Dijet Production by Double Pomeron Exchange at the Tevatron

Koji Terashi

The Rockefeller University, New York, NY 10021

(Representing the CDF Collaboration)

- Introduction
- Experimental Setup
- Event Selection
- Kinematic Properties
- DPE Dijet Production Cross Section
- Factorization Test
- Summary

Goal

First direct observation of dijet events with DPE topology.

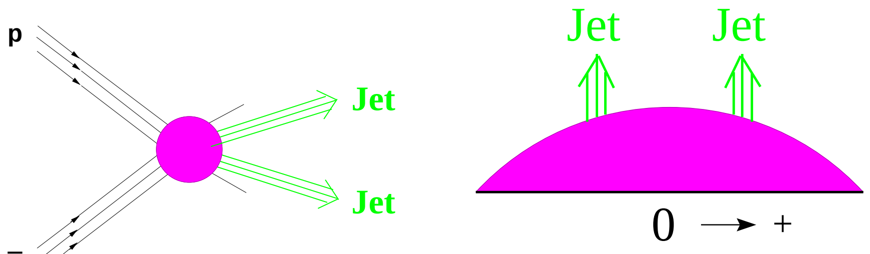
GOAL

- **Look into**
  - kinematic properties,
  - production cross section.

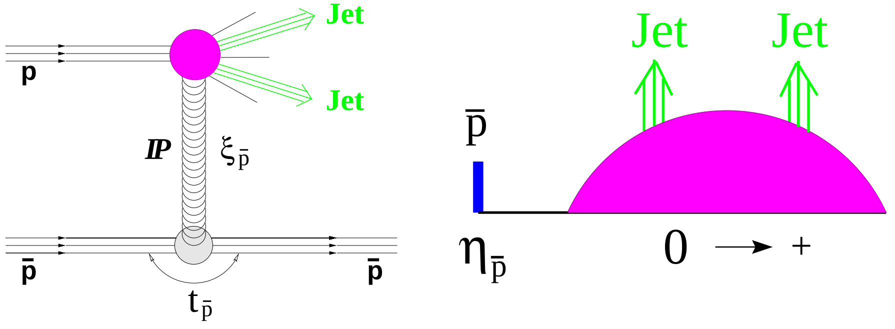
- **Test factorization property.**

Factorization :
Breakdown found in SD between 1.8 TeV $\bar{p}p$ (Tevatron) and 300 GeV ep (HERA).

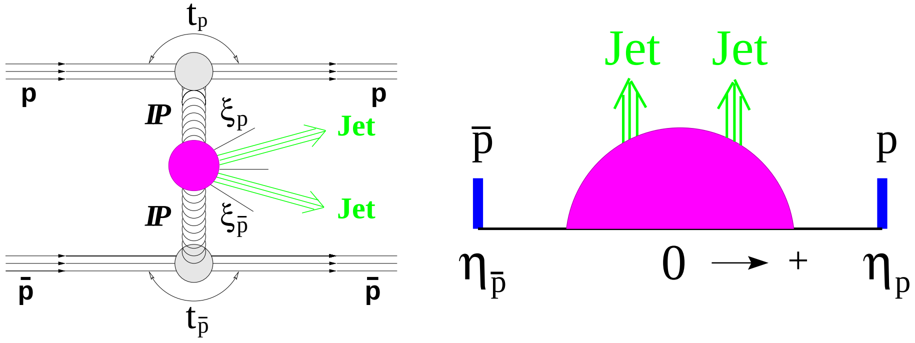
Hold or not within the $\bar{p}p$, i.e, between SD in 1.8 TeV and DPE in ∼400GeV?



