On tracking requirements for jet measurements

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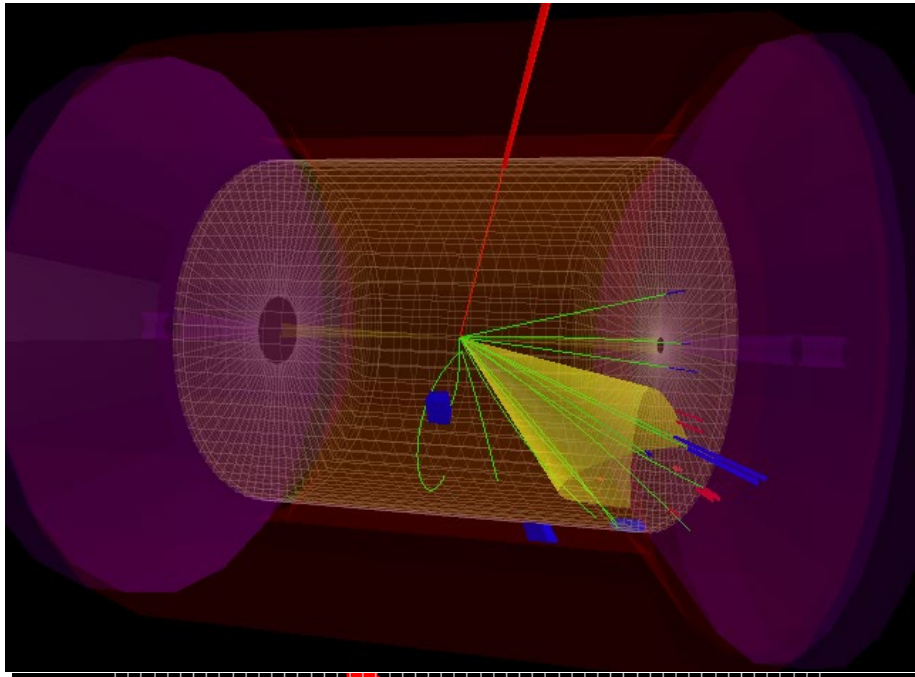
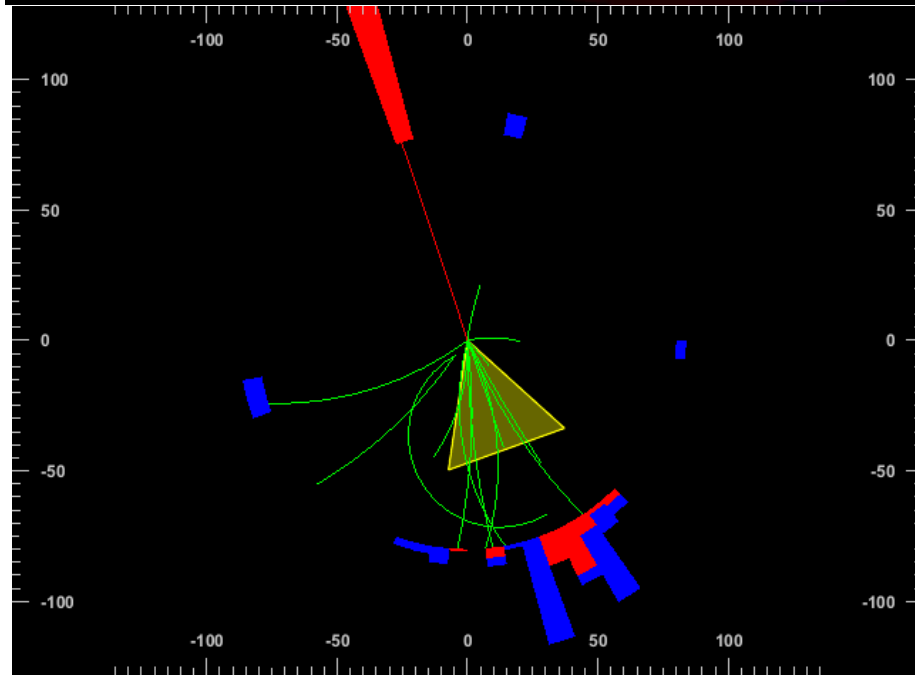
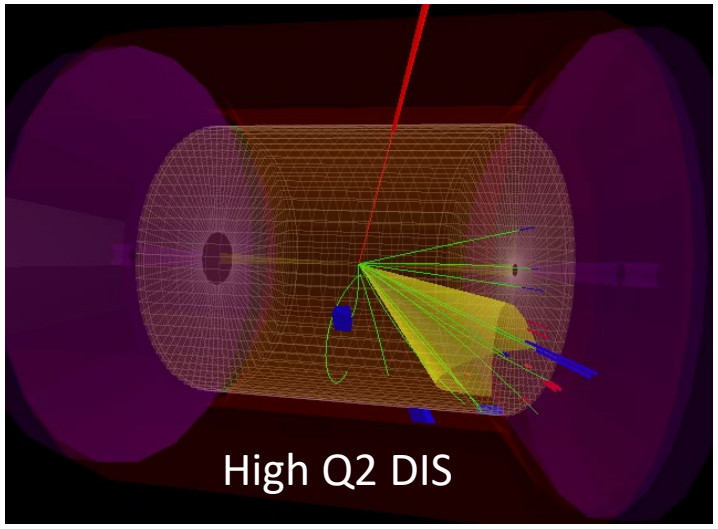
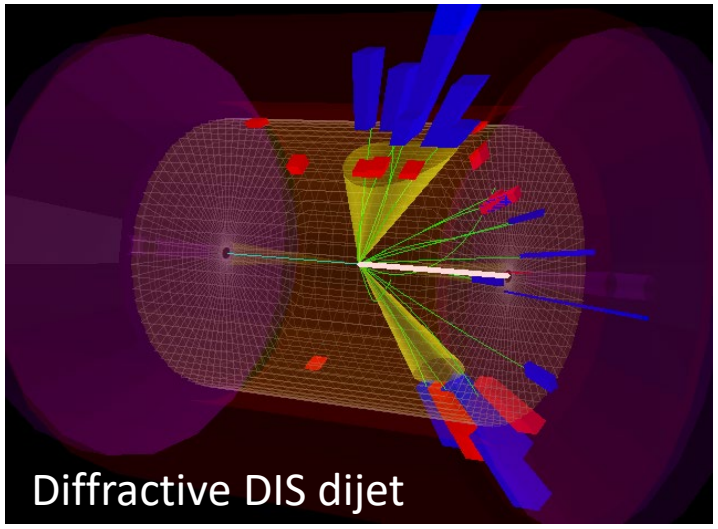
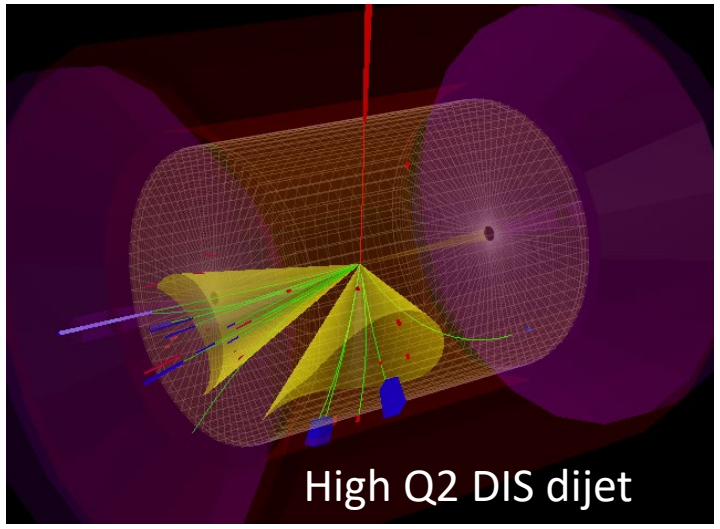


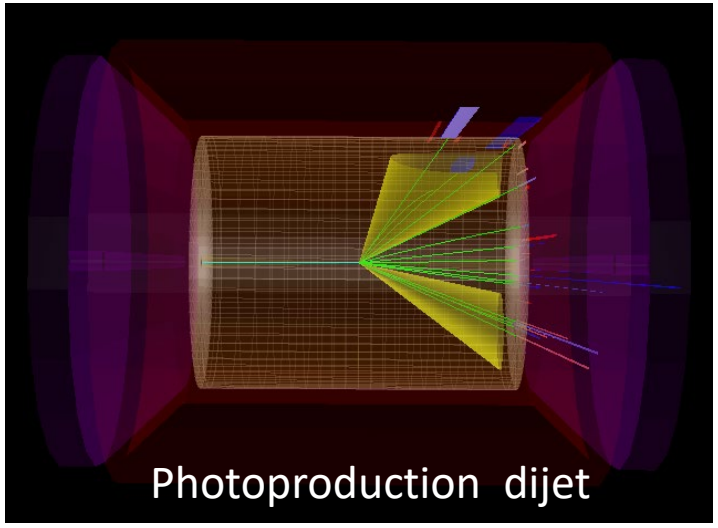


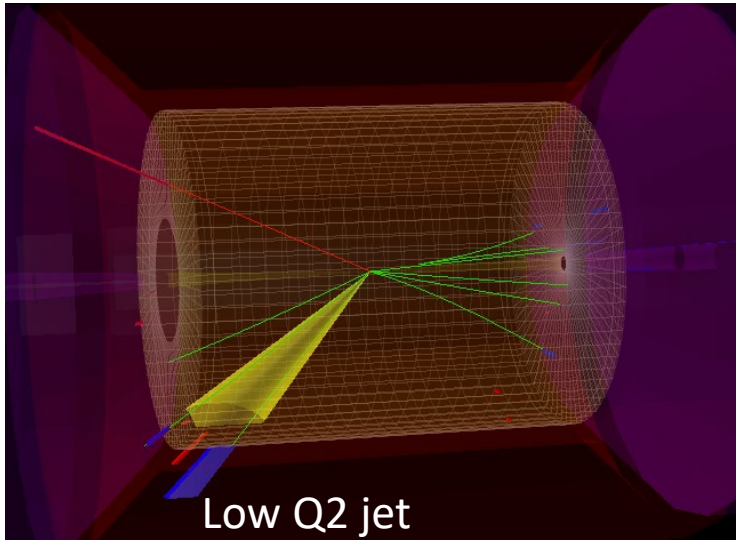
Why jets?
Because jets are most of what colliders do

