Elastic Scattering at √s=1.96 TeV Using the DØ Forward Proton Detector
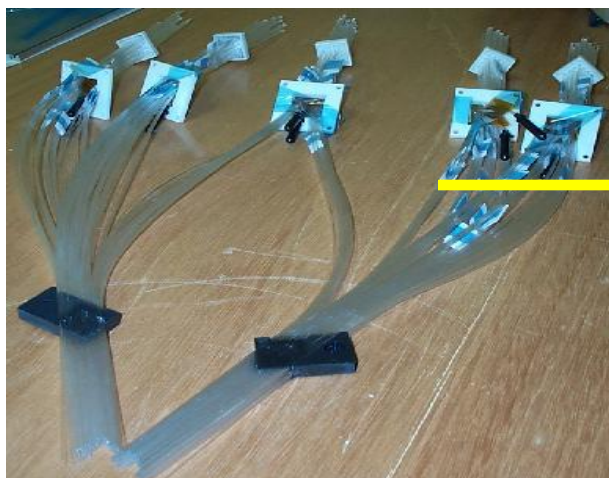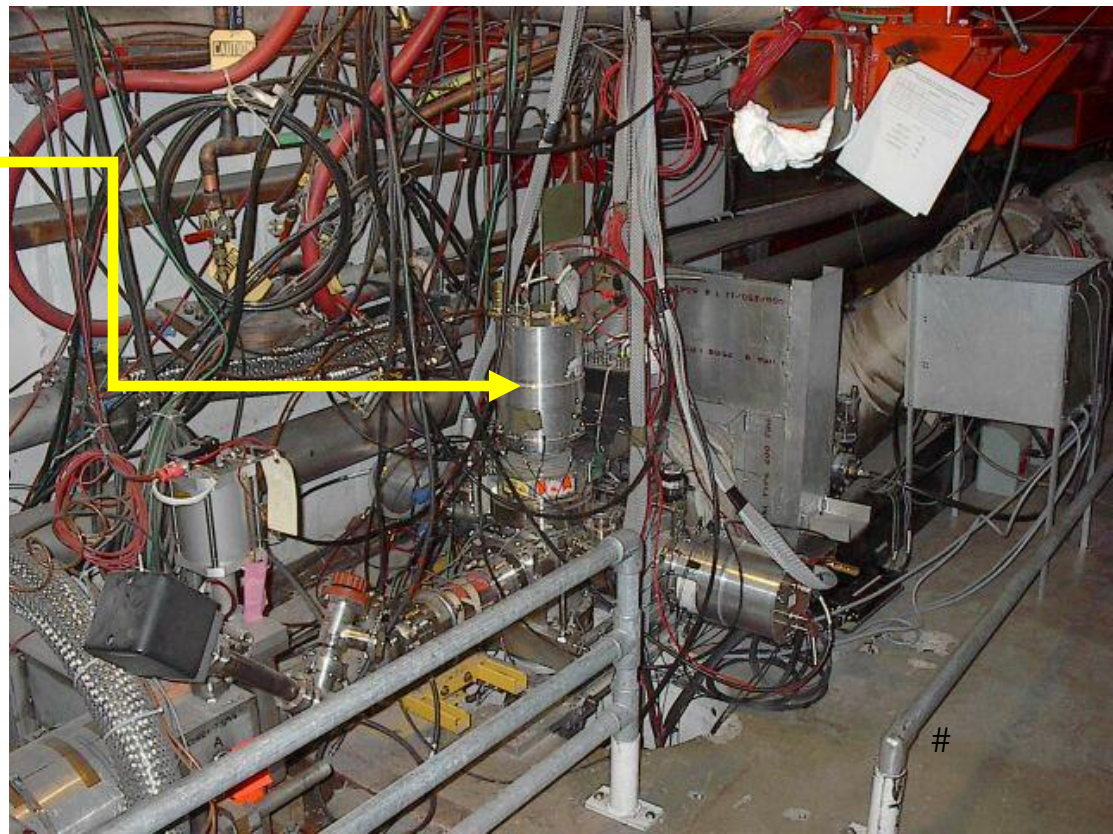
Andrew Brandt University of Texas, Arlington
on behalf of DØ Collaboration

**An FPD Quadrupole castle with four detectors installed**

Elastic Scattering

- The particles after scattering are the same as the incident particles

- $\xi = \Delta p / p = 0$ for elastic events; $t = -(p_i - p_f)^2$

- The cross section can be written as:

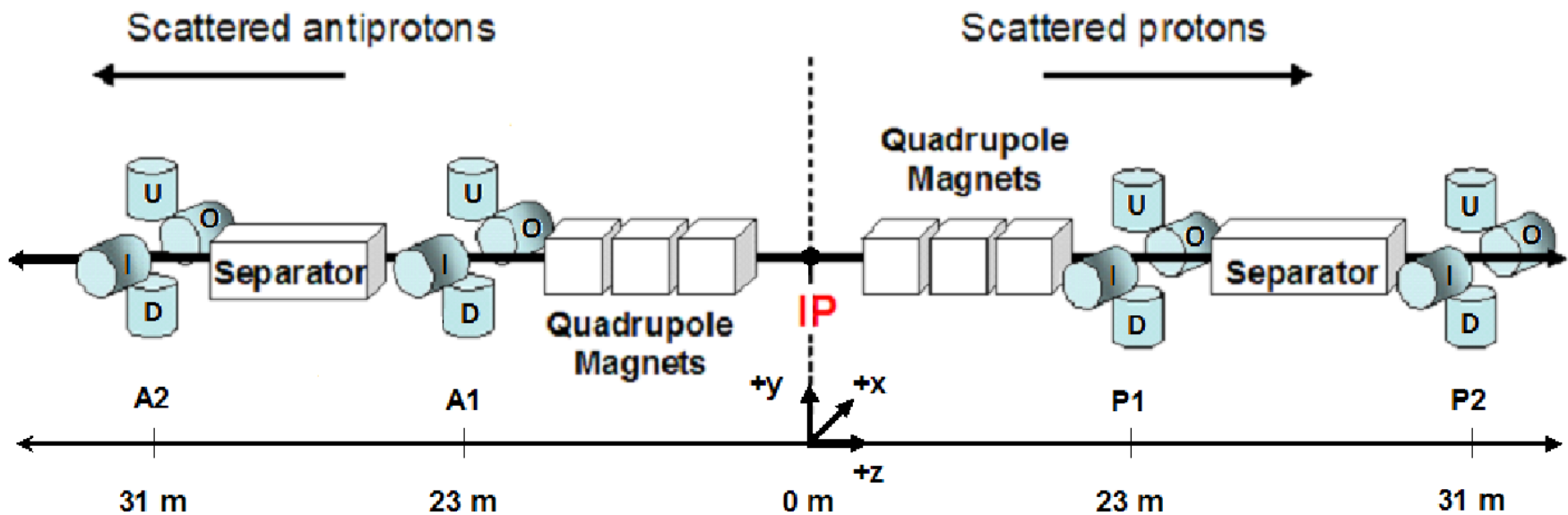$$\frac{d\sigma/dt}{(d\sigma/dt)_{t=0}} = e^{bt} \cong 1 - b(p\theta)^2$$

- This has the same form as light diffracting from a small absorbing disk, thus processes with one or more intact protons are referred to as diffraction

- Characterized by a steeply falling |t| distribution and a dip where the slope becomes much flatter

Elastic "dip" Structure from Phys. Rev. Lett. 54, 2180 (1985).
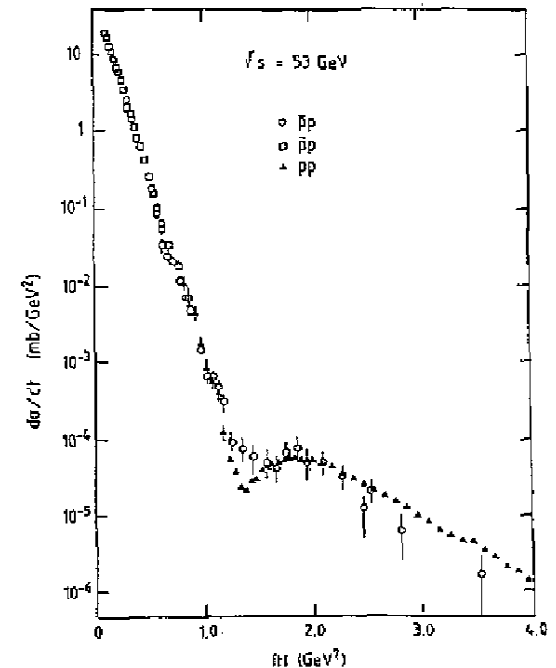
Forward Proton Detector

