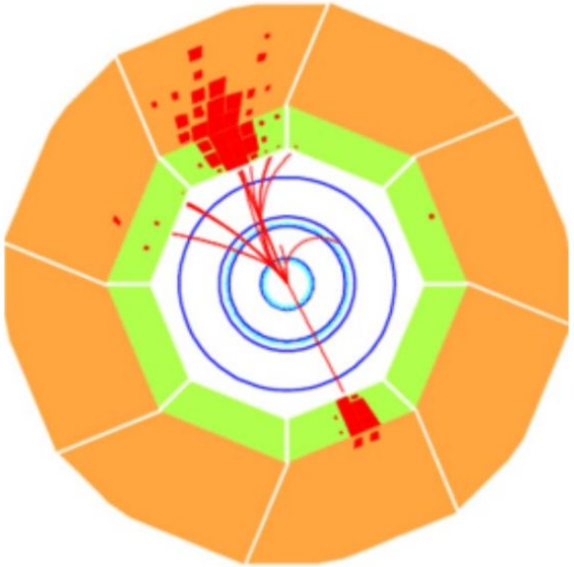
Measurement of lepton-jet correlations in DIS

Miguel Arratia,
on behalf of the H1 Collaboration



UC RIVERSIDE

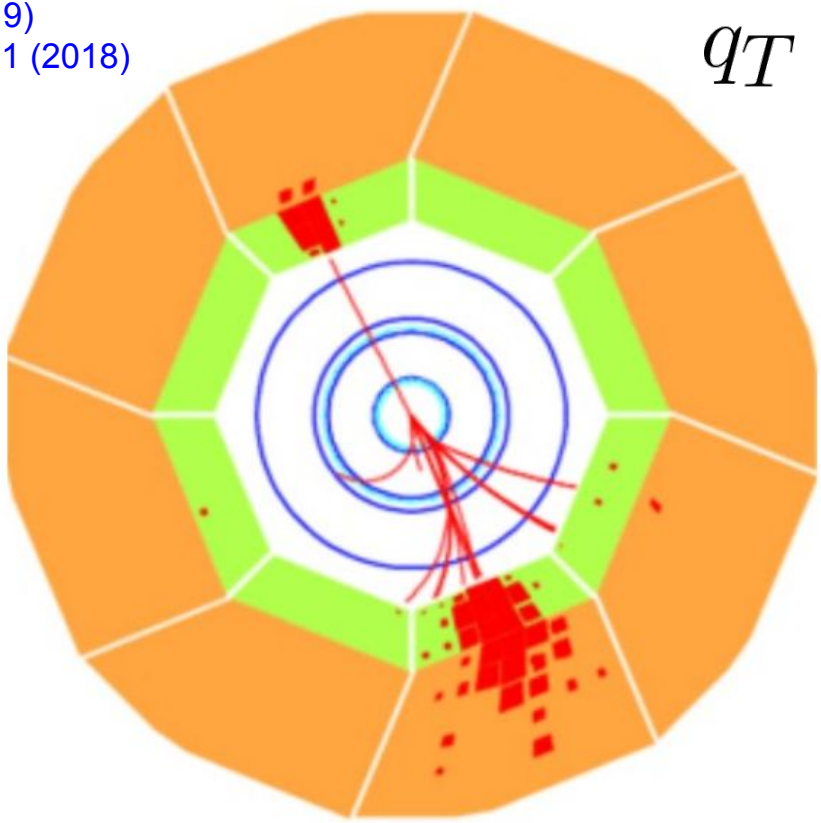
Jefferson Lab

H1

A new channel to probe for quark TMDs and evolution

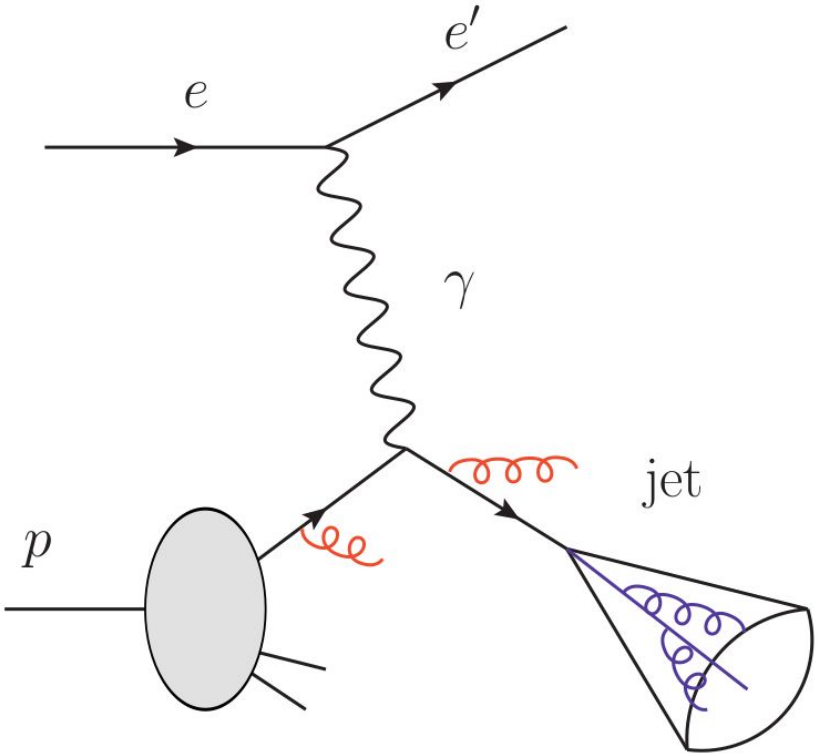
Liu et al. PRL. 122, 192003 (2019)
Gutierrez et al. PRL. 121, 162001 (2018)

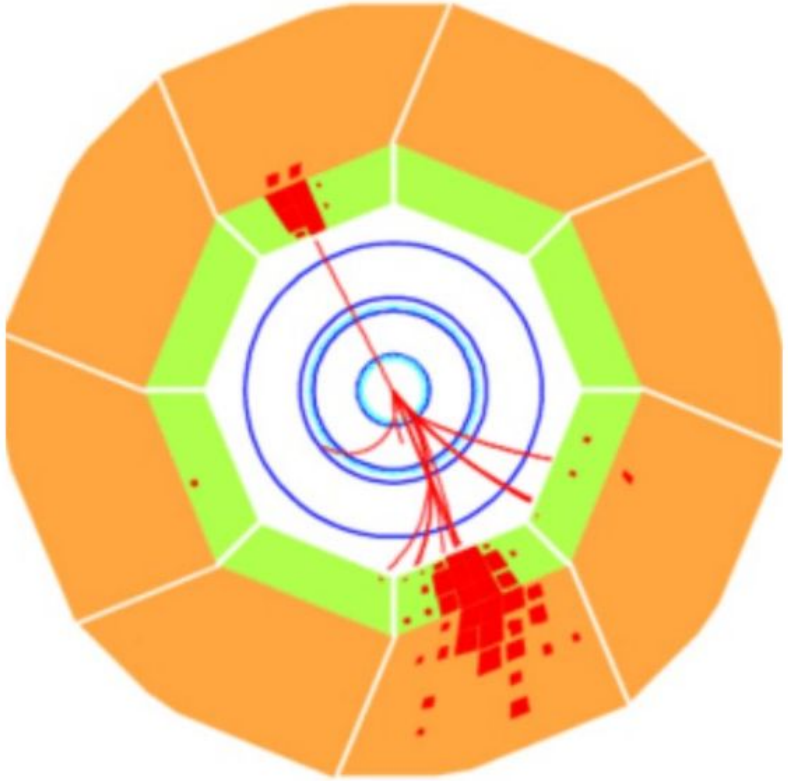
$$q_T = |\vec{k}_{l\perp} + \vec{p}^{\,j}_{\perp}|$$



DIS Born-level configuration

$\gamma^* q \to q$





Motivation

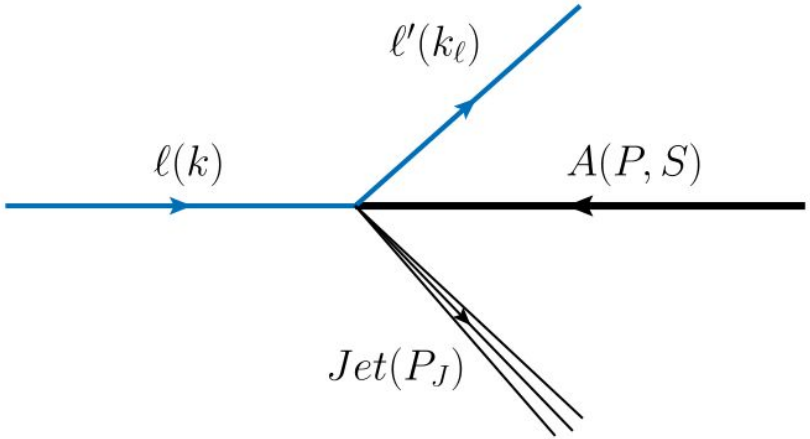
Lepton-jet imbalance $q_T = |\vec{k}_{l\perp} + \vec{p}^{\,j}_{\perp}|$

In Born-level configuration

Probes quark TMD PDFs

Liu et al. PRL. 122, 192003 (2019)

