London, DIS 2008

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Jet Substructure in NC DIS

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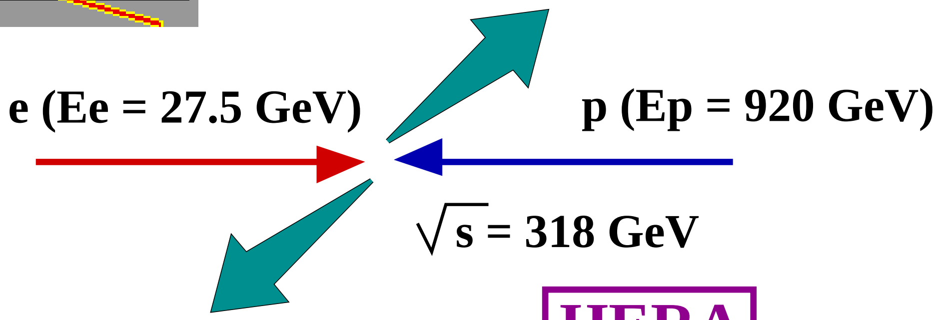
ZEUS Collaboration

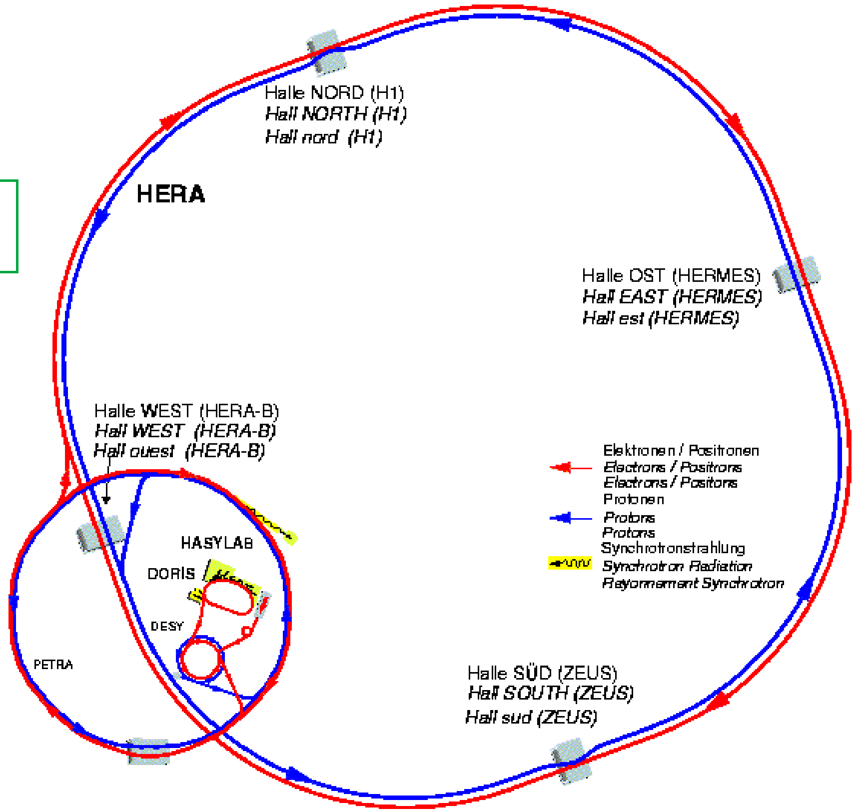


e (Ee = 27.5 GeV)

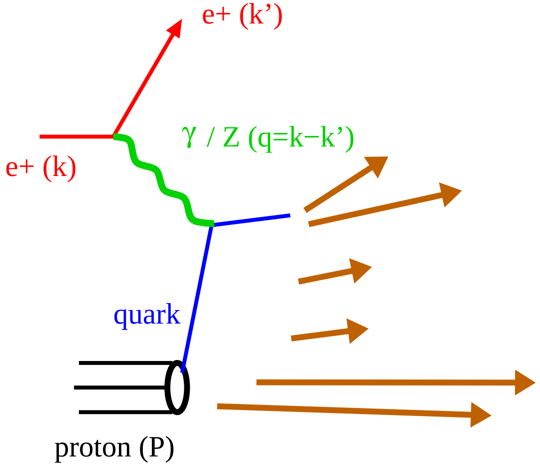
p (Ep = 920 GeV)

$\sqrt{s} = 318$ GeV

HERA



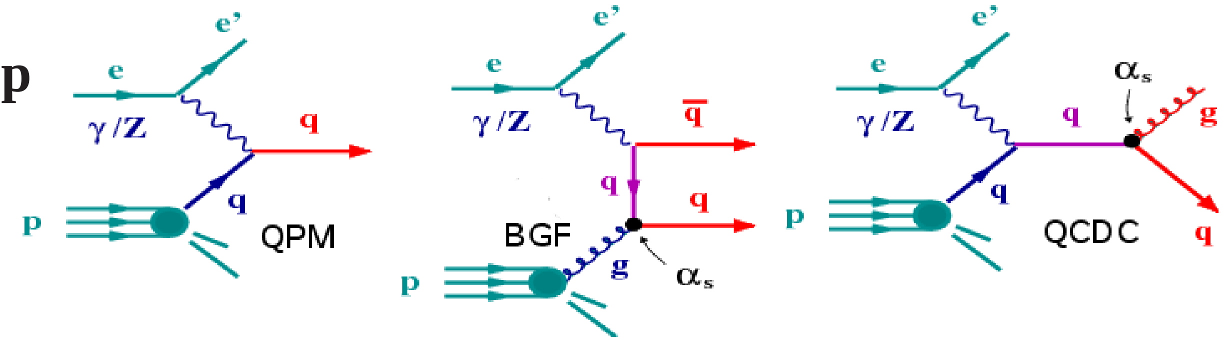
NEUTRAL CURRENT DEEP INELASTIC SCATTERING



For a given ep centre-of-mass energy, $\sqrt{s}$, the fully inclusive cross section for $ep \longrightarrow e + X$ 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 $\mathcal{O}(\alpha_s) \longrightarrow$



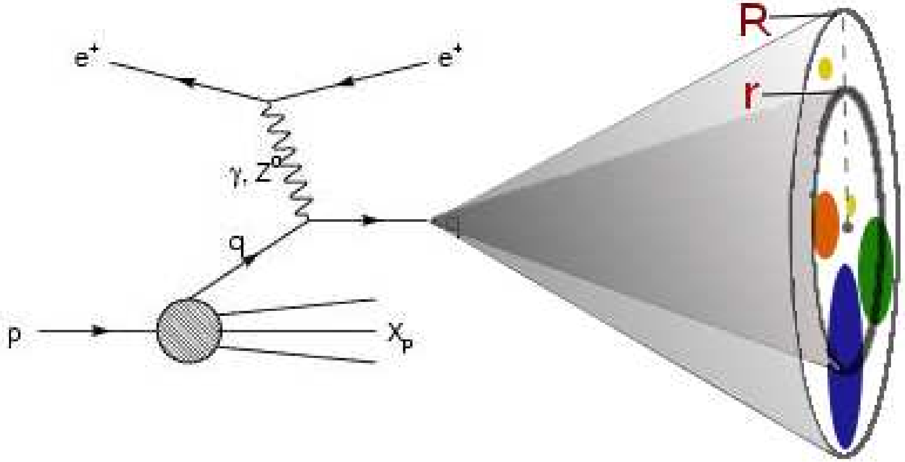
Measurements of jet cross sections in NC DIS at high Q^2 have allowed precise tests of the pQCD calculations

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

as well as precise determinations of α_s

NOW: Let's further test pQCD... ⟶

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:

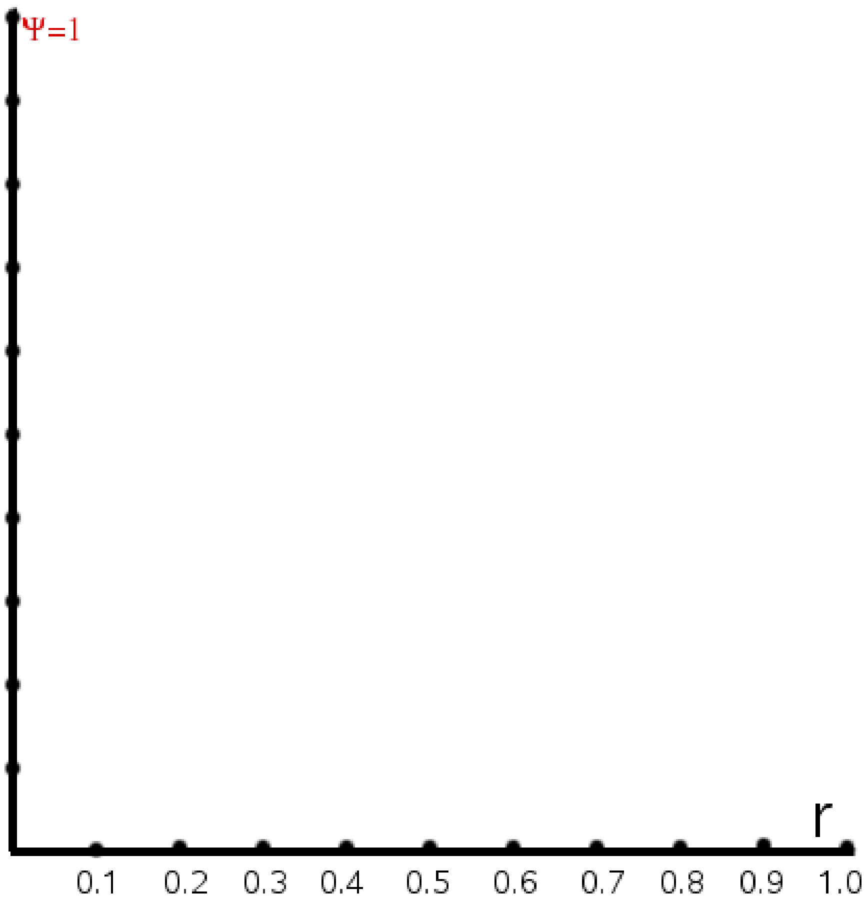
$$\psi(r) = \frac{E_T(r)}{E_T^{jet}}$$

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

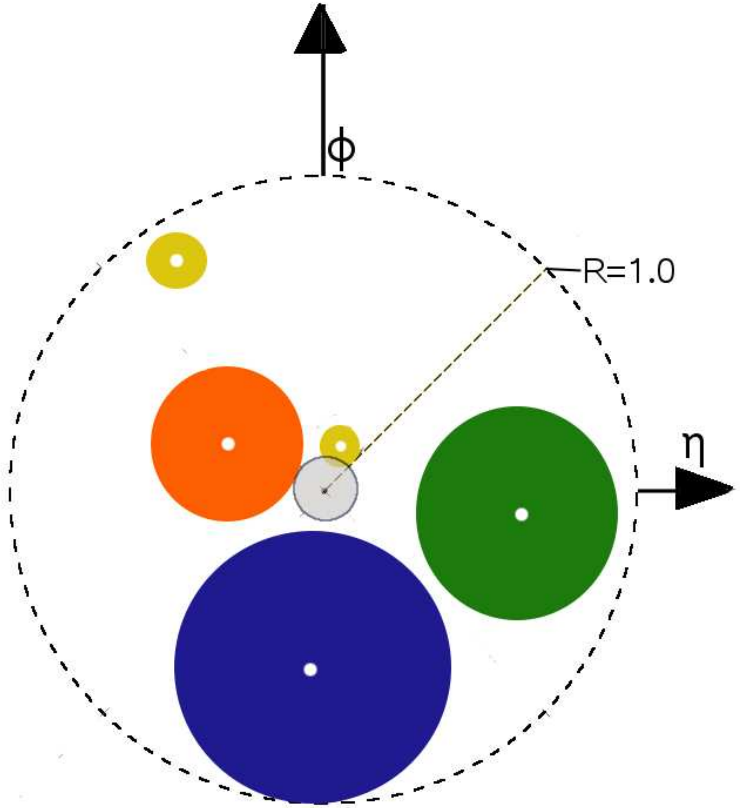
For a sample of jets, it is defined as the average integrated jet shape.

