# Experimental results on diffractive dijets at CDF

Michele Gallinaro

(on behalf of the CDF collaboration)

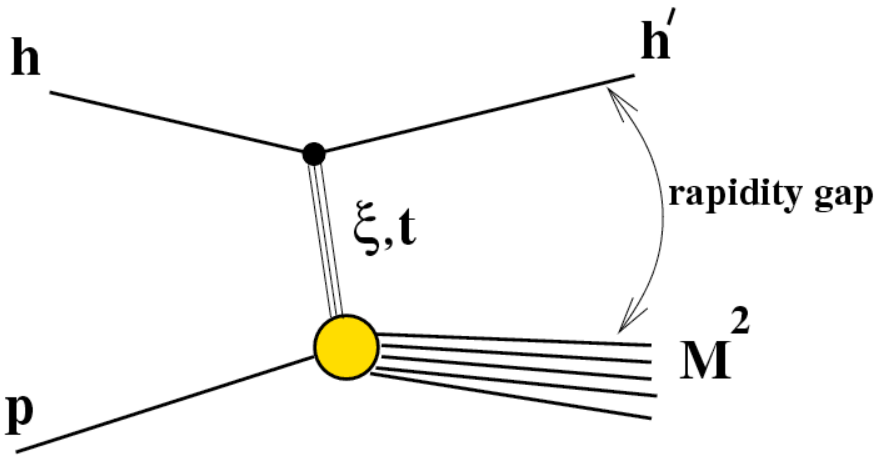
June 26, 2009

- Introduction
- Diffractive production (dijets, W/Z, Forward jets)
- Exclusive production (dijets)
- Conclusions

# Hadronic diffraction

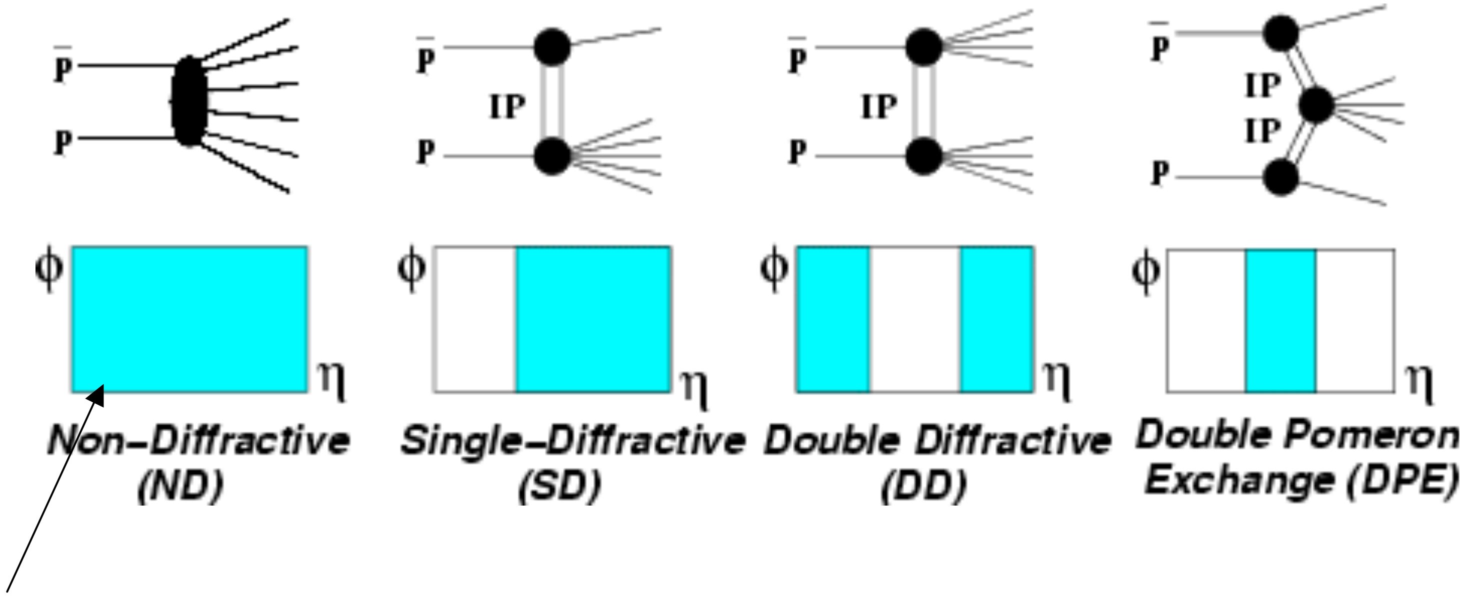
Elastic and diffractive processes
⇨ leading hadron emitted at small angle

The exchange ("pomeron") is colorless
⇨ large rapidity gap



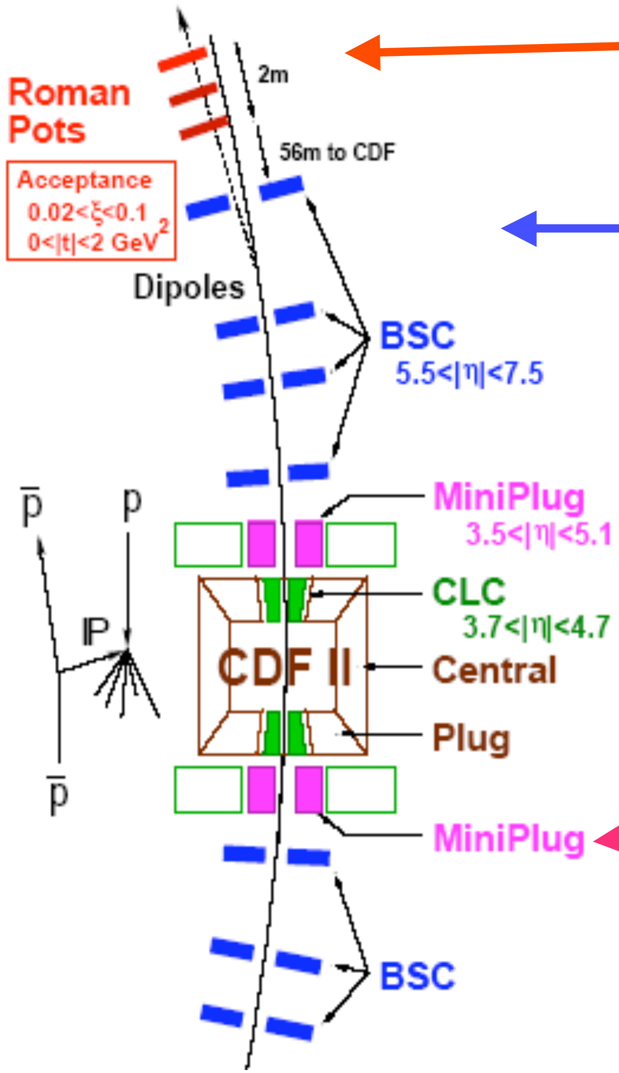
# Introduction

- In diffraction no quantum numbers are exchanged



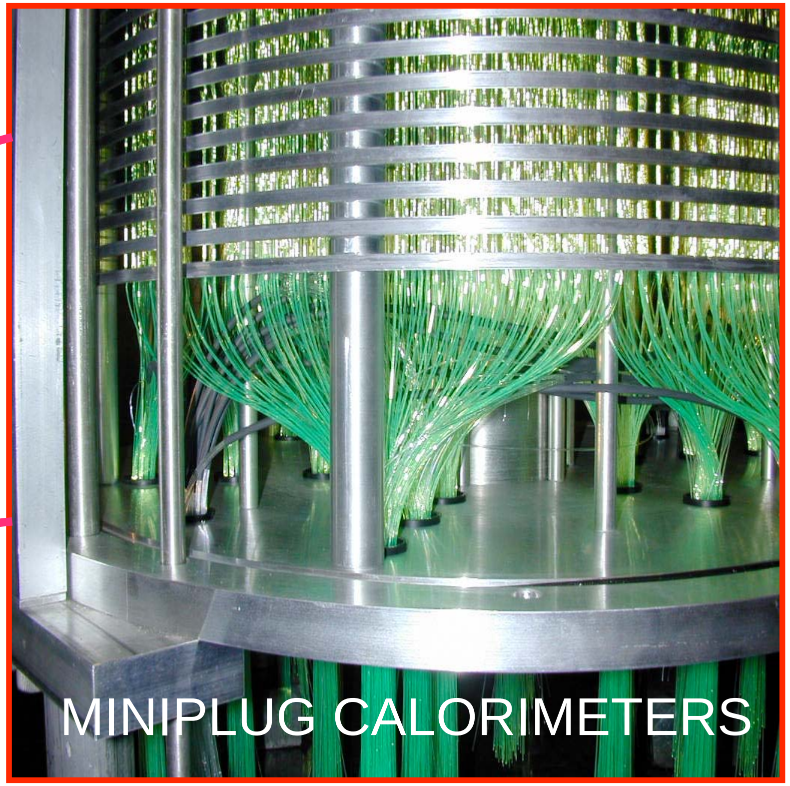

Shaded area corresponds
to particle production

# CDF central and forward detectors

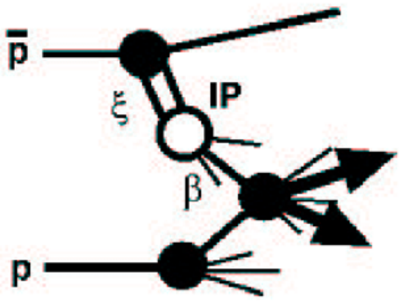



ROMAN POT DETECTORS

BEAM SHOWER COUNTERS: used to reject ND events



# Diffractive dijets




ξ: fraction of anti-proton momentum loss

β: fraction of Pomeron momentum carried by parton

parton $x_{Bj} \equiv \beta \cdot \xi$

$$x_{Bj} = \frac{\sum_{jet} E_T \cdot e^{-\eta}}{\sqrt{s}}$$

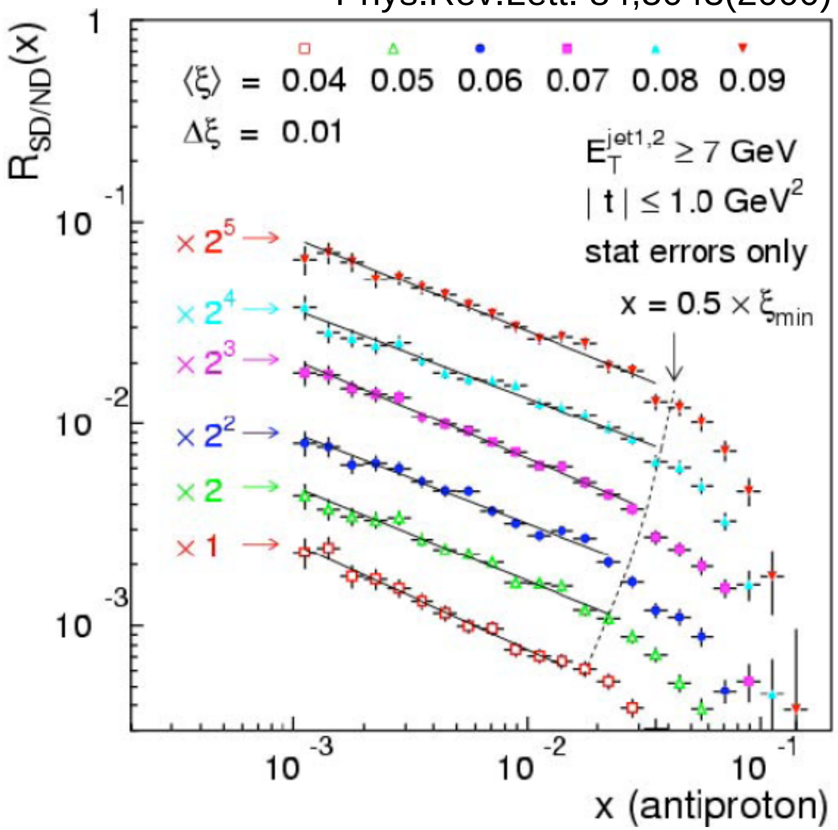
Measure SD/ND ratio of dijet rates

$$\frac{\sigma(SD_{jj})}{\sigma(ND_{jj})} = \frac{F^D_{jj}(x)}{F_{jj}(x)} \quad \text{(LO QCD)}$$

$$R_{SD/ND} = R_0 \cdot x^{-0.45}$$

⇨**no significant ξ dependence**

Phys.Rev.Lett. 84,5043(2000)



