New results on diffraction from CDF

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on behalf of the CDF collaboration

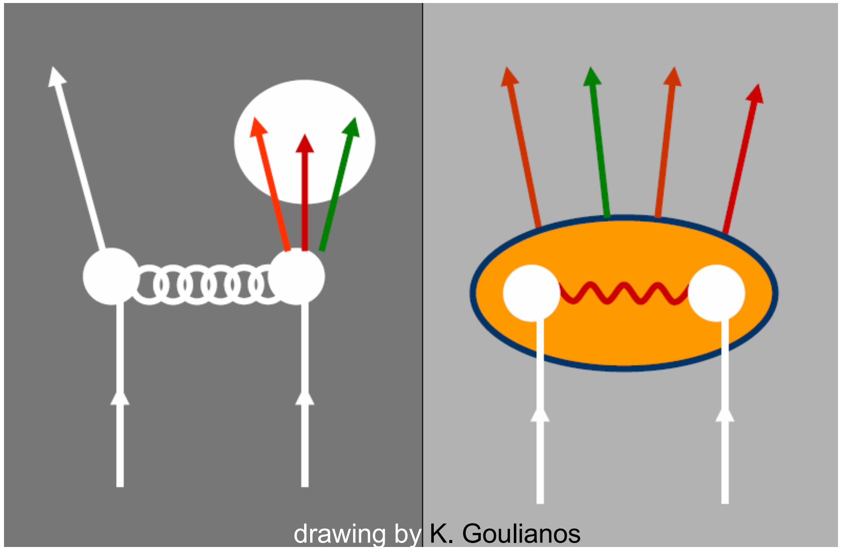
- ✓ diffractive structure function
- ✓ t-distribution
- ✓ exclusive processes

Hadronic interactions

Diffractive

vacuum exchange

Protons retain their quantum numbers



Non-Diffractive

color exchange

Protons acquire color and break apart

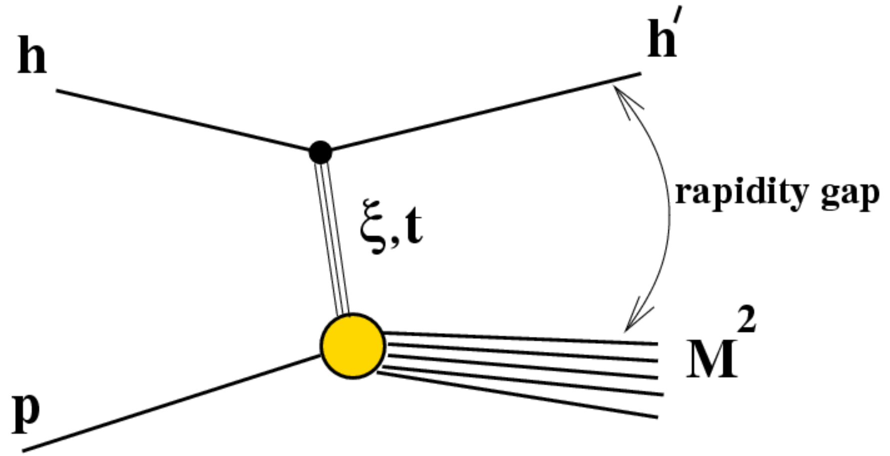
Goal: understand the nature of the colorless exchange

Hadronic diffraction

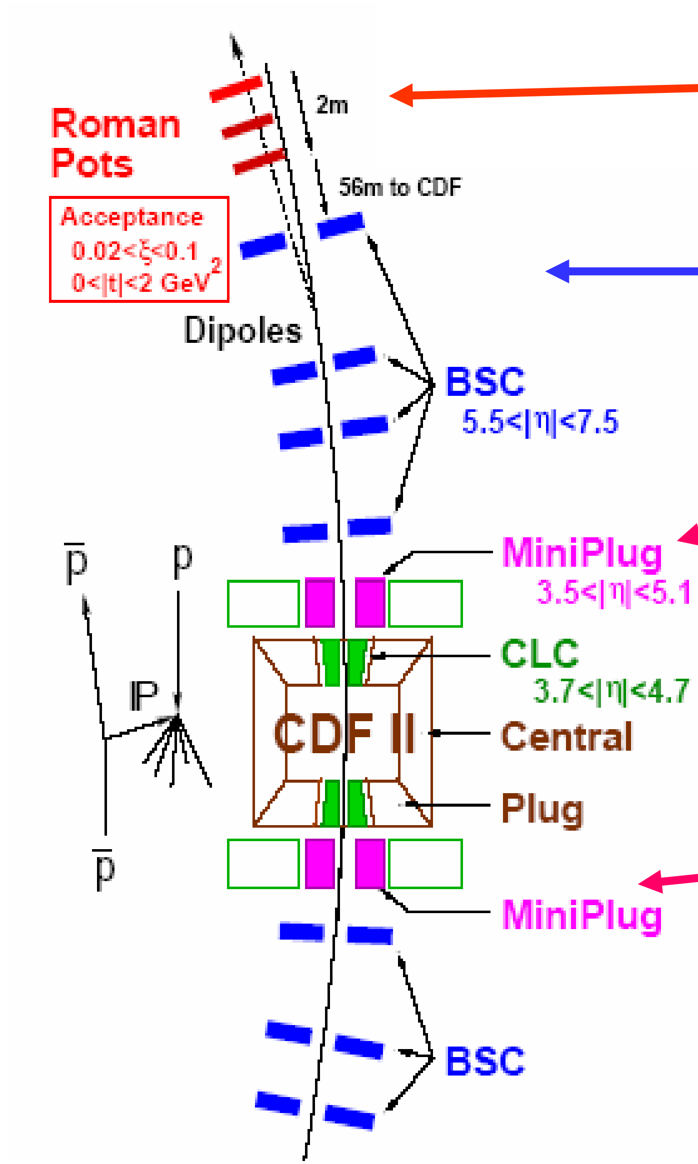
Small momentum transfer

Elastic and diffractive processes
⇨ leading hadron emitted at small angle

The exchange (“pomeron”) is colorless
⇨ large rapidity gap

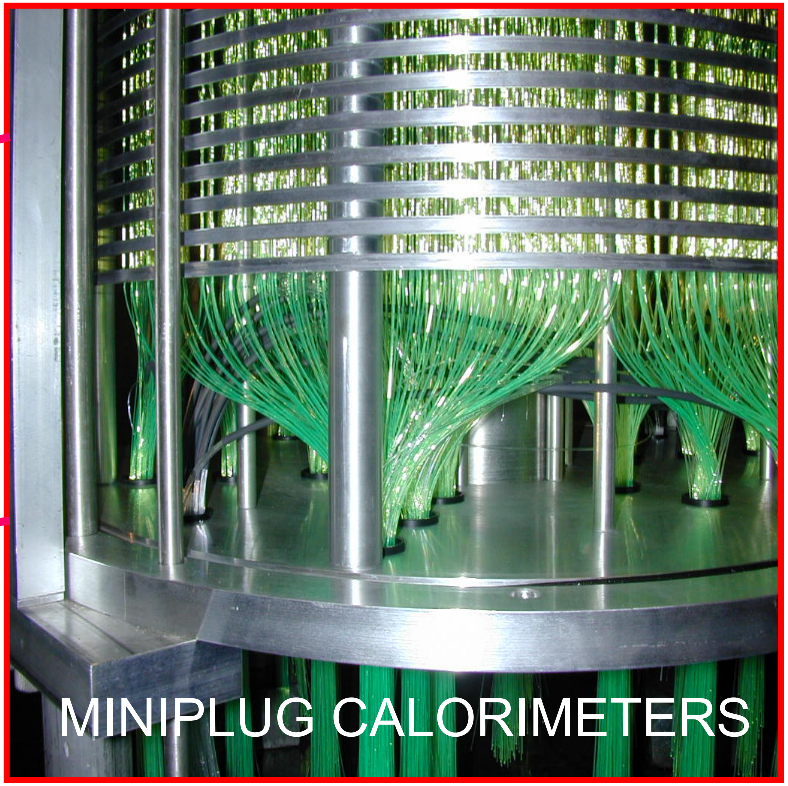


Run II diffractive program

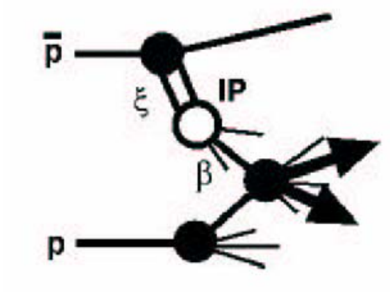


ROMAN POT DETECTORS

BEAM SHOWER COUNTERS: used to reject ND events



Diffractive dijets



ξ: fraction of anti-proton momentum loss
β: fraction of pomeron momentum carried by parton

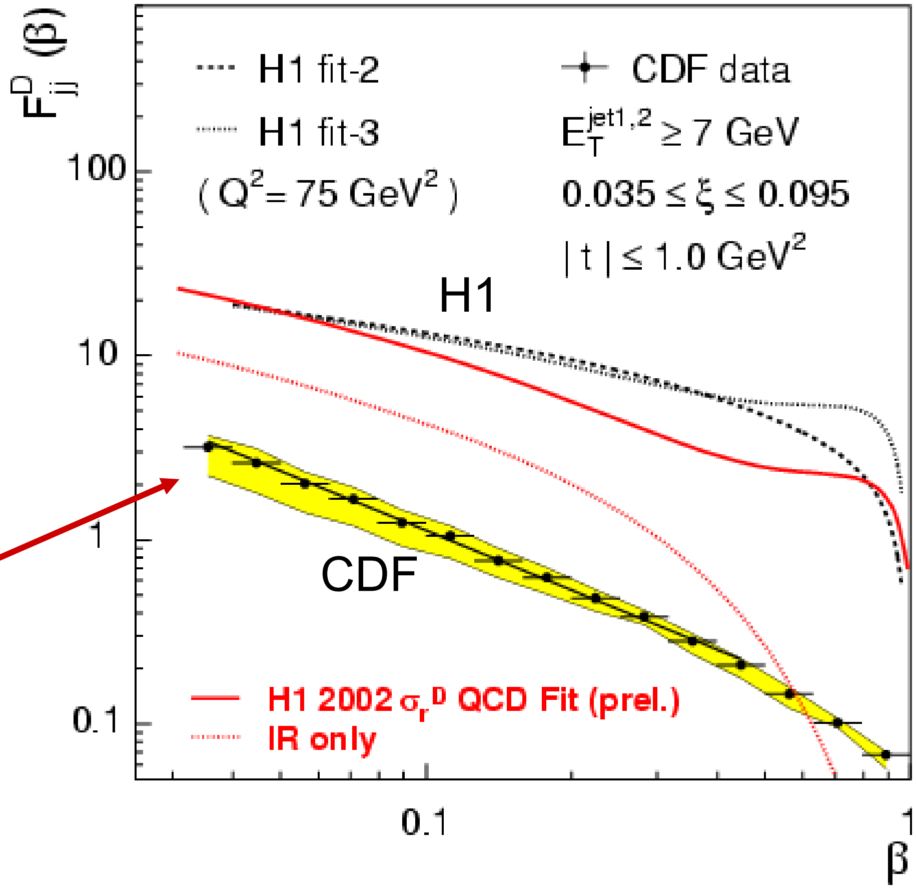
parton $x_{Bj} \equiv \beta \cdot \xi$

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

Measure SD/ND ratio of dijet rates

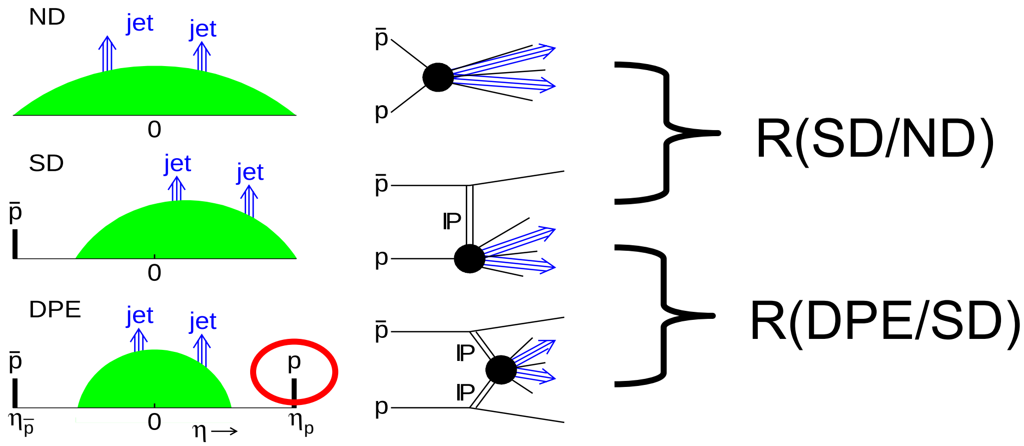
$$\frac{\sigma(SD_{jj})}{\sigma(ND_{jj})} = \frac{F_{jj}^{D}(x)}{F_{jj}(x)}$$ (LO QCD)

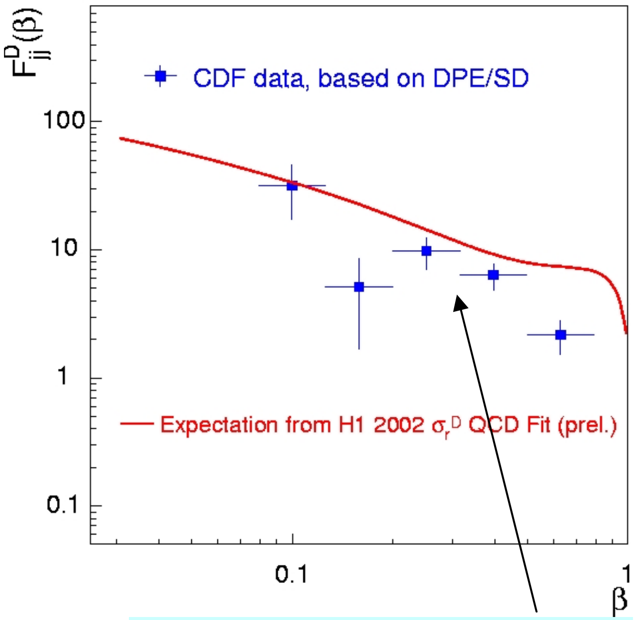
CDF Run I result suppressed
by factor of ~10 relative to HERA



⇨breakdown of QCD factorization

Restoring factorization



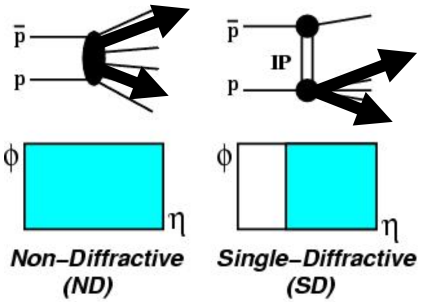


factorization is restored !

