Charged multiplicities in inclusive and diffractive deep-inelastic ep scattering at HERA

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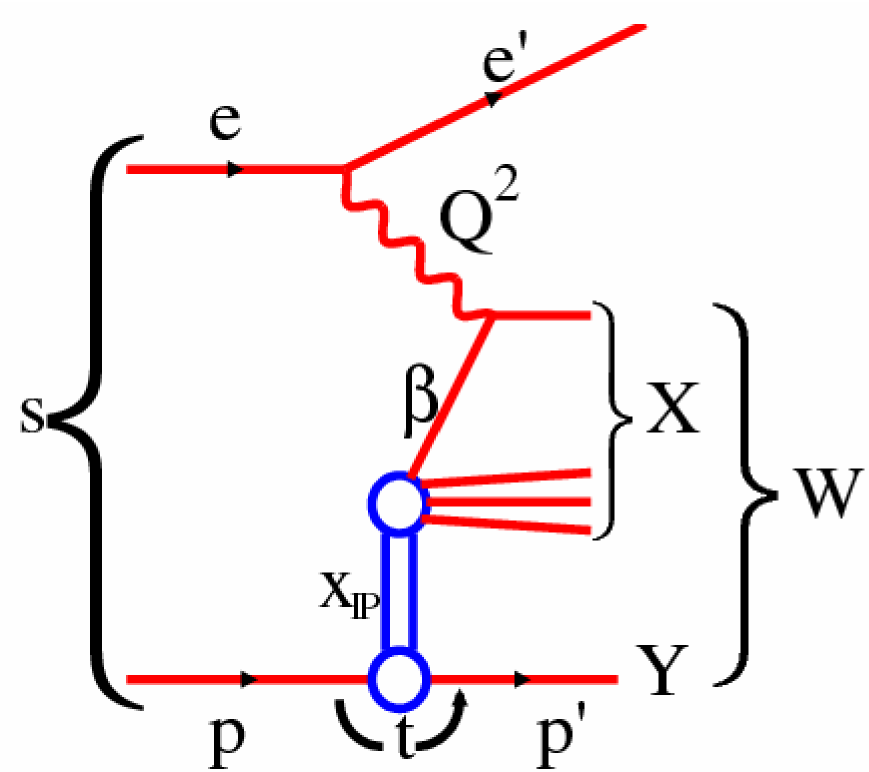
On behalf of H1 and ZEUS collaborations

abstracts 377 & 642

Outline

- H1: Charged particle multiplicity (distributions)
  - Kinematic dependences of <n> in DDIS
  - Comparison of DIS with diffractive DIS (DDIS)
- ZEUS: What is correct energy scale in Breit-frame and in hadronic CM frame for comparisons with other processes?
- Apologies for incomplete coverage

Diffraction: ep -> e' + X + Y



~ 10% of DIS events have a rapidity gap

$$t = (p - p')^2$$

$$\beta = x_{quark/IP}$$

$$x_{IP} = x_{IP/proton}$$

M_X: inv. mass of diffractive system X

$$M_X^2 = Q^2 \frac{1-\beta}{\beta}$$

$$\text{rapidity-gap} \sim \ln \frac{1}{x_{IP}}$$

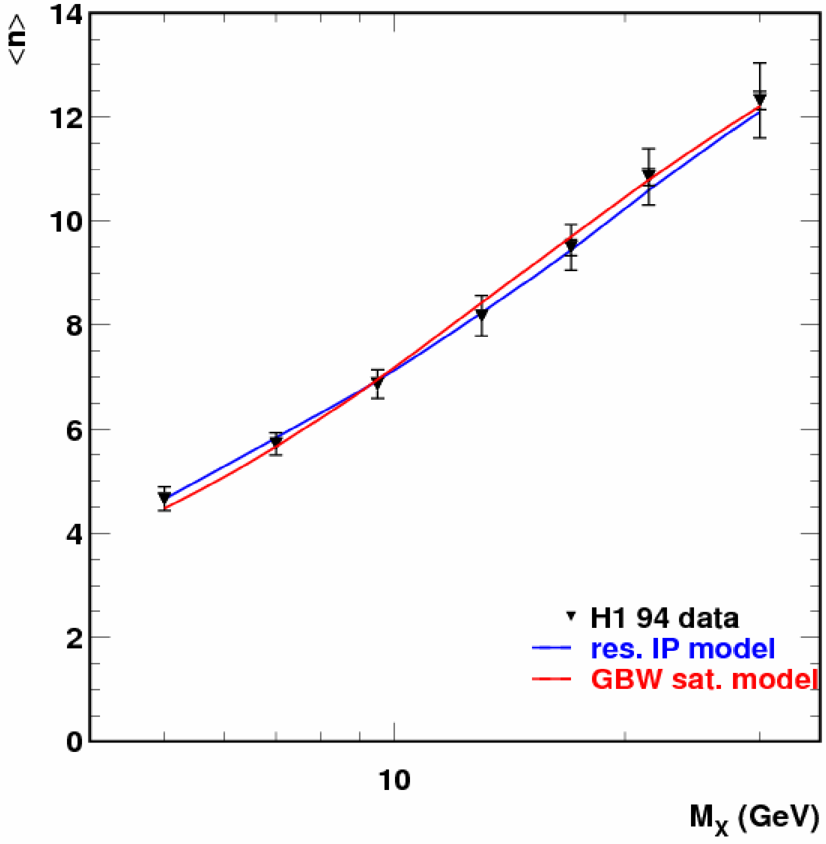
H1 analysis : Motivation

- Previous H1 analysis on 94 data
  - Dependence of <n> on M_X only

  DDIS: W,x,Q^2, β, x_{IP} ,t, M_X

  Which kinematic variables are relevant for multiplicity?

