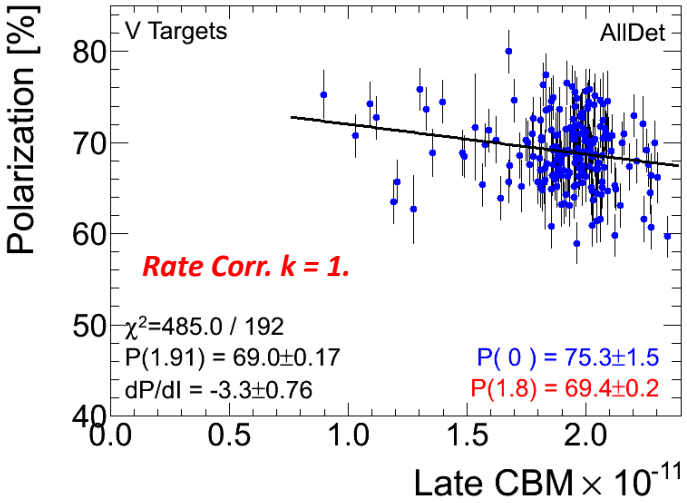


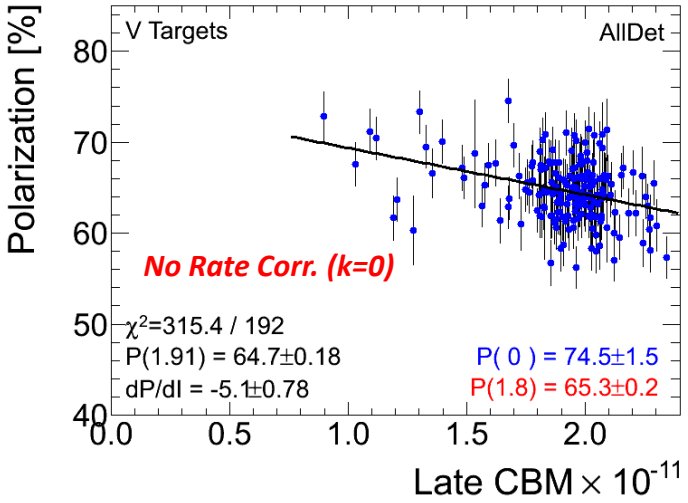
- *In a single Si strip, rate per bunch is r ≈ 0.05-0.10 (depends on intensity, emittance, target, …)*
- *The Data Acquisition may take only one events per bunch.*
- *No good event may be detected even if both coincide signals are good.*
- *The measured Polarization is underestimated:*

$$P_{\mathrm{meas}} = P \times (1 - kr)$$

- *The parameter k may be evaluated using experimental data (separately for each detector) with accuracy about 20%:*
- *ONLINE the value of k=1 is used (consistent with previous runs)*

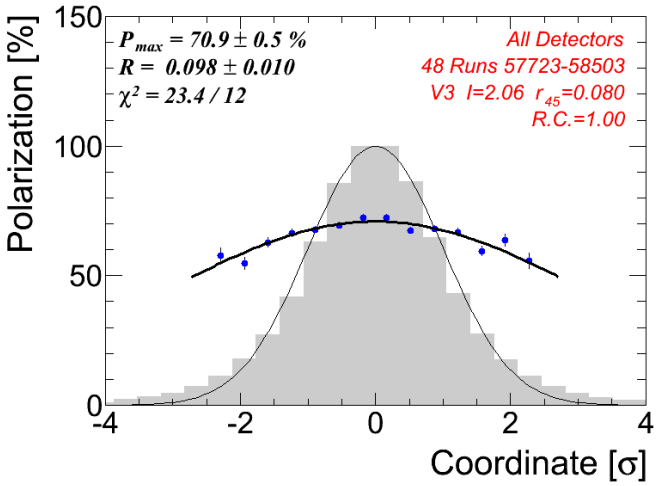
RHIC Ref. Runs:

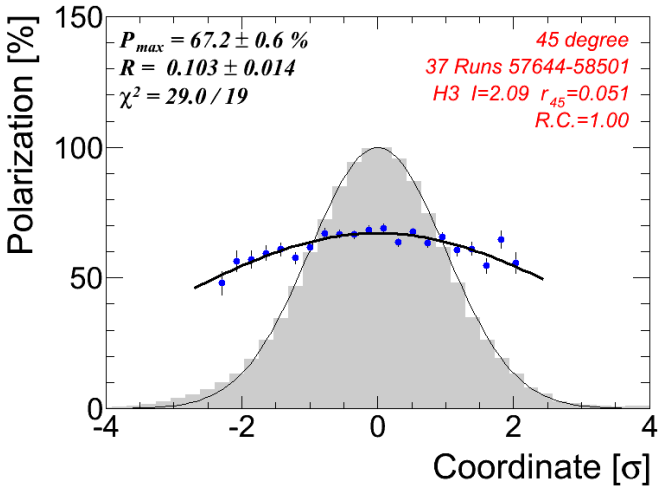




In Run13, the average rate correction is 6% (for RHIC ref. runs).
Uncertainty in the parameter k propagates to a ~ 1% uncertainty in the measured polarization.

AGS p-Carbon: Polarization Profiles





Target	Late CBM	P_{max}	R	P_0	P_{source}
V3	2.06	70.9 ± 0.5	0.098 ± 0.010	81.2 ± 1.1	81.2 ± 0.1
V3	1.51	74.2 ± 0.5	0.113 ± 0.010	85.5 ± 1.3	82.0 ± 0.1
V3	1.05	74.7 ± 0.8	0.049 ± 0.015	80.1 ± 1.6	81.6 ± 0.1
H3	2.09	67.2 ± 0.6	0.103 ± 0.014	77.5 ± 1.0	81.0 ± 0.1
H3	1.50	72.3 ± 0.8	0.093 ± 0.017	84.1 ± 1.3	82.2 ± 0.1
H3	1.08	73.2 ± 0.9	0.047 ± 0.016	78.6 ± 1.6	81.7 ± 0.1
V3	1.91	69.0 ± 0.2	Fixed target	79.7 ± 1.0	81.1 ± 0.1

$$P_0 = P_{\max}^{(x)}\sqrt{1+R_x}(1+R_y) = P_{\max}^{(y)}\sqrt{1+R_y}(1+R_x)$$

- The calculated value of P_0 is consistent with source polarization P_{source} within a ***few percent*** accuracy.

- **For RHIC Fills:**

  $\langle P \rangle \approx 66\%$

  $R_x \approx R_y \approx 0.10 \pm 0.01$

RHIC p-Carbon Polarimeters

pCarbon measurement Database is available on WEB (Maintained by D. Smirnov)
http://www.phy.bnl.gov/cnipol/rundb/

RHIC Polarimetry Results: p-Carbon Measurement Database - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.phy.bnl.gov/cnipol/rundb/?rp=13&rn=&himg=&pi=&mt=2&be=24&to=&ti=&sb=Select

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RHIC Polarimetry Results: p-Ca...

Contact CNIPol, Dmitri Smirnov

Home pC Measurements Fill Results Summary Plots Target History

p-Carbon Measurements

Run period: Run 13

Run: Use "%" to match any number of characters, use "_"

Graph:

Polarimeter: **Type:** sweep **Beam energy:** 24

Select

Runs selected: 1146

Export to CSV file: download

1 2 3 4 5 6

Run	Date & Time	Polarimeter ▼▲	Polarization, % ▼▲	Prof. Ratio R	Type	Beam Energy, GeV	Target
17601.203	Jun 09, 2013 16:42:31 Sun	B2D	61.9 ± 15.6	0.26 ± 0.80	sweep	23.70	H5
	Jun 09, 2013			0.67 ±			

RHIC Polarimetry Results: Summary Plots - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.phy.bnl.gov/cnipol/summary/?ana=run13_phys_lattice12#pcarbon

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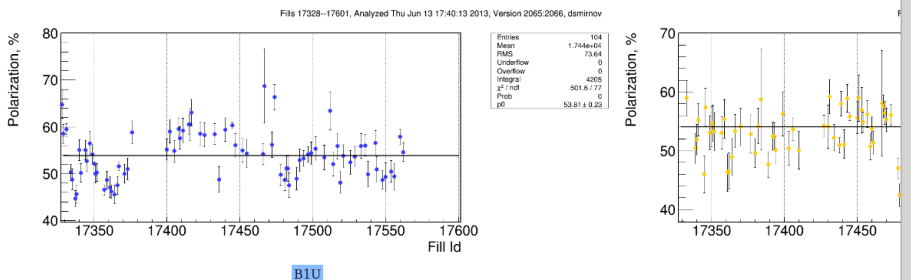
RHIC Polarimetry Results: Sum...

