Diffractive W and Z Production at Tevatron

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- Diffractive W / Z
- Exclusive Z search
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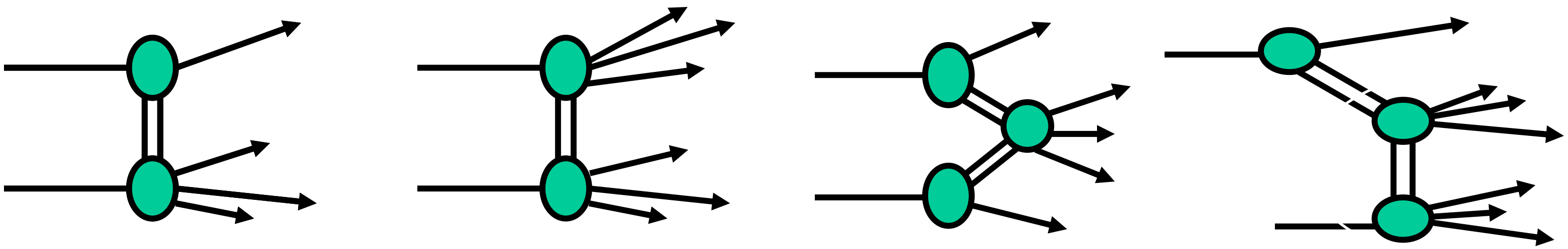
Diffraction
and Exclusive Production at CDF

soft and hard topologies studied

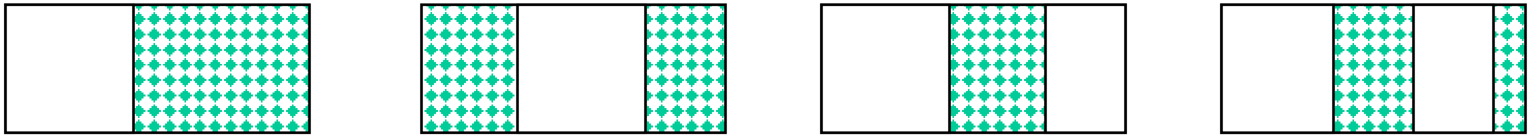


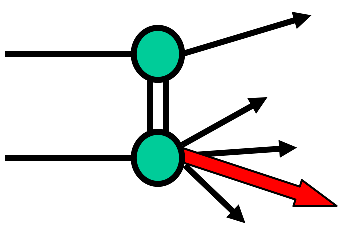
Single **D**iffraction dissociation (**SD**)

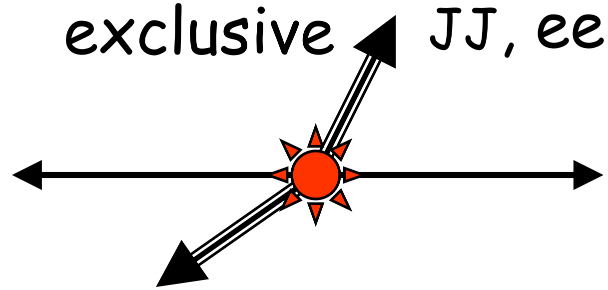
Double **D**iffraction dissociation (**DD**)

Double **P**omeron **E**xchange (**DPE**)

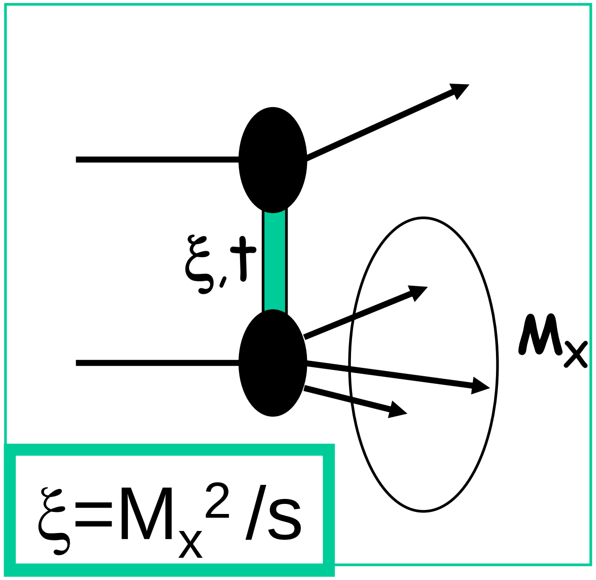
Single + **D**ouble **D**iffraction (**SDD**)

