DIS09 26-30 April, MADRID

Subjet Distributions in NC DIS

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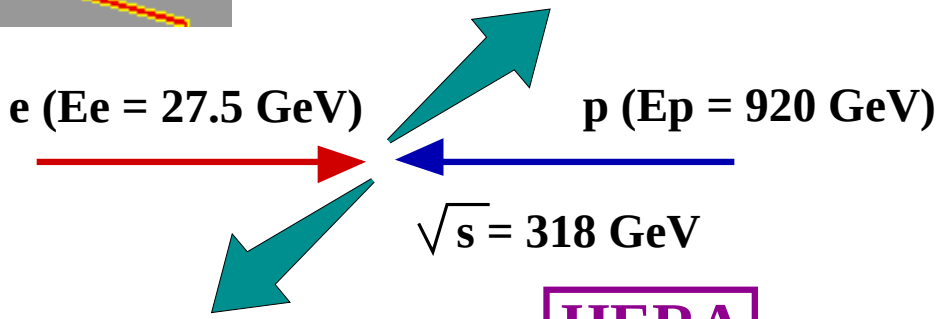
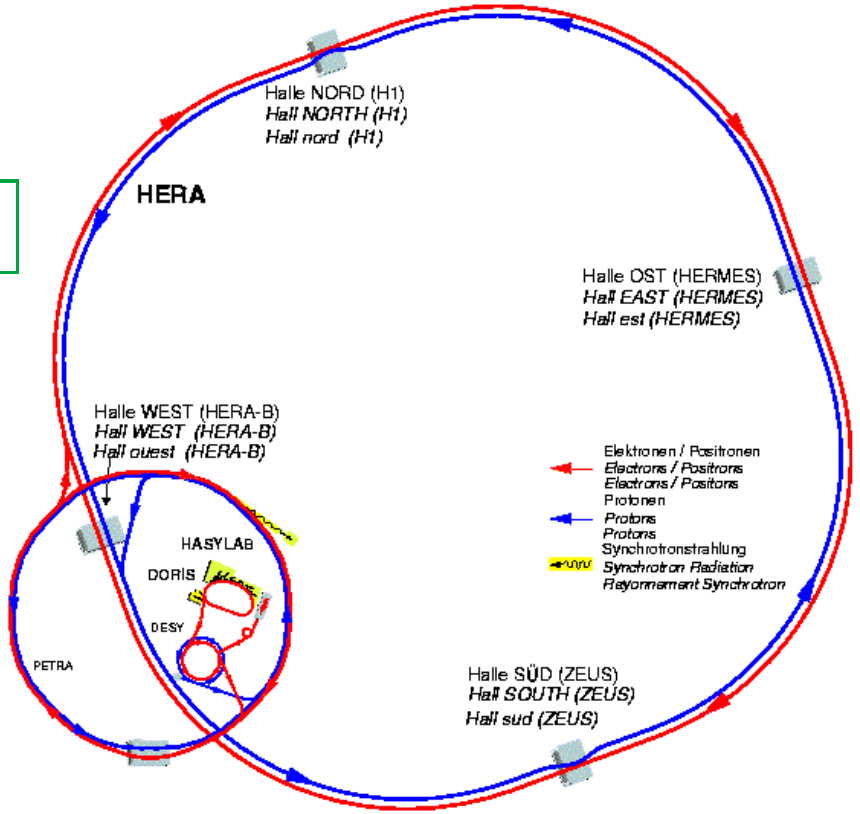
ZEUS Collaboration





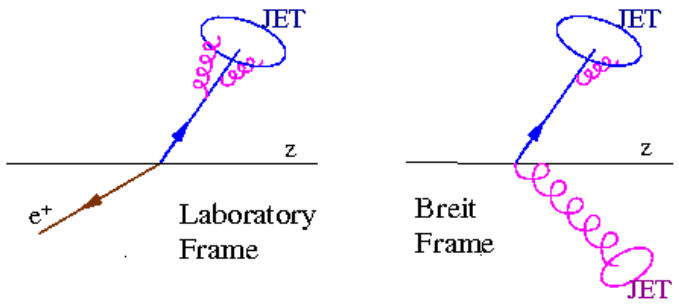
Internal Structure of Jets

- **The investigation of the internal structure of jets gives insight into the transition between a parton produced in a hard process and the experimentally observable jet of hadrons.**

- **At sufficiently high E_T^{jet}, the internal structure of jets is expected to be calculable in pQCD, since the fragmentation effects are small.**

- **Parton radiation is described in pQCD by means of the splitting funtions $P_{ab}(x, \mu)$, which give the probability of a parton b arising from a parton a with a fraction x of its momentum.**

- **$O(\alpha_s^2)$ calculations can be obtained in the laboratory frame with up to have 3 partons in one jet, which corresponds to the NLO contribution to substructure.**



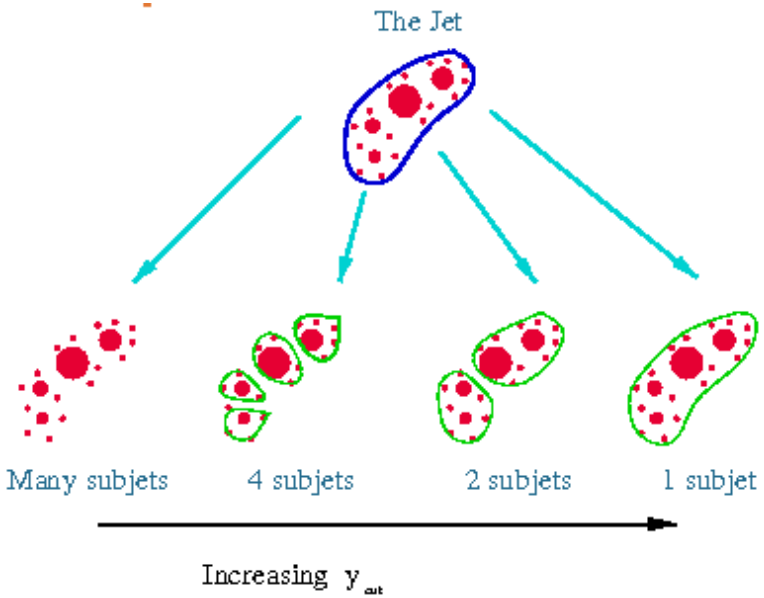
- **The internal structure of jets can be studied my means of subjets.**

