Fragmentation in Diffractive DIS at HERA

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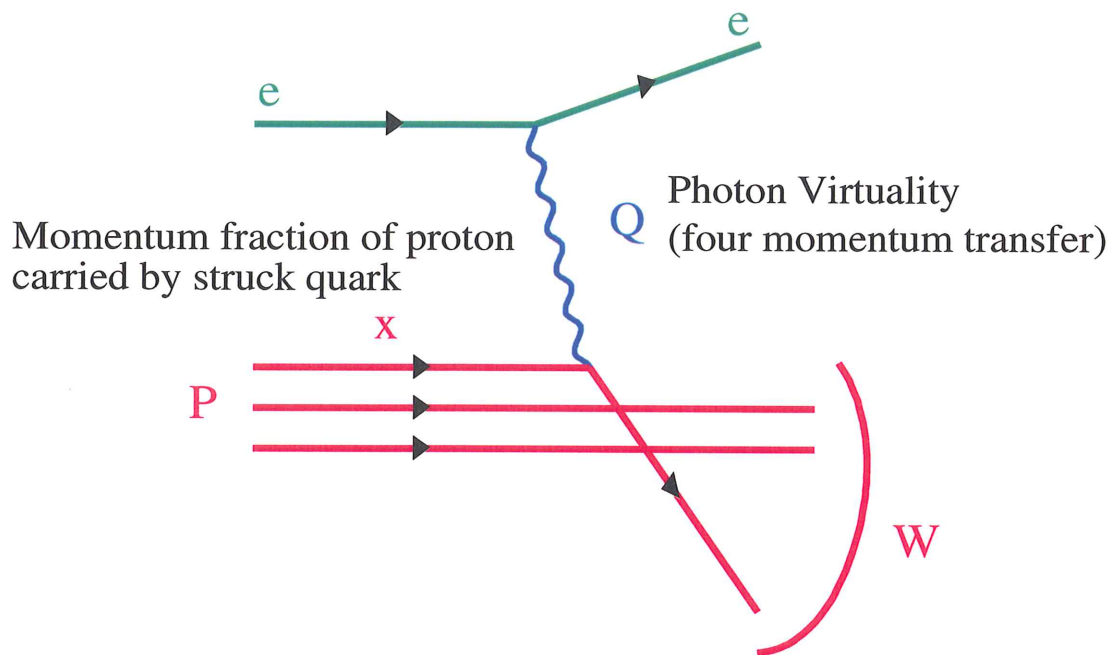
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Overview

- Definitions and Descriptions
  - DIS and diffraction
  - The Breit Frame
  - Models of diffraction
- Rapidity
- Fragmentation Function
  - Peak and widths
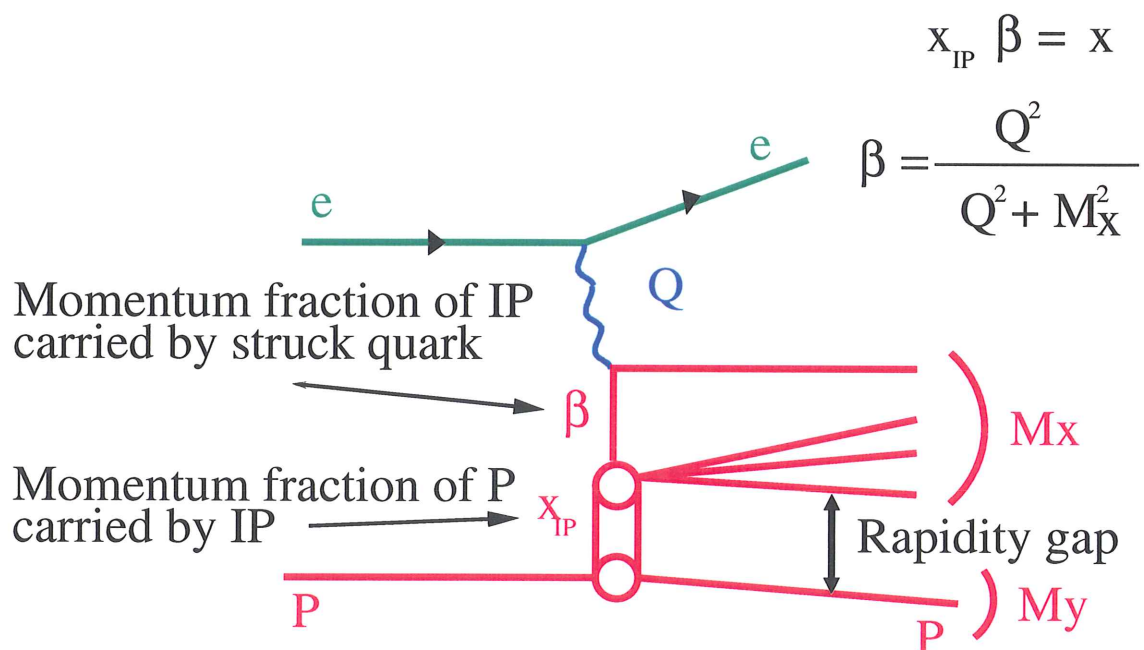 - Average Charged Multiplicity
- Conclusions

Motivation

- Compare the charged track longitudinal momentum spectra of DIS with diffraction.

- Test quark fragmentation Universality (quark from $e^+e^- \to q\bar{q} \equiv$ struck quark from $ep \equiv$ struck quark from $e\mathbb{P}$).

