21 November 2002
RHIC Jet Target Review
G. Bunce

Calibration of the proton-carbon CNI Polarimeters

P_{Jet} ---> P_{beam} ---> $A_{pC\,CNI}$ ---> P_{beam} ---> experiments

$A_{pC\,CNI} = \varepsilon_{pC} / P_{beam}$ $P_{beam} = \varepsilon_{pC} / A_{pC\,CNI}$

$\varepsilon = (N_{left} - N_{right}) / (N_{left} + N_{right})$

(simplified: $N_{left,\uparrow}$, $N_{left,\downarrow}$, $N_{right,\uparrow}$, $N_{right,\downarrow}$)

$\Delta P_{beam}/P_{beam}|_{Jet} \oplus \Delta\varepsilon/\varepsilon|_{pC\,CNI} \oplus \Delta\varepsilon/\varepsilon|_{pC\,CNI} \oplus \Delta A_N/A_N|_{pC\,CNI} = \Delta P_{beam}/P_{beam}$

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1. Introduction to pC CNI polarimetry
2. Layout of polarimeter, how the measurement is made
3. An example of measurements, and false asymmetries
4. Presentation of systematic error issues and what we know about them
5. The carbon beam measurement of $A_N|_{pC\,CNI}$
6. Other issues we have thought of (and which need to be quantitatively addressed)
7. Summary of issues to measure P_{beam} to 5% of itself, discussion of additional options

1. Introduction to proton-carbon CNI Polarimetry

a. Traditional method of polarimetry for medium energy protons is pp elastic at observed peak in –t (0.15 $(\mathrm{GeV/c})^2$).

---$A_N \propto 1 / p_{beam}$, $A_N = .01$ at 24 GeV

b. CNI has predicted $A_N \propto (g-2 /2)_{proton} \approx .04$

---non-zero and energy independent
---large cross section
---but, must measure A_N (possible hadronic spin-flip contribution)
---inelastics / elastics ≈ 1%

c. proton-carbon: ultra thin carbon ribbon targets available from Bill Lozowski at IUCF (150 angstroms x 5 μm x 1" !)

---allow recoil carbon to escape
---high rate, but not too high
---target survives beam heating (actually robust !)

d. slow carbon recoil

---recoil angle near 90°, almost independent of p_{beam}
---time of flight ---> velocity, E ---> mass (clear i.d.)
---carbon recoil arrives out of time of prompt background

E950: J. Tojo et al., PRL 89, 052302-1 (2002)

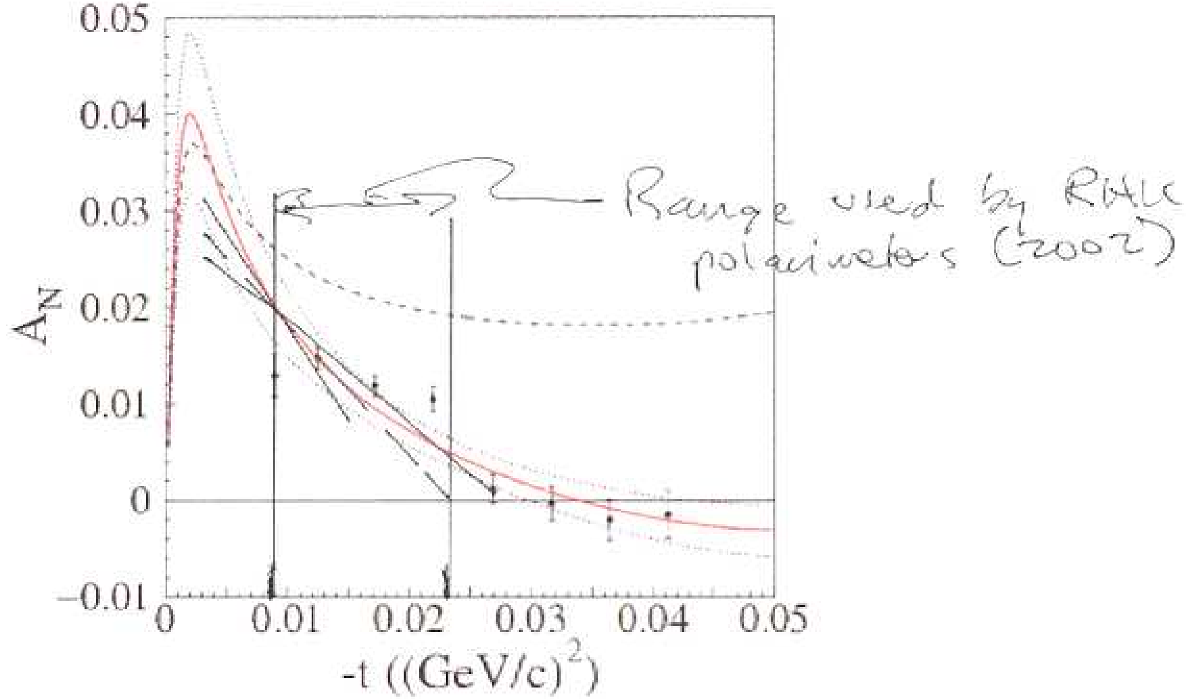
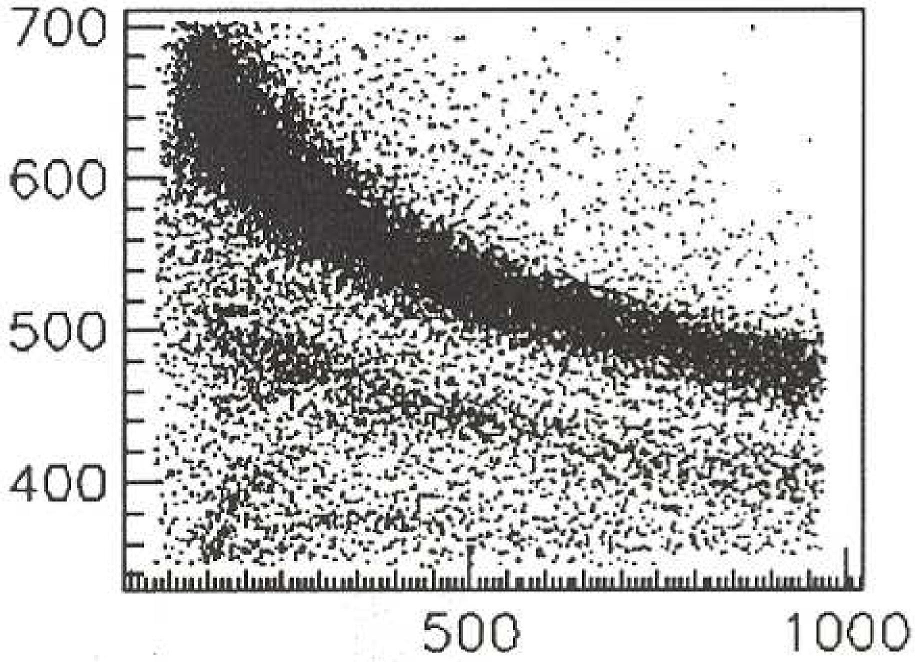
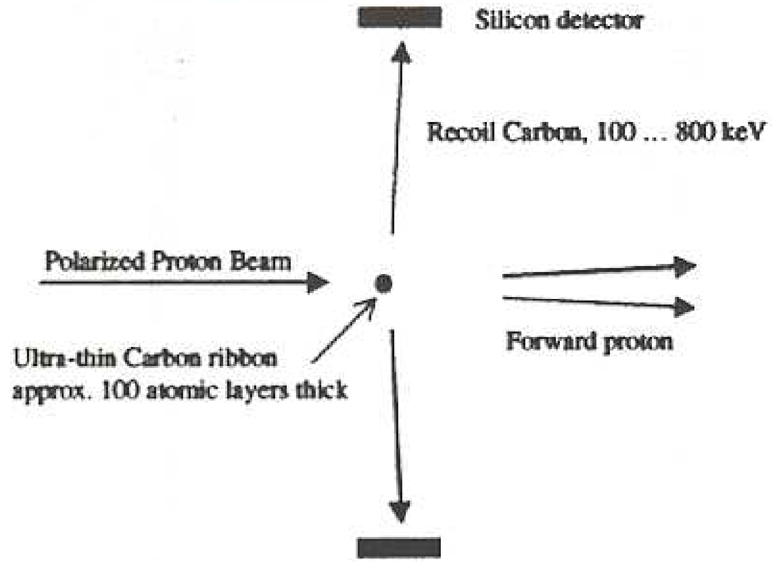


FIG. 3 (color online). The analyzing power, $\mathcal{A}_N$, for pC elastic scattering in the CNI region. The error bars on the data points are statistical only. The solid line is the fitted function from theory [4]. The dotted lines are the 1-sigma error band of the fitting result. The dashed line is the theoretical function with no hadronic spin-flip amplitude ($r_5 = 0$).

