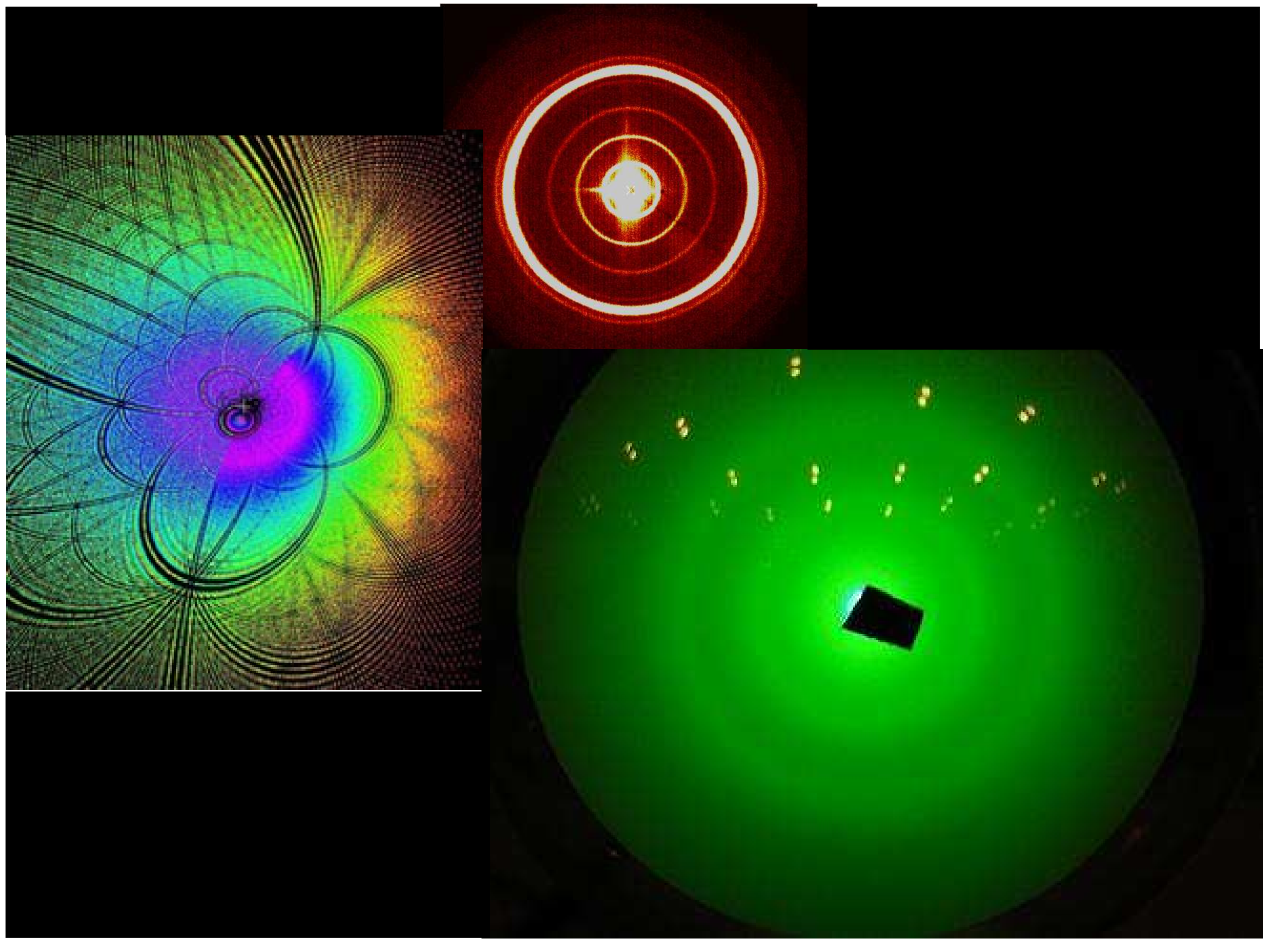
Diffractive Physics at D0



DIS 2003

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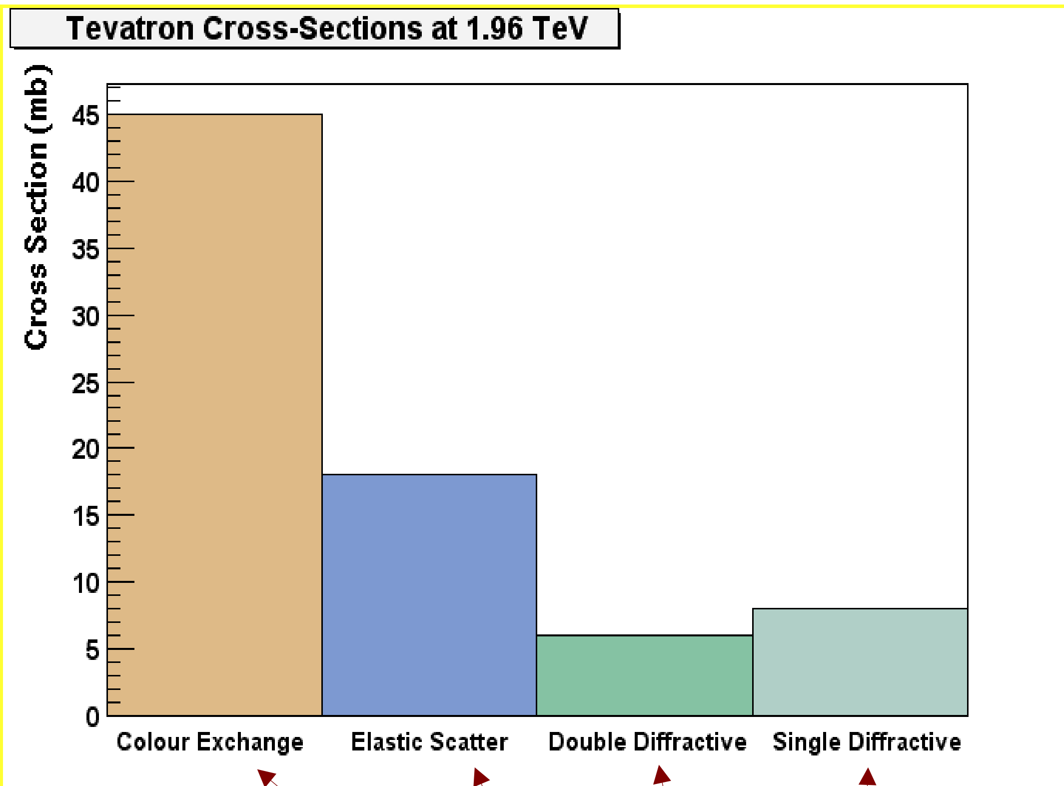
What is Diffractive Physics at a 1.96 TeV Hadron Collider ?

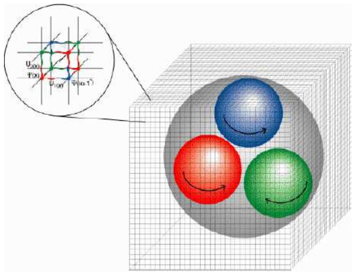
A lot of physics that is observed at the Tevatron is described by colour exchange perturbative QCD. There’s also electro−weak on a somewhat smaller scale.