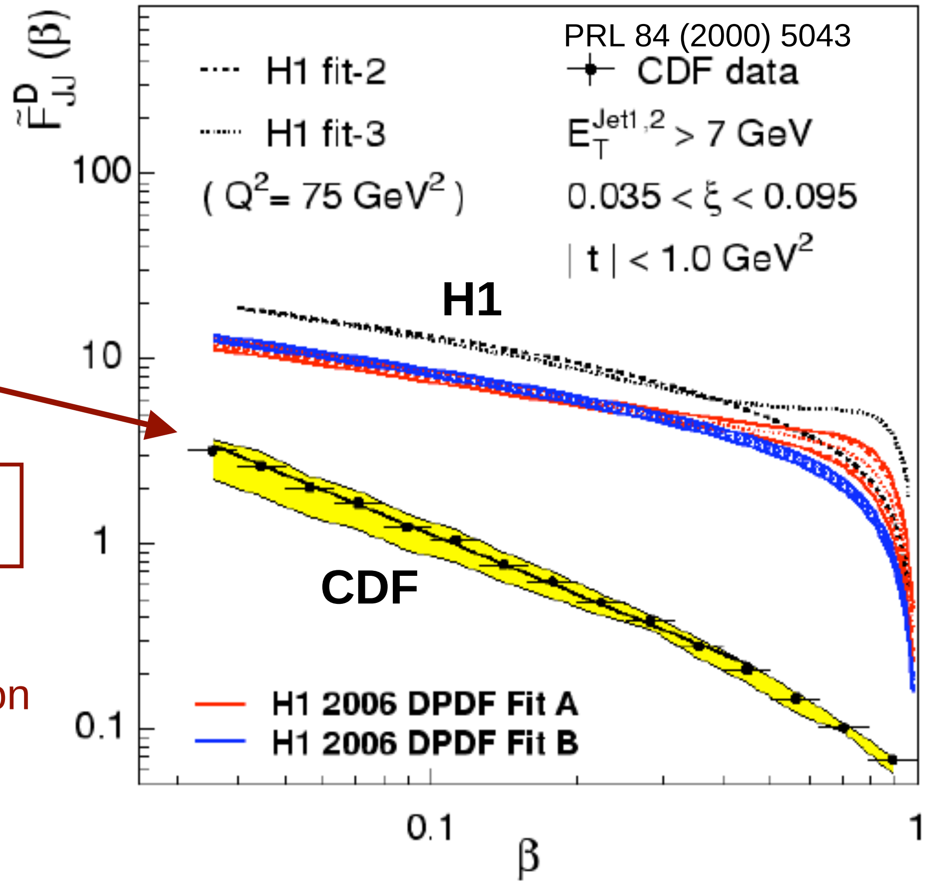

**in the ratio SD/ND many systematic uncertainties cancel out**

# Diffractive structure function

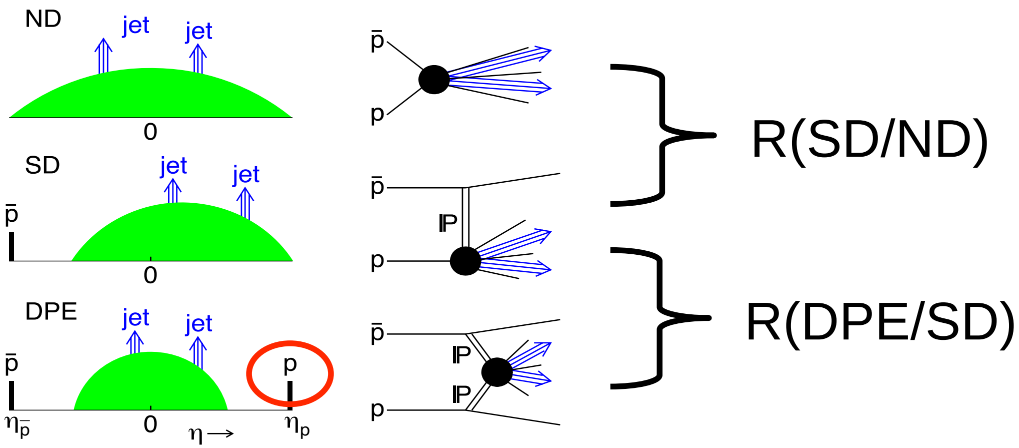
CDF Run I result suppressed
by factor of ~10 relative to HERA

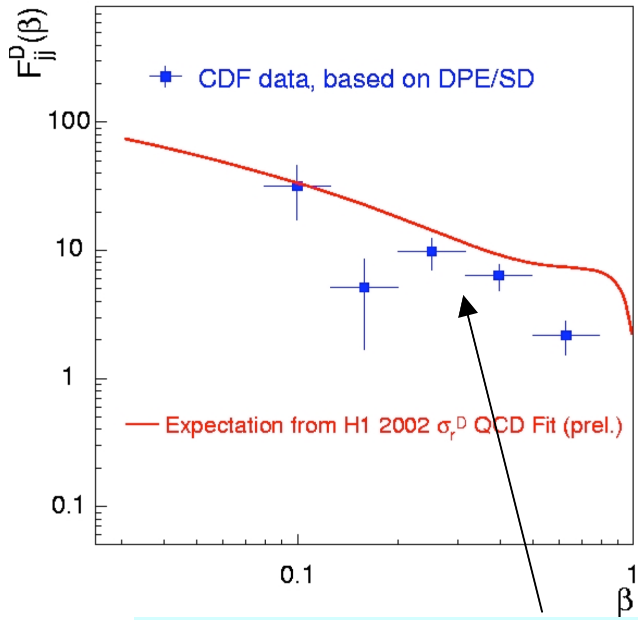
⇨breakdown of QCD factorization

Discrepancy can be attributed to additional
color exchange which spoil the gap formation



# Restoring factorization



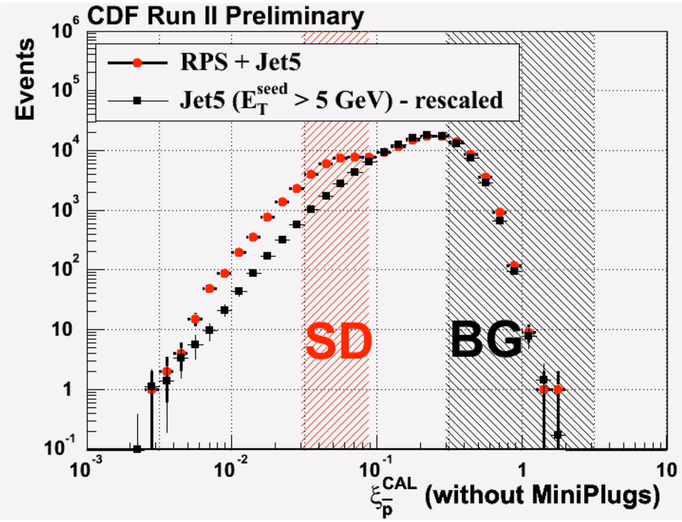

factorization is restored !

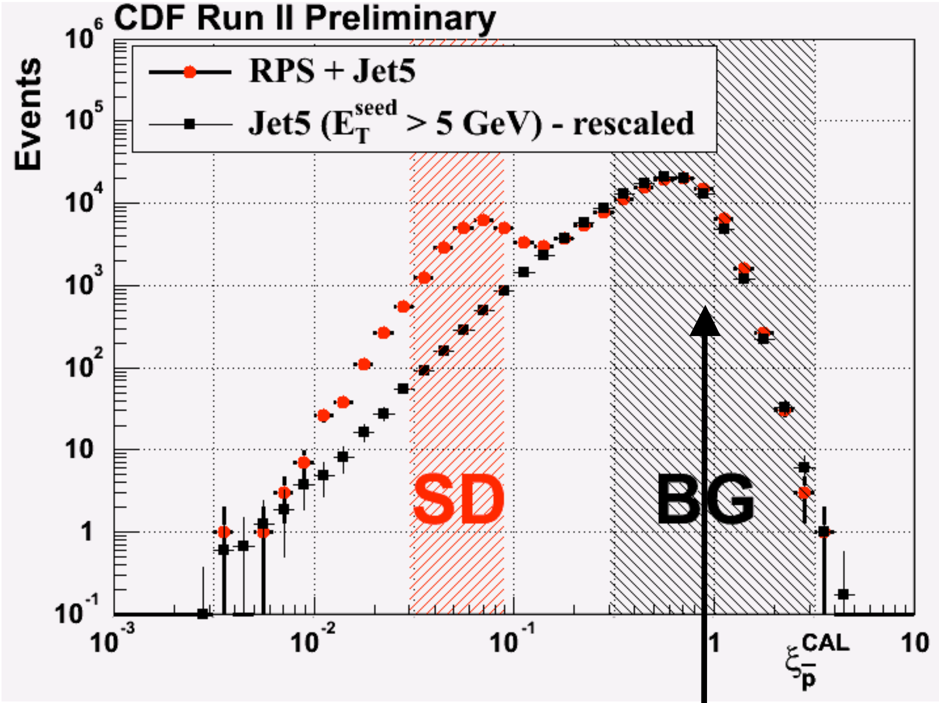
The diffractive structure function measured using DPE events is approximately the same as the one expected from HERA

# Event selection in Run II

**ξ:** momentum loss fraction of pbar

$$\xi = \frac{\Sigma_{(\text{all towers})} E_T e^{-\eta}}{\sqrt{s}}$$

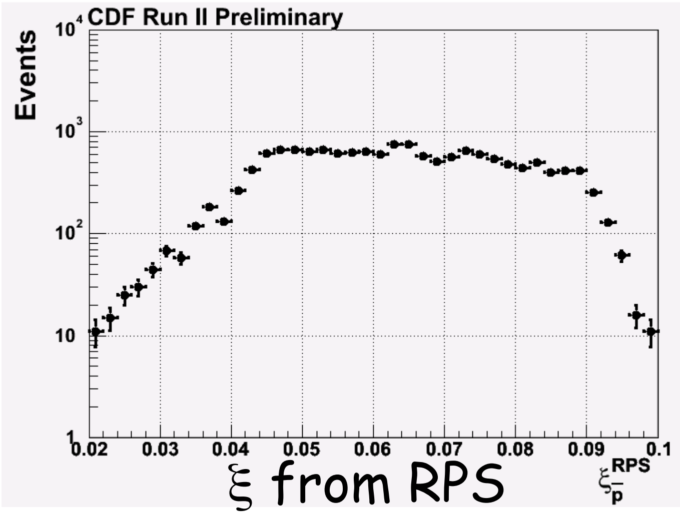


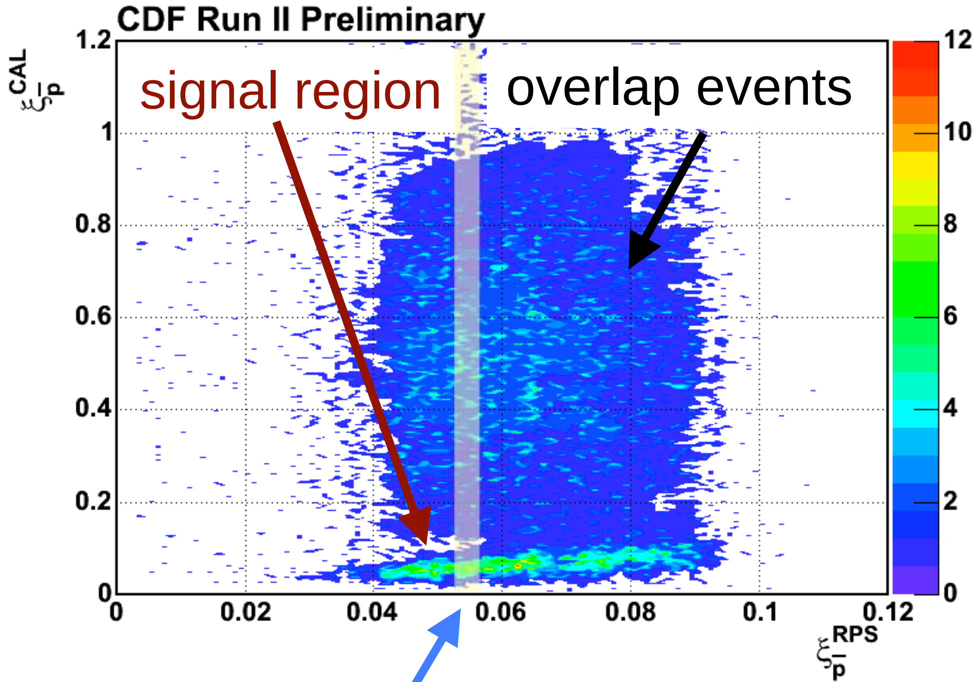



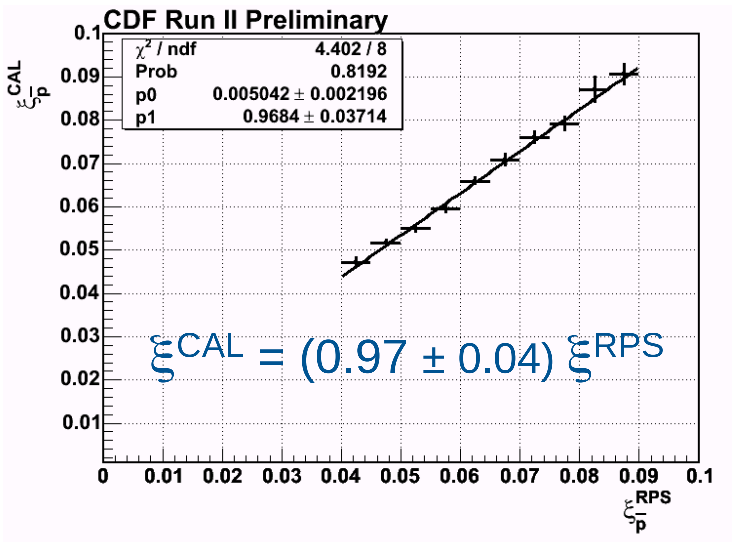

overlap events
(multiple $p\bar{p}$ interactions)

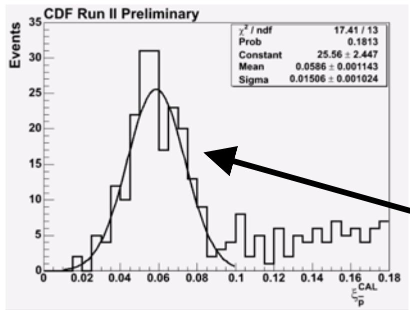
MP energy scale: ±30% →Δlogξ = ±0.1
RP acceptance (0.03<ξ< 0.09) ~ 80%