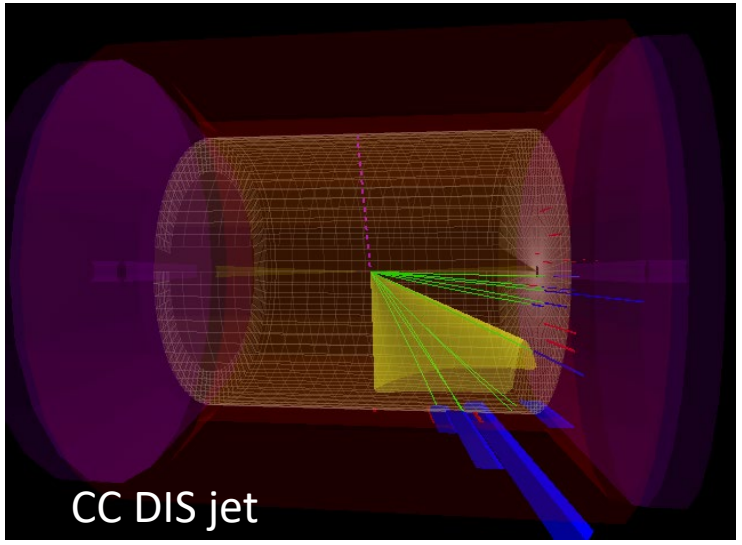




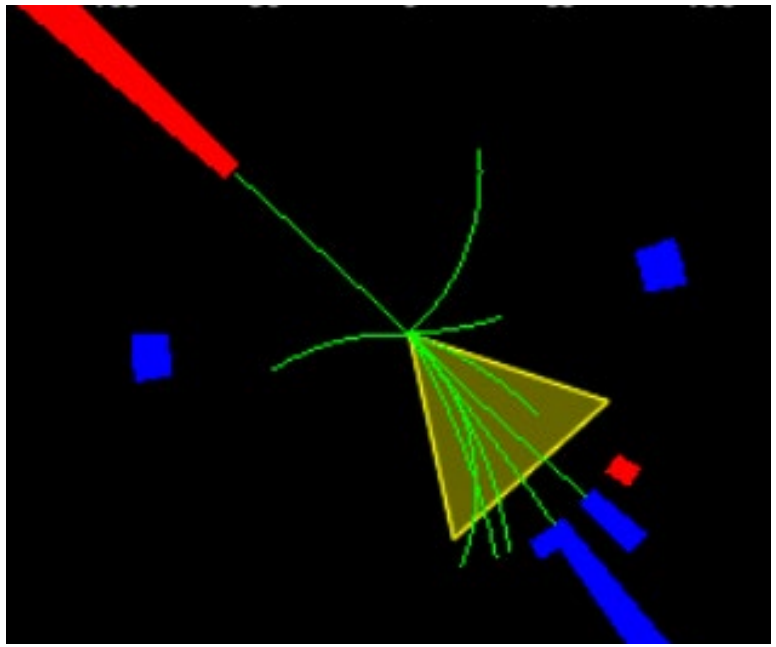


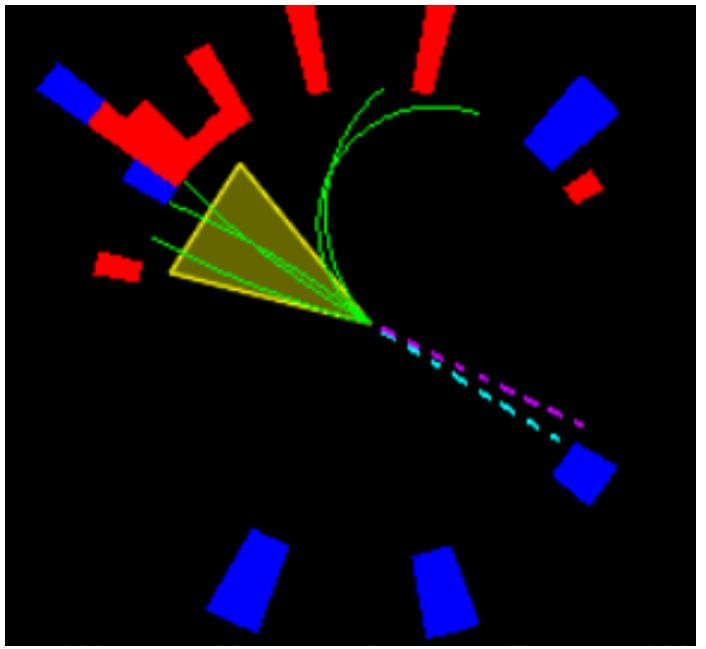






EIC, a jet factory, will make the first jets in nuclear DIS and proton-polarized DIS





Unique jet physics program,
unlike any previous collider (even HERA!!)

The EIC science program with jets

Jets as tools to realize the EIC science goals — Recent publications

- The spin of the proton, PDFs

  Hinderer, Schlegel, Vogelsang `15, `17, Abelof, Boughezal, Liu, Petriello `16, Boughezal, Petriello, Xing `18, Aschenauer, Chu, Page `19, Borsa, Florian, Pedron `20, Arratia, Furletova, Hobbs, Olness, Sekula `20

- 3D nucleon/nucleus tomography

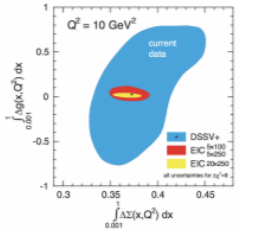
  Zheng, Aschenauer, Lee, Xiao, Yin `18, Liu, FR, Vogelsang, Yuan `19, Gutierrez-Reyes, Scimemi, Waalewijn, Zoppi `19, Hatta, Mueller, Ueda, Yuan `19, Arratia, Kang, Prokudin, FR `20

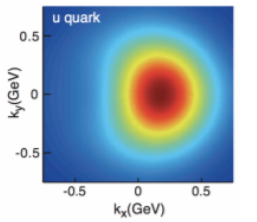
- Saturation, a new form of gluon matter

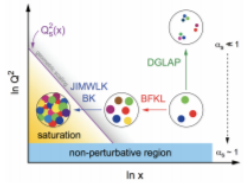
  Hatta, Xiao, Yuan `17, Salazar, Schenke `19, Roy, Venugopalan `19, Kang, Liu `19

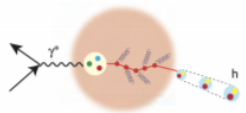
- Hadronization and quarks and gluons in the nucleus

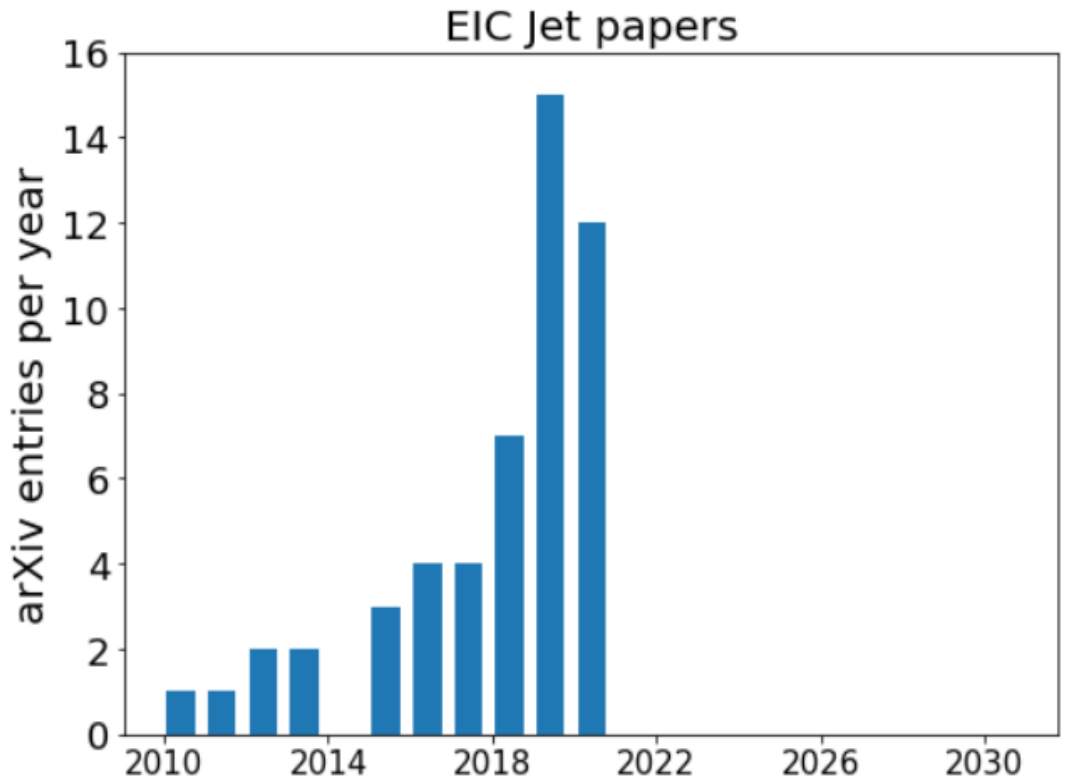
  Klasen, Kovarik `18, Aschenauer, Lee, Page, FR `19, Qin, Wang, Zhang `19, Arratia, Song, FR, Jacak `19, Li et al. `20





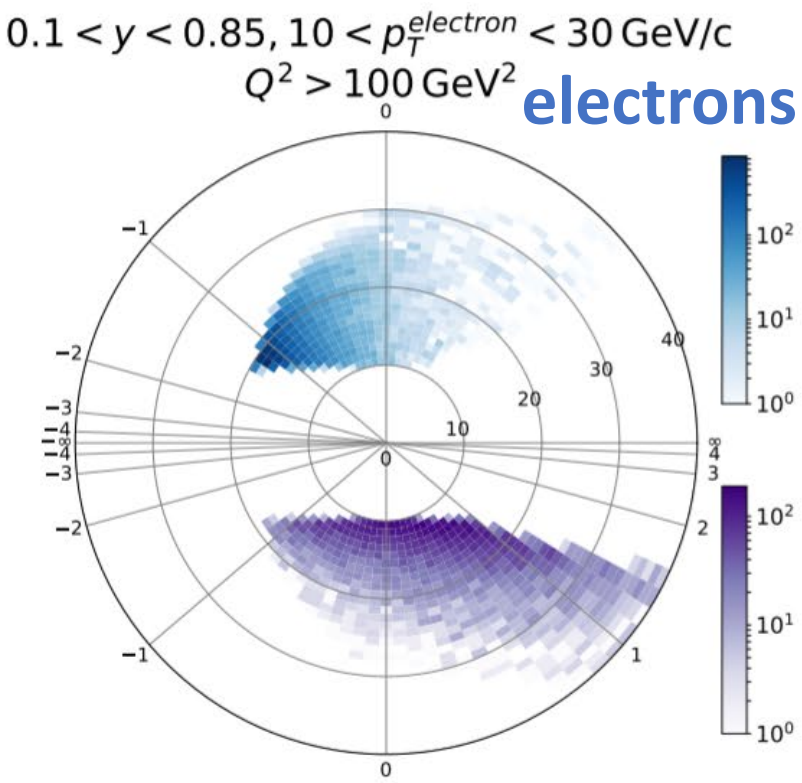




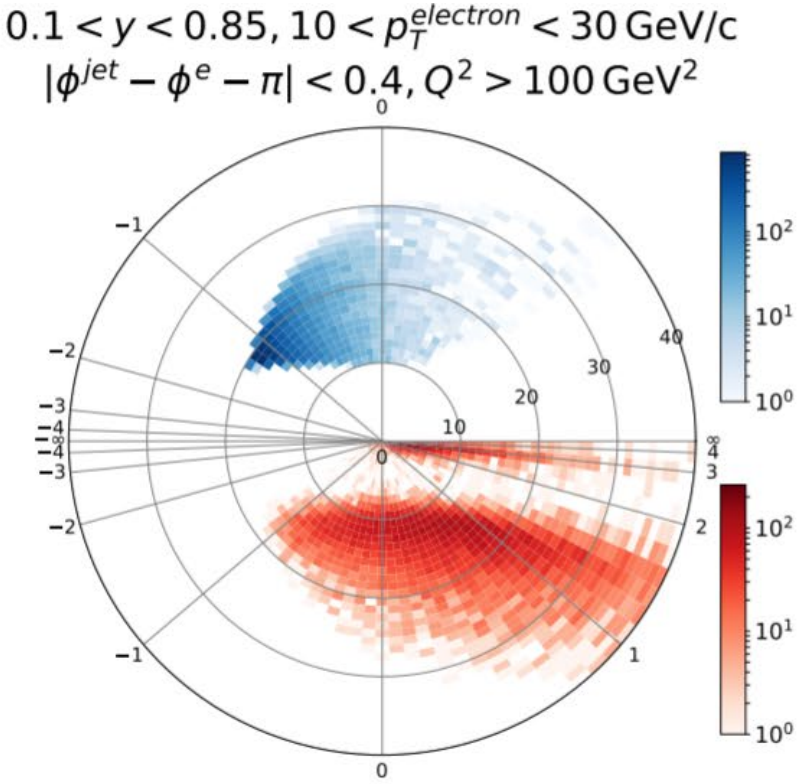


Slide by Felix Ringer presented during "Jet Observables" workshop.

