‘Rapidity Gap’ Physics at

S. Levonian,
representing H1 collaboration

1. Introduction
2. Experimental Environment
3. Rapidity Gap Events in
   - Photoproduction
   - DIS
4. Diffractive Contribution to F_2

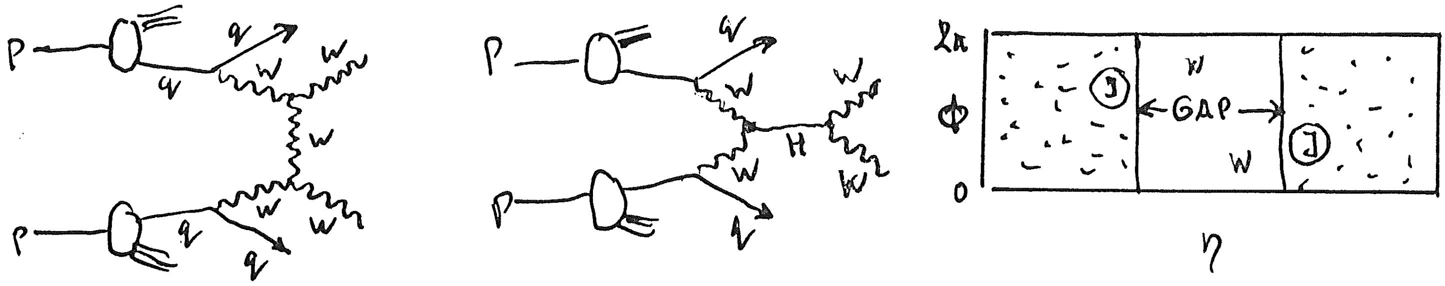
Mini-school ‘Diffraction at HERA’
DESY, Hamburg, 5. May. 1994

"HEP of the 21-st century will be a rapidity gap physics"

(Unknown Author)

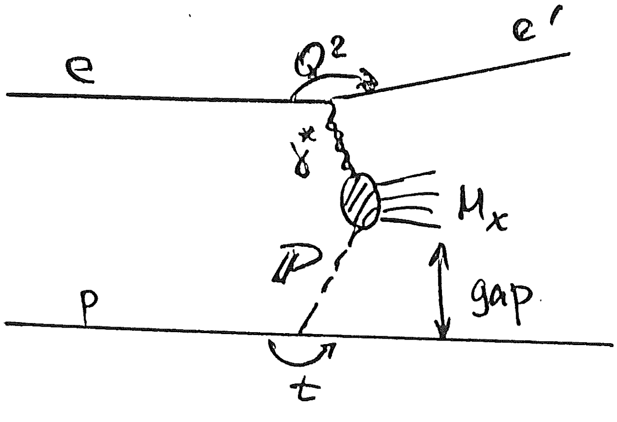
There could be various reasons for the rapidity gaps!

① J.D. Bjorken:



NOT in this talk ! (wait for 21-st century...)

② Diffractive processes:



THE TOPIC TODAY

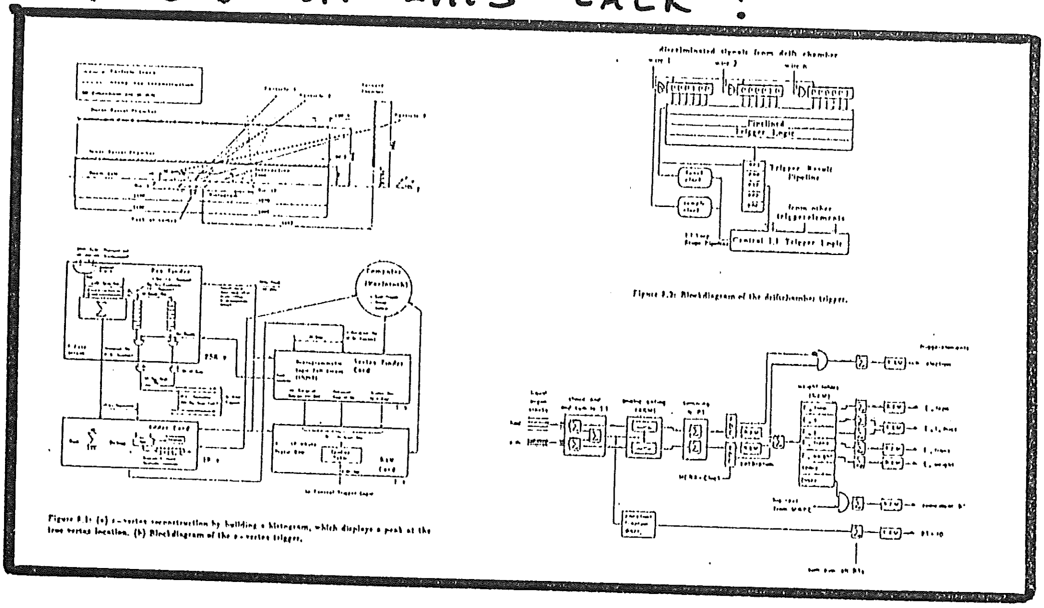
(and background for 21st century HEP ?)

③ Other processes:

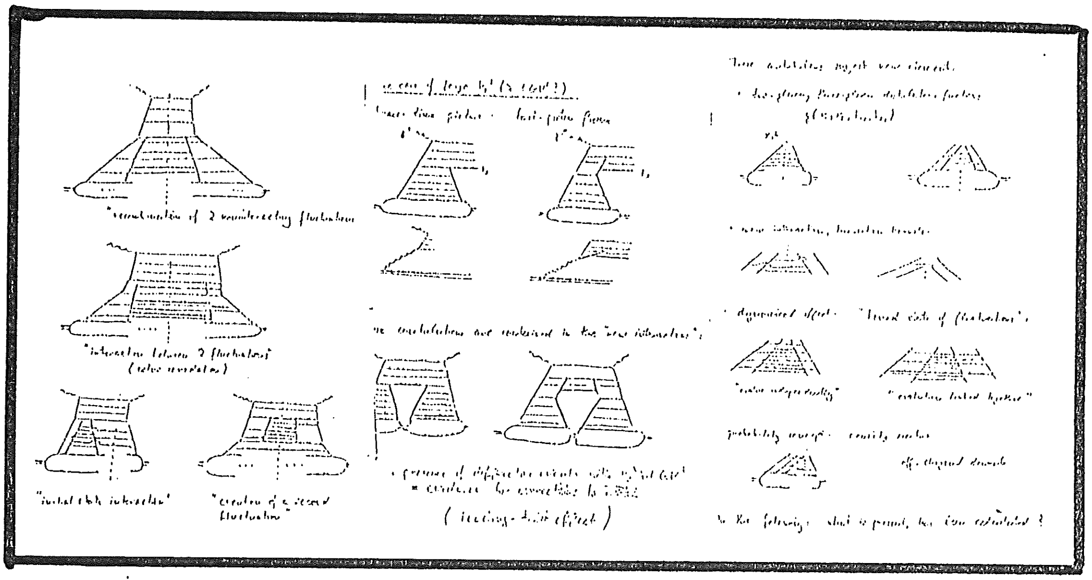
- π-exchange , . . .
- statistical fluctuations
- . . .

(Background for us)

NOT in this talk!

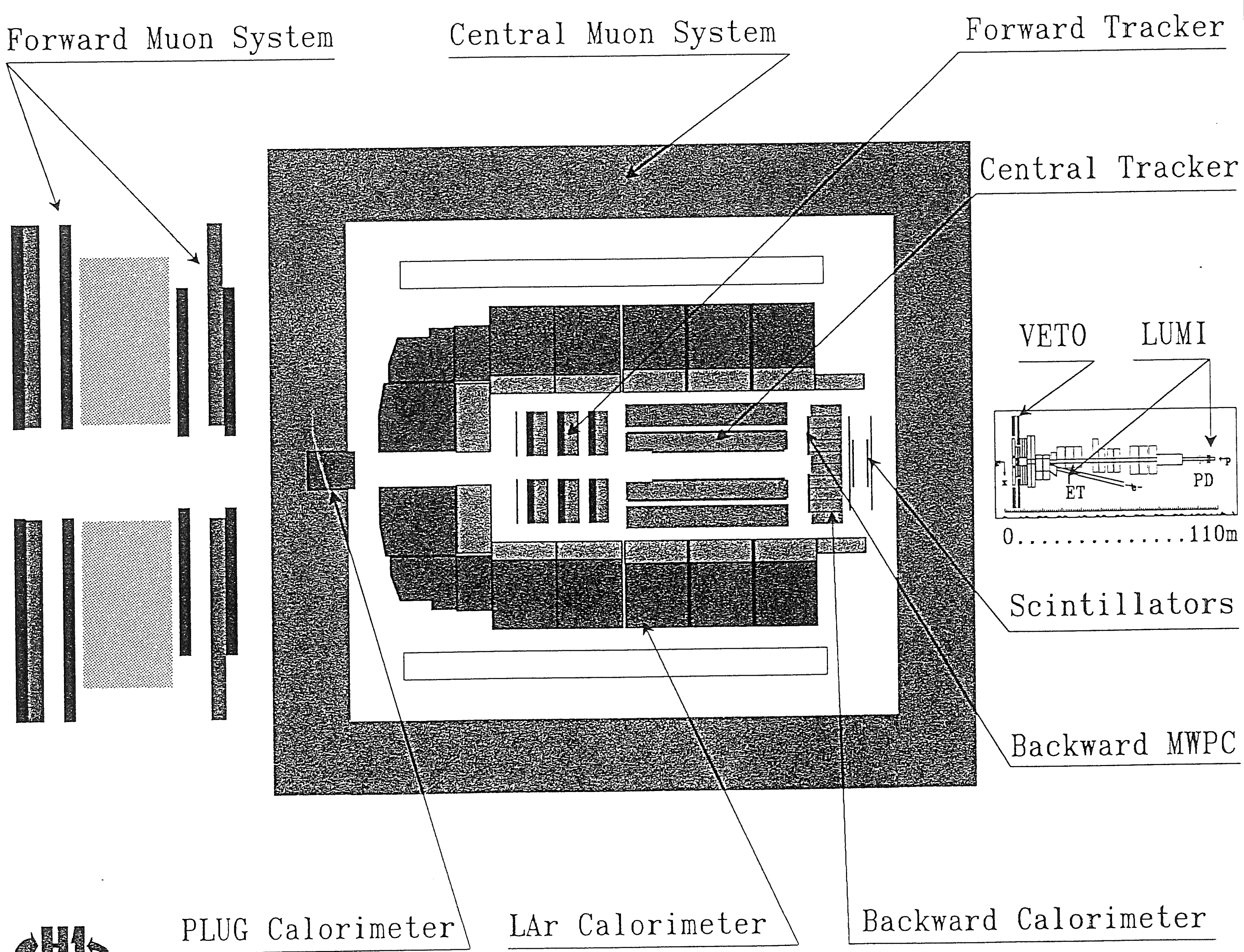


PRELIMINARY RESULTS!

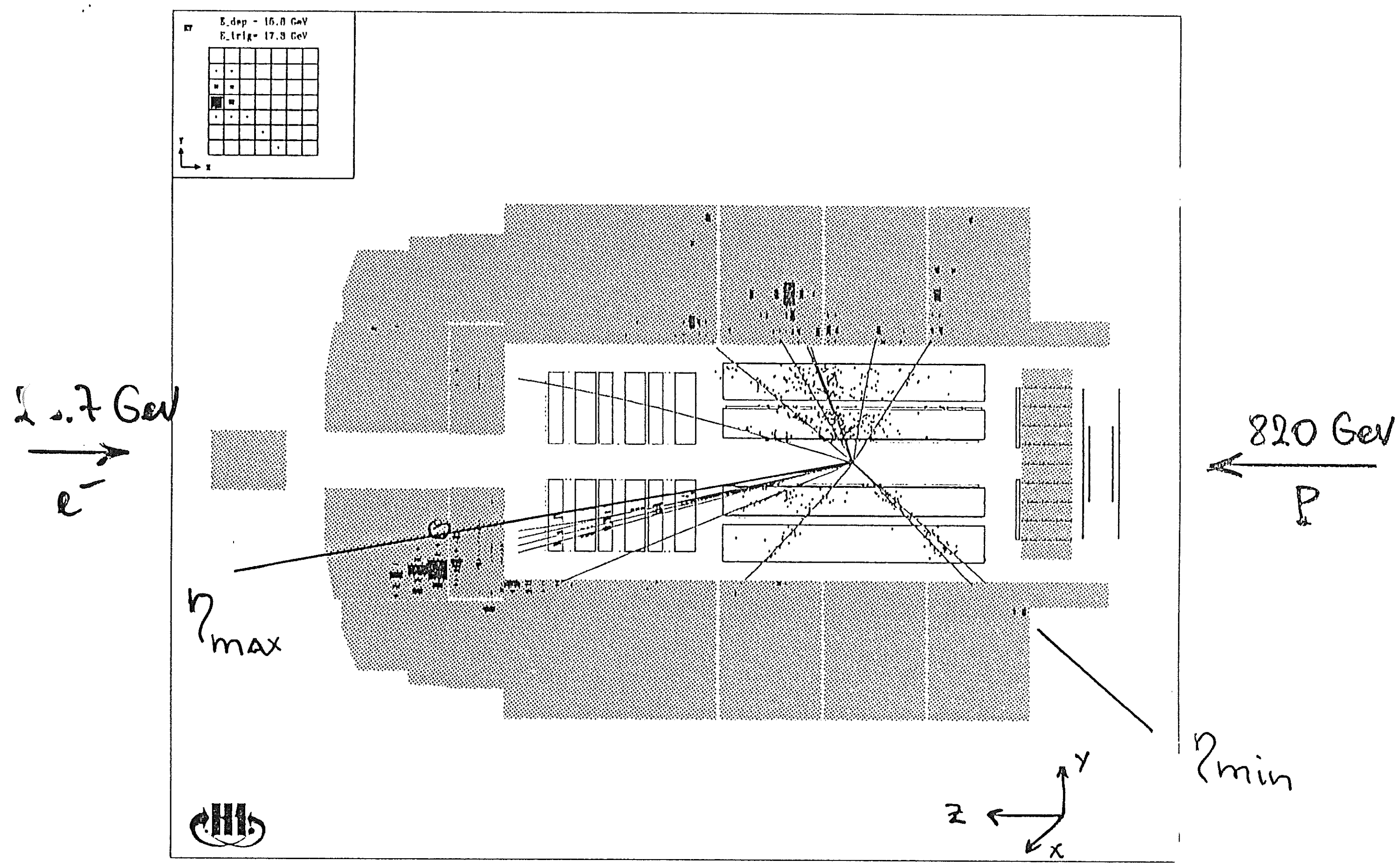


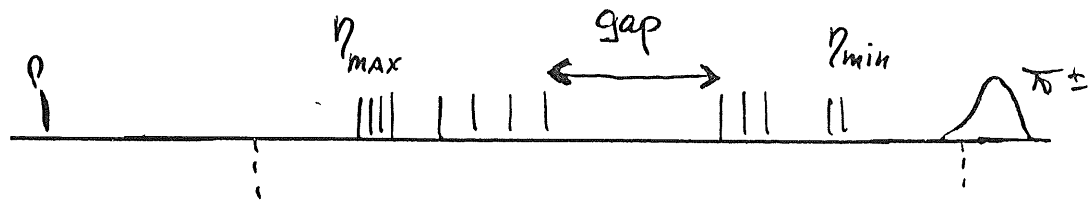
NOT in this talk!

THE H1 DETECTOR



Nomenclature





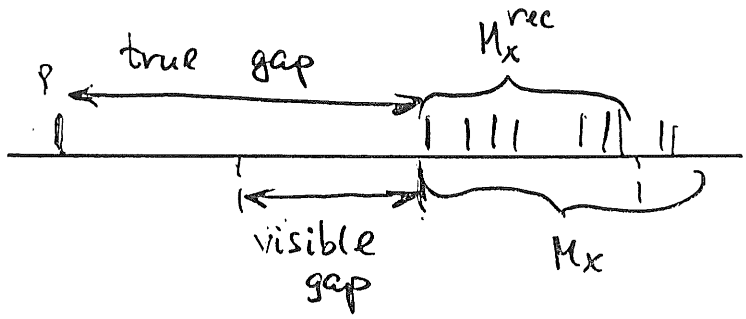
$$\eta = -\ln\left(\tan\frac{\theta}{2}\right)$$

$\{ep \rightarrow e'p\, M_x\}$

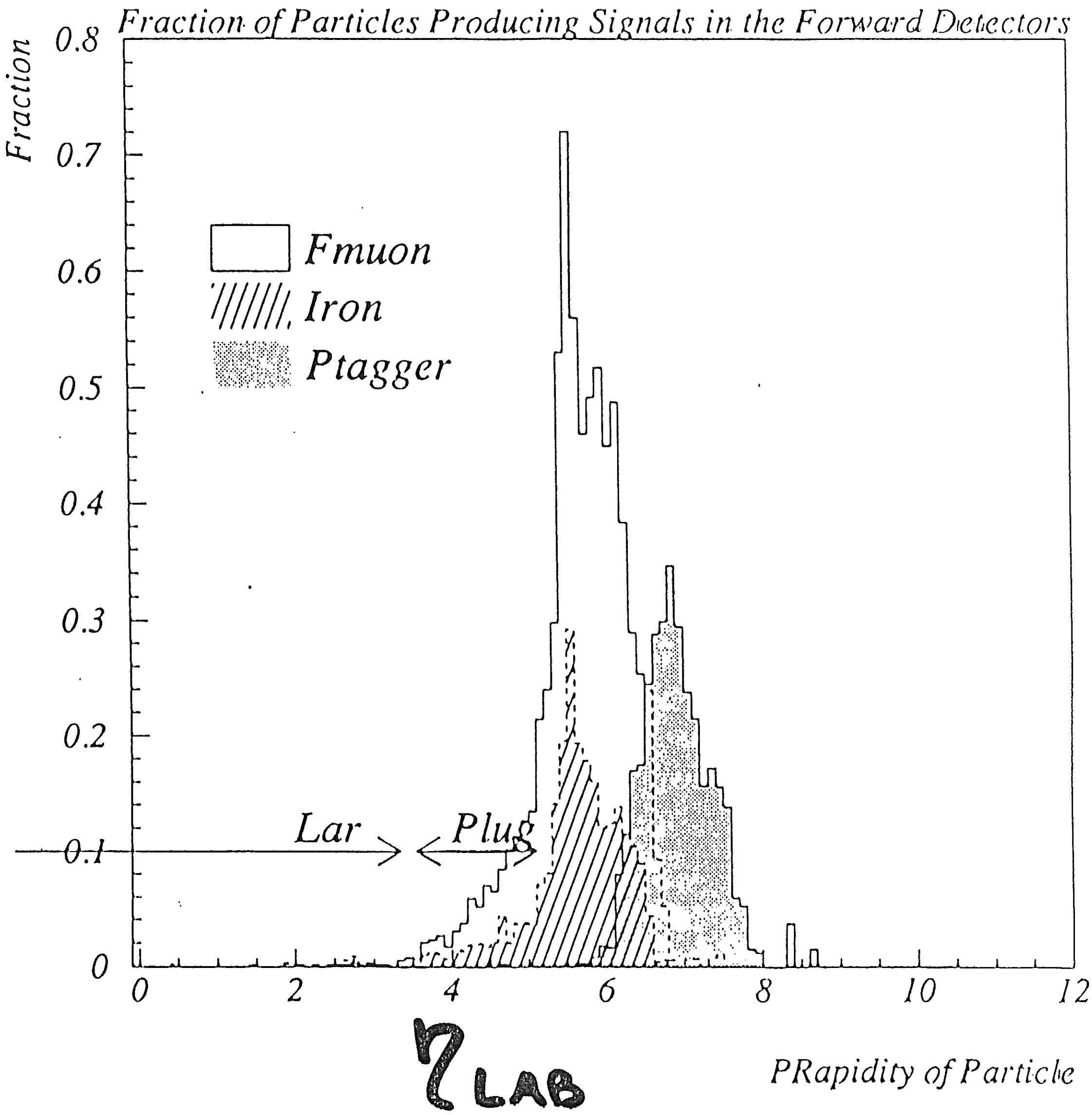
$x \equiv x_{BJ}$

$x_{\mathbb{P}/p} = \frac{M_x^2}{s}$

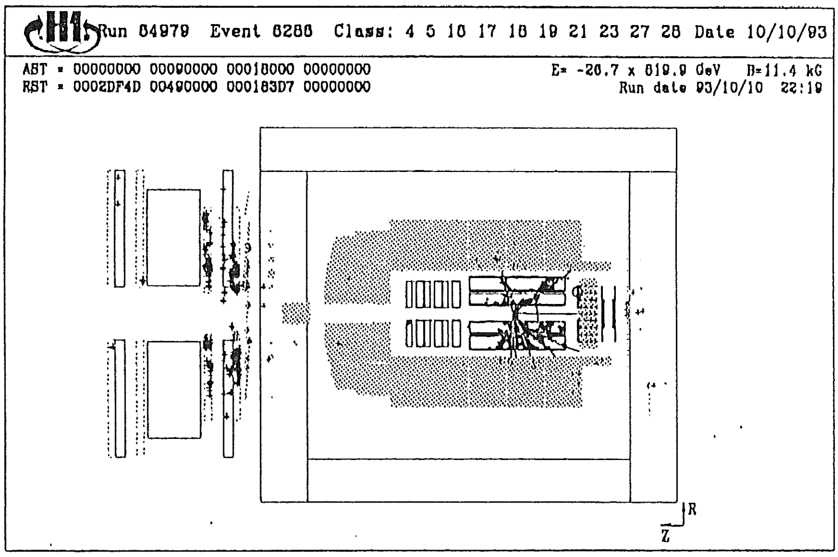
$x_{g/\mathbb{P}}$: e.g. $xG(x) = 6x(1-x)$



