Charged Particle Multiplicity in DIS

Progress Report
ZEUS Collaboration Week

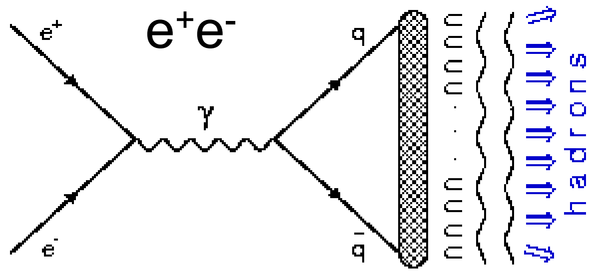
M. Rosin, D. Kçira, and A. Savin
University of Wisconsin
L. Shcheglova
Moscow State University, Institute of Nuclear Physics

June 24th, 2004

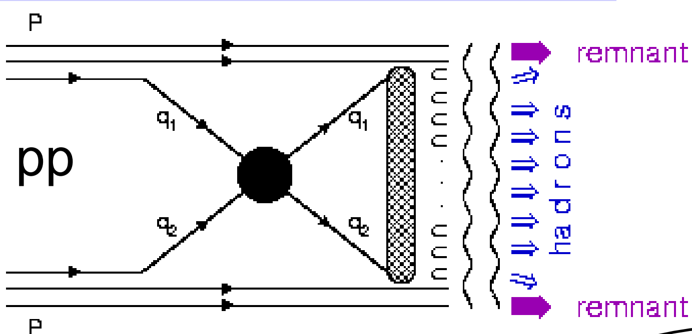
Outline

- Introduction and motivation
- Data selection & simulation
- Control plots
- Correction methods
- Measurement of $\langle n_{ch} \rangle$ vs. M_{eff}
- Comparison of analyses
- Systematics
- Checks in the Breit frame
- Summary and plan

Multiplicity e^+e^- and pp



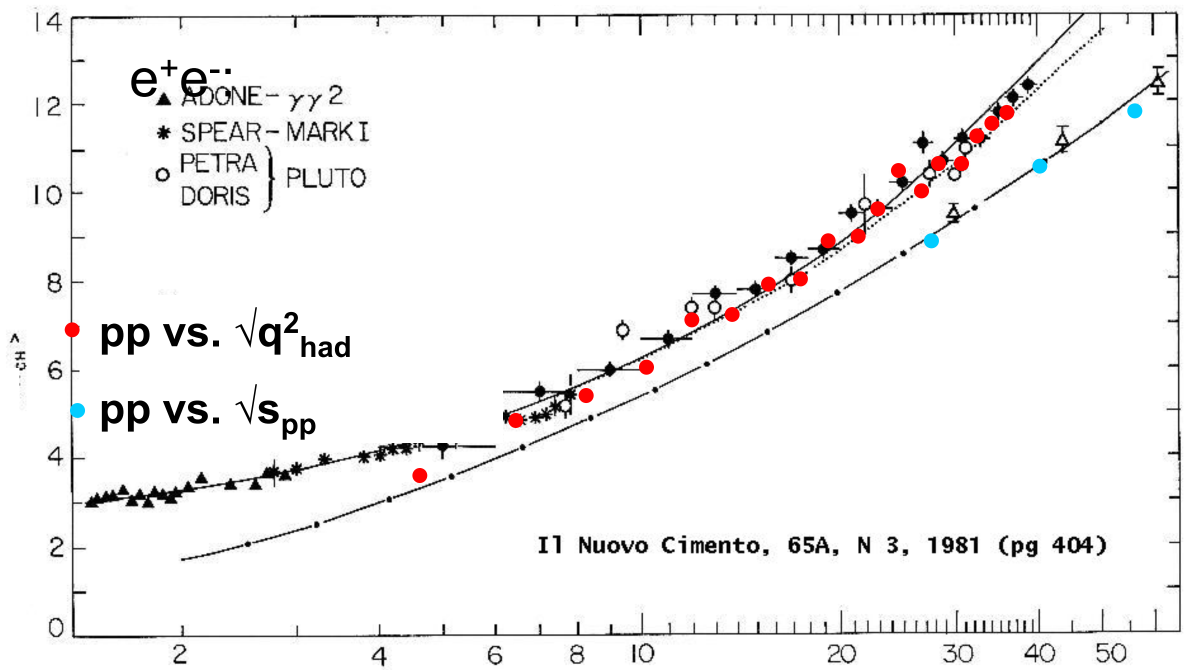
$$\sqrt{s_{e^+e^-}} = \sqrt{\left(p_{e^-} + p_{e^+}\right)^2}$$



$$\sqrt{s_{pp}} = \sqrt{\left(p_p + p_p\right)^2}$$

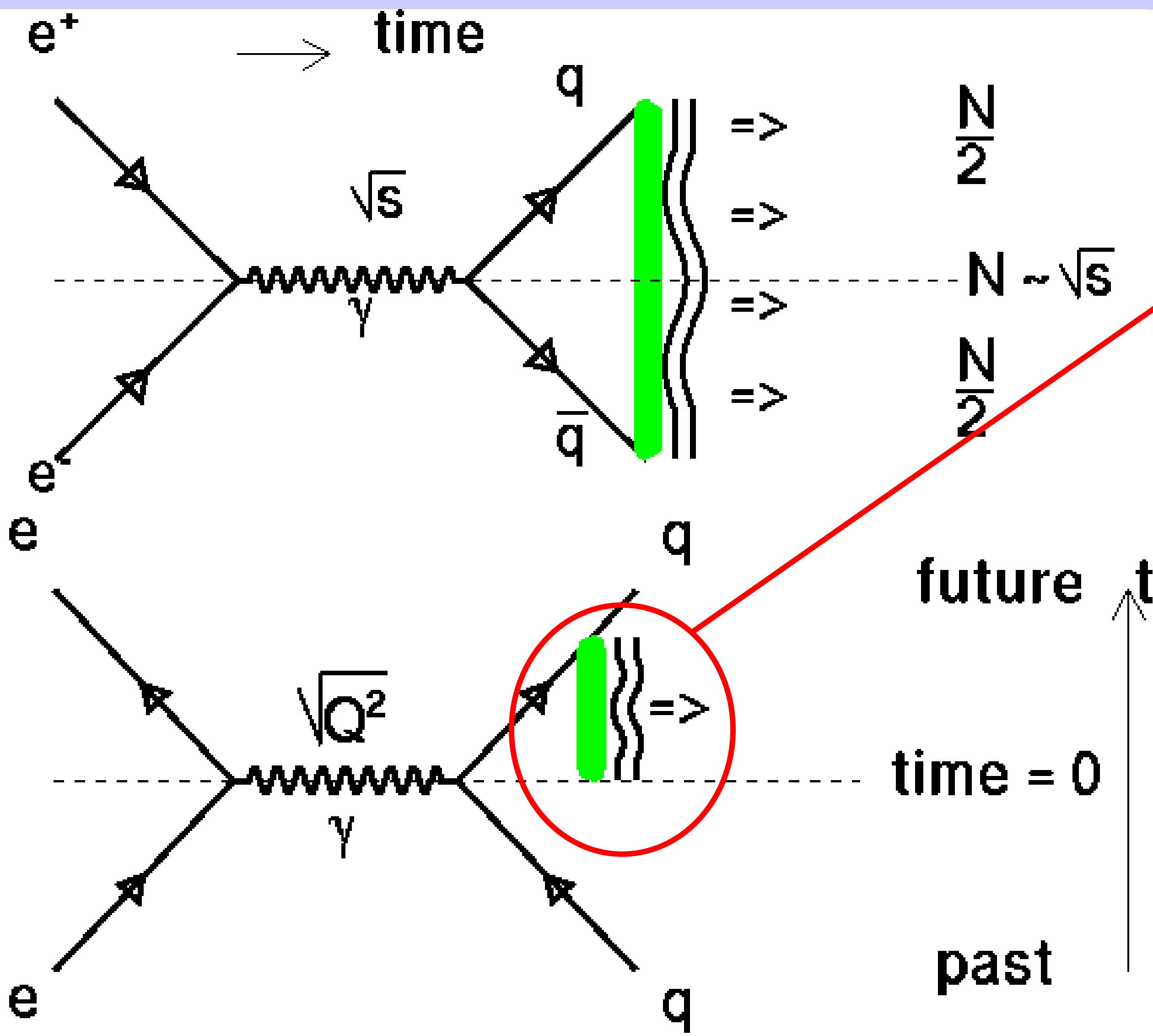
Invariant mass of pp

$$\sqrt{\left(q_{tot}^{had}\right)^2} = \sqrt{\left[\left(q_1^{inc} - q_1^{leading}\right) + \left(q_2^{inc} - q_2^{leading}\right)\right]^2}$$



- Agreement between e^+e^- and pp plotted vs. pp invariant mass

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

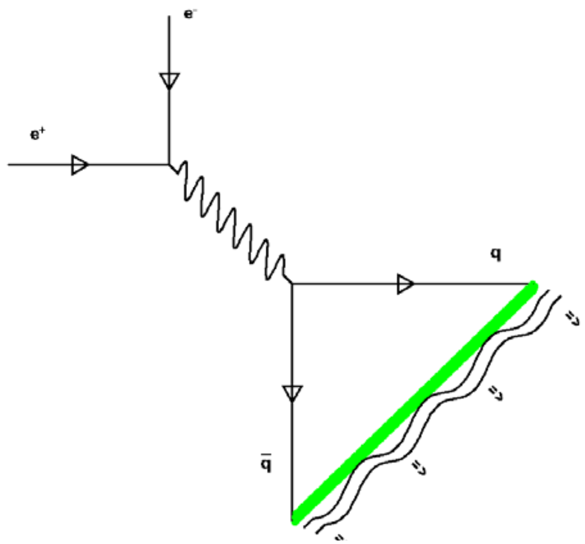


Breit Current region of ep similar to one hemisphere of e^+e^-

Use Q as scale, multiply hadrons by 2

Where does other end of the string connect?

