Diffraction Results from CDF

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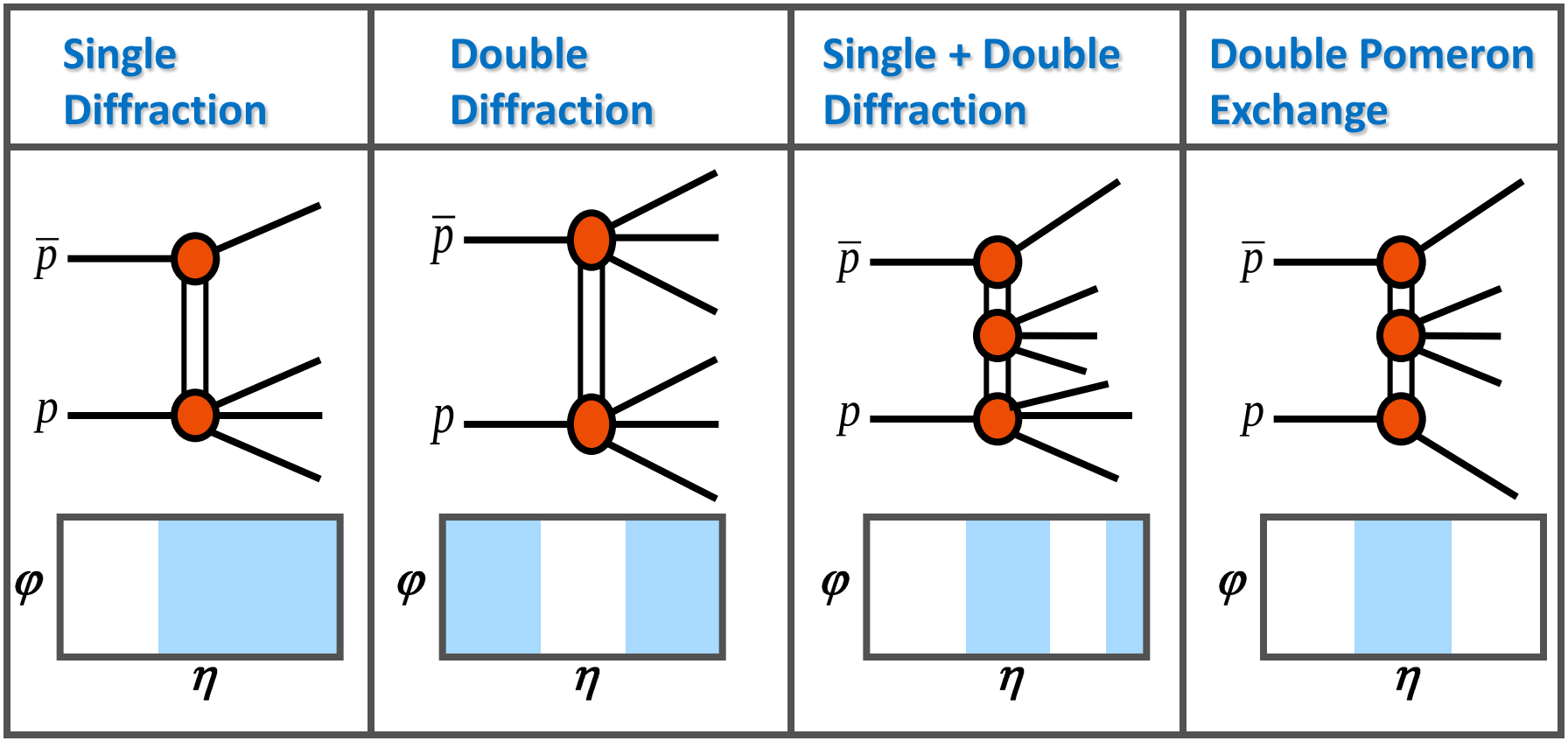
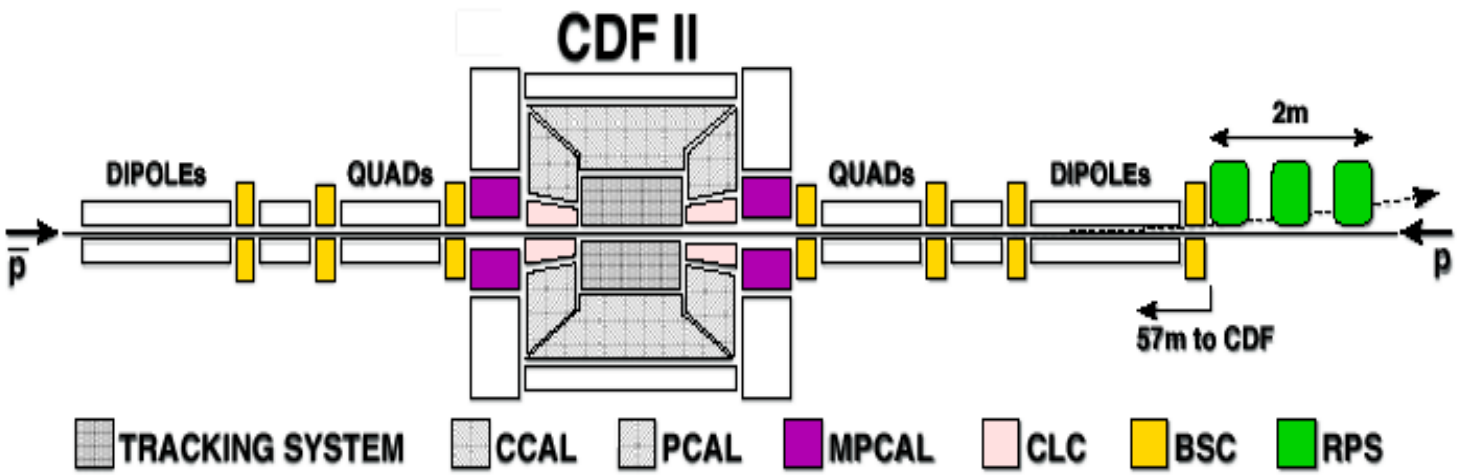
Introduction



