Diffraction at CDF

12th International Conference on Elastic and Diffractive Scattering
Forward Physics and QCD – Blois2007

Hamburg, Germany, 21-25 May 2007

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The Rockefeller University

(for the CDF collaboration)

Contents

- Introduction
- Diffractive structure function
- Exclusive Production

$\bar{p}$-p Interactions

<u>Non-diffractive:</u>

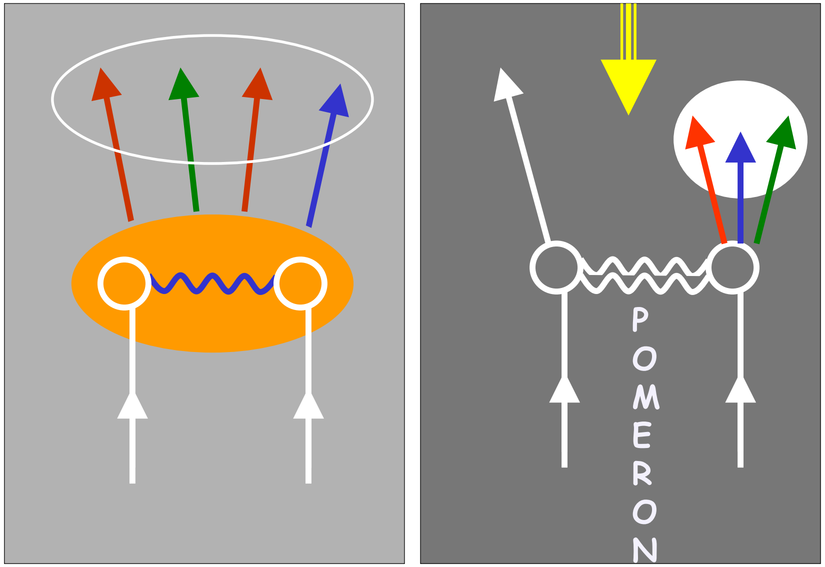
Color-exchange

Incident hadrons acquire color and break apart

<u>Diffractive:</u>

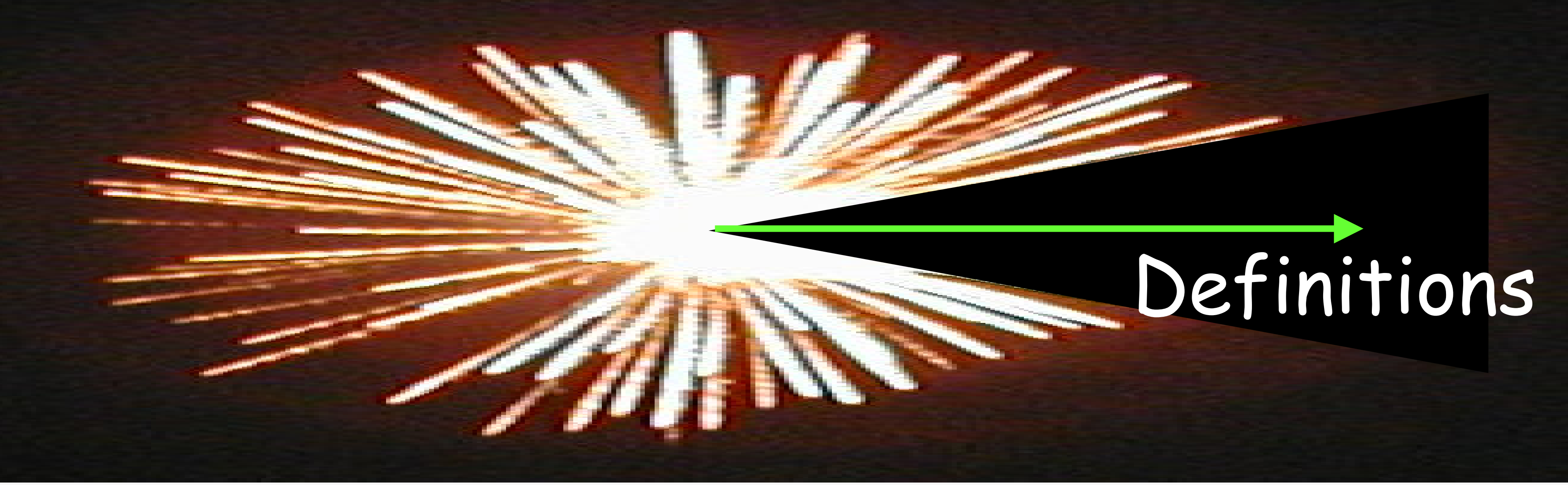
Colorless exchange with vacuum quantum numbers

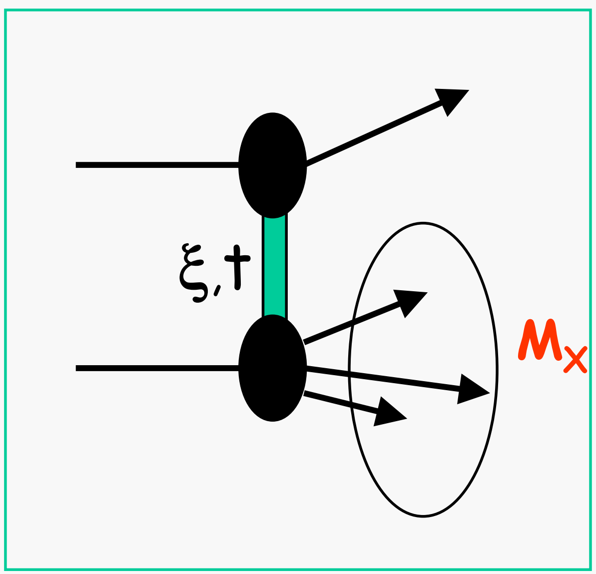
rapidity gap

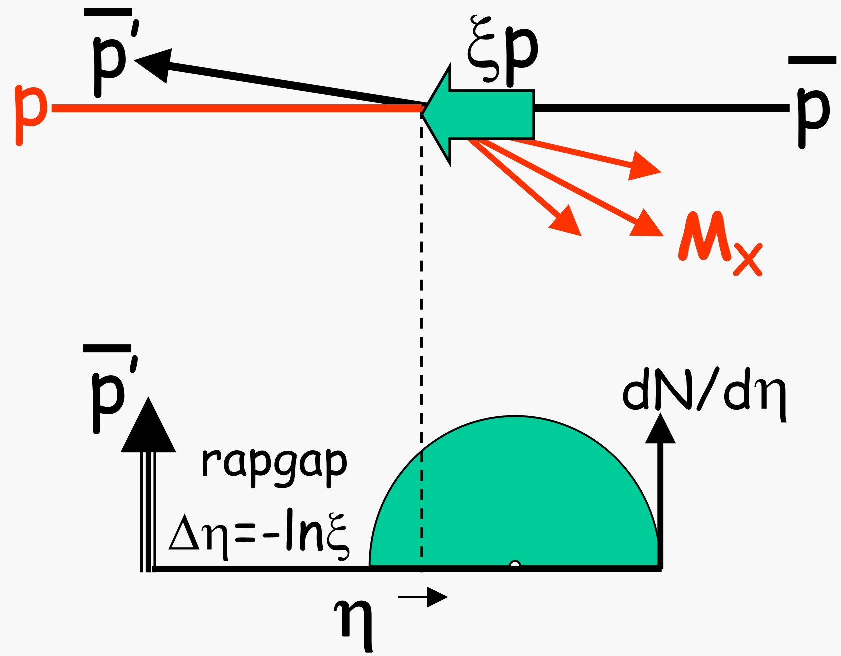


Incident hadrons retain their quantum numbers remaining colorless

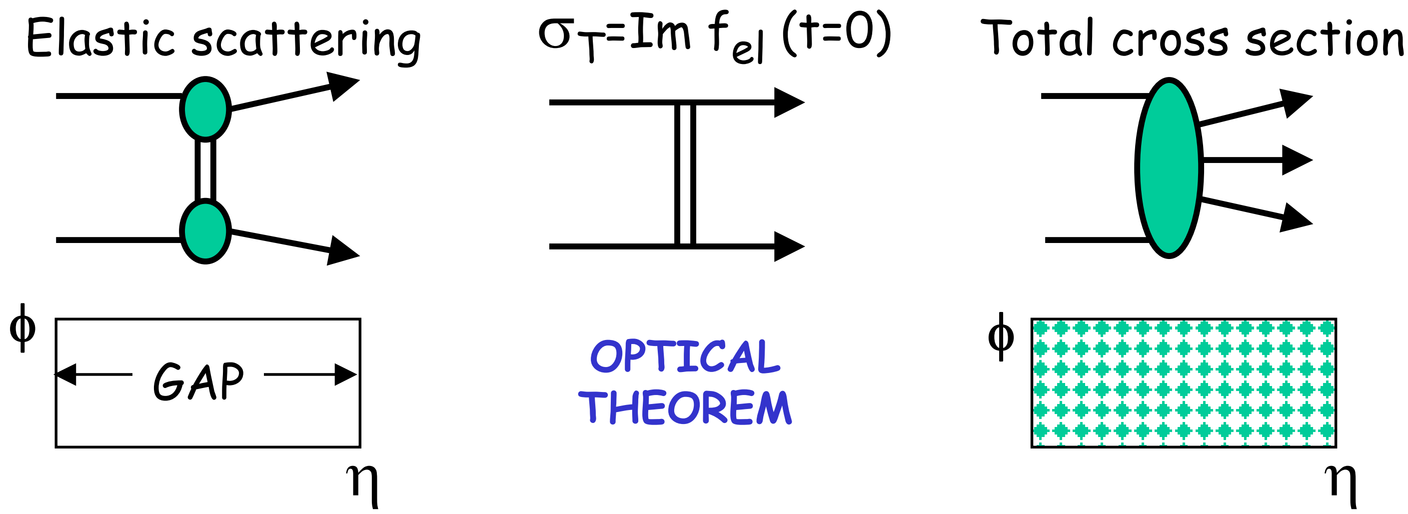
<u>Goal</u>: understand the QCD nature of the diffractive exchange