- **Subjets are obtained within a jet by reapplying the k_T cluster algorithm on all the particles belonging to the jet, until for every pair of clusters the distance between them is greater than d_{cut}, with**

$$d_{cut} = y_{cut}(E_T^{jet})^2 \qquad y_{cut} = \text{resolution parameter}$$

- **The remaining clusters are called subjets.**

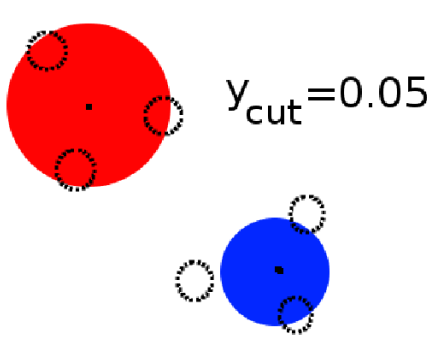
- **The subjet multiplicity depends on the value of y_{cut}**

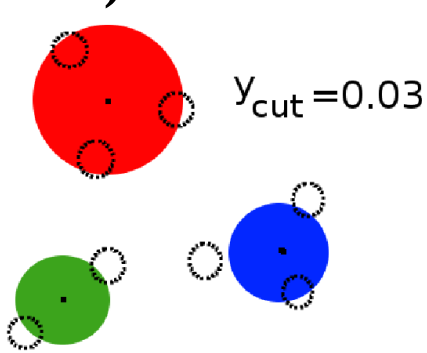


- In this analysis, jets were reconstructed in NC DIS events with $Q^2 > 125\ GeV^2$
- The jets must satisfy:

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

- We studied in detail the pattern of QCD radiation from a primary parton by measuring normalised cross sections as a function of the subjet observables in two different jet samples.
- The first sample corresponds to jets with exactly two subjets at a value of $y_{cut} = 0.05$. (82 pb^{-1} of ZEUS data)
- The second sample corresponds to jets with exactly three subjets at a value of $y_{cut} = 0.03$. (334 pb^{-1} of ZEUS data)



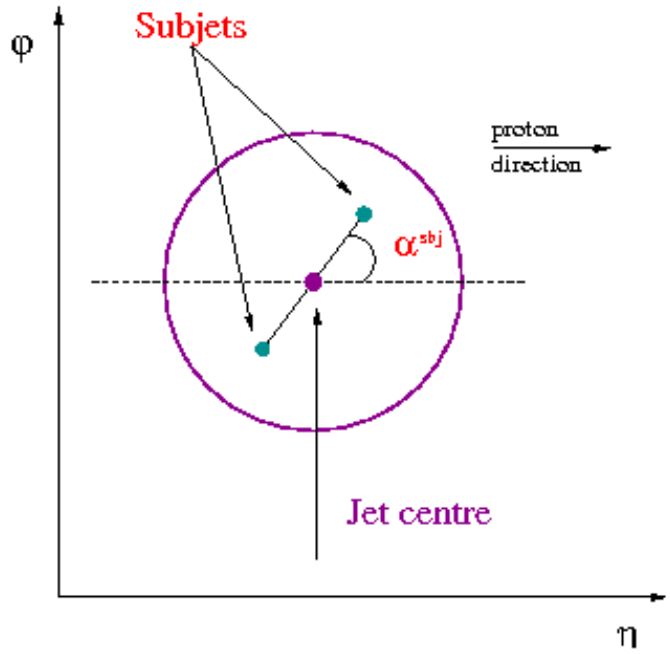


- **Measurements of normalised cross sections as functions of observables sensitive to the pattern of parton radiation:**

$$E_T^{sbj}/E_T^{jet},\ \eta^{sbj}-\eta^{jet},\ |\phi^{sbj}-\phi^{jet}| \text{ and } \alpha^{sbj}$$

and their variation with the scale by studying the dependence with:

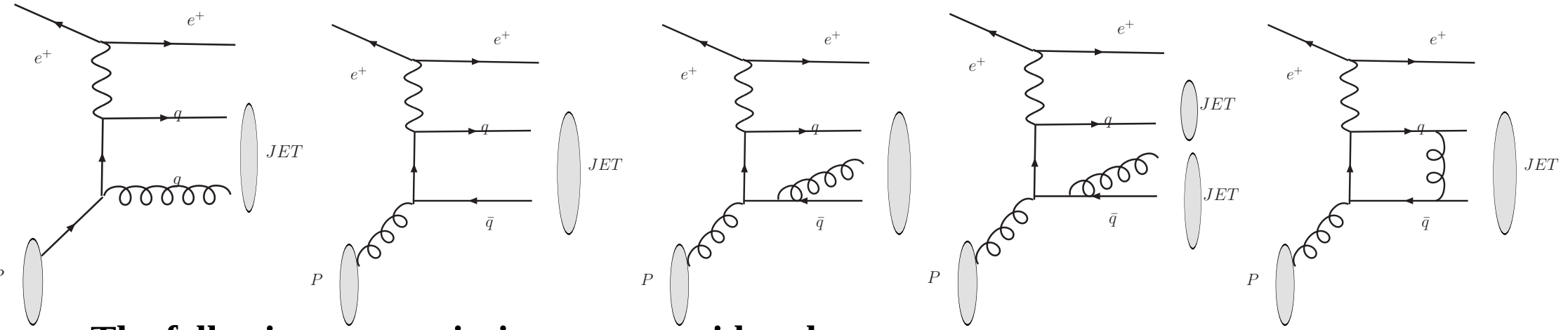
$$E_T^{jet},\ Q^2 \text{ and } x_{BJ}$$



- **The value of $y_{cut}=0.05$ and $y_{cut}=0.03$ chosen are a compromise between statistics,resolution and hadronisation corrections.**

NLO CALCULATIONS

- **Next to leading order calculations were performed using DISENT**
- **Some of the contributing diagrams are**



