Diffraction at the Tevatron

Andy Pilkington
The University of Manchester

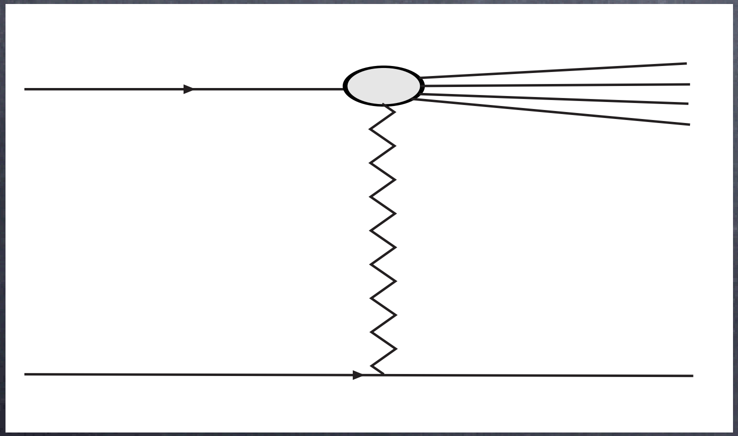
Talk given at YETI 08, IPPP, Durham.

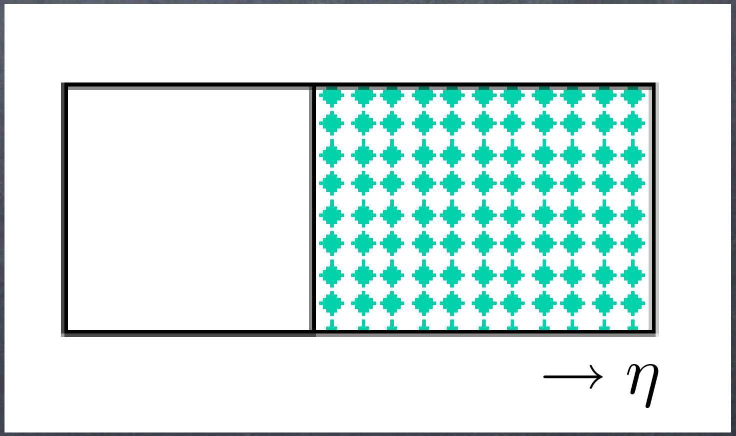
Overview

- Introduction to diffractive physics.
- Partonic nature of the diffractive exchange
- Exclusive diffraction
- Gaps between jets
- Conclusions

