RHIC Polarimetry

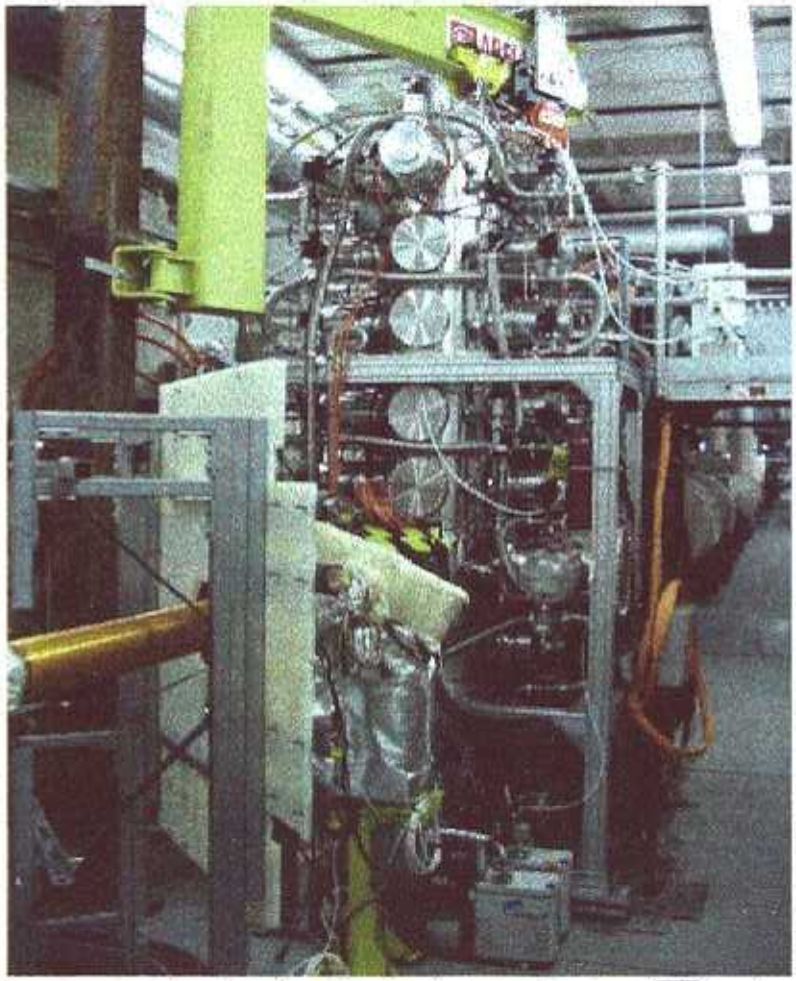
Status of Polarimeters

Progress during 2004

Plans for 2005

Analysis of JET and RHIC *pC*

Where do we stand and what next



Alessandro Bravar et al.

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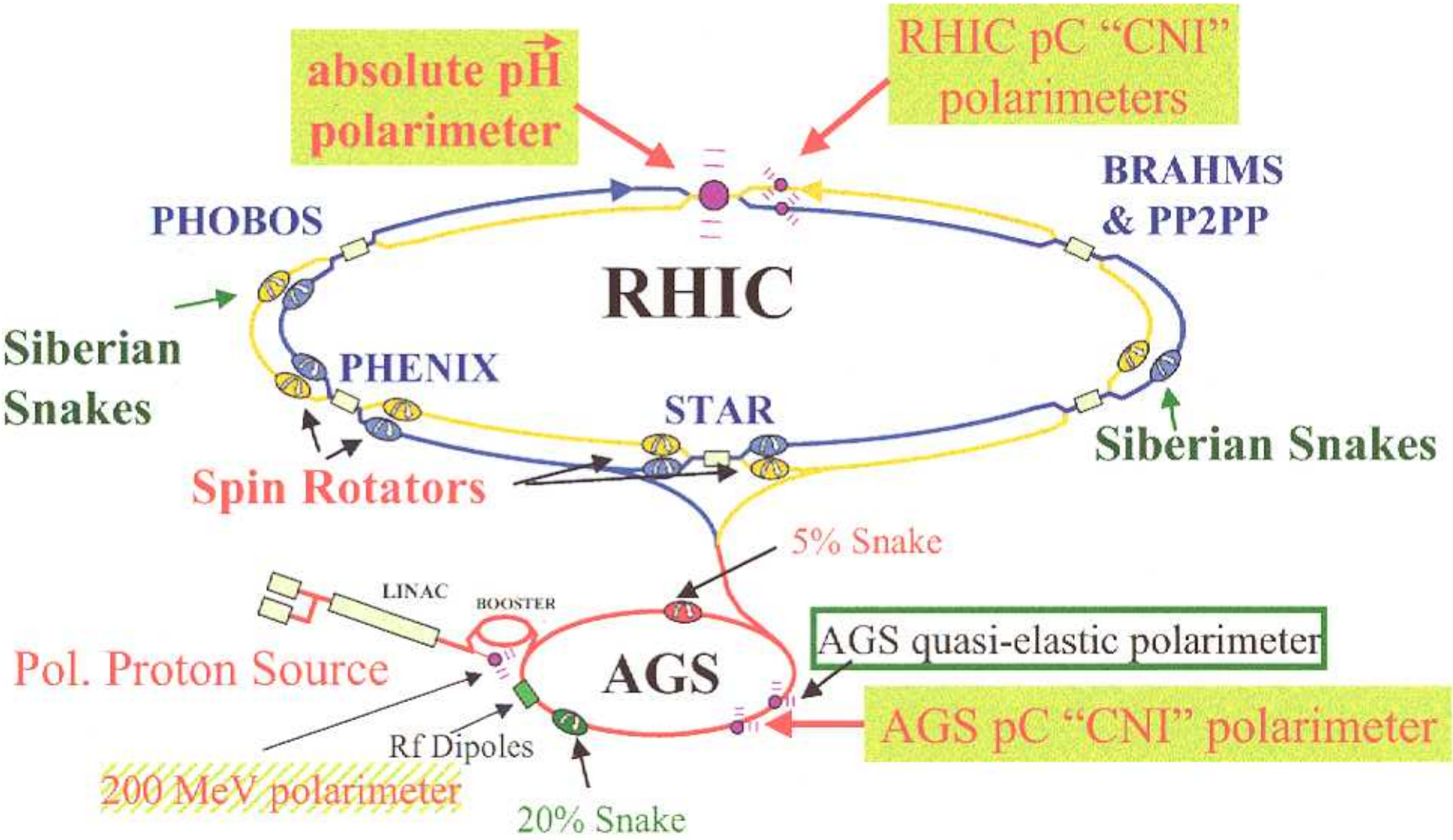
RSC meeting, July 22 '04

RHIC *pp* accelerator complex & Polarimeters



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AGS *pC* polarimeter

- No more beam induced pickups !
  - solved all intensity related issues
  - works reliably up to and above 2×10^{11} p / bunch
- Further developments in parallel with RHIC *pC* upgrades
  - faster DAQ
  - automated calibrations
  - computer controlled Power Supplies
- 45^0 detectors ?
  - in principle ready, need more electronics
- Pending issues to be solved before next run: TARGET !
  - target position
  - polarimeter chamber alignment w.r.t. beam
- Otherwise, ready to restart operations anytime (few days to warm up)