# Multiple interactions in Run II



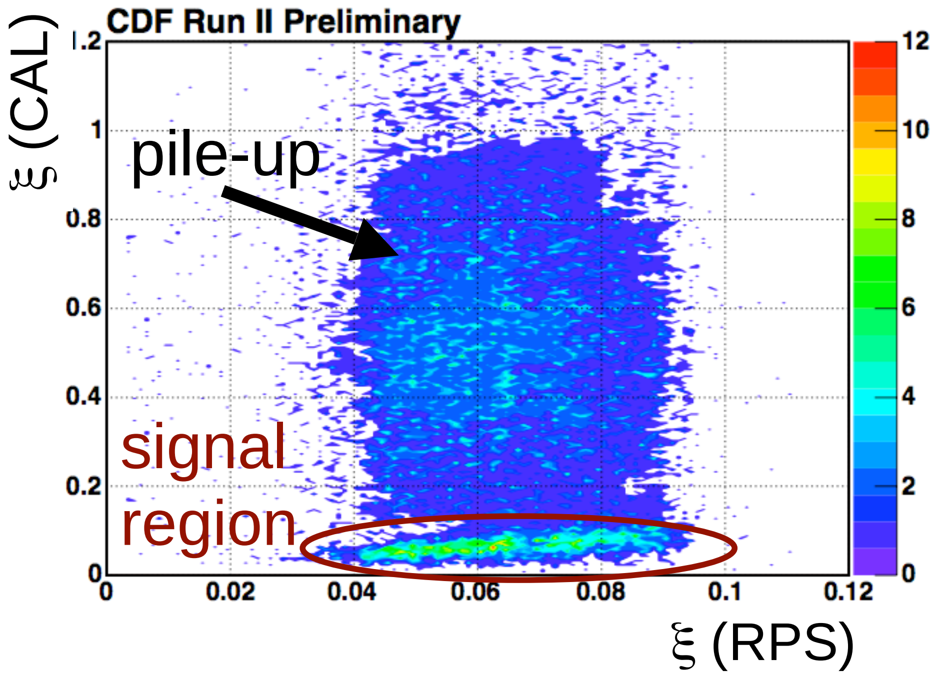



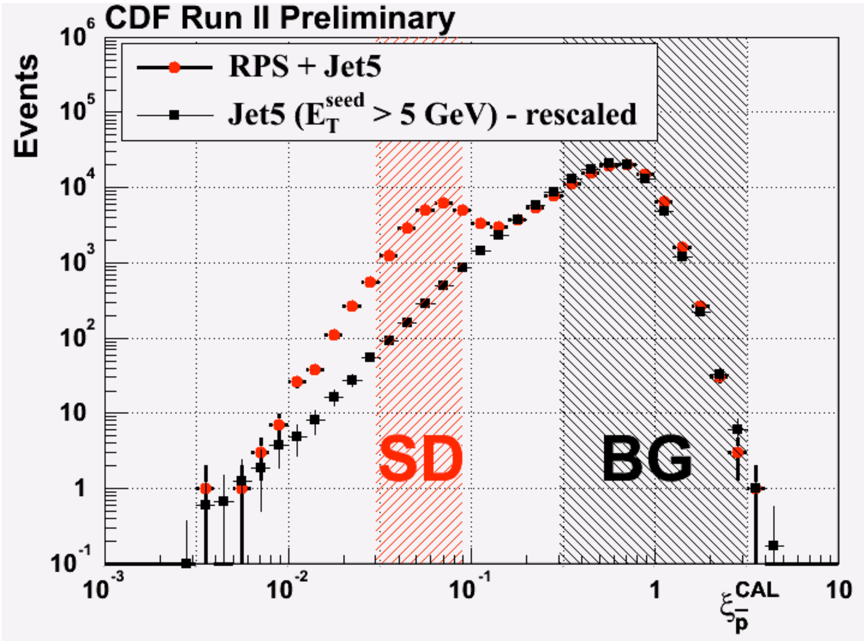

$\xi^{cal}$ distribution
for slice of $\xi^{RPS}$

$\sigma$ / mean ~ 30%

# Multiple interactions in Run II

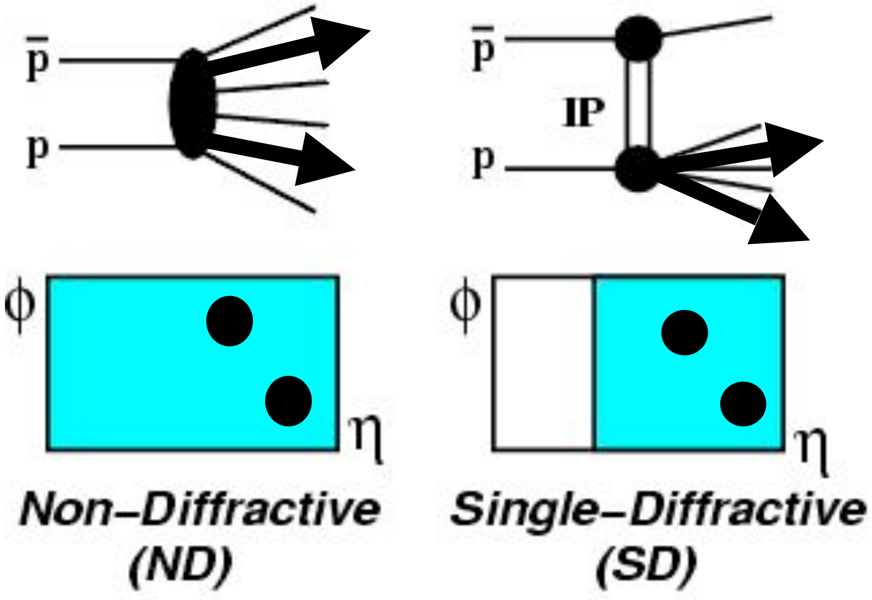
- Multiple proton-antiproton interactions spoil diffractive signature




- Measure ξ from calorimeter and from RP tracking
- Reject multiple interactions
  - exclude ξ>0.1 (ND+SD interactions)

