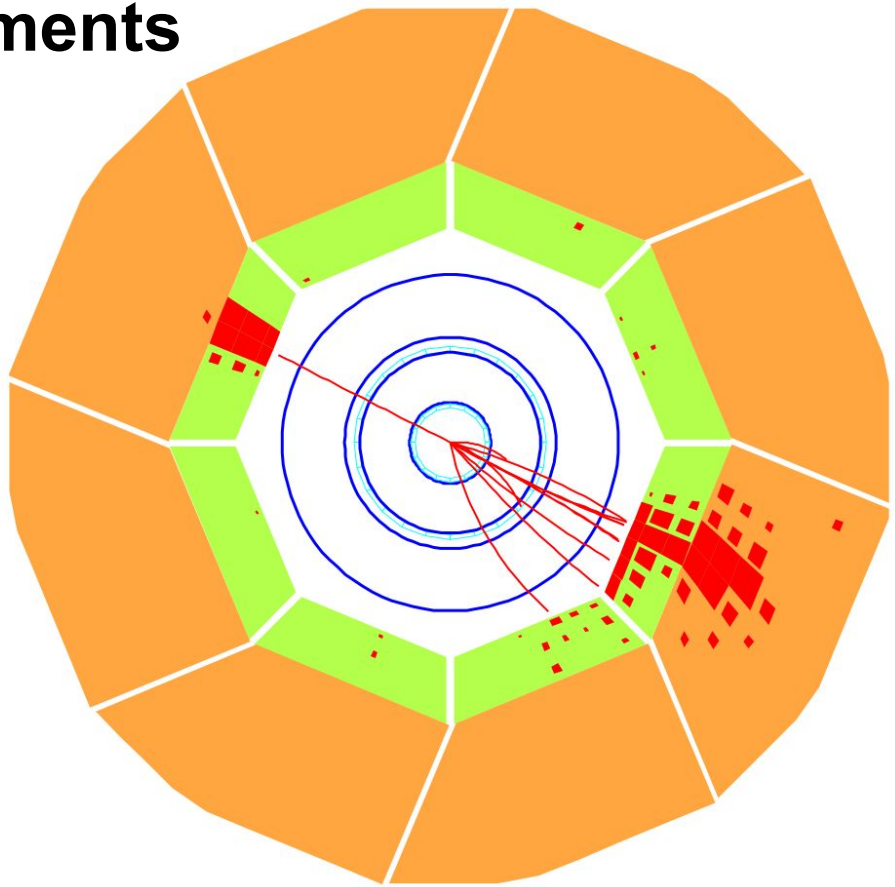
New precision jet measurements in DIS with H1@HERA

Miguel Arratia



Precision QCD predictions for ep Physics at the EIC
1-5 August 2022

Was the HERA jet program not already done?

2019

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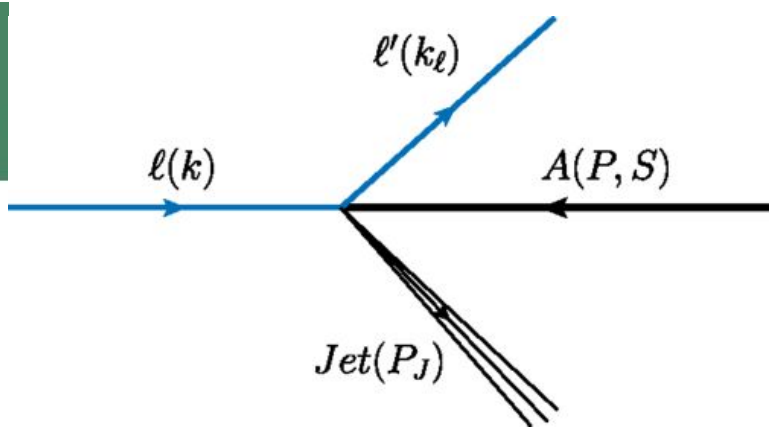
Lepton-Jet Correlations in Deep Inelastic Scattering at the Electron-Ion Collider

Xiaohui Liu, Felix Ringer, Werner Vogelsang, and Feng Yuan

Phys. Rev. Lett. **122**, 192003 – Published 15 May 2019



2018-19

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Transverse-Momentum-Dependent Distributions with Jets

Daniel Gutierrez-Reyes, Ignazio Scimemi, Wouter J. Waalewijn, and Lorenzo Zoppi
Phys. Rev. Lett. **121**, 162001 – Published 16 October 2018

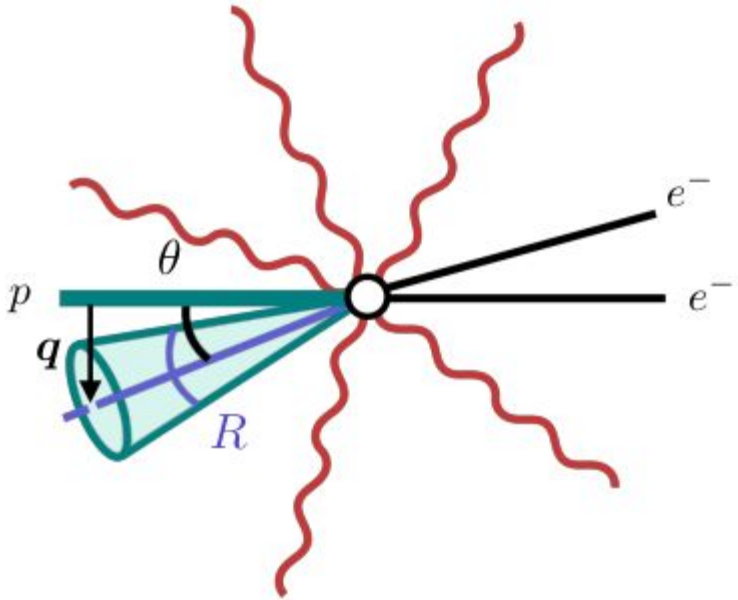
Springer Link

Regular Article - Theoretical Physics | Open Access | Published: 04 October 2019

Transverse momentum dependent distributions in e^+e^- and semi-inclusive deep-inelastic scattering using jets

Daniel Gutierrez-Reyes, Ignazio Scimemi, Wouter J. Waalewijn & Lorenzo Zoppi

Journal of High Energy Physics **2019**, Article number: 31 (2019) | Cite this article



2020-22

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Jet Production in Polarized Deep Inelastic Scattering at Next-to-Next-to-Leading Order

Ignacio Borsa, Daniel de Florian, and Iván Pedron
Phys. Rev. Lett. **125**, 082001 – Published 21 August 2020

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Inclusive-jet and dijet production in polarized deep inelastic scattering

Ignacio Borsa, Daniel de Florian, and Iván Pedron
Phys. Rev. D **103**, 014008 – Published 8 January 2021

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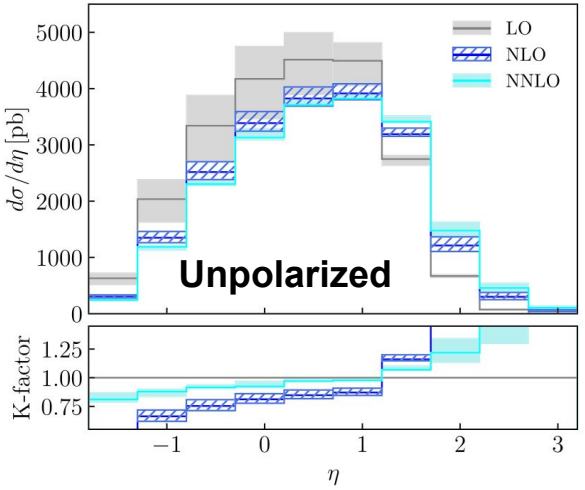
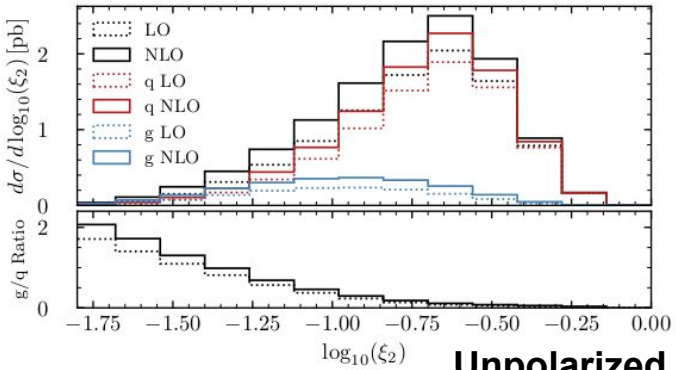
Dijet production in neutral current and charged current polarized deep inelastic scattering

Ignacio Borsa, Daniel de Florian, and Iván Pedron
Phys. Rev. D **105**, 074025 – Published 25 April 2022

Progress for polarized DIS motivates new unpolarized reference measurements …





2021

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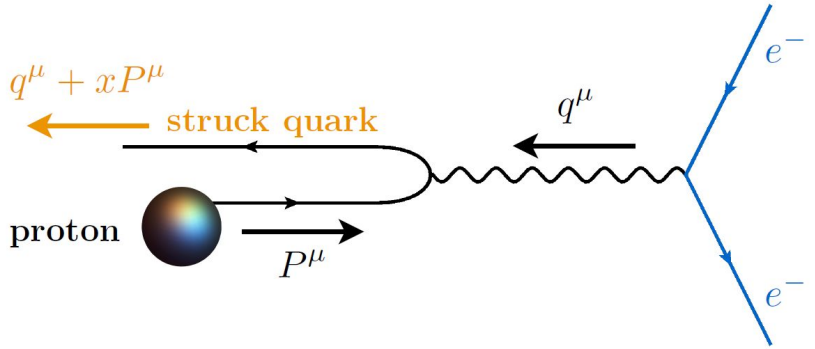
Asymmetric jet clustering in deep-inelastic scattering

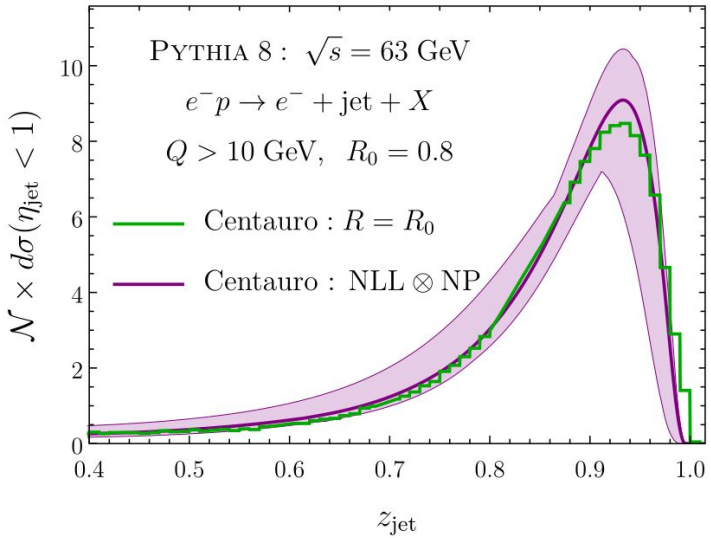
M. Arratia, Y. Makris, D. Neill, F. Ringer, and N. Sato
Phys. Rev. D **104**, 034005 – Published 9 August 2021



Centauro jet algorithm

$$d_{ij} = (\bar{\eta}_i - \bar{\eta}_j)^2 + 2\bar{\eta}_i\bar{\eta}_j(1 - \cos(\phi_i - \phi_j))$$

$$\bar{\eta}_i \equiv -\frac{2Q}{\bar{n}\cdot q}\frac{p_i^\perp}{n\cdot p_i}$$



2020

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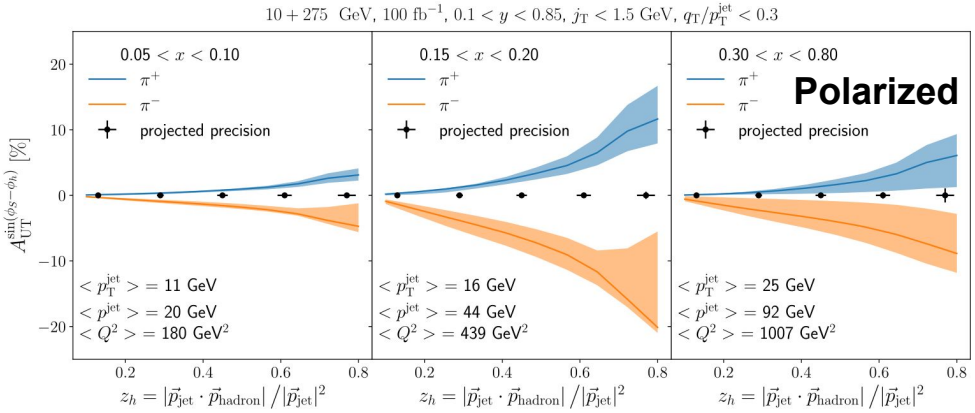
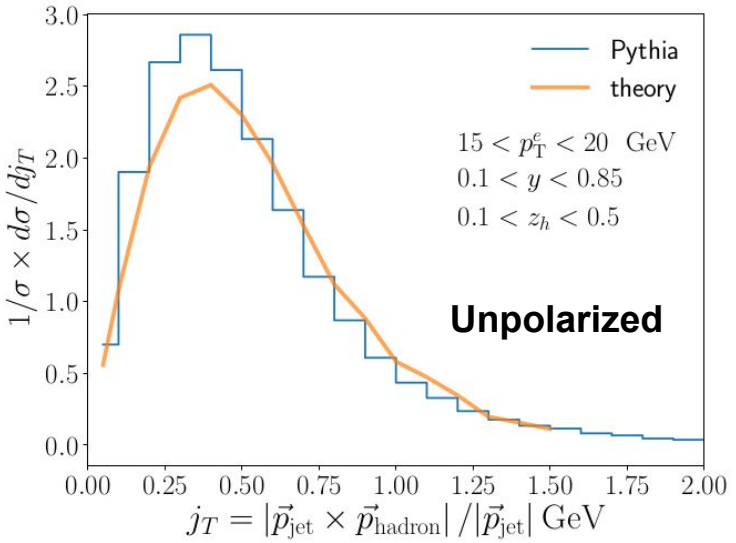
Jet-based measurements of Sivers and Collins asymmetries at the future electron-ion collider

Miguel Arratia, Zhong-Bo Kang, Alexei Prokudin, and Felix Ringer
Phys. Rev. D **102**, 074015 – Published 22 October 2020



"Hadron in jet measurements in DIS"



Springer Link

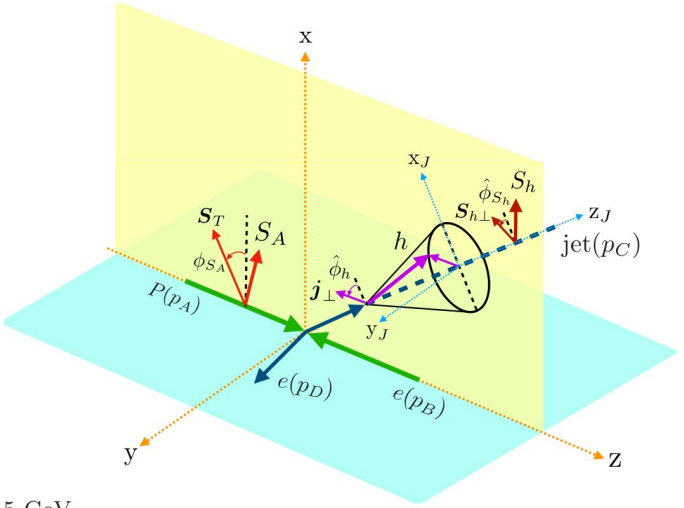
2021

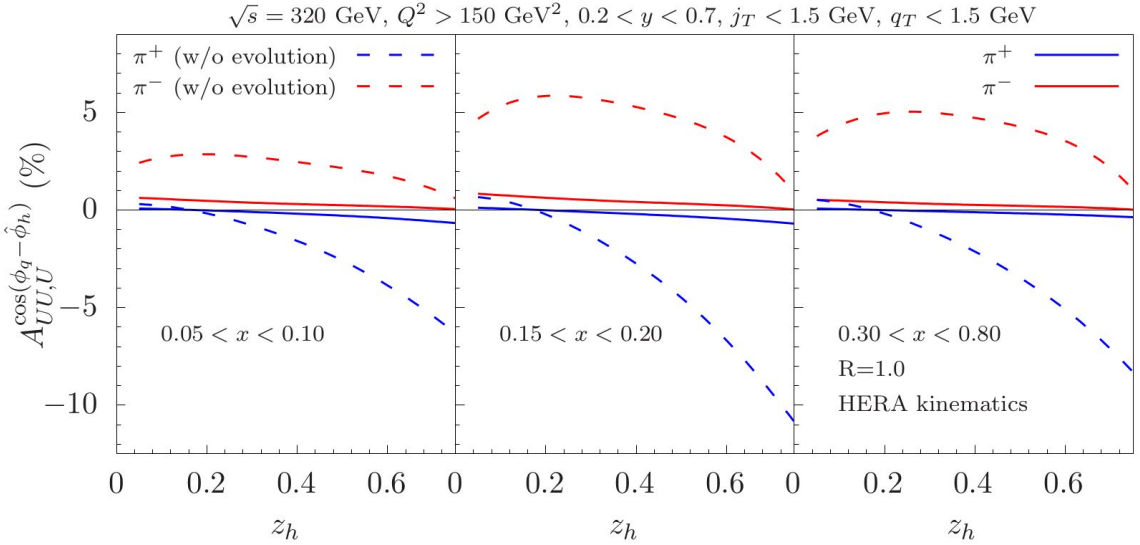
Regular Article - Theoretical Physics | Open Access | Published: 02 November 2021

Spin asymmetries in electron-jet production at the future electron ion collider

Zhong-Bo Kang, Kyle Lee ✉, Ding Yu Shao & Fanyi Zhao

Journal of High Energy Physics **2021**, Article number: 5 (2021) | Cite this article





Prediction for HERA

2021

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Anisotropy in Dijet Production in Exclusive and Inclusive Processes

Yoshitaka Hatta, Bo-Wen Xiao, Feng Yuan, and Jian Zhou
Phys. Rev. Lett. **126**, 142001 – Published 6 April 2021

