Update on CDF Results on Diffraction

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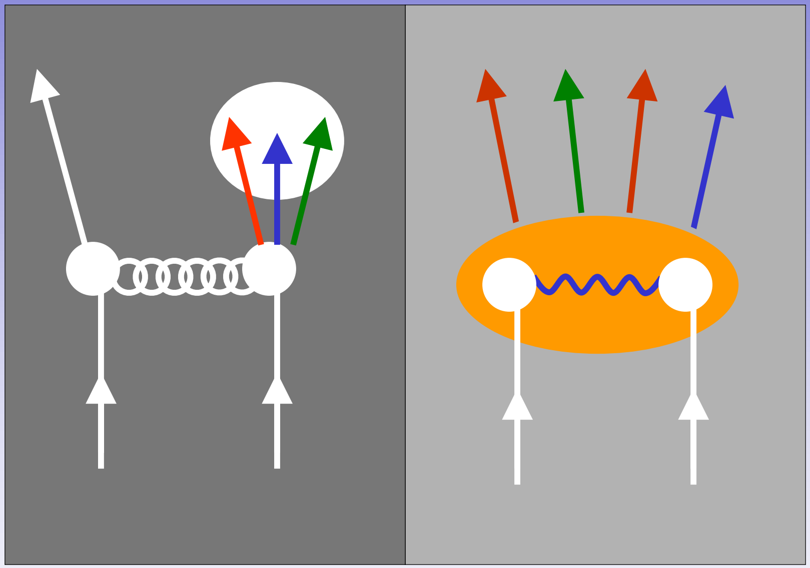
DIS 2005
27 April – 1 May
Madison, Wisconsin

$\bar{p}$-p Interactions

<u>Diffractive:</u>

vacuum exchange

Protons retain their quantum numbers



<u>Non-diffractive:</u>

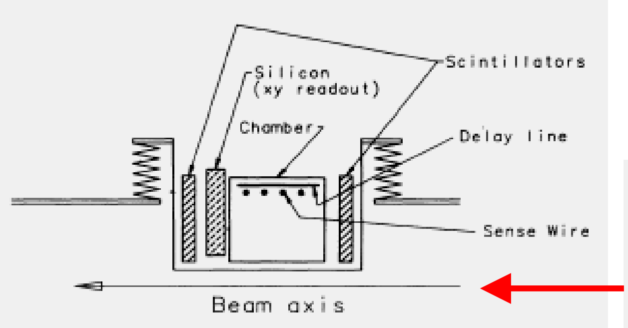
color exchange

Protons acquire color and break apart

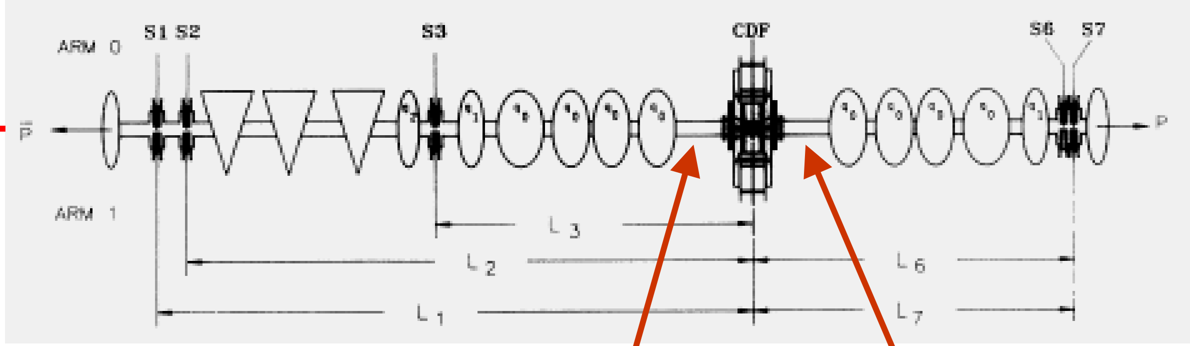
Goal: understand the nature of the colorless exchange

