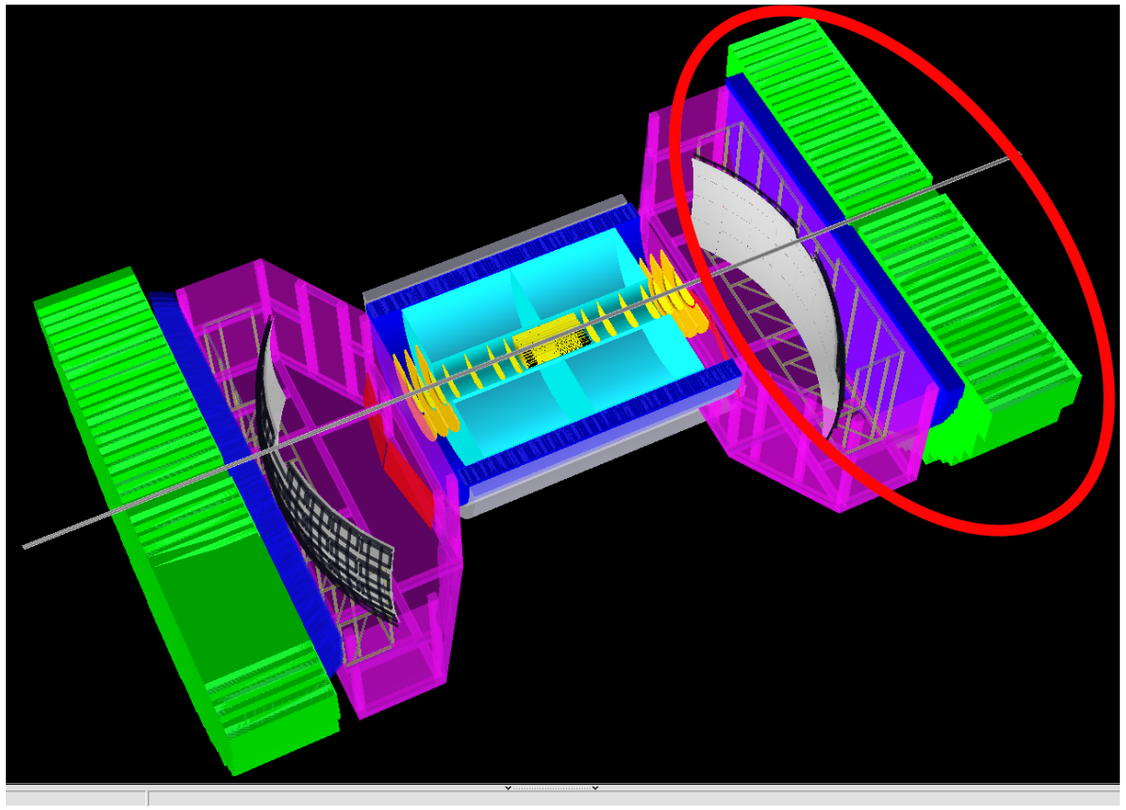
Sources for:

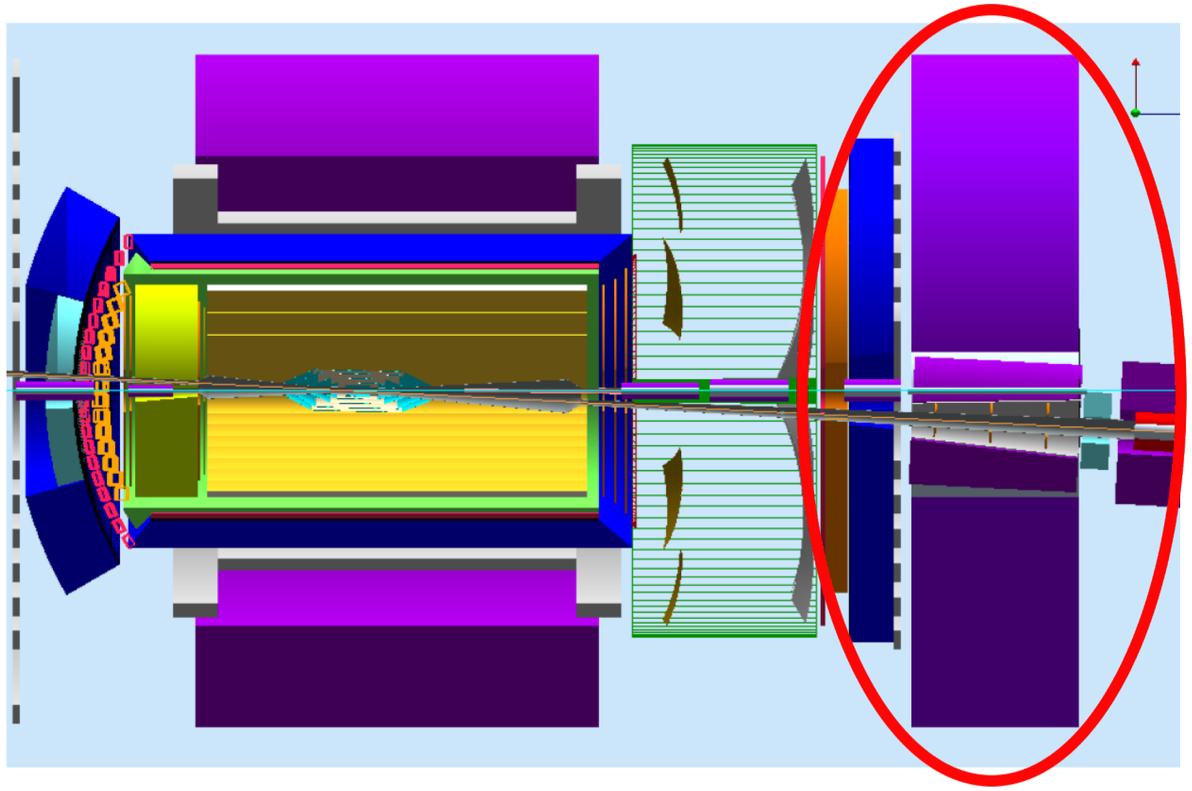
- energy scale
- occupancy
- rates
- some discussion for energy resolution
- radiation environment (eRD1 reports)
- practical considerations

1. https://wiki.bnl.gov/eic/index.php/Detector_Design_Requirement

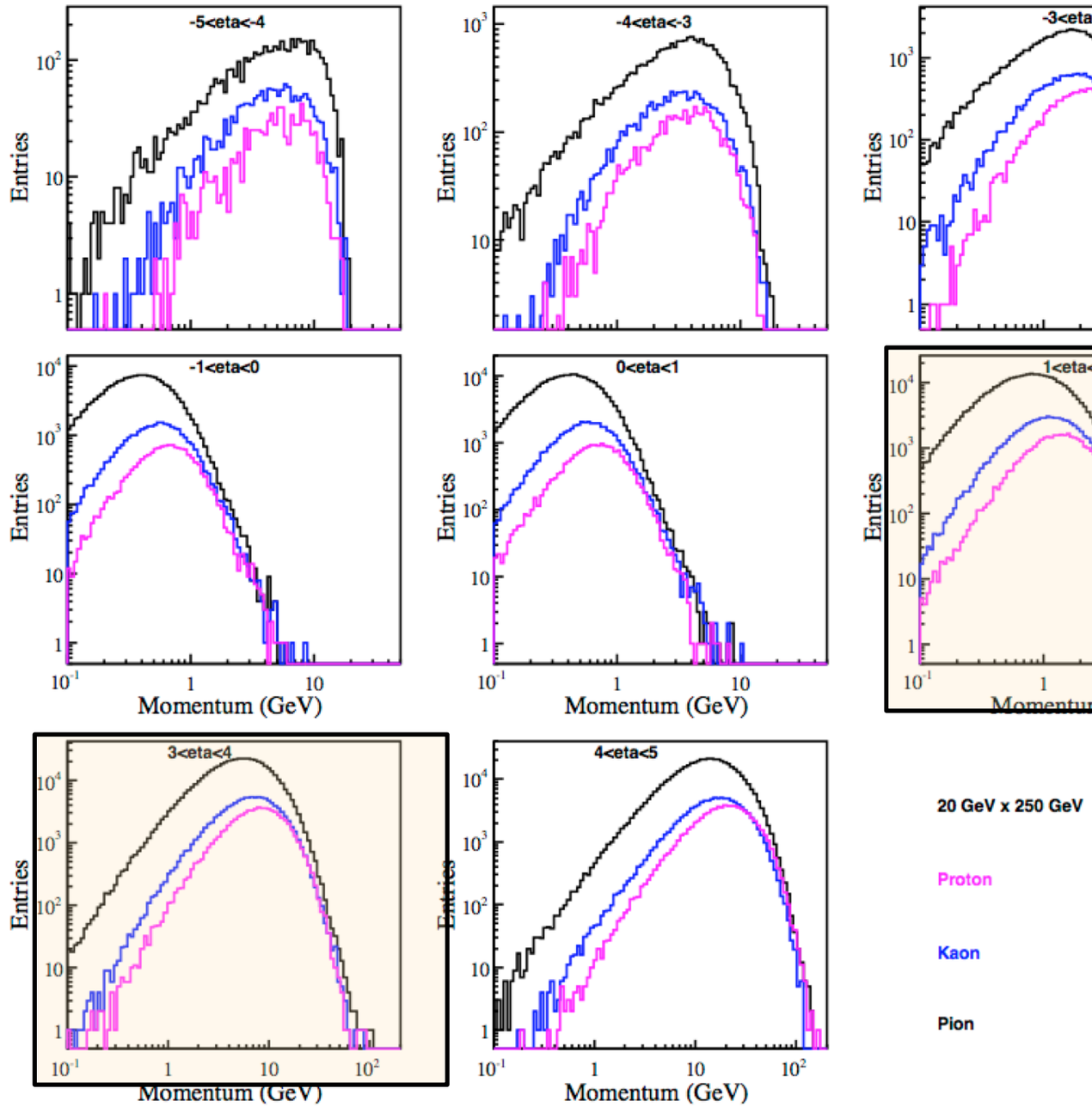
2. *"Experimentla Aspects of Jet Physics at a Future EIC" B.S.Page, X. Chu, E.C. Aschenauer arXiv:1911.00657v2*