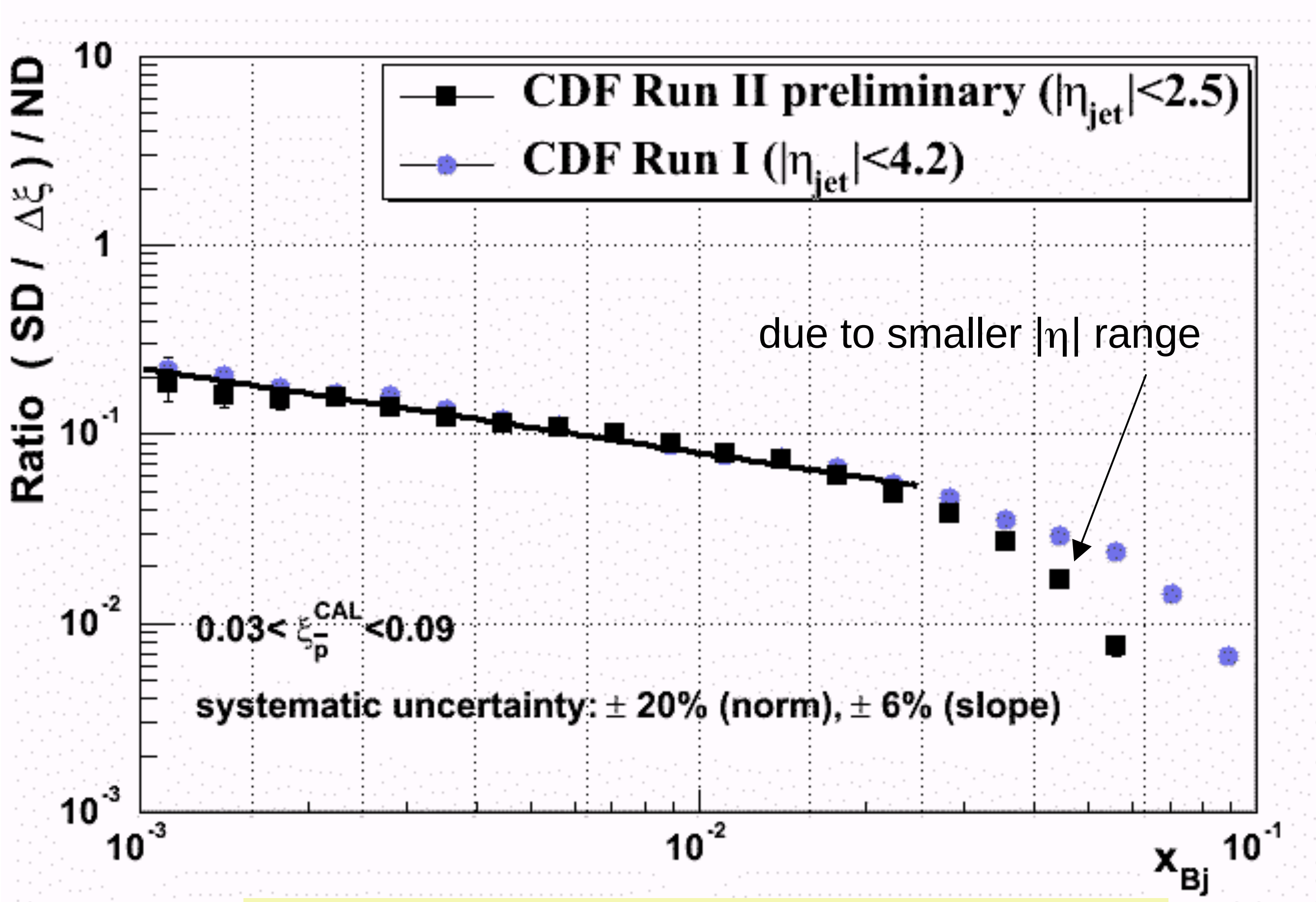
# Diffractive structure function




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

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

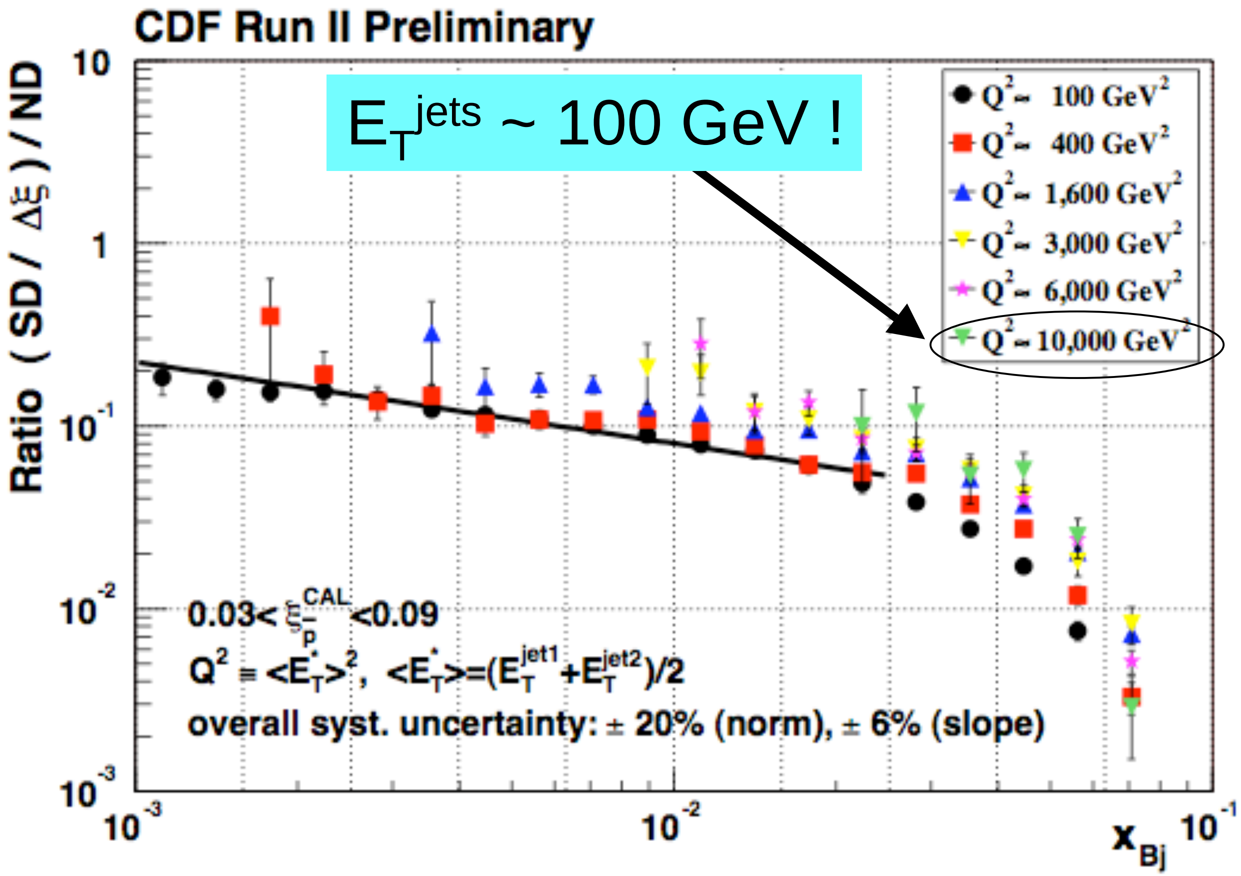
# SD/ND ratio




ratio of SD/ND dijet event rates

⇨ confirms Run I results

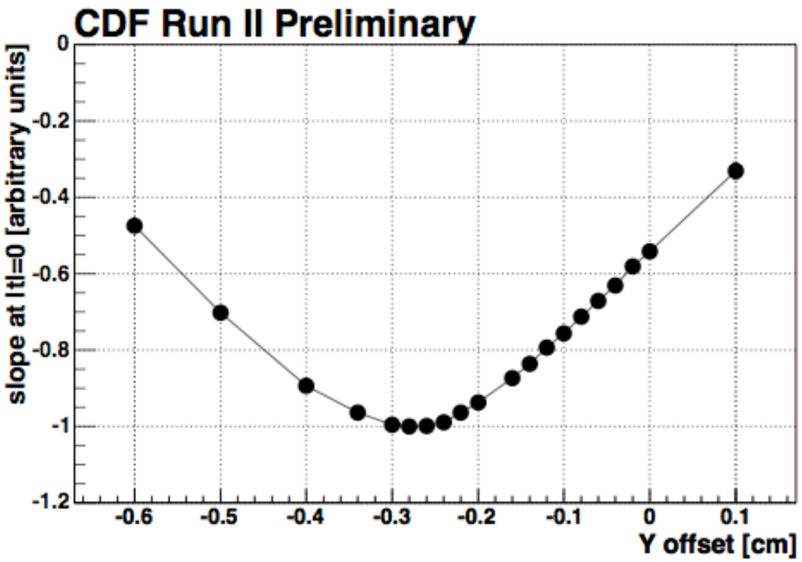
# $Q^2$ dependence



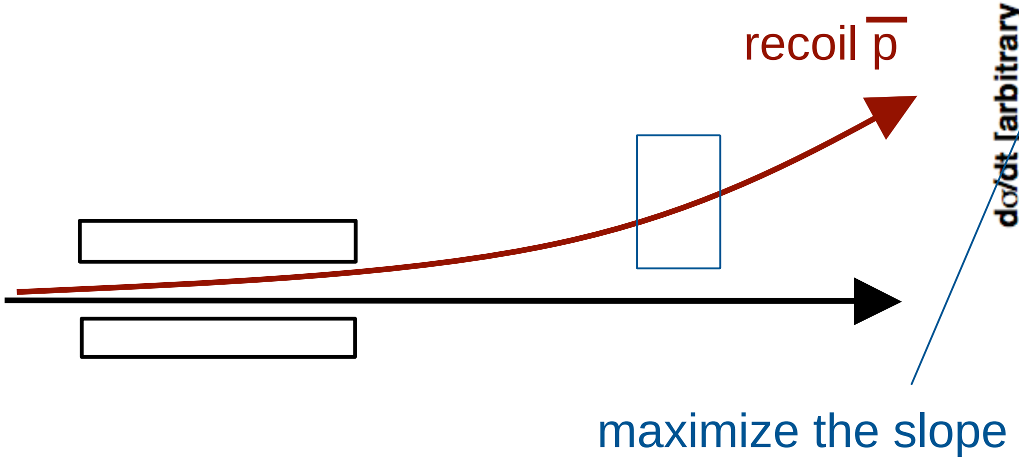

small $Q^2$ dependence for $100 < Q^2 < 10{,}000$ GeV$^2$

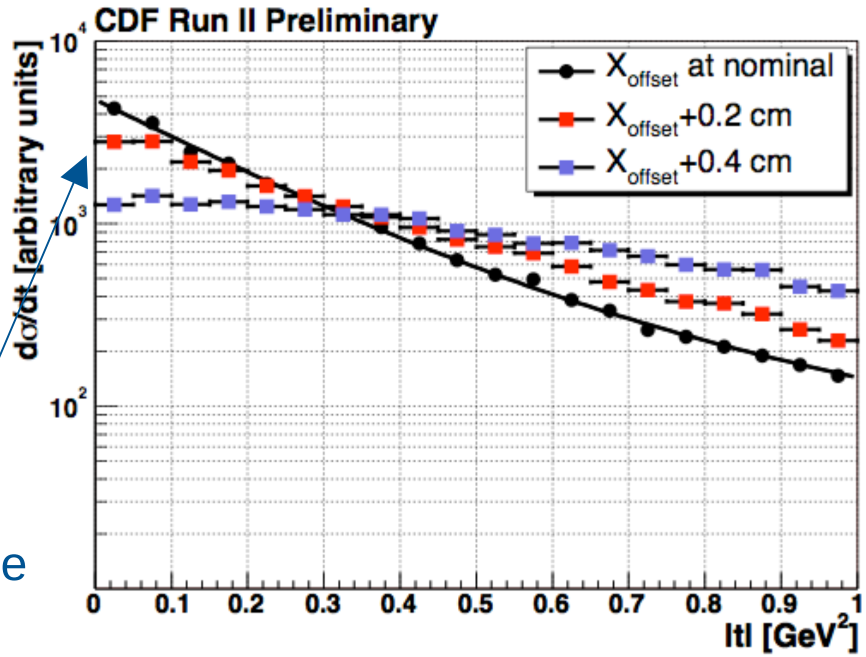
⇨ Pomeron evolves as proton

# RPS dynamic alignment

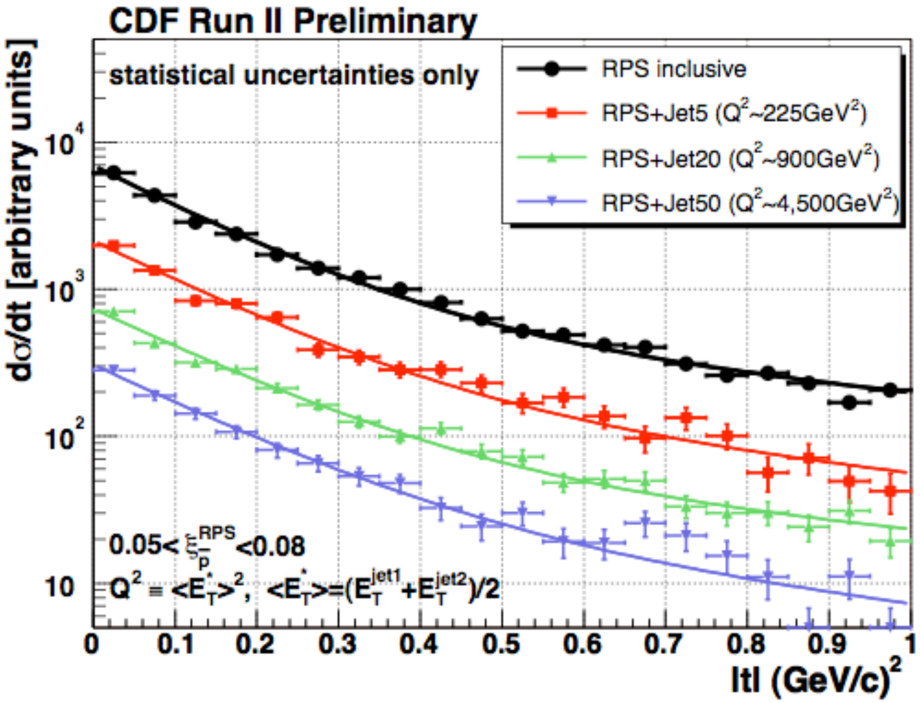


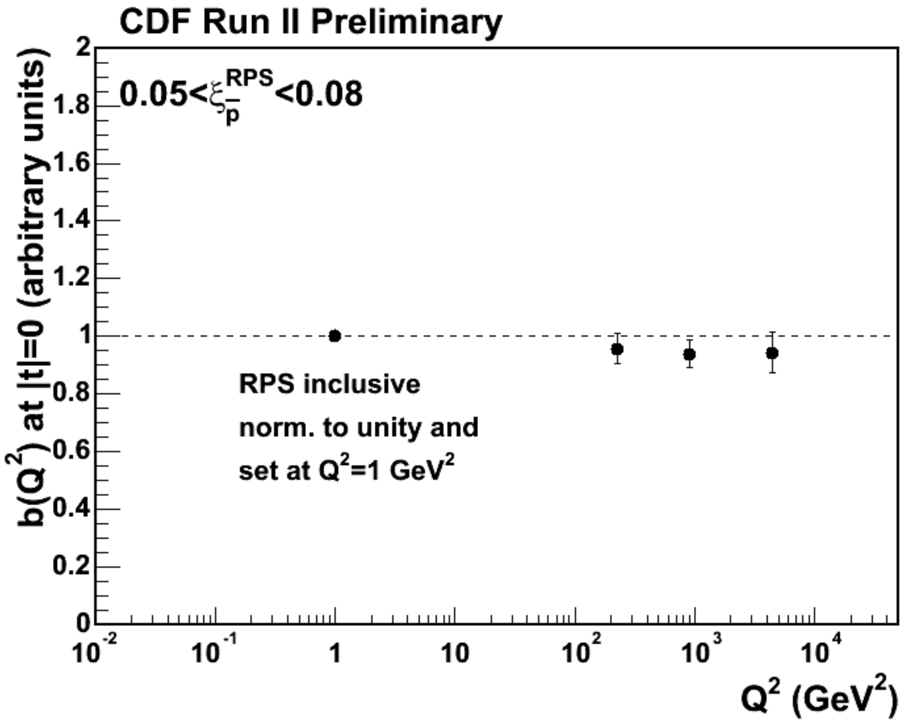

maximize the |t|-slope
(normalized to max slope)
⇨determine X and Y offsets



# |t| distribution

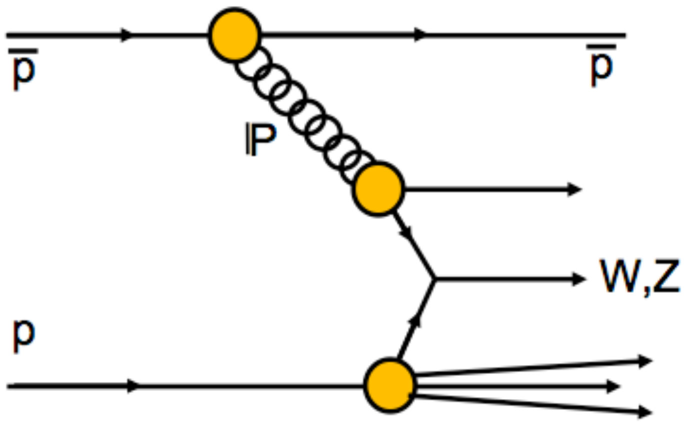


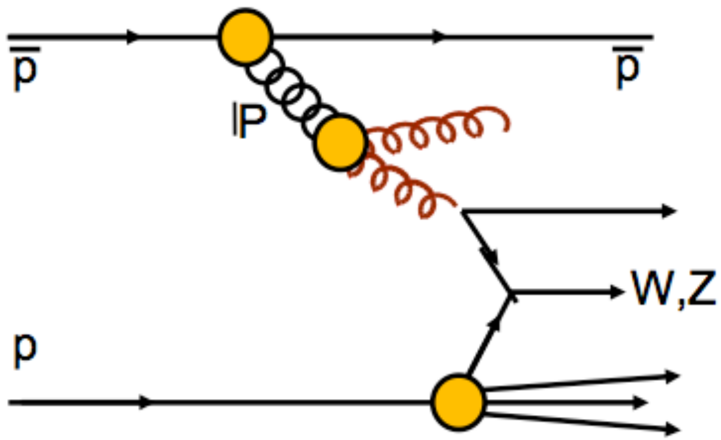




- No diffraction `dips’ observed at |t|<1
- Soft and hard diffractive events have the same slope

# Diffractive W/Z production

Study W/Z boson production helps to determine the **quark** content of the Pomeron




At LO, the W/Z is produced by a quark in the Pomeron

or

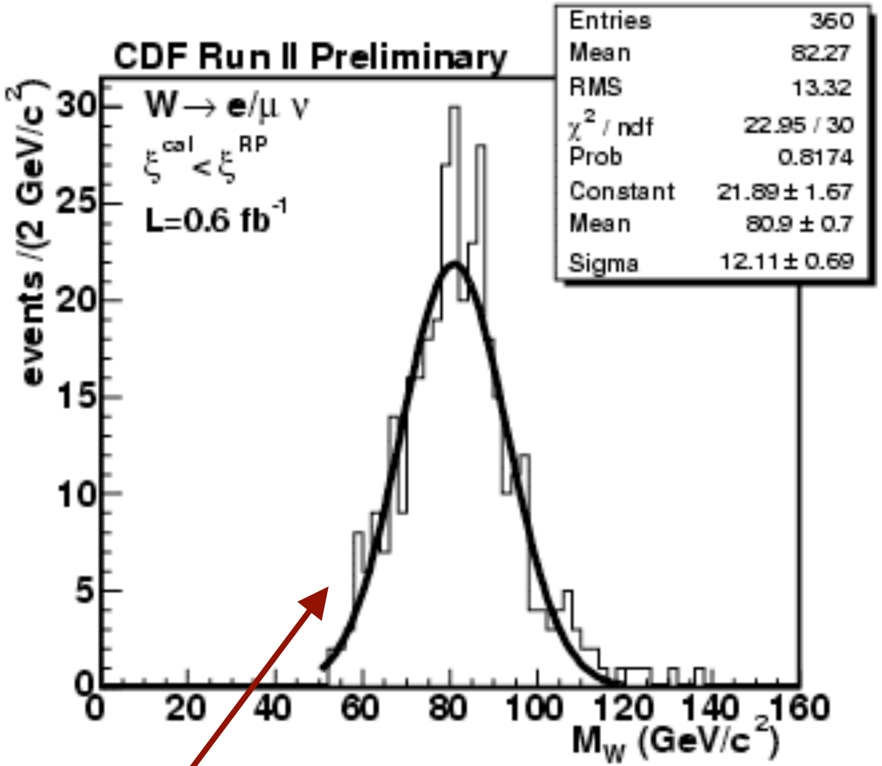
Production by a gluon is <u>suppressed</u> by $\alpha_s$. Can look at additional jet.

# Diffractive W/Z production (cont)

- Identify diffractive events using RPS
- Calculate $\xi$ from calorimeter
- In W production, difference $\xi^{cal}$-$\xi^{RPS}$ is due to missing $E_T$, and $\eta_\nu$.