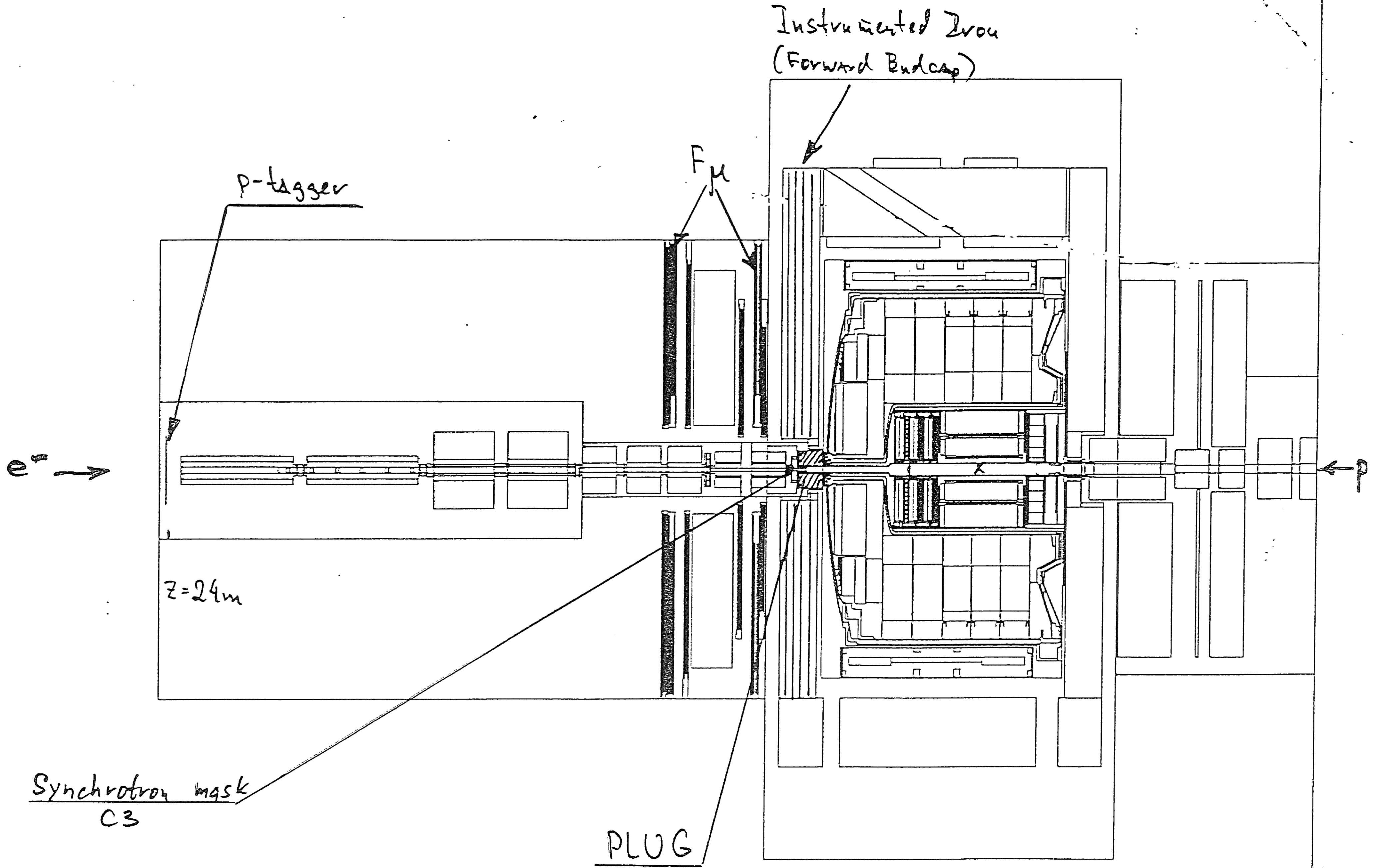
94/01/26 19.22



Fraction of Particles Producing Signals in the Forward Detectors
Fraction
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Fmuon
Iron
Ptagger
Lar
Plug
0
2
4
6
8
10
12
η LAB
PRapidity of Particle

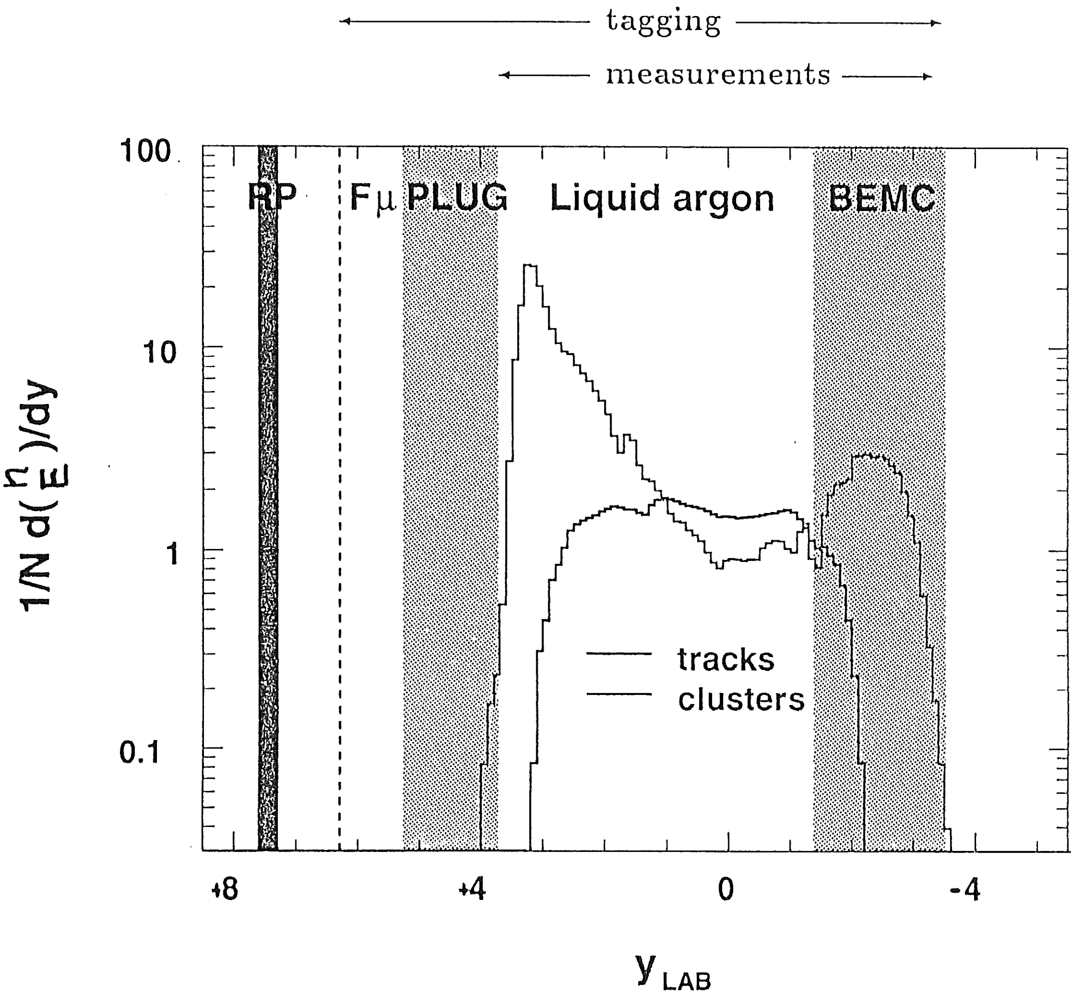


Run 64979 Event 6286 Class: 4 5 16 17 18 19 21 23 27 28 Date 10/10/93
AST = 00000000 00090000 00018000 00000000
RST = 0002DF4D 00490000 000183D7 00000000
E= -26.7 x 819.9 GeV B=11.4 kG
Run date 93/10/10 22:19
R
Z



Instrumented Iron
(Forward Endcap)
p-tagger
Fμ
e⁻ →
← p
z=24m
Synchrotron mask
C3
PLUG

Sketch of the H1 acceptance



H1 capability in rapidity gap physics

Year	Measurements	Tagging	Roman Pots
1993	$-3.4 < \eta < 3.6$	$-3.4 < \eta < 6.6$	no
1994	$-3.4 < \eta < 5.2$	$-3.4 < \eta < 6.6$	2 (partially)
1995	$-4.0 < \eta < 5.2$	$-4.0 < \eta < 6.6$	2 (complete)
?			more

Two independant analyses are possible:

① η_{max}

$$\eta_{max}\{\text{reconstructed objects}\} < (1.5 \div 1.8)$$

$$\text{rec. objects} = \begin{cases} \text{clusters}, & E > 0.4\ \text{GeV} \\ \text{tracks}, & p_t > 0.15\ \text{GeV/c} \end{cases}$$

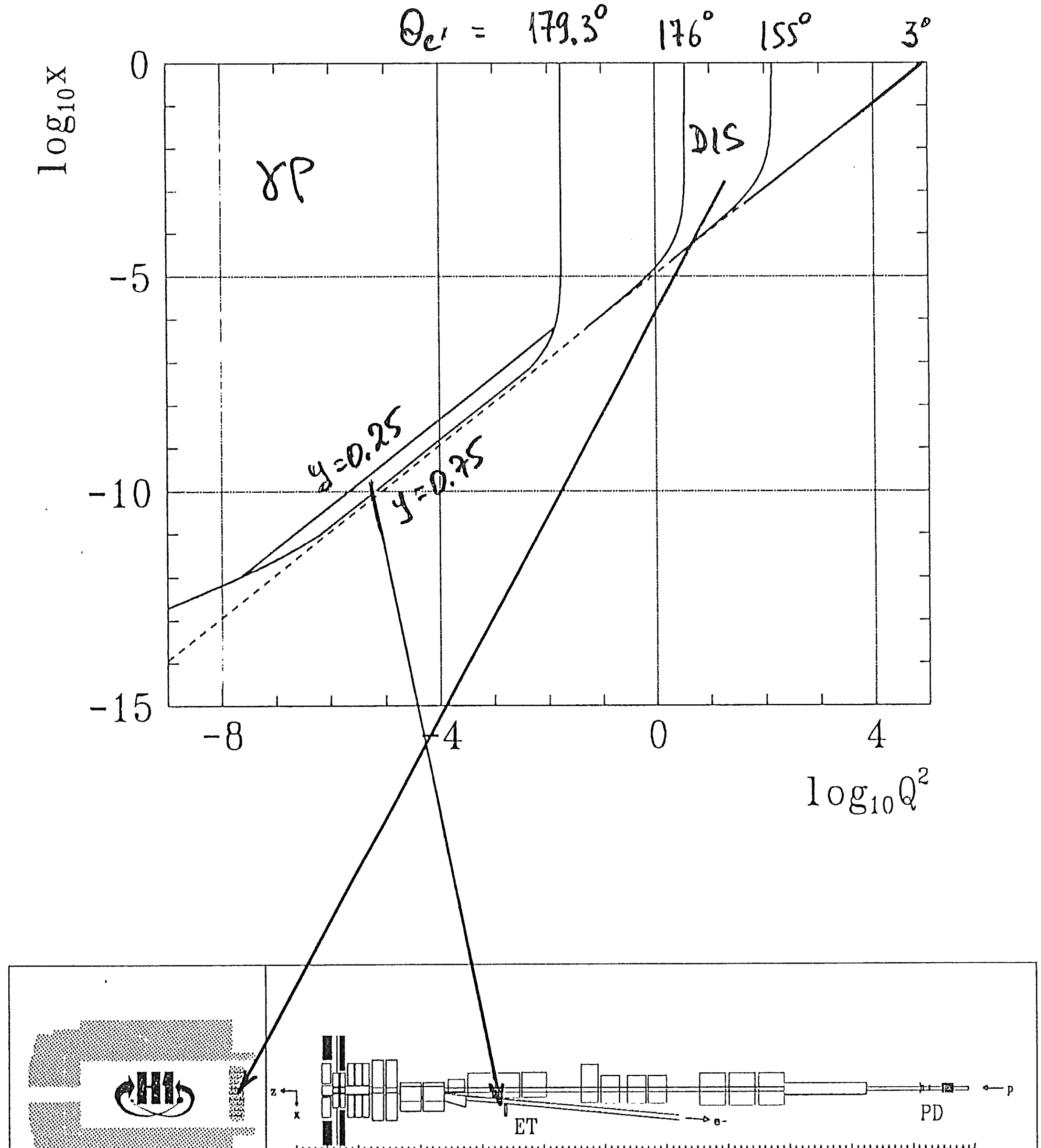
② 'Forward veto'

E (PLUG calorimeter) < 1.0 GeV
N ($F\mu$ rec. segments) ≤ 1
N_{hits} (p-tagger) $\lesssim 1$
$\eta_{max} \lesssim 3.0$

} 'and'

↘

- Extends available range of M_x ($x_{\mathbb{P}/p}$)
- Provide a nice cross check



$$\frac{\sigma_E}{E} \approx \frac{10\%}{\sqrt{E(\mathrm{GeV})}}$$

MC models

1. PYTHIA $(Q^2 \simeq 0)$

$$\frac{d^4\sigma(ep \to epX)}{dy dQ^2 dt dM^2} = f_{\gamma^*/e}(y, Q^2)\frac{1}{M^2}e^{b(s)t}$$

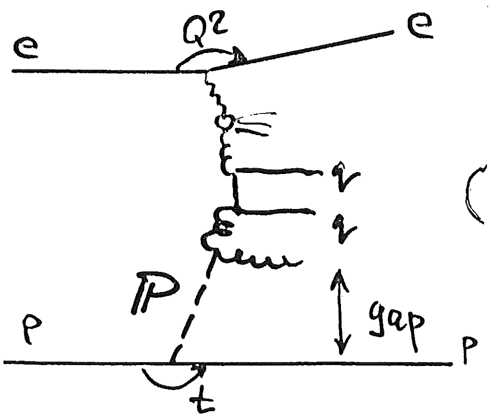
with

$$f_{\gamma^*/e}(y, Q^2) = \frac{\alpha}{\pi}\left((1 - y + \frac{y^2}{2})\frac{1}{yQ^2} - \frac{m_e^2 y}{Q^4}\right)$$

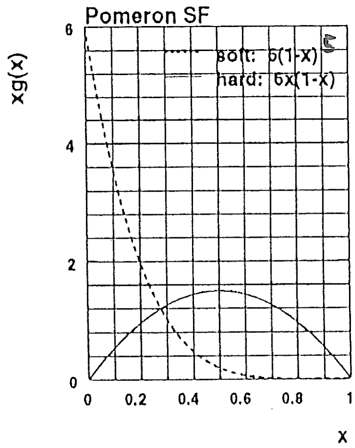
2. VMD $(Q^2 > 5GeV^2)$

$$F(y, Q^2) = \left(\frac{1}{1 + Q^2/m_V^2}\right)^2 [1 + \epsilon(Q^2, y)R_{LT}(Q^2, y)]; \qquad R_{LT} = \frac{\frac{Q^2}{m_V^2}}{1 + \frac{Q^2}{m_V^2}}$$

