EIC ENDCAP CALORIMETRY SIMULATION WITH GEANT4

ZHIWAN XU, (UCLA)

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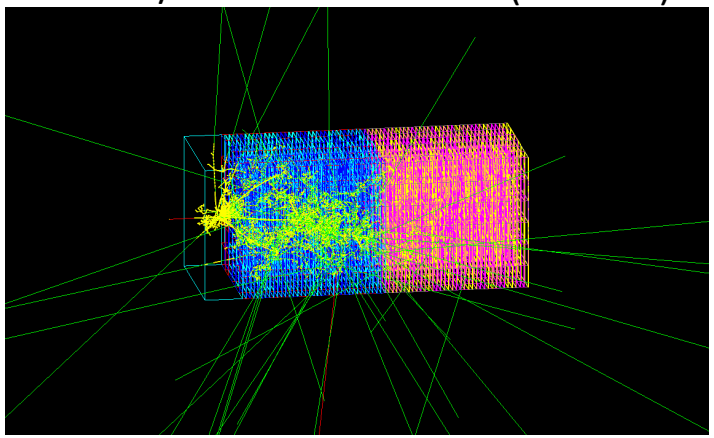
Introduction

- EIC detectors are designed binary: EMCal section followed with Fe/Sc HCal section
- Ristrictions on longitudinal space to be tight as 120cm HCAL, 40 cm ECal, requiring compact detectors and readout
- around 5 λ_{int} at highest pseudo rapidity
  1. SHASHLYK (Phenix, STAR Forward)
  2. WScFi (STAR Forward 2014)
  3. Fe/Sc (STAR Forward 2020)

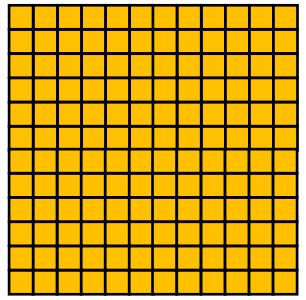
Z= 36.3 / 17 cm + 82.8 cm + (82.8 cm)

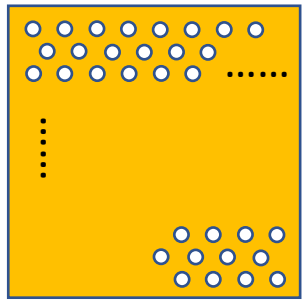


	Material	x_i	λ_{int}, mm	λ_{eff}, mm
HCal	Fe	20/23	168	187
	Sc	3/23	795	
Shashlyk	Pb	1.5/5.5	171	398
	Sc	4/5.5	795	

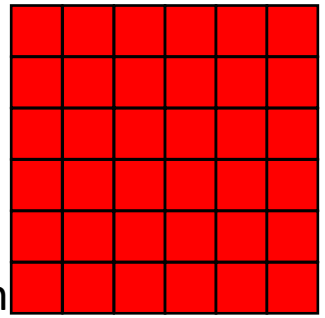
	Material	x_i	λ_{int}, mm	λ_{eff}, mm
W/ScFi	96% W + 4% Sc	0.7998	127.3	153
	Sc	0.2002	795	

5 cm





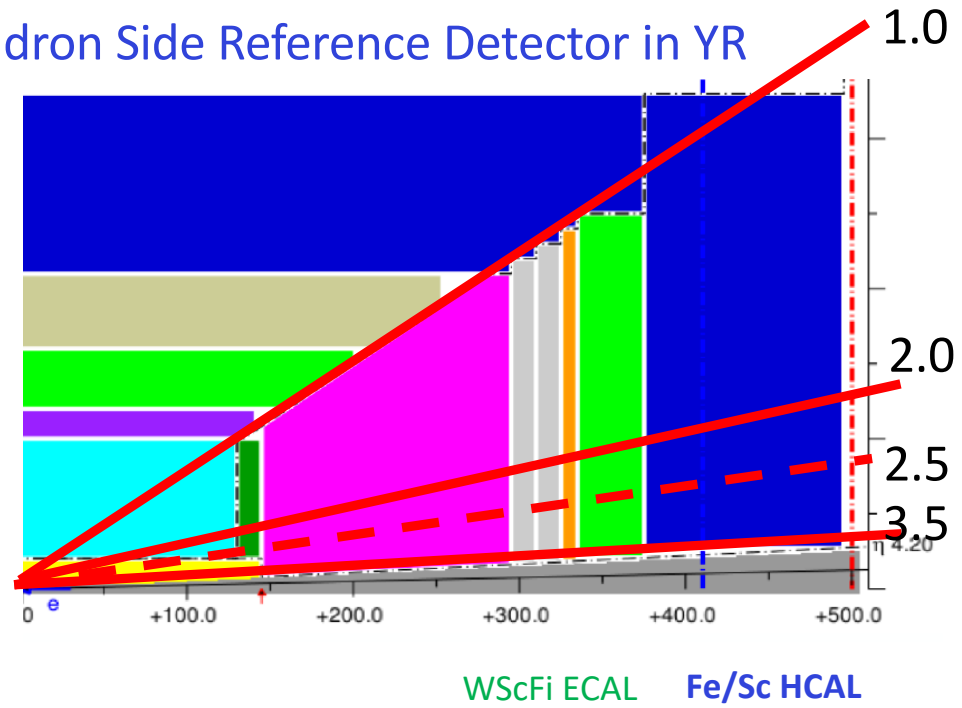
10 cm



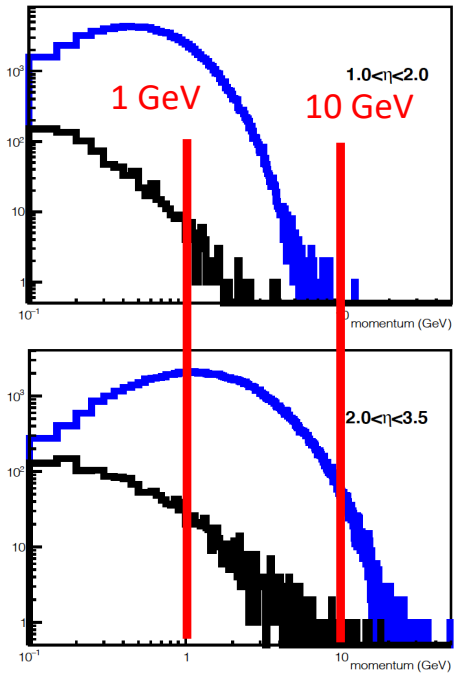
Shashlyk (front) W/ScFi (front) ideal hcal (front)

EIC EndCap Energy

Hadron Side Reference Detector in YR



WScFi ECAL **Fe/Sc HCAL**



Inclusive, 18 GeV x 275 GeV

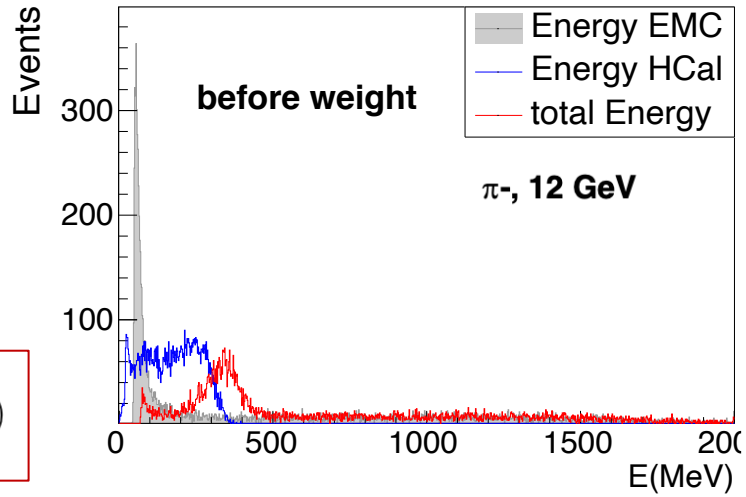
- requirements for energy resolution ~ $50\%/\sqrt{E}$ +10% level.

