

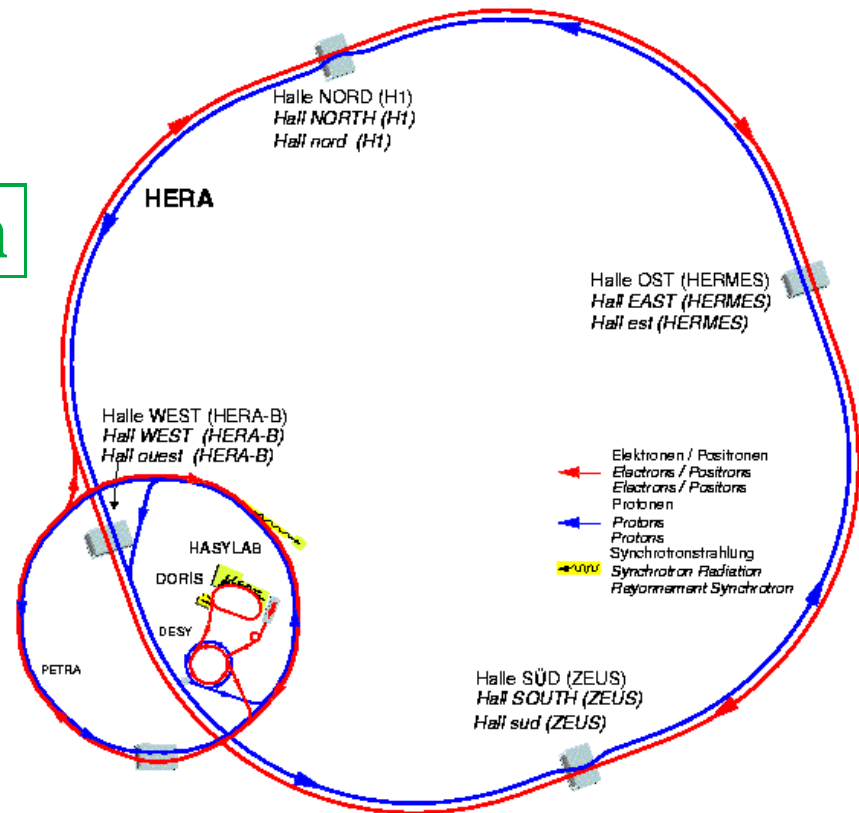
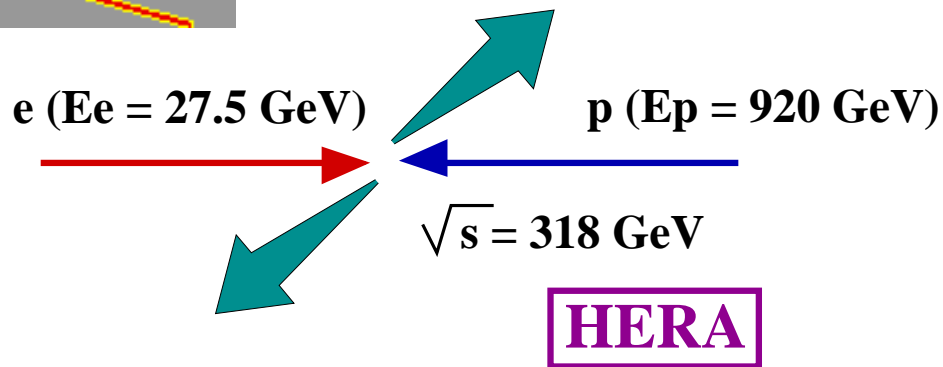
DIS09 26-30 April, MADRID

Subjet Distributions in NC DIS

Elias Ron (Universidad Autónoma de Madrid, Spain)

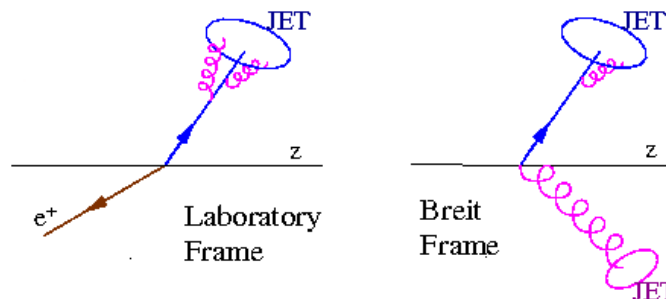


ZEUS Collaboration



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 functions $P_{ab}(x, \mu)$, 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**.

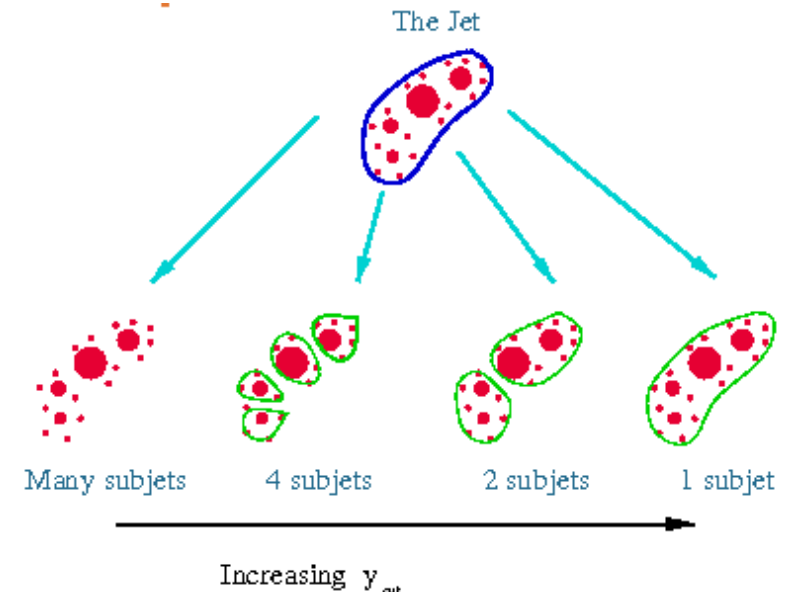


- The internal structure of jets can be studied by means of **subjects**.
- Subjects are obtained within a jet by **reapplying the k_T cluster algorithm** on all the particles belonging to the jet, until for every pair of clusters the distance between them is greater than d_{cut} , with