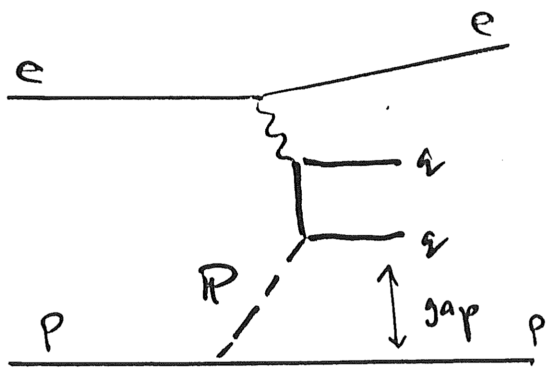
3. POMPYT $(Q^2 \simeq 0)$



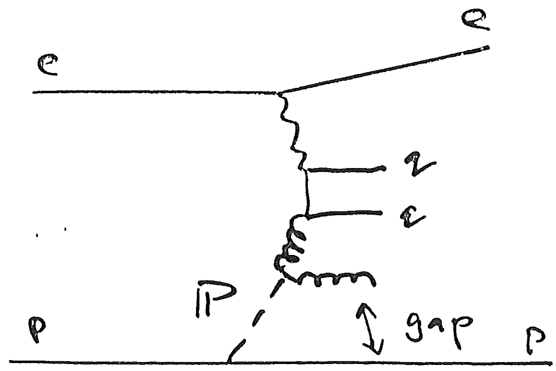
$(p_t > p_{min} \simeq 2GeV)$



4. RAPGAP $(Q^2 > 5GeV^2)$

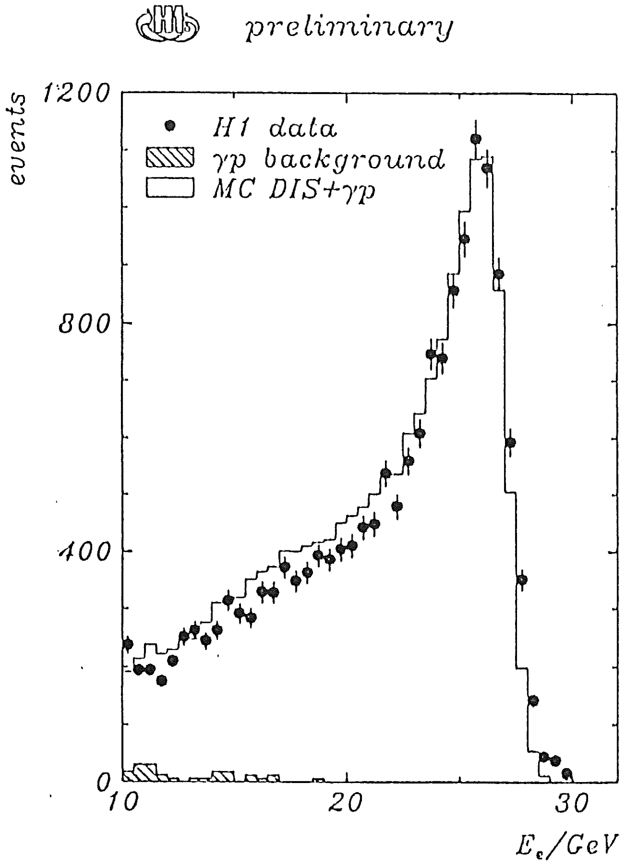


Quark SF_{P}

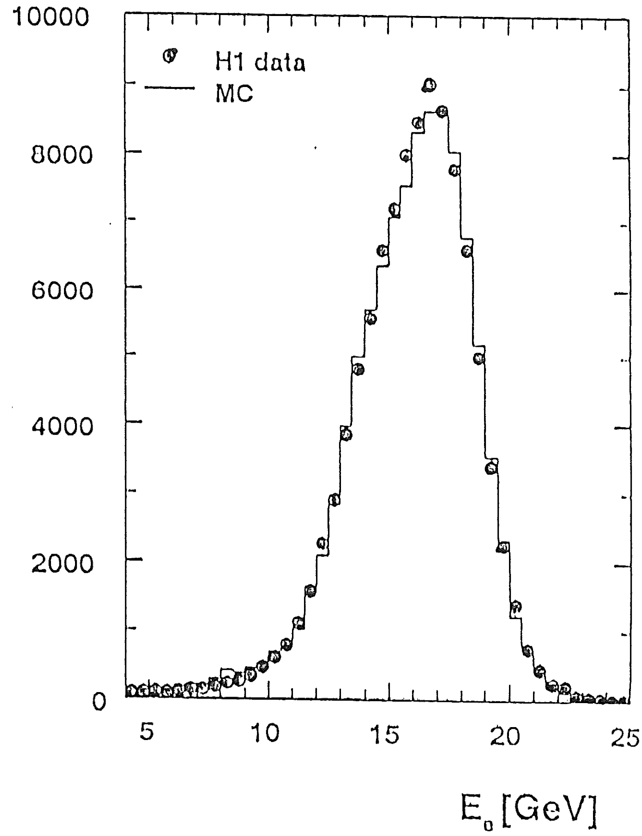


Gluonic SF_{P}

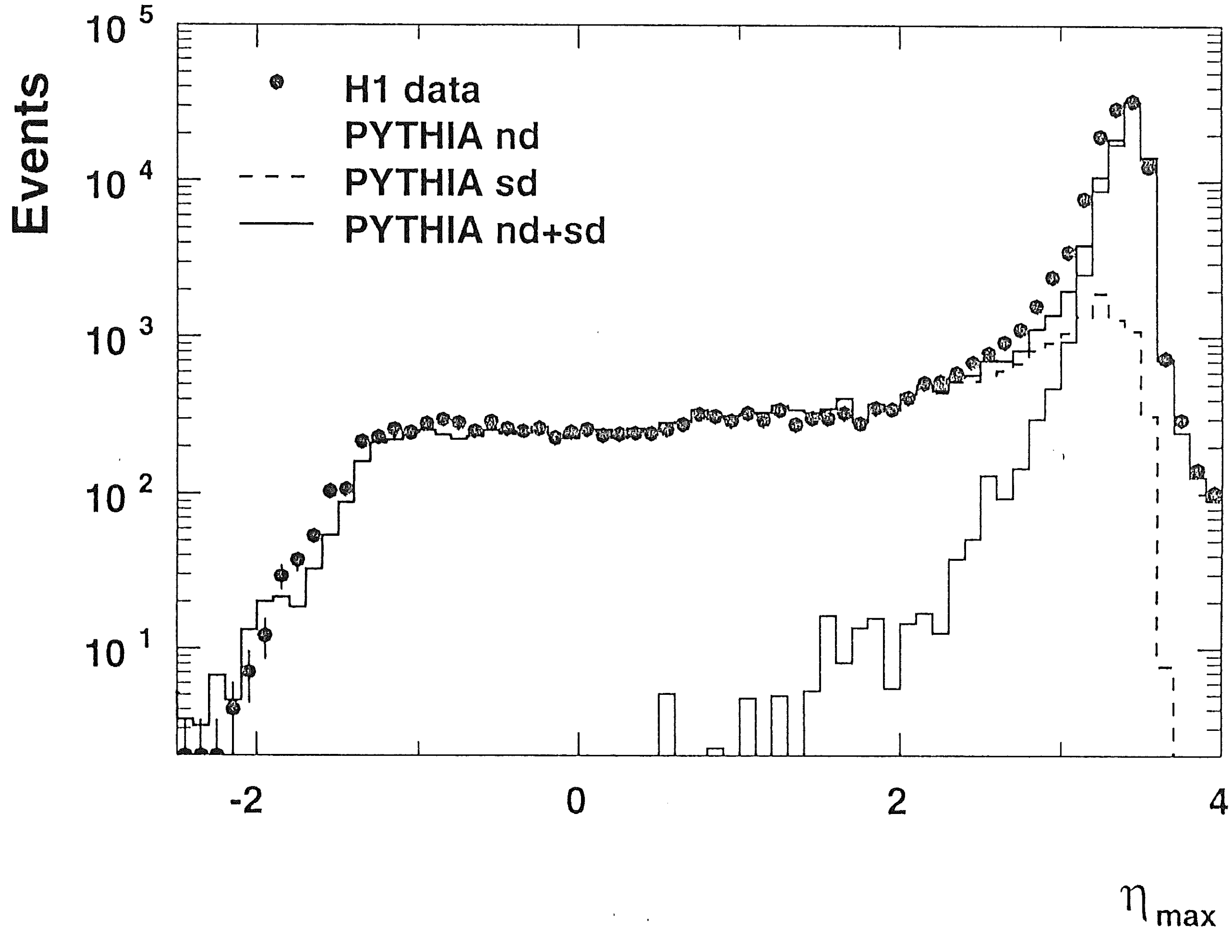
BEMC



e-TAGGER

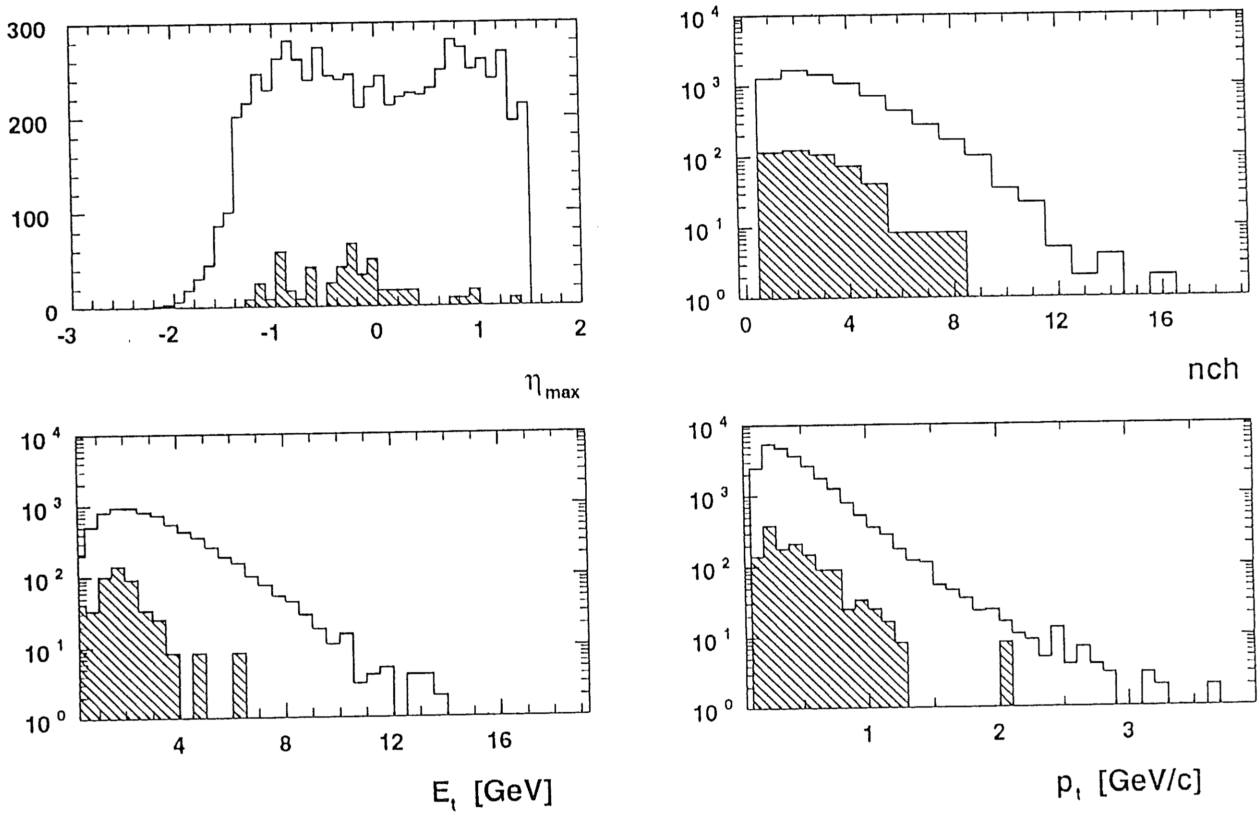


DIS sample	Parameter	γp sample
273 nb^{-1}	Luminosity used	289 nb^{-1}
5 ÷ 100	Q^2 [GeV^2]	10^{-8} ÷ 10^{-2}
> 12	E_e [GeV]	8 ÷ 20
14,500	Total # of events	320,000
η_{max} < 1.8 575	Rap. gap. selection # of events	η_{max} < 1.5 14200
e-gas: < 2% γp! ≈ 3%	Remaining bgr.	e-gas ≈ 5.9±0.6%



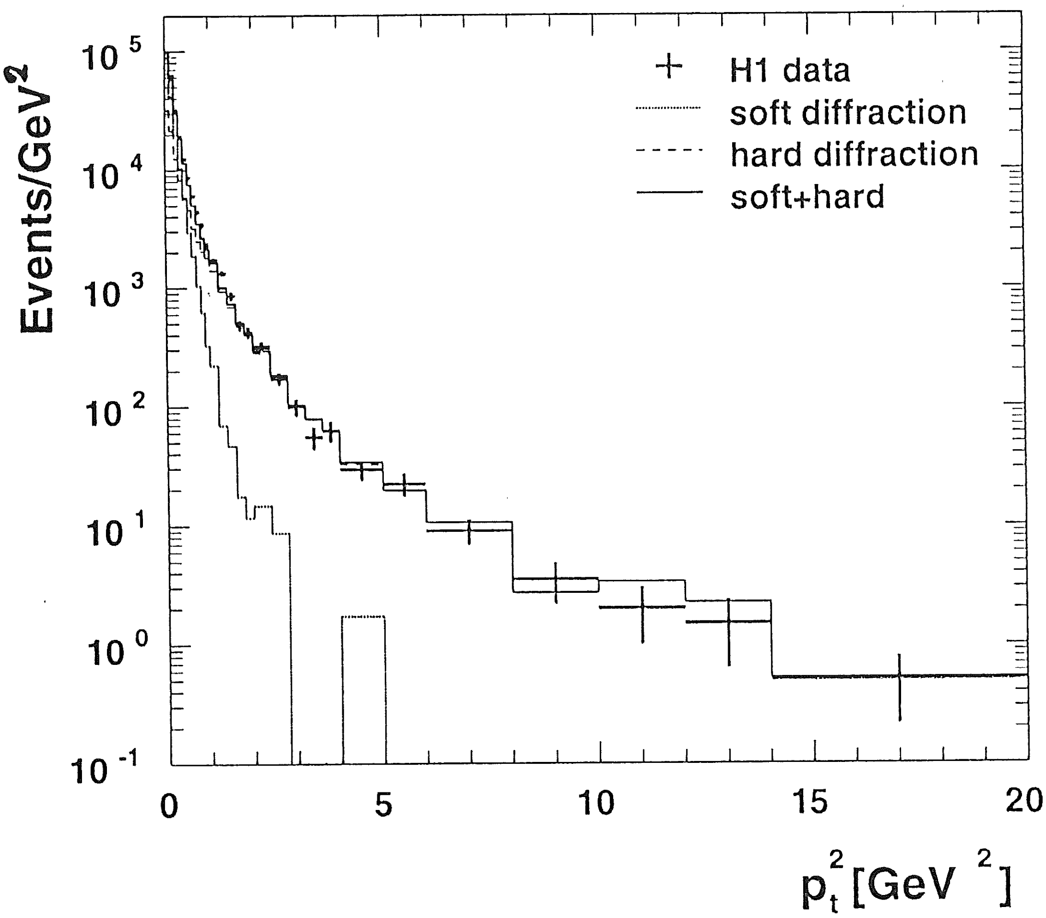
Events
H1 data
PYTHIA nd
PYTHIA sd
PYTHIA nd+sd
10^5
10^4
10^3
10^2
10^1
-2
0
2
4
η_{max}

Remaining e-gas background in large rapidity gap γp sample



$$< R_e > = \frac{I_e^{total}}{I_e^{pilot}} = 8.3 \pm 0.2$$

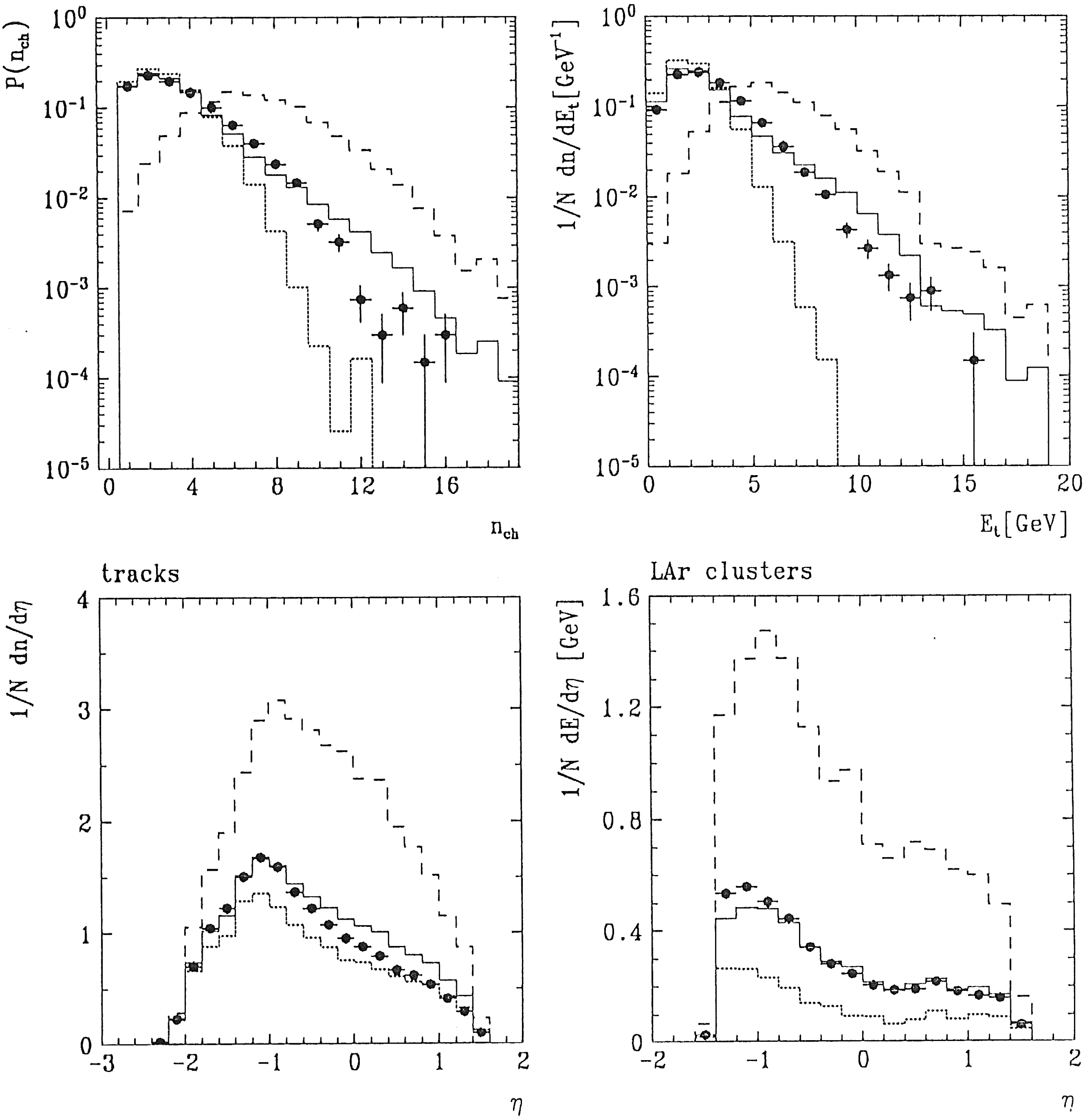
$\eta_{max} < 1.5$



Inclusive charged particle distribution in the large rapidity gap γp events.

↳ **Jets ?**

⌖ H1 data (preliminary)



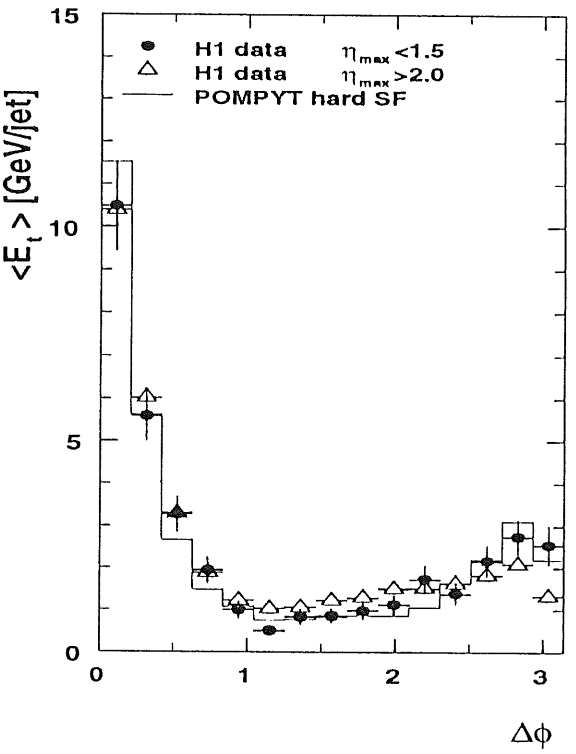
---- POMPYT hard SF, $\hat{p}_t > 2$ GeV

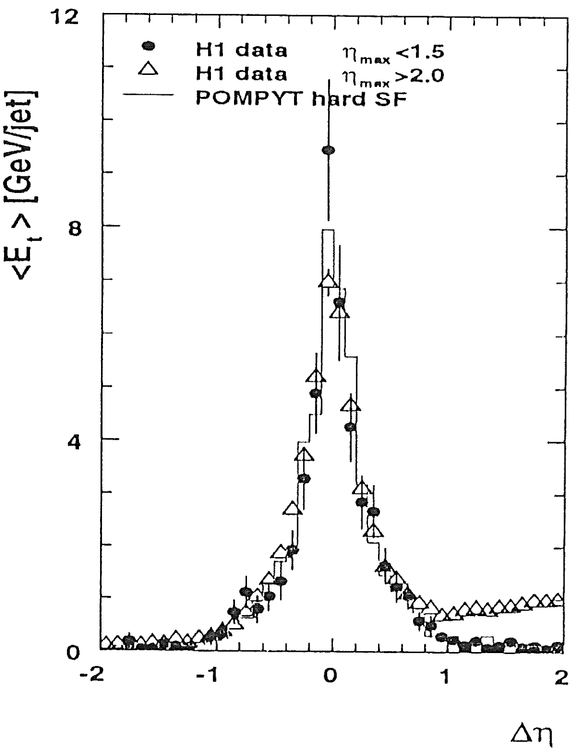
.... PYTHIA soft single γ-diff. diss.