Inclusive (Non-Diffractive) Dijet



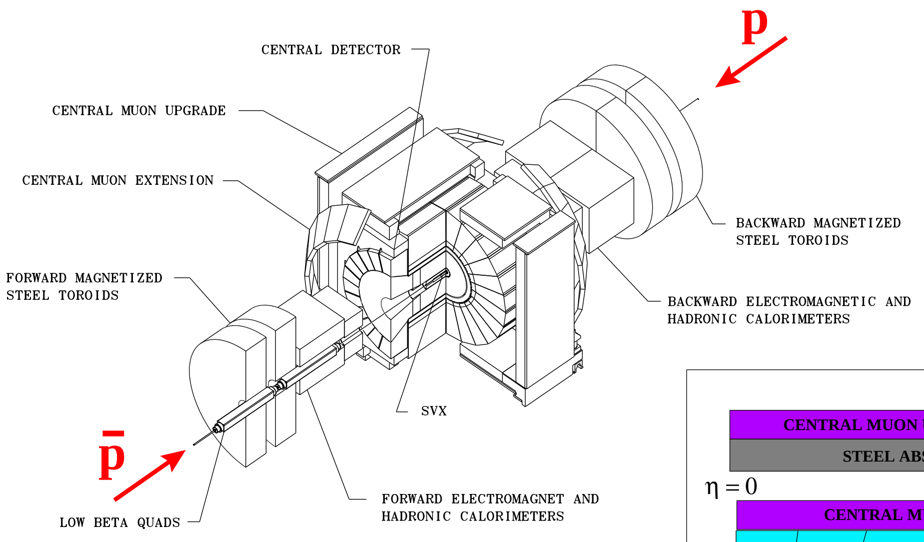
Single Diffractive Dijet

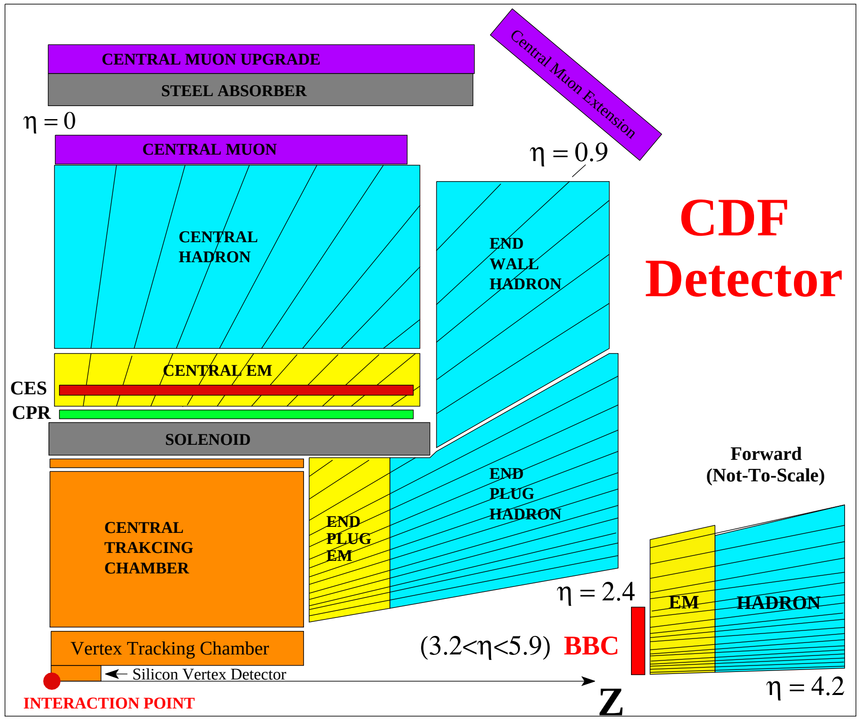


Double Pomeron Exchange Dijet

The CDF Detector

Collider Detector at Fermilab





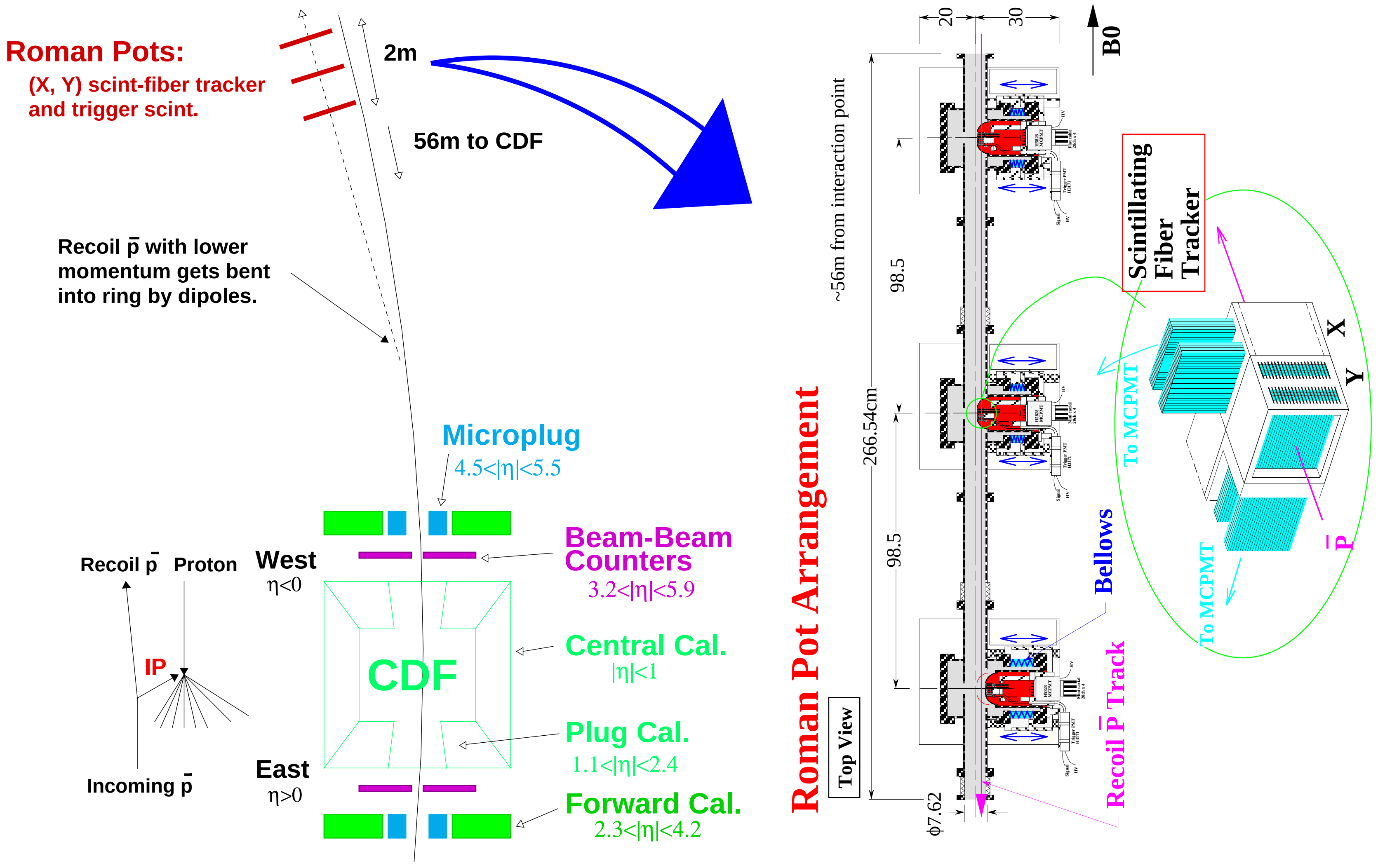
pseudo-rapidity

$$\eta = -\ln\tan(\theta/2)$$

θ : angle with respect to the p direction $(=+z)$

Hard Diffraction Experiment (1995–96)

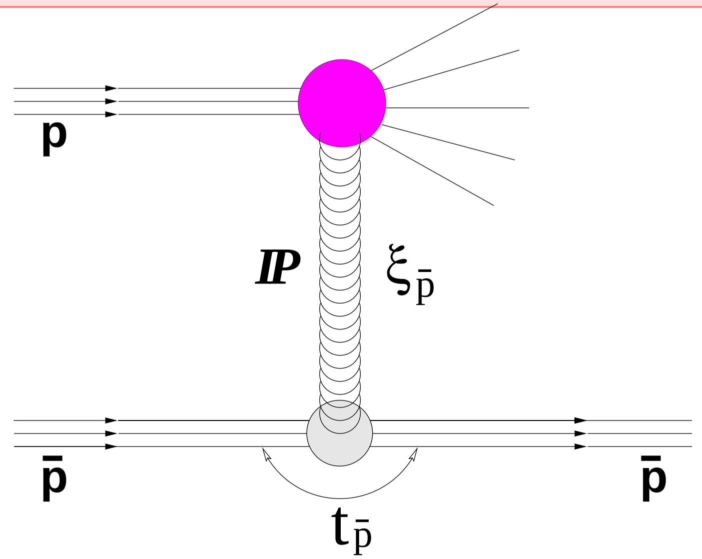
CDF Detector + Roman Pot Spectrometer (RPS)



Event Selection : Inclusive Diffraction

Event Selection for the Process:

$$\boxed{\bar{p} + p \rightarrow \bar{p} + X}$$



Requirements for

Roman Pot Spectrometer

- Coincidence of the trigger counters with $\bar{p}$ timing.
- Trigger signal consistent with 1 MIP.
- One reconstructed $\bar{p}$ track.
- All 3 RPSs have one hit.

Central CDF Tracking Detector

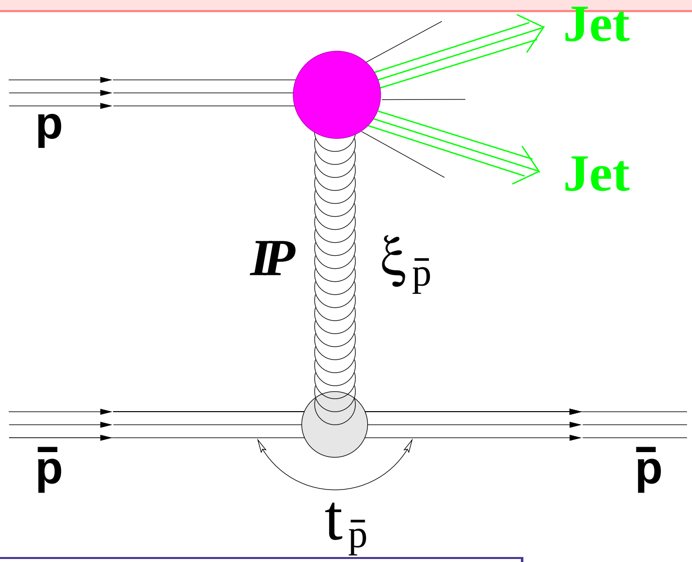
- Only one vertex per event.
  $\rightarrow$ Remove events with multiple interactions.
- The Z_{vertex} is within $\pm 60\,\mathrm{cm}$ around the detector center.

$0.035 < \xi_{\bar{p}} < 0.095$, $|t_{\bar{p}}| < 1.0\,\mathrm{GeV}^2$
Sample of 1,639K diffractive events.