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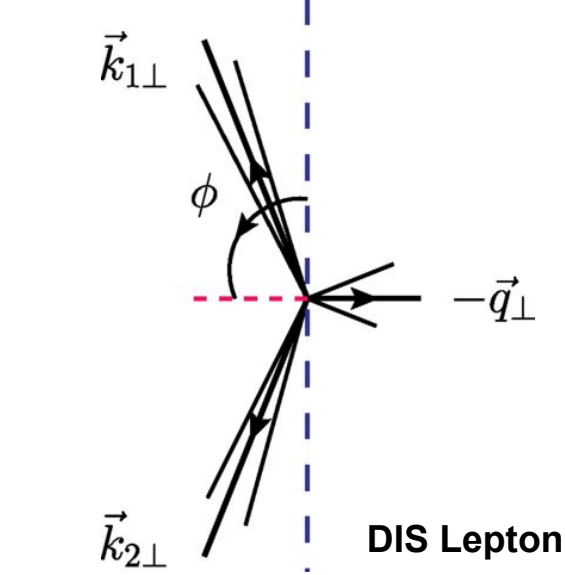
Azimuthal angular asymmetry of soft gluon radiation in jet production

Yoshitaka Hatta, Bo-Wen Xiao, Feng Yuan, and Jian Zhou
Phys. Rev. D **104**, 054037 – Published 27 September 2021



DIS Lepton-jet

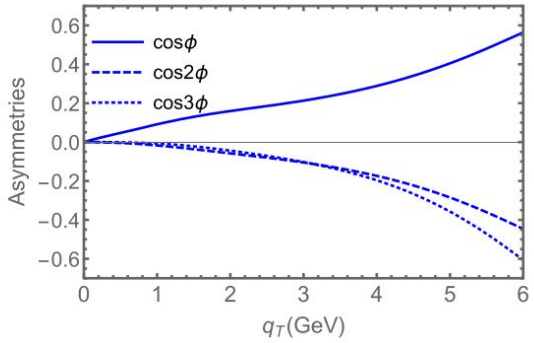
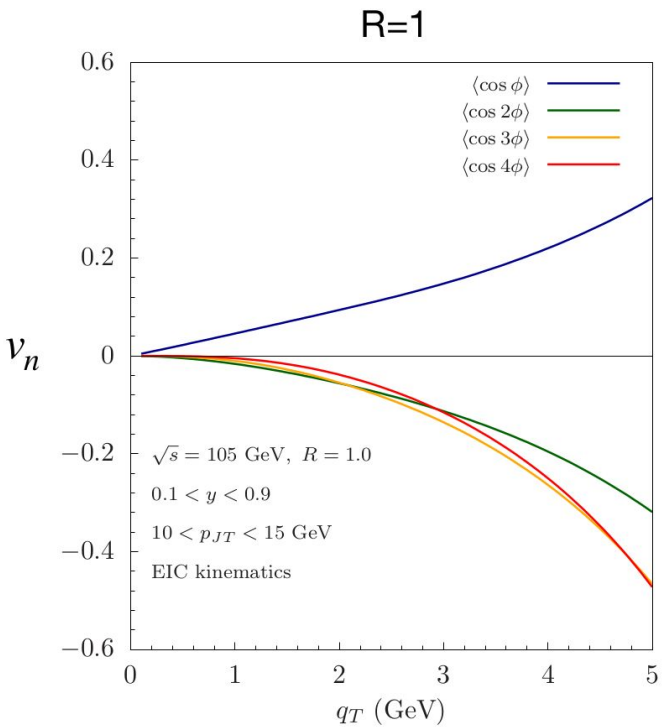
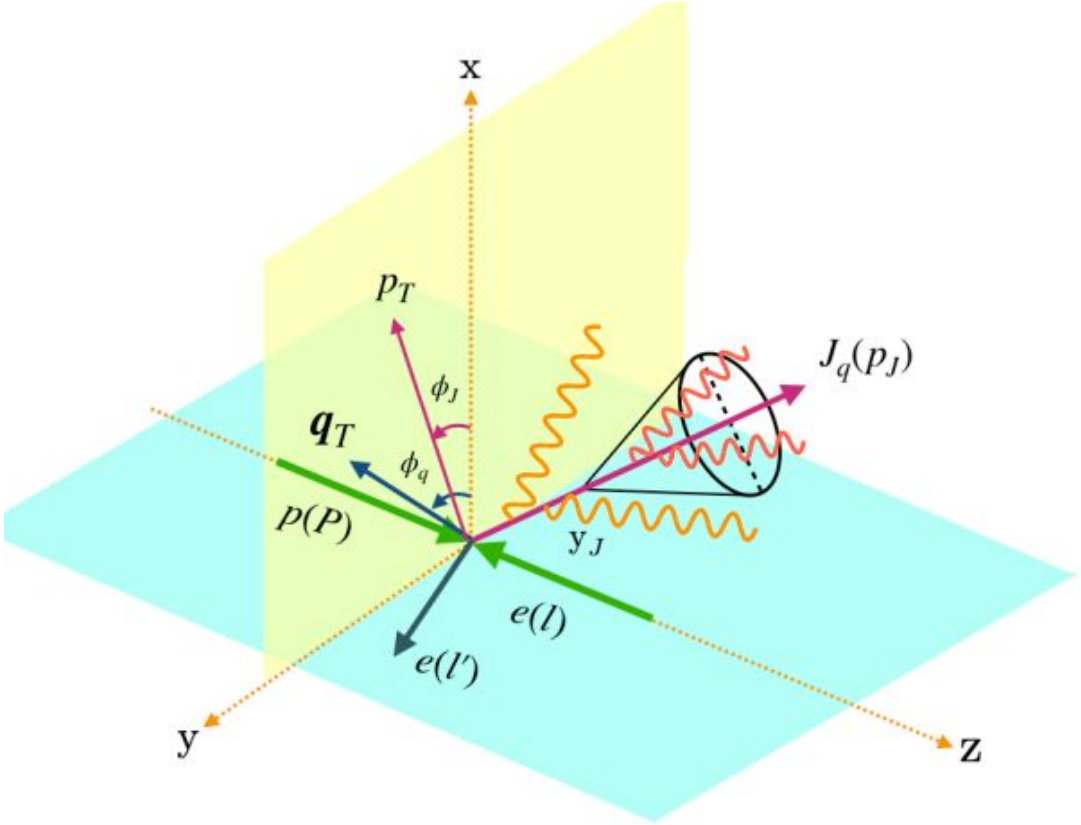


FIG. 4. Azimuthal asymmetries in lepton-jet production in ep collisions at $\sqrt{s} = 140\,\text{GeV}$, $P_\perp = 20\,\text{GeV}$, $y_l = 1.5$, $Q = 25\,\text{GeV}$, $g_\Lambda = 0.1$ GeV with different jet cone sizes $R = 0.4$ (top panel) and $R = 1.0$ (bottom panel).

F. Zhao et al. DIS 2022: Jet azimuthal anisotropy in ep collisions





2020

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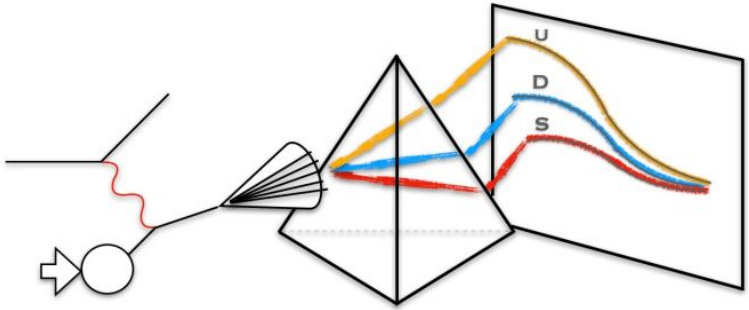
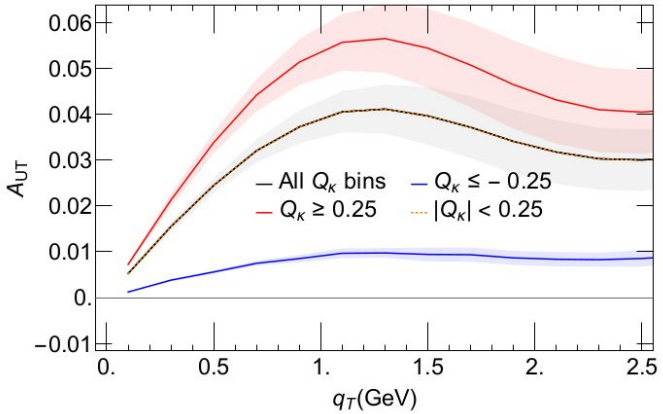
Jet Charge: A Flavor Prism for Spin Asymmetries at the Electron-Ion Collider

Zhong-Bo Kang, Xiaohui Liu, Sonny Mantry, and Ding Yu Shao
Phys. Rev. Lett. **125**, 242003 – Published 8 December 2020





2022

KeAi
CHINESE ROOTS GLOBAL IMPACT

Fundamental Research

Available online 3 March 2022

In Press, Corrected Proof

Article

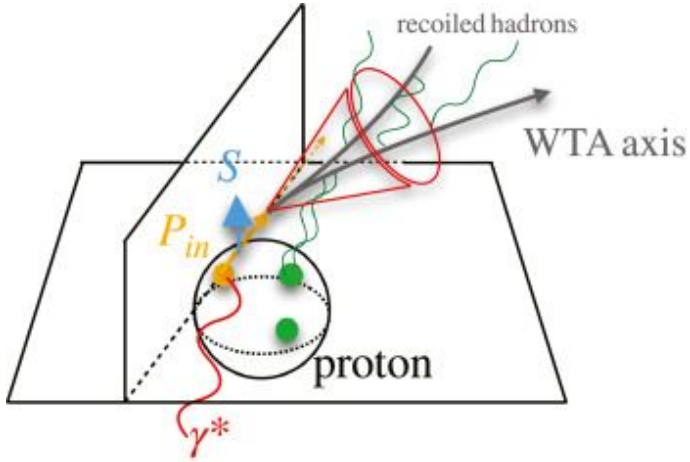
The time-reversal odd side of a jet

Xiaohui Liu [a, b], Hongxi Xing [c, d]

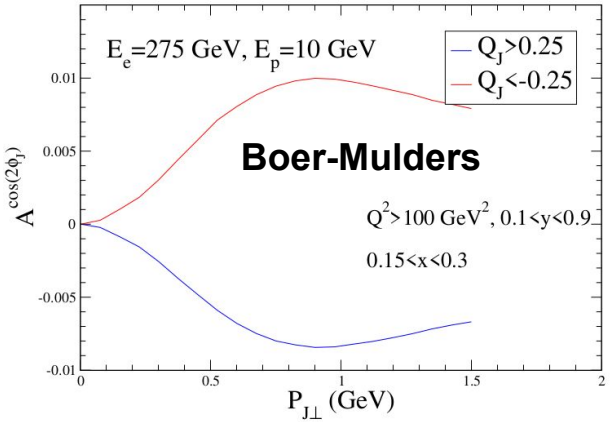
Unveiling Nucleon 3D Chiral-Odd Structure with Jet Axes

Wai Kin Lai (South China Normal U. and UCLA), Xiaohui Liu (Beijing Normal U. and Peking U., CHEP), Manman Wang (Beijing Normal U.), Hongxi Xing (South China Normal U.)

May 9, 2022

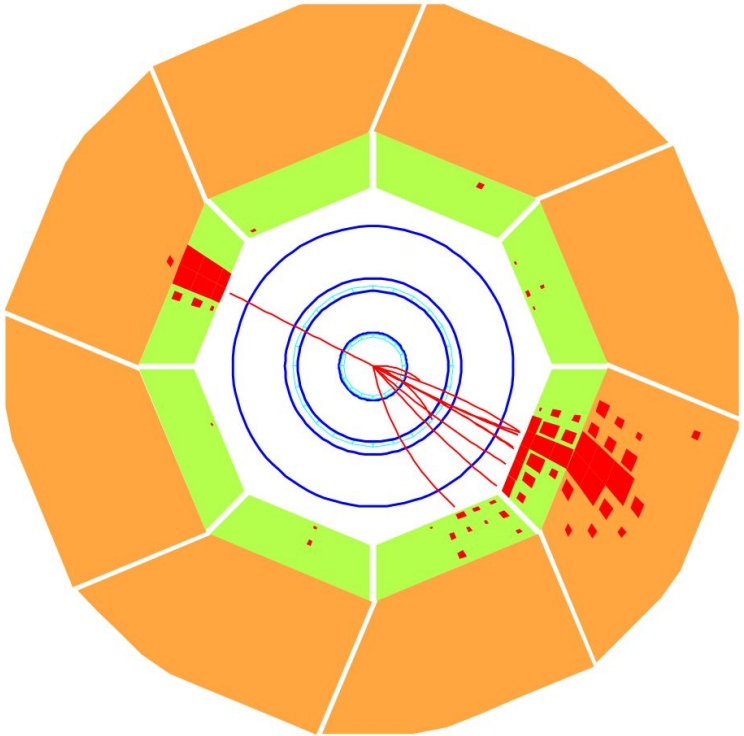


$e+p \rightarrow e+J_{WTA}+X$ (EIC)



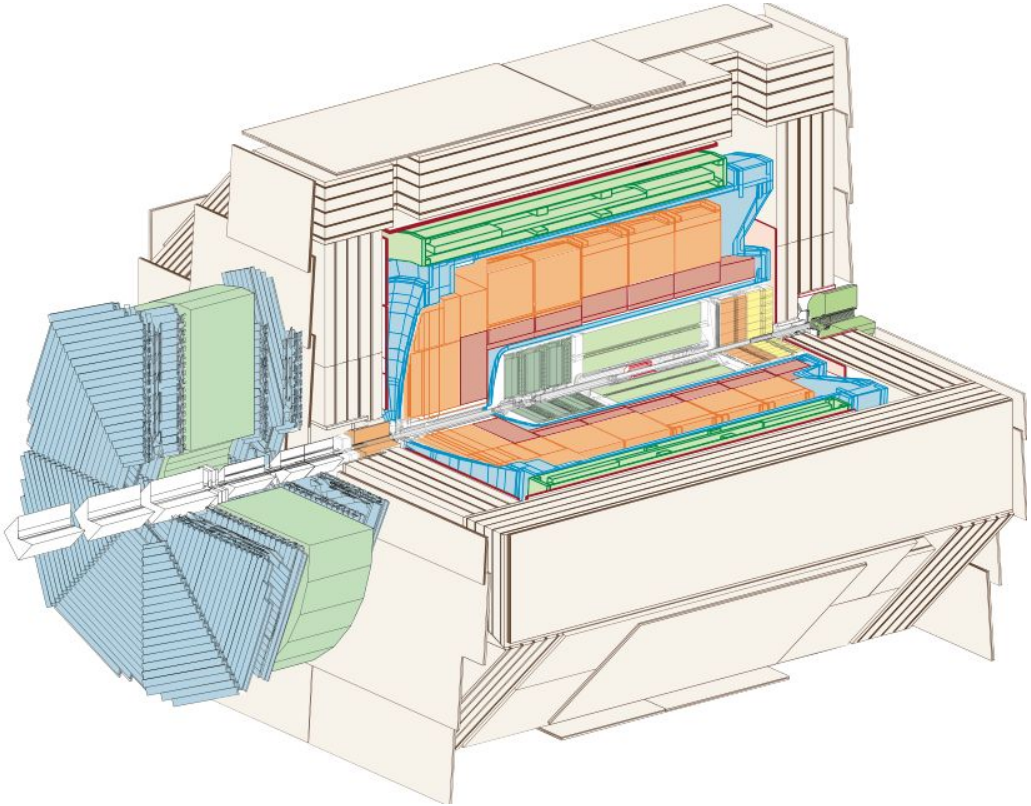
Was the HERA jet program not already done?

