Measurement of 1-jettiness in deep-inelastic scattering at HERA

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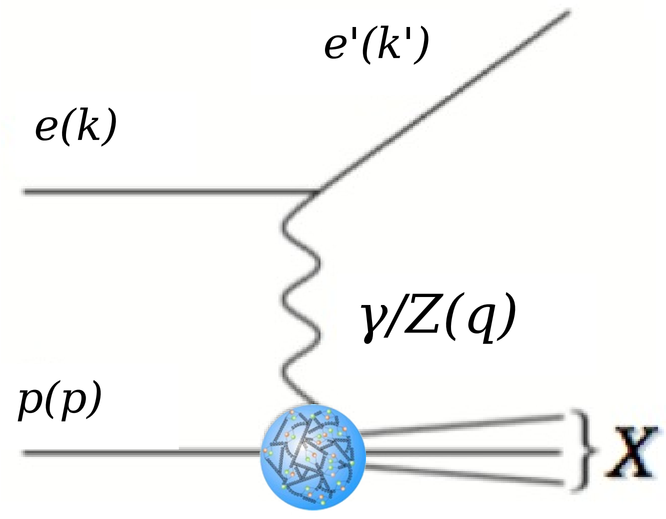
Neutral current deep-inelastic scattering

Neutral current deep-inelastic scattering

- Process: ep → e'X
- Electron or positron



Kinematic variables

- Virtuality of exchanged boson Q^2

$$Q^2 = -q^2 = -(k - k')^2$$

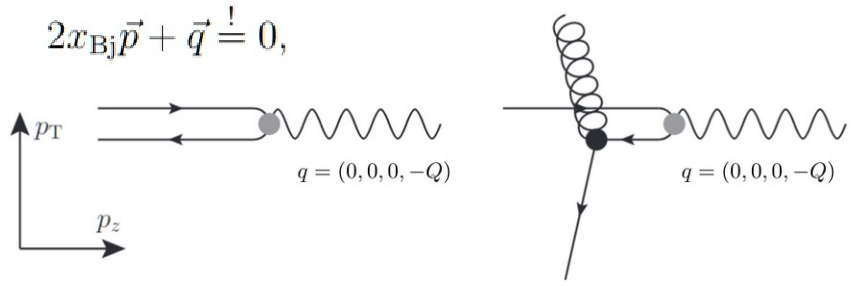
- Inelasticity, Bjorken-x and center-of-mass energy

$$y = \frac{p \cdot q}{p \cdot k} \qquad Q^2 = s \cdot x_{\mathrm{Bj}} \cdot y$$

The Breit frame

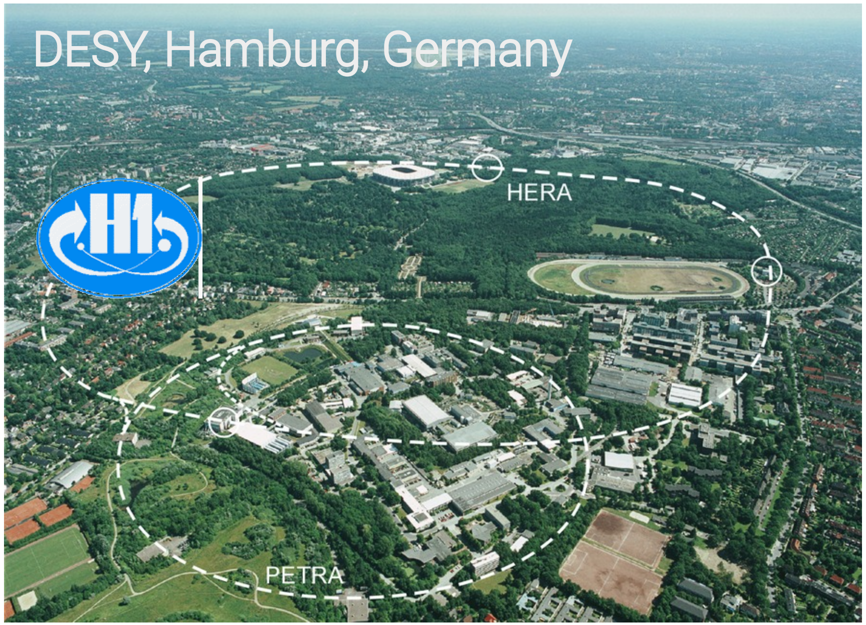
- Exchanged virtual boson collides 'head-on' with parton from proton ('brick-wall' frame)

$$2x_{\mathrm{Bj}}\vec{p} + \vec{q} \stackrel{!}{=} 0,$$



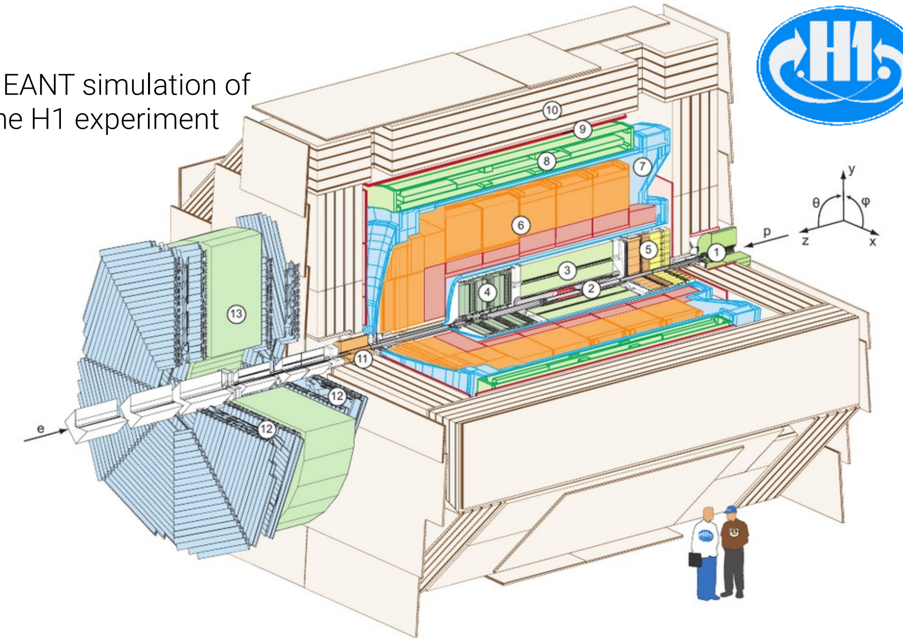
The H1 experiment at HERA

HERA electron-proton collider at DESY



- HERA I: 1994 – 2000
  HERA II: 2003 – 2007
- E_e=27.6 GeV, E_p=920GeV
  $\sqrt{s}$ = 300 or 319 GeV