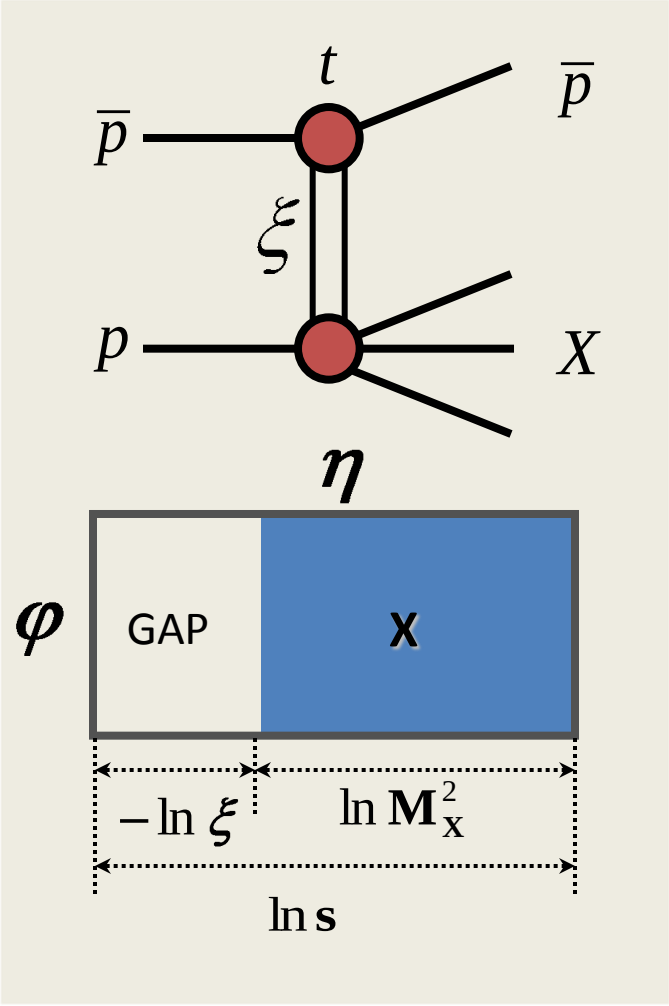
Diffractive interactions at hadron colliders are defined as those in *which no quantum numbers* are exchanged between the colliding particles

CDF II Detectors



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

Kinematics of Diffractive Events



t - four-momentum transfer squared

ξ - fractional momentum loss of antiproton

M_X - mass of system X

$\xi = M_X^2/s$

Selection of Diffractive Events

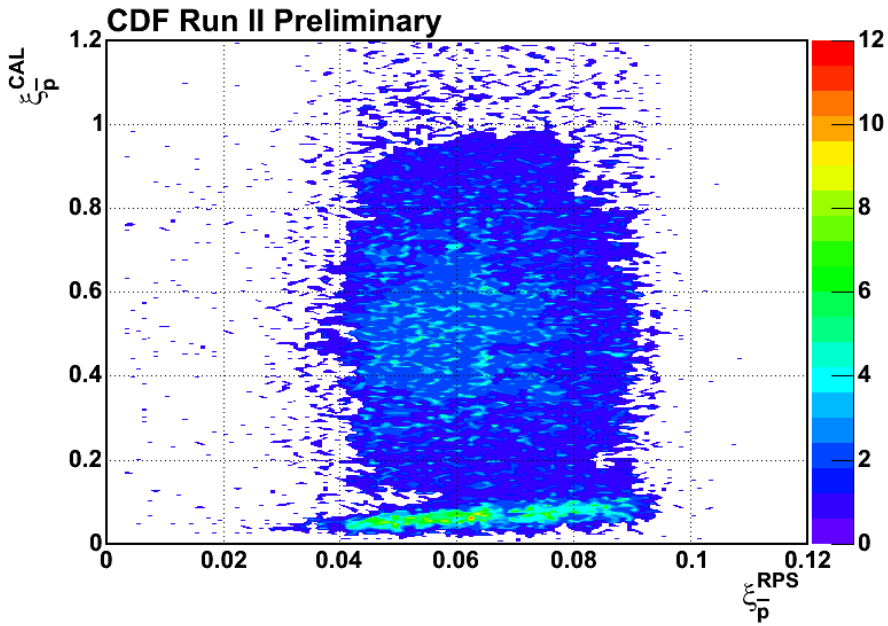
- CDF Roman Pots acceptance ~80% for $0.03<\xi_{pbar}<0.10$, $|t_{pbar}|<1(GeV/c)^2$
- by presence of rapidity gap

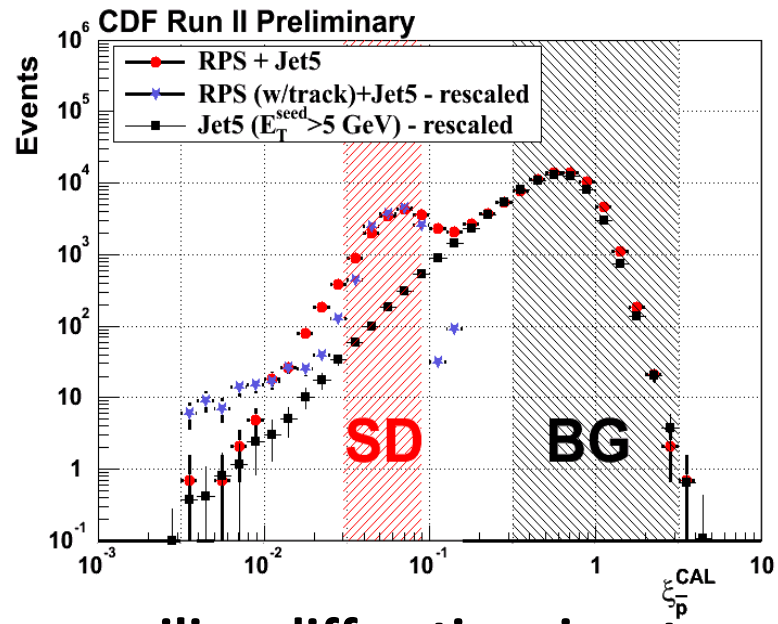
Methods

- Determine ξ using Roman Pot Spectrometer tracking
- Also can determine ξ from E_T in calorimeters

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

important to have MiniPlugs





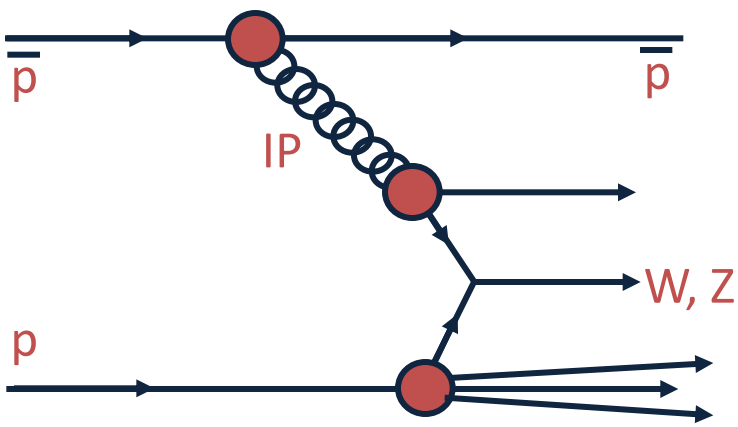
Main challenge: multiple interactions spoiling diffractive signatures

