Simulation study of dual readout calorimeter for ECCE at the EIC

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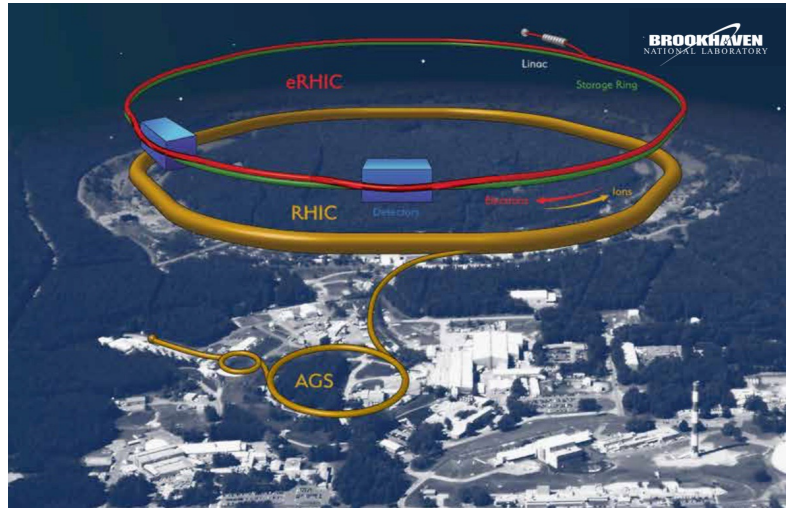
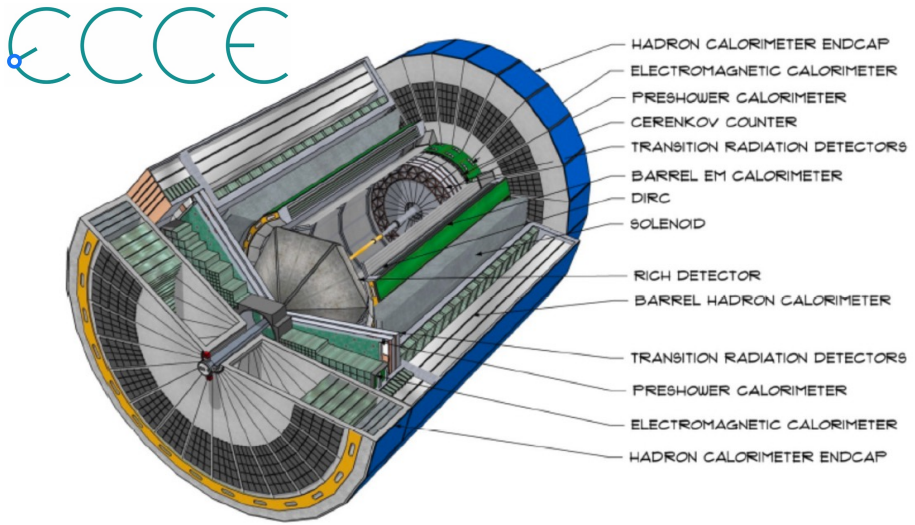
ECCE at EIC

- Electron Ion Collider(EIC):
  - Future particle accelerator facility to be built at BNL
  - To study detailed structure of proton and nucleus

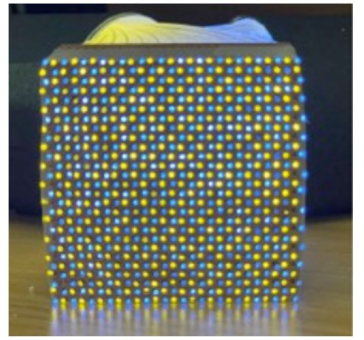


- EIC Comprehensive Chromodynamic Experiment(ECCE):
  - A consortium, not yet a collaboration
  - Optimize detectors for delivering the full EIC science mission
  - A Dual-readout calorimeter was proposed for upgrade plan of forward hadron calorimeter

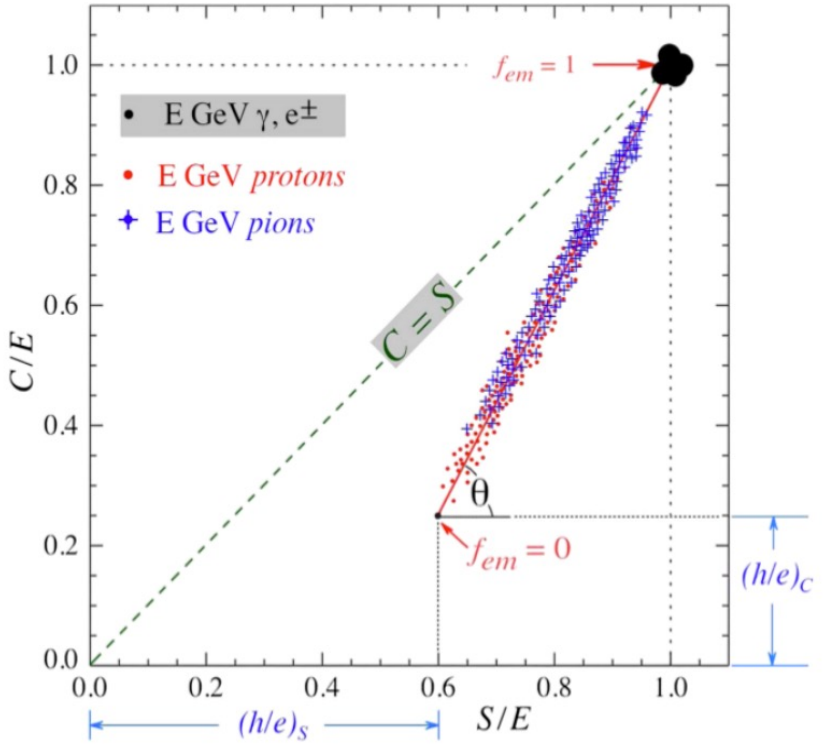


Dual-Readout Calorimeter(DRC)