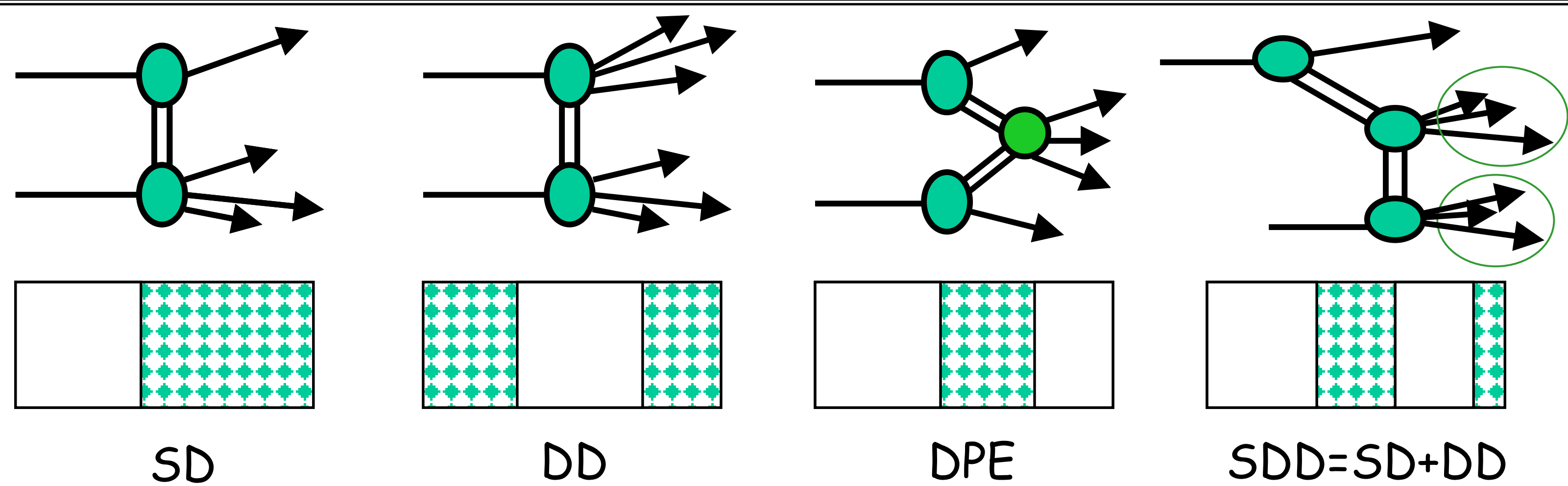

Definitions


ξ,t
Mx


p̄'
ξp
p
p̄
Mx
p̄'
dN/dη
rapgap
Δη=-lnξ
η

Diffraction at CDF

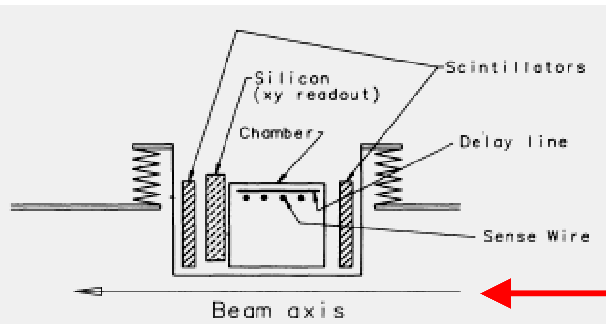




Rapidity Gaps in Fireworks

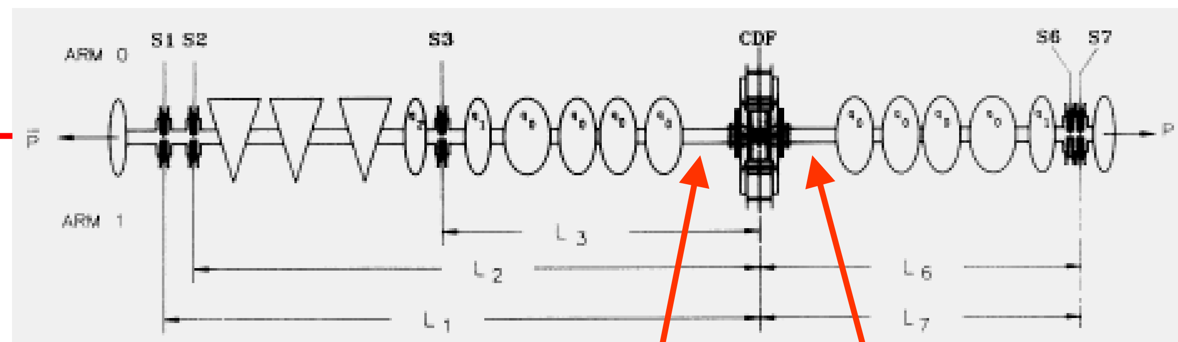
CDF Run-IØ (1988-89)

Elastic, diffractive, and total cross sections @ 546 and 1800 GeV



Roman Pot Spectrometers

CDF-I

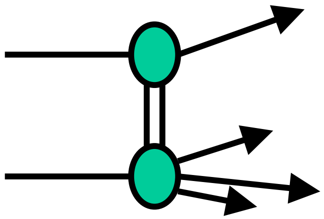


Roman Pot Detectors

- Scintillation trigger counters
- Wire chamber
- Double-sided silicon strip detector

Roman Pots with Trackers up to $|\eta| = 7$

Total SD x-section



Factorization →

$$\frac{d^2\sigma_{SD}}{dt\,d\xi} = f_{IP/p}(t,\xi) \bullet \sigma_{IP-\bar{p}}(M_X^2)$$

Pomeron flux

$$\sigma_{SD} \sim s^{2\varepsilon}$$

❖ Regge theory

σ_{SD} exceeds σ_T at

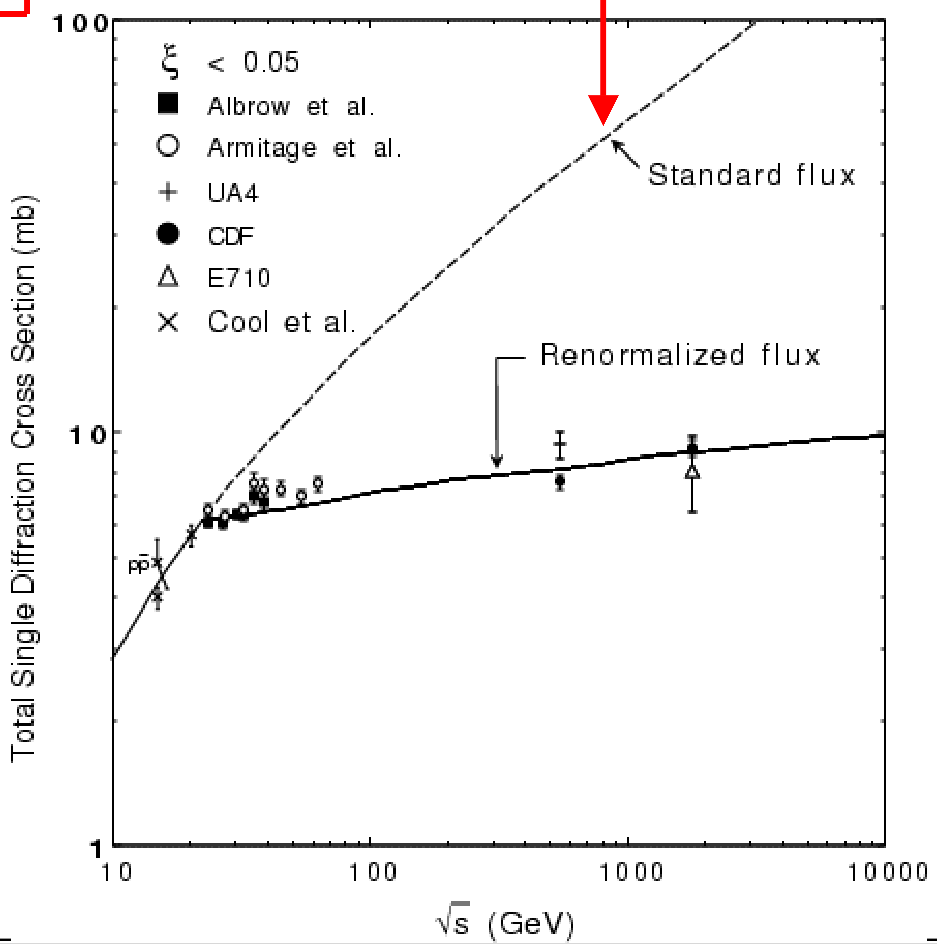
$$\sqrt{s} \approx 2\ \mathrm{TeV}.$$

❖ Renormalization

Pomeron flux integral (re)normalized to unity

KG, PLB 358 (1995) 379

$$\int_{\xi_{min}}^{0.1} \int_{t=-\infty}^{0} f_{IP/p}(t,\xi)\, d\xi\, dt = 1$$



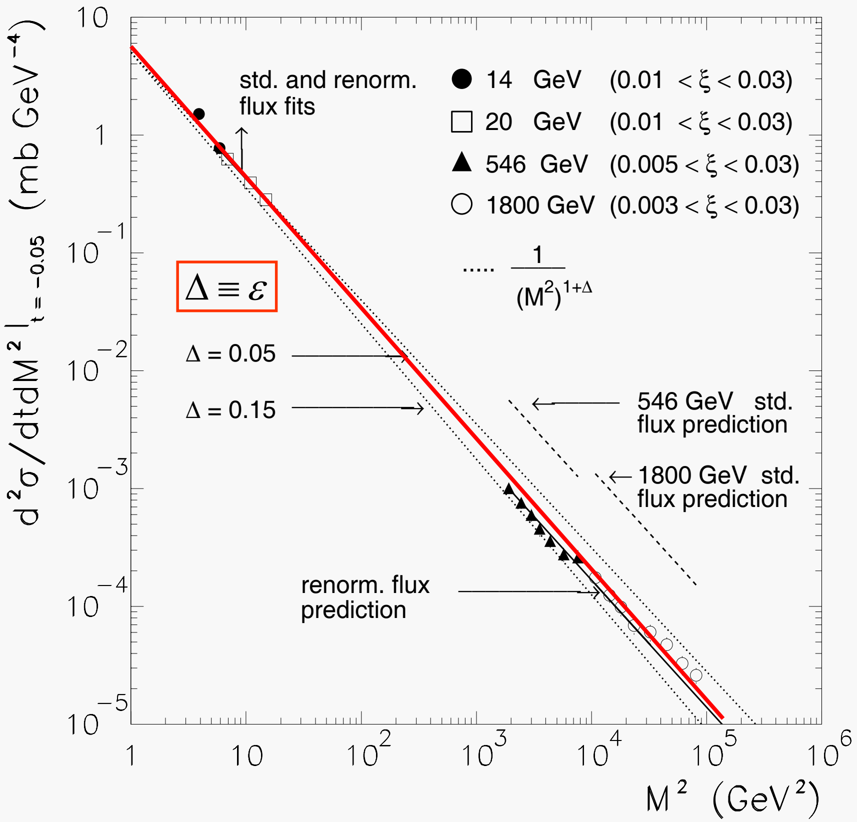
A Scaling Law in Diffraction

KG&JM, PRD 59 (1999) 114017

renormalization

$$\frac{d\sigma}{dM^2} \propto \frac{s^{2\varepsilon \to 1}}{(M^2)^{1+\varepsilon}}$$

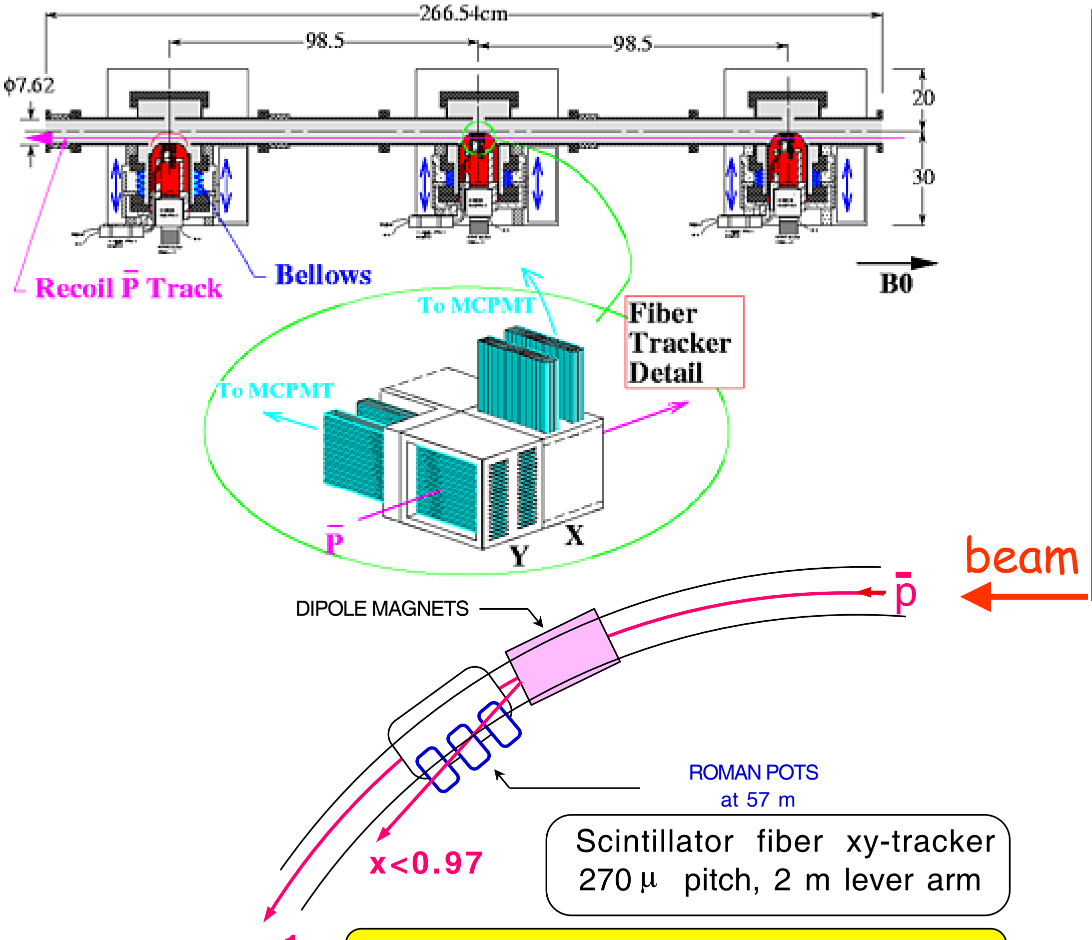
➔ Independent of S over 6 orders of magnitude in M² !



Factorization breaks down so as to ensure M²-scaling!

