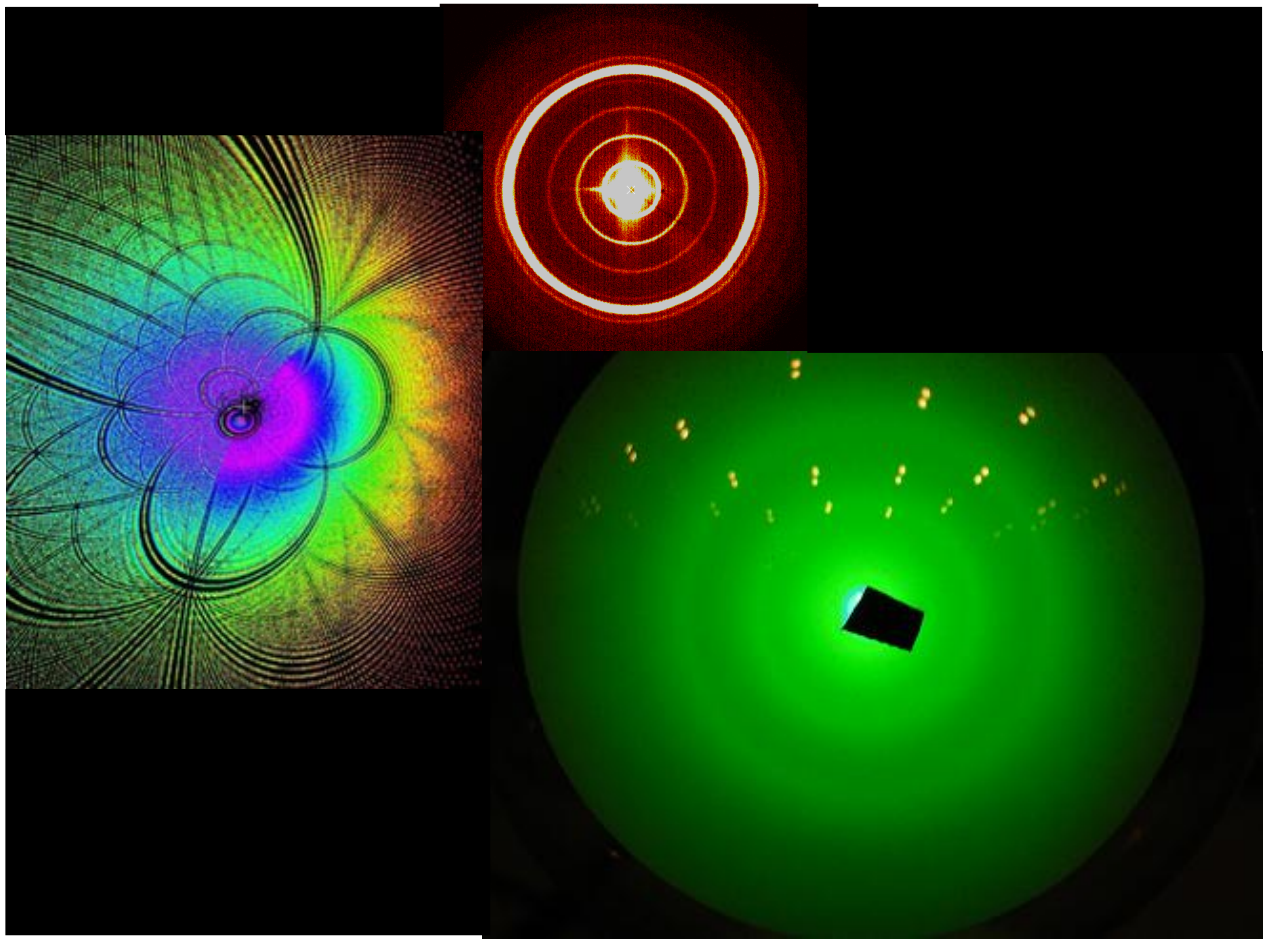
Diffractive Physics at D0



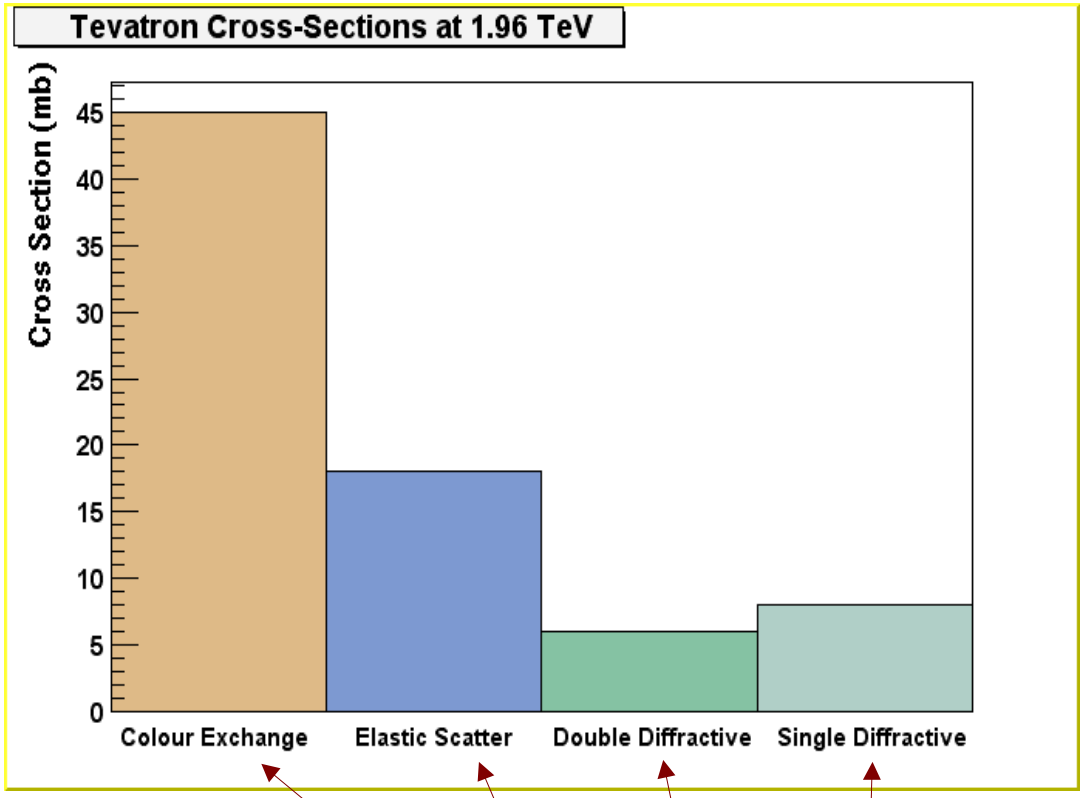
DIS 2003

Kyle Stevenson

INDIANA UNIVERSITY

What is Diffractive Physics at a 1.96 TeV Hadron Collider ?

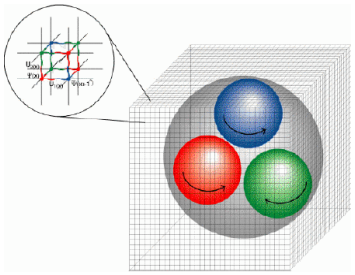
A lot of physics that is observed at the Tevatron is described by colour exchange perturbative QCD. There's also electro-weak physics on a somewhat smaller scale.



$$\sigma_{tot} = \sigma_{pt} + \sigma_{el} + \sigma_{dd} + \sigma_{sd}$$

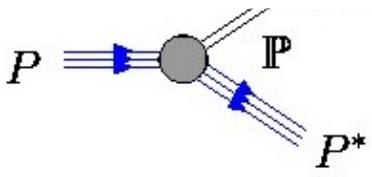
But there is also a vast amount of data that isn't described by (more familiar) colour exchange pertubative interactions at the Tevatron !

What's going on there ?