use $\xi^{cal} < 0.1$ to reject overlap events → non-diffractive contributions

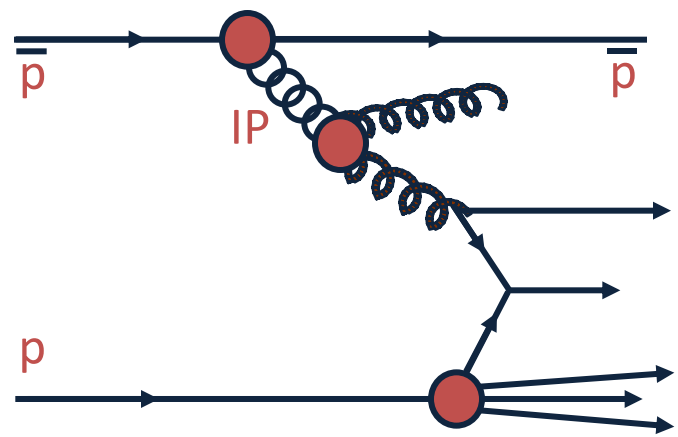
Diffractive W/Z Production

Diffractive W/Z production probes the quark content of the Pomeron

- to Leading Order
  the W/Z are produced
  by a **quark** in the Pomeron

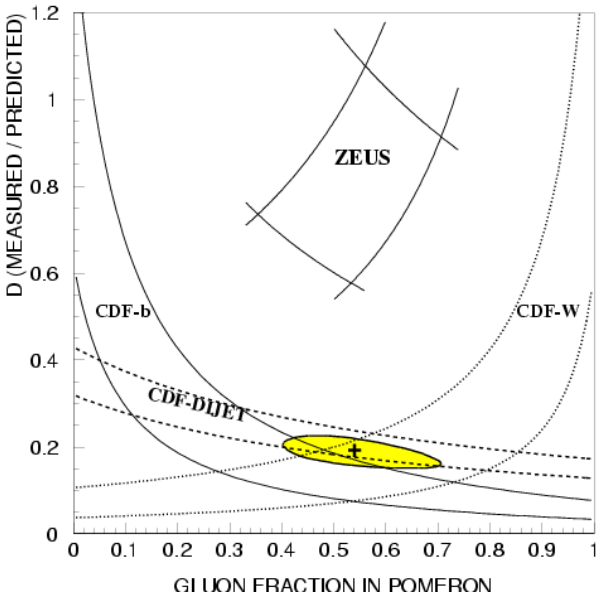


- production by gluons is
  suppressed by a factor
  of α_s
  and can be distinguished by
  an associated jet



Diffractive W –previous results

- Run I studies used rapidity gap method
- instead of Roman-pots
- CDF Phys Rev Lett **78**, 2698 (1997)
  - Fraction of W events due to SD [1.15 0.51(stat) 0.20(syst)]%
  - Observed fraction of events with a jet consistent with production via quarks
- DØ Phys Lett B **574**, 169 (2003)
  - Fraction of events with rap gap (uncorrected for gap survival)
  - W: $[0.89^{+0.19}_{-0.17}]\%$
  - Z: $[1.44^{+0.61}_{-0.52}]\%$
- Difference in CDF/D0 interpretation is the question of gap survival .



Diffractive W Production – Run II

Identify diffractive events using Roman Pots:

accurate event-by-event ξ measurement

no gap acceptance correction needed

can still calculate ξ^{cal}

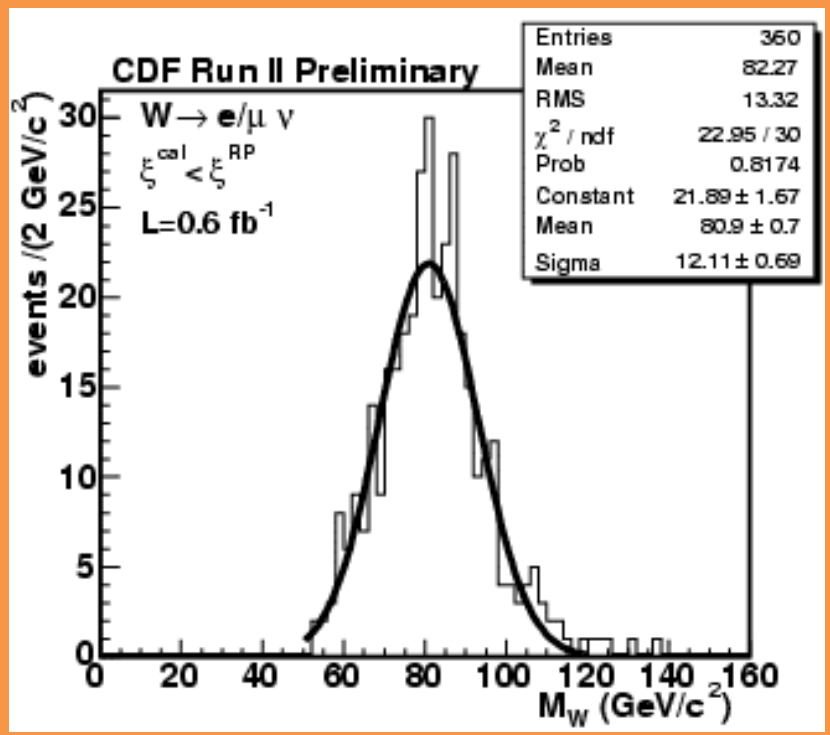
$$\xi^{cal} = \sum_{towers} \frac{E_T}{\sqrt{s}} e^{-\eta}$$

In W production, the difference between ξ^{cal} and ξ^{RP} is related to missing E_T and η_ν

$$\xi^{RP} - \xi^{cal} = \frac{E_T}{\sqrt{s}} e^{-\eta_\nu}$$

allows to determine:

neutrino and W kinematics

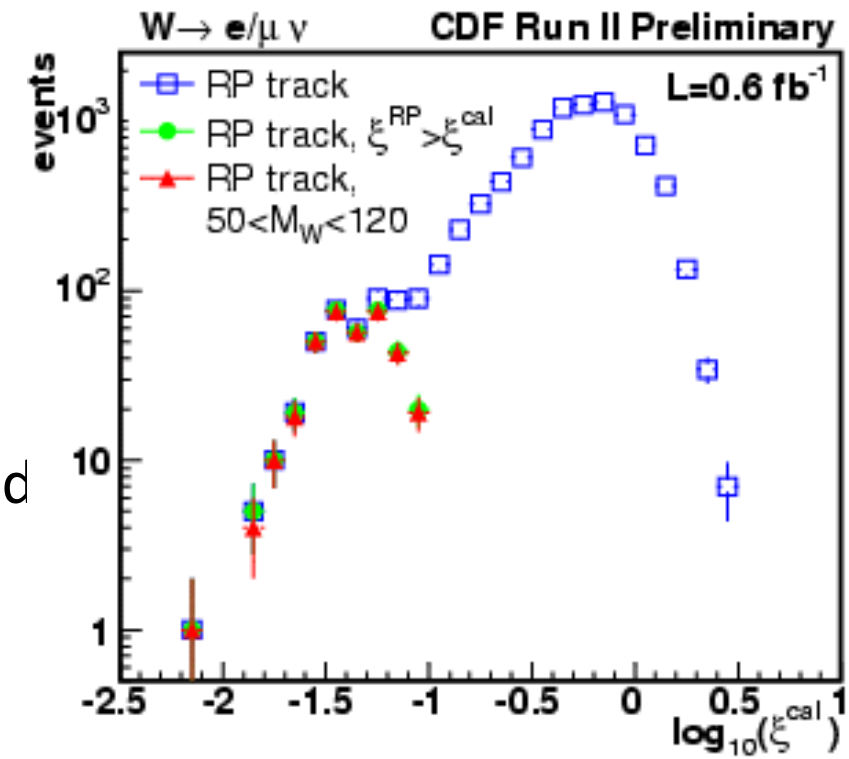


reconstructed diffractive W mass

Diffractive W Production Measurement

- $\xi^{cal} < \xi^{RP}$ requirement removes most events with multiple pbar-p interactions

- $50 < M_W < 120$ GeV/c^2 requirement on the reconstructed W mass cleans up possible mis-reconstructed events

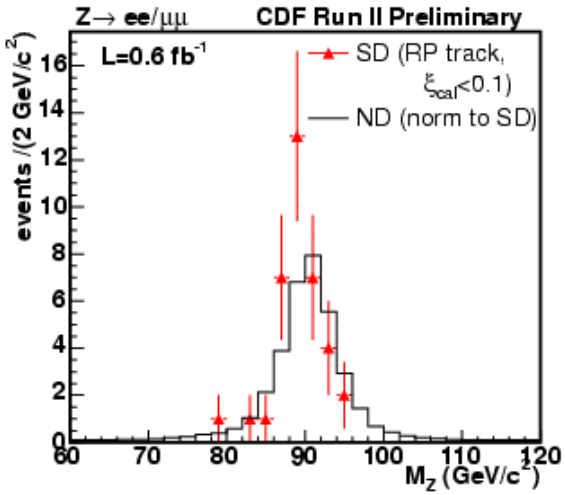


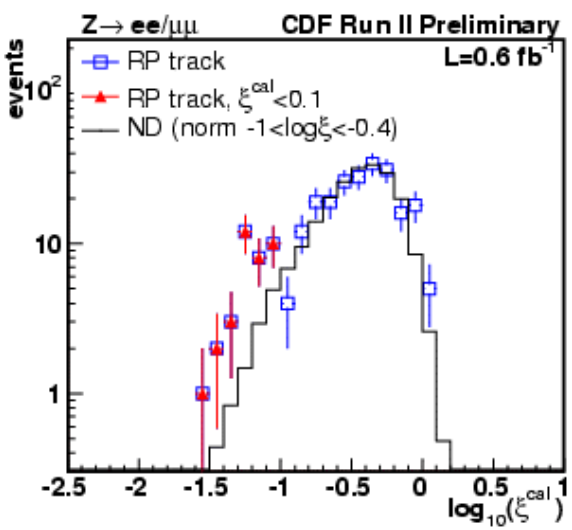
Fraction of diffractive W

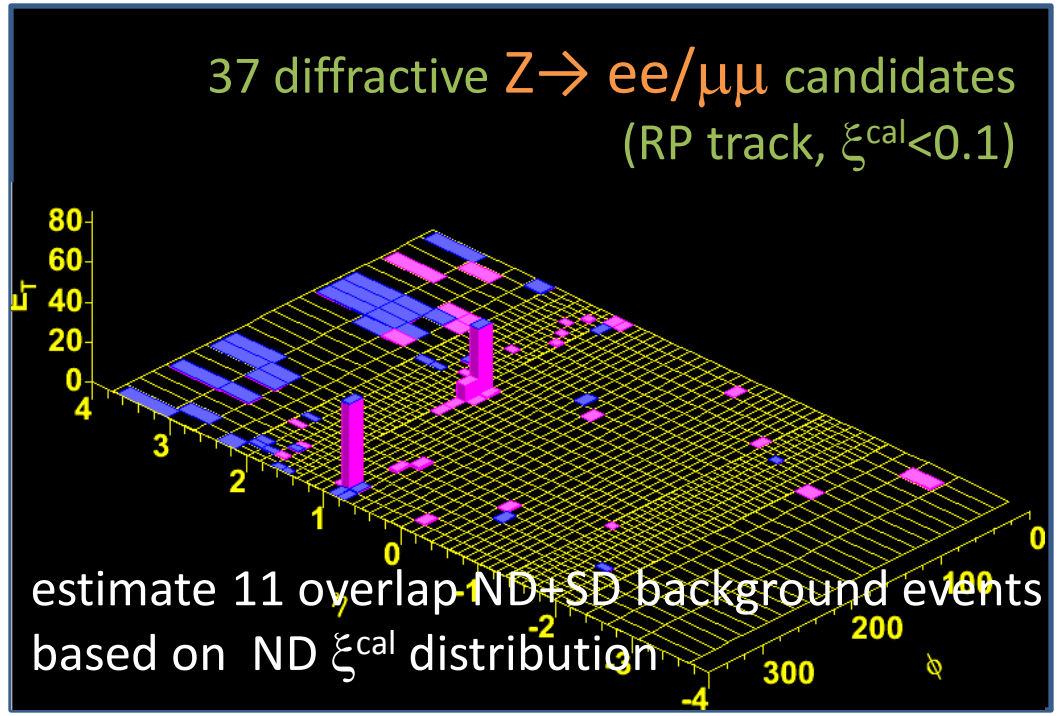
R_W (0.03<ξ<0.10, |t|<1)= [0.97 ±0.05(stat) ±0.10(syst)]%