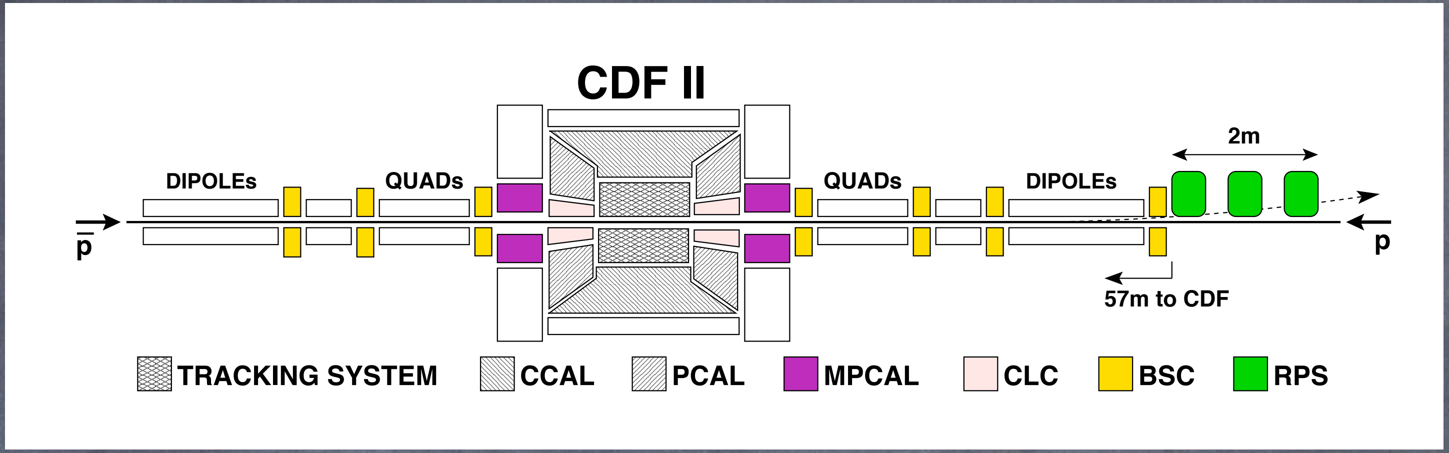
Diffraction

- Diffractive events are characterised by a large rapidity gap, i.e a large region in the detector devoid of particle activity.
- Diffractive events occur due to a t-channel exchange of an object that is colour singlet and has the quantum numbers of the vacuum (the Pomeron).
- e.g. elastic scattering; single diffractive dissociation (below).



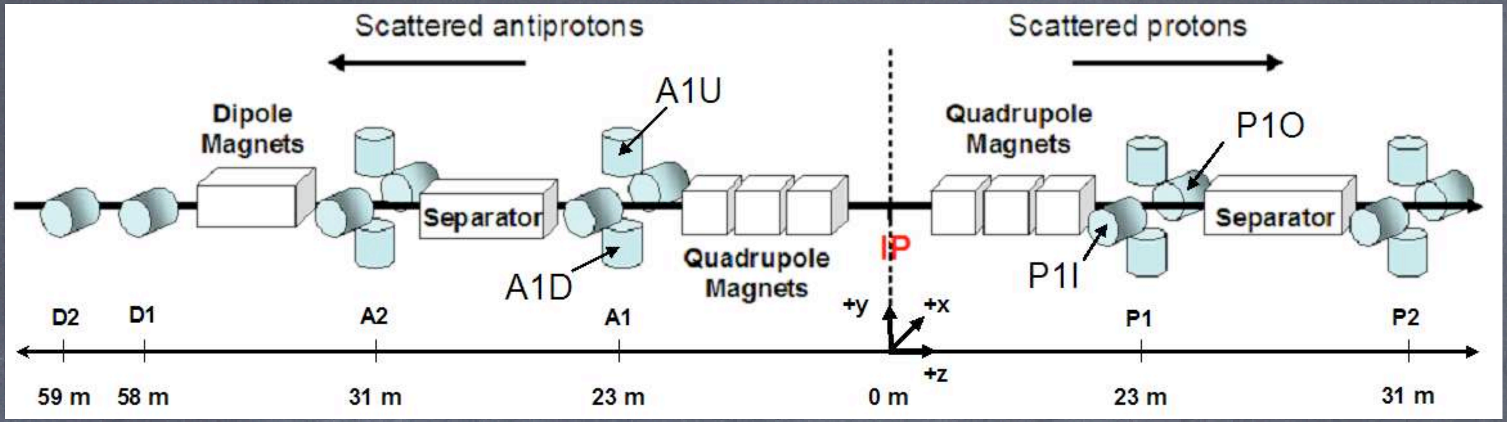


Diffraction at CDF



- Typical set-up for a diffractive experiment.
- Search for rapidity gaps in:
  - Calorimeters (PCAL, MPCAL) - i.e. little energy deposited.
  - Scintillation counters (BSC) - i.e. no hits.
- Forward proton tagger to tag/measure outgoing anti-proton (RPS).

Diffraction at D0



- Forward proton detectors fully installed in Jan 2004 on both sides of the IP.
- Trigger took another 18 months to get working - built from scratch.