CDF Run-I

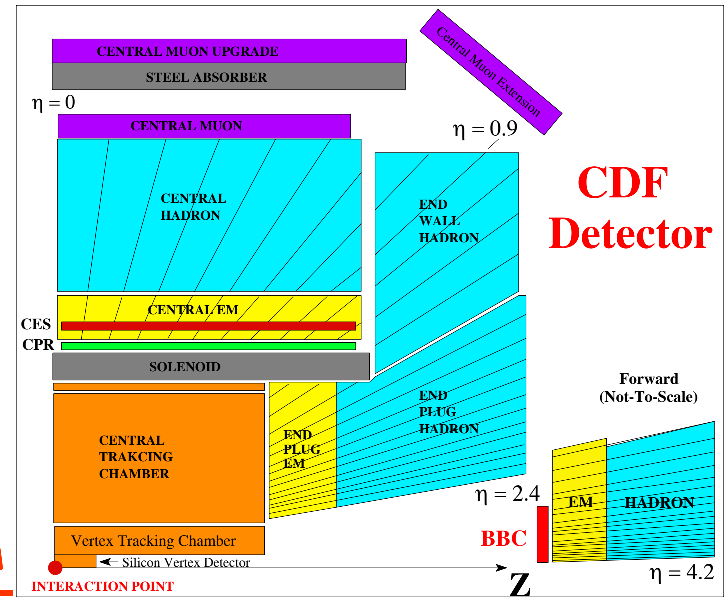
Run-IC



Scintillator fiber xy-tracker
270 μ pitch, 2 m lever arm

Acceptance: 0 < |t| < 1, 0.03< ξ < 0.1

Run-IA,B

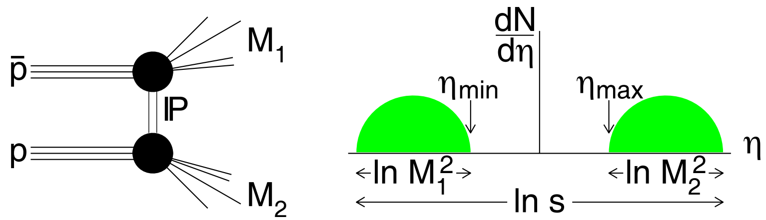


Forward Detectors

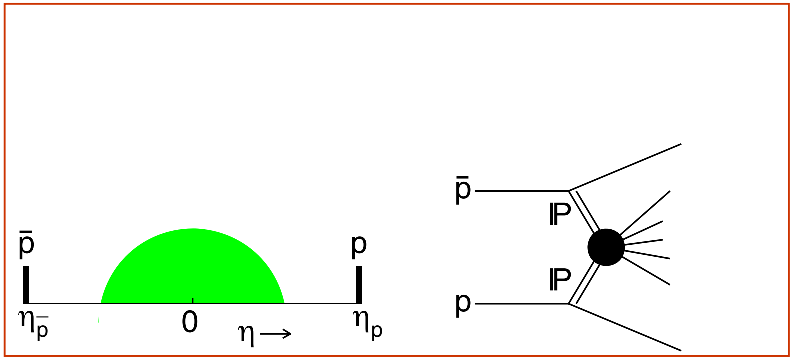
BBC 3.2<η<5.9

FCAL 2.4<η<4.2

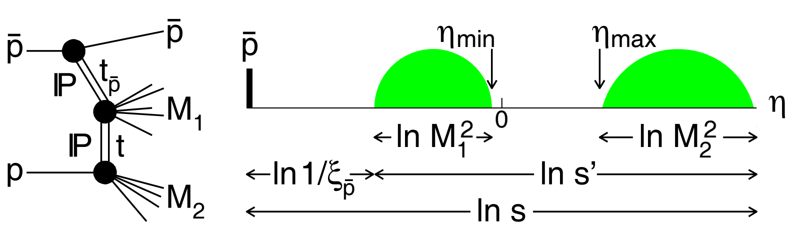
Central and Multigap Diffraction



- **Double Diffraction Dissociation**
  - **One central gap**



- **Double Pomeron Exchange**
  - **Two forward gaps**



- **SDD: Single+Double Diffraction**
  - **One forward gap+ one central gap**

Rate for second diffractive gap is not suppressed!

Diffractive Fractions

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

Fraction:
SD/ND ratio at 1800 GeV

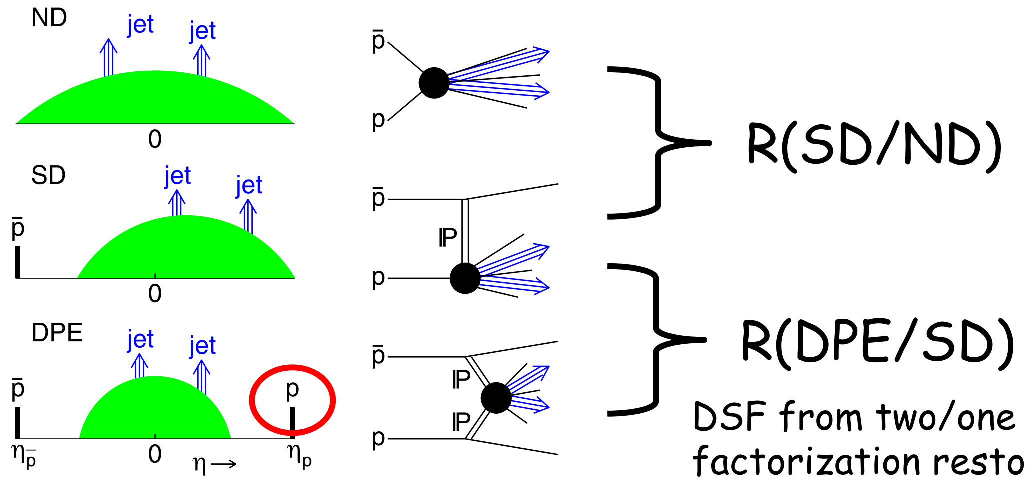
	Fraction(%)
W	1.15 (0.55)
JJ	0.75 (0.10)
b	0.62 (0.25)
J/ψ	1.45 (0.25)

All ratios ~ 1%
➔ ~ uniform suppression
~ FACTORIZATION !

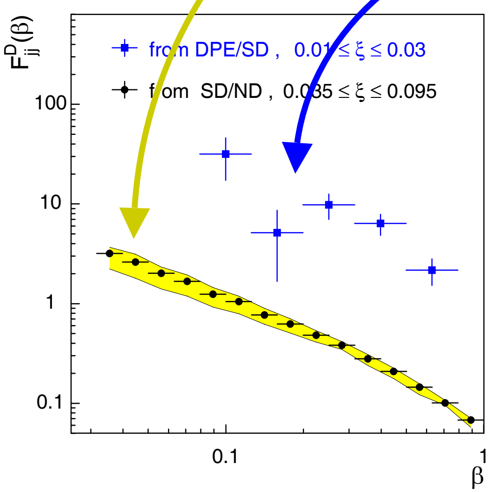
Diffractive ^{non}/Factorization

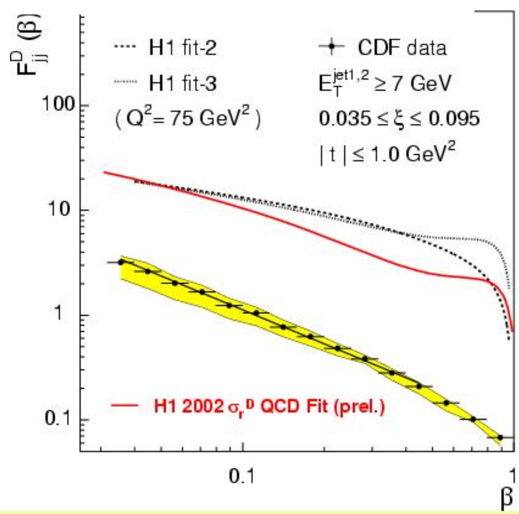
β=momentum fraction of parton in Pomeron

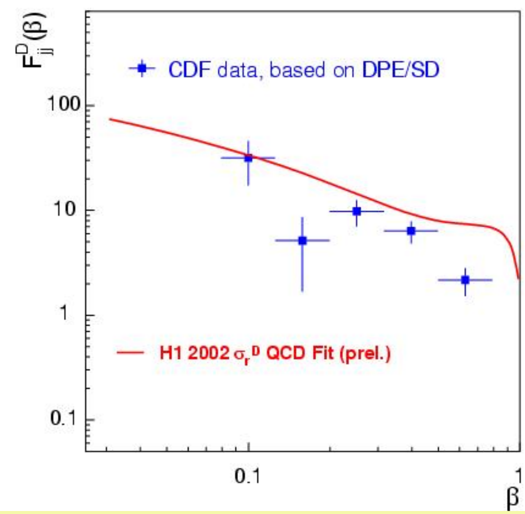
$$\beta = x_{Bj}/\xi$$



DSF from two/one gap: factorization restored!





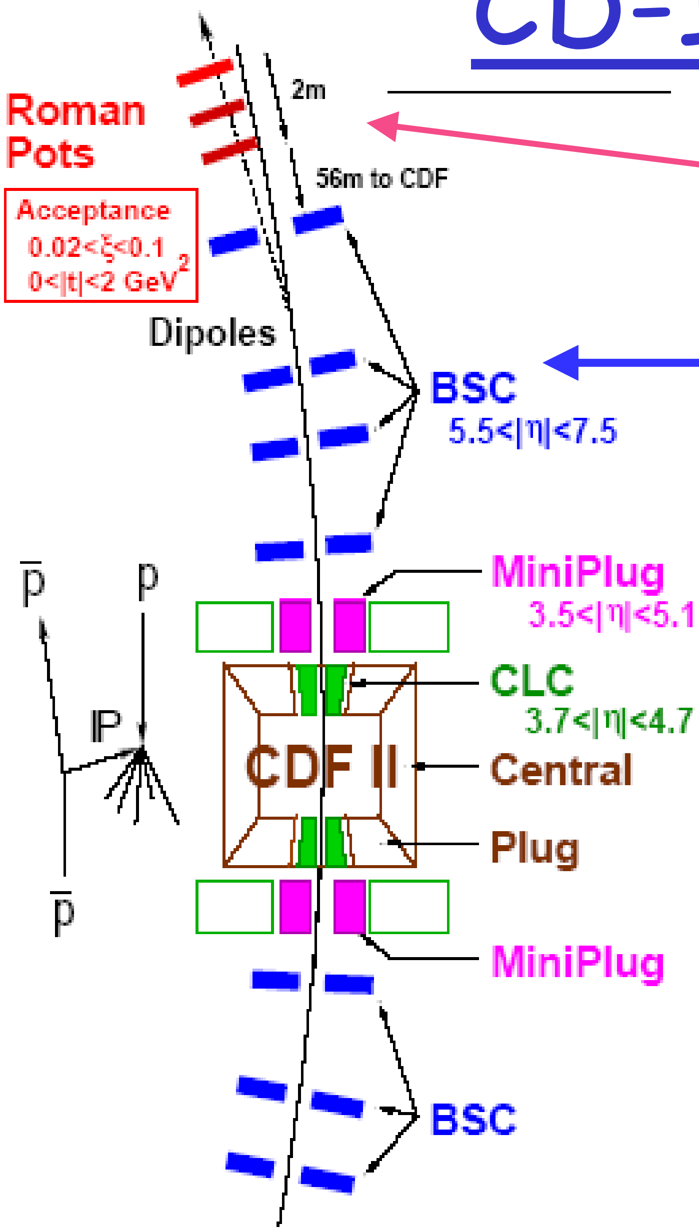


The diffractive structure function measured on the proton side in events with a leading antiproton is NOT suppressed relative to predictions based on DDIS