NOT QUITE YET…




BACK
TO THE FUTURE

The H1 experiment at HERA

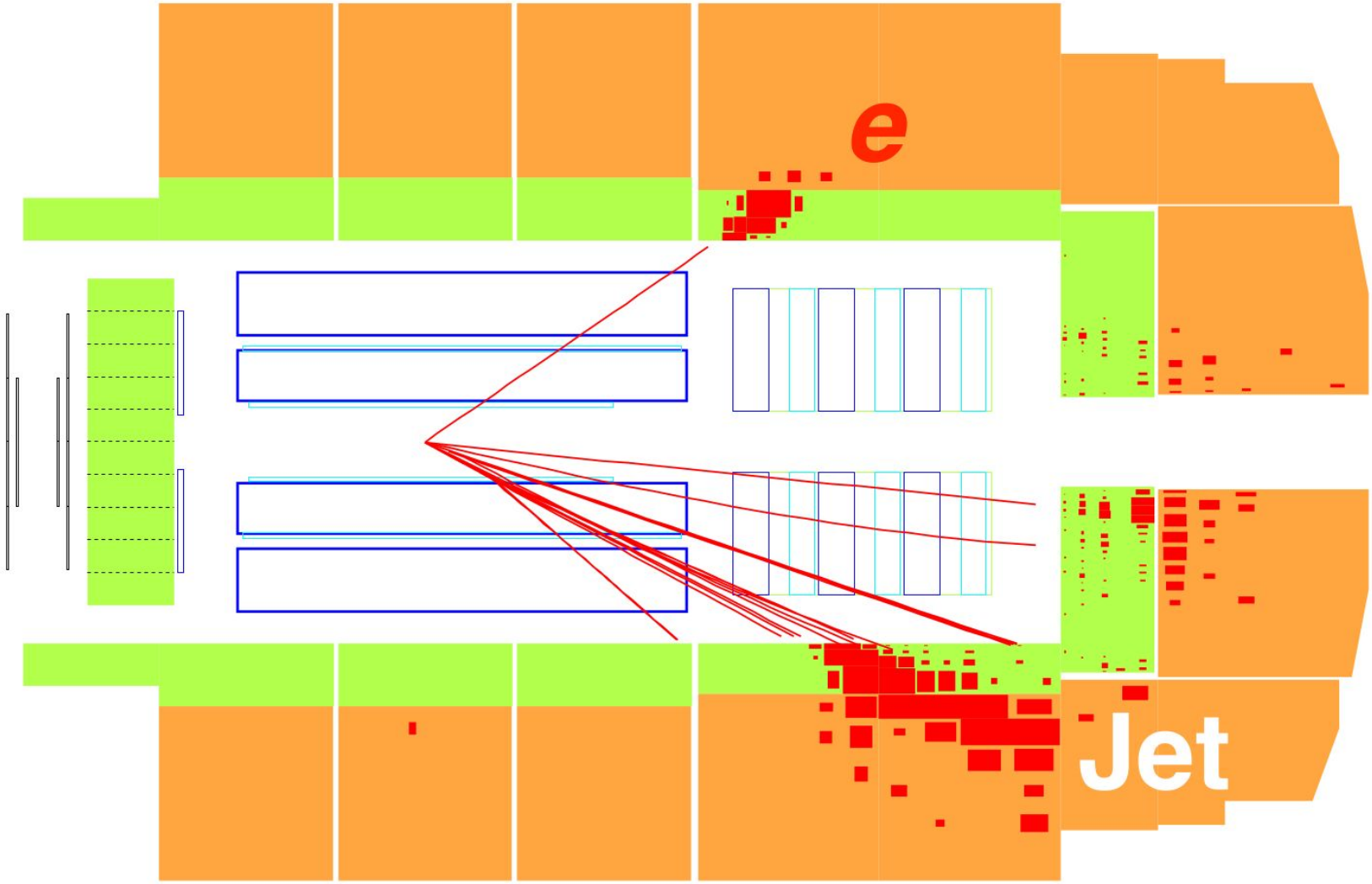


- Tracking system
(silicon tracker, jet chambers, proportional chambers)
- LAr calorimeter (em/had)
- Scintillating fiber calorimeter

Both combined using an energy flow algorithm

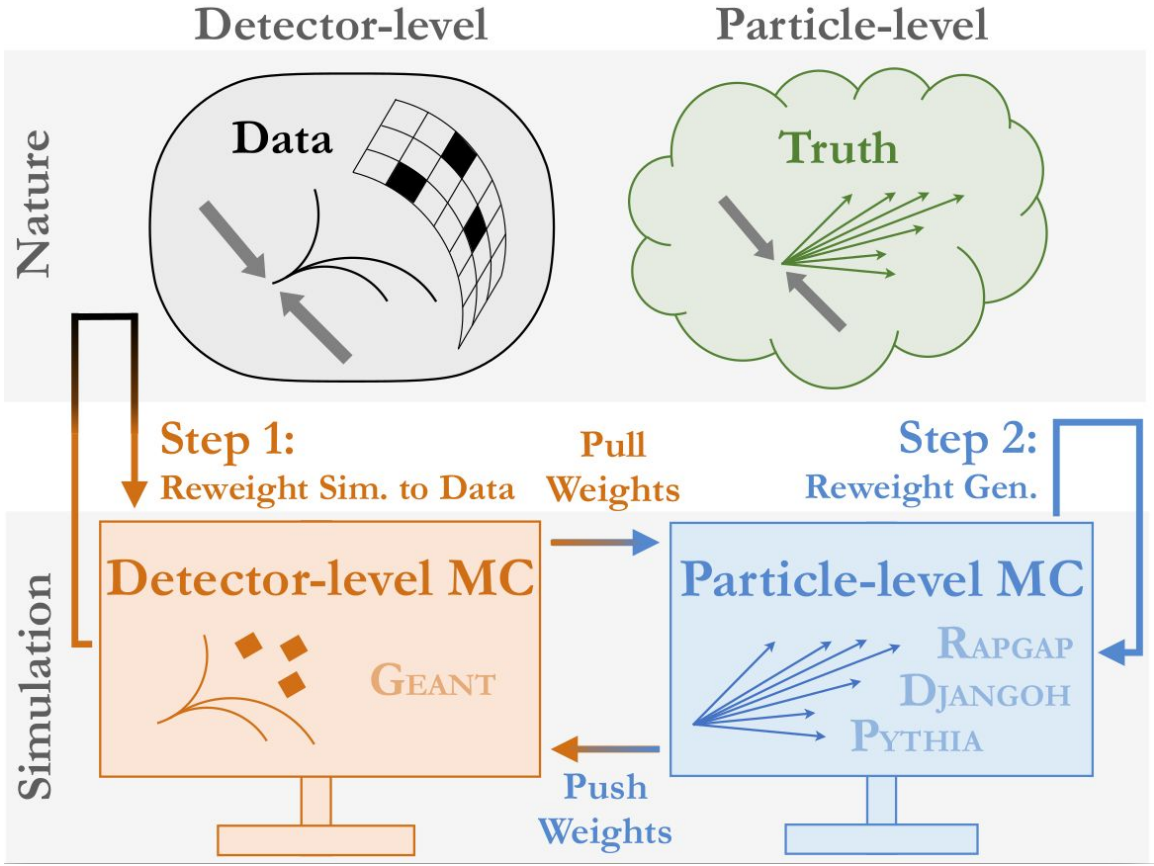
1% Jet energy scale

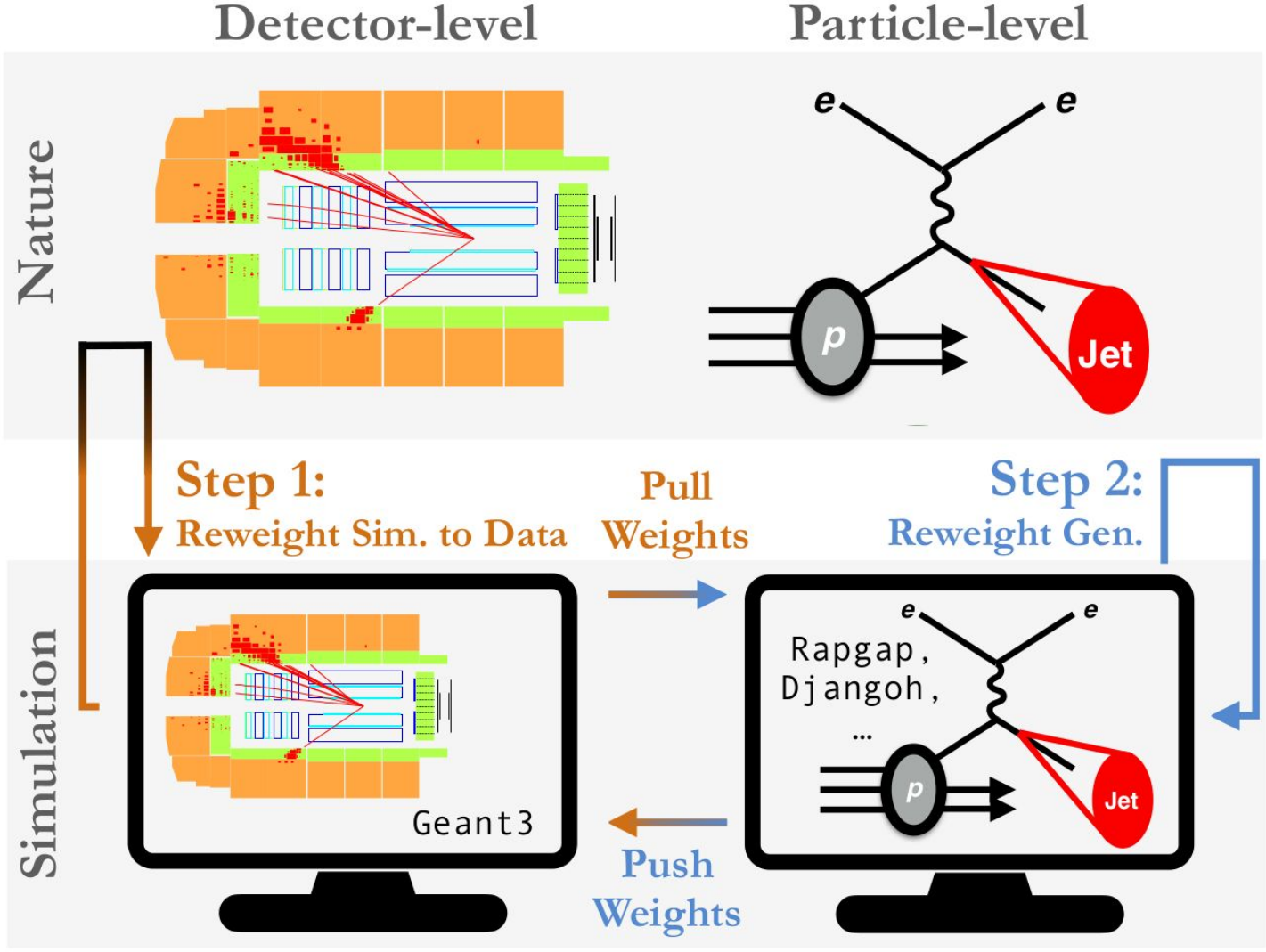
0.5-1% lepton energy scale


e
Jet

Unfolding with Omnifold (via machine-learning).

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




Detector-level
Particle-level
Nature
e
e
p
Jet
Step 1:
Reweight Sim. to Data
Pull
Weights
Step 2:
Reweight Gen.
Simulation
Geant3
Rapgap,
Djangoh,
...
e
e
p
Jet
Push
Weights

2022

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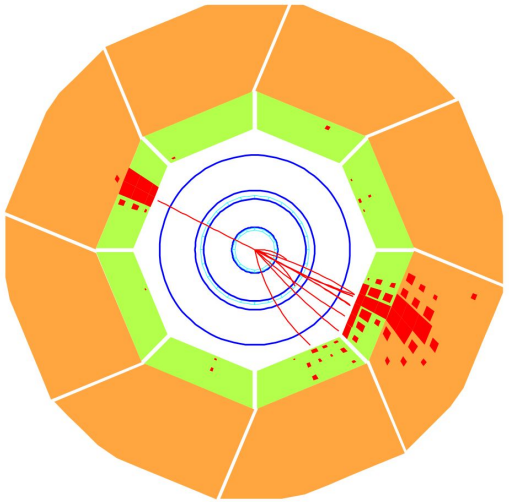
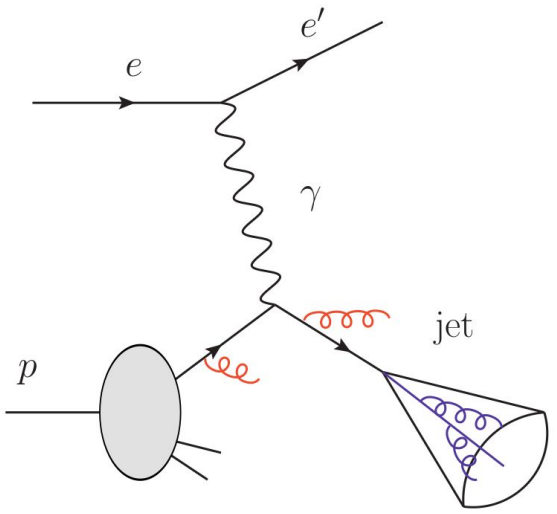
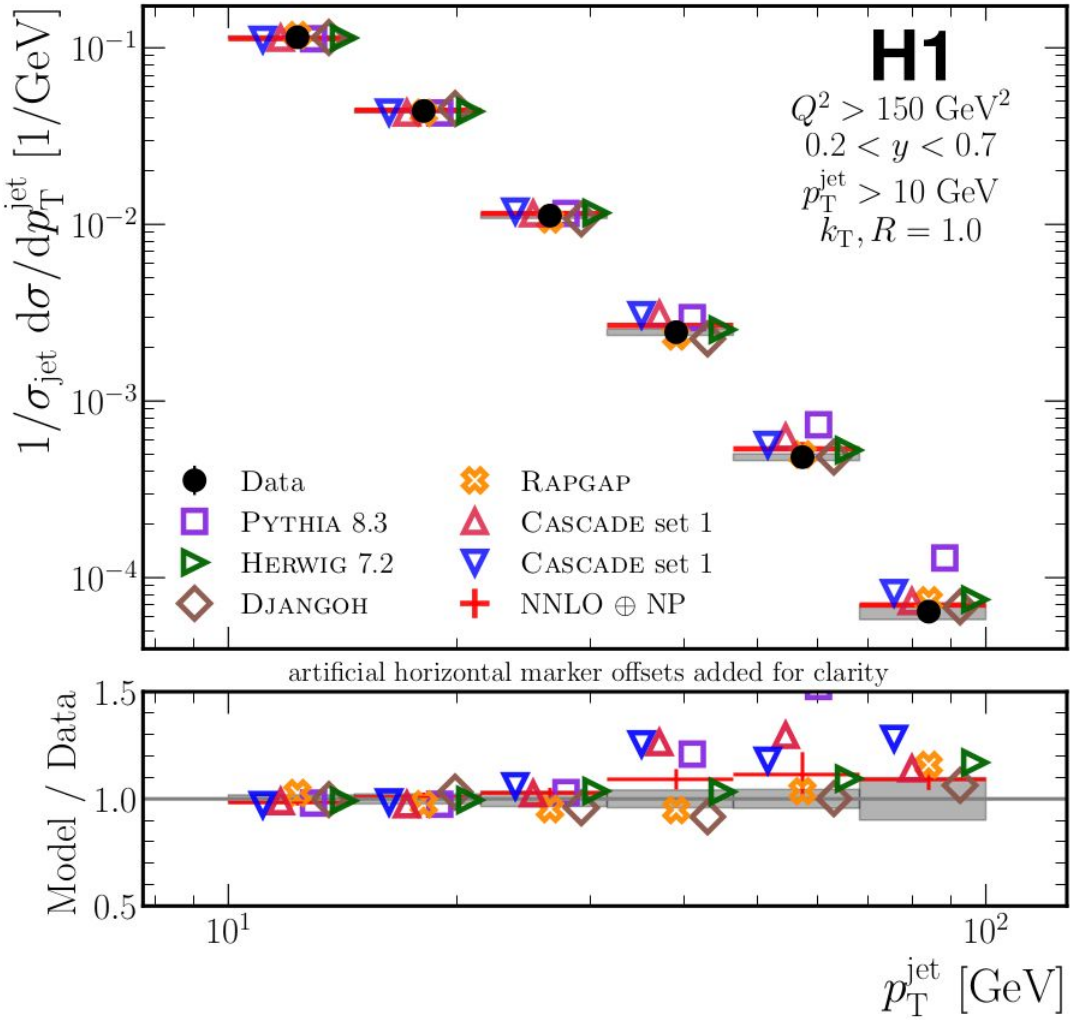
Measurement of Lepton-Jet Correlation in Deep-Inelastic Scattering with the H1 Detector Using Machine Learning for Unfolding

V. Andreev *et al.* (H1 Collaboration)
Phys. Rev. Lett. **128**, 132002 – Published 31 March 2022

Article | References | No Citing Articles | Supplemental Material | PDF | HTML | Export Citation