Event Selection : Diffractive Dijet

Event Selection for the Process:

$$\boxed{\bar{p} + p \rightarrow \bar{p} + jet + jet + X}$$



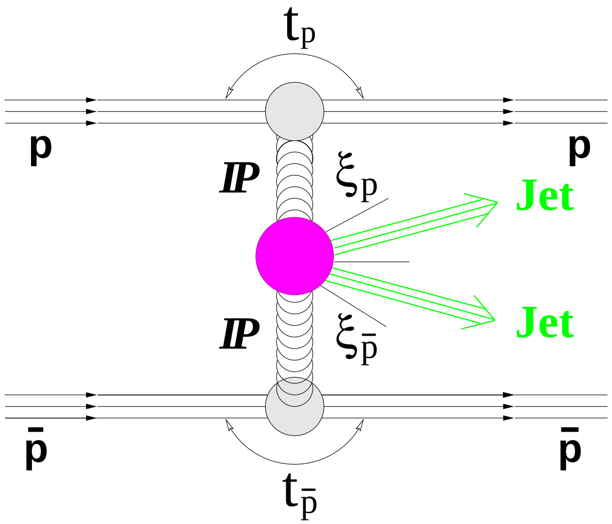
Requirement of

the presence of $\geq$ 2 jets in the CDF calorimeter.

- CDF standard jet reconstruction algorithm used.
- CDF standard jet energy calibration applied.
- Measured underlying event energy subtracted.
- Remove contamination from overlapped non-diffractive background.

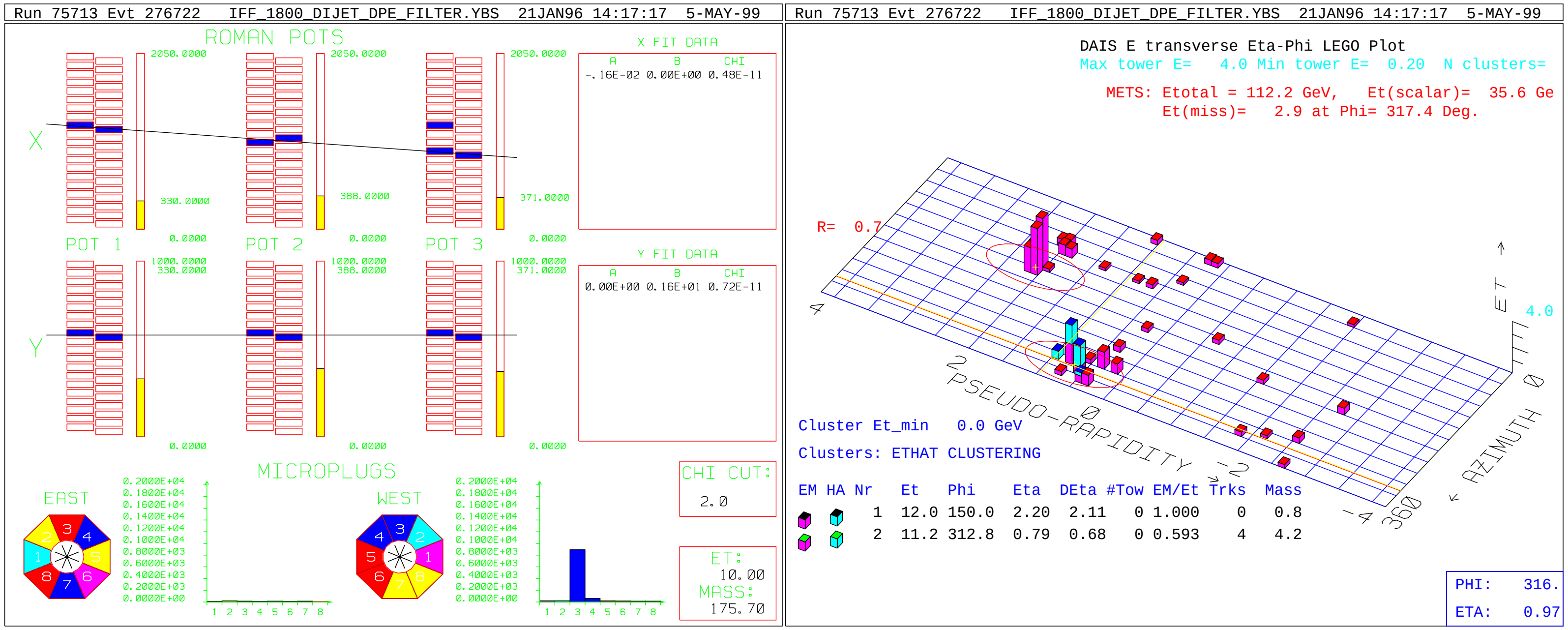
➡ Sample of 27,405 (4,866) events with dijets of transverse energy $E_T^{jet1,2} > 7$ (10) GeV.

DPE Dijet Candidate with a Roman Pot Track

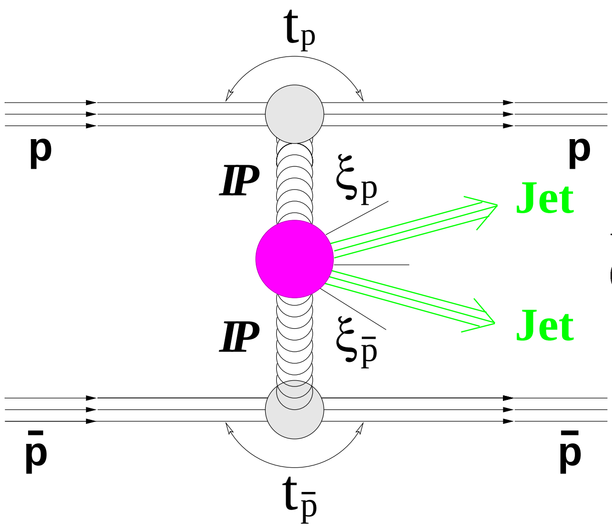


- jet 1 : $E_T = 19.0\,\text{GeV},\ \eta = 2.2$
- jet 2 : $E_T = 18.1\,\text{GeV},\ \eta = 0.79$
- recoil $\bar{p}$: $\xi_{\bar{p}} = 0.070,\ |t_{\bar{p}}| = 0.0097\,\text{GeV}^2$
- rapidity gap on p side :
  no particles within $2.4 < \eta < 5.9$

