

QCD Measurements at DØ

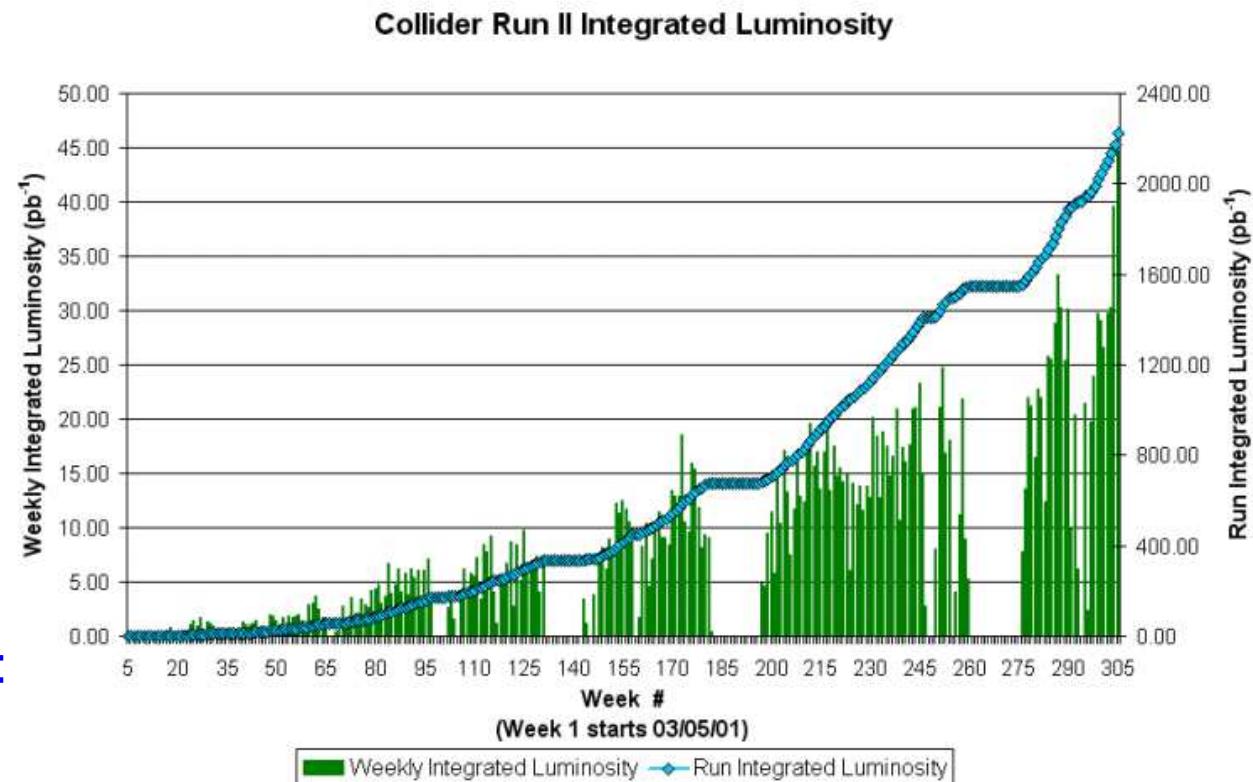
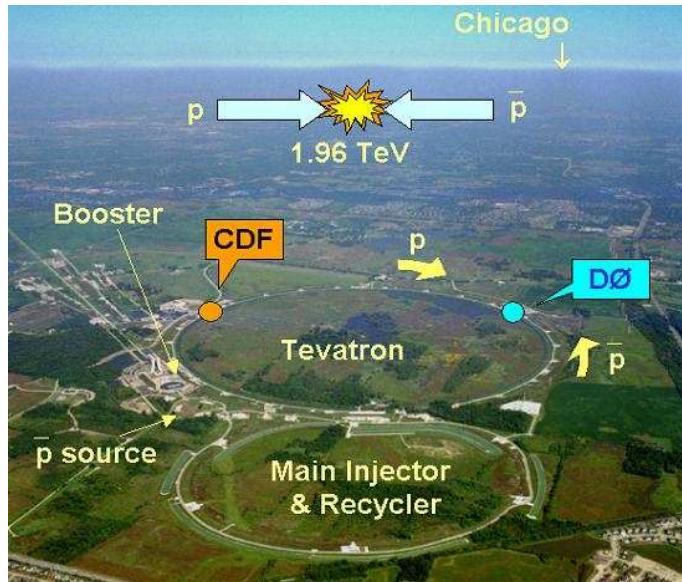
Duncan Brown
University of Texas
-Arlington-



Seminar, University of Virginia
January 24th 2007

TeVatron Collider at Fermilab

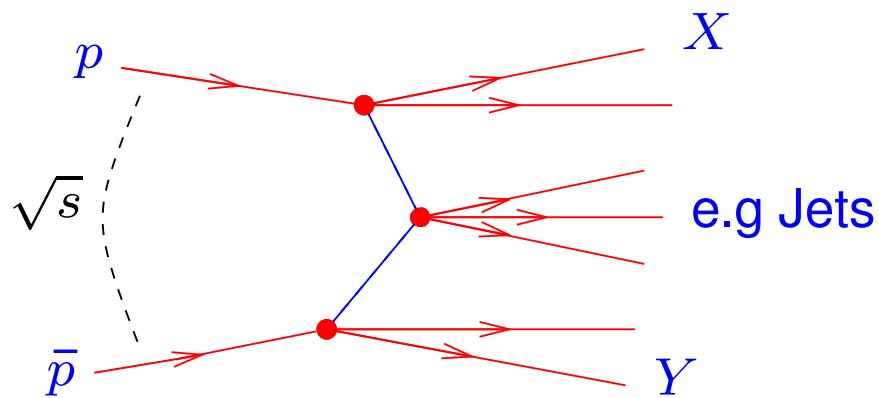
- Proton-Antiproton Collisions at Center-of-Mass $\sqrt{s} = 1.96 \text{ TeV}$



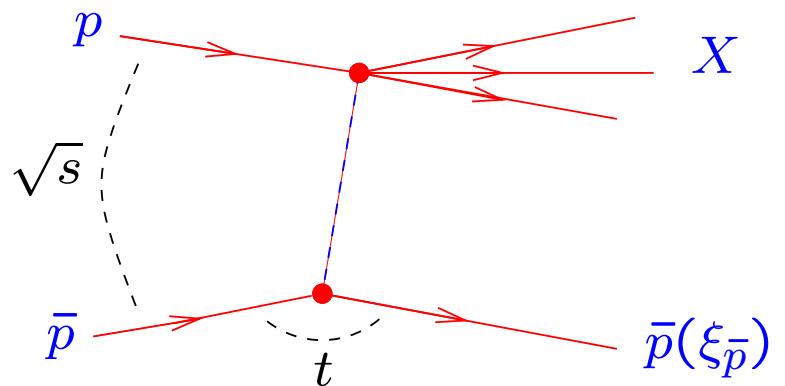
- Two Multi-Purpose Detectors:
⇒ CDF and DØ
- Many Recent Improvements to Accelerator and Detector Operations
⇒ Delivered / Recorded Integrated Luminosities $\mathcal{L} > 1 \text{ fb}^{-1}$

QCD Processes at the TeVatron

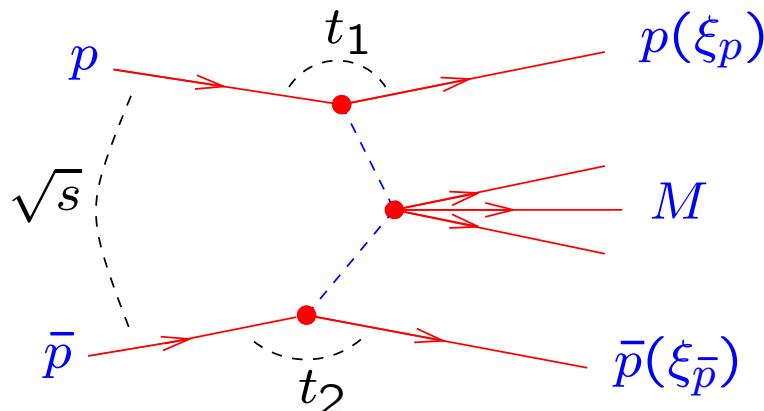
Inclusive Production



Single Diffraction



Diffractive Central Production

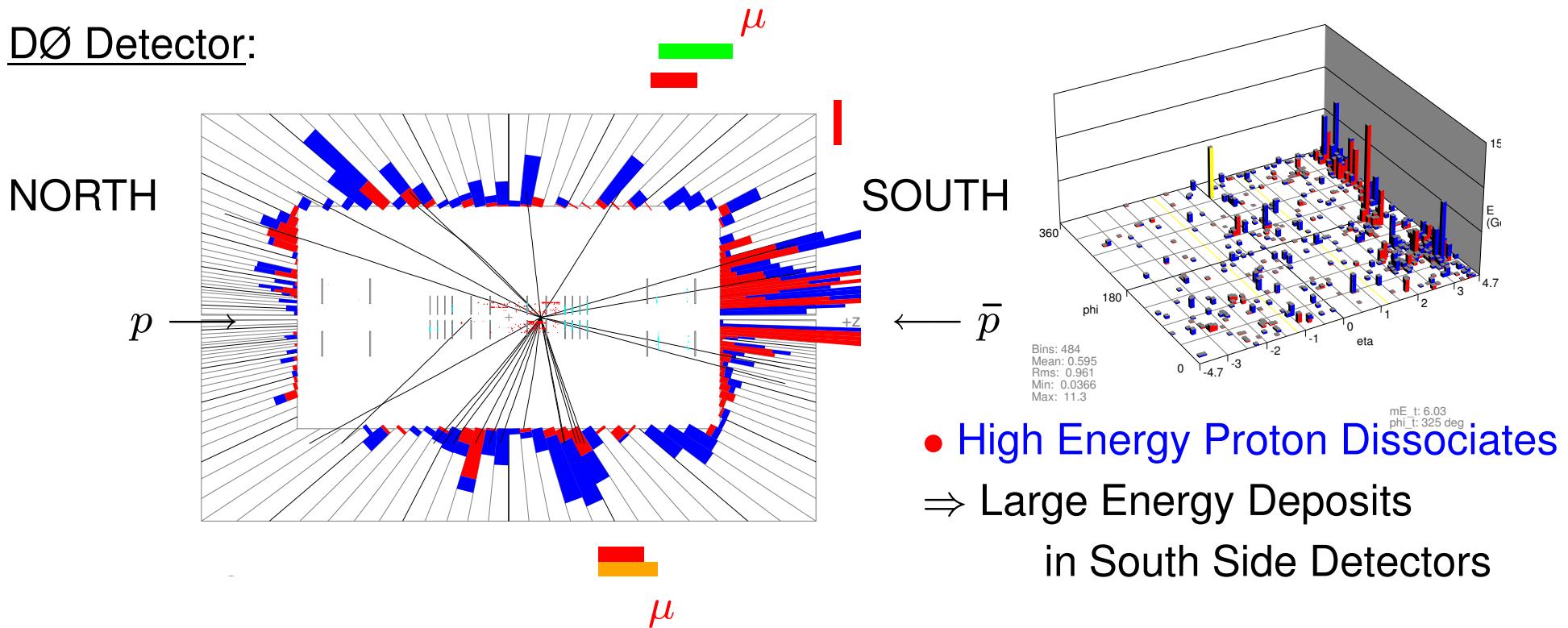


⇒ Simultaneous Probe of Different Final States

$\sqrt{s} = 1.96 \text{ TeV}$ (Run II)	$p\bar{p}$ c.o.m energy	t	4-mom. transfer squared	ξ_p	fractional proton mom. loss	$\xi_{\bar{p}}$	fractional antiproton mom. loss
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Experimental Signatures

