

London, DIS 2008

April 9th, 2008

Jet Substructure in NC DIS

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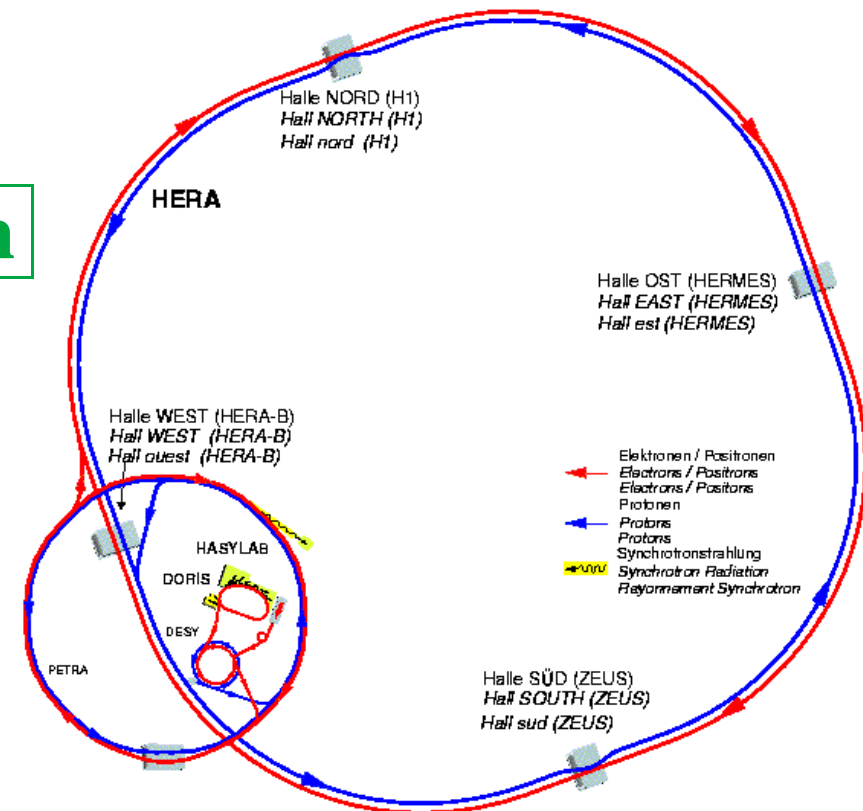
ZEUS Collaboration

e ($E_e = 27.5$ GeV)

p ($E_p = 920$ GeV)

$\sqrt{s} = 318$ GeV

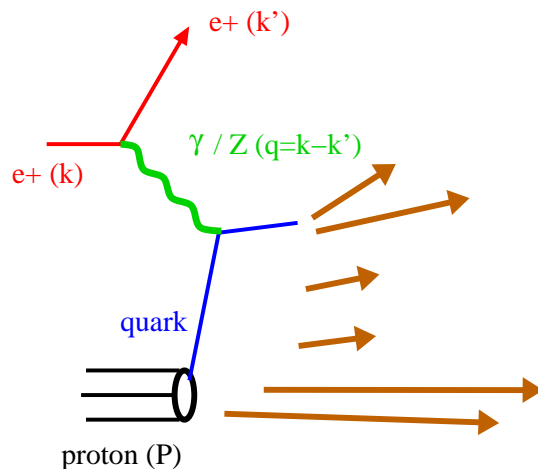
HERA



NEUTRAL CURRENT DEEP INELASTIC SCATTERING

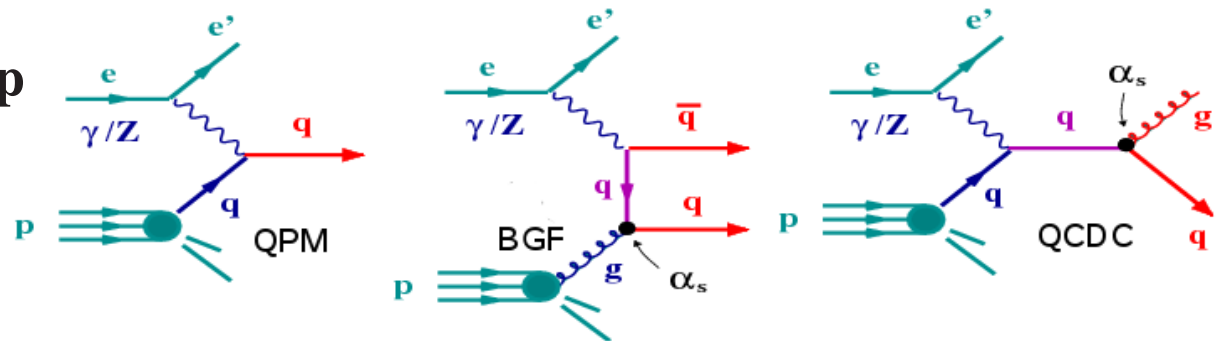
For a given ep centre-of-mass energy, \sqrt{s} , the fully inclusive cross section for $ep \rightarrow e + X$ can be described by two independent kinematic variables, e.g.

$$Q^2 = -(k - k')^2 \text{ and } x_{Bj} = Q^2 / (2P \cdot q)$$



Jet production in neutral current deep inelastic scattering up to $\mathcal{O}(\alpha_s) \rightarrow$

Measurements of jet cross sections in NC DIS at high Q^2 have allowed precise tests of the pQCD calculations

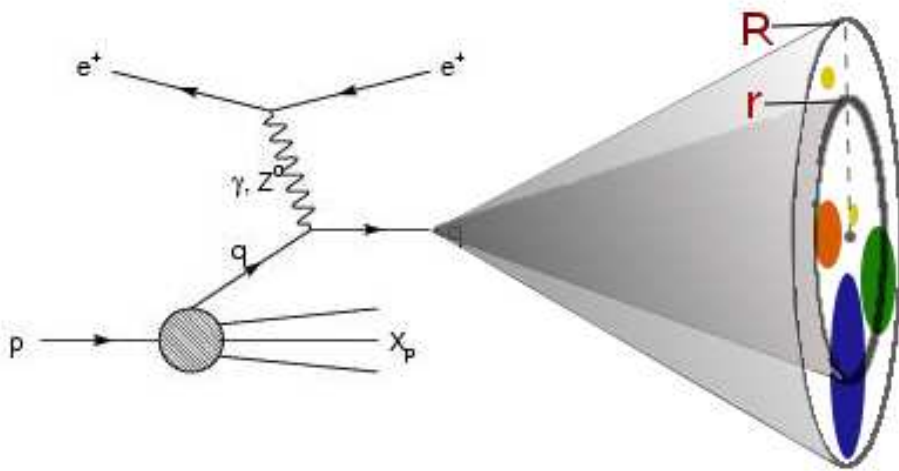


$$d\sigma_{jet} = \sum_{a=q,\bar{q},g} \int dx f_a(x, \mu_F^2) d\hat{\sigma}_a(x, \alpha_s(\mu_R), \mu_R^2, \mu_F^2)$$

as well as precise determinations of α_s

NOW: Let's further test pQCD... \rightarrow

At sufficiently high E_T^{jet} of the jets, the contribution of **fragmentation** to the jet substructure becomes negligible and the **main contribution comes from parton radiation**. Thus, jet substructure is a testing ground for **perturbative QCD**.



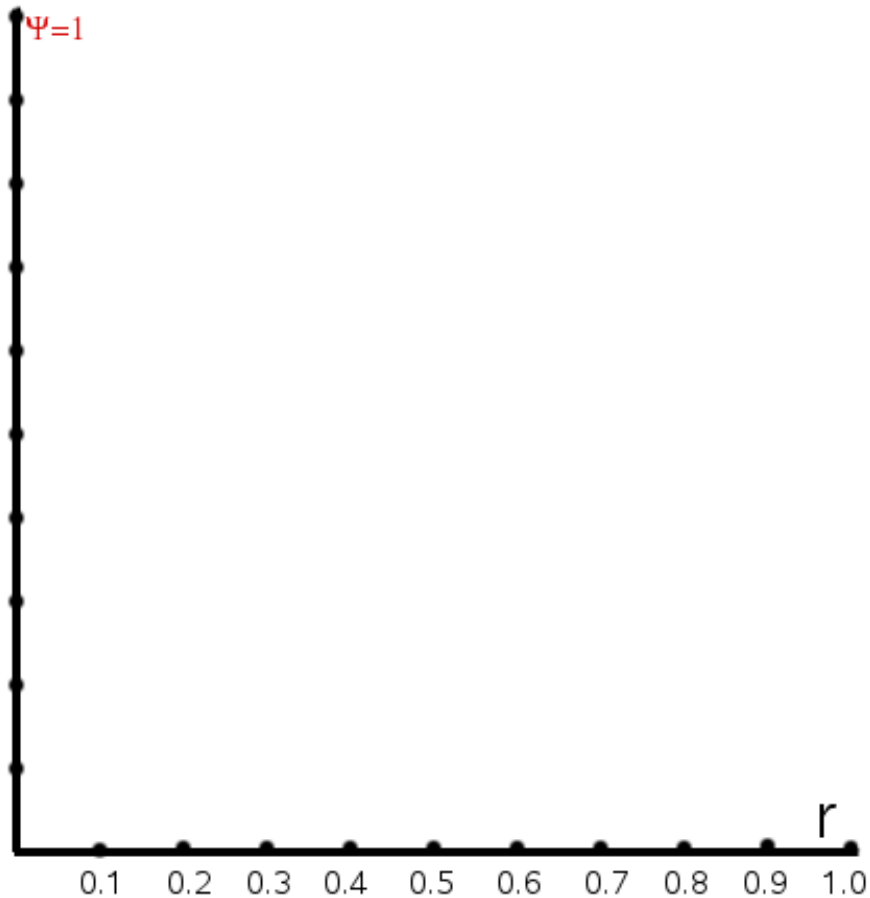
In this analysis, jet substructure is studied by means of the **integrated jet shape**, which, for one jet, is defined as:

$$\psi(r) = \frac{E_T(r)}{E_T^{jet}}$$

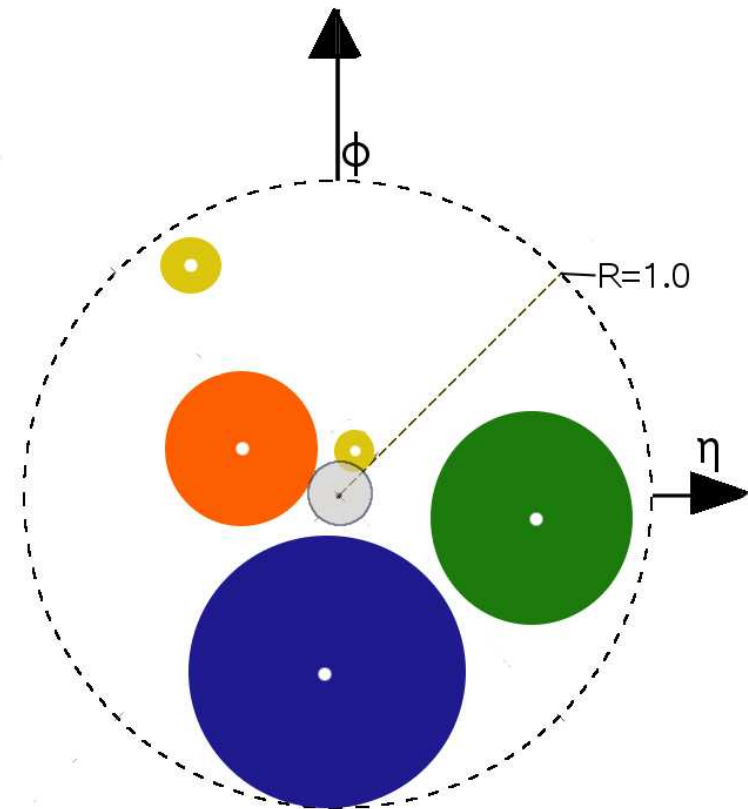
The integrated jet shape at value r is the **fraction of the total E_T** of the jet contained within a circle of radius r in the $\eta - \phi$ plane concentric with the jet axis. For a sample of jets, it is defined as the average integrated jet shape.

