Experimental results on diffraction at CDF

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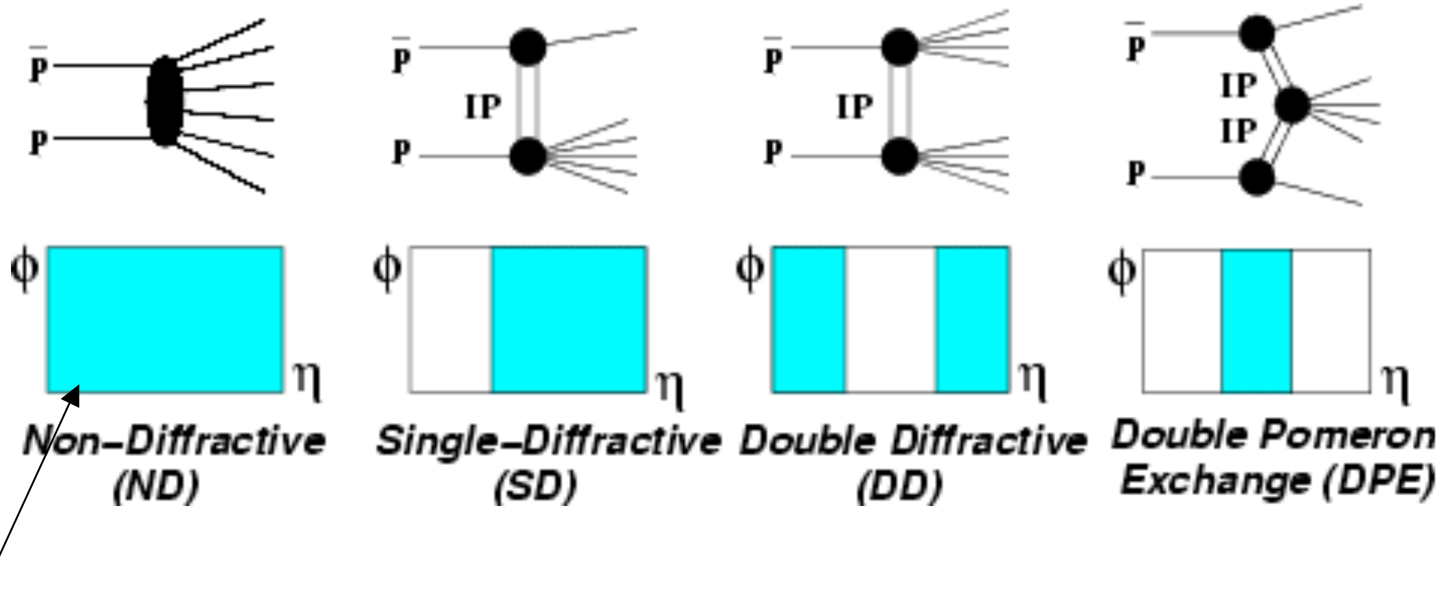
(on behalf of the CDF collaboration)

May 28, 2010

- Introduction
- Diffractive production (dijets, W/Z, Forward jets)
- Exclusive production (dijets, $\gamma\gamma$, ee)
- Conclusions

Introduction

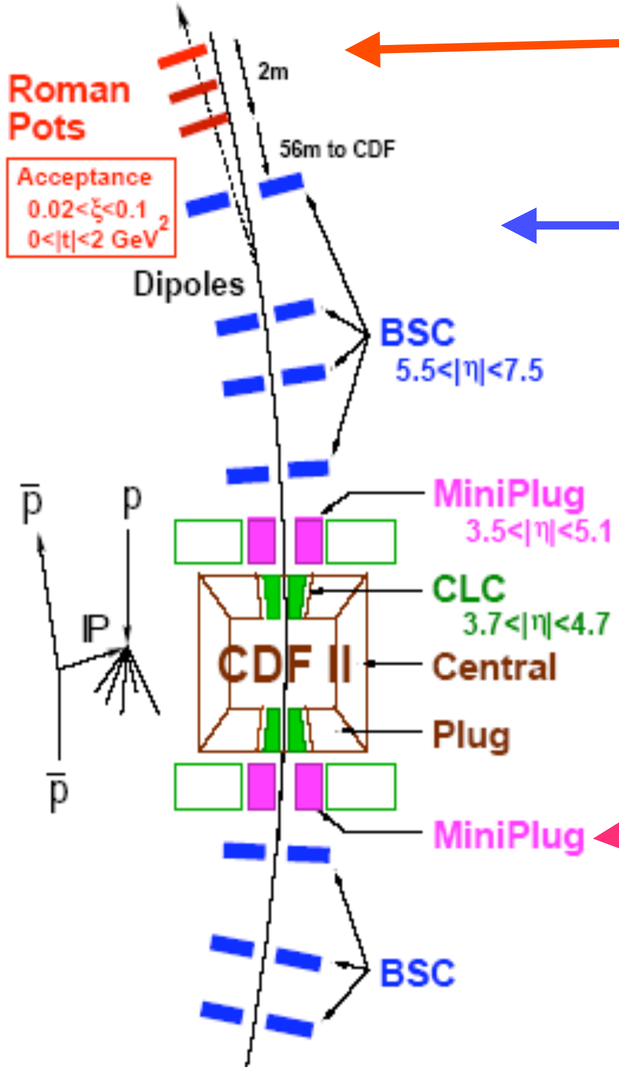
- In diffraction no quantum numbers are exchanged



Shaded area corresponds to particle production

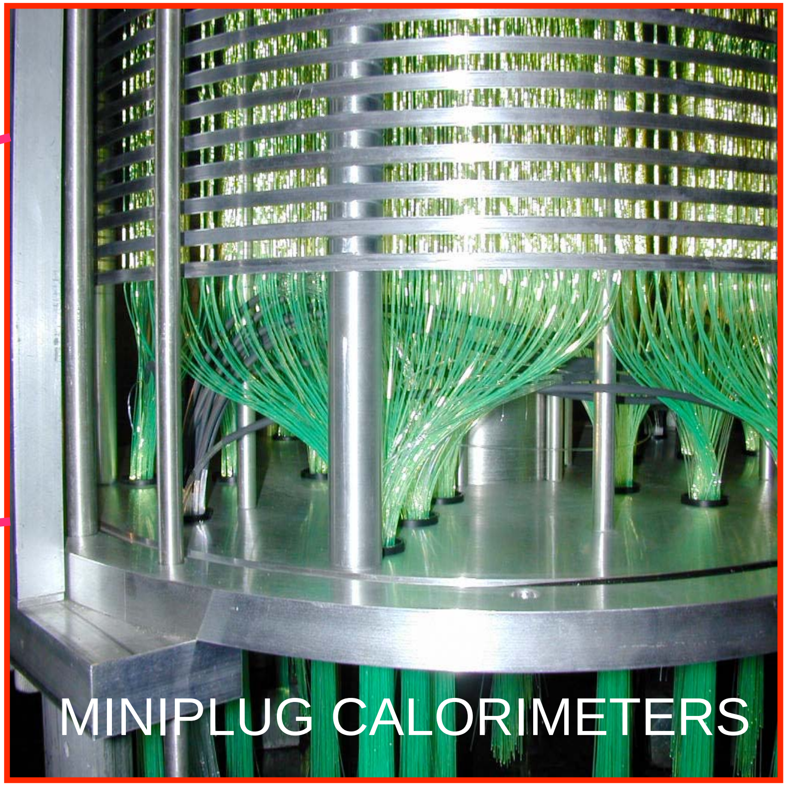
For overview see K. Goulianos' talk

CDF central and forward detectors



ROMAN POT DETECTORS

BEAM SHOWER COUNTERS: used to reject ND events

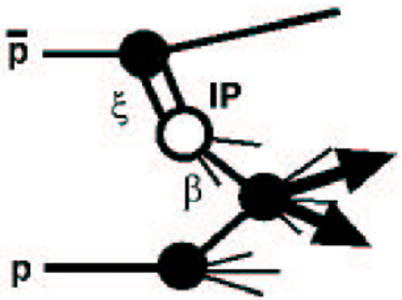


MINIPLUG CALORIMETERS

Single diffraction

- Examine partonic structure of diffractive exchange using high-p_T probes (hard diffraction)
- Confirm and extend the kinematical reach of Run I results
  - Diffractive dijet production in ranges of Q^2
  - Diffractive structure functions

Diffractive dijets



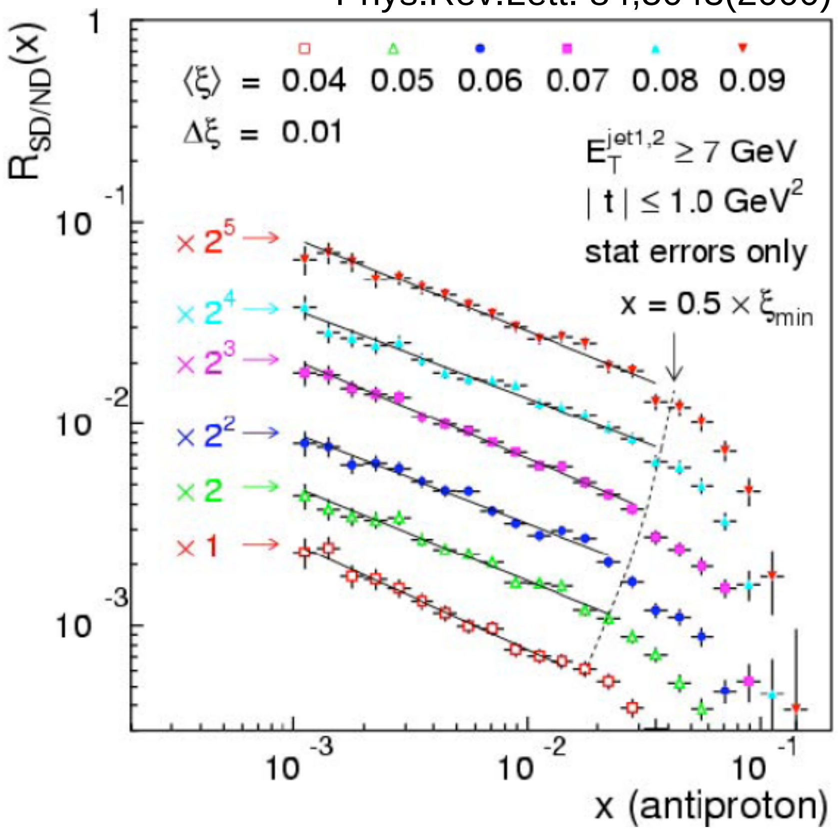
ξ: fraction of anti-proton momentum loss

β: fraction of Pomeron momentum carried by parton

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

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

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



Measure SD/ND ratio of dijet rates

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

measure — extract — known — (LO QCD)

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

⇨**no significant ξ dependence**

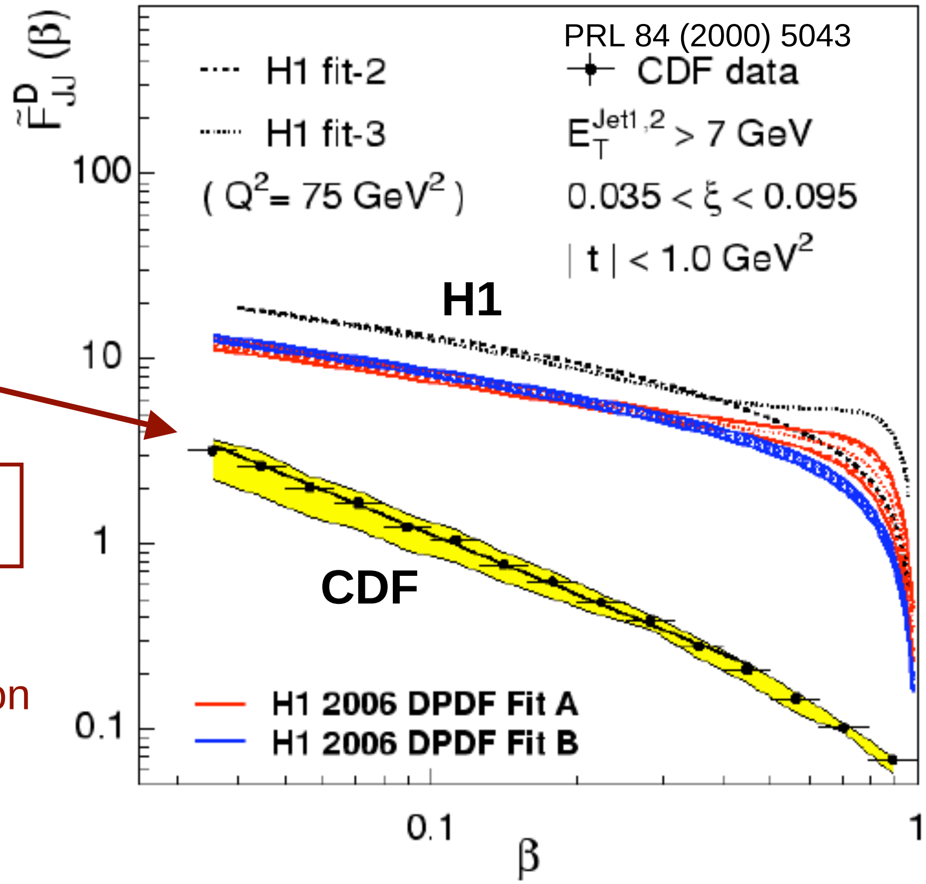
in the ratio SD/ND many systematic uncertainties cancel out