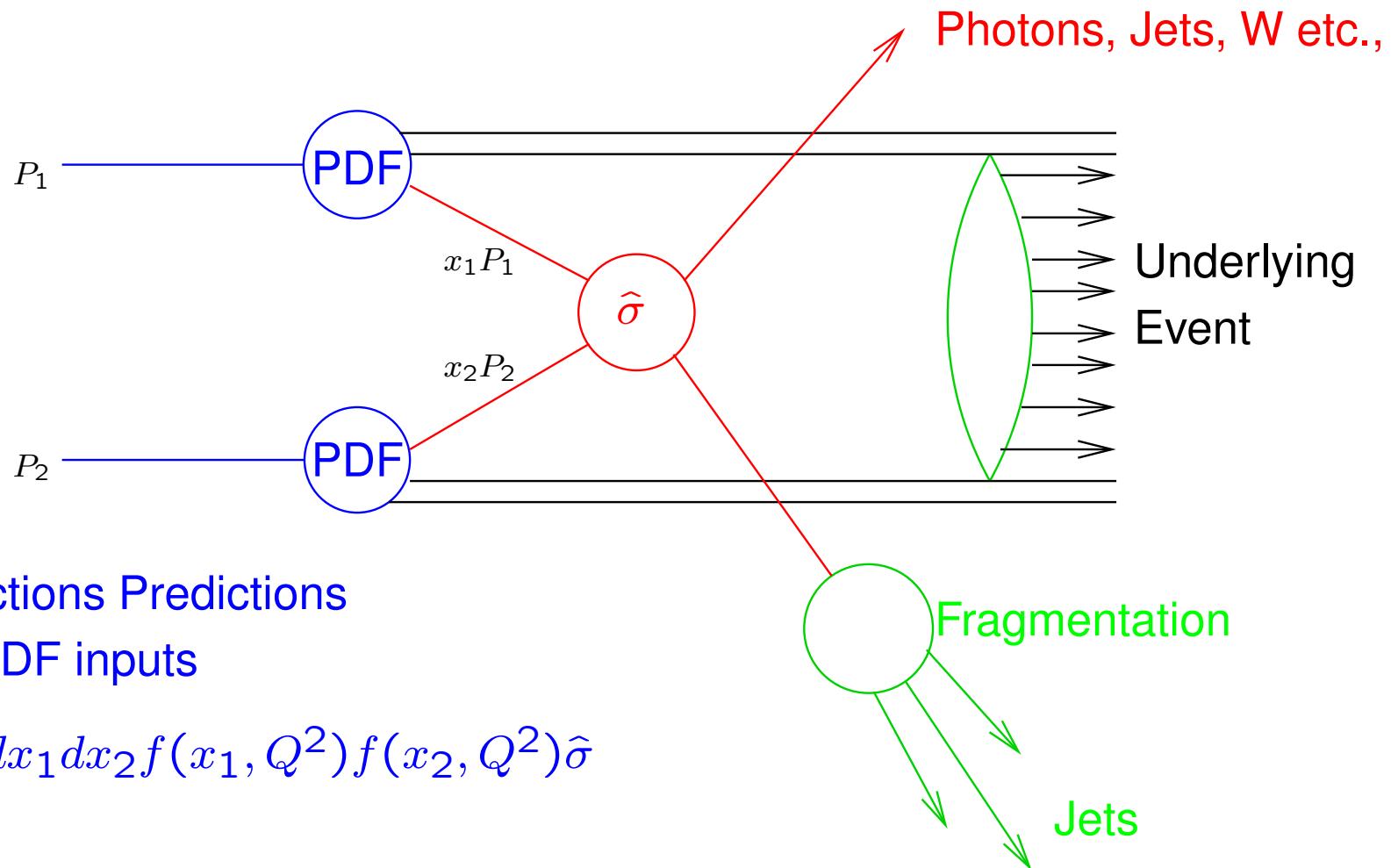
DØ Detector:



- High Energy Antiproton Scatters through Small Angle
⇒ No Scattered Antiproton in Main Detectors
⇒ Region of Low Level Energy Deposition: North Side Detectors
- Two Identified Large p_T Muon Tracks
⇒ Candidate Single Diffractive $Z \rightarrow \mu^+ \mu^-$ Event

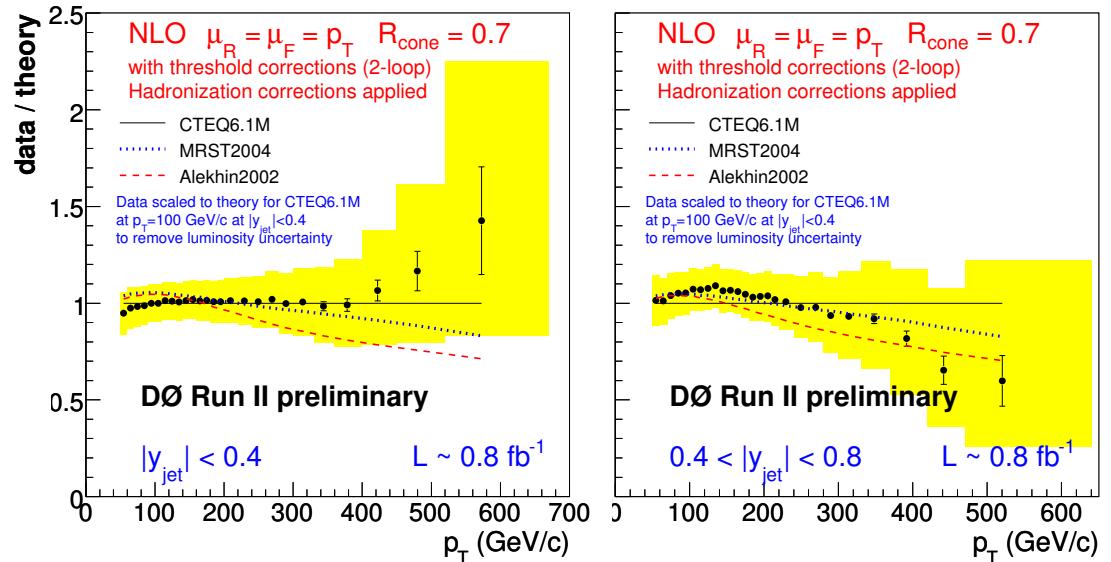
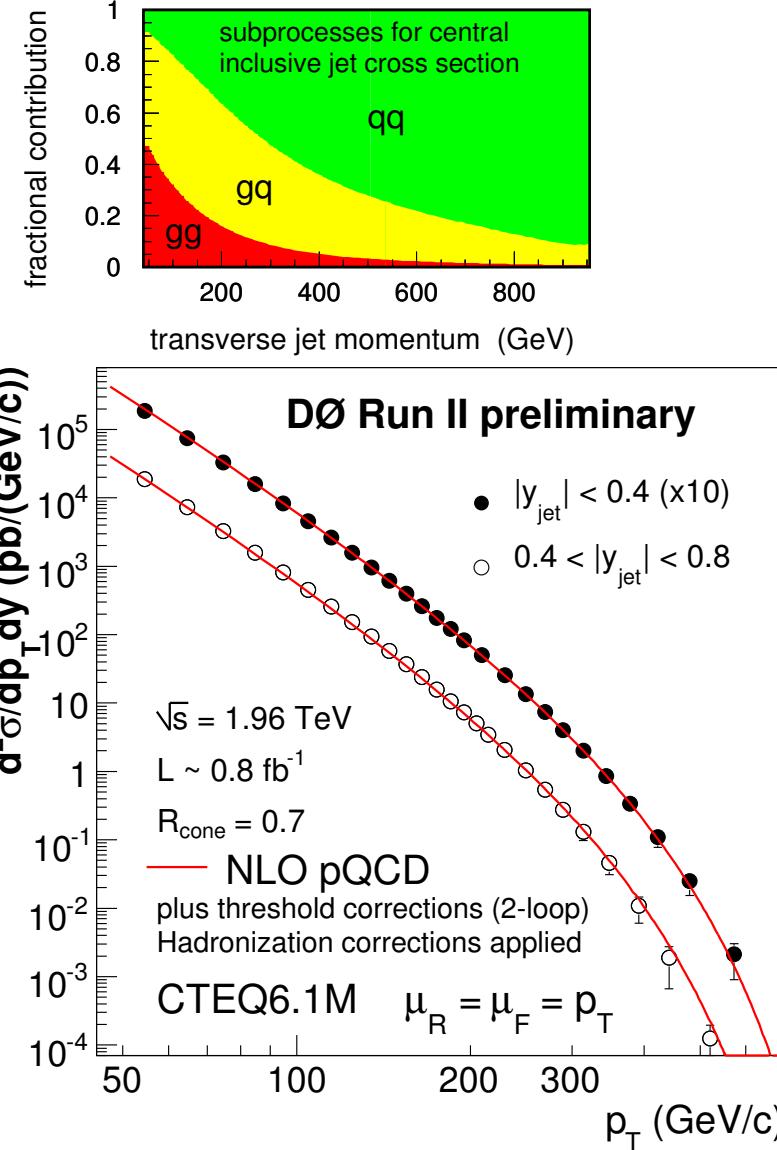
Probing Parton Distributions

in the Proton ...



Inclusive Jet Production

Probe Parton Distributions



- Data / Theory Normalised
at $P_T = 100 \text{ GeV}$
- Shape Consistent with Expectations
(PYTHIA)

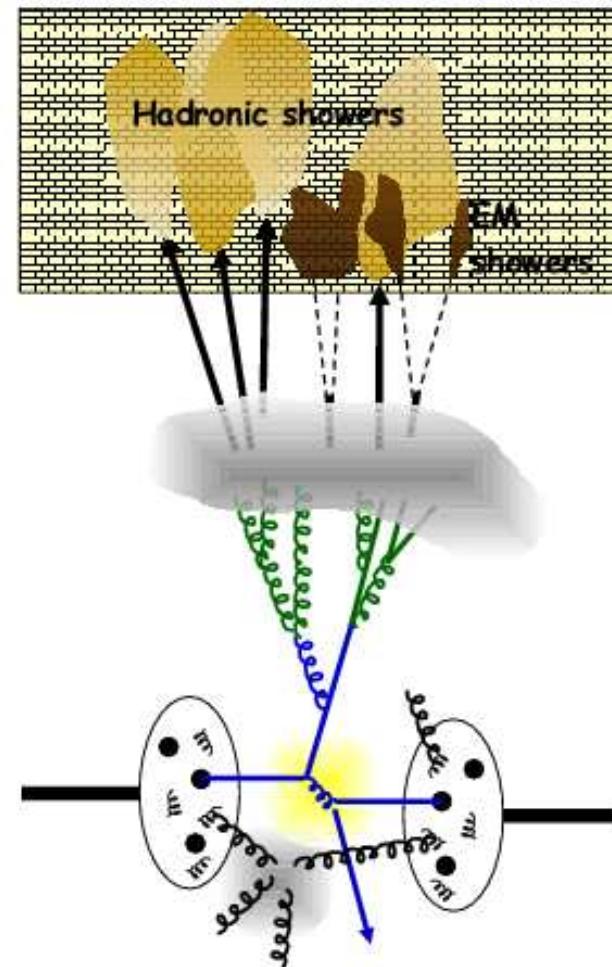
DØ Jet Selection: Midpoint Cone Algorithm