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

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

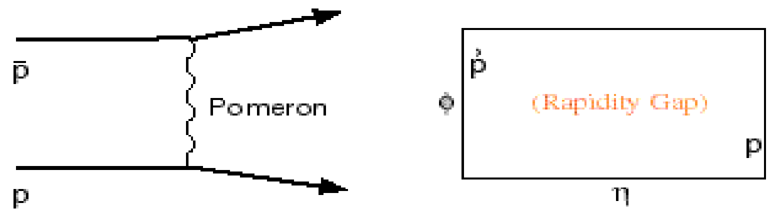
These generally model the interaction through the exchange of a vector 'pomeron'. Usually used to describe soft diffractive & eleastic collisions.

2) Resolved Pomeron Models

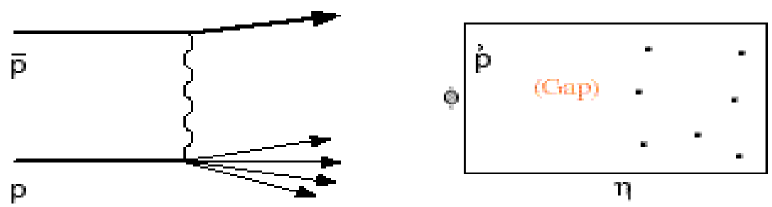
These models are extensions of the standard Regge theory style Pomeron and identify the Pomeron as a composite object with it's own parton substructure.

Various Experimental Signatures for Diffraction

Soft Processes:

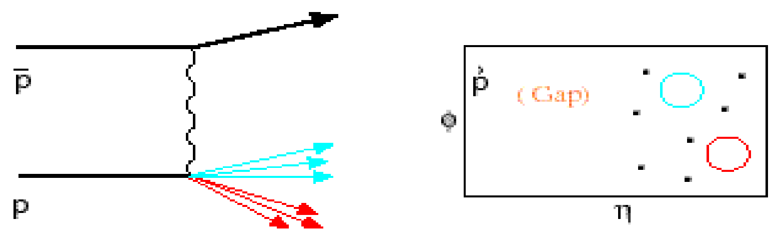


Elastic Scattering

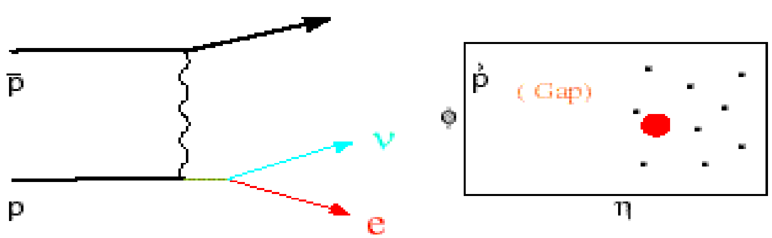


Single Diffraction

Hard Processes:



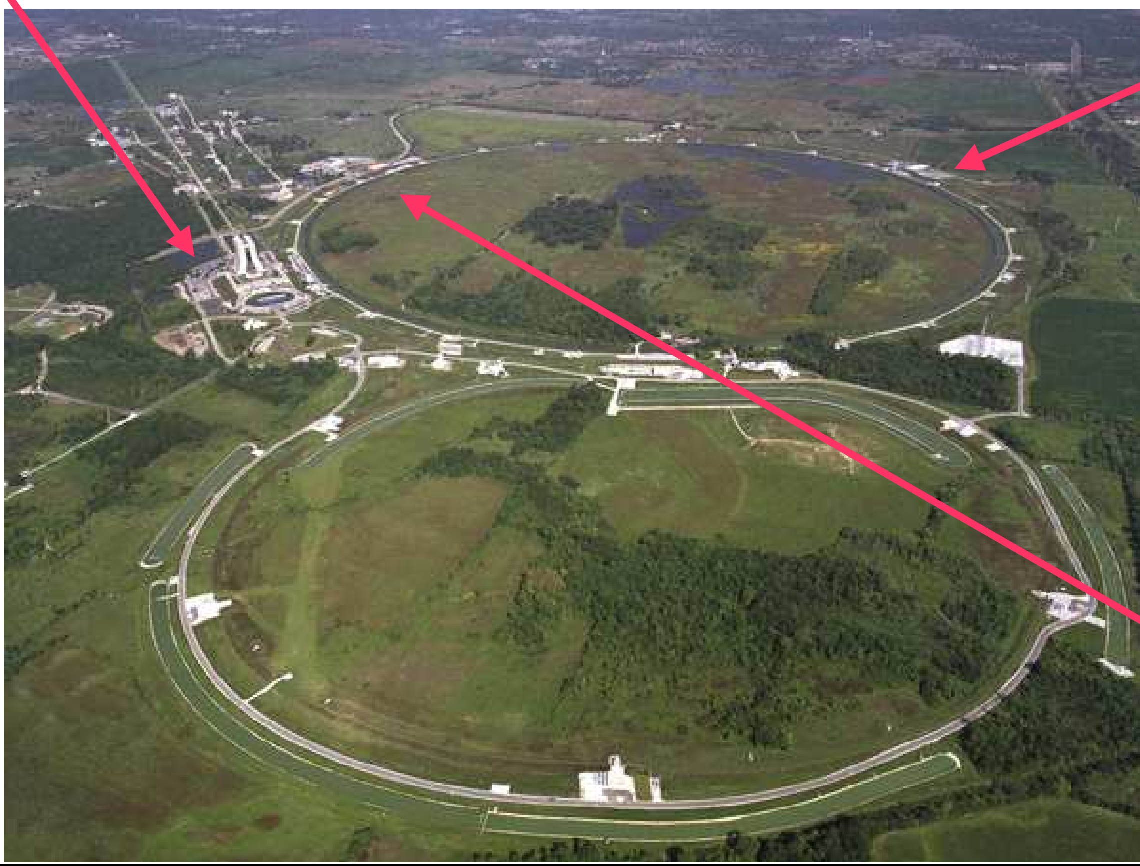
Hard Single Diffraction

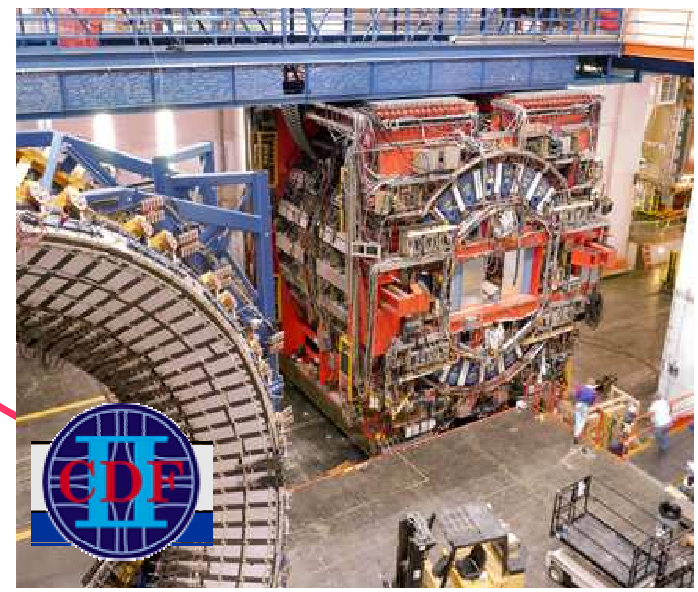


Diffractive W

The Tevatron – Smashing Protons in the 21st Century

CMS –1.96 TeV for Run–II
Two experiments

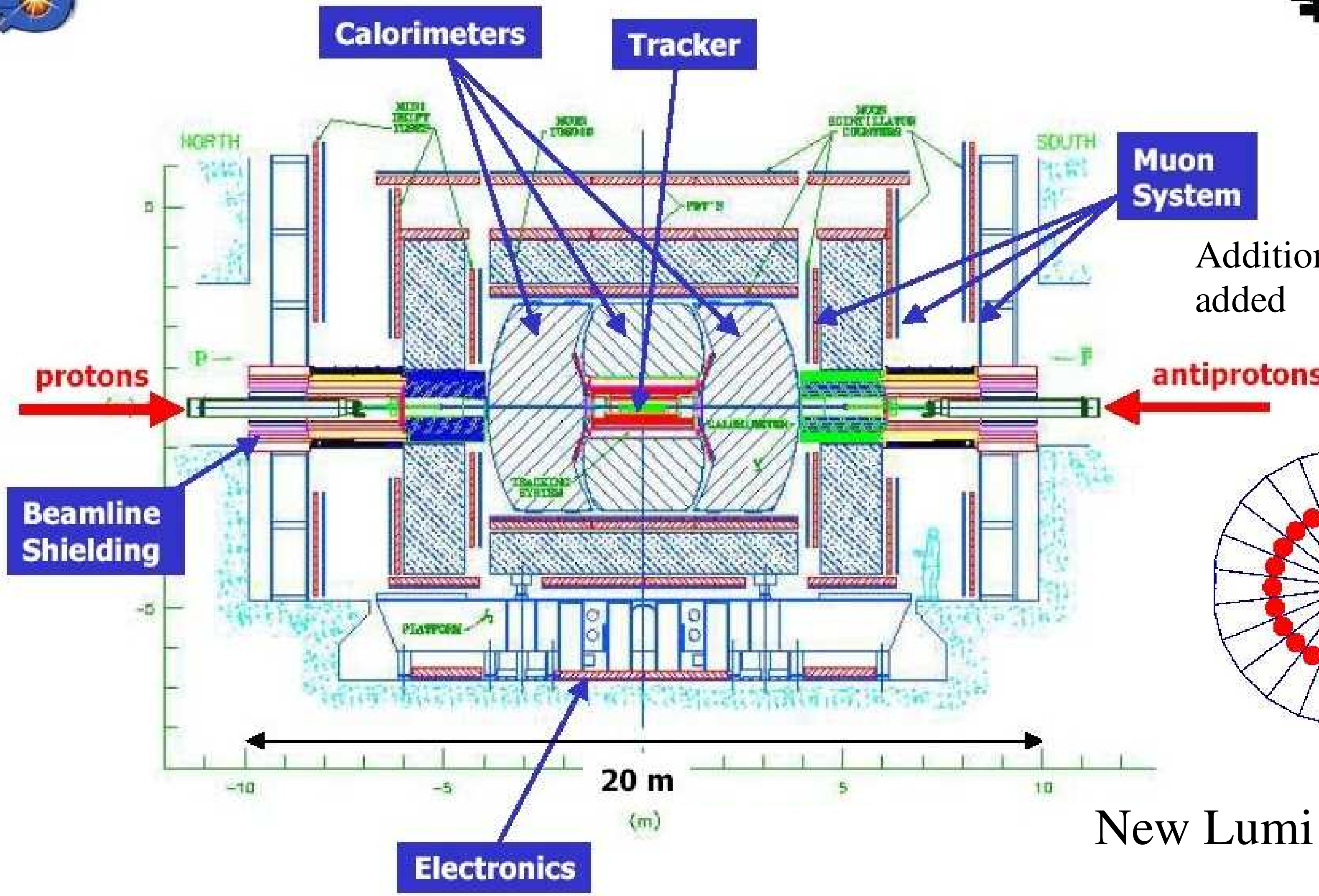




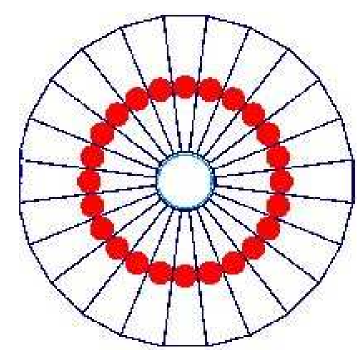
Broadbrush View of the Detector – The Upgrade

