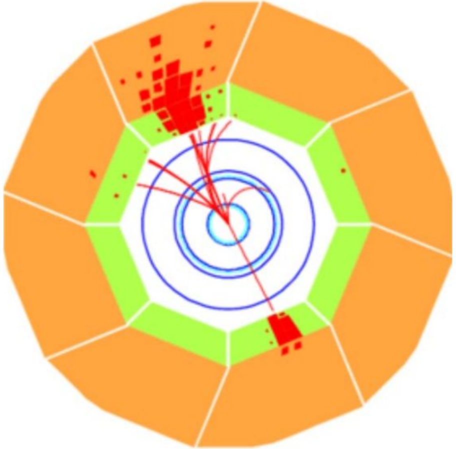
Jet-based TMD measurements with H1 data, unfolded using machine-learning techniques



Miguel Arratia,
on behalf of the H1 Collaboration

UC RIVERSIDE

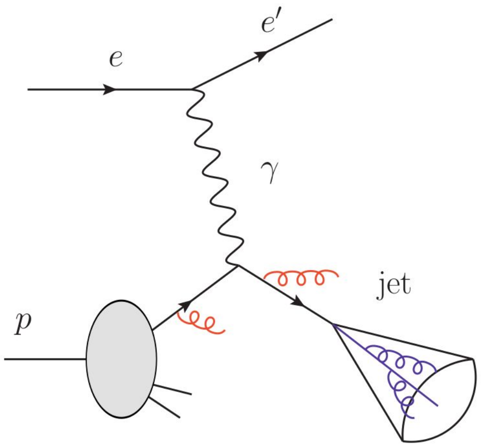
Jefferson Lab

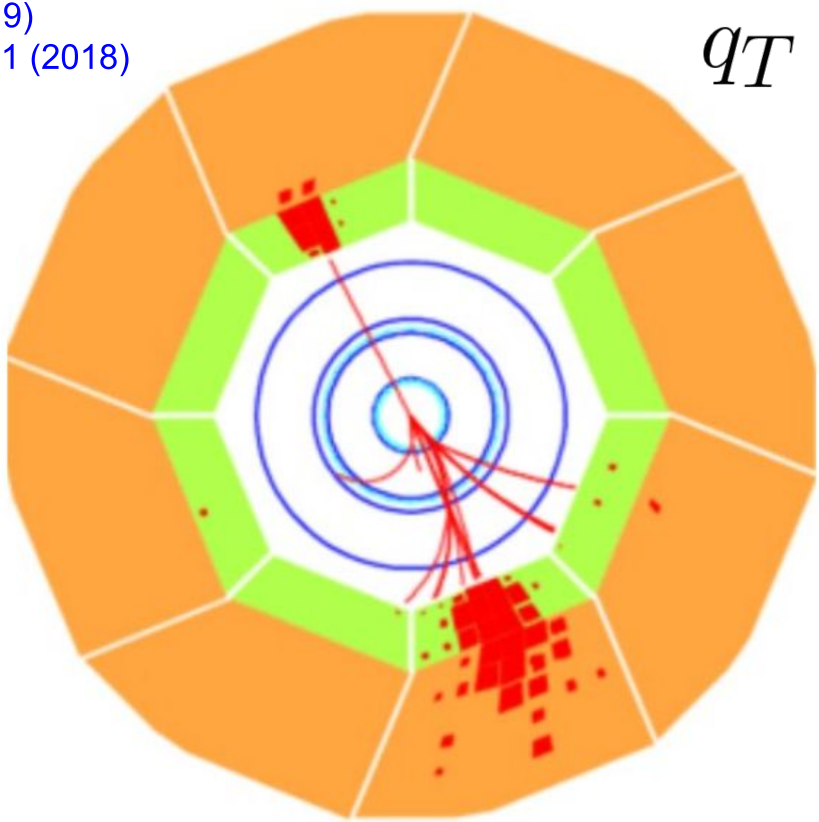
ML4Jets 2021 , July 2021

A new channel to probe for quark TMDs and evolution

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

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





Motivation

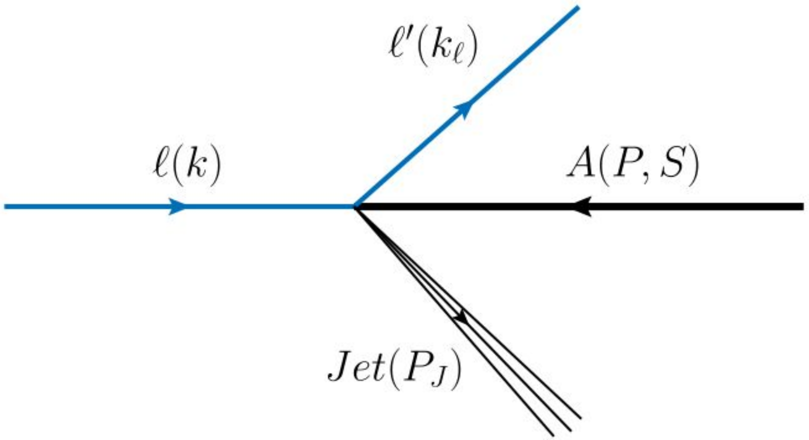
Lepton-jet imbalance $q_T = |\vec{k}_{l\perp} + \vec{p}^{\,j}_{\perp}|$

In Born-level configuration

Probes quark TMD PDFs

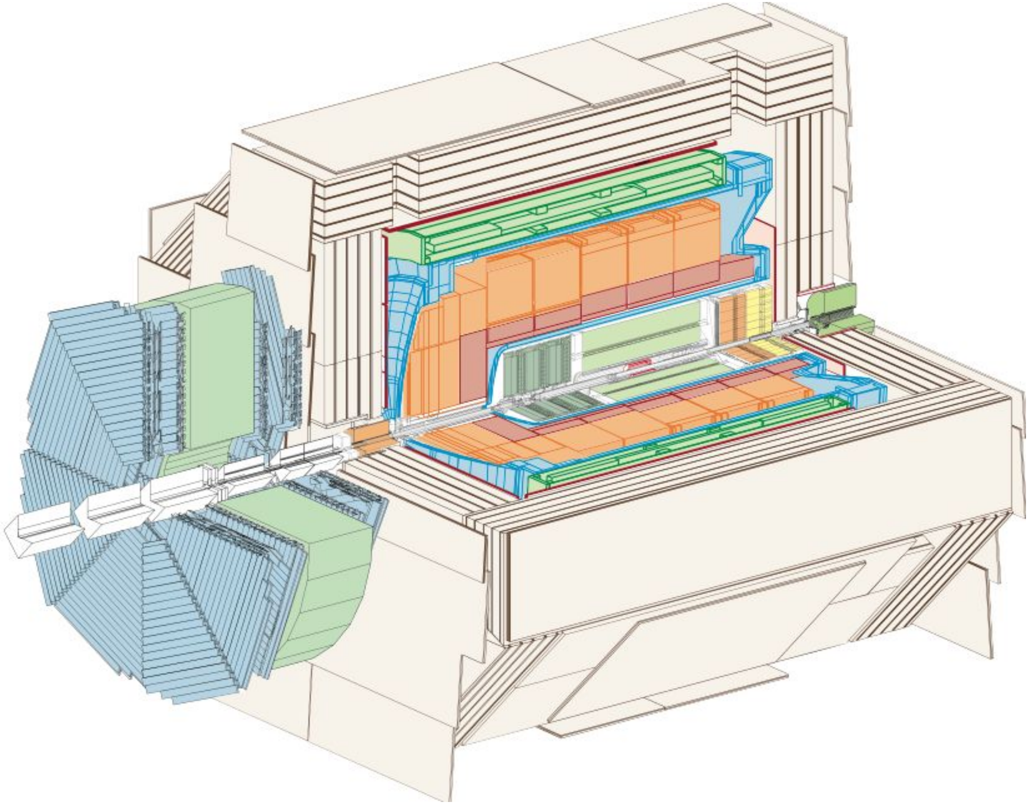
Liu et al. PRL. 122, 192003 (2019)