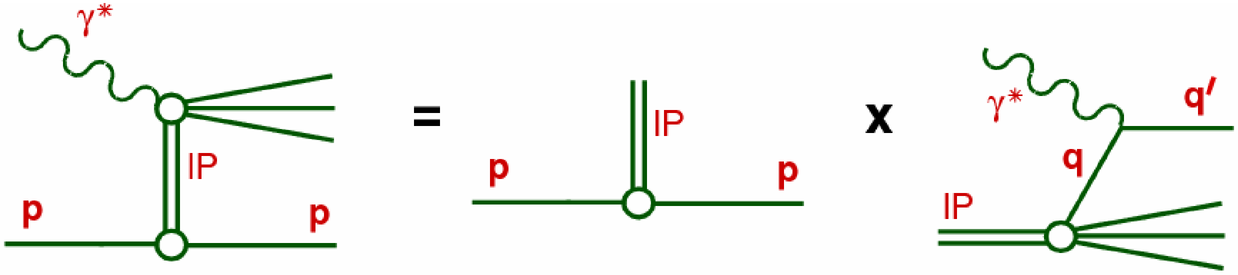
- H1 2000 DDIS data:
  - Large statistics allows more differential study: W, Q^2, β dependences at fixed M_X
  - Compare DIS and DDIS



A model for diffraction

Combine QCD & Regge theory: resolved Pomeron model

- Proton infinite momentum frame
- Colorless Pomeron (IP) is built up of quarks/gluons → diffractive PDF's
- Based on QCD and Regge factorization: naïve, probably incorrect but works…!



$$F_2^D(x_{I\!P}, t, \beta, Q^2) = f_{I\!P/p}(x_{I\!P}, t)\; F_2^{I\!P}(\beta, Q^2)$$

- **Regge factorization implies diffractive final state is independent of proton (fractional) energy loss x_{IP}**
- Need sub-leading Reggeon (IR) component besides Pomeron to fit the F_2^D Diffractive Structure Function data

H1: Data selection DIS and DDIS

2000 nominal vertex data: 46.65 pb^{-1}

Data corrected via Bayesian unfolding procedure:
- DIS MC: DJANGOH 1.3, proton pdf CTEQ5L
- DDIS MC: RAPGAP resolved pomeron

DIS selection:

- Good reconstruction of scattered electron
- Kinematic cuts:
  - $0.05 < y_{av} < 0.65$
  - $5 < Q^2 < 100$ GeV^2
  - $80 < W < 220$ GeV

DDIS selection:

- Rapidity gap:
  - No activity in the forward detectors
  - $\eta_{max} < 3.3$
- Kinematic cuts:
  - $4 < M_X < 36$ GeV
  - $x_{IP} < 0.05$

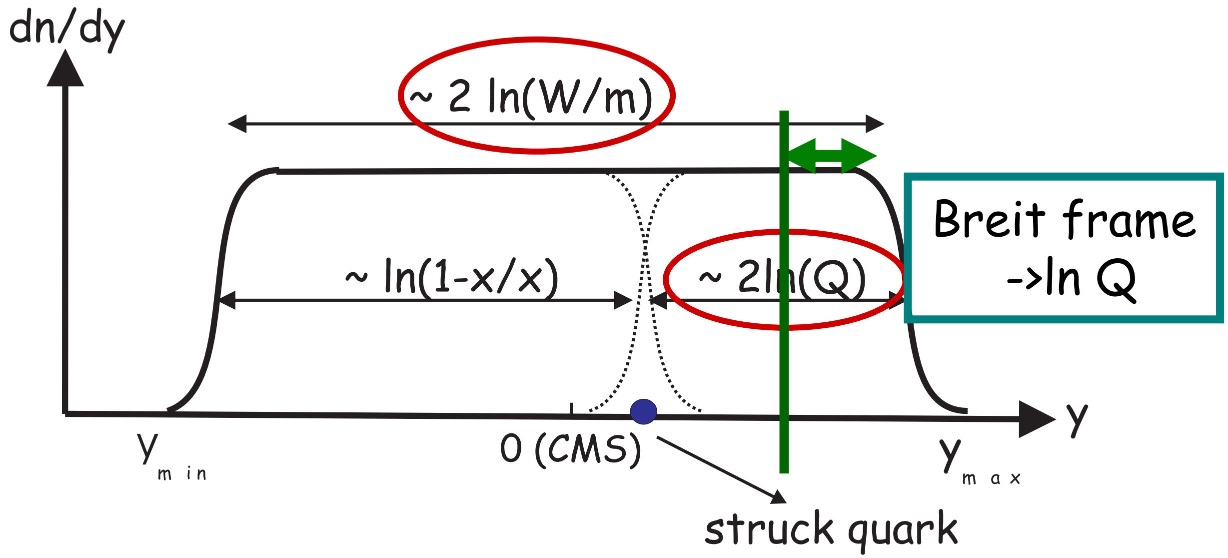
Use charged particles with $\eta^*>1$ (acceptance > 90%) in γ^*p CMS frame

