Event shape measurement in deep-inelastic $e^{\pm}p$ scattering

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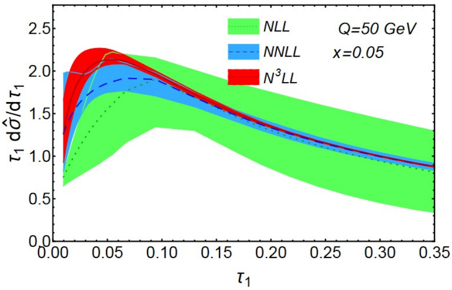
Motivation

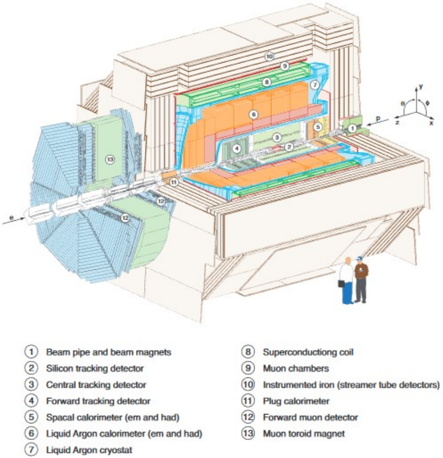
- Measure the 1-jettiness event shape observable τ_1^b in deep-inelastic $e^{\pm}p$ scattering
- Accurate theoretical calculations available (analytical $O(\alpha_s)$ cross sections in combination with N^{3}LL resummation) [1, 2]
- Small theoretical uncertainties for τ_1^b
- Observable is sensitive to α_s and parton distribution functions
- HERA has high centre of mass energy $\sqrt{s}$ and luminosity L



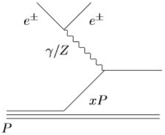
Theory prediction for the 1-jettiness [3].

H1 detector

- H1 is a multipurpose collider experiment at DESY (Hamburg)
- Deep-inelastic $e^{\pm}p$ scattering at $E_e = 27.5$ GeV and $E_p = 920$ GeV $\rightarrow \sqrt{s} \approx 320$ GeV
- Data taken from 2003 to 2007 $\Rightarrow$ Integrated luminosity 351.6pb^{-1}
- Two run periods e^+p, two run periods e^-p
- Obtain tracks for the analysis from the Central Tracking Detector (3) and the Forward Tracking Detector (4)
- Cluster information from the Liquid Argon Calorimeter (6)

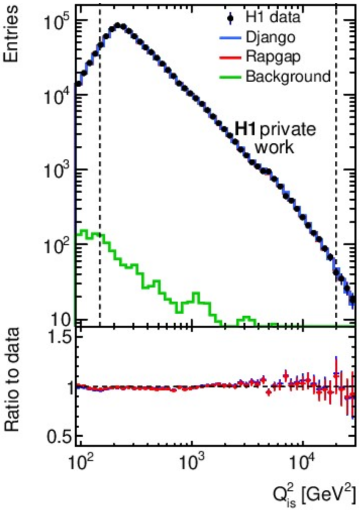


Schematic drawing of the H1 detector with its main components [4].



Neutral current DIS diagram.

- Use IΣ method [5] used for reconstruction of Bjorken x, inelasticity y and momentum transfer Q^2
- Measure the observable in the phase space
  $0.2 < y < 0.7$
  $150\ \mathrm{GeV}^2 < Q^2 < 20000\ \mathrm{GeV}^2$
- Low background in selected region
- Two different MC generators Django and Rapgap are available
- Excellent agreement between data and MC



Q^2 distribution and ratio to data. Selected phase space confined by dashed lines.

1-jettiness definition

- Define 1-jettiness as [2]

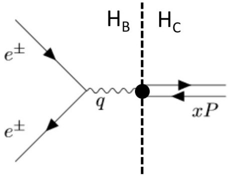
$$\tau_1^b = \frac{2}{Q^2} \cdot \sum_{i \in X} \min\{q_B \cdot p_i, q_J \cdot p_i\}$$

with $q_B^b = x \cdot P$ ($x \cdot P$: momentum of incoming parton)
and $q_J^b = q + x \cdot P$ ($q^2 = -Q^2$: momentum transfer)

- Derive an expression for τ_{zQ} by boosting to the Breit frame (virtual photon completely space-like, collides with proton along z-axis) [3, 6]

$$\tau_{zQ} = 1 - \frac{2}{Q} \cdot \sum_{i \in H_c} p_{i,z}$$

⇒ Only particles in the current hemisphere contribute
⇒ Both definitions are equivalent on hadron level $\tau_{zQ} = \tau_1^b$



Feynman diagram for DIS in the Breit frame.