Diffractive structure function

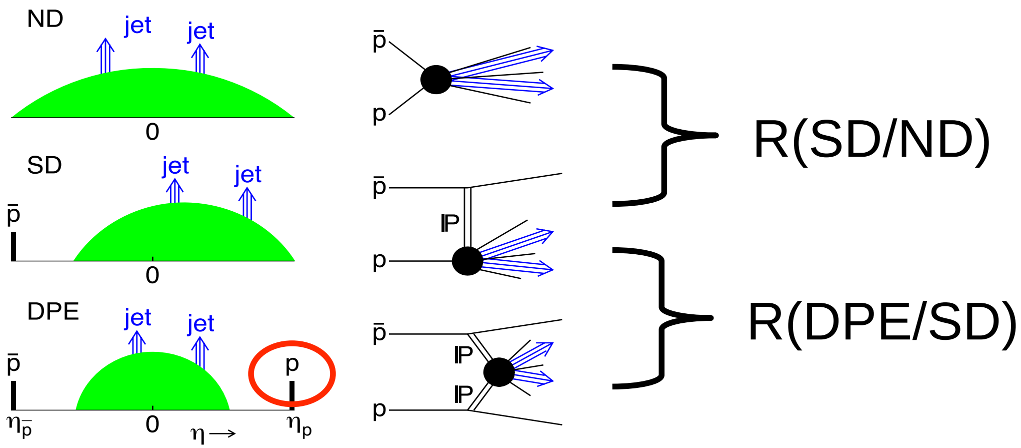
CDF Run I result suppressed
by factor of ~10 relative to HERA

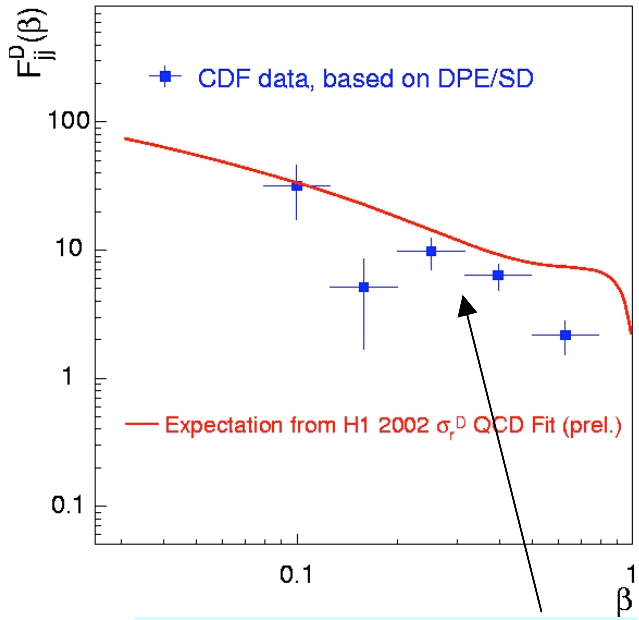
⇨breakdown of QCD factorization

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



Restoring factorization





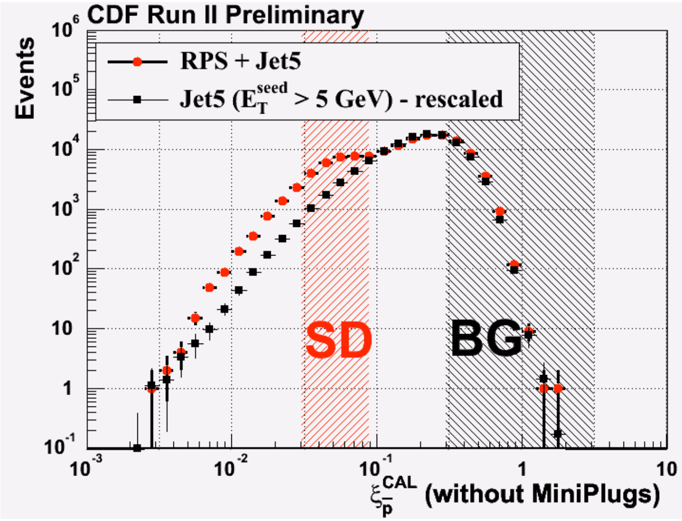
factorization is restored !

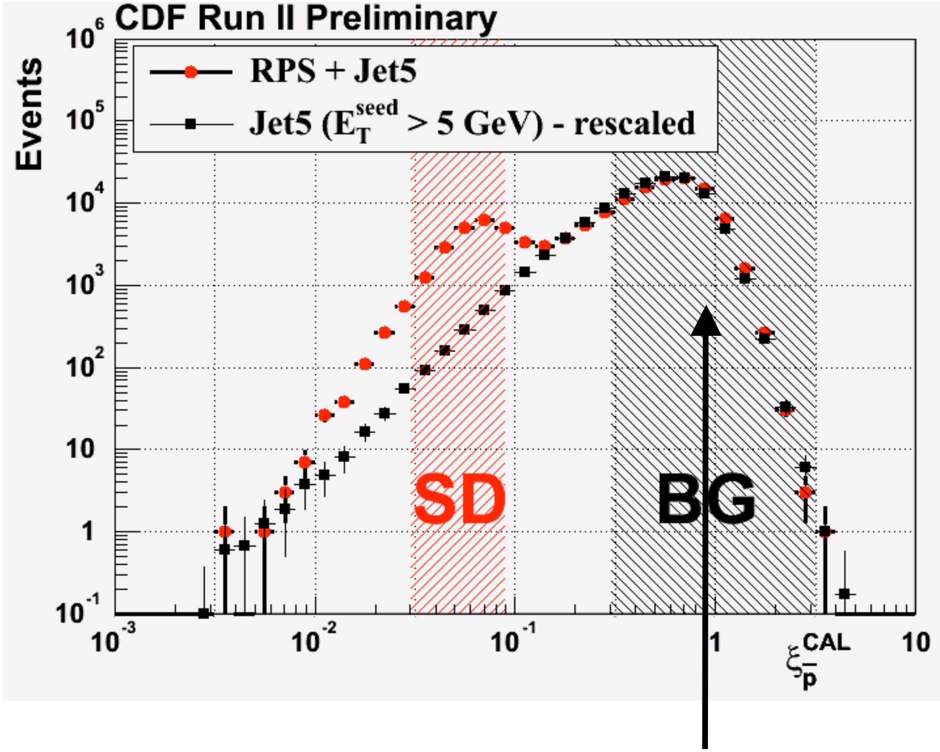
The diffractive structure function measured using DPE events is approximately the same as the one expected from HERA

Event selection in Run II

ξ: momentum loss fraction of pbar

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



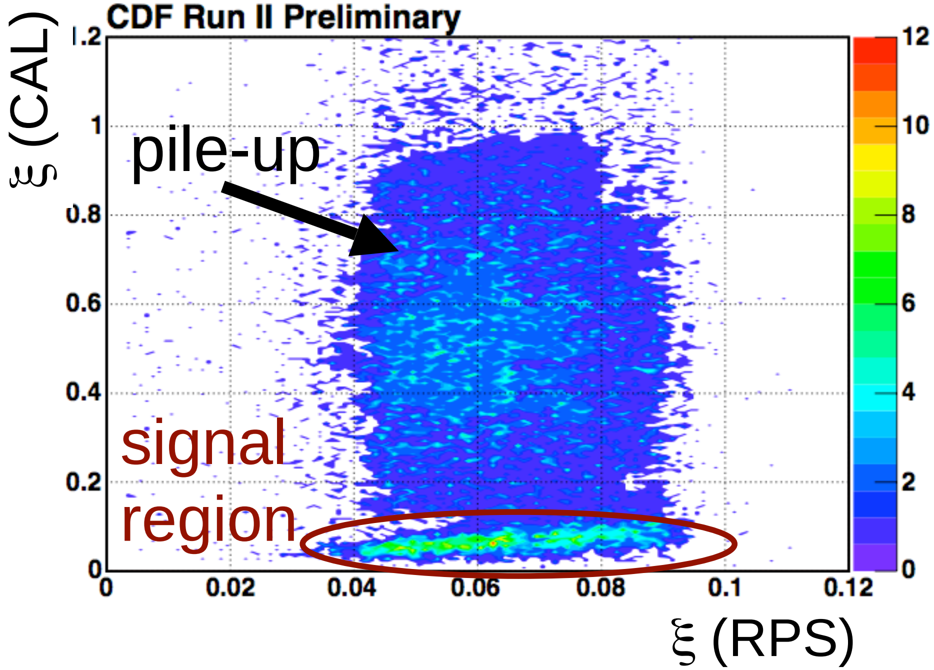


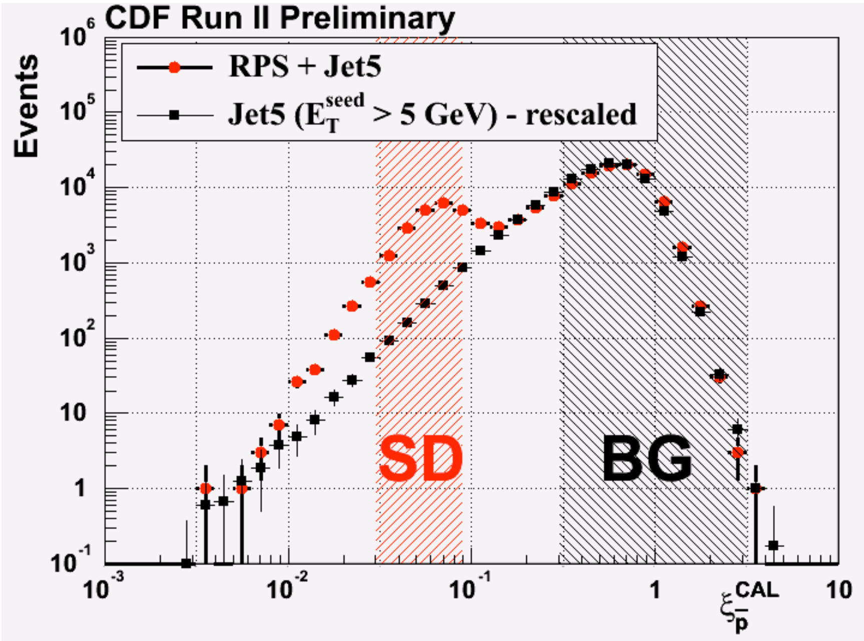
overlap events
(multiple $p\bar{p}$ interactions)

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

Multiple interactions in Run II

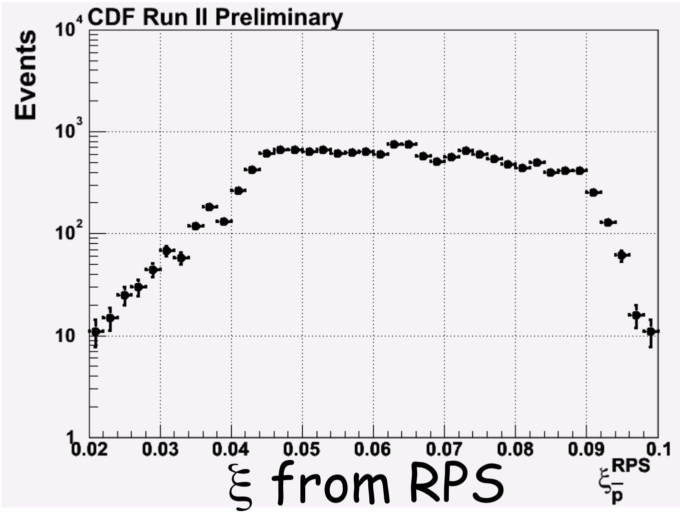
- Multiple proton-antiproton interactions spoil diffractive signature

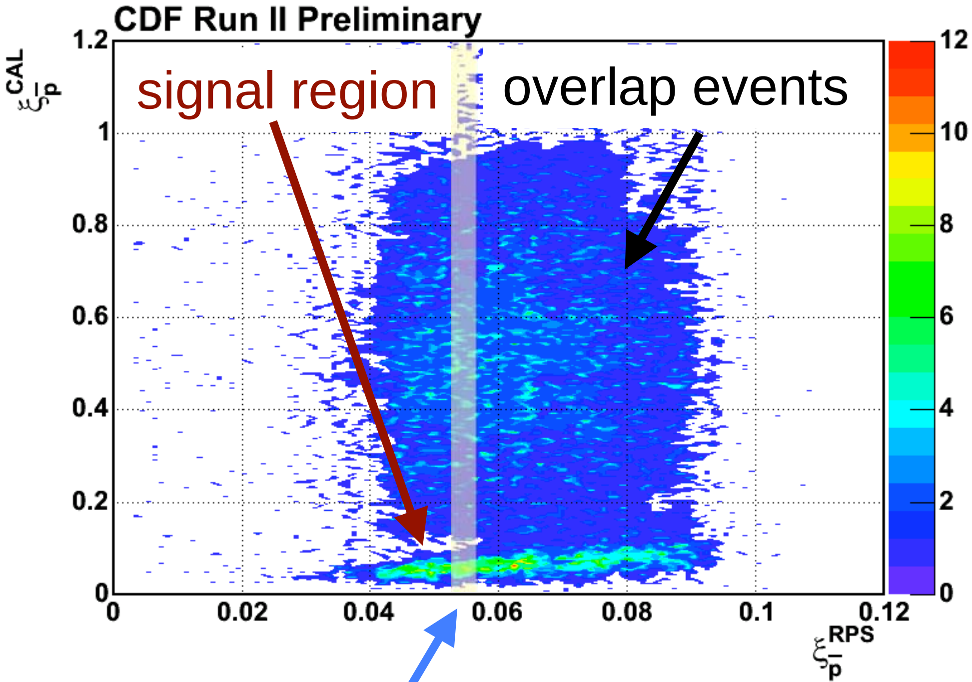


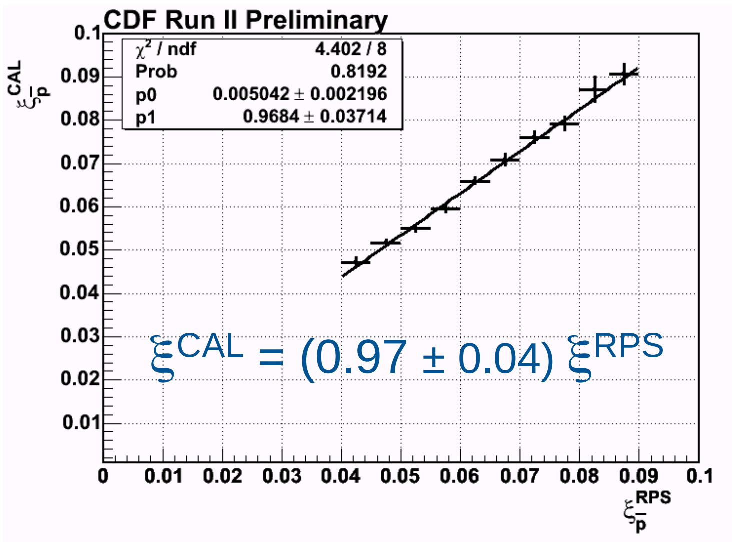


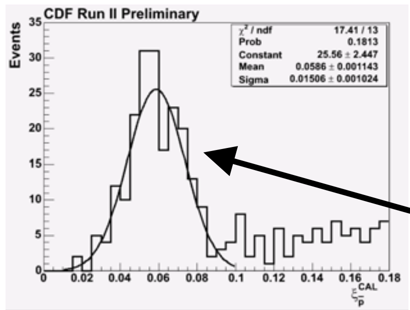
- Measure ξ from calorimeter and from RP tracking
- Reject multiple interactions
  - exclude ξ>0.1 (ND+SD interactions)