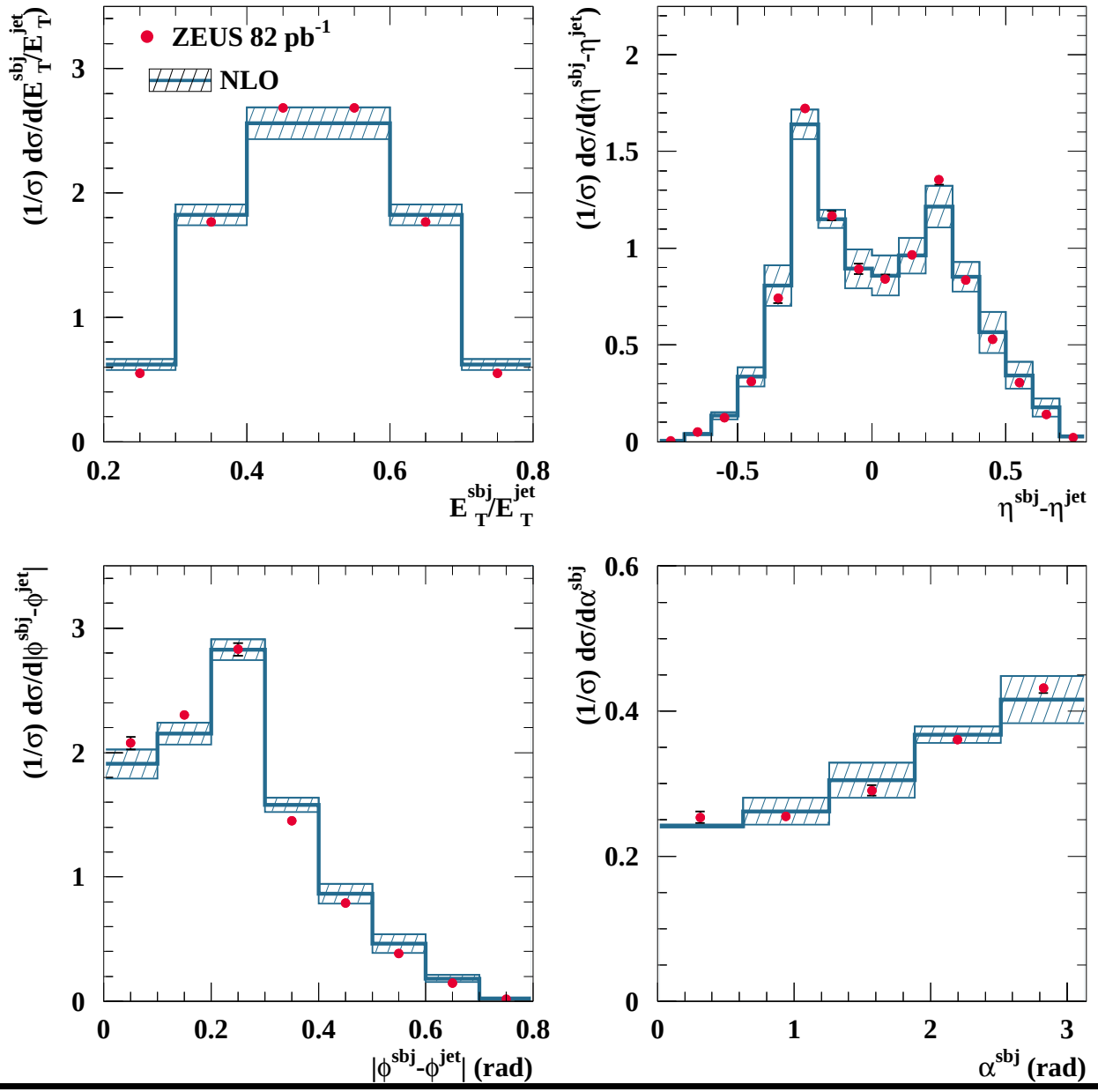
- **The following uncertainties were considered:**
  - → Uncertainty in the modelling of the parton shower
  - → Contribution of higher-order terms
  - → Choice of μ_F
  - → Uncertainty in PDFs
  - → Uncertainty in α_s

DATA vs NLO: RESULTS

Two-subjet jets

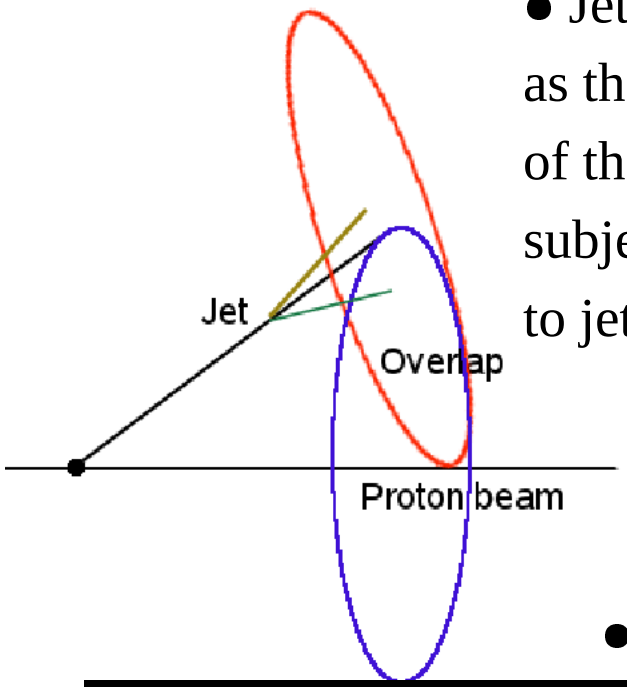
- Normalised cross sections for:
  - E_T^{sbj} / E_T^{jet}
  - $\eta^{sbj} - \eta^{jet}$
  - $|\phi^{sbj} - \phi^{jet}|$
  - α^{sbj}

