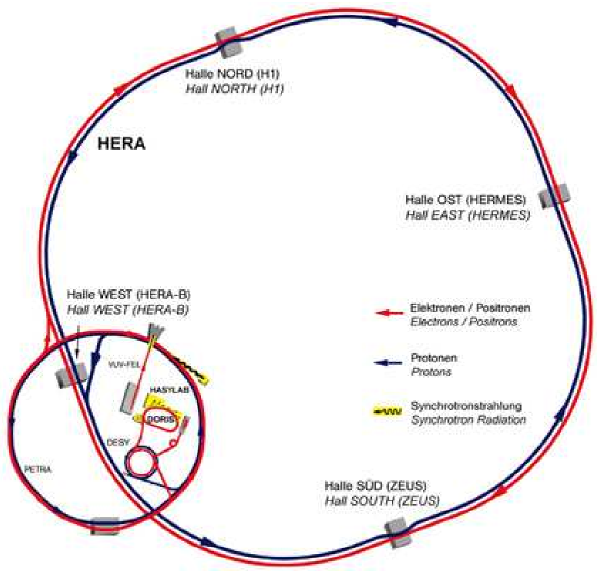
EPS 2005

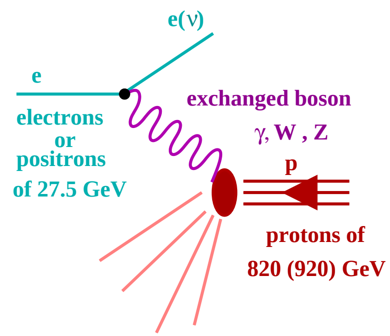
Jet Correlations at HERA

Marcos Jiménez

Universidad Autónoma de Madrid

On behalf of the ZEUS collaboration





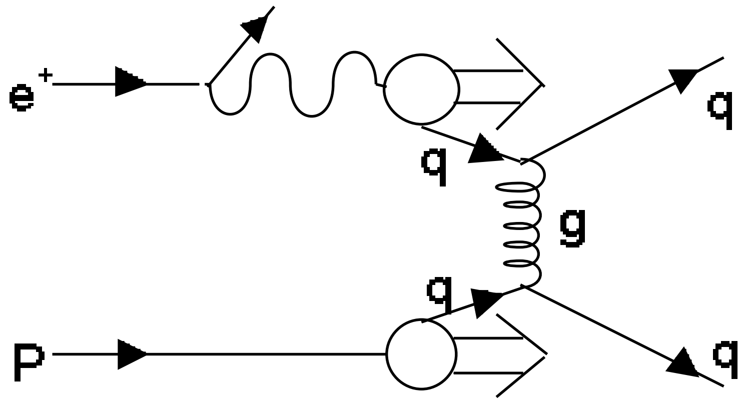
→ **Interjet energy flow in photoproduction**

→ **Study of colour dynamics in photoproduction**

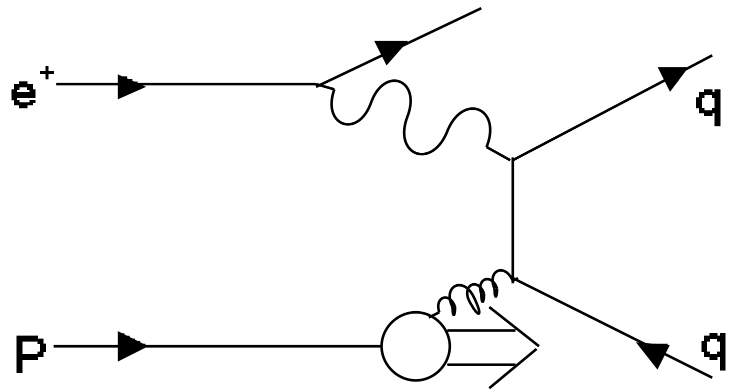
→ **Angular correlations in three-jet production in NC DIS**

- Jet production in ep collisions at HERA provides a testing ground for QCD
- The biggest contribution to the production of jets comes from photoproduction($Q^2 \sim 0$)
- At leading order, two processes contribute to the dijet photoproduction cross section:

RESOLVED



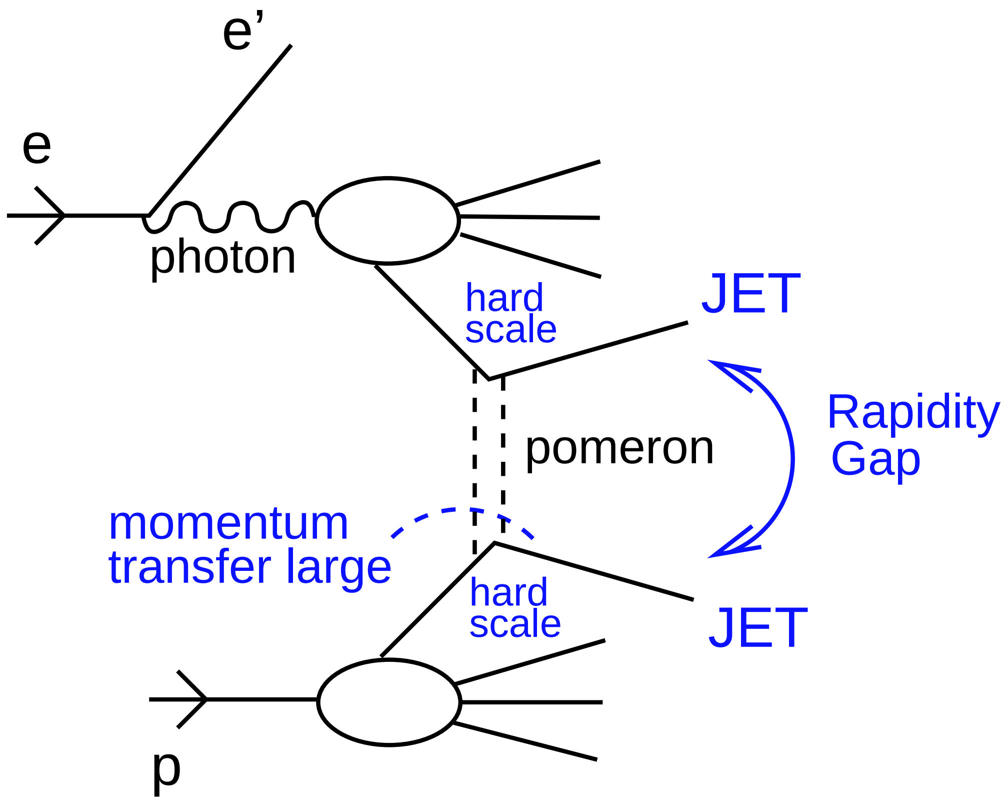
DIRECT

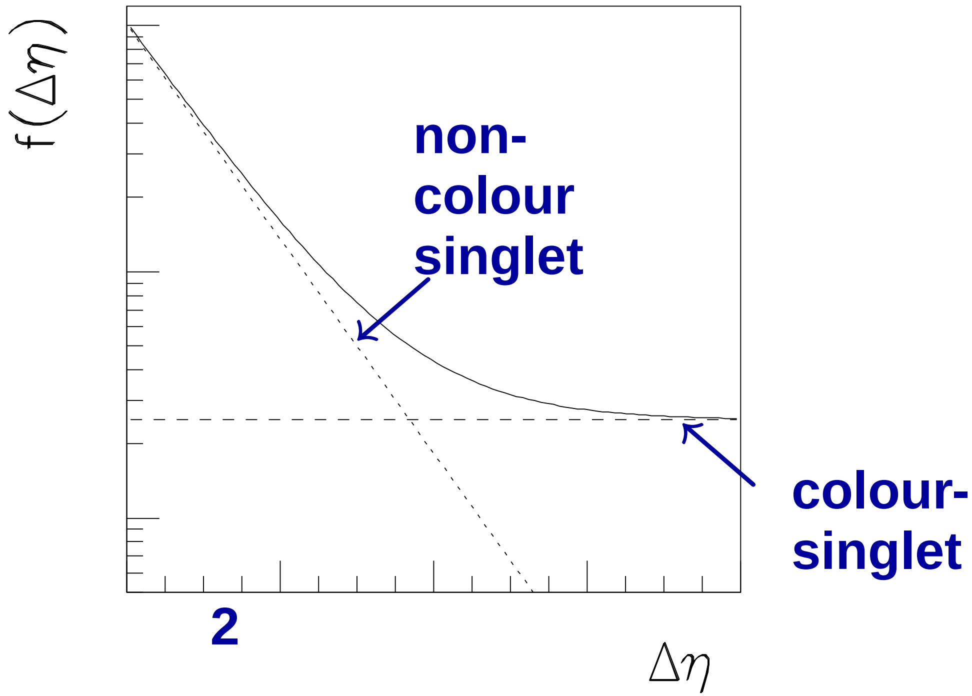


$$\sigma_{jet} \propto \sum_i \sum_j f_{\gamma/e} \otimes f_{i/\gamma} \otimes f_{j/p} \hat{\sigma}$$

$$x_\gamma^{OBS} = \frac{E_{T,1} e^{-\eta,1} + E_{T,2} e^{-\eta,2}}{2yE_e}$$

- **Events with two jets of high E_T separated by a large rapidity gap are ideal to study colour-singlet exchange with a large momentum transfer**





$$\textbf{gap-fraction} \equiv f(\Delta\eta) = \frac{d\sigma_{gap}/d\Delta\eta}{d\sigma/d\Delta\eta}$$

- **DATA SELECTION**

  $L = 38.6 \pm 0.6\, pb^{-1}$ **(ZEUS 96-97 running period)**

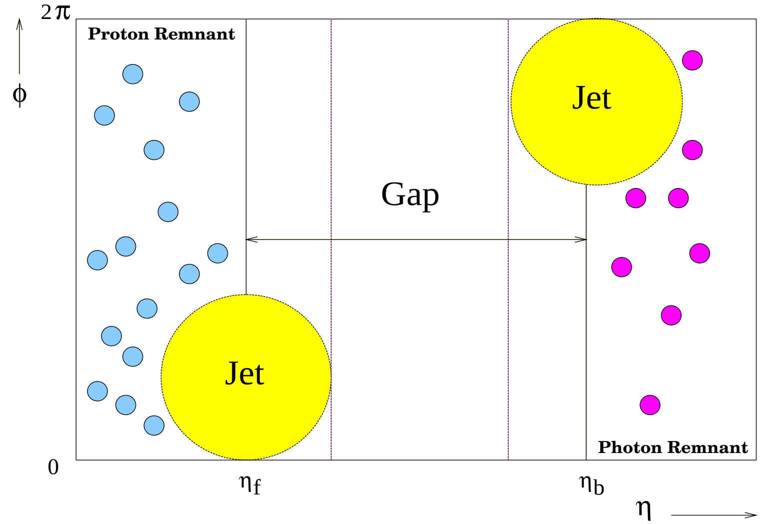
- **Two-jet events are selected in the kinematic region:**

