ML-assisted measurements of lepton-jet asymmetries in DIS @ H1

Benjamin Nachman

Lawrence Berkeley National Laboratory

on behalf of the **H1** Collaboration

bpnachman.com

bpnachman@lbl.gov

@bpnachman

bnachman

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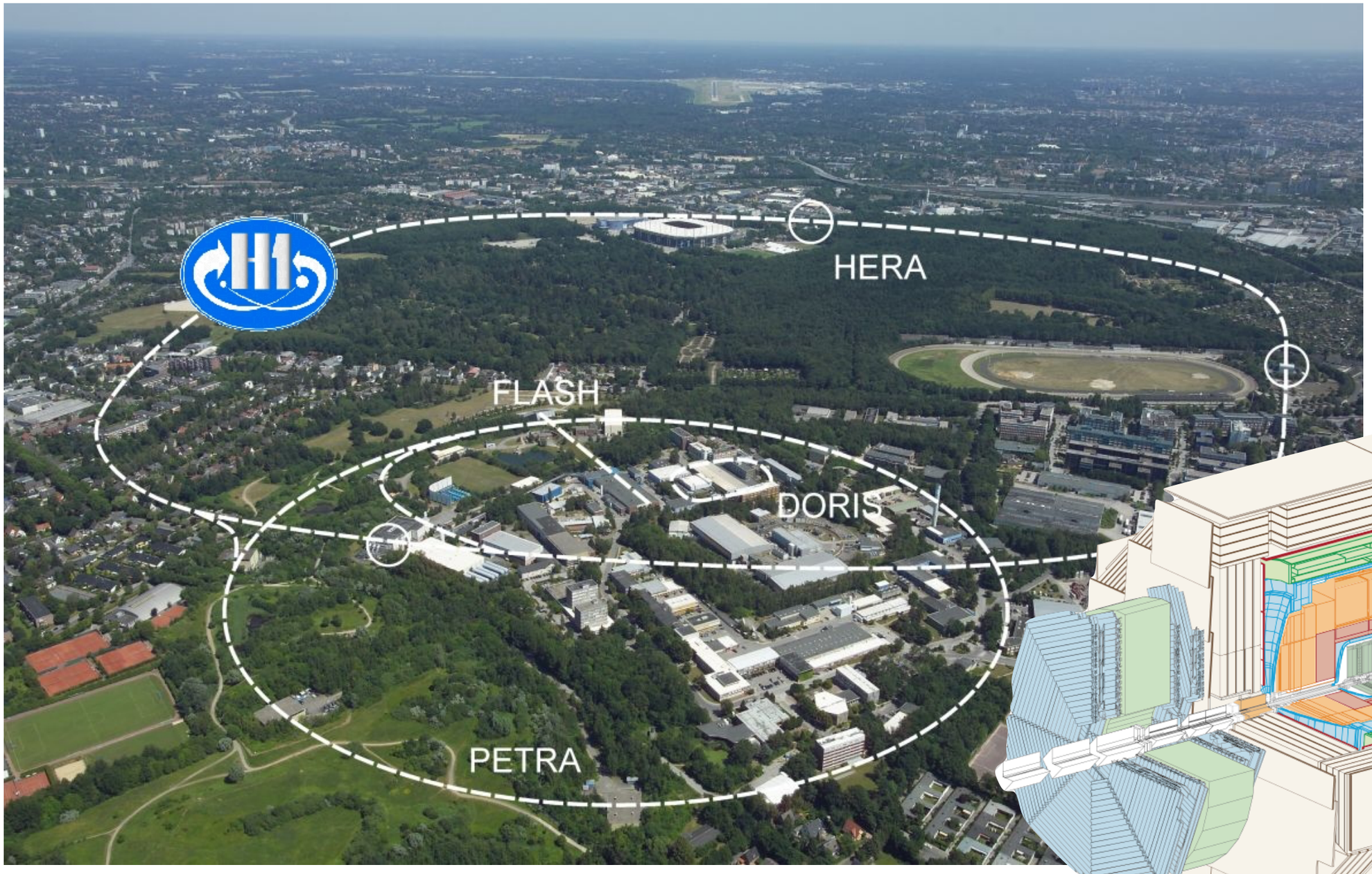
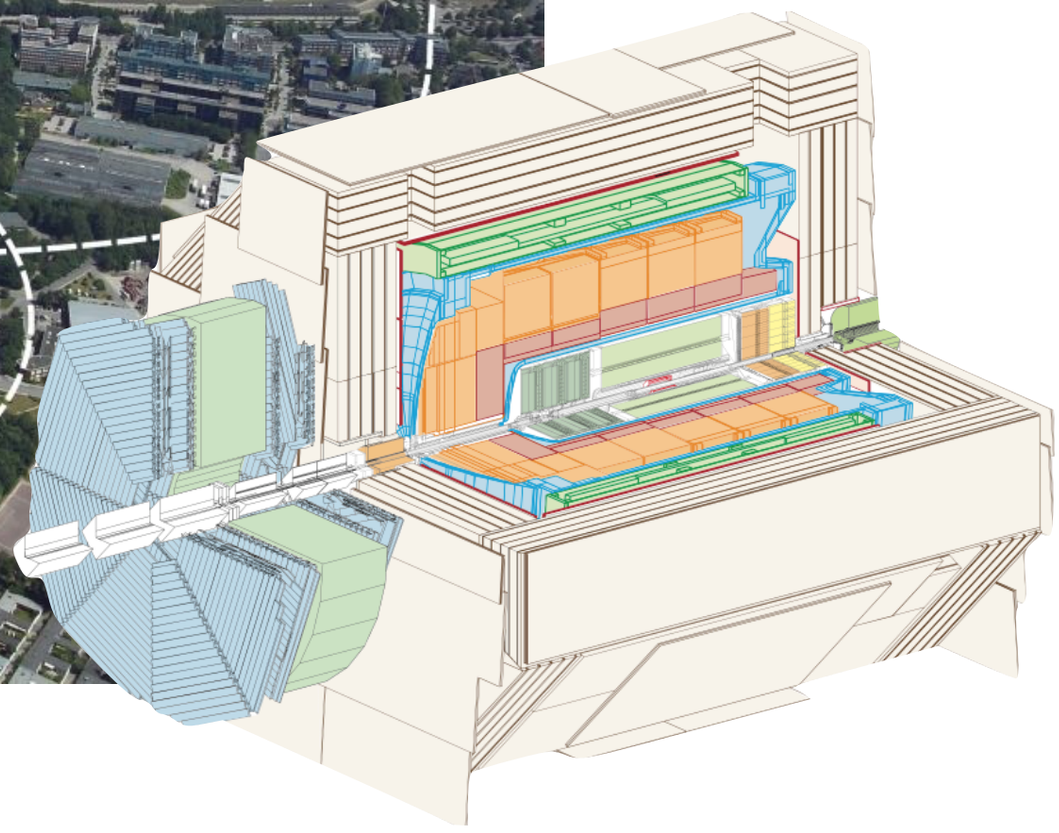
H1 @ HERA

H1 was one of two multipurpose experiments at HERA.