Partonic Nature of the Diffractive Exchange

Diffraction + Hard Scatter

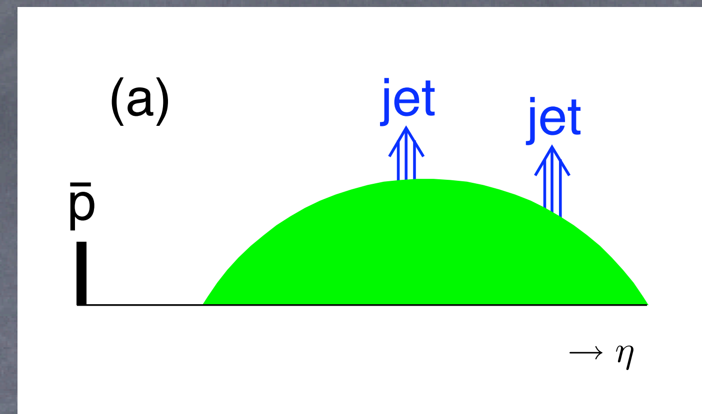
JET STRUCTURE IN HIGH MASS DIFFRACTIVE SCATTERING

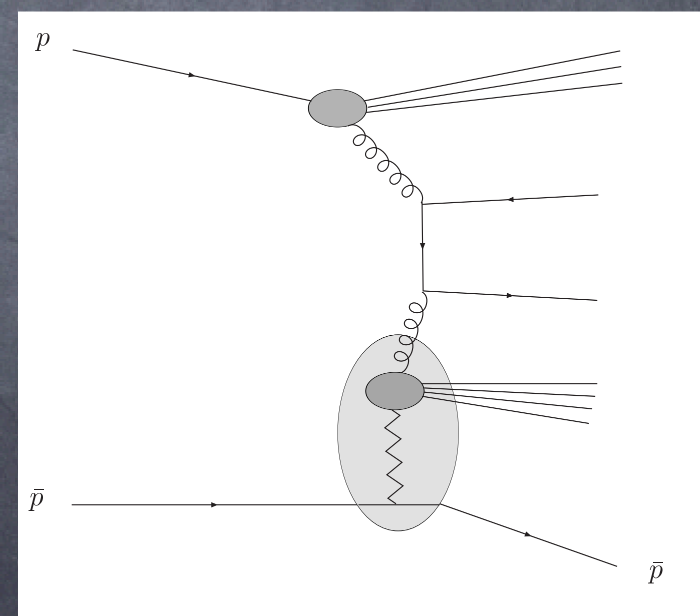
G. Ingelman
CERN, CH-1211 Geneva 23, Switzerland

P.E. Schlein
University of California *), Los Angeles, CA 90024, USA

A B S T R A C T

We suggest that high-p_t jets may emerge from diffractively produced high mass states. Experimental measurements of such high-p_t structure would give new and valuable insight about the nature of the exchanged pomeron, or pomeron-like object. With the assumption of an effective gluon distribution for the pomeron structure, we estimate the cross-section for the process $\bar{p} + p \to \bar{p} + X$, where X contains two high-p_t jets. Observable rates are found at SPS and Fermilab collider energies.





Confirmed by UA8 at the $Sp\bar{p}S$.

Diffractive PDFs

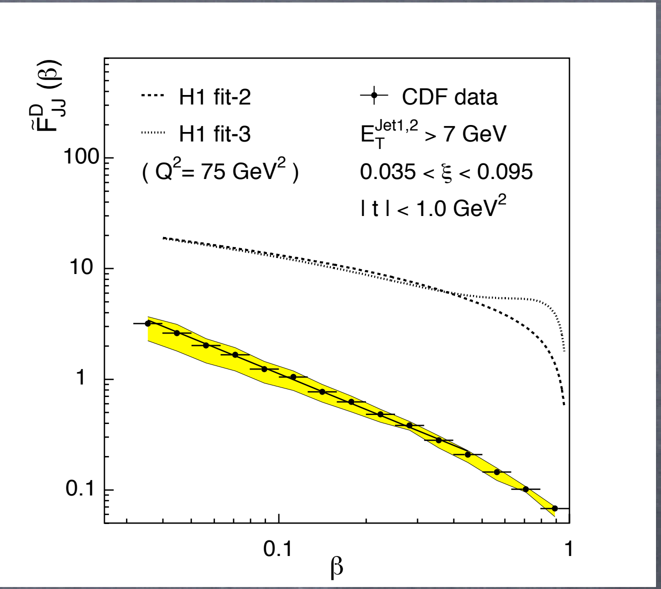
- Di-jet production in single diffraction can be written in a way consistent with QCD factorisation using a diffractive PDF:

$$d\sigma_{\bar{p}p\to\bar{p}JJX} = \left[\sum_{i,k} \int dx_1 g_{i/p}\left(x_1, Q^2\right) \int d\beta\, g_{k/\bar{p}}\left(\xi, t, \beta, Q^2\right)\right] d\sigma_{ik\to JJ}$$