Kinematics: Bjorken Plot

DIS

$W^2 \sim Q^2/x$

$Y_{max} = \ln(W/m_\pi)$

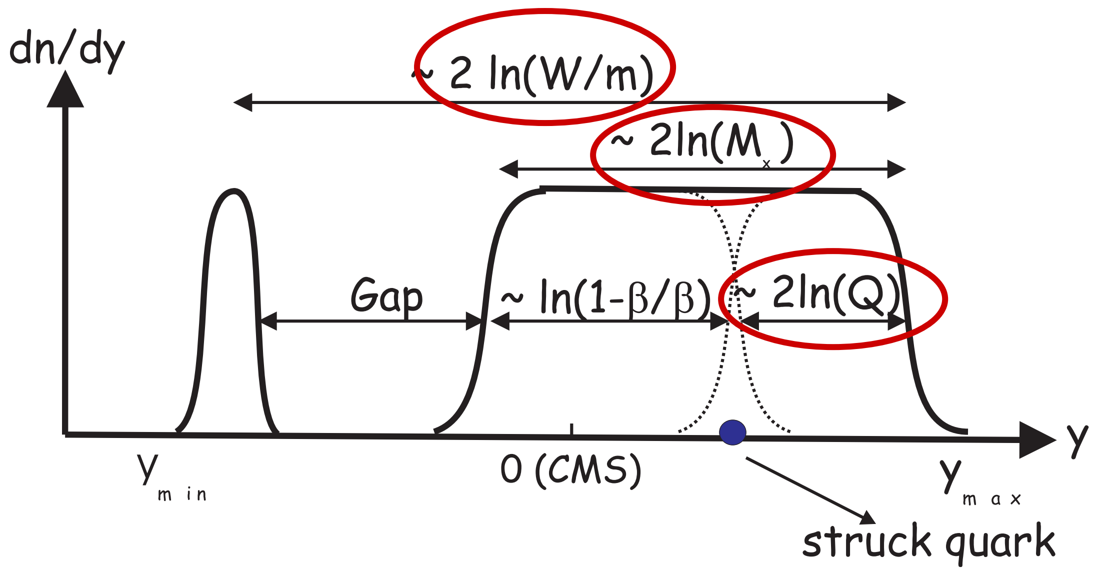


In DDIS β plays role of x in DIS

DDIS

$$M_X^2 = Q^2 \frac{1-\beta}{\beta}$$

$$\text{gap} \sim \ln \frac{1}{x_{IP}}$$

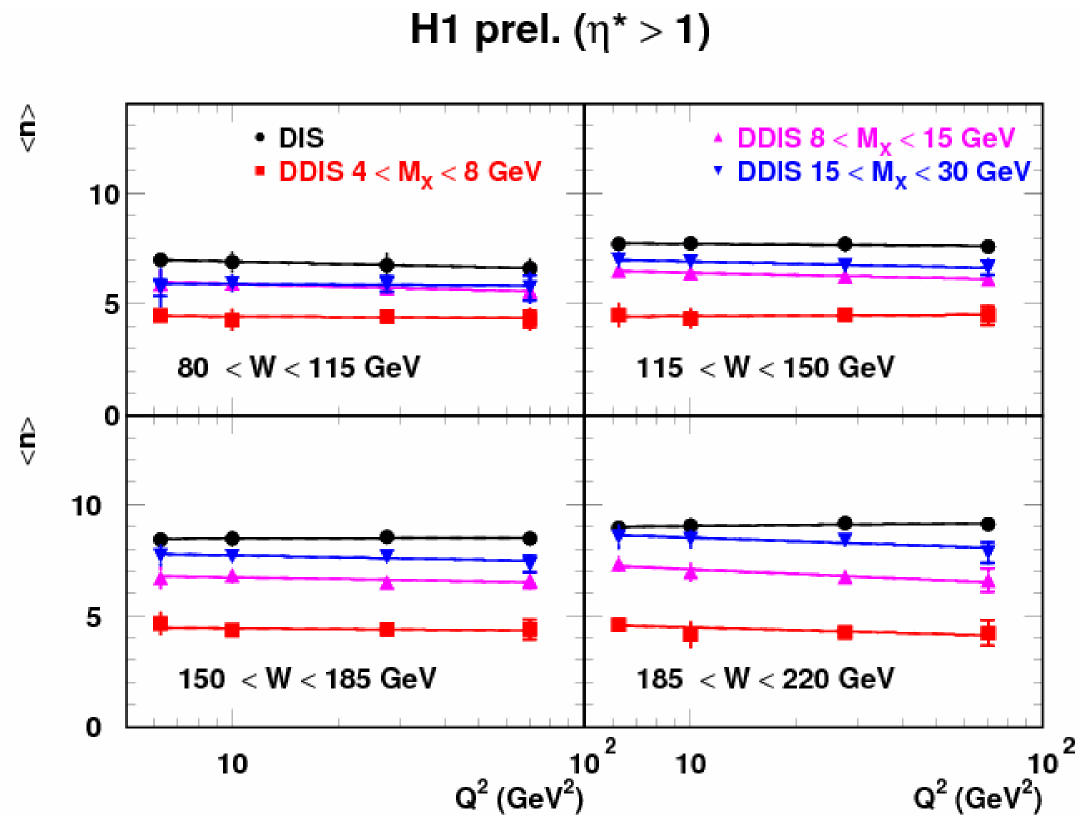


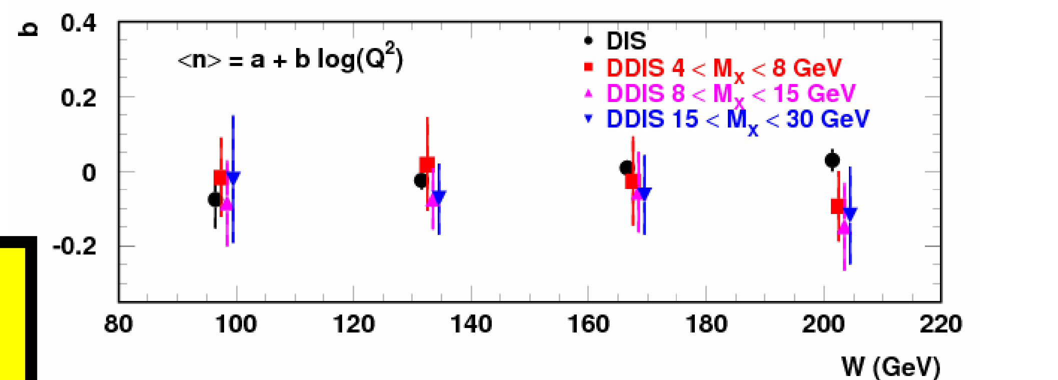
H1: $\langle n \rangle (Q^2)$ in DIS & DDIS at fixed W

- DIS data
- DDIS data (fixed M_X)

- No stat. signif. dependence on Q^2
- Weak W-dependence in DDIS

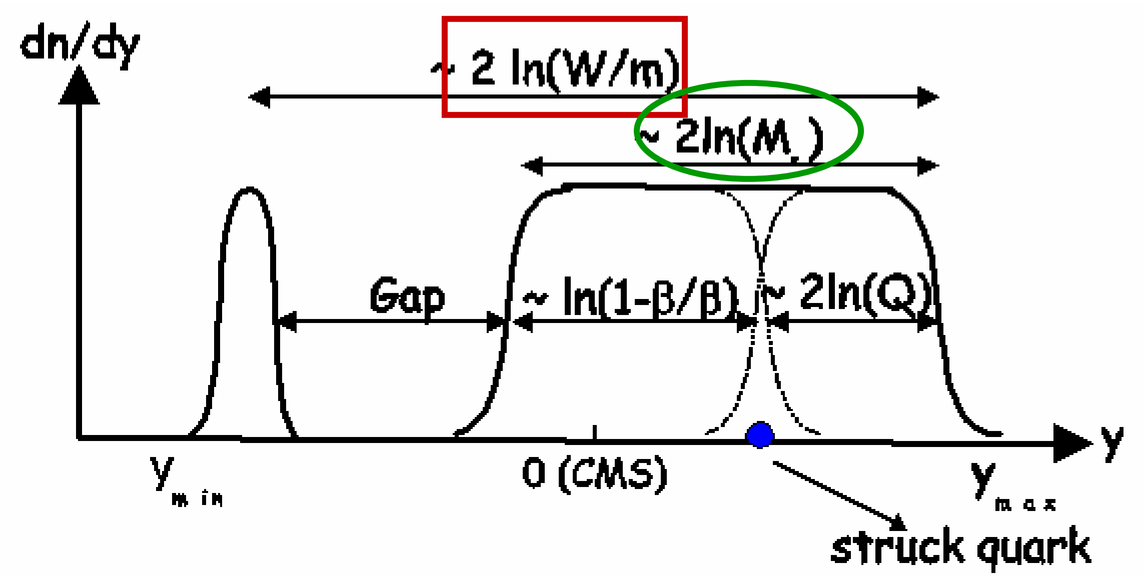
- Fit $\langle n \rangle$ to
  $\langle n \rangle = a + b \log(Q^2)$





Further: Rapidity spectra show very weak Q^2 dependence

W dependence of <n> in DDIS ?