$$\langle \psi(r) \rangle = \frac{1}{N_{jets}} \sum_{i=1}^{N_{jets}} \frac{E_T^i(r)}{E_T^i}$$

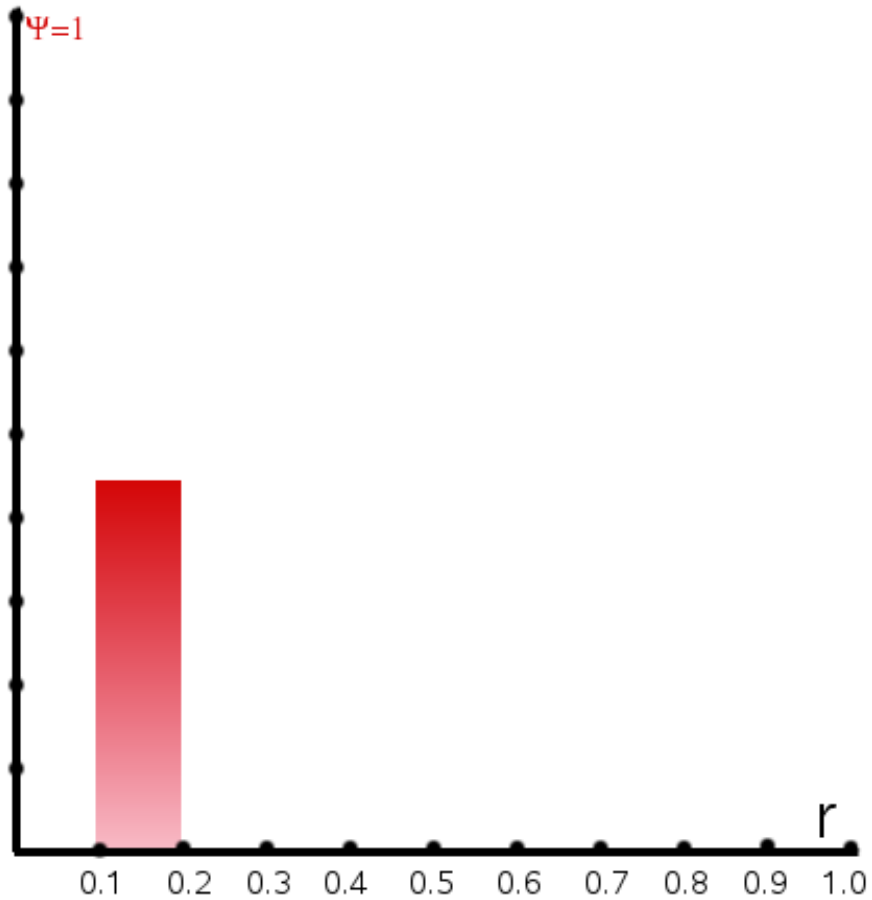
Integrated jet shape $\psi(r)$



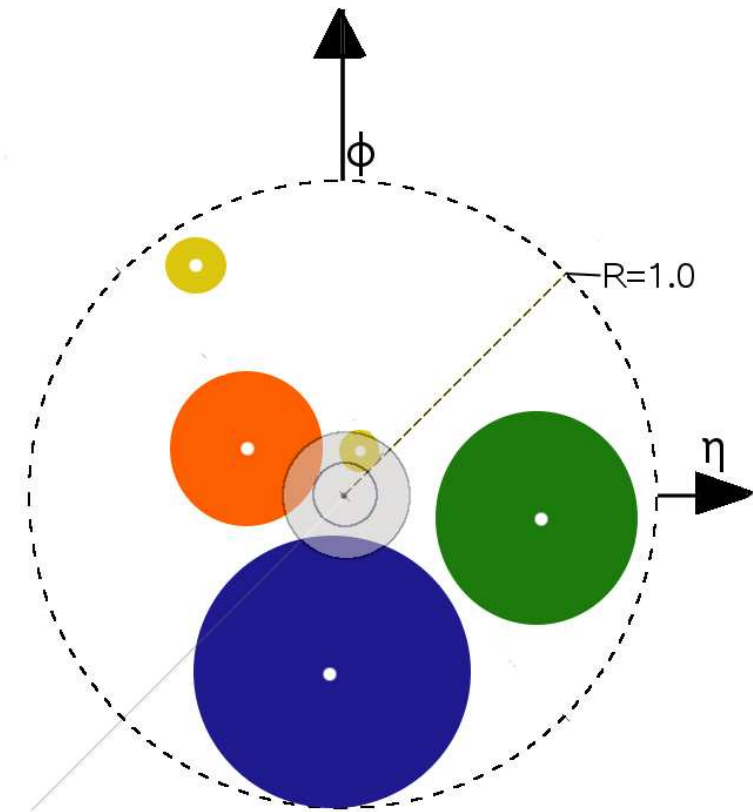
No entries for $\psi(r)$ at $r = 0.1$



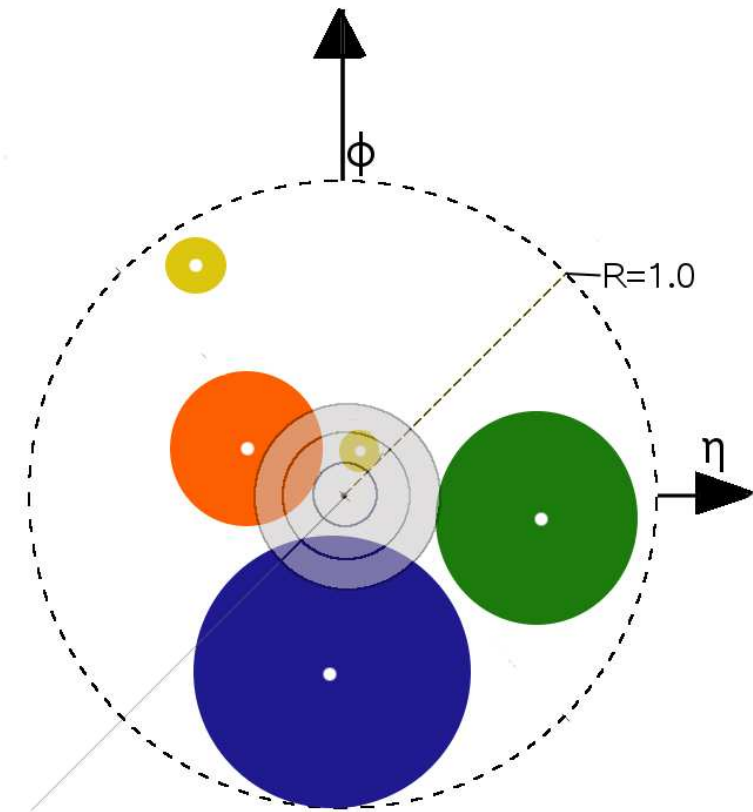
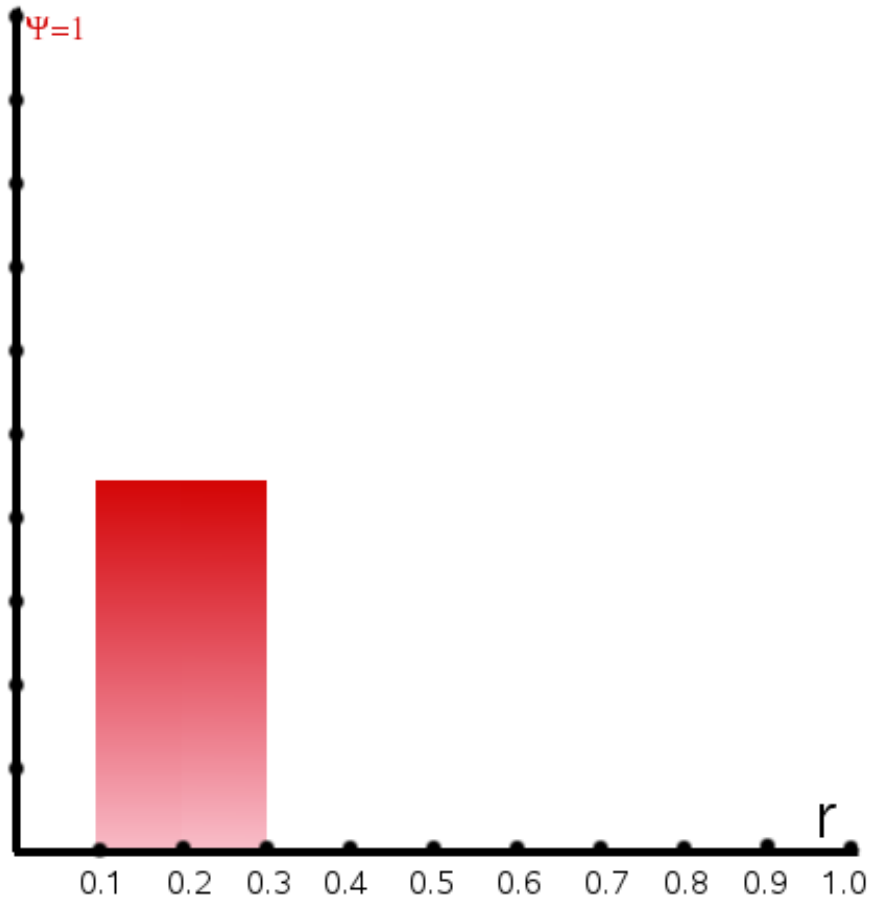
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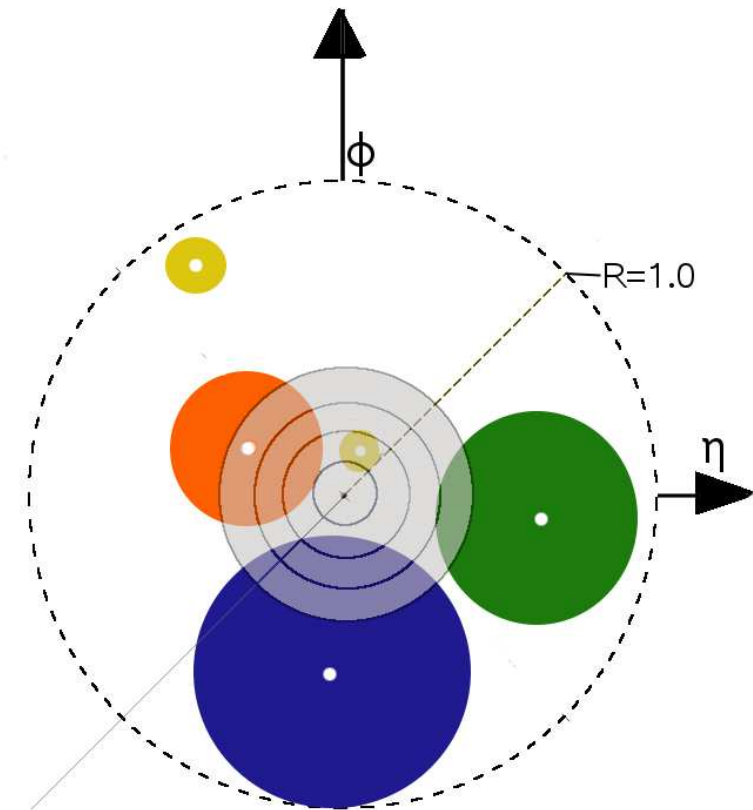
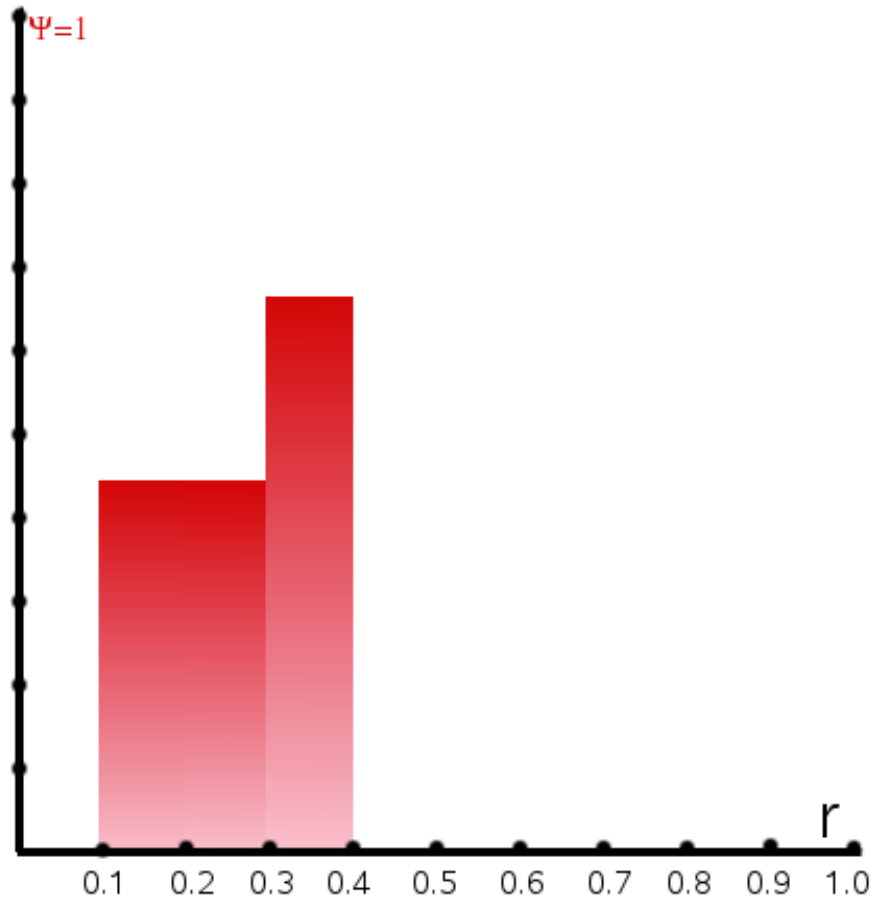
First contribution, at $r = 0.2$