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

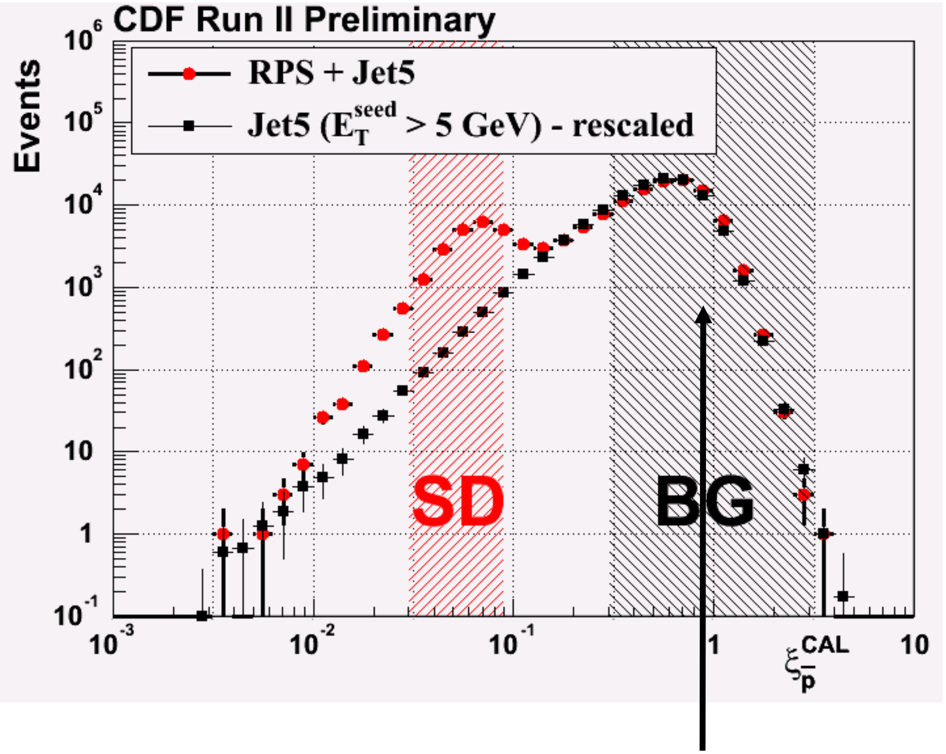
⇨more results will be available soon

Diffractive dijets

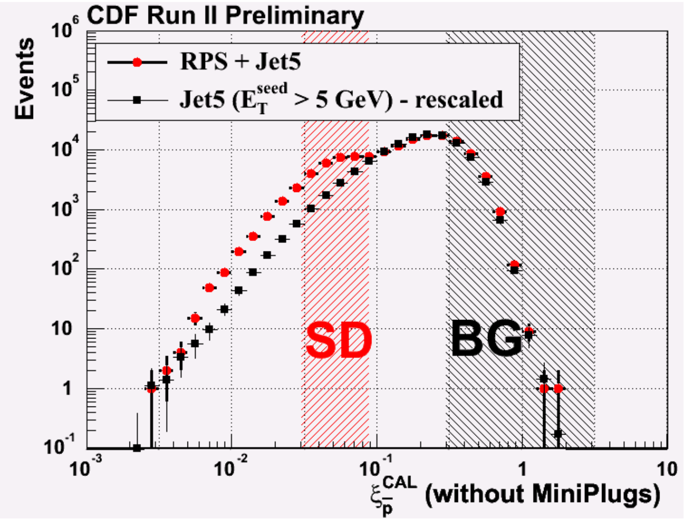


ξ: momentum loss fraction of pbar

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

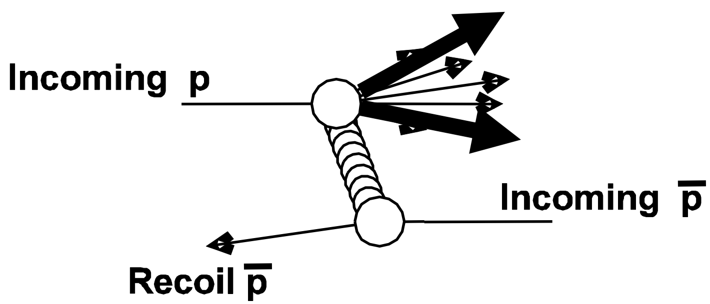


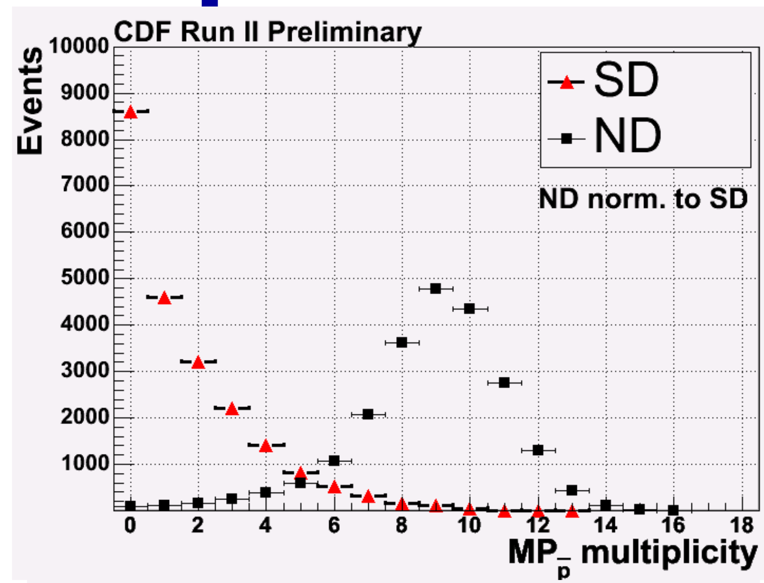
overlap events
(multiple $p\bar{p}$ interactions)



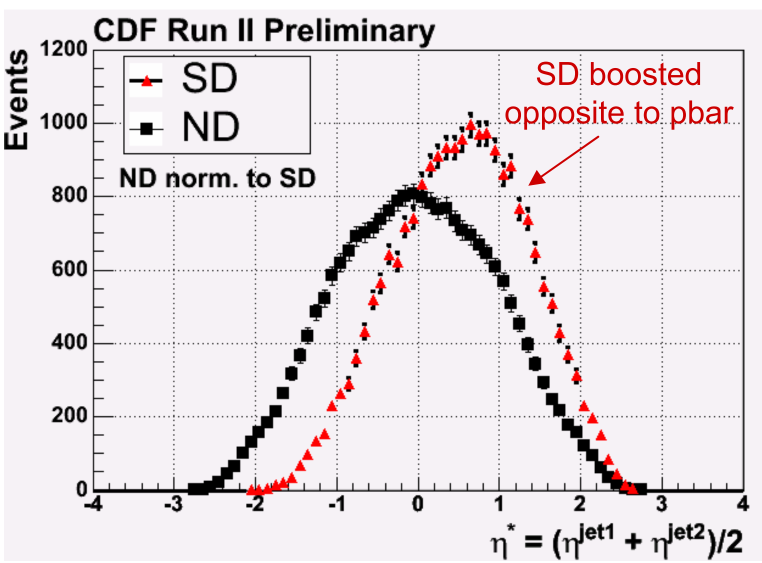
MP energy scale: ±30% →$\Delta\log\xi$ = ±0.1
RP acceptance (0.03<ξ< 0.09) ~ 80%