Run II results

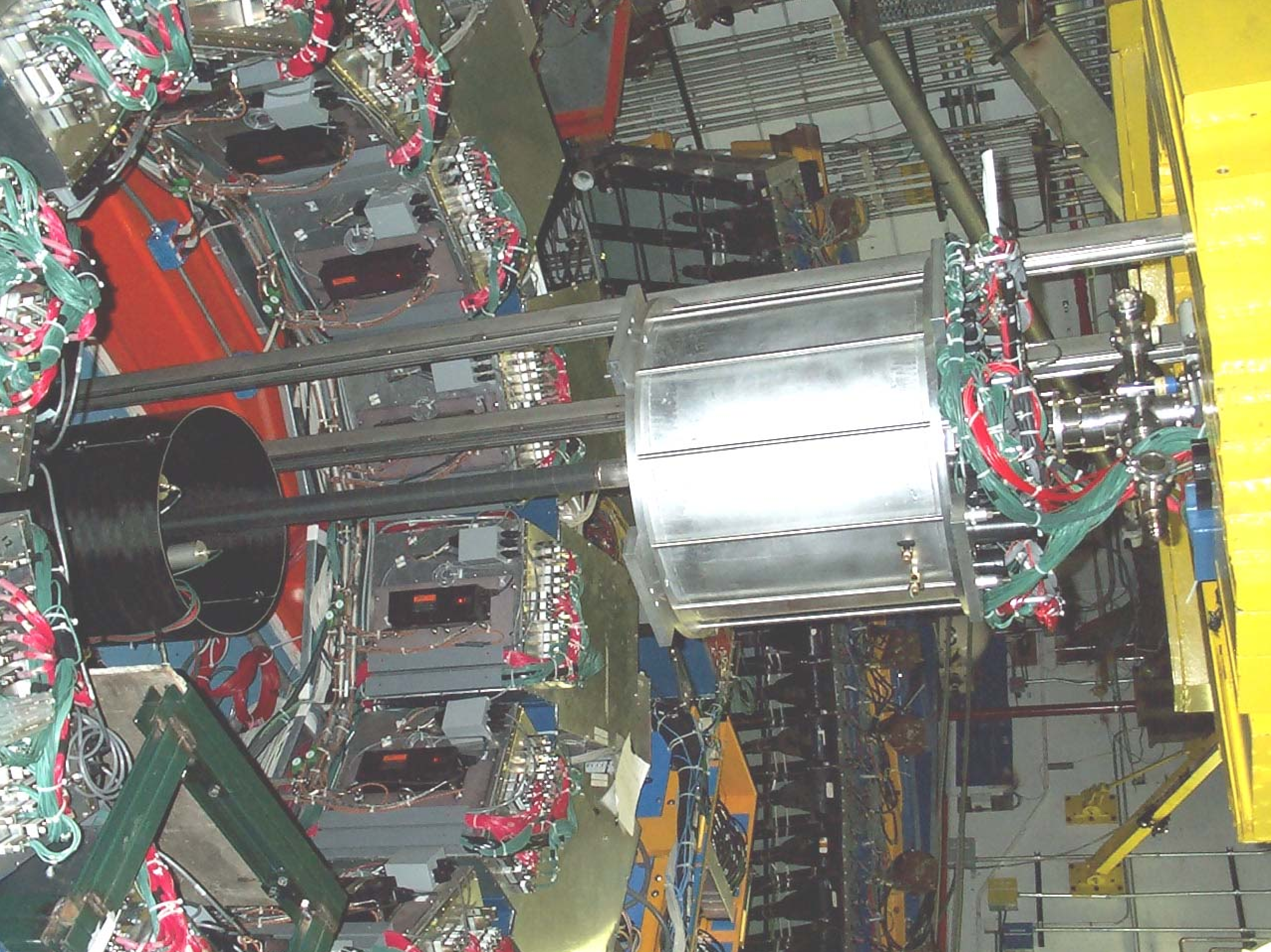
- CDF-II detectors
- Diffractive structure function
- Exclusive Production

CD-II Detectors

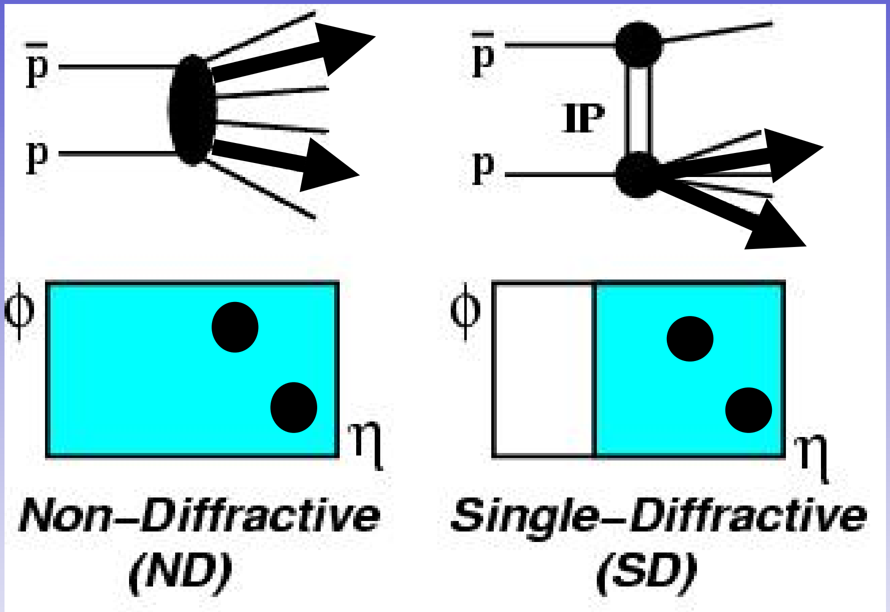


ROMAN POT DETECTORS

BEAM SHOWER COUNTERS:
Used to reject ND events



DIFFRACTIVE STRUCTURE FUNCTION



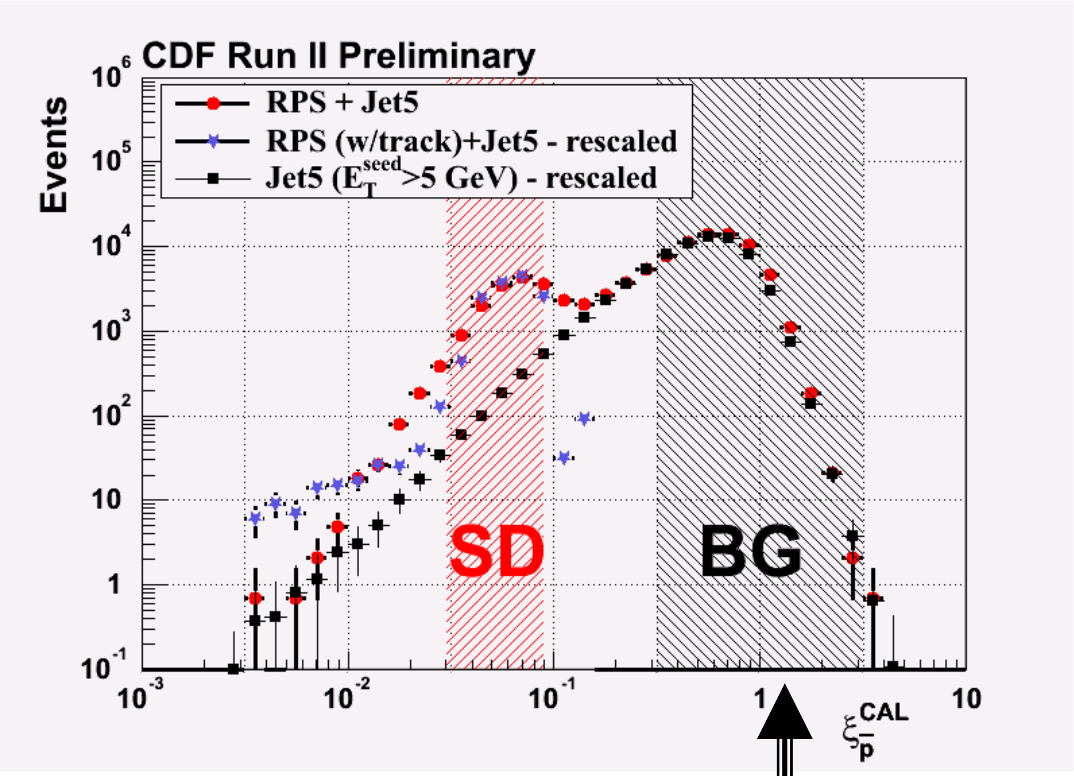
$$R(x_{Bj}) \equiv \frac{Rate_{jj}^{SD}(x_{Bj})}{Rate_{jj}^{ND}(x_{Bj})}$$

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

Systematic uncertainties due to energy scale and resolution cancel out in the ratio

Diffractive Dijet Signal

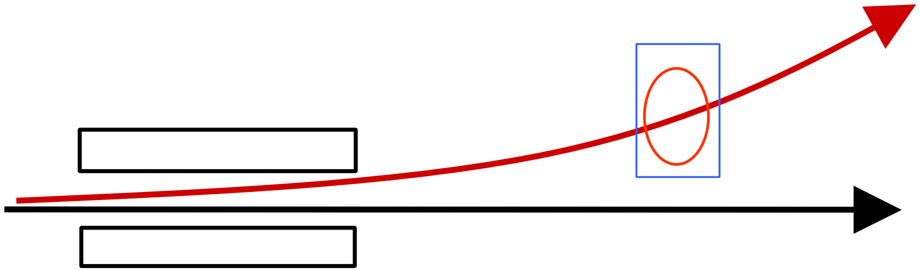
- Bulk of data taken with RPS trigger but no RPS tracking
- Extract ξ from calorimeter information
- Calibrate calorimetric ξ using limited sample of RPS tracking data
- Subtract overlap background using a rescaled dijet event sample
- Verify diffractive ξ range by comparing ξ^{RPS} with ξ^{CAL}



$$\xi^{CAL} = \frac{\sum_{\text{all towers}} E_T \, e^{-\eta}}{\sqrt{s}}$$

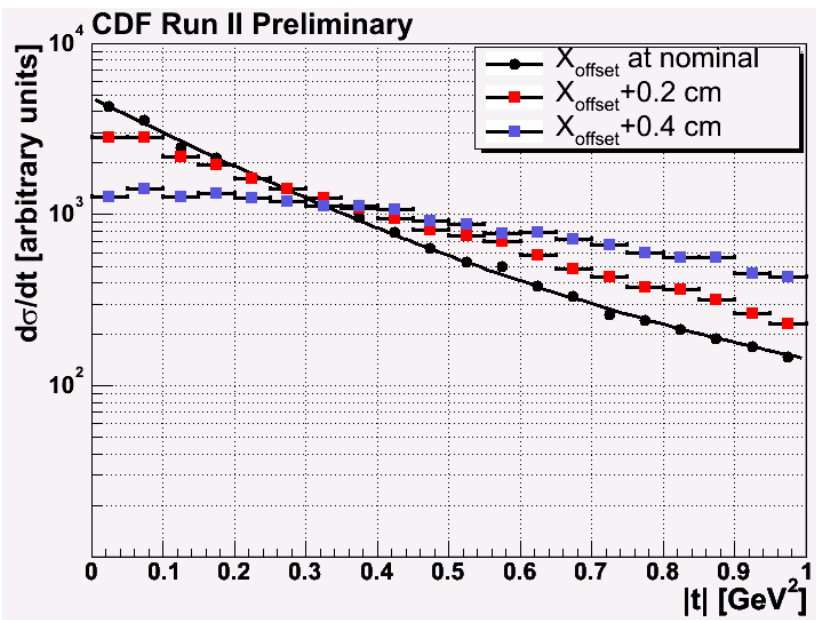
Overlap events: mainly ND dijets plus SD low ξ RPS trigger