CDF Run 1-0 (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

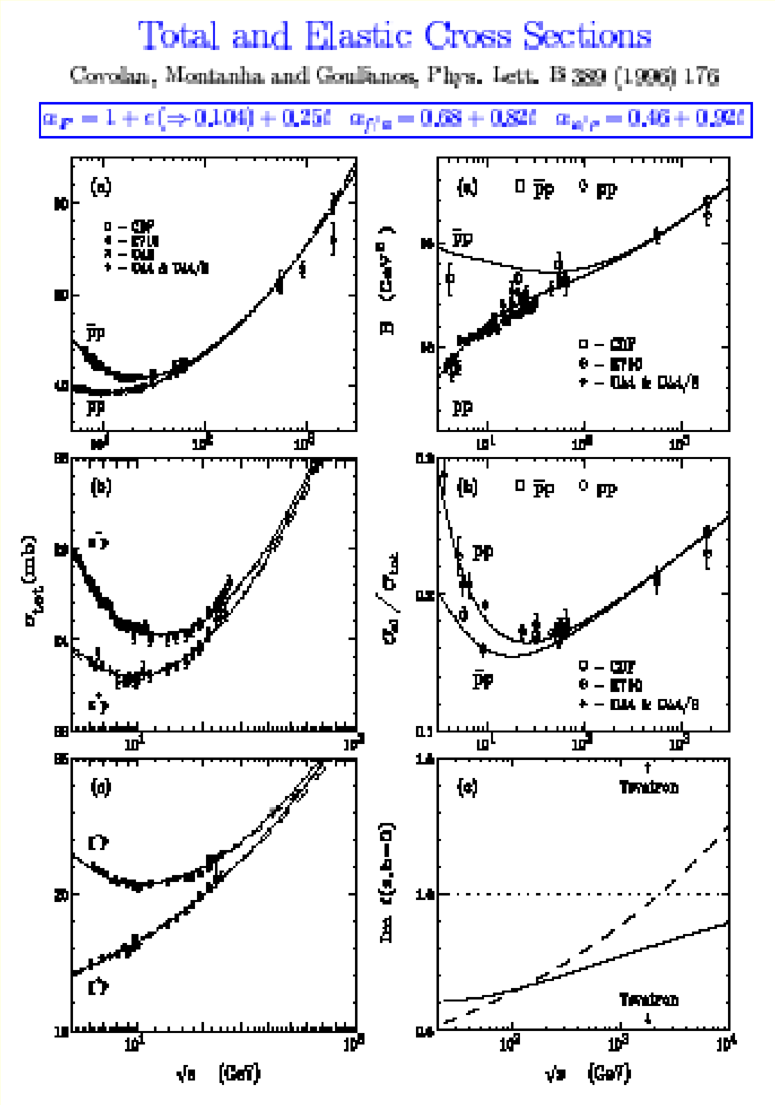
Additional Detectors

Trackers up to $|\eta| = 7$

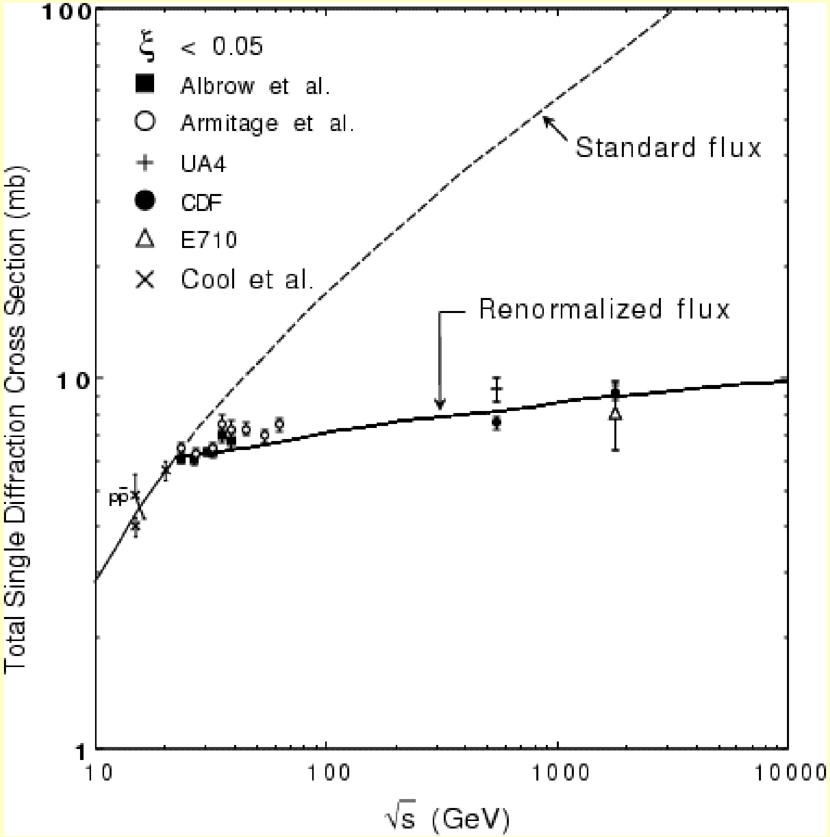
Results

- 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**

Run 1-0 results in perspective

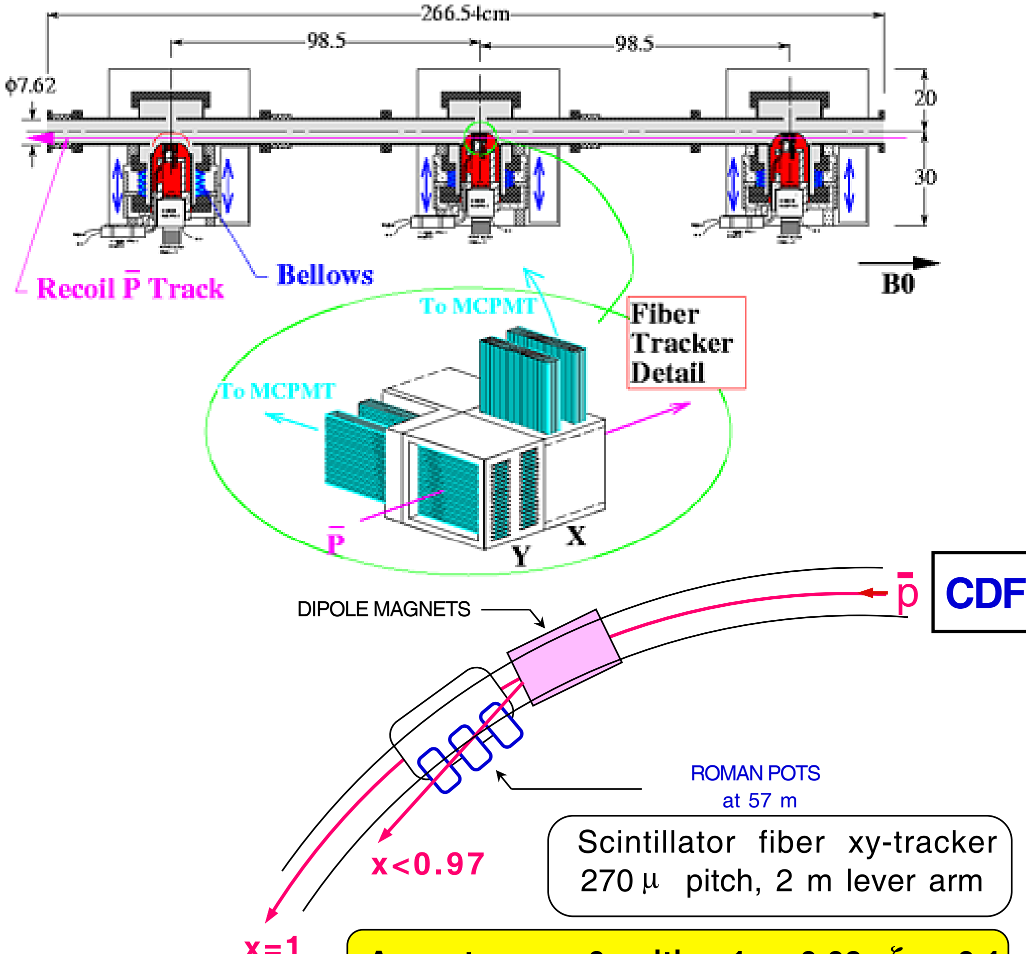


KG, PLB 358 (1995) 379



CDF Run 1 (1992-1995)

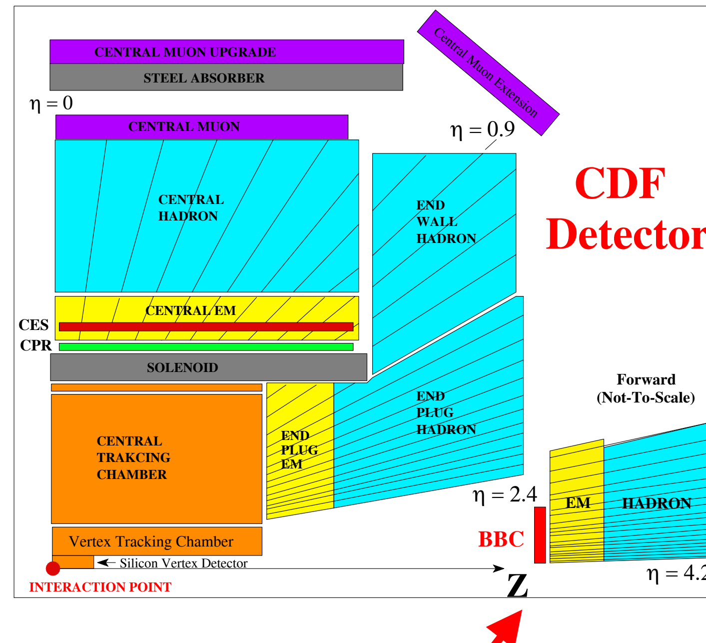
Run-IC



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

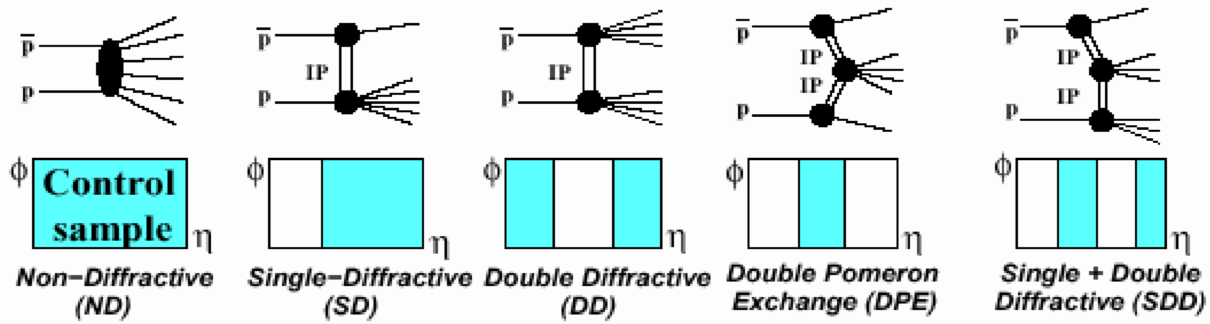
FCAL 2.4<η<4.2

Diffraction@CDF in Run I

16 papers

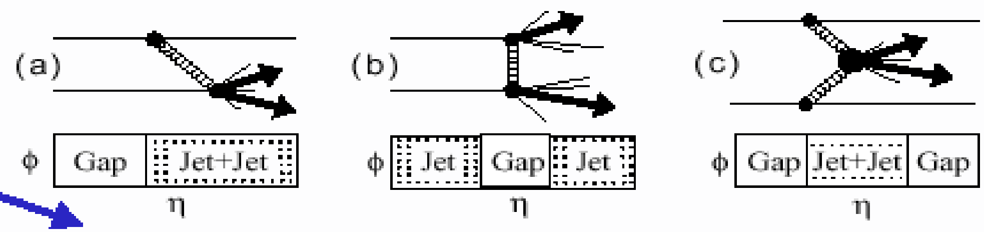
- ❑ Elastic scattering PRD 50 (1994) 5518
- ❑ Total cross section PRD 50 (1994) 5550
- ❑ Diffraction

SOFT diffraction



SD	DD	DPE	SDD
PRD 50 (1994) 5535	PRL 87 (2001)141802	PRL 93(2004)141601	PRL 91(2003)011802

HARD diffraction



PRL references

W 78 (1997) 2698	JJ 74 (1995) 855	JJ 85 (2000) 4217
JJ 79 (1997) 2636	JJ 80 (1998) 1156	
b-quark 84 (2000) 232	JJ 81 (1998) 5278	
J/ψ 87 (2001) 241802		