RHIC proton-carbon polarimeter



Energy vs. ToF spectrum



- 2-3% energy independent analyzing power for small-angle elastic scattering in the Coulomb-Nuclear Interference (CNI) region
- Slow recoil Carbon detected in between bunch crossings
- Fiber target allows for polarization profile measurement

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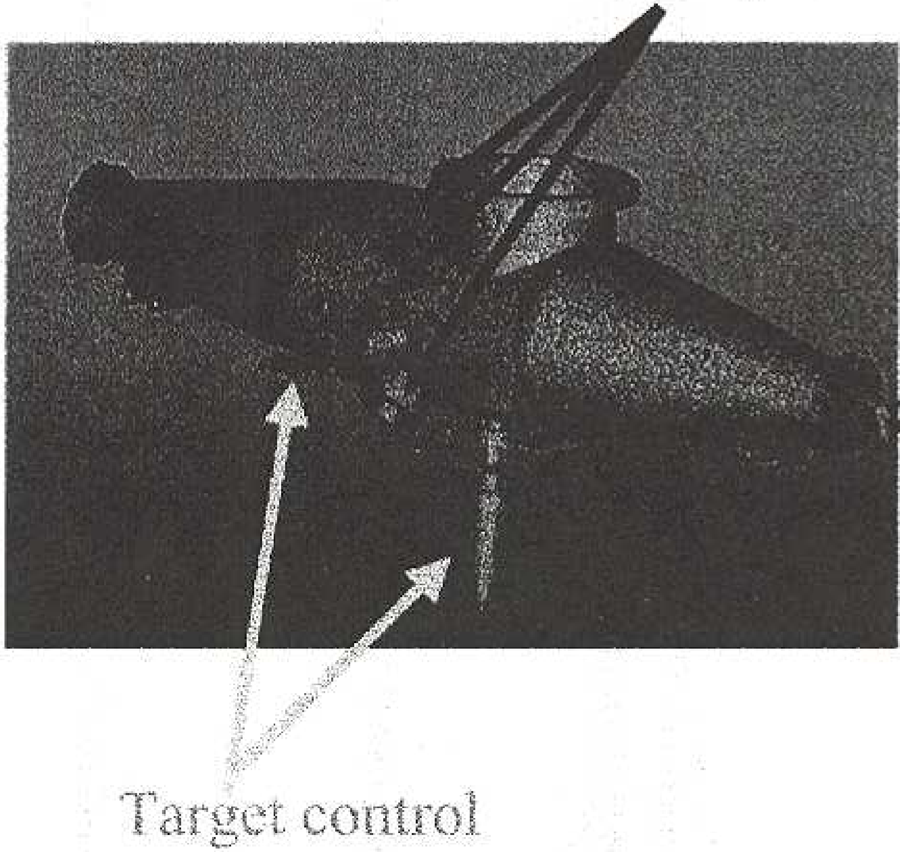
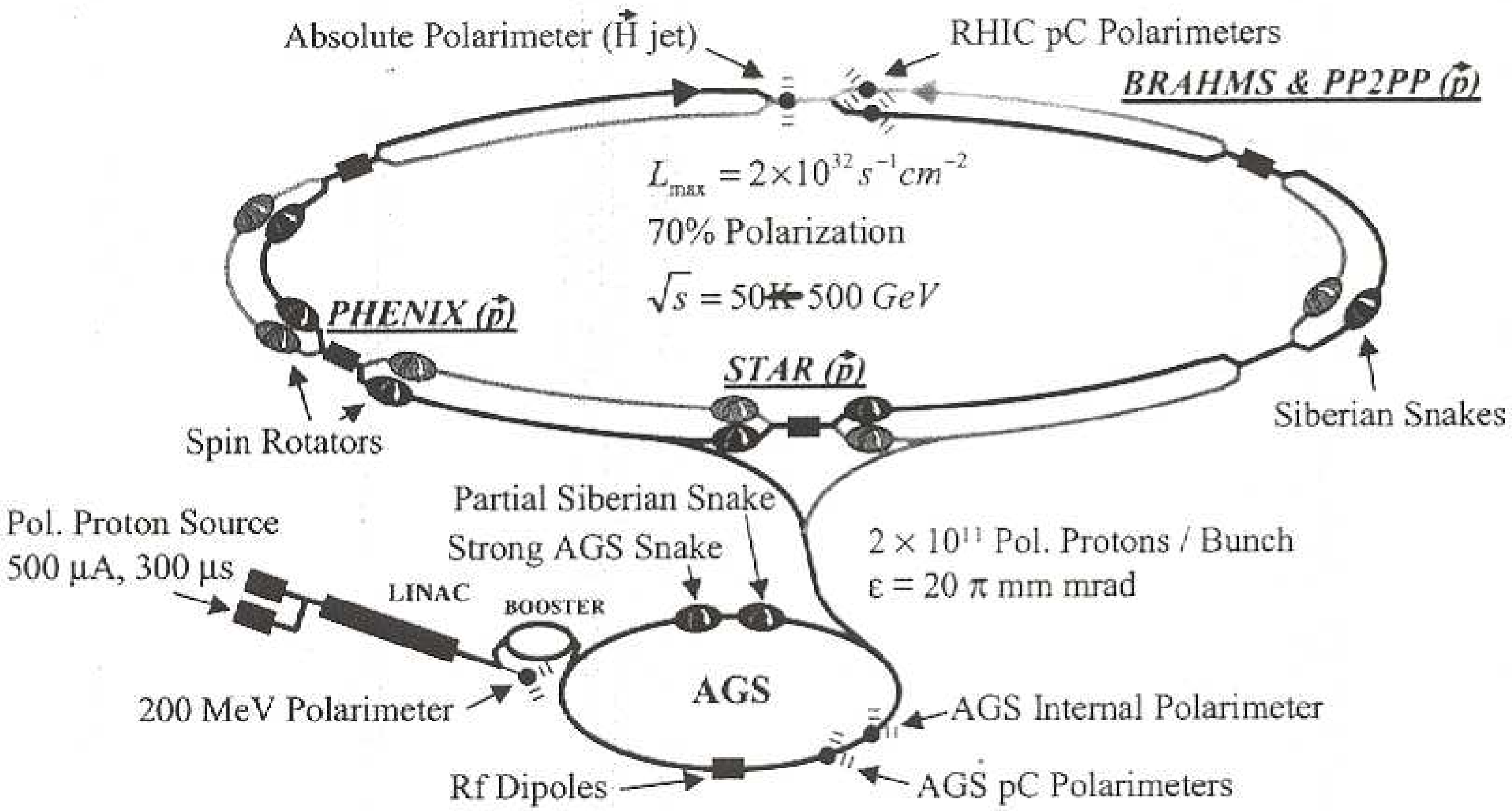
RHIC Polarimeter Chamber at BNL



Chamber photo with polarimeter crew

Polarized Proton Collisions in RHIC



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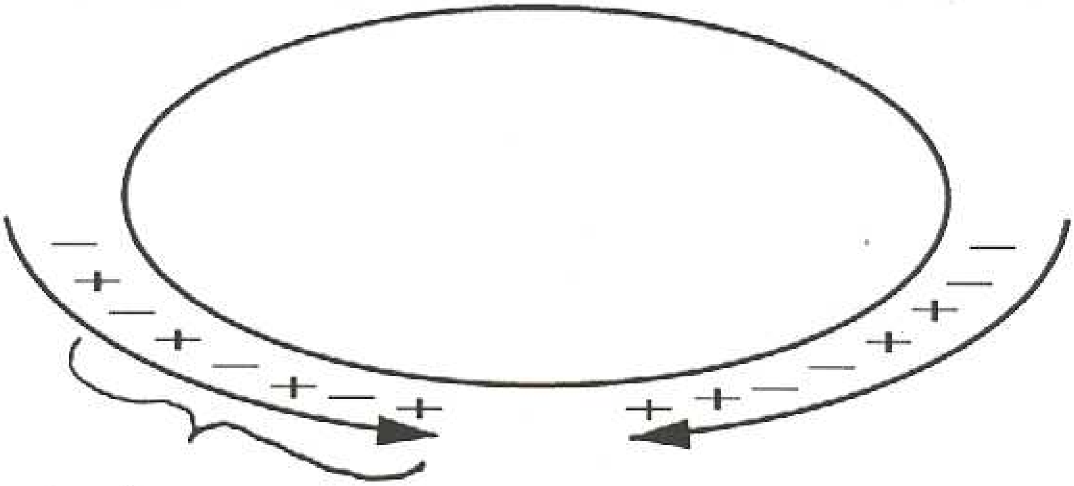