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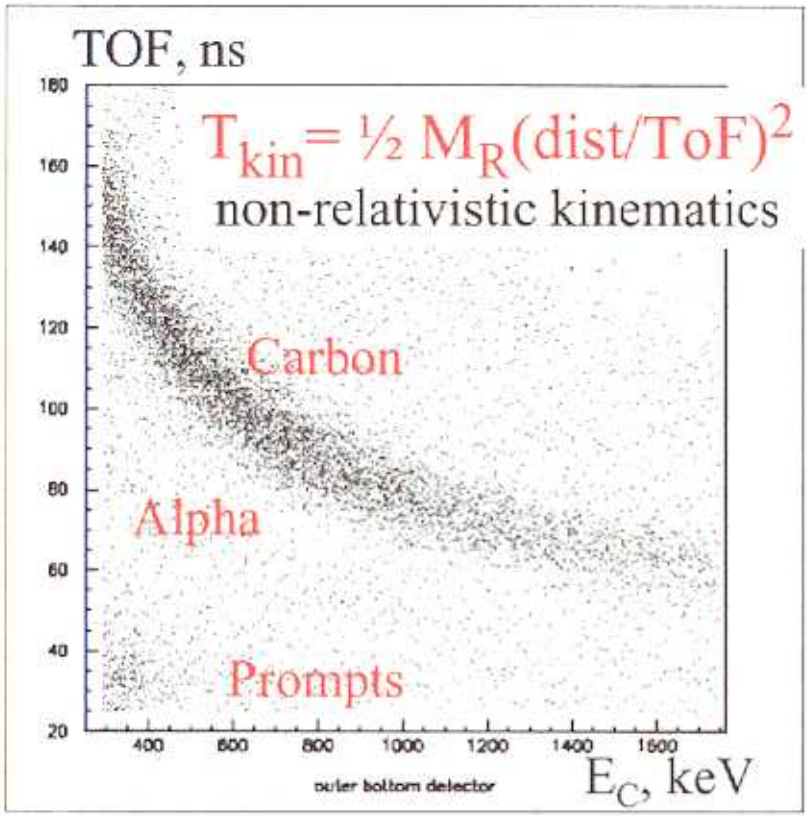
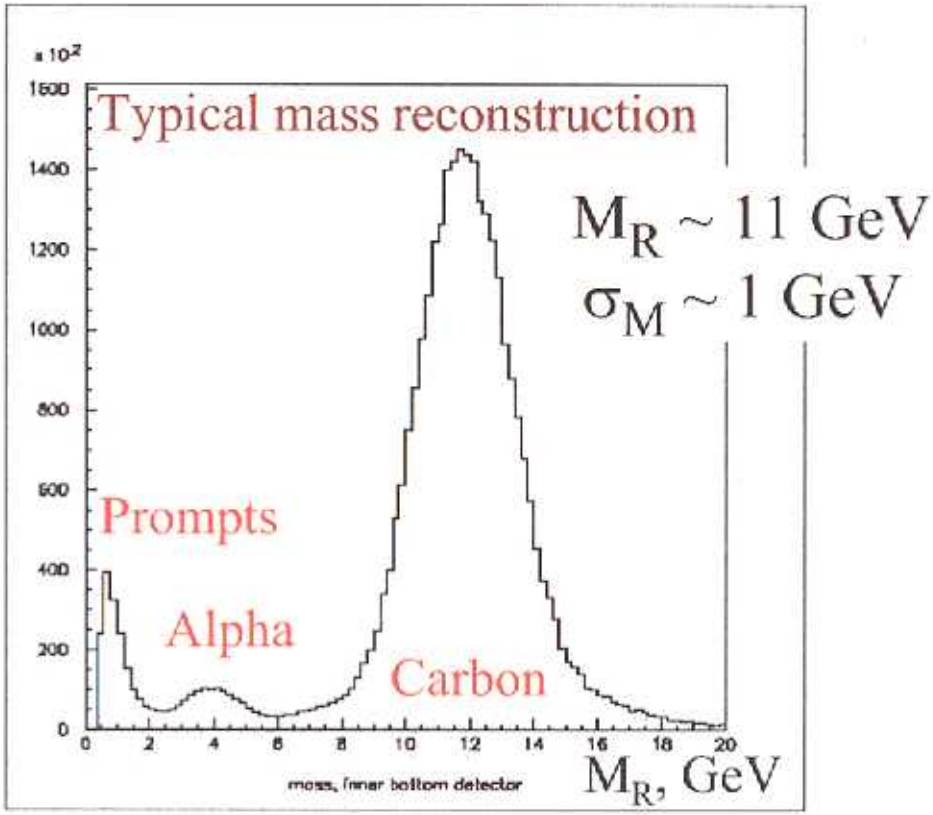
Performance





- Very clean data
- Good separation of recoil carbon from α ($C^* \rightarrow \alpha + X$) and prompts
  very low background, may allow going to very high $|t|$ values
- Low χ^2 of sequential measurements – stable operation

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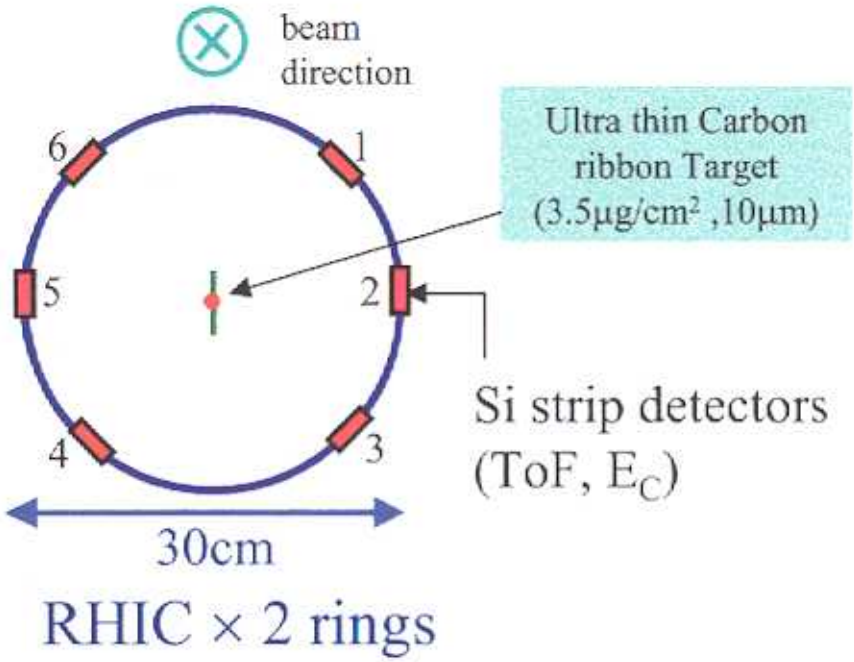
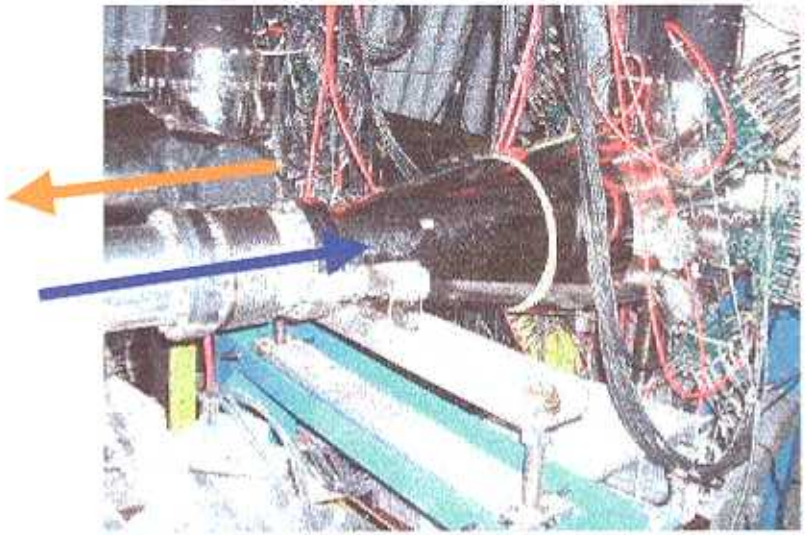
RHIC *pC* Polarimeters



