# Detector optimization w.r.t. the BMR

Yukun Shi, Hanhua Cui, Jiechen Jiang,

# OutLine



- Background
- Local parameter optimization
  - Calorimeter Cell size
  - Calorimeter Layer
- Global parameter optimization
  - TPC and B field – Hanhua Cui
  - Acceptance and solenoid – Jiechen Jiang
- Conclusion

# OutLine

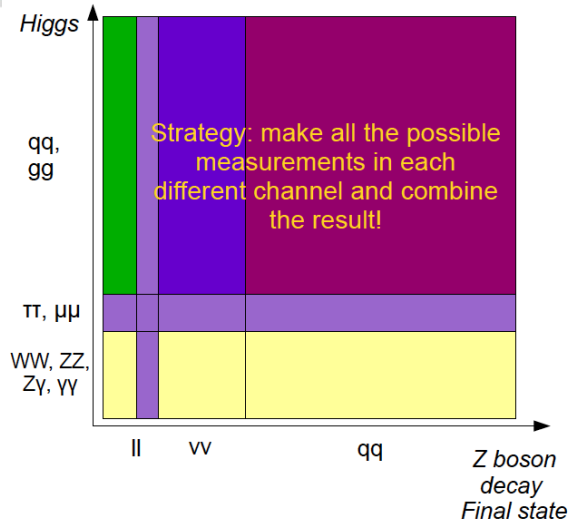


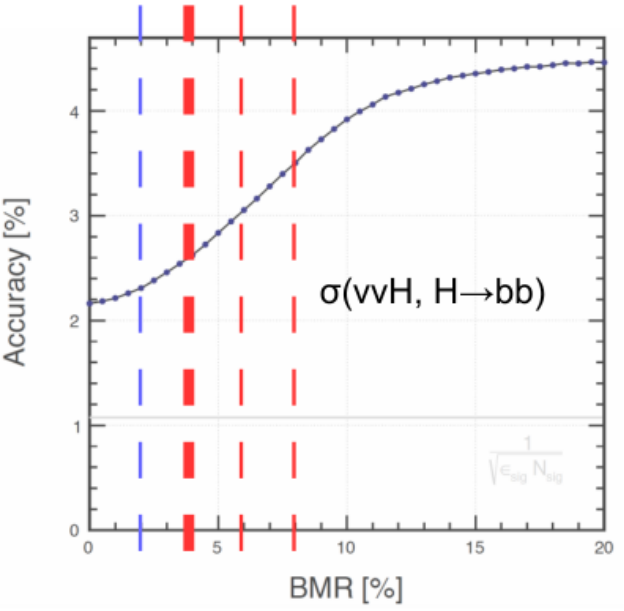
- Background
- Local parameter optimization
  - Calorimeter Cell size
  - Calorimeter Layer
- Global parameter optimization
  - TPC and B field – Hanhua Cui
  - Acceptance and solenoid – Jiechen Jiang
- Conclusion

