Electroproduction of dijets at small jet separation

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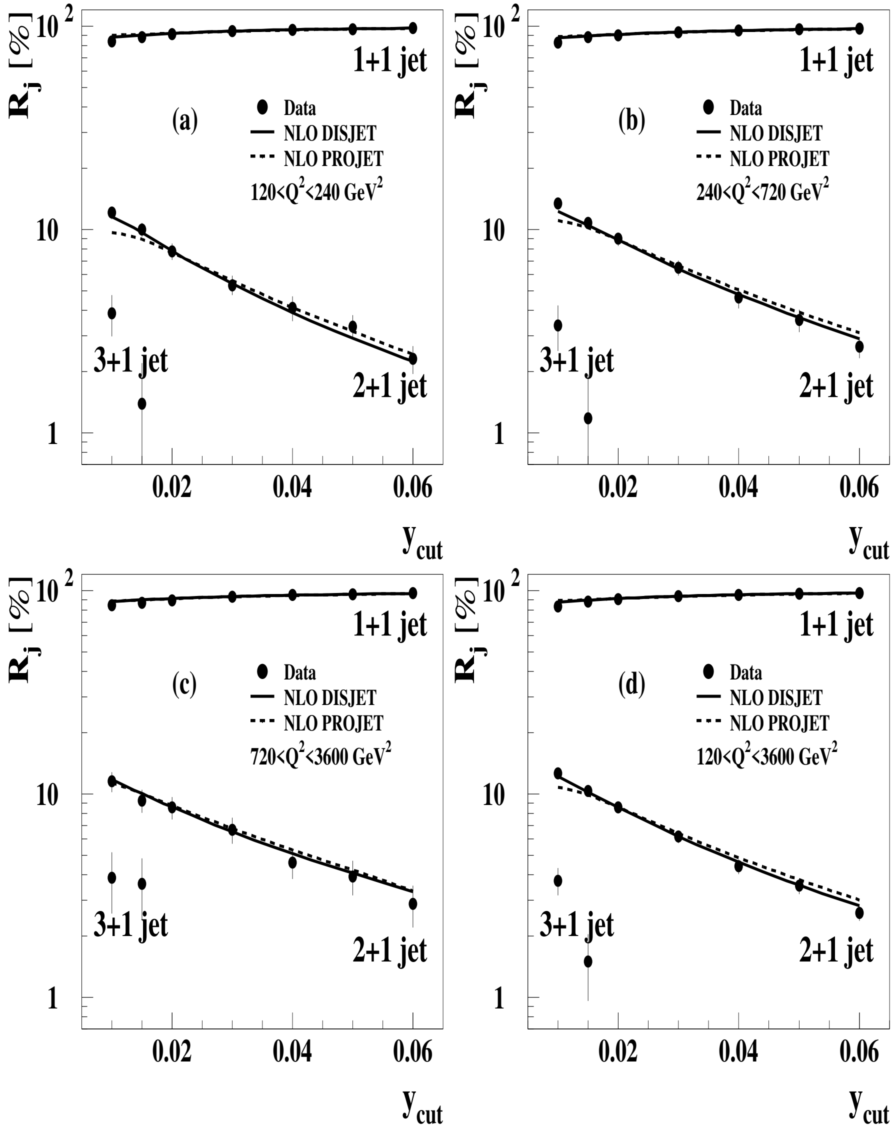
- **Modified Durham Jet algorithm**
- **Some results studying jet separation dependence in DIS**
- **Motivation for this analysis**
- **H1 data and dijet selection**
- **Results**
- **Summary**

Modified Durham ($k_\perp$) jet algorithm in DIS

- Originally, improvement of JADE jet algorithm for e^+e^- annihilation
- Modified for DIS: add proton-remnant 4-vector $=$ missing momentum
  - compute all combinations $k^2_{\perp ij} = 2\min[E_i^2, E_j^2](1 - \cos\theta_{ij})$
  - combine the pair with the minimum $k^2_{\perp ij}$
  - combine until, for example, exactly $(2+1)$-jets are found
  - define **significant** dijets by imposing a lower limit on $y_2 = k^2_{\perp ij}/\text{scale}^2$, with W or Q typically chosen as scale
- In DIS, algorithm typically applied in the Lab frame $\longrightarrow$ no boost error
- With W as scale $\longrightarrow$ partial cancellation of hadronic energy scale uncertainty