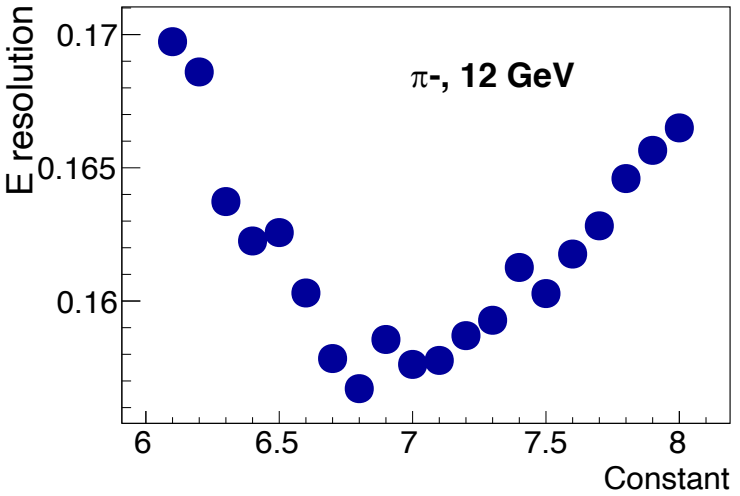
- Low energy hadrons mostly, except of very forward region pseudorapidity 3-4
- Proper choice of EMCal technology is important
  - ~1 GeV pions, deposits ~50% of energy in Ecal

Weighting techniques

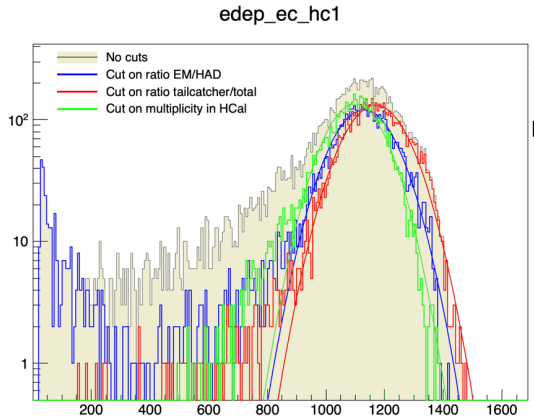
- EM Cal: Optimal weighting
- HCal: tail catcher
  - Efficiency
- Hcal: reweighting

