Measurement of Lepton-Jet correlation in DIS with H1 at HERA, using machine learning for unfolding

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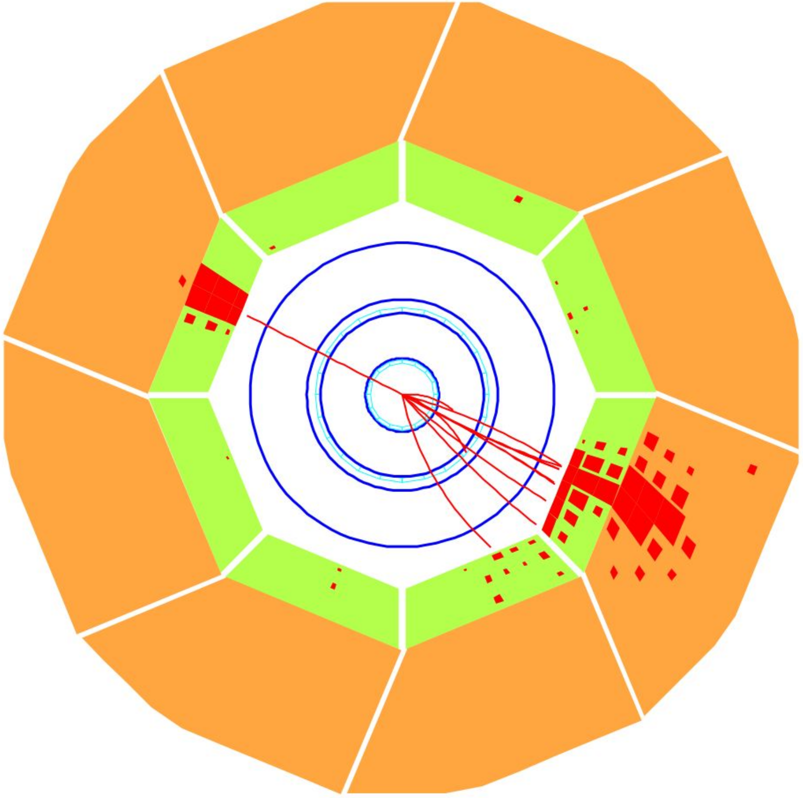
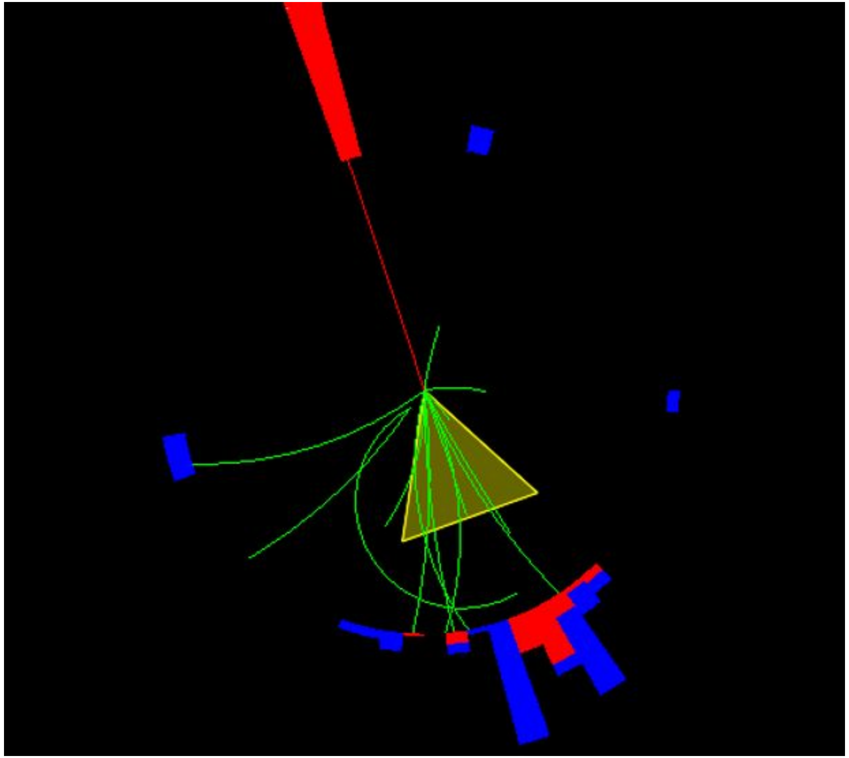
CALIFORNIA EIC CONSORTIUM



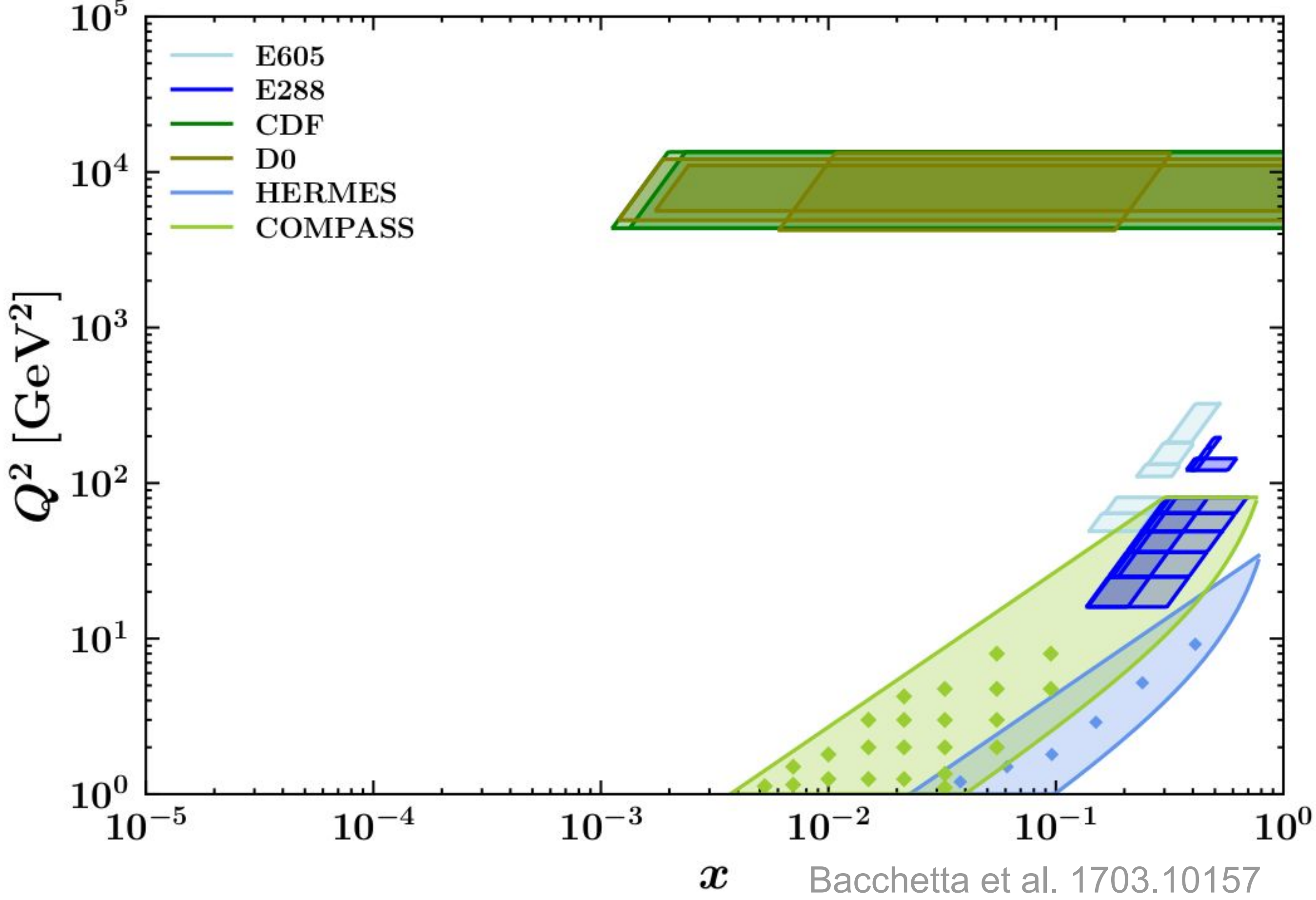
A new channel to probe for quark transverse-momentum distributions (TMDs) and evolution

Liu et al. PRL. 122, 192003, Gutierrez et al. PRL. 121, 162001



*"The advantage of the lepton-jet correlation as compared to the standard SIDIS processes is that it **does not involve TMD fragmentation functions.**"*

Existing TMD data

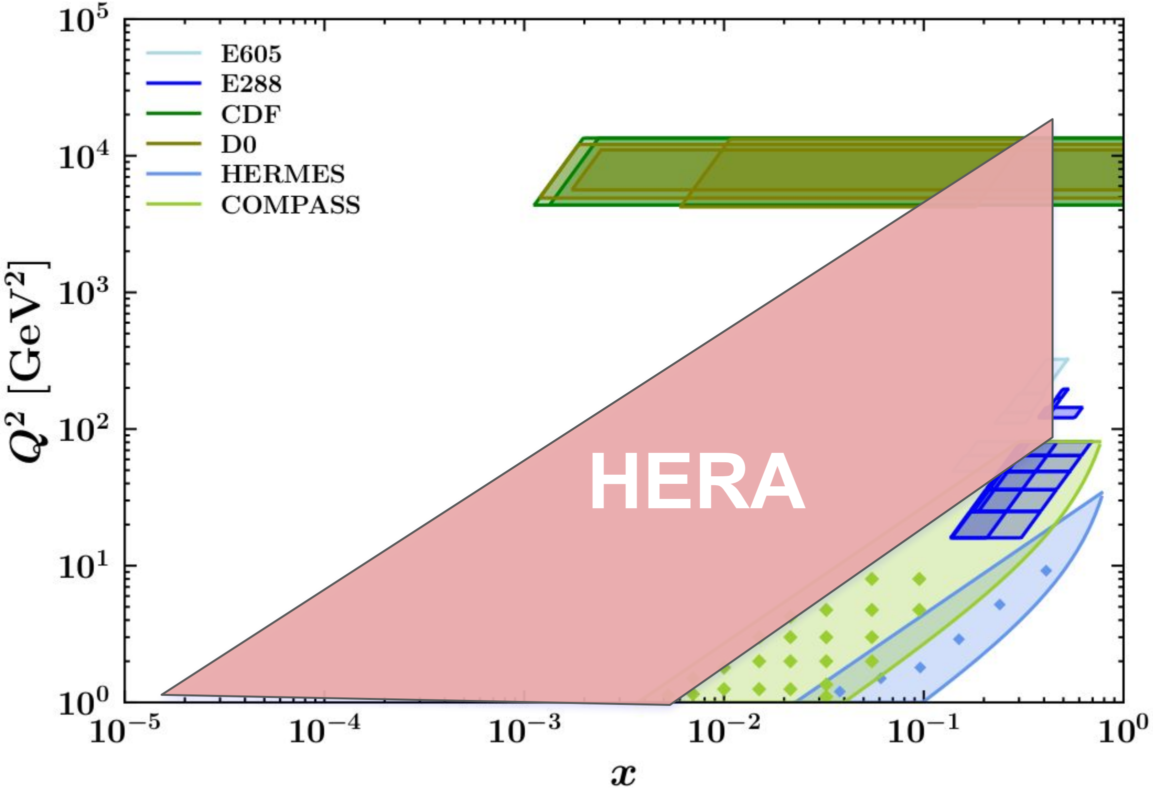


Bacchetta et al. 1703.10157

Constraining TMD evolution with HERA data

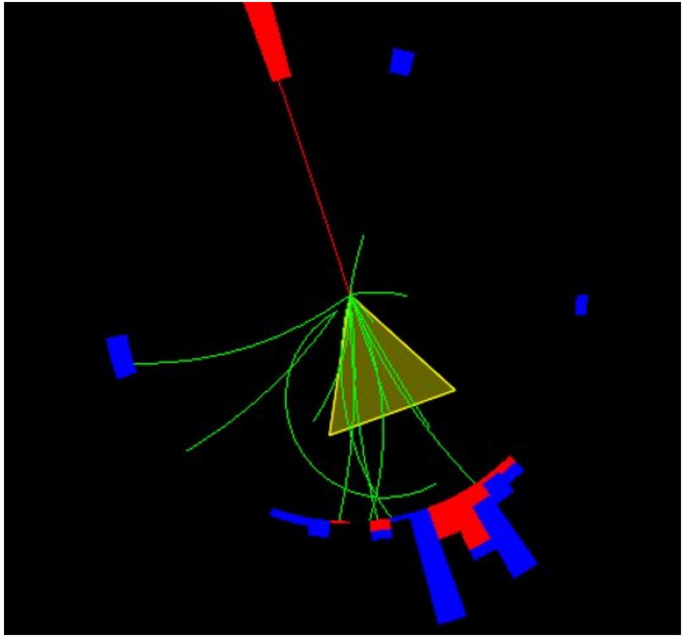
Bridging DIS from fixed-target exp. and high Q2 Drell-Yan at colliders.