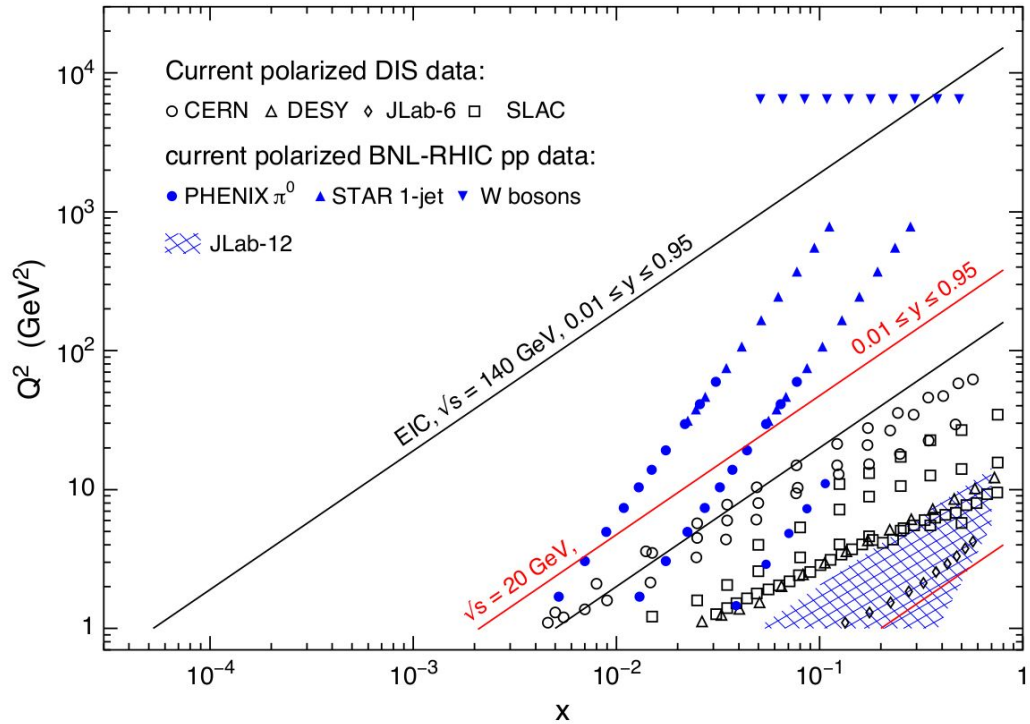
Gutierrez et al. PRL. 121, 162001 (2019)



$$\frac{d^5\sigma(\ell p \to \ell' J)}{dy_\ell d^2k_{\ell\perp} d^2q_\perp} = \sigma_0 \int d^2k_\perp d^2\lambda_\perp x f_q(x, k_\perp, \zeta_c, \mu_F)$$
$$\times H_{\mathrm{TMD}}(Q, \mu_F) S_J(\lambda_\perp, \mu_F)$$
$$\times \delta^{(2)}(q_\perp - k_\perp - \lambda_\perp).$$

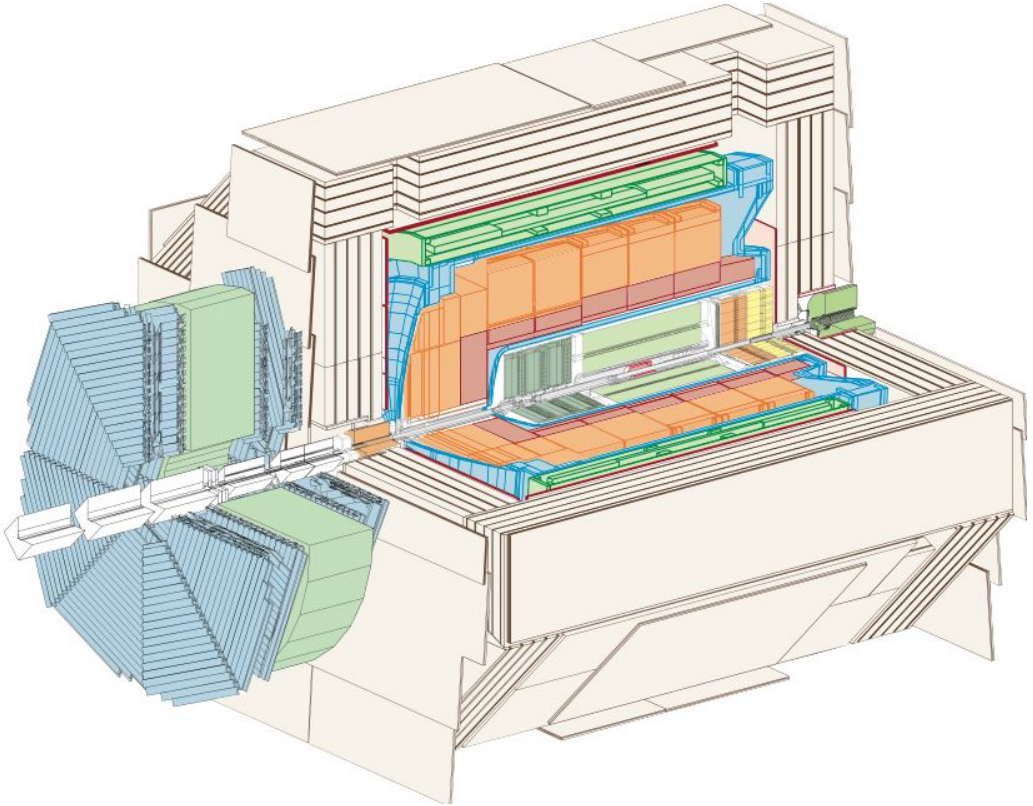
Constraining TMD evolution

H1 can bridge low Q2 DIS from fixed-target exp. and high Q2 Drell-Yan at colliders.
Fixing open issues of TMD factorization & universality



Unpolarized TMD DIS measurements
Important baseline for EIC

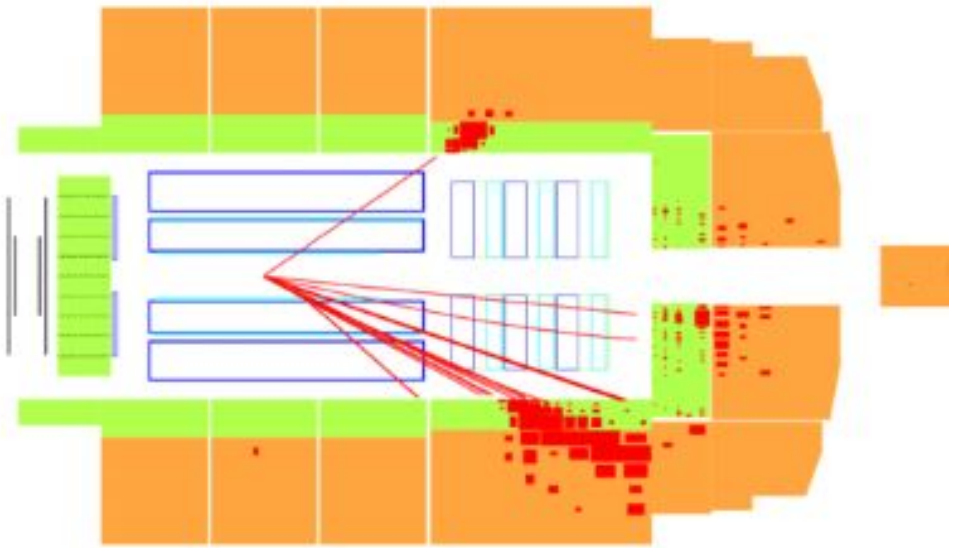
The H1 experiment at HERA



- Tracking system
(silicon tracker, jet chambers,
proportional chambers)
- LAr calorimeter (em/had)
- Scintillating fiber
calorimeter

Both combined using
an energy flow algorithm

Accurate and precise jet and lepton measurements



Neural-net based in-situ jet calibration for data and MC.

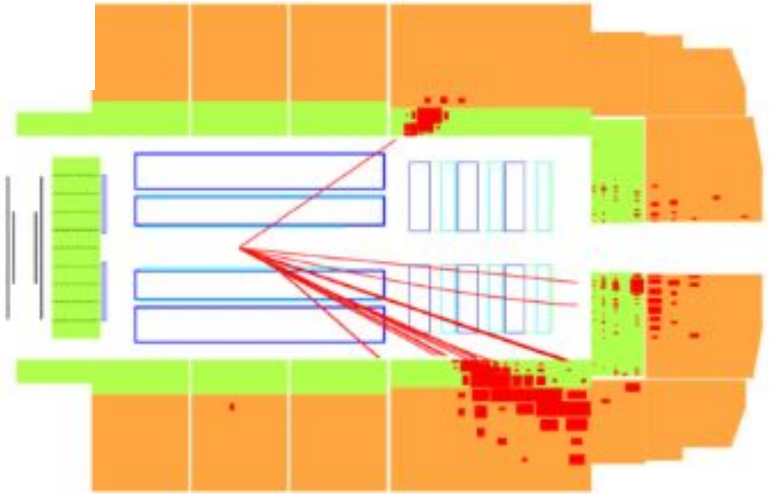
1% Jet energy scale

0.5-1% lepton energy scale

DIS kinematic reconstruction (sigma method)

