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

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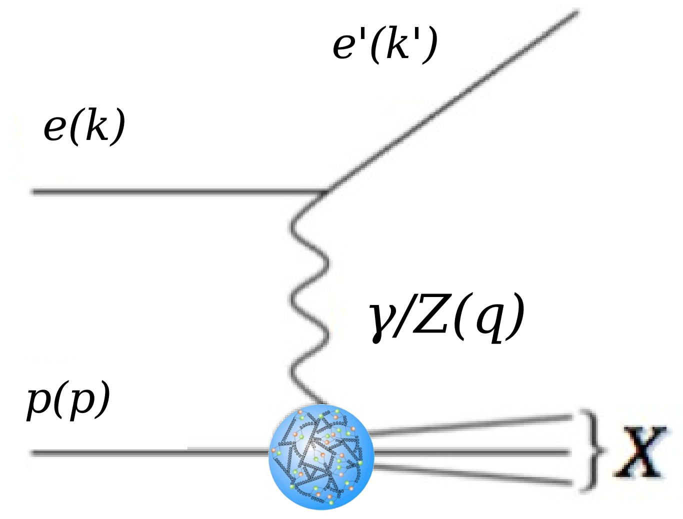
Neutral current deep-inelastic scattering

Neutral current deep-inelastic scattering

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



Kinematic variables

- Virtuality of exchanged boson Q^2

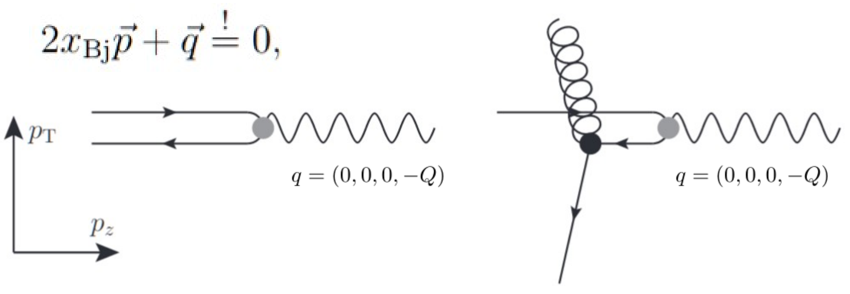
$$Q^2 = -q^2 = -(k - k')^2$$

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

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

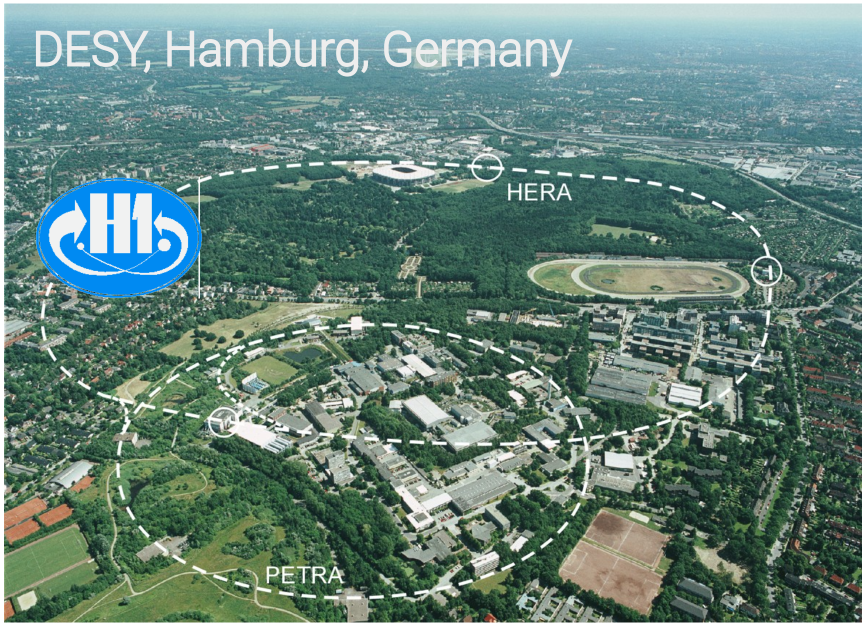
The Breit frame

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



The H1 experiment at HERA

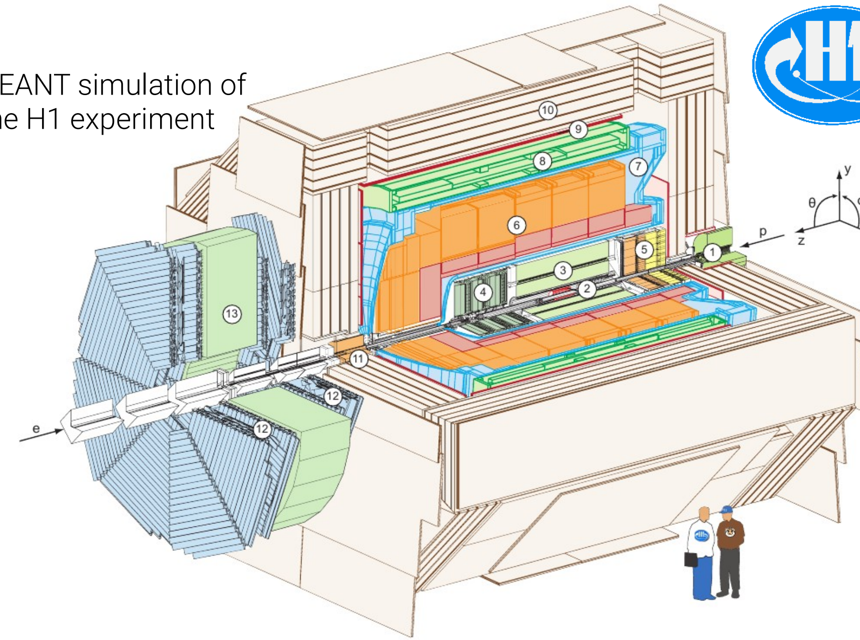
HERA electron-proton collider at DESY



- 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

GEANT simulation of the H1 experiment



