Elastic Scattering at √s=1.96 TeV Using the DØ Forward Proton Detector

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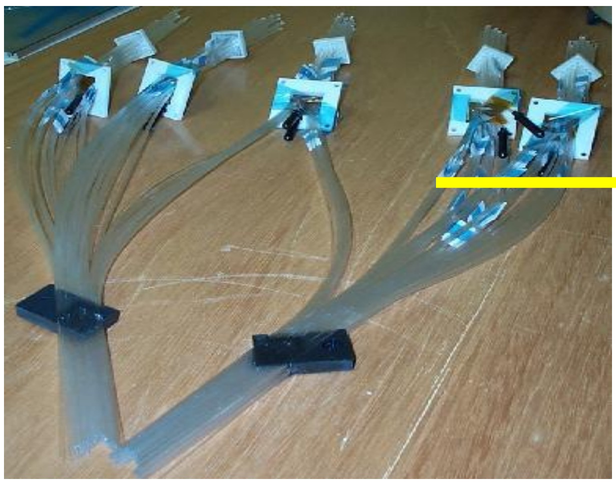
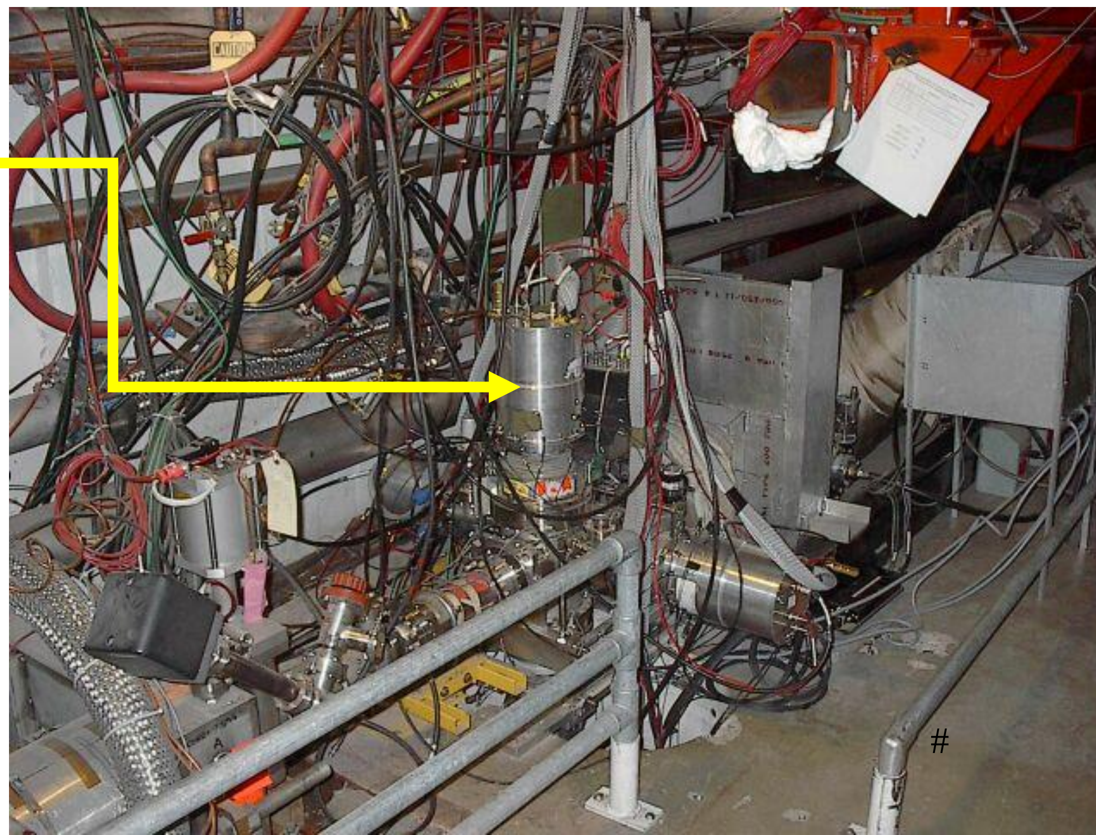
on behalf of DØ Collaboration





An FPD Quadrupole castle with four detectors installed

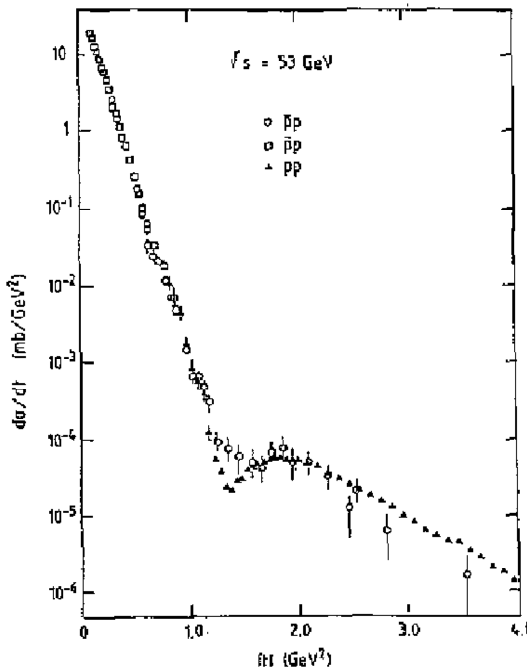
Elastic Scattering

- 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:

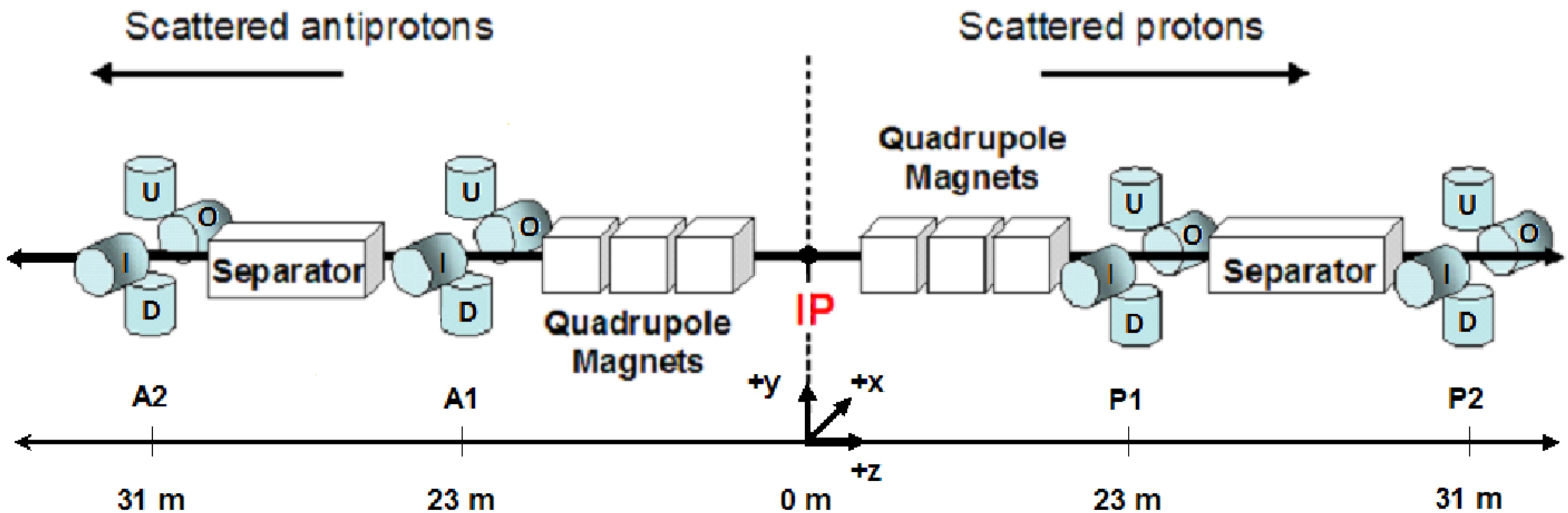
$$\frac{d\sigma/dt}{(d\sigma/dt)_{t=0}} = e^{bt} \cong 1 - b(p\theta)^2$$