Multiple interactions in Run II





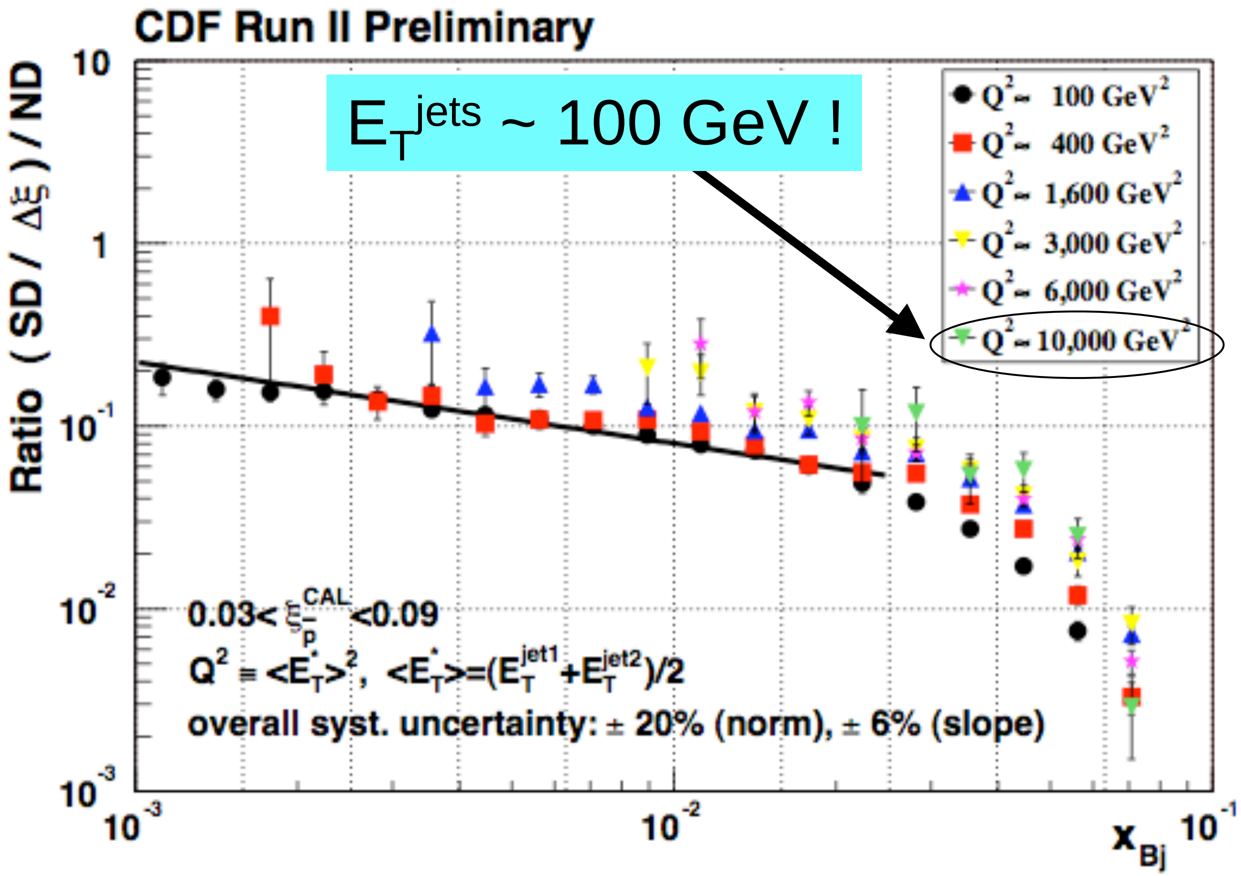




ξ^{cal} distribution for slice of ξ^{RPS}

σ / mean ~ 30%

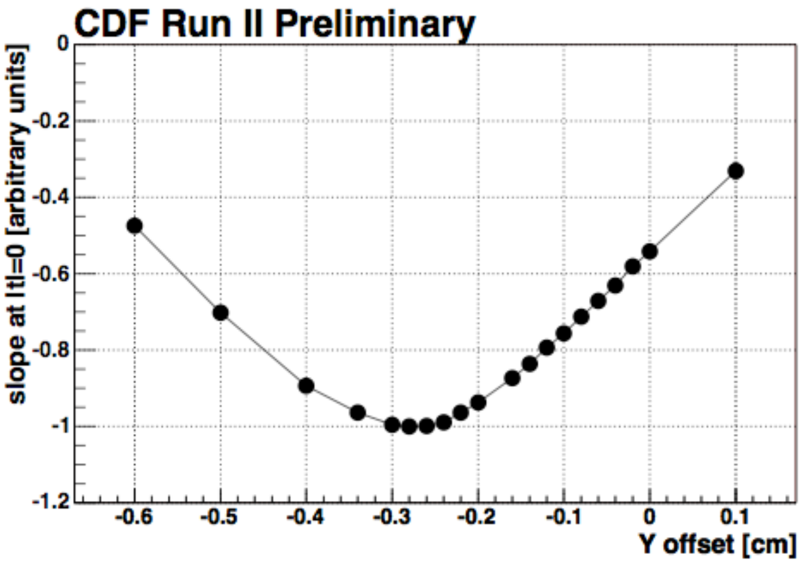
Q^2 dependence



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

⇨ Pomeron evolves as proton

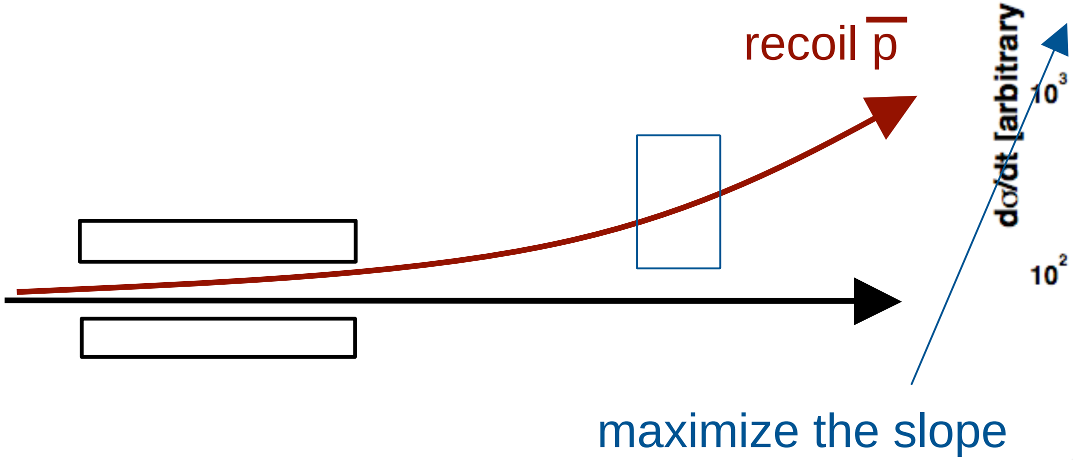
RPS dynamic alignment

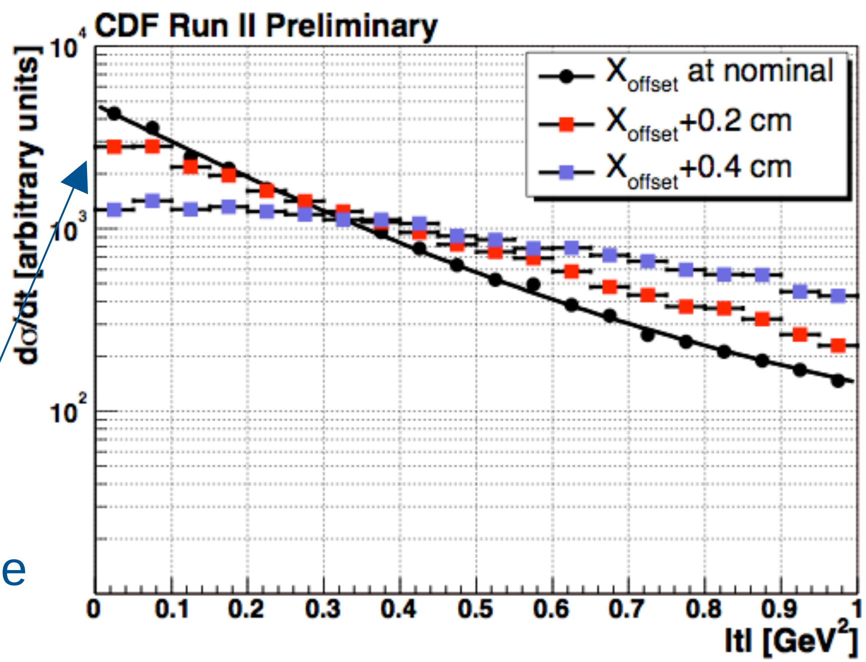


arXiv:hep-ex/0606024

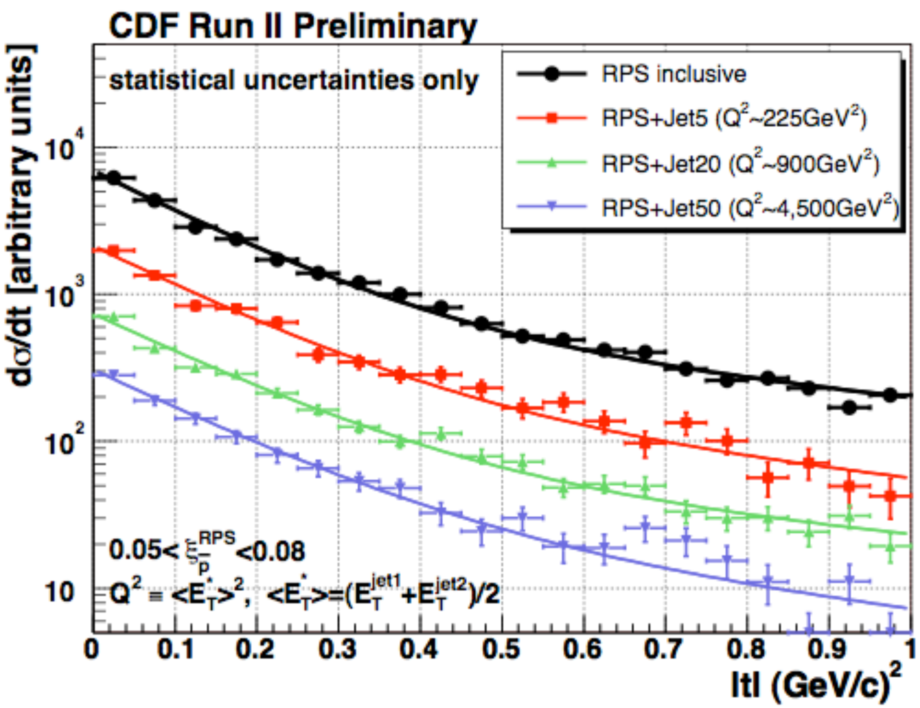
maximize the |t|-slope
(normalized to max slope)

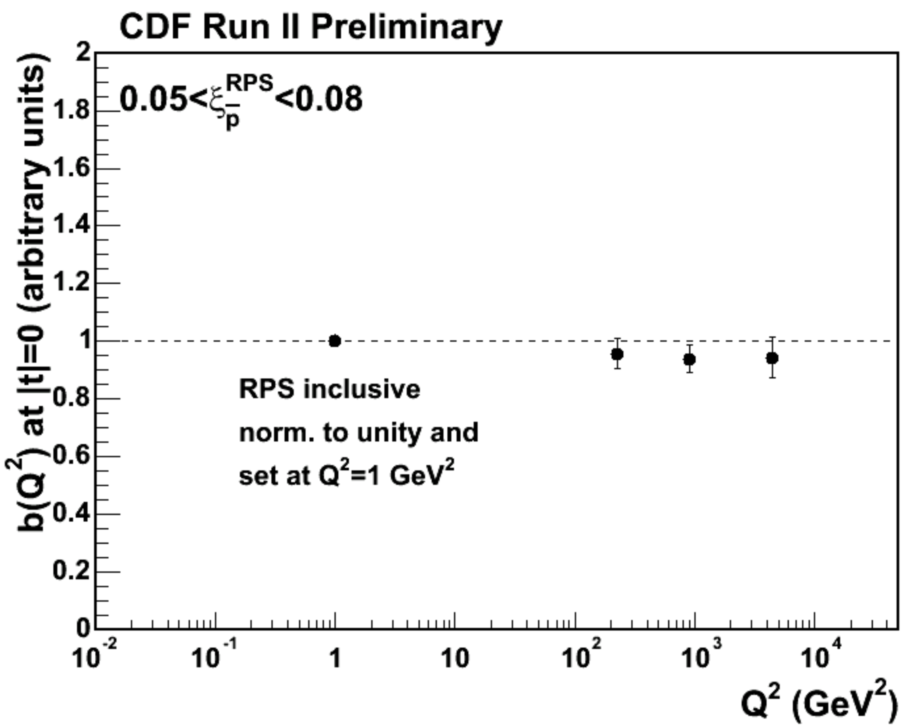
⇨determine X and Y offsets





|t| distribution

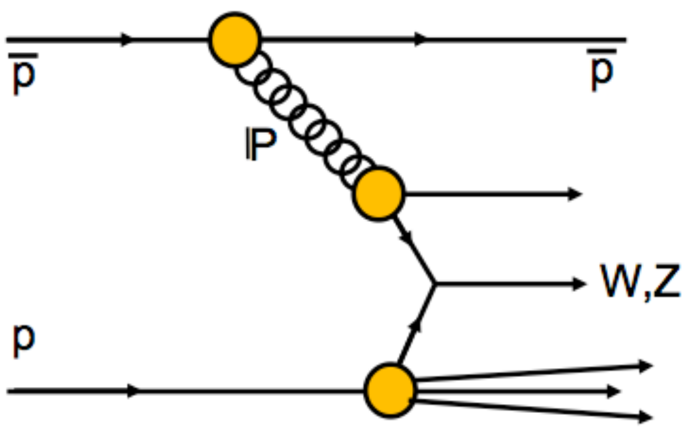


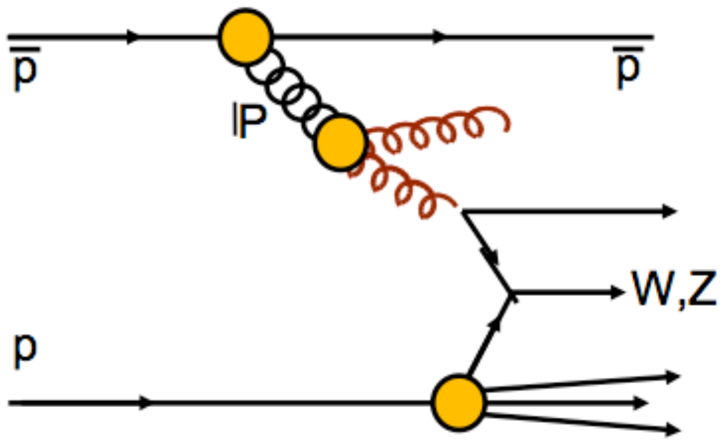


- No diffraction `dips' observed at |t|<1
- Soft and hard diffractive events have the same slope

