DIFFRACTION NEWS FROM CDF

DIFFRACTION 2010
International Workshop on Diffraction in High-Energy Physics

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http://physics.rockefeller.edu/dino/myhtml/conference.html

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- ❑ Introduction
- ❑ Diffractive *W* and *Z* production
- ❑ Diffractive structure function in dijet production
- ❑ Central gaps in min-bias and dijet events
- ❑ Conclusions

DIFFRACTIVE AND NON-DIFFRACTIVE INTERACTIONS

Non-diffractive → no gaps

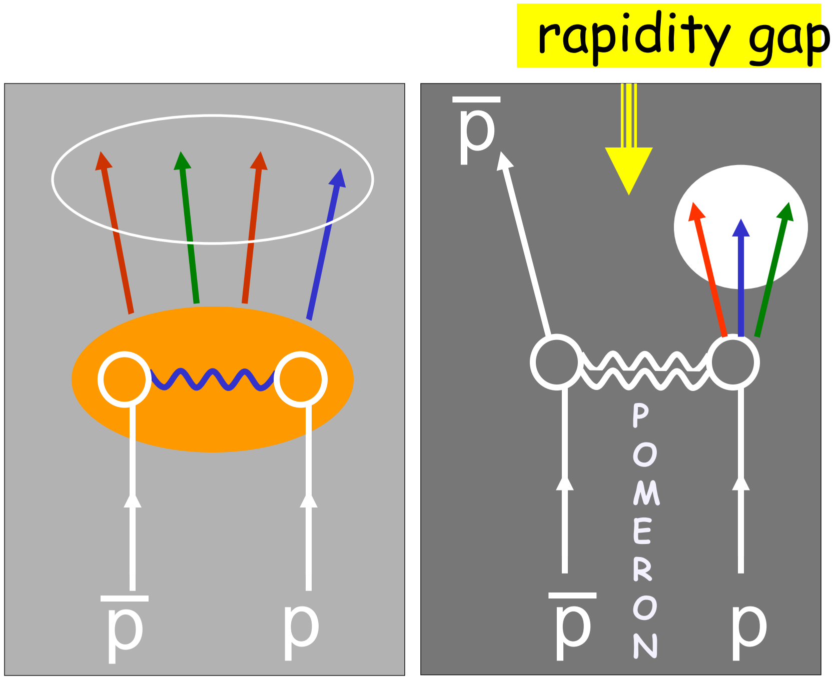
- Color-exchange

Diffractive → gaps

- Colorless exchange with vacuum quantum numbers

Incident hadrons acquire color and break apart

CONFINEMENT

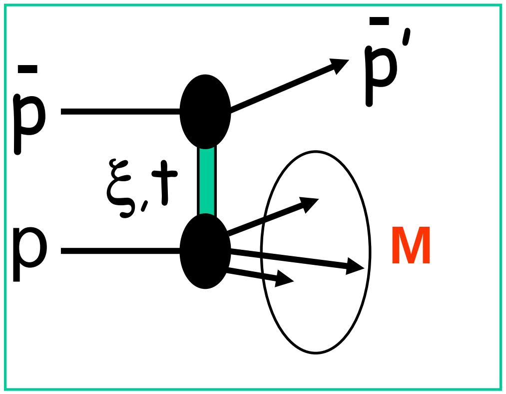


Incident hadrons retain their quantum numbers remaining colorless

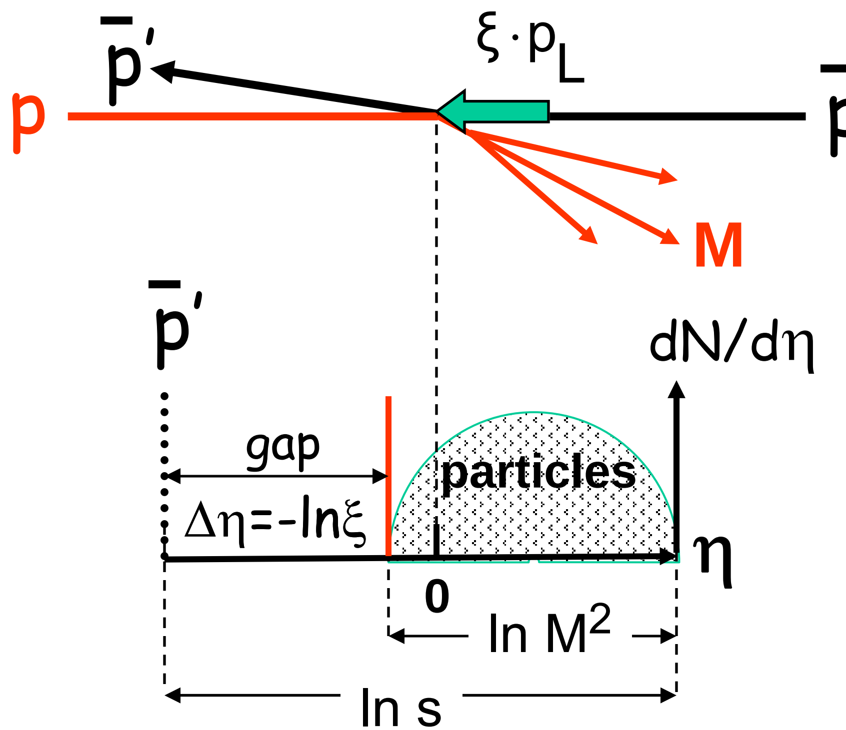
pseudo-DECONFINEMENT

Goal: understand the QCD nature of the diffractive exchange

Definitions



$$1-x_L \equiv \xi = \frac{M^2}{s}$$

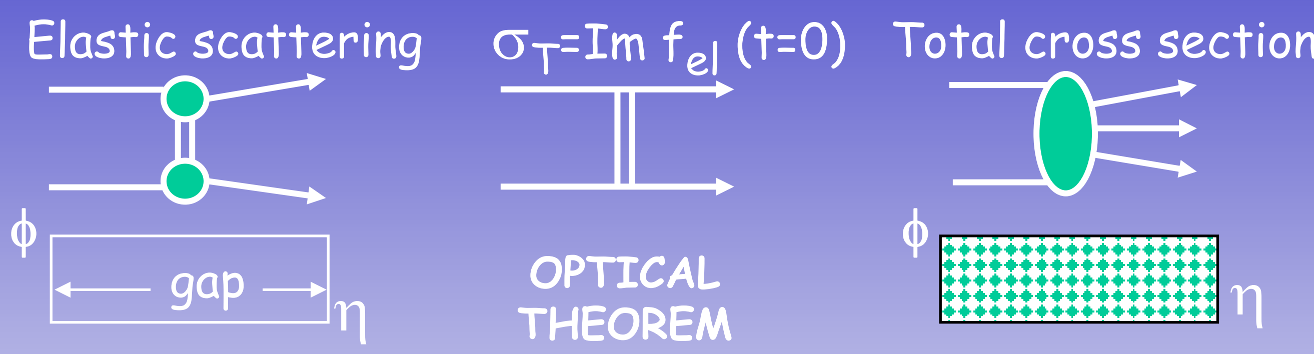


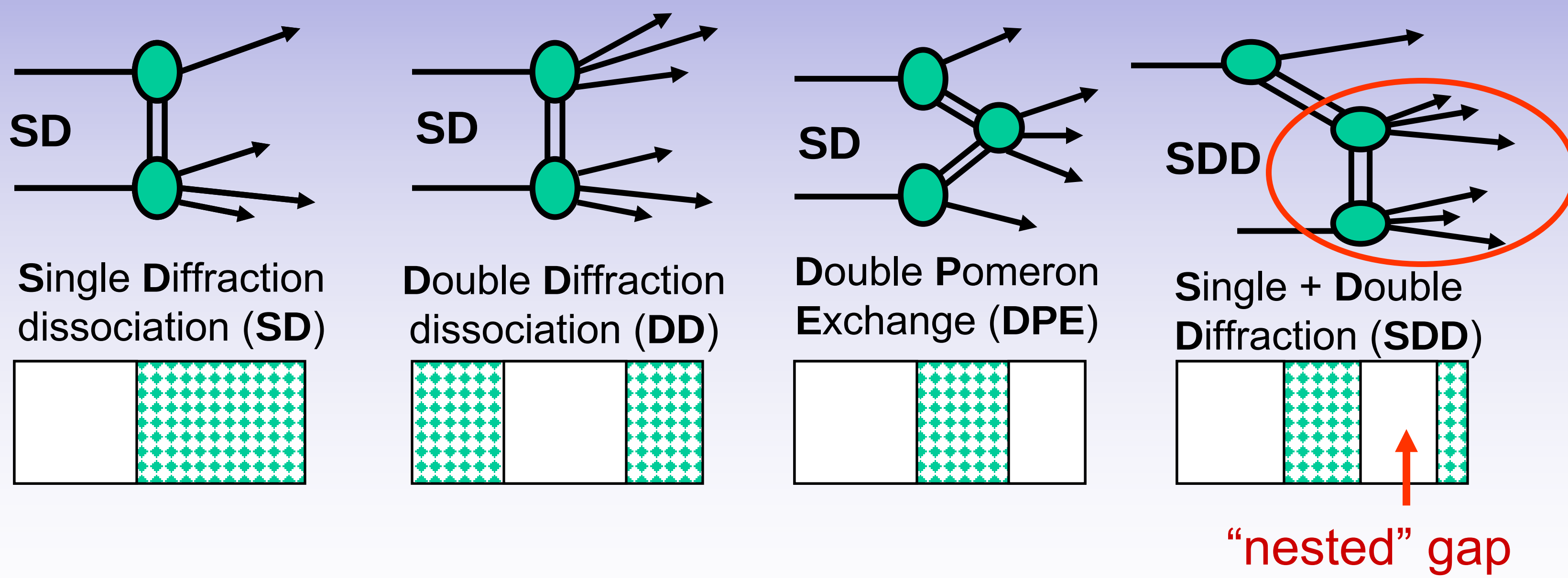
No radiation →
no price paid for increasing diffractive gap size

$$\left(\frac{d\sigma}{d\,\Delta\eta}\right)_{t=0} \approx \text{constant} \Rightarrow \frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \Rightarrow \frac{d\sigma}{dM^2} \propto \frac{1}{M^2}$$

Diffraction at CDF in Run I

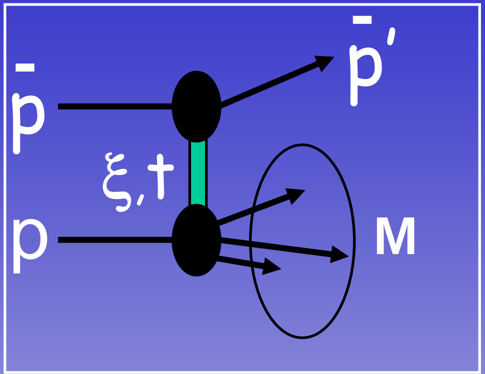
http://physics.rockefeller.edu/publications.html