'multi-purpose' detector

- Asymmetric design with trackers, calorimeter, solenoid, muon-chambers, forward & backward detectors, …
- More on H1 in talks by:
  B. Nachman. T. Janssen, S. Chuan

The 1-jettiness event shape

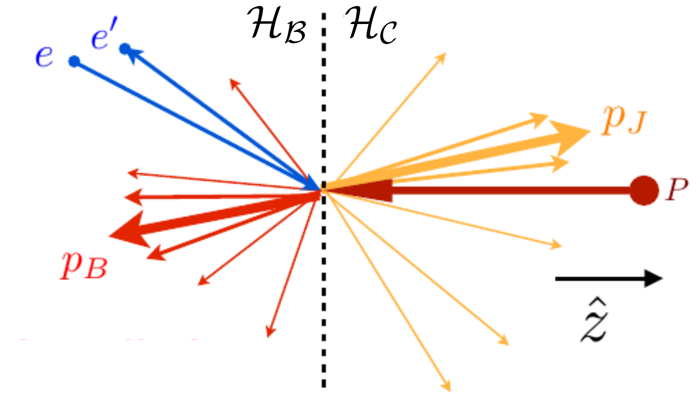
DIS thrust normalised to boson axis

- 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

Breit frame

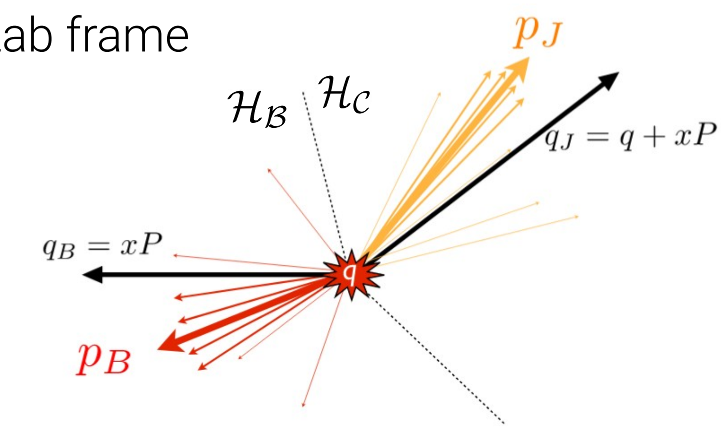


1-jettiness

- Axes: incoming parton, and q+xP

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

Lab frame



Equivalence

$$\tau_Q = \tau_1^b$$

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

Inclusive DIS data

HERA-II data

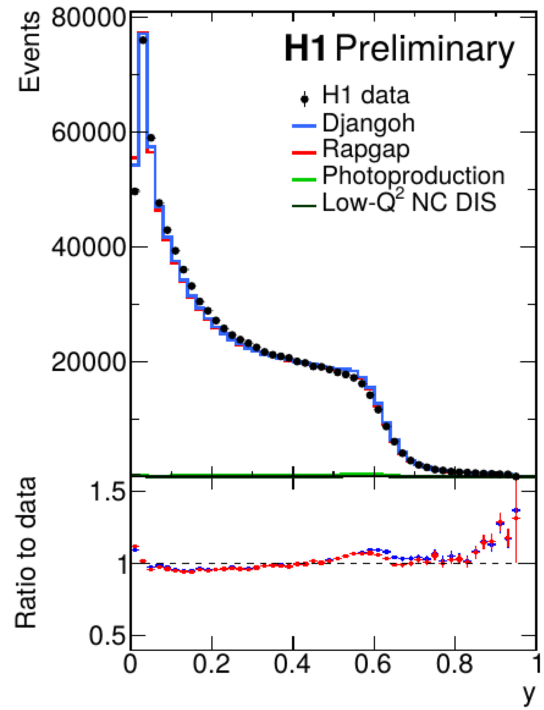
- Trigger requires high-energetic cluster in LAr calorimenter
  → electron or hadron
  → >99% efficient for y<~0.7
- High-Q^2 region: Q^2>150 GeV^2
- Luminosity L=351 pb^{-1}