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

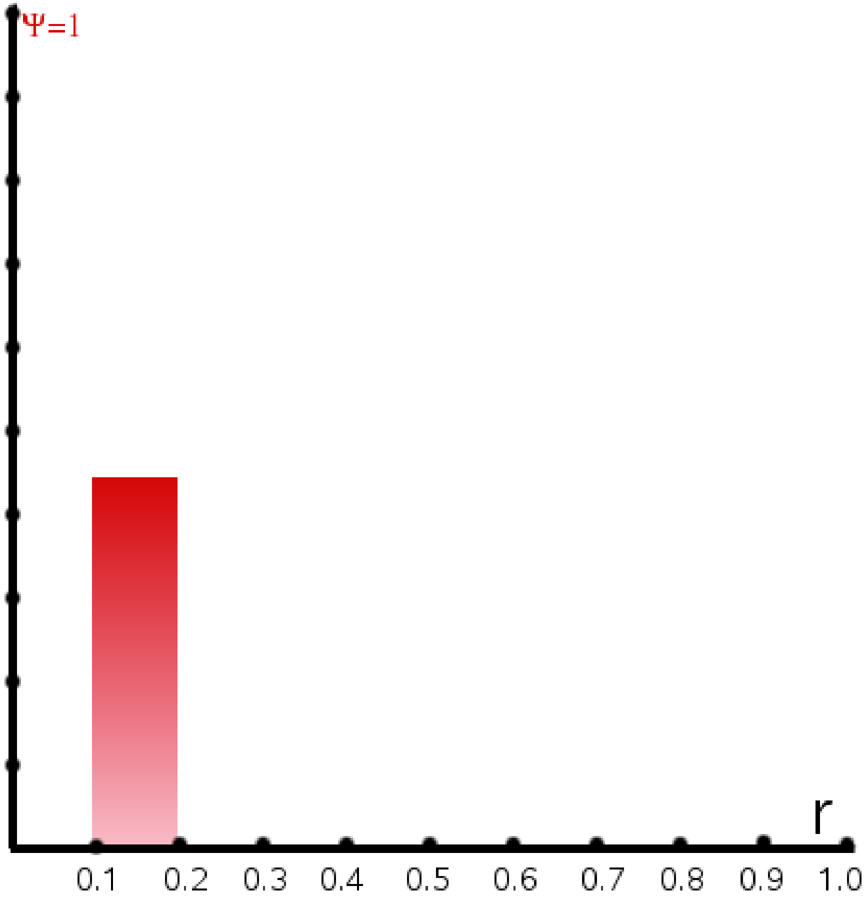
Integrated jet shape $\psi(r)$

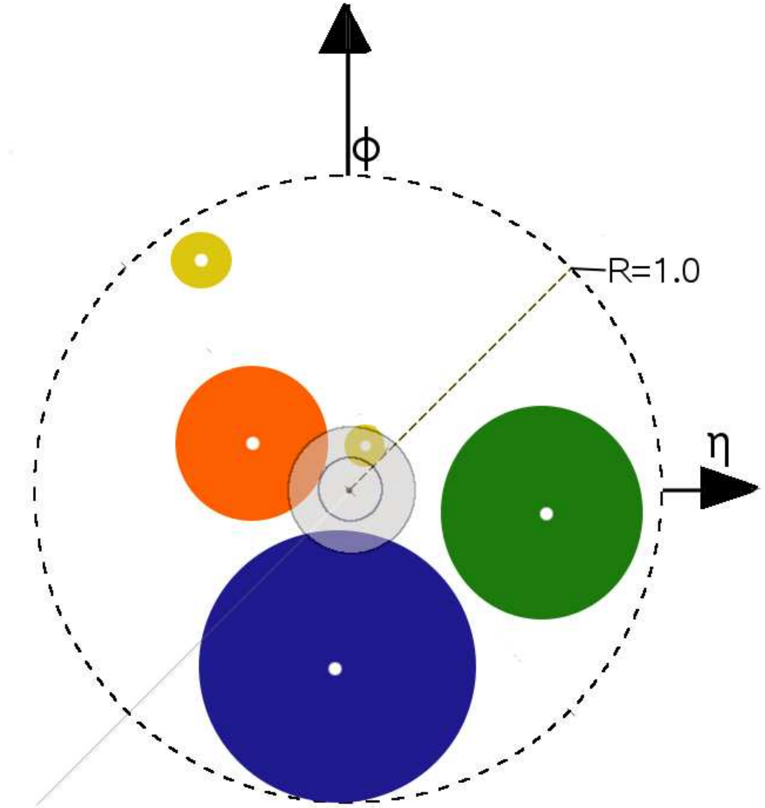


No entries for $\psi(r)$ at $r = 0.1$



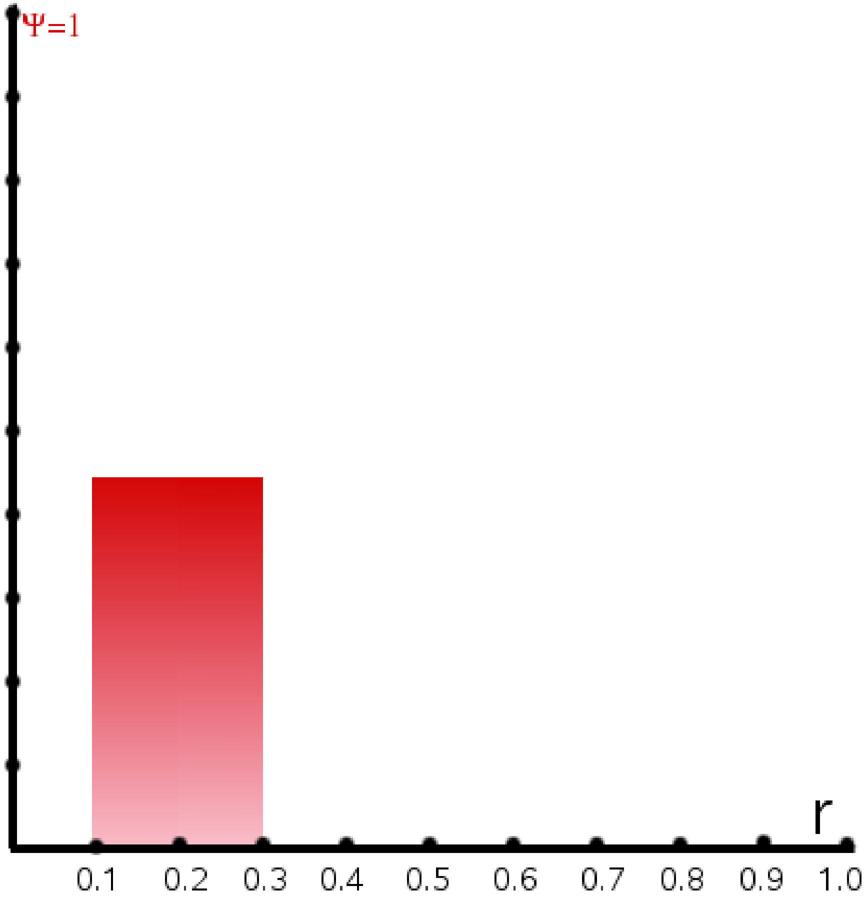
Integrated jet shape $\psi(r)$

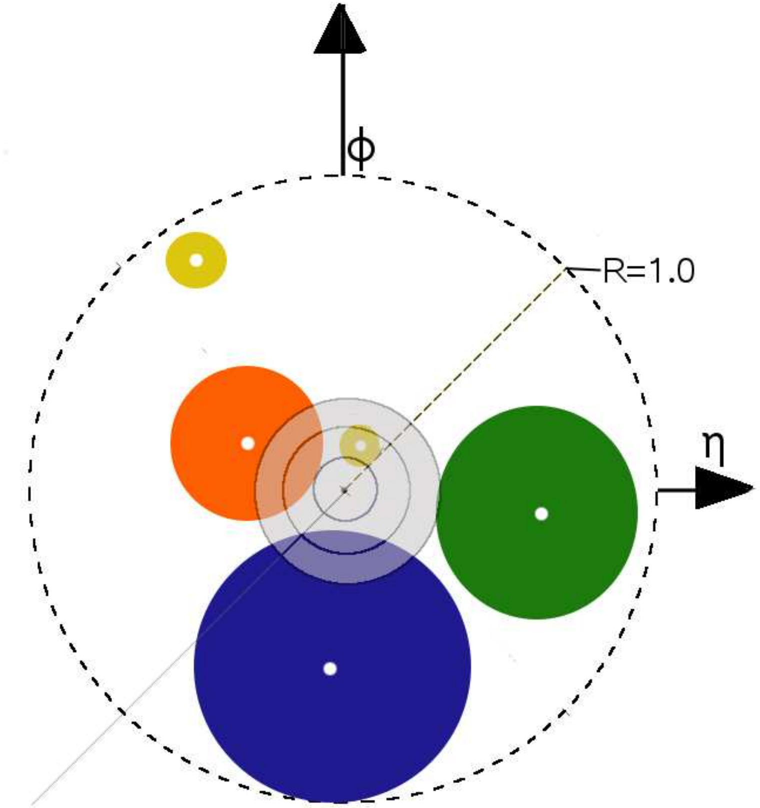




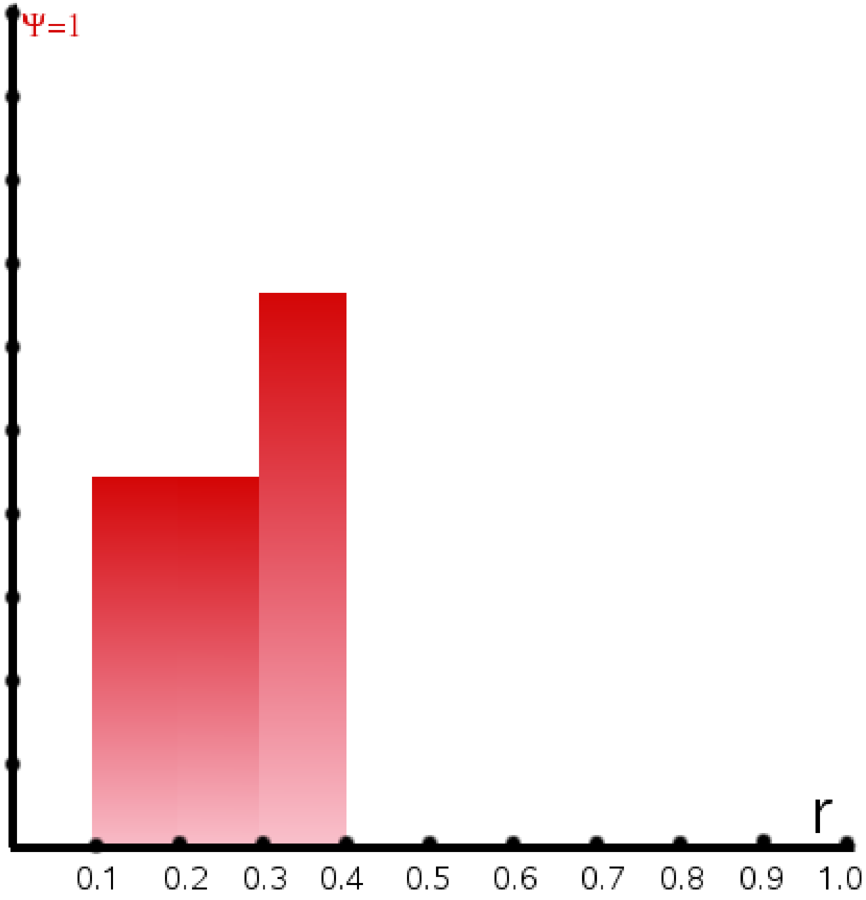
First contribution, at $r = \mathbf{0.2}$