with roman pots

JJ	84 (2000) 5043
JJ	88 (2002) 151802

Diffractive Fractions @ CDF

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

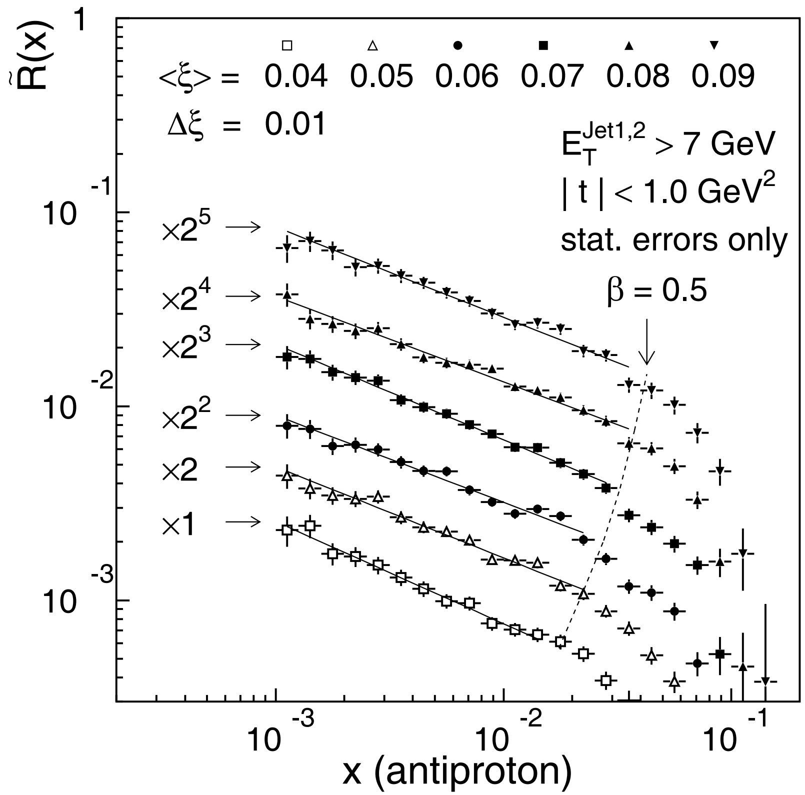
Fraction:
SD/ND ratio at 1800 GeV

Hd	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

R(SD/ND) vs x_{Bj}

$$R(x) = \frac{F_{jj}^{SD}(x)}{F_{jj}^{ND}(x)}$$

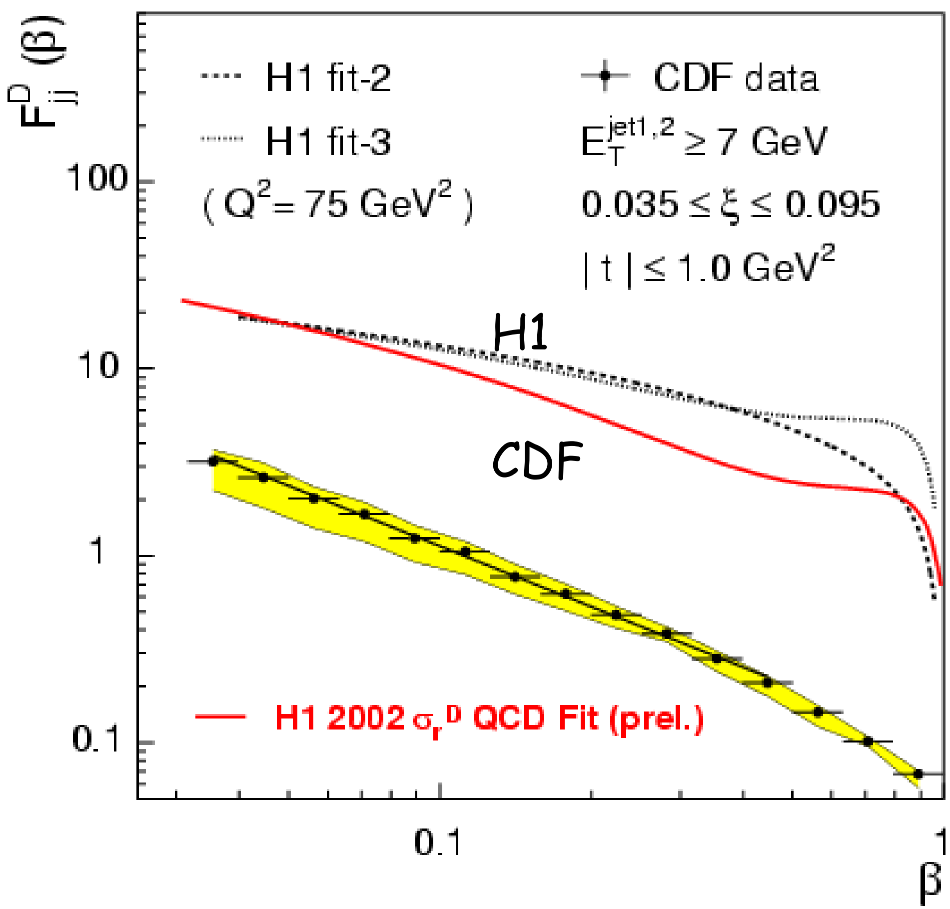


$0.035 < \xi < 0.095$

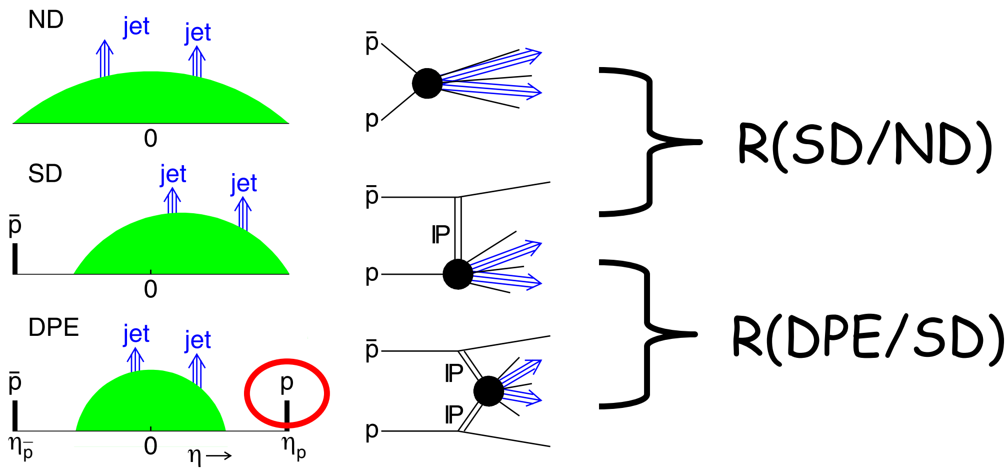
Flat ξ dependence

$$R(x) = x^{-0.45}$$

Tevatron vs HERA: Breakdown of QCD Factorization



Restoring Factorization



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 2 Diffractive Program

- Single Diffraction
  - ξ and Q^2 dependence of F_{jj}^D
  - Process dependence of F^D (W, J/ψ)
- Double Diffraction
  - Jet-Gap-Jet: $\Delta\eta^{gap}$ for fixed large $\Delta\eta^{jet}$
- Double Pomeron Exchange
  - F_{jj}^D on p-side vs ξ-pbar

Also:

Exclusive central production

- Dijets, χ_c

Other

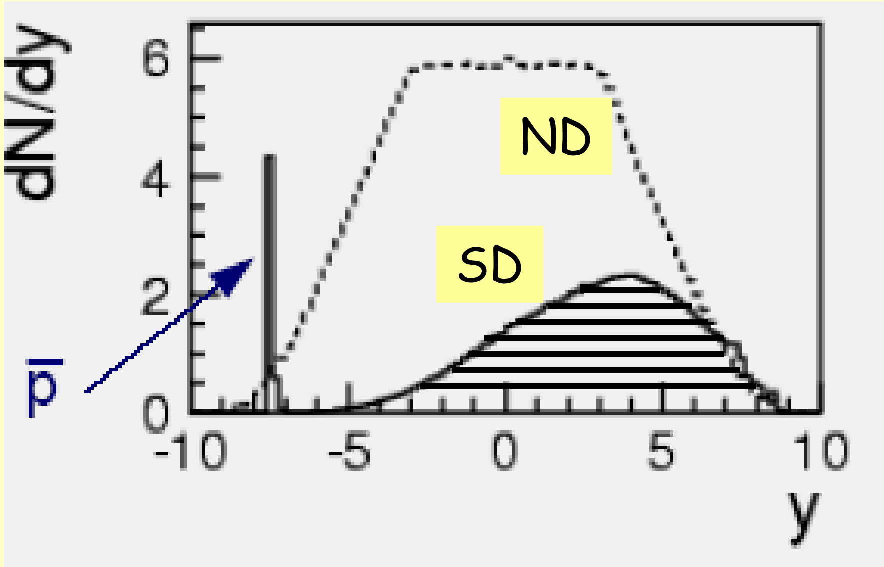
- Tev4LHC issues

SD and ND collisions

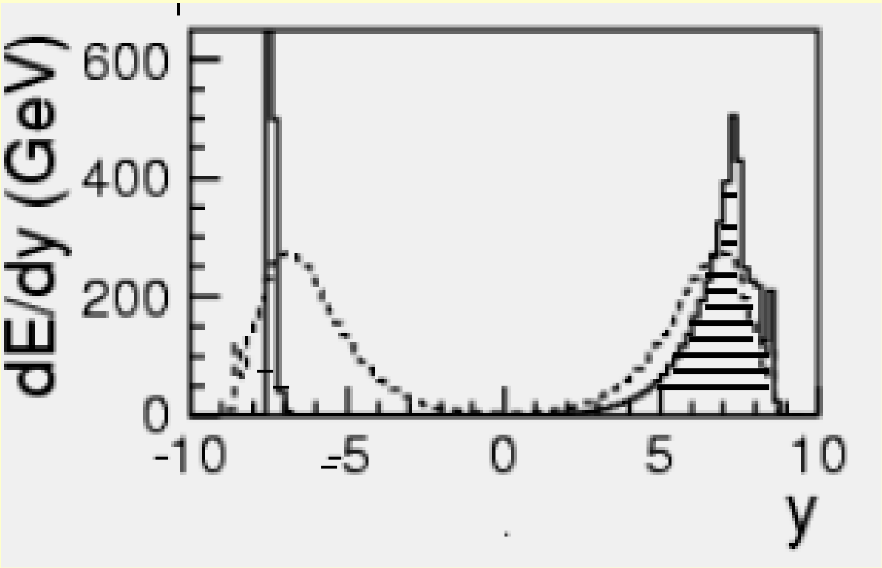
$$\text{SD:}\quad \bar{p}p \to \bar{p} + \text{gap} + X$$