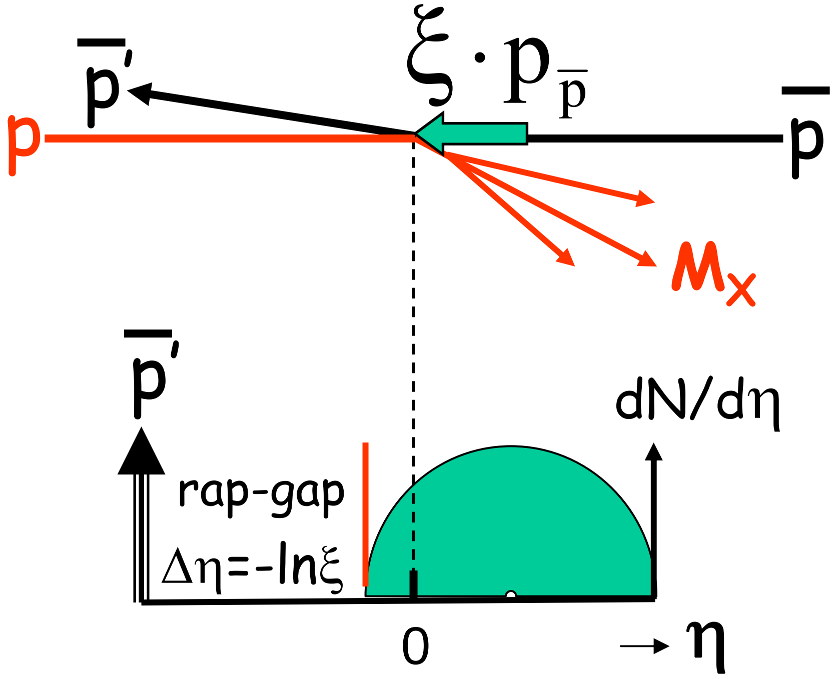




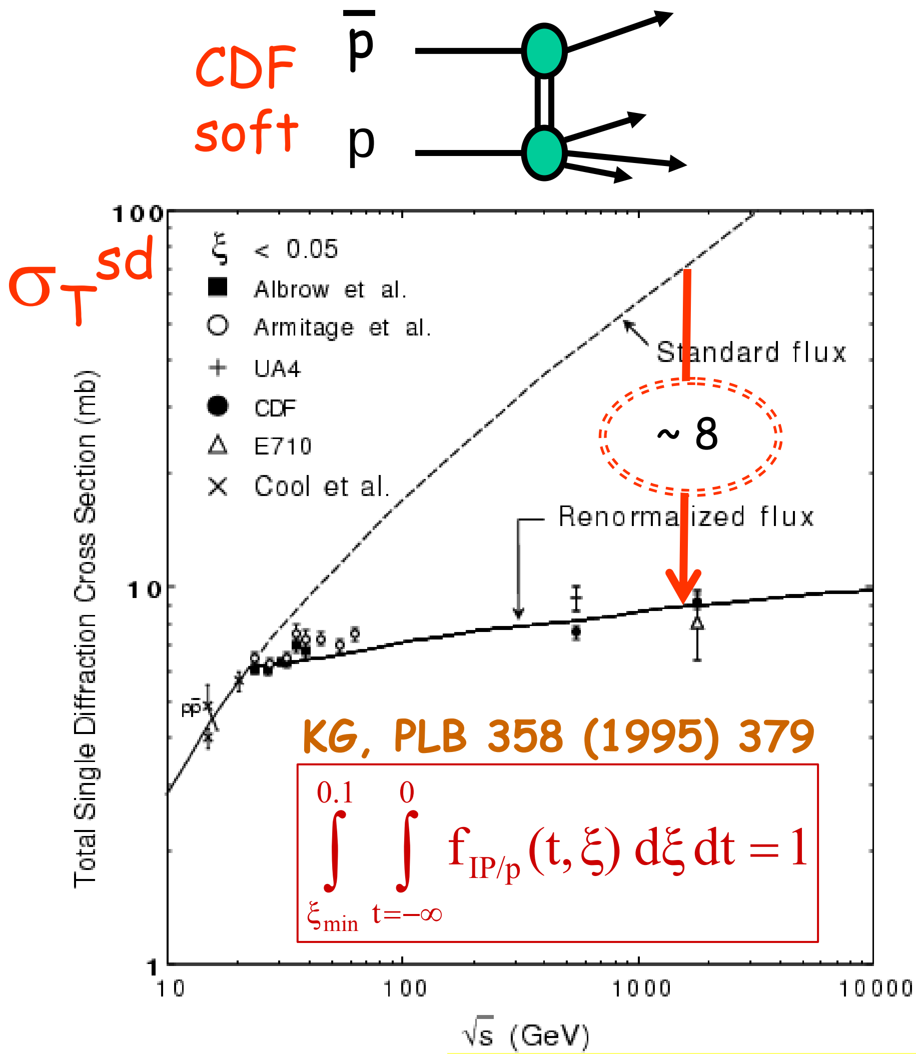


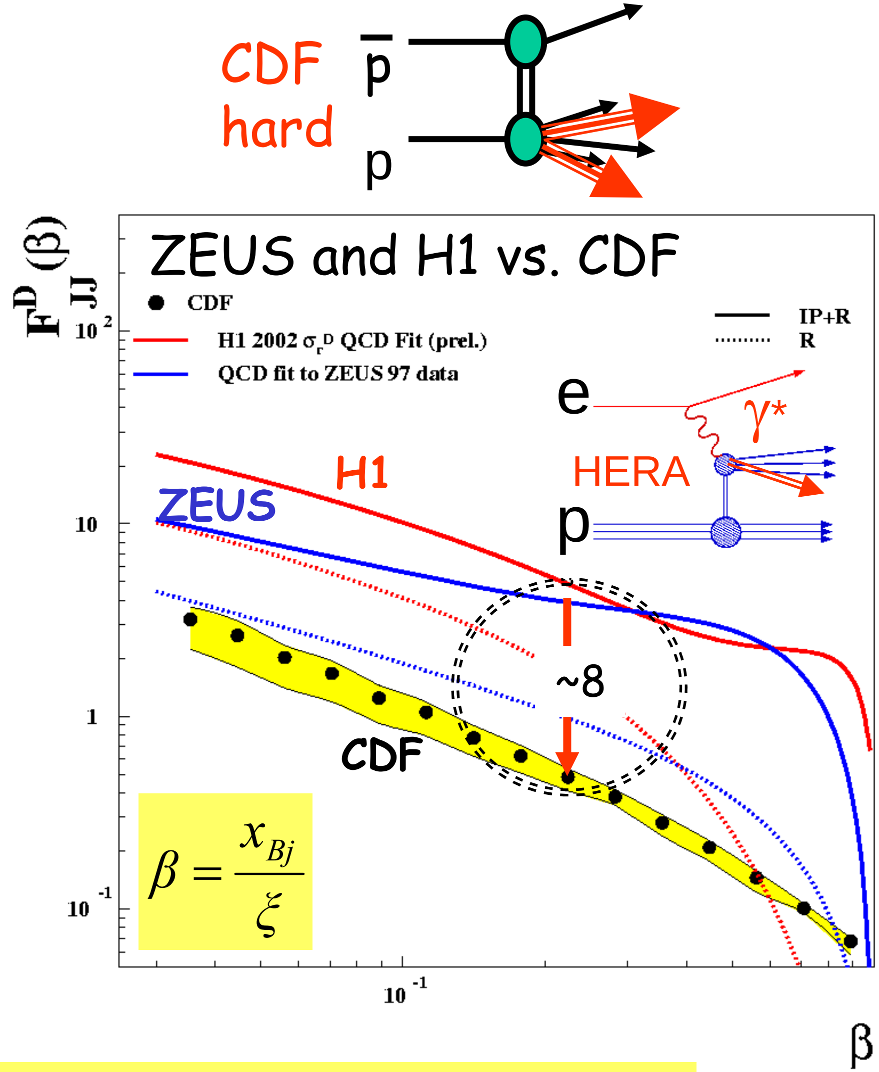

diffractive
signature
recoil p̄ or rap-gap


ξ,t
Mx
ξ=Mx² /s


p̄'
ξ·p_p̄
p
p̄
Mx
p̄'
rap-gap
Δη=-lnξ
dN/dη
0
→ η

Breakdown of factorization

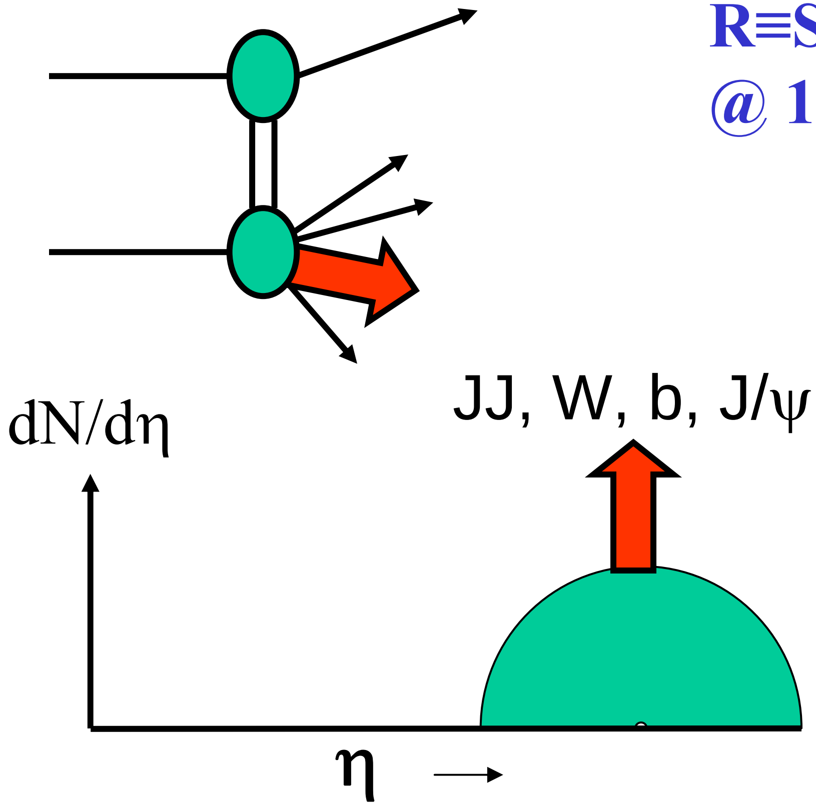




same suppression factor in soft and hard diffraction
➔ gap survival responsible for suppression

CDF hard diffraction fractions

$$\bar{p}p \rightarrow (\Uparrow + X) + \text{gap}$$



Fraction:
R≡SD/ND ratio
@ 1800 GeV

⇧	Fraction (R) %
JJ	0.75 +/- 0.10
W	0.115 +/- 0.55
b	0.62 +/- 0.25
J/ψ	1.45 +/- 0.25

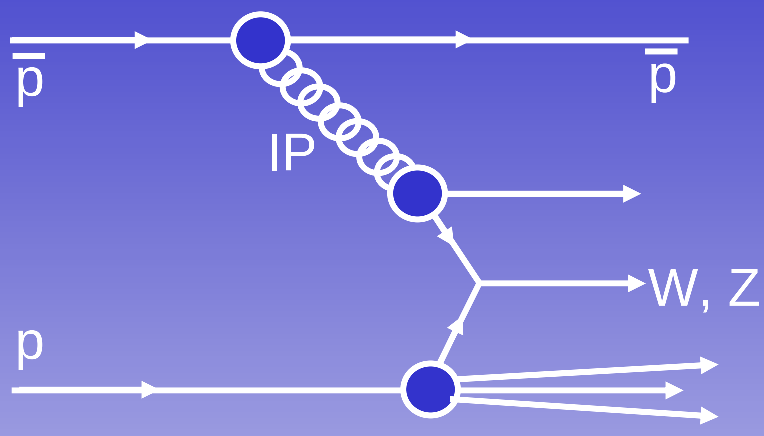
All fractions ~ 1%
(differences due to kinematics)
- ~ uniform suppression
- ~ FACTORIZATION !

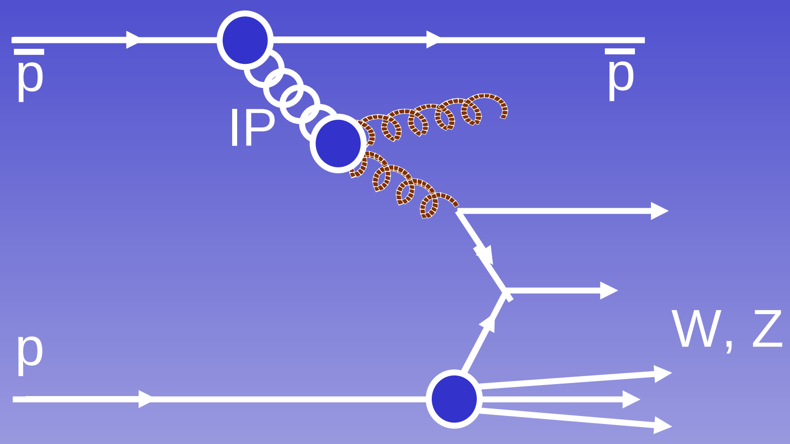
→ suppression due to gap survival

DIFFRACTIVE W / Z PRODUCTION

- LO diagrams
