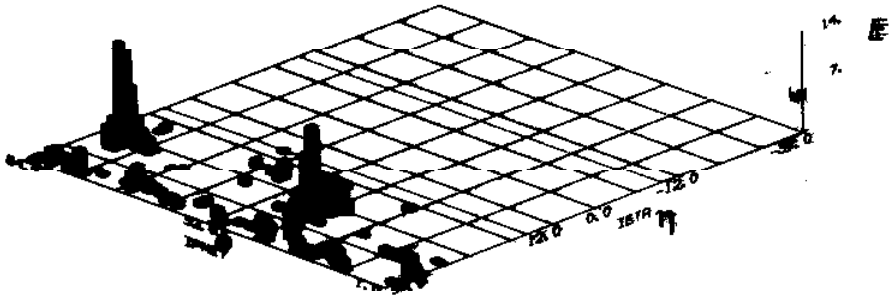
Hard Diffraction at DØ

Andrew Brandt
Fermilab

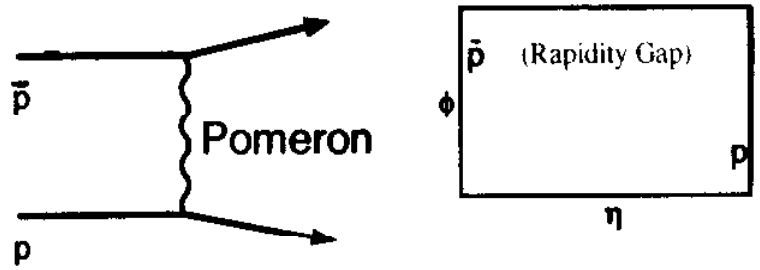


- Single Diffractive Jet Production
- Hard Double Pomeron Search
- Run II Forward Proton Detector

DIS '97
April 16, 1997
Chicago, IL

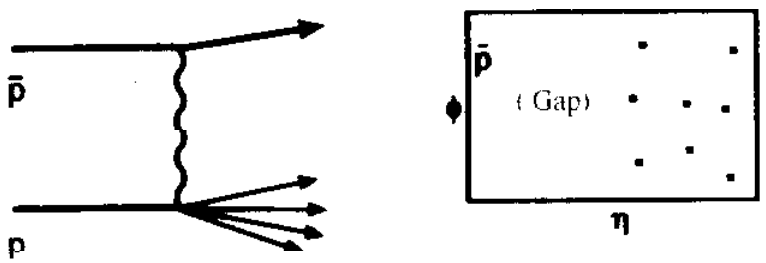
Rapidity Gaps and Color-Singlet Exchange

Soft Processes:



Elastic Scattering

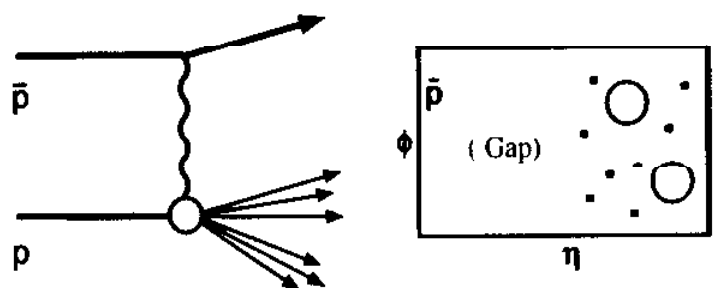
- *Measured by E710,CDF at 1800GeV*



Single Diffraction

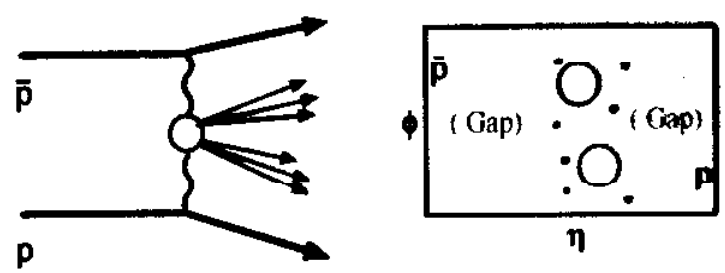
- *Measured by E710,CDF at 1800GeV*

Hard Processes (Jet production)



Hard Single Diffraction

- ***Observed by UA8 (630GeV), HERA (ep)***

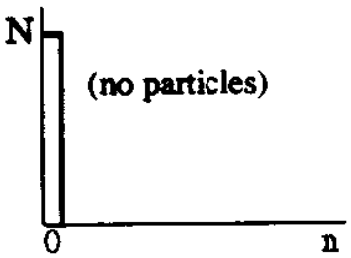


Hard Double Pomeron

- *UA1 observed **double** gap events*

Color-Singlet Signature → Rapidity Gaps

Color-Singlet | **Color Exchange** | Inclusive Multiplicity



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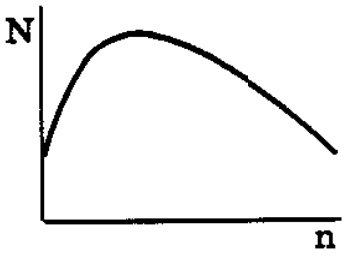

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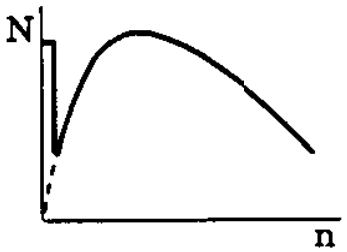


Fragmentation
Spectator Interactions
Detector Noise

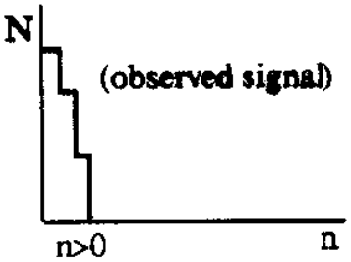
↓

Particle Detection Inefficiency

↓

Decreased S/B

↓



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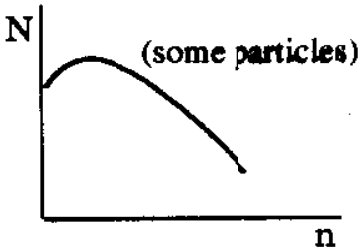

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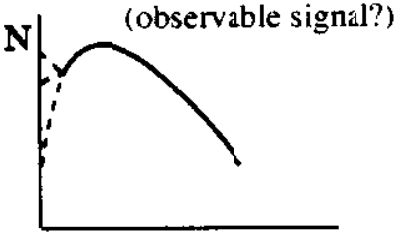
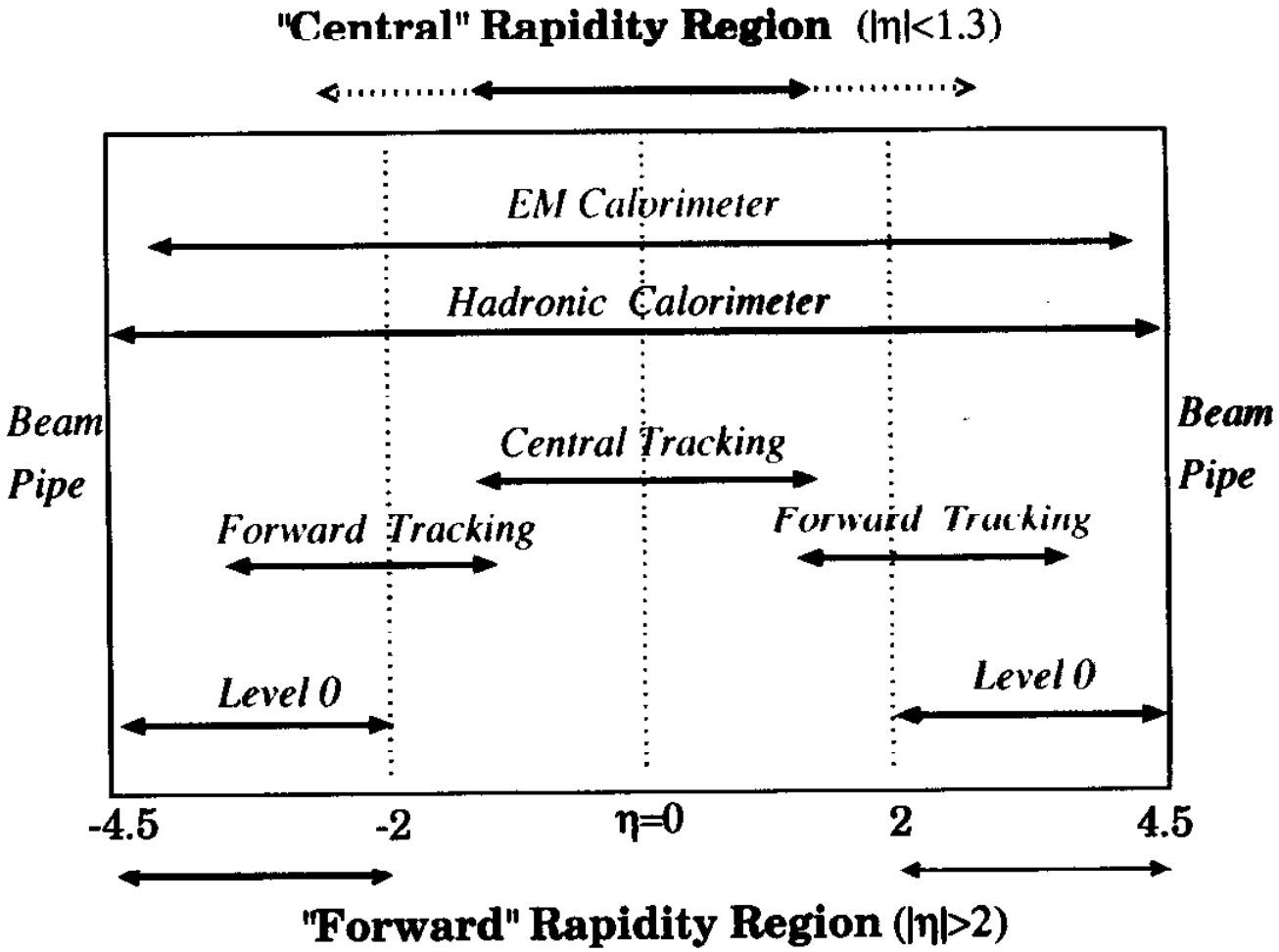