- NLO calculations give an adequate prediction of the data

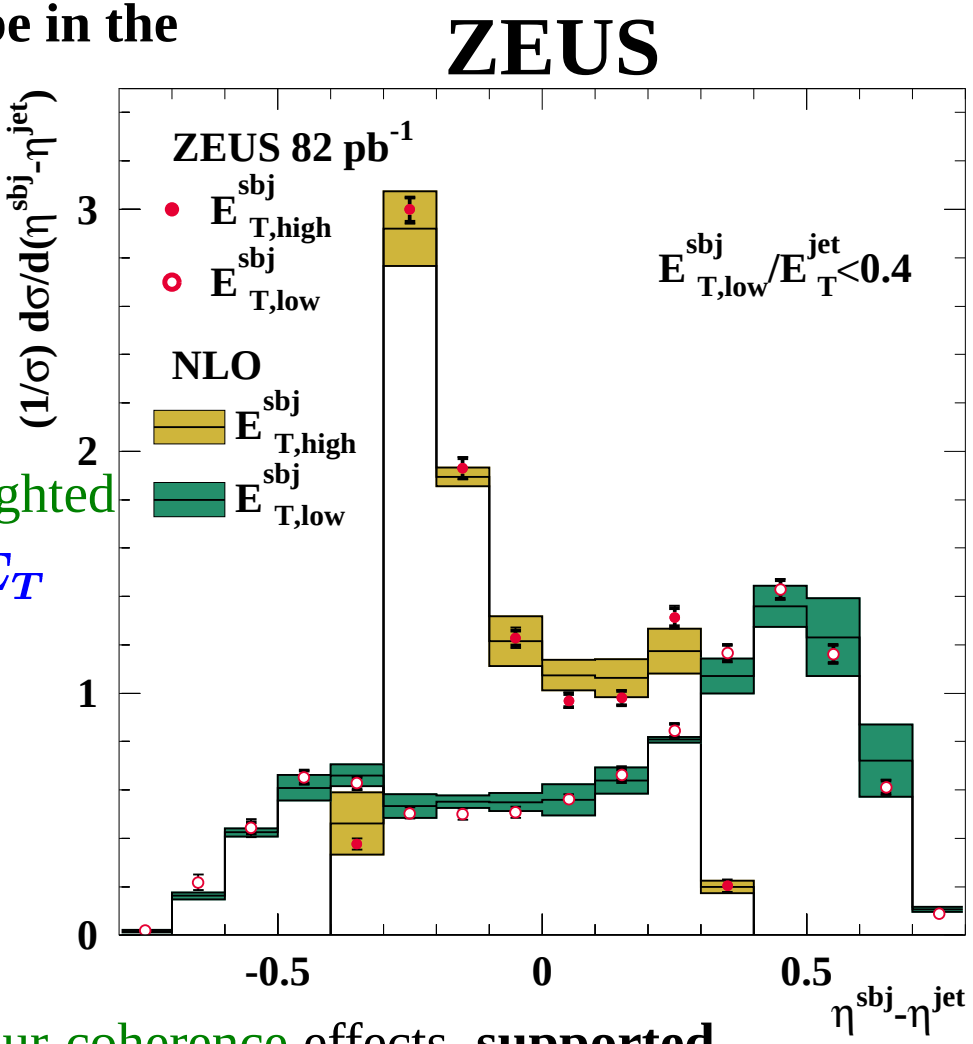


- **We also study the coherence effects between initial and final states parton radiation.**

- **Soft emissions (low-E_T subjets) will tend to be in the direction of the proton beam.**
- **Highest E_T subjet expected to be in the rear part of the jet.**



- Jet axis is reconstructed as the transverse-energy-weighted of the subjet axes. Highest E_T subjet tends to be closer to jet axis.



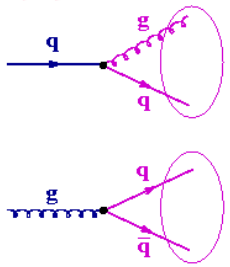
- Expectation of the colour-coherence effects **supported**.

DATA vs NLO: RESULTS

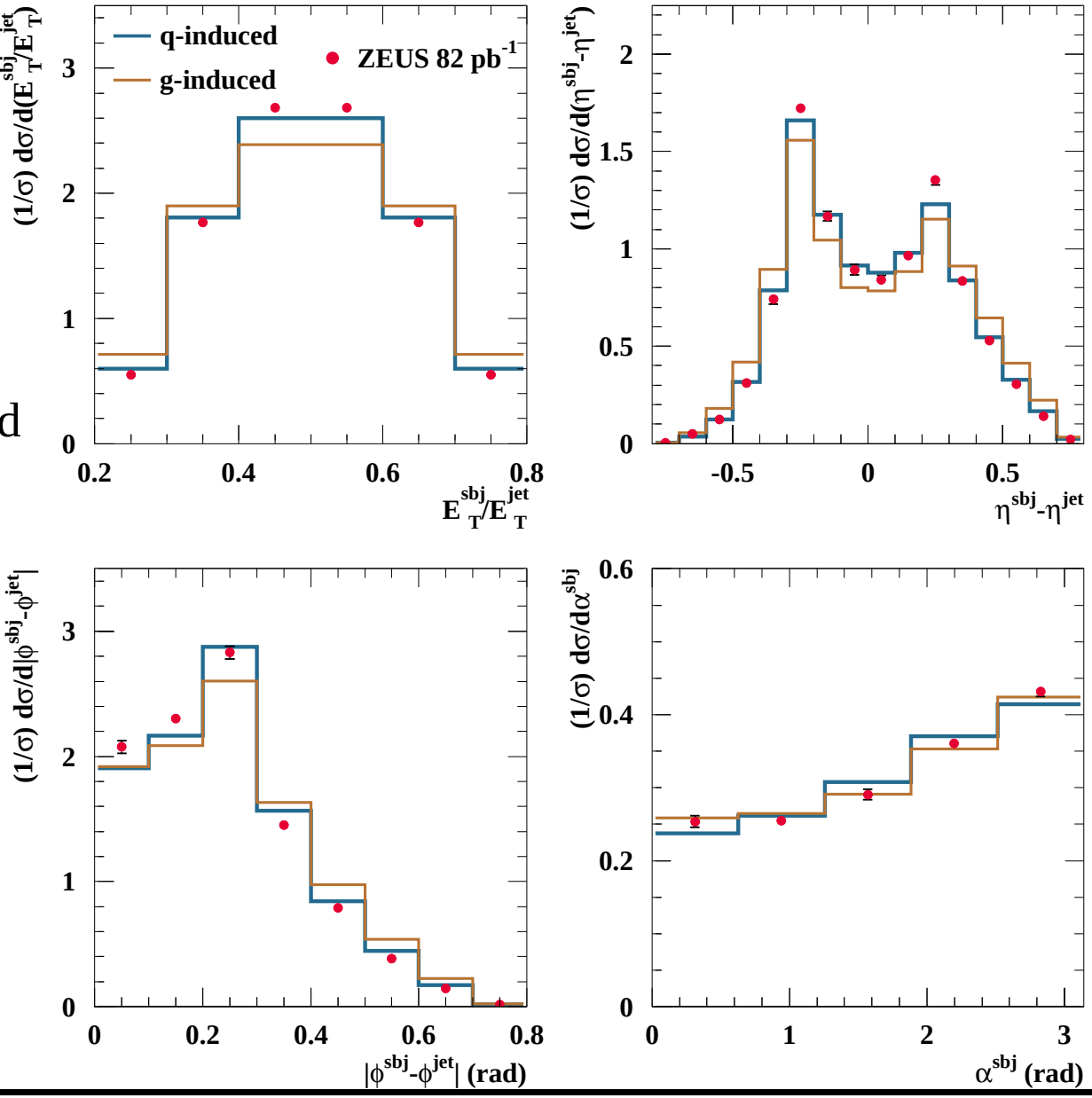
- Normalised cross sections for:
  - E_T^{sbj} / E_T^{jet}
  - $\eta^{sbj} - \eta^{jet}$
  - $|\phi^{sbj} - \phi^{jet}|$
  - α^{sbj}

  versus the **gluon-** and **quark-** induced processes separately.

