Charged Particle Multiplicity in DIS

ZEUS Collaboration Meeting

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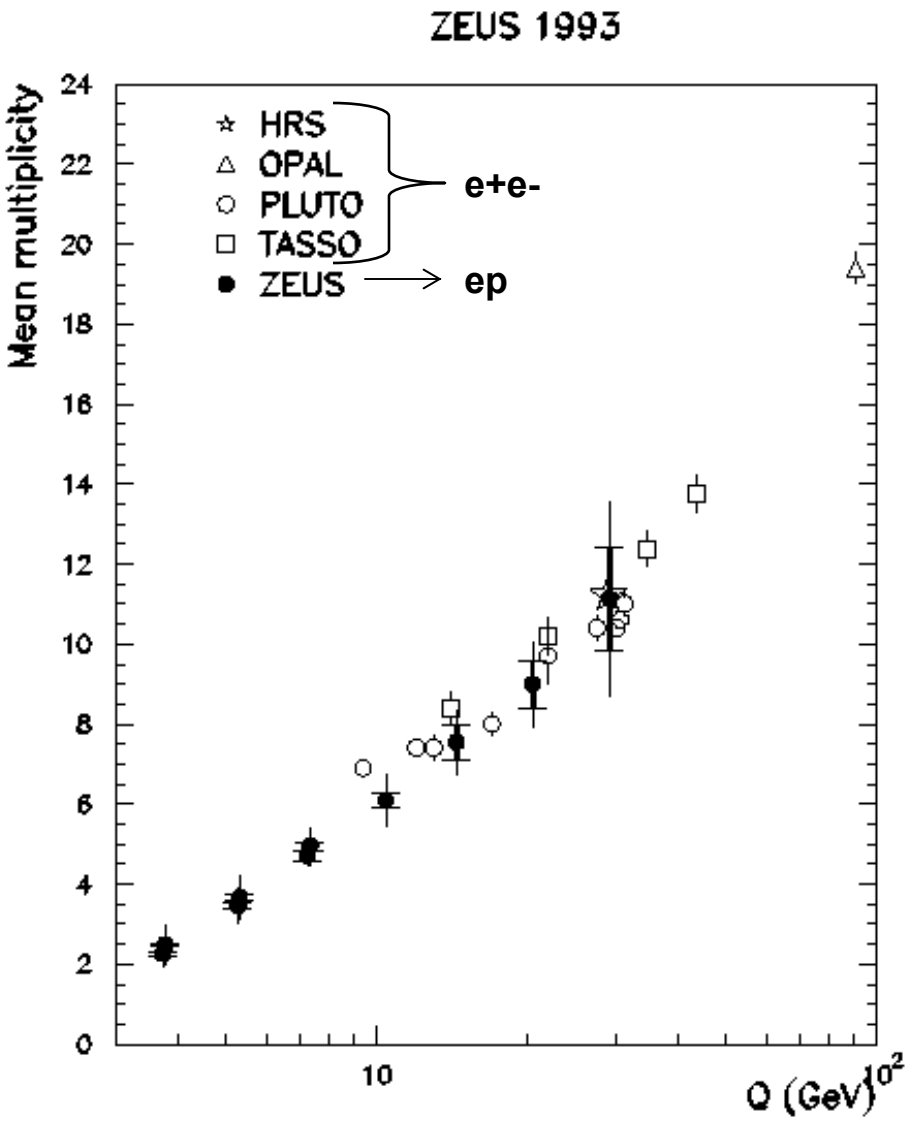
Outline

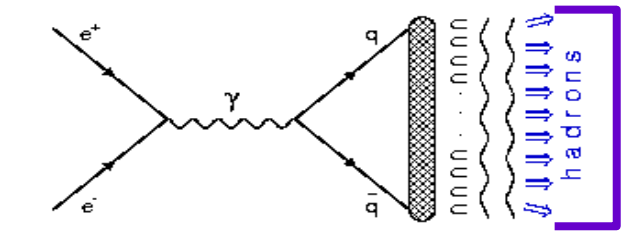
- Universal dependence of mean charged multiplicity, $\langle n_{ch} \rangle$, on effective energy going into particle production, W_{had}, for e^+e^-, pp, and ep.
- Introduction of M_{eff} and motivation for its use as an energy scale
- Data selection & simulation
- Resolutions and systematics
- Measurements of $\langle n_{ch} \rangle$ vs. effective mass
- Comparison to second analysis
- Trigger studies
- Summary and plan