inside RHIC ring @IP12



- 2 × 72 channels read out with Wave Form Digitizers (2 × 48 in 2003)
- very large statistics per measurement (~ 20 × 10^6 events) → detailed analysis
  - bunch by bunch analysis
  - channel by channel (each channel is an "independent polarimeter")
  - 45° detectors: sensitive to vertical and radial components of $\vec{P}_{beam}$
    → unphysical asymmetries

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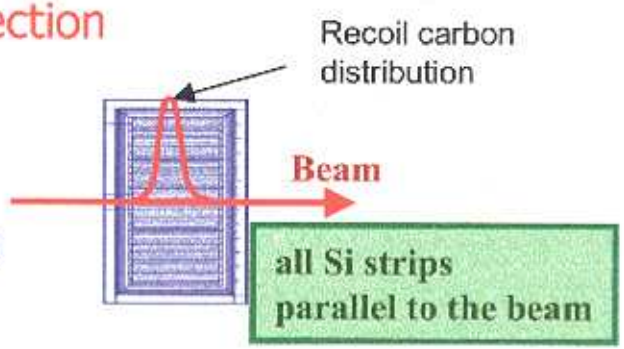
New ++ features from Run-04

- All Si detectors (strips) now parallel to the beam direction
- Readout all 72 strips (48 strips in Run-03)
  - approximately double the acceptance
  - no direct information about longitudinal target position



- Additional information : revolution numbers
  → event builder
  - complete time stamp for each event
  - although independent, all channels can be correlated
- Lowered the Carbon energy threshold to get better dP/P (400keV → 320keV)
  - A_N=0.016, Nev=20M → dP=1.4% (in Run-03: 2.0%)
  - however smaller signals !
    & more sensitive on dead layer correction !
- Several minor improvements on electronics
  → Very stable operation / performance during the whole run
- Several ramp measurements
- Spin tune measurements

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pC Polarimeter systematic issues

- calibration only at 22 GeV to ± 30%
  assume: A_N (E950) = A_N (24.3 GeV) = A_N (100 GeV)
  soon will have absolute calibration from JET target
- observed systematic error of relative measurements to $\Delta P = \pm 3\%$
- during '04 run very stable operation
  - effective A_N for each measurement very stable and around 1.5 %
  - very low backgrounds
- energy scale
  - dead layer energy correction
    small change → small change in $|t|$ → significant change in $A_N(t)$
  - however radiation damage not an issue
- beam wake fields induced pickups
  - solved in AGS, will be implemented in RHIC for '05 run
- beam polarization profile
  - the *pC* CNI polarimeter sees only the beam center while the experiments & JET integrate over the whole profile

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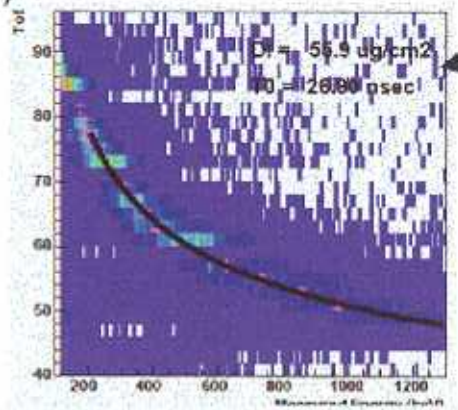
Update on Si dead layer

Osamu

Si dead layer is estimated by kinematic fit (2parameters) to carbon locus
Energy scale set by AM α source
A run with low bunch intensity (~0.1x10^{11}/bunch) was used

$$Tof(ns) = \sqrt{\frac{M_C}{2}\frac{Distance}{\sqrt{E_{elastic}}}} + t_0$$

$$E_{elastic} = f(E_{deposit}, D_{width})$$

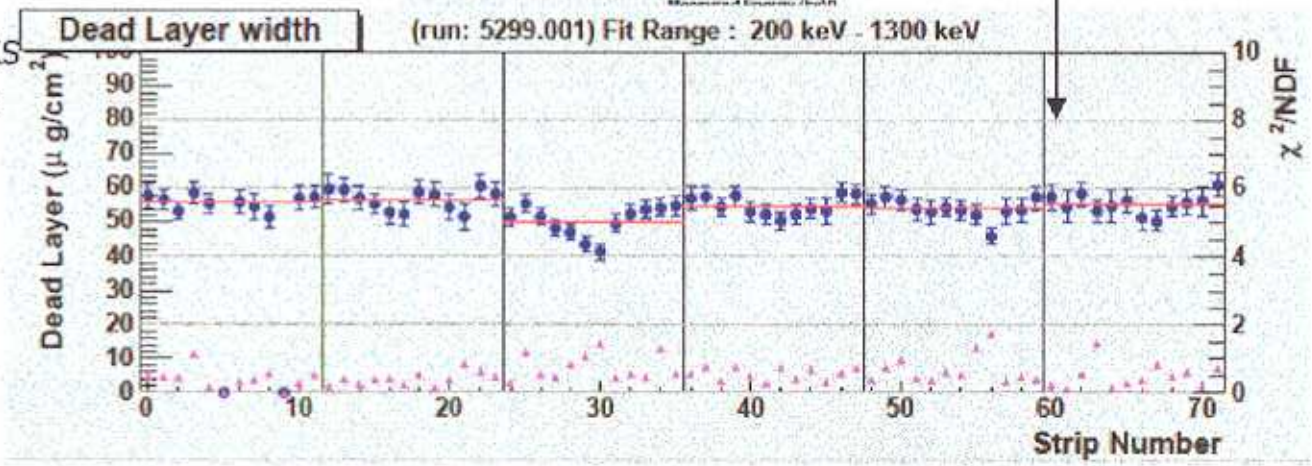


fit example for one strip

Fit result summary strip by strip distribution
blue – estimated values
pink – χ^2 of the fit

