Diffraction at the Tevatron: CDF Results

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→ presented on behalf of the CDF Collaboration ←

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Milos island, Greece, 5-10 September 2006

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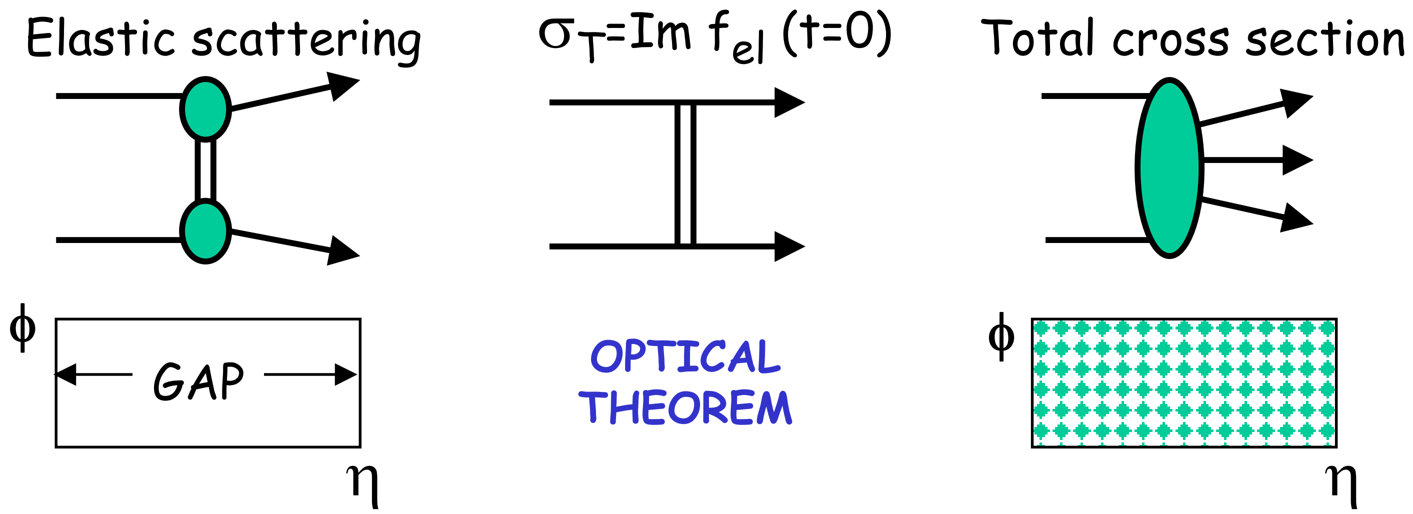
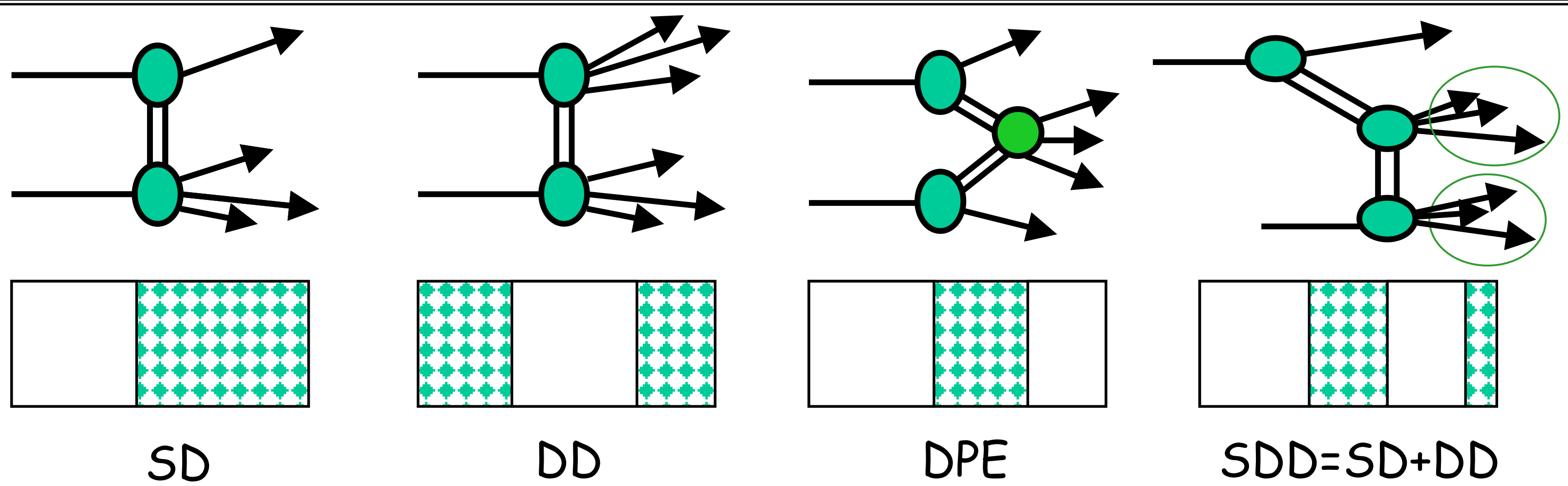
- Run-I diffraction @ CDF
- Run II results
  - ✓ Diffractive structure function
    - ➔ x_{Bj}, Q^2, and t dependence
  - ✓ Exclusive production
    - ➔ dijet & diphoton

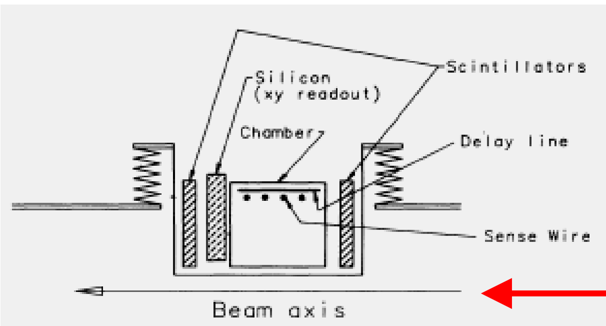
Run-I Diffraction @ CDF



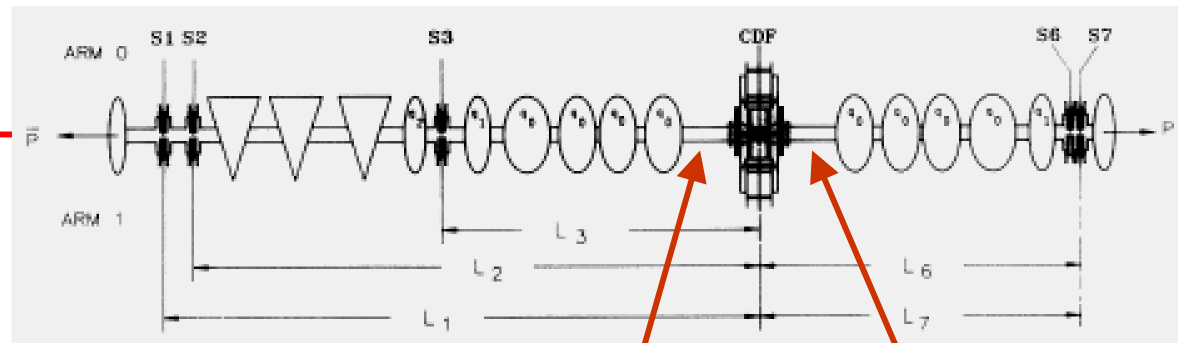


Run I-0 (1988-89)

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



Roman Pot Spectrometers



Roman Pot Detectors

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

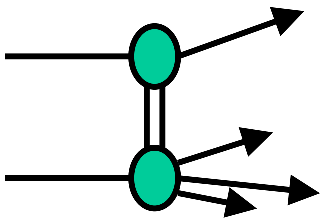
Additional Detectors

Trackers up to $|\eta| = 7$

Results

- Total cross section $\sigma^{tot} \sim s^{\varepsilon}$
- Elastic cross section $d\sigma/dt \sim \exp[2\alpha' \ln s]$ → shrinking forward peak
- Single diffraction Breakdown of Regge factorization