DØ Rapidity Coverage

(For jets and tagging particles; not to scale)



$n_{(D0)}$ ~ approximation to particle multiplicity

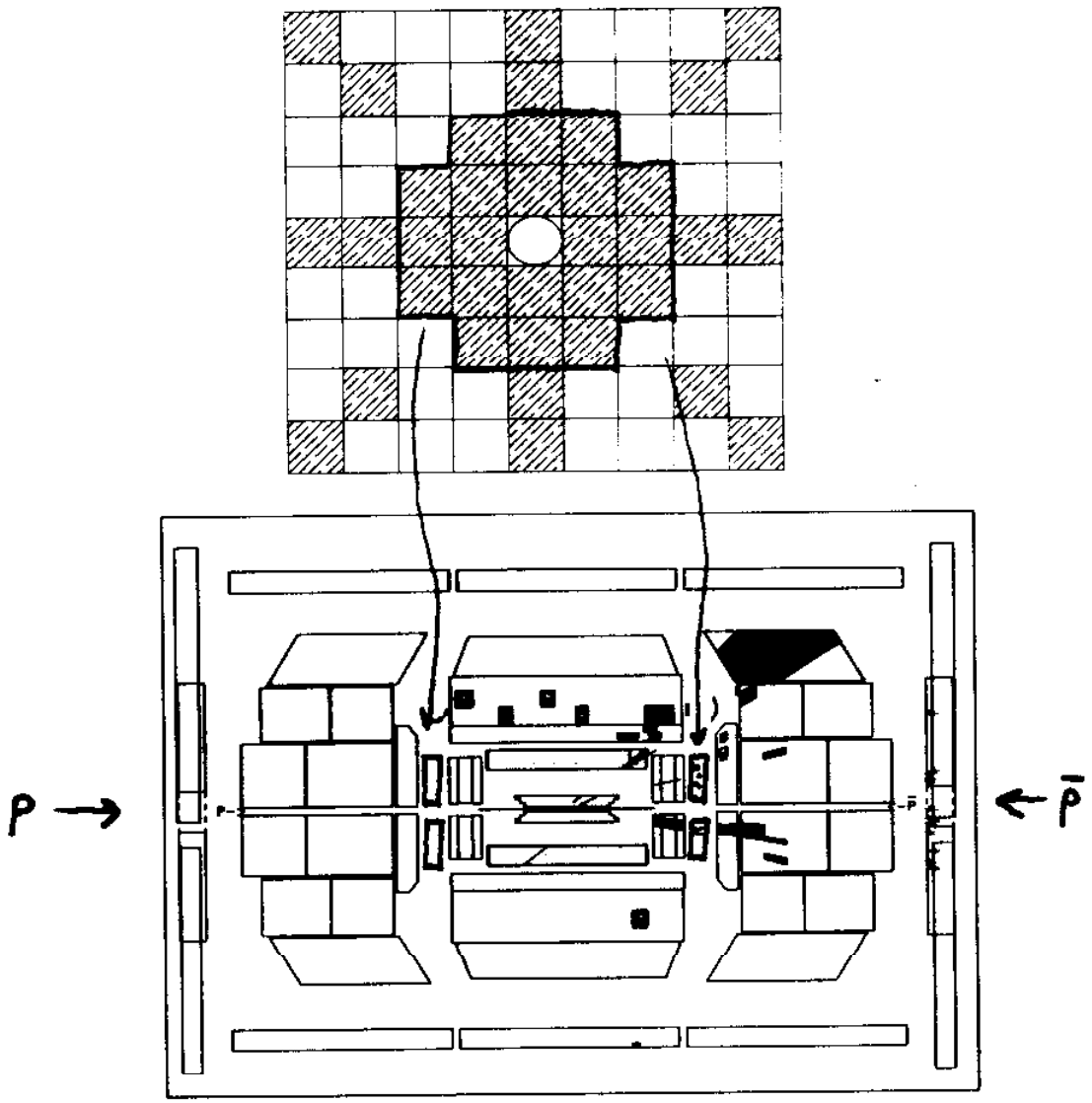
n_{EM} = # of EM towers with E_T(central), E(forward) > 200MeV

n_{HAD} = # of Hadronic towers w/ E_T>600MeV(cent), E>400MeV(fwd)

n_{TRK} = # of charged tracks(central), track-segments(forward)

n_{L0} = # of Level 0 scintillator tiles hit

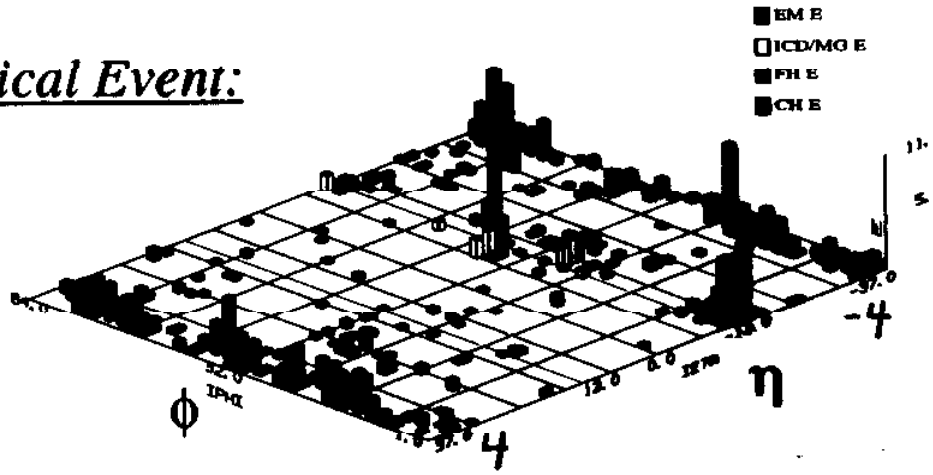
Level 0 (LØ)



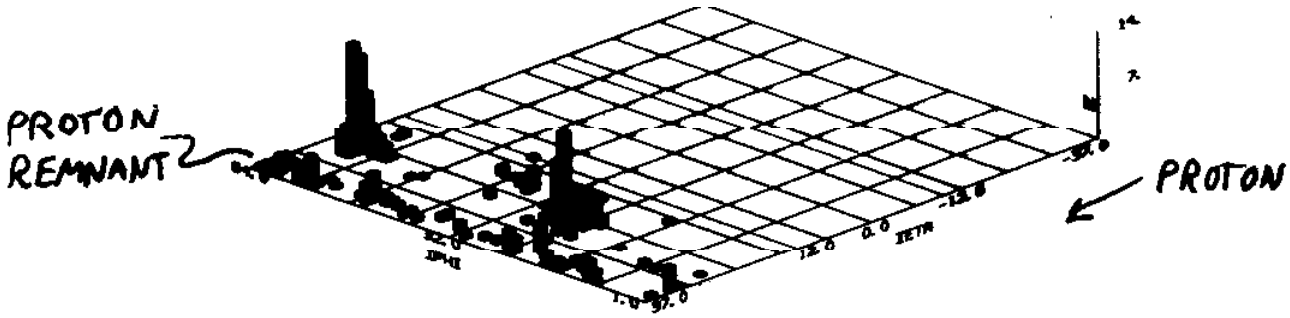
- Typically used in D-Zero triggers to tag inelastic scattering
- Can be ignored for inclusive trigger
- Used as a veto for triggering on Single Diffractive and Double Pomeron Exchange topologies

DØ Dijet Events: η–φ Legos

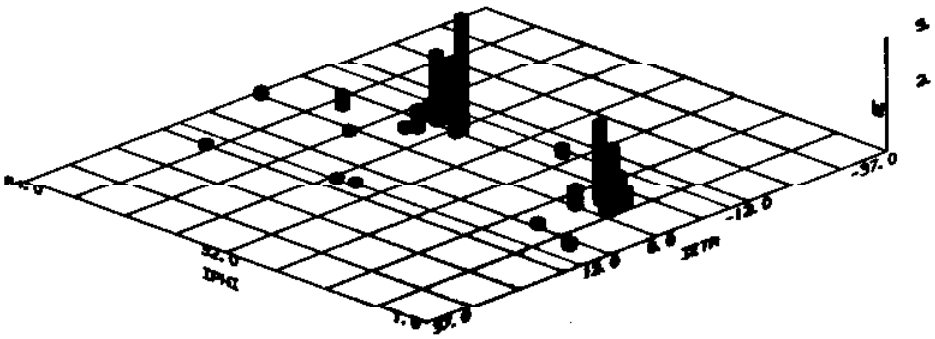
Typical Event:



HSD topology:

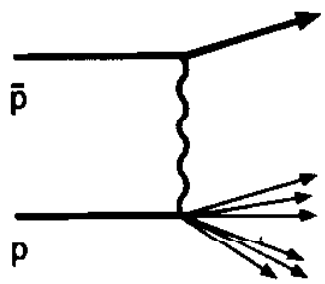


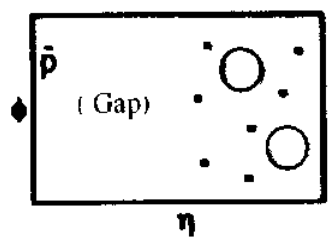
HDPE topology:



Hard Single Diffraction

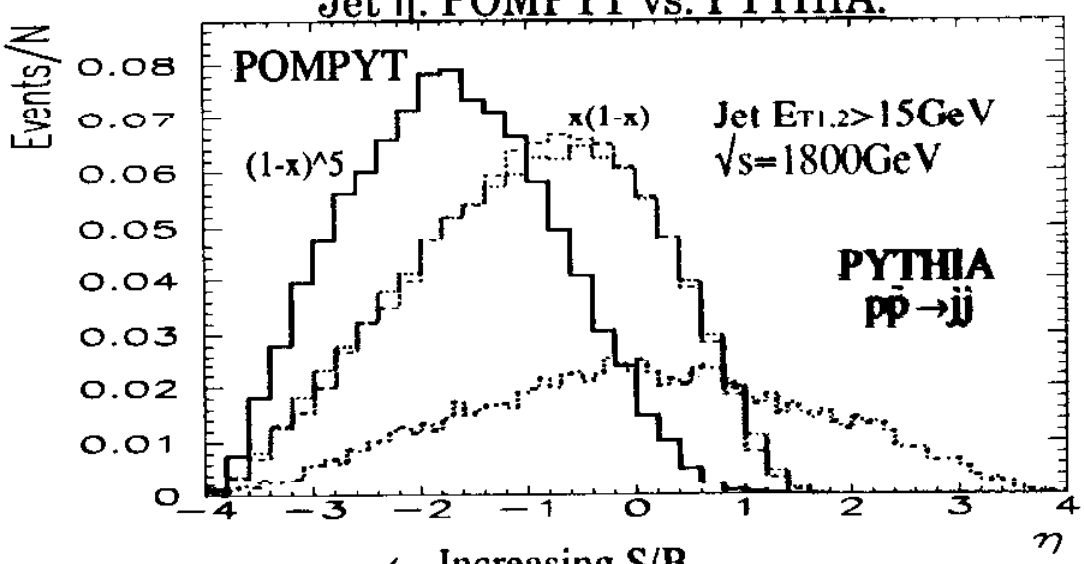
$$p\bar{p} \rightarrow p\ (or\ \bar{p}) + jj$$





- Model pomeron exchange by POMPYT (Bruni+Ingelman)
  - Choice: 2 gluon or 2-quark pomeron structure, xG(x) ~ x(1-x)
    Also soft gluon structure, xG(x) ~ (1-x)^5
  - Pomeron has <~ 5% of (anti-)proton momentum
- Expect boosted jets for SD:

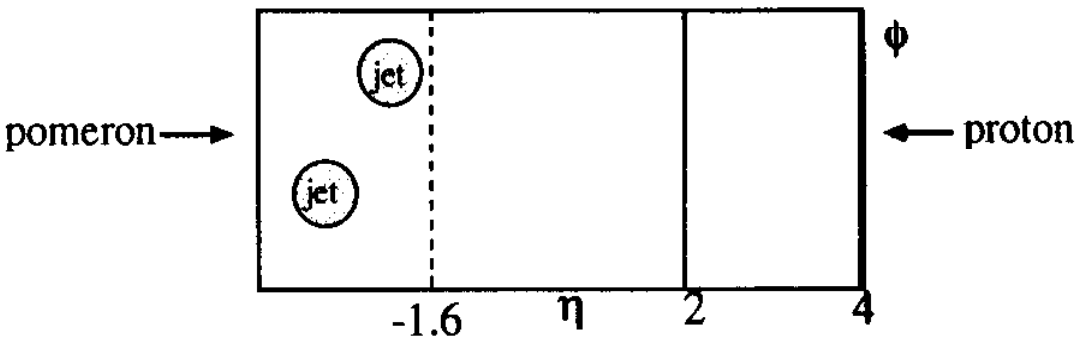
Jet η: POMPYT vs. PYTHIA:

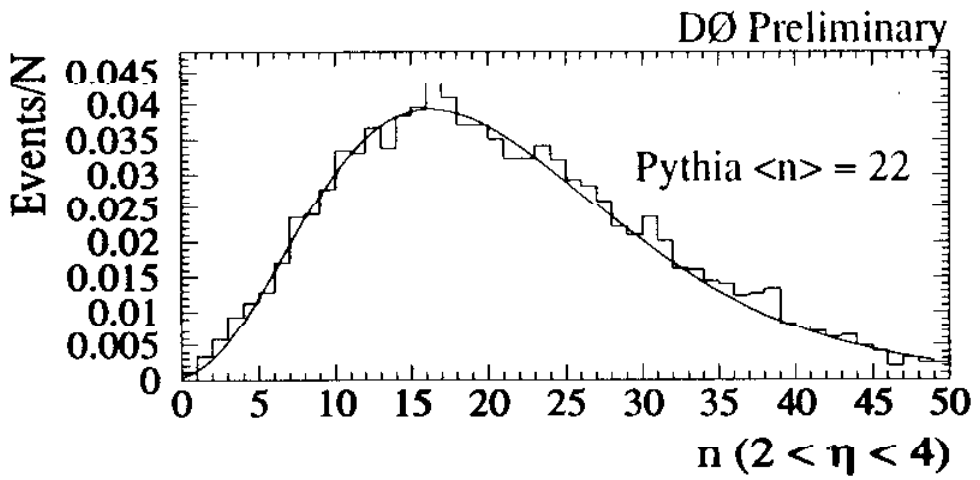


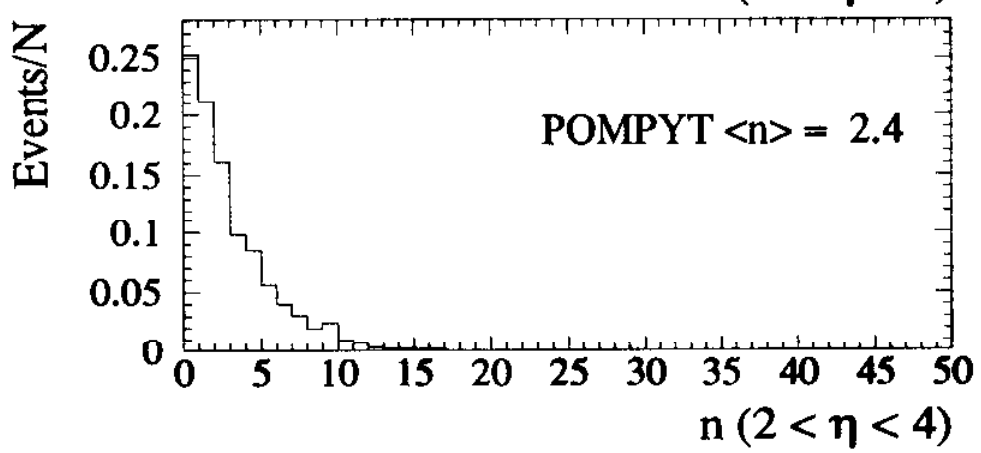
← Increasing S/B

Monte Carlo Multiplicity

2 jets: $E_T > 12$ GeV, $\eta < -1.6$

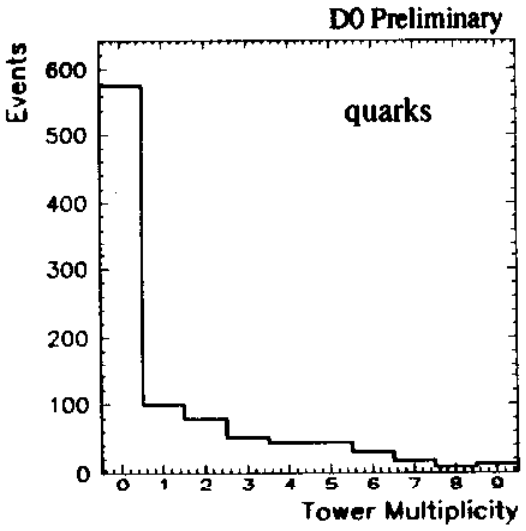






MC Gap Efficiency

After detector simulation:



- Only those in the "0" bin are tagged as rapidity gaps.
- To calculate true cross-section, need to know the tagging efficiency.

→ ε_{gap}

Then $\sigma(\text{true}) = \sigma(\text{gap})/\varepsilon_{gap}$

	Soft Gluons	Two Gluons	Two Quarks
1800 GeV	23%	76%	56%

D0 Preliminary

- ε_{gap} varies widely between models
- Compare to data to possibly narrow model choice

ARTICLE

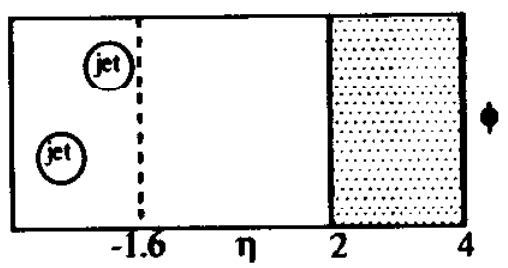
Same-side Jet Data Samples

Trigger: 2 jets, $E_T > 12$ GeV, $|\eta| > 1.6$, and $\eta_1 \bullet \eta_2 > 0$

Cuts	1800GeV	630GeV
• None	56000	57000
• 2 'good' jets $\lvert\eta_{1,2}\rvert>1.6$, $\eta_1 \bullet \eta_2>0$	37000	38000
• $E_{T1,2} > 12$ GeV	35000	21000
• Single interaction	25000	12000
• Future Statistics	5×	2-3×

Method:

Search for hard single diffraction → plot multiplicity on side opposite dijets



→ n_{EM} = # of EM towers with E > 200MeV

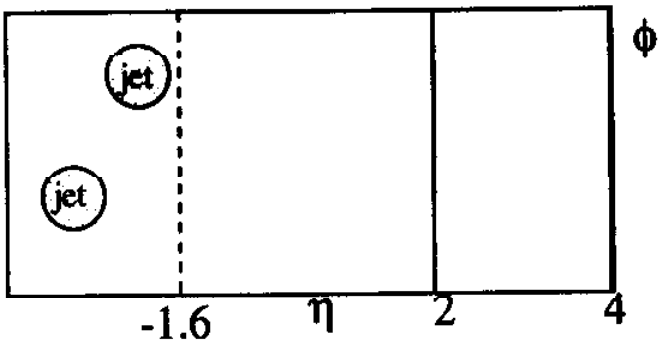
n_{HAD} = # of Hadronic towers with E>400MeV

n_{TRK} = # of track-segments

n_{L0} = # of Level 0 scintillator tiles hit

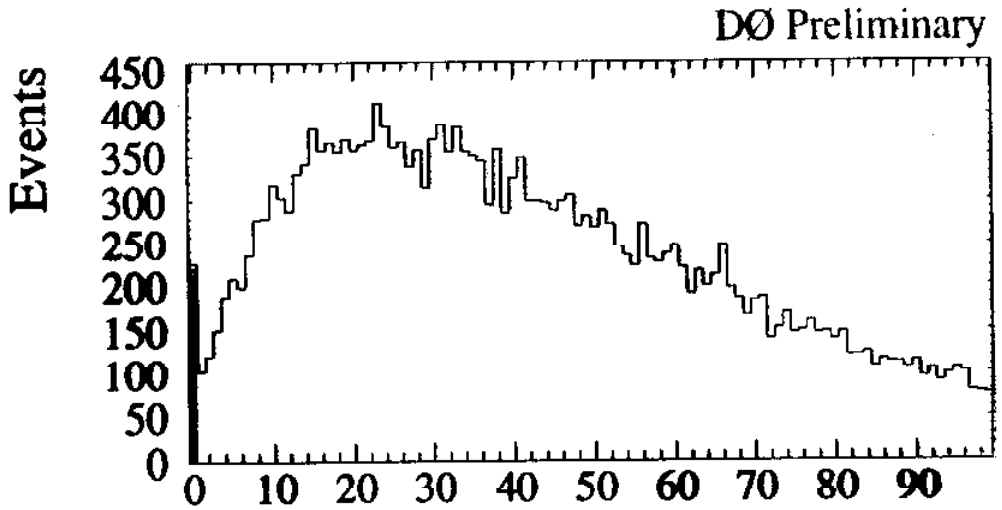
Calorimeter Multiplicity

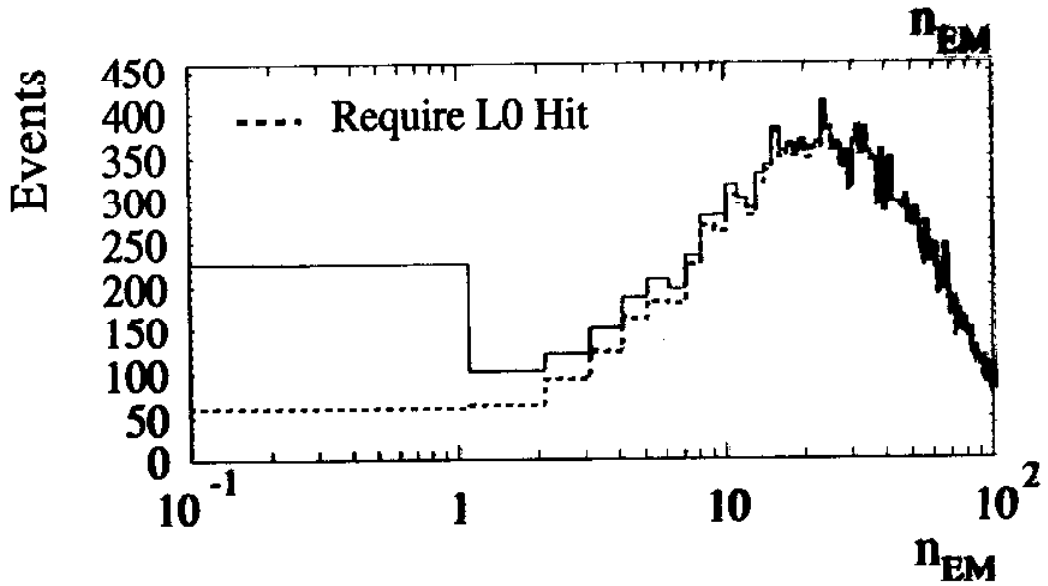
$\sqrt{s}$ = 1800 GeV



2 jets: $E_T > 12$ GeV

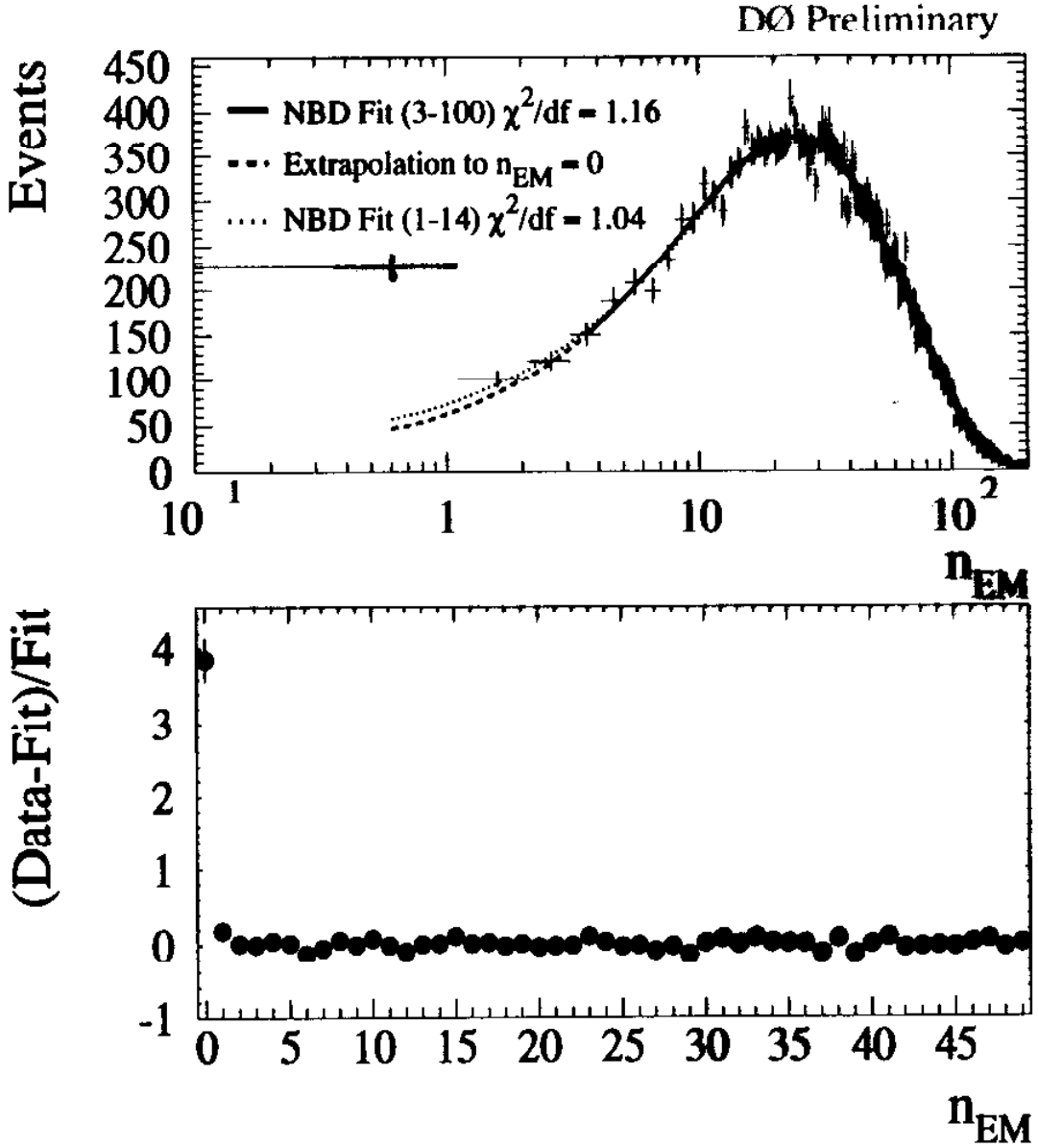
$|\eta| > 1.6$, $\eta_1 \cdot \eta_2 > 0$