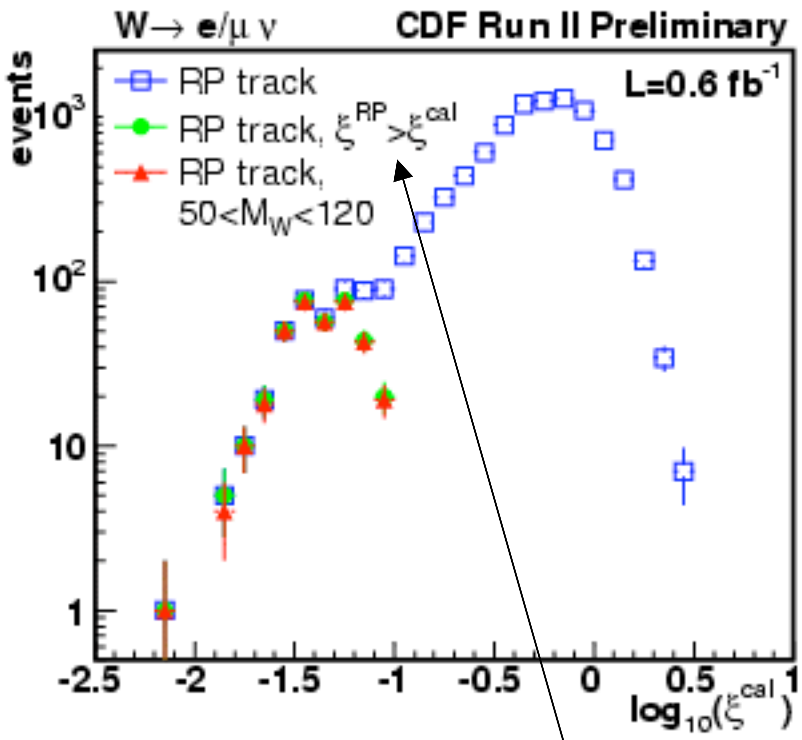
$$\xi^{RP} - \xi^{cal} = \frac{\not{E}_T}{\sqrt{s}} e^{-\eta_\nu}$$

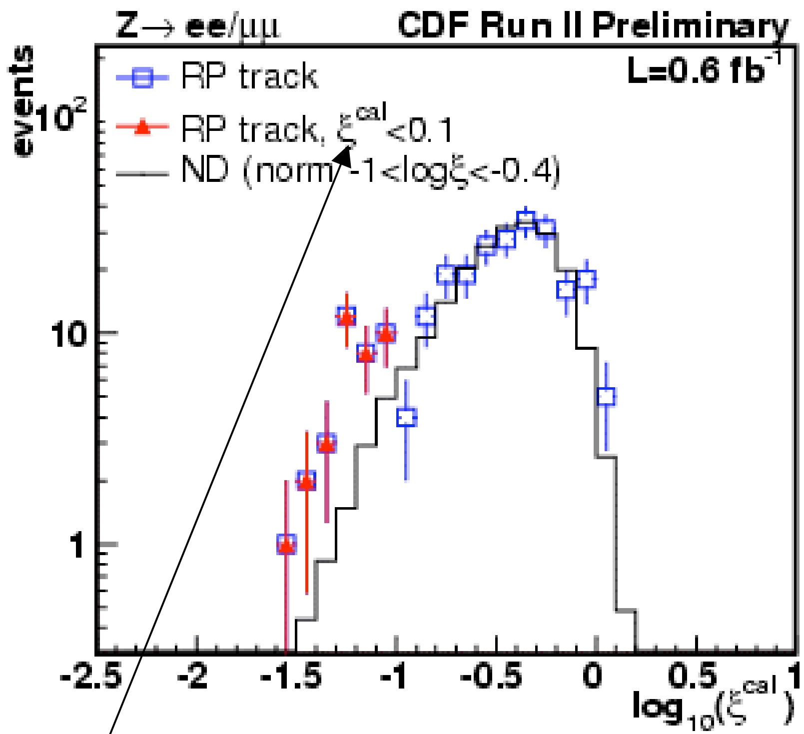
- Can estimate:
  - neutrino kinematics
  - W kinematics
  - $x_{Bj}$
- Next: Determine structure function in diffractive W production




reconstruct W invariant mass

# Diffractive W/Z production (cont)




Remove events with non diffractive W/Z production+soft SD interaction

# Diffractive W/Z measurement

- Measured fractions:

$R_W$ = 0.97 ± 0.05(stat) ± 0.11(syst) %
$R_Z$ = 0.85 ± 0.20(stat) ± 0.11(syst) %

- Run I diffractive W studies performed with rapidity gap instead of RPS
- CDF: Phys.Rev.Lett. 78,2698(1997)
  - Fraction of events due to SD for x<0.1: **[1.15±0.51(stat)±0.20(syst)]%**
  - Combined with other SD measurements (b-quark,jet), quark-gluon content of the Pomeron is determined: $f=0.54^{+0.16}_{-0.14}$
- D0: Phys.Rev.Lett.B 574,169(2003)
  - Fraction of events with rapidity gap:
  - W: **[$0.89^{+0.19}_{-0.17}$]%**
  - Z: **[$1.44^{+0.61}_{-0.52}$]%**
  - [If correction for rapidity gap acceptance is applied…R(W): 5.1%]

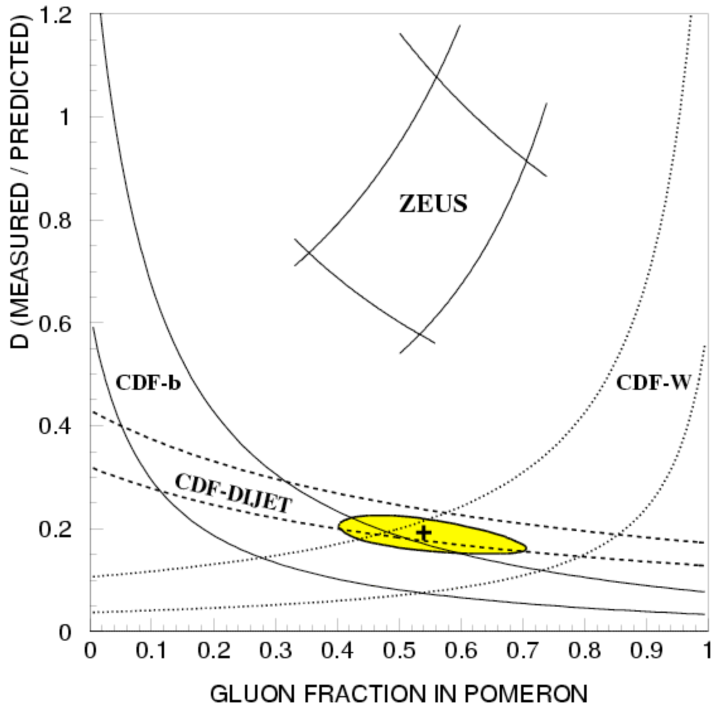
# Diffractive rates

$$p\bar{p} \rightarrow X + \text{gap}$$

Measured SD/ND fractions at 1.8 TeV

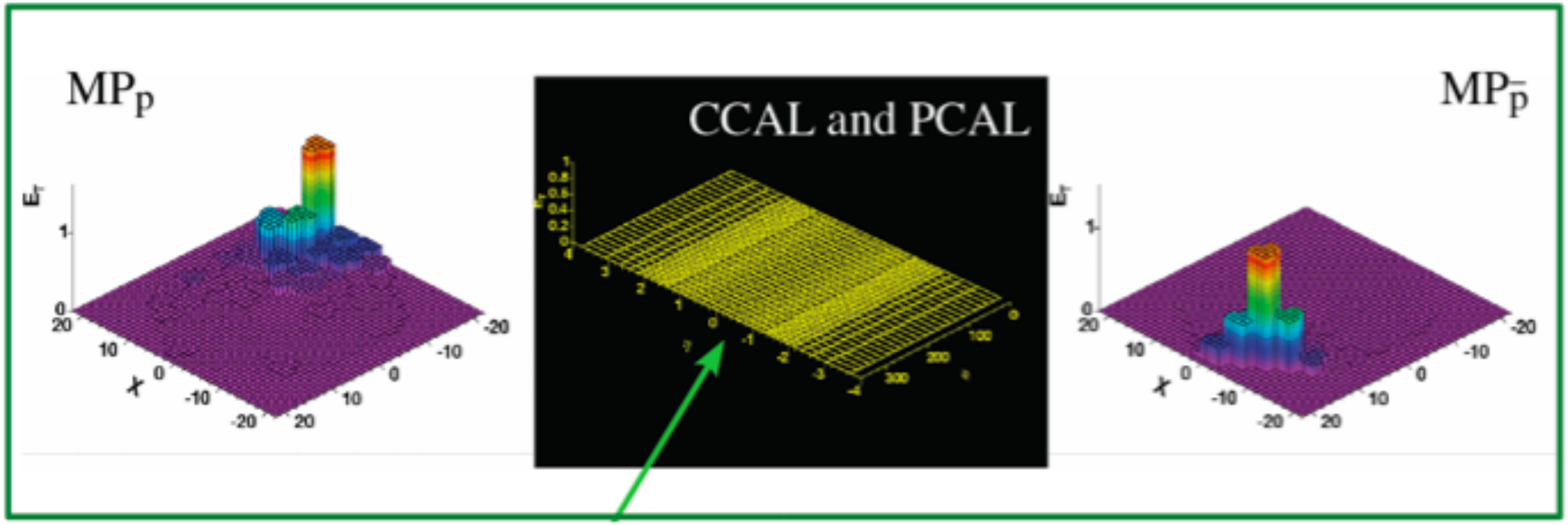
| PRL | process | fraction [%] |
|---|---|---|
| 84 (1997) 2698 | W(eν) | 1.15 (0.55) |
| PLB 574 (2003) 169 | Z | 1.44 (0.60) |
| 84 (1997) 2636 | jet-jet | 0.75 (0.10) |
| 84 (2000) 232 | b | 0.62 (0.25) |
| 87 (2001) 241802-1 | J/ψ | 1.45 (0.25) |

W probes quark component ($q\bar{q}\rightarrow W$)

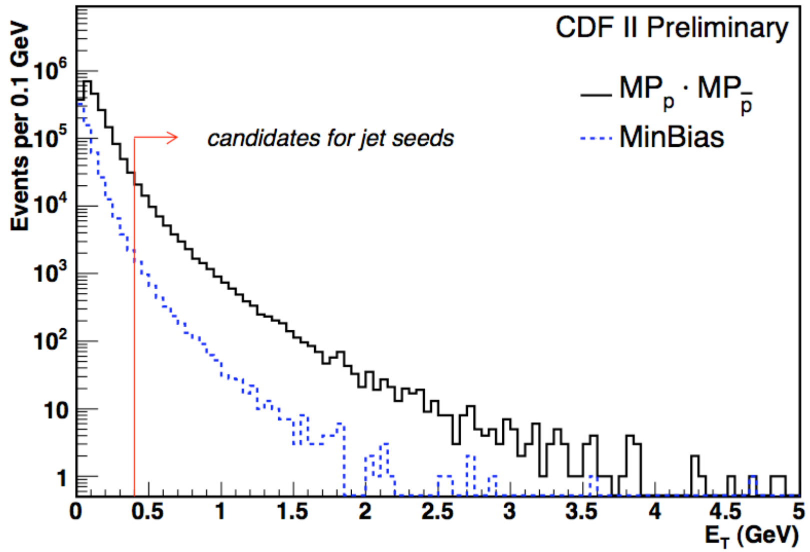



All SD/ND fractions ~ 1%
Different sensitivities to quark/gluon
⇨gluon fraction $f_g$=0.54 (0.15)

# Central gap between forward jets

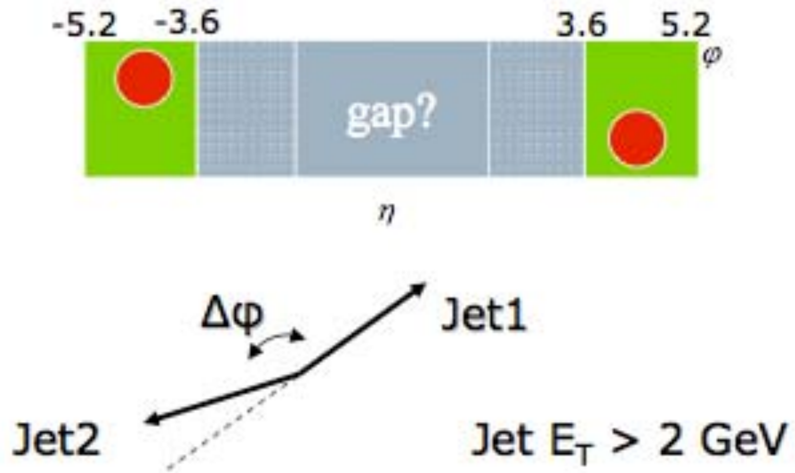



Rapidity gap in Central and Plug calorimeter

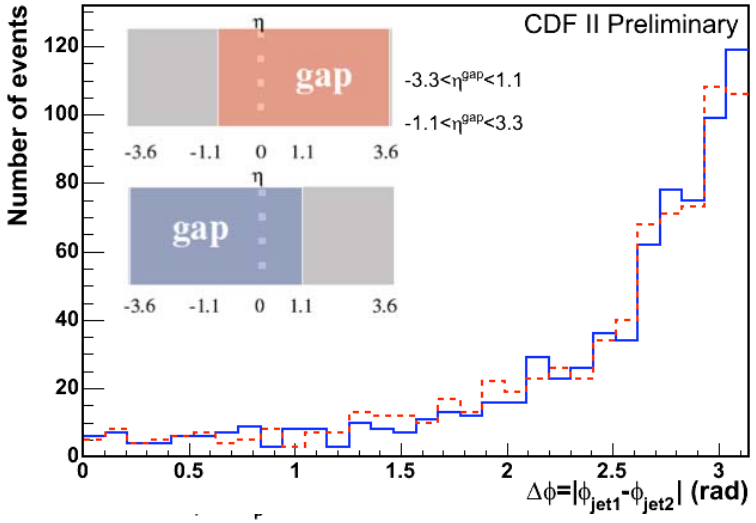



- Characterize gap formation
  - fraction of gap events (soft and hard interactions)
  - dependence on gap size
- Mueller-Navelet jets