- Characteristic of the DRC
  - Consists of two different optical fibers for readout to measure the “fraction of EM shower (f_{em})” in the hadronic shower
  - High energy resolution comes from dual-readout correction



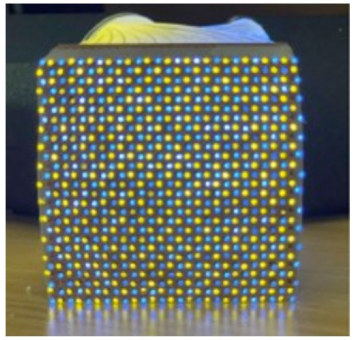
	material
Scintillation	Polystyrene
Cherenkov	PMMA
Absorber	Cu / W(candidate)



Ratio of measured energy and initial energy

Dual-Readout Calorimeter(DRC)

- Characteristic of the DRC
  - Consists of two different optical fibers for readout
    to measure the “fraction of EM shower (f_{em})” in the hadronic shower
  - High energy resolution comes from dual-readout correction
- Simulation configuration for study
  - A simulation framework exists already for FCC experiment
    -> utilized only the endcap part
    -> tower thickness reduced by half (2.5 m -> 1.25 m)



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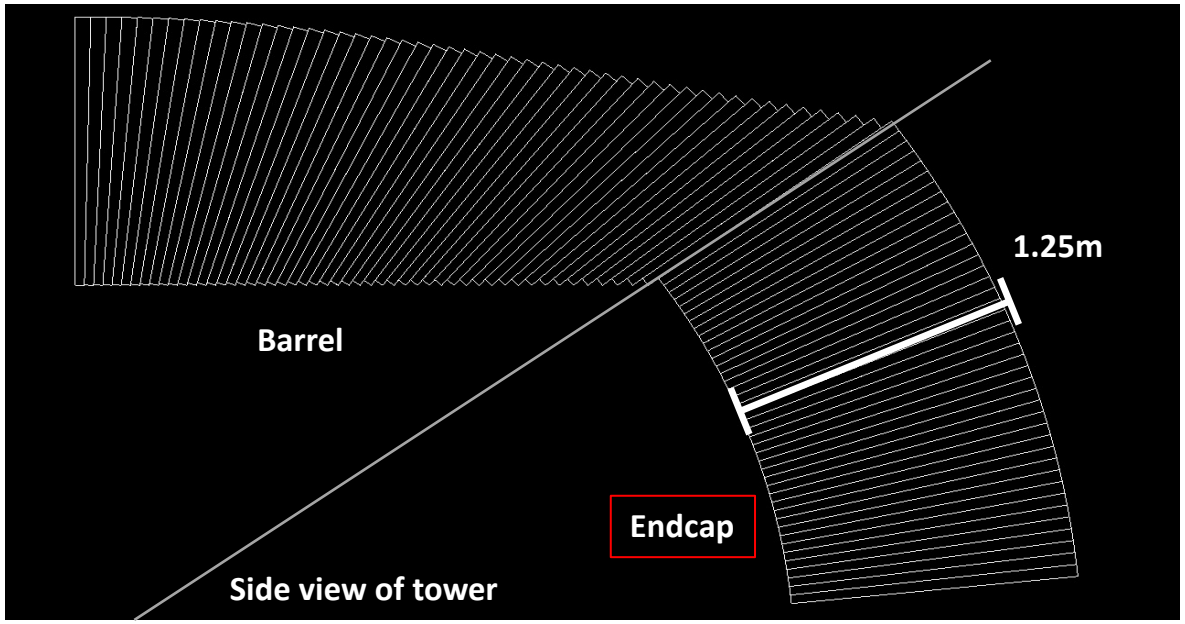
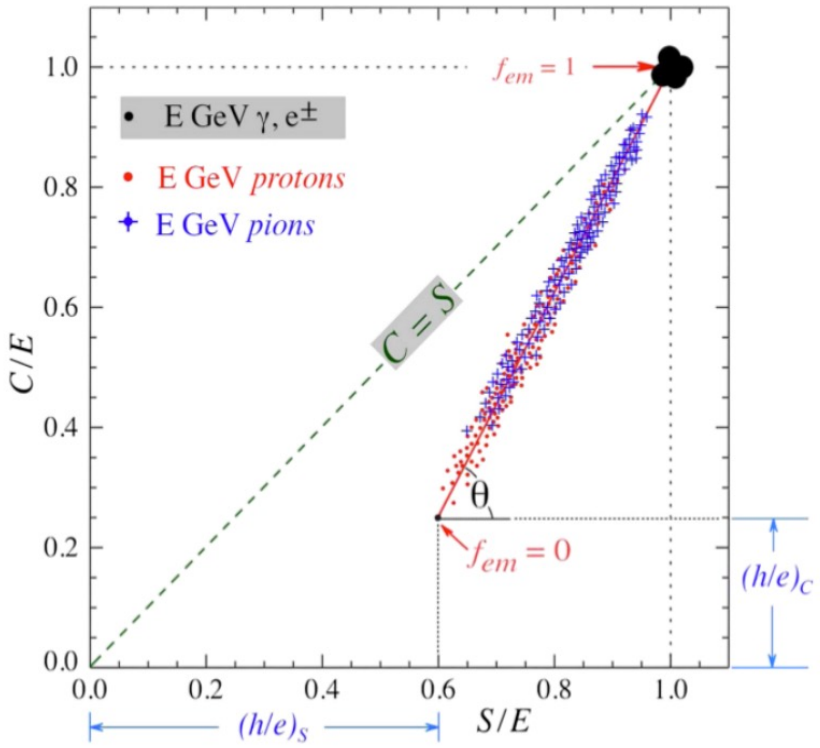
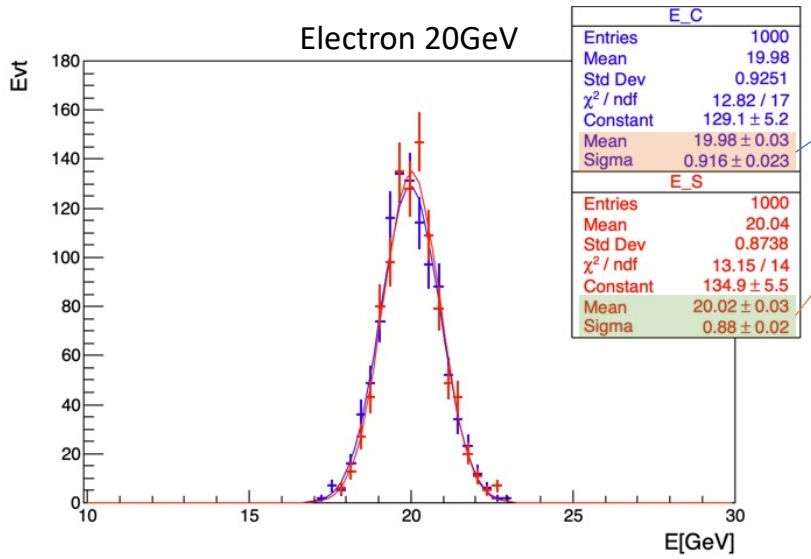
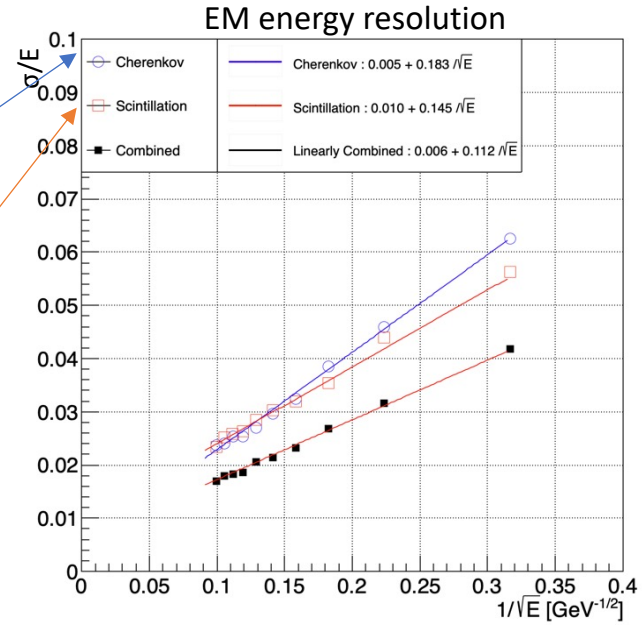