Early experimental evidence for universality

- The current region in the Breit frame is analogous to a single hemisphere of e+e- annihilation; Q for ep reactions corresponds to W_{had} for e+e- reactions
- Mean charged multiplicity, $\langle n_{ch} \rangle$, vs. Q shows logarithmic dependence for both e+e- and ep on the effective energy going into hadronization
- Universal dependence of $\langle n_{ch} \rangle$ observed in e+e- and ep reactions in Breit frame.
- Now move to lab frame; see the effects of target region

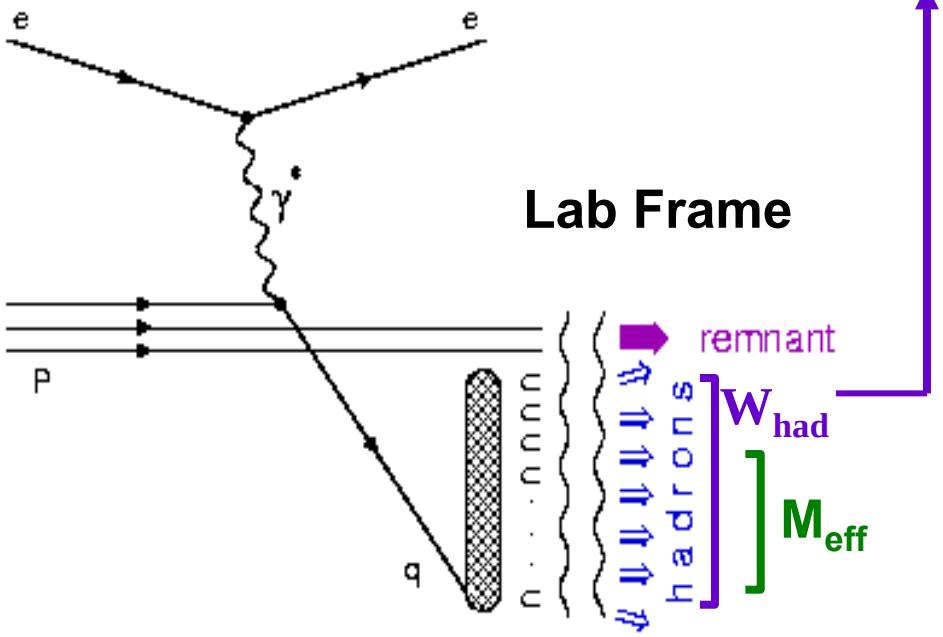


Motivation for the use of M_{eff} as energy scale



W_{had}

Similarity of particle production at e+e- and ep colliders



Lab Frame

W_{had}

M_{eff}

- Similarity of W_{had} dependence on $\langle n_{ch} \rangle$ has been observed
- A common W_{had} dependence on $\langle n_{ch} \rangle$ implies the production of secondary particles is similar in the different interactions
- Study the dependence of $\langle n_{ch} \rangle$ of the observed part of the produced HFS on it's total invariant mass, M_{eff}

W_{had}: HFS measured in full phase space

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

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

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: $|x| > 15$ cm or $|y| > 15$cm (in RCAL) "Box cut"
  - $40 \text{ GeV} < E\text{-}p_z < 60 \text{ GeV}$
  - 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**
  - $Q^2_{da} > 25 \text{ GeV}^2$
  - $y_{el} < 0.95$
  - $y_{JB} > 0.04$
  - $70 \text{ GeV} < W < 225 \text{ GeV}$ ($\mathbf{W^2 = (q + p)^2}$)

705,381 events after all cuts (38 pb^{-1})

Event simulation

- **Ariadne ’97 6v2.4** (Simulates both ’96 and ’97 data; no changes in detector)
  - Matrix elements at LO pQCD **O**(α_s)
  - Parton showers: CDM
  - Hadronization: String Model
  - Proton PDF’s: CTEQ-4D