⇨**There are 8 quadrupole spectrometers 4 each (Up, Down, In, Out) on the outgoing proton (P) and anti-proton (A) sides, with each spectrometer comprised of two detectors (1, 2)**

⇨**Use Tevatron lattice and scintillating fiber hits to reconstruct ξ and $|t|$ of scattered protons (anti-protons)**

⇨**The acceptance for $|t| > |t_{min}|$ where t_{min} is a function of pot position: for standard operating conditions $|t| > 0.8$ GeV^2**

FPD Detectors
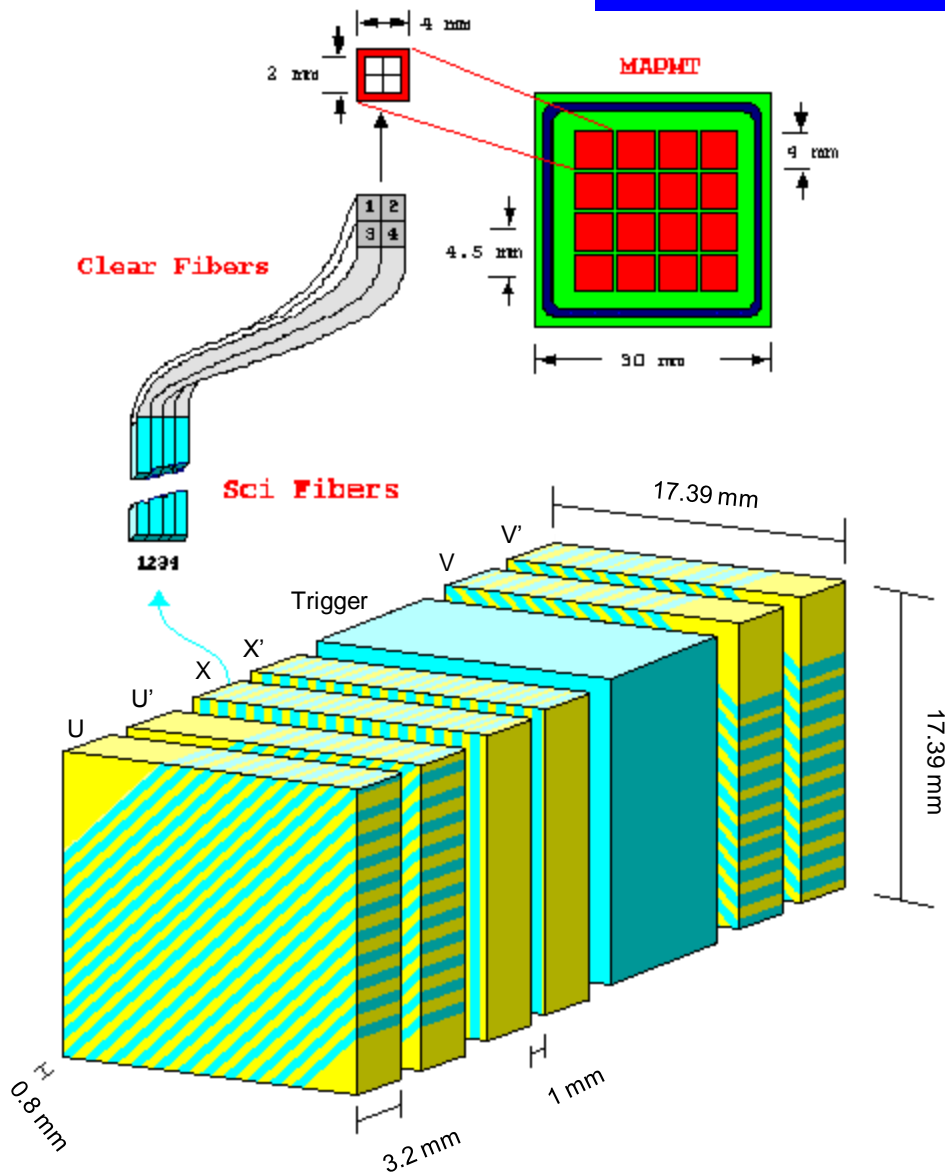
- 3 layers in detector: U and V at 45° degrees to X, 90° degrees to each other

- Each layer has two planes (prime and unprimed) offset by ~2/3 fiber

- Each channel contains four fibers

- Two detectors in a spectrometer

- Scintillator for timing (primariliy used for halo rejection)

Large β* Store

❖ In 2005 DØ proposed a store with special optics to maximize the |t| acceptance of the FPD

❖ In February 2006, the accelerator was run with the injection tune, β* =1.6m (about 5x larger than normal)

❖ Only 1 proton and 1 anti-proton bunch were injected

❖ Separators OFF (no worries about parasitic collisions with only one bunch)

❖ Integrated Luminosity (**30   4 nb^{-1}**) was determined by comparing the number of jets from Run IIA measurements with the number in the Large β* store

❖ A total of 20 million events were recorded with a special FPD trigger list

__Track Finding__

- ## **Alignment**
  - **Use over-constrained tracks that pass through horizontal and vertical detectors to do relative alignment of detectors and use hit distributions to align detectors with respect to the beam**
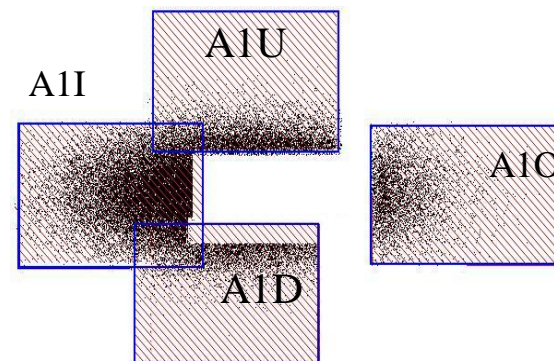
- ## **Hit Finding**
  - **Require less than 5 hit fibers per layer (suppresses beam background)**
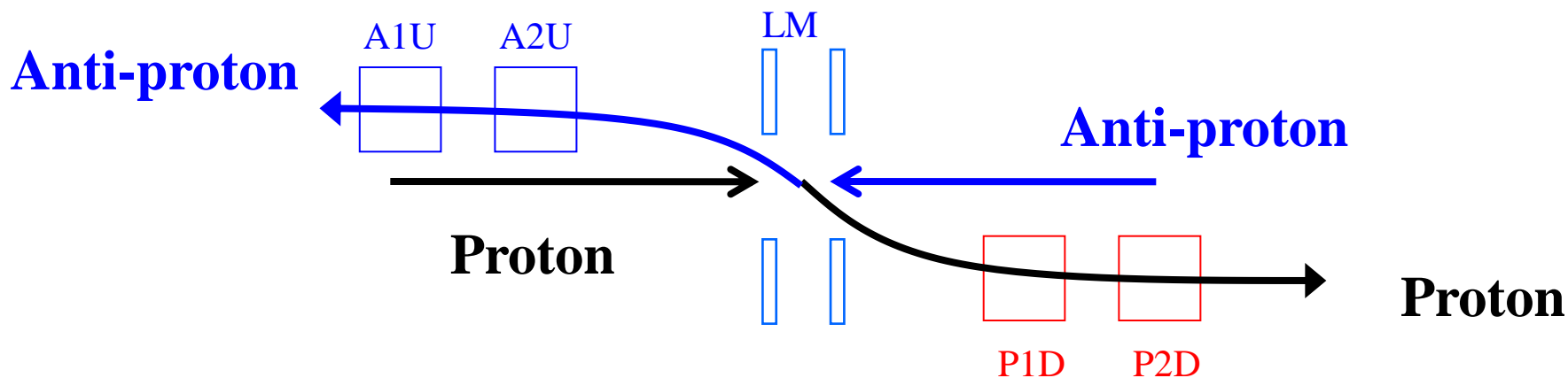 - **Use intersection of fiber layers to determine a hit**

- ## **Track Reconstruction.**
  - **For events with good hits in both detectors, use the aligned hit values and the Tevatron lattice transport equations to reconstruct the proton track**