- 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

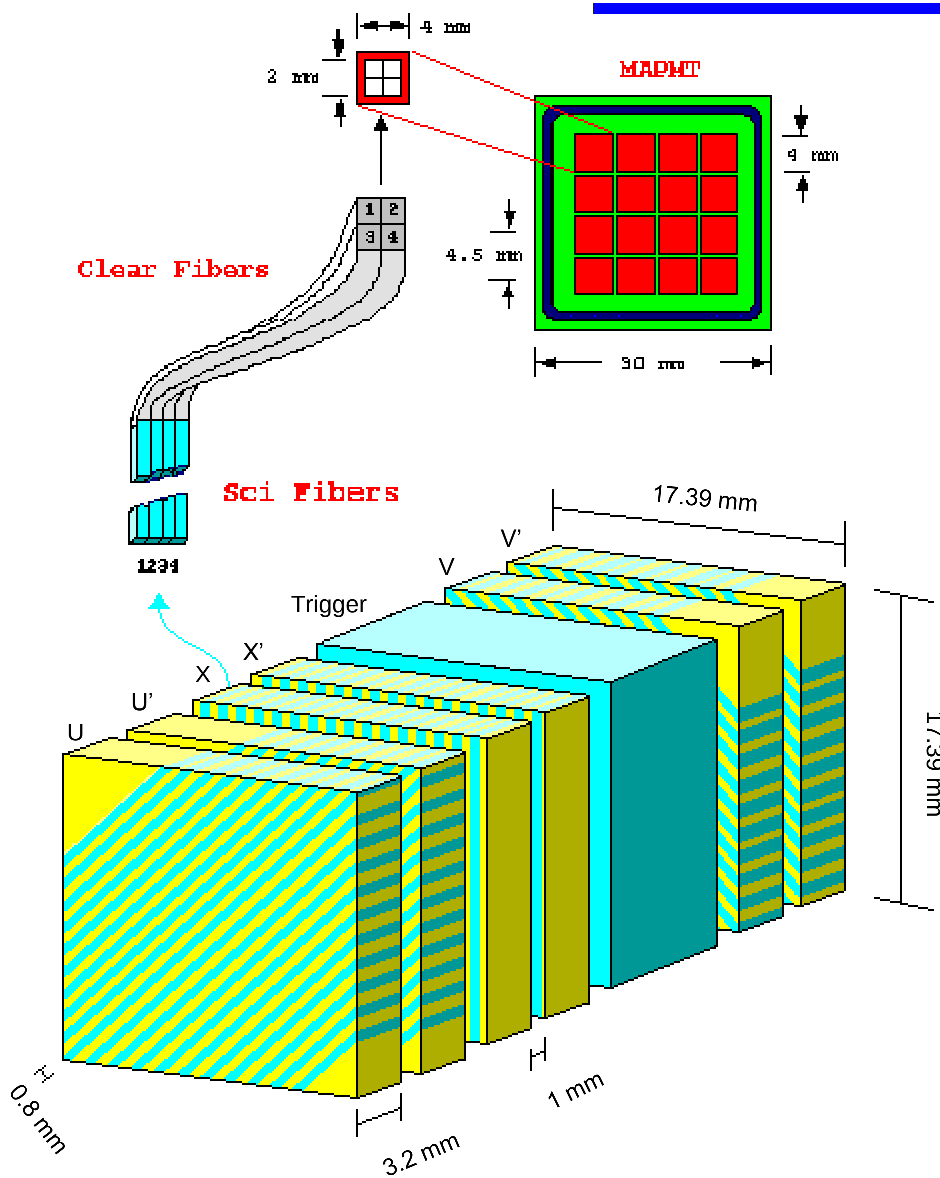


⇨There are 8 quadrupole spectrometers 4 each (Up, Down, In, Out) on the outgoing proton (P) and anti-proton (A) sides, with each spectrometer comprised of two detectors (1, 2)

⇨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



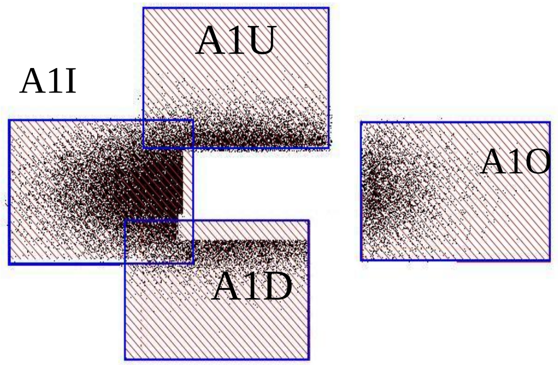
- 3 layers in detector: U and V at 45º degrees to X, 90º degrees to each other
- Each layer has two planes (prime and unprimed) offset by ~2/3 fiber
- Each channel contains four fibers
- Two detectors in a spectrometer
- Scintillator for timing (primariliy used for halo rejection)

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, $\beta^* = 1.6$m (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**

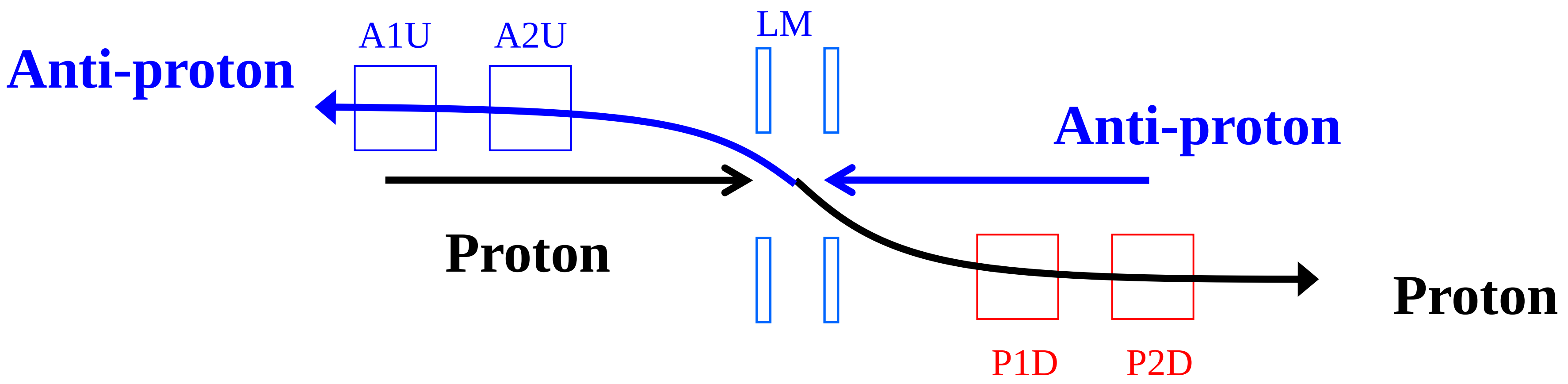


- **Hit Finding**
  - **Require less than 5 hit fibers per layer (suppresses beam background)**
  - **Use intersection of fiber layers to determine a hit**