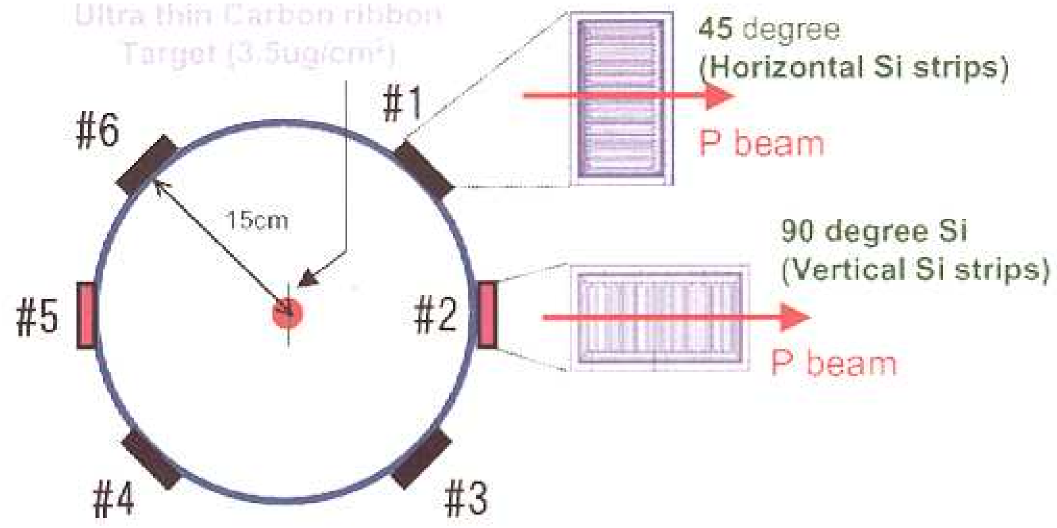
Commissioning:
loaded 6 bunches
~2 μsec apart

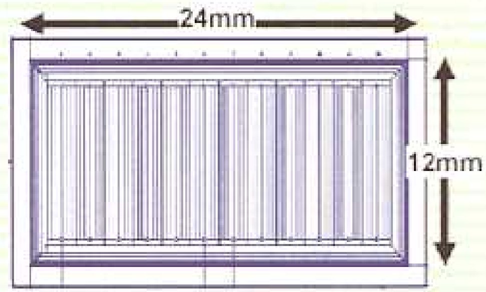
2001 Spin run:
load 60 bunches
~200 nsec apart

2002 Spin run:
load 120 bunches
~100 nsec apart

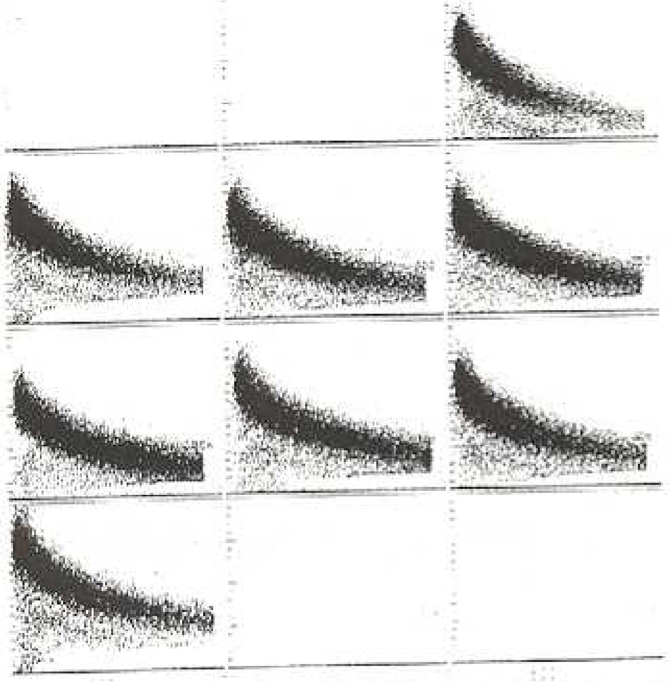
Layout of the 6 silicon detectors in RHIC Polarimeter