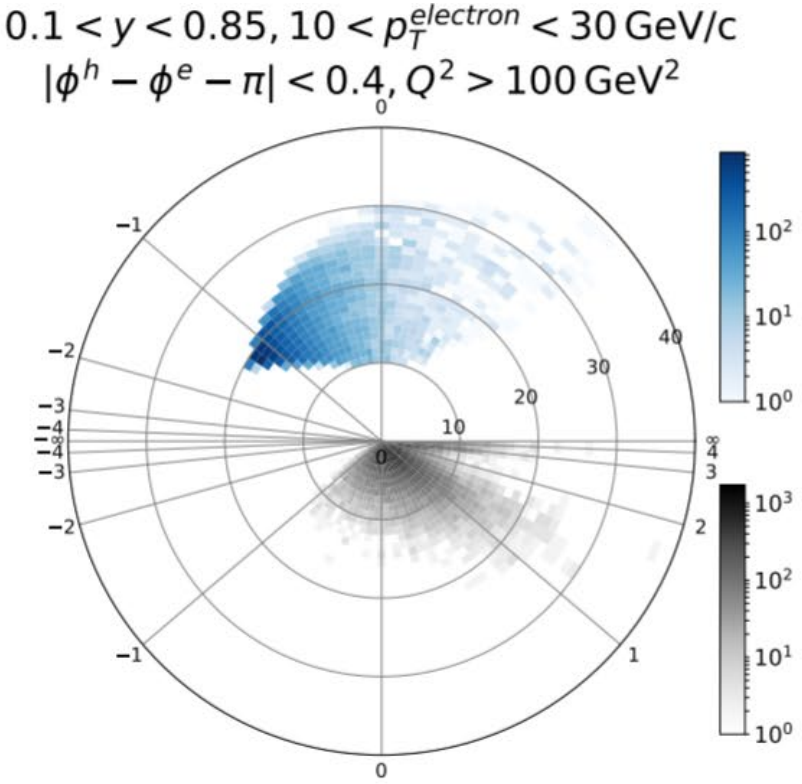
Jets are excellent proxies for parton kinematics



Struck quark



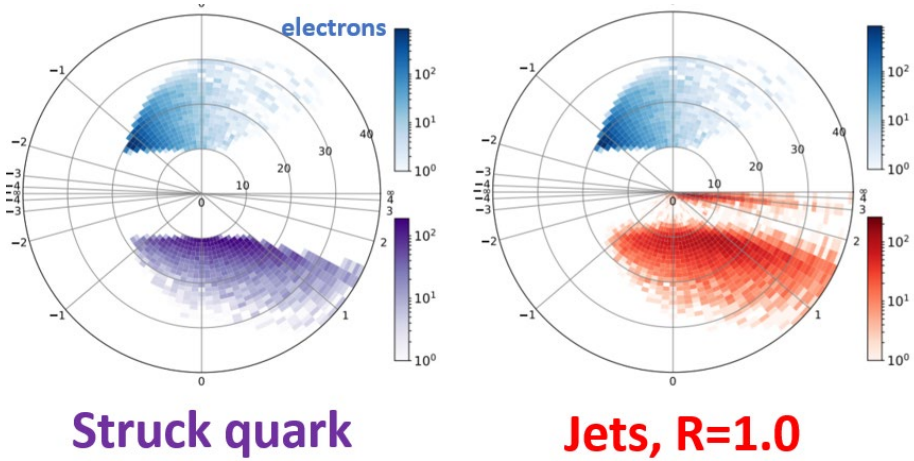
Jets, R=1.0



Hadrons

Phys. Rev. C 101, 065204 (2020)

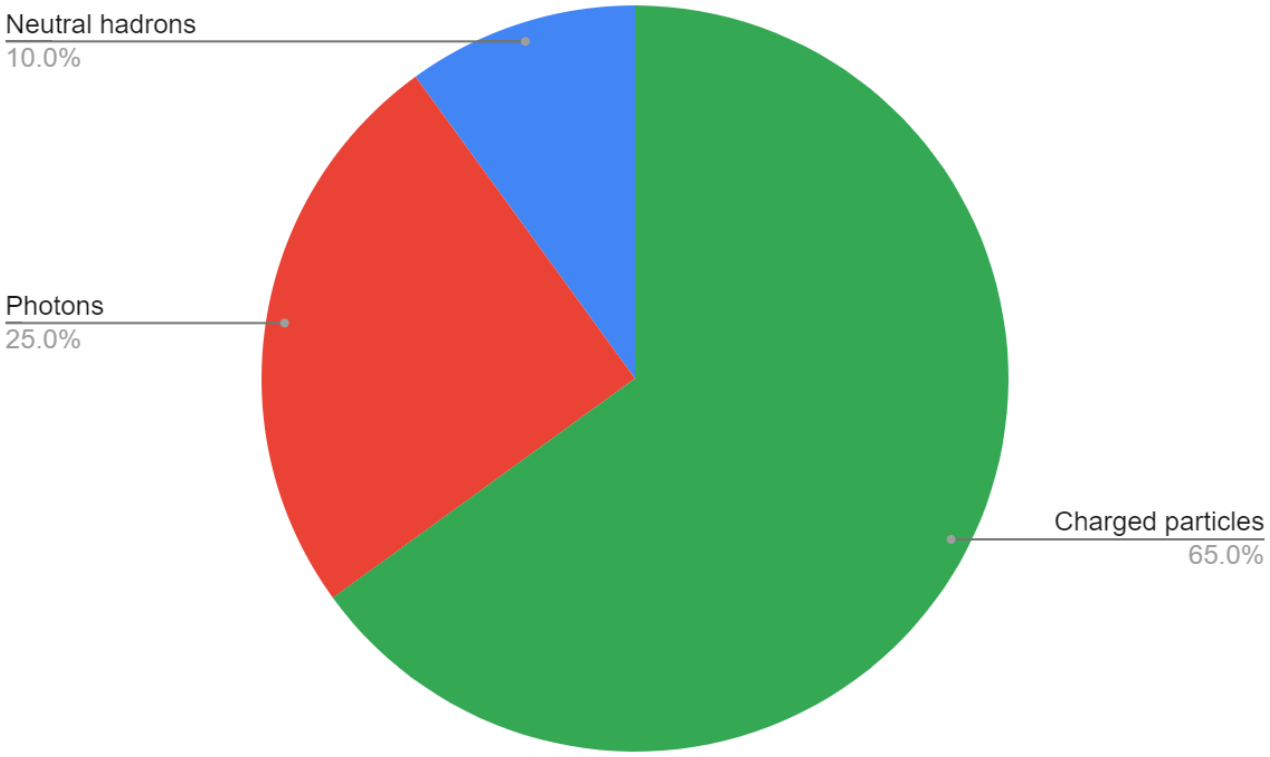
Jets are excellent proxies for parton kinematics , provided that:

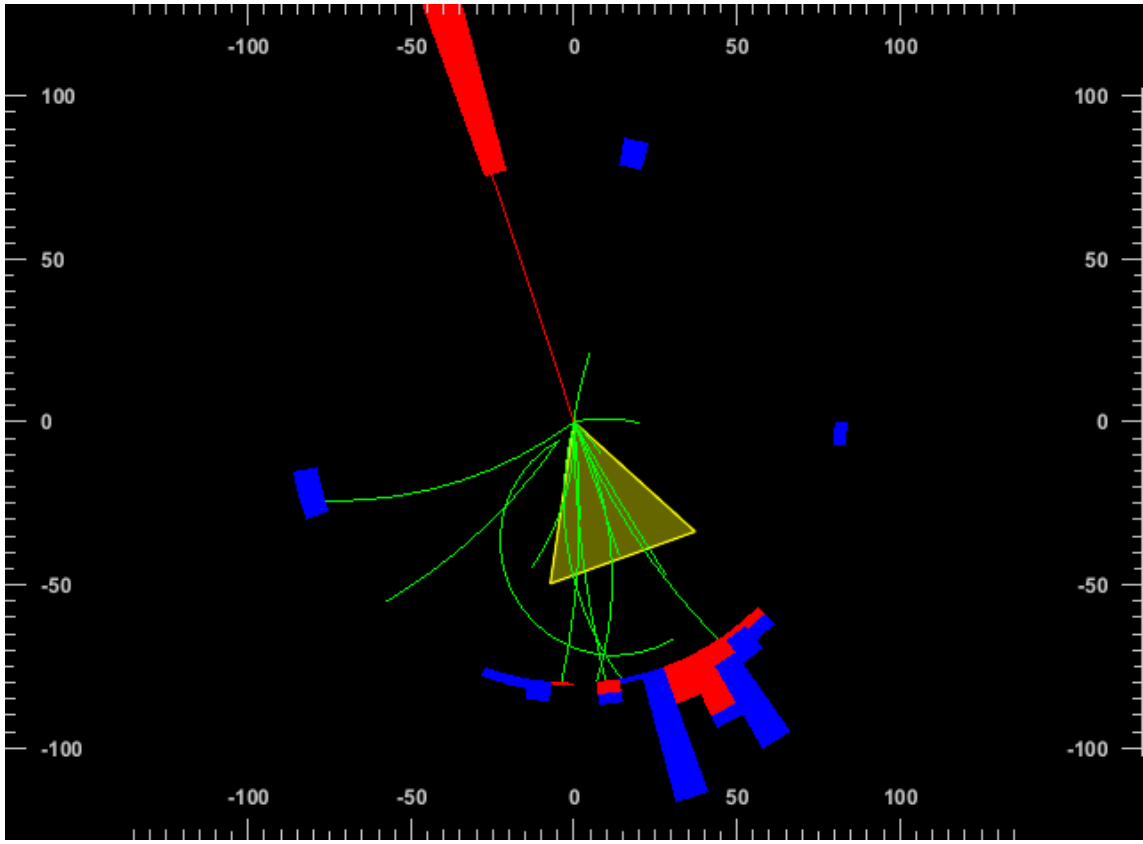


- **We capture most of particles in jet. Large radius required.**
  HERA experience shows that R=1.0 leads to O(1)% “hadronization corrections”.
  Only possible because DIS is a clean environment.
- **We measure both charged and neutral particles in the jet (~4-10 total on average)**

  Defining “charge-only jets” would introduce model-sensitivity to fragmentation, completely defying the purpose of jets in the first place.
  While such approach works for heavy-ion physics at LHC (x100 higher energy than EIC), it does not really match EIC accuracy needs.

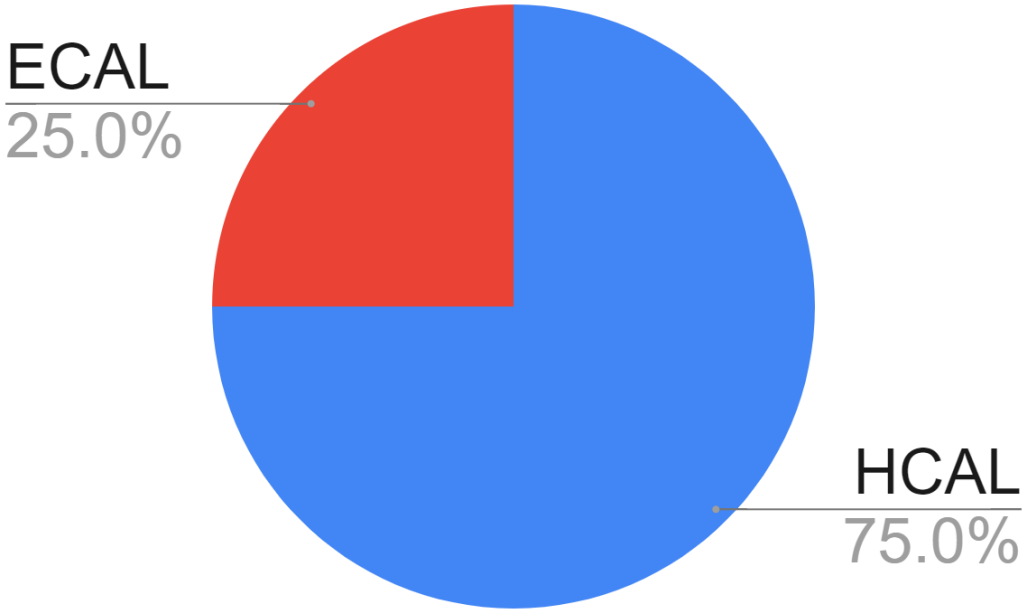
What is in a jet?