- Test various models of diffraction
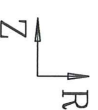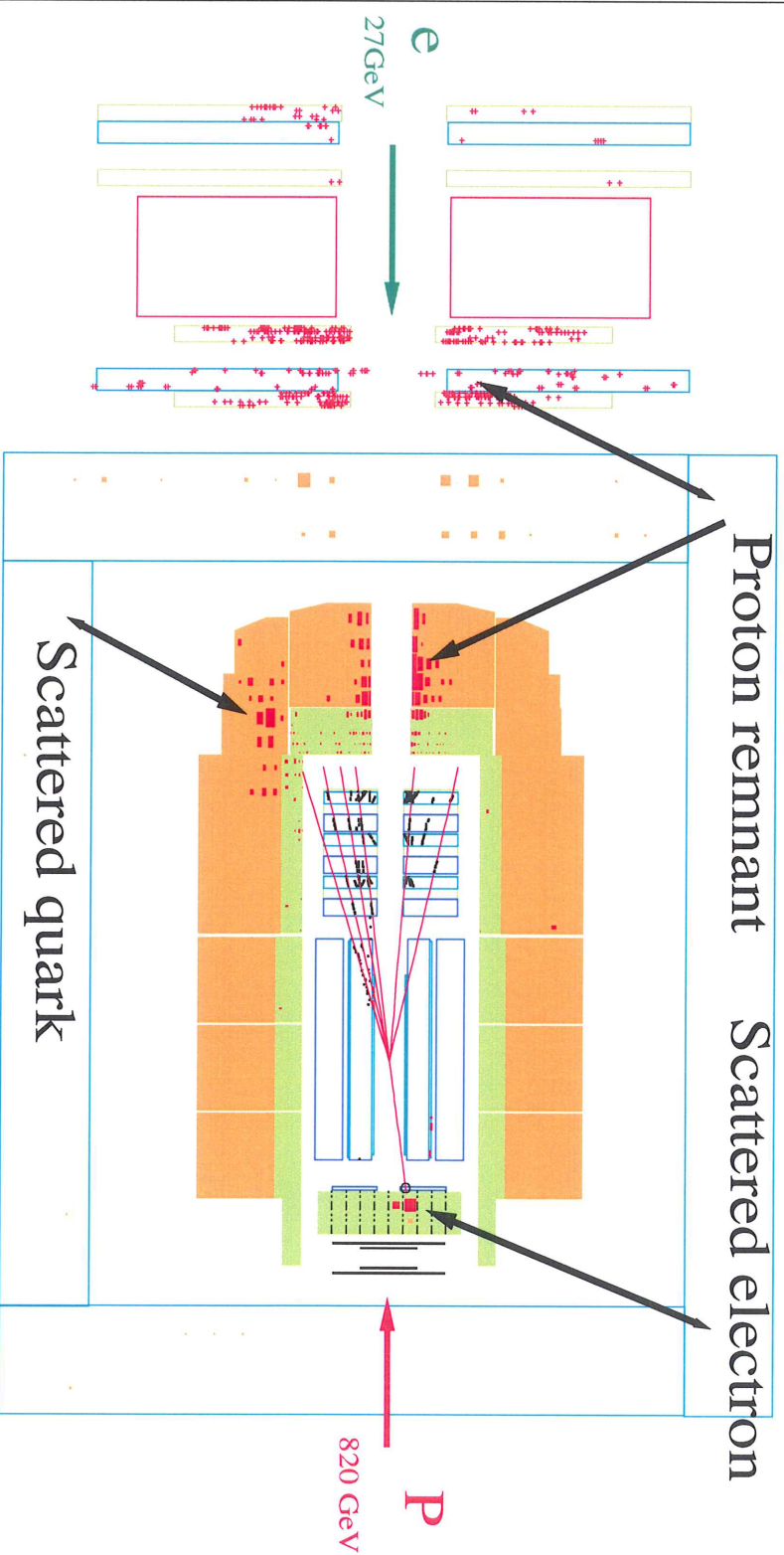
Useful Definitions

QPM Picture of DIS:

Momentum fraction of proton carried by struck quark

x

Q Photon Virtuality (four momentum transfer)

P

W

Diffractive DIS:

$$x_{IP}\,\beta = x$$

$$\beta = \frac{Q^2}{Q^2 + M_X^2}$$

Momentum fraction of IP carried by struck quark

β

Momentum fraction of P carried by IP

x_{IP}

Mx

Rapidity gap

My

P

2

Run 64901 Event 33275 Class: 10 11 18 23   Date 22/02/1994

$12 < Q^2 < 100$ GeV $0.055 < y < 0.6$ SEE $= 14$ GeV

e
27 GeV

P
820 GeV

Proton remnant   Scattered electron

Scattered quark
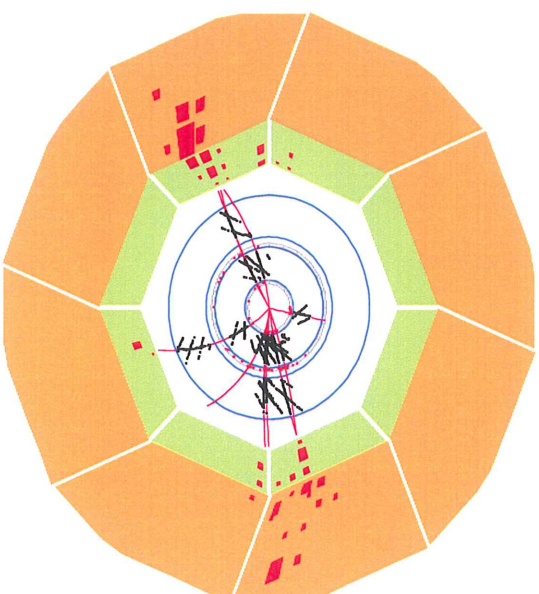
Z   R

Run 84629   Event 76749   Class: 3 10 11 15 20 25 26 28   Run date 16/08/94

DIS Rapgap Event

Scattered electron

Rapidity Gap

$3 < M_x < 36\,\text{GeV}$

$x_{IP} < 0.05$ $M_Y < 1.6\,\text{GeV}$

Breit Frame

$\rightarrow$ z

Non–diffractive
DIS

$P_z = -\dfrac{Q}{2}$

$P_z = +\dfrac{Q}{2}$

γ

e^+

P

Diffractive DIS

$P_z = -\dfrac{Q}{2}$

$P_z = -\dfrac{Q}{2}$

γ

e^+

$q = (0,0,0,-Q)$

P   P

$E^* / 2$ $E^* / 2$

q $\bar{q}$

$Q = E^*$ $e^+ e^- \longrightarrow q\,\bar{q}$
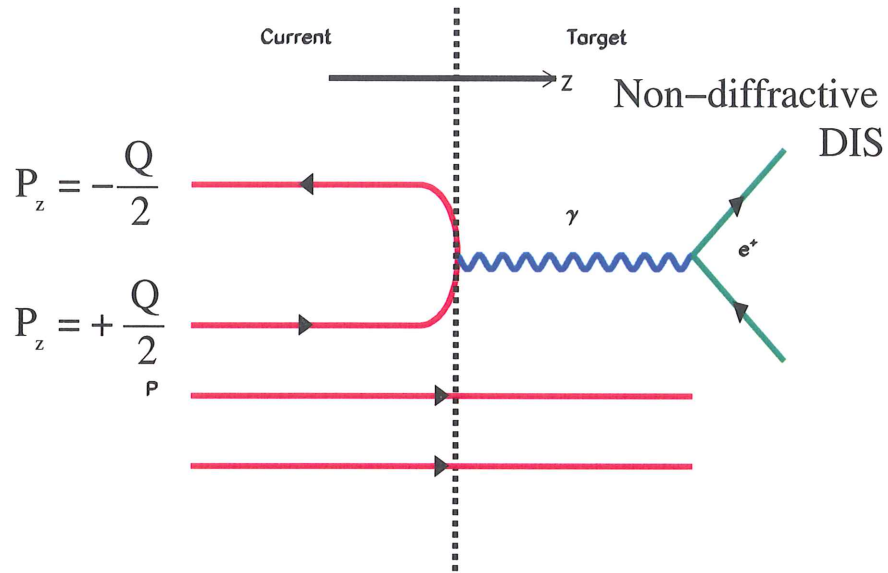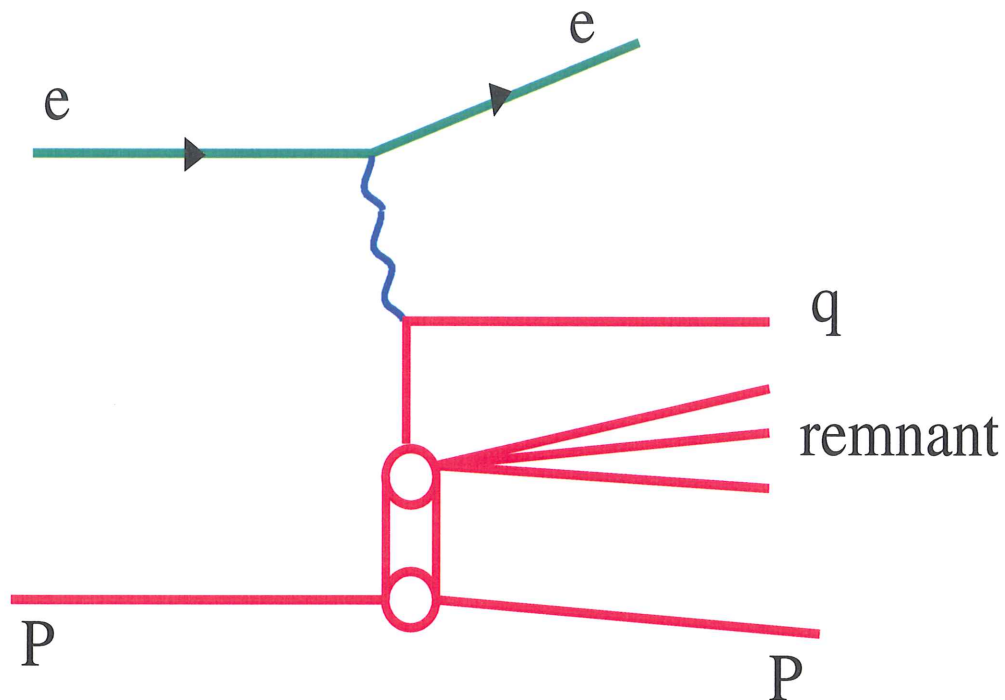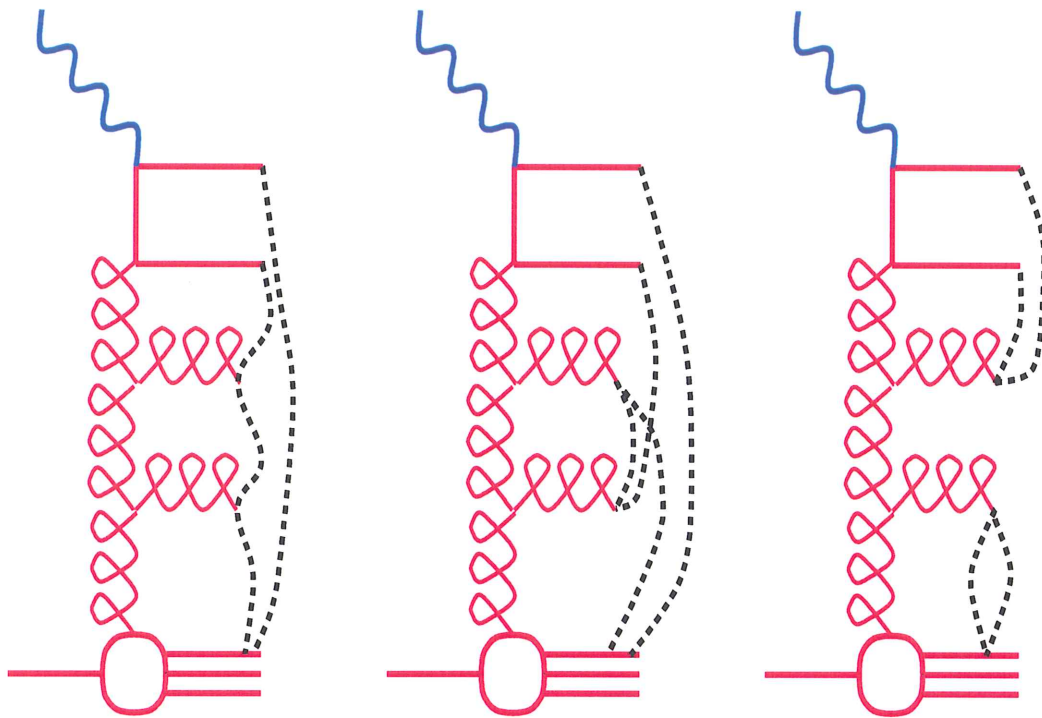
Resolved Pomeron Model

- Ingelman and Schlein[1]

- Treat pomeron as hadron within the proton.

- Similar to proton and photon structure functions

- H1 fits; quark dominated fit 1, flat gluon fit 2, peaked gluon fit 3

- Monte-Carlo: RAPGAP

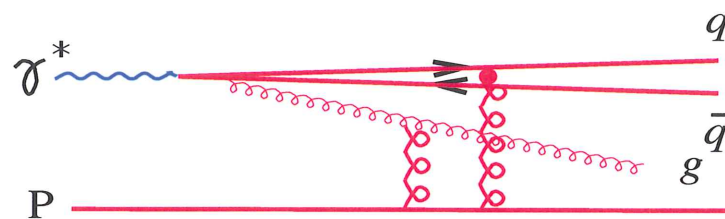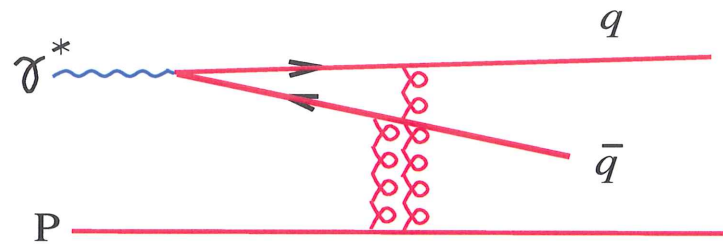[1]Phys. Lett. B152 (1985) 256

Soft Colour Interactions

- Ingelman, Edin, Rathsman[2]

- Normal ep scattering + colour neutralisation through soft gluon

- Original model, universal colour rearrangement probability

- New model, generalised area law

- Monte-Carlo: LEPTO

[2]Phys. Lett. B 366 (1996) 371

Colour Dipole and 2-Gluon Models

Scattering of $q\bar{q}$ and $q\bar{q}g$ colour dipoles off the proton via 2 gluon exchange.

$q\bar{q}$ production at medium and high β (small M_x)

$q\bar{q}g$ production at Low β (large M_x)