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

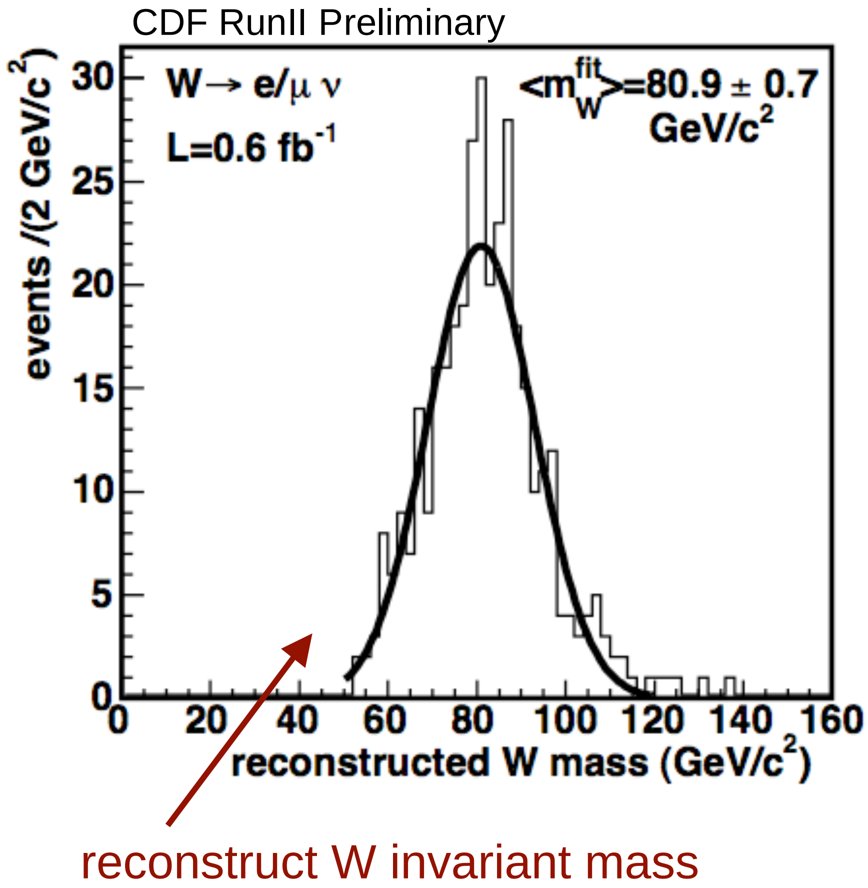
Production by a gluon is suppressed by α_s. Can look at additional jet.

Diffractive W/Z production (cont)

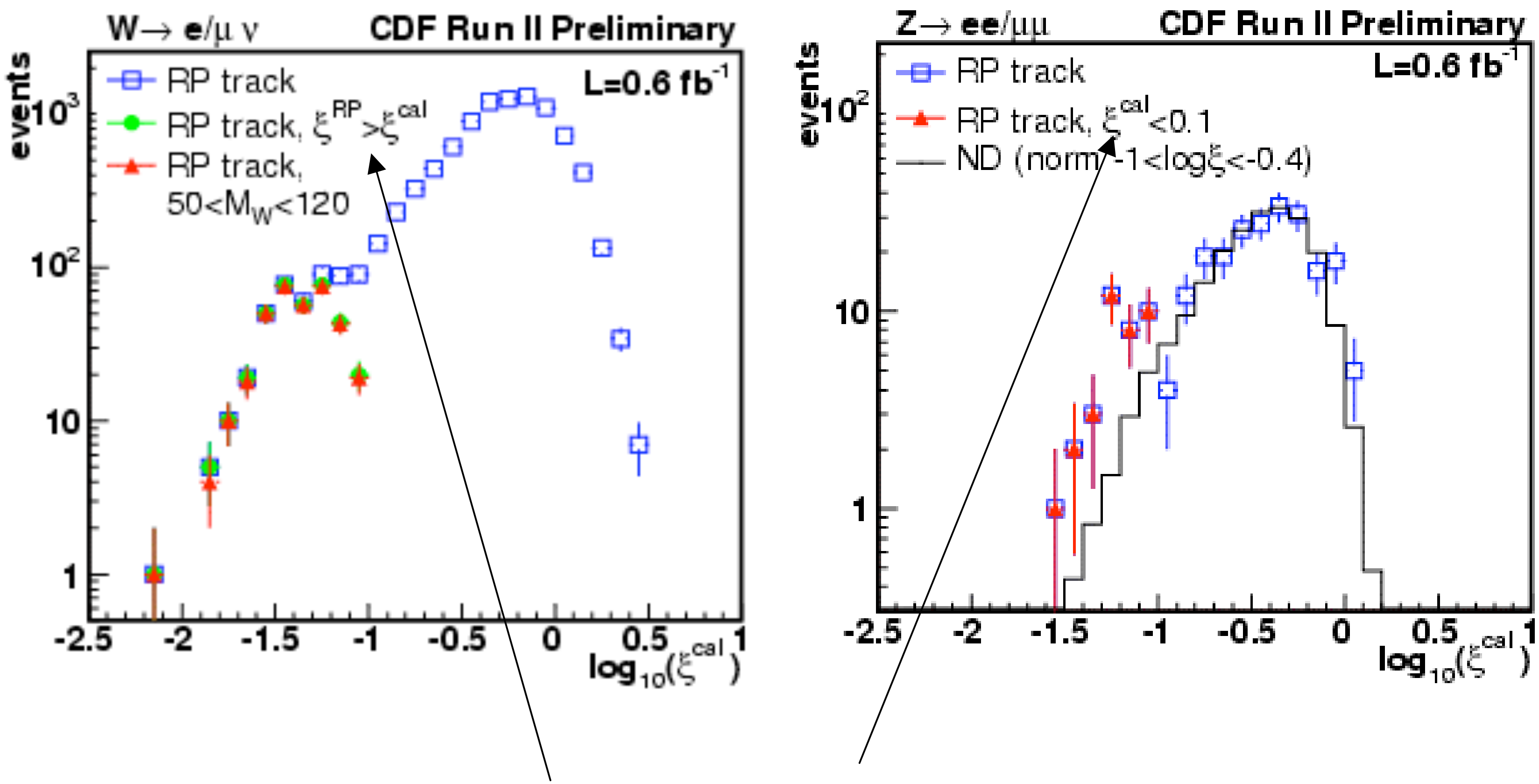
- Identify diffractive events using RPS
- Calculate ξ from calorimeter
- In W production, difference ξ^{cal}-ξ^{RPS} is due to missing E_T, and η_ν.

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

- Can estimate:
  - neutrino kinematics
  - W kinematics
  - x_{Bj}
- Then, determine structure function in diffractive W production



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) ± 0.10(syst) %
R_Z = 0.85 ± 0.20(stat) ± 0.08(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%]

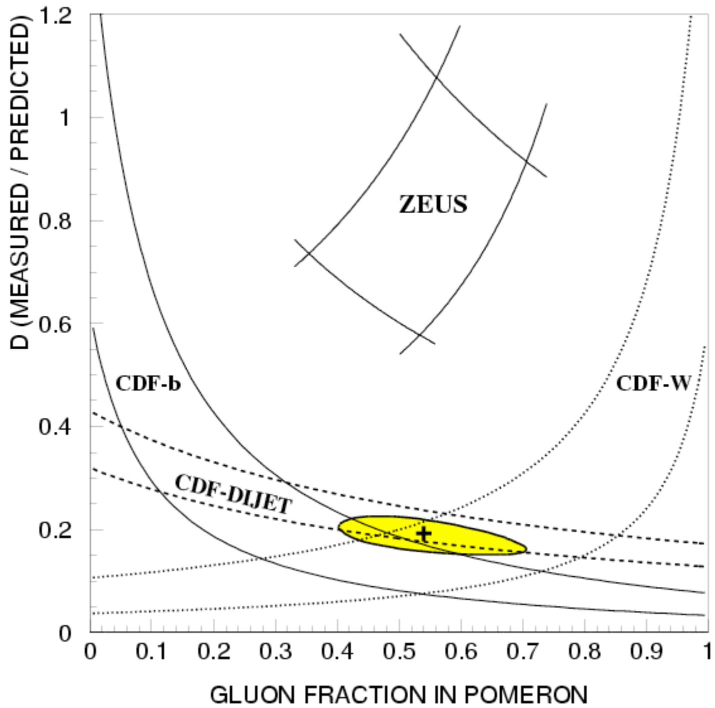
Diffractive rates

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

Measured SD/ND fractions at 1.8 TeV

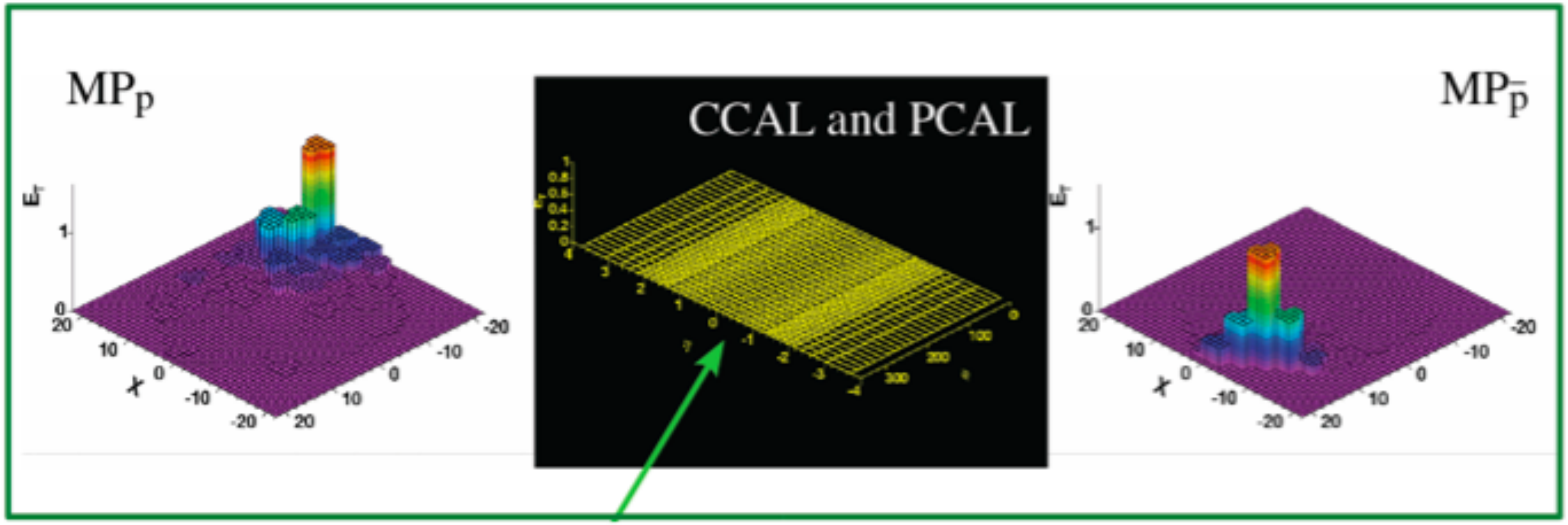
PRL	process	fraction [%]
84 (1997) 2698	W(eν)	1.15 (0.55)
PLB 574 (2003) 169	Z	1.44 (0.60)
84 (1997) 2636	jet-jet	0.75 (0.10)
84 (2000) 232	b	0.62 (0.25)
87 (2001) 241802-1	J/ψ	1.45 (0.25)