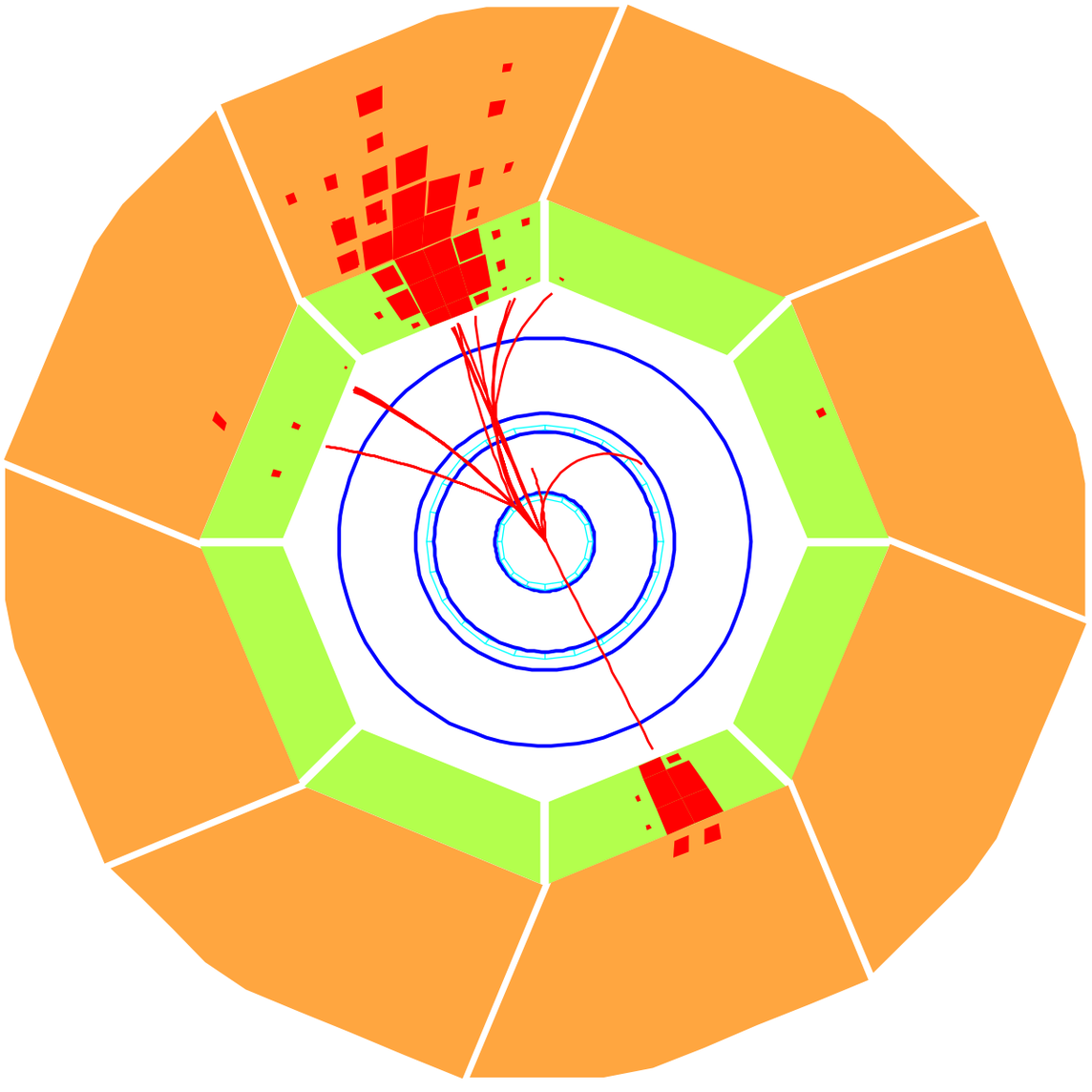




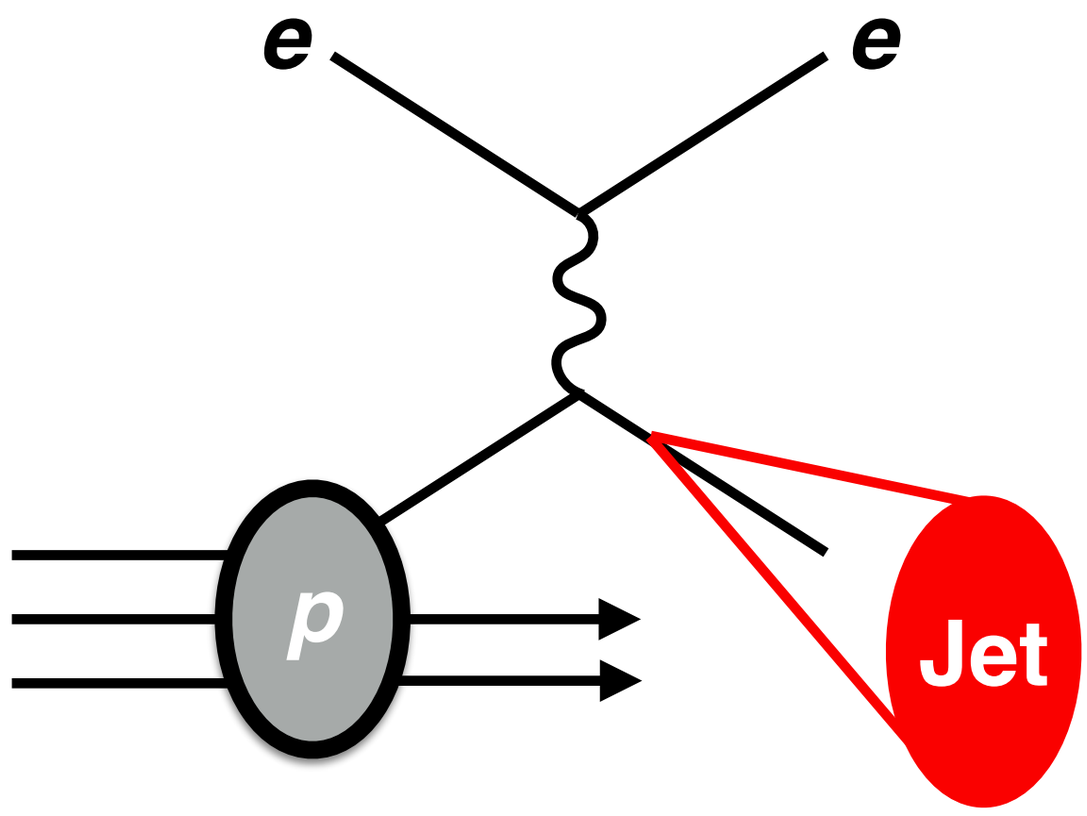
H1 @ HERA

H1 was one of two multipurpose experiments at HERA.

For this talk: 2006-2007 data, 136 pb^{-1}, 320 GeV

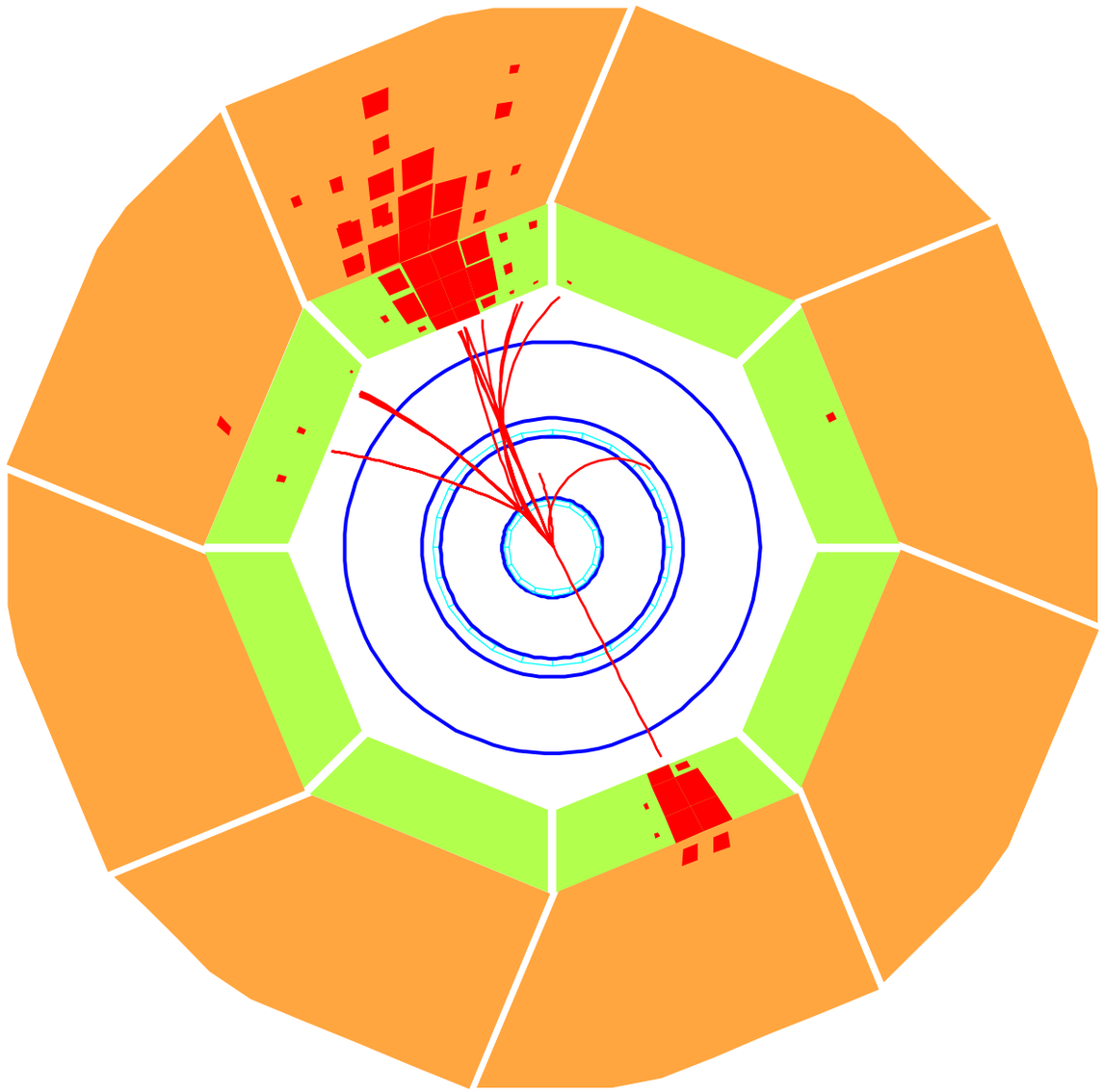


I'll present measurements of the electron-jet inbalance



Why electron-jet imbalance?

Born-level configuration, electron and jet are back-to-back

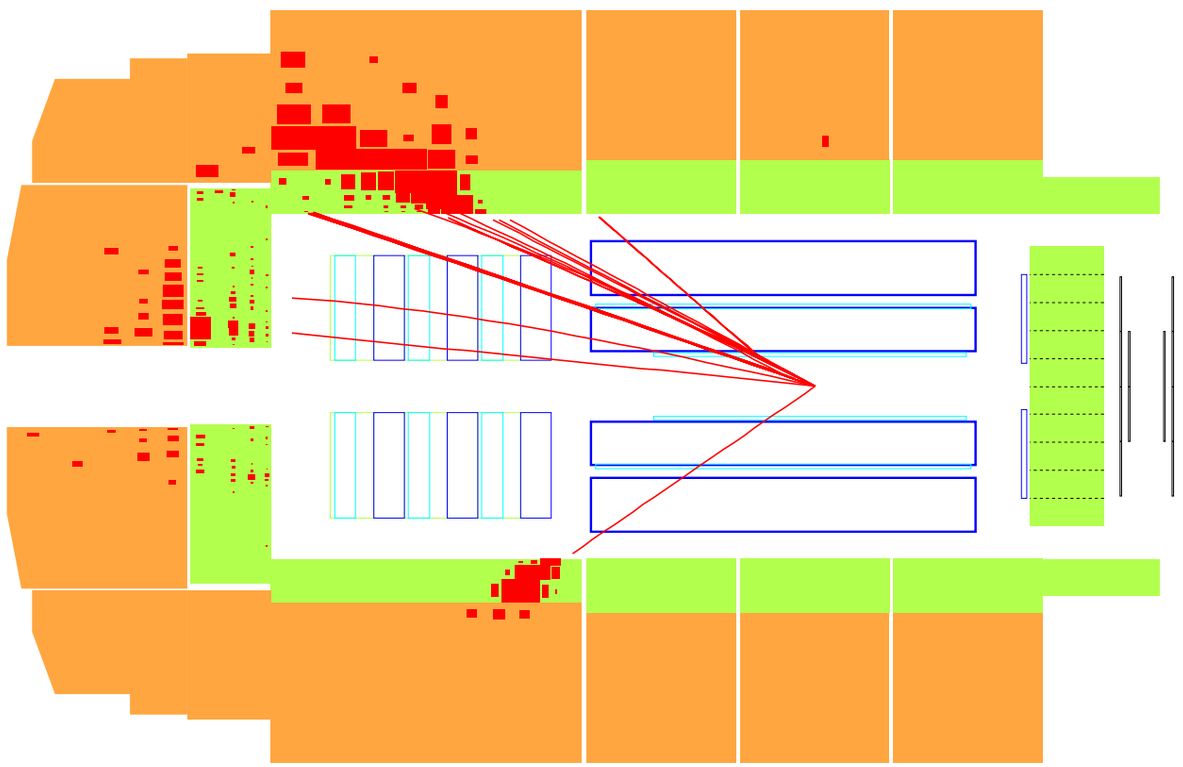


Typically, jets are studied in the Breit frame, where the Born-level configuration is discarded