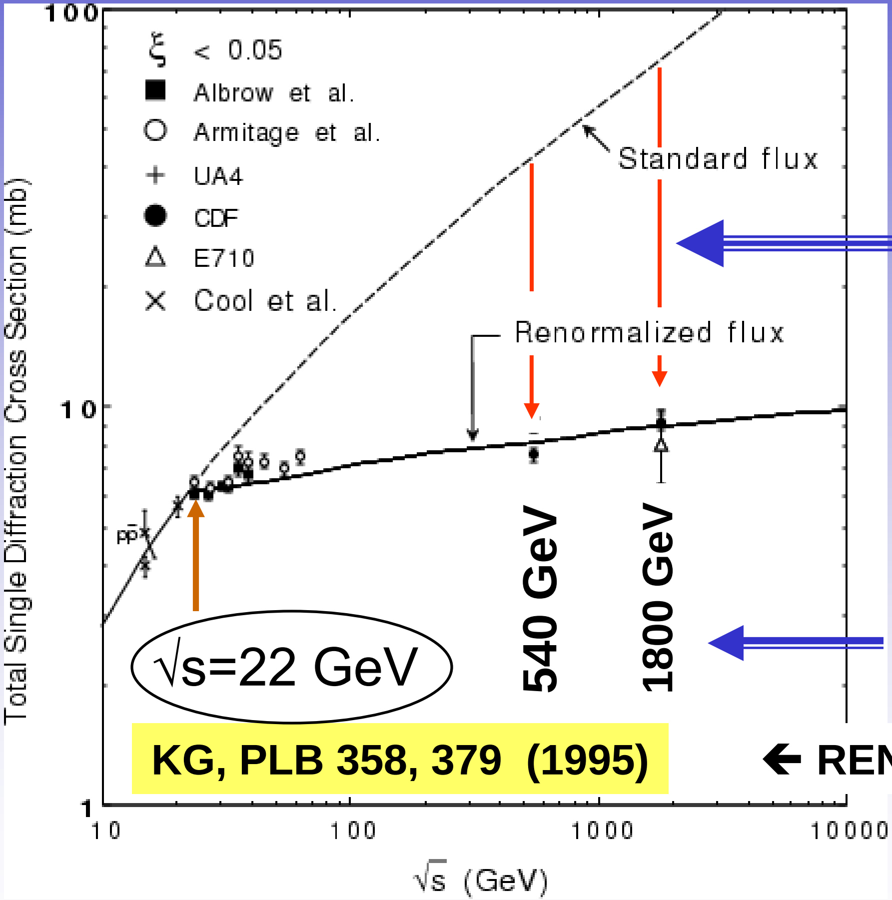


σ^T_{SD} ($\bar{p}p$ & pp)

➔ suppressed relative to Regge for √s>22 GeV



σ^T_{SD} mb



Factor of ~8 (~5) suppression at √s = 1800 (540) GeV

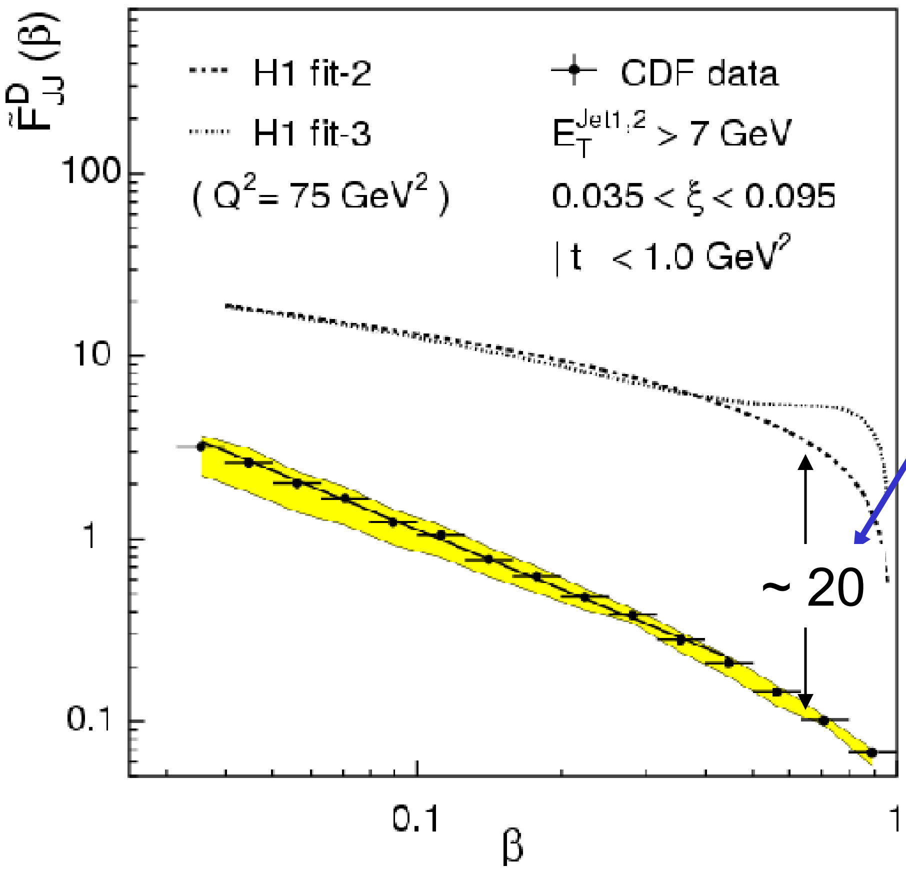
CDF Run I results

← RENORMALIZATION MODEL

Diffractive Structure Function (DSF)

→ **breakdown of QCD factorization**

Run I **PRL 84, 5043 (2000)**



$$\bar{p}p \to \bar{p} + [\text{dijet} + X]$$

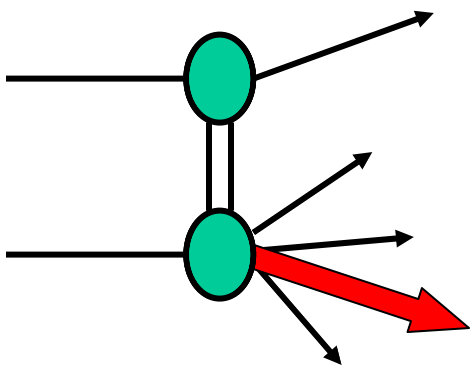
suppression factor is 2.5 times larger than in soft diffraction

This contradicted the RENORM prediction that it should be ~ 8 → as in soft diffraction

β → momentum fraction of parton in "Pomeron"

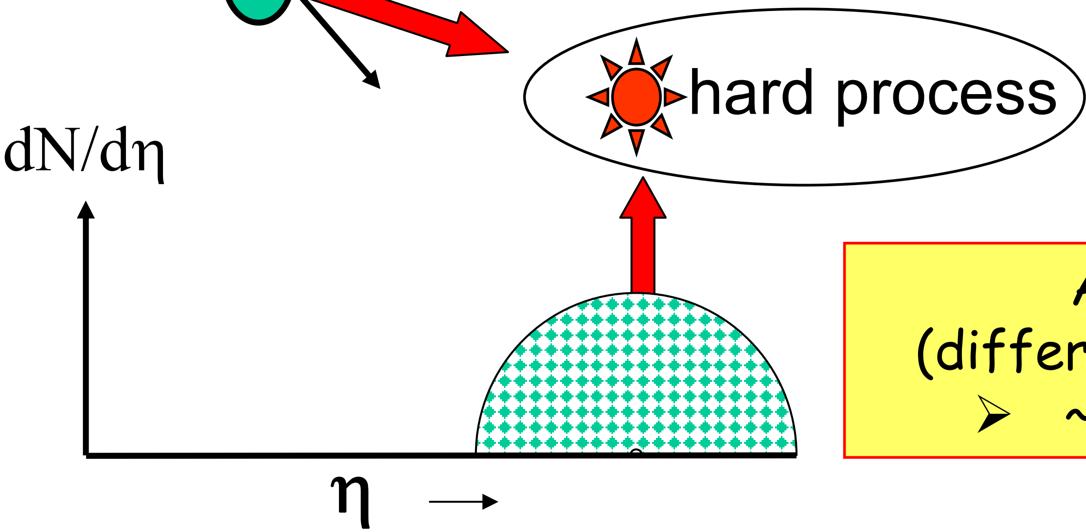
Run I Hard diffractive fractions

$$\bar{p}p \to (\ast + X) + \text{gap}_p \text{ or gap}_{pbar}$$



<u>Fraction:</u>
SD/ND ratio
@ 1800 GeV

✹	Fraction %
JJ	0.75 +/- 0.10
W	1.15 +/- 0.55
b	0.62 +/- 0.25
J/ψ	1.45 +/- 0.25



All fractions ~ 1%
(differences due to kinematics)
➢ ~ FACTORIZATION !

Puzzles from run I diffraction at CDF

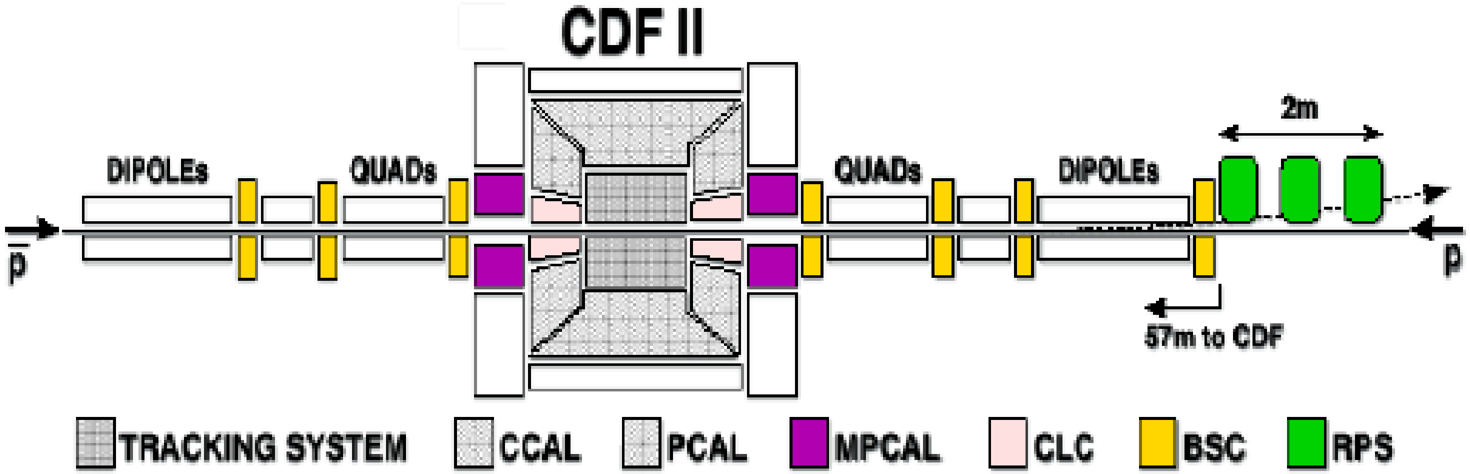
❑ gap fractions are suppressed relative to theory predictions, both for soft (Regge) and hard diffraction
…but
factorization holds among processes at the same energy, just like at HERA

❑ DSF at $\sqrt{s}$=1800 GeV suppressed by factor ~ 20 while Regge by factor ~8 → contradicts RENORM prediction

Why Run II Diffraction at CDF?