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



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

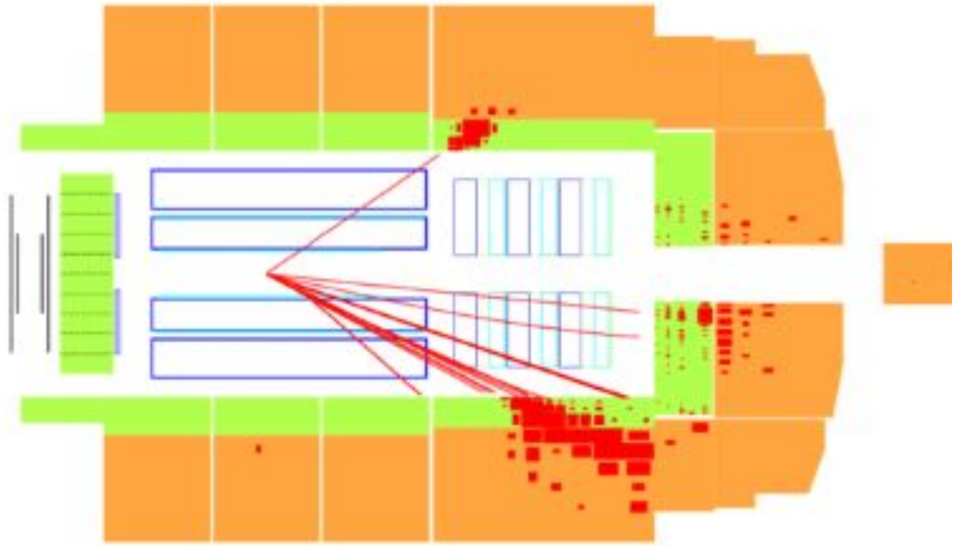
The H1 experiment at HERA



- 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



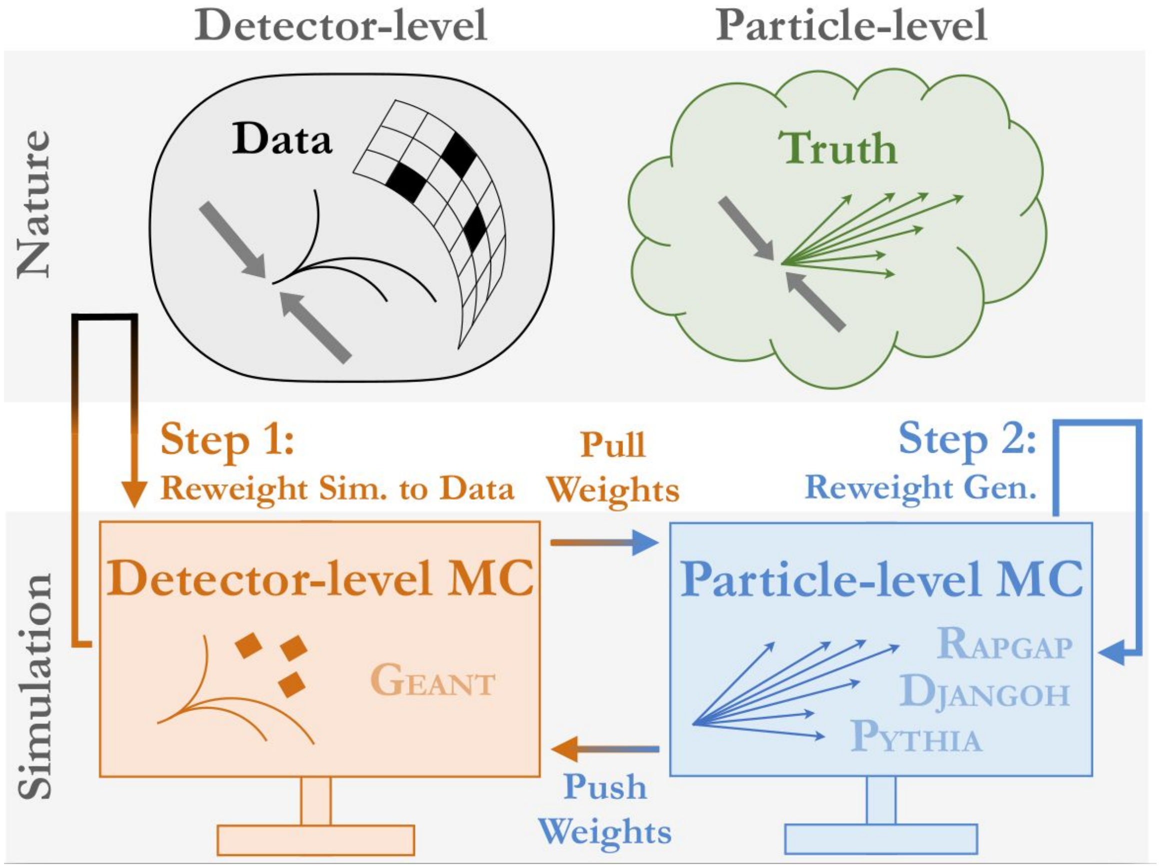
Neural-net based in-situ jet calibration for data and MC.

1% Jet energy scale

0.5-1% lepton energy scale

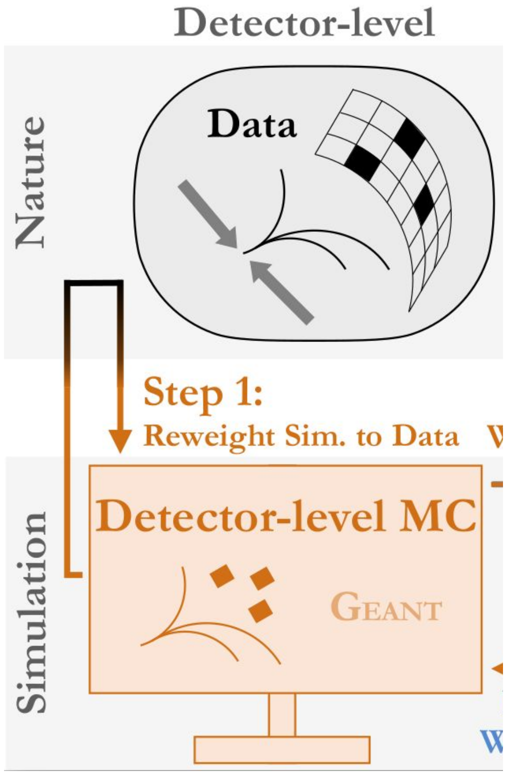
Unfolding with Omnifold (via machine-learning).

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



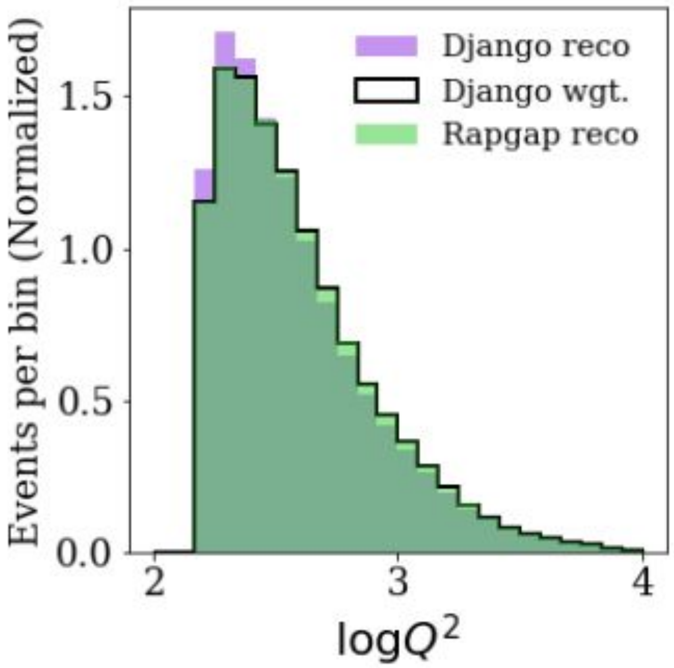
This is the **first-ever** measurement that uses machine-learning to correct for detector effects.