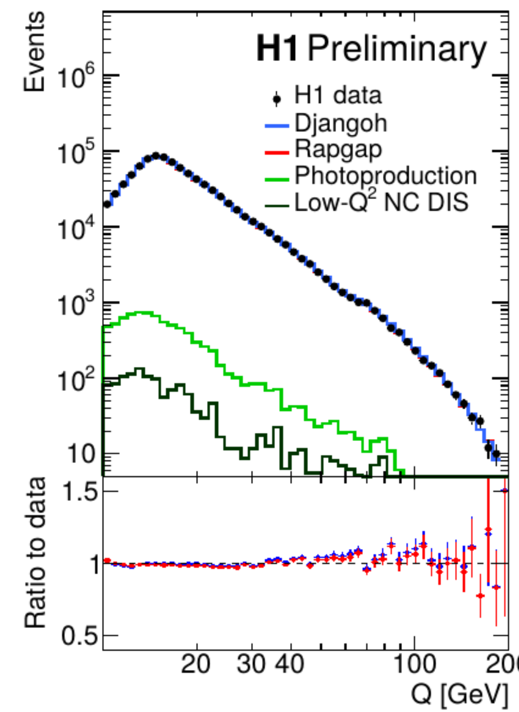
Signal Monte Carlo models

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

Little background in incl. DIS

- photoproduction
- low-Q^2 NC DIS





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

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

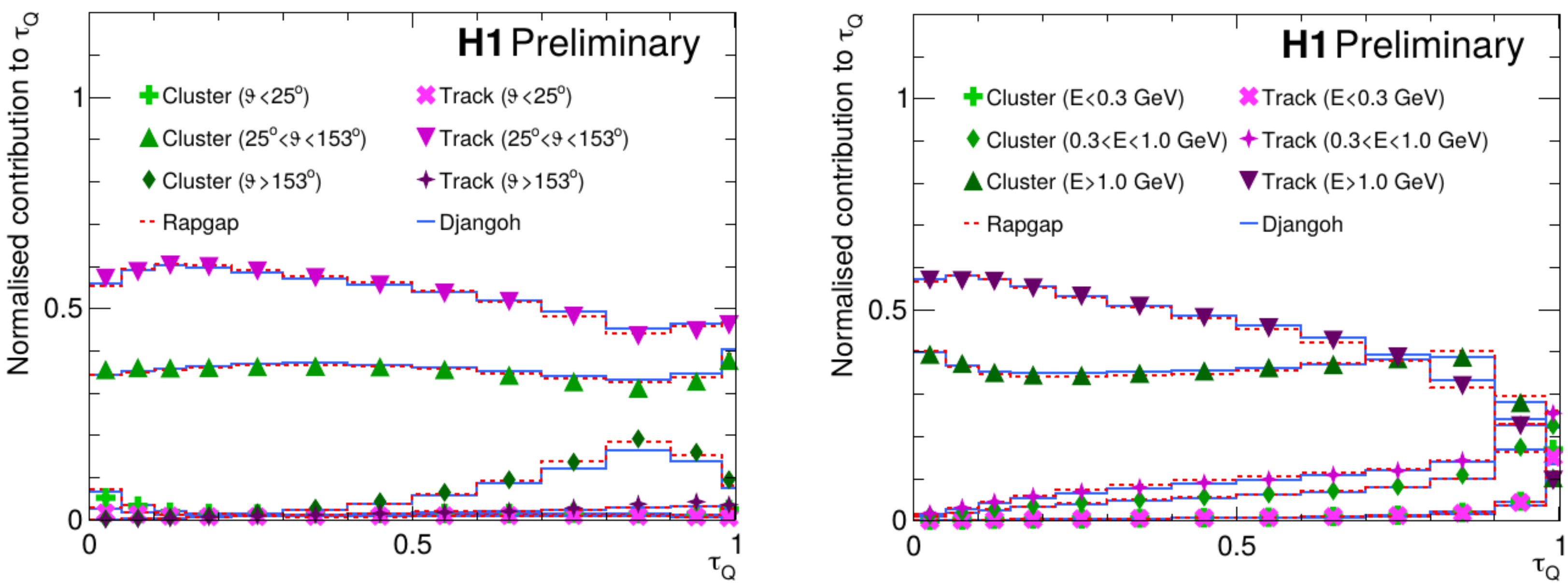
DIS thrust – a 4π observable

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

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)