2 p-Carbon Polarimeters ↑ top ↑

2.1 Unscaled Polarization ↑ top ↑

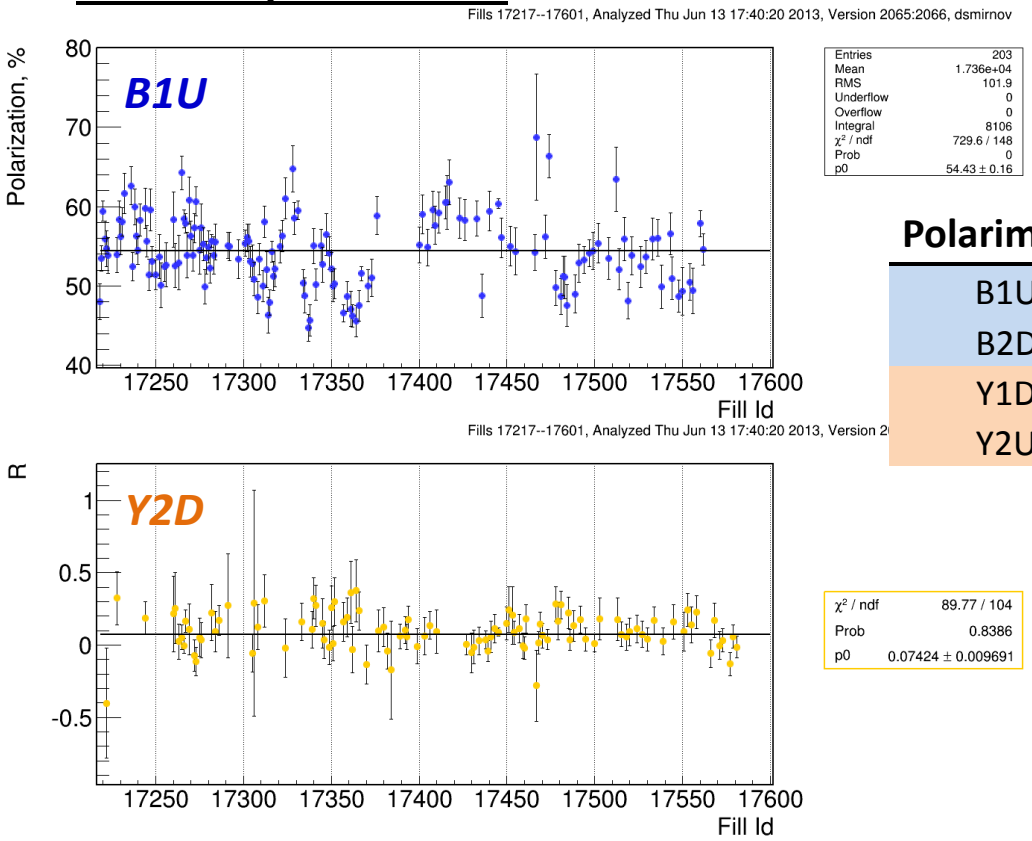
2.1.1 24 GeV ↑ top ↑



RHIC p-Carbon: Measurements at Injection

Expectations: $P_B = 0.96\ P_{AGS}$
$P_Y = 0.99\ P_{AGS}$
$R_{B,Y} = R_{AGS}$

Unscaled polarization



Polarimeter	<P>	R_x	R_y
B1U	54.4 ± 0.2	0.081 ± 0.007	0.048 ± 0.014
B2D	55.0 ± 0.2	0.059 ± 0.009	0.066 ± 0.010
Y1D	53.9 ± 0.2	0.088 ± 0.009	0.044 ± 0.015
Y2U	54.7 ± 0.2	0.082 ± 0.014	0.066 ± 0.014