Same excellent liquid Ar based Calorimetry as Run I

Vastly improved – SMT + CFT



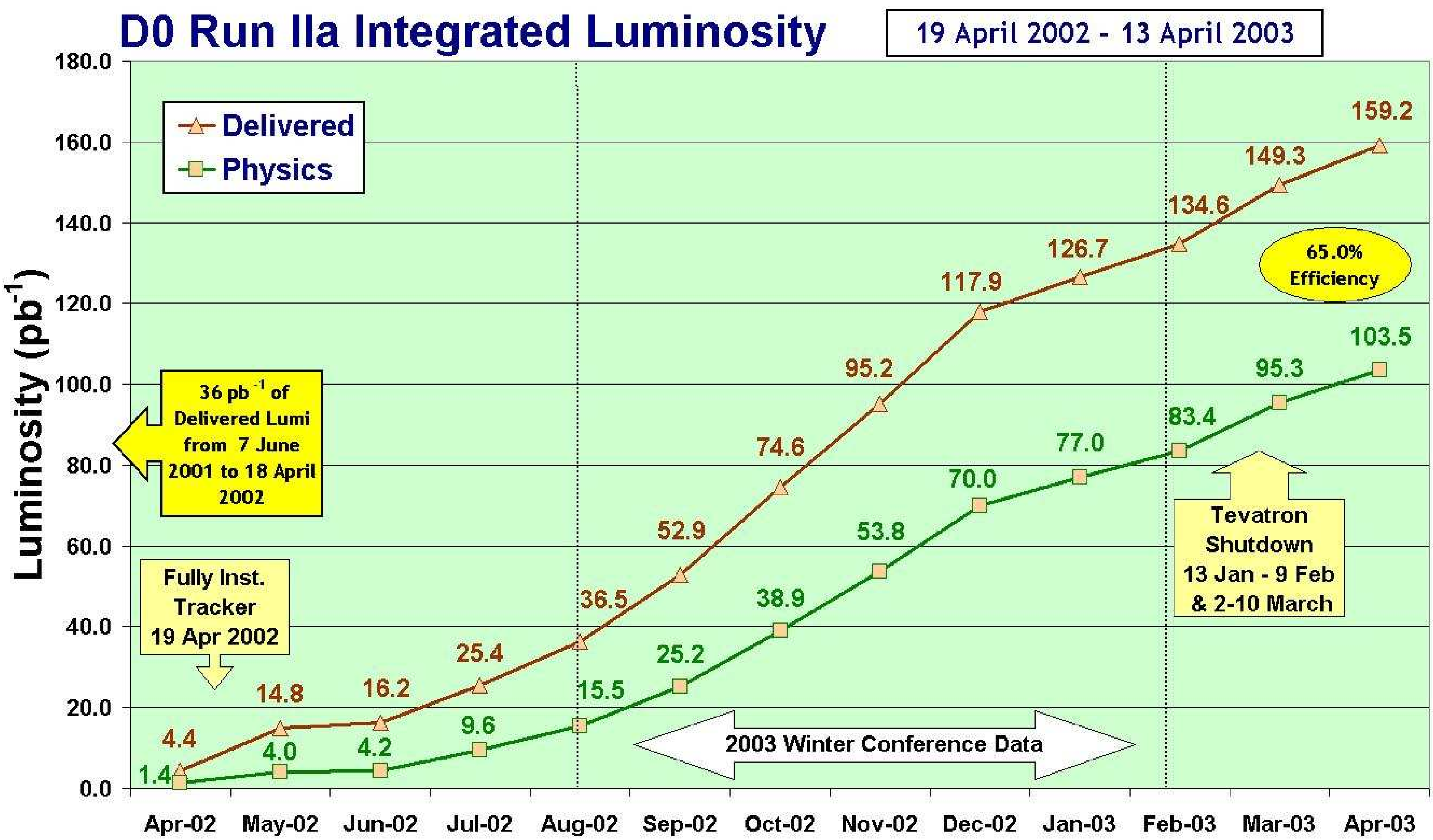
Additional coverage added



New Lumi Counters

Almost completely replaced for Run–II

Luminosity Delivered at Run−II

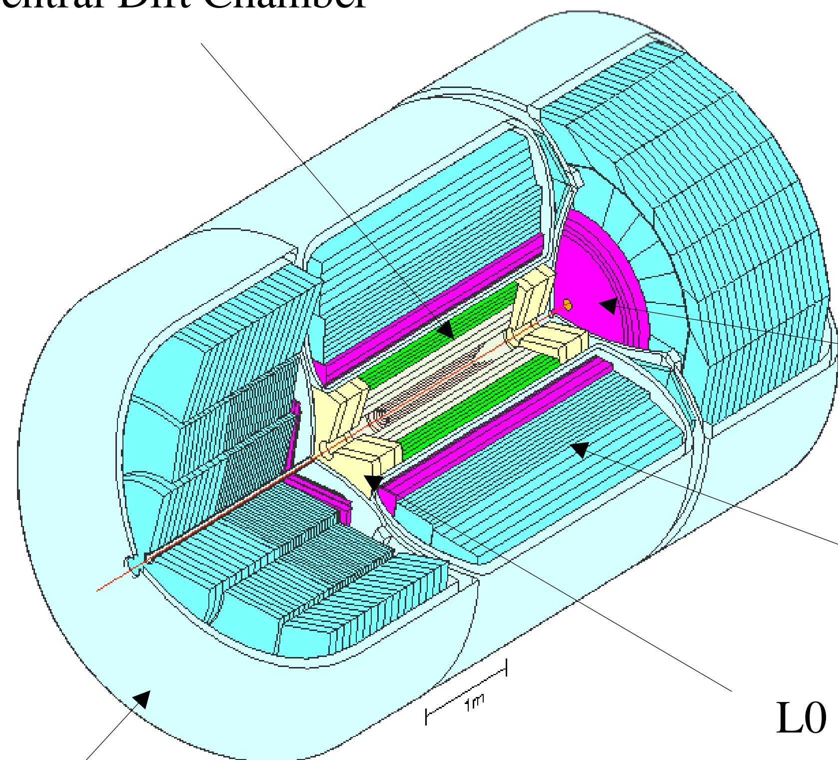


Run−II Design Luminosity $2 \times 10^{-32} \mathrm{cm}^{-2} \mathrm{s}^{-1}$

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

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

The Run−I Era D0 Detector



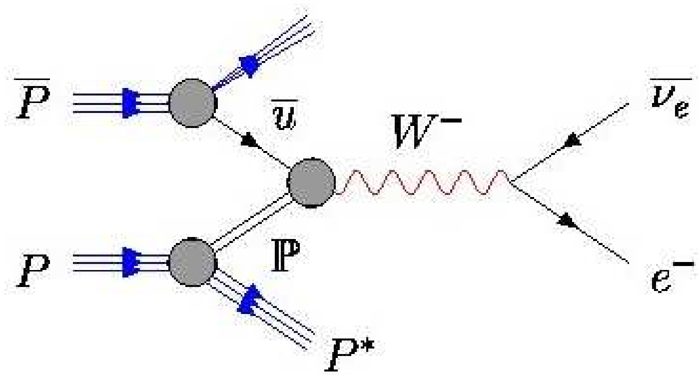
Central Tower Thresholds

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	$3.2 < \|\eta\| < 5.2)$

Diffractive W Production at D0



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.

W's Quick Guide to W Diffractive Production

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

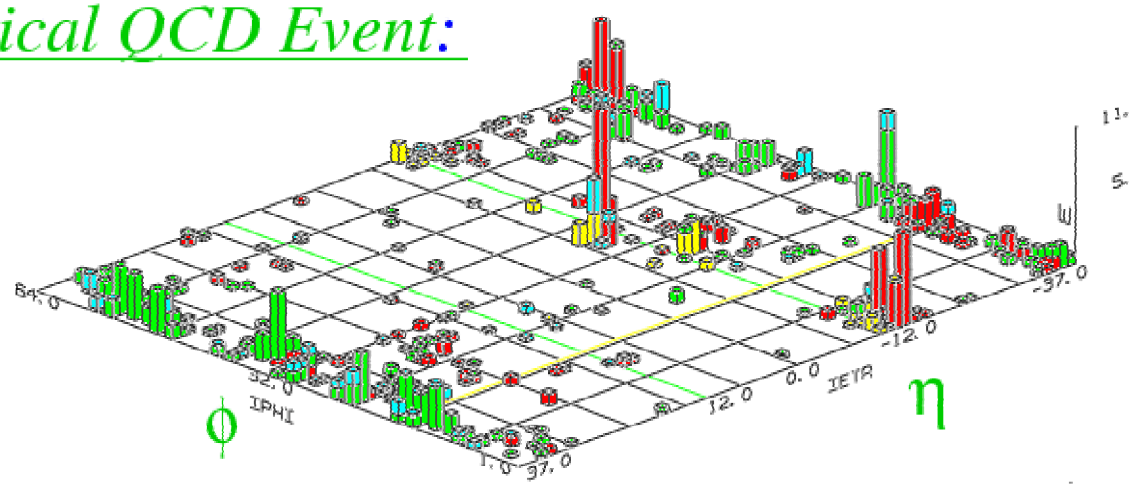
$$F_{\mathbb{P}/p}(x_{\mathbb{P}}) = N\int dt\ \exp(4.6t)\left(\frac{1}{x_{\mathbb{P}}}\right)^{1.90+0.52t}$$

Pomeron Structure

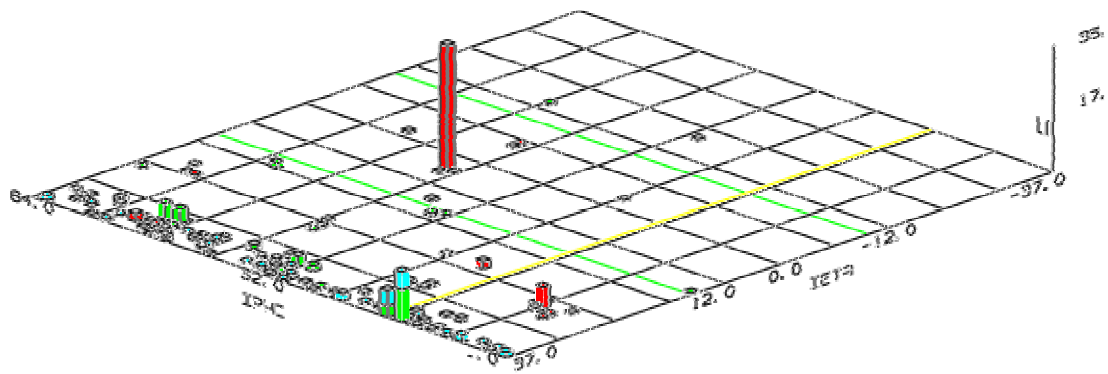
(Anti)Proton Structure

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 Event Selection for the W and Z Boson Sample Used