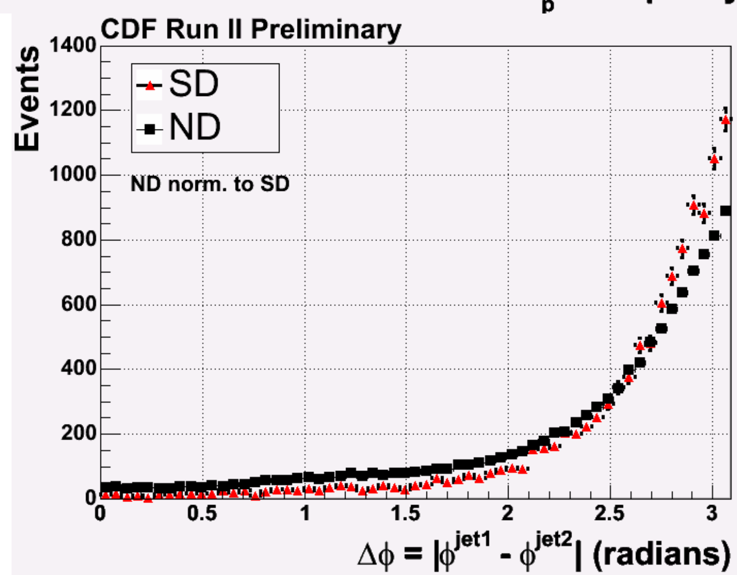
Kinematic Properties



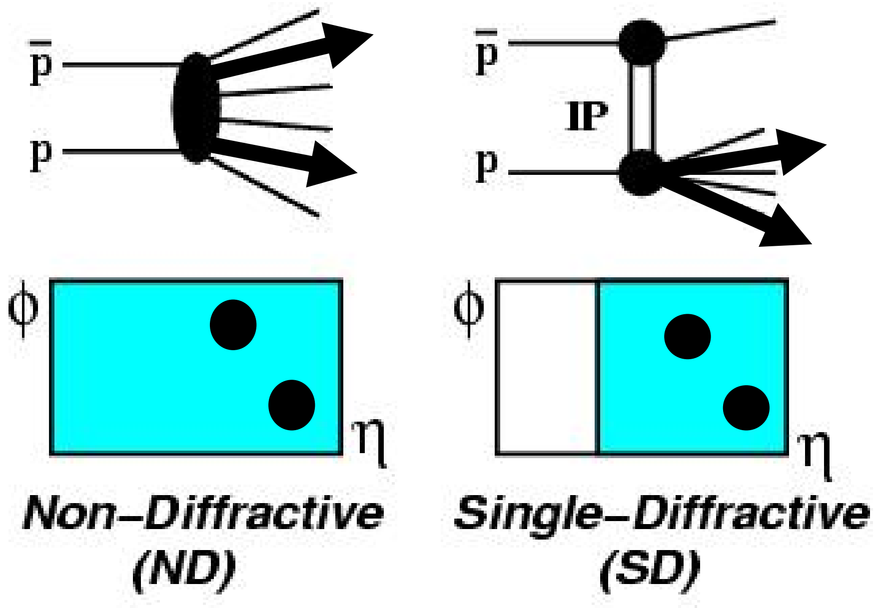


compare ND and SD





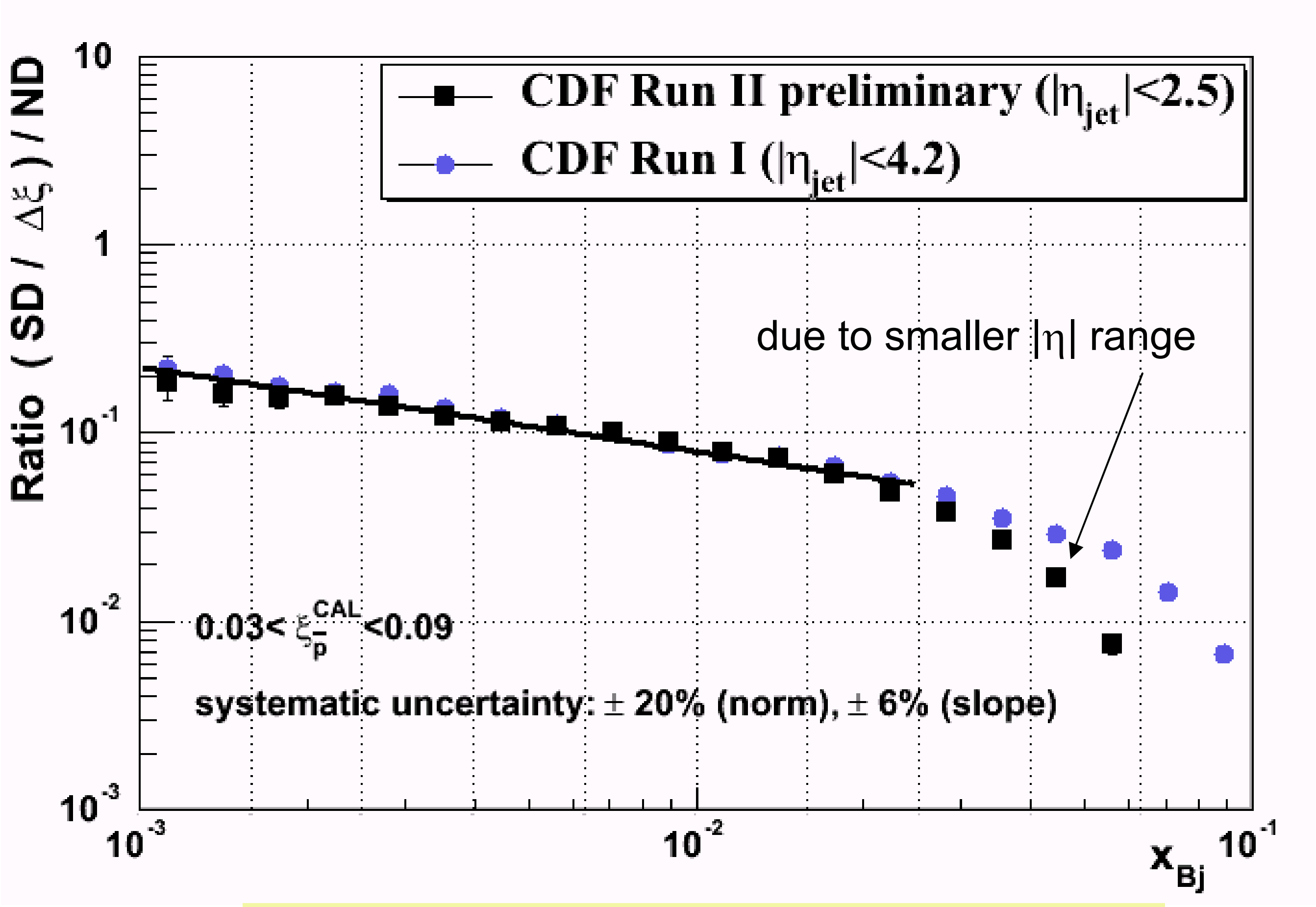
Diffractive structure function



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

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

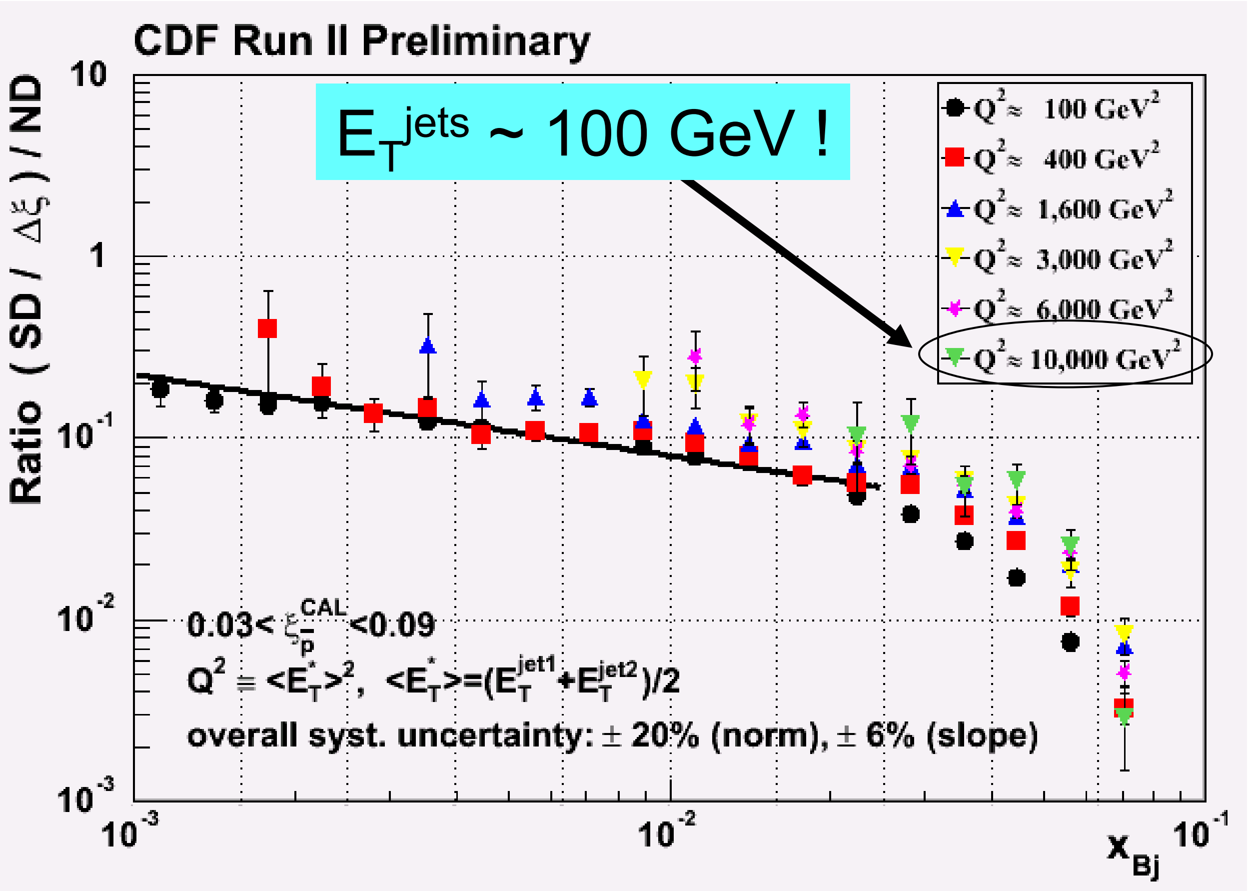
SD/ND ratio



ratio of SD/ND dijet event rates

⇨ confirms Run I results

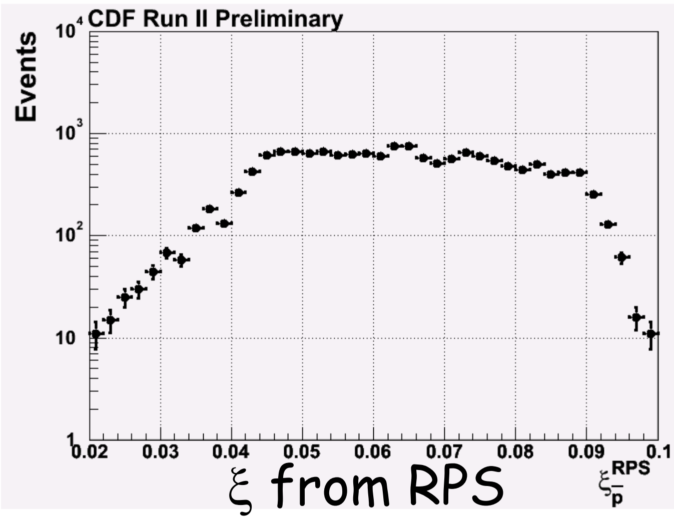
Q^2 dependence

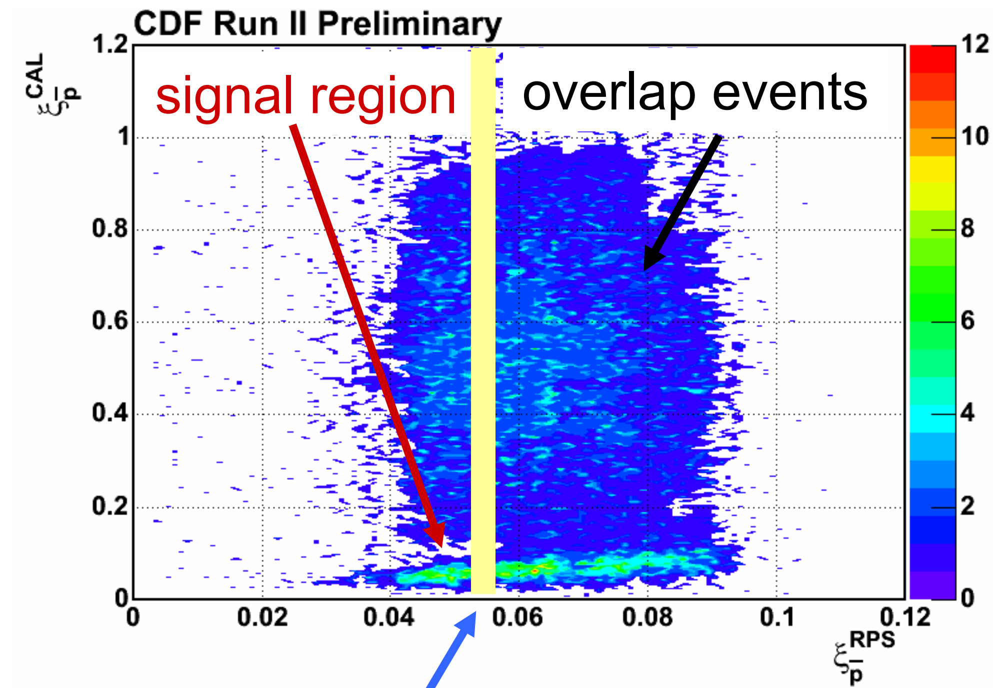


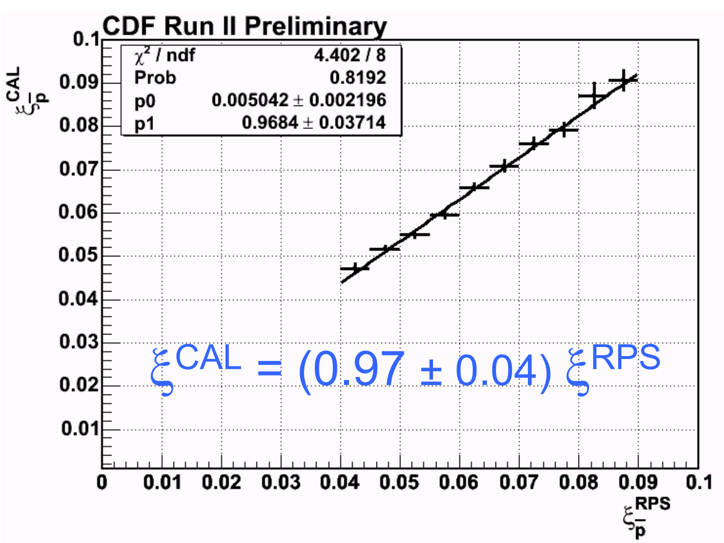
small Q^2 dependence for $100 < Q^2 < 10{,}000$ GeV^2

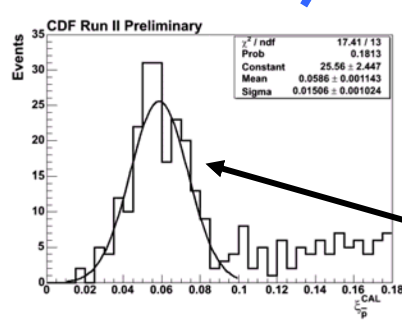
⇨ Pomeron evolves as proton

ξ: RPS vs calorimeter





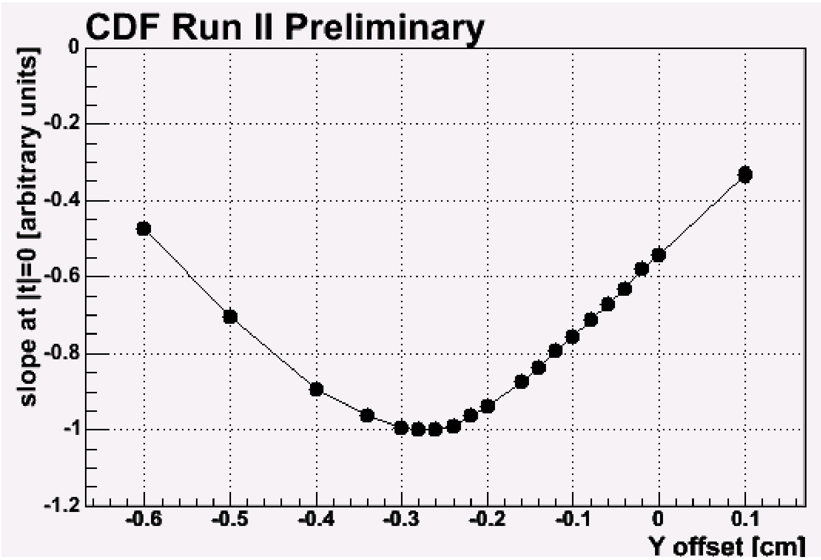




ξ^{cal} distribution for slice of ξ^{RPS}

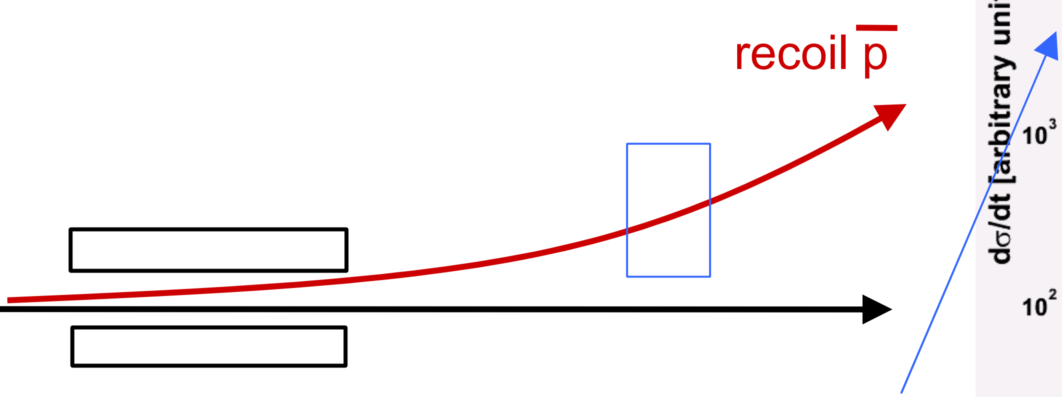
σ / mean ~ 30%

RPS dynamic alignment

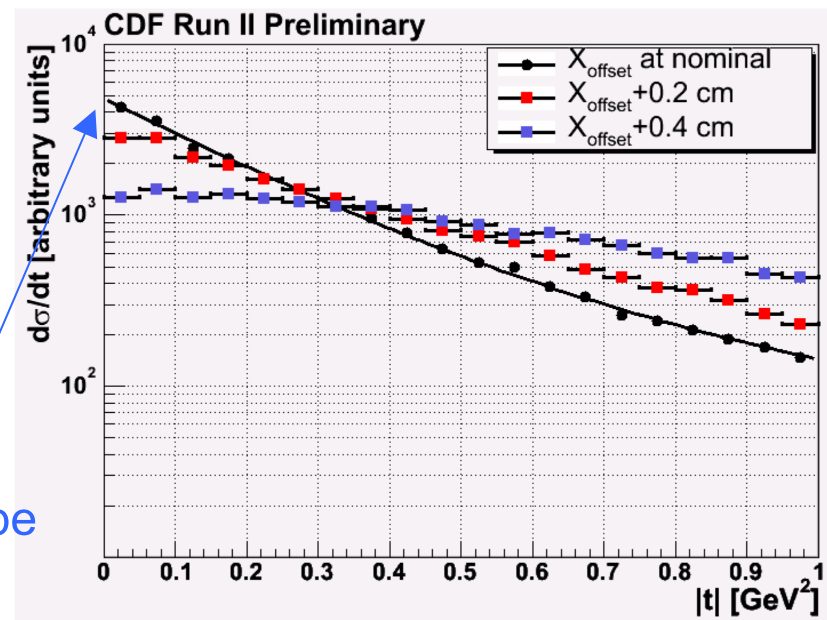


maximize the |t|-slope
(normalized to max slope)