Reweighting the reco-level distributions

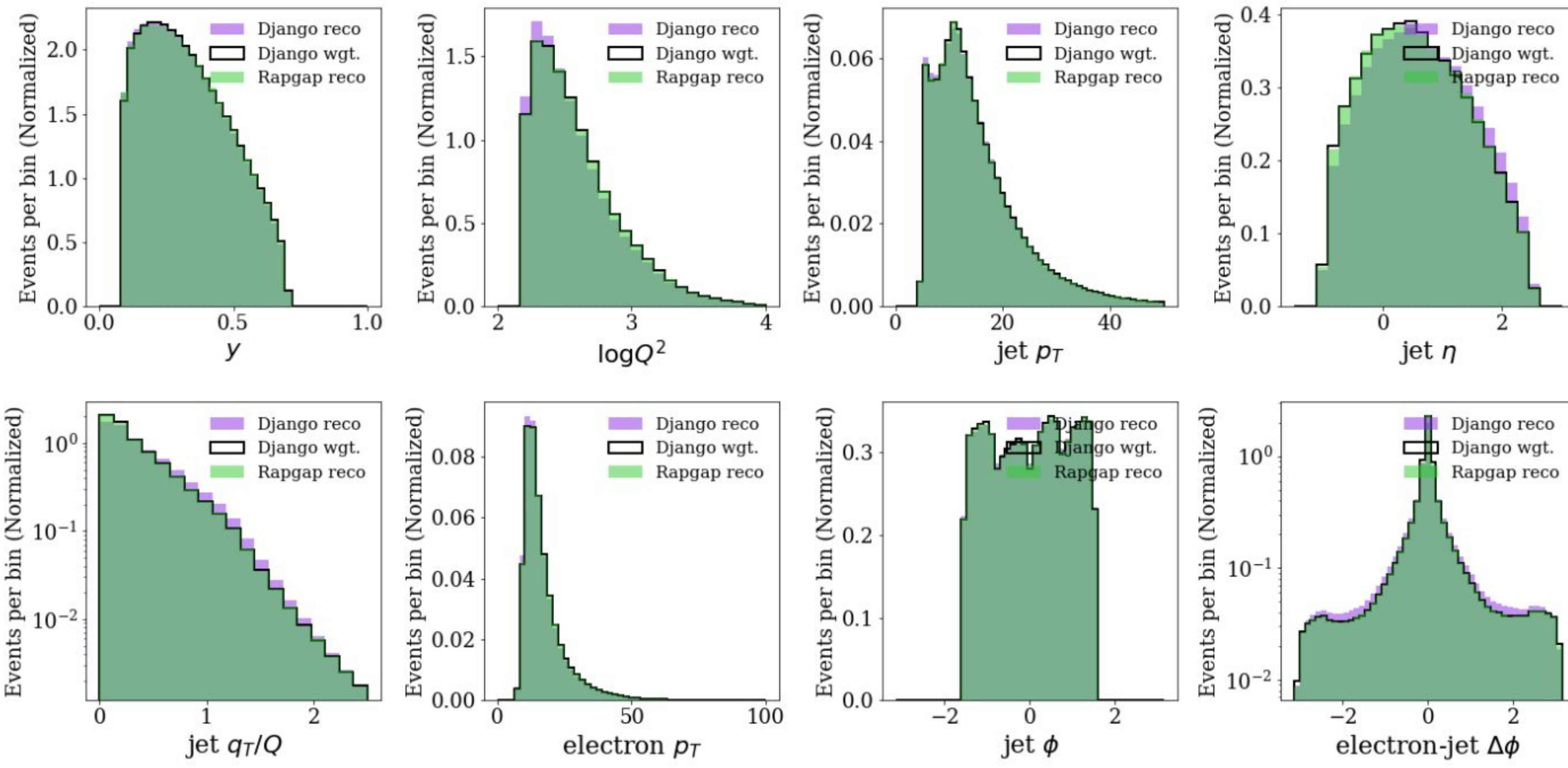


We use simple fully connected networks with a few hidden layers.

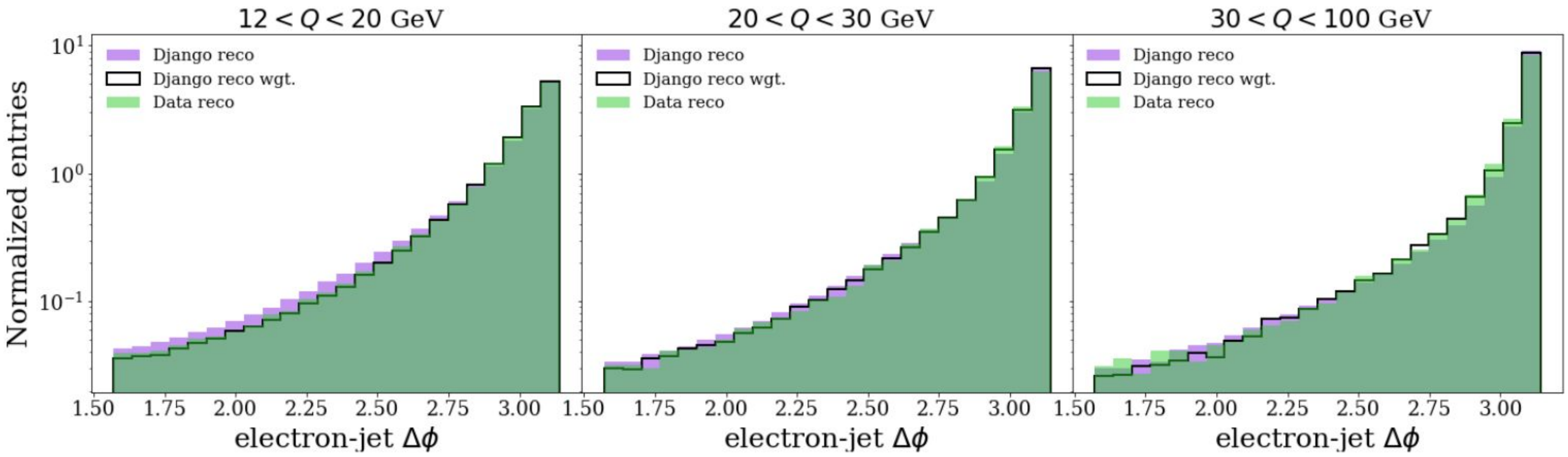
The distribution is binned for illustration, but the reweighting is unbinned.



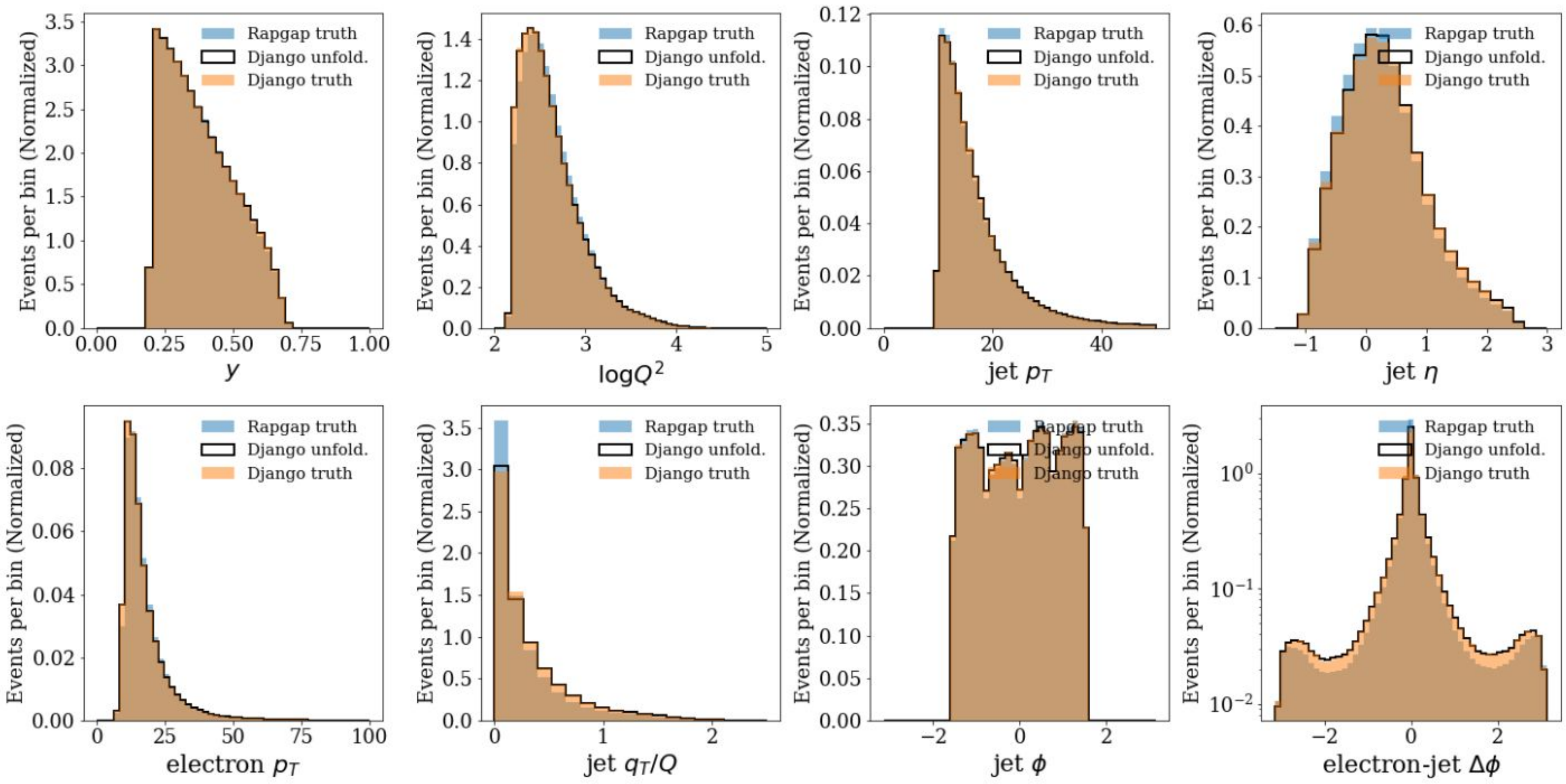
All these distributions are simultaneously reweighted



Weighting works well multidimensionally (unbinned)



