Jets for 3D imaging

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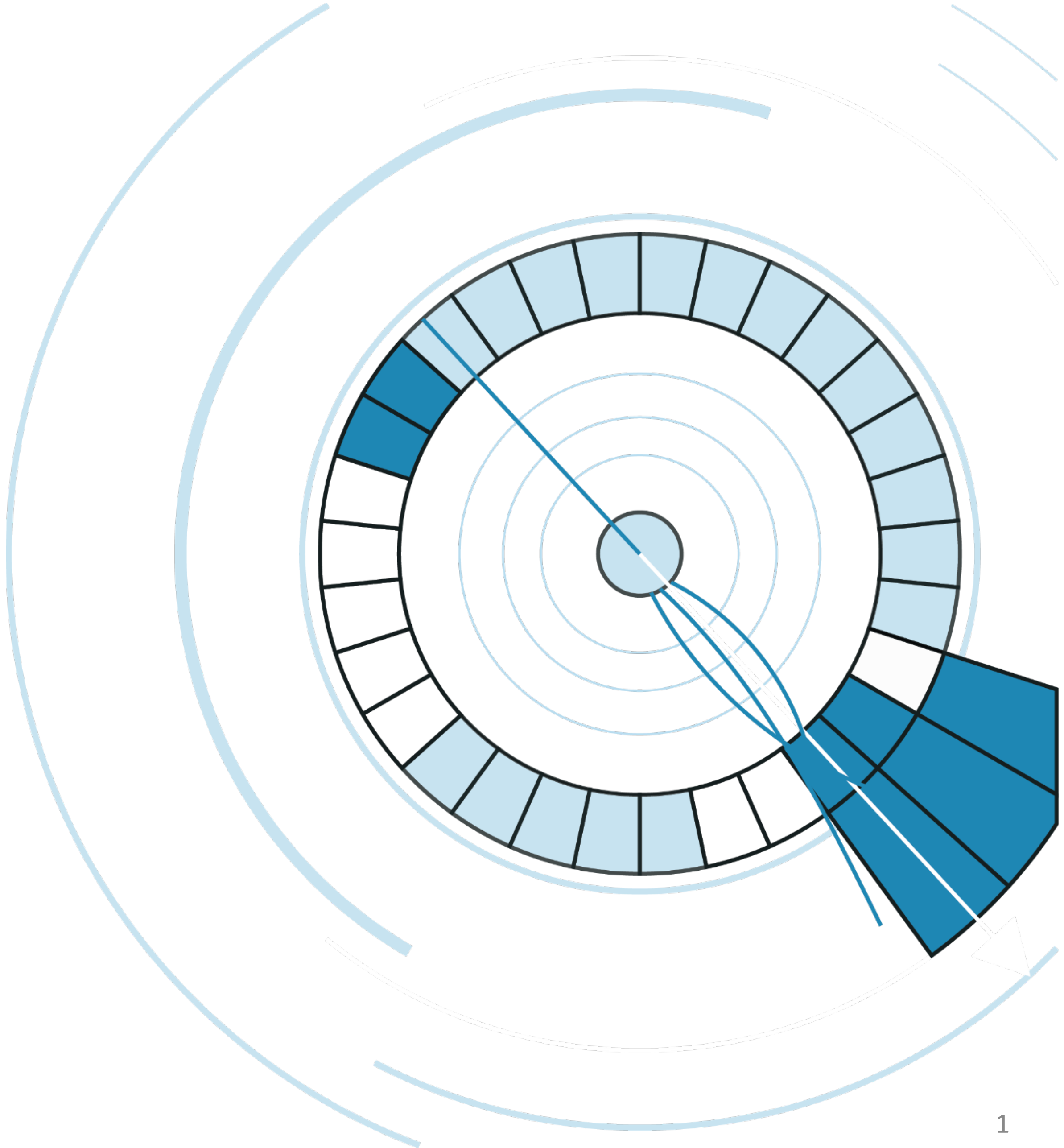
Calorimetry group, May 19th 2020



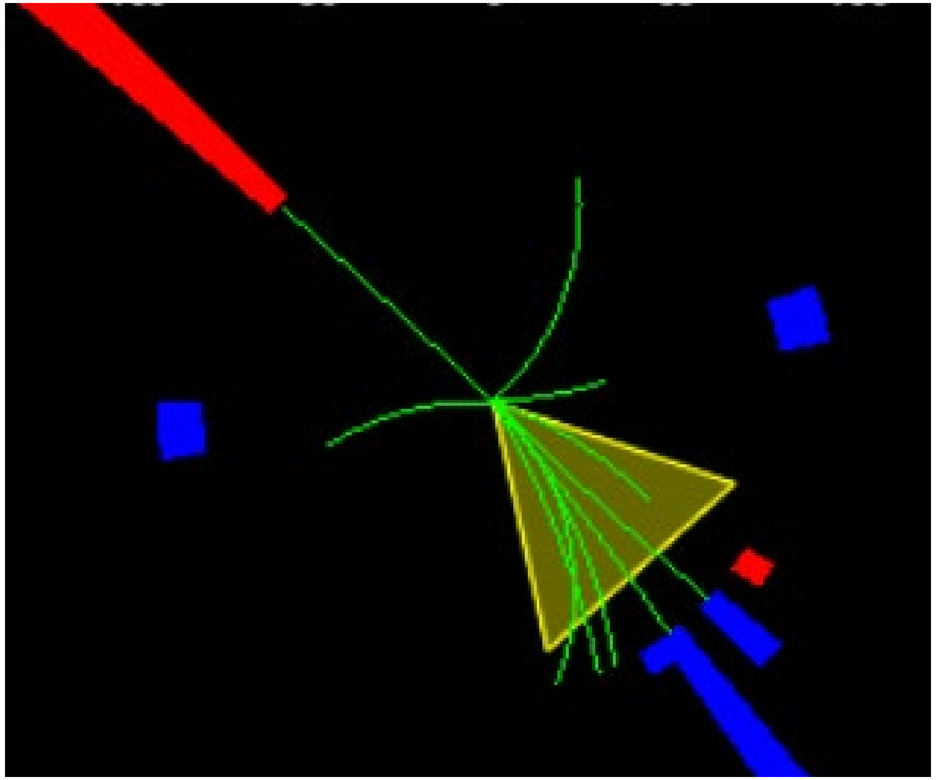
Requirements of "Jets for 3D imaging" program
(under construction)

Table 1: Channels listed are increasingly demanding. For every row consider all requirements above as well. The (x, Q^2) dependence of the observables is omitted for brevity. Date: May 18, 2020, Miguel Arratia

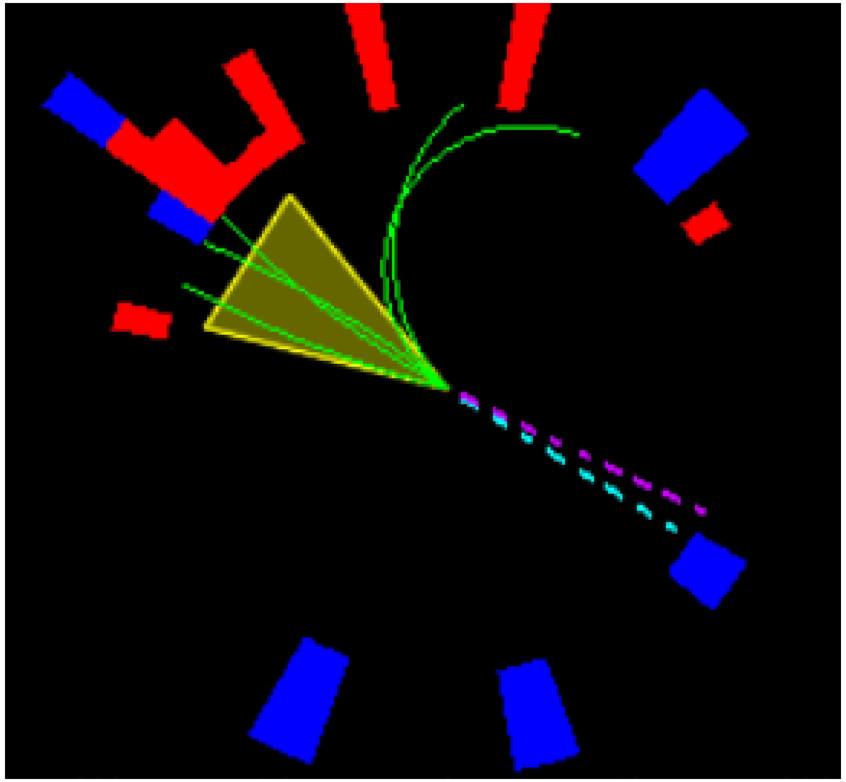
Channel	Observable	Goal	Physics-driven requirement	Category	numbers
e-jet (NC) 100 fb^{-1}	$d\sigma$, $A_{UT}(\Delta\phi)$	k_T-dependence of quark Sivers	$\Delta\phi$ res. << intrinsic width $R = 1.0 \rightarrow$ had. corr. $O(1)\%$ particle-flow reco	Jet res. Acceptance Granularity	jet $dE/E < 15\%$ 2π, $\lvert\eta\rvert < 3.5$ HCAL and ECAL endcap $\Delta\phi \times \Delta\eta \leq 0.025 \times 0.025$
h-in-jet (NC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	q-transversity	$+ dp/p$ at high $z <$ jet dE/E	Tracker PID	$dp/p < 5\%$ at 50 GeV $\eta < 3.5$ and 40 GeV
ν-jet (CC) 100 fb^{-1}	$d\sigma$, A_{UT}	u Sivers	$\Delta\phi << 0.3$ rad Bkg. rej. to phot and NC >70% survival prob. for 5 bins per-decade in x, Q^2	E_T^{miss} res. Acceptance Jet/E_T^{miss} res.	$dE_T^{miss}/E_T^{miss} < 15\%$ 2π, $\lvert\eta\rvert < 3.5$ HCAL and ECAL E>100 MeV thres. ECAL E>400 MeV thres. HCAL $p_T > 100$ MeV tracker $dx/x < 20\%$, $dE_T^{miss}/E_T^{miss} < 15\%$
h-in-jet (CC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	u-transversity	—	—	—
c-jet (CC) 100 fb^{-1}	$d\sigma$, A_{LL}	s PDF& helicity	charm-tagging	Tracker PID	c-jet tag at $> 10\%$ (<0.05%) DCA = 20 μm, $\approx$ 100% eff. TBD
h-in-c-jet (CC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	s-transversity	—	—	—
c-jet (e^+ CC) 100 fb^{-1}	$d\sigma$, A_{LL}	$s/\bar{s}$ asymmetry	positrons	—	—