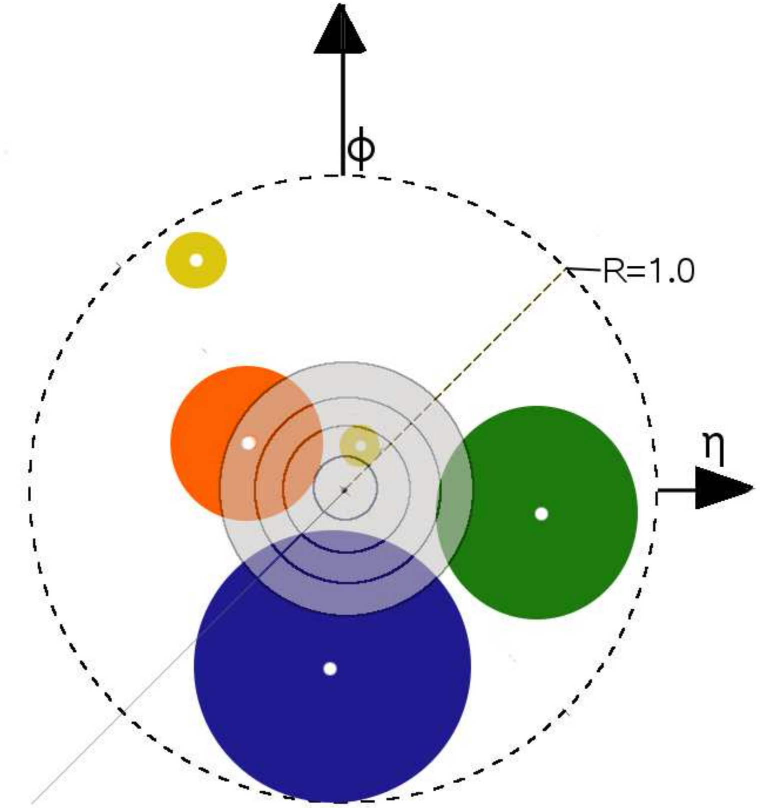
Integrated jet shape $\psi(r)$



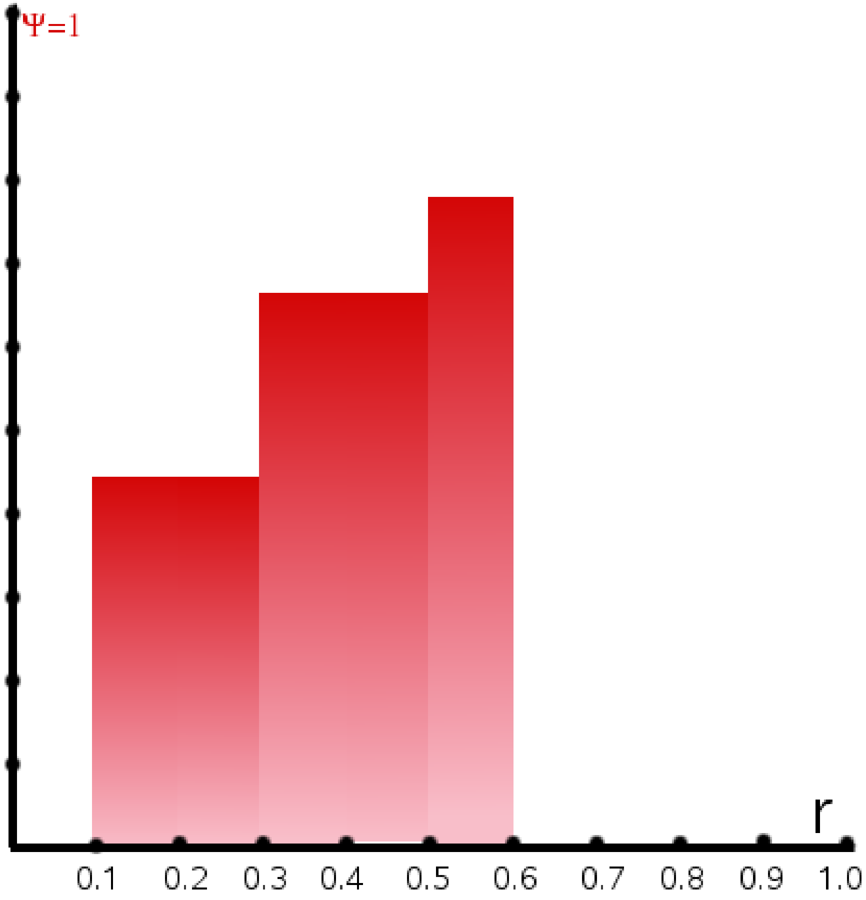


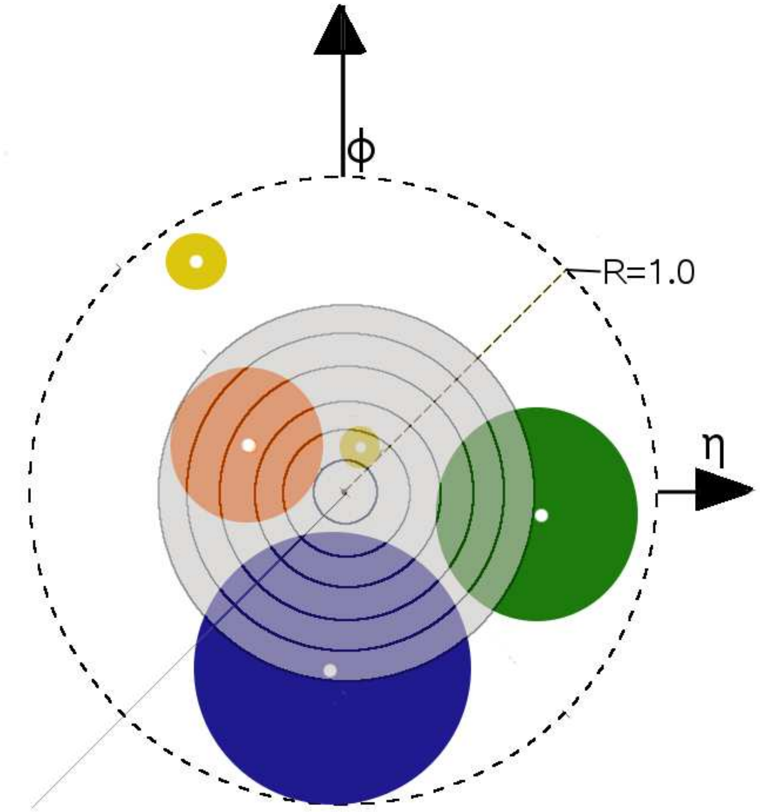
Integrated jet shape $\psi(r)$



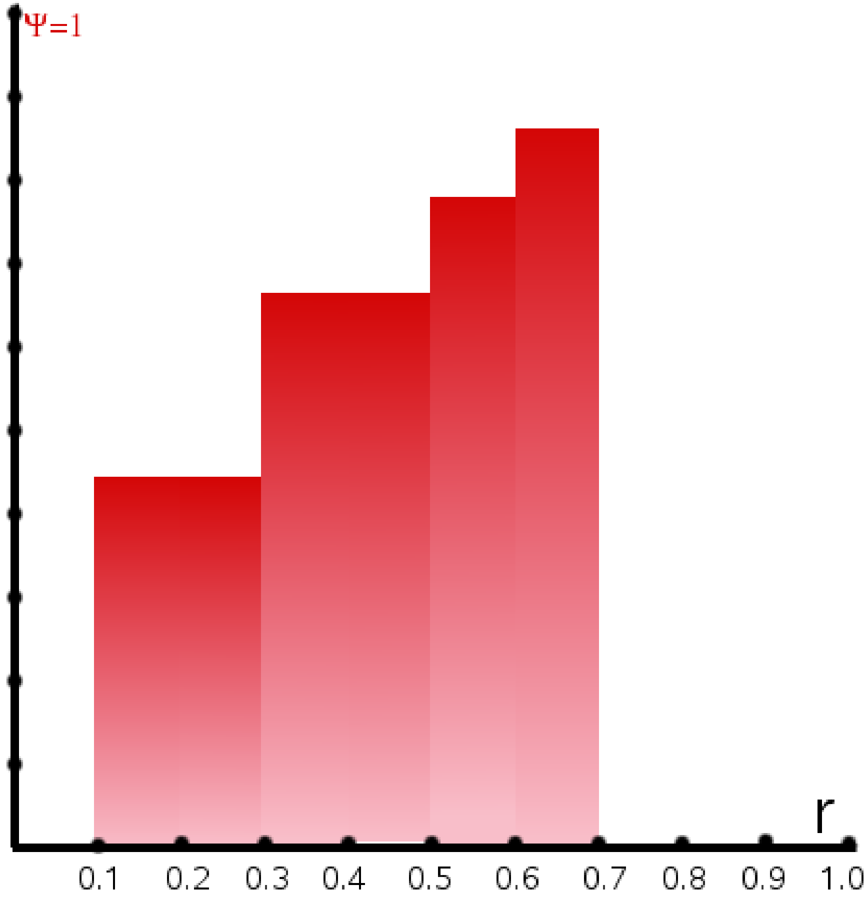


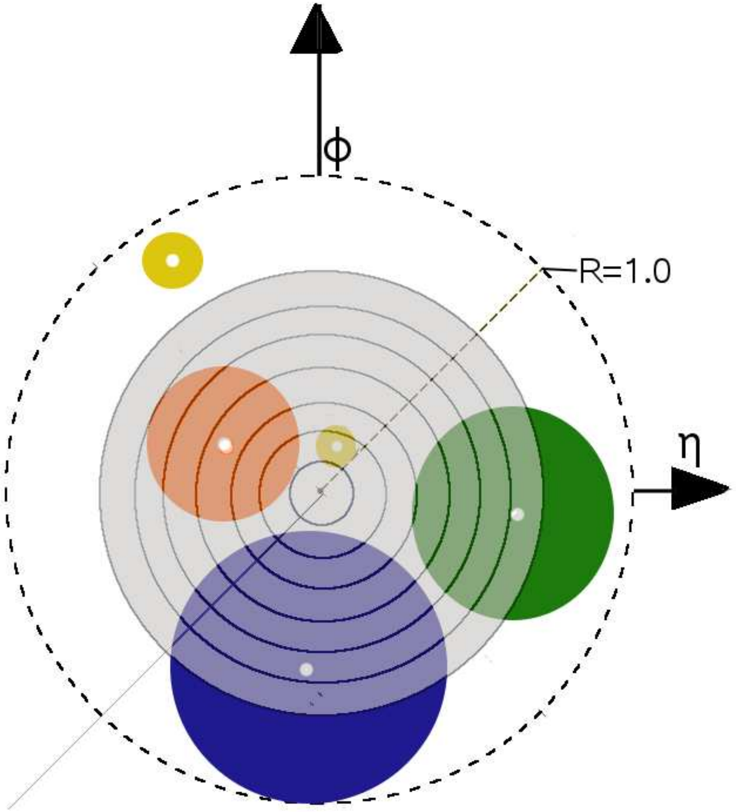
Integrated jet shape $\psi(r)$



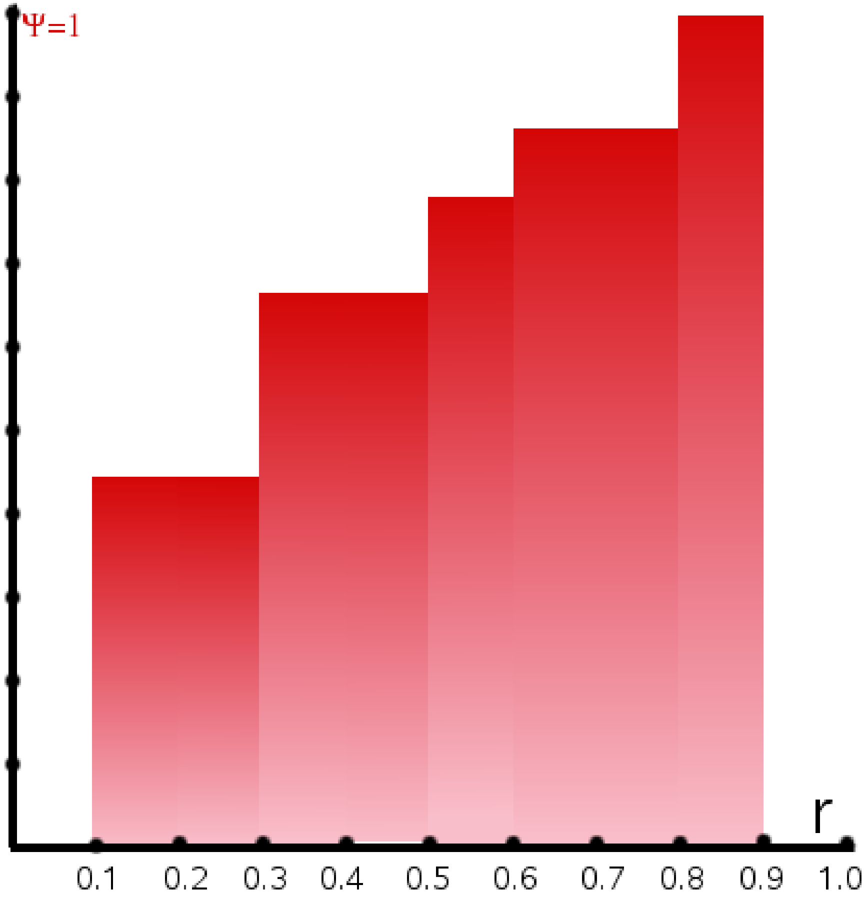


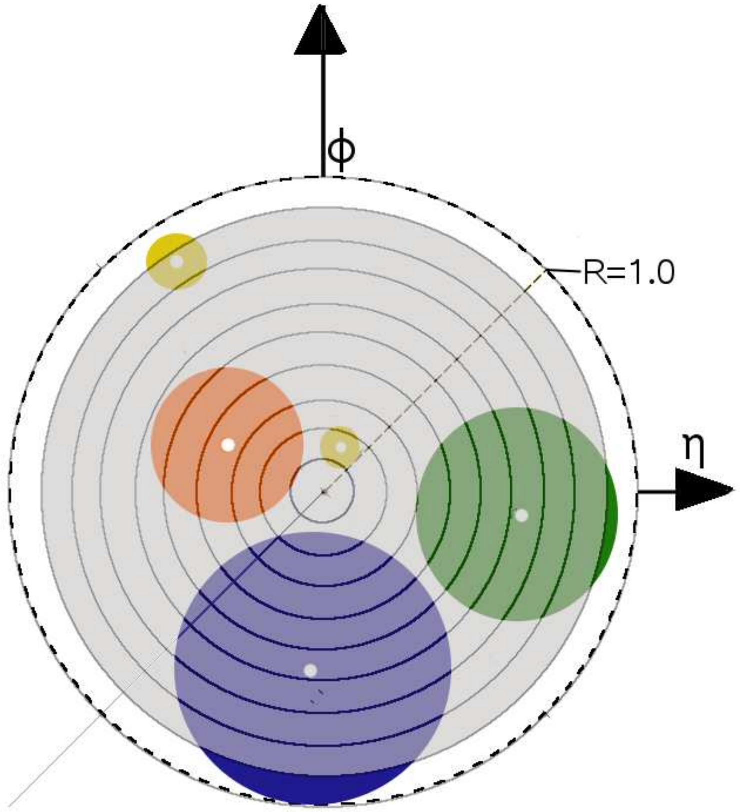