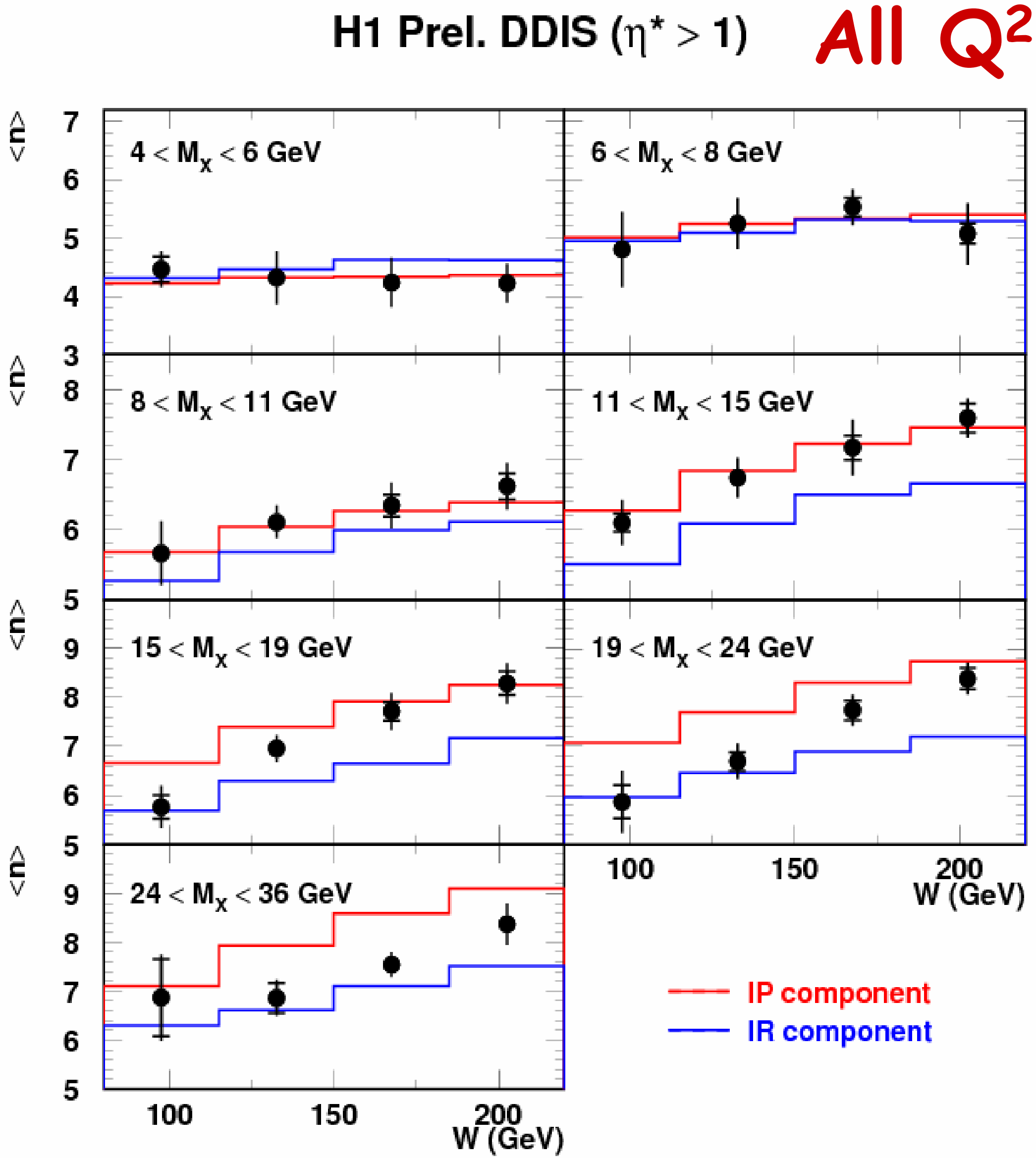
- Changing W with M_X fixed = changing gap width
- Gap ~ ln(1/x_{IP}) thus … effectively

  investigate dependence on x_{IP} of <n>

W dep. of <n> at fixed M_X in DDIS

- At fixed M_X : changing W means changing gap and x_{IP}
- Regge factorization means diffractive pdf's AND Final state properties independent of x_{IP}
- W-dependence = breaking of Regge factorization
- In resolved Pomeron model: pomeron + reggeon
- Large M_X : Data move from Reggeon to Pomeron as W grows