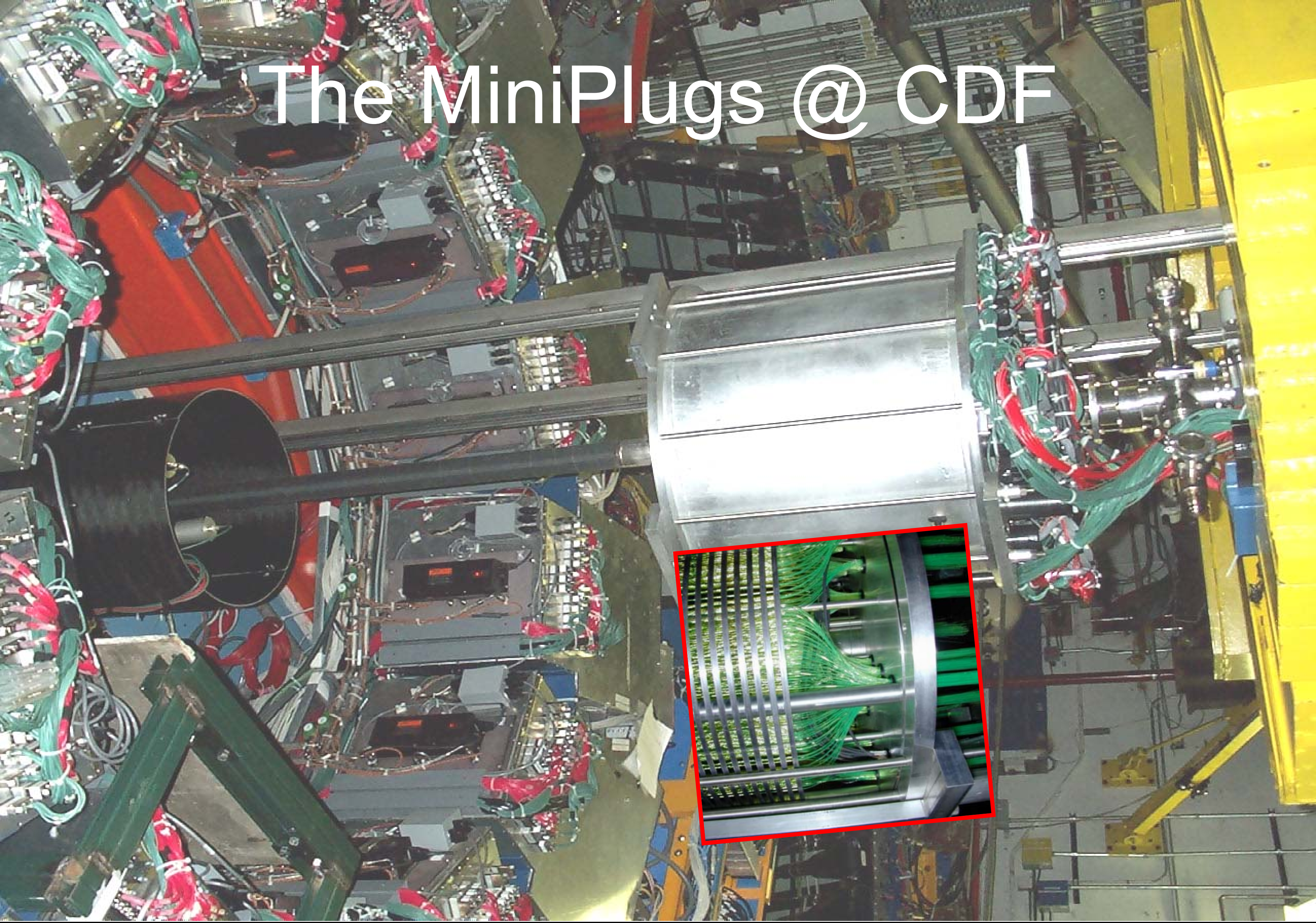
- ❑ Resolve question on soft vs. hard diffraction suppression – are they really different?
- ❑ Make precise measurement of the DSF in dijets
  - – sensitive to gluon pdf's
- ❑ Measure diffractive *W/Z* production
  - – sensitive to quark pdf's
- ❑ Central gaps in soft and hard diffraction
  - – BFKL, Mueller-Navelet, other
- ❑ Aim to observe exclusive dijet production
  - – important for diffractive Higgs searches

The CDF II Detector – plan view

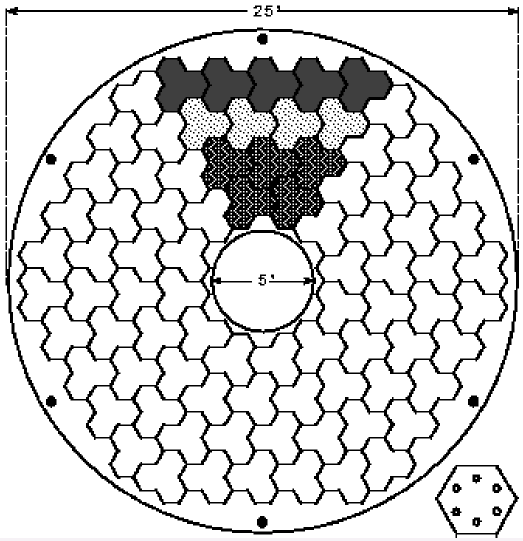


Tracking	–	Tracking Detectors	$\lvert\eta\rvert < 2.0$
CCAL, PCAL	–	Calorimeters	$\lvert\eta\rvert < 3.6$
RPS	–	Roman Pot Spectrometers	$0.02 < \xi < 0.1$ $0 < \lvert t\rvert < 2\ \mathrm{GeV}^2$
BSC	–	Beam Shower Counters	$5.4 < \lvert\eta\rvert < 7.4$
MPCAL	–	MiniPlug Calorimeters	$3.5 < \lvert\eta\rvert < 5.1$

The MiniPlugs @ CDF



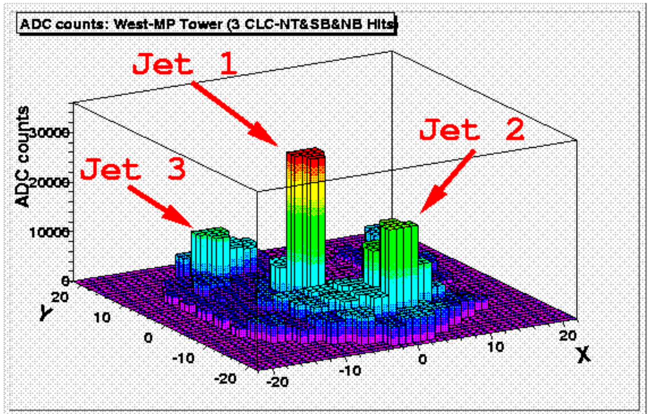
Measurements ^{w}/the MiniPlugs

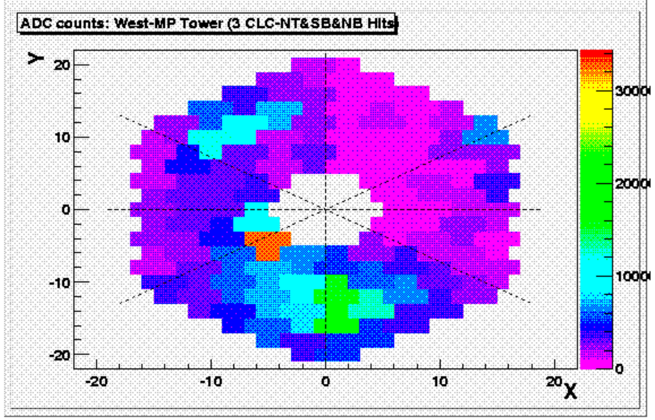


MP TOWER STRUCTURE

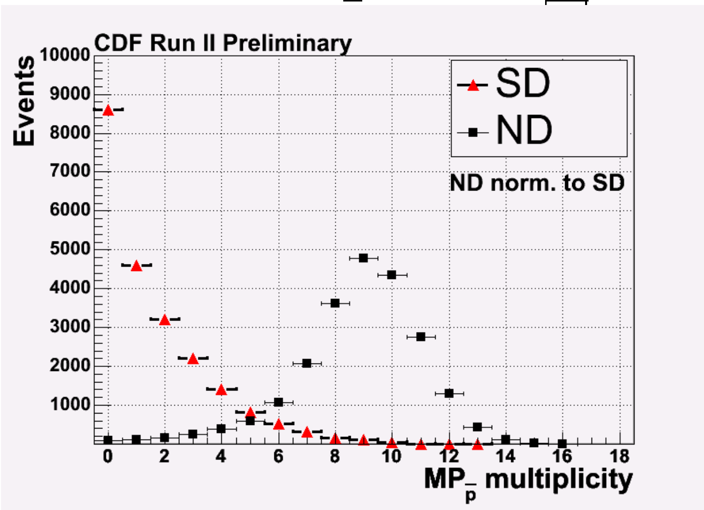
MULTIPLICITY @ POSITION

ENERGY





$$\xi^{CAL} = \frac{\Sigma_i E_T^i e^{-\eta_i}}{\sqrt{s}}$$



Multiplicity of SD and ND events

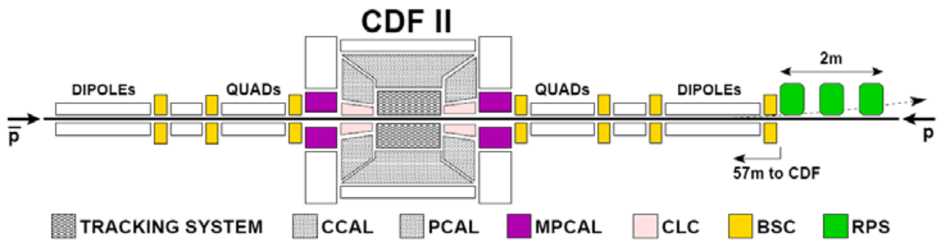
NIM A 430 (1999)
NIM A 496 (2003)
NIM A 518 (2004)

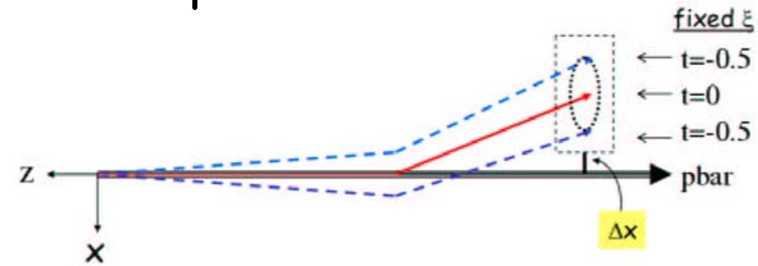
ADC counts in MiniPlug towers in a pbar-p event at 1960 GeV.