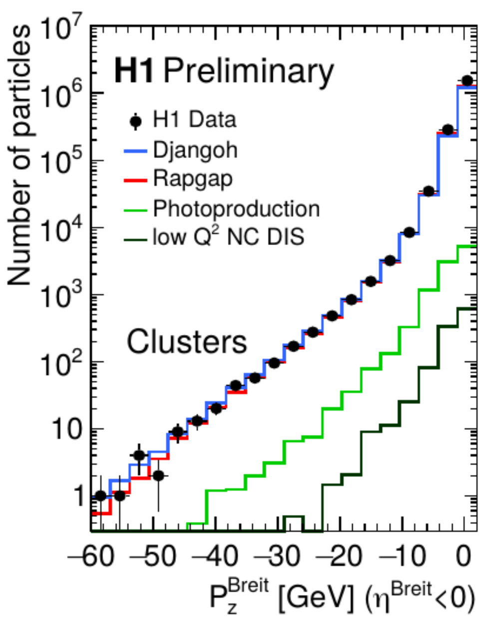
1-jettiness – DIS thrust

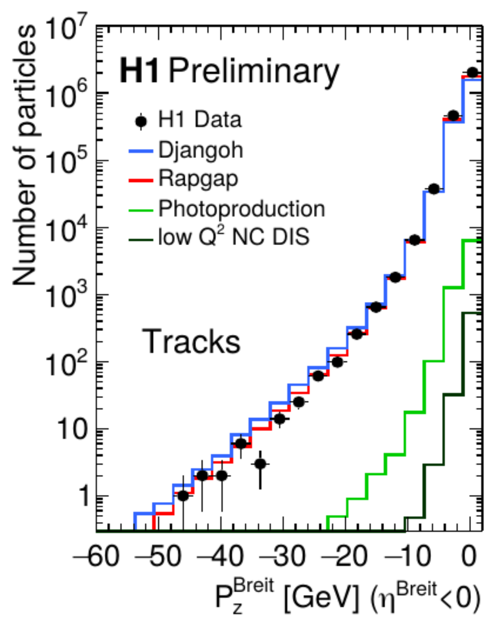
DIS thrust: sum of longitudinal momenta

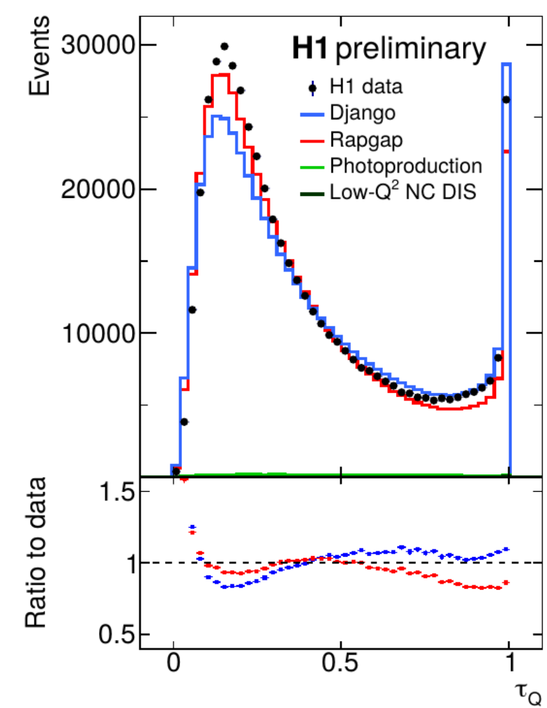
- Longitudinal momenta in Breit frame are well measured and well modelled by simulation for clusters and tracks

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

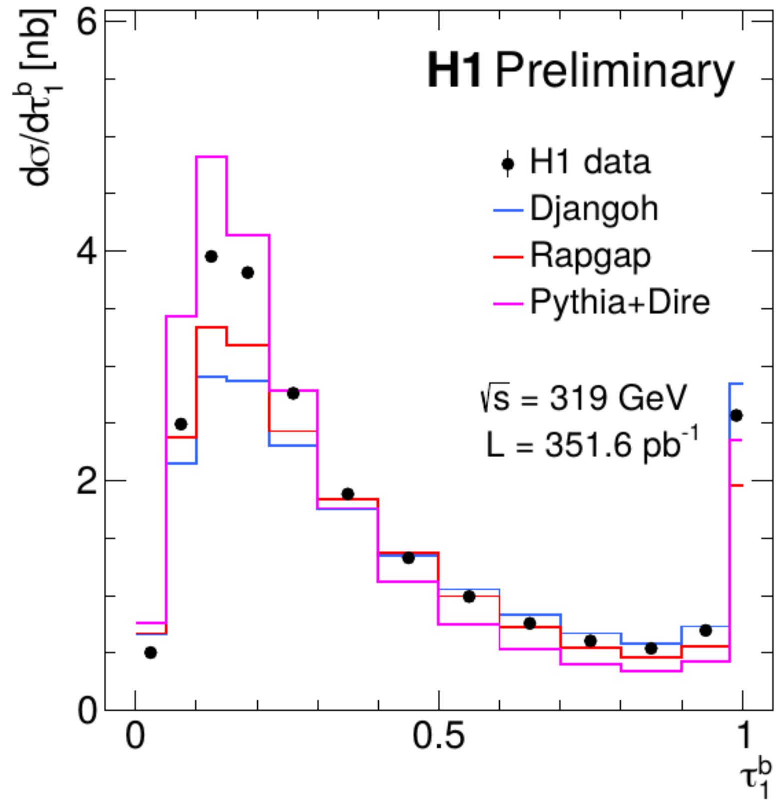
- Djangoh 1.4: Color-dipole-model (CDM)
- Rapgap 3.1: ME + parton shower
- Pythia8.3 + Dire