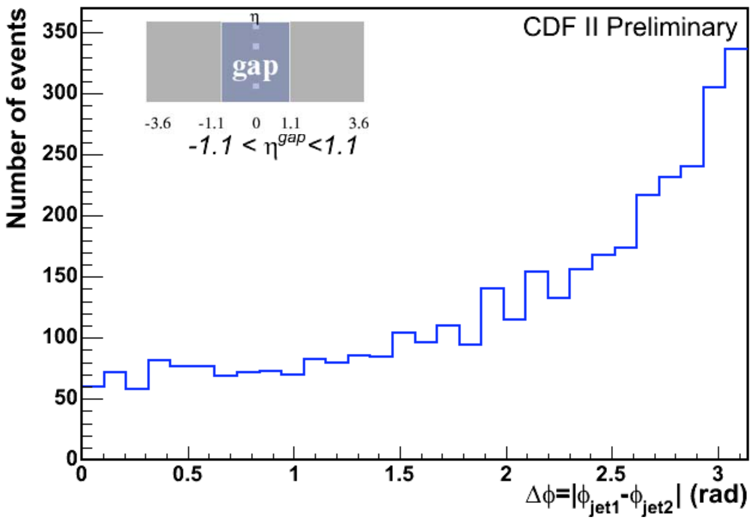
# Jet Δϕ correlation

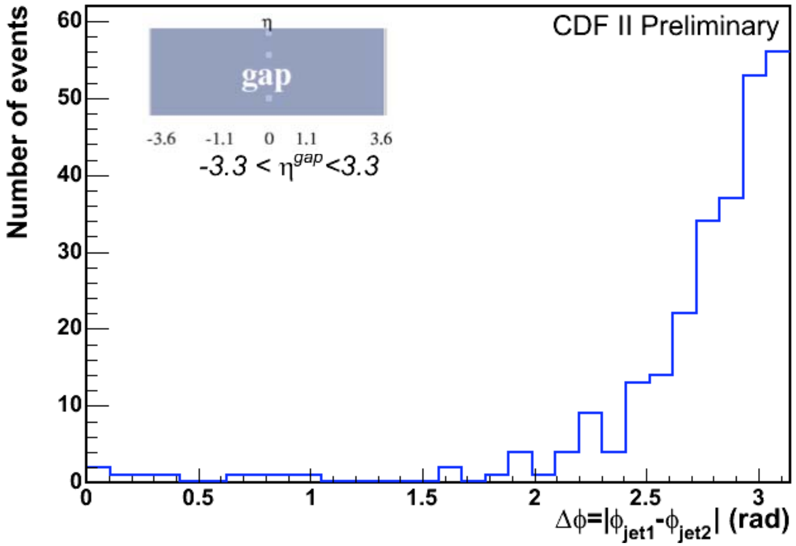



Δϕ for MP$_p$•MP$_{\bar{p}}$ jets with CCAL•PCAL$_{p/\bar{p}}$ gap

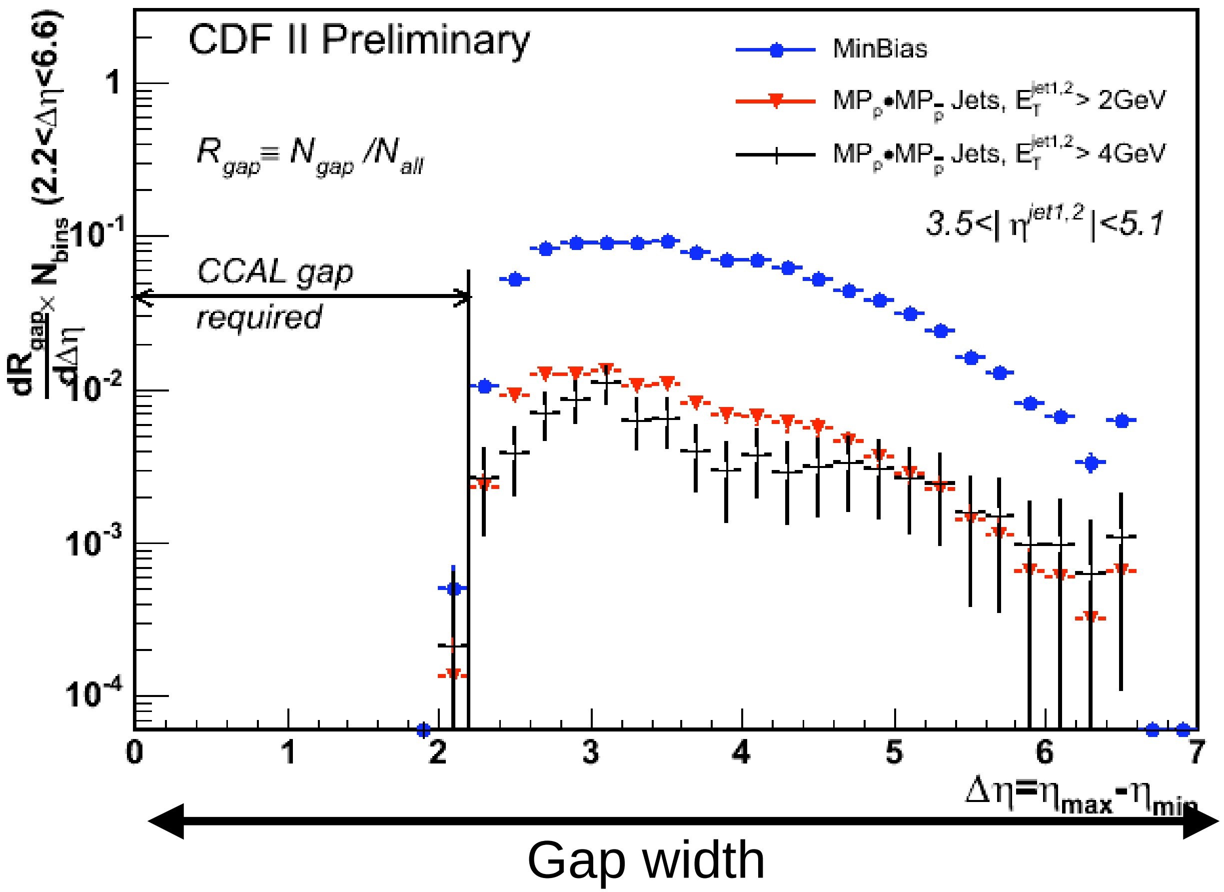


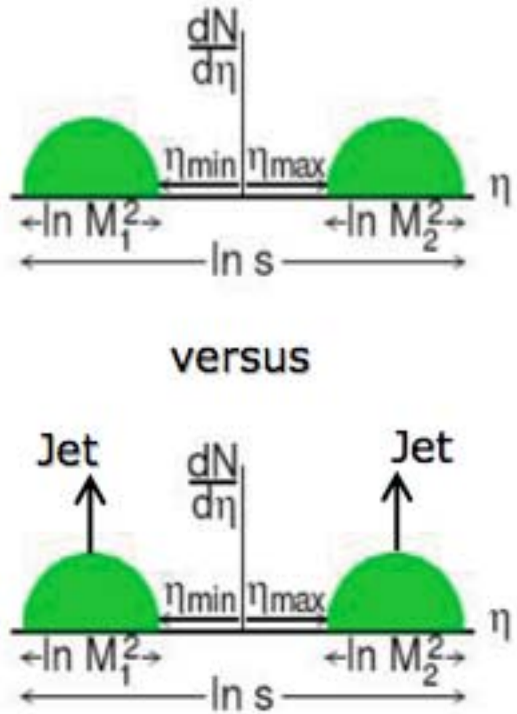

Δϕ for MP$_p$•MP$_{\bar{p}}$ jets with CCAL gap



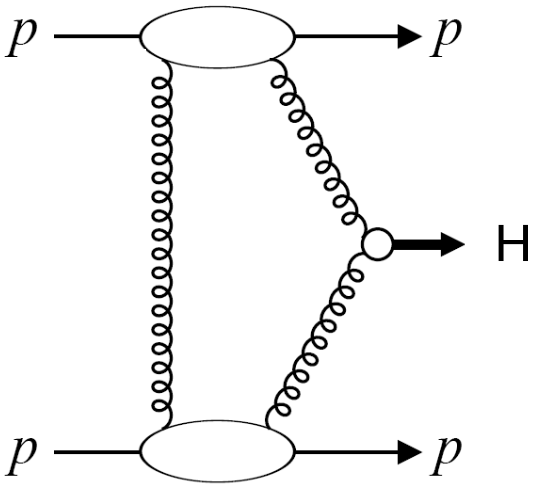
# Rapidity gap event fraction




- Event fraction is ~10% in soft events, and ~1% in jet events
- Shapes are similar

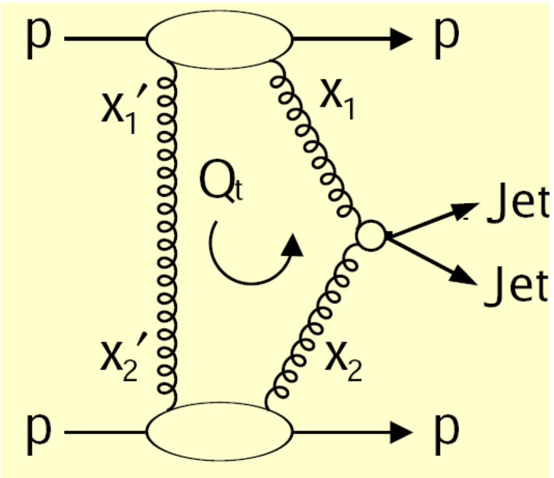
# Exclusive production




✓clean process
✓exclusive $b\bar{b}$ suppressed

Khoze Martin Ryskin: $\sigma_H$(LHC)~3 fb, signal/bkg~3 (if $\Delta M_{miss}$=1 GeV)

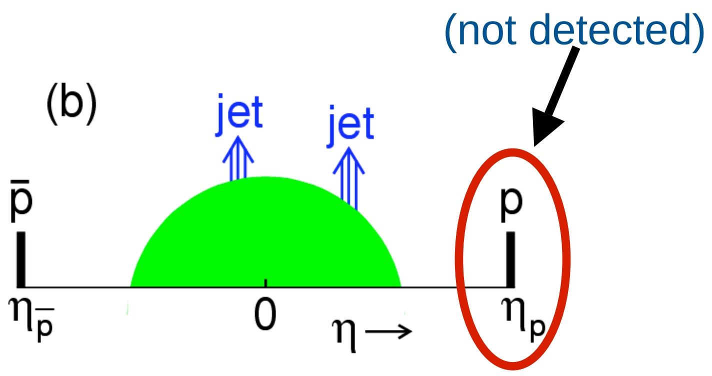
Attractive Higgs discovery channel at the LHC



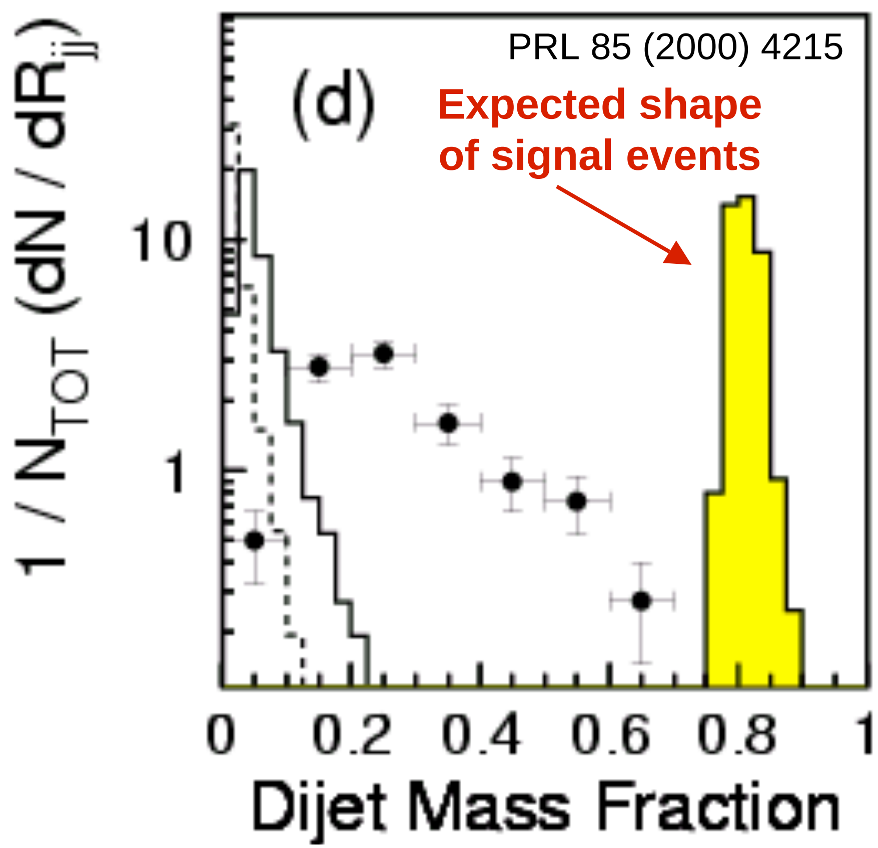

⇨much larger cross section

<u>Goal:</u>
- ➢measure exclusive dijet production (if it exists)
- ➢test/calibrate Higgs predictions at LHC

# Exclusive dijets in Run I




Mass fraction: $R_{jj} = \frac{M_{jj}}{M_X}$

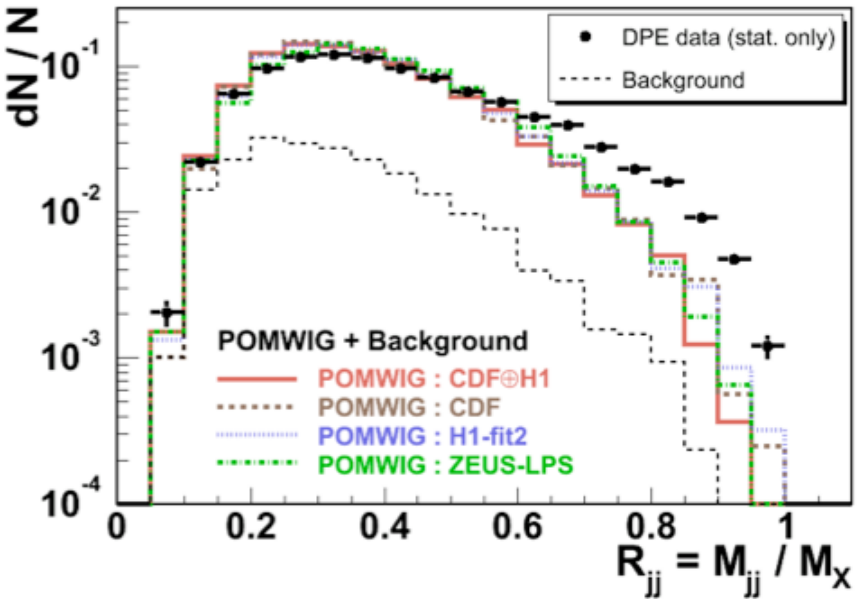



Exclusive dijet limit:
Run I: PRL 85 (2000) 4215
⇨ $\sigma_{jj}$ (excl.) < 3.7 nb (95% CL)

