Multijet production at HERA

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On behalf of H1 and ZEUS Collaborations

Contents:

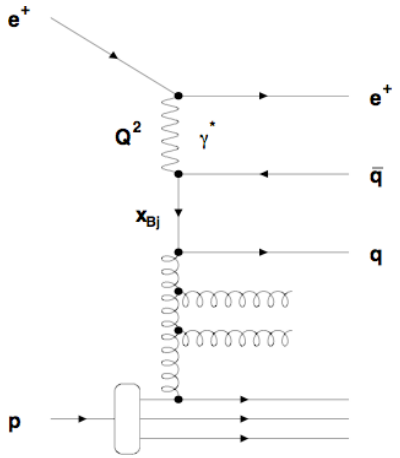
- Multijet production at low-x in DIS
- Angular correlation between jets
- Multijet production in charged current DIS
- Three and four-jet final states in photoproduction
- Minijets in DIS

EPS 2007

20/July/2007 - Manchester - UK

Multijet at low-x

- Parton dynamics (low-x_{bj})



. In general, at high Q^2, high x, DGLAP equation (partons E_T ordering) describes the data

. At lower x, parton emission increases, DGLAP approach may not work

. Jet cross sections at low-x: sensitive to unordered gluon radiation

. Good ground to test the limit of validity of DGLAP

*** See next talk by Guenter Grindhammer ***

Multijet at low-x

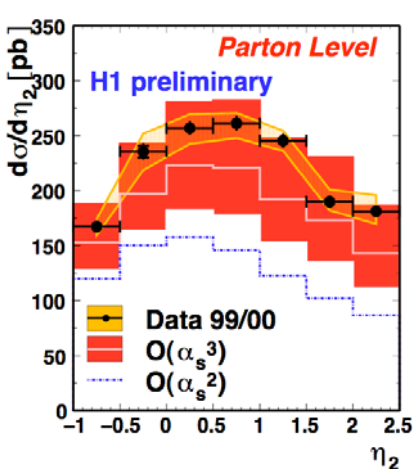
H1 Collaboration - Event Selection:

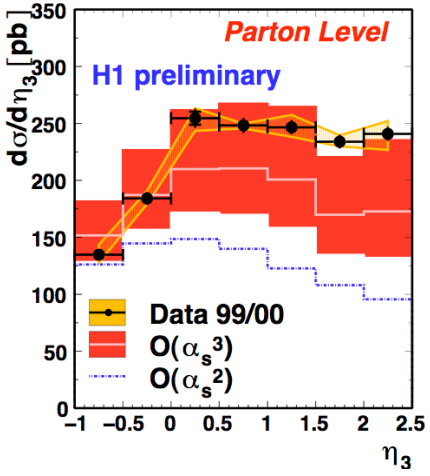
$0.1 < y < 0.7$ $\quad 4 < Q^2 < 80\ GeV^2$

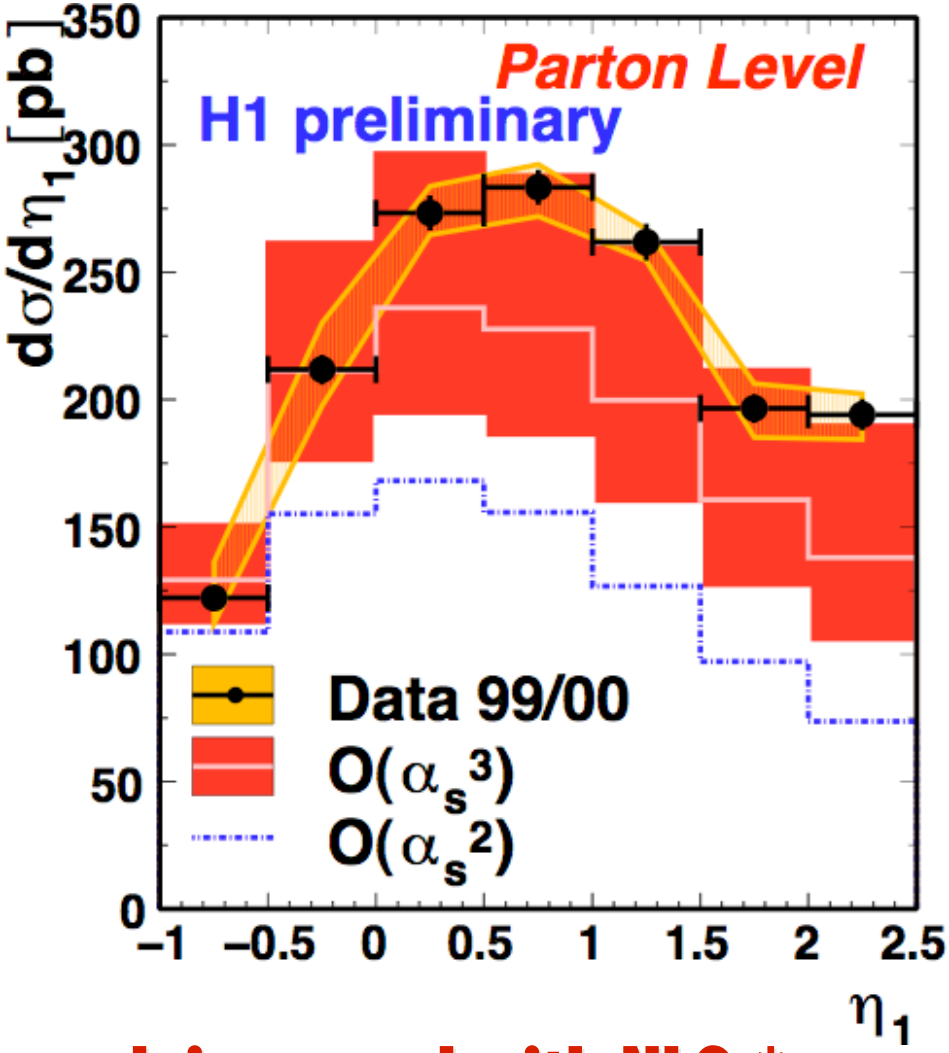
$10^{-4} < x < 10^{-2}$ $\quad$ At least 3 jets with

$E_{t\ jet1} > 4\ GeV$ $\quad E_{t\ jet2} + E_{t\ jet3} > 9\ GeV$

$-1 < \eta^{lab} < 2.5$, $\quad$ one of them $-1 < \eta^{lab} < 1.3$

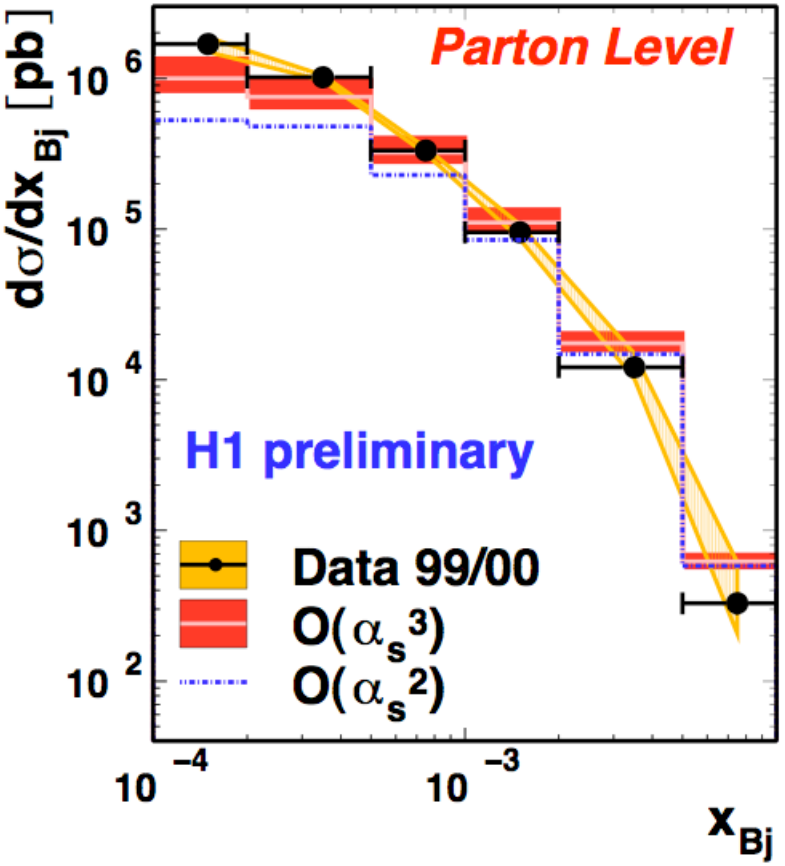






*** Description of the data pretty much improved with NLO ***

Multijet at low-x



$O(\alpha_s^3)$ calculation

(as in NLOjet++ program)

gives very good description of the data

Exception at very low-x (see next talk)