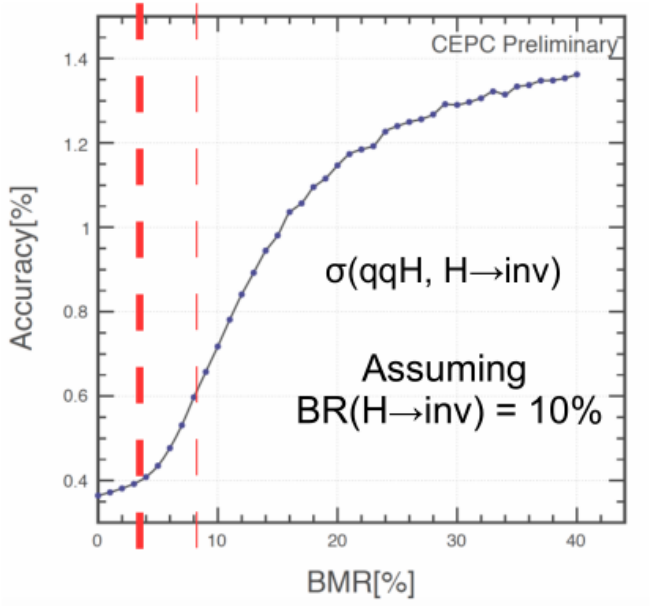
# Physics Requirement

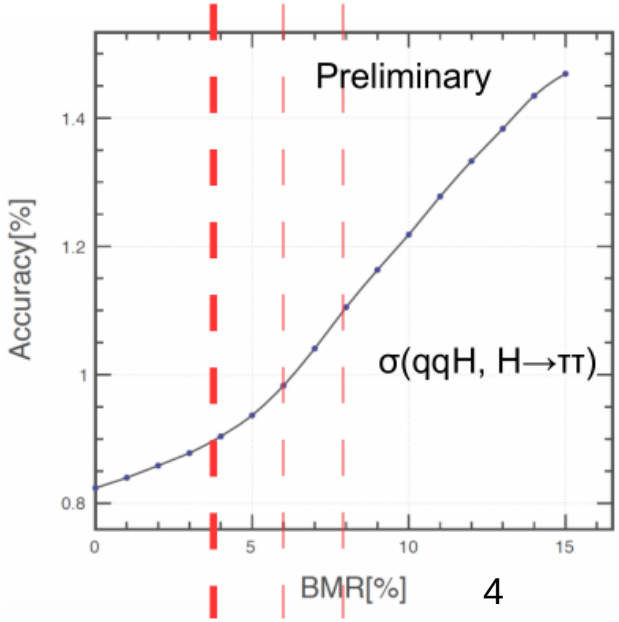


- The CEPC Higgs production is dominated by higgstrahlung process, 97% of ZH events have Jets in their final states
- The requirement from benchmark physics processes on boson mass resolution(BMR) : 4%