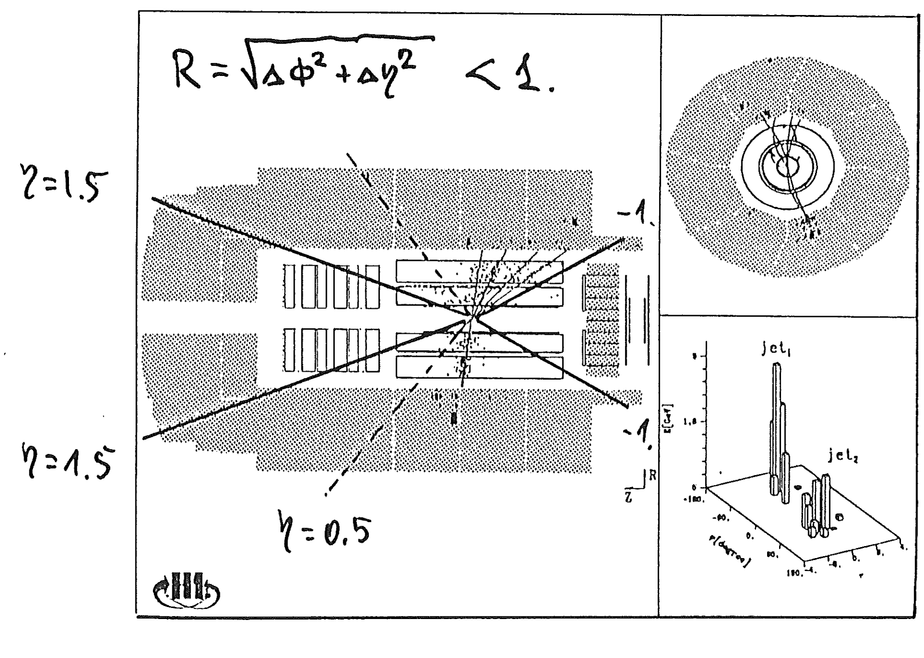
—— (1-α) soft + α hard (α = 0.12 ± 0.03)

Jet profiles

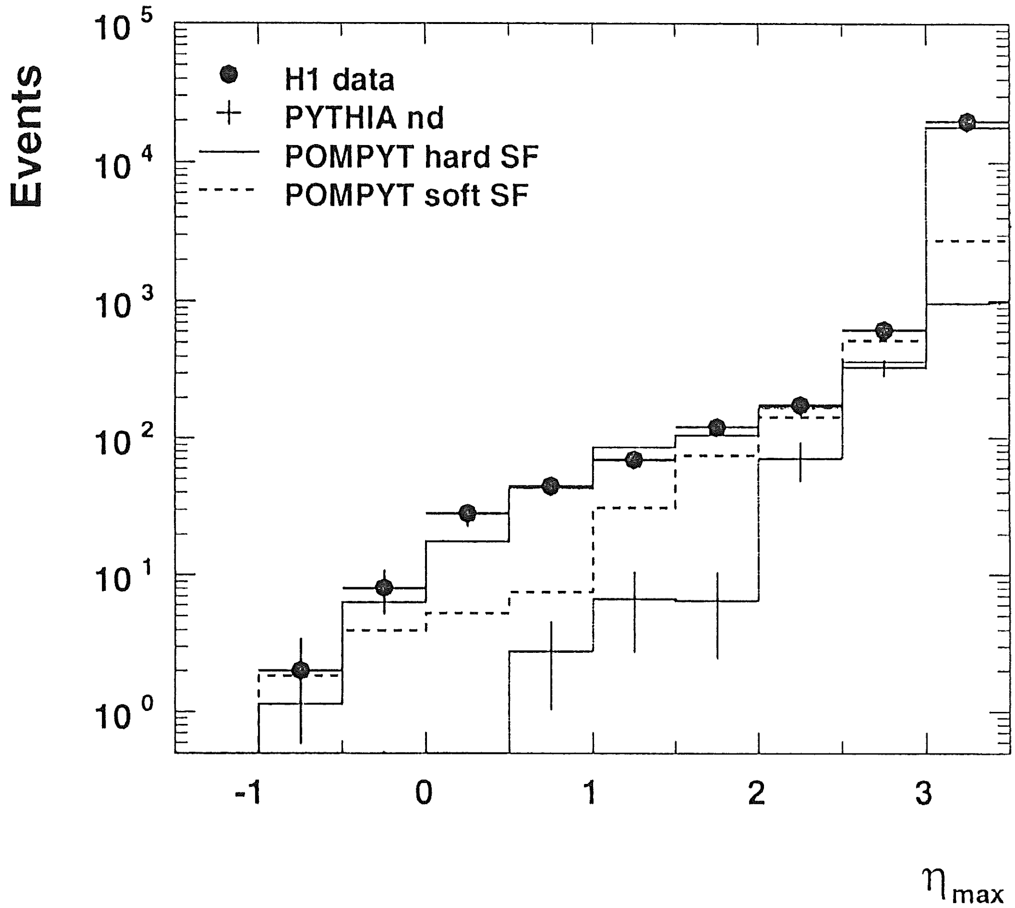
$4 < E_{t\ jet} < 6$ GeV $\quad -1 < \eta_{jet} < 0.5$





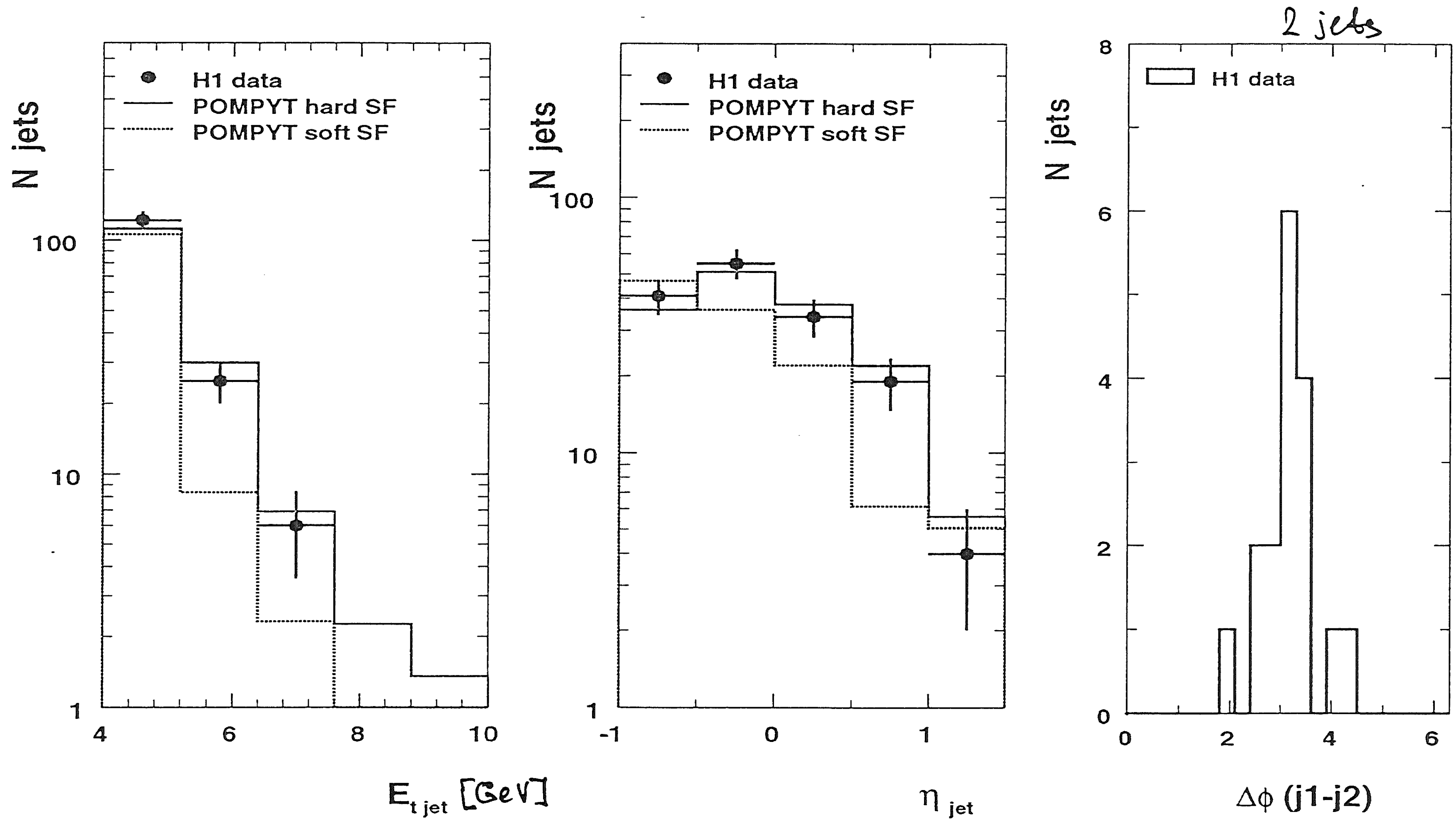


$E_t > 5$ GeV $\quad E_{t\ jet} > 4$ GeV $\quad -1 < \eta_{jet} < 1.5$



$\mathcal{L} = 289 \pm 13\ nb^{-1}$

Shape comparison (hard * 0.75 soft * 4.0)



$\times\ G(x) = G x(1-x)$

$\times\ G(x) = G (1-x)^5$

Jet rates. Data vs Monte Carlo

$(E_t > 6GeV \quad E_{t\ jet} > 4GeV \quad -1 < \eta < 1.5 \quad \eta_{max} < 1.5)$

Sample	Events	1 jet events (%)	2 jet (%)	2-j/1-j
Data	1003	11.8	2.4	0.20±0.05
POMPYT hard SF ($\hat{p}_t > 2$GeV)	1726	21.6	3.6	0.17±0.02
POMPYT soft SF ($\hat{p}_t > 2$GeV)	359	9.5	–	< 0.03
POMPYT soft SF ($\hat{p}_t > 3$GeV)	238	19.3	2.1	0.10±0.03

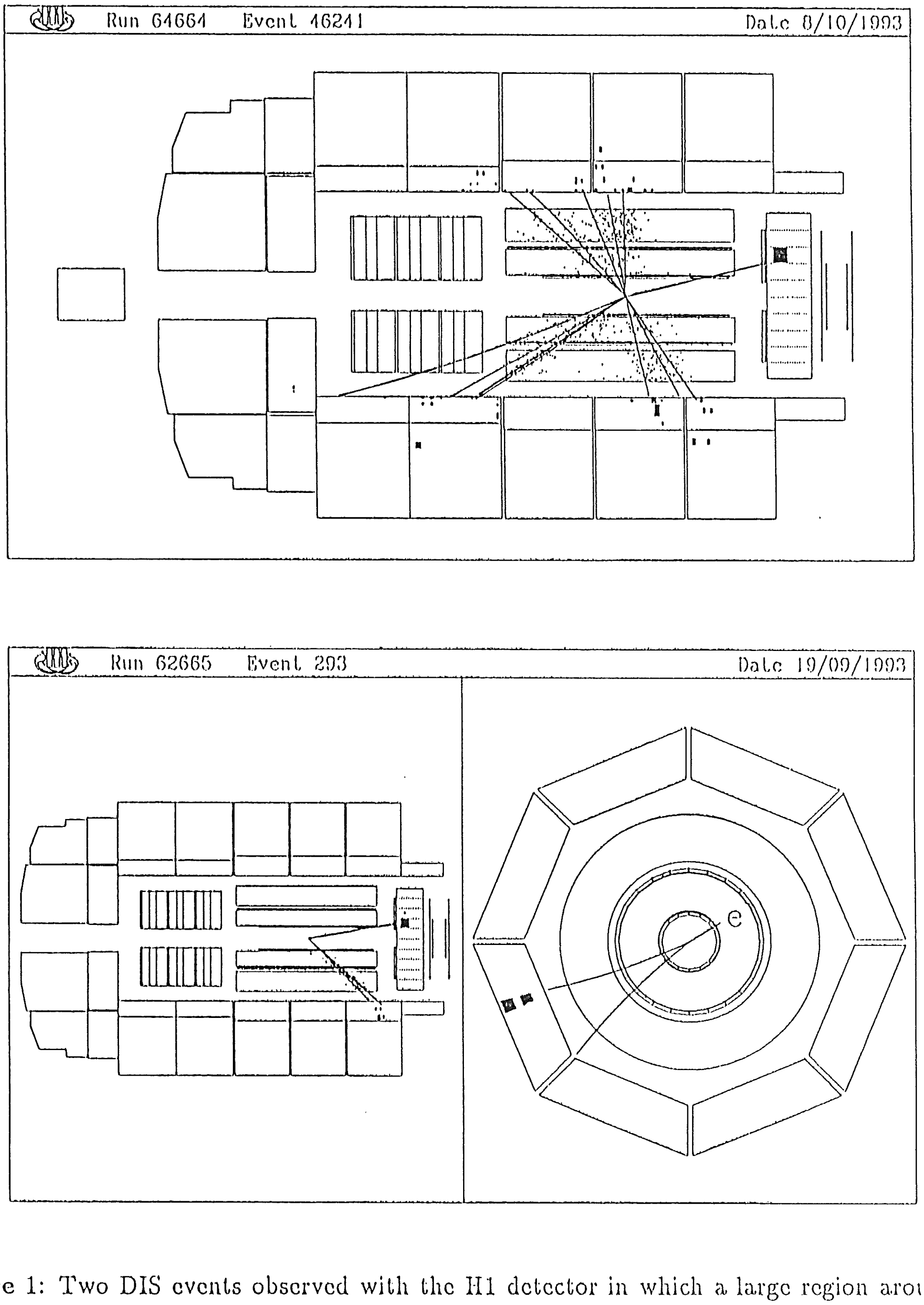
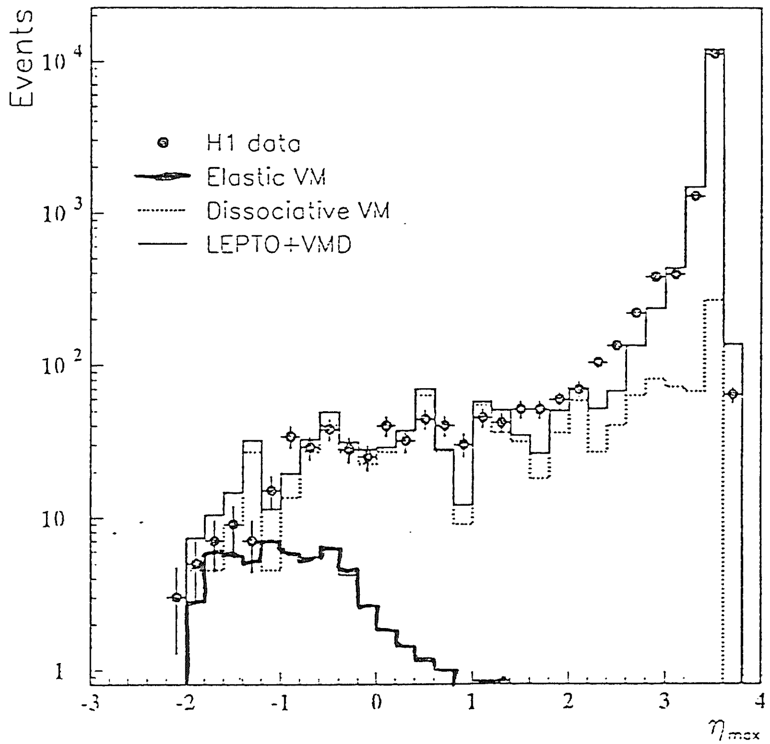
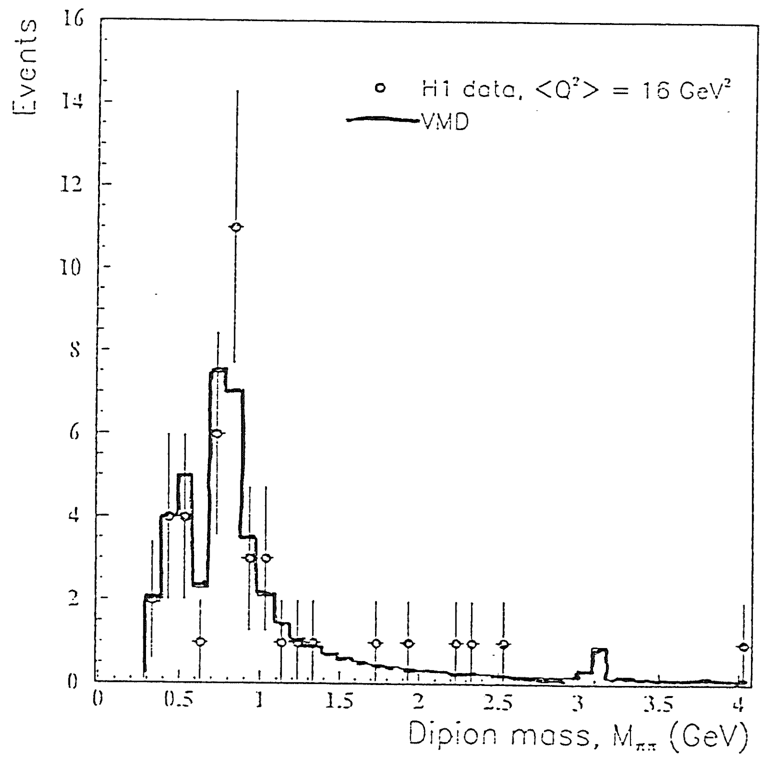


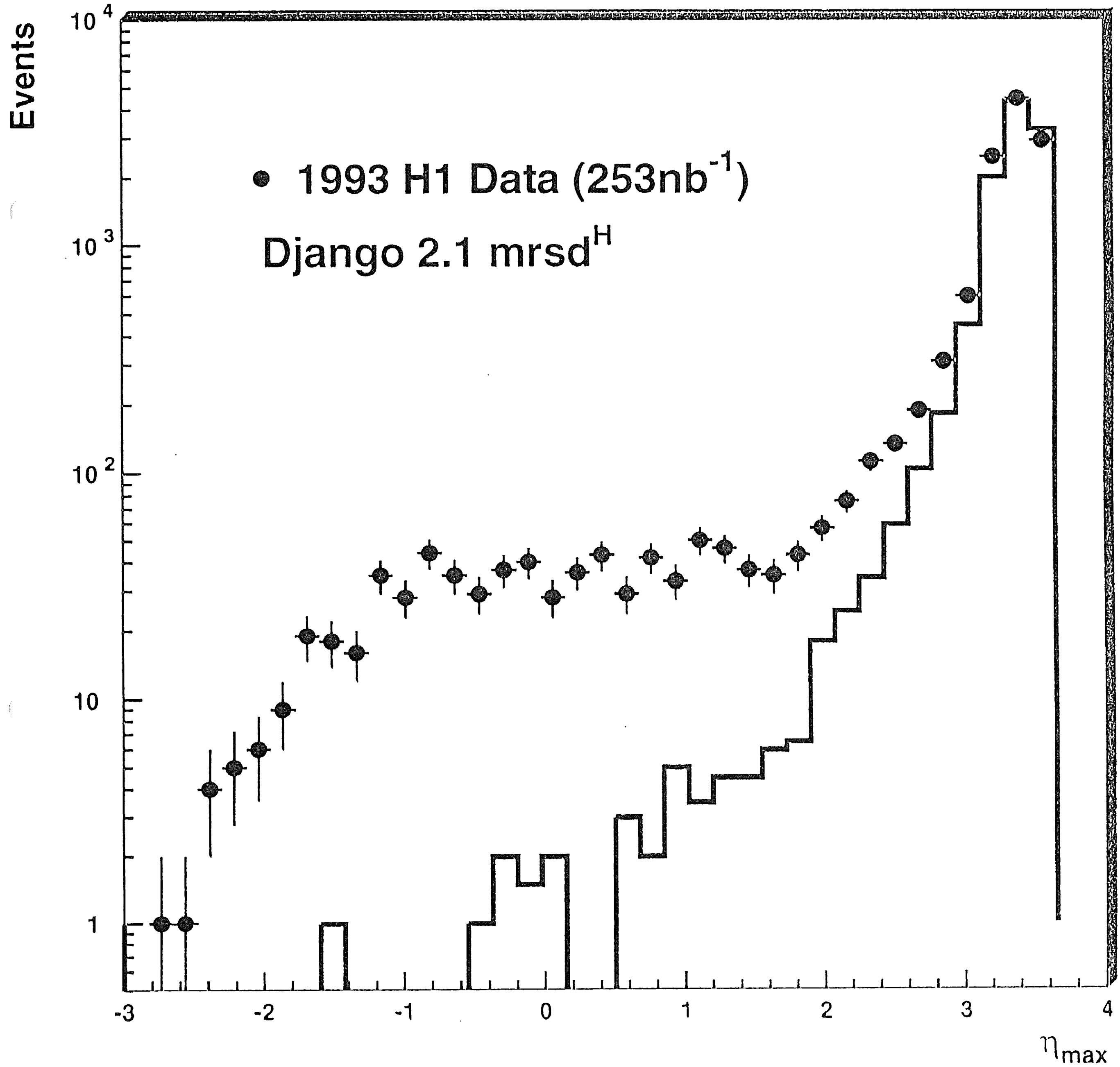
Figure 1: Two DIS events observed with the H1 detector in which a large region around the proton direction (to the left) is devoid of energy flow; the upper, (r, z) view, has high charged track multiplicity, and the lower, (r, z) and (r, ϕ) views, contains two oppositely charged tracks with associated calorimeter energy; in both the electron incident from the left is scattered and detected in the backward electromagnetic calorimeter (BEMC).