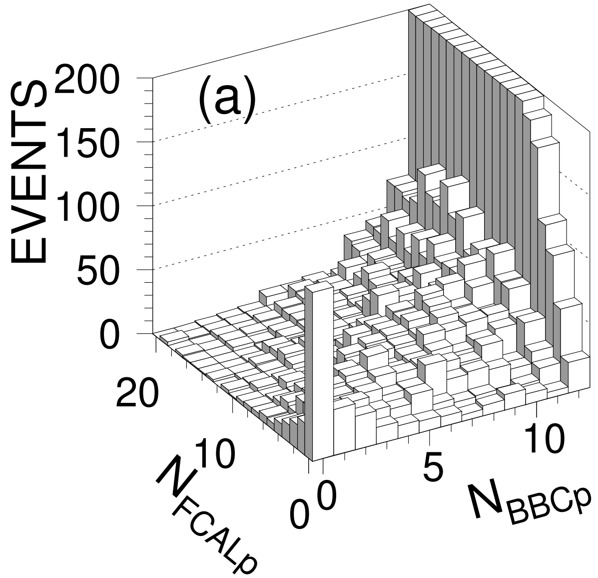
CDF Preliminary ($\sqrt{s}$=1800 GeV)



DPE Event Selection



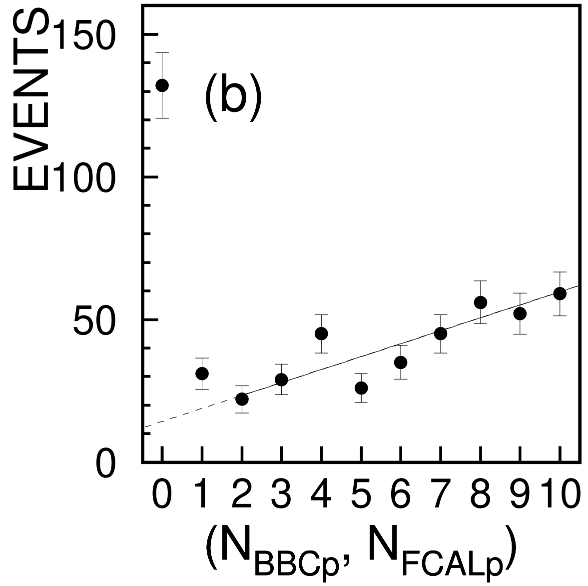
$E_T^{jet1,2} > 7\,\mathrm{GeV}$
$0.035 < \xi_{\bar{p}} < 0.095$
$|t_{\bar{p}}| < 1.0\,\mathrm{GeV}^2$



(a) An excess of (0,0)=gap events
DPE production of jets.

(b) Diagonal Multiplicity Fit :
$N_{DPE}(0,0) =$
$117.7 \pm 12.1(\mathrm{stat})$ events.

SD background
14.3 ± 11.0(syst-fit) events



Kinematic Properties : ξ of (Anti)Proton

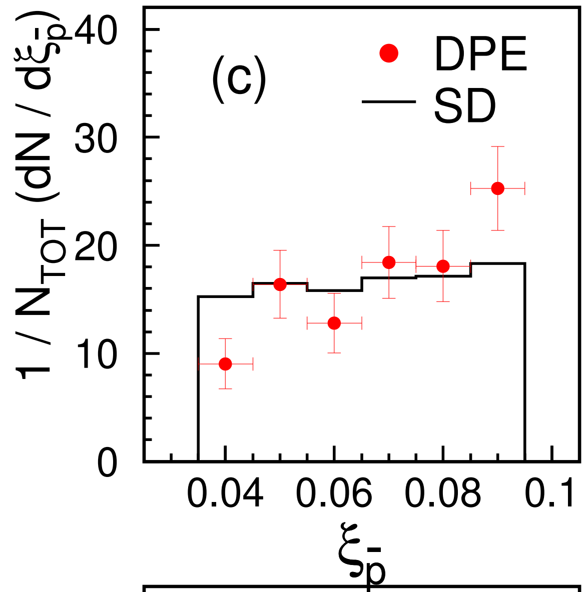
- **Antiproton Momentum Loss $\xi_{\bar{p}}$**
  - Measured by RPS.
  - Corrected for the RPS acceptance.