H1 experiment at HERA



'multi-purpose' detector

- Asymmetric design with trackers, calorimeter, solenoid, muon-chambers, forward & backward detectors, …
- More on H1 in talks by:
  H. Klest. V. Mikuni, M. Mondal, M. Arratia

The 1-jettiness event shape

DIS thrust normalised to boson axis

- Normalisation with 2/Q

$$\tau_Q = 1 - \frac{2}{Q}\sum_{i\in\mathcal{H}_\mathcal{C}} P_{z,i}^{\mathrm{Breit}}$$

- Infrared safe, and free of non-global logs

1-jettiness

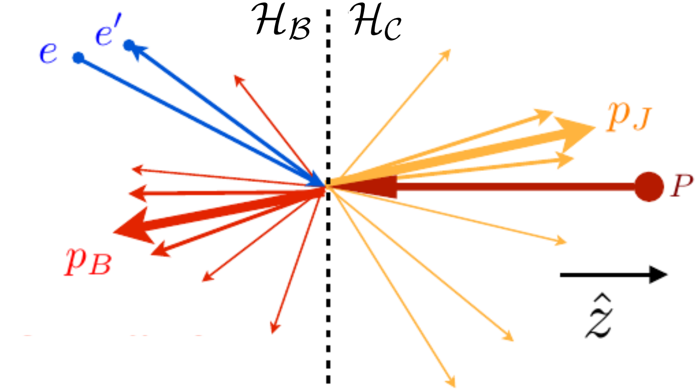
- Axes: incoming parton, and q+xP

$$\tau_1^b = \frac{2}{Q^2}\sum_{i\in X}\min\{xP\cdot p_i, (q+xP)\cdot p_i\}$$

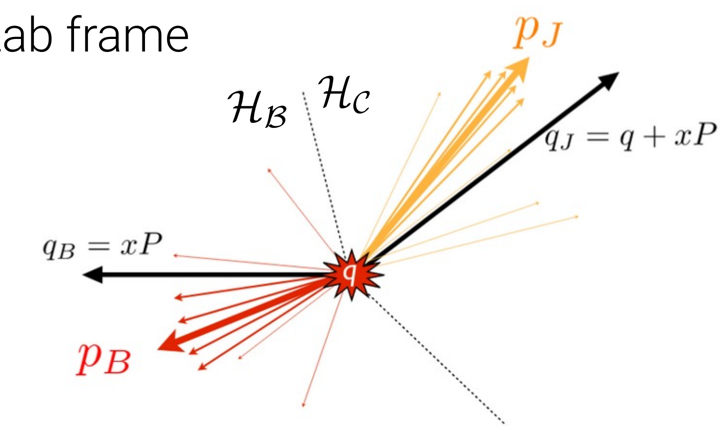
Equivalence

$$\tau_Q = \tau_1^b$$

Breit frame



Lab frame



Sketch taken from Kang, Lee, Stewart [Phys.Rev.D 88 (2013) 054004]

Inclusive DIS data

HERA-II data

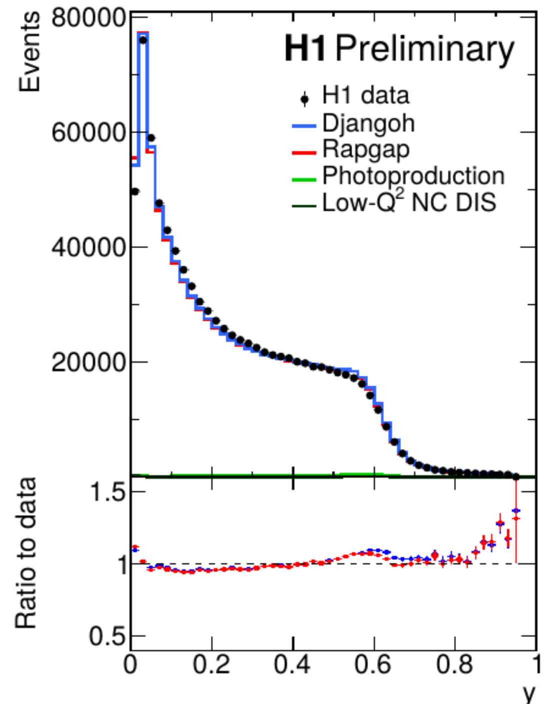
- Trigger requires high-energetic cluster in LAr calorimenter
  → electron or hadron
  → >99% efficient for y<~0.7
- High-Q^2 region: $Q^2>150$ GeV²
- Luminosity L=351 pb^{-1}

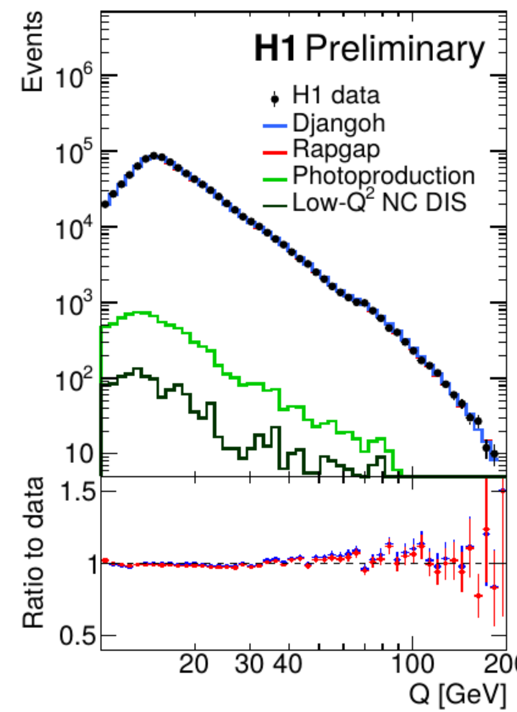
Signal Monte Carlo models

- Rapgap (ME+PS) and
- Djangoh (CDM)

