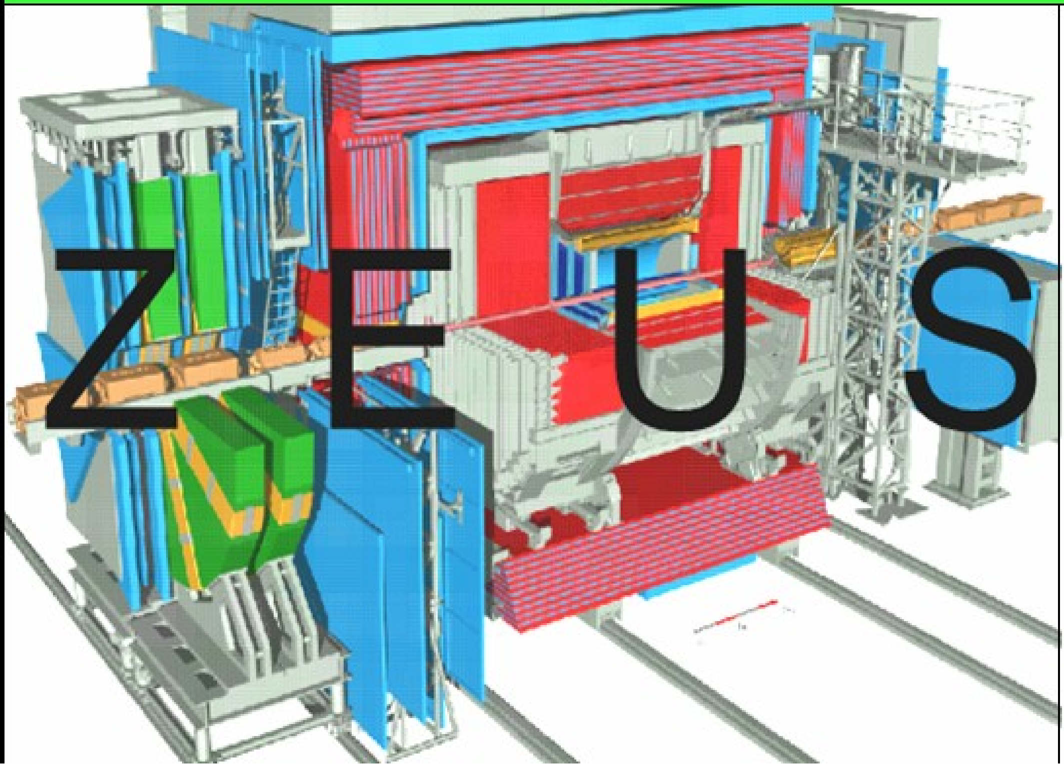
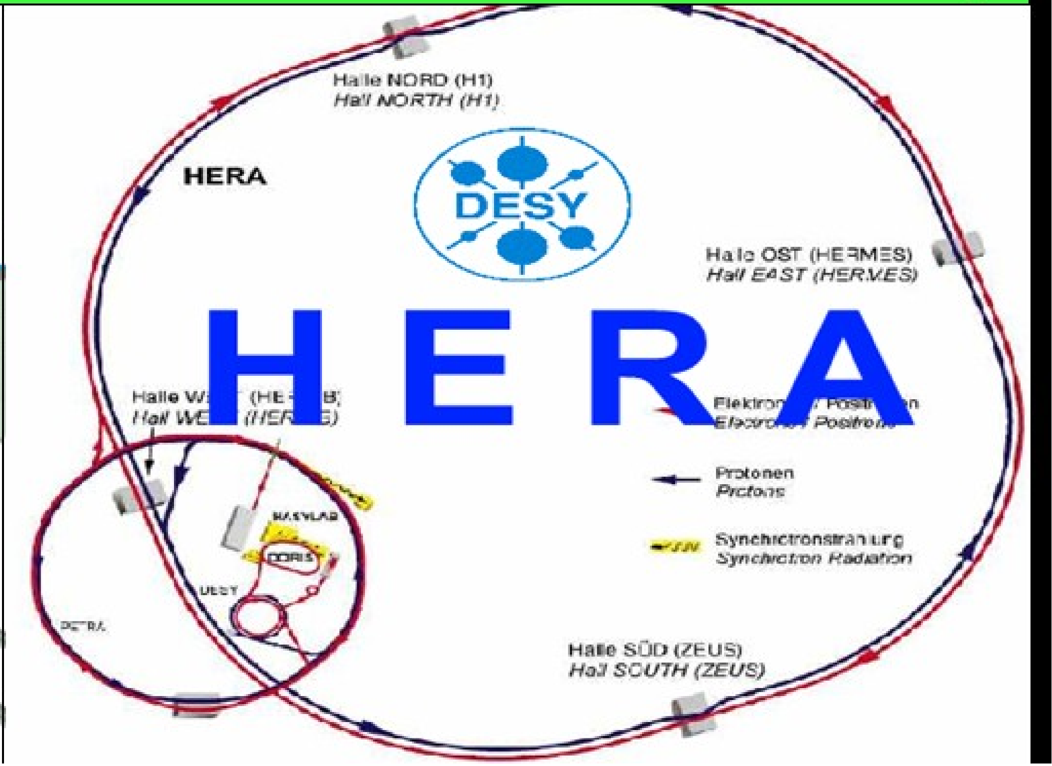
Subjet distributions

Angular correlations in three-jet events

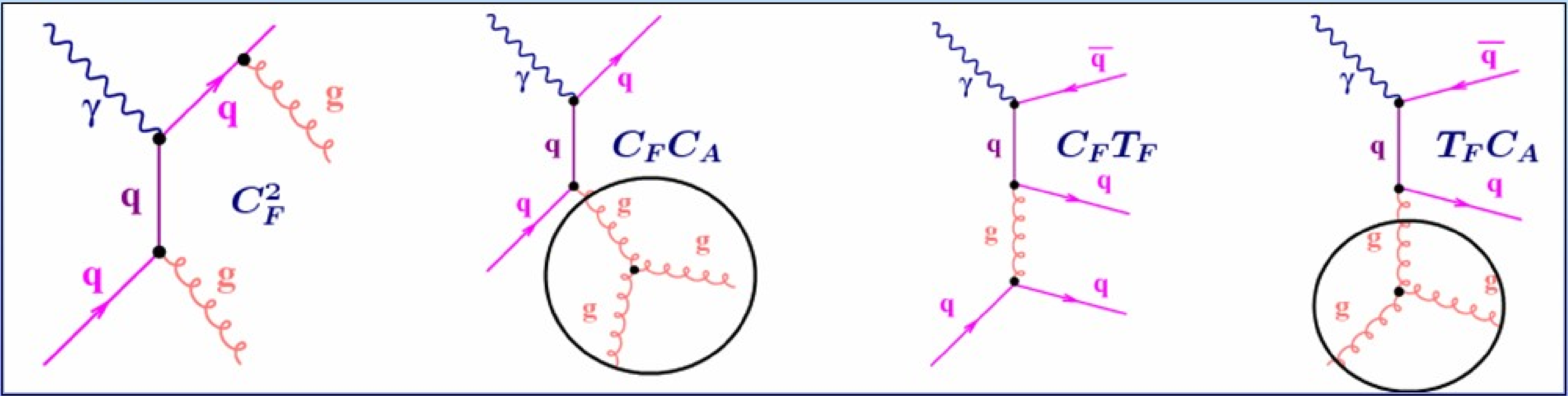
Elías Ron (Universidad autónoma de Madrid)





Introduction

- Three jet events arising from hard interactions at HERA allow the study of the **underlying gauge structure of QCD**.
- The dynamics of a gauge theory such as QCD is determined by the colour factors C_F, C_A and T_F.