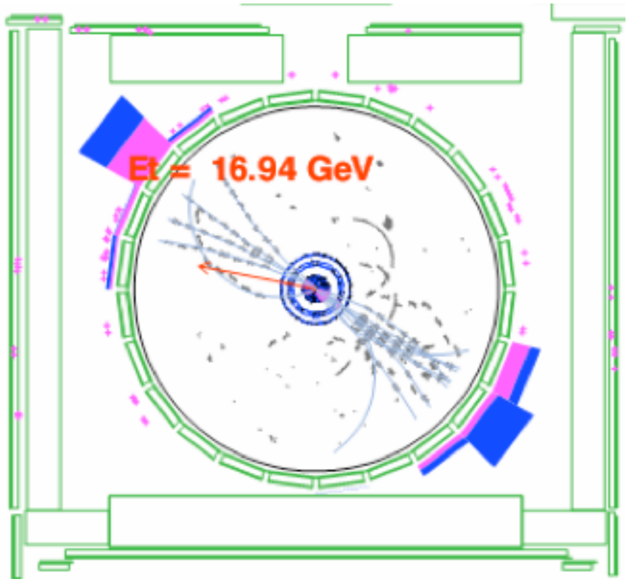
# Observation of exclusive dijets

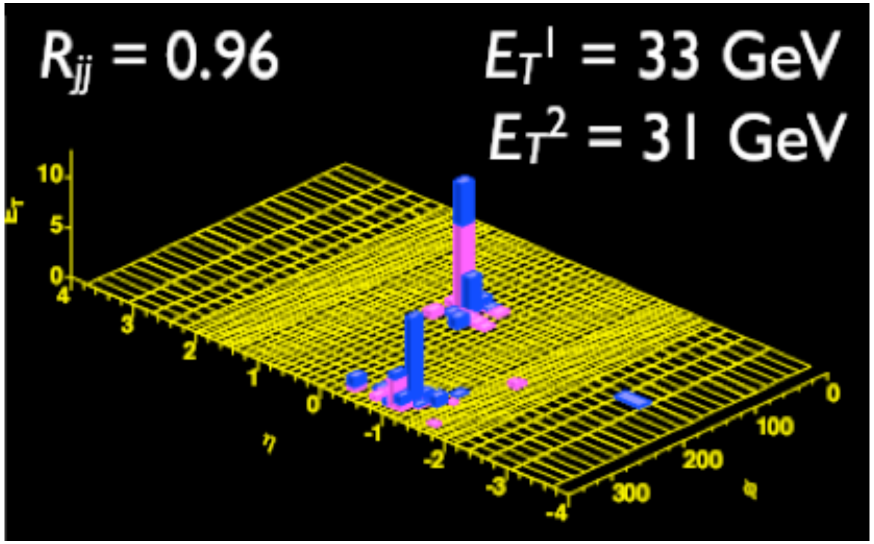
Phys.Rev.D77:052004,2008

Observe excess over
inclusive DPE at large Mjj



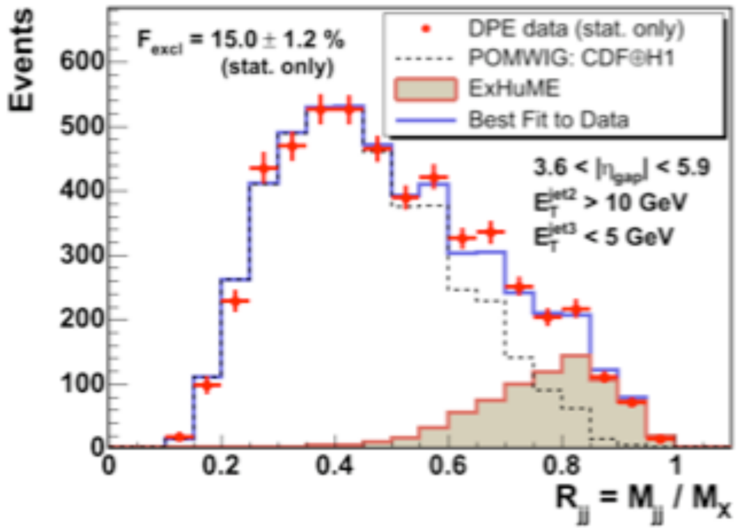

⇨ exclusive signal?

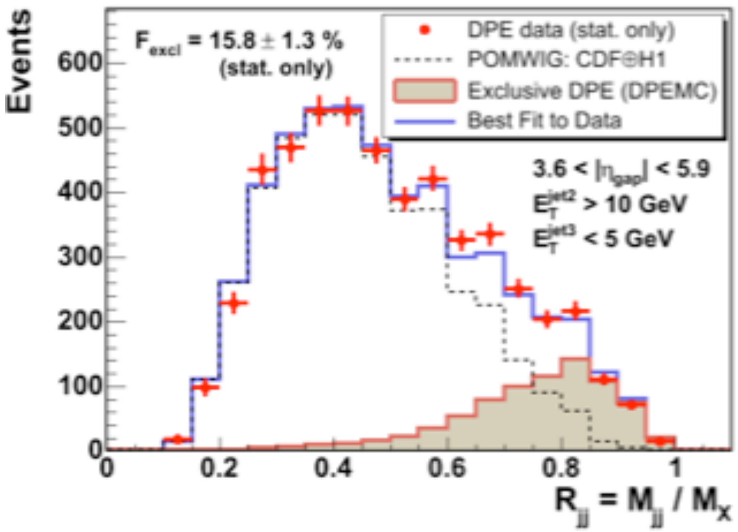


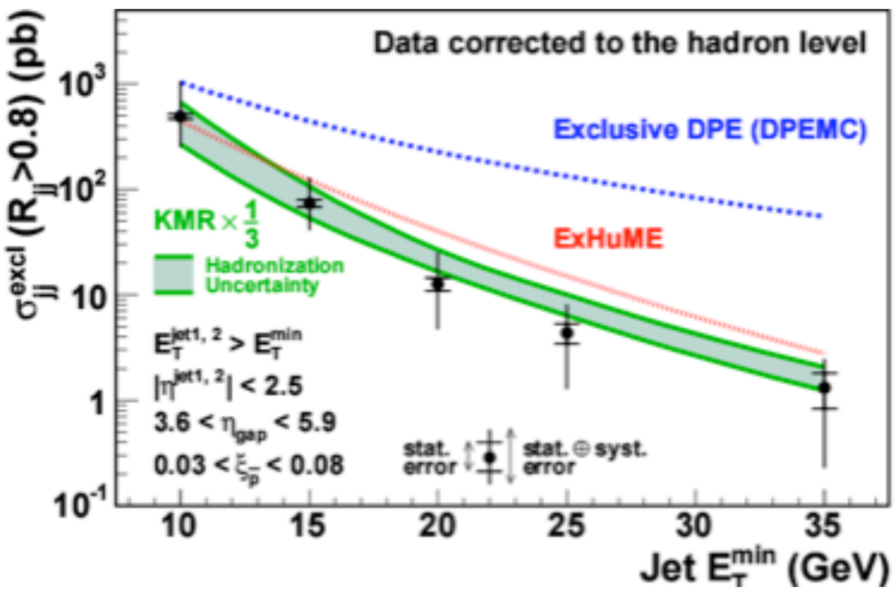
# Exclusive dijet cross section

Phys.Rev.D77:052004,2008




- $R_{jj}$ shape described by MC based on two models (ExHuME, DPEMC)
- Cross section agrees with ExHuME
- Data favor KMR model (uncertainty ~factor of 3)

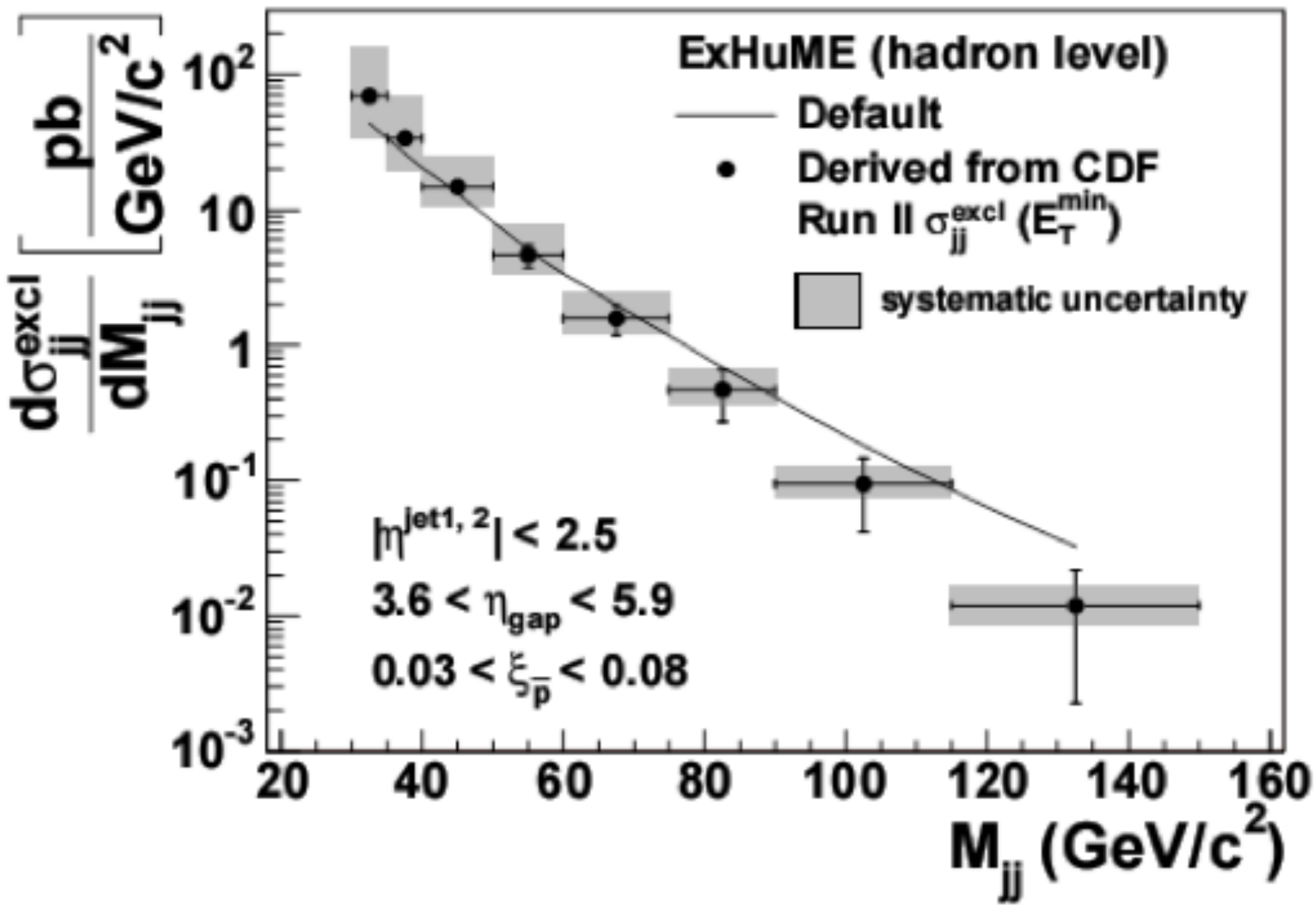


# Summary

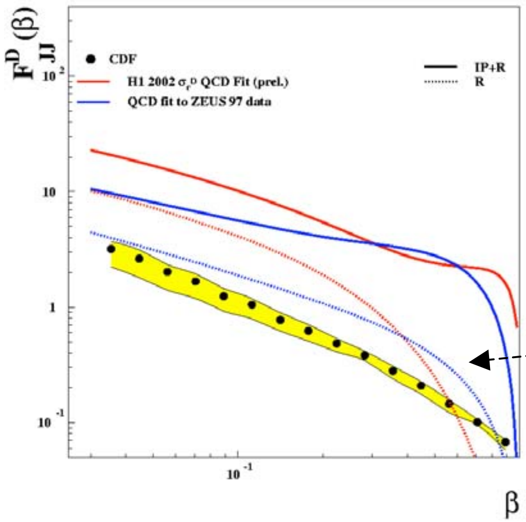
- CDF diffractive program continuing the improvement of understanding of diffractive processes
  - measured DSF at different $Q^2$ values
  - measured t-distribution in diffractive events
  - Dijets, W/Z, forward jets, exclusive jets
- Comparison of diffractive and non-diffractive processes
- Measurements of exclusive production important to calibrate predictions for exclusive Higgs production at LHC
- General tools which can be used at LHC:
  - Roman Pot dynamic alignment
  - use calorimeter information to measure $\xi$

# backup

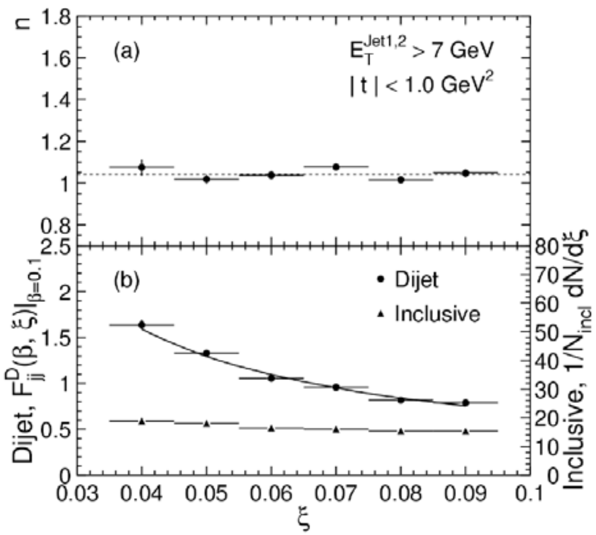
# Exclusive cross section



# a few comments



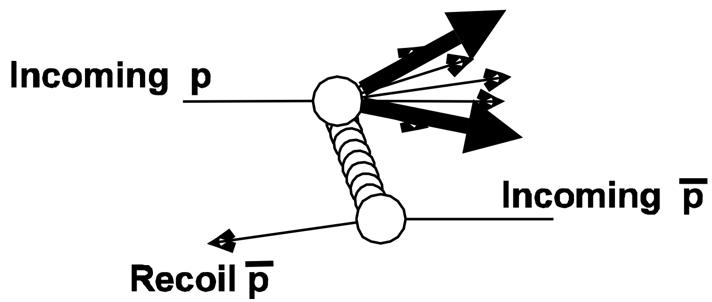

- large uncertainty at high β (no coverage!) but result stable at low β
- small reggeon contribution