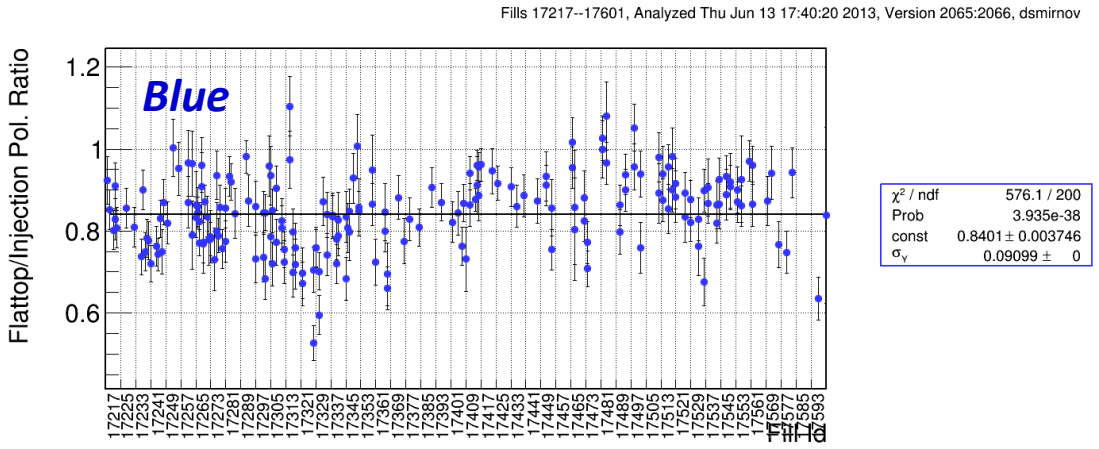
$$\langle P \rangle = 55.3 \pm 0.1\%$$
$$\langle R_x \rangle = 0.080 \pm 0.003$$
$$\langle R_y \rangle = 0.058 \pm 0.006$$

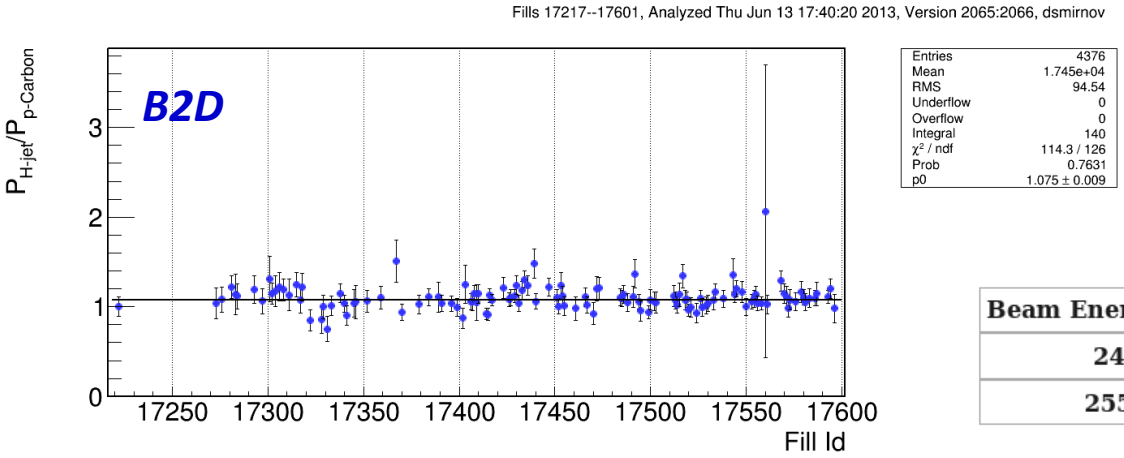
Results are consistent between RHIC polariimeters but inconsistent with AGS

$\langle P_{AGS} \rangle = 66 \pm 1\%$ $\langle R_{AGS} \rangle = 0.10 \pm 0.01$

***pCarbon* polarimeter is used for relative measurements only,**
however a better understanding of discrepancy between AGS and RHIC data is needed.