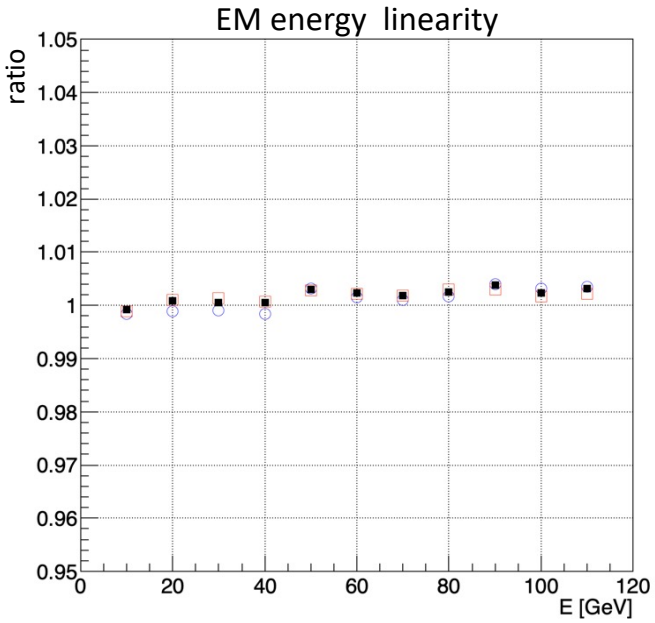


Ratio of measured energy and initial energy

EM performance study



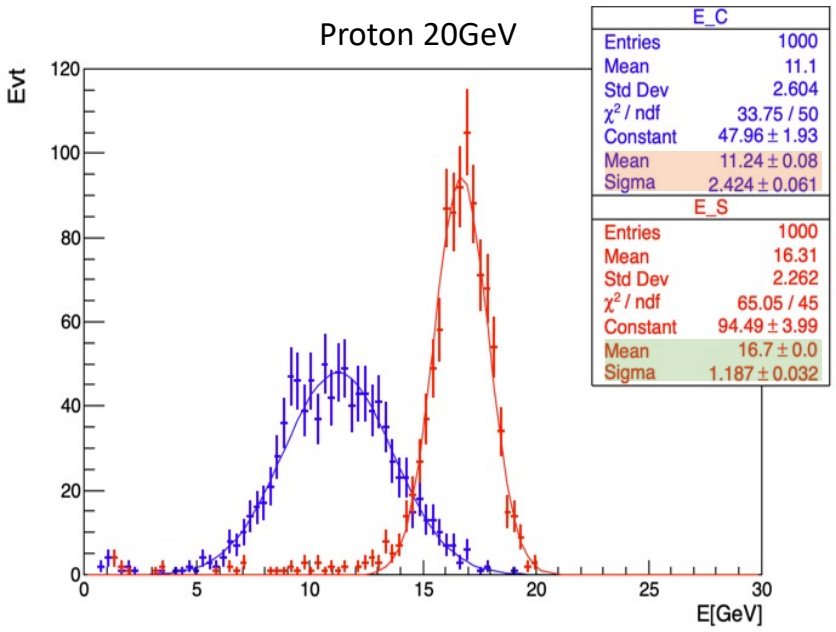


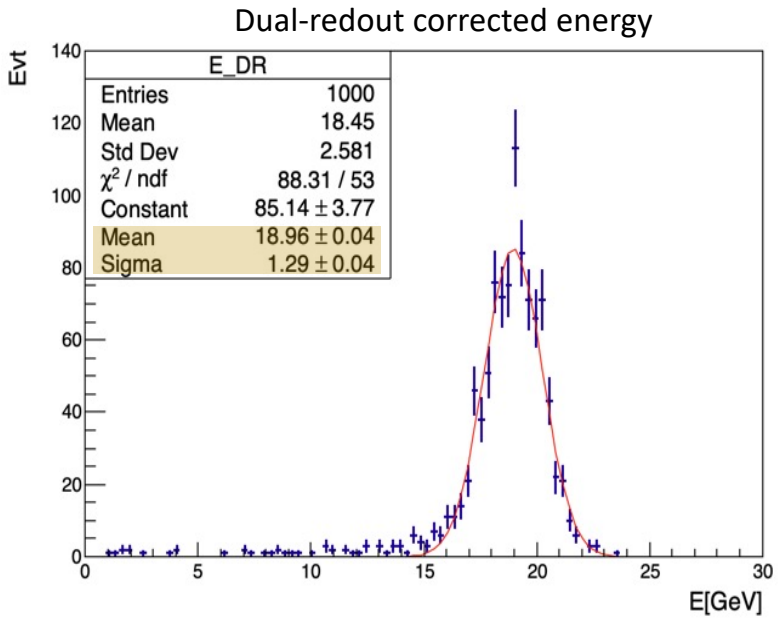


- Energy Calibration
  - Tuned by 20GeV electron at all endcap tower

- EM Energy resolution & linearity
  - Both channels show almost same performance
  - Linear combination used for resolution and linearity rather than dual-readout correction