Fixing open issues of TMD factorization & universality

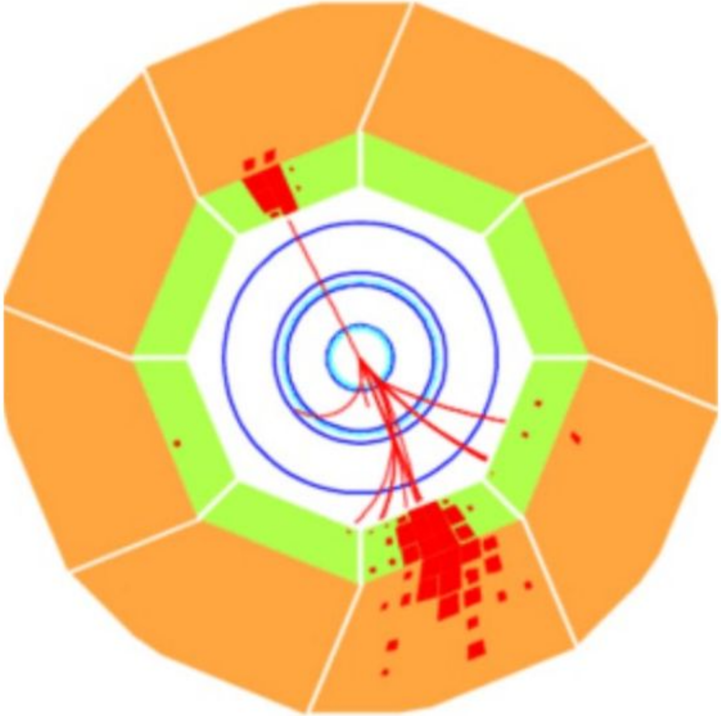


We can actually explore the feasibility of these measurements and test the TMD calculations with the unpolarized data taken at HERA

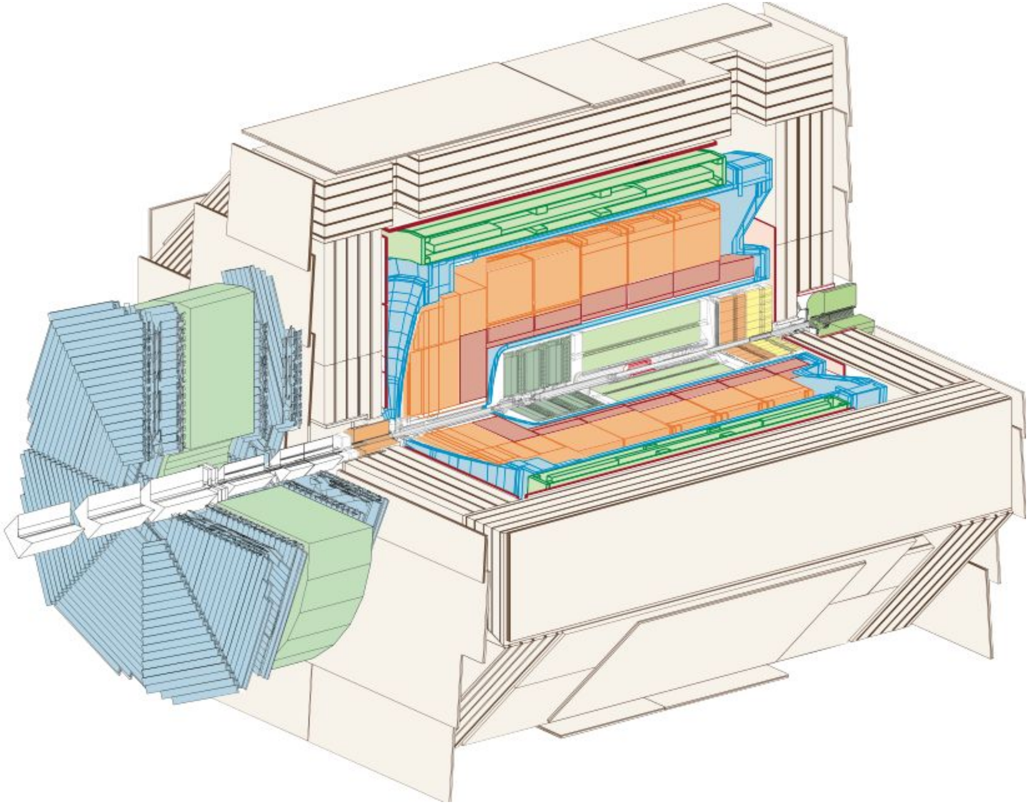
EIC



H1@HERA



The H1 experiment at HERA



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

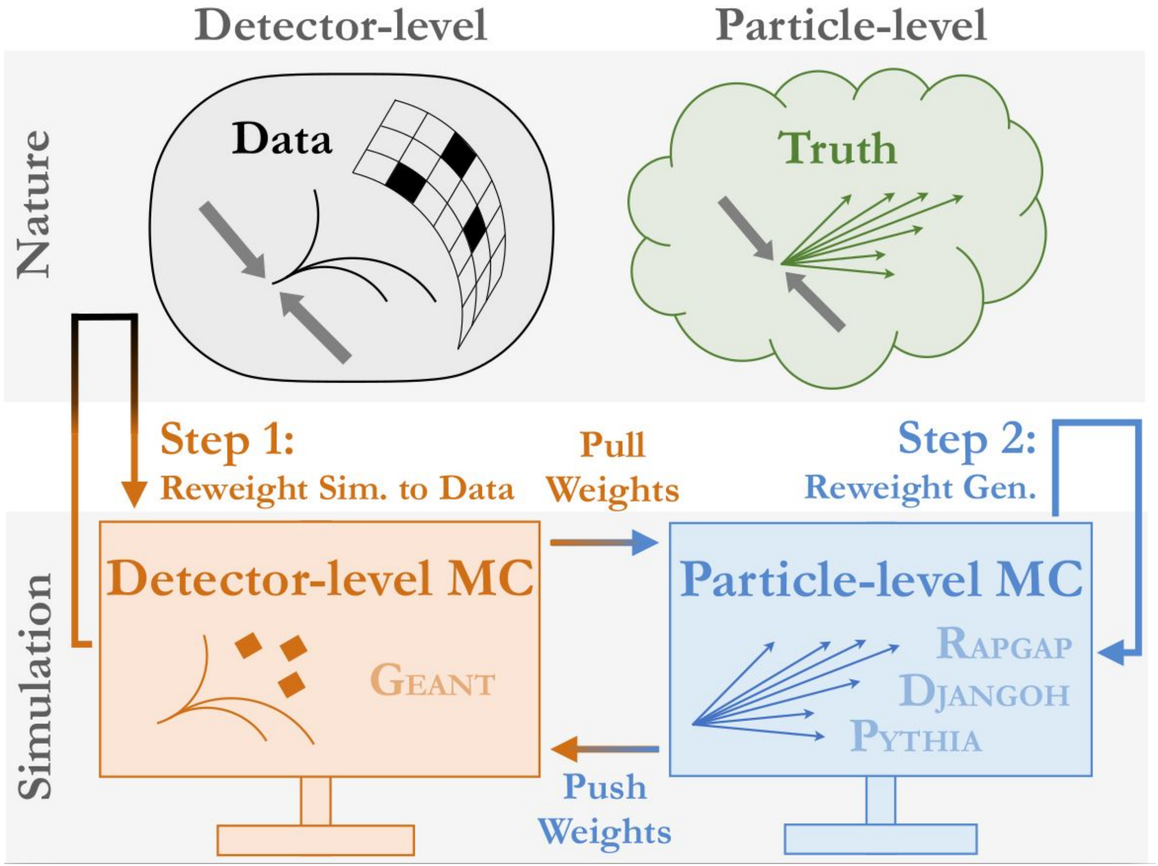
Both combined using
an energy flow algorithm

1% Jet energy scale

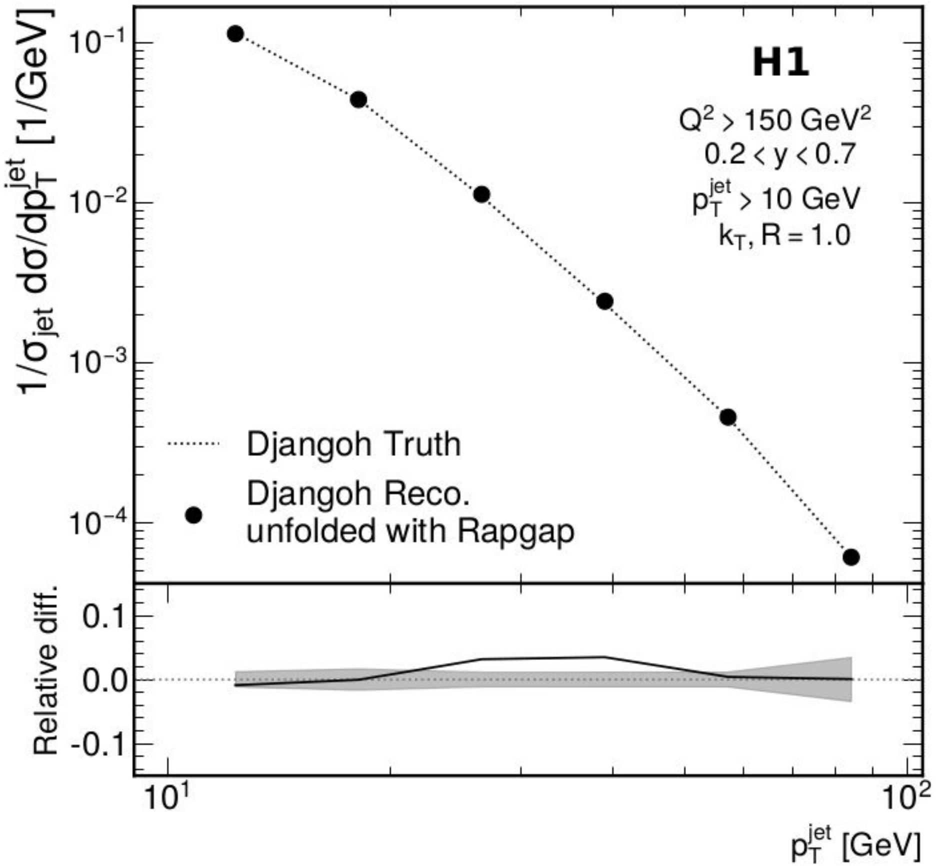
0.5-1% lepton energy scale

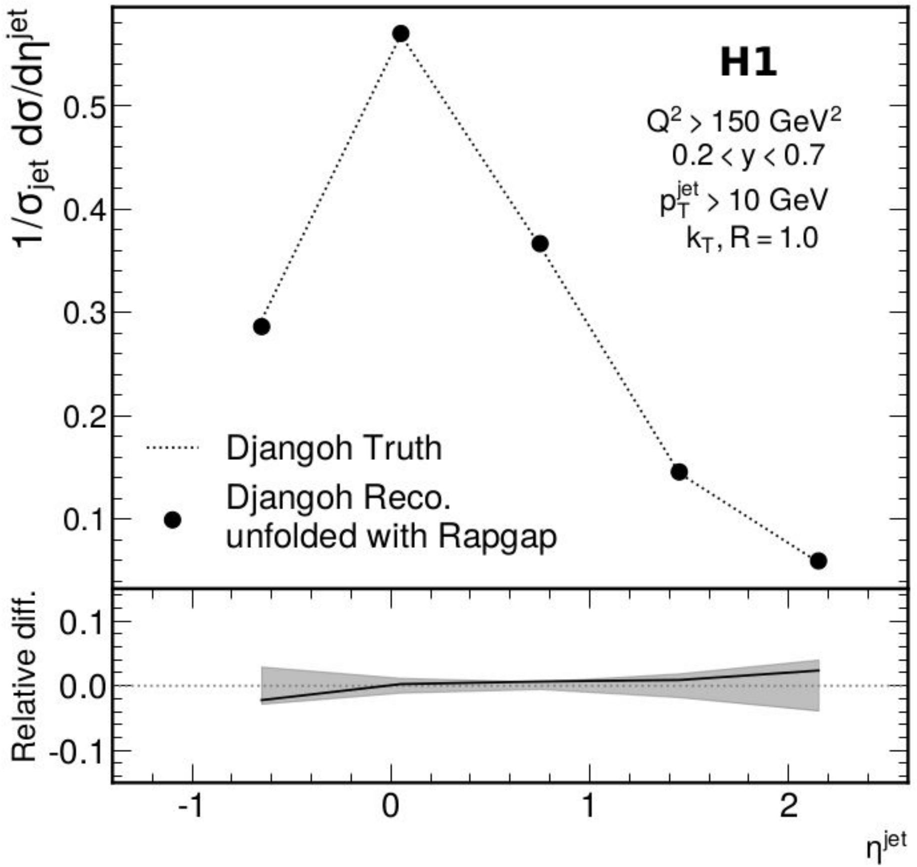
Unfolding with Omnifold (via machine-learning).