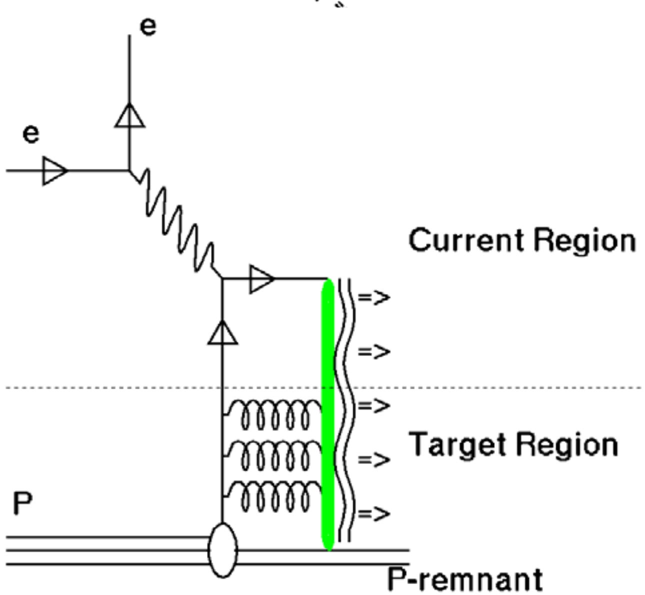
Multiplicity: ep vs. e^+e^- (2)



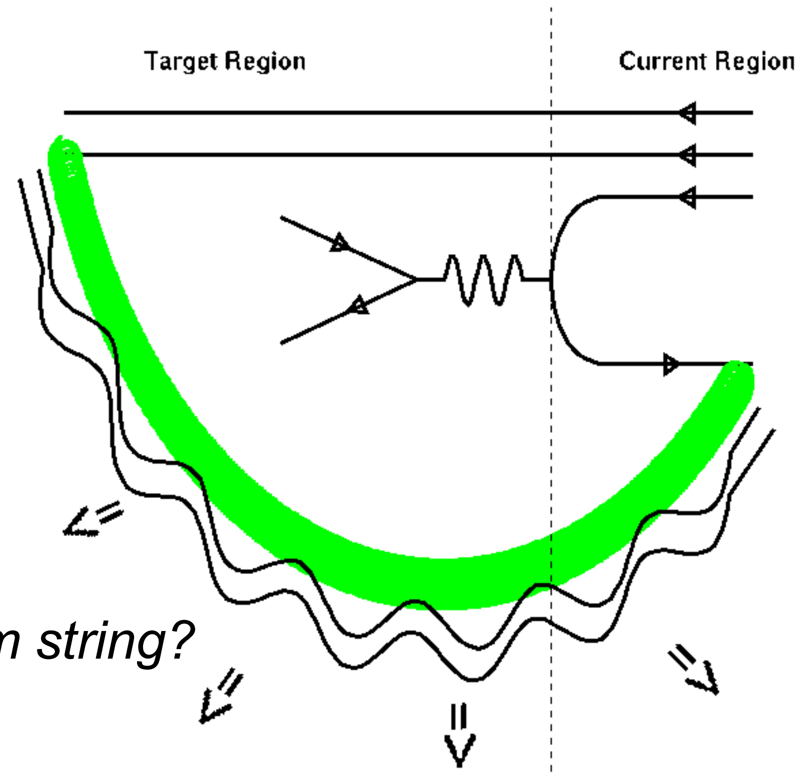
ep hadronization compared to e^+e^-.

ep: Split into Current and Target Region – one string two segments.

Use invariant masses of the string (Lab) and segments (Breit).

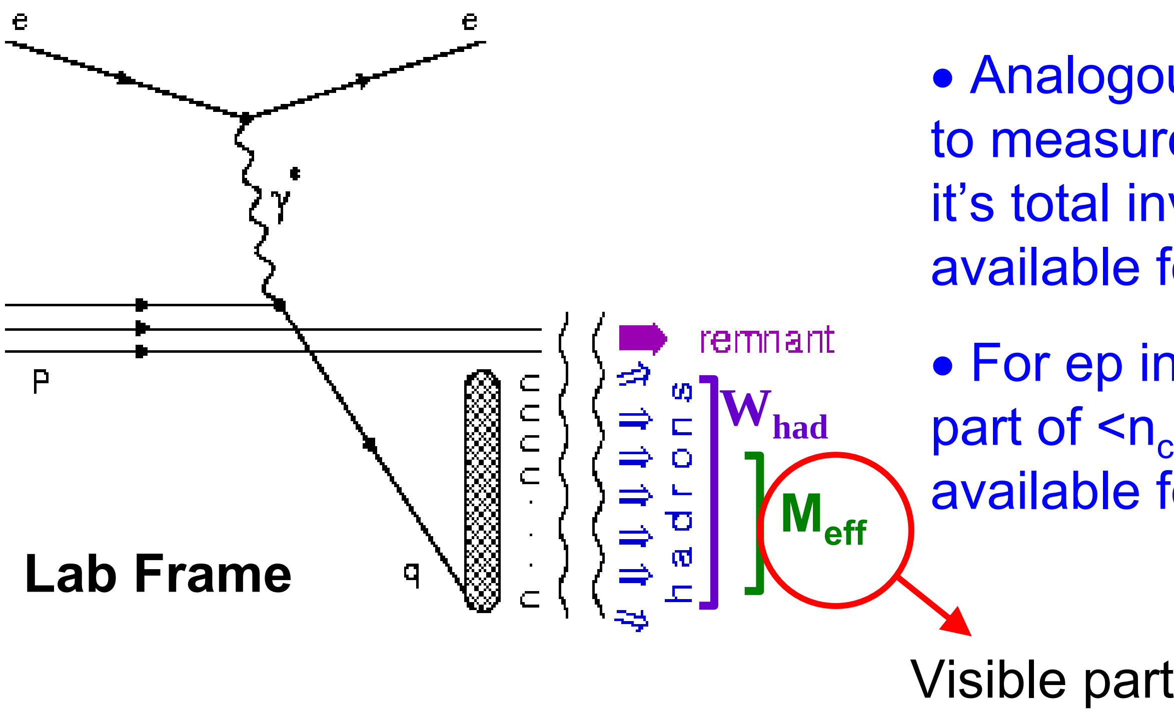


Breit Frame =>



Uniform string?

The use of M_{eff} as energy scale



- Analogous to the pp study, is natural to measure dependence of <n_{ch}> of on it's total invariant mass. (Energy available for hadronization)
- For ep in lab frame, measure visible part of <n_{ch}> vs. visible part of energy available for hadronization: M_{eff}