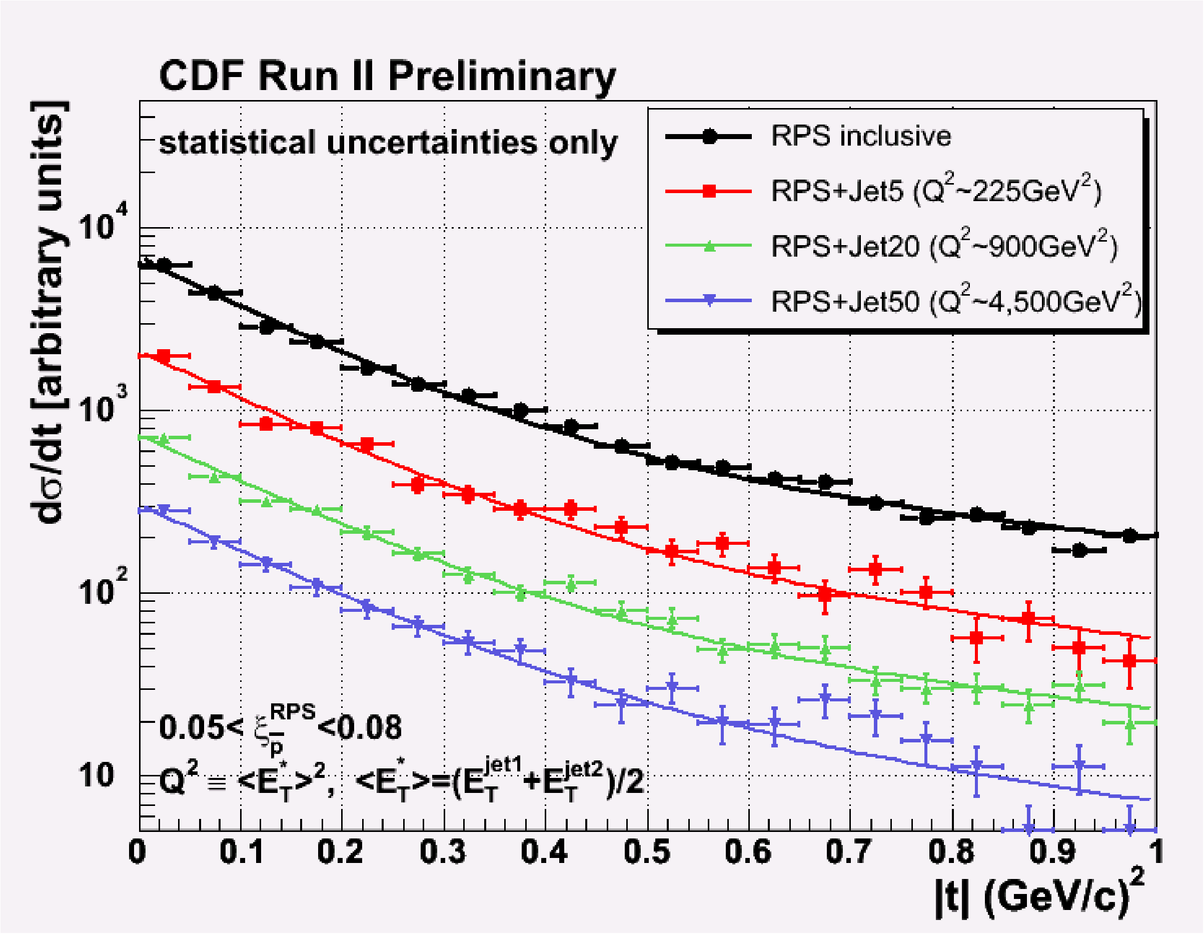
⇨determine X and Y offsets



maximize the slope



t-distribution

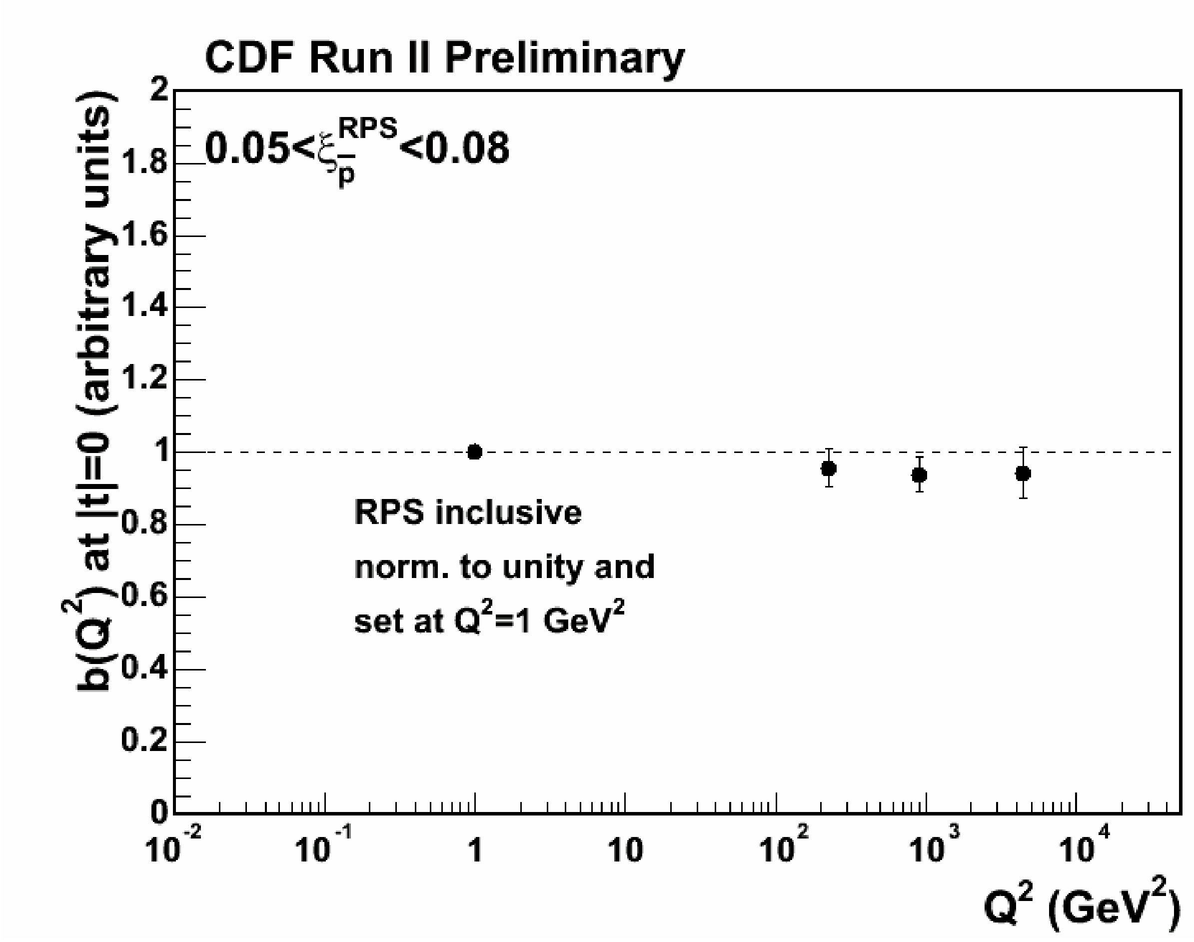


fit t-distribution to a double exponential using:

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

⇨no diffraction 'dips' observed for |t|<1

t-slope vs Q^2



Soft and hard diffractive events have the same slope

⇨ same slope over the region 0< Q^2 <4,500 GeV^2

t-distribution

1) measure absolute value:
   - ➢ systematics under evaluation

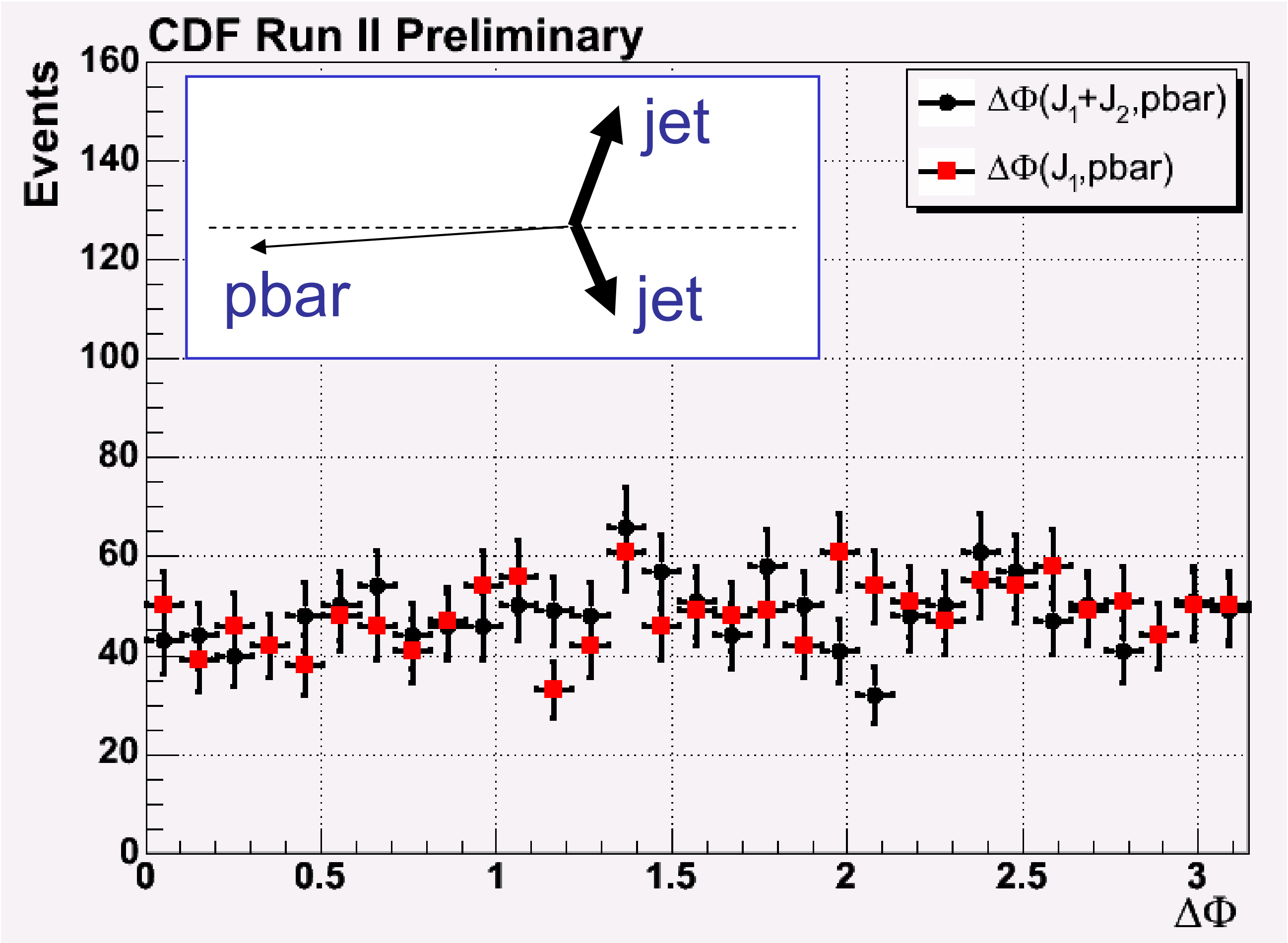
2) diffraction minima:
   - ➢ no minima for |t|<1
   - ➢ extend range at larger |t| values (soon)

3) Q^2 dependence:
   - ➢ slope at t=0 is independent of Q^2

low luminosity run data currently being analyzed

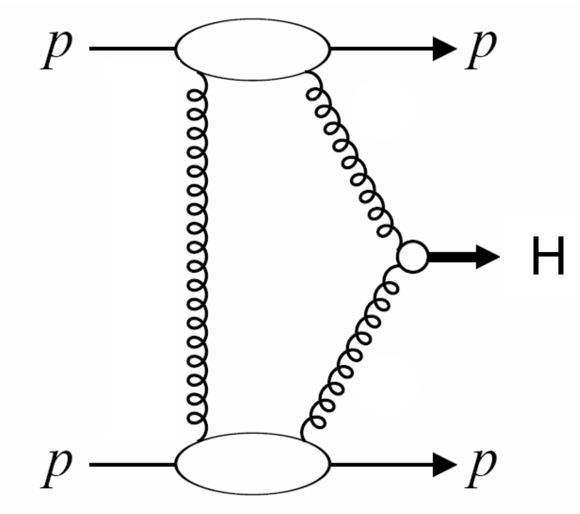
⇨ more results soon

Δϕ (pbar-dijets)



⇨ no apparent Δϕ correlation

Exclusive Higgs



✓clean process

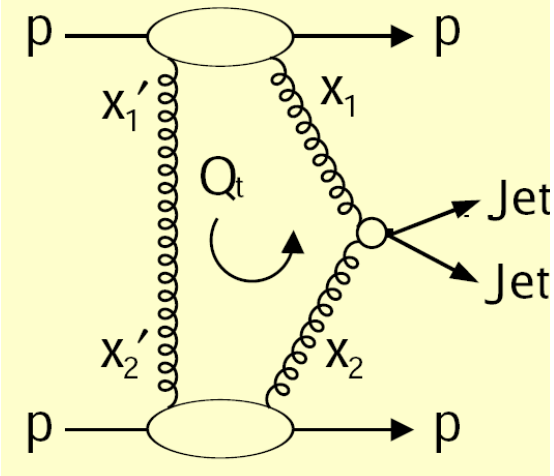
✓exclusive $b\bar{b}$ suppressed

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

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)

Attractive Higgs discovery channel at the LHC

see more in the "Diffractive Higgs and LHC" session!