- beam into page
- silicon mounted inside of vacuum chamber



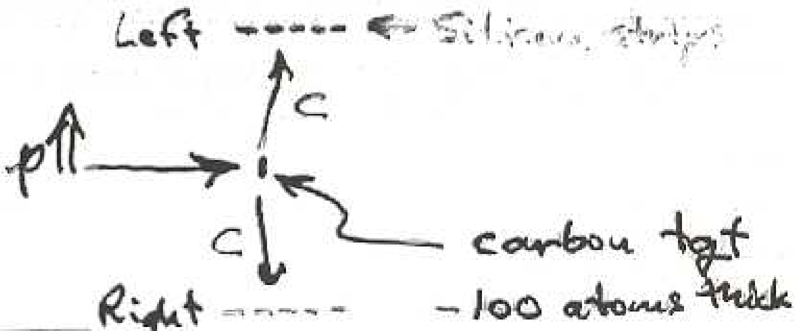


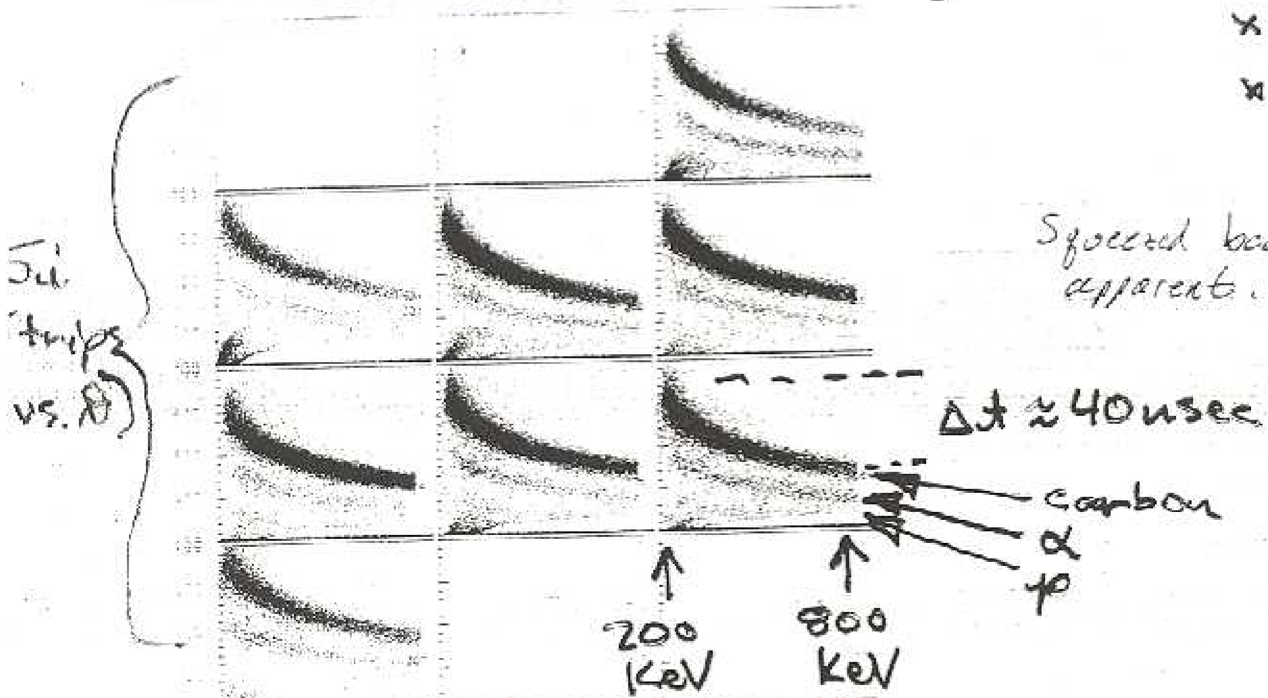
12x Si-strip detector



Bunched Beam / no squeeze

Polarimeter in RHIC

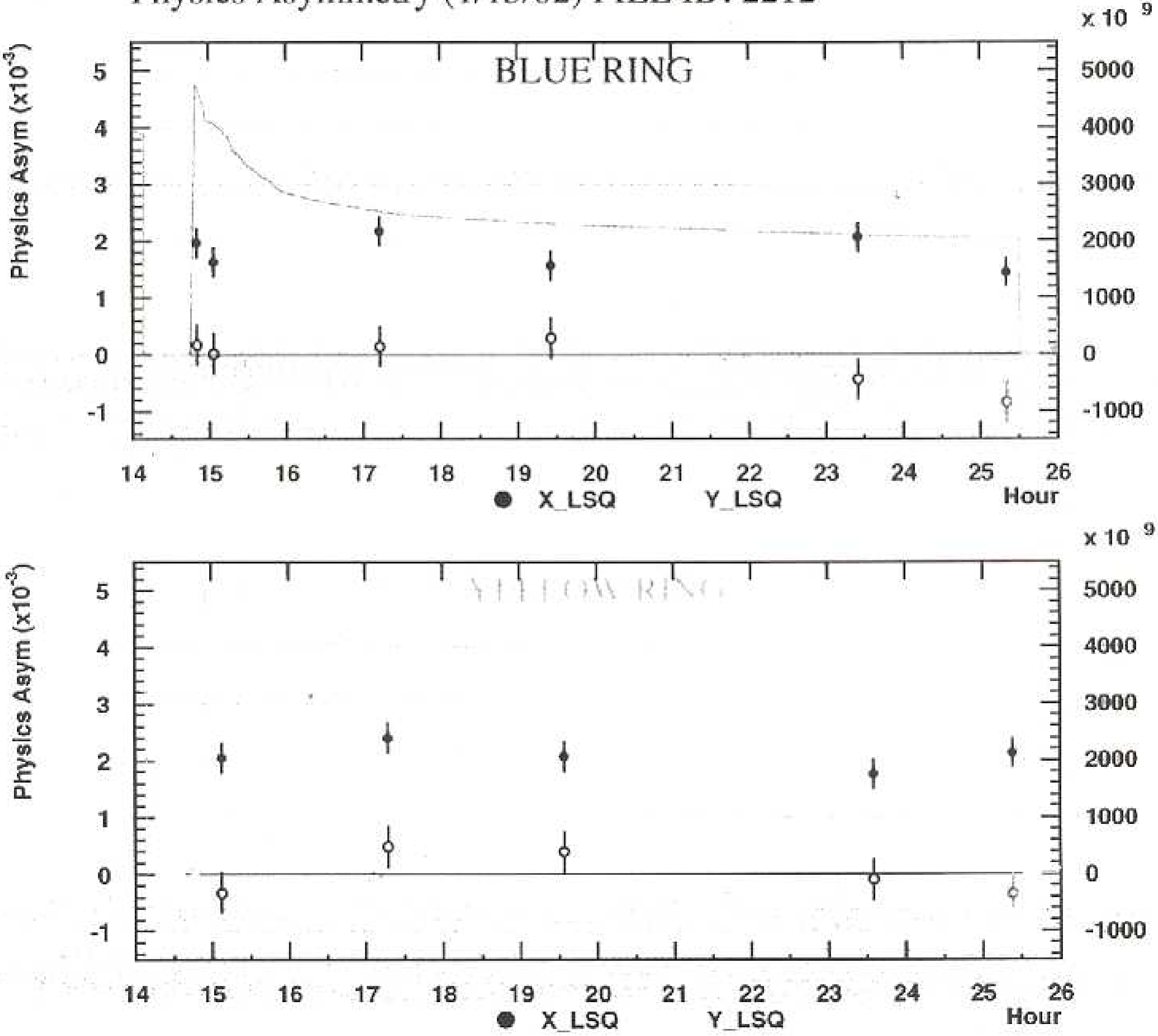




Squeezed beam ; α peak apparent.

$$\text{Asym} \approx \frac{\text{Left} - \text{Right}}{\text{Left} + \text{Right}} \approx k \, P_{beam} \left(\frac{g-2}{2}\right)_p \times \sigma_{total\ pC}$$

Physics Asymmetry (1/13/02) FILL ID: 2212



4. Systematic Error Issues and What We Know About Them

P_{Jet} ---> P_{beam} ---> $A_{pC\ CNI}$ ---> P_{beam} ---> experiments

$A_{pC\ CNI} = \varepsilon_{pC} / P_{beam}$ $\qquad$ $P_{beam} = \varepsilon_{pC} / A_{pC\ CNI}$

$\Delta P_{beam}/P_{beam}|_{Jet} \oplus \Delta\varepsilon/\varepsilon|_{pC\ CNI} \oplus \Delta\varepsilon/\varepsilon|_{pC\ CNI} \oplus \Delta A_N/A_N|_{pC\ CNI} = \Delta P_{beam}/P_{beam}$

How well do we do now?

a. Compare independent measurements with 6 detectors, 2 polarimeters.

--- 45° vs. 90° measurements
--- false asymmetries: up-down, cross 45°
--- use $P_{beam} = 0$ bunch patterns, measure asymmetries
--- fit φ - dependence of 6 detectors, bunch by bunch ---> χ^2

b. Detector and beam related studies

--- noise in silicon strips ---> abort gap information
--- debunched beam ---> abort gap information
--- compare silicon counts/bunch current vs. bunch
--- pileup ---> WFD pulse integral vs. pulse height
--- stability of t definition: target and dead layer E_{loss}

c. Backgrounds

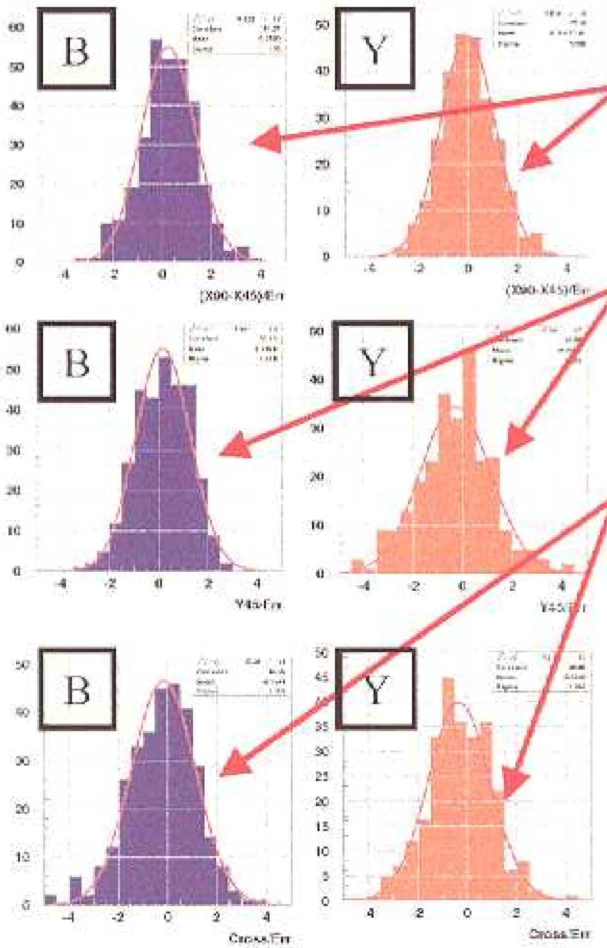
--- target out (frame in)
--- $pC \rightarrow p^*C$, $pC \rightarrow pC^*$ ---study kinematics, lifetimes
---issue for Cp↑ calibration
--- recoil mass plot

<u>Conclusions:</u> --- from data ($\Delta\varepsilon/\varepsilon|_{pC\ CNI} \oplus \Delta A_N/A_N|_{pC\ CNI}$) </= 3%

--- from dead layer study $\Delta A_N/A_N|_{pC\ CNI} \approx 4\%$

False asymmetry distributions

(data Dec.22th-End, no energy correction, bunch selection level-2 (tight cut))



(X90-X45)/Err
- Mean 0.25(B) / -0.02(Y)
- Sigma 1.11(B)/ 1.10(Y)

σ_{syst} = B: $0.5\sigma_{stat}$
Y: $0.5\sigma_{stat}$

Y45/Err
- Mean 0.16(B) / -0.30(Y)
- Sigma 1.11(B)/ 1.43(Y)

σ_{syst} = B: $0.5\sigma_{stat}$
Y: $1.0\sigma_{stat}$

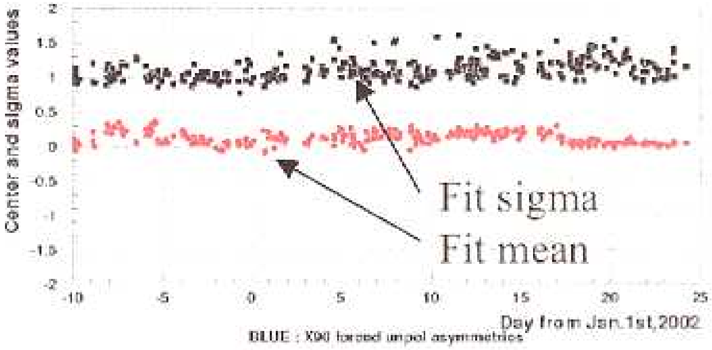
Cross/Err
- Mean -0.17(B) / -0.32(Y)
- Sigma 1.30(B)/ 1.26(Y)