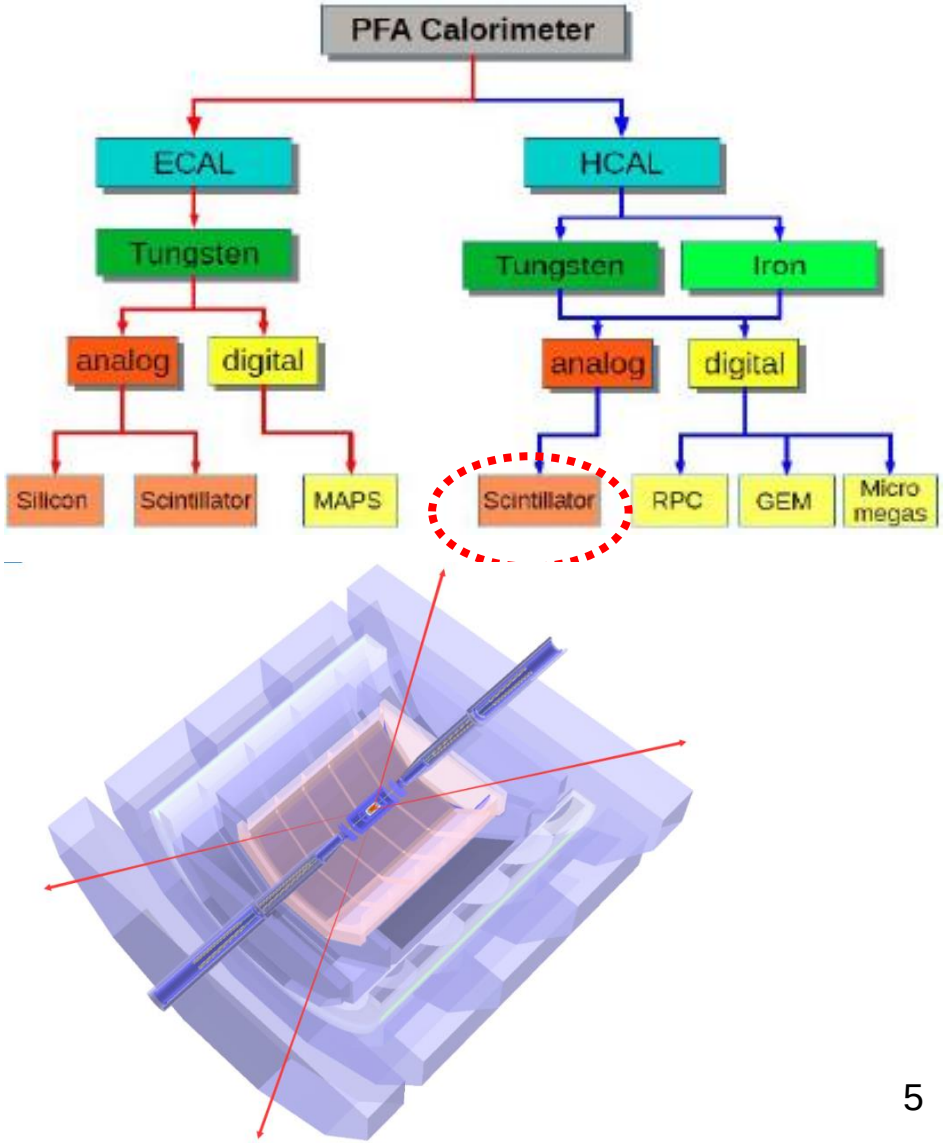




From Manqi Ruan

# Geometry



- TPC Tracker
  - R: 1.8m
  - Length: 4.7m
- B field: 3T
- ECAL
  - 30 layers
  - Absorber:2.8 mm tungsten
  - Si:10×10×0.5 $mm^3$
  - PCB:2 mm
- HCAL
  - 40 layers
  - Absorber:20 mm Steel
  - Scintillator:40×40×3 $mm^3$
  - PCB:2 mm

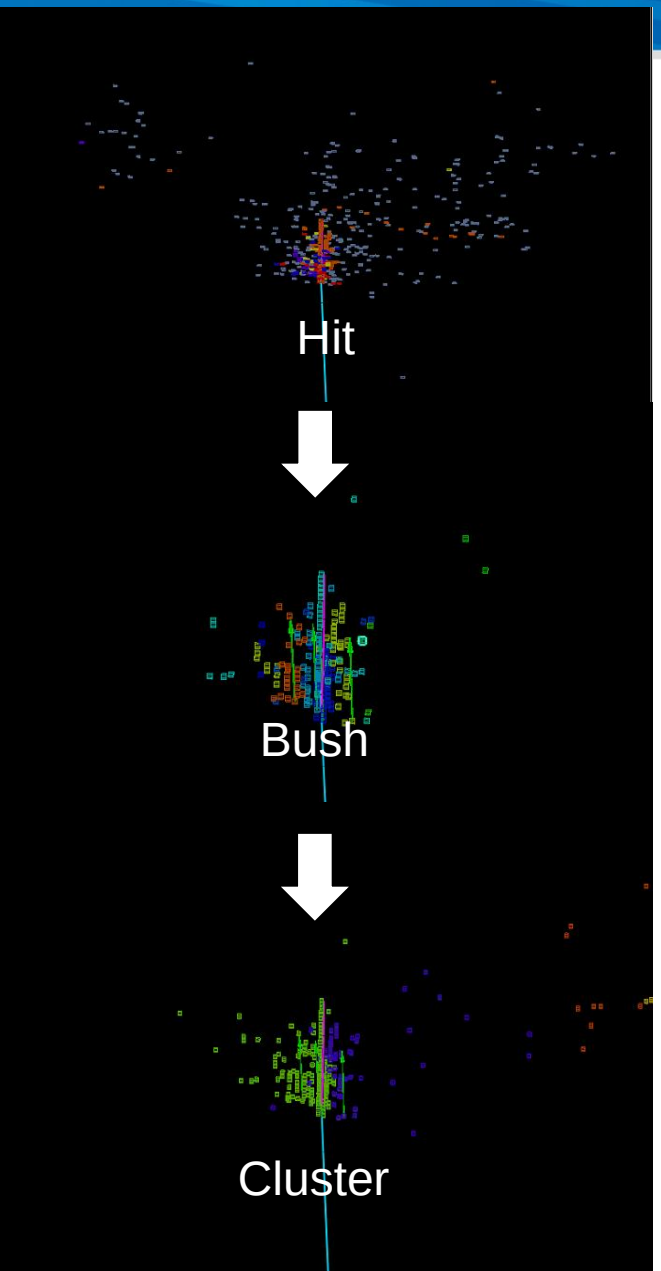


# OutLine



- Background
- Local parameter optimization
  - Calorimeter Cell size
  - Calorimeter Layer
- Global parameter optimization
  - TPC and B field – Hanhua Cui
  - Acceptance and solenoid – Jiechen Jiang
- Conclusion