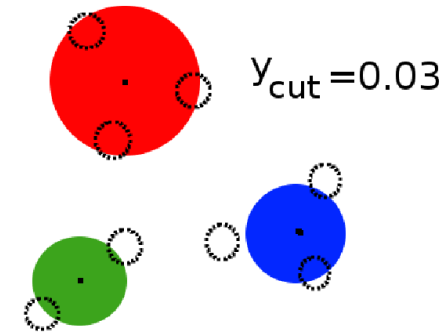
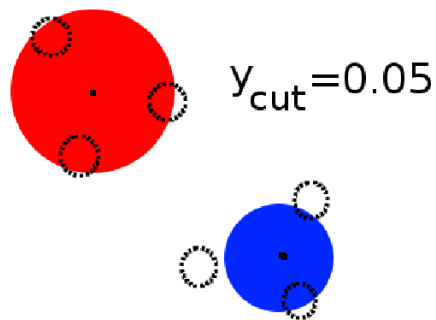
$$d_{cut} = y_{cut} (E_T^{jet})^2$$

y_{cut} = resolution parameter

- The remaining clusters are called **subjects**.
- The **subject multiplicity** depends on the value of y_{cut}



- In this analysis, jets were reconstructed in NC DIS events with $Q^2 > 125 \text{ GeV}^2$
- The jets must satisfy:
 $E_T^{jet} > 14 \text{ GeV}$ 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 **subject observables** in two different jet samples.
- The first sample corresponds to jets with **exactly two subjects** at a value of $y_{cut} = 0.05$. (82 pb^{-1} of ZEUS data)
- The second sample corresponds to jets with **exactly three subjects** at a value of $y_{cut} = 0.03$. (334 pb^{-1} of ZEUS data)



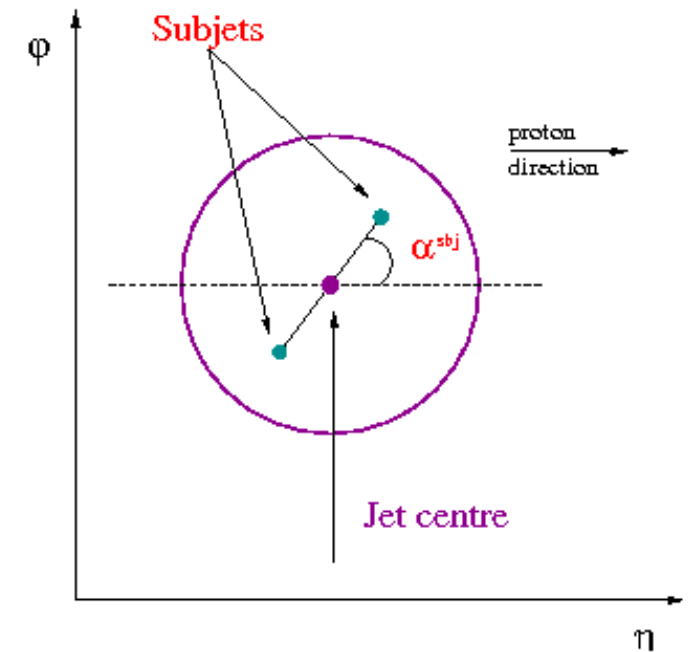
- Measurements of normalised cross sections as functions of observables **sensitive** to the **pattern of parton radiation**:

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

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

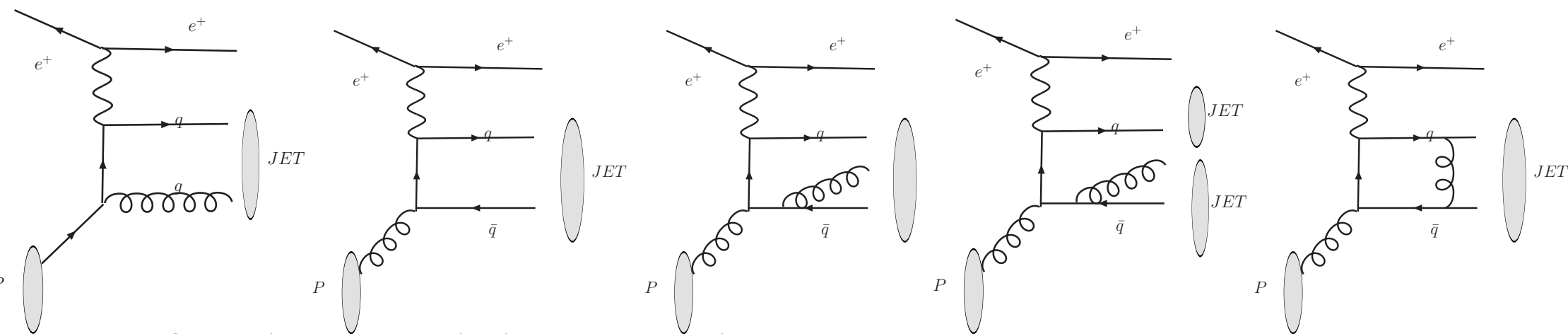
$$E_T^{jet}, Q^2 \text{ and } x_{BJ}$$

- 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:

$$-E_T^{sbj} / E_T^{jet}$$

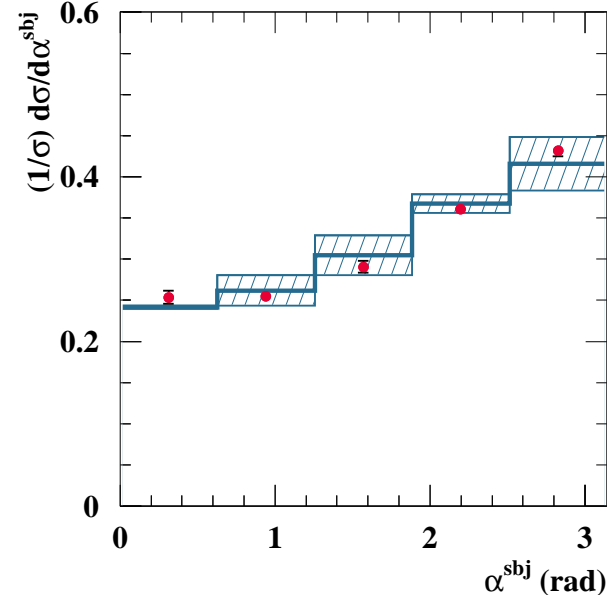
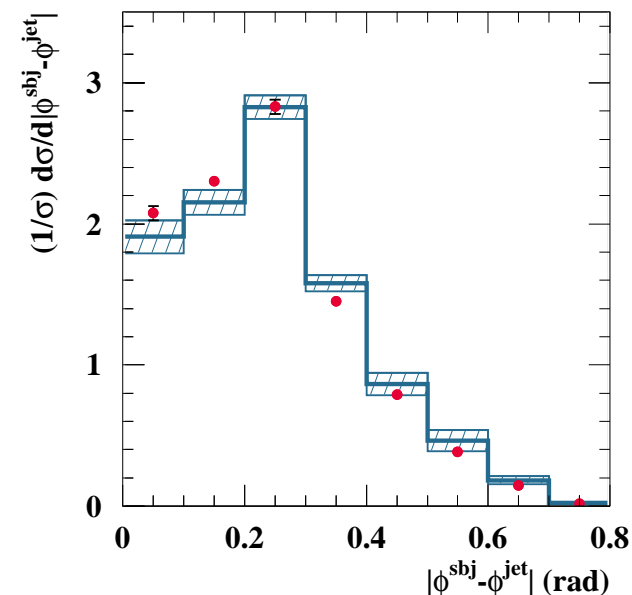
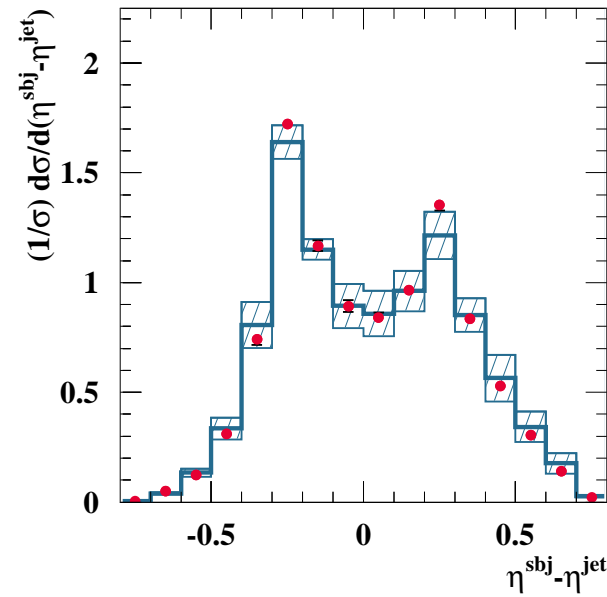
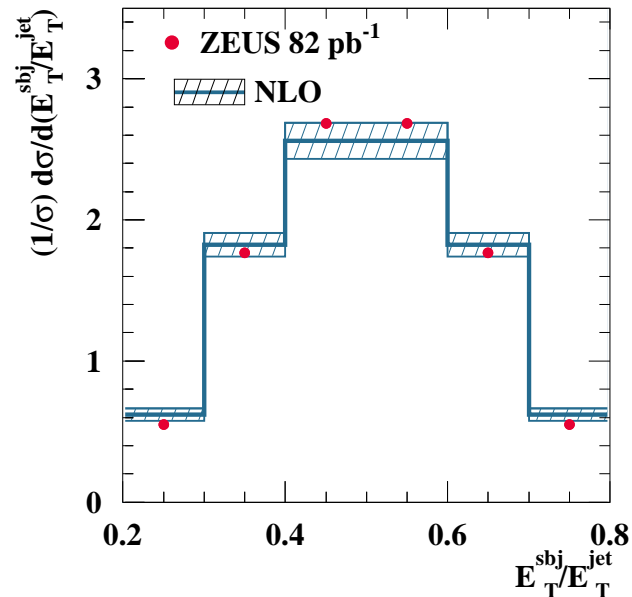
$$-\eta^{sbj} - \eta^{jet}$$

$$-|\phi^{sbj} - \phi^{jet}|$$

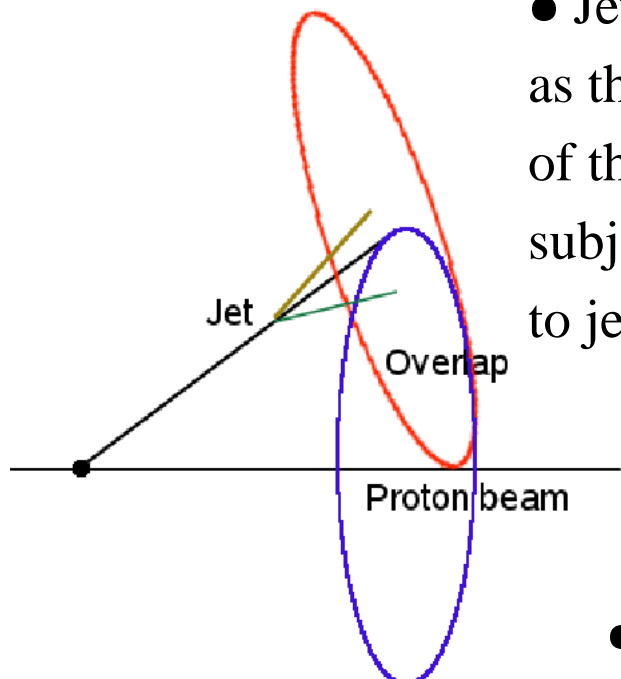
$$-\alpha^{sbj}$$

- NLO calculations give an adequate prediction of the data

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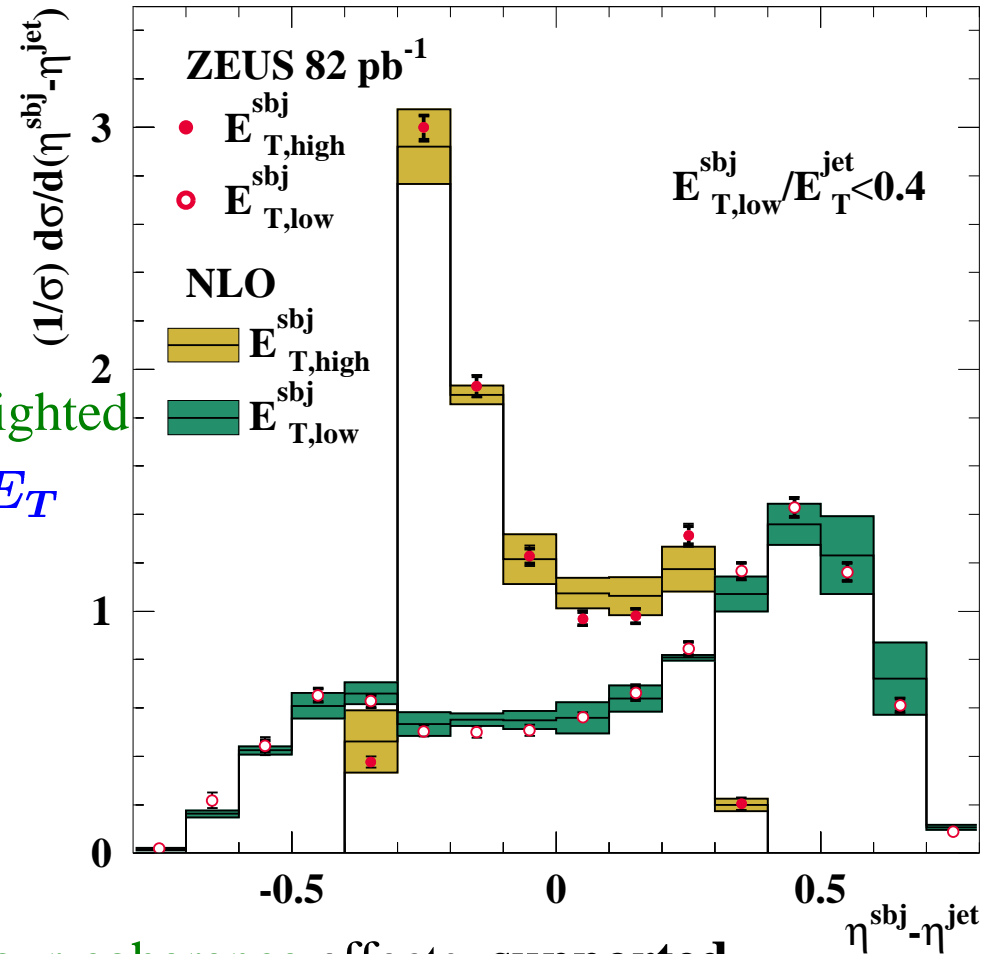
- We also study the **coherence effects** between initial and final states parton radiation.
- Soft emissions (low- E_T subjects) will tend to be in the direction of the **proton beam**.
- Highest E_T subject expected to be in **the rear part** of the jet.



