Recent Results on Diffraction and Exclusive Production from CDF

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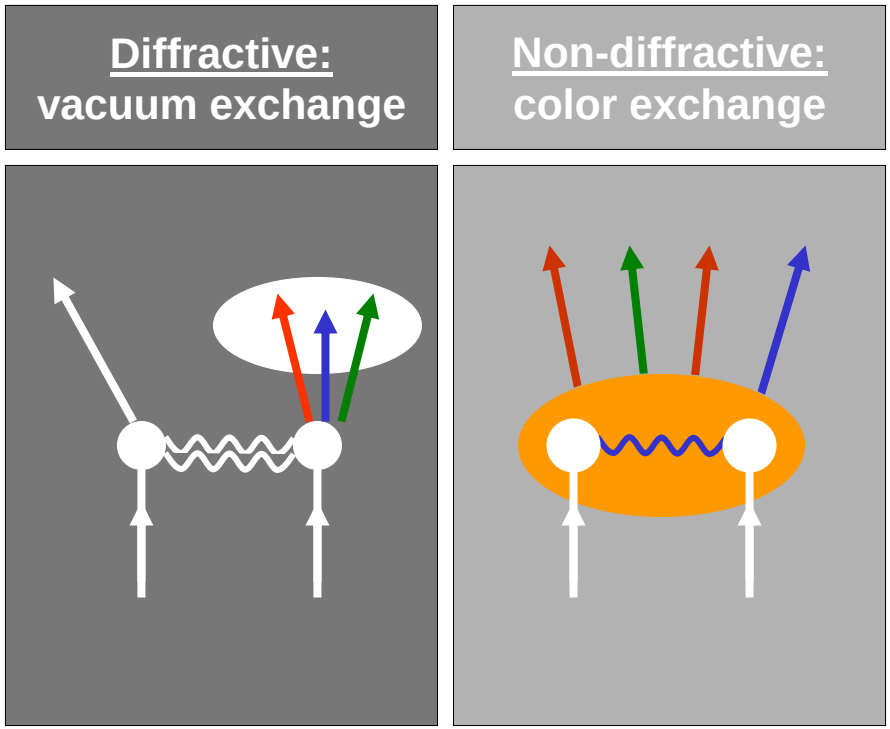
Outline

- Introduction
- Diffractive Structure Function
- Exclusive Production
  - Exclusive Dijet Production
  - Exclusive e^+e^- Production
  - Exclusive Di-Photon Production

Introduction

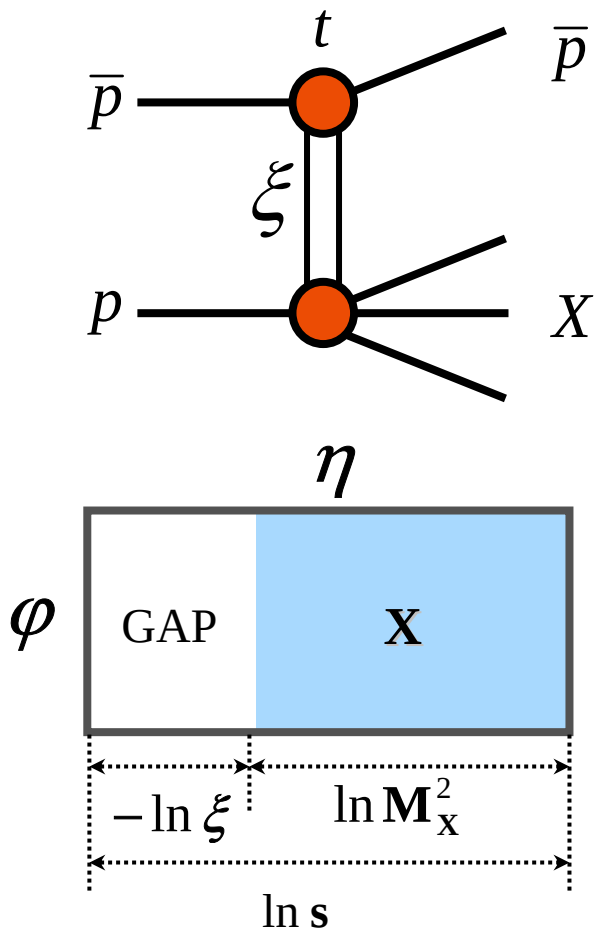


Goals of Diffractive Program at CDF:

To understand the nature of colorless exchange

To test the feasibility of diffraction as a tool to search for new physics at the LHC

Diffraction at the Tevatron



Kinematic Variables -

t - 4-momentum transfer squared

ξ - momentum fraction of antiproton carried by the diffractive exchange

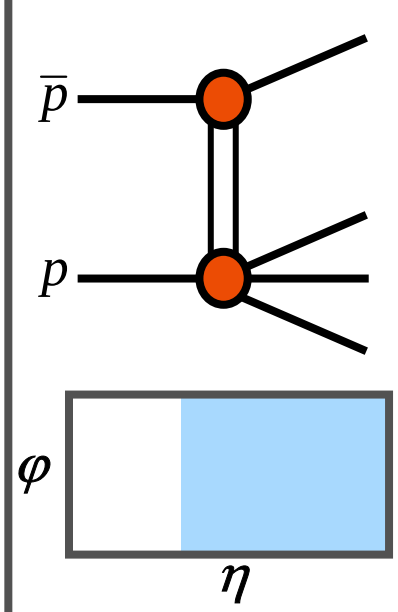
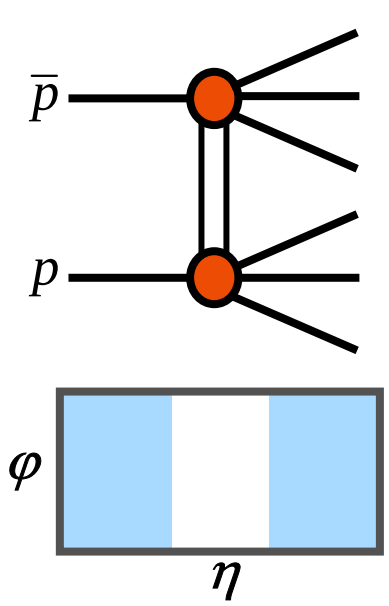
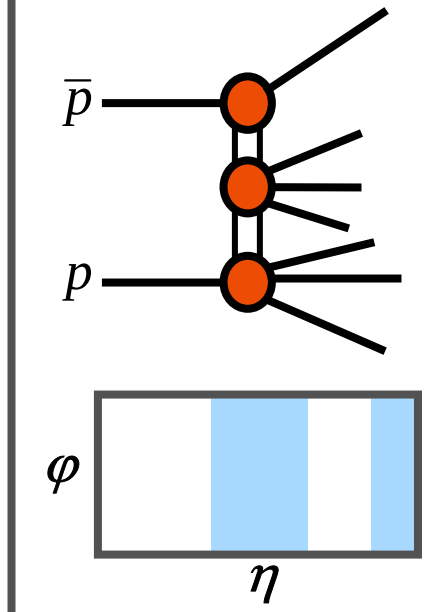
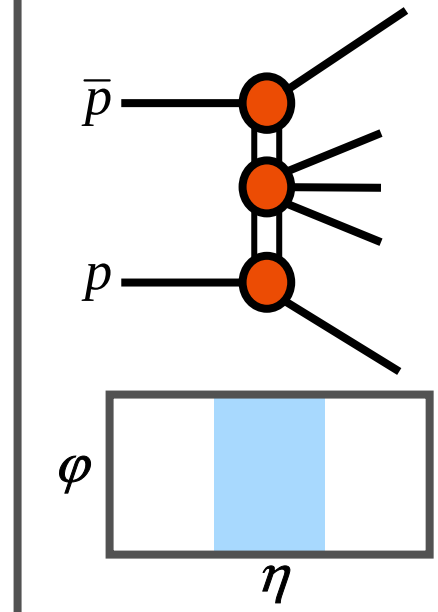
$\mathbf{M_X}$ - mass of system X

$$\xi = \frac{\mathbf{M}_X^2}{\mathbf{s}}$$

Goal:

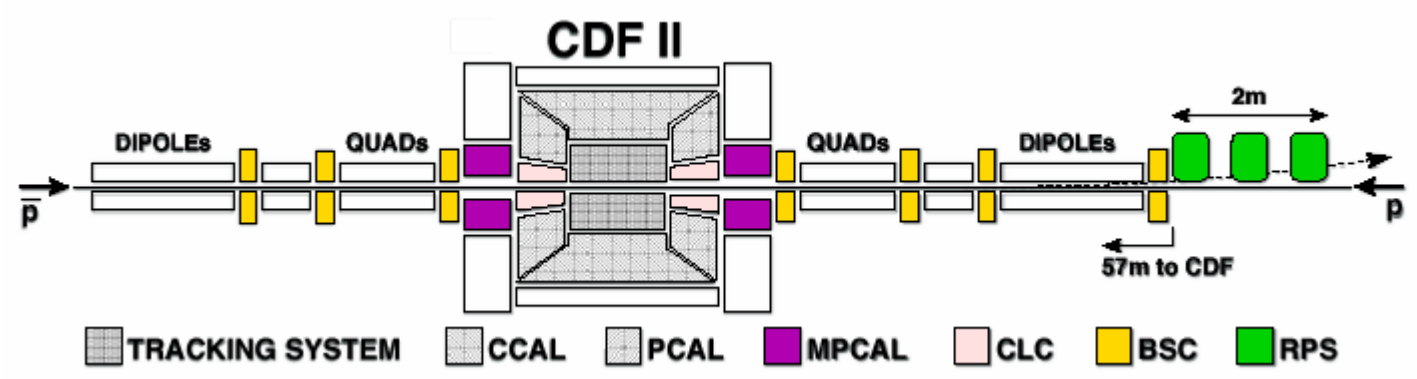
To study the partonic structure of diffractive exchange