Carbon locus based on (Amplitude, TDC at max pulse height) is used for the fit

TDC bins at the periodical peaks (highest, and lowest of 6-point structure in WFD, expected to have wrong timings) removed from the fit



ISSUES

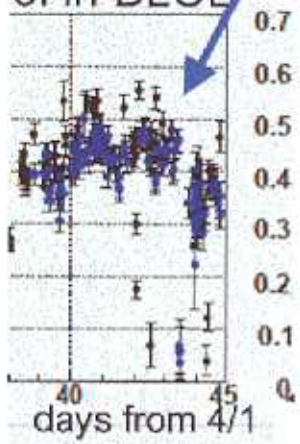
- Mean value (54μg/cm^2) large compared to estimates from B implantation energy (40keV→ 33μg/cm^2)
- baseline shifts / subtractions, beam pickups, energy calibration, additional SiO_2 layer are possible explanations
- Try other parameterizations for better fit results
- Comparisons with Tandem tests and ^{241}Am source measurements are necessary, however, ultimately the thickness of the entrance window must come from the actual data

Osamu

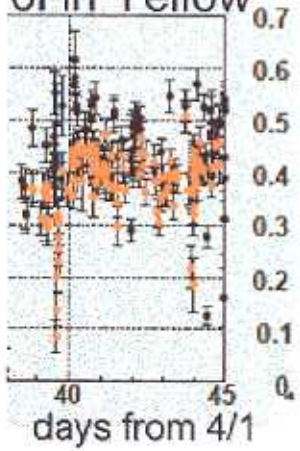
Low blue polarization during last 1.5 days

Polarization drop was observed, when the target was switched from vertical to horizontal (black:24GeV color:100GeV)

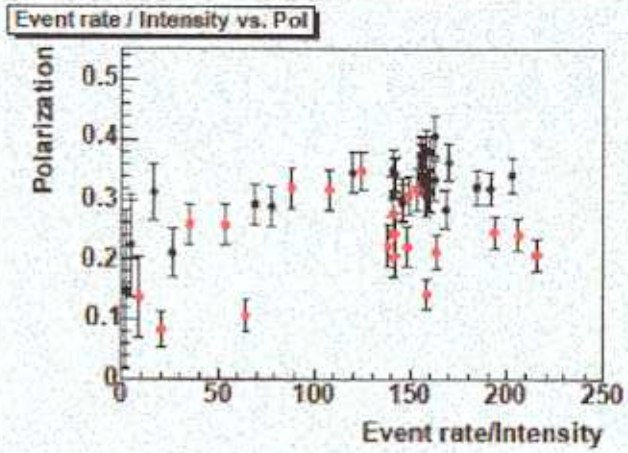
Pol in BLUE

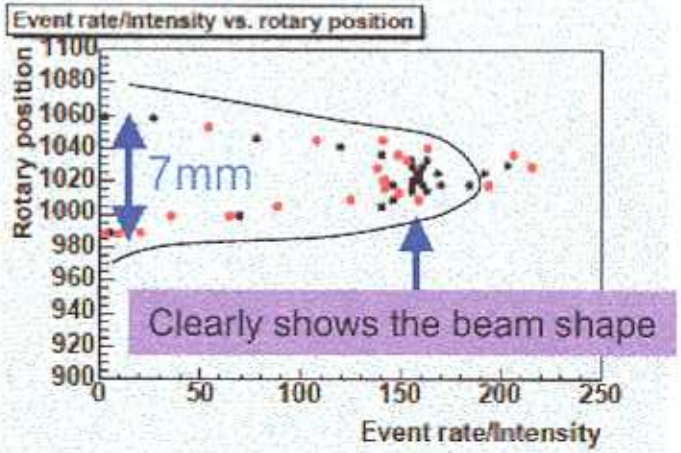


Pol in Yellow



Some correlations for this horizontal target





It is understood that the flattop (100GeV) runs in the last 1.5days (Black points) are mostly taken at the center of the beam

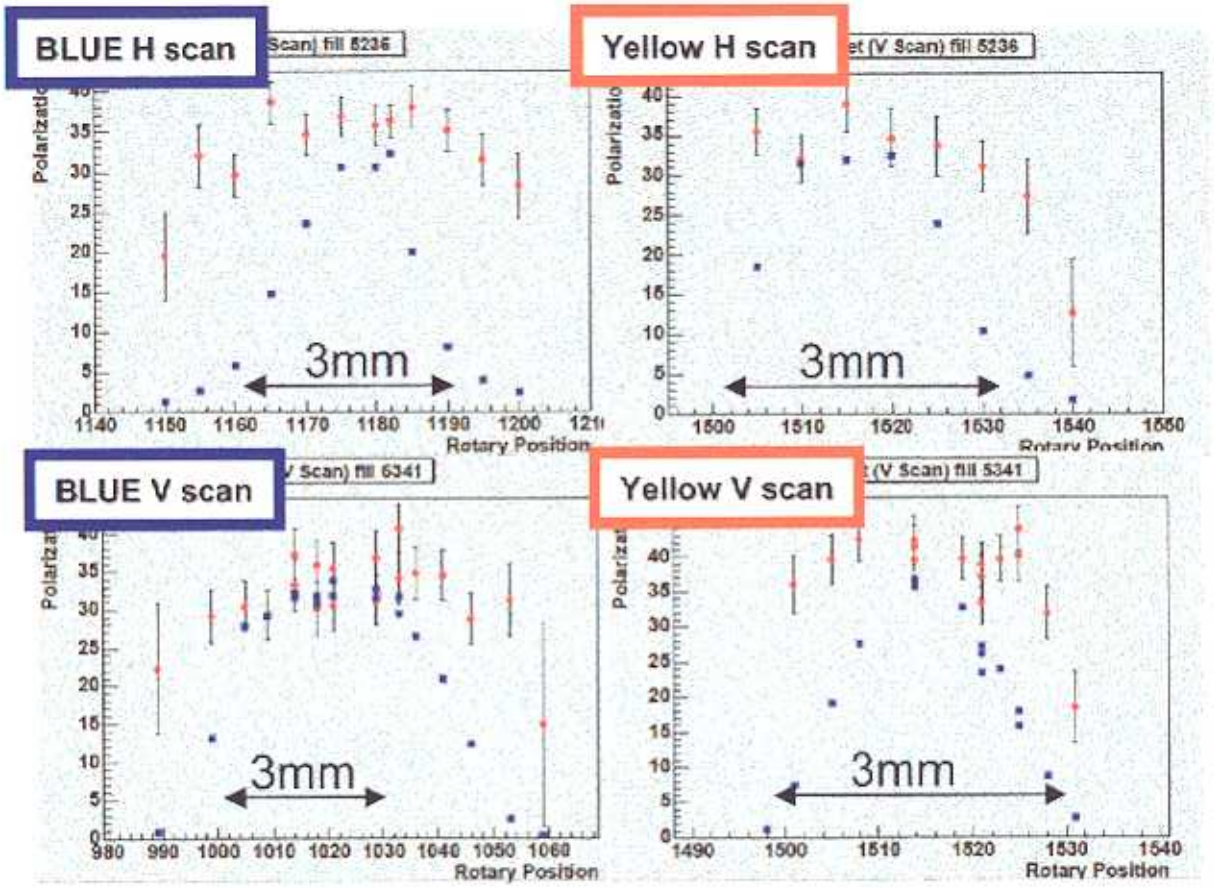
Red points are the data from other period of time when this target was used (in April)