Integrated jet shape $\psi(r)$



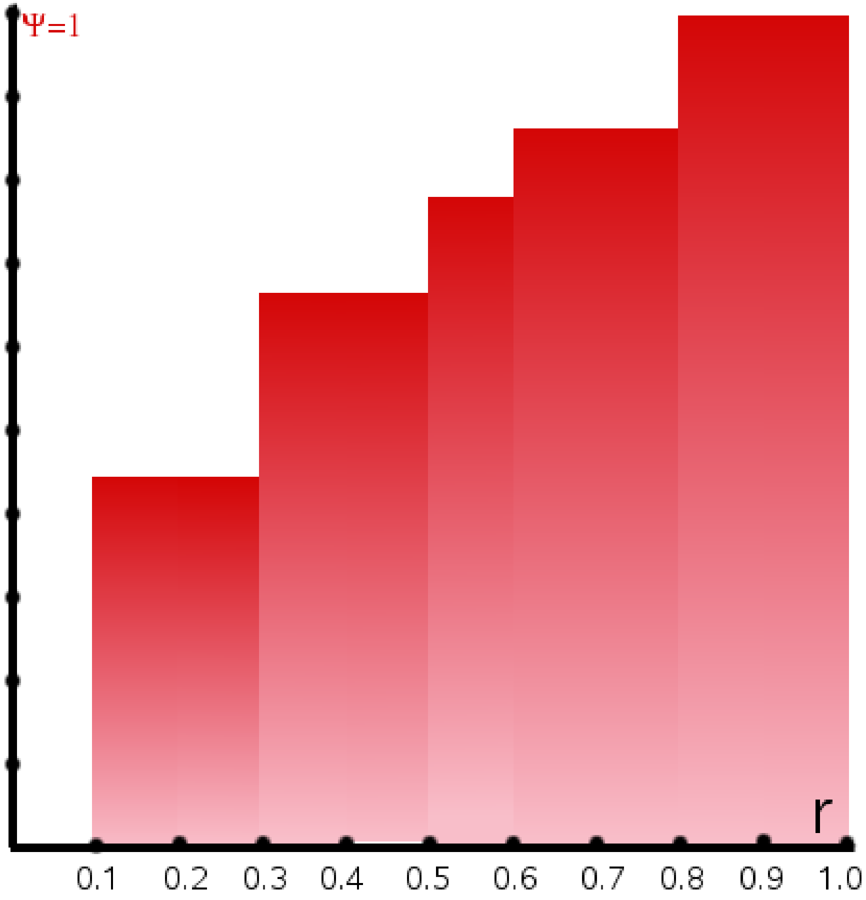


Integrated jet shape $\psi(r)$

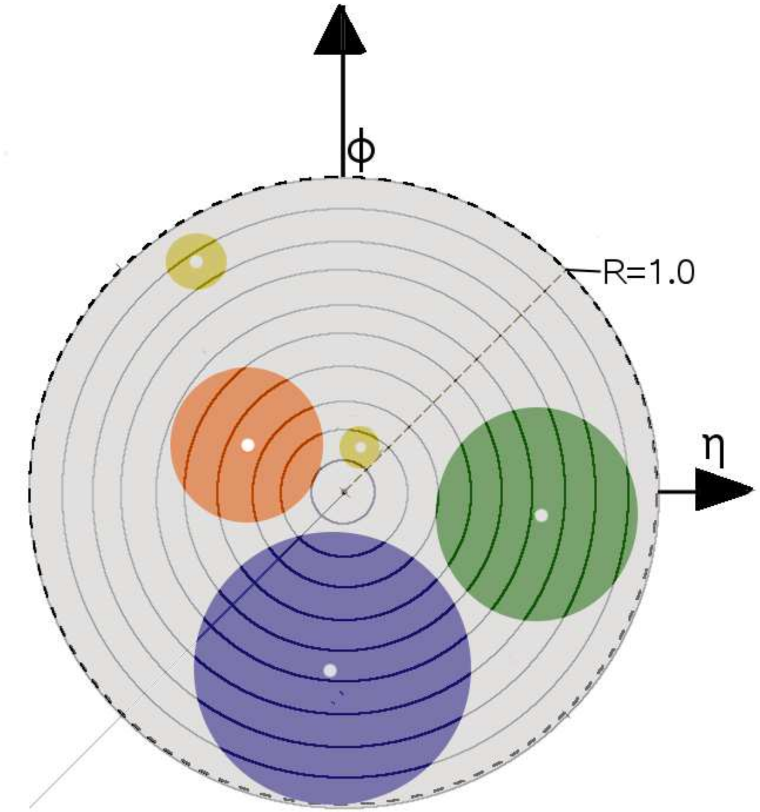




Integrated jet shape $\psi(r)$

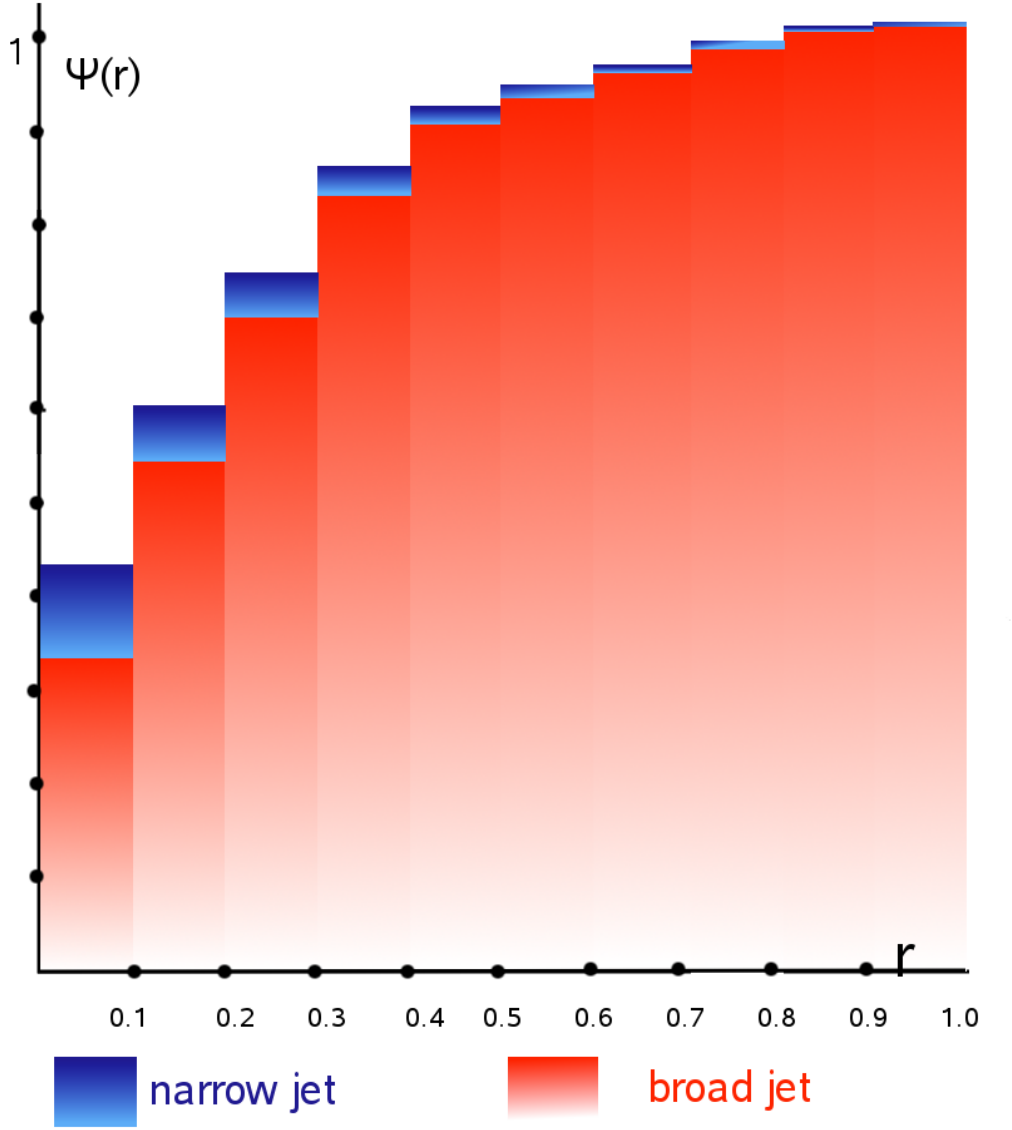


For this particular jet...



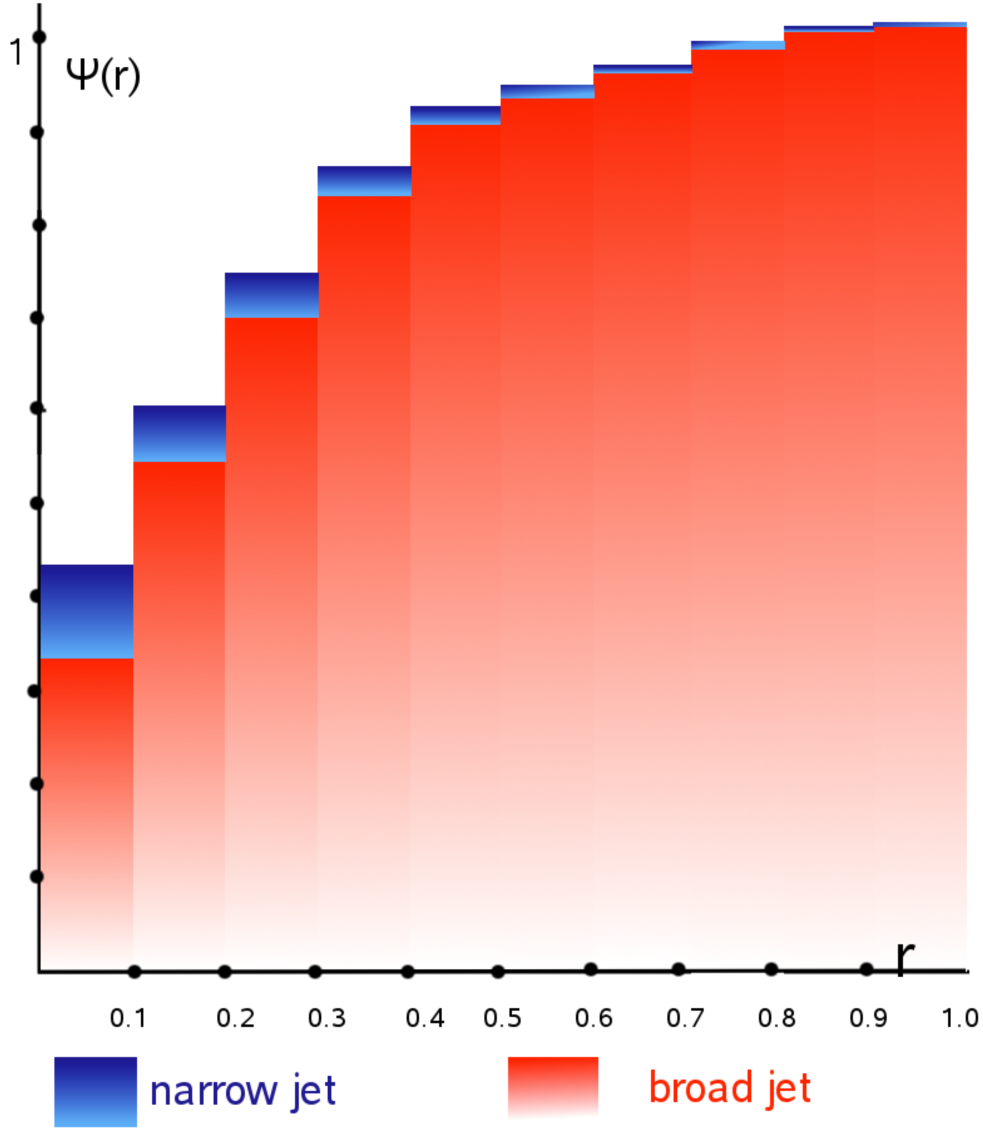
However, for a sample of jets...⟶