However, jet production in the lab frame can be useful for probing Transverse Momentum Dependent (TMD) Parton Distribution Functions (PDFs)

See e.g. Lieu et al. PRL (2019) 192003;
Gutierrez et al. PRL (2018) 162001

Jets at H1

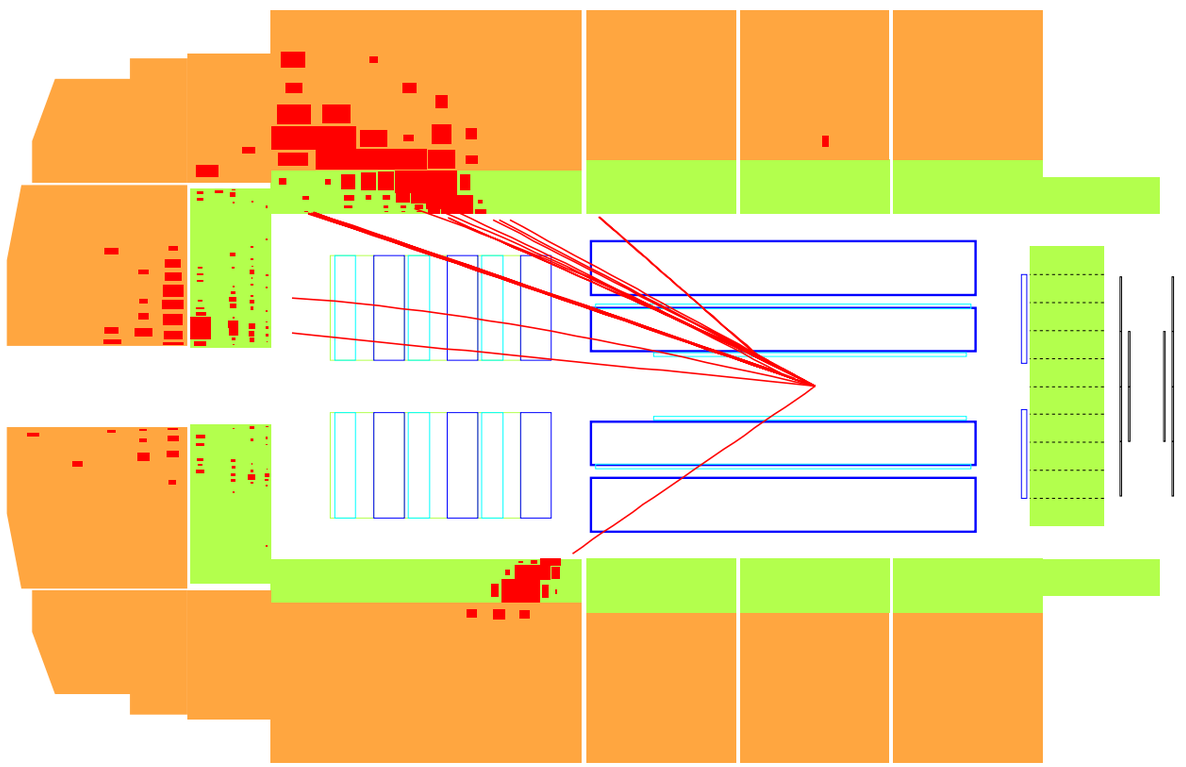


Energy flow algorithm (HFS) combines information from tracker and calorimeters

Neural network-based energy regression

1% jet energy scale uncertainty; 0.5-1% lepton energy scale uncertainty

Jets at H1



Energy flow algorithm (HFS) combines information from tracker and calorimeters

Neural network-based energy regression

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Challenge: **unfold multidimensional phase space**

Jets at H1

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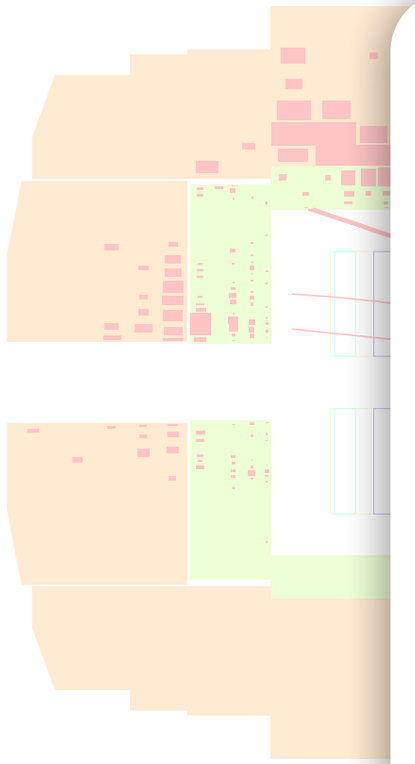