σ_{syst} = B: $0.8\sigma_{stat}$
Y: $0.8\sigma_{stat}$

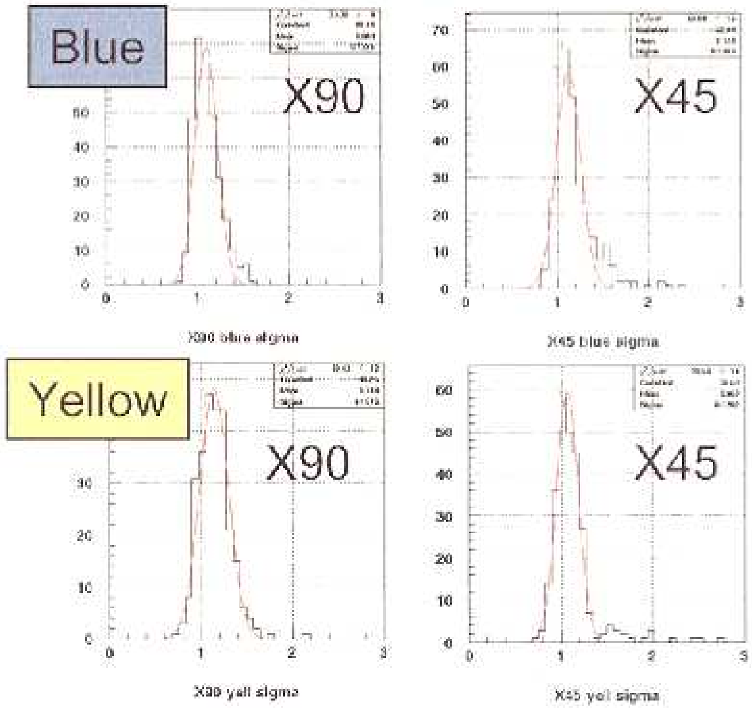
The size of systematic error is estimated with this relation, assuming leftover after subtracting the statistical contribution can be attributed to systematic errors.

$$\sigma_{systematic} = \sqrt{\sigma^2_{observed} - \sigma^2_{statistics}}$$

Randomized spin bit patterns ($P_{beam} = 0$)



Fitting sigma distributions



- Basic idea is to see the distribution of physics asymmetries with forced un-polarized spin bit pattern
- Random combinations of un-polarized spin bit patterns are iteratively tried for each CNI run
- Left plots shows the Gaussian sigma distribution from the fittings to each measurement

X90

σ_{syst} = B: $0.5\sigma_{stat}$
Y: $0.5\sigma_{stat}$

X45

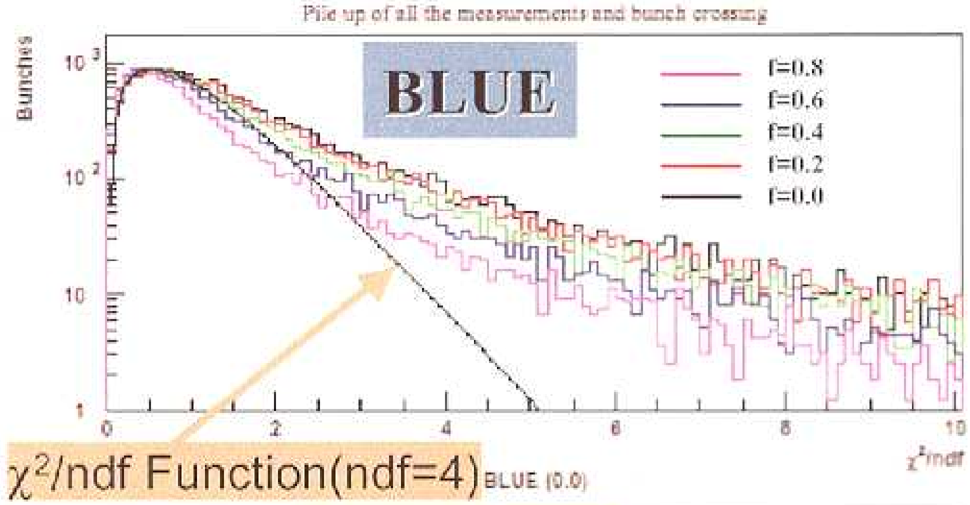
σ_{syst} = B: $0.6\sigma_{stat}$
Y: $0.4\sigma_{stat}$

Fit detector Φ dependence : $\frac{N_i(\Phi)}{N_0(\Phi)} = a + \varepsilon \sin\Phi$

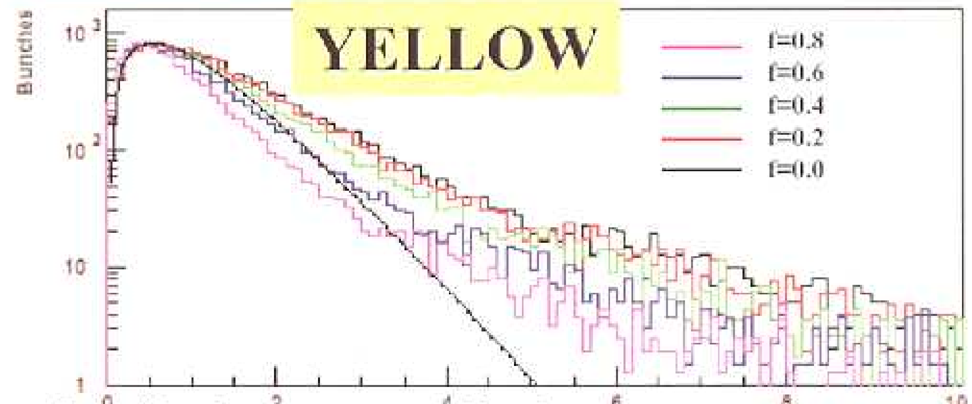
i = each bunch

0 = "standard bunch"

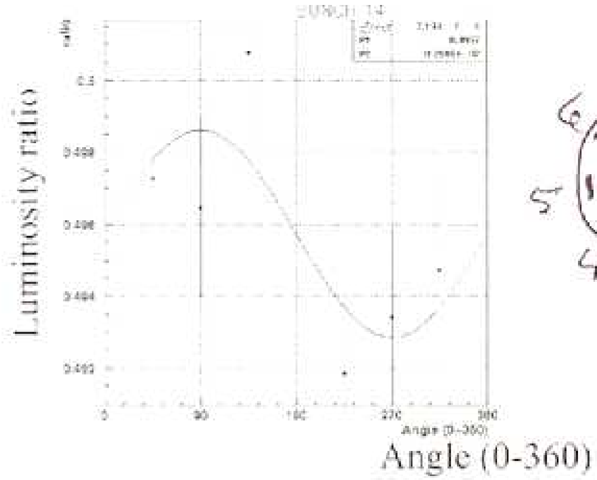
Scaled χ^2/ndf distributions

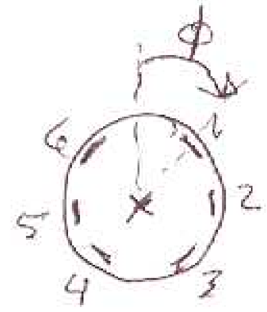


χ^2/ndf Function(ndf=4)



- Distributions are normalized with the maximum contents





$$\chi^2 = \sum_{\text{detector}} \left(\frac{(x_i - \bar{x}_i)^2}{\sigma_{stat}^2 + \sigma_{sys}^2} \right)$$

$$= \frac{1}{(1+f^2)} \sum_{\text{detector}} \left(\frac{(x_i - \bar{x}_i)^2}{\sigma_{stat}^2} \right)$$