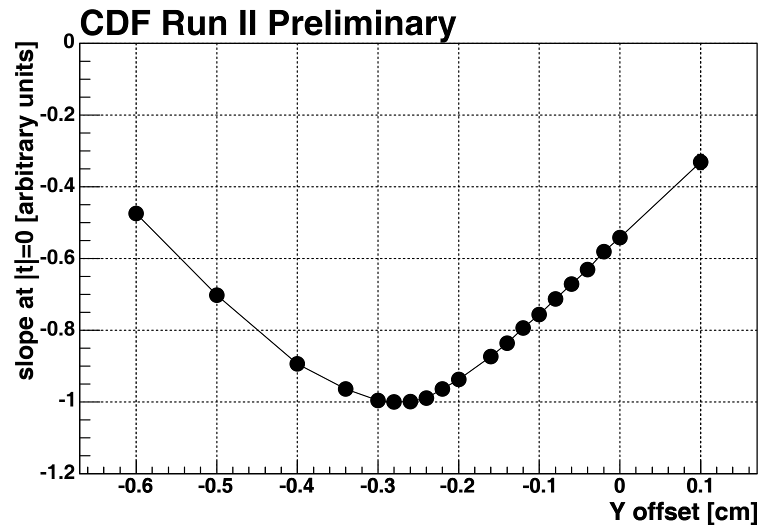
Alignment of RPS using Data

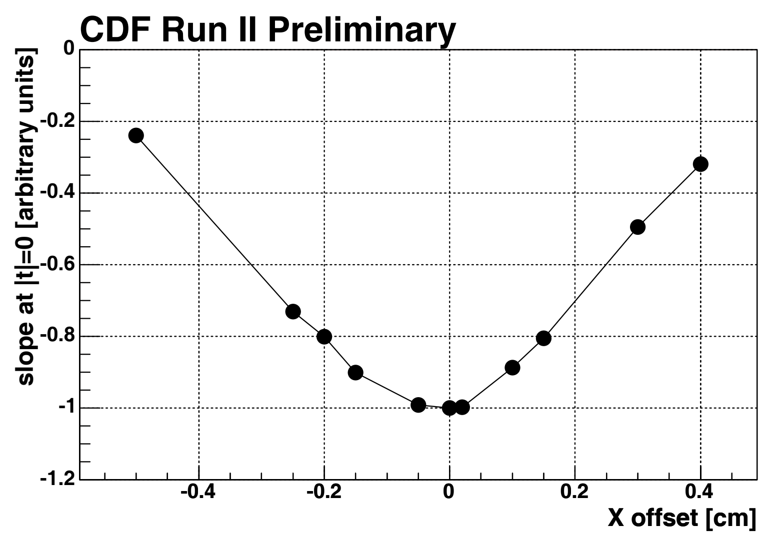


maximize the |t|-slope

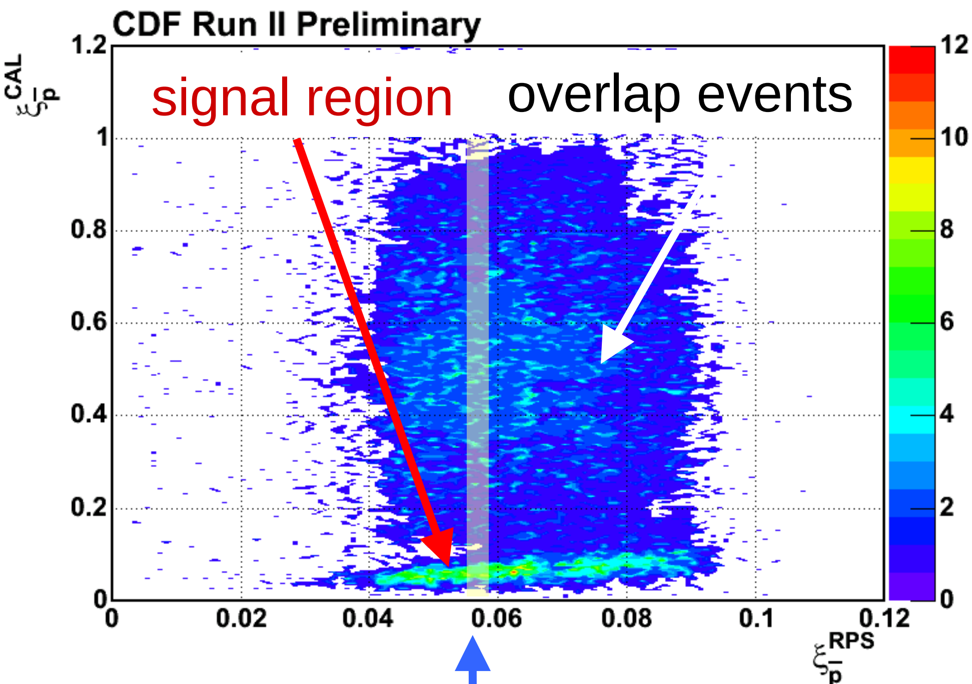
⇨ determine X and Y offsets

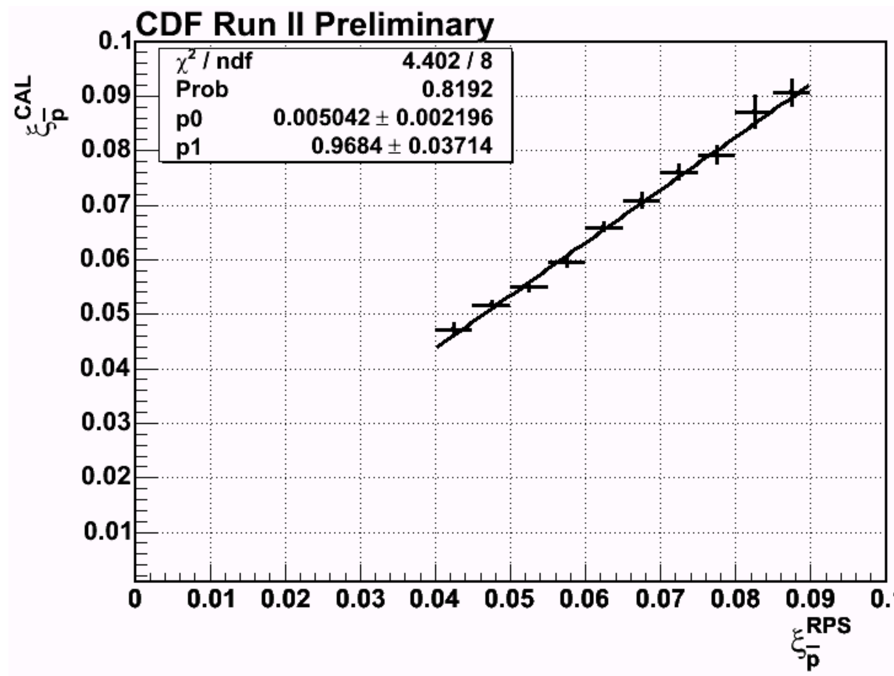


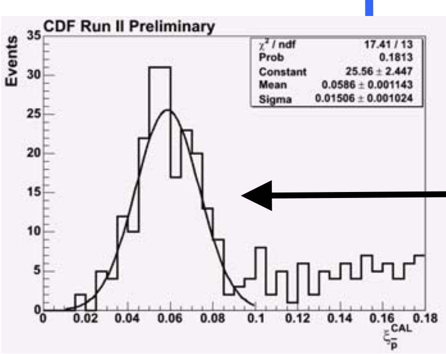




ξ^{CAL} Calibration





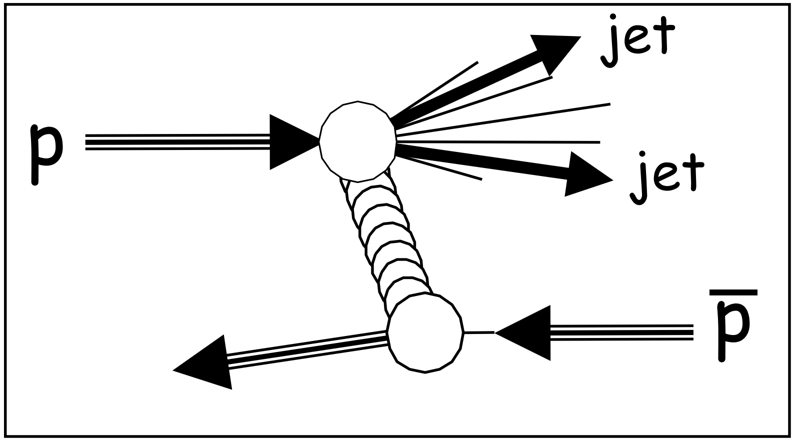


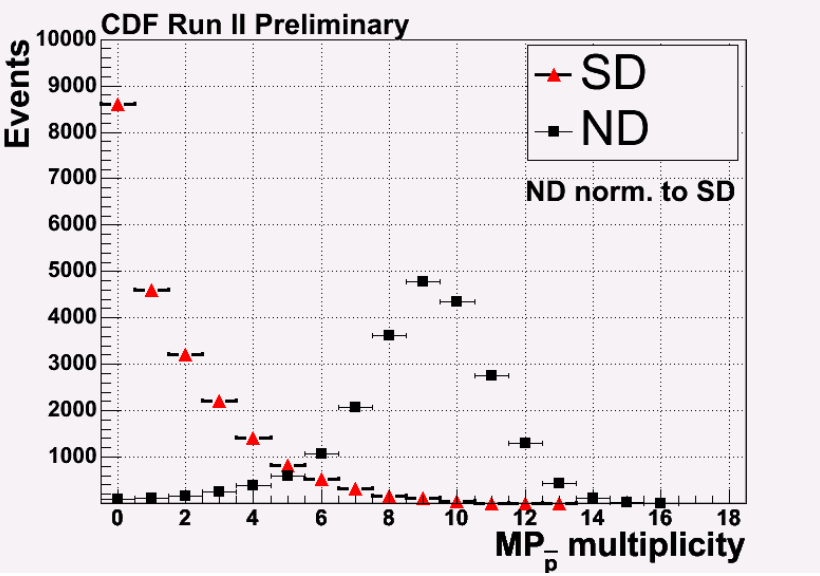
ξ^{cal} distribution for slice of ξ^{RPS}

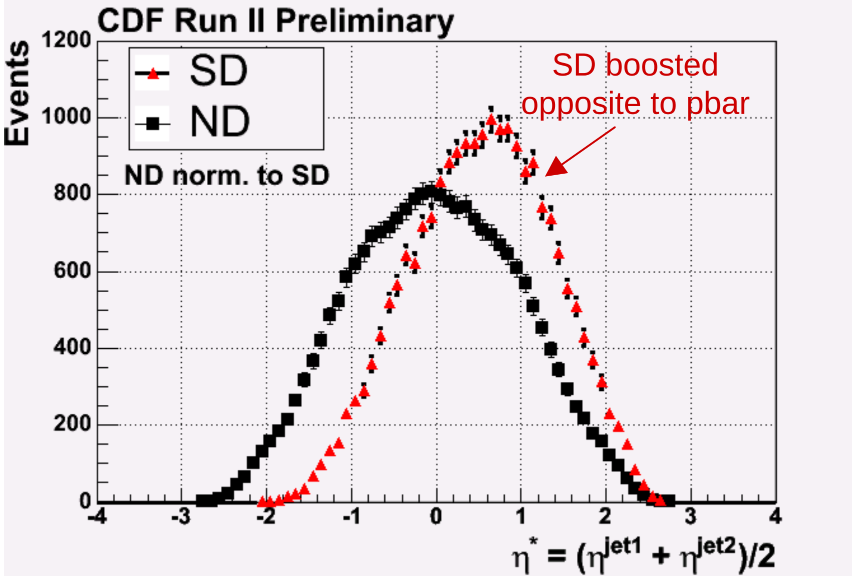
σ / mean ~ 30%

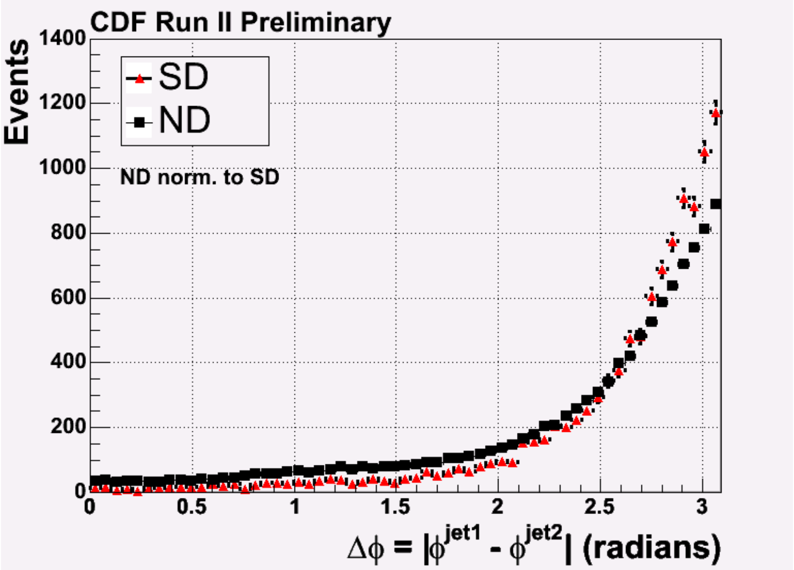
$$\xi^{CAL} = (0.97 \pm 0.04)\ \xi^{RPS}$$