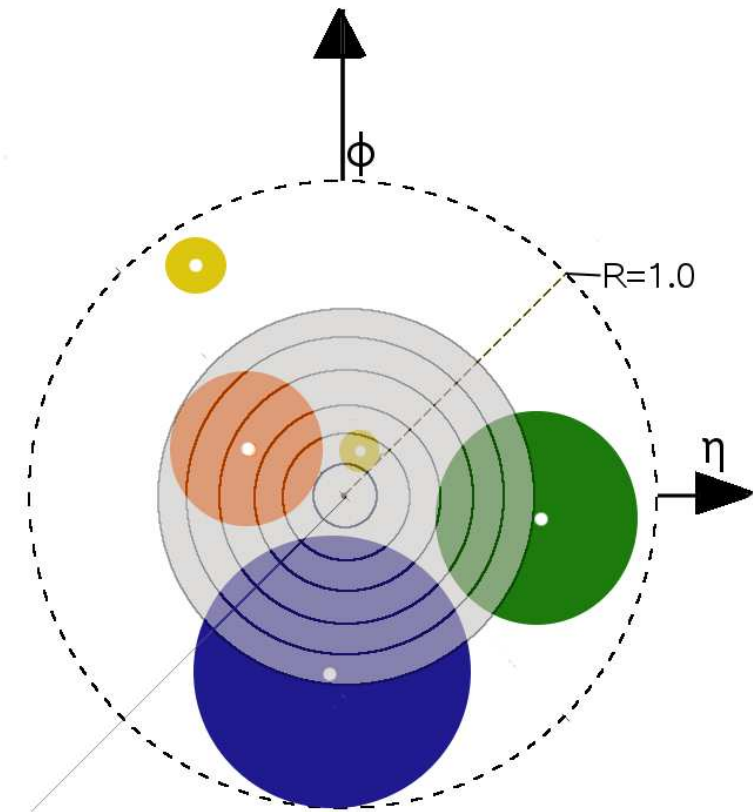
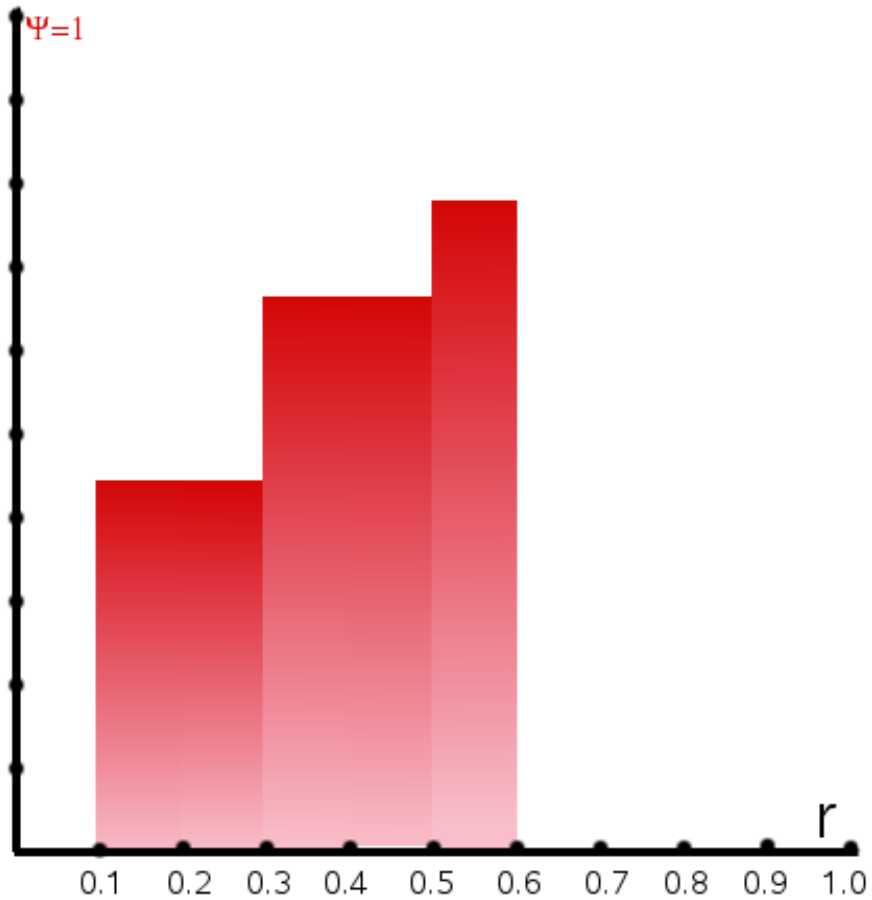
Integrated jet shape $\psi(r)$



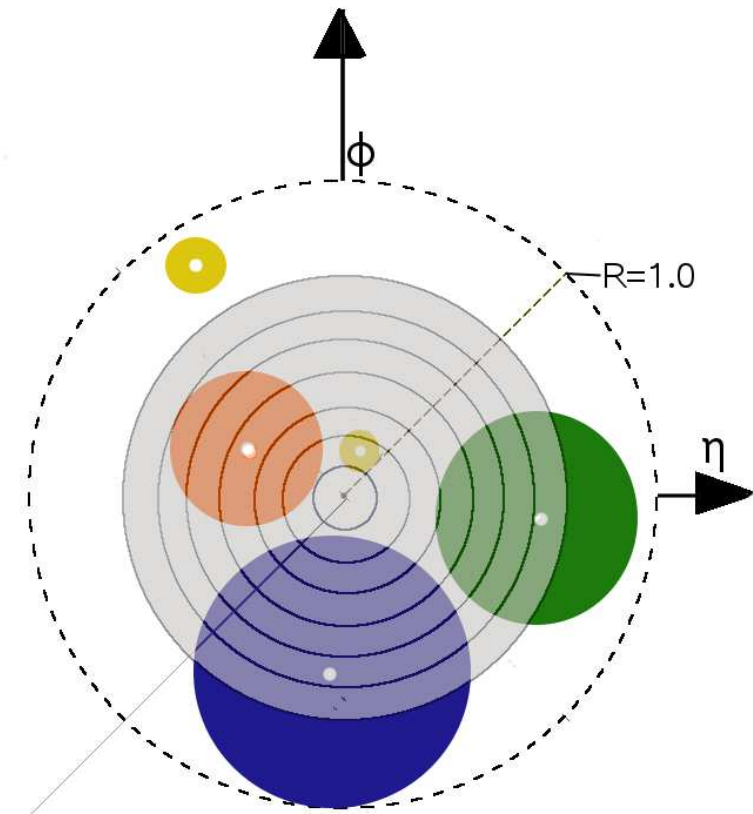
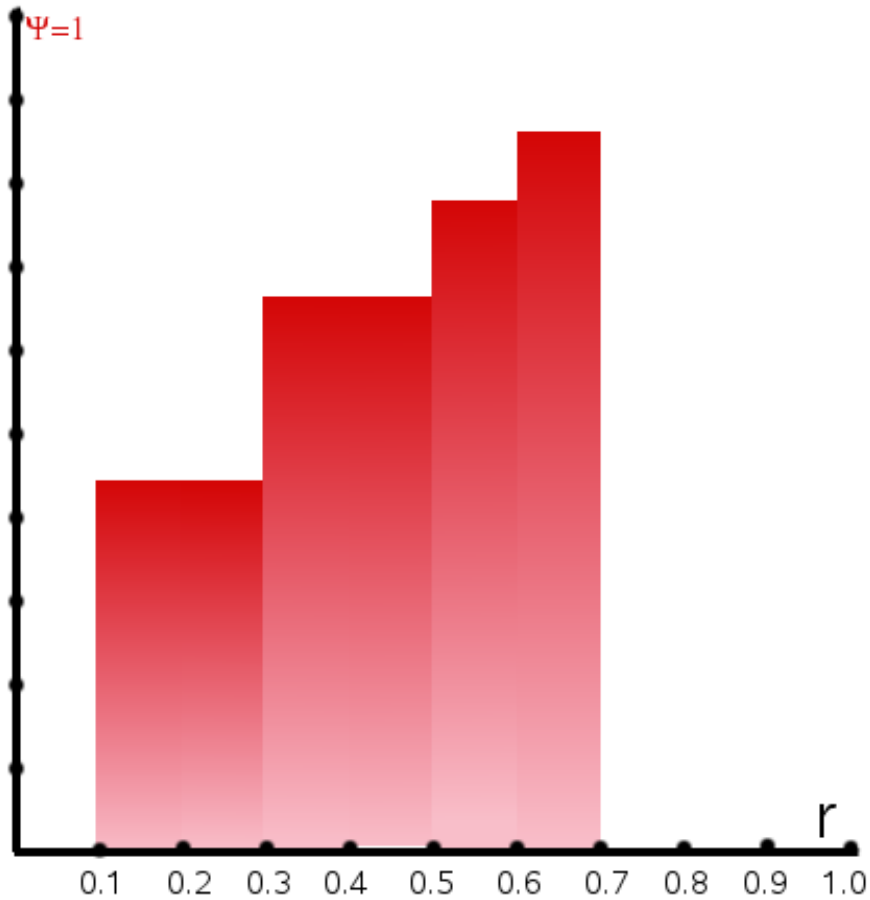
Integrated jet shape $\psi(r)$