- Motivation
- CDF II detectors
  - ➔ miniplugs
  - ➔ measurements ^{W}/miniplugs
  - ➔ dynamic alignment
- Analysis
  - ➔ selection requirements
  - ➔ reconstructed diffractive W mass
  - ➔ rejection of multiple interactions
- Diffractive W / Z results

Diffractive LO W/Z diagrams





- Diffractive W production probes the quark content of the Pomeron
  - To leading order, the W is produced by a quark in the Pomeron

- 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 - motivation

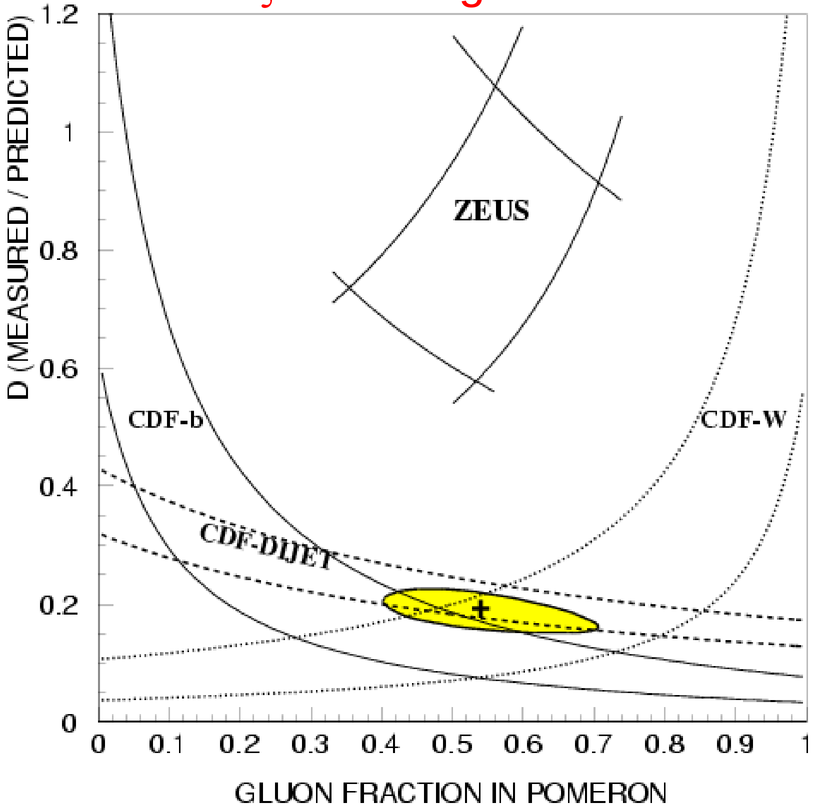
- In Run I, combining diffractive dijet production with diffractive W production was used to determine the quark/gluon content of the Pomeron ===➔
- In Run II, we aim at determining the diffractive structure function for a more direct comparison with HERA.
- To accomplish this we use:
  - ➢ New forward detectors
  - ➢ New methodology
  - ➢ More data

