# Recent results on multiplicity from ZEUS

**Michele Rosin**

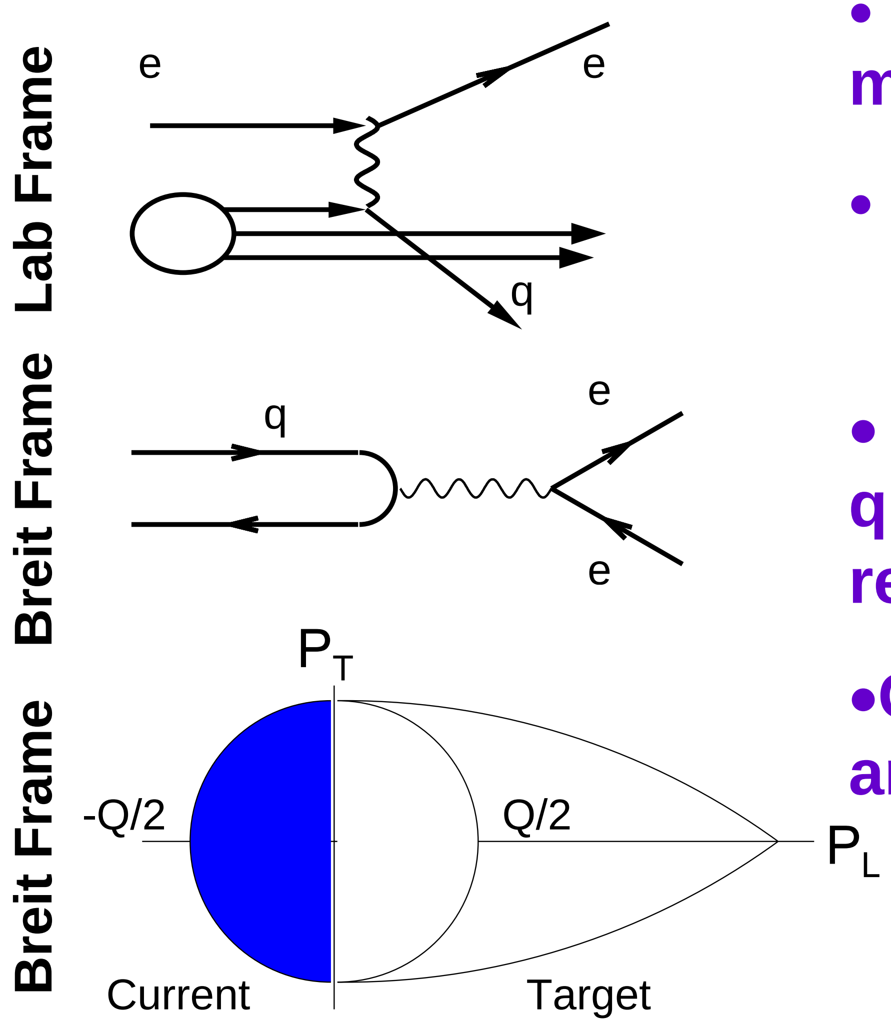
on behalf of the ZEUS Collaboration

University of Wisconsin, Madison

DIS 2005, Madison WI
April 29, 2005

# $e^+e^-$ & ep : Breit Frame

DIS event




- Use Breit frame to compare multiplicity for ep to $e^+e^-$
- Breit Frame definition:

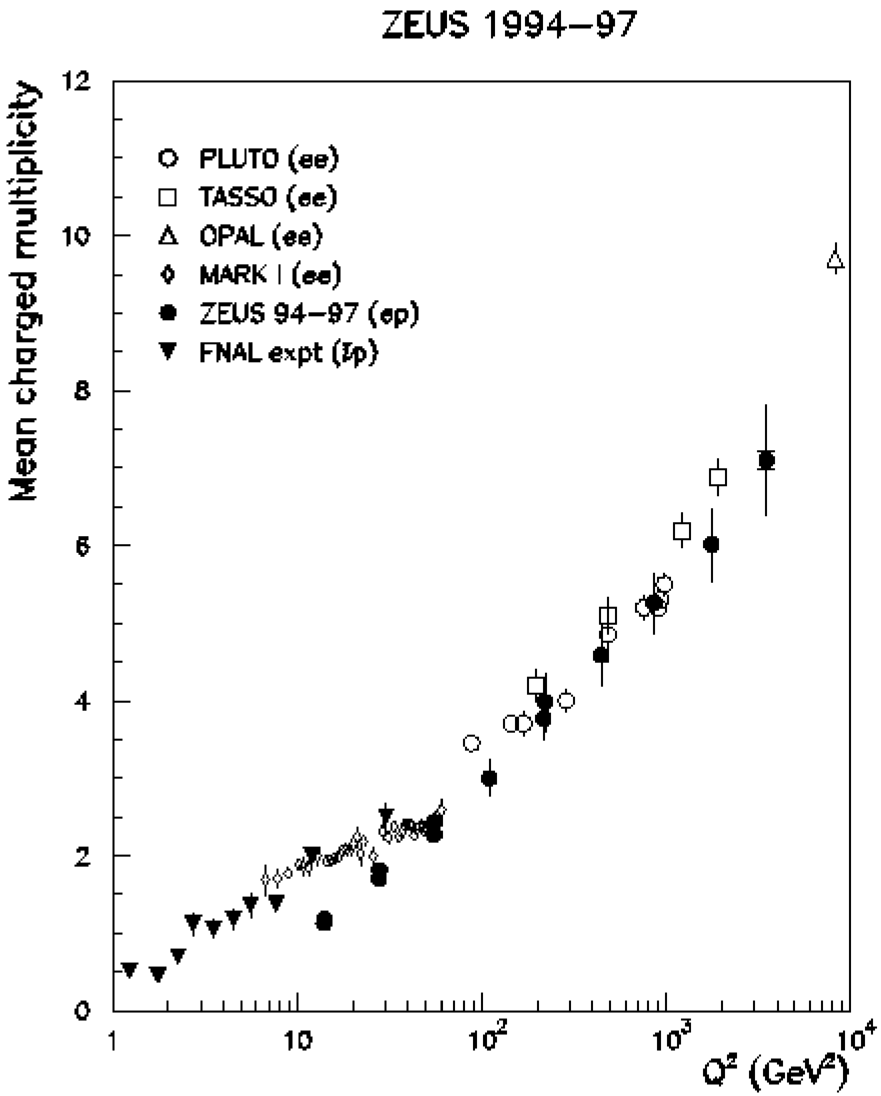
$$2xP + q = 0$$

- “Brick wall frame” incoming quark scatters off photon and returns along same axis.
- Current region of Breit Frame is analogous to $e^+e^-$.