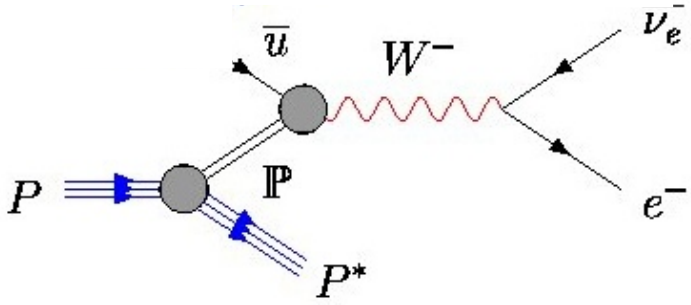
The Various Models Used to Model Diffraction Phenomenon

Various takes on similar principles :-



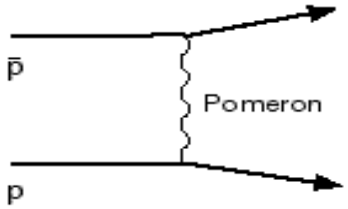
1) Unresolved Pomeron Models
These generally model the interaction through the exchange of a vector 'pomeron'. Usually used to describe soft diffractive & elastic collisions.

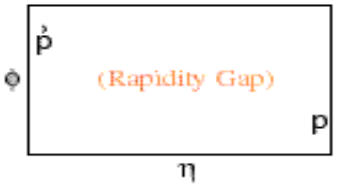
2) Resolved Pomeron Models
These models treat the Pomeron as a composite object with its own parton substructure.



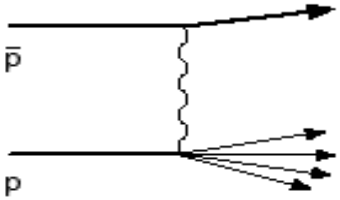
Various Experimental Signatures for Diffraction

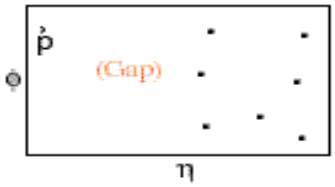
Soft Processes:





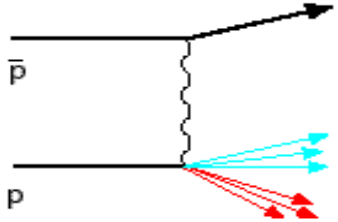
Elastic Scattering

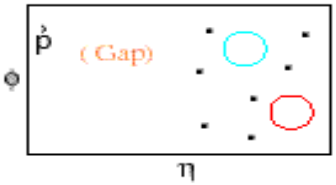




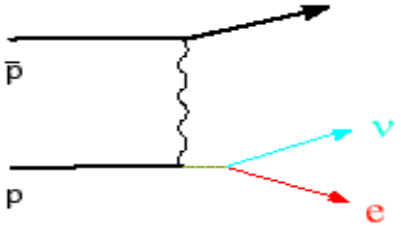
Single Diffraction

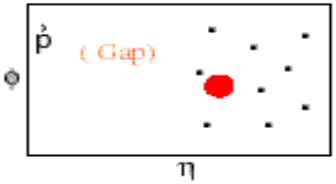
Hard Processes:



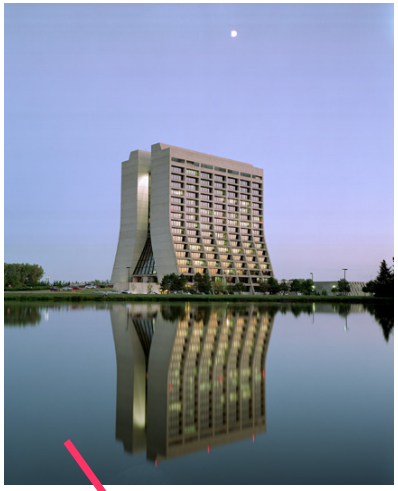


Hard Single Diffraction





Diffractive W

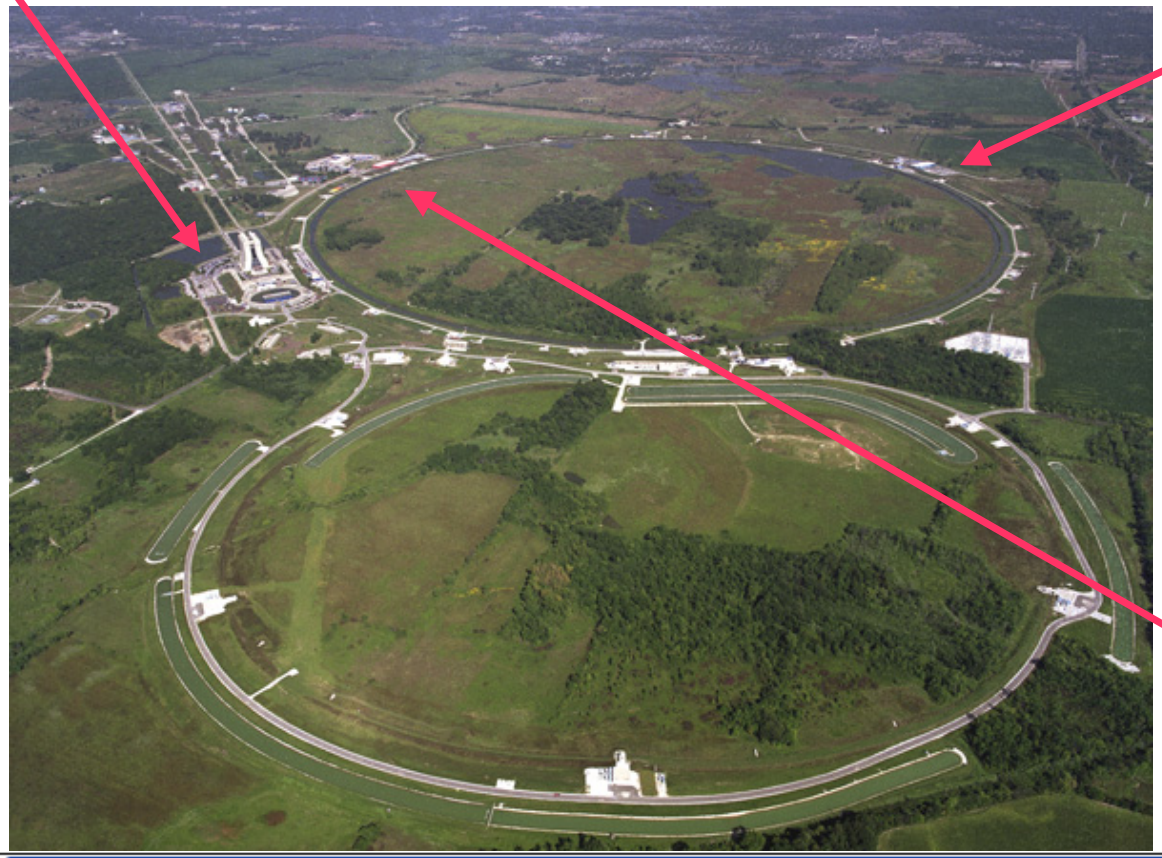


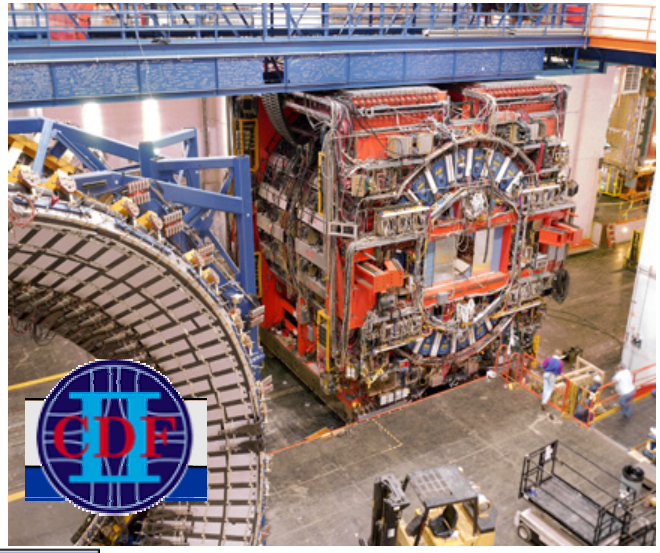
The Tevatron - Smashing Protons in the 21st Century