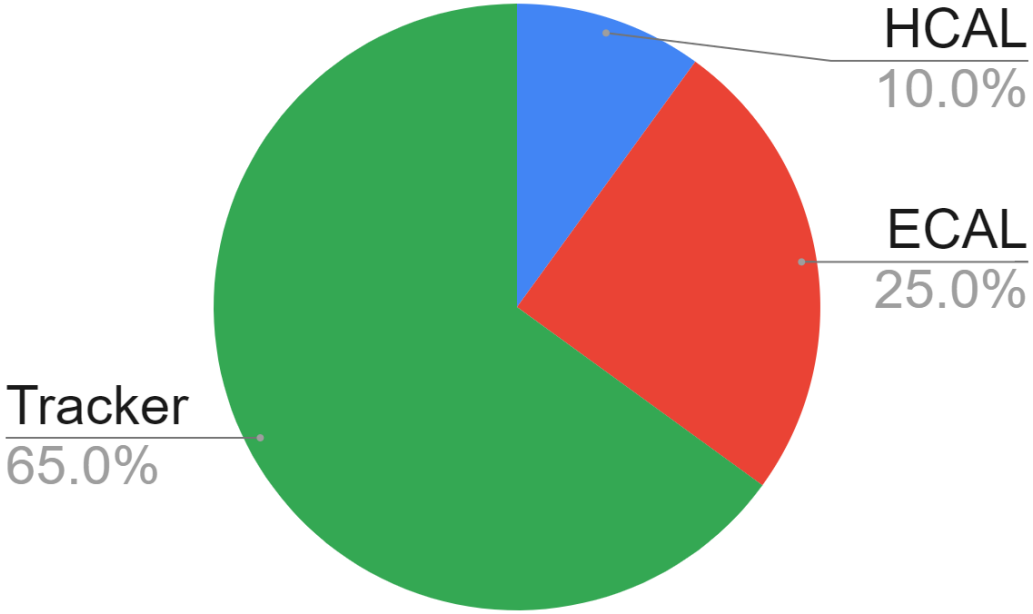


Two options to measure jets

Purely calorimetric

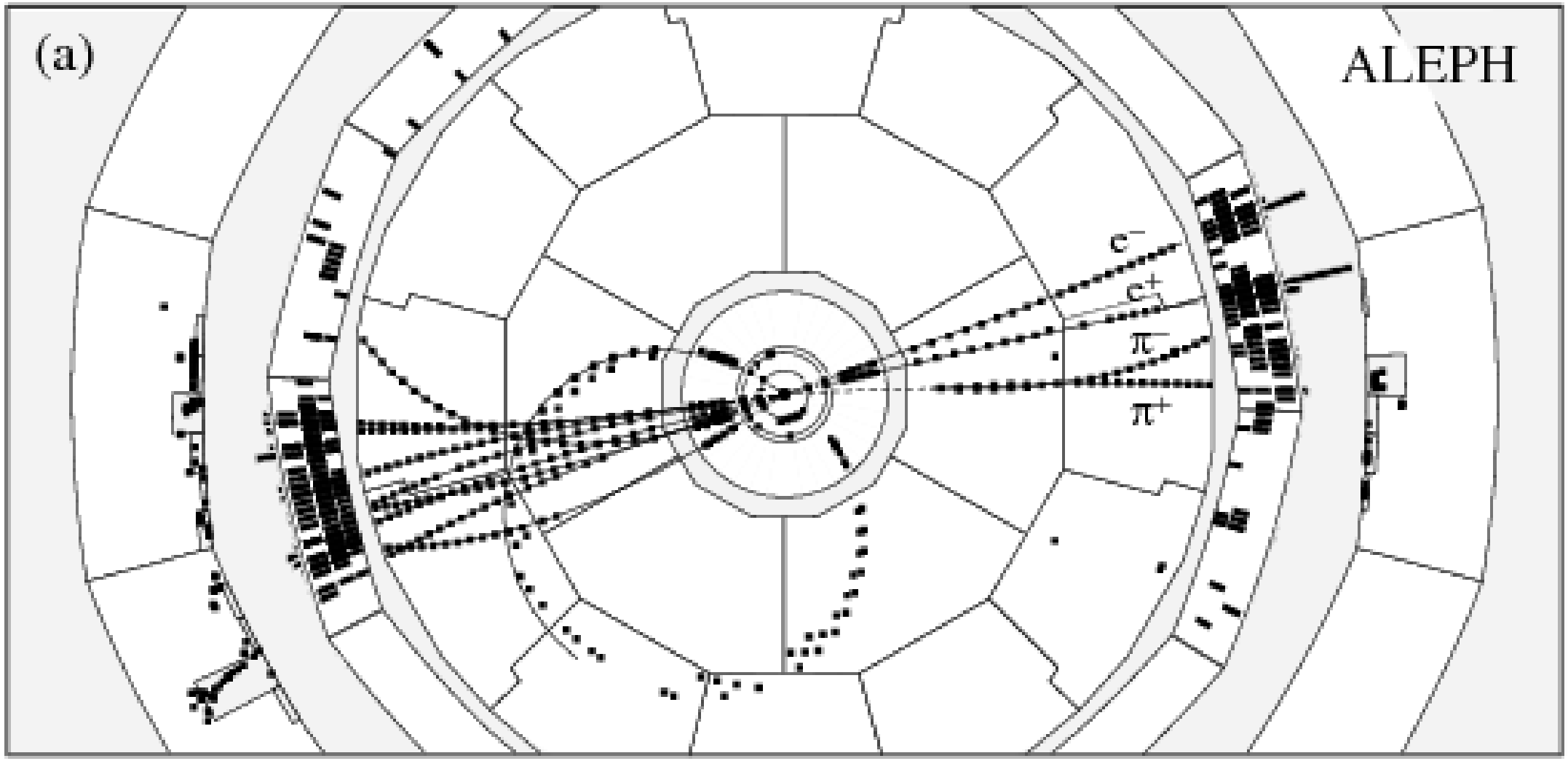


“Energy-flow” method



At high energies both methods yield similar jet energy resolution
At EIC energies, the choice for “energy-flow” is a no brainer

Energy-flow is not precisely new…



(Used by ALEPH@LEP, CDF@Tevatron, H1@HERA, CMS@LHC, and is planned at sPHENIX@RHIC …)

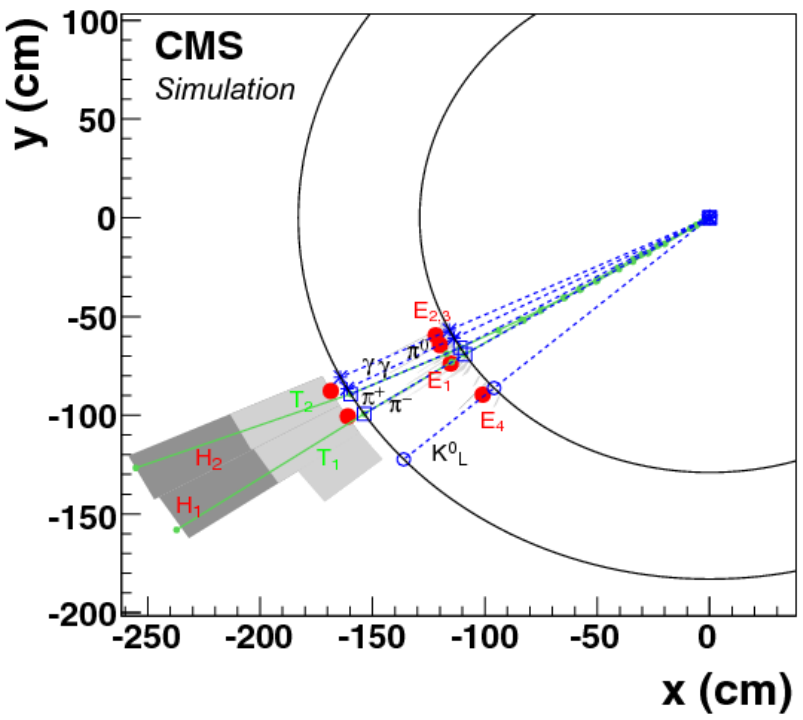
“Energy-flow” method

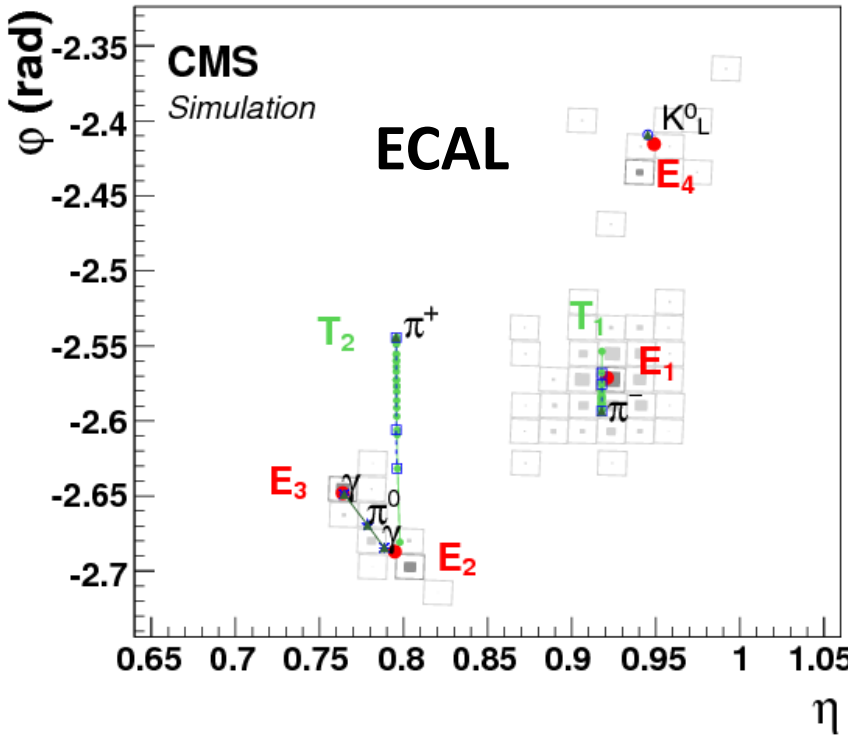
(1) charged tracks and identified leptons contributions are taken from their tracking measurement
(2) γ and π^0 from the electromagnetic calorimetry
(3) neutral hadron from both calorimeter measurement
(4) the last component being the residual from charged hadrons or γ which should be kept at the lowest level

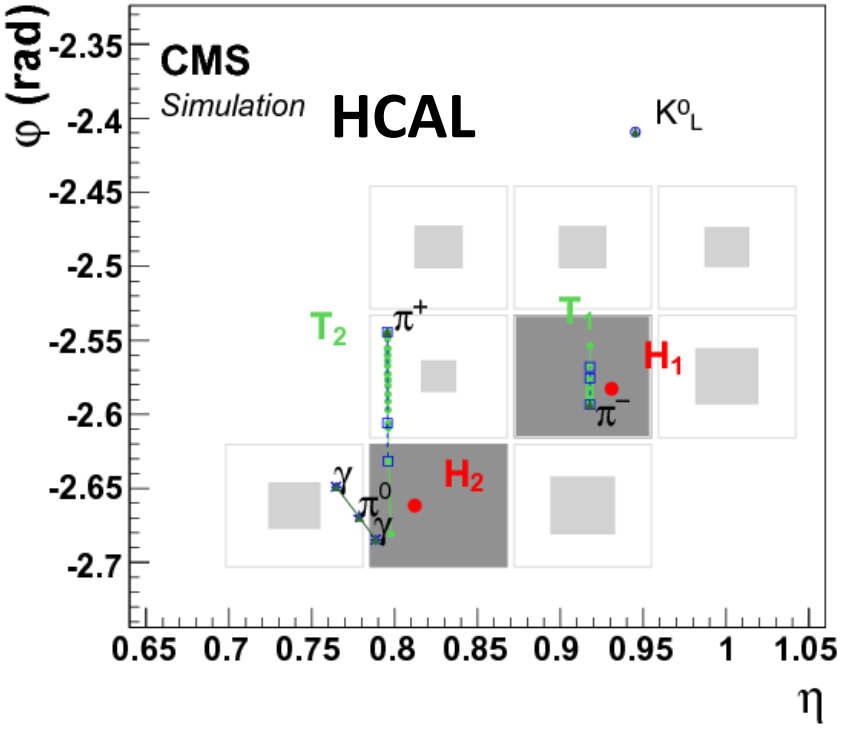
http://hal.in2p3.fr/in2p3-00012827/document