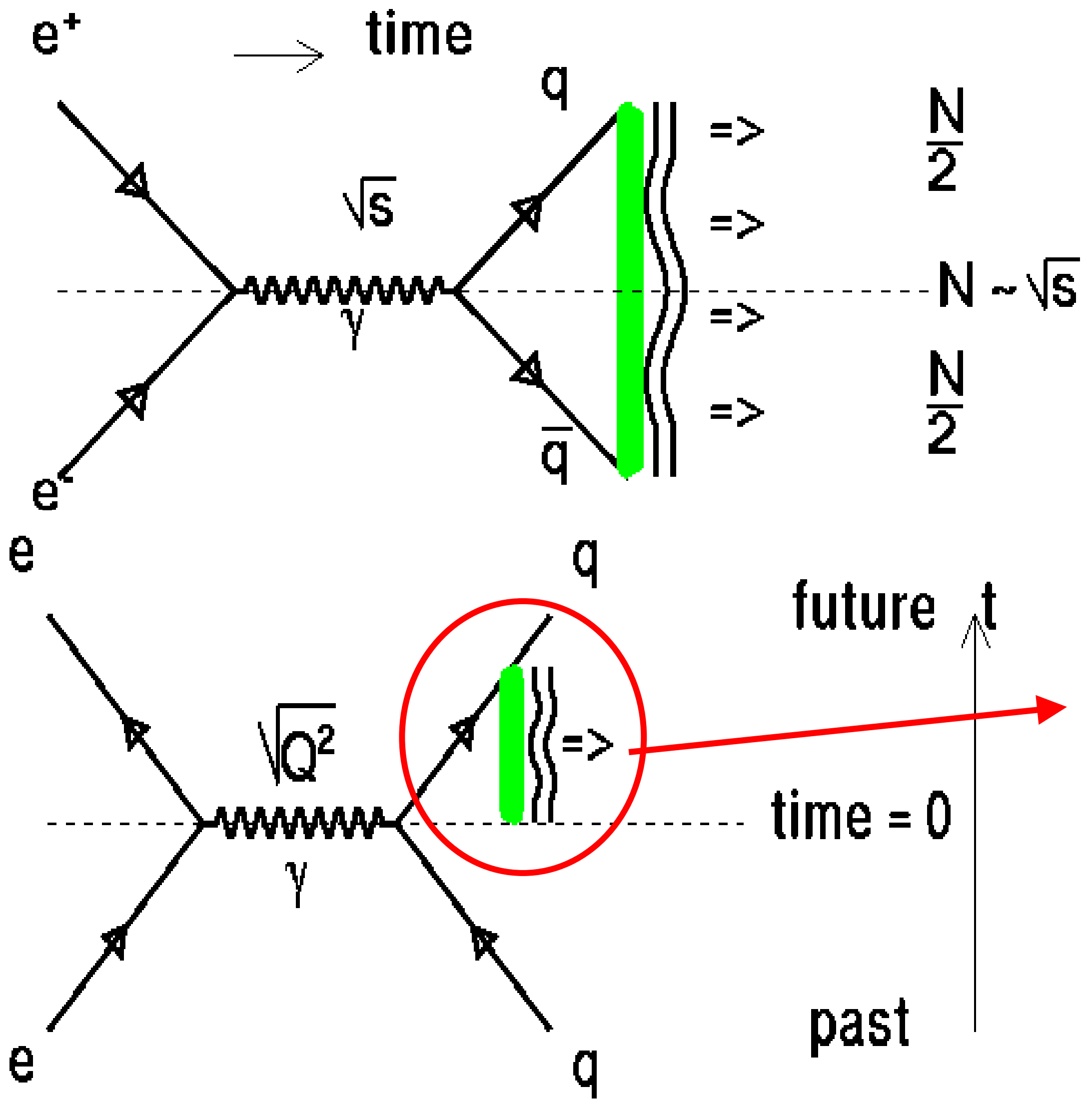
# Measurement vs. Q in Breit Frame

- Current region Breit frame multiplicity vs. Q (hemisphere) shown along with $e^+e^-$ data (whole sphere divided by 2)
- Consistent with $e^+e^-$ data for high $Q^2$
- ep has gluon radiation whereas $e^+e^-$ does not– source of disagreement at low $Q^2$ ??
- Idea of current analysis: Understand current and target multiplicity and compare to $e^+e^-$