- At leading order in α_s, the **3-jet cross section** in NC DIS can be expressed as:

$$\sigma_{ep\rightarrow 3\text{jets}} = C_F^2 \cdot \sigma_A + C_F C_A \cdot \sigma_B + C_F T_F \cdot \sigma_C + T_F C_A \cdot \sigma_D$$

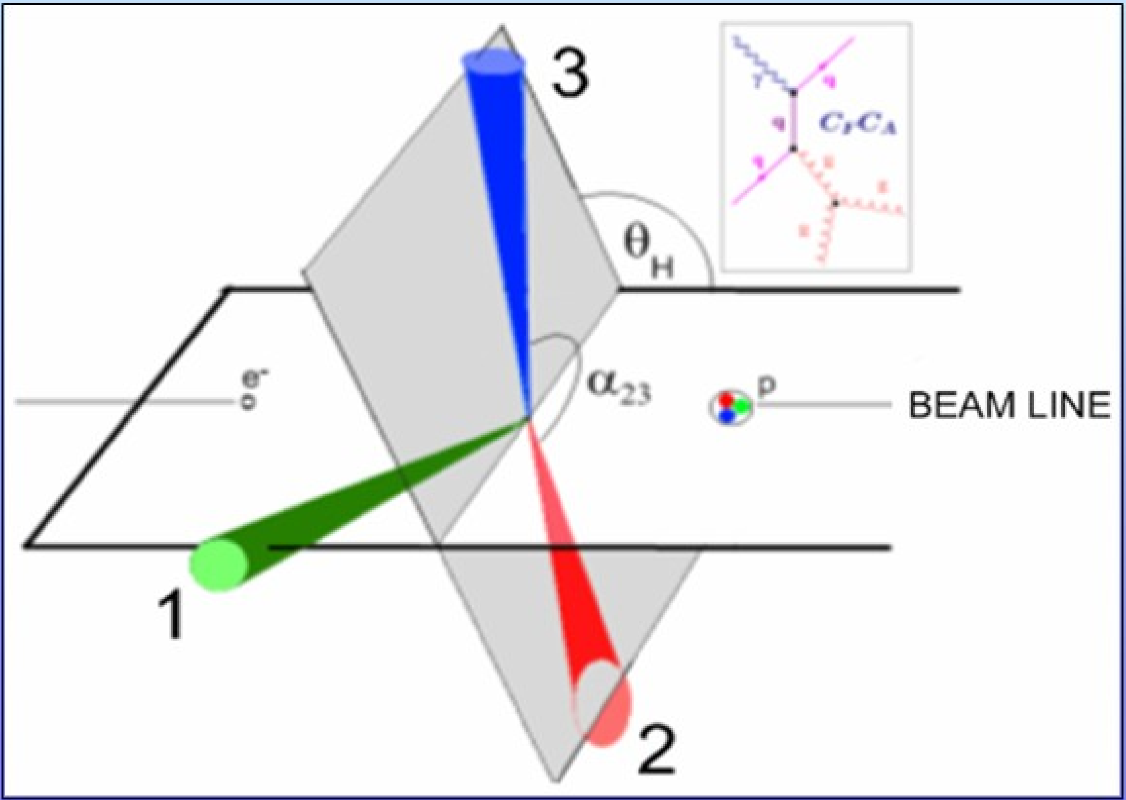
- **Angular correlations between jets can be defined in DIS providing sensitivity to the different colour configurations.**

Introduction

$\underline{\theta_H}$: Angle between the plane determined by the **highest** transverse energy jet (**green**) and the beam line, and the plane determined by the two lowest transverse energy jets (**red** and **blue**)

α_{23}:Angle between the lowest transverse energy jets (**red** and **blue**).

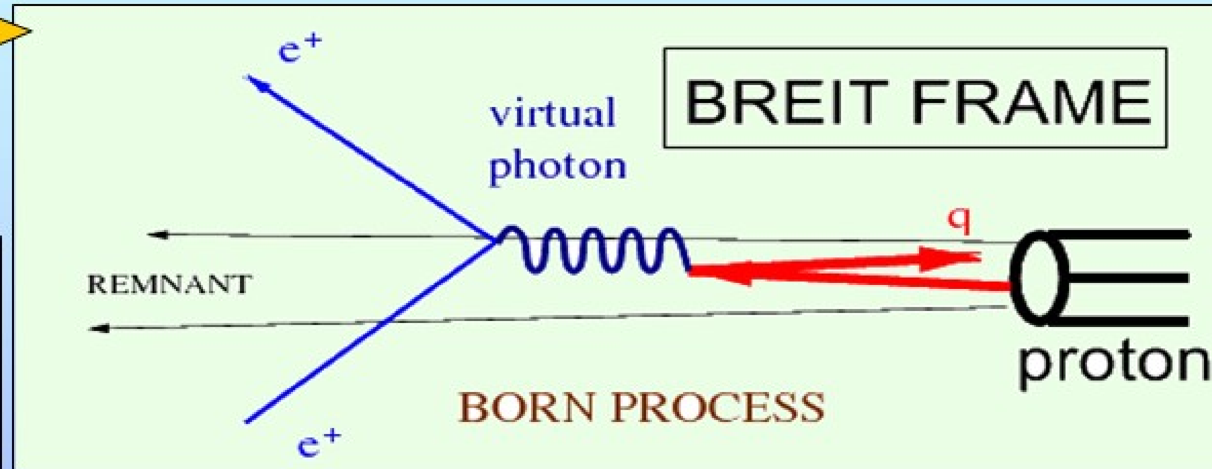
$\eta_{\max}^{jet}$: pseudorapidity of the **most forward jet**.



$$\cos(\beta_{KSW}) : \cos\left[\frac{1}{2}\left(\angle[(\vec{p}_1 \times \vec{p}_3),(\vec{p}_2 \times \vec{p}_B)] + \angle[(\vec{p}_1 \times \vec{p}_B),(\vec{p}_2 \times \vec{p}_3)]\right)\right]$$

Jet Events

- **JETS were searched using the k_T cluster algorithm in the inclusive mode in the Breit frame.**



- The kinematic region is:

$\rightarrow Q^2 > 125$ GeV^2,

$|cos\gamma_h| < 0.65$

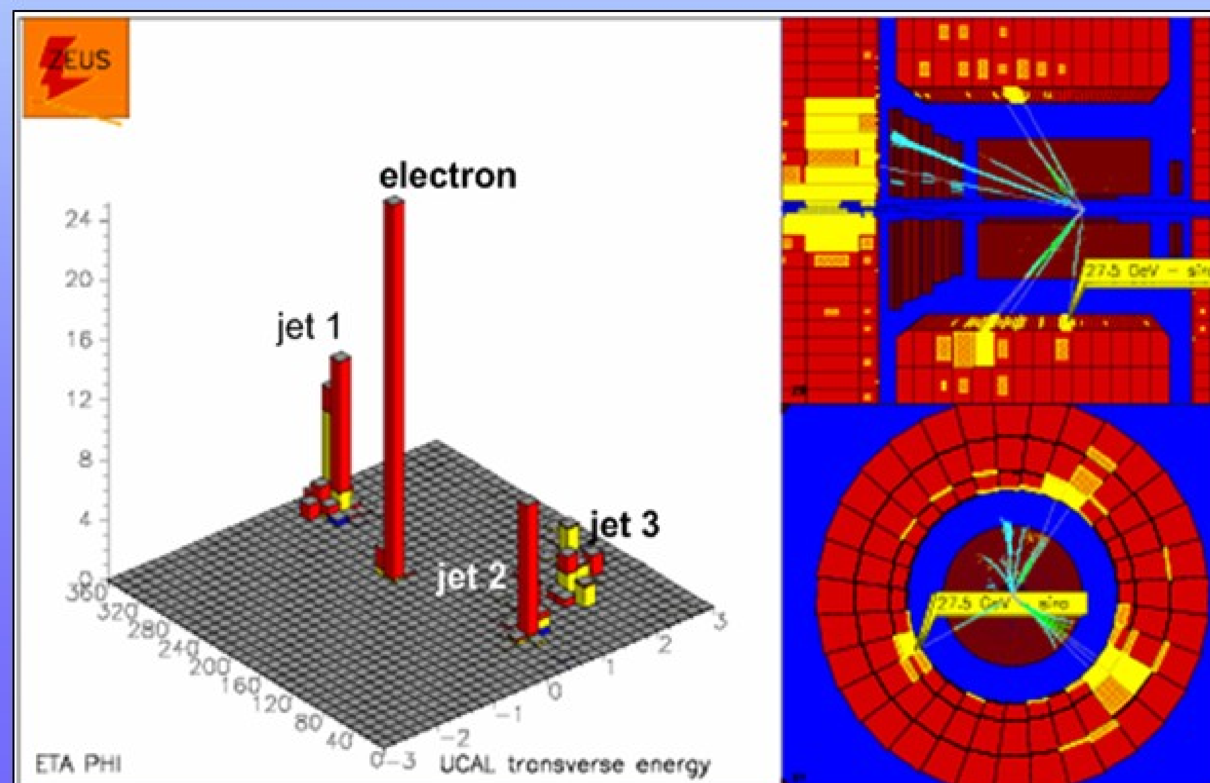
$-2 < \eta_B^{jet} < 1.5$

$\rightarrow$ at least 3 jets of $E_{T,B}^{jet1} > 8$ GeV,

$E_{T,B}^{jet2,3} > 5$ GeV

The event sample consists of **1015 jet events** in the range:

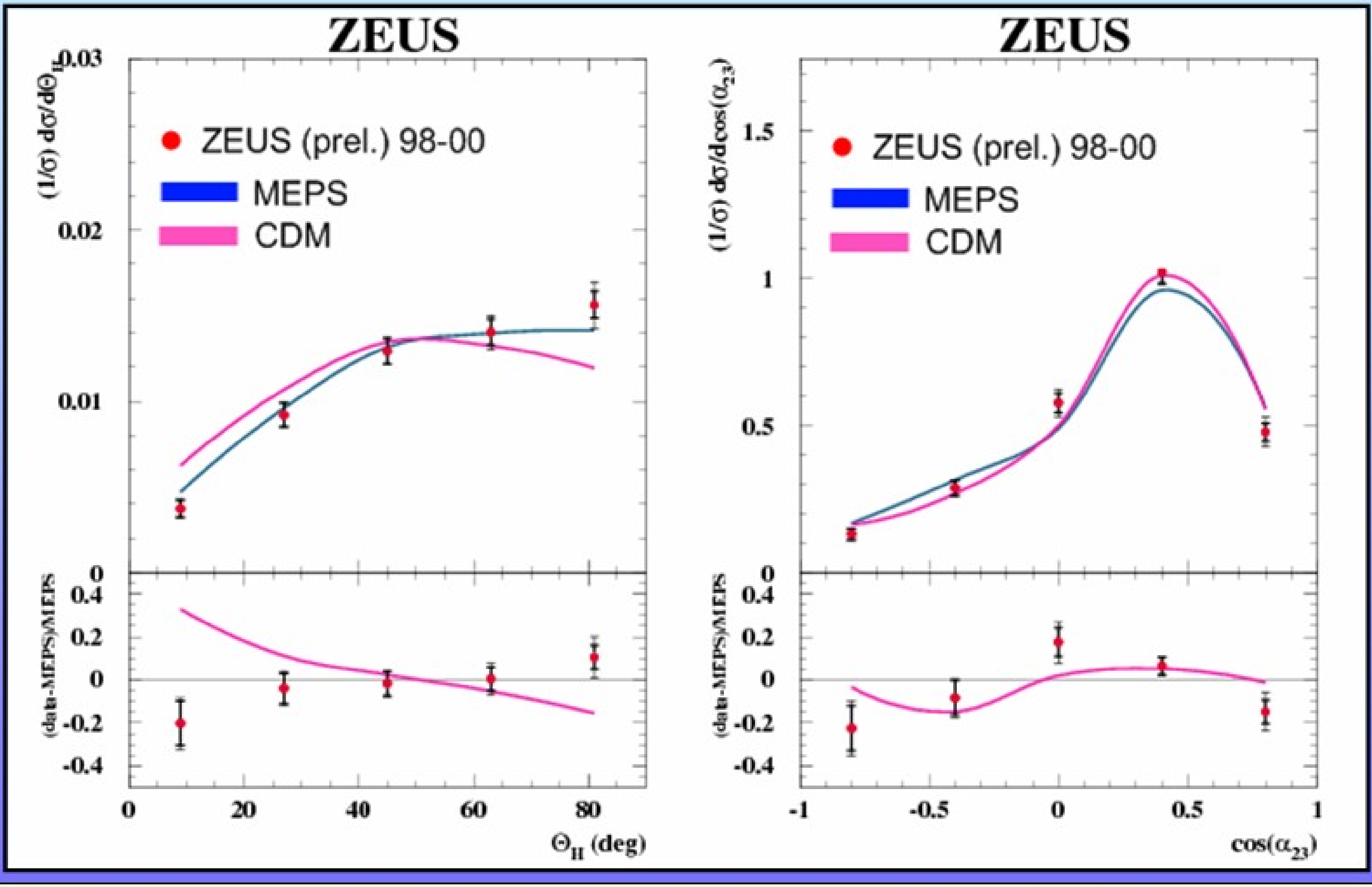
$$0.004 < x < 0.2$$



Angular Correlations in three-jet events at HERA

Data vs. Monte Carlo

θ_H, α_{23}, β_{KSW} and η_{max}^{jet} normalised cross sections vs. **Color Dipole Model** (CDM) and **Matrix-element + Parton-shower** (MEPS) of LEPTO



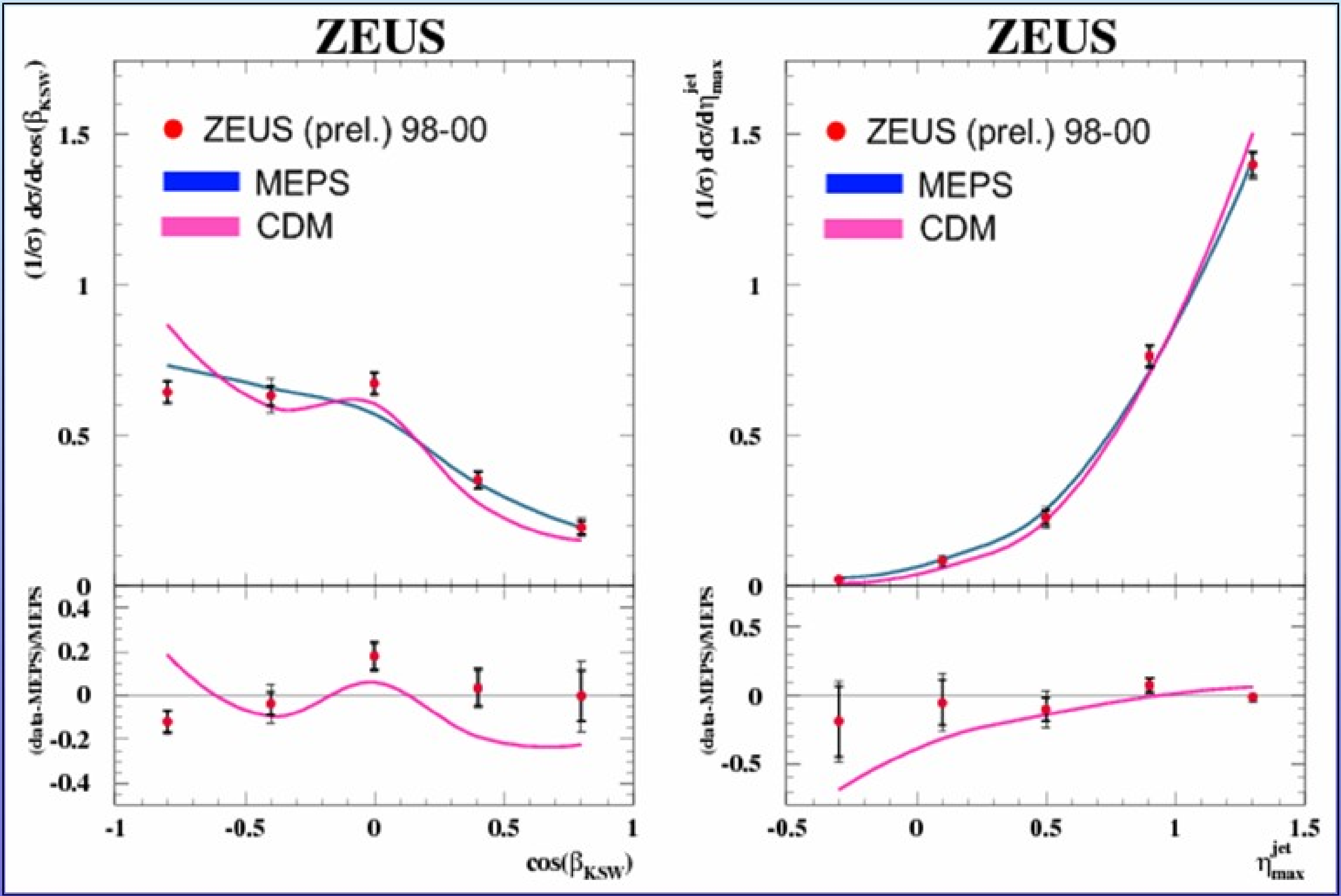
Cross sections for θ_H and $\cos(\alpha_{23})$