Single particle reconstruction

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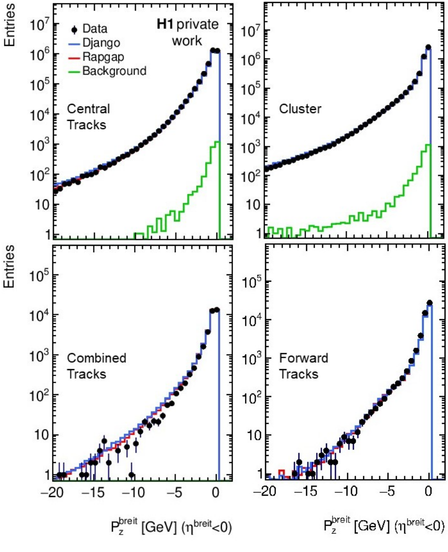
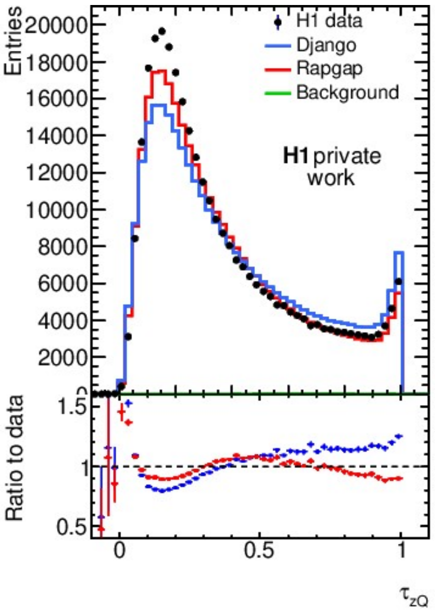
- τ_1^b is a full phase space observable
- τ_{zQ} is experimentally preferred, since only particle with $\eta^{breit} < 0$ contribute
- H1 uses particle-flow algorithm to reconstruct particle candidates
- Tracks are reconstructed by combining details from different sub-detectors (FTD, CTD)
- A single-particle study is performed: Study p_Z-measurment of contributing particles

⇒ Very good agreement for all detector components over the entire p_Z-range



- Reasonable agreement between data and MCs
- Both MCs underestimate the resummation region $\tau_{zQ} \approx 0.2$
- Django has harder spectrum than Rapgap
- Few events with $\tau_{zQ} < 0$ beacause of QED radiation
  $\Rightarrow$ Needs to be corrected for

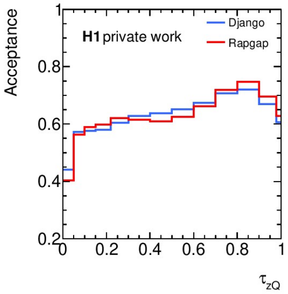


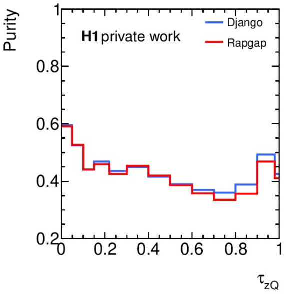
Acceptance and purity for binned distribution

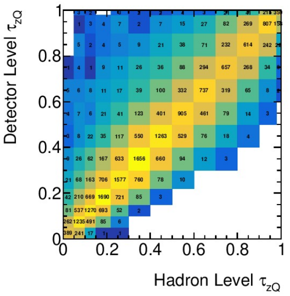
- Study acceptance and purity distribution to find suitable binning

$$Acceptance = \frac{N_{\text{rec}}}{N_{\text{gen}}} \qquad Purity = \frac{N_{\text{stay}}}{N_{\text{rec}}}$$

- Defined 13 bins in τ_{zQ}:
  $[0.0, 0.05, 0.10, 0.15, 0.22, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 0.98, 1.0]$







$\Rightarrow$ Acceptance around 60% for each bin, purity around 40%

Migration matrix for reduced Rapgap data sample.