- **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

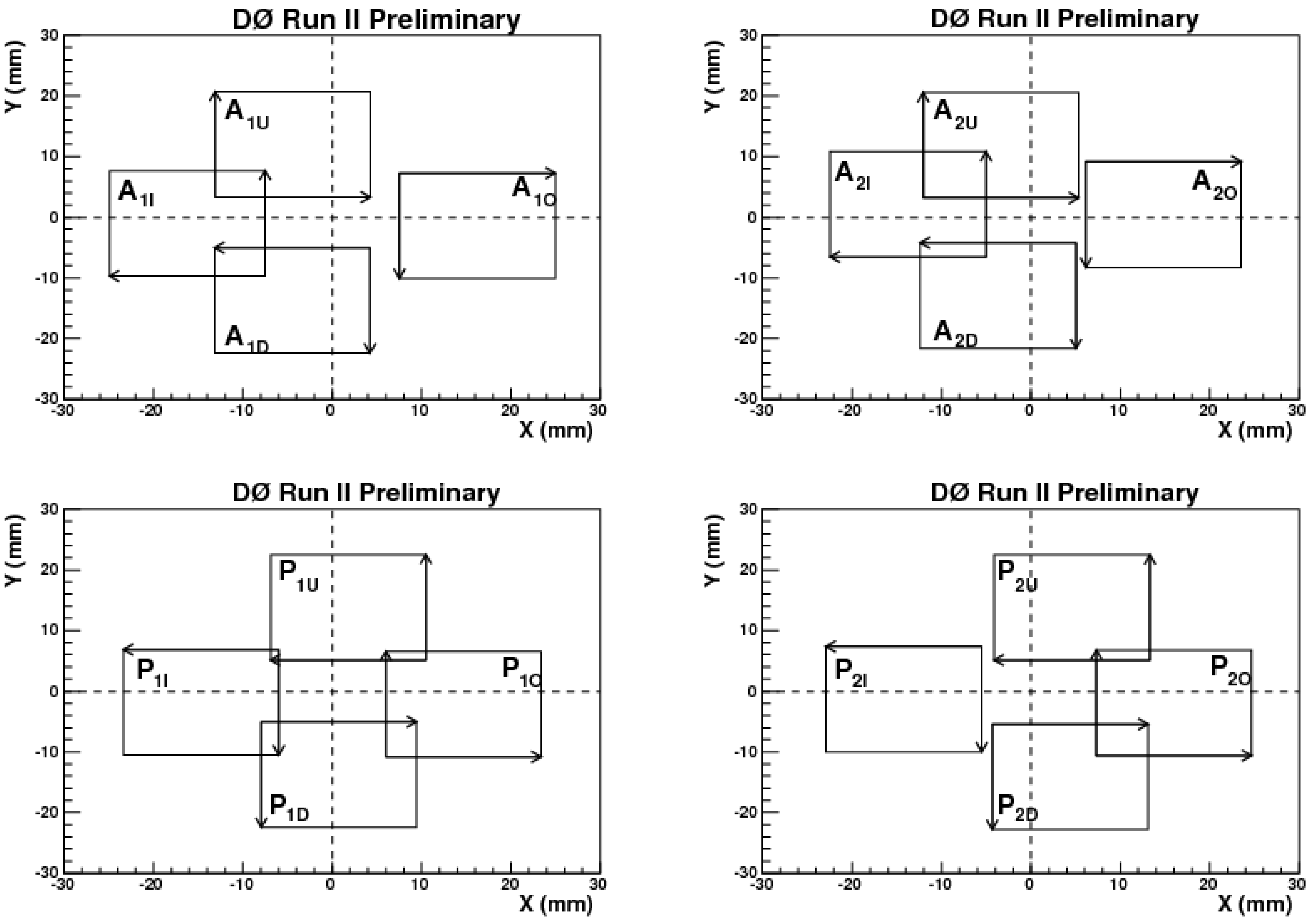
Elastic events have tracks in diagonally opposite spectrometers



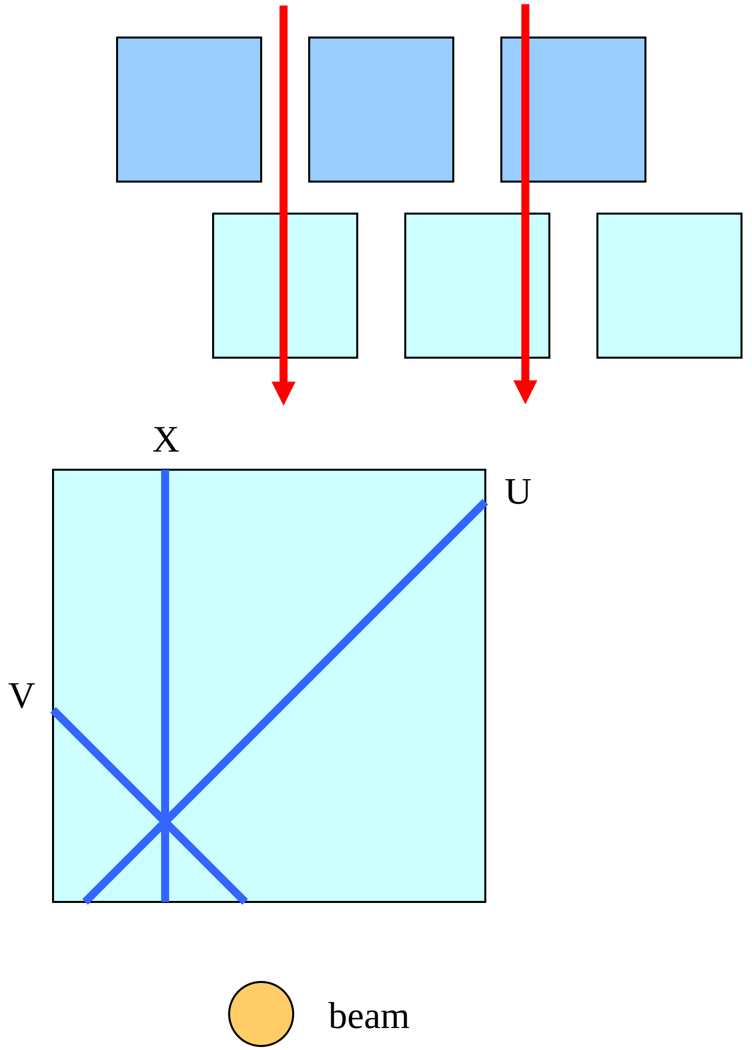
Momentum dispersion in horizontal plane results in more halo (beam background) in the IN/OUT detectors, so concentrate on vertical plane AU-PD and AD-PU to maximize |t| acceptance while minimizing background