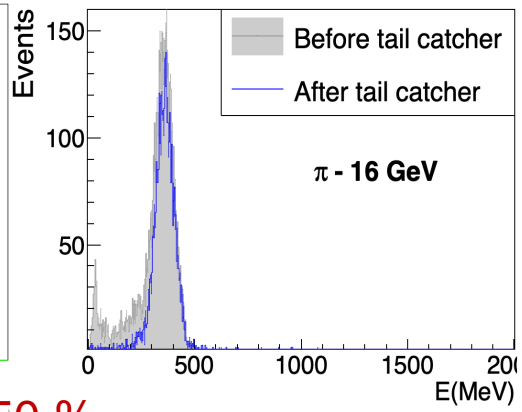
$$E_i' = E(1 - \frac{C}{E_{tot}} E_i)$$



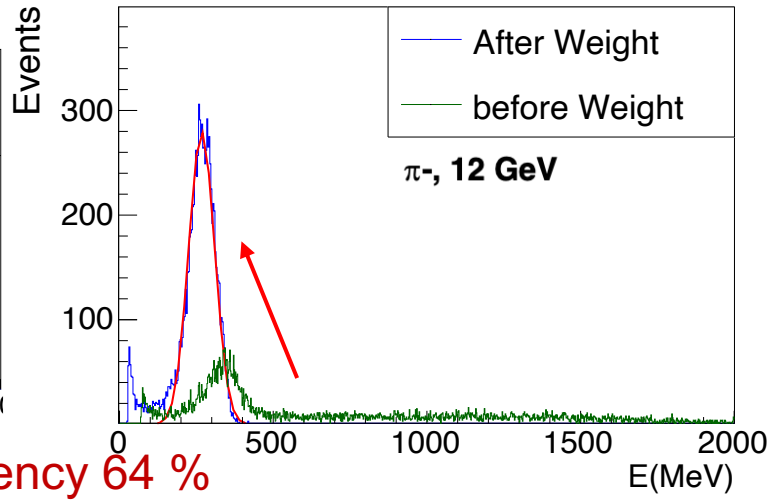


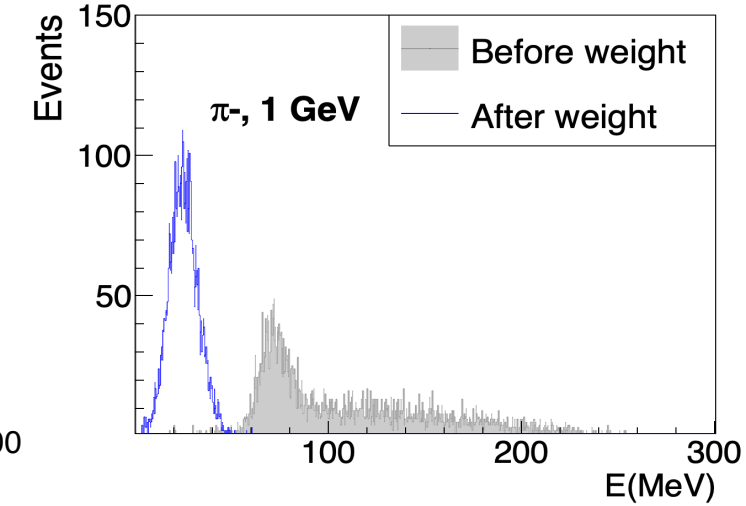
E = 12 GeV. at 0 incident angle





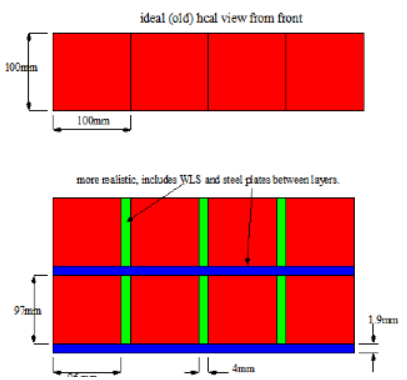
E = 64 GeV. Efficiency 50 %

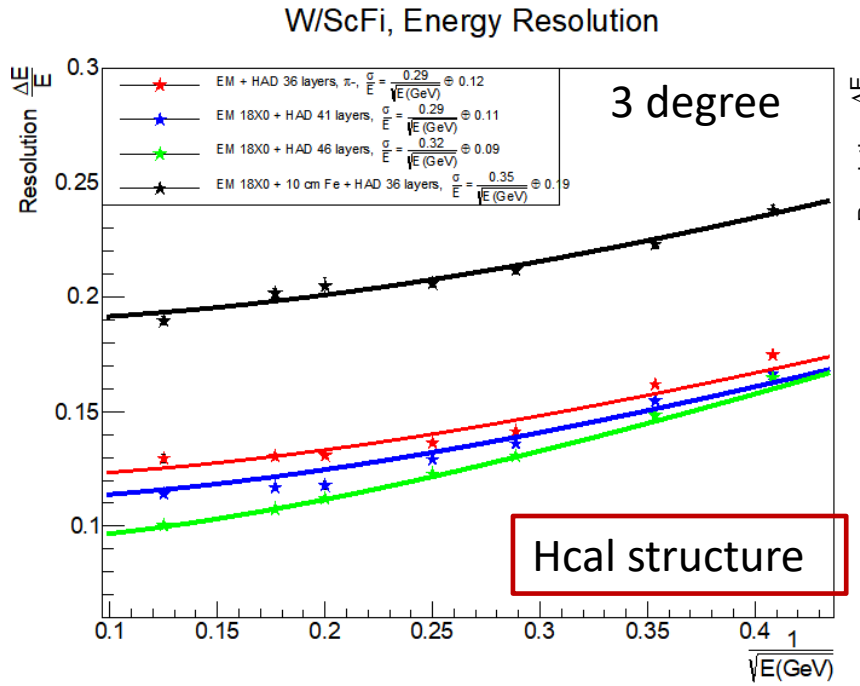


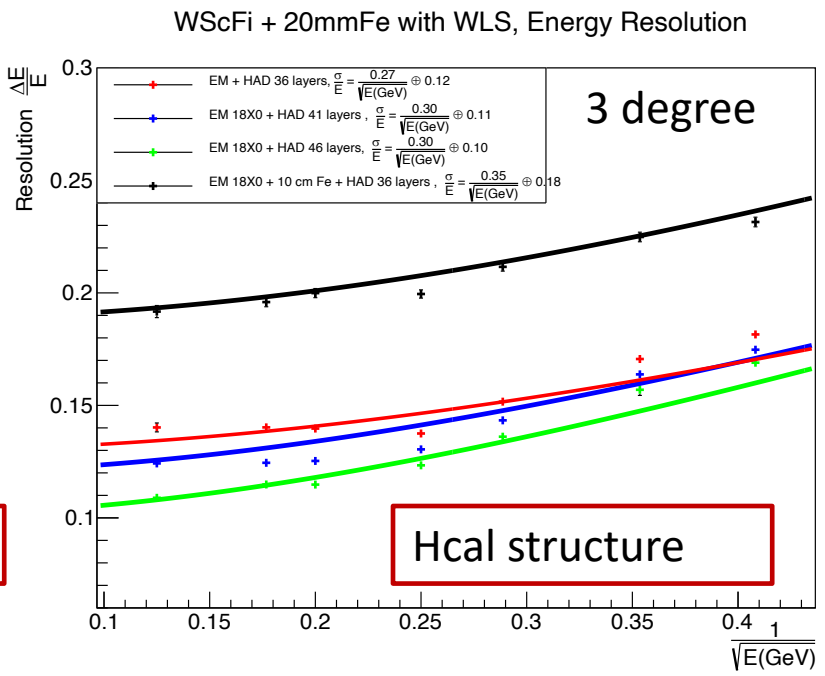


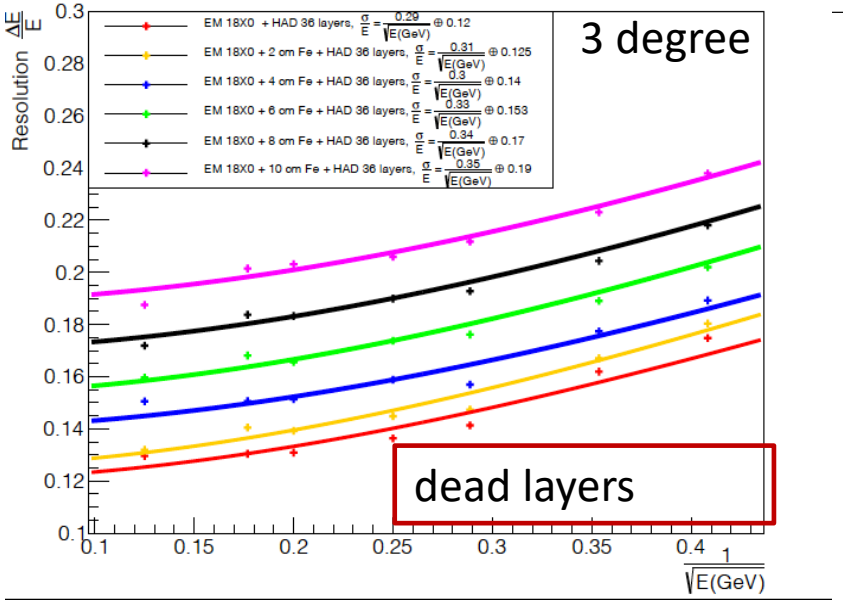
E = 16 GeV. Efficiency 64 %