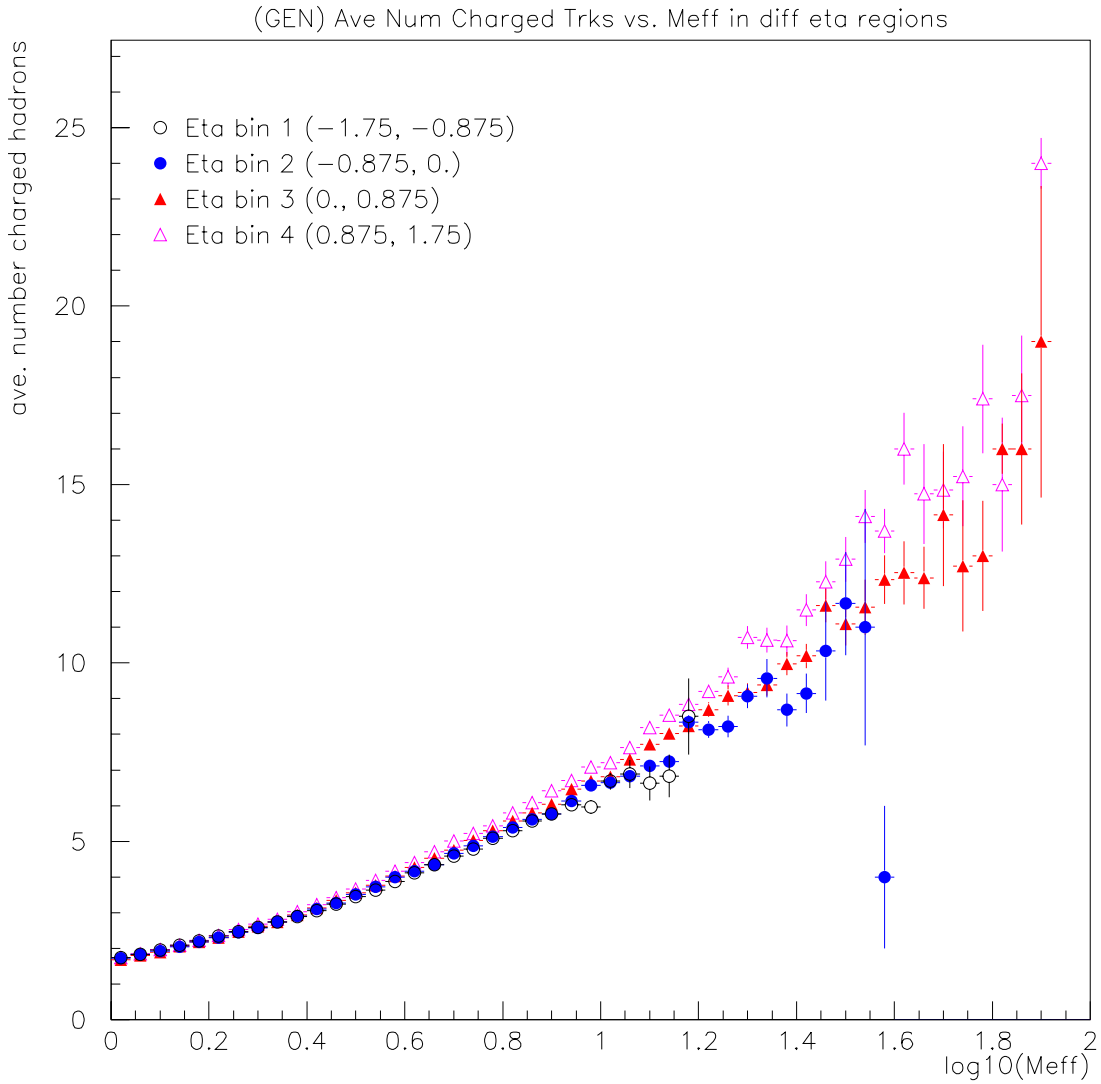
Luminosity of MC : 2.48 pb^{-1}

Validation of analysis method

Can we look at just the observed part of the HFS?