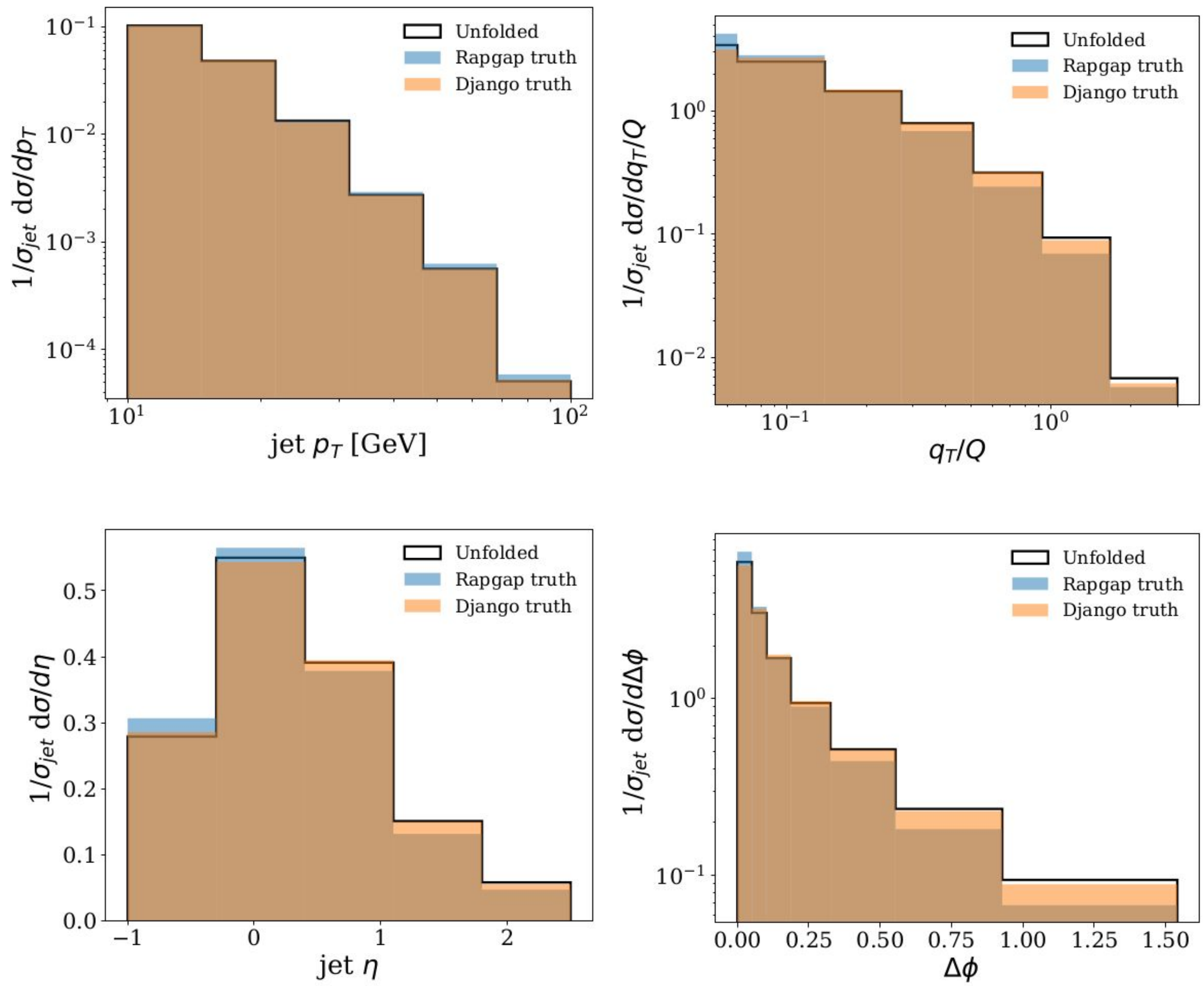
Closure tests (Pseudodata: Django, Response: Rapgap)