European Physics Journal C11 (1999) 251-270

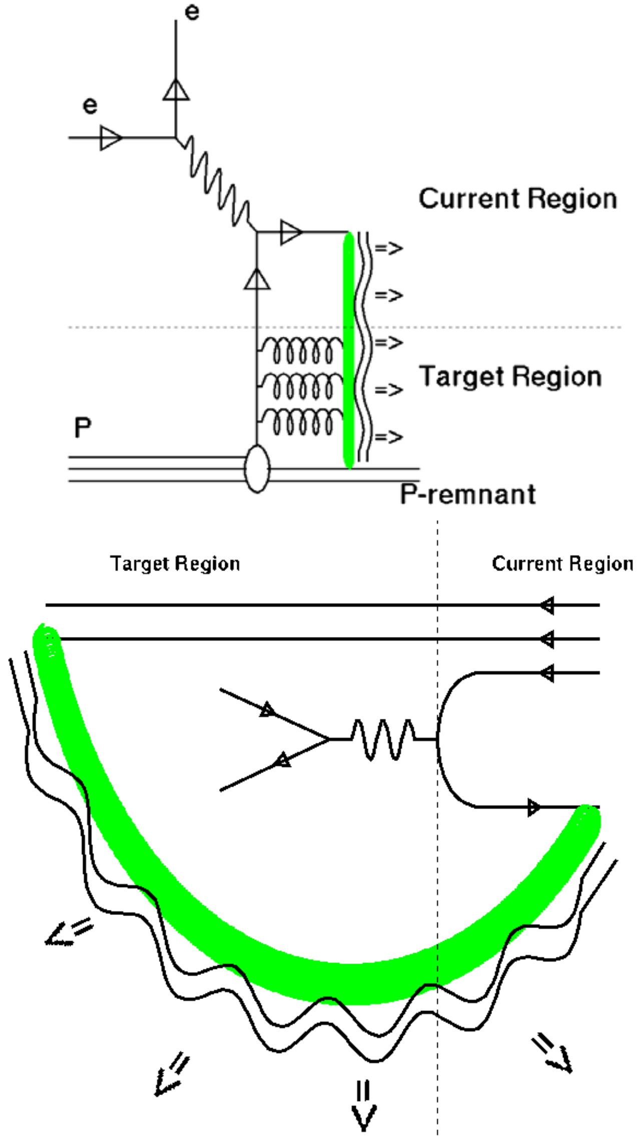


# Multiplicity: ep vs. $e^+e^-$ (1)




- $e^+e^-$: boson with virtuality $\sqrt{s}$ produces 2 quarks & hadronization is between 2 colored objects q and $\bar{q}$
- ep: In the hard collision between the photon & quark only 1 final quark is produced, so the 2nd quark on the diagram is the incoming one
- current region of Breit frame for ep similar to one hemisphere of $e^+e^-$

# Multiplicity: ep vs. $e^+e^-$ (2)

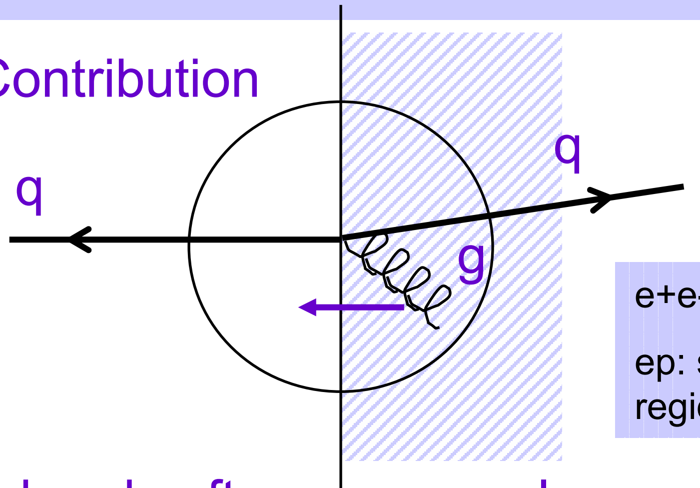



- ep: Split into Current and Target Region – one string two segments.
- In ep we have a color field between 2 colored objects the struck quark and the proton remnant
- When we use $Q^2$ as a scale we are assuming the configuration is as symmetric as it is in $e^+e^-$, but it isn't
- This asymmetric configuration leads to migration of particles from the current region to the target region

*Breit Frame diagram*

# Gluon radiation, Q, and $2{*}E_{Breit}$

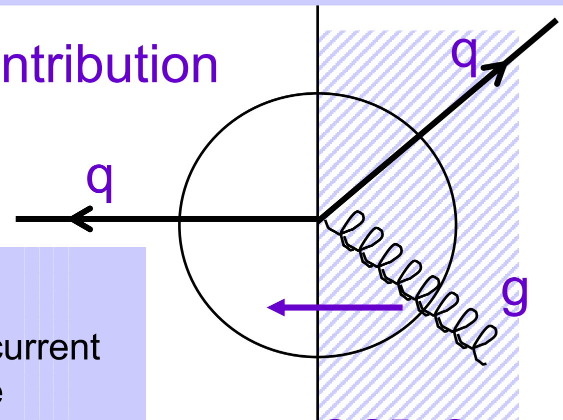
Soft Contribution




e+e-: whole sphere

ep: shaded region: current region of Breit frame

Hard Contribution




QCD Compton

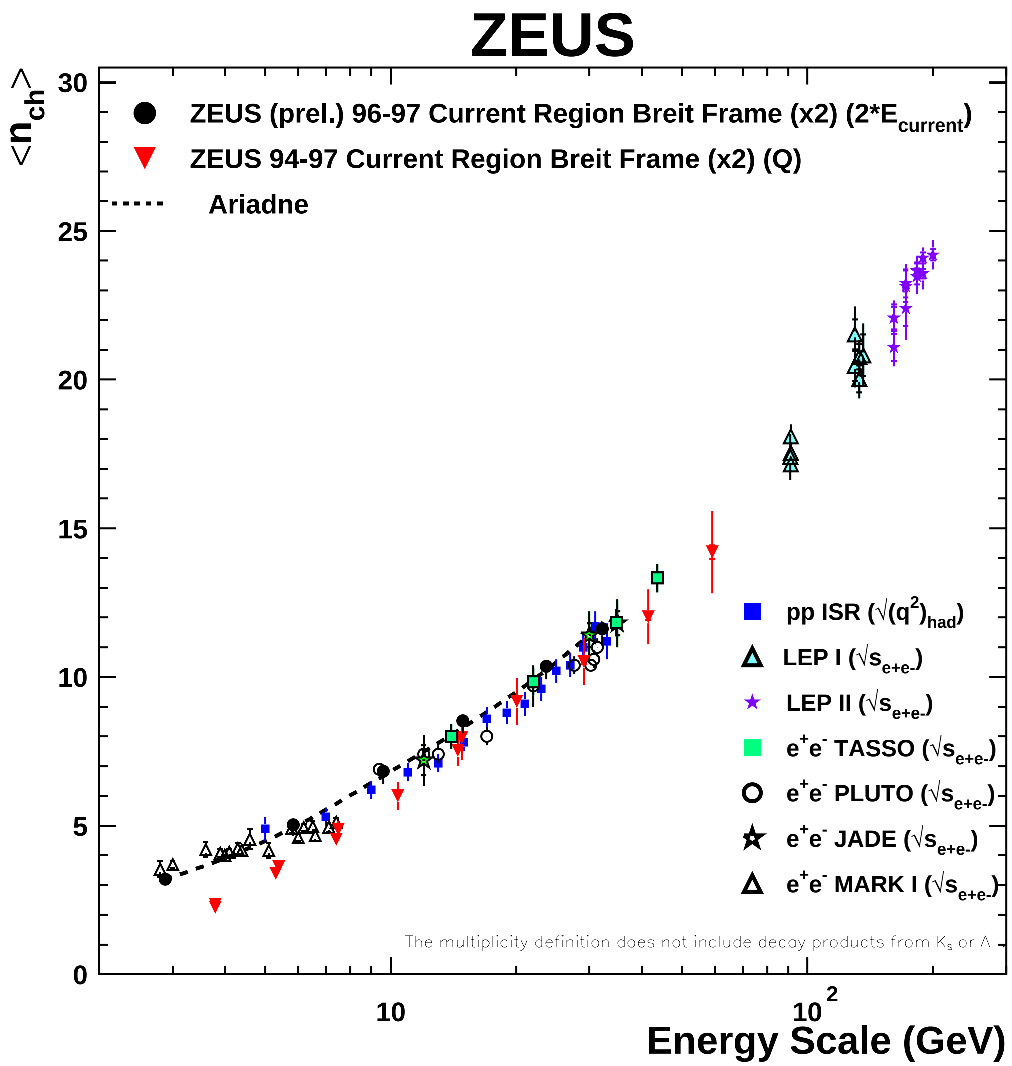
- In hard and soft processes gluon radiation occurs
- These gluons can migrate to target region
- Total energy in the current region of Breit frame and multiplicity are decreased due to these migrations ($Q^2$ is not)
- Effect is more pronounced for low $Q^2$ : more low energy gluons
- Must use $2{*}E_{Breit}$ instead of Q for comparing with $e^+e^-$