consistent with Run I result, extrapolated to all ξ

Diffractive Z





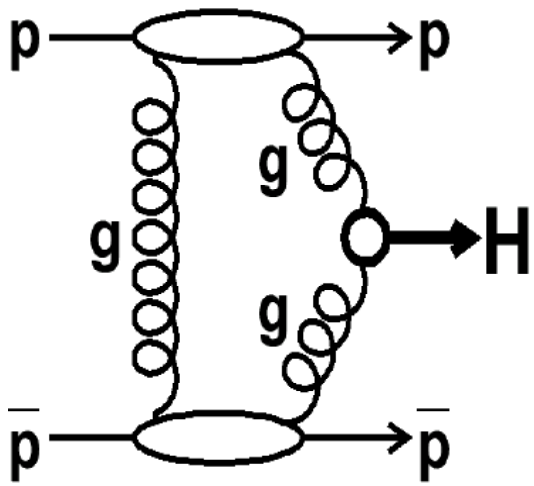


Fraction of diffractive Z

R_Z (0.03< ξ <0.10, |t|<1)=

[0.85±0.20(stat) ±0.08(syst)]%

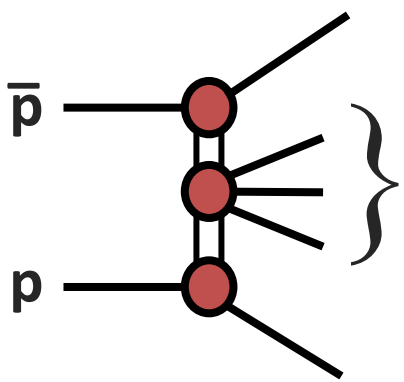
Exclusive Production



➔ suppression at LO of the background sub-processes (J_z=0 selection rule)

➔ "exclusive channel" → clean signal (no underlying event)

- At the Tevatron we use similar processes with larger cross sections to test and calibrate theor. predictions



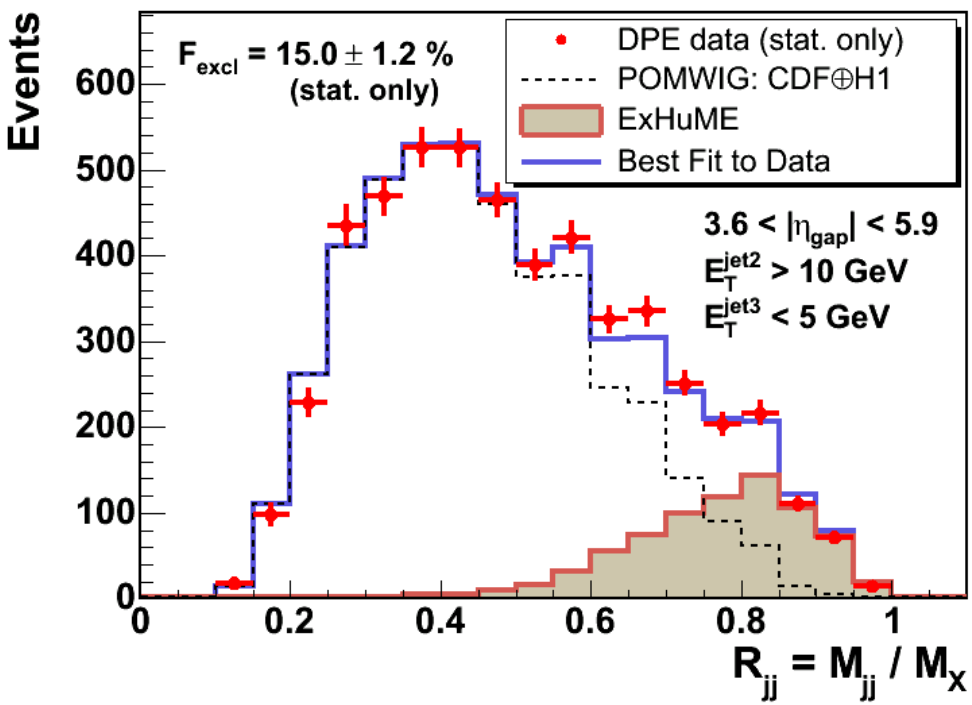
Dijets,

$\gamma\gamma$,

χ_c

Exclusive Dijet Production

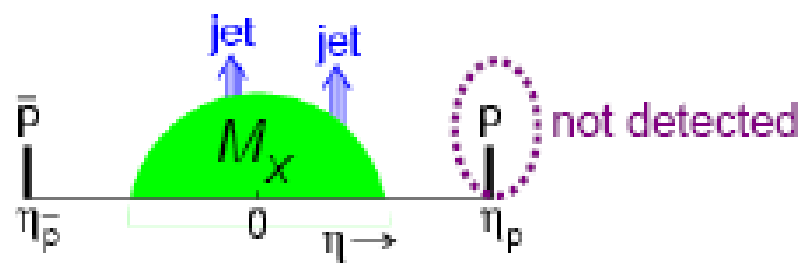
PRD 77, 052004 (2008)



Method:

Select inclusive diffractive dijet events produced by DPE

p+p →IP+ IP→p+X(≥2 jets)+gap

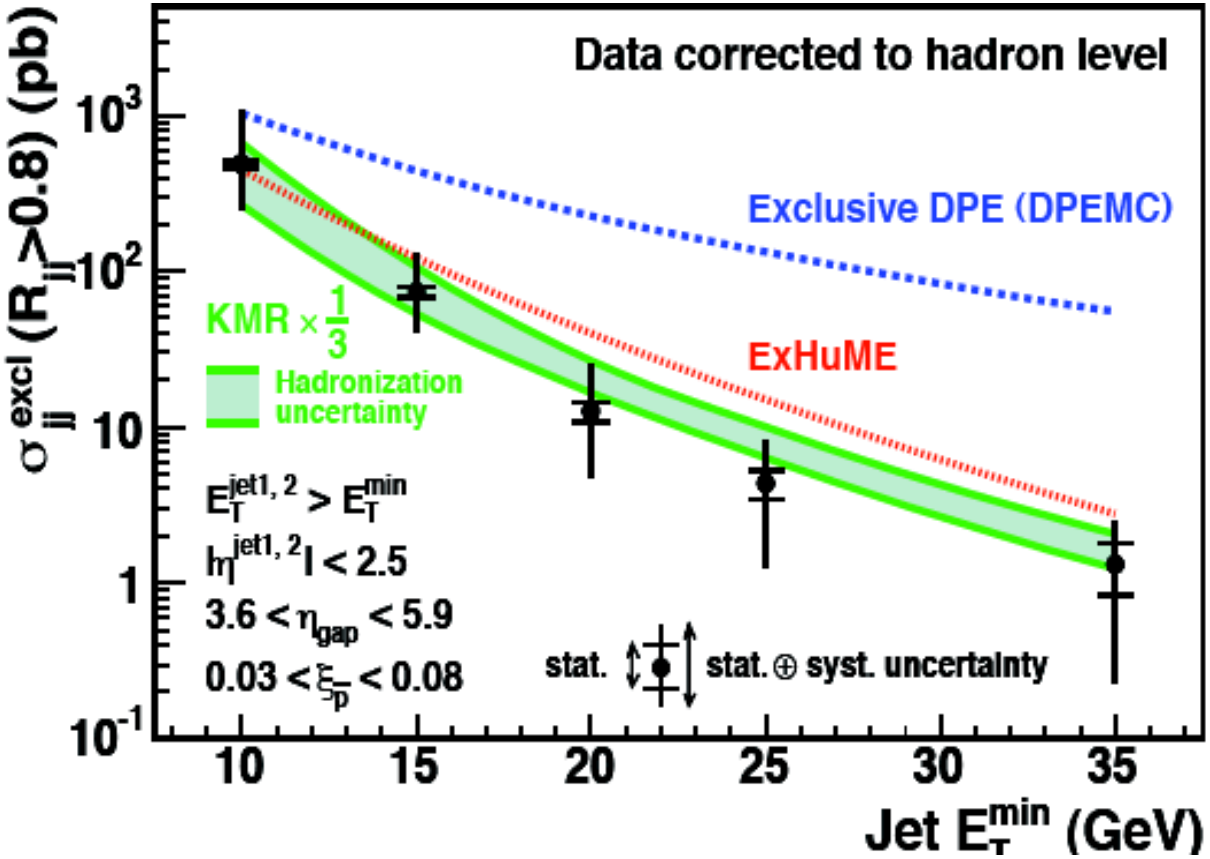


Reconstruct $R_{jj} = \frac{M_{jj}}{M_X}$, where

M_{jj} - dijet mass, M_X - mass of system X

Exclusive Dijet Production

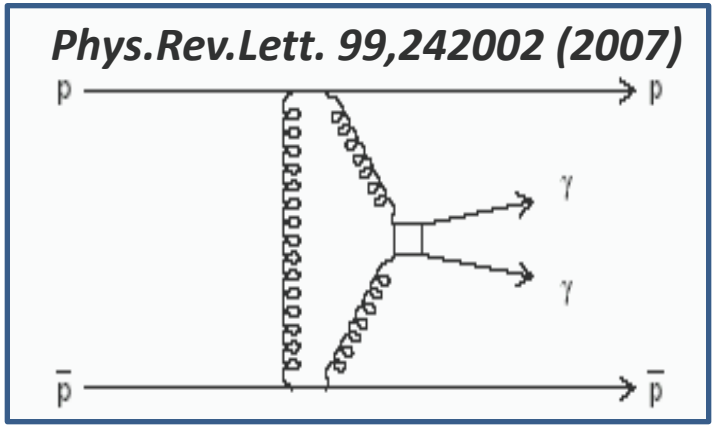
PRD 77, 052004 (2008)



- Exclusive dijet cross section compared with MC based on two models : ExHuME, and excl. DPE DPEMC.
- Cross section disfavors exclusive DPE model.
- Calculation by Khoze, Martin, and Ryskin shows good agreement

*Eur. Phys J C**14, 525 (2000).***

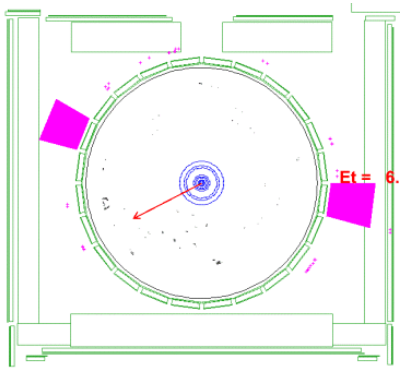
Exclusive $\gamma\gamma$ Production



3 candidates observed:

2 events are good $\gamma\gamma$ candidates

1 event is good $\pi^0\pi^0$ candidate



$E_T(\gamma) > 5$ GeV

$|\eta(\gamma)| < 1.0$

Theoretical Prediction:

V.A.Khoze et al. Eur. Phys. J C38, 475 (2005)

σ (with our cuts) = (36 +72 – 24) fb

= 0.8 +1.6 –0.5 events.

Cannot yet claim "discovery" as b/g study *a posteriori*,

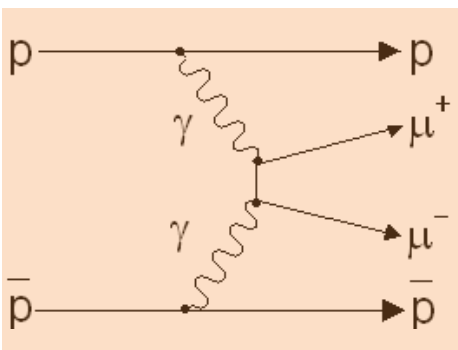
2 events correspond to σ ~ 90 fb, agreeing with Khoze *et al.*

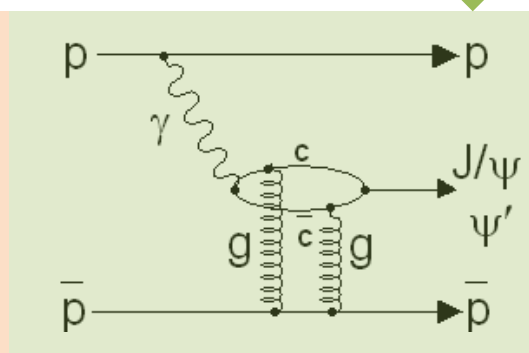
Exclusive Dimuon Production

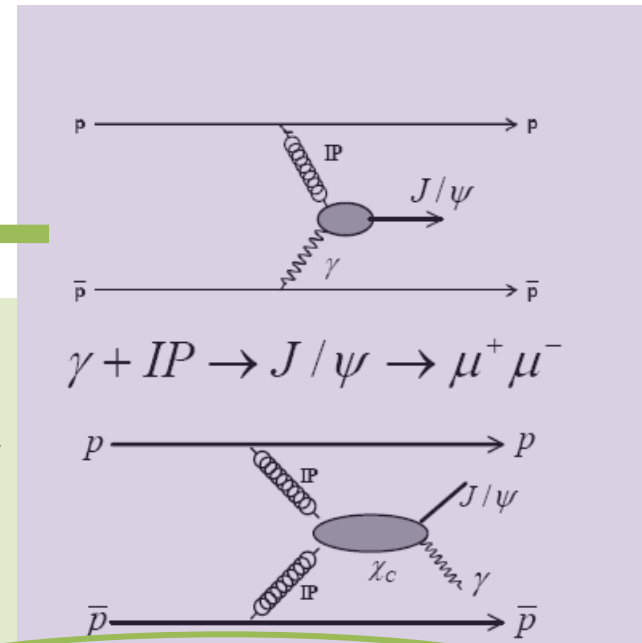
$$p + p \rightarrow p + \mu^+ \mu^- + p$$

3 GeV/c^2 <$M_{\mu\mu}$<4 GeV/c^2

Many Physics Processes in this data:







exclusive χ_c in DPE

Exclusive J/ψ and ψ(2s)