Resummation region

- Not well described by MC models

Fixed order region

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

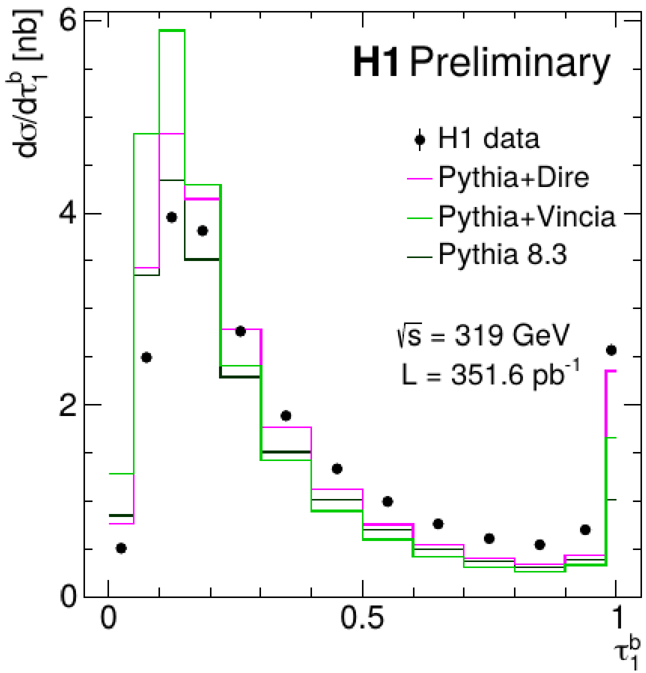


$$150 < Q^2 < 20\,000\,\mathrm{GeV}^2$$
$$0.2 < y < 0.7$$

Single differential cross sections

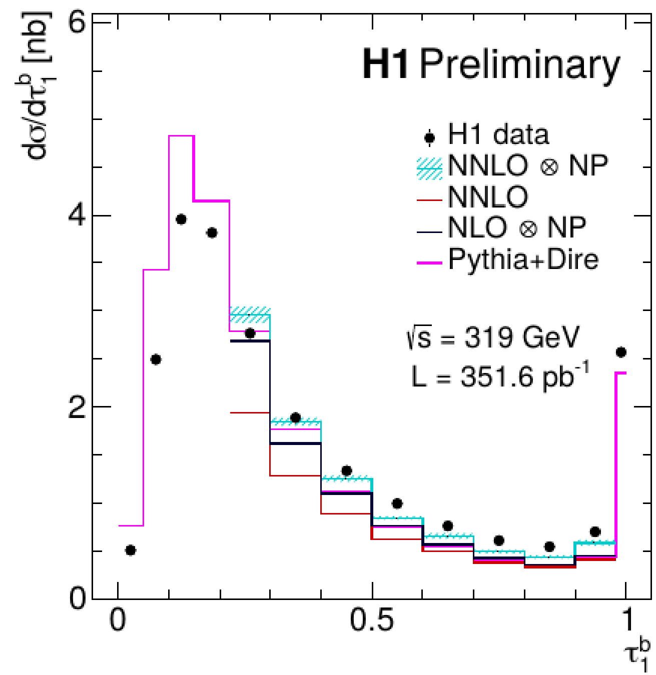
Comparison with Parton shower models

- 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

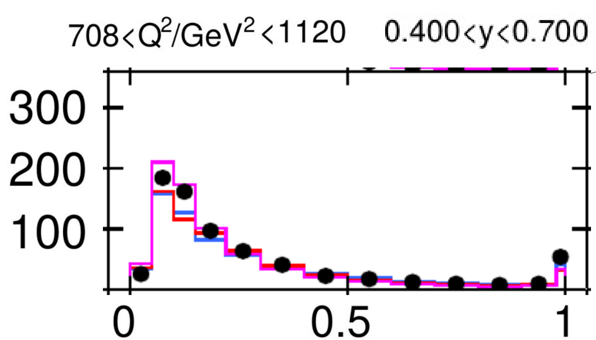
3D cross sections

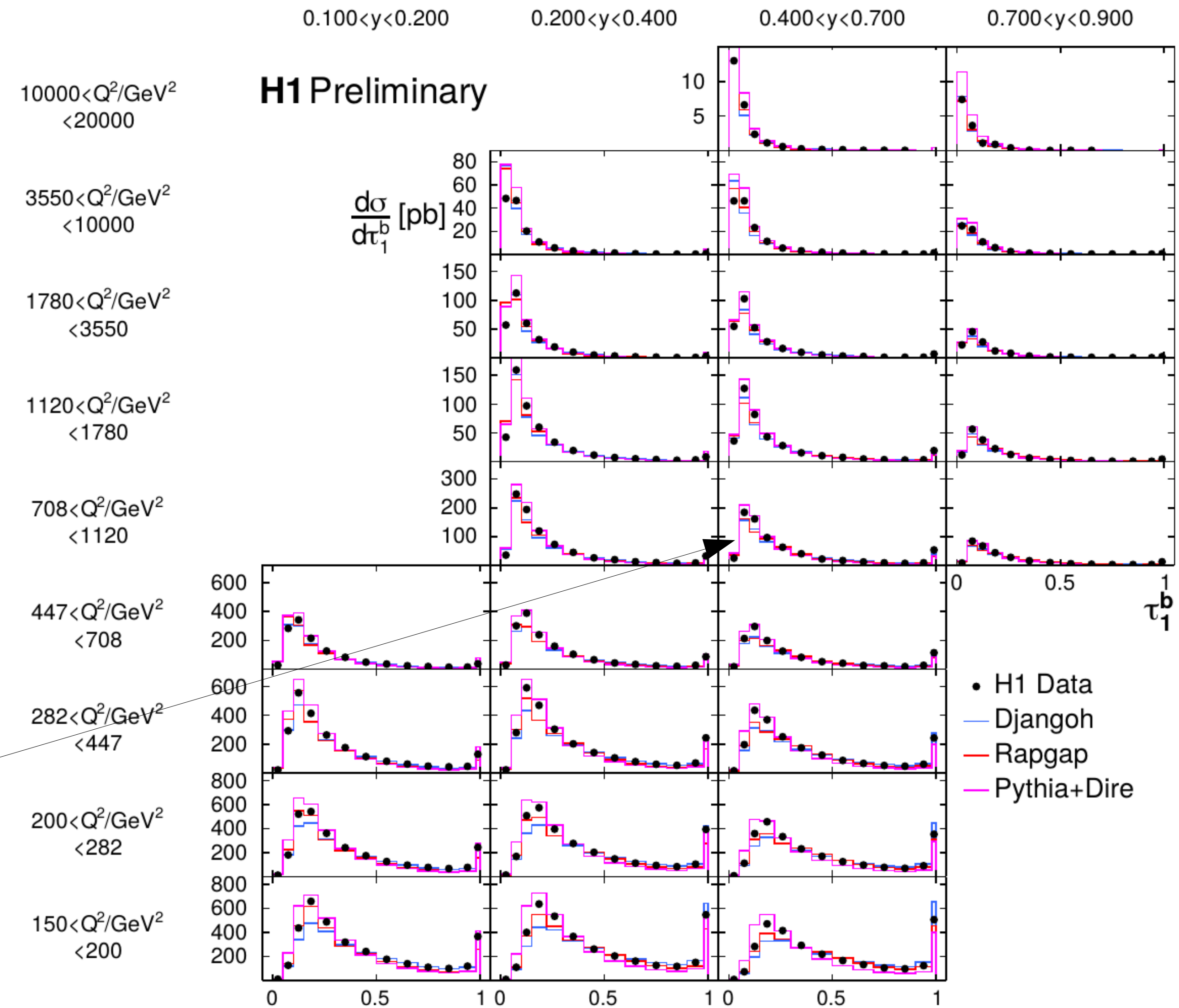
→ higher Q^2

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

→ higher y (lower x)