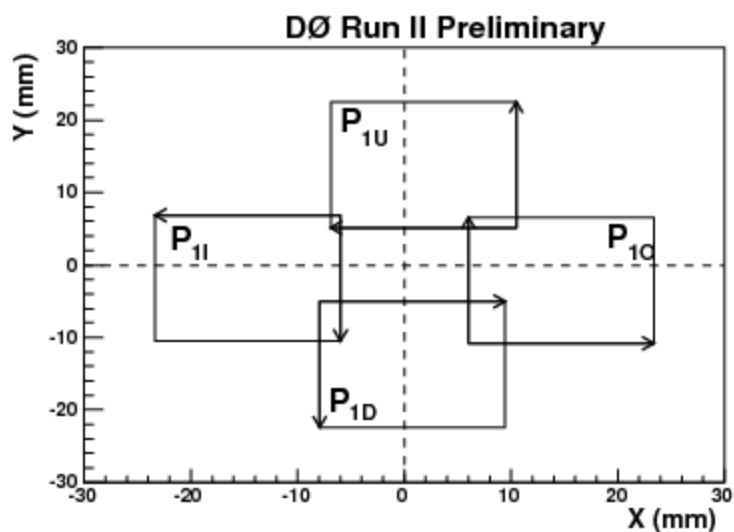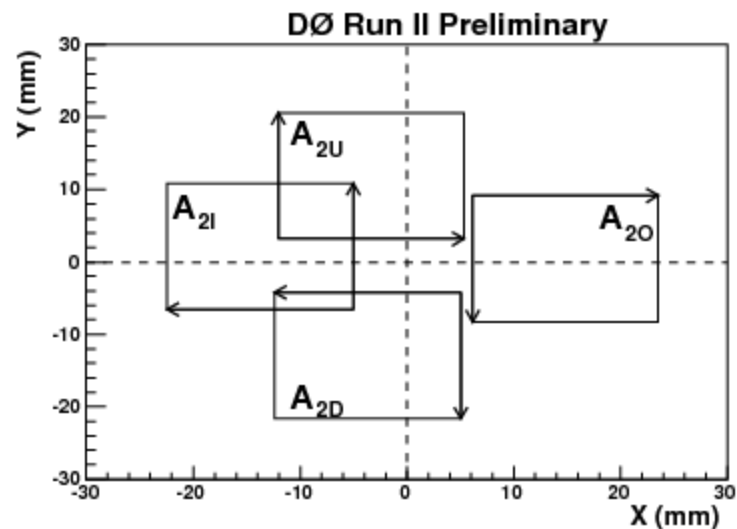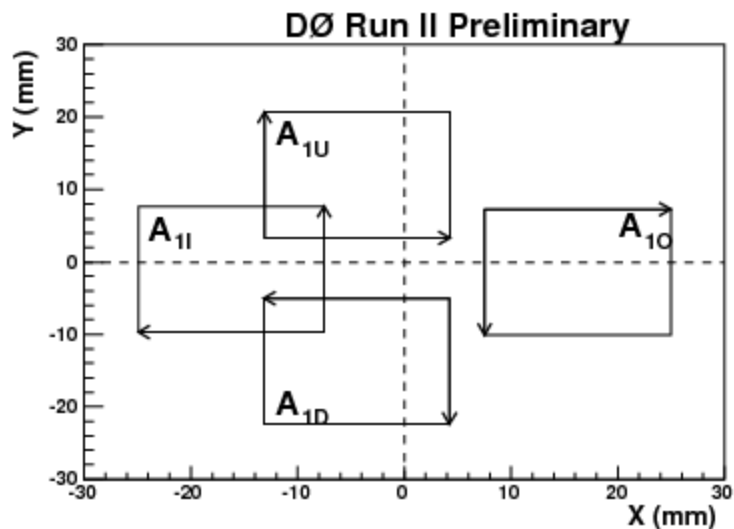# Elastic Spectrometer Combinations

Momentum dispersion in horizontal plane results in more halo (beam background) in the IN/OUT detectors, so concentrate on vertical plane AU-PD and AD-PU to maximize |t| acceptance while minimizing background
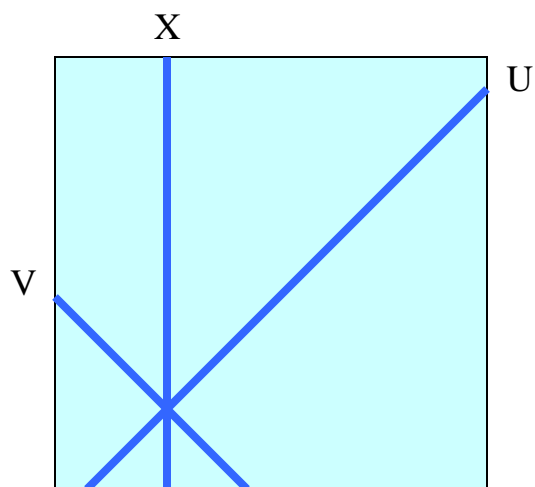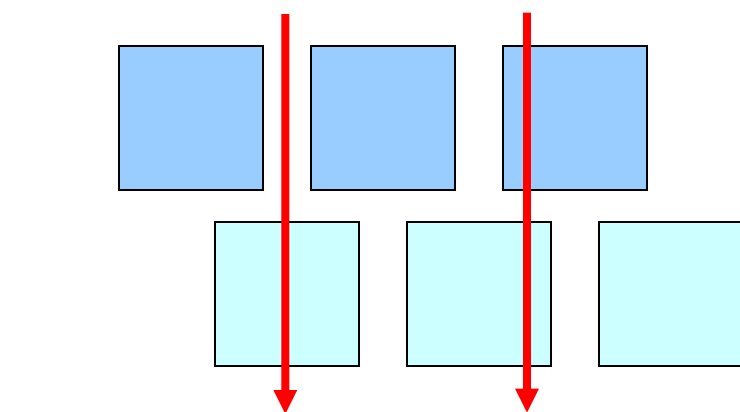
AU-PD combination has the best |t| acceptance

Detector Positions after Alignment
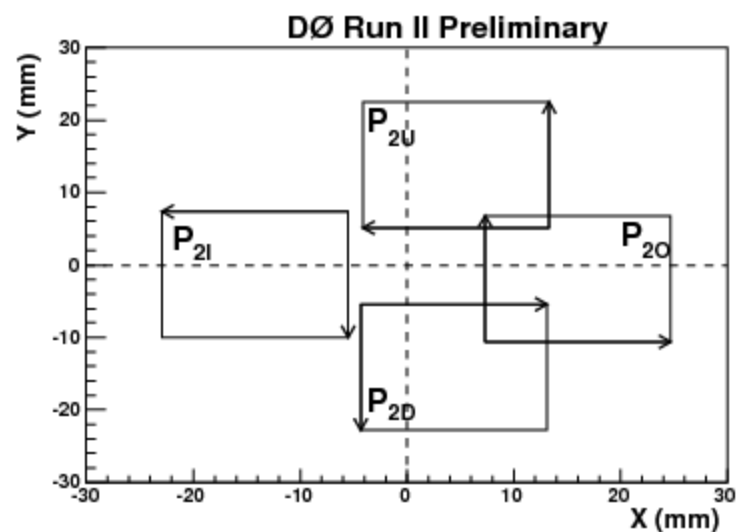
Hit Finding

- Combination of fibers in a plane determine a segment

- Need two out of three possible segments to get a hit
  - U/V, U/X, X/V (or U/X/V)
    - reconstruct x and y position in detector
    - use alignment to go from detector to beam coordinates