Longitudinal target position was also confirmed to be correct with $-t$ slope

False asymmetries (cross/radial) were normal

During the run the X45 asymmetires always consistent with X90 ones

RHIC polarization profile



- Polarization
- Beam Intensity

H Scan --horizontal scan with vertical target

V Scan – vertical scan with horizontal target

large polarization profile in vertical direction (small profile in horizontal)
observed position dependent fluctuation in polarization measurements

an issue for "calibration": the JET integrates over the full beam profile
the *pC* CNI polarimeter measures the beam center

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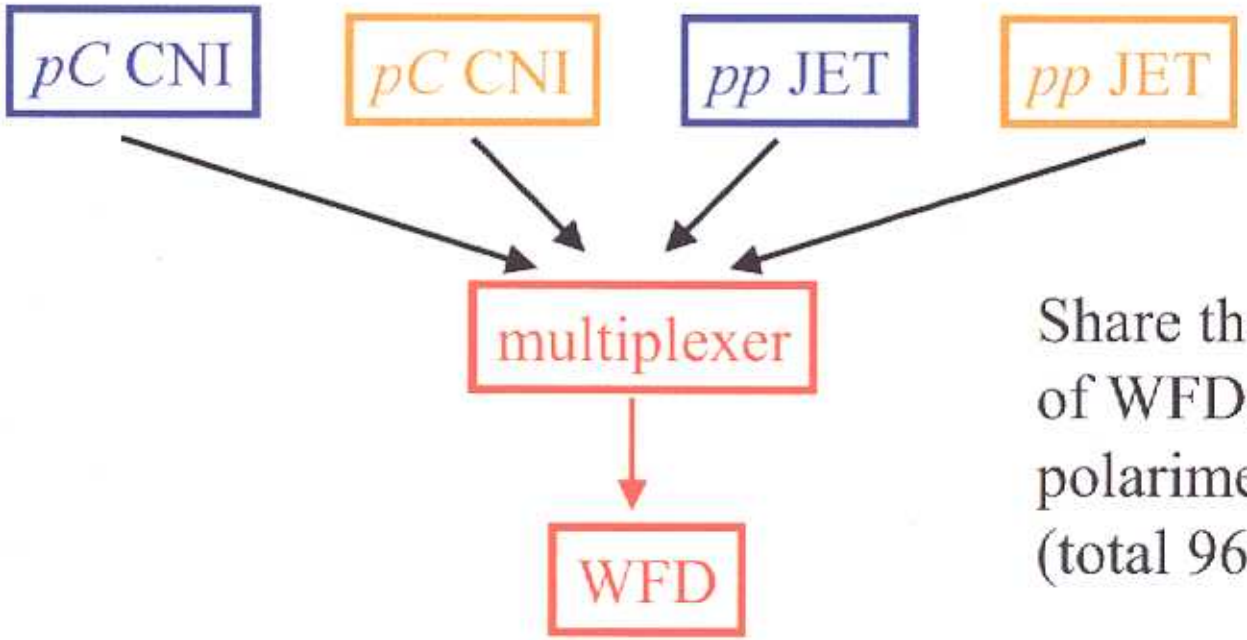
Running scheme in 2004

alternate measurements with *pp* CNI (JET) and *pC* CNI polarimeters about each hour

pp measurement: only fraction of whole statistics
pC measurement: $> 2 \times 10^7$ events (full measurement)



Share the same set of WFDs for all RHIC polarimeters (total 96 ch.)

same WFD code for *pC* CNI and JET polarimeters

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2005 *pC* upgrades

- Rebuild polarimeter as the AGS to remove beam pickups
  - for 2005 run will use UHV components everywhere
    however not all materials can be baked
- Definitively solve all target related issues
- All upgrade works / developments expected to be fully completed before the end of 2004 (vacuum, detectors, electronics, slow control, etc.)
  - however not in time for installation before the cool down
  - install during 3 day shut down for JET target installation
- New scheme for target controls and
  New scheme for polarization measurements
- Faster DAQ
- Upgraded FPGA algorithms
- 2nd generation Front End electronics
- Solve all Si entrance window (dead layer) related issues
- however not yet ready for 120 bunch mode operation

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Recoil Si spectrometer

$A_N^{beam}(t) = -A_N^{target}(t)$

for elastic scattering only!