- τ_1=1 becomes enhanced





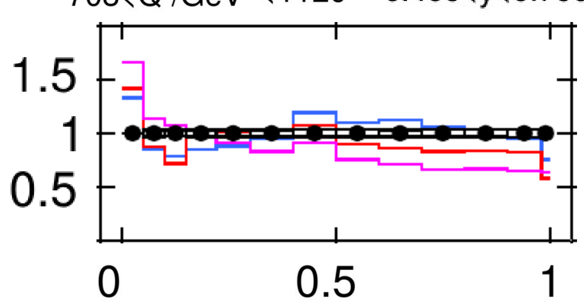
3D cross sections

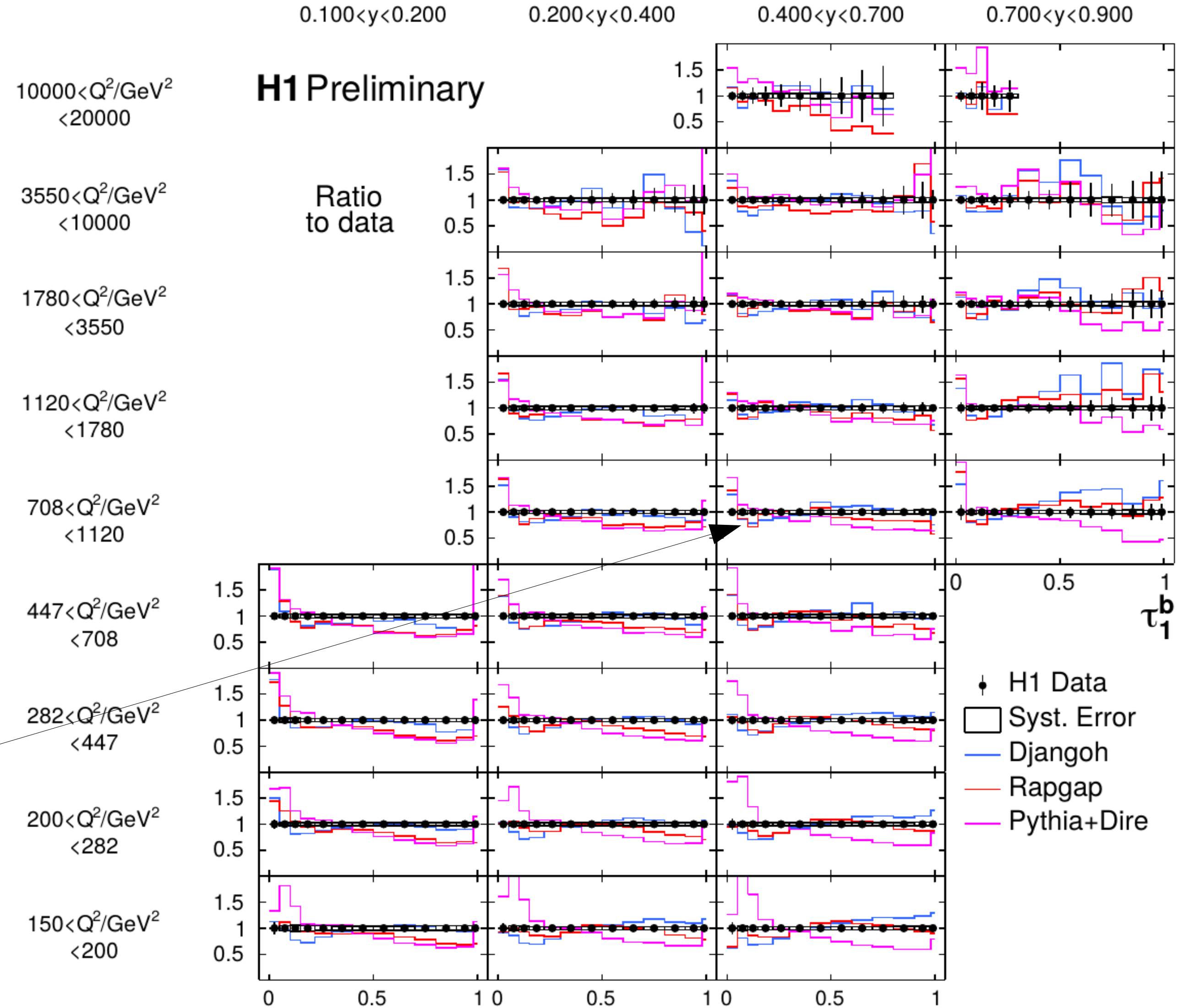
Ratio to data

- 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