Center of Mass Energy

1.96 TeV for Run-II

Two experiments

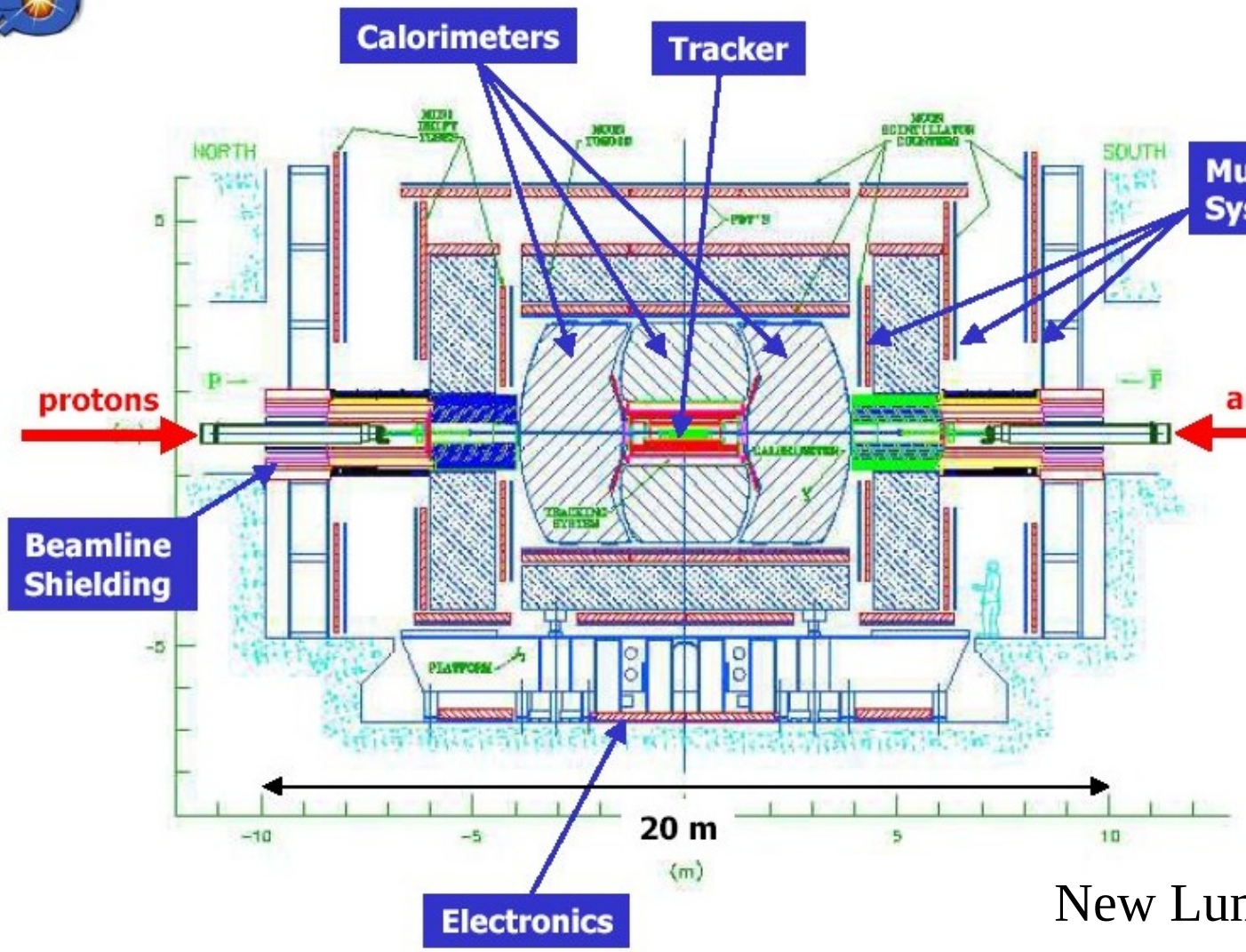


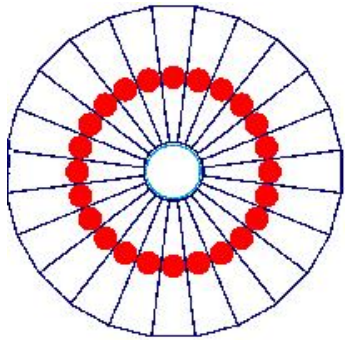


Broadbrush View of the Detector - The Upgrade

Same excellent liquid Ar based Calorimetry as Run I

Vastly improved - SMT + CFT

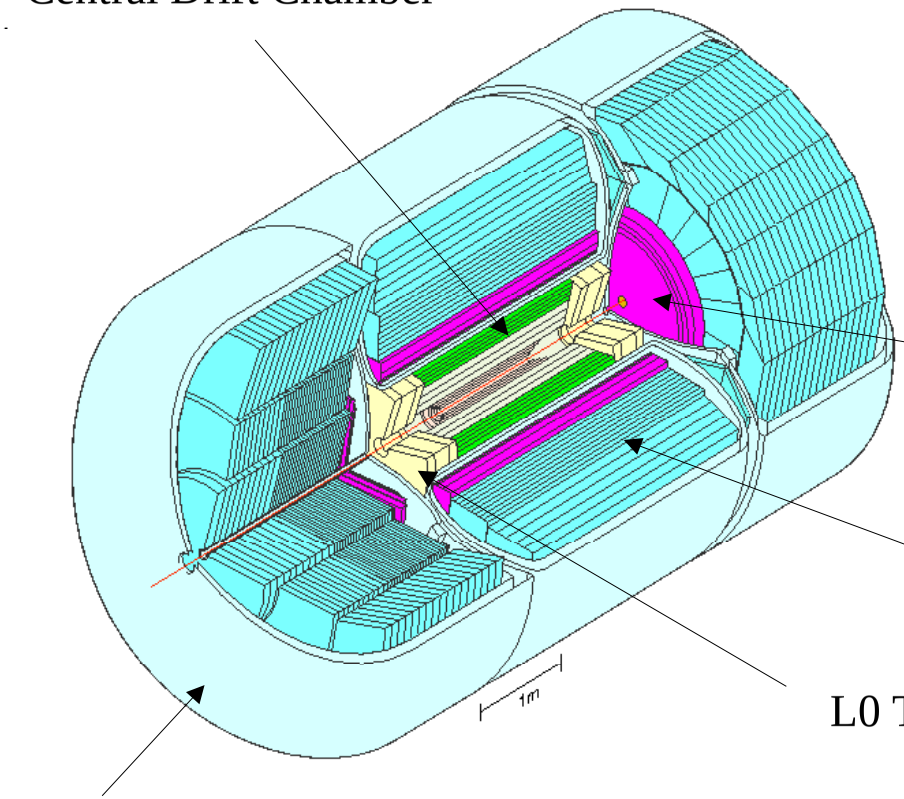




New Luminosity Counters

Almost completely replaced for Run-II

The Run-I Era D0 Detector



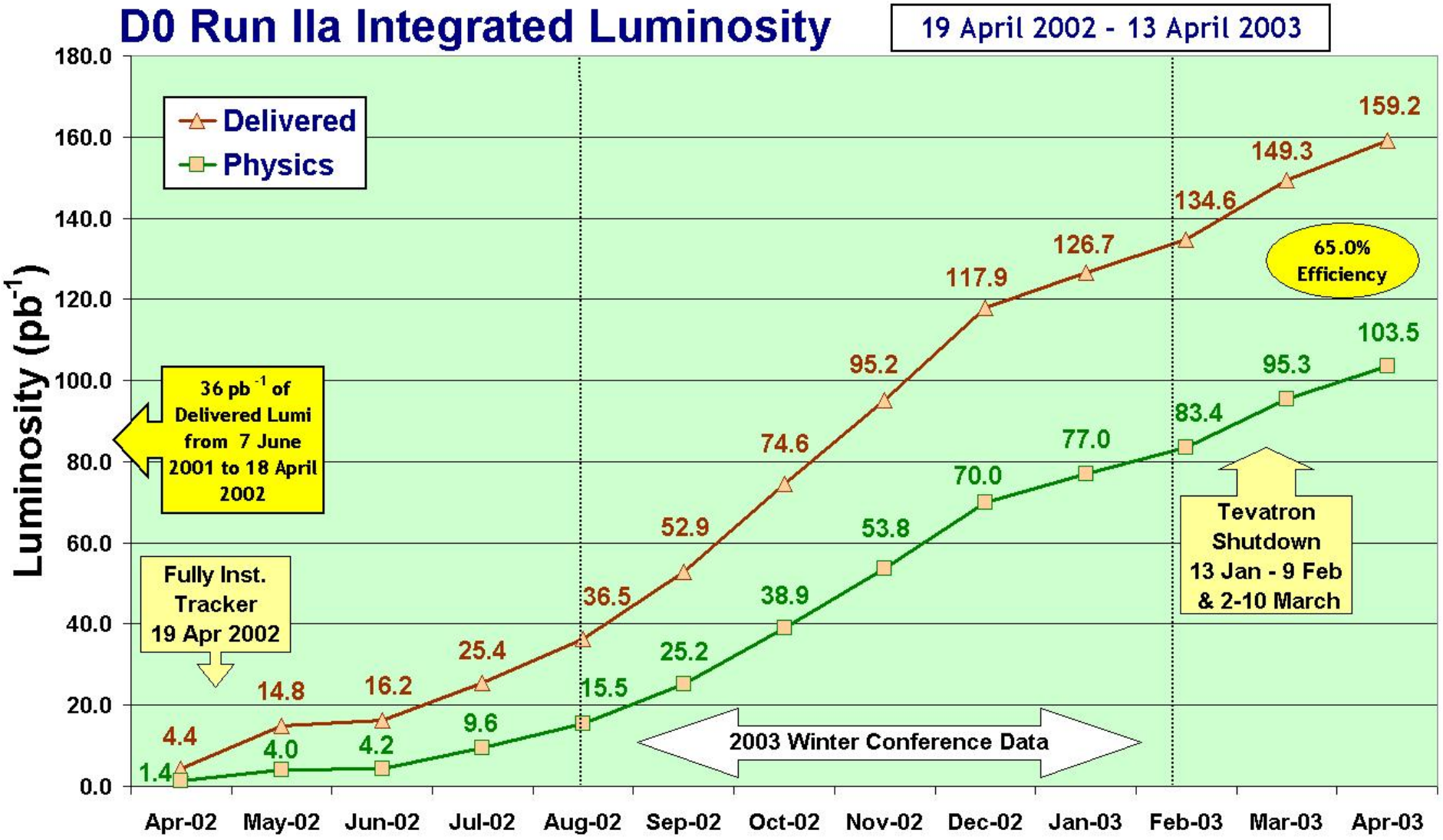
Central Tower Thresholds

EM Calorimeter	E_T > 200 MeV	$\|\eta\| < 1.0$

Forward Tower Thresholds

EM Calorimeter	E > 150 MeV	$2.0 < \|\eta\| < 4.1$
Had. Calorimeter	E > 500 MeV	$3.2 < \|\eta\| < 5.2$)

Luminosity Delivered at Run-II

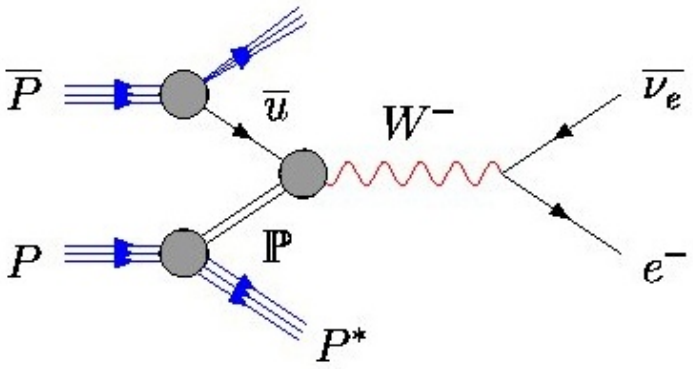


Run-II Design Luminosity $2 \times 10^{-32} cm^{-2} s^{-1}$

Current Run-II Luminosity $4 \times 10^{-31} cm^{-2} s^{-1}$

... but Beam Div is pushing this no. up relentlessly

W and Z Boson Production at D0 by the Diffractive Process