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

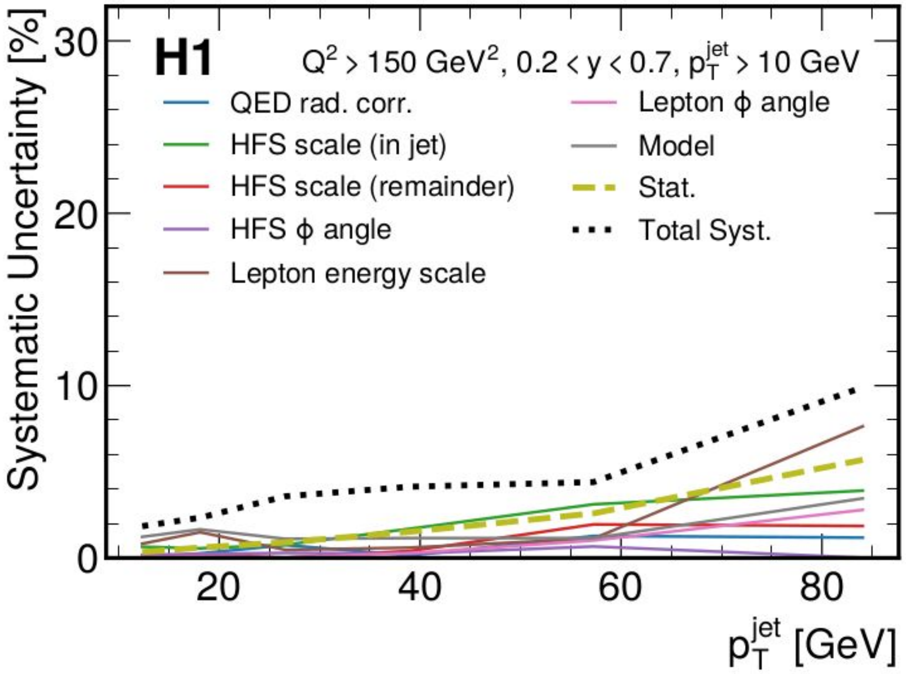


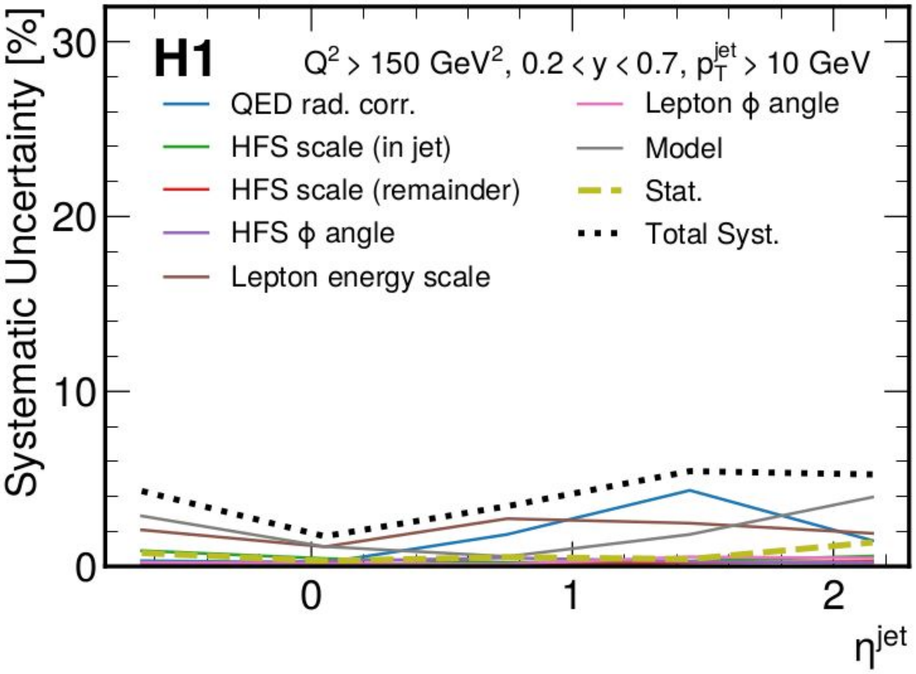
Closure tests (Pseudo Data: Django, Response: Rapgap)



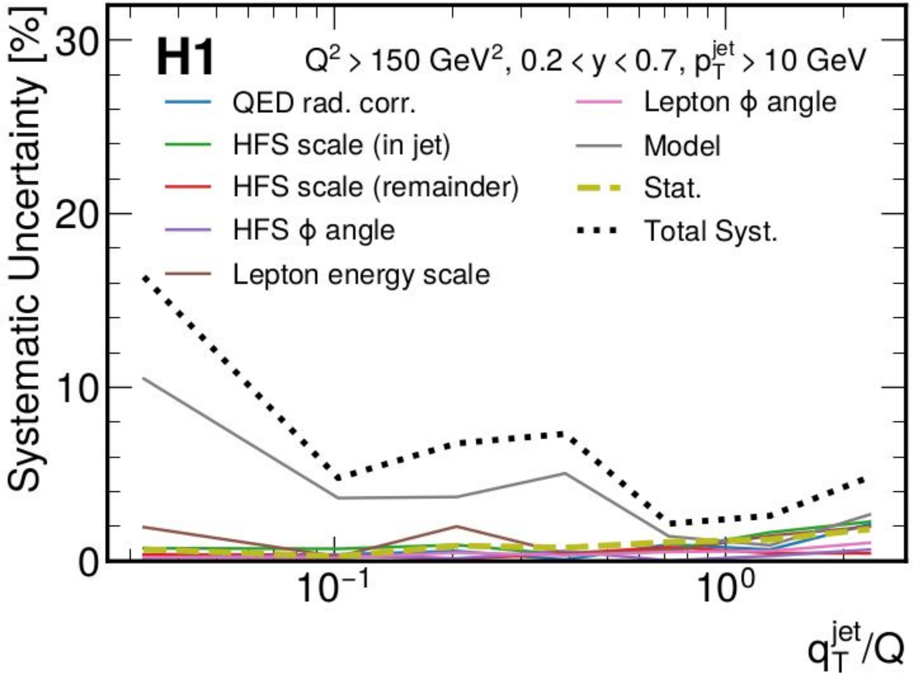


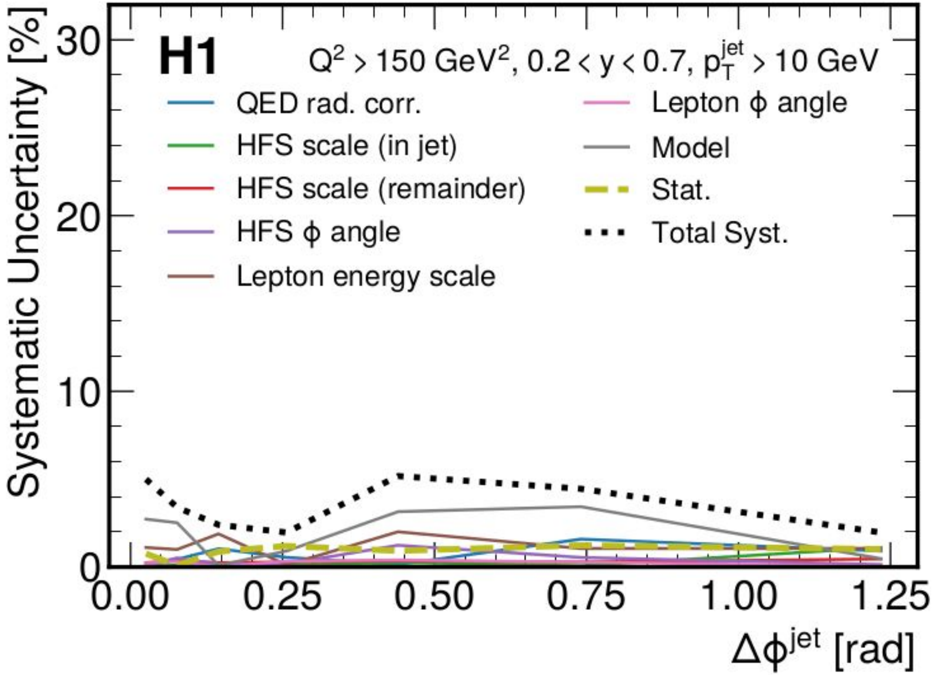
Systematic uncertainties





Systematic uncertainties

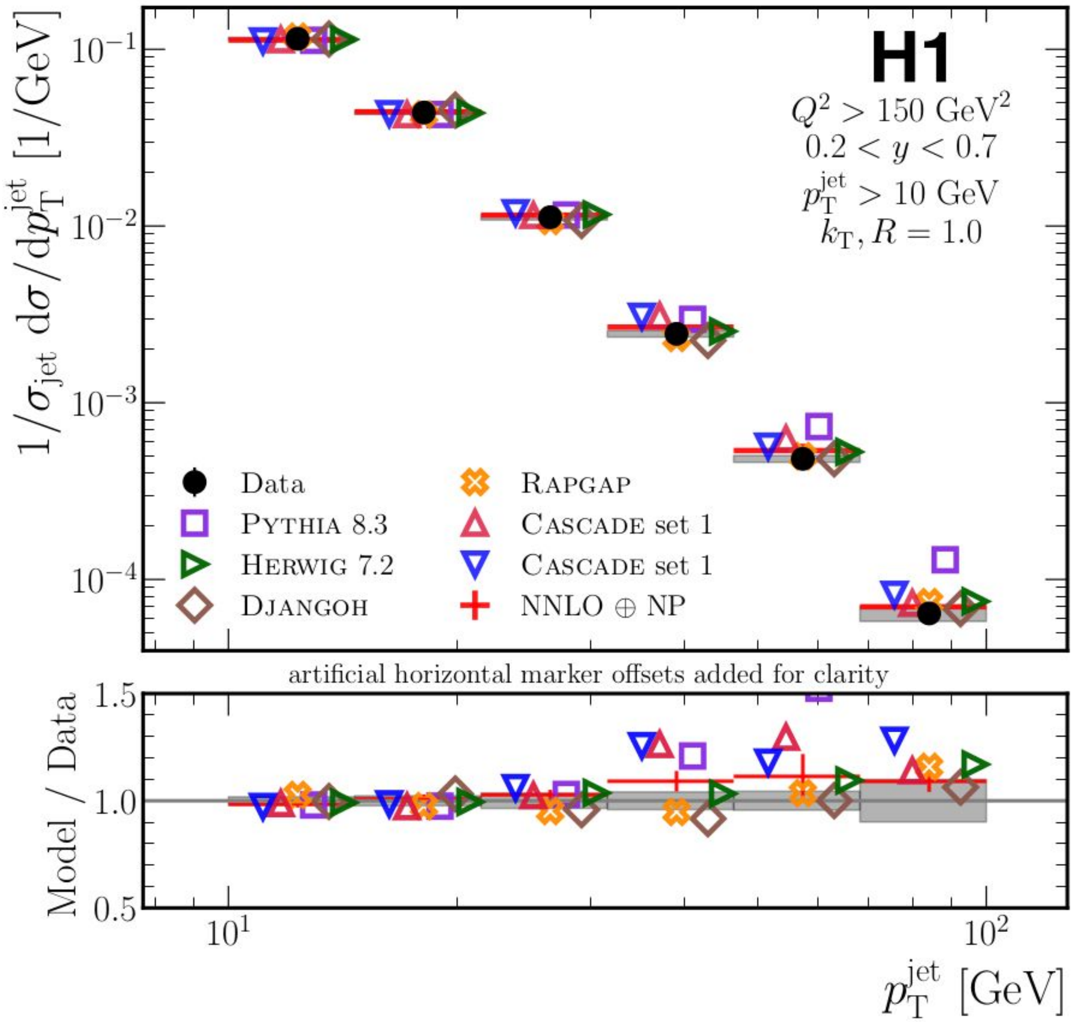




Measurement of lepton-jet correlation in deep-inelastic scattering with the H1 detector using machine learning for unfolding