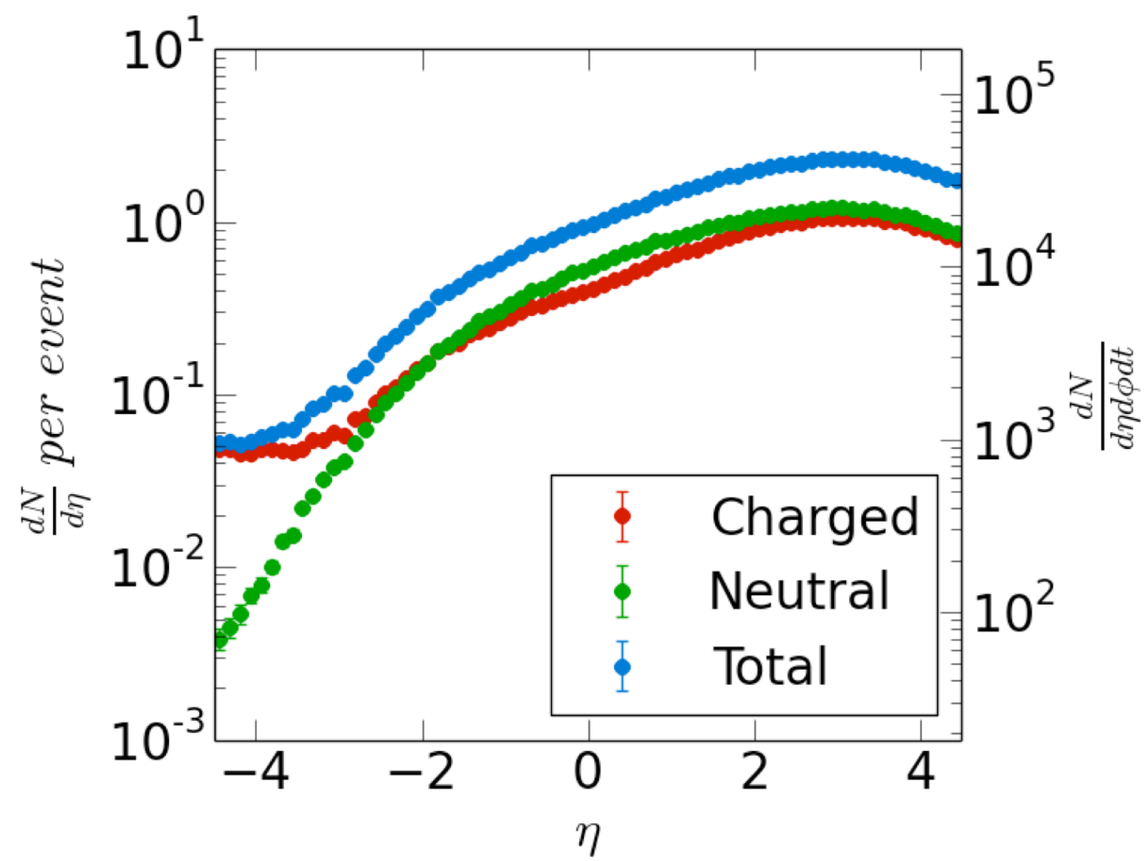
3. *"Jets as precision probes in electron-nucleus collisions at the Electron-Ion Collider" M. Arratia, Y. Song, F. Ringer, B. Jacak.* arXiv:1912.05931





Energy range, Rates





https://wiki.bnl.gov/eic/index.php/Detector_Design_Requirements

Inclusive Jets

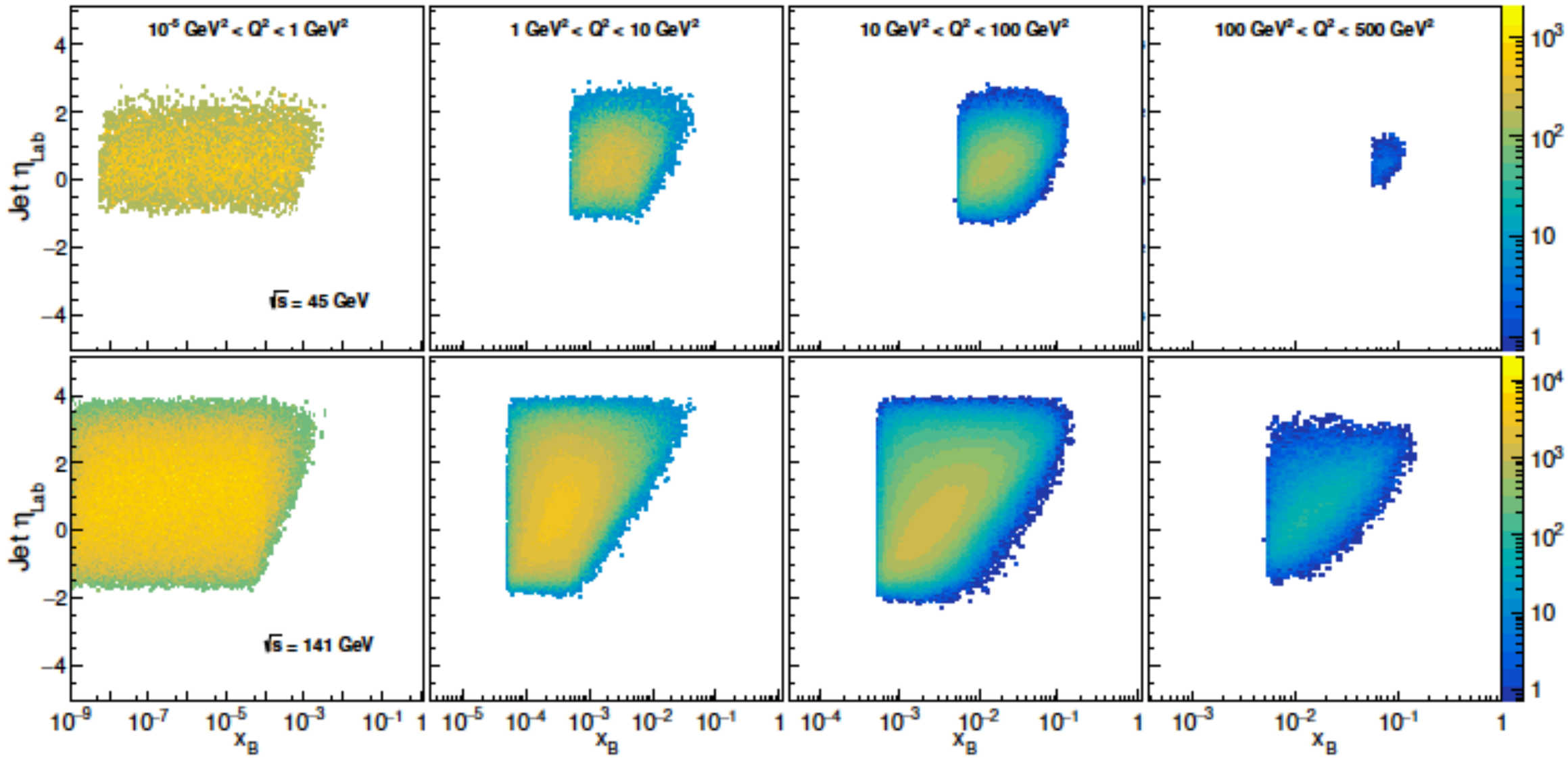
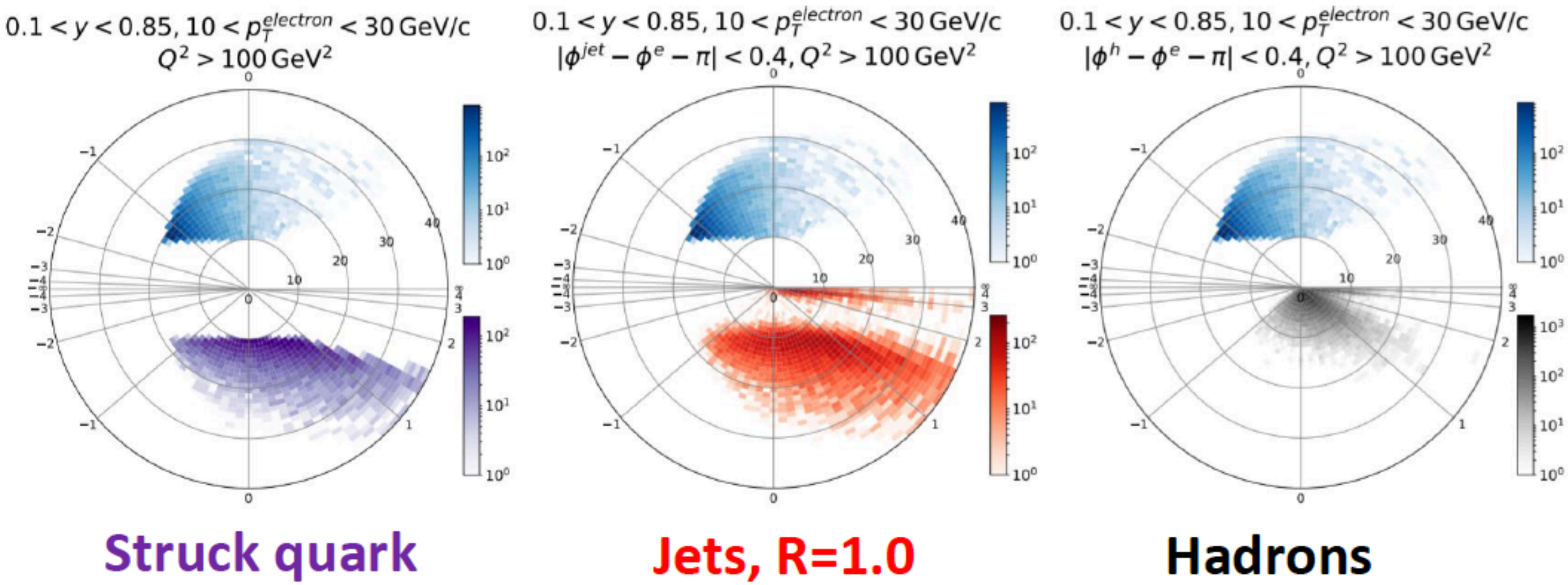


FIG. 6. [color online] Inclusive jet laboratory pseudorapidity vs x_B for Q^2 bins of $10^{-5} - 1.0$ GeV^2 (left column), 1-10 GeV^2 (middle-left column), 10-100 GeV^2 (middle-right column), and 100-500 GeV^2 (right column) for center-of-mass energies of 45 GeV (upper row) and 141 GeV (bottom row). The resolved, QCDC, and PGF subprocesses are shown. Note that the top and bottom rows are separately scaled to the counts expected for 1 fb^{-1} of integrated luminosity.