Hadron Performance study

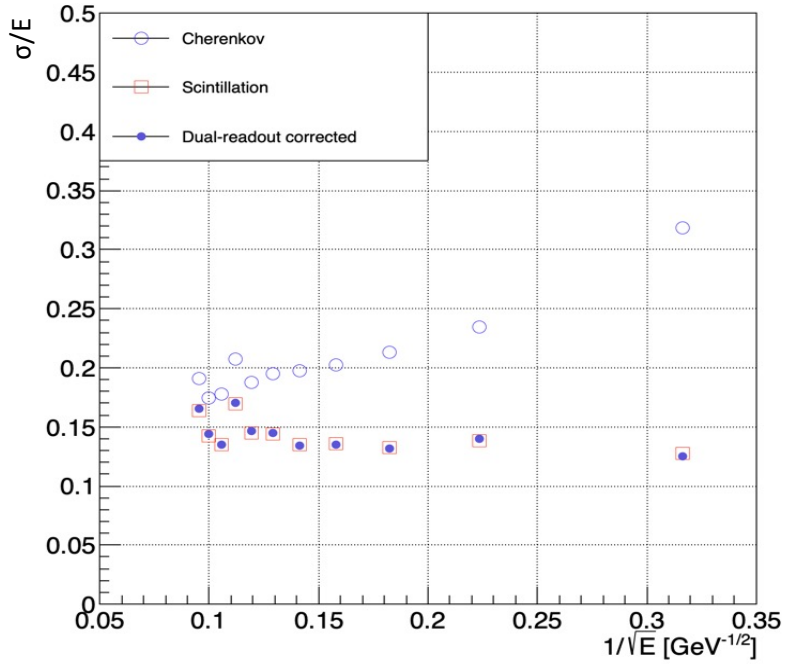




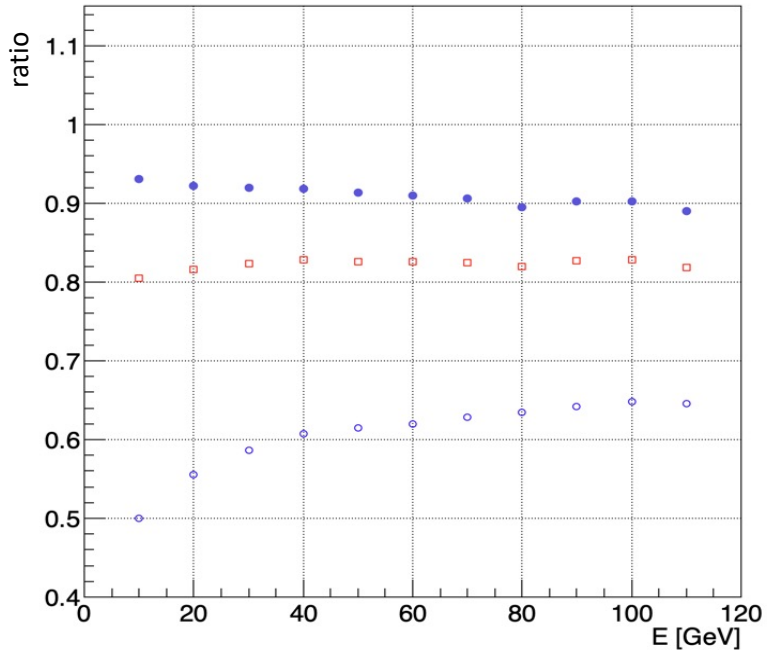
- Energy deposition
  - Different distribution of each channels due to different response
- Dual-readout correction
  - Combined two channels signal to measure hadron shower precisely
  - Dual-readout corrected energy seems to recover initial energy (20 GeV)