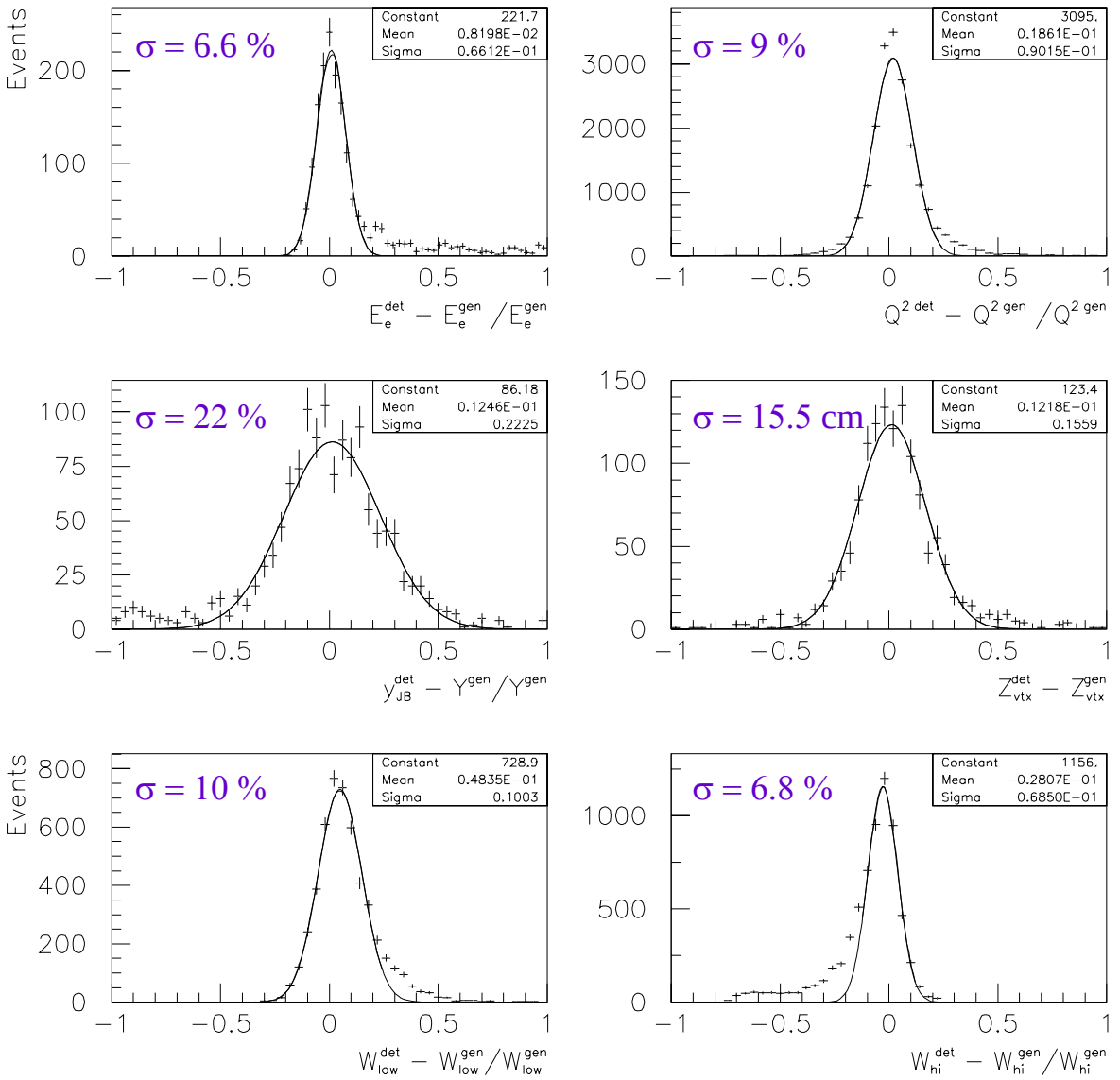
Study η dependence using generated events

- The dependence of $\langle n_{ch} \rangle$ on the M_{eff} of the produced system for ep generated events is the same in different regions of phase space
- Can use the observed part of the produced HFS, with good tracking ($|\eta| < 1.75$) for studying this dependence



Resolutions of kinematic variables

- Resolutions well behaved
- Use standard deviations for excursions in systematic studies