Little background in incl. DIS

- photoproduction
- low-Q^2 NC DIS





$$y = y_\Sigma = \frac{\Sigma}{\Sigma + E_{e'}(1-\cos\theta_{e'})}$$

$$Q^2 = Q^2_\Sigma = \frac{E^2_{e'}\sin^2\theta_{e'}}{1-y_\Sigma}$$

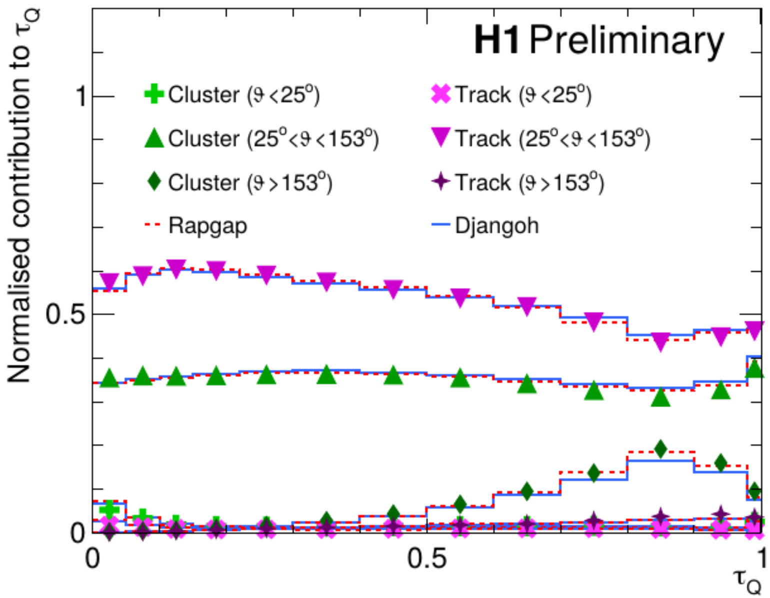
DIS thrust – a 4π observable

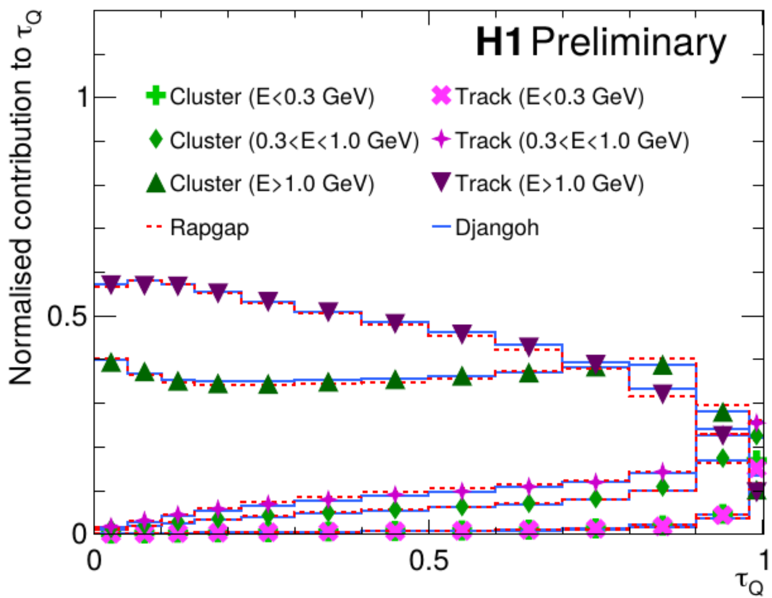
$$\tau_Q = 1 - \frac{2}{Q}\sum_{i\in\mathcal{H}_\mathcal{C}} P^{\rm Breit}_{z,i}$$

All particle candidates in all DIS events contribute

- Particles are reconstructed using a particle-flow algorithm,
  → combining cluster and track information without double-counting of energy

Normalised contribution to τ_Q for different ranges in polar angle θ and energy



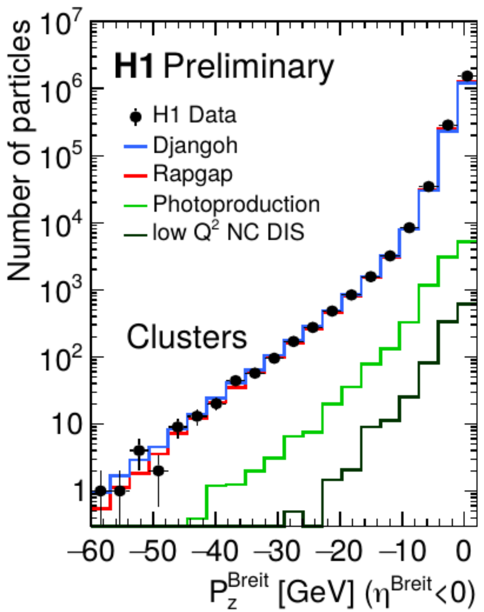


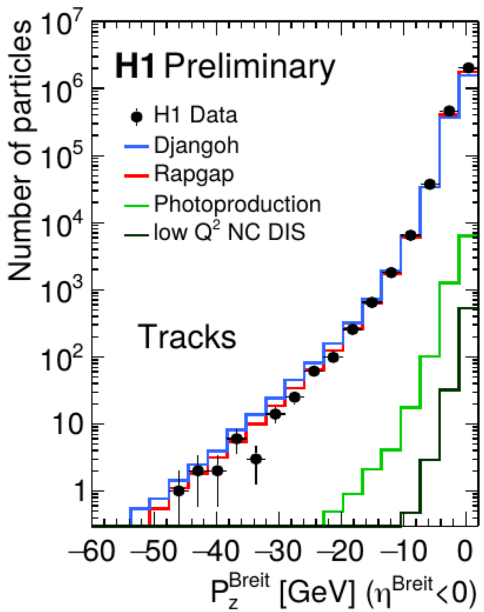
- Mainly tracks and clusters in the central part of the detector contribute (25°<θ<153°)
- Mainly particles with high energy contribute (E>1.0GeV)