$P_{beam} = -P_{target} \cdot \varepsilon_N^{beam} / \varepsilon_N^{target}$

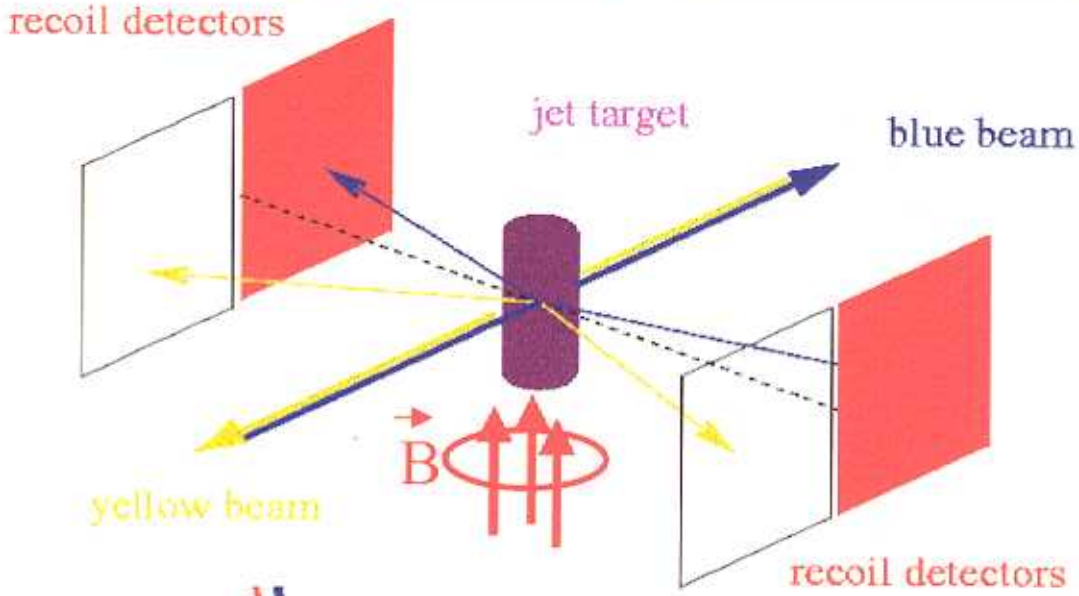
6 Si detectors covering blue beam

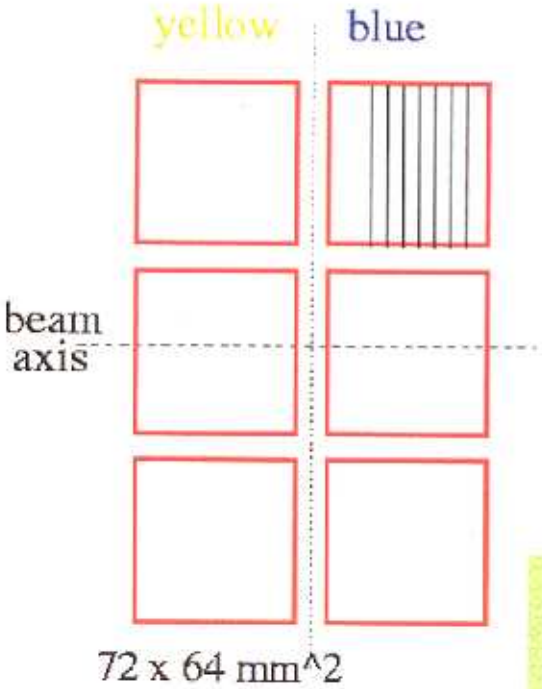
MEASURE

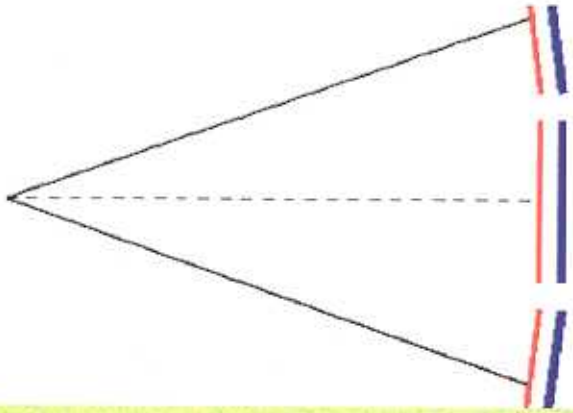
- energy (res. < 50 keV)
- time of flight (res. < 2 ns)
- scattering angle (res. ~ 5 mrad)

of recoil protons from

$pp \rightarrow pp$ elastic scattering







HAVE "design" azimuthal coverage

one Si layer only

⇒ smaller energy range

⇒ reduced bckgrnd rejection power

Si detectors from BNL Inst. and Hamamatsu

Electronics developed by BNL Inst. and Physics

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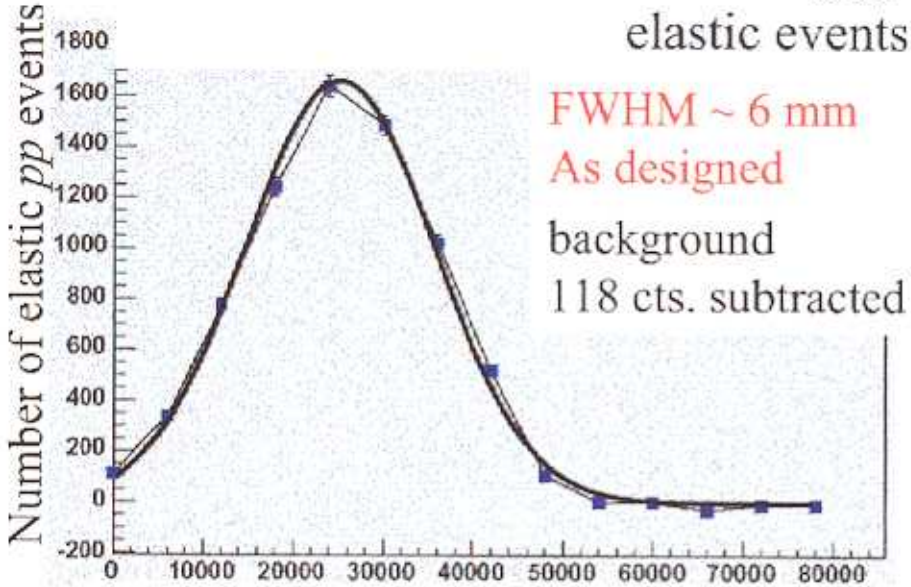
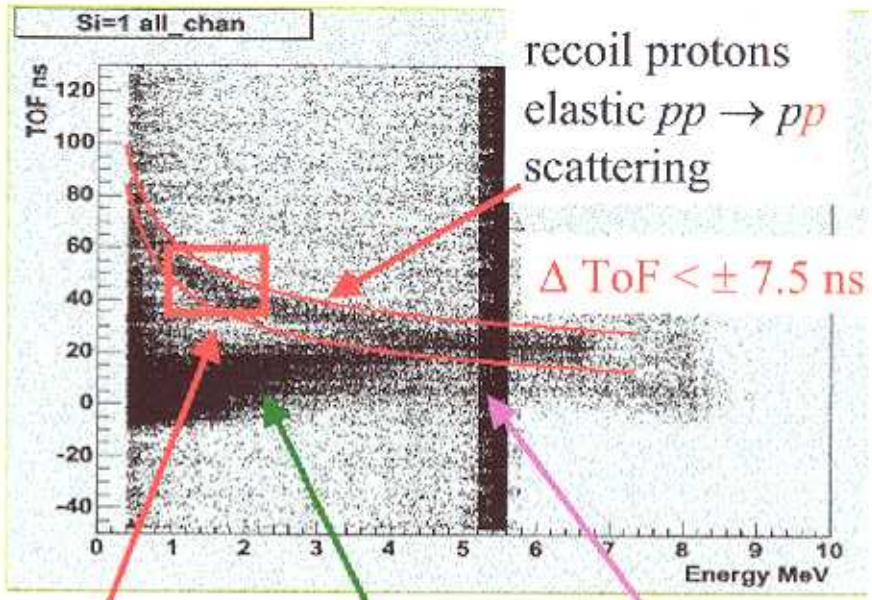
pp elastic data collected

ToF vs E_{REC} correlation
$T_{kin} = \frac{1}{2} M_R (dist/ToF)^2$

JET Profile: measured selecting *pp* elastic events



Hor. pos. of Jet 10000 cts. = 2.5 mm



recoil protons elastic $pp \rightarrow pp$ scattering

Δ ToF < ± 7.5 ns

CNI peak A_N
$1 < E_{REC} < 2$ MeV

prompt events and beam gas

α source calibration

- recoil protons unambiguously identified !
- 100 GeV ~ 700,000 events at the peak of A_N ~ 100 hours
  (~ 2 - 3 × 10^6 total useful *pp* elastic events)
- 24 GeV ~ 120,000 events at the peak of A_N ~ 17 hours
  (~ 4 × 10^5 total useful *pp* elastic events)