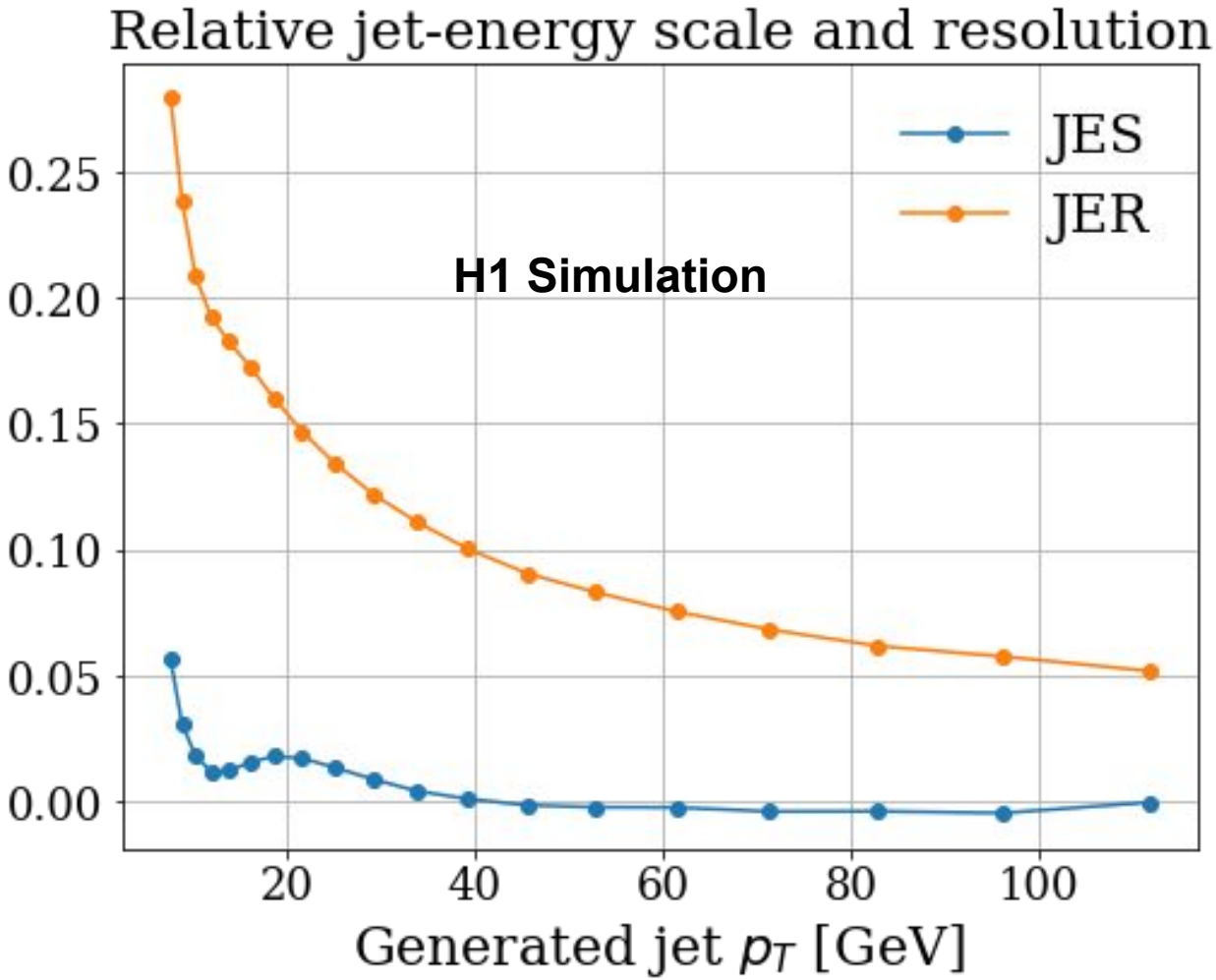
$$y = \frac{\sum_{i \in had}(E_i - p_{i,z})}{\sum_{i \in had}(E_i - p_{i,z}) + E_{e'}(1 - \cos\theta_{e'})}$$

$$Q^2 = \frac{E_{e'} \sin^2 \theta_{e'}}{1 - y},$$



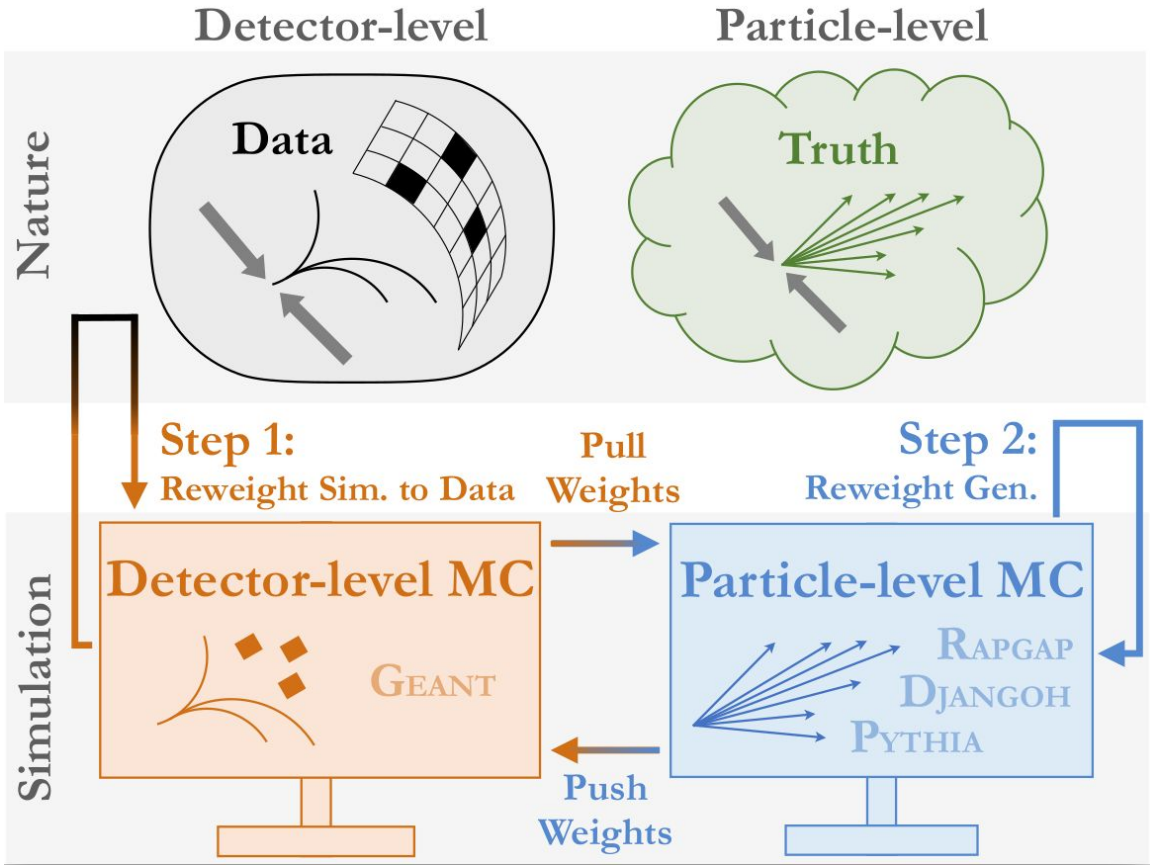
*No QED rad. Corrections applied for this preliminary result

Jet performance
(energy flow reconstruction)



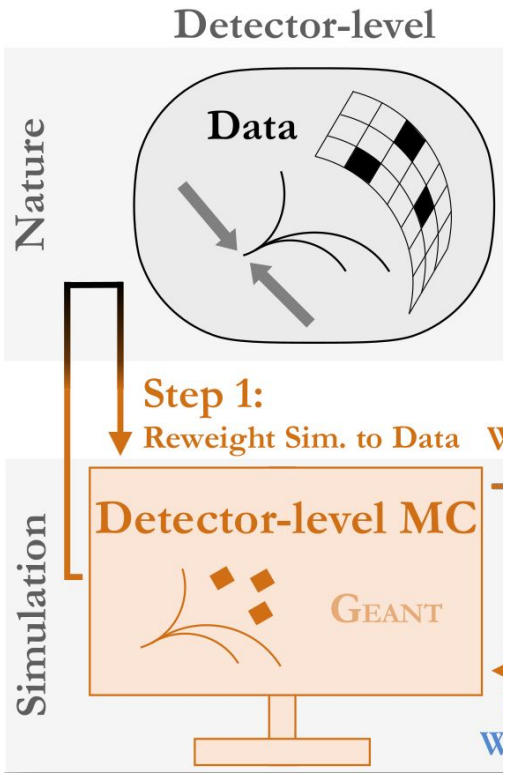
Unfolding with Omnifold (via machine-learning).

Andreassen et al. PRL **124**, 182001 (2020)



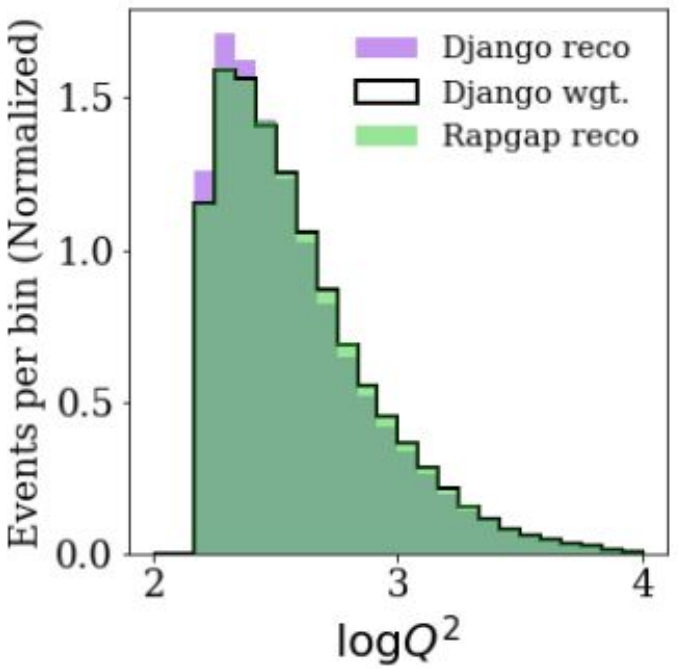
This is the **first-ever** measurement that uses machine-learning to correct for detector effects.