  $E_T^{jet1} \geq 6$ **GeV** $\qquad E_T^{jet2} \geq 5$ **GeV**

  $|\eta^{jet1,2}| < 2.4 \qquad |\frac{1}{2}(\eta^{jet1} + \eta^{jet2})| < .75$

  $2.5 < \Delta\eta < 4$

Example of rap-gap event



- **Energy flow between jets**

$$E_T^{GAP} = \sum_{i>2} E_T^{jeti}$$

$$\eta^{jeti} \epsilon (\eta^{jet}_{forward}, \eta^{jet}_{backward})$$

Monte Carlo Models

Without colour-singlet exchange

PYTHIA 6.1 and HERWIG 6.1

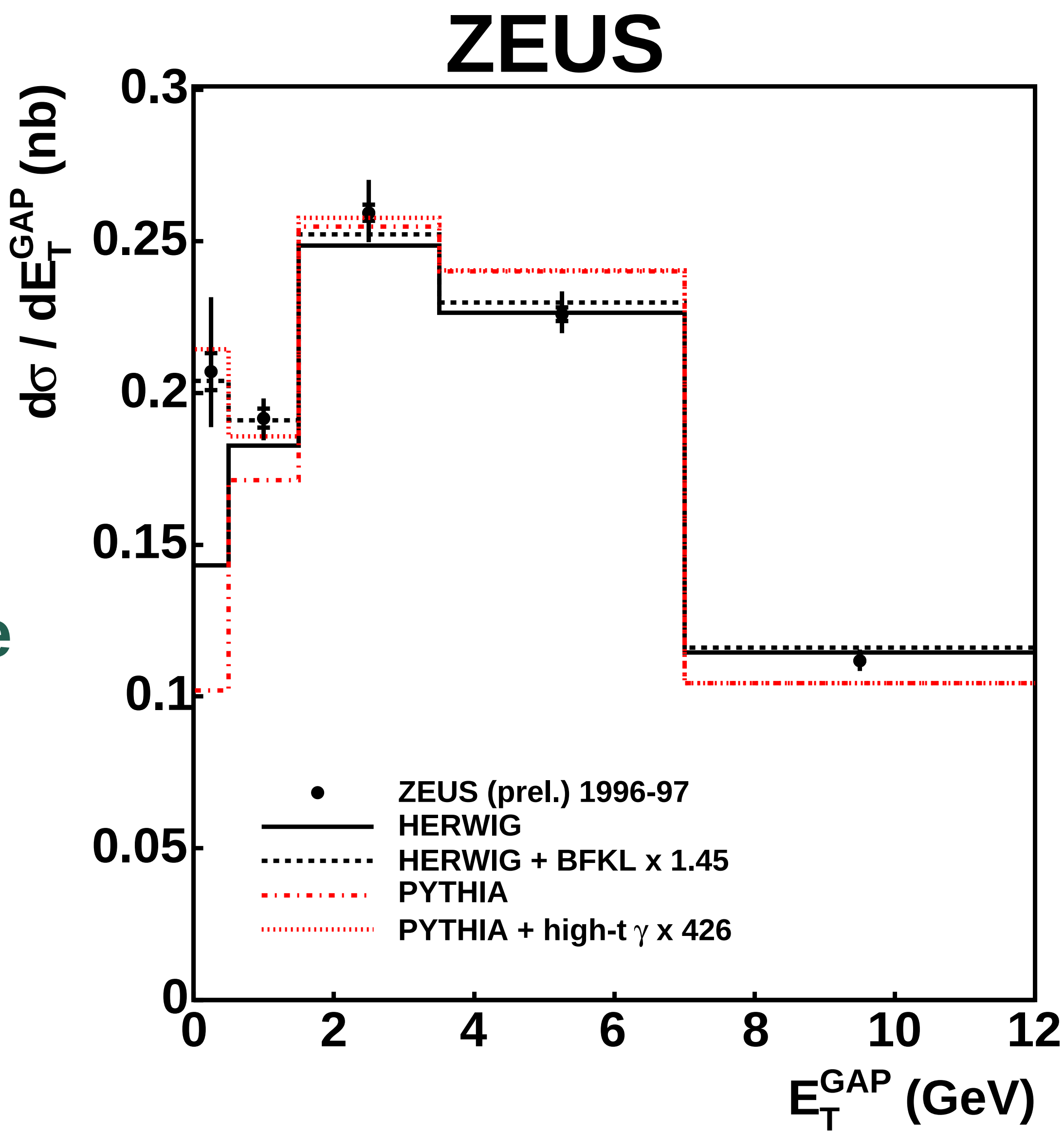
- tuned to the E_T^{GAP} distribution in the high E_T^{GAP} region
- direct and resolved combined by fitting the x_γ^{OBS} distributions to the data
- resolved contains multiparticle interactions

With colour-singlet exchange

HERWIG-BFKL $\longrightarrow$ uses BFKL pomeron as exchange object

PYTHIA-High-t γ $\longrightarrow$ uses high-t photon as exchange object (purpose is simply to match the data)

- Comparison of measured $d\sigma/dE_T^{GAP}$ with MC models



- MCs with 3-4 $\%$ colour-singlet exchange contribution agree with data in low E_T^{GAP} bins

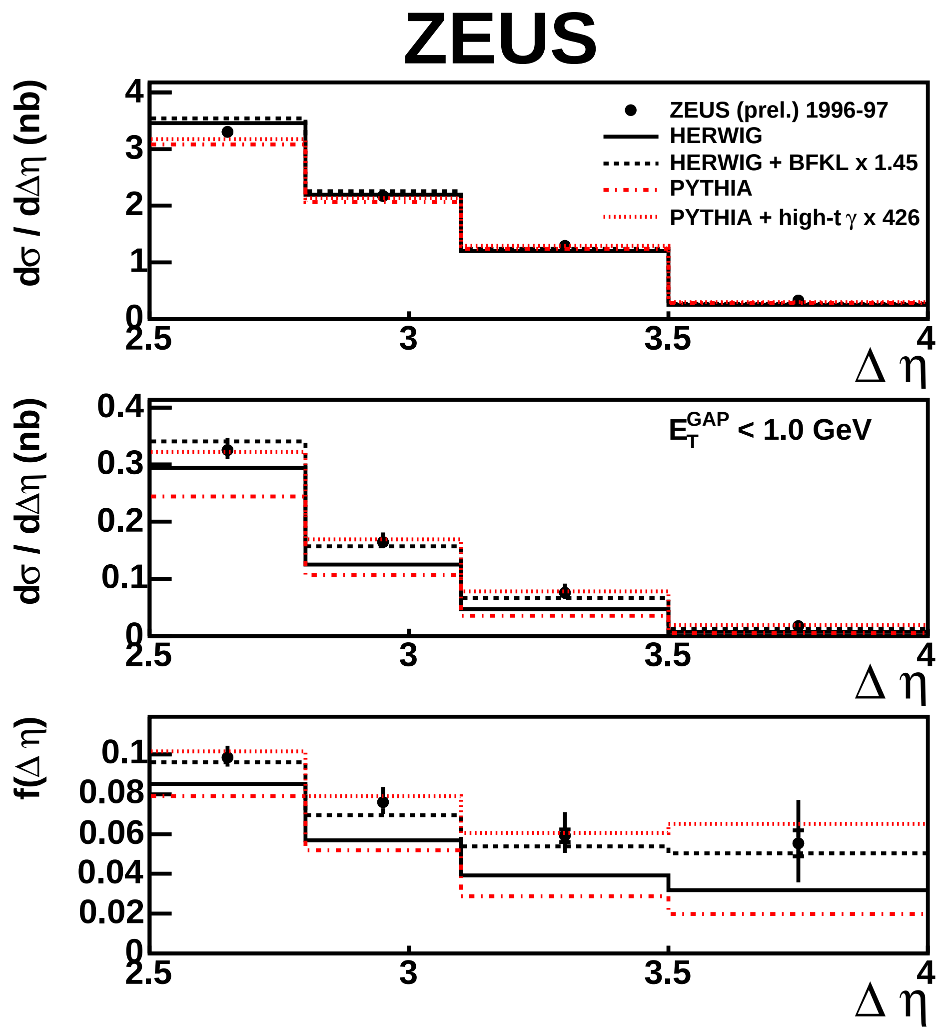
- **Differential cross sections in $\Delta\eta$**