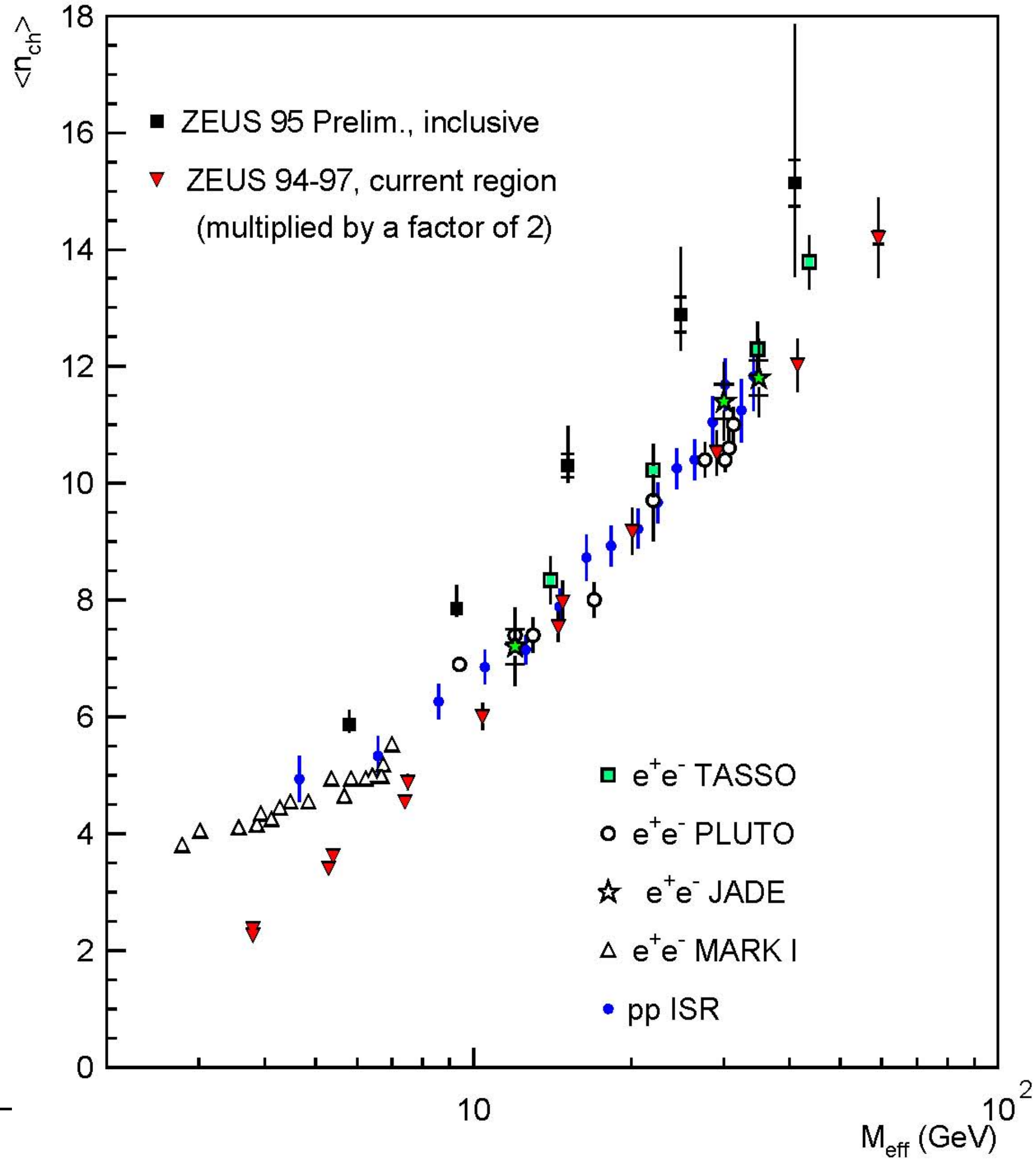
$$M_{eff}^2 = (\sum_{i \neq e'} E^i)^2 - (\sum_{i \neq e'} p_x^i)^2 - (\sum_{i \neq e'} p_y^i)^2 - (\sum_{i \neq e'} p_z^i)^2$$

M_{eff}: HFS measured in the detector where the tracking efficiency is maximized

e^+e^-, pp, ep, 4 questions

- Differences between ep and e+e- and between Breit and Lab
- Is difference due to:
  1. Analysis method?
  2. use of frame (Lab, Breit)?
  3. quark / gluon distributions?
  4. Choice of scale?
- New analysis seeks to answer these questions

=> Analysis description



1996-97 Data sample

- **Event Selection**
  - Scattered positron found with $E > 12$ GeV
  - A reconstructed vertex with $|Z_{vtx}| < 50$ cm
  - Scattered positron position cut: radius > 25cm
  - 40 GeV < $E\text{-}p_z$ < 60 GeV
  - Diffractive contribution excluded by requiring $\eta_{max} > 3.2$
- **Track Selection**
  - Tracks associated with primary vertex
  - $|\eta| < 1.75$
  - $p_T > 150$ MeV
- **Physics and Kinematic Requirement**
  - $Q^2_{da} > 25$ GeV^2
  - $y_{el} < 0.95$
  - $y_{JB} > 0.04$
  - 70 GeV < W < 225 GeV **($W^2 = (q + p)^2$)**

735,007 events
after all cuts
(38.58 pb^{-1})

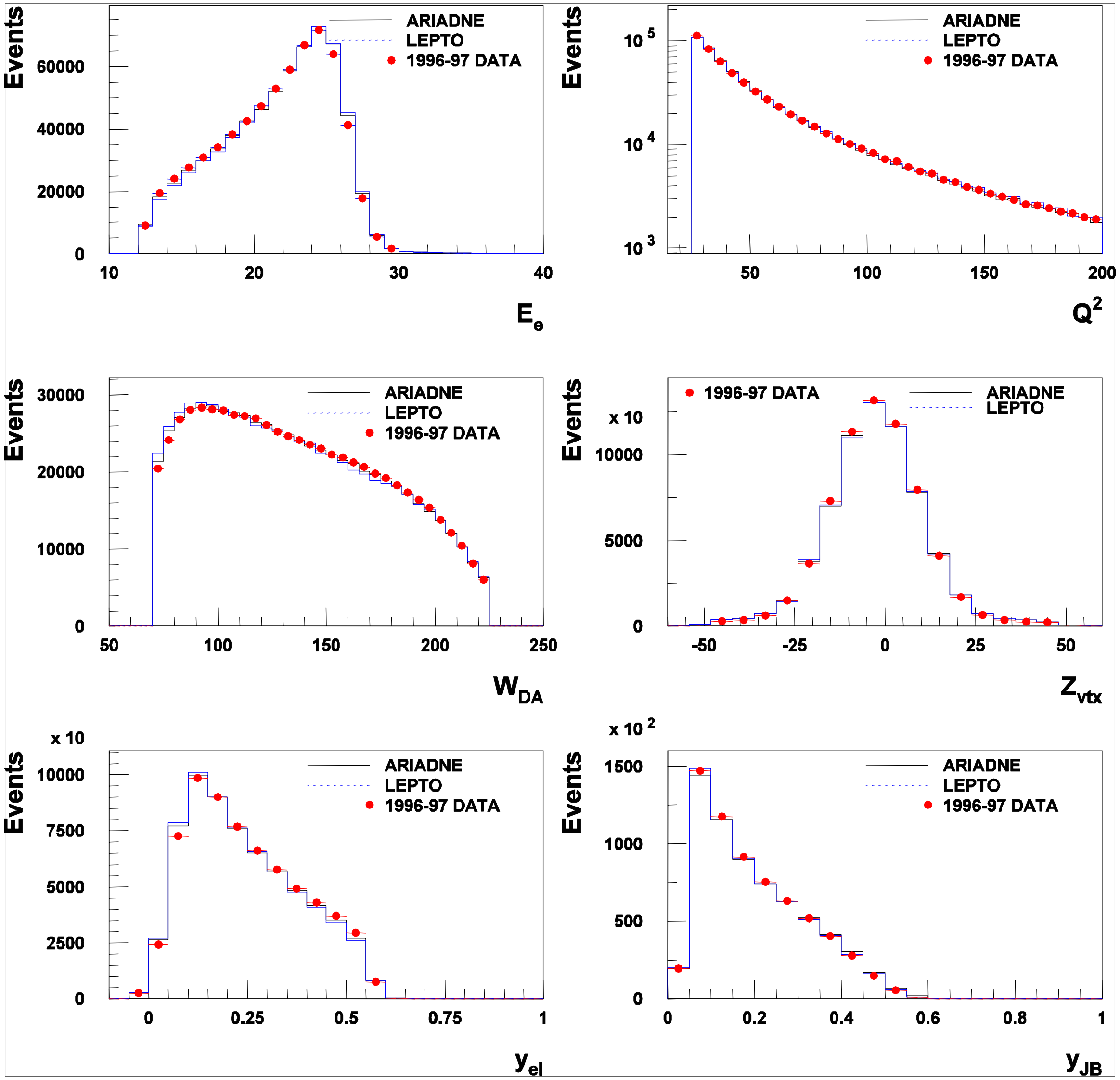
Event simulation

- Ariadne '96-'97 4.08
  - Matrix elements at LO pQCD O(α_s)
  - Parton showers: CDM
  - Hadronization: String Model
  - Proton PDF's: CTEQ-4D
- Lepto 6.5.1
  - Including SCI
  - Also generated Lepto without SCI