Closure tests

Pseudodata: Djangoh

Response: Rapgap

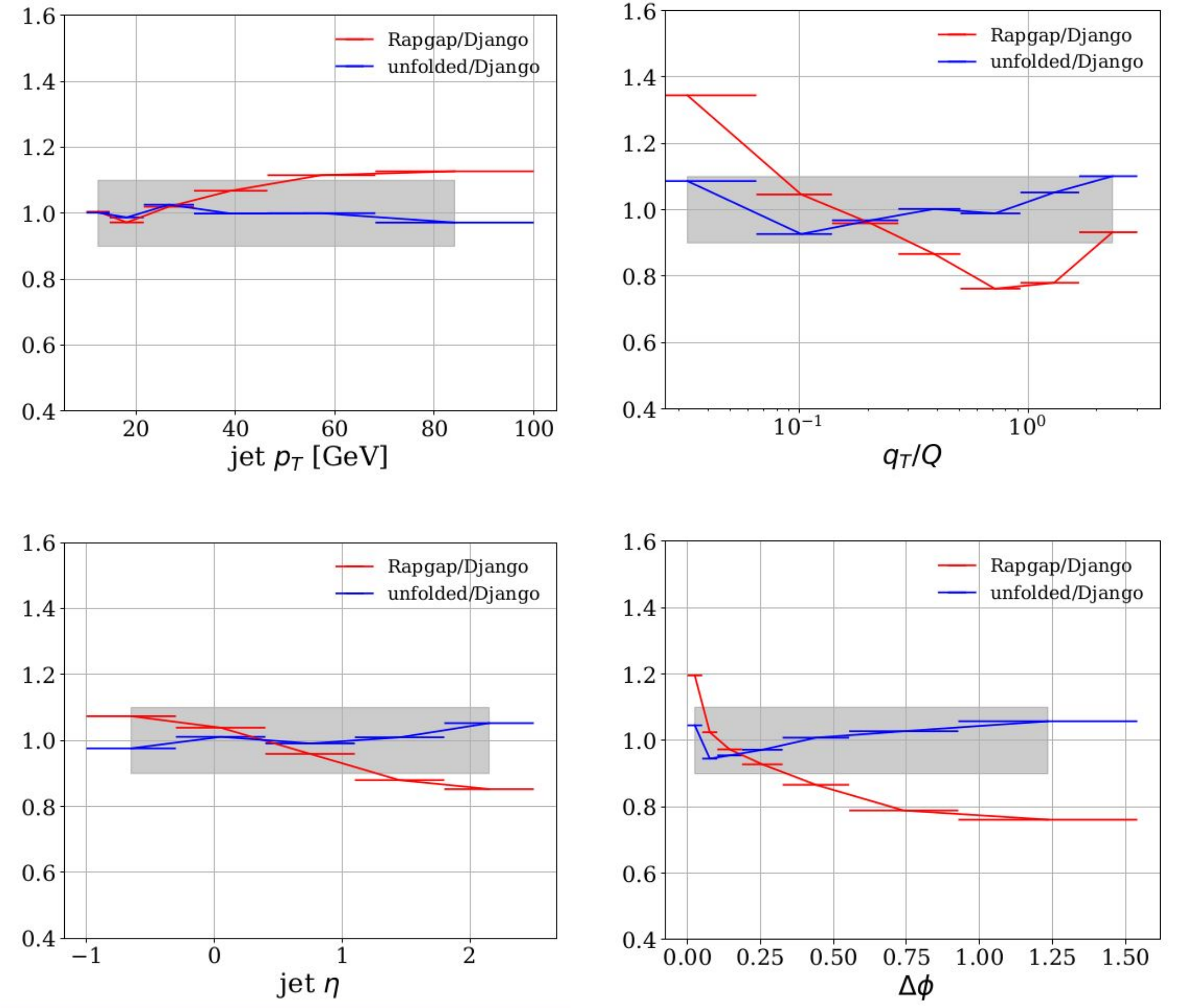


Closure tests

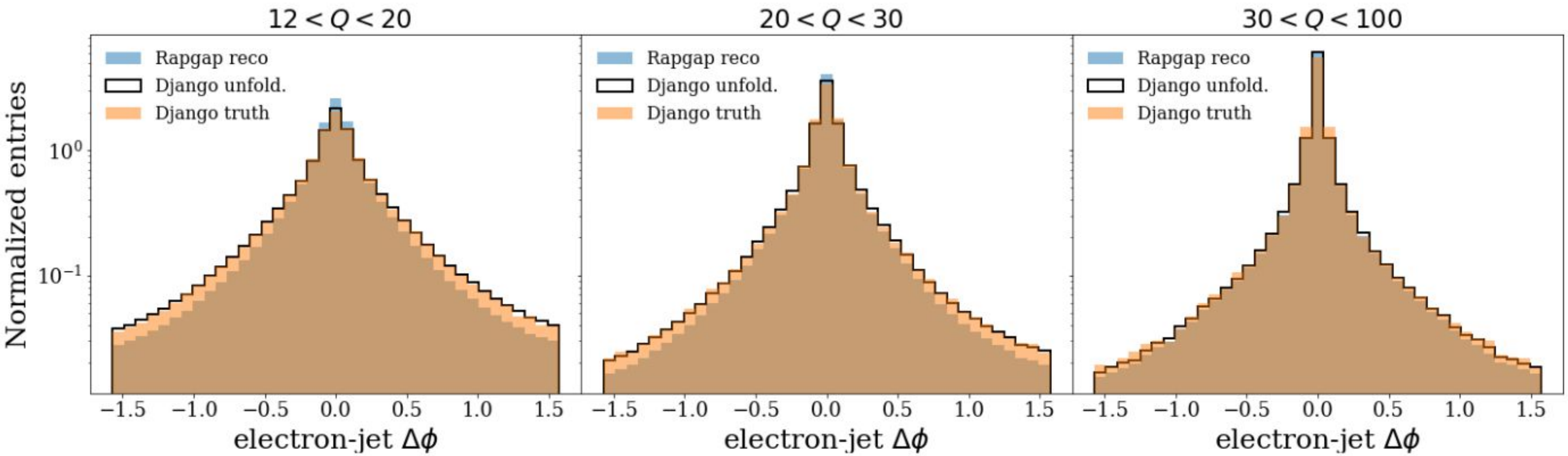
Pseudo Data: Djangoh

Response: Rapgap

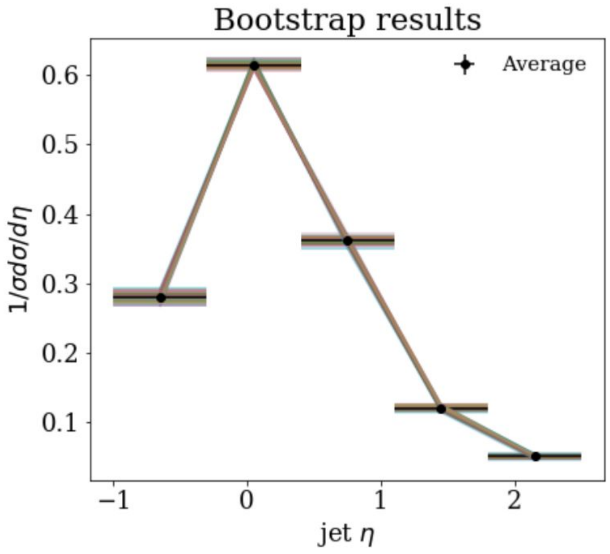
Closure to within 10% or less in all distributions
Similar results obtained With Rapgap as pseudo data

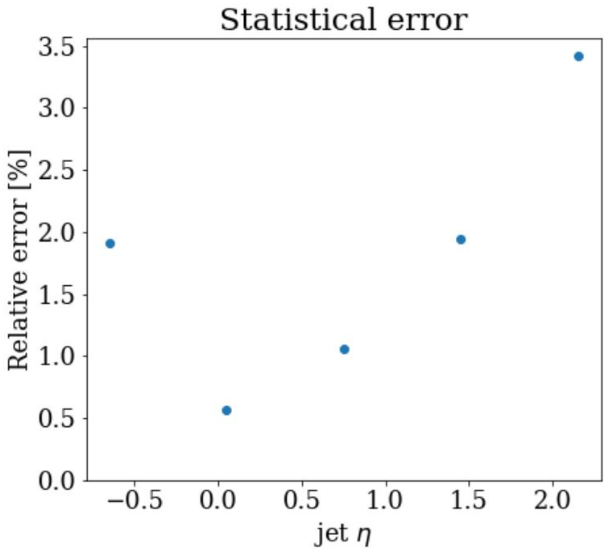


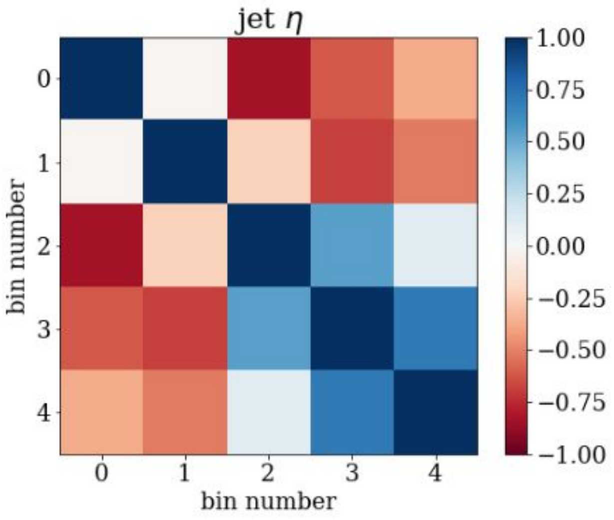
Closure test works well when binned in Q...



Statistical uncertainties estimated with bootstrap, e.g







Preliminary Results

https://www-h1.desy.de/h1/www/publications/htmlsplit/H1prelim-21-031.long.html

H1prelim-21-031
April 5, 2021

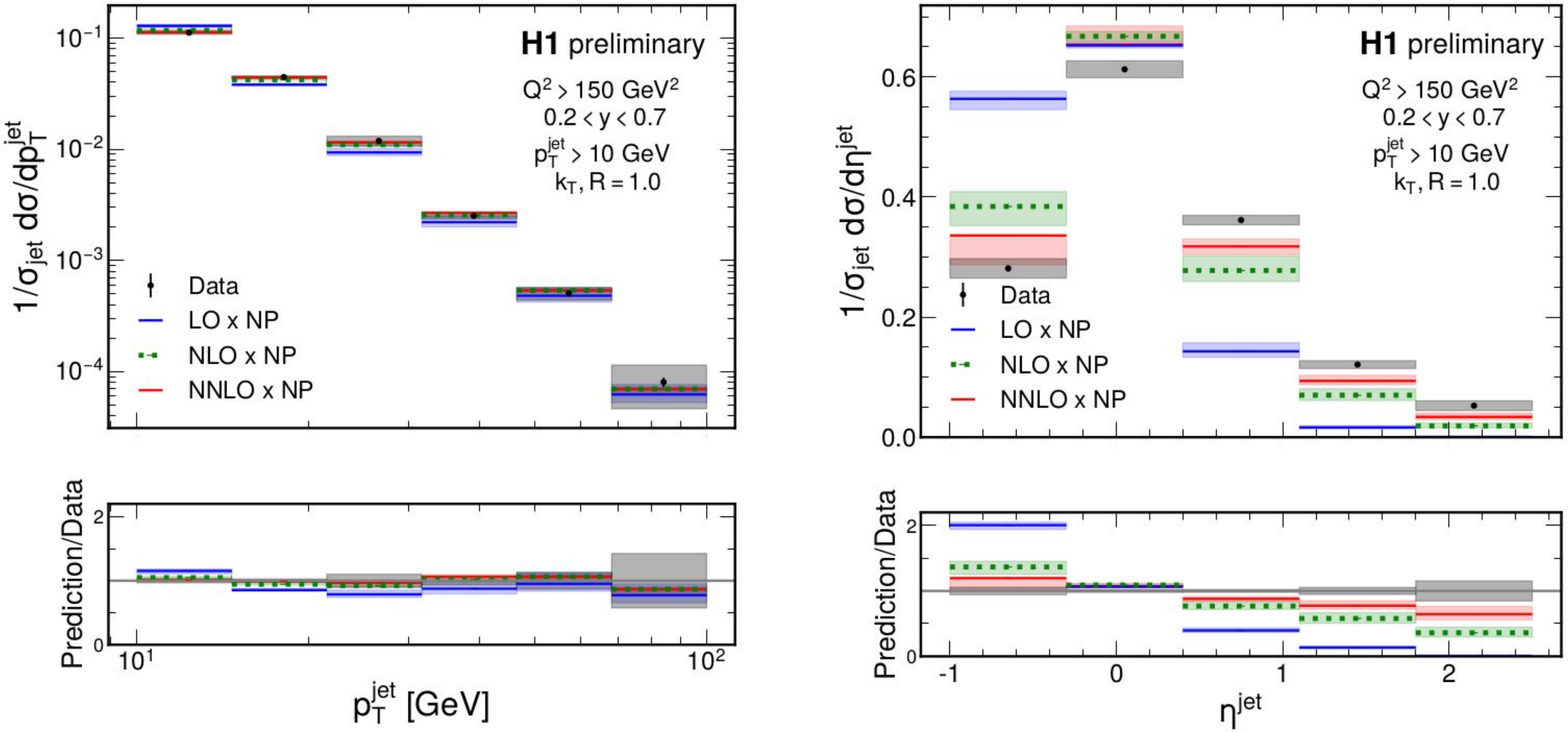
Measurement of lepton-jet correlations in high Q^2 neutral-current DIS with the H1 detector at HERA