Saturation model

- Golec-Biernat & Wusthoff[3]
- Monte-Carlo: RAPGAP

Other Models

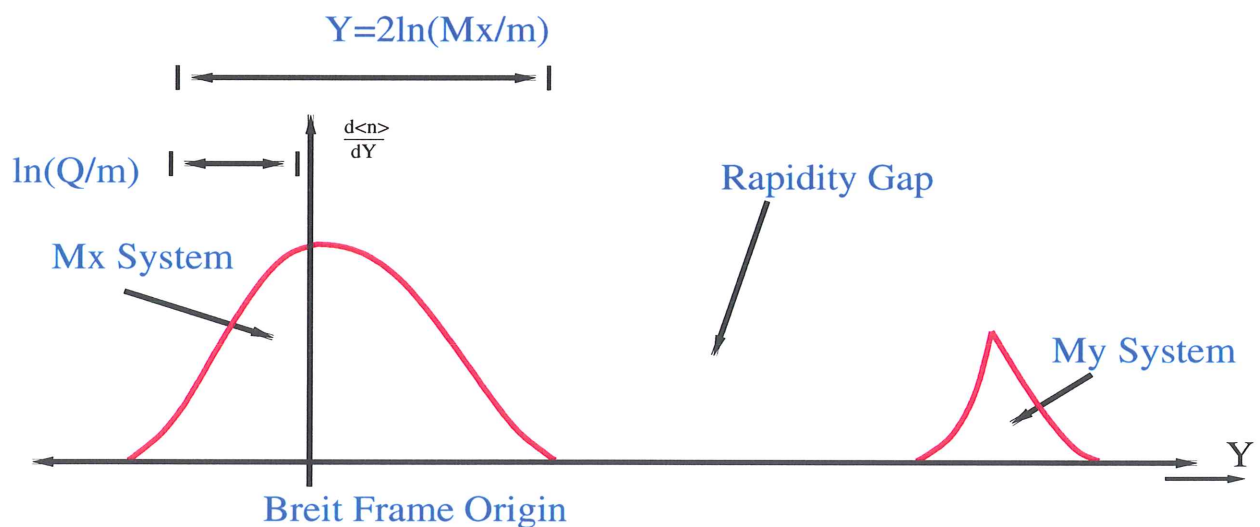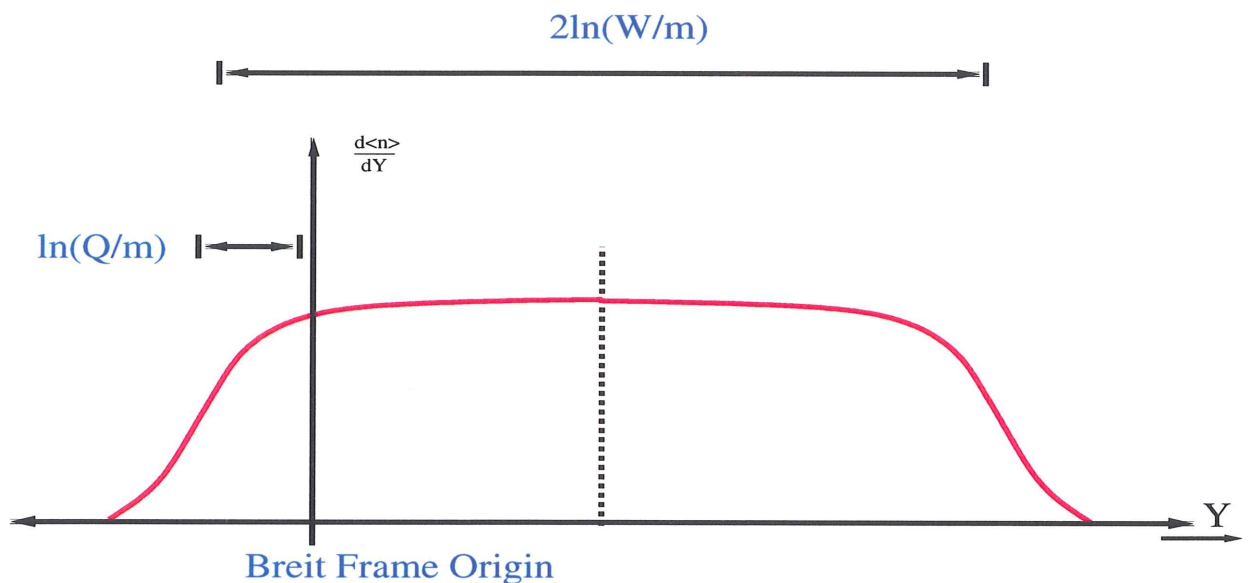- Bartels, Jung, Lotter, Wusthoff

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[3]Phys. Rev D 59 (1999) 014017
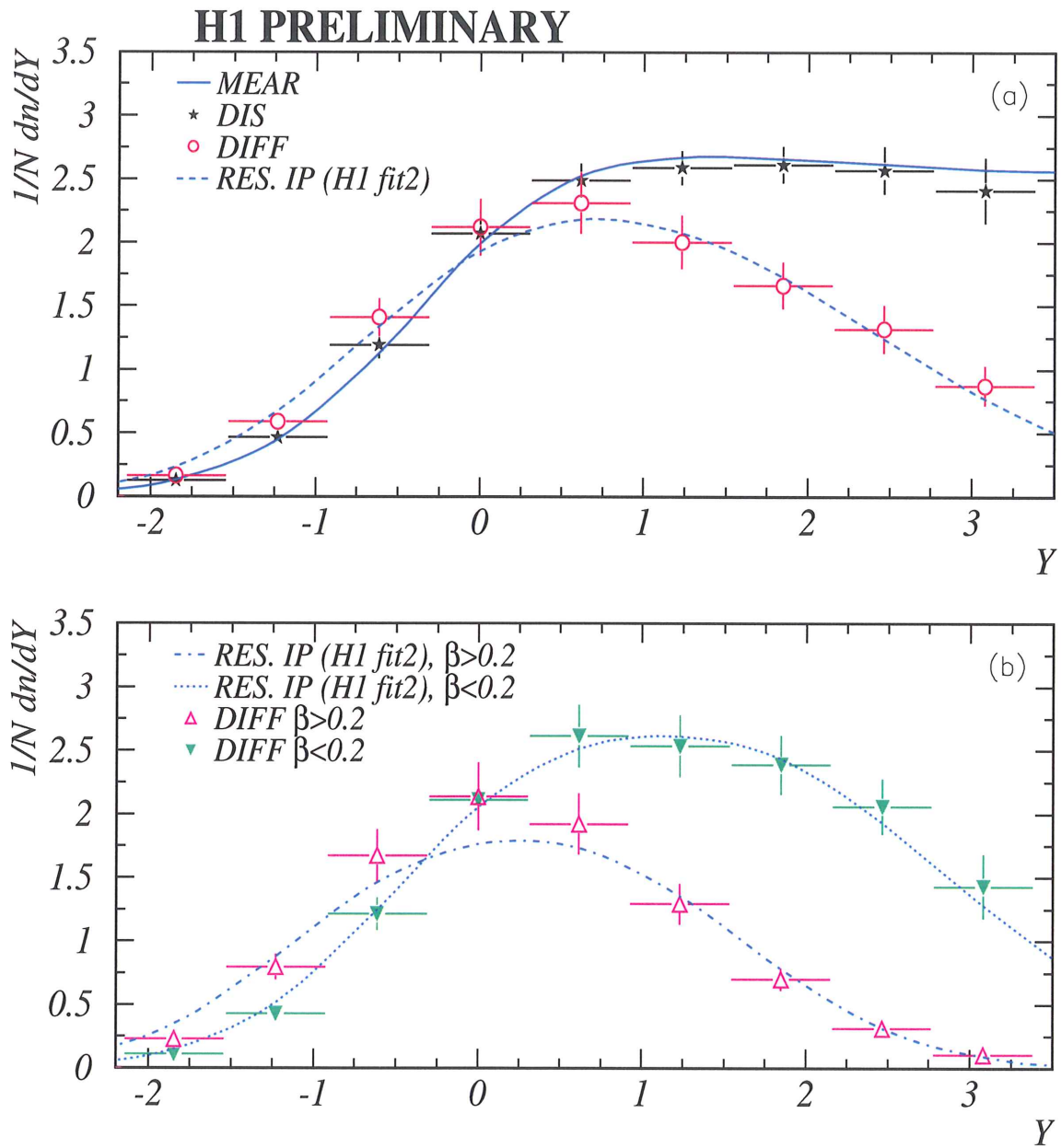
Rapidity Spectra (1)

$$Y = \frac{1}{2} \ln \left(\frac{E + P_z}{E - P_z} \right)$$

E = energy of particle (assuming pion mass - corrections made using Monte-Carlo)