Luminosity of MC : 36.5 pb^{-1}

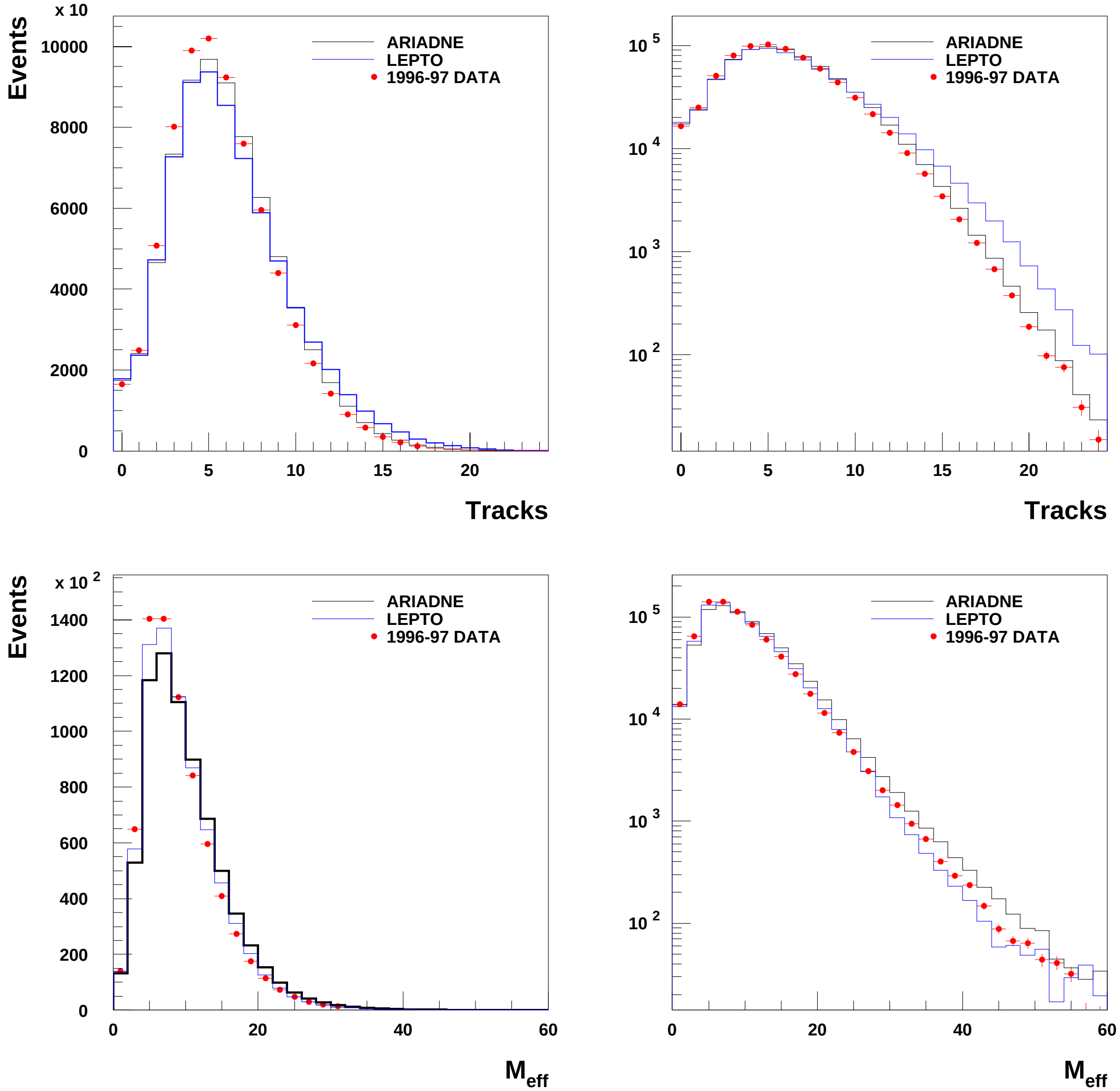
Kinematic Variables

- 96-97 data compared to ARIADNE and LEPTO for kinematic variables
- Both ARIADNE and LEPTO show good agreement for kinematic variables

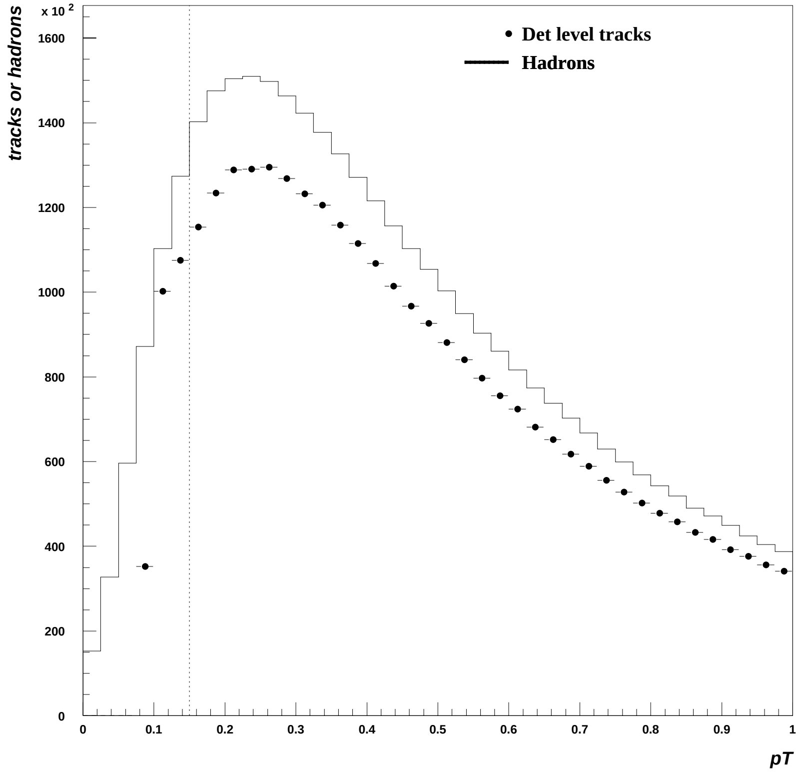


Lab analysis: M_{eff} & Tracks

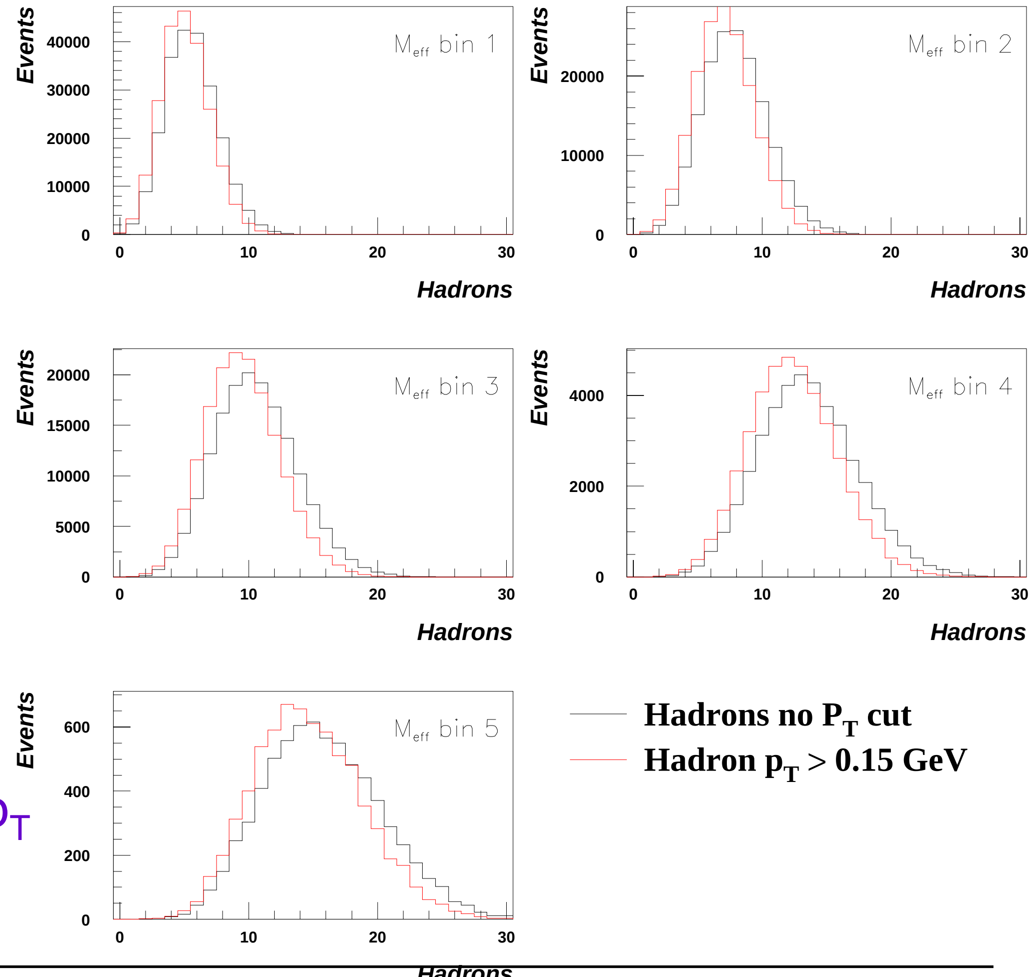
- LEPTO and ARIADNE comparisons to tracks and M_{eff}
- Tracks better described by ARIADNE
- M_{eff} better described by LEPTO
- Will compare also with LEPTO without SCI



Correction to hadron level: bin by bin



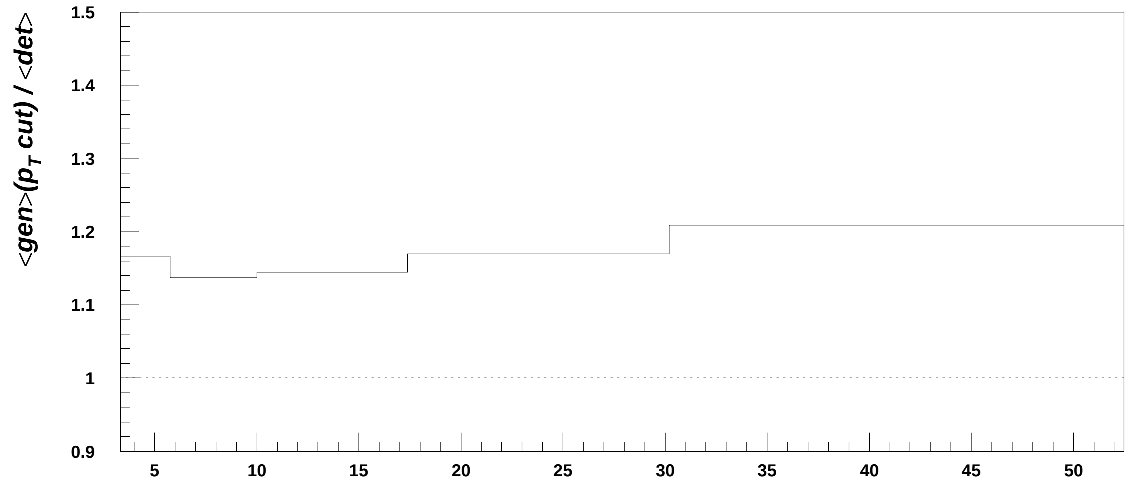
Part one: correct to hadron level using only hadrons generated with $p_T > 0.15$ GeV



Part two: correct for hadrons with lower p_T, using ratio of <gen> with p_T cut to <gen> no p_T cut in each bin.