Phys Rev Lett **78**, 2698 (1997)

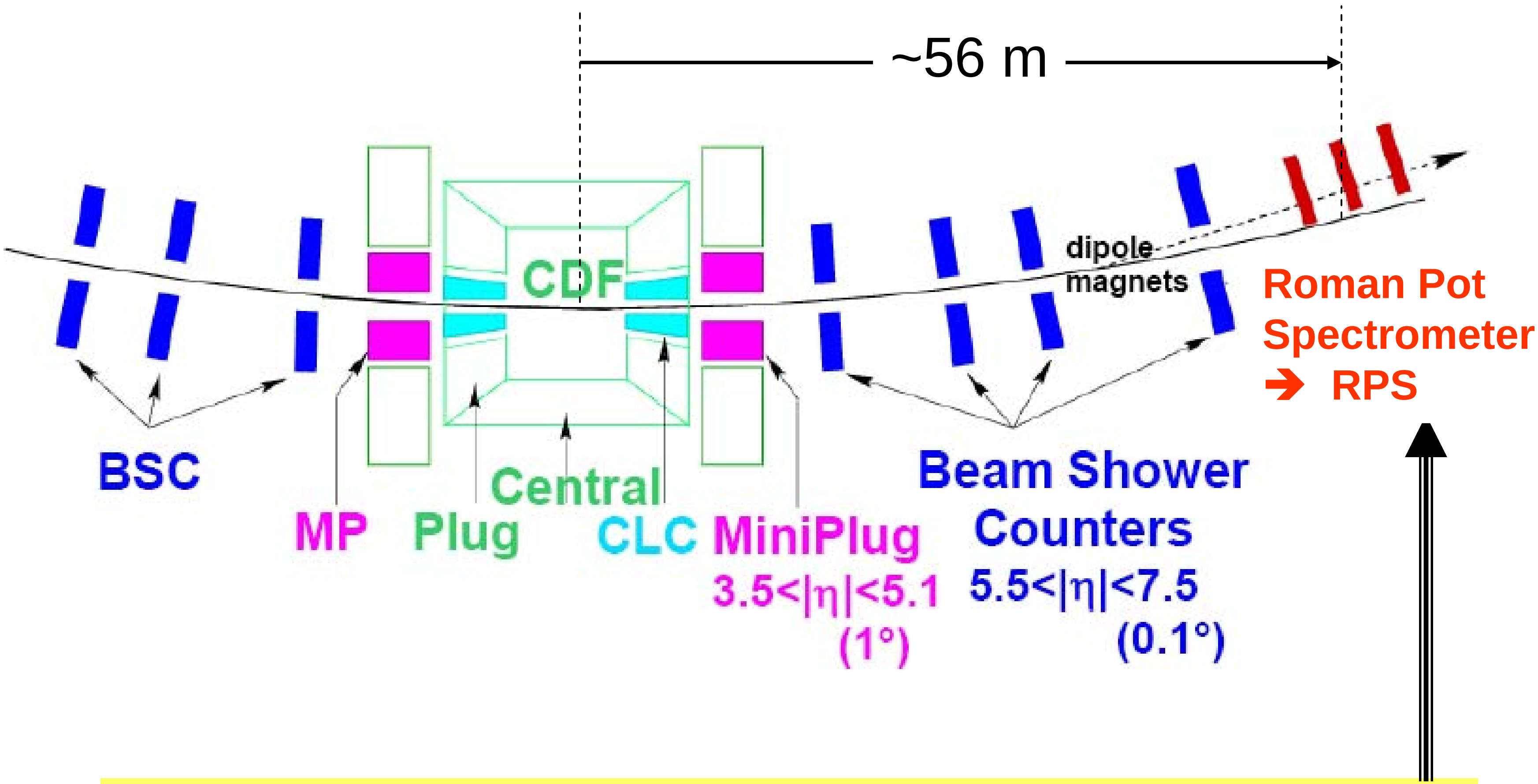
Fraction of W events due to SD

R_W=[1.15±0.51(stat)±0.20(syst)]%

for ξ<0.1 integrated over t

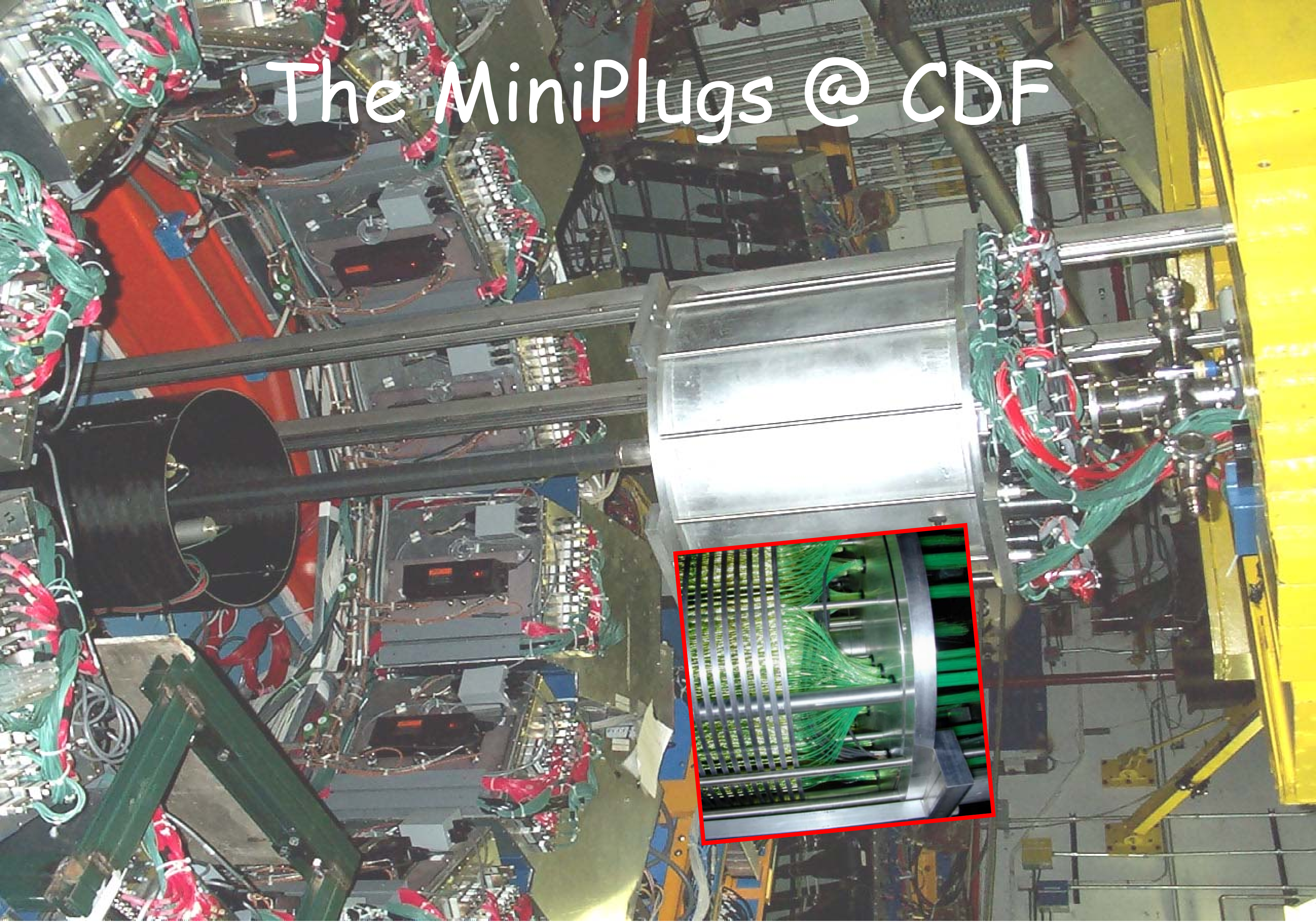


The CDF II detectors

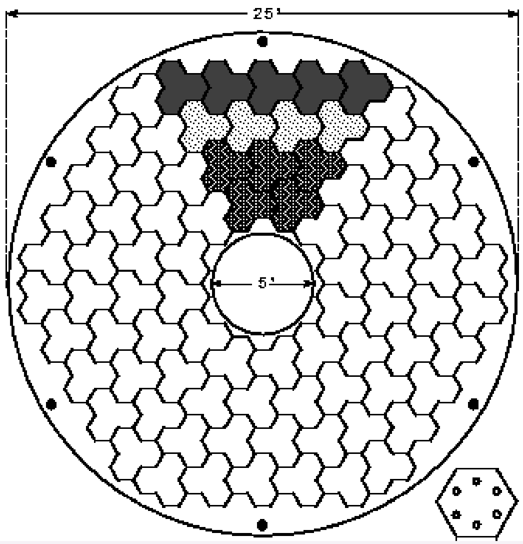


RPS acceptance ~80% for $0.03 < \xi < 0.1$ and $|t| < 0.1$

The MiniPlugs @ CDF



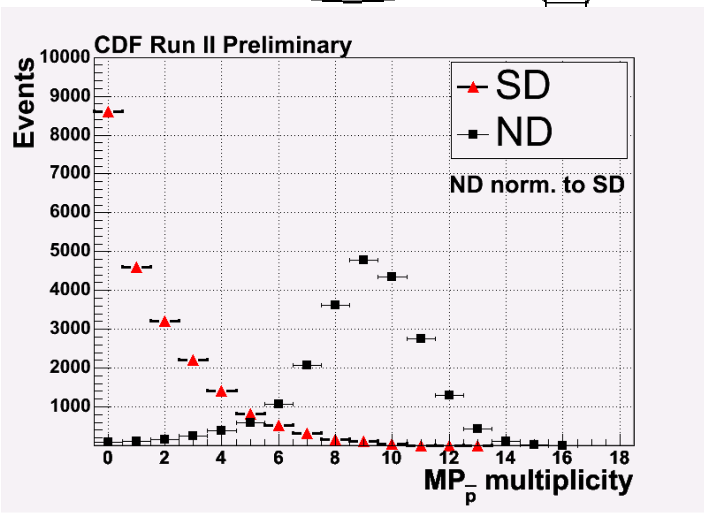