Good agreement with both Monte Carlo models, MEPS does a better description

Angular Correlations in three-jet events at HERA

Data vs. Monte Carlo

θ_H, α_{23}, β_{KSW} and normalised cross sections vs. **Color Dipole Model** (CDM) and **Matrix-element + Parton-shower** (MEPS) of LEPTO



Cross sections for $\cos(\beta_{KSW})$ and $\eta^{jet}_{\max}$

Good agreement with both Monte Carlo models, MEPS does a better description

Angular Correlations in three-jet events at HERA

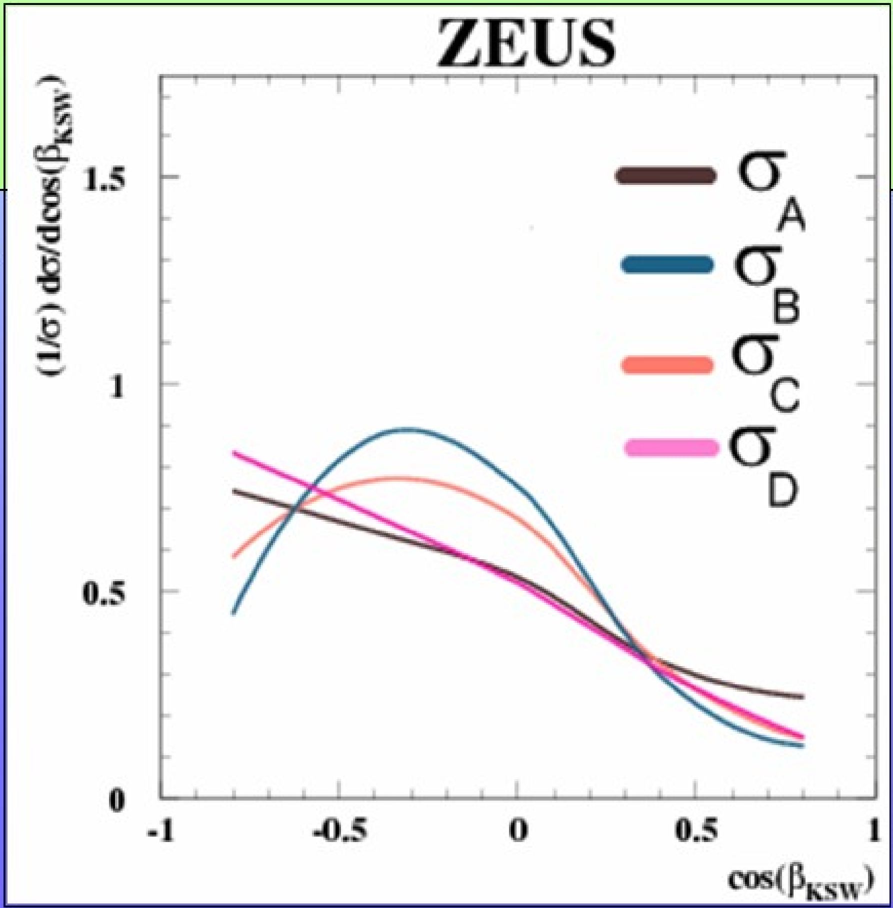
Data vs. Monte Carlo

Predictions for the colour components at $O(\alpha_s^2)$ have been calculated with the program DISENT with:

- pPDFs: CTEQ6M1 set
- α_S was calculated at two loops with $\alpha_s(M_Z) = 0.118$
- Renormalization scale $\mu_R = Q$
- Factorisation scale $\mu_F = Q$

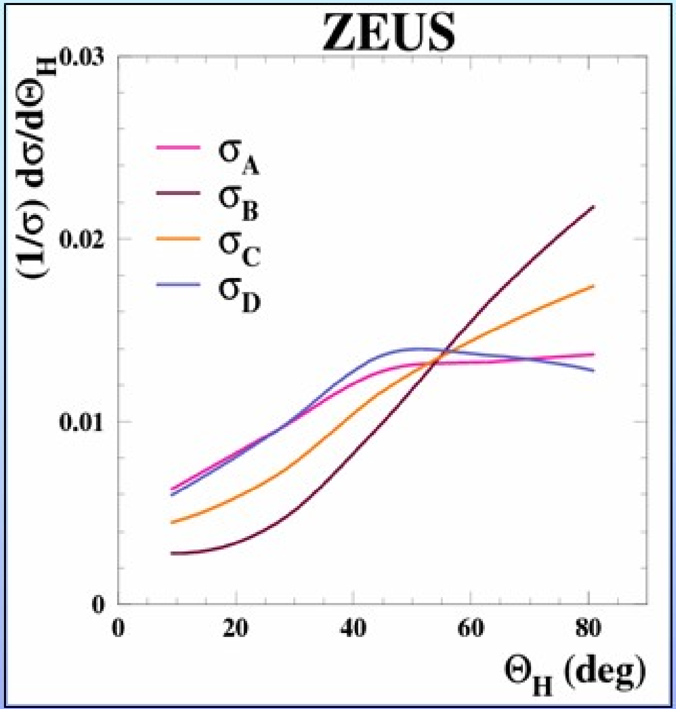
For **SU(3)**, the predicted relative contributions of each colour configuration are:

- σ_A 23% C_F^2
- σ_B 13% $C_F C_A$
- σ_C 39% $C_F T_F$
- σ_D 25% $T_F C_A$

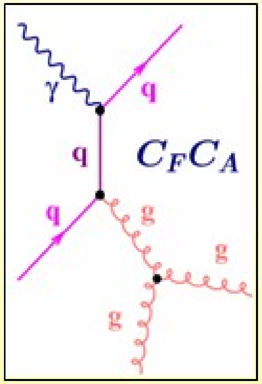


Angular Correlations in three-jet events at HERA

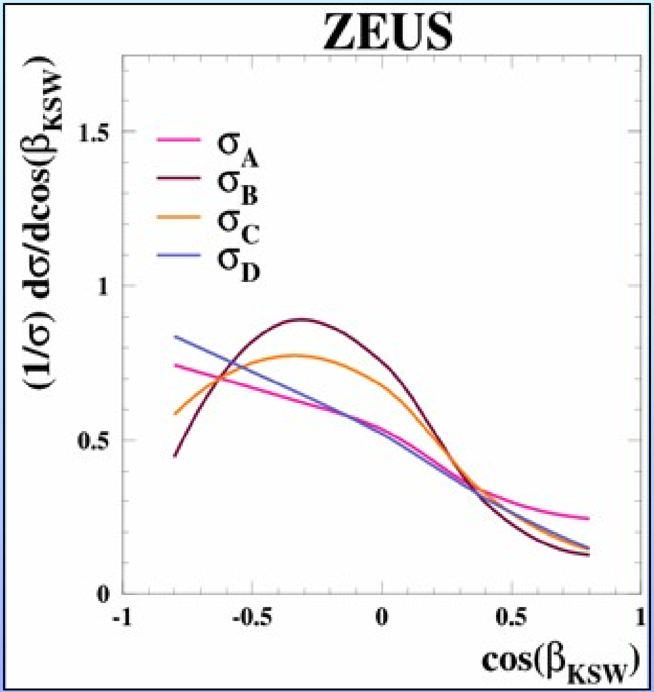
Data vs. Contributions

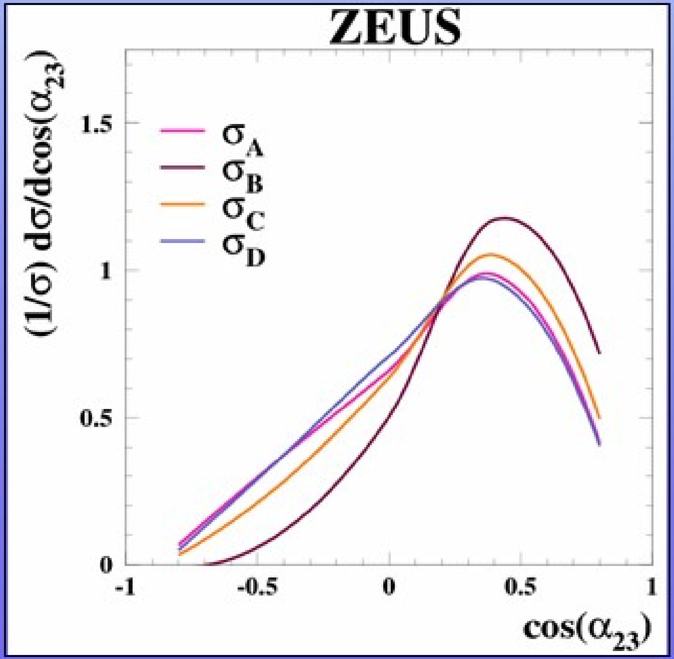


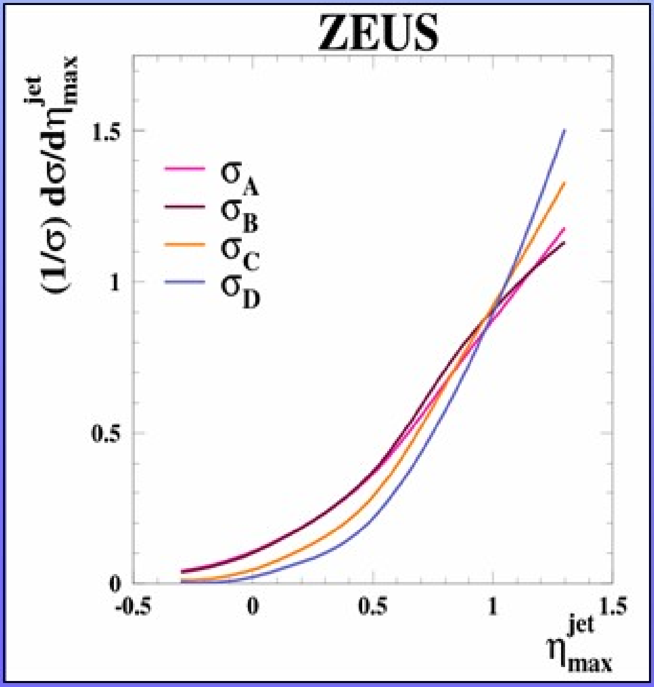
The distributions for σ_B (triple-gluon vertex in quark induced processes) have a very different shape than the others.



The distribution in η^{jet}_{max} for σ_D (triple-gluon vertex in gluon induced processes) has a different shape than the others



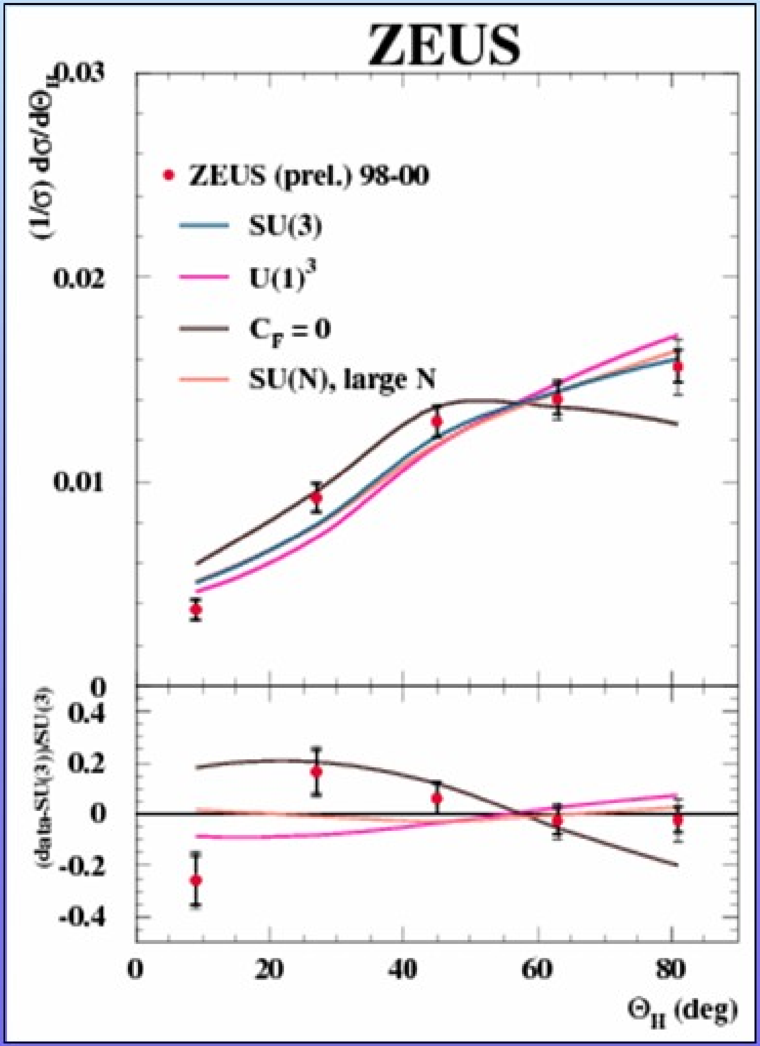


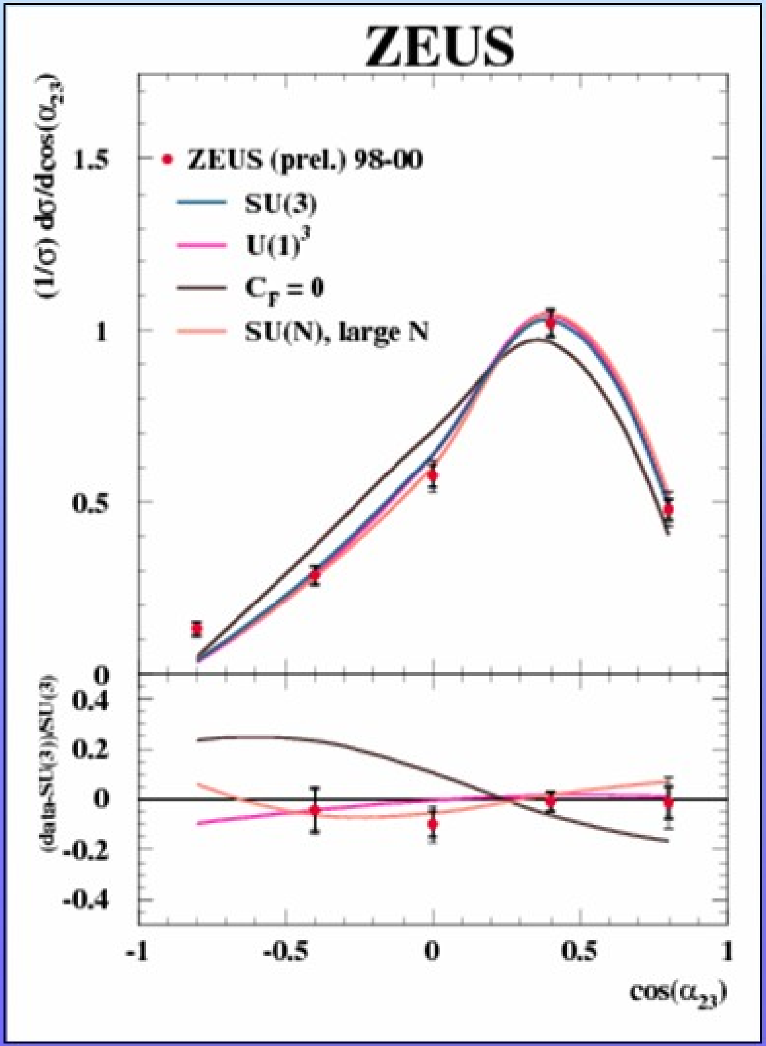


Angular Correlations in three-jet events at HERA

Data vs. Gauge groups.

Measured normalised differential cross sections as functions of Θ_H and $\cos(\alpha_{23})$ are compared with the calculatios of DISENT based on SU(3), $U(1)^3$, SU(N) for large N and $C_F=0$.