J/ψ production

243 ±21 events

$d\sigma/dy|_{y=0}$ = 3.92 ± 0.62 nb

Theoretical Predictions

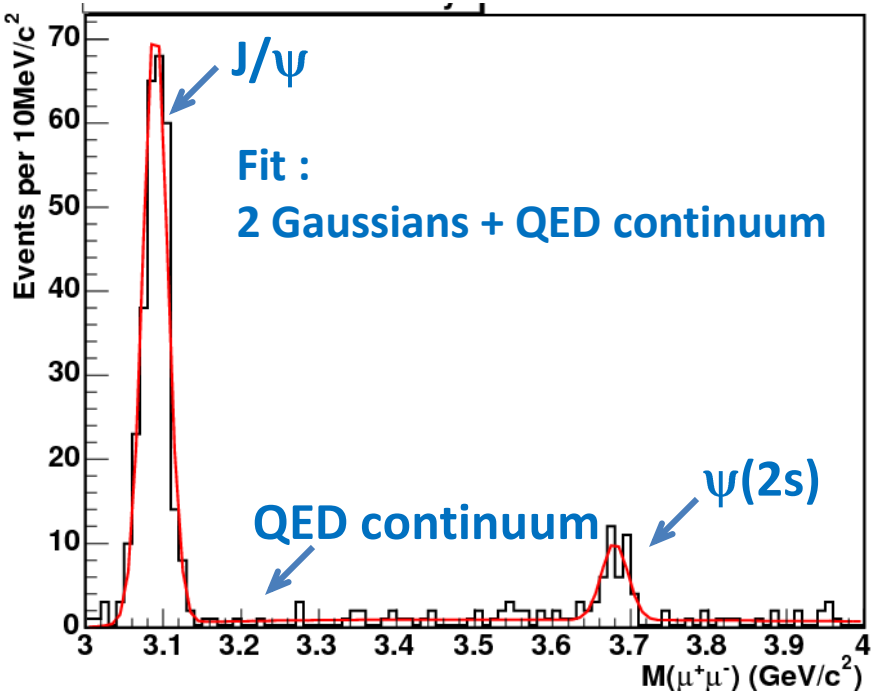
2.8 nb [Szczurek07,],

2.7 nb [Klein&Nystrand04],

3.0 nb [Conclaves&Machado05], and

3.4 nb [Motkya&Watt08].

PRL 242001 (2009)



Ψ(2s) production

34±7 events

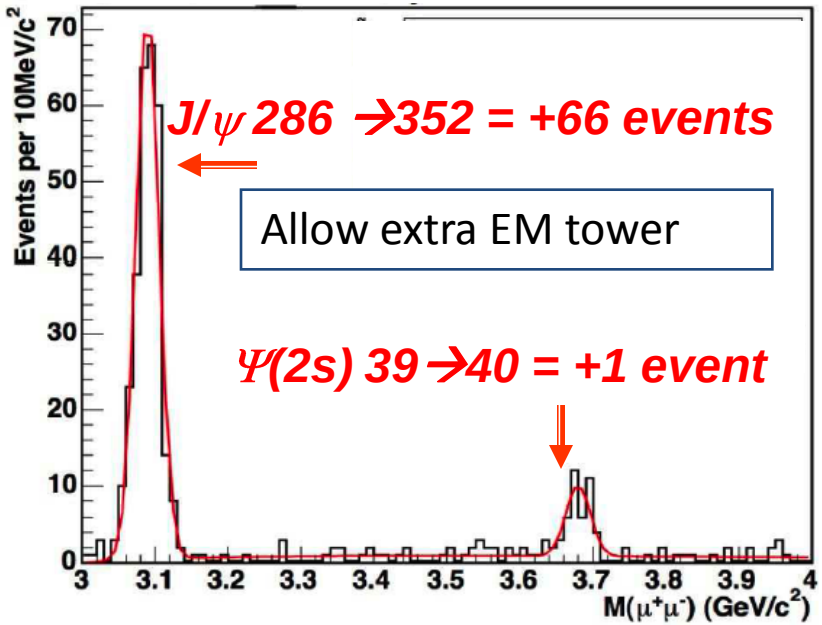
$d\sigma/dy|_{y=0}$ = 0.54 ± 0.15 nb

R = ψ(2s)/J/ψ = 0.14 ± 0.05

In agreement with HERA: R = 0.166 ± 0.012 in a similar kinematic region

Exclusive $\chi_c \rightarrow J/\psi(\rightarrow \mu^+\mu^-)+\gamma$

PRL 242001 (2009)



➔ Allowing EM towers (E_T >80MeV)

large increase in the J/ψ peak

minor change in the ψ(2s) peak

↓

Evidence for

$\chi_c \rightarrow J/\psi + \gamma$ production

$d\sigma/dy|_{y=0}$ = 75 ± 14 nb,

compatible with theoretical predictions

160 nb (Yuan 01)

90 nb (KMR01)

Conclusions

The long-standing diffractive program at CDF continues to improve our understanding of the diffractive processes.