RHIC p-Carbon: Polarization Ratios





Polarimeter	P_{255}/P_{24}	P_{jet}/P_{255}
B1U	0.83	1.08
B2D	0.85	1.08
Y1D	0.84	1.13
Y2U	0.88	1.12

pCarbon polarization was scaled in further analysis

Beam Energy, GeV	B1U	Y1D	B2D	Y2U
24	1.06 ± 0.02	1.09 ± 0.02	1.11 ± 0.03	1.08 ± 0.03
255	1.06 ± 0.02	1.09 ± 0.02	1.11 ± 0.03	1.08 ± 0.03

RHIC p-Carbon: Flattop Summary

Fills 17201 – 17324 (Run13 Lattice)

Polarimeter	<P>	dP/dt	R_x	dR_x/dt	R_y	dR_y/dt	P_0
B1U	49.2 ± 0.3	-0.49 ± 0.09	0.23 ± 0.01	0.019 ± 0.006			75.6
B2D	50.1 ± 0.6	-0.37 ± 0.14			0.25 ± 0.02	0.025 ± 0.010	77.0
Y1D	47.5 ± 0.3	-1.12 ± 0.07	0.21 ± 0.02	0.027 ± 0.007			73.6
Y2U	47.3 ± 0.5	-0.87 ± 0.11			0.28 ± 0.02	0.003 ± 0.009	73.3

Fills 17328 – 17601 (Run12 Lattice)

Polarimeter	<P>	dP/dt	R_x	dR_x/dt	R_y	dR_y/dt	P_0
B1U	48.9 ± 0.3	-0.35 ± 0.04	0.22 ± 0.01	0.012 ± 0.006	0.14 ± 0.02	0.007 ± 0.003	68.1
B2D	50.1 ± 0.2	-0.27 ± 0.03	0.14 ± 0.01	0.006 ± 0.004	0.14 ± 0.02	0.008 ± 0.003	65.1
Y1D	55.0 ± 0.3	-0.08 ± 0.04	0.18 ± 0.01	0.000 ± 0.007	0.09 ± 0.02	-0.001 ± 0.003	66.5
Y2U	54.1 ± 0.3	-0.19 ± 0.03	0.14 ± 0.01	-0.001 ± 0.003	0.17 ± 0.01	0.020 ± 0.005	72.1

- *The values of <P> and R are given for the begin of the store*
- *Polarization and profile R decays are given per hour*
- *P_0 is calculated zero emittance polarization*

The measured value of R may be underestimated due to electrostatic interaction loose targets with beam. This may give an explanation for the small values or P_0.
However, since $R < \sqrt{P_{\mathrm{source}}/\langle P_{\mathrm{jet}}\rangle - 1} \approx 0.21$, such an uncertainty in R does not affect much the estimate of the $P_{coll.}$ (A. Zelenski)