Jet Selected in a Cone:

$$R = \sqrt{(\Delta\phi)^2 + (\Delta y)^2}$$

Additional Iteration: Use Midpoints
between Pairs of Jets

Jets with Overlapping Cones:
Merged or Splitted



Measured Jet Energies Scaled:

$$E_{corr} = \frac{E_{meas} - \Omega}{RS}$$

where Ω : Offset

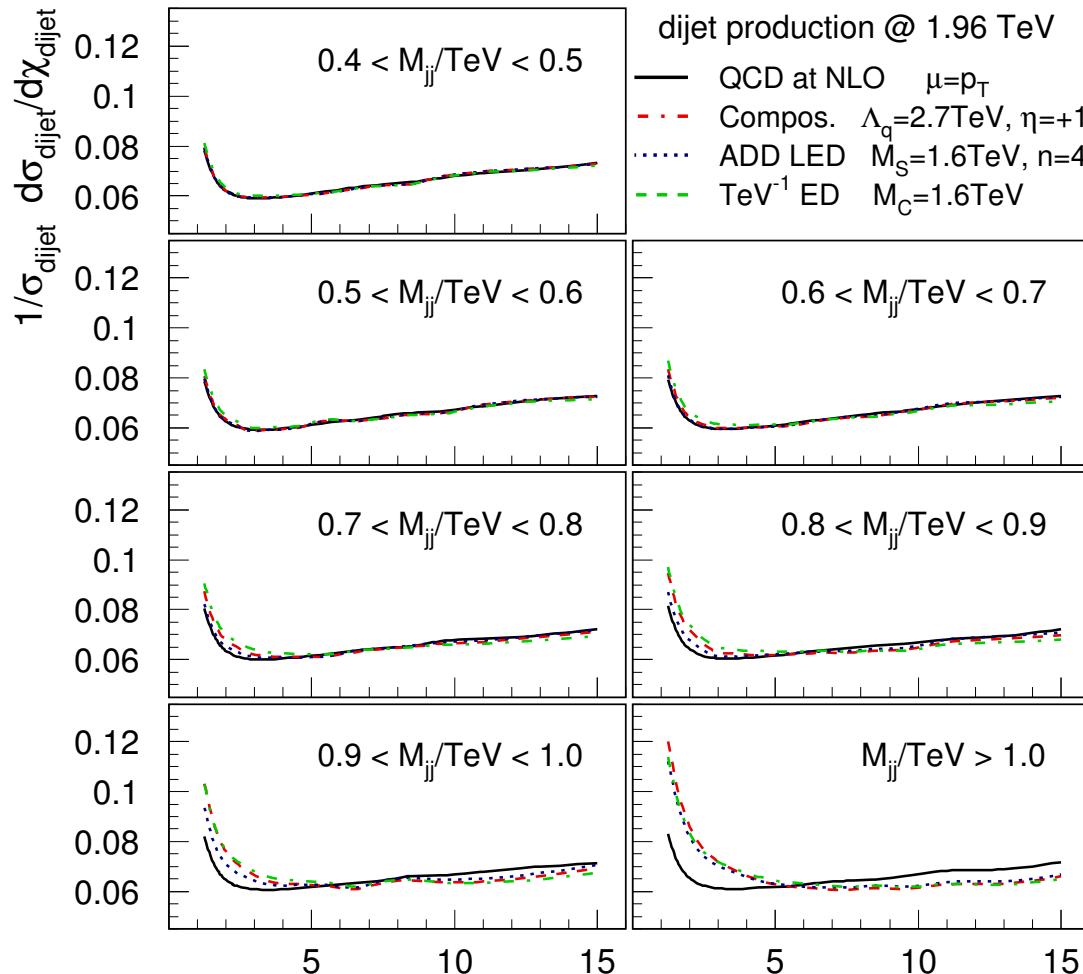
R : Response

S : Showering

- Now Extending Forward with Reduced JES Syst. Uncertainties.

Dijet χ Distribution

Search for Deviations from Point-like Parton Behaviour

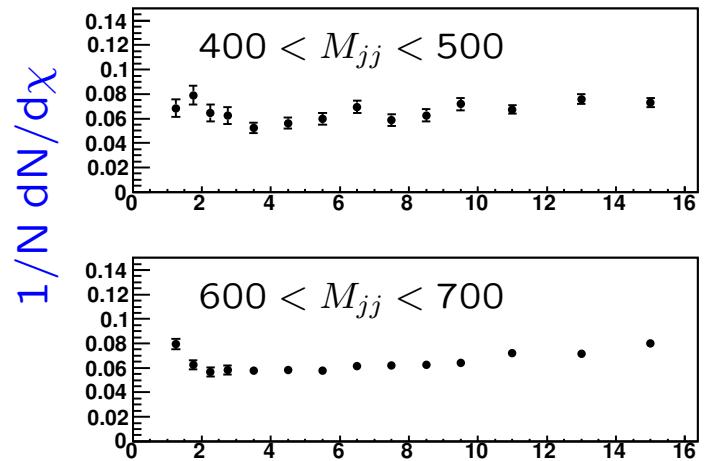


Expected Stronger Sensitivity
at Large M_{jj} (e.g. Improved Limits)

$$\chi_{\text{dijet}} = \exp(|\Delta y|)$$

$$\chi = \exp(y_1 - y_2)$$

In Progress: Extension to
Large Measured Dijet
Masses

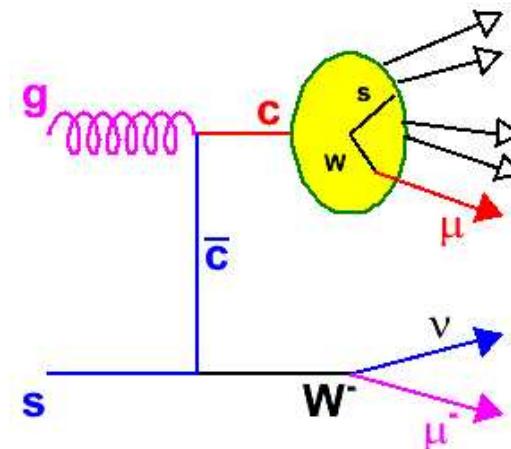


$W + \text{Charm Jet Production}$

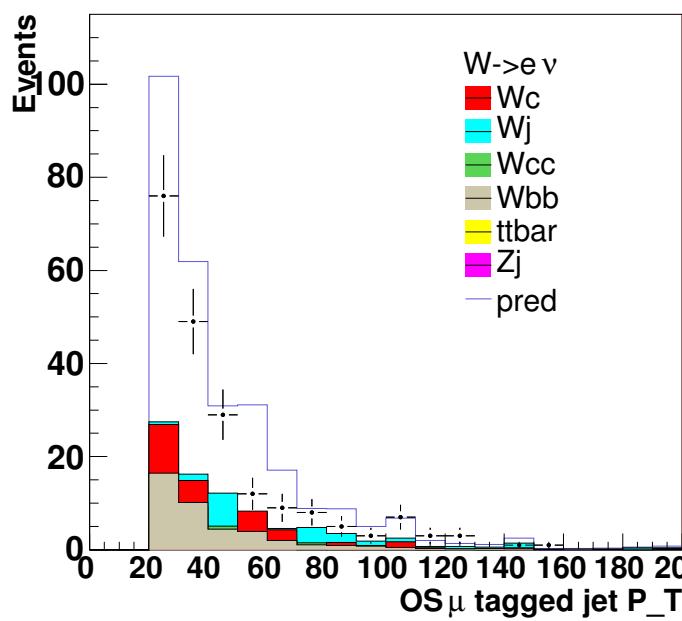
Probe of Strange Quark Contribution

Select Charm Jets with Muon Tag

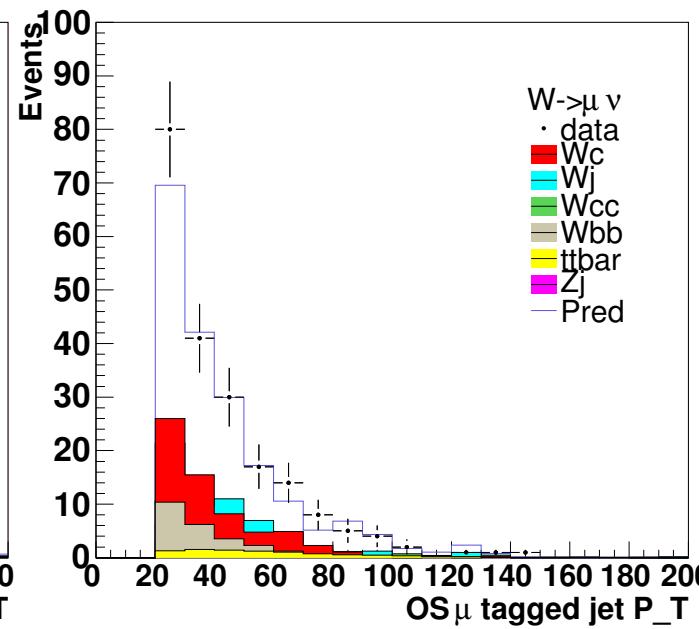
Signal Channel: Opposite Sign Lepton from W Decay



Electron Channel



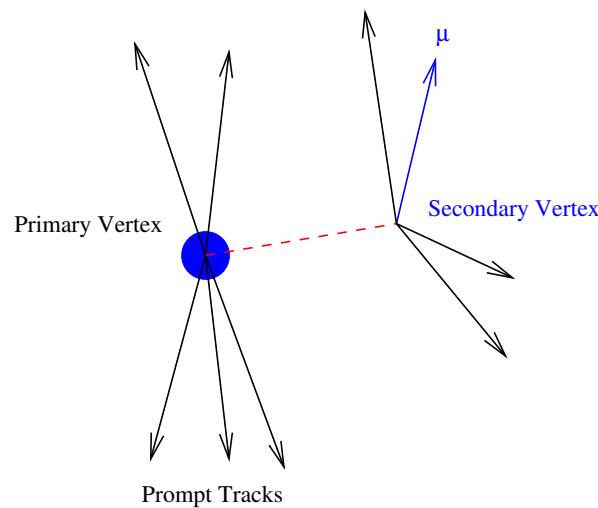
Muon Channel



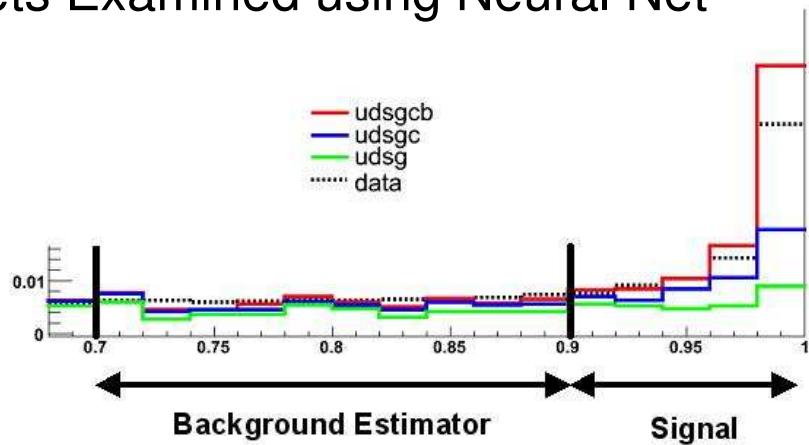
- Extraction of Charm Jet Fraction + Systematic Uncertainties in Progress