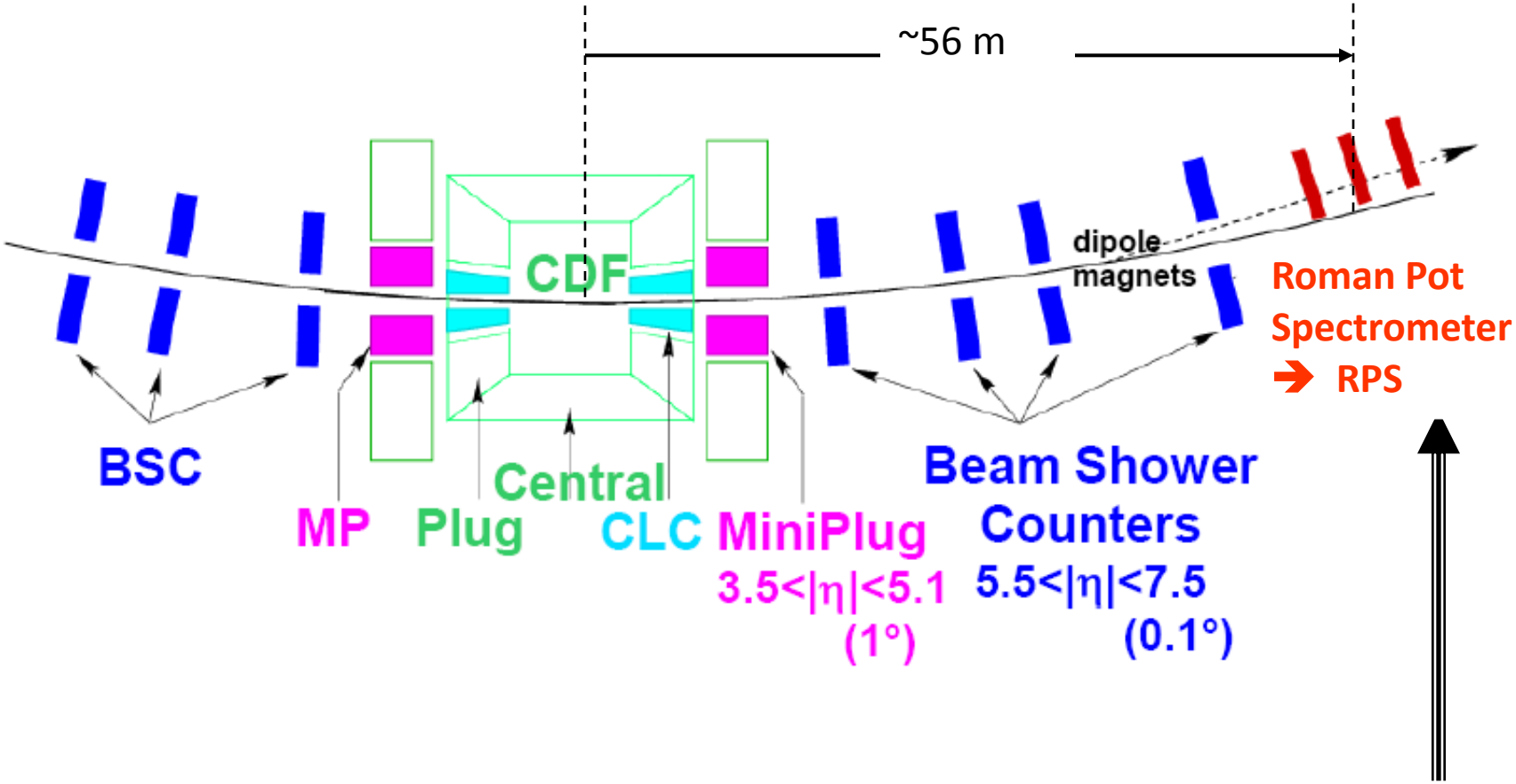
- Diffractive W/Z measurement with RP:
  - W diffractive fraction confirms Run I rapidity gap result

R_W $(0.03<\xi<0.10,\ |t|<1)$= [0.97 ± 0.05(stat) ± 0.10(syst)]%
$R_Z$$(0.03<\xi<0.10,\ |t|<1)$= [0.85 ± 0.20(stat) ± 0.08(syst)]%

- Exclusive Production
  - observation of exclusive dijet production
  - search for exclusive $\gamma\gamma$ production (3 candidates)
  - observation of exclusive χ_c, J/ψ, $\psi(2s)$

Back up

CDF II Detectors



RPS acceptance ~80% for 0.03 < ξ < 0.1 and |t| < 0.1

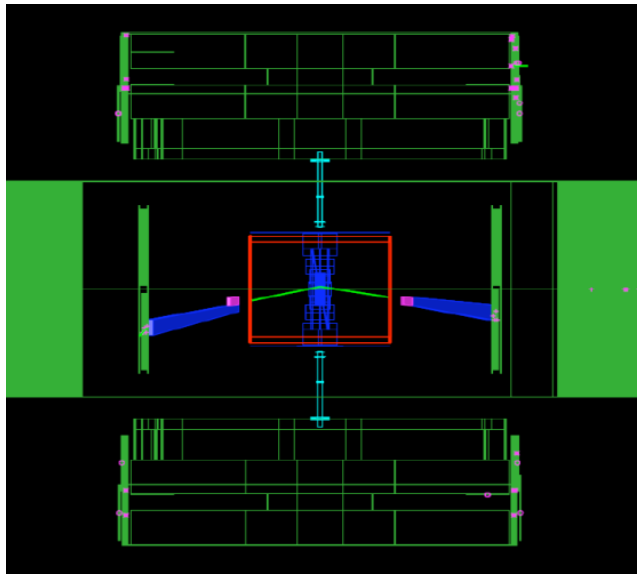
W/Z Selection

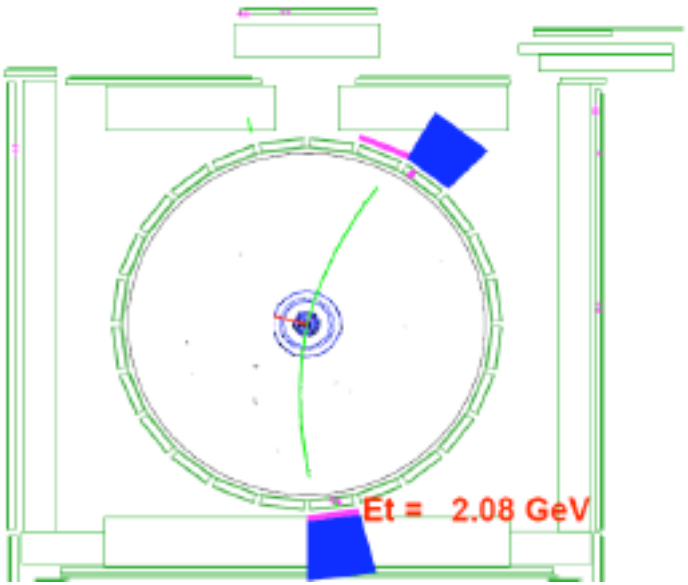
$$E_T^e(p_T^\mu) > 25\,\text{GeV}$$
$$\not{E}_T > 25\,\text{GeV}$$
$$40 < M_T^W < 120\,\text{GeV}$$
$$|Z_{vtx}| < 60\,\text{cm}$$

$$E_T^{e1}(p_T^{\mu 1}) > 25\,\text{GeV}$$
$$E_T^{e2}(p_T^{\mu 2}) > 25\,\text{GeV}$$
$$66 < M^Z < 116\,\text{GeV}$$
$$|Z_{vtx}| < 60\,\text{cm}$$

- RPS trigger counters – require MIP
- RPS track - $0.03 < \xi < 0.10$, $|t| < 1\text{GeV}^2$
- W➔ $\xi^{cal} < \xi^{RP}$, $50 < M_W(\xi^{RPS}, \xi^{cal}) < 120\ \text{GeV}^2$
- Z ➔ $\xi^{cal} < 0.1$

Exclusive Dimuon Production





$$p + \bar{p} \rightarrow p + \mu^+ \mu^- + \bar{p}$$

$3\ \mathrm{GeV}/c^2 < M_{\mu\mu} < 4\ \mathrm{GeV}/c^2$

Trigger:

muon + track + forward rapidity gaps in BSCs

2 oppositely charged muon tracks with $p_T > 1.4$ GeV/c, $|\eta| < 0.6$

$\varepsilon_{excl} \sim 0.093 \Rightarrow L = 1.48\ \mathrm{fb}^{-1}$ but $L_{eff} \sim 140\mathrm{pb}^{-1}$