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

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

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DATA vs NLO: RESULTS

- Normalised cross sections for:

$$-E_T^{sbj} / E_T^{jet}$$

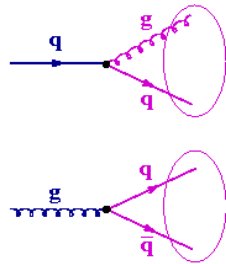
$$-\eta^{sbj} - \eta^{jet}$$

$$-|\phi^{sbj} - \phi^{jet}|$$

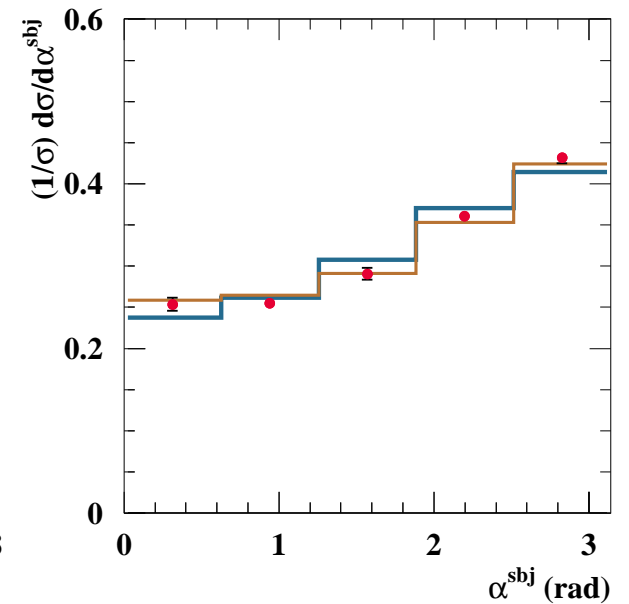
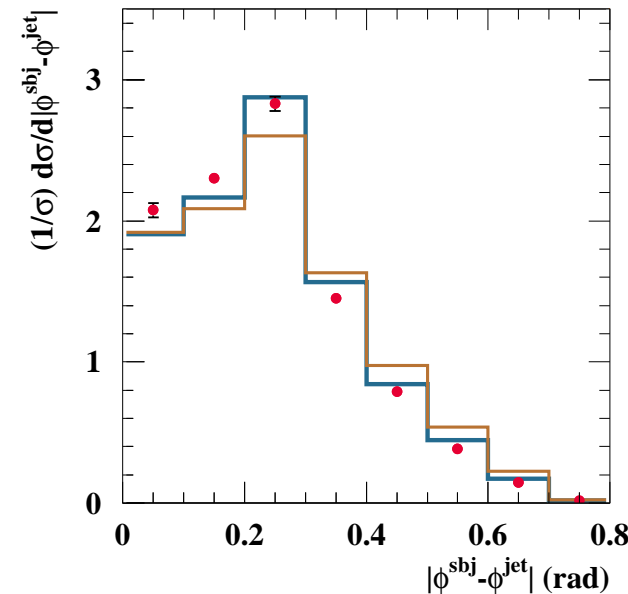
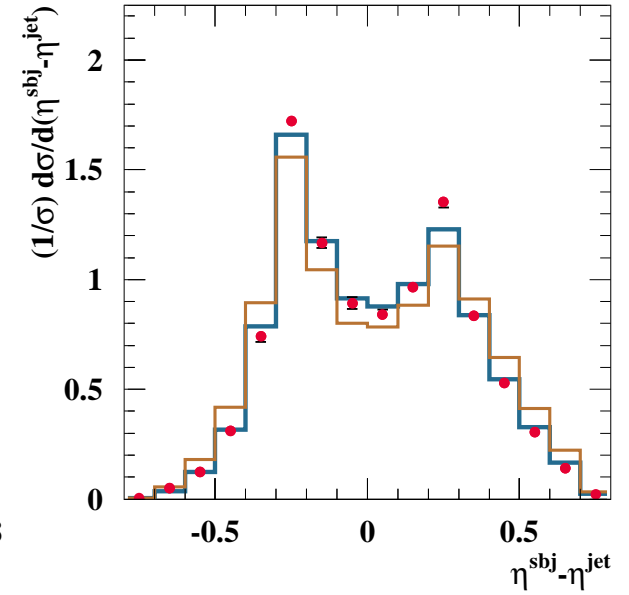
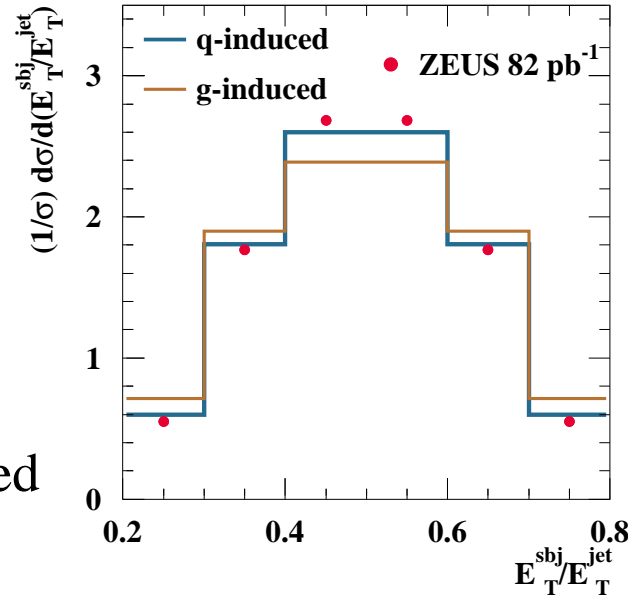
$$-\alpha^{sbj}$$

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.