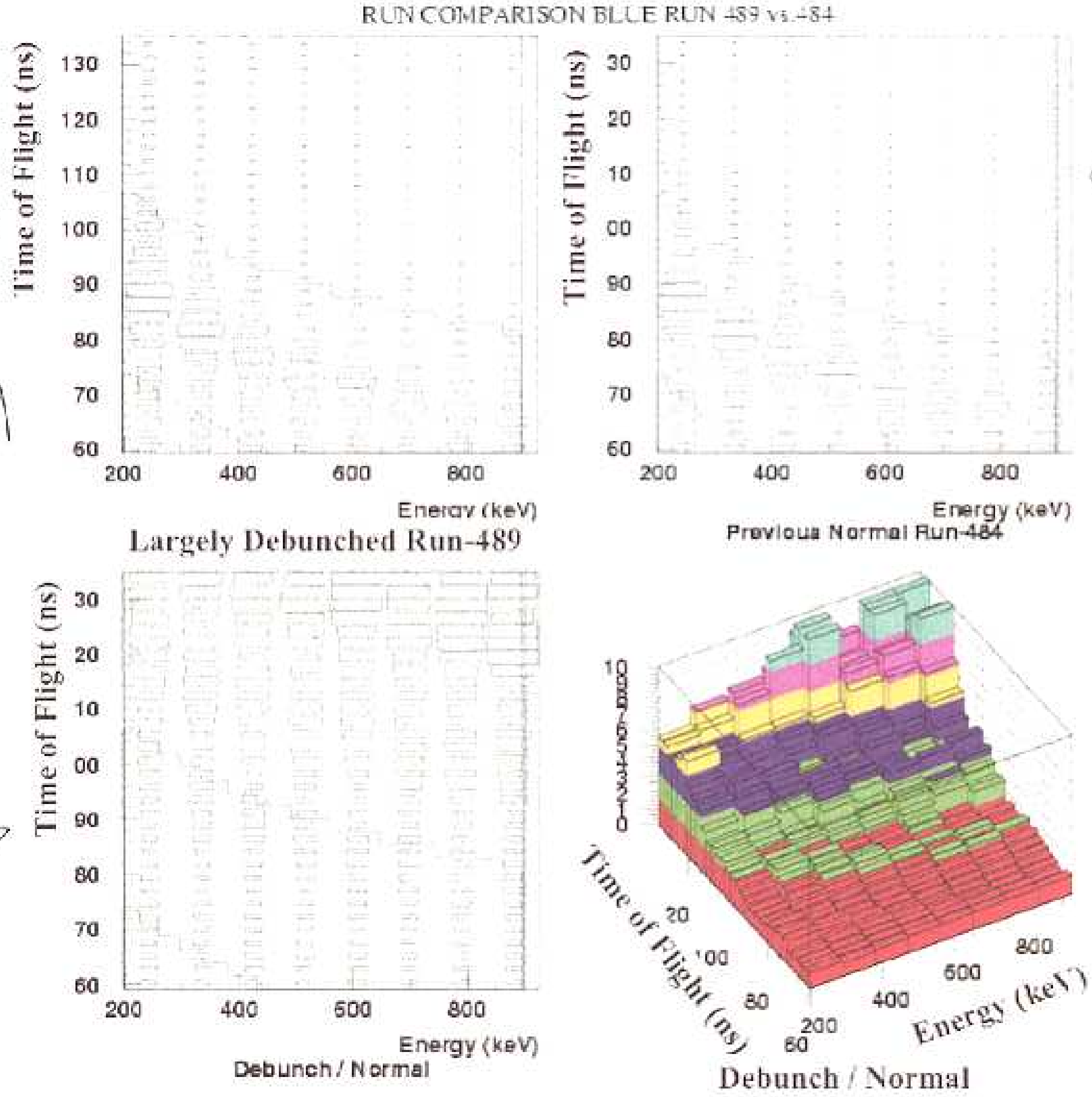
Debunched beam (seen for 5 fills)

debunched beam observed by RHIC →

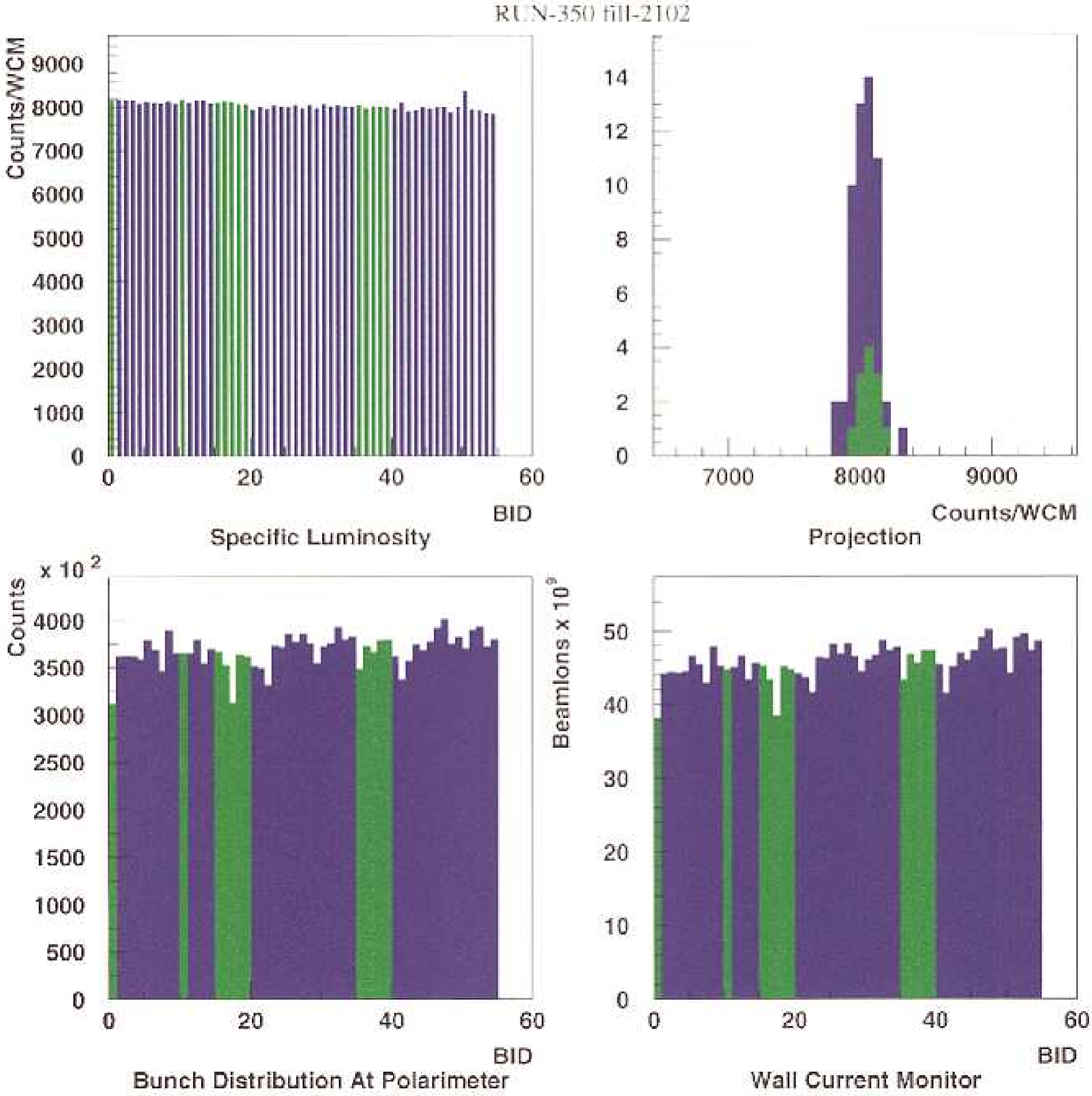
$\frac{\sum_i I_i \text{ (bunches)}}{I_{total} \text{ (no bunch timing)}}$ ⇐ [K]