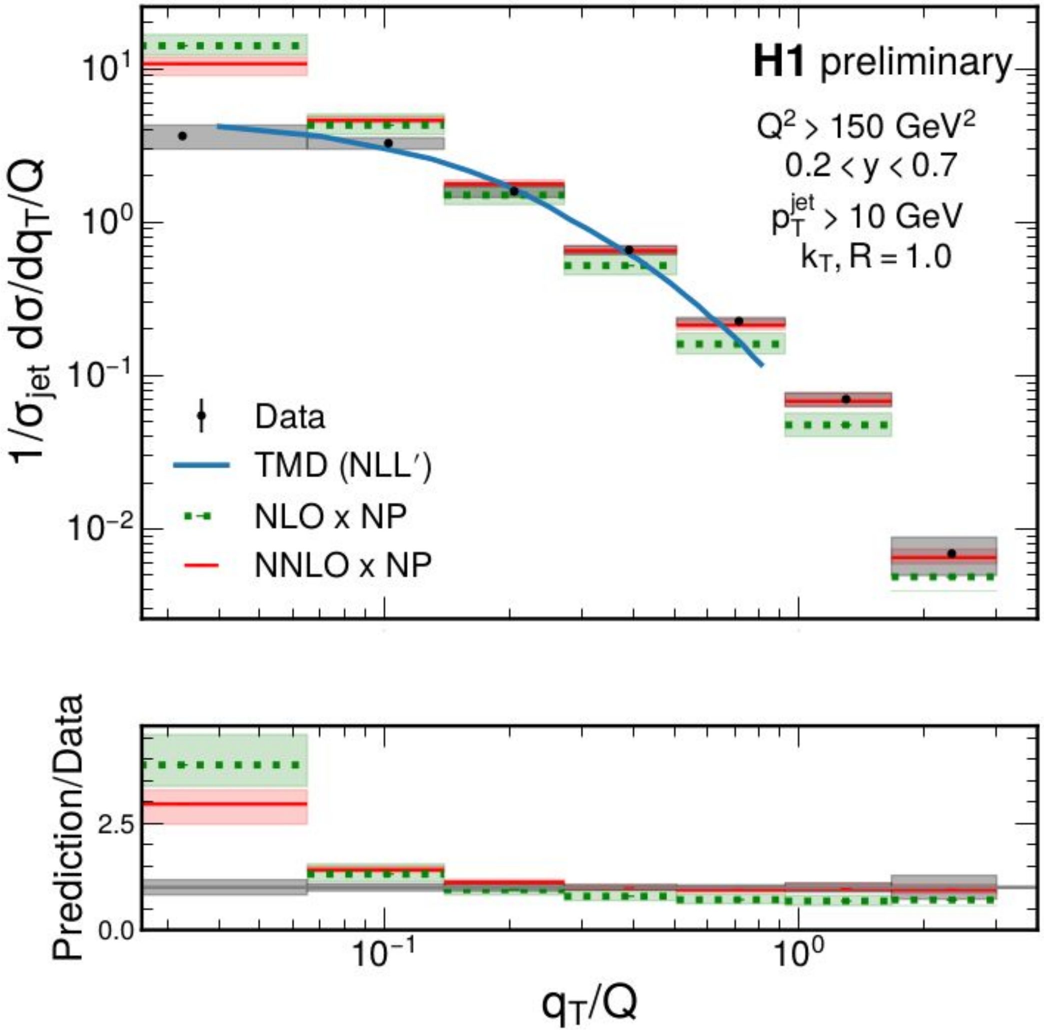
The H1 Collaboration

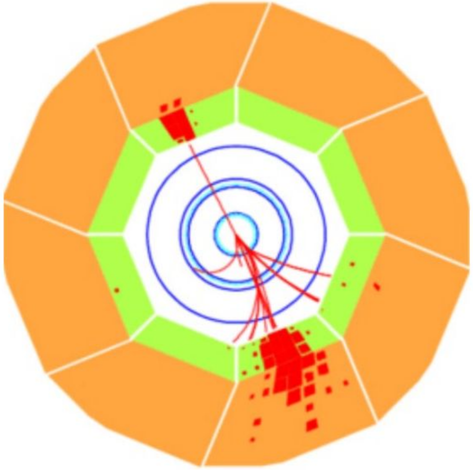
Abstract

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



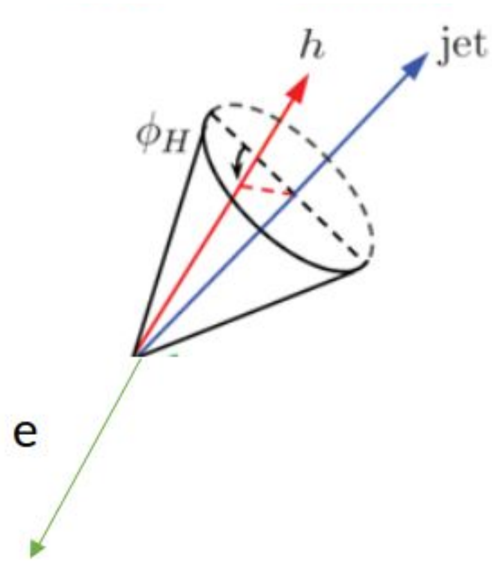




TMD calculation does a great job at low qT; collinear calculation does a great job at large qT.

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

Outlook: azimuthal correlations of “hadron-in-jet” measurements in DIS. Can be 10+ D!



- These will be highly differential measurements, need to constrain angles between hadrons and jet and electrons Motivated in PRD 102, 074015 (2020)

- Have become practically possible with unbinned unfolding (Omnifold)

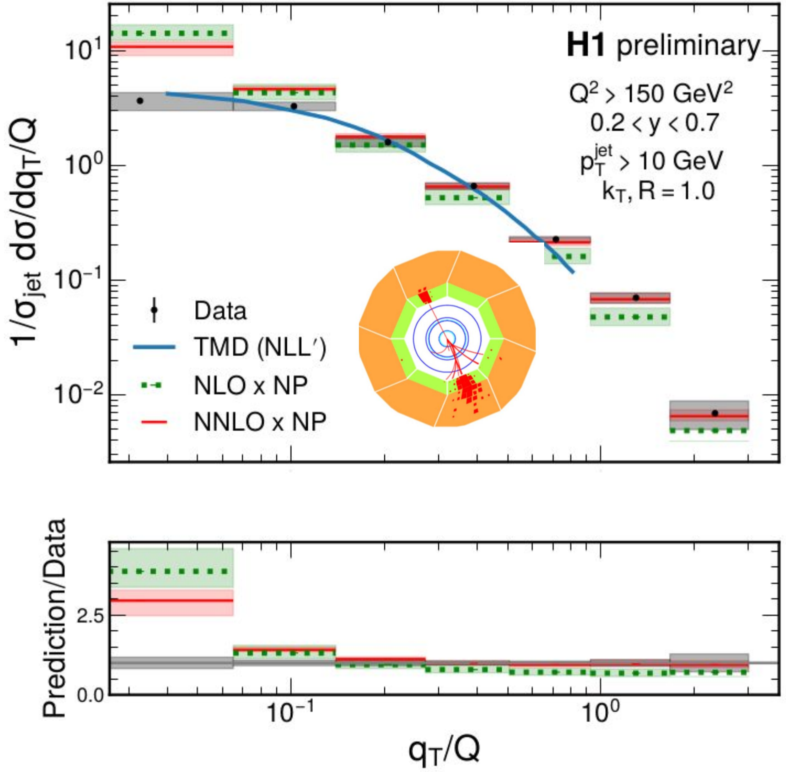
- Possible with H1 data, crucial reference for EIC program (which will add polarization and PID)

Outlook (for brave souls): unbinned measurement!

See Ben’s talk in PhysTeV 2021: https://indico.in2p3.fr/event/24331/timetable/#20210614.detailed

