Polarized Proton-Proton Elastic Scattering Experiment at RHIC

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OUTLINE of the TALK

- **Physics motivation of the experiment;**
- **Description of the experiment ;**
- **Analysis of the 2003 run data;**
- **Status of analysis;**
- **Summary.**

Spin Dependence in Proton Proton Elastic Scattering at RHIC

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Seminar June 2, 2004

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pp2pp experiment

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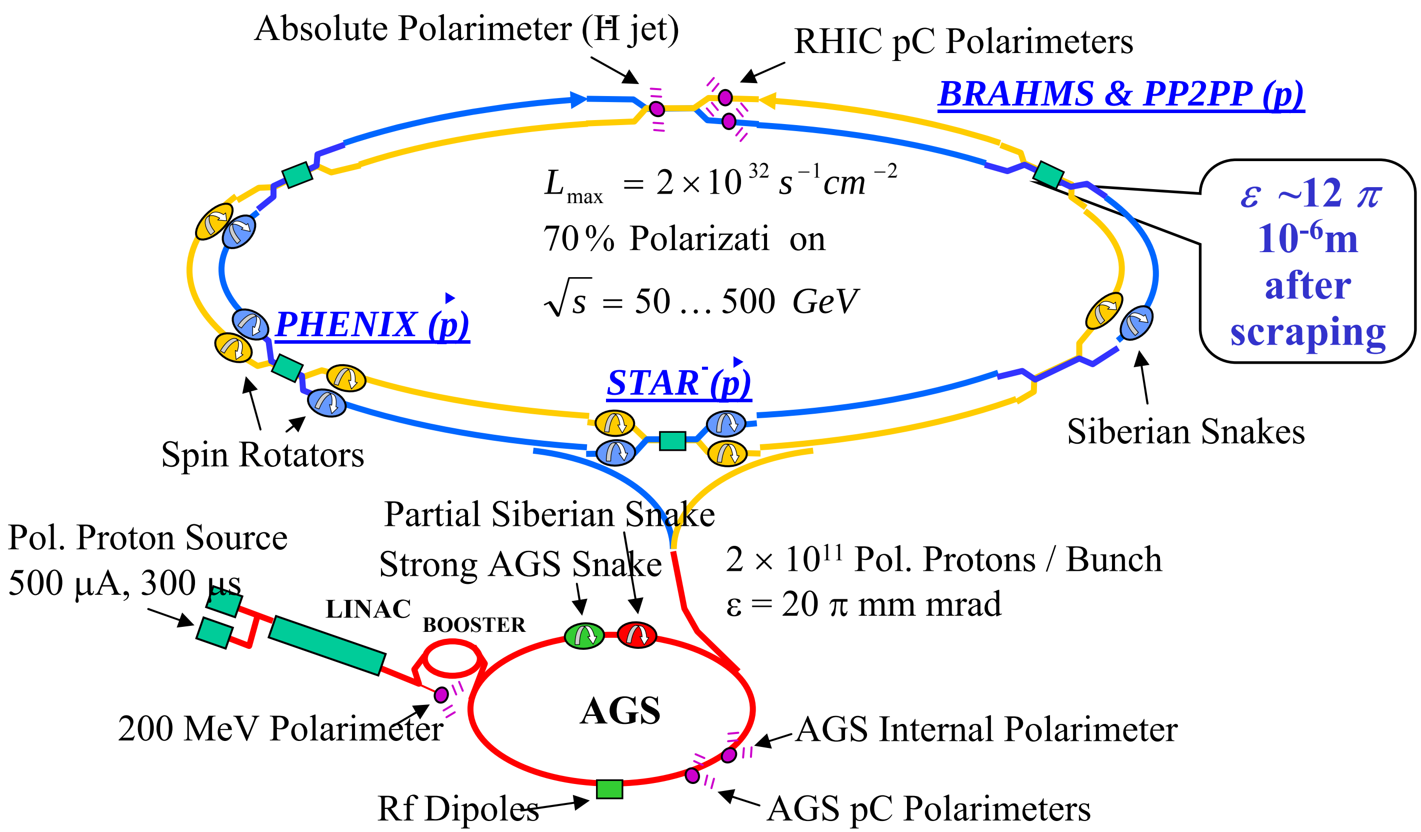
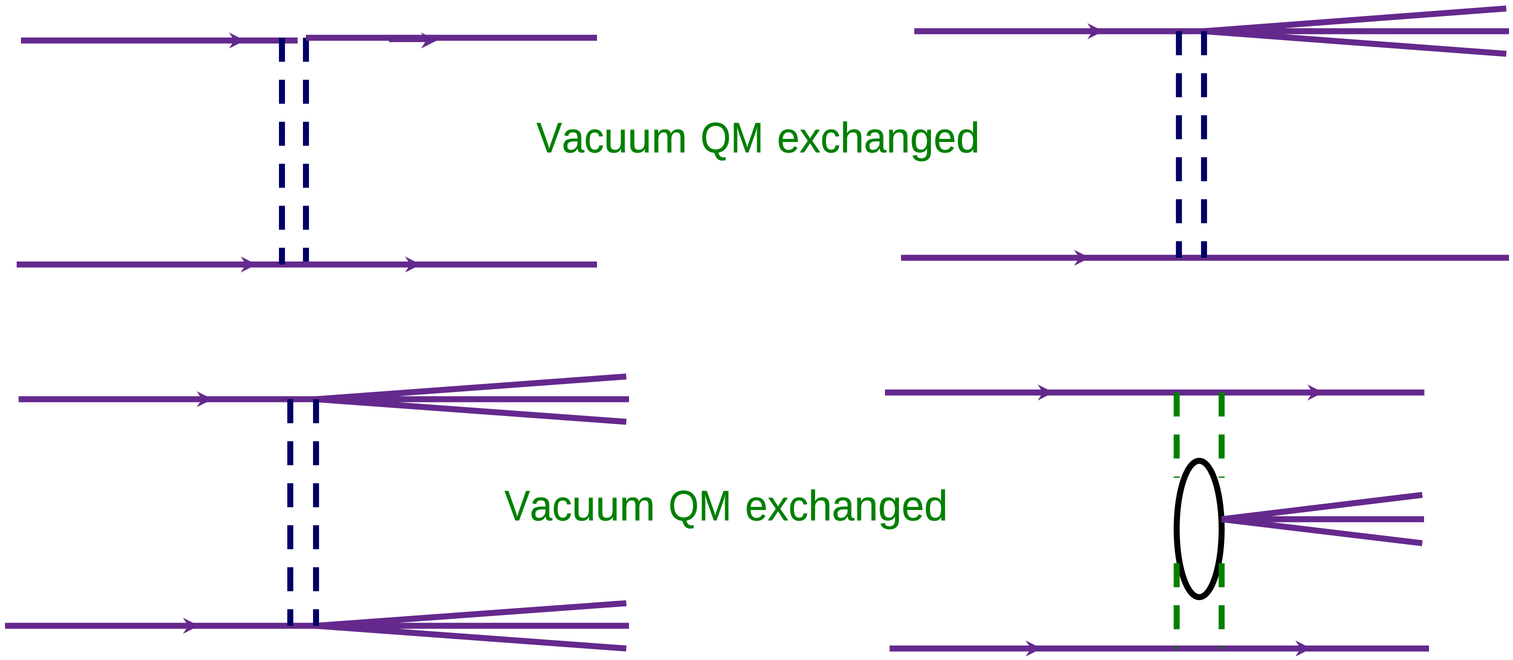
Polarized Proton Collisions in RHIC



Diffraction process

h1 + h2 $\rightarrow$ h1 + h2 elastic

h1 + h2 $\rightarrow$ h1 + h2 + X diffractive X= particles, jets, W, J/Ψ, glueballs….

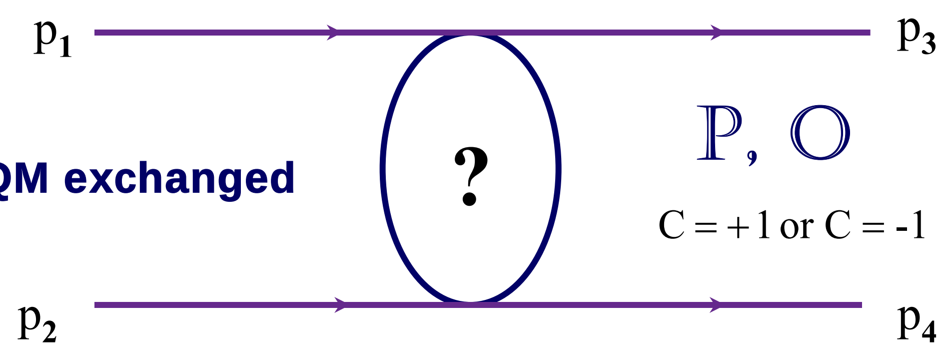


The exchange of vacuum QM numbers leads to rapidity gap production

For the rapidity gap to be present it is necessary that the spectator parts of the colliding protons not produce particles in the rapidity gap.