- Can also get an x directly from the x segment (can compare these x measurements to measure resolution)
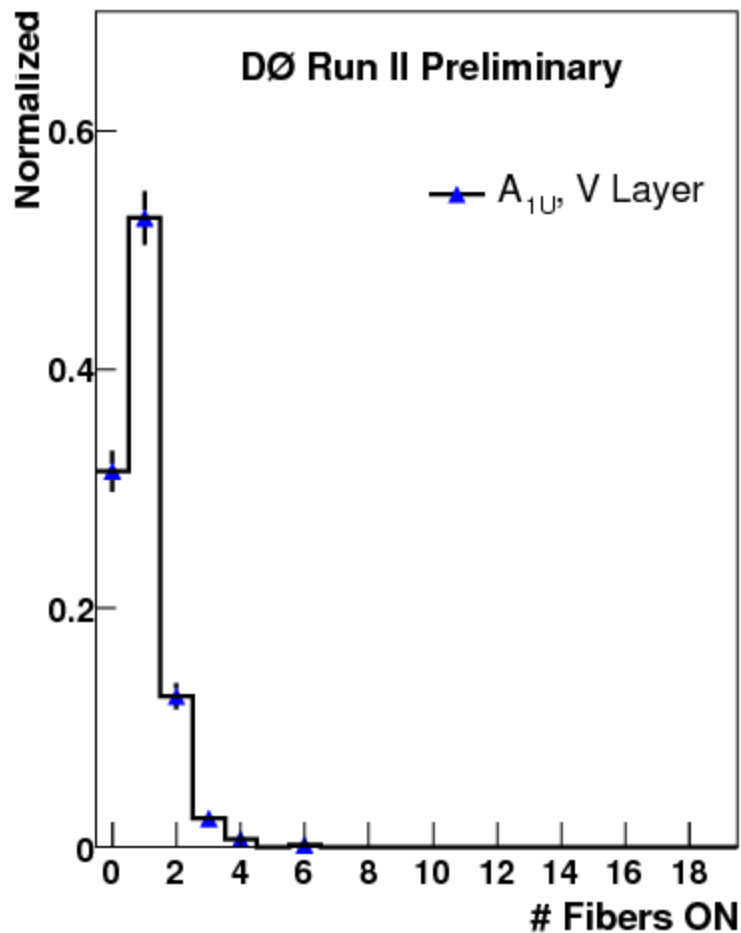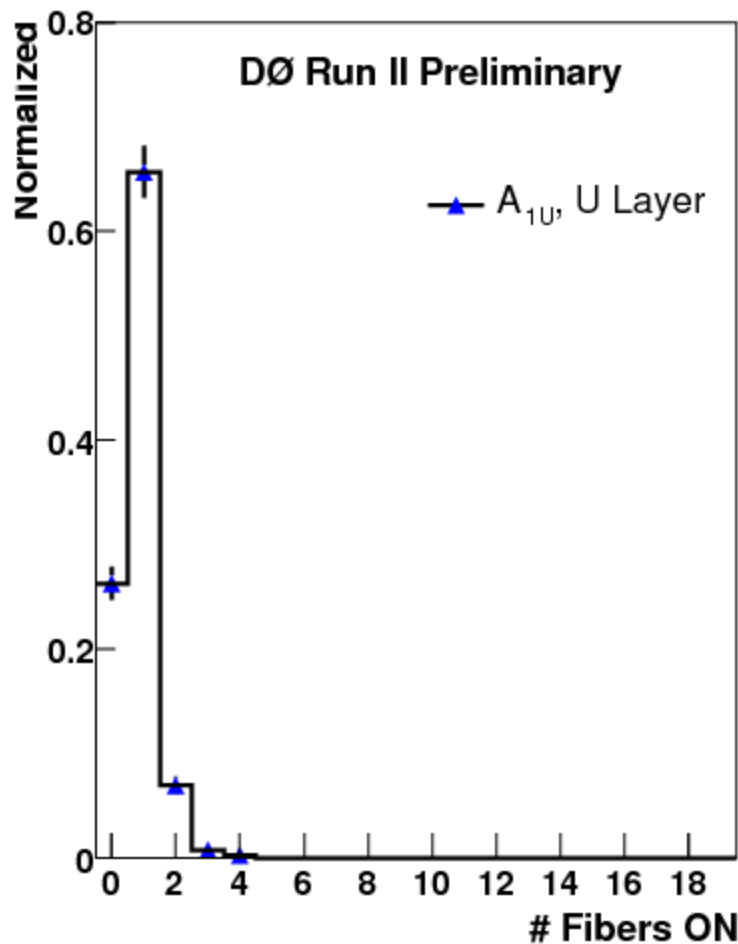
Fiber Correlations within a Detector
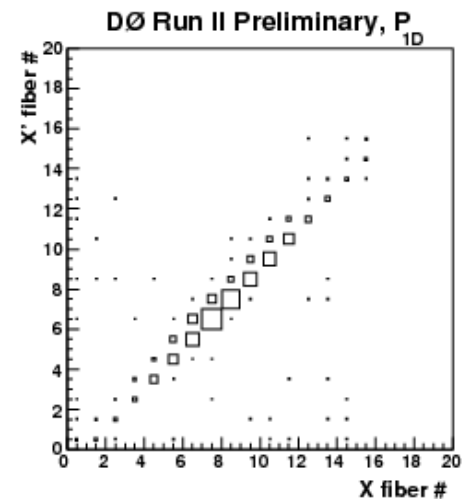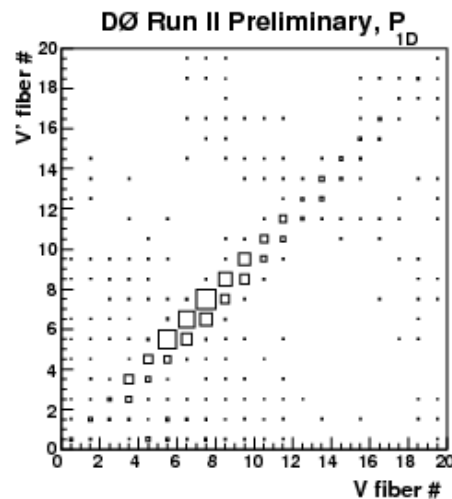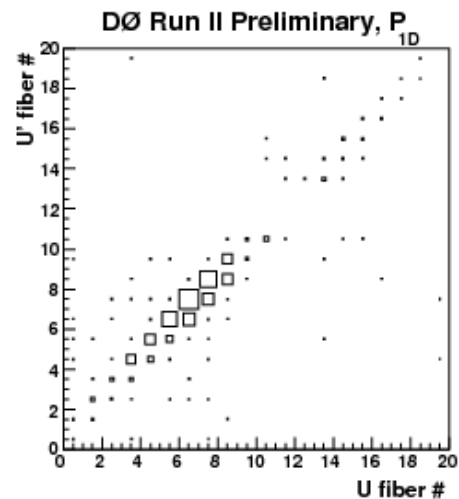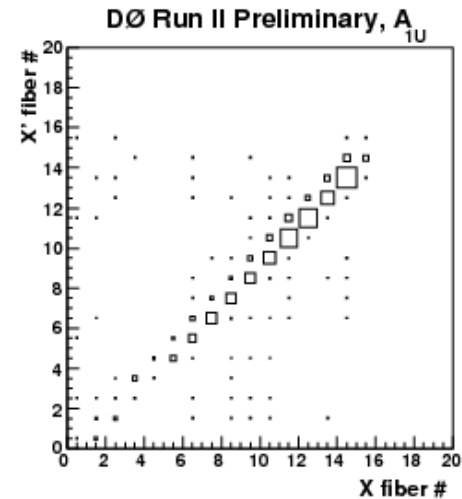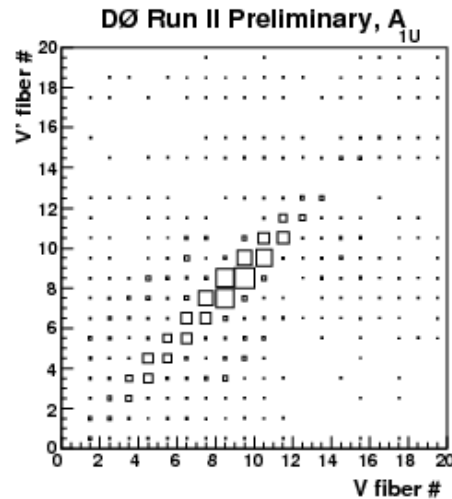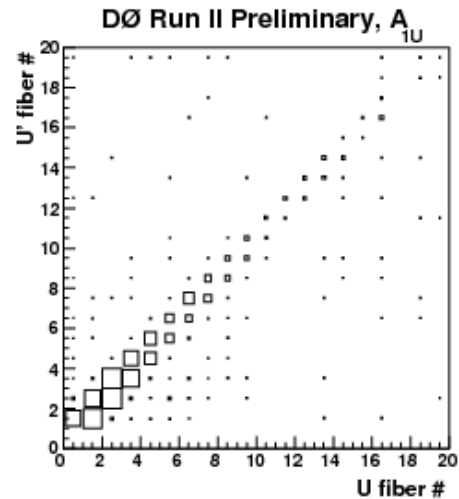
Correlations between fibers in the primed and unprimed plane of each layer in AU-PD elastic candidates
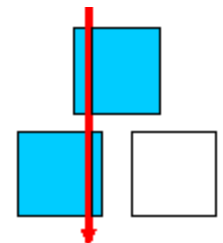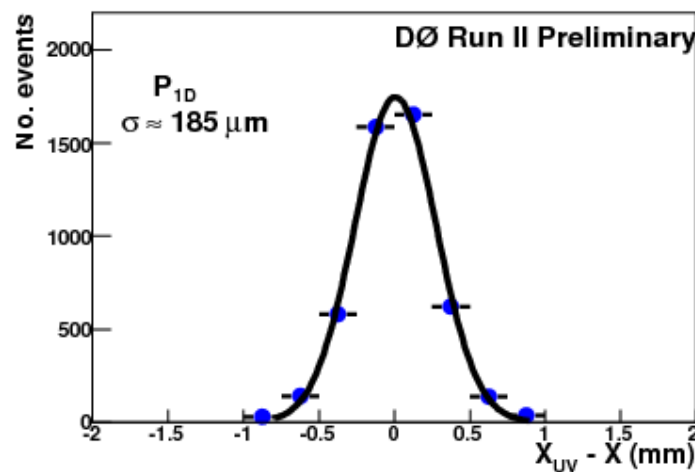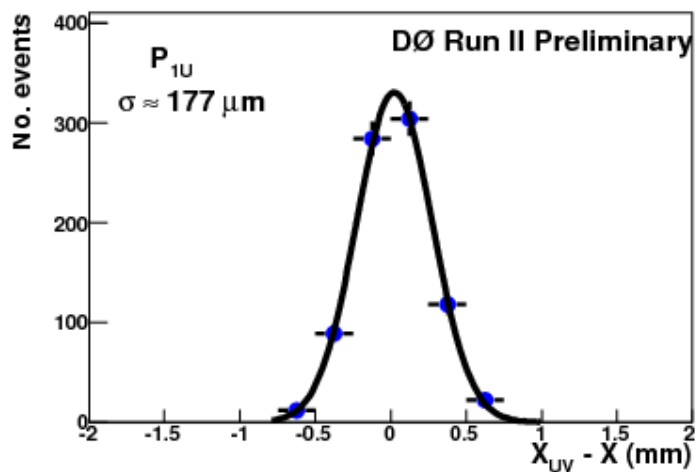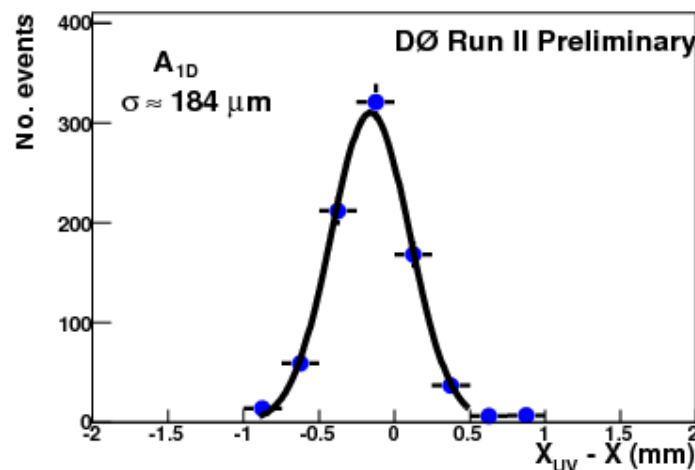
Layer Multiplicity for Elastic Candidates