P_z = Longitudinal Momentum

H1 PRELIMINARY
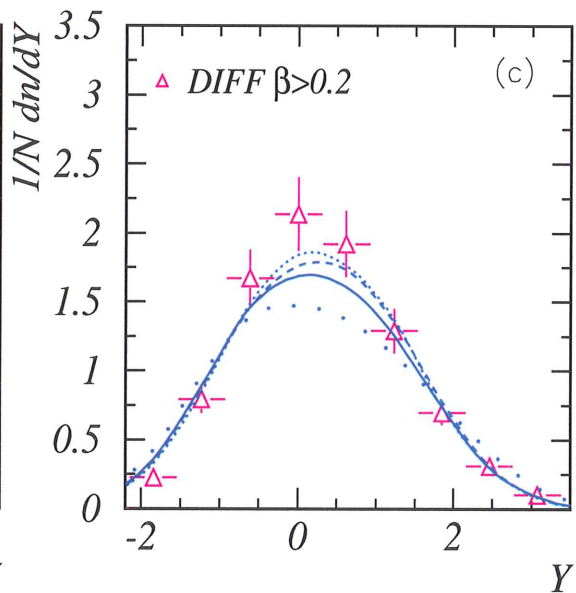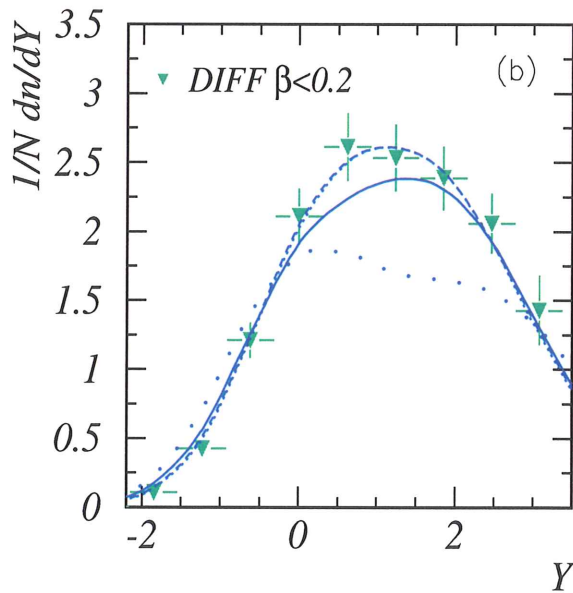
(a) Legend: MEAR, DIS, DIFF, RES. IP (H1 fit2)

(b) Legend: RES. IP (H1 fit2), $\beta > 0.2$; RES. IP (H1 fit2), $\beta < 0.2$; DIFF $\beta > 0.2$; DIFF $\beta < 0.2$

- Best Models
- Difference between DIS and DIFF.
- Difference between high and low β DIFF.
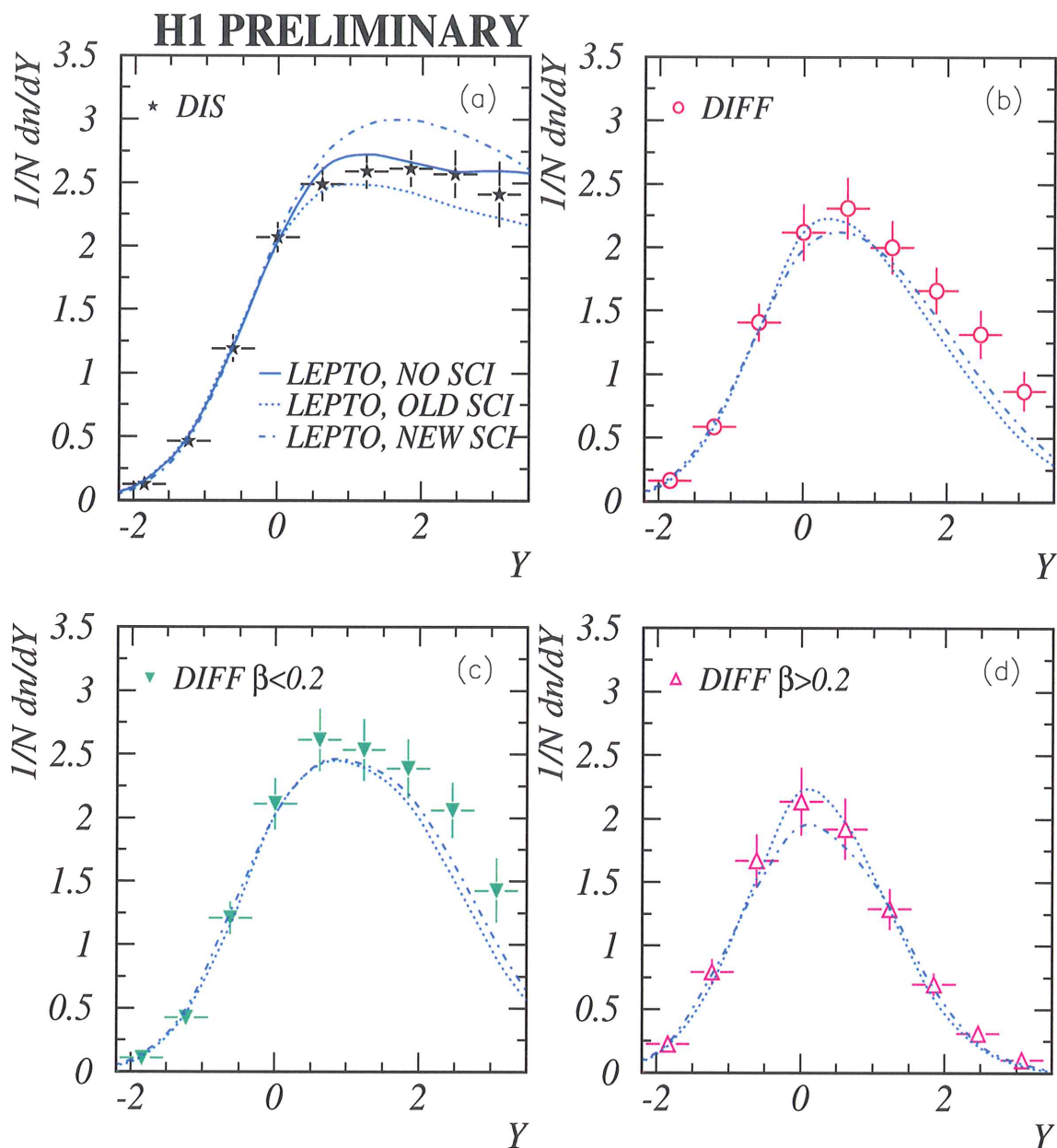
H1 PRELIMINARY

- · · *RES. IP (H1 fit1)*
- - - *RES. IP (H1 fit2)*
- · · · · *RES. IP (H1 fit3)*
- —— *Saturation model*

- Fit 2 and 3 indistinguishable.
- Fit 1 fails (already known), sensitivity to different models.
- Saturation Model, low central multiplicity
- Sensitivity at low β.