Hadron Performance study

Hadron energy resolution



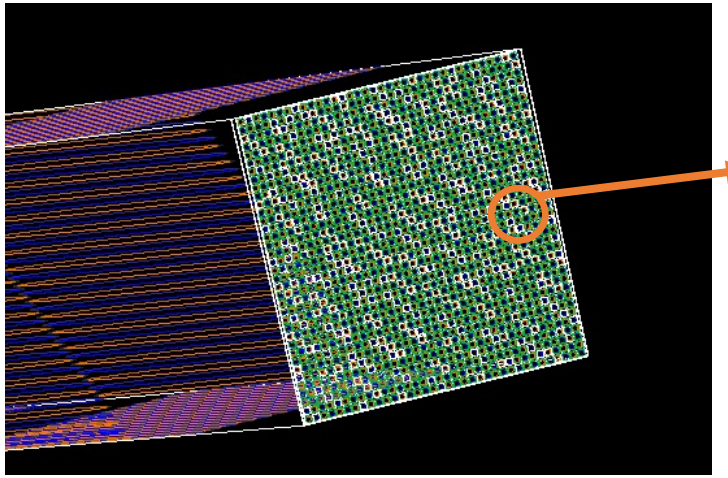
Hadron energy linearity

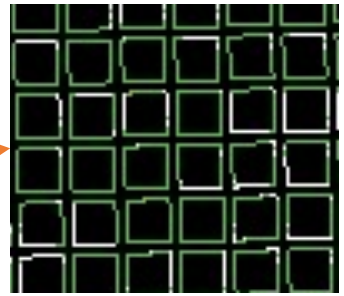


- Hadron Energy resolution & linearity
  - Energy linearity shows that dual-readout corrected energy recovered initial energy
  - Resolution of dual-readout corrected energy is similar with scintillation channel

FCC - DRC and ECCE - DRC

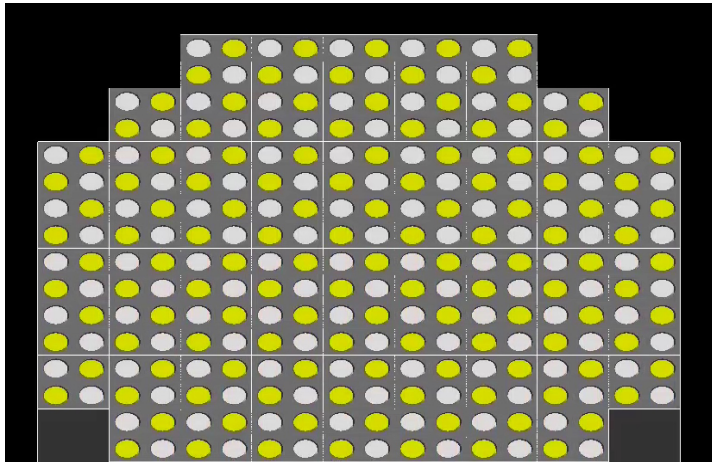
- DRC in FCC framework
  - Full geometry are implemented
    - Fibers with cladding, absorber and readout materials, SiPM





SiPM in FCC framework

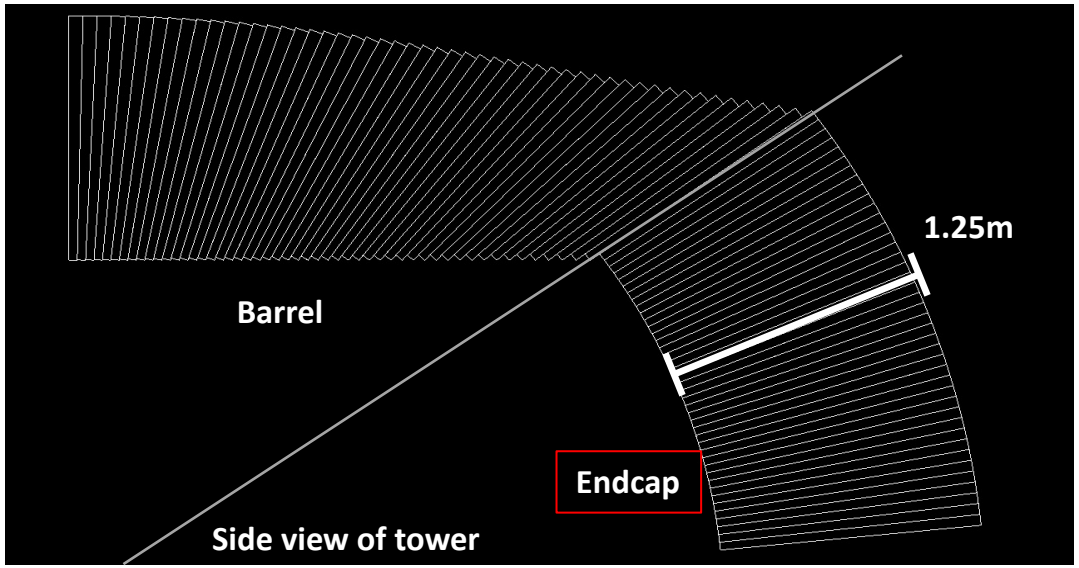
- DRC in ECCE framework
  - Light version of DRC was implemented
    - only fibers and absorber