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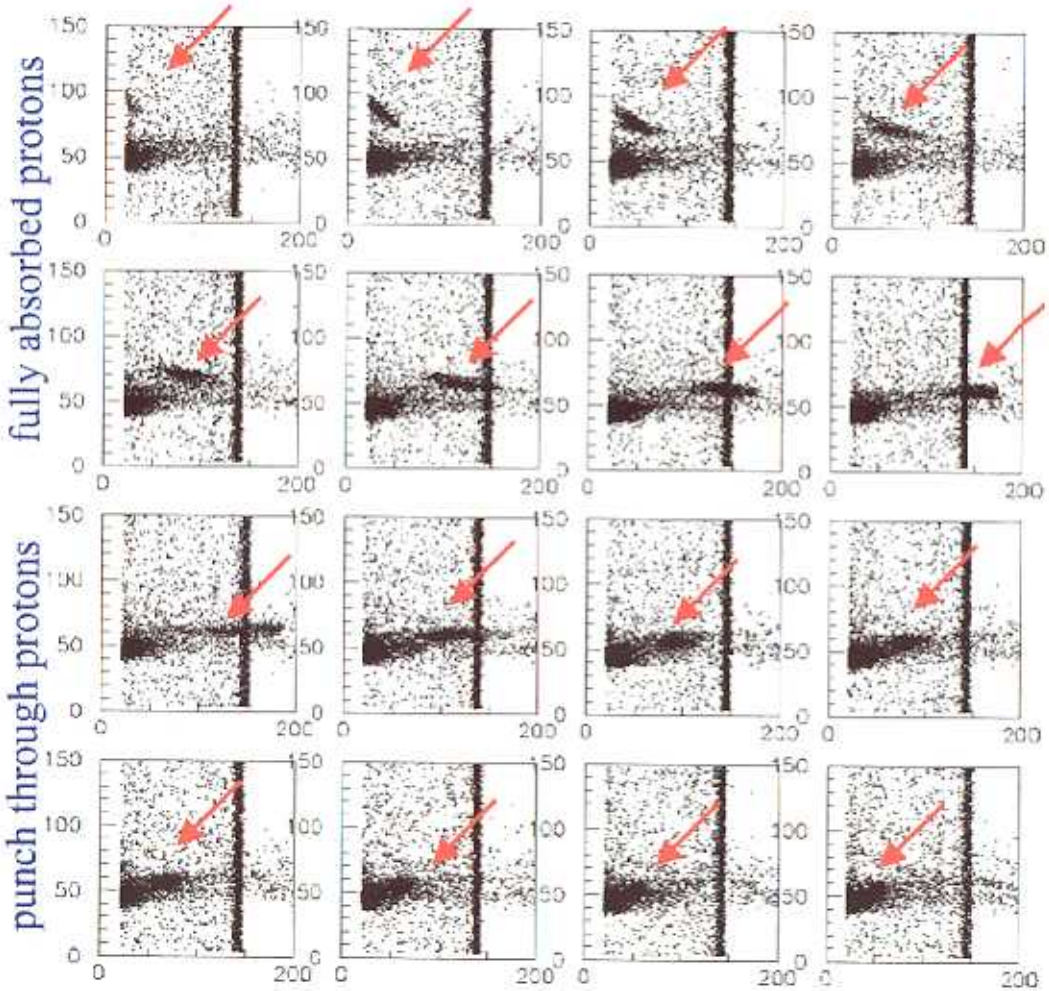
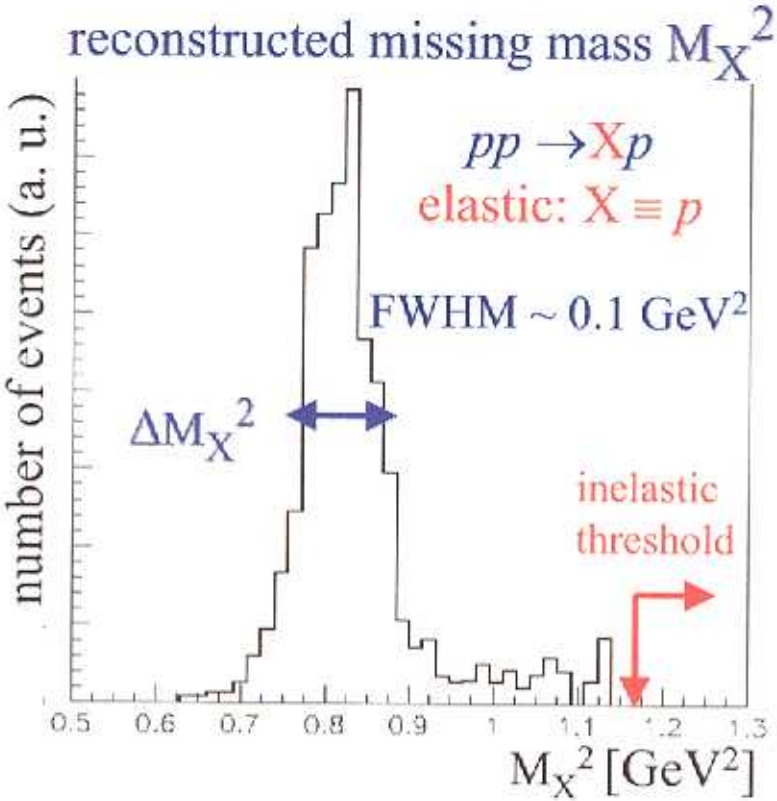
Energy - Position correlations

$T_{kin} \propto \theta^2$ (i.e. position^2)



TDC vs ADC individual channels



pp elastic events clearly identified !

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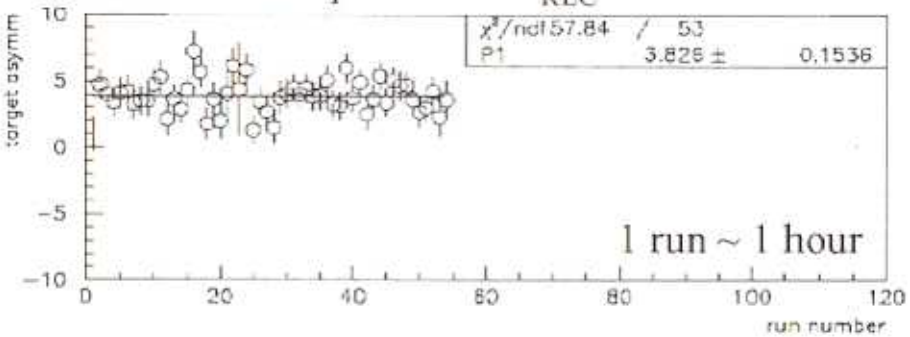
"ONLINE" measured asymmetries & Results

ONLINE ≡ statistical errors only
no background corrections
no systematic studies
no false asymmetries studies
approximate run selection

data divided into 3 p energy energy bins

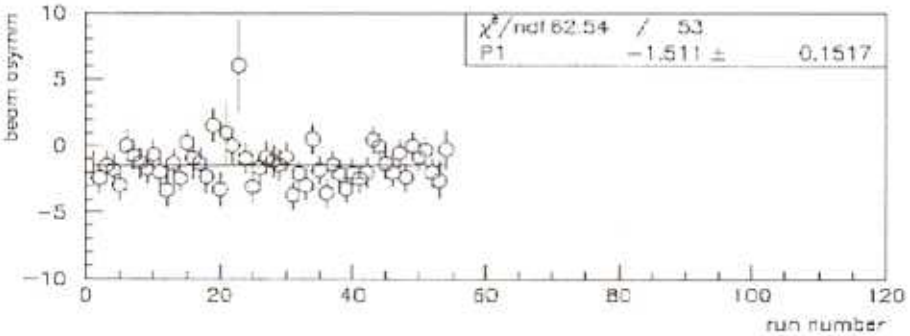
an example: $750 < E_{REC} < 1750$ keV

"Target": average over beam polarization



blue beam with alternating bunch polarizations: ↑↓ ↑↓ ↑↓ …

"Beam": average over target polarization



good uniformity from run to run (stable JET polarization)
JET polarization reversed each ~ 5 min.