Calorimeter Multiplicity with Fit

$\sqrt{s}$ = 1800 GeV

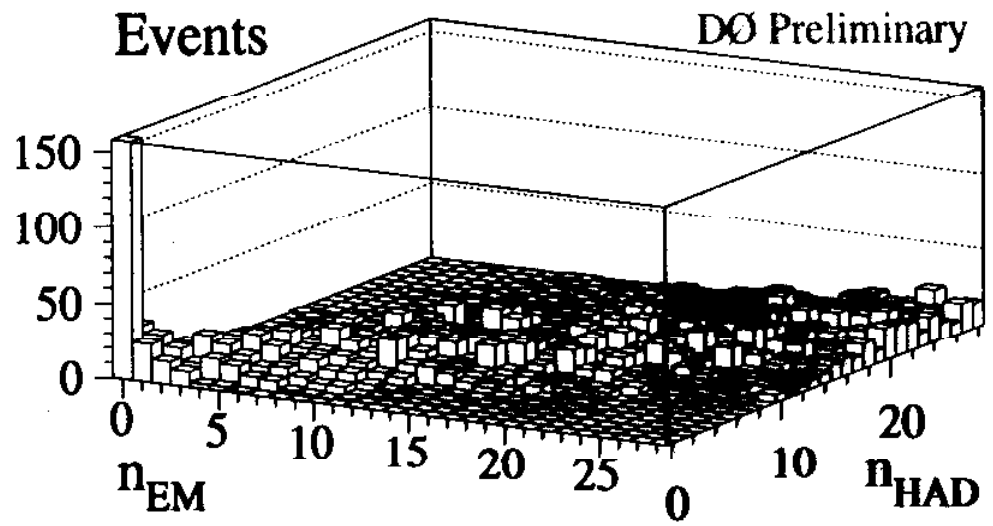


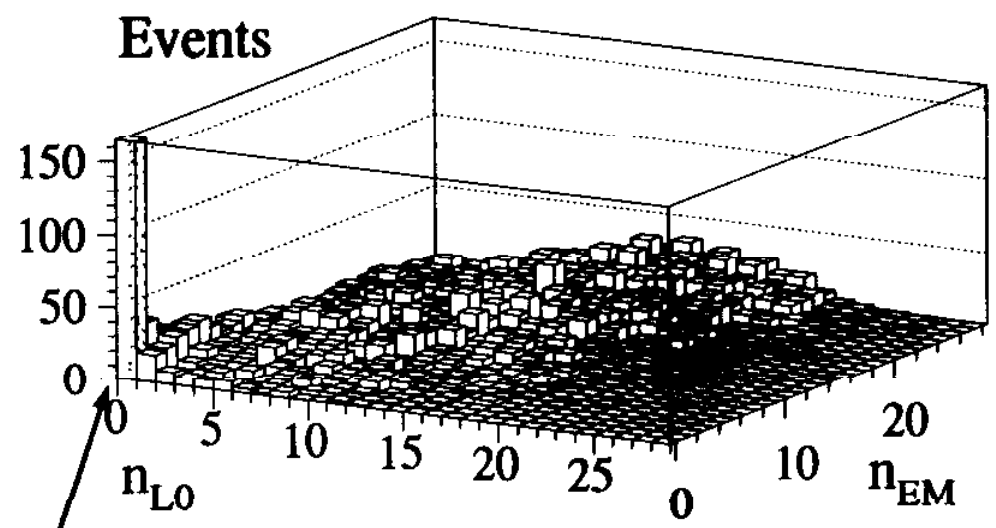
f = (Data(0) - Fit(0)) / N = (0.67 ± 0.05) %

Error = Statistical + Error on extrapolation

Multiplicity Correlations

$\sqrt{s}$ = 1800 GeV

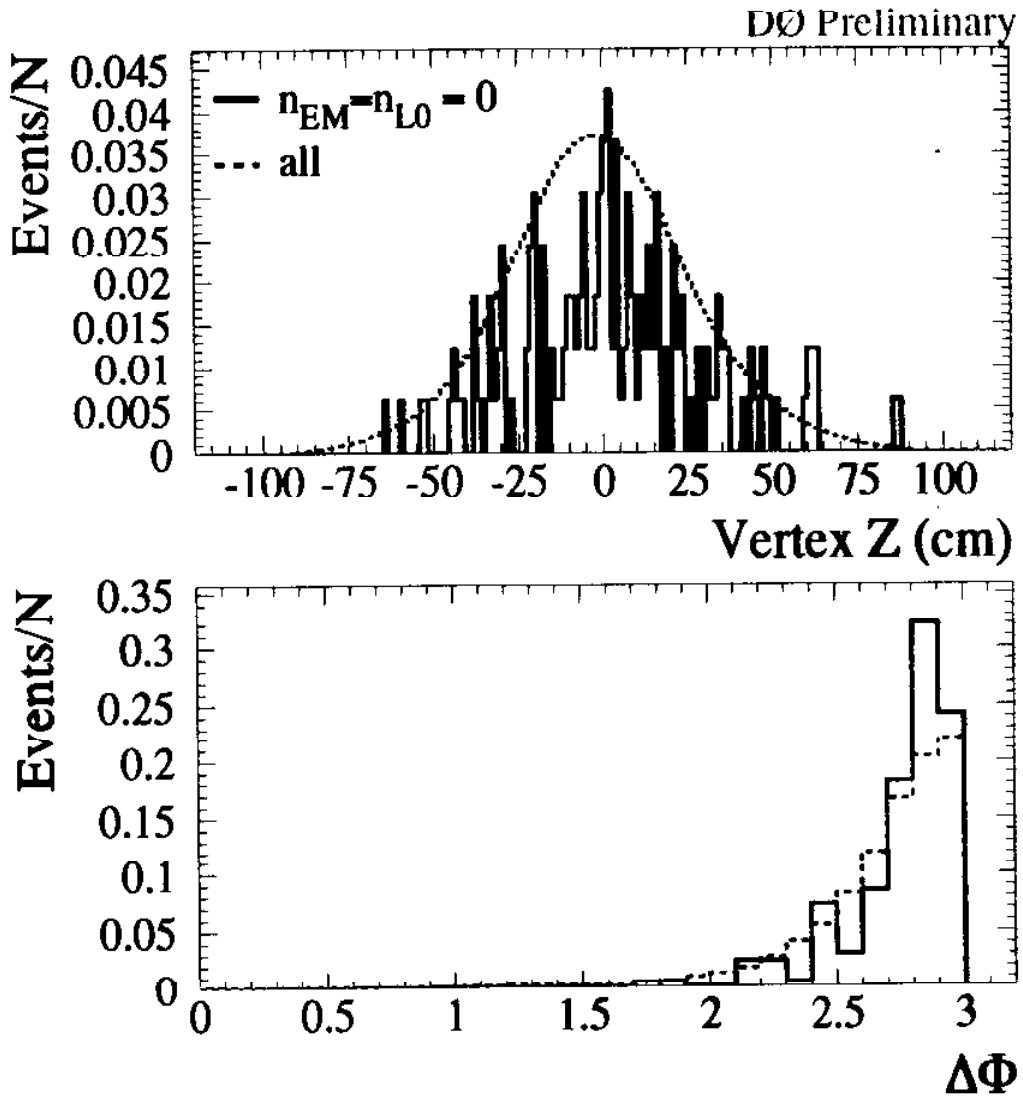




Hard SD Candidates $n_{EM} = n_{L0} = 0$

Event Characteristics

$\sqrt{s}$ = 1800 GeV

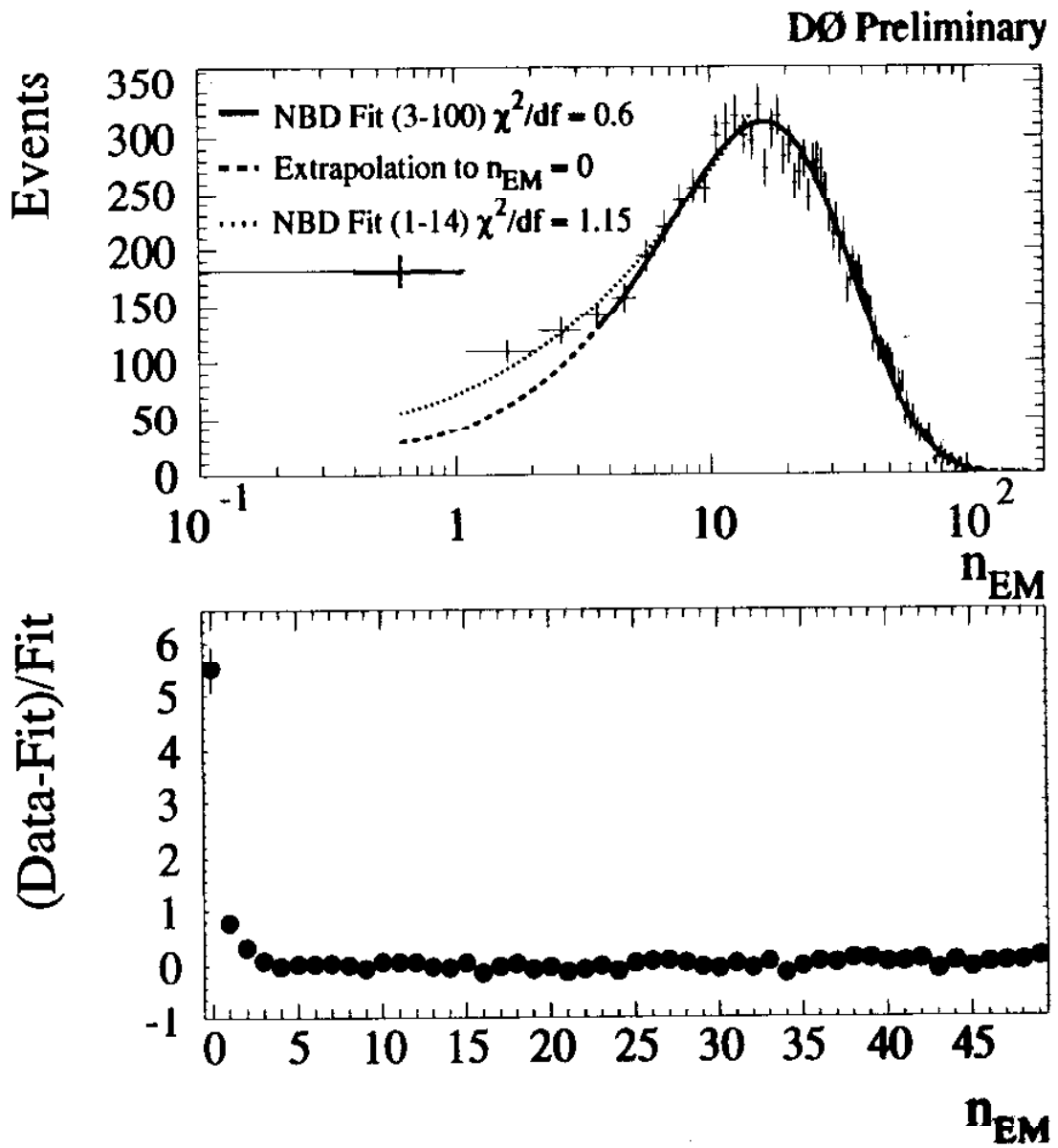


Jets in diffractive candidate events are well behaved in all variables and show typical transverse and longitudinal development