Reweighting the reco-level distributions

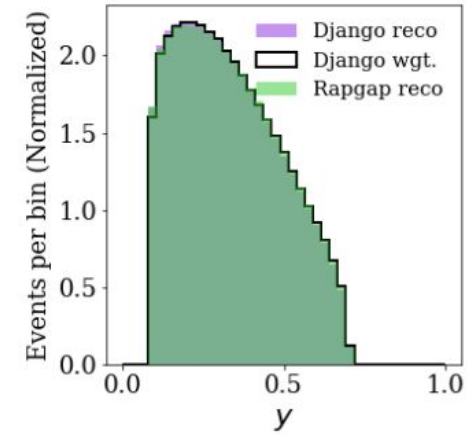


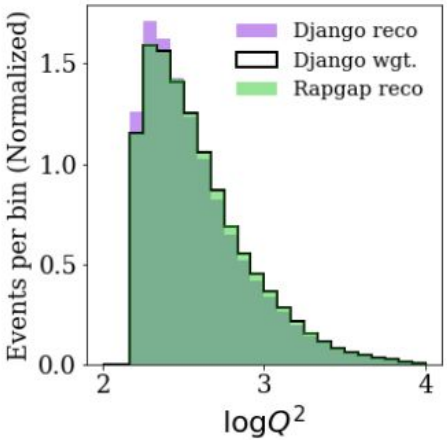
We use simple fully connected networks with a few hidden layers.

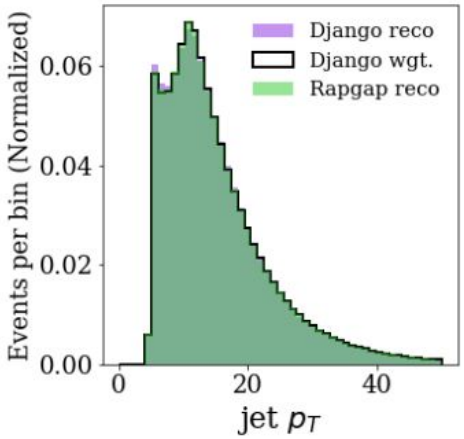
The distribution is binned for illustration, but the reweighting is unbinned.

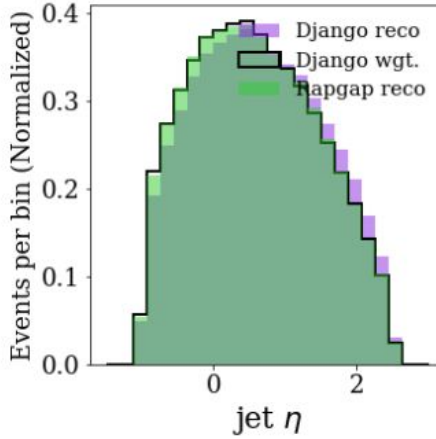


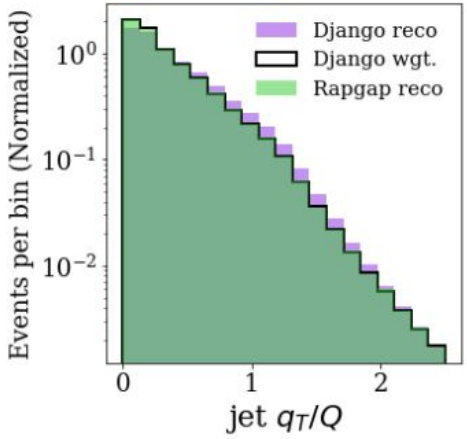
All these distributions are simultaneously reweighted