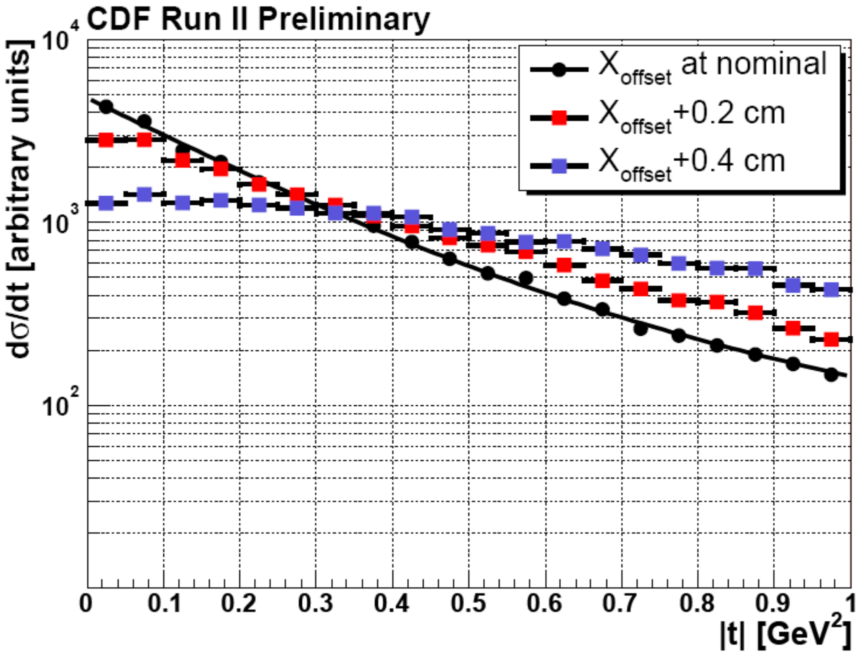
- "jet" indicates an energy cluster and may be just a hadron.
- 1000 counts ~ 1 GeV

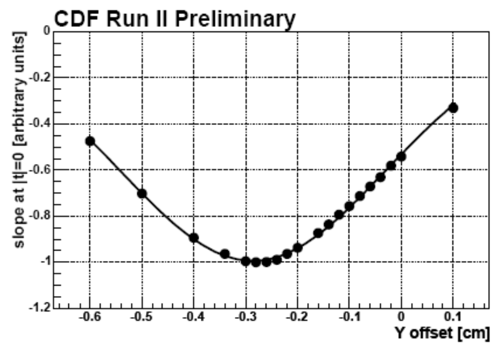
Dynamic Alignment of RPS Detectors

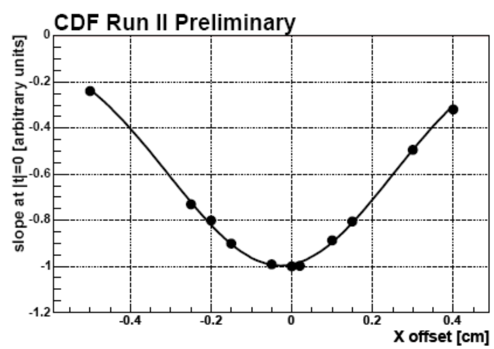
Method: iteratively adjust the RPS X and Y offsets from the nominal beam axis until a maximum in the b-slope is obtained @ t=0.











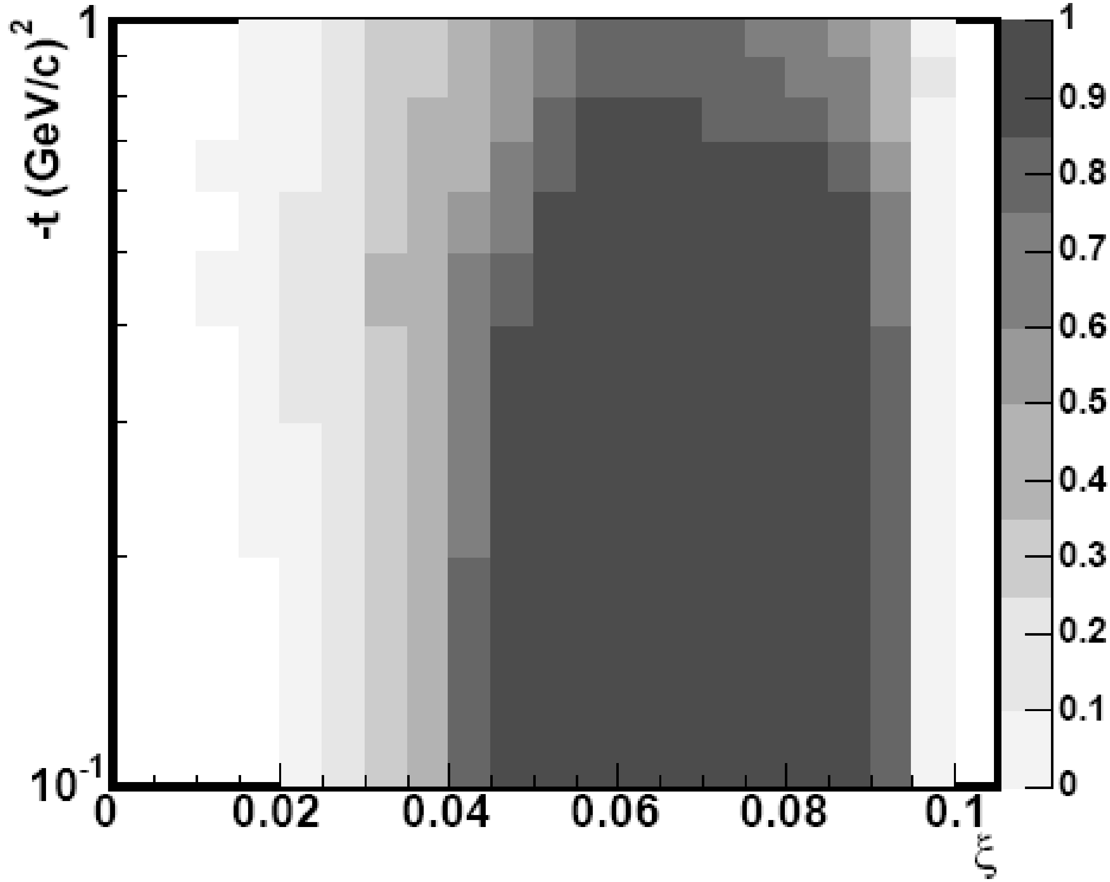
Limiting factors

1-statistics
2-beam size
3-beam jitter

@ CDF
w/lowlum data

$\pm 30\ \mu m$

RPS acceptance

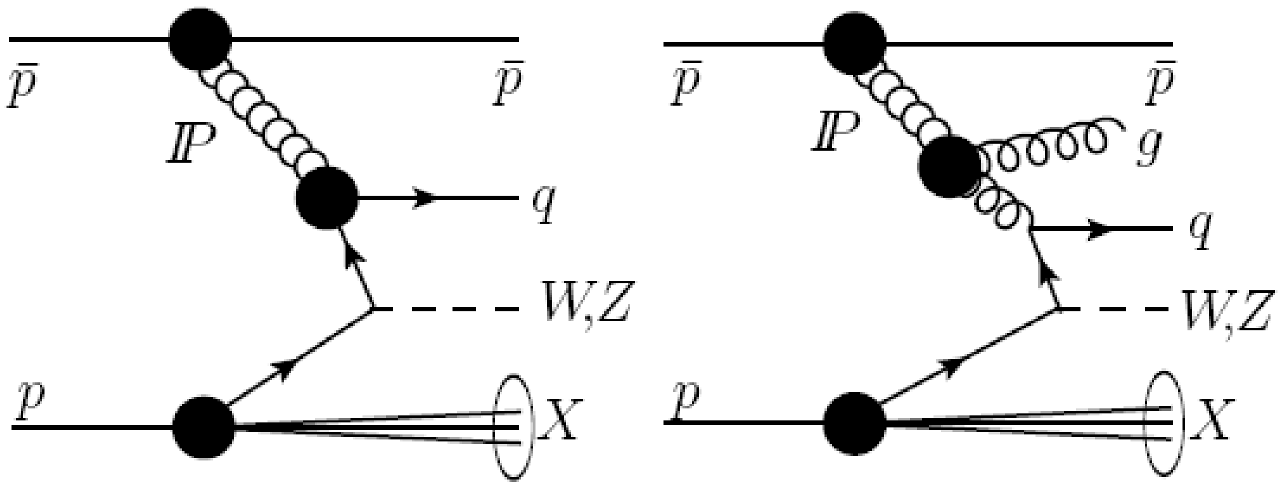


From PRD (submitted)

FIG. 3: RPS acceptance as a function of ξ and t obtained from simulation using the transport parameters between the nominal interaction point and the Roman pots.

Diffractive W/Z production

status: submitted to PRD



- In LO QCD *W* probes the quark content of diffractive exchange
- Production by gluons is suppressed by a factor of α_S, and can be distinguished from quark production by an associated jet

Diffractive W/Z analysis

Using RPS information:

- No background from gaps due to multiplicity fluctuations
- No gap survival probability problem
- The RPS provides accurate event-by-event ξ measurement
- Determine the full kinematics of diffractive W production by obtaining η_ν using the equation:

$$\xi^{RPS} - \xi^{cal} = \frac{\not{E}_T}{\sqrt{s}} e^{-\eta_\nu}$$

where

$$\xi^{cal} = \sum_{towers} \frac{E_T}{\sqrt{s}} e^{-\eta}$$

This allows determination of:

- W mass

  and potentially (not enough range in present case)

  - x_{Bj} distribution
  - Diffractive structure function

Data and event selection

0.6 fb-1 of integrated luminosity data

TABLE I: W and Z events passing successive selection requirements.