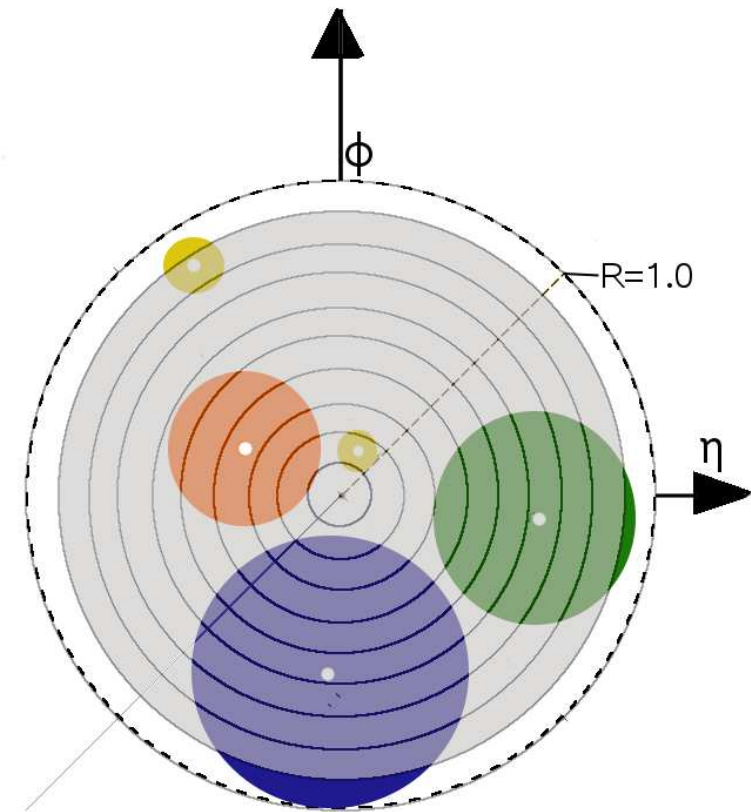
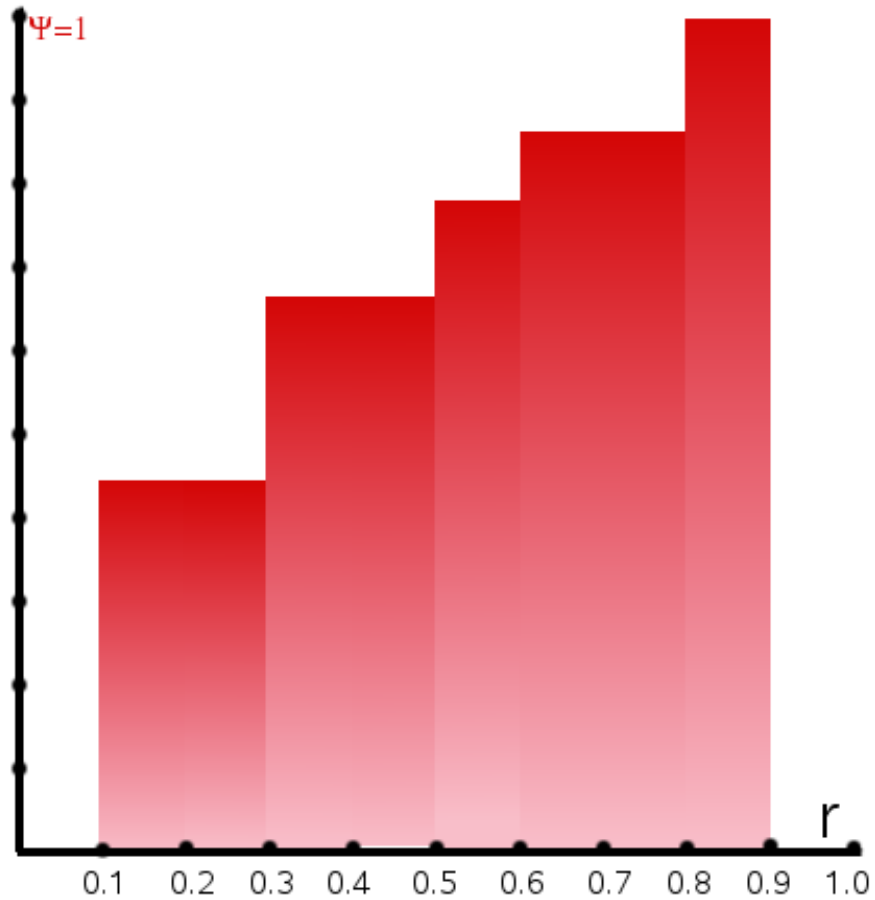
Integrated jet shape $\psi(r)$



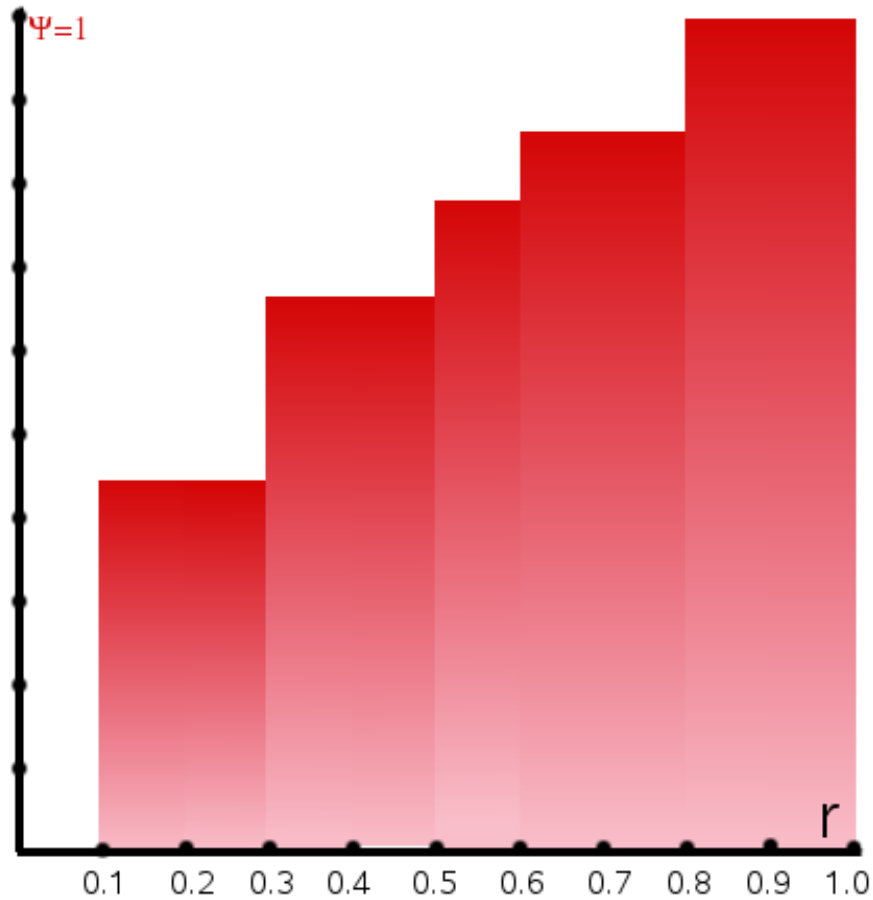
Integrated jet shape $\psi(r)$



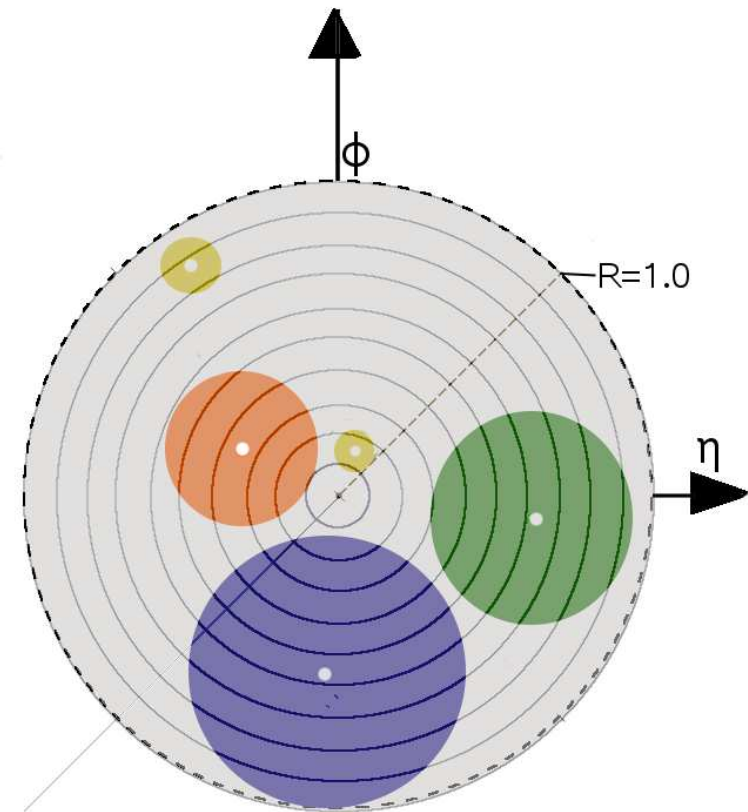
Integrated jet shape $\psi(r)$



Integrated jet shape $\psi(r)$

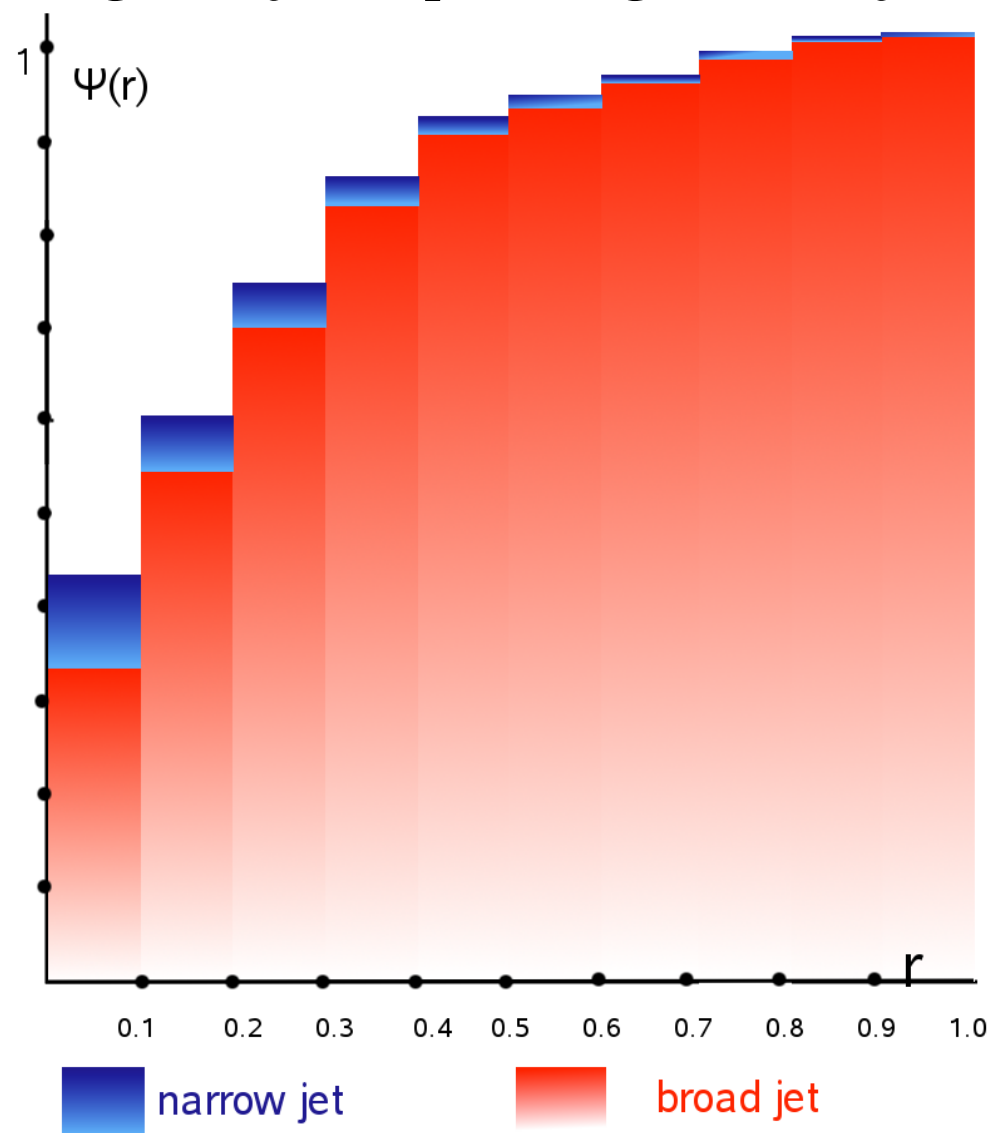


For this particular jet...