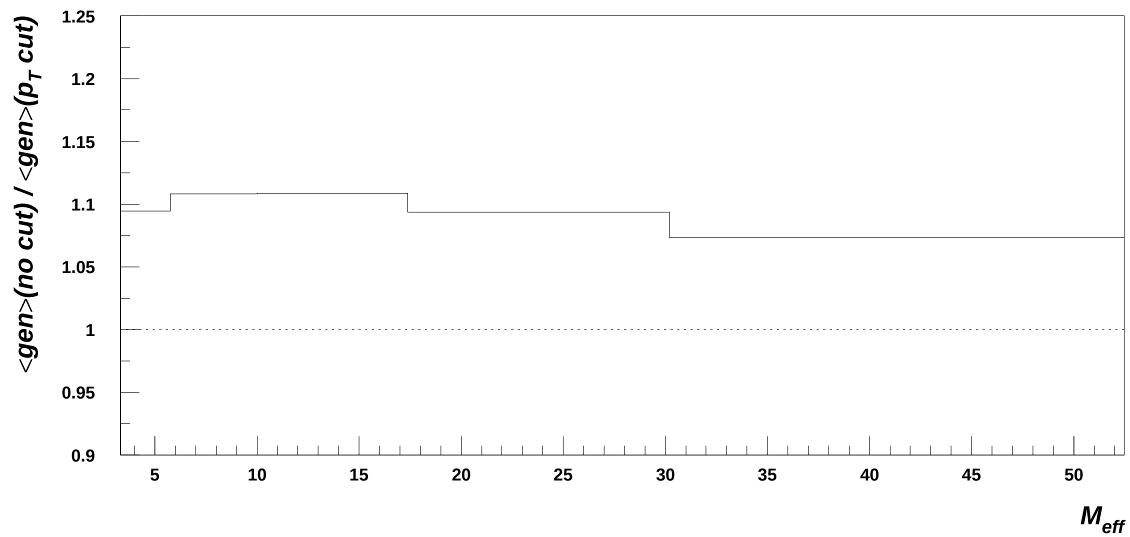
Correction to hadron level: bin by bin

Correction for detector effects



Ariadne - Lepto very similar (see later)

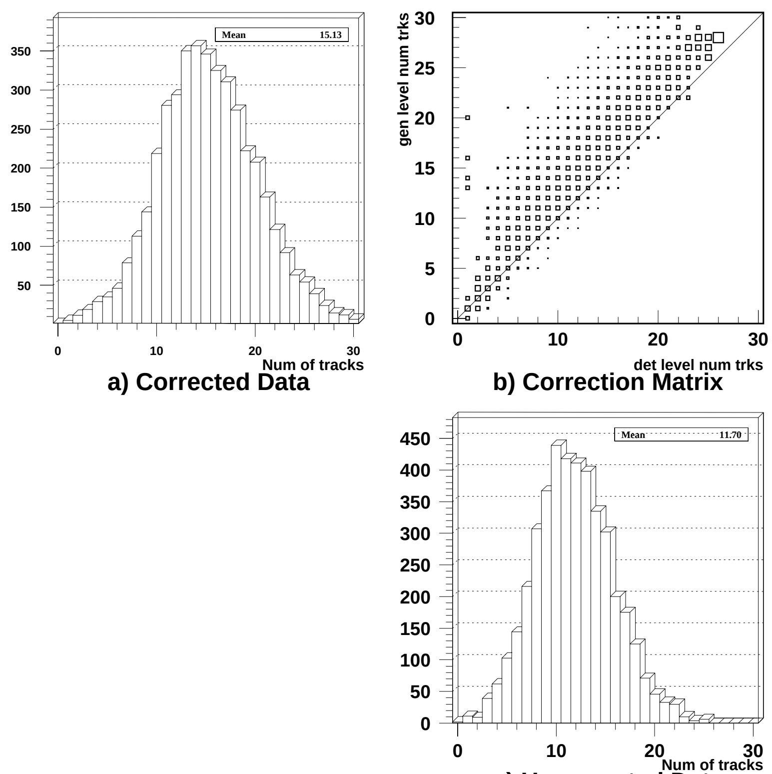
Correction of hadrons of pT > 0.15 to all hadrons



Correction to hadron level: matrix

$$M_{p,o} = \frac{\text{No. of events with p tracks generated when o tracks were observed}}{\text{No. events with o tracks observed}}$$

Matrix Correction Meff Bin 5



a) Corrected Data

b) Correction Matrix

c) Uncorrected Data

The matrix relates the observed to the generated distributions of tracks in each bin of M_{eff} by:

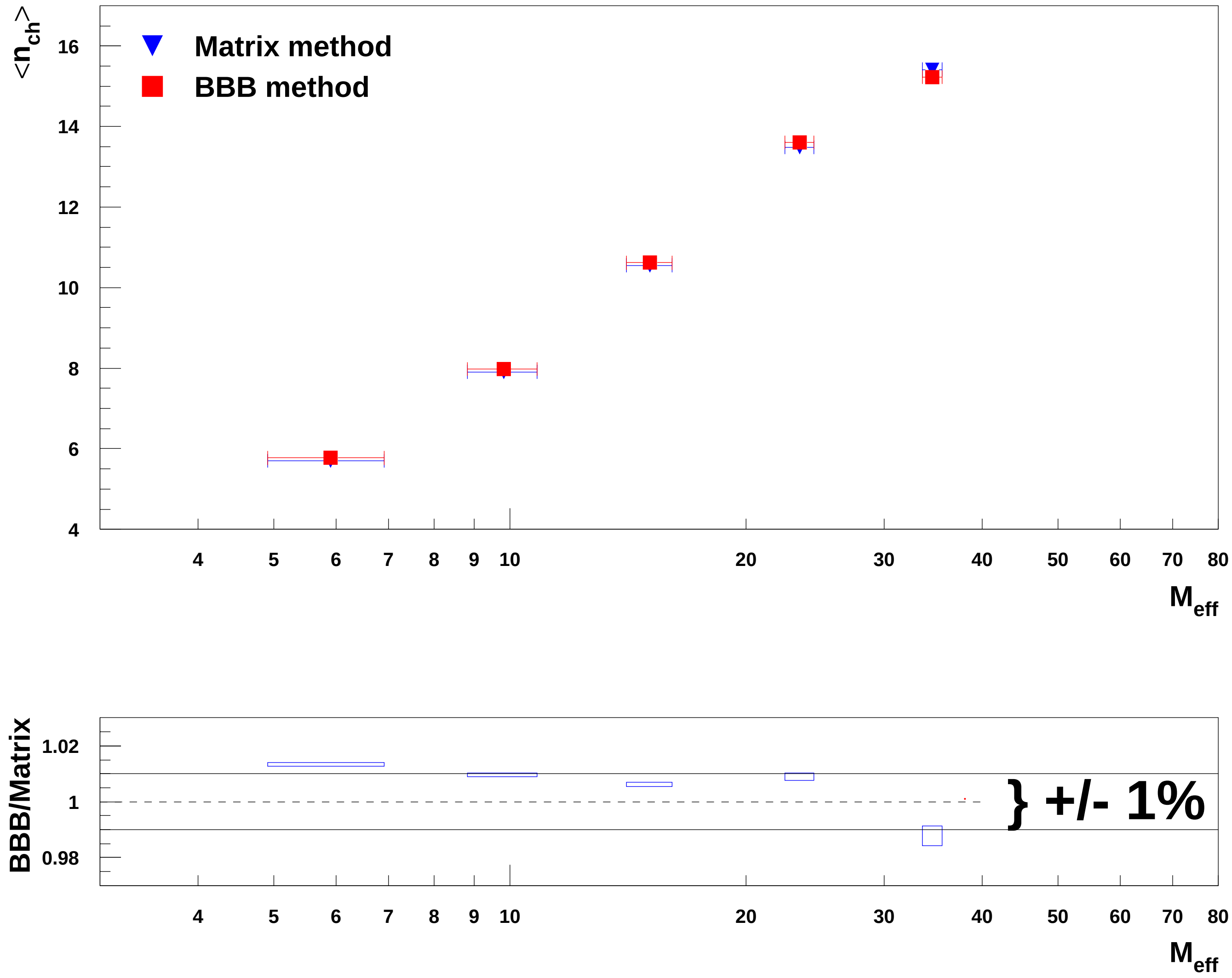
$$P_p = \sum_o M_{p,o} \cdot P_o$$

- Matrix corrects tracks to hadron level
- ρ corrects phase space to hadron level

$$\rho = \frac{\text{Hadrons passing gen level cuts}}{\text{Hadrons passing det level cuts}}$$