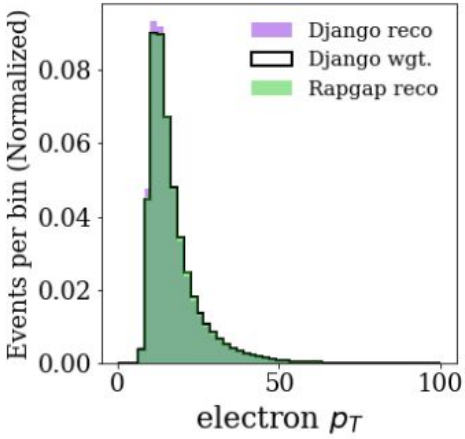


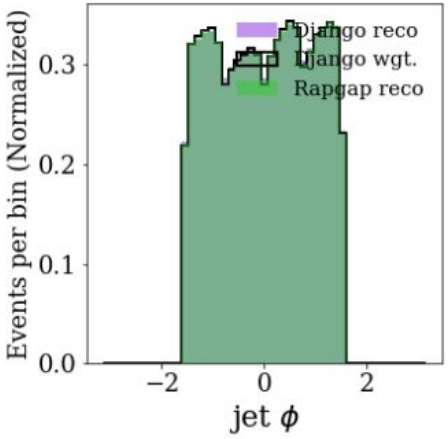


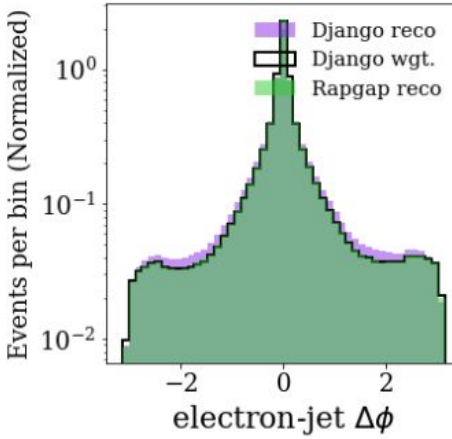








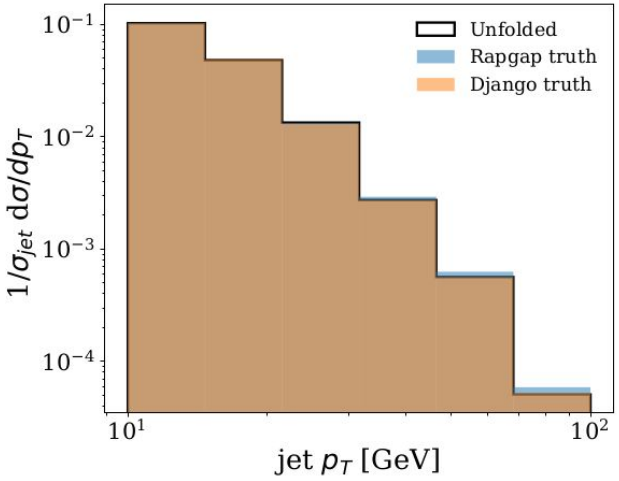


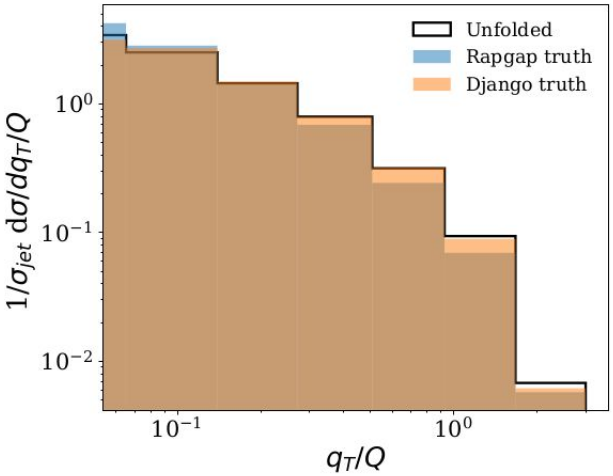


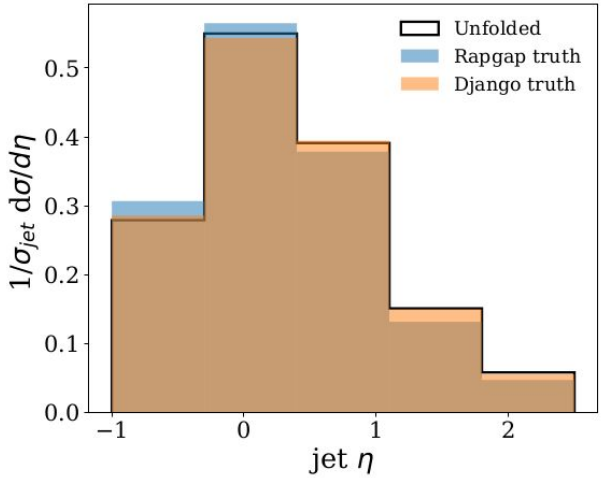
Closure tests

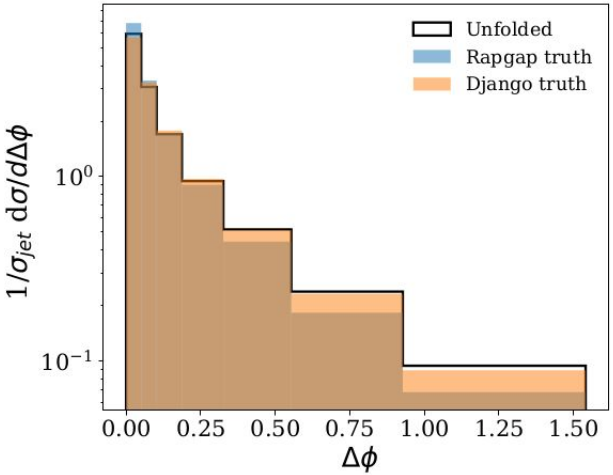
Pseudodata: Djangoh

Response: Rapgap







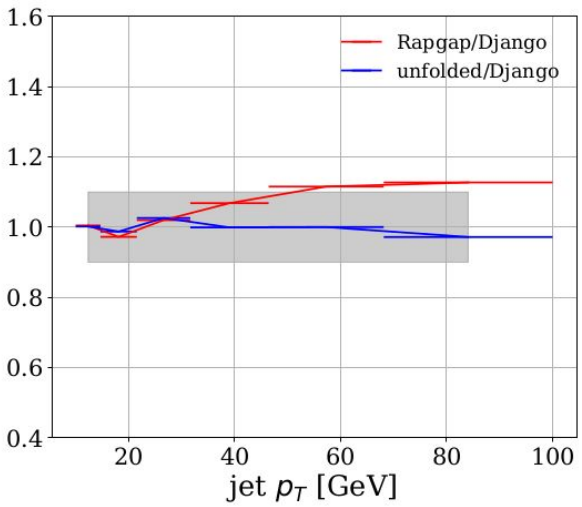


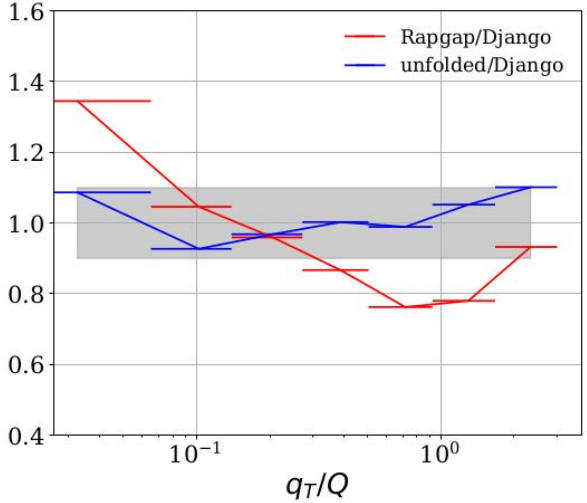
Closure tests

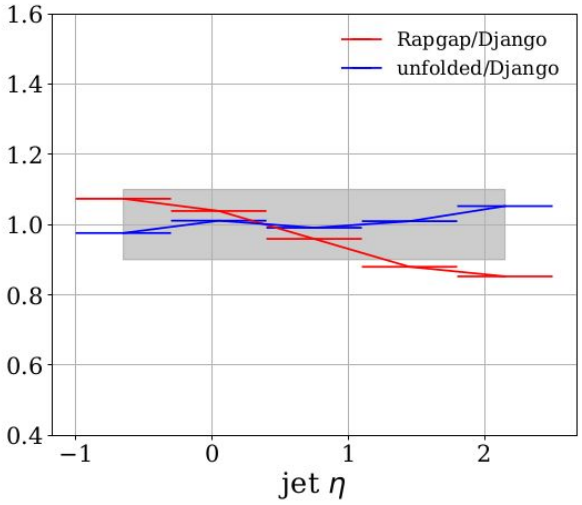
Pseudo Data: Djangoh

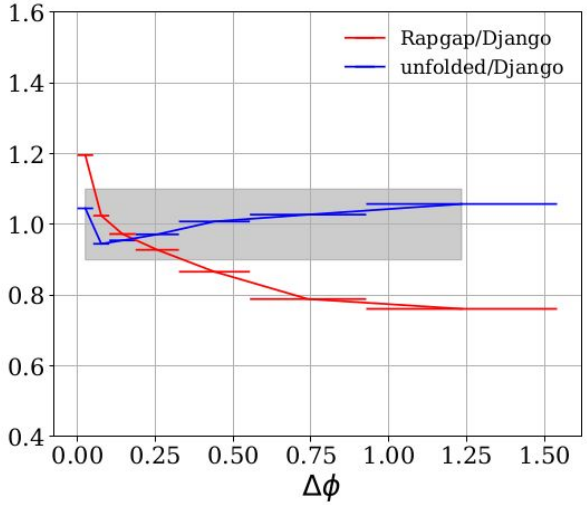
Response: Rapgap

Closure to within 10% or less in all distributions
Similar results obtained
With Rapgap as pseudo data









Preliminary Results

H1prelim-21-031
April 5, 2021

https://www-h1.desy.de/h1/www/publications/html/1prelim-21-031.long.html

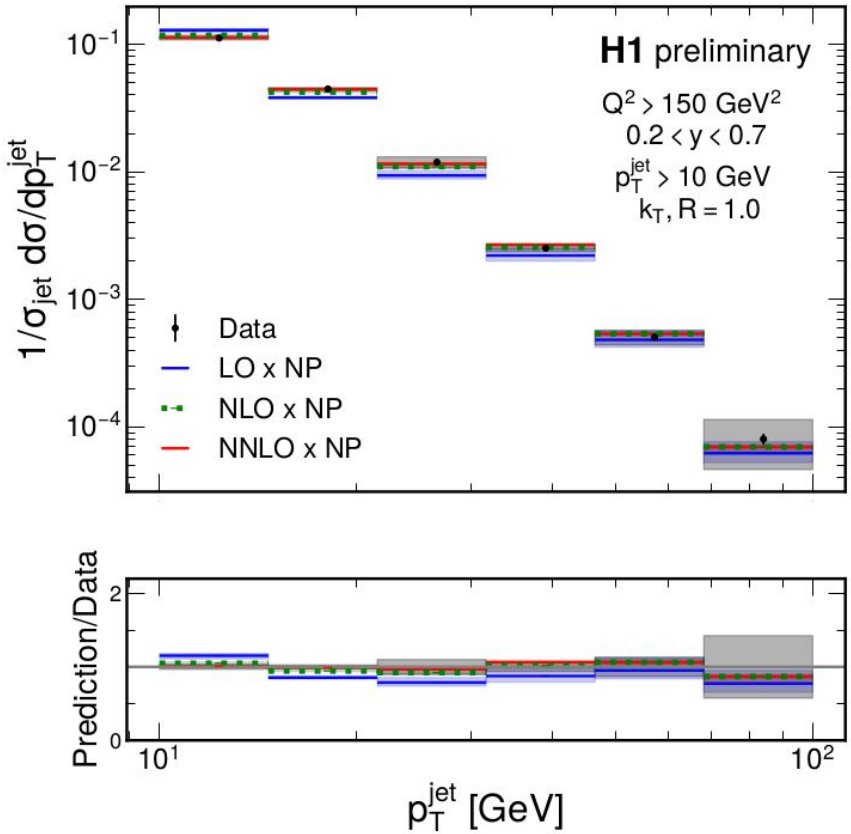
Measurement of lepton-jet correlations in high Q^2 neutral-current DIS with the H1 detector at HERA

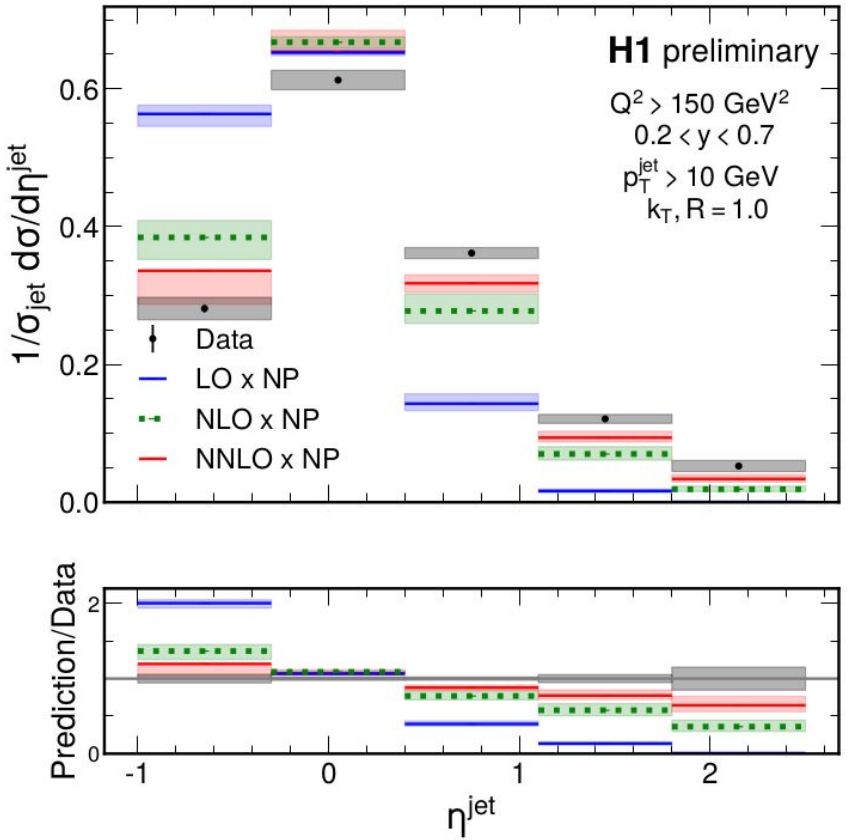
The H1 Collaboration

Abstract

A measurement of jet production in high Q^2 neutral-current DIS events close to the Born-level configuration $\gamma^* q \to q$ (Born kinematics) is presented. This cross section is measured deferentially as