Measurements ʷ/the MiniPlugs



MP TOWER STRUCTURE

MULTIPLICITY @ POSITION

ENERGY



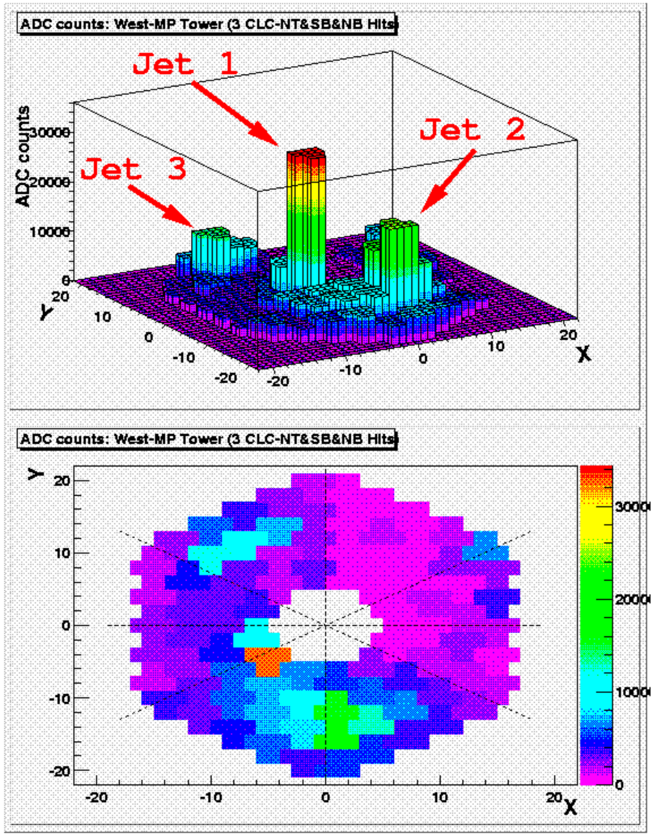
Multiplicity of SD and ND events

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

NIM A 430 (1999)

NIM A 496 (2003)

NIM A 518 (2004)

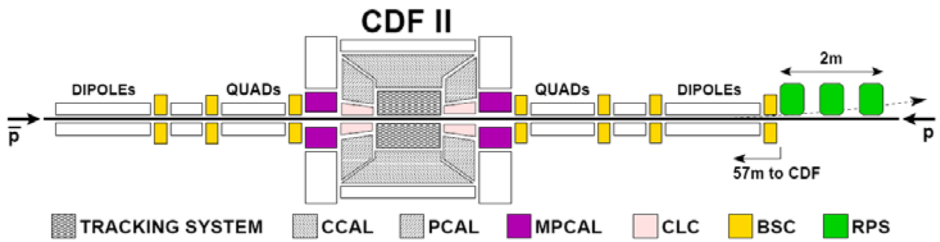


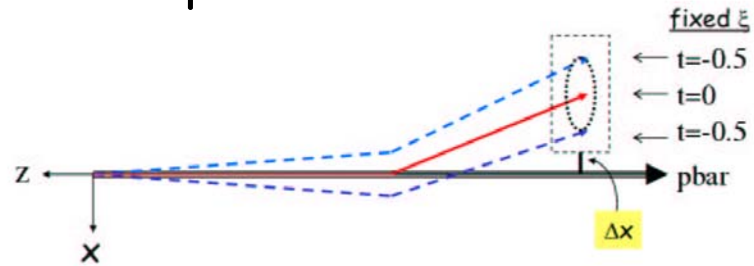
ADC counts in MiniPlug towers in a pbar-p event at 1960 GeV.