Diffraction in Run I at CDF

Single Diffraction	Double Diffraction	Single + Double Diffraction	Double Pomeron Exchange
			

Published 14 papers

Forward Detectors in Run II



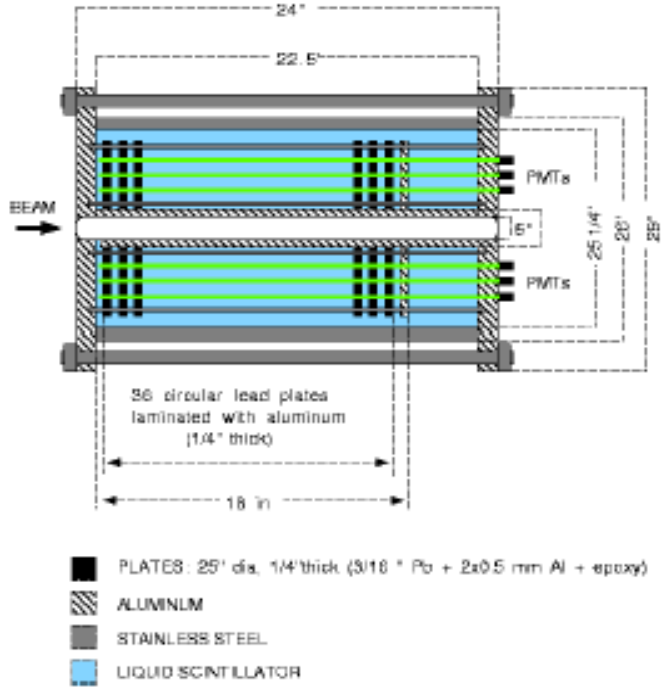
RPS – Roman Pot Spectrometers $0.02 < \xi < 0.1$, $0 < |t| < 2\ \mathrm{GeV}^2$

BSC – Beam Shower Counters $5.4 < |\eta| < 7.4$

MPCAL – MiniPlug Calorimeters $3.5 < |\eta| < 5.2$

MiniPlug Calorimeters

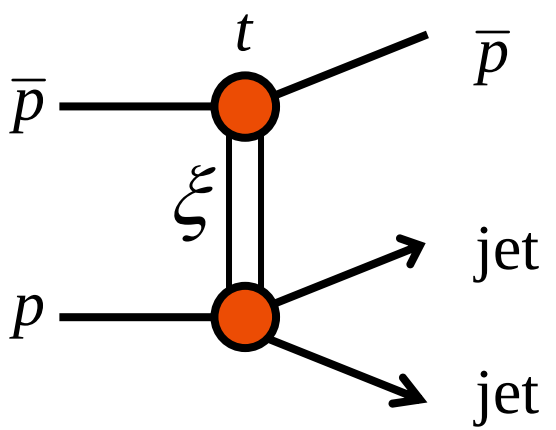
Nucl. Instrum. Meth. ***A****518 (2004) 42.*
Nucl. Instrum. Meth. ***A****496 (2003) 333.*



designed to measure the energy and lateral position of both electromagnetic and hadronic showers

"towerless" geometry – no dead regions

Diffractive Structure Function



Diffractive dijets

$$\sigma(\bar{p}p \to \bar{p}X) \approx F_{jj} \otimes F_{jj}^{D} \otimes \hat{\sigma}(ab \to jj)$$

Study the **diffractive structure function**

$$F_{jj}^{D} = F_{jj}^{D}(x, Q^2, t, \xi)$$

Experimental Determination of F_{jj}^{D}

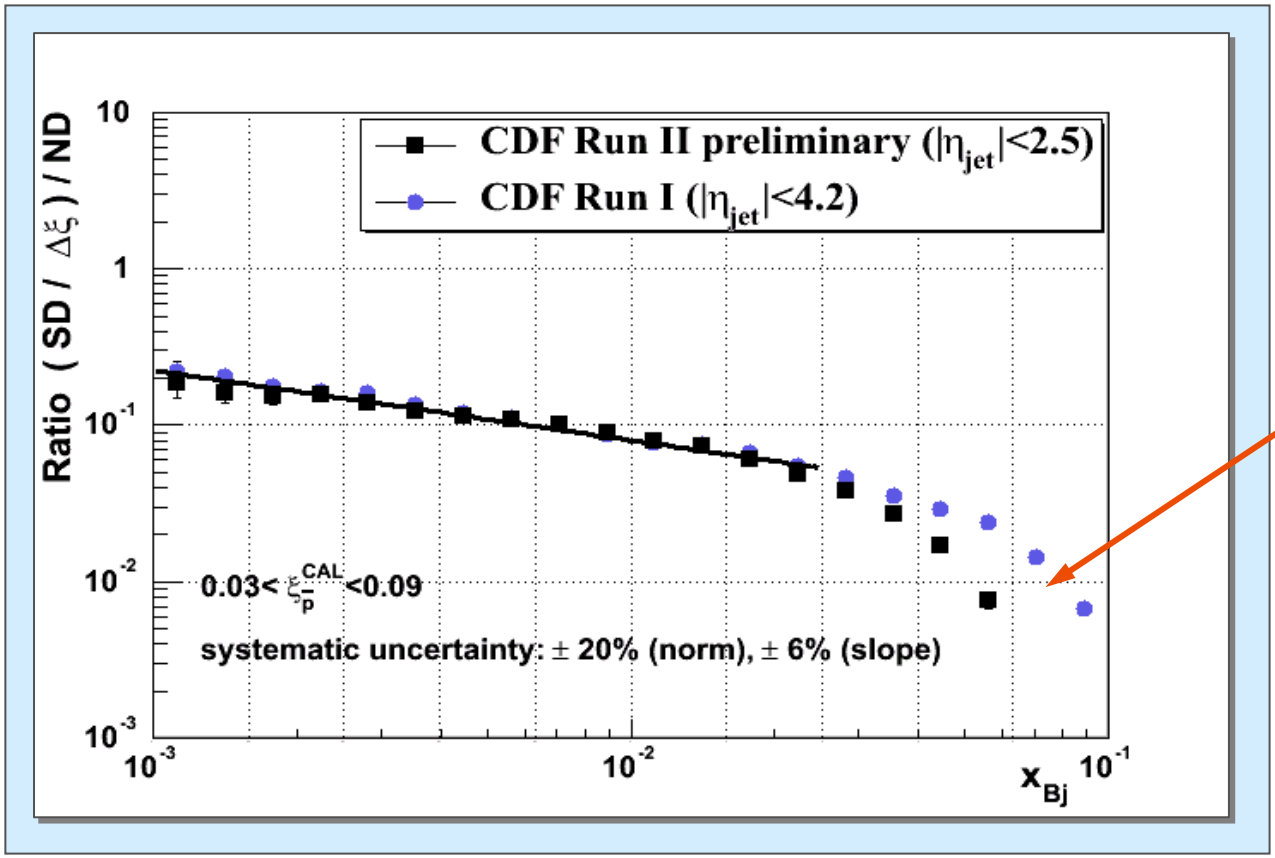
Hard diffraction:
production of high p_T dijets

$$R_{\frac{SD}{ND}}(x,\xi) = \frac{\sigma(SD_{jj})}{\sigma(ND_{jj})} = \frac{F_{jj}^{D}(x,Q^2,\xi)}{F_{jj}(x,Q^2)} \text{ (LO QCD)}$$