Inclusive dijets

With an $E_T^{GAP} < 1$

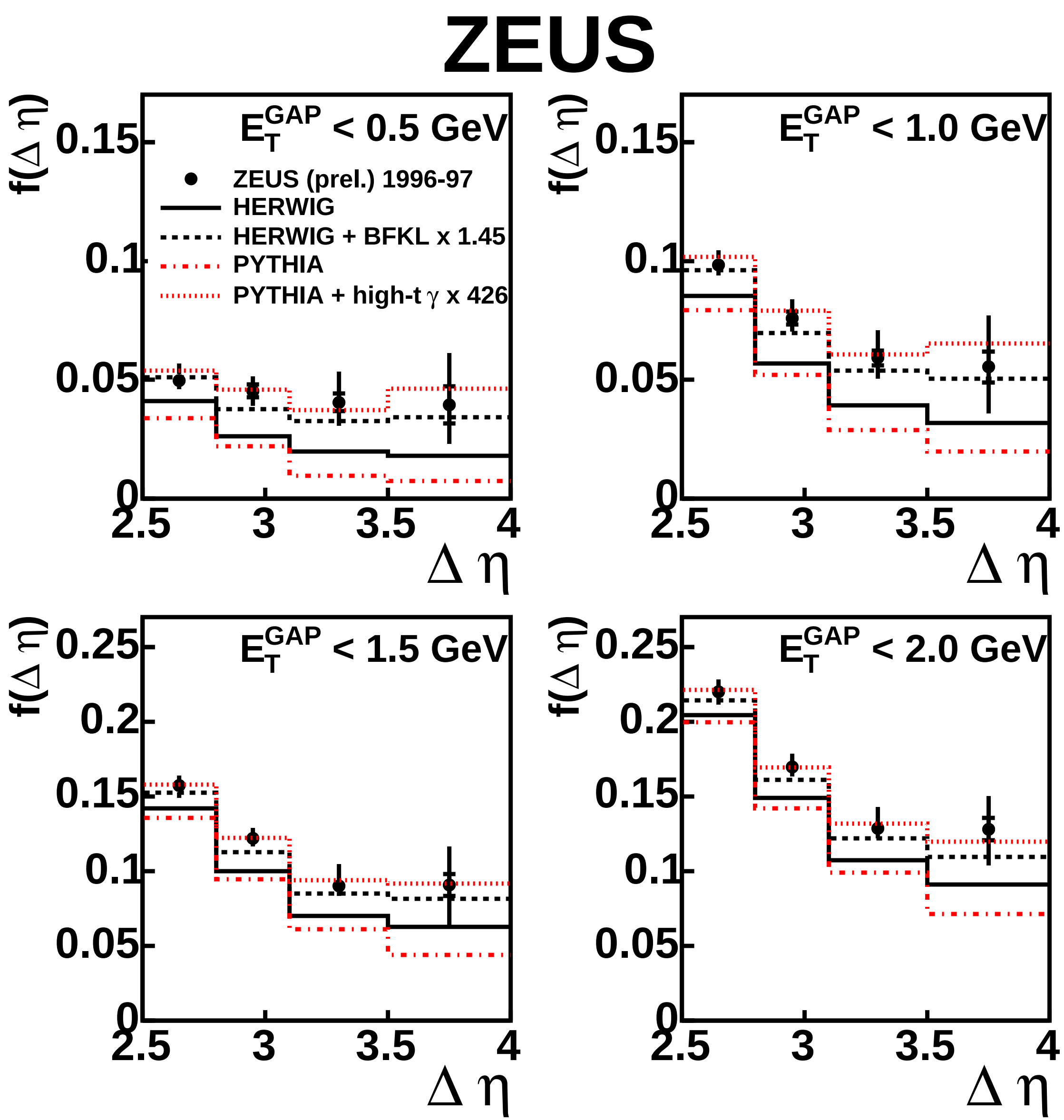
Gap fraction

$$\equiv f(\Delta\eta) = \frac{d\sigma_{gap}/d\Delta\eta}{d\sigma/d\Delta\eta}$$



- **The contribution from the colour-singlet is consistent data at high $\Delta\eta$**

- Gap fraction for different E_T^{GAP} thresholds:

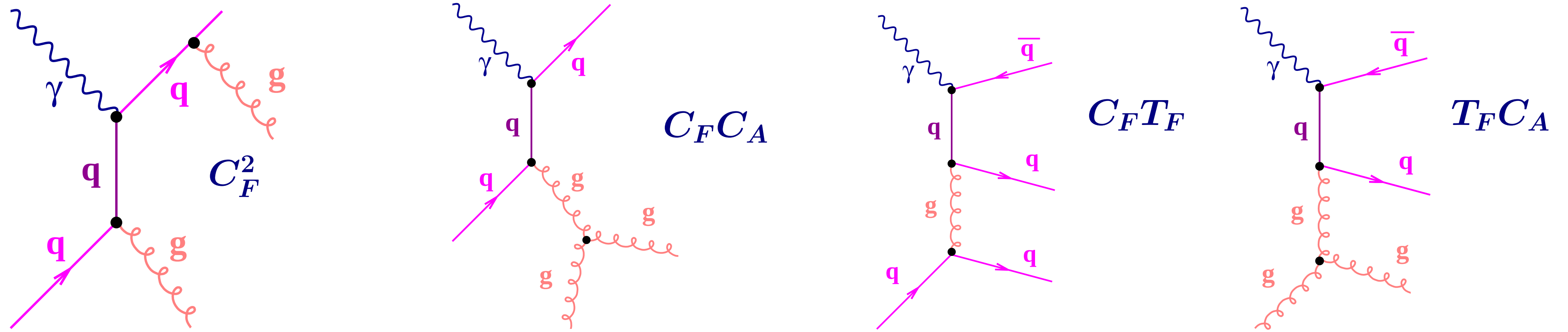


- MC model with colour singlet exchange:

$\longrightarrow$ provides excess to the exponential seen in the data

Angular correlations in three-jet events at HERA

- **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 color factors C_F, C_A, and T_F**



- **At LO, the 3-jet cross section can be expressed in terms of the colour factors**

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

- **Angular correlation variables among jets can be defined in PHP and DIS**

  $\longrightarrow$ **sensitive to the contributions from the different processes**

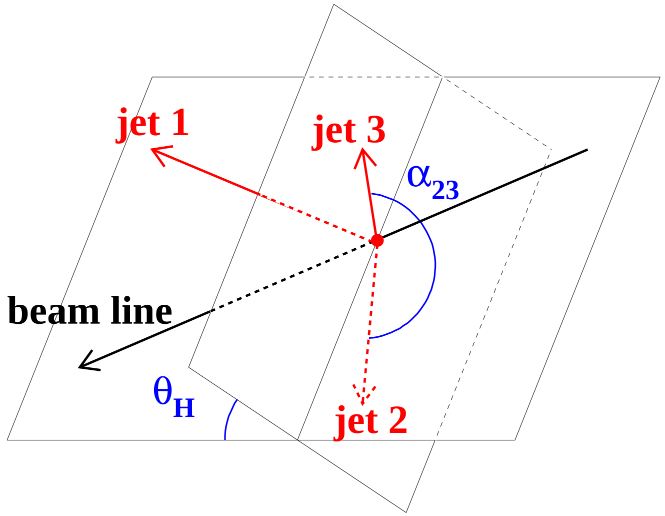
  $\longrightarrow$ **sensitive to the underlying symmetry group**