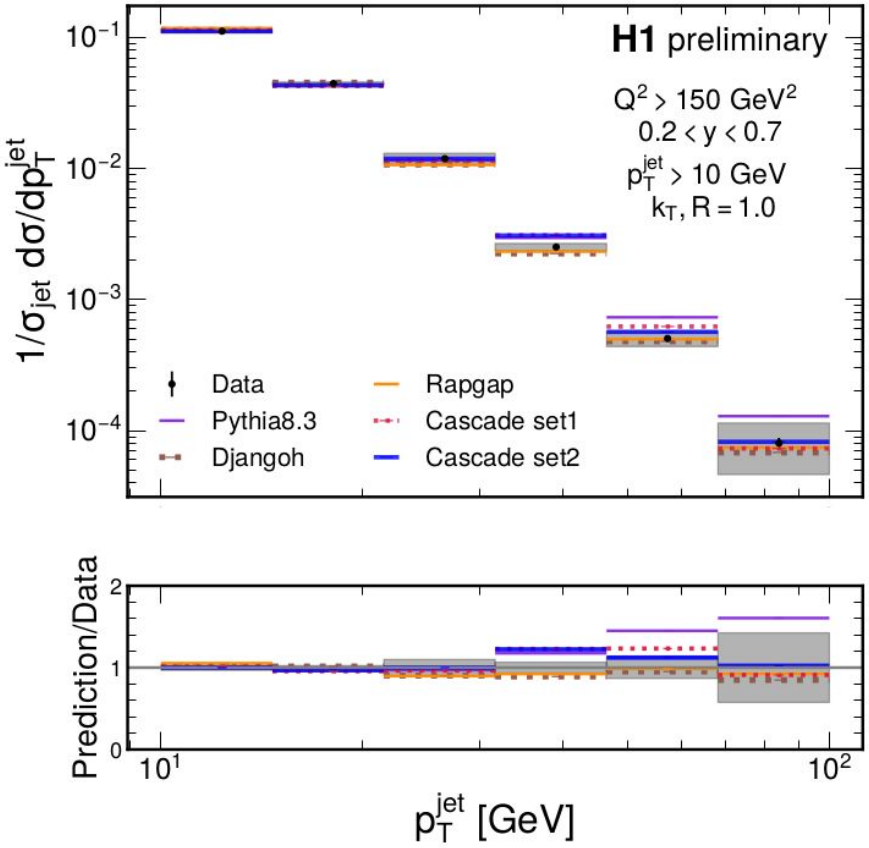
Jet transverse momentum and pseudorapidity

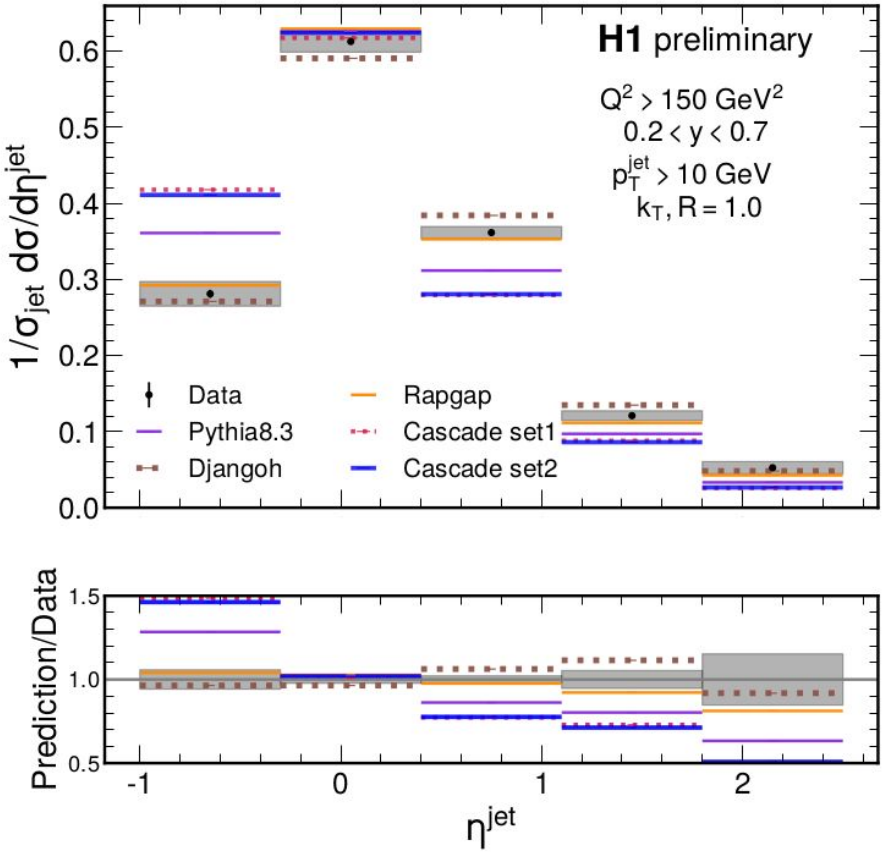




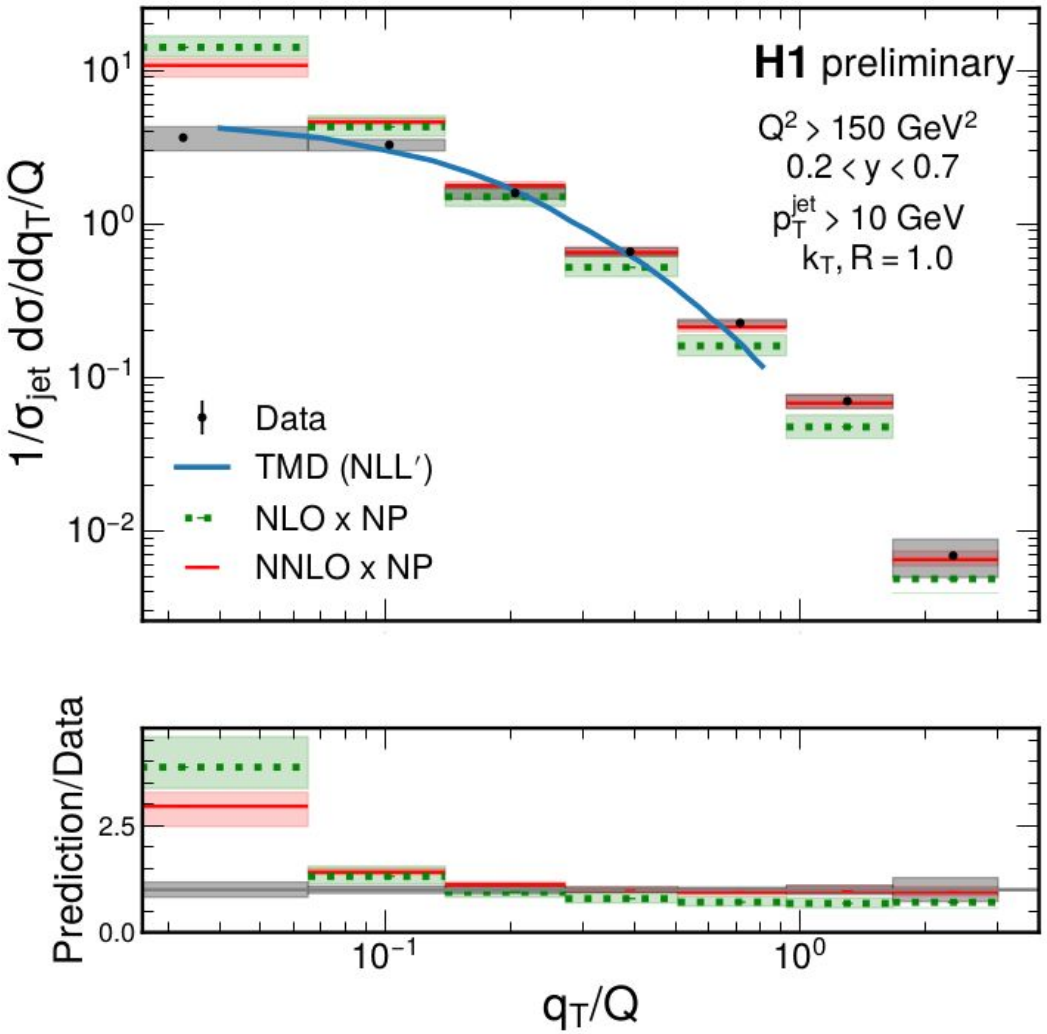
- Well described, quick convergence
- Hints at need of NNNLO

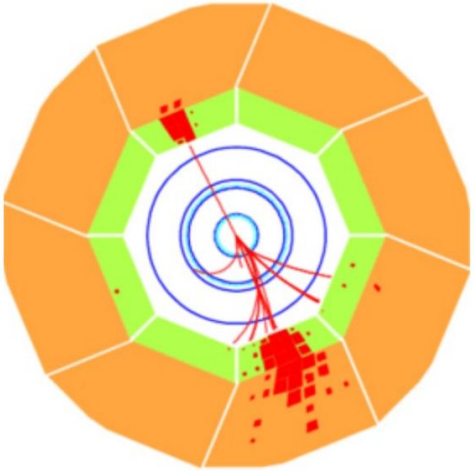
Jet transverse momentum and pseudorapidity





- Djangoh and Rapgap provide give good description; Pythia8, Cascade miss pseudorapidity



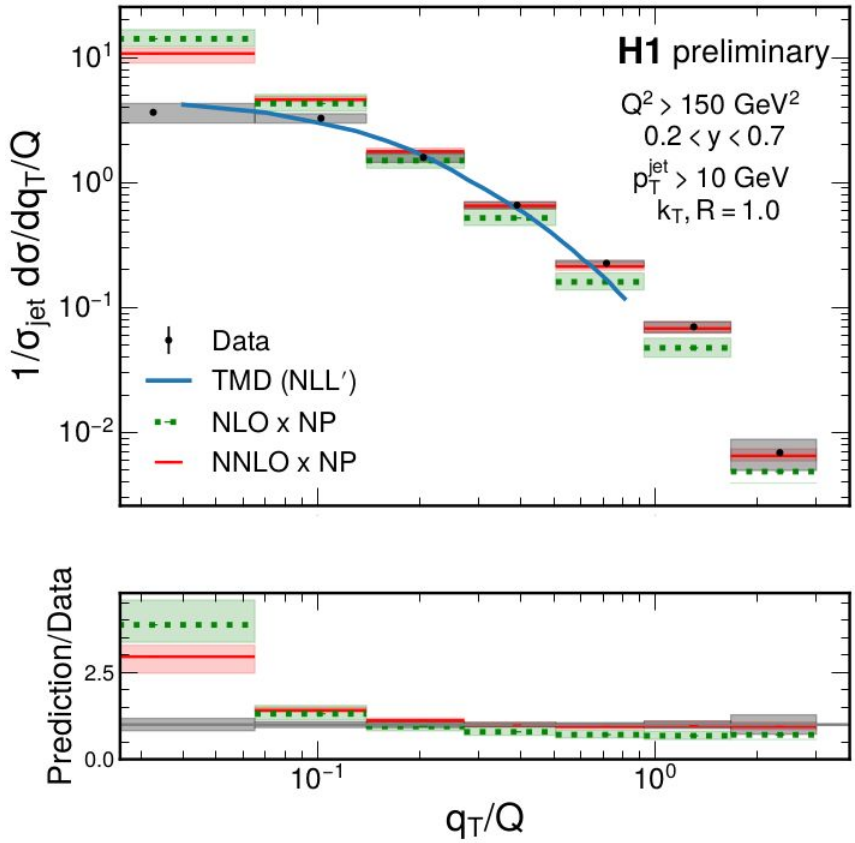


TMD calculation does a great job at low qT; collinear calculation does a great job at large qT.