EIC EndCap energy resolution under different conditions – realistic structure



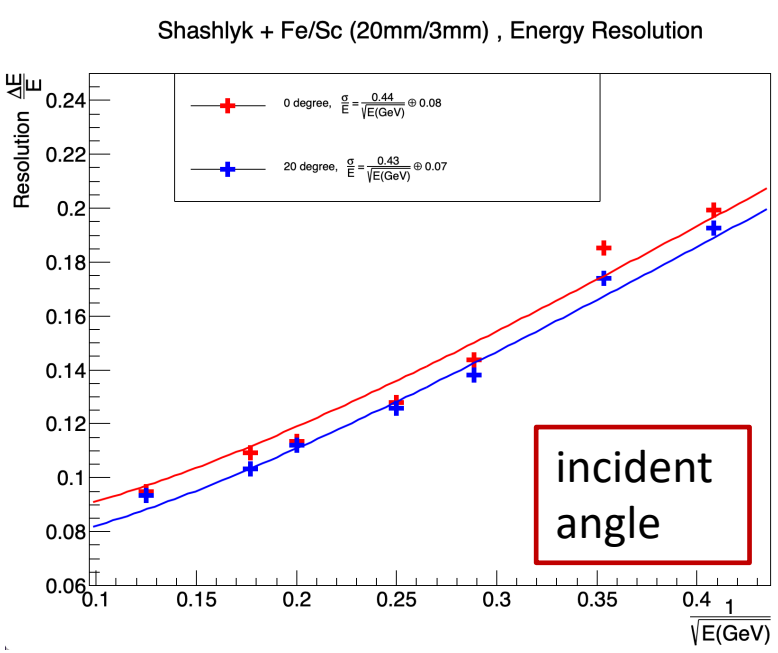


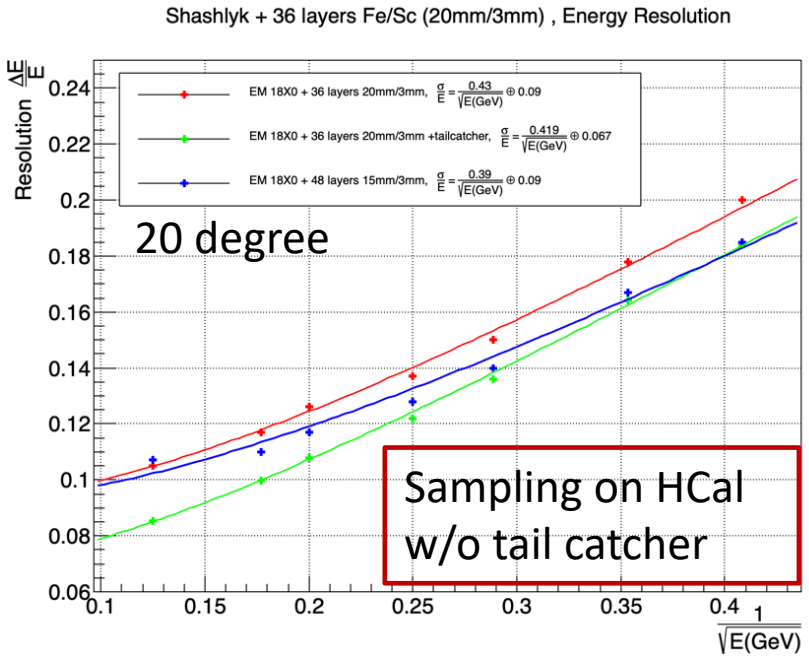


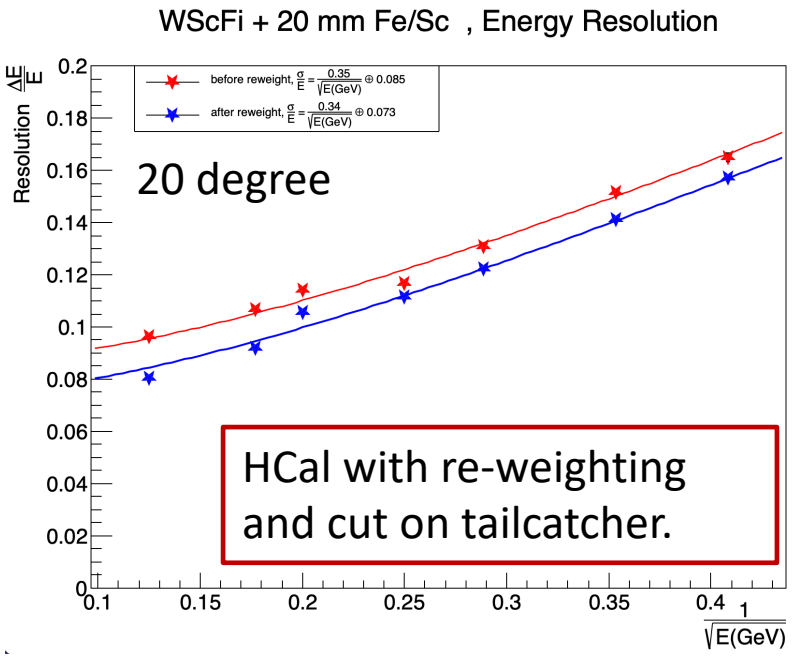


- Hcal + WLS and steel plate, little impact on stochastic term 0.29/ $\sqrt{E}$ - 0.27/ $\sqrt{E}$
- Increasing HCal layers mostly decrease constant term, with smaller energy resolution.
- Adding dead layers increase the stochastic term a lot