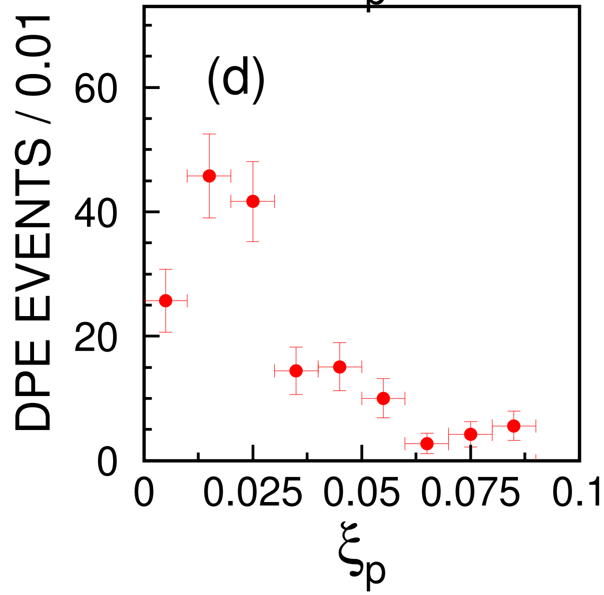
- **Proton Momentum Loss ξ_p**
  - Calculated from all particles in an event.
  - Energies in the calorimeter and BBC used.

$$\Rightarrow \xi_p = f_{calib} \times \frac{1}{\sqrt{s}} \sum_{i=1}^{all} E_T^i \, e^{+\eta_i}$$

Calibration $f_{calib} = \langle \xi_{\bar{p}}^{RPS} / \xi_{\bar{p}}^{rec} \rangle = 1.7$

$\xi_{\bar{p}}^{rec} = \frac{1}{\sqrt{s}} \sum_{i=1}^{all} E_T^i \, e^{-\eta_i}$





(c) Rising trend of DPE to SD with increasing $\xi_{\bar{p}}$.

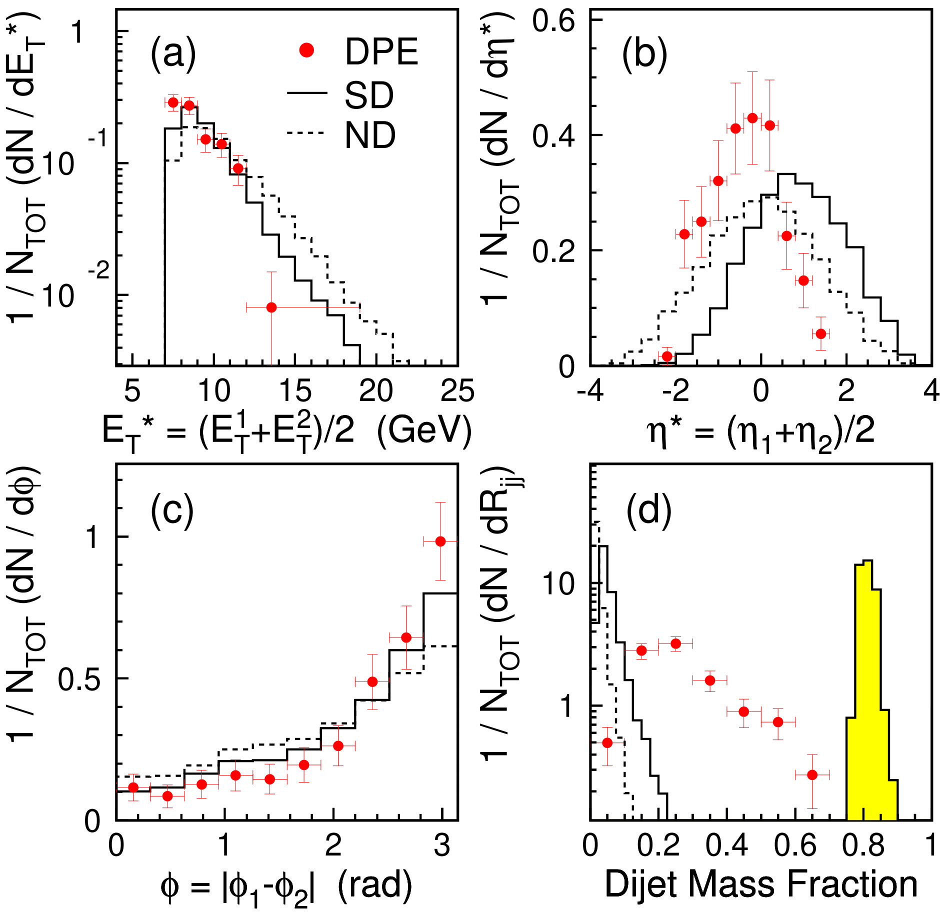
$\rightarrow$ lower c.m. energy in DPE than in SD.

(d) Large fraction of DPE events have $0.01 < \xi_p < 0.03$, that is smaller than $\xi_{\bar{p}}$.

(rapidity gap requirement)

Kinematic Properties : Dijet

- **Similar E_T^* spectra but DPE and SD slightly faster drop than ND.**
- **DPE dijets boosted to $-\eta^*$ because $\xi_p < \xi_{\bar{p}}$.**
  SD dijets boosted to $+\eta^*$, ND dijets is symmetric.
- **DPE dijets more back-to-back than SD and ND.**
- **Higher dijet mass fraction in DPE**
  $\Rightarrow$ dijets dominate the central DPE system.