Ratio τ_1^b/τ_{zQ} on particle level

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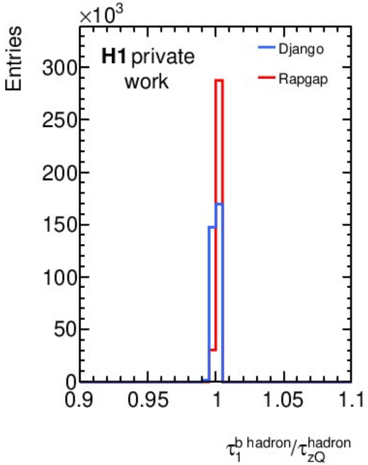
Validate the equality of τ_1^b and τ_{zQ}

- Compare τ_1^b and τ_{zQ} on hadron level
- Exclude all events with electron initial or final state radiation ($e \to \gamma e$)

$\Rightarrow$ Distribution of τ_1^b matches distribution of τ_{zQ} on non-radiative hadron level

$\Rightarrow$ QED radiation is well understood, can be corrected

$\Rightarrow$ Measure τ_{zQ} and compare it to calculations for τ_1^b



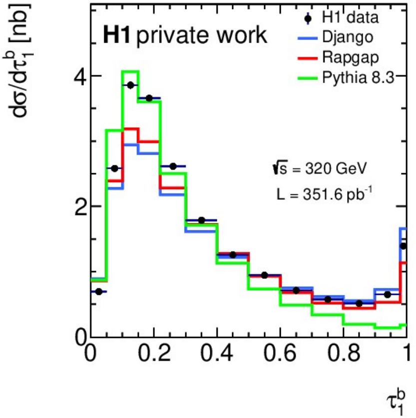
τ_1^b cross section

- First results for differential cross section $d\sigma/d\tau_1^b$
- Integrated Luminosity $L = 351.6\ \text{pb}^{-1}$
- Using bin-by-bin detector corrections c_i
- Differential cross section in bin i with width Δ_i defined as:

$$\left(\frac{d\sigma}{d\tau_1^b}\right)_i = \frac{N_i^{data} - N_i^{bkgd}}{L \cdot \Delta_i} \cdot c_i$$

⇒ Data compared to recent Pythia 8.3 + Vincia prediction

⇒ Good agreement for lower τ_1^b values, but underestimates high-τ_1^b region



Differential cross section $\frac{d\sigma}{d\tau_1^b}$.

Conclusion

Summary

- Measure 1-jettiness τ_1^b in neutral current DIS at H1
- Measured the detector level τ_{zQ} distribution
- Defined binning in τ_{zQ}
- Validated the equality of τ_{zQ} and τ_1^b on hadron level
- Presented first results for single-differential cross section $\frac{d\sigma}{d\tau_1^b}$

Outlook

- Measure triple-differential cross section $\frac{d^3\sigma}{d\tau_1^b dx dQ^2}$
- Study systematic uncertainties
- Apply advanced unfolding methods
- Expand analysis to larger phase space
- Probe sensitivity of τ_1^b to α_s and PDFs

[1] Z. Kang, X.Liu, S. Mantry, The 1-Jettiness DIS event shape: NNLL + NLO results, *arXiv:1312.0301v2*, 2014

[2] D. Kang, C. Lee, I. Stewart, Using 1-Jettiness to Measure 2 Jets in DIS 3 Ways, *arXiv:1303.6952v2*, 2013.

[3] D. Kang, DIS Event Shape at N^3LL, https://indico.cern.ch/event/341292/contributions/1739091/attachments/670208/921244/DIS2015-kang.pdf, 2015

[4] R. Kogler, Measurement of Jet Production in Deep-Inelastic *ep* Scattering at HERA, DESY-THESIS-2011-003, 2010

[5] U. Bassler, G. Bernardi, On the Kinematic Reconstruction of Deep Inelastic Scattering at HERA: the Σ Method, *arXiv:hep-ex/9412004v1*, 1994

[6] D. Kang, C. Lee, I. Stewart, Analytic Calculation of 1-Jettiness in DIS at O(α_s), *arXiv:1407.6706v1*, 2014.