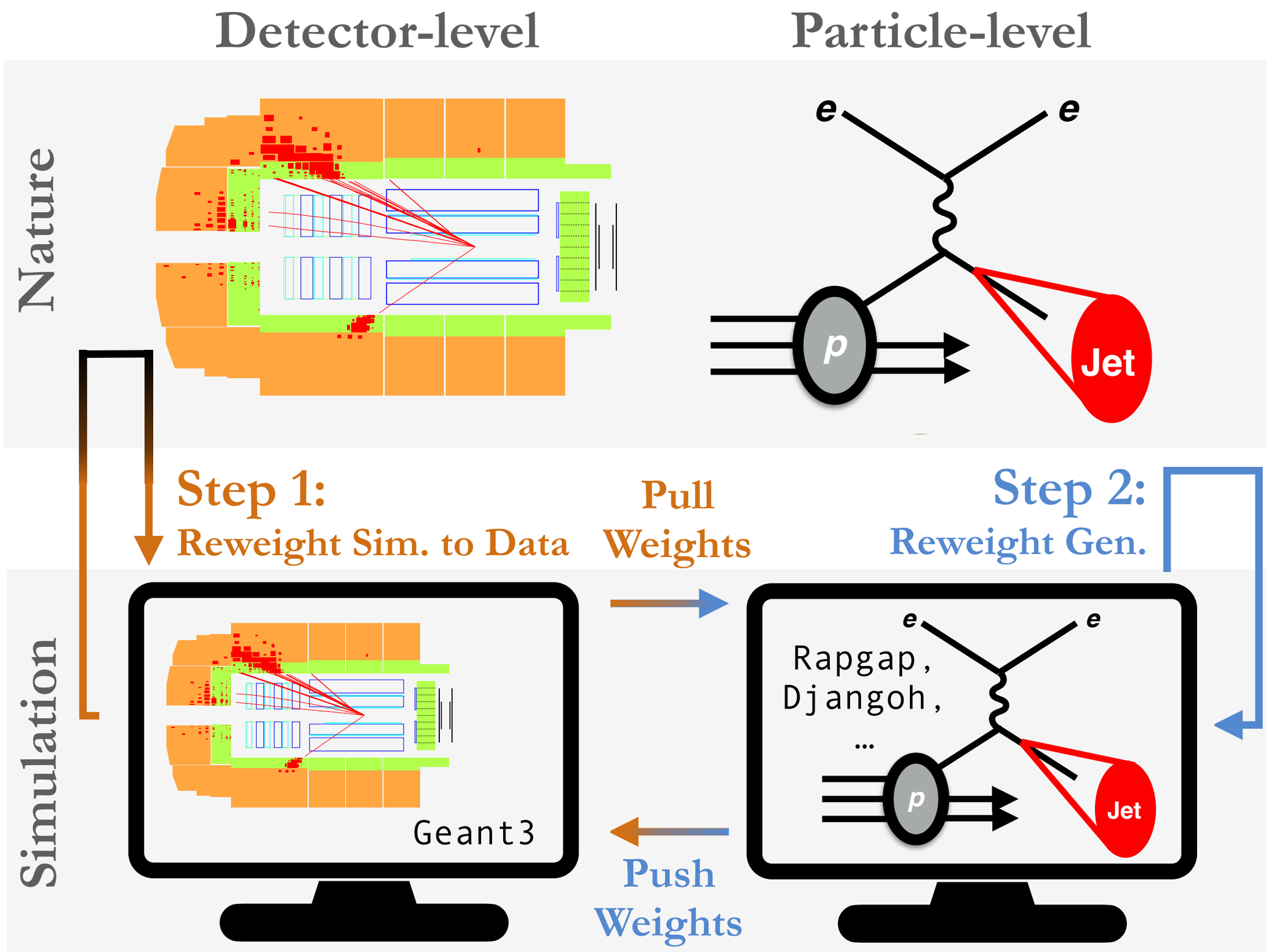
Solution: **use deep learning!**

…can do unbinned, high (and variable-)dimensional unfolding

based sion cale lepton ertainty

Challenge: **unfold multidimensional phase space**

Unfold by iterating: OmniFold



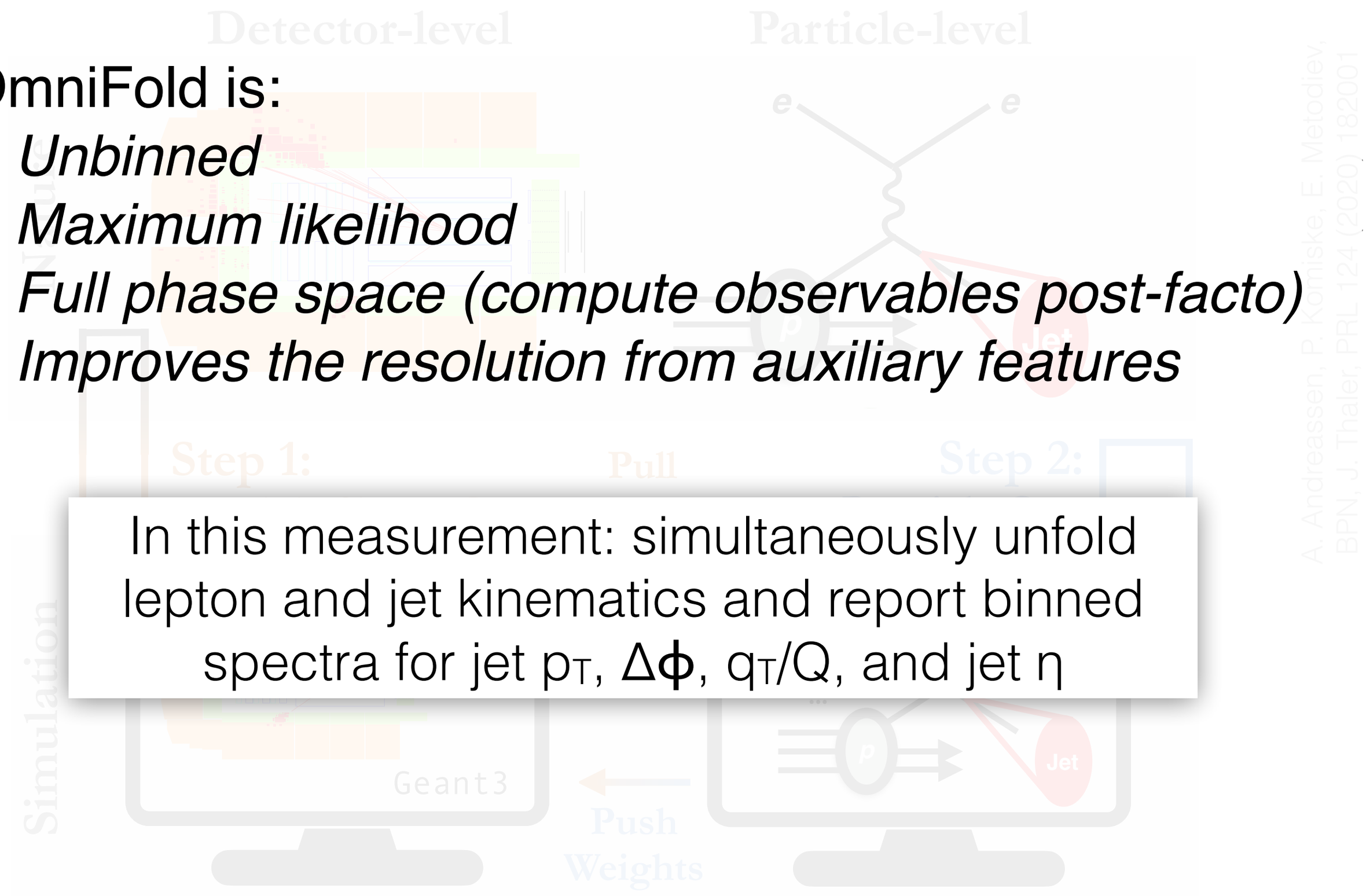
A. Andreassen, P. Komiske, E. Metodiev, BPN, J. Thaler, PRL 124 (2020) 182001

Unfold by iterating: OmniFold

OmniFold is:

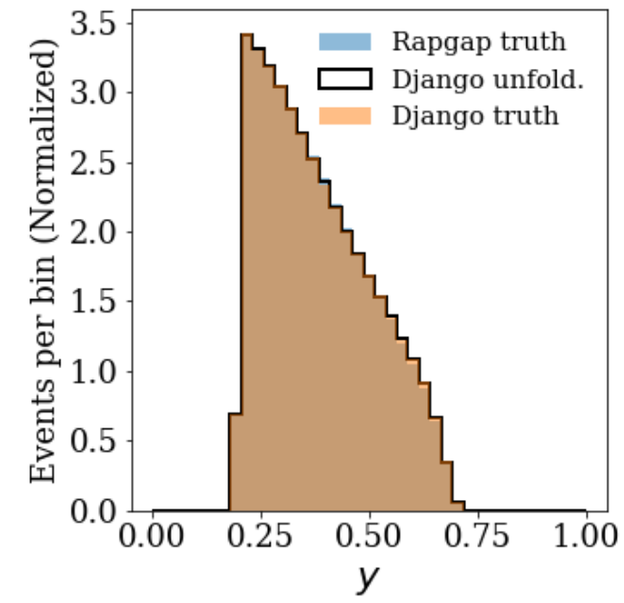
- *Unbinned*
- *Maximum likelihood*
- *Full phase space (compute observables post-facto)*
- *Improves the resolution from auxiliary features*

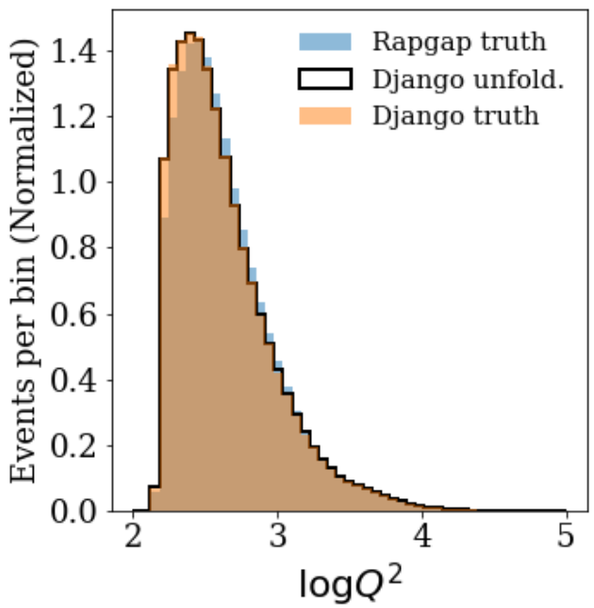
In this measurement: simultaneously unfold lepton and jet kinematics and report binned spectra for jet p_T, $\Delta\phi$, q_T/Q, and jet η

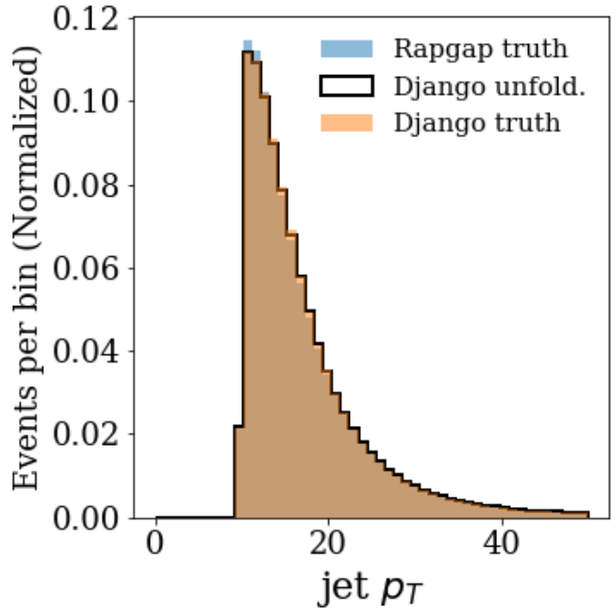


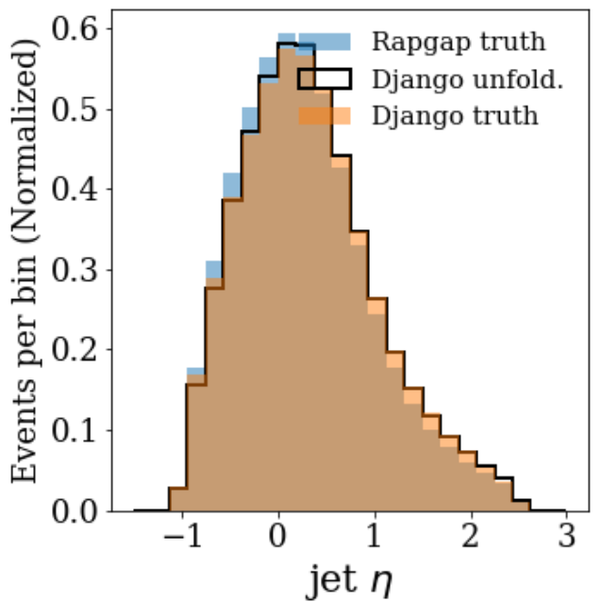
OmniFolding *ep* simulations

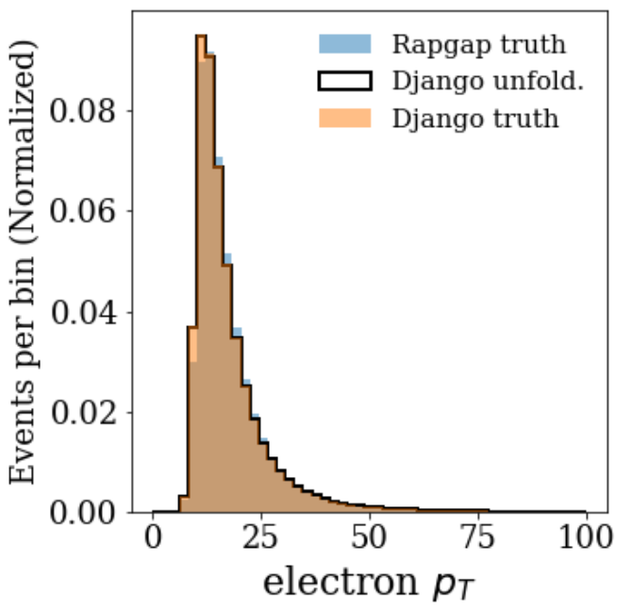
We see excellent closure for the full phase space!