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

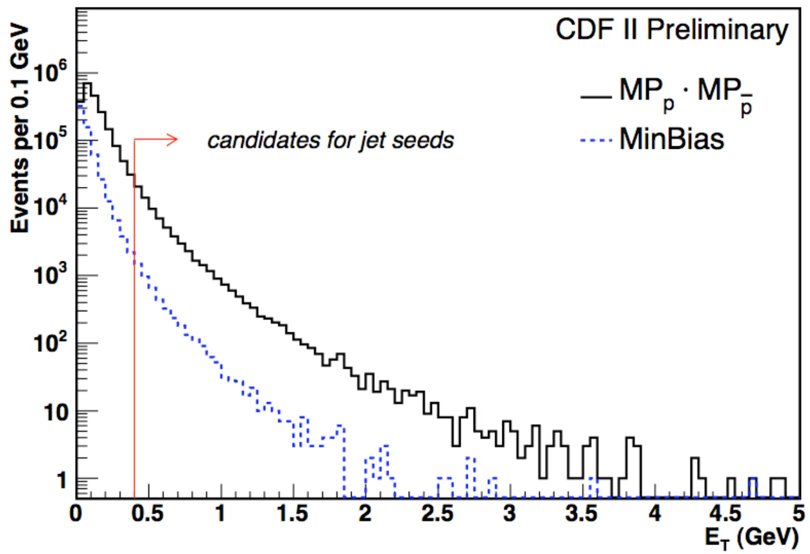


- All SD/ND fractions ~ 1% ⇨ uniform suppression
- Different sensitivities to quark/gluon ⇨ gluon fraction f_g=0.54 (0.15)

Central gap between forward jets

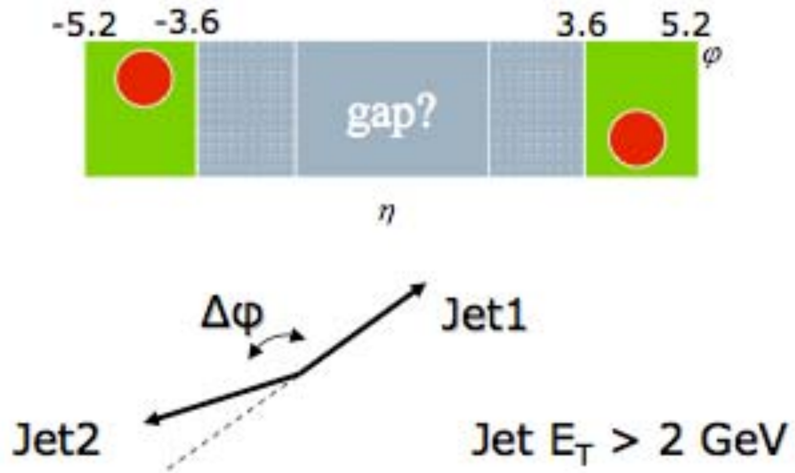


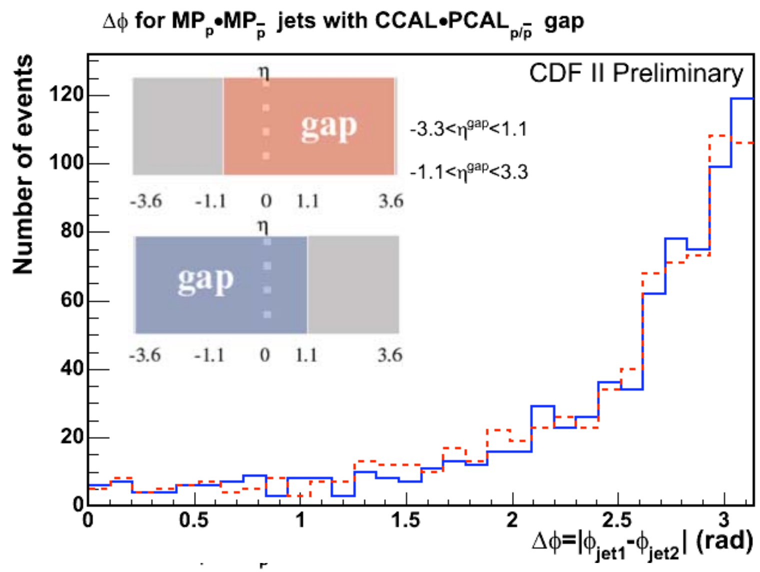
Rapidity gap in Central and Plug calorimeter

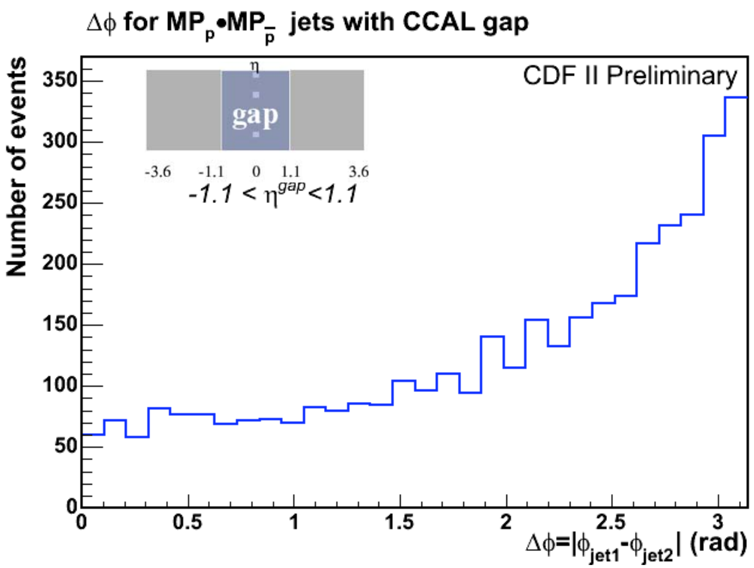


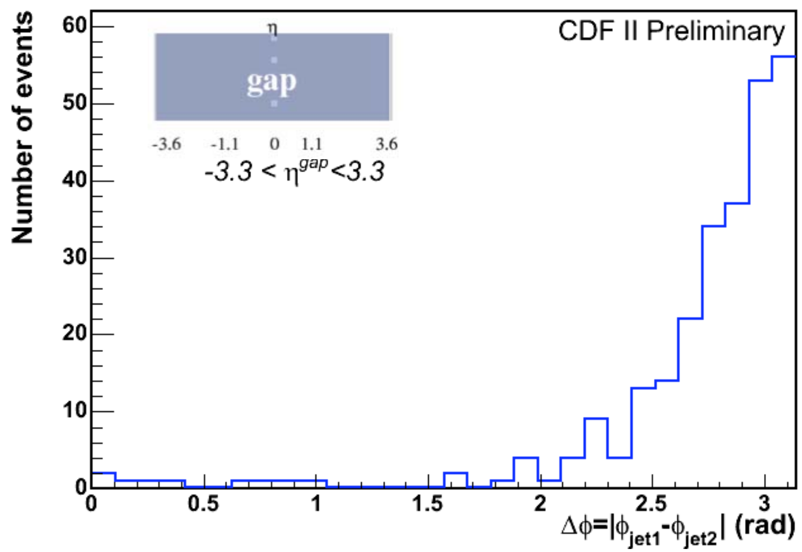
- Characterize gap formation
  - fraction of gap events (soft and hard interactions)
  - dependence on gap size
- Mueller-Navelet jets

Jet Δϕ correlation

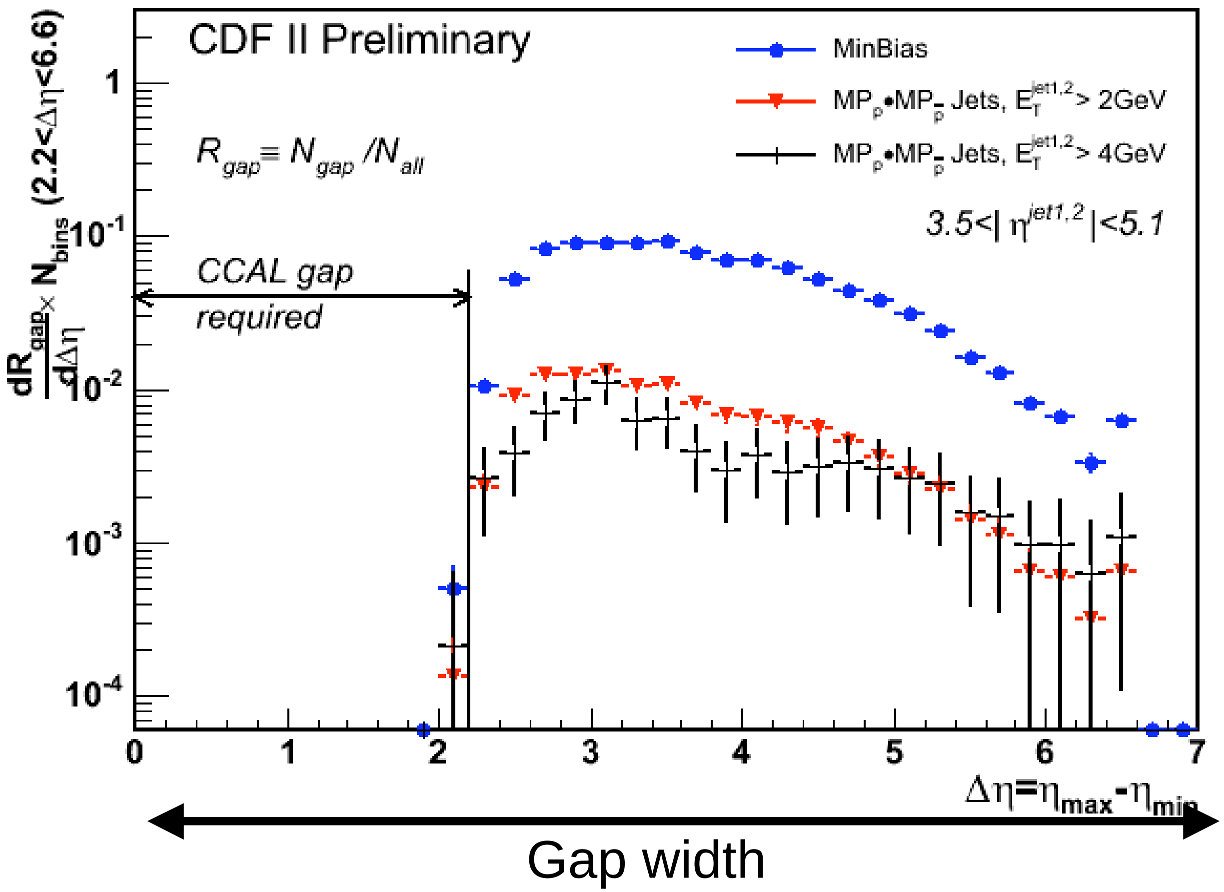


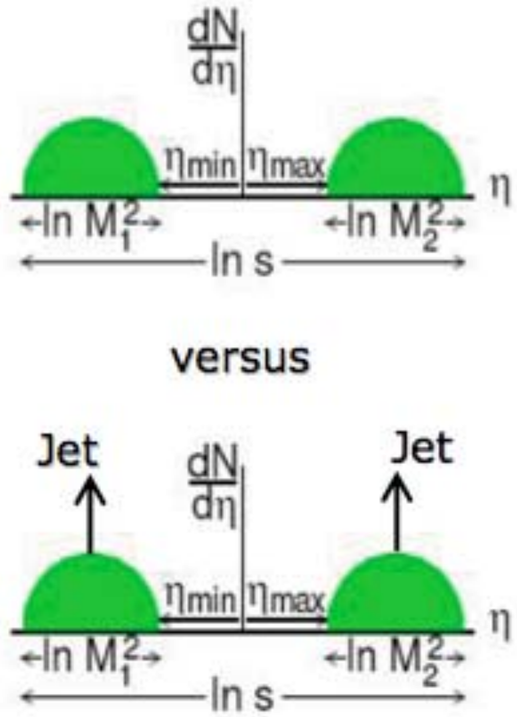






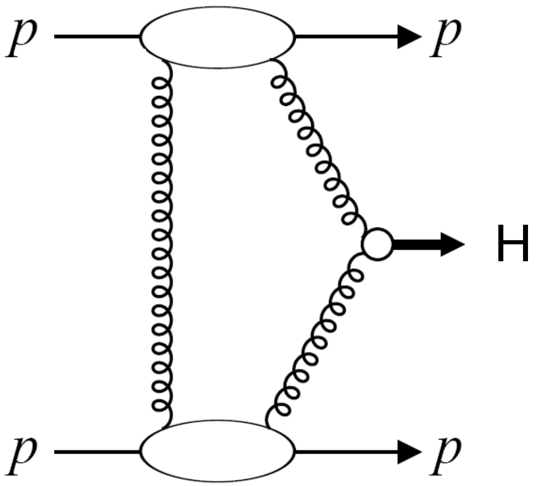
Rapidity gap event fraction





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

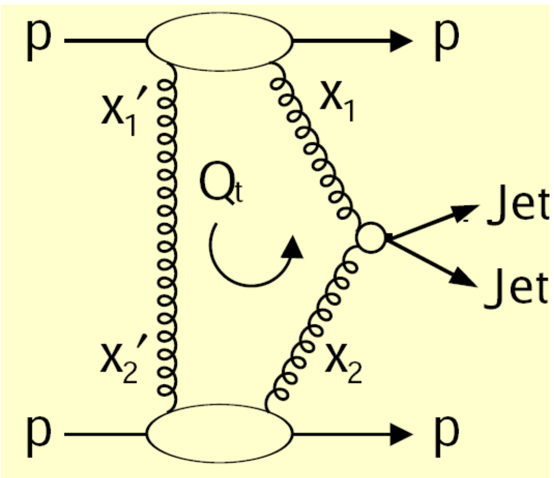
Exclusive production



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

Khoze Martin Ryskin: σ_H(LHC)~3 fb, signal/bkg~3 (if ΔM_{miss}=1 GeV)