AU-PD combination has the best |t| acceptance

Detector Positions after Alignment

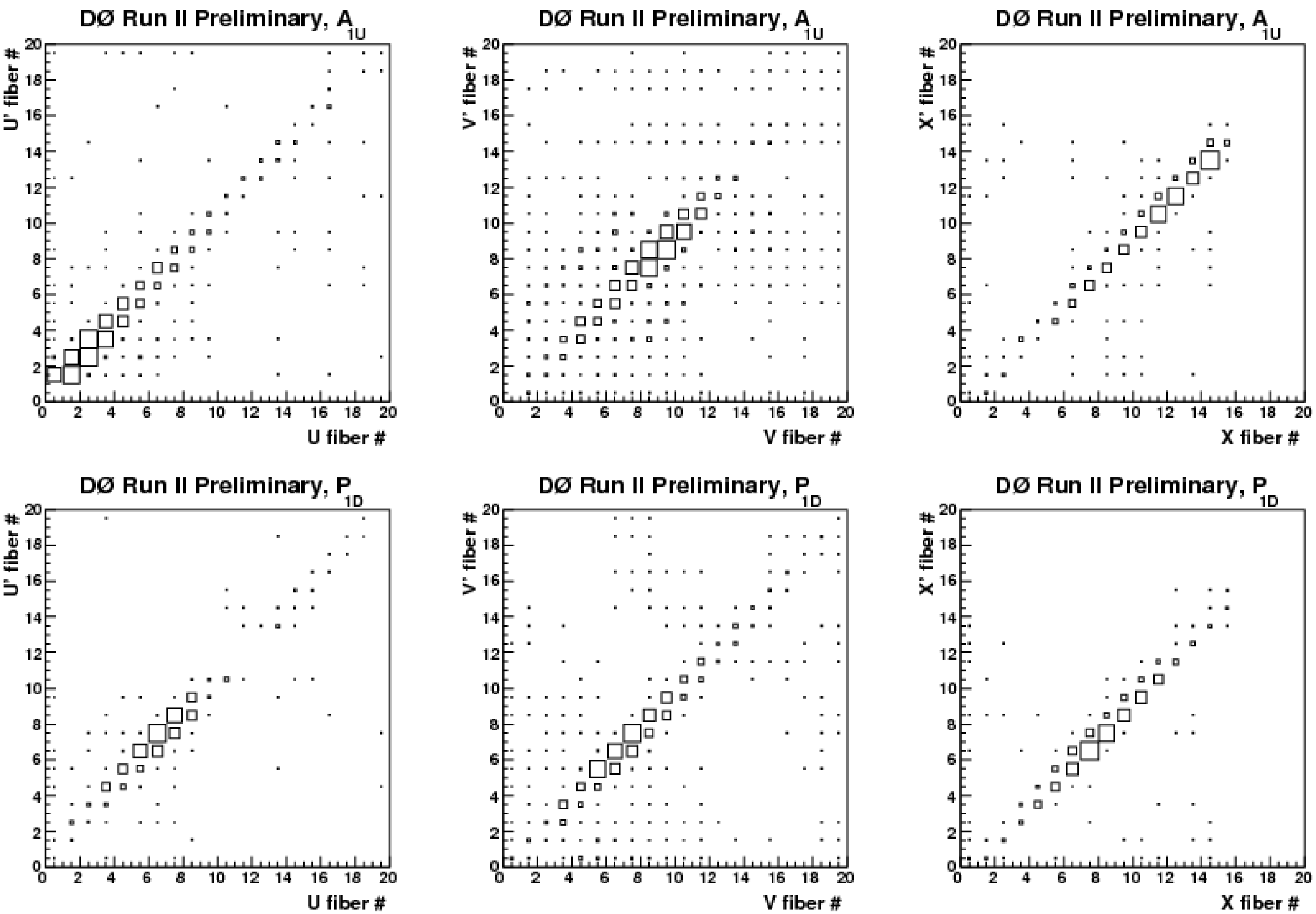


Hit Finding

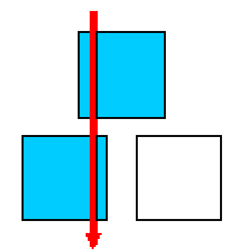


- Combination of fibers in a plane determine a segment
- Need two out of three possible segments to get a hit
  - U/V, U/X, X/V (or U/X/V)
    - reconstruct x and y position in detector
    - use alignment to go from detector to beam coordinates
- Can also get an x directly from the x segment (can compare these x measurements to measure resolution)

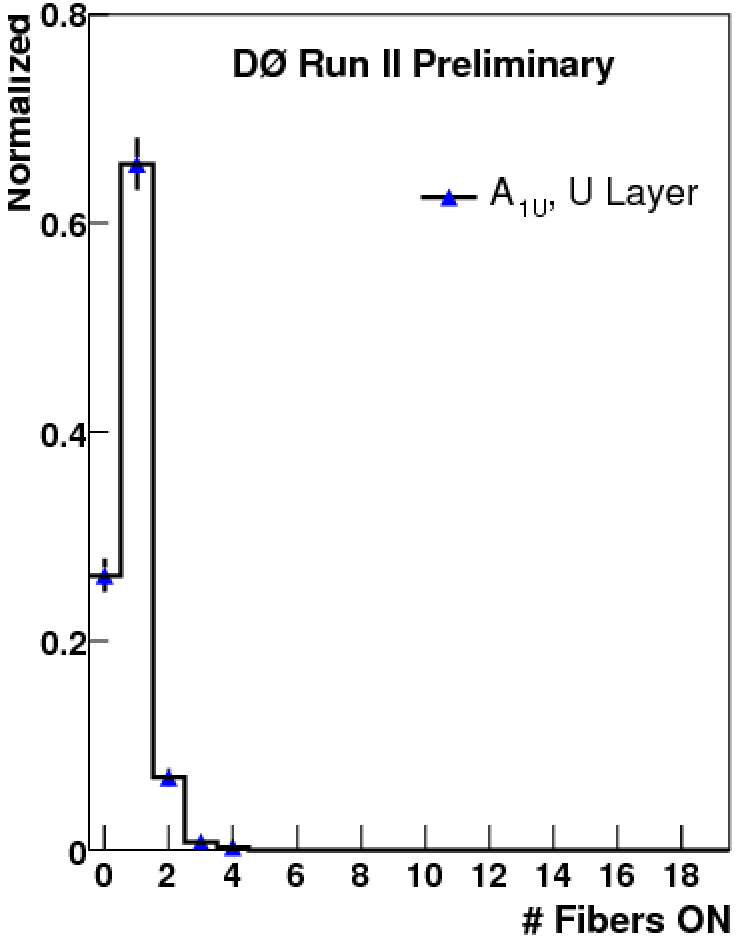
Fiber Correlations within a Detector

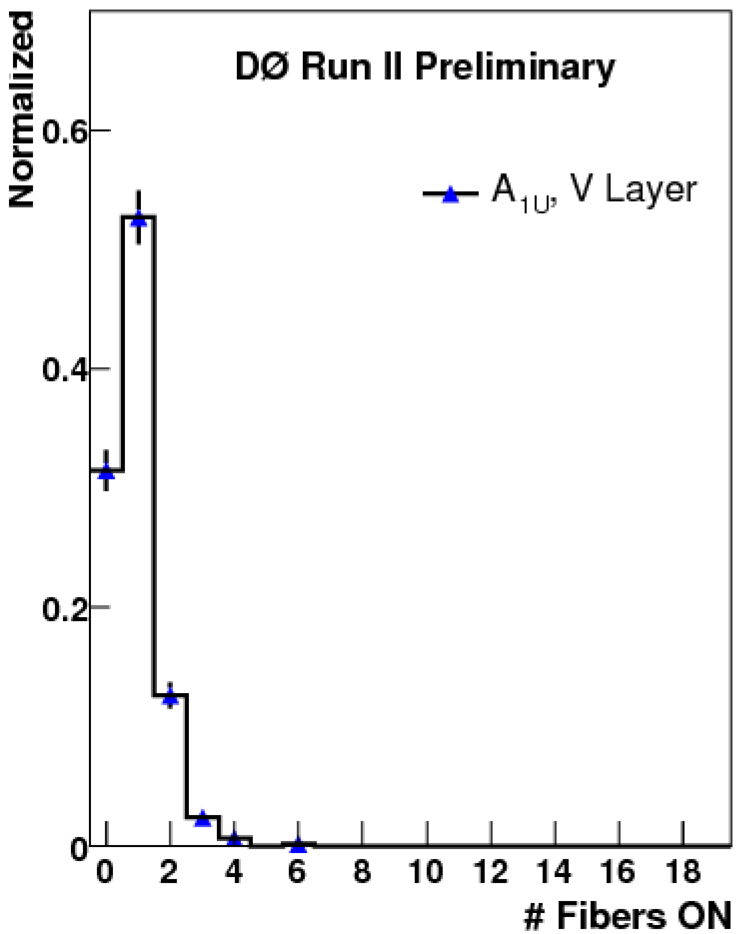


Correlations between fibers in the primed and unprimed plane of each layer in AU-PD elastic candidates