- The $\mathbf{g_{k/\bar{p}}\left(\xi, t, \beta, Q^2\right)}$ is the diffractive PDF.
    - ξ is the longitudinal momentum loss of the anti-proton
    - t is the momentum transfer
    - β is the fraction of pomeron momentum that enters the hard scatter

Factorisation breaking at CDF

- dPDFs measured at H1 and ZEUS in diffractive DIS.
- Predicted SD di-jet structure function at Tevatron does not match measured structure function at CDF.
- Indicates a breakdown of QCD factorisation.



- CDF also performed successful searches for single diffractive production of W, b-quark and J/psi.

PROCESS	W	J/Psi	di-jets	b-quark
RATIO (SD/ND) %	1.51 ± 0.71	1.45 ± 0.24	0.75 ± 0.14	0.62 ± 0.35

- But, the SD/ND ratios were much smaller than the ratios predicted from dPDFs measured at HERA (factor of 3-10).

Soft-survival probability

- The observed cross section, for diffractive processes, is given by

$$\sigma_{\mathbf{obs}} = \mathbf{S^2}\,\sigma_{\mathbf{fact}}$$

- The soft-survival, S^2, is the probability that, during the proton-antiproton interaction, the are no additional scatters between spectator partons in the colliding hadrons.

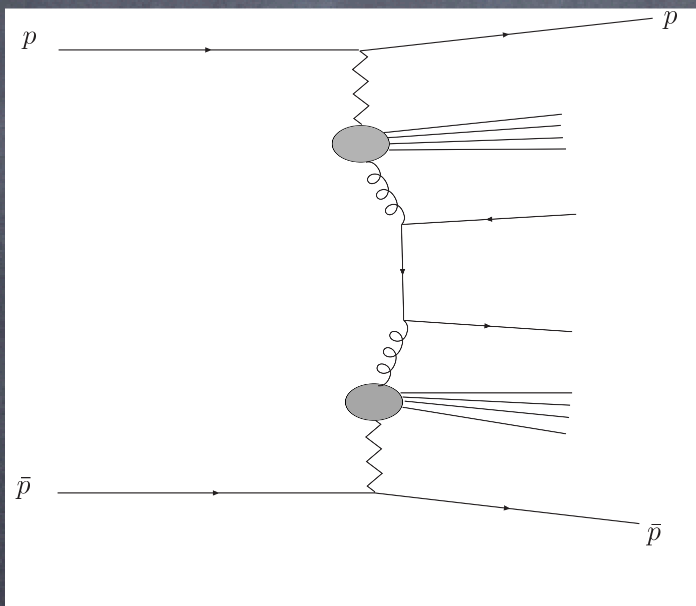
- Hence the ratio of SD to ND events will be given by

$$R_{ND}^{SD} = \frac{S^2 \sigma_{fact}^{SD}}{\sigma_{fact}^{ND}}$$

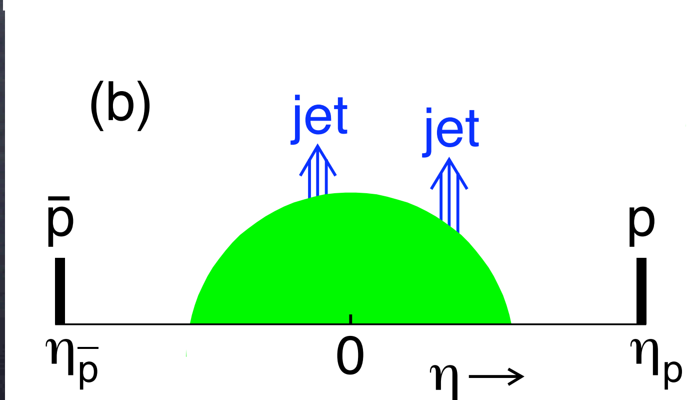
- The soft survival probability is dependent on the centre-of-mass energy of the collision and must be measured. S^2 is approx 0.1 at the Tevatron.