Goal is to measure precisely azimuthal angle between lepton and jet

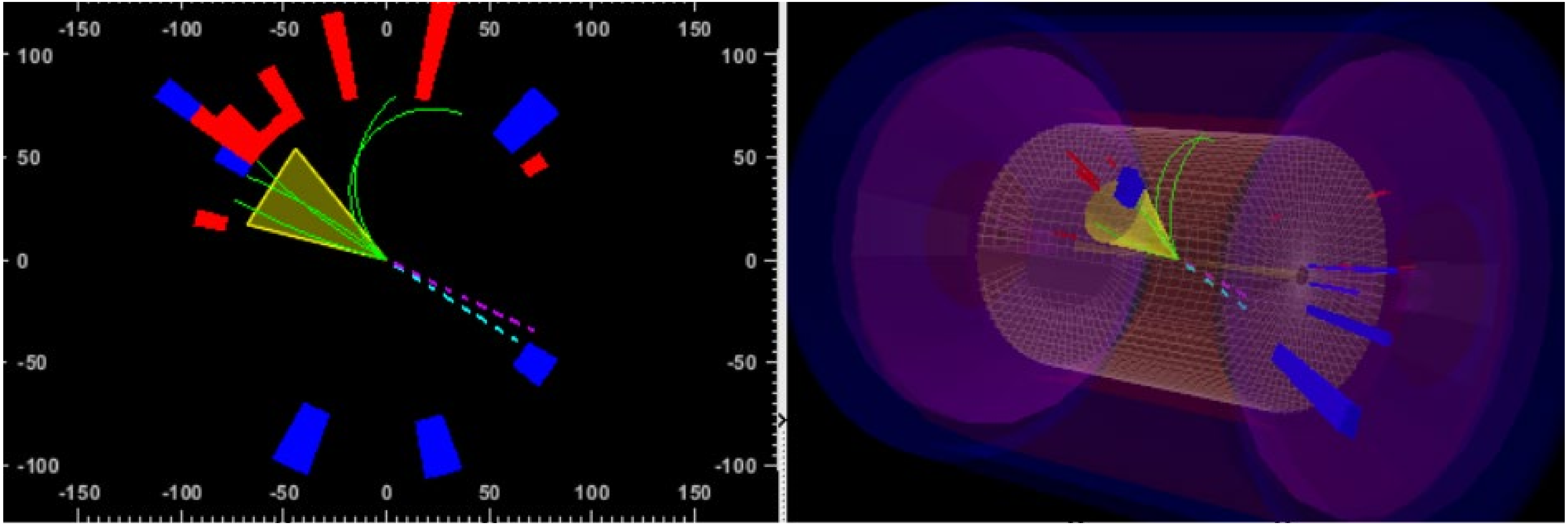
Electron-jet



Neutrino-jet



Charged-current DIS at the EIC



Delphes fast simulation of an EIC detector and Pythia8 charged-current DIS event

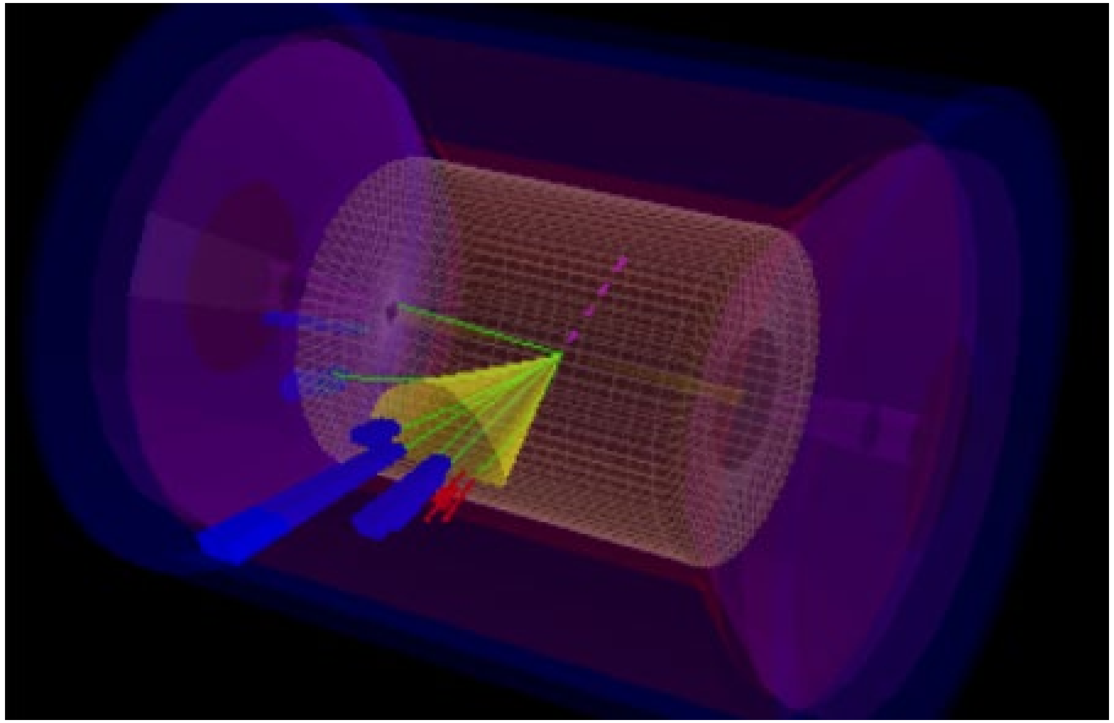
EIC detector in Delphes

https://github.com/miguelignacio/delphes_EIC/blob/master/delphes_card_EIC.tcl

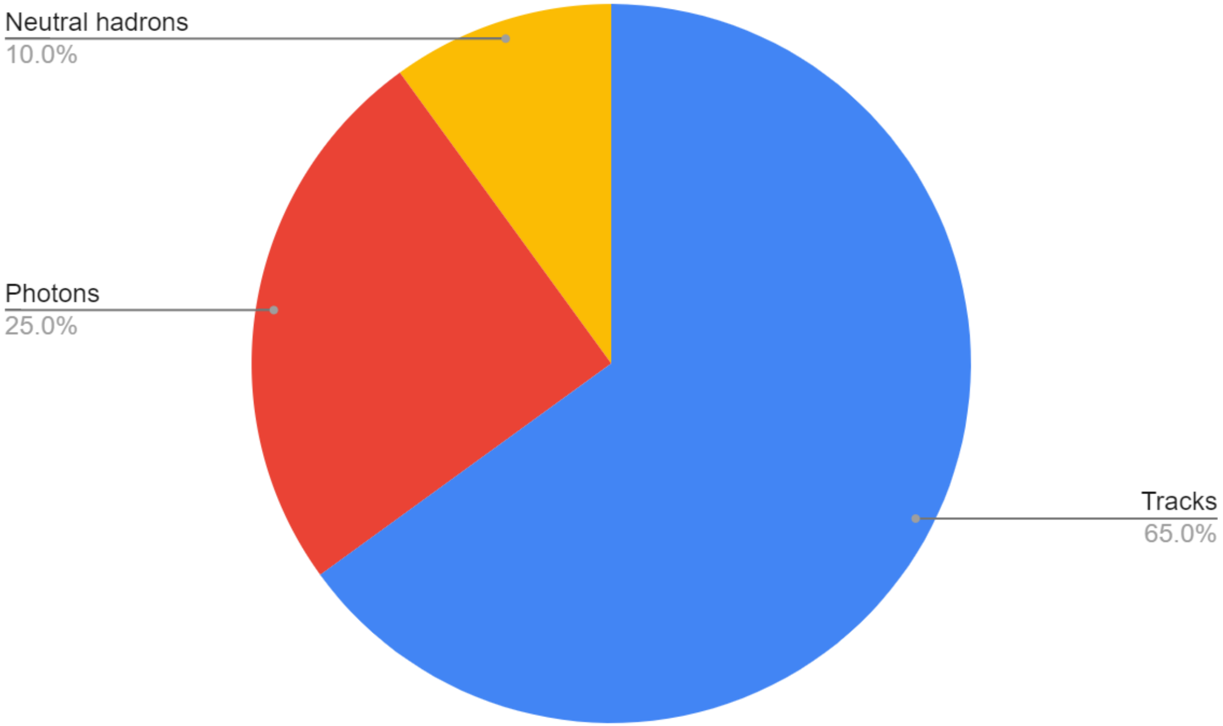
Tracking resolution, EMCAL resolution and HCAL resolution as in EIC detector handbook.

In addition:

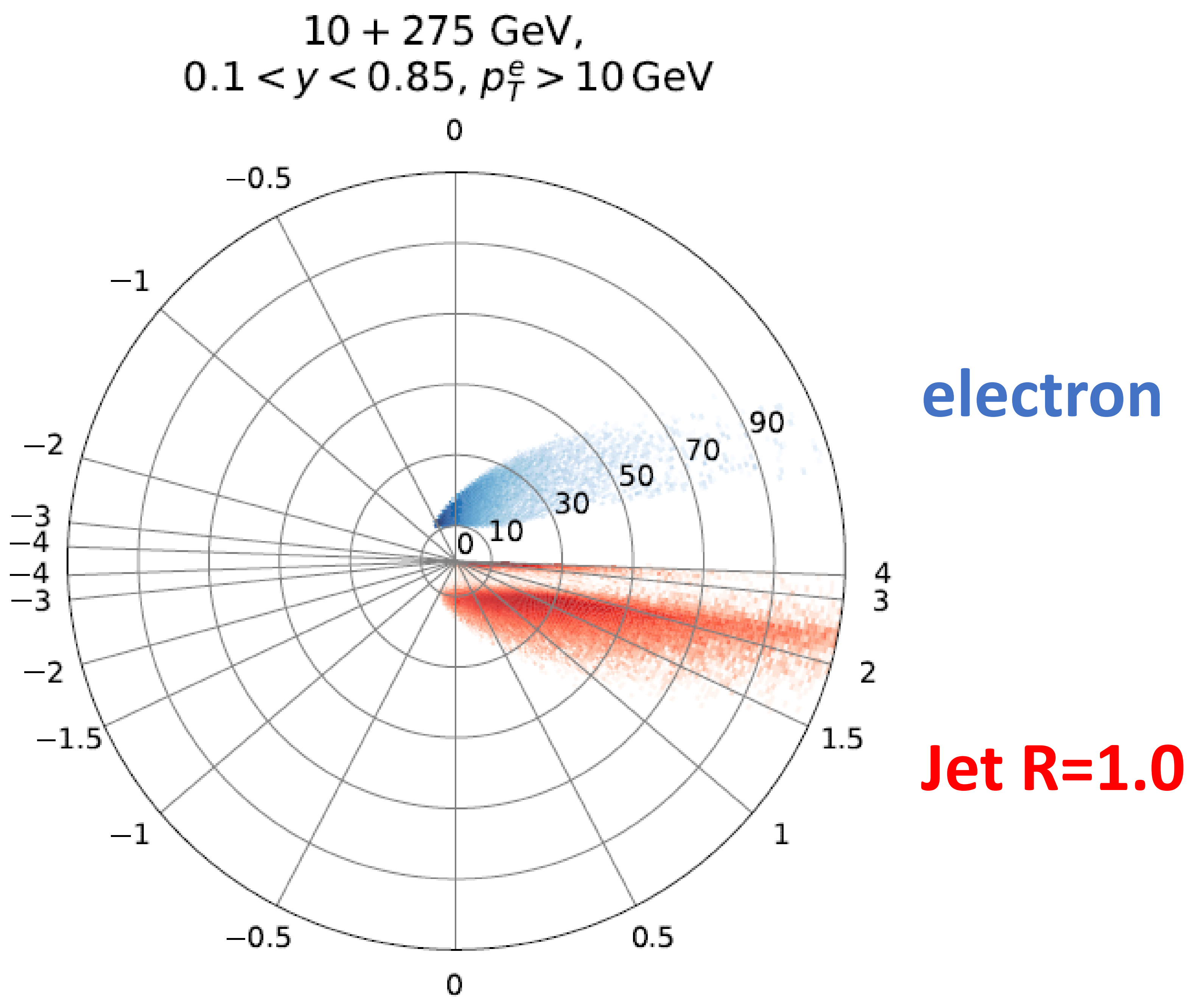
- B=1.5 T, R=0.80 m, L = 1 m
- EMCAL granularity (dphi x deta):
  0.02 x 0.02 for |eta|<3.5
- HCAL granularity (dphi x deta):
  0.1 x 0.1 for |eta|<1.0
  0.025 x 0.025 for 1.0 |eta|<4.0
  (10x10 cm2 at 3.6 m)
- HCAL resolution:
  100%/sqrt(E) + 10% in barrel (0.0—1.0)
  50%/sqrt(E) + 10% in encap (1.0—4.0)
- Tracking threshold 100 MeV pT;
  EMCAL threshold of 100 MeV; (noise ~ 30 MeV per tower)
  HCAL threshold of 500 MeV; (noise ~100 MeV per tower)
- No PID yet, but it can be included (LHCb is in Delphes).
  Need parametrization of efficiency and mis-identification matrix