Comparison of bin-by-bin and matrix methods

- Methods agree better than 2% in all M_{eff} bins
- use bin-by-bin for results
- Matrix sensitive to statistics
- Use matrix method considered as a systematic check



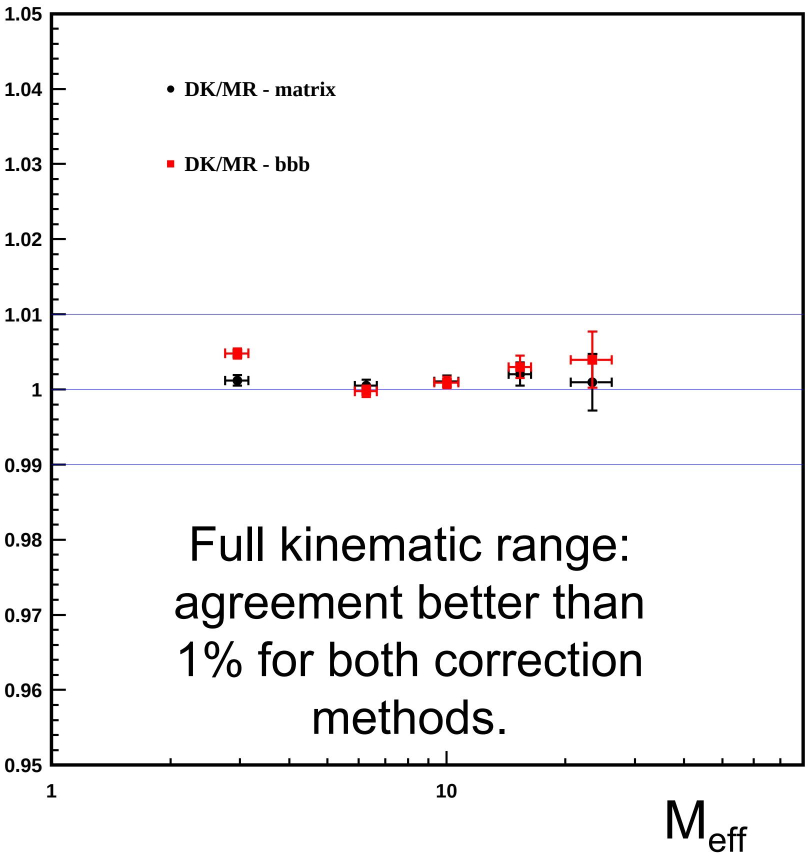
Correlated & Uncorrelated Systematics

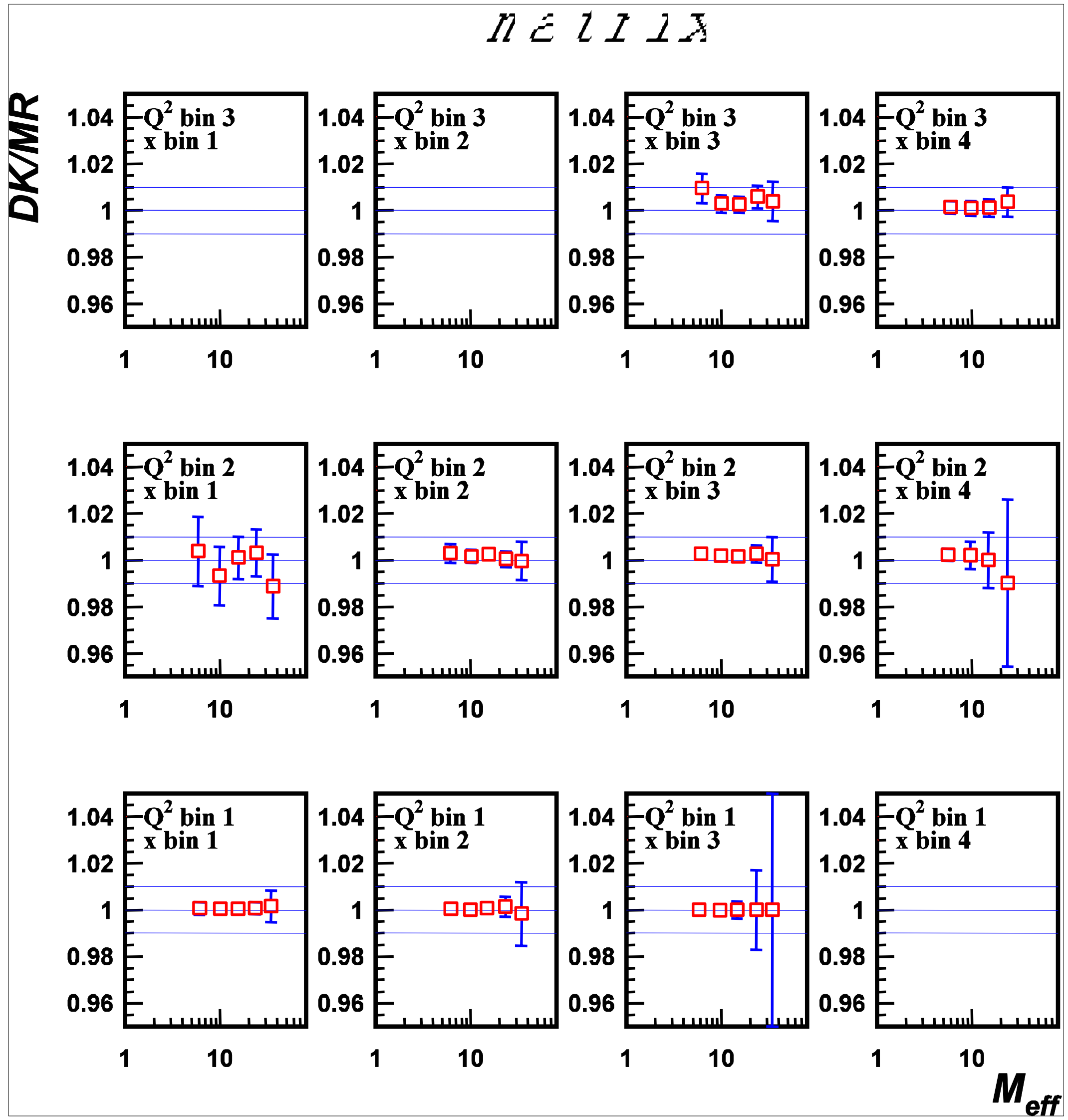
Systematic	Change	% Difference in M_{eff} bins				
		Bin 1	Bin 2	Bin 3	Bin 4	Bin 5
matrix instead of bin-by-bin		1.3%	0.9%	0.6%	0.9%	1.2%
LEPTO instead of ARIADNE		< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
Ee'	± 1 GeV	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
Radius Cut	± 1cm	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
Q^2	± 1.6 GeV^2	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
y_{JB}	± .0006	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
Track p_T	-.03/+.05GeV	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
Z_{vtx}	± 5 cm	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
W	± 19 GeV	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
E - p_z	± 5 GeV	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%

CAL energy scale	± 3 %	1.1%	1.2%	1.1%	0.8%	0.5%

Check with 2nd analysis: total, Q^2 and x bins

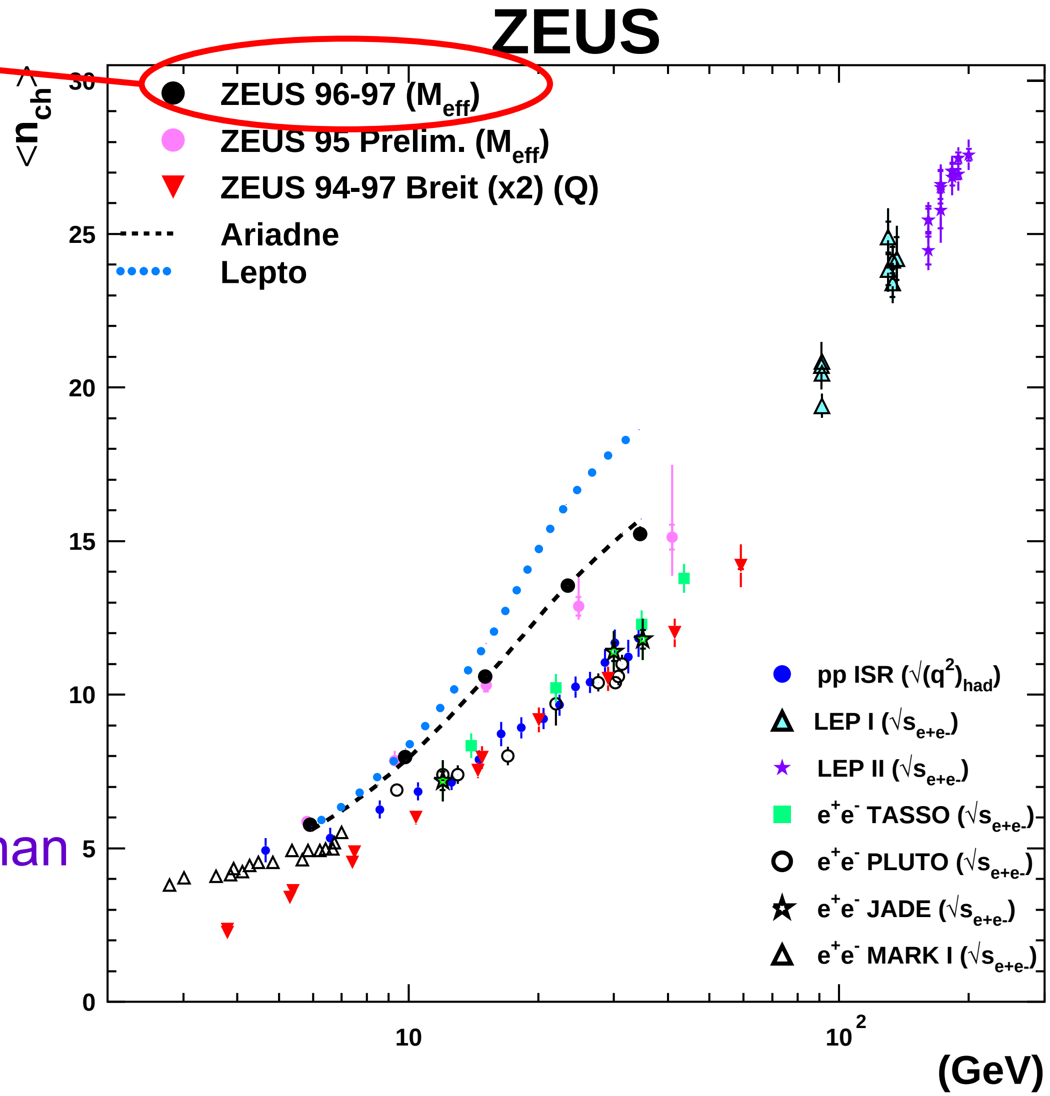
- Agreement between 1st and 2nd analysis within 1% for total and in bins of x and Q^2