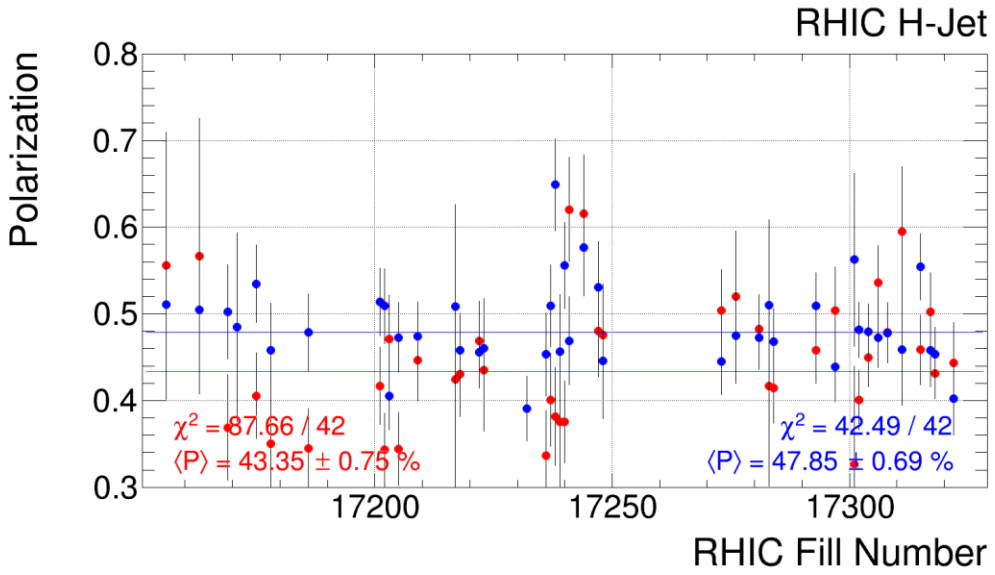
Polarization measurement in the H-Jet

Early Analysis:

Fills 17201 – 17324 (Run13 Lattice)

$$\langle P_Y \rangle = 43.4 \pm 0.8\%$$

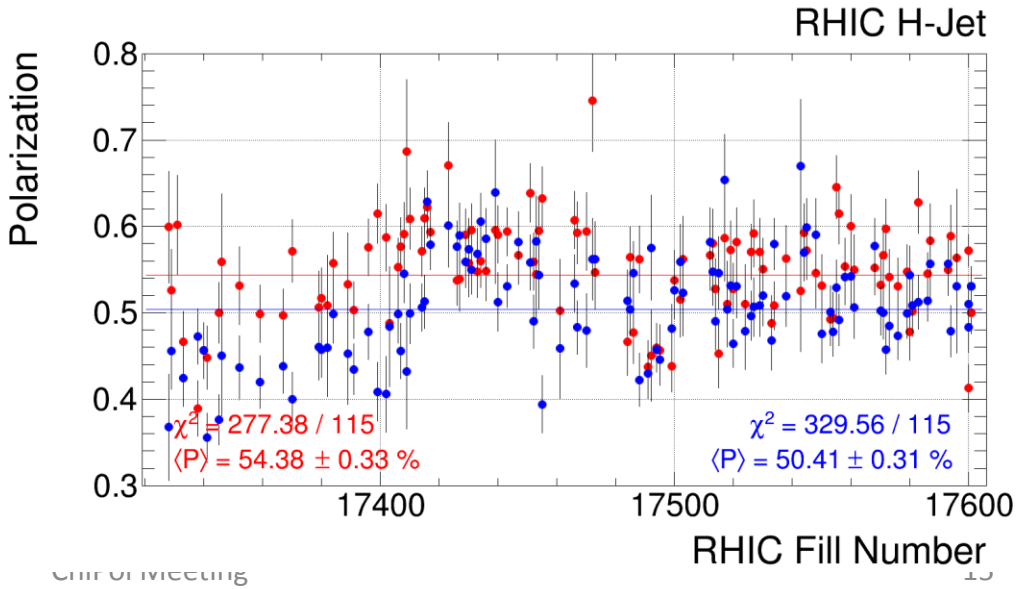
$$\langle P_B \rangle = 47.9 \pm 0.7\%$$



Fills 17328 – 17601 (Run12 Lattice)

$$\langle P_Y \rangle = 54.4 \pm 0.3\%$$

$$\langle P_B \rangle = 50.4 \pm 0.3\%$$



Systematic Errors in the H-Jet Measurements

$$P_{beam} = P_{jet} \times (a_{beam}/a_{jet})$$

Jet Polarization: there are 2 hydrogen components in the jet:

- atomic with (measured) polarization $P_{BR} \approx 96\%$
- *molecular (unpolarized)*

The admixture of molecular hydrogen was measured to be $\varepsilon \approx 3\%$ but, but systematic errors of this measurement is not well known. The average polarization $P_{jet} = (1-\varepsilon) \times P_{BR}$ should be used in analysis

Background:

$$\mathbf{A_N^{eff}} = \frac{\mathbf{A_N} + \mathbf{r}\mathbf{A_N^{bgr}}}{\mathbf{1}+\mathbf{r}} = \mathbf{A_N}\frac{\mathbf{1}+\alpha\mathbf{r}}{\mathbf{1}+\mathbf{r}}; \qquad \alpha = \mathbf{A_N^{bgr}}/\mathbf{A_N}$$