# reconstruction overview

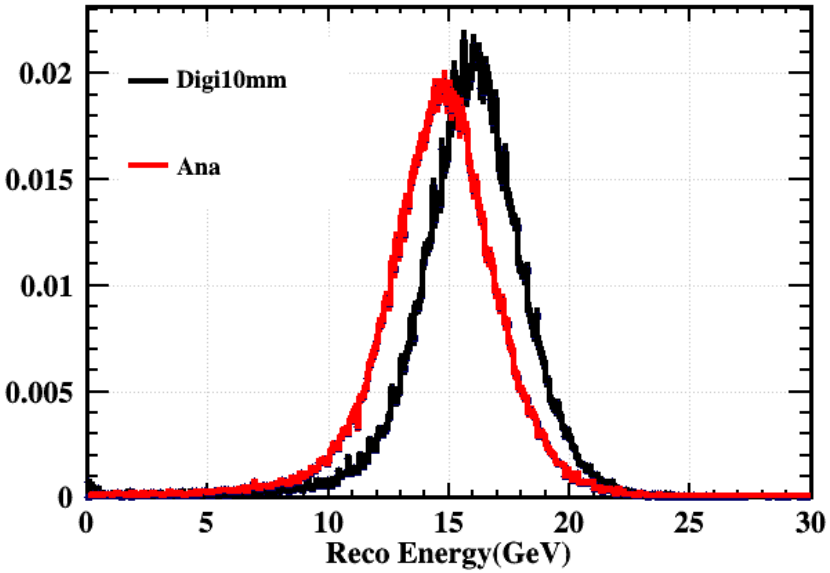


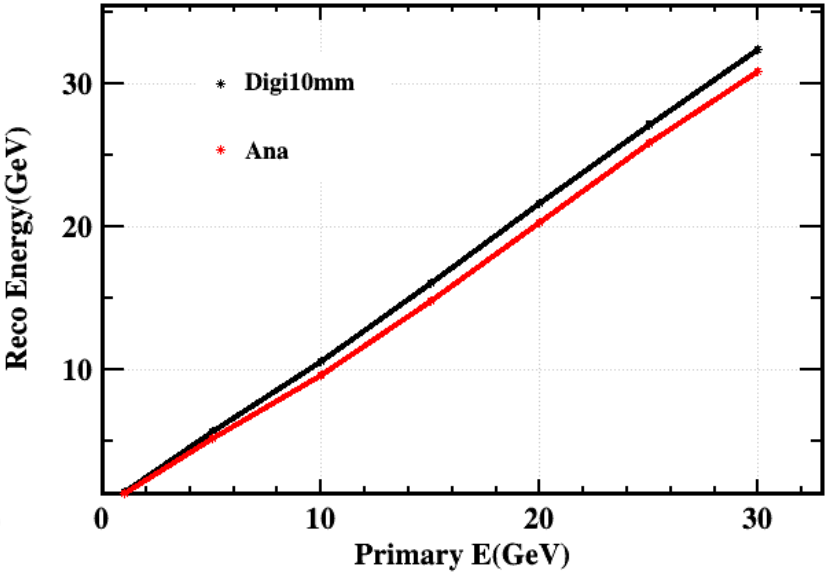

- The Geometry is built in 1mm Cell for calorimeters
- Merge the small cells into a bigger one(e.g. 10mm), apply a calibration constant for each sampling calorimeter
- Connect hits into a bush, connect bushes into a cluster, match tracks and clusters, build a particle from a cluster
- The higgs is reconstructed by the recoil mass method