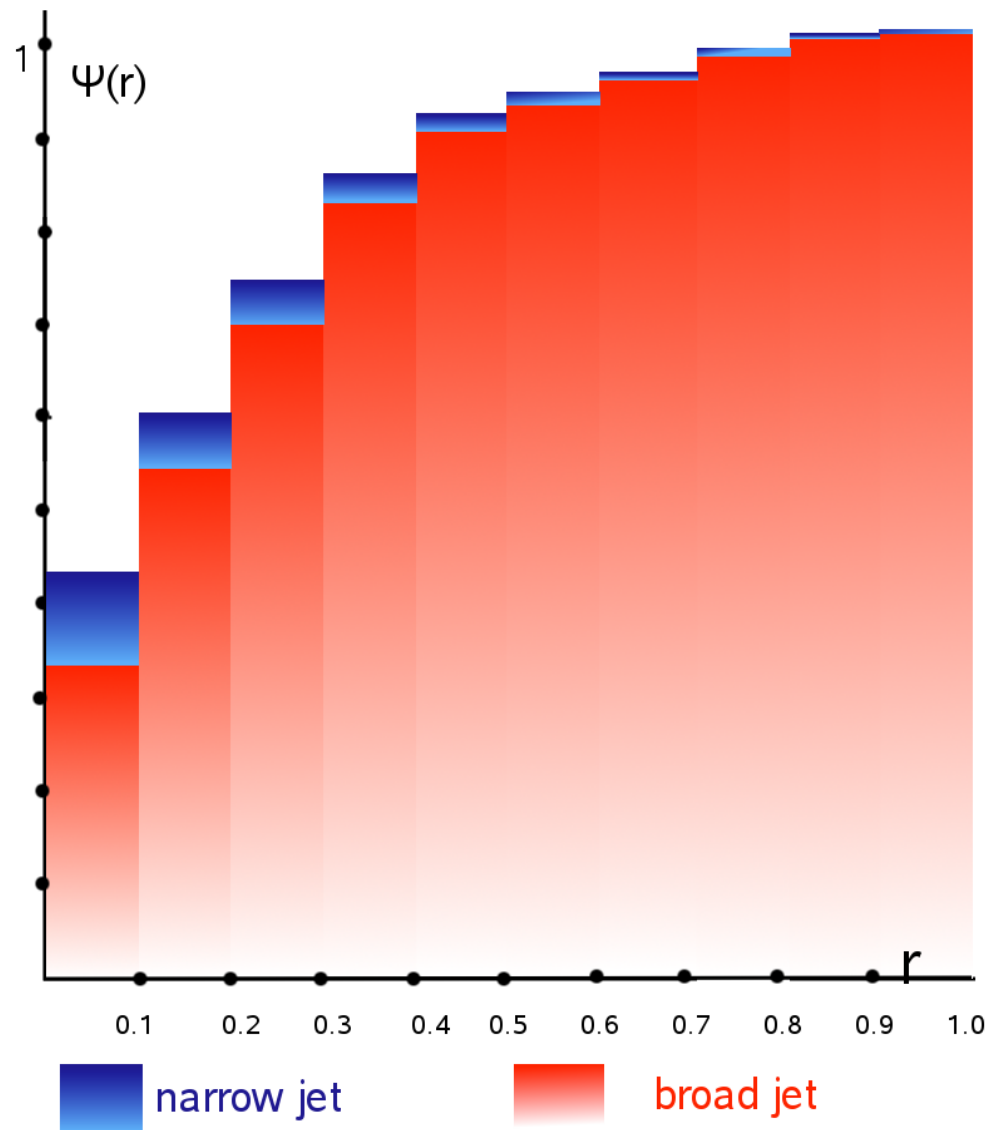
However, for a sample of jets...→

Integrated jet shape averaged over a jet sample



pQCD predicts that jets that have been initiated by a **gluon** are **broader** than those initiated by a **quark** due to the higher color charge of the **gluons**

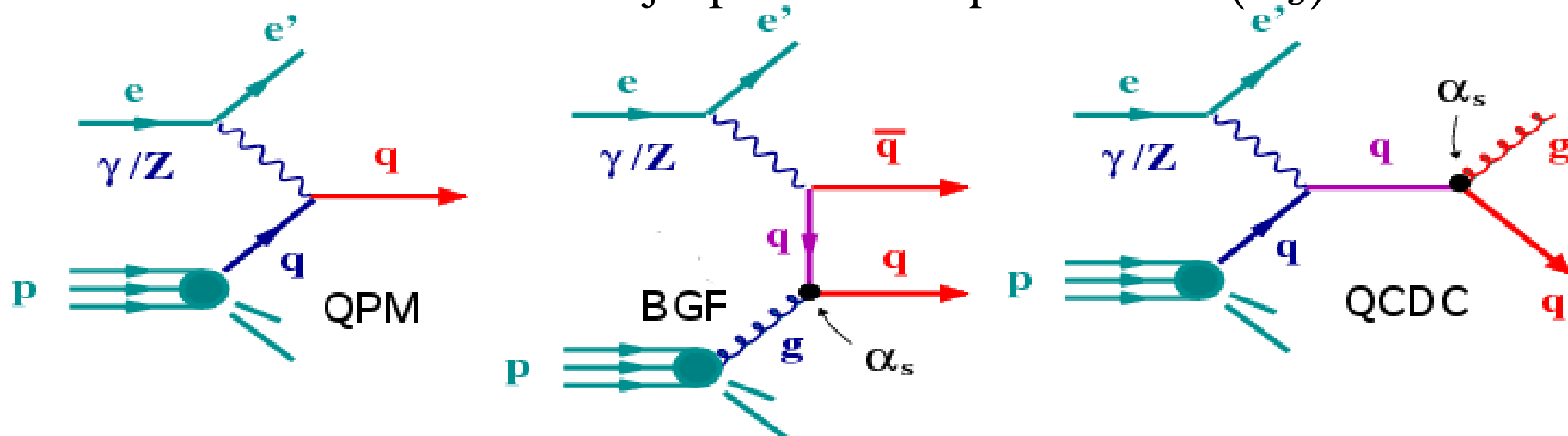
Integrated jet shape averaged over a jet sample



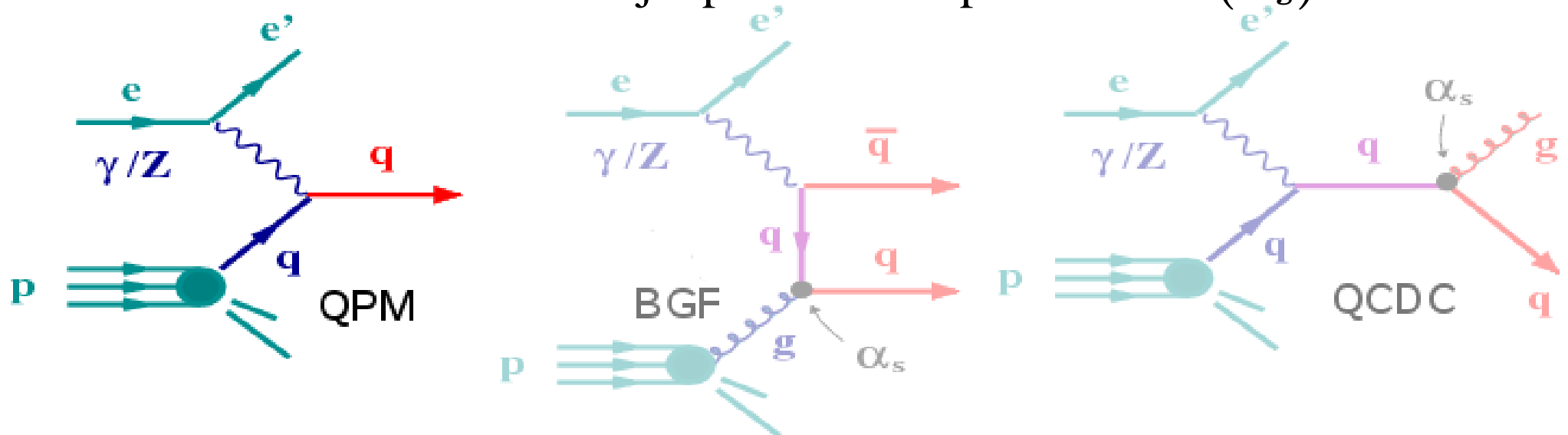
pQCD predicts that jets that have been initiated by a **gluon** are broader than those initiated by a **quark** due to the higher color charge of the **gluons**

The aim of the analysis is to verify this prediction in the context of **ep collisions** and further test the **predictions of pQCD** about jet substructure.

Contributions to jet production up to order $O(\alpha_s)$



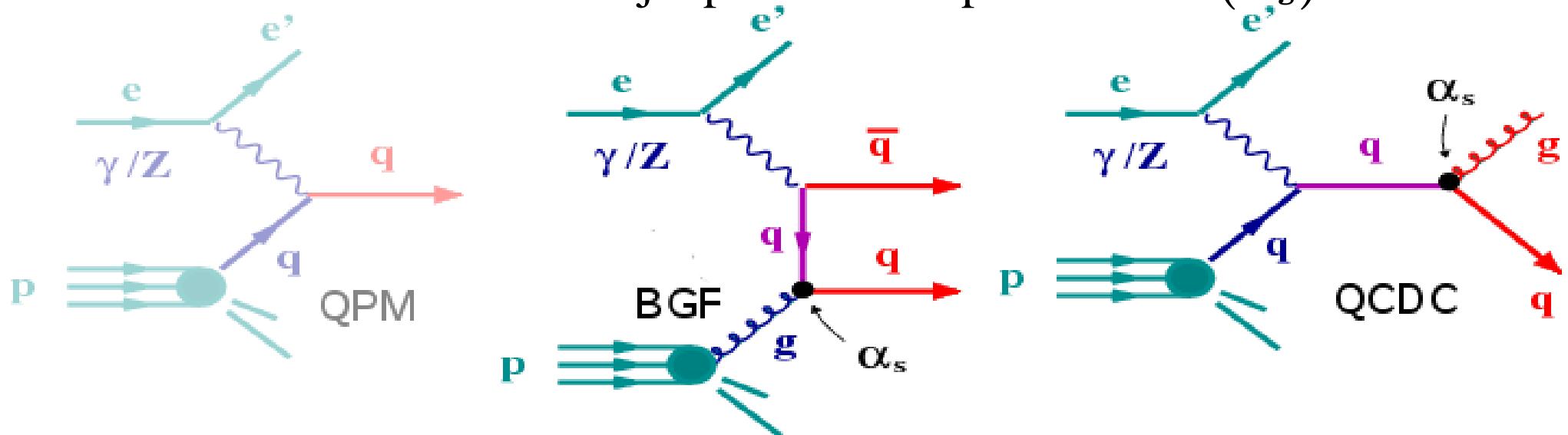
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Contributions to jet production up to order $O(\alpha_s)$ 

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1. Jets in events where there is **one and only one** jet with $E_T^{jet} > 14 \text{ GeV}$

QPM events are the main contribution to single-jet production. This jet sample is expected to be enriched with **quark-initiated** jets.