EIC EndCap energy resolution under different conditions

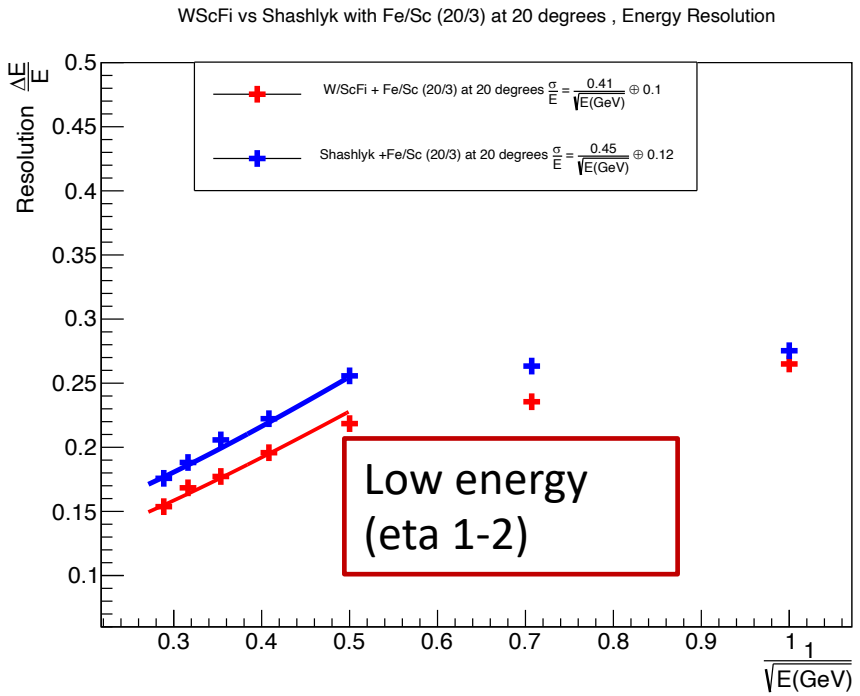


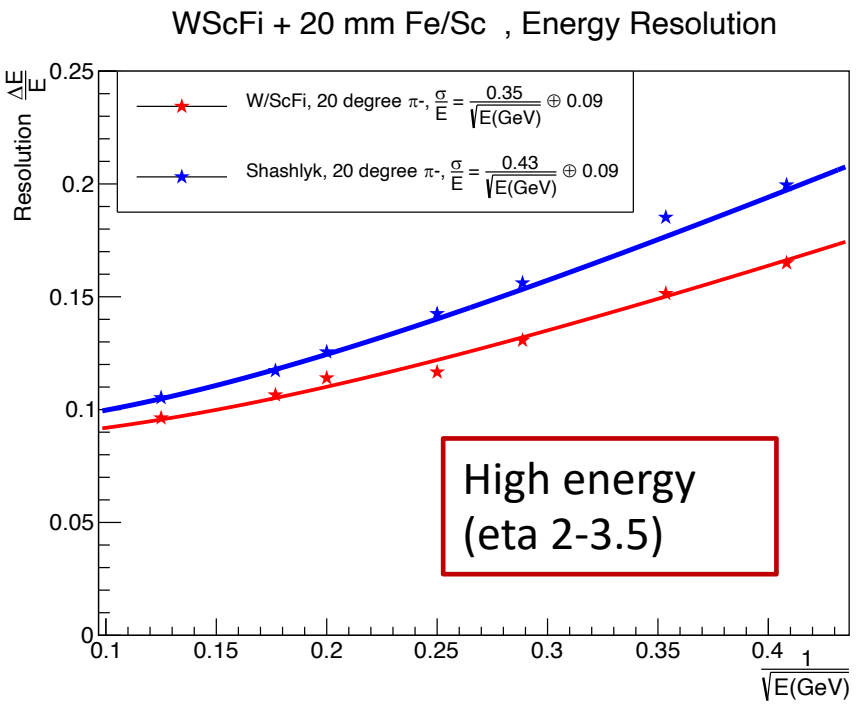




- Incident particle angle 0 degree vs 20 degree, little impact on stochastic term
- Finer sampling (15mm) have smaller stochastic terms, however longer geometry size
- W/ScFi performs much better, with 0.35/ $\sqrt{E}$, compared with Shashlyk 0.43/ $\sqrt{E}$
- Re-weighting on Hcal leads to a notable improvement at loss of efficiency 90%(6 GeV) - 50%(64 GeV)

EIC EndCap energy resolution under different conditions- Energy



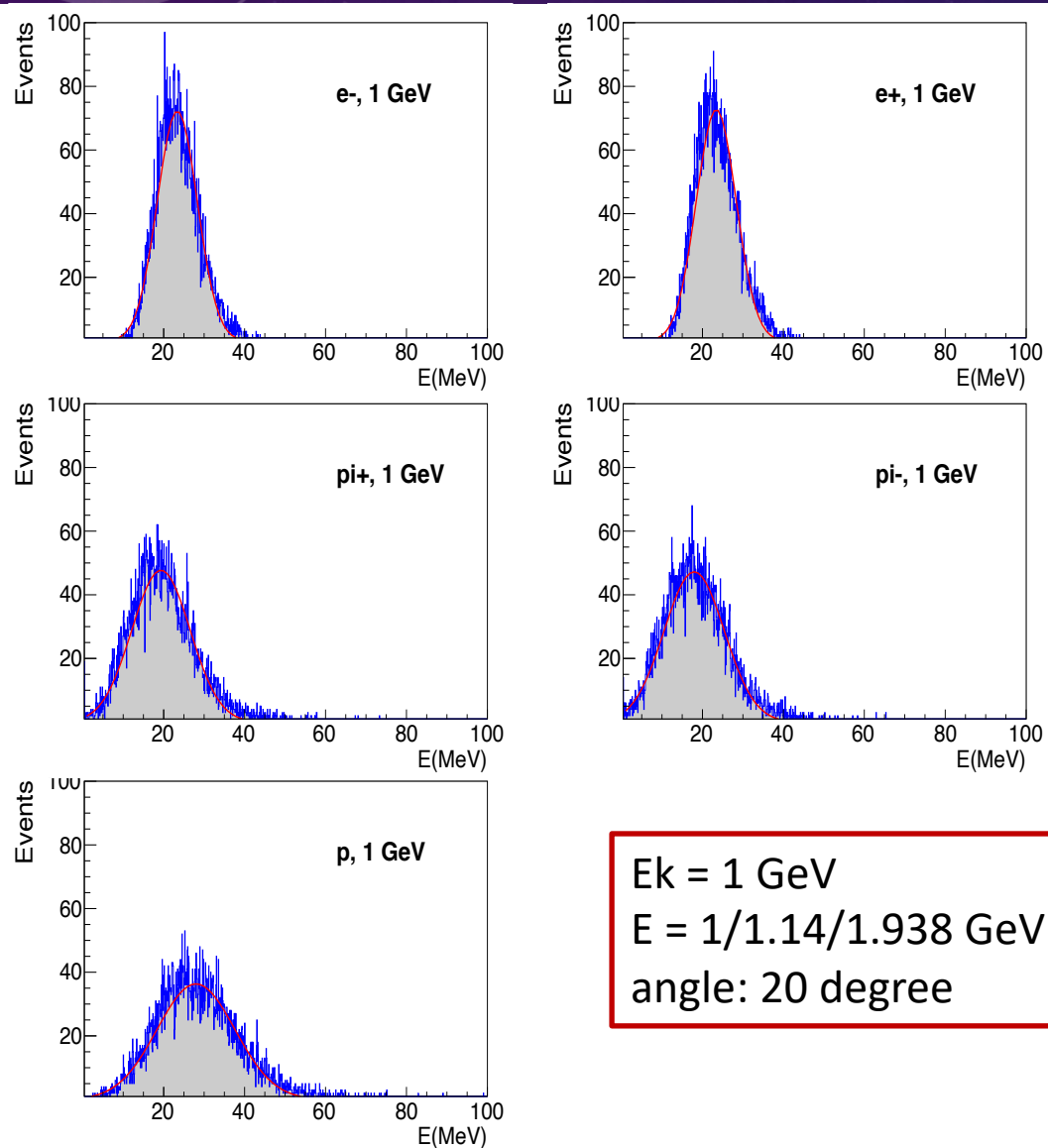


- Most energy of hadrons in EIC central detector are usually below 10 GeV. Only in very forward rapidity region it goes to ~100 GeV
- fit ranges should be restricted to particular energy ranges (> 4 GeV) and pseudo rapidity (< 2.5)

EIC EndCap performance in e/h ratio

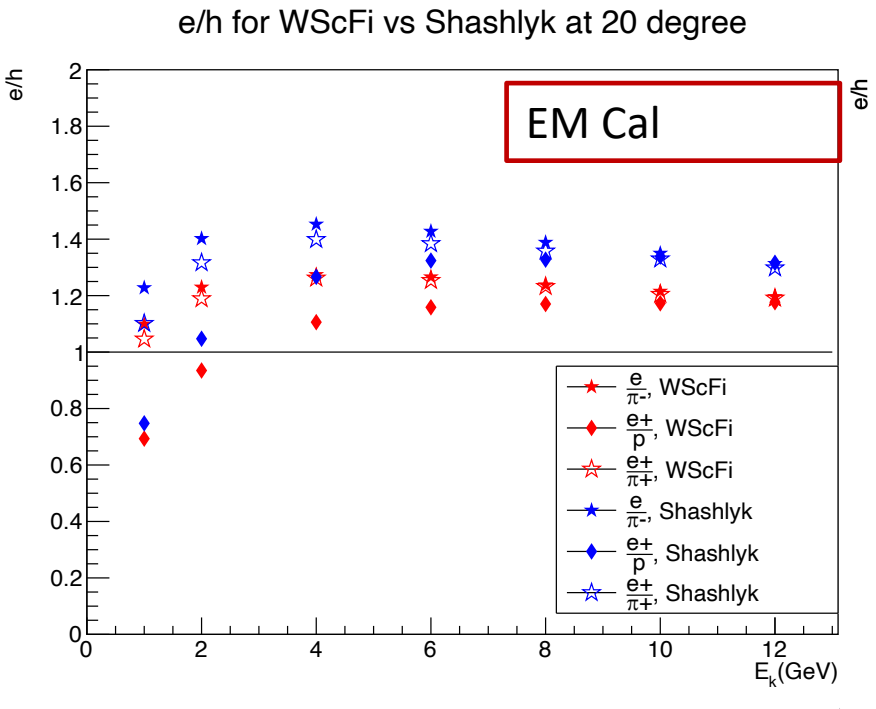
- One way to optimize the system is to consider how e/h is close to 1
- response of different calorimeter systems to electrons and hadrons