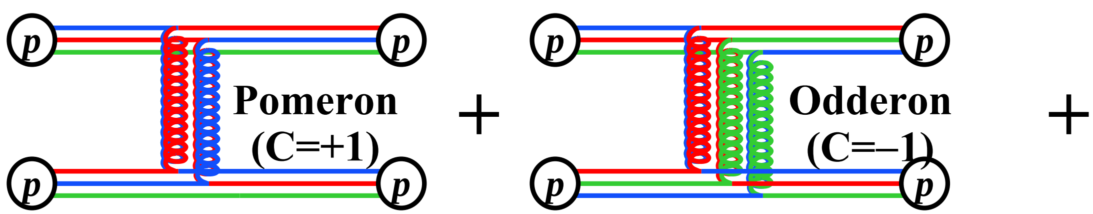
Process of Elastic Scattering

Vacuum QM exchanged



$$A(pp \to pp) = A_P + A_O$$
$$A(p\bar{p} \to p\bar{p}) = A_P - A_O$$

Perturbative QCD Picture



$s = (p_1 + p_2)^2 =$ (C.M energy)^2 $t = (p_1 - p_3)^2 = -$ (four momentum transfer)^2

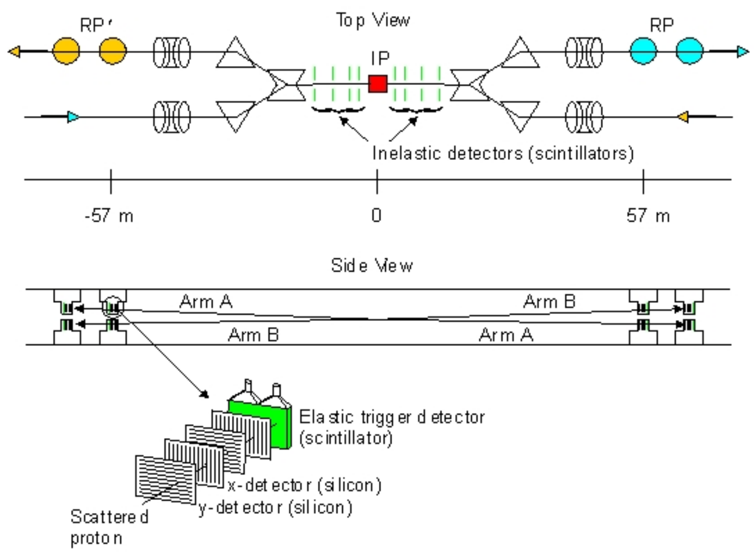
$s \to \infty$ $|t| \leq 1$ (GeV/c)^2 – Non-perturbative regime

Elastic scattering $d\sigma/dt$ + optical theorem $\Rightarrow$ total cross section σ_{tot}

General Comments on pp Elastic Scattering

1. The elastic scattering process contributes about 20% of the total interaction cross section.
2. pp and $p\bar{p}$: the predicted total cross sections still differ in RHIC range, the difference needs to be measured experimentally.
3. The Odderon, an exchange with C = -1, has not been observed, even though QCD predicts its existence, a comparison of the diffractive minimum pp and $p\bar{p}$ could provide an answer.
4. Most of the σ_{el} is in the non-perturbative regime of QCD.
5. Spin dependence is a total unknown in the RHIC $\sqrt{s}$ range 50-500 GeV.
6. Great potential for measuring spin dependence in elastic scattering, connection between polarized and unpolarized (dip and A_N crossing zero) will help study dynamics of vacuum exchange processes in QCD.

Principle of the Measurement



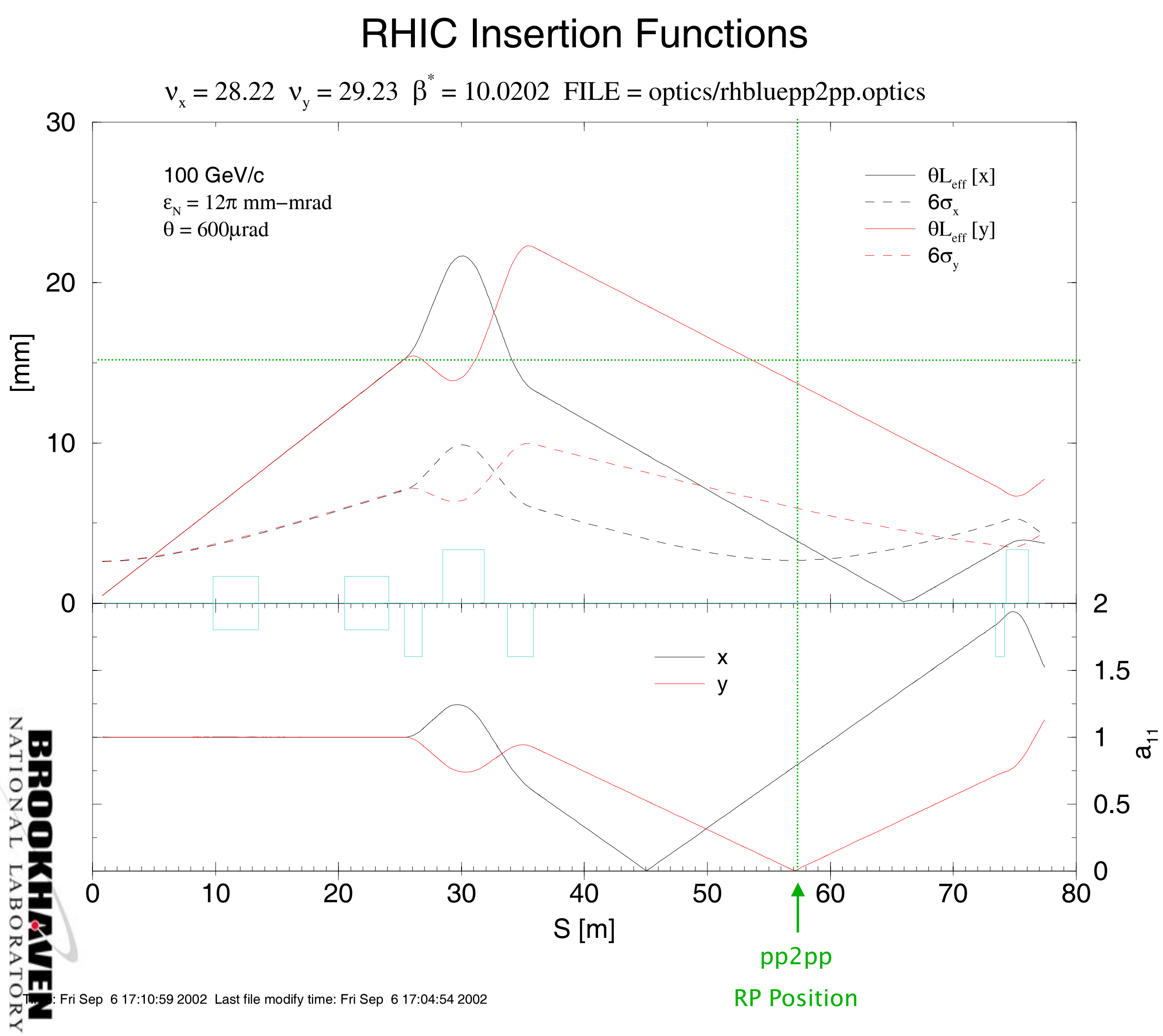
- Elastically scattered protons have very small scattering angle θ^*, hence beam transport magnets determine trajectory scattered protons
- The optimal position for the detectors is where scattered protons are well separated from beam protons
- Need Roman Pot to measure scattered protons close to the beam without breaking accelerator vacuum

Beam transport equations **relate measured position at the detector to scattering angle**

$$\begin{pmatrix} x_D \\ \Theta_D^x \\ y_D \\ \Theta_D^y \end{pmatrix} = \begin{pmatrix} a_{11} & L_{eff}^x & a_{12} & a_{14} \\ a_{12} & a_{22} & a_{23} & a_{24} \\ a_{13} & a_{23} & a_{33} & L_{eff}^y \\ a_{14} & a_{24} & a_{34} & a_{44} \end{pmatrix} \begin{pmatrix} x_0 \\ \Theta_x^* \\ y_0 \\ \Theta_y^* \end{pmatrix}$$