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**

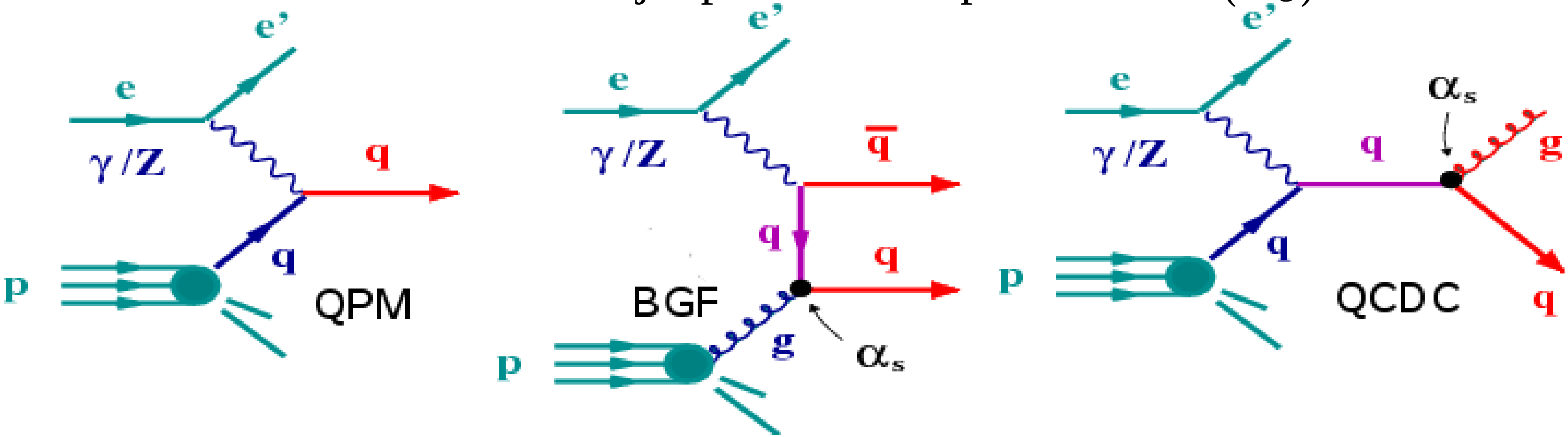
Integrated jet shape averaged over a jet sample



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**

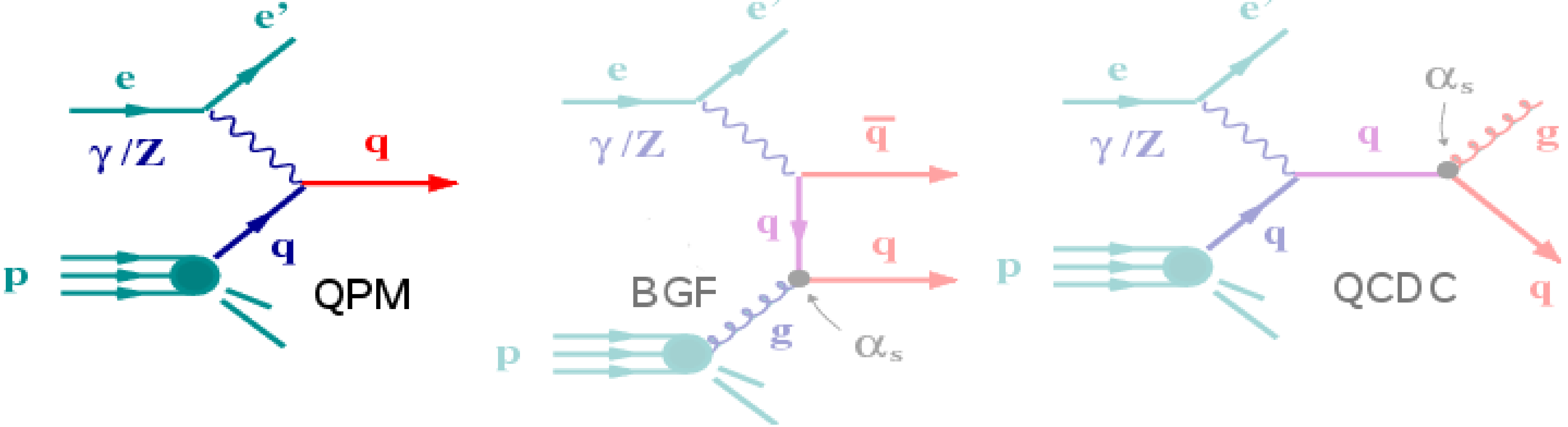
The aim of the analysis is to verify this prediction in the context of ***ep* collisions** and further test the predictions of pQCD about jet substructure.