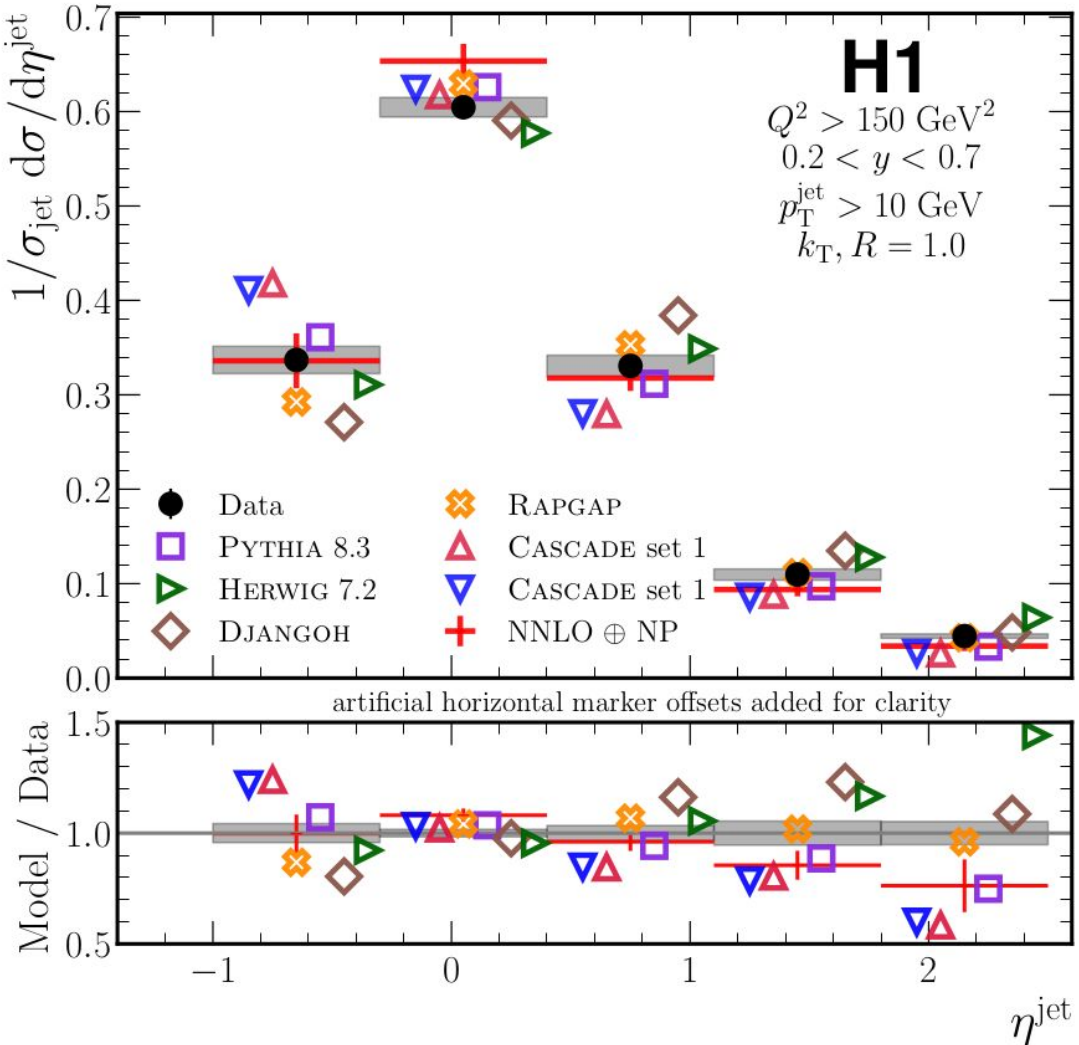






Jet transverse momentum

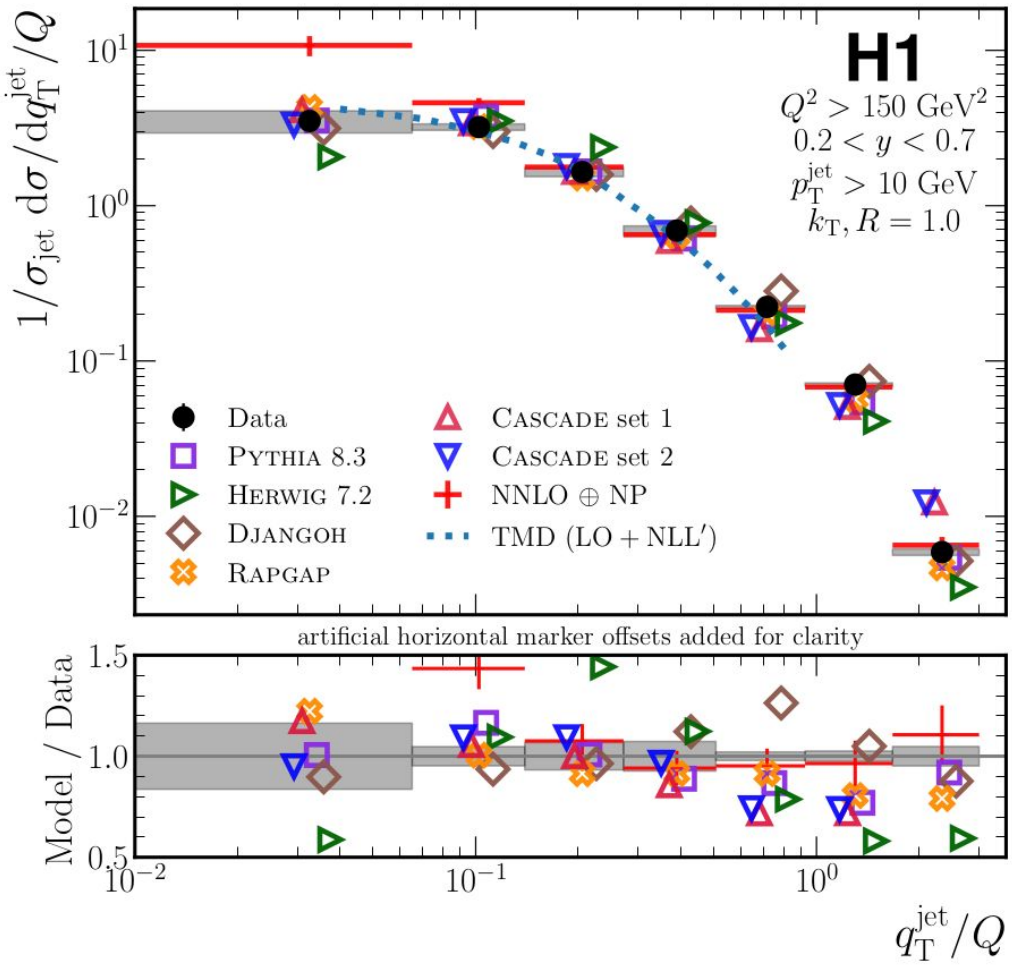
Well described by NNLO calculation, and some MCs like Herwig and Djangoh



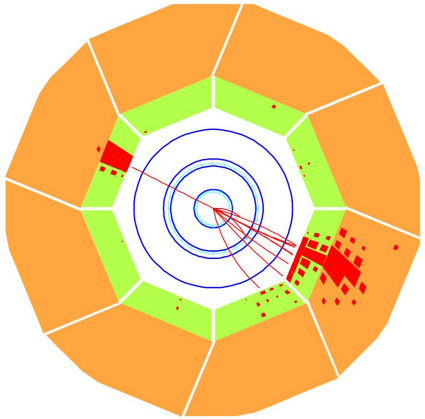
Jet pseudorapidity

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

Well described by Rapgap

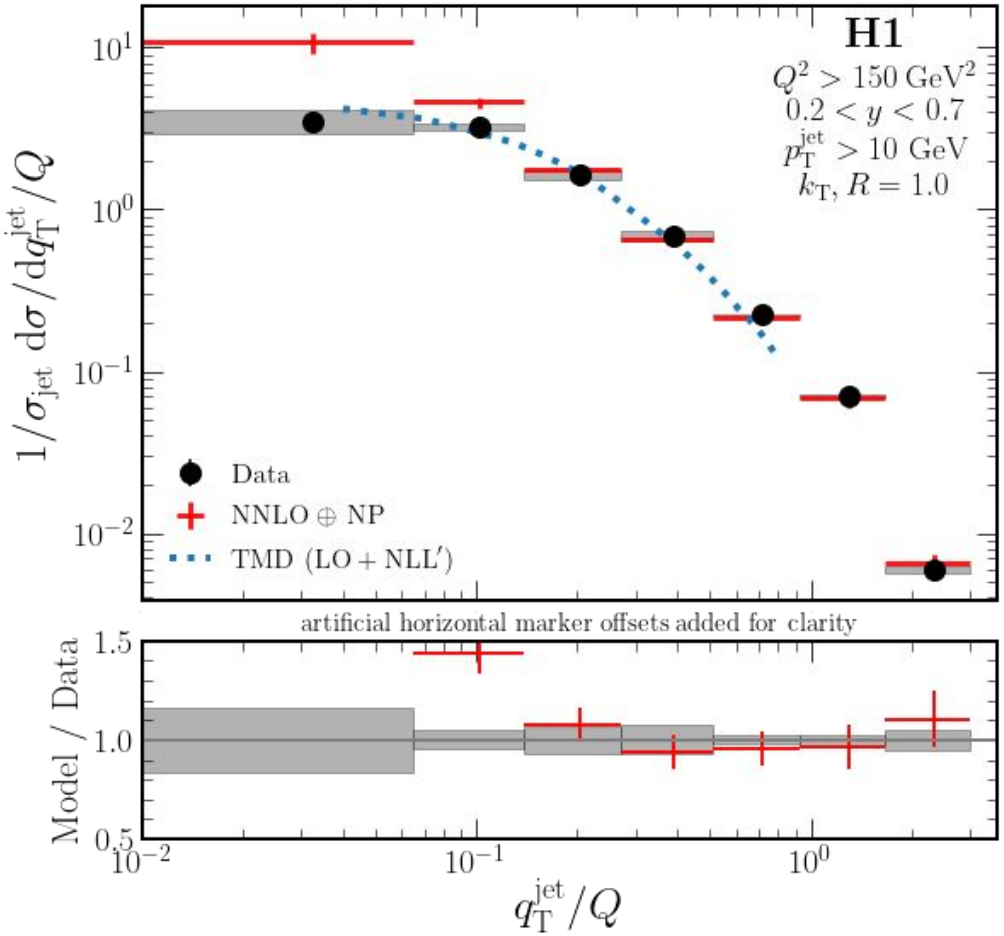


Lepton-jet momentum imbalance $q_T = |\vec{p}_T^{\,e} + \vec{p}_T^{\,\text{jet}}|$



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

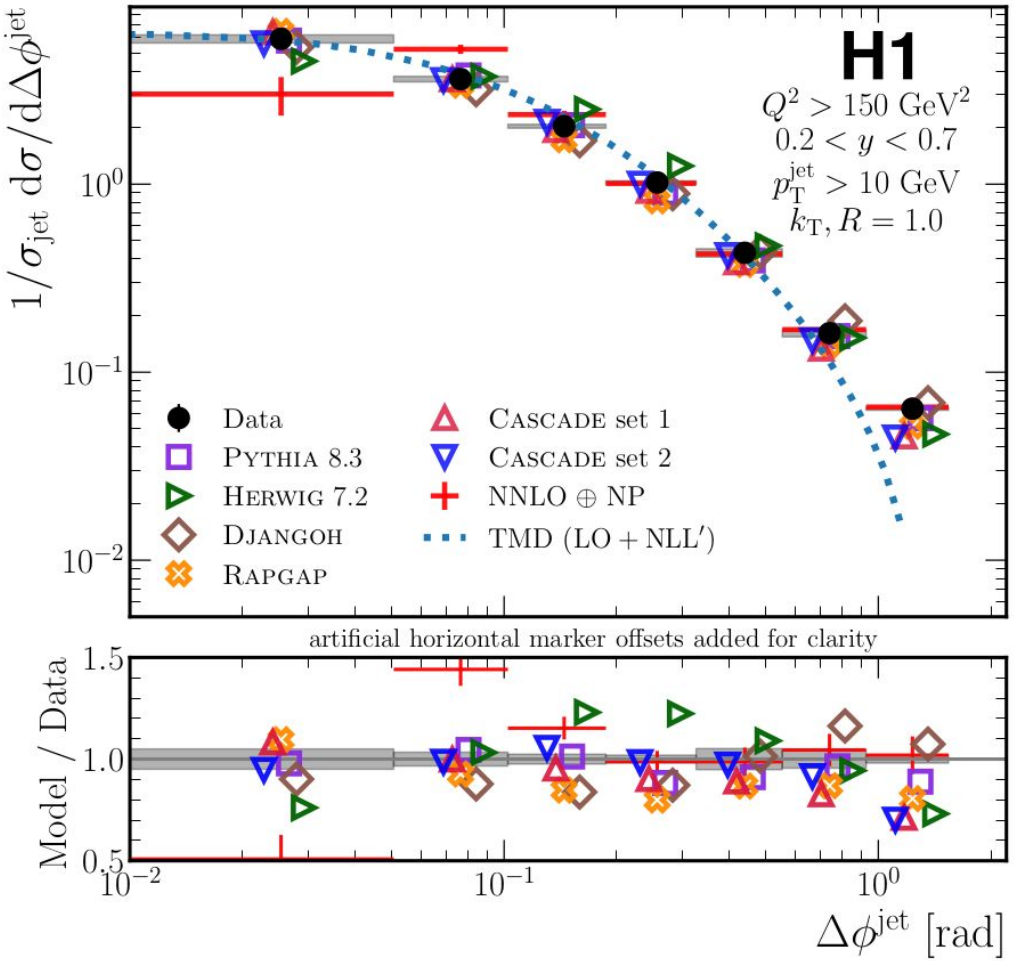


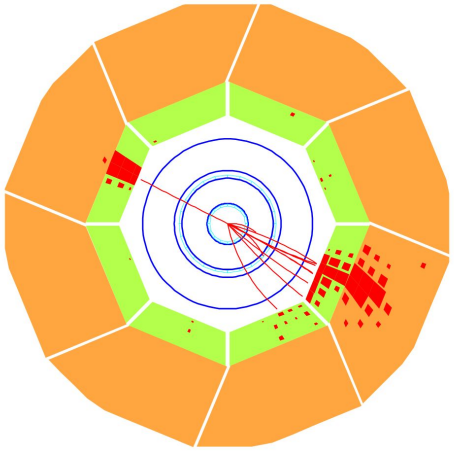
Textbook example of "matching" between collinear and TMD frameworks

First time seen in DIS!

(not seen in fixed-target DIS)

Lepton-jet azimuthal correlations



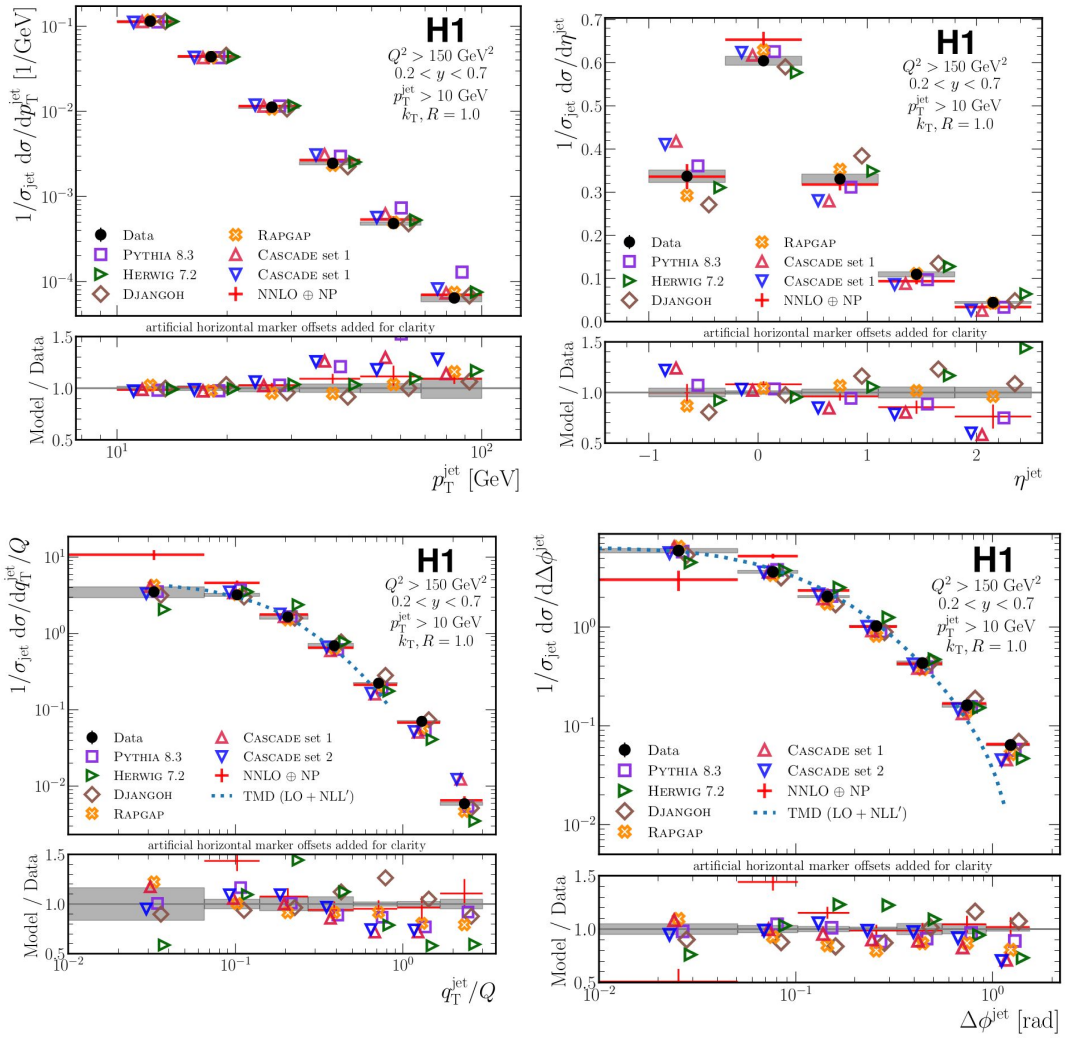


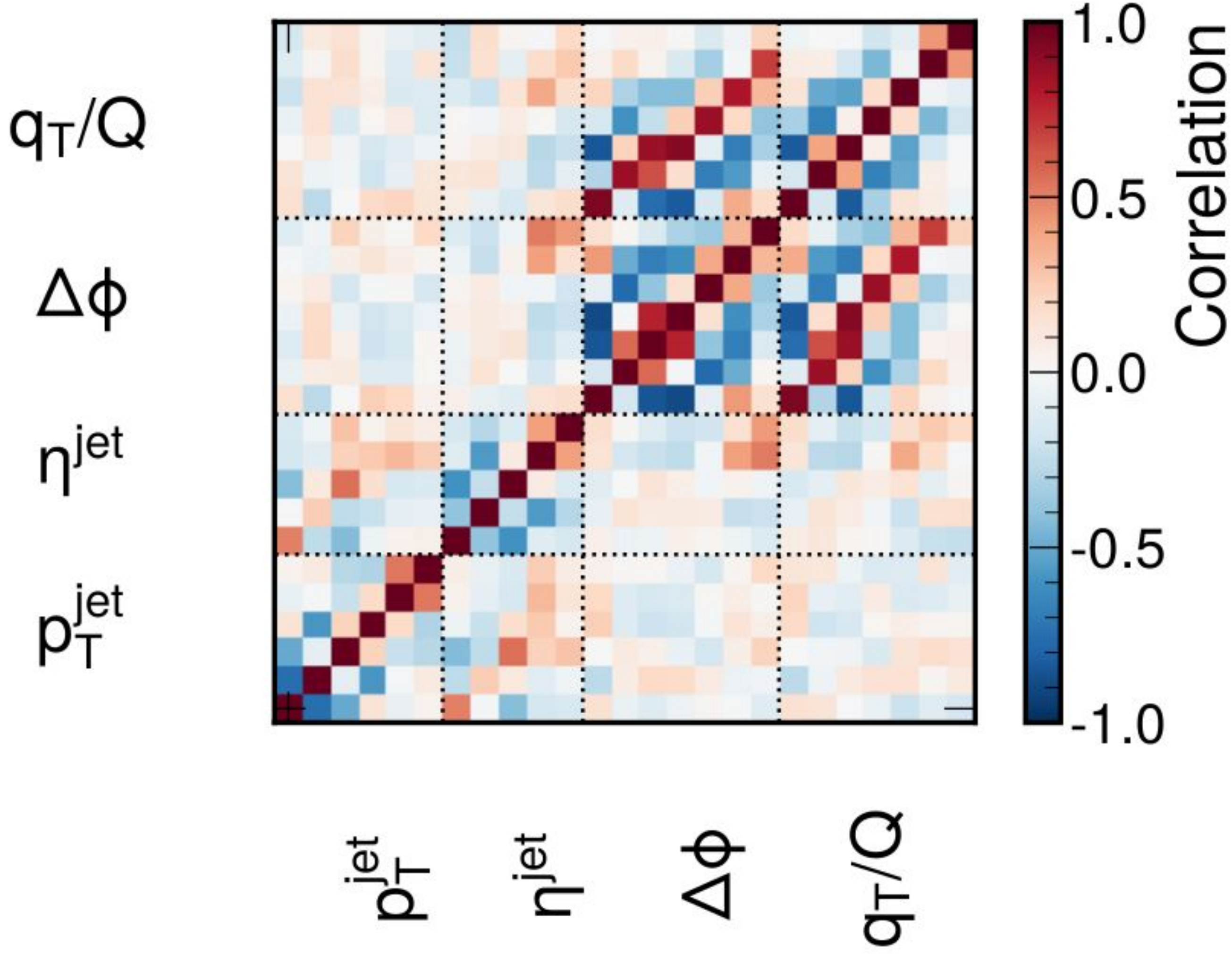
TMD calculation does a great job at low qT; collinear calculation does a great job at large qT.