All Q^2

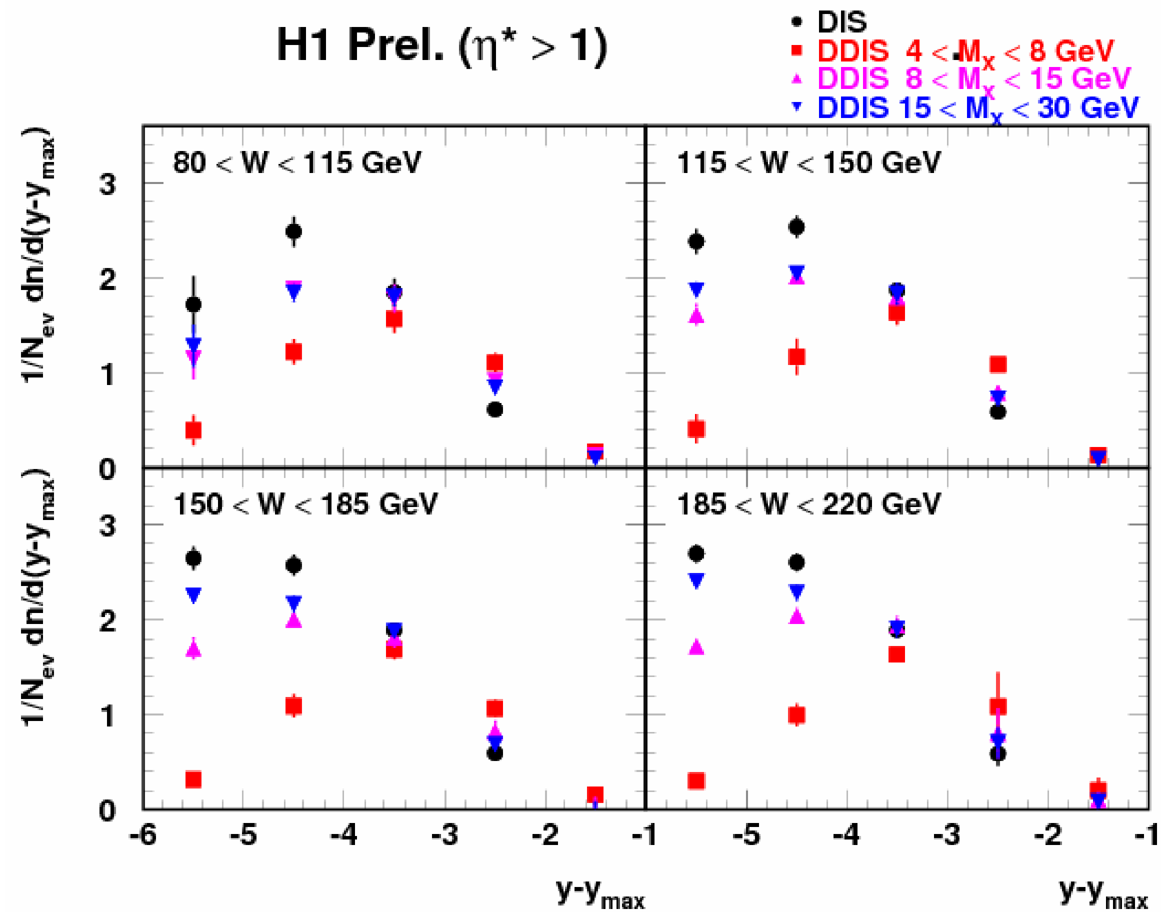


Particle Density in y: DIS ↔ DDIS

- $(1/N)\, dn/d(y-y_{max})$

- Central region:

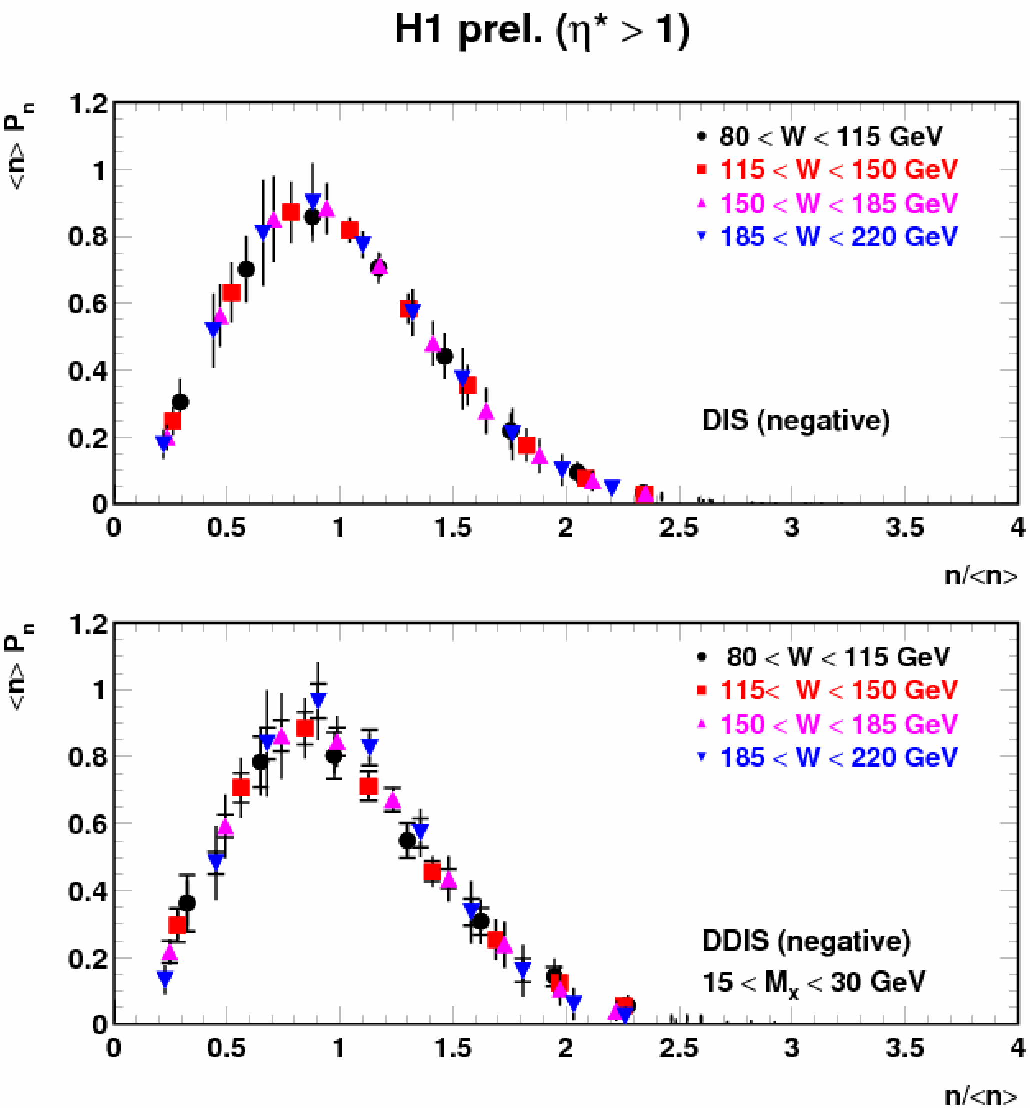
  particle density similar for DIS and high M_X DDIS



DDIS & DIS particle density not much different although $M_X << W$

DDIS = gluon-rich system →higher multiplicity

Comparison DIS & DDIS: KNO scaling



- Negative particles
- $\psi(z) = \langle n \rangle P_n$ vs $z = n/\langle n \rangle$
- Approximate KNO scaling for DIS and DDIS
- Shape of KNO distribution similar for DIS and DDIS
- Implies that correlations are very similar

H1 : Summary

Charged particle multiplicity

- studied for DIS and DDIS in ep at HERA

Kinematic dependences

- <n> in DIS: main dependence only on W, not Q^2 or x separately
- <n> in DDIS: main dependence on M_X not on Q^2 and β separately (and a bit on W: Regge factorization breaking),

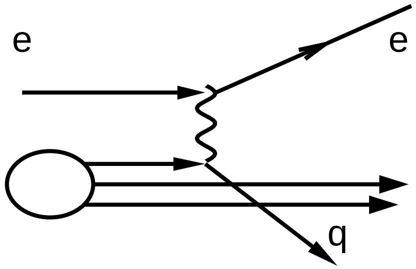
Comparison DIS and DDIS

- DIS and DDIS: density in rapidity similar at highest M_X
- DIS and DDIS: approximate KNO scaling & same shape.