- The $O(\alpha_S^2)$ prediction: 82% of **q-induced** and 18% of **g-induced**
- The data are better described by the prediction of the **q-induced** processes.



ZEUS



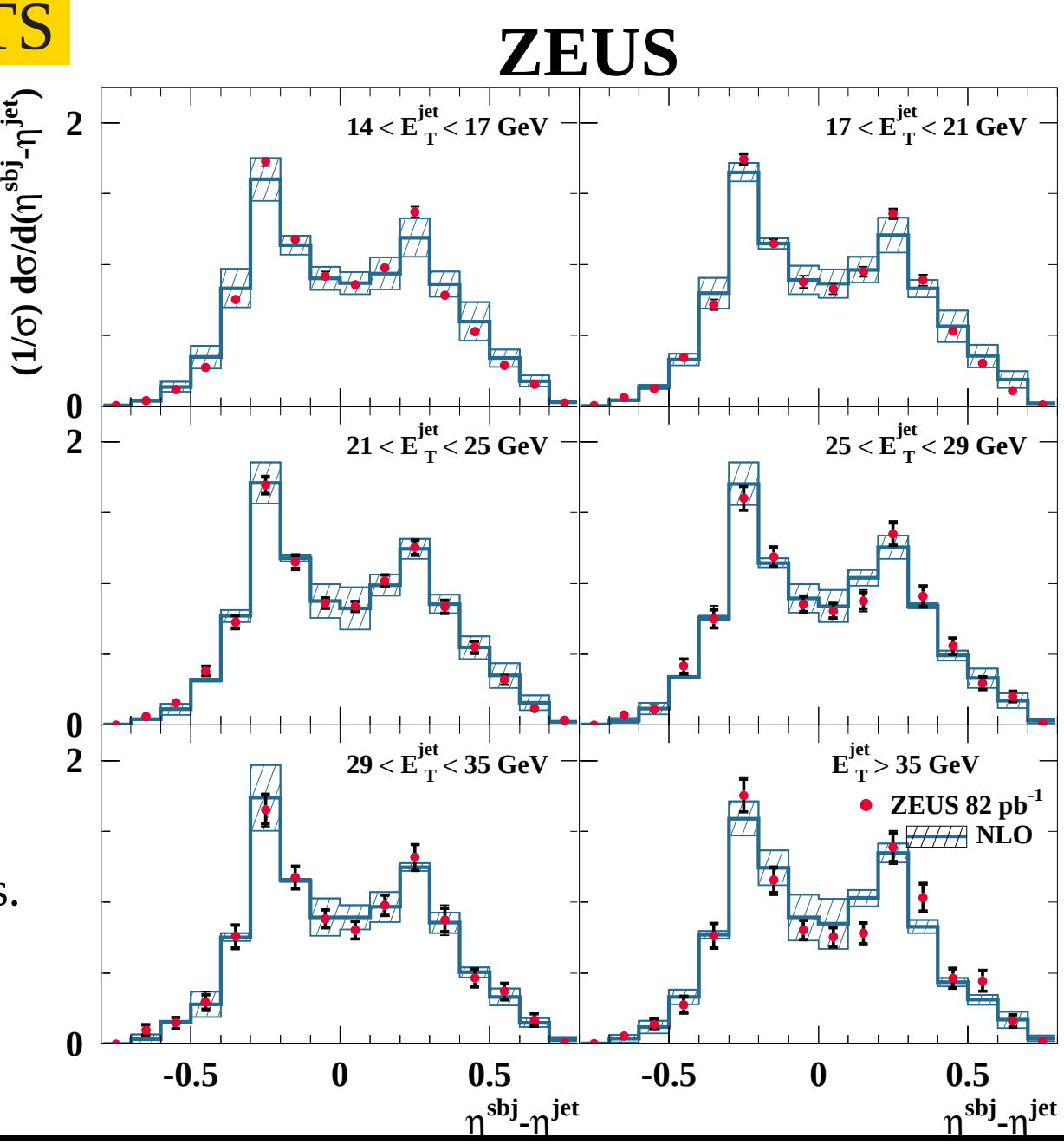
DATA vs NLO: RESULTS

Two-subjet jets

Dependence with E_T^{jet}

- Data have similar shape for all E_T regions, which agrees with the expected scaling behaviour of the splitting functions.

- These features are reasonably reproduced by the NLO calculations.



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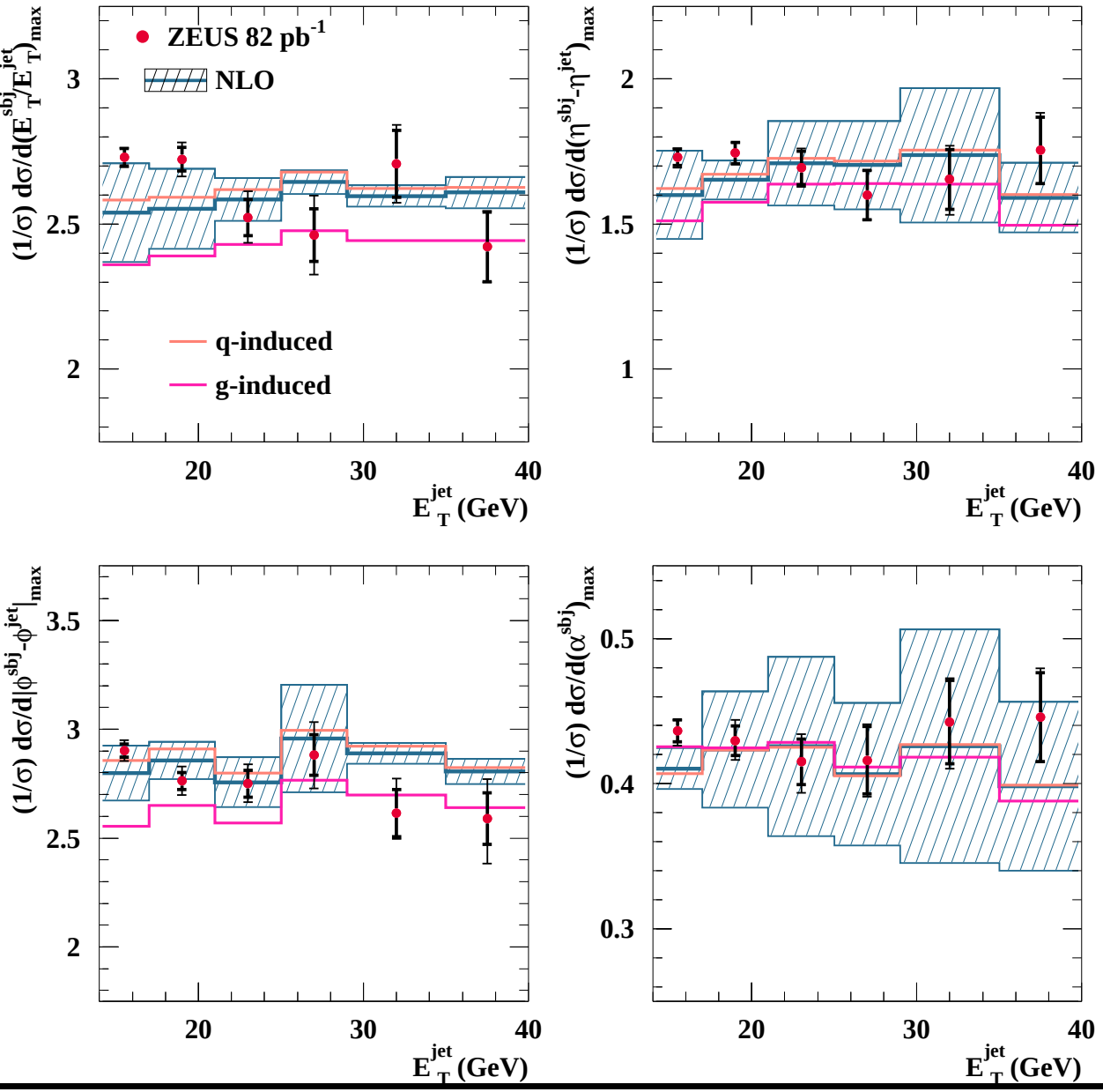