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2. The jet with the **lowest** E_T^{jet} in events with **two and only two jets** with $E_T^{jet_{1,2}} > 14 \text{ GeV}$ and such that the two jets are **close to each other**.

BGF and QCDC are the main contributions to two-jet production. By selecting jets that are near and taking the low E_T^{jet} one, we expect to **enhance** the contribution from QCDC and therefore **enrich** the sample with **gluon-initiated** jets.

Signal Selection for NC DIS

- The NC DIS data sample is selected from $368 pb^{-1}$ in the kinematic region of:

$$Q^2 > 125 \text{ GeV}^2$$

The jets are identified in the laboratory frame using the **K_T Cluster Algorithm**.

- The first jet sample consists of jets in events with **one and only one jet** such that:

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

- The second jet sample consists of the lowest E_T^{jet} jet in events with **two and only two jets** such that:

$$E_T^{jet_{1,2}} > 14 \text{ GeV} \text{ and } -1 < \eta^{jet_{1,2}} < 2.5$$

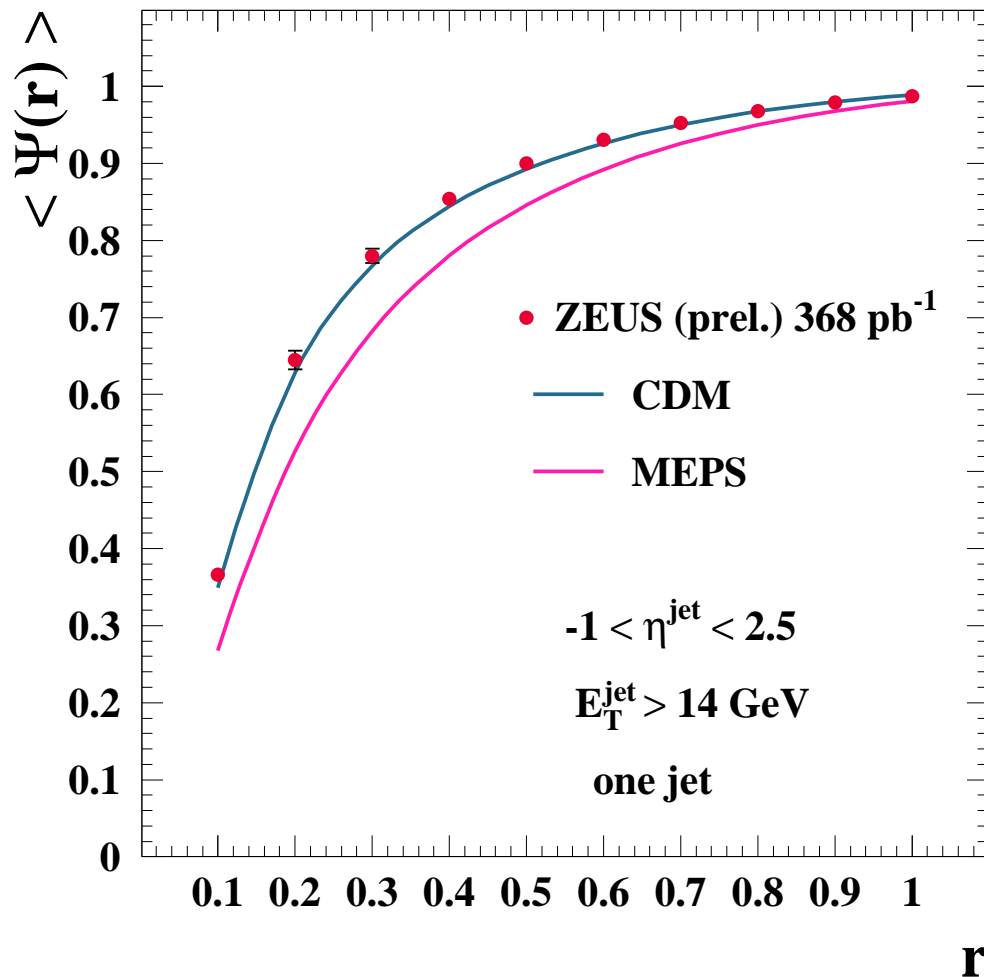
- The **distance** between the two jets in the $\eta - \phi$ plane is required to be:

$$d_{12} = \sqrt{(\eta^{jet_1} - \eta^{jet_2})^2 + (\phi^{jet_1} - \phi^{jet_2})^2} \leq D$$

two values of D have been considered, $D = 2$ and $D = 2.5$

RESULTS

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- The data have been corrected for **detector effects**

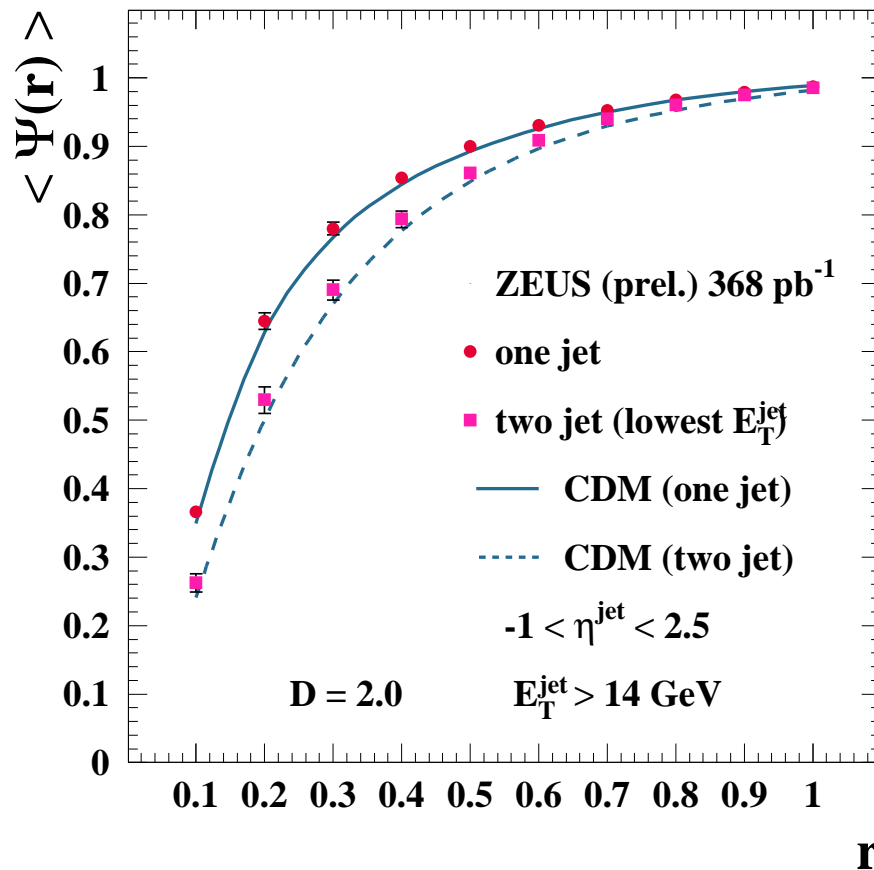
$$\langle \Psi_{dat}^{cor}(r) \rangle = \frac{\langle \Psi_{MC,RW}^{had}(r) \rangle}{\langle \Psi_{MC,RW}^{cal}(r) \rangle} \langle \Psi_{dat}(r) \rangle$$

using samples of Monte Carlo-generated events
 (Ariadne=CDM and LEPTO=MEPS)

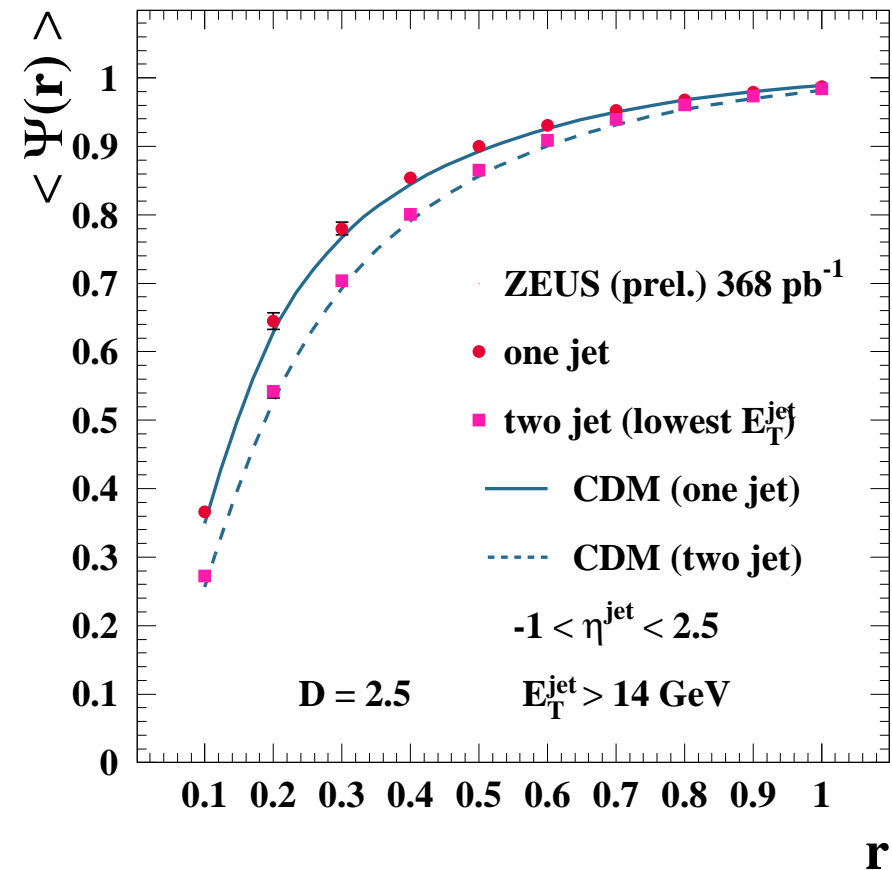
As well, the data have been corrected for QED.

- Comparison with the **absolute predictions** of the Monte Carlo models.

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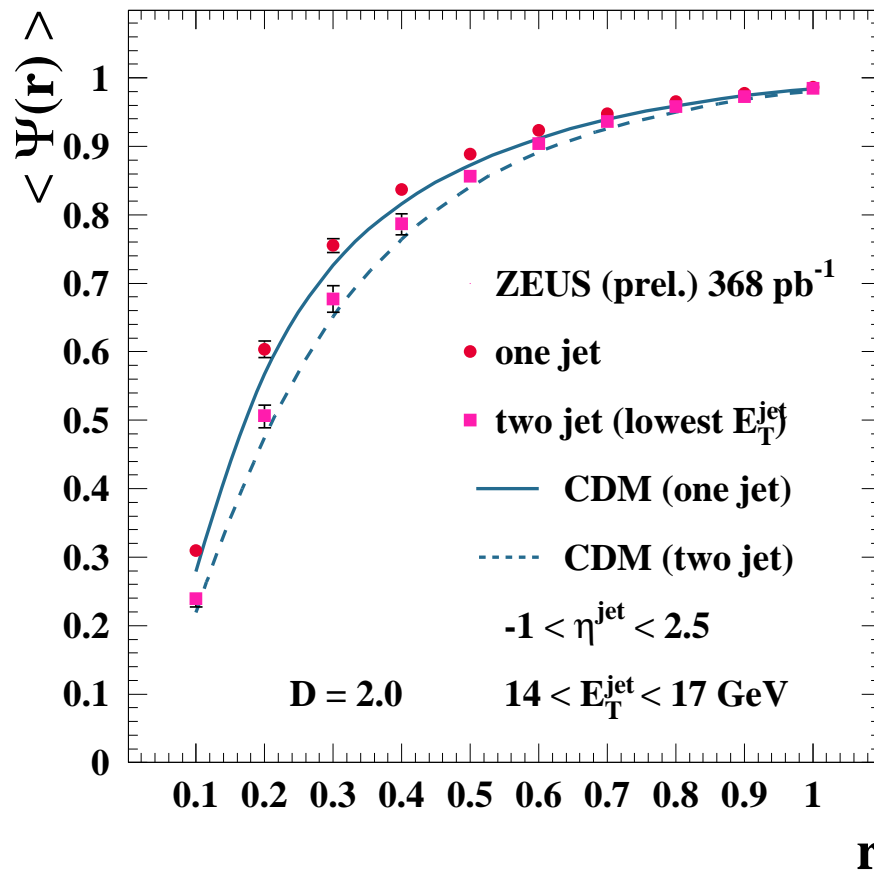


Comparison between data and Monte Carlo predictions (CDM).