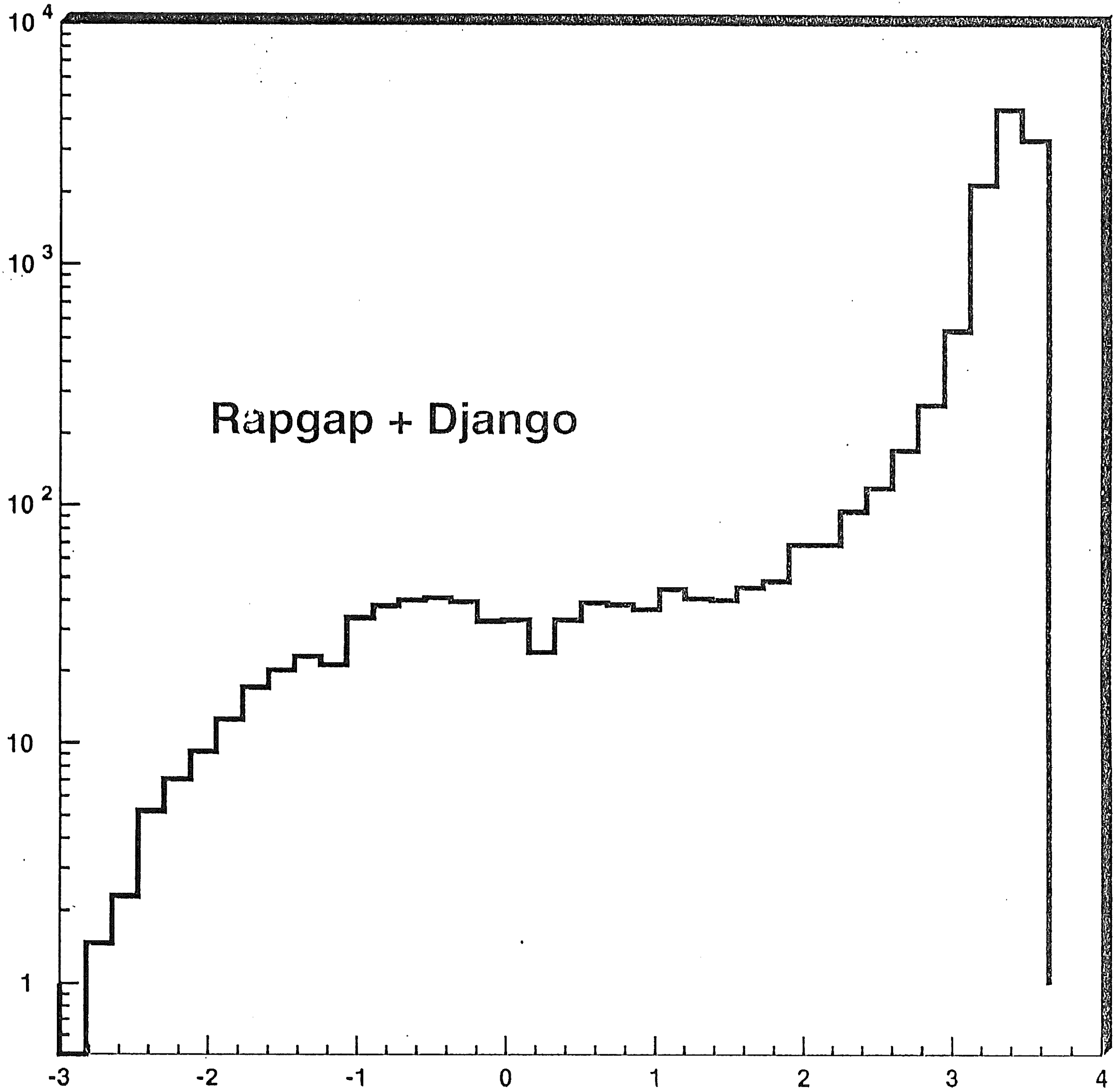


2-prong (+-) subsample (45 events)

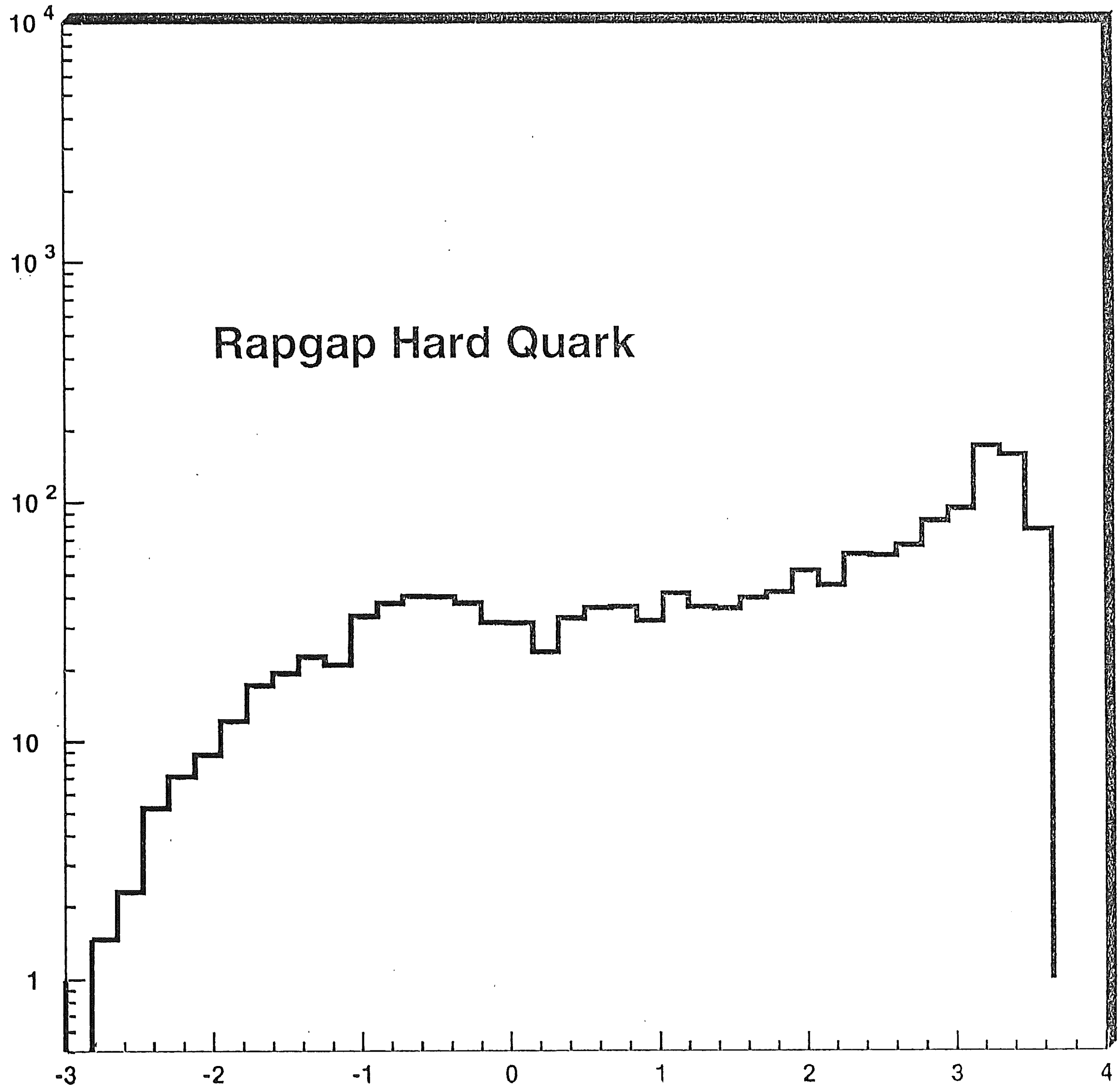


Observation of Events with a Rapidity Gap

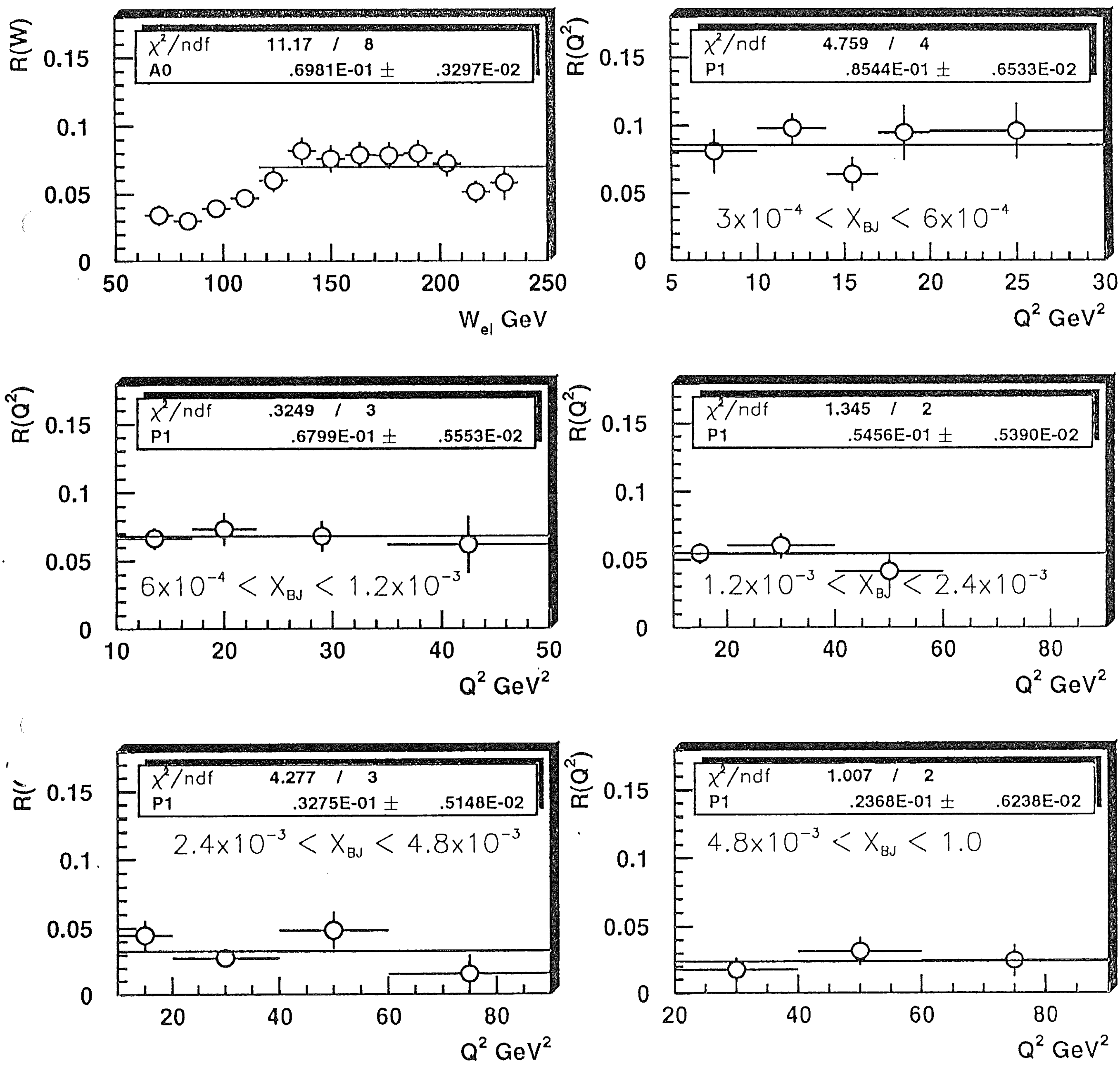




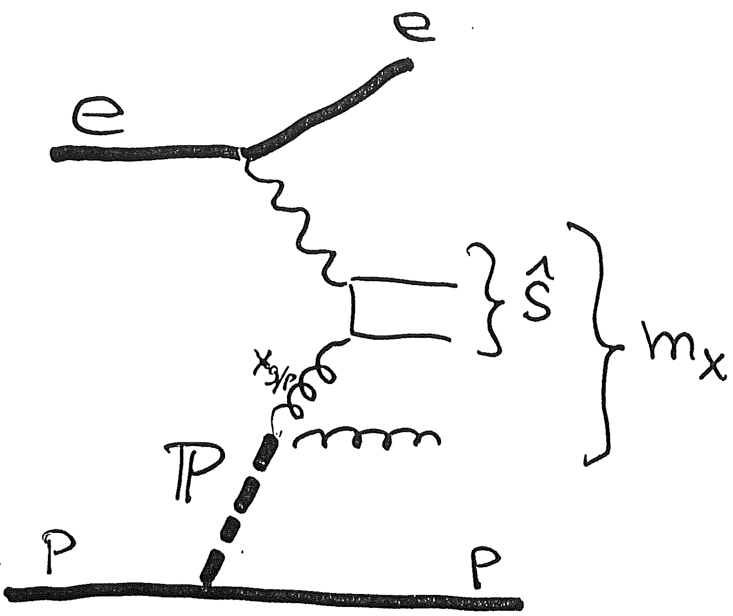
Rapgap + Django
10 4
10 3
10 2
10
1
-3
-2
-1
0
1
2
3
4


Rapgap Hard Quark
10 4
10 3
10 2
10
1
-3
-2
-1
0
1
2
3
4

$R(Q^2)$ in bins of x_{BJ}



Glue in $\mathbb{P}$



$$x_{g/\mathbb{P}} = \frac{\hat{s} + Q^2}{m_X^2 + Q^2}$$

$E_e > 10\,GeV$

$10 < Q_e^2 < 80\,GeV^2$

$W^2 > 3000\,GeV^2$

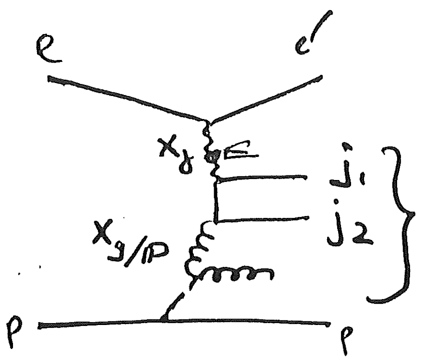
$\rightarrow$ 2 jets (LUCELL)

in LAB

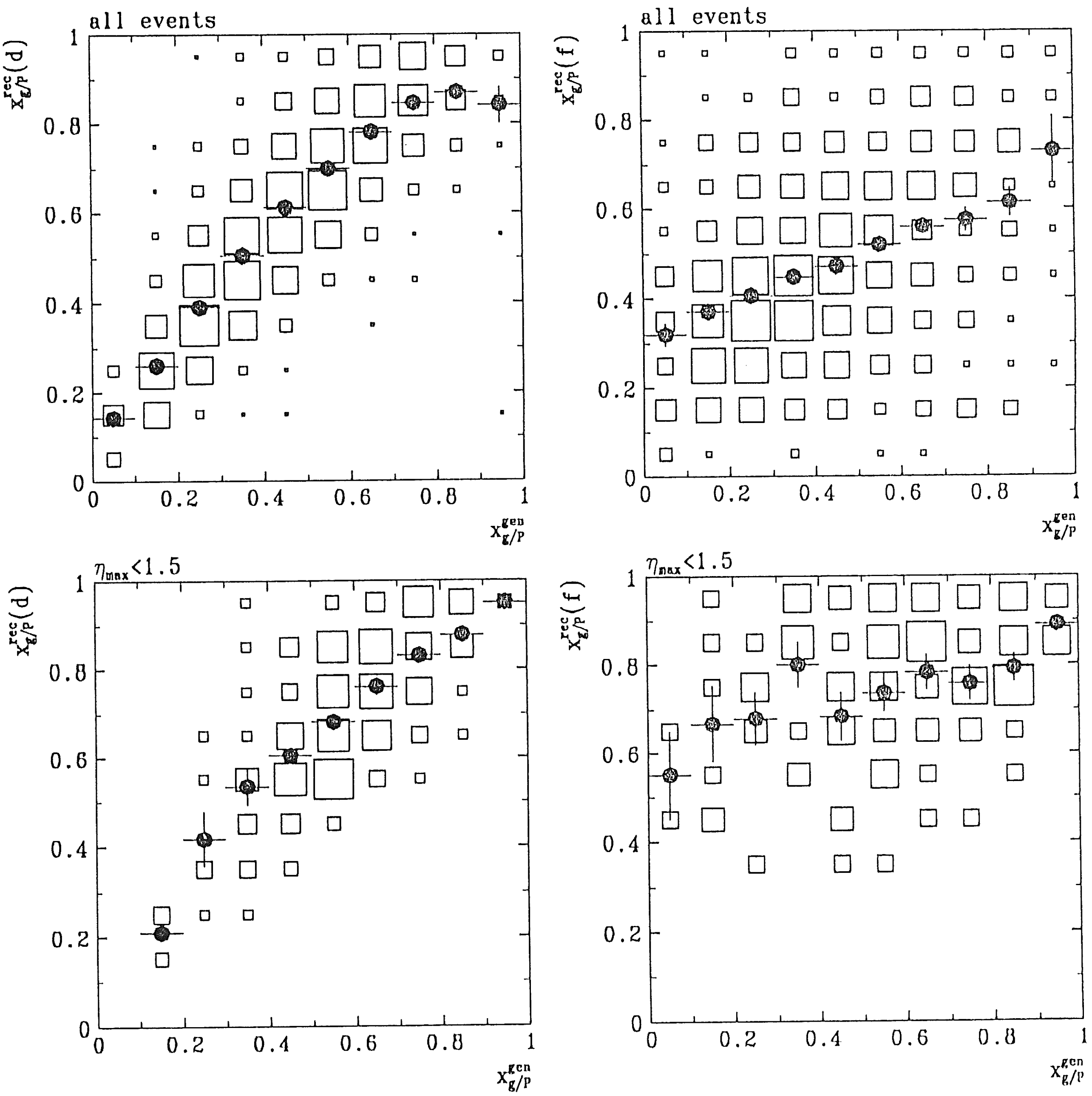
$-3 < \eta < 3$

$E_T > 3.5\,GeV$

$m^2_{j_1 j_2} > 100\,GeV^2$



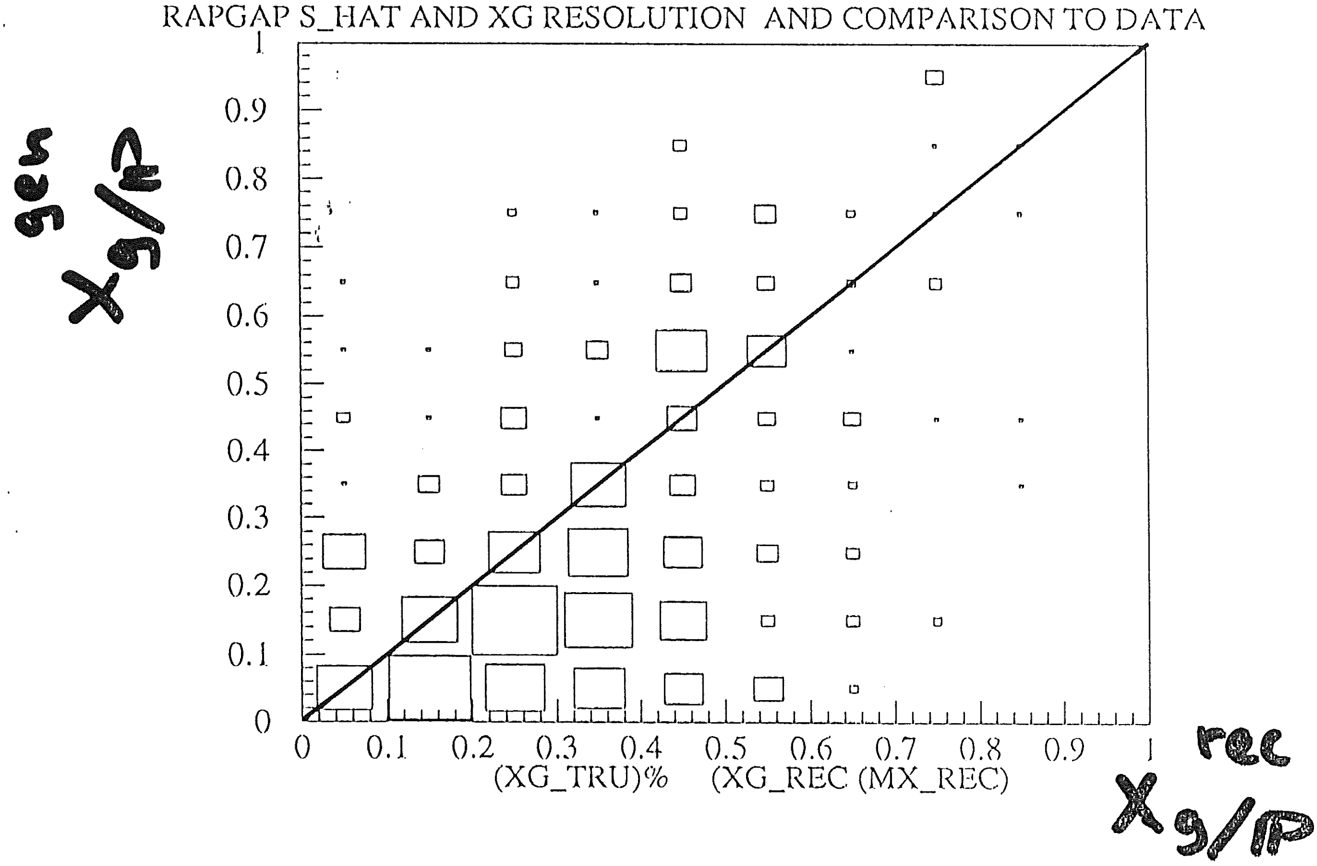
$$x_{g/P} = \frac{(E+p_z)_{jets}}{(E+p_z)}$$