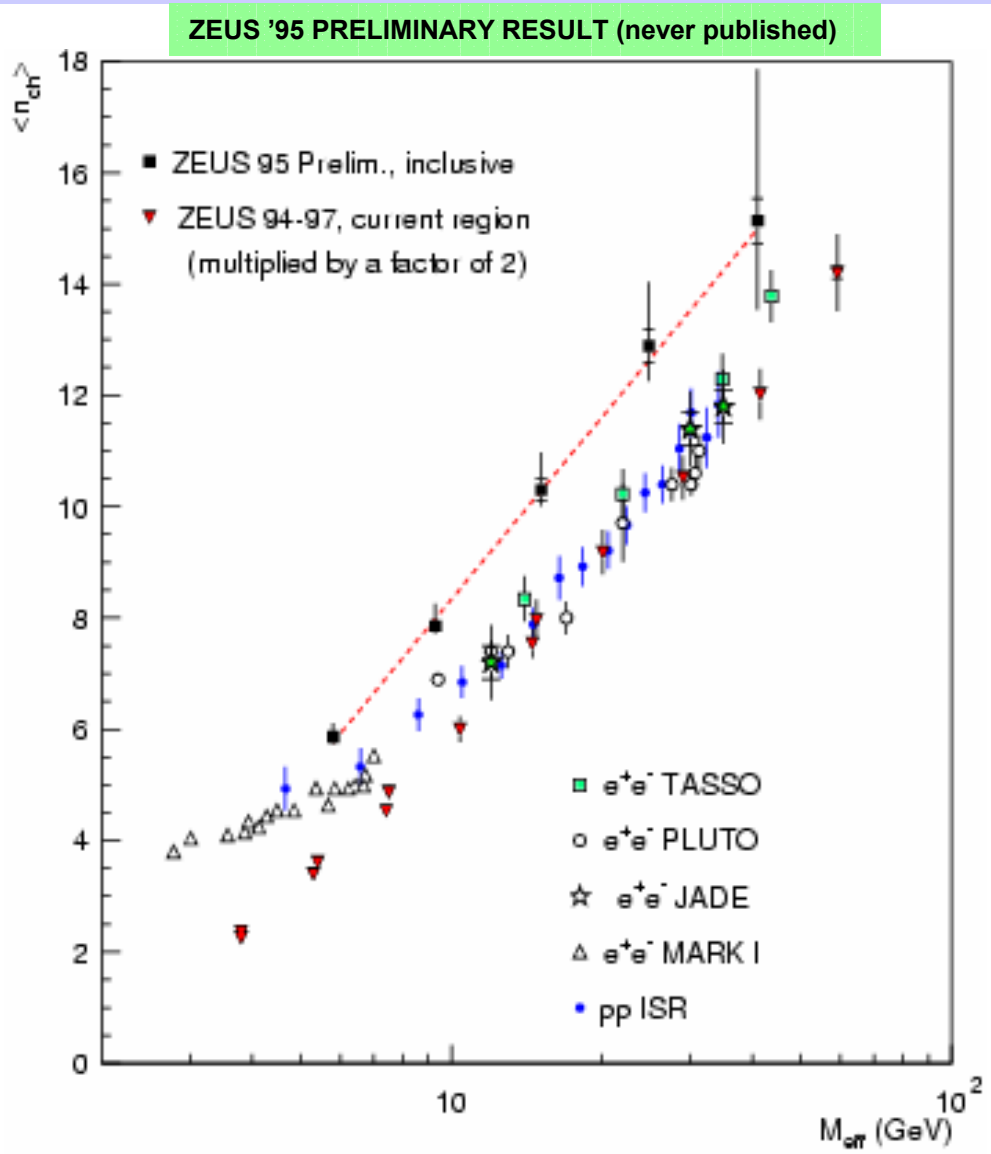
Correlated & Uncorrelated Systematics

Systematic	Change	% Difference in M_{eff} bins				
		Bin 1	Bin 2	Bin 3	Bin 4	Bin 5
Ee'	± 1 GeV	< 0.5%	< 0.5%	< 0.5%	0.8 %	1.2%
Box Cut	± 1cm	< 0.5%	< 0.5%	< 0.5%	0.67%	0.62%
Q^2	± 2.25 GeV^2	3.35%	2.08%	2.17%	2.08%	0.91%
y_{JB}	± .008	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
y_{el}	± .05	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
Z_{vtx}	± 15 cm	< 0.5%	< 0.5%	< 0.5%	0.53%	0.75%
W (upper)	± 15 GeV	< 0.5%	< 0.5%	< 0.5%	< 0.5%	2.0%
W (lower)	± 7 Gev	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%
E - p_z	± 2 GeV	< 0.5%	< 0.5%	< 0.5%	0.62%	< 0.5%