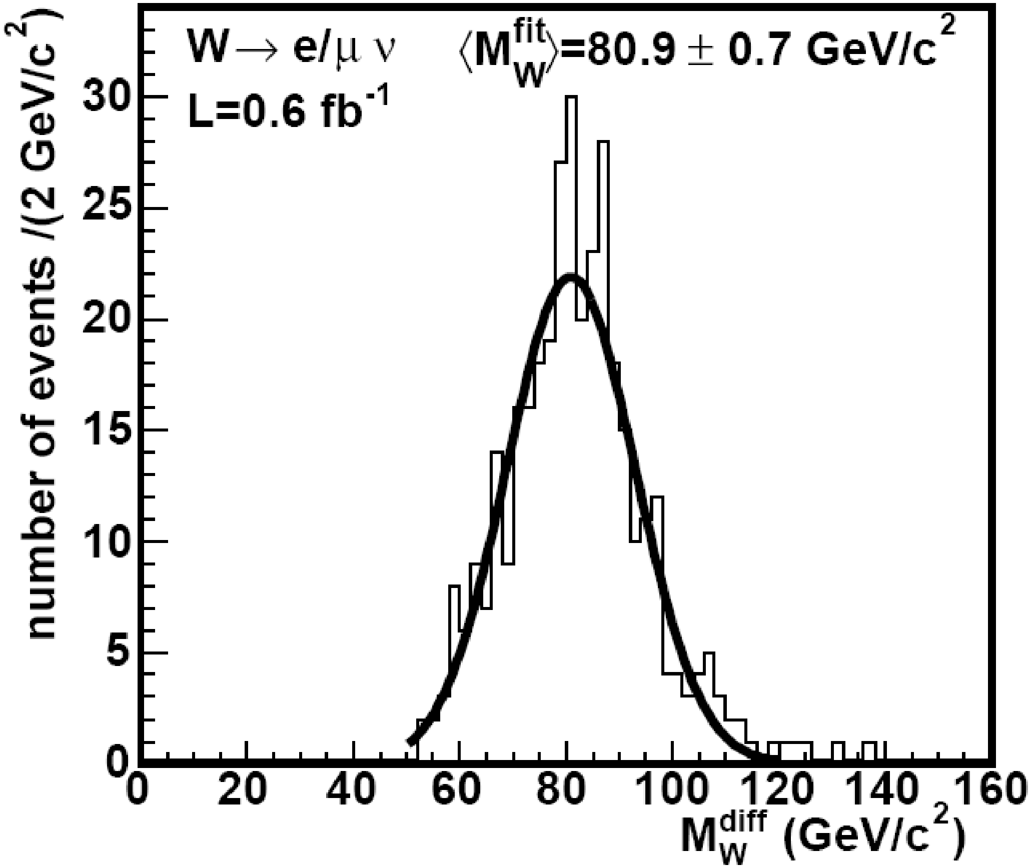
	$W \to e\nu$	$W \to \mu\nu$	$W \to l(e/\mu)\nu$
RPS-trigger-counters	6663	5657	12 320
RPS-track	5124	4201	9325
$50 < M_W < 120$	192	160	352
	$Z \to ee$	$Z \to \mu\mu$	$Z \to ll$
RPS-trigger-counters	650	341	991
RPS-track	494	253	747
$\xi^{\text{cal}} < 0.10$	24	12	36

← W

← Z

$$\xi^{\text{cal}}_{\bar{p}} = \sum_{i=1}^{N_{\text{towers}}} \frac{E_T^i}{\sqrt{s}} e^{-\eta^i}$$

Reconstructed M_W^{diff}

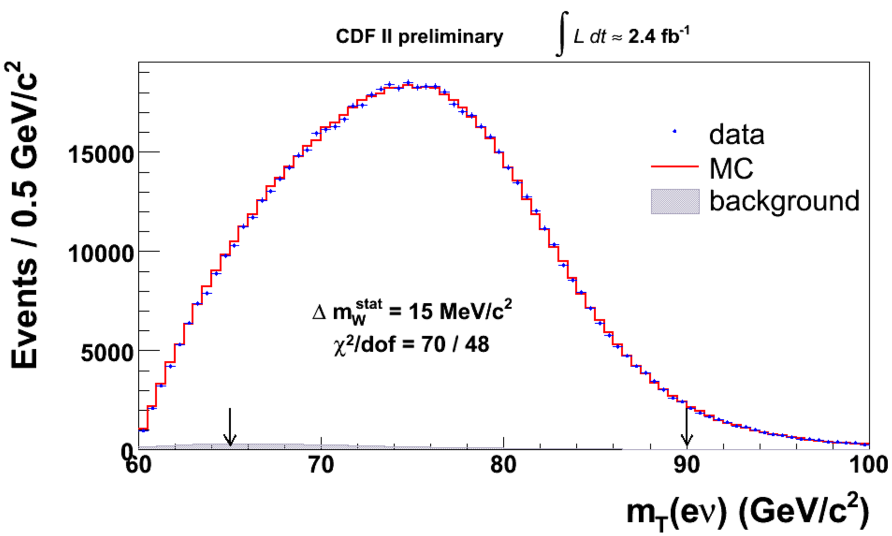


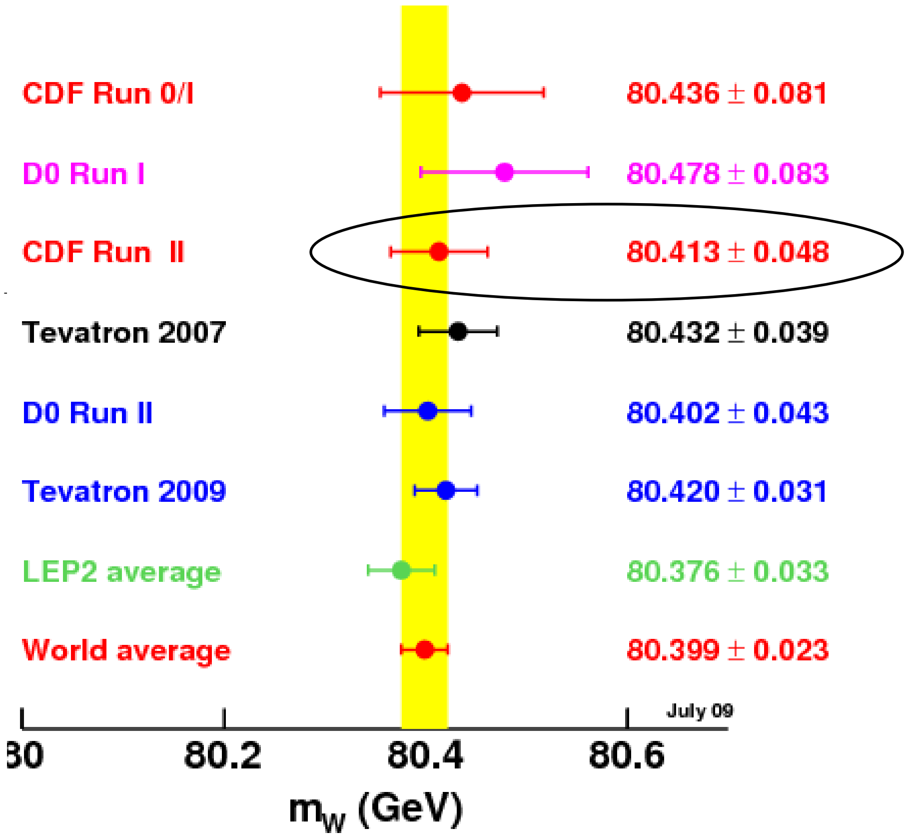
- ❑Reconstructed W mass using the 352 diffractive events fitted with a Gaussian.

M_W from inclusive W→e/μ+ν

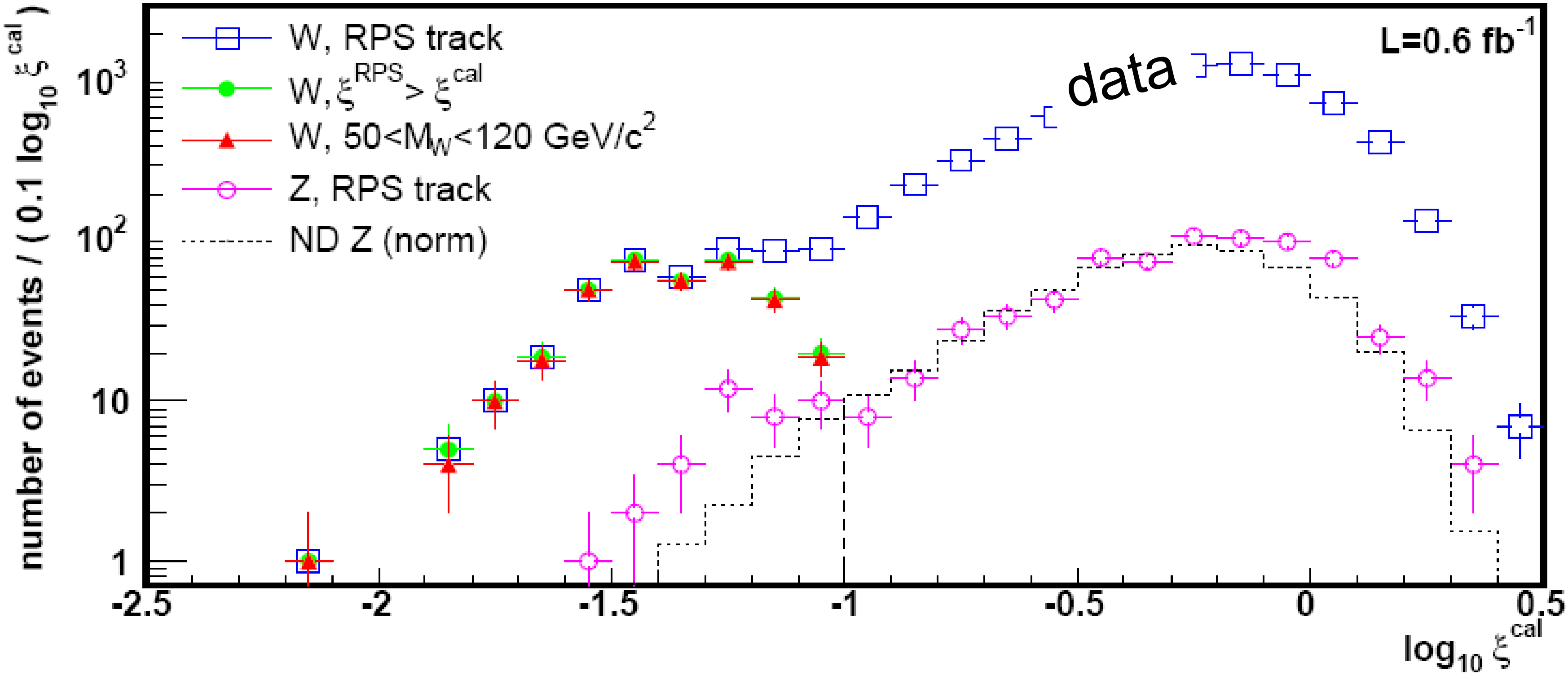
Method: compare transverse M^W data with MC

$$M_T^W = \sqrt{2(p_T^l p_T^\nu - \vec{p}_T^{\,l} \cdot \vec{p}_T^{\,\nu})}/c$$





ξ^{cal} distribution



Diffractive W/Z fractions

$$R_W(R_Z) = \frac{2 \cdot N_{SD}^{W}(N_{SD}^{Z})}{A_{\mathrm{RPS}} \cdot \epsilon_{\mathrm{RPStrig}} \cdot \epsilon_{\mathrm{RPStrk}} \cdot N_{ND}^{1-\mathrm{int}}}$$

~80% 68-80% ~87% $f_{1\text{-int}}$ =(25.6±1.2)%

R_W (0.03 < ξ < 0.10, |t|<1)= [0.97 ± 0.05(stat.) ± 0.10(syst.)]%

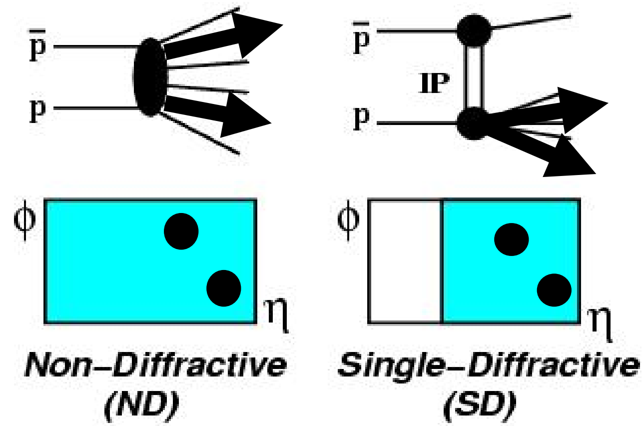
Run I: R^W =1.15±0.55 % for ξ_{min}<ξ<0.1