Jet energy budget

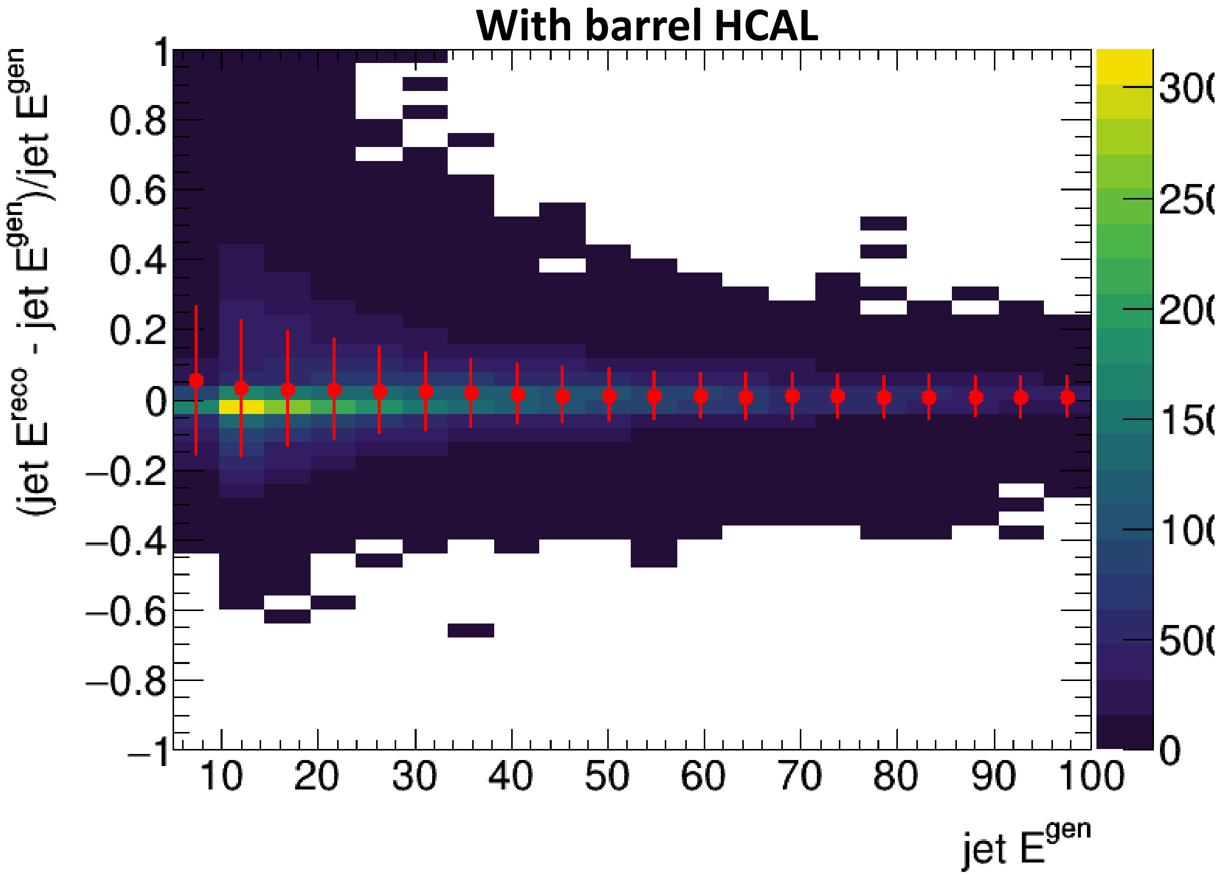


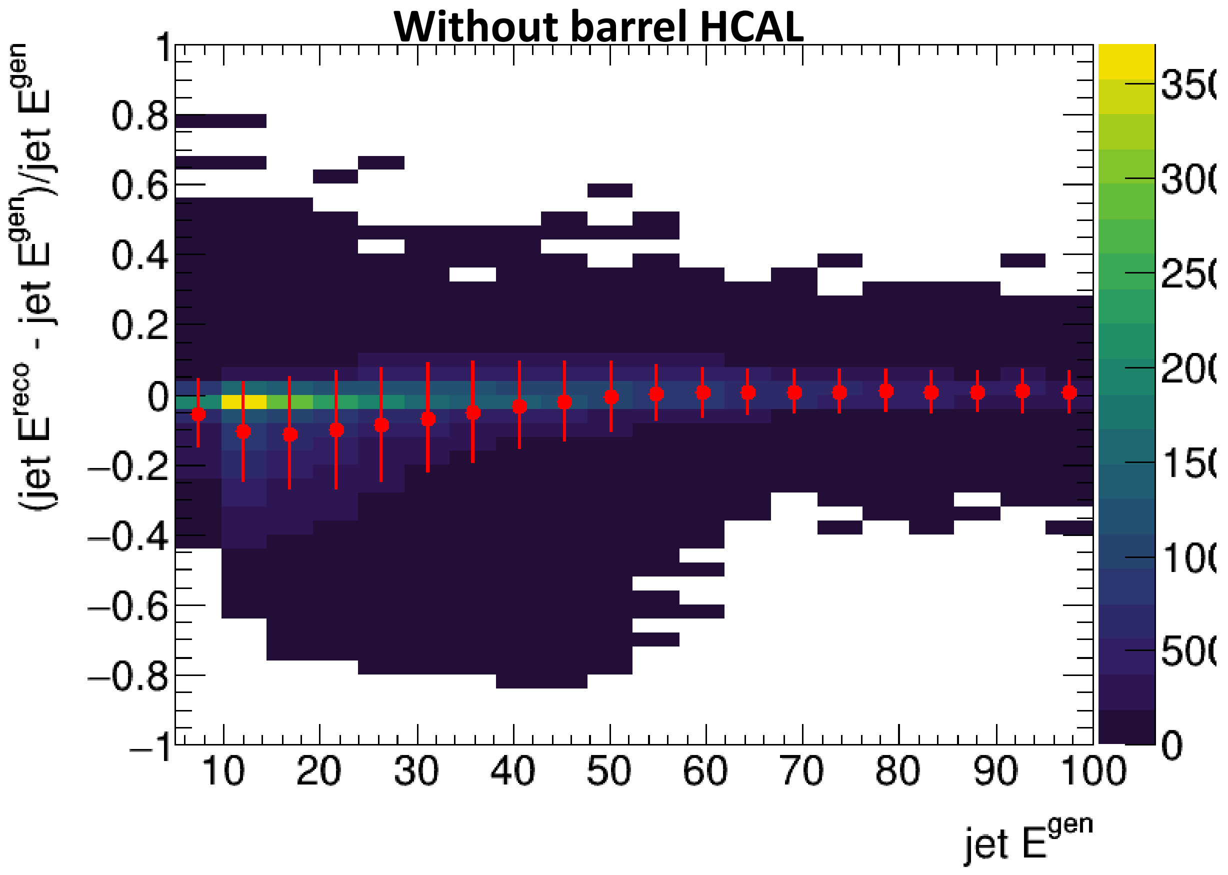
- For accurate jet measurements, we need to be able to capture 100% of the jets.
- HCAL is crucial to cover it all.
- Thresholds also important.
- Accurate missing energy measurements crucially depend on measuring everything.



10 + 275 GeV,
0.1 < y < 0.85, p_T^e > 10 GeV
0
−0.5
−1
−2
−3
−4
−4
−3
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2
3
4
0
10
30
50
70
90
electron
Jet R=1.0