Angular correlations variables

Variables used to study the angular correlations in 3-jet events:

$\longrightarrow \theta_H$: **the angle between the planes determined by the highest-E_T^{jet} jet and the beam, and the two lowest-E_T^{jet} jets**

$\longrightarrow \alpha_{23}$: **the angle between the two lowest-E_T^{jet} jets**



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

$\longrightarrow \eta_{\rm max}^{\rm jet}$: **the η of the most forward jet in the Breit frame (only measured in DIS)**

Photoproduction sample

- Data collected with the ZEUS detector during 95-00 corresponding to a luminosity of $127 pb^{-1}$

3 jets of $E_T > 14$ GeV $x_\gamma^{OBS} > 0.7$ $\rightarrow x_\gamma^{OBS} = \sum_{i=1}^{3} \frac{E_{T,i} e^{-\eta,i}}{2yE_e}$

$-1 < \eta < 2.5$ $Q^2 < 1$ GeV ^{2}

$\rightarrow$ 2233 three-jet events

DIS sample

- Data collected during 98-00 with a luminosity of 81.7 pb^{-1}

3 jets of: $E_{T,}^{\text{jet1}} > 8$ GeV $E_{T,\text{B}}^{\text{jet2,3}} > 5$ GeV

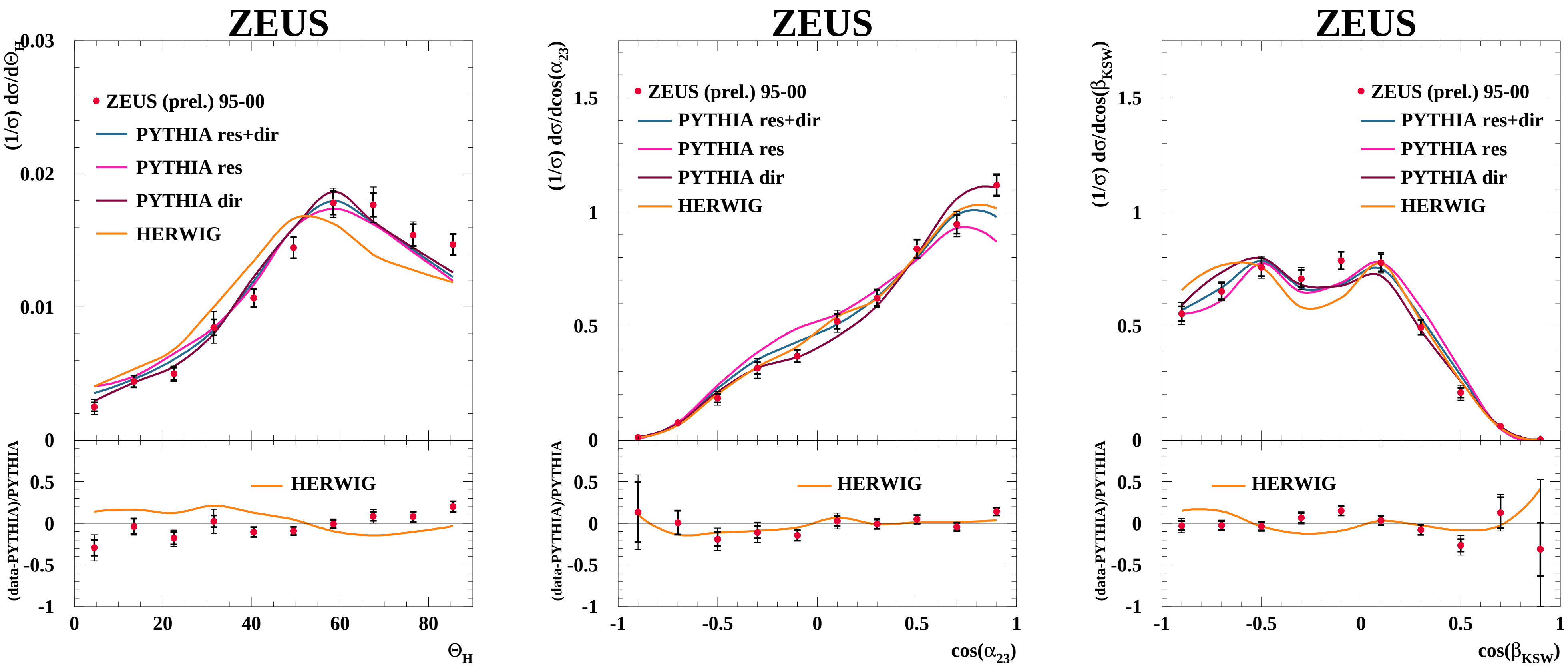
$-2 < \eta^{\text{jet}} < 1.5$ $Q^2 > 125$ GeV^2

$|cos\gamma_h| < 0.65$

$\rightarrow$ 1015 three-jet events

Photoproduction: data vs MC models

- θ_H, α_{23}, and β_{KSW} normalised cross sections compared with **Pythia 6.1 and Herwig 6.1**:



⟶ MC models also give a good description in DIS

- Fixed-order $\mathcal{O}(\alpha\alpha_s^2)$ have been made for each color combination (assuming SU(3)):

Photoproduction using the program by Klasen,Kleinwort and Kramer

$\longrightarrow$ pPDFs: MRST99 set

$\longrightarrow \mu_R = \mu_F = E_T^{max}$

- predicted relative contributions:

$13\%\ \sigma_A,\ 10\%\ \sigma_B,\ 45\%\ \sigma_C,\ 32\%\ \sigma_D$

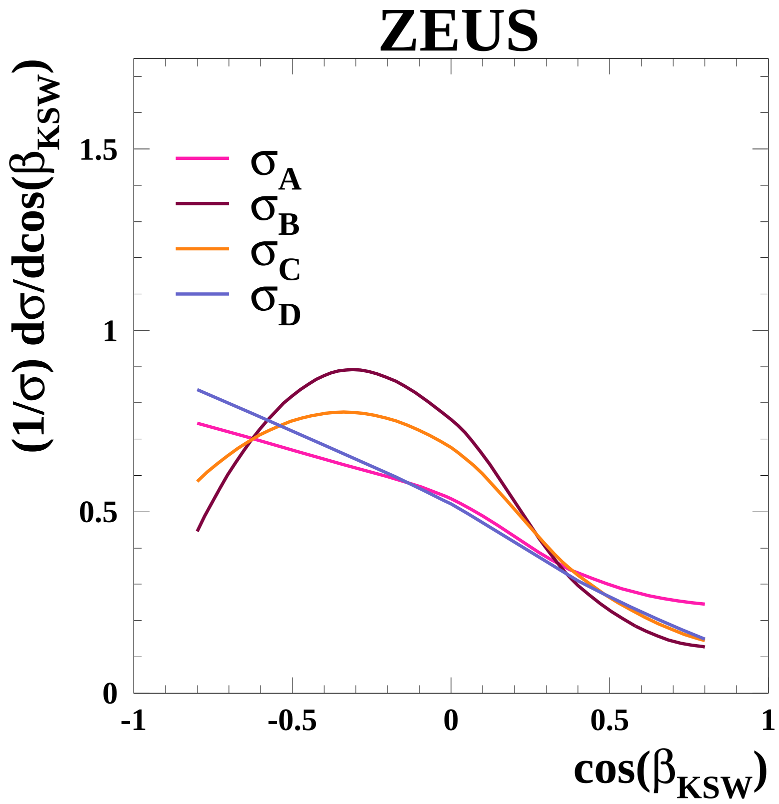
DIS using the program DISENT

$\longrightarrow$ pPDFs: CTEQ6M1 set

$\longrightarrow \mu_R = \mu_F = Q$

- predicted relative contributions:

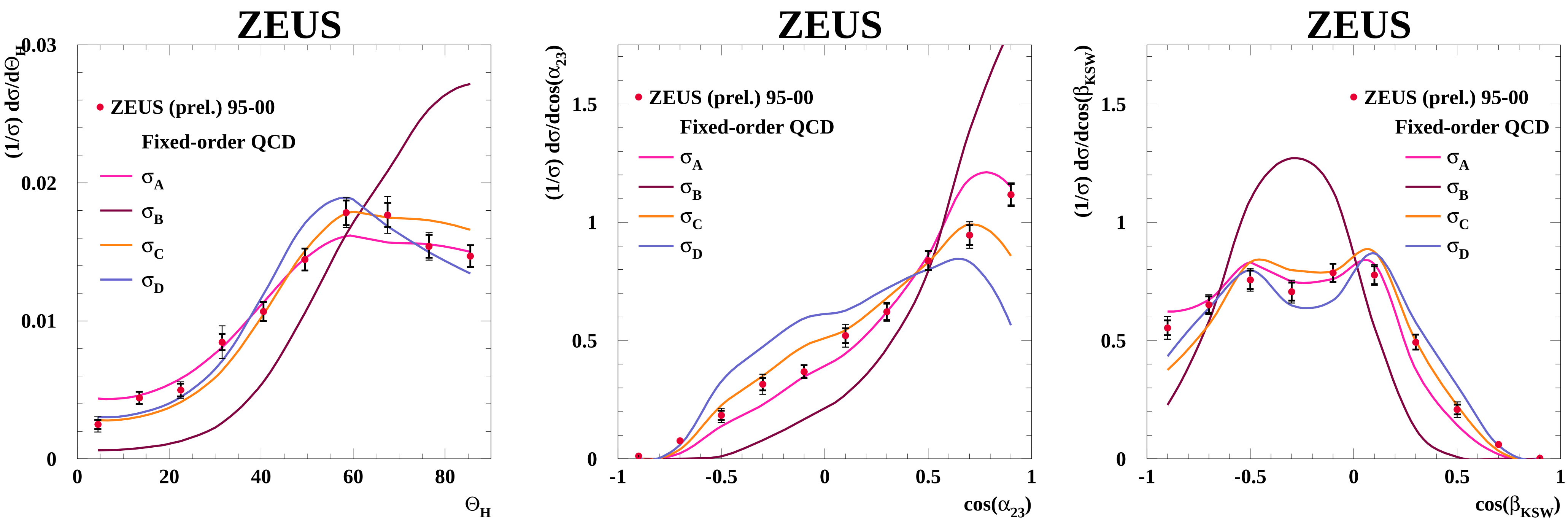
$23\%\ \sigma_A,\ 13\%\ \sigma_B,\ 39\%\ \sigma_C,\ 25\%\ \sigma_D$



$\cos(\beta_{KSW})$ angle in DIS

Photoproduction

- θ_H, α_{23}, and β_{KSW} normalised cross sections compared with the colour components:



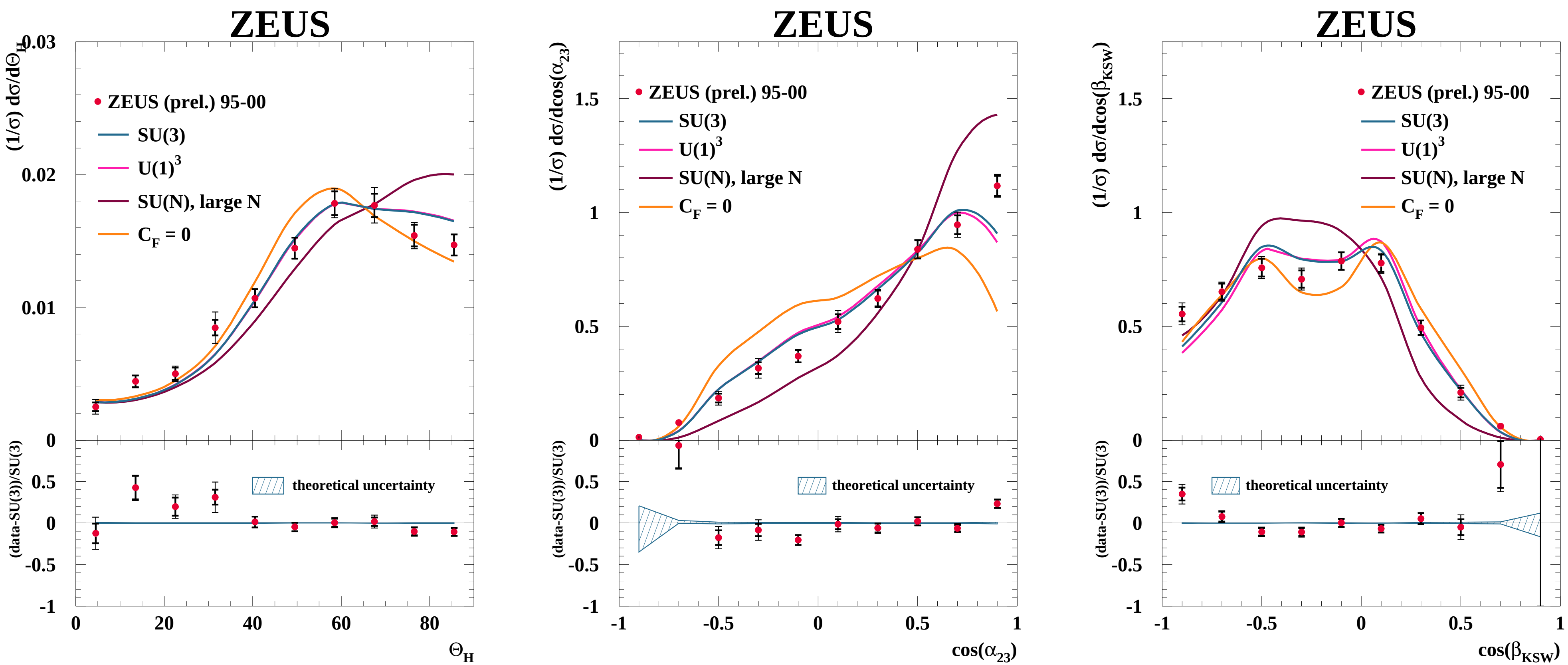
→ σ_B shape is very different

→ There is sensitivity to the different color components

→ Similar sensitivity seen in variables for DIS

Photoproduction

- θ_H, α_{23}, and β_{KSW} normalised cross sections compared with the predictions of different symmetry groups:



→ **The predictions of $C_F = 0$ and SU(N) , large N, are disfavoured by data**

→ **Reasonable description of data by SU(3)**

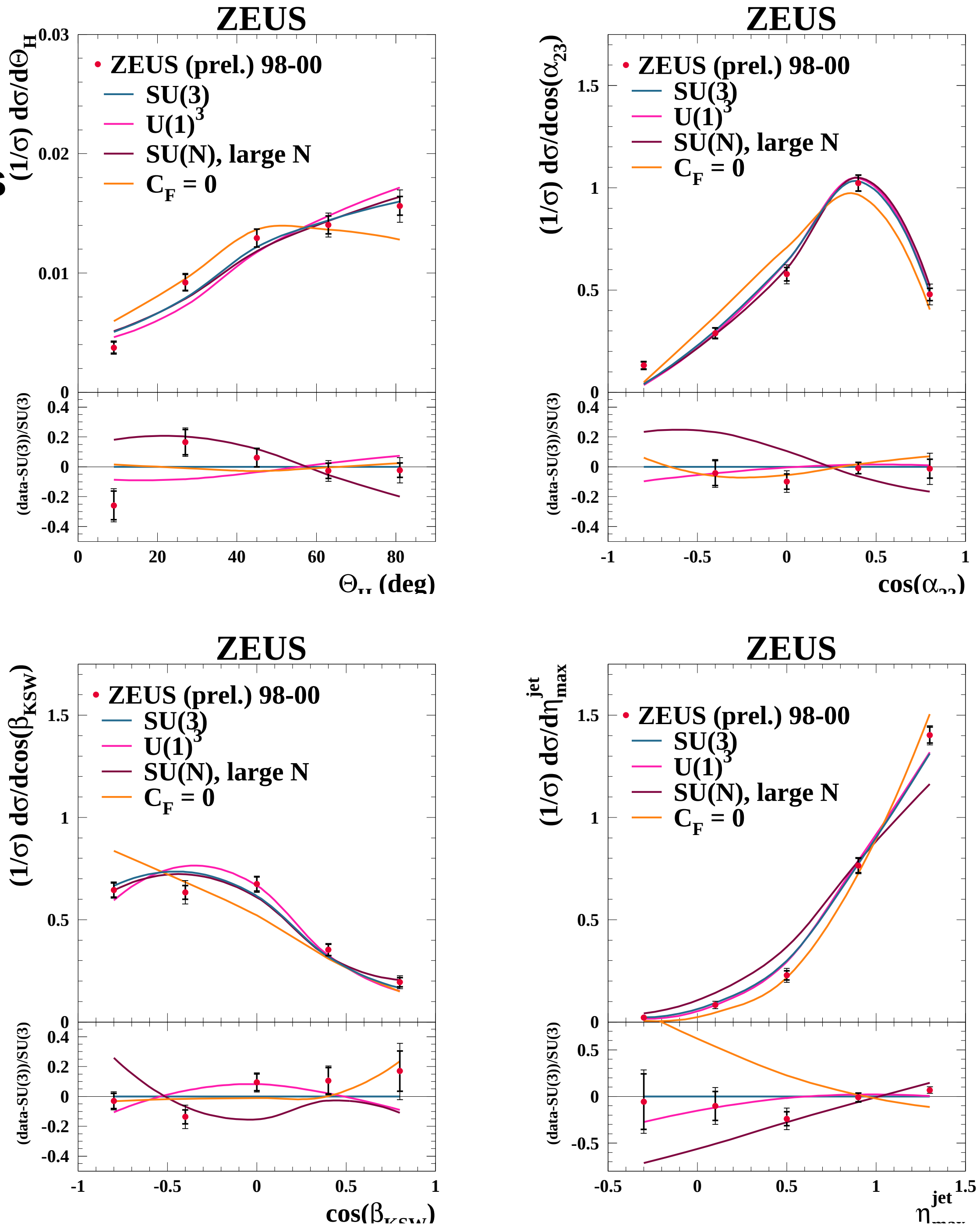
Normalised cross sections in DIS

DIS $\theta_H, \alpha_{23}, \beta_{KSW}$ **and**

η^{jet}_{max} **normalised cross sections**

compared with the predictions

of different symmetry groups



$\longrightarrow$ U(1)^3 **show some differences wrt SU(3), but still limited by statistics**

- Measurements of rapidity gaps in inclusive dijet events in PHP have been made using 96-97 ZEUS data

$\longrightarrow$ MC models with color-singlet contribution are consistent with measured $d\sigma/dE_T^{GAP}$,and $d\sigma/d\Delta\eta$ distributions

$\longrightarrow$ For $f(\Delta\eta)$, the color-singlet contribution gives an excess over exponential decay consistent with data

- Angular correlations in 3-jet events in PHP and NC DIS have been measured using 95-00 ZEUS data