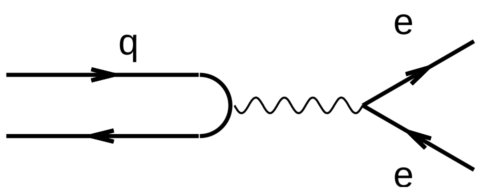
ZEUS: e^+e^- & ep : Breit Frame

DIS event

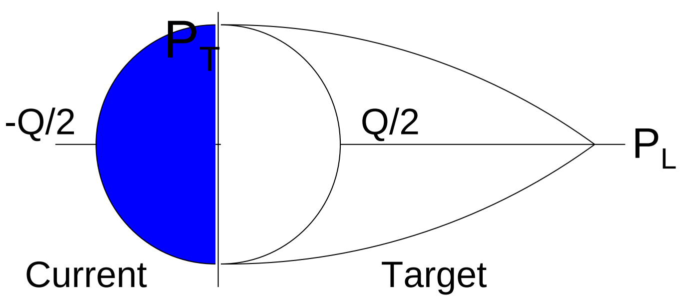
Lab Frame



Breit Frame



Breit Frame



- Use Breit frame to compare multiplicity in ep to (one hemisphere) of e^+e^-
- Breit Frame definition:

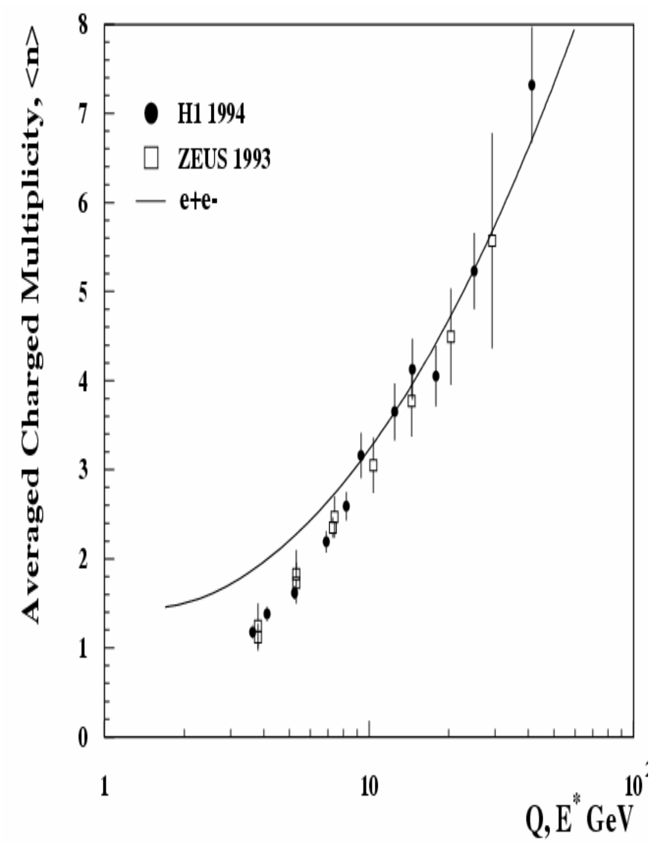
$$2xP + q = 0$$

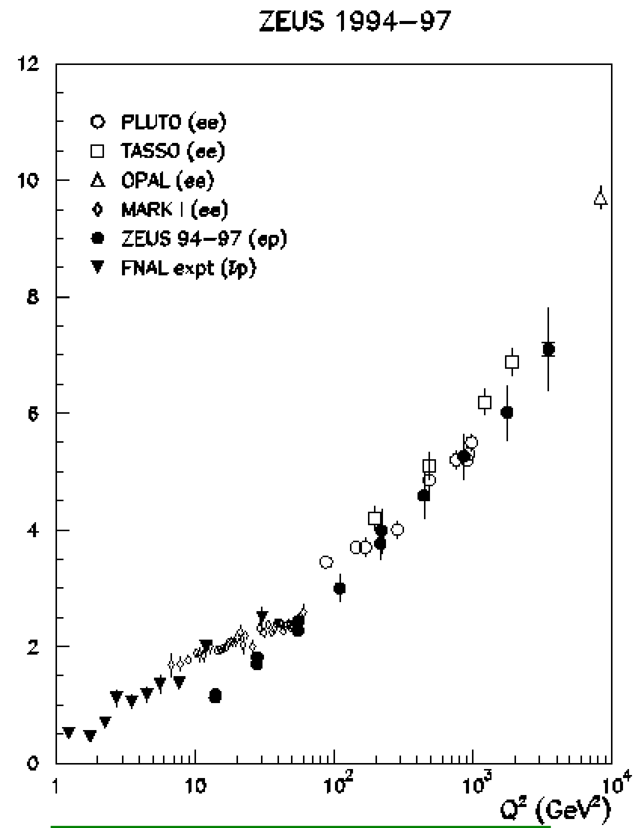
- "Brick Wall frame": incoming quark scatters off photon and returns along same axis.
- Current region (CR) of Breit Frame is analogous to e^+e^- in 0^{th} order pQCD =Quark-Parton Model and energy = Q/2
- But: QCD Compton and Boson-Gluon Fusion processes → Particle migration out of current region

K.H.Streng et al. ZPC 2 (1979) 237; S. Chekanov J.Phys. G (1999) 59, hep-ph/9806511; 9810477

- Energy in CR < Q/2
- **ZEUS: use measured energy in CR of Breit Frame as energy scale**