No migrations: $E_{Breit} = \frac{\sqrt{Q^2}}{2}$

With migrations: $\begin{cases} N < N_{expected} \\ E_{Breit} < \frac{\sqrt{Q^2}}{2} \end{cases}$

# $<n_{ch}>$ vs. $2^*E_{current}$

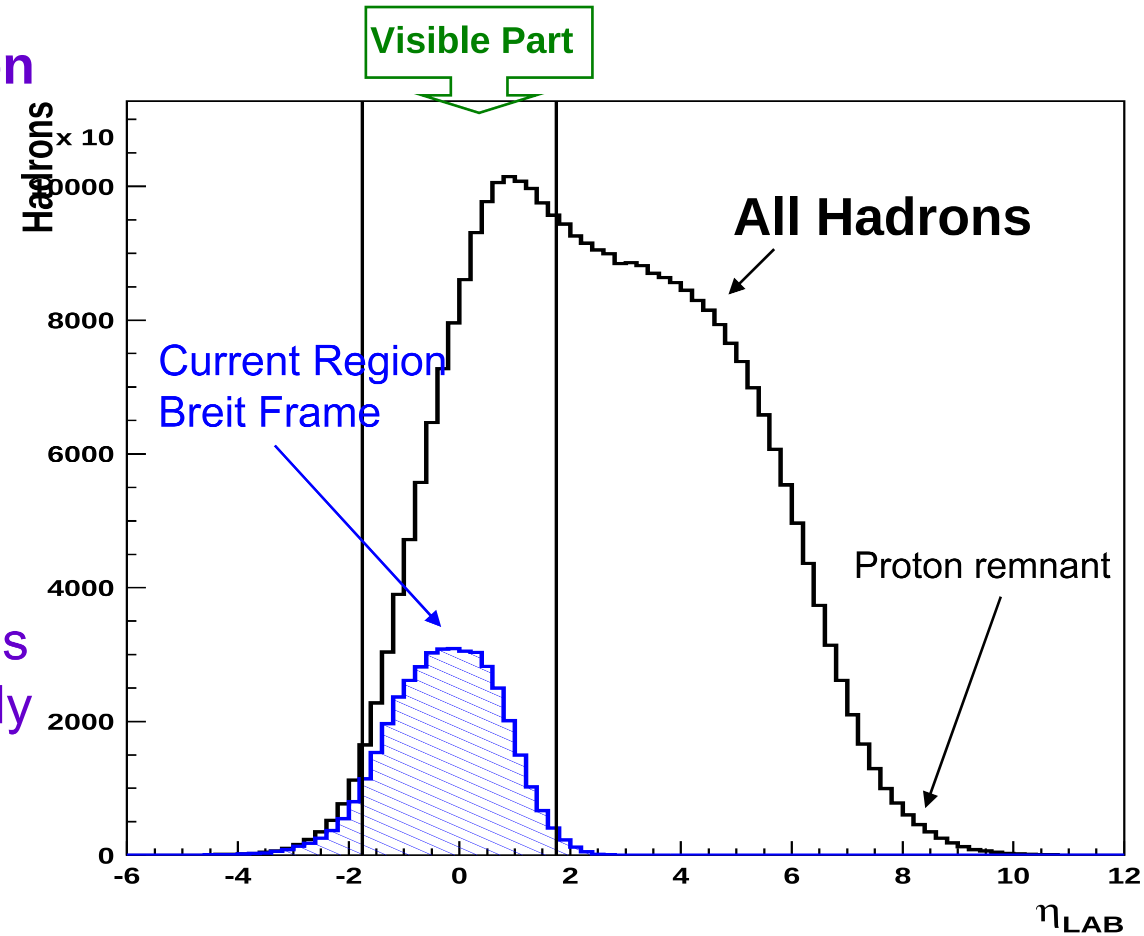
- Measurement of multiplicity dependence on $2^*E_{current}$ compared to previous ZEUS measurement vs. Q, and to $e^+e^-$ and pp data ($<n_{ch}>$ is multiplied by 2 for comparison)
- 2*E gives better description of multiplicity at lower energy
- Current region understood, would also like to compare the target region of ep to $e^+e^-$ but…