CAL energy scale	± 3 %	1.1%	1.4%	1.3%	< 0.5%	< 0.5%

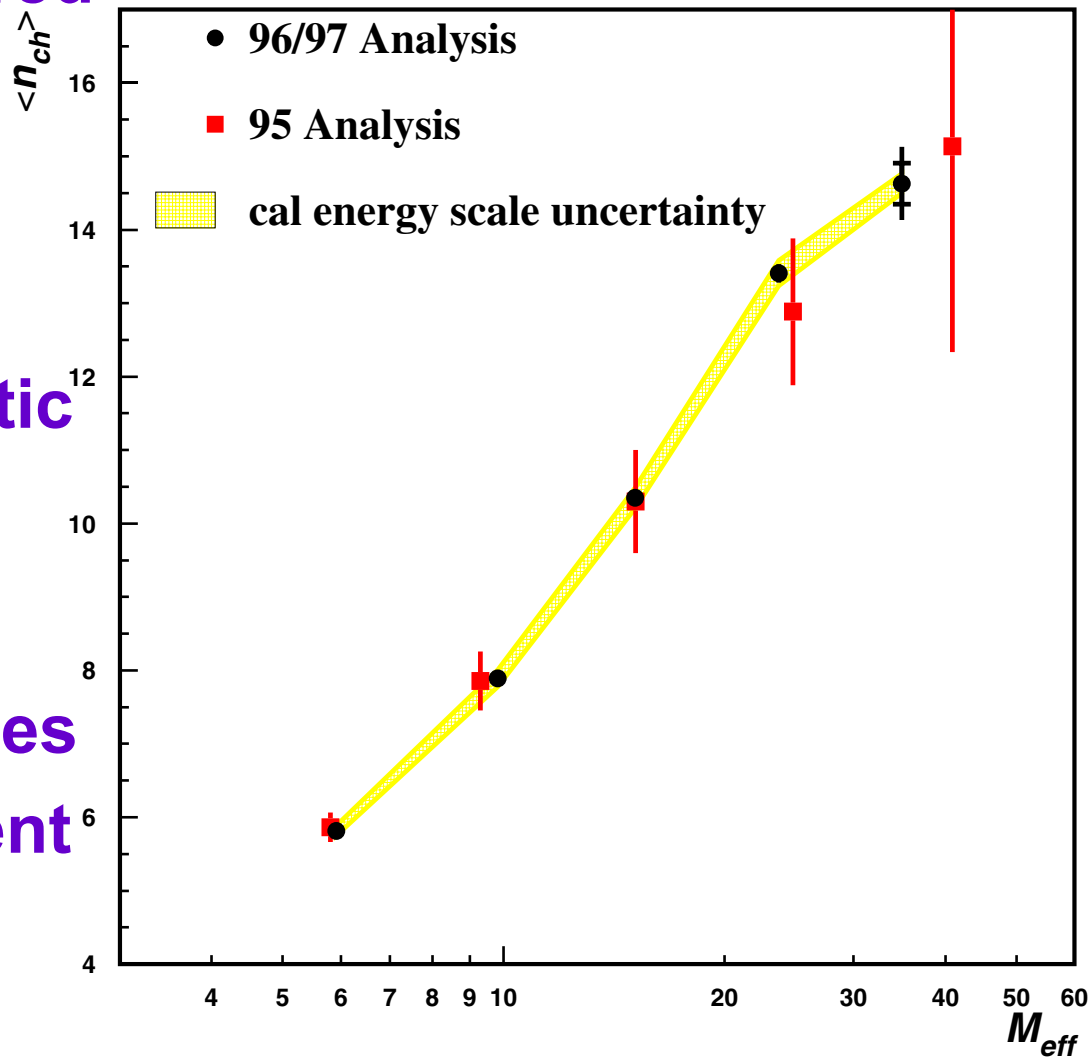
1995 ZEUS measurement in lab frame

- Compare $\langle n_{ch} \rangle$ vs. M_{eff} dependence in e^+e^-, pp, and ep (ZEUS).
- $\langle n_{ch} \rangle$ proportional to log M_{eff}
- $\langle n_{ch} \rangle$ 15% above corresponding e^+e^-
- Suggestion: difference due to ep color dynamics at the pre-hadronization stage.