1-jettiness – DIS thrust

DIS thrust: sum of longitudinal momenta

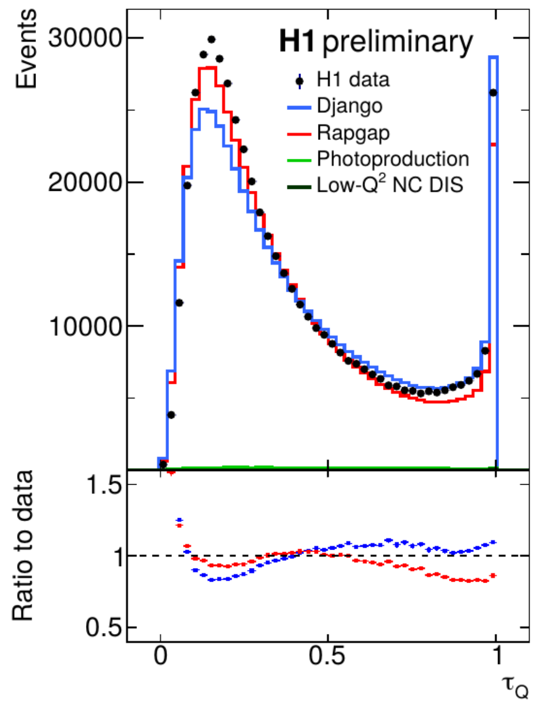
- Longitudinal momenta in Breit frame are well measured and well modelled by simulation for clusters and tracks





DIS thrust

- Reasonable agreement between data and MC, as expected from the two physics models (ME+PS, CDM)
- Full τ range measurable



Single differential cross sections

1-jettiness cross sections

- Unfolded using bin-by-bin method
- Corrected for QED radiative effects
- range: $0 \leq \tau \leq 1$
- stat. & syst. uncertainties smaller than markers

Comparisons with Monte Carlo models

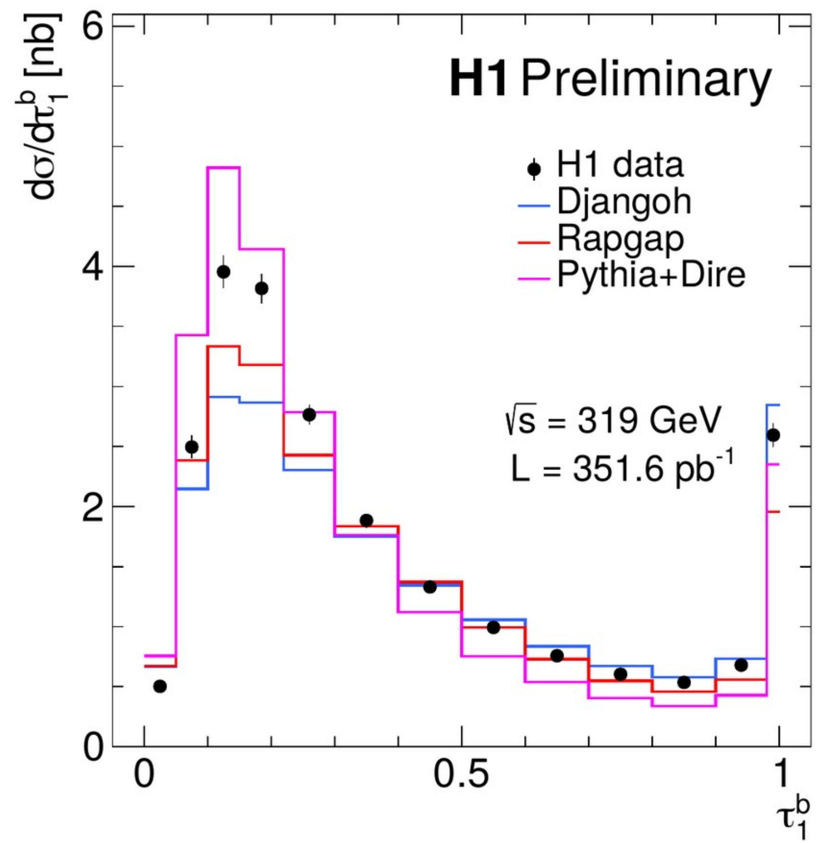
- Djangoh 1.4: Color-dipole-model (CDM)
- Rapgap 3.1: ME + parton shower
- Pythia8.3 + Dire