➔ [0.97±0.47 (stat and syst) % within 0.03 < ξ < 0.10 & |t|<1

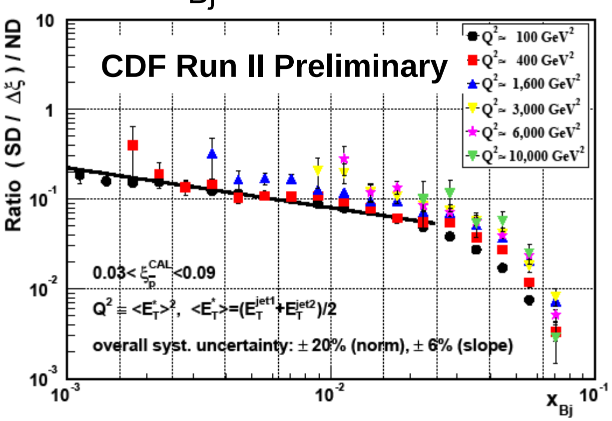
R_Z (0.03 < ξ < 0.10, |t|<1)= [0.85 ± 0.20(stat.) ± 0.08(syst.)]%

DSF from Dijets in Run II

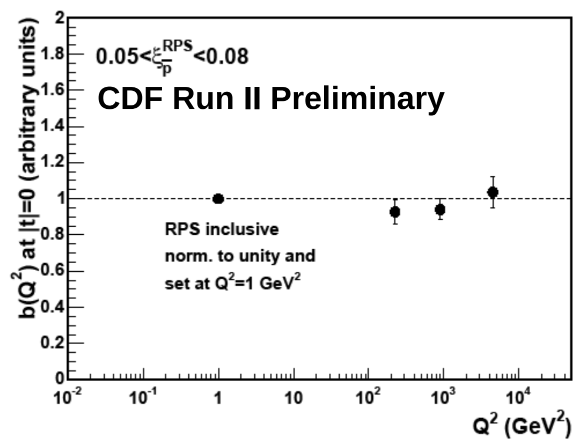
$$R(x_{Bj}) \equiv \frac{Rate_{jj}^{SD}(x_{Bj})}{Rate_{jj}^{ND}(x_{Bj})} \Rightarrow \frac{F_{jj}^{SD}(x_{Bj})}{F_{jj}^{ND}(x_{Bj})}$$



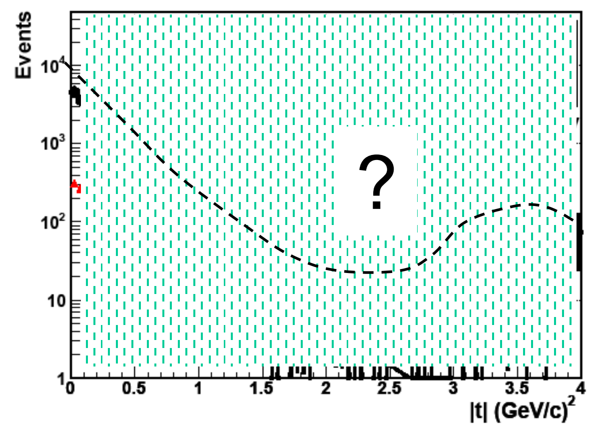
x_{Bj} - distribution



b - slope of t-distribution



t - distribution

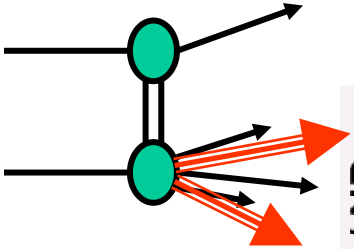


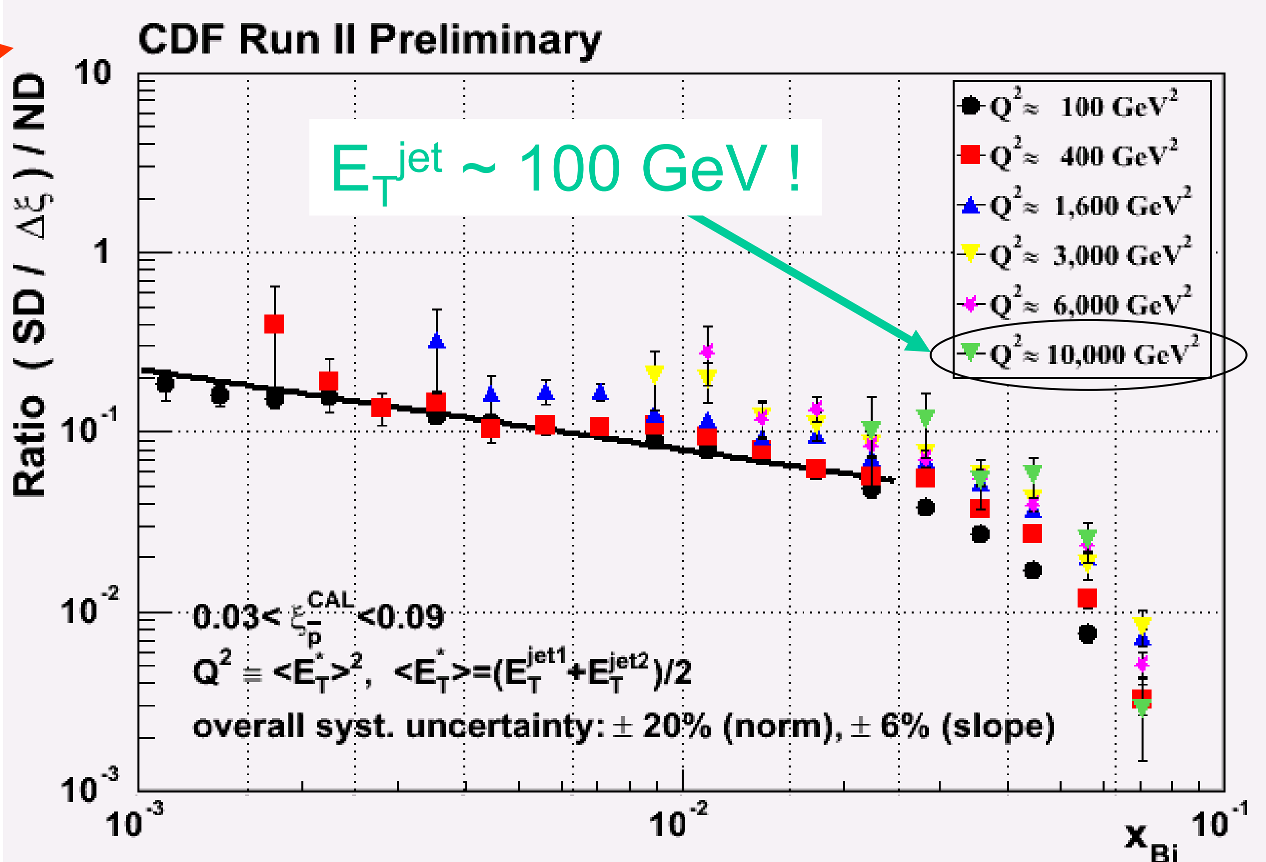
- The x_{Bj}-distribution of the SD/ND ratio has no strong Q^2 dependence
- the slope of the t-distribution is independent of Q^2
- the t-distribution ?????? diffraction minimum ??????

➢ all three results ➔ "first observation"

Diffractive structure function – Run II

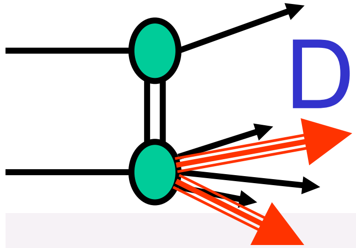
Q^2 - dependence





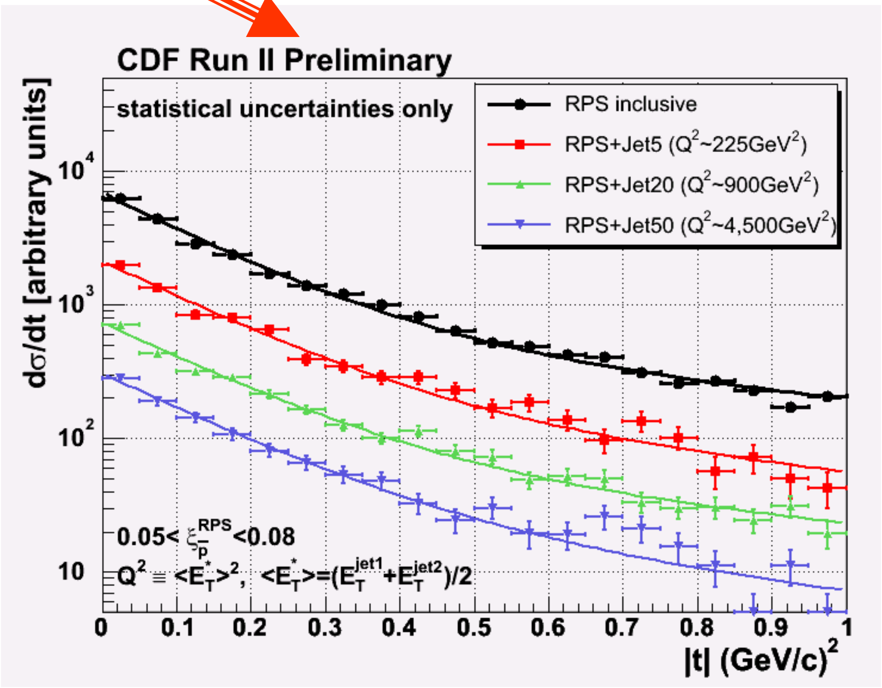
- Small Q^2 dependence in region $100<Q^2<10\,000$ GeV^2 where $d\sigma^{SD}/dE_T$ & $d\sigma^{ND}/dE_T$ vary by a factor of ~10^4 !

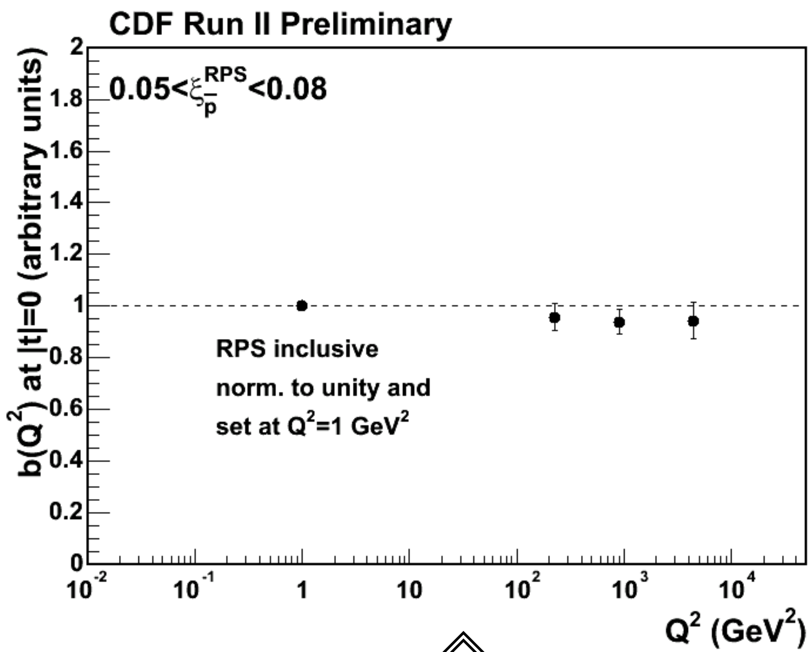
➔ The Pomeron evolves as the proton !