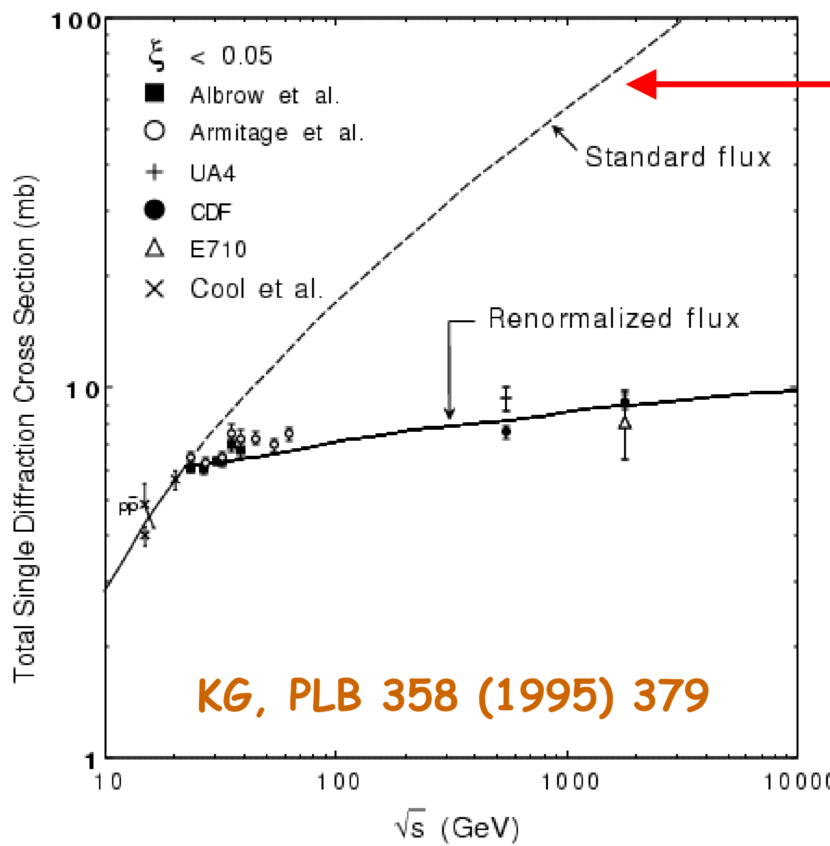
Breakdown of Regge factorization



Factorization →

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

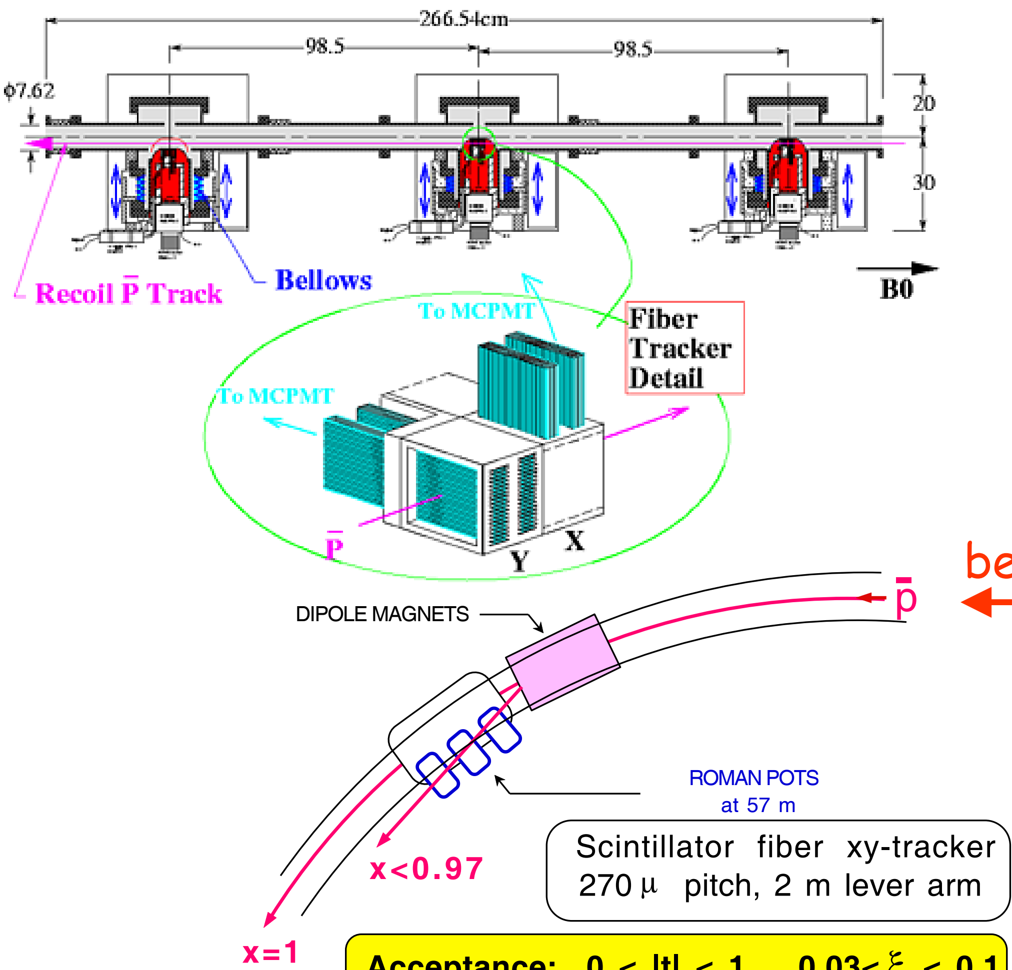
Pomeron flux



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

Run-IA,B,C

Run-IC

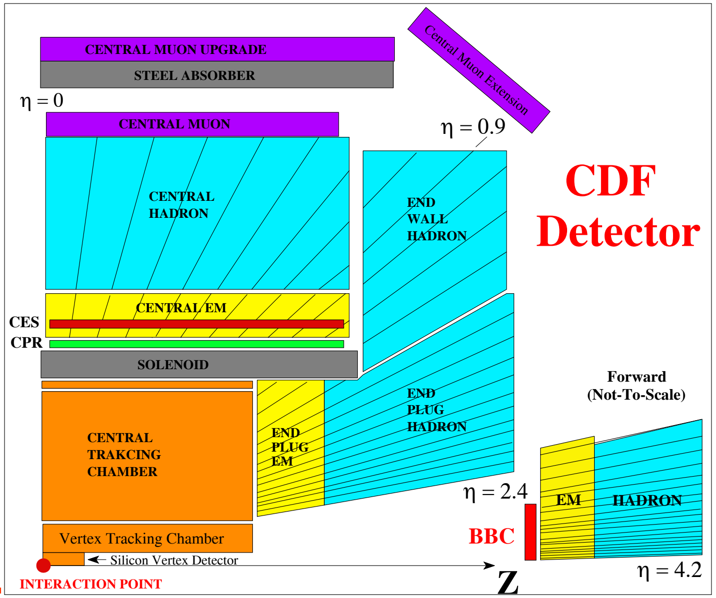


beam

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

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

Run-IA,B

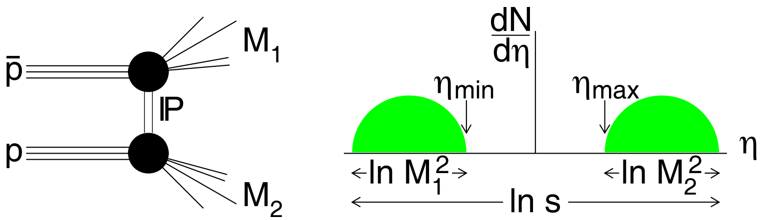


Forward Detectors

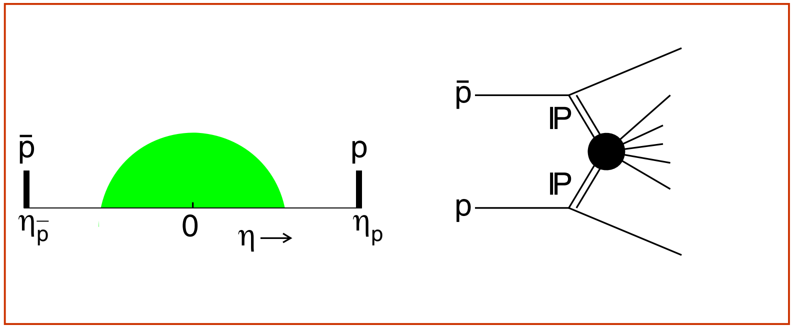
BBC 3.2<η<5.9

FCAL 2.4<η<4.2

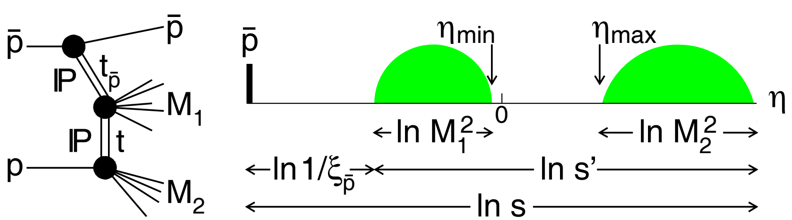
Central and Double Gaps @ CDF



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



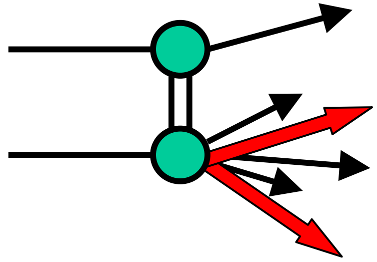
- **Double Pomeron Exchange**
  - Two forward gaps

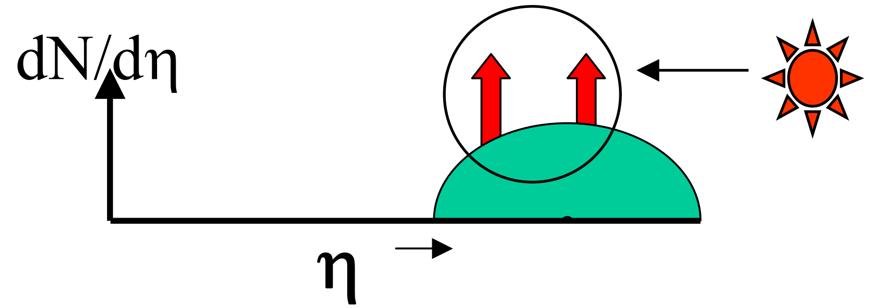


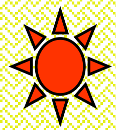
- **SDD: Single+Double Diffraction**
  - One forward + one central gap

Results: DD, like SD, is suppressed
The formation of the second gap in two-gap events is not suppressed!

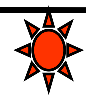
Hard Diffractive Fractions @ CDF





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

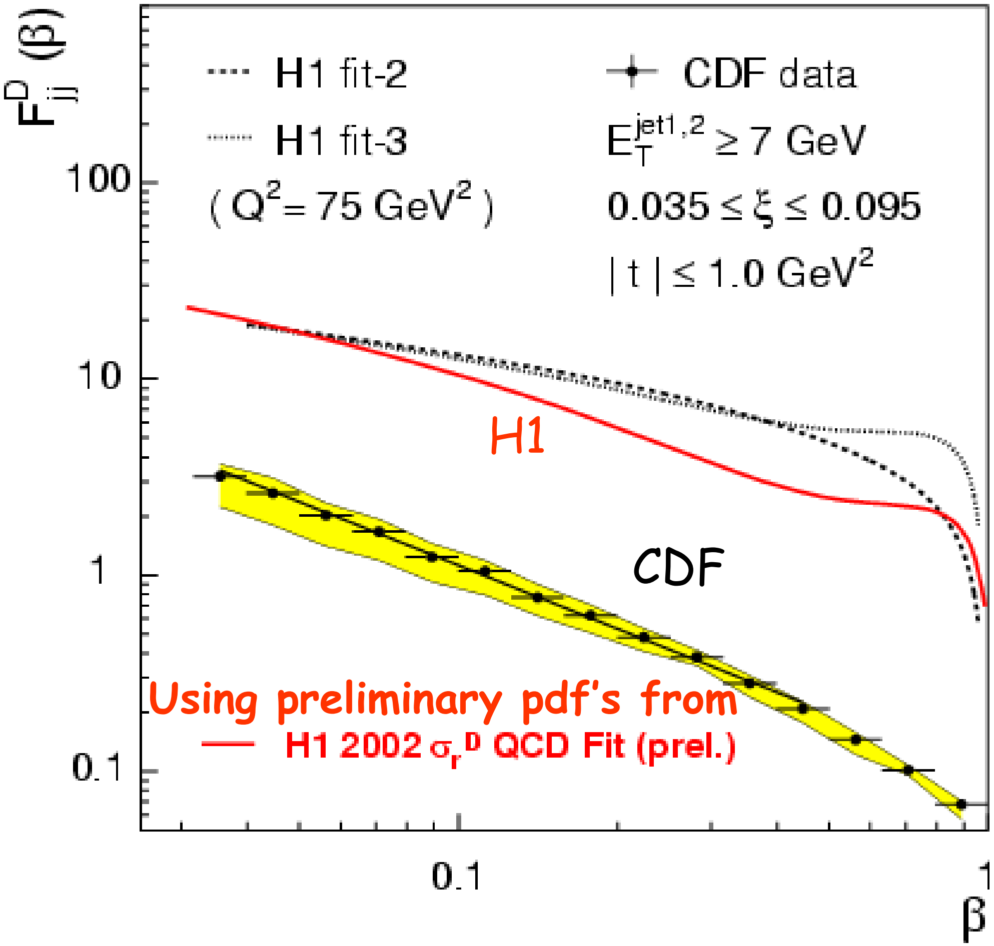
Fraction:
SD/ND ratio at 1800 GeV

	% 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 Structure Function:

Breakdown of QCD Factorization

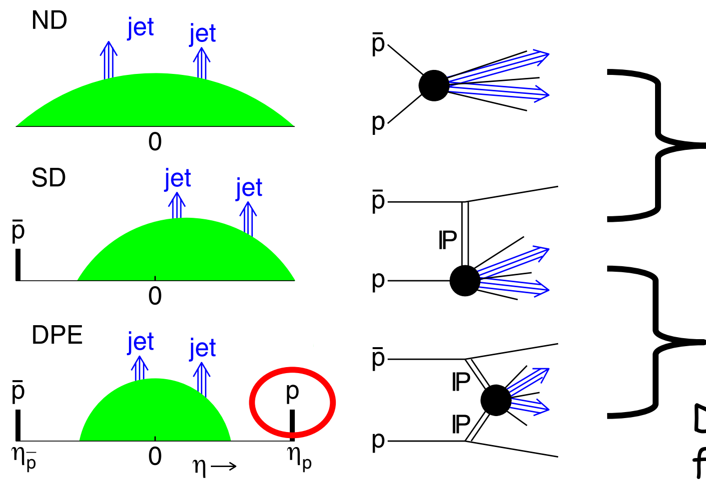


β = momentum fraction of parton in Pomeron

The diffractive structure function at the Tevatron is suppressed by a factor of ~10 relative to expectation from pdf's measured by H1 at HERA

Similar suppression factor as in soft diffraction relative to Regge expectations!

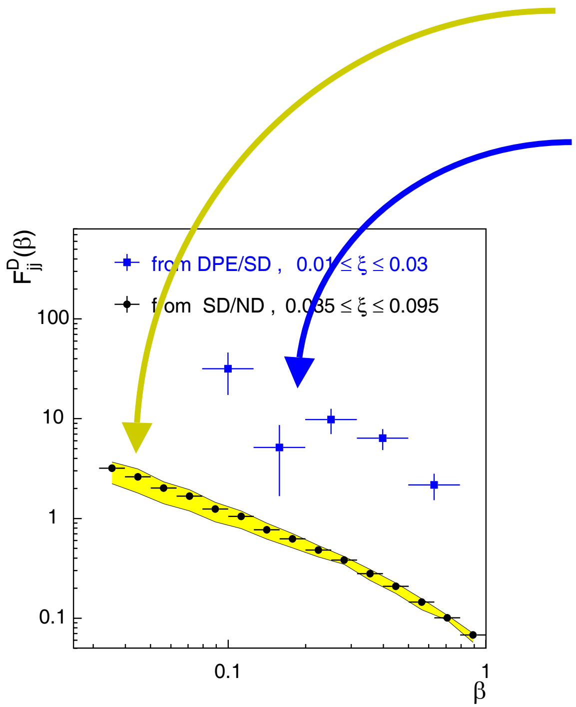
Restoring factorization: multigap diffraction

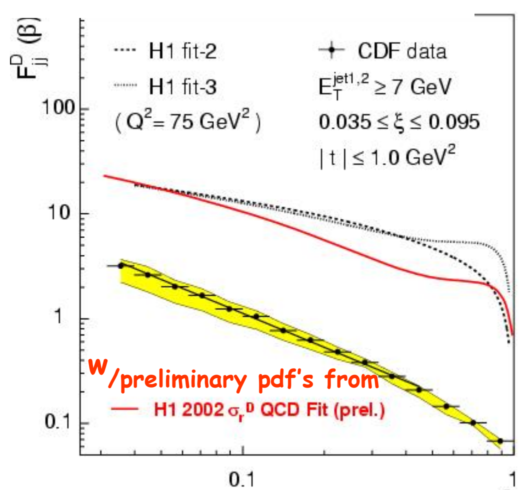


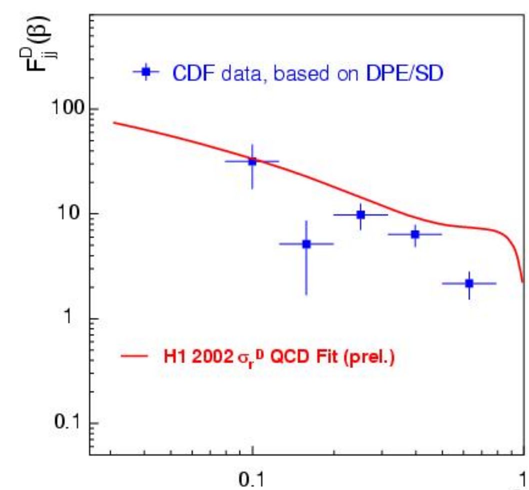
R(SD/ND)

R(DPE/SD)