Variable		N Events
filter	electron + $\not{E}_T$	119,890
No Level 0 Requirement in trigger	Run number > 85277	84,310
Main Ring Cuts		63,978
Single Interaction		17,870
Central Calorimeter or Endcap Calorimeter	$\lvert\eta_{det}\rvert < 1.1$ $1.5 < \lvert\eta_{det}\rvert < 2.5$	17,626
Electron Quality	isolation, shape, EM fraction	17,201
E_T and $\not{E}_T$	> 25 GeV	12,622
Total e W sample		12,622
Final Central e sample	$\lvert\eta_{det}\rvert < 1.1$	8,724
Final Forward e sample	$1.5 < \lvert\eta_{det}\rvert < 2.5$	3,898

Table 1: Central and Forward W electron event selection criteria.

Standardised Event selection for W's and Z's

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.

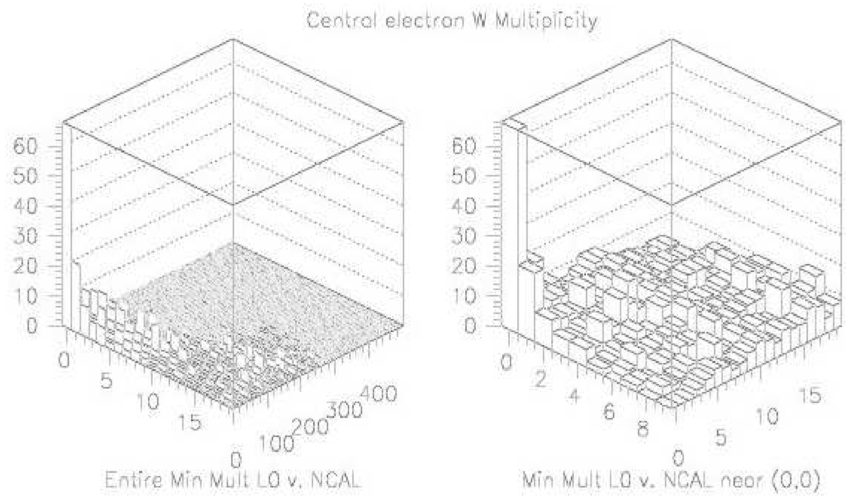
$$3.0 \leq |\eta| \leq 5.2$$

Variable		N Events
filter	two electrons	13,912
No Level 0 Requirement in trigger	Run number > 85277	10,023
Main Ring Cuts		8,751
Single Interaction		2,381
Central Calorimeter or Endcap Calorimeter	$\lvert\eta_{det}\rvert < 1.1$ $1.5 < \lvert\eta_{det}\rvert < 2.5$	1,781
E_T of electrons	> 25 GeV	1,149
Electron Quality 1 tight 1 loose	isolation, shape, EM fraction	893
Invariant Mass window		811
Total e Z sample		811

Table 2: Z electron event selection criteria.

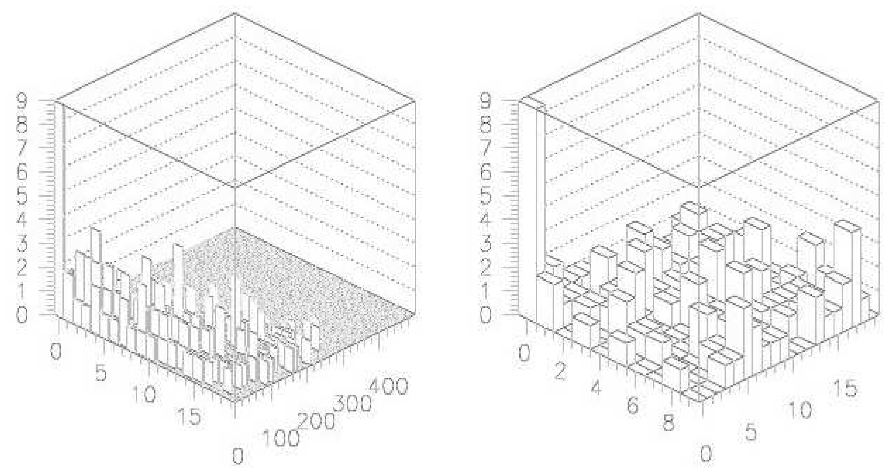
Results from the W and Z Diffractive Analysis

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



Event activity in rap–gap. for W–Events

Event activity in rap–gap. for Z–Events



First clear evidence of diffractive Z production !

Results from the W and Z Diffractive Analysis

1) First diffractive Z events seen.

2) Measured ratios of W/Z Diffractive production to W/Z total 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**

First observation of Z Diffractive

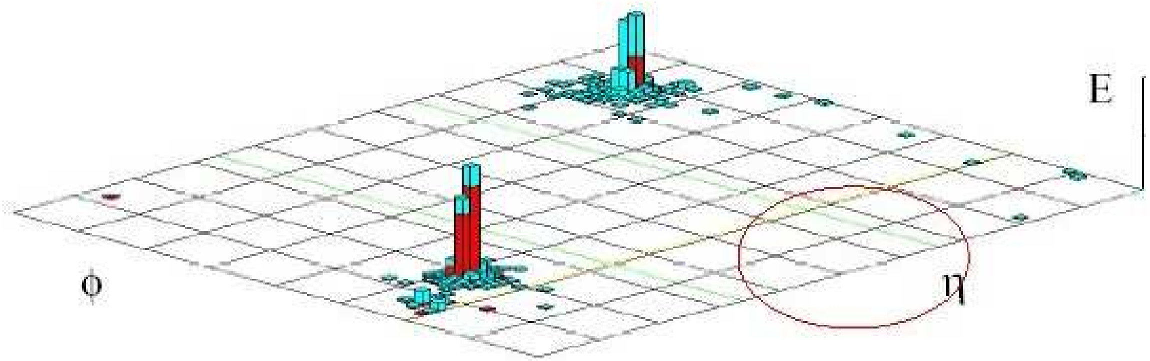
DØ Preliminary

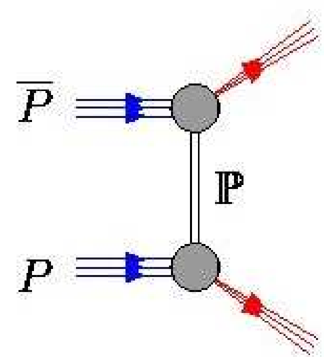
(*) Includes correction for multiple interaction contamination.
Sys error dominated by background fitting.

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.