Jet rates as a function of the minimum jet separation

ZEUS 1994



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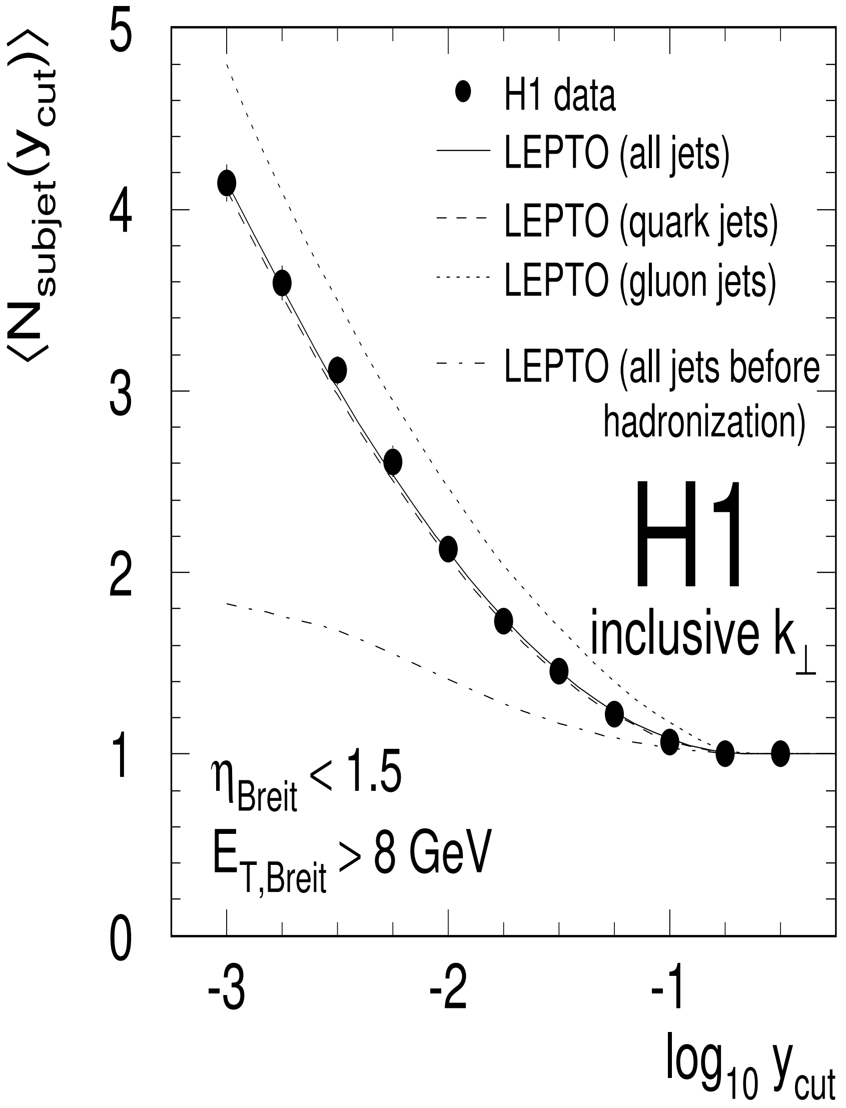
- Modified JADE jet algo used: $y_{ij} = 2E_iE_j(1-\cos\theta_{ij})/W^2$
- Jet rates well described by pQCD for $y_{\rm cut} > 0.01$
- α_s determined using R_{2+1} for $y_{\rm cut} = 0.02$

Subjet multiplicities as a function of the minimum jet separation



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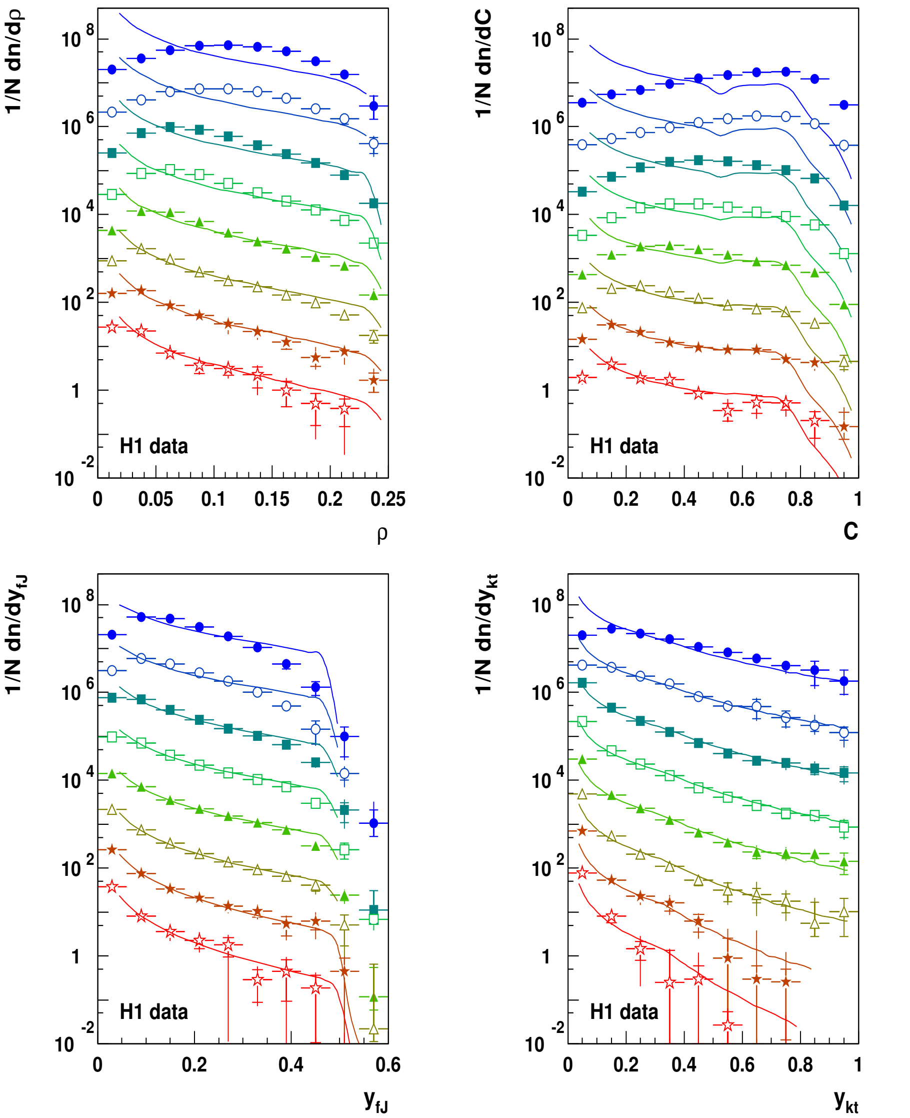
- Subjet multiplicity for jets with $E_T > 8$GeV as a function of y_{cut}
- Inclusive $k_\perp$ jet algo, based on longit. boost-invariant quantities $(E_T, \Delta\eta, \Delta\phi)$, applied in the Breit frame
- Data well described by **LO + PS** MC model for $y_{\text{cut}} \geq 0.001$