Multijet at low-x

ZEUS Collaboration

Event selection:

$0.1 < y < 0.6$ $\quad 10 < Q^2 < 100\ GeV^2$

$10^{-4} < x < 10^{-2}$ $\quad$ 2 or 3 jets with

$E_t^{jet1} > 7\ GeV$ $\quad E_t^{jet2(3)} > 5\ GeV$

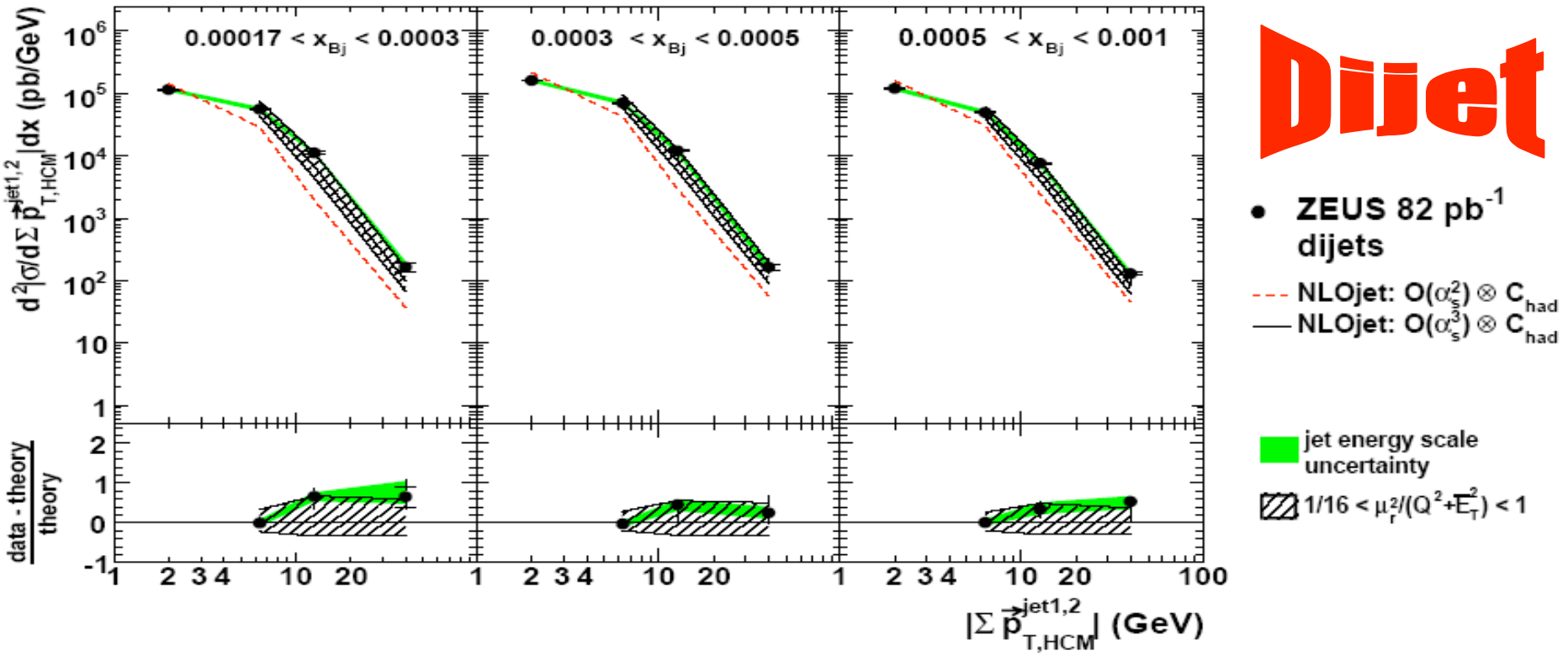
$-1 < \eta^{lab} < 2.5$

Variables:

$|\Sigma p^{jet1,2}_{T,HCM}|$ = transverse component of the vector sum of the two jet momenta with the highest hadronic center of mass E_T

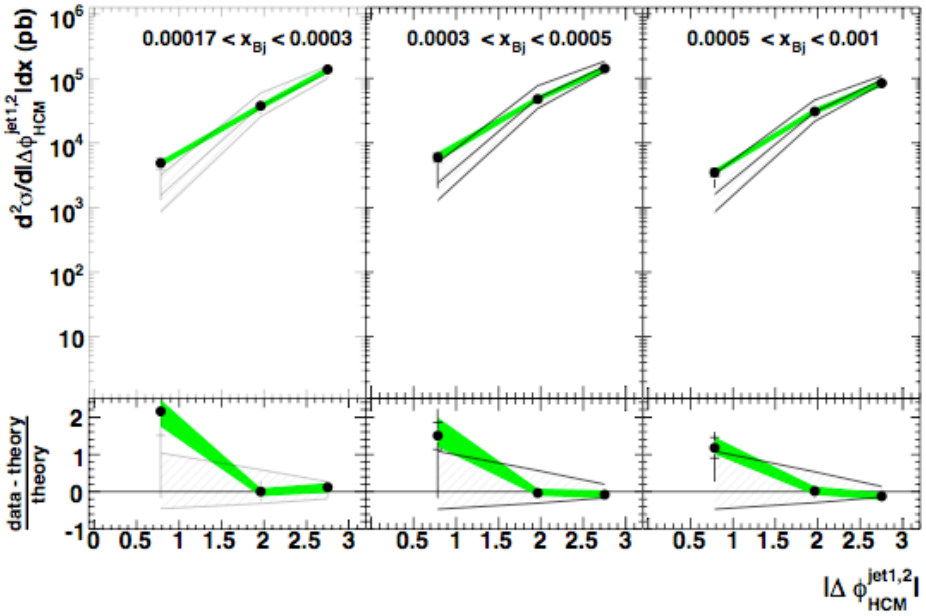
$|\Delta\Phi^{jet1,2}_{T,HCM}|$ = azimuthal separation btw the same two jets