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DATA vs NLO: RESULTS

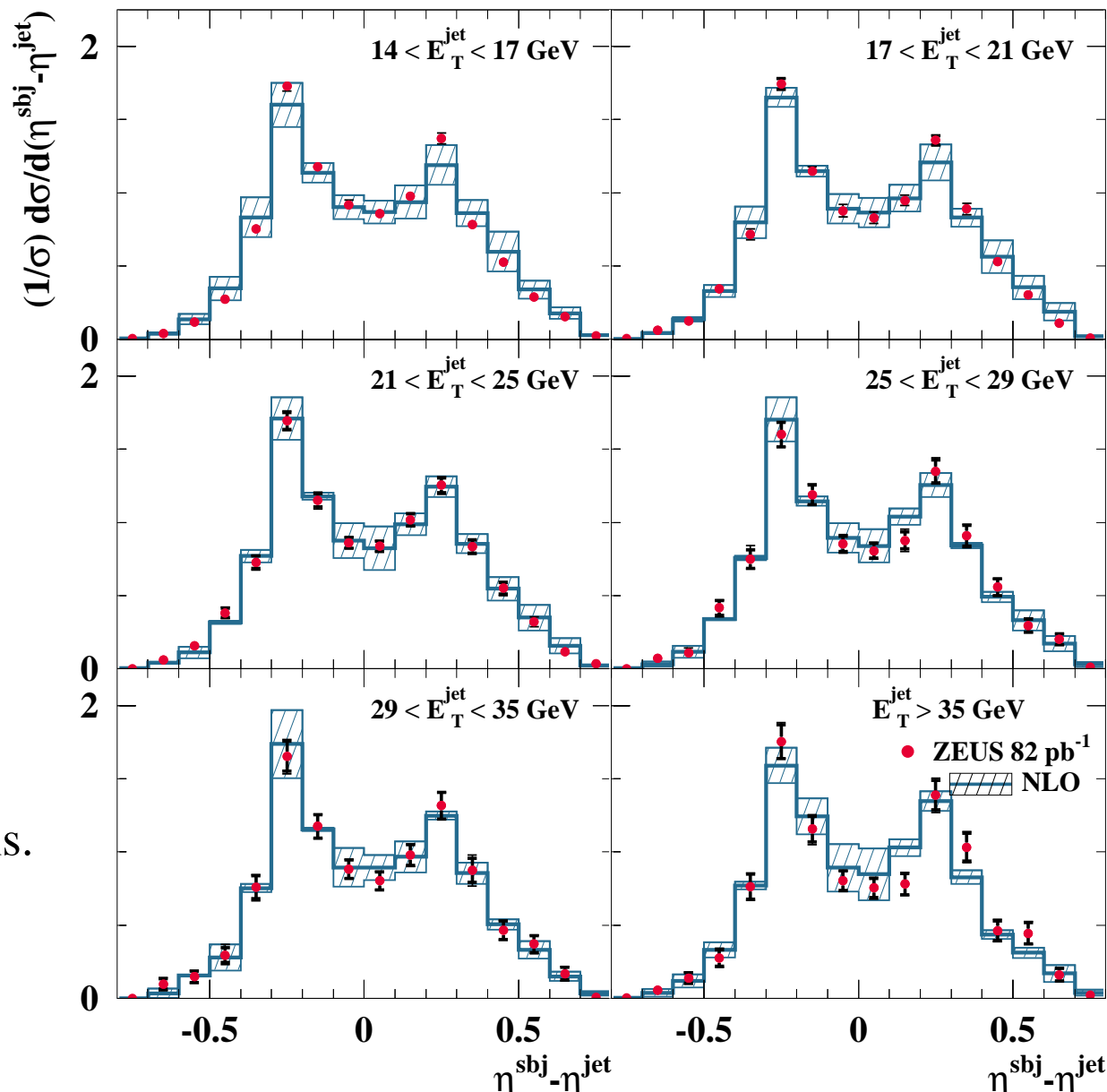
Two-subjet jets

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

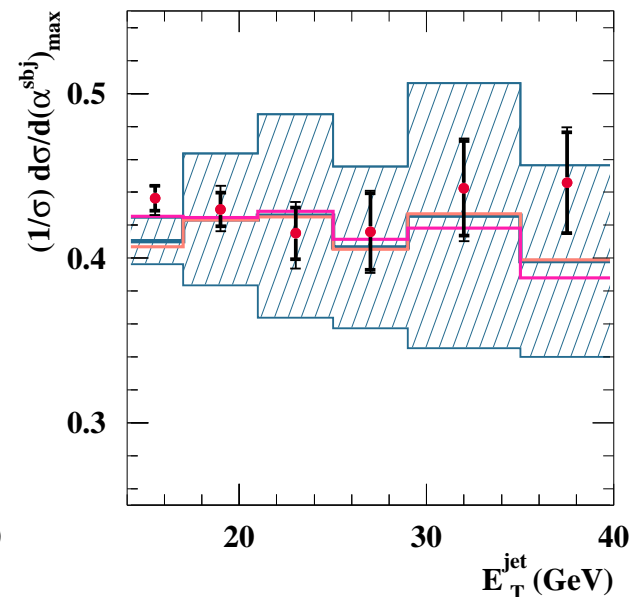
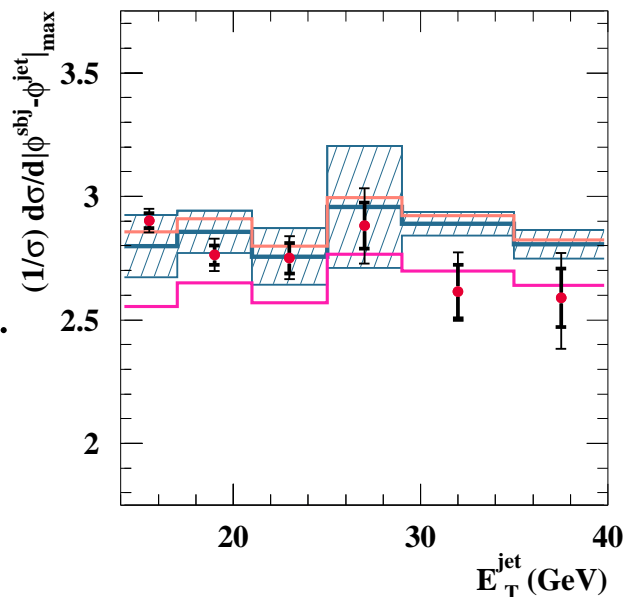
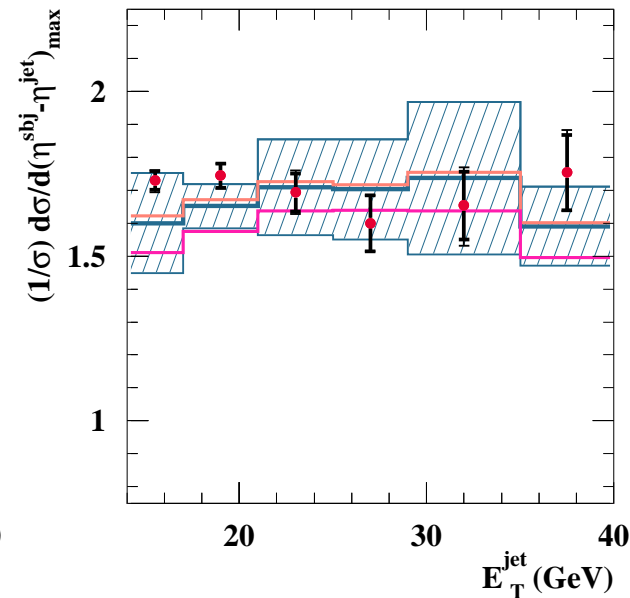