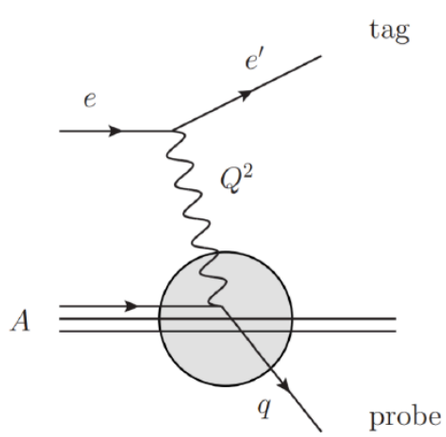
Experimentla Aspects of Jet Physics at a Future EIC"
B.S.Page, X. Chu, E.C. Aschenauer arXiv:1911.00657v2

Jets are excellent proxies for quark kinematics



24

Requirements for tag and probe studies:



1. Kinematics such that the leading-order DIS process dominates.
2. Event kinematics constrained by the electron measurement only.
3. The jet must be matched to the struck quark by separating it from the beam remnant.

arXiv:1912.05931

"Jets as precision probes in electron-nucleus collisions at the Electron-Ion Collider" M. Arratia, Y. Song, F. Ringer, B. Jacak. arXiv:1912.05931

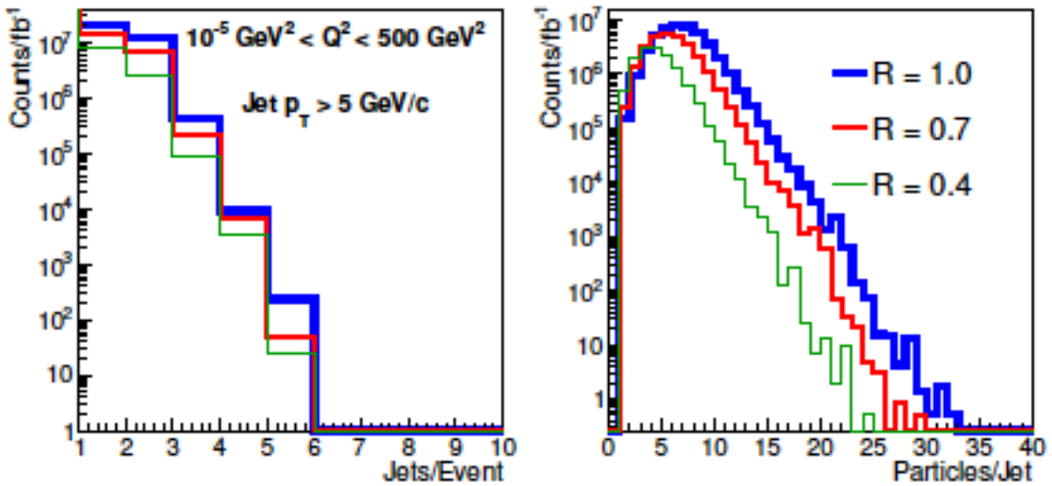
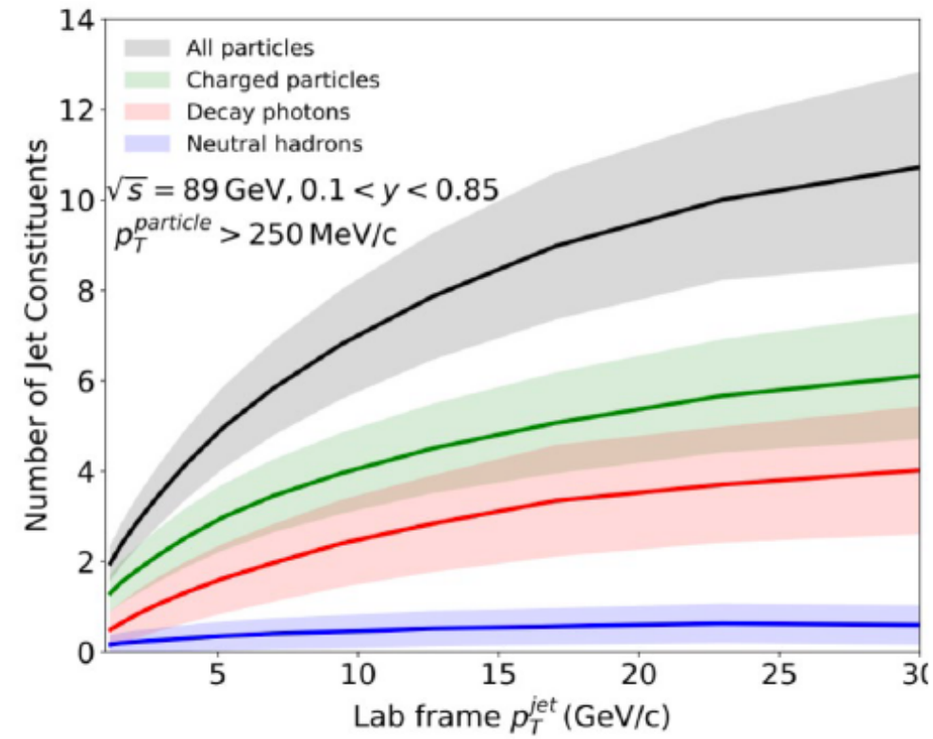
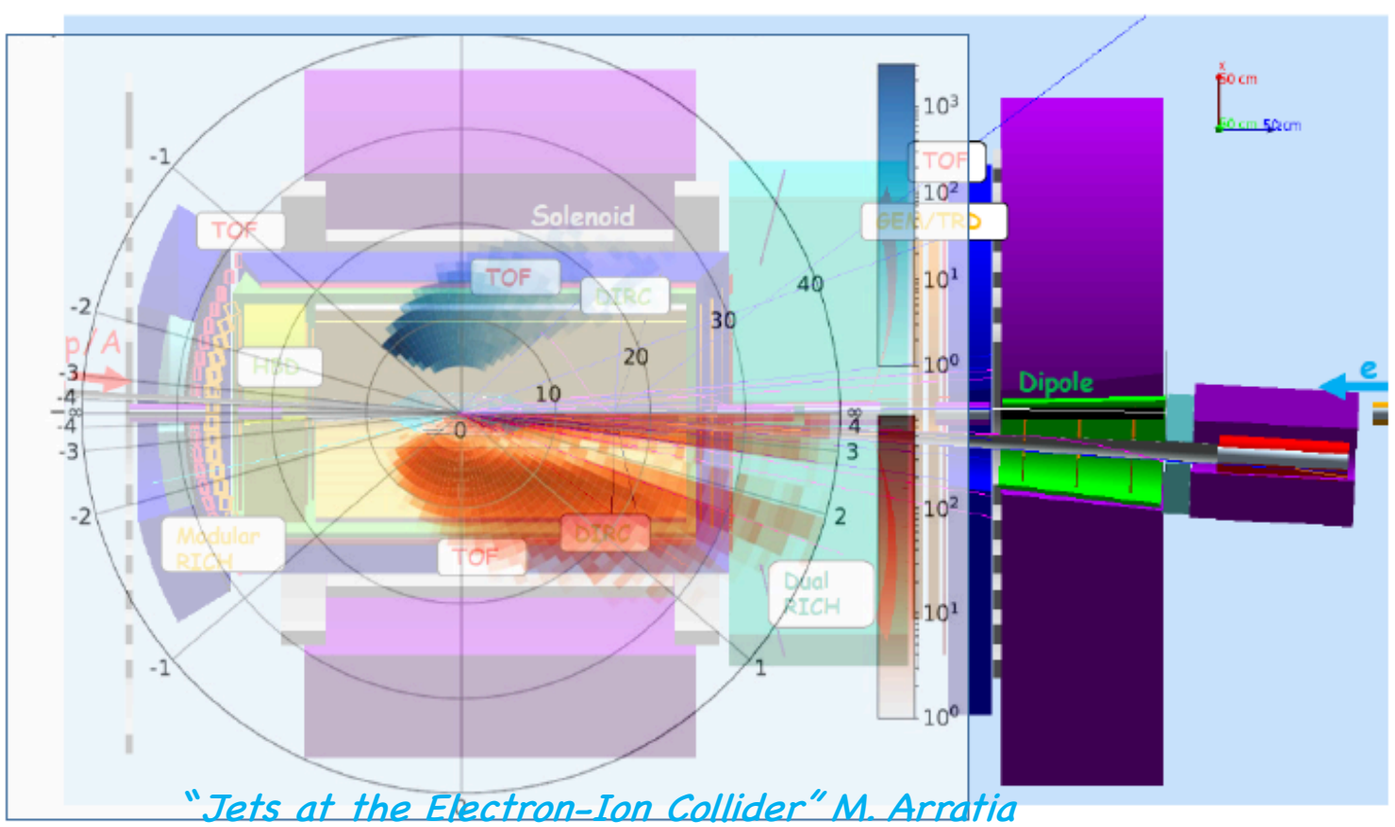


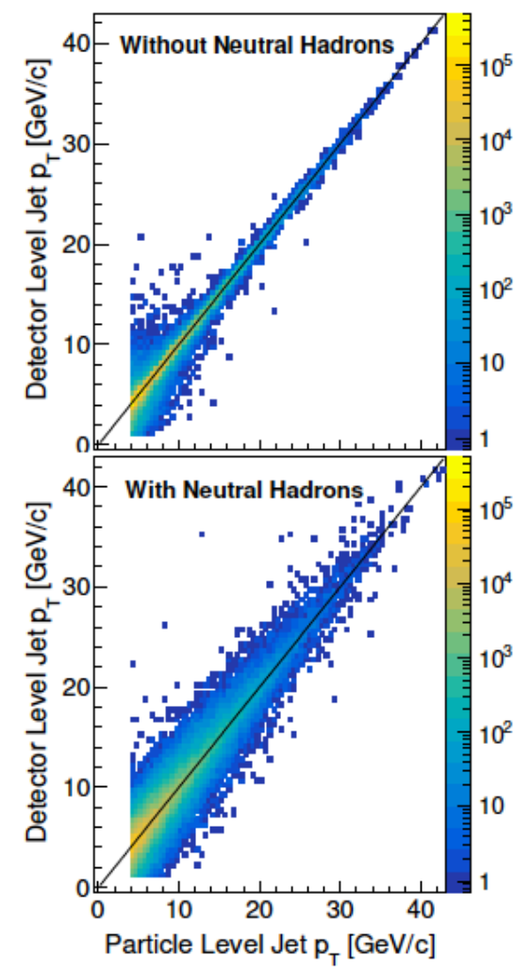
FIG. 2. [color online] Comparison of jet multiplicity (left panel) and particle multiplicity within the jet (right panel) for the anti-k$_T$ algorithms and three resolution parameters R = 1.0, 0.7, and 0.4. The Q^2 range is between 10^{-5} GeV^2 and 500 GeV^2 and the Resolved, QCDC, PGF, and leading order DIS subprocesses have been combined. *Ref.2*



Gaps in calorimeter coverage could limit large-R jets...