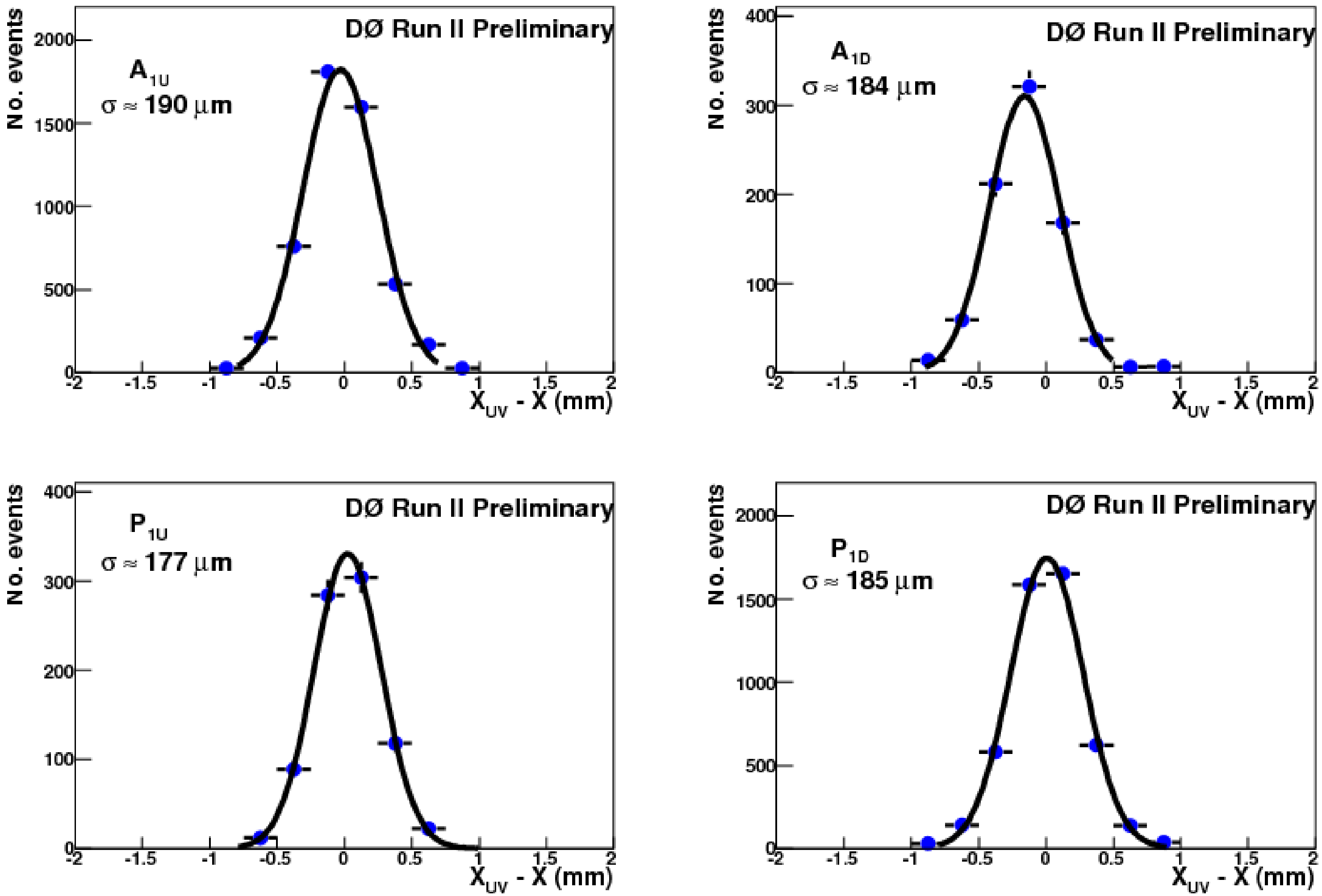
Layer Multiplicity for Elastic Candidates





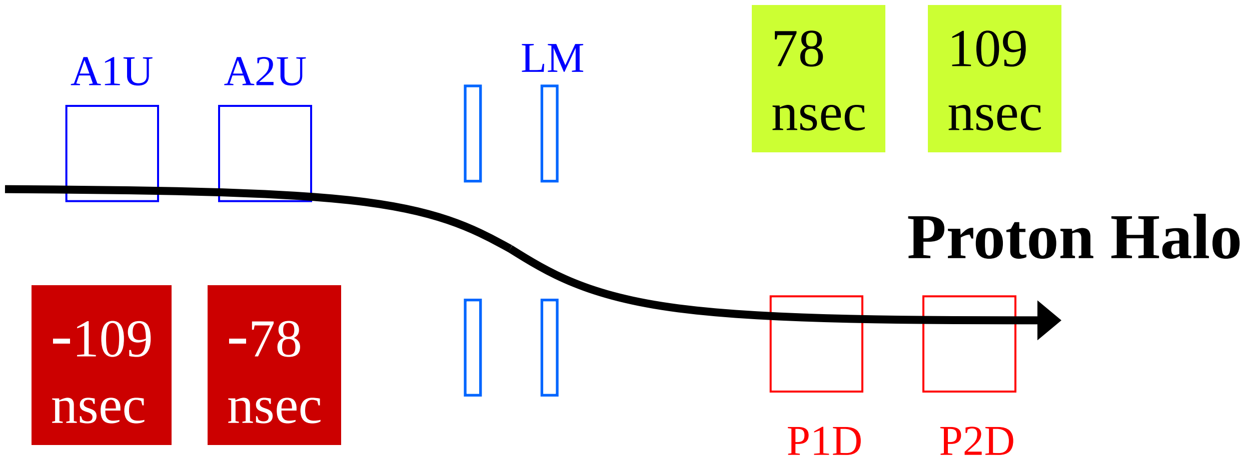
Elastic events have low fiber multiplicity