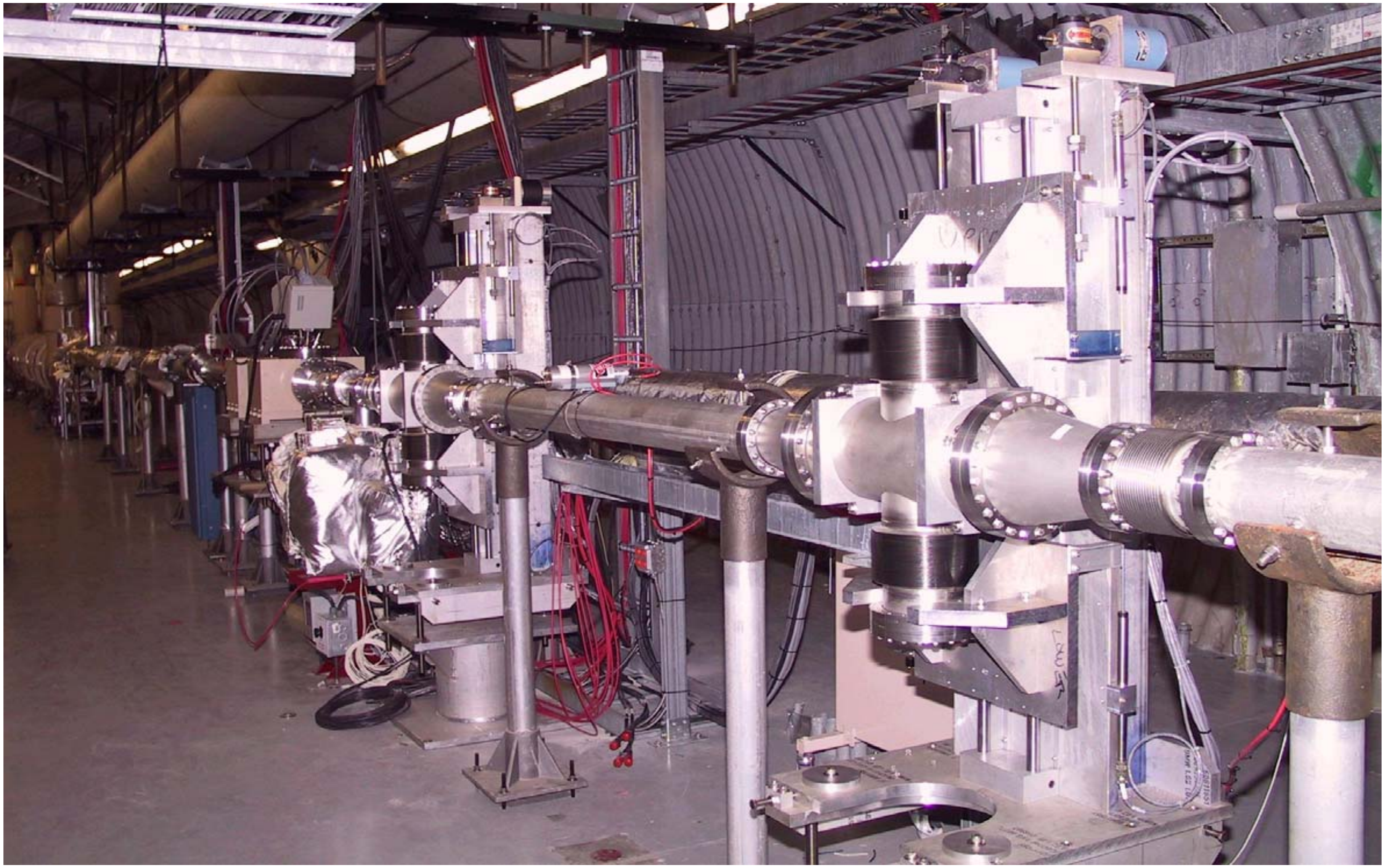
x_0, y_0: Position at Interaction Point
Θ^*_x Θ^*_y : Scattering Angle at IP
x_D, y_D : Position at Detector
Θ^x_D, Θ^y_D : Angle at Detector