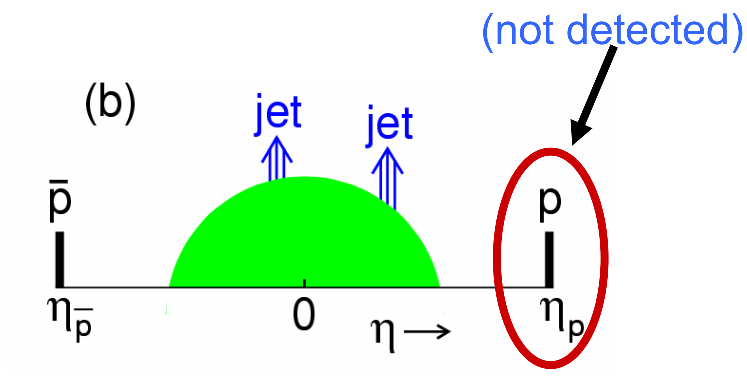


⇨much larger cross section

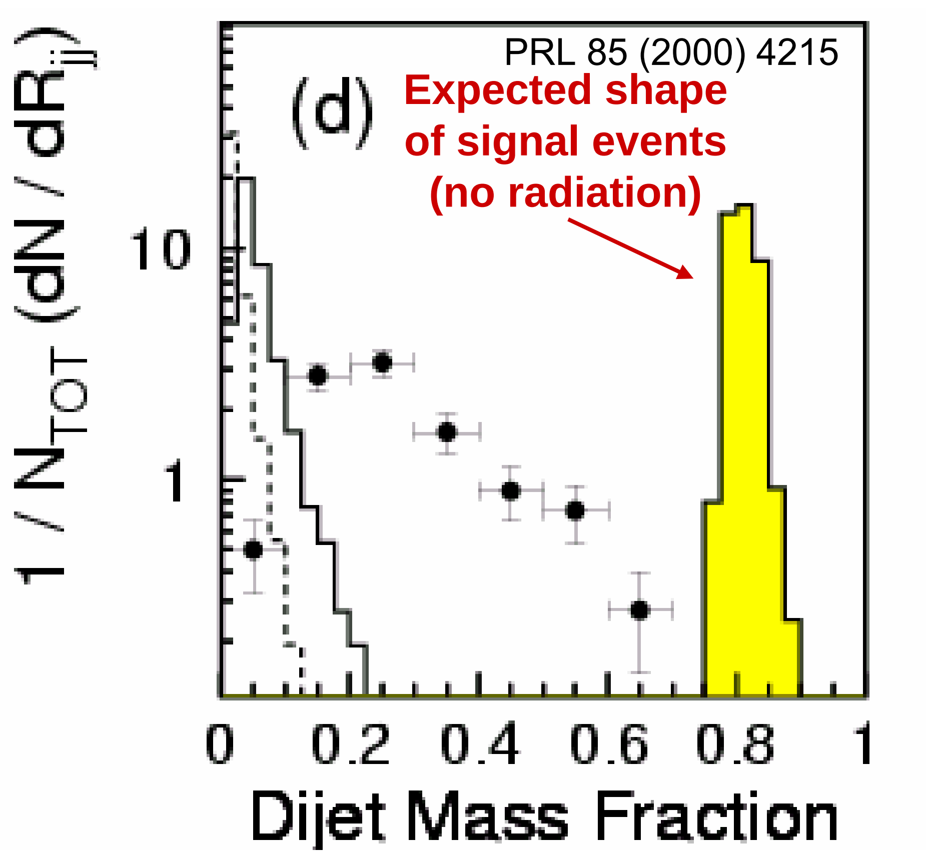
Goal:

- measure exclusive production (if it exists)
- calibrate Higgs predictions at LHC
  - ⇨ use it as "standard candle"

Exclusive Dijets in Run I



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

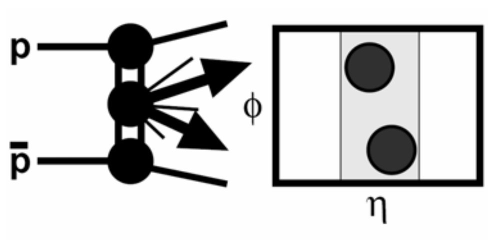


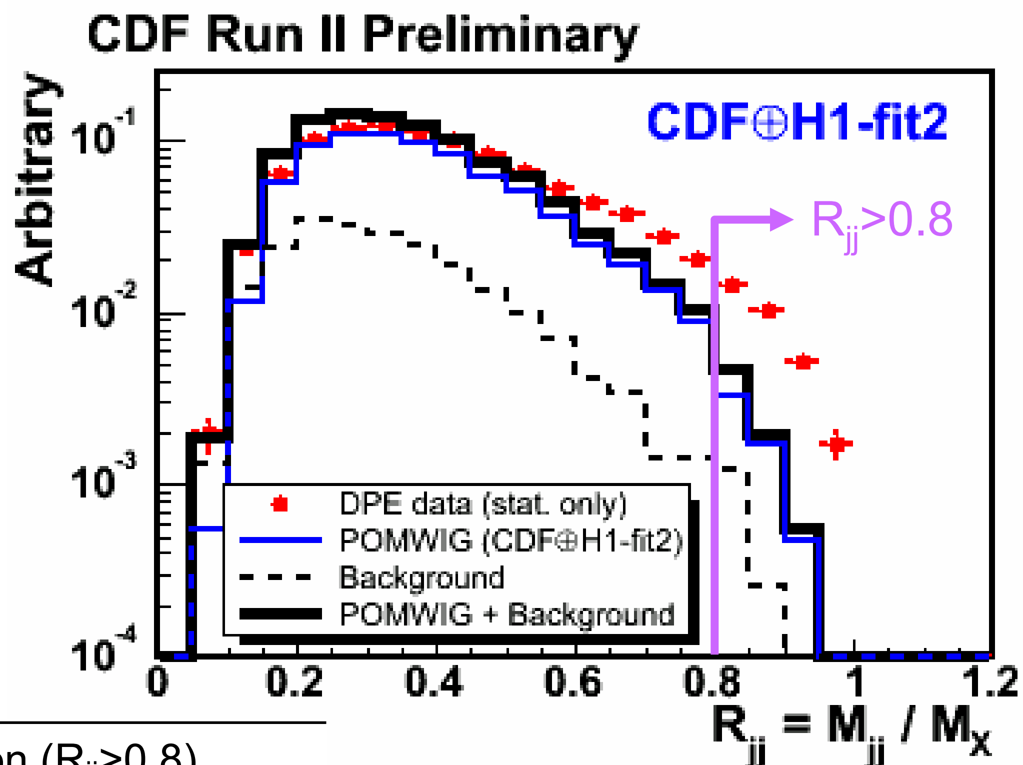
Exclusive dijet limit:
Run I: PRL 85 (2000) 4215

⇨ σ_{jj} (excl.) < 3.7 nb (95% CL)

theory predicts ~1 nb (Run I kinematics)

Dijet Mass Fraction





rate falls smoothly as $R_{jj} \rightarrow 1$
excess of event at large R_{jj}

⇨ exclusive signal?

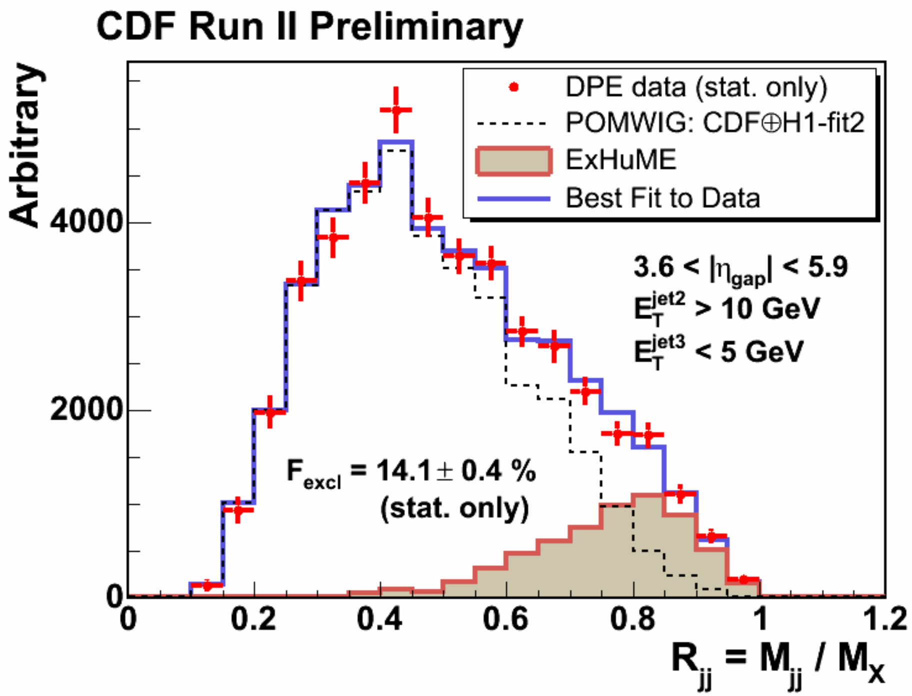
previous result:

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

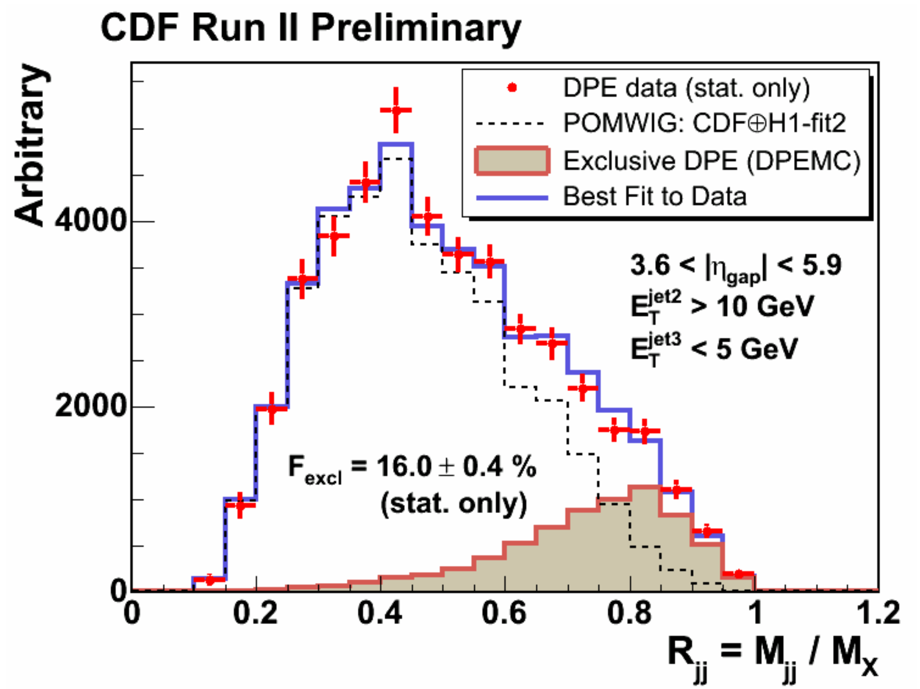
Khoze, Kaidalov, Martin, Ryskin, Stirling – hep/ph-0507040
~ 20-30 pb (factor of 2 uncertainty)

⇨need to estimate the background in the signal region

Comparison Data/MC



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



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

⇨ excess of events at high R_{jj} is well described by the exclusive dijet production models
(different assumptions do not change results)

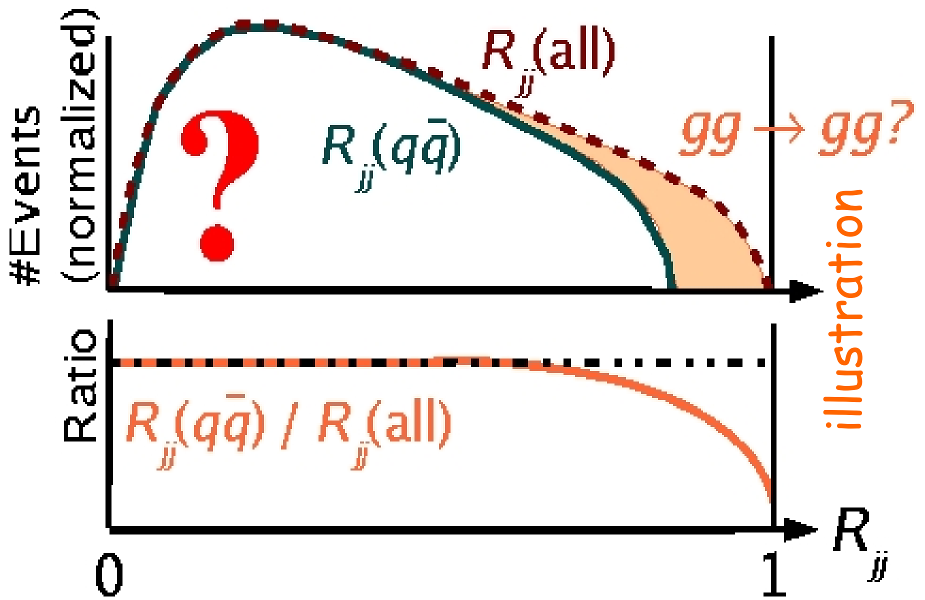
Heavy flavor exclusive dijets

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

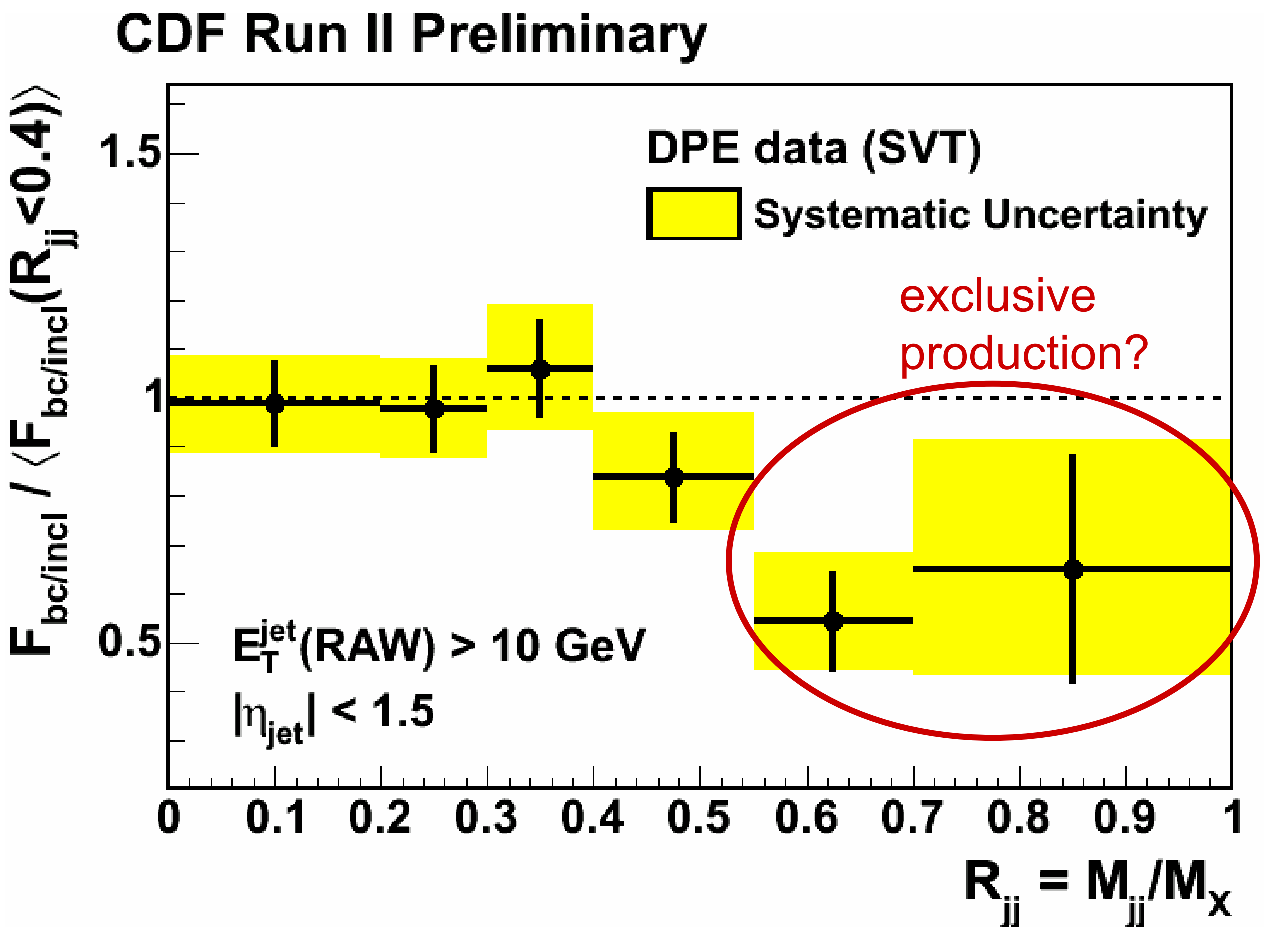
Pros: -many systematics cancel out
-good HF quarks id
-small g mistag O(1%)