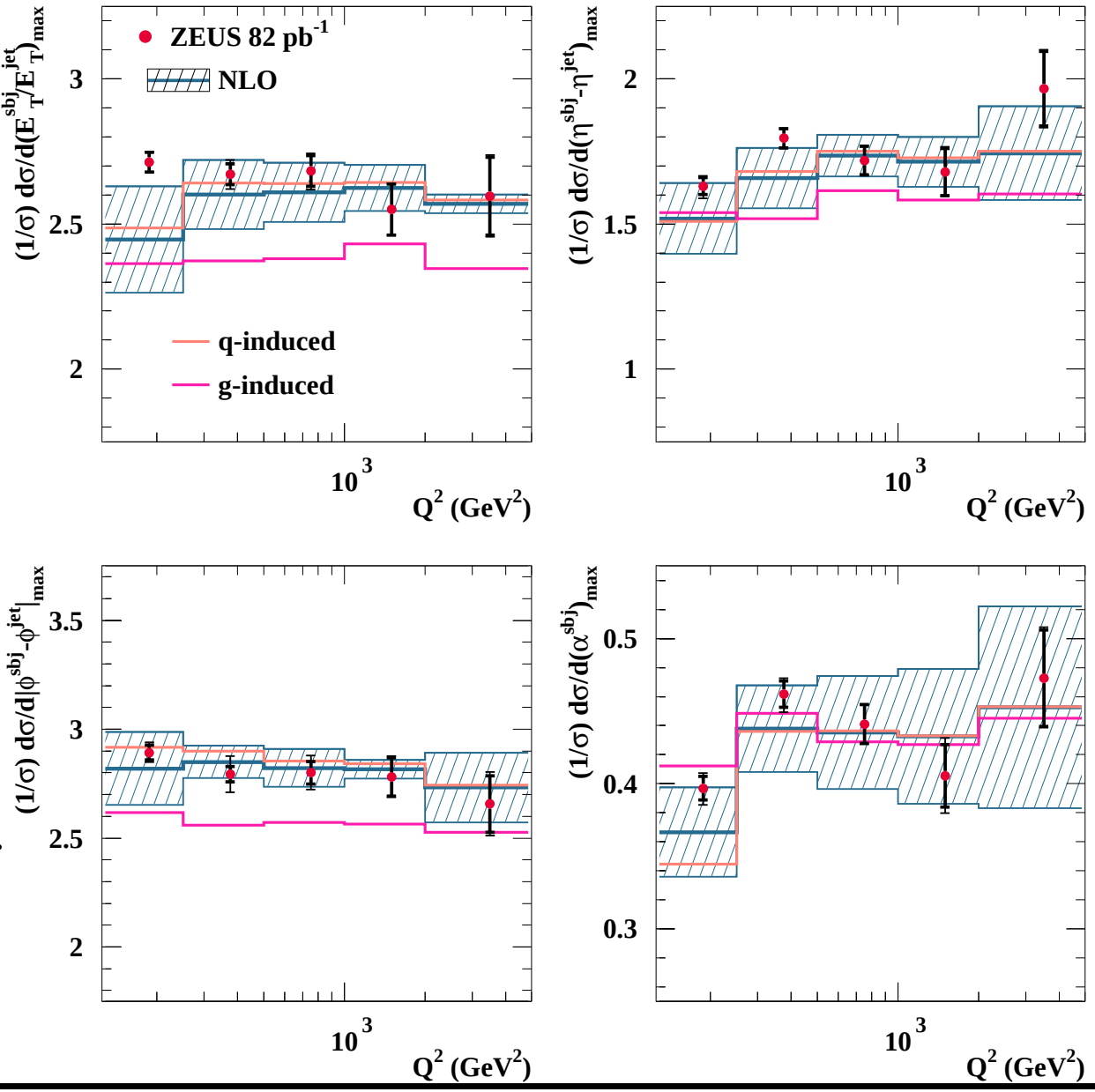
DATA vs NLO: RESULTS

Two-subjet jets

Dependence with Q^2

- fraction of gluon-induced events varies from **32%** in the first bin to **14%** in the other regions.
- At low Q^2 scaling violations are more prominent.
- These features are reasonably reproduced by the NLO calculations.