Jet energy resolution



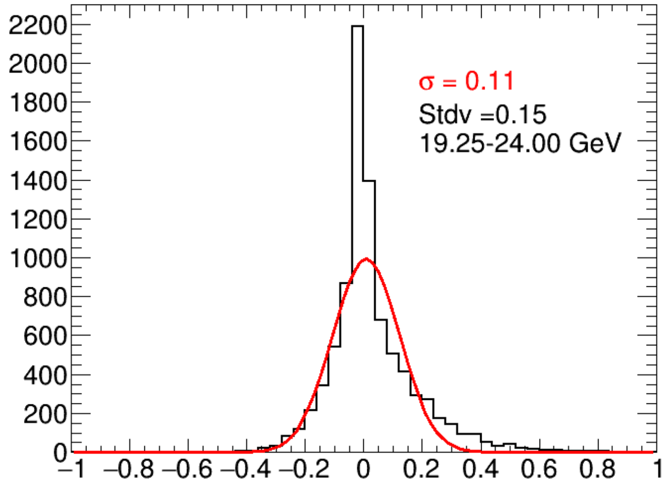


Strong bias at low jet energy

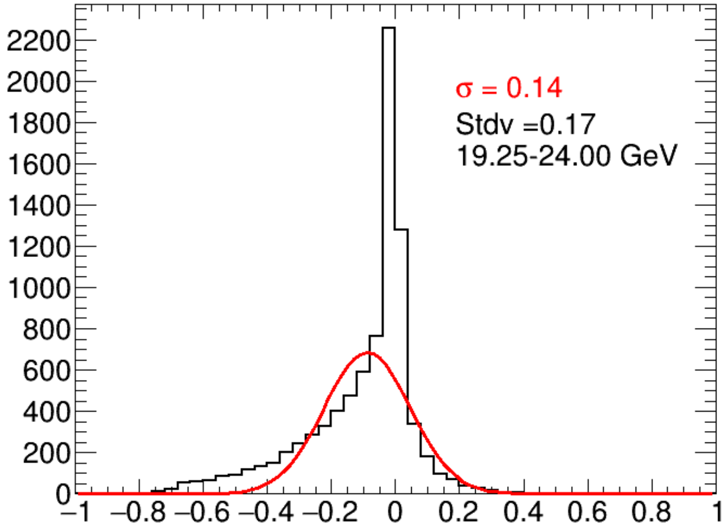
Jet energy resolution

~20 GeV

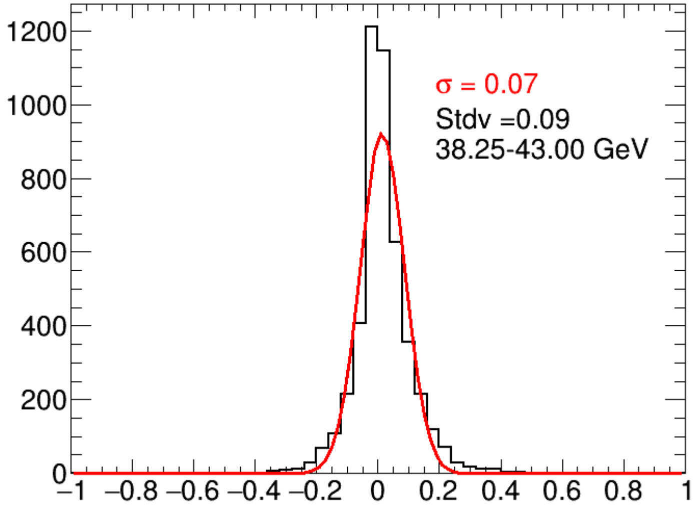
With barrel HCAL

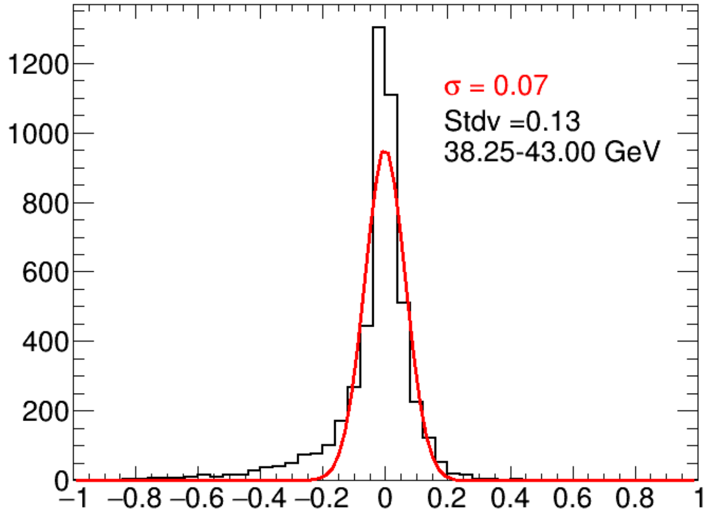


Without barrel HCAL



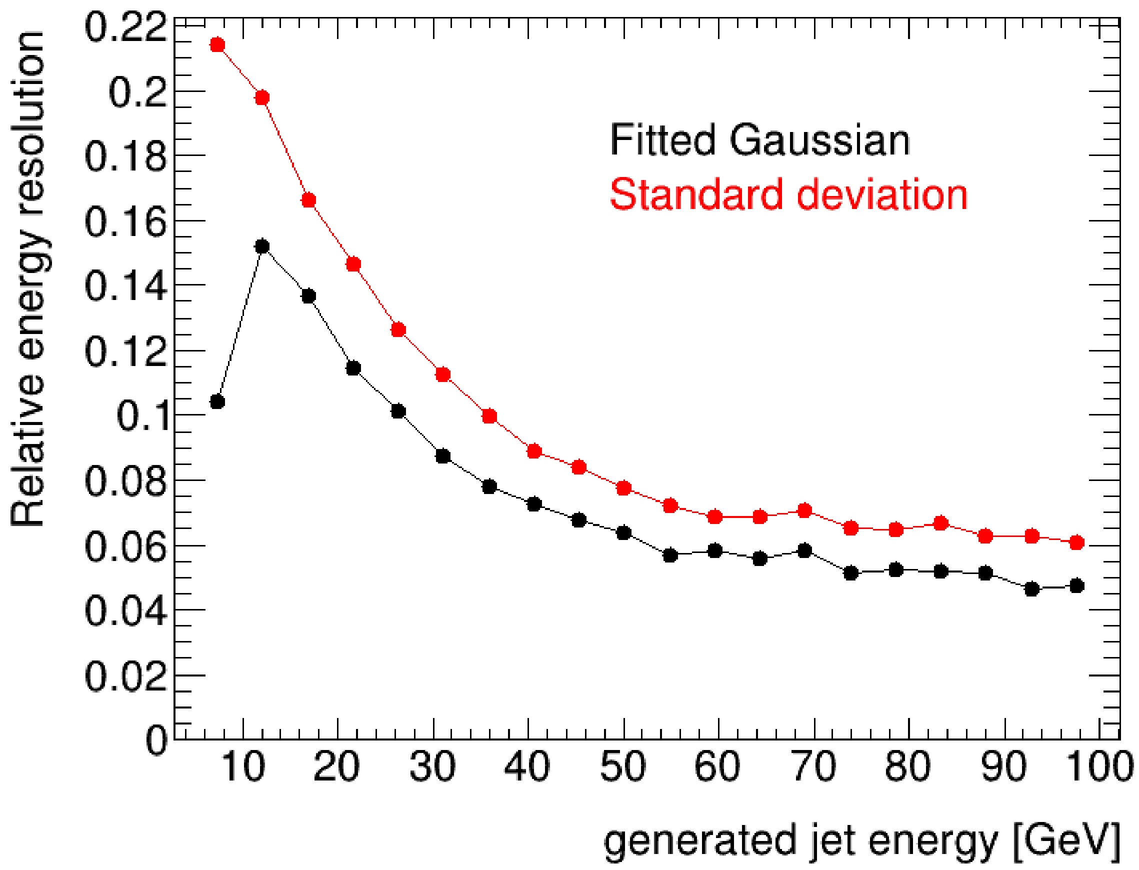
~40 GeV



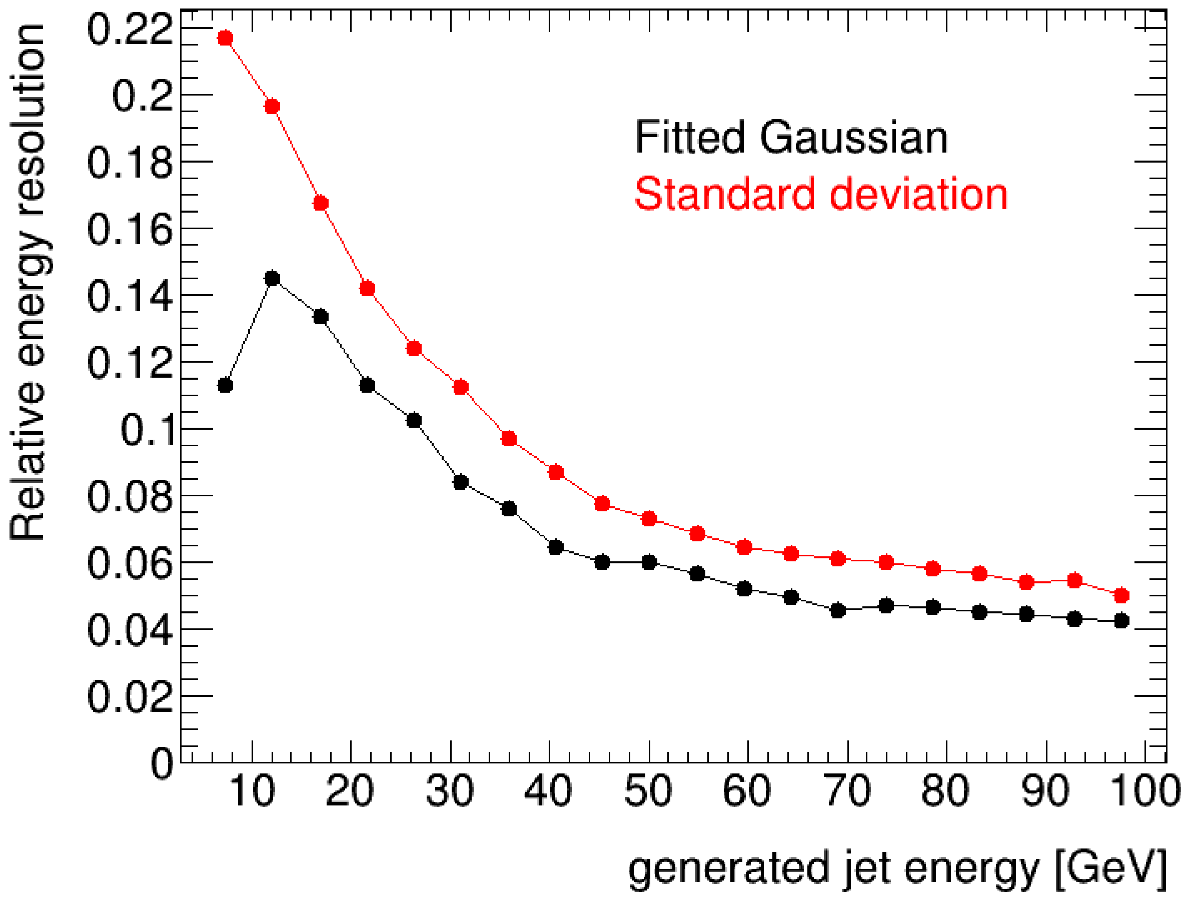


Jet energy resolution

50%/sqrt(E) + 10%

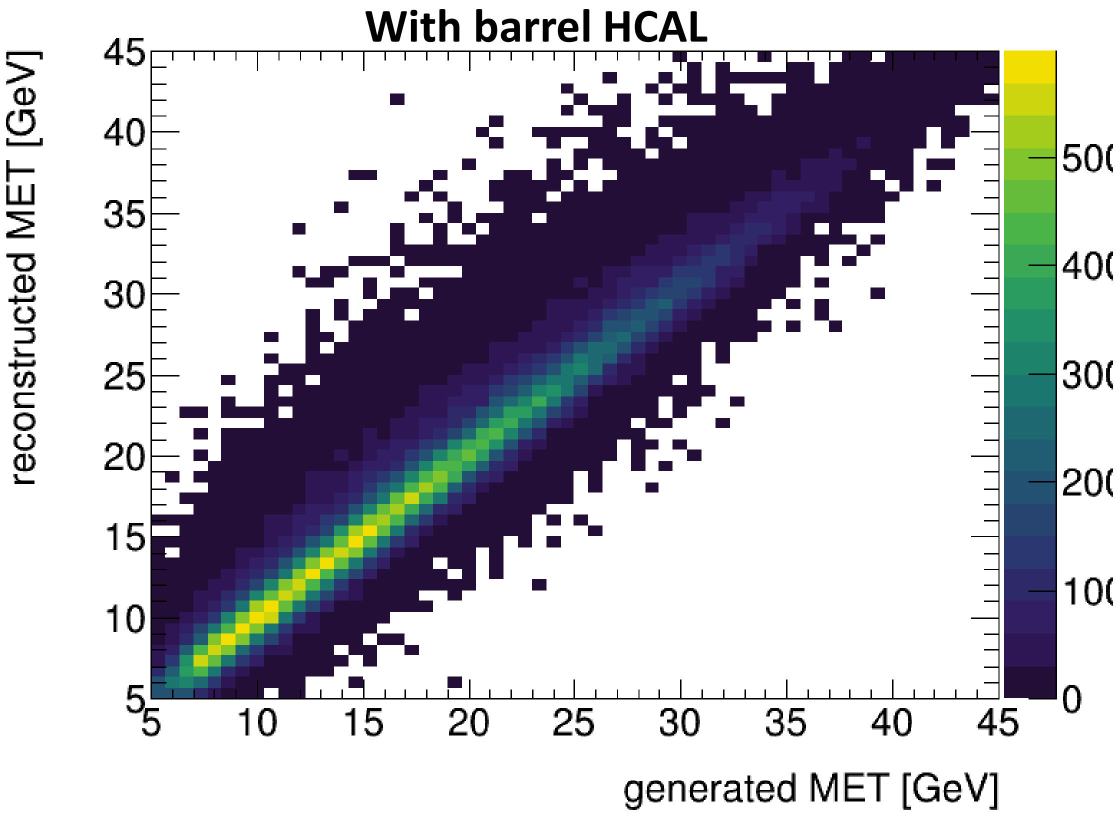


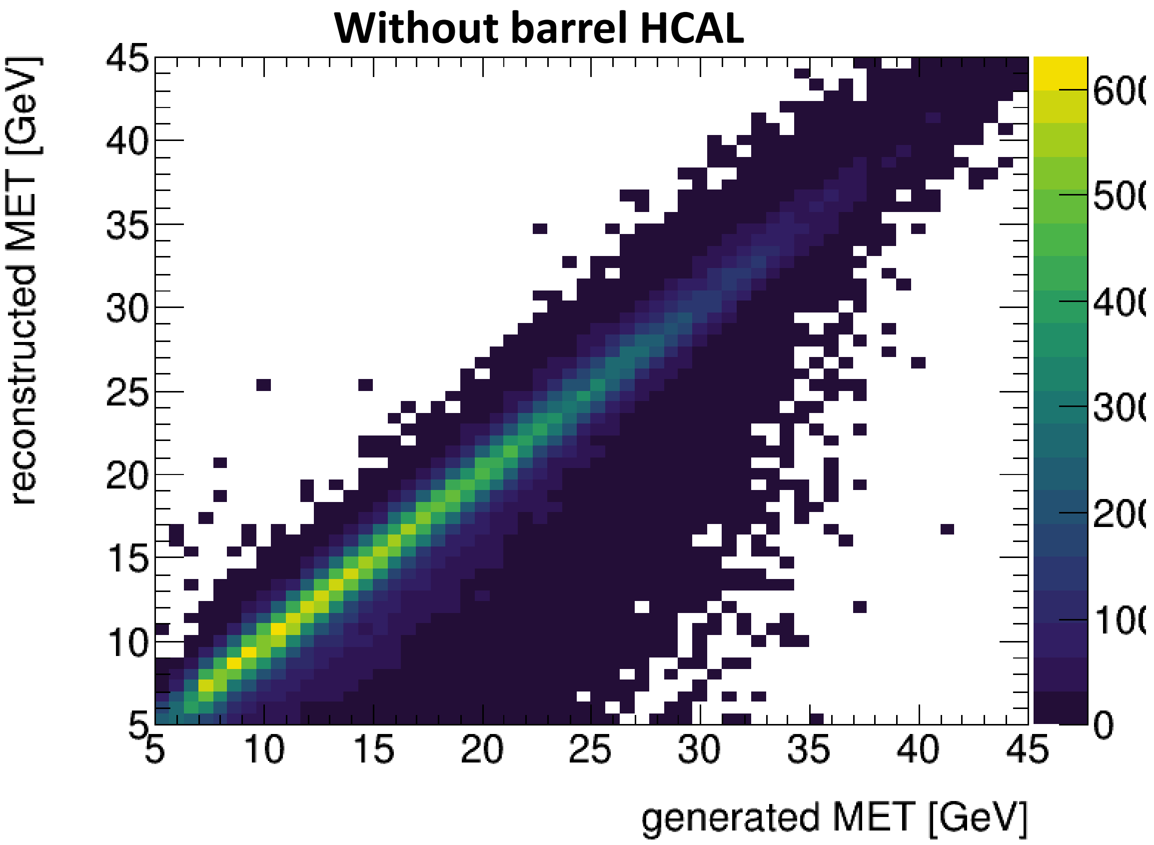
50%/sqrt(E) + 5%



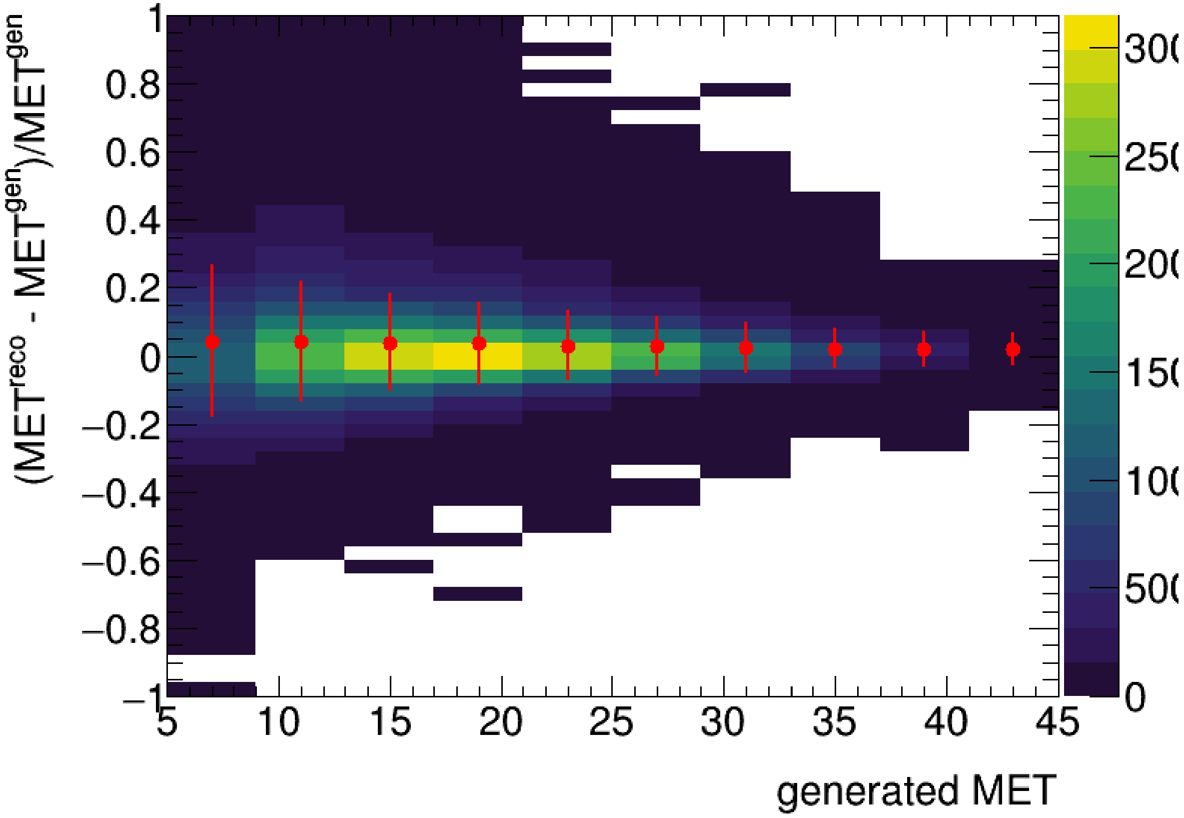
Not strong effect, but need to revisit with more realistic tracking resolution