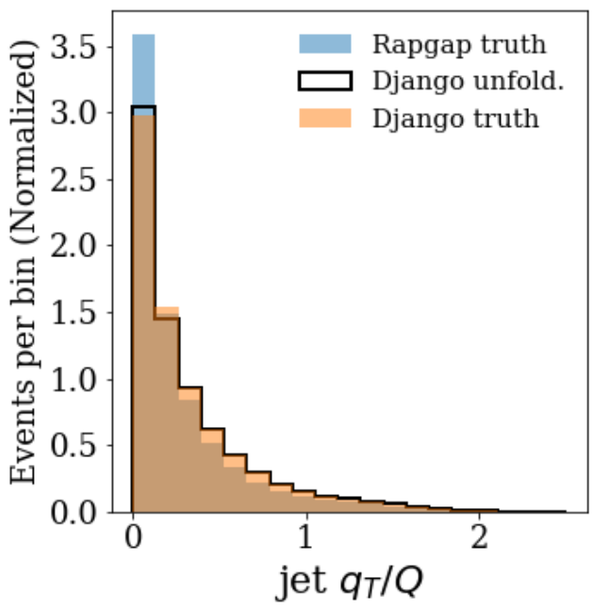


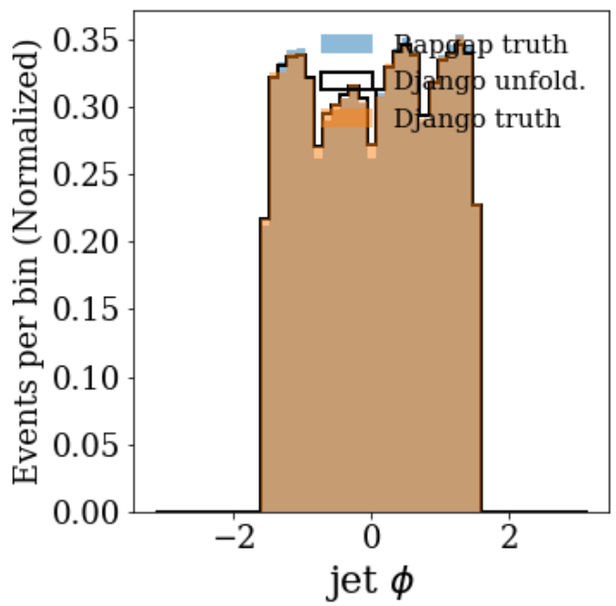


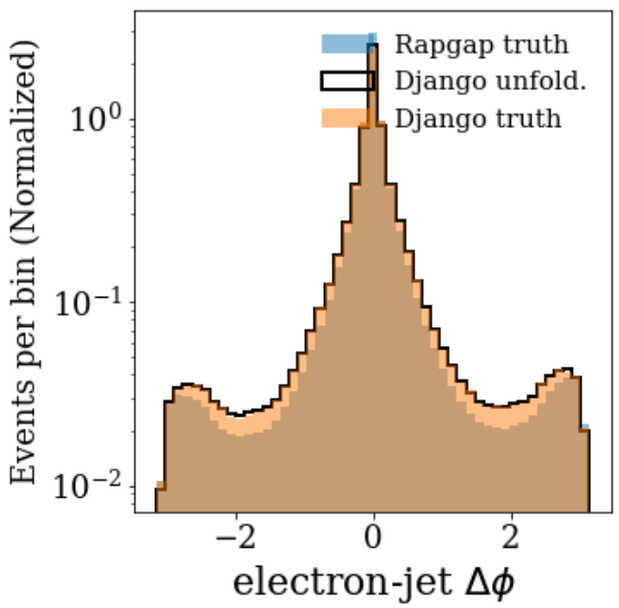












Results

2108.12376

DESY 21-130, ISSN 0418-9833

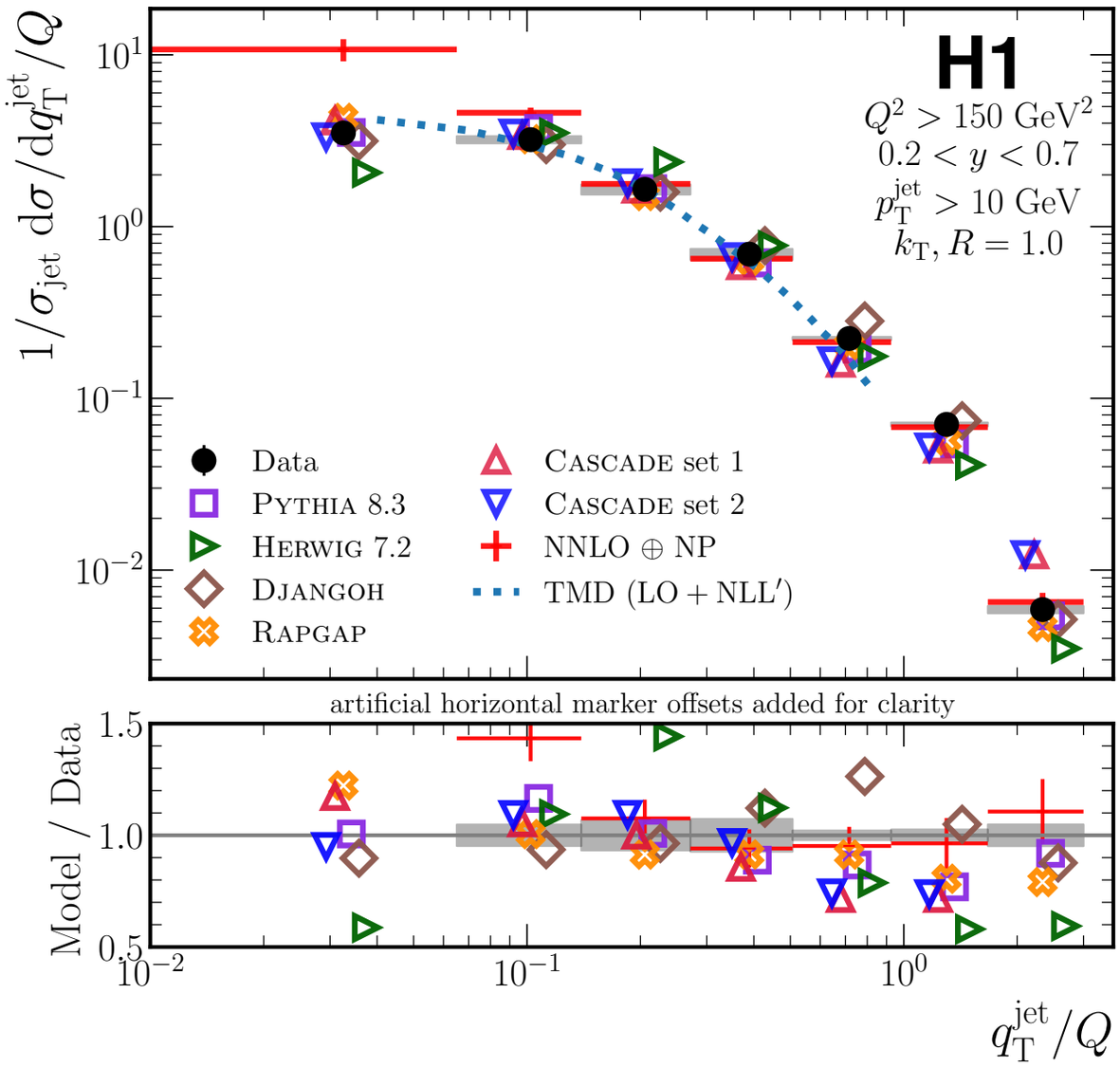
Measurement of lepton-jet correlation in deep-inelastic scattering with the H1 detector using machine learning for unfolding

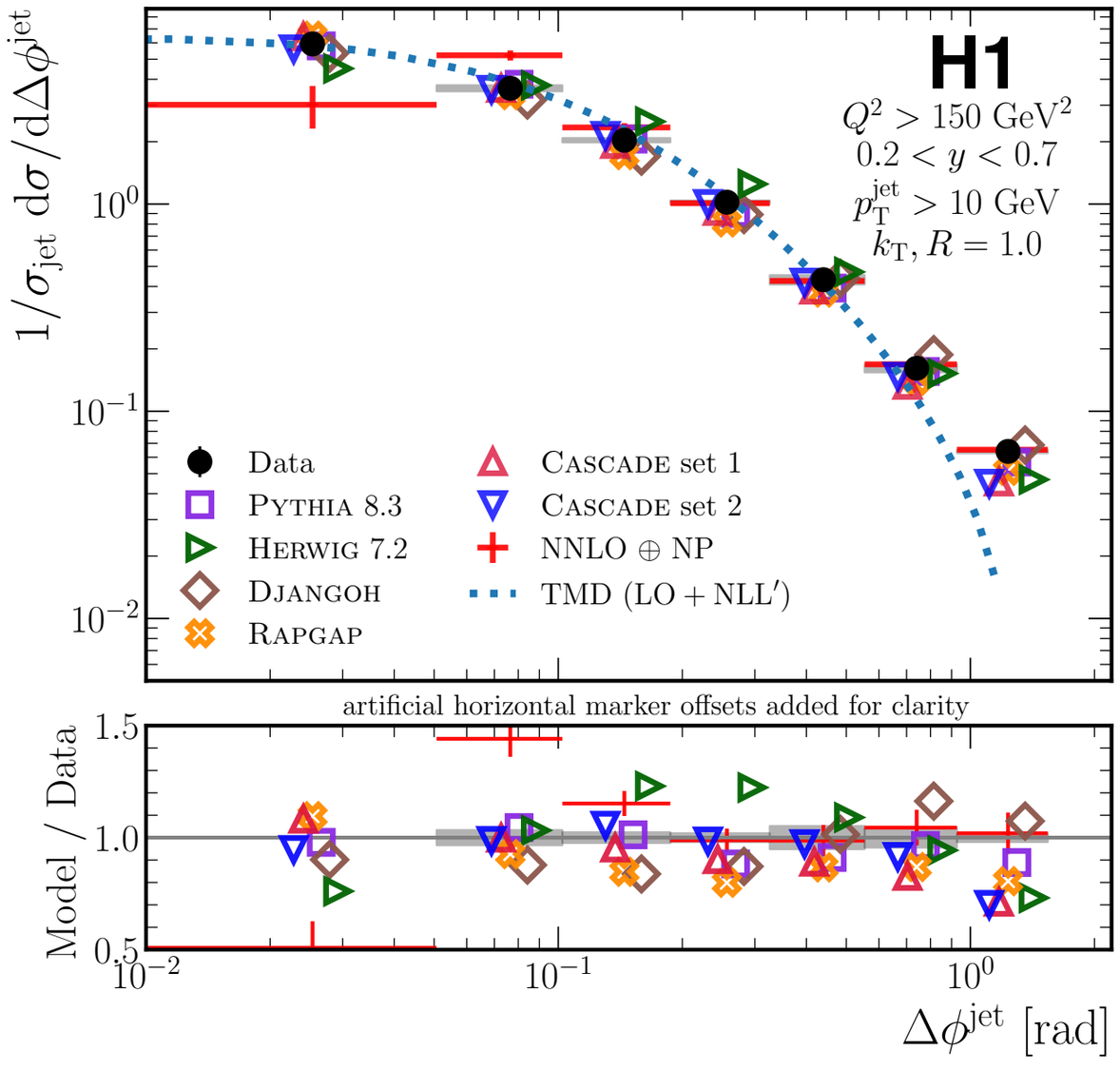
H1 Collaboration*

(To be submitted to Physical Review Letters)
(Dated: August 30, 2021)