Early results: $\langle n_{ch} \rangle$ vs. Q in Breit Frame





ZEUS: EPJ C11 (1999) 251-270

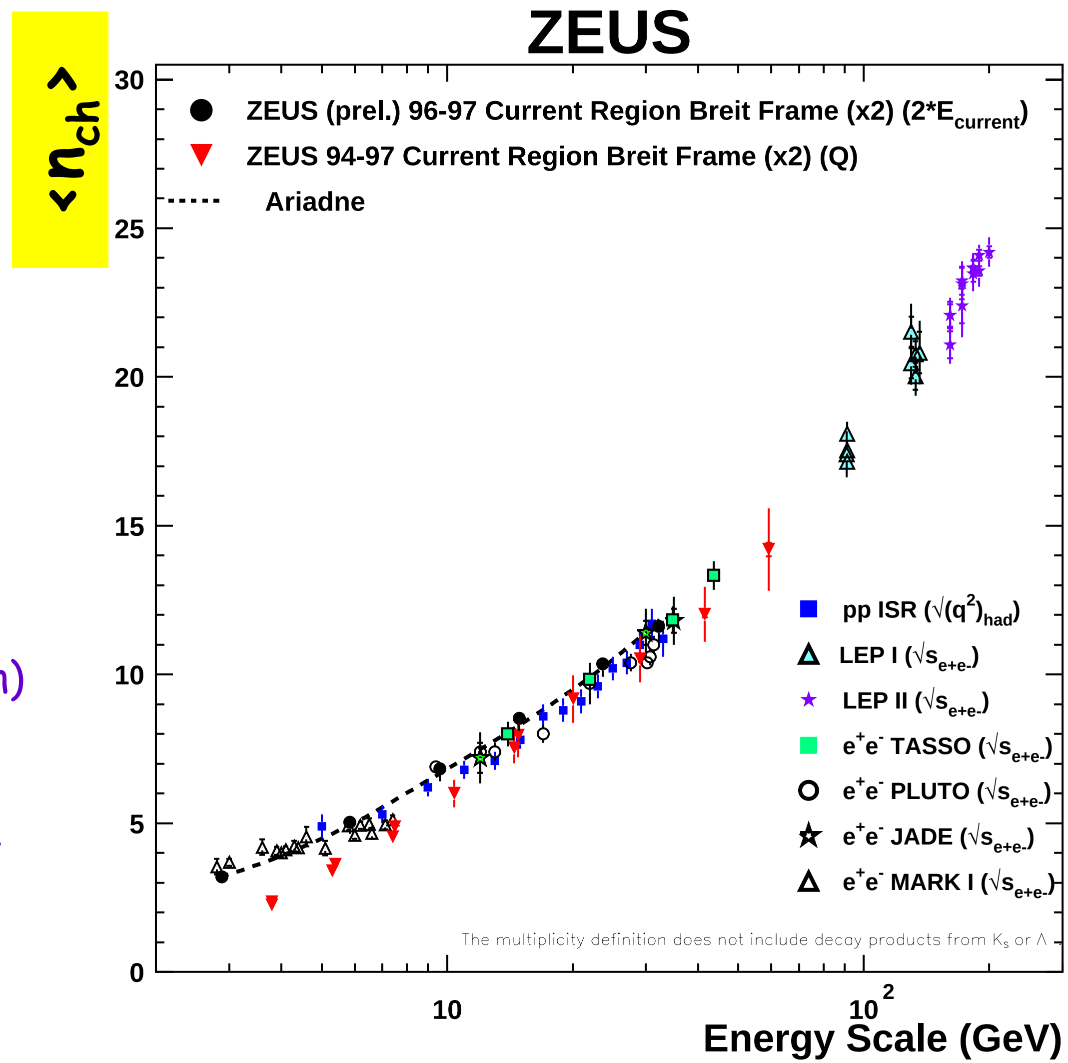
- Current region Breit frame multiplicity vs. Q ↔ e^+e^- data (divided by 2)
- Consistent with e^+e^- data for high Q^2
- Lower than e+e⁻ at low Q2

ZEUS DIS: $\langle n_{ch} \rangle$ vs. $2{*}E_{current}$

- NC DIS: $Q^2 > 25$ GeV^2 and $70 < W < 225$ GeV
- Measurement of $\langle n_{ch} \rangle$ dependence on $2{*}E_{current}$ compared to previous ZEUS measurement vs. Q (in red) , and to e^+e^- and pp data

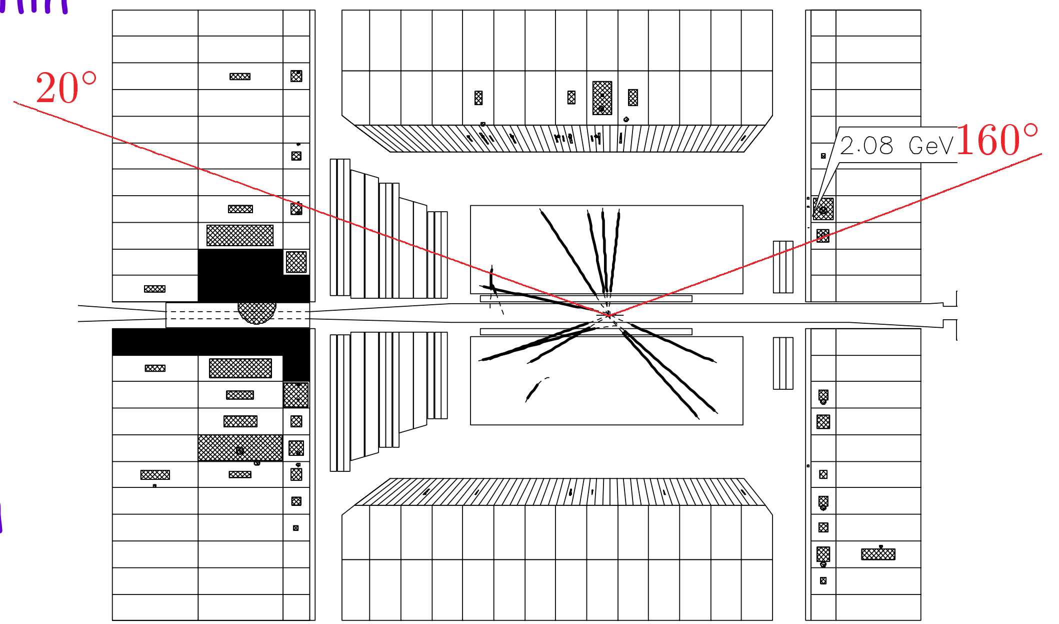
($\langle n_{ch} \rangle$ multiplied by 2 for comparison)