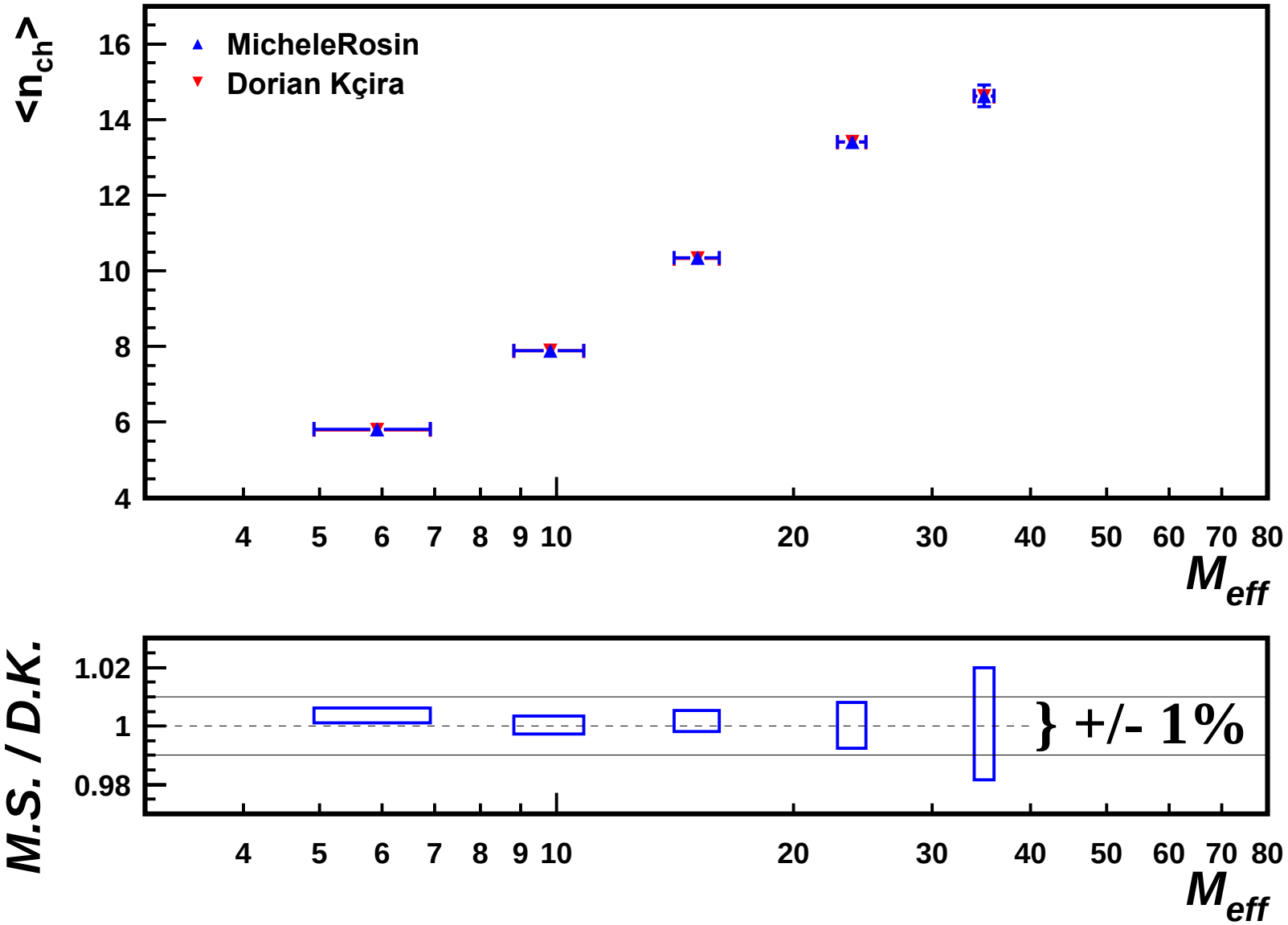


$\langle n_{ch} \rangle$ vs. M_{eff} : '96-'97 vs. '95

- This analysis compared to 1995 study
- Data corrected to hadron level
- Full error bars: statistical & systematic uncertainties aded in quadrature
- Inner error bars: statistical uncertainties
- Reasonable agreement with 1995 ZEUS preliminary result



Comparison to 2nd analysis



Trigger studies by L. Shcheglova

Group	Run Range	#Runs	Non-prescaled DIS01	DIS03
1	21186-21631	445	Yes, 12x6	14x14
2	21634-22447	795	-	14x14
3	22451-22462	11	Yes, 12x6	r >25
3	22673-25336	427	Yes, 12x6	r >25
4	22466-22662	196	-	r >25
4	25344-27899	2500	-	r >25

Lydia has investigated the possibility to go to lower Q^2.