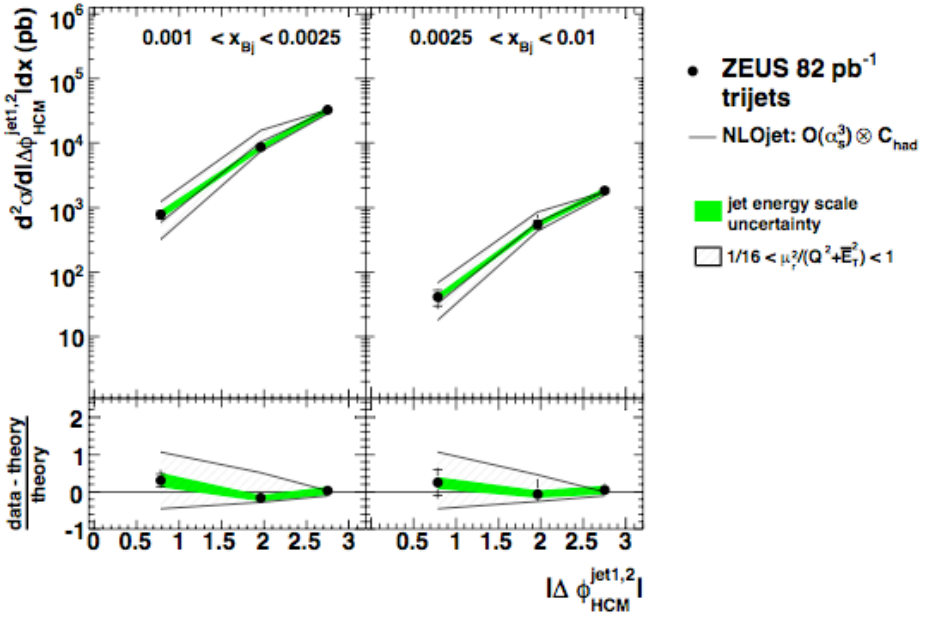
Multijet at low-x



Data well described by pQCD calculations when NLO correction is included

Multijet at low-x





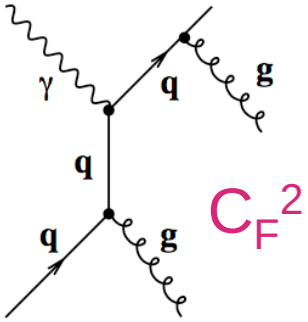
Trijet

Data well described by pQCD

Angular correlations

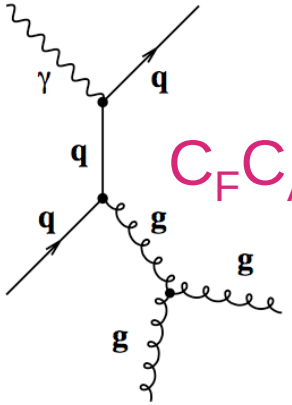
- Three jet events allow the study of the underlying gauge structure of QCD

- The dynamics of a gauge theory such as QCD is determined by the colour factors C_A, C_F, T_F



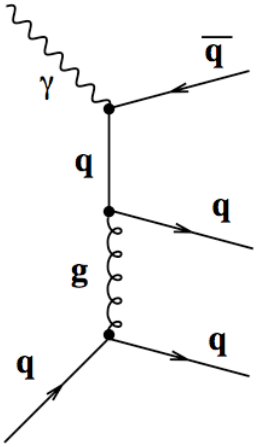
C_F^2

σ_A



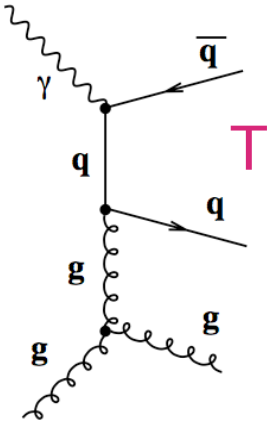
$C_F C_A$

σ_B



$C_F T_F$

σ_C



$T_F C_A$

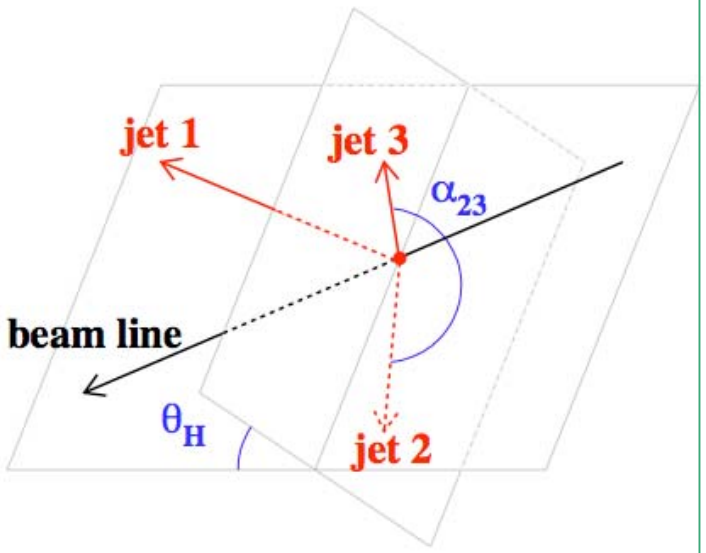
σ_D

$$\sigma_{ep \to 3jets} = C_F^2\, \sigma_A + C_F C_A\, \sigma_B + C_F T_F\, \sigma_C + T_F C_A\, \sigma_D$$

Angular correlations

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

θ_H = angle btw planes determined by
highest transverse energy jet and beam line
and by the two lowest transverse energy jets



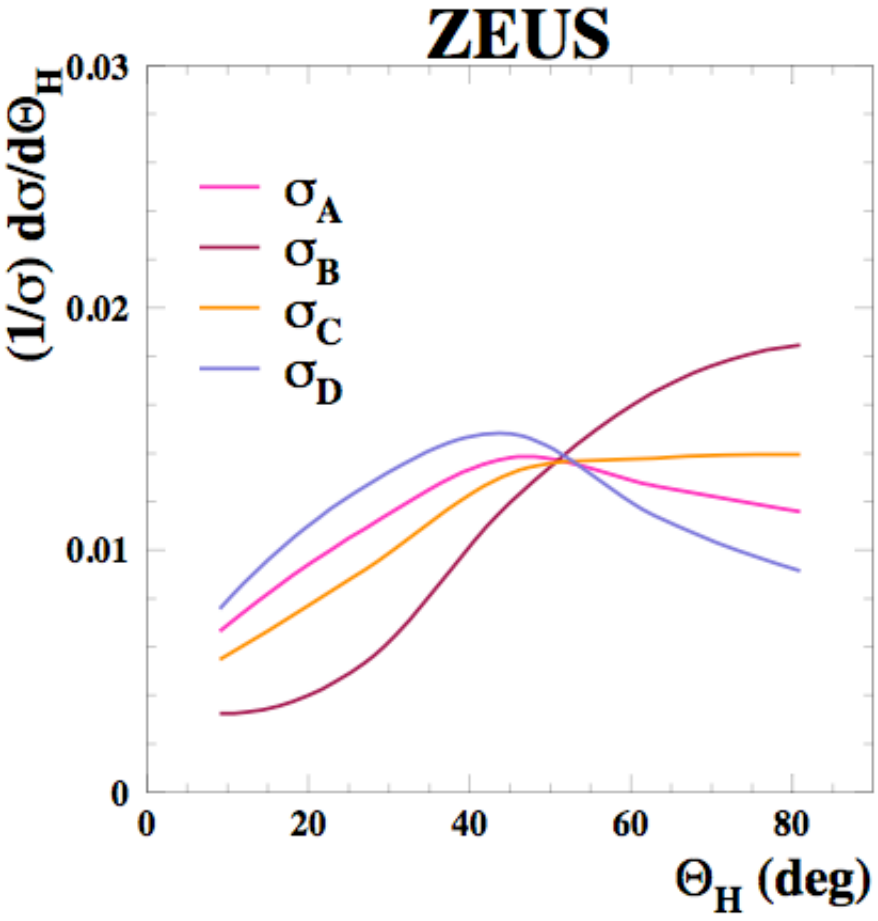
α_{23}= angle btw the two lowest transverse energy jet

η_{max} = pseudorapidity of the most forward jet

$$\cos(\beta_{KSW}) = \cos[1/2(\angle[(p_1 x p_3),(p_2 x p_B)] + \angle[(p_1 x p_B),(p_2 x p_3)]\,]$$

(p_B=unity vector in the beam direction)