Dijet Properties

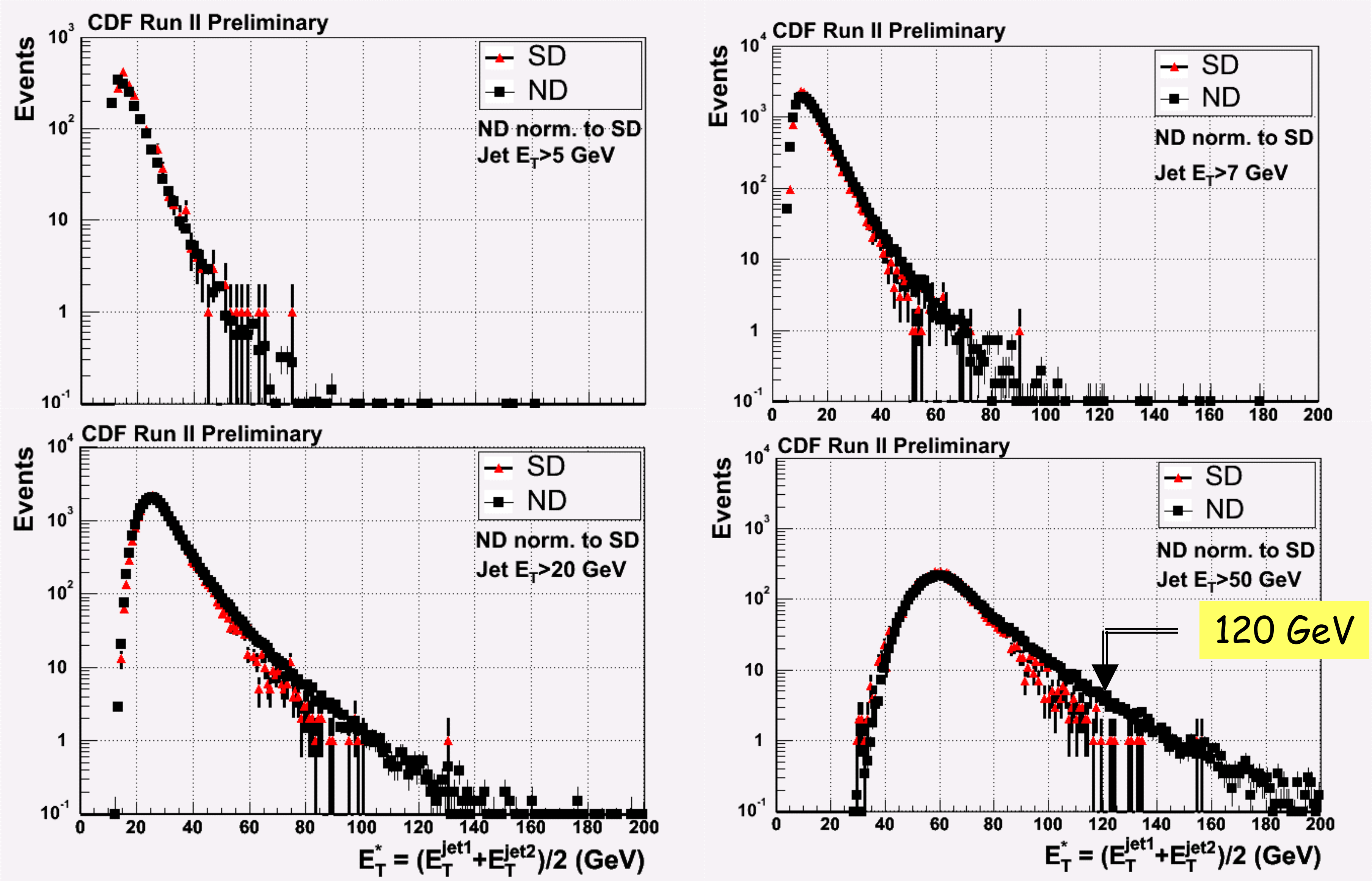




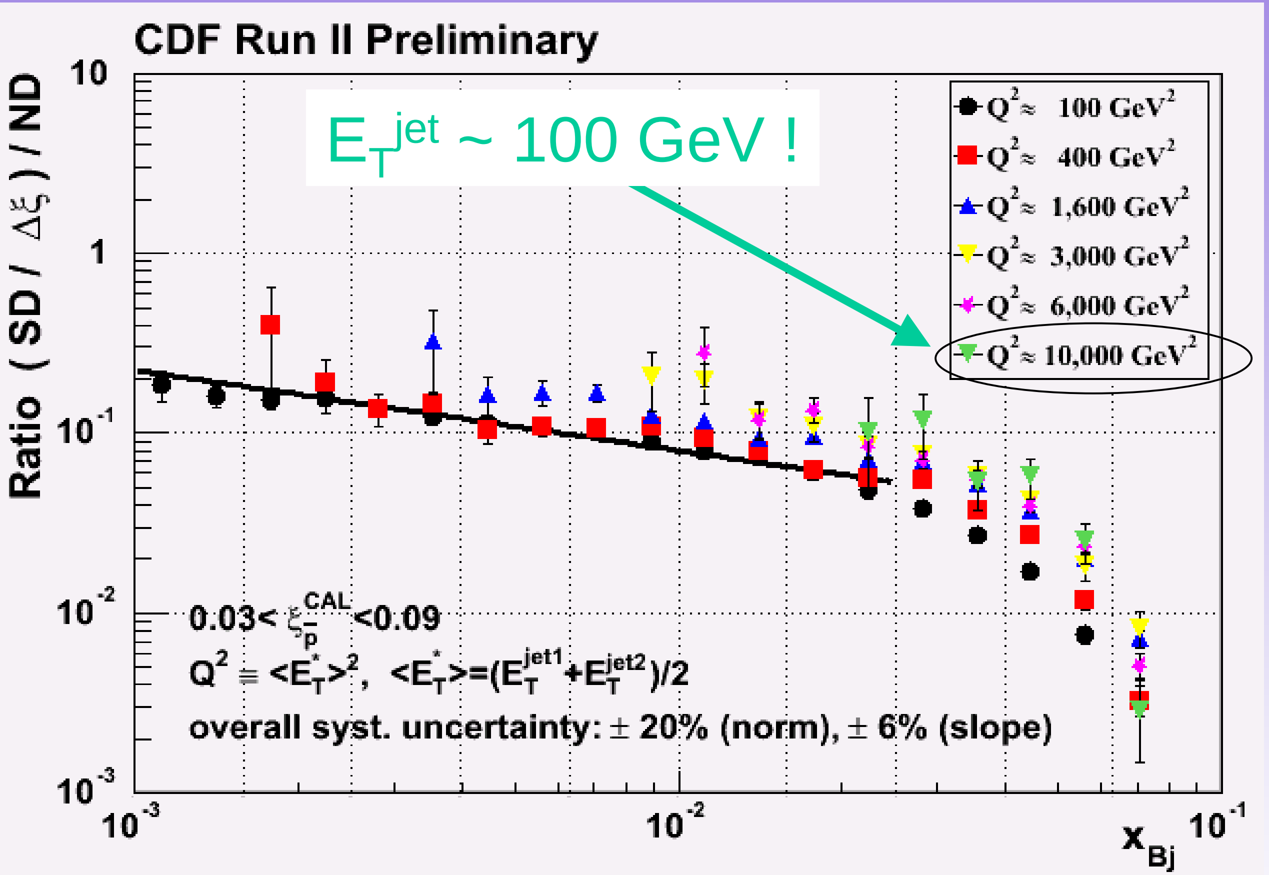




E_T distributions



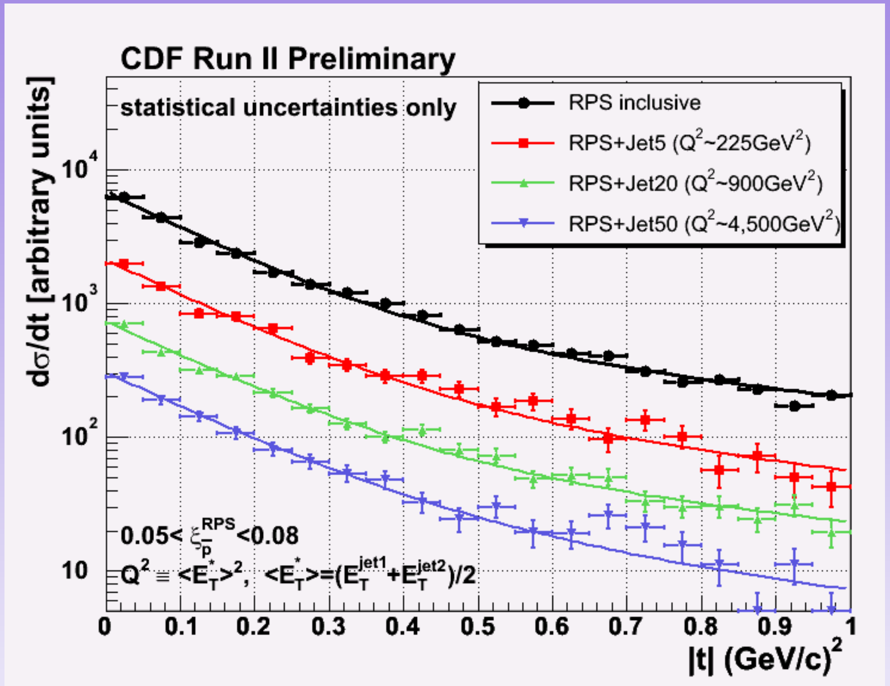
Diffractive Structure Function:
Q^2 dependence

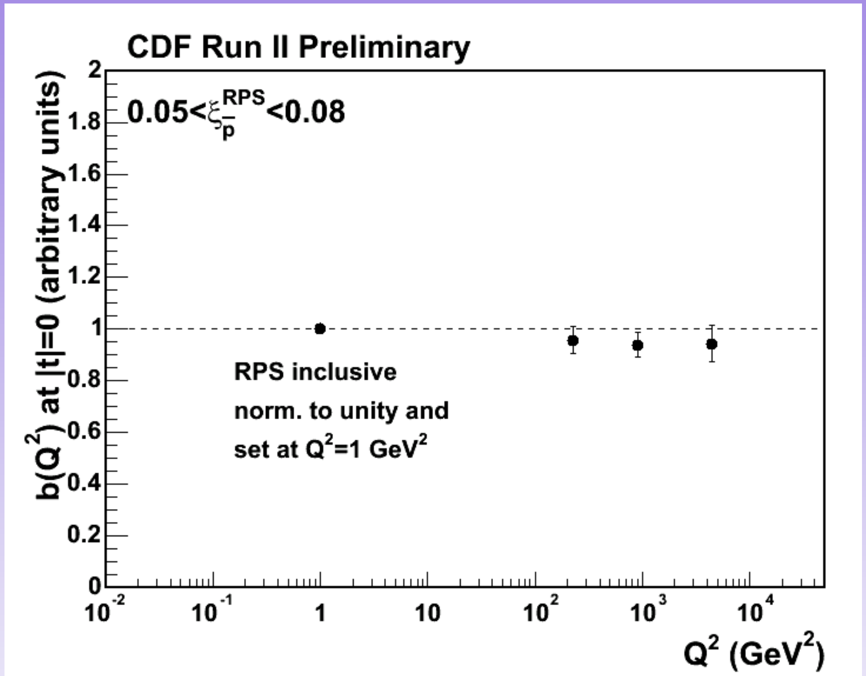


Small Q^2 dependence in region $100 < Q^2 < 10{,}000$ GeV^2

⇨ Pomeron evolves as the proton!