Resummation region

- Not well described by MC models

Fixed order region

- Django & Rapgap perform well
- Pythia+Dire underestimate data



$150 < Q^2 < 20\,000\ \mathrm{GeV}^2$

$0.2 < y < 0.7$

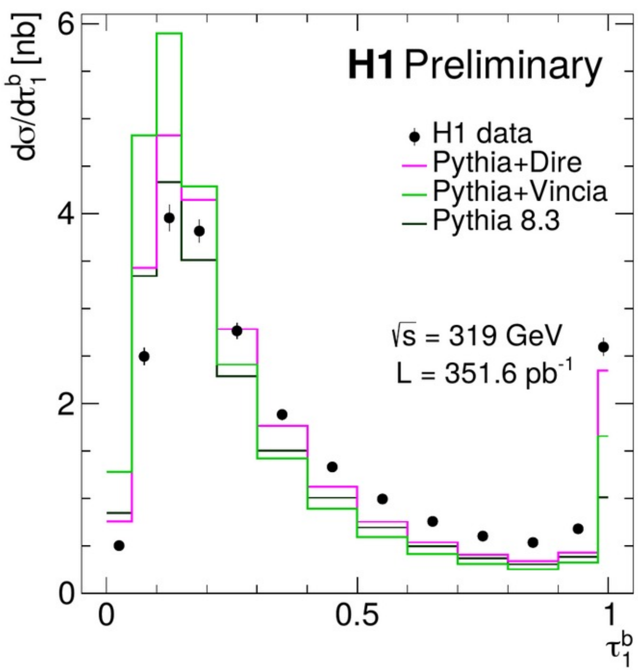
Single differential cross sections

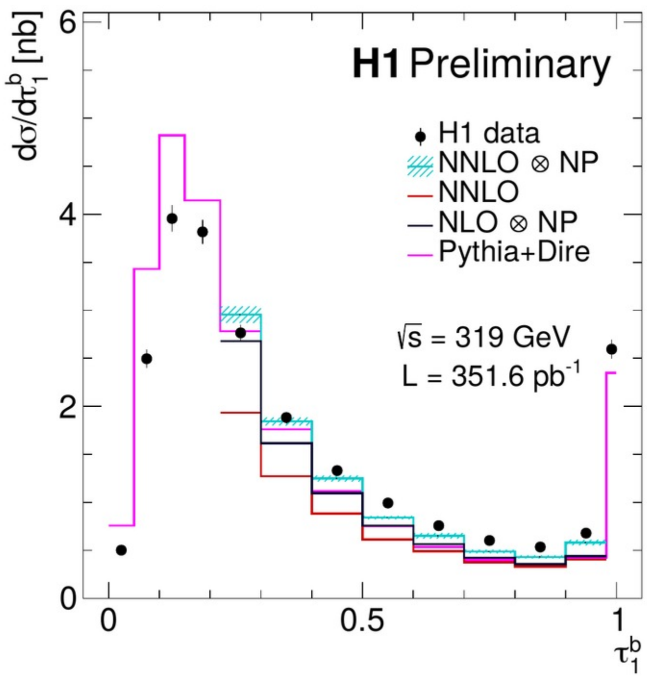
Comparison with Parton shower models

- Resummation region has strong dependence on different parton showers
- No PS model provides a fully satisfactory description
- 'Pythia default' PS underestimates τ=1

γp → 2jets NNLO prediction from NNLOJET

- NP corrections from Pythia8.3 (sizeable)
- NNLO provides reasonable description of fixed-order region
- NNLO improves over NLO





3D cross sections

Large cross section & sizeable data

→ triple-differential cross sections as functions of:

Q^2, y, τ_1

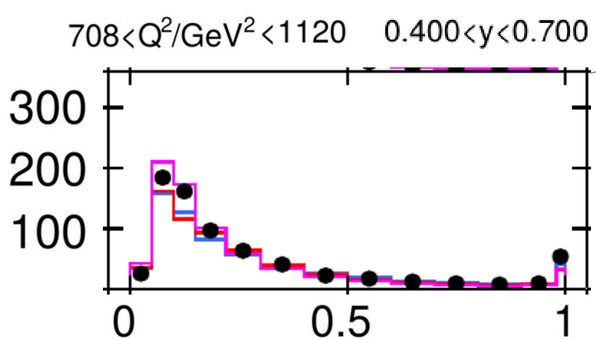
3D cross sections

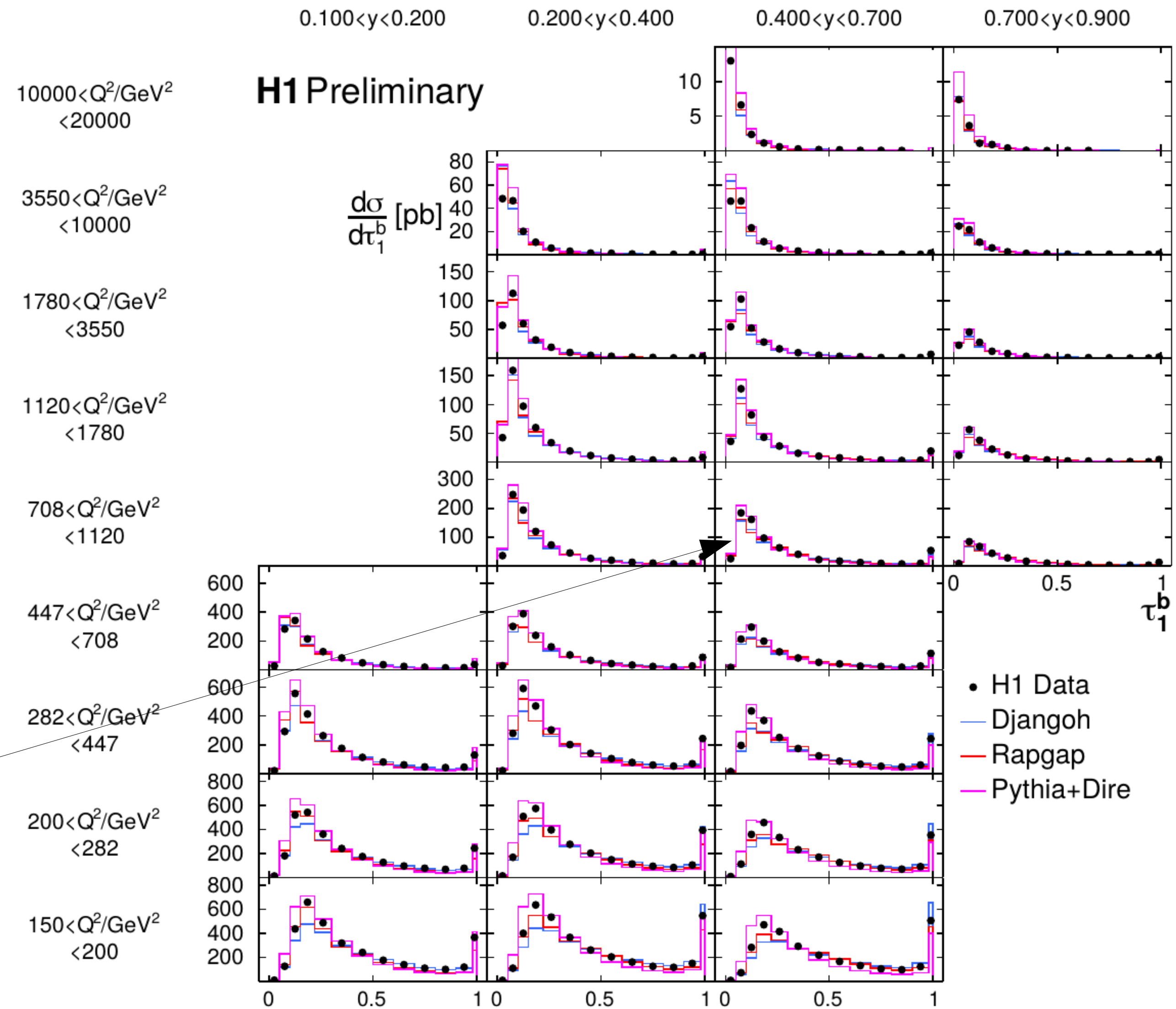
→ higher Q^2

- 'peak' moves to lower τ
- bulk region lowers

→ higher y (lower x)