Angular correlations



Different shapes for each contribution

The same for the other angular correlations

Data can potentially distinguish different colour configurations

Angular correlations

ZEUS - Event selection:

. $Q^2 > 125$ GeV^2

. $|\cos\gamma_h| < 0.65$

. 3 jets (kt cluster, Breit frame) with

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

$E_{t,B}^{jet\ 1} > 8$ GeV

$E_{t,B}^{jet\ 2} > 5$ GeV, $E_{t,B}^{jet\ 3} > 5$ GeV

- Compare data to:

. SU(3) prediction (QCD):

✓ $C_A/C_F = 9/4$ $T_F/C_F = 3/8$

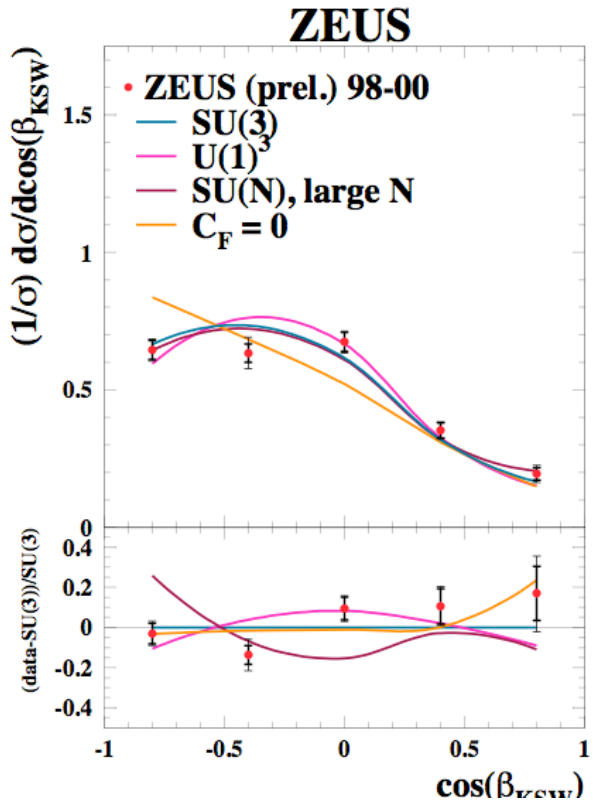
. An abelian gluon model (no gluon self coupling) based on $U(1)^3$ predicts

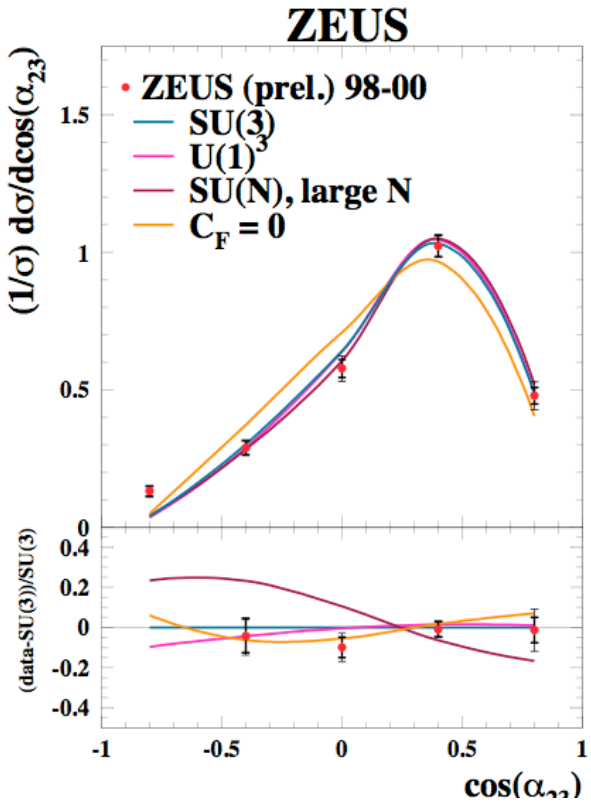
✓ $C_A/C_F = 0$ $T_F/C_F = 3$

. A non-abelian model based on SO(3) predicts

✓ $C_A/C_F = 1$ $T_F/C_F = 1$

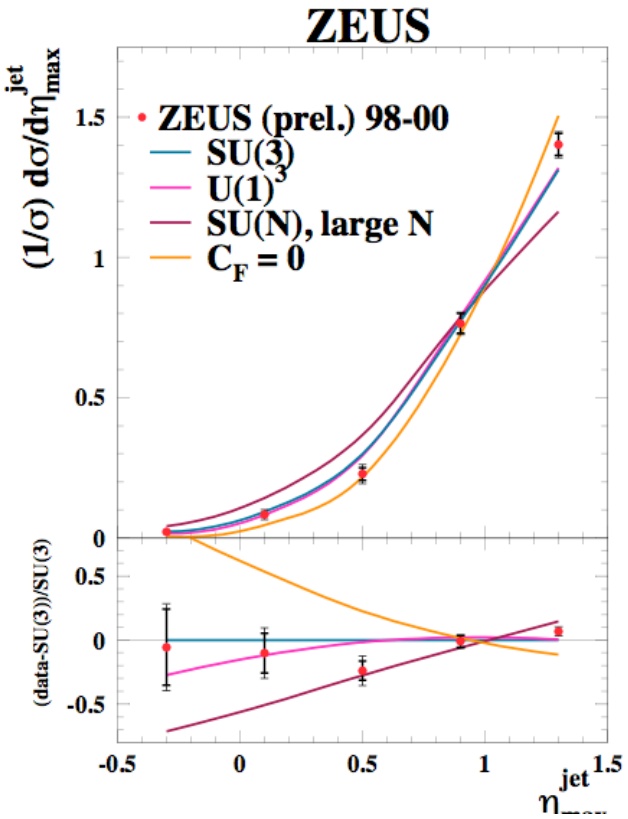
Angular correlations

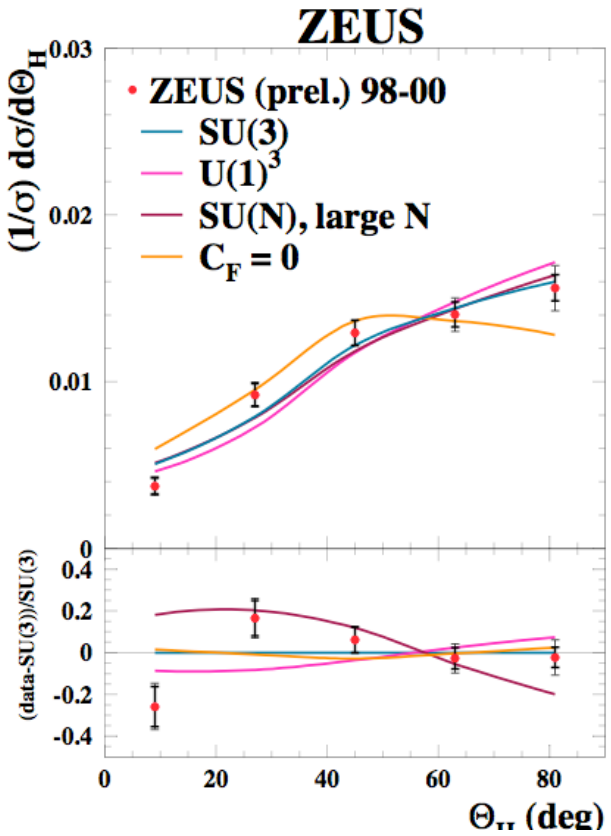




- C_F=0 and SU(N) large N disfavoured
- SU(3) [QCD] describes data
- similar to $U(1)^3$: no sensitivity to distinguish yet

Angular correlations





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Jets in charged current DIS

- **Charged current DIS:**

. Testing QCD and the electroweak sector of the Standard Model:

  - CC DIS jet cross sections sensitive to α_s and to M_W

. Sensitive to the presence of new physics

. HERA II data: longitudinally-polarized lepton beams

Jets in charged current DIS

Event selection:

180 pb^{-1} e^-p data

. $Q^2>200$ GeV^2

. $y<0.9$

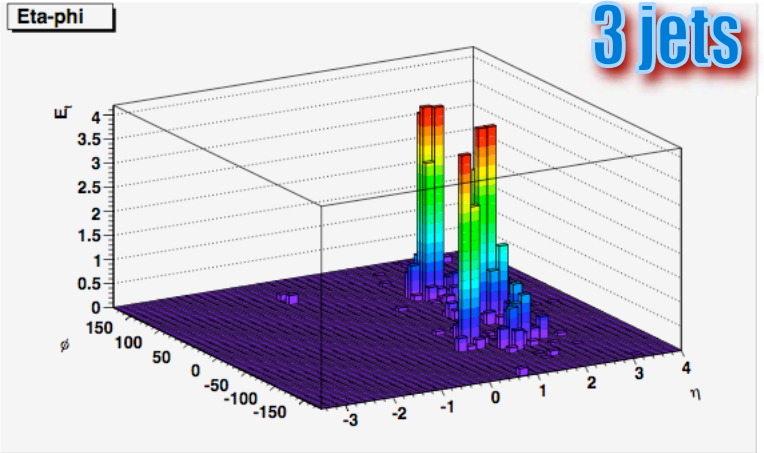
1, 2 or 3 jets with

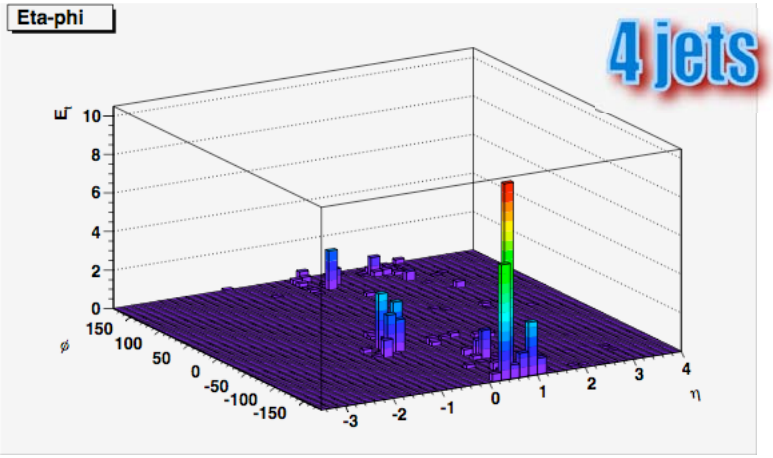
$-1< \eta^{jet}<2.5$

$E_t^{jet\ 1}>14$ GeV

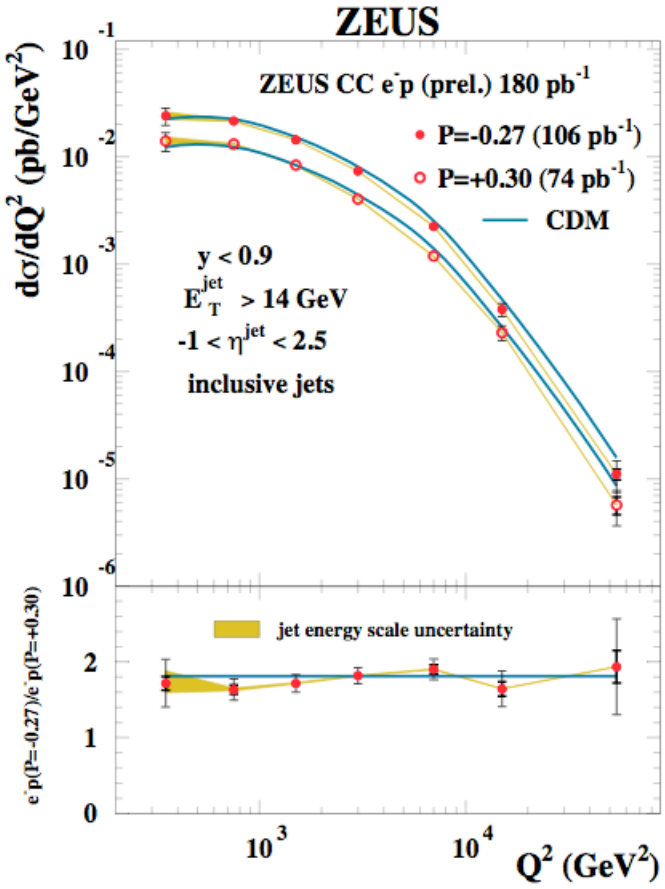
$E_t^{jet\ 2}>5$ GeV, $E_t^{jet\ 3}>5$ GeV