Normalized dijet cross section as a function of the minimum jet separation



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- normalized cross section for y-values for which the transition from $(2+1)$ to $(1+1)$-jets occurs from low to high ranges in Q^2
- Modified Jade and inclusive $k_\perp$ jet algo in the Breit frame are used
- Data of interest to understand power corrections and α_s
- Data well described by NLO QCD

Motivation for this analysis

- pQCD describes y_2 distributions down to small values ($k_{\perp ij} \approx$ few GeV)
- QCD models based on LO+PS describe subjet multiplicities down to $y_{\text{cut}} \approx 0.001$ ($k_{\perp ij} \approx 0.3$ GeV)

- What is the minimum y_2 or $k_{\perp ij}$ for which NLO QCD gives a good description of the characteristics of dijets ?
- Can these dijet distributions also be described by LO+PS MC models ?

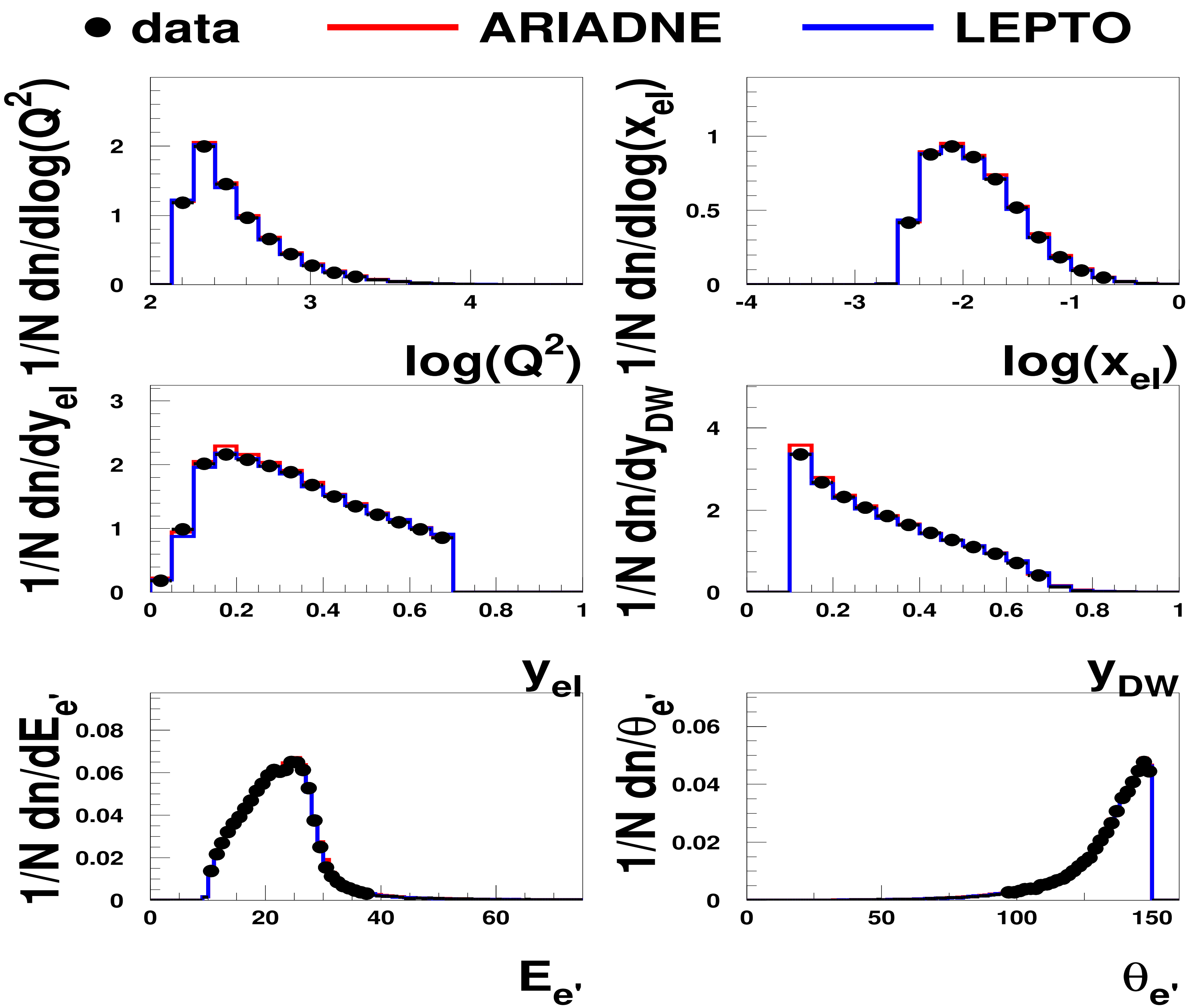
H1 data and jet selection

- $150 < Q^2 < 35000$ GeV^2
- inelasticity $0.1 < y < 0.7$
- $30 < E - P_z < 70$ GeV

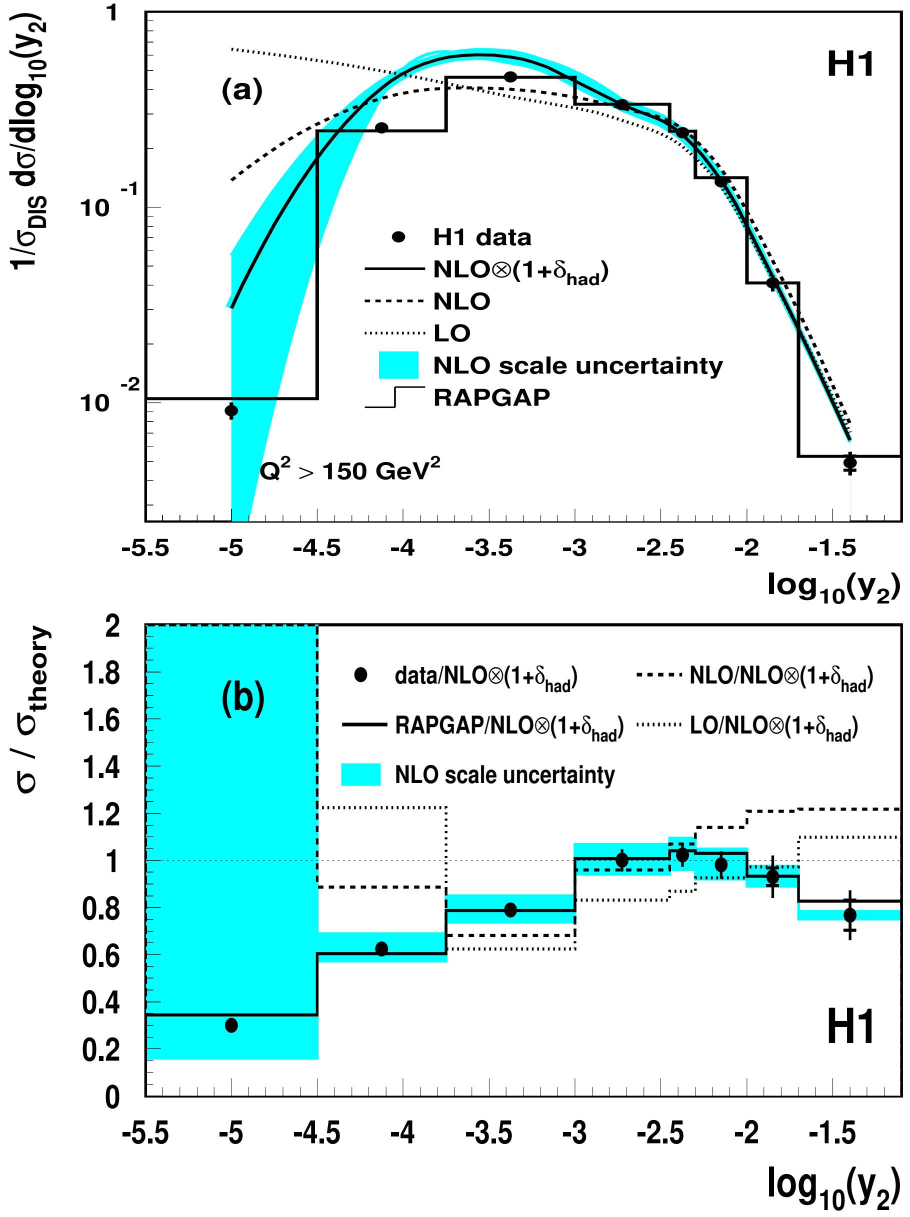
$\Rightarrow\ \approx\ 60000$ DIS events for $\mathcal{L} = 35$ pb^{-1}

- apply modified Durham jet algo in the Lab frame
- use $y_2 = \min k^2_{\perp ij}/W^2$
- demand $10^\circ < \theta_{\text{jet}} < 140^\circ$

Data/MC: DIS event kinematics



Dijet rate as a function of the minimum jet separation



Each event contributes only once!