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



We consider two different samples of jets:

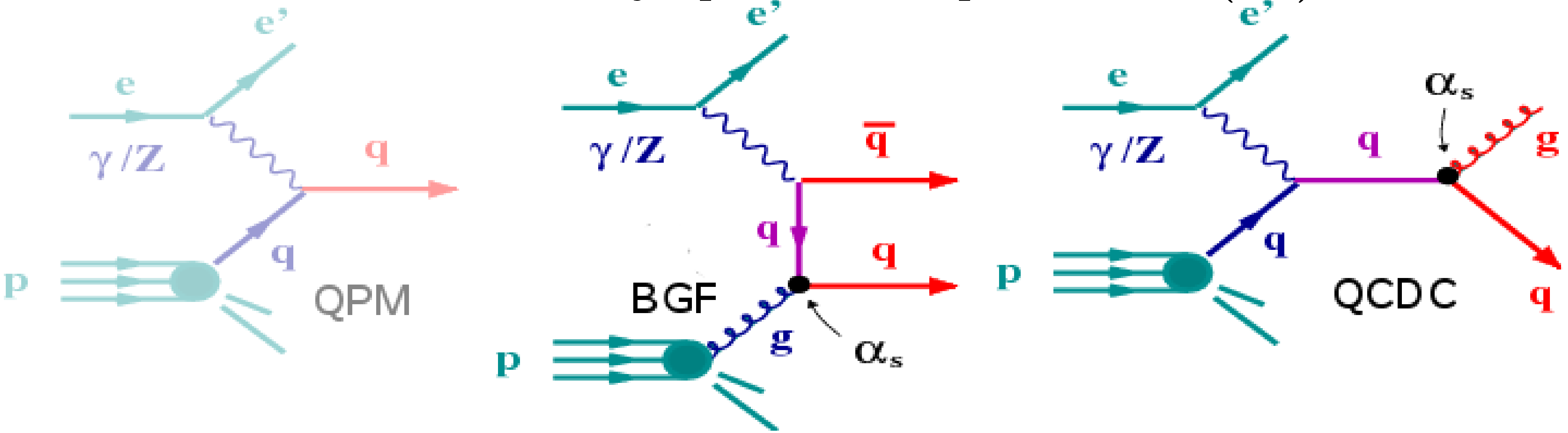
Contributions to jet production up to order $O(\alpha_s)$



We consider two different samples of jets:

1.Jets in events where there is **one and only one** jet with $E_T^{jet} > 14\ GeV$ QPM events are the main contribution to single-jet production. This jet sample is expected to be **enriched** with quark-initiated jets.

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



We consider two different jet samples:

1.Jets in events where there is one and only one jet with $E_T^{jet} > 14\,GeV$
QPM events are the main contribution to single-jet production. This jet sample is expected to be enriched with quark-initiated jets.

2.The jet with the lowest E_T^{jet} in events with **two and only two jets** with $E_T^{jet_{1,2}} > 14\,GeV$ 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 $\boldsymbol{368 pb^{-1}}$ in the kinematic region of:

$$\boldsymbol{Q^2 > 125\, GeV^2}$$

The jets are identified in the laboratory frame using the $\boldsymbol{K_T}$ **Cluster Algoritm.**

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

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

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

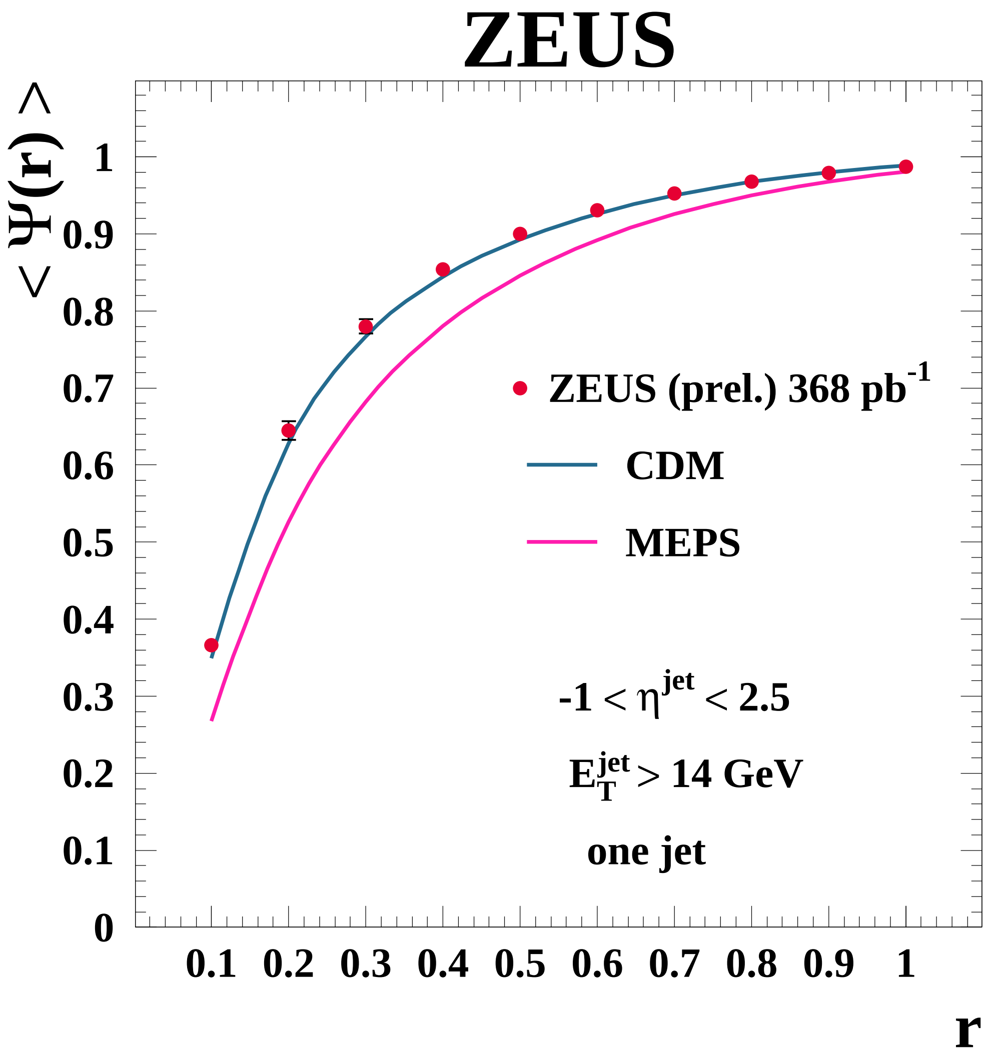
$$\boldsymbol{E_T^{jet_{1,2}} > 14\, GeV} \text{ and } \boldsymbol{-1 < \eta^{jet_{1,2}} < 2.5}$$

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

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

two values of $\boldsymbol{D}$ have been considered, $\boldsymbol{D = 2}$ and $\boldsymbol{D = 2.5}$

RESULTS



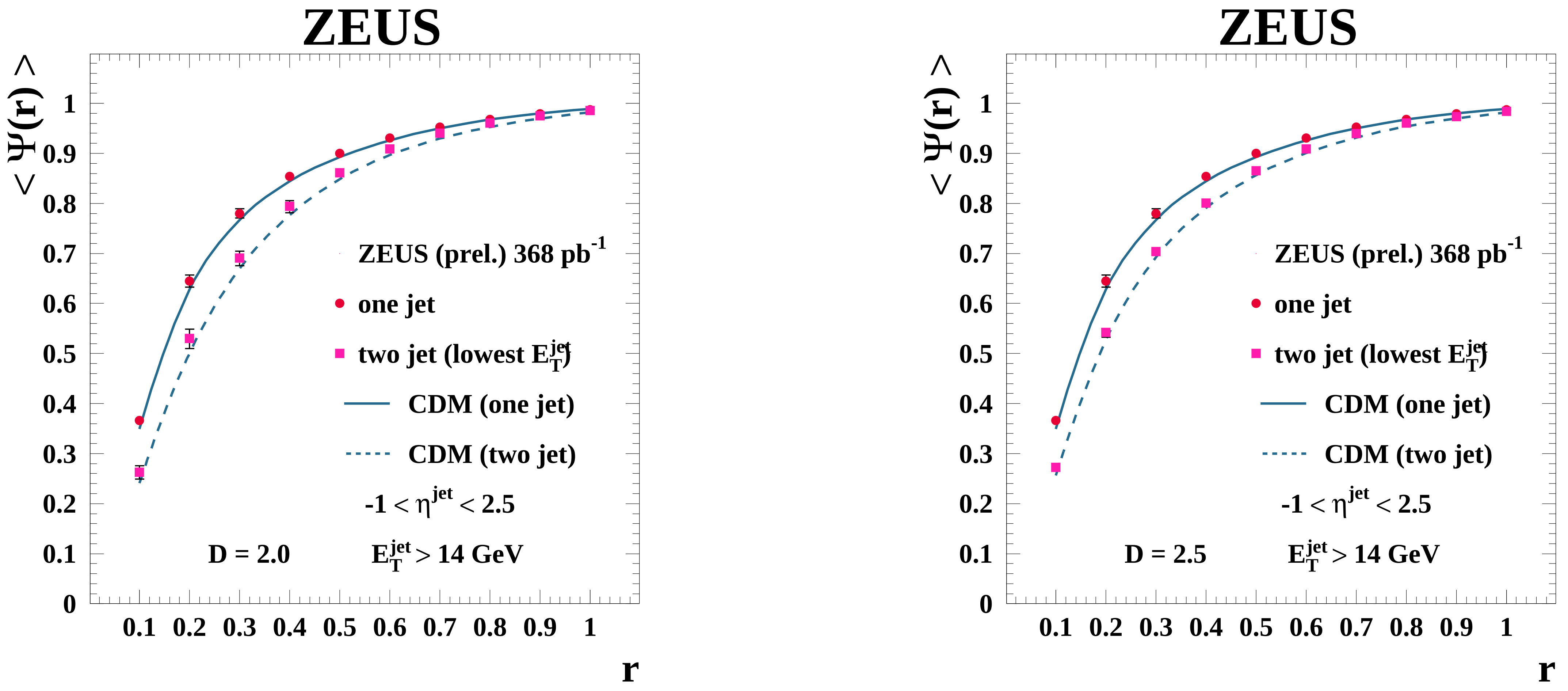
- The data have been corrected for **detector effects**

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

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

As well, the data have been corrected for QED.