Data known PDF

Diffractive Structure Function:

x_{Bj} dependence

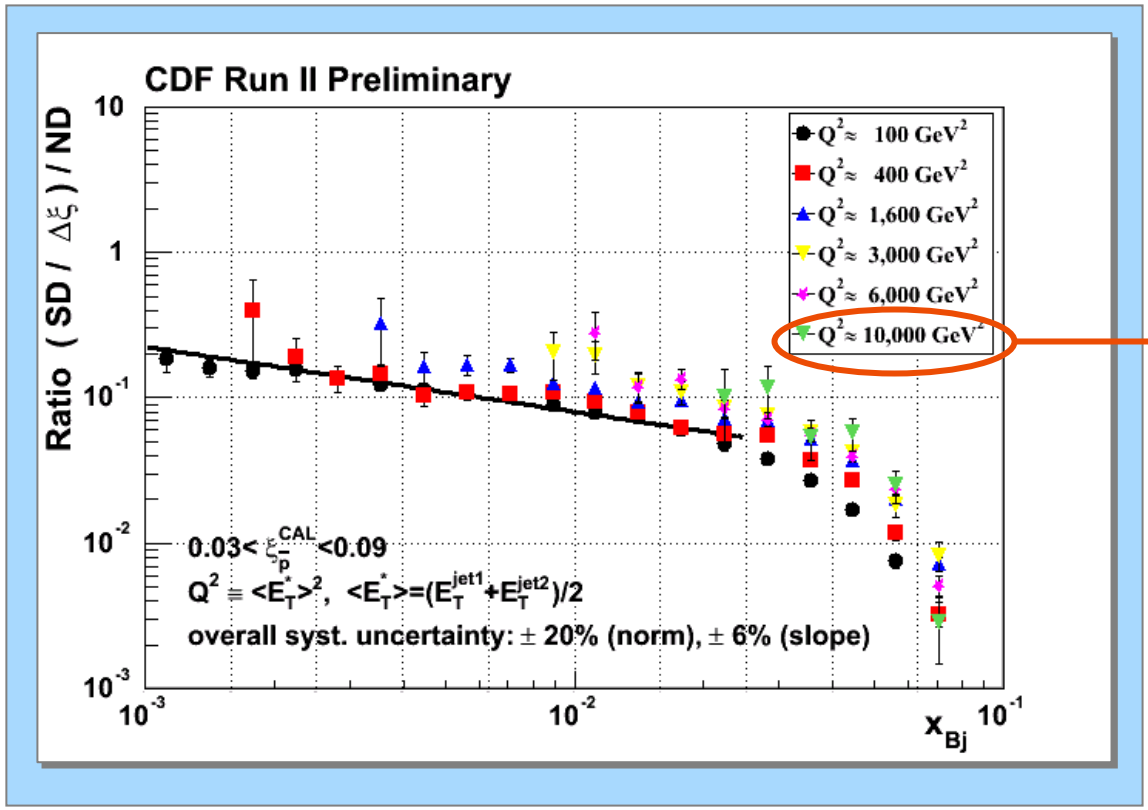


different jet acceptance

Confirms Run I results

Diffractive Structure Function:

Q^2 dependence



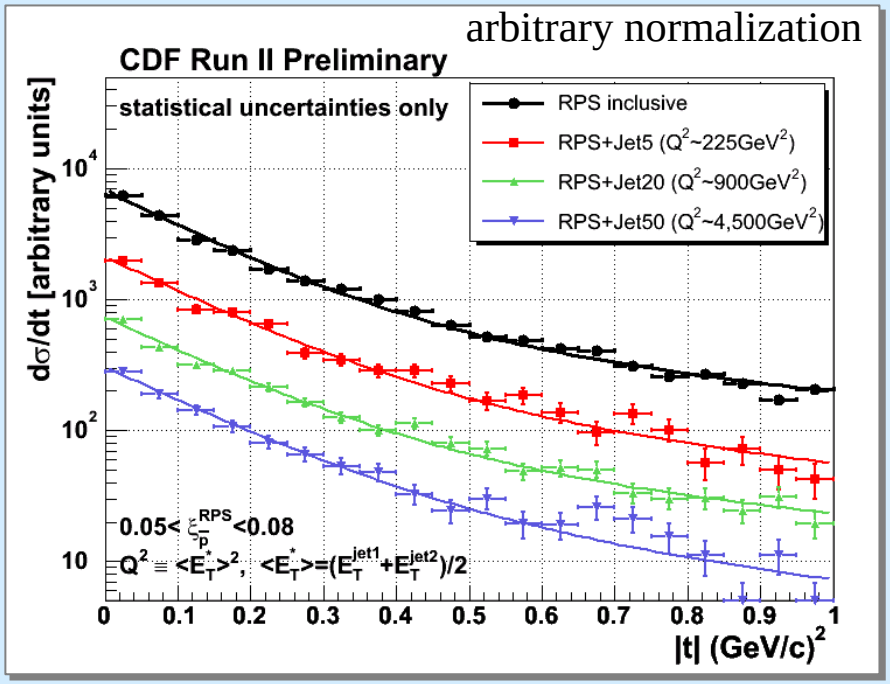
100 GeV jets

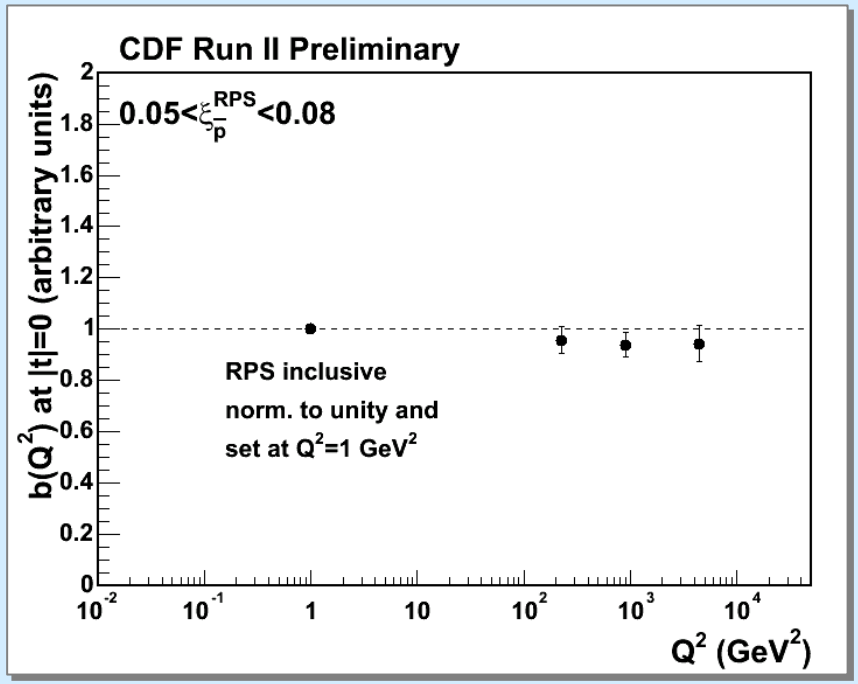
No significant Q^2 dependence in $100 < Q^2 < 10000$ GeV^2

Pomeron evolves like proton?

Diffractive Structure Function

t dependence



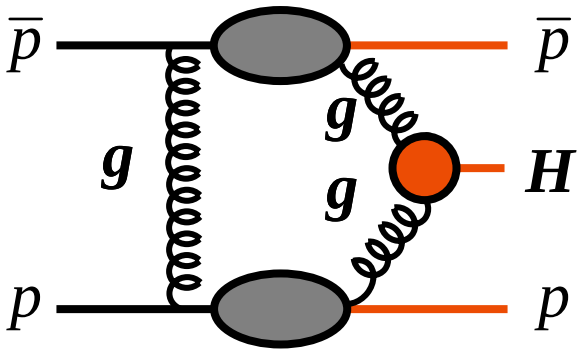


Fit $\mathrm{d}\sigma/\mathrm{dt}$ to a double exponential

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

same slope at t=0 for entire region of $Q^2 < 4500\ \mathrm{GeV}^2$

Exclusive Higgs Production



Attractive channel for Higgs discovery at LHC

- suppression at LO of the background sub-processes (J_z=0 selection rule)
- "exclusive channel" →clean signal (no underlying event)

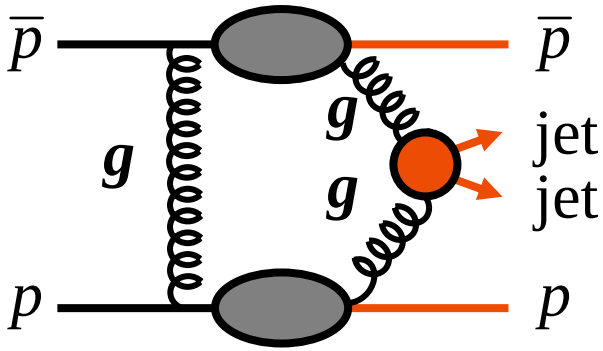
Standard Model light Higgs:

$$p + p \rightarrow p + H(\rightarrow b\bar{b}) + p$$

$$M_H = M_{miss} = (s \cdot \xi_p \cdot \xi_{\bar{p}})^{1/2}$$

$\sigma_H^{excl} < 0.1$fb at Tevatron, ~1-10 fb at LHC

Exclusive Dijet Production



to calibrate

theoretical calculations
for exclusive Higgs production
at LHC :

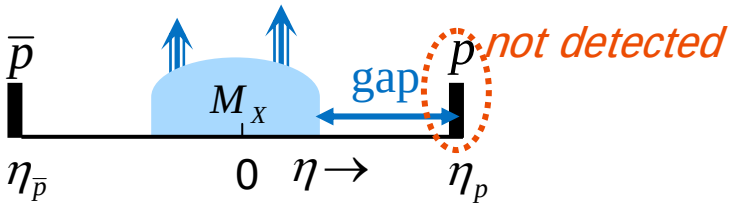
study

similar processes with
higher cross sections:
exclusive dijet,
di-photon production

Method:

Select diffractive dijet events
produced by DPE (Double Pomeron Exchange)

$$p + \bar{p} \rightarrow \bar{p} + X(\geq 2\,jets,...) + gap$$



Reconstruct

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

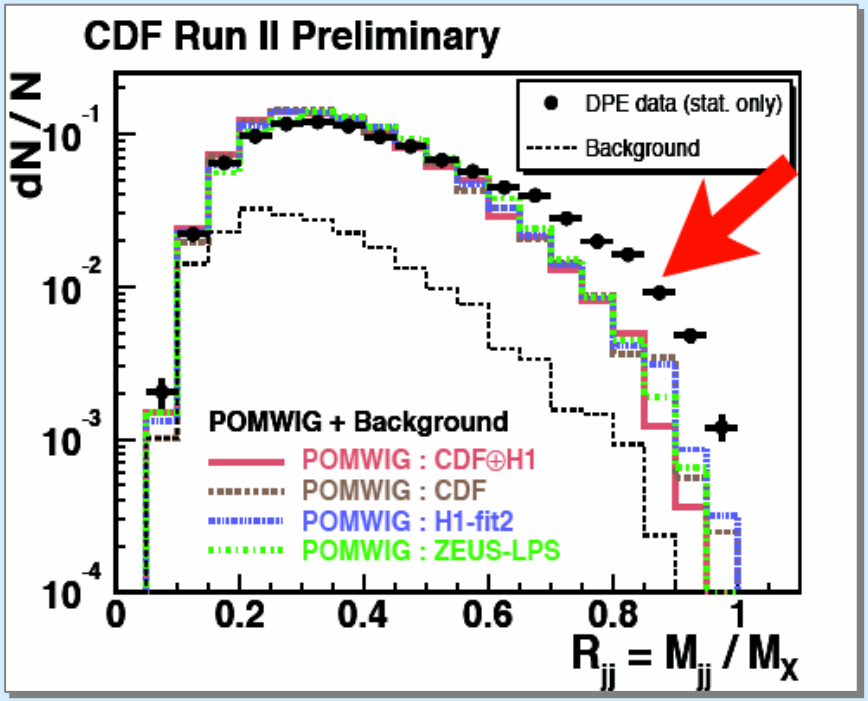
$$M_{jj} = \sqrt{(E_{jet1} + E_{jet2})^2 - (P_{jet1} + P_{jet2})^2} \text{ is dijet mass}$$

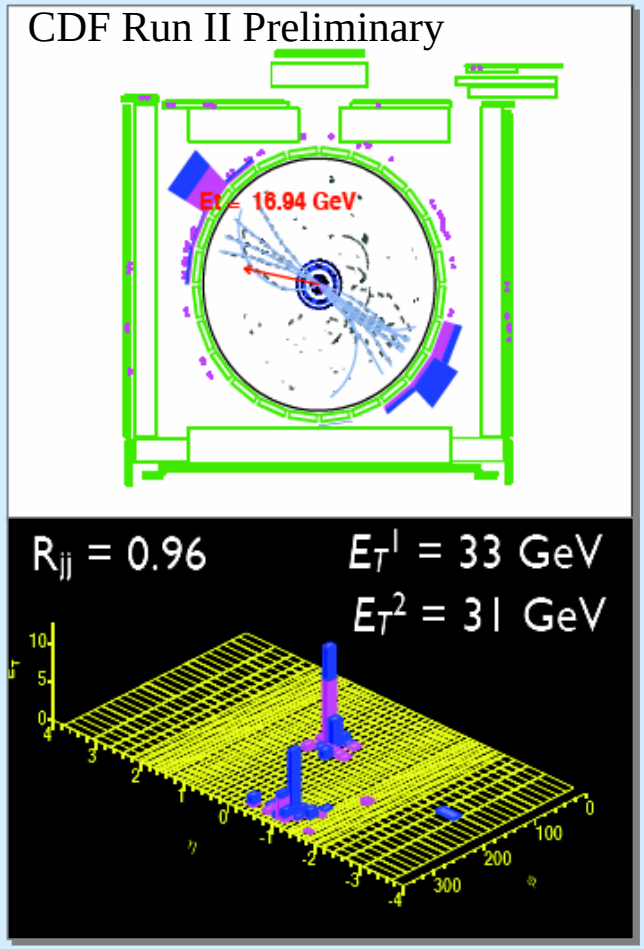
M_X – mass of system X

Compare

background with DPE Monte Carlo POMWIG
uncertainty from different Pomeron PDFs

Exclusive Dijet Production





Excess in data over MC predictions for high R_{jj} values

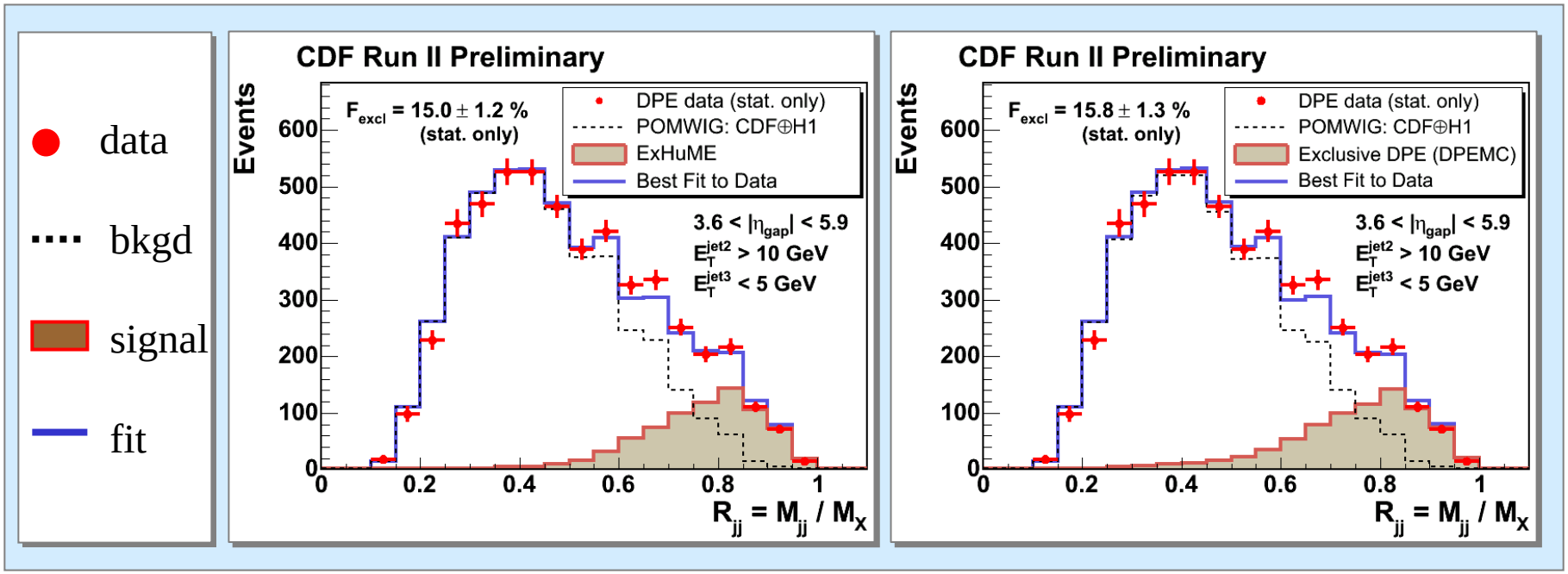
Signal at R_{jj}=1 is smeared due to shower/hadronization effects,

NLO $gg \to ggg, q\bar{q}g$ contributions

Exclusive Dijet Production

MC fit to R_{jj}

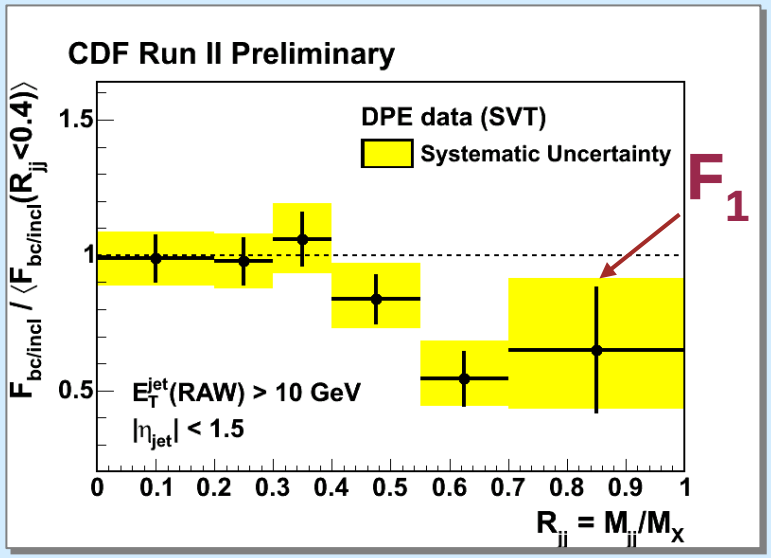
Binned likelihood fits (MC normalizations as free parameters)

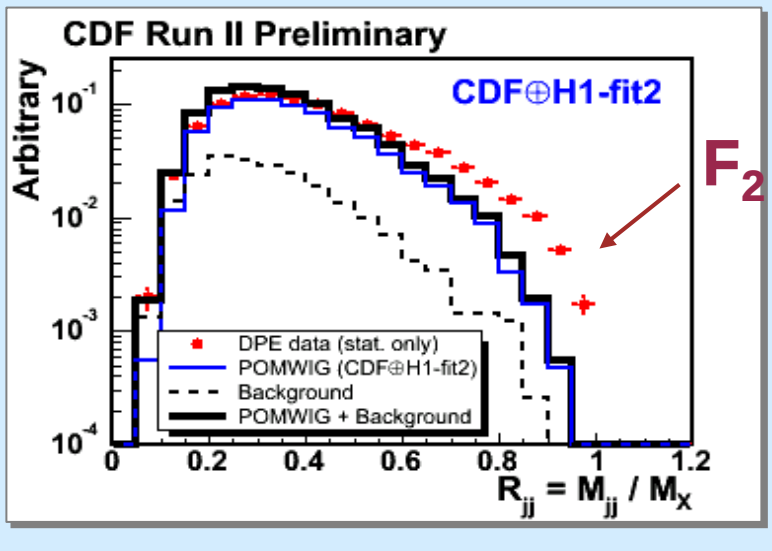


Signal MC ExHuME
CPC 175,232 (2006)