Large overlap between collinear and TMD frameworks

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

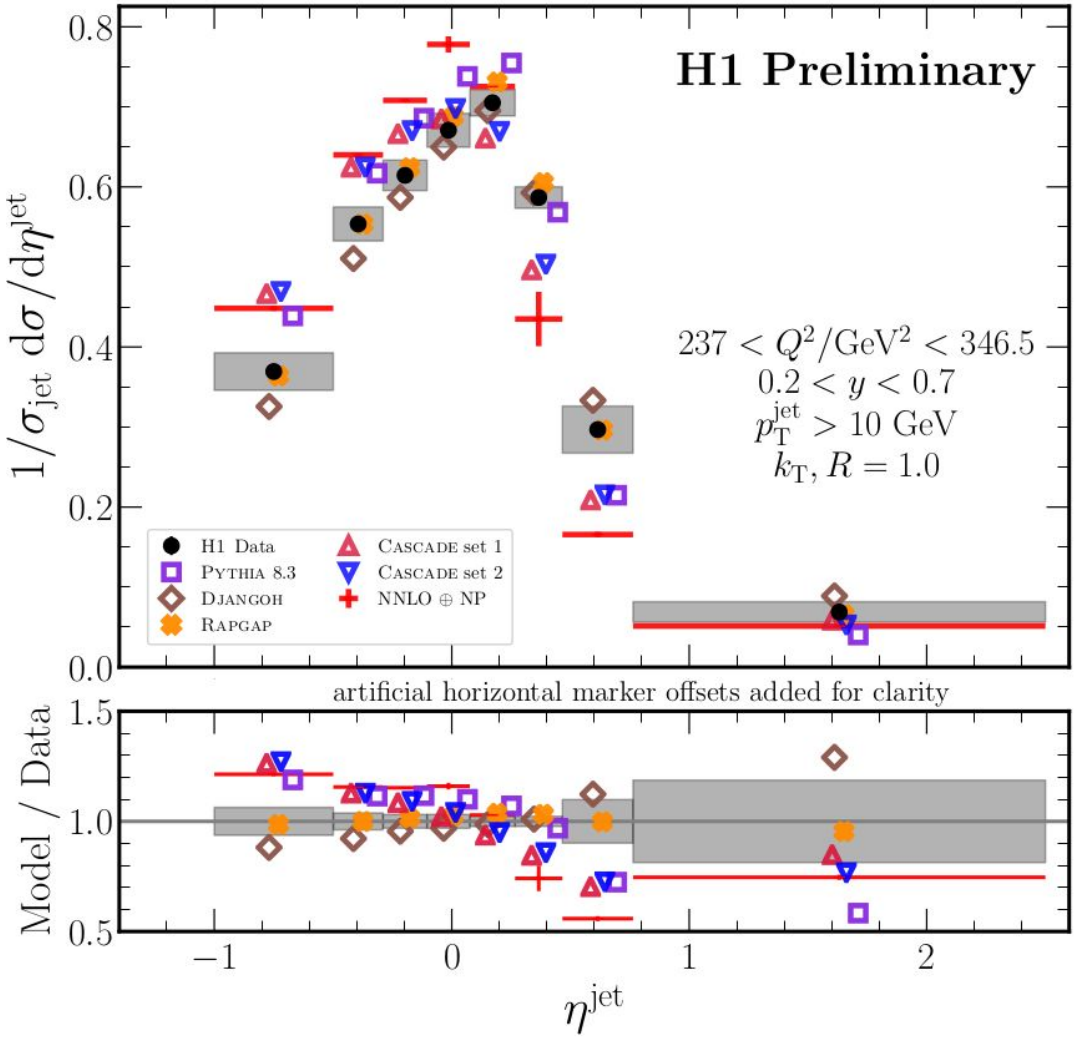
First-ever measurement that uses machine-learning to correct for detector effects.

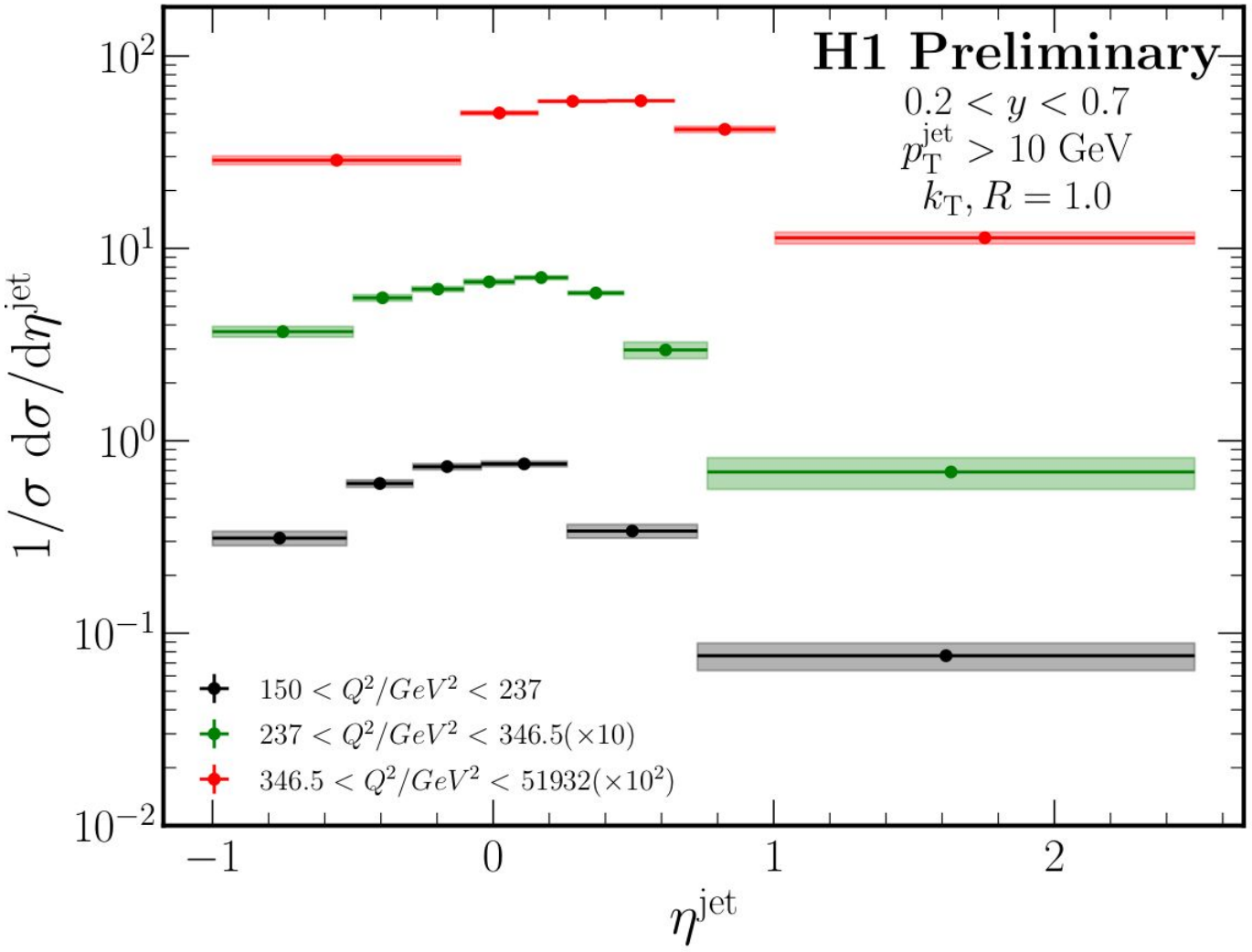




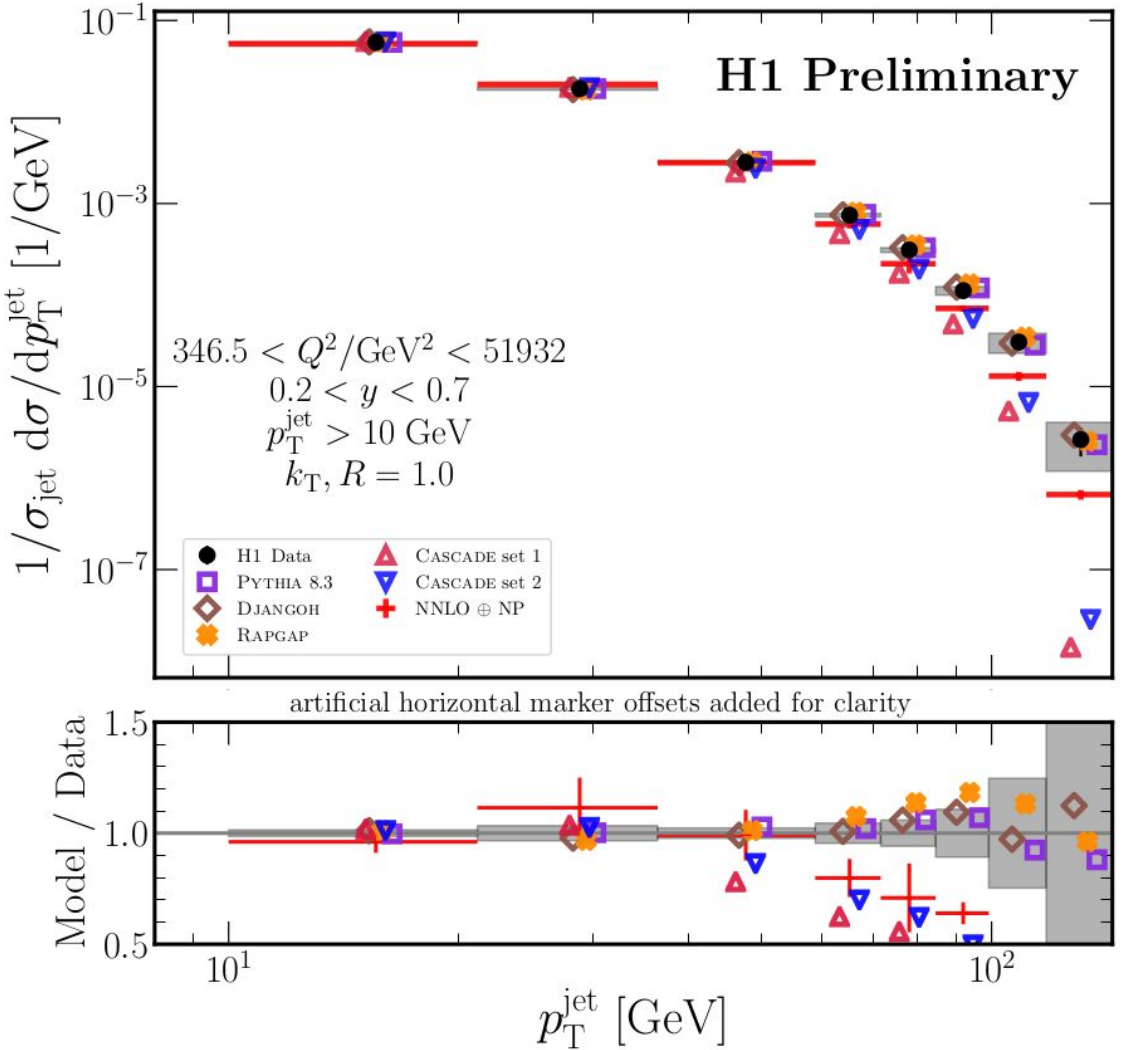
q_T/Q
$\Delta\phi$
η^{jet}
p_T^{jet}
1.0
0.5
0.0
-0.5
-1.0
Correlation

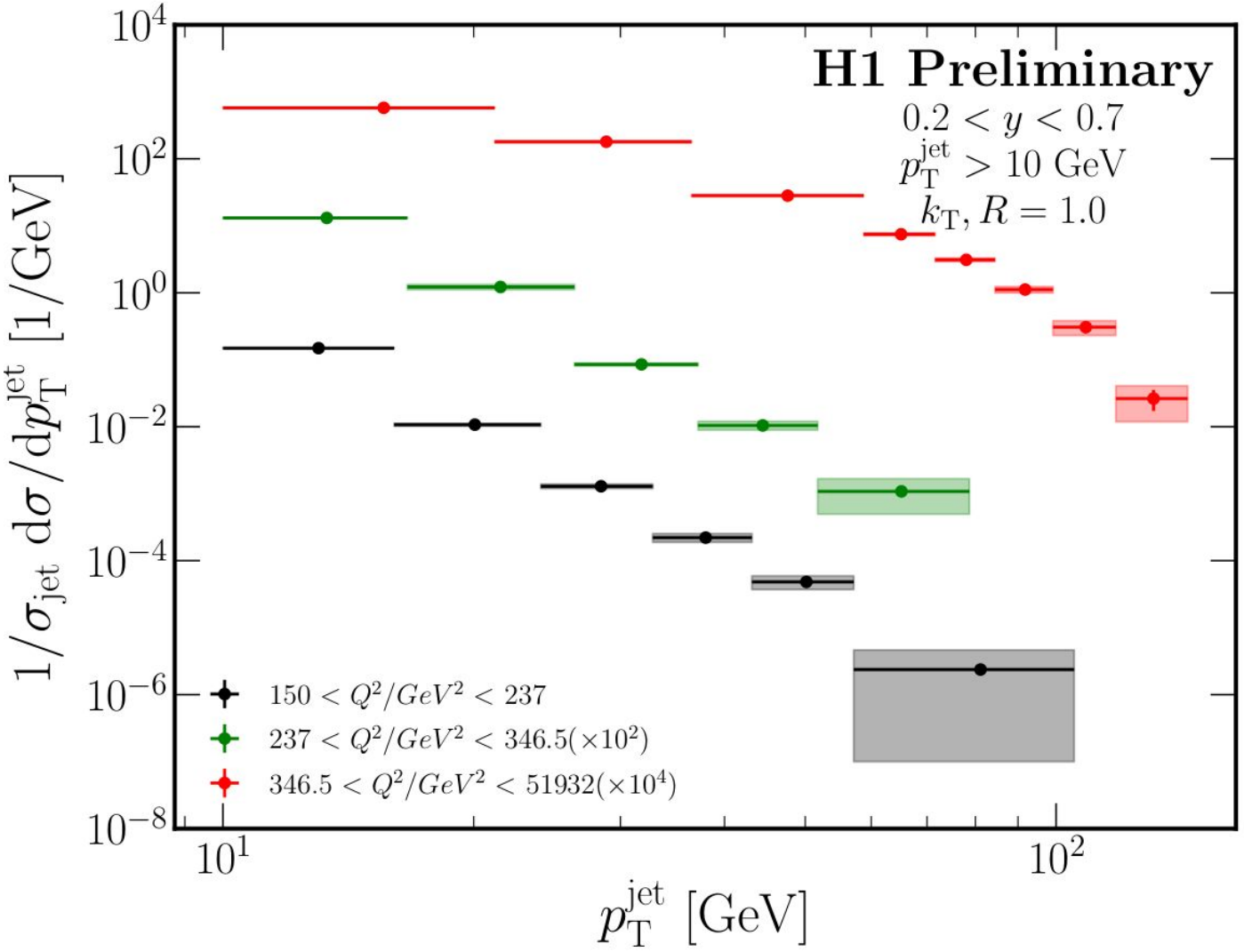
Jet pseudorapidity in slice of Q2.




H1 Preliminary
$0.2 < y < 0.7$
$p_{\mathrm{T}}^{\mathrm{jet}} > 10$ GeV
$k_{\mathrm{T}}, R = 1.0$
$150 < Q^2/GeV^2 < 237$
$237 < Q^2/GeV^2 < 346.5(\times 10)$
$346.5 < Q^2/GeV^2 < 51932(\times 10^2)$
$1/\sigma\ \mathrm{d}\sigma/\mathrm{d}\eta^{\mathrm{jet}}$
η^{jet}
10^2
10^1
10^0
10^{-1}
10^{-2}
-1
0
1
2

Jet transverse momentum in slice of Q2.