# Visible multiplicity in Breit frame

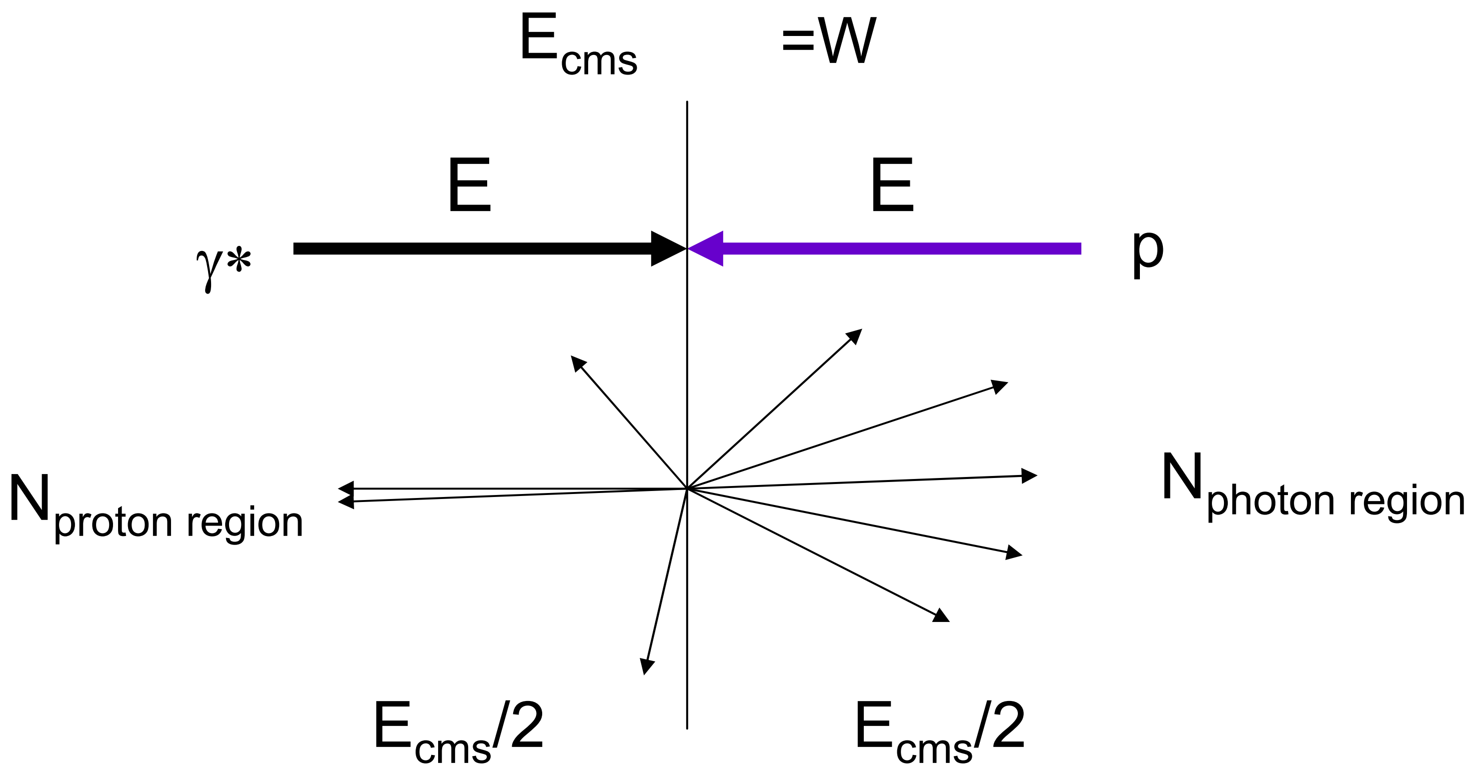
**…comparing the target region is not possible:**

- **Breit Frame**: 90% of hadrons in current region visible in detector, only 30% of target region hadrons are visible
- Can't easily measure target hadrons, but these are a huge portion of the produced hadrons which we would still like to study
- Need some other way to investigate these particles



# Hadronic center of mass frame

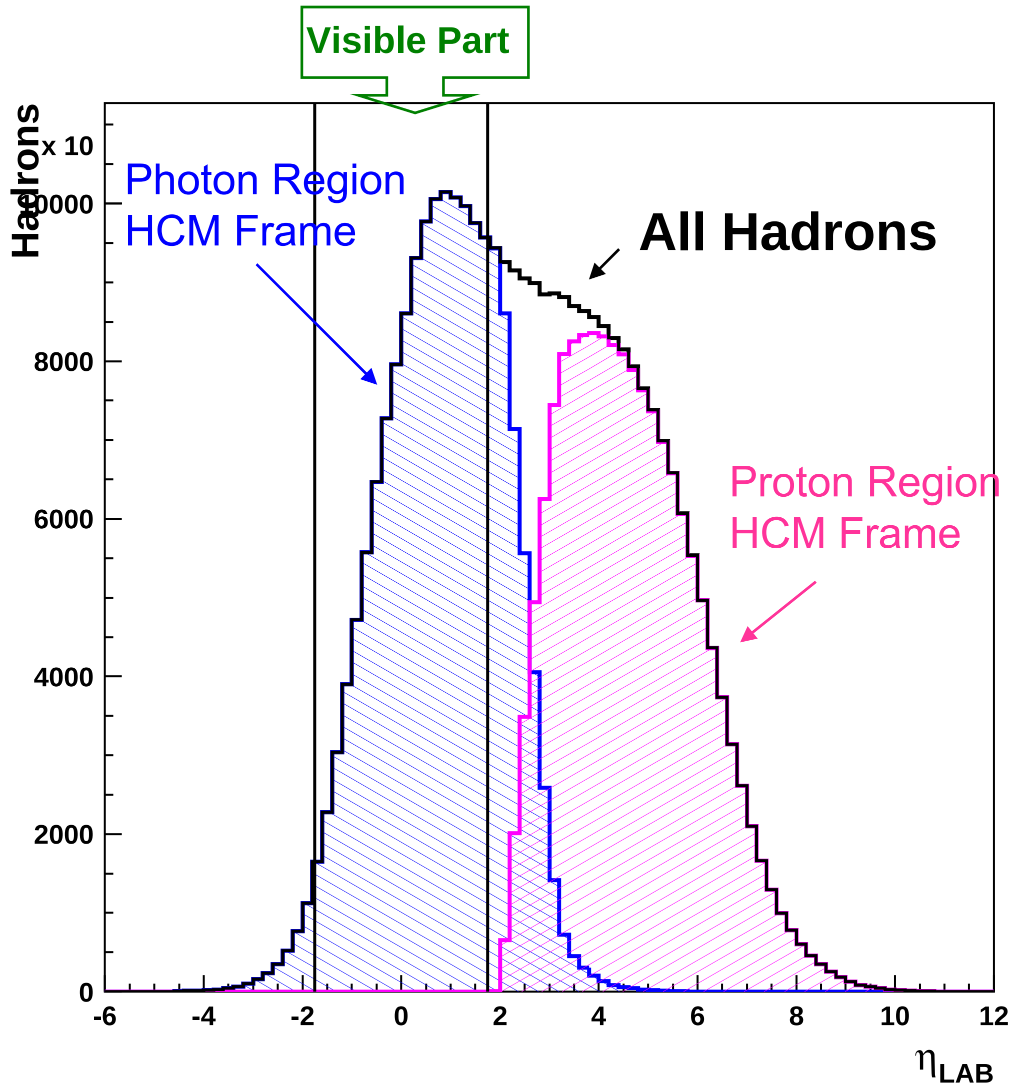
**Hadronic center of mass energy is W** $W = \sqrt{(q+P)^2}$