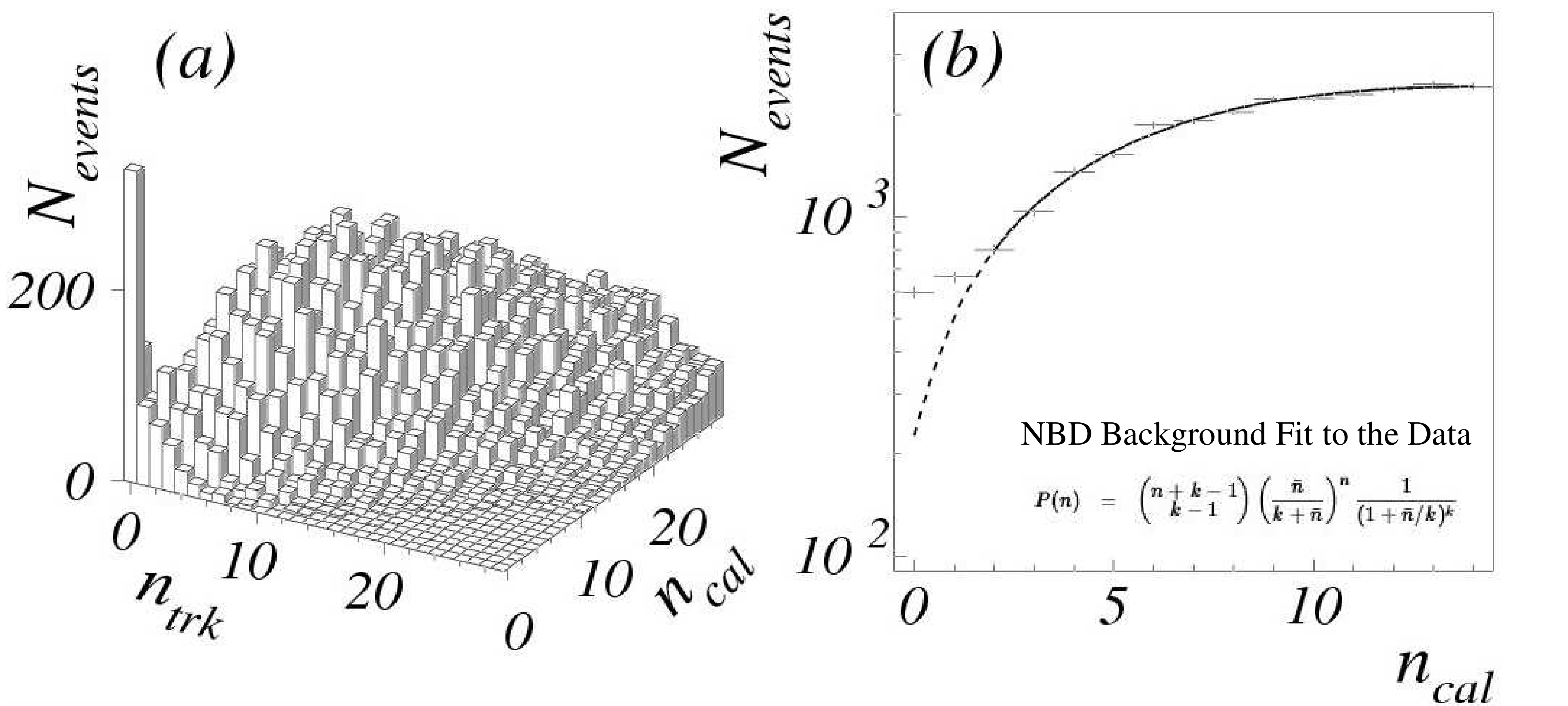




Example of a hard Pomeron exchange event. No colour flow gives rise to observed rapidity gap.

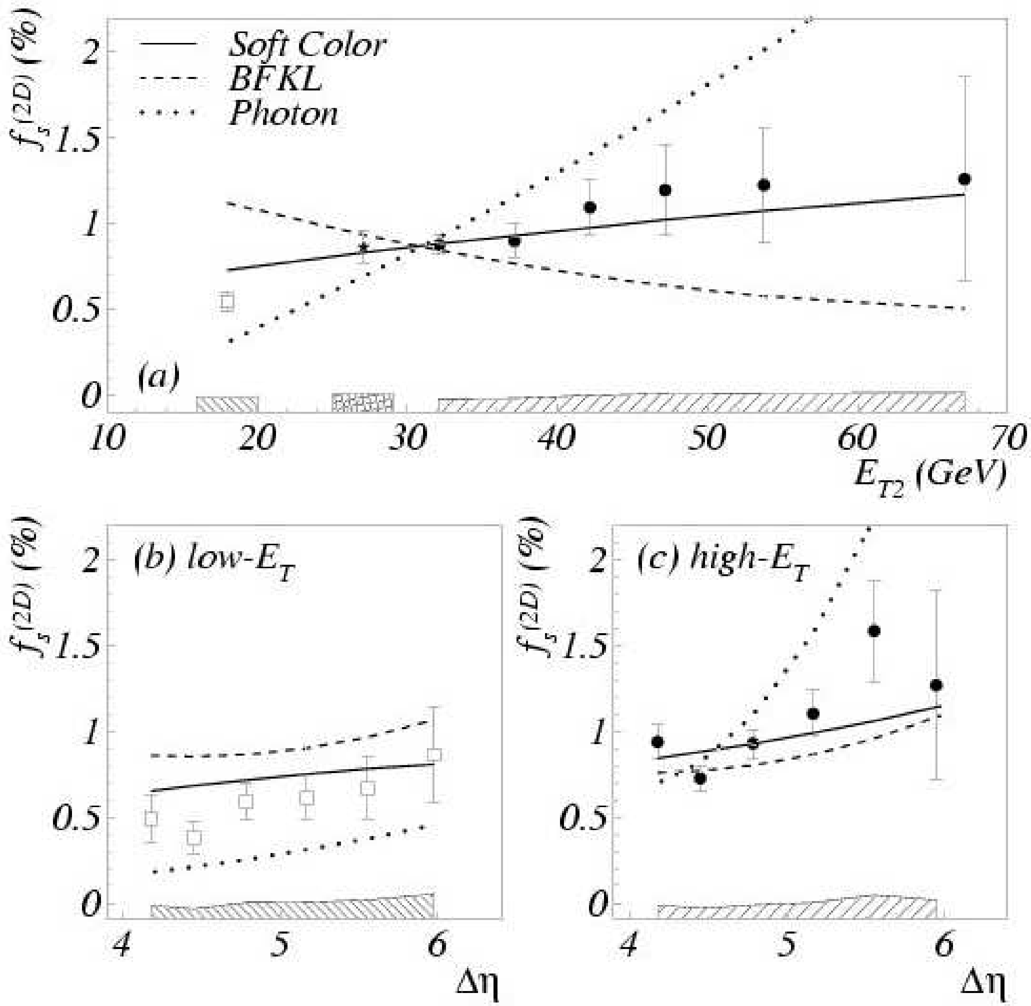
Single Hard Colourless Exchange

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

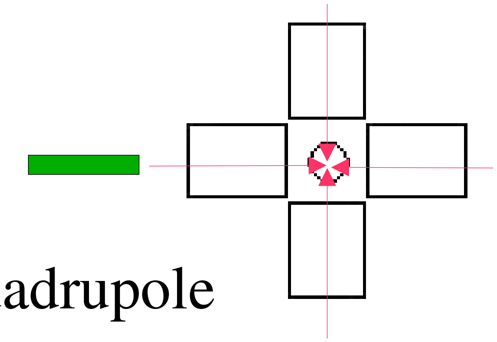
Single Hard Colourless Exchange



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.