➡ Gap events contain good jets

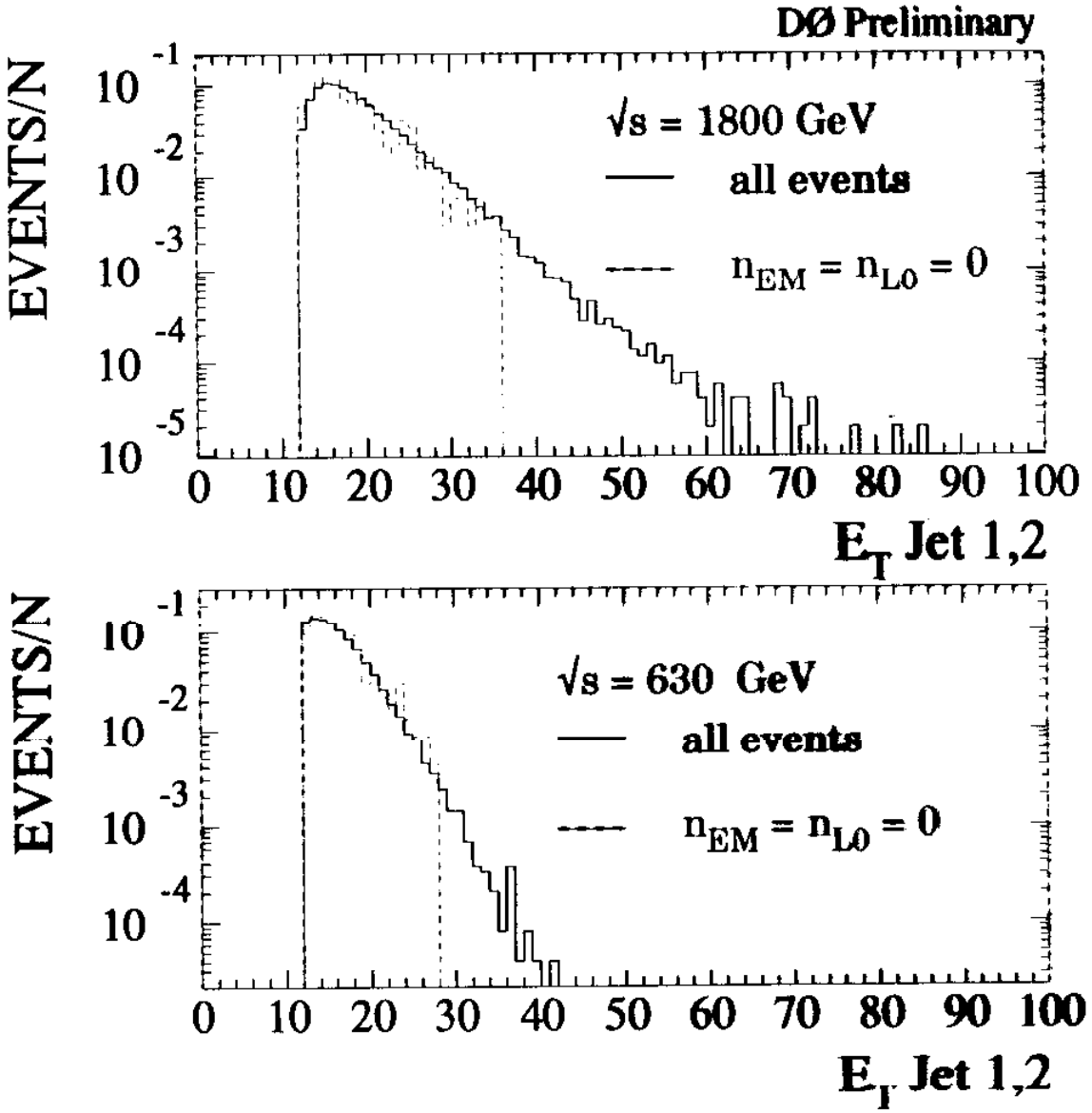
Calorimeter Multiplicity with Fit

$\sqrt{s} = 630$ GeV



Excess ~ 1 - 2 %

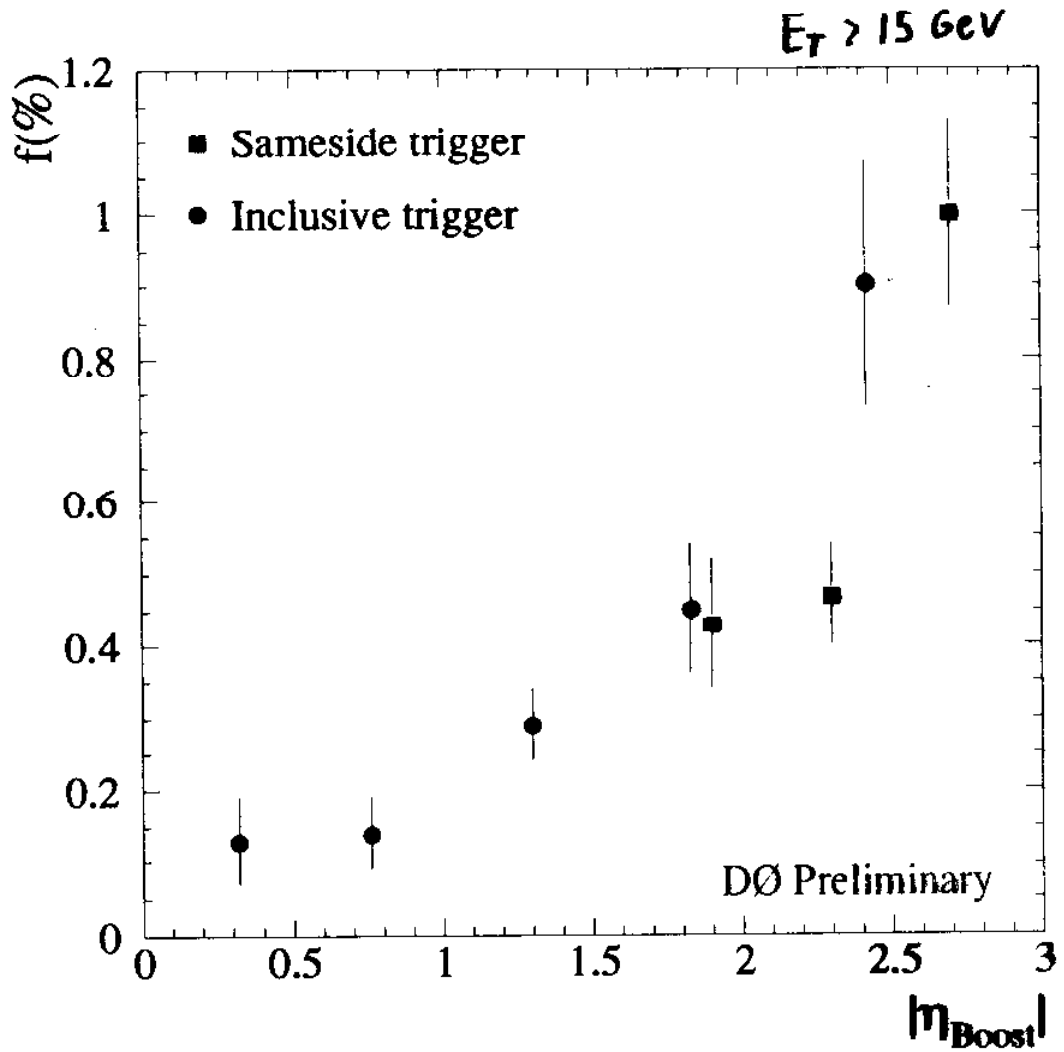
Jet E_T: $\sqrt{s}$ = 630 GeV and 1800 GeV