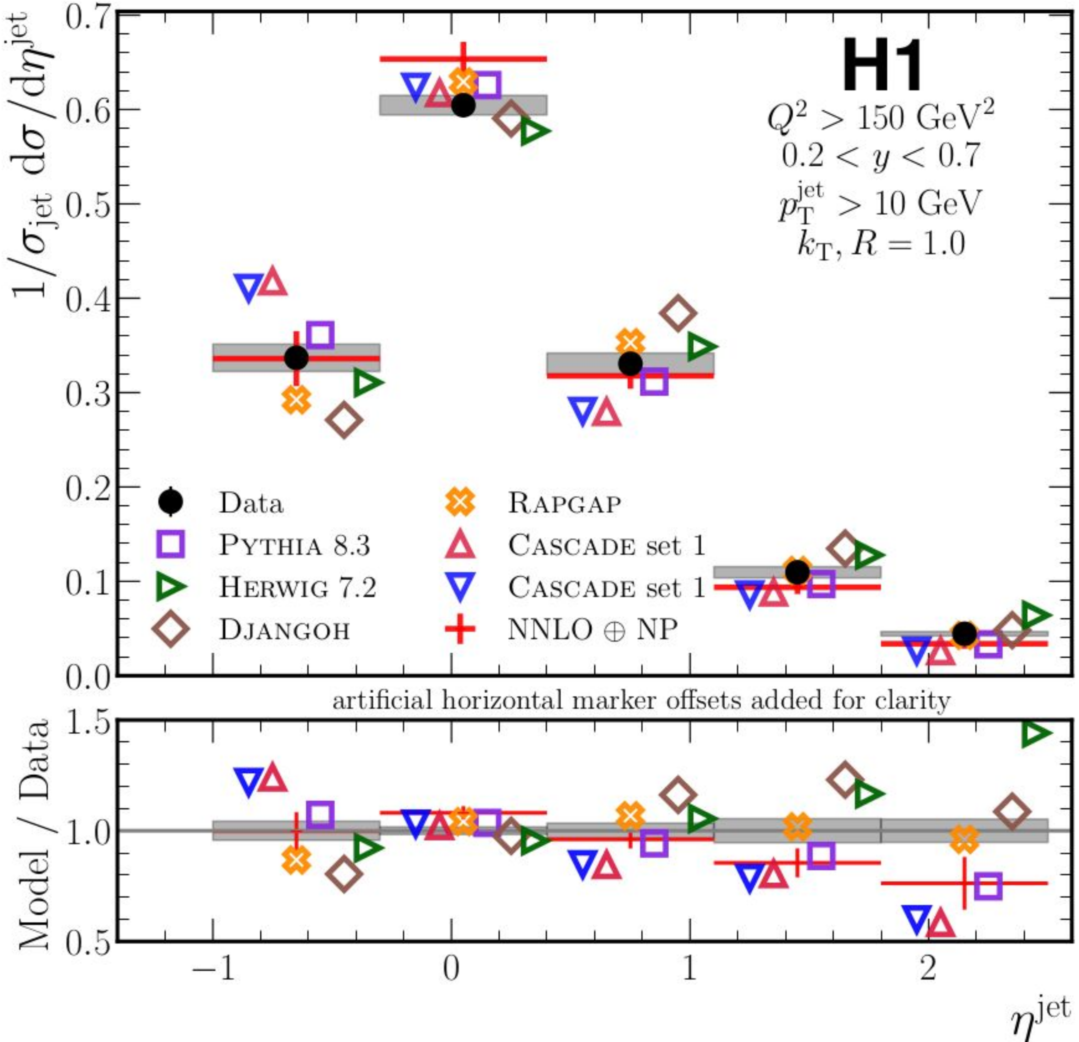
H1 Collaboration • V. Andreev (LPI, Moscow (main)) et al. (Aug 27, 2021)

e-Print: 2108.12376 [hep-ex]



Jet transverse momentum

Well described by NNLO calculation, and some MCs like Herwig and Djangoh

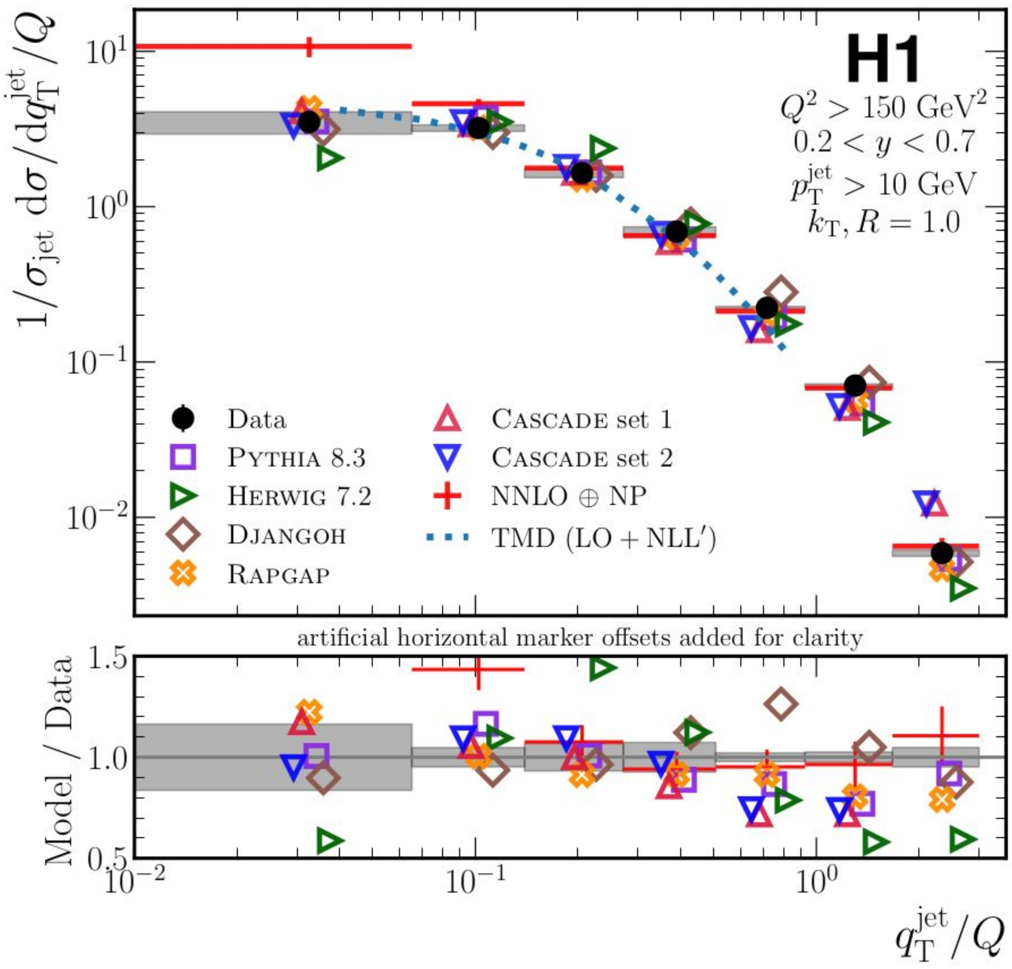


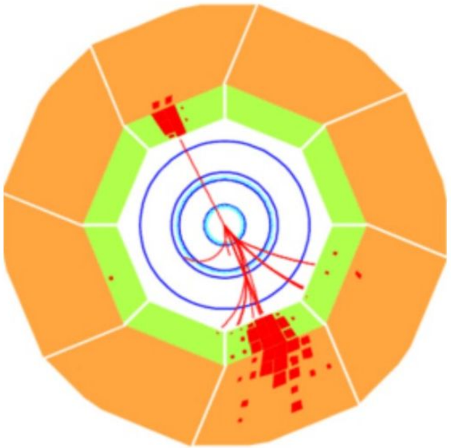
Jet pseudorapidity

Not well described at large pseudorapidity by NNLO, missing higher-order terms.

Well described by Rapgap

Lepton-jet momentum imbalance $q_T = |\vec{p}_T^{\,e} + \vec{p}_T^{\,jet}|$

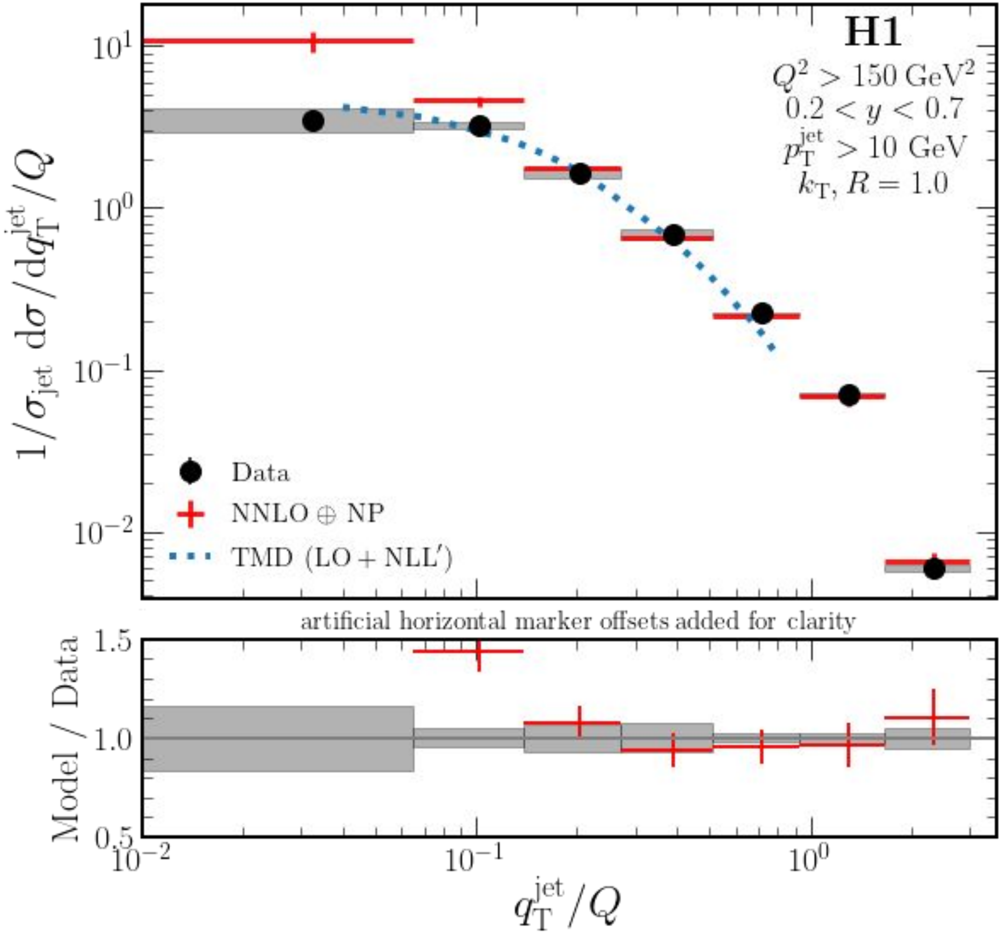




TMD calculation does a great job at low qT; collinear calculation does a great job at large qT.

Large overlap between collinear and TMD frameworks

Momentum imbalance

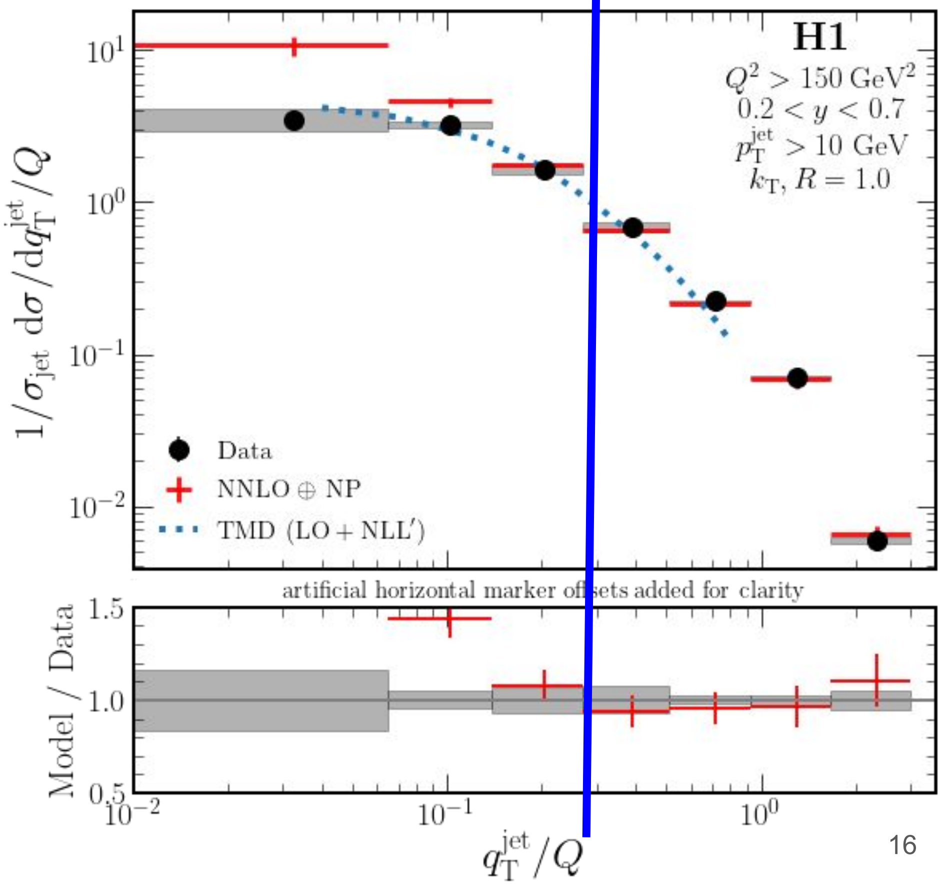


Textbook example of matching

First time seen in DIS!