The first measurement of lepton-jet momentum imbalance and azimuthal correlation in lepton-proton scattering at high momentum transfer is presented. These data, taken with the H1 detector at HERA, are corrected for detector effects using an unbinned machine learning algorithm (OmniFold), which considers eight observables simultaneously in this first application. The unfolded cross sections are compared to calculations performed within the context of collinear or transverse-momentum-dependent (TMD) factorization in Quantum Chromodynamics (QCD) as well as Monte Carlo event generators. The measurement probes a wide range of QCD phenomena, including TMD parton distribution functions and their evolution with energy in so far unexplored kinematic regions.

Results





Excellent agreement with fixed order at high q_T, excellent agreement with TMD prediction at low q_T.

Results

H1prelim-22-031

Machine learning-assisted measurement of multi-differential lepton-jet correlations in deep-inelastic scattering with the H1 detector

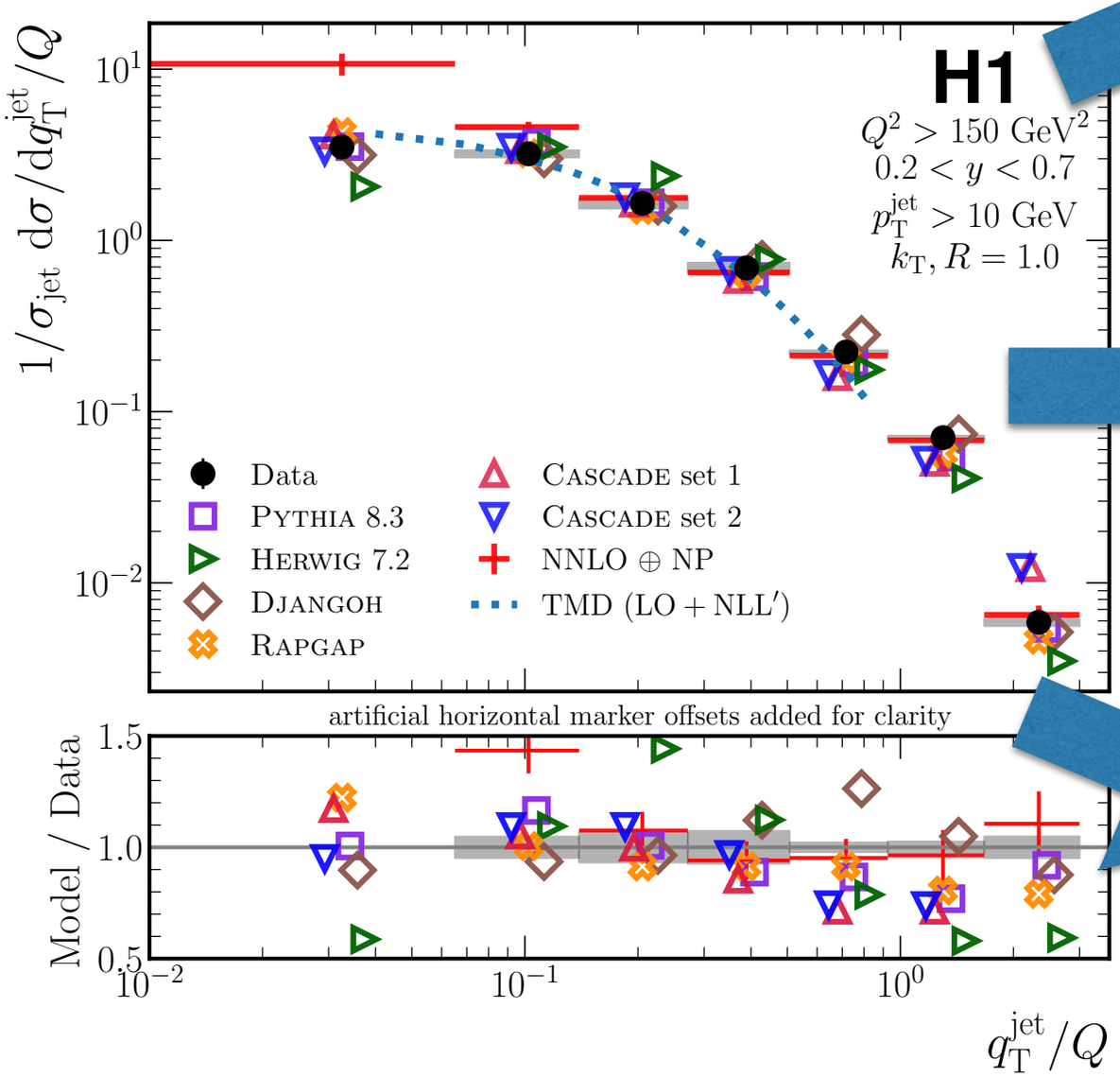
H1 Collaboration

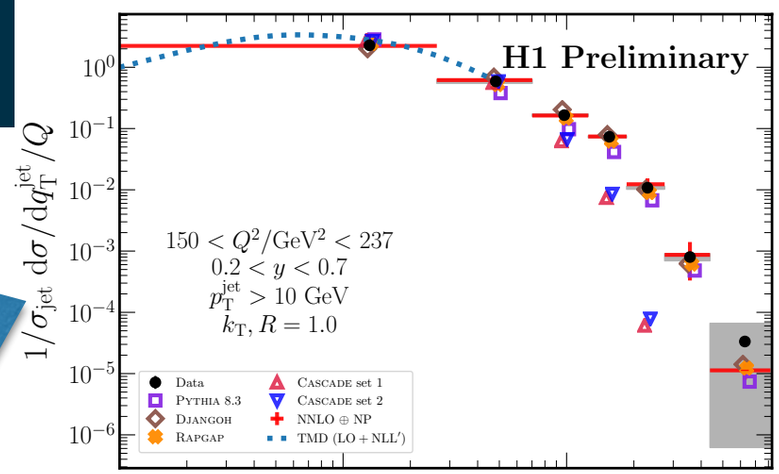
Abstract

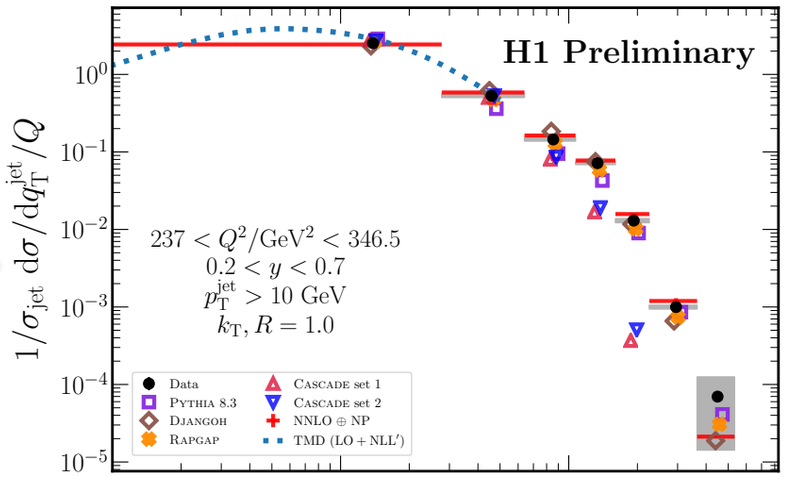
The lepton-jet momentum imbalance in deep inelastic scattering events offers a useful set of observables for unifying collinear and transverse-momentum-dependent frameworks for describing high energy Quantum Chromodynamics (QCD) interactions. We recently performed a measurement of this imbalance in the laboratory frame using positron-proton collisions from HERA Run II [1]. With a new machine learning method, the measurement was performed simultaneously and unbinned in eight dimensions. The results in Ref. [1] were presented projected onto four key observables. This paper extends those results by showing the multi-differential nature of the unfolded result. In particular, we present lepton-jet correlation observables deferentially in kinematic properties of the scattering process, Q^2 and y. We compare these results with parton shower Monte Carlo predictions as well as calculations from perturbative QCD and from a Transverse Momentum Dependent (TMD) factorization framework.