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

$P_{beam} = 36.9\ \% \pm 1.9\ \%$

$\langle P_{beam}\ (pC\ \mathrm{CNI}) \rangle = 38.1\ \%$

No major surprises ?

(statistical errors only !)

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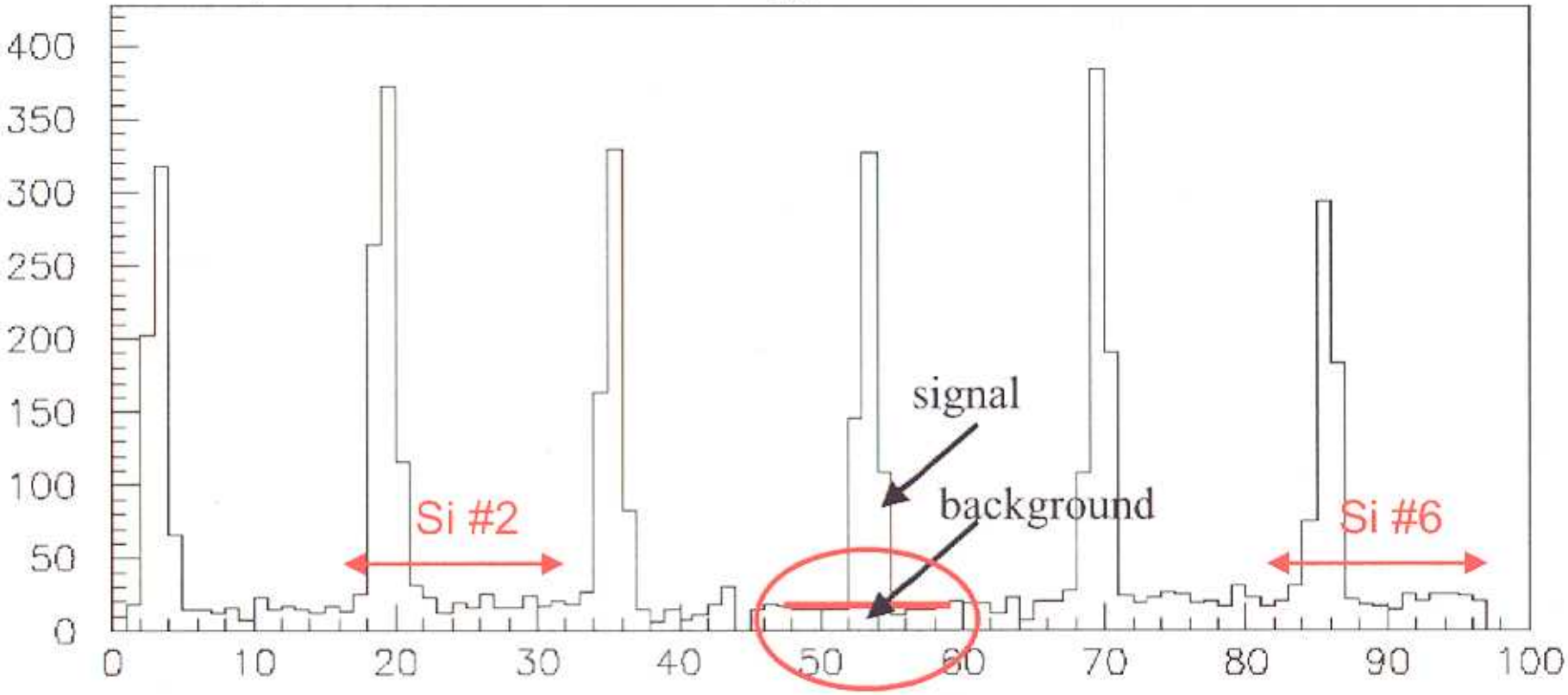
Event selections

Strip distribution for energy interval: 1250 – 1750 keV



visually implement the energy / angle correlation in selecting elastic *pp* events

typically, for each energy bin, select 3 to 4 strips per detector

future: replace this selection with a selection on M_X

Background only from selected channels not from whole detector (4 – 5 × smaller !)

Total Backgrounds < 8 %, α source ~ 4%, Physics Background ~ 4 %

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Backgrounds

- Divide sources of backgrounds in different categories
- α source: $\sim 2 - 4$ %
  unpolarized, uncorrelated $\rightarrow$ only dilution of measured asymmetries
  cancels in double ratio $\varepsilon_B / \varepsilon_T \rightarrow P_{beam}$
- beam gas interactions $\sim 1 - 3$ %
  (mostly from Blue beam)
- target interactions < 5%
  (estimated from the "data")

All backgrounds can be further reduced with tighter selections.

This level of backgrounds will not change our "ONLINE" conclusions, however need to take into account when finalizing the analysis

More dedicated studies being performed
in particular upper limit on "physics" background asymmetry

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The Road to P_{beam} with the JET target

Requires several independent measurements

0 JET target polarization P_{target} (Breit-Rabi polarimeter)

1 A_N for elastic *pp* in CNI region: $A_N = -1 / P_{target}\, \varepsilon_N'$

2 $P_{beam} = 1 / A_N\, \varepsilon_N''$

1 & 2 can be combined in a single measurement: $P_{beam} / P_{target} = -\varepsilon_N' / \varepsilon_N''$

"self calibration" works for elastic scattering only

3 CALIBRATION: A_N^{pC} for *pC* CNI polarimeter in covered kinematical range:

$A_N^{pC} = 1 / P_{beam}\, \varepsilon_N'''$

(1 +) 2 + 3 measured simultaneously with several insertions of carbon target

4 BEAM POLARIZATION: $P_{beam} = 1 / A_N^{pC}\, \varepsilon_N''''$ to experiments

at each step pick-up some measurement errors:

$$\frac{\Delta P_{beam}}{P_{beam}} = \left(\frac{\Delta P_{target}}{P_{target}}\right) \oplus \left(\frac{\Delta \varepsilon}{\varepsilon}\right)_{pp} \oplus \left(\frac{\Delta A_N}{A_N}\right)_{pC} \oplus \left(\frac{\Delta \varepsilon}{\varepsilon}\right)_{pC} \leq 6\%$$

expected precision

transfer calibration measurement

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What next for JET in 2005

- Complete Setup - install Si detectors also for the Yellow beam
  - several discussions with instrumentation division
  - agreed to process 16 wafers $\Rightarrow$ should yield 8 good detectors
  - expect delivery sometime in December '04
  - then we need about 10 weeks for installation / operation readiness

- Slower shaping amplifiers and new shaper boards
- New hybrid preamplifiers

- Extend $|t|$ range $\Rightarrow$ increase F.o.M. of JET polarimeter

- Add shutters to turn off the α sources for data taking

Prepare for the next run

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