Pomeron is emitted (flux by Regge/Pomeron theory) & a hard scatter then occurs between the pomeron & a quark within the proton.

Nice measurement since it proves directly that the pomeron has a quark component to it.

$$\frac{d\sigma}{d\eta} = \frac{1}{2s}\sum_{ij}\int d(\cos\theta)\int\frac{dx_{\mathbb{P}}}{x_{\mathbb{P}}}\int d\hat{s}\, F_{\mathbb{P}/p}(x_{\mathbb{P}})\, f_{i,\mathbb{P}}(\beta,\mu^2)\, f_{j,\bar{p}}(x,\mu^2)\,\hat{s}\,\frac{d\hat{\sigma}_{ij}}{d\hat{t}}$$

$$F_{\mathbb{P}/p}(x_{\mathbb{P}}) = N\int dt\ \exp(4.6t)\left(\frac{1}{x_{\mathbb{P}}}\right)^{1.90+0.52t}$$

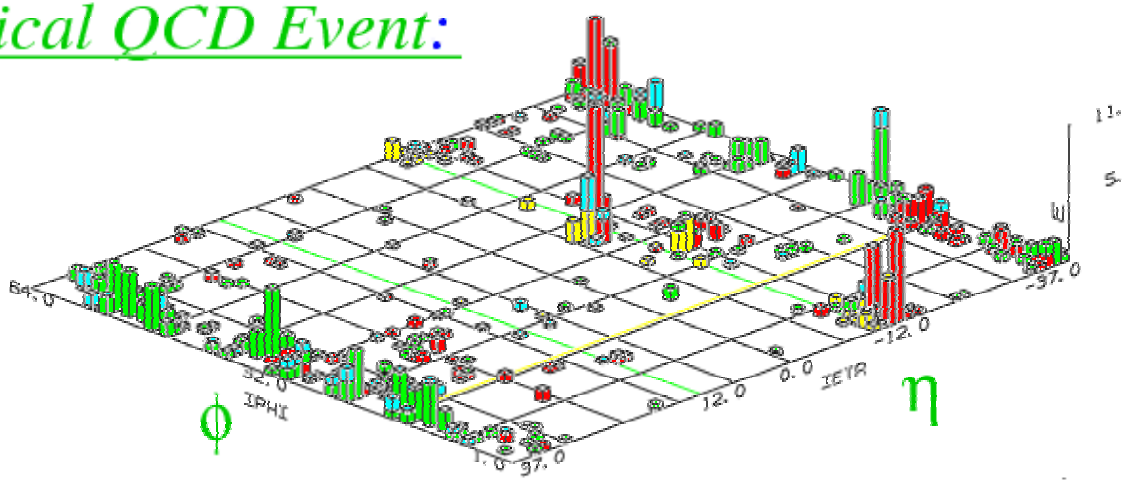
Pomeron Structure

(Anti)Proton Structure

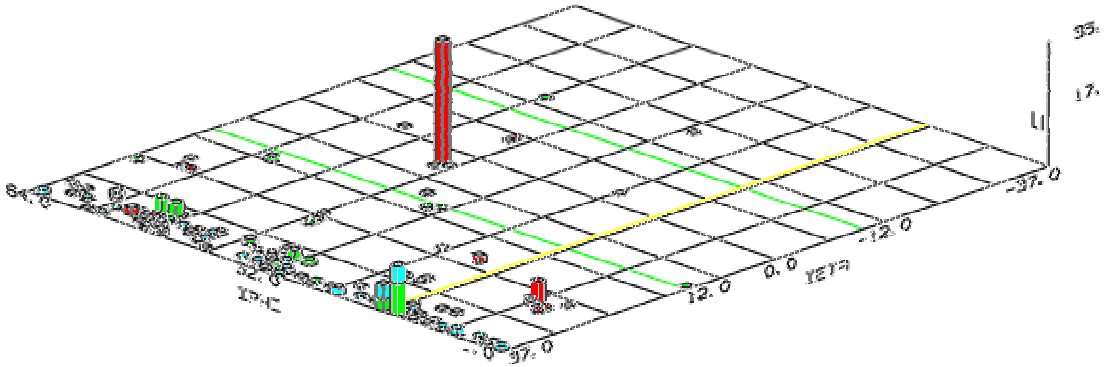
(Very) Quick Guide to Diffractive Production of Vector Bosons

Event Display Showing a Typical Diffractive W Event

Typical QCD Event:



Diff W topology:



No colour flow results in a rapidity gap. Anti-proton makes off down the beam-pipe relatively untouched !