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



⇨ use b-quark jets

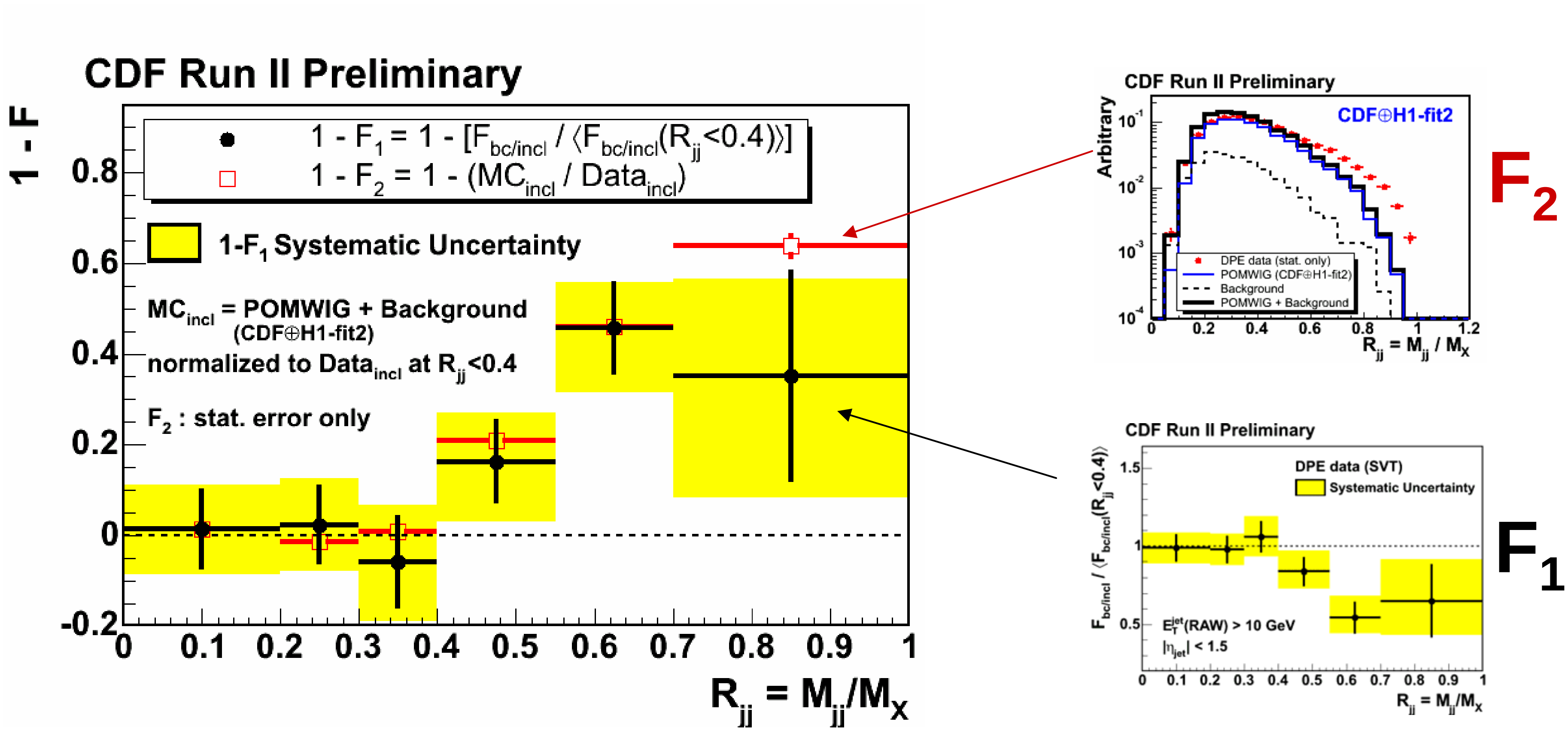
b-tagged jet fraction



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

⇨ ratio decreases at high Rjj

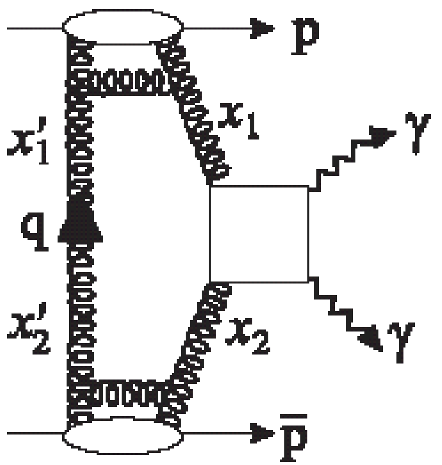
Exclusive dijet production



comparison of inclusive jet rate and heavy flavor

⇨ consistent with exclusive dijets

Exclusive $\gamma\gamma$ production



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

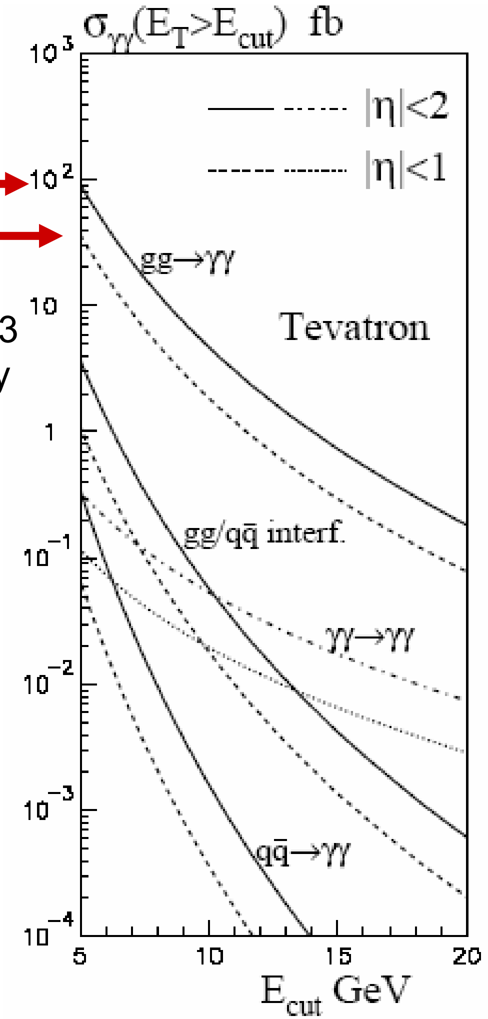
~40 events/fb^{-1} with $p_T(\gamma)$>5 GeV/c, $|\eta|$<1.0

the effective luminosity must be considered since additional interactions "populate" gaps

~100 fb

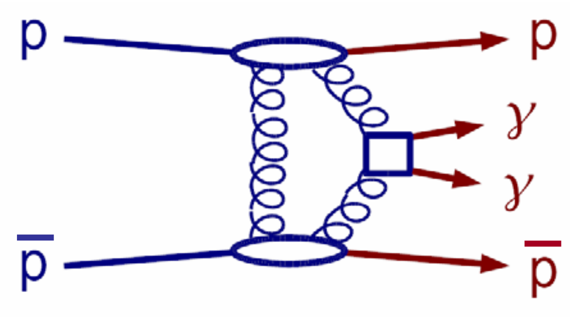
~40 fb

factor of 2-3 uncertainty

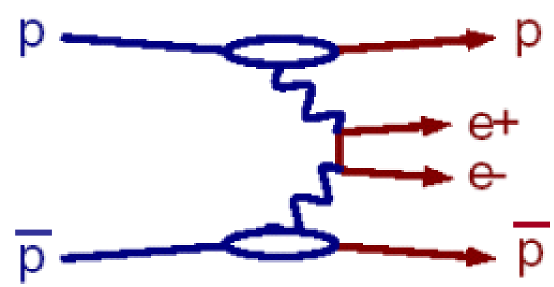


Khoze, Kaidalov, Martin, Ryskin, Stirling, hep-ph/0507040

Exclusive ee/$\gamma\gamma$ search



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



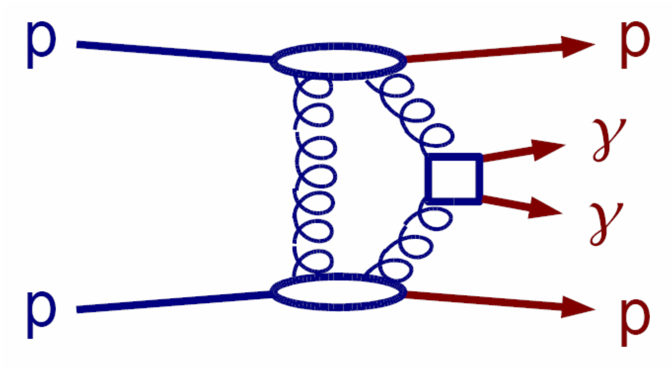
QED process: cross-check to exclusive $\gamma\gamma$

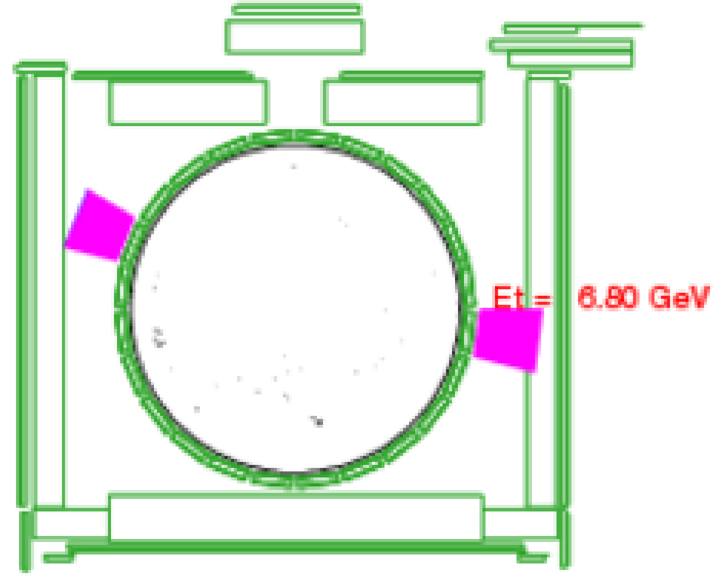
- ✓do not detect (anti)proton
- ✓require 2 EM showers (E_T>5 GeV, $|\eta|<2$)
- ✓veto all calorimetry and BSCs except 2 EM showers
- ✓L~530 pb^{-1} delivered ($L_{effective}$=46 pb^{-1})

⇨19 events have 2 EM showers +"nothing"

caveat: "nothing" above threshold

Exclusive $\gamma\gamma$ search

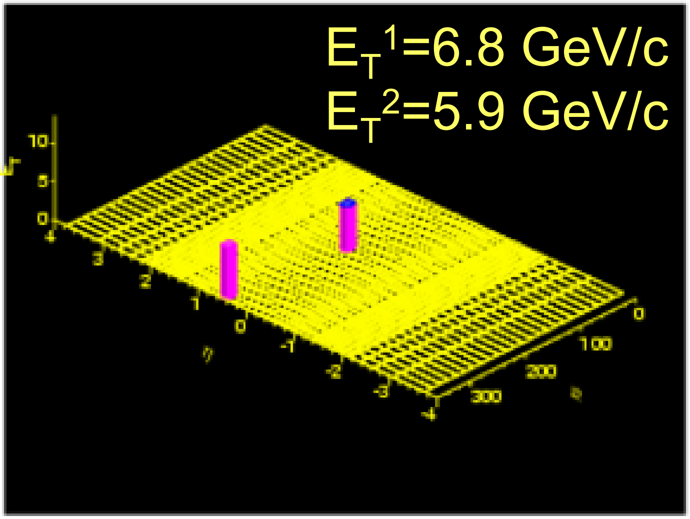




⇨ 3 candidate events found

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

$$\sigma_{MEASURED} = 0.14\ ^{+0.14}_{-0.04}\ (stat) \pm 0.03\ (sys)\ pb$$

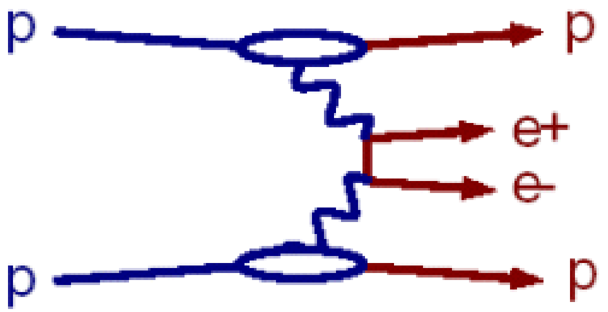


good agreement with KMR:

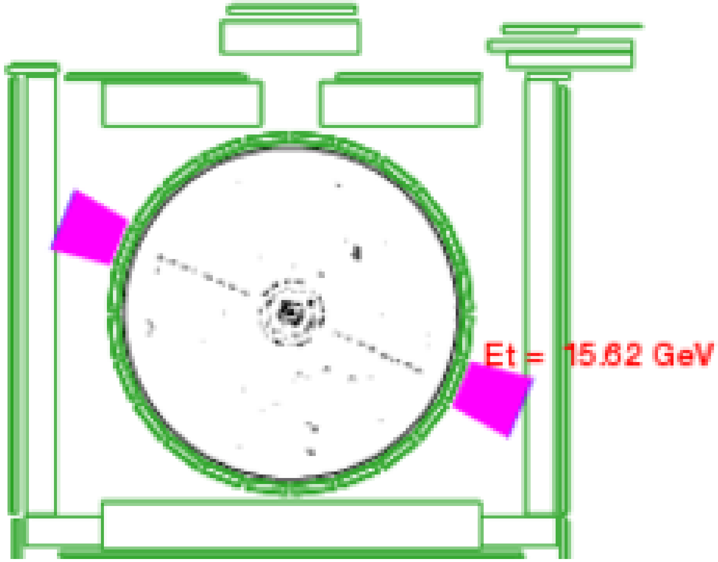
$$\sigma_{KMR} = 0.04 \pm (\times 2 - 3)\ pb$$