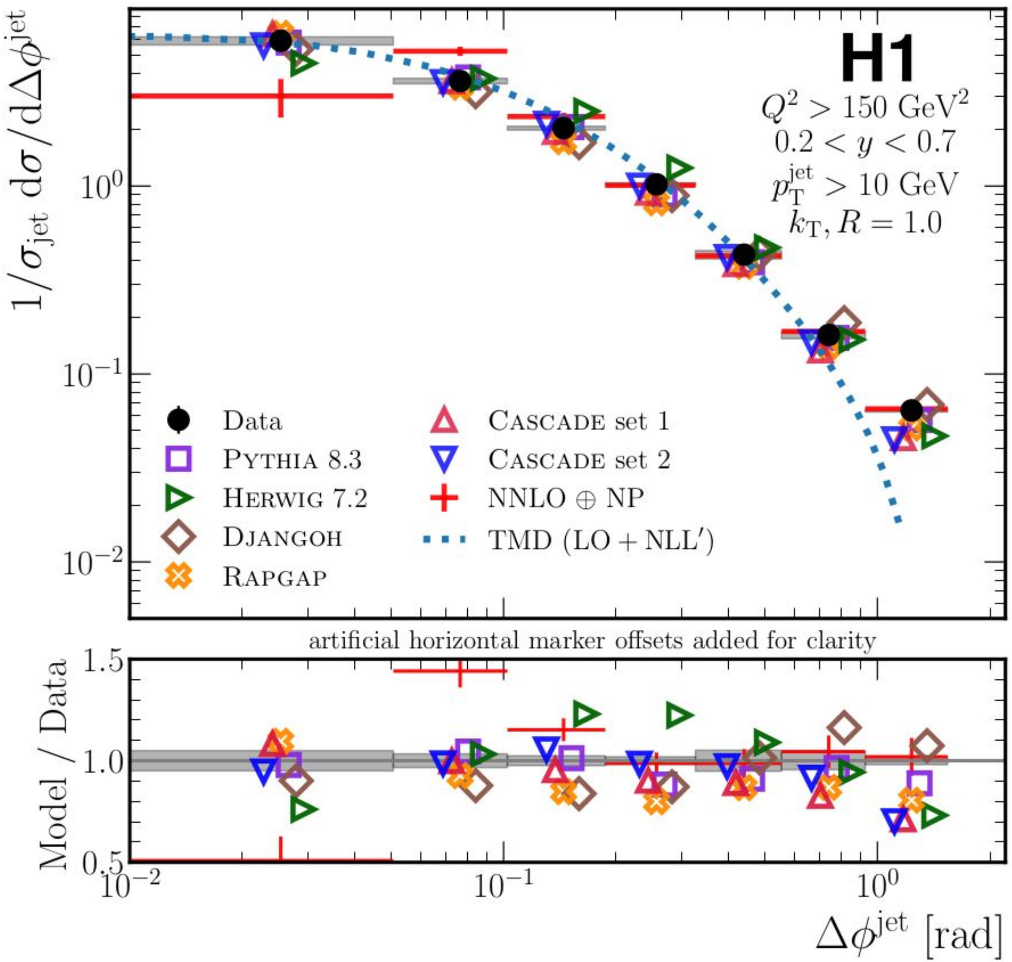
TMD calculation, without free parameters, describes data over wide kinematic range

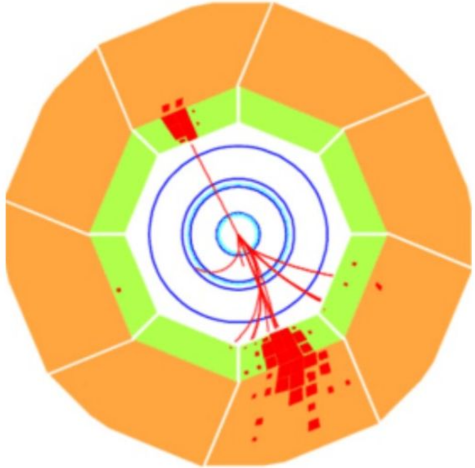
$$\frac{d^5\sigma(\ell p \to \ell' J)}{dy_\ell d^2k_{\ell\perp} d^2q_\perp} = \sigma_0 \int d^2k_\perp d^2\lambda_\perp x f_q(x, k_\perp, \zeta_c, \mu_F) \times H_{\rm TMD}(Q, \mu_F) S_J(\lambda_\perp, \mu_F) \times \delta^{(2)}(q_\perp - k_\perp - \lambda_\perp).$$



- TMD calculations by F. Yuan and Z. Kang, TMD PDFs and soft factors extracted from low Q2 DIS and DY data. Sun et al. arXiv:1406.3073

Lepton-jet azimuthal correlations





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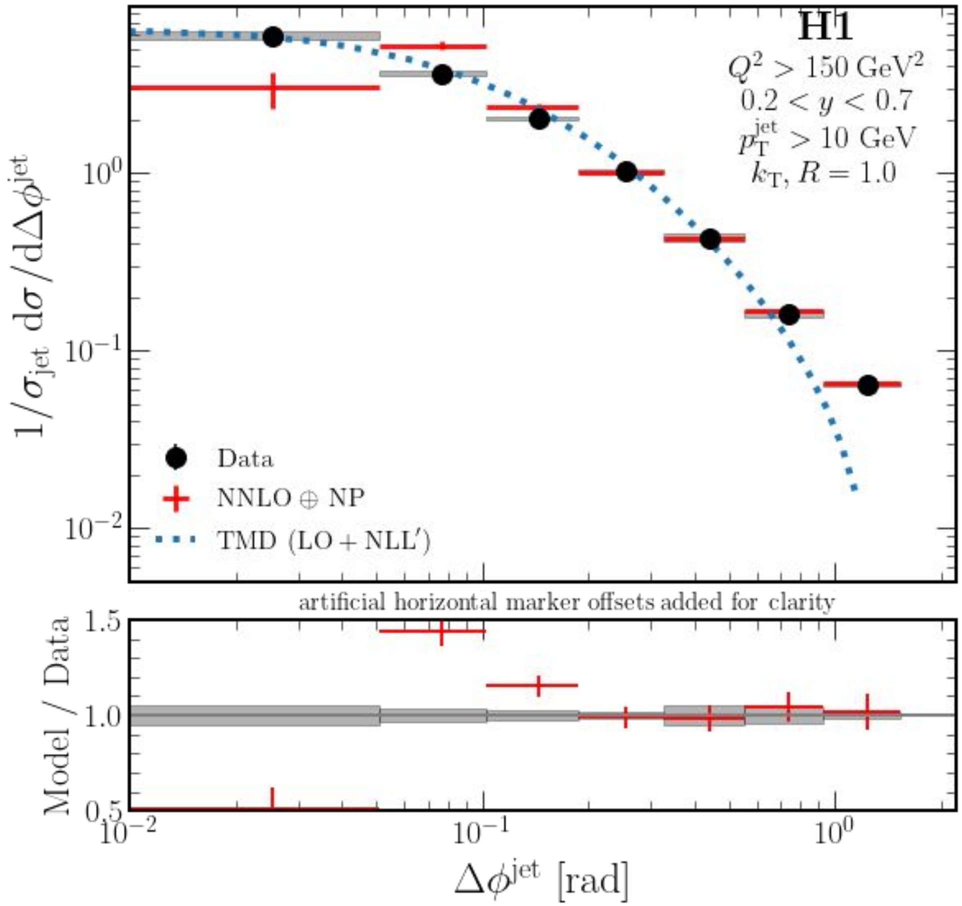
Azimuthal correlation

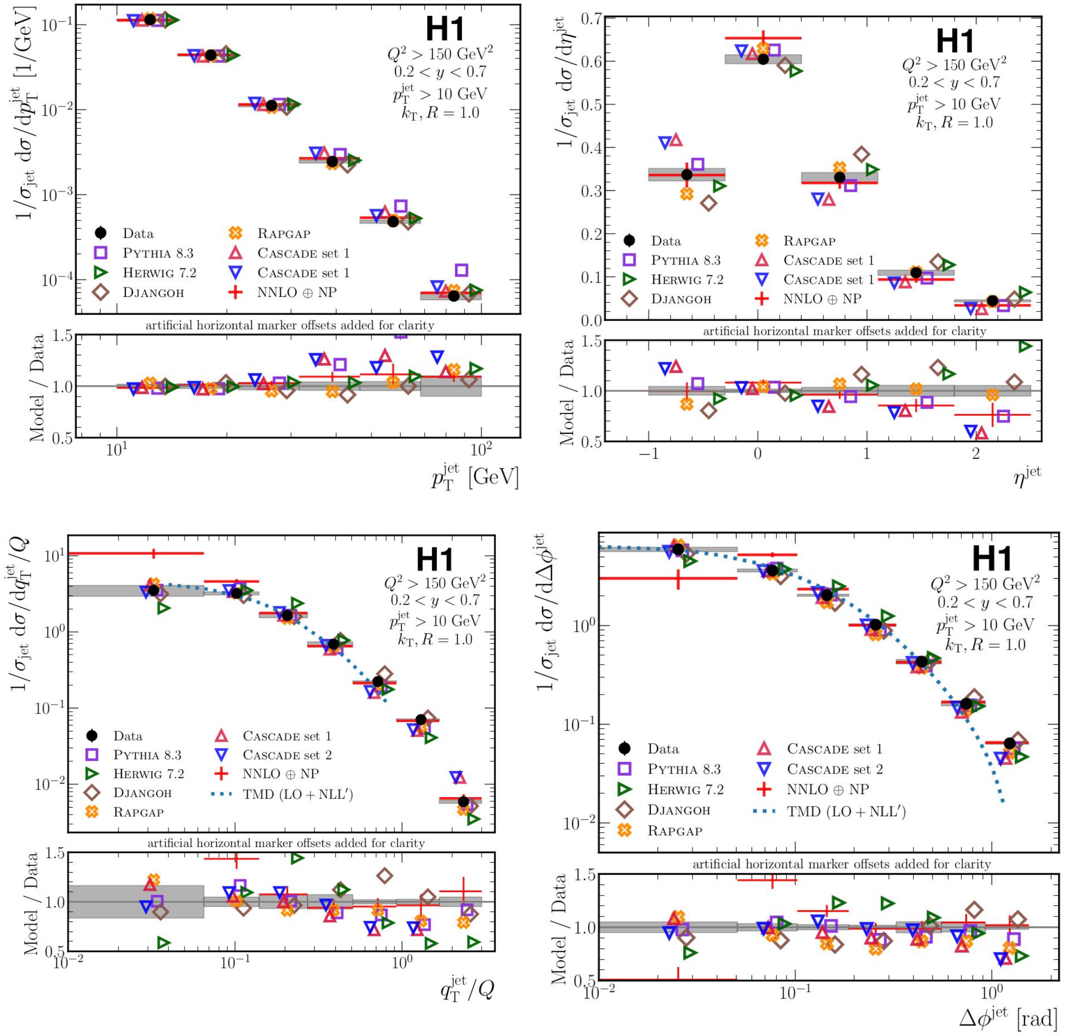


Textbook example of matching

First time seen in DIS!