Detector Resolutions



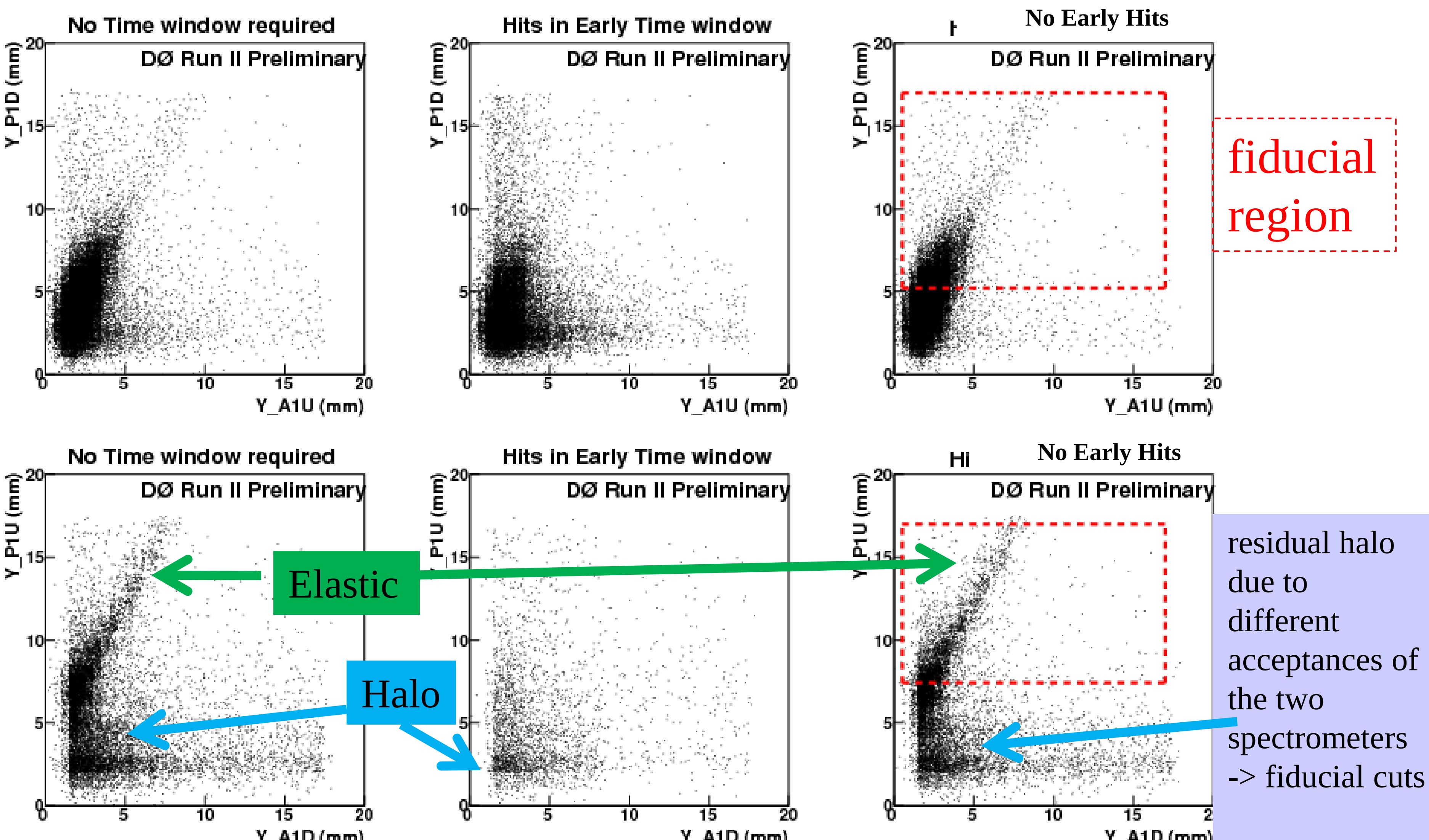
x_{uv}-x_x=$\sqrt{2}\sigma$

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



Measuring Cross Section

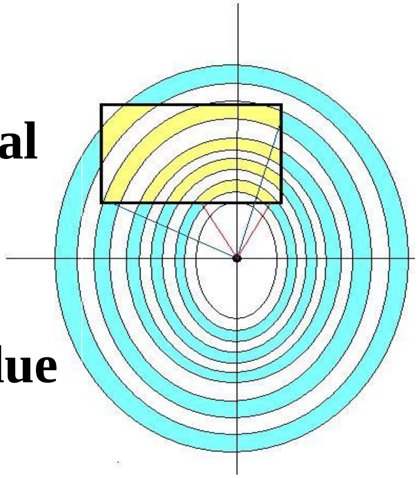
1. Count elastic events
2. Divide by luminosity
3. Correct for acceptance and efficiency
4. Unsmearing correction for |t| resolution
5. Subtract residual halo background
6. Take weighted average of four measurements
   (2 elastic configurations each with two pot positions)

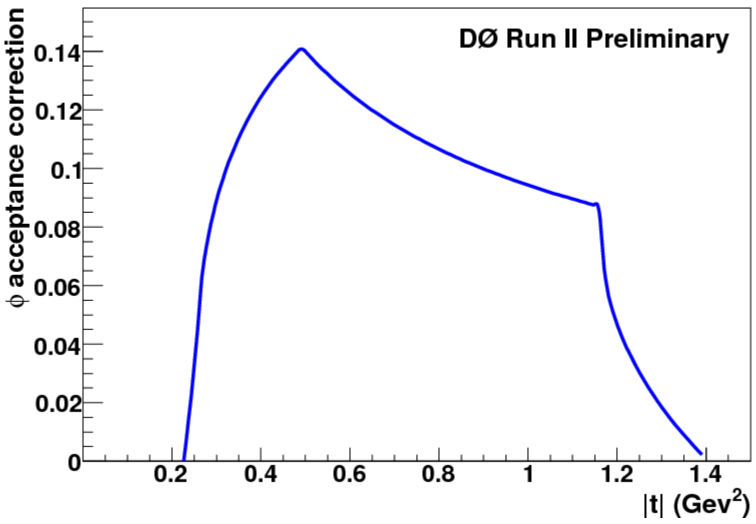
$$\frac{d\sigma}{dt} = \frac{1}{L \cdot A \cdot \varepsilon} \frac{dN}{dt}$$

Correcting Cross Section

Corrections:

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

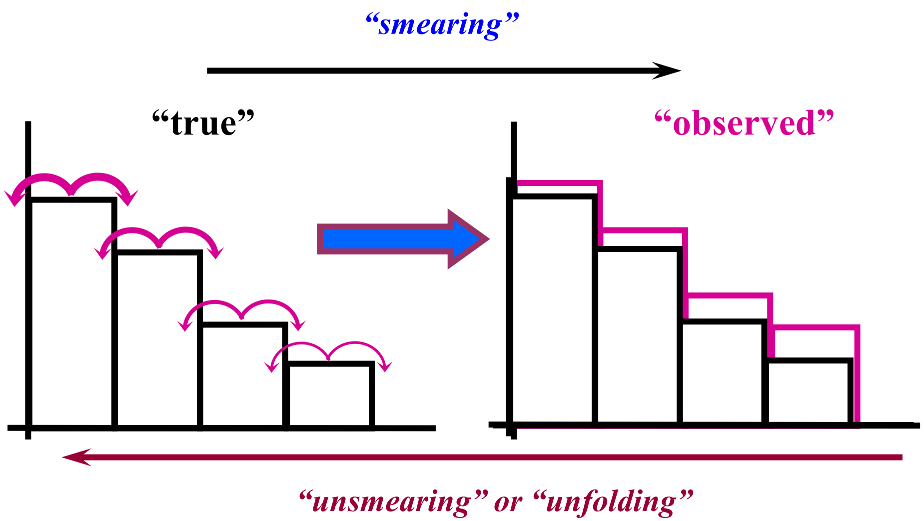




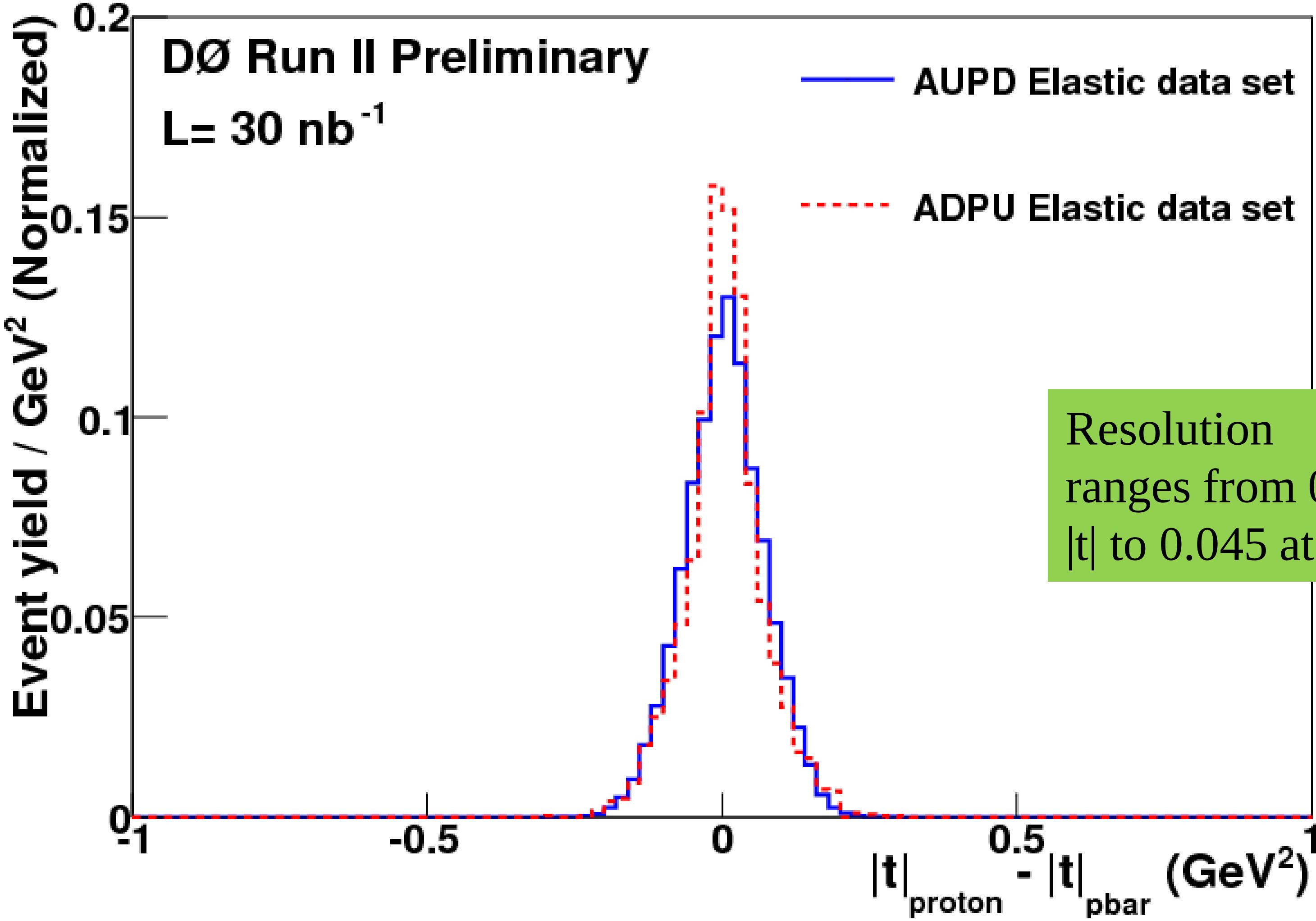
2) Unsmearing correction due to beam divergence, |t| resolution (standard approach using ansatz function)