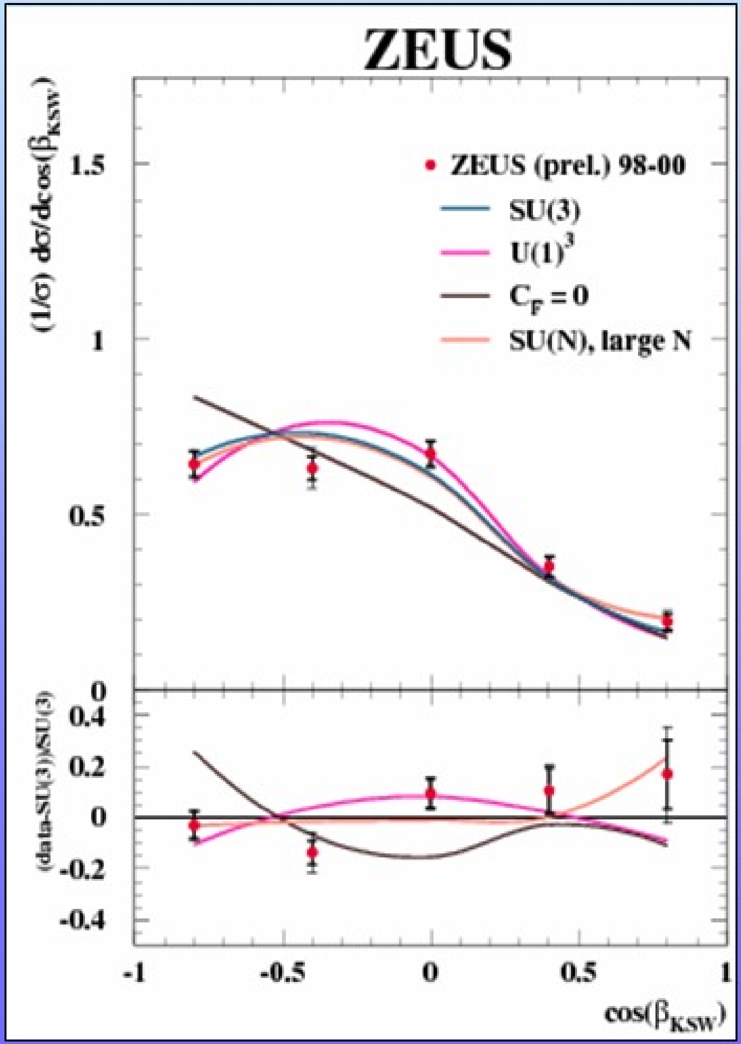


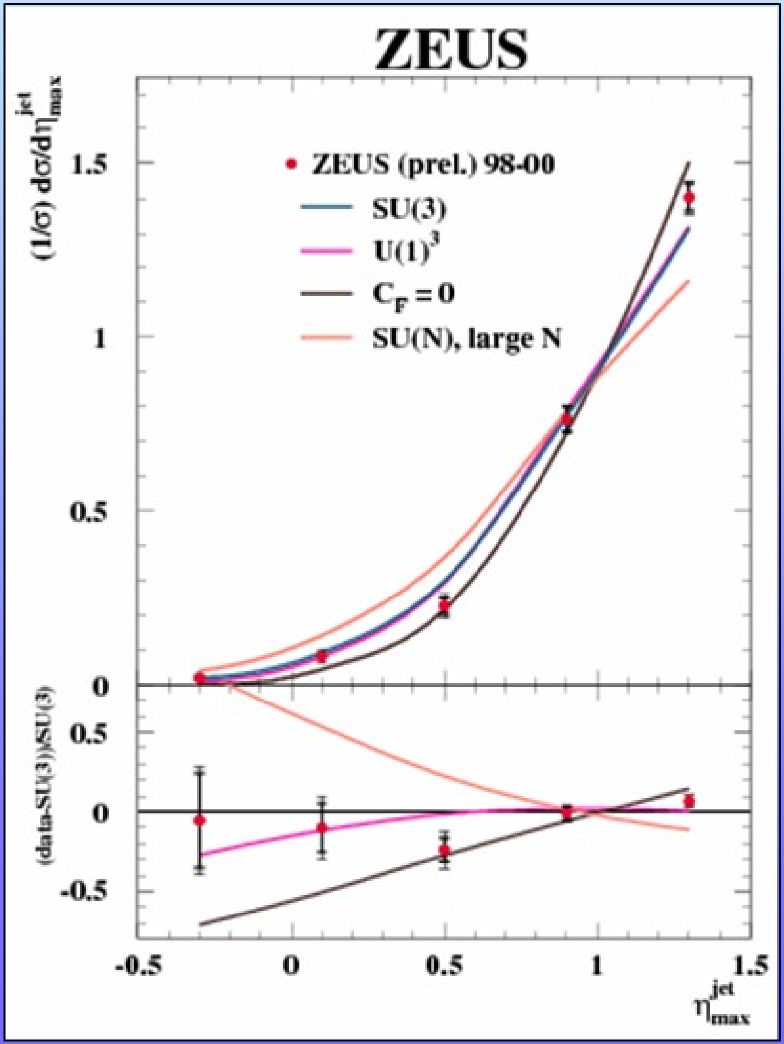


Angular Correlations in three-jet events at HERA

Data vs. Gauge groups.

Measured normalised differential cross sections as functions of $\cos(\beta_{KSW})$ and $\eta_{jet,max}$ compared with the calculations of DISENT based on SU(3), $U(1)^3$, SU(N) for large N and $C_F=0$.





Summary

- Angular correlations (Θ_H, α_{23}, β_{KSW} η^{jet}_{max})in three-jet events in NC DIS have been measured using 82 pb^{-1} in the kinematic region defined by $Q^2 > 125$ GeV^2 and $|\cos\gamma_h| < 0.65$

- Fixed-order calculations separated according to the colour configurations were used to study the sensitivity of the angular distributions to the **underlying gauge structure**:
    - Θ_H, α_{23}, β_{KSW} distinguish well the contribution from the **triple-gluon vertex in quark-induced processes**
    - η^{jet}_{max} distinguishes the contribution coming from the **triple-gluon vertex in gluon induced processes**.

- The measurements are consistent with the admixture of color configurations as predicted by **SU(3).**

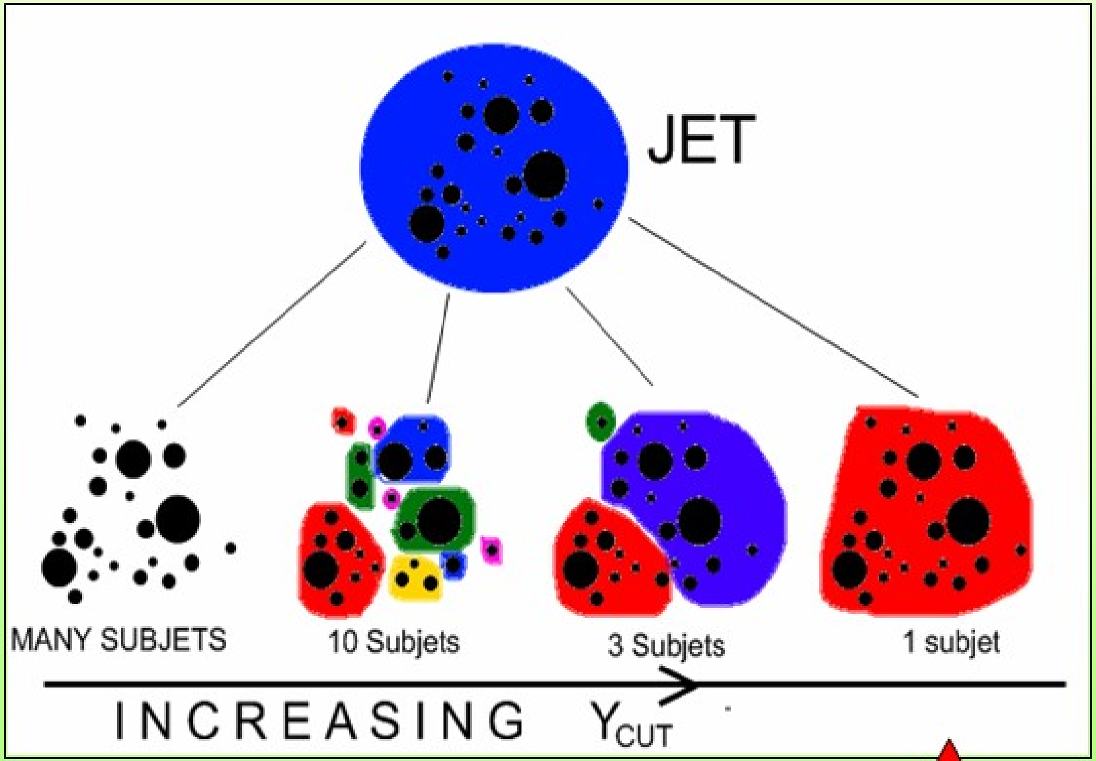
- The data disfavour SU(N) in the limit of large N and $C_F = 0$.

Subjet Distributions

At high transverse energy the fragmentation effects **become negligible** and the main contribution to the jet substructure comes **from parton radiation**.