Rapidity: Model comparison (2)

- Best description of DIS given by LEPTO with no SCI.
- Large difference between NEW and OLD SCI versions for DIS
- Little difference between versions for DIFF.
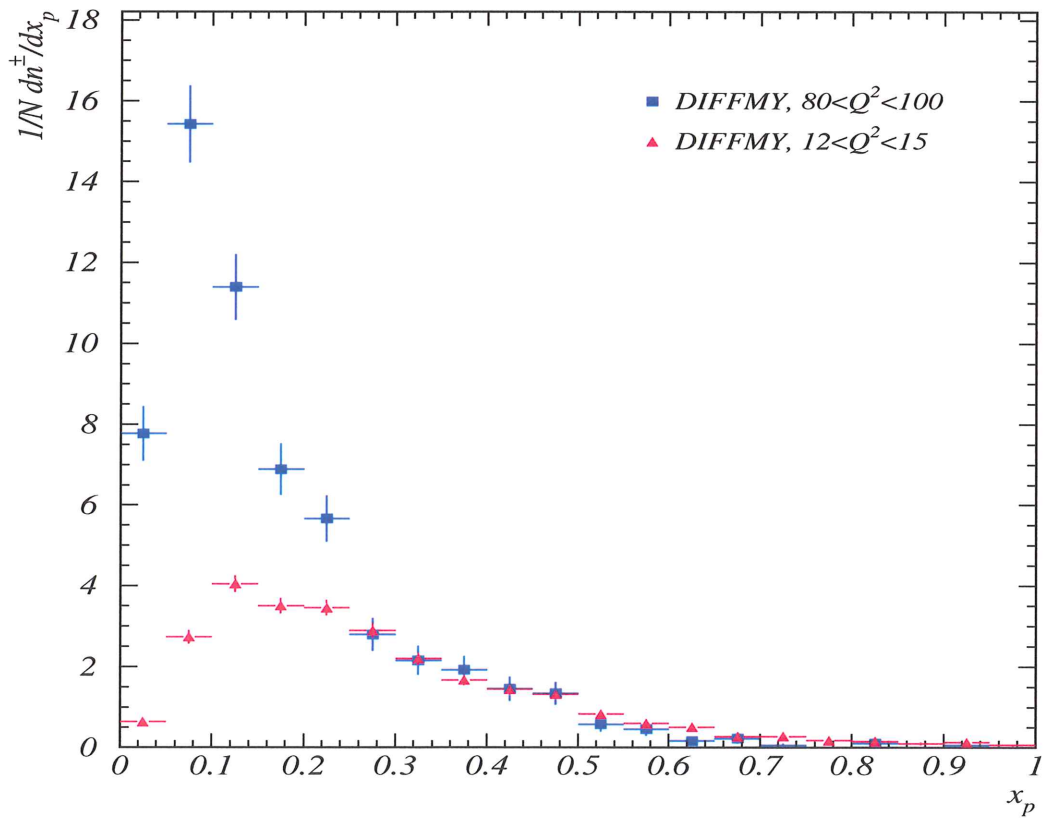- Multiplicity too low in target region at low β.

Fragmentation Function (1)

Inclusive Scaled Momentum distribution,

$$x_p = \frac{2p}{Q}$$

Event Normalised Charged track density

$$D\left(x_p\right) = \frac{1}{N_{events}} \left(\frac{dn^{\pm}}{dx_p}\right)$$
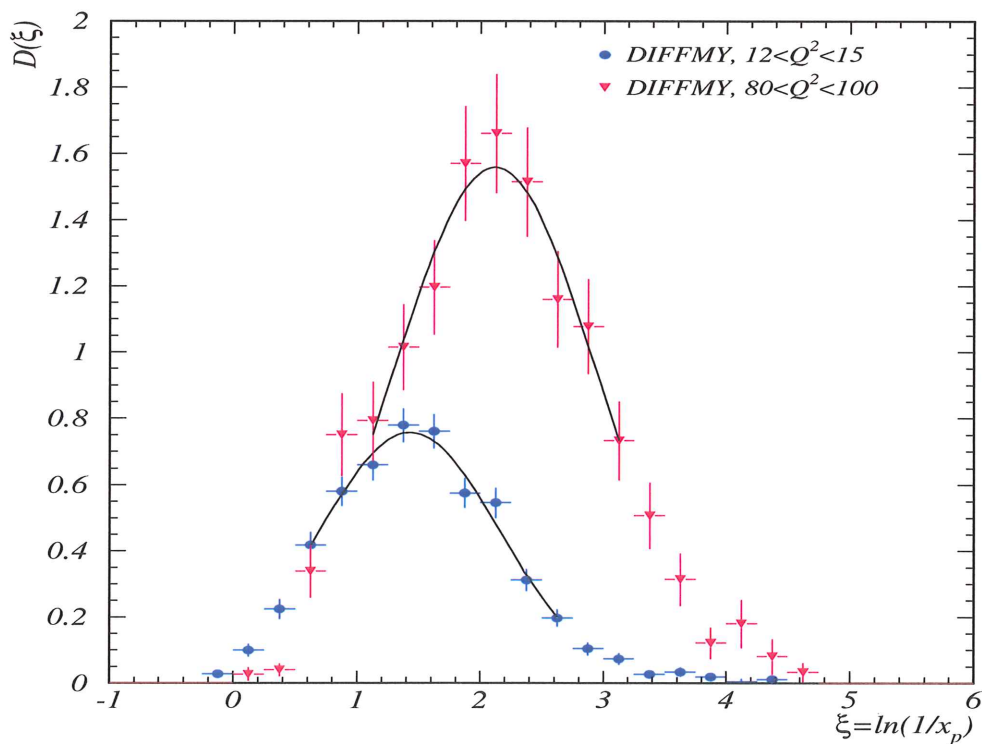
Fragmentation Function (2)