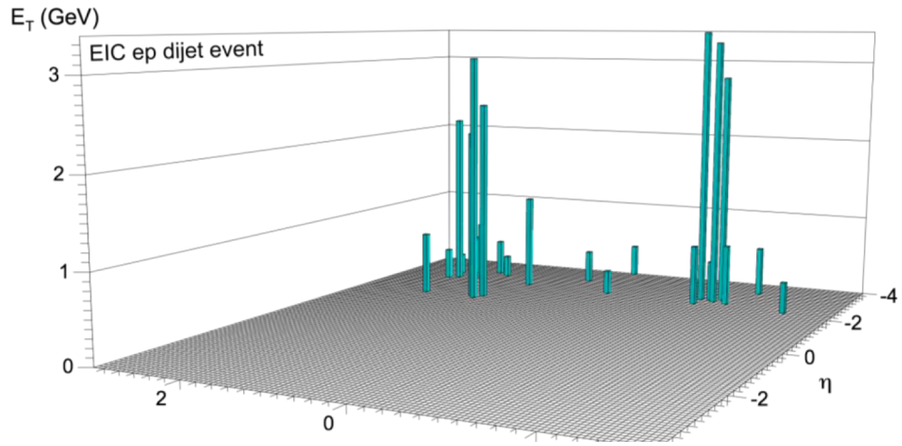


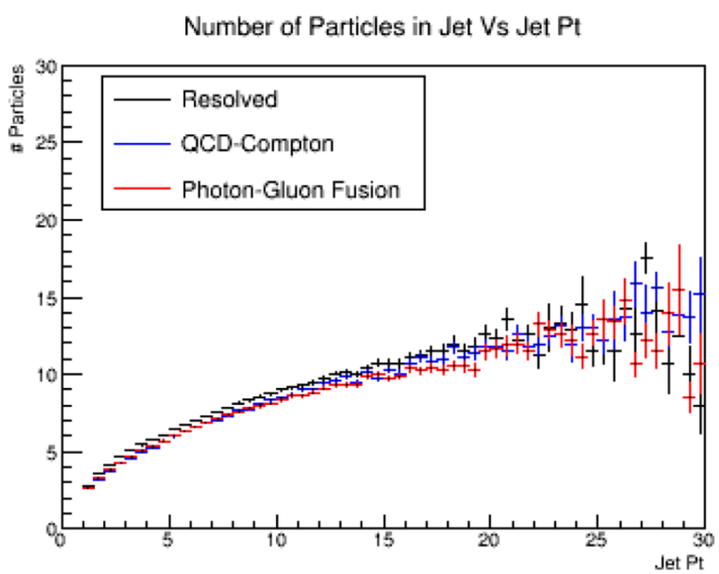
"Jets at the Electron-Ion Collider" M. Arratia
NP Seminar, UCLA Feb.14 2020

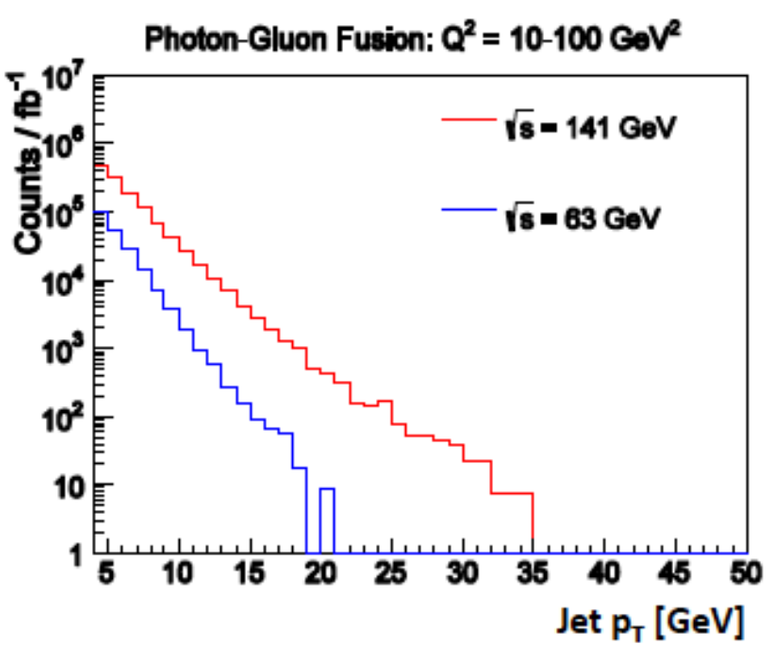


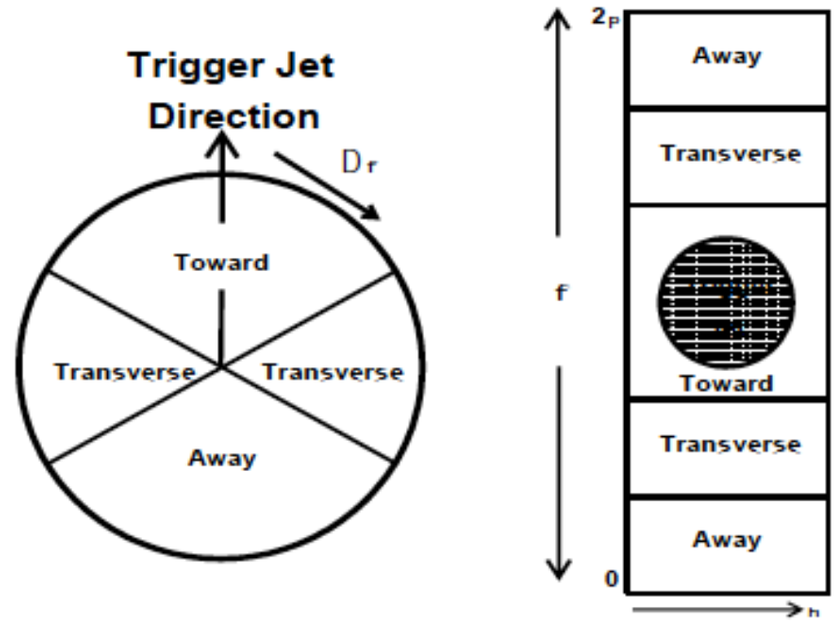
HCAl as a Veto? Ref.2

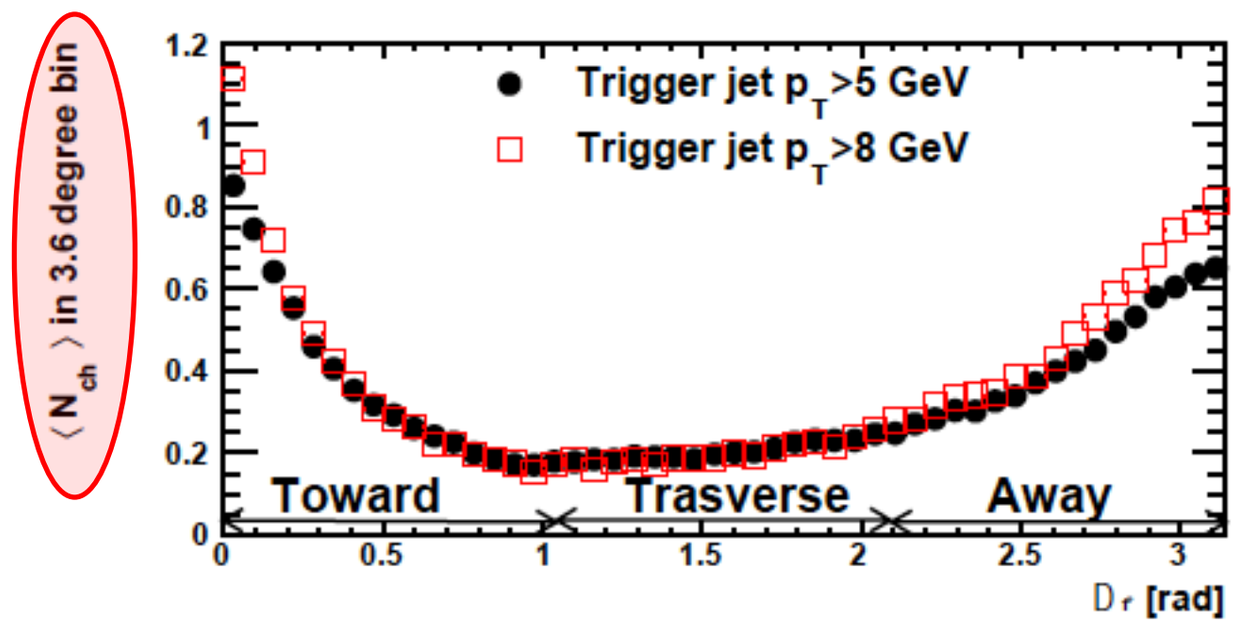
Jets at EIC











- E.C. Aschenauer et.al. "The Electron – Ion Collider Assessing the energy dependence of Key Measurements" arXiv:1708.01527v3
- B.Page, Santa Fe, Jets and Heavy Flavor Workshop, Jan 29, 2018

- Jets are soft, occupancy and rates are low.
- Large R, Noise due to degradation of SiPMs. (Neutrons, Absorber type, see eRD1 reports)

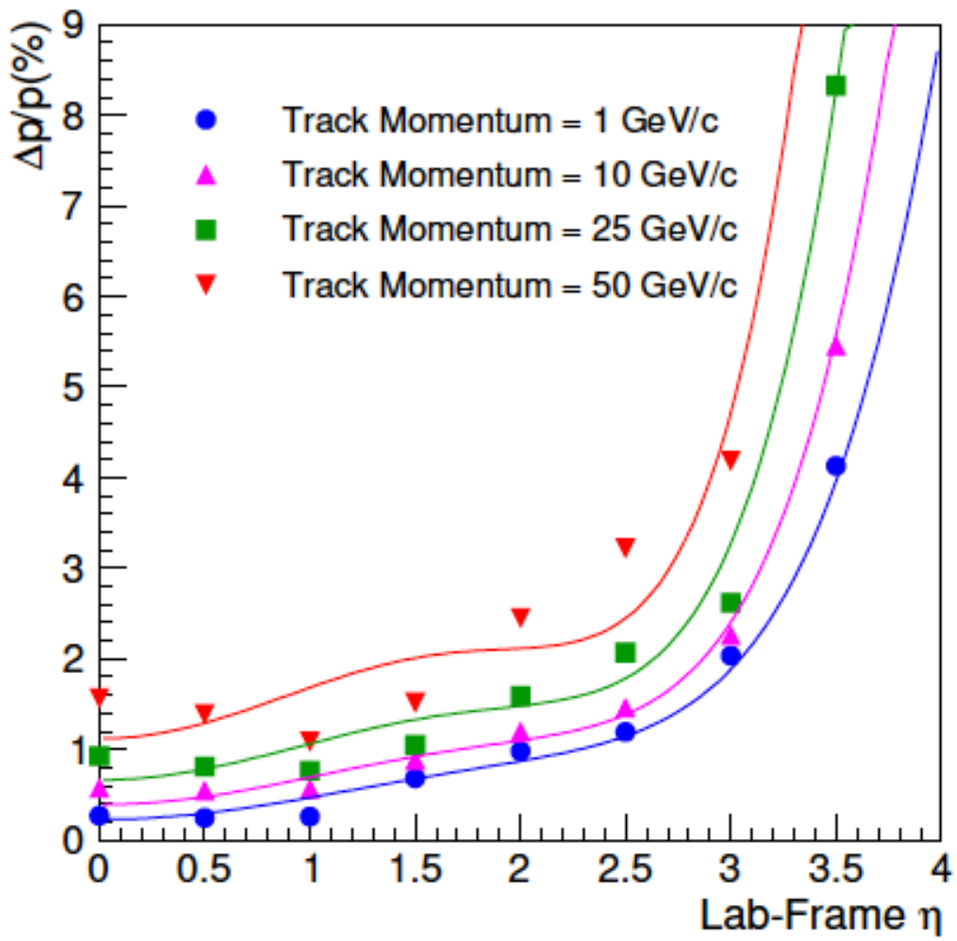


FIG. 17. [color online] Track momentum resolution assumed for the smearing generator as a function of track pseudorapidity. The points represent extractions of resolution at specific momenta and pseudorapidity from simulation of a model BeAST tracking detector and the curves are instances of the function used to fit the points that was passed to the smearing generator.