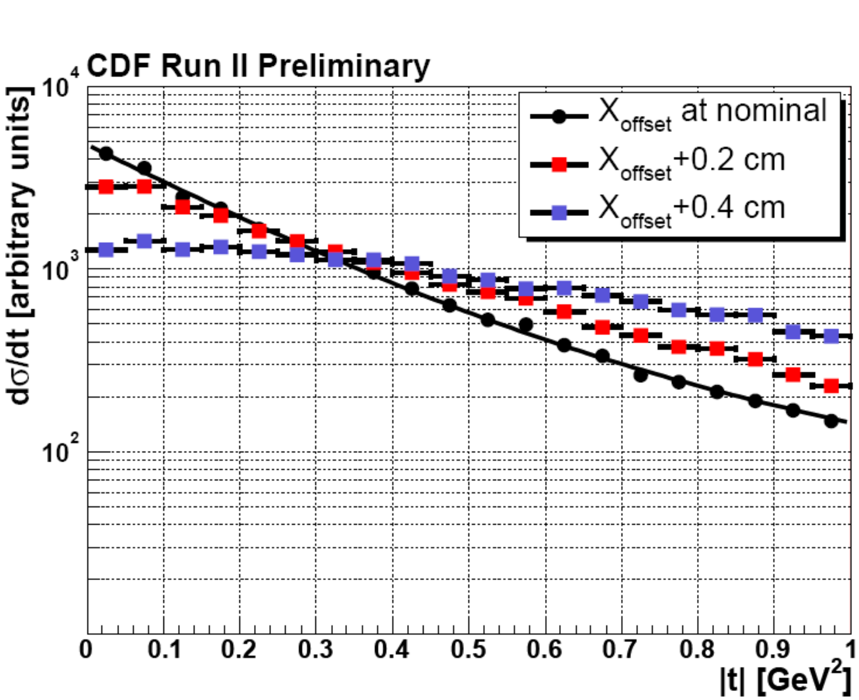
- "jet" indicates an energy cluster and may be just a hadron.
- 1000 counts ~ 1 GeV

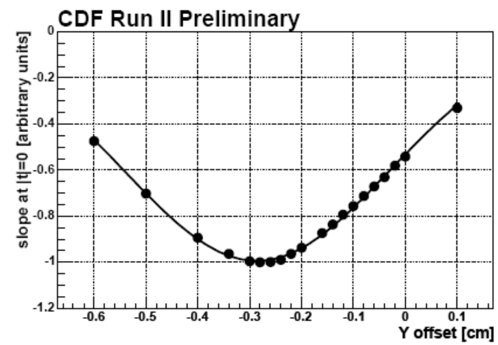
Dynamic Alignment of RPS Detectors

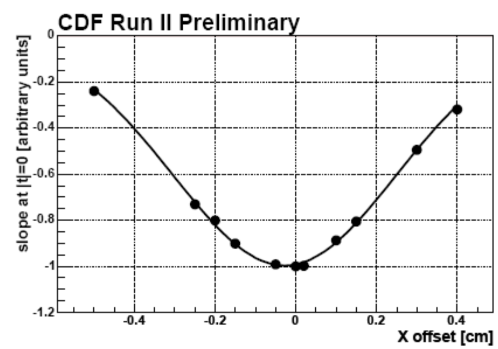
Method: iteratively adjust the RPS X and Y offsets from the nominal beam axis until a maximum in the b-slope is obtained @ t=0.











Limiting factors

1-statistics
2-beam size
3-beam jitter

@ CDF
w/lowlum data

$\pm 30\ \mu m$

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
- x_{Bj}
- Diffractive structure function

W/Z selection requirements

Standard W/Z selection

$E_T^e(p_T^\mu) > 25\text{ GeV}$

$\not{E}_T > 25\text{ GeV}$

$40 < M_T^W < 120\text{ GeV}$

$|Z_{vtx}| < 60\text{ cm}$

$E_T^{e1}(p_T^{\mu 1}) > 25\text{ GeV}$

$E_T^{e2}(p_T^{\mu 2}) > 25\text{ GeV}$

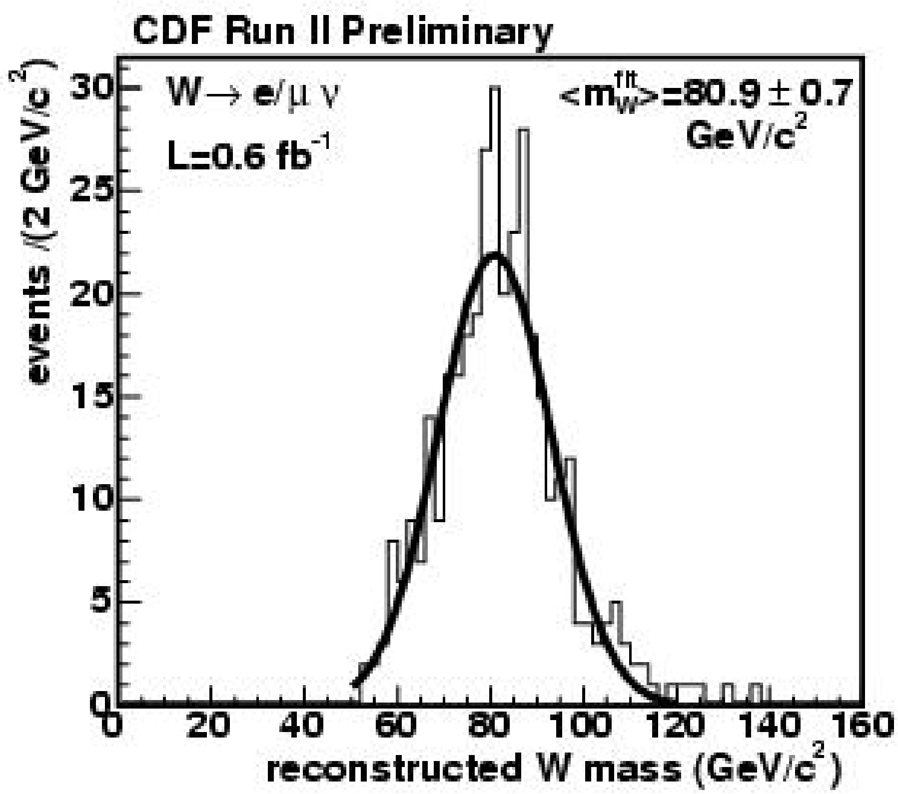
$66 < M^Z < 116\text{ GeV}$

$|Z_{vtx}| < 60\text{ cm}$

Diffractive W/Z selection

- RPS trigger counters - MIP
- RPS track - $0.03 < \xi < 0.10$, $|t| < 1$
- W➔ $50 < M_W(\xi^{RPS}, \xi^{cal}) < 120$
- Z ➔ $\xi^{cal} < 0.1$