Elastic events have low fiber multiplicity

Detector Resolutions
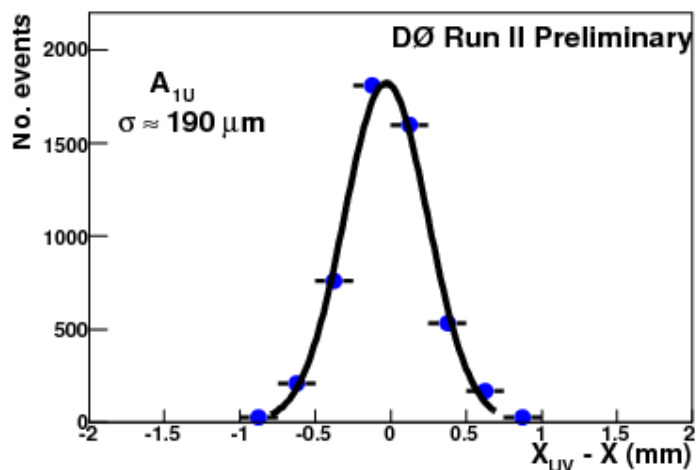
$$x_{uv} - x_x = \sqrt{2}\sigma$$

Halo Rejection
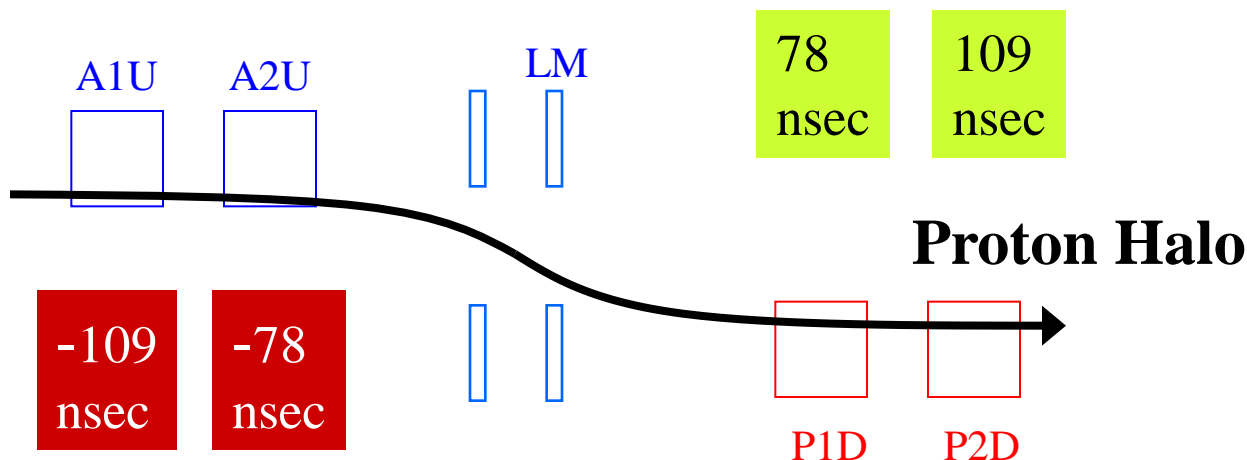
- The in-time bit is set if a pulse detected in the in-time window (consistent with a proton originating from the IP)
- The halo bit is set if a pulse is detected in early time window (consistent with a halo proton)
- We can reject a large fraction of halo events using the timing scintillators (depending on the pot locations)

Correlations Between Detectors

No Time window required — DØ Run II Preliminary
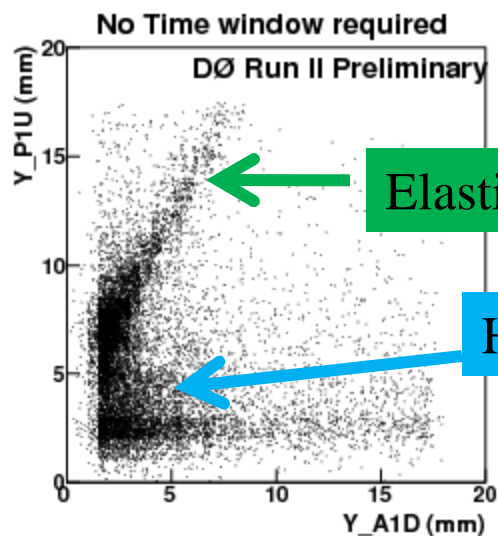
Hits in Early Time window — DØ Run II Preliminary

No Early Hits — DØ Run II Preliminary

fiducial region

Elastic

Halo

residual halo due to different acceptances of the two spectrometers -> fiducial cuts