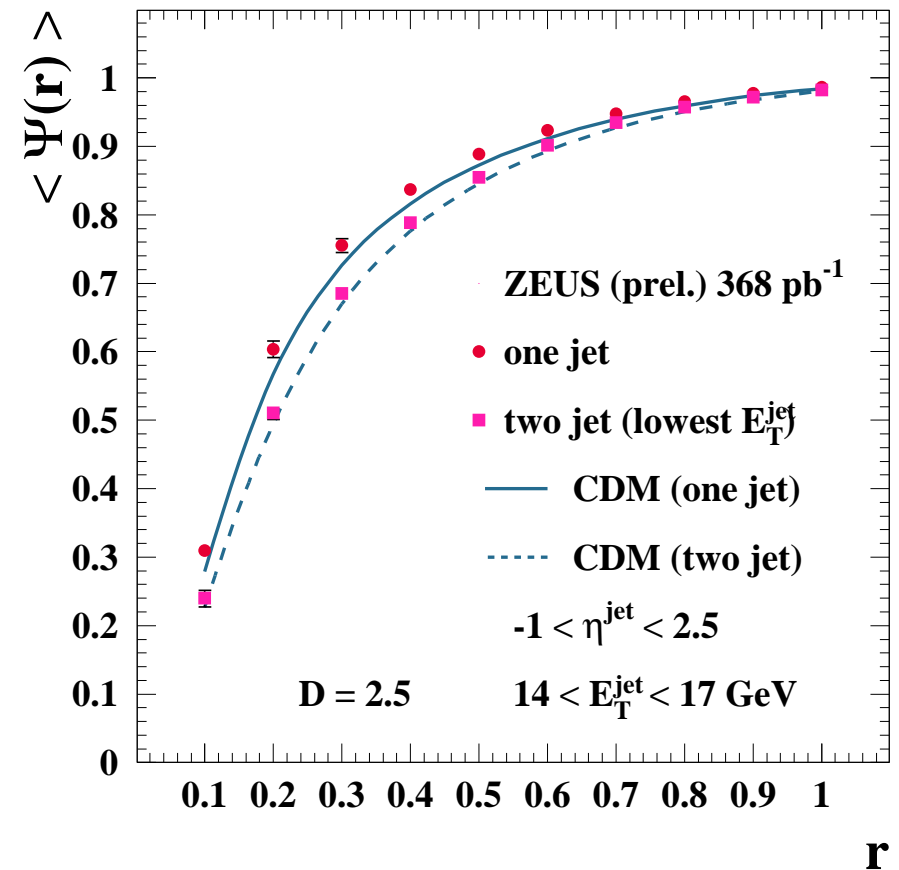
- A **significant difference** between the samples is observed.
- The lowest E_T^{jet} jet in the two-jet sample is **broader**.
- **Good agreement** with the predictions of Ariadne.

Dependence of the integrated jet shape with E_T^{jet} ?

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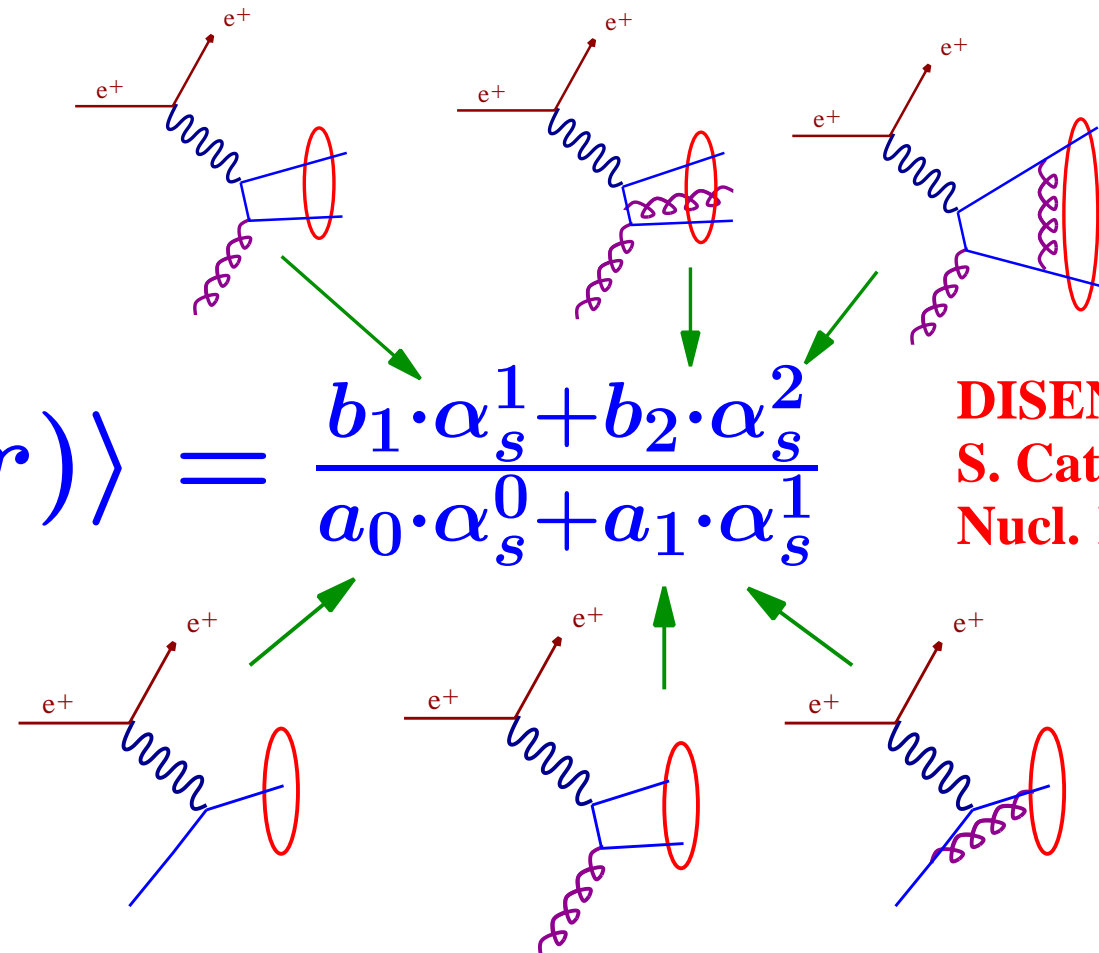
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Comparison between data and Monte Carlo predictions (Ariadne).

- The E_T^{jet} is now **restricted between 14 GeV and 17 GeV**.
- The difference between the samples is **still observed**.
- **Reasonable agreement** with the predictions of Ariadne.

NLO QCD calculations for **one-jet production**

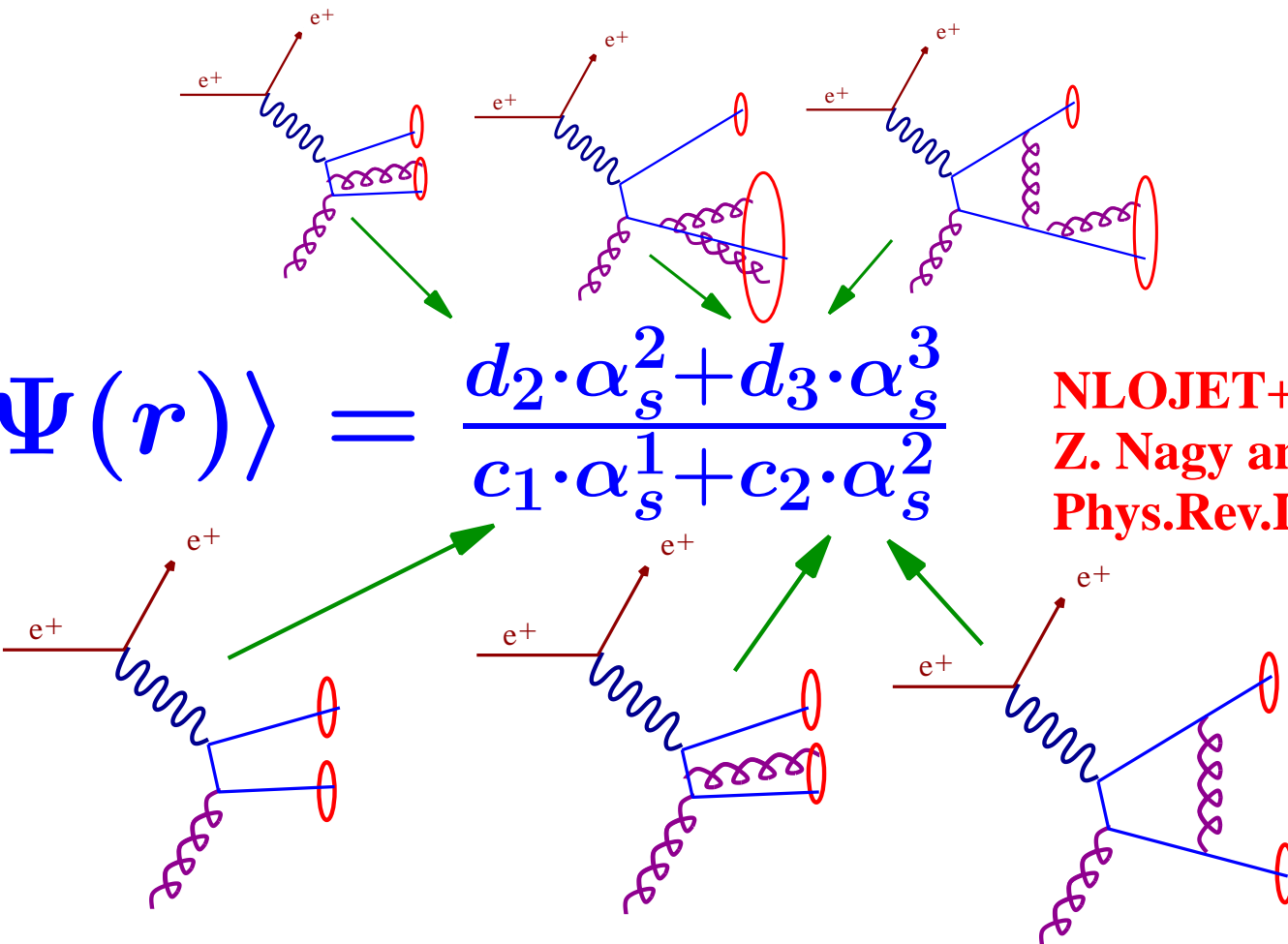


$$\langle 1 - \Psi(r) \rangle = \frac{b_1 \cdot \alpha_s^1 + b_2 \cdot \alpha_s^2}{a_0 \cdot \alpha_s^0 + a_1 \cdot \alpha_s^1}$$

DISENT program
S. Catani and M.H. Seymour
Nucl. Phys. B485 (1997) 291

- **DISENT program:** $\alpha_s(M_Z) = 0.118$; $\mu_R = \mu_F = Q$; CTEQ6 proton PDFs
 → **Dominant theoretical uncertainty:** terms beyond NLO, $< 5\%$ for $r \geq 0.2$