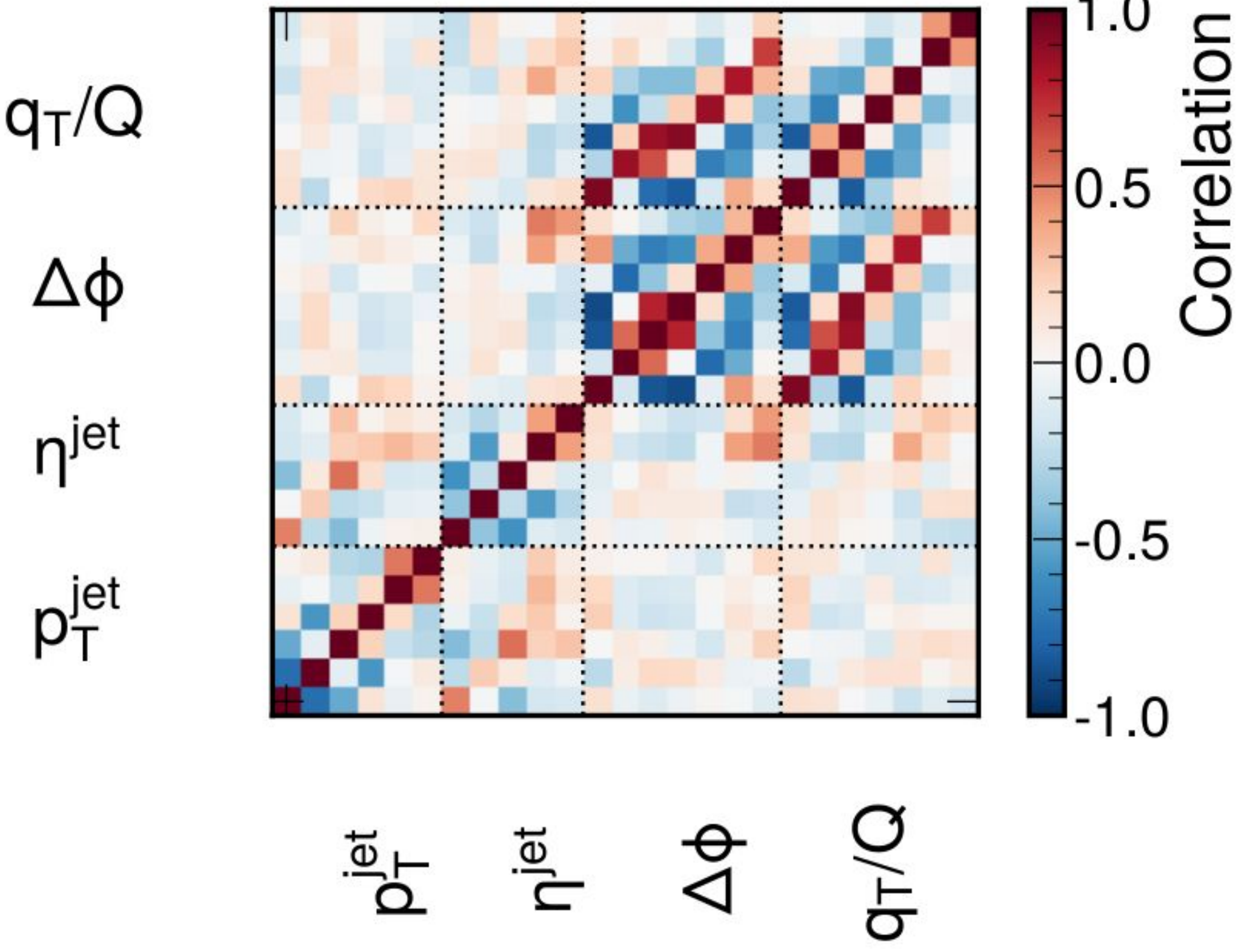
Omnifold allowed us to do a simultaneous, unbinned “unfolding”

First measurement that uses machine-learning to correct for detector effects.



Correlation matrix

- Simultaneous Unfolding of these observables
- Unbinned (binned here for reference)



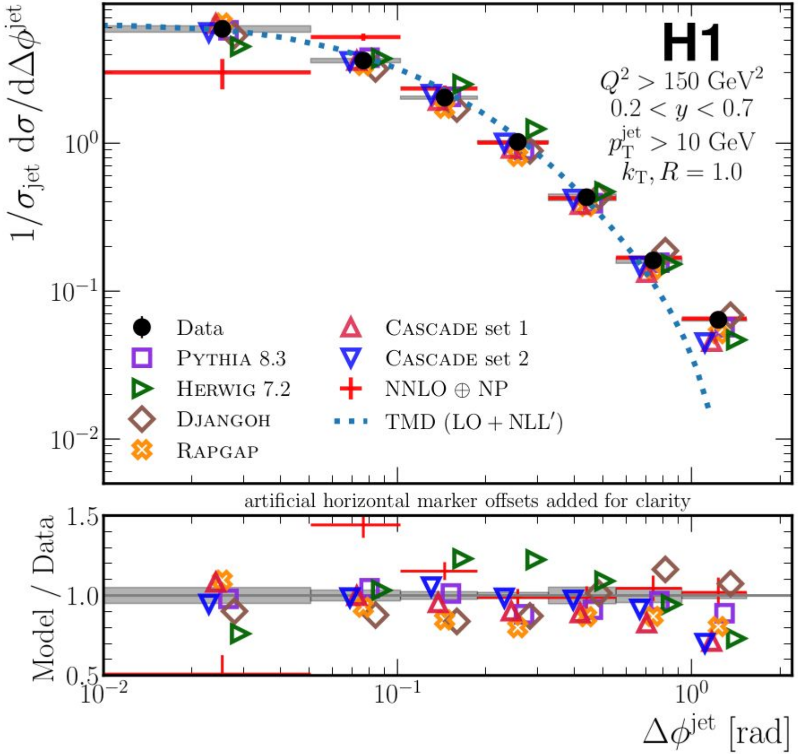
Summary

- New 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**

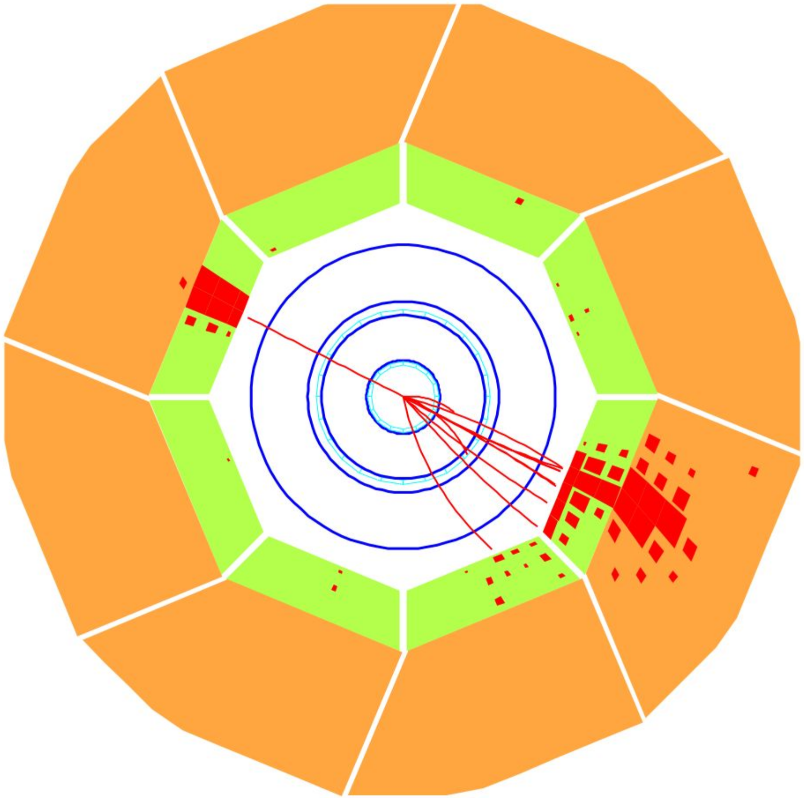
- **First-ever measurement that uses machine-learning to correct for detector effects.** (using Omnifold method)

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



Stay tuned for more HERA results coming soon..

Stay tuned for more AI applications!

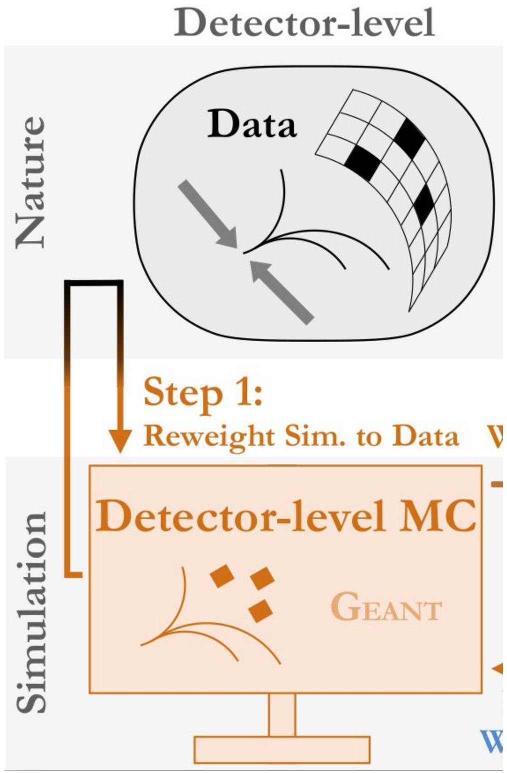


Please mark your calendar!

May-June 2022, TBD	**Workshop: Hera-4 EIC-Workshop @ CFNS** **Location:** Stony Brook University **Organizers:** Miguel Arratia (UC Riverside/Jlab), Daniel Britzger(MPP), Yulia Furletova (Jlab), Z.Tu (BNL/CFNS), Felix Ringer (LBNL), Bernd Surrow (Temple U)