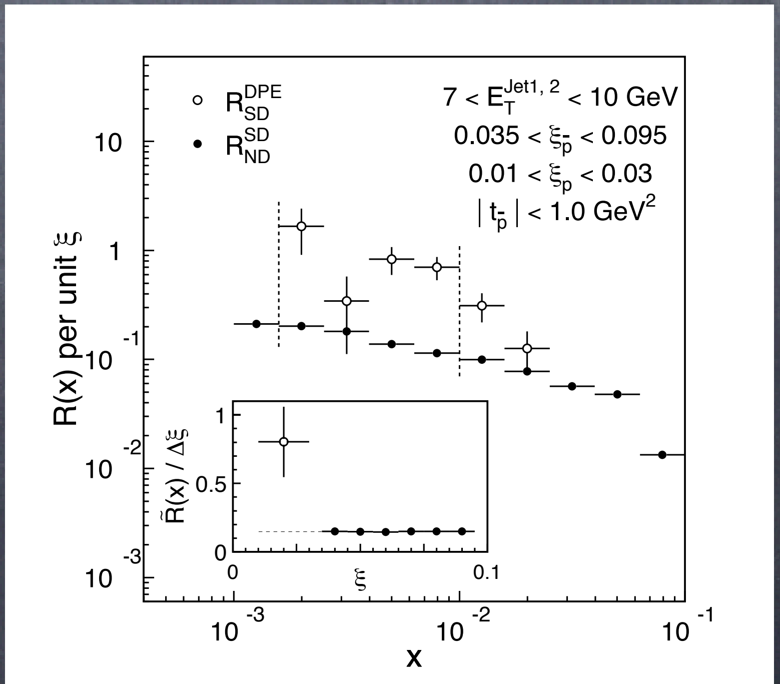
DPE di-jet observation at CDF

In double pomeron exchange (DPE), both partons entering the hard scatter come from a diffracted proton.



$$R_{SD}^{DPE} = \frac{S^2\, \sigma_{fact}^{DPE}}{S^2\, \sigma_{fact}^{SD}}$$





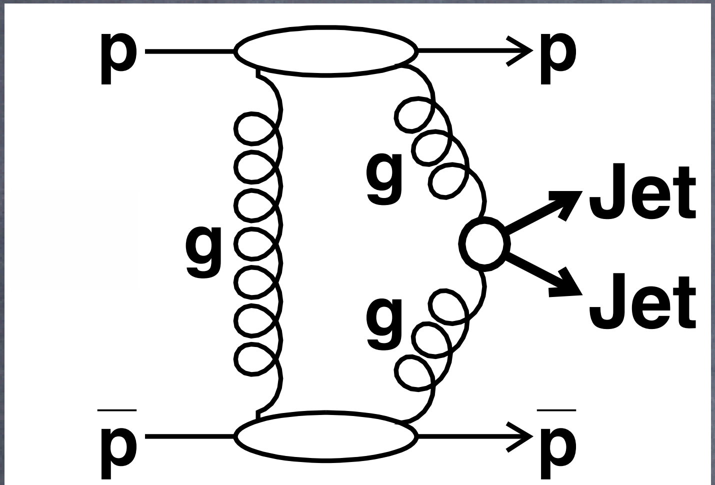
Use of diffractive PDFs at the LHC

- Investigate soft-survival dynamics at 14 TeV.
- SD/DPE production of W, Z, J/Psi, b-quark, top quark.
- Using rapidity gaps in analyses is only possible up to a luminosity of 10^{33} cm^{-2} s^{-1} due to pile-up.