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

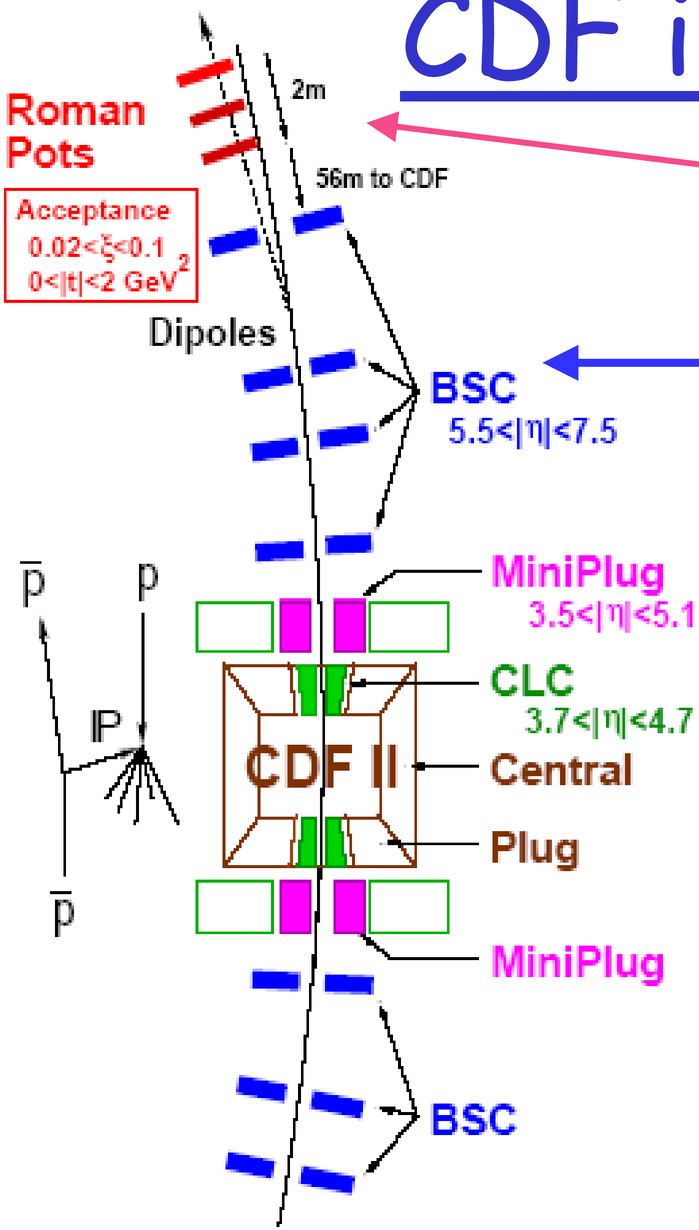
Run II Results

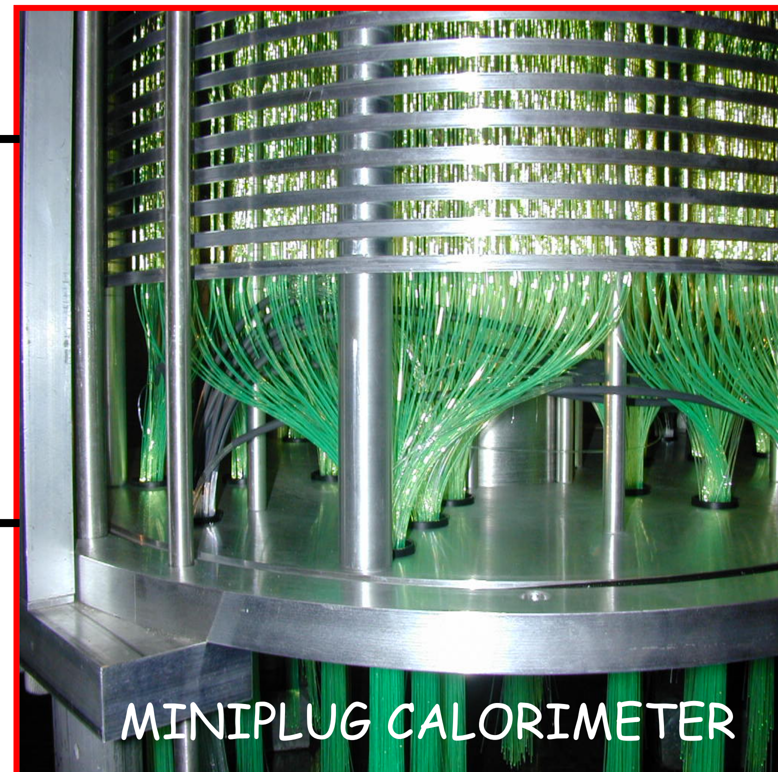
- Diffractive structure function
  NEW:
  - Q^2 - dependence
  - t - dependence
- Exclusive production
  - dijet
  - diphoton

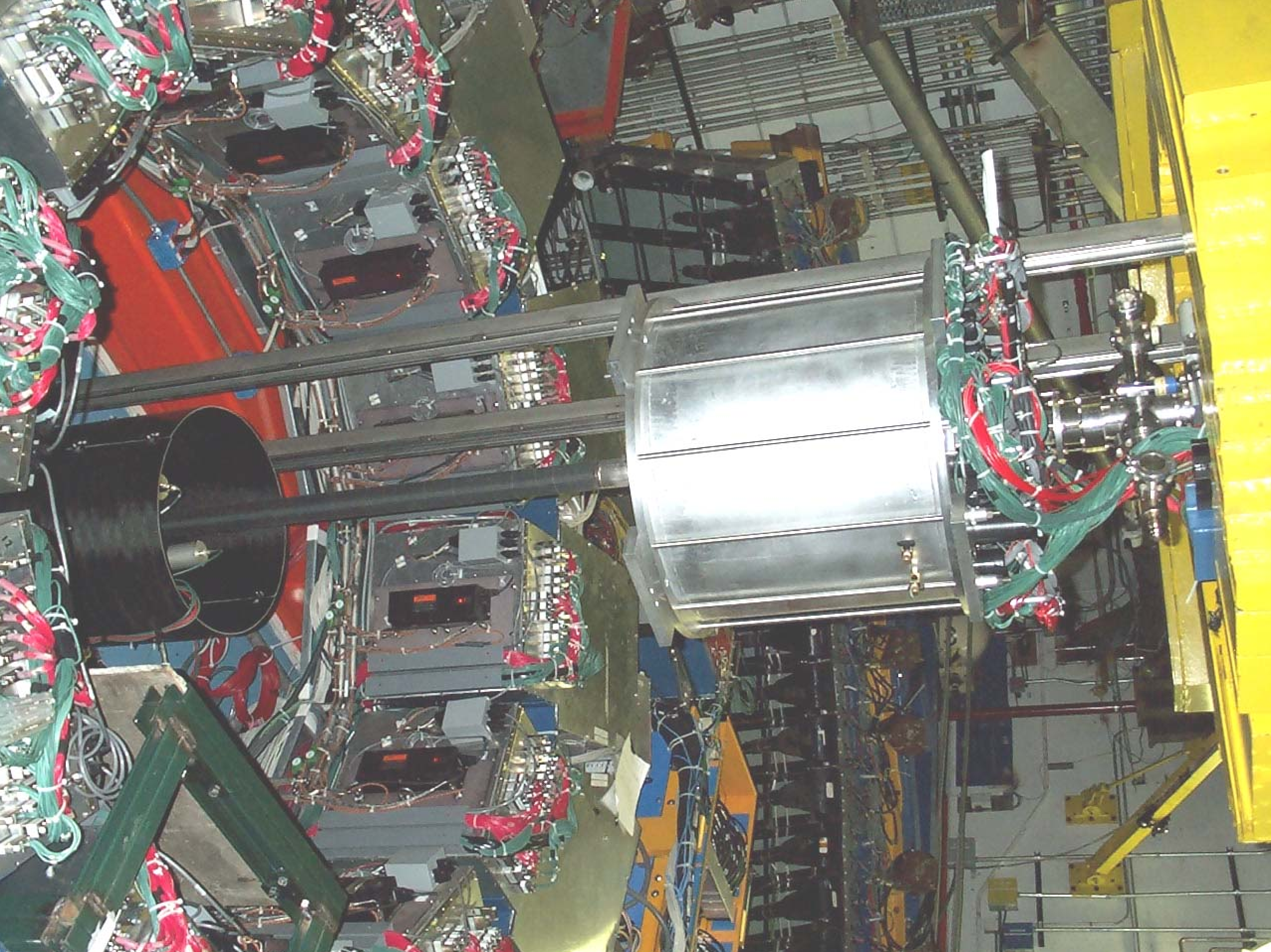
CDF in Run-II

ROMAN POT DETECTORS

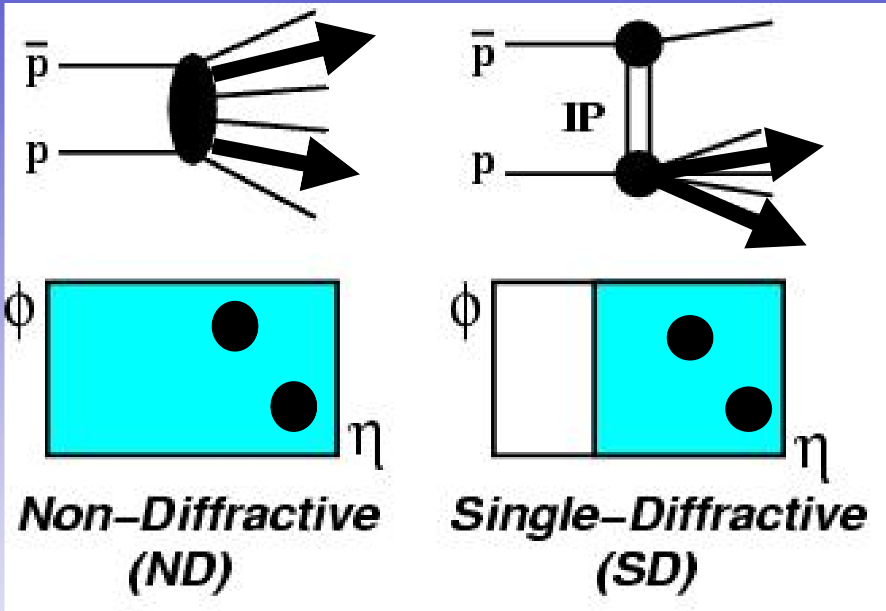
BEAM SHOWER COUNTERS:
Used to reject ND events







DIFFRACTIVE STRUCTURE FUNCTION



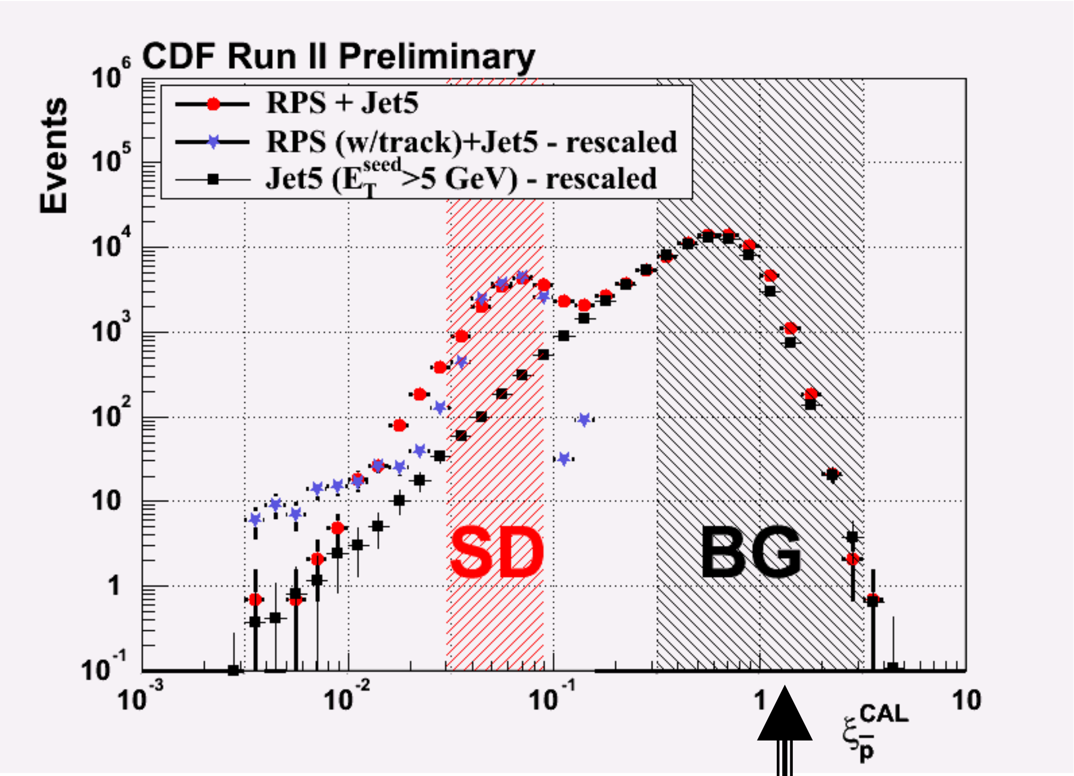
$$R(x_{Bj}) \equiv \frac{Rate_{jj}^{SD}(x_{Bj})}{Rate_{jj}^{ND}(x_{Bj})}$$

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

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

Diffractive Dijet Signal

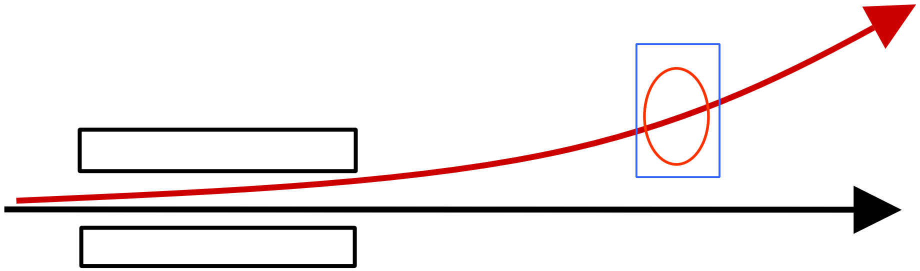
- Bulk of data taken with RPS trigger but no RPS tracking
- Extract ξ from calorimetric information
- Calibrate calorimetric ξ using limited sample of RPS tracking data
- Subtract overlap background using a rescaled dijet event sample
- Verify diffractive ξ range by comparing ξ^{RPS} with ξ^{CAL}



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

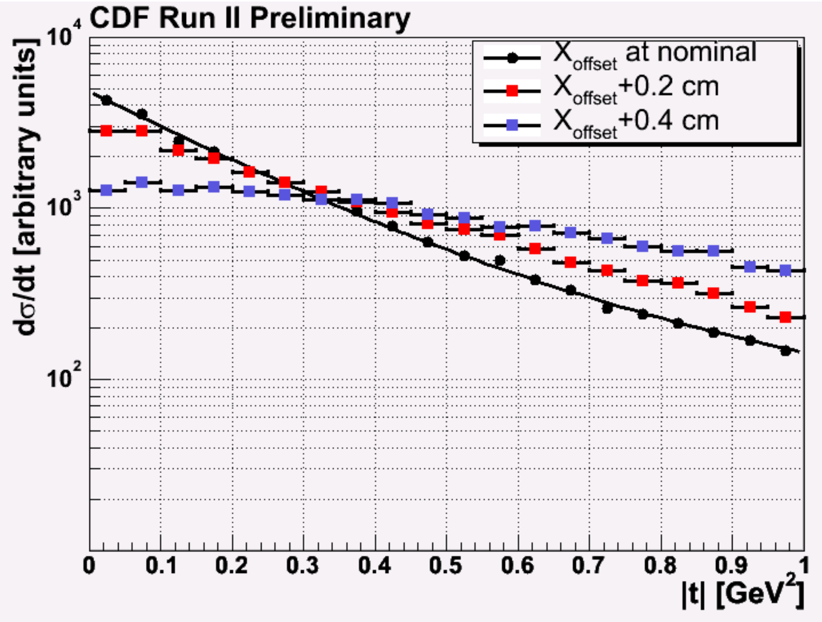
Overlap events: mainly ND dijets plus SD low ξ RPS trigger