For $y_2 \geq 0.001$ (1/3 of DIS events)

- small k-factors (NLO/LO)
- small renormalization scale dependence ($Q/2 \leq \mu_R \leq 2Q$)
- small hadronization corrections

$\Rightarrow$ Good description of data by NLO QCD; better pdfs at high y_2

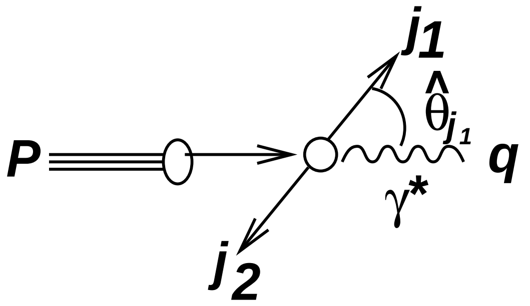
$LO + PS$ as implemented in RAPGAP describes the data over the full y_2 range, i.e. multiple parton emissions at low y_2 are well described

Characteristic dijet observables

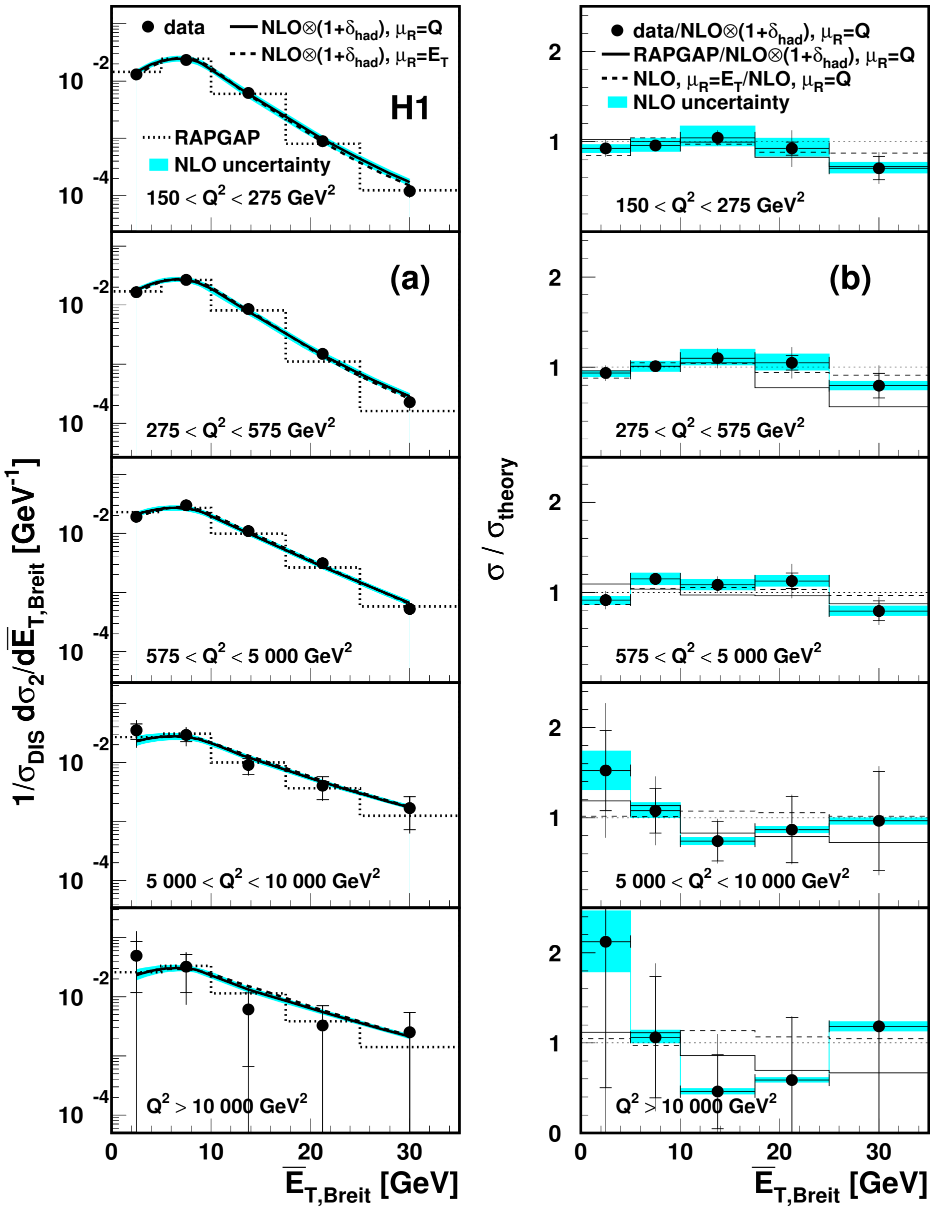
Good description of y_2 for $y_2 \geq 0.001$ ($k_\perp > 2$ GeV) by NLO QCD