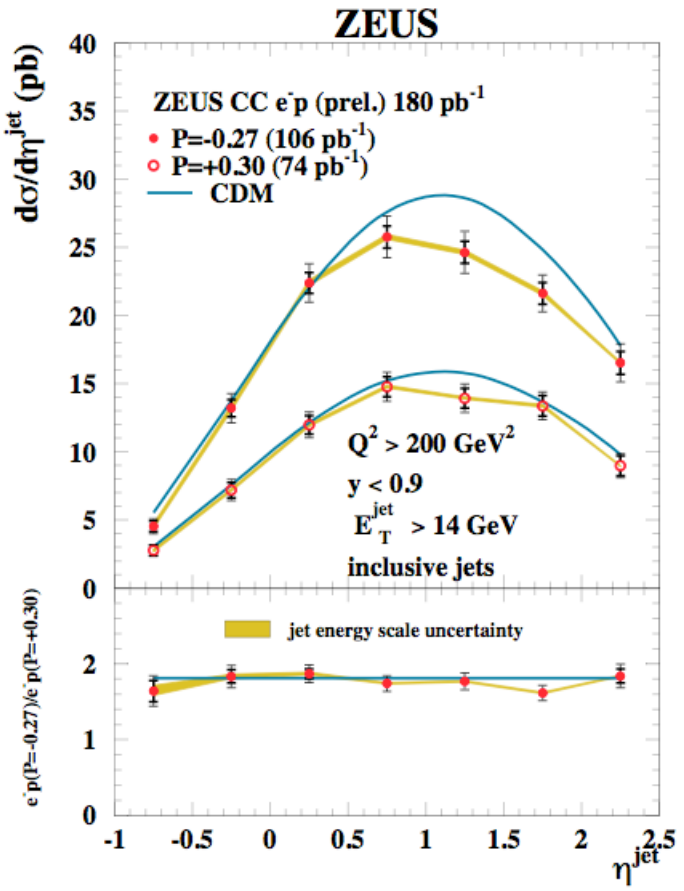
* A few events with 4 jets *





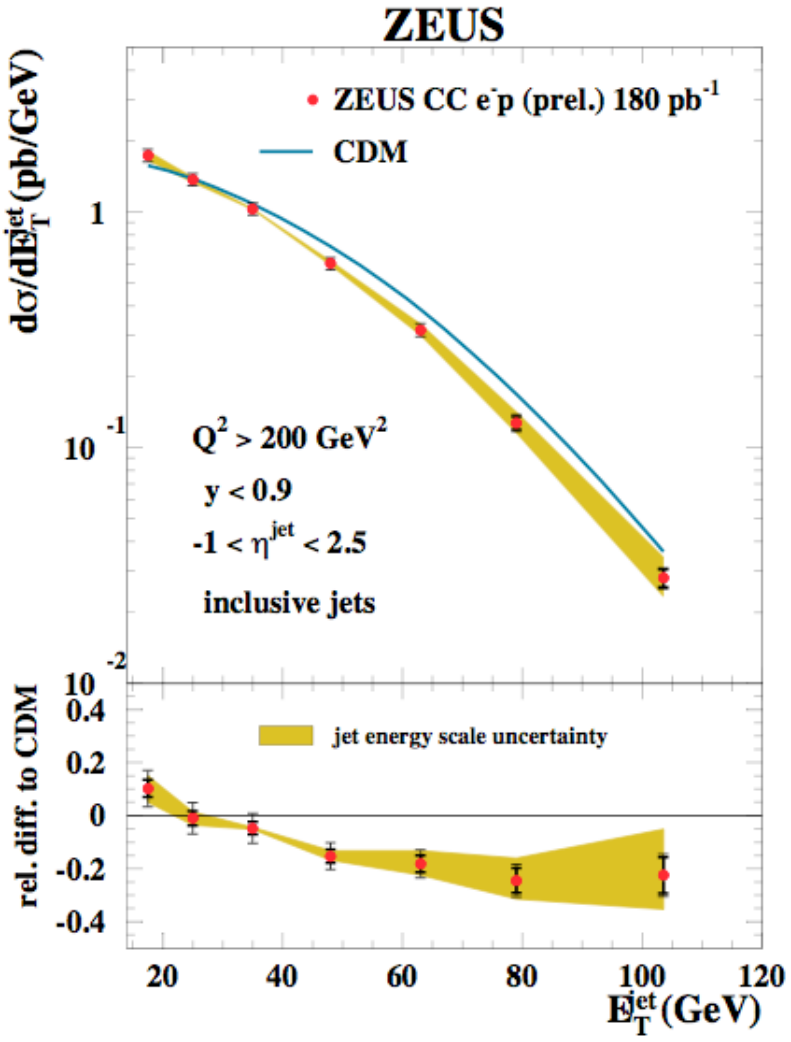
Jets in charged current DIS





Inclusive jets: ratio of + and - polarized is well described by SM

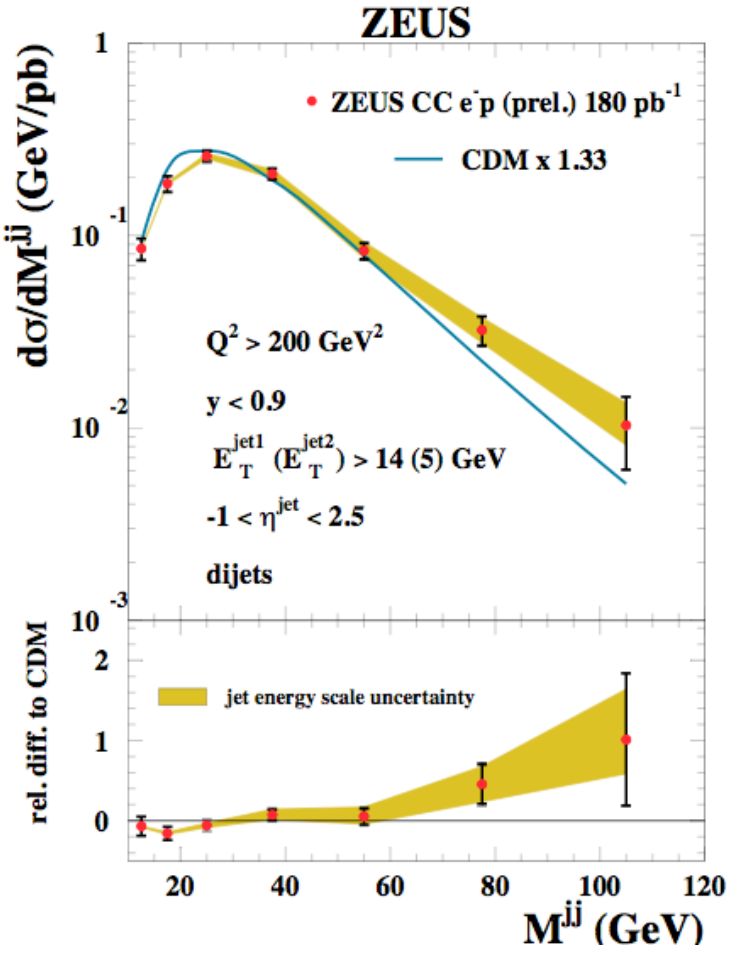
Jets in charged current DIS

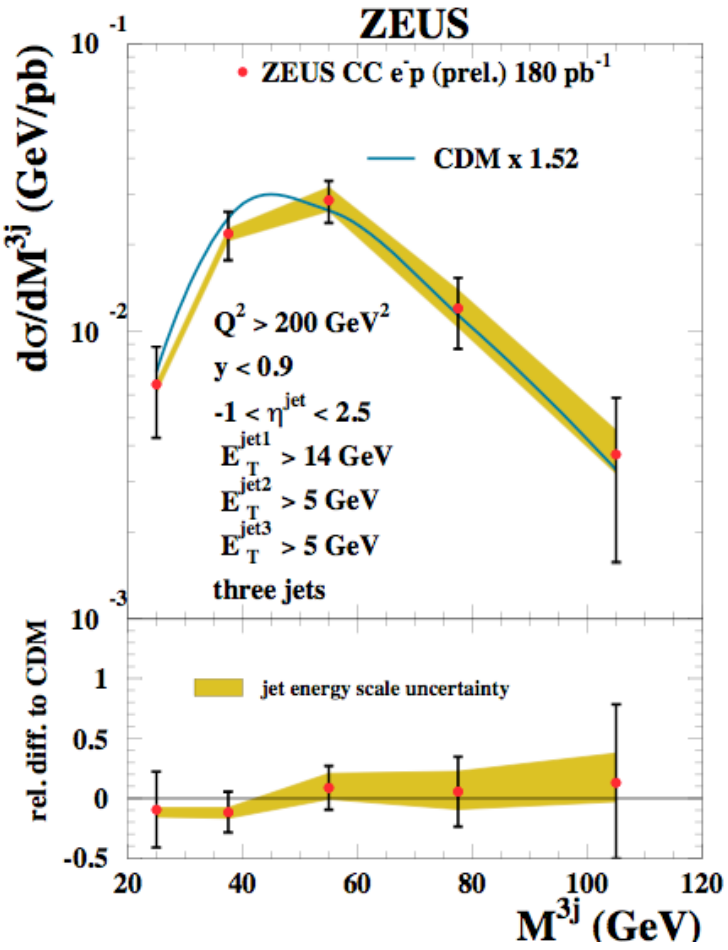


Inclusive jets:

unpolarized-corrected cross section is not well described by QCD

Jets in charged current DIS

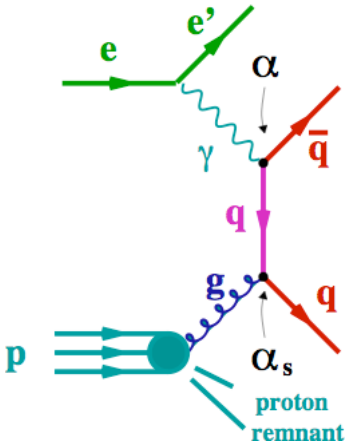




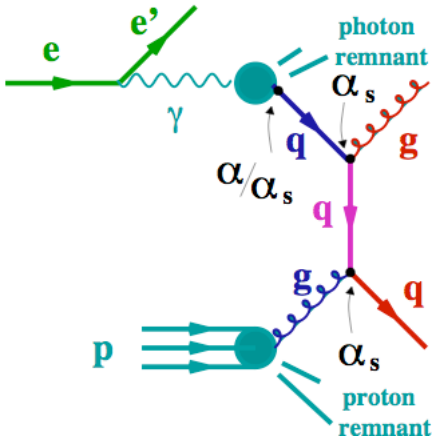
. Two and three jets: unpolarized-corrected cross section