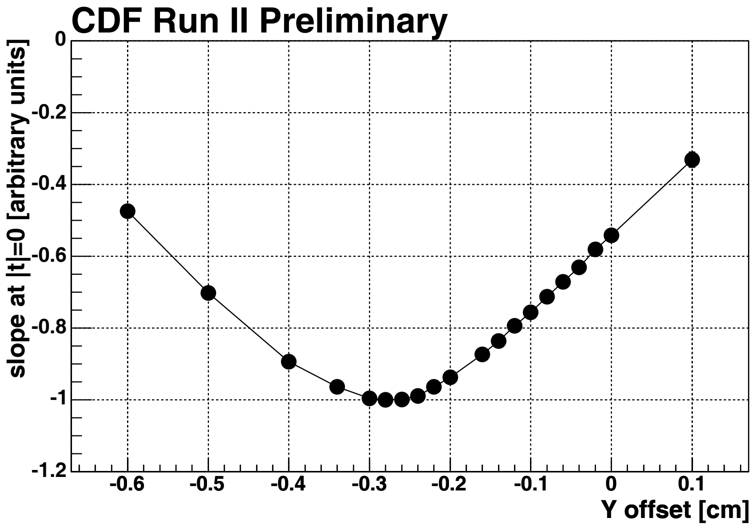
Alignment of RPS using Data

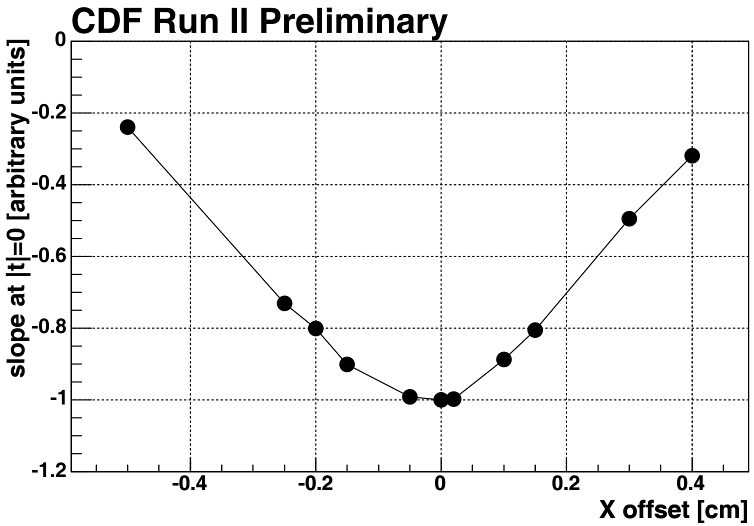


maximize the |t|-slope

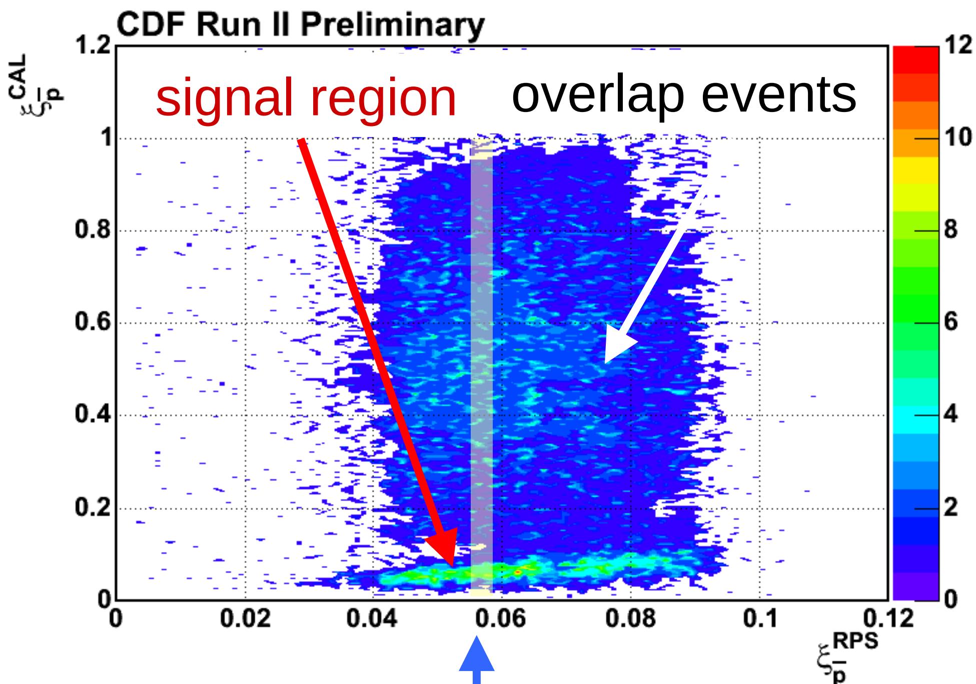
⇨ determine X and Y offsets

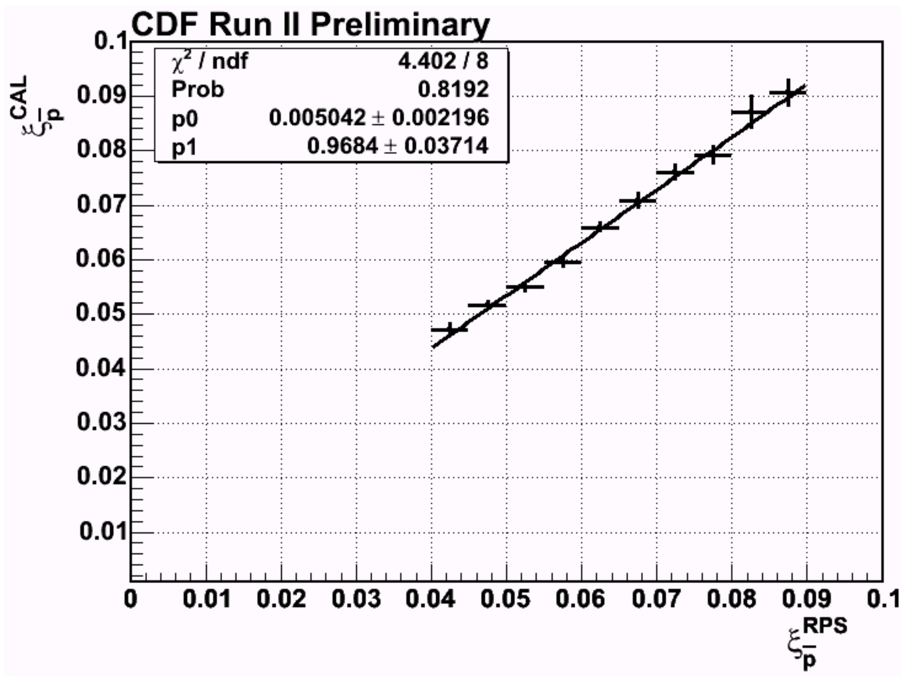


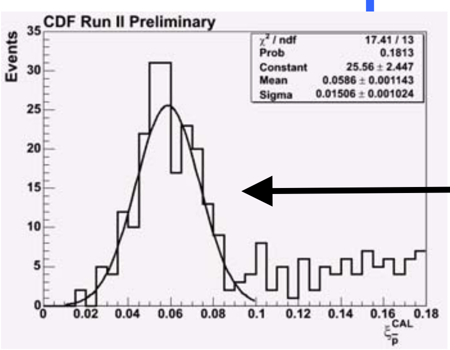




ξ^{CAL} Calibration





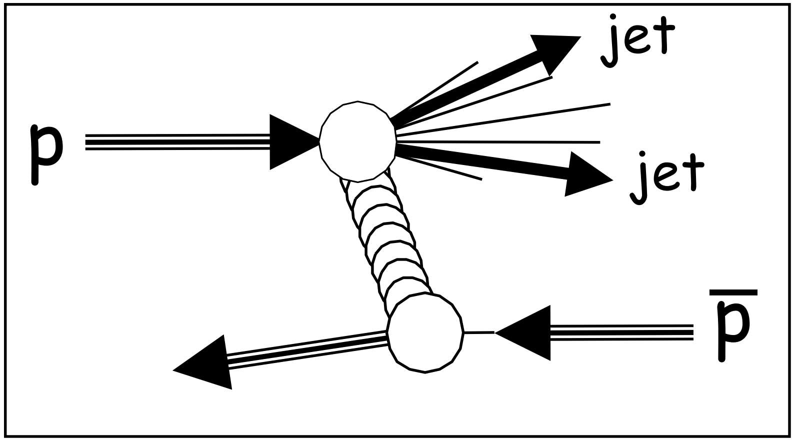


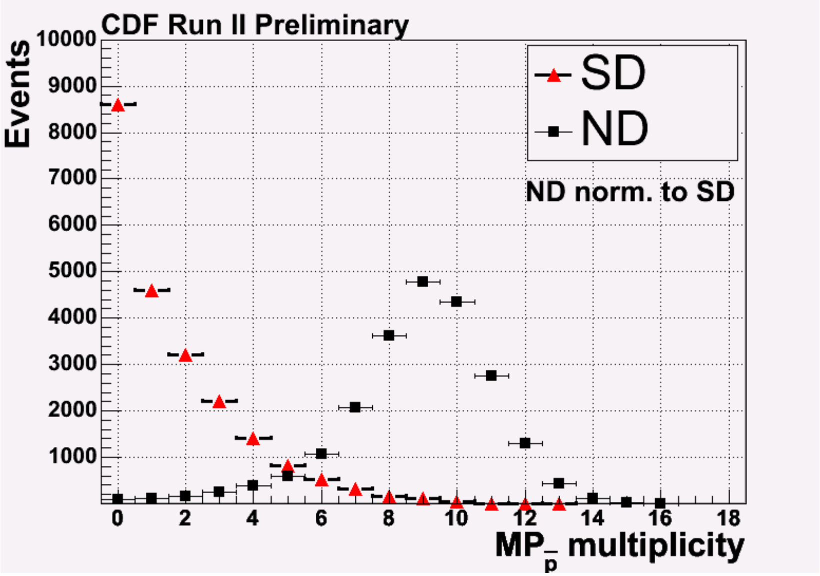
ξ^{cal} distribution for slice of ξ^{RPS}

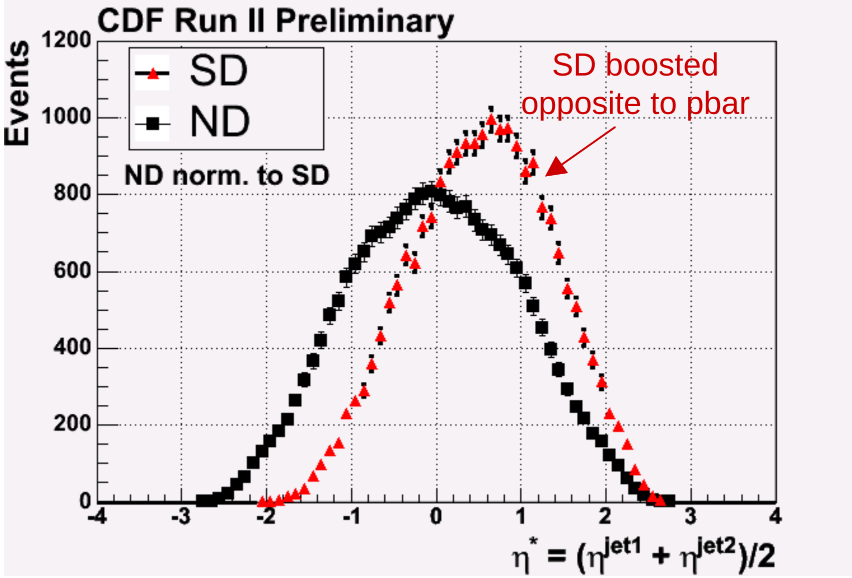
σ / mean ~ 30%

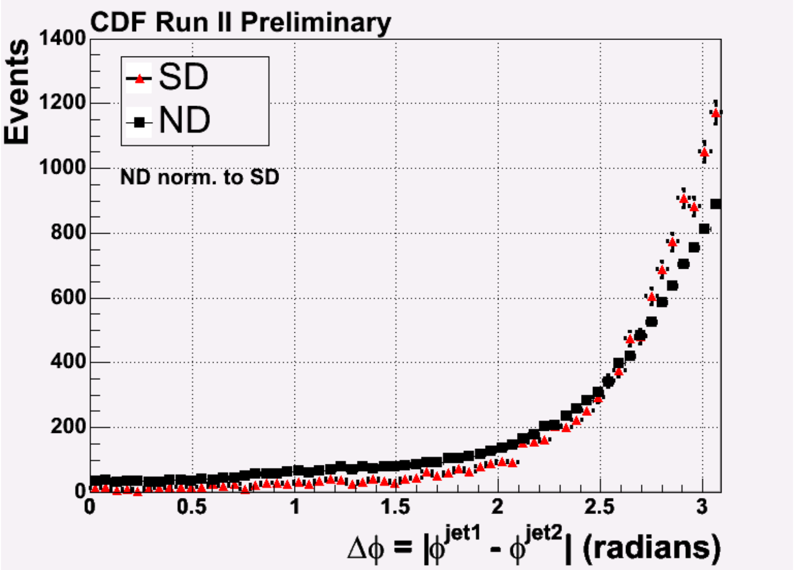
$$\xi^{CAL} = (0.97 \pm 0.04)\, \xi^{RPS}$$