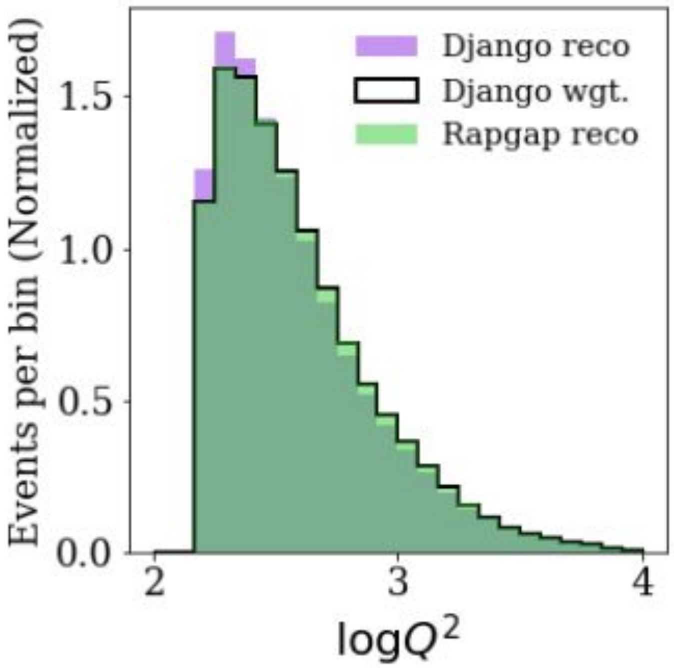
backup

Reweighting the reco-level distributions

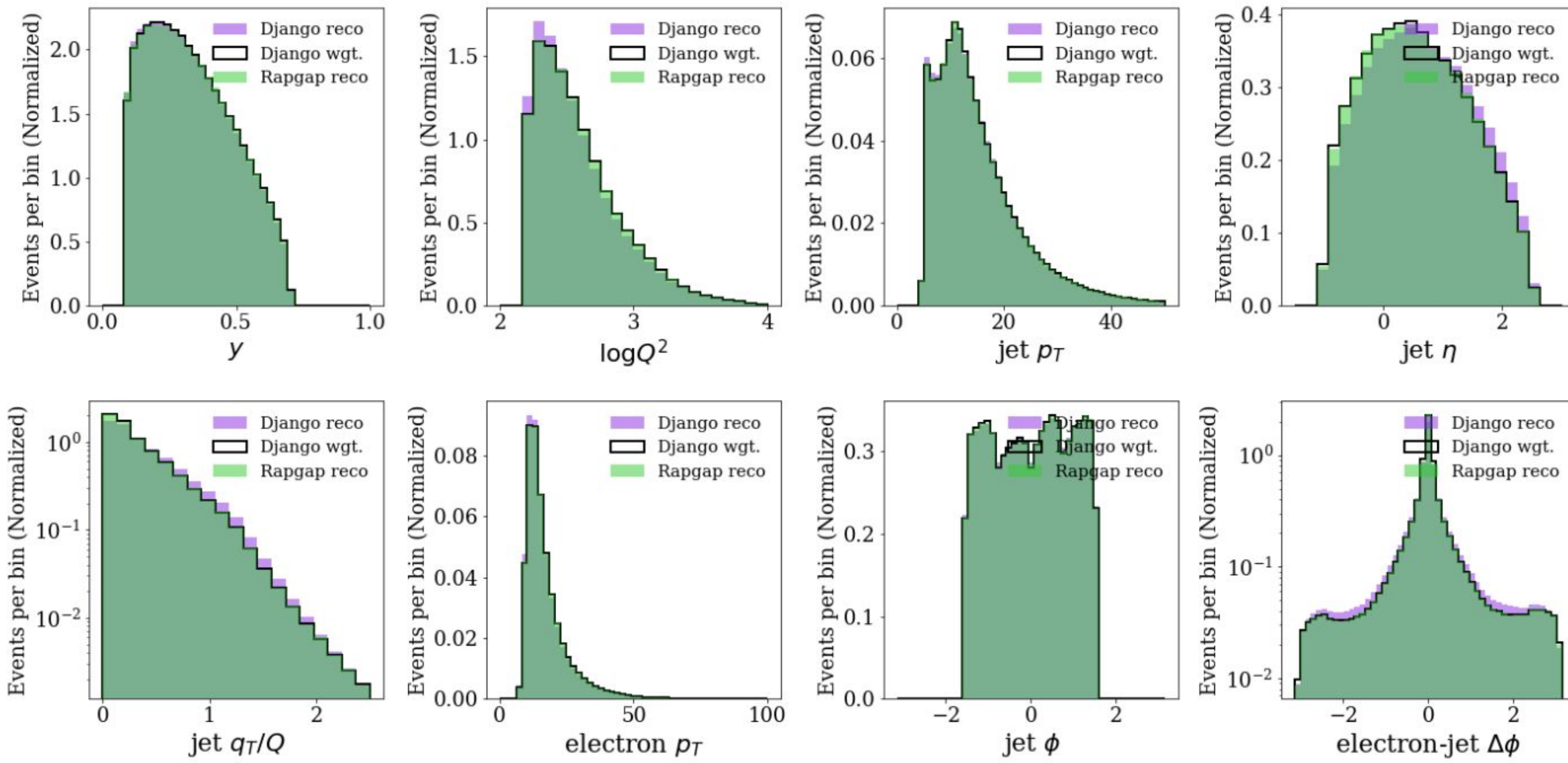


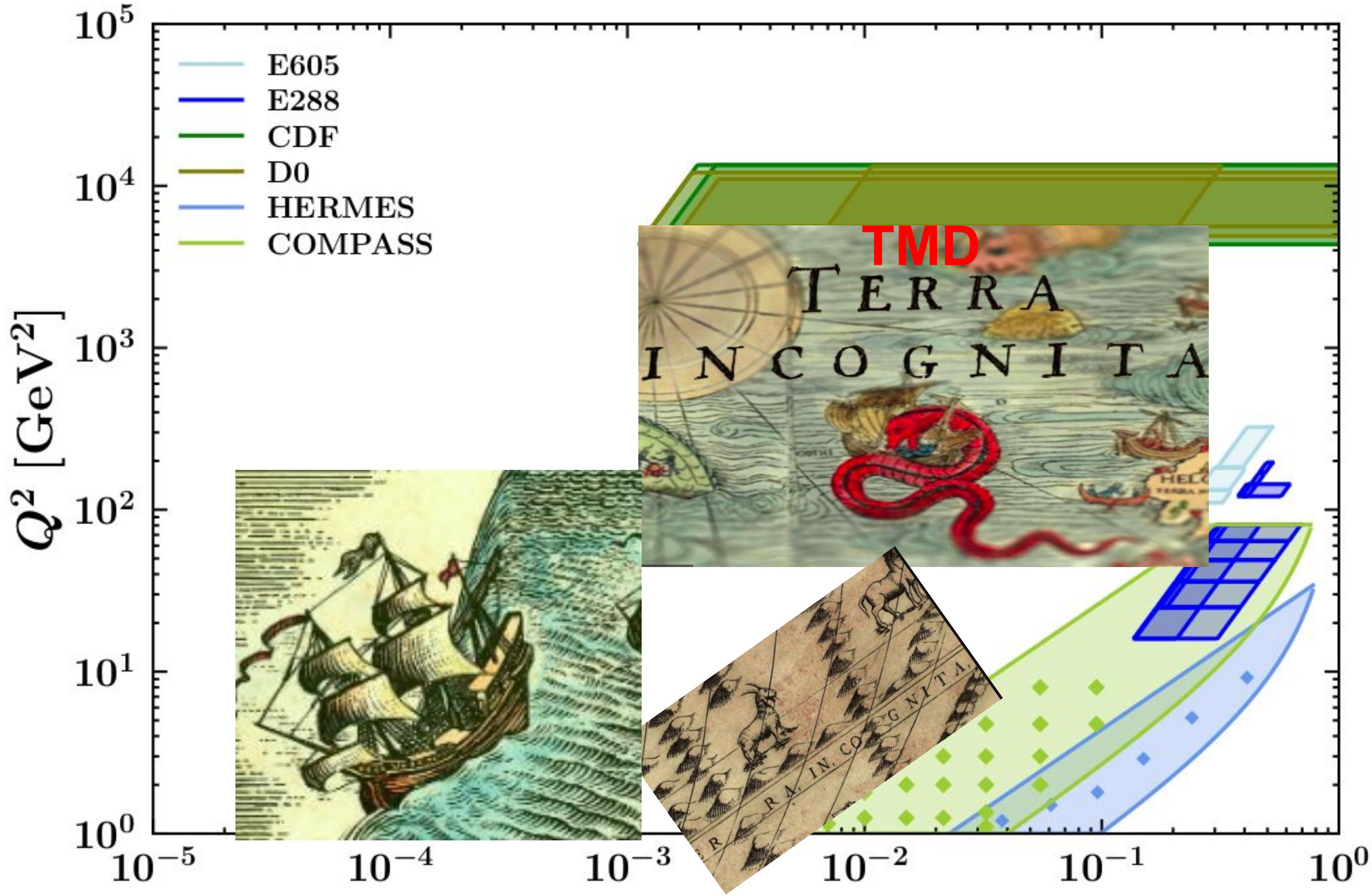
We use simple fully connected networks with a few hidden layers.

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

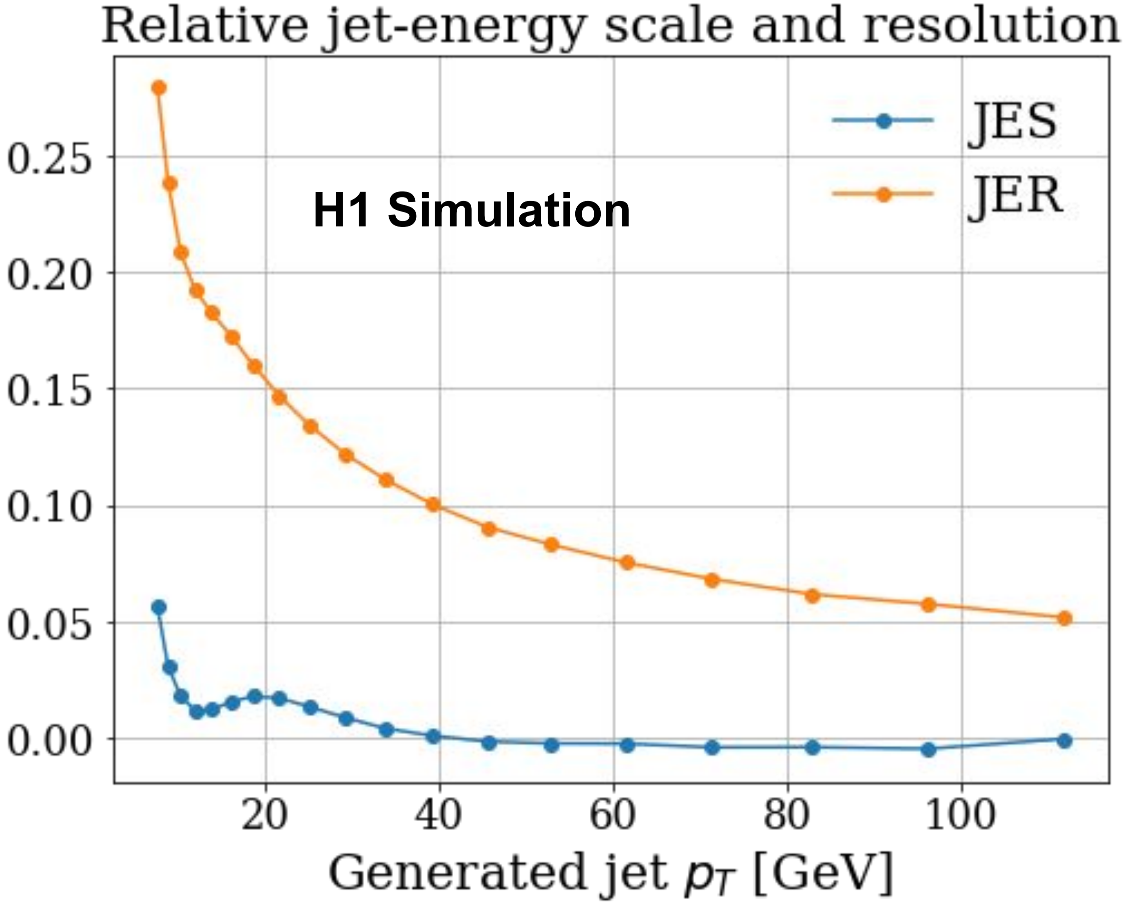


All these distributions are simultaneously reweighted




E605
E288
CDF
D0
HERMES
COMPASS
TMD
TERRA
INCOGNITA
Q^2 [GeV^2]
x
10^0
10^1
10^2
10^3
10^4
10^5
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0

Jet performance
(energy flow reconstruction)