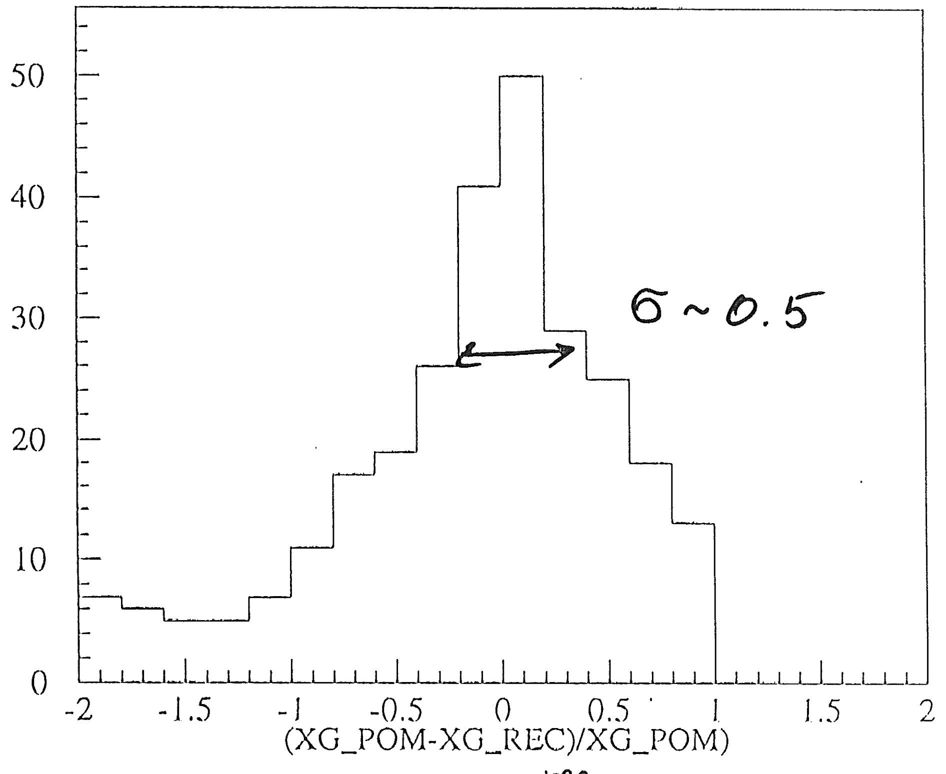


correlations between true and reconstructed $x_{g/P}$ in photoproduction

RAPGAP MC

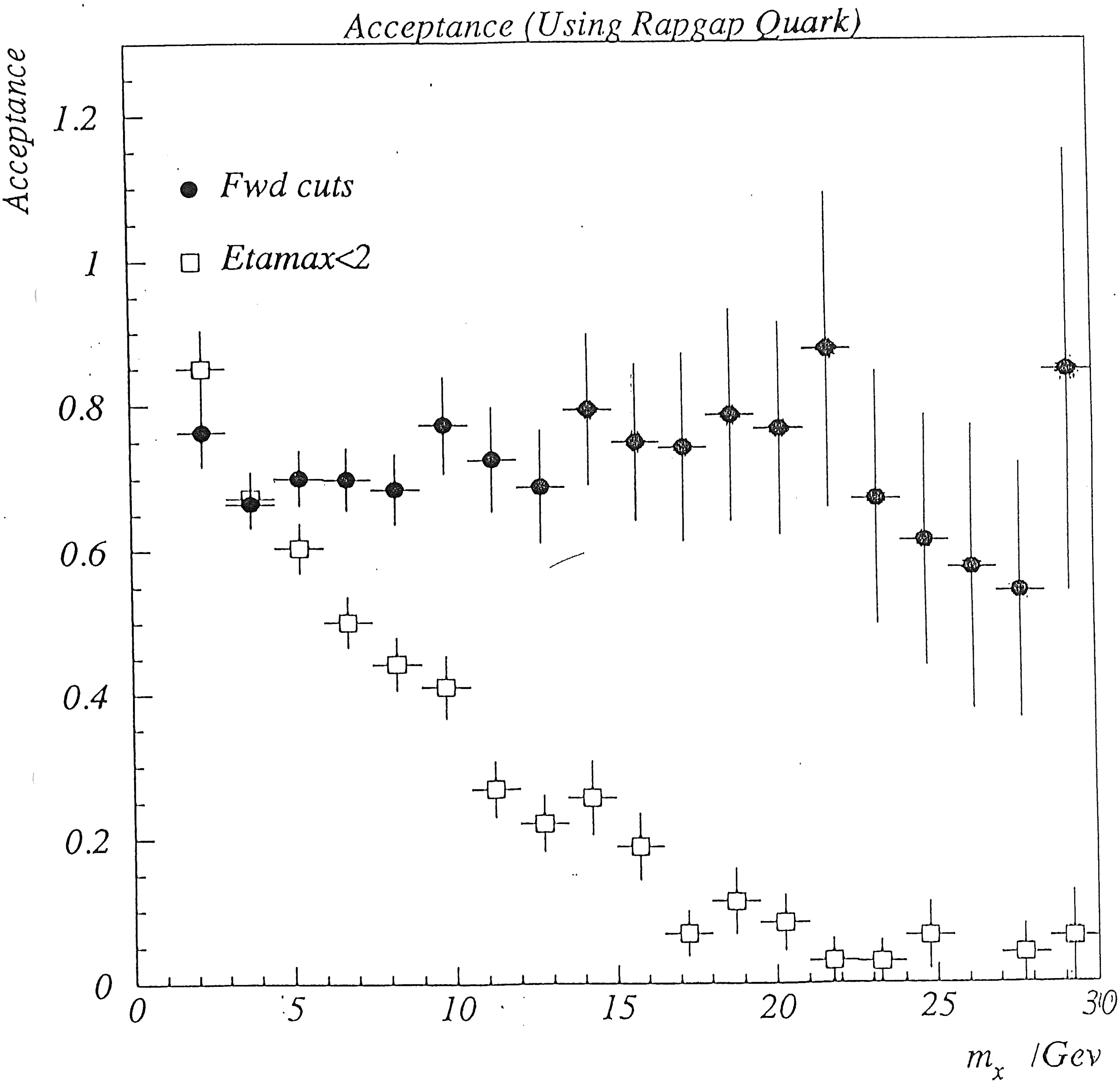
RAPGAP S_HAT AND XG RESOLUTION AND COMPARISON TO DATA



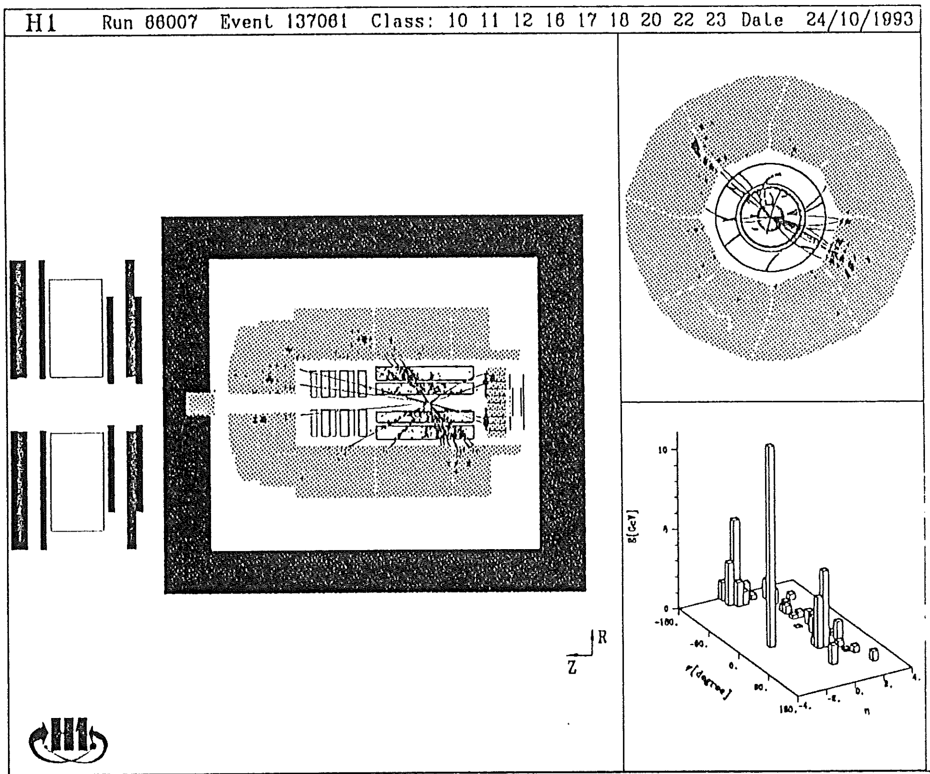


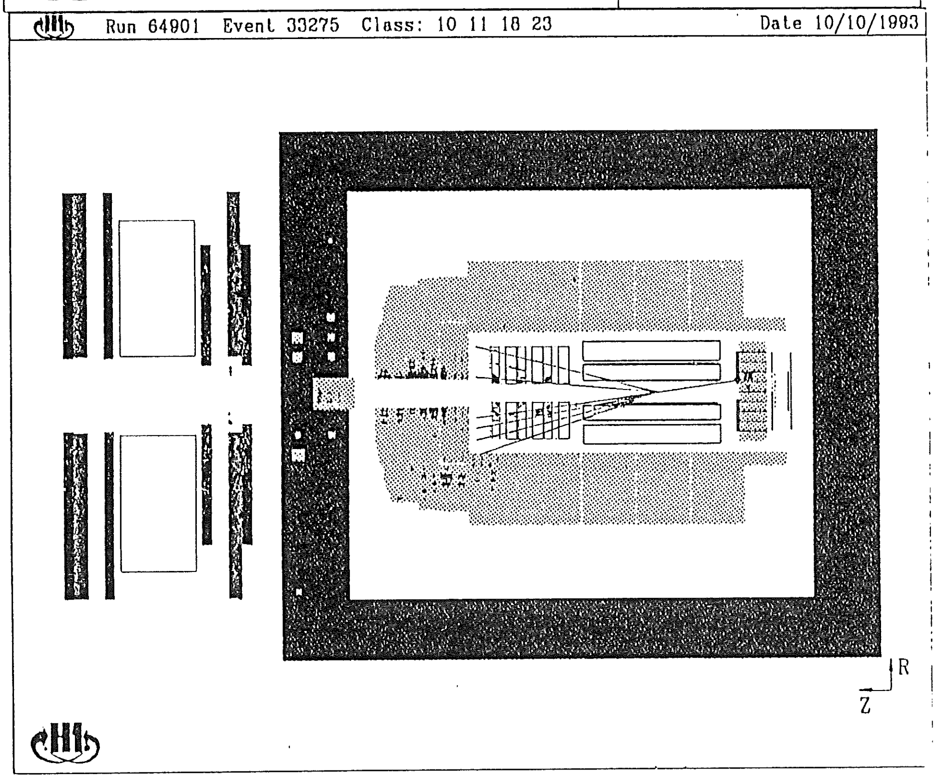
$$\left(1 - \frac{x_{g/P}^{rec}}{x_{g/P}^{gen}}\right)$$

94/04/12 19:09

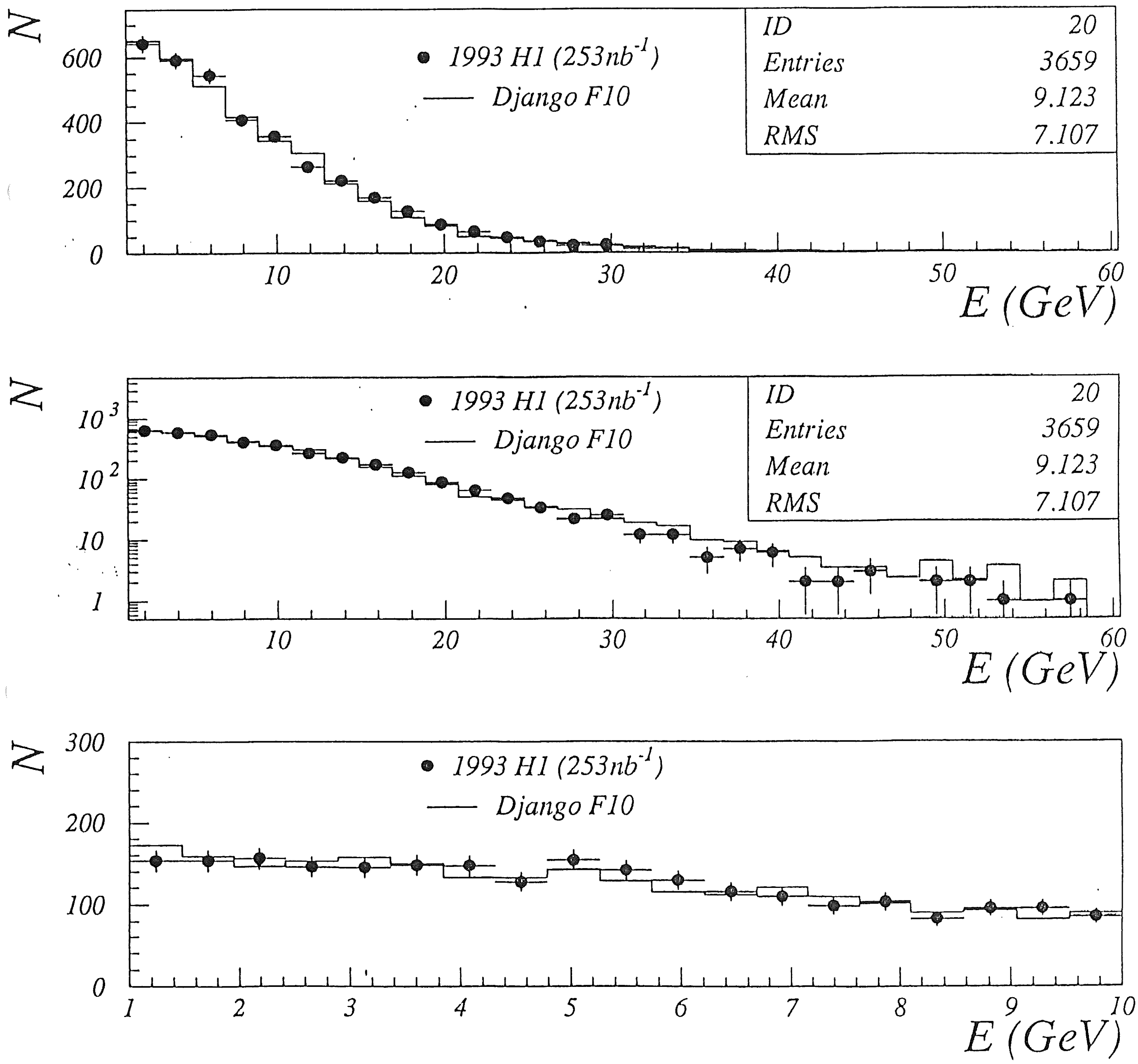


Acceptance (Using Rapgap Quark)
Acceptance
1.2
1
0.8
0.6
0.4
0.2
0
Fwd cuts
Etamax<2
0
5
10
15
20
25
30
m_x /Gev

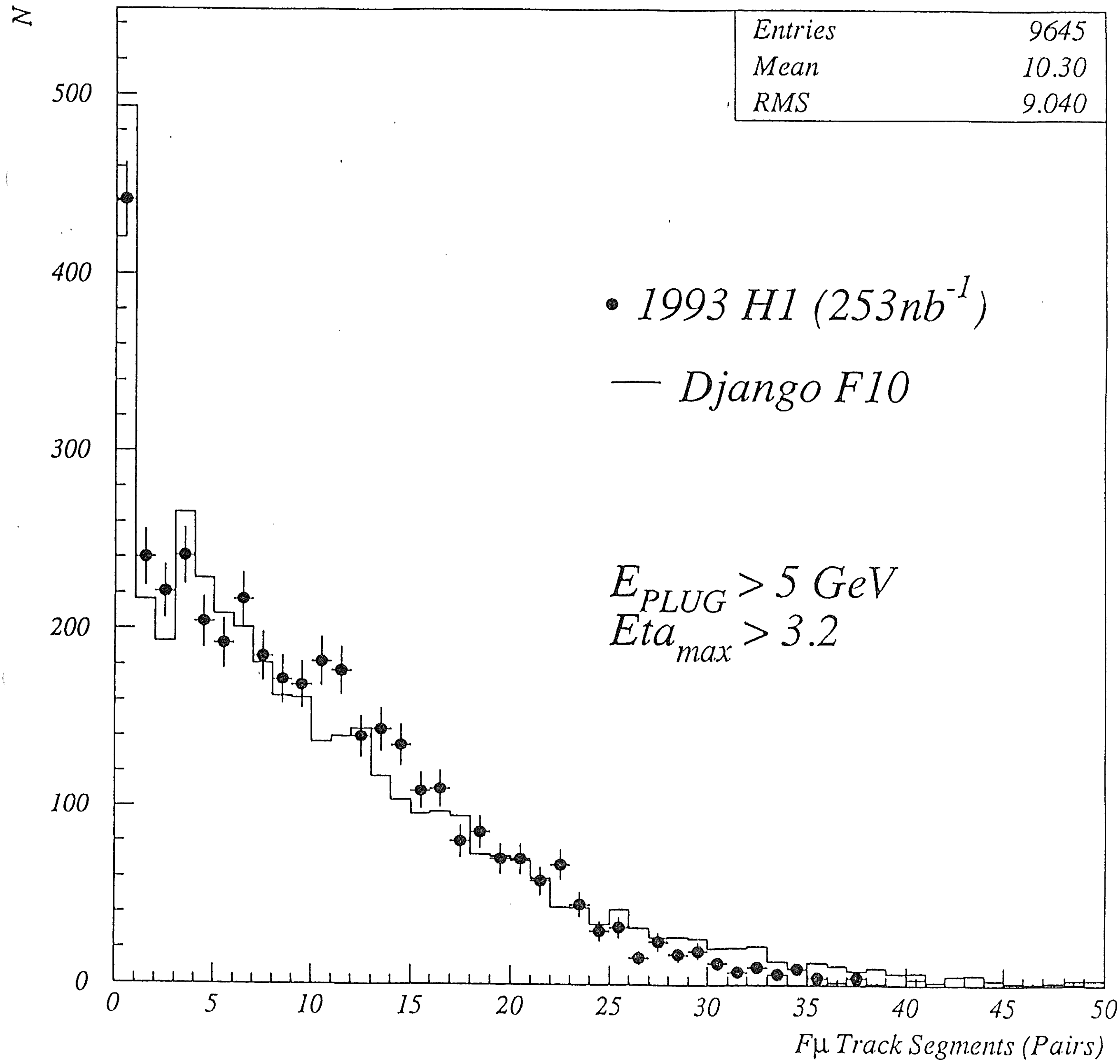

H1 Run 66007 Event 137061 Class: 10 11 12 16 17 18 20 22 23 Date 24/10/1993
R
Z


Run 64901 Event 33275 Class: 10 11 18 23 Date 10/10/1993
R
Z

Plug Energies after Rescaling (MC * 0.6)