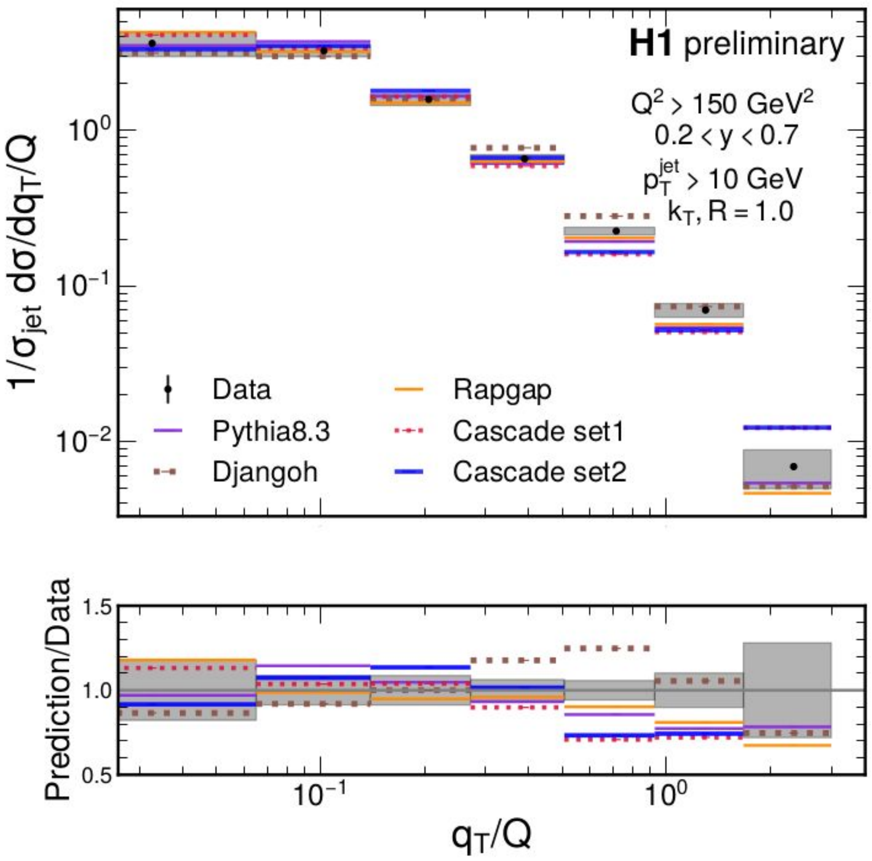
Summary

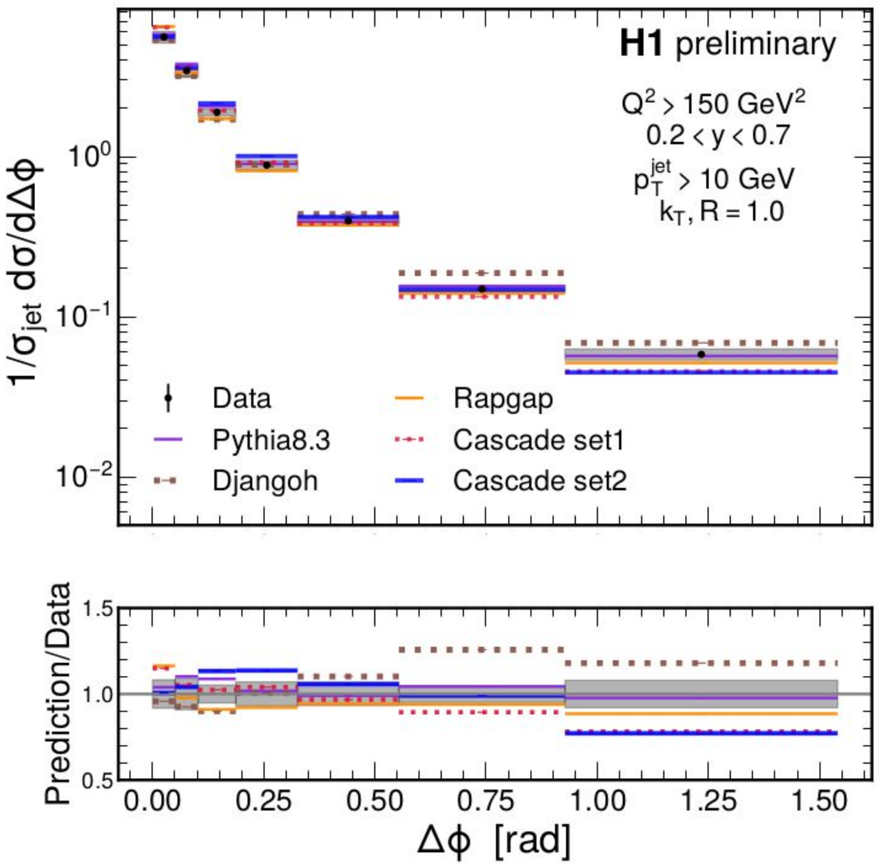
- We report a measurement of lepton jet momentum and azimuthal imbalance in DIS, which provide **a new way to constrain TMD PDFs and their evolution**
- **First-ever measurement that uses machine-learning to correct for detector effects.** (using Omnifold method)
- This is the first measurement in a series of studies that aim at creating a **pathfinder program for the future EIC**



Backup

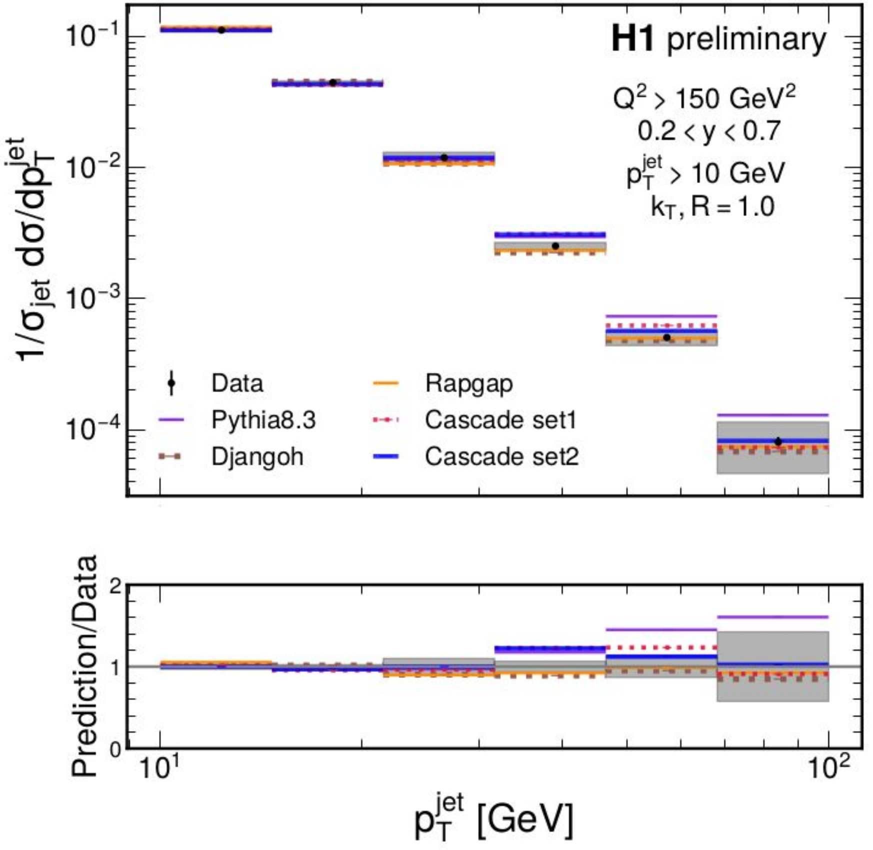
Data well described by MC generators, which "bracket data"