Attractive Higgs discovery channel at the LHC

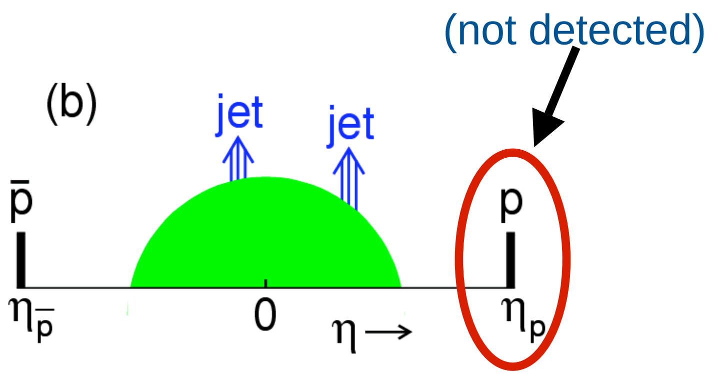


⇨much larger cross section

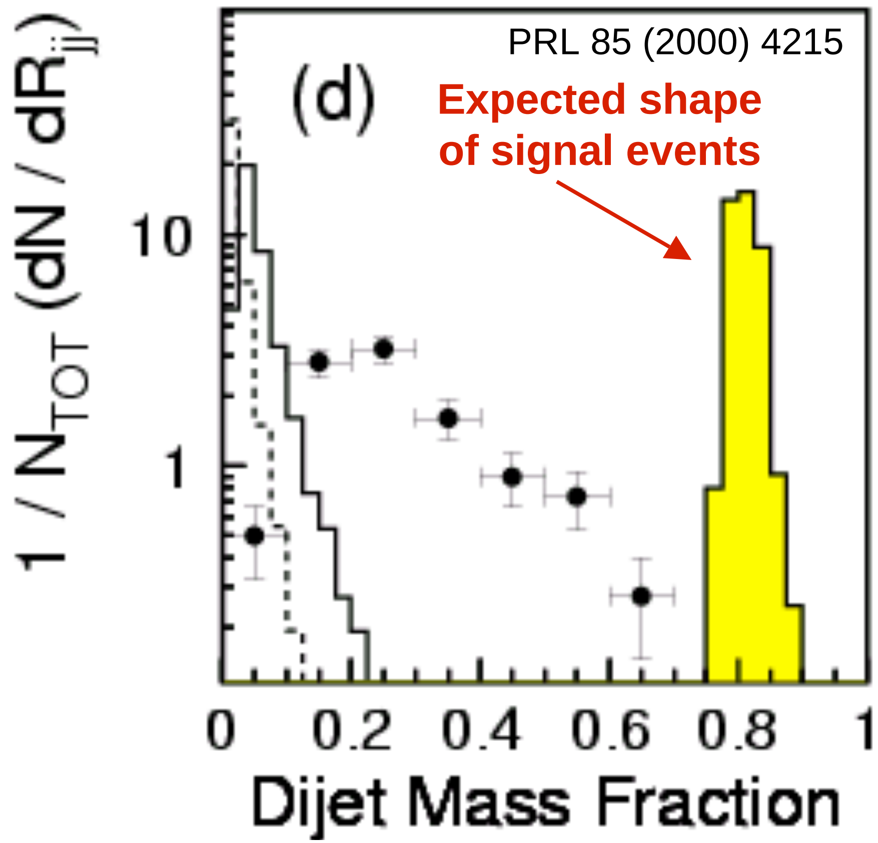
Goal:

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

Exclusive dijets in Run I



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

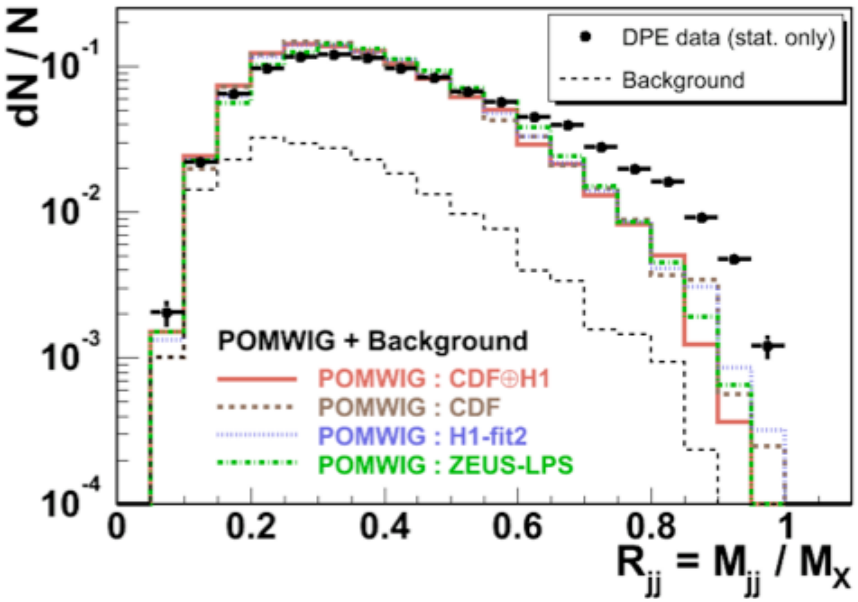


Exclusive dijet limit:
Run I: PRL 85 (2000) 4215
⇨ σ_{jj} (excl.) < 3.7 nb (95% CL)

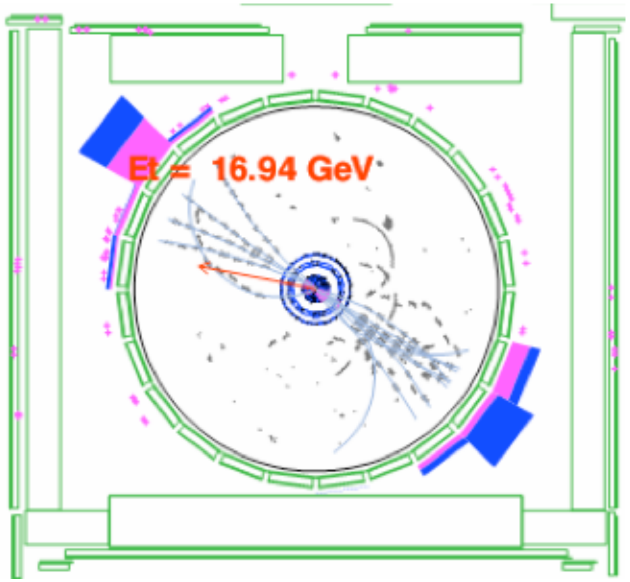
Observation of exclusive dijets

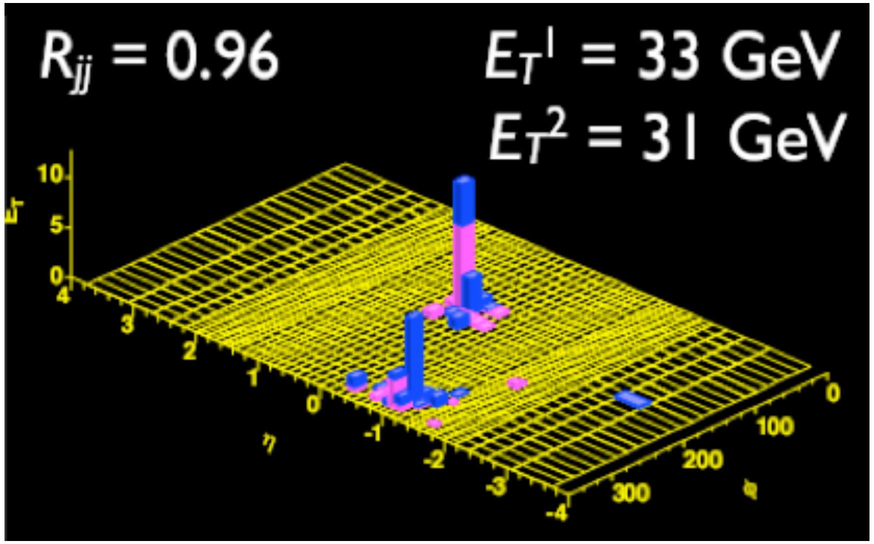
Phys.Rev.D77:052004,2008

Observe excess over
inclusive DPE at large Mjj



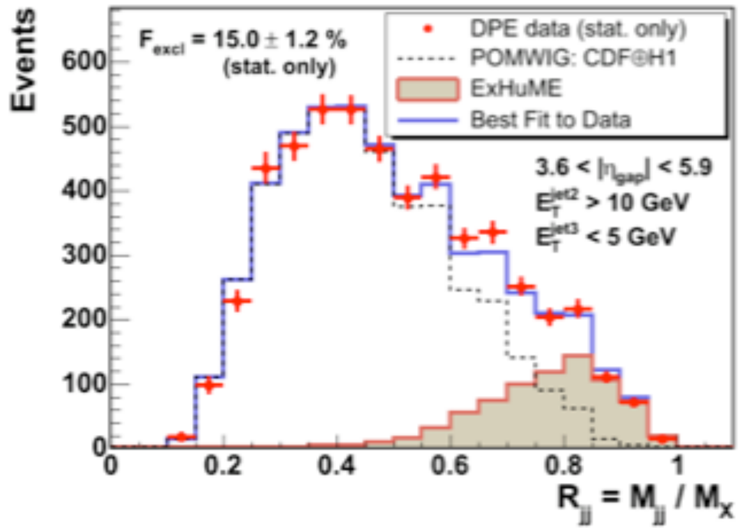
⇨ exclusive signal?

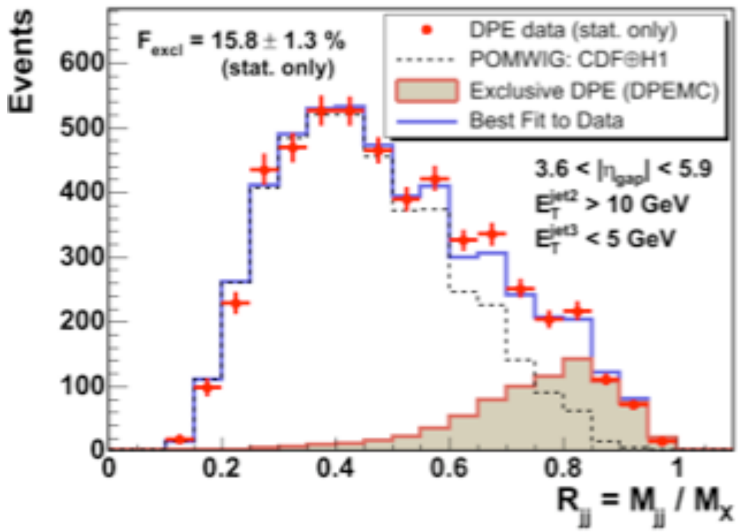




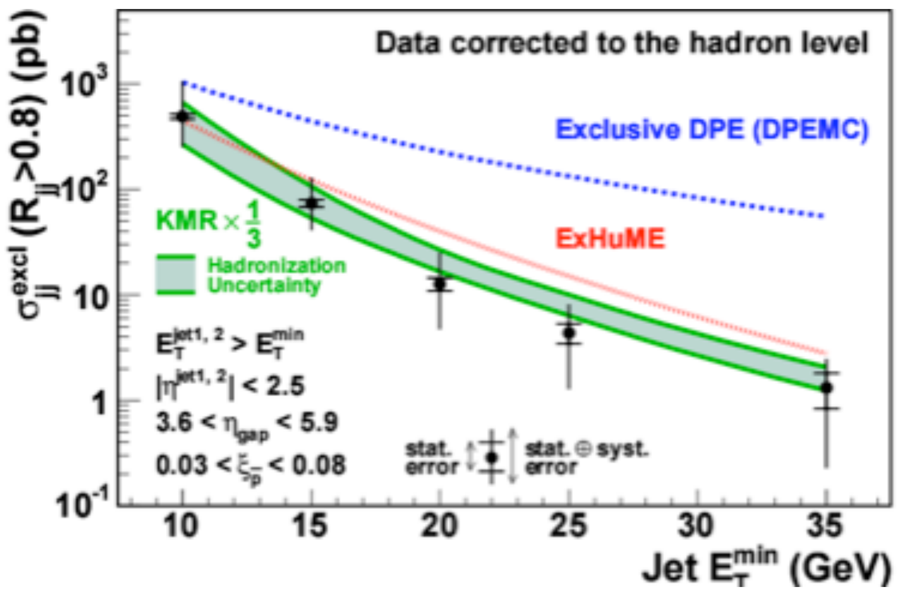
Exclusive dijet cross section

Phys.Rev.D77:052004,2008

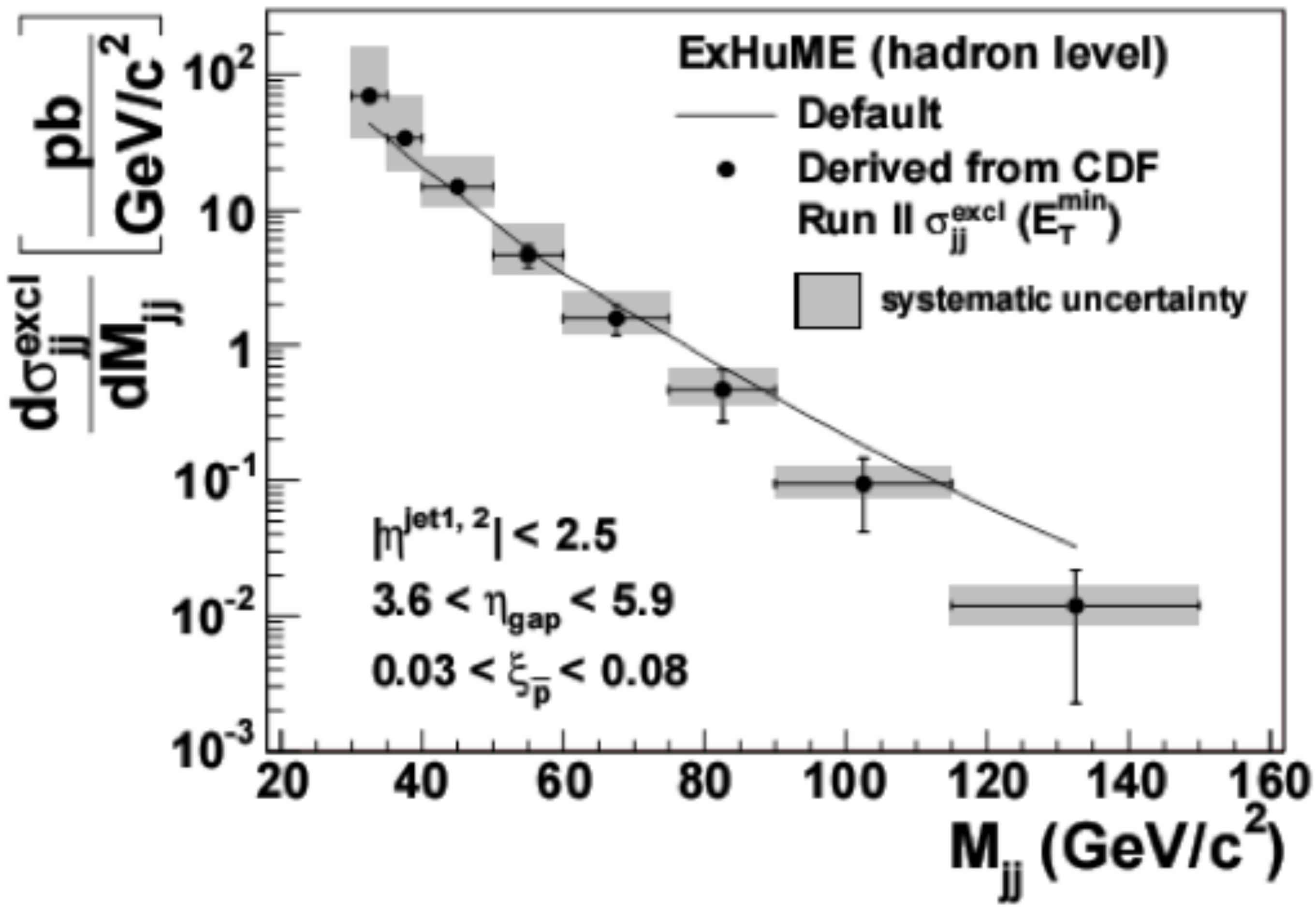




- R_{jj} shape described by MC based on two models (ExHuME, DPEMC)
- Cross section agrees with ExHuME
- Data favor KMR model (uncertainty ~factor of 3)