# Energy reconstruction



- Geometry is the steel scintillator sampling calorimeter
  - Analog readout: $E = ECAL\ E \times a + HCAL\ E \times b_{Ana}$
  - Digital readout: $E = ECAL\ E \times a + HCAL\ Hitno \times b_{Digi}$
  - 0.5MIP threshold is applied for all cells
  - a is applied for each cell in ECAL and b for HCAL



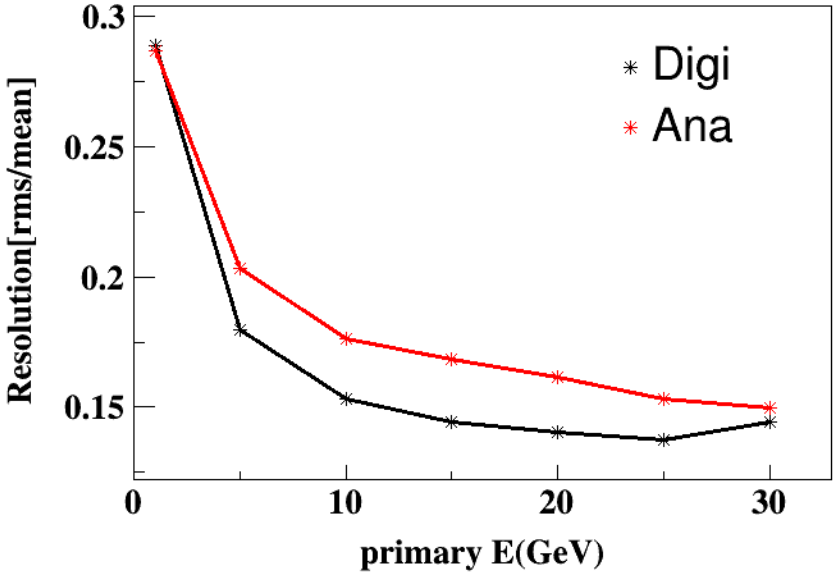




KL reconstructed energy and linearity for different readout modes

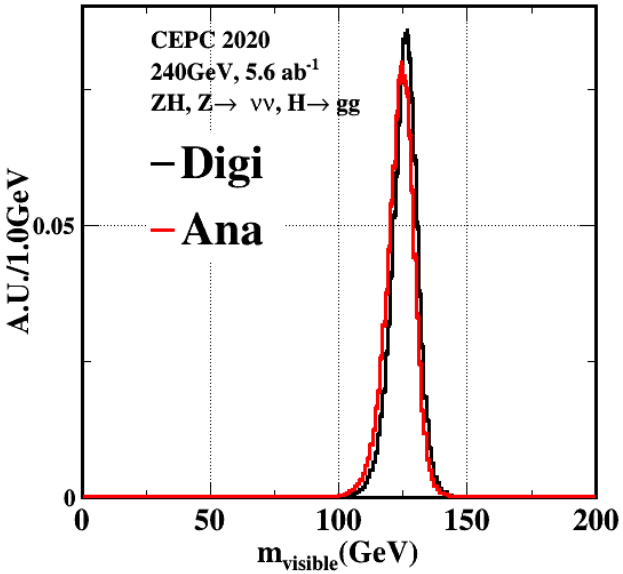
# BMR



- vvH-gg Event
- Selection at truth level
  - Initial state radiation: $\sum P_T^{ISR}$ < 1GeV
  - Neutrinos in Higgs decay products: $\sum P_T^{\nu}$ < 1GeV
  - Acceptance of the detector: $|\cos\theta_{jet}| < 0.85$