(yellow peak : expectation for DPE with only two jets, no underlying energy)

DPE Dijet Production Cross Section

For the kinematical range of
$0.035 < \xi_{\bar{p}} < 0.095$, $0.01 < \xi_p < 0.03$ and $|t_{\bar{p}}| < 1.0\,\mathrm{GeV}^2$ with
jets confined within $-4.2 < \eta < 2.4$,

$$\sigma_{\mathrm{DPE}}(E_T^{jet1,2} > 7\,\mathrm{GeV}) = 43.6 \pm 4.4(\mathrm{stat}) \pm 21.6(\mathrm{syst})\,\mathrm{nb}$$

$$\sigma_{\mathrm{DPE}}(E_T^{jet1,2} > 10\,\mathrm{GeV}) = 3.4 \pm 1.0(\mathrm{stat}) \pm 2.0(\mathrm{syst})\,\mathrm{nb}$$

Systematic Uncertainties:

	$E_T^{jet1,2} > 7\,\mathrm{GeV}$	$E_T^{jet1,2} > 10\,\mathrm{GeV}$
Jet Energy Scale	40.5 %	39.2 %
Underlying Event Energy	16.7 %	25.5 %
SD Background under (0,0) Bin	9.6 %	25.6 %
Inclusive Diffraction Cross Section	20.0 %	
Rapidity Gap Acceptance	4.4 %	
Cut Efficiencies, Acceptances etc.	4.8 %	
(ξ, t) resolution	1.5 %	
Total	**49.6 %**	**57.4 %**

Kinematic Properties : Bjorken-x of Parton

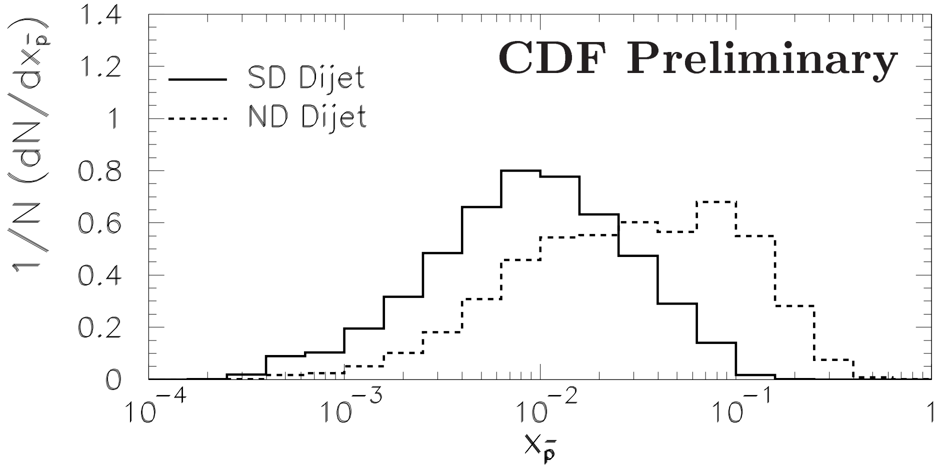
Fractional Momentum of the $\bar{p}$ (p) carried by the Struck Parton

(reconstructed from 2 jets + 3rd jet if $E_T^{jet3} > 5\,\mathrm{GeV}$)

$$x_{\bar{p}} = \frac{\sum_{i=1}^{jets} E_T^i e^{-\eta_i}}{\sqrt{s}}$$

Ratio $R_{ND}^{SD}(x_{\bar{p}}, \xi_{\bar{p}})$

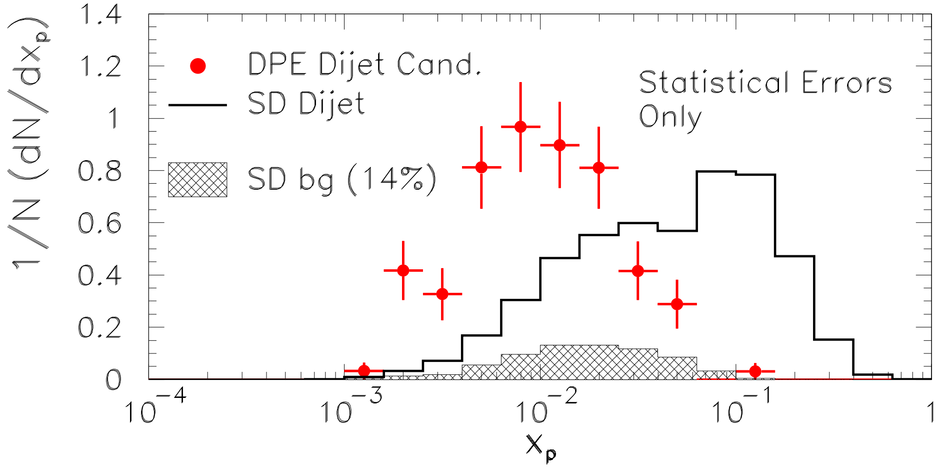
= **Ratio of diff to non-diff $\bar{p}$ structure functions**



$$x_p = \frac{\sum_{i=1}^{jets} E_T^i e^{+\eta_i}}{\sqrt{s}}$$

Ratio $R_{SD}^{DPE}(x_p, \xi_p)$

= **Ratio of diff to non-diff p structure functions**



$R_{SD}^{DPE} = R_{ND}^{SD}$ / $R_{SD}^{DPE} \neq R_{ND}^{SD}$ **at same (x, ξ) ➡ Factorization holds. / breaks.**