Missing transverse-energy

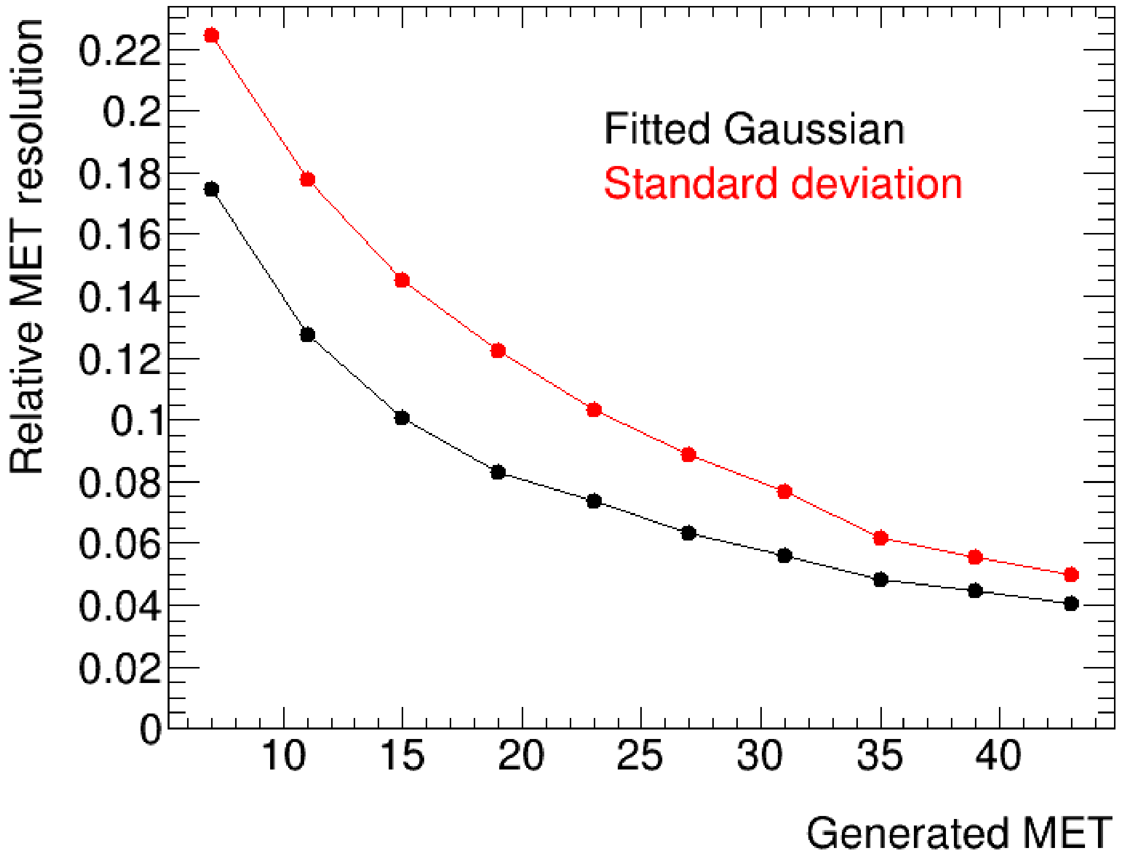




Neutrino pT

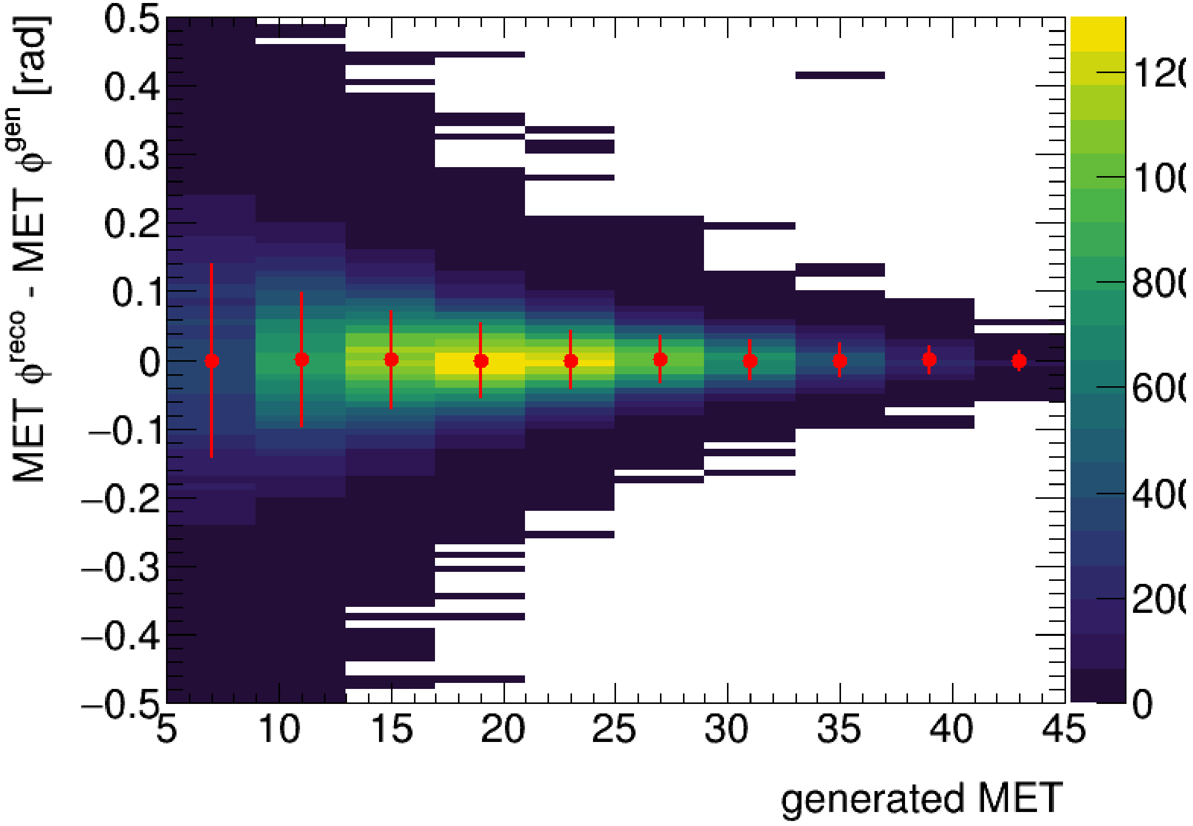


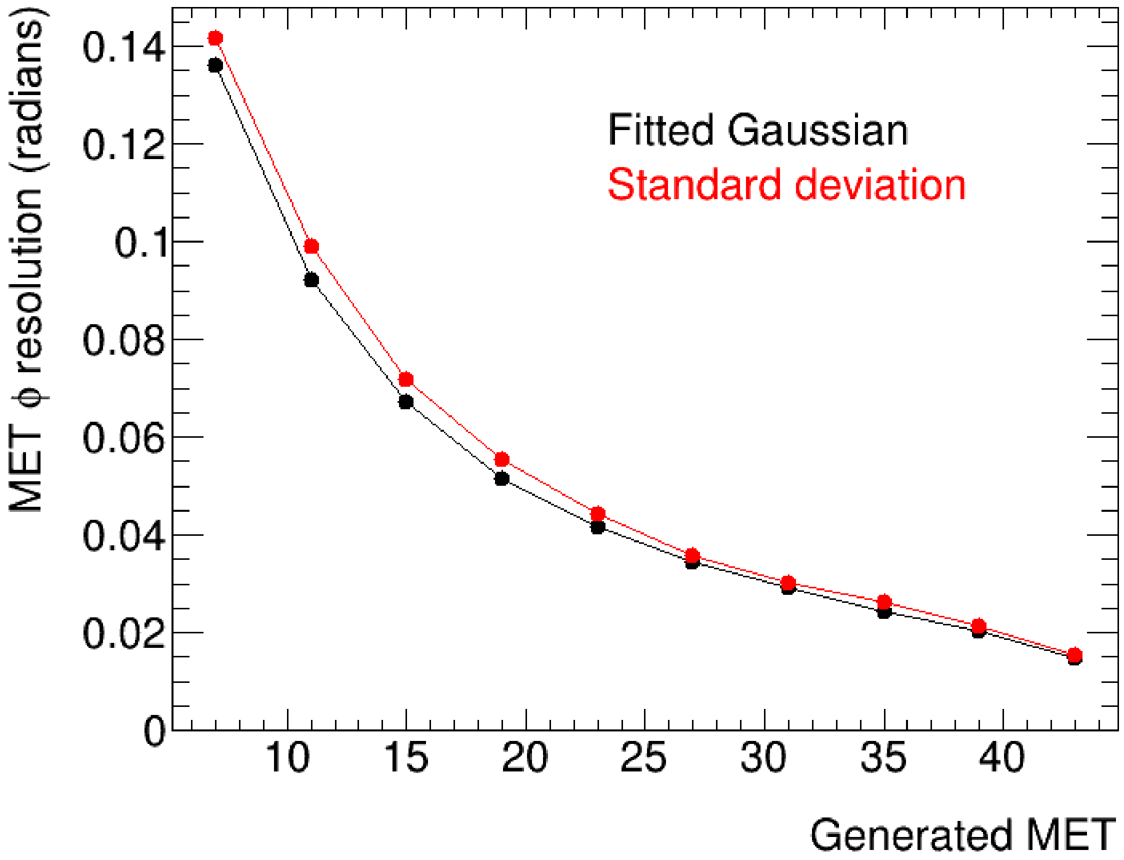
(METreco - METgen)/METgen
generated MET



Relative MET resolution
Fitted Gaussian
Standard deviation
Generated MET

Neutrino azimuthal angle

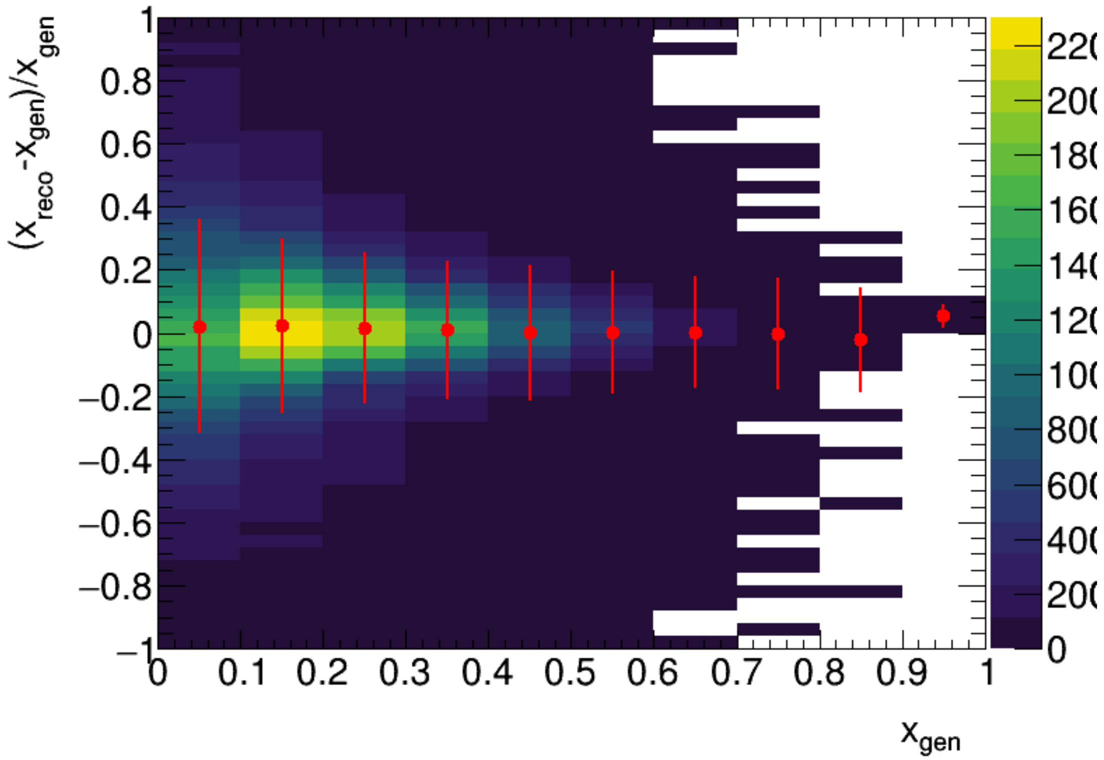




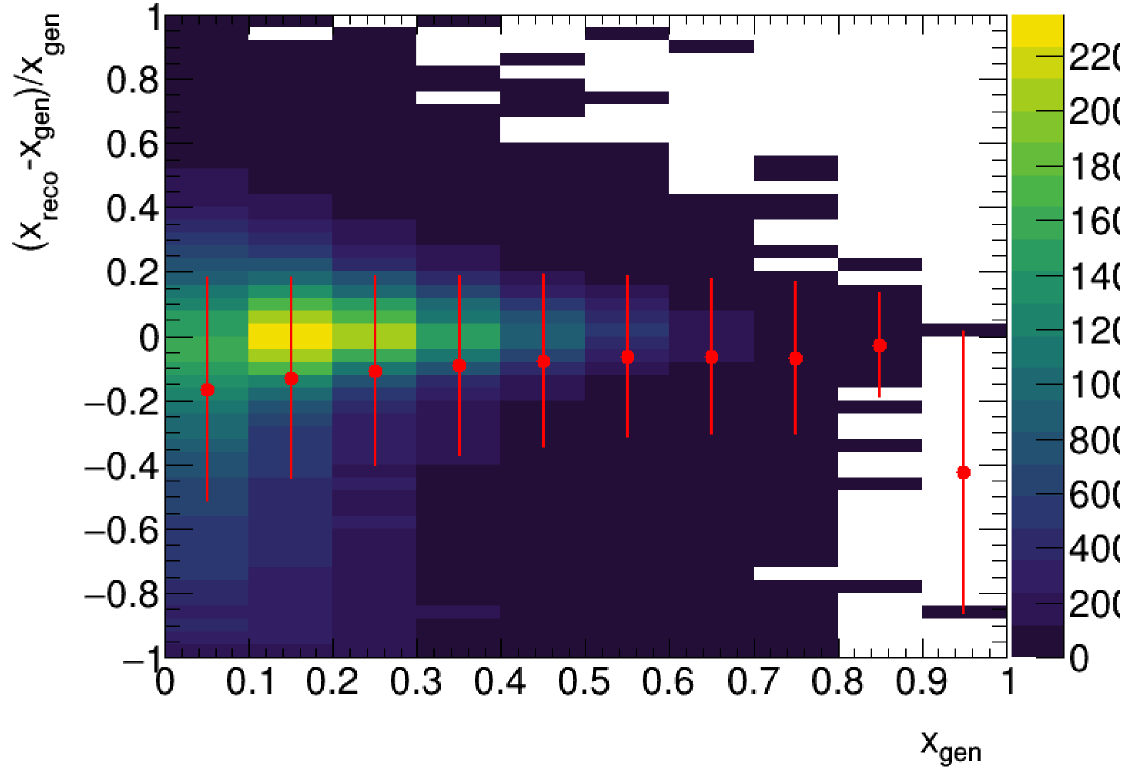
