

Observation of Events with an Empty Hemisphere in the Breit Frame and Differential Cross Section Measurement



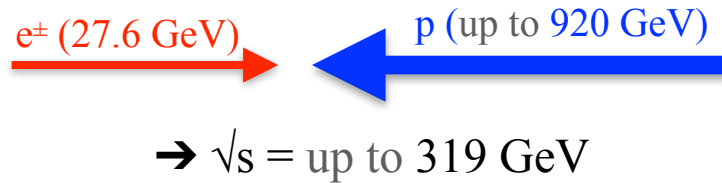
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Based on “Observation and differential cross section measurement of neutral current DIS events with an empty hemisphere in the Breit frame”, [arXiv:2403.08982](https://arxiv.org/abs/2403.08982), submitted to EPJC

HERA ep Collider and H1 Experiment

H1 was a general purpose detector at the unique electron-proton collider HERA, operated over 15 years until 2007



The measurement presented here is based on

Data taken in 2003 - 2007 @ $\sqrt{s} = 319 \text{ GeV}$

Integrated luminosity: 351.1 pb^{-1}

Deep Inelastic Scattering (DIS)

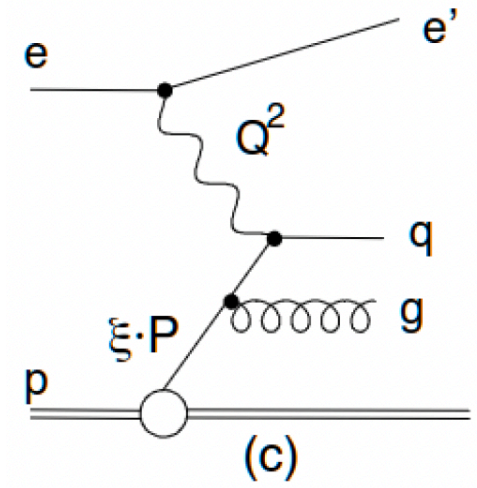
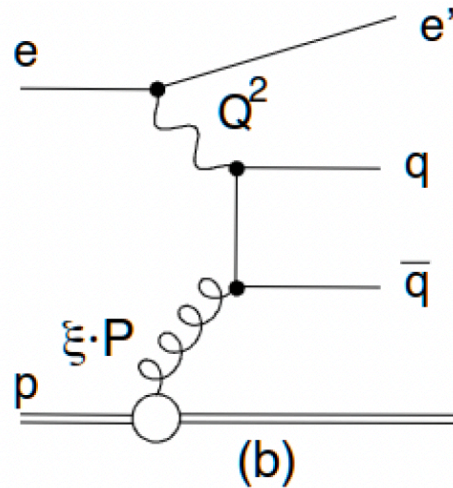
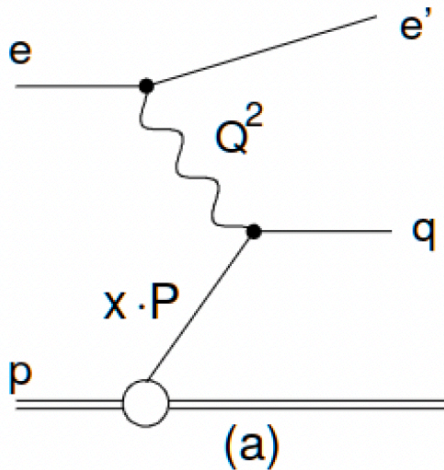
Leading order: parton model