Andrew Brandt UTA   DPF 2011 Brown University
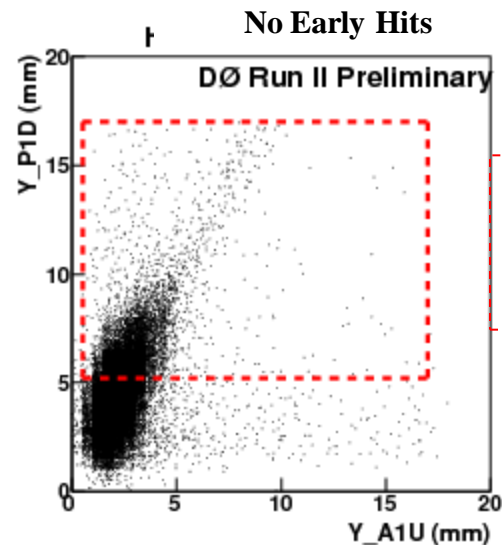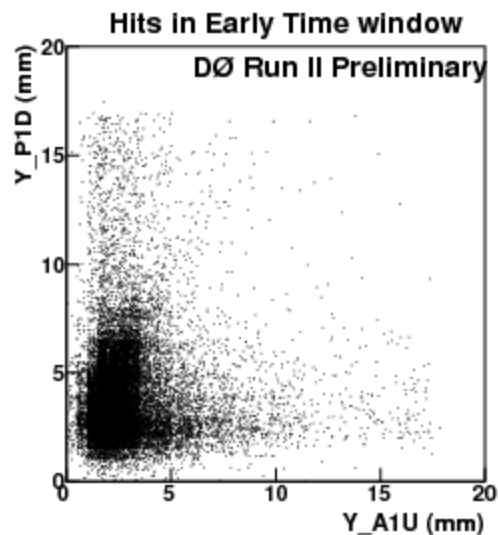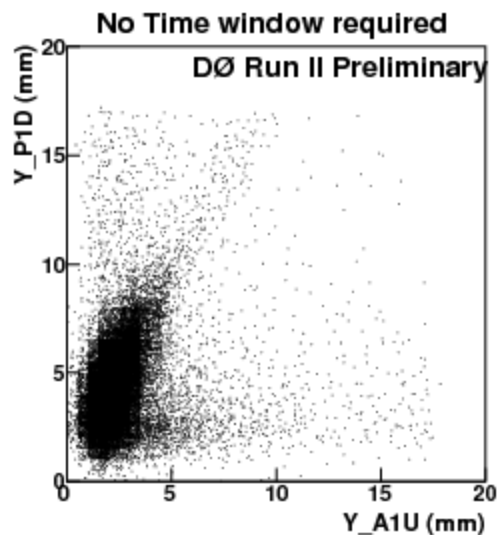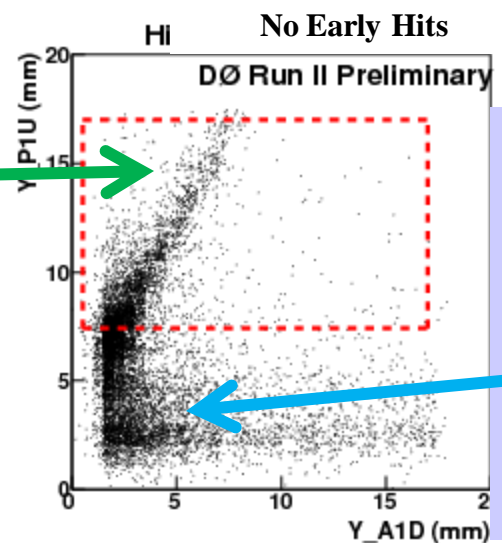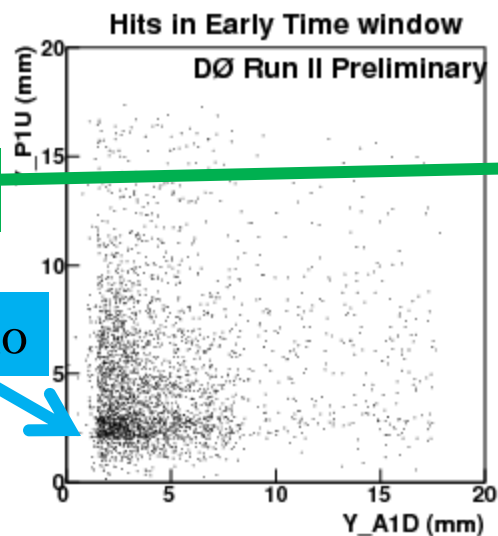
Measuring Cross Section

1. Count elastic events
2. Divide by luminosity
3. Correct for acceptance and efficiency
4. Unsmearing correction for |t| resolution
5. Subtract residual halo background
6. Take weighted average of four measurements
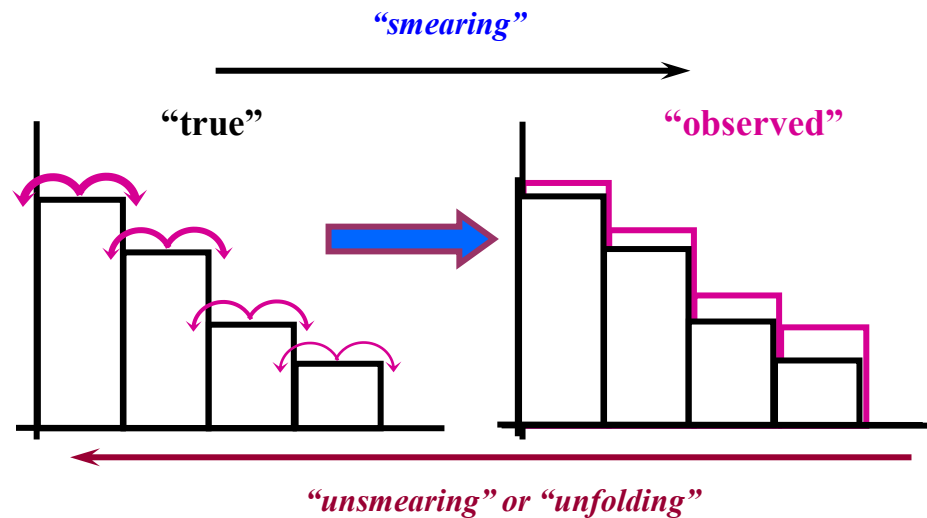   (2 elastic configurations each with two pot positions)

$$\frac{d\sigma}{dt} = \frac{1}{L \cdot A \cdot \varepsilon} \frac{dN}{dt}$$

Correcting Cross Section

Corrections:

1) φ acceptance (geometrical loss due to finite size of opposite spectrometer)

2) Unsmearing correction due to beam divergence, |t| resolution (standard approach using ansatz function)

3) Efficiency: use triggers requiring A1-P1 or A2-P2 hits, offline demand 3rd hit, then measure efficiency of 4th detector

4) Use side bands to measure and subtract background

DØ Run II Preliminary

φ acceptance correction

|t| (Gev^2)

"smearing"

"true"   "observed"

"unsmearing" or "unfolding"