KL energy resolution for different readout modes

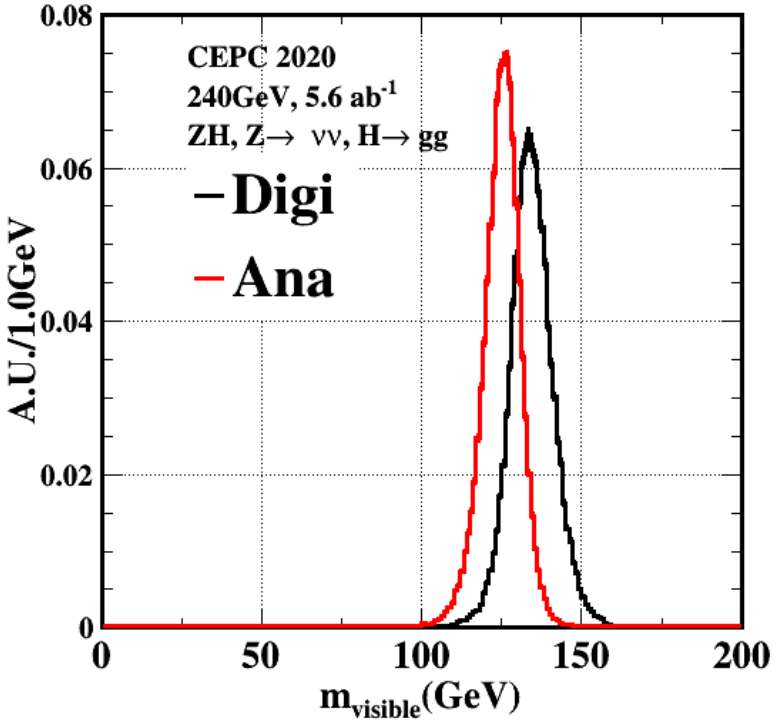



Reconstructed $m_{visible}$ HCAL Cell 10mm

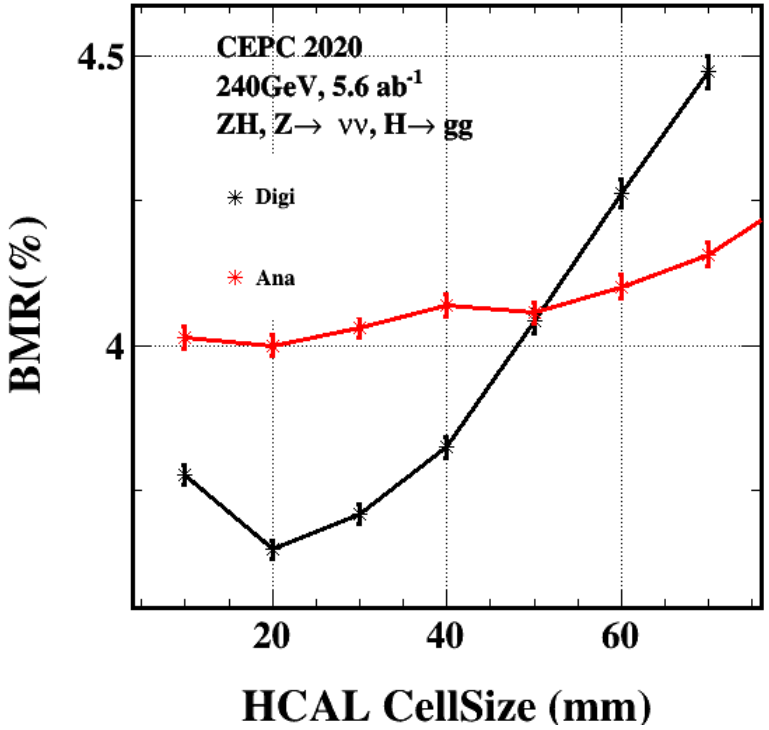
# HCAL Cell Size - BMR



- BMR is get by fitting $m_{visible}$
- The $b_{Digi}$ for different HCAL cell size is different