First order in QCD

Neutral Current (NC) process

$$\gamma^* + g \rightarrow q + \bar{q}$$

$$\gamma^* + q \rightarrow q + g$$

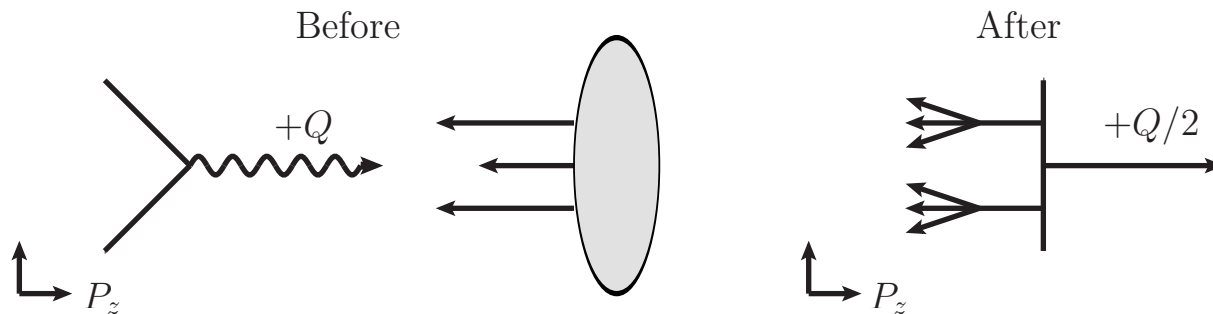


Q^2 being photon's momentum transfer q squared

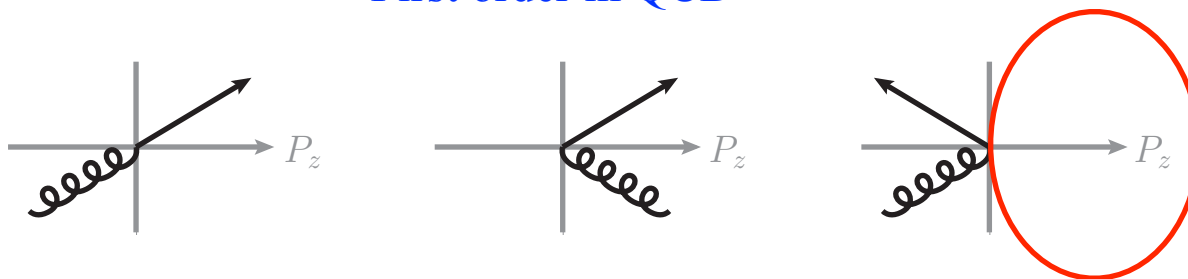
x/ξ - fraction of proton's momentum carried by a struck parton

Breit Frame

Leading order: parton model



First order in QCD



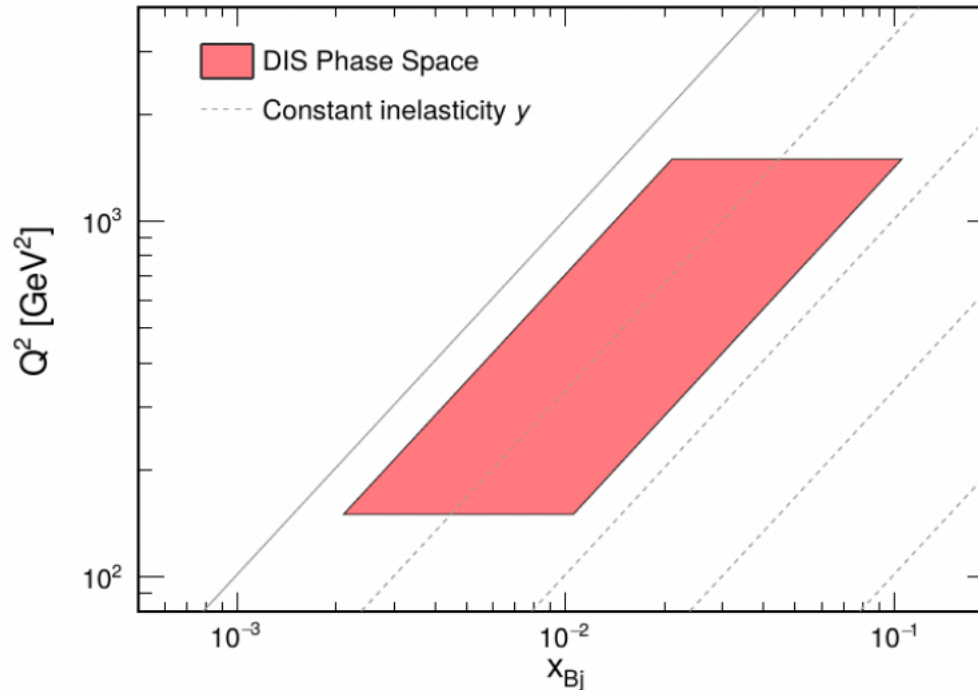
Lacking higher orders predictions

Empty (current) hemisphere events (EHes)
predicted already in 1979 ([link](#))