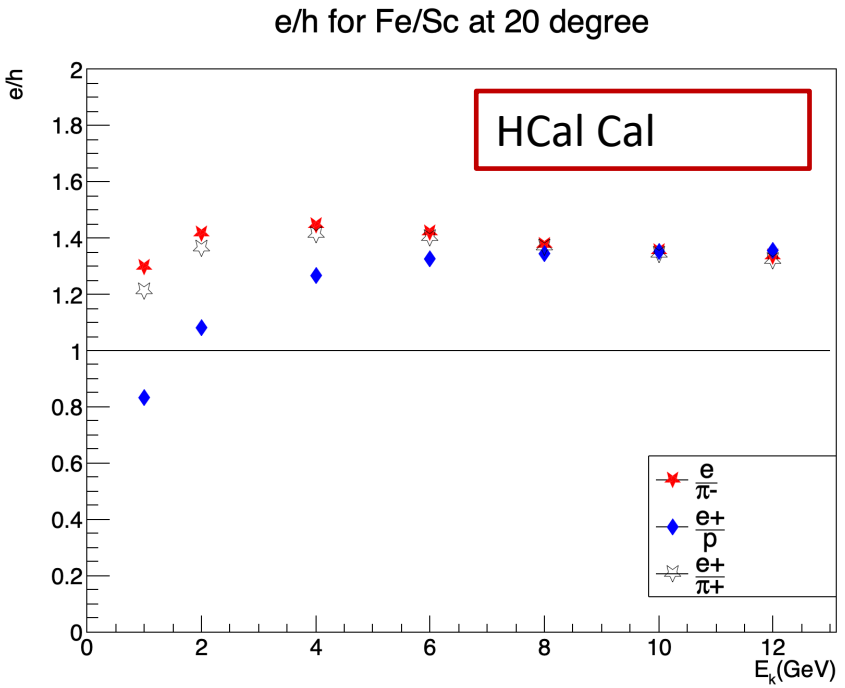
1. W/ScFi ~ 9 interaction length (sufficiently long 2 meters)
2. Pb/Sc ~ 9 interaction length.(650 layers)
3. Fe/Sc ~9 interaction length.(73 layers)