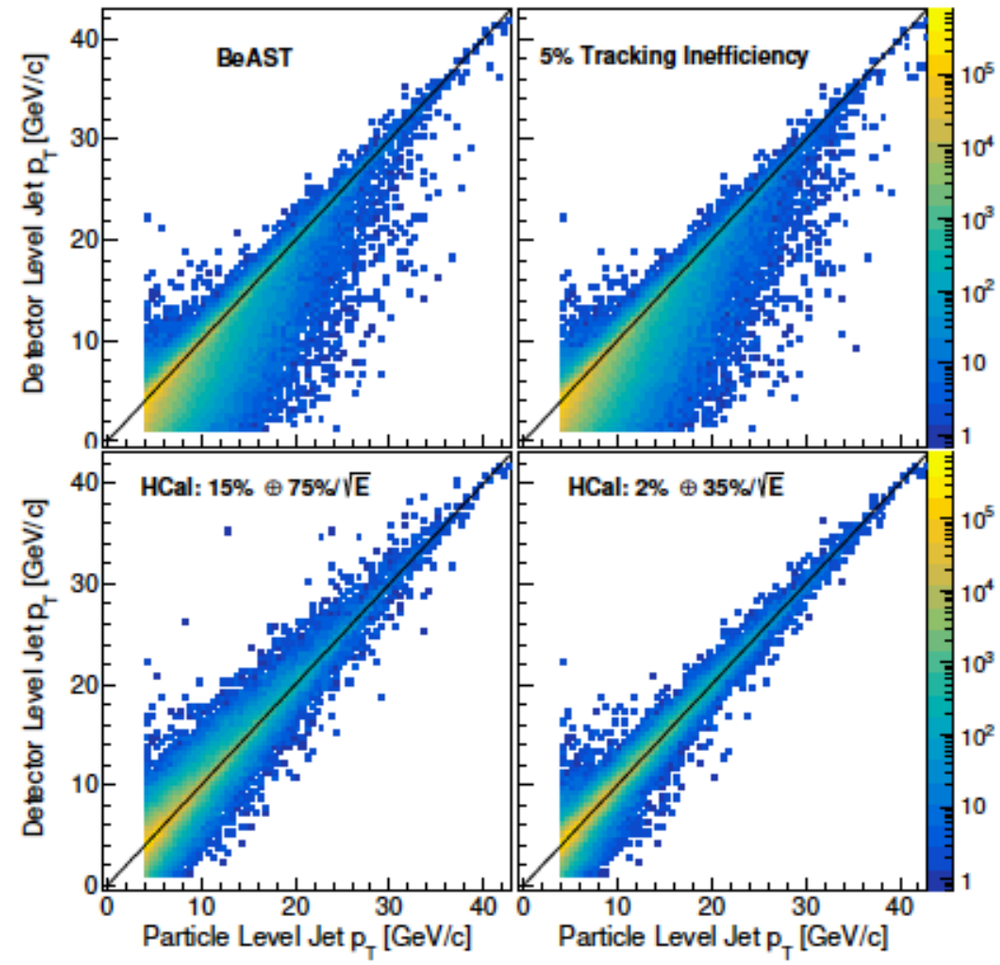


FIG. 18. [color online] Correlation between particle level and smeared jet p_T for the BeAST detector setup (upper left), BeAST assuming a 5% track finding inefficiency (upper right), and BeAST assuming a mid-rapidity hadron calorimeter with resolution $15\% \oplus \frac{75\%}{\sqrt{E}}$ (lower left) and resolution $2\% \oplus \frac{35\%}{\sqrt{E}}$ (lower right).

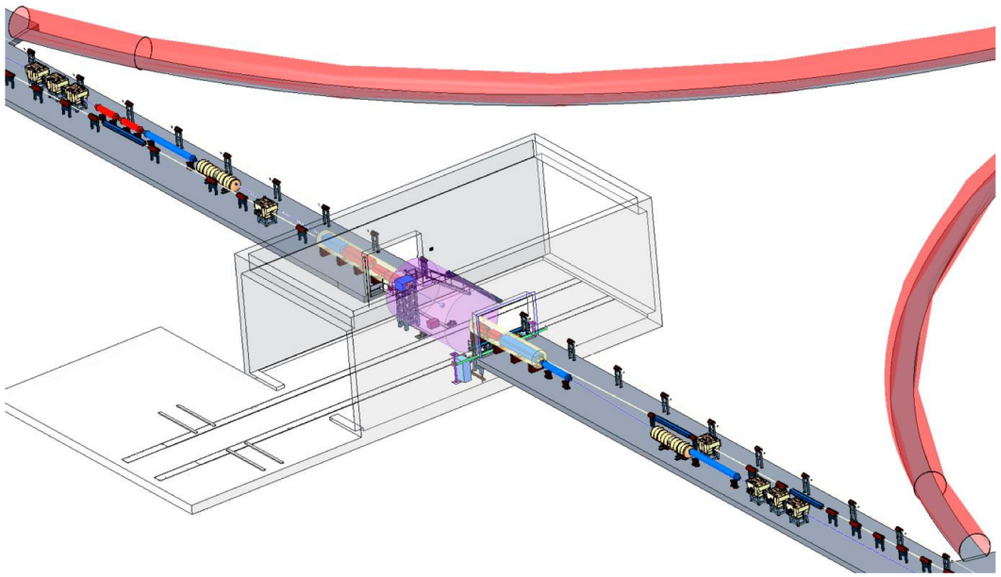
Jets and QCD

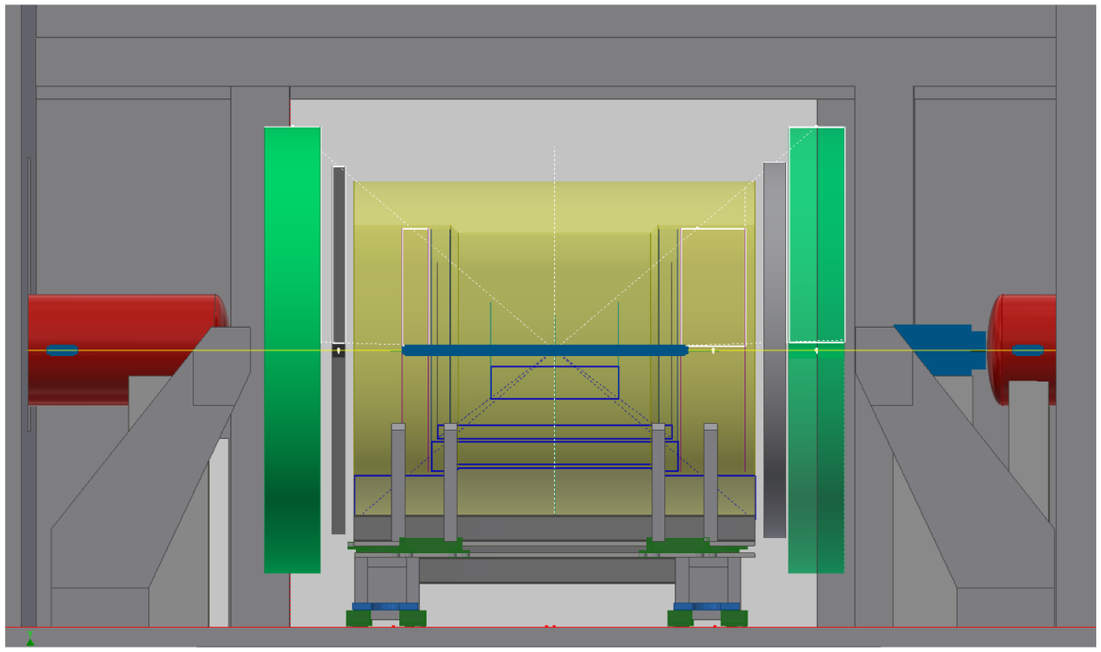
SPEAR, DORIS, PEP, PETRA, LEP
HERA – CALO Jets
TEVATRON- CALO, Energy Flow
RHIC- Energy Flow
LHC - CALO, Jet-Plus-Track, Particle Flow
EIC – Particle Flow, CALO?