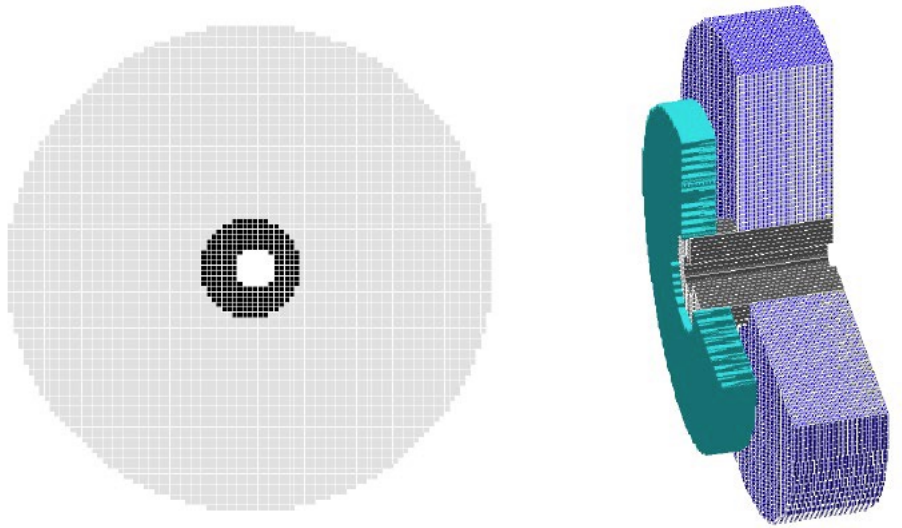
End of towers in ECCE framework

FCC - DRC and ECCE - DRC

- DRC in FCC framework
  - Full geometry are implemented
    - Fibers with cladding, absorber and readout materials, SiPM
  - Projective shape due to hermetic geometry



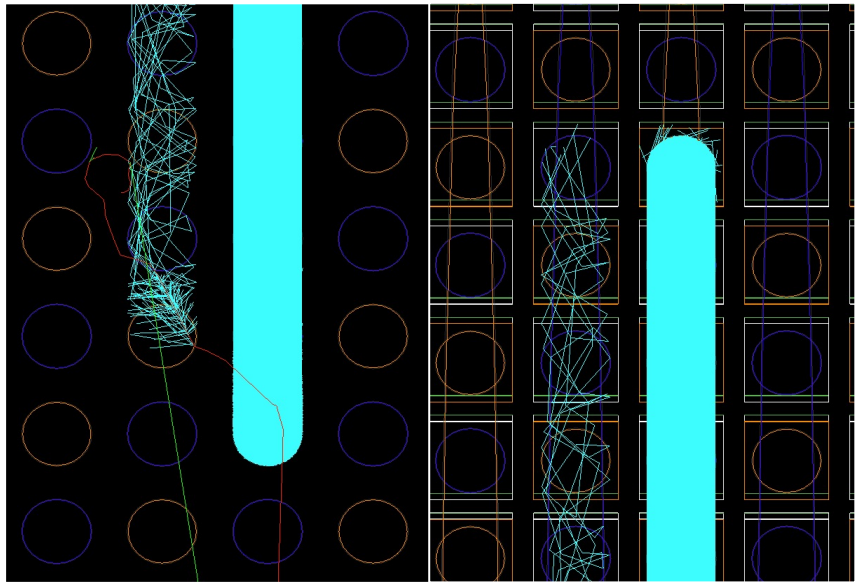
- DRC in ECCE framework
  - Light version of DRC was implemented
    - only fibers and absorber
  - Rectangular shape



DRC design at ECCE framework

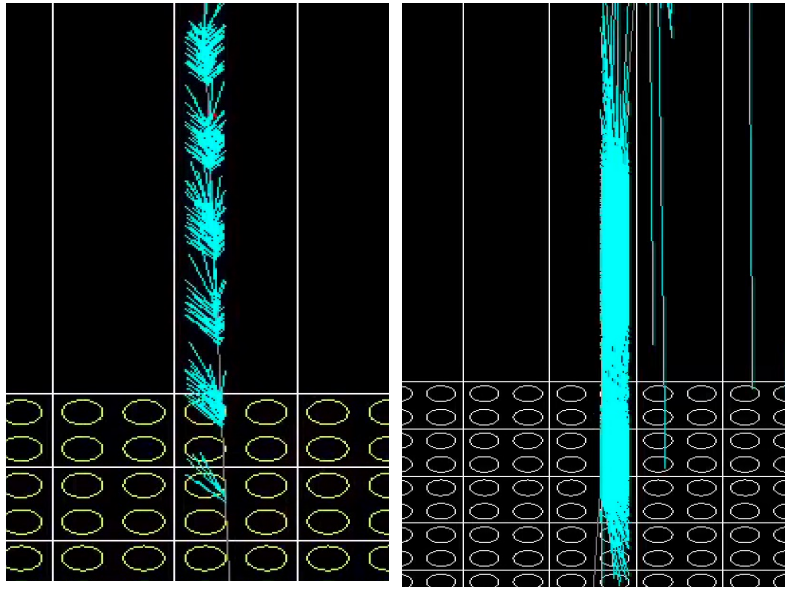
FCC - DRC and ECCE - DRC

- DRC in FCC framework
  - Full geometry are implemented
    - Fibers with cladding, absorber and readout materials, SiPM
  - Projective shape due to hermetic geometry
  - Use SiPM to measure energy deposition -> optical photon propagation is required