δ|t|
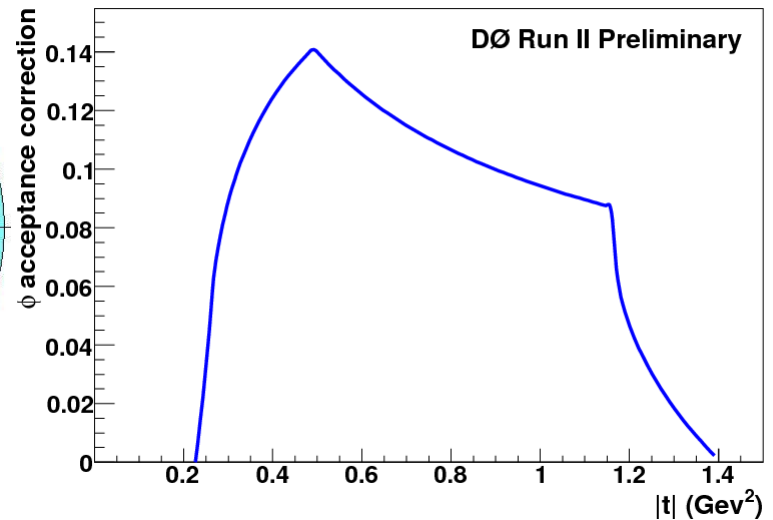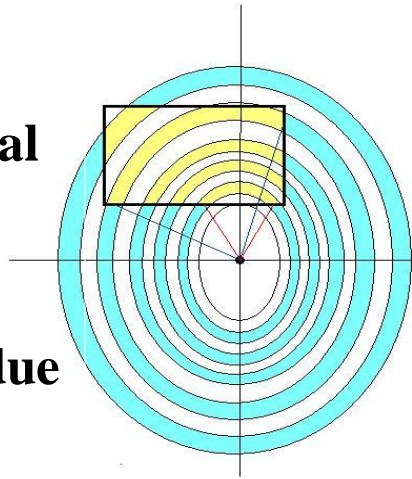
Resolution ranges from 0.02 at low |t| to 0.045 at high |t|
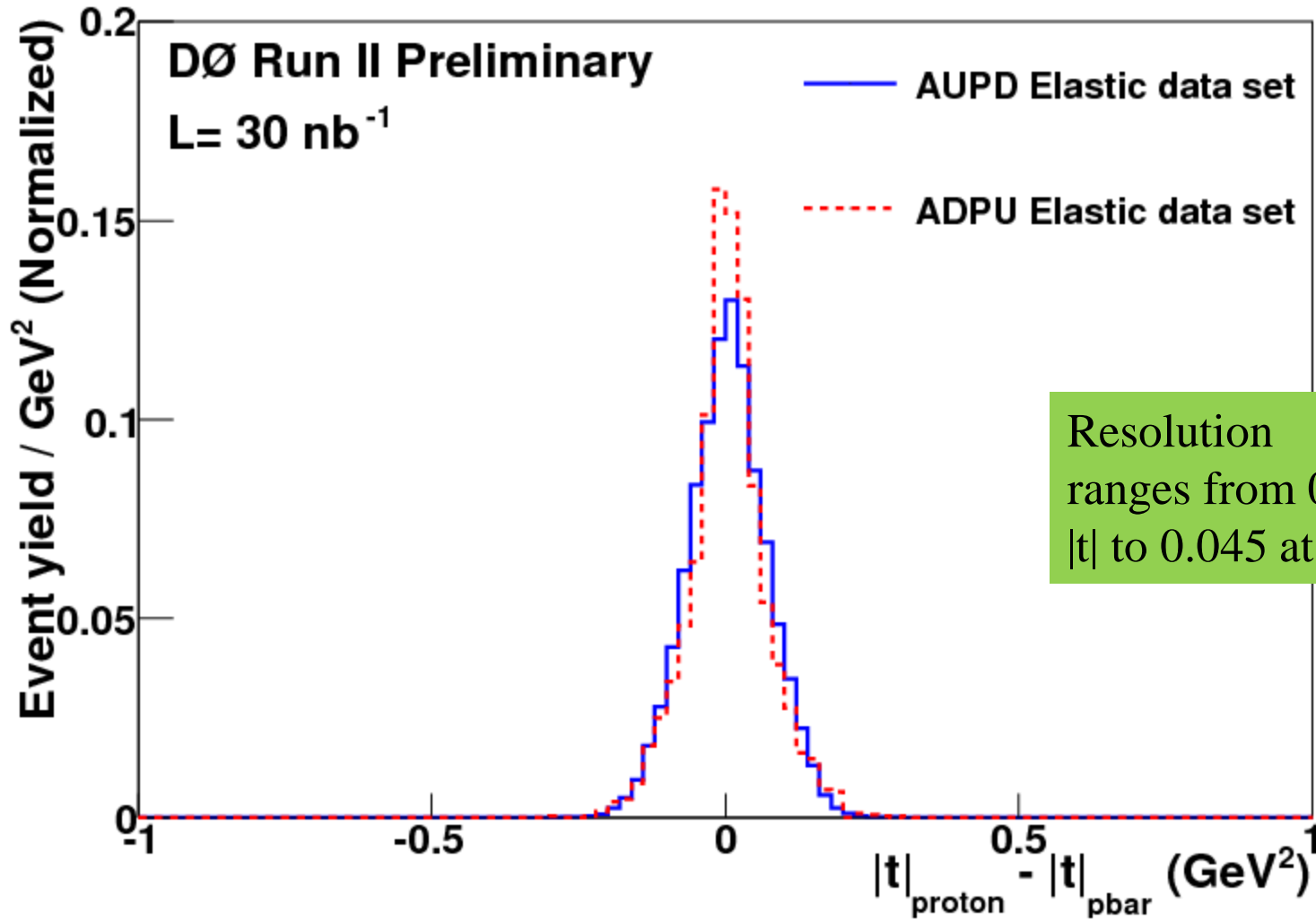
Observe expected colinearity between proton and anti-proton

Measurement of Elastic Slope (b)

DØ Run II Preliminary, L= 30 nb⁻¹

$- - - - -$ $C \exp(-b|t|)$

$b = 16.5 \pm 0.1 \pm 0.8 \ \mathrm{GeV}^{-2}$

- Systematic error dominated by trigger efficiency correction (this is likely to be significantly smaller in final result, which just missed the DPF deadline)
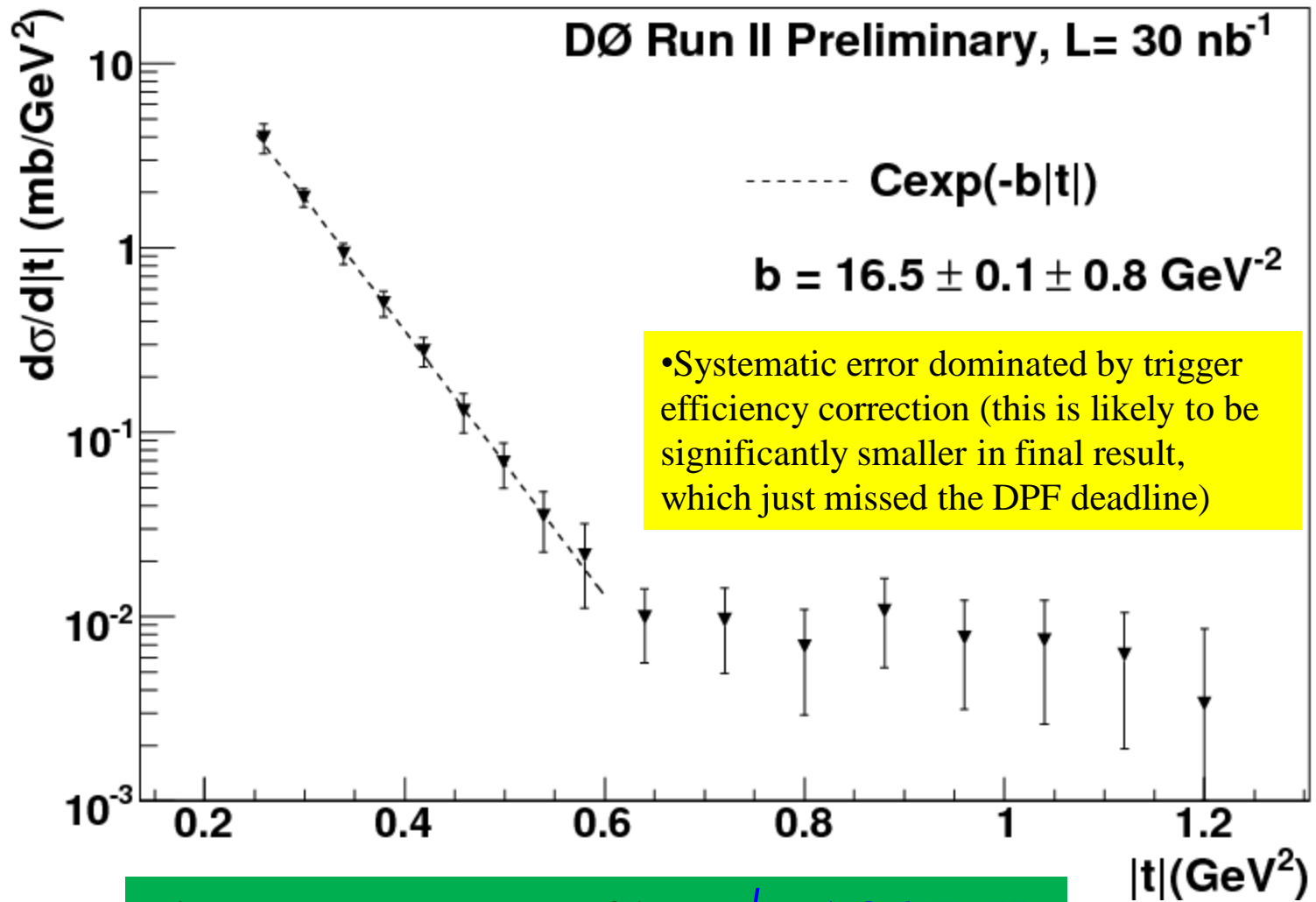
First measurement of b at √s=**1.96 TeV**