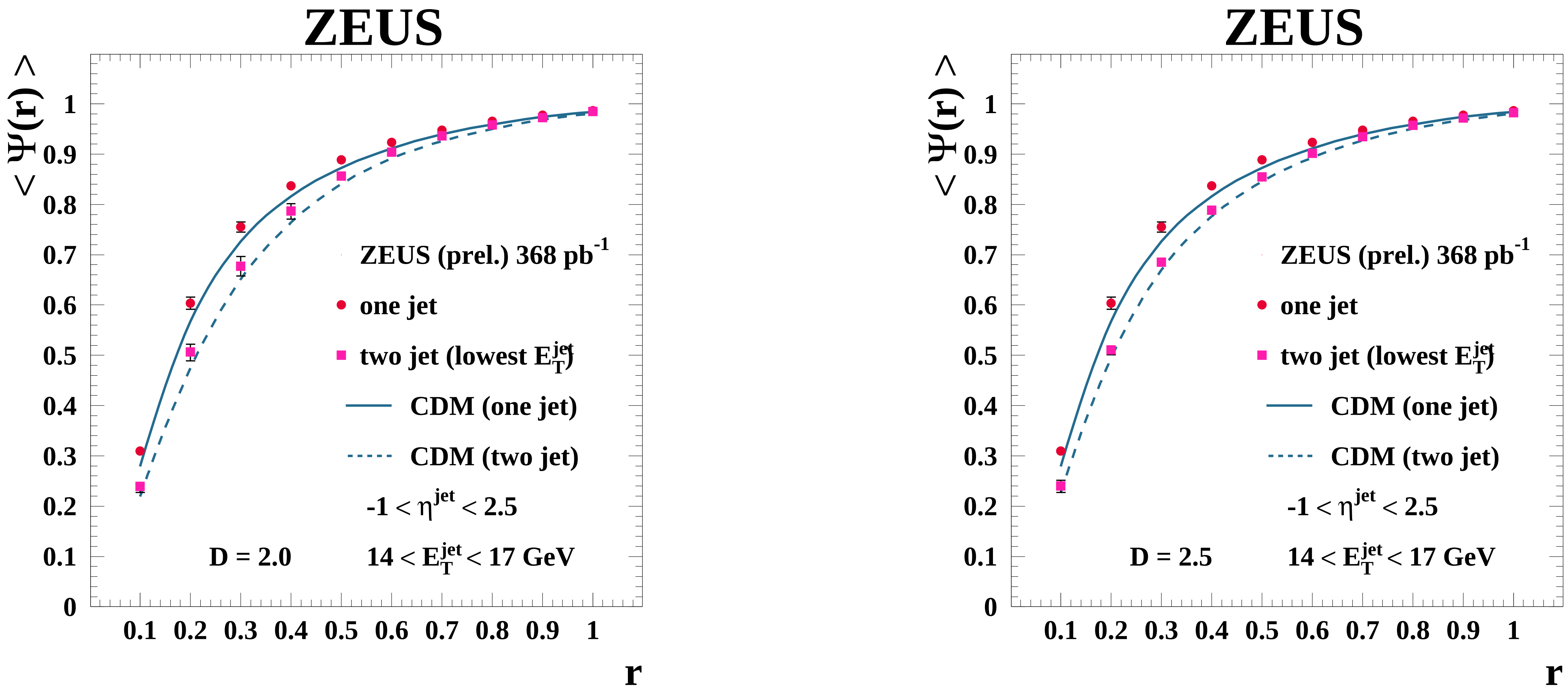
- Comparison with the **absolute predictions** of the Monte Carlo models.



Comparison between data and Monte Carlo predictions (CDM).

- A **significative 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.

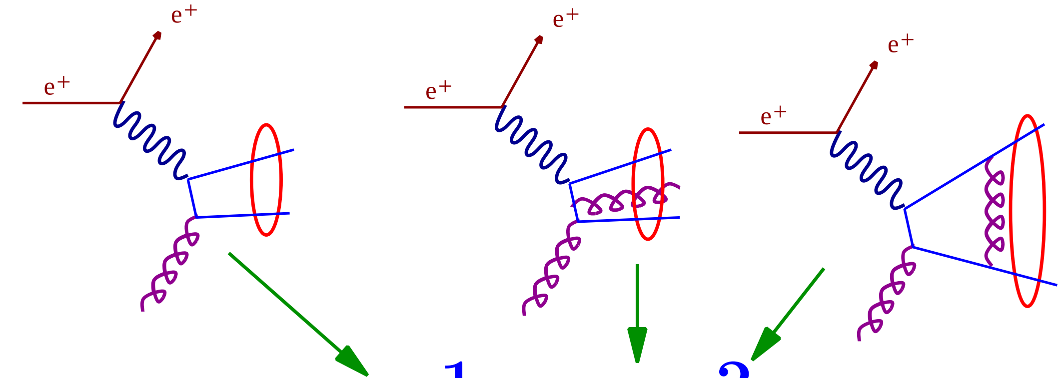
Dependence of the integrated jet shape with E_T^{jet}?



Comparison between data and Monte Carlo predictions (Ariadne).

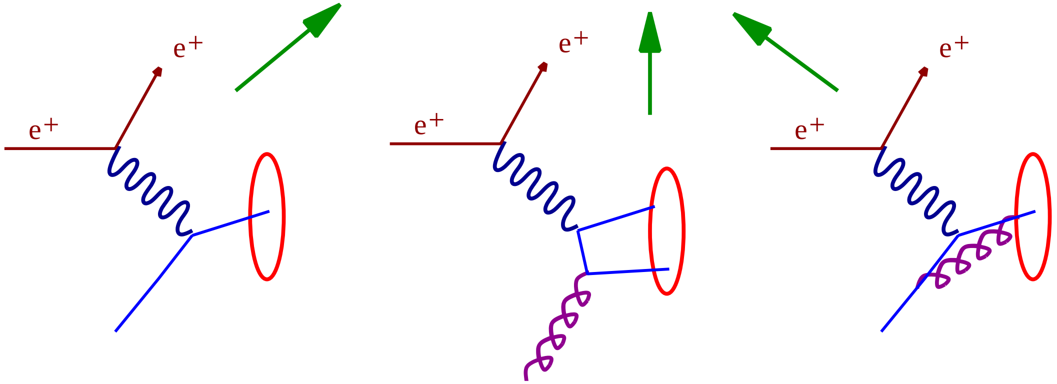
- The E_T^{jet} is now **restricted between 14 GeV and 17 GeV**.
- The difference between the samples is **still observed.**
- **Reasonable agreement** with the predictions of Ariadne.

NLO QCD calculations for one-jet production



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

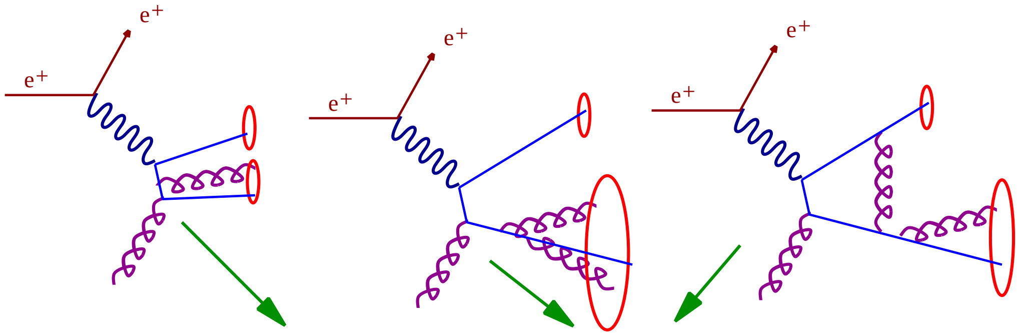
DISENT program
S. Catani and M.H. Seymour
Nucl. Phys. B485 (1997) 291



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

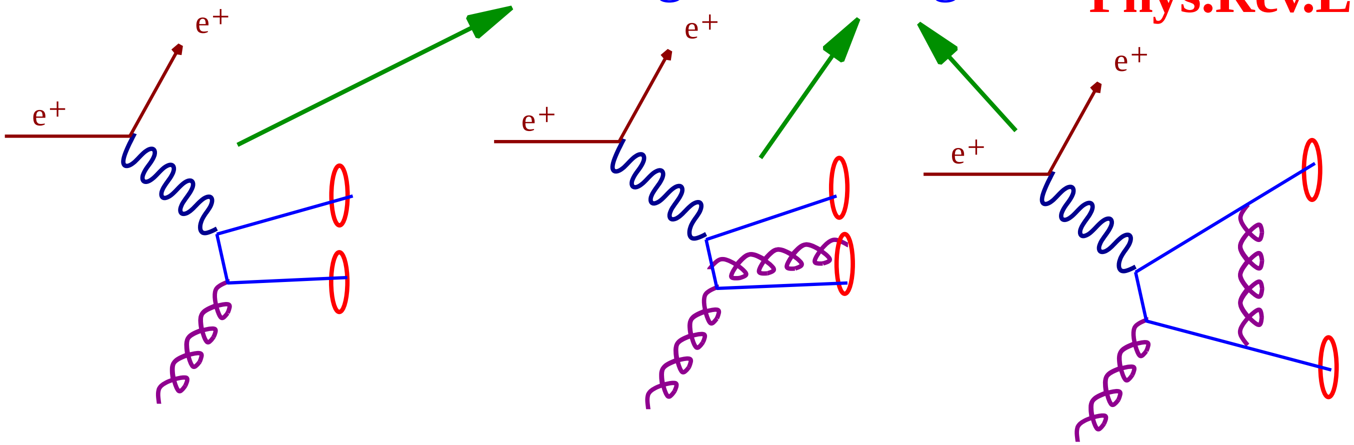
→ **Dominant theoretical uncertainty: terms beyond NLO,** $< 5\%$ **for** $r \geq 0.2$