$N_{photon\ region}$ vs W

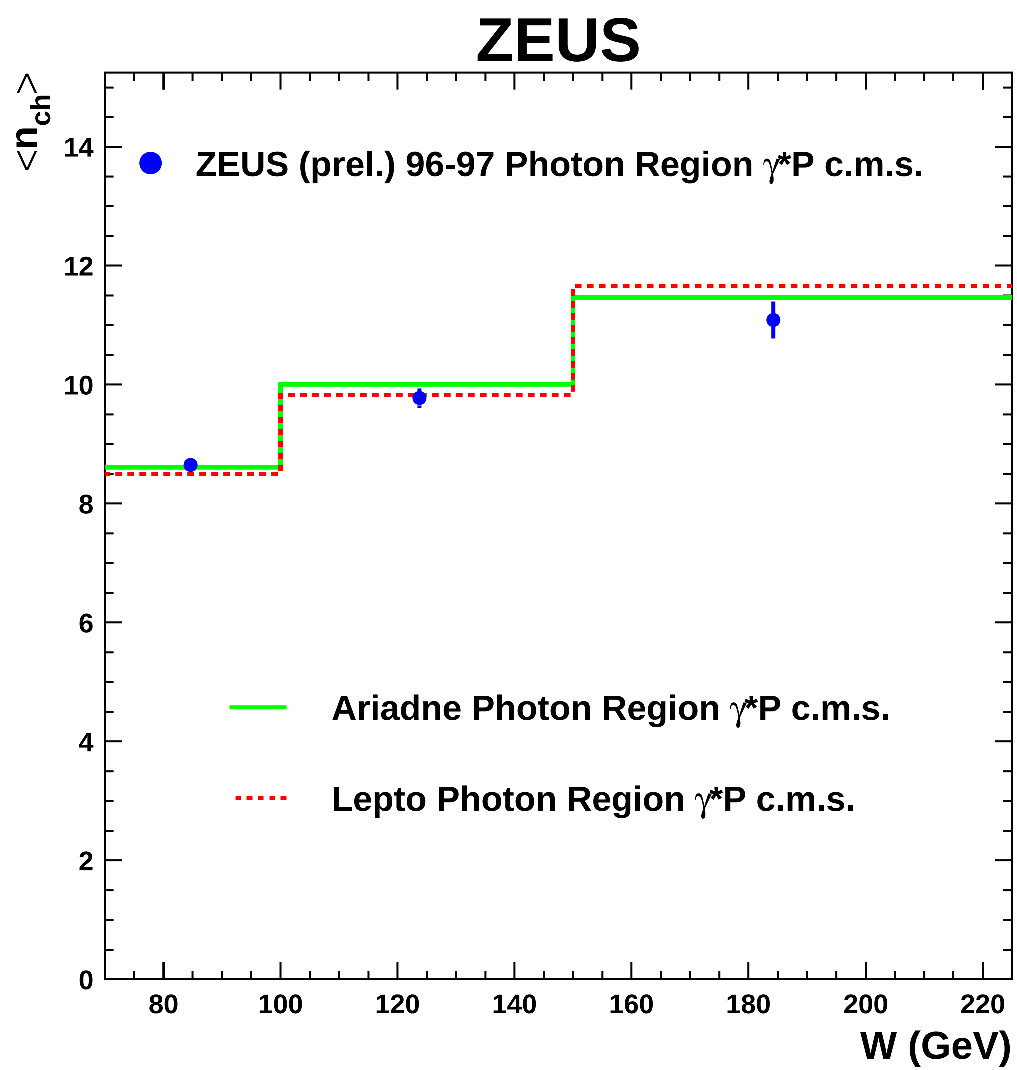
# Visible multiplicity in HCM frame

- **HCM Frame:** Photon region dominated by contribution from target region of Breit frame (~80% of visible hadrons)
- Photon region HCM frame well contained in visible part of detector