Diffractive Structure Function:
t- dependence





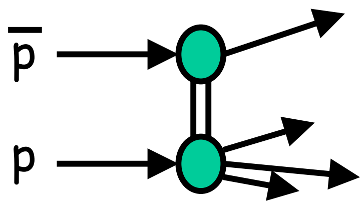
Fit dσ/dt to a double exponential:

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

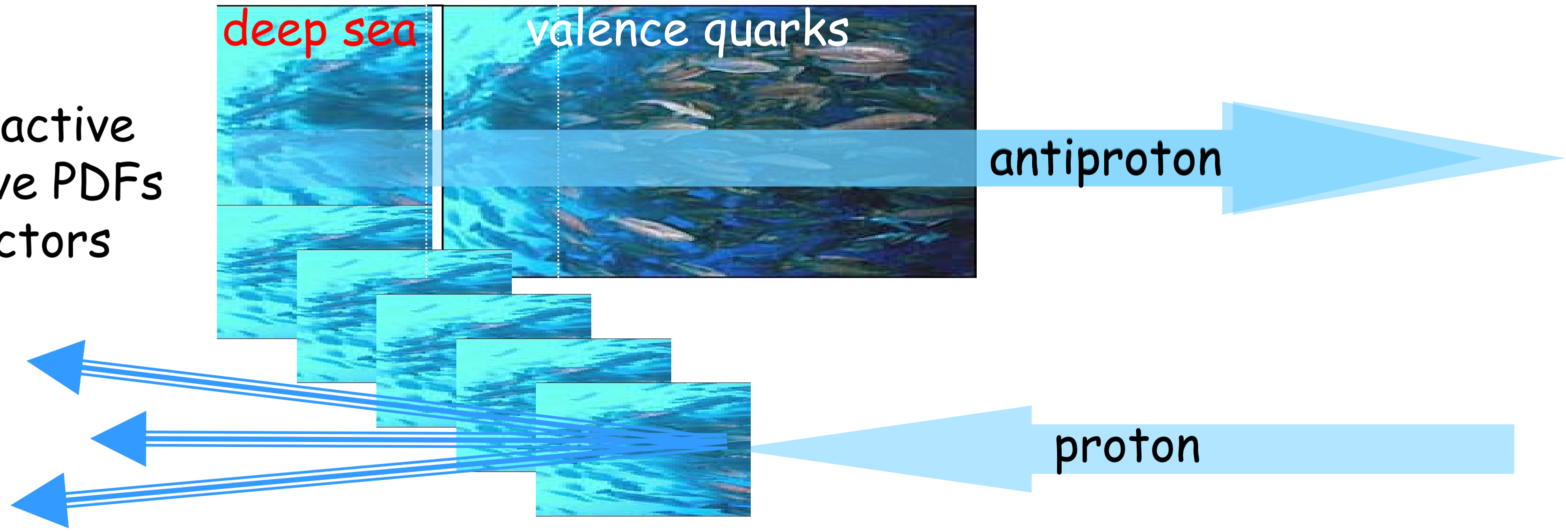
- No diffraction dips
- No Q2 dependence in slope from inclusive to $Q^2 \sim 10^4$ GeV^2

- Same slope over entire region of $0 < Q^2 < 4{,}500$ GeV^2 across soft and hard diffraction!

Hard Diffraction in QCD

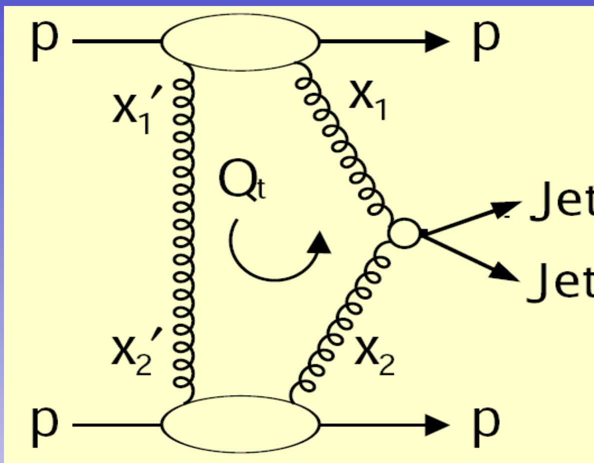


Derive diffractive
from inclusive PDFs
and color factors



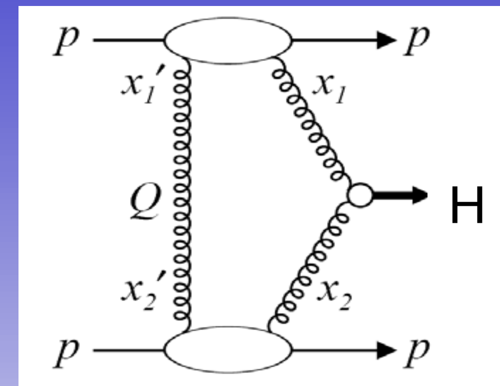
EXCLUSIVE PRODUCTION

Measure exclusive jj & $\gamma\gamma$ → → → Calibrate predictions for H production rates @ LHC



Bialas, Landshoff,
Phys.Lett. B 256,540 (1991)
Khoze, Martin, Ryskin,
Eur. Phys. J. C23, 311 (2002);
C25,391 (2002);C26,229 (2002)
C. Royon, hep-ph/0308283
B. Cox, A. Pilkington,
PRD 72, 094024 (2005)
OTHER……………………………

Discovery channel



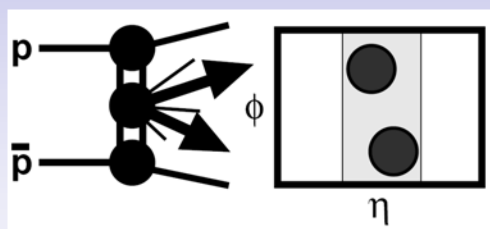
KMR: σ_H(LHC) ~ 3 fb
S/B ~ 1 if ΔM ~ 1 GeV

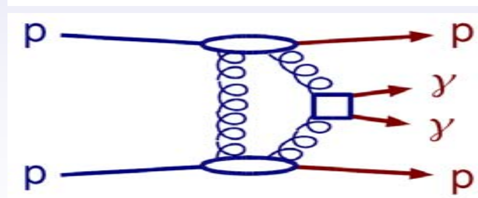
Search for exclusive dijets:

Measure dijet mass fraction

$$R_{jj} = \frac{M_{jj}}{M_X(\text{all calorimeters})}$$

Look for signal as $R_{jj} \rightarrow 1$





Search for exclusive $\gamma\gamma$

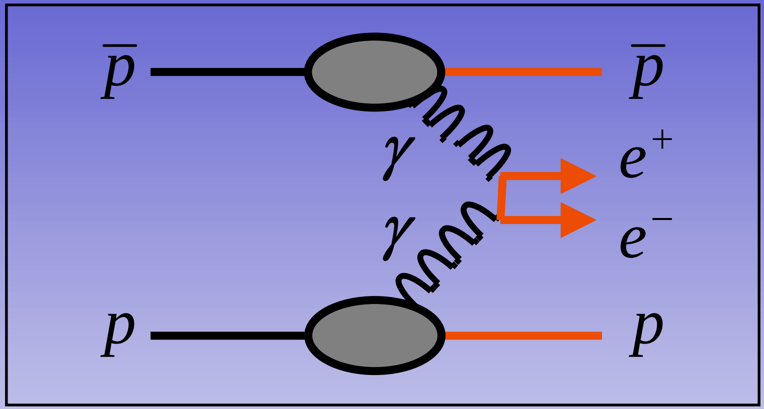
- ✓ 3 candidate events found
- ✓ 1 (+2/-1) predicted from ExHuME MC
- ➢ estimated ~1 bgd event from $\pi^0\,\pi^0$, $\eta\,\eta$

$$\sigma < 410\ \text{fb}\ (95\%\ \text{C.L.})$$

Exclusive e^+e^- Production

PRL 98, 112001 (2007)

First observation in hadron colliders



$$16\ \text{candidates}: \mathrm{E_T} > 5\ GeV, |\eta| < 2$$

$$\text{Backgound}: 1.9 \pm 0.3\ \text{events}$$

$$5.5\,\sigma \quad \text{observation}$$

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

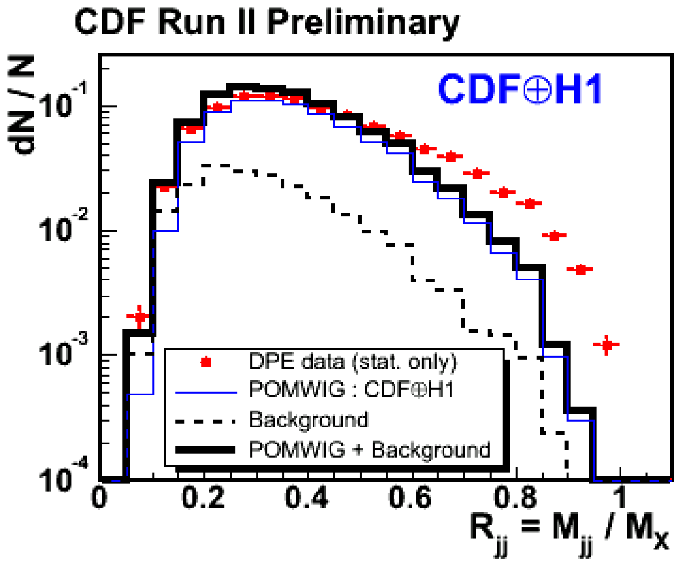
$$\sigma_{LPAIR} = 1.71 \pm 0.01\ pb$$

agrees with LPAIR MC (QED)

Exclusive Dijet Signal

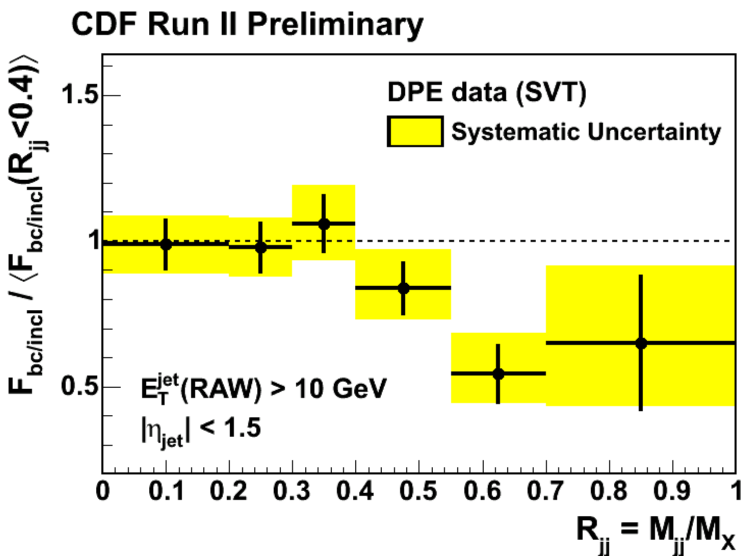
DIJETS

Dijet fraction – all jets



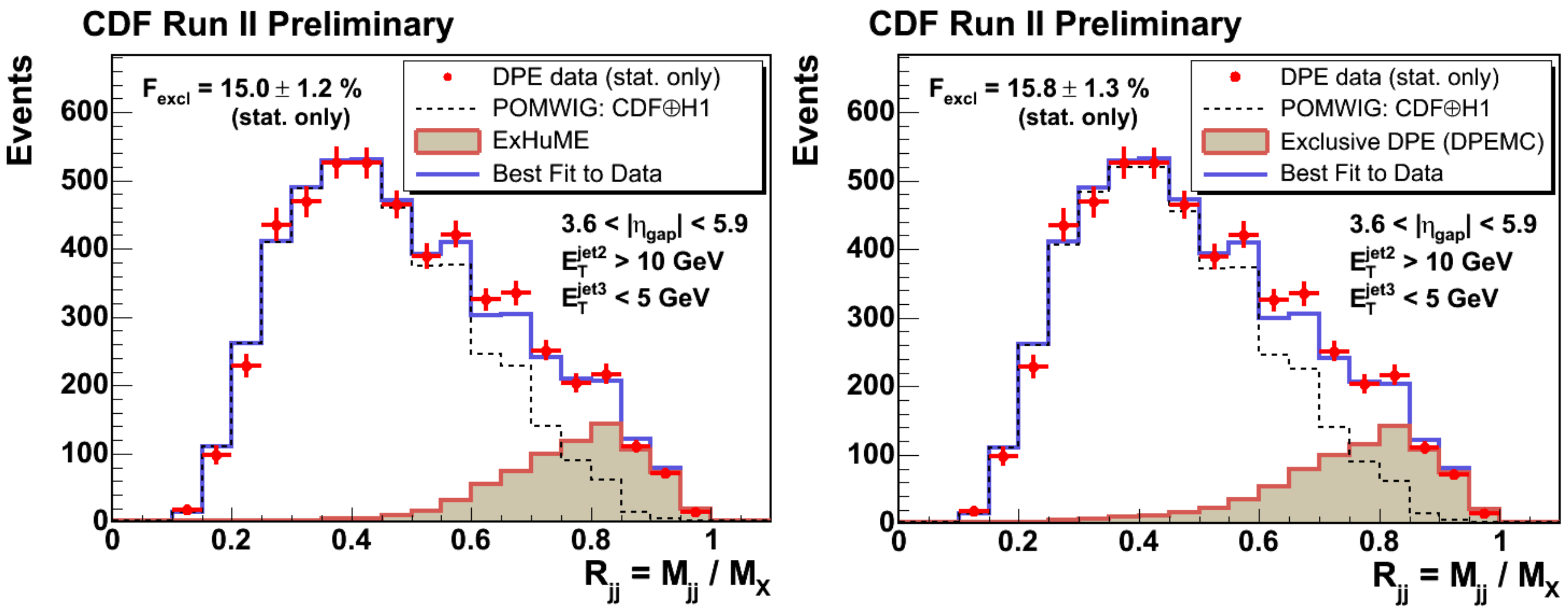
Excess over MC predictions at large dijet mass fraction