Production of Heavy Flavor Jets

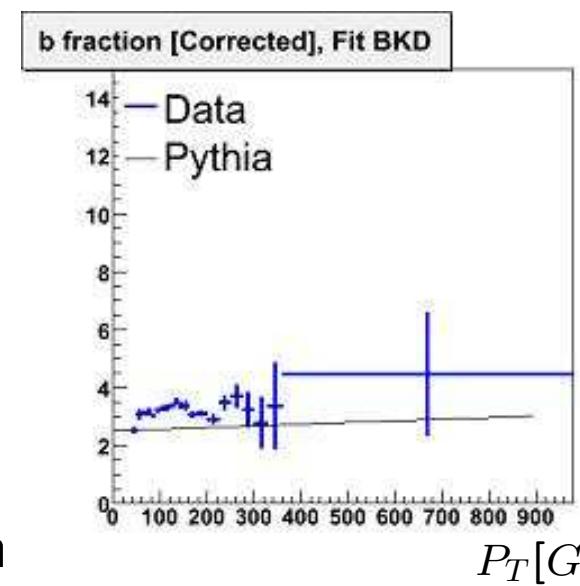
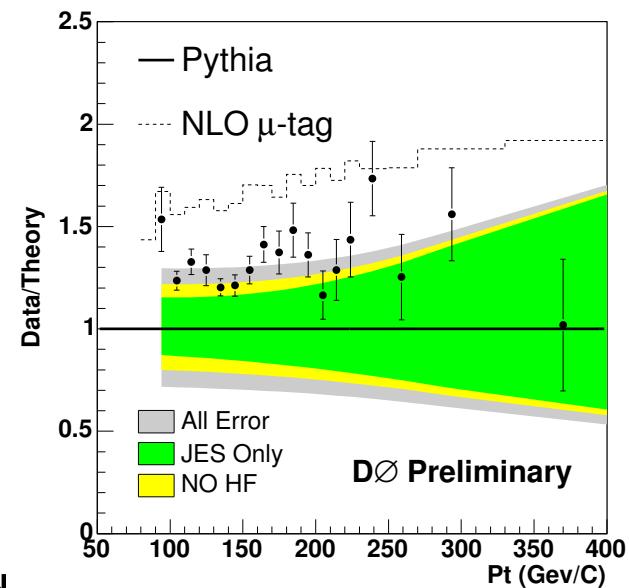
- Select HF Jets with μ and Secondary Vertex



- Extract B Contribution (In Progress): Selected Jets Examined using Neural Net

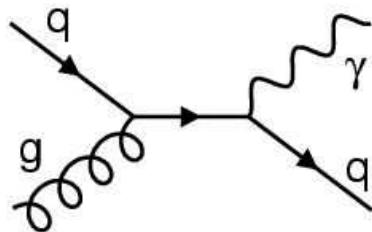


- Background Area Determined for Signal Region



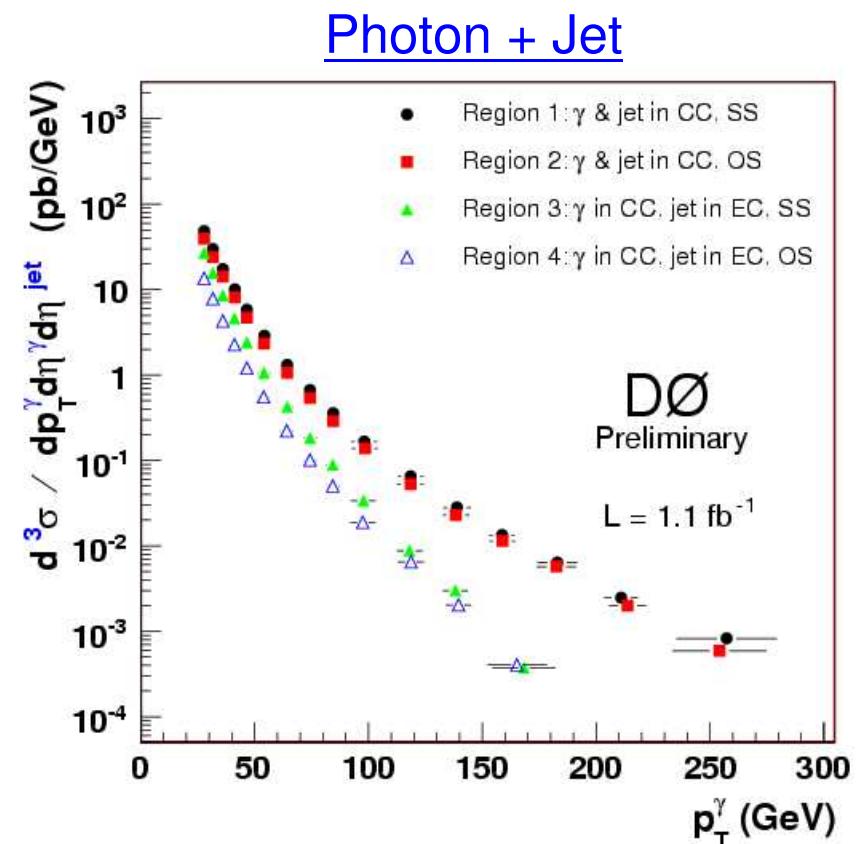
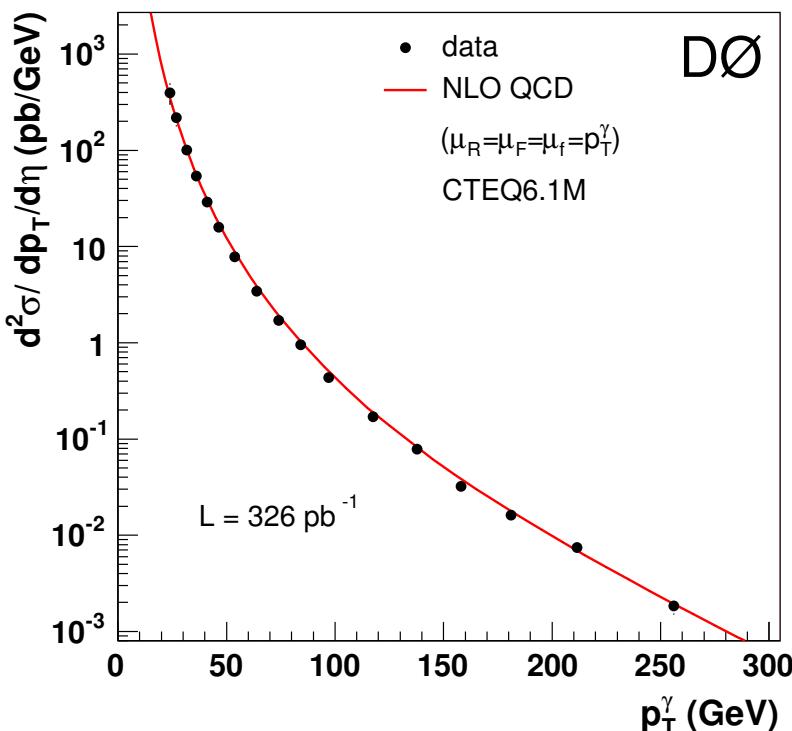
Photon + Jet Production

- Probe of Gluon Distribution at Large P_t^γ



⇒ Can extract $G(x, Q^2)$

Inclusive Photon



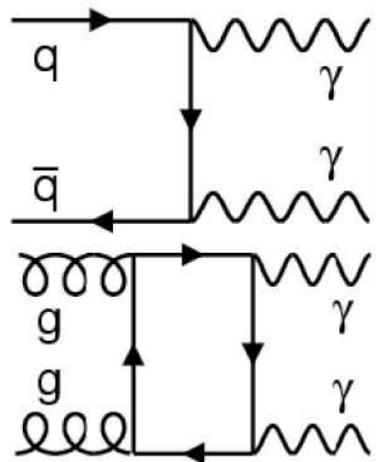
Differential Distributions in Four Regions:

Jet CC: γ same side / opposite side

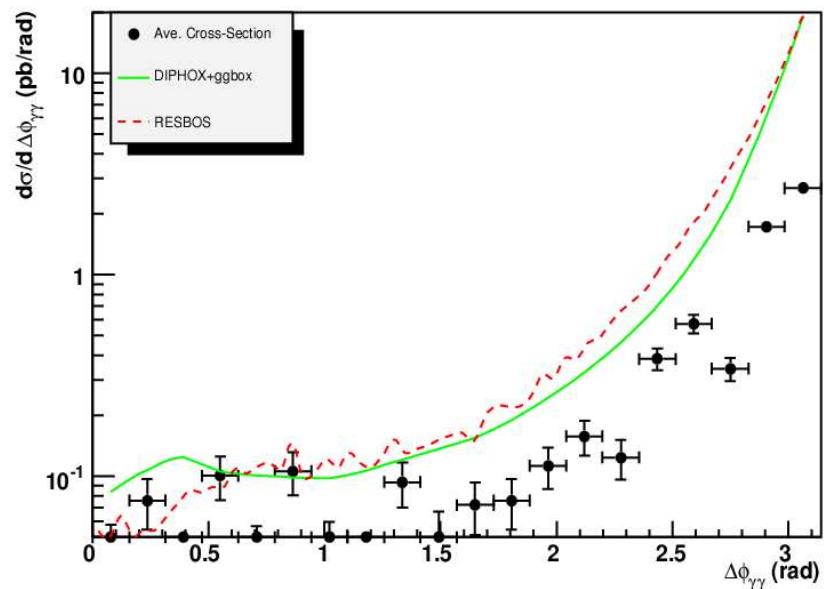
Jet EC: γ same side / opposite side

Prel. Comparisons to JetPhox
 in Progress

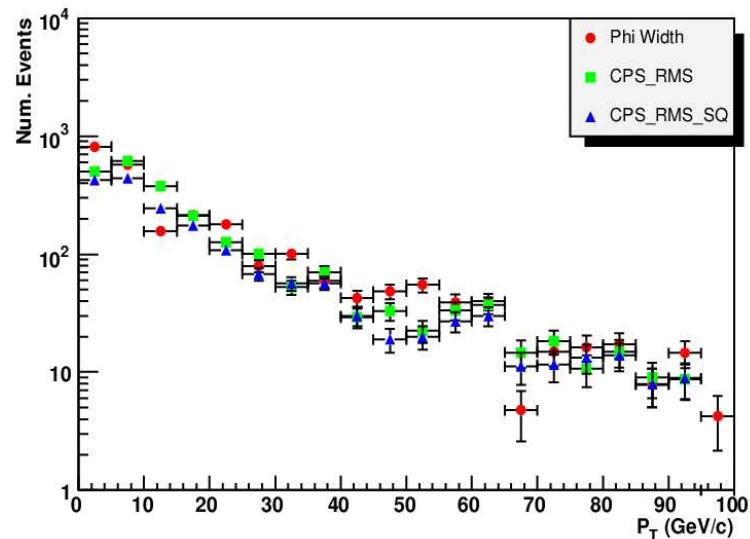
Di-Photon Production



- Acceptance and Efficiency Corrections in Progress



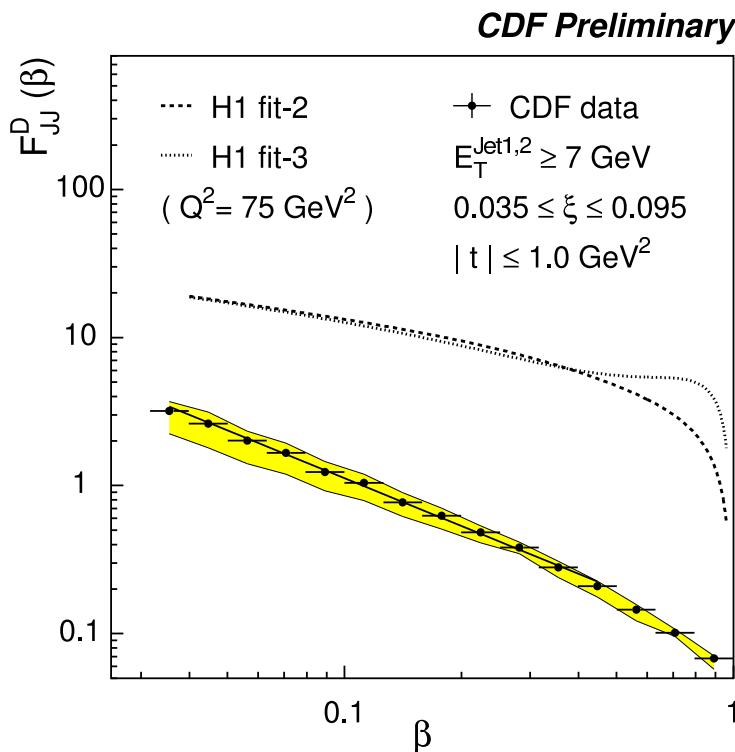
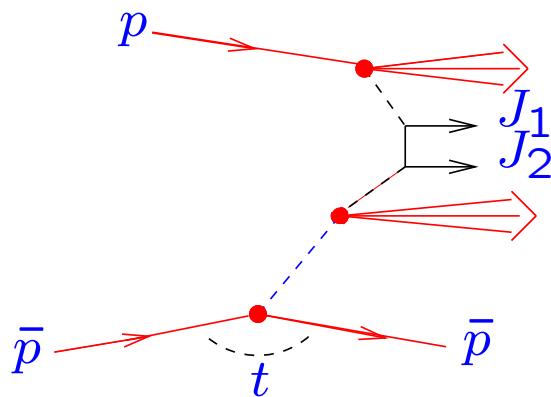
Extract Di-Photon Contribution from Candidate EM Clusters (Matrix Method)