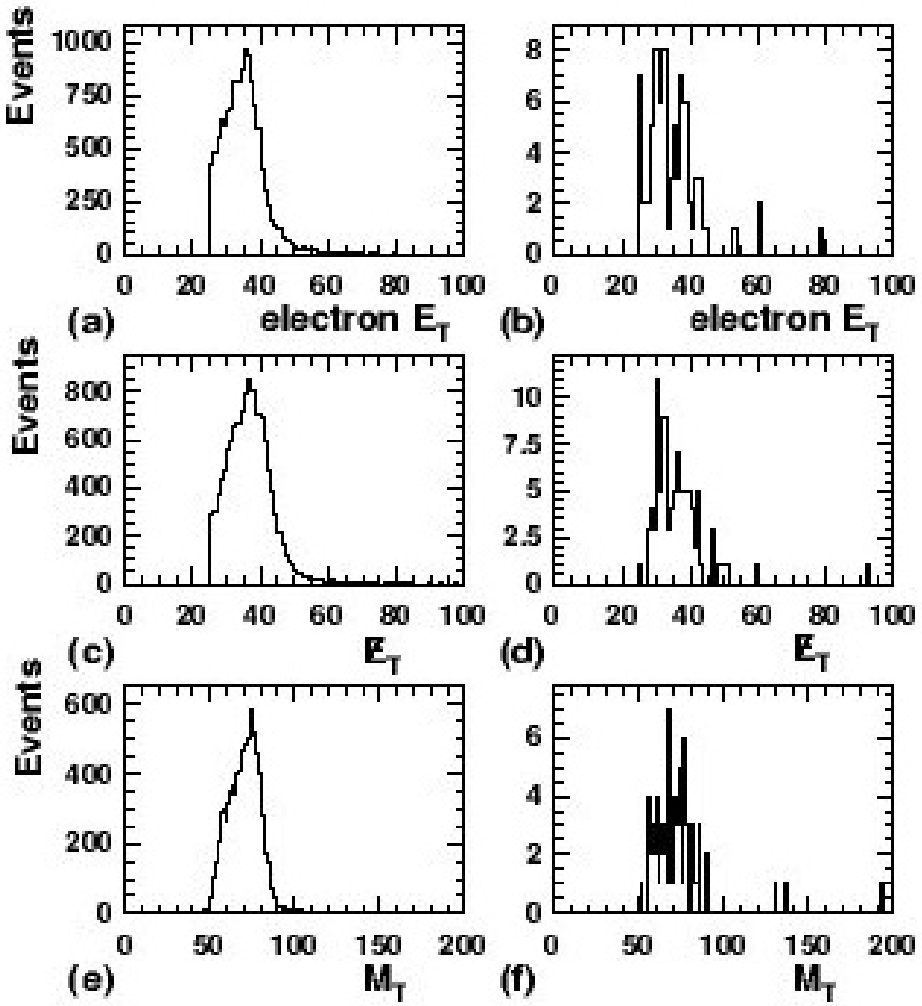
The W and Z Boson Sample Used for the Analysis

Standardised Event selection for W's and Z's with additional constraint of an L0 scintillator timing cut
(enforce single interactions). Reduces both W & Z sample by ~70%.

This gets the lot, normal electro-weak + the diffractive events.

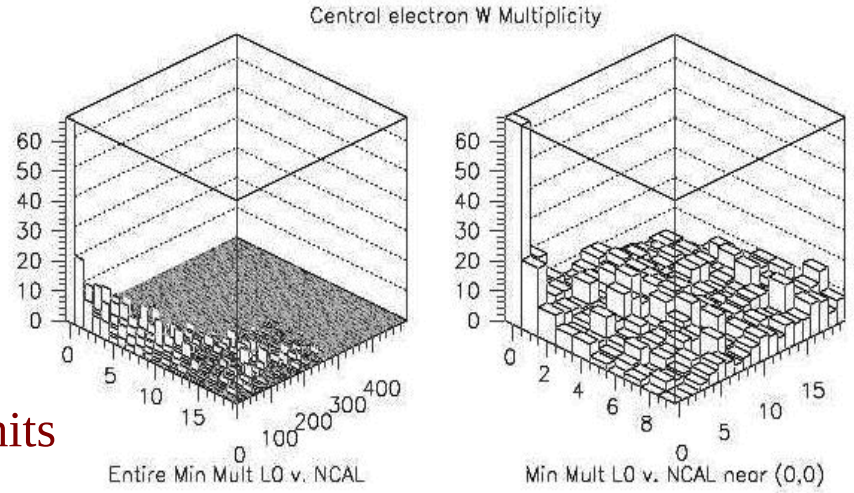
In order to get the diffractive events look for calorimeter activity in the gap region.

$$3.0 \leq |\eta| \leq 5.2$$



Results from the W and Z Diffractive Analysis

Distinct excess can be seen in the (0,0) bin indicating strong evidence of diffractive vector boson production.



L0 hits

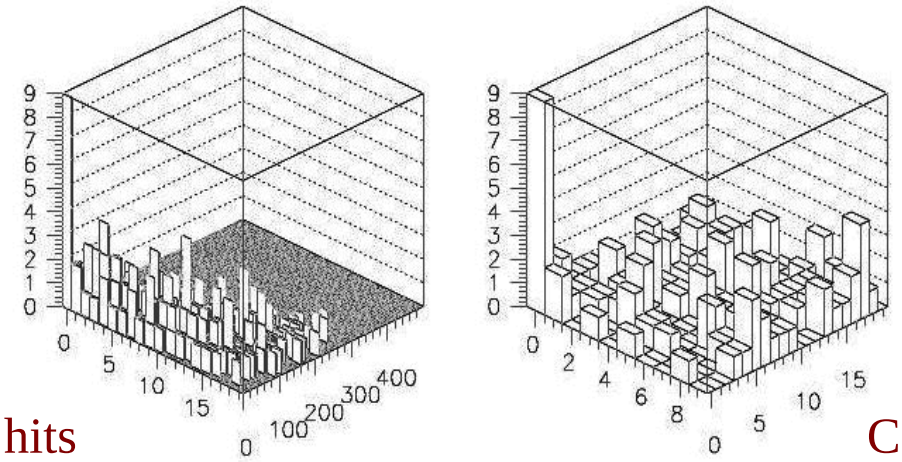
Cal Tow

Event activity in rap-gap region for W-Events

$$3.0 \leq |\eta| \leq 5.2$$

Event activity in rap-gap. for Z-Events

First clear evidence of diffractive Z production !



L0 hits

Cal Tow

Results from the W and Z Diffractive Analysis

1) First diffractive Z events seen by a HEP experiment !

2) Measured ratio of W/Z bosons by diffractive production to total rate of W/Z boson production.

Sample	Gap Fraction (%) Diffractive/All (*)	Probability that Background would fluctuate to the Data in the (0,0) bin for W and Z Data	
W cent	1.08 + 0.19 - 0.17	1×10^{-14}	**7.7σ**
W fwd	0.64 + 0.18 - 0.16	6×10^{-8}	**5.3σ**
W All	**0.89 + 0.20 – 0.19**	3×10^{-14}	**7.5σ**
Z	**1.44 + 0.62 - 0.54**	5×10^{-6}	**4.4σ**

DØ Preliminary

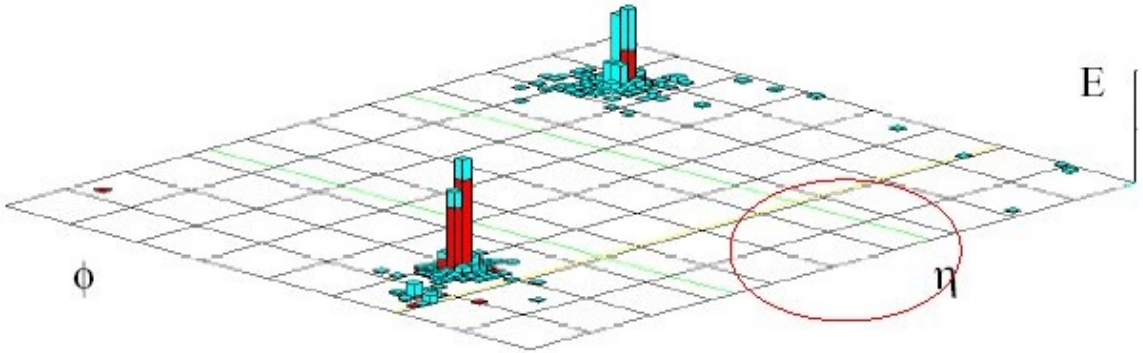
First observation of Z Diffractive

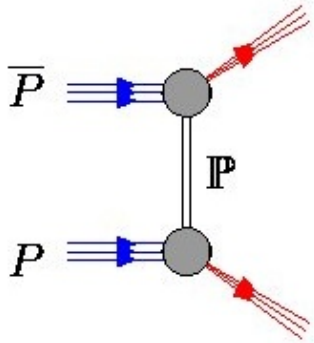
(*) Includes correction for multiple interaction contamination.
Sys error dominated by background fitting.