- $2{*}E_{current}$ gives better description of multiplicity at low energy



ZEUS: Effective Mass experimental method

- Measure hadronic final state within $\Delta\eta$ for best acceptance in the central tracking detector (CTD)
- Measure # charged tracks, reconstruct number of charged hadrons
- Measure invariant mass of the system (M_{eff}) in corresponding $\Delta\eta$ region
- Energy is measured in the Calorimeter (CAL)



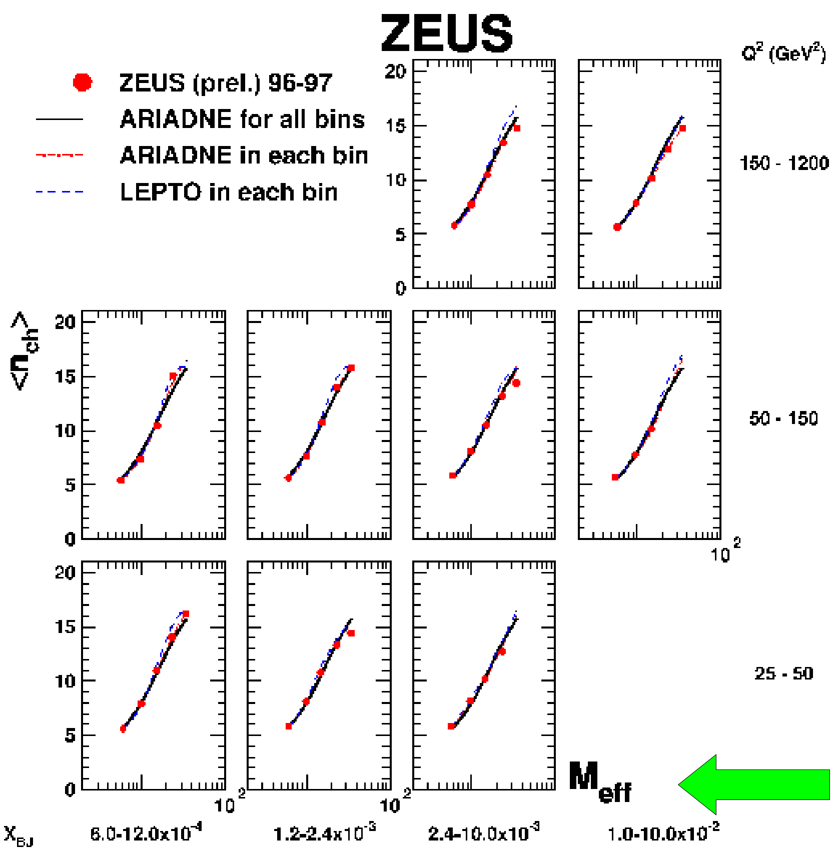
$$M_{eff}^2 = (\sum_{i \neq e'} E^i)^2 - (\sum_{i \neq e'} p_x^i)^2 - (\sum_{i \neq e'} p_y^i)^2 - (\sum_{i \neq e'} p_z^i)^2$$

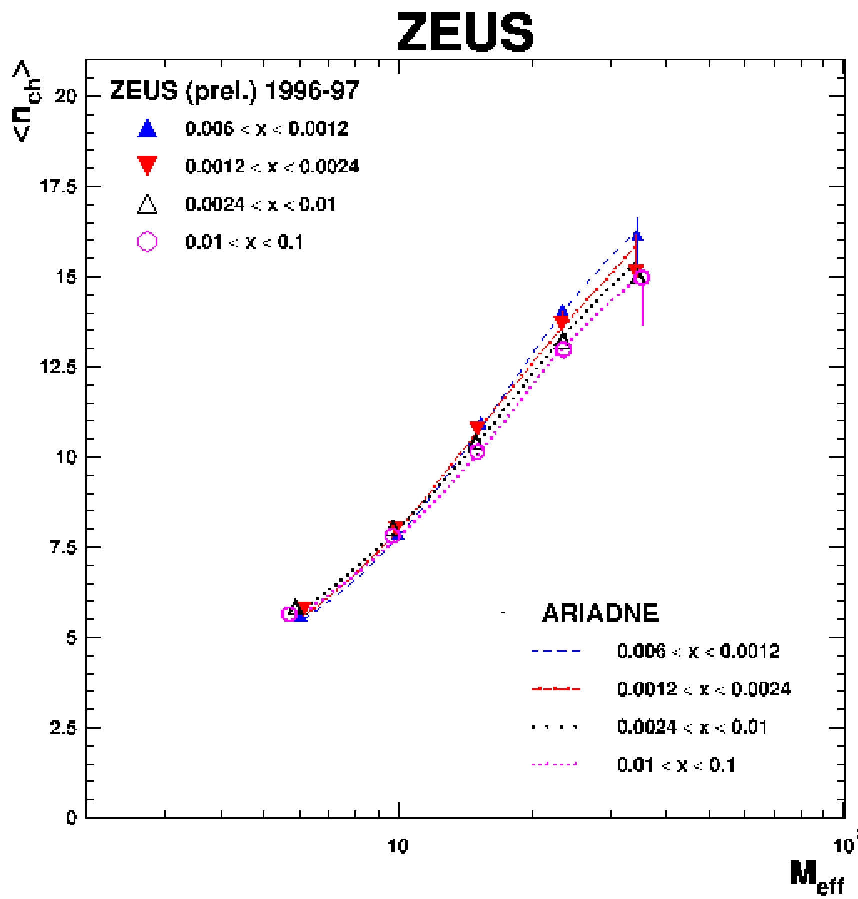
Study: $\langle n_{ch} \rangle$ vs. M_{eff}

CTD

CAL within the CTD acceptance

ZEUS: Lab frame: $\langle n_{ch} \rangle$ vs. M_{eff} in x and Q^2 bins





- Data described by ARIADNE
- LEPTO slightly above data
- No Q^2 dependence observed

- Lab frame multipl. vs. M_{eff}, in x_{Bj}-bins with Ariadne predictions.
- weak x_{Bj}-dependence in both data and Monte Carlo.

ZEUS : Summary

- Measurement in current region of the Breit frame shows similar dependence to e^+e^- if $2{*}E_{current}$ is used as the scale (black dots)
- The same dependence is observed for the photon region of the γ^*p frame vs. W: (blue dots) (not discussed here)
- <n> in lab. frame vs. M_{eff} shows no Q^2 dependence and weak x-dependence