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



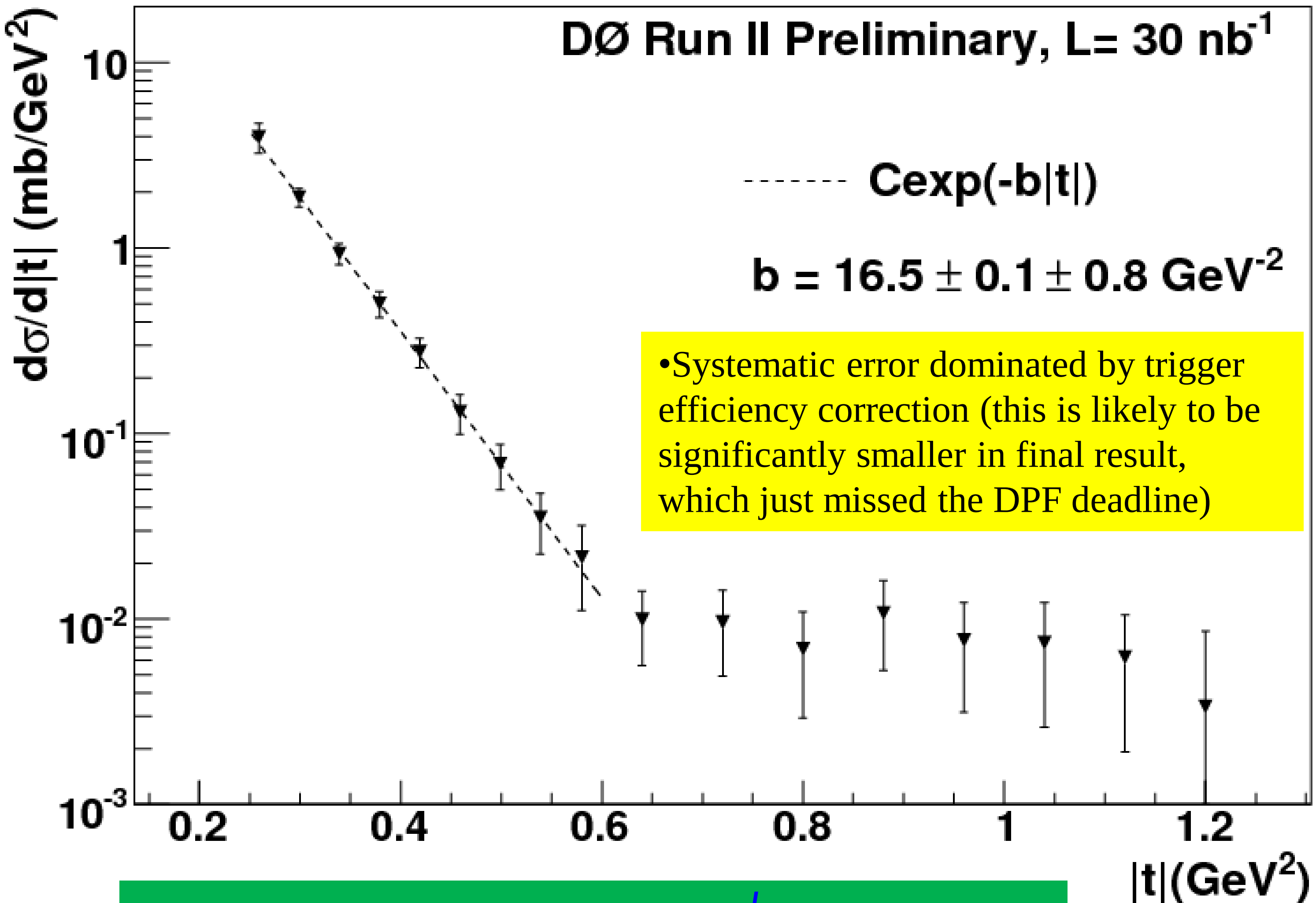
δ|t|



Resolution ranges from 0.02 at low |t| to 0.045 at high |t|

Observe expected colinearity between proton and anti-proton

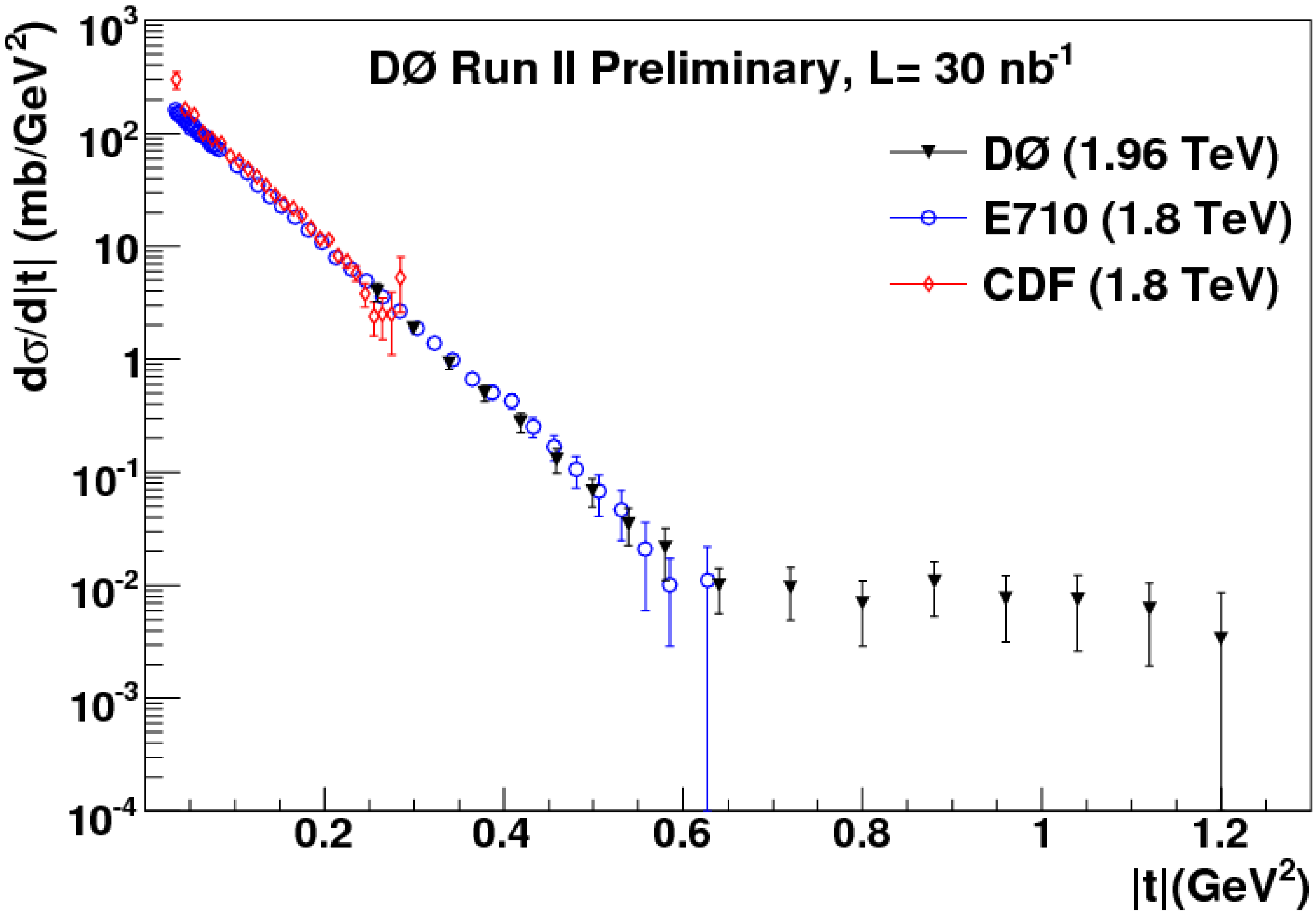
Measurement of Elastic Slope (b)



•Systematic error dominated by trigger efficiency correction (this is likely to be significantly smaller in final result, which just missed the DPF deadline)

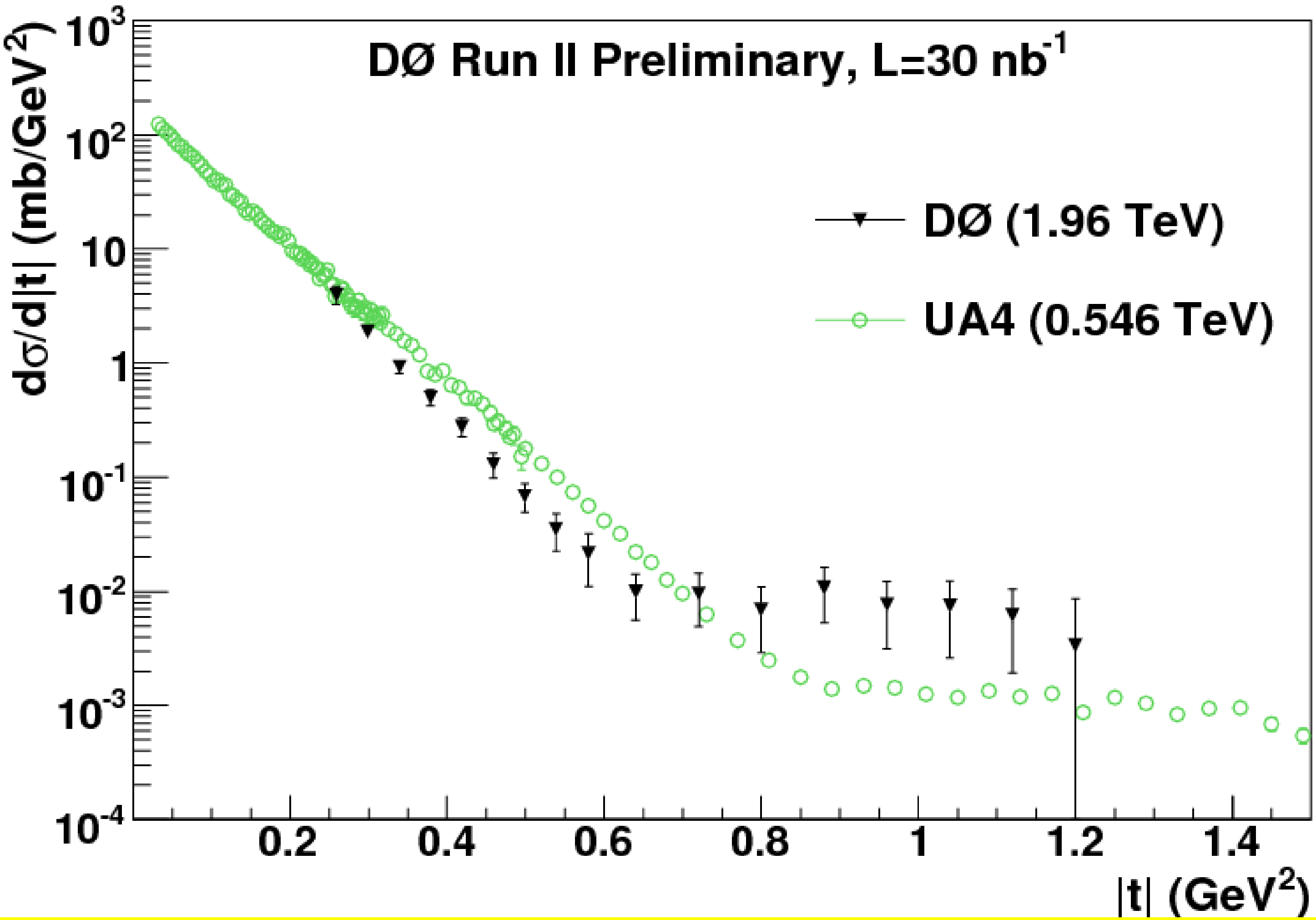
First measurement of b at $\sqrt{s}$=1.96 TeV

dσ/d|t| Compared to E710+CDF



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: $0.2 < |t| < 1.2$ GeV^2 the first such measurement at **$\sqrt{s}$=1.96 TeV**
- For $0.2<|t|<0.6$ GeV^2 we have measured the elastic slope

  $b = 16.5 \pm 0.1 \pm 0.8$ 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**