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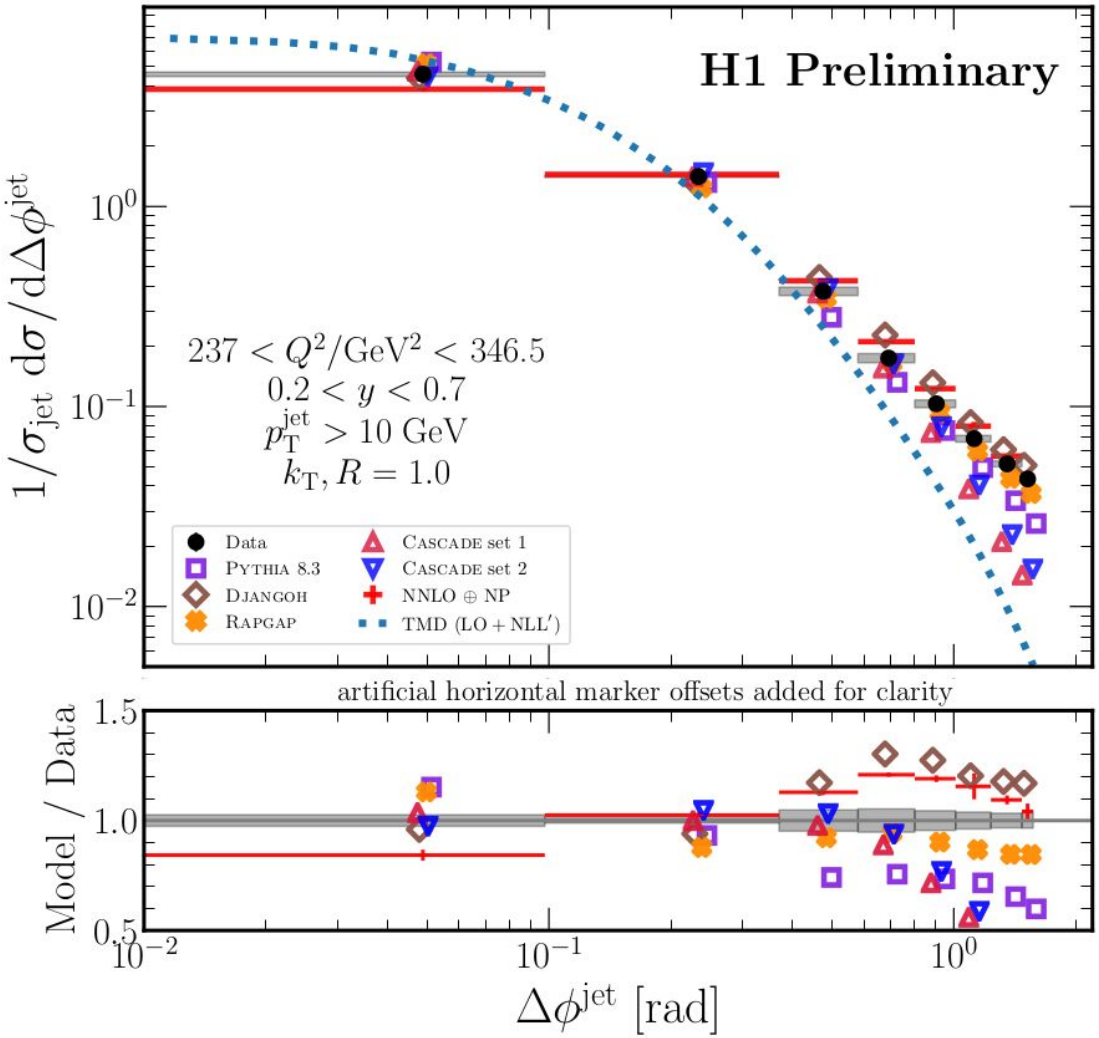
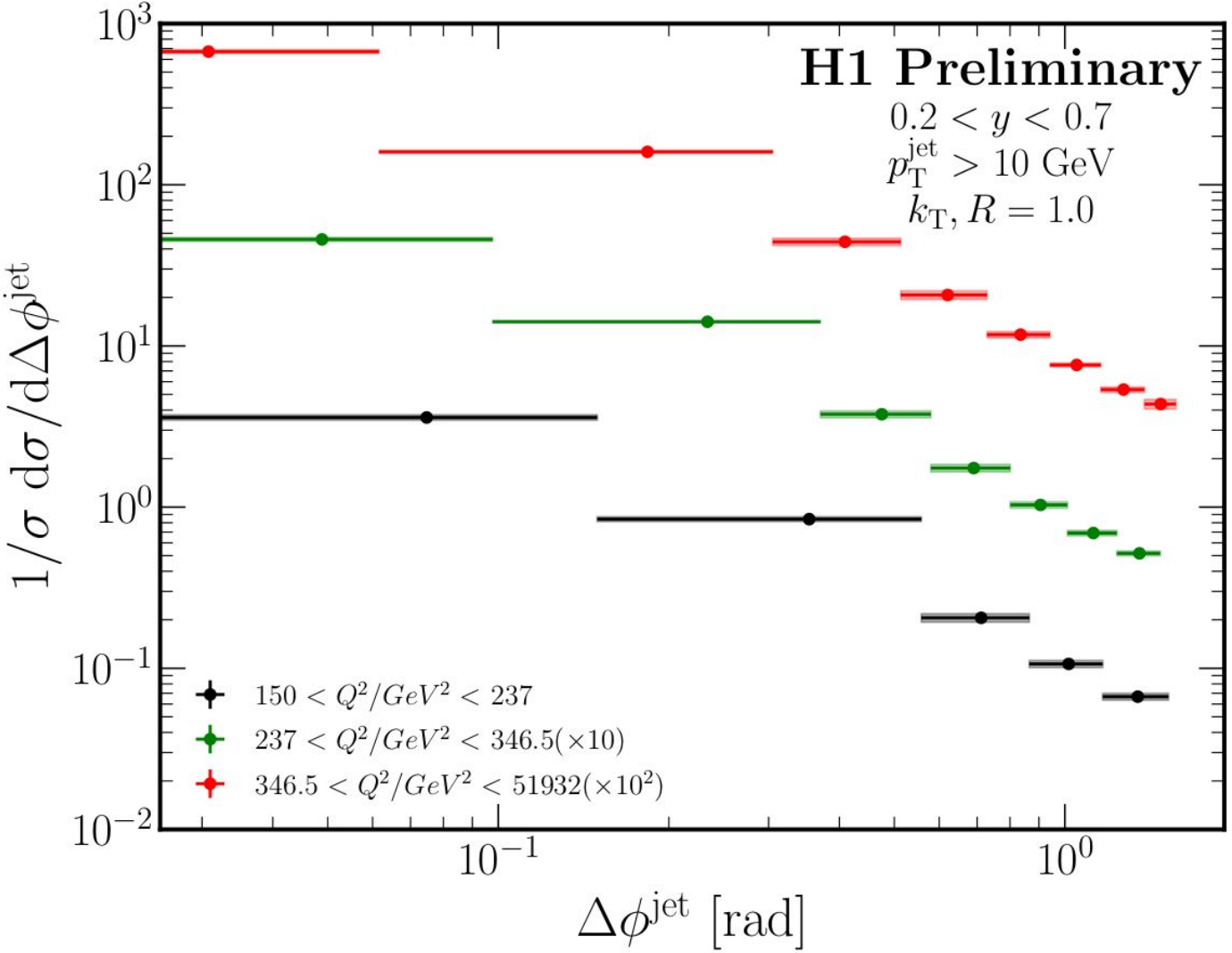
$k_{\mathrm{T}}, R = 1.0$
$150 < Q^2/GeV^2 < 237$
$237 < Q^2/GeV^2 < 346.5(\times 10^2)$
$346.5 < Q^2/GeV^2 < 51932(\times 10^4)$
$1/\sigma_{\mathrm{jet}}\, \mathrm{d}\sigma/\mathrm{d}p_{\mathrm{T}}^{\mathrm{jet}}$ [1/GeV]
$p_{\mathrm{T}}^{\mathrm{jet}}$ [GeV]

Lepton-jet azimuthal correlation in slice of Q2.




H1 Preliminary
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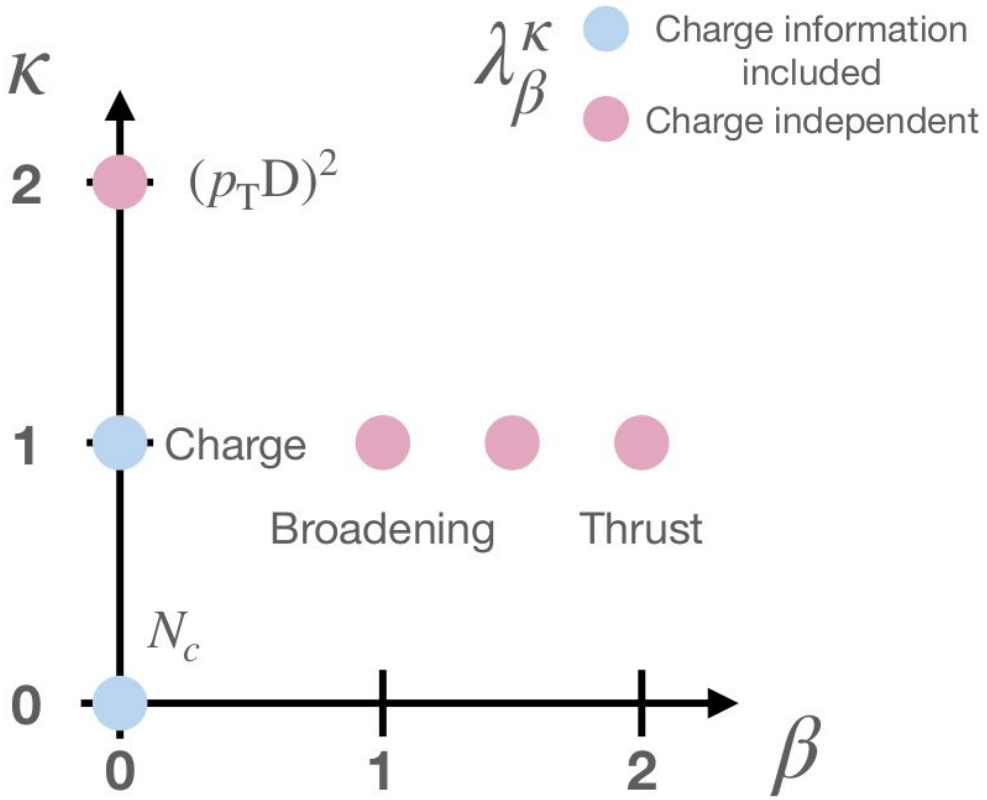
$k_{\mathrm{T}}, R = 1.0$
$150 < Q^2/GeV^2 < 237$
$237 < Q^2/GeV^2 < 346.5(\times 10)$
$346.5 < Q^2/GeV^2 < 51932(\times 10^2)$
$1/\sigma\ \mathrm{d}\sigma/\mathrm{d}\Delta\phi^{\mathrm{jet}}$
$\Delta\phi^{\mathrm{jet}}$ [rad]

Jet substructure observables with machine learning

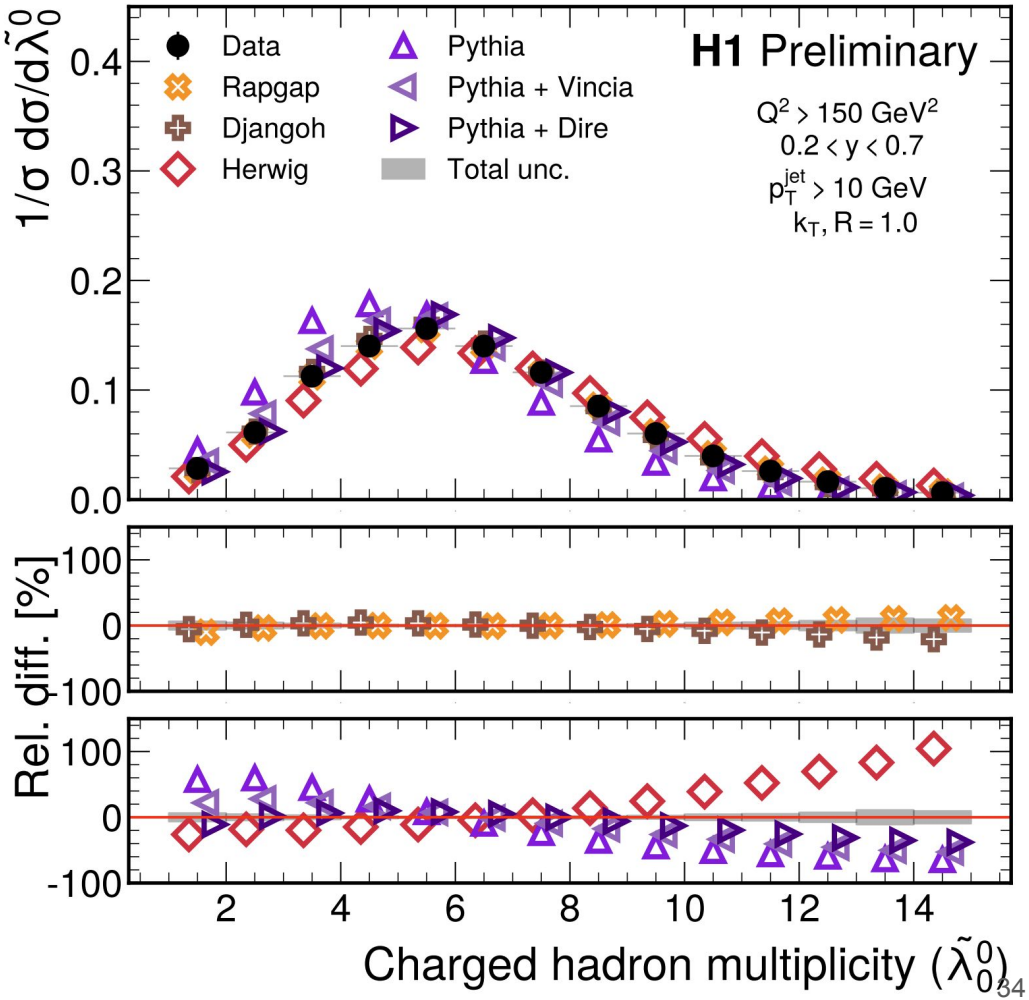
https://www-h1.desy.de/h1/www/publications/htmlsplit/H1prelim-22-034.long.html

$$\lambda_\beta^\kappa = \sum_{i \in \text{jet}} z_i^\kappa \left(\frac{R_i}{R_0} \right)^\beta$$

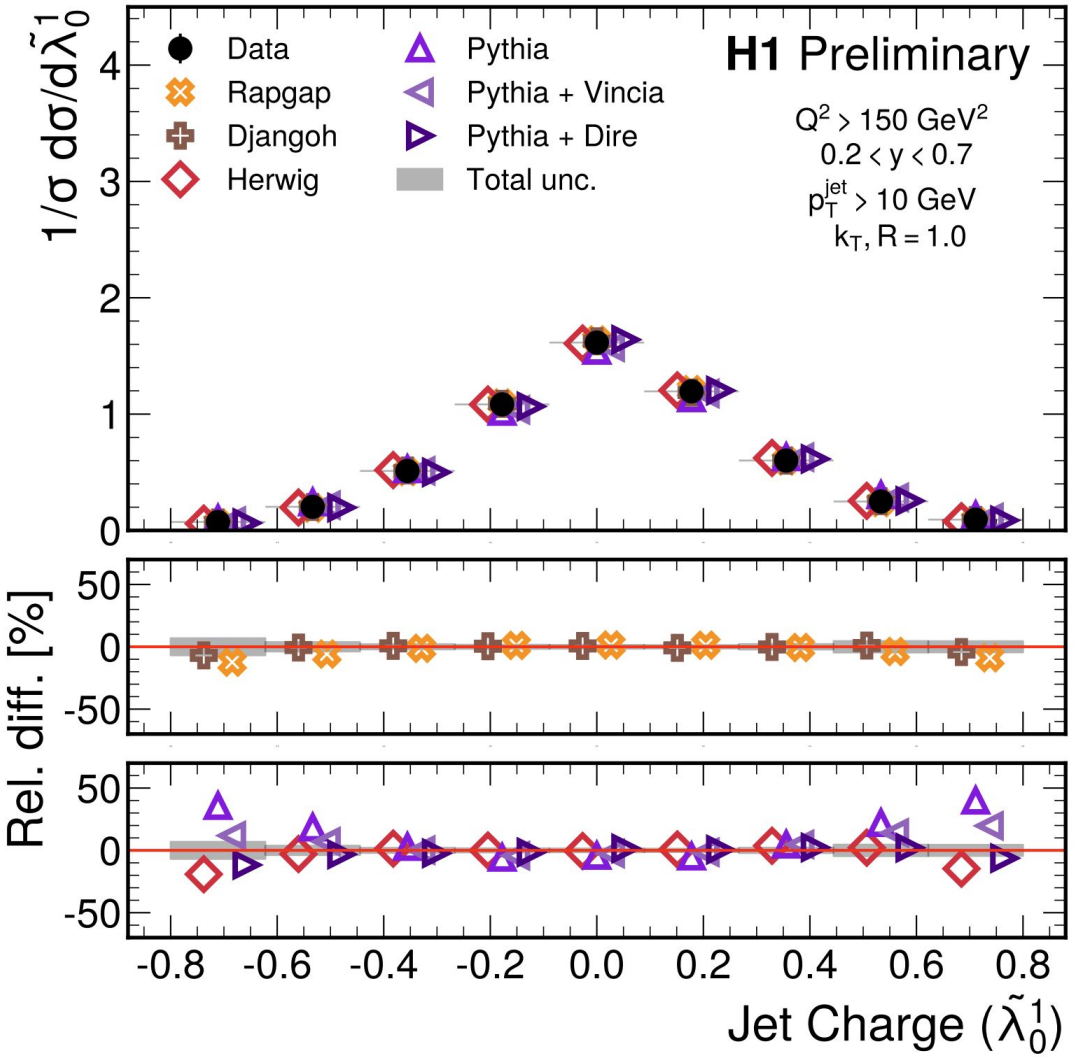
$$\tilde{\lambda}_0^\kappa = Q_\kappa = \sum_{i \in \text{jet}} q_i \times z_i^\kappa .$$