Large overlap-> Data will help constrain matching between TMD and collinear pQCD frameworks

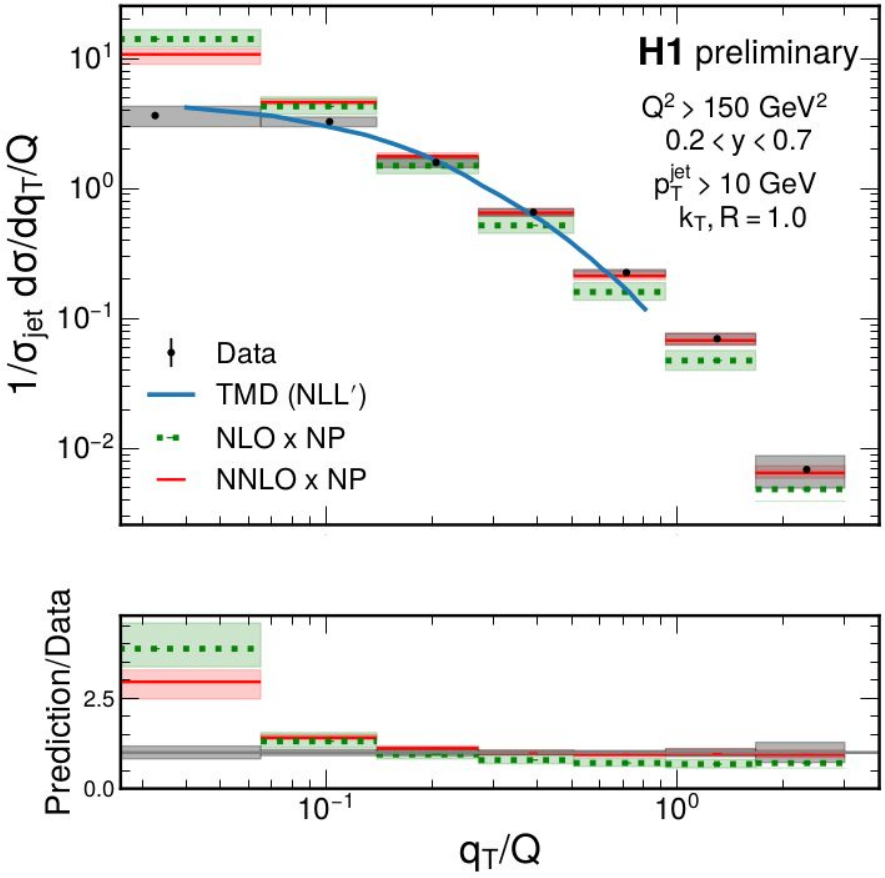
TMD calculation, without free parameters, describes data over wide kinematic range

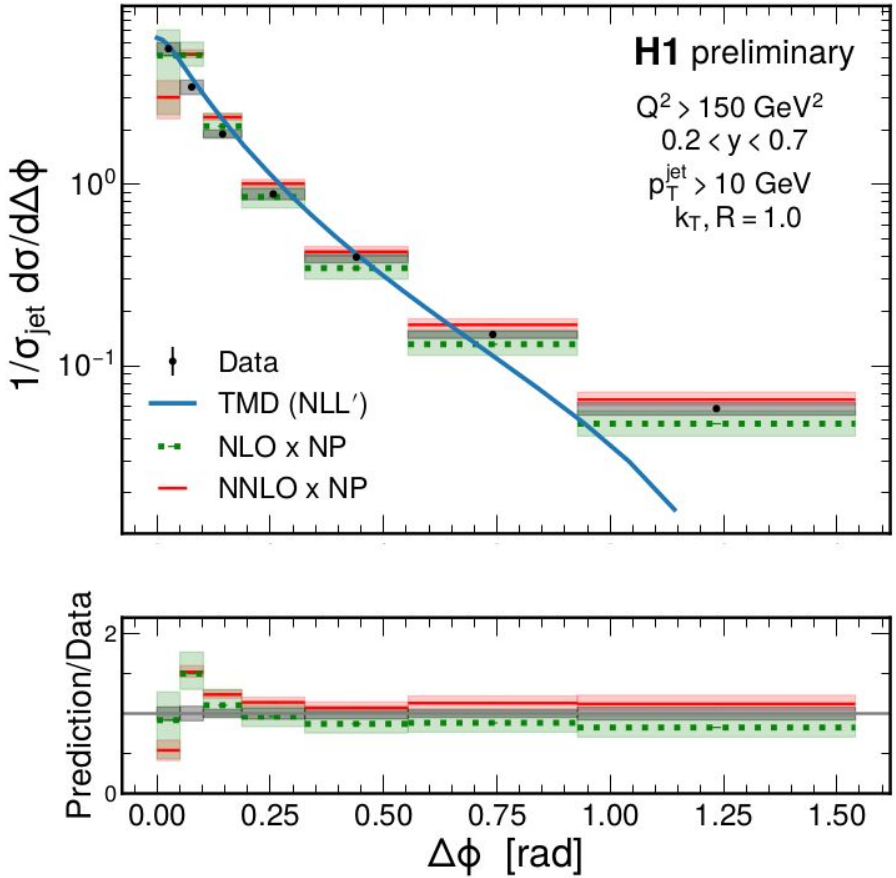
$$\frac{d^5\sigma(\ell p \to \ell' J)}{dy_\ell d^2k_{\ell\perp} d^2q_\perp} = \sigma_0 \int d^2k_\perp d^2\lambda_\perp x f_q(x, k_\perp, \zeta_c, \mu_F) \times H_{\mathrm{TMD}}(Q, \mu_F) S_J(\lambda_\perp, \mu_F) \times \delta^{(2)}(q_\perp - k_\perp - \lambda_\perp).$$



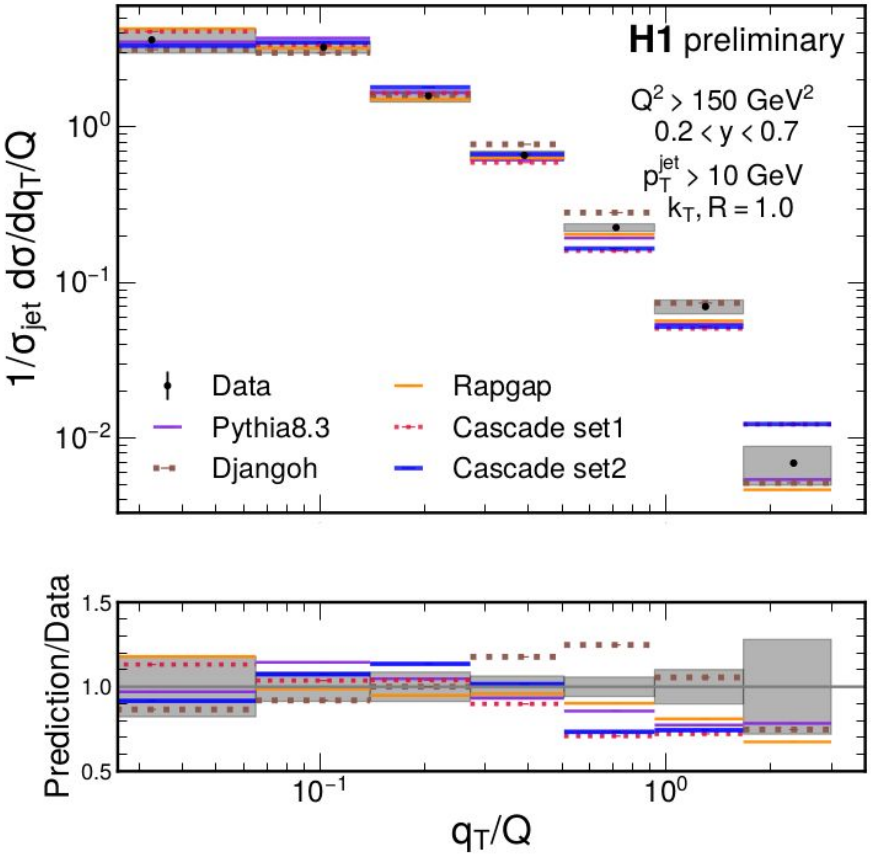
- TMD PDFs and soft factors extracted from low Q2 DIS and DY data. Sun et al. arXiv:1406.3073
- Recently tested in Echeverria et al. JHEP 01 (2021) 126
- pQCD calculations from Borsa et al. PRL. 125, 082001 (2020)