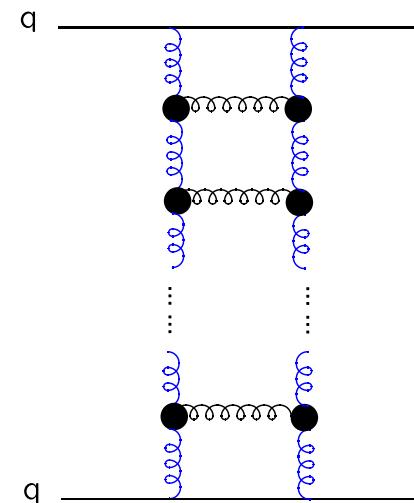
⇒ Differential Di-Photon Angular (and Mass) Distributions

Probing Parton Distributions

in the Pomeron ...



- Lowest Order: Two Gluon Exchange
- Evolve to Higher Orders



⇒ QCD Pomeron: Non-Trivial Effective
'Gluonic' Exchange

- Can Introduce an Effective Pomeron Structure Function
- Ingelman, Schlein (1985) Phys. Lett. B152

Single Diffractive Z Production

- Select Events with Small Fractional Beam Momentum Loss:

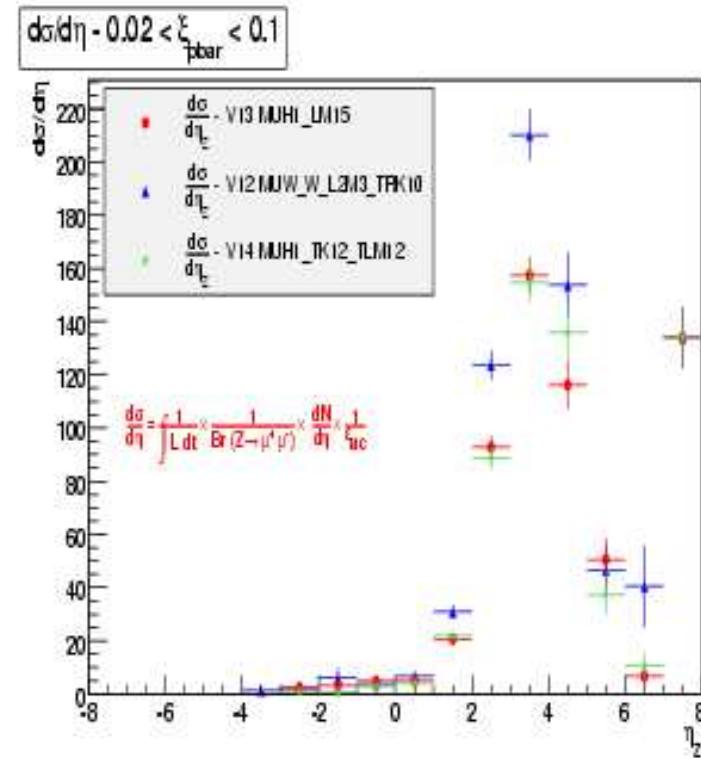
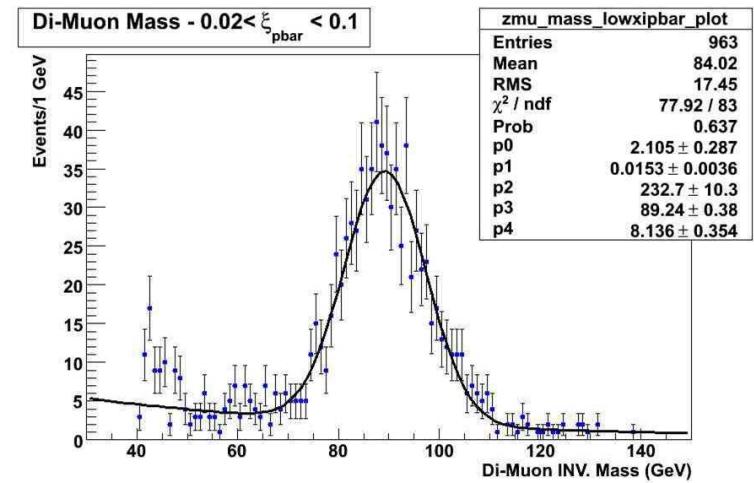
$$\xi_{\bar{p}} = \frac{\sum E_T \exp(-\eta)}{\sqrt{s}}$$

- Events Selected via $Z \rightarrow \mu^+ \mu^-$ Decay

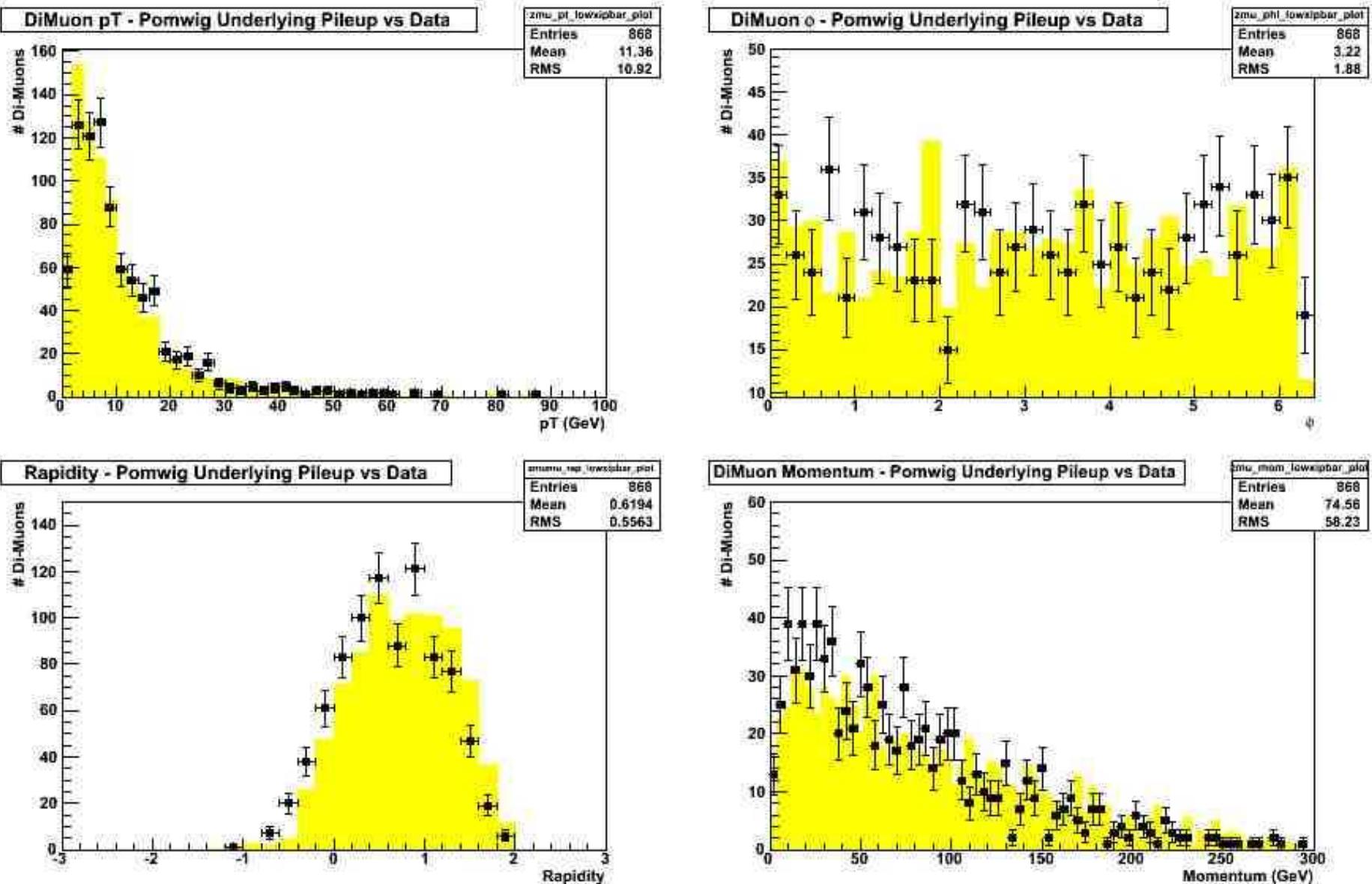
- Minimum Accessible ξ from Mass and Decay Properties:

$$\xi \sim \frac{M_X^2}{s}$$

- Diffracted System Boosted
(Details Depend on Structure Func.)