ZEUS

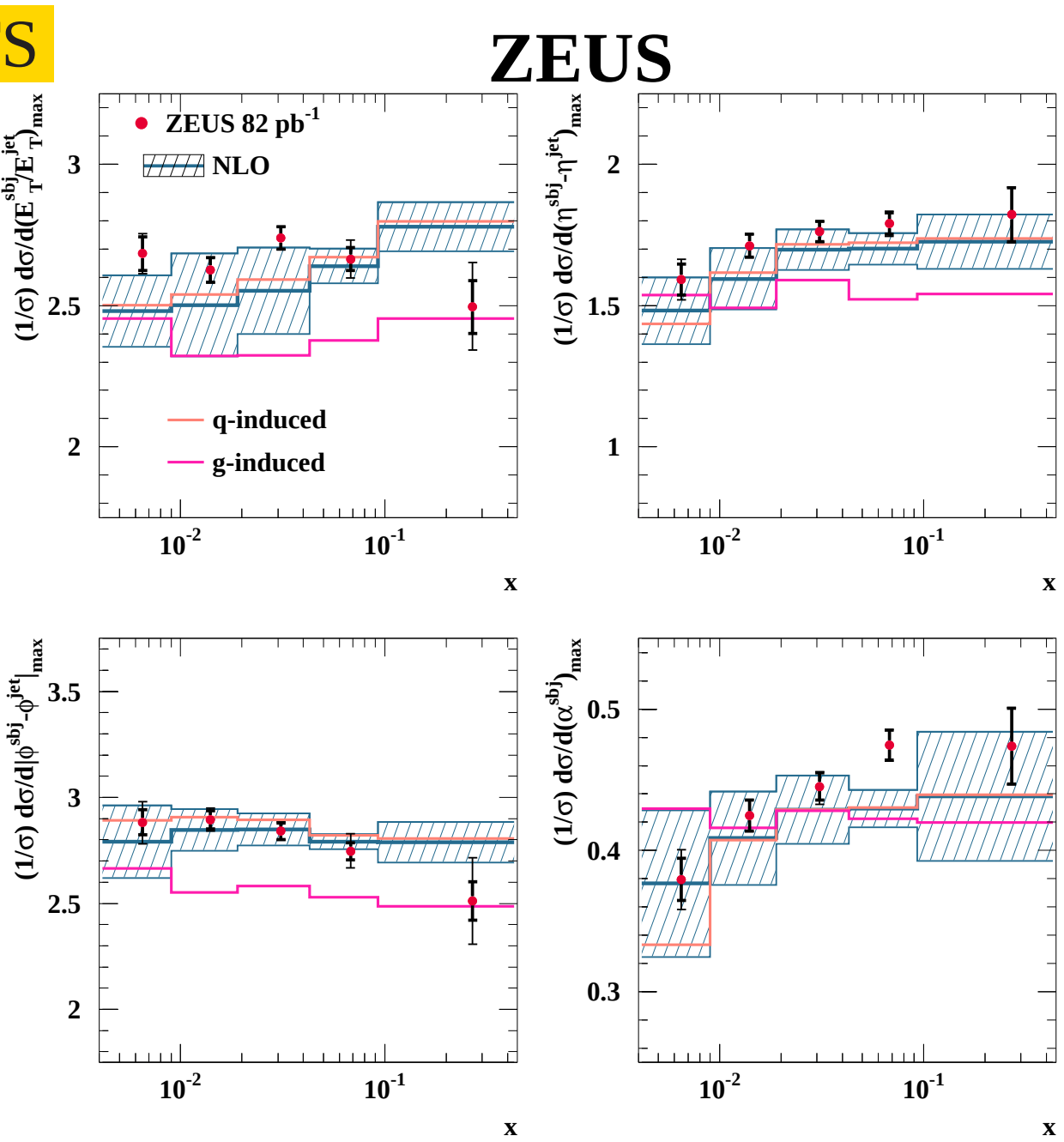


DATA vs NLO: RESULTS

Two-subjet jets

Dependence with x_{BJ}

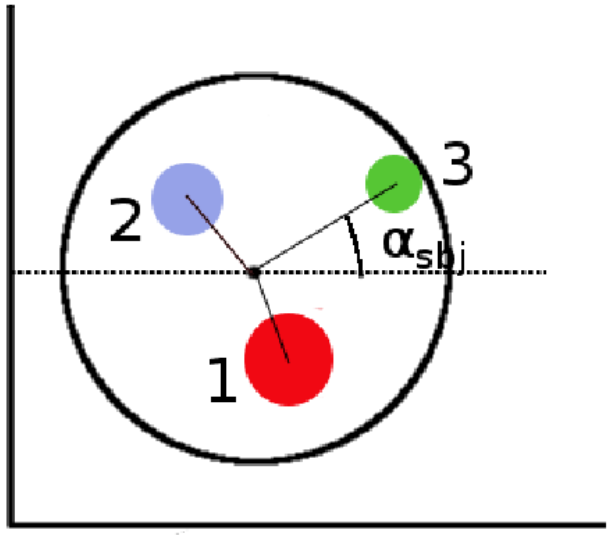
- Data have similar shape for all x_{BJ} regions, which agrees with the expected scaling behaviour of the splitting functions.
- At low x_{BJ} scaling violations are more prominent.
- Similar features as in Q^2



Three-subjet jet structure

● **We now extend our studies of jet substructure by measuring subjet cross sections with respect to the variables:**

→ α^{sbj} **: The angle, as viewed from the jet centre in the** $\eta - \phi$ **plane, between the lowest** E_T **subjet and the proton beam direction.**