An exclusive component to diffraction

Central Exclusive Production

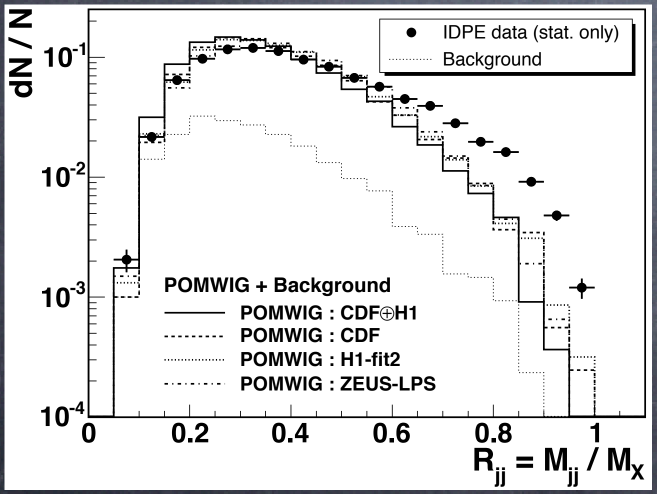
- A perturbative calculation of a hard diffractive process.

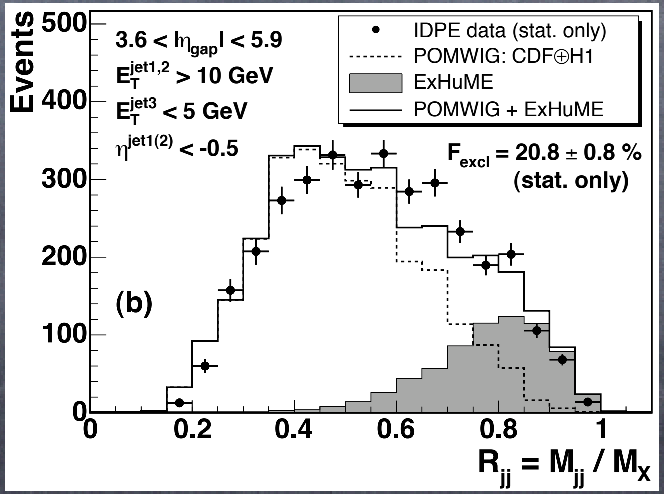


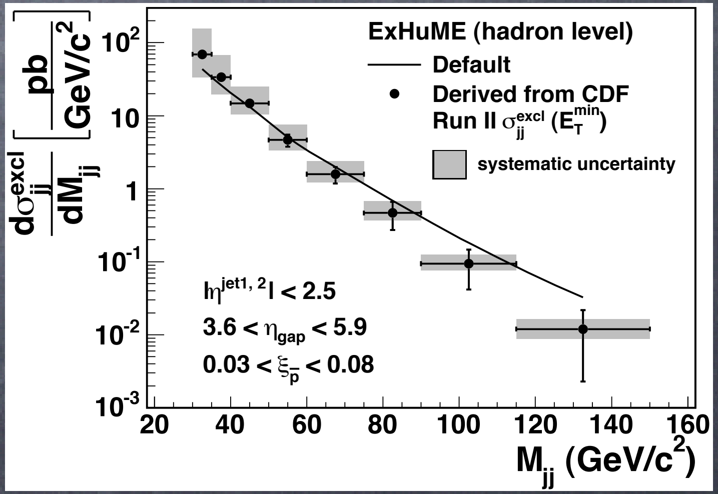
- proton and antiproton remain intact (as in DPE).
- All of energy/momentum lost by protons goes into the production of a hard scatter (no pomeron remnants).
- Could obtain mass of central system from the outgoing protons (four-momentum conservation).
- At CDF, can tag outgoing anti-proton and measure momentum, but no forward proton detector.

Observation of CEP at CDF Run II

- Created a DPE sample by tagging the outgoing antiproton and requiring a large rapidity gap on the proton side.
- Examined the ratio (Rjj) of the mass of the di-jets compared to the mass of everything in the calorimeters.