Beam Transport

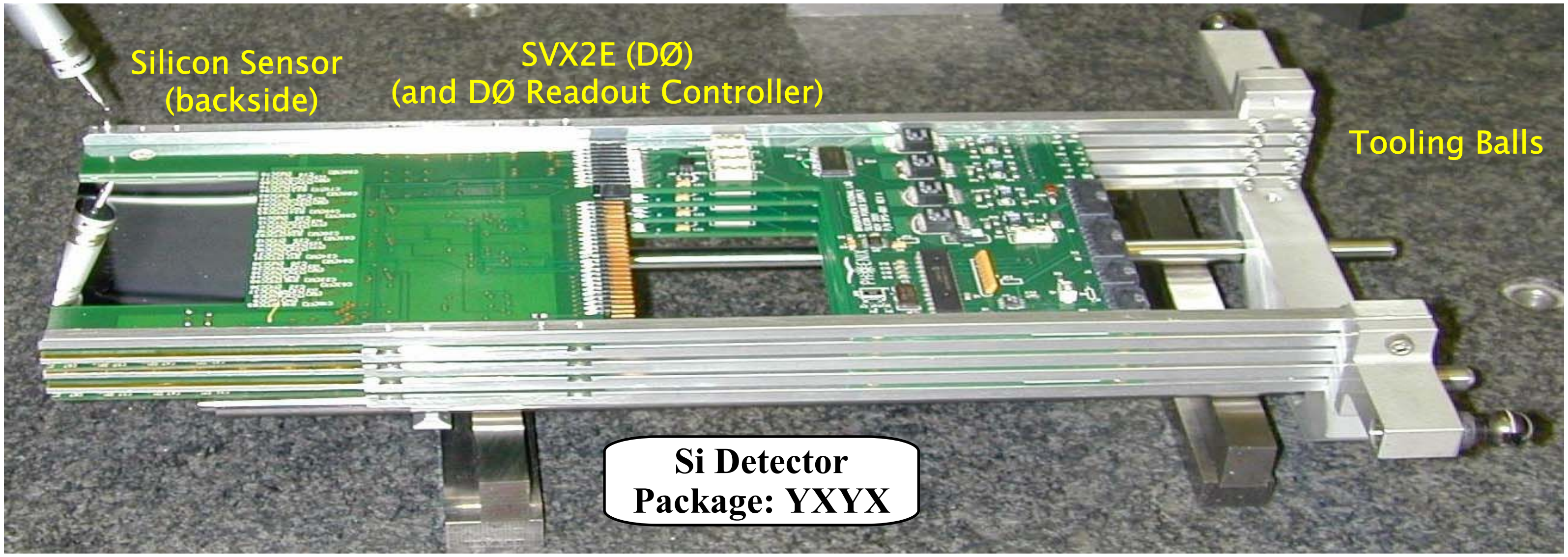


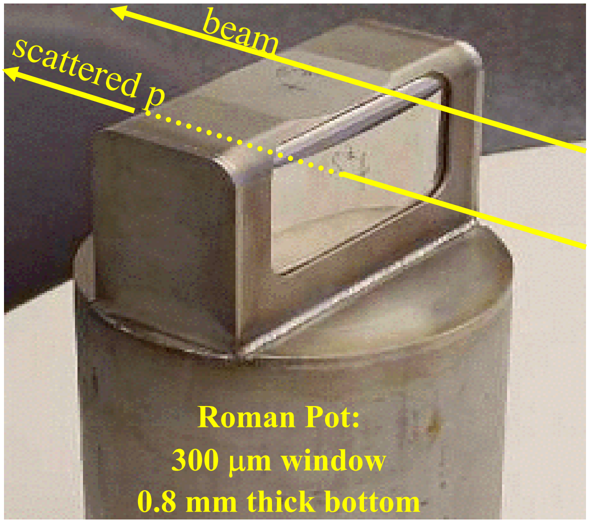
S. Tepikian

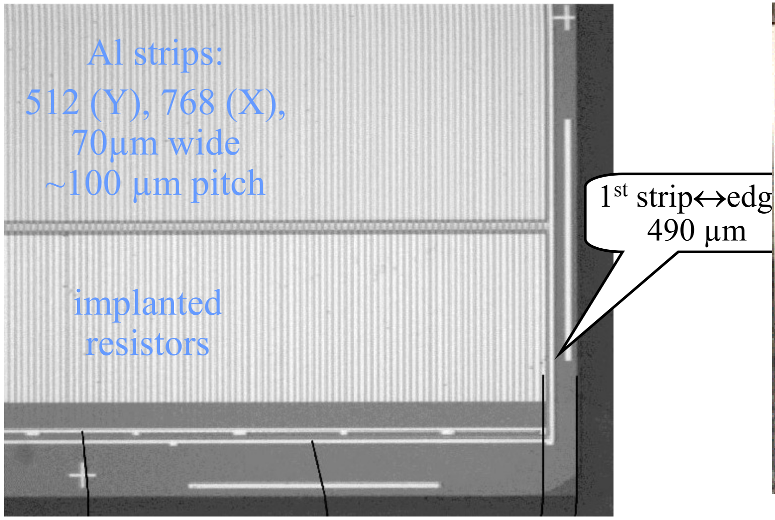
The pp2pp Experimental Setup

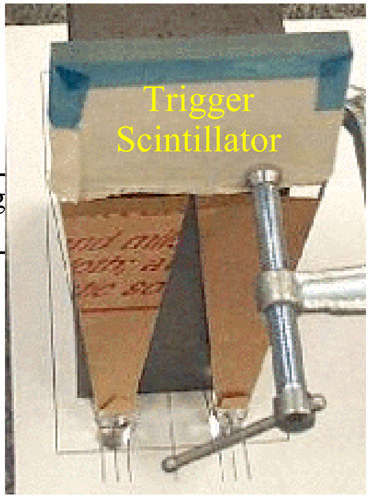


Detector Package







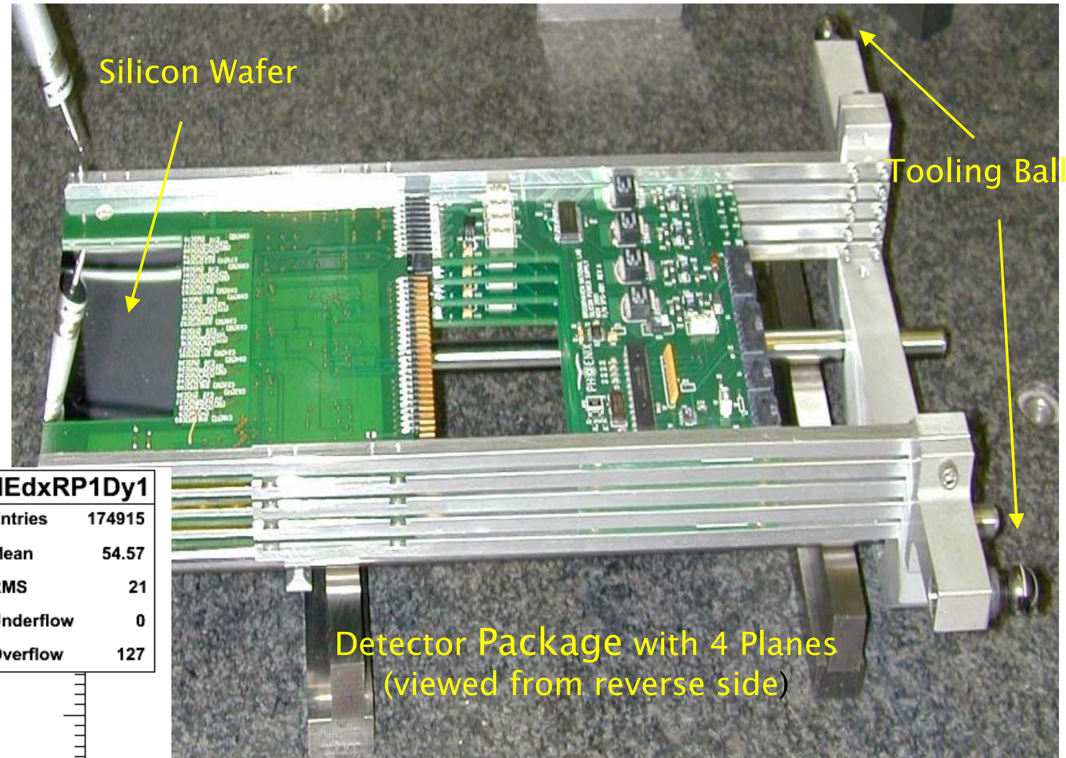


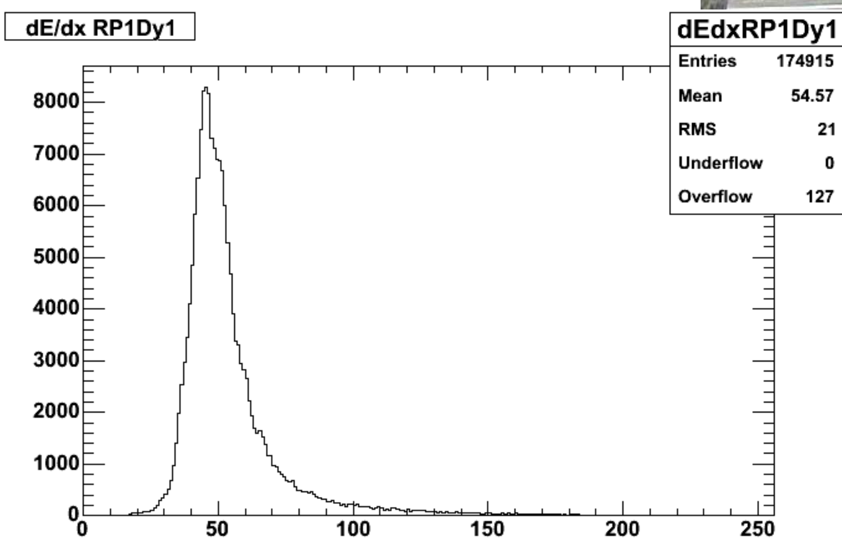
Detector Package: Si Microstrip Detectors

MIP deposits 200 keV in silicon
(~58,000 electron-hole pairs)

SN ratio ≈ 11(measured)

14 out of 16 planes very high efficiency





400 micron thick Silicon

Good Position Resolution
with Strip Pitch ~100 micron

Where we left off: Forward slope B in 2002 run

Fit $|t|$-distribution with

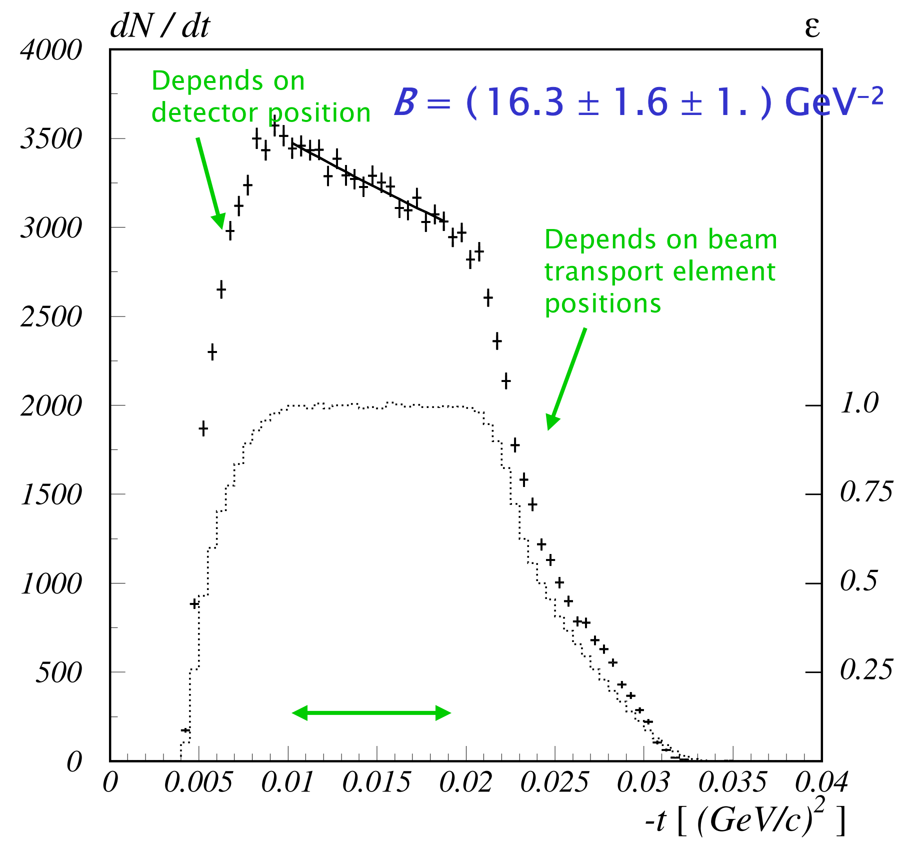
$$\frac{dN}{dt} = C\left[\frac{4\pi(\alpha G_E^2)^2}{t^2} + \frac{(1+\rho^2)\sigma_{tot}^2 e^{+Bt}}{16\pi} + \frac{(\rho+\Delta\Phi)\alpha G_E^2 \sigma_{tot} e^{+\frac{1}{2}Bt}}{t}\right]$$

Using fits to world data of $\sigma_{tot} = 51.6$ mb and $\rho = 0.13$

Fit B for $0.010\ \text{GeV}^2 \le |t| \le 0.019\ \text{GeV}^2$

$B = (16.3 \pm 1.6 \pm 1.)\ \text{GeV}^{-2}$

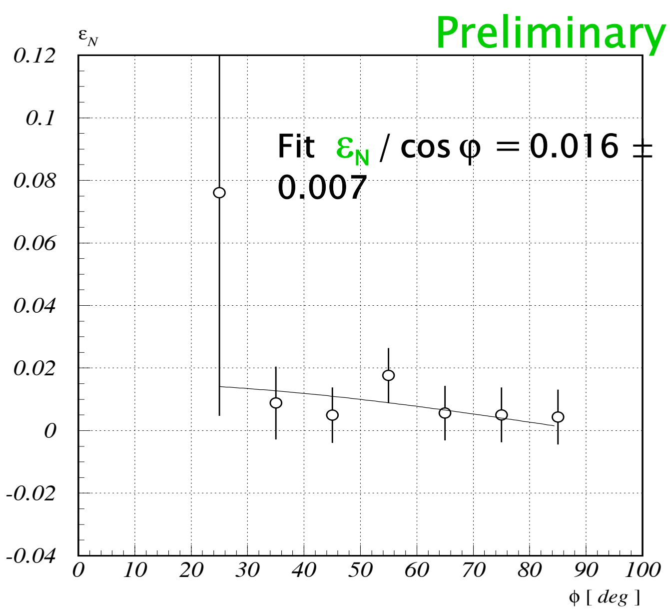
Phys. Lett. B 579 (2004) 245-250



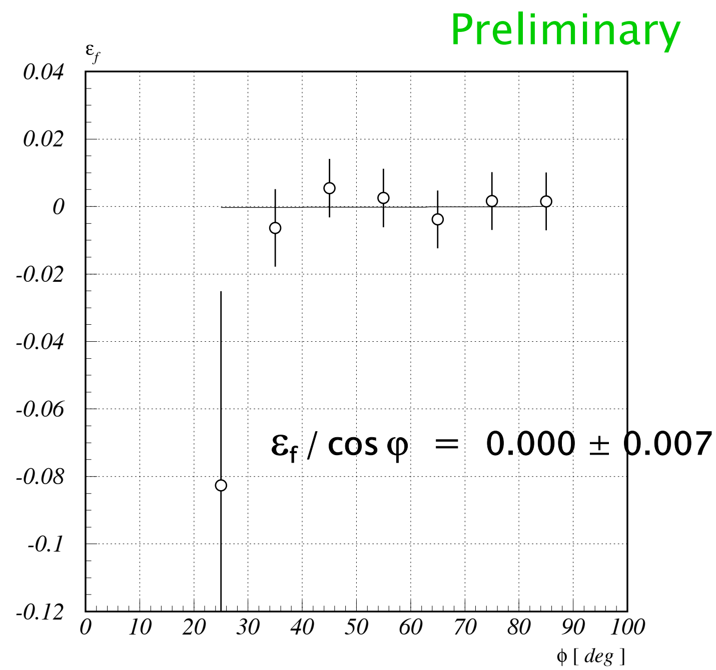
Where we left off: A_N Stephen B

Single spin asymmetry A_N arises in CNI region mainly from interference of hadronic non-flip amplitude with electromagnetic spin-flip amplitude