Exclusive DPE as input to DPEMC
CPC 167,217 (2005)

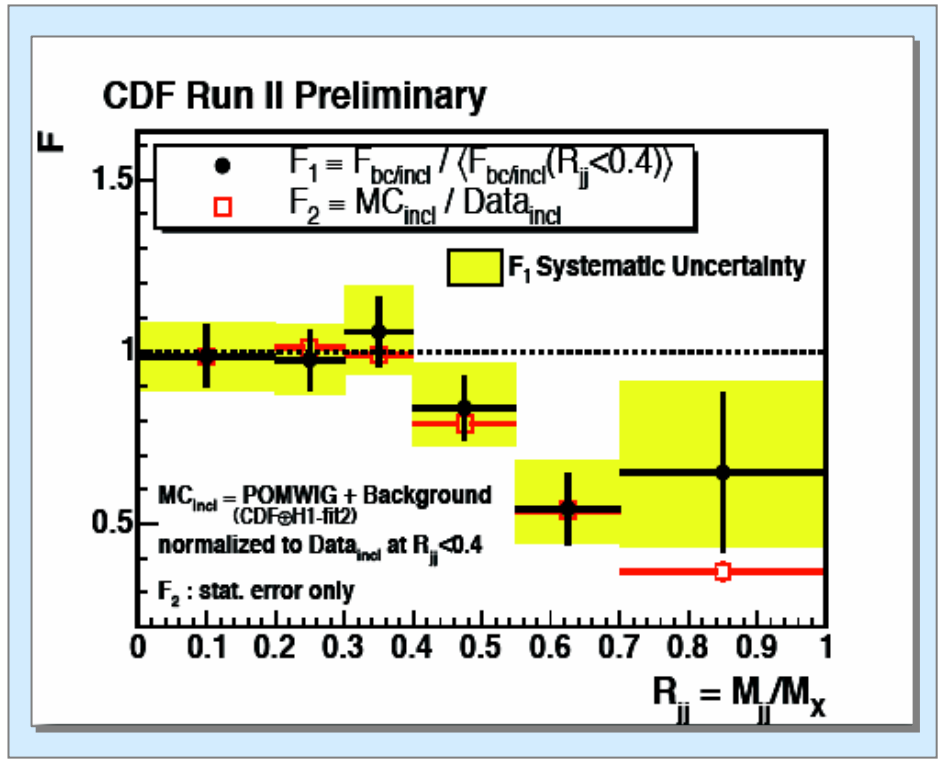
Exclusive Dijet Production





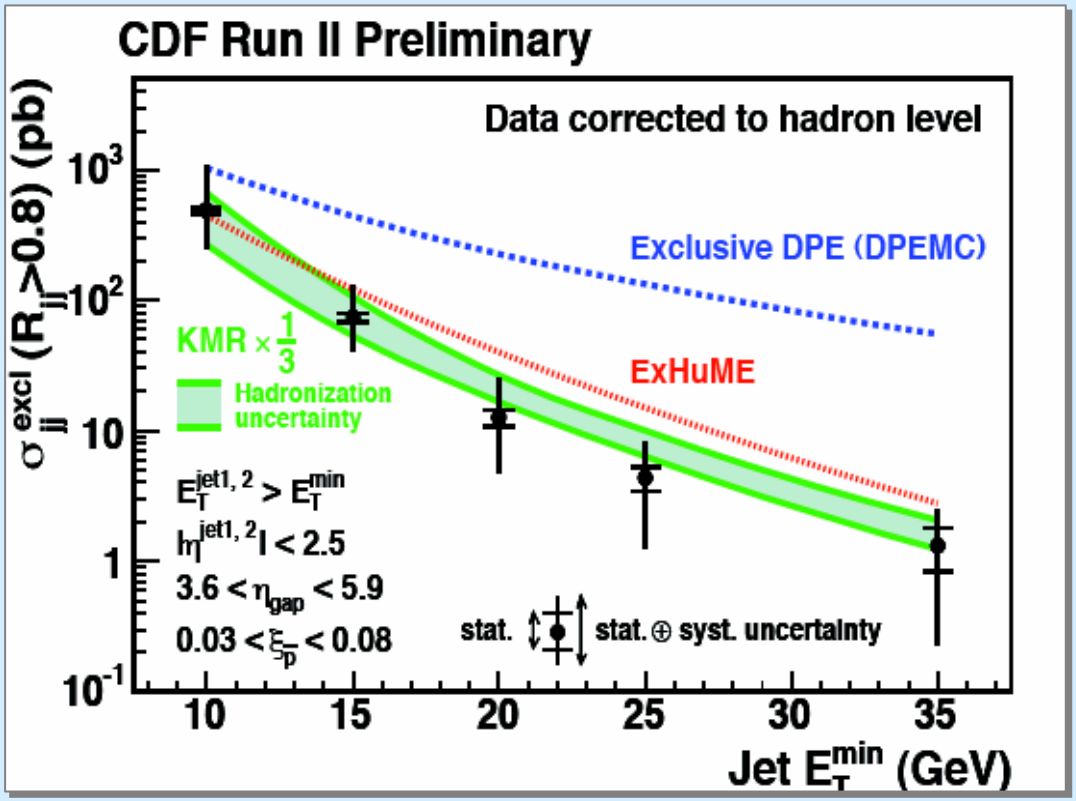
LO exclusive $gg \rightarrow q\bar{q}$ is supressed ($J_z = 0$ rule)

➔Look for heavy flavor jet suppression at high Rjj



The two results are consistent with each other

Exclusive Dijet Cross Section



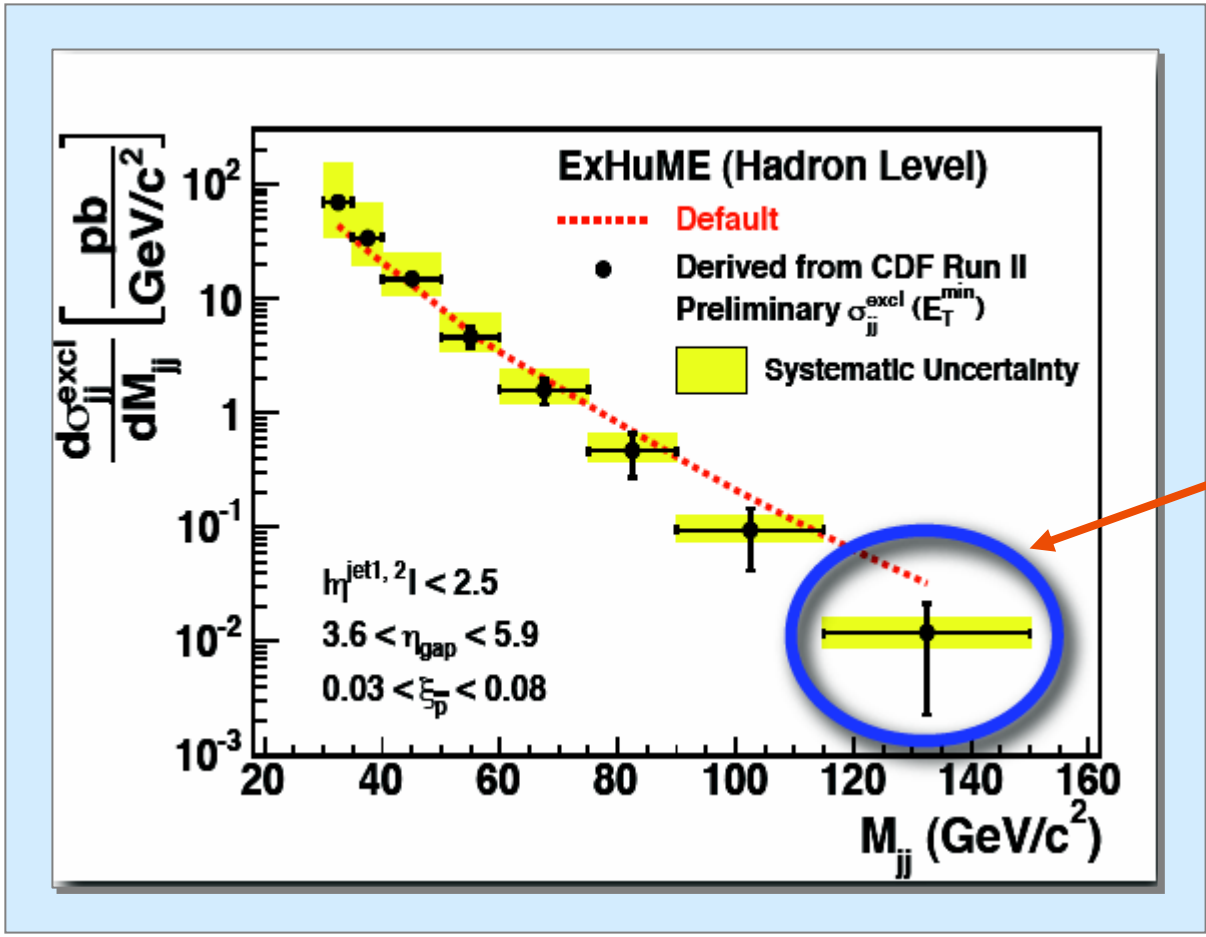
Data prefers ExHuME and KMR calculations