Energy flow in practice

CMS Collaboration *JINST* 12 (2017) P10003

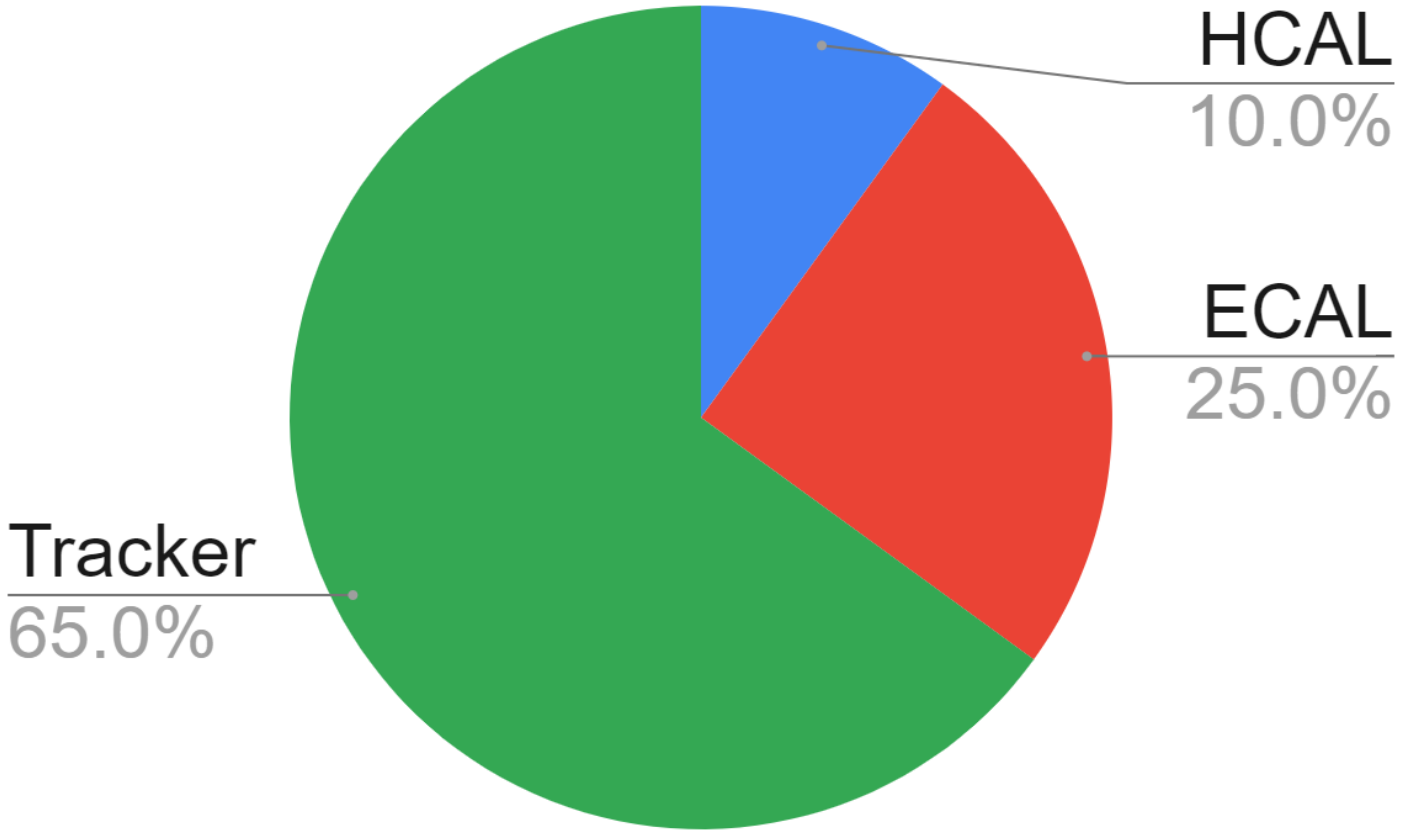




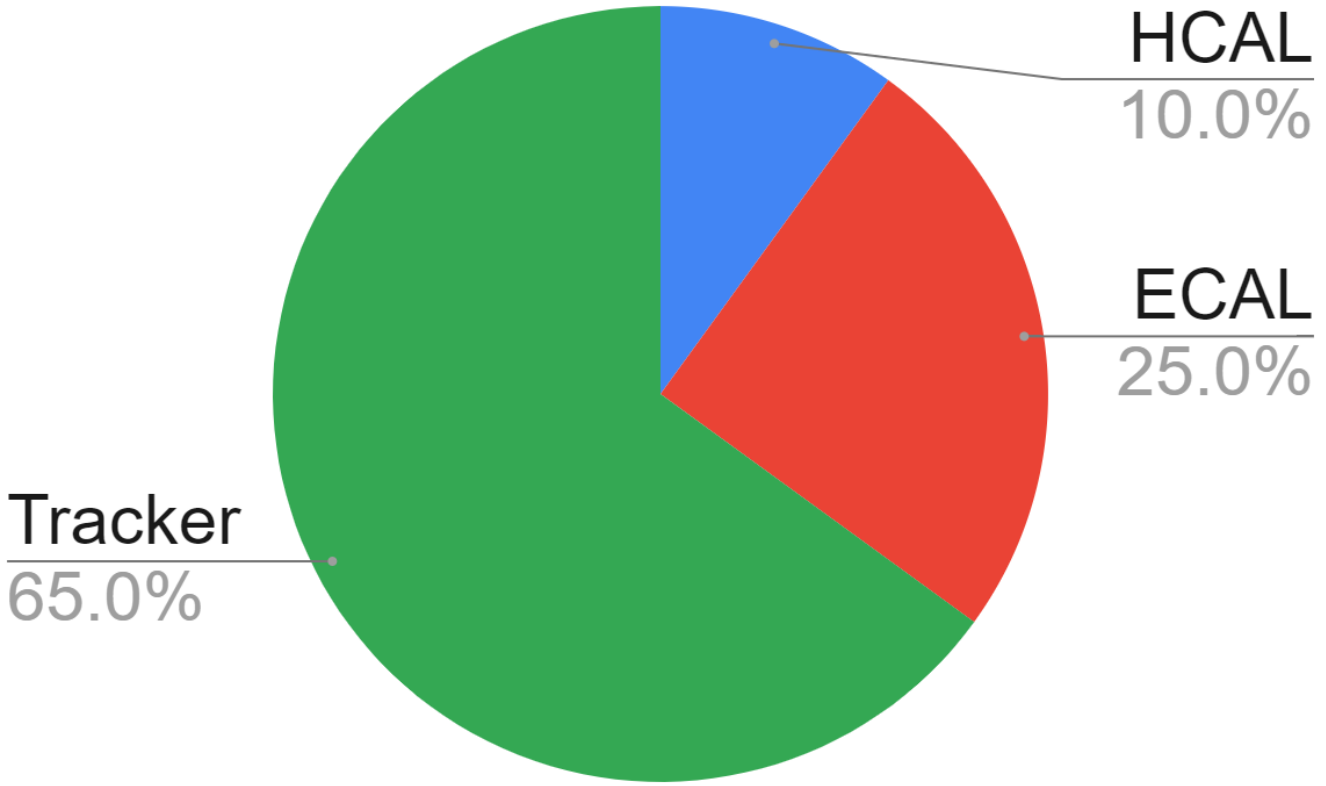


Granularity of calorimeters key, “confusion” drives the resolution

With just tracking, the glass if half full (half empty)



Jet energy resolution with energy-flow method is driven by measurement of neutrals