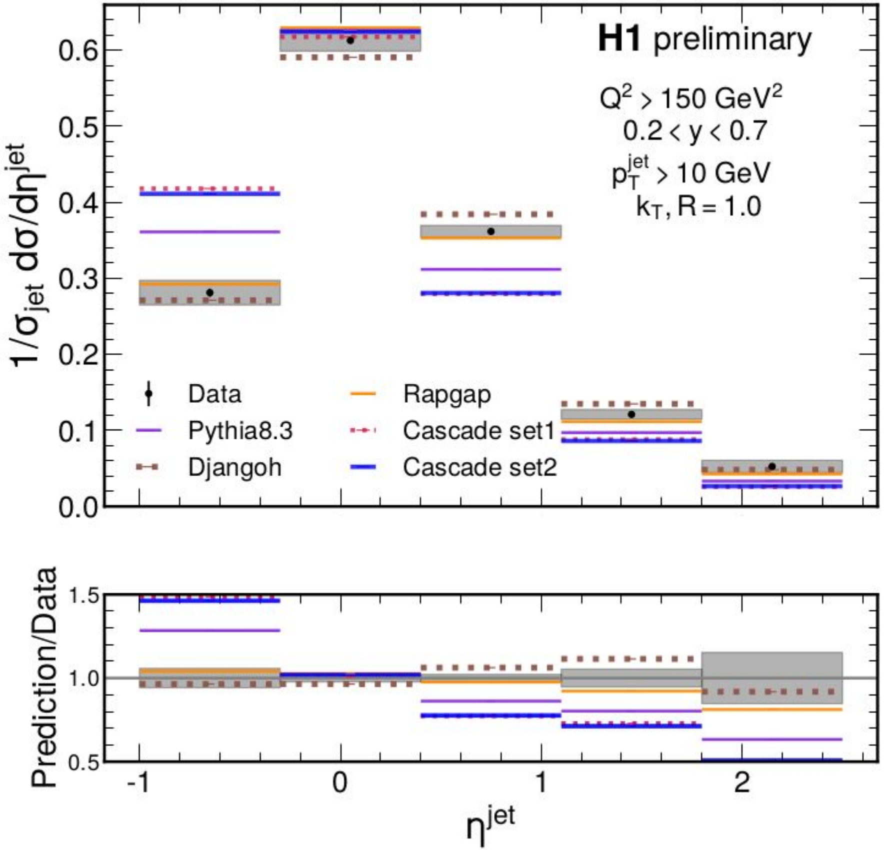




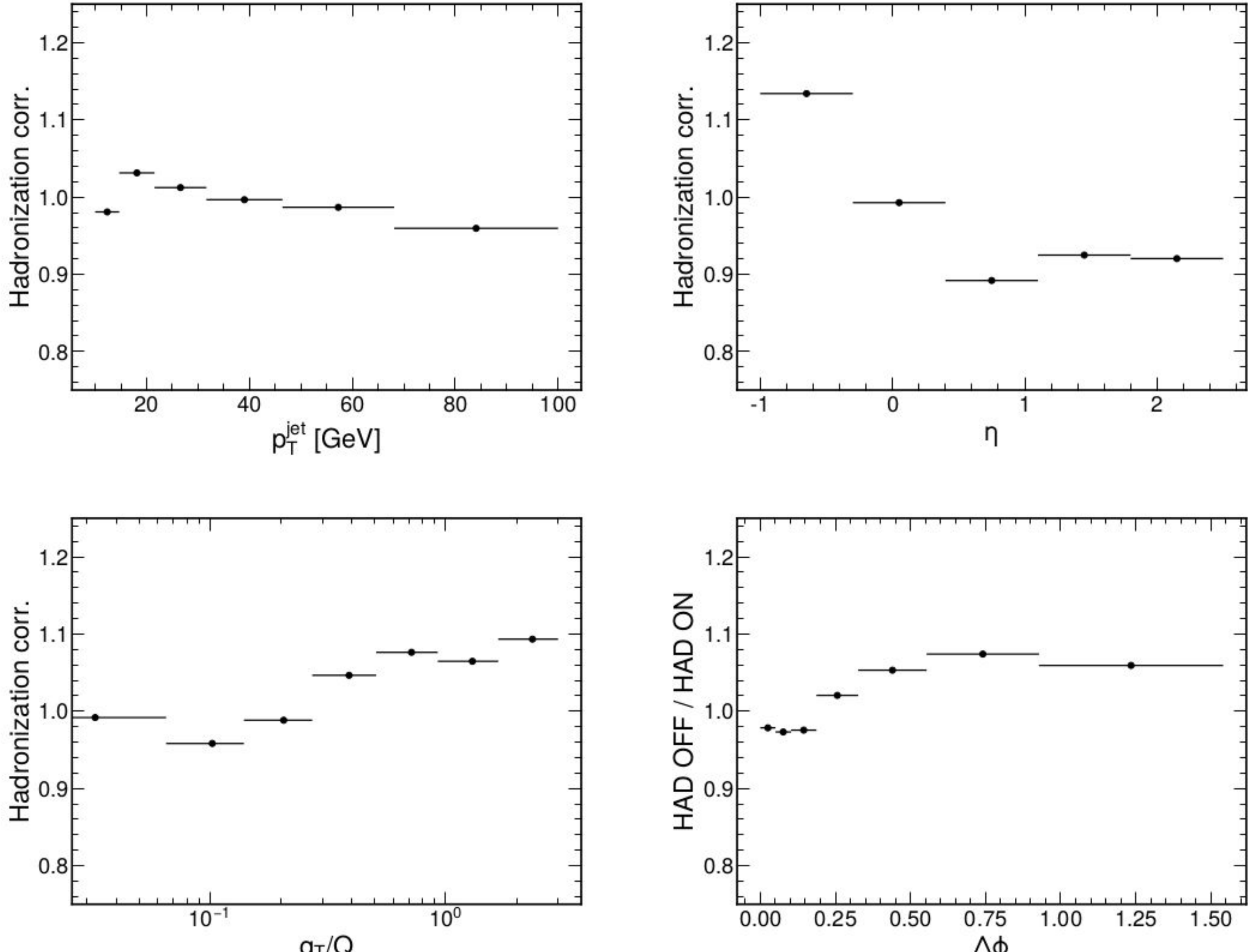
CASCADE (TMD-based) describes low values well but misses large values

Jet transverse momentum and pseudorapidity

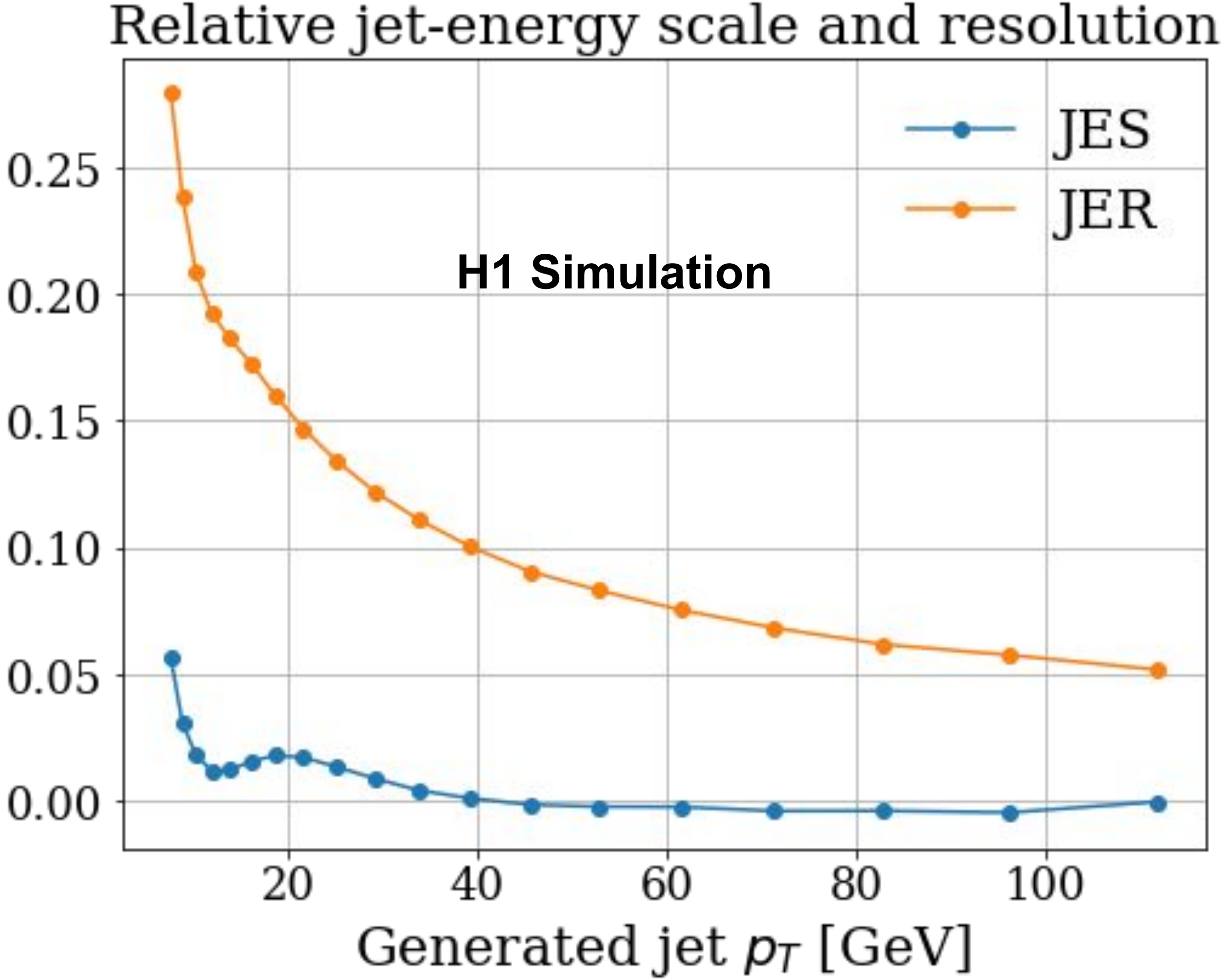




- **Djangoh and Rapgap provide give good description; Pythia8, Cascade miss pseudorapidity**


Hadronization corr.
p_T^jet [GeV]
η
Hadronization corr.
HAD OFF / HAD ON
Δϕ

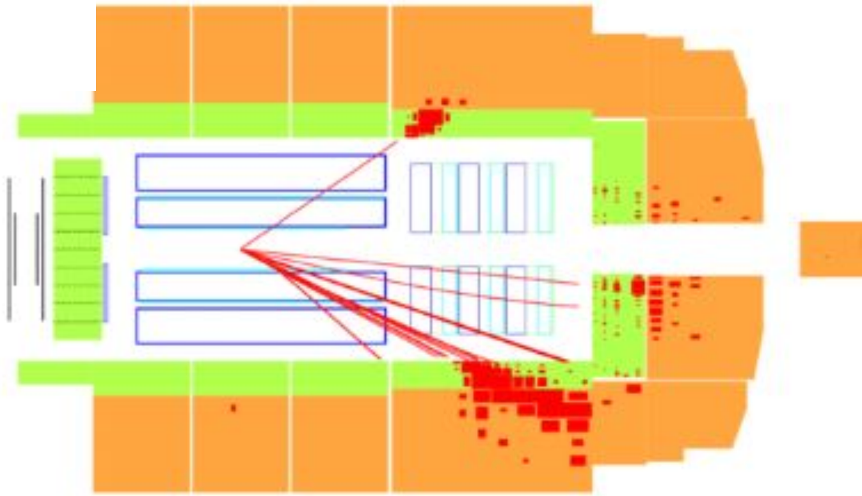
Jet performance
(energy flow reconstruction)



DIS kinematic reconstruction

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

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



*No QED rad. Corrections applied for this preliminary result