Exclusive cross section



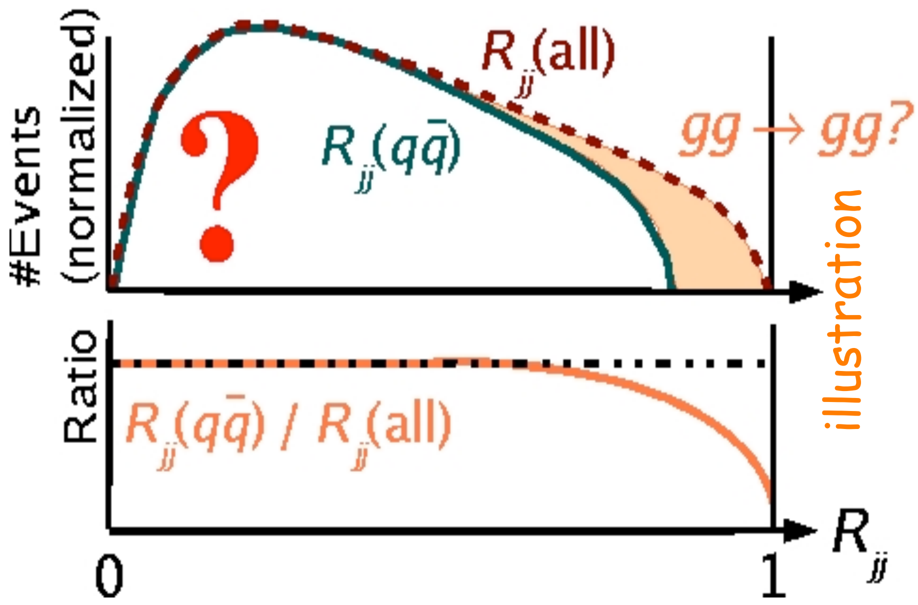
Exclusive dijets w/heavy flavor

Theory:
J_Z=0 spin selection rule
gg→gg dominant contribution at LO
gg→$q\bar{q}$ suppressed when $M_{jj} >> m_q$

Experimental method:
normalize R_{jj} for $q\bar{q}$ to R_{jj} for all jets
⇨look for event suppression at large R_{jj}

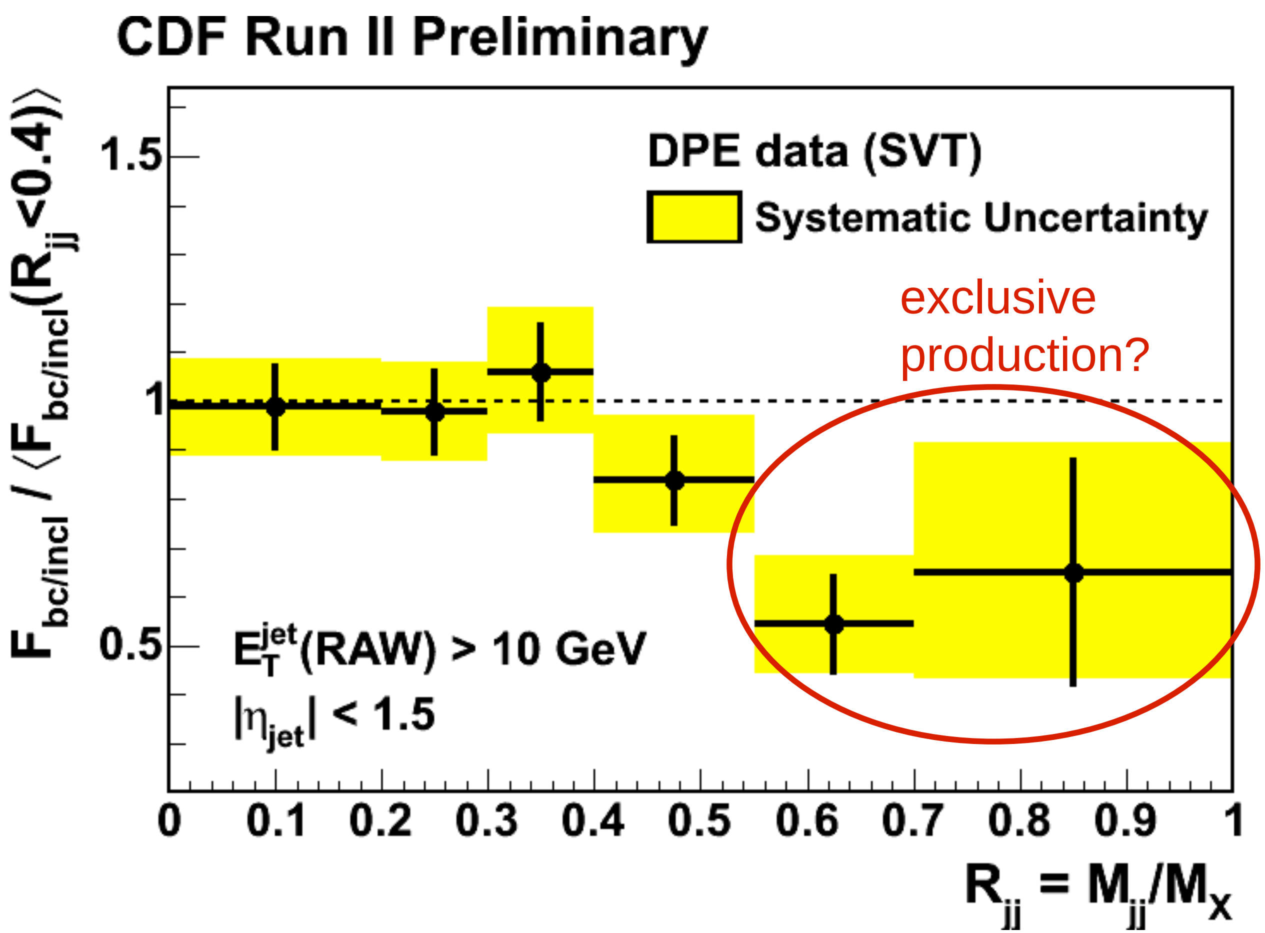
Pros: -many systematics cancel out
-good HF quarks id
-small g mistag O(1%)

Cons: -heavy quark mass:
contribution from exclusive b/c



⇨ use b-quark jets

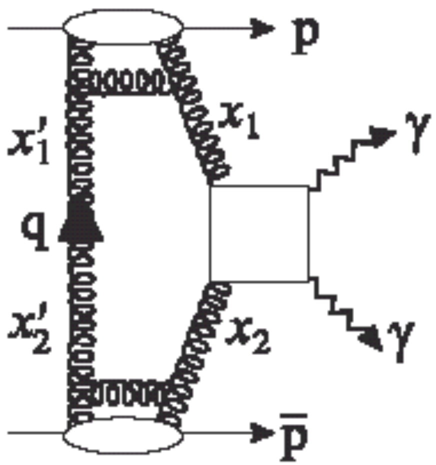
b-tagged jet fraction



ratio of b/c jets to all jets (norm. to R_{jj}<0.4)

⇨ ratio decreases at high R_{jj}

Exclusive γγ production



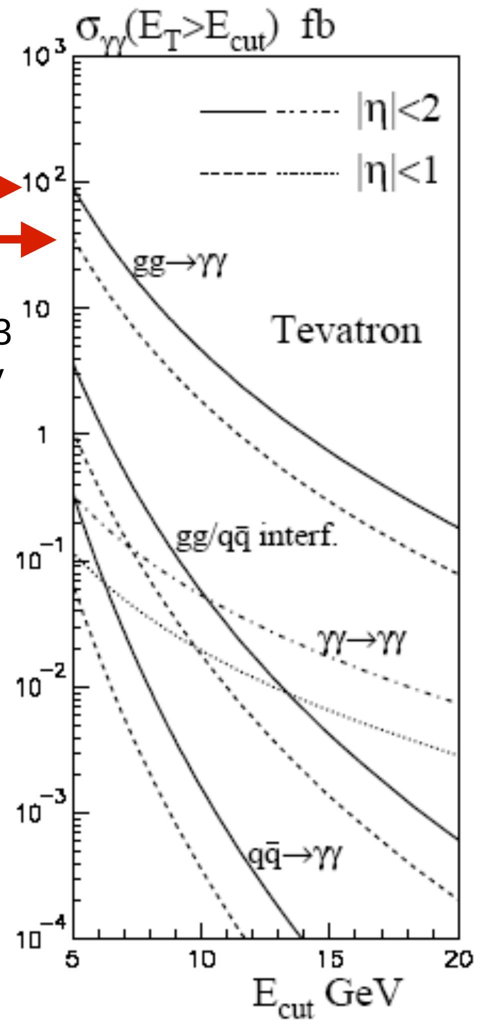
- QCD diagram same as pHp
- smaller cross section than exclusive dijets

~40 events/fb^{-1} with $p_T(\gamma)$>5 GeV/c, |η|<1.0

the effective luminosity must be considered
since additional interactions “populate” gaps

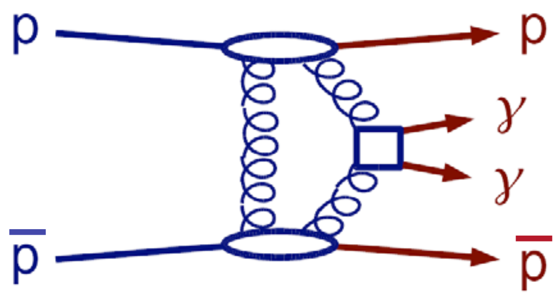
~100 fb
~40 fb

factor of 2-3
uncertainty

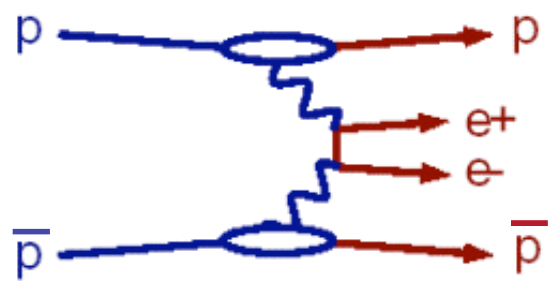


Khoze, Kaidalov, Martin, Ryskin,
Stirling, hep-ph/0507040

Exclusive ee/γγ search



$$p\bar{p} \rightarrow p + \gamma\gamma + \bar{p}$$



QED process: cross-check to exclusive γγ

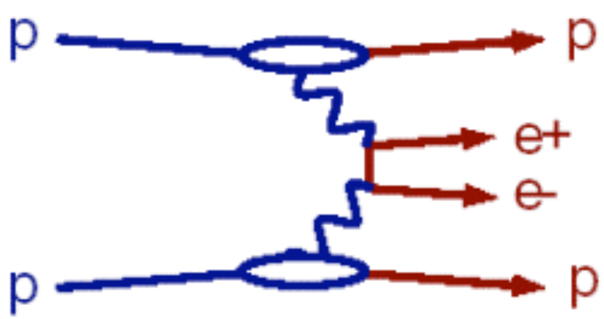
- ✓do not detect (anti)proton
- ✓require 2 EM showers (E_T>5 GeV, $|\eta|<2$)
- ✓veto all calorimetry and BSCs except 2 EM showers
- ✓L~530 pb^{-1} delivered ($L_{effective}$=46 pb^{-1})

⇨19 events have 2 EM showers +”nothing”