Motivate the measurement

Kinematic Phase Space for Inclusive NC DIS Events

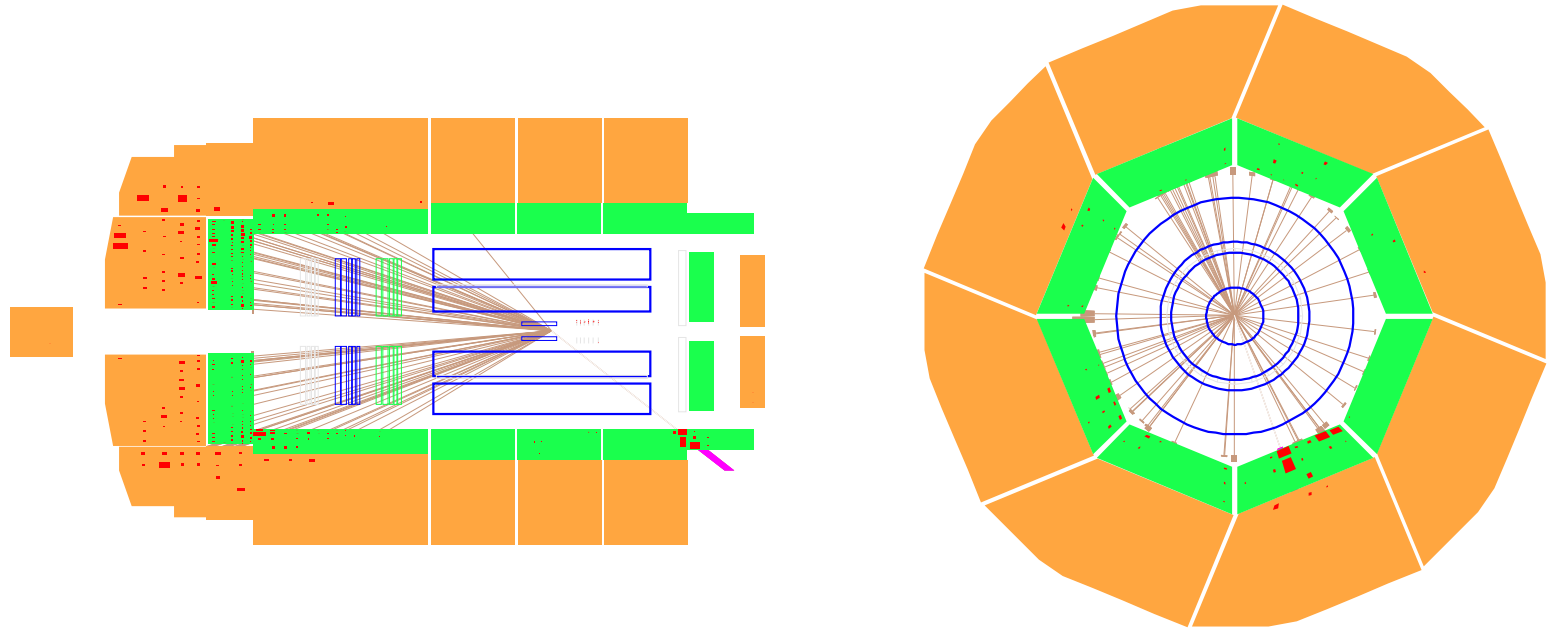
$$150 < Q^2 < 1500 \text{ GeV}^2, \quad 0.14 < y < 0.7$$



Main analysis requirements:

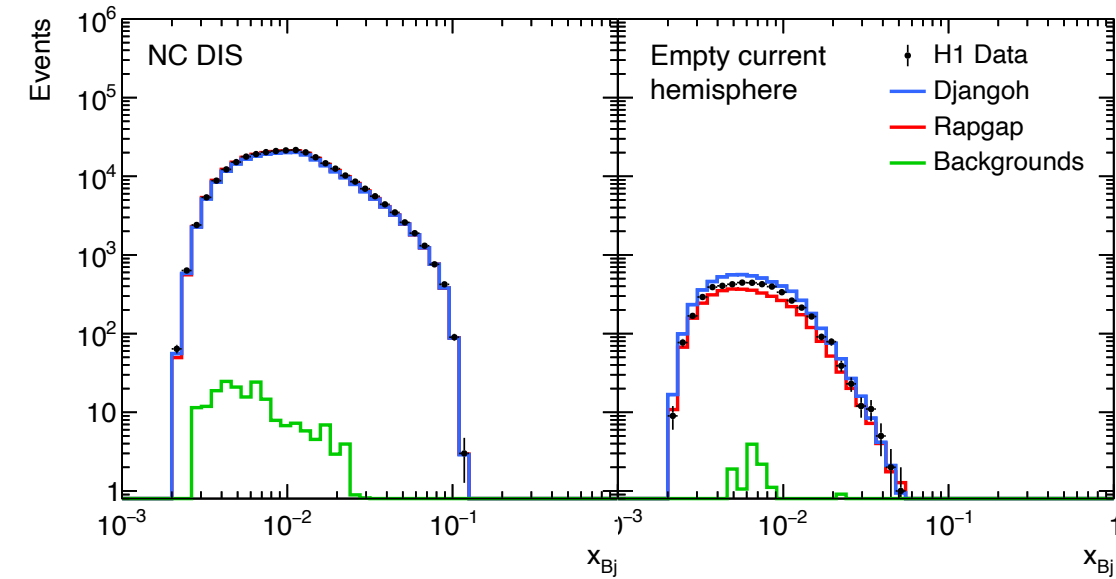
- One scattered electron with $E > 11$ GeV
- Energy flow based hadronic final state (HFS) objects
- The total longitudinal momentum $E - p_z$ [45, 62] GeV

One Example of EHEs



EHEs often have characteristic signatures with high particle multiplicity in the forward region