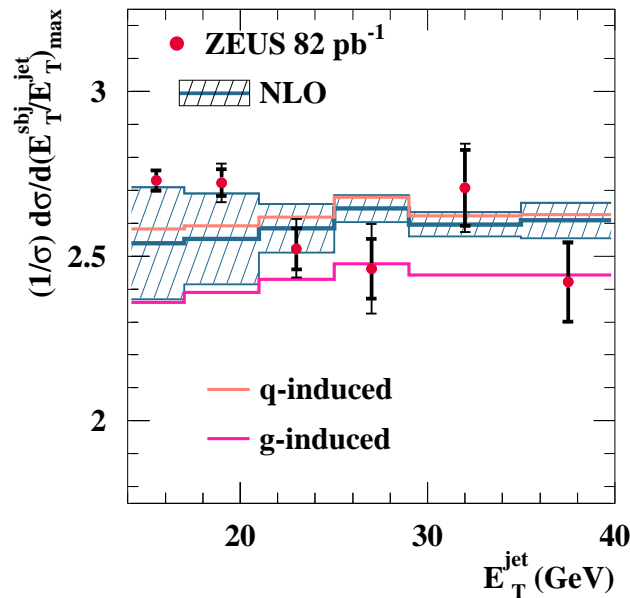
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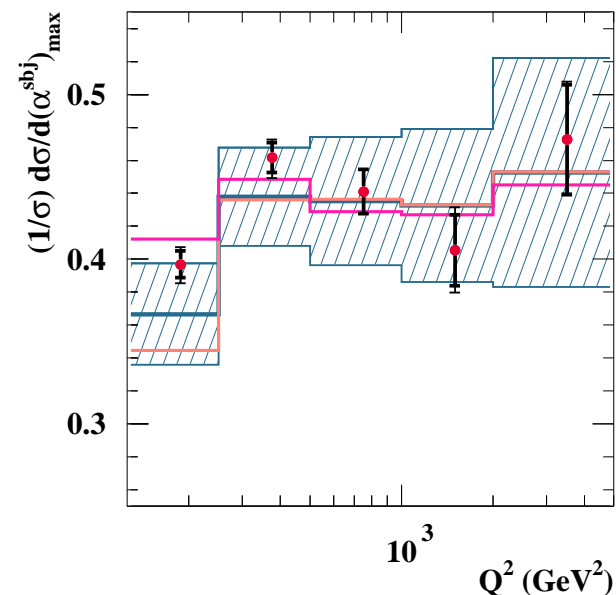
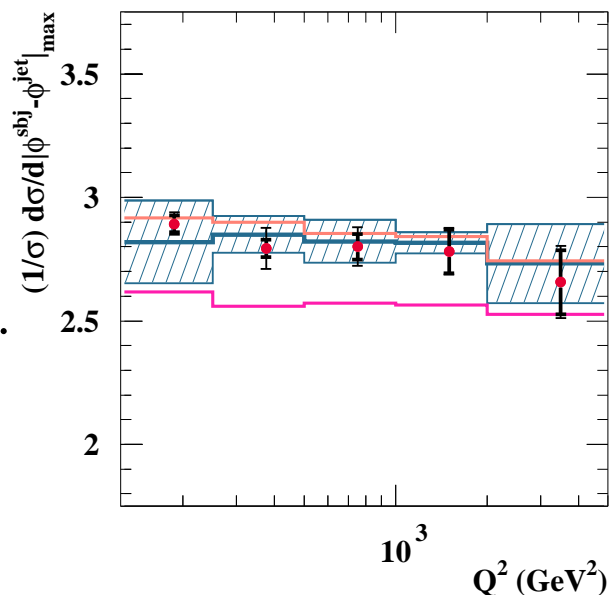
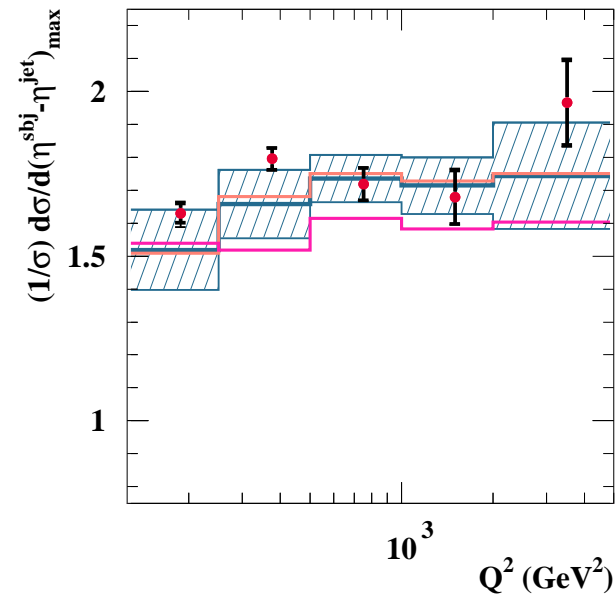
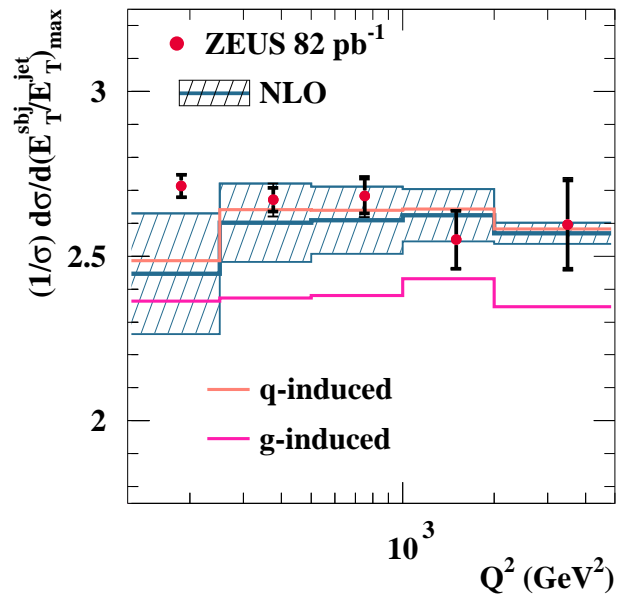
DATA vs NLO: RESULTS