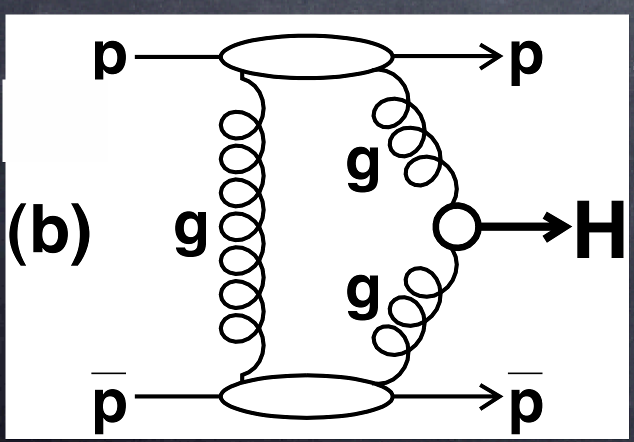


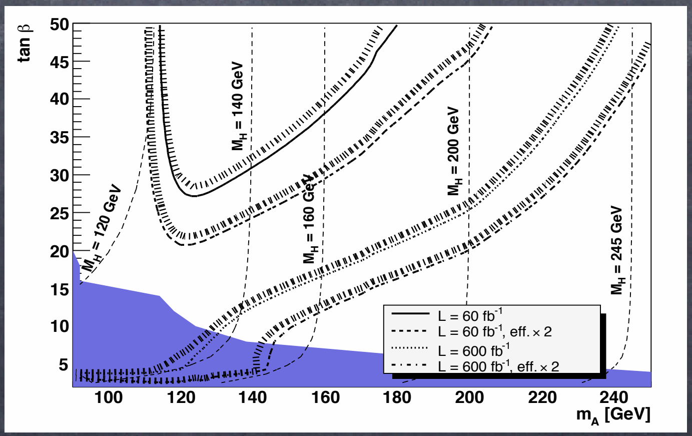


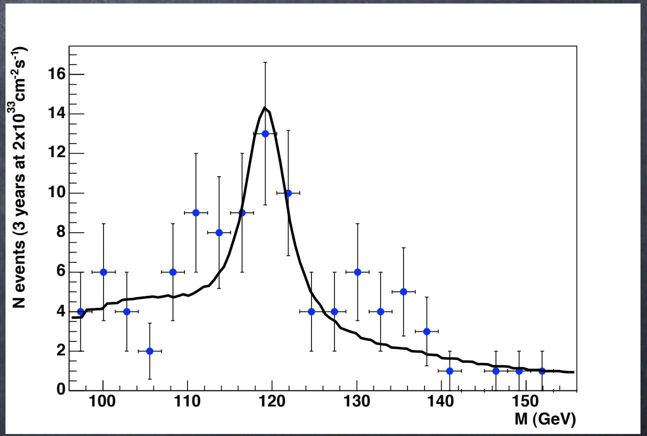
- Excess observed, which is consistent with a central exclusive component (6σ).

CEP at the LHC

- CEP offers an additional way to measure new physics, e.g Higgs boson production (SM,MSSM,NMSSM), long-lived gluinos,........
- Forward proton detectors: FP420: Proposal to upgrade CMS/ATLAS to have forward proton detectors 420m either side of the interaction point. At 220m: TOTEM detectors around CMS, RP220 upgrade proposed at ATLAS.
- Mass of centrally produced resonance measured with a resolution of approximately 2GeV. e.g H->$b\bar{b}$ in MSSM observable (below).