Dijet Properties

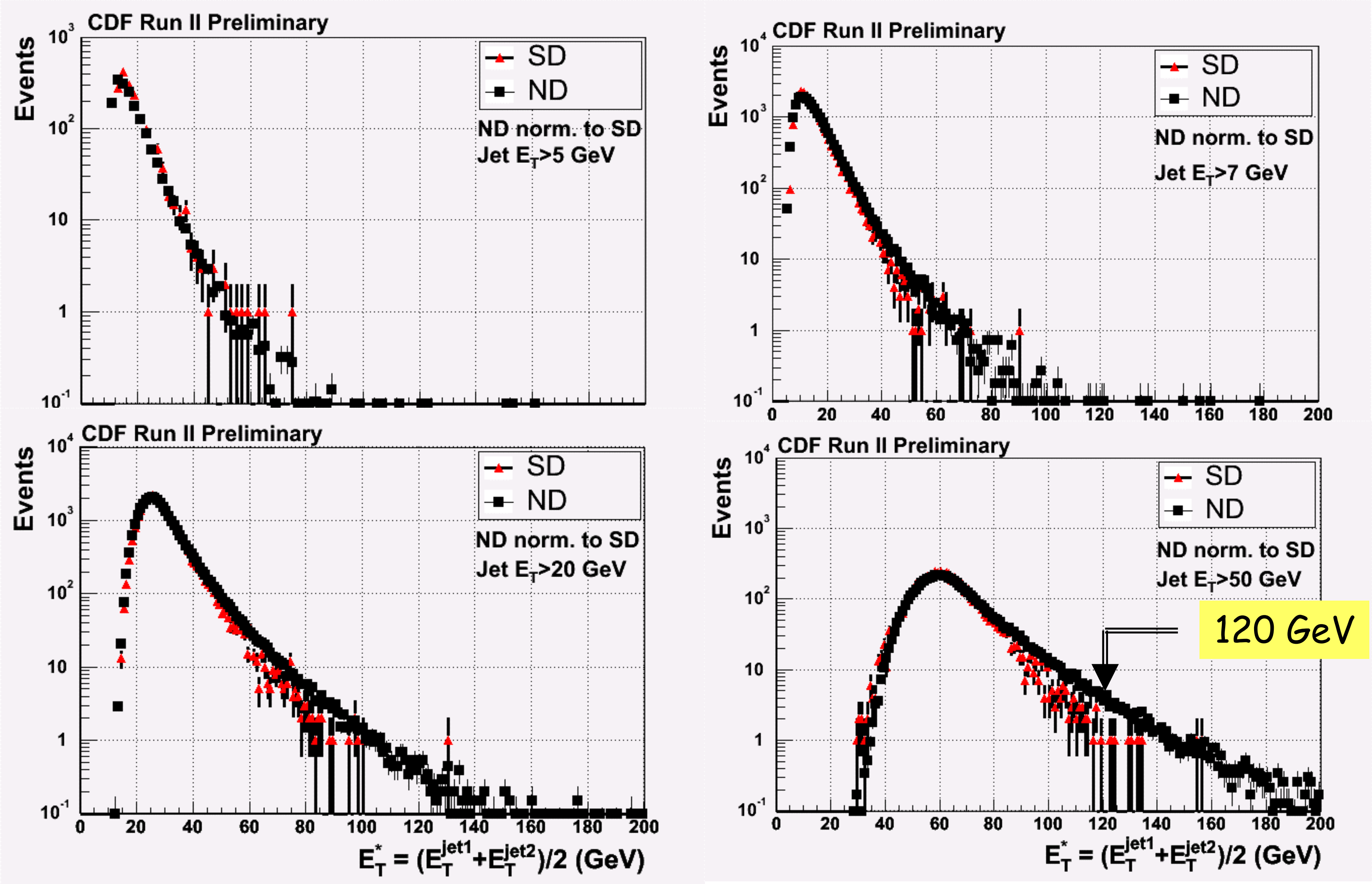




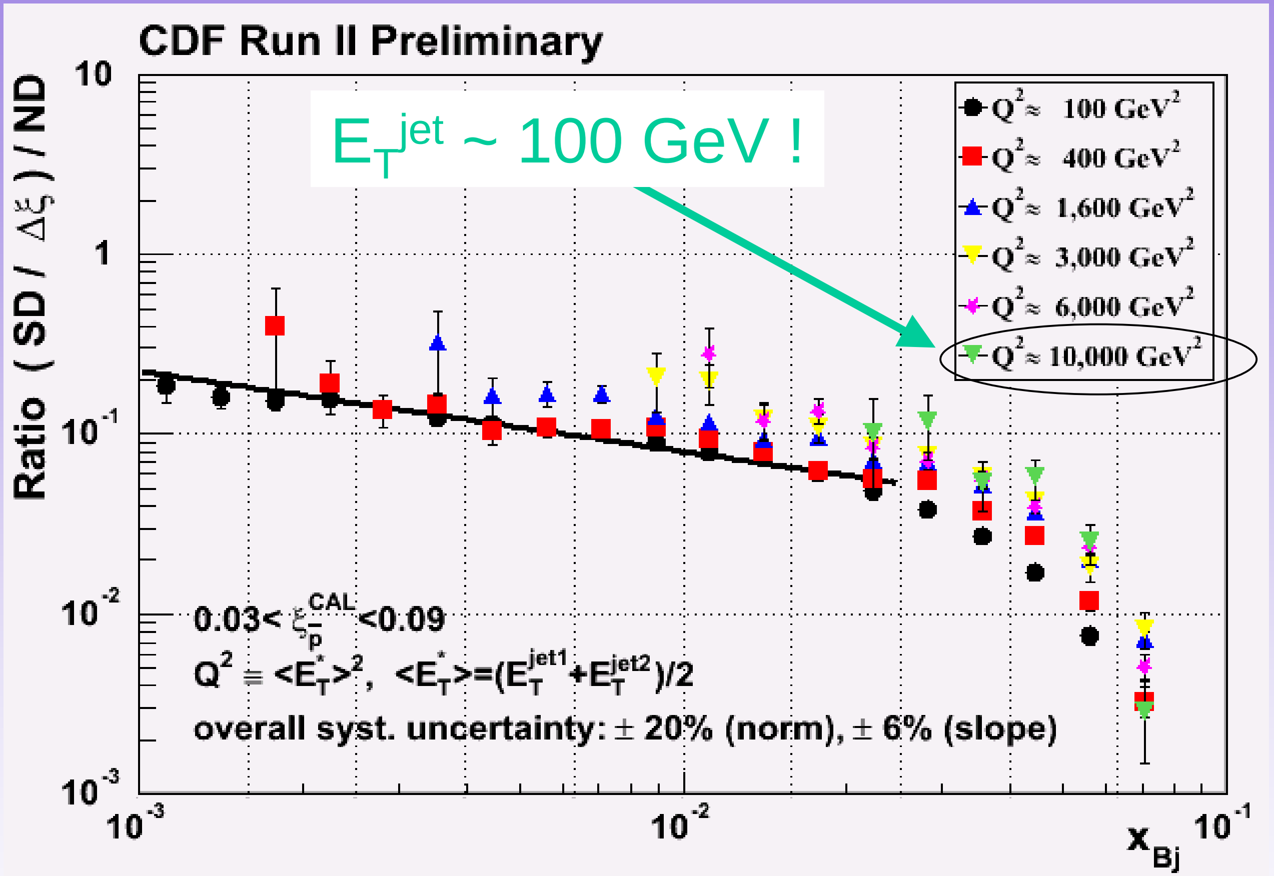




E_T distributions



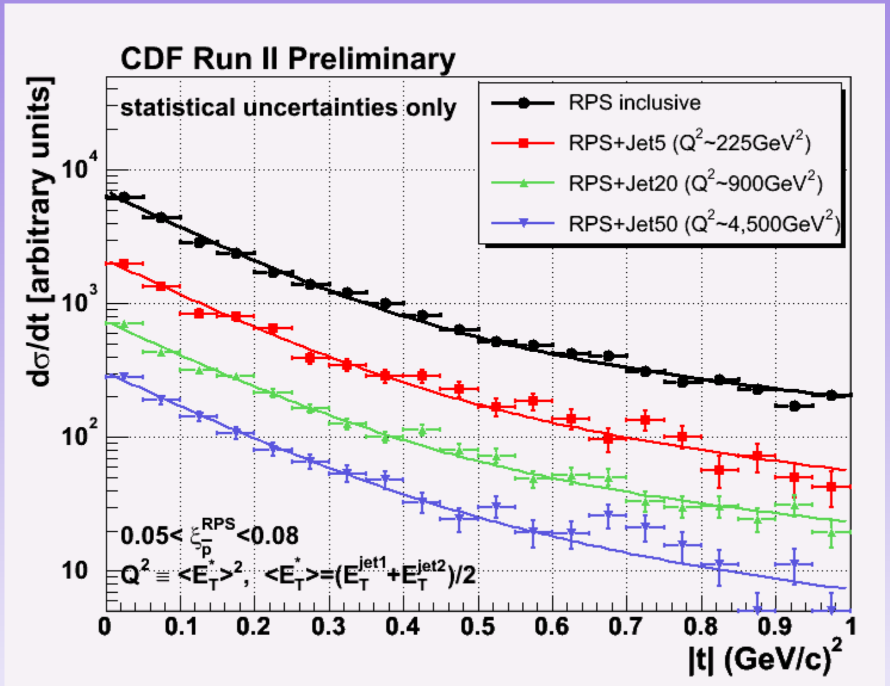
Diffractive Structure Function:
Q^2 dependence

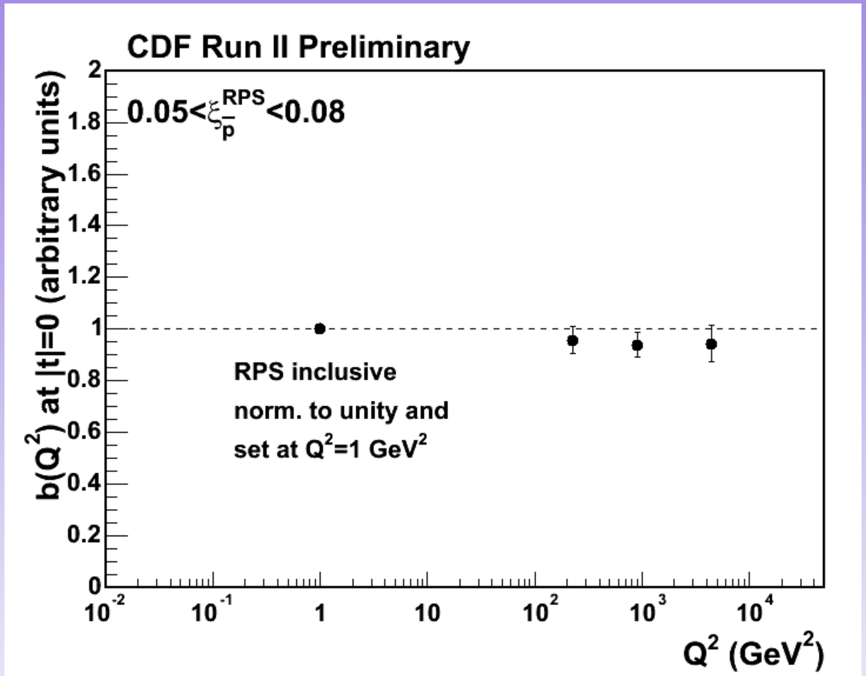


Small Q^2 dependence in region $100 < Q^2 < 10{,}000$ GeV²

⇨ **Pomeron evolves as the proton!**

Diffractive Structure Function:
t- dependence





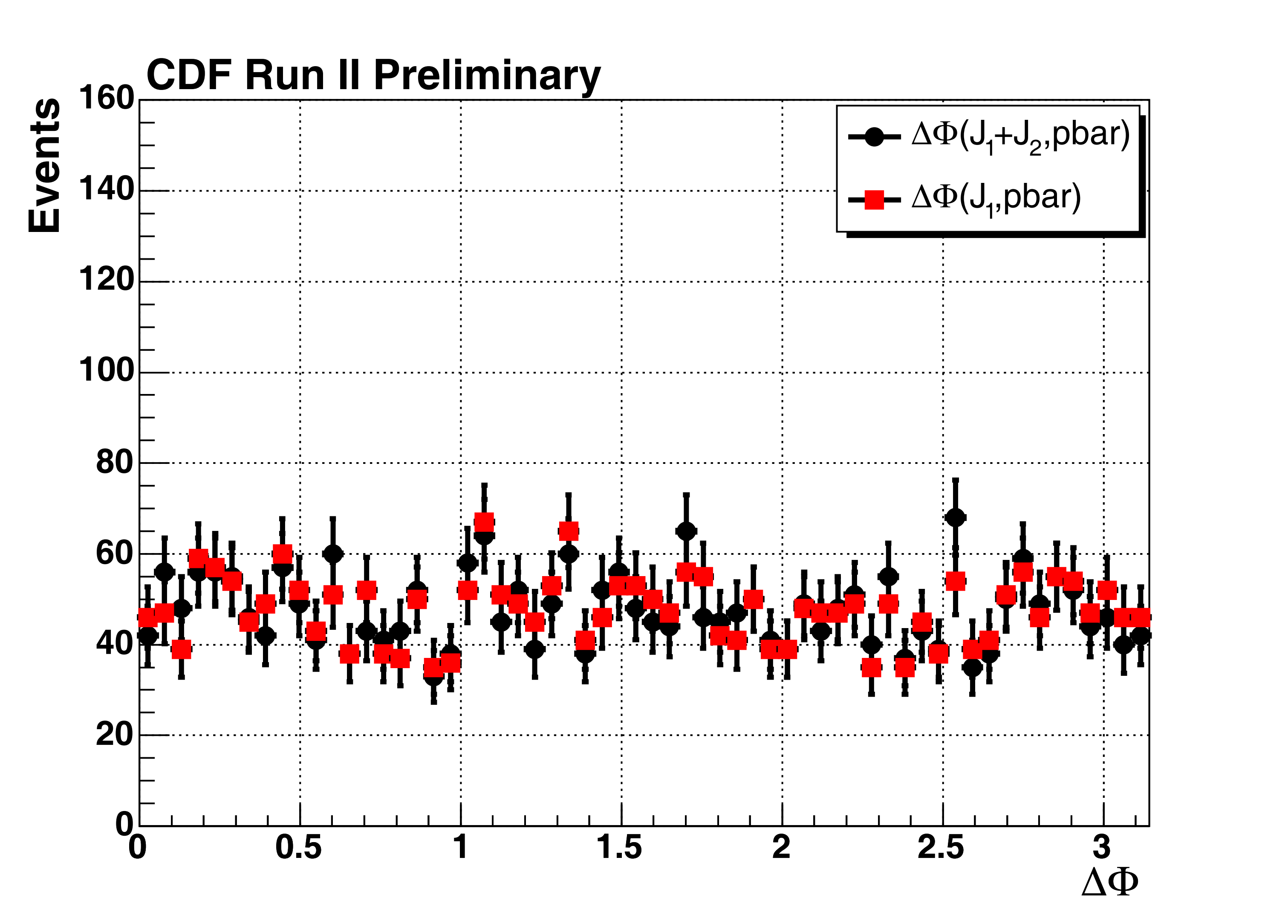
Fit dσ/dt to a double exponential:

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

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

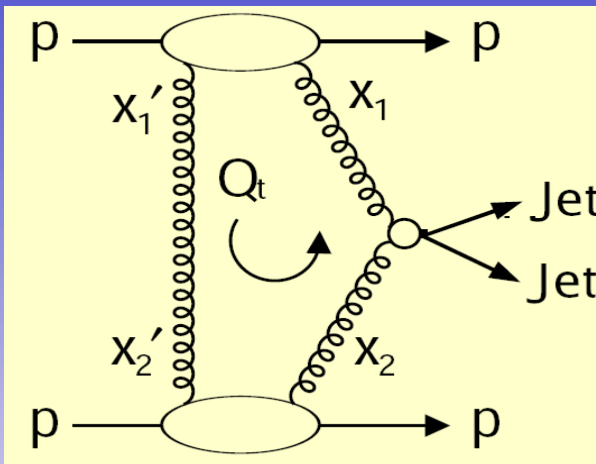
- Same slope over entire region of $0 < Q^2 < 4{,}500$ GeV^2 across soft and hard diffraction!