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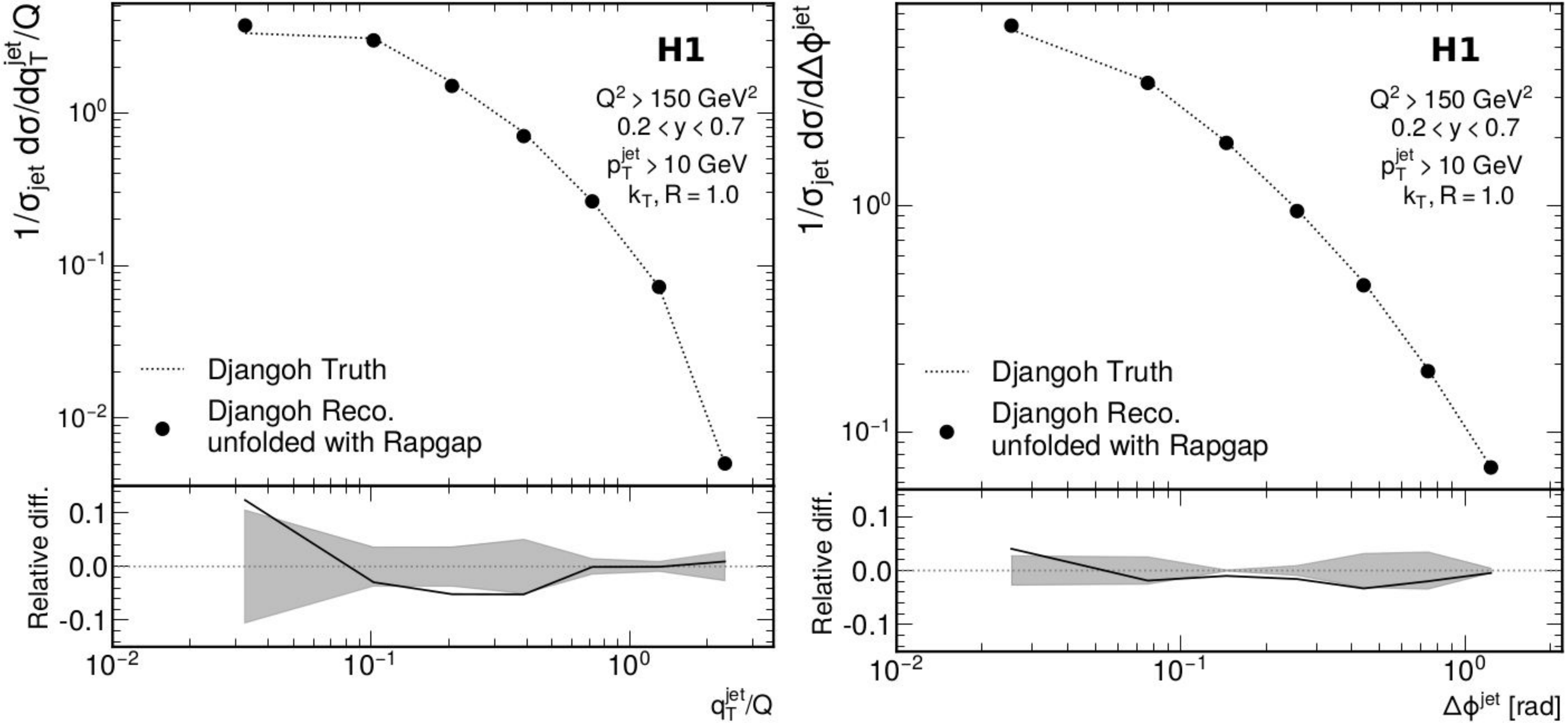
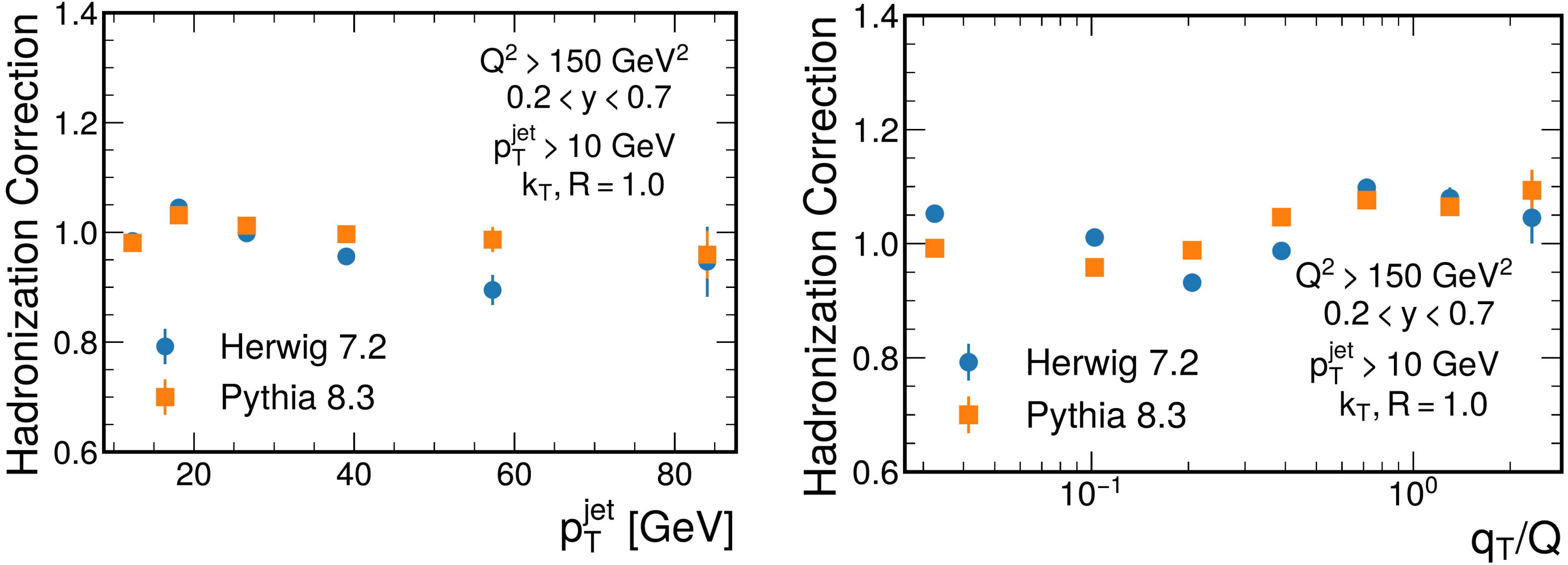
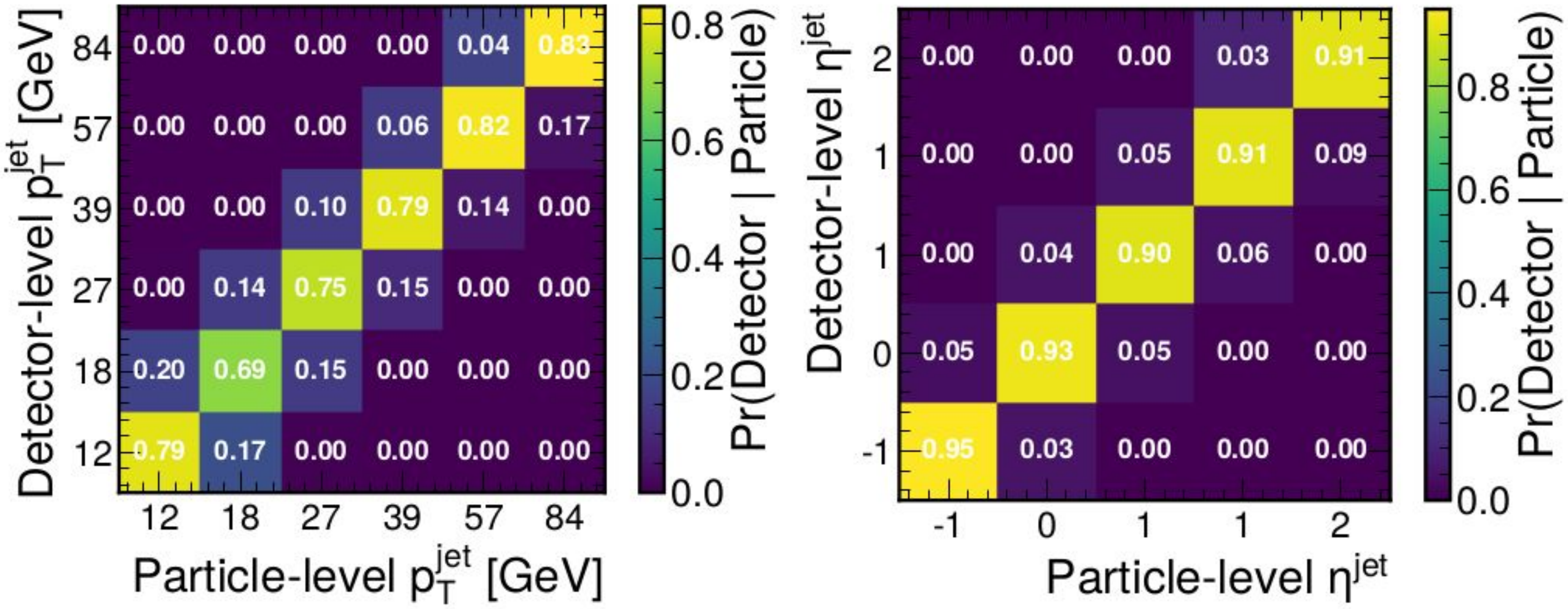


Hadronization corrections (applied to NNLO calculation)



Small, and consistent with Pythia8 and Herwig despite different models of hadronization

Response matrices
(not actually used as our results are unbinned, but just for reference)



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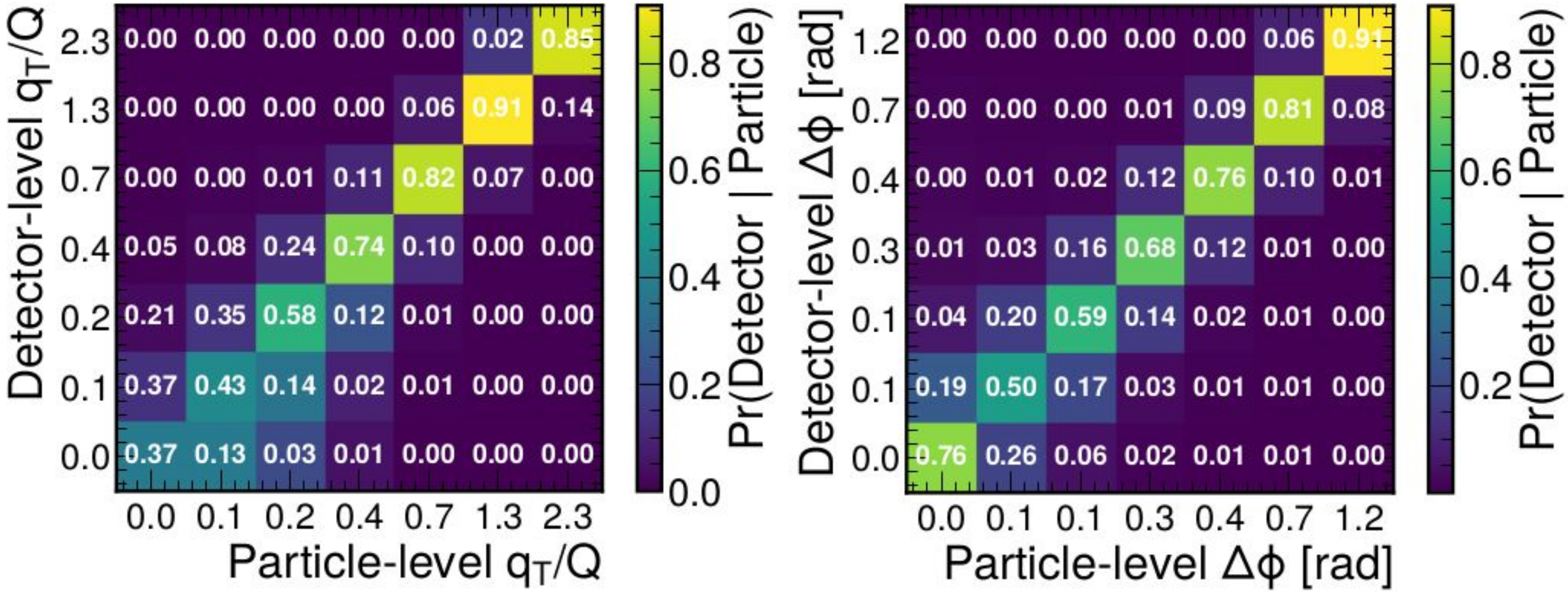
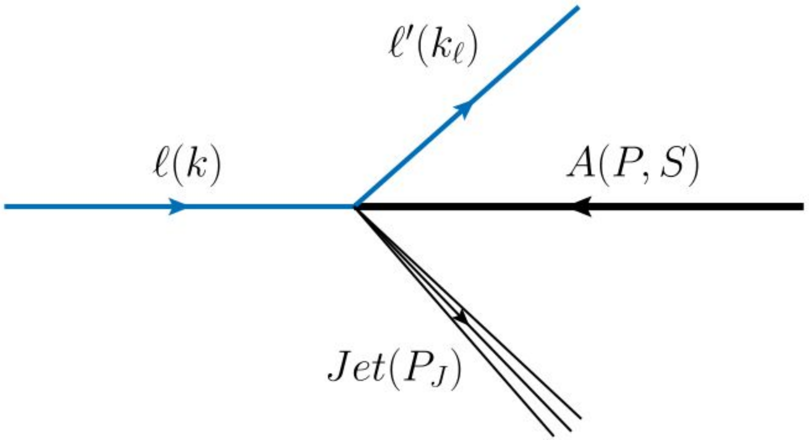


Lepton-jet imbalance $q_T = |\vec{k}_{l\perp} + \vec{p}^{\,j}_{\perp}|$

In Born-level configuration

Probes quark TMD PDFs

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



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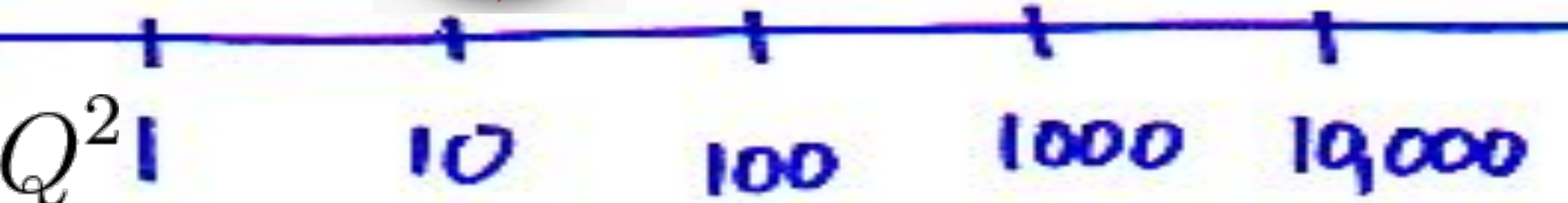
Evolution: Endgame



Weighting works well multidimensionally (unbinned)