Diffractive structure function – Run II

t - dependence





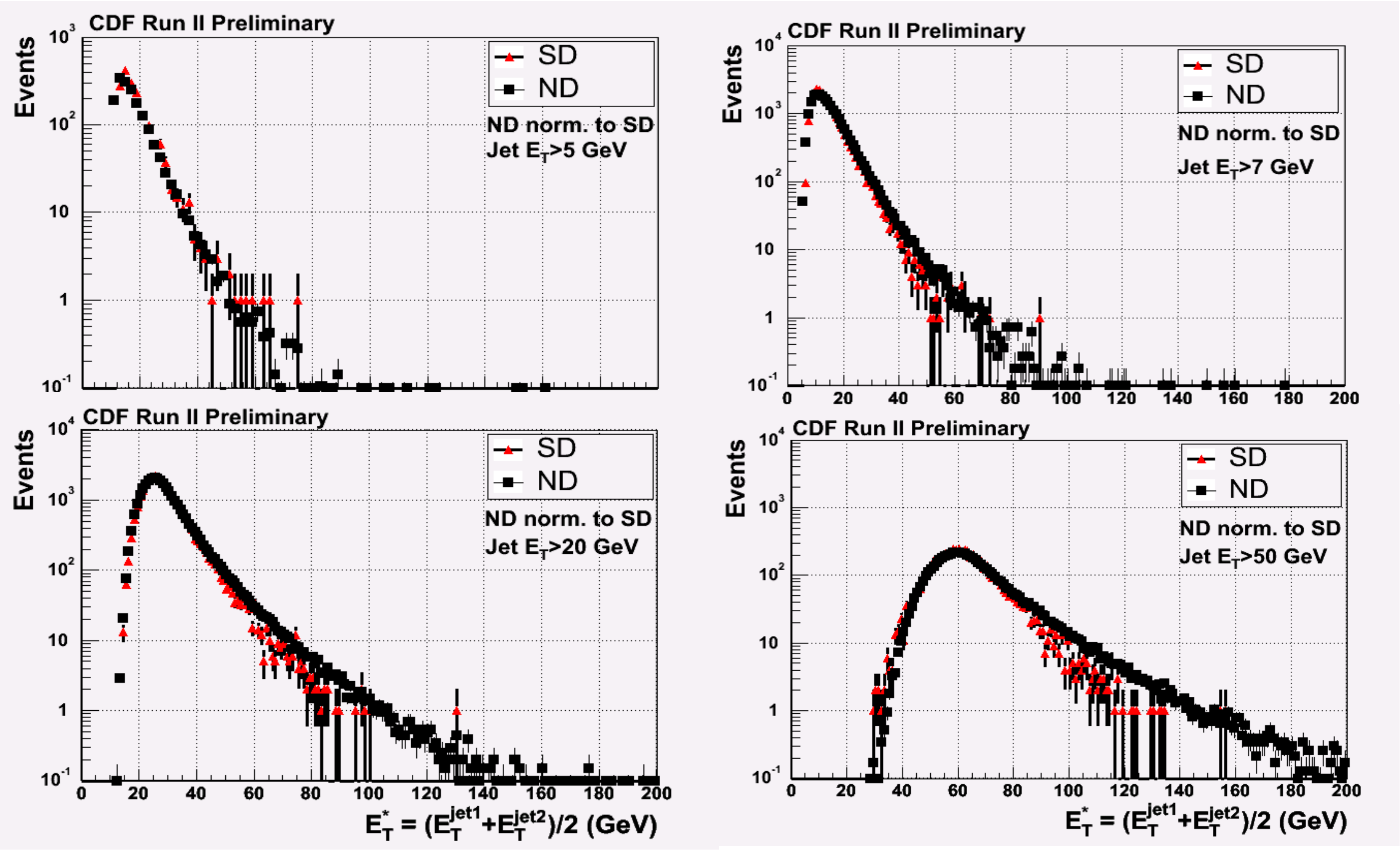
Fit dσ/dt to a double exponential:

$$F = 0.9 \cdot e^{b_1 \cdot t} + 0.1 \cdot e^{b_2 \cdot t}$$

- No diffraction dips
- No Q2 dependence in slope from inclusive to $Q^2 \sim 10^4$ GeV^2

- Same slope over entire region of $0 < Q^2 < \sim 10\,000$ GeV^2!

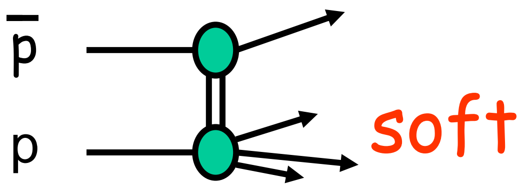
Dijet E_T distributions

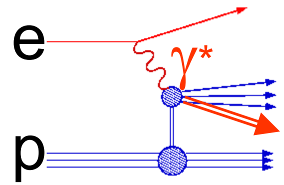


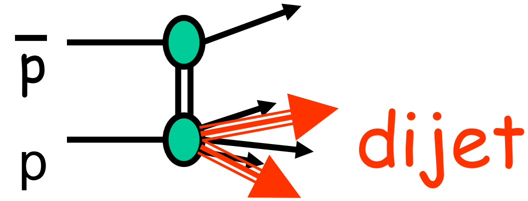
→ similar for SD and ND over 4 orders of magnitude