Comparison Kinematic Distribution: Inclusive vs EHE

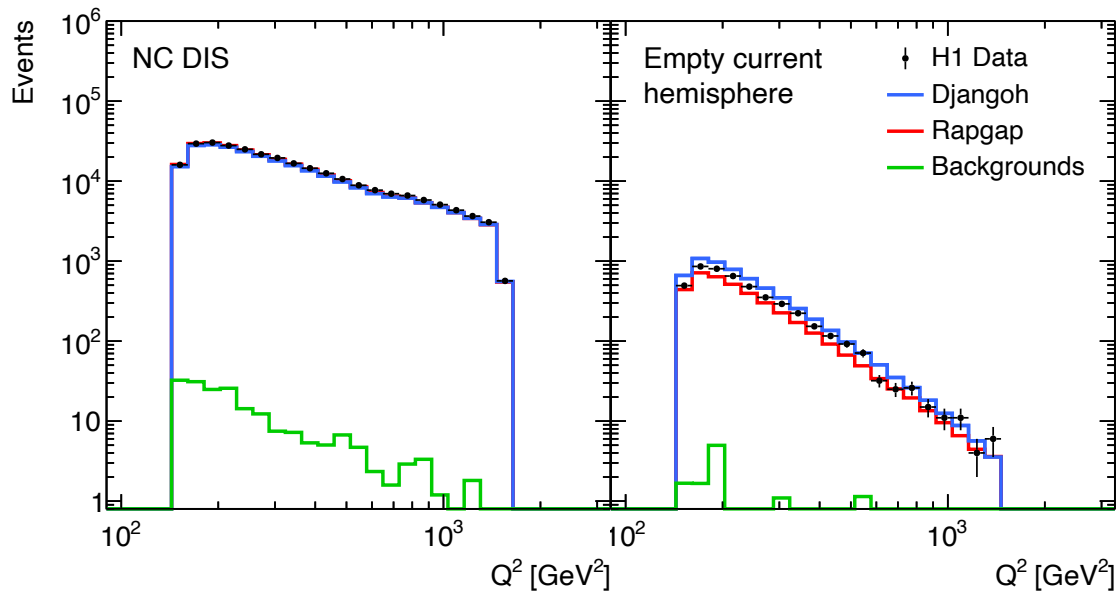


Left: Inclusive NC DIS events

Right: EHEs

Inclusive NC DIS event sample
~ two orders of magnitude
larger than the EHE one

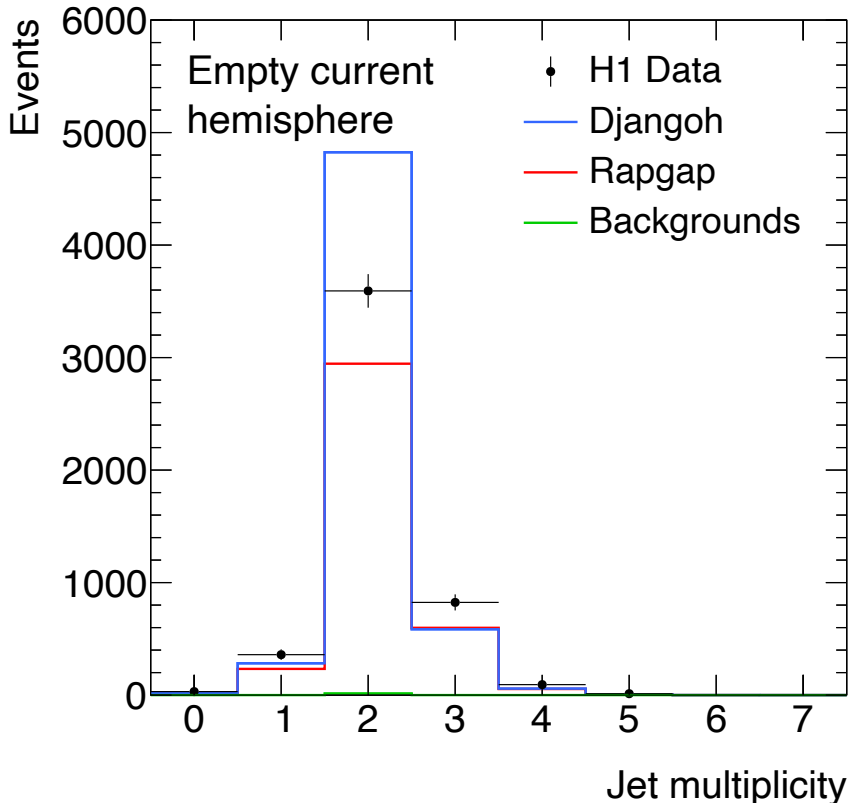
The background contribution is
tiny



Number of Jets in EHEs

EHEs are predicted at $\mathcal{O}(\alpha_s)$

→ Two jet topologies in the Breit frame

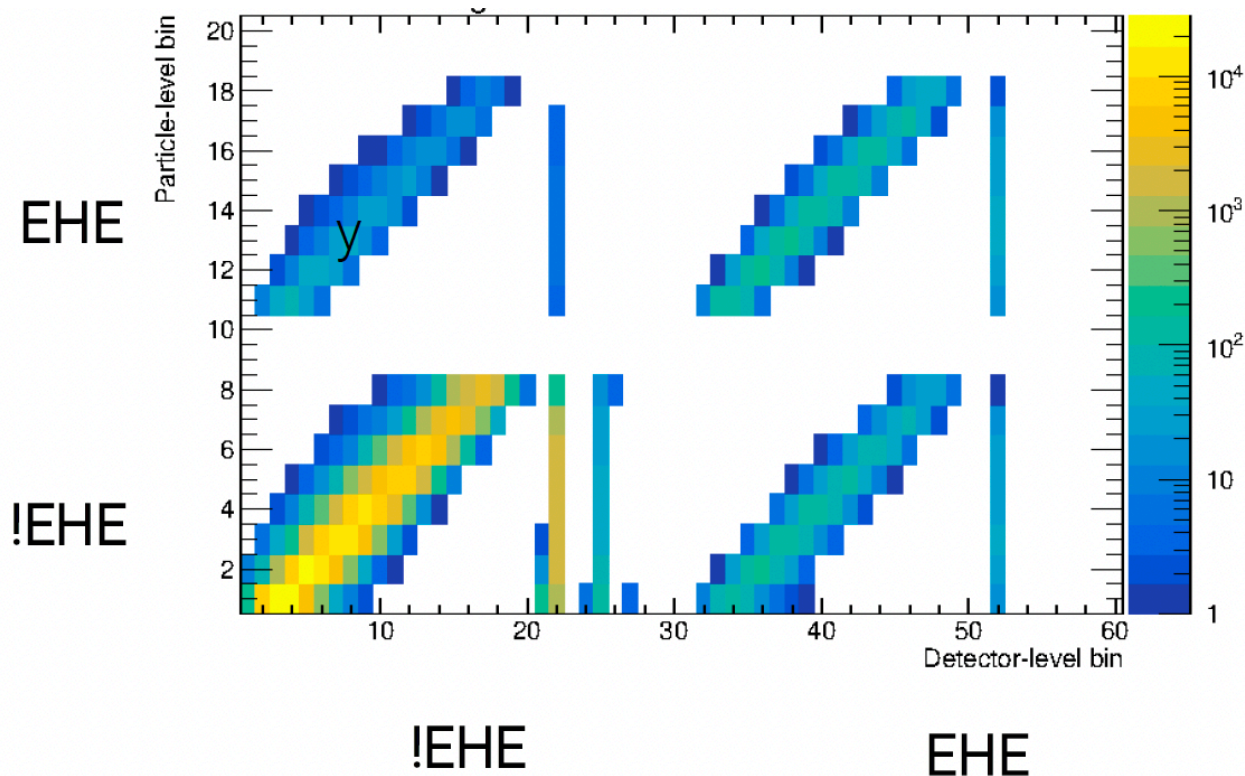


Jet multiplicity at detector level confirms that EHEs are predominantly two-jet events

Jets reconstructed using kt algorithm with a radius parameter of $R = 1$

Unfolding: Detector \rightarrow Particle Level

Measured distributions of EHE and non-EHE (!EHE) in y (shown below), x_{Bj} and Q^2 at detector level are unfolded to particle level



Unfolding based on [TUnfold package](#)

Migration matrix = Average of Django and Rapgap

Inclusive NC DIS = EHE + !EHE

Inclusive Fraction

$$r = \frac{\sigma(E_C=0)}{\sigma(\text{NC DIS})} = 0.0112 \pm 3.9\%_{\text{stat}} \pm 4.5\%_{\text{syst}} \pm 1.6\%_{\text{mod}}$$