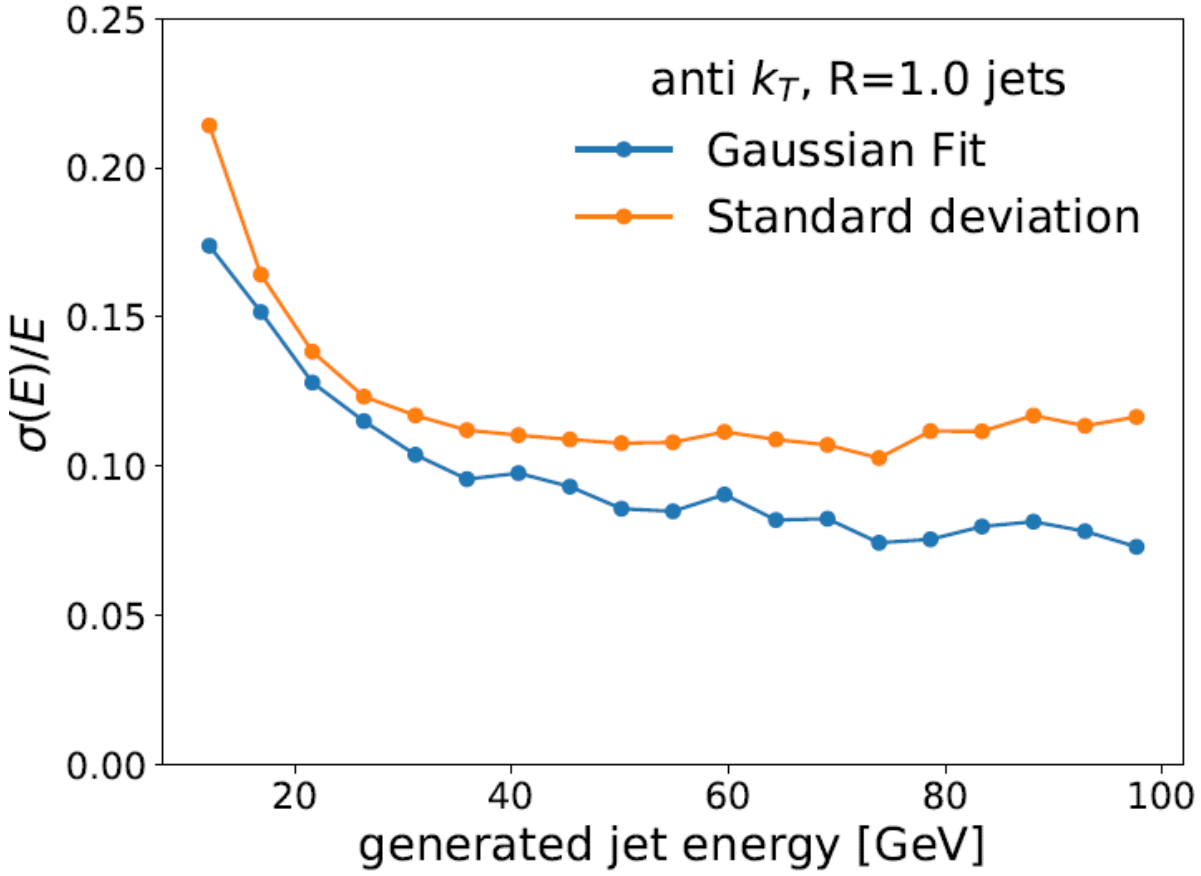


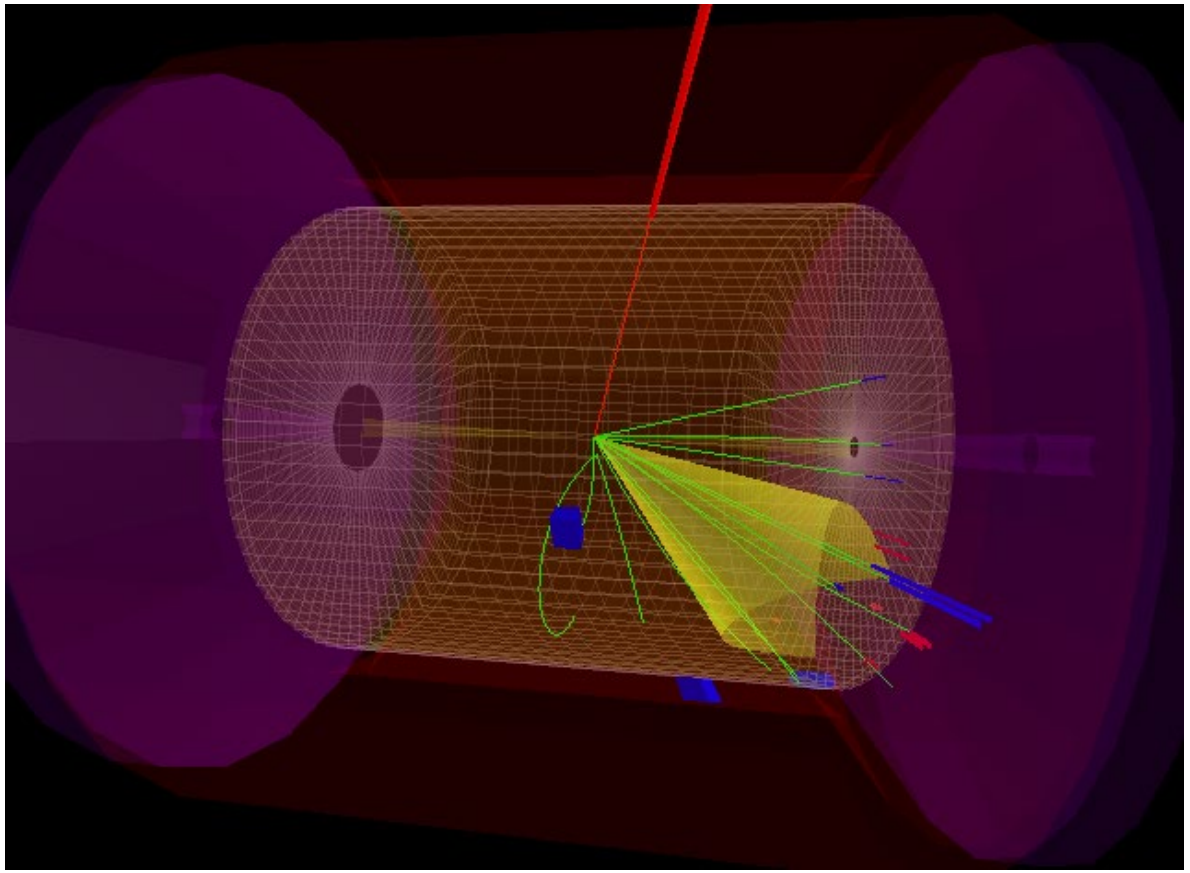
Tracking resolution is negligible

Energy-flow performance expected at EIC

arXiv:2007.07281

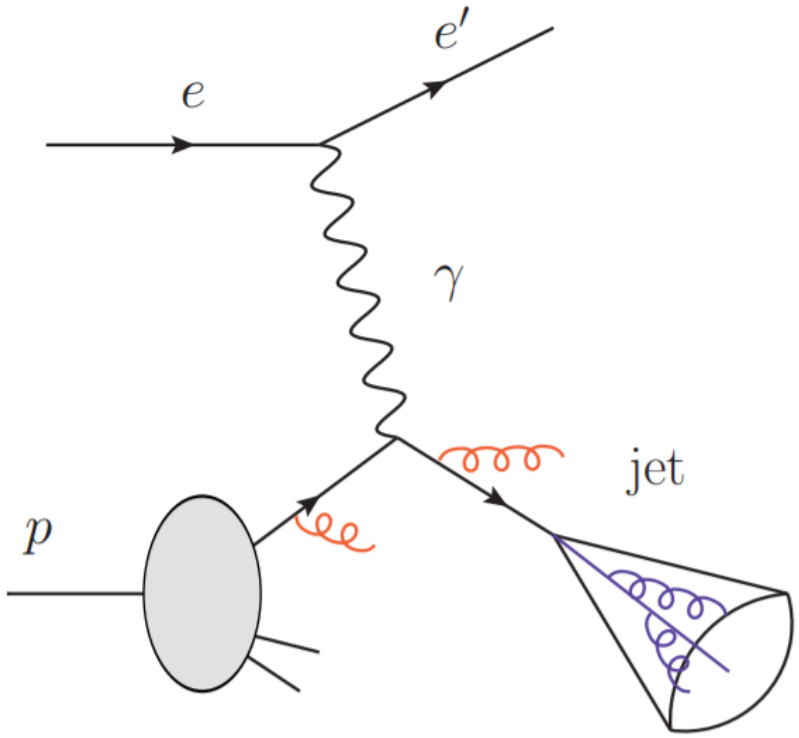
Jet energy resolution



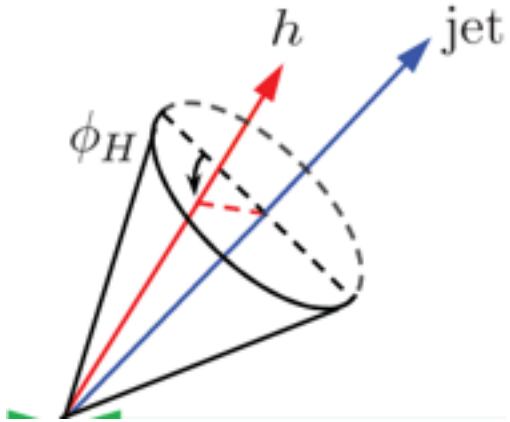


But tracking resolution still relevant for fragmentation (aka “hadron-in-jet”) measurements, e.g:

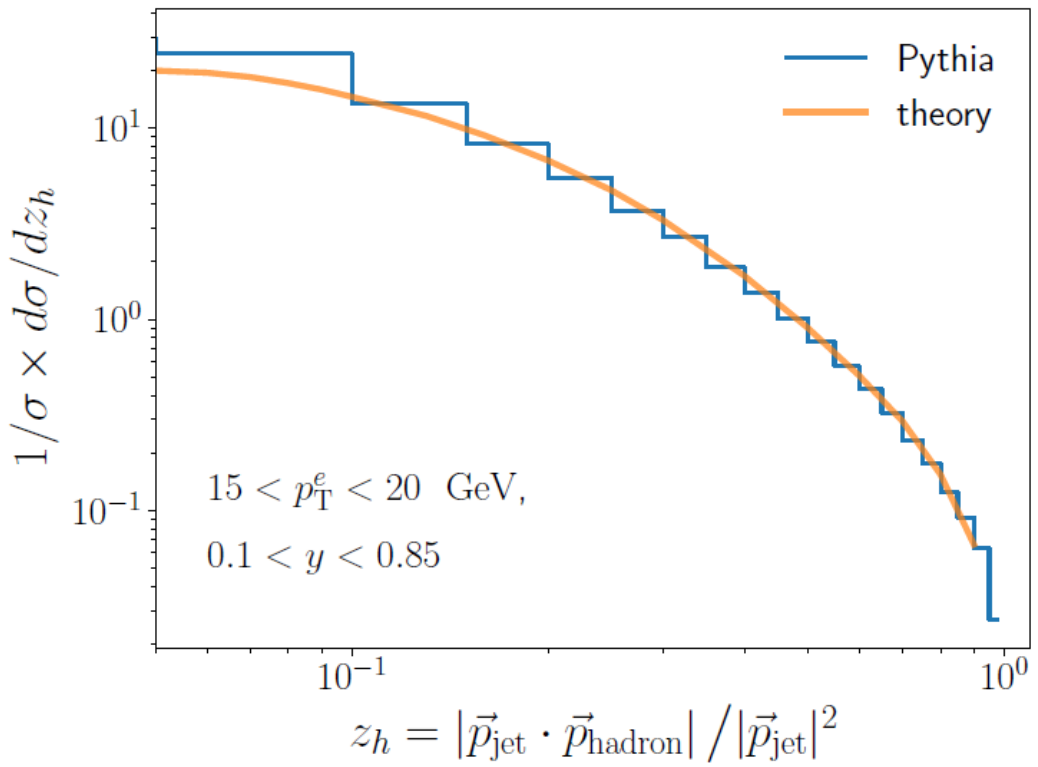
Jet-based measurements of Sivers and Collins asymmetries at the future Electron-Ion Collider arXiv:2007.07281

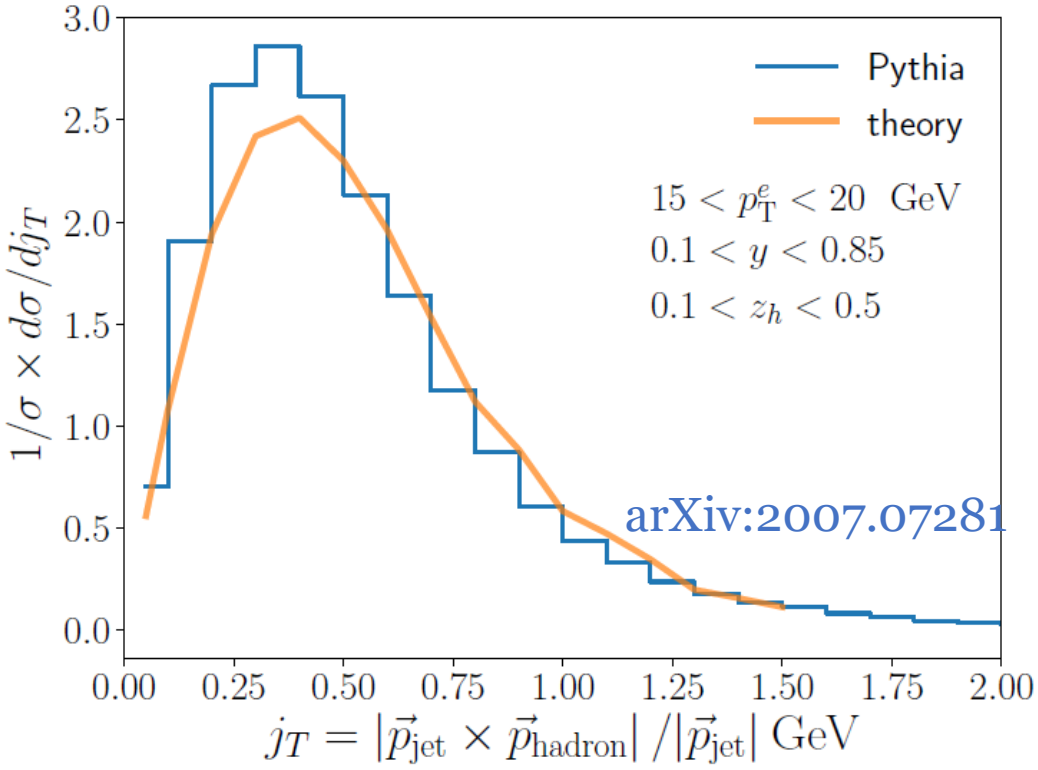


$$e + p(\vec{s}_T) \to e + (\mathrm{jet}(\vec{q}_T)\, h(z_h, \vec{j}_T)) + X\,.$$



Hadron-in-jet distributions

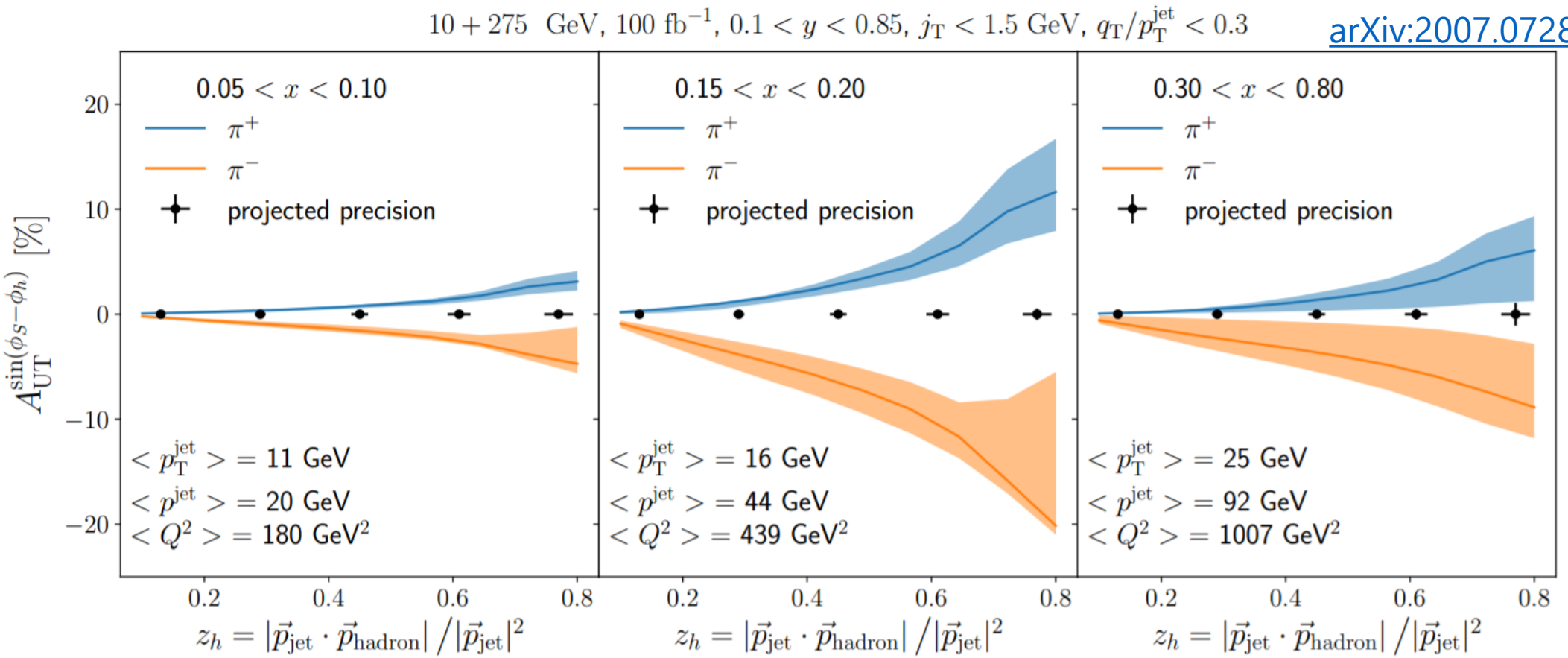




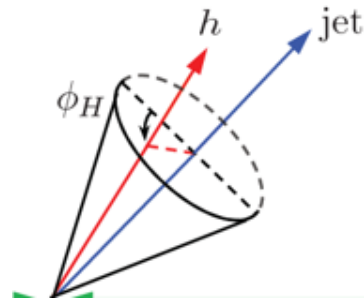
Resolution depends on both jet energy and tracking momentum resolution. Improving momentum resolution beyond jet-energy resolution would not improve the measurement.