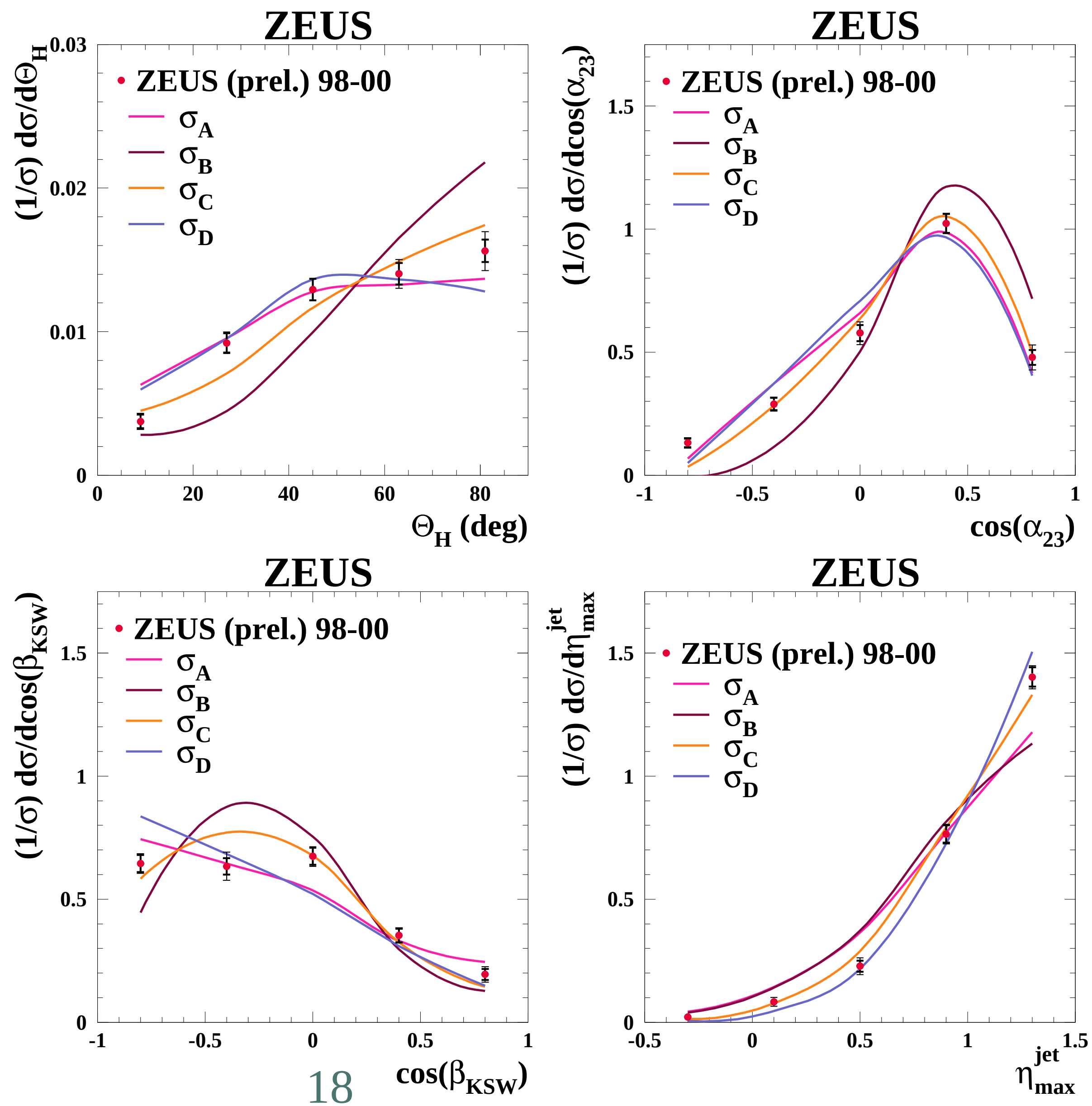
$\longrightarrow$ Differences between SU(3) and U(1)^3 fixed order calculations are found in $cos(\beta_{KSW})$ and η_{max}^{jet}, but still limited by the data

$\longrightarrow$ The data clearly disfavour calculations where SU(N), for large N, or $C_F = 0$ have been assumed

$\longrightarrow$ All the three-jet angular correlation measurements are consistent with the admixture of colour configurations as predicted by SU(3)

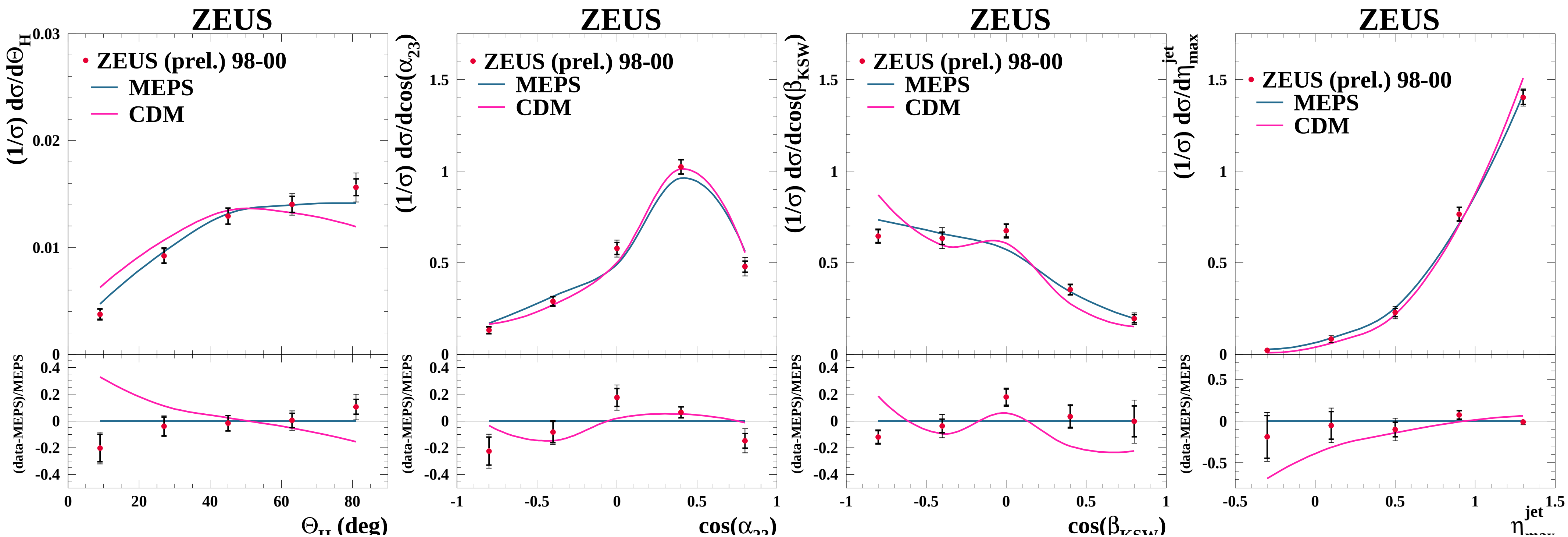
Normalised cross sections in DIS

DIS θ_H, α_{23}, β_{KSW} **and** η_{max}^{jet} **normalised cross sections compared with the colour components:**



DIS: data vs MC models

- θ_H, α_{23}, β_{KSW} and $\eta^{\text{jet}}_{\text{max}}$ normalised cross sections vs Color Dipole Model (CDM) and Matrix-element + Parton-shower (MEPS) of LEPTO:



→ **The predictions of MEPS give a good description of the data**

→ **The predictions of CDM give a somewhat poorer description**