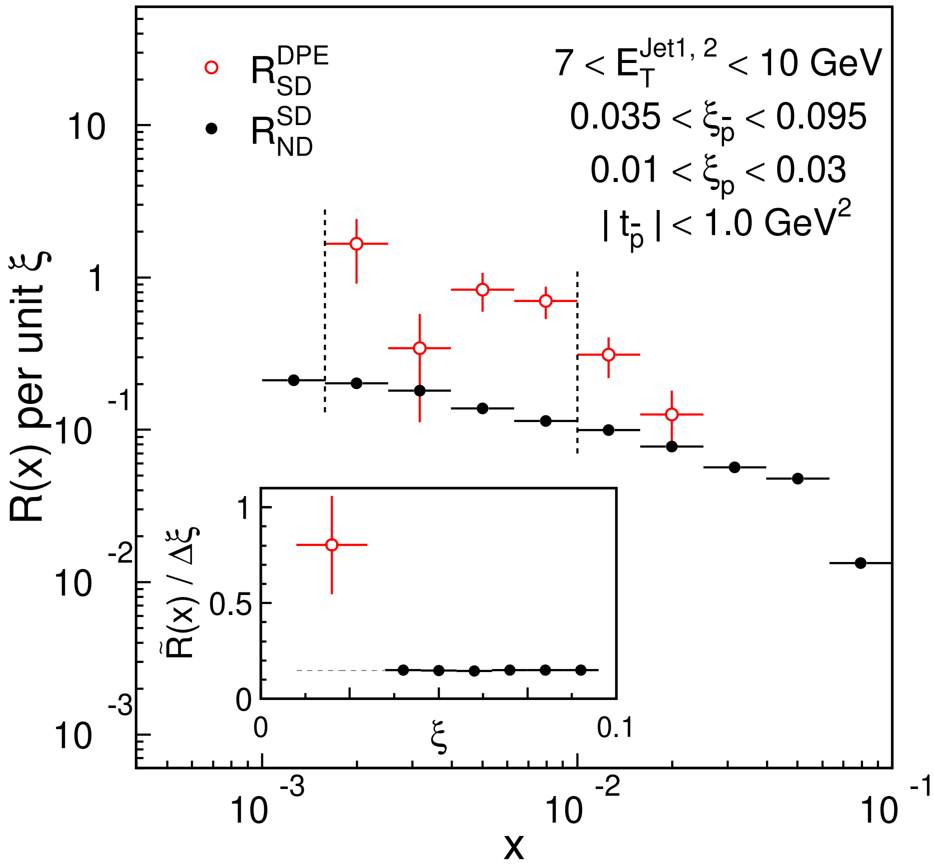
Factorization Test at the Tevatron

$R^{DPE}_{SD}(x_p)$ and $R^{SD}_{ND}(x_{\bar{p}})$

- normalized per unit ξ
- stat error only
- systematic error $\approx 20\,\%$

Inset: $\tilde{R}(x)$ vs ξ

- $\tilde{R}$ = weighted average of R within $10^{-2.8} < x < \xi_p^{min}$
- normalized per unit ξ



$$\tilde{R}^{DPE}_{SD} = 0.80 \pm 0.26$$
$$\tilde{R}^{SD}_{ND} = 0.15 \pm 0.02$$

(yielded by straight line fit extrapolated to $\xi = 0.02$.)

$$\boxed{D \equiv \tilde{R}^{SD}_{ND}/\tilde{R}^{DPE}_{SD} = 0.19 \pm 0.07}$$

Deviation of D from unity ➡ Breakdown of Factorization

Summary

- Reported the first observation of dijet events with a Double Pomeron Exchange topology in $\bar{p}p$ collisions at $\sqrt{s} = 1.8\,\mathrm{TeV}$.

- Production cross sections measured to be

  $$\sigma_{\mathrm{DPE}}(E_T^{jet1,2} > 7\,\mathrm{GeV}) = 43.6 \pm 4.4(\mathrm{stat}) \pm 21.6(\mathrm{syst})\,\mathrm{nb},$$
  $$\sigma_{\mathrm{DPE}}(E_T^{jet1,2} > 10\,\mathrm{GeV}) = 3.4 \pm 1.0(\mathrm{stat}) \pm 2.0(\mathrm{syst})\,\mathrm{nb},$$

  for the kinematic range of $0.035 < \xi_{\bar{p}} < 0.095$, $0.01 < \xi_p < 0.03$ and $|t_{\bar{p}}| < 1.0\,\mathrm{GeV}^2$ with jets confined within $-4.2 < \eta < 2.4$.

- Ratios R_{SD}^{DPE} and R_{ND}^{SD} measured as functions of x_p and $x_{\bar{p}}$, respectively.

- Breakdown of factorization found as a non-unity of the ratio $D \equiv \tilde{R}_{ND}^{SD}/\tilde{R}_{SD}^{DPE} = 0.19 \pm 0.07$.