Photon propagation at FCC framework

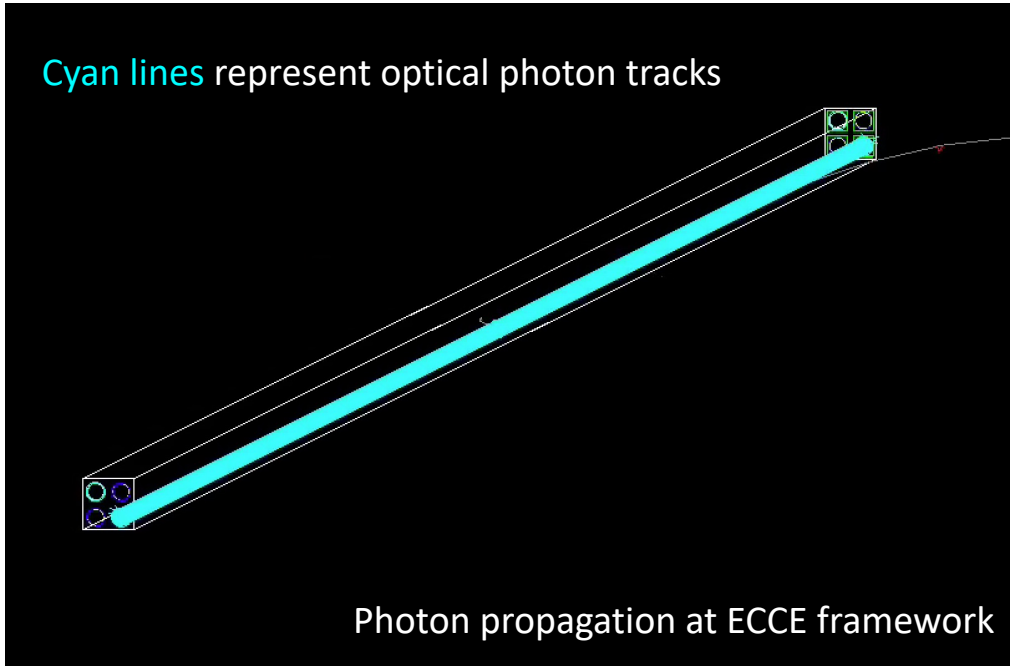
- DRC in ECCE framework
  - Light version of DRC was implemented
    - only fibers and absorber
  - Rectangular shape
  - Energy deposition directly from fiber material -> propagation is not required



Photon propagation at ECCE framework

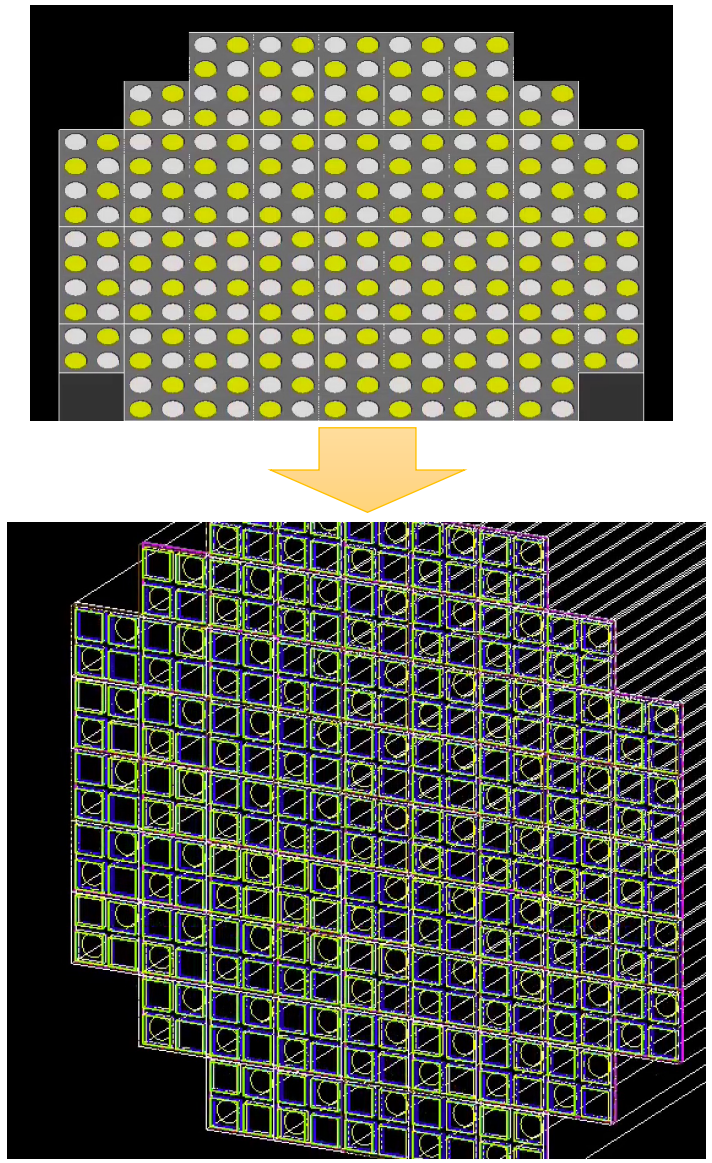
DRC Migration status

- Optical photon propagation
  - Implemented cladding at the outside of fibers
  - Applied reflective index at tower, fiber materials



DRC Migration status

- Optical photon propagation
  - Implemented cladding at the outside of fibers
  - Applied reflective index at tower, fiber materials
- Readout implementation
  - SiPM with sub-materials are implemented
    - SiPM and filter
- Readout test
  - (ongoing)Test of readout by using optical photon
  - Validate the readout by comparing directly readouts from fiber