$$A_N(t) = \frac{1}{P_{beam} \cdot \cos\varphi} \frac{N_{\uparrow\uparrow}(t) + N_{\uparrow\downarrow}(t) - N_{\downarrow\downarrow}(t) - N_{\downarrow\uparrow}(t)}{N_{\uparrow\uparrow}(t) + N_{\uparrow\downarrow}(t) + N_{\downarrow\downarrow}(t) + N_{\downarrow\uparrow}(t)} \propto \frac{\mathcal{Im}\,[\,\Phi_5^{*}\,\Phi_+\,]}{d\sigma / dt}$$ for small t



Raw Asymmetry



False Asymmetry

What's new in Run 2003

	Engineering 2002	2003
Number of RP stations	**2**	**4**
Number of Si planes	**16**	**32**
Number of elastic events	$3 \cdot 10^5$	$3 \cdot 10^6$
Beam momentum	**100 GeV**	
Number of bunches	**55**	
β^*	**10 m**	
Beam emittence ε [mm mrad]	12π	17π
|t|-range	$0.004\text{-}0.035\ (GeV/c)^2$	
Proton intensity	$5 \cdot 10^{11}$	$19 \cdot 10^{11}$
Proton beam polarization (estimate)	**0.24**	**0.37**

How analysis is done?

1. We have three analysis groups: ITEP, Krakow/BNL, Stephen B.
2. Because of the new setup a new analysis code has been developed in ITEP, Krakow/BNL. Stephen upgraded his code to work with the new data.
3. A separate group at BNL works on scintillation counter information.
4. Simulations are done at BNL.
5. Beam transport information comes from CAD.

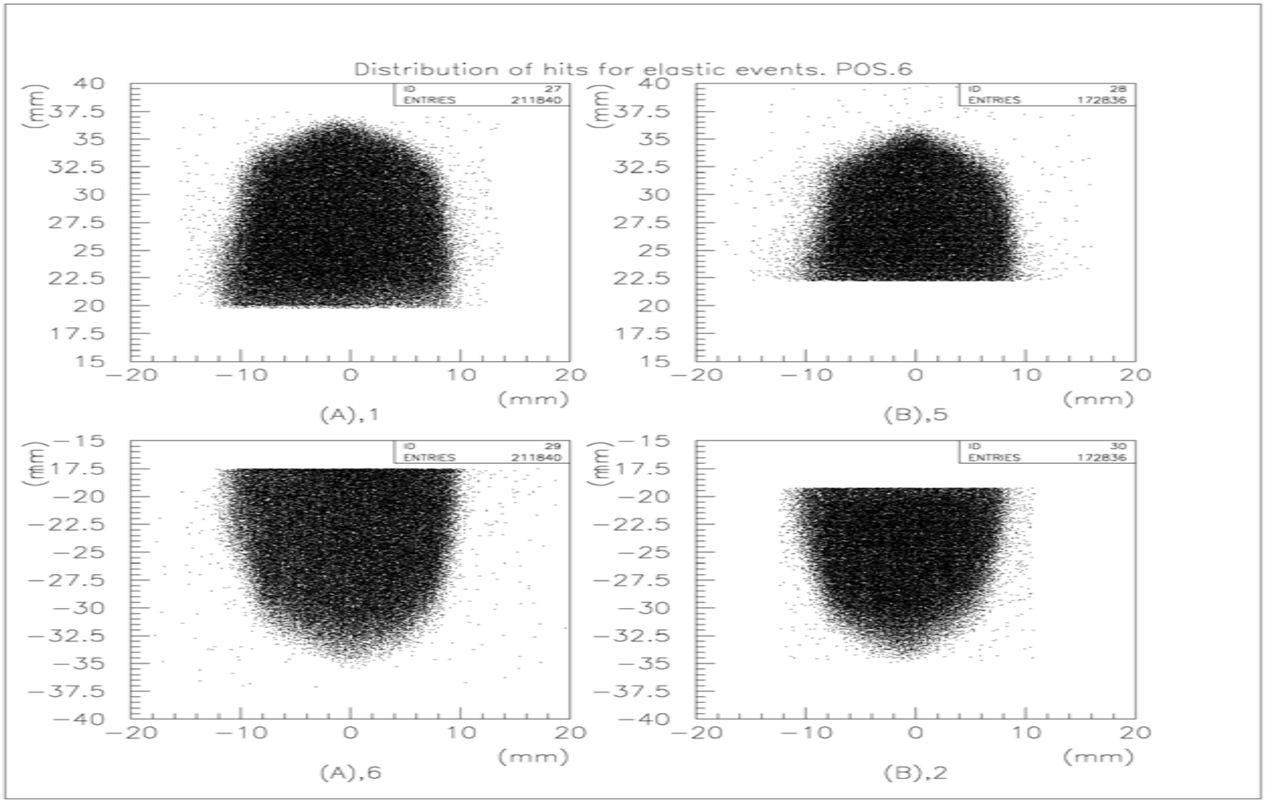
Elastic event analysis ITEP Moscow and Krakow/BNL

ANALYSIS FOSCUS of ANALYSIS IS NOW ON UNDERSTANDING SYSTEMATIC EFFECTS

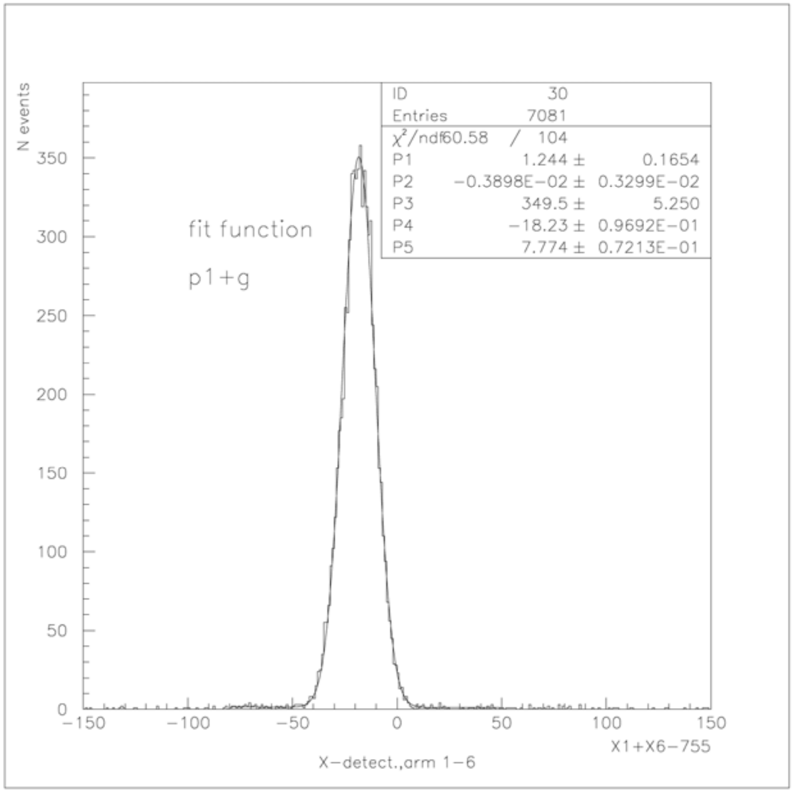
1. Pedestal value, pedestal width (σ) and dead channels are determined.
2. Valid hit is dE/dx with 5σ above pedestal;
3. Cluster size is $\leq$ 5 consecutive strips above pedestal cut;
4. Elastic events are reconstructed using correlations of hits and track reconstruction(ITEP) bema parameters are determined;
5. Clean events, one track per event four RPs are used for full reconstruction, offsets calculation, (x0,y0) (Krakow/BNL);
6. Clean events with one track per event in RP1 and RP3 for dN/dt distributions, to get large statistics.