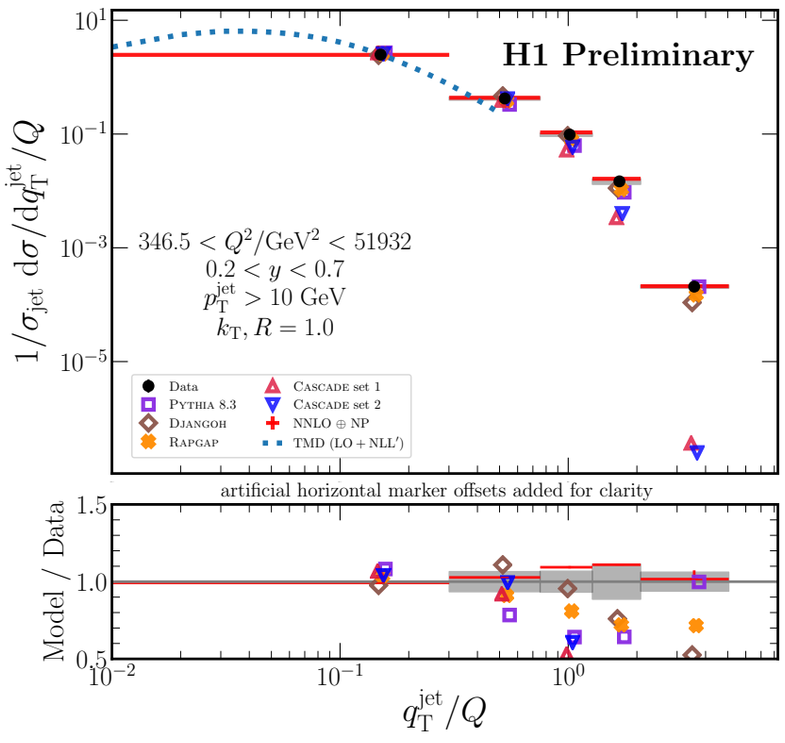
Results

Differential in Q^2 for free!









Results

H1prelim-23-031

Machine learning-assisted measurement of azimuthal angular asymmetries in deep-inelastic scattering with the H1 detector

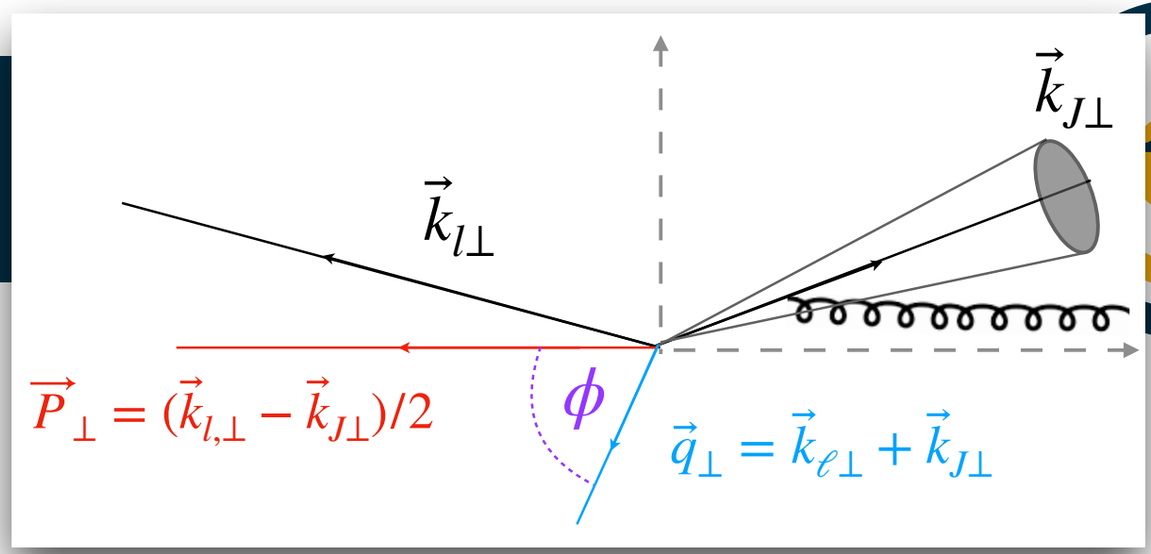
H1 Collaboration

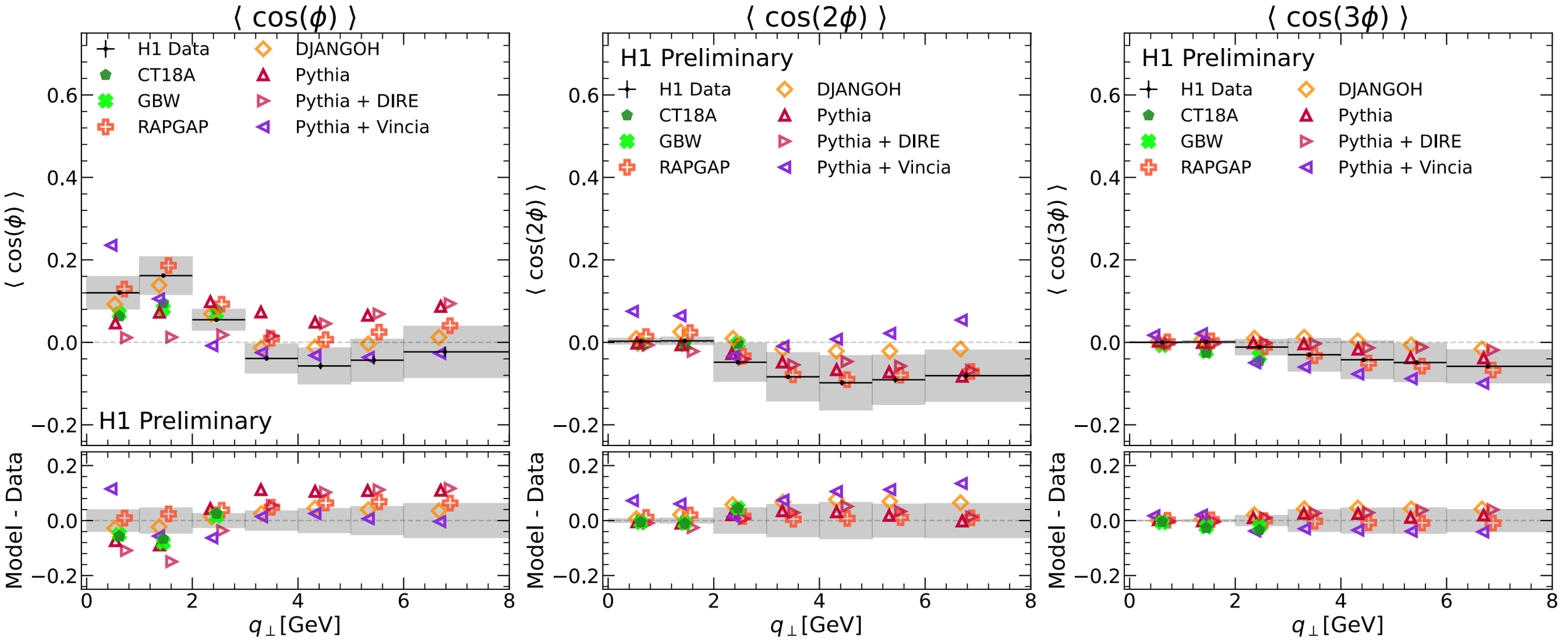
Abstract

Jet-lepton azimuthal asymmetry harmonics are measured in deep inelastic scattering data collected by the H1 detector using HERA Run II collisions. When the average transverse momentum of the lepton-jet system, $|\vec{P}_\perp|$, is much larger than the total transverse momentum of the system, $|\vec{q}_\perp|$, the asymmetry between $\vec{P}_\perp$ and $\vec{q}_\perp$ is expected to be generated by initial and final state soft gluon radiation and can be predicted using perturbation theory. Quantifying the angular properties of the asymmetry therefore provides a novel test of the strong force and is also an important background to constrain for future measurements of intrinsic asymmetries generated by the proton's constituents through Transverse Momentum Dependent (TMD) Parton Distribution Functions (PDF). Moments of the azimuthal asymmetries are measured using a machine learning technique that does not require binning and thus does not introduce discretization artifacts.

Results

Probe soft gluon radiation (as a background to TMDs)



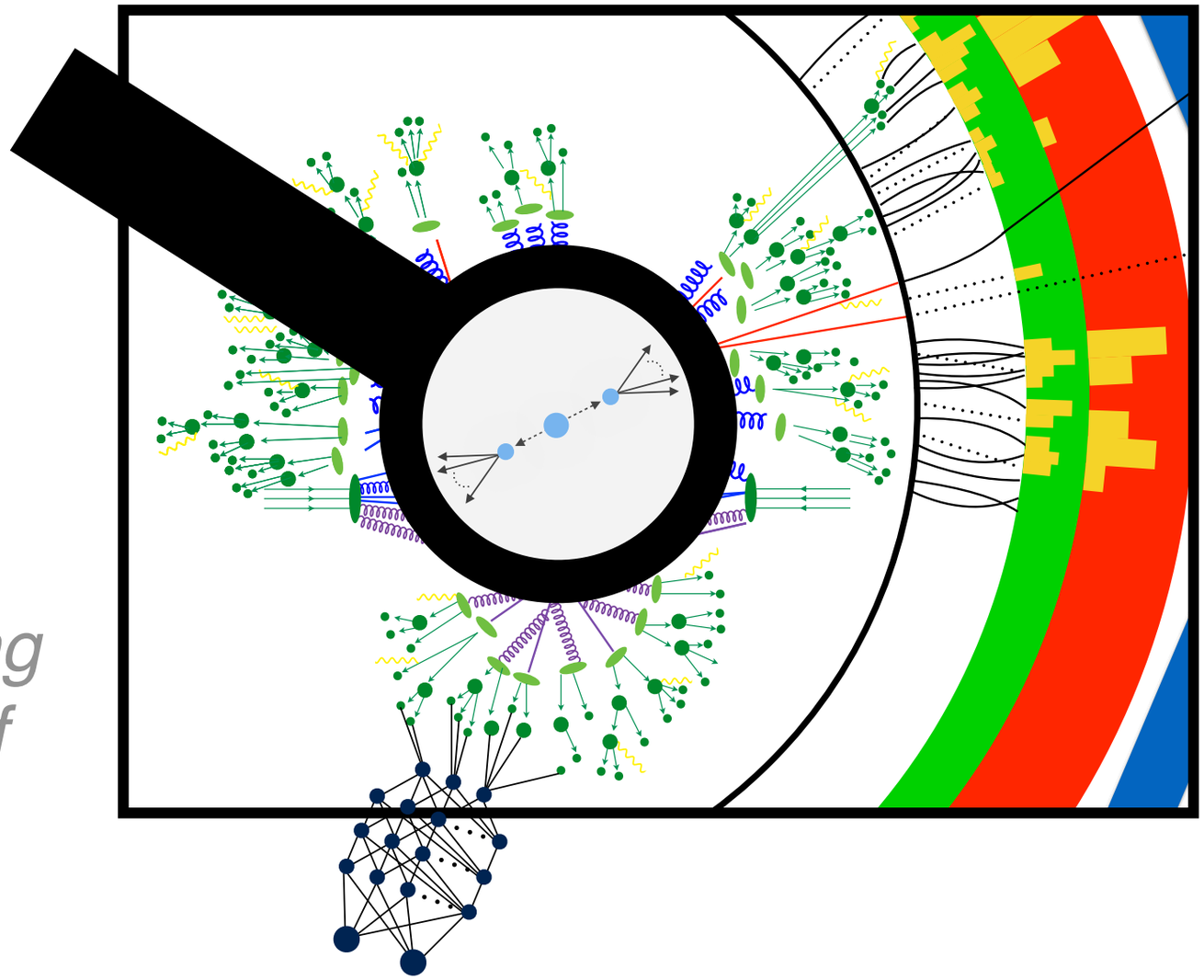


N.B. Pythia not tuned to these data!