Because of changing prescales for DIS01 and changing radius for DIS03, must use a weighting scheme

Created a mixed sample of DIS01 & DIS03 to get agreement with MC

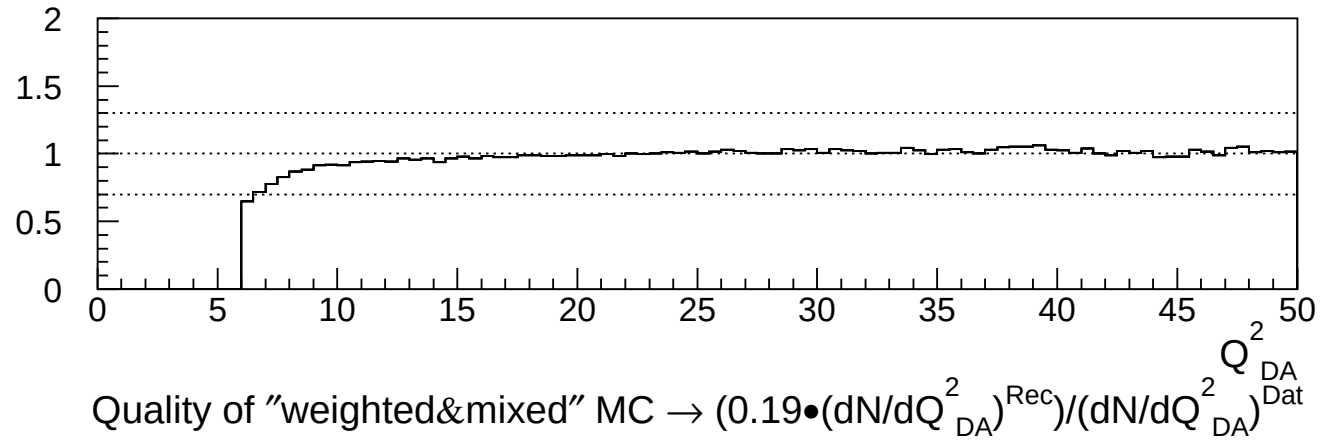
The weighting scheme is described in detail here:

http://amzeus.desy.de/~sumstine/trigger_study/weighting_foils.ps

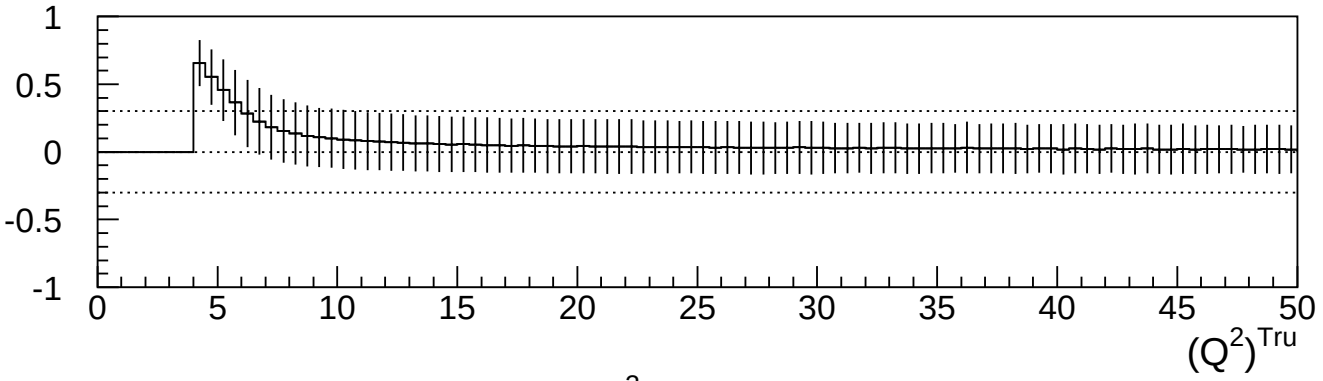
Results of reweighting

Good agreement between data and MC down to Q^2 = 15 or 10 GeV^2

Currently Q^2 > 25, but lowering Q^2 cut can increase the kinematic lever arm



Quality of ″weighted&mixed″ MC → $(0.19 \bullet (dN/dQ^2_{DA})^{Rec})/(dN/dQ^2_{DA})^{Dat}$



Relative resolution → $\langle((Q^2_{DA})^{Rec} - (Q^2)^{Tru})/(Q^2)^{Tru}\rangle$ vs. $(Q^2)^{Tru}$

Summary

- The dependence of $\langle n_{ch} \rangle$ on the M_{eff} of the produced system for ep generated events is the same for restricted eta regions
- Systematic errors are small, dominated by CAL energy scale
- Trigger study shows possibility of going to lower Q^2
- Agreement between 1st and 2nd analyses less than 1%
- $\langle n_{ch} \rangle$ vs. M_{eff} agrees with 1995 ZEUS preliminary results

Plan

- Increase statistics of ARIADNE MC.
- Study systematic effect of using different MC (LEPTO)
- Look at Breit frame for consistency check
- Study diffractive events; combine ARIADNE & RAPGAP