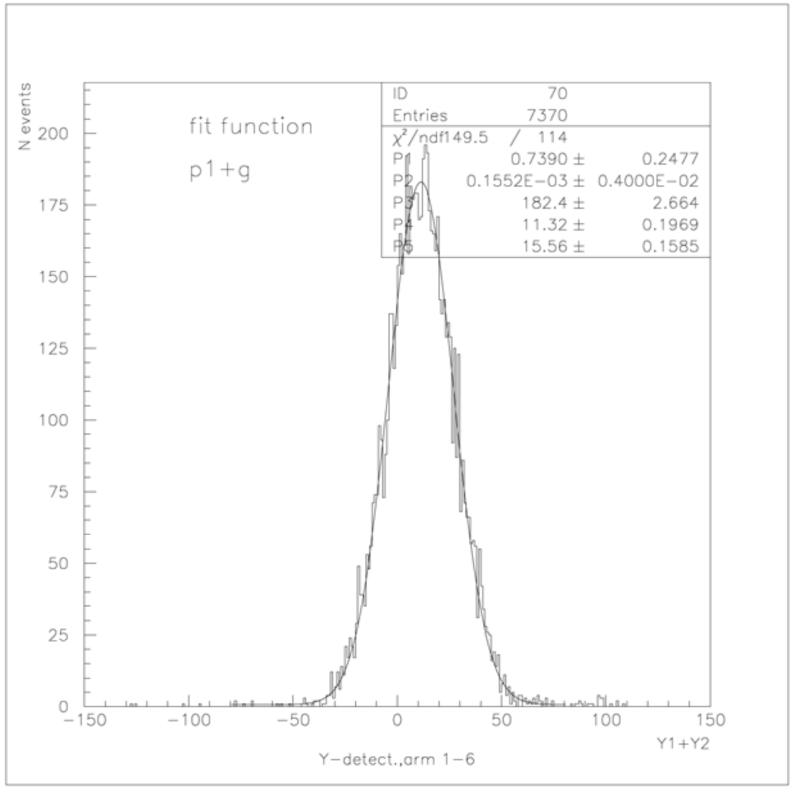
Show 1/3 of the data

Elastic Events Hit Distribution ITEP



Elastic Events x-x, y-y correlations (ITEP)

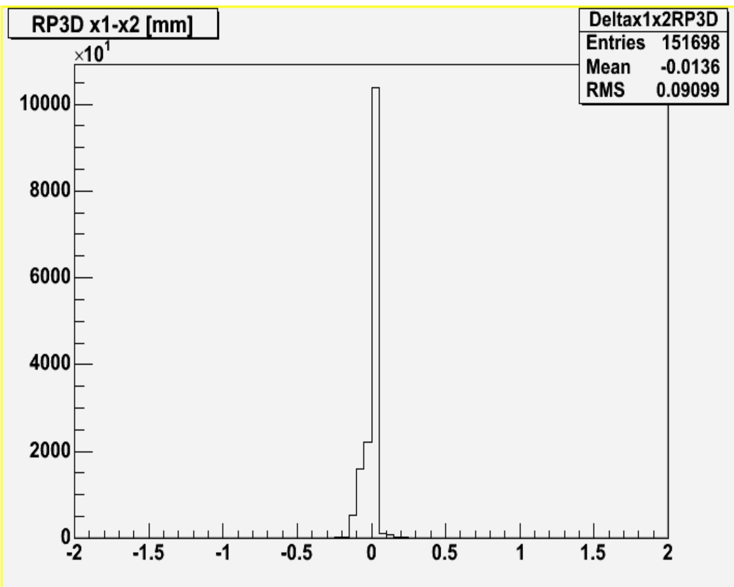


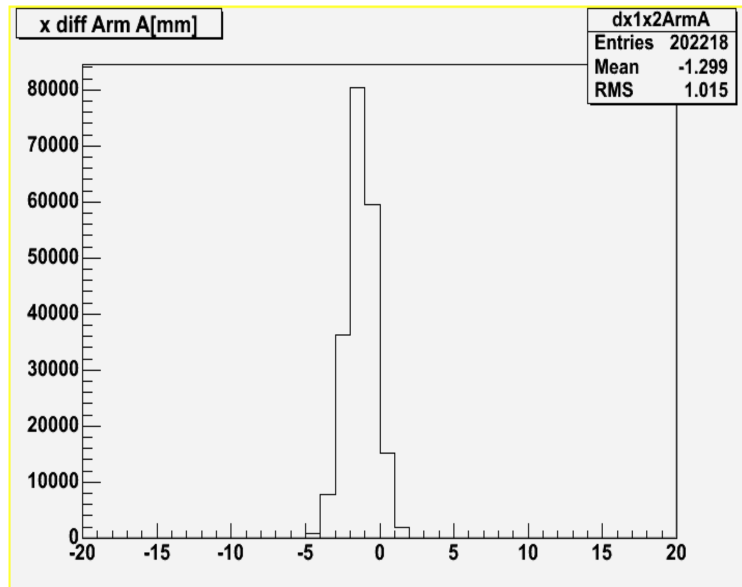


Elastic Events: Krakow/BNL

Hit is defined if the distance in two consecutive planes **Δx1x2** < 200μm

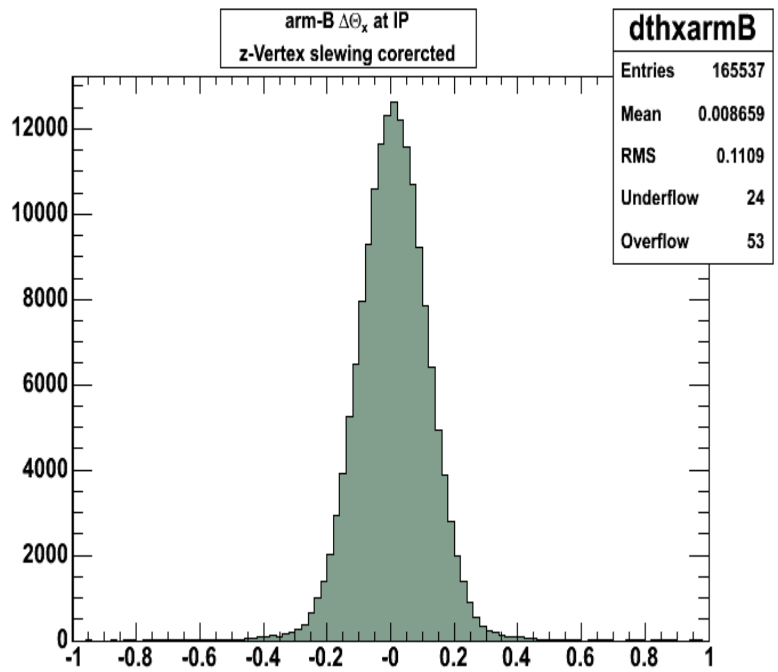
Hits are correlated with hits in Roman pot on the other side of IP (collinearity) **Δx < 3σ**