To examine turnover region recast in terms of ξ

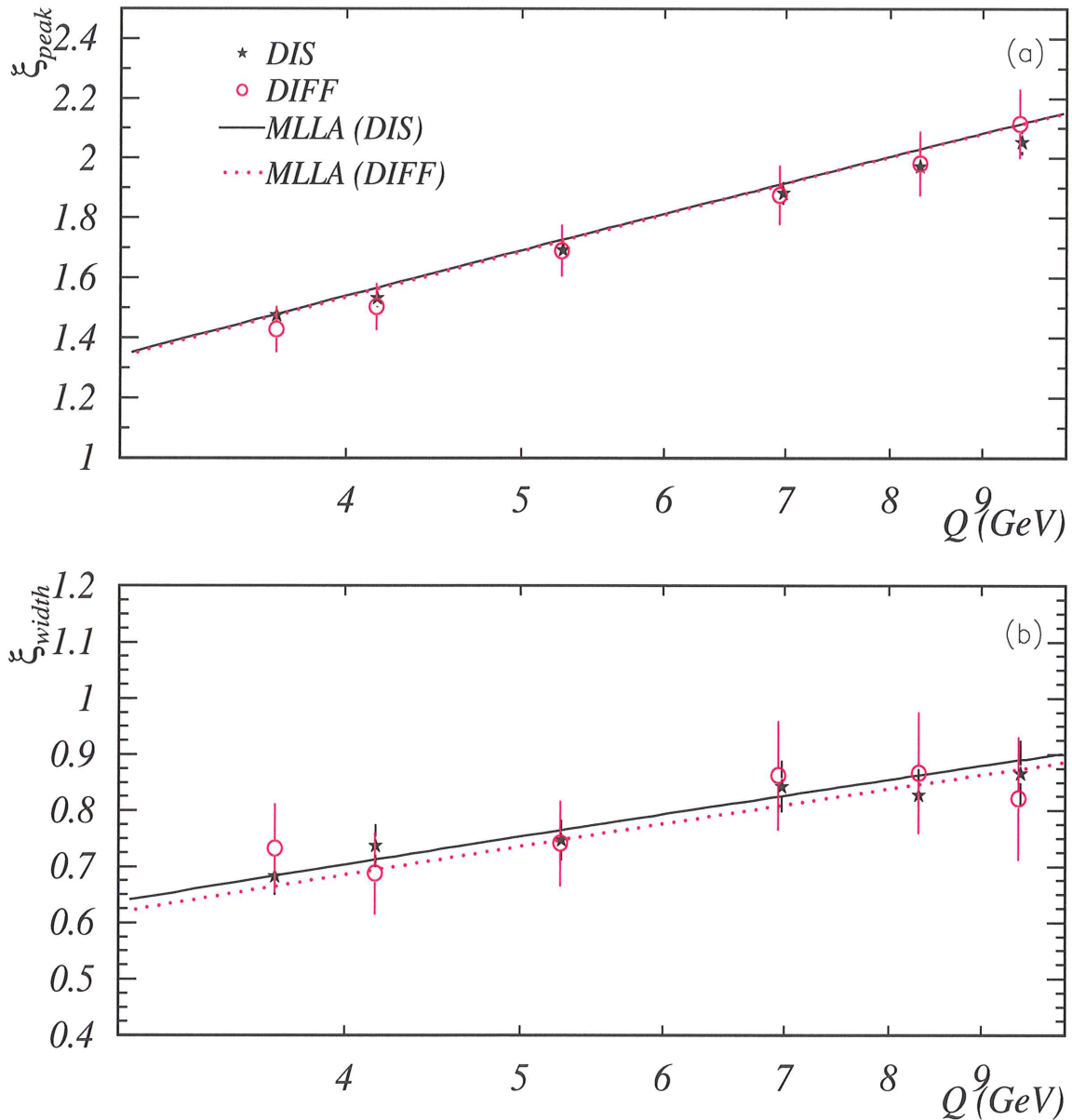$$\xi = \ln\left(\frac{1}{x_p}\right)$$

$$D^{\pm}(\xi) = \frac{1}{N}\left(\frac{dn^{\pm}}{d\xi}\right)$$

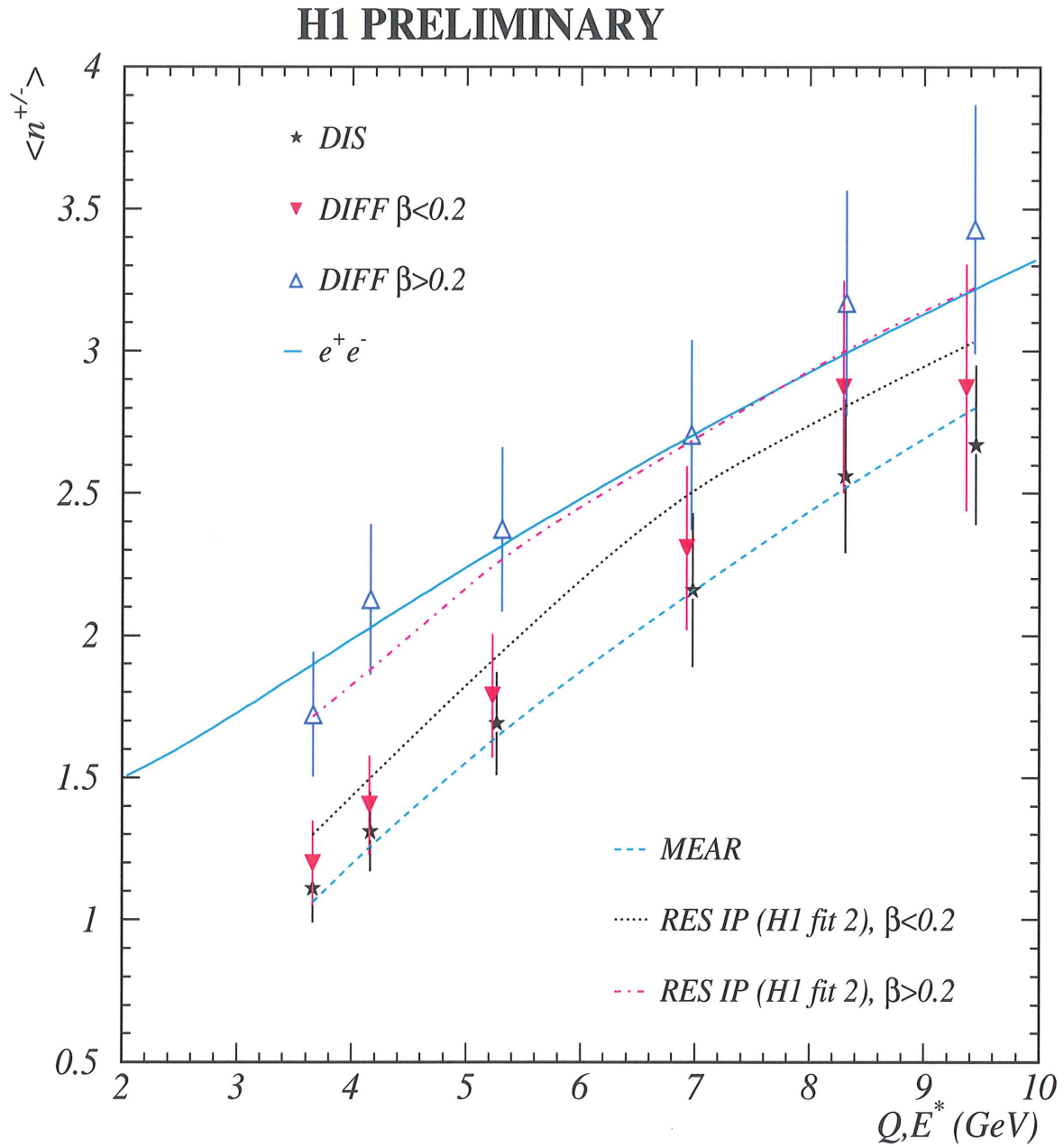- MLLA predicts that in the region of the peak the shape is approximately Gaussian. Predicts evolution with Q.