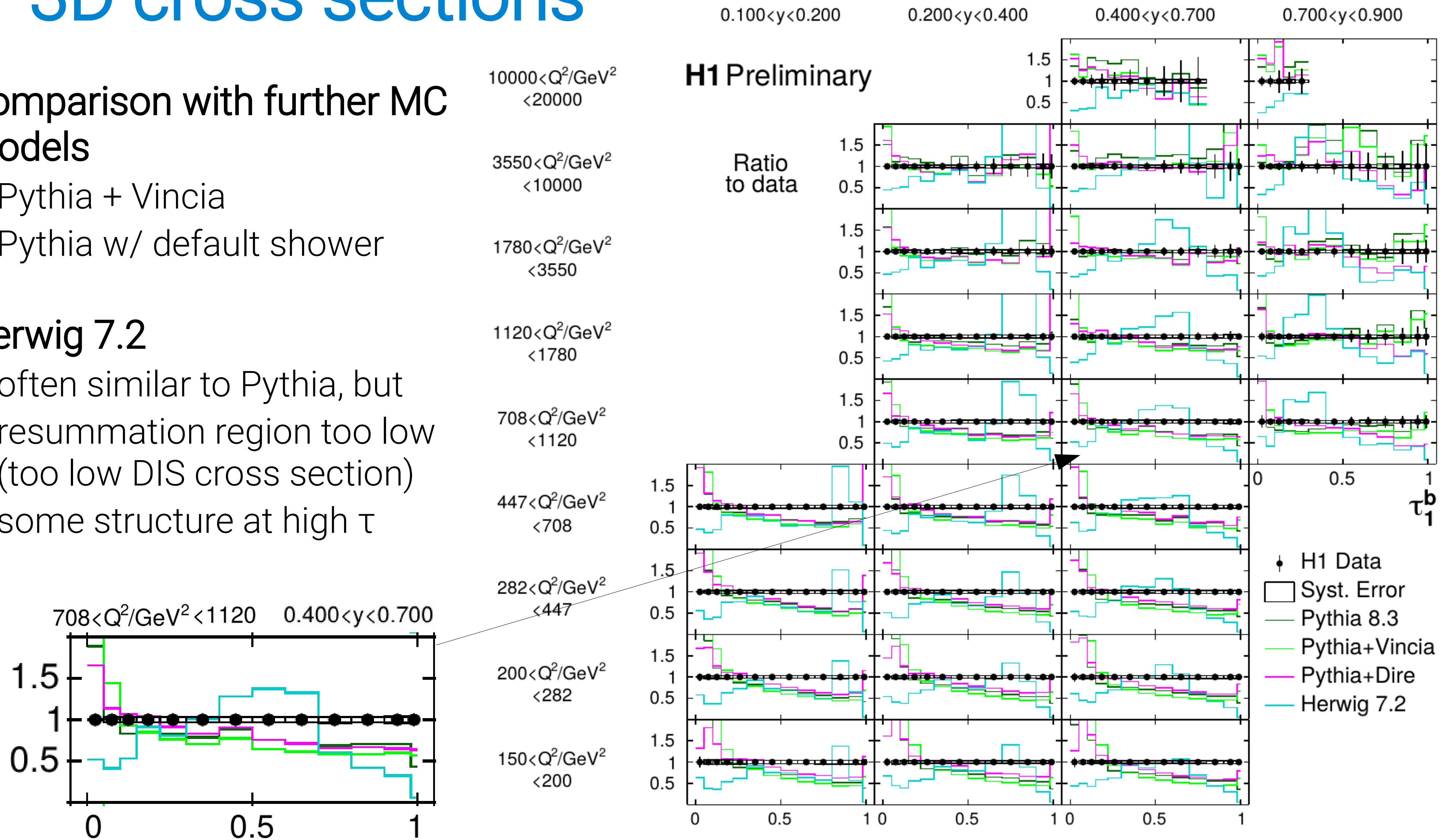
3D cross sections

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

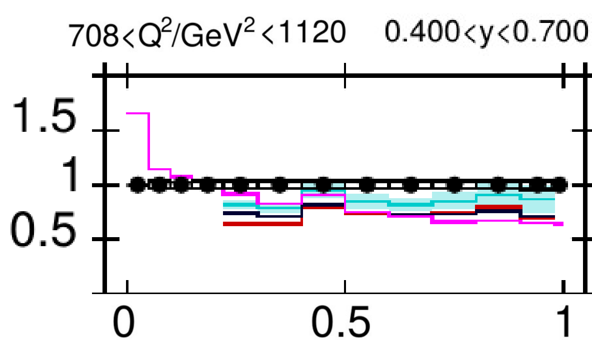


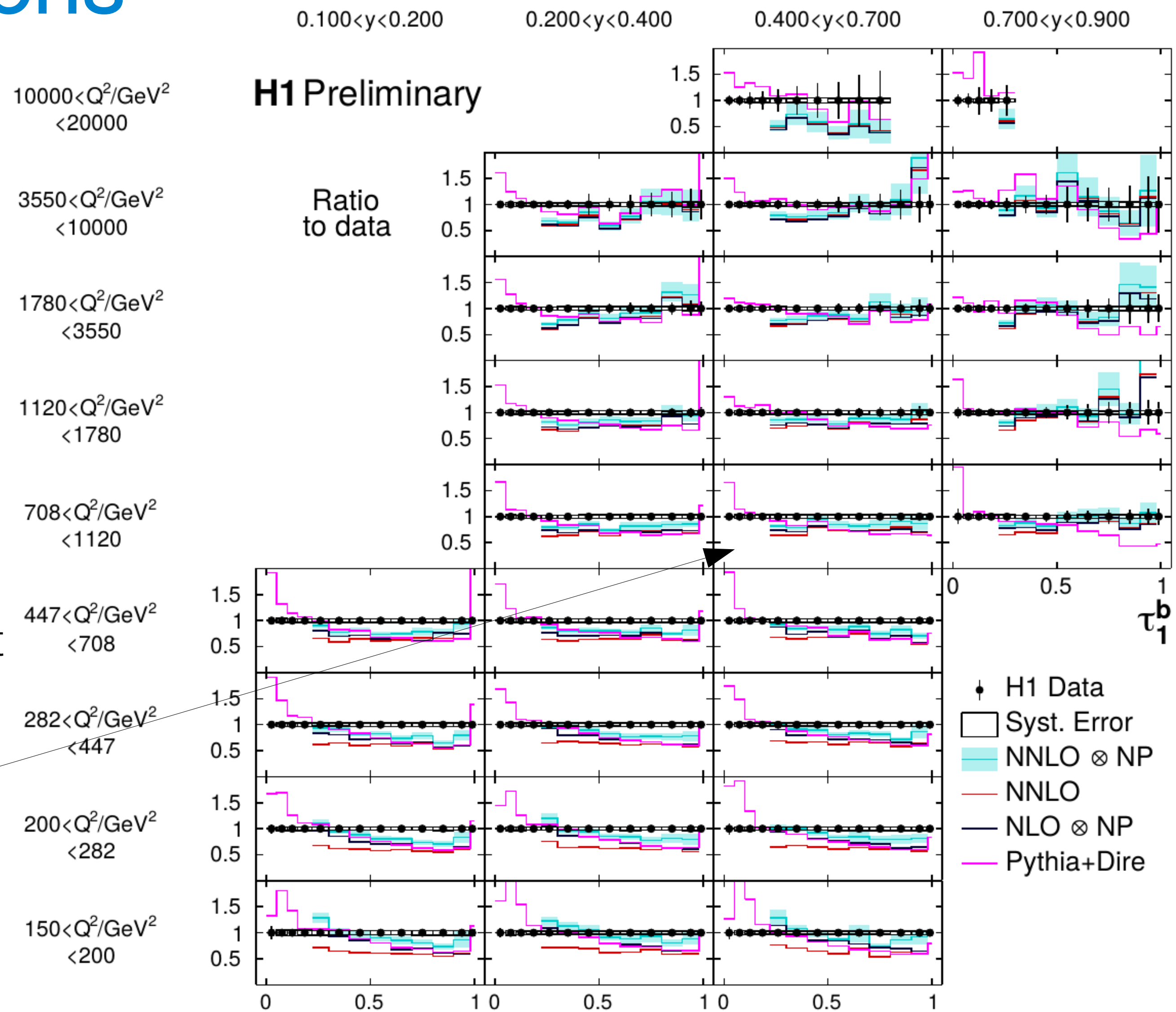
3D cross sections

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



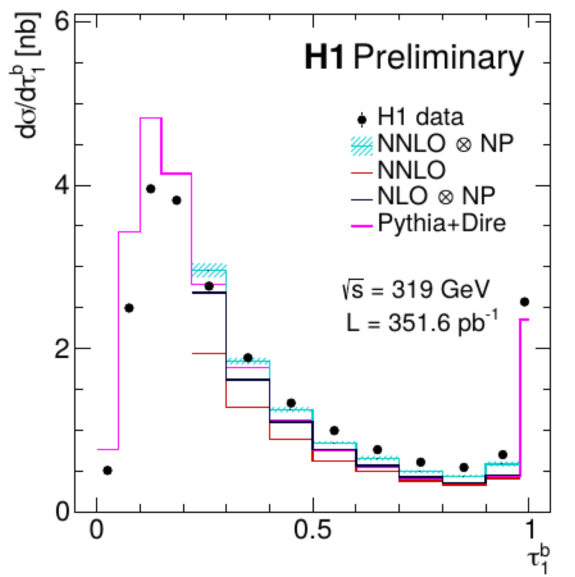


Summary and outlook

- 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