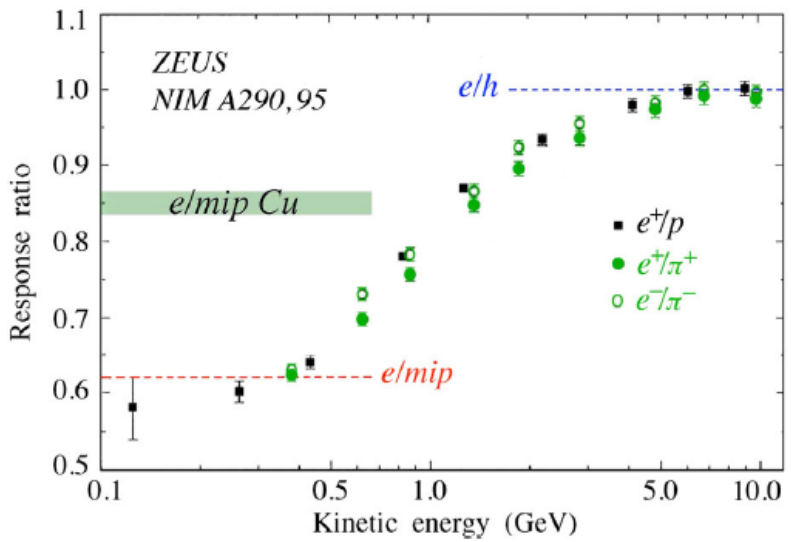


Ek = 1 GeV
E = 1/1.14/1.938 GeV
angle: 20 degree

Ratio of e/h ratio at 9 interaction length



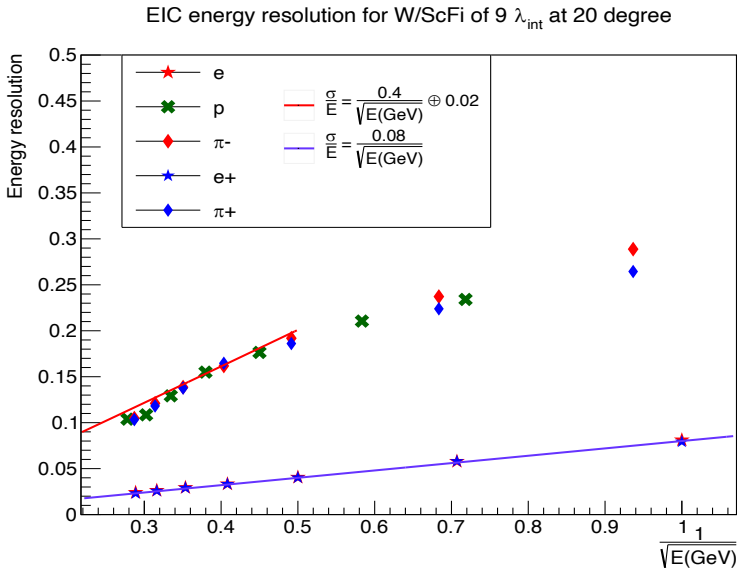


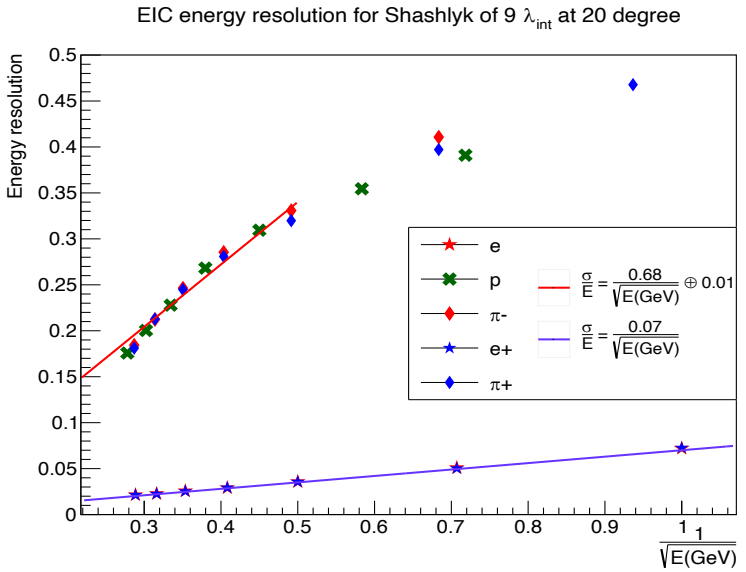


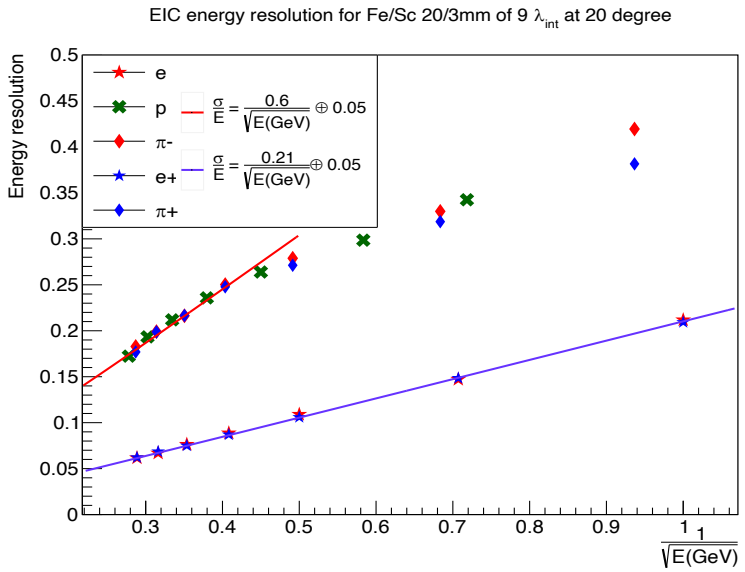
ZEUS measurements (CERN)

- ECal and HCal have different e/h response for different particles
- Most e/h ration are above 1, different from ZEUS results which are from experiments.
- Combination of WScFi + Fe/Sc works better at low energy range, could be from its closer e/h to 1 then for Shashlyk EMcal.

Hypothetical EIC EndCap resolutions at 9 interaction length







- The energy resolution for hardrons turned out to stay within same area for low energy
- At longer enough distance, with no leakages from the detectors, SHASHLYK has highest stochastic term ($0.68/\sqrt{E}$), while its interaction length also longest (~ 400 mm).
- The W/ScFi has better response for different particles

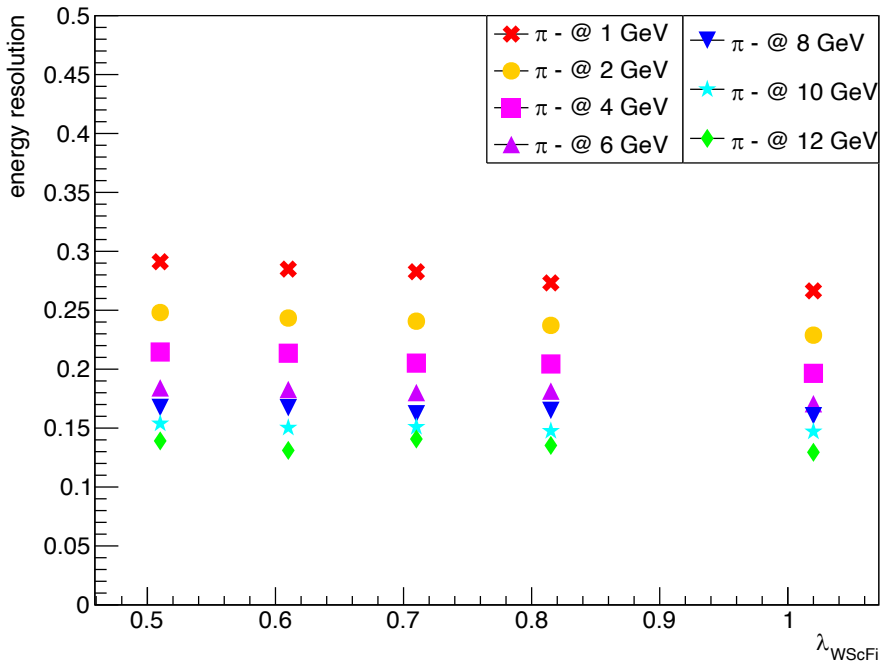
EIC EndCap resolutions at different depth of EMC (longitudinal configurations)

Table 3: Effective interaction length for W/ScFi calorimeter

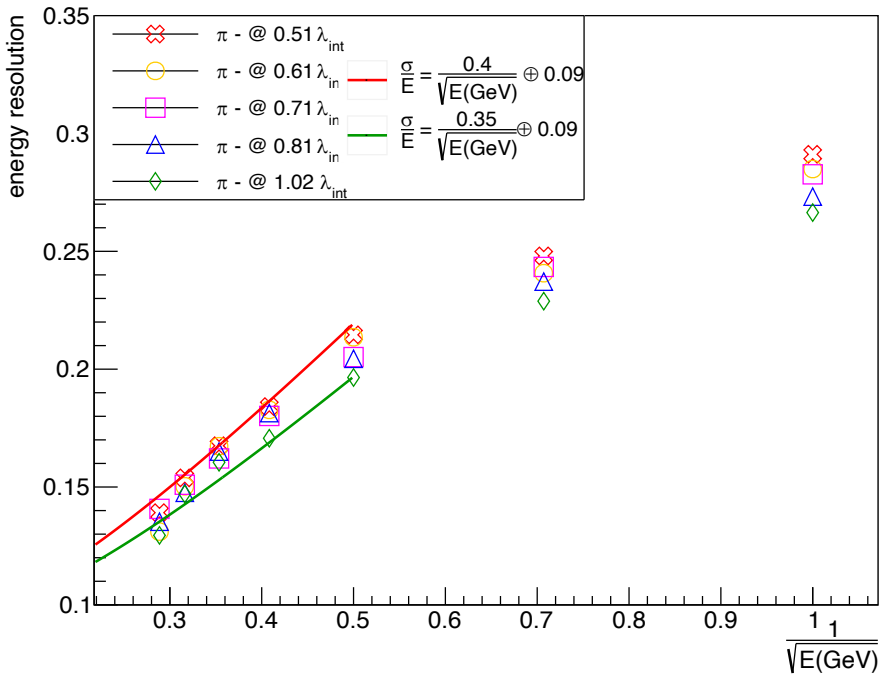
L (W/ScFi),$\lambda_{W/ScFi}$	0.51	0.61	0.71	0.81	1.02
L, mm	78	93.6	109.2	124.8	156
L (Fe/Sc),$\lambda_{Fe/Sc}$	4.5	4.4	4.3	4.2	4
L, layers	37	36	35	34	33