- τ_1=1 becomes enhanced





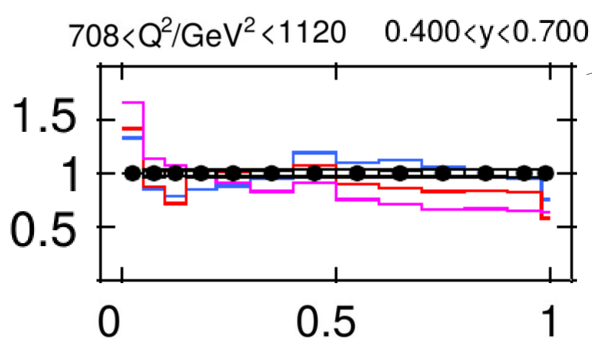
3D cross sections

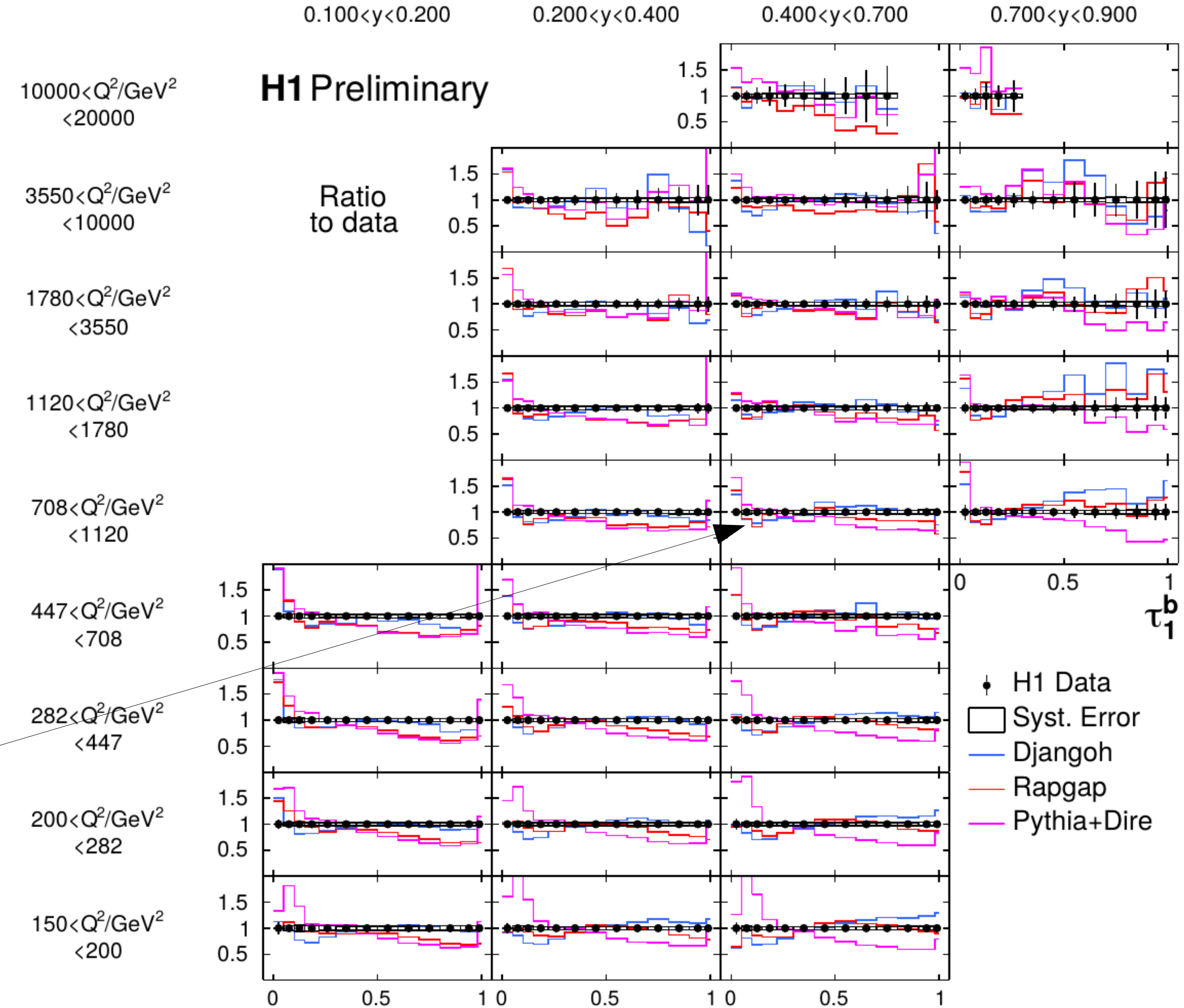
Ratio to data

- Stat. uncertainties of a few to O(10%)
- Syst. uncertainties are of the order of 5%

'classical' MC models

- Perform reasonably well over entire phase space
- Pythia+Dire similar to Rapgap at low y, but too large at low τ