Single Hard Colourless Exchange

D0's Ratio of Coloured to Colourless Events

Data for this study taken from Run-I samples. Data available for both 630 GeV cms and 1800 GeV cms.

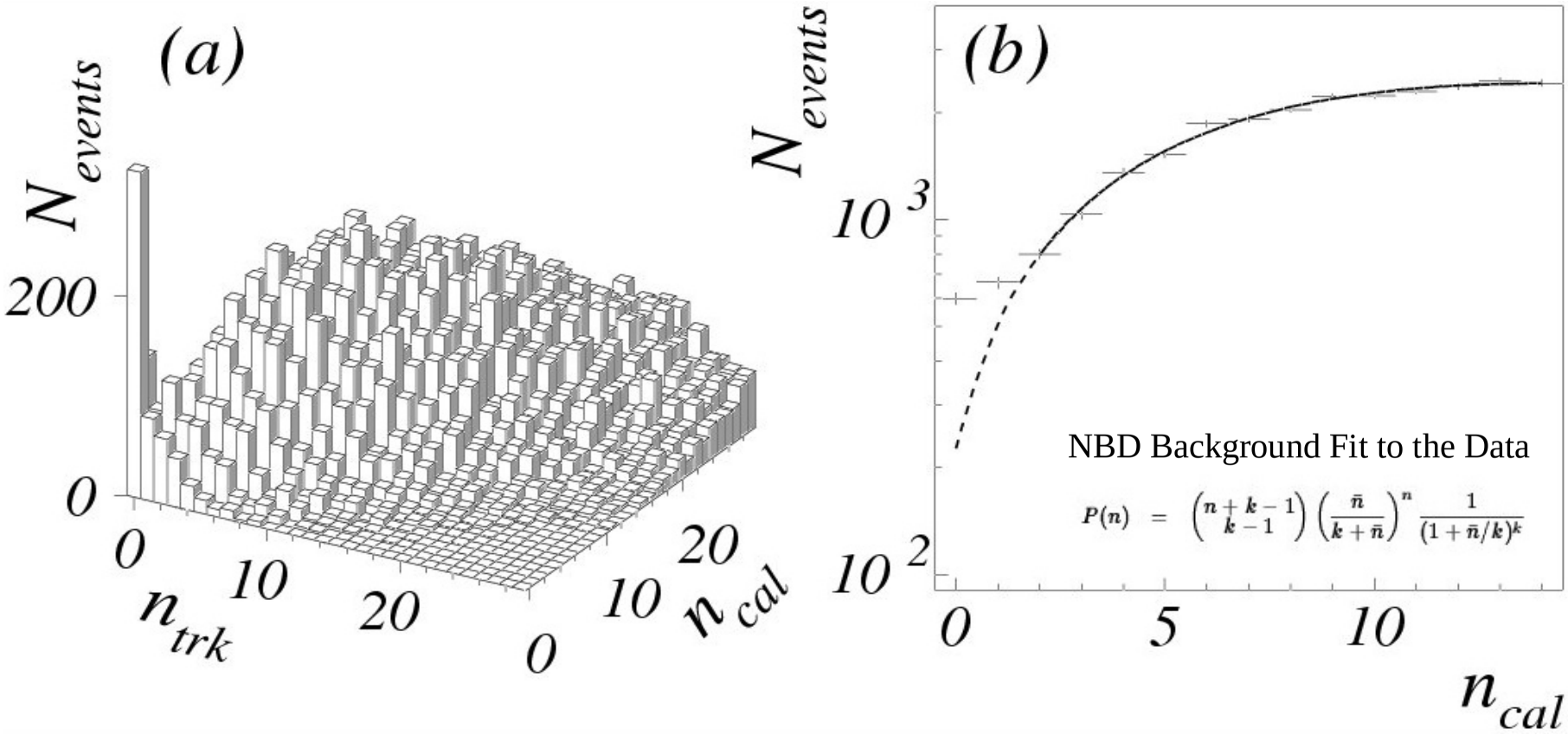




Example of a hard Pomeron exchange event. No colour flow gives rise to observed rapidity gap.

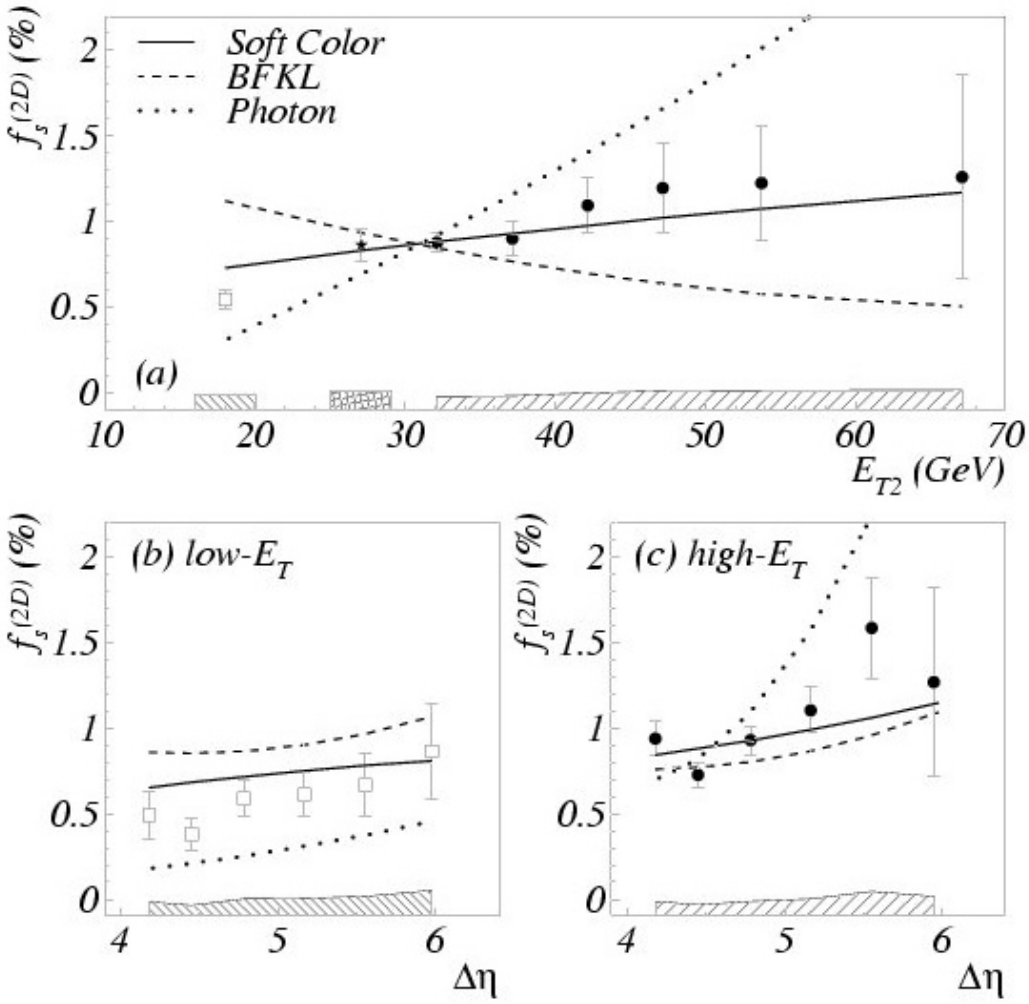
Single Hard Colourless Exchange

The graphs below show the track multiplicities in the gap region. Note the low mutiplicity excess. The fit on the RHS shows the plot of calorimeter towers with a fit to the colour exchange background.