Subjets are resolved within a jet by reapplying the **k_T cluster algorithm** on all the particles belonging to a jet. Subjets are all the particles within a jet which are at a distance bigger than d_{cut} from each other, where d_{cut} is:

$$d_{\mathrm{cut}} = y_{\mathrm{cut}} \cdot (E_T^{\mathrm{jet}})^2$$

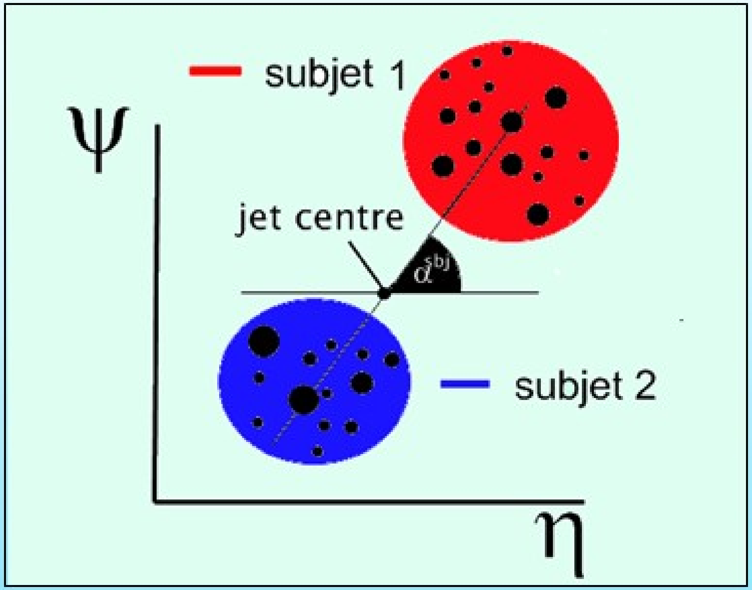


The subjet multiplicity depends on the value chosen for the parameter y_{cut}

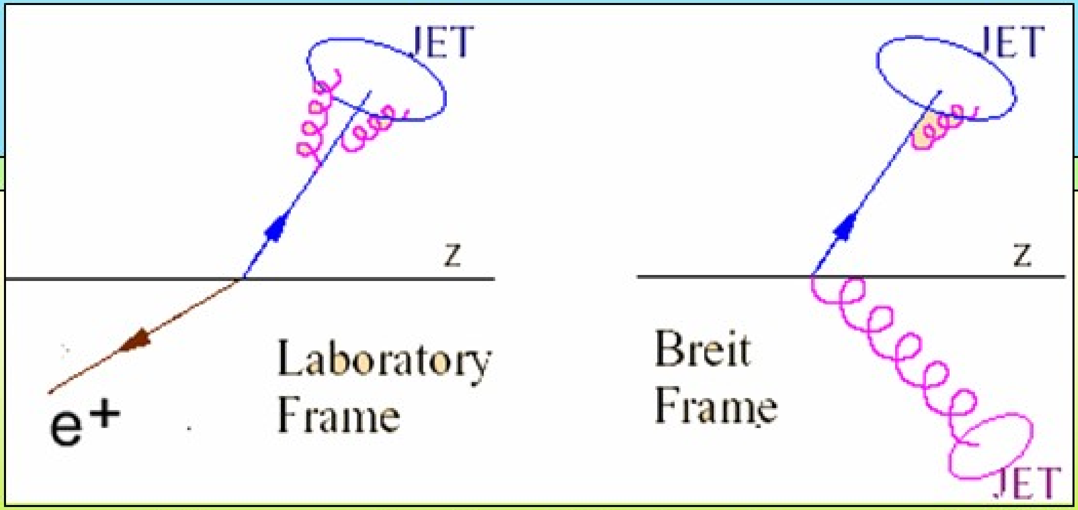
Subjet Distributions

Variables and selection.

The pattern of QCD radiation has been studied by means of differential cross sections with respect to the variables:



- α^{sbj}, the angle between the highest E_T subjet and the beam line, as seen from the jet axis.
- E_T^{sbj} / E_T^{jet}
- $\eta_{sbj} - \eta_{jet}$
- $\left|\phi_{sbj} - \phi_{jet}\right|$



The kinematic range is:

$Q^2 > 125\ GeV^2$

$E_T^{jet} > 14\ GeV \quad -1 < \eta^{jet} < 2.5$

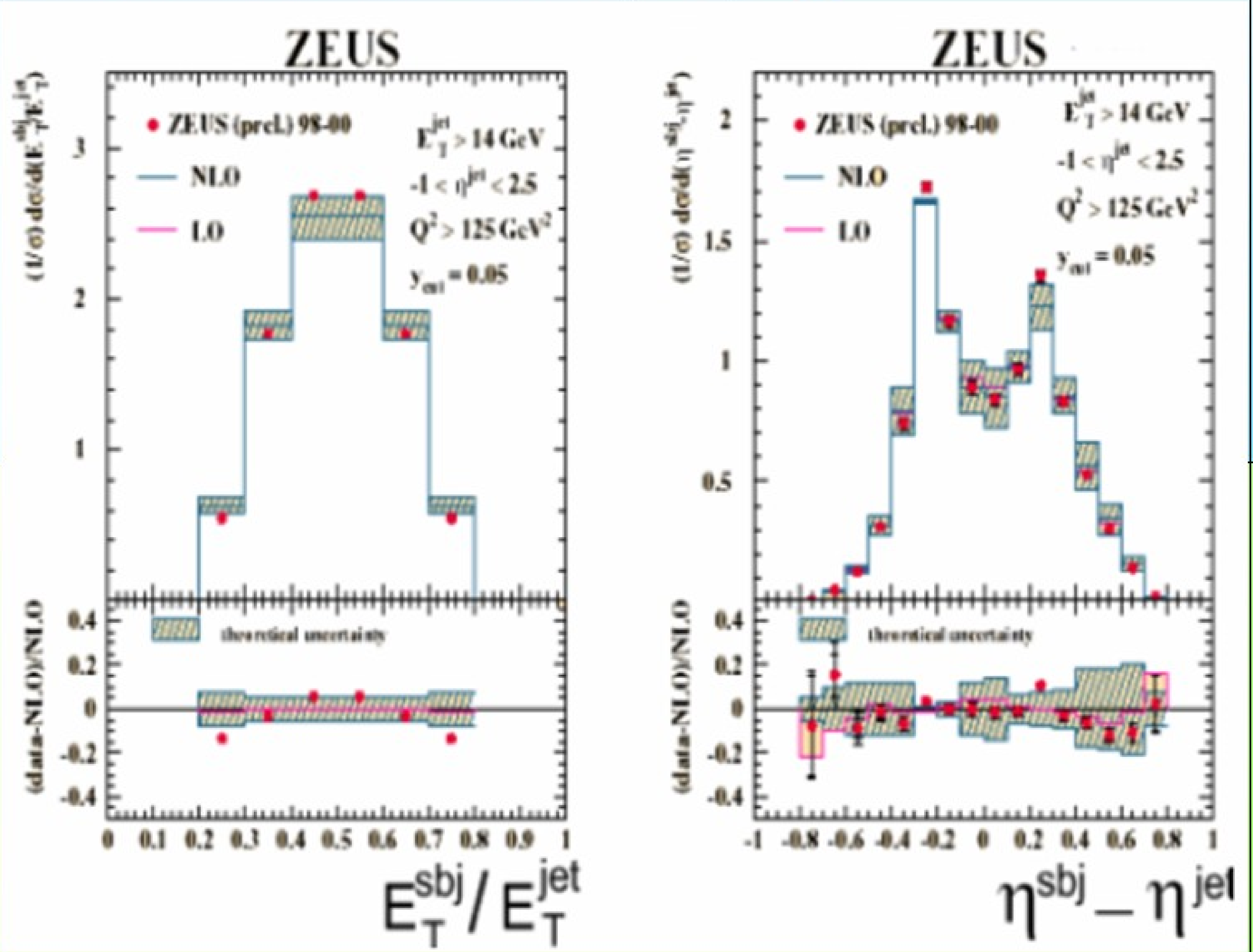
Final Sample: Jets in the lab frame with exactly 2 subjets at $y_{cut} = 0.05$

Subjet Distributions

QCD predictions vs Data

Fixed-order QCD predictions were calculated at LO and NLO using DISENT with:

- α_s was calculated at two loops with $\alpha_s(M_Z) = 0.1175$
- Renormalisation and factorisation scales were: $\mu_R = \mu_F = Q$
- pPDFs: MRST99 sets
- Calculations were corrected to hadron level to compare with the data