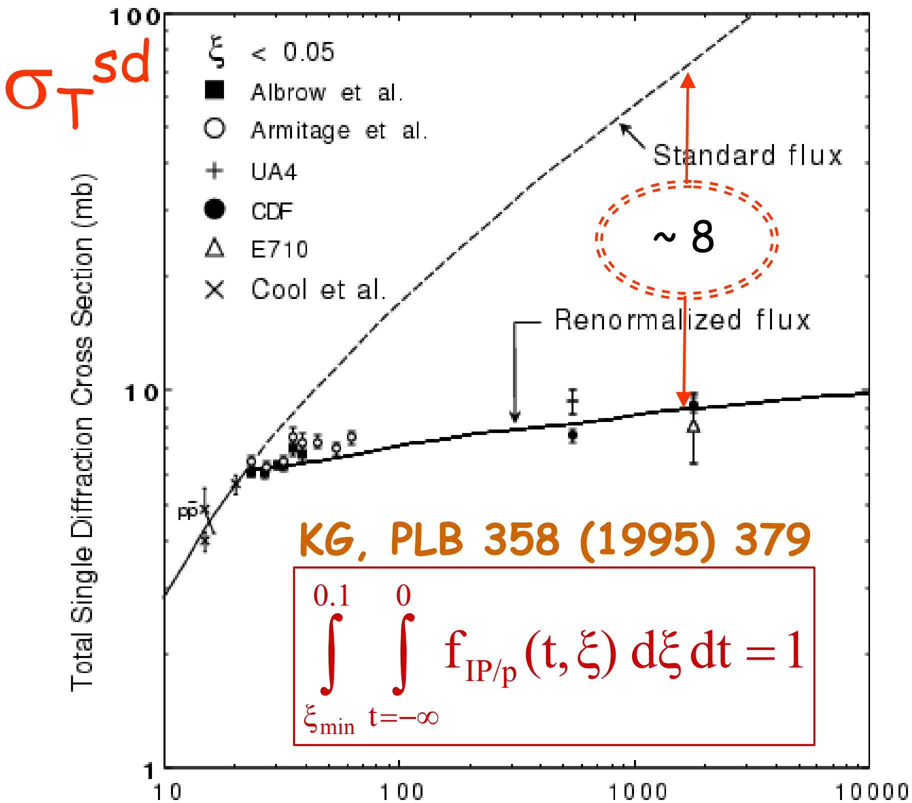
Kinematics

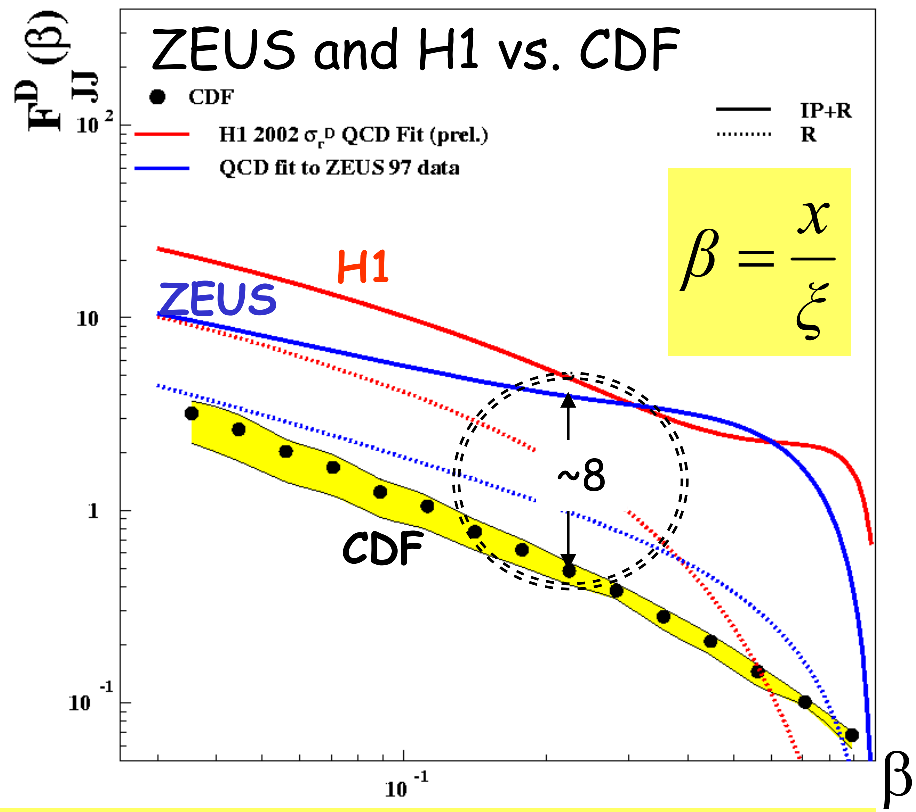
$\sigma^{T}{}_{SD}$ and dijets





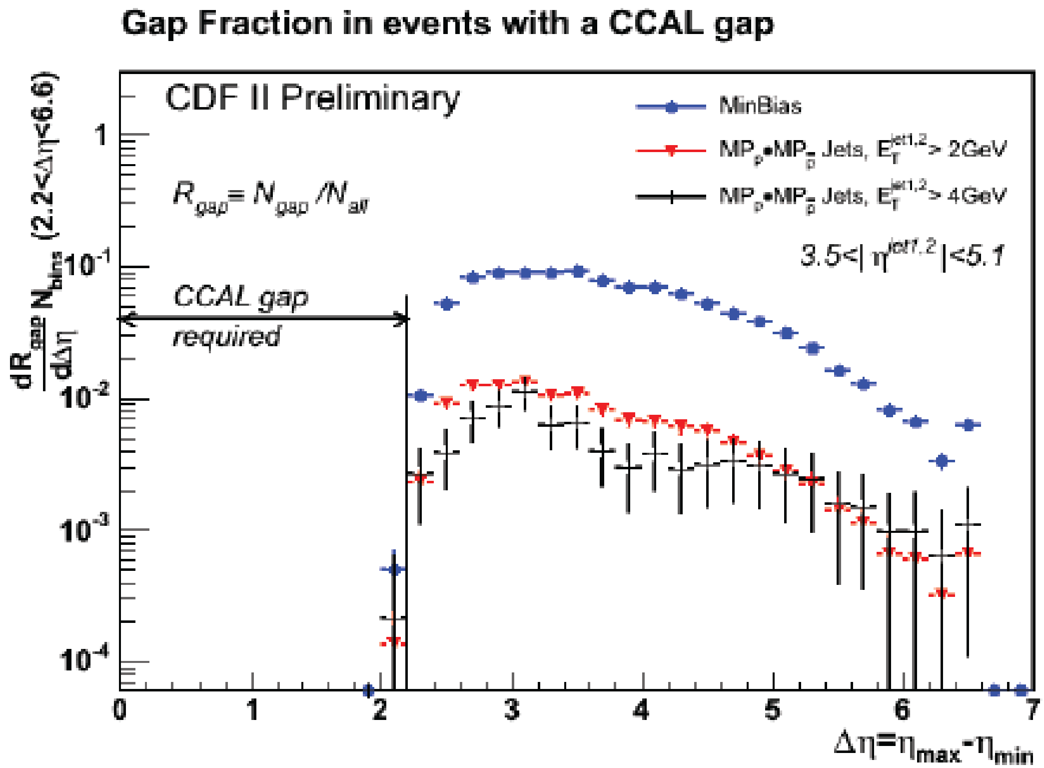


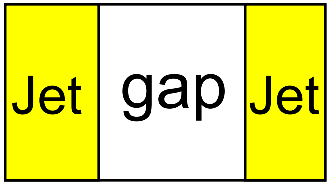




Magnitude: same suppression factor in soft and hard diffraction!
Shape of β distribution: ZEUS, H1, and Tevatron – why different slapes?

CENTRAL GAPS





The distribution of the gap fraction $R_{gap}=N_{gap}/N_{all}$ vs $\Delta\eta$ for MinBias ($CLC_p \bullet CLC_{pbar}$) and MiniPlug jet events ($MP_p \bullet MP_{pbar}$) of $E_{T(jet1,2)}$>2 GeV and $E_{T(jet1,2)}$> 4 GeV.

The distributions are similar in shape within the uncertainties.

SUMMARY

- Results were presented for diffractive W and Z fractions based on Run II CDF data using a Roman Pot Spectrometer (RPS) to measure the recoil pbar momentum.
- The W fraction is in good agreement with the fraction measured in Run I based on a rapidity gap analysis.
- The Z fraction is about 10% smaller than the W fraction, just as in non-diffractive events
- A progress report was presented on the diffractive structure function in dijet production and on an analysis on central rapidity gaps in min-bias and very forward dijet events.

thank you

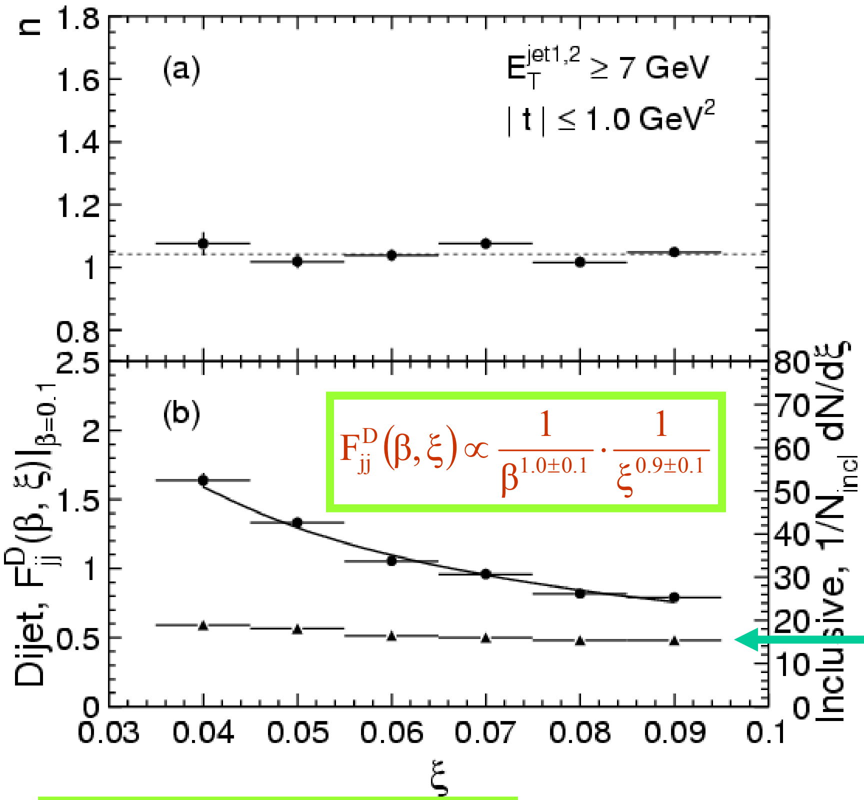
for your attendance

QUESTIONS?

BACKUP

… use for last minute results

ξ & β dependence of F^D_{jj} – Run I



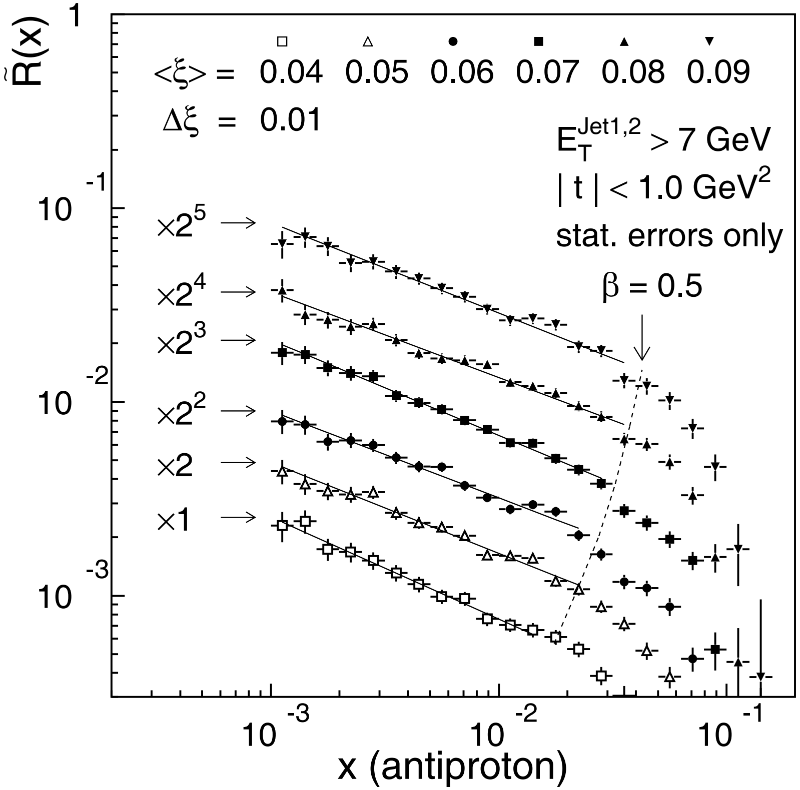
$$\frac{d\sigma_{incl}}{d\xi} \propto \text{constant}$$

$$F^D_{jj}(\beta,\xi) \sim \frac{1}{\beta} \cdot \frac{1}{\xi}$$

Pomeron dominated

D/ND dijet ratio vs. x_{Bj}@ CDF

CDF Run I



$$R(x) = \frac{F_{jj}^{SD}(x)}{F_{jj}^{ND}(x)}$$

$0.035 < \xi < 0.095$

Flat ξ dependence for β < 0.5

$$R(x) = x^{-0.45}$$

$F^D_{JJ}(\xi,\beta,Q^2)$ @ Tevatron

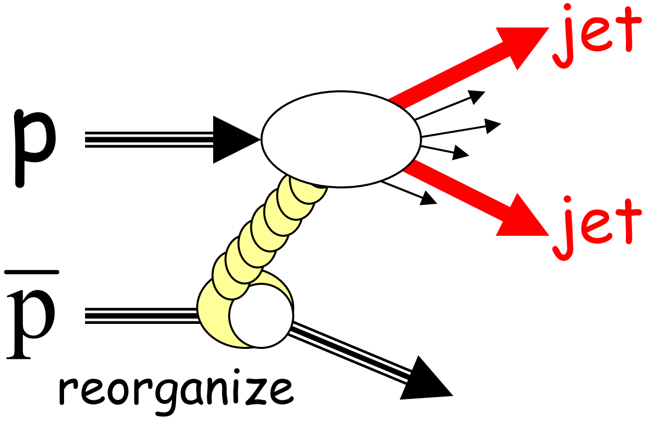
$$F^D(\xi,\beta,Q^2) = \mathrm{N}_{\mathrm{renorm}}\frac{1}{\xi^{1+2\varepsilon}}\cdot\frac{C(Q^2)}{(x/\xi)^{\lambda(Q^2)}} = \frac{2\varepsilon}{(\beta\, s)^{2\varepsilon}}\cdot\frac{1}{\xi^{1+2\varepsilon}}\cdot\frac{C(Q^2)}{\beta^{\lambda(Q^2)}}$$

$$\mathrm{N}^{-1}_{\mathrm{renorm}} = \int_{\xi_{\min}}^{1}\frac{d\xi}{\xi^{1+2\varepsilon}} \xrightarrow{\xi_{\min}=\frac{x_{\min}}{\beta}\approx\frac{1}{\beta\, s}} \frac{(\beta\, s)^{2\varepsilon}}{2\varepsilon}$$

RENORM $\Rightarrow$ $R^{SD}_{ND}(x) = \frac{2\varepsilon}{s^{2\varepsilon}}\frac{1}{\xi^{1-\lambda(Q^2)}}\cdot x^{-(2\varepsilon)}$

$$\varepsilon_g = 0.2 \rightarrow x^{-0.4}$$

Diffractive dijets @ Tevatron



$$F^D(\xi, x, Q^2) \propto \frac{1}{\xi^{1+2\varepsilon}} \cdot F(x/\xi, Q^2)$$