$$\text{ND:}\quad \bar{p}p \to X$$

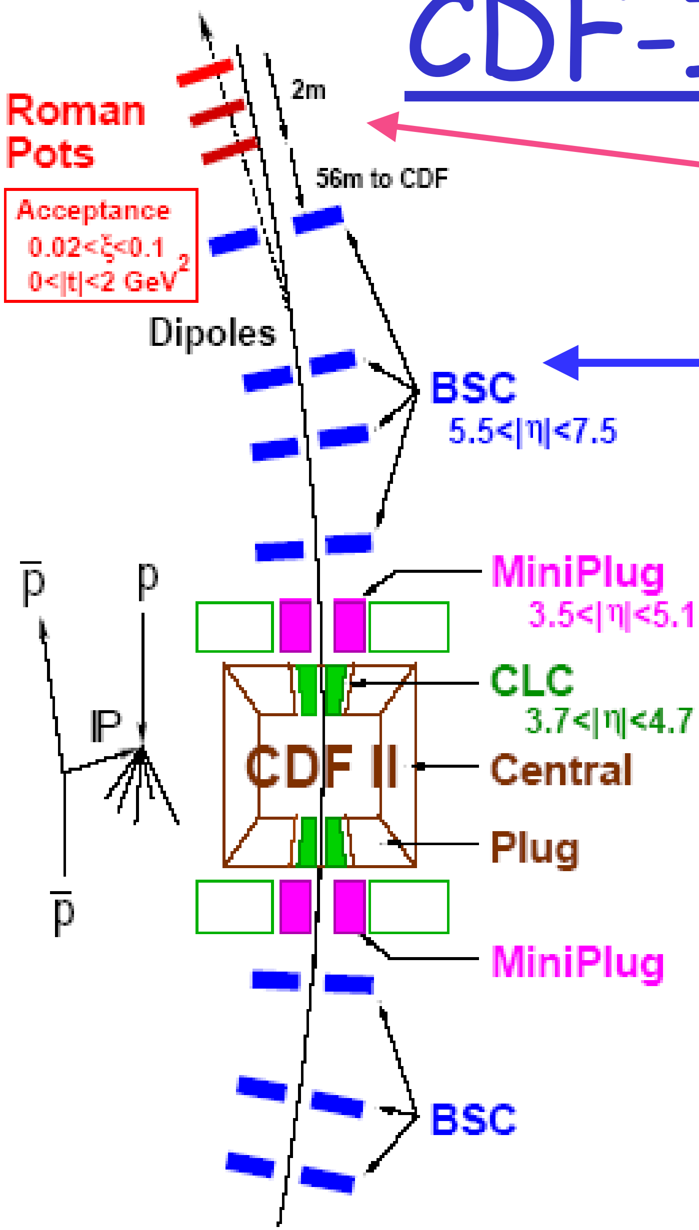
Particle density



Energy flow

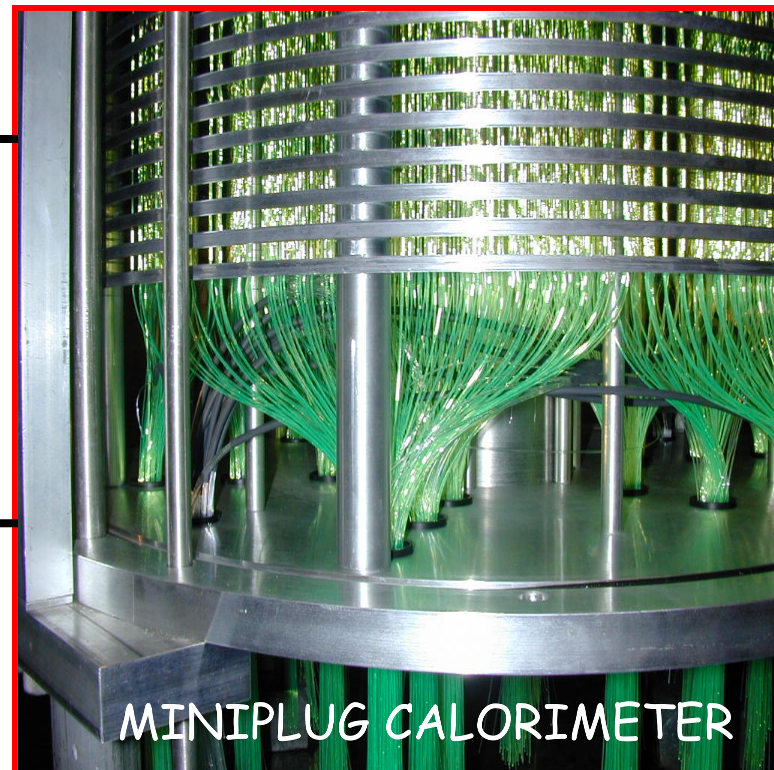


CDF-II



ROMAN POT DETECTORS

BEAM SHOWER COUNTERS:
Used to reject ND events

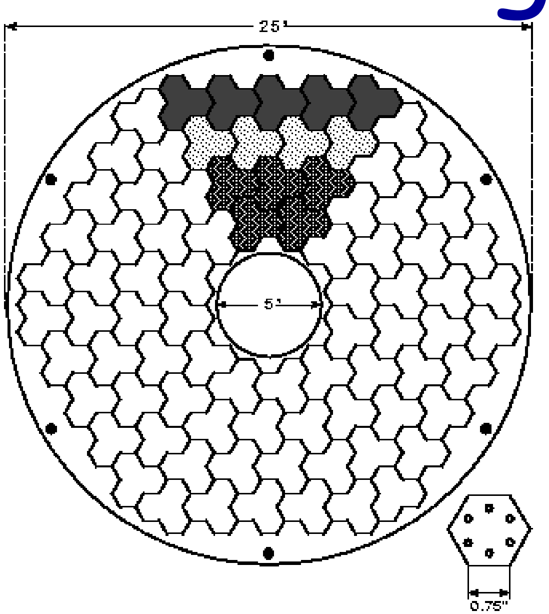


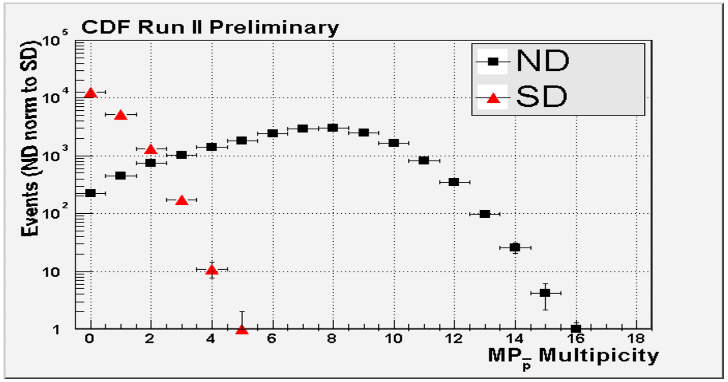
Artist's View of MiniPlug

84 towers

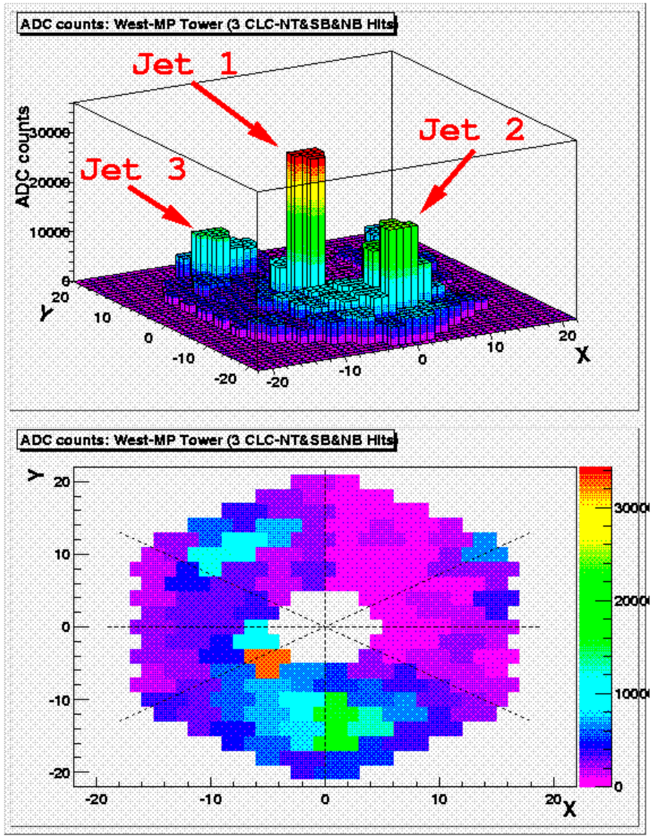
25 in

MiniPlug Run II Data





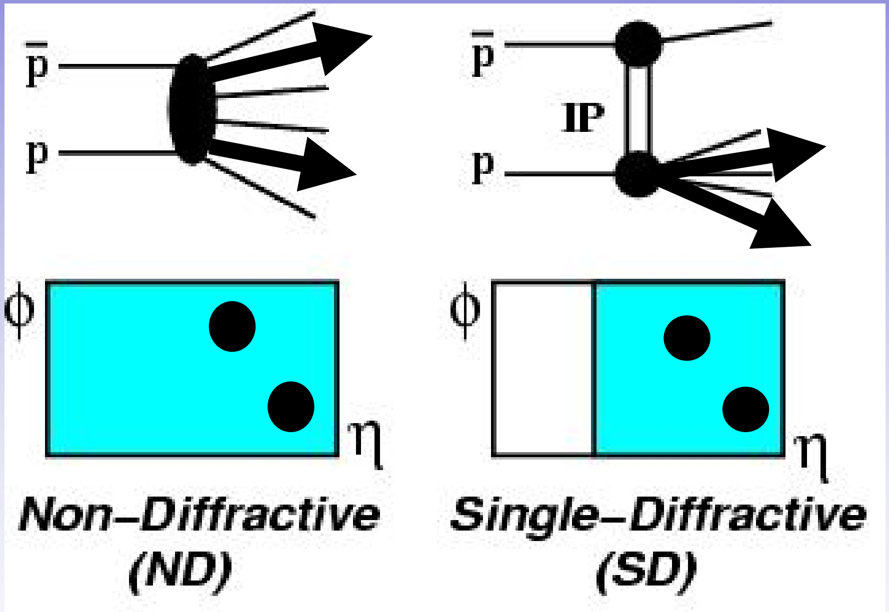
Multiplicity distribution in SD and ND events



ADC counts in MiniPlug towers in a pbar-p event at 1960 GeV.

- "jet" indicates an energy cluster and may be just a hadron.