3D cross sections

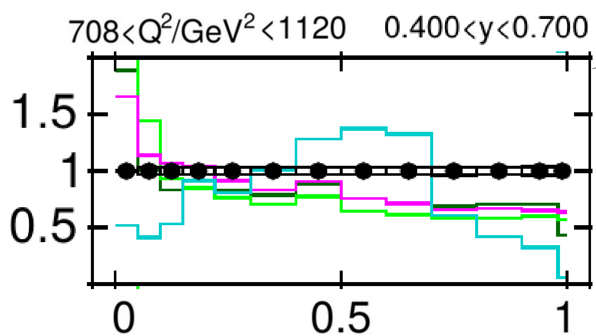
Comparison with further MC models

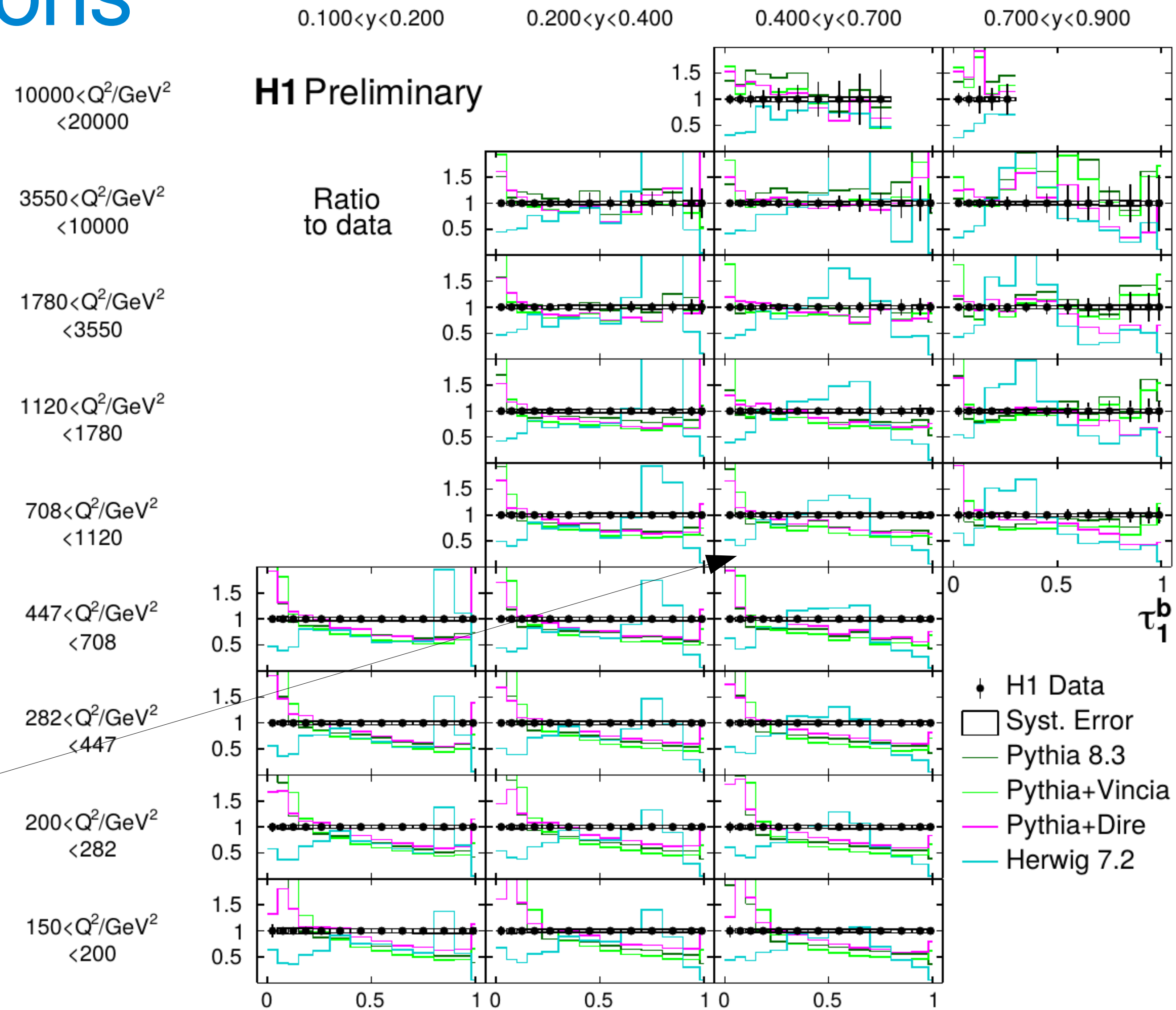
- Pythia + Vincia
- Pythia w/ default shower

Herwig 7.2

- often similar to Pythia, but
- resummation region too low
  (too low DIS cross section)
- some structure at high τ

→ See talk by H. Klest (Tue,17:30) for 'groomed' τ_1^b and updated HERWIG predictions