Conclusions and outlook

Today, I have presented (reused) ML-based unfolding for studying lepton-jet asymmetries.

This is the beginning of an exciting program to advance our study of QCD into higher dimensions!

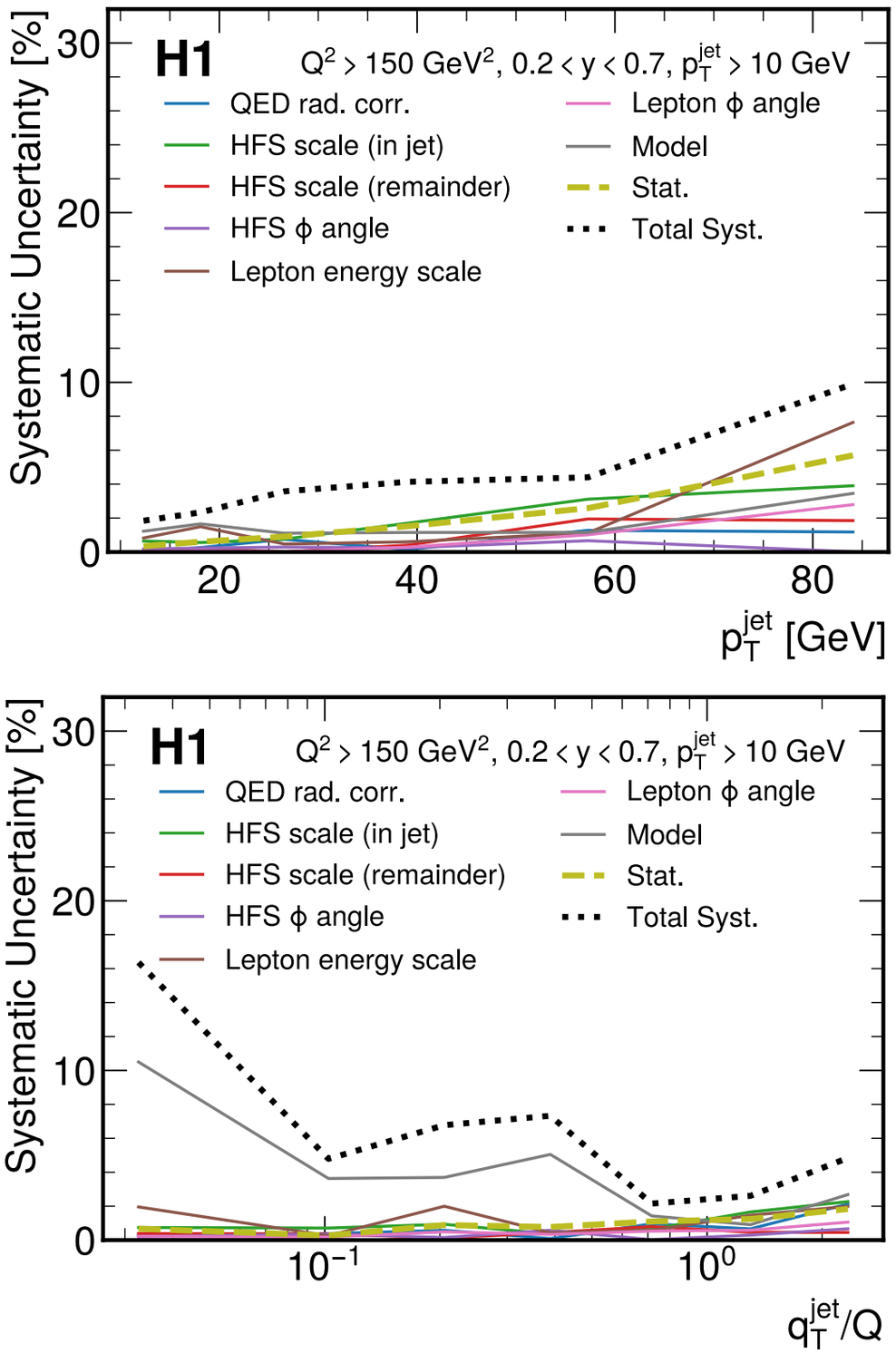


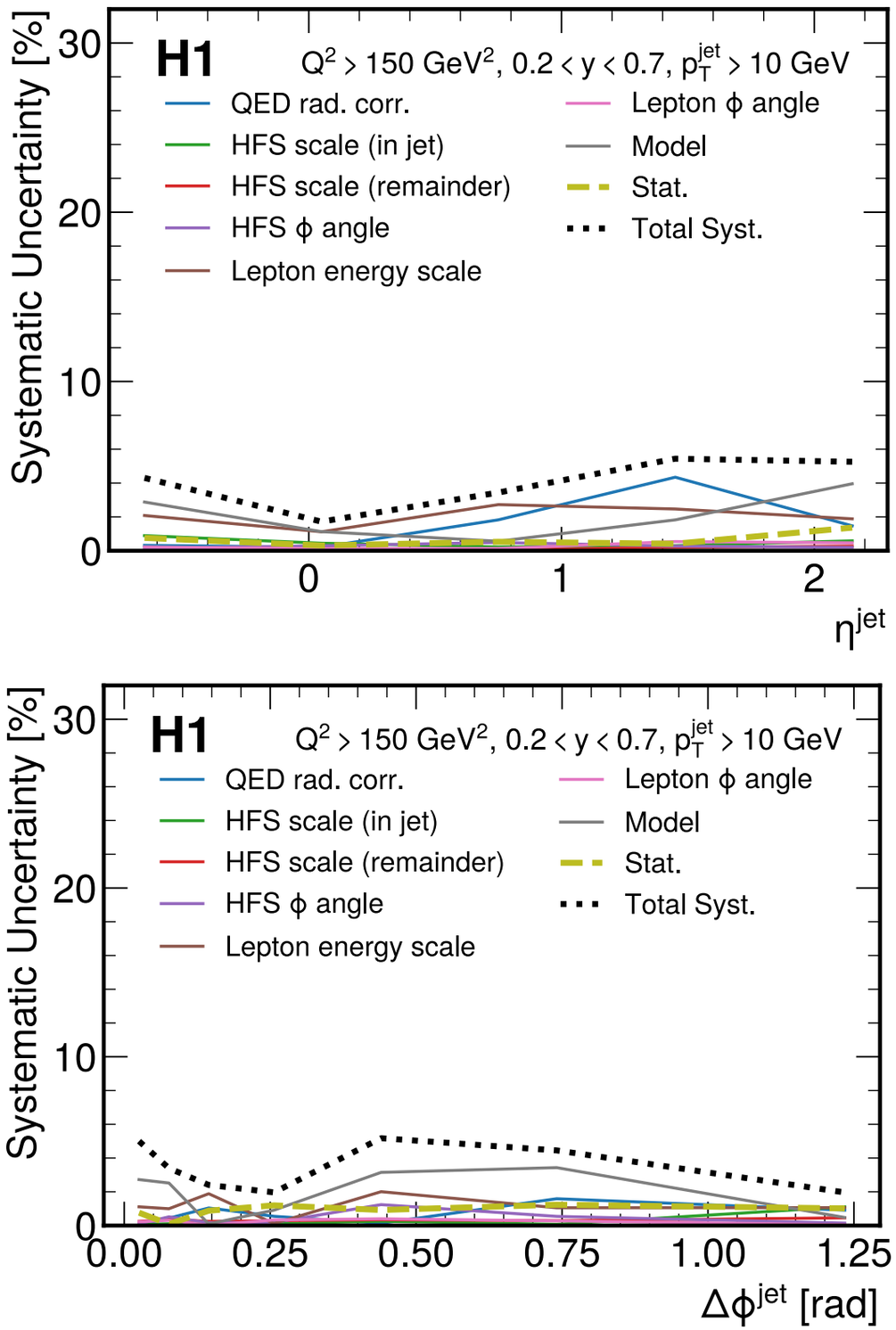
These particular measurements are exciting in their own right and provide a pilot program for the EIC.

Backup

See also this talk by Fernando Torales Acosta!

Results


H1
$Q^2 > 150\ \mathrm{GeV}^2$, $0.2 < y < 0.7$, $p_T^{jet} > 10$ GeV
QED rad. corr.
HFS scale (in jet)
HFS scale (remainder)
HFS ϕ angle
Lepton energy scale
Lepton ϕ angle
Model
Stat.
Total Syst.
Systematic Uncertainty [%]
p_T^{jet} [GeV]
q_T^{jet}/Q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HFS ϕ angle
Lepton energy scale
Lepton ϕ angle
Model
Stat.
Total Syst.
Systematic Uncertainty [%]
η^{jet}
$\Delta\phi^{jet}$ [rad]

Results

Simultaneous for free!
(binning is for illustration)

H1
Stat. Uncertainty

$Q^2 > 150\ \mathrm{GeV}^2$
$0.2 < y < 0.7$
$p_T^{jet} > 10\ \mathrm{GeV}$
k_T, R = 1.0