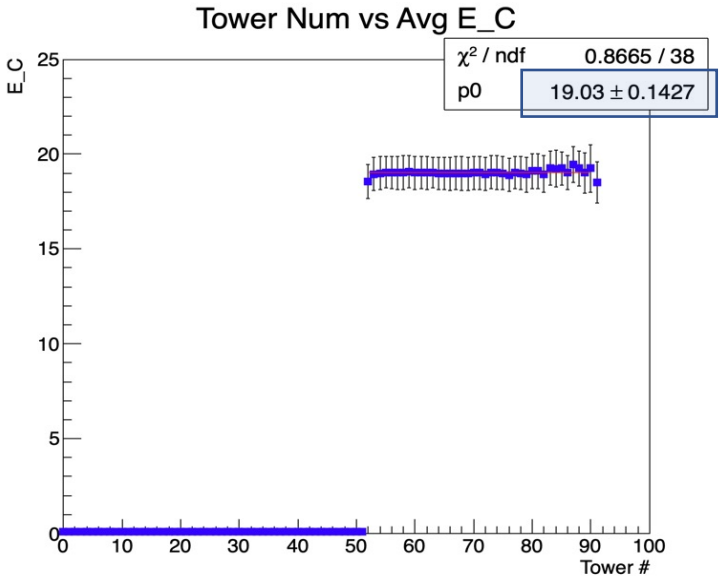
End of towers in ECCE framework

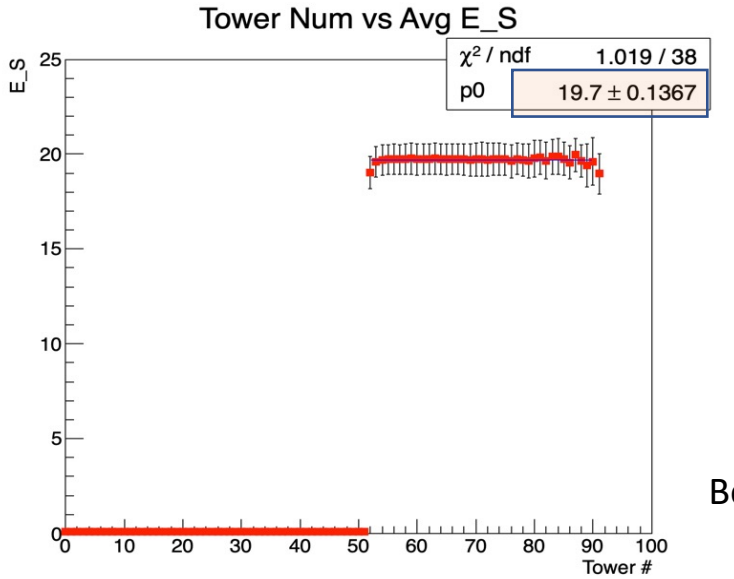
Summary & Plan

- Performance study
  - For electron, DRC shows good EM energy resolution and linearity
  - For hadrons, dual-readout correction improve energy linearity, but resolution is similar with scintillation channel
- Migration status
  - Basic performance study is done with FCC framework
  - Listed up the major differences between two framework
  - implement photon readout is underway
  - Plan to compare the performance by each framework after migration
- Plans on ECCE framework after migration
  - Plan to compare the performance by each framework after migration
  - Other studies (jet measurement, absorber material study) will be performed in ECCE simulation framework

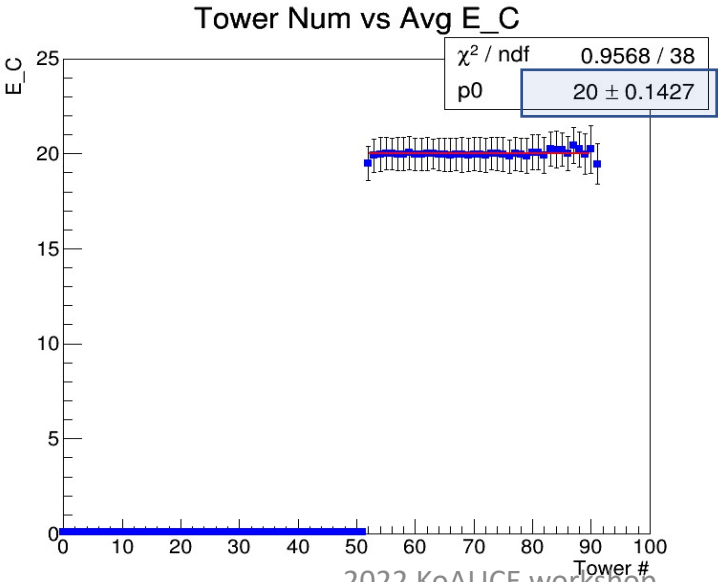
Backup. Calibration

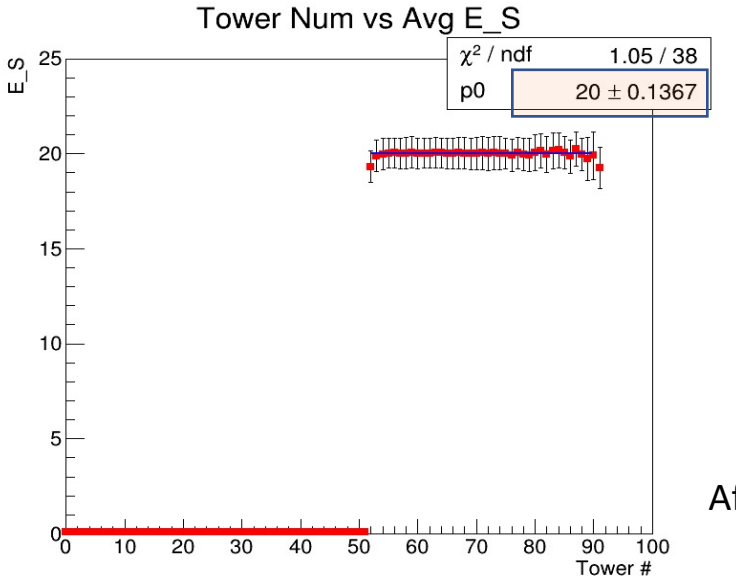
- Simulation:
  - Particle : electron
  - Energy : 20GeV
  - Tower : Endcap region
    (52^{th} ~ 91^{th})





Before calibration





After calibration

Backup. Dual-readout correction formula & 100GeV proton

- Formula:

$$E_{S,C}=E[f_{em}+(h/e)(1-f_{em})]$$

$$f_{em}=\frac{(h/e)_C-(E_C/E_S)(h/e)_S}{(C/S)[1-(h/e)_S]-[1-(h/e)_C]}$$

$$\cot\theta=\frac{1-(h/e)_S}{1-(h/e)_C}=\chi$$

$$E=\frac{E_S-\chi E_C}{1-\chi}$$