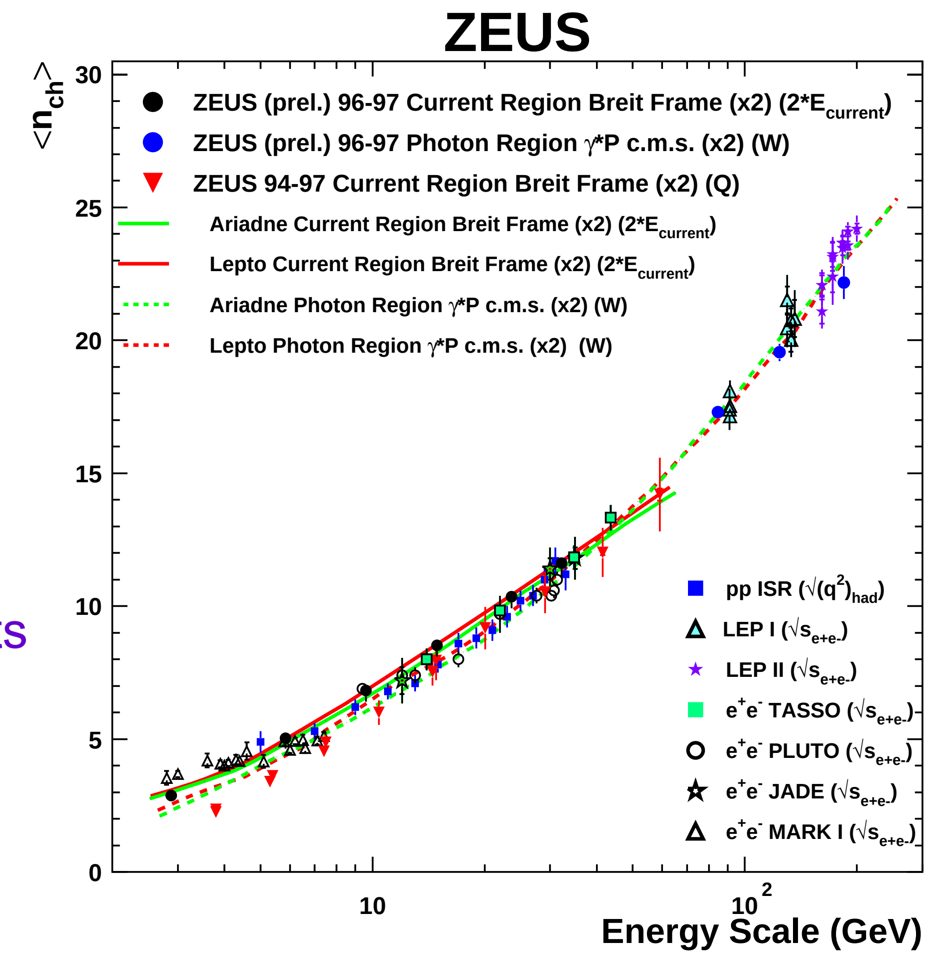
# Multiplicity vs. W in HCM

- Measurement of Multiplicity in photon region of HCM frame vs. W.
- Both Lepto and Ariadne describe the data: last bin slightly above
- Like to compare current region Breit frame and photon region HCM frame to $e^+e^-$
- Must multiply $\langle n_{ch} \rangle$ by 2 because both measurements are for hemispheres and $e^+e^-$ is total sphere



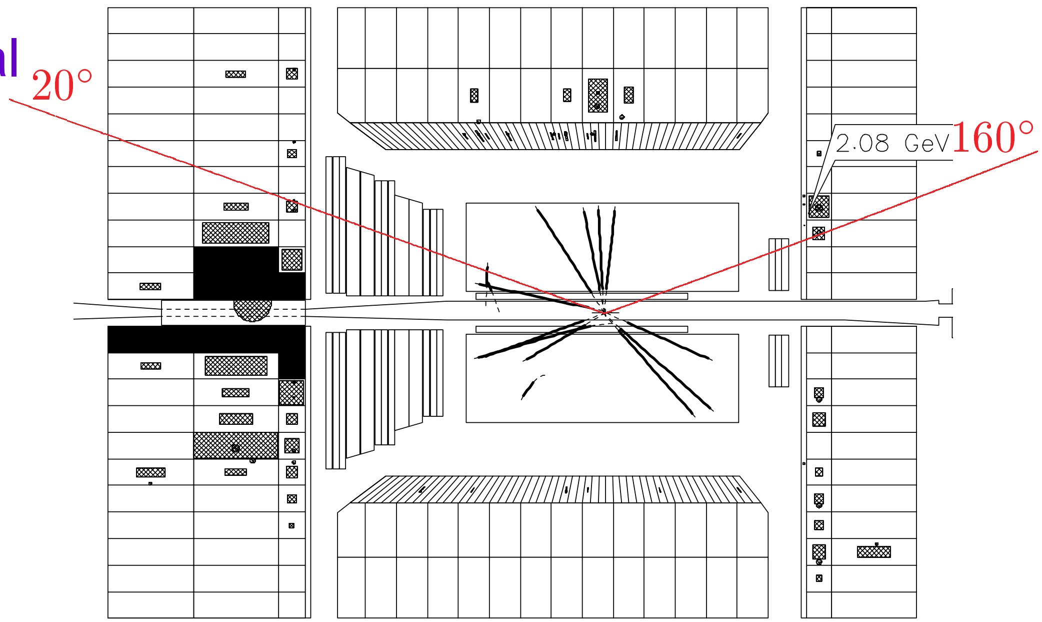
# Multiplicity in current region of Breit and HCM frames compared to e+e- and pp

- Measurements in current region of Breit frame and photon region of HCM frame multiplied by 2.
- There is agreement with $e^+e^-$ at low and high energy and with the pp results which are plotted vs. $\sqrt{q^2}_{had}$ (the scale with the leading particles removed)
- the HCM prediction has been extended to lower energies where a measurement isn't possible (region is outside detector acceptance) and it agrees with all the points at low energy
- One can also measure $\langle n_{ch} \rangle$ vs. the invariant mass of the corresponding hadronic system. Measure only what is visible in detector & minimize effect of acceptance correction



# Charged Hadrons & 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 (Meff) in corresponding $\Delta\eta$ region.
- Energy is measured in the Calorimeter (CAL)