$$dp/p \text{ at high } z < \text{jet } dE/E$$

Hadron-in-jet Collins asymmetries

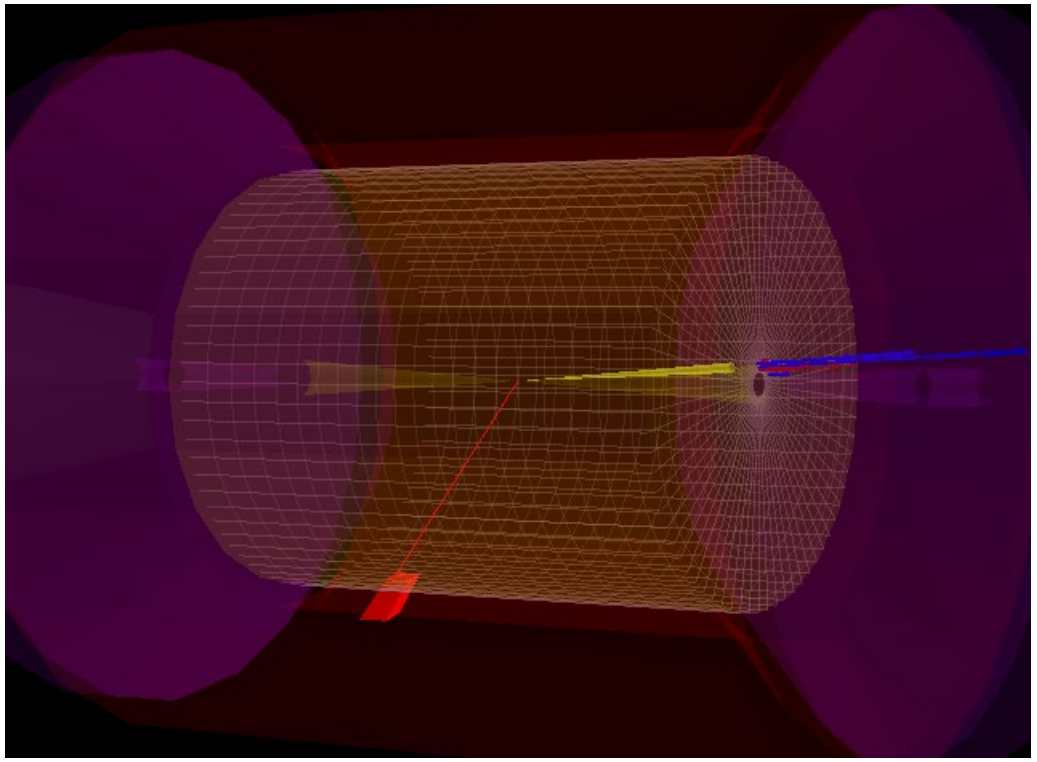


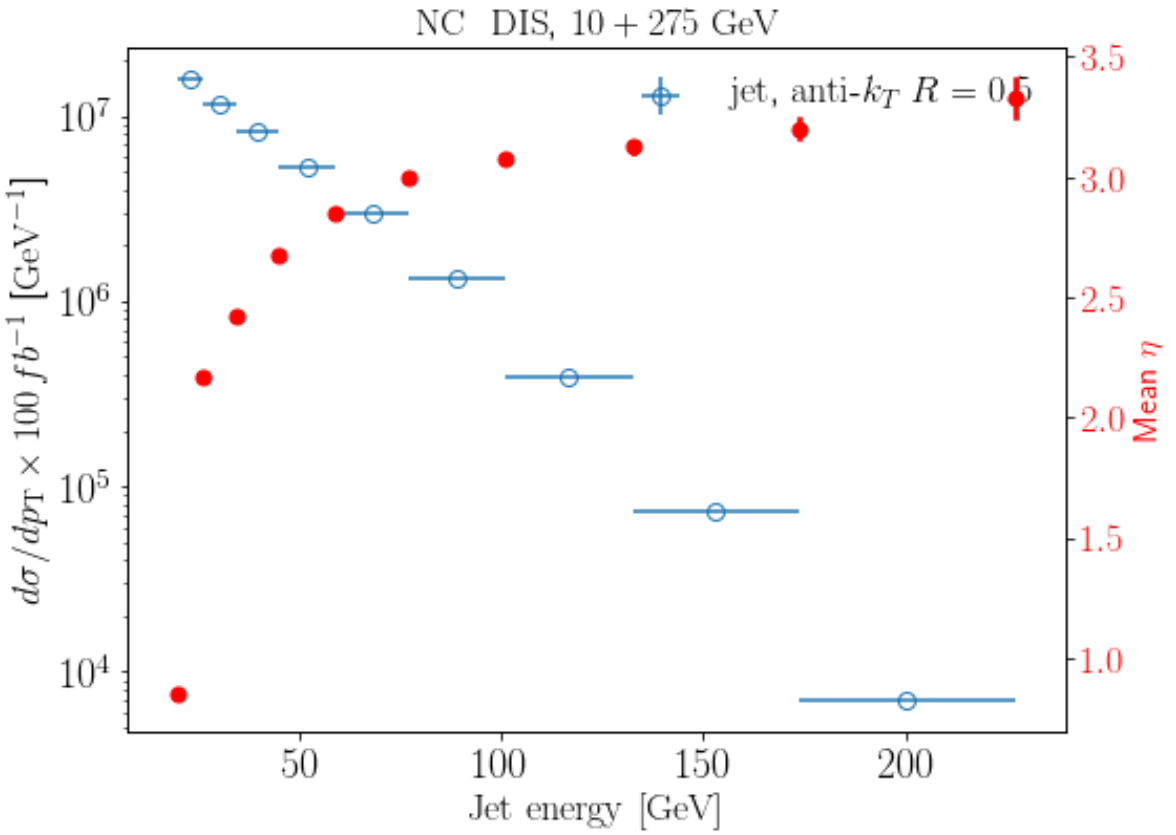
arXiv:2007.07281



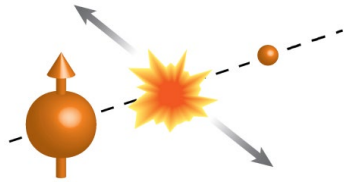
- Most stringent requirements come from high-x domain, O(100 GeV) jet.
  -> Need that dp/p < 8% for tracks with ~60 GeV p at pseudorapidity ~ +2.0