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

Exclusive *ee* search



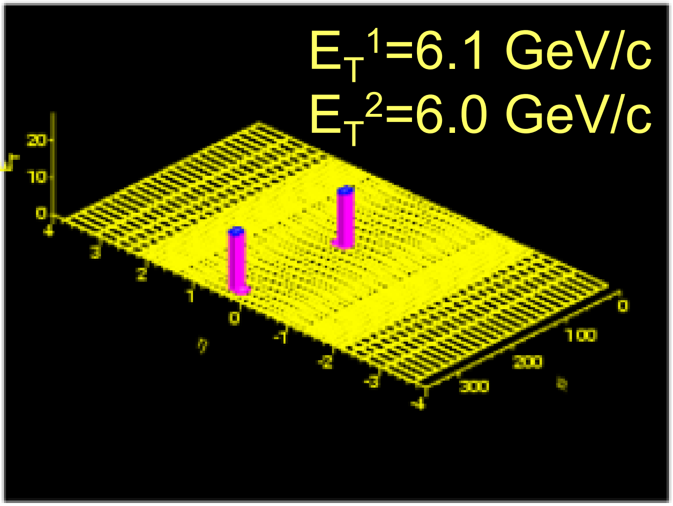
control sample for $\gamma\gamma$ search



⇨16 candidate events found

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

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



good agreement with LPAIR:

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

Summary

diffractive structure function:

✓ confirm and extend Run I results
✓ Q^2 dependence pomeron evolves like proton

t-distribution of diffractive events:

✓ slope at t=0 is independent of Q^2
✓ measure absolute value and larger |t| ⇨ soon

observed exclusive production:

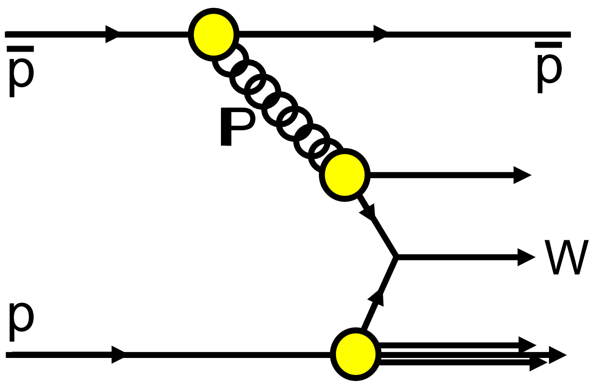
✓ events consistent with exclusive dijet production
✓ heavy flavor jets suppressed at large R_{jj}
✓ first indication of exclusive $\gamma\gamma$ events

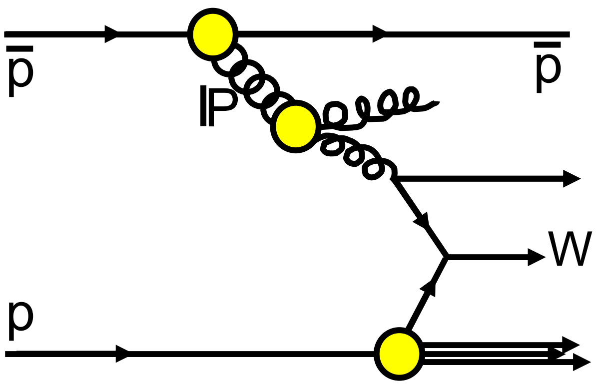
The End

Diffractive W

Study diffractive W-boson production, and the partonic structure of the Pomeron by a comparison to the diffractive di-jet production

- Run I: 8,246 W(eν) events - PRL 78 (1997), 2698
- R_W (SD/ND)= 1.15 ± 0.51(stat) ± 0.20(syst) %





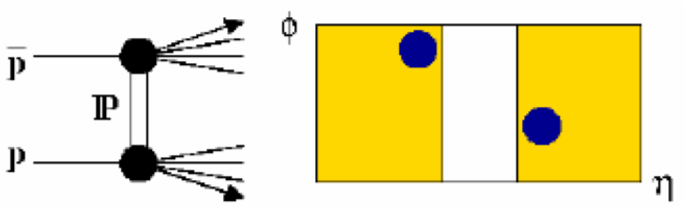
hard-quark dominated Pomeron

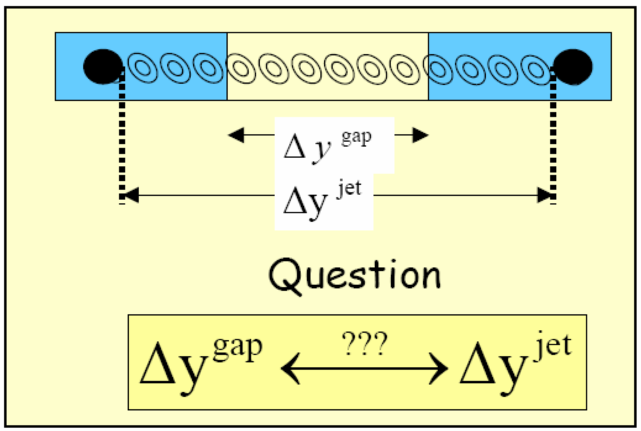
or

hard-gluon dominated Pomeron
(rate lower by α_s)

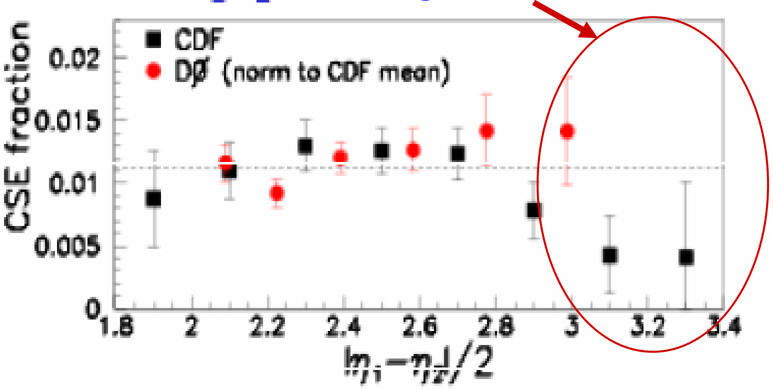
Gap between jets

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





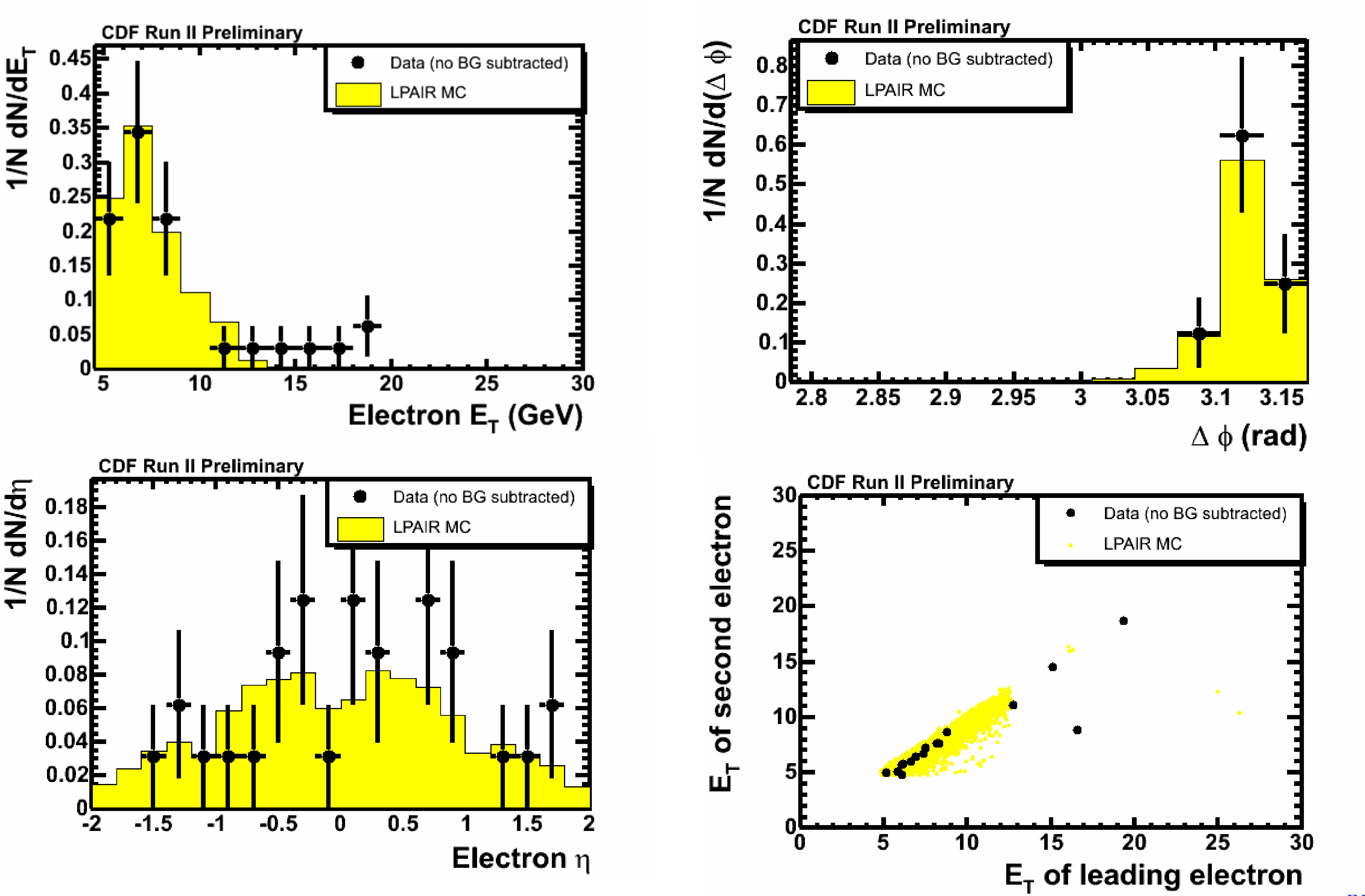
extend range in Run II



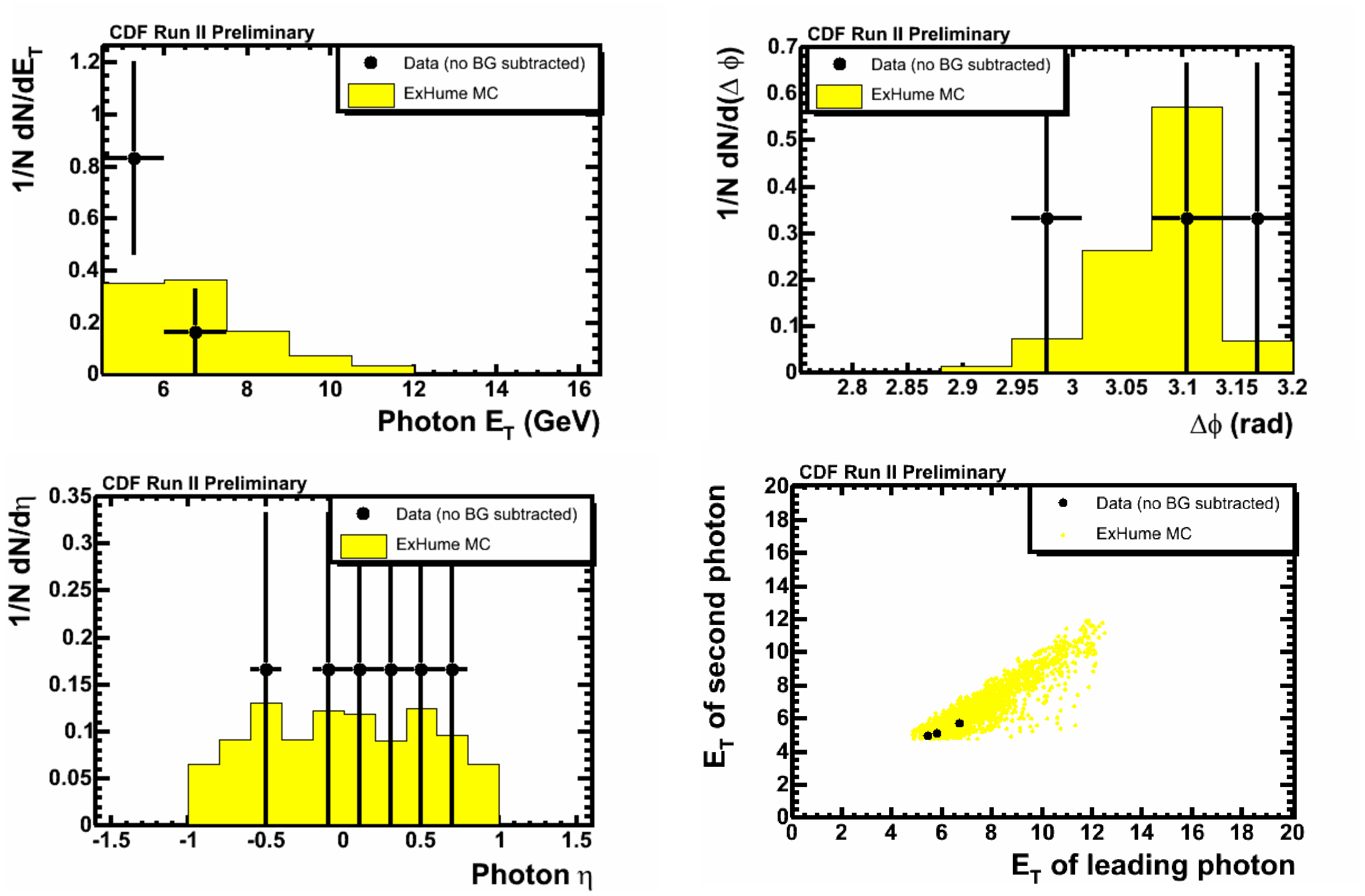
Is the diffractive exchange BFKL-like or simply a color rearrangement?