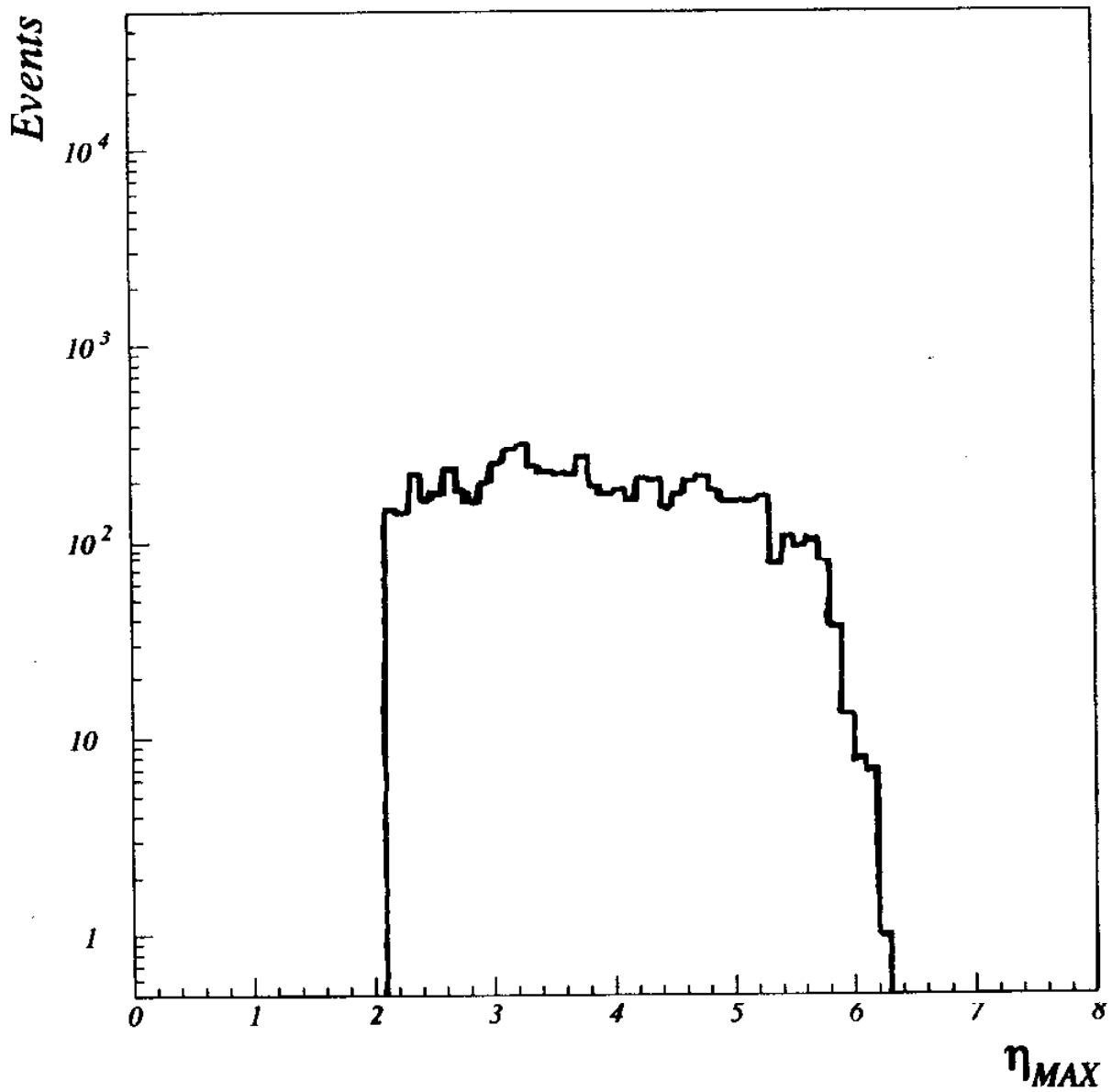
Excess vs η_{Boost}

$\sqrt{s}$ = 1800 GeV

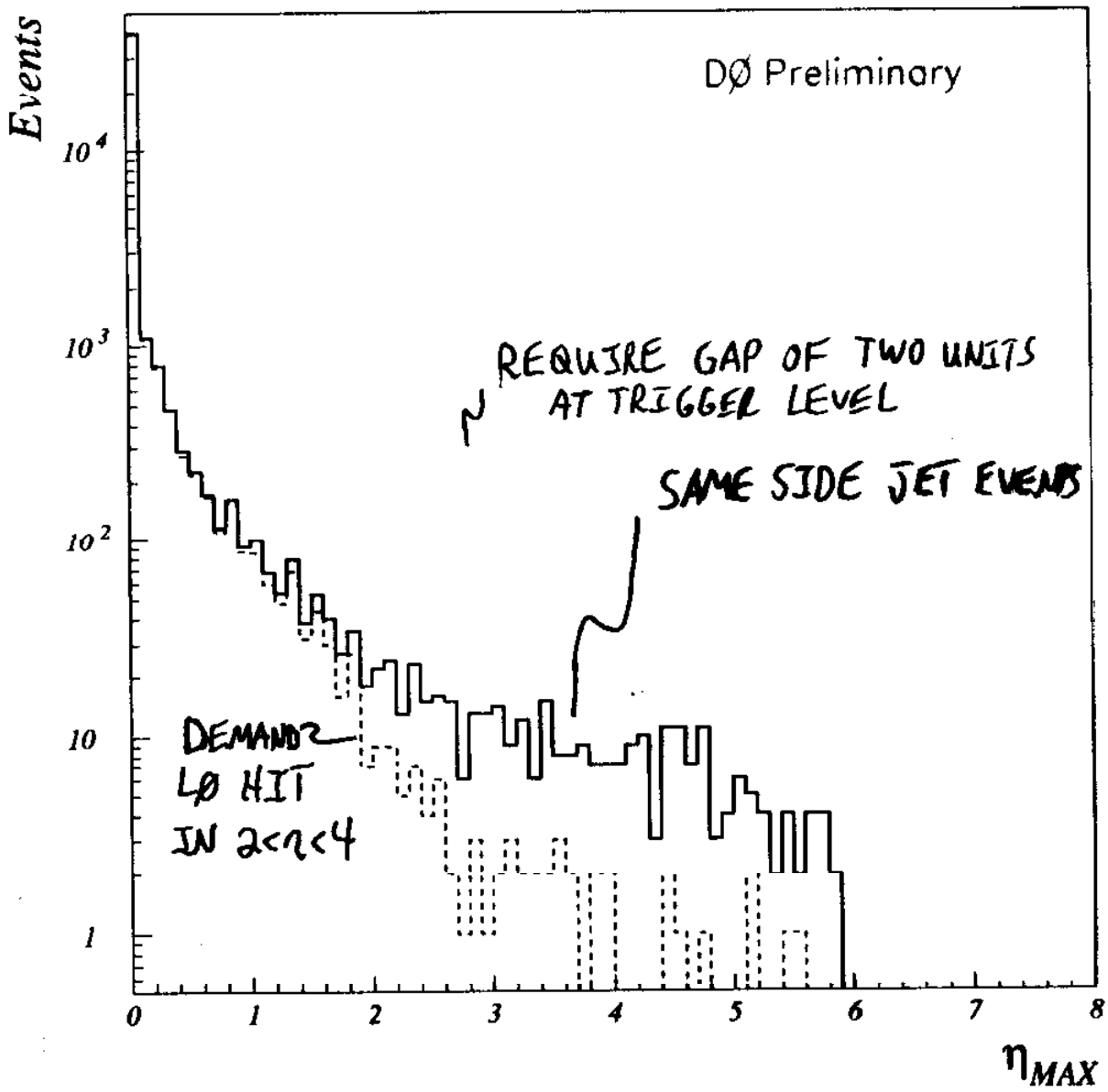
$$\eta_{Boost} = (\eta_1 + \eta_2)/2$$

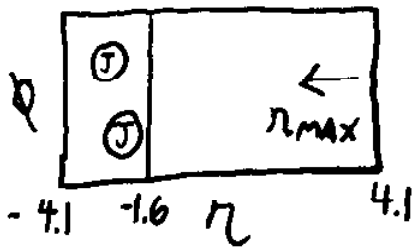


- Excess increases with increasing η_{Boost}
  - $\Rightarrow$ Qualitatively consistent with expectations from hard diffraction


Events
10^4
10^3
10^2
10
1
0
1
2
3
4
5
6
7
8
η_{MAX}

SIZE OF RAPIDITY GAP

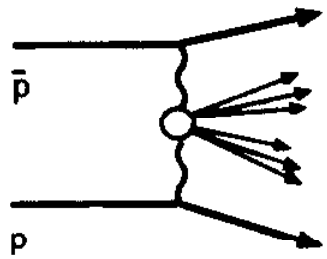




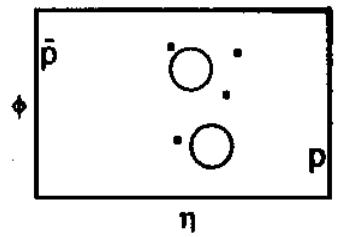
$\eta_{MAX} = 0 \Rightarrow$ NO GAP

$\eta_{MAX} \gg 0 \Rightarrow$ LARGE GAP

Hard Double Pomeron Exchange



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



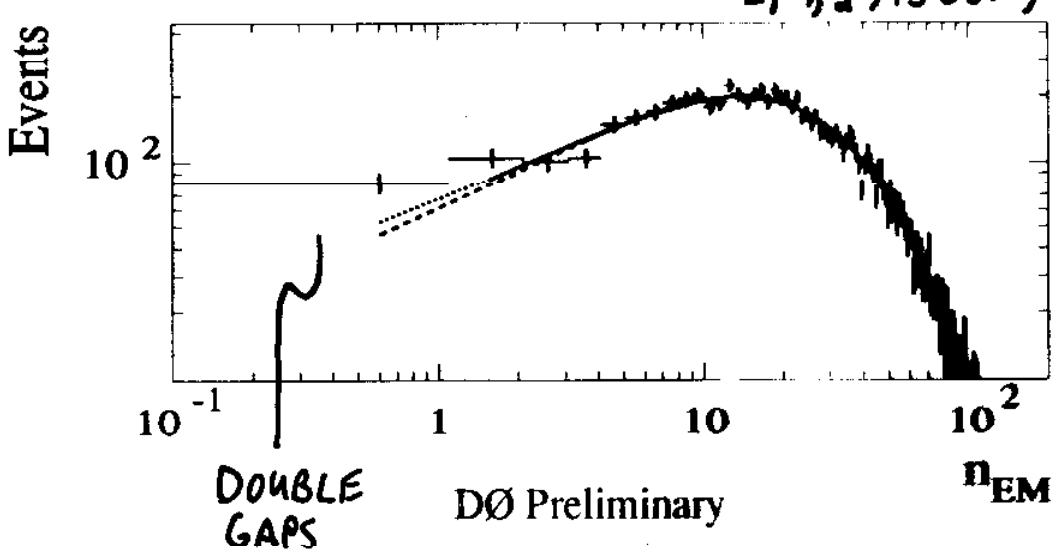
★ Single Gap Trigger: Inc Jet Trigger + one-side $n_{L0}=0$