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

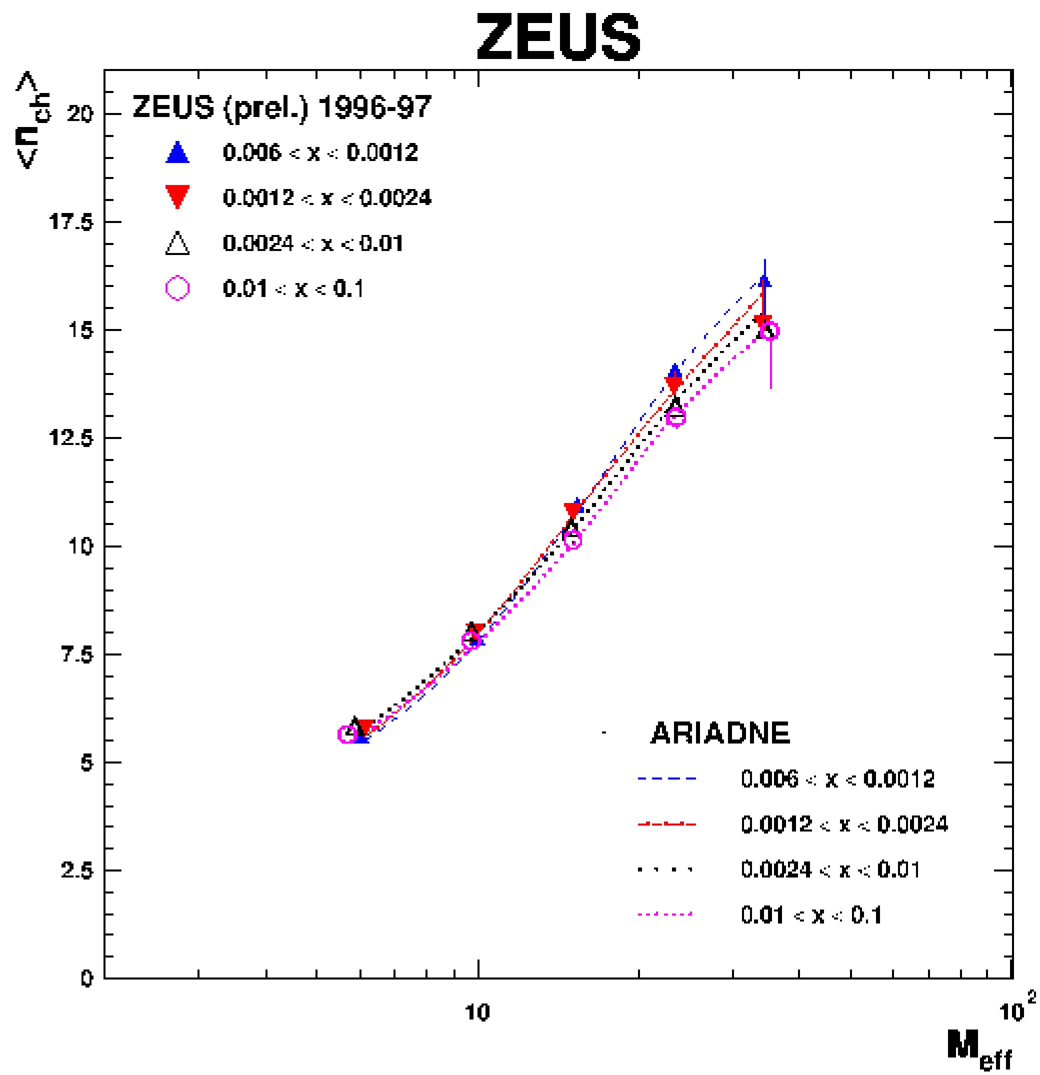
Study: <$n_{ch}$> vs. $M_{eff}$

CTD

CAL within the CTD acceptance

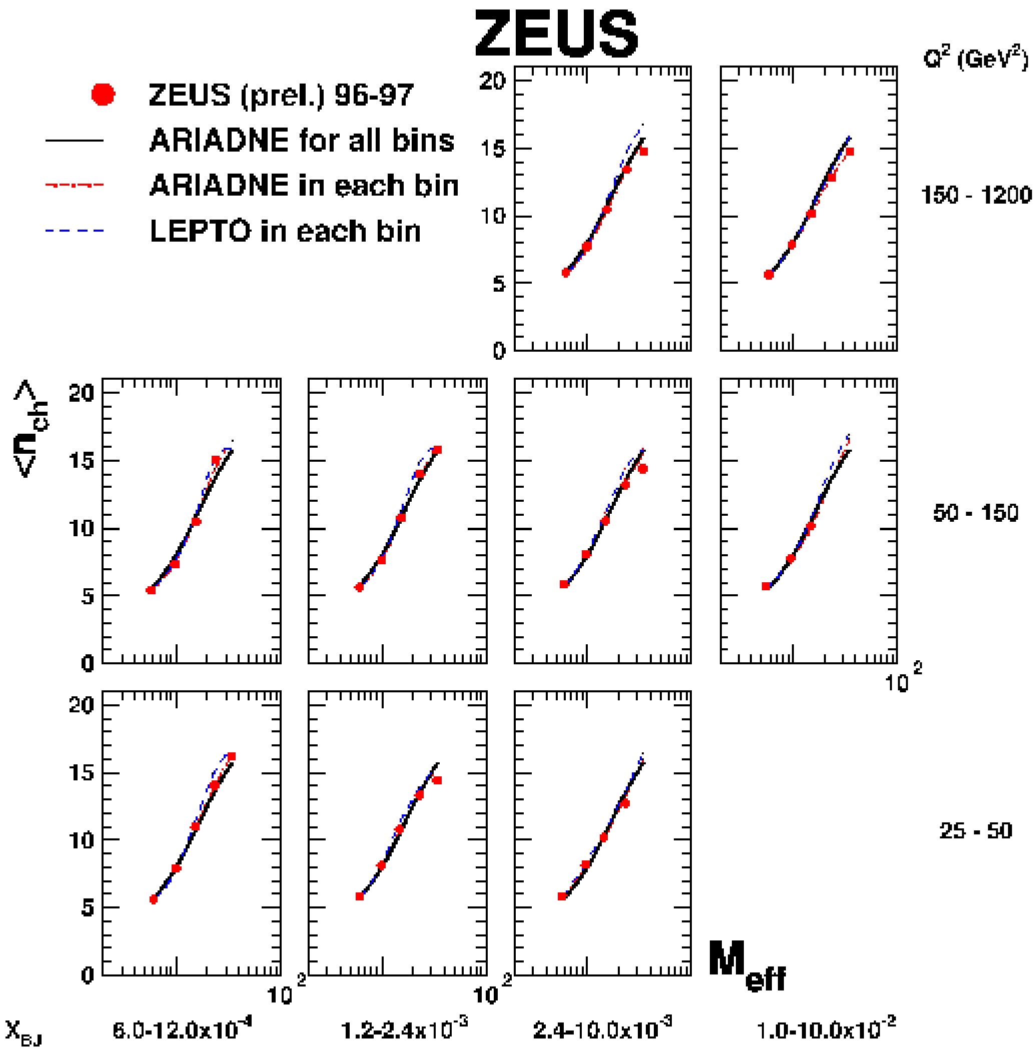
# Lab frame: <$n_{ch}$> vs. $M_{eff}$ in x bins

- Plot shown previously at ICHEP 2004
- Lab frame multiplicity vs. $M_{eff}$, shown in 4 x bins, with Ariadne predictions.
- x range split into similar bins as in previous multiplicity paper.
- weak x dependence in both data and Monte Carlo observed.
- $Q^2$ dependence? => next slide



# Lab frame: x and $Q^2$ bins

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



# Summary

- For the 1st time, the measurement of mean charged multiplicity had been extended to a higher energy scale than previously measured in ep collisions.
- Measurement in current region of the Breit frame shows similar dependence to $e^+e^-$ if $2*E_{current}$ is used as the scale
- The same dependence is observed for the photon region of the HCM frame vs. W.