$\Rightarrow$ Study characteristic jet observables for $\approx 1/3$ of all DIS events

- $\overline{E}_{T,\mathrm{Breit}}$: mean transverse energy of the dijets in the Breit frame
- θ_{fwd}, θ_{bwd}: polar angles of forward and backward jets
- Observables directly related to LO QCD matrix elements:
  - $x_p = \frac{Q^2}{2\xi P\cdot q} = \frac{x}{\xi} = \frac{Q^2}{Q^2+m_{12}^2}$
  - $z_p = \frac{P\cdot \min_{i=1,2} p_i}{P\cdot q} = \frac{1}{2}\min_{i=1,2}(1-\cos\theta_i^\star) = \frac{\min_{i=1,2} E_i(1-\cos\theta_i)}{\sum_{i=1,2} E_i(1-\cos\theta_i)}$



Dijets: $\overline{E}_{T,\text{Breit}}$ distribution in different ranges of Q^2

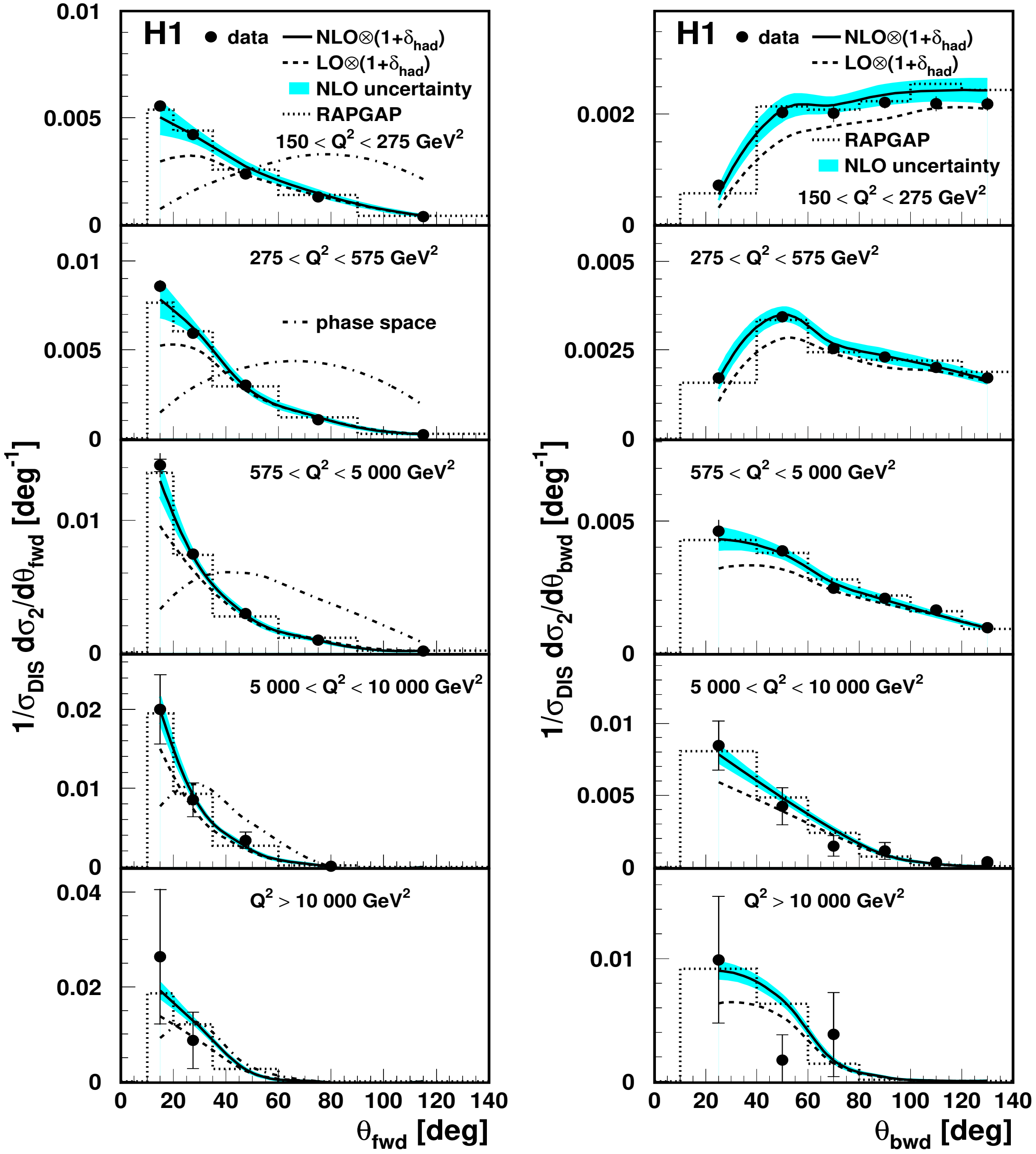


- sizeable fraction of events have $\overline{E}_{T,\text{Breit}} < 5$ GeV
- $< \overline{E}_{T,\text{Breit}} > \approx 6$ GeV
- NLO QCD calculation: 2 renormalization scales used:
  - $\mu_R = Q$
  - $\mu_R = \overline{E}_{T,\text{Breit}}$