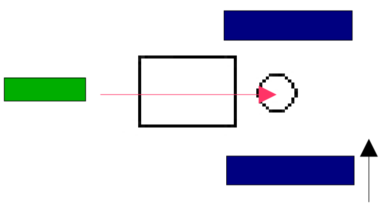
The results indicate that the Soft Colour Model best descibes the D0 Data. This theory models the exchange of a single gluon colour cancellation via further gluon emission.

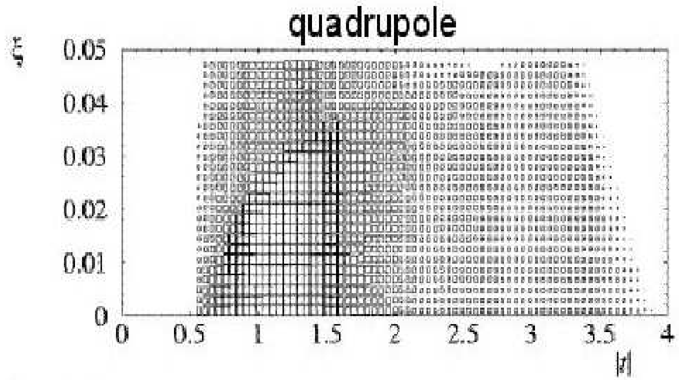
The Forward Proton Detector at Run–II

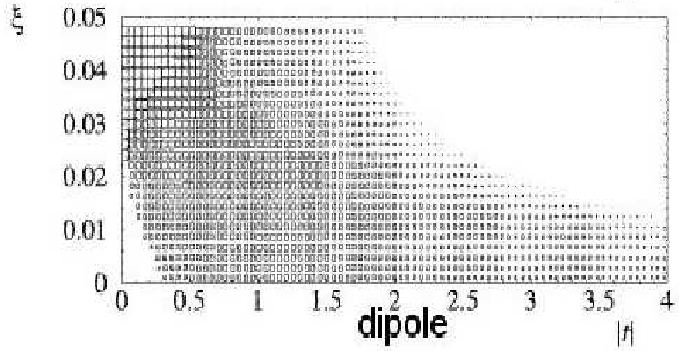


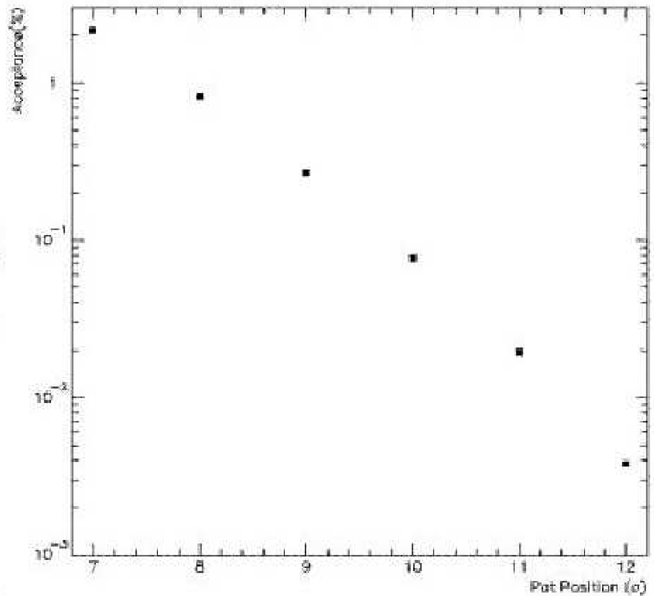
Quadrupole

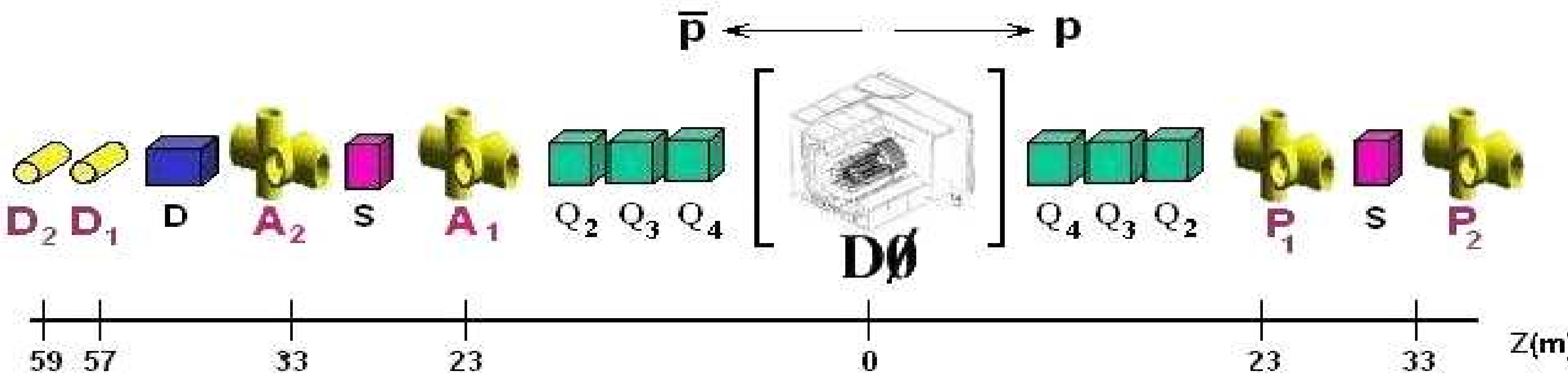
Dipole Castle



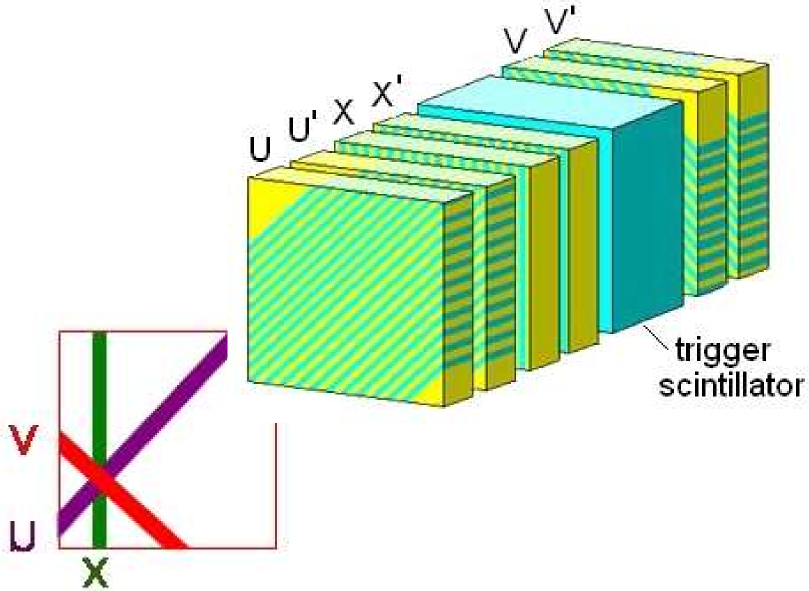








The Detectors used in the Roman Pots



800 micron fibres are joined into waveguides.