Diffractive dijets: $\Delta\phi=\phi_{pbar}-\phi_{dijet}$



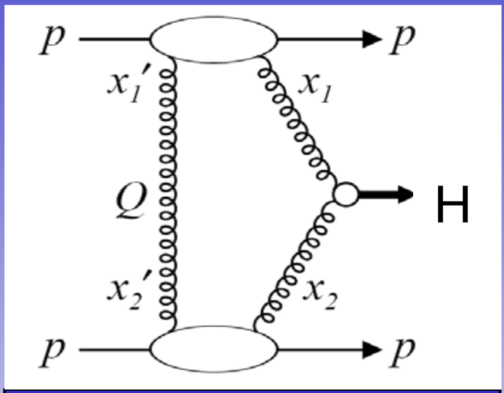
EXCLUSIVE PRODUCTION

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……………………….

Clean discovery channel

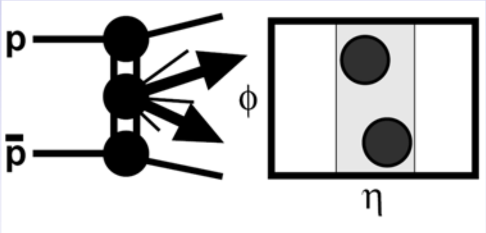


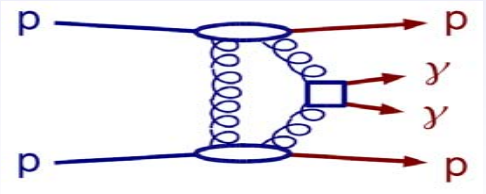
KMR: σ_H(LHC) ~ 3 fb
S/B ~ 1 if ΔM ~ 1 GeV

Search for exclusive dijets:
Measure dijet mass fraction

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

Look for signal as M_{jj} ➔ 1





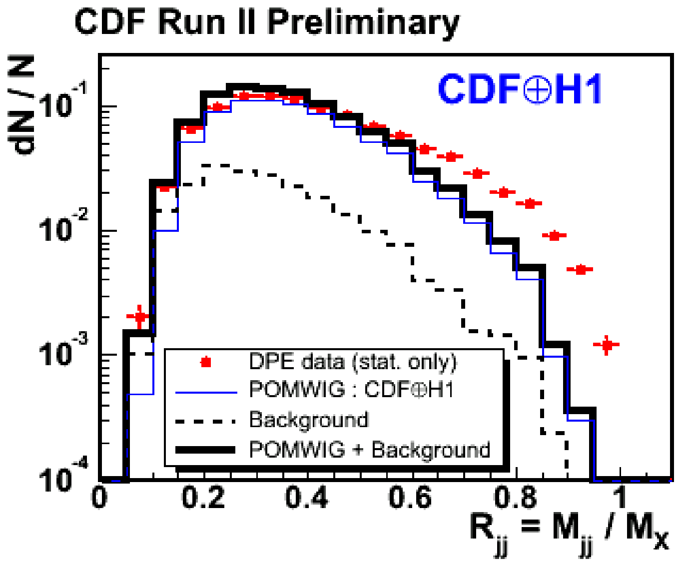
Search for exclusive $\gamma\gamma$

Search for events with two high E_T gammas and no other activity in the calorimeters or BSCs

Exclusive Dijet Signal

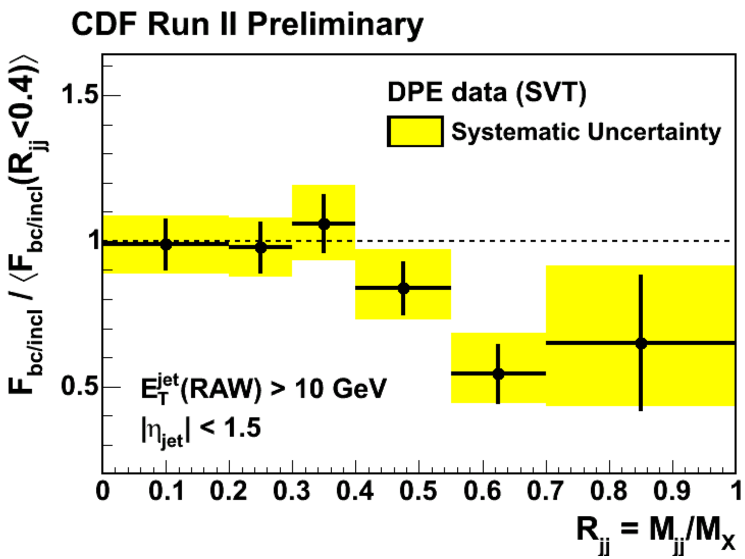
DIJETS

Dijet fraction – all jets



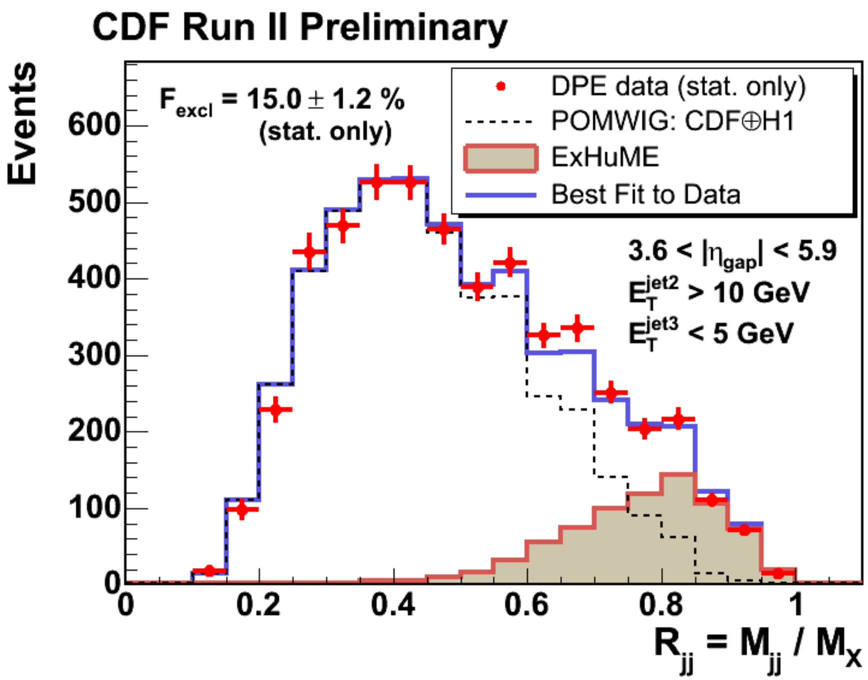
Excess over MC predictions at large dijet mass fraction

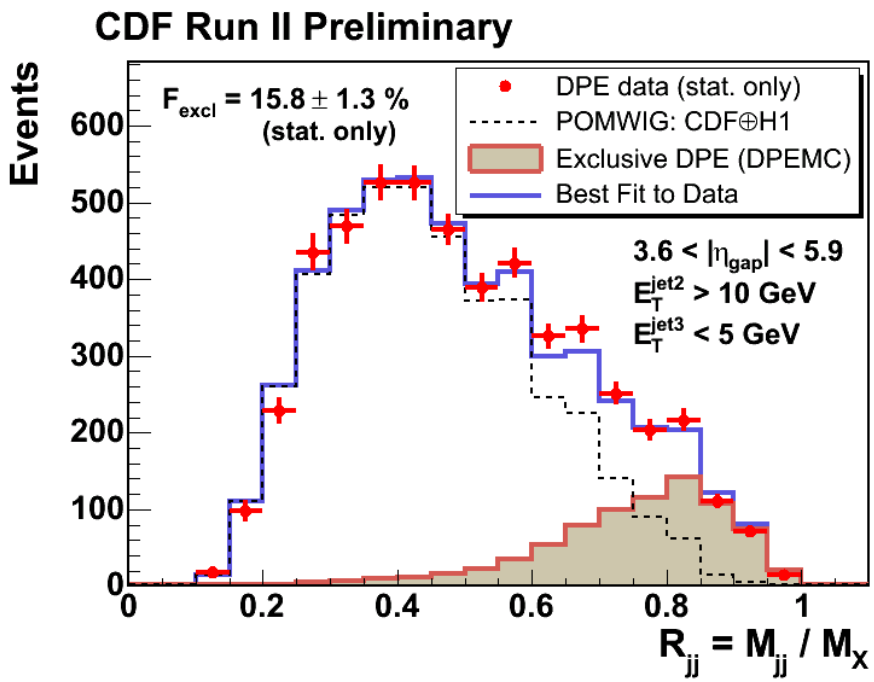
b-tagged dijet fraction



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

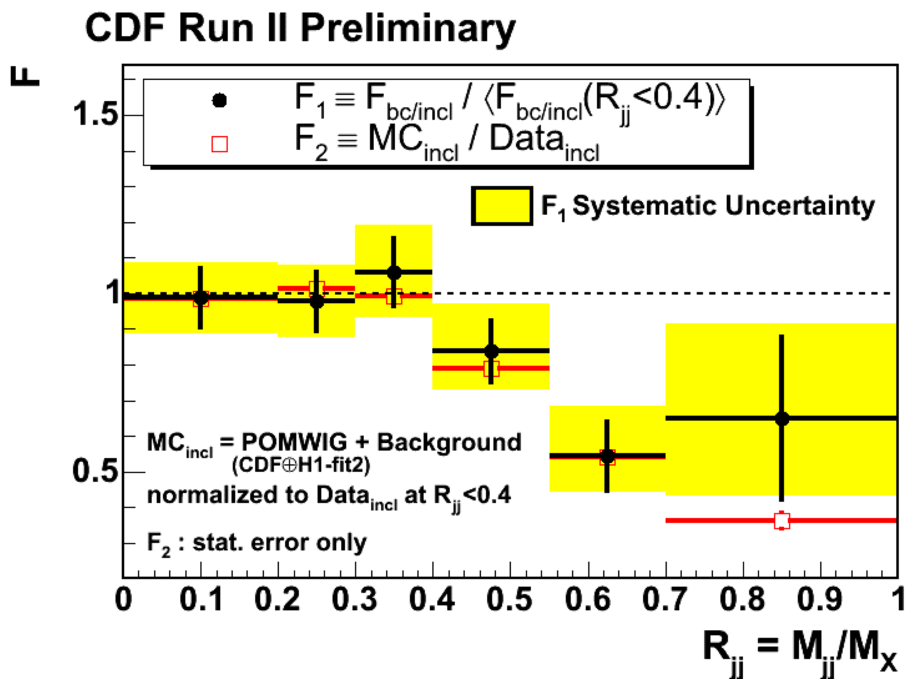
Exclusive DPE (DPEMC)
➔ non-pQCD based on Regge theory

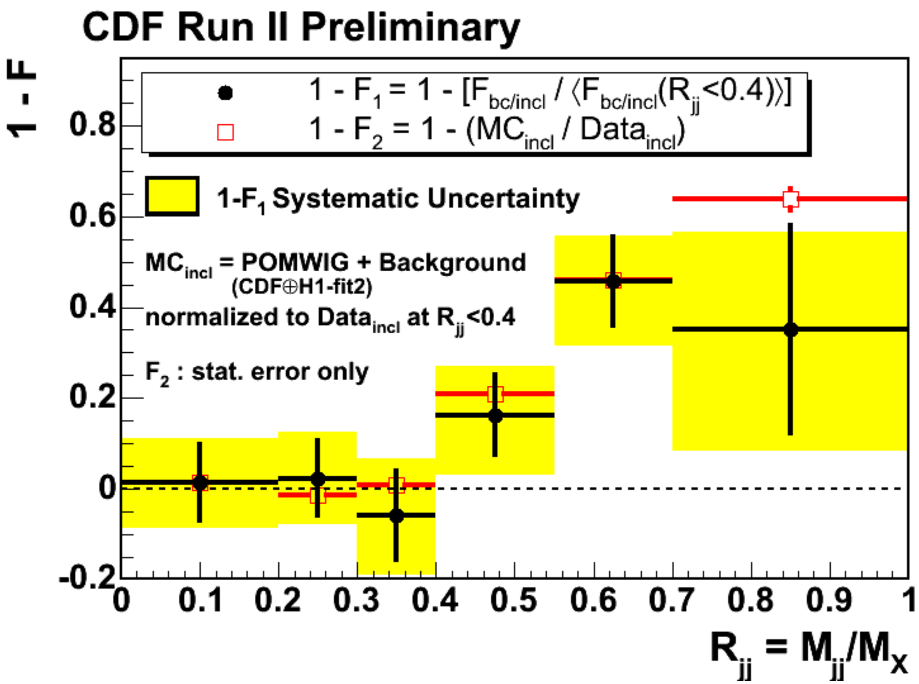
Shape of excess of events at high R_{jj}
is well described by both models