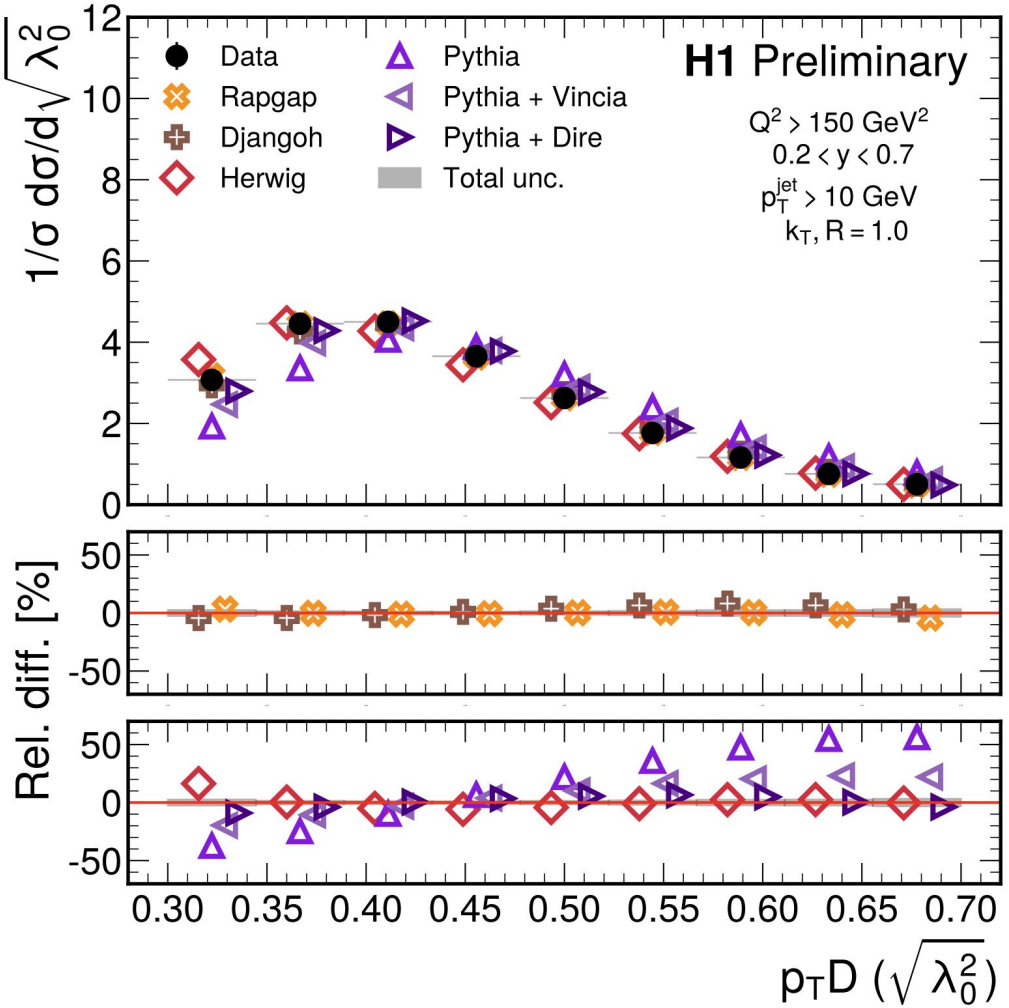
Charged hadron Multiplicity



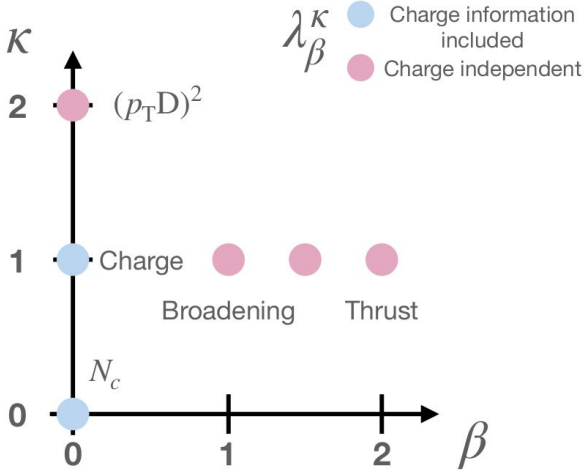
Jet charge

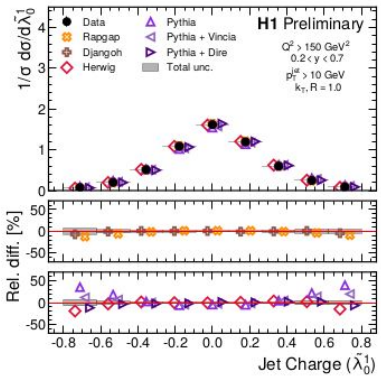

Data
Rapgap
Djangoh
Herwig
Pythia
Pythia + Vincia
Pythia + Dire
Total unc.
H1 Preliminary
$Q^2 > 150$ GeV^2
$0.2 < y < 0.7$
$p_T^{jet} > 10$ GeV
k_T, R = 1.0
$1/\sigma\, d\sigma/d\tilde{\lambda}_0^1$
Rel. diff. [%]
Jet Charge $(\tilde{\lambda}_0^1)$

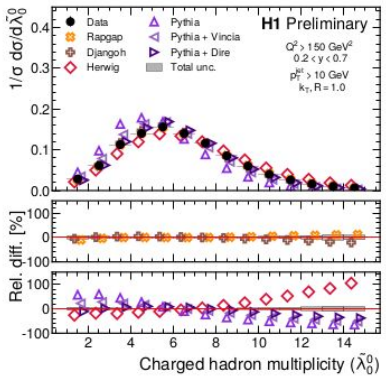
Dispersion

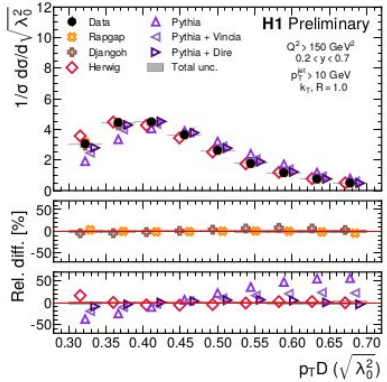

Data
Rapgap
Djangoh
Herwig
Pythia
Pythia + Vincia
Pythia + Dire
Total unc.
H1 Preliminary
$Q^2 > 150$ GeV^2
$0.2 < y < 0.7$
$p_T^{jet} > 10$ GeV
k_T, R = 1.0
$1/\sigma\, d\sigma/d\sqrt{\lambda_0^2}$
Rel. diff. [%]
$p_T D\ (\sqrt{\lambda_0^2})$

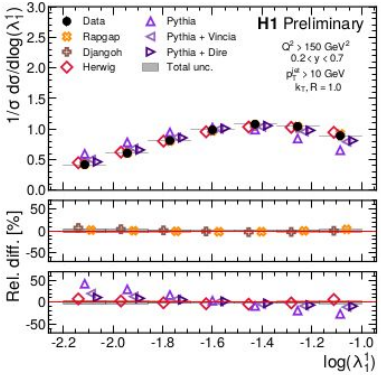
All of them unfolded simultaneously!!!

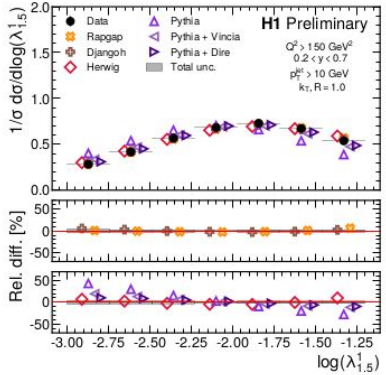


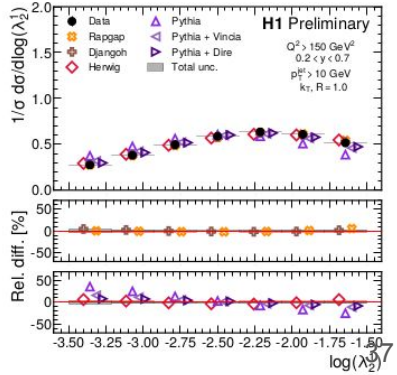




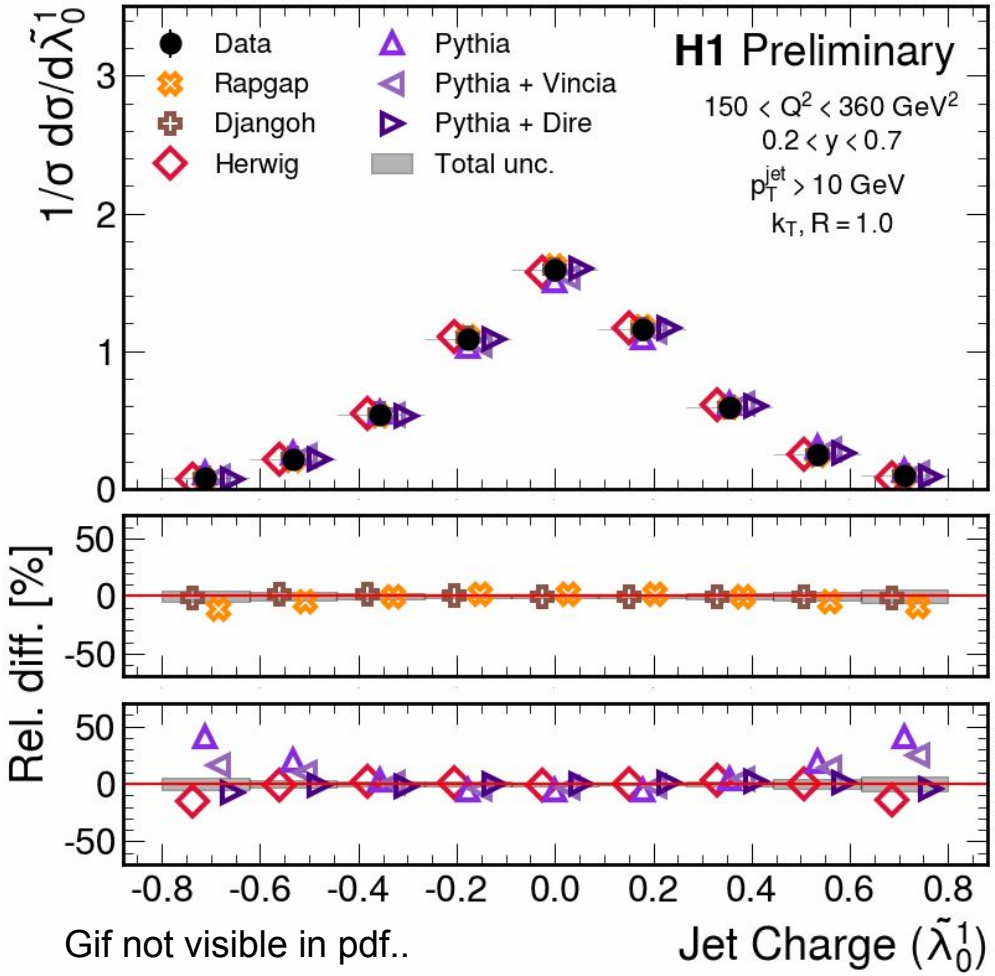






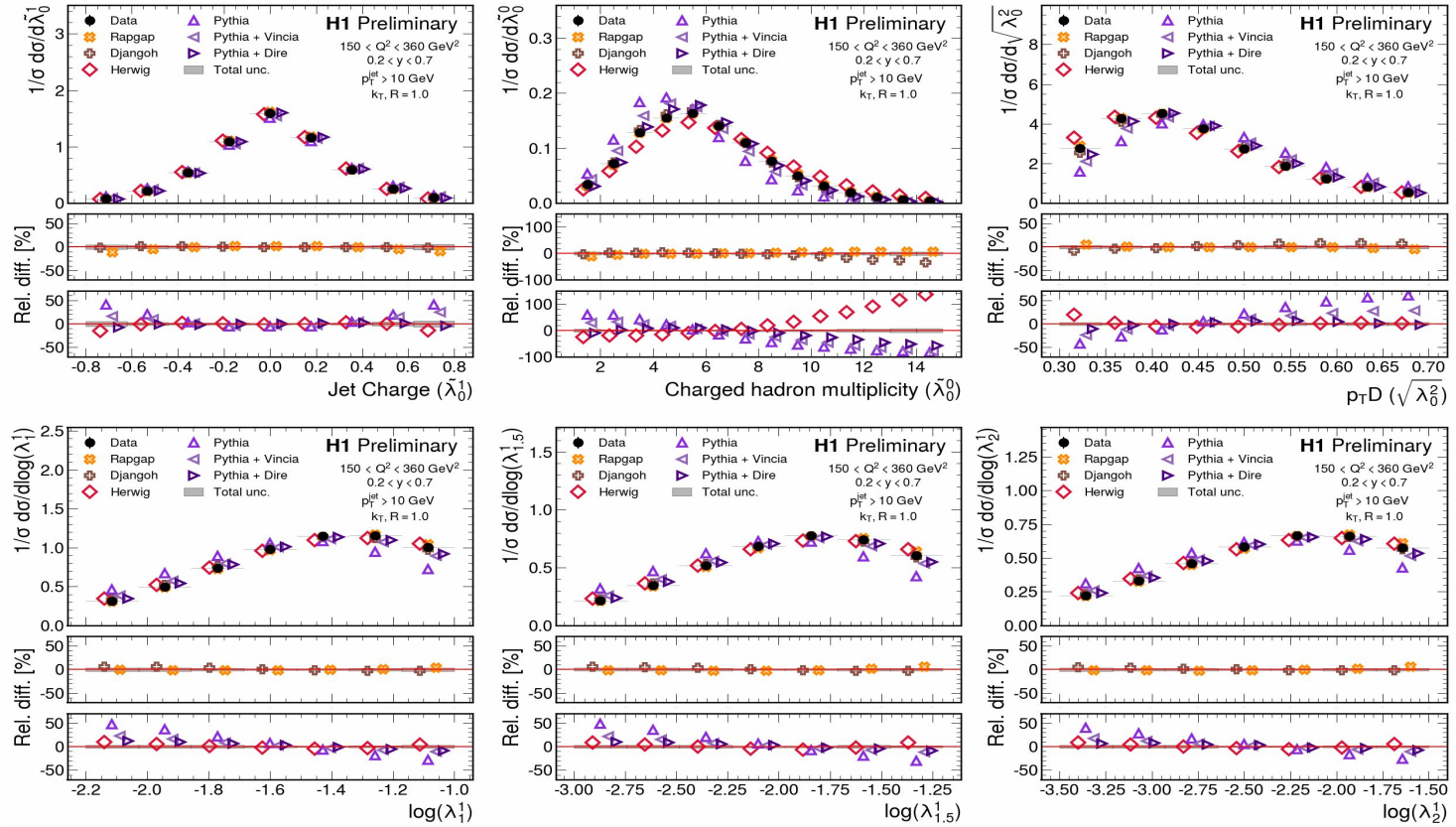


Jet Charge Differentially in Q2

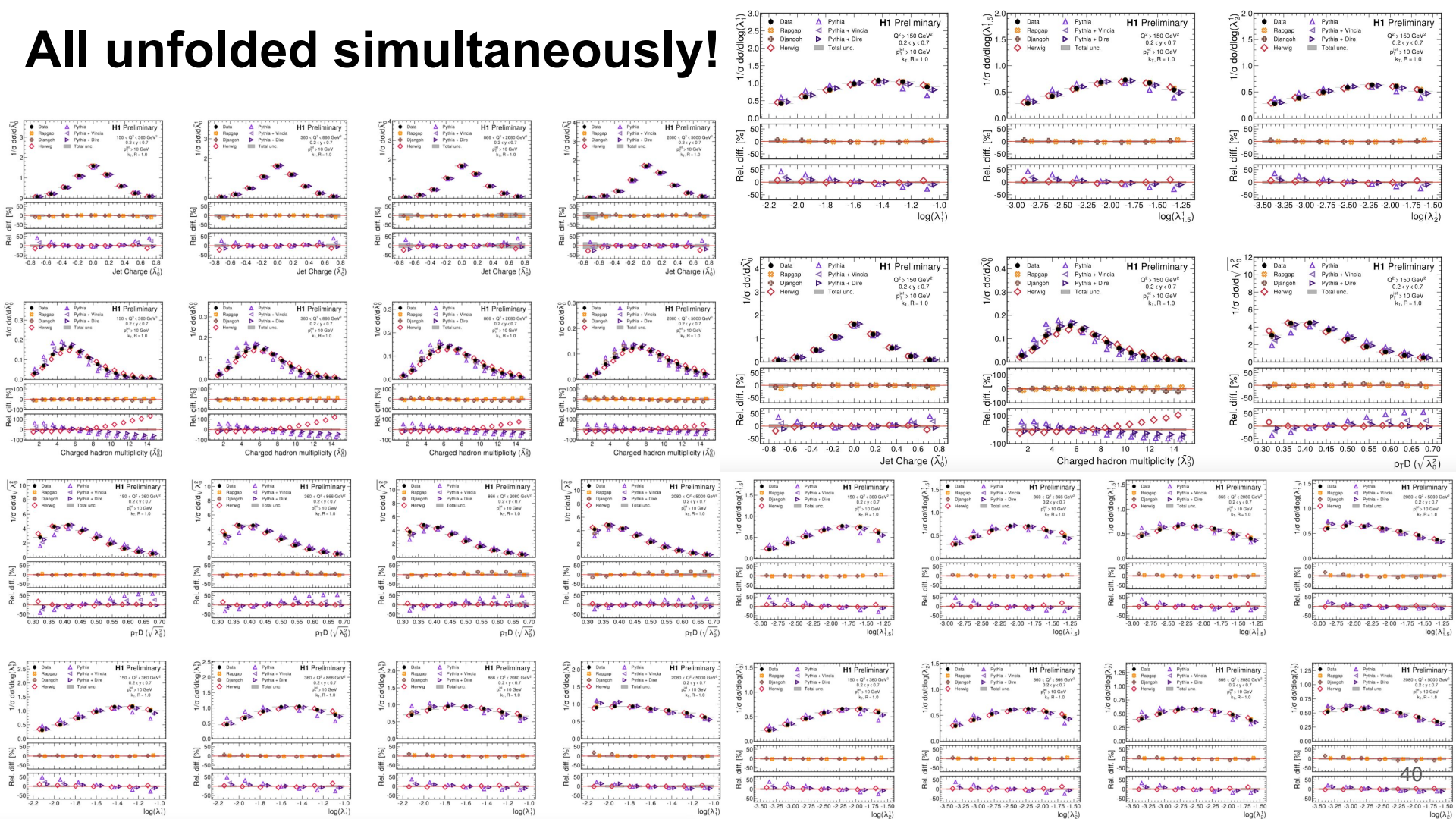


Gif not visible in pdf..