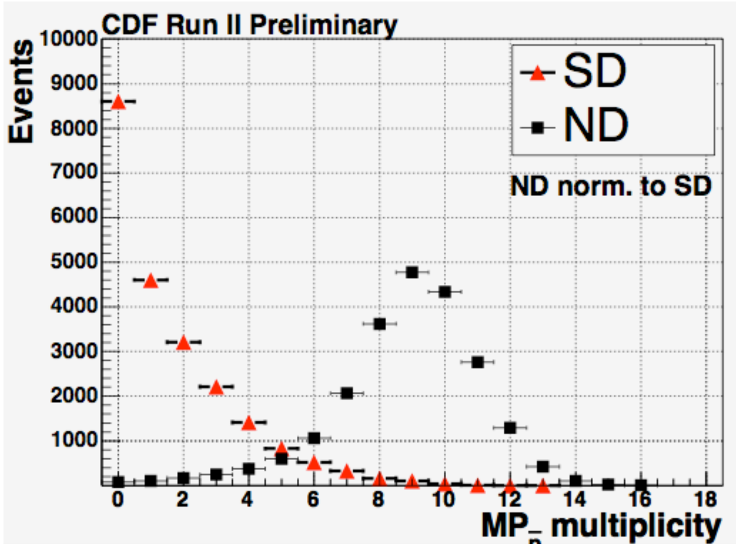



- $F_{jj}^D(\beta,\xi) \sim 1/\beta^n$ [indep. of ξ]
  - ⇨ no change from IP to IR region
- $F_{jj}^D(\beta=0.1,\xi) \sim 1/\xi^m$ m=1.0±0.1 for dijets
  - ⇨ dijets are IP dominated, `inclusive' more IR like

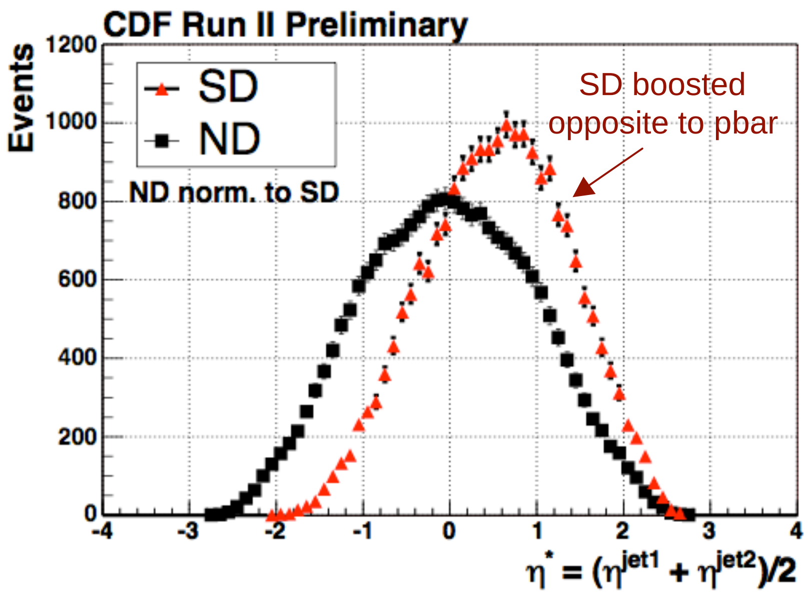
**ξ-**dependence is IP like (m for IP is ~1.1, for IR ~0 at Tevatron)

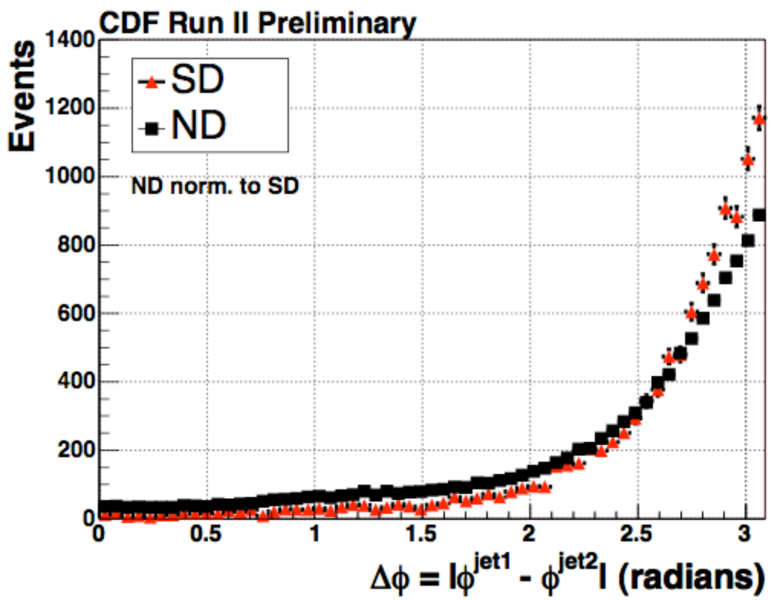
# Kinematical properties



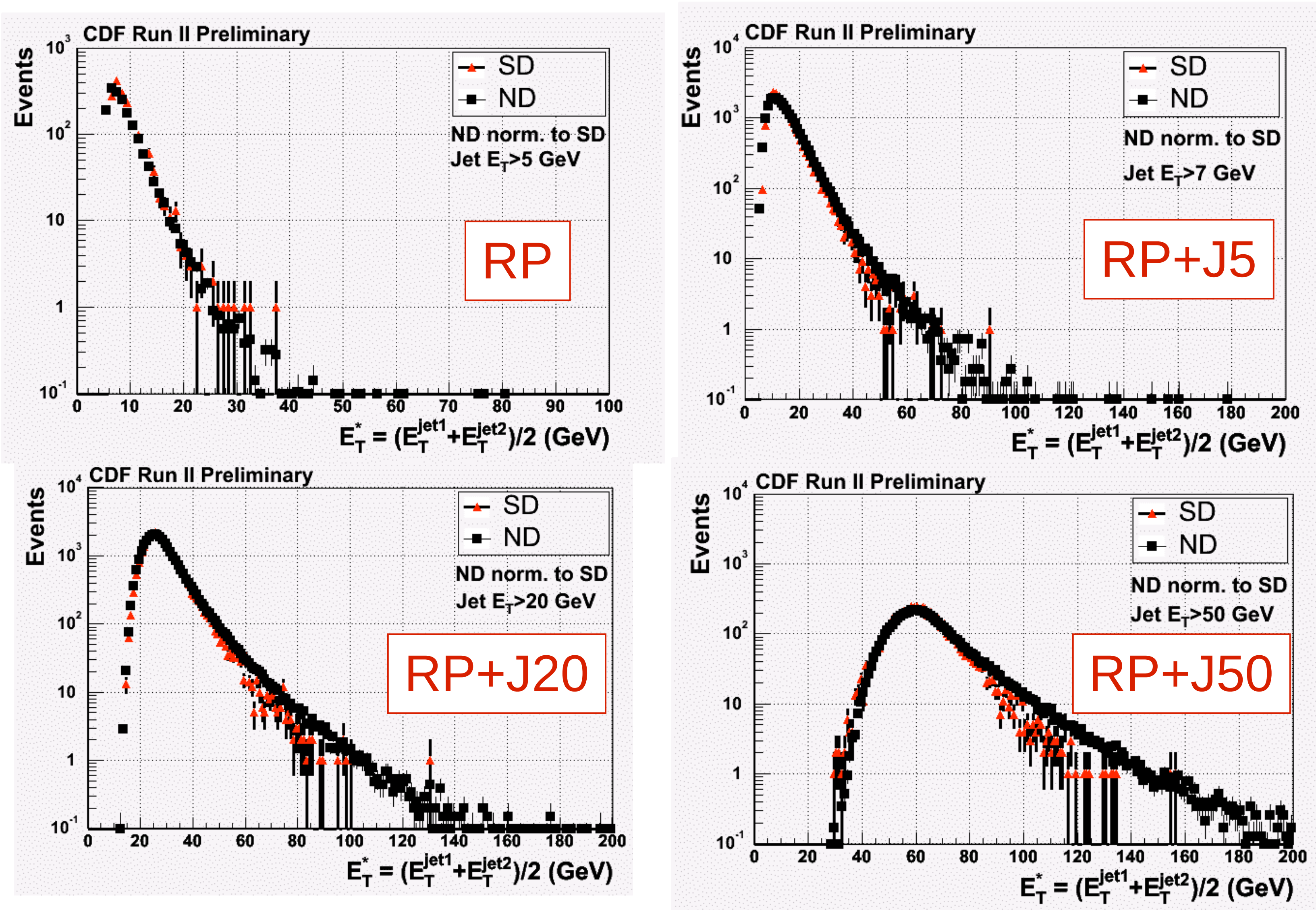




⇨compare ND and SD



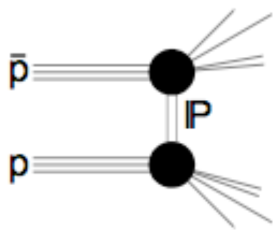



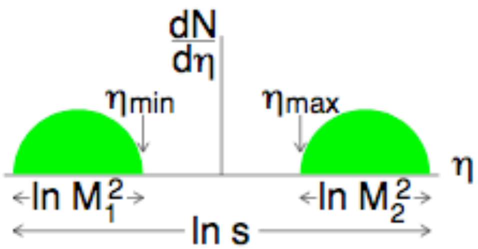
# Transverse energy



# Rapidity gap fraction vs gap width

- Soft double diffraction
- No hard scattering required
- Look for rapidity gaps

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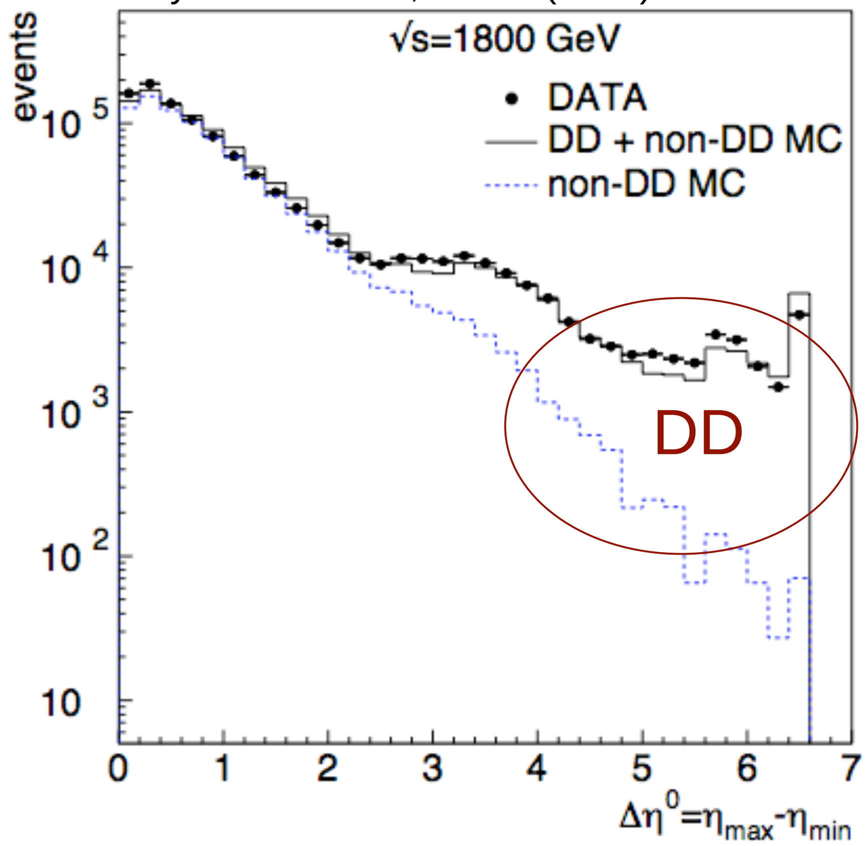
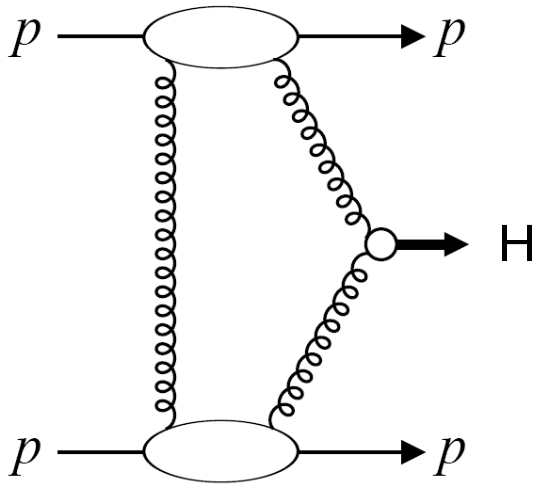


# Exclusive production

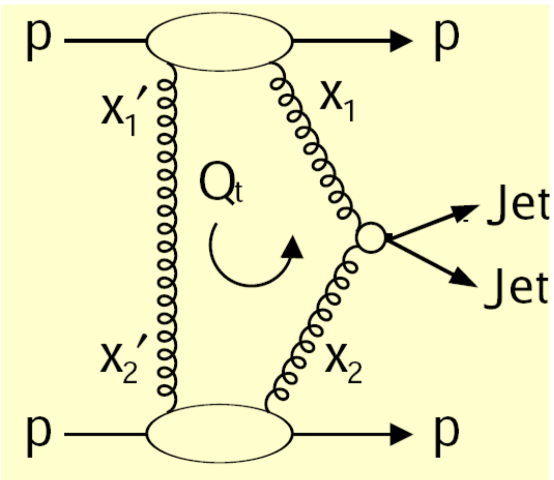



✓clean process

✓exclusive $b\bar{b}$ suppressed

Khoze Martin Ryskin: $\sigma_H$(LHC)~3 fb, signal/bkg~3 (if $\Delta M_{miss}$=1 GeV)

Attractive Higgs discovery channel at the LHC




⇨much larger cross section

Goal:

- ➢measure exclusive dijet production (if it exists)
- ➢test/calibrate Higgs predictions at LHC