jj_{excl}: Exclusive Dijet Signal

COMPARISON

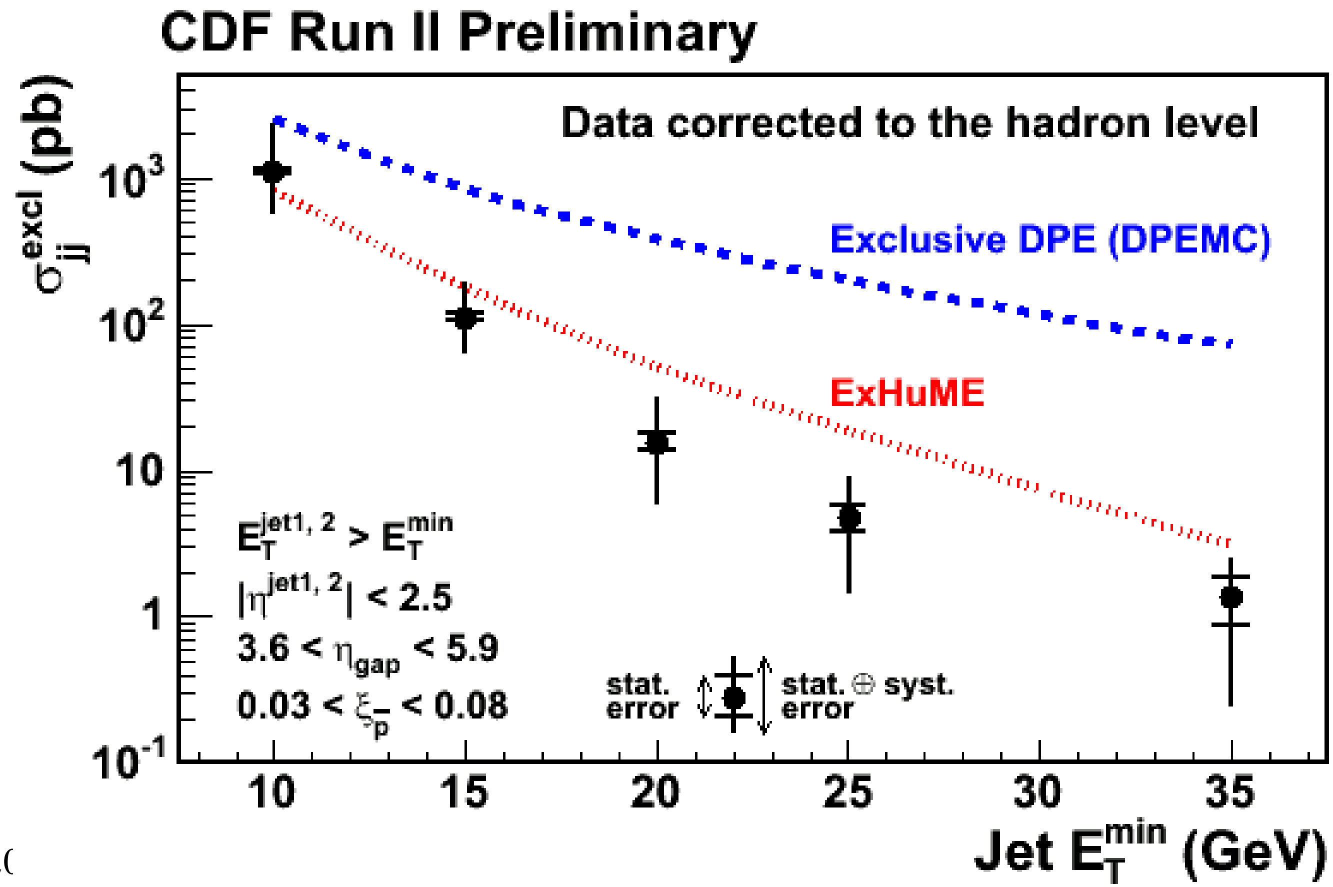
Inclusive data vs MC @ b/c-jet data vs inclusive





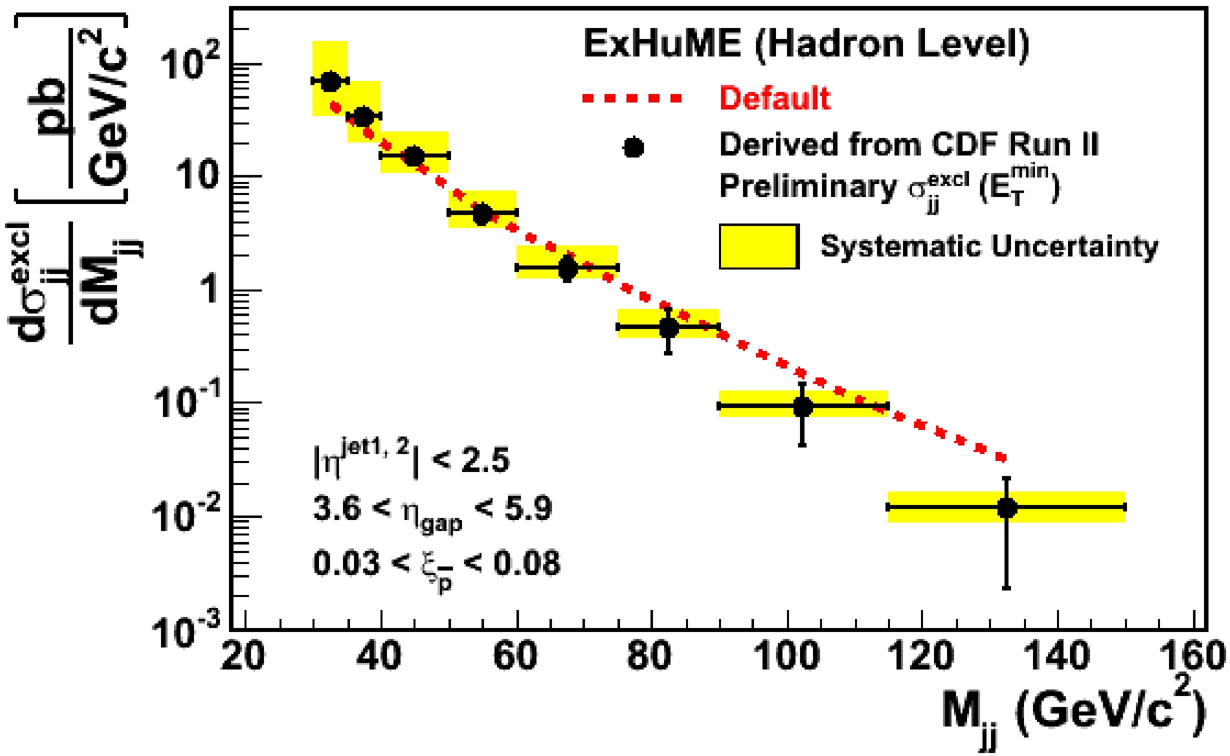
JJ_{excl} : x-section vs E_T(min)

Comparison with hadron level predictions
ExHuME (red)
Exclusive DPE in DPEMC (blue)



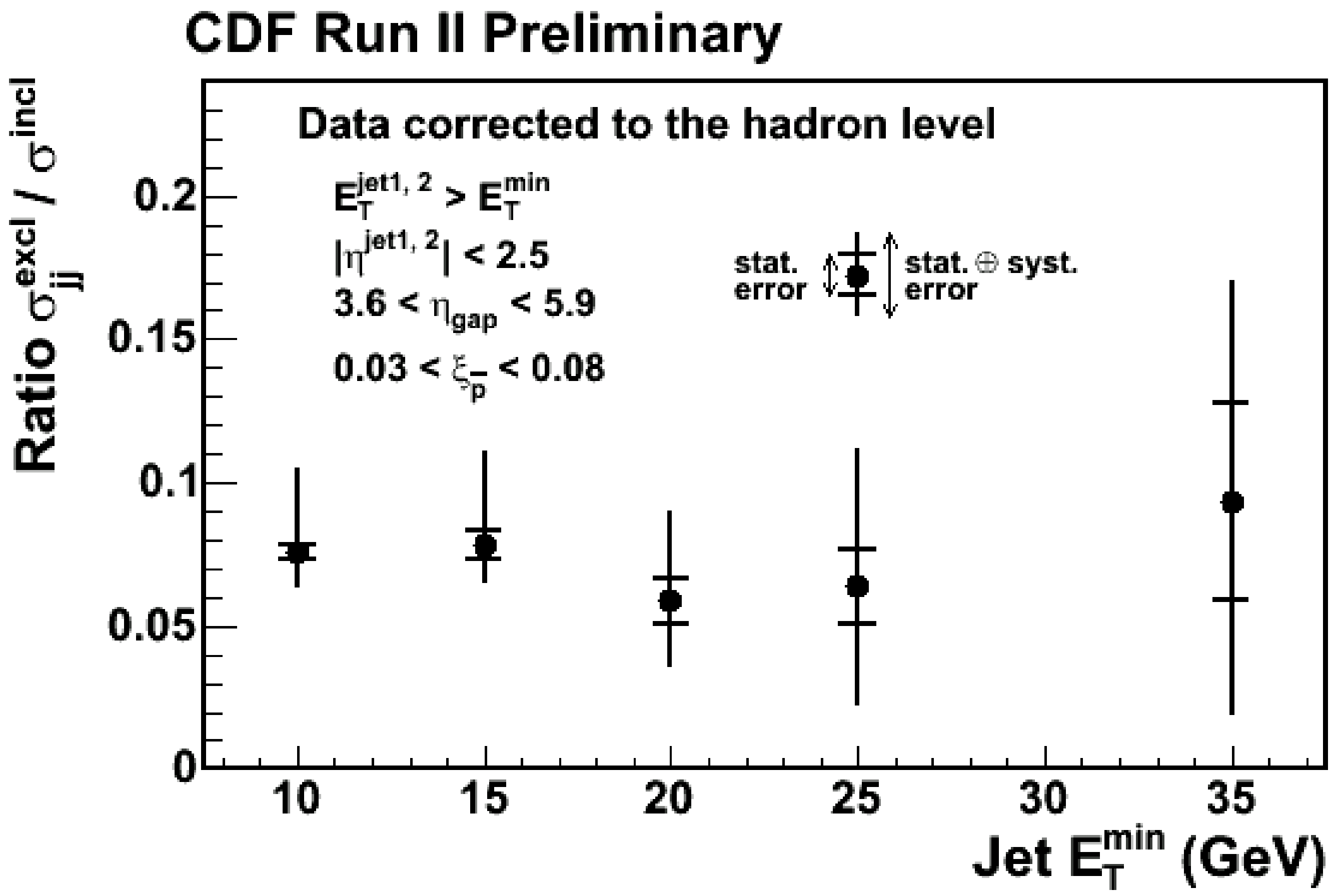
JJ_{excl} : cross section predictions

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

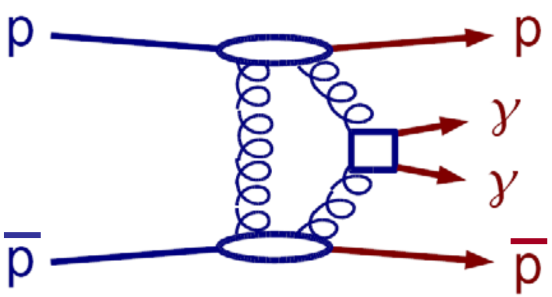


Statistical and systematic errors are propagated from measured cross section uncertainties using ExHuME M_{jj} distribution shapes.

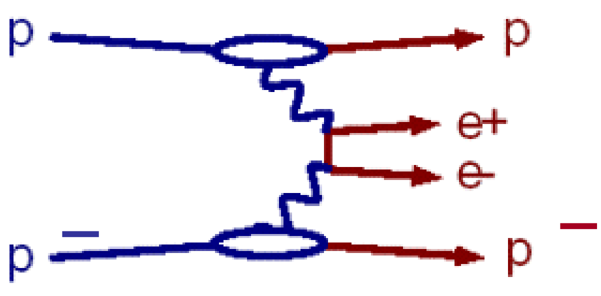
JJ_{excl}: R(excl/incl) vs ET_{min}



Exclusive $\gamma\gamma$/ee Search



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

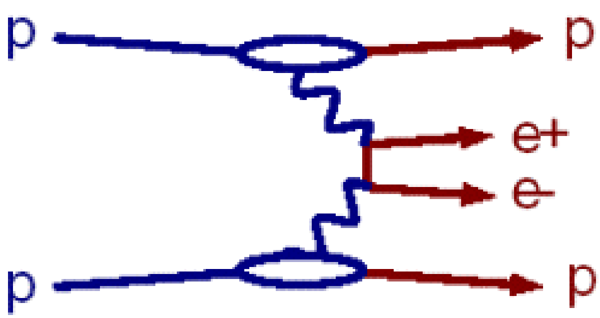


QED process: cross-check to exclusive $\gamma\gamma$

- ✓ (anti)proton not detected
- ✓ require 2 EM showers (E_T>5 GeV, |h|<2)
- ✓ veto on all BSCs and cal towers except for those of the 2 EM showers
- ✓ L~530 pb^{-1} delivered ➔ $L_{effective}$=46 pb^{-1}

✓⇨ 19 events with 2 EM showers + "nothing" [above threshold]

Exclusive *ee* Search



control sample for $\gamma\gamma$ search

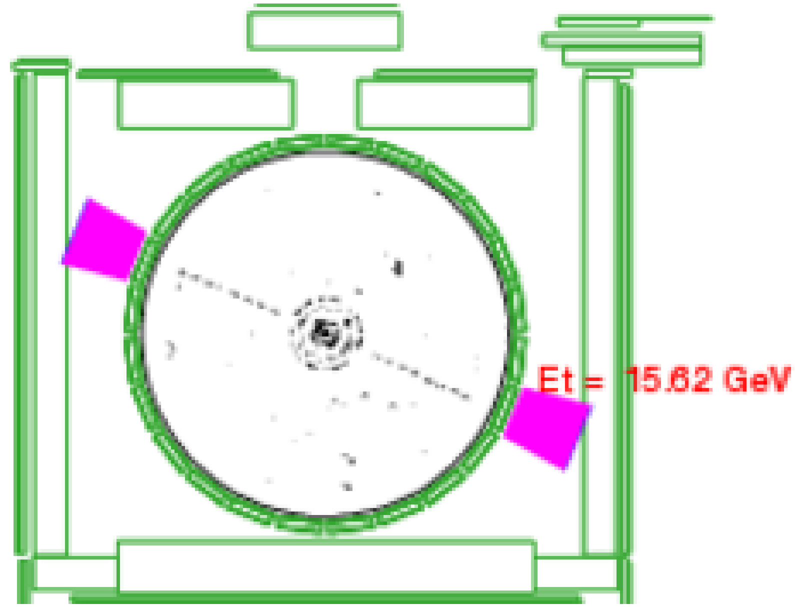
⇨16 candidate events found

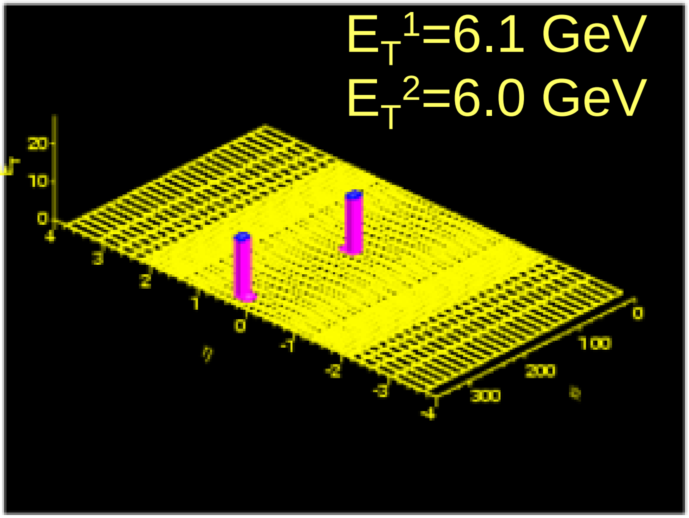
background $2.1^{+0.7}_{-0.3}$ events

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

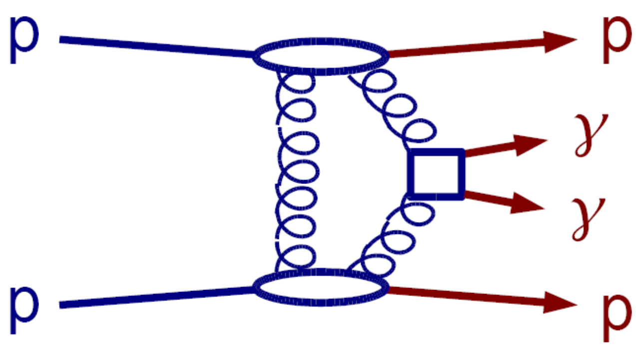
good agreement with LPAIR:

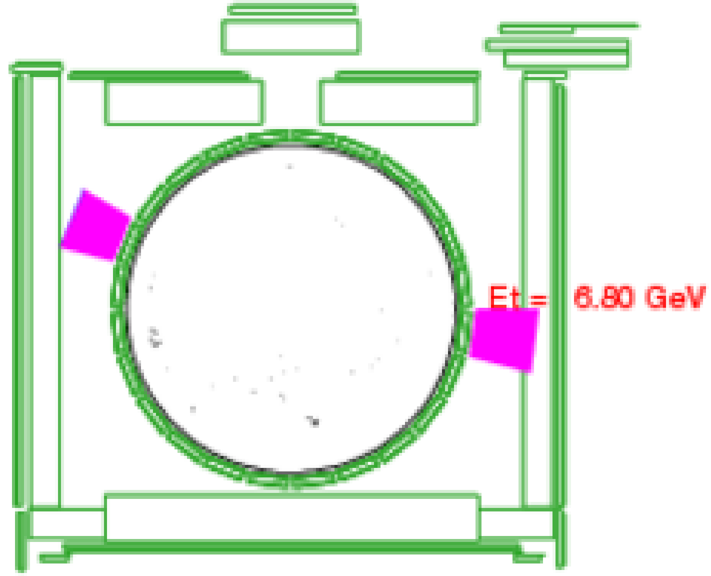
$\sigma_{LPAIR} = 1.711 \pm 0.008\ \text{pb}$





Exclusive $\gamma\gamma$ Search



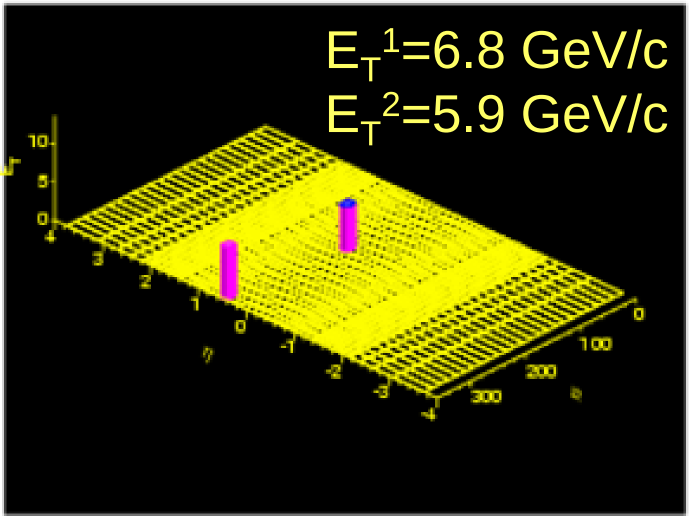


3 events are found.

1^{+3}_{-1} events are predicted from ExHuME MC

Monk & Pilkington. hep-ph/0502077

Background estimate is not yet complete



Summary

Run I

- Suppression of single gap diffraction
- M^2 - scaling: $d\sigma/dM^2$ independent of s
- Non-suppressed double-gap to single-gap ratios

Run II

- Diffractive structure function vs x_{Bj}, Q^2, and t
  ➔ Composite Pomeron
  made up from proton pdf's ?
- Exclusive production; dijet and diphoton
  ➔ Diffractive Higgs @ LHC under control

BACKUP

p̄-p Interactions

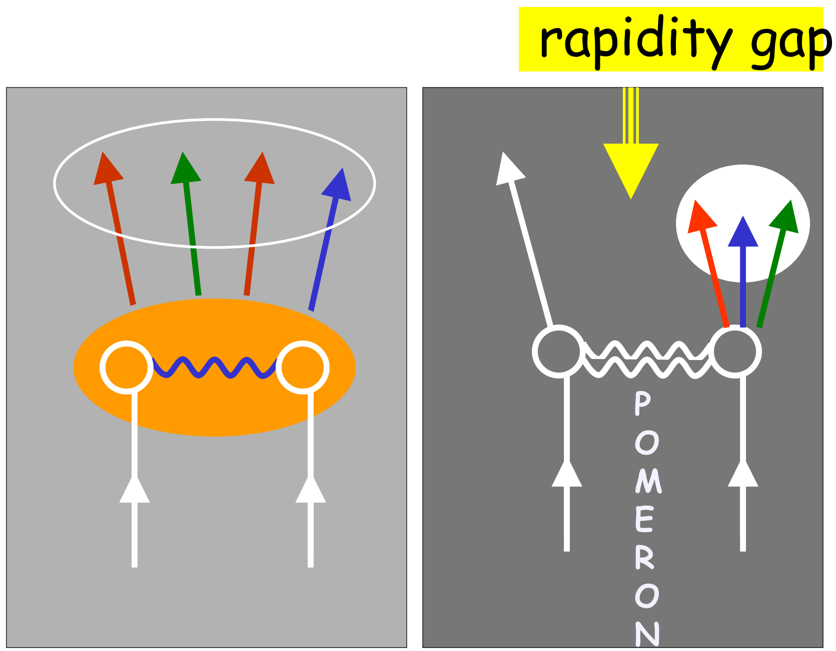
Non-diffractive:

Color-exchange

Diffractive:

Colorless exchange
^{w}/vacuum quantum numbers

Incident hadrons acquire color and break apart



Incident hadrons retain their quantum numbers remaining colorless

Goal: understand the QCD nature of the diffractive exchange

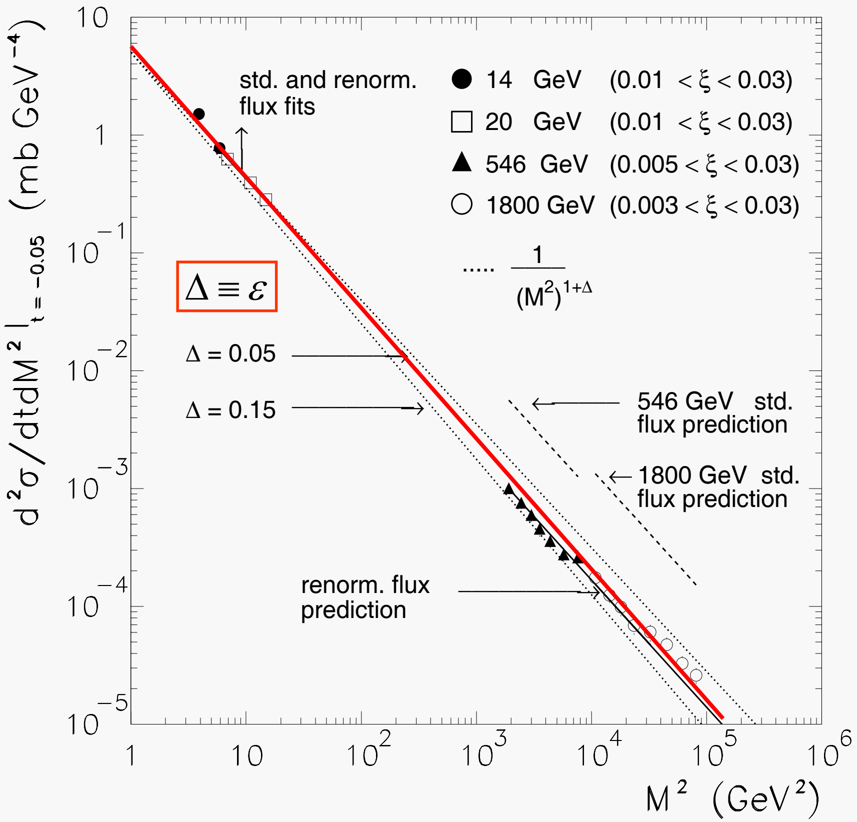
M² - scaling

KG&JM, PRD 59 (1999) 114017

renormalization

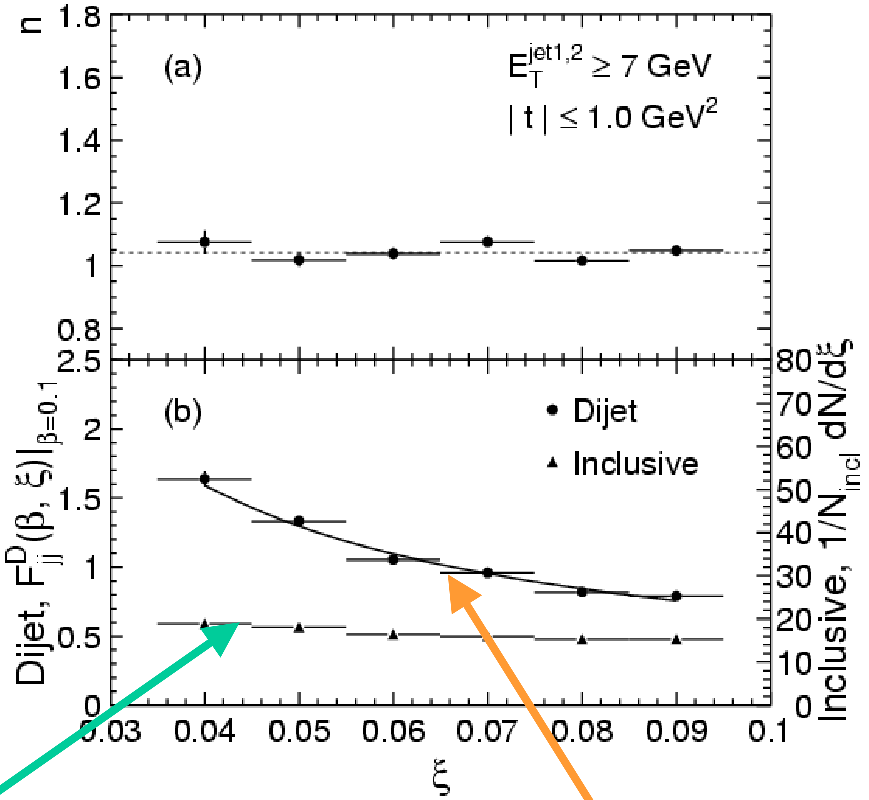
$$\frac{d\sigma}{dM^2} \propto \frac{s^{2\varepsilon} \rightarrow 1}{(M^2)^{1+\varepsilon}}$$

➔ Independent of S over a range of six orders of magnitude in M² !



Factorization breaks down so as to ensure M²-scaling!

ξ-dependence: Inclusive vs Dijet

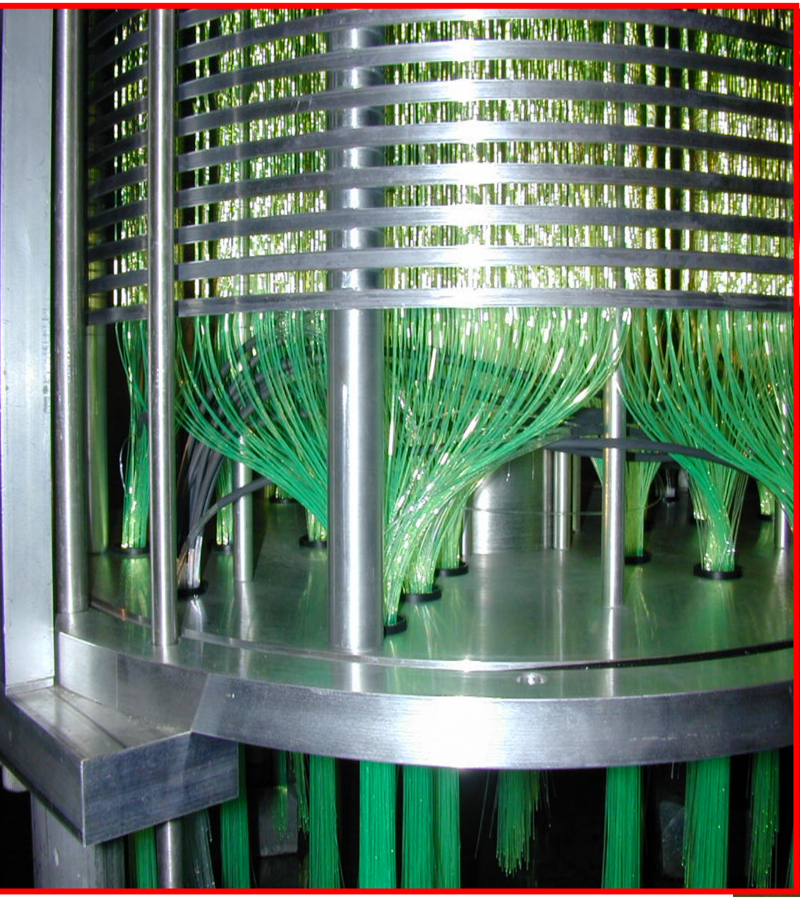


$$\frac{d\sigma_{incl}}{d\xi} \propto \text{constant}$$

$$F_{jj}^D(\beta,\xi) \propto \frac{1}{\beta^n} \cdot \frac{1}{\xi^m} \quad (n = 1.0 \pm 0.1, \quad m = 0.9 \pm 0.1)$$

Pomeron dominated

The MiniPlug Calorimeters



About 1500 wavelength shifting fibers of 1 mm dia. are 'strung' through holes drilled in $36\times\frac{1}{4}$" lead plates sandwiched between reflective Al sheets and guided into bunches to be viewed individually by multi-channel photomultipliers.