Work in progress: low luminosity run data being analyzed

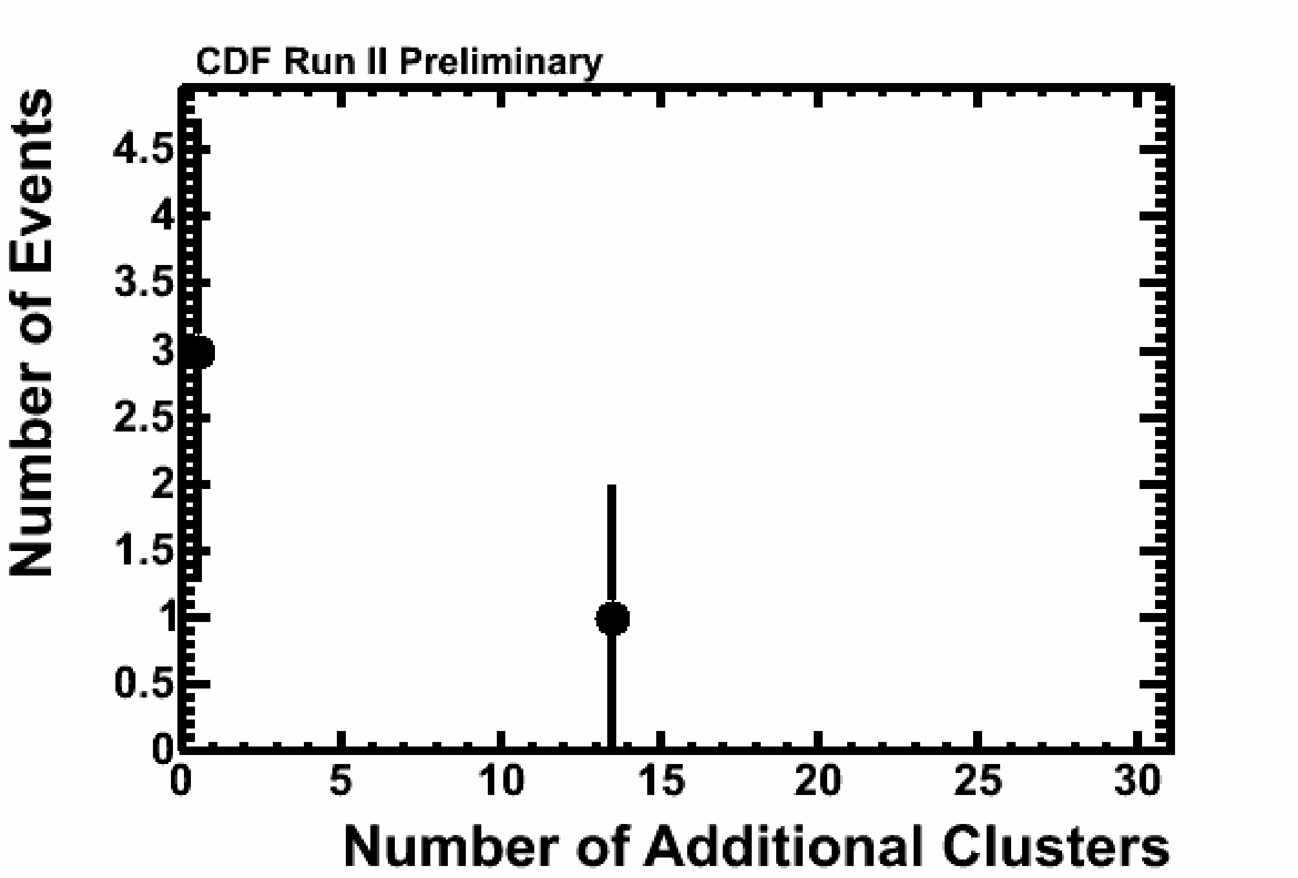
ee candidate events



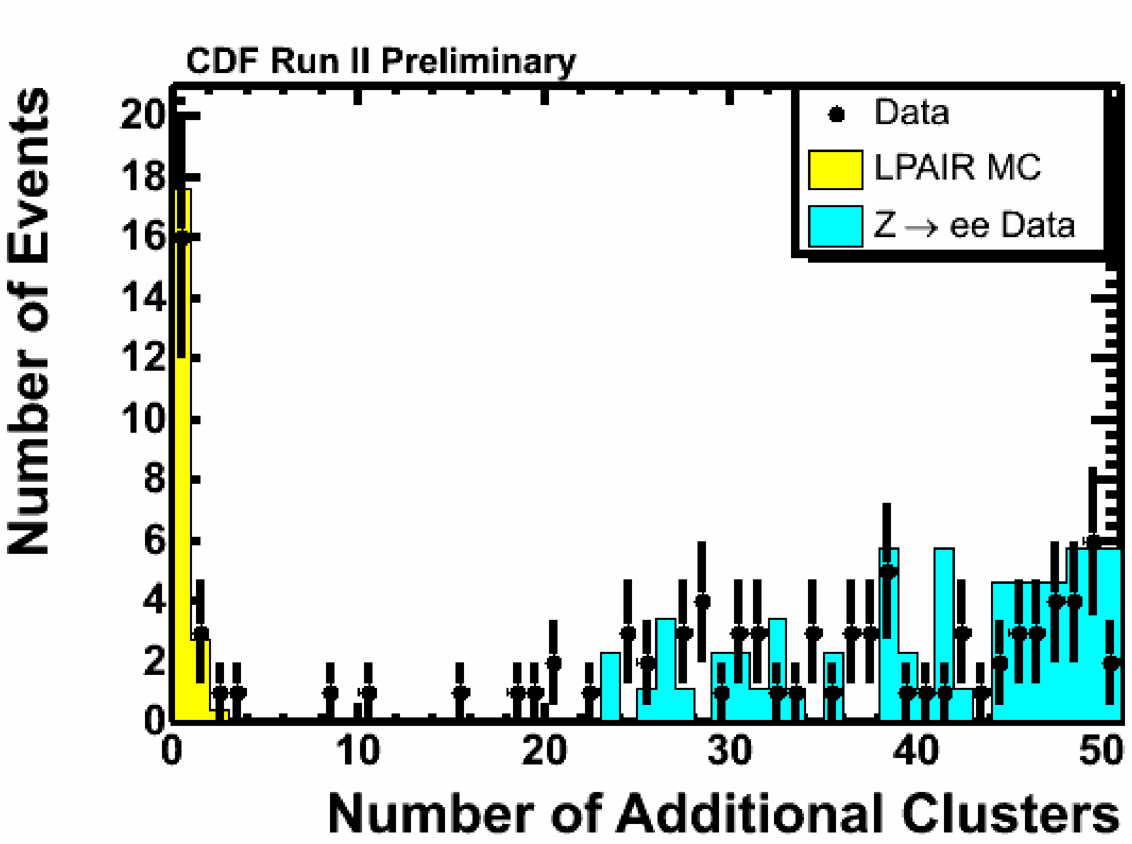
γγ candidate events



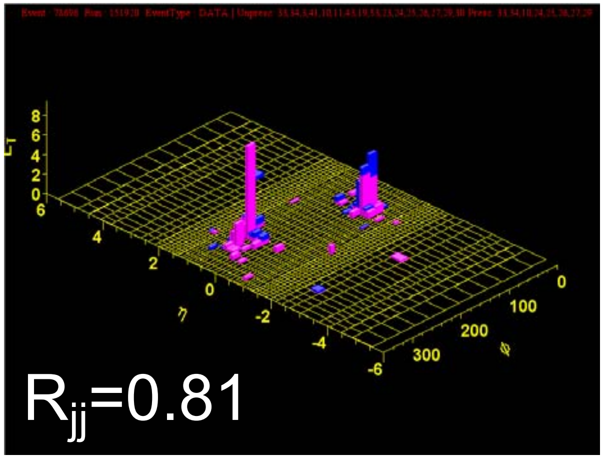
γγ: event multiplicity

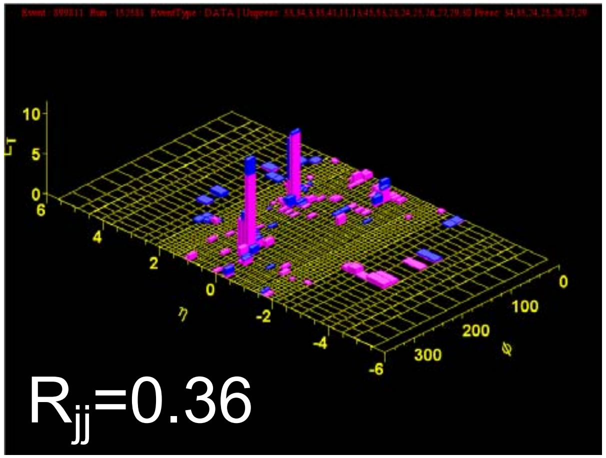


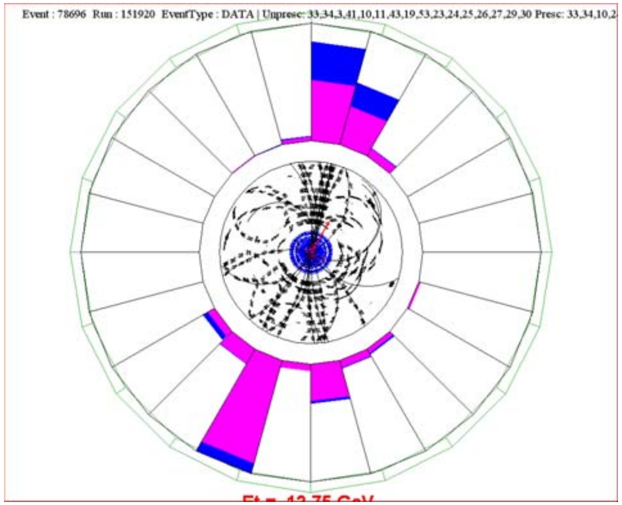
ee: event multiplicity

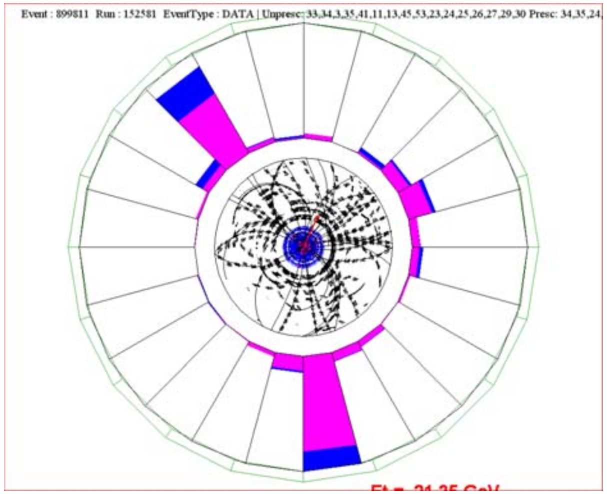


Exclusive Dijet Events ?

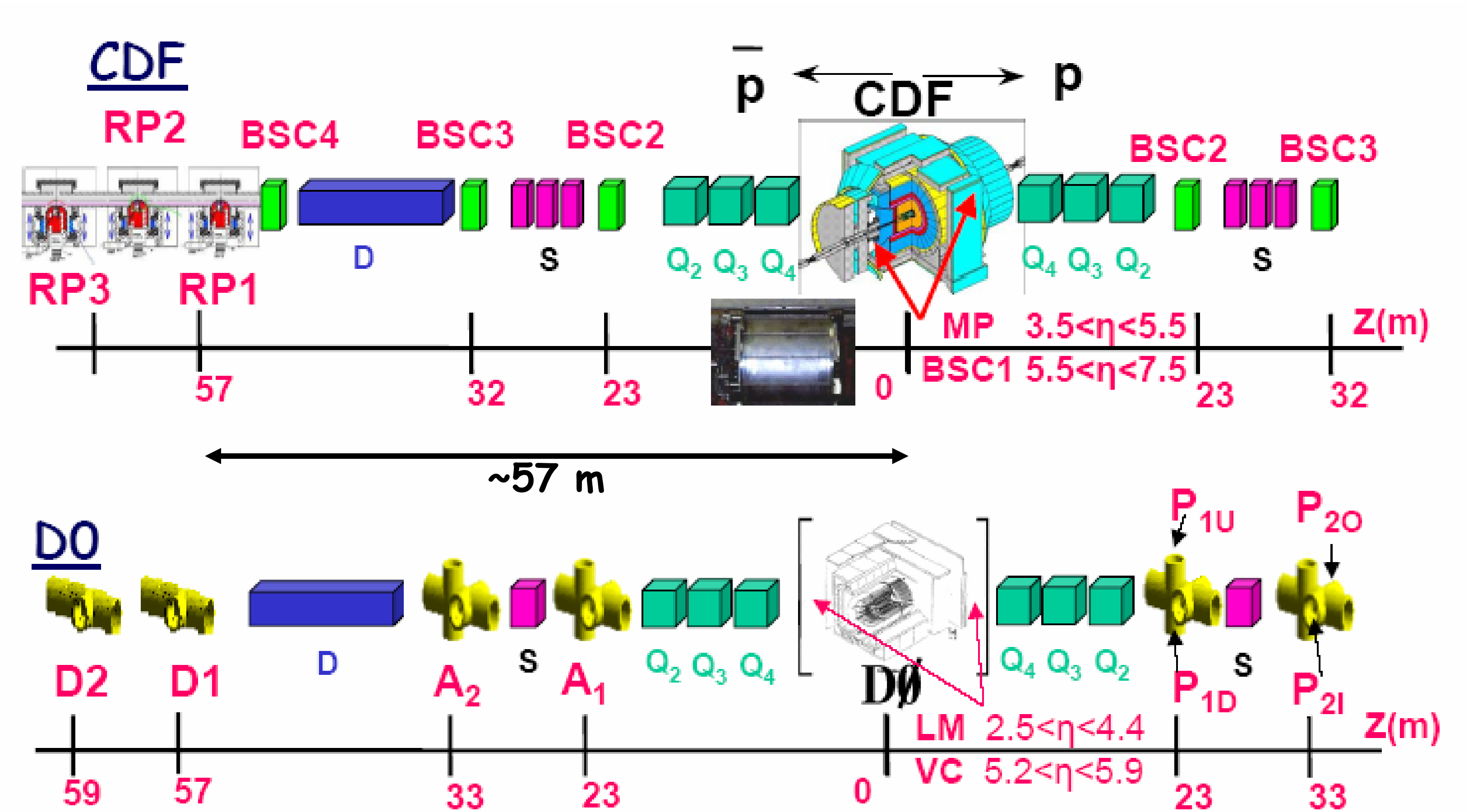








Run II detectors



RPS tracking