New measurement in the LAB

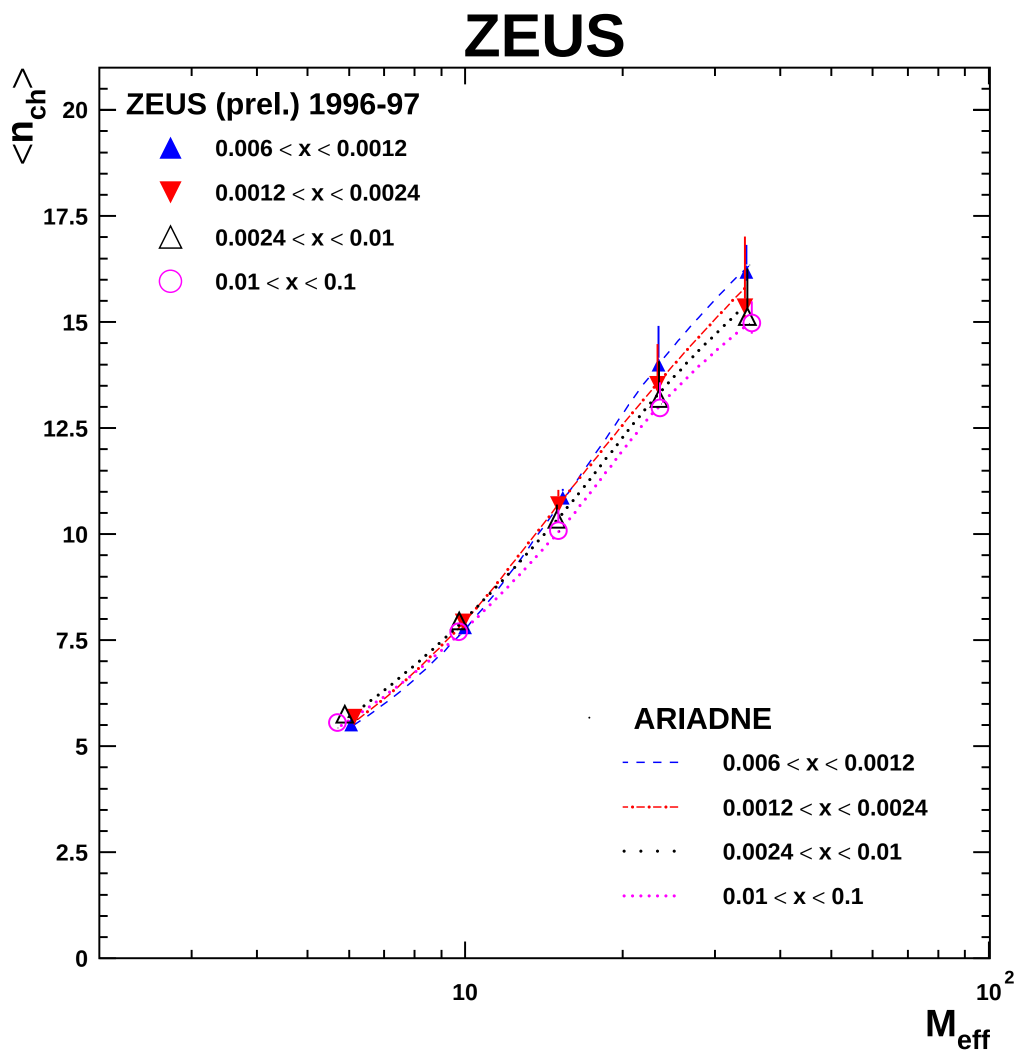
New 96-97 Lab Data



- Good agreement with 1995 prelim. points, with smaller statistical, systematic errors
- Confirm difference ep vs. e^+e^- and pp.
- ARIADNE describes data dependence, LEPTO higher than the data

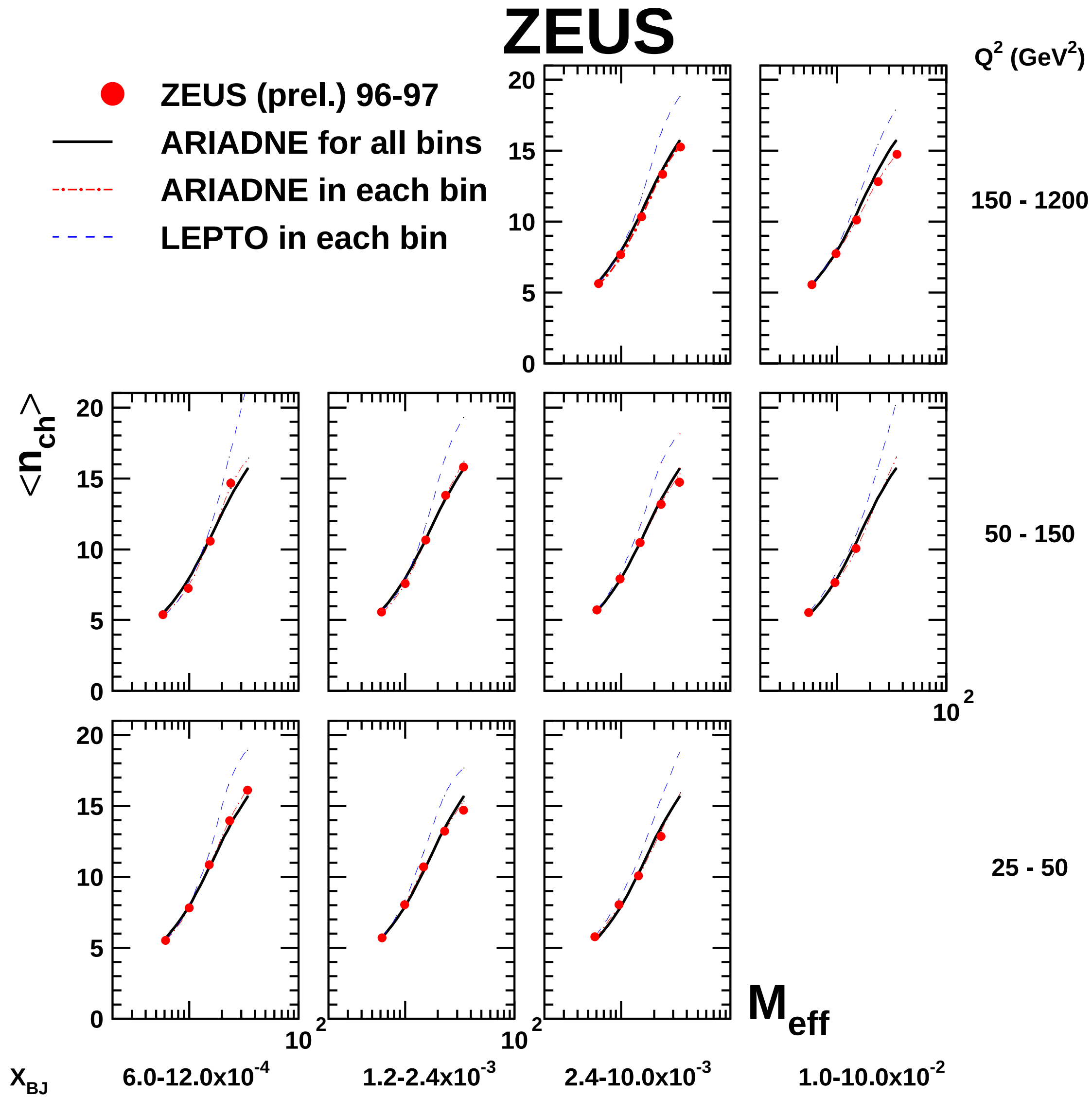
Lab frame: $\langle n_{ch} \rangle$ vs. M_{eff} in x bins