$r \sim 5\%$ is background level

For Jet asymmetry $\alpha = 0$. For beam asymmetry α is unknown and may be as large as 1 (e.g for beam gas protons).

$$\mathbf{P_{meas}} = \mathbf{P_{beam}}(\mathbf{1}+\alpha\mathbf{r})$$

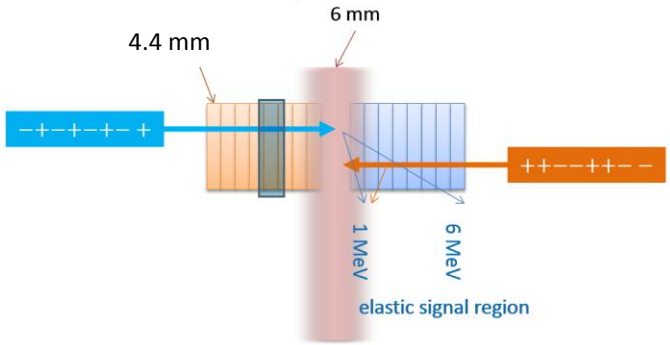
(some previous experimental estimates gave $\alpha \approx 0$)

In ONLINE analysis the value of $P_{jet} = 92\%$ was used.

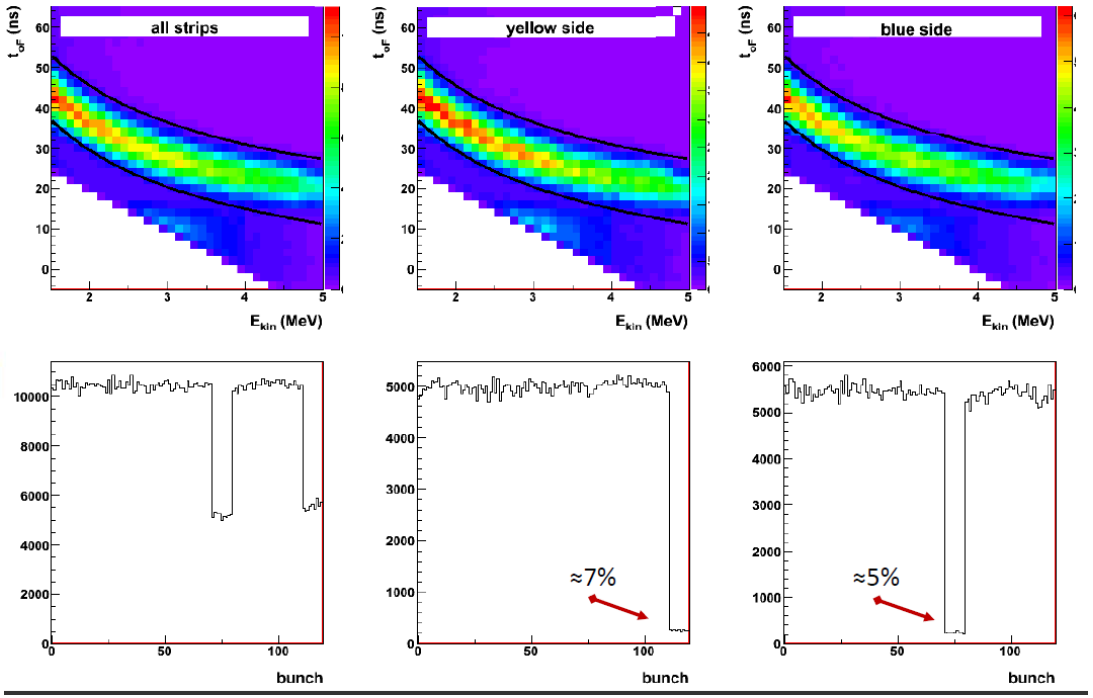
Estimation of background effect. Method I

Oleg Eyser:

Detector Geometry

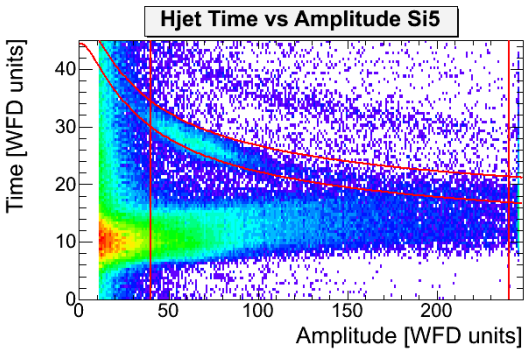


Elastic p+p Signal (Fill 17568, 8 hours)



- ***Bunches with a single beam (abort gaps) may be employed to understand background***
- ***Single beam stores (blue and yellow) at the end of Run 13***
- ***The method is under development.***

Estimation of background effect. Method II



For elastic pp-scattering:

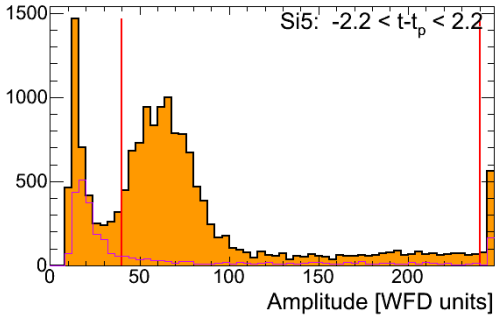
$$\frac{z}{L} = \sqrt{\frac{T}{2M_p}\frac{E_{\text{beam}} + M_p}{E_{\text{beam}} - M_p}} \Rightarrow z = \zeta\sqrt{T}$$

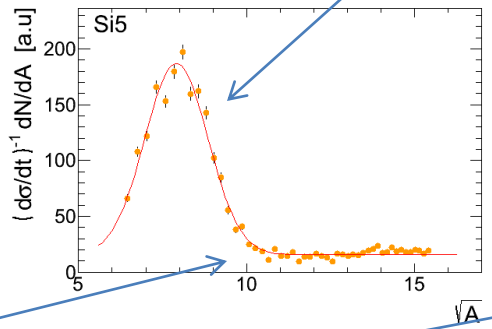
z-profile of the jet (smeared by Si strip size) is approximated by :

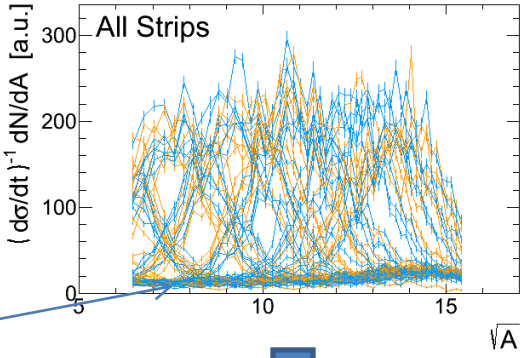
$$\left[\left(\frac{d\sigma_{pp}}{dt}\right)^{-1}\frac{dN}{dA}\right](\sqrt{A})$$

Background may be expected to be the same in all strips strip s

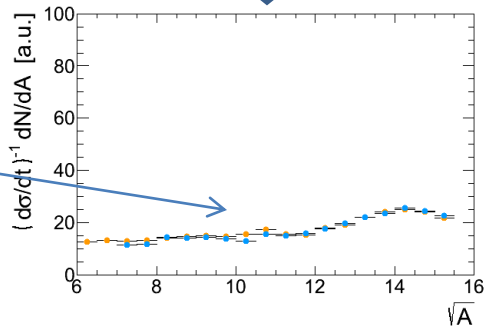
The method is not verified yet !







- *Two methods for background subtraction*
  - *from the fit*
  - *average background*
- *The peak position is associated with well known (from geometry) energy. In such a calibration t_0 may be determined with accuracy of about 200 ps, and proton energy may be calibrated with accuracy better than 2%*
- *By product detector geometry may be aligned.*
- *α-particles and prompt indicated more complicated background*



Summary

- AGS / RHIC polarimeters provides fast and detailed information about beam polarization
- Finalizing of the Run13 analysis is underway.
- Some improvement of understanding of the performance of polarimeters is still needed.
- Contemplating upgrades of the DAQ software to use Red Hat 6.3/6.4, also looking into using new VME based WFD from