Exclusive DPE (DPEMC) – exclusive DPE model (based on non –pQCD Bialas Landshoff model) as an input to DPE MC

KMR x1/3 – Khoze, Martin, Ryskin at LO (factor 3 uncertainty) hep-ph/0507040

ExHuME – ExHuME Monte Carlo

Exclusive Dijet Mass Distribution

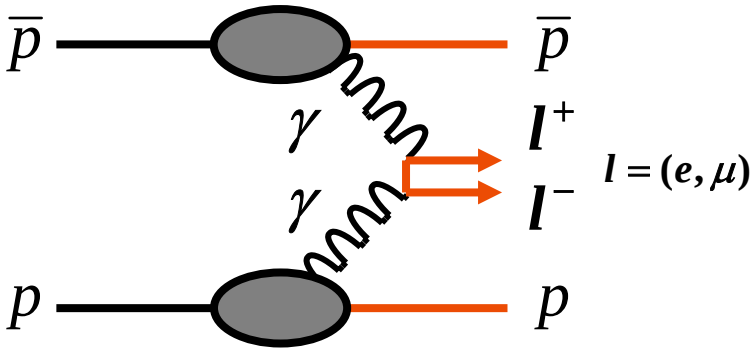


Higgs mass range!

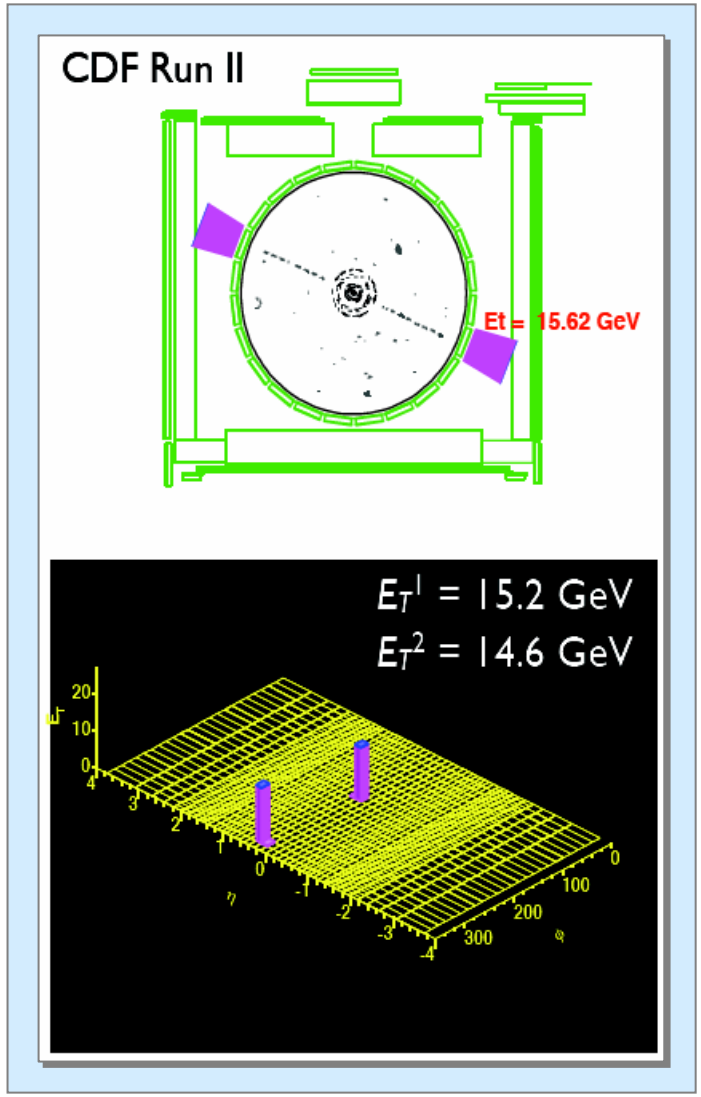
unfold measured σ_{jj}^{excl} to $d\sigma_{jj}^{excl} / dM_{jj}$ using ExHuME

Exclusive e^+e^- Production

*PRL **98**, 112001 (2007)*



QED mediated process,
cross section is well known
good control sample
for search of $\bar{p}p \to \bar{p}\gamma\gamma p$



16 similar events are found

Select e^+e^- events:

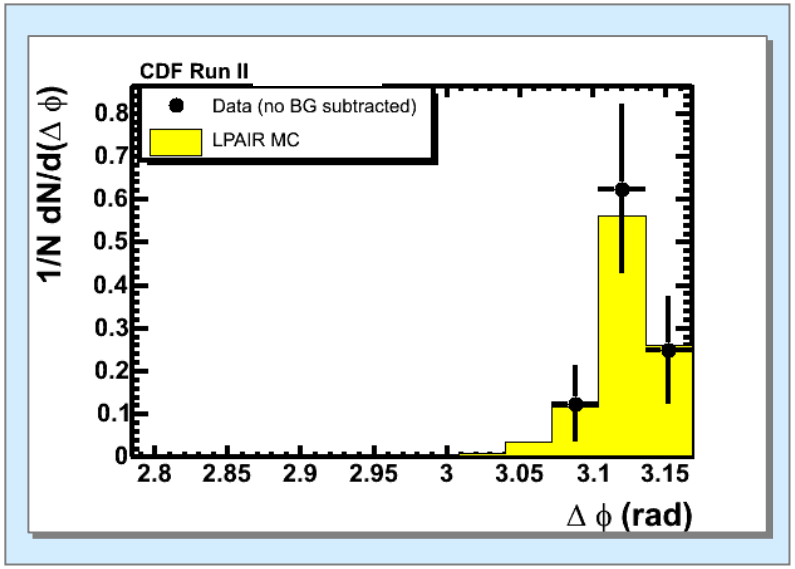
reconstruct e^+e^-

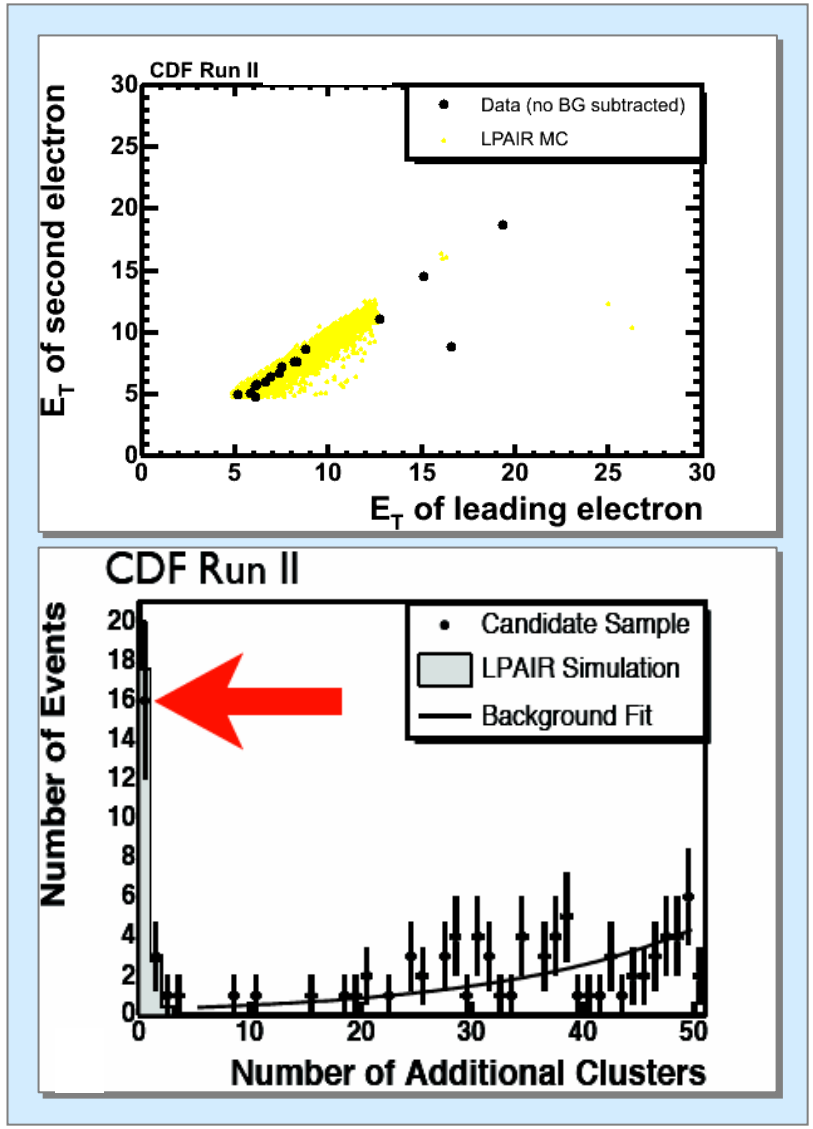
with $E_T > 5$ GeV, $|\eta| < 2$

request no additional calorimeter activity

protons are not tagged

Exclusive e^+e^- Production





16 candidate events

Backgound estimate : 1.9 ± 0.3 events

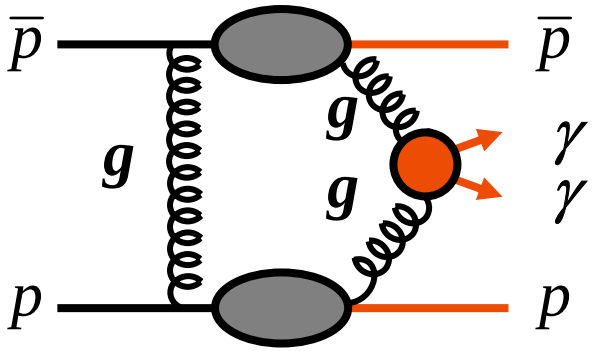
$5.5\,\sigma$ observation

$$\sigma_{\exp} = 1.6^{+0.5}_{-0.3}(stat) \pm 0.3(syst)\ pb$$

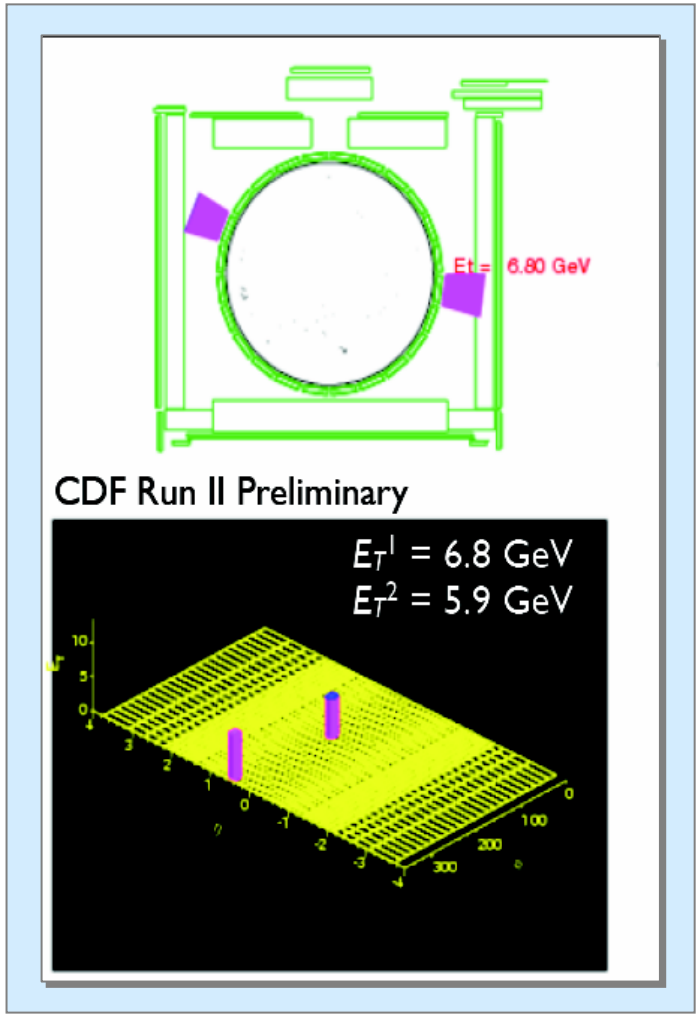
$$\sigma_{LPAIR} = 1.71 \pm 0.01\ pb$$

agrees with LPAIR MC (QED prediction)

Exclusive $\gamma\gamma$ Production



factor of 3 ~ 4 uncertainty
in the cross section



Exclusive di-photon events:
select in the same way as e^+e^-,
(except for tracking veto)
with E_T>5 GeV, |η|<1

agreement of exclusive e^+e^- cross section
provides cross check of the methodology

Exclusive $\gamma\gamma$ Production

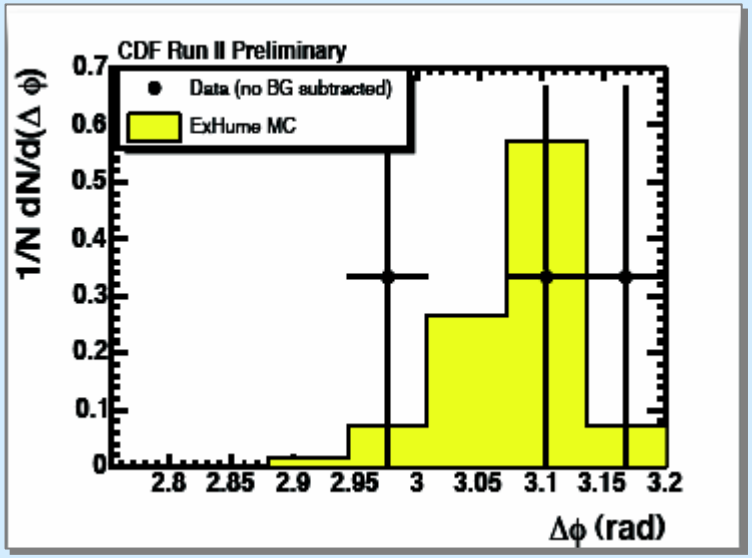
3 candidate events
including $\pi^0\pi^0$ or $\eta\eta(\pi^0, \eta \to \gamma\gamma)$

Backgound estimate :
0.09 ± 0.04 events

$3.7\,\sigma$ evidence for combined
exclusive $(\gamma\gamma, \pi^0\pi^0, \eta\eta)$ signal

$\sigma_{exp}(\bar{p}p \to \bar{p}\gamma\gamma p) < 410$ fb (95% C.L.)

Khoze, Martin, Ryskin :
$\sigma_{\gamma\gamma} \sim 40$ fb (factor 3 uncertainty)



Summary

CDF results on Diffraction

Diffractive Structure function

Extended Run I results using single diffractive dijets

- no Q^2 dependence
- slope at t=0 is independent of Q^2

Exclusive Production

Observed excess events at high R_{jj} being consistent with exclusive dijets

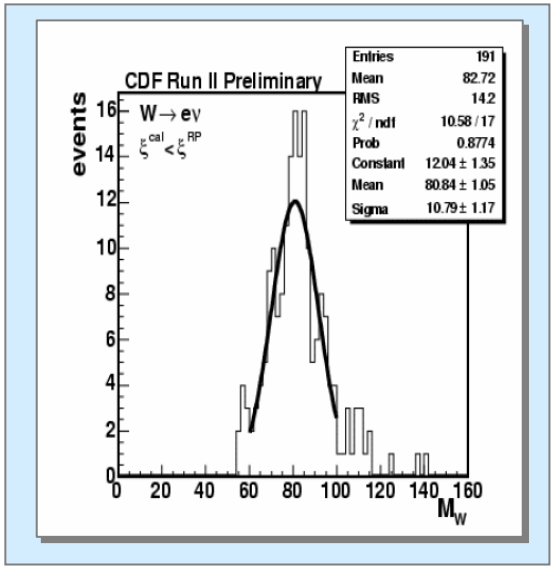
Observed events being consistent with exclusive $\gamma\gamma$ production