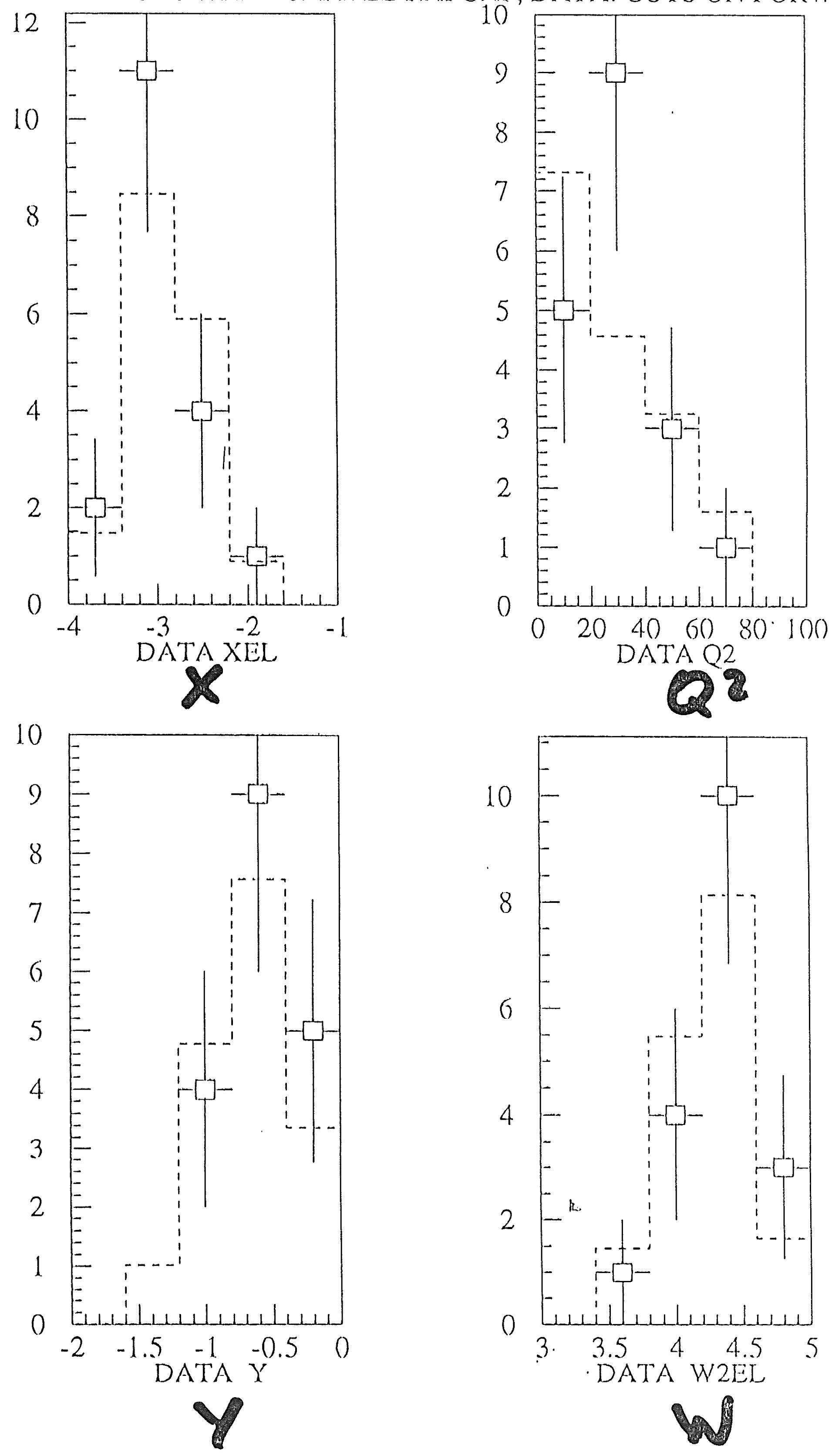


Number of Fμ Track Segments

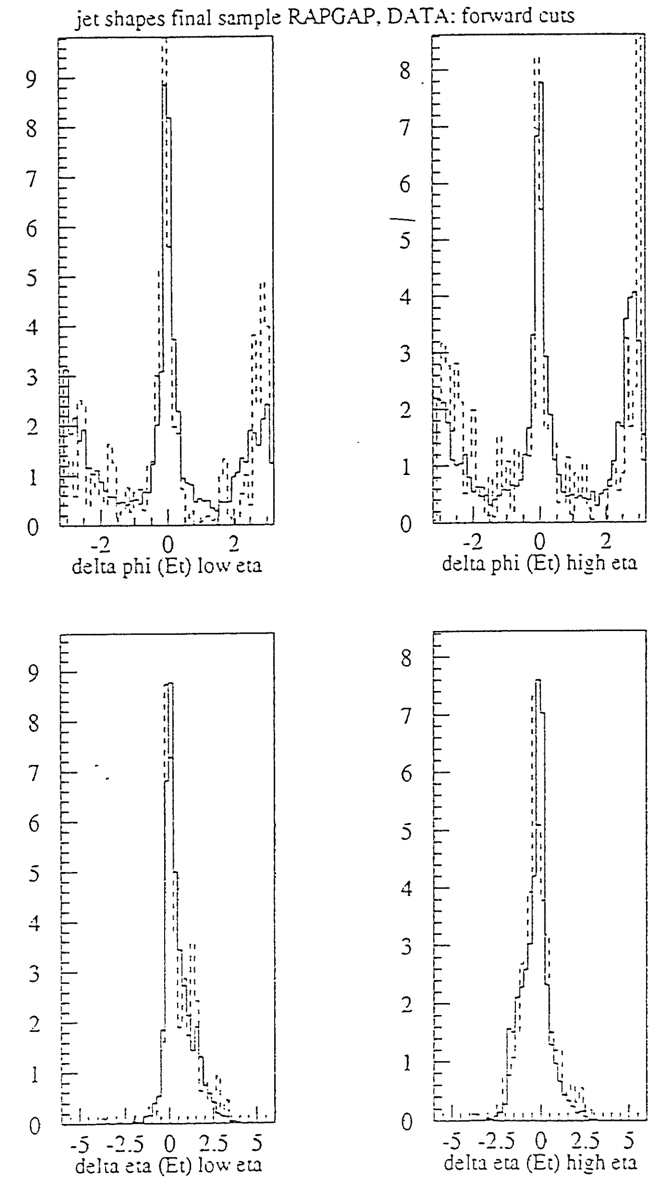


Kinematical variables

KINEMATIC CHECKS FINAL SAMPLE RAPGAP, DATA: CUTS ON FORWARD



Jet profiles



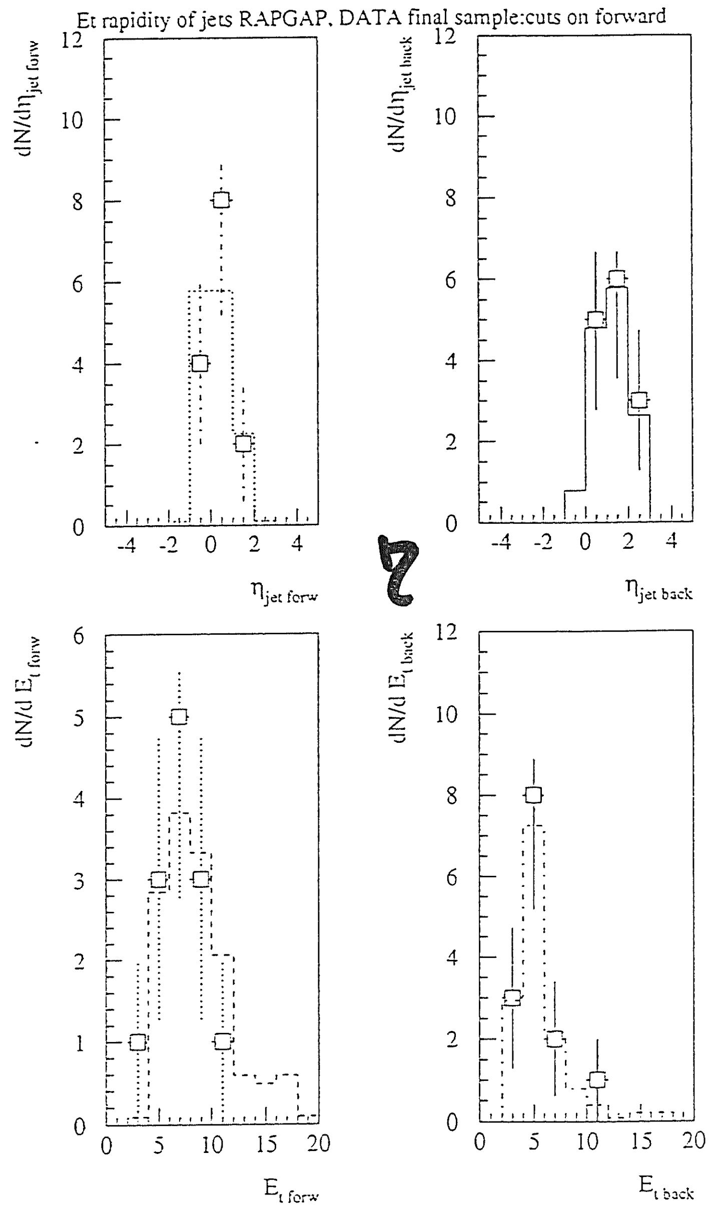
E_T

$\Delta\phi$

$\Delta\eta$

Low η_i high η_i

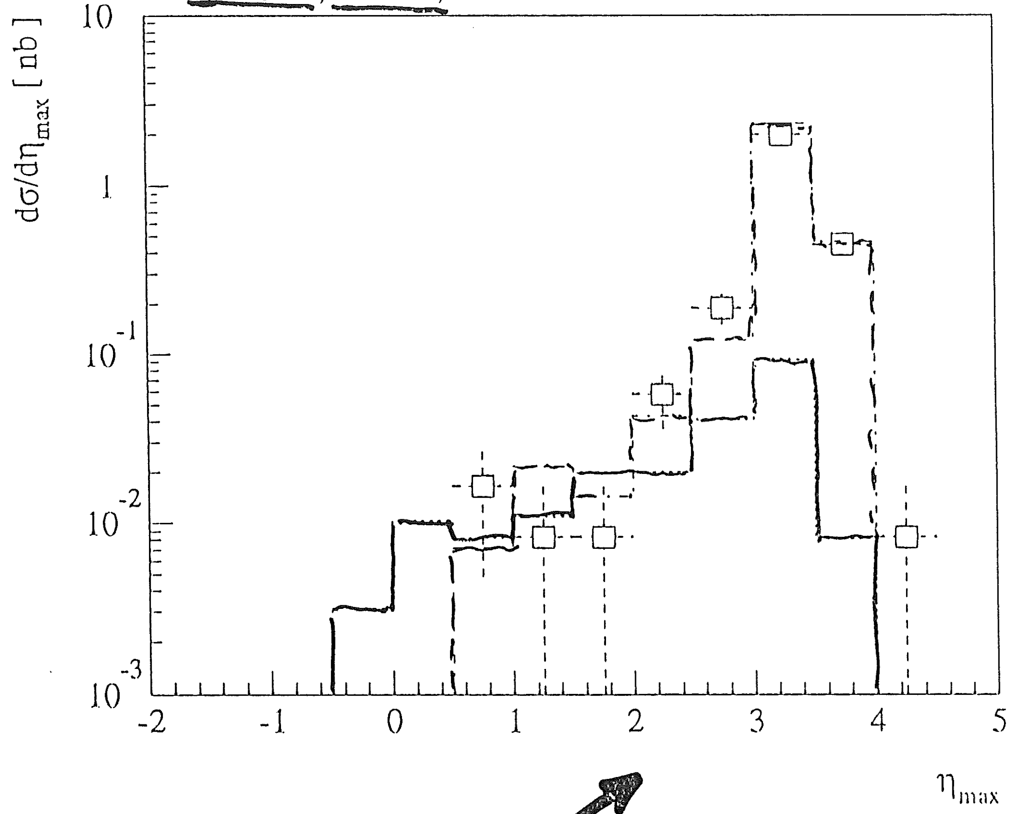
Incl. jet spectra



η

E_T

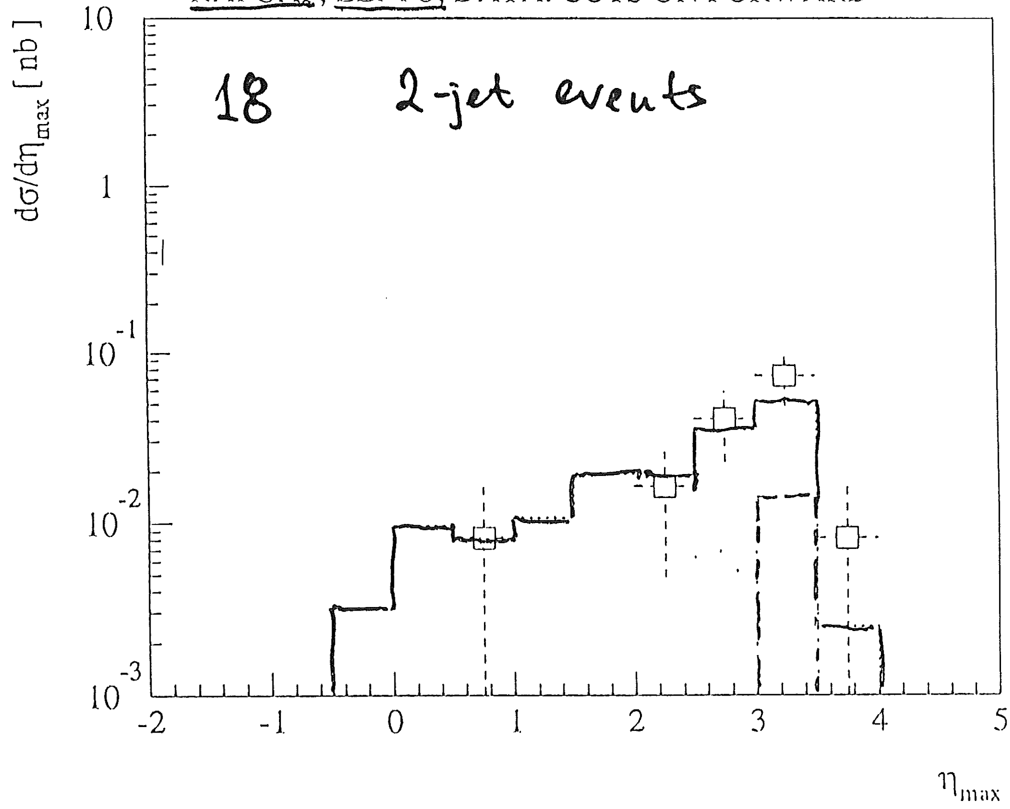
RAPGAP, LEPTO, DATA: NO FORWARD CUTS



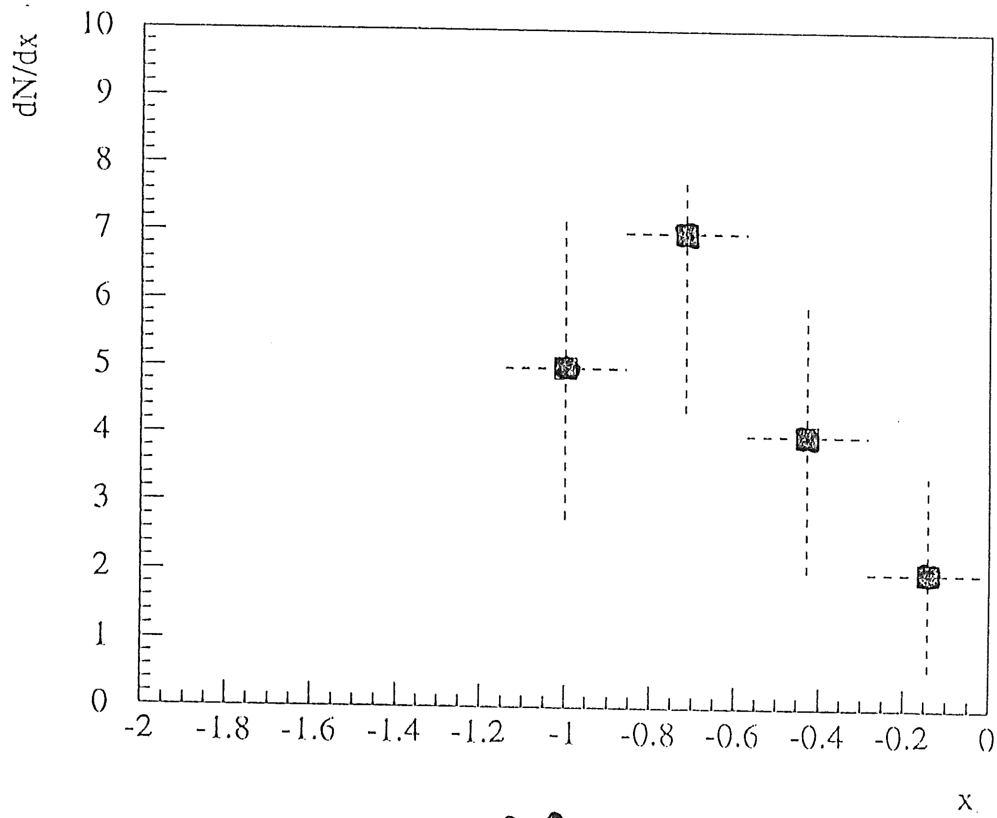
Fwd cut → BEFORE

→ AFTER

RAPGAP, LEPTO, DATA: CUTS ON FORWARD



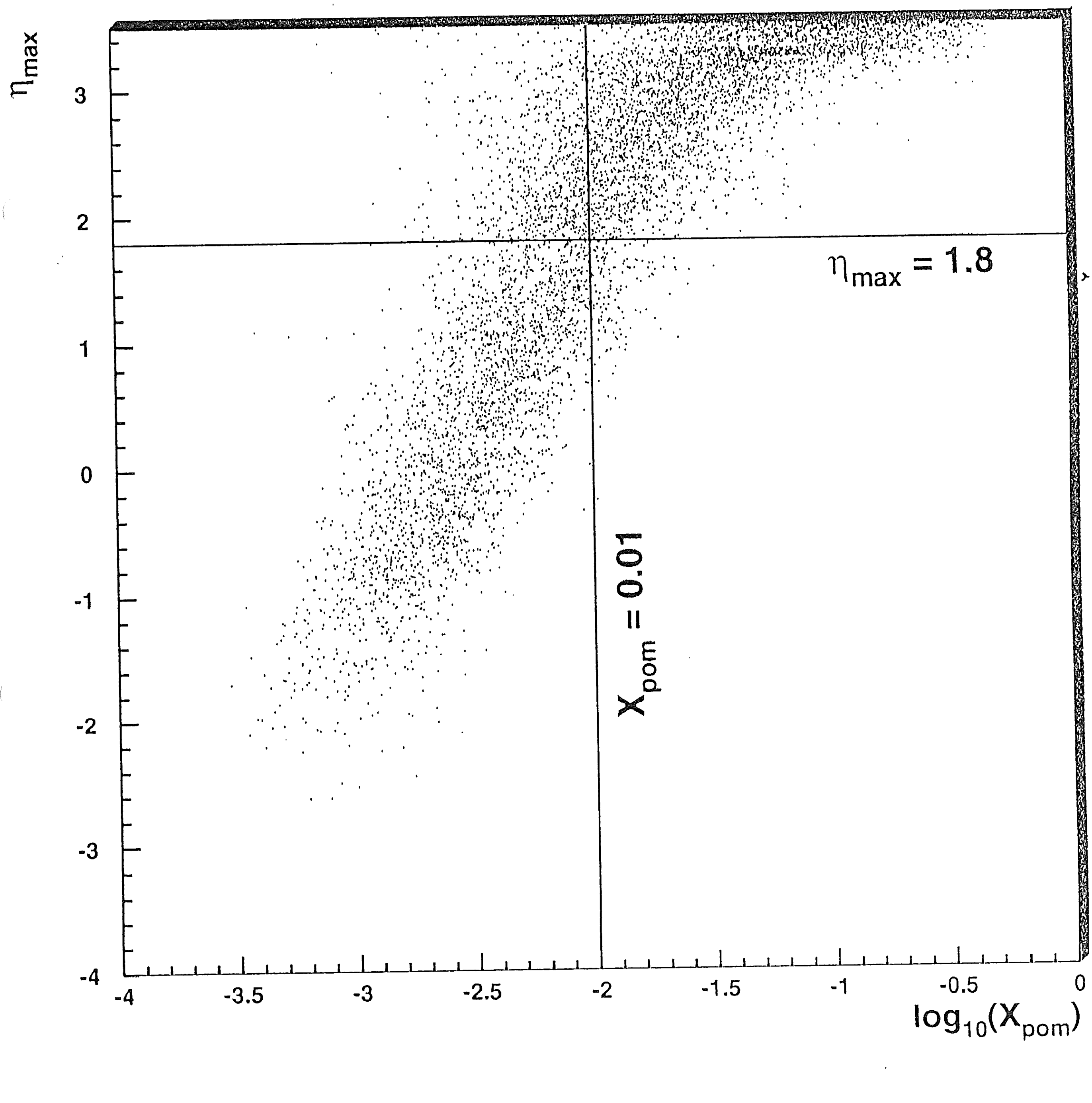
Not acceptance corrected!