Keep total length of the calorimeter system at 5 interaction length and vary depth of EMcal section from 0.5 to 1 interaction length.

energy resolution of WScFi vs percentage of interaction length

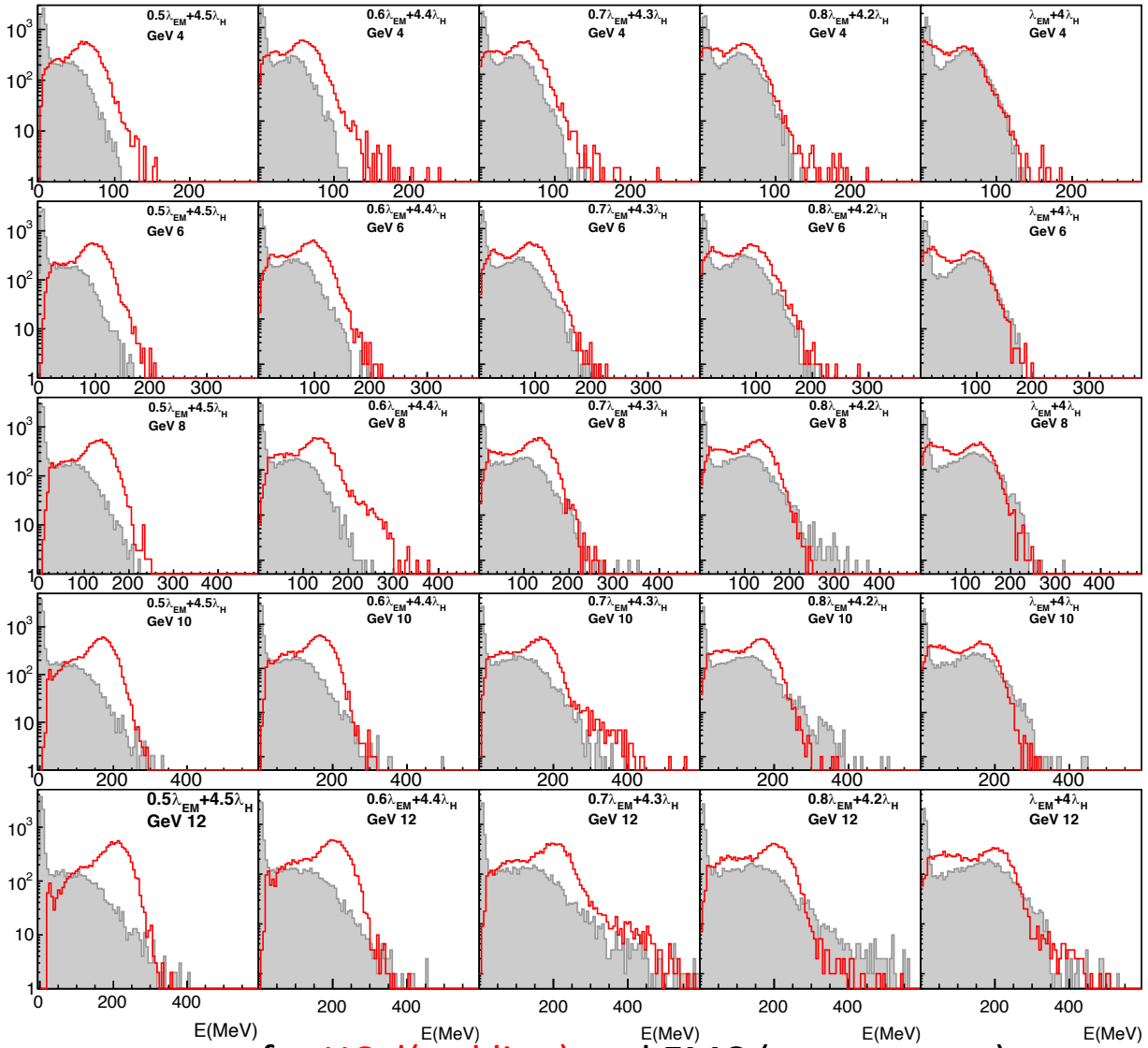


EIC energy resolution for different interaction length of W/ScFi

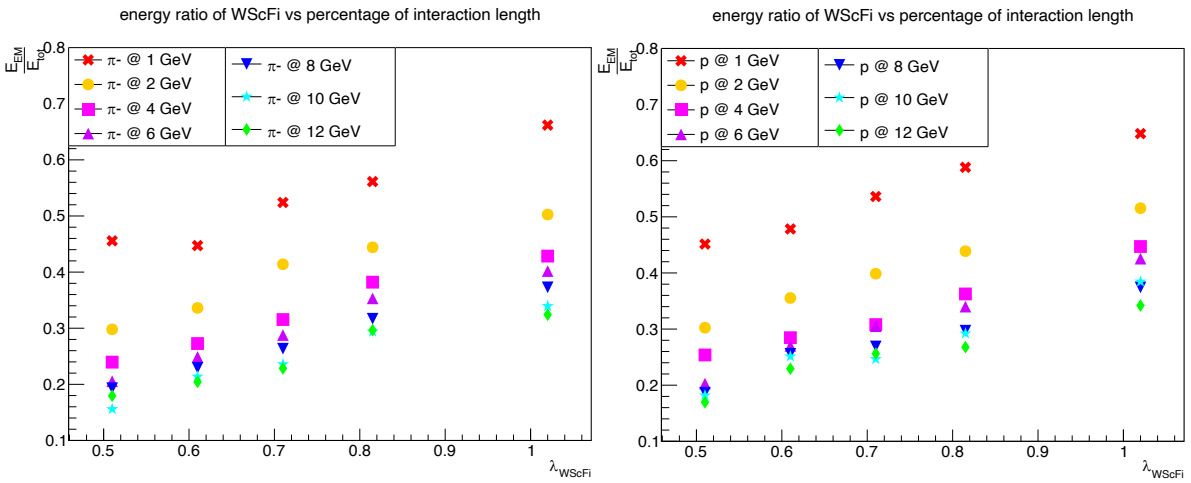


Small improvement in energy resolution of the system with increased depth of the EMCal section.

Energy spectrum at different longitudinal configurations



spectrum for HCal(red line) and EMC (grey pattern)



- Energy deposited in EMCal goes higher
- Increasing depth of Ecal help to improve energy resolution of the system for low energy hadrons

Conclusions

- We investigate different instrumental effects, such as sampling fraction in hcal section, on energy resolution.
- Tail catcher method allows to control leakages from back at the cost of efficiency (90% for lower than 6 GeV to 50% at 64 GeV). With cut on tail catcher and re-weighting Hcal towers, resolution looks good with stochastic term at ~35% and constant term at ~7%.
- e/h ration shows that W/ScFi has better performance in lower energy to different particles.
- Change in the depth of W/ScFi give some impact to energy resolution and spectrum.
- …We will continue investigate the depth of Ecal, and methology to improve the Ecal resolution for futural study on energy-flow, jets etc.

THANK YOU