Data / MC Comparisons

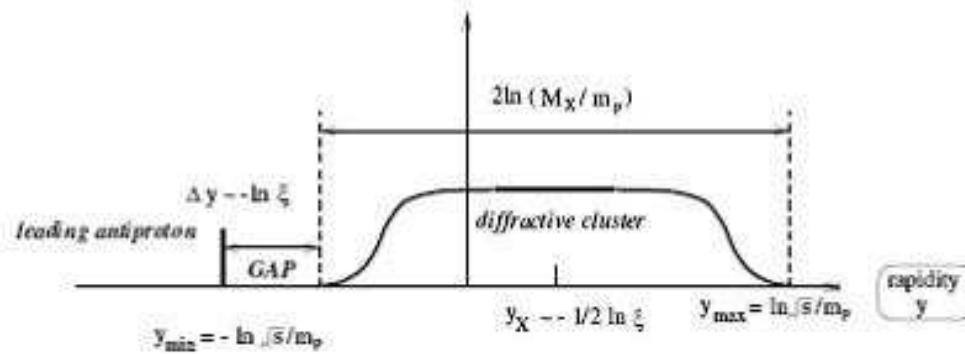


MC POMWIG Gives Reasonable Description of Data

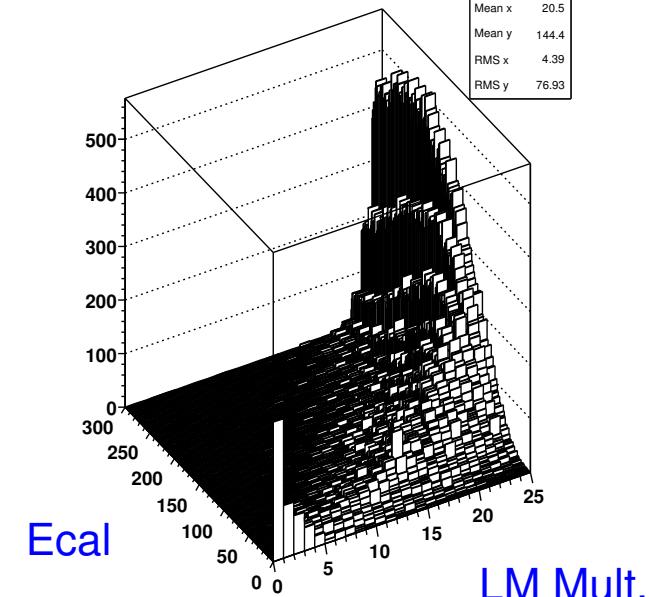
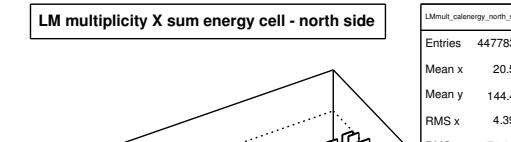
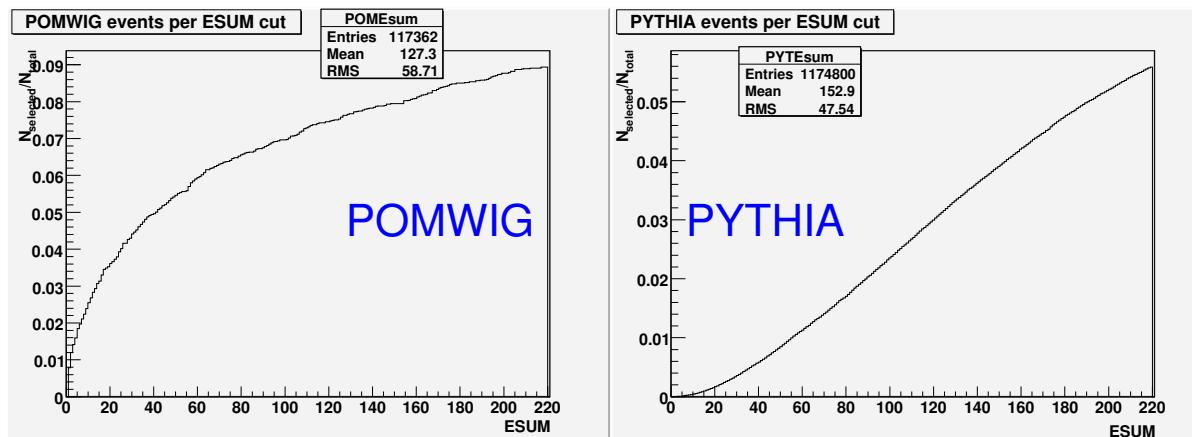
BKGD Suppression

- Expect Low Activity in Forward Detectors

DATA: J/ψ Events



- MC Expectations: Di-Jet Events

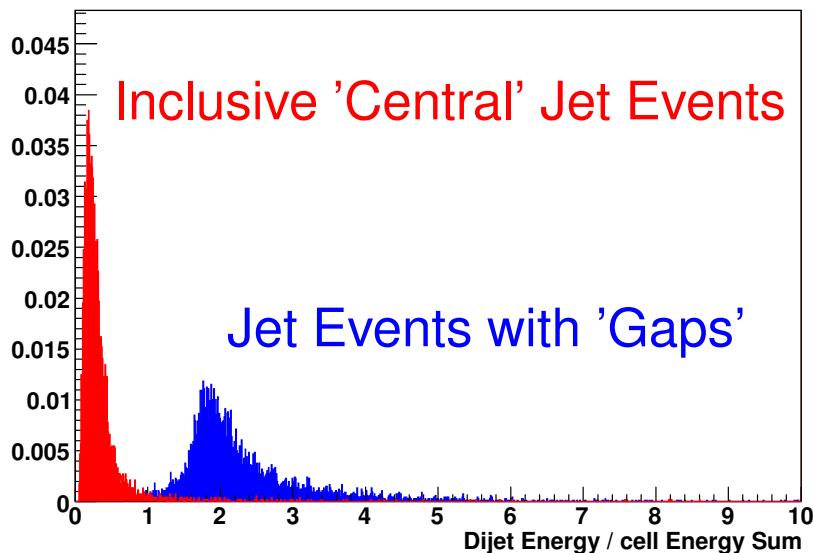
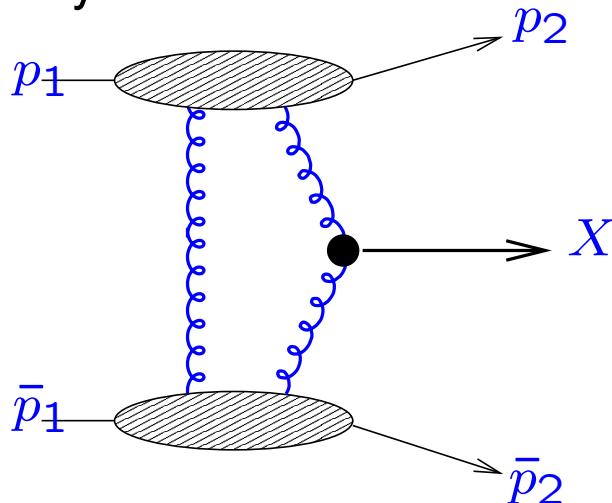


⇒ Tuning Low Activity Cut

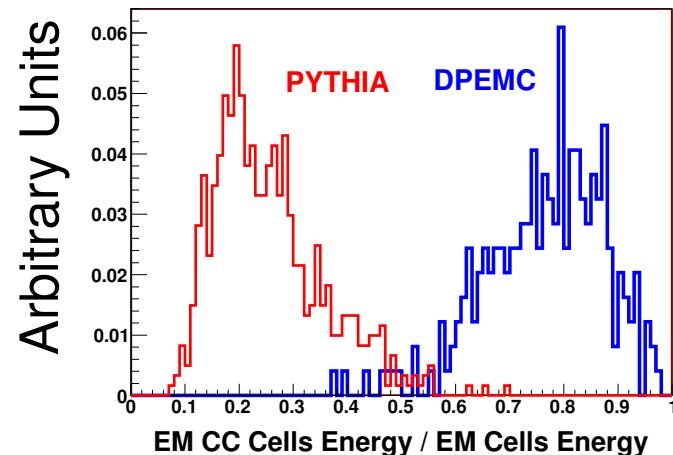
- Demand Low Summed Energy Deposit in Forward Calorimeter

Diffractive $p\bar{p} \rightarrow pX\bar{p}$ Scattering

- Search for Exclusive Production of Central Systems



MC Expectations



• DATA: Dijet Events

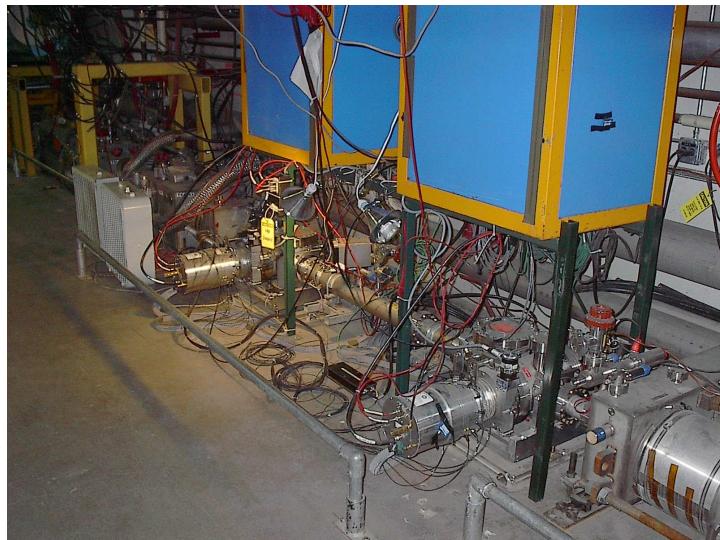
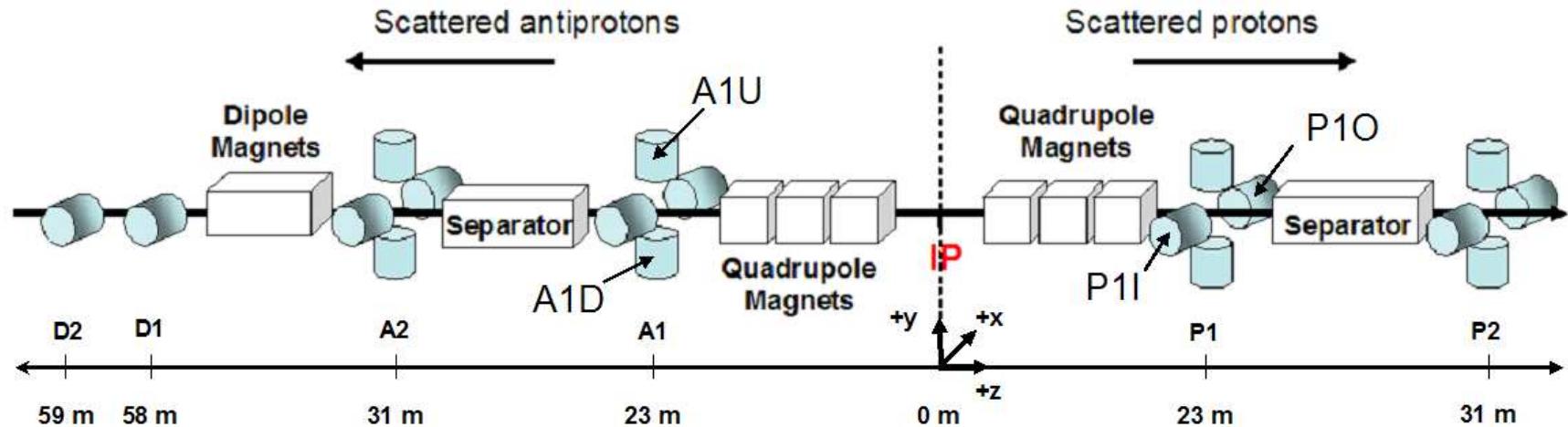
Measure Energy Deposited in Central System

Compare to Total Event Energy

⇒ Constrain Predictions for LHC

Run II: DØ Forward Proton Detectors

Nine Momentum Spectrometers Each Comprised of 2 Scintillating Fiber Detectors



Located behind Existing Dipole and
(low- β) Quadrupole Accelerator Magnets

Position Detectors Housed Inside Steel
Containers (Roman Pots)

⇒ Operate \sim mm from Beam
(Outside Ultra High Vacuum)

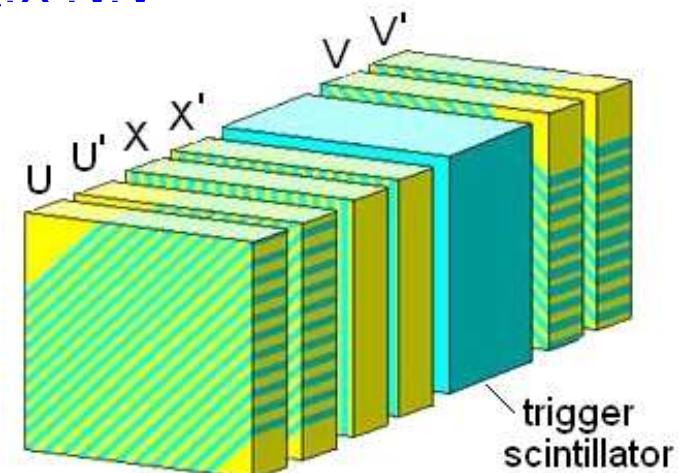
⇒ Can Reconstruct High Energy Scattered Protons and Antiprotons

DØ Forward Proton Detector

- 6 Layers of Scintillating Fiber Channels: U,U',X,X',V,V'
(Each Channel is made up of four fibers)

- 20 Fiber Channels in 'U' and 'V' layers;
16 Fiber Channels in 'X' layers

- 1 Trigger Scintillator layer
(Fast Photomultiplier Tube Readout)