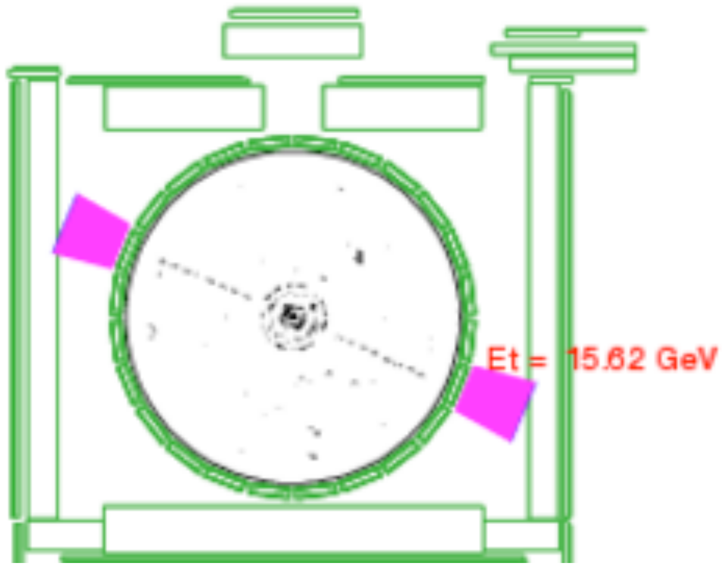
caveat: “nothing” above threshold

Exclusive ee search

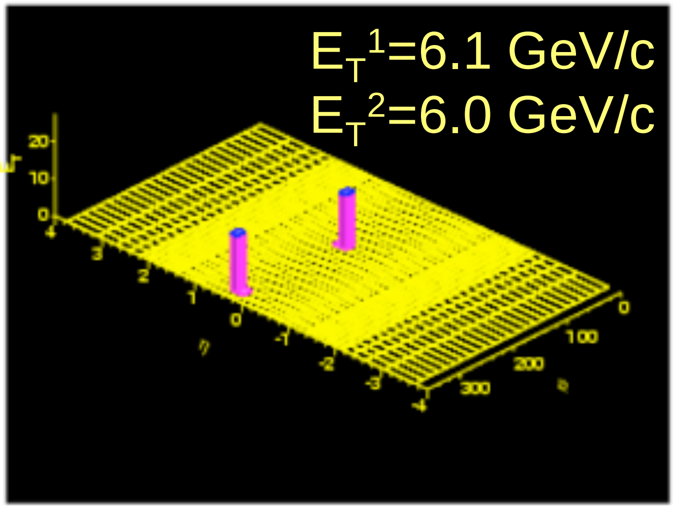
Phys.Rev.Lett.98:112001,2007



control sample for $\gamma\gamma$ search



⇨16 candidate events found
background: 1.9±0.3 events

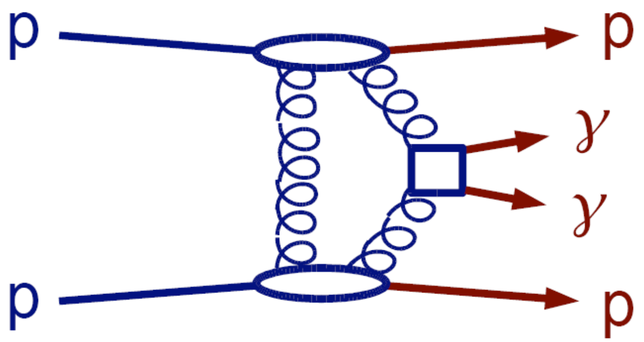


$$\sigma_{MEASURED} = 1.6\,^{+0.5}_{-0.3}\,(stat) \pm 0.3\,(sys)\;pb$$

good agreement with LPAIR:
$\sigma_{LPAIR} = 1.711 \pm 0.008\;pb$

Exclusive γγ search

Phys.Rev.Lett.99:242002,2007



⇨ 3 candidate events found

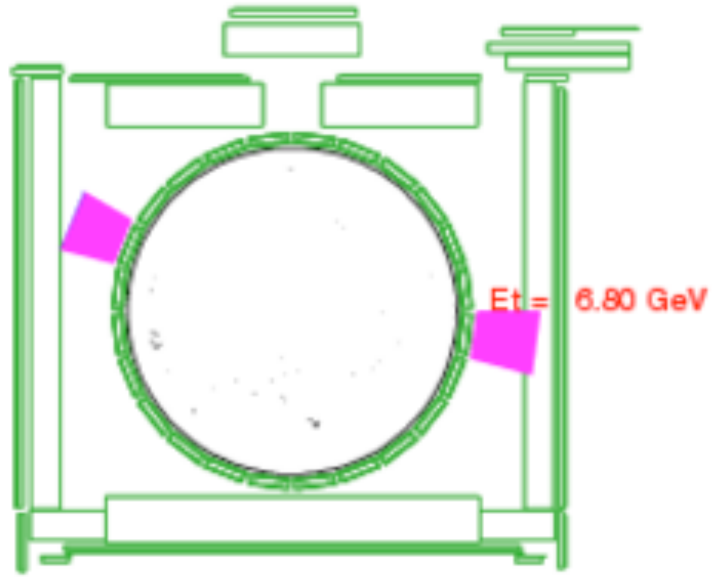
background: $0.0^{+0.2}_{-0.0}$ events

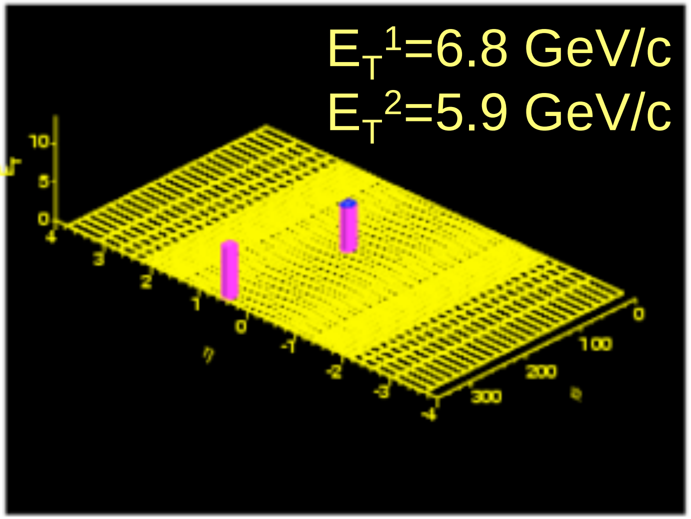
$\sigma_{measured}$ < 410 fb

good agreement with KMR:

$\sigma_{KMR} = 36 \pm ^{72}_{24}$ (x2-3) fb

⇨ σ_H ~ 10 fb (if H exists)
within a factor ~ 2-3 , higher in MSSM



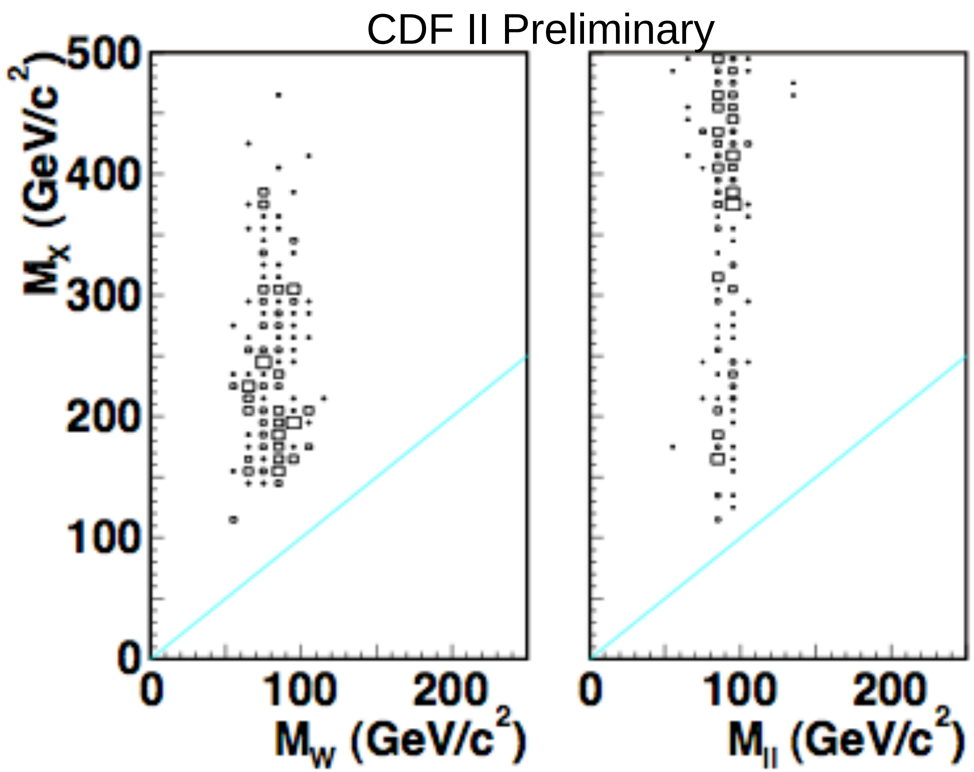


Exclusive Z production

- Limits on exclusive Z production with “nothing else” in the detector PRL 102, 222002 (2009)

Also from “diffractive Z production”:

- System mass M_X vs M_{ll}
- Exclusive candidates are expected to fall on the diagonal
- Depends on thresholds
- Cross-test with W/Z production

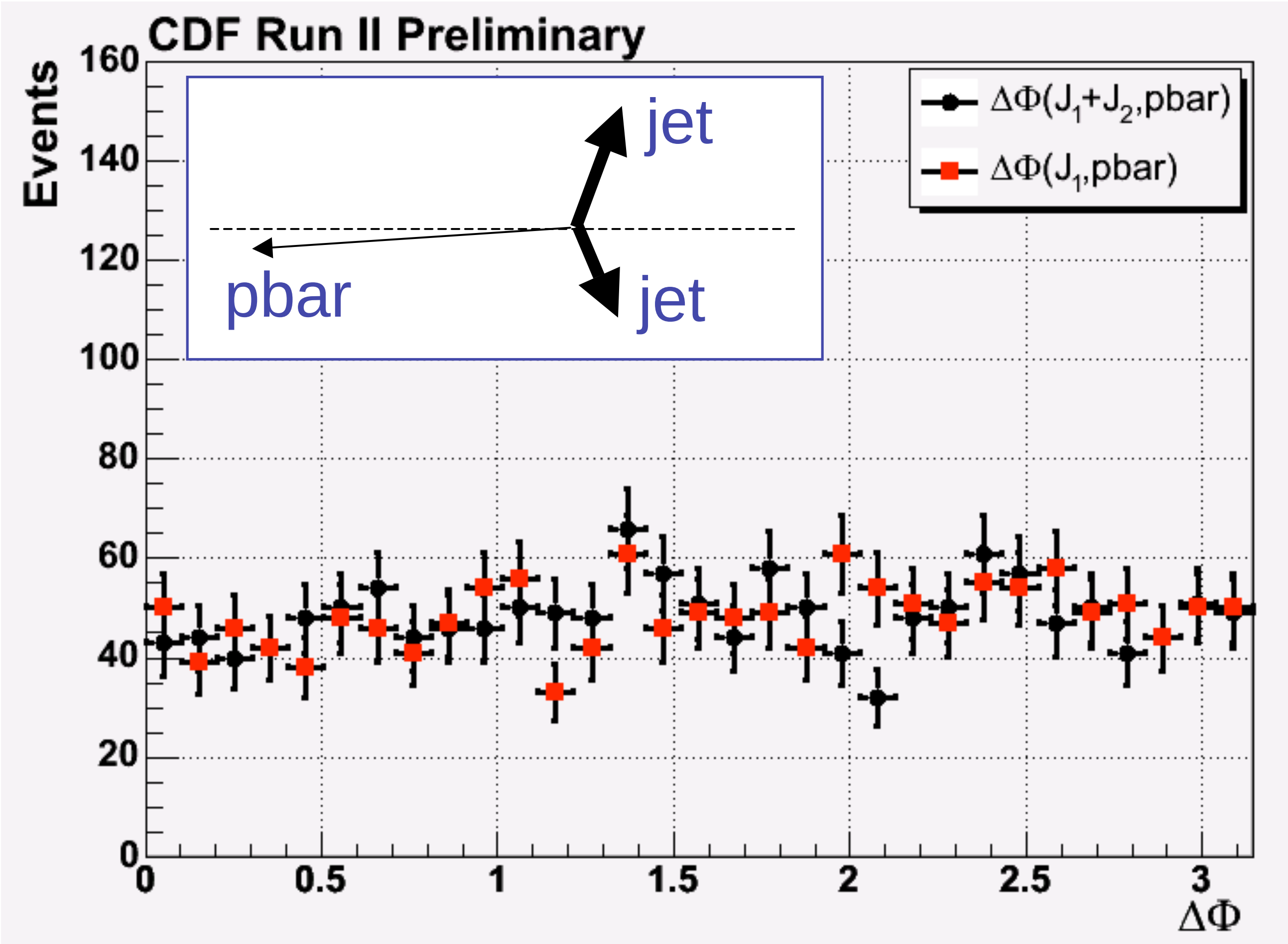


Summary

- 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, etc.
- 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 ξ

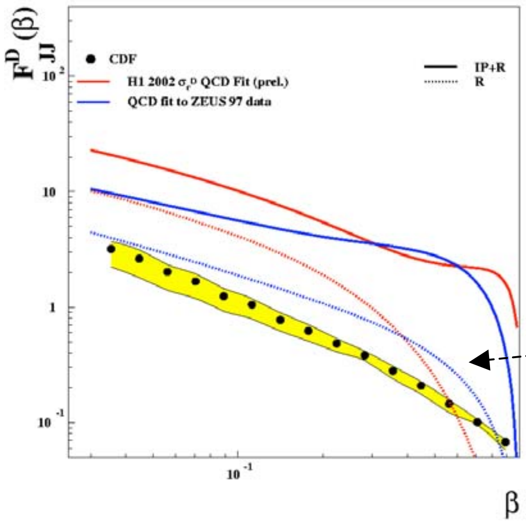
backup

(un)correlation



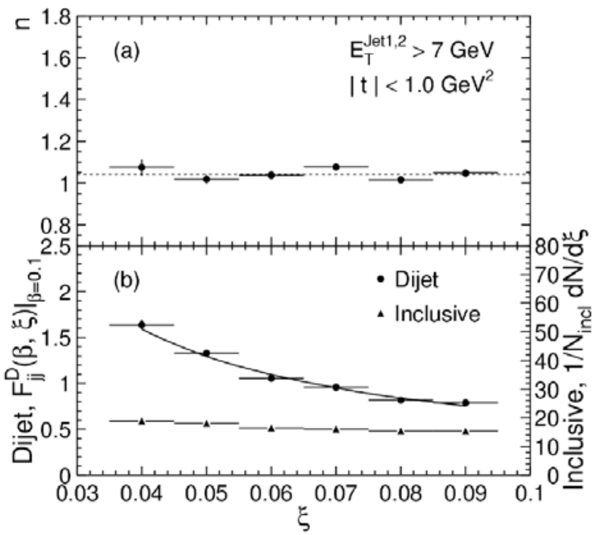
⇨no apparent $\Delta\phi$ correlation

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)

Rapidity gap fraction vs gap width

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