Diffractive Structure Function

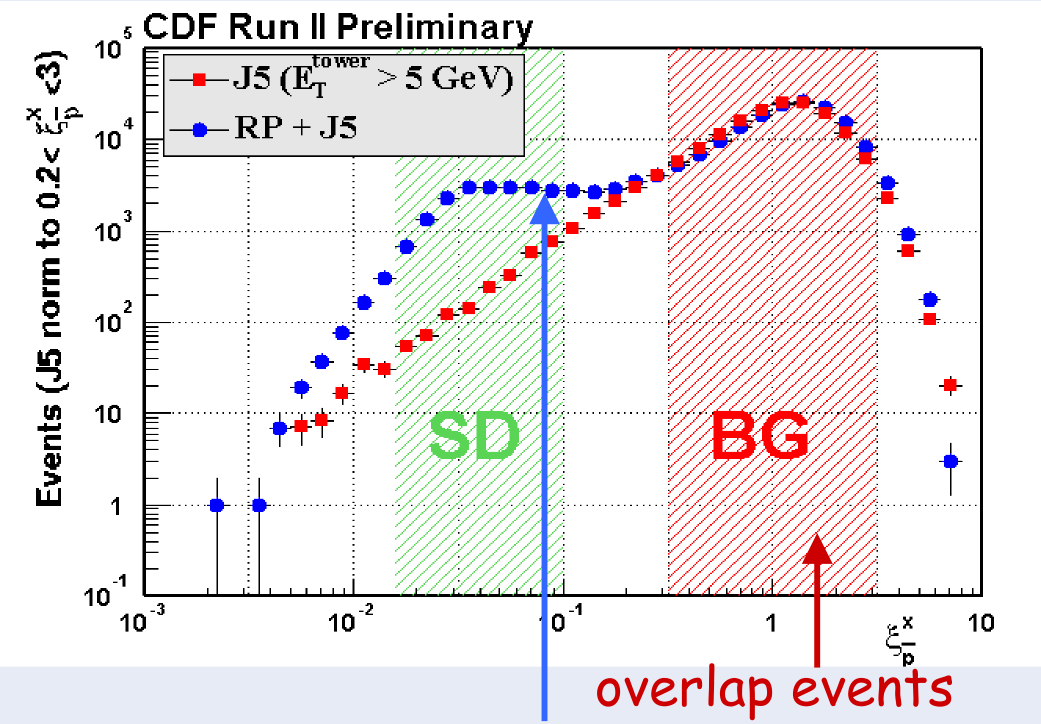


$$R(x_{Bj}) \equiv \frac{Rate_{jj}^{SD}(x_{Bj})}{Rate_{jj}^{ND}(x_{Bj})}$$

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

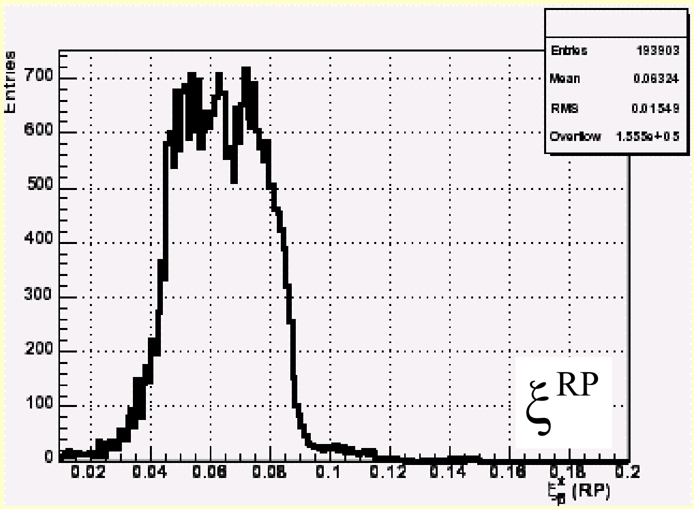
Diffractive Dijet Sample

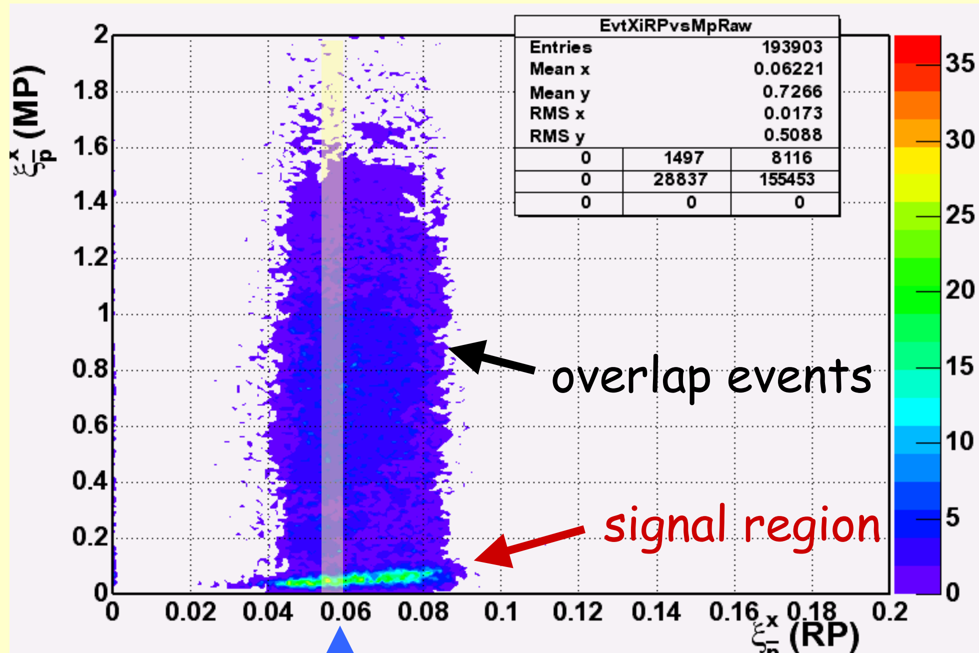
$$\xi = \frac{\Sigma_{\text{all towers}} E_T e^{-\eta}}{\sqrt{s}}$$

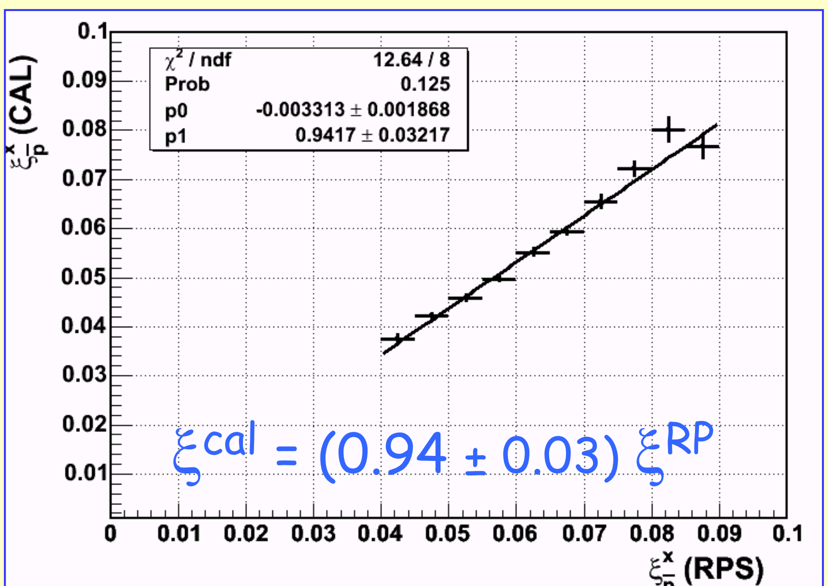


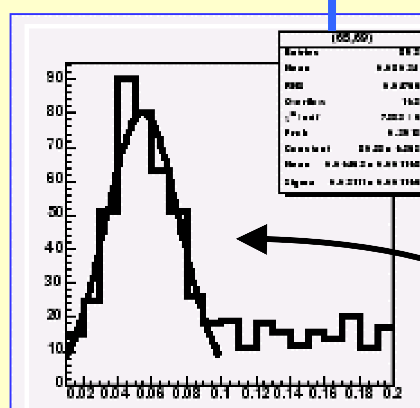
$$\frac{d\sigma}{d\xi} \sim \frac{1}{\xi} \Rightarrow \frac{d\sigma}{d\log\xi} \sim \text{constant}$$