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.

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DATA vs NLO: RESULTS

Two-subjet jets

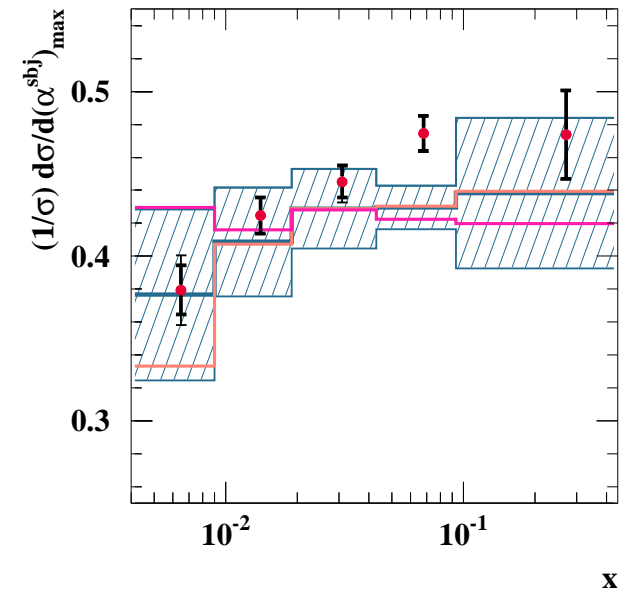
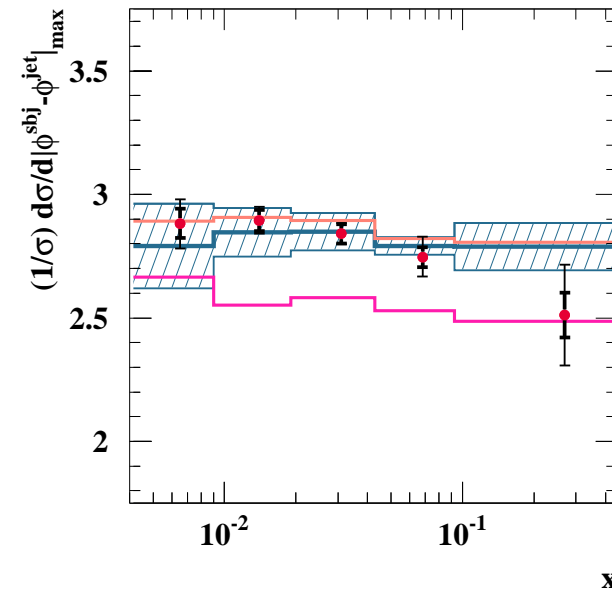
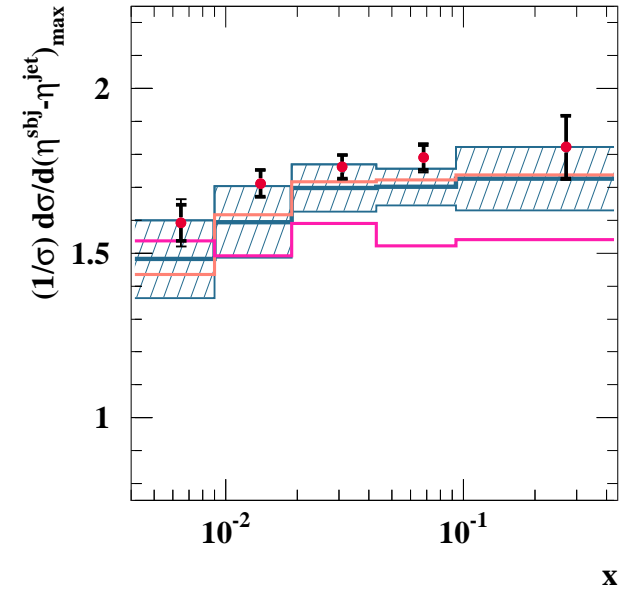
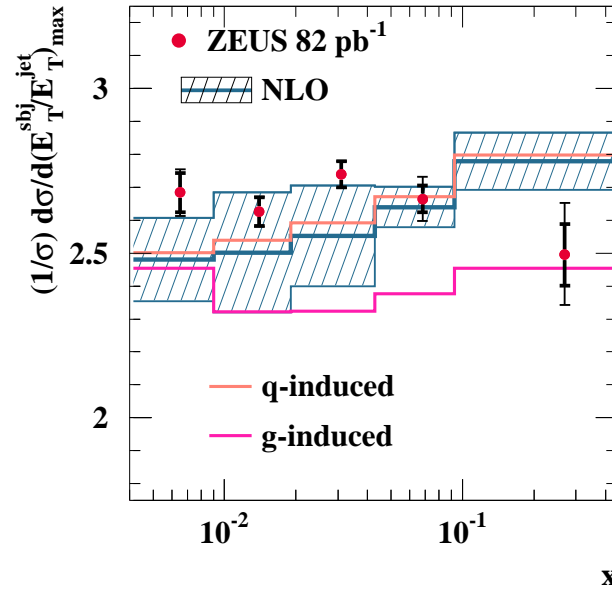
Dependence with x_{BJ}

- 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

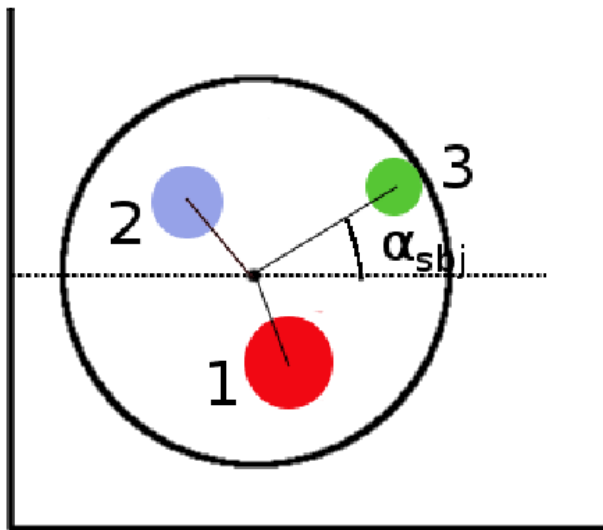
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Three-subjet jet structure

- 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.