  $\rightarrow$ differences are small

NLO QCD and LO+PS (RAPGAP) describe the data well

Dijets: θ_{fwd} and θ_{bwd} distributions in different ranges of Q^2



θ_{fwd}:

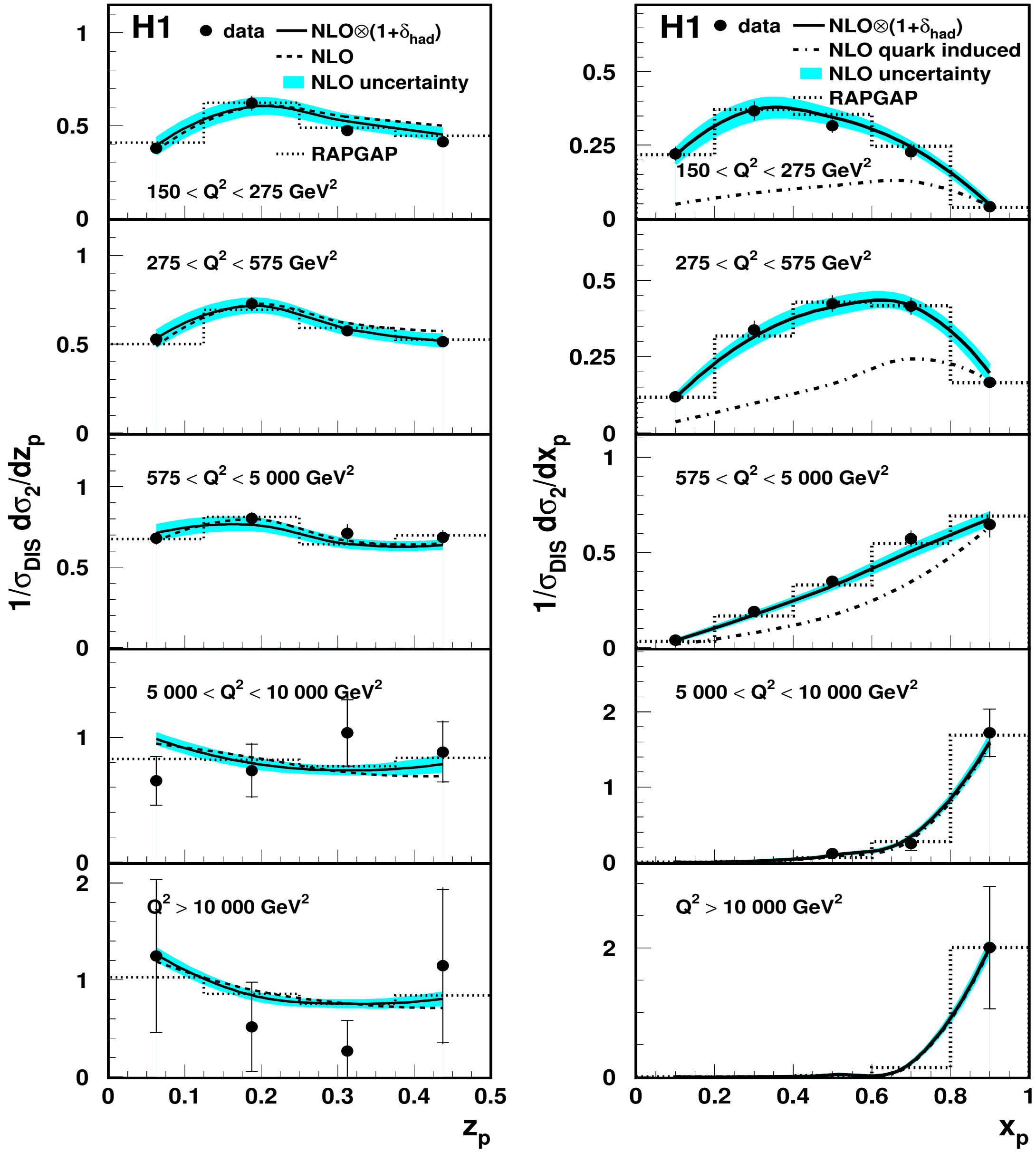
- strong increase with decreasing θ_{fwd} due to ISR
- LO, at small Q^2, or phase space are unable to describe data

θ_{bwd}:

- with increasing Q^2 max. shifts into fwd region due to increasing momentum fraction of proton

⇒ Data are well described by NLO QCD and LO+PS (RAPGAP)