. good agreement in shape with CDM (except dijet high mass)

Multijet in photoproduction

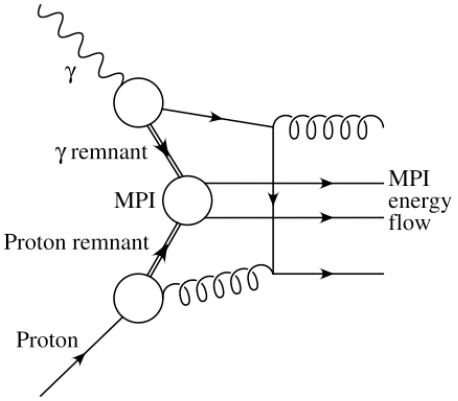


Direct photon



Resolved photon

- PHP: Multi-Parton Interactions



. Multijet photoproduction (resolved γ) is sensitive to MPIs

. 4-jet PHP: the highest order process ever measured at HERA

. No NLO calculation available yet

Multijet in photoproduction

Event selection:

$Q^2<1$ $0.2<y<0.85$

3 or 4 jets with

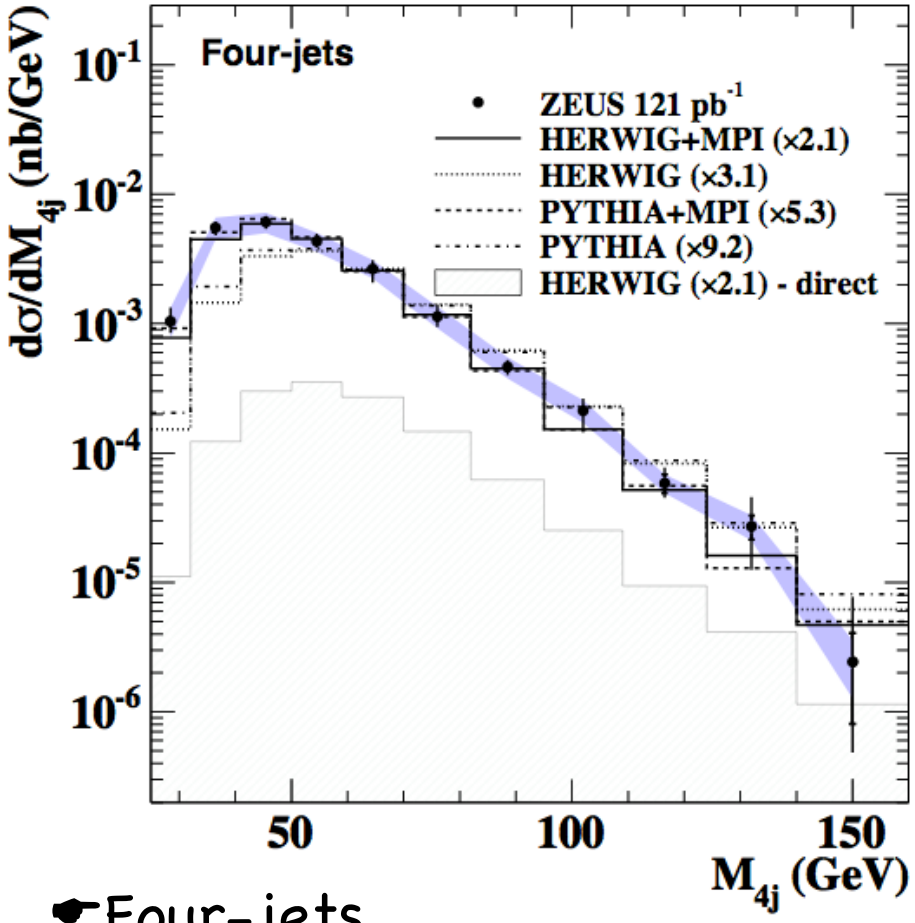
$|\eta|<2.4$ $E_T>6$ GeV

Two mass regions:

$25\leq M_{nj}\leq 50$ GeV $M_{nj}\geq 50$ GeV

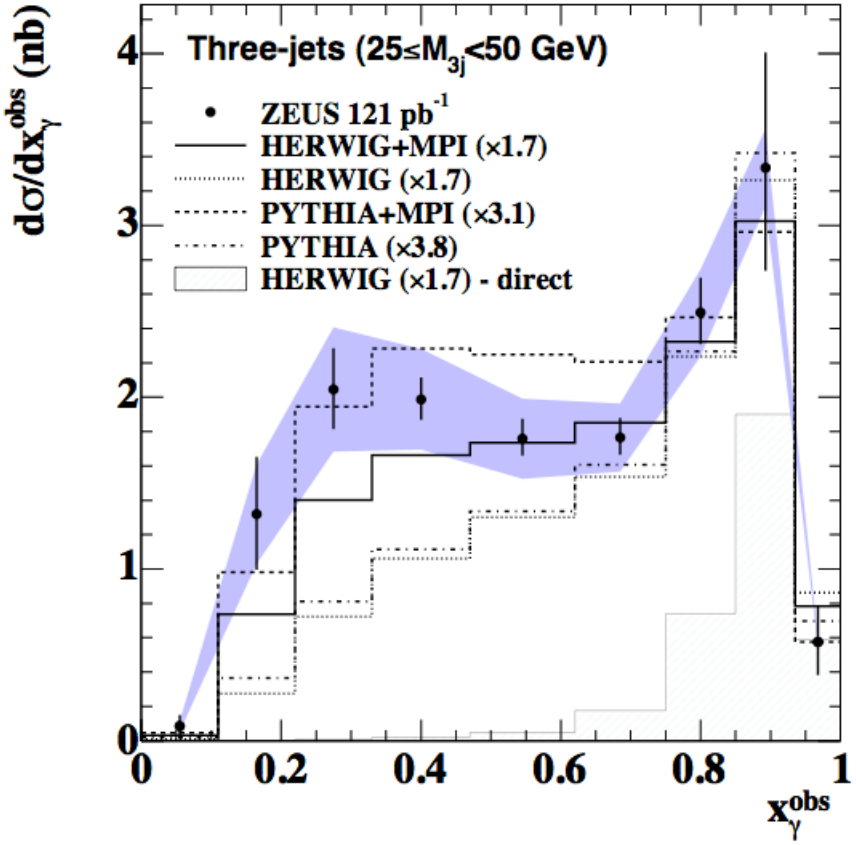
(low mass more sensitive to MPIs)

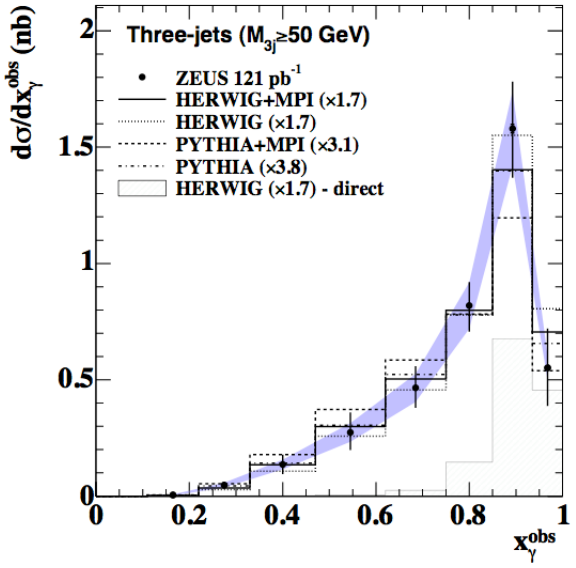
MC with MPI improves description of the data