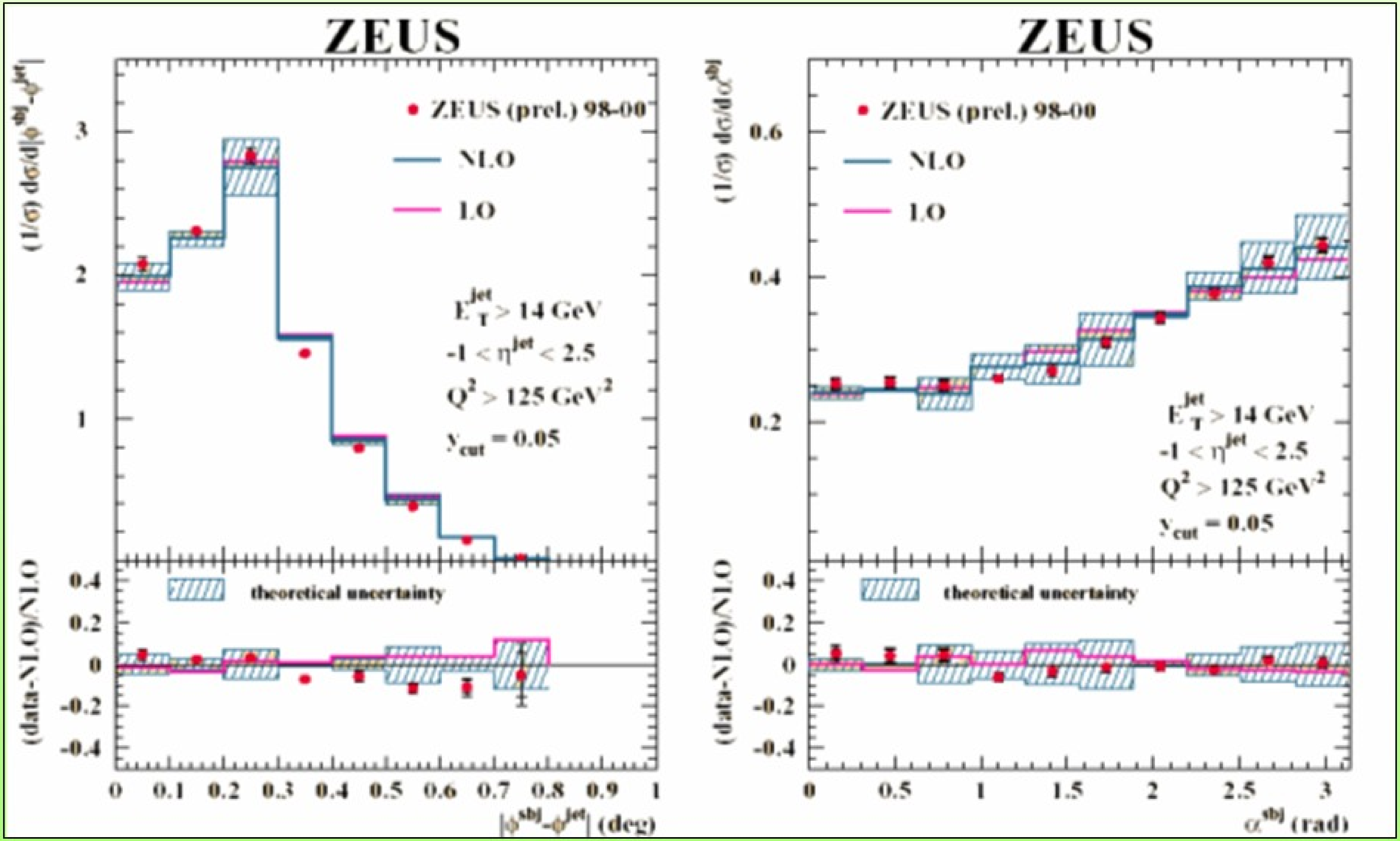


NLO predictions describe the data within ±10%

Subjet Distributions

QCD predictions vs Data

Normalised differential cross sections for α^{sbj} and $|\phi_{sbj} - \phi_{jet}|$

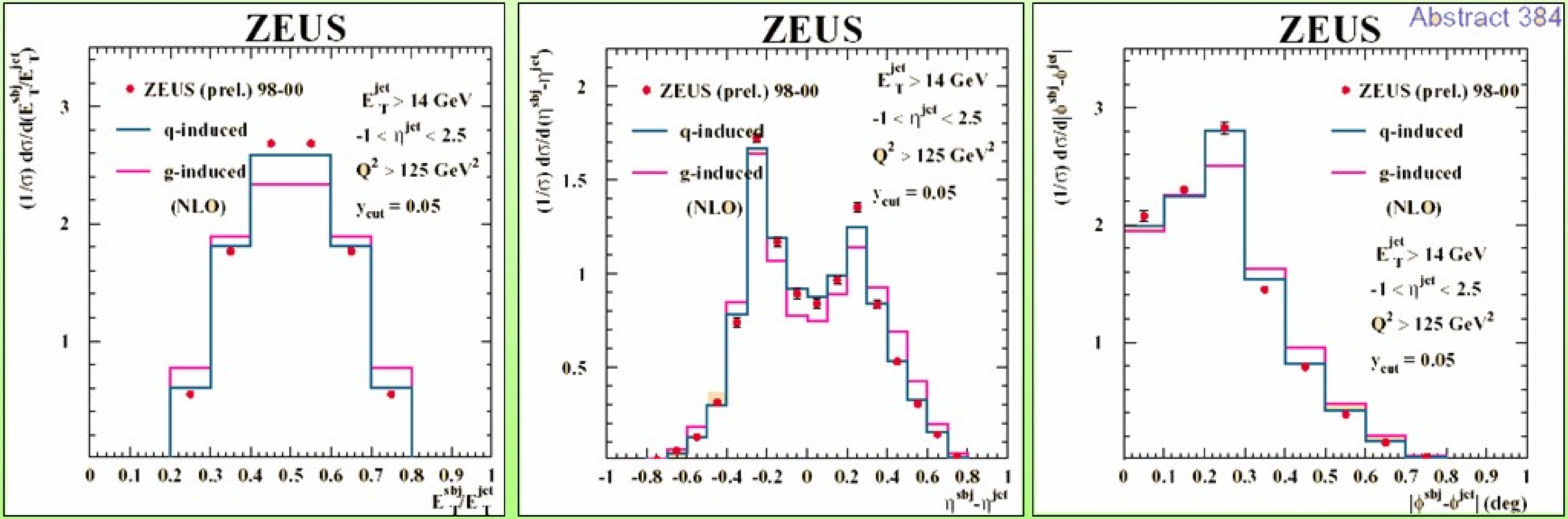


NLO predictions describe the data within ±10%

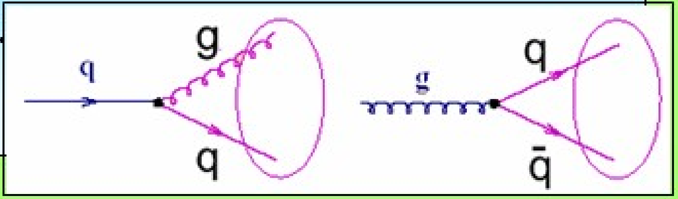
Subjet Distributions

Data vs. qq and qg

Normalised differential cross sections for $|\phi_{sbj} - \phi_{jet}|$, $\eta_{sbj}-\eta_{jet}$ and E_T^{sbj}/E_T^{jet} are compared with calculations for **quark-** and **gluon**-induced processes separately. The prediction of **QCD** is **82%** of quark-induced processes and **18%** of gluon induced.



Comparison shows that the data are better described by the calculations for jets arising from a qg pair than those coming from a $q\overline{q}$ pair.



Summary

- Normalised differential subjet cross sections for jets with **exactly** two subjets for $y_{cut}=0.05$ in inclusive-jet NC **DIS** have been measured using **82 pb^{-1}** in the kinematic region defined by **$Q^2 >$ 125 GeV^2**.

- The data show that the two subjets:
  - **tend to have similar transverse energies,**
  - **tend to be close to each other**
  - the highest E_T subjet **tends to be in the rear part** with respect to jet axis.

- Reasonable description of data by fixed-order **QCD** calculations:
  - ➢ The pattern of parton radiation as predicted by **QCD** **explains the subjet topology in the data.**
  - ➢ The data are consistent with the **dominance of quark-induced** processes.