All of them unfolded simultaneously!!!
& differentially in Q2

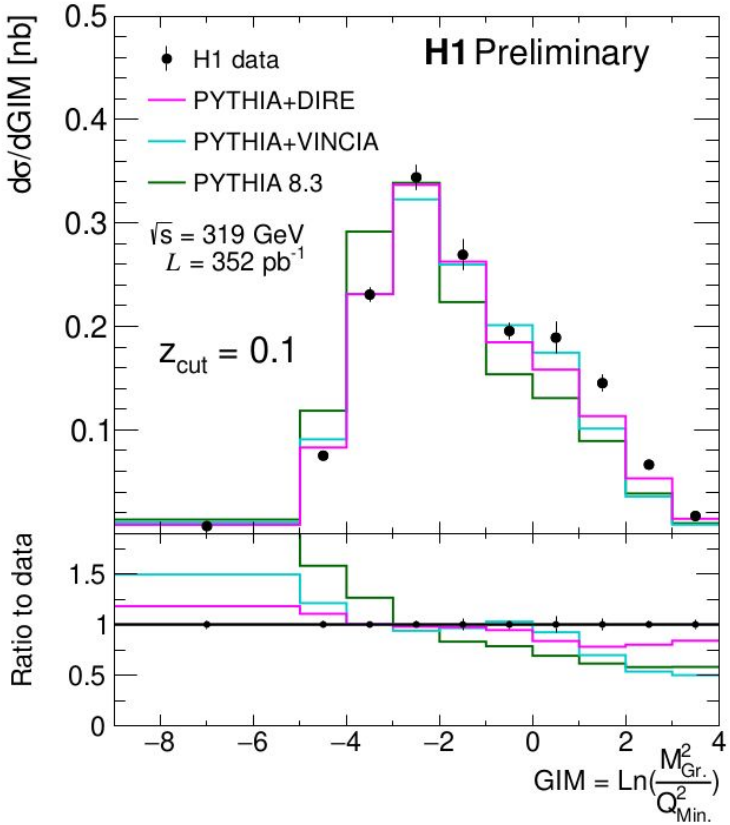


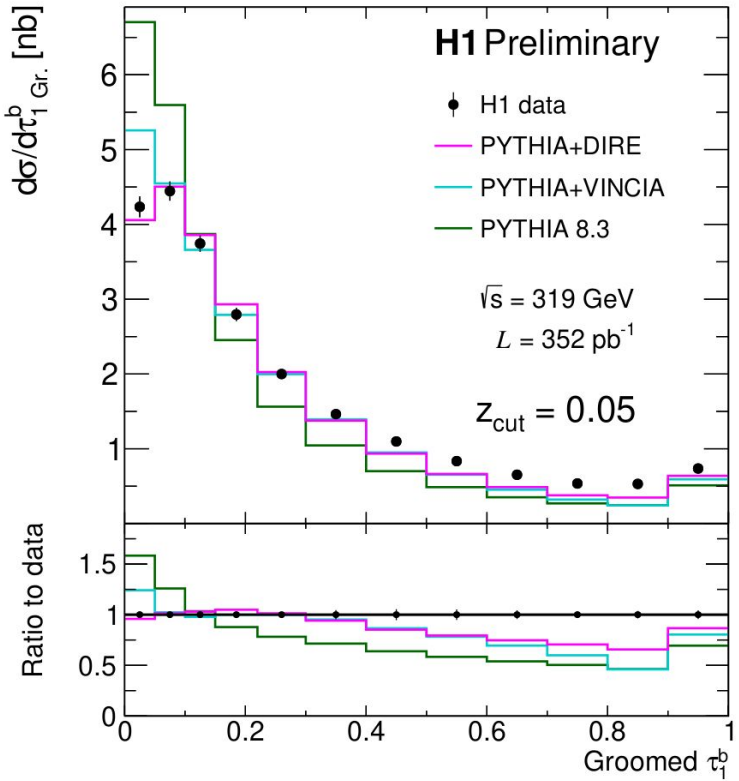
All unfolded simultaneously!



Event shapes with grooming using Centauro metric

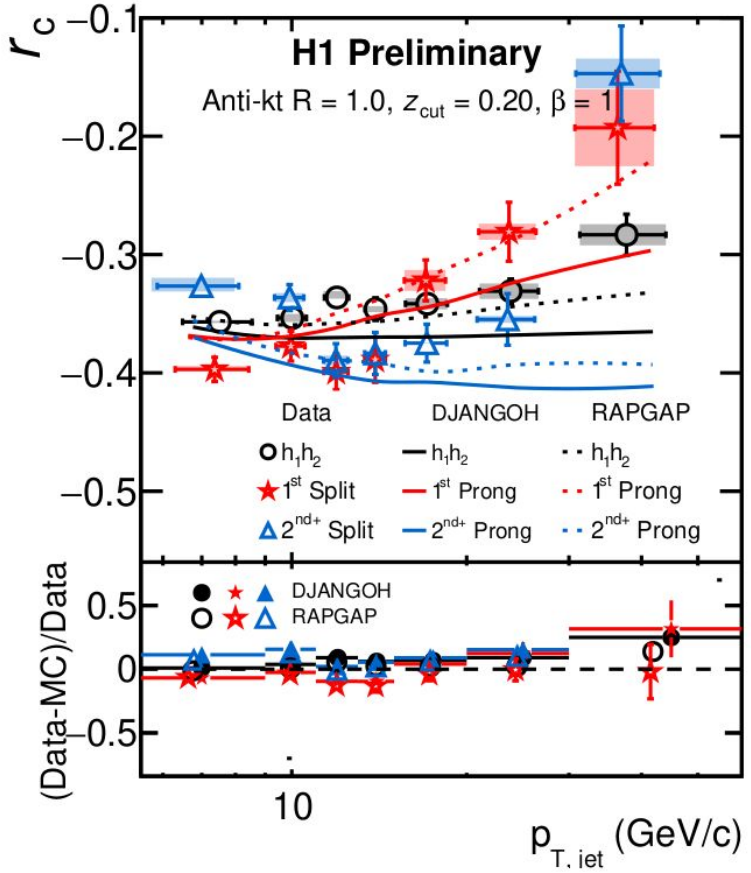
https://www-h1.desy.de/h1/www/publications/htmlsplit/H1prelim-22-033.long.html

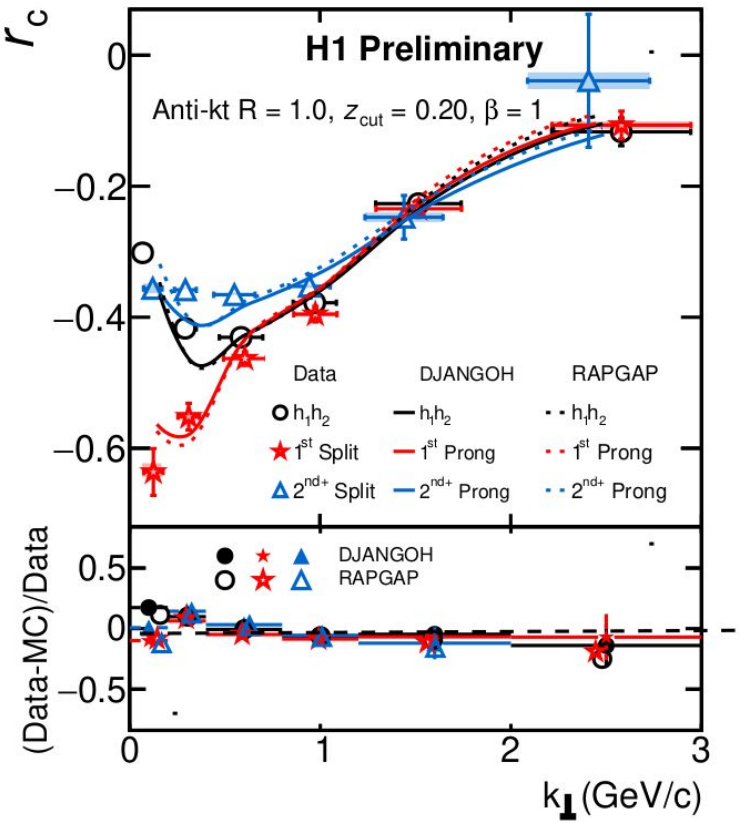




Charge-asymmetryjet substructure

https://www-h1.desy.de/h1/www/publications/htmlsplit/H1prelim-22-032.long.html

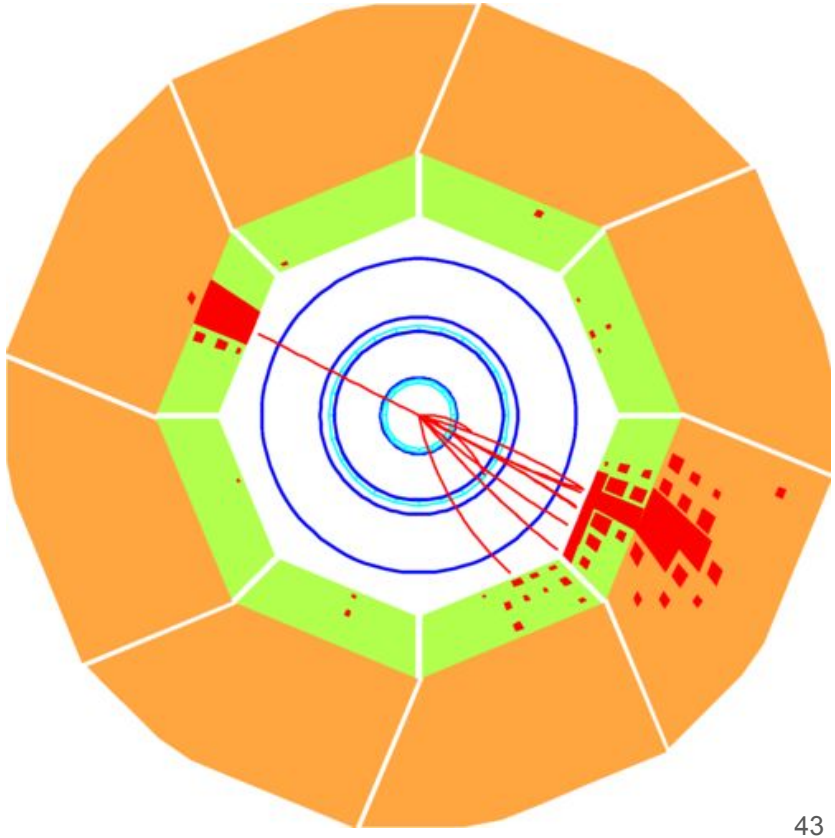




The road towards EIC during this decade

Every jet-related observable in ep collisions **can and will be measured** with H1 data

The ultimate "reference" for future polarized ep and eA data at EIC



H1prelim-22-034 Jet Substructure at high Q**2 using machine learning
Document H1 Info
Figures: (1) (2a) (2b) (2c) (2d) (2e) (2f) (3a) (3b) (3c) (3d) (3e) (3f) (3g) (3h) (3i) (3j) (3k) (3l) (3m) (3n) (3o) (3p) (3q) (3r) (5k) (5l) (5m) (5n) (5o) (5p) (5q) (5r) (5s) (5t) (5u) (5v) (5w) (5x) (use mouse for preview)

H1prelim-22-033 Groomed event shaps in high Q**2 DIS
Document H1 Info
Figures: (5a) (5b) (5c) (5d) (5e) (5f) (5g) (5h) (5i) (5j) (5k) (5l) (6a) (6b) (6c) (6d) (6e) (6f) (7a) (7b) (7c) (7d) (7e) (7f) (7g)

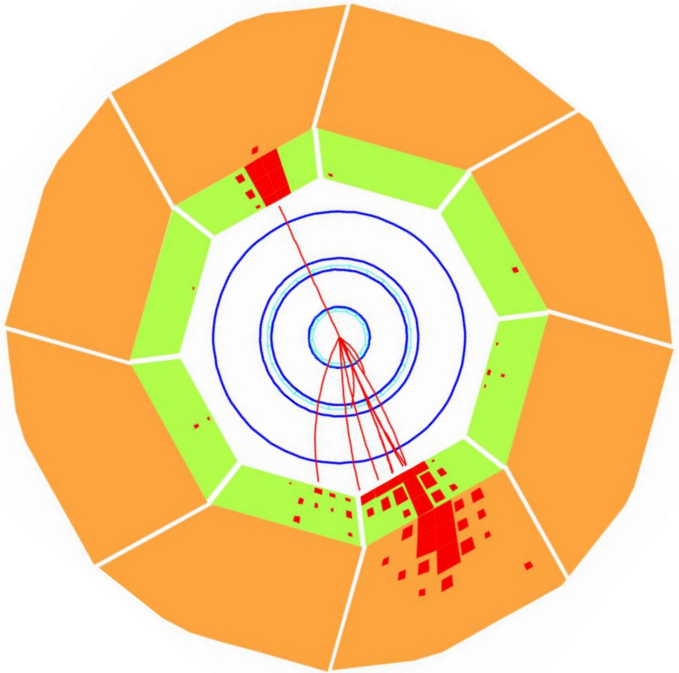
H1prelim-22-032 Charge asymmetry Jet substructure in DIS
Document H1 Info
Figures: (1) (2) (3a) (3b) (3c) (4a) (4b) (5a) (5b) (6) (7) (9) (10) (11) (12) (13) (14) (use mouse for preview)

H1prelim-21-032 Measurement of 1-jettiness in the Breit Frame at high Q^2
Document H1 Info

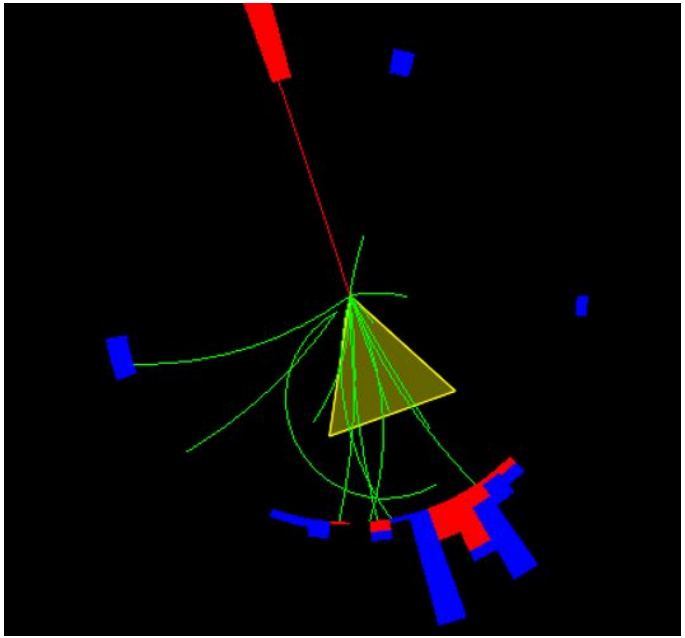
Stay tuned.
Just the beginning of a new & rich jet program

https://www-h1.desy.de/publications/H1preliminary.short_list.html

H1@HERA



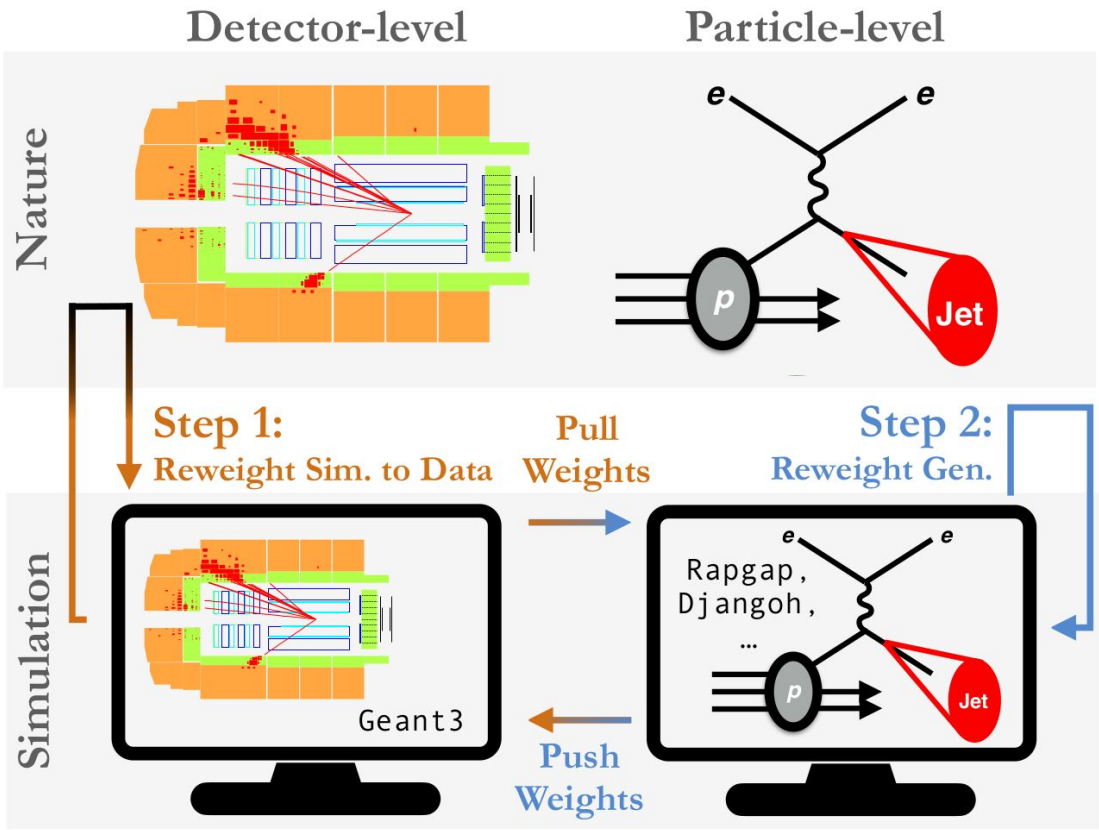
EIC



Some speculative stuff

H1 Collaboration Phys. Rev. Lett. 128, 132002

was the first baby step towards unbinned cross-sections…



First-ever demonstration of
unbinned unfolding,
unbinned acceptance corr.
unbinned efficiency correction

But we reported
Binned cross-sections…

Check out our white paper on the subject.

Perhaps in the future
we will just exchange replicas …

Journal of Instrumentation

PAPER

Publishing unbinned differential cross section results

Miguel Arratia[1,2], Anja Butter[3], Mario Campanelli[4], Vincent Croft[5], Dag Gillberg[6], Aishik Ghosh[7,8], Kristin Lohwasser[9], Bogdan Malaescu[10], Vinicius Mikuni[11], Benjamin Nachman[8,12]
+ Show full author list

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Journal of Instrumentation, Volume 17, January 2022
Citation Miguel Arratia *et al* 2022 *JINST* **17** P01024

8 Conclusions and Outlook

This report has presented a proposal for publishing unbinned differential cross section measurements and predictions. The methodology for unbinned measurements has been enhanced in part because of recent advances in machine learning. Unbinned measurements can always be rebinned and analyzed with traditional methods. In order to make best use of future measurements that use these tools, it is important to have some community standards and guidelines. We hope that this paper will serve the purpose of having a concrete proposal to discuss with all of the relevant experimental and theoretical communities. This is foreseen to be the start of an evolving community dialogue, in order to accommodate future developments in this field that is currently rapidly evolving.