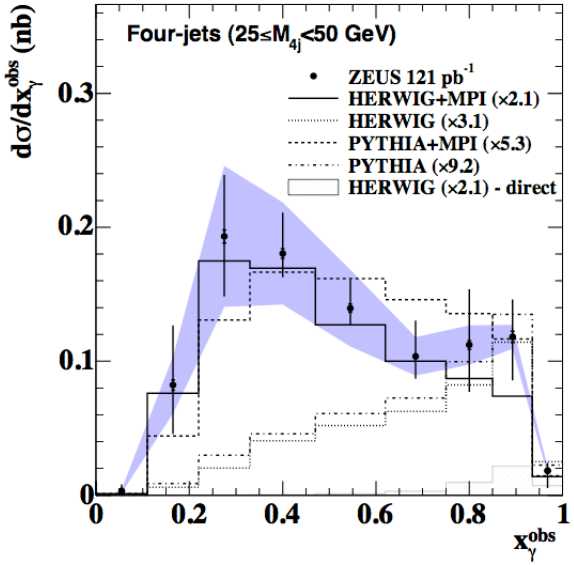


- Four-jets
- Similar results for three-jets

Multijet in photoproduction







General improvement adding MPIs to LO MC

Mini-Jets in DIS

. Minijets: multi parton interactions

Back to DIS: if P_T of interacting partons is larger than Q_2: hadron-like (resolved) photon

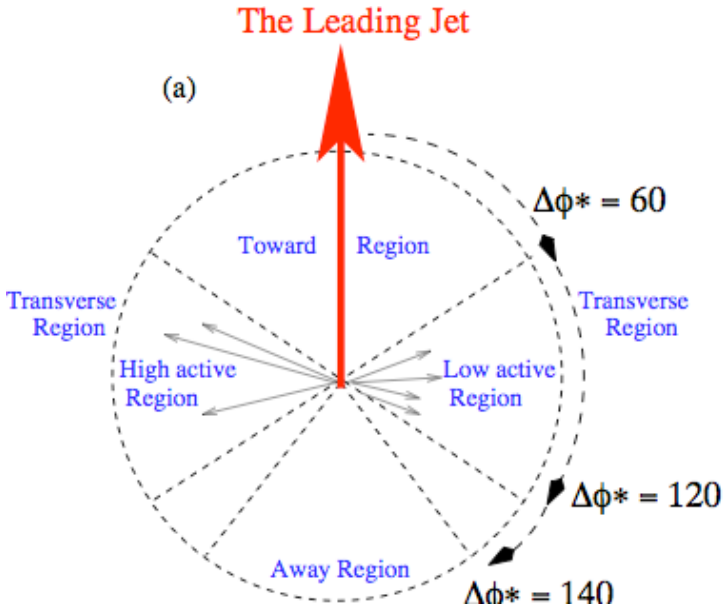
Strategy:

Define and isolate a leading jet

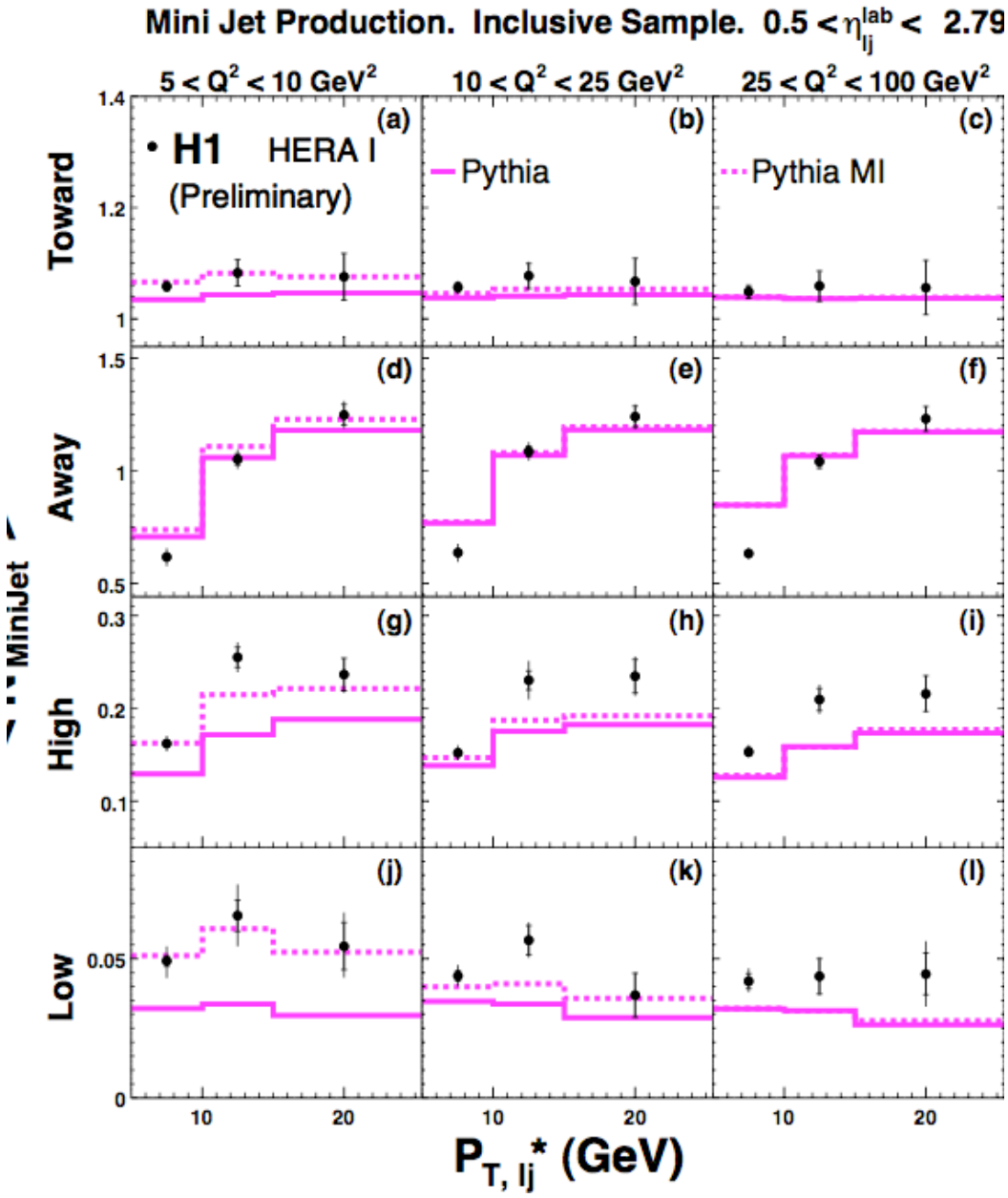
Search for activity in regions of space where contributions from the primary interaction is expected to be small

Low (high) activity regions:

region which contains the least (most) transverse momentum



Mini-Jets in DIS



Average multiplicity of minijets as a function of leading jet P_T

At low Q^2:
MPI improves agreement between PYTHIA and data

At higher Q^2:
Little effect of MPI

[Activity regions defined In fig previous page]

Conclusions

- Multijet in the forward region
  - parton dynamics studied in the low-x_{bj} region where DGLAP expected to fail
  - agreement with data pretty much improved going from $O(\alpha_S^2)$ to $O(\alpha_S^3)$
- Multijet in charged current DIS
  - The cross sections ratios for +/- e beam polarization is well described by SM
  - LO MC (Colour Dipole Model): does not describe inclusive jets

    reasonable for 2 jets, shape in agreement for three jets
- Multijet in DIS: angular correlations btw jets:
  - data consistent with admixture of colour configuration predicted by SU(3)
  - data disfavour $T_F/C_F \approx 0$ (as predicted by SU(N), large N) or $C_F=0$
  - Not enough sensitivity to distinguish btw gauge groups SU(3) and $U(1)^3$
- Minjets in DIS and Multijet in photoproducion
  - At low Q^2, adding MPIs to MCI models improved the description of the data