Track & Tower Gap Multiplicities at 1.8 TeV

Single Hard Colourless Exchange

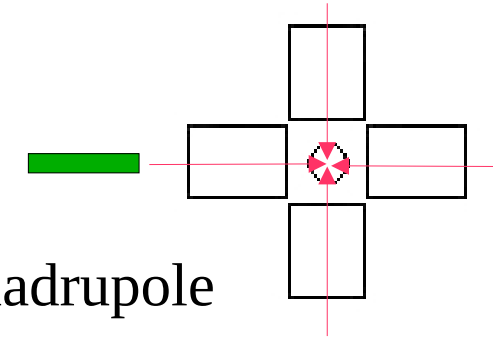


The ratio of the size of colourless event sample (n < 1) to our total sample for the Tevatron Run-I sample can be extracted from this data selection.

The results indicate that the Soft Colour Model best descibes the D0 Data. This theory models the exchange of a single gluon colour cancellation via further gluon emission.

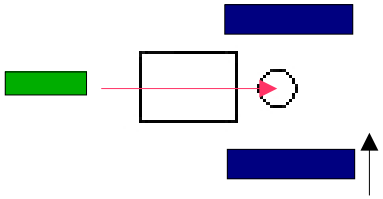
BFKL with intercept at 0.5 LO

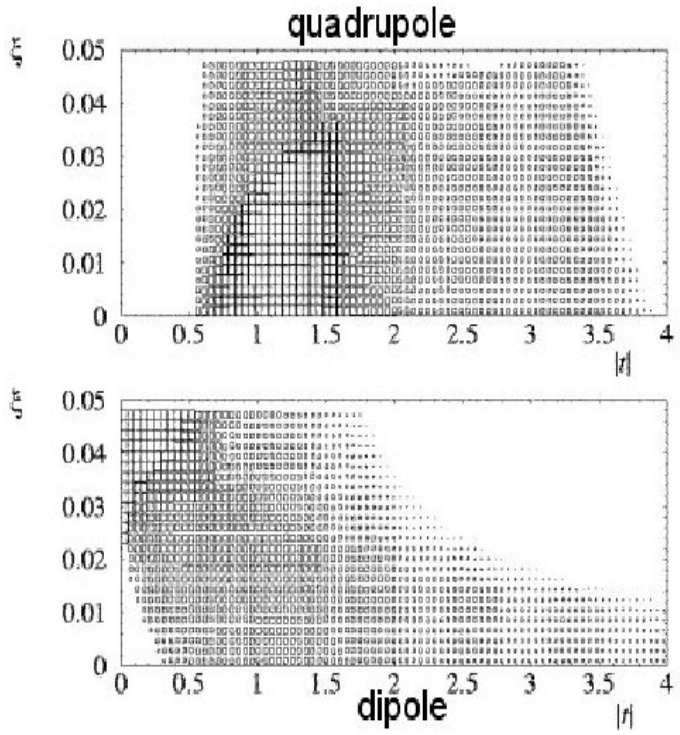
The Forward Proton Detector at Run-II



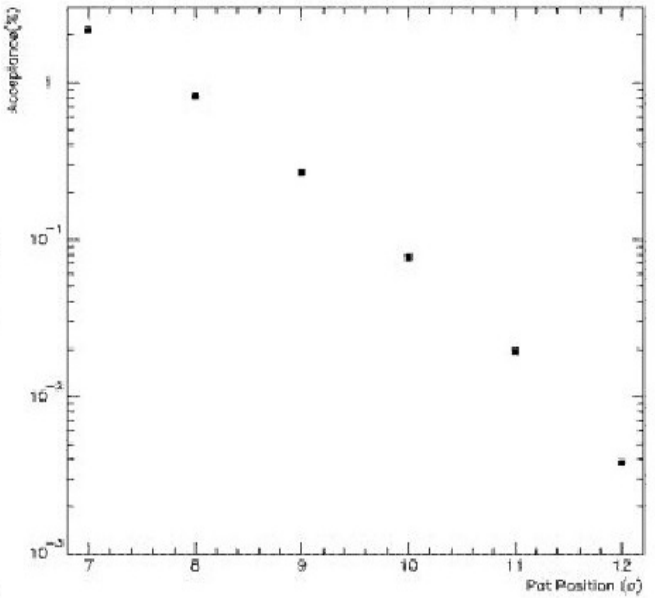
Quadrupole

Dipole Castle

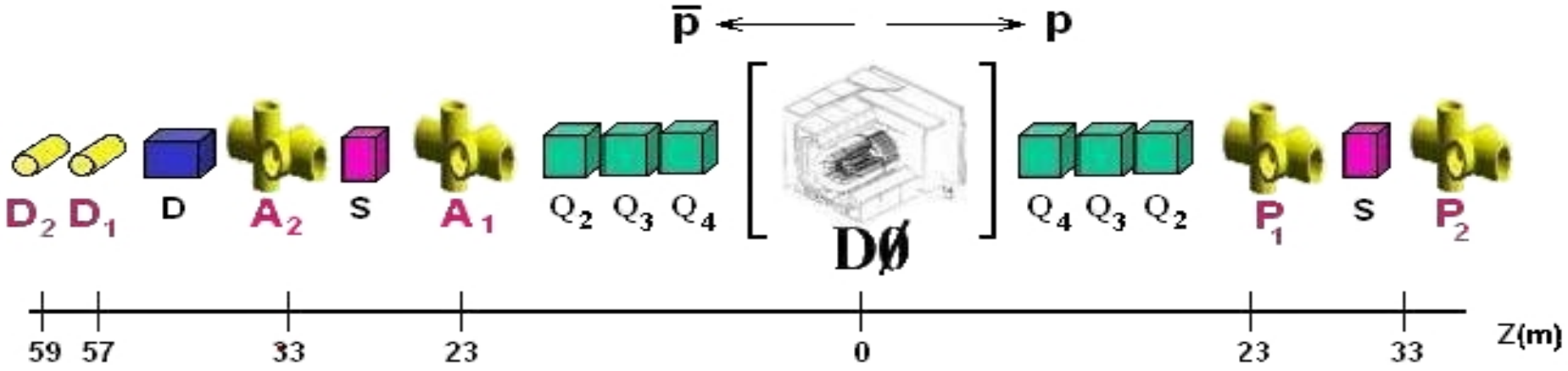




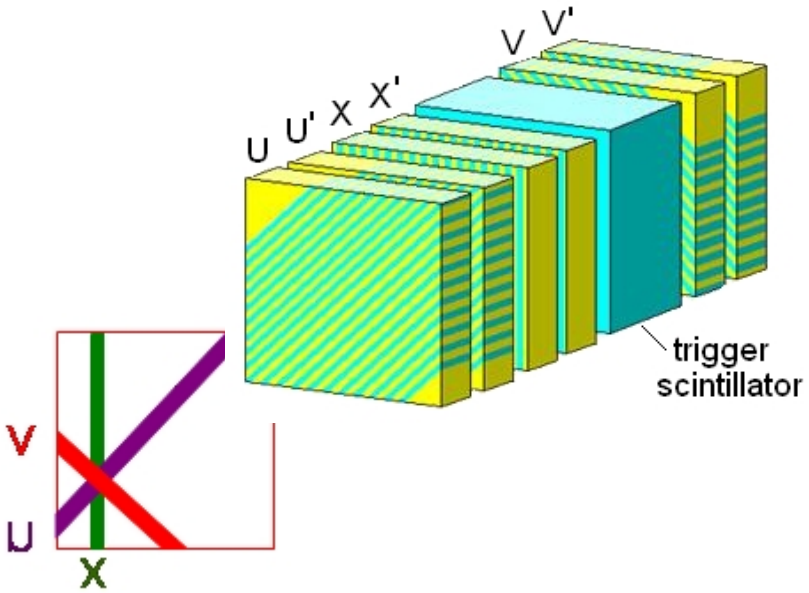
Acceptance (%)