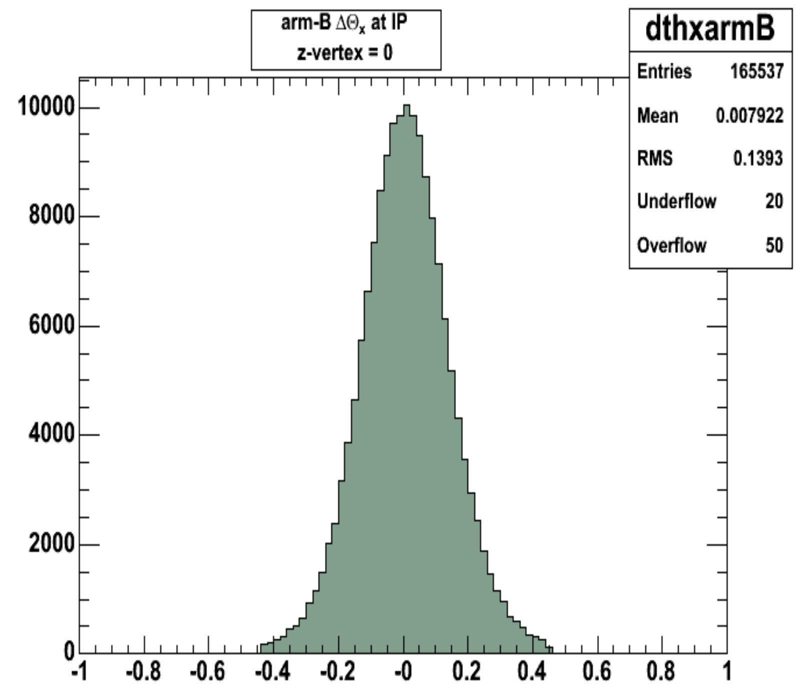




Elastic Events: Krakow/BNL

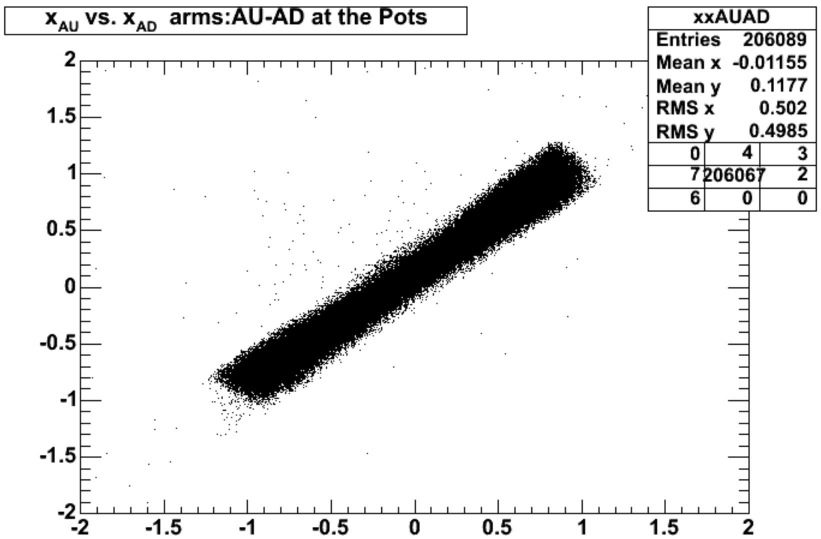
Beam angles and angular correlation

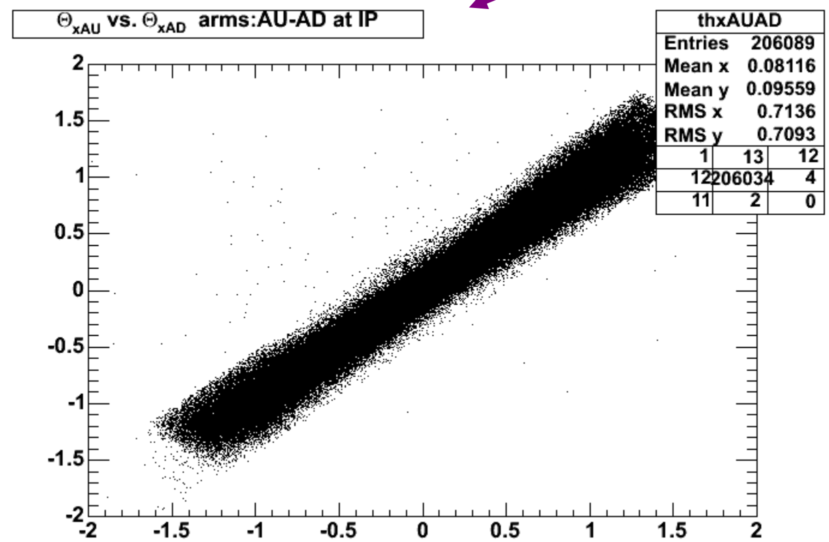


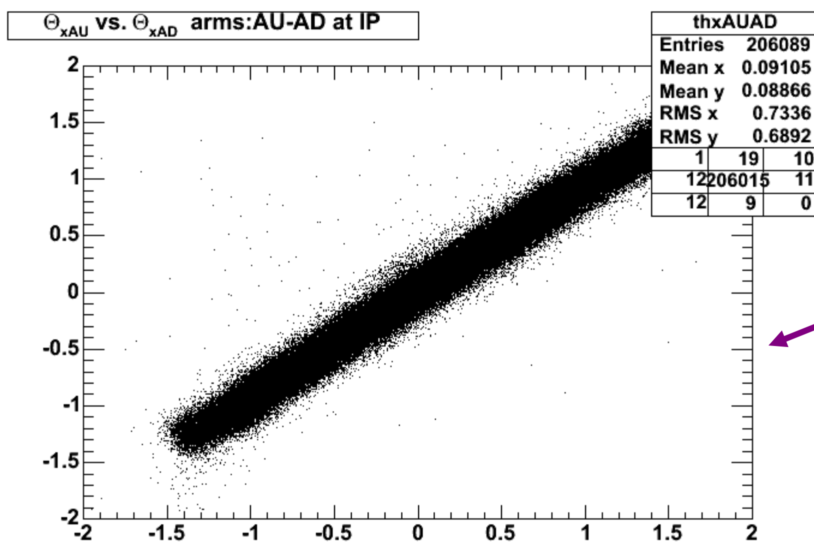


Correlation plots after z-vertex Correction

Before

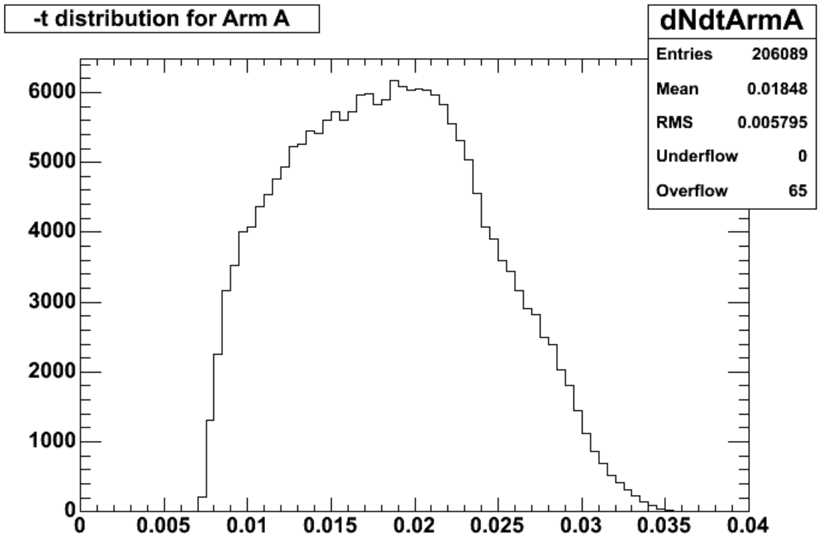


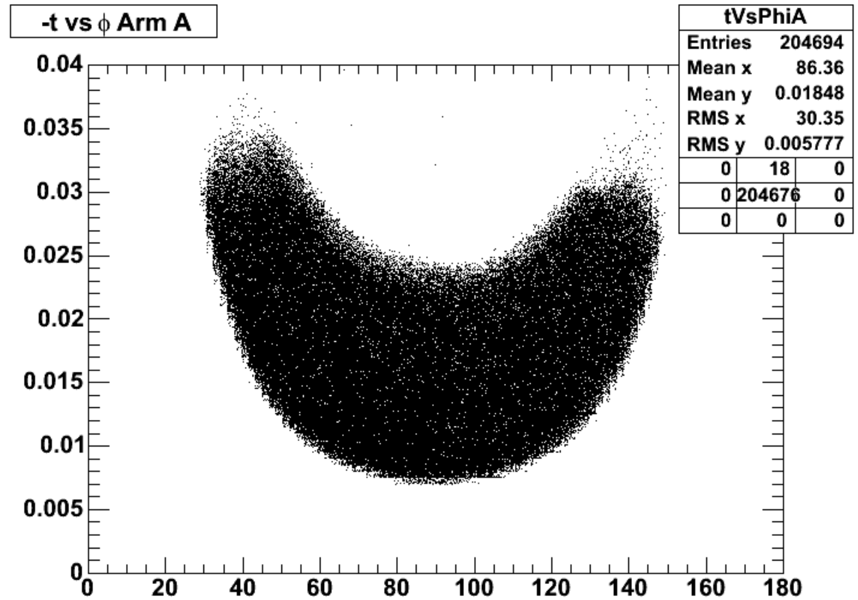


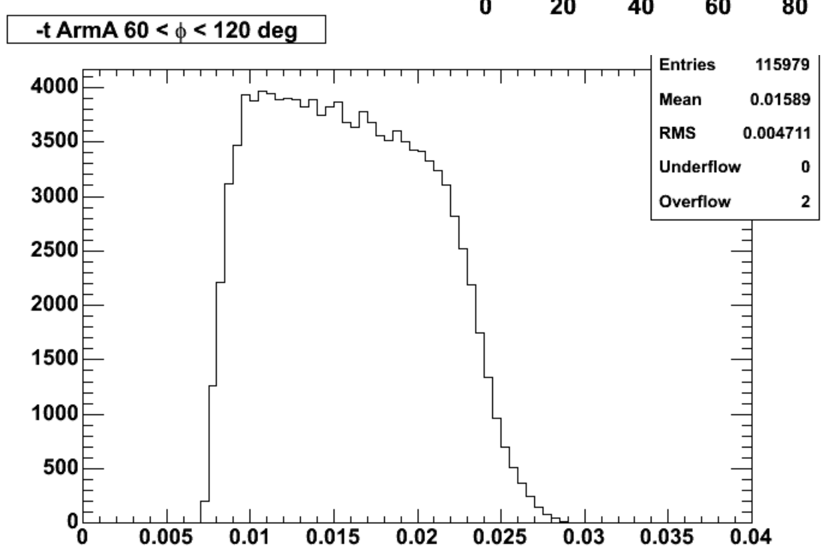


After

Elastic Events: Krakow/BNL





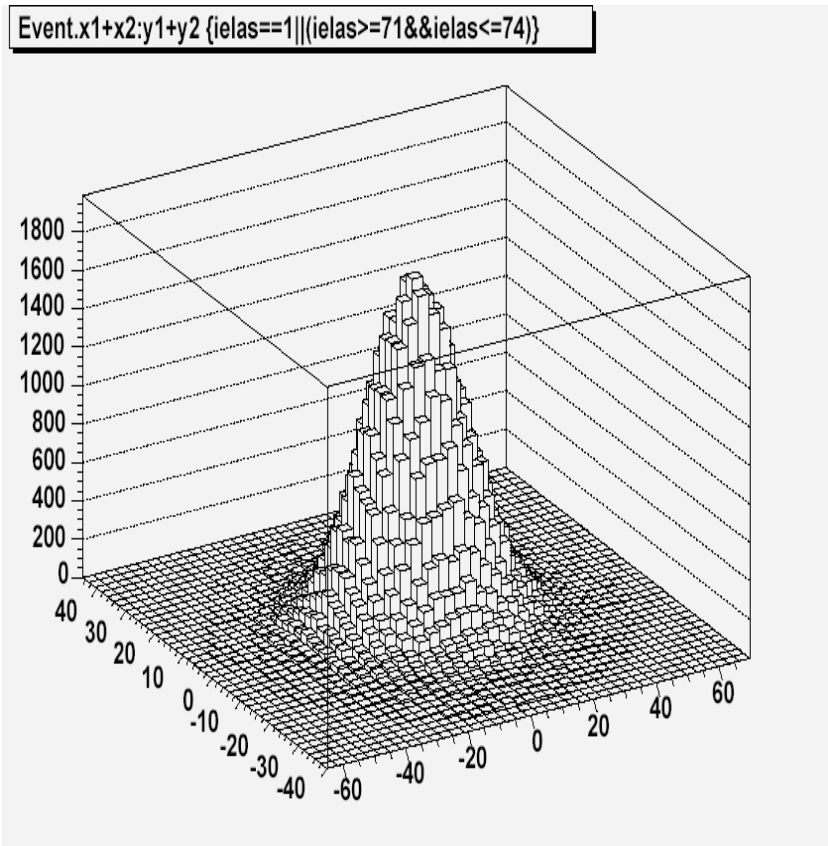


Elastic event analysis Krakow/BNL (cut effects on 1/3 data)

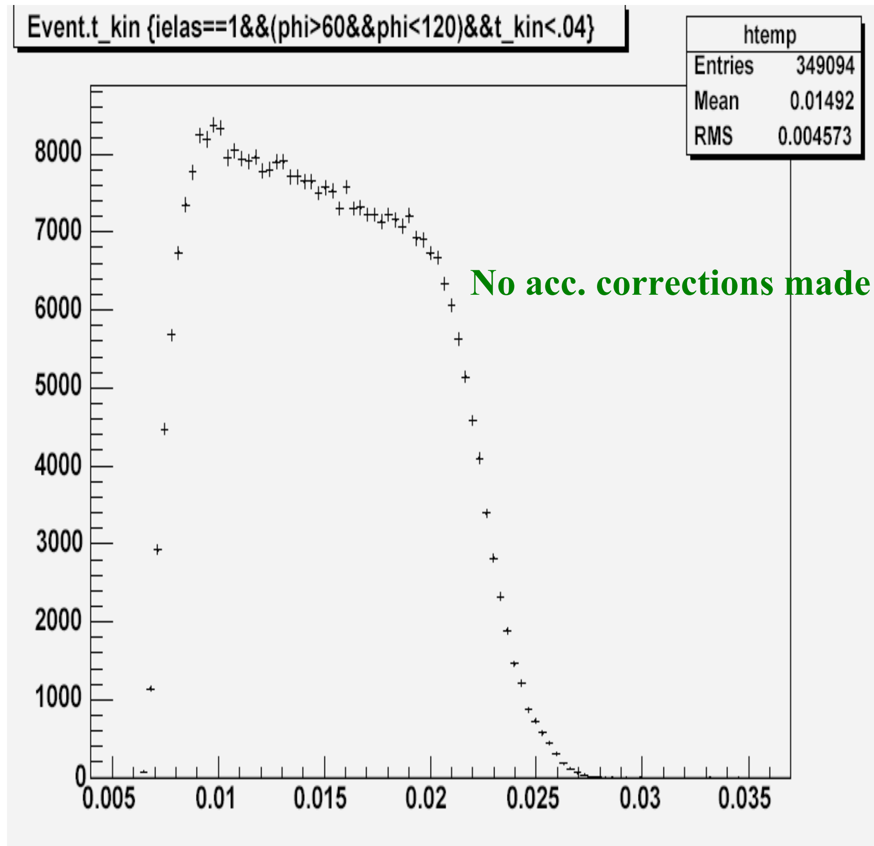
CUT DESCRIPTION	# Events
All Events	**931k**
Elastic trigger	**901k**
Events with hits in Si detectors (Si active area < trig. scint. Area)	**775k**
Events with enough # of hits for reconstr. in fid. area (≥ 3 hits/event)	**664k**
Events with low background in fid. area (multi hits/tracks)	**473k**
Good events Arm A + B (one track only using x,y correlations)	**374k**
Good events arm A	206k
Good events arm B	168k
Colinearity $3\sigma(\Delta\theta_x,\Delta\theta_y)$ arm A	203k
Colinearity $3\sigma(\Delta\theta_x,\Delta\theta_y)$ arm B	165k
$0.01 < -t < 0.02$ $(\mathrm{Gev/c})^2$ arm A (dN/dt fit region)	131k
$0.01 < -t < 0.02$ $(\mathrm{Gev/c})^2$ arm B (dN/dt fit region)	93k

Elastic Analysis 2003 run: SB

x-y correlations



dN/dt (not corrected)



Summary

1. **We have a very clean data set, very few dead or noisy channels:**
   - **Excellent silicon detection efficiency;**
   - **Measurement of local angles with new RPs allows reconstruction of (x_0,y_0).**
2. **Because of less scraping $-t_{min}$ is not as small as in the Engineering Run, it is not a problem for B or A_N.**
3. **Given good data sample we have, the systematic errors are very important to determine.**
4. **We expect to get the transport matrices soon, their knowledge is crucial to improve systematic error**