ξ^{RP} vs ξ^{cal}





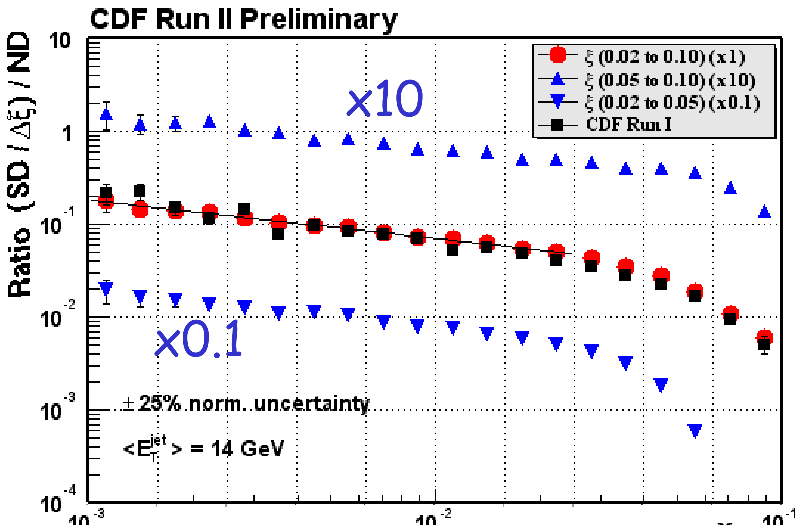




ξ^{cal} distribution for slice of ξ^{RP}

σ/mean ~ 30%

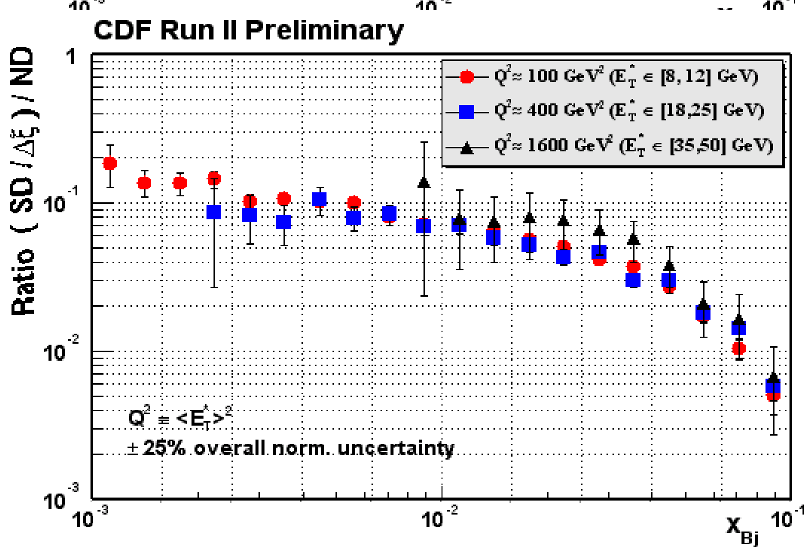
$R^{SD}_{ND}(x_{B_J})$



Ratio of SD/ND dijet event rates

- agreement with Run 1 result
- no ξ dependence in 0.03<ξ<0.1

⇨ confirms Run I results



No appreciable Q^2 dependence

in region $100 < Q^2 < 1{,}600$ GeV^2

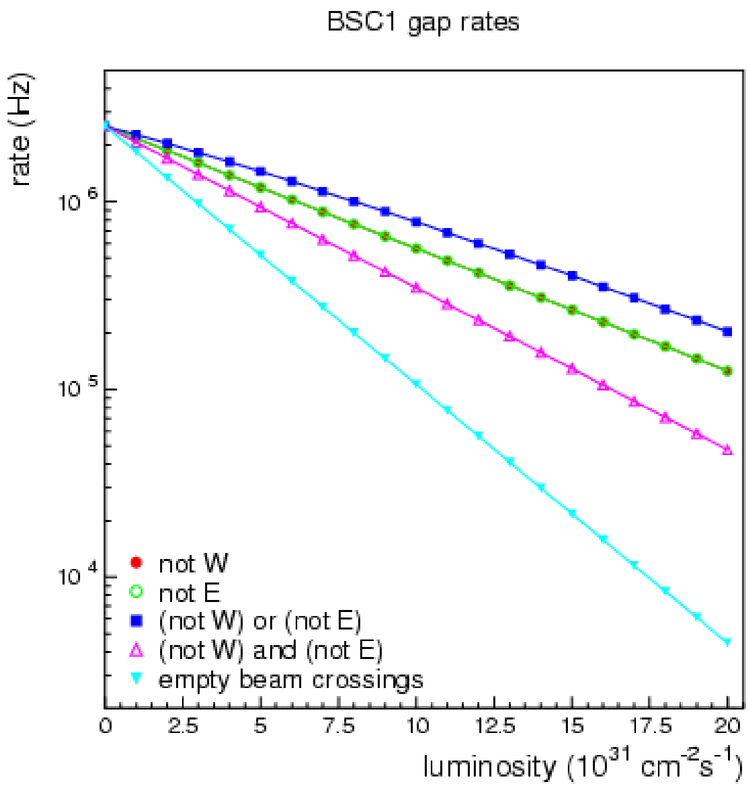
⇨ Pomeron evolves as proton

MORE DATA CURRENTLY AT HAND

F_{jj}^{D} @ low ξ

Measure ξ-dependence of Fjj(ξ,β,t) down to ξ~0.001

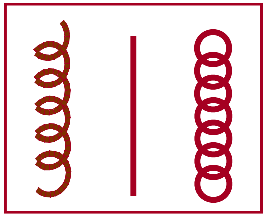
using gap trigger



STATUS:
Data at hand
Analysis in progress

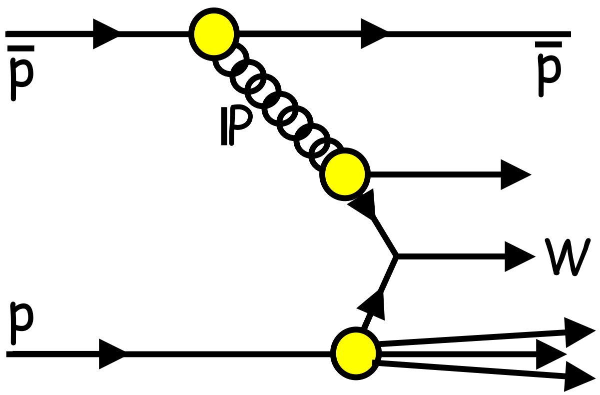
Diffractive W production

Probes the quark content of the Pomeron
➔ More direct comparison with HERA

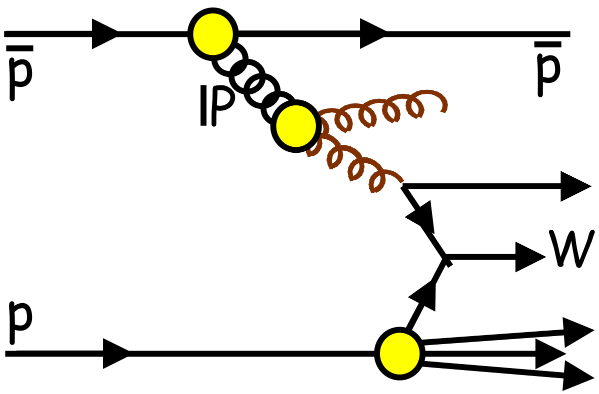


Run I: 8,246 W(ev) events - PRL 78 (1997), 2698

R_W (SD/ND) = 1.15 ± 0.51(stat) ± 0.20(syst) %



hard-quark dominated Pomeron



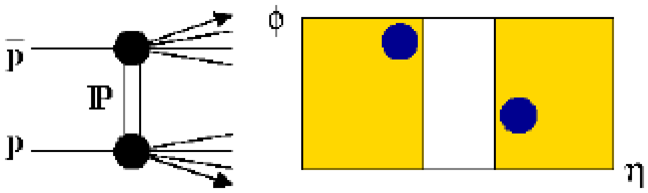
hard-gluon dominated Pomeron
(rate lower by α_s)

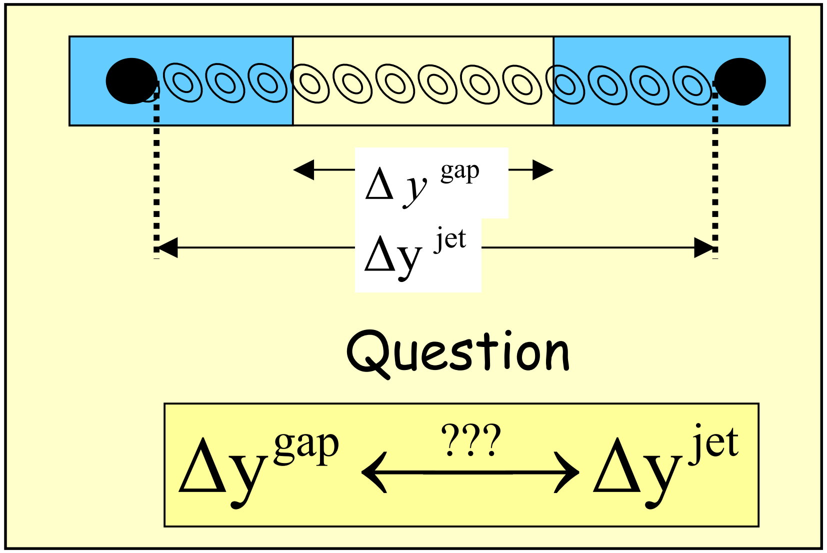
Status: data at hand, analysis in progress

Gap Between Jets

Is the diffractive exchange BFKL-like
or simply a color rearrangement?

$$\bar{p} + p \rightarrow \text{Jet} + \text{Gap} + \text{Jet}$$





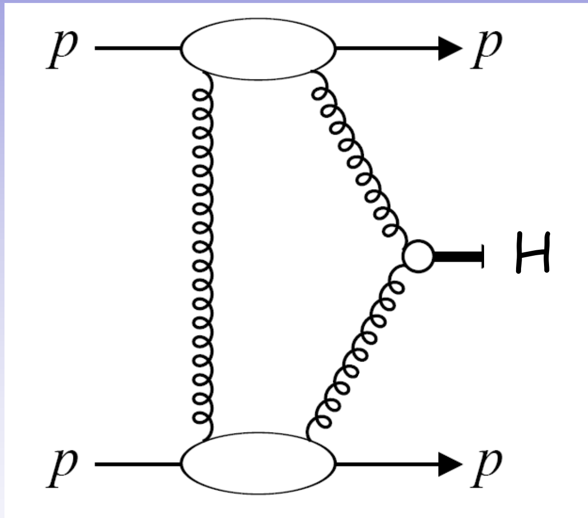
Work in progress: low luminosity run needed

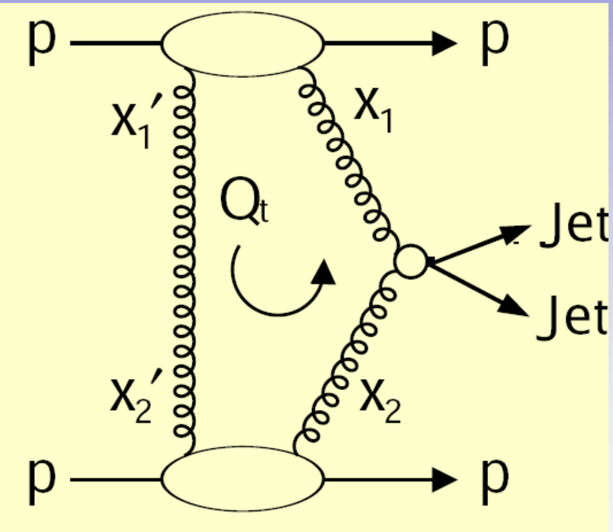
Exclusive Dijet Production

Use dijet rate to calibrate Higgs production calculations

Khoze, Martin, Ryskin: Eur. Phys. J. C23, 311 (2002); C25,391 (2002);C26, 229 (2002)

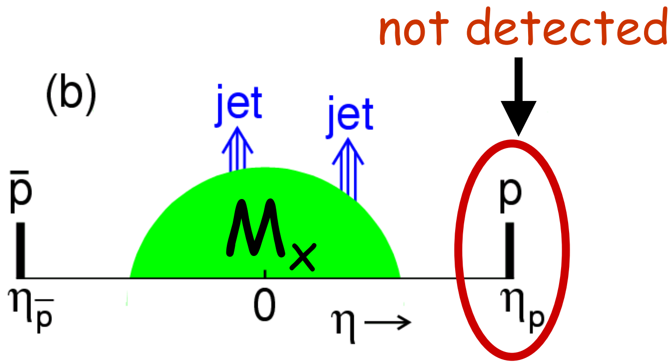
Boonekamp, Peschanski, Royon: PRL 87, 251806(2001)





Exclusive Dijets in Run 1

PRL 85 (2000) 4215



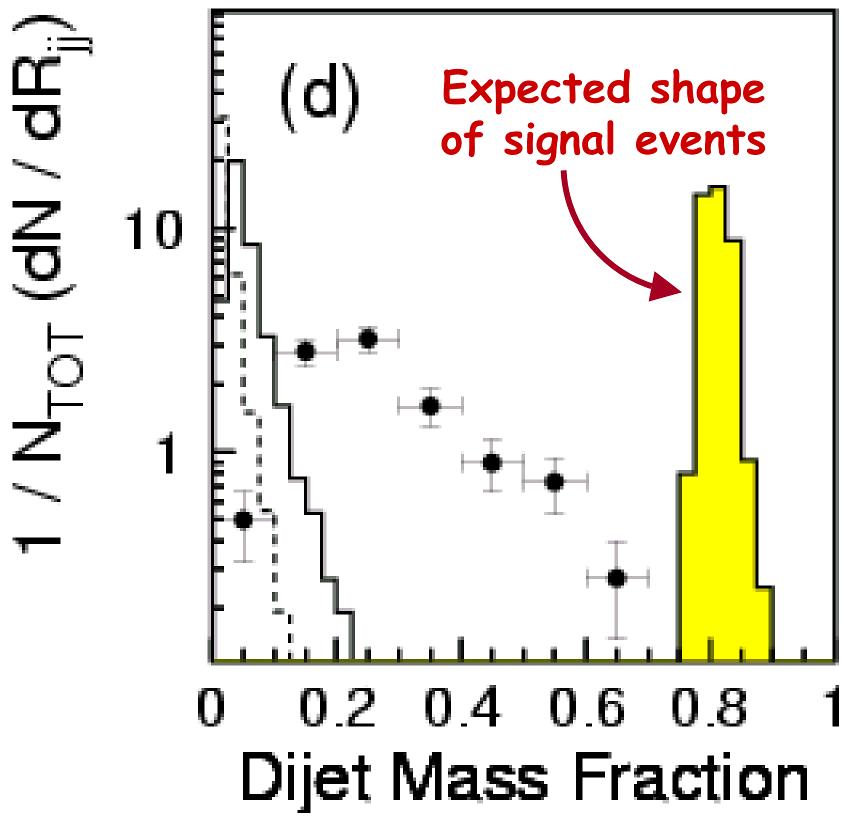
Dijet Mass fraction

$$R_{jj} = \frac{M_{jj}}{M_X}$$

Exclusive dijet limit:

σ_{jj} (excl.) < 3.7 nb (95% CL)

Theoretical expectation (KMR) ~1 nb

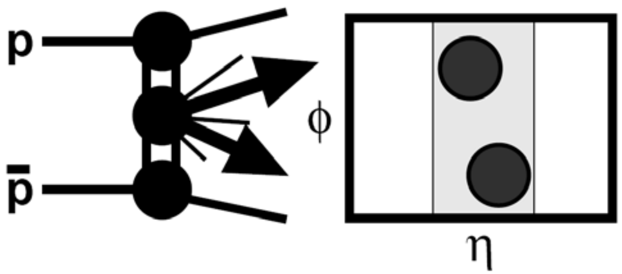


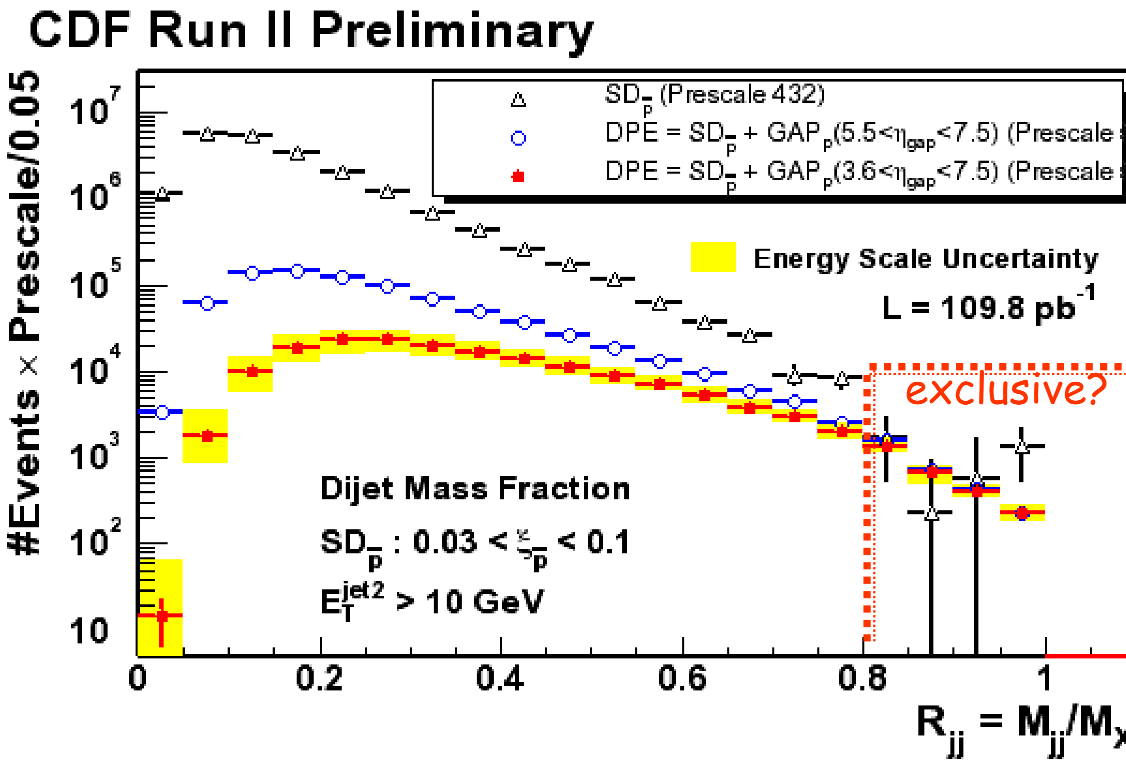
Run 2 dijet mass fraction

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

$\bar{p}p \rightarrow \bar{p} + JJ + gap^{proton}_{5.5<\eta<7.5}$

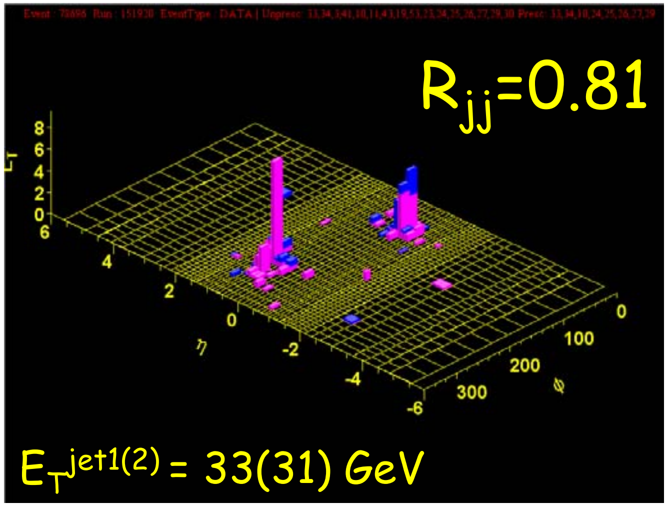
$\bar{p}p \rightarrow \bar{p} + JJ + gap^{p}_{3.6<\eta<7.5}$

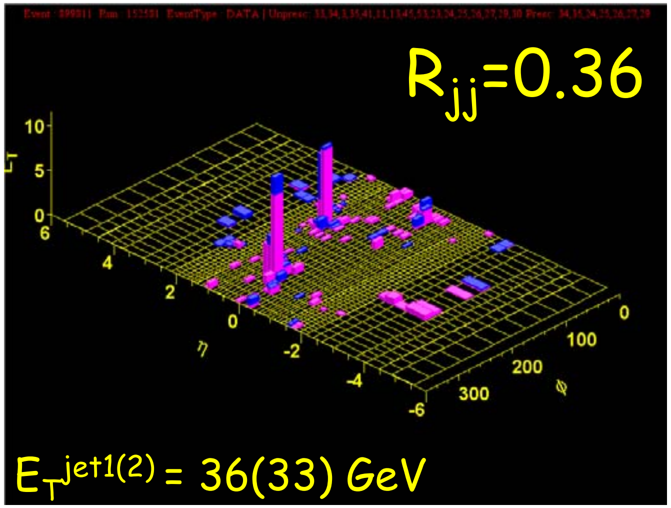


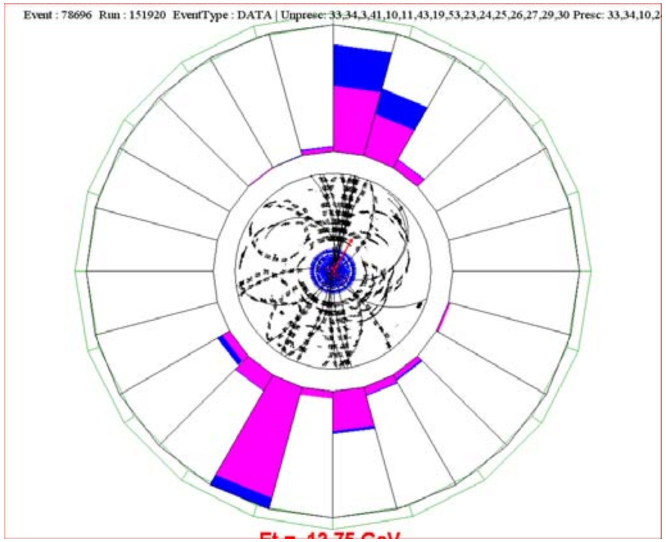


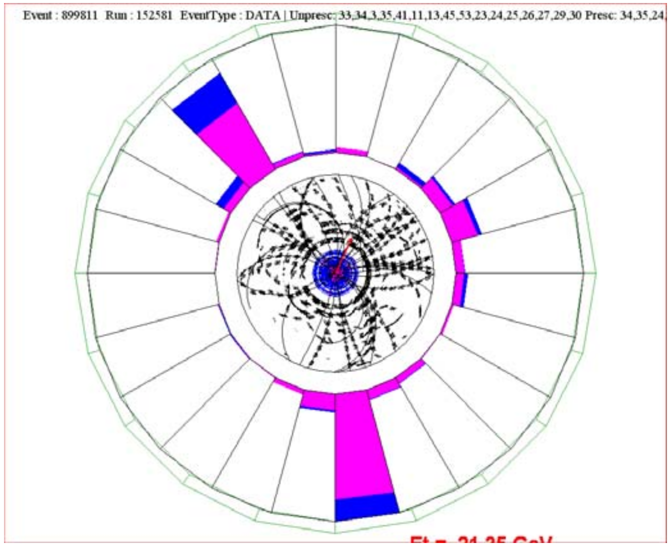
Minimum E_T(Jet1)	Cross section (R_{jj}>0.8)
10 GeV	1.1 ± 0.1(stat) ± 0.5(syst) nb
25 GeV	25 ± 3(stat) ± 10(syst) pb

Exclusive Dijet Events ?