Position (sigma of beam posn)



The Detectors used in the Roman Pots



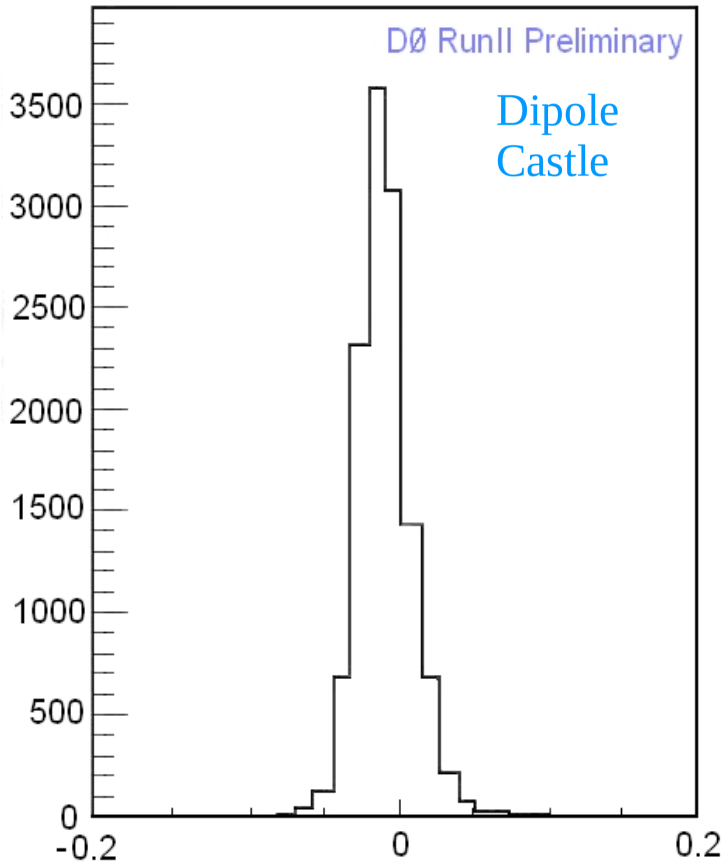
800 micron fibres are joined into waveguides.

Gives 16 channels for each X plane and 20 for the diagonals.

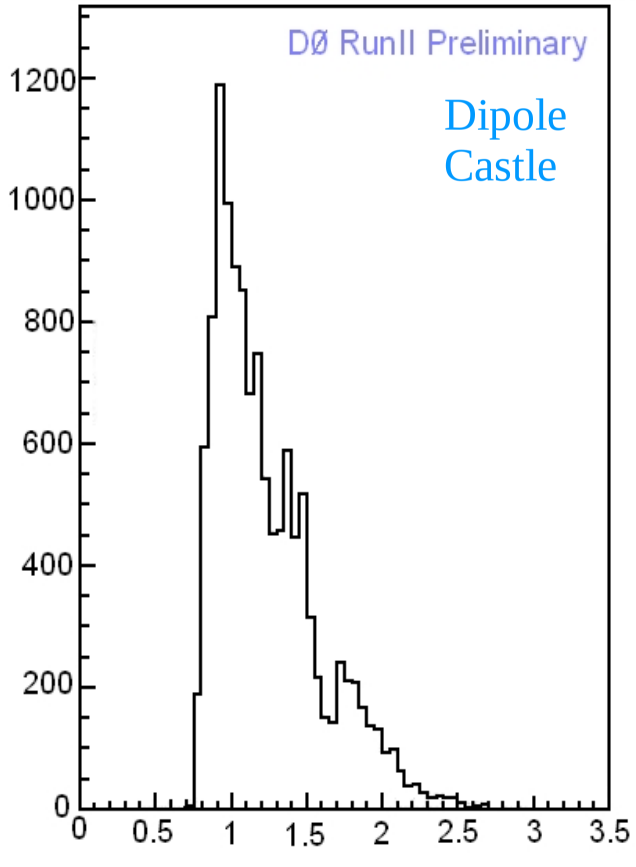
Grouping of Scintillator fibers are used as the detector component. Polystyrene core with para-terphenyl active scintillator & 3-hydroxyflavone wavelength shifter.

Readout with MAPT - 16 channel multi-anode photo-multiplier tubes

Initial Results from the Forward Proton Detector



Pomeron Momentum Fraction



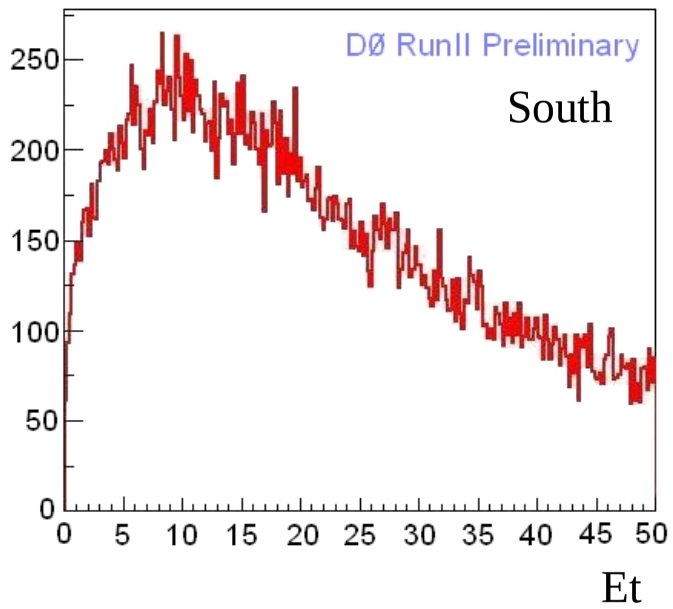
Mometum transfer to Pomeron

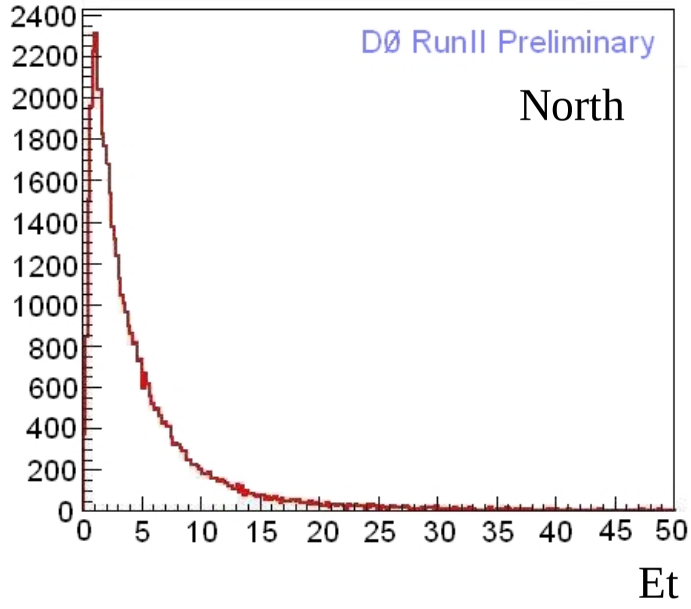
Full integration of the FPD with the D0 readout system has been achieved and the system is now being tested.

Preliminary Diffraction Results at Run-II

Events were selected requiring (in this instance) that the luminosity counters fired only on the South side (no requirement for N). Also require a jet > 25 GeV/c and impose quality cuts (>5 tracks, well defined Primary vertex).

Use scintillator timing requirements to improve quality for now (work being done on electronics for gap triggers).





Summed Et of Calorimeter cells > 100 MeV between a rapidity of 2.6 and 4.1

Clear evidence of Diffraction at Run-II :- Measurements on the way !

Summary of Results & Future Directions

1) Solid physics results from Run I paving the way for Run II.

2) The FPD will allow much more precise kinematics to be determined for Run II results (we can now see the proton & anti-protons).

3) Much better triggering allows us to directly tag interesting diffractive events with the FPD.

Look out for a new W/Z diffractive analysis with much better statistics. Elastic scatter measurements and double pomeron exchange measurements.

Soon we can expect good measurements of the pomeron quark and gluon content using the Forward Proton Detector !