NLO QCD calculations for **two-jet production**

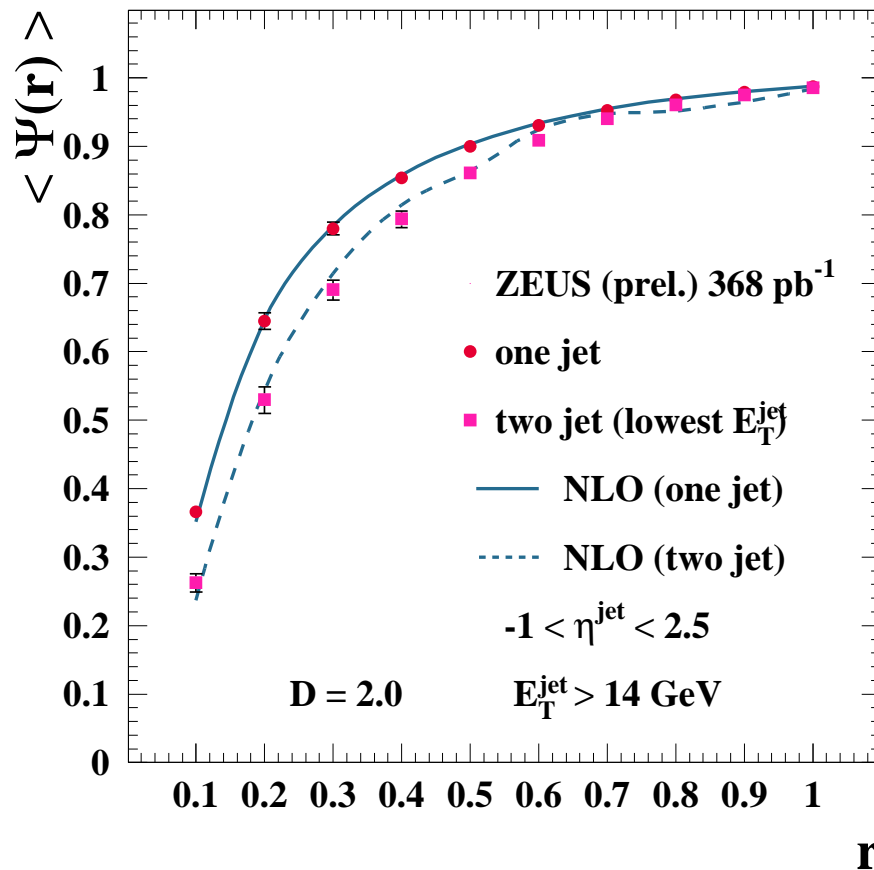


$$\langle 1 - \Psi(r) \rangle = \frac{d_2 \cdot \alpha_s^2 + d_3 \cdot \alpha_s^3}{c_1 \cdot \alpha_s^1 + c_2 \cdot \alpha_s^2}$$

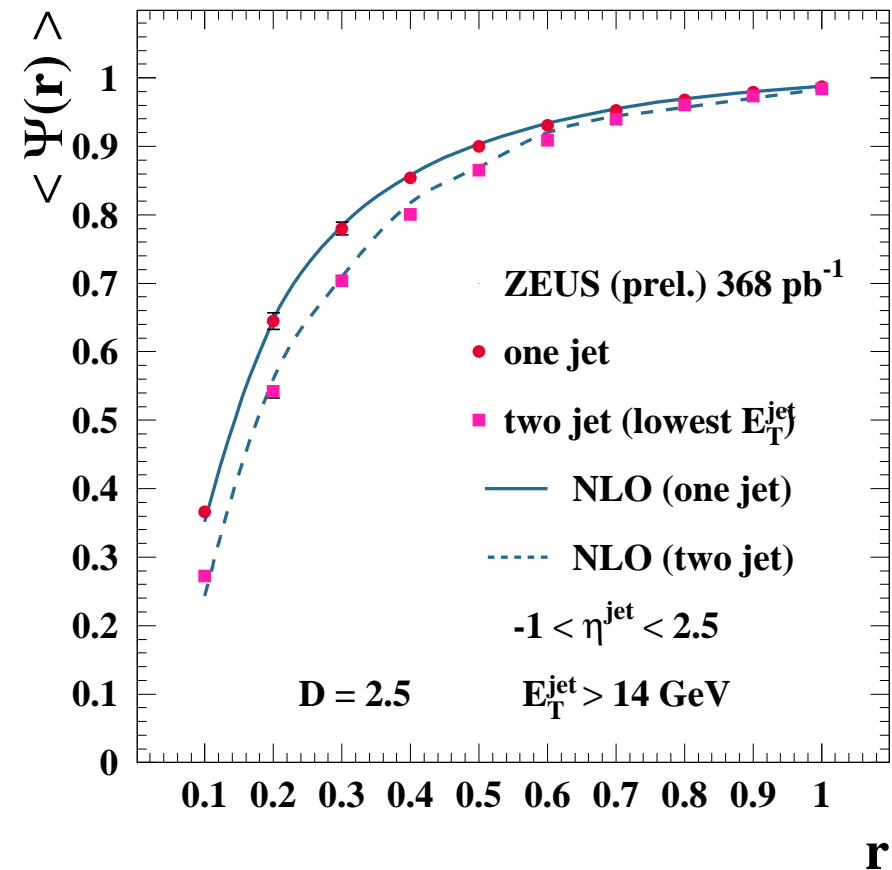
NLOJET++ program
Z. Nagy and Z. Trocsanyi
Phys.Rev.Lett. 87 (2001) 082001

- **NLOJET++ program:** $\alpha_s(M_Z) = 0.118$; $\mu_R = \mu_F = Q$; CTEQ6 proton PDFs

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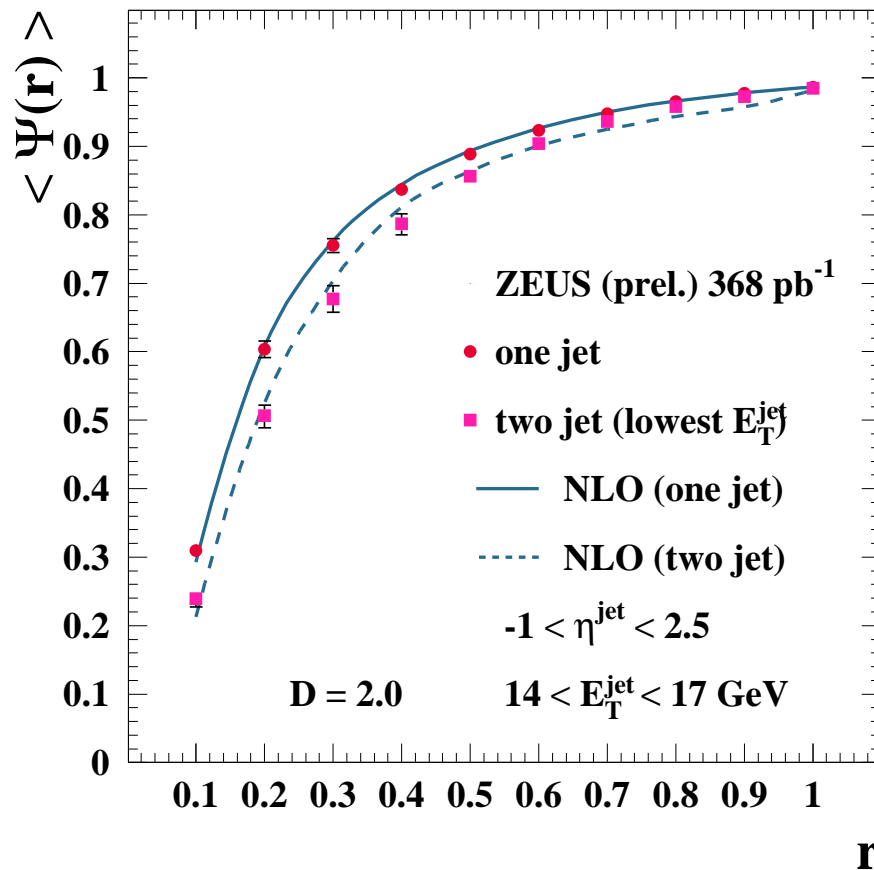
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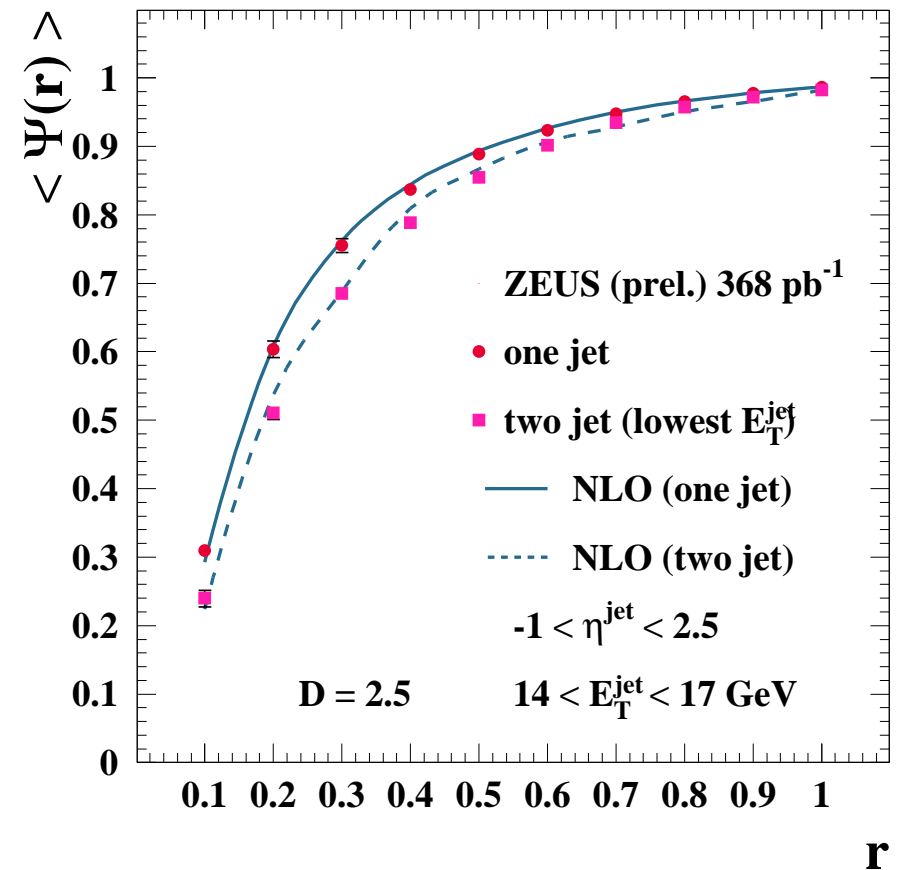
Comparison between data and Next to Leading Order calculations.

- The calculations have been corrected for hadronisation effects ($< 10\%$ for $r > 0.4$)
- **Good agreement.** The difference between the two jet samples is reproduced.

ZEUS



ZEUS



Comparison between data and Next to Leading Order calculations

- The E_T^{jet} is now **restricted between 14 GeV and 17 GeV**.
- The difference between the samples is **still reproduced** by the NLO calculations.
- **Good agreement** between data and NLO.

SUMMARY

- Measurements of the integrated jet shape in the regime of NC DIS using 368pb^{-1}
- The integrated jet shape was studied for **two different samples of jets**:
 - Jet sample expected to be enriched with **quark-initiated jets**
 - Jet sample expected to be enriched with **gluon-initiated jets**
- The integrated jet shape for the lowest E_T^{jet} jet in the two-jet events is **broader** than the single-jet events sample, even in the same range of E_T^{jet}
- The predictions of the Ariadne Monte Carlo model **agree** with the data reasonably **well**.
- Next to Leading Order calculations **are able** to reproduce the differences between the jet samples and yield a good agreement with the data.