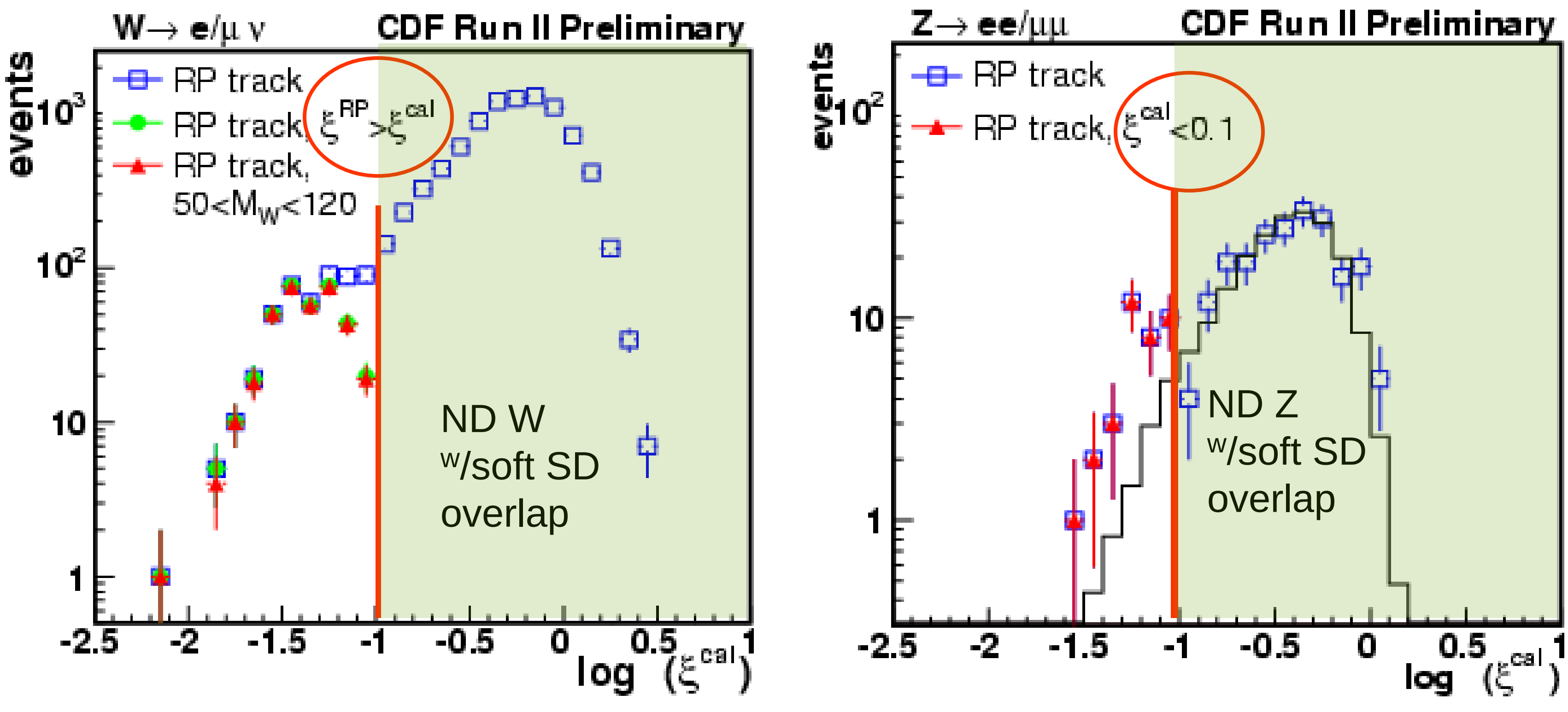
Reconstructed Diffractive W-Mass



CDF W mass (press release 2007): 80,413 +/- 48 MeV/c^2

Rejection of Multiple Interactions

$W \rightarrow e\nu$ or $\mu\nu$ $Z \rightarrow ee$ or $\mu\mu$



- ❑ $\xi^{RPS} > \xi^{CAL}$ effective in rejecting overlaps in W case

➔ cannot be applied in Z case (no missing ν)

Diffractive W/Z results

R^W (0.03 < ξ < 0.10, |t|<1)= [0.97 ± 0.05(stat) ± 0.11(syst)]%

Run I: R^W =1.15±0.55 % for ξ<0.1 ➔ estimate **0.97±0.47 %** in **0.03 < ξ < 0.10 & |t|<1**

R^Z (0.03 < ξ < 0.10, |t|<1)= [0.85 ± 0.20(stat) ± 0.11(syst)]%

CDF/DØ Comparison – Run I (ξ < 0.1)

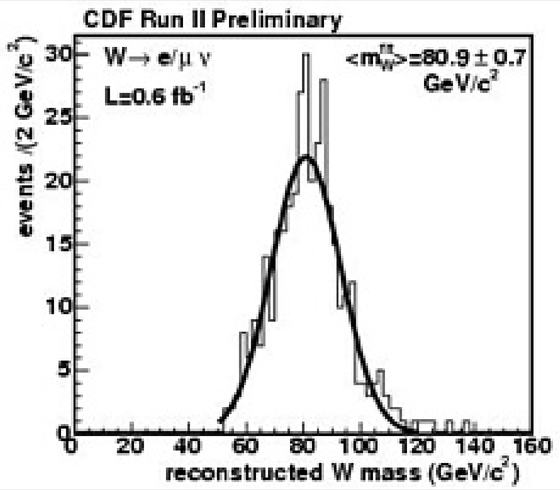
CDF	DØ
CDF PRL 78, 2698 (1997)	DØ Phys Lett B **574**, 169 (2003)
R^W=[1.15±0.51(stat)±0.20(syst)]%	R^W=[5.1±0.51(stat)±0.20(syst)]%
w/gap acceptance A^{gap}=81% (from MBR/PYTHIA Monte Carlo)	w/gap acceptance A^{gap}=(21±4)% (model dependent)
➢ uncorrected for A^{gap} :	➢ uncorrected for A^{gap} :
R^W=(0.93±0.44)%	R^W=[0.89+0.19-0.17]%
R^Z =? (not measured in Run I)	R^Z=[1.44+0.61-0.52]%

stay tuned for results on $F^D_{W/Z}$

Fermilab Result of the Week

Thursday, March 12 2009

Racking up diffractive W bosons at CDF



The reconstructed W mass in diffractive events confirms the accuracy of the antiproton kinematics determined using the CDF Roman-pot detectors.