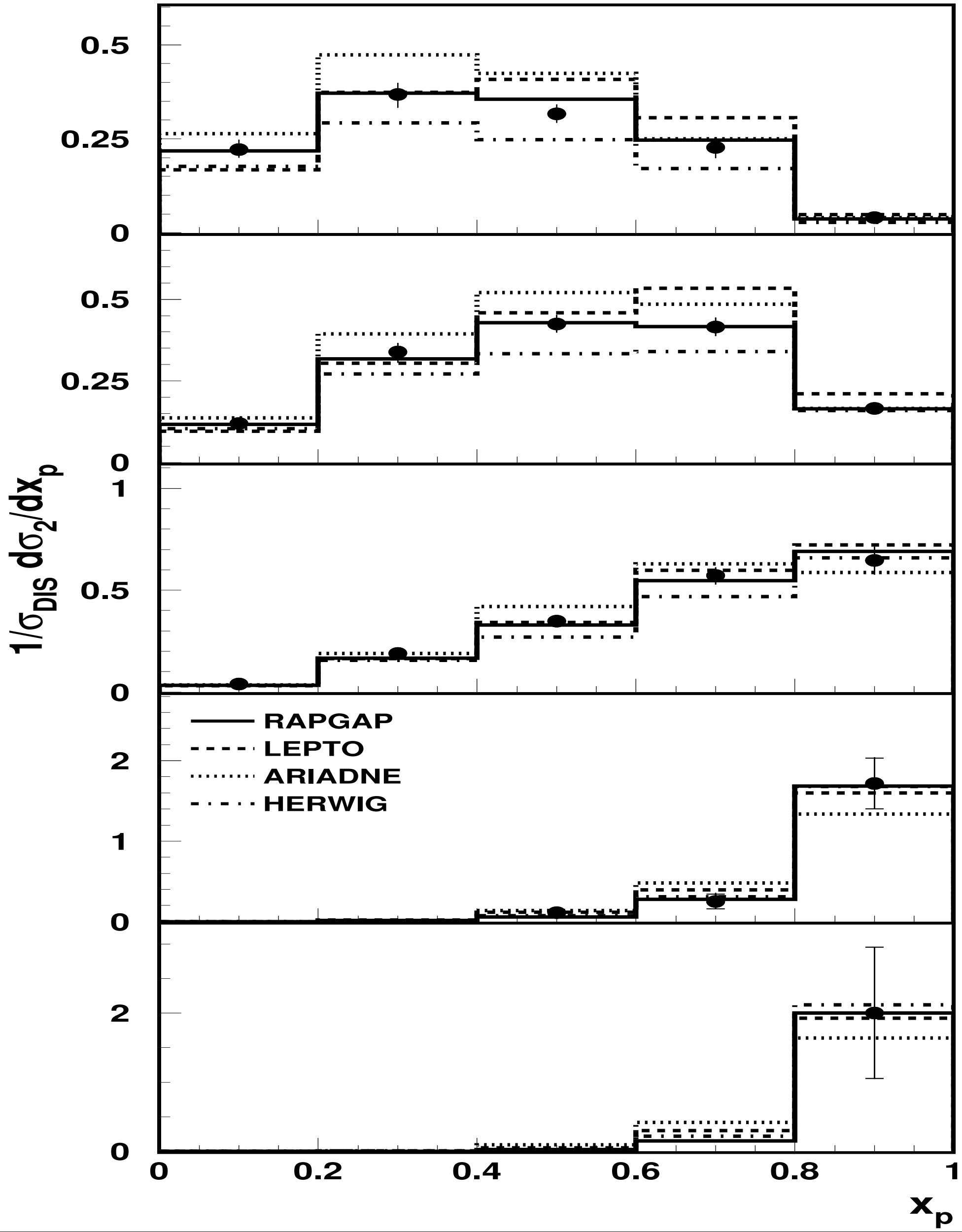
Dijets: z_p and x_p distributions in different ranges of Q^2



- the quark-induced contribution of the NLO calc. varies from 30% at the lowest Q^2 to almost 100% at the highest Q^2
- this illustrates that the measurements are sensitive to both the quark and the gluon-initiated contributions

$\Rightarrow$ Data are again well described by NLO QCD and LO+PS (RAPGAP)

Dijets: Comparison with other LO+PS QCD MC models



ARIADNE, HERWIG and LEPTO, with parameters tuned during 98/99 MC workshop, fail to describe parts of the x_p and other distributions, particularly in the lower Q^2-ranges

Summary

- The minimum jet separation is investigated for which NLO QCD can give a good description of dijet production in DIS in the range $150 < Q^2 < 35000$ GeV^2 .

- The min. jet separation is found to be small ($y_2 = 0.001$), selecting a dijet sample containing $\approx$ 1/3 of the DIS events compared to $\approx$ 1/10 obtained with more typical jet selection criteria.

- NLO QCD provides a good description of the data for both renormalization scales, $\mu_R = Q$ and $\mu_R = \overline{E}_{T,\mathrm{Breit}}$.

- QCD in the approximation of LO+PS as implemented in RAPGAP provides a good description of all the data.