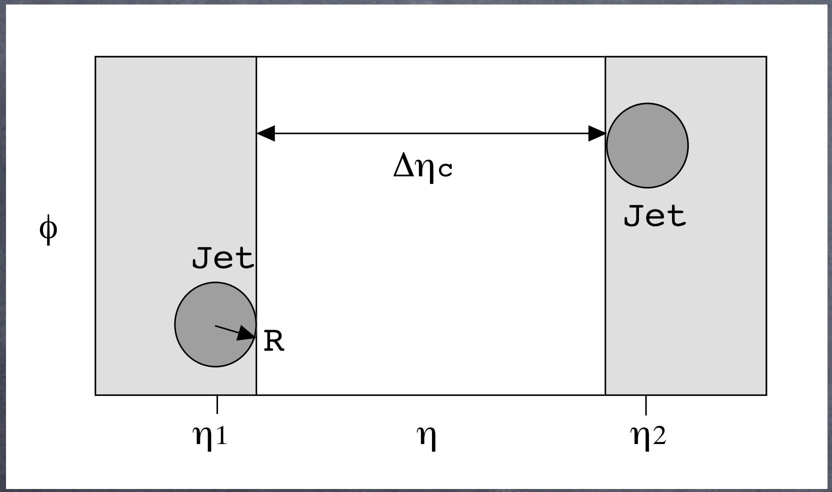




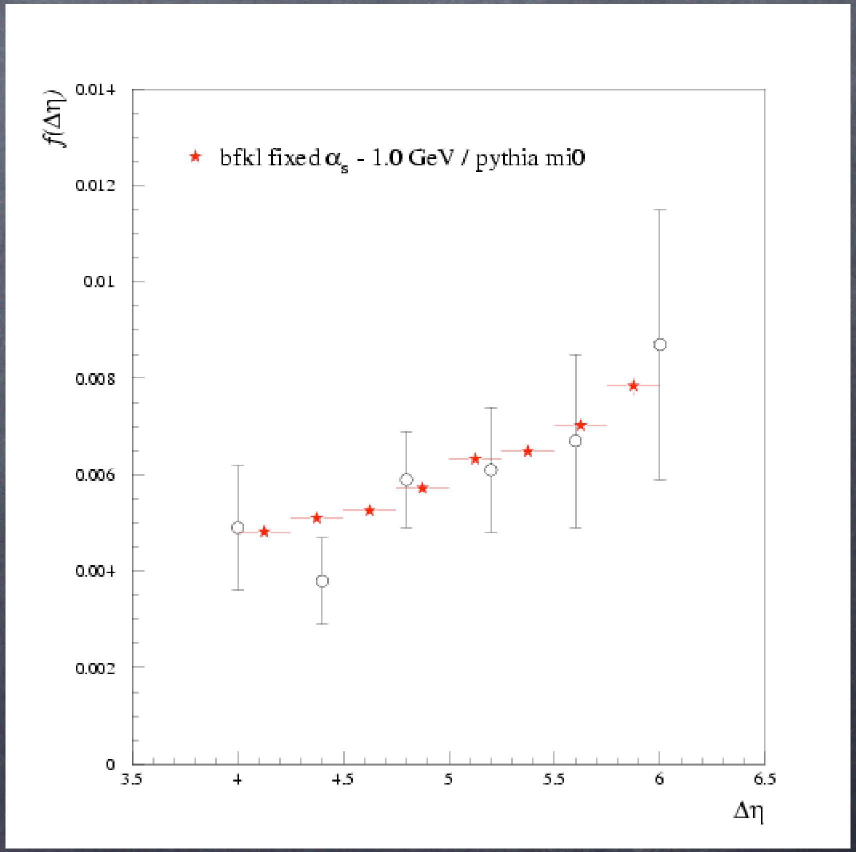
The perturbative pomeron

Gaps between jets at D0

- Hard colour singlet exchange between partons in the proton.
- Scattered partons produce high transverse energy jets - expect the BFKL perturbative pomeron (gluon ladder) as it is high-t process.



BFKL predicts a rise in (partonic) cross section as a function of $\Delta\eta$.



Gaps between jets at the LHC

- Higher centre-of-mass energy at LHC opens up more phase space for the gaps-between-jets process - measure larger gaps.
- Possibly provide further evidence for BFKL exchange.
- Another method to measure soft-survival probability.

Conclusions

- Diffraction has been extensively measured at the Tevatron and will be further measured at the LHC.
- The diffractive exchange can be described by using a partonic picture.
- Central exclusive production, recently measured by CDF, offers a unique way to discover new physics at the LHC.