$\frac{\text{Debunched}}{\text{Bunched}}$ →

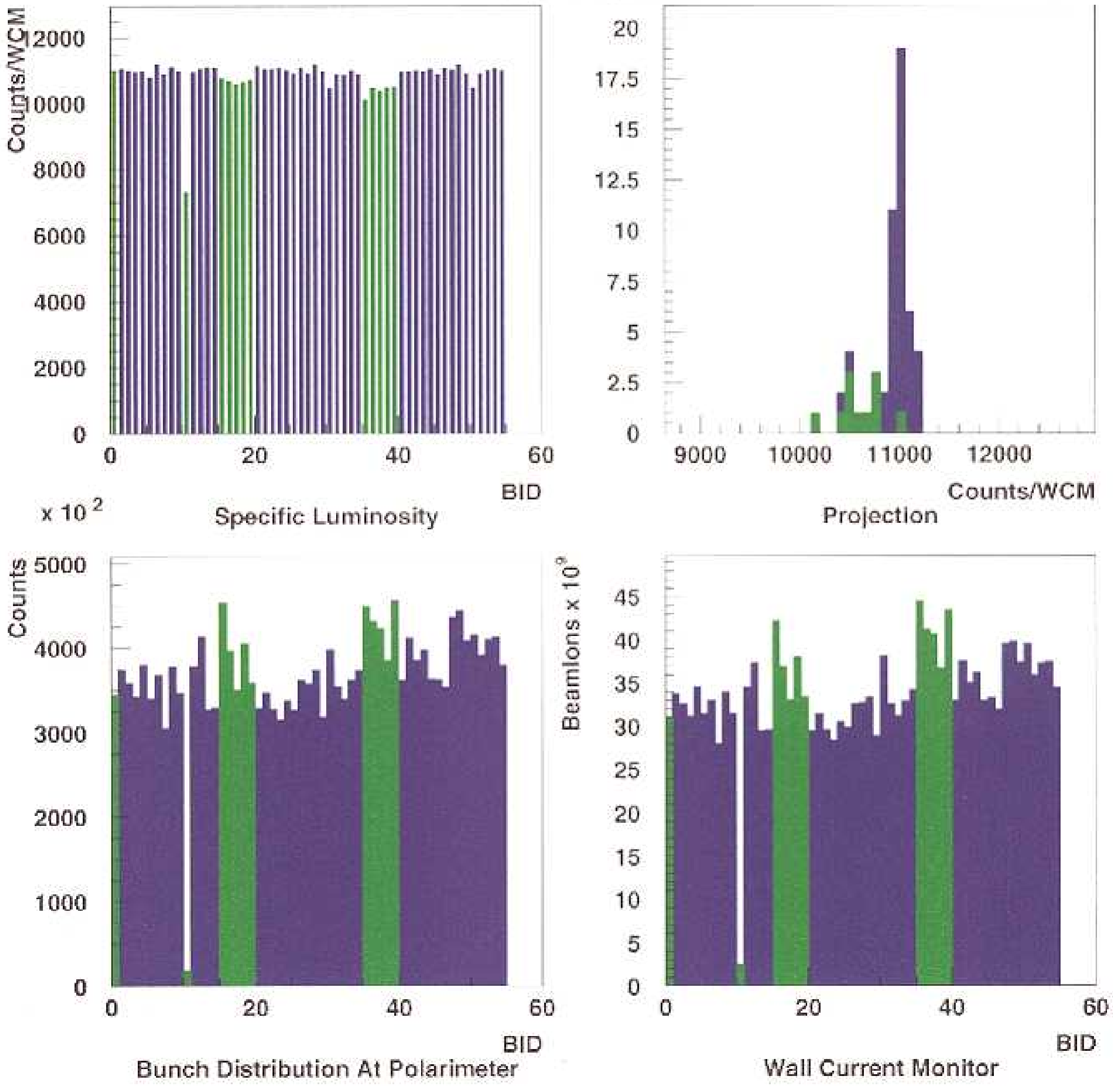
← normal



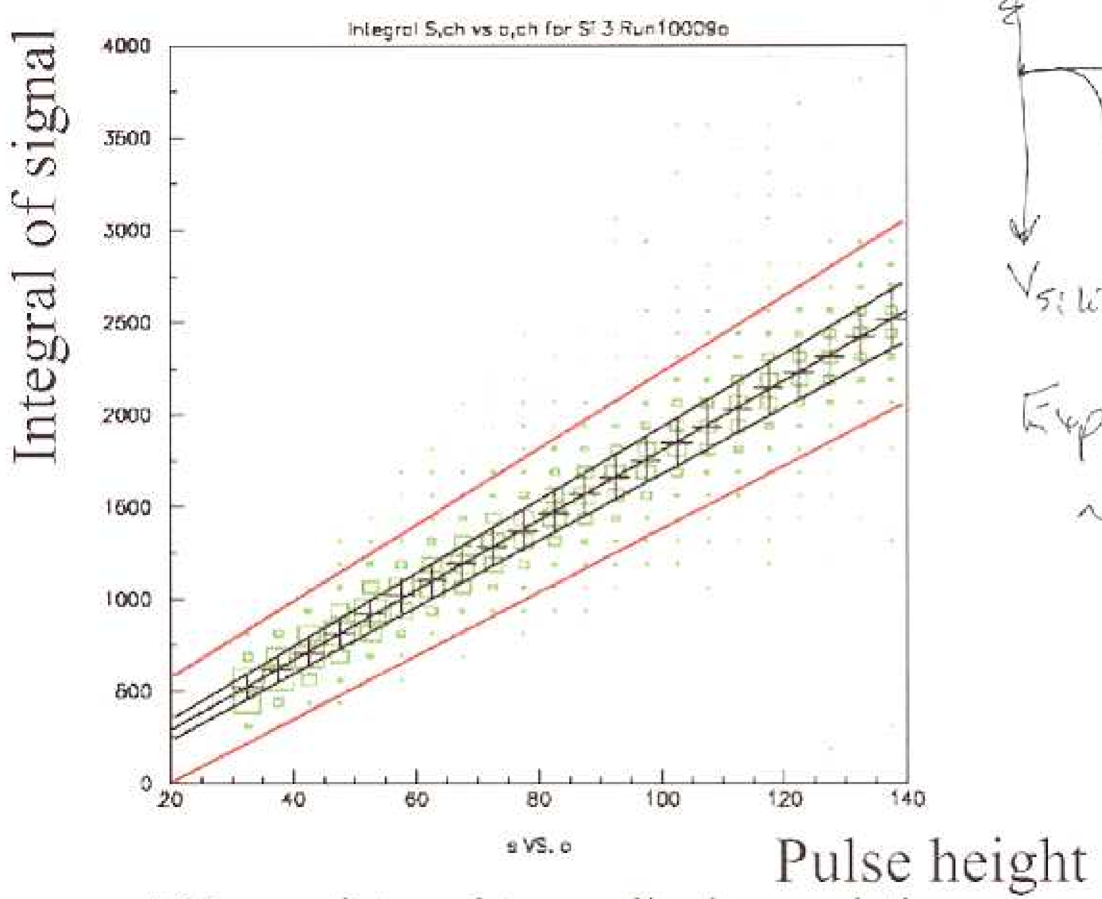
Silicon detector counts normalized to bunch current.