NLO QCD calculations for two-jet production

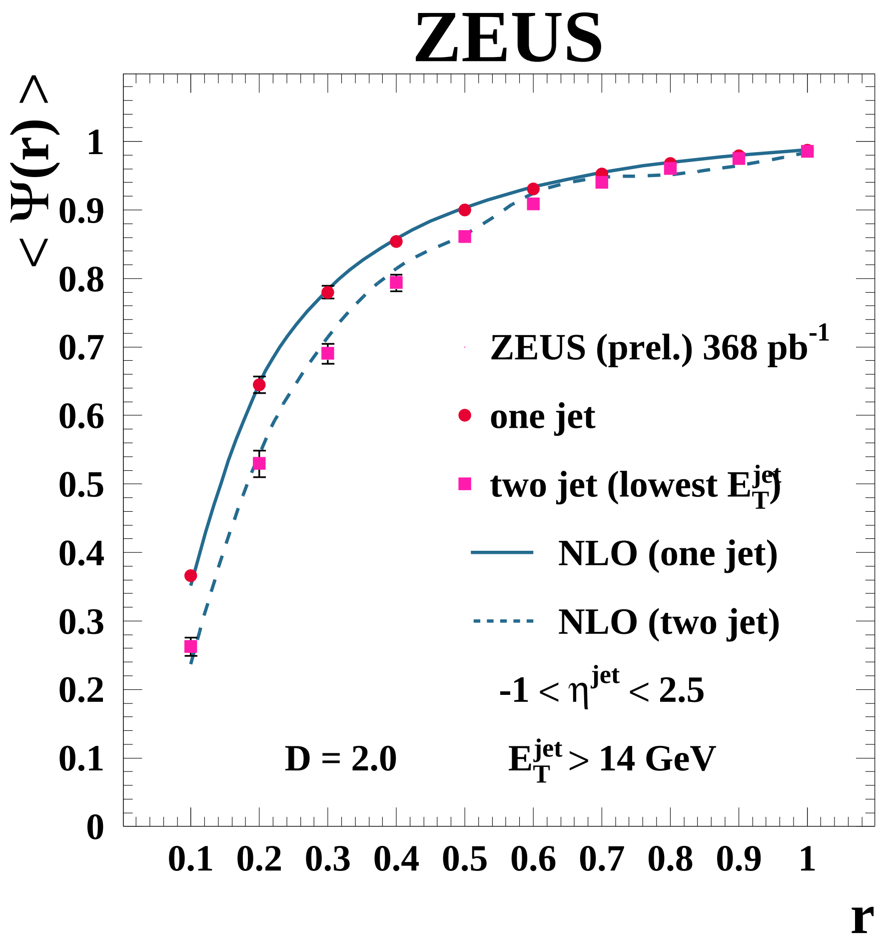


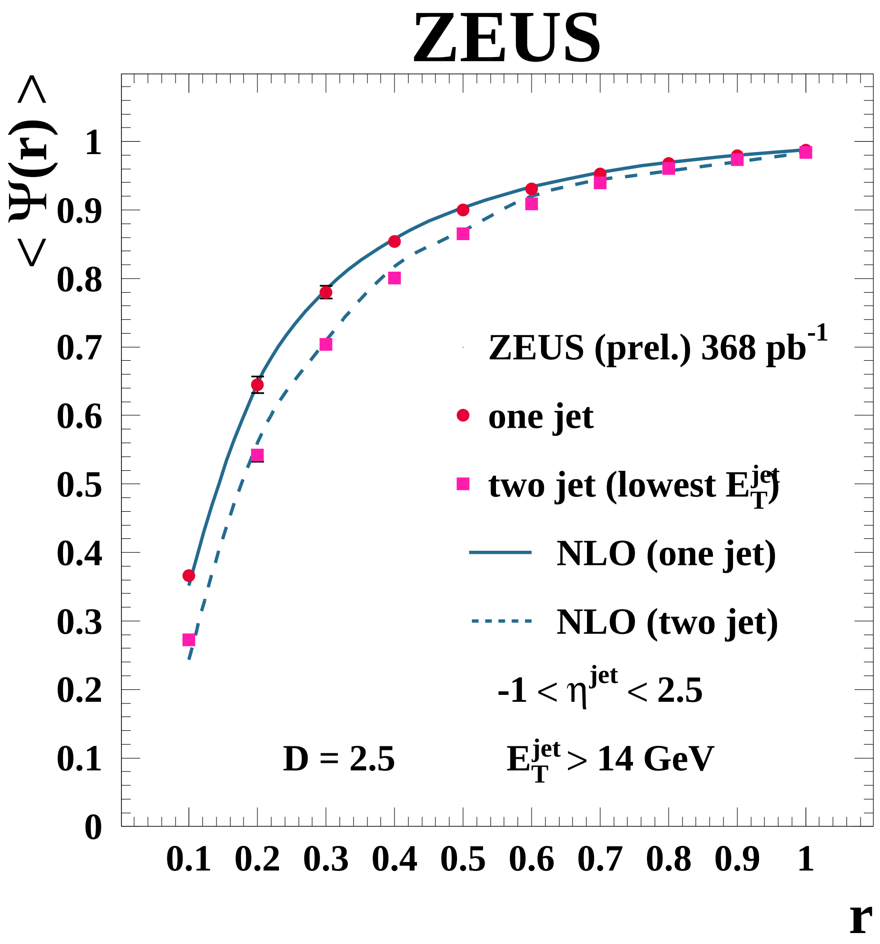
$$\langle 1-\Psi(r)\rangle = \frac{d_2\cdot\alpha_s^2+d_3\cdot\alpha_s^3}{c_1\cdot\alpha_s^1+c_2\cdot\alpha_s^2}$$

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



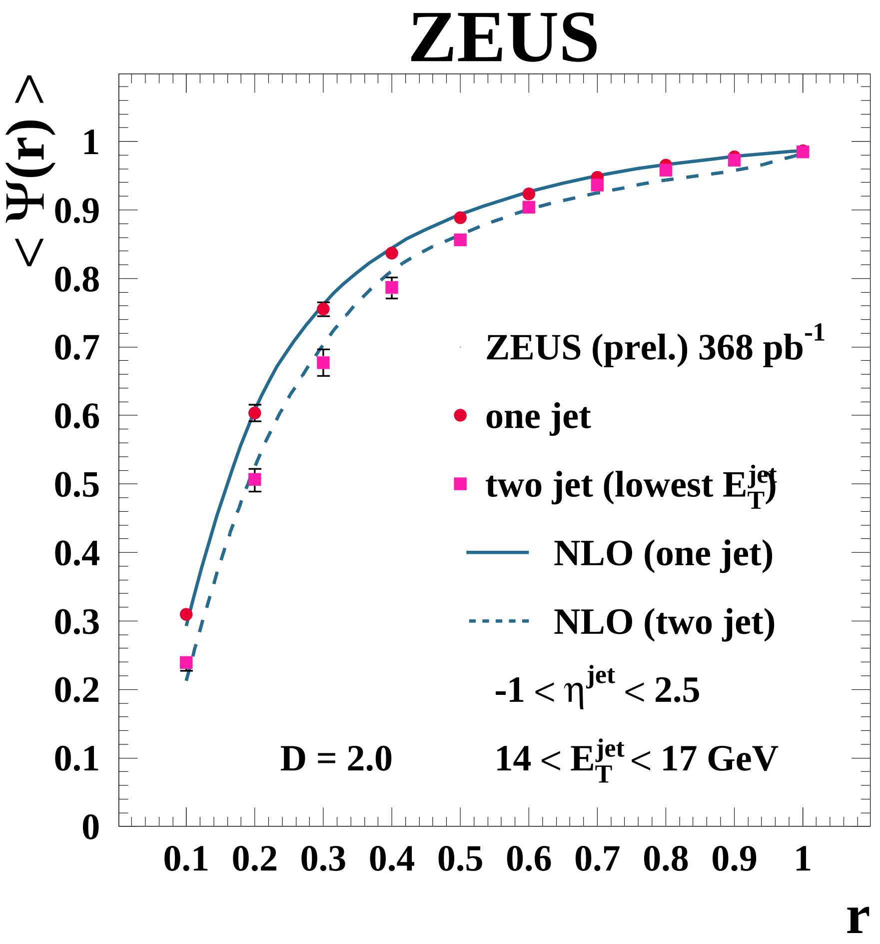
- **NLOJET++ program:** $\alpha_s(M_Z) = 0.118$; $\mu_R = \mu_F = Q$; **CTEQ6 proton PDFs**

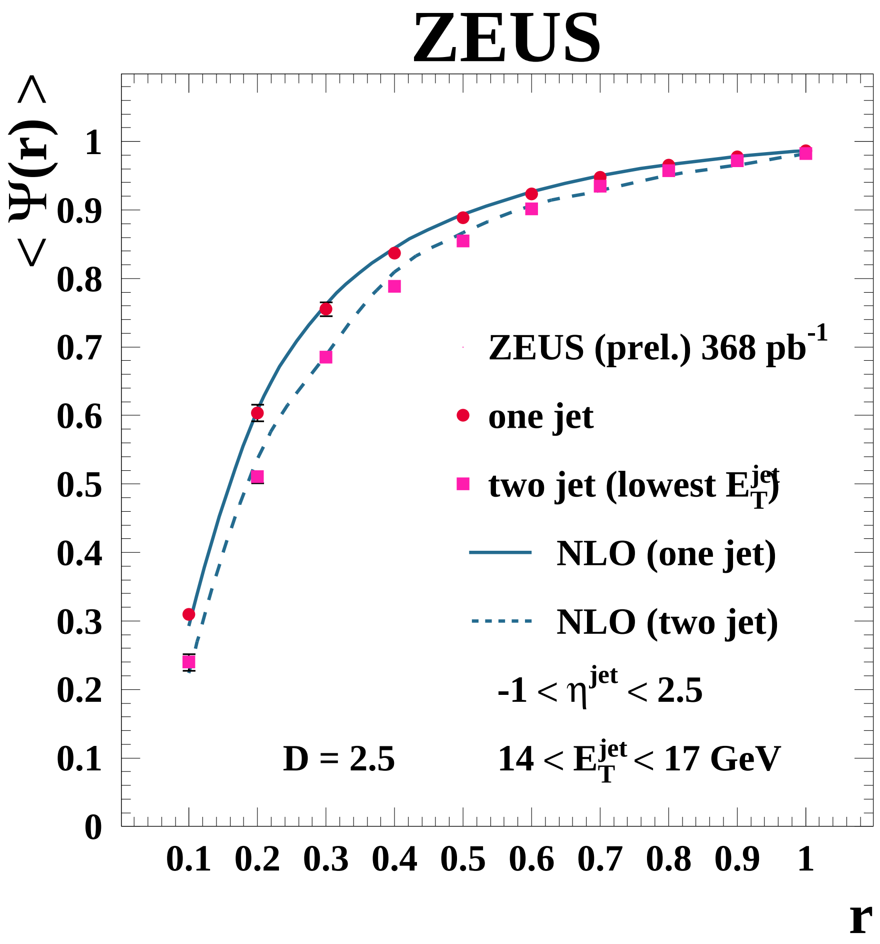




Comparison between data and Next to Leading Order calculations.

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





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.