- Check if ep vs. e+e- and pp difference is due to quark and gluon distributions: study x and Q^2 dependence
- x range split into similar bins as in previous multiplicity paper.
- weak x dependence in both data and MC observed not sufficient to explain difference
- Q^2 dependence? => next page



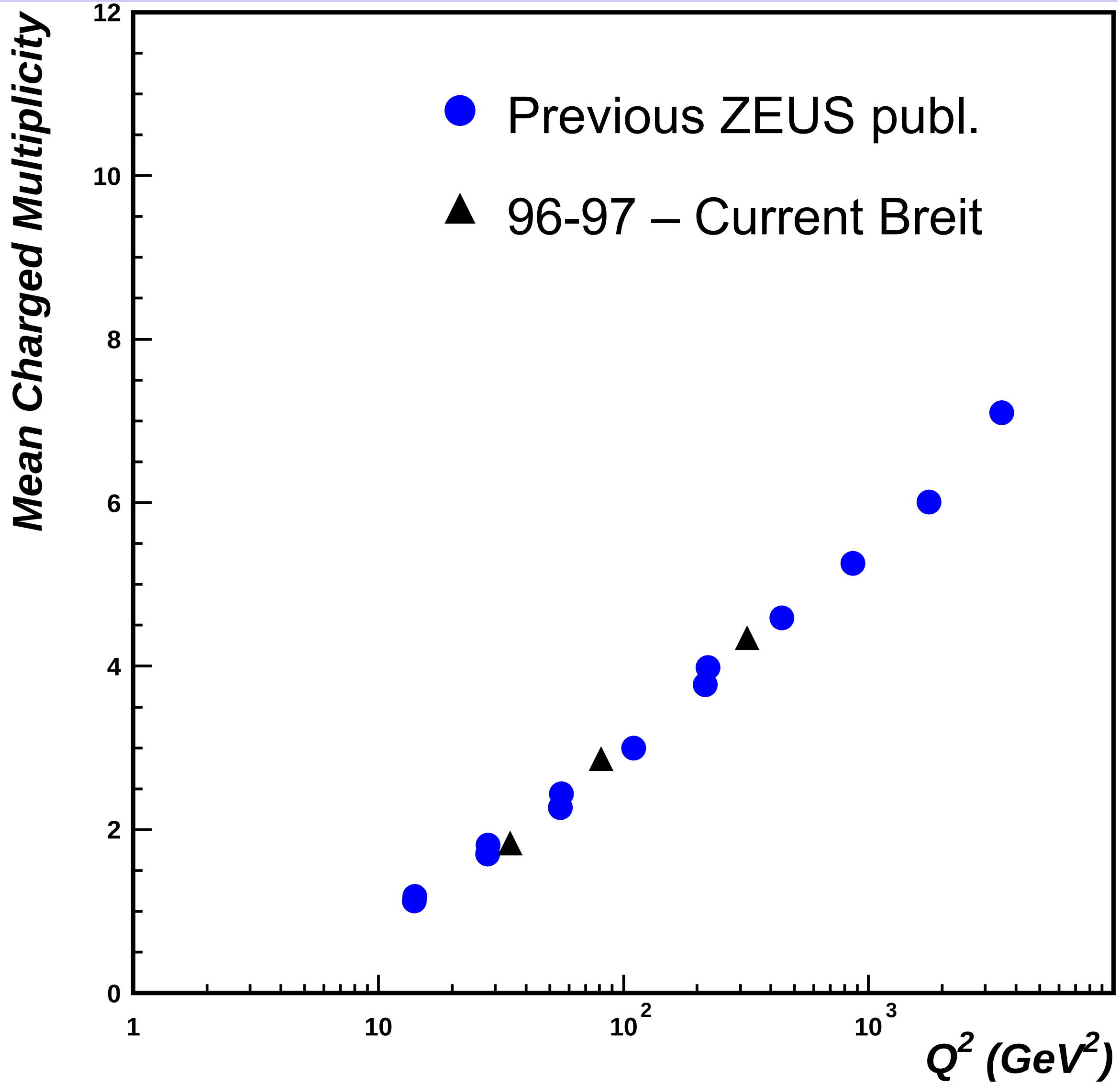
Lab frame: x and Q^2 bins

- Data described by ARIADNE
- LEPTO above data
- No Q^2 dependence observed
- Difference not due to quark / gluon distributions in the proton



Breit Frame: Current Region Analysis

- New analysis agrees with previously published ZEUS result in the Current Region of the Breit Frame for scale Q.
- Previous ZEUS publication: Eur. Phys. J.C 11, 251-270 (1999)

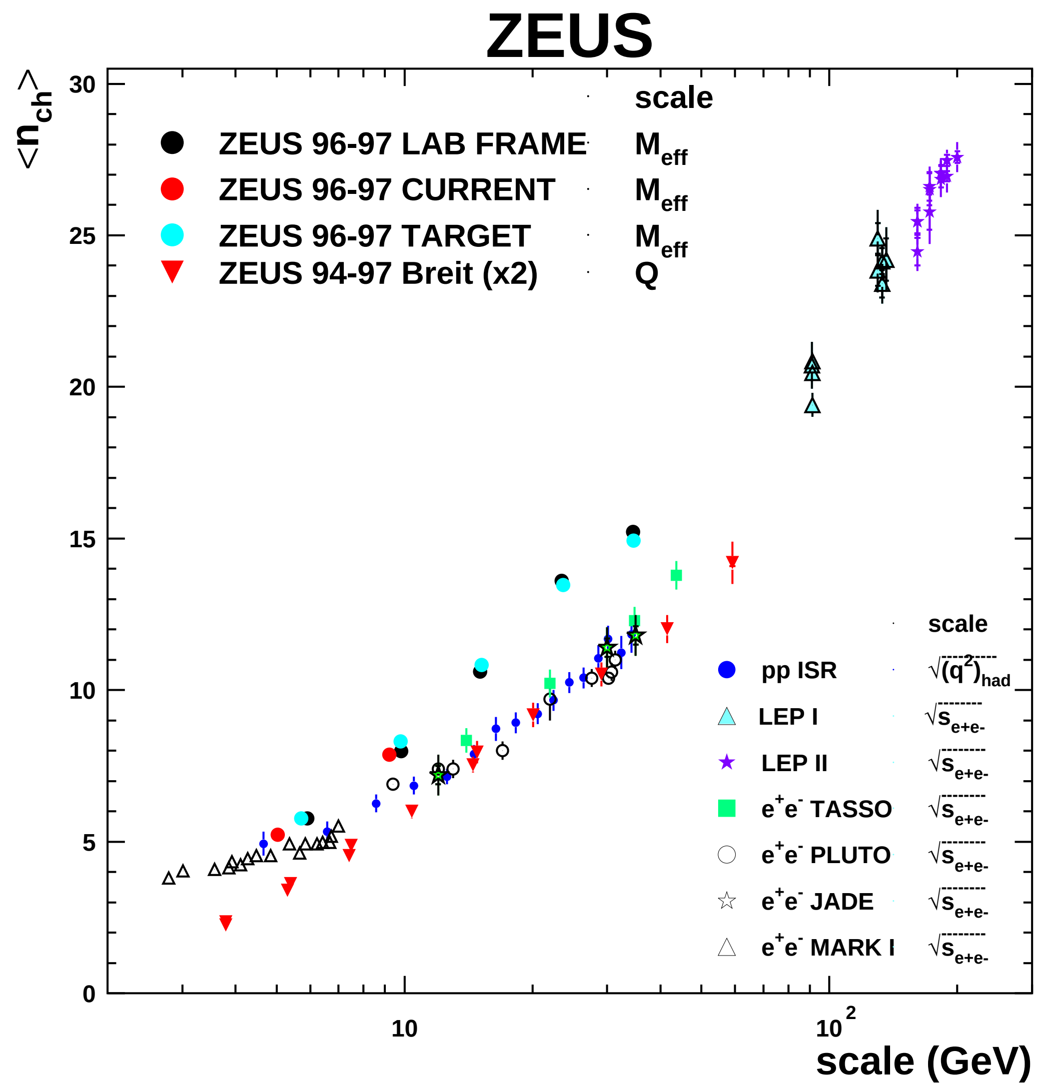


Breit Frame - Change to scale M_{eff}

Using M_{eff} agreement between:

- Lab frame
- Breit Frame Current Region
- Breit Frame Target Region

=> String is "uniform"



Summary

Measured mean charged multiplicity in the Lab and Breit frame. Compared to predictions, to other ZEUS data, and e+e-

Difference ep vs. e+e- and pp:

- not due to experimental measurement.
- not due to the choice of frame (Lab Breit).
- not due to quark/gluon distributions.
- is due to choice of scale (Q vs. M_{eff})

Plans for the future

- Finish checks in the Breit frame.
- Run on Lepto without SCI
- Make results preliminary: soon!