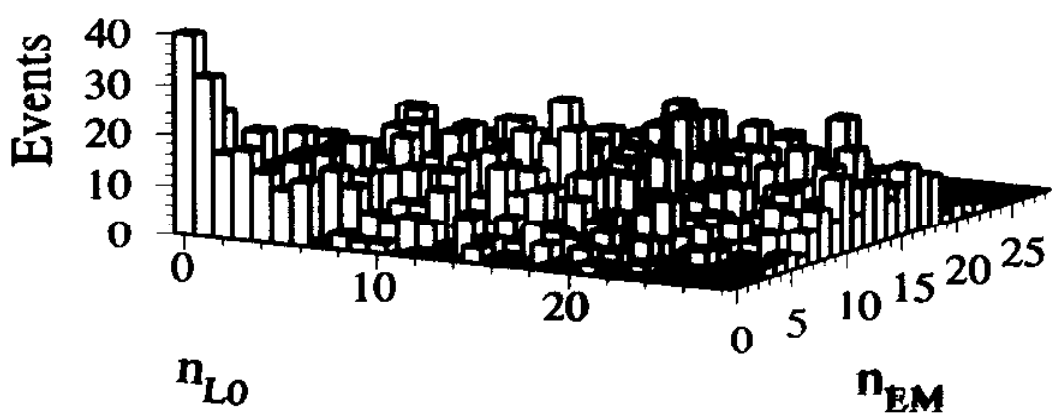
→ Enhance SD statistics: 40k events

→ Search for Double Pomeron Exchange

• Demand $n_{EM}=n_{L0}=0$ one side, plot opposite-side:

$E_{T\,1,2} > 15$ GeV ; $|\eta_{1,2}| < 1$





Hard Double Pomeron Cross Section

Theory Predictions:

- For 2 Jets, $E_T > 15$ GeV, $|\eta| < 1$
  - Inclusive jets: $\sigma_{INC} \sim 10\ \mu b$ (LO Theory, PYTHIA)
  - HDPE Signal: $\sigma_{\mathbb{P}\mathbb{P}} = 40$ nb (Collins & Berera)
  - $\gamma\gamma$ Background: $\sigma_{\gamma\gamma} \sim 50$ fb (Drees)

Experimental determination:

$$\sigma_{\mathbb{P}\mathbb{P}} = \sigma_{INC} * f_{SD/INC} * f_{DP/SD}$$

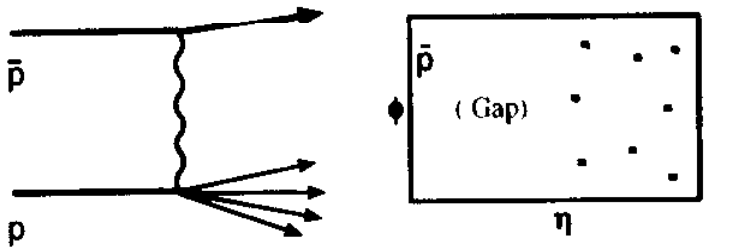
$f_{SD/INC}$ = Excess measured in Inclusive Sample

$f_{DP/SD}$ = Excess measured in Single Gap Sample

$$f_{SD\ INC} * f_{DP/SD} \sim O(10^{-6})$$ (DØ Preliminary)

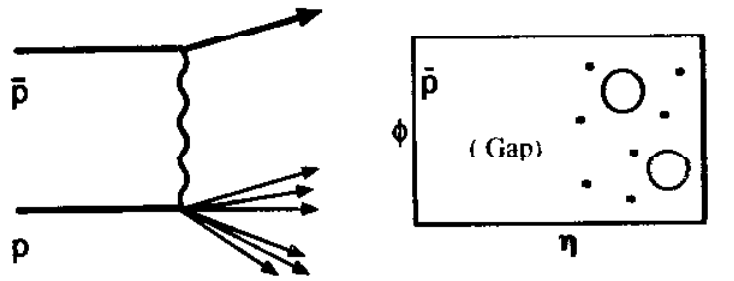
Physics Processes Measurable with the FPD

FPD ≡ FORWARD PROTON DETECTOR



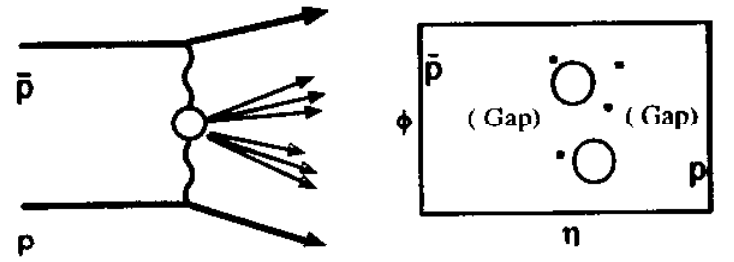
Single Diffraction (SD)

BACKGROUND
MONITOR
t - DEPENDENCE



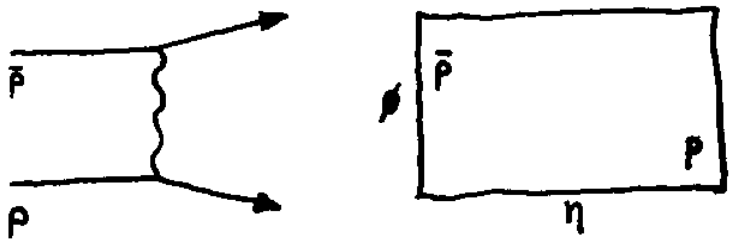
Hard Single Diffraction

DIFF JET $\sigma(\xi, t)$
DIFF W, J/ψ, $b\bar{b}$
POMERON STRUCTURE



Hard Double Pomeron

σ_{PP}
POMERON STRUCTURE
GLUEBALL SEARCH
NEW PHYSICS?



ELASTIC

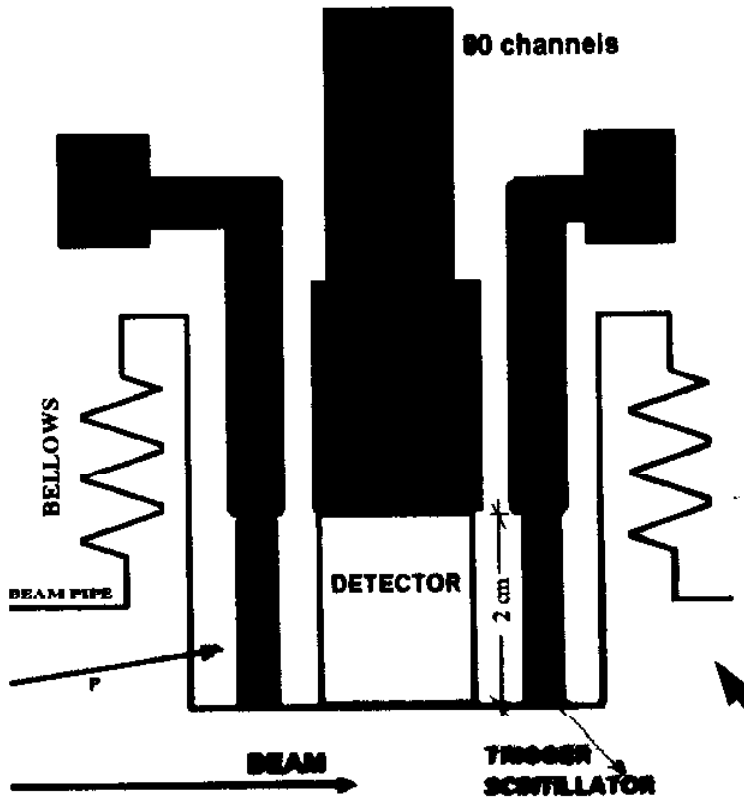
ALIGNMENT
LUM MONITOR
t - DEPENDENCE

WHY ADD FPD?

- DØ is GENERAL PURPOSE DETECTOR; adding Forward Proton Sub-Detector allows access to wide range of physics processes with modest resources.
- Interest in Hard Diffraction growing dramatically, due to recent results from HERA, CDF and DØ
- For next 10 years much of this physics ***can only be done at Tevatron*** (Need large $\sqrt{s}$)
- Some processes well-established, but not accurately measured (Diffractive dijet),
- Others likely exist (Hard Double Pomeron) but not yet observed.
- Chance for new physics:

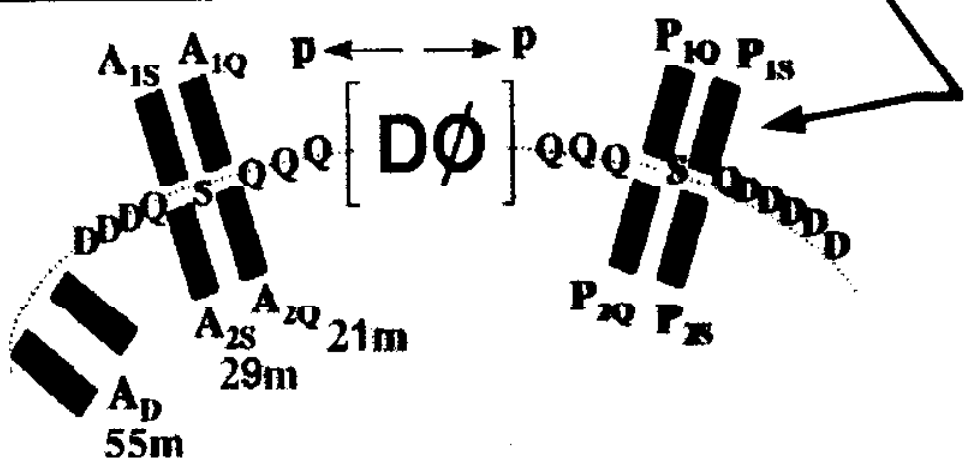
  Centauros, Disoriented Chiral Condesates, Glueballs, Higgs,...

FORWARD PROTON DETECTOR



POT

Spectrometer layout



4 quadrupole spectrometers: $t_{min} > 0.4$ GeV^2

1 dipole spectrometer : $\xi > 0.04$

Hard Diffraction Summary

- Striking rapidity gap signal opposite same-side dijets at $\sqrt{s} = 1800$ and $\sqrt{s} = 630$ GeV
- Excess increases with increasing η_{Boost}
- Double gaps observed at $O(10^{-6})$ of inclusive jet events
- Systematics and Pomeron structure studies underway
- For Run II propose addition of Forward Proton Detector