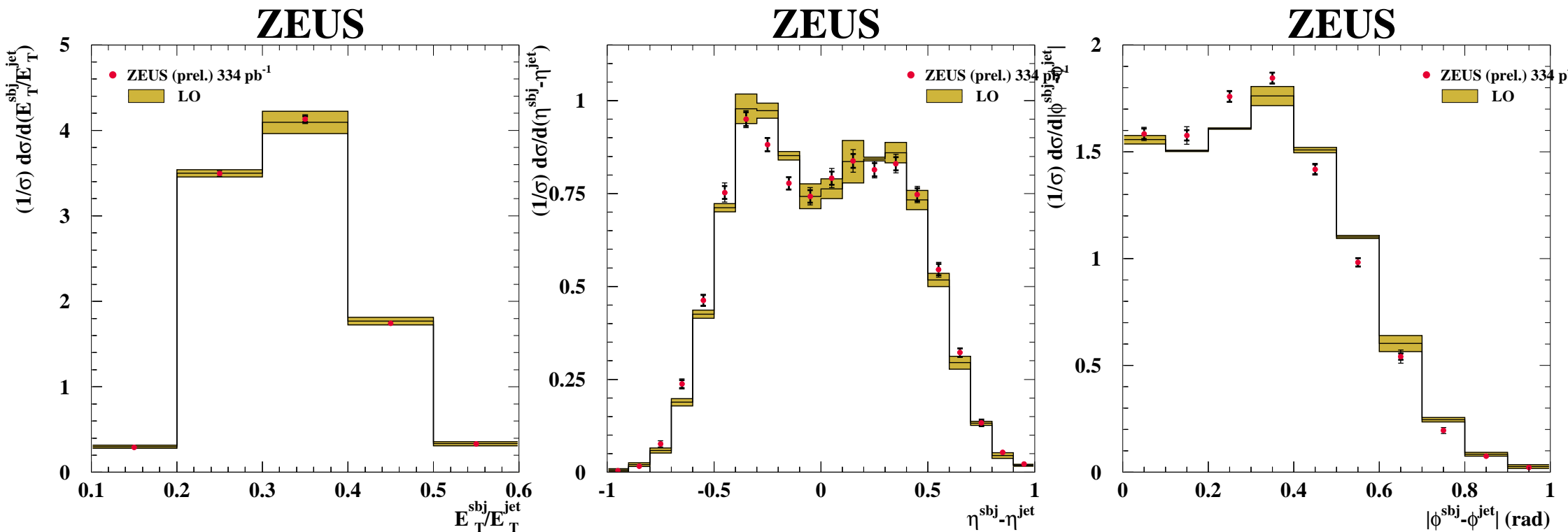


DATA vs LO: RESULTS

- Normalised cross sections for:

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

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



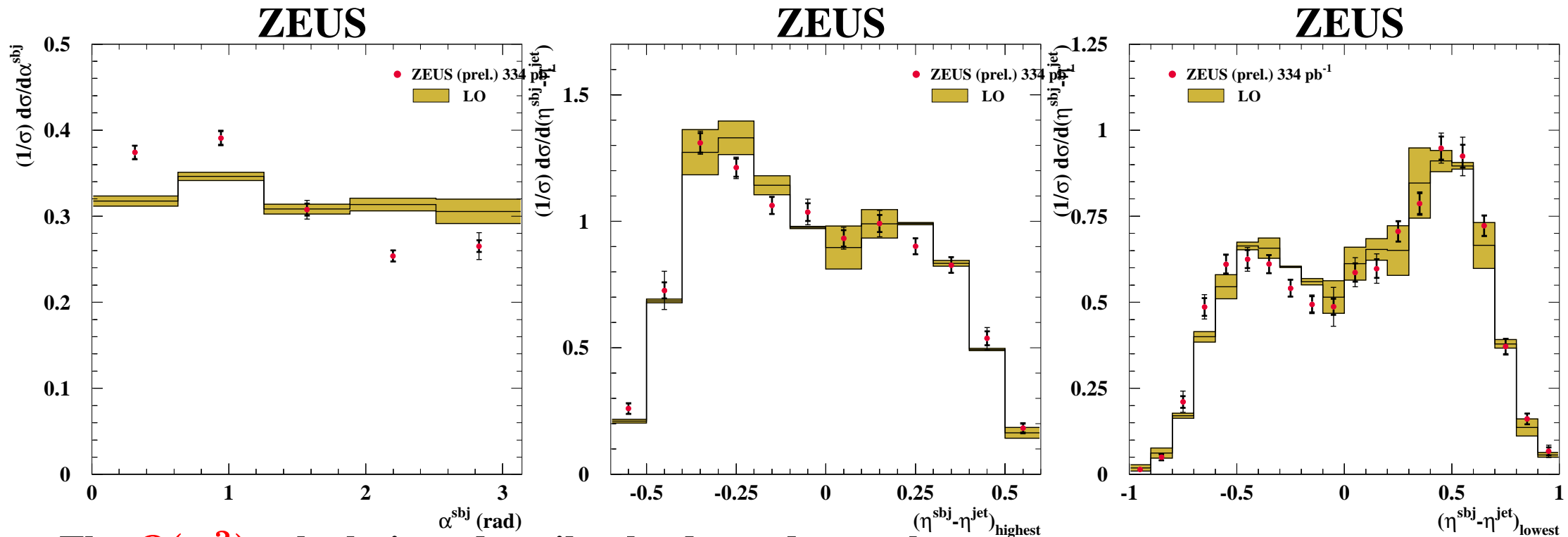
The $O(\alpha_s^2)$ calculations describe the data adequately.

DATA vs LO: RESULTS

- Normalised cross sections for:

$$\alpha^{sbj}, \eta_{high}^{sbj} - \eta^{jet}, \eta_{low}^{sbj} - \eta^{jet}$$

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



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

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 initial 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**.