Observed exclusive e^+e^- production – cross check for di-photons

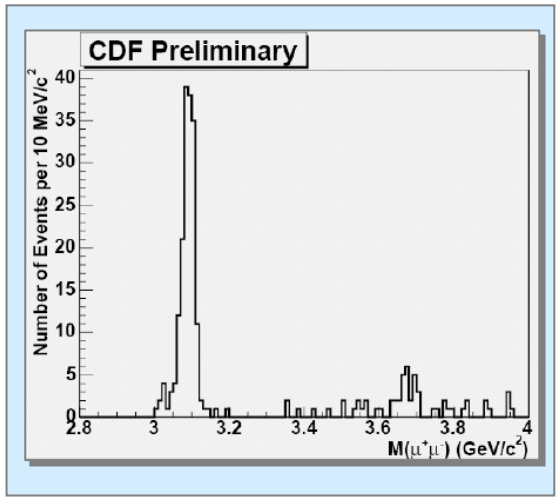
More interesting results are coming…

Work in Progress

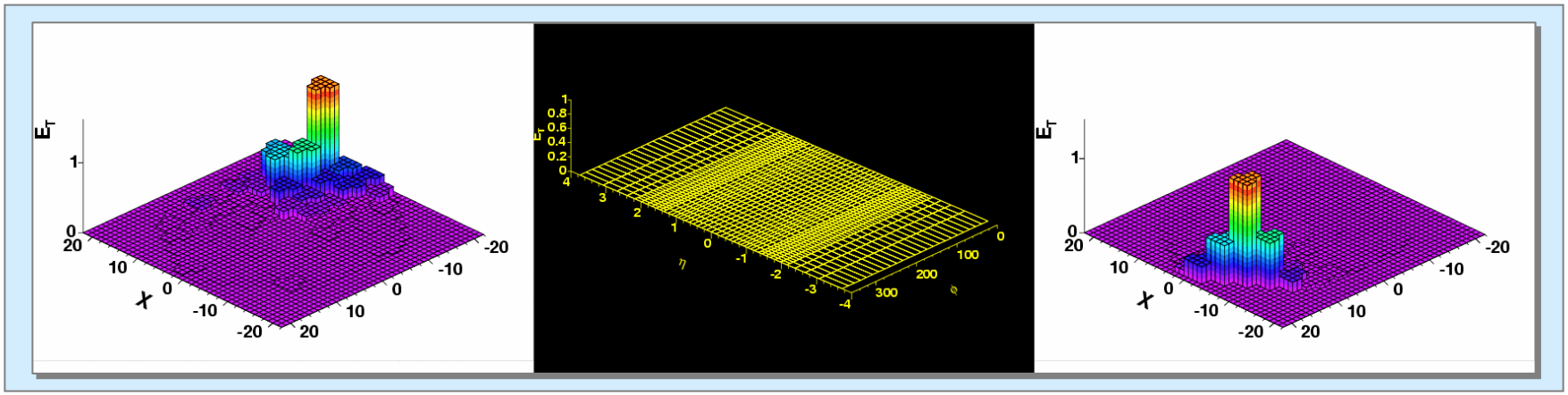
Diffractive W Production



Exclusive Di-muon Production

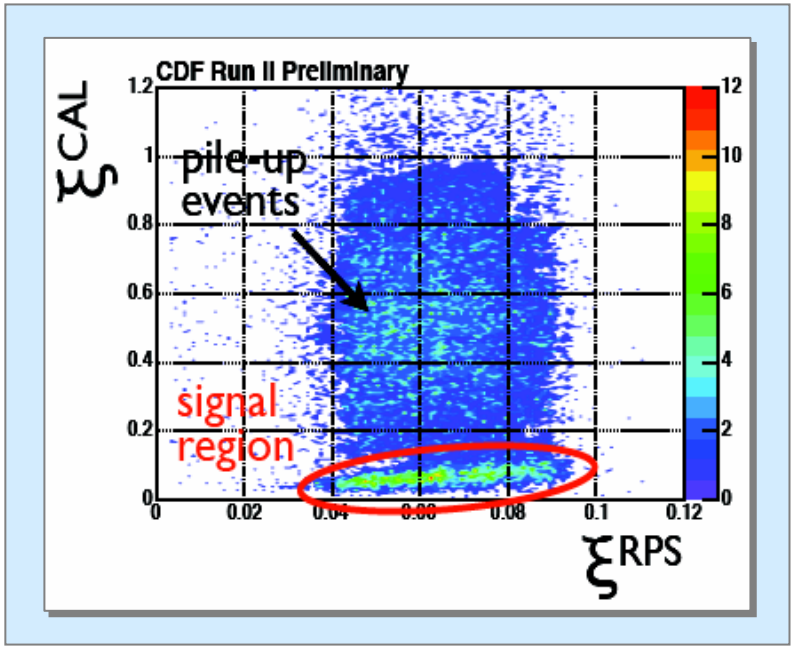


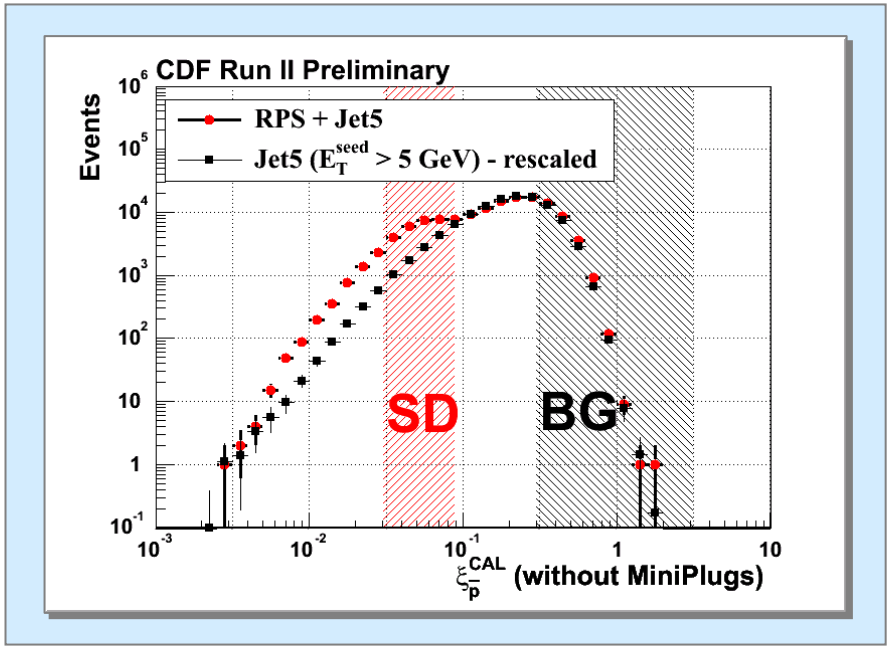
Rapidity Gaps between Jets



Pile-up Events

One of the main problems: multiple interactions – spoil diffractive events

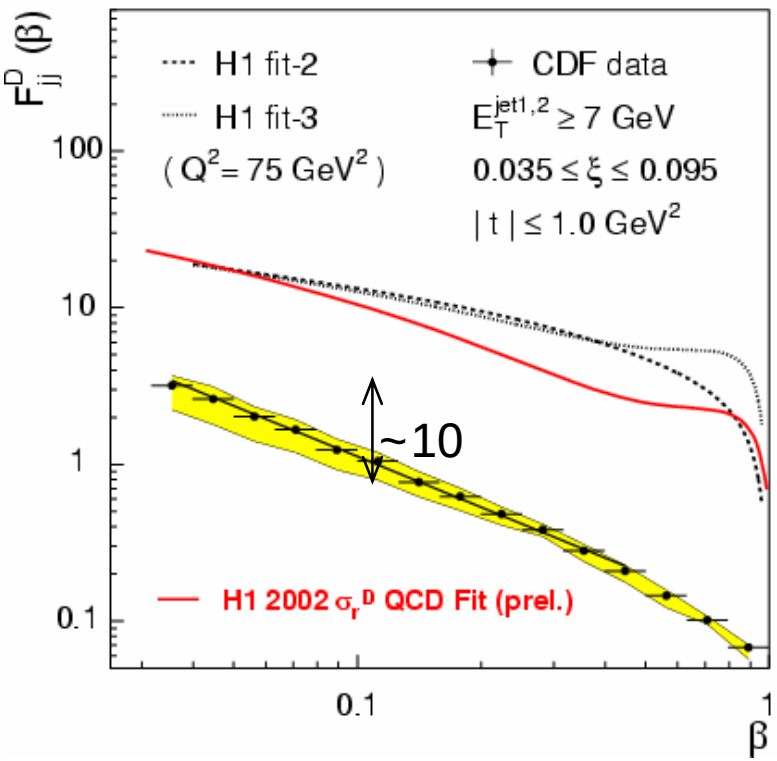


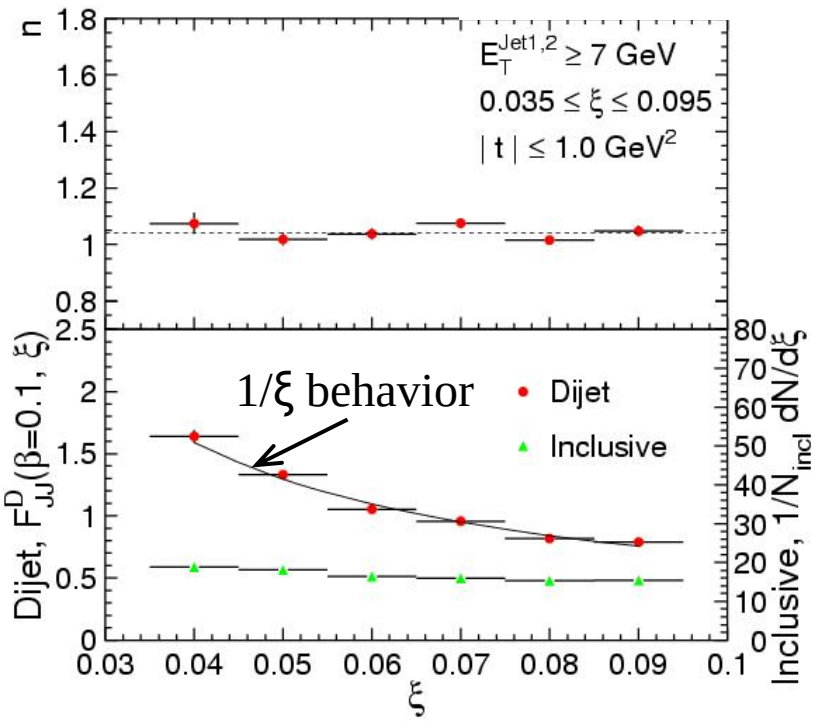


$$\xi_{cal} = \frac{\sum_{towers} E_T e^{-\eta}}{\sqrt{s}}$$

$L_{inst} \sim 2 \cdot 10^{31}\ cm^{-2}\ s^{-1}$

Diffractive Structure Function





discrepancy in normalization

⇩

QCD factorization breakdown

$$F_{jj}^{D} = C\beta^{-n}\xi^{-m}$$

Regge factorization holds

for $\beta < 0.5$

$n = 1.0 \pm 0.1$

$m = 0.9 \pm 0.1$

Pomeron exchange