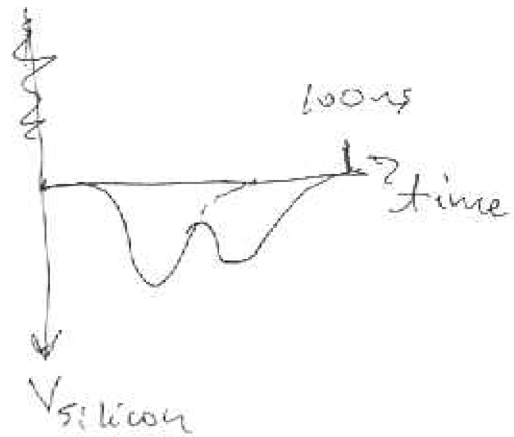


RUN-417 fill-2127



Pileup tool: ∫silicon signal vs. pulse height

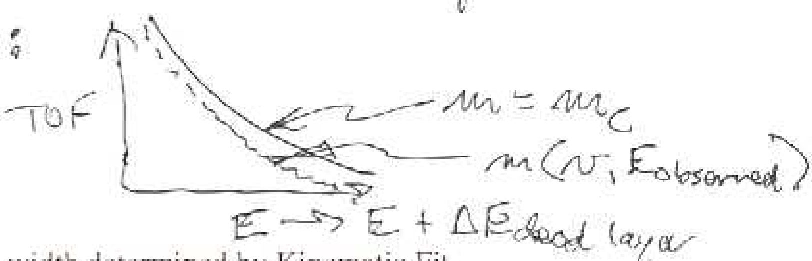




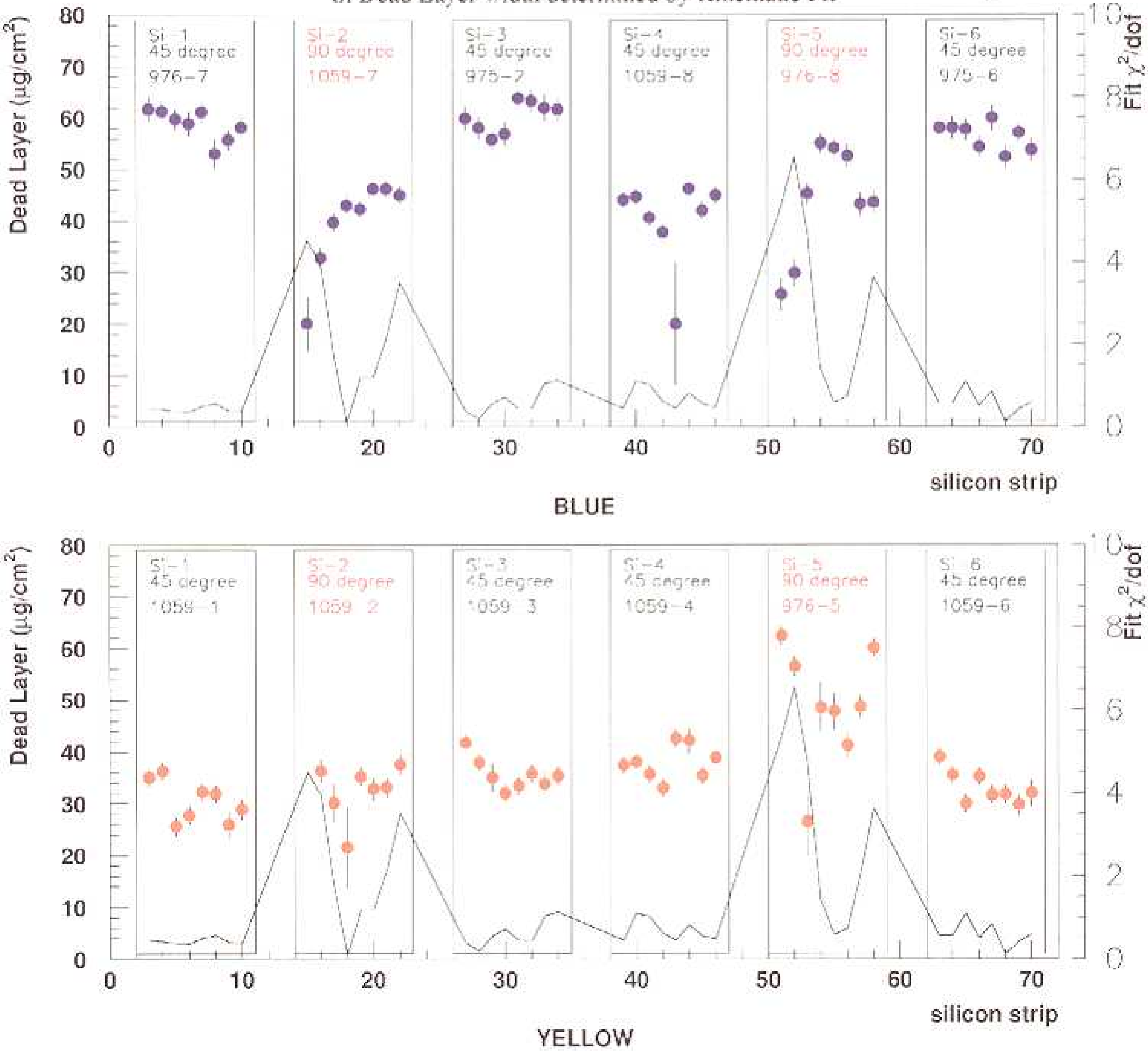
Expected pileup $\sim \frac{1}{2}\%$ (2002)

- Narrow integral to amplitude correlation (25 KeV) because of signal shaping
- Most noise from the Si detector

Uncertainty in $\overline{A_N}$ from uncertainty of silicon Dead Layer:



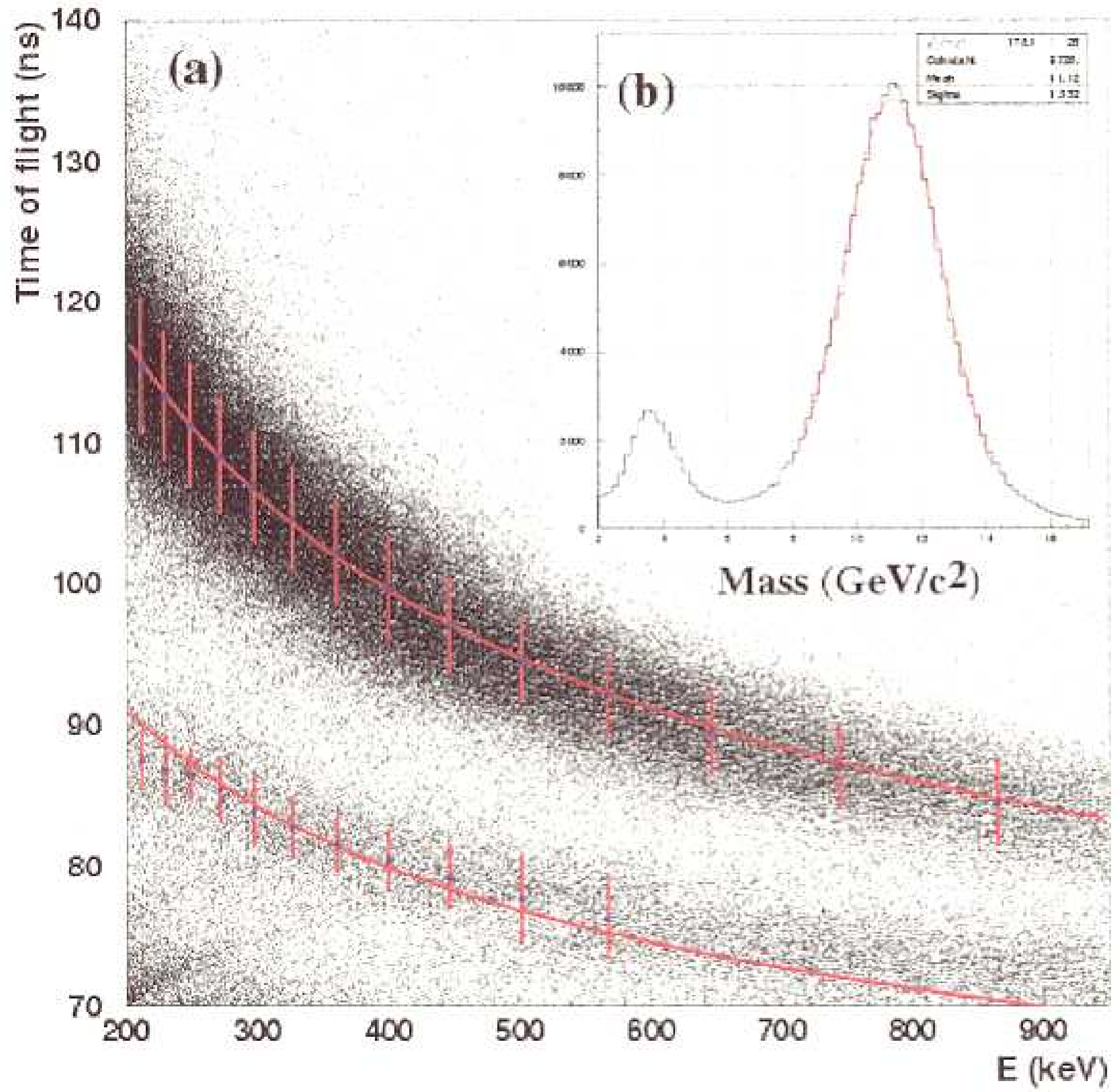
Si Dead Layer width determined by Kinematic Fit



① Comparing wafers ⟹ Δ dead layer $< \pm 10\,\mu g/cm^2$

② $\Delta E_{Loss} = \pm 25$ keV at $-t = .84 \times 10^{-2} \Rightarrow \delta t \pm .06\ (GeV/c)^2$

③ $\frac{\Delta \overline{A_N}}{\overline{A_N}} \approx \frac{\delta t}{\Delta t} = \frac{\pm .06}{1.5} = \pm 4\%$


(a)
(b)
Time of flight (ns)
140
130
120
110
100
90
80
70
200
300
400
500
600
700
800
900
E (keV)
Mass (GeV/c2)

5. Carbon beam calibration

Use carbon beam, elastic scattering in CNI region from polarized jet target, measure $A_N|_{pC}$ directly!

--- G. Igo and I. Tanihata

--- can only reach equivalent of 100 GeV

--- requires that $A_N|_{pC}$ (detector) = $A_N|_{pC}$ (physics)

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6. Other issues which we have thought of and which need study

--- polarization of beam at pC polarimeter vs. at jet (not a problem)

--- polarization profile of beam

--- the jet, pC polarimeters, and collider expts. weight the polarization differently

---> profile measurements of P_{beam} with pC polarimeters

--- continuous measurement with jet vs. sampling with pC polarimeter

Summary of issues to measure P_{beam} to 5% of itself

Calibrate pC polarimeter:

P_{Jet} ---> A_{pp} ---> P_{beam} ---> $A_{pC\ CNI}$ ---> P_{beam} ---> experiments

$3\% \oplus 2\% \oplus 2\% \oplus 3\% \oplus 3\% = \pm 6\%$

Use polarized jet directly:

P_{Jet} ---> A_{pp} ---> P_{beam} ------------------------------> experiments

$3\% \oplus 2\% \oplus 2\% = \pm 4\%$

Carbon beam measurement with jet, calibrate pC polarimeter

Denser unpolarized jet, use A_{pp} from polarized jet directly

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Many studies and issues on beam <---> pC polarimeter interactions

$$\Delta P_{beam}/P_{beam}|_{Jet} \oplus \Delta\varepsilon/\varepsilon|_{pC\ CNI} \oplus \Delta\varepsilon/\varepsilon|_{pC\ CNI} \oplus \Delta A_N/A_N|_{pC\ CNI} = \Delta P_{beam}/P_{beam}$$