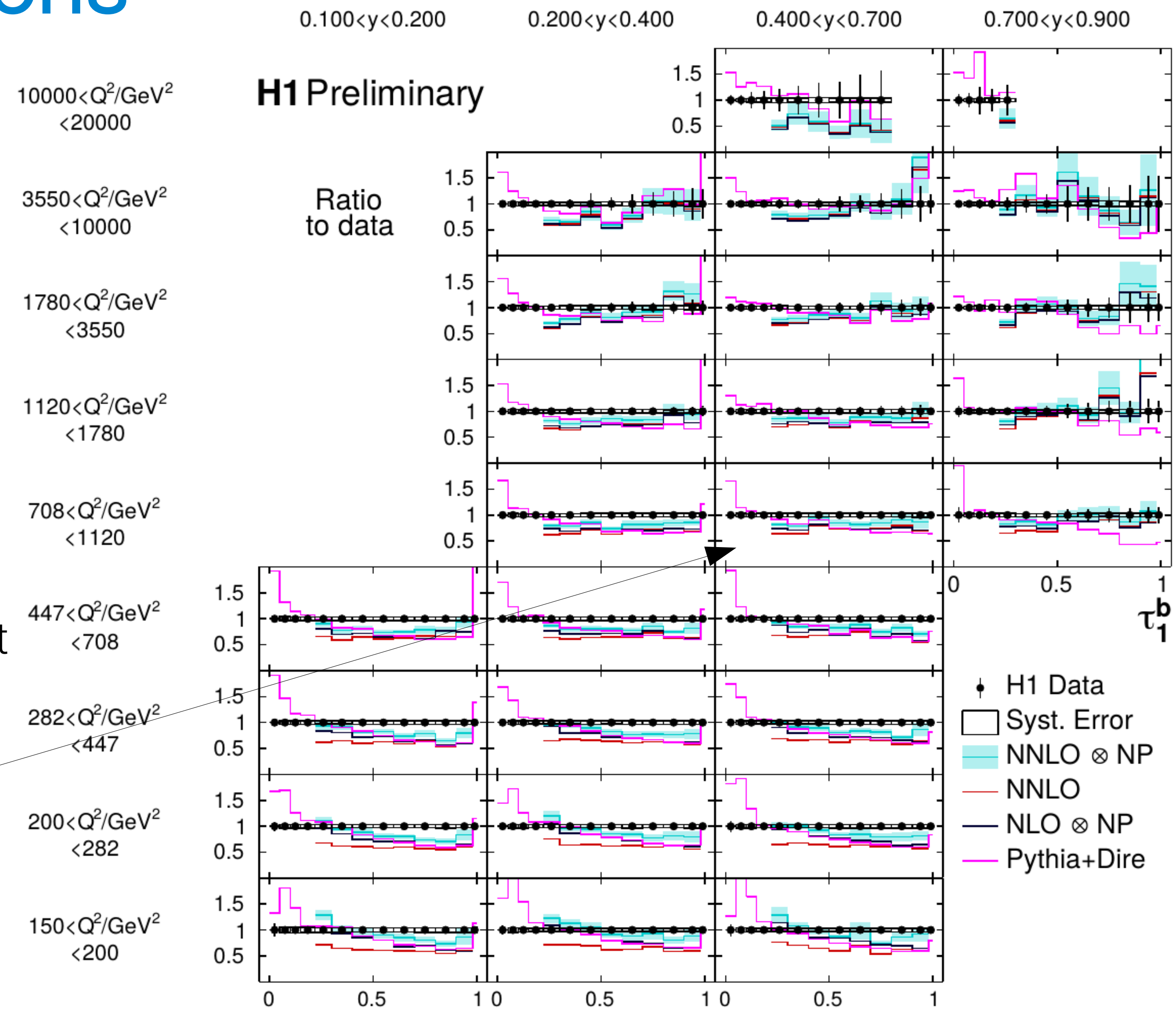


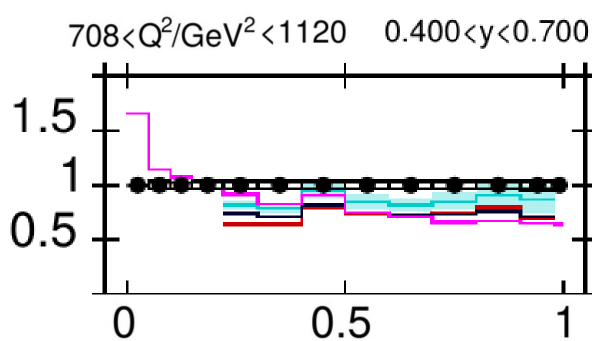
3D cross sections

NNLO pQCD (ep → 2 jets)

- Reasonable description in entire phase space:
- Improved description with increasing Q^2
- small scale uncertainites

- Altogether:
  NNLO improves over NLO
  NP corrections are Q^2 dependent



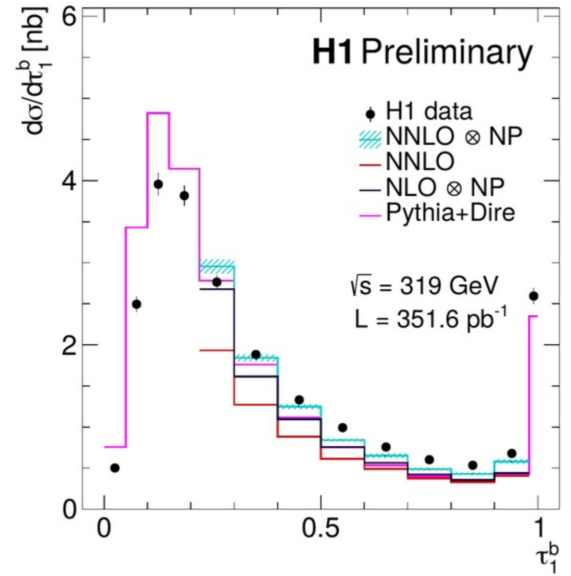


Summary and outlook

- A first measurement of the 1-jettiness event shape observable in NC DIS was presented: $\sqrt{s}$=319 GeV, Q^2>150GeV^2, 0.1 < y < 0.9, 0 ≤ τ ≤ 1
- 1-jettiness is equivalent to DIS thrust normalised with 2/Q
  → defined for every NC DIS event

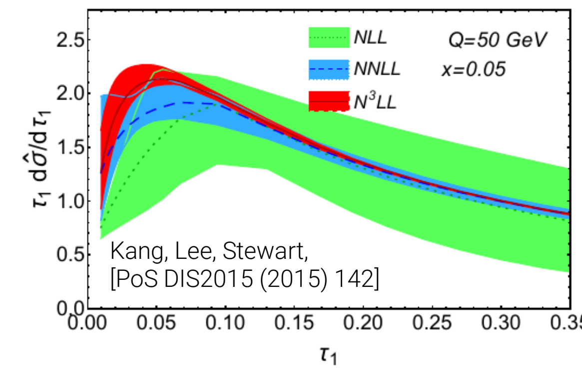
- 'Classical' Monte Carlo models provide a good description of the data
- Modern Monte Carlo models provide a reasonable description

- NNLO fixed order predictions (ep→2jets) provide good description in the region of validity, but hadronisation corrections are large



Outlook

- N3LL and N3LO DIS predictions need to be confronted with data
- sensitivity to α_s and PDFs need to be explored
- Data will become useful for improving (DIS) MC genererators



H1prelim-21-032
July 2021
Submitted to ISMD2021 and EPS-HEP21 conferences

Measurement of the 1-jettiness event shape observable in deep-inelastic electron-proton scattering at HERA

H1 Collaboration

Abstract

A first measurement of the 1-jettiness event shape observable in neutral-current deep-inelastic electron-proton scattering is presented. The 1-jettiness observable τ_b^1 is defined such that it is equivalent to the thrust observable defined in the Breit frame. The data were taken in the years 2003 to 2007 with the H1 detector at the HERA *ep* collider at a center-of-mass energy of 319 GeV and correspond to an integrated luminosity of $351.6\,\mathrm{pb}^{-1}$. The triple-differential cross sections are presented as a function of the 1-jettiness τ_b^1, the event virtuality Q^2 and the inelasticity y in the kinematic region $Q^2 > 150\,\mathrm{GeV}^2$. The data have sensitivity to the parton distribution functions of the proton, the strong coupling constant and to resummation and hadronisation effects. The data are compared to selected predictions.

https://www-h1.desy.de/h1/www/publications/htmlsplit/H1prelim-21-032.long.html

α_s dependence ±5%