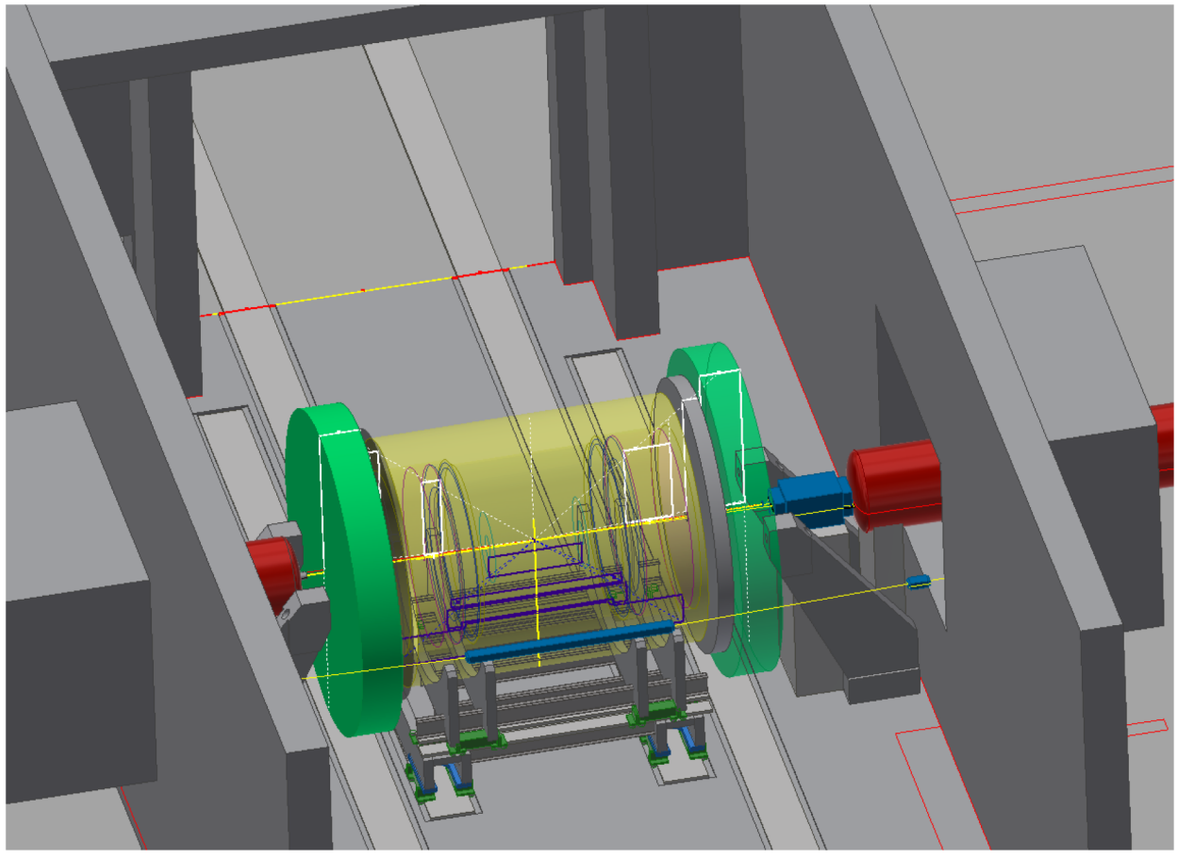
Tracker provides superior resolution.
4% @ 50 GeV -> Calorimeter energy resolution
28%/√(E) ⊕ 0

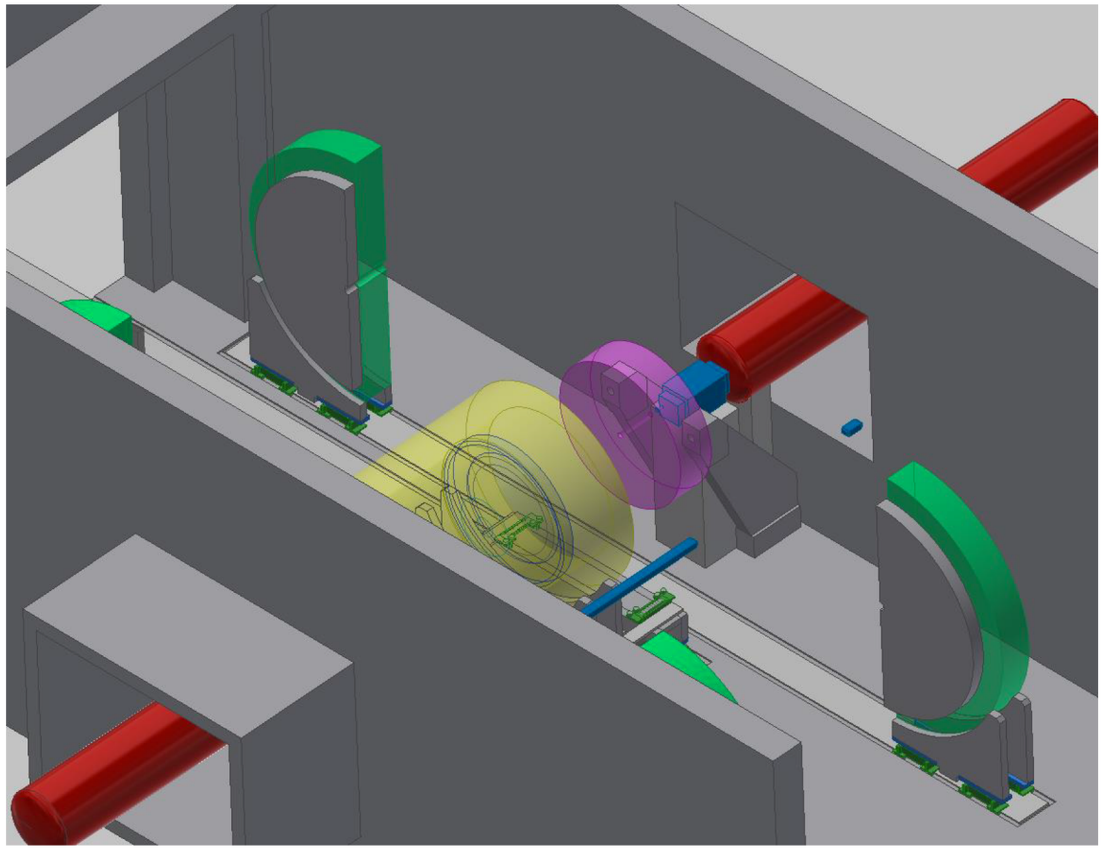
Constant term for EndCap will be more like ~10%...

e-RHIC, BeAST @ IP6 (STAR IP). Practical limitations



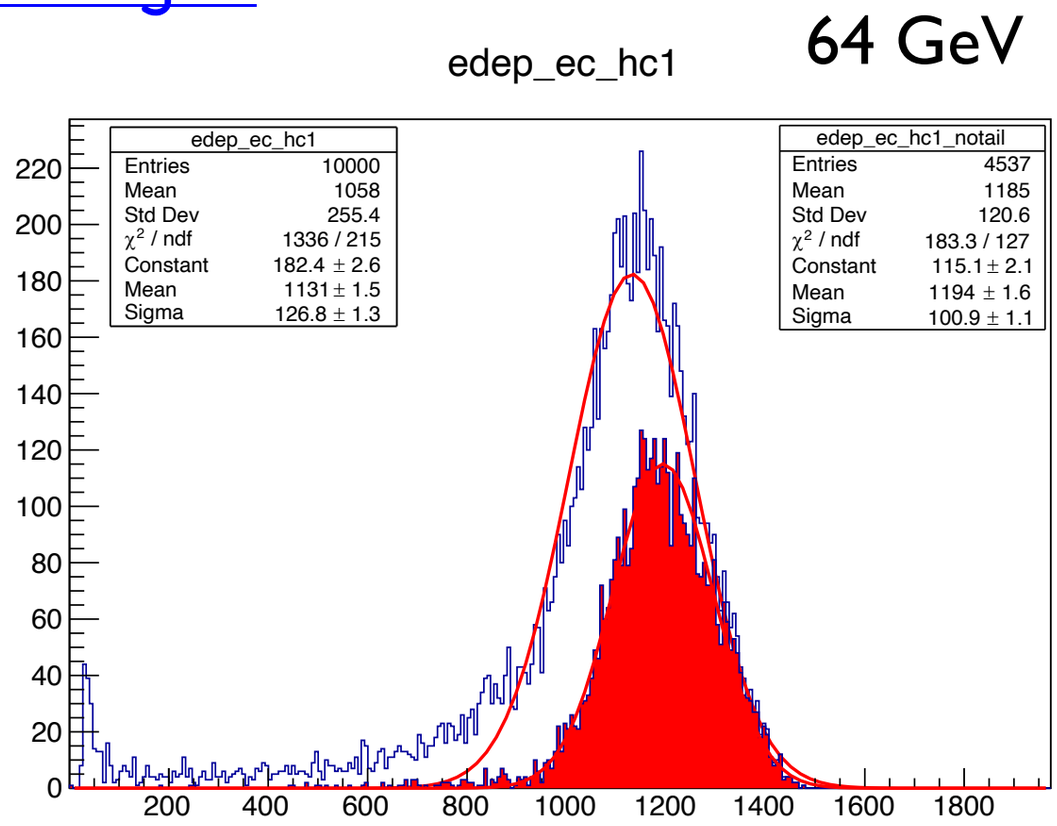


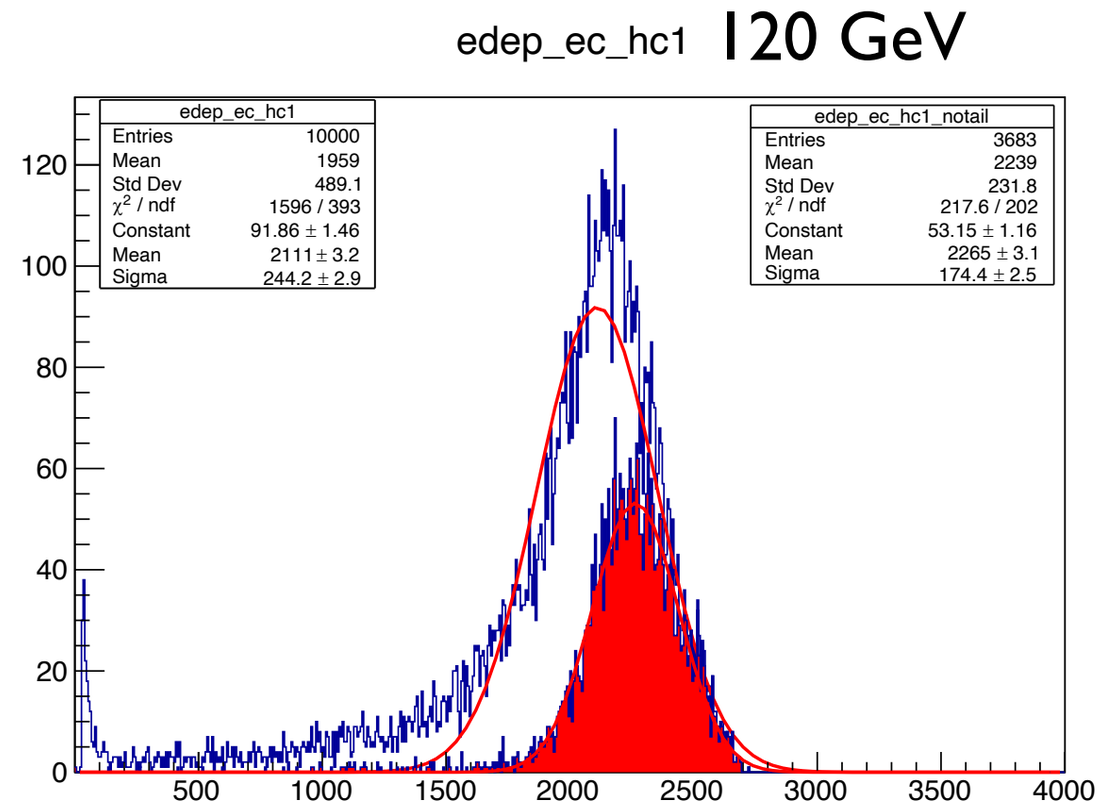




BNL group, E.C.Aschenauer et.al.
Hadron EndCap, Diameter ~ 7m, Thickness 1.2 m, Weight 200 t,

Leakages.