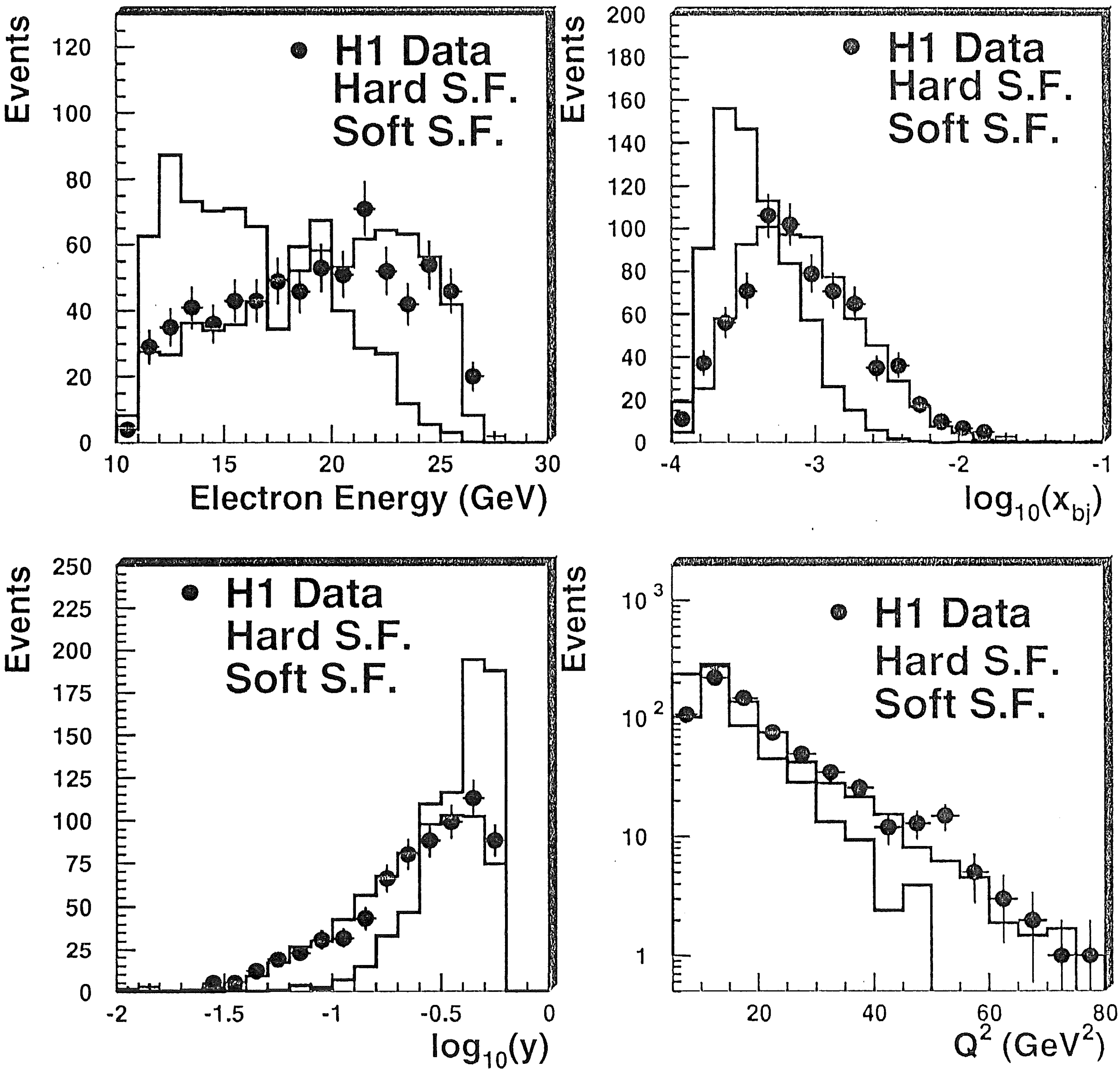
$X_{g/IP}$

↘ advertisement for future ...

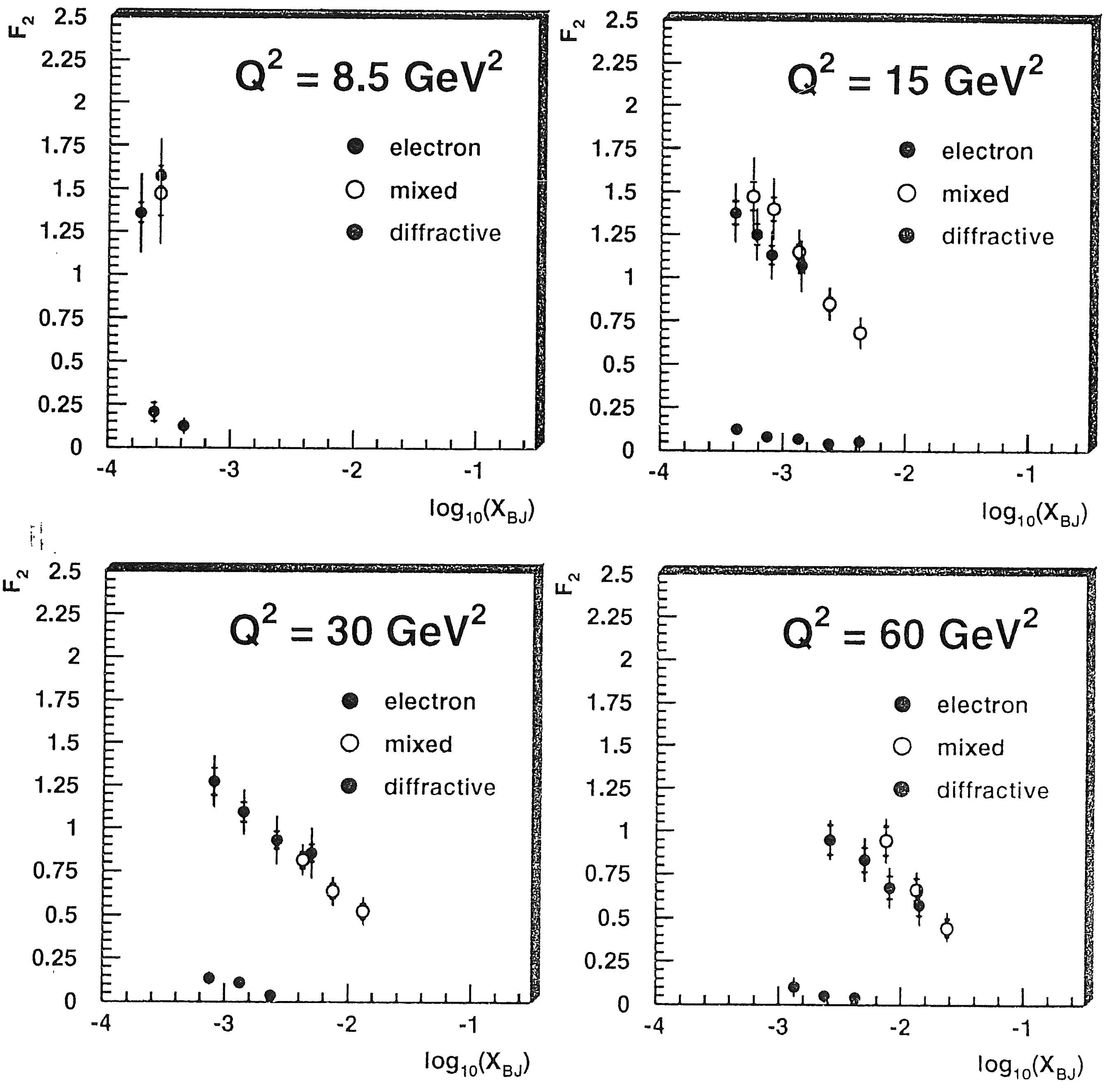
Correlation between η_{max} and X_{pom}



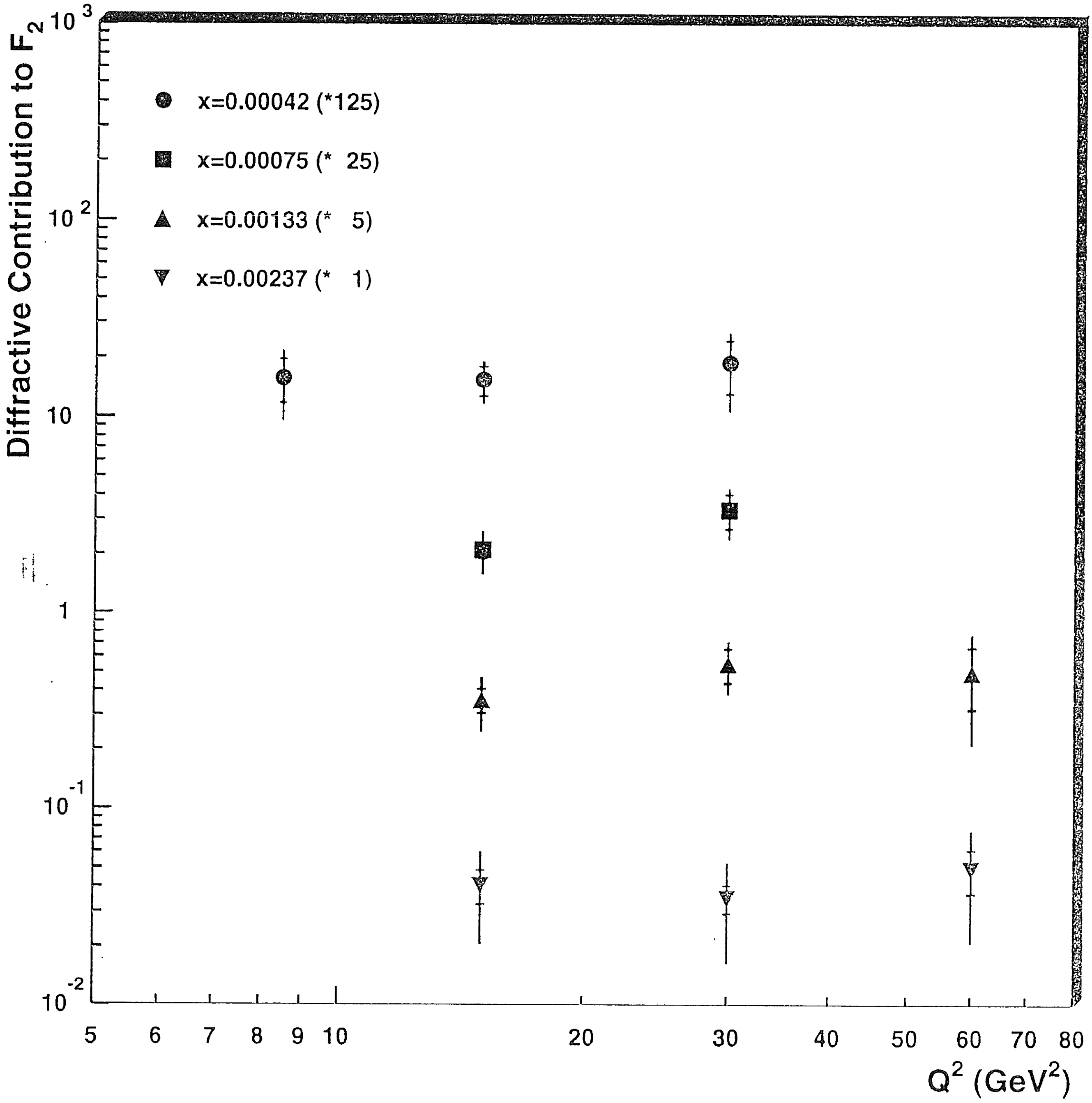
Description of Rapidity Gap Events by RAPGAP



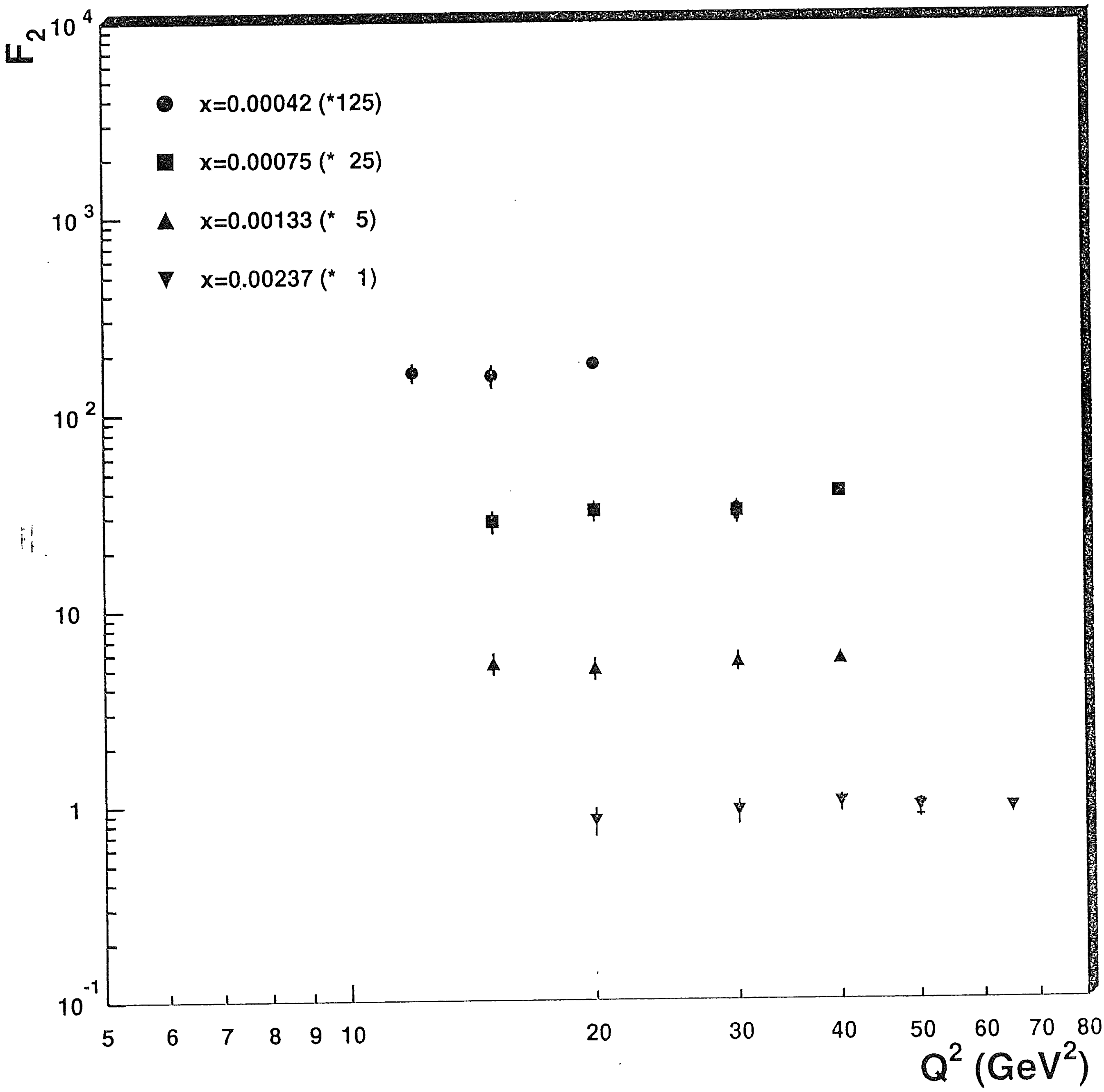
Diffractive Contribution to $F_2(x,Q^2)$
H1 Preliminary



Q^2 Evolution



Q^2 Evolution



(Provocative) SUMMARY

1. Large rapidity gap events were found in H1 (no surprise) and studied both in γp ($Q^2 < 0.01\,GeV^2$) and DIS ($Q^2 > 5\,GeV^2$)

2. Use of the forward detectors shows the possibility of potential improvements in the analysis of rapidity gap phenomena

3. A clear evidence of the hard scattering in diffractive-like rapidity gap events has been found in γp interactions at HERA energies.

4. Inclusive jet distributions and relative 2/1 jet yield shows some preference of the hard gluonic structure of $\mathbb{P}$ over the soft one (in the framework of the model used for the comparison with data)

5. Rapidity gap events in D.I.S. are also well described by the monte Carlo model using hard IP_{SF}

6. An attempt to decribe entire D.I.S. rap.gap. sample by the VMD motivated model leads to unrealistic inelastic/elastic diffraction ratio.

7. Using forward detectors, a larger M_X in the rap.gap. events can be accessed and therefore jets can be found as well.
This demonstrate a potential possibility to measure gluonic content of the Pomeron at HERA.

8. F_2^D has been measured in the kinematic region $x_P \leq 10^{-2}$

9. The measured F_2^D cannot explain, by itself, the steep rise in F_2 with decreasing x_{BJ}

10. There is no evidence that F_2^D $(x_P < 0.01)$ evolves differently in Q^2 than F_2

H1 Collaboration

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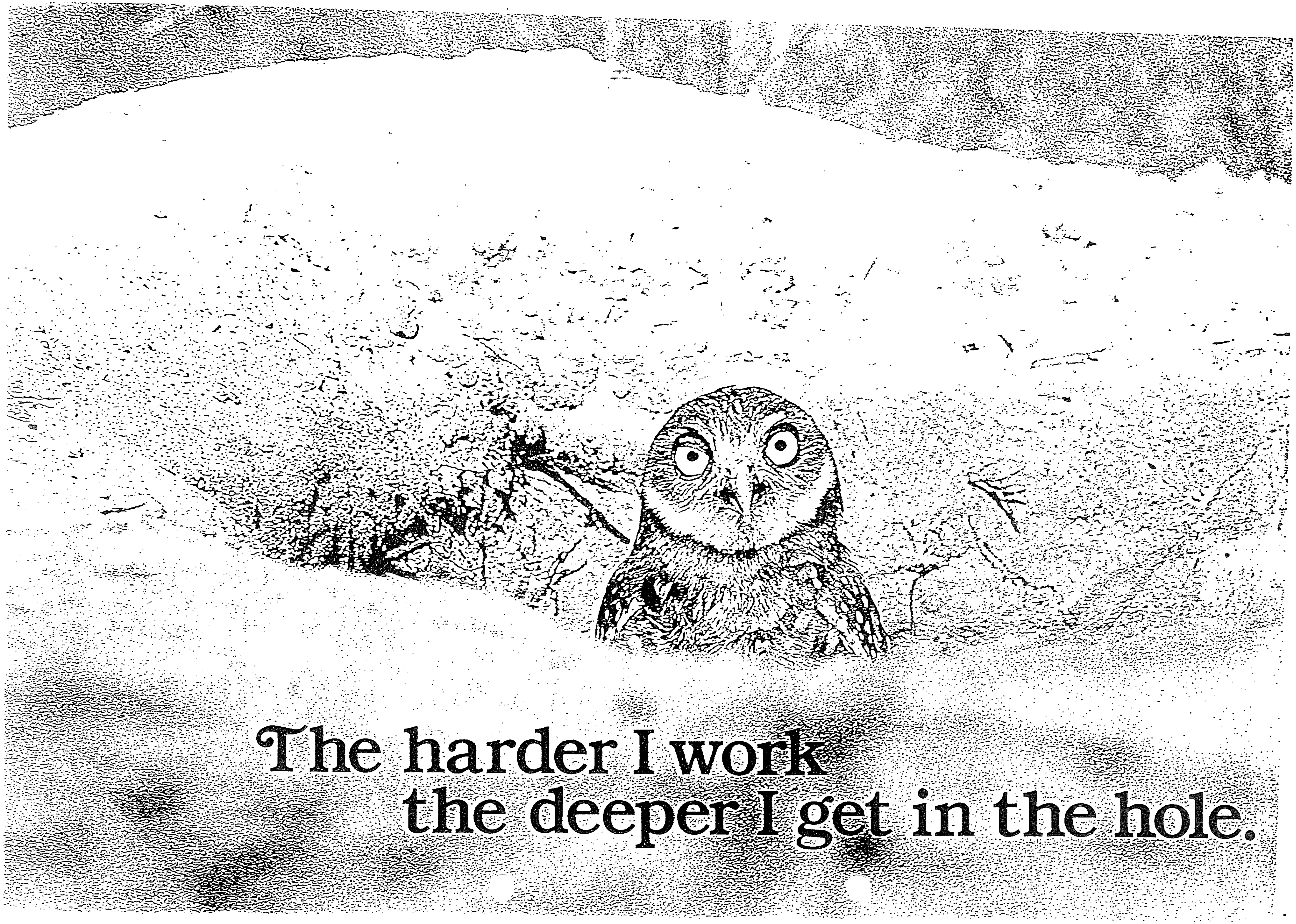
The harder I work
the deeper I get in the hole.