5. **We will use data to cross check the transport.**

Yellow –waiting for

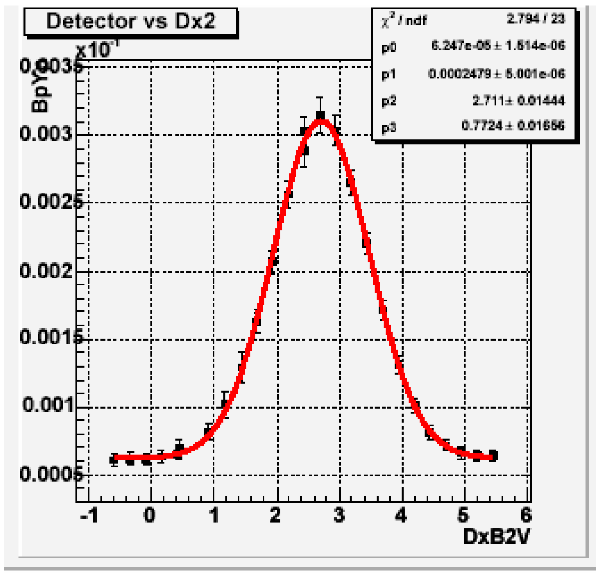
$$\begin{pmatrix} a_{11} & L^x_{eff} & a_{12} & a_{14} \\ a_{12} & a_{22} & a_{23} & a_{24} \\ a_{13} & a_{23} & a_{33} & L^y_{eff} \\ a_{14} & a_{24} & a_{34} & a_{44} \end{pmatrix}$$

Blue – already have it

$$\begin{pmatrix} a_{11} & L^x_{eff} & a_{12} & a_{14} \\ a_{12} & a_{22} & a_{23} & a_{24} \\ a_{13} & a_{23} & a_{33} & L^y_{eff} \\ a_{14} & a_{24} & a_{34} & a_{44} \end{pmatrix}$$

Summary - continued

Estimate of statistical error	Run 2002	Run 2003
Nuclear slope ΔB	1.6 $(GeV/c)^{-2}$	0.35 $(GeV/c)^{-2}$
Raw asymmetry $\Delta\varepsilon_N$	0.007	0.001
Total cross section $\Delta\sigma_{Tot}$		2-3 mb



Van der Meer scans will be used to determine luminosity.

Possible Continuation in the Future

The program can be implemented by running at the two energies, which are part of the running of RHIC Spin: $\sqrt{s}$ = 200 GeV and $\sqrt{s}$ =500 GeV.

Taking advantage of already existing and debugged equipment of the pp2pp experiment the goals can be accomplished in three phases.

PHASE I: Run with current setup **(ρ, A_N, A_{NN}, improve σ_{tot}, $d\sigma/dt$, b,)**

β^*=20 m, p_{beam}=100 GeV/c $\Rightarrow$ $0.003<|t|<0.02(\mathrm{GeV/c})^2$;

β^*=10 m, p_{beam}=250 GeV/c $\Rightarrow$ $0.025<|t|<0.12(\mathrm{GeV/c})^2$.

PHASE II: Install Roman Pots between DX and D0 magnets **($d\sigma/dt$, b, A_N, A_{NN})**

β^*=3m, p_{beam}= 250 GeV/c $\Rightarrow$ $0.2<|t|<1.3(\mathrm{GeV/c})^2$

β^*=3m, p_{beam}= 100 GeV/c $\Rightarrow$ $0.02<|t|<0.12(\mathrm{GeV/c})^2$

PHASE III: Upgrade RHIC power supplies at our IP to allow β^*=100m optics and move Roman Pots to 70m position **(σ_{tot}, $d\sigma/dt$, b, ρ, A_N, A_{NN})**

β^*=100m, p_{beam}=100 and 250 GeV/c $\Rightarrow$ $|t|$ CNI region