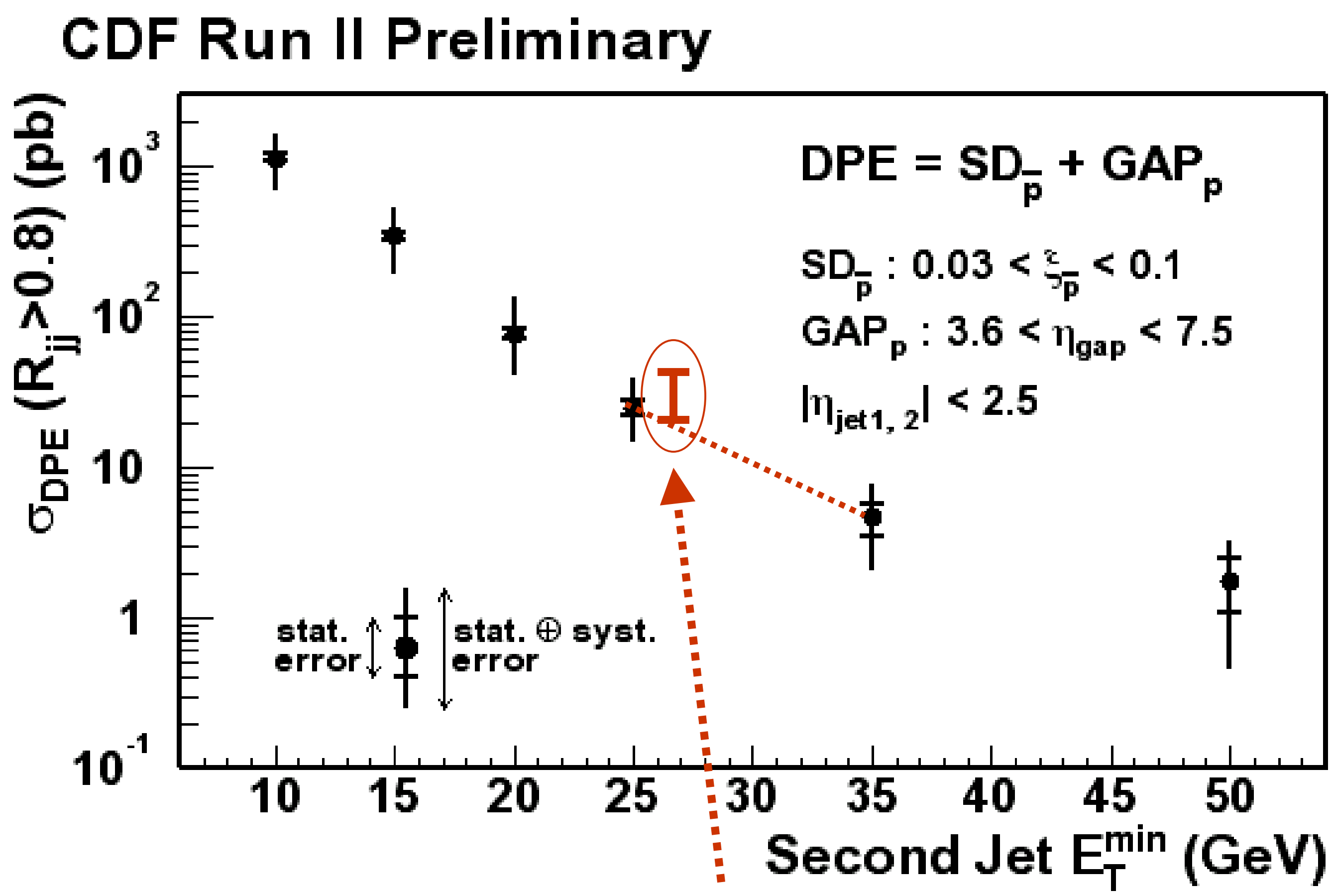








Limits on Exclusive production



Martin, Kaidalov, Khoze, Ryskin, Stirling
hep-ph/0409258): ~ 40 pb (E_T>25 GeV) (factor ~2 uncertainty)

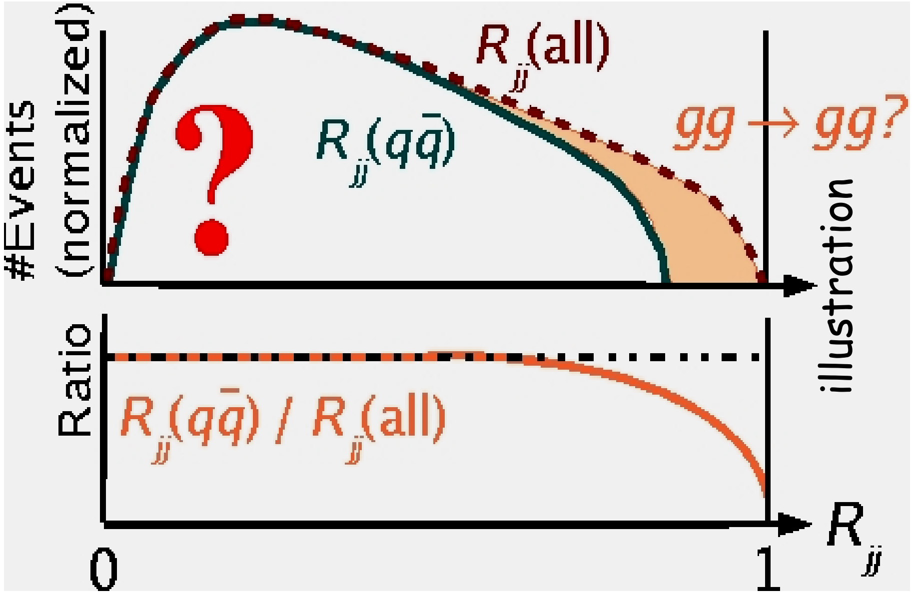
Heavy flavor exclusive dijets

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

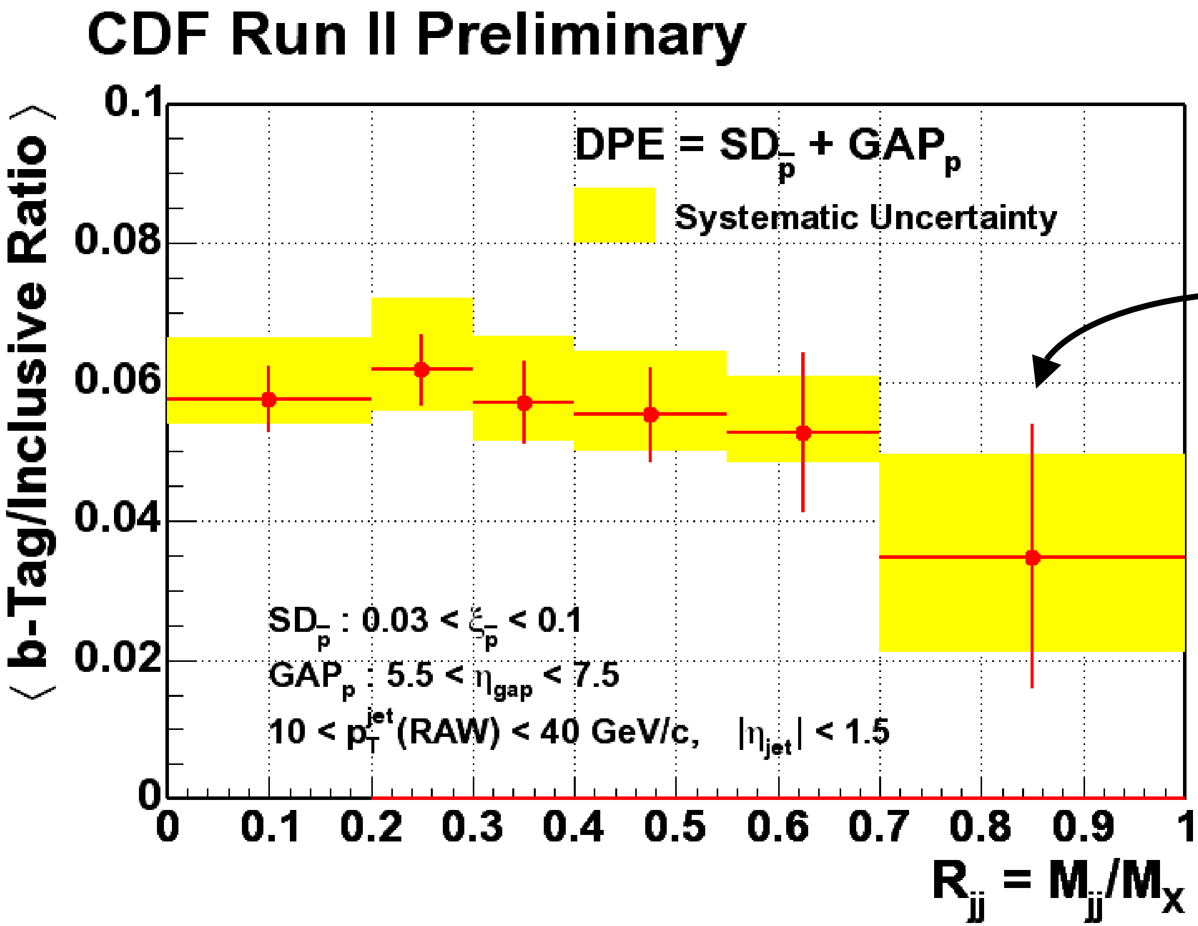
Experimental method:
normalize $R_{jj}(q\bar{q})$ to R_{jj}(all jets)
⇨ look for suppression at large R_{jj}

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

Cons: heavy quark mass:
suppression is not complete



Heavy flavor tagged dijet fraction



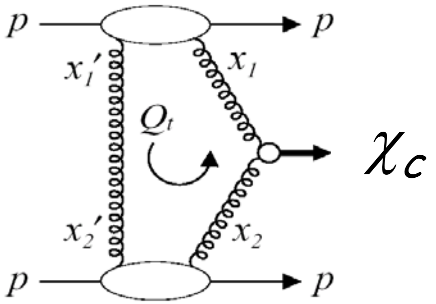
exclusive production?

<u>need</u>:

- to compare with MC
- more data !

$R_{btag}(R_{jj}>0.7)/R_{btag}(R_{jj}<0.4)=$**0.59** ± 0.33 (stat) ± 0.23 (syst)

Exclusive χ_c



$p\bar{p} \rightarrow p\,\chi_c\,\bar{p}$

$\quad \hookrightarrow J/\psi\ \ \gamma \rightarrow \mu\mu\ \ \gamma$

From inclusive J/ψ data:

Cross section **upper limit**: $\sigma_{excl}(J/\psi+\gamma) = 49 \pm 18(stat) \pm 39(syst)$ pb

Khoze, Martin, Ryskin, and Stirling ⟶ ~ 70 pb [Eur. Phys. J. C 35, 211 (2004)]

STATUS: data from new gap + J/ψ + gap trigger are being analyzed

CONCLUSION

Run 2

- CDF has a comprehensive Run 2 diffractive program
- Data at hand are being analyzed
- More data are being collected
- Proposal for low luminosity (~10^{30}) run under study

Beyond Run 2

- Tev4LHC studies