We can think of elastic scattering as two billiard balls colliding and recoiling in different directions, with the physical properties of the balls unchanged. If we imagine those balls interacting by exchanging an object, that object must move from one ball to the other, still leaving those balls unchanged. The object does not carry away any properties of the balls.

In diffractive scattering, on the other hand, one ball, we'll call the cue ball, remains the same and continues with almost its original momentum, while the other, we'll call the eight ball, breaks up into pieces. Since the cue ball keeps its properties, we can think of the object exchanged as the same one as in elastic scattering.

Diffractive scattering can occur at the Tevatron collider. Because the exchanged object doesn't carry any properties of the particles, theory predicts that an empty gap with no particles will be present in the event between the diffractive antiproton, the cue ball, and the particles produced when the proton, the eight ball, breaks up.

Previously, diffractive W-boson production, where one piece of the broken eight ball is a W boson, was measured by looking for these gaps. Recently, CDF scientists have improved upon the study of diffractive scattering by using special apparatus called Roman pots, which allow detectors to be located inside the beam pipe. These detectors measure the diffractive antiproton.

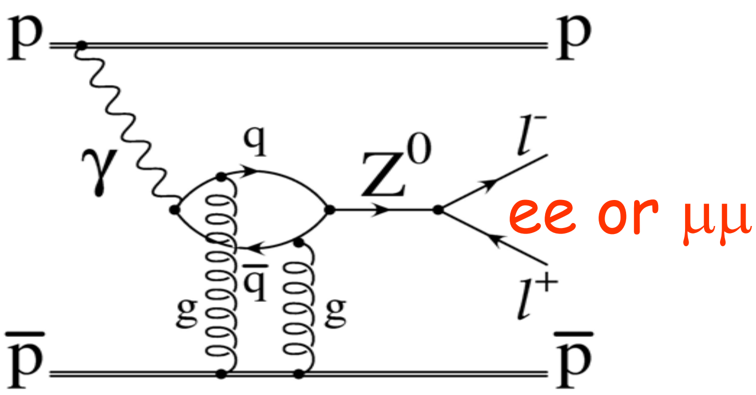
Scientists look for W bosons, which decay into an electron or muon plus a neutrino, using standard methods, including inferring the missing transverse energy from the neutrino, which doesn't interact in the detector. In addition, they combine the information from the antiproton measurement with energy measurements in the rest of the detector to determine the neutrino's longitudinal momentum. This technique is the only way to fully reconstruct the W kinematics with leptons at a hadron collider.

With this new result on diffractive W-boson production, CDF scientists removed ambiguities from other methods that rely on identifying particle-free gaps in the events. CDF scientists found that at the Tevatron, about 1 percent of W and Z bosons are produced diffractively.

– *edited by Craig Group*

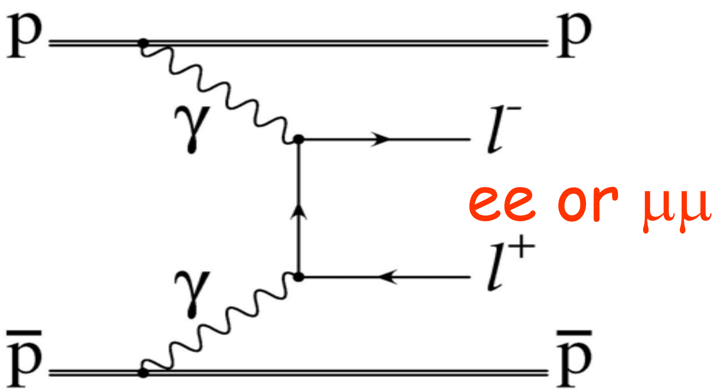
Mary Convery, of Fermilab, and Dino Goulianos, of Rockefeller University, have been collaborating on diffractive physics since 1997.

Exclusive Z / $\gamma\gamma \to \ell\ell$ studies*



[1] Phys. Rev. D78, 014023 (2008)
[2] Eur. Phys. J., C56 33 (2008)
[3] Phys. Rev. D72,036007

Exclusive Z SM cross section:
0.3 fb [Motyka & Watt][1]
1.3 fb [Goncalves & Machado][2]
Expect ~0.6 - 2.6 events in 2 fb^{-1}
(not including 3.37% leptonic BF).
➔Search for BSM physics,
e.g. color sextet quark model[3]: much enhanced cross section expected.



Exclusive di-lepton cross section:
- Background to exclusive Z
- Can be used to calibrate forward proton detectors:

$$\xi = s^{-1/2} \sum p_T e^{-\eta}$$

* see Emily Nurse http://www.fp420.com/conference/dec2008/index.html

Exclusive z / $\gamma\gamma \to \ell\ell$ results

$\mathcal{L}$ = 2.20 (2.03) fb^{-1} in the electron (muon) channels

e+e- or $\mu+\mu$- with $p^T > 25$ GeV
$|\eta_\mu^1| < 1.0$, $|\eta_{\mu 2}| < 1.5$
$|\eta_e^1| < 1.3$, $|\eta_e^2| < 3.6$
require $82 < M_{\ell\ell} < 98$ GeV

$W \to \ell \nu$ events used as a control to study exclusivity cuts

CDF Run II Preliminary

Exclusive di-leptons

$\sigma (pp \to p \ell \ell p) = 0.24^{+0.13}_{-0.10}$ pb

$M_{\ell\ell} > 40$ GeV, $|\eta_\ell| < 4.0$

[LPAIR prediction: σ = 0.256 pb]

Exclusive Z

$\sigma(Z_{excl}) < 0.96$ pb @ 95% C.L.

SM: 0.3 fb [Motyka & Watt]
1.3 fb [Goncalves & Machado]

SUMMARY

- Overview of diffraction at CDF
  - Breakdown of factorization – HERA vs. Tevatron
  - CDF hard diffraction fractions ~1 % – factorization?
  - Gap survival responsible for suppression
- Diffractive W/Z with Roman Pot Spectrometer tagging
  - W diffractive fraction in agreement with Run I

R^W $(0.03 < \xi < 0.10, |t|<1)$= [0.97 ± 0.05(stat) ± 0.11(syst)]%

  - W and Z diffractive fractions are equal within error

R^Z $(0.03 < \xi < 0.10, |t|<1)$= [0.85 ± 0.20(stat) ± 0.11(syst)]%

- Exclusive Z production – $\sigma(Z^{excl})$< 0.96 pb @ 95% C.L.
  (~ 1 fb expected in the SM)


thank you