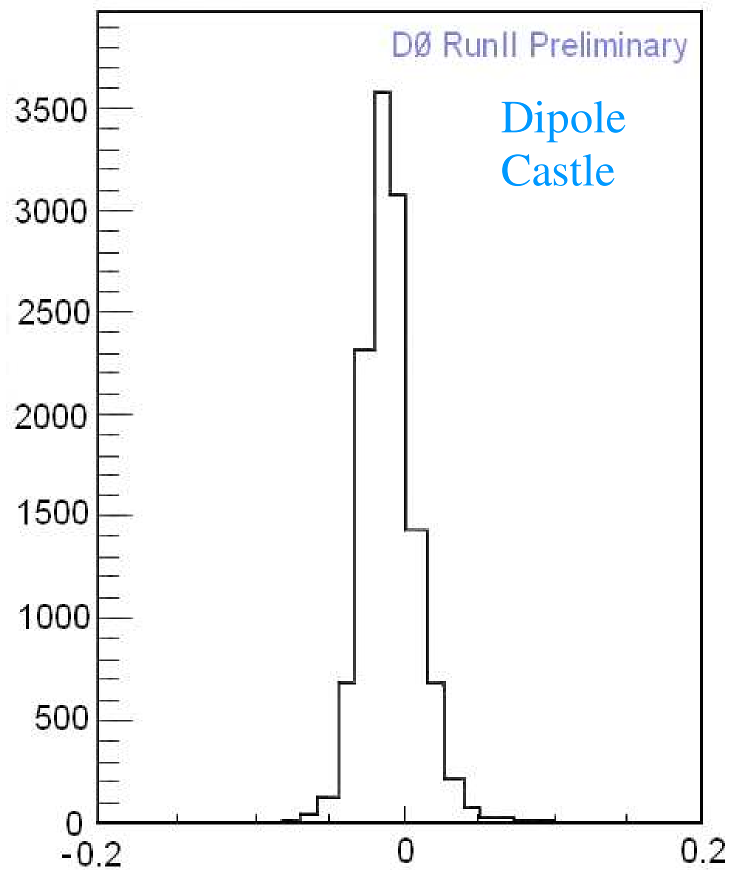
Gives 16 channels for each X plane and 20 for the diagonals.
Readout handled

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

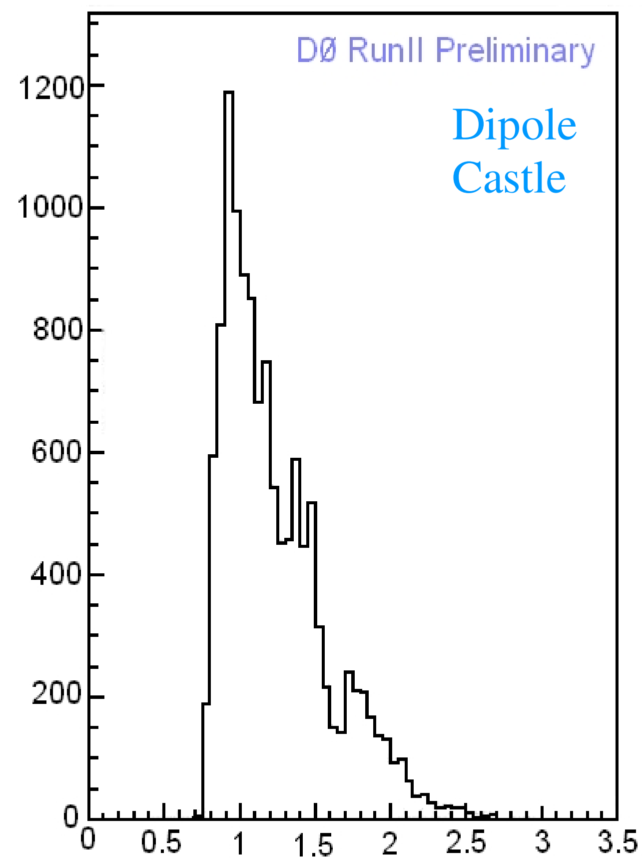
Readout with MAPT – 16 channel multi–anode photo–multiplier tubes

Comissioning of the Run−II Forward Proton Detector

Initial Results from the Forward Proton Detector



Pomeron Momentum Fraction



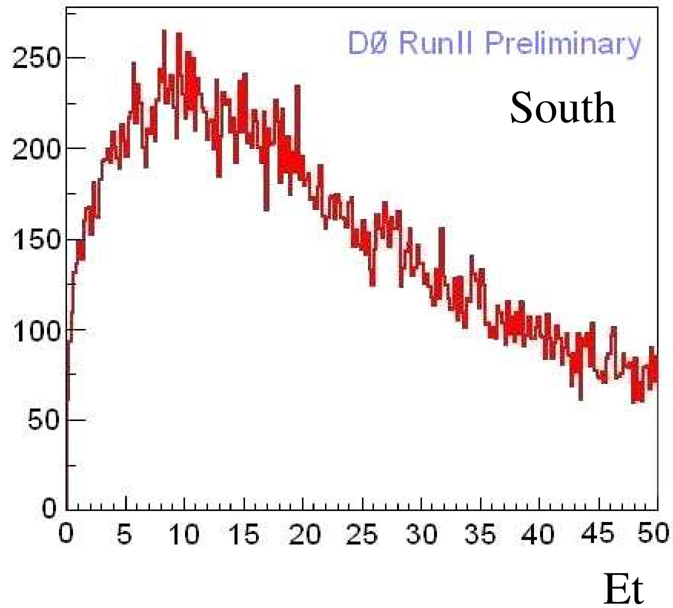
Mometum transfer to Pomeron

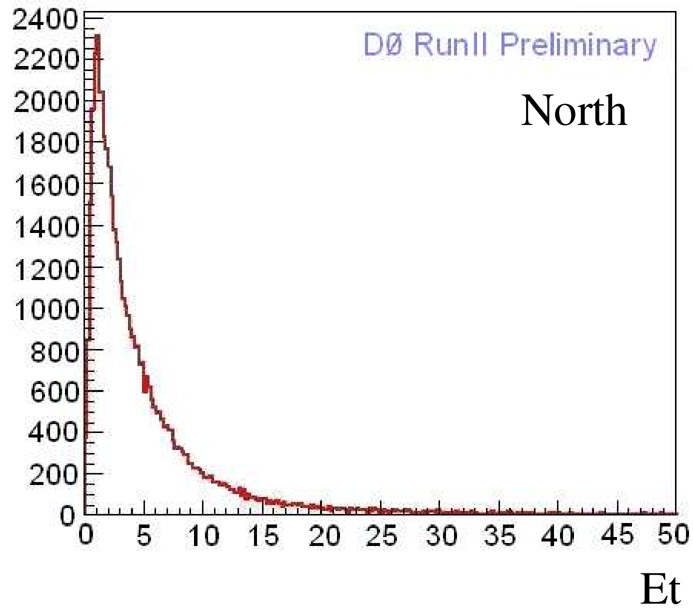
The FPD is currently been run in a comissioning standalone mode. Full integration with the D0 readout system will occur later this year.

Preliminary Diffraction Results at Run–II

Events were selected requiring (in this instance) that the luminosity counters fired only on the South side (gap requirement for N). Also require a jet > 25 GeV/c and impose quality cuts (>5 tracks, well defined Primary vertex).

Use scintillator coincidence requirement to improve quality for now.





Total of Cal 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 the Talk

Reserve Slide