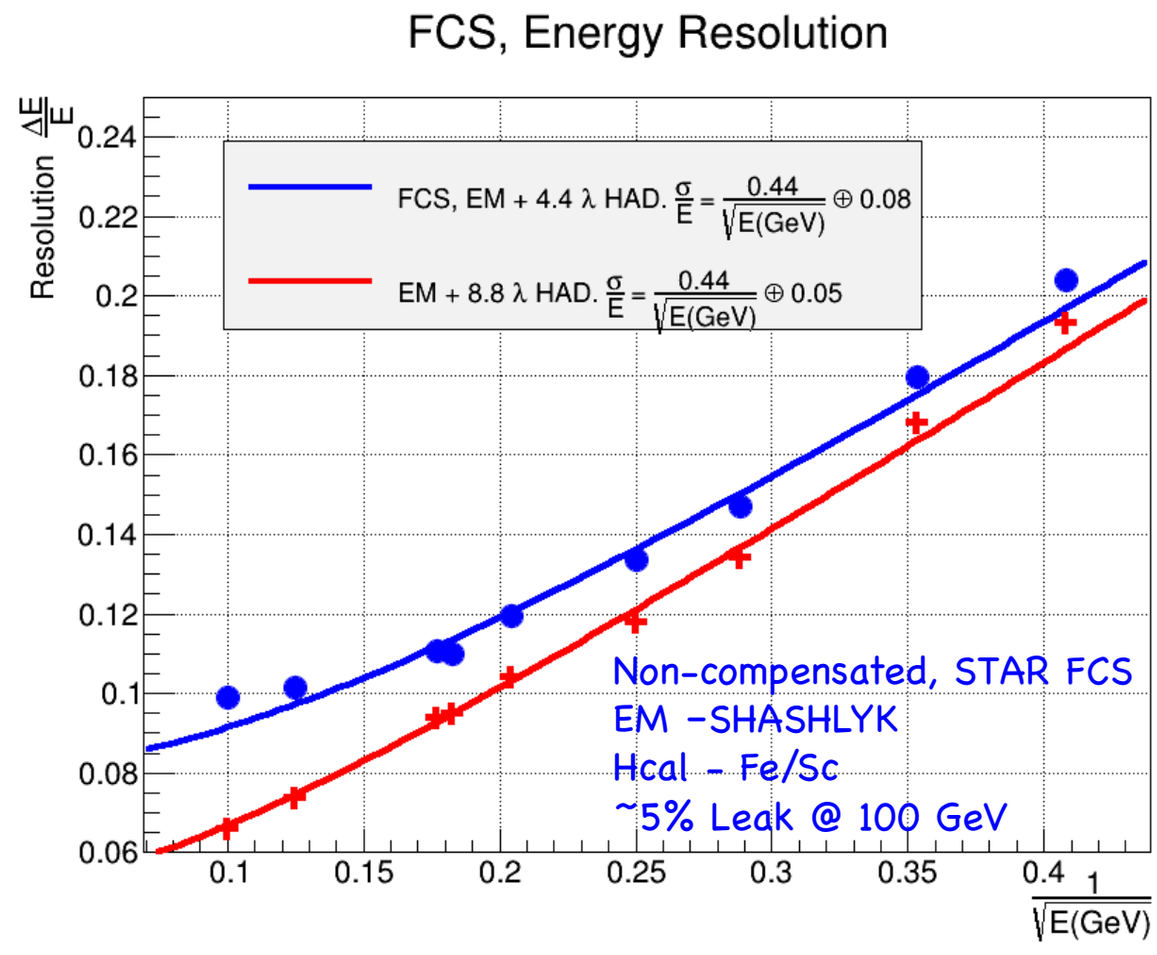


eRD1 R&D for Hadron EndCap.
Optimization for 4D systems:
a) Shashlyk + Fe/Sc
(improved STAR FCS, 2022)
b) W/ScFi + Fe/Sc

Component	Pseudorapidity Range	Resolution
Back EMCal	$-4.0 < \eta < -2$	$\frac{1.5\%}{\sqrt{E}} \oplus 1\%$
Mid-Back EMCal	$-2 < \eta < -1$	$\frac{7\%}{\sqrt{E}} \oplus 1\%$
Mid EMCal	$-1 < \eta < 1$	$\frac{10\%}{\sqrt{E}} \oplus 1\%$
Fwd EMCal	$1 < \eta < 4.0$	$\frac{10\%}{\sqrt{E}} \oplus 1\%$
Fwd/Back HCal	$1 < \lvert\eta\rvert < 4.0$	$\frac{50\%}{\sqrt{E}} \oplus 10.0\%$
Lo Res Mid Hcal	$-1 < \eta < 1$	$\frac{75\%}{\sqrt{E}} \oplus 15\%$
Hi Res Mid Hcal	$-1 < \eta < 1$	$\frac{35\%}{\sqrt{E}} \oplus 2\%$

TABLE I. Assumed energy resolutions and psuedorapidity ranges for the electromagnetic and hadron calorimeters included in the detector smearing model.

Ref.2

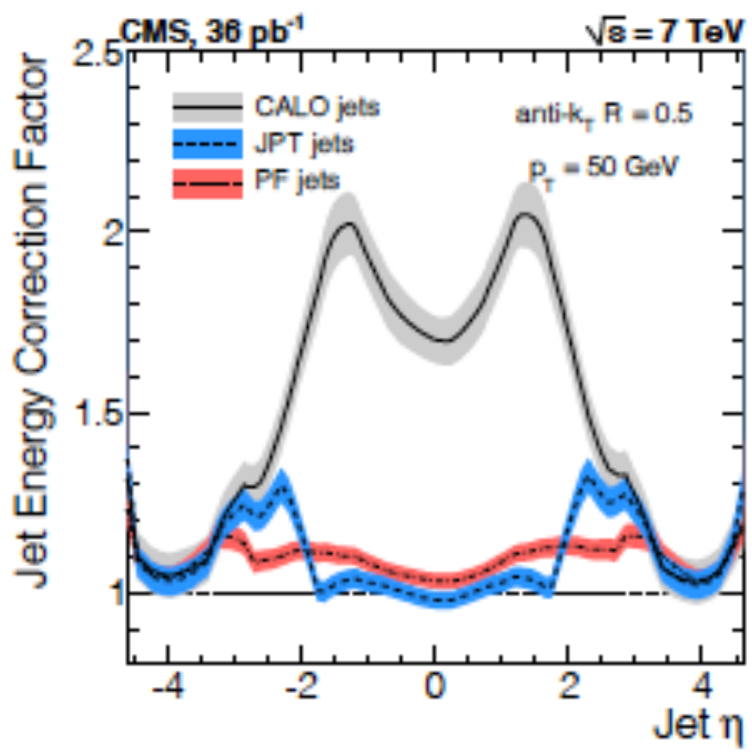


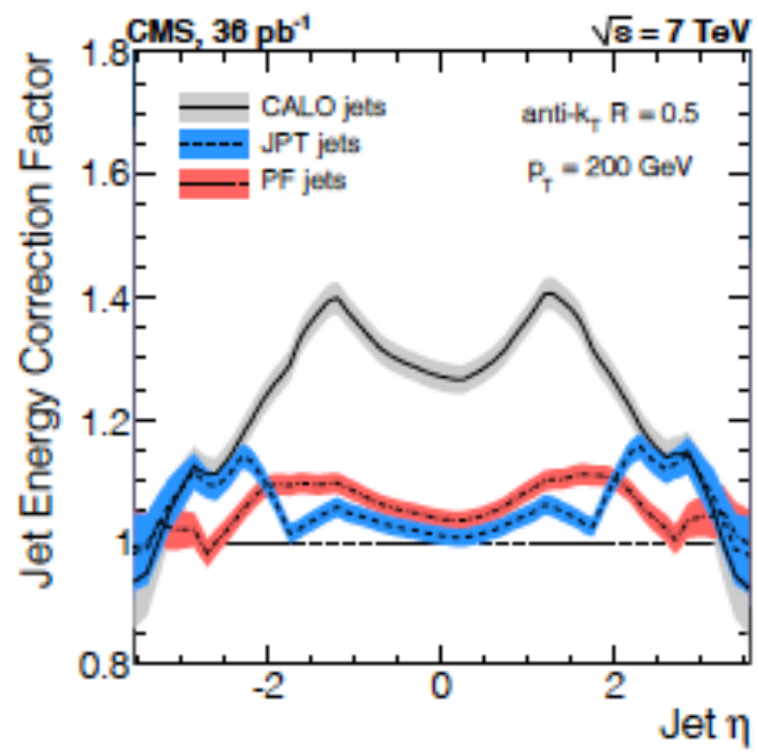
Jet physics at an EIC is relatively new topic.

Ref. 2 & 3 has a lot of information to start with.

There are difficult things such as:
Jet Energy Scale, p_t resolution, systematics...(100 of pages of CMS notes)
These may be very detector specific, has to be discussed for global detector optimization not just calorimeters.

Similarly, discussion related to readout (streaming vs triggering).