dσ/d|t| Compared to E710+CDF

D0 Run II Preliminary, L= 30 nb^{-1}

- ▼ DØ (1.96 TeV)
- ○ E710 (1.8 TeV)
- ◇ CDF (1.8 TeV)
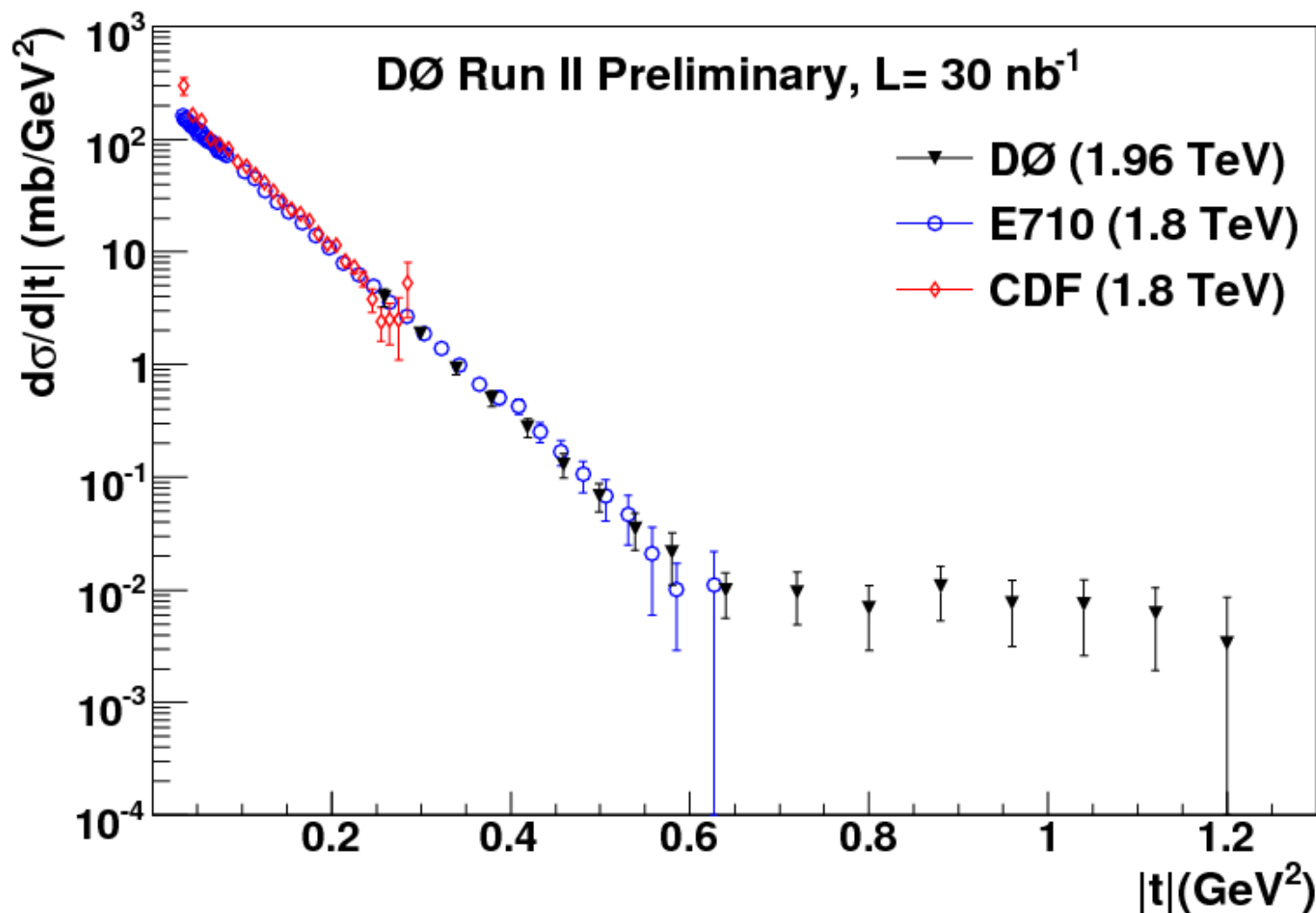
E710/CDF for √s=1.8 TeV; expect logarithmic dependence with √s

dσ/d|t| Compared to UA4
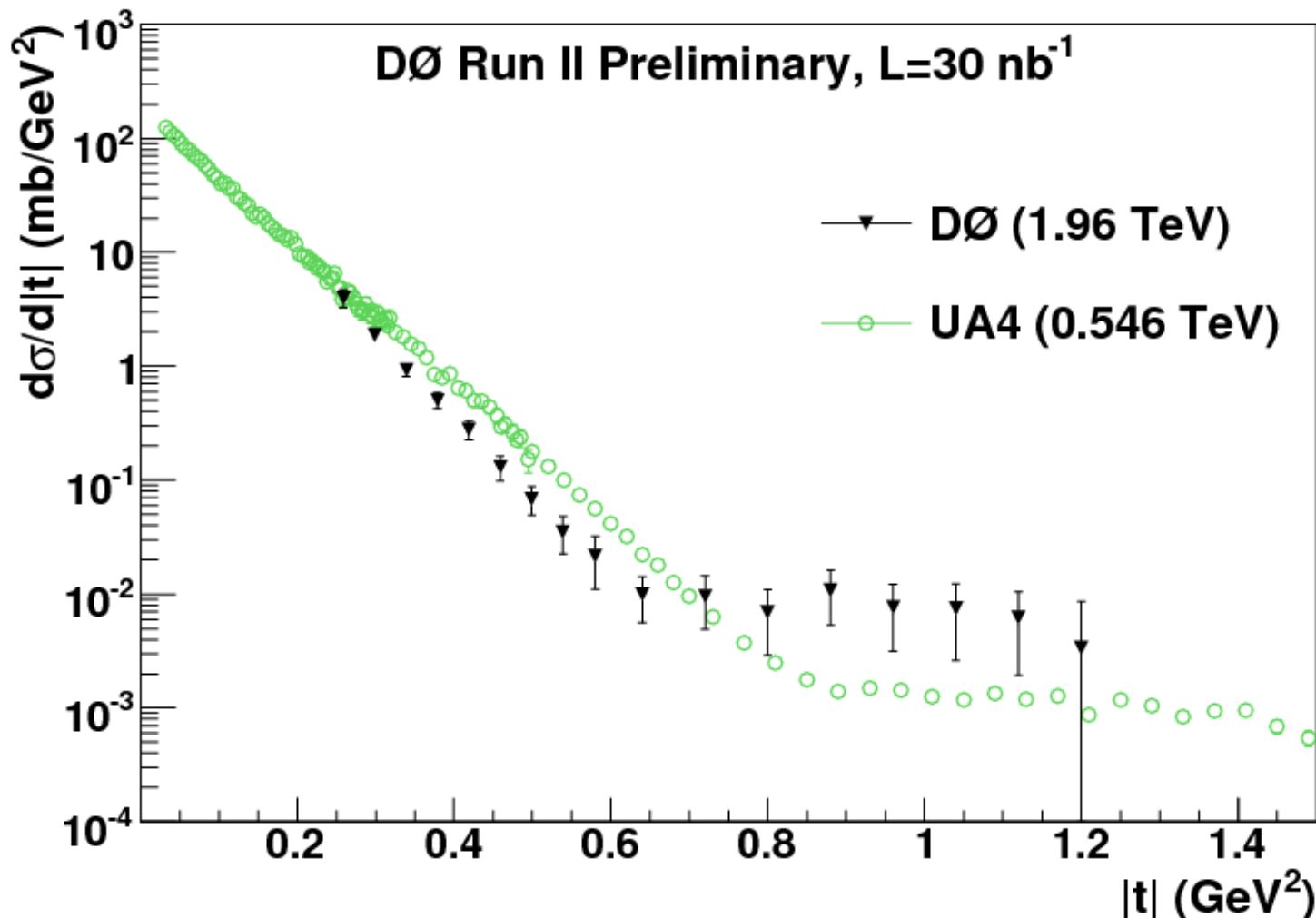
Slope steeper and slope change earlier for higher √s (shrinkage)

Conclusions

- We have measured $d\sigma/d|t|$ for elastic scattering over the range: $0.2 < |t| < 1.2 \text{ GeV}^2$ the first such measurement at **√s=1.96 TeV**

- For $0.2 < |t| < 0.6 \text{ GeV}^2$ we have measured the elastic slope

  b=16.5 ± 0.1 ± 0.8 GeV^{-2}

- We observe that the elastic slope is steeper and changes slope earlier than lower energy data such as UA4

Extra Points

- **Paper is in final review stages to be submitted to PRD in next few weeks**

- **Arnab Pal (UTA Ph. D. student) just defended his thesis on single diffractive cross section, analysis in early review stages**