Bjorken x performance

$$y_{\mathrm{JB}} = \frac{\sum_i (E_i - p_{Z,i})}{2\ E_e}, \qquad Q^2_{\mathrm{JB}} = \frac{(p_T^{\mathrm{miss}})^2}{1 - y_{\mathrm{JB}}} \qquad \text{and} \qquad x_{\mathrm{JB}} = \frac{Q^2_{\mathrm{JB}}}{s\ y_{\mathrm{JB}}},$$

With barrel HCAL



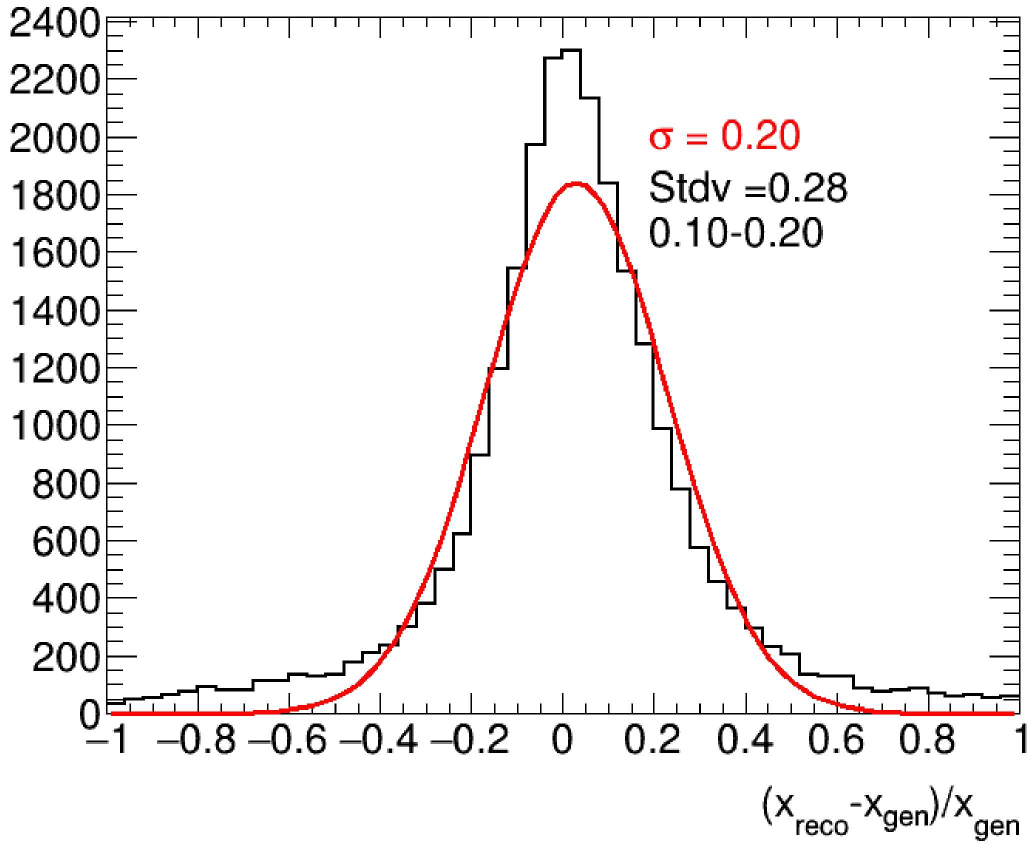
Without barrel HCAL



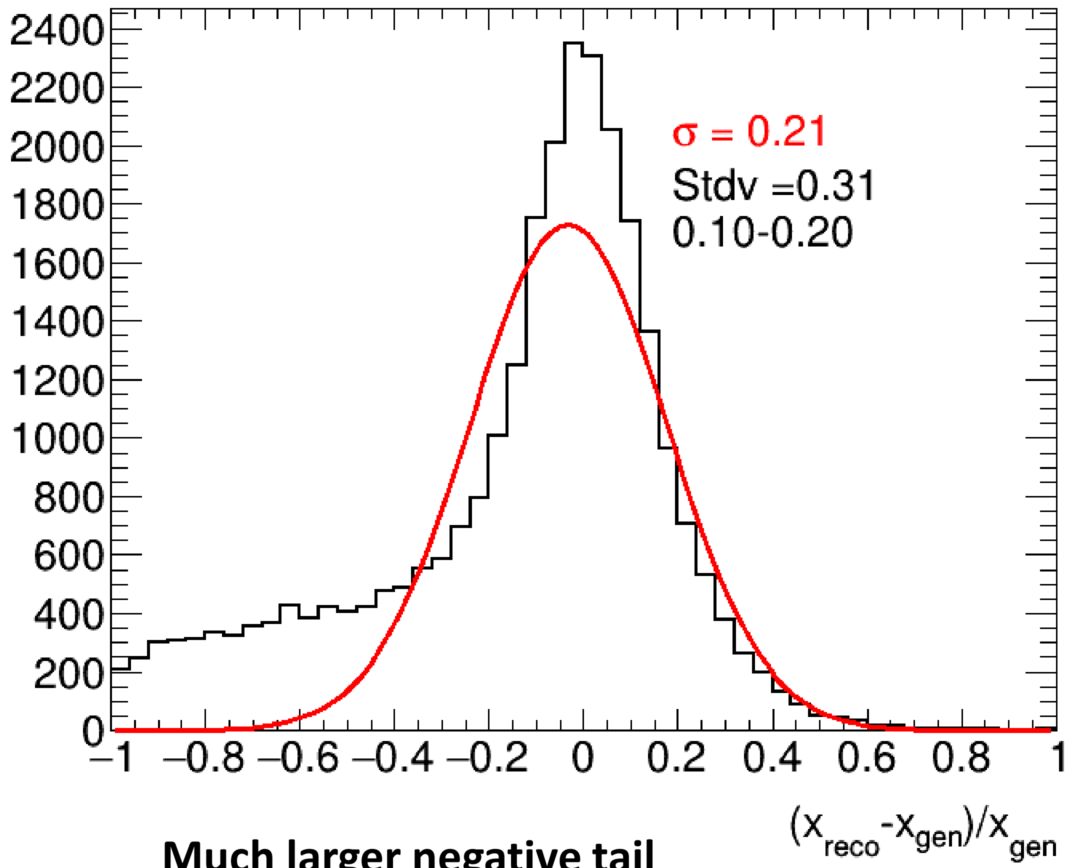
Strong bias at low x
(low jet energy)