Forward jets, a tough challenge for tracking

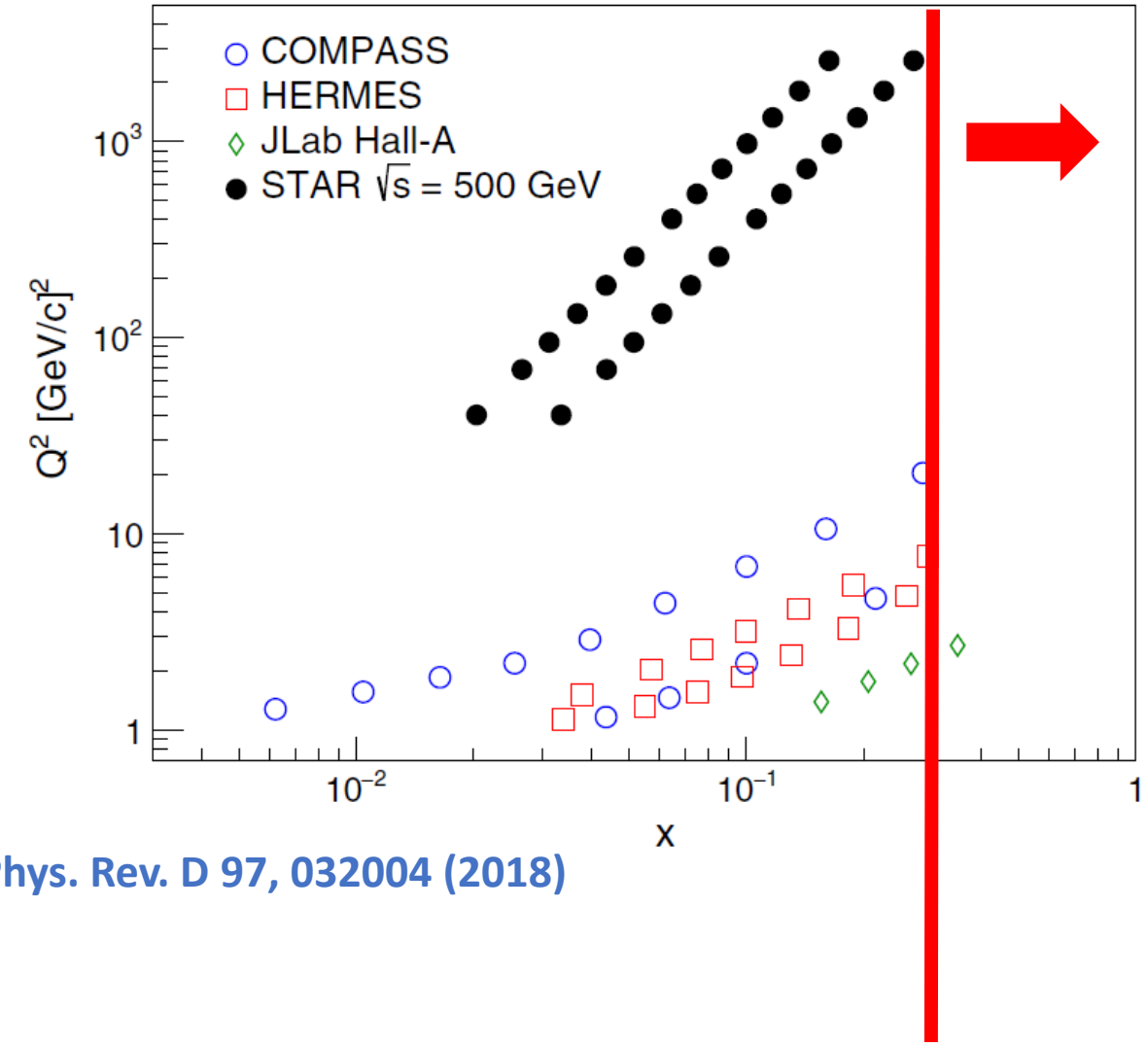




The high-x frontier

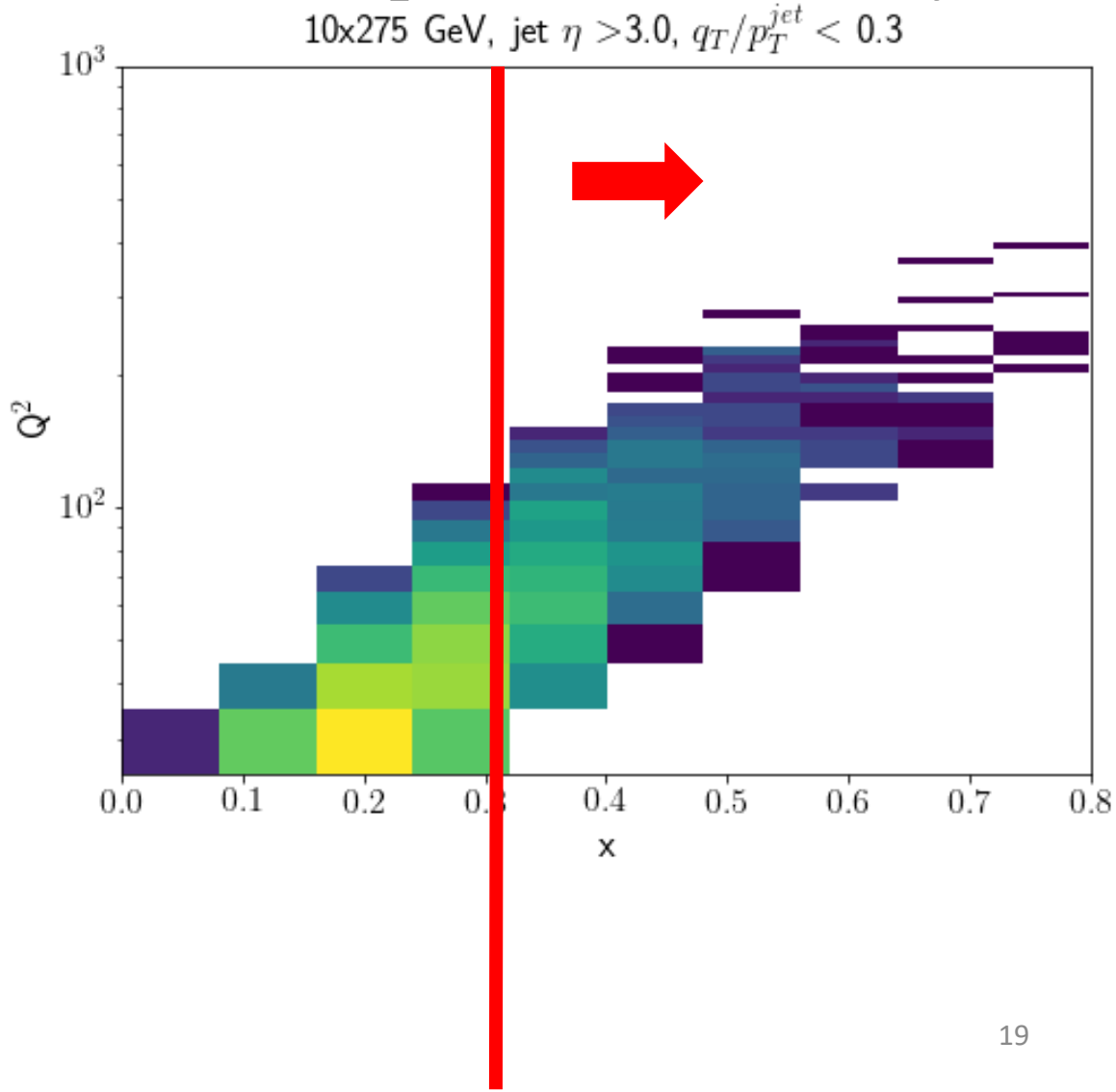


Existing transversely-polarized data

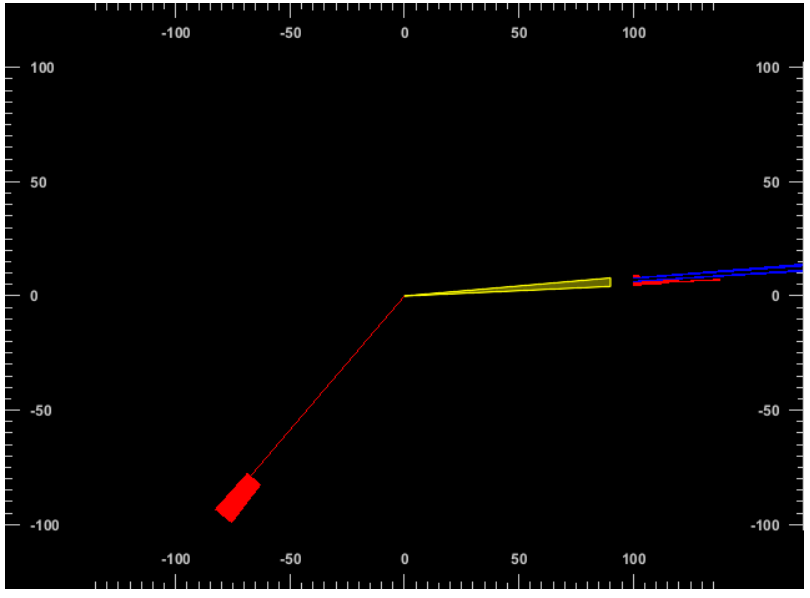


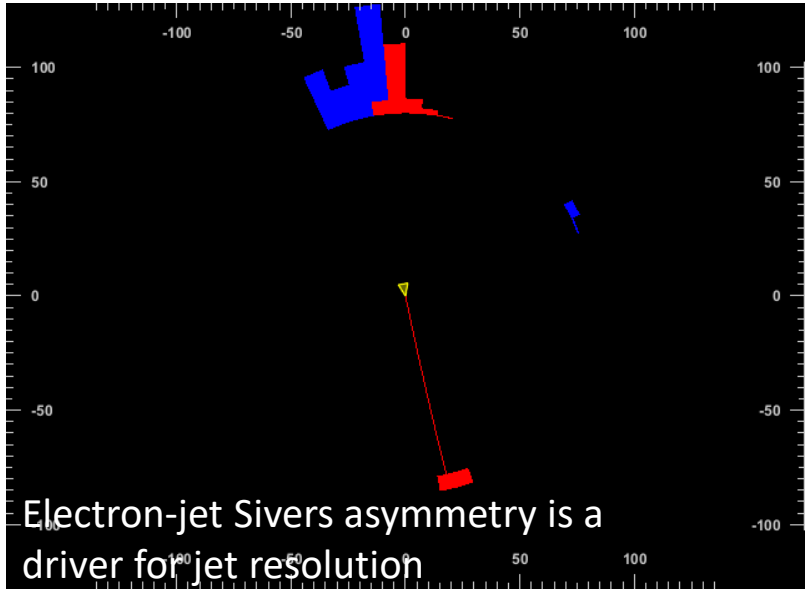
Phys. Rev. D 97, 032004 (2018)

EIC potential of forward jets



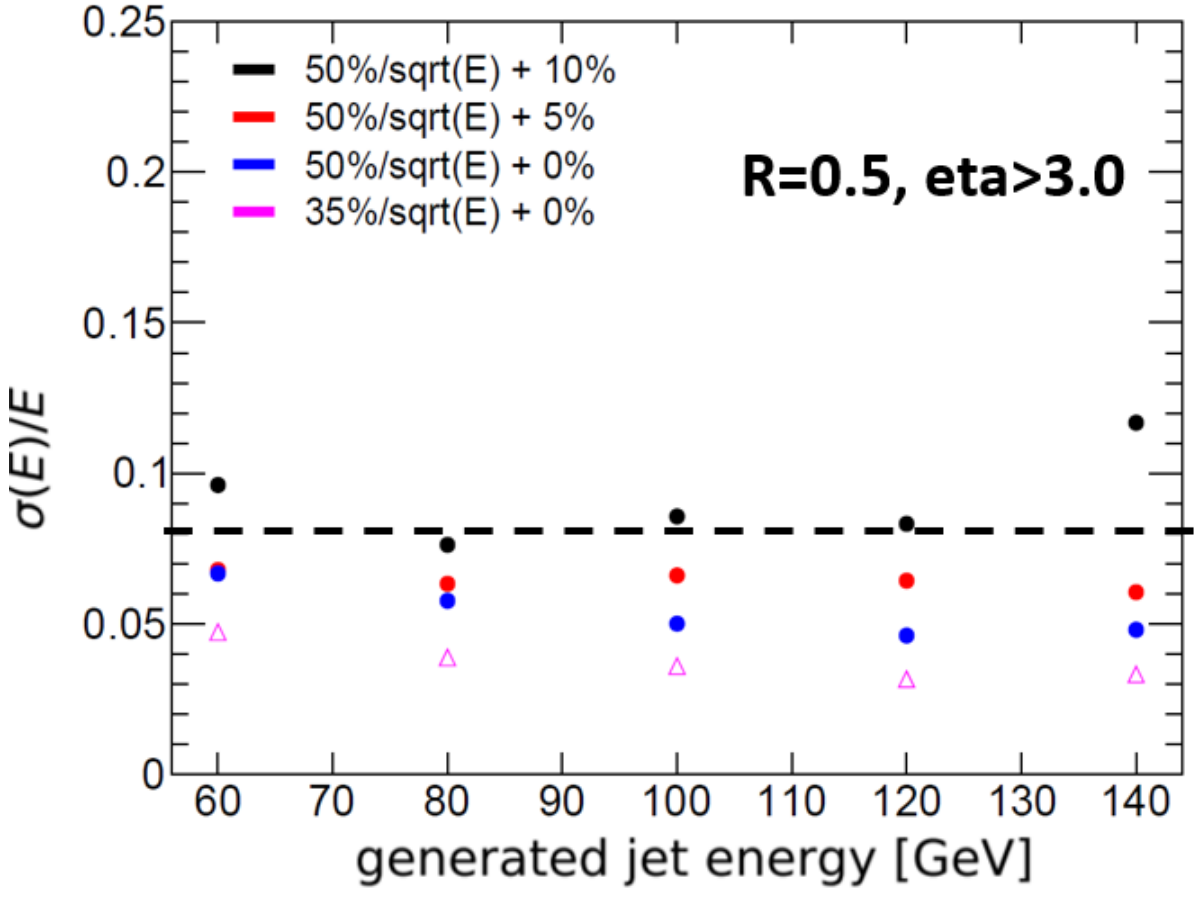
Does the tracker have a fighting chance vs HCAL?





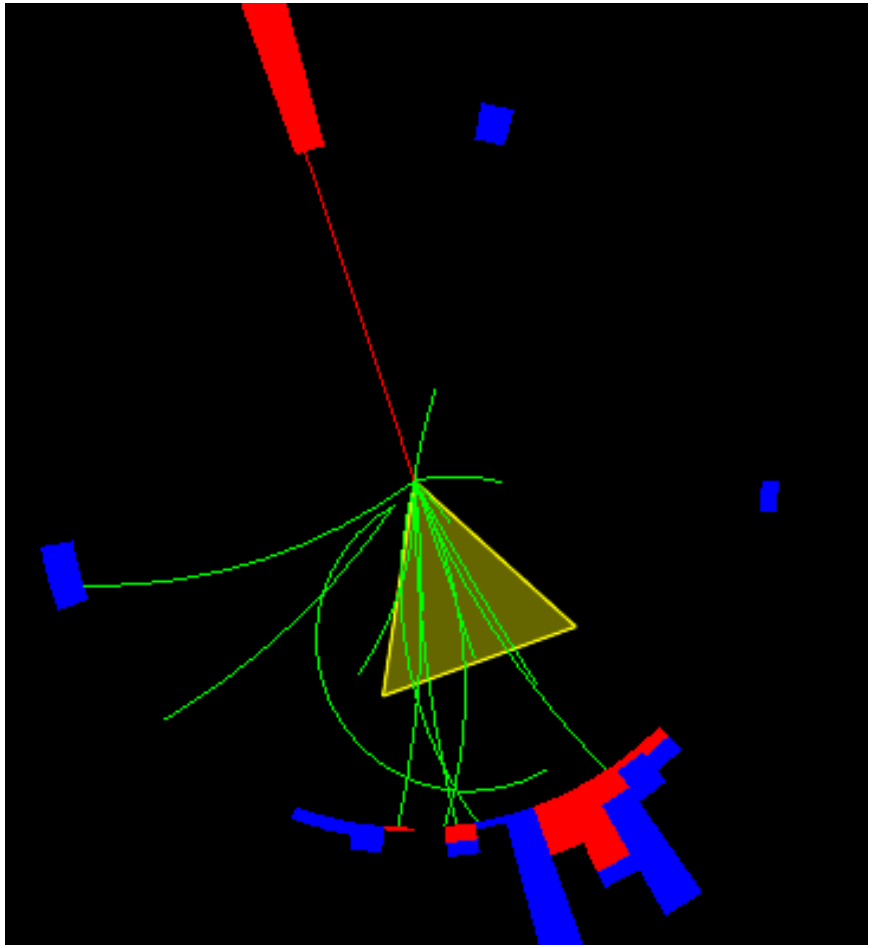
Electron-jet Sivers asymmetry is a driver for jet resolution

Purely calorimetric reconstruction



Summary

- “Energy flow” method is a no-brainer for EIC jet measurements (except perhaps at very forward rapidity).
- In contrast to SIDIS, for jets there is no need or gain in improving tracking resolution. Performance with B=1.5 T magnet is OK for most (all?) jet measurements.
- For EIC jets, every particle is precious. Need low threshold (~100 MeV) with high efficiency.
  Beware of the 3.0 T field.
- Jets and SIDIS offer opportunity for complementarity for both detector and physics.



Topics:

- Jets for studies of spin, and transverse-momentum-dependent and generalized- parton distributions (TMDs and GPDs)
- Jet observables, advantages and complementarity at the EIC
- Novel jet-substructure observables
- pQCD and effective-field-theory techniques for jets
- 3D and 5D imaging with exclusive jets (GPDs and Wigner functions)
- Connections to Lattice QCD
- Parton-shower developments
- Detector requirements for the EIC

You are welcome to attend virtually to the inaugural event in this new workshop series. Registration open at:
https://indico.bnl.gov/event/8066/overview

Second edition will be hosted by CFNS in 2021