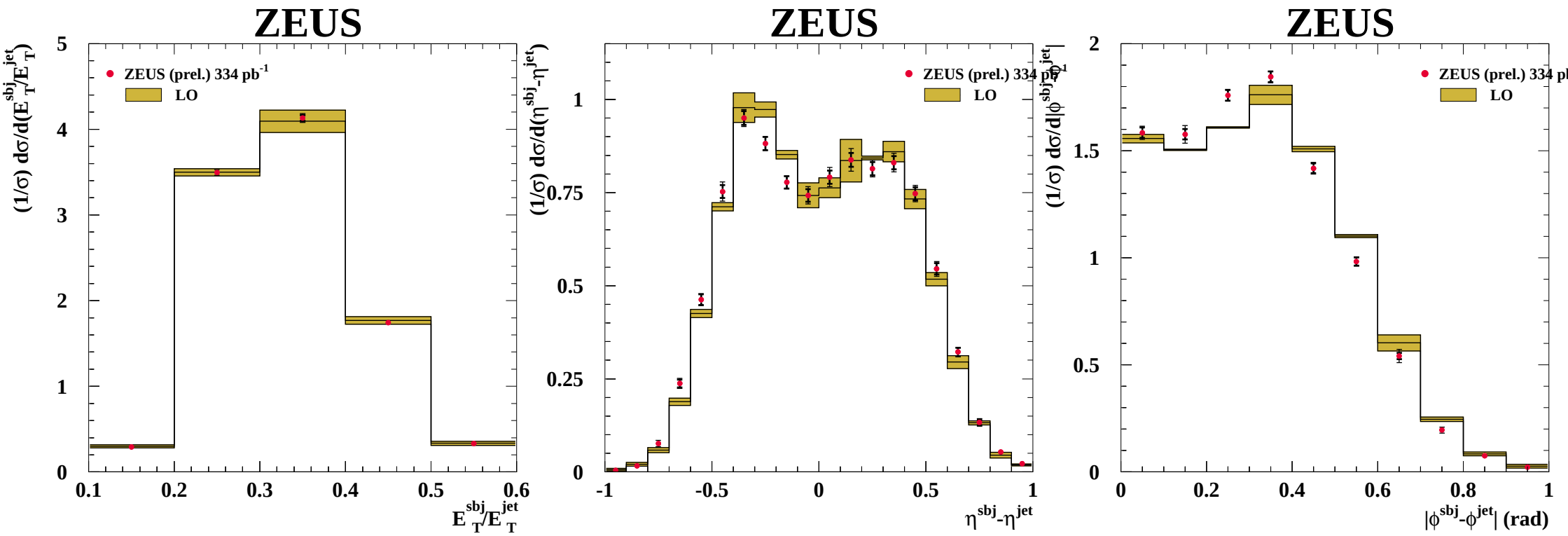


DATA vs LO: RESULTS

- Normalised cross sections for:

E_T^{sbj}/E_T^{jet}, $\eta^{sbj} - \eta^{jet}$, $|\phi^{sbj} - \phi^{jet}|$

Three-subjet jets at $y_{cut} = 0.03$



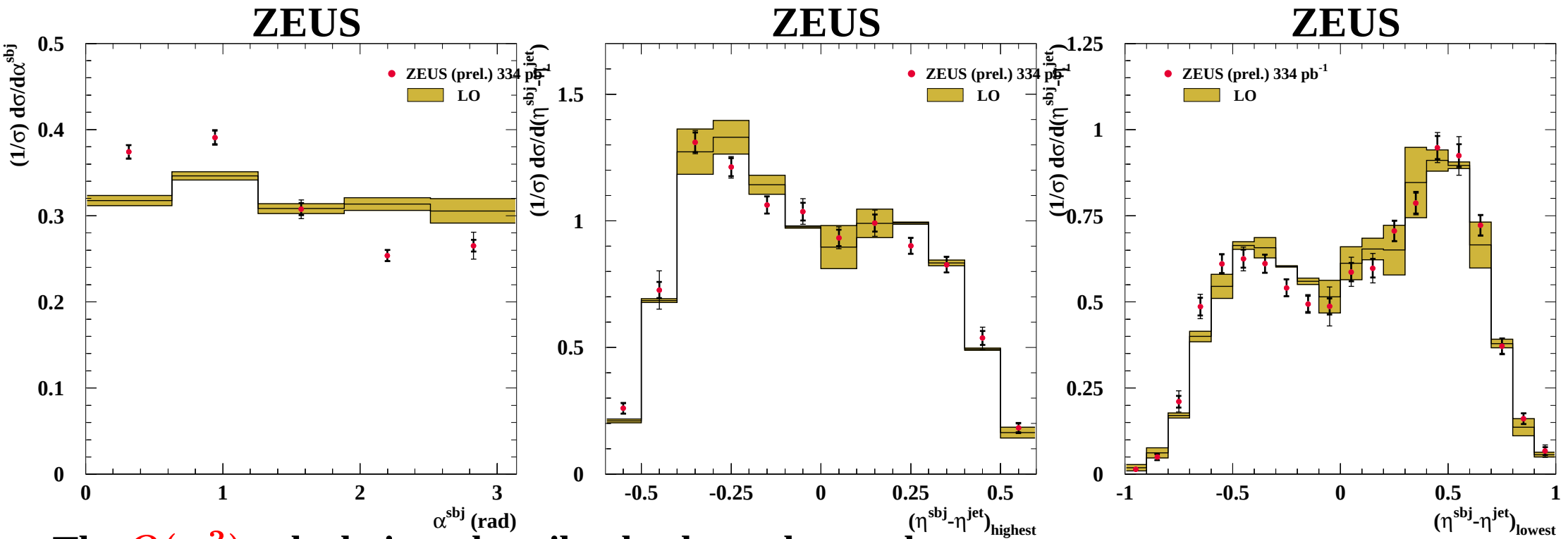
The $O(\alpha_s^2)$ calculations describe the data adequately.

DATA vs LO: RESULTS

- Normalised cross sections for:

α^{sbj}, $\eta^{sbj}_{high} - \eta^{jet}$, $\eta^{sbj}_{low} - \eta^{jet}$

Three-subjet jets at $y_{cut} = 0.03$



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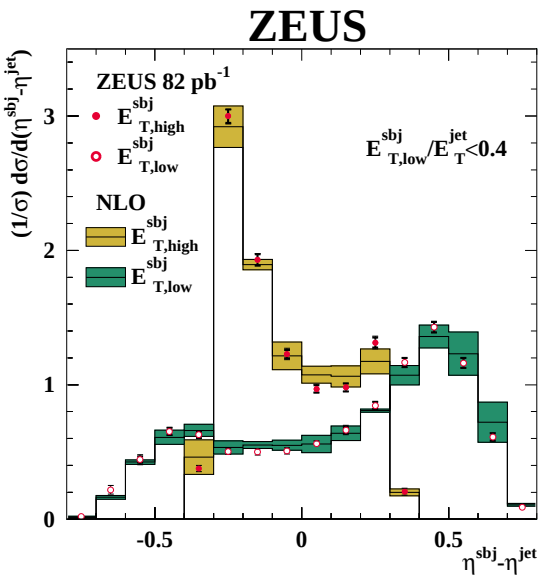
CONCLUSIONS



- The data show:
  -Subjets tend to have similar transverse energies.
  -The lowest E_T subjet tends to be in the forward direction.
  This supports the presence of **colour coherence effects** between inital and final states.
- In the two-subjet sample:
  -A weak dependence on E_T^{jet} is observed, in agreement with the expected scaling behaviour of the splitting functions.
  -At low Q^2 and low x some differences are observed, which can be attributed to scaling violations.
- This features about the pattern of QCD radiation, as well as the evolution of the cross sections with the scale are **reasonably** well described by the NLO calculations.
- As well, the data are better described by the calculations for jets arising from a quark-gluon pair.