Bjorken x performance

With barrel HCAL



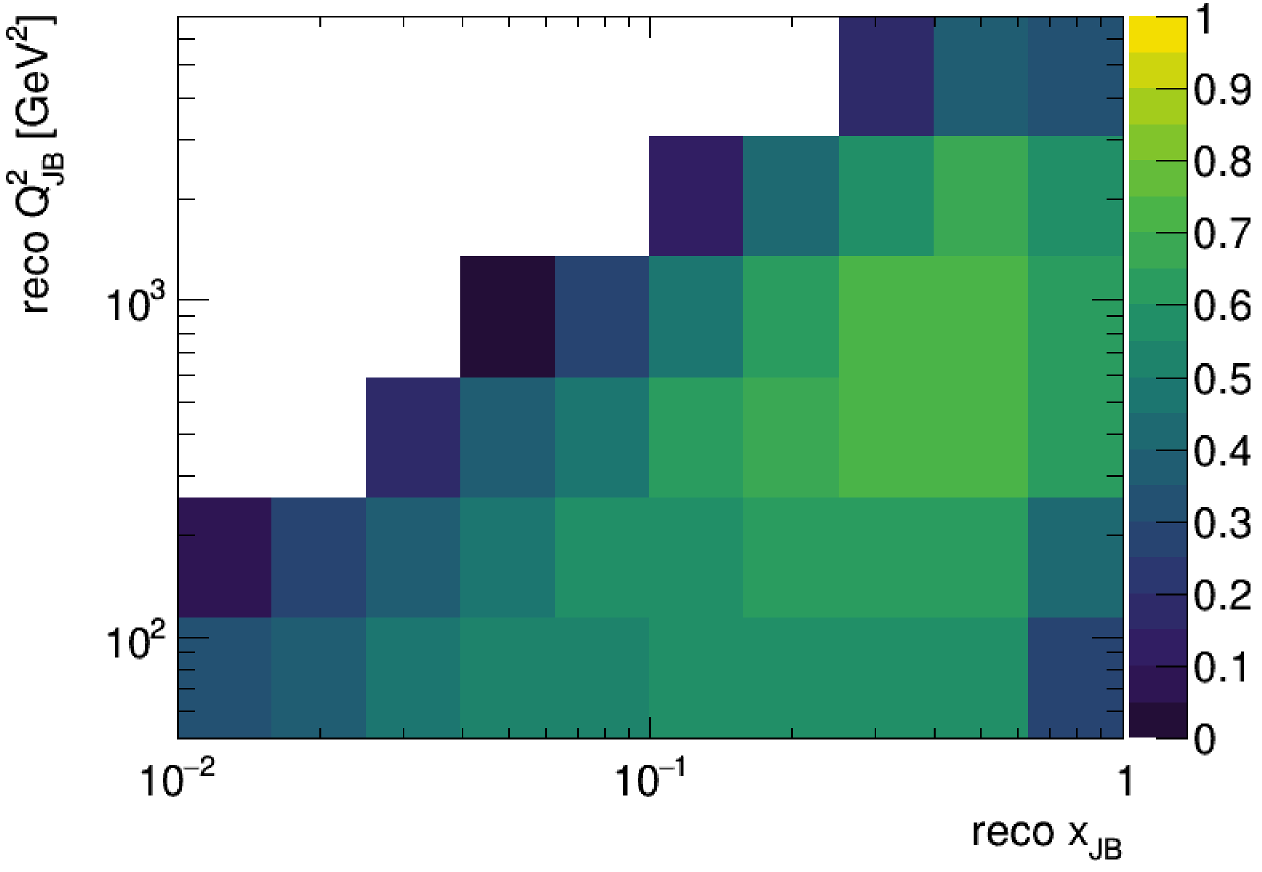
Without barrel HCAL



Much larger negative tail (low jet energy)

Jacquet-Blondel Purity

$$\text{purity} = (N_{gen} - N_{out})/(N_{gen} - N_{out} + N_{in})$$



- Reasonable purity reached at high-x and high Q2. (similar conclusion reached in Aschenauer et al. Phys. Rev. D 88, 114025 (2013))
- This is one figure of merit, but one should not forget to consider non-Gaussian tails in response…

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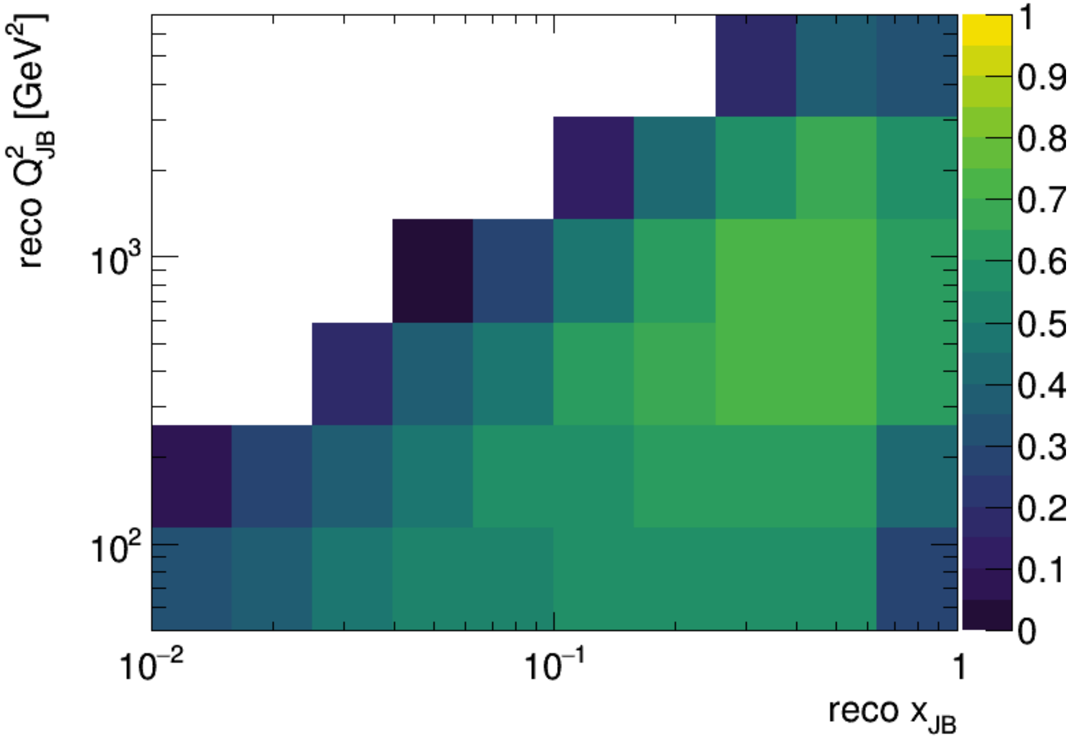
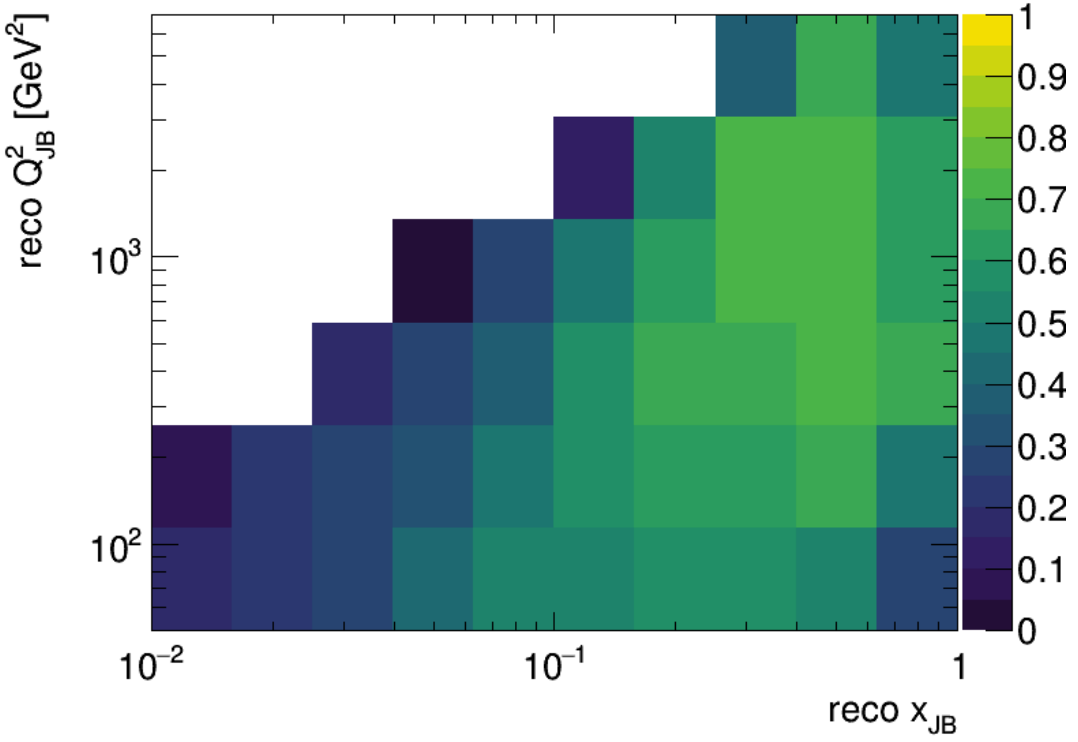
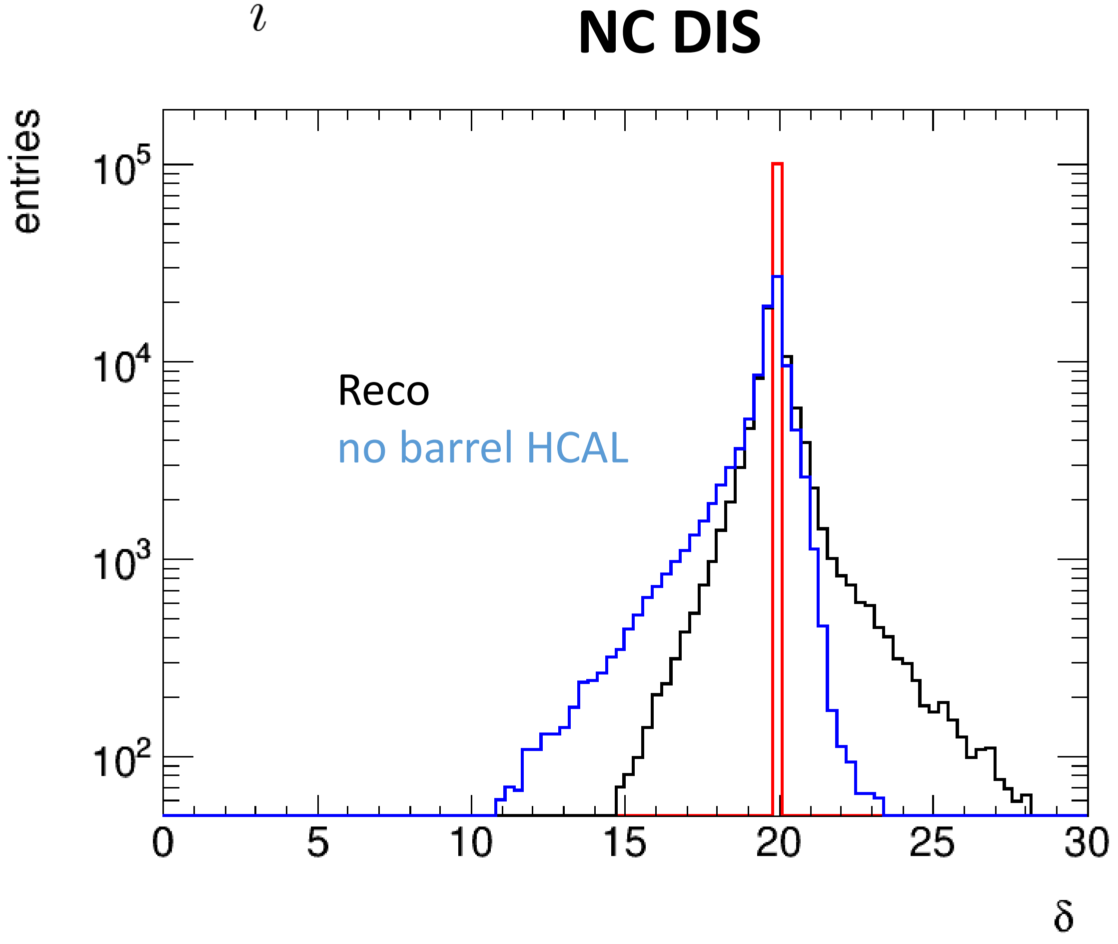