b-tagged dijet fraction



Exclusive b-jets are suppressed by J_Z= 0 selection rule

R_{JJ}(excl): Data vs MC



ExHuME (KMR): gg→gg process
➔ uses LO pQCD

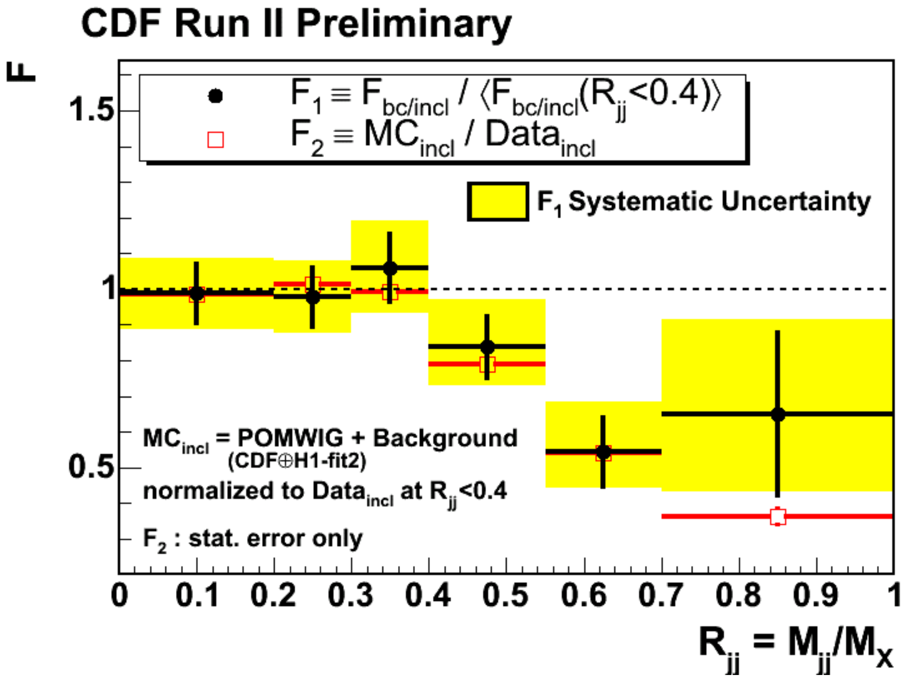
Exclusive DPE (DPEMC)
➔ non-pQCD based on Regge theory

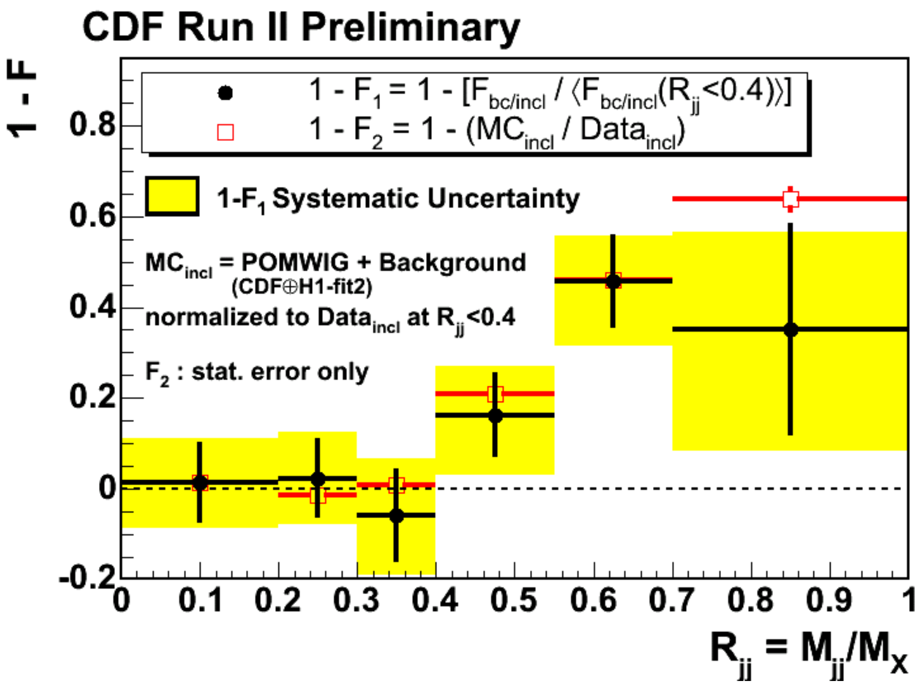
Shape of excess of events at high R_{jj}
is well described by both models

jj_{excl}: Exclusive Dijet Signal

COMPARISON

Inclusive data vs MC @ b/c-jet data vs inclusive



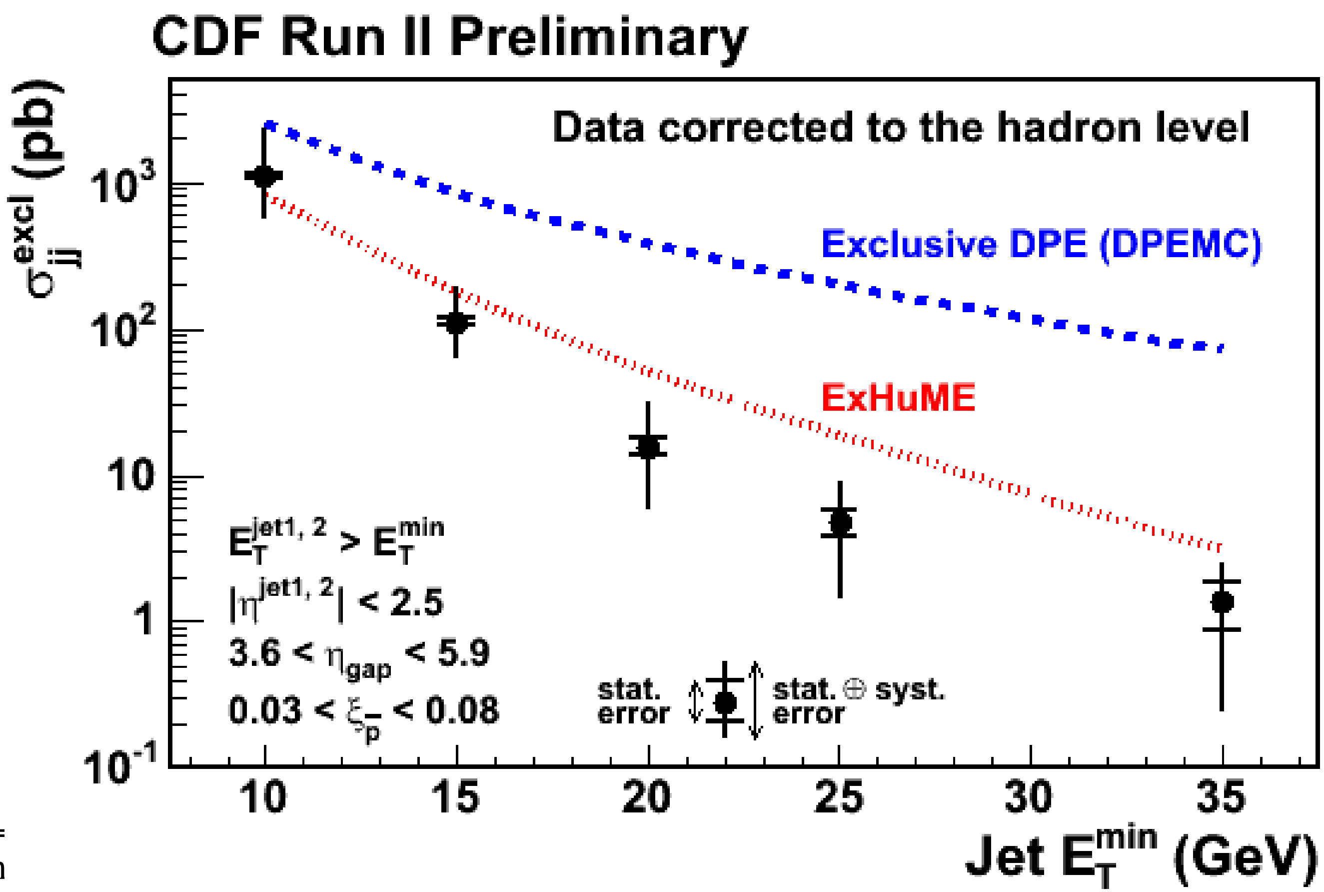


JJ_{excl} : x-section vs E_T(min)

Comparison with hadron level predictions

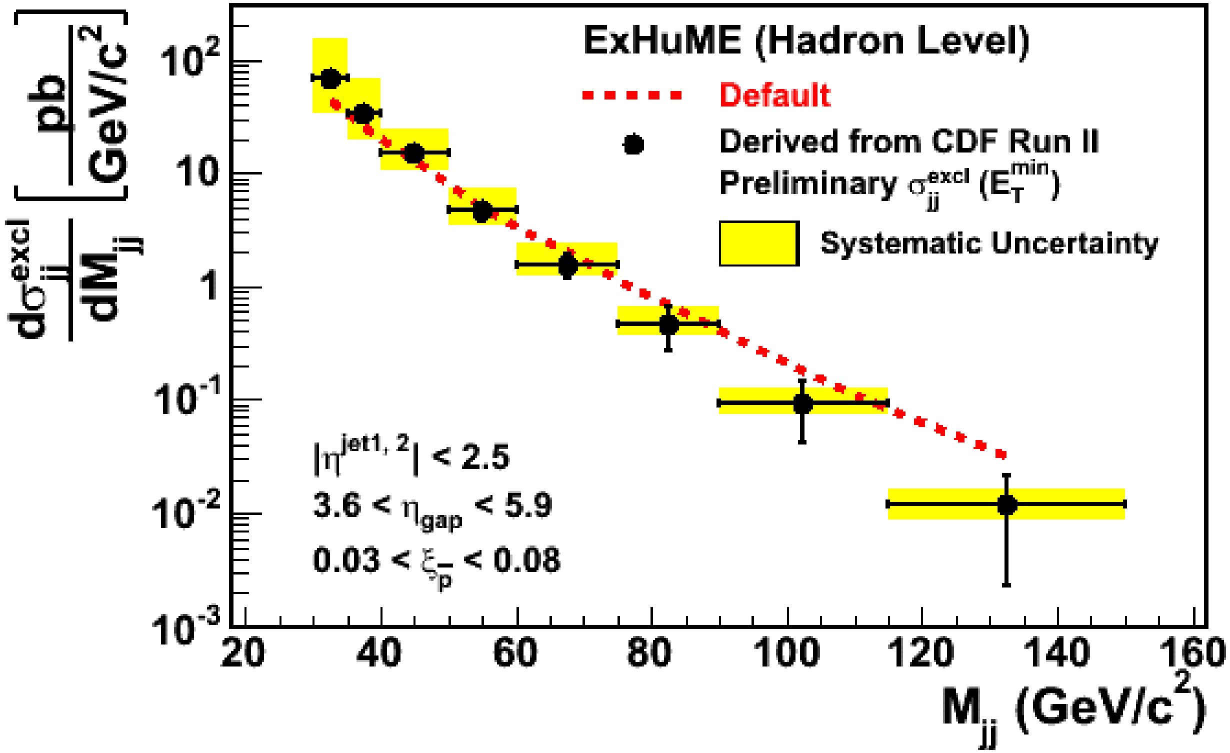
ExHuME (red)

Exclusive DPE in DPEMC (blue)



JJ_{excl} : cross section predictions

ExHuME Hadron-Level Differential Exclusive Dijet Cross Section vs Dijet Mass
(dotted/red): Default ExHuME prediction
(points): Derived from CDF Run II Preliminary excl. dijet cross sections



Statistical and systematic errors are propagated from measured cross section uncertainties using ExHuME M_{jj} distribution shapes.

Summary

CDF - what we have learnt

- M^2 - scaling ➔ $d\sigma/M^2$ not a function of s
- multigap diffraction ➔restoration of factorization!
- flavor independence of diffractive fractions
- small Q2 dependence of SD/ND x_{BJ}-distributions
- t-distributions independent of Q2
- exclusive dijet cross sections favor the perturbative QCD over the DPE approach

LHC - what to do

- Elastic and total cross sections & ρ-value
- High mass (➔4 TeV) and multi-gap diffraction
- Exclusive production (FP420 project)

For a QCD perspective, see Tuesday's talk on:
"Pomerom Intercept and Slope: the QCD connection"