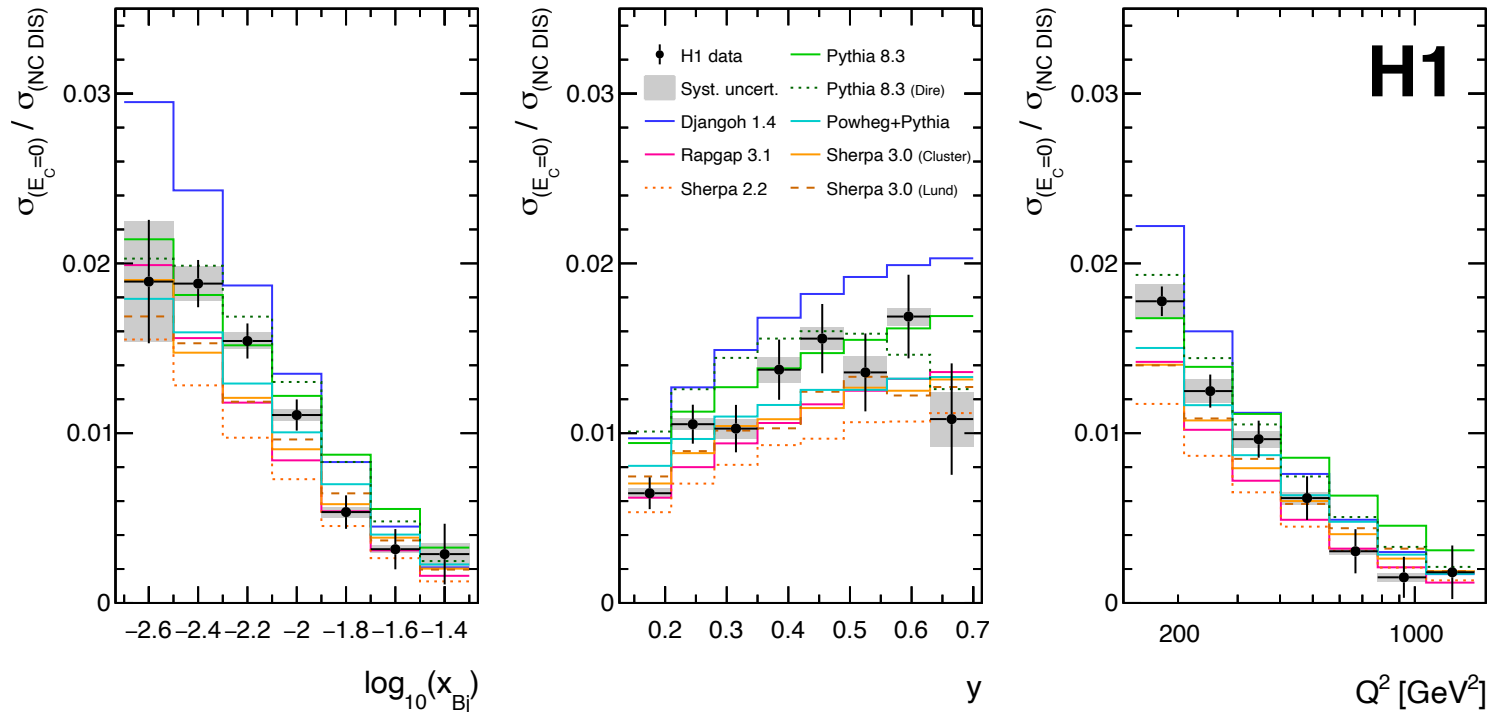
	r	δr
Data	0.0112	$\pm 3.9\%_{\text{stat}}$ $\pm 4.5\%_{\text{syst}}$ $\pm 1.6\%_{\text{mod}}$
Djangoh 1.4	0.0150	$\pm 0.1\%_{\text{stat}}$
Rapgap 3.1	0.0096	$\pm 0.1\%_{\text{stat}}$
Pythia 8.3	0.0127	$\pm 0.1\%_{\text{stat}}$
Pythia 8.3 (Dire)	0.0120	$\pm 0.1\%_{\text{stat}}$
Powheg+Pythia	0.0107	$\pm 0.1\%_{\text{stat}}$
Sherpa 3.0 (Cluster)	0.0100	$\pm 0.1\%_{\text{stat}}$
Sherpa 3.0 (Lund)	0.0101	$\pm 0.3\%_{\text{stat}}$
Sherpa 2.2	0.00818	$\pm 0.5\%_{\text{stat}}$

Table 1 Comparison of the fraction r of empty current hemisphere events in NC DIS with various predictions in the analyzed phase space $150 < Q^2 < 1500 \text{ GeV}^2$ and $0.14 < y < 0.7$.

Events with empty hemisphere are only $\sim 1\%$ of the inclusive NC DIS events but the fraction is measured with a total relative uncertainty of 6.2%

Different predictions have only only stat uncertainties quoted but they do envelop the measurement

Differential Fractions



Fraction of empty current hemisphere decreases with increasing x_{BJ} , Q^2 and decreasing y

The measurement is compared with predictions of various event generators with measurement precision better than the spread of predictions

Summary

First measurement of the fraction empty hemisphere events (EHEs) over NC DIS events both inclusively and differentially as functions of x_{Bj} , y , Q^2 in the phase space of $150 < Q^2 < 1500 \text{ GeV}^2$ and $0.14 < y < 0.7$

The measurement can help to improve and validate parton shower and hadronization models

The current hemisphere in the Breit frame of ep collisions \sim one hemisphere of e^+e^- or pp collisions, yet such EHEs are absent in the latter collisions

Need higher-order QCD prediction+hadronization model to check the impact on these EHEs