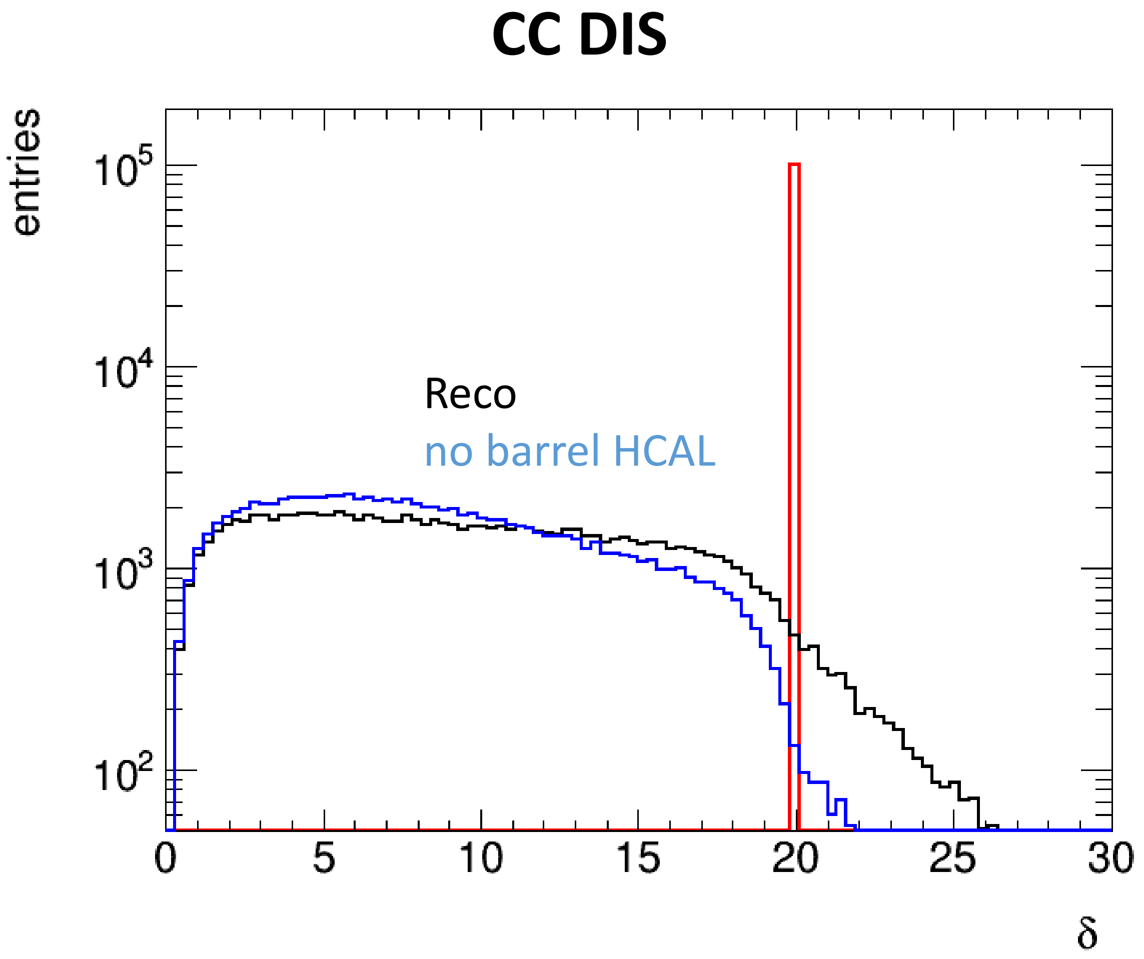
Without barrel HCAL



Background rejection

$$\delta = \sum_i E_i(1 - \cos\theta_i)$$





- If one misses track of electron but measures cluster (or viceversa), delta-cut useful to veto NC DIS. Ongoing studies to quantify impact in cross-section

Requirements of "Jets for 3D imaging" program (under construction)

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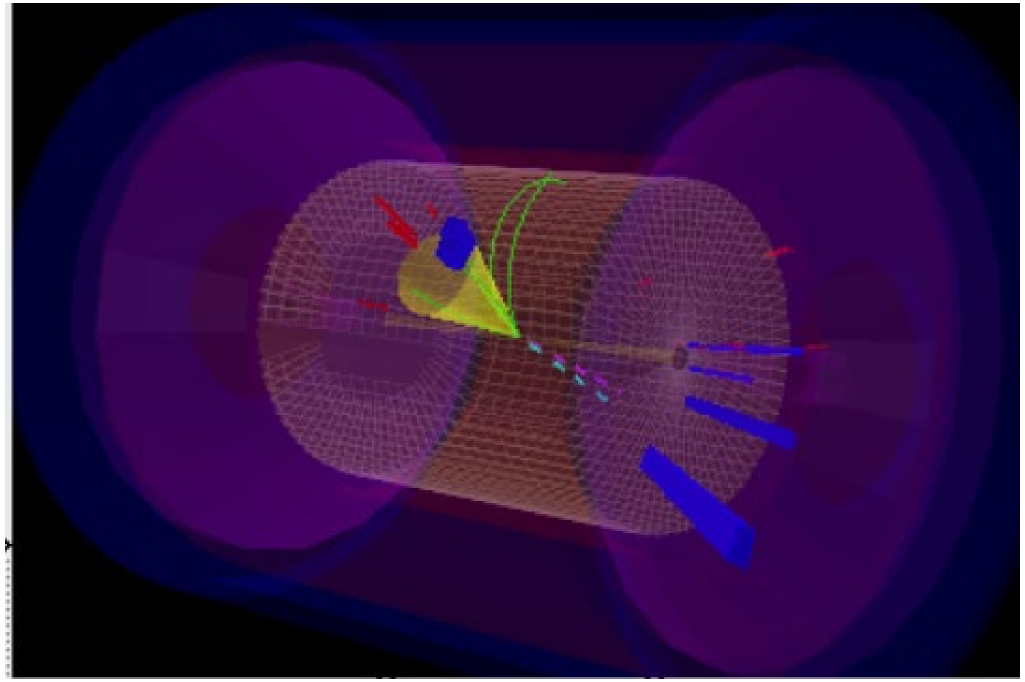
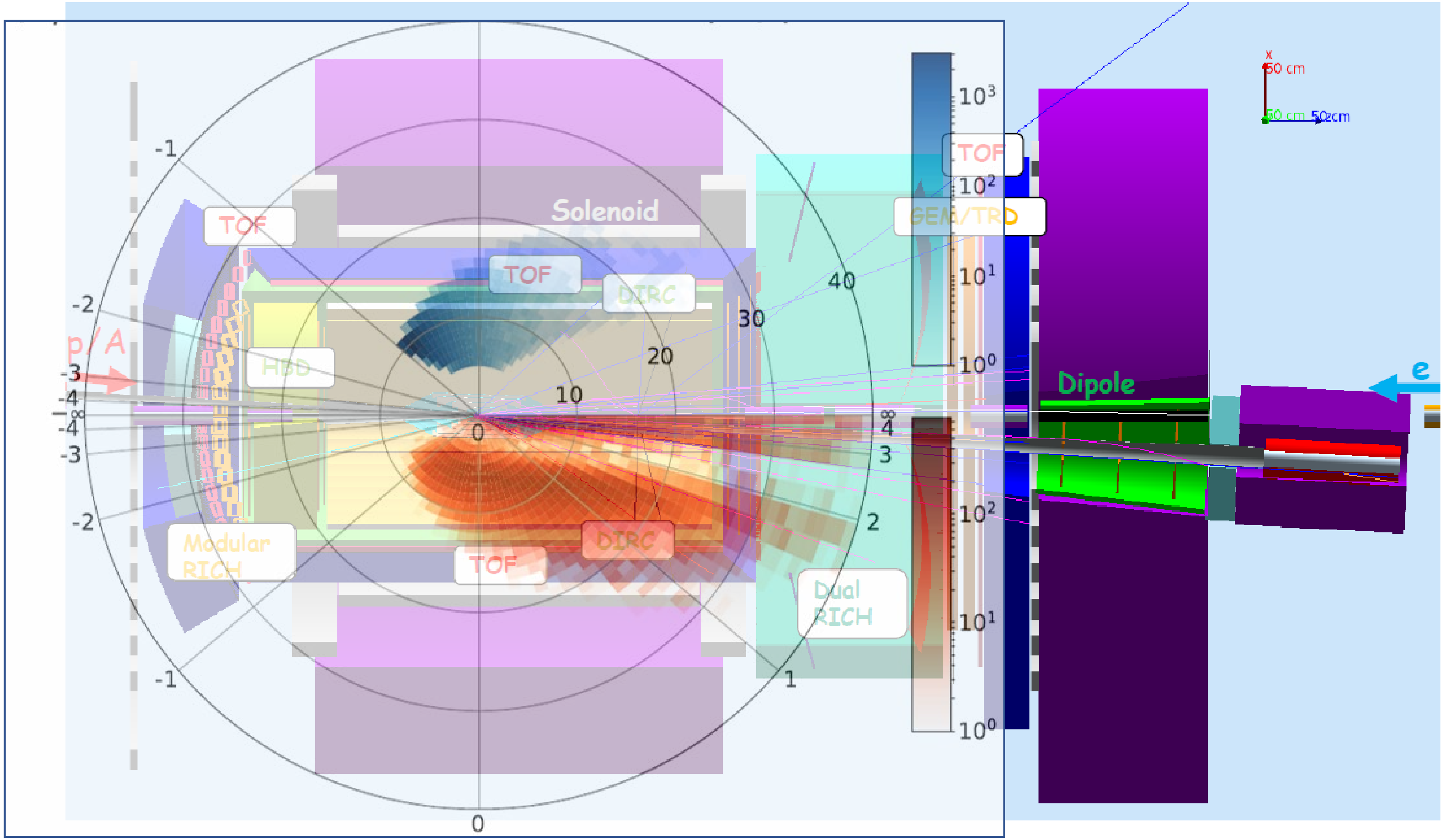
h-in-c-jet (CC) 100 fb^{-1}	$d\sigma$, $A_{UT}(z_h, j_T)$	s-transversity	—	—	—
c-jet (e^+ CC) 100 fb^{-1}	$d\sigma$, A_{LL}	$s/\bar{s}$ asymmetry	positrons	—	—

"a hermetic detector (also called a 4π detector) is a particle detector designed to observe ***all possible decay products*** *of an interaction between subatomic particles in a collider by* ***covering as large an area*** *around the interaction point as possible and incorporating multiple types of sub-detectors"* ***Source:*** **Wikipedia**



Mind the gap



Solenoid
TOF
TOF
TOF
TOF
DIRC
DIRC
HBD
Modular RICH
Dual RICH
GEM/TRD
p/A
Dipole
e
10
20
30
40
-1
-2
-3
-4
-1
-2
-3
-4
1
2
3
4
0
0
10^3
10^2
10^1
10^0
10^2
10^1
10^0
50 cm