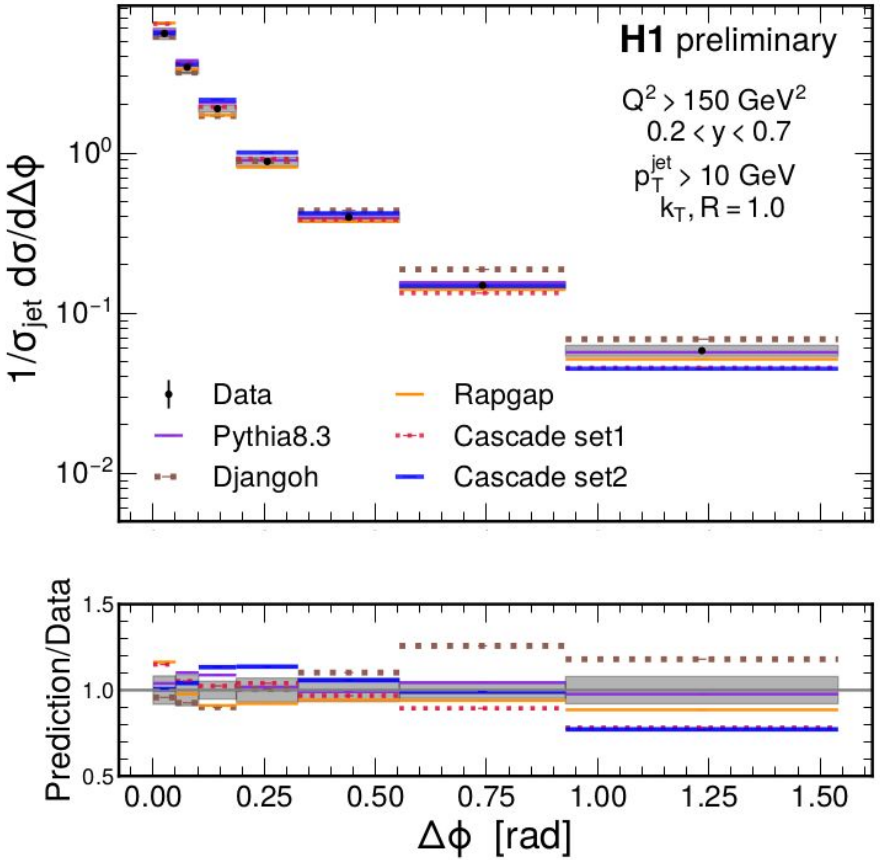
Qualitatively the same results for azimuthal angle correlation





Data well described by MC generators, which “bracket data”





CASCADE (TMD-based) describes low values well but misses large values

Summary

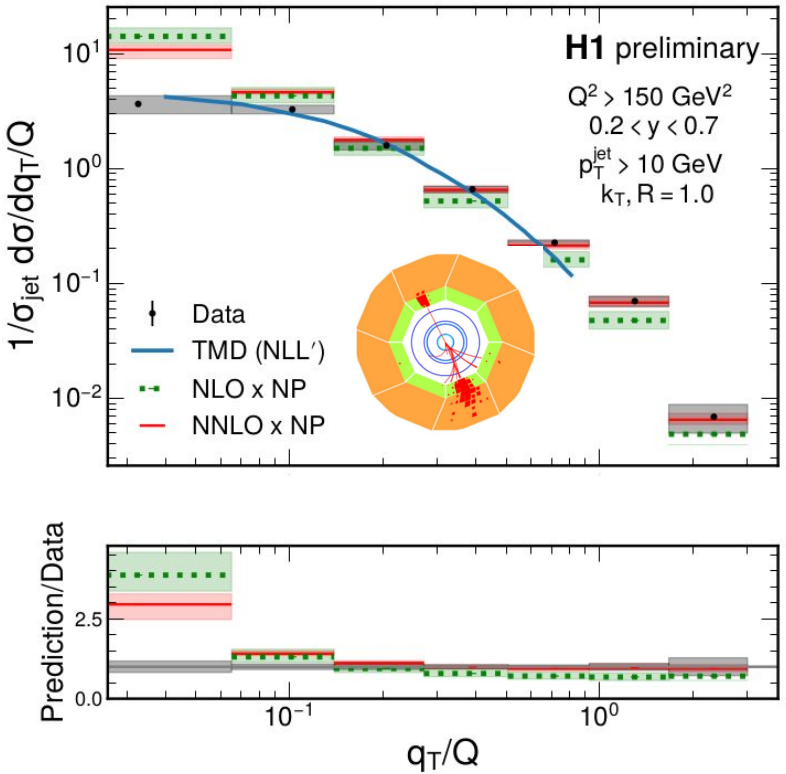
- We report a measurement of lepton jet momentum and azimuthal imbalance in DIS, which provide **a new way to constrain TMD PDFs and their evolution**

- Pure TMD calculation does a great job at low qT;
  Pure collinear calculation does a great job at large qT.
  Large overlap. Data can **constrain matching between TMD and collinear frameworks**

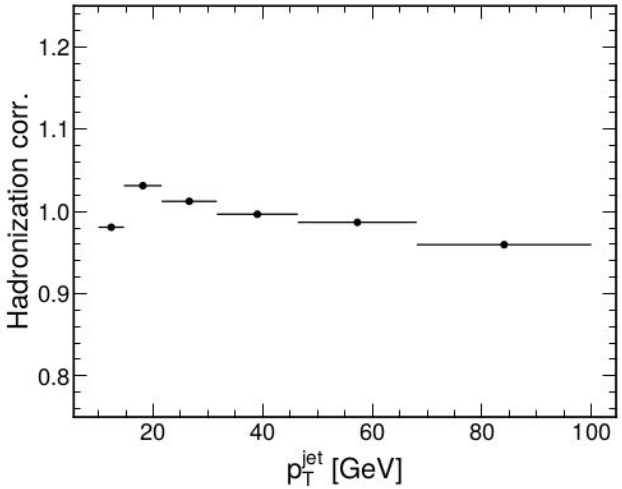
- We also report jet transverse momentum and pseudorapidity distributions. Reasonable well described by pQCD and MC generators

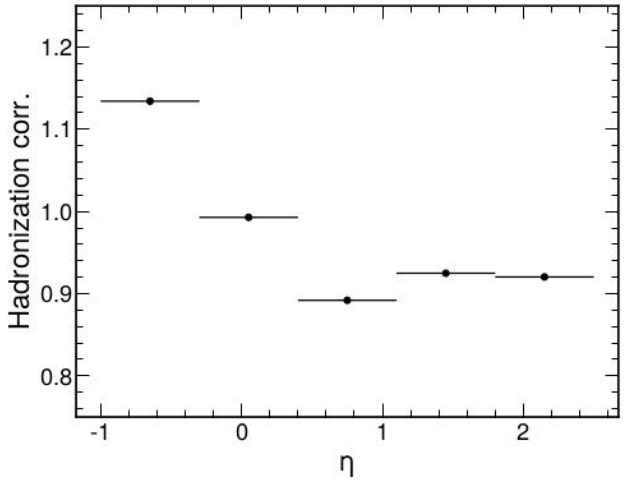
- **First-ever measurement that uses machine-learning to correct for detector effects.** (using Omnifold method)

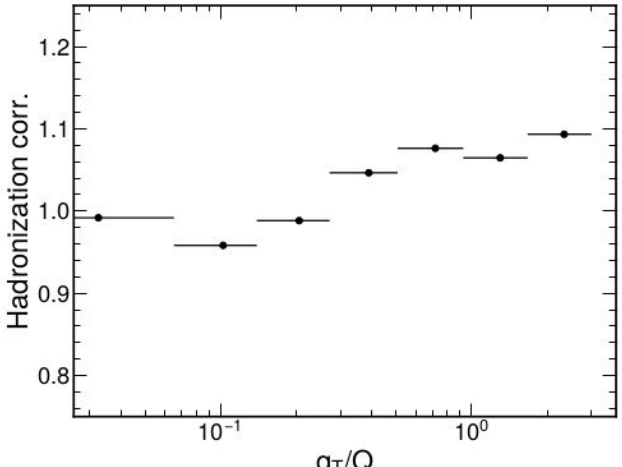
- This is the first measurement in a series of studies that aim at creating a **pathfinder program for the future EIC**

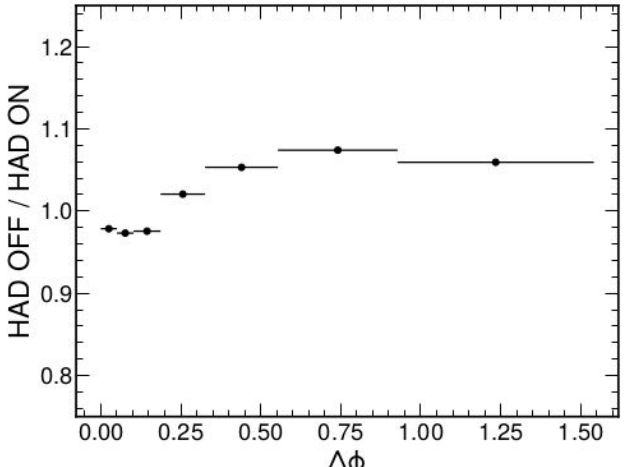


Backup


Hadronization corr.
1.2
1.1
1.0
0.9
0.8
20
40
60
80
100
p_T^{jet} [GeV]


Hadronization corr.
1.2
1.1
1.0
0.9
0.8
-1
0
1
2
η


Hadronization corr.
1.2
1.1
1.0
0.9
0.8
10^{-1}
10^{0}
q_T/Q


HAD OFF / HAD ON
1.2
1.1
1.0
0.9
0.8
0.00
0.25
0.50
0.75
1.00
1.25
1.50
Δφ