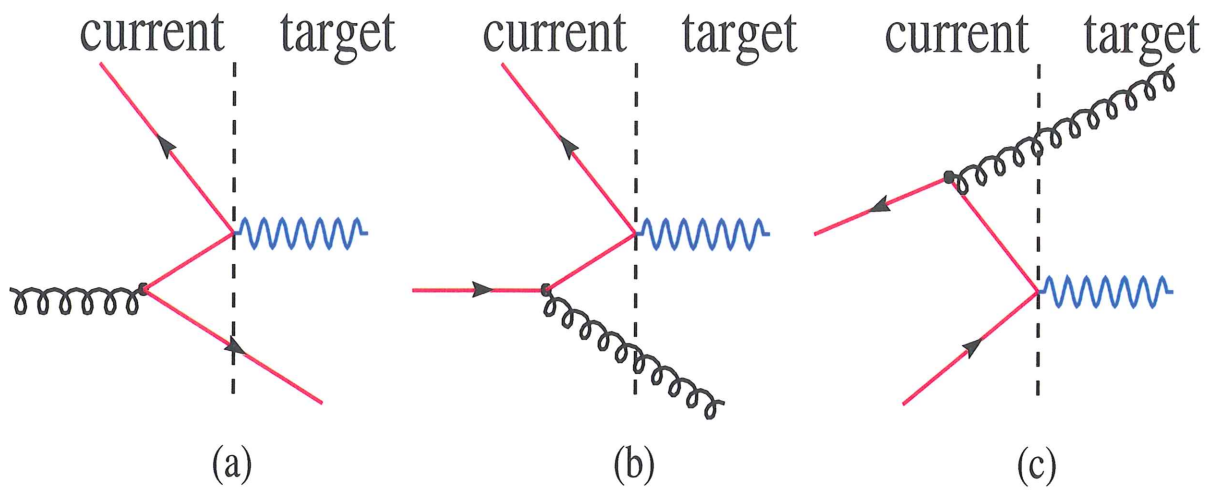# Fragmentation Function (3)

H1 PRELIMINARY

- Very Good agreement between DIS and DIFF.
- Very similar MLLA fits.
- Results lend further support for concept of quark fragmentation universality. ($e^+e^- \rightarrow q\bar{q}$, $ep \rightarrow e'X$, $ep \rightarrow e'XY$)
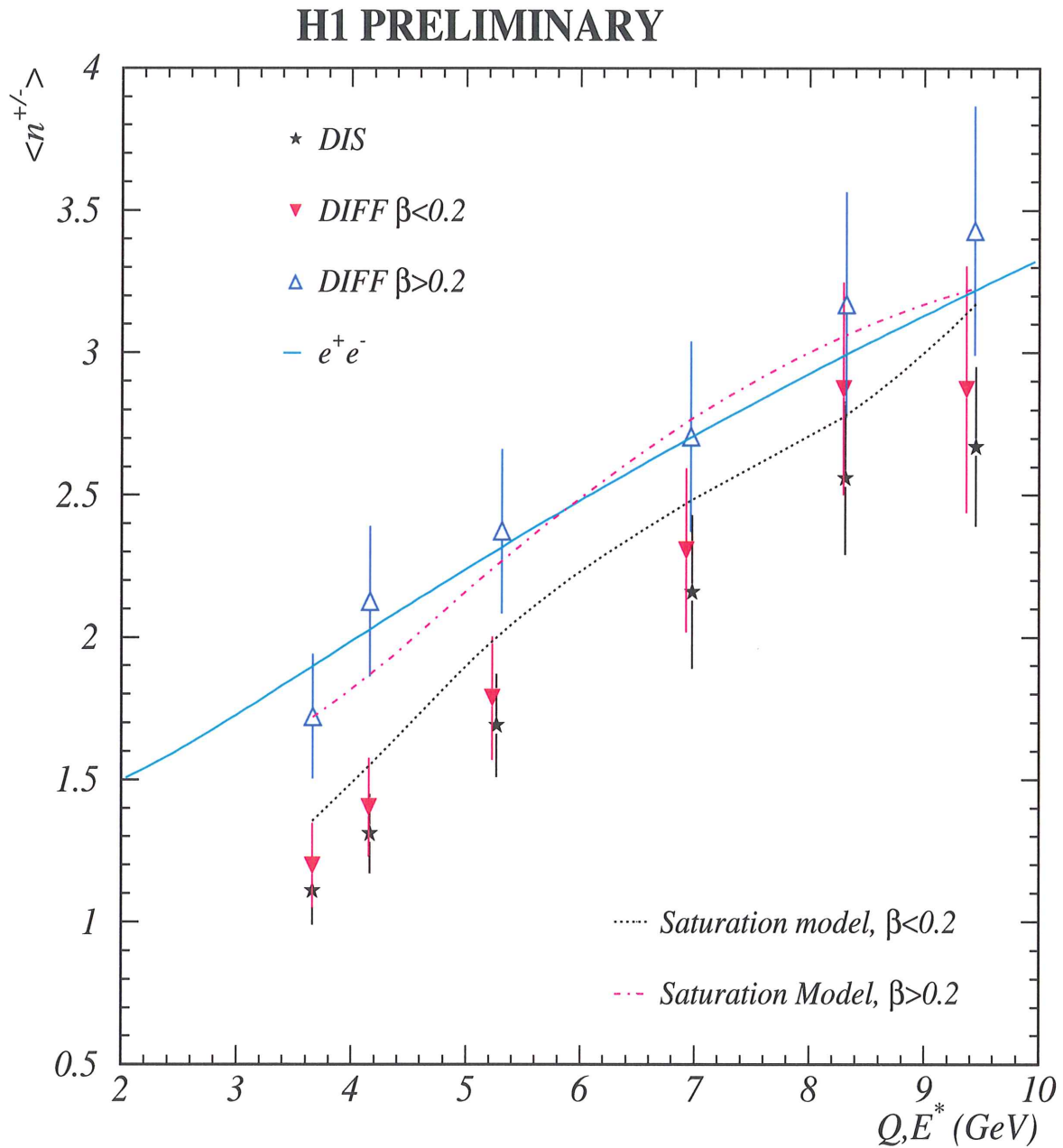
Average Charged Multiplicity (1)

- Difference between $e^+e^- \rightarrow q\bar{q}$ and DIS due to LO QCD effects.
- High β DIFF similar to $e^+e^- \rightarrow q\bar{q}$.
- Low β DIFF similar to DIS.
- Models describe data.

QCD LO Processes

(a) (b) (c)

- Lower Multiplicity in current region due to LO QCD.
- Similar effect seen in Diffraction?
- Difference also seen in most Diffractive models.

Average Charged Multiplicity (2)

- Saturation overestimates multiplicity in current region at low β.
- Otherwise description of data reasonable.

Conclusions

- Best description of data obtained from Resolved pomeron model (H1 fit 2 or 3) for diffraction and MEAR for DIS.

- Other models able to at least qualitatively describe the various distributions.

- Differences between high and low β can be interpreted the as result of gluon emission at low β (large M_x) leading to a depleted or empty current region and hence multiplicity is similar to DIS.

- At high β (small M_x) the limited phase space restricts gluon emission and hence multiplicity is similar to $e^+e^- \rightarrow q\bar{q}$.

- Phase space effect, not restricted to any one particular model.

- Further support for concept of quark fragmentation universality