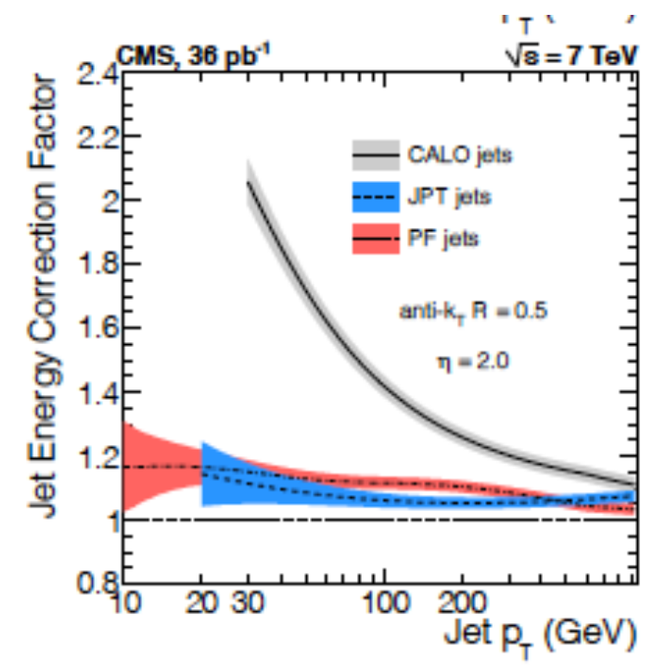


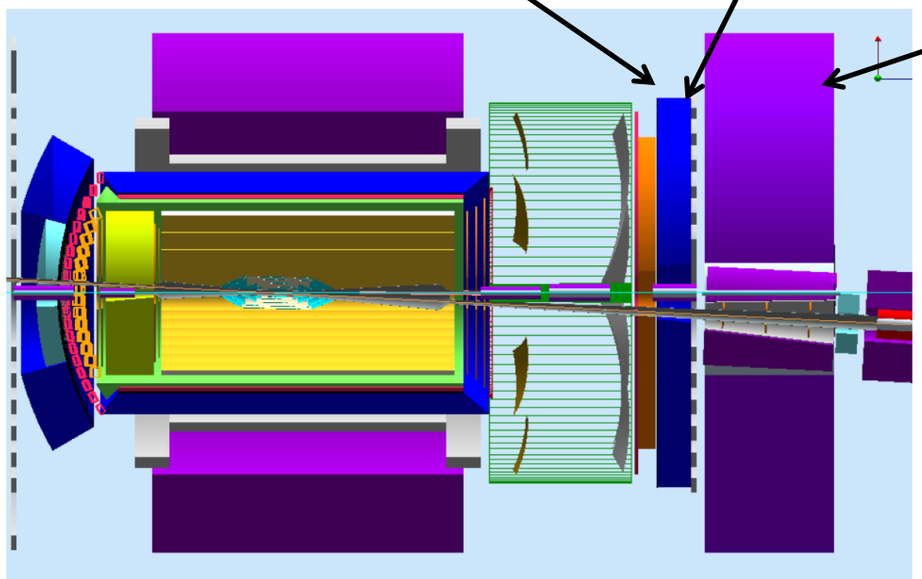
Figure 26: Total jet-energy-correction factor, as a function of jet η for $p_T = 50\,\text{GeV}$ (left) and $p_T = 200\,\text{GeV}$ (right). The bands indicate the corresponding uncertainty.

Important Limiting factors for high resolution HCals

EMCal (e/h =X)

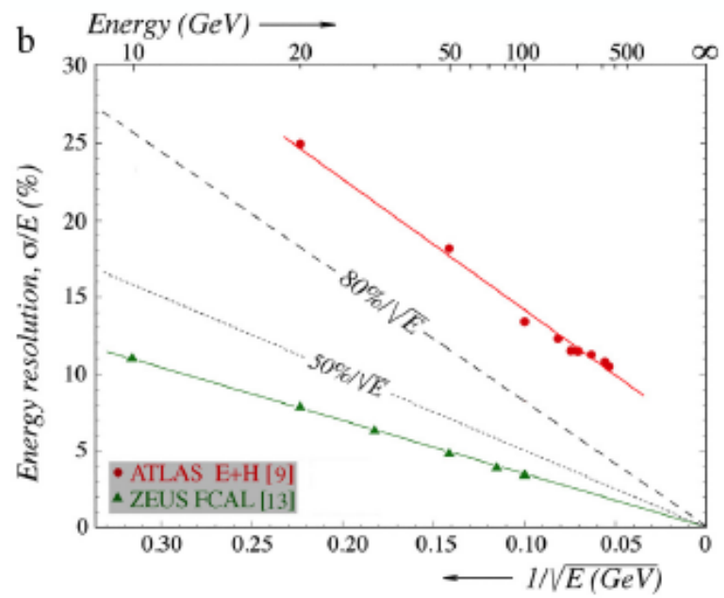
Dead Material

Hcal (e/h =Y)



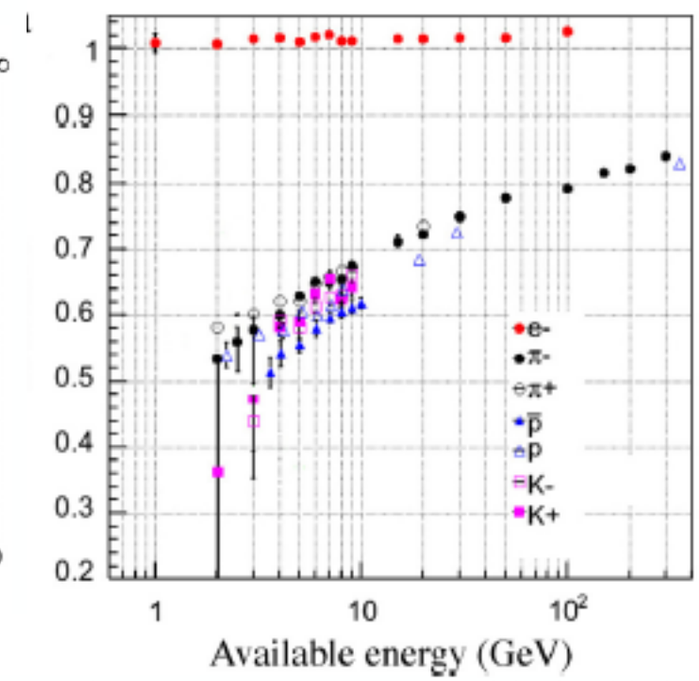
Deviation from $1/\sqrt{E}$ scaling in hadronic energy resolution

ATLAS Calorimeter



Non-linear response to hadrons

CMS Calorimeter

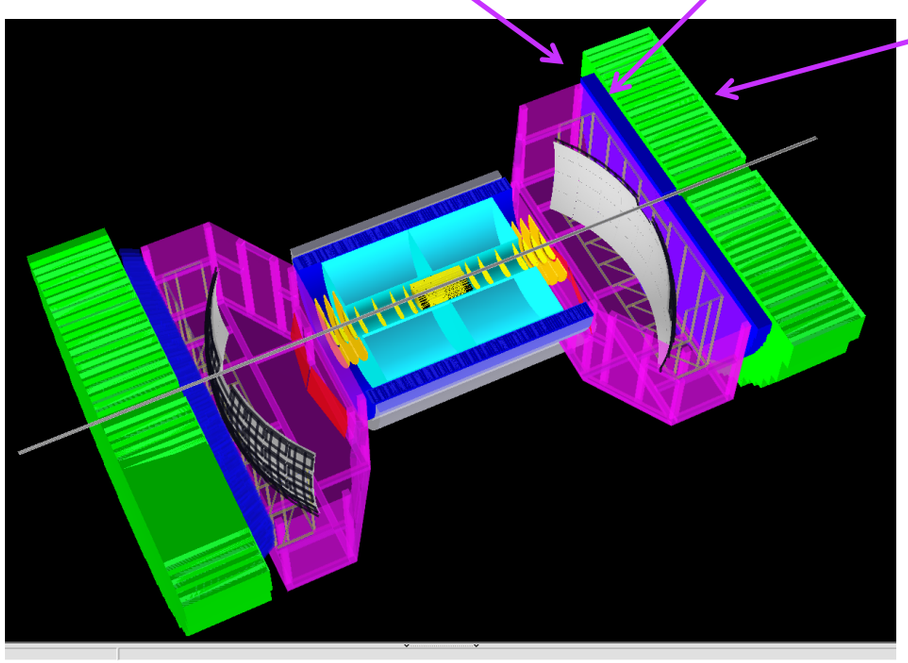


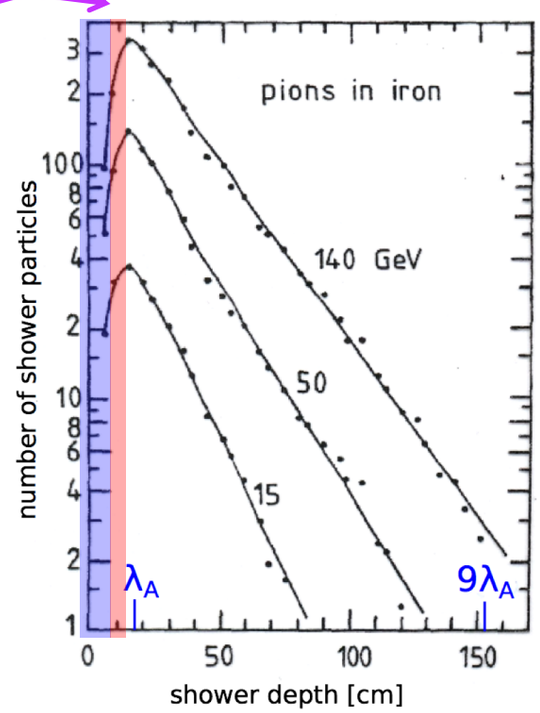
S.Lee, M.Livan, R.Wigmans CALOR 2018

Compensated EMCal (e/h =1)

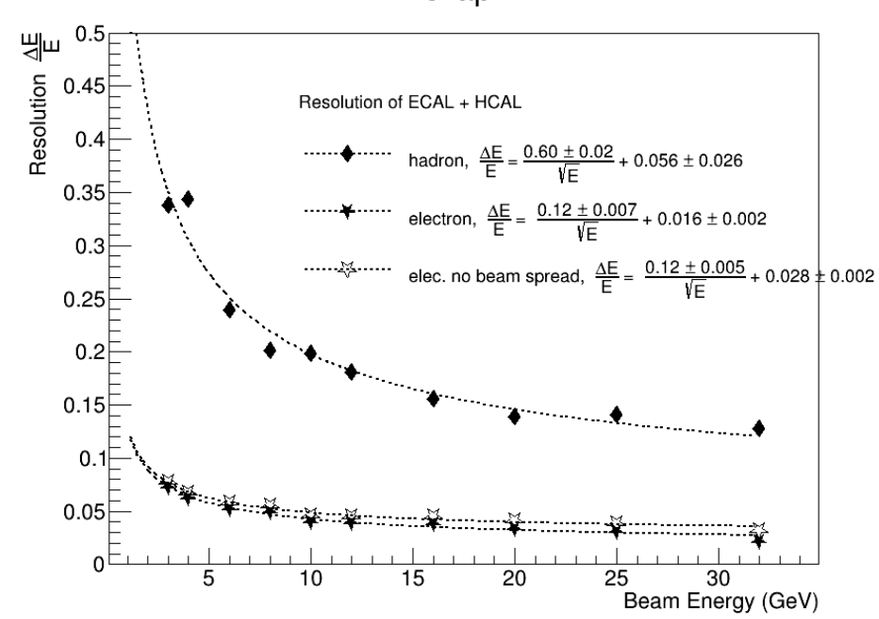
Dead Material 10cm Fe

Compensated Hcal e/h =1





Graph



ZEUS, Pb/Sc 'homogenius', larger size – 44%/√E