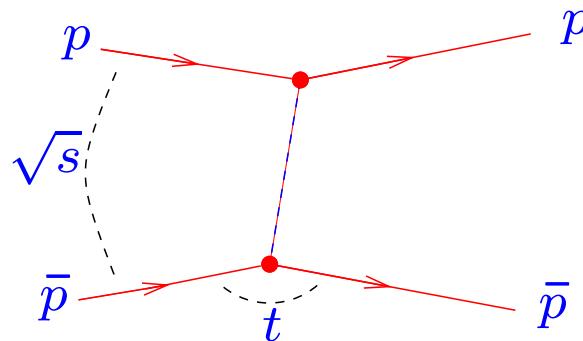
- Channels of 'U' and 'V' layers orientated at $\pm 45^\circ$ to 'X'
 \Rightarrow 3 Planes for Reconstruction
- Primed and Unprimed Channels Offset w.r.t each other (by 2/3 Fiber)
 \Rightarrow Finer Hit Resolution

Since Jan. 2004:

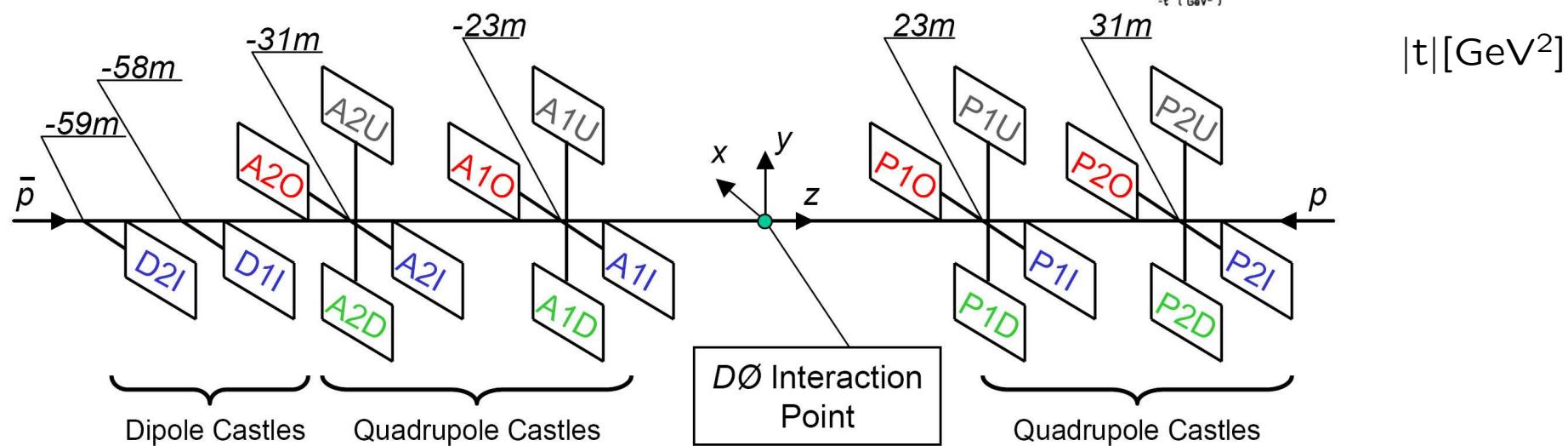
All 18 Scintillating Fiber Detectors regularly brought close to the beam line
(Dipole Detectors since Feb 2003)

FPD Detector Alignment

- Elastic $p\bar{p} \rightarrow p\bar{p}$ Scattering



- Events Selected using Forward Quadrupole Spectrometers

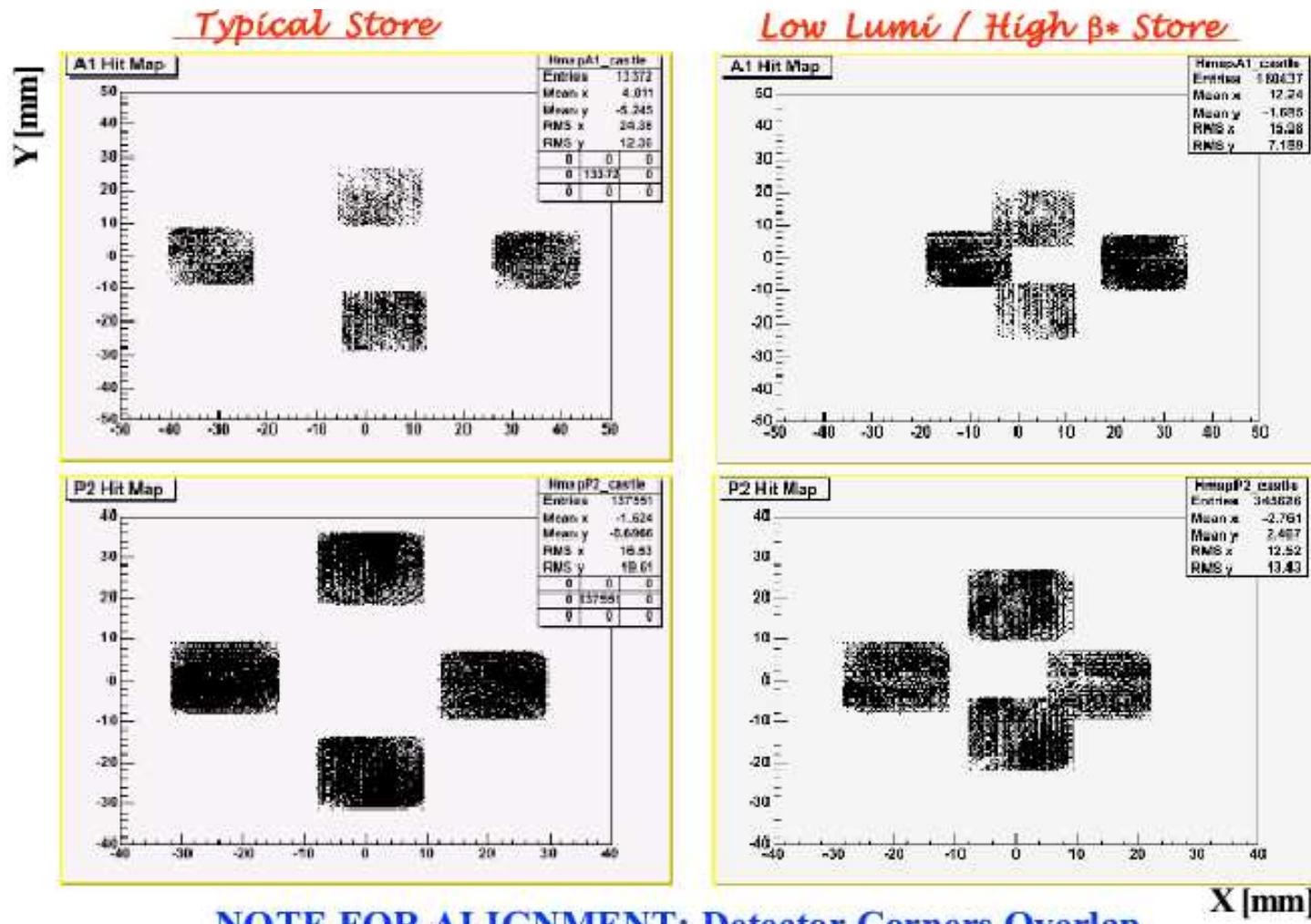


- Proton and Antiproton Hits in Back-to-Back Spectrometers

Special TeVatron Stores

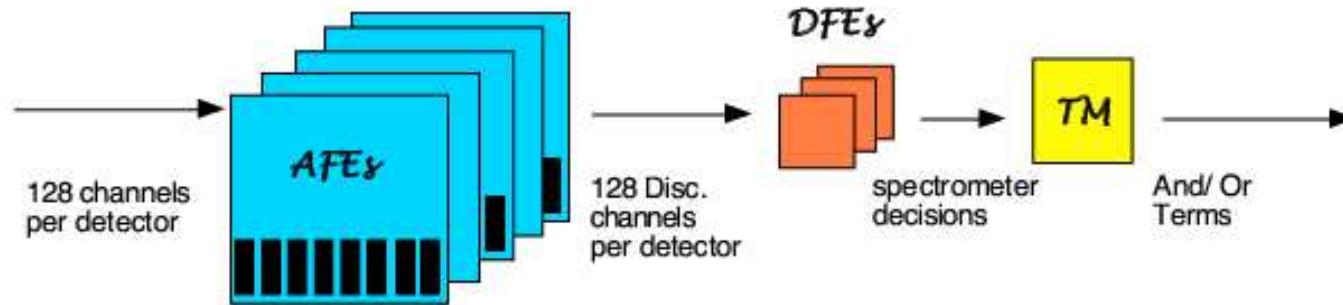
- Single High- β^* / Low Luminosity Store

⇒ Narrower Beam at Detectors, $p\bar{p}$ Collisions at DØ Only
(Beam Separators Off, 1-on-1 Bunch Structure)



FPD Trigger System

Level 1 Trigger Based on Detector Fiber Information



Digital Front End:

Calculate No. of Wide Segment Hits in Each Detector

Forms Spectrometer Decisions based on Product of Hit Multiplicities

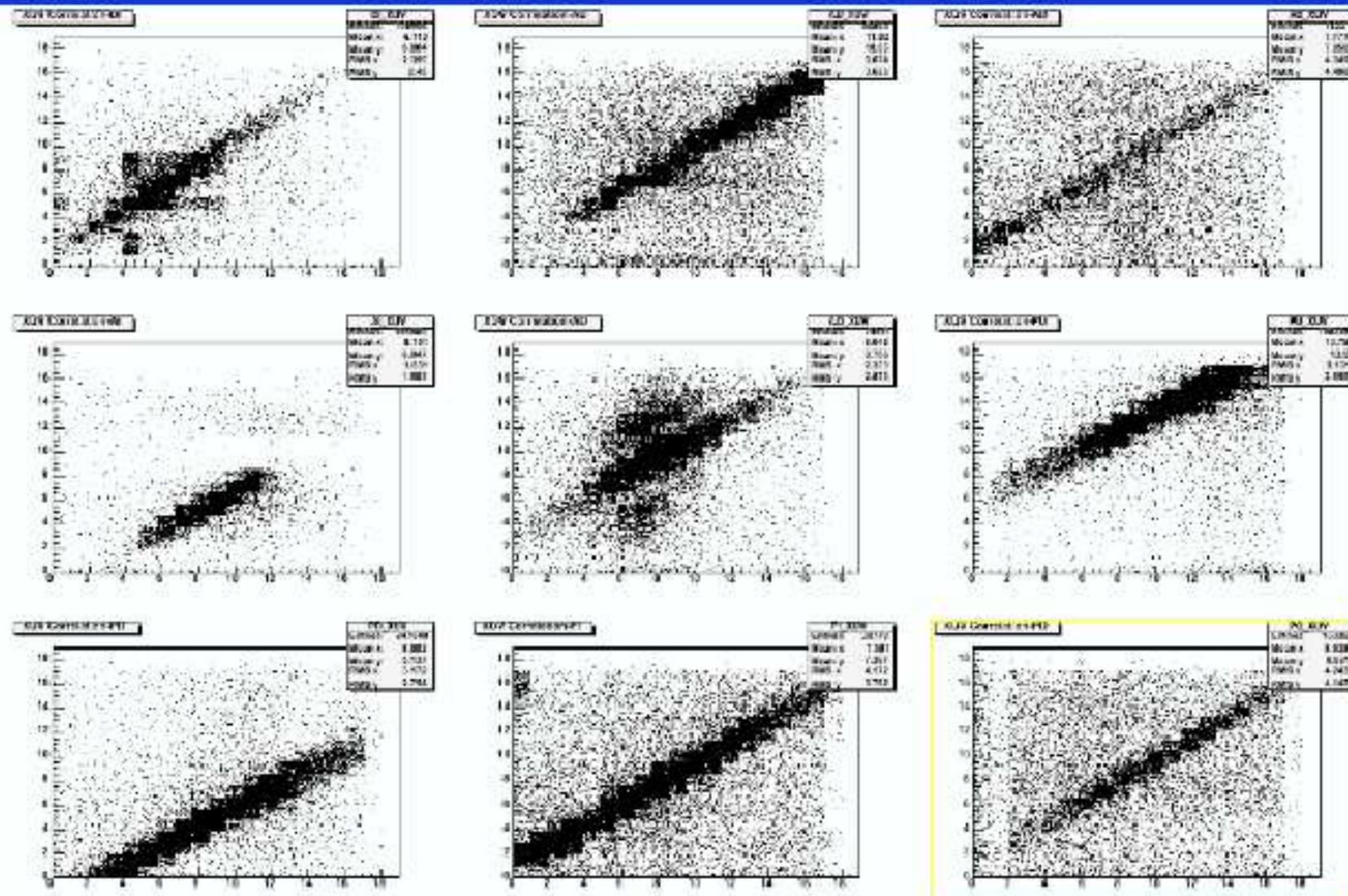
Trigger Manager:

Forms Elastic and Double Pomeron Spectrometer Coincidences

Developed / Implemented / Commissioned / Completed in 2005

RUN 215421: Trigger Level Detector Correlations

$X_2 [mm]$

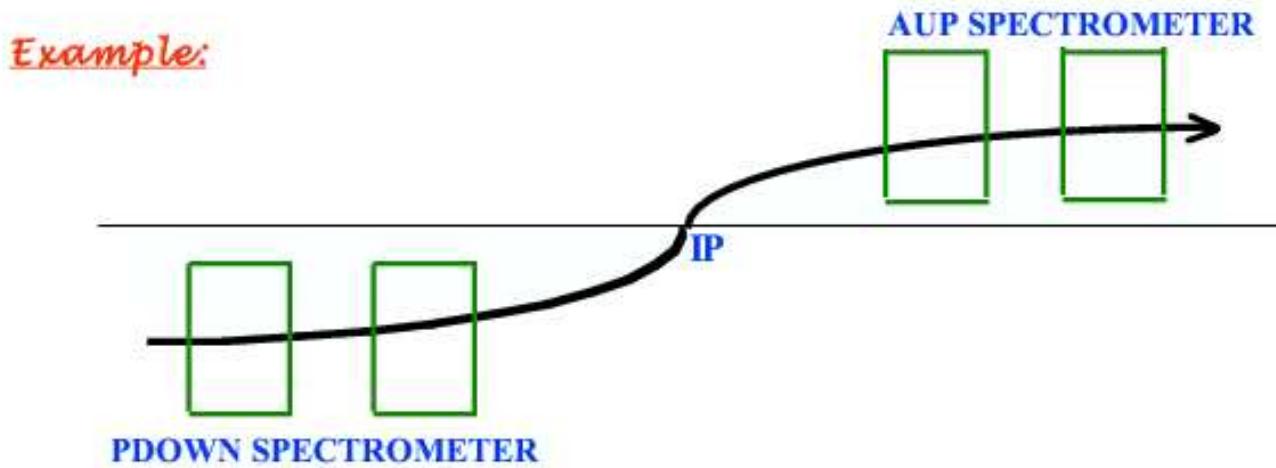


Correlations in all Spectrometers

$X_1 [mm]$

Halo Background Suppression

Dedicated Studies: Particles Passing Intime through Spectrometer,
Pass Earlier through Opposite Spectrometer



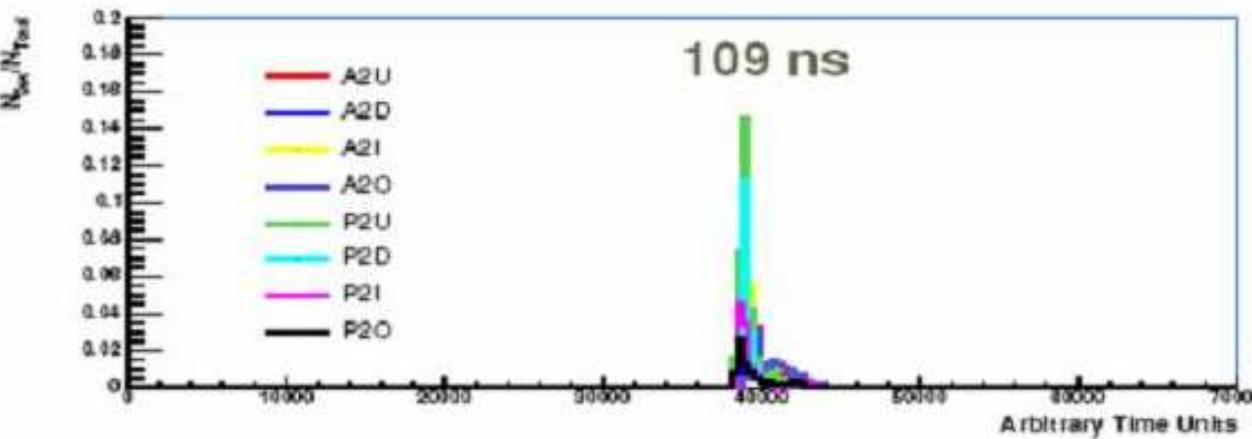
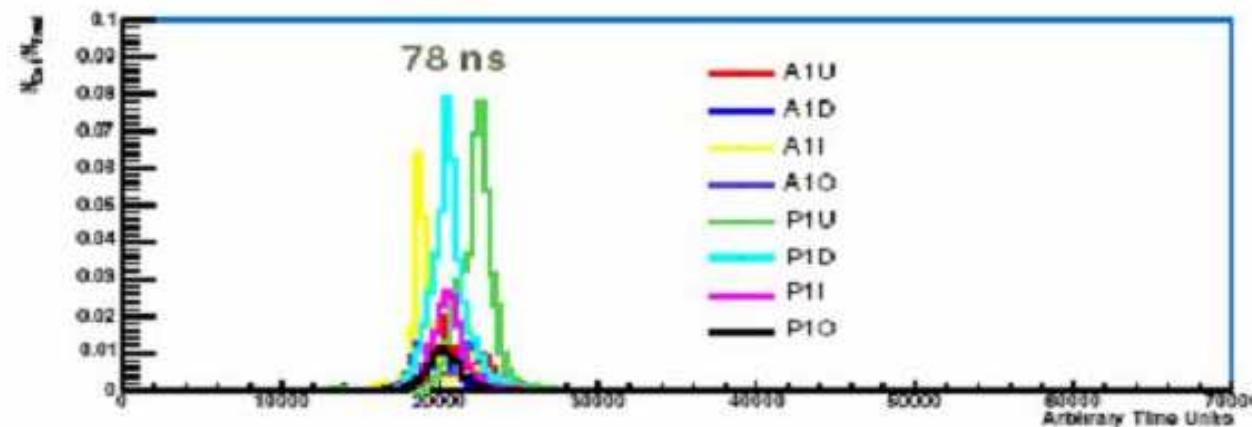
Measure Pulse Times using Individual Detector Scintillators
(FPD Timing Electronics)

Signal Timing Bit: Set if Pulse (Leading Edge) Detected above
Threshold Intime

Halo Timing Bit: If Pulse Also Detected (Above Threshold) in Earlier
Timing Window

Detector Timing Distributions

Relative Pulse Heights

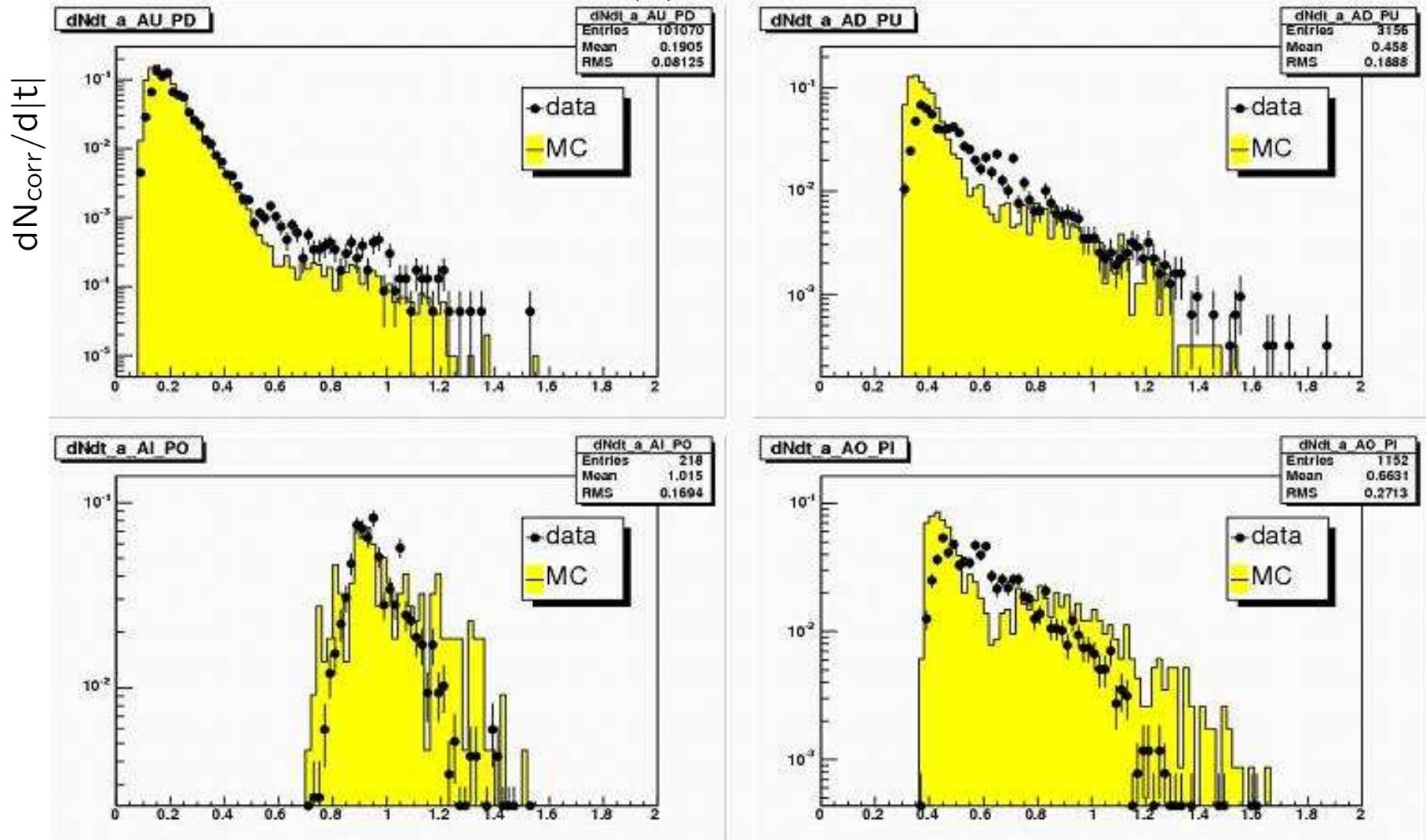


Arbitrary Time Units

- Signal Thresholds Optimisation \Rightarrow Increased Efficiency

Elastic $p\bar{p} \rightarrow p\bar{p}$ Scattering

Differential Measurement of Elastic $|t|$ Distribution



- Correction for FPD Detector Efficiencies in Progress

$|t| [\text{GeV}^2]$

Summary and Outlook

- QCD Measurements Already Providing Insight into:
 - Parton Distributions
 - Structure of the Diffractive Exchange
- Extensive Forward Proton System at DØ
 - First Diffractive Measurements with Large Triggered Data Samples

Future Increase in Statistics:

- Higher Precision Tests over a Larger Kinematic Region