Reconstructed $m_{visible}$
HCAL Cell 70mm



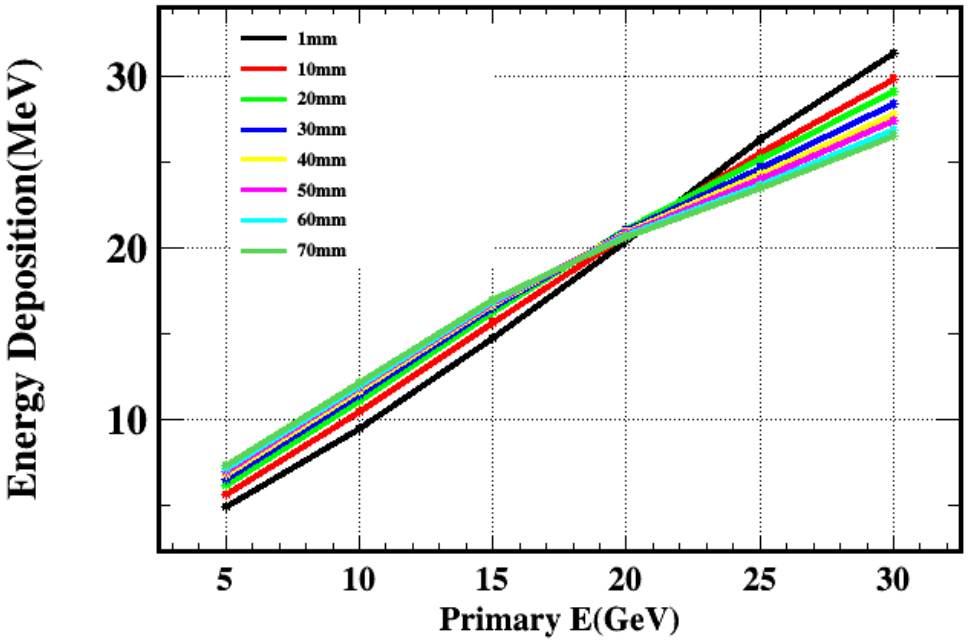

HCAL Cell Size - BMR

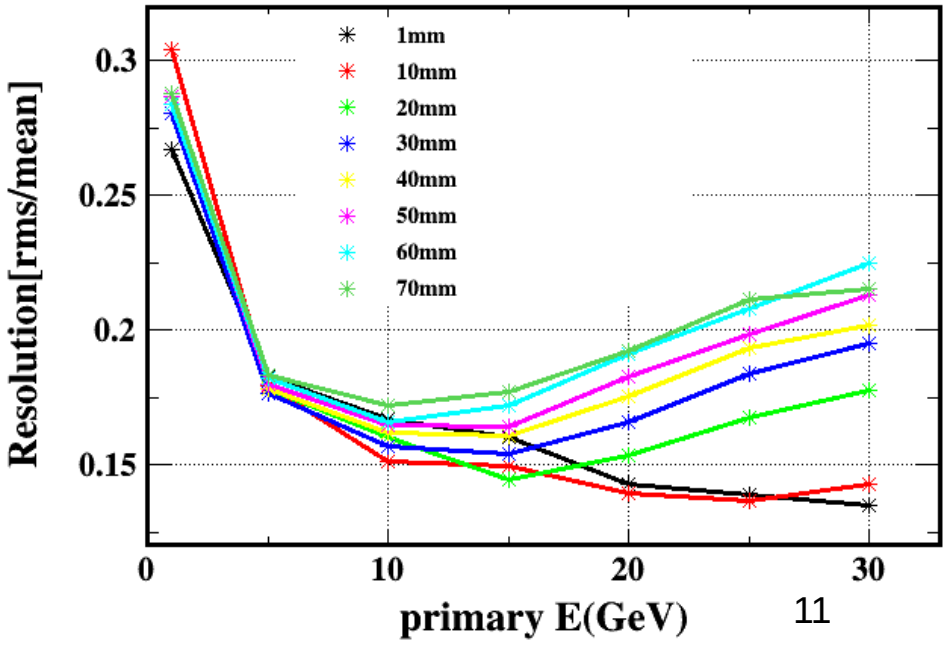
# Digital readout



- Hadron response has a strong correlation with HCAL Cell Size with digital readout
- This correlation can be removed since the larger cells are merged from 1mm cells
- Special energy reconstruction: $\mathrm{E}_{10m}^{cell} = \mathrm{hitno}_{1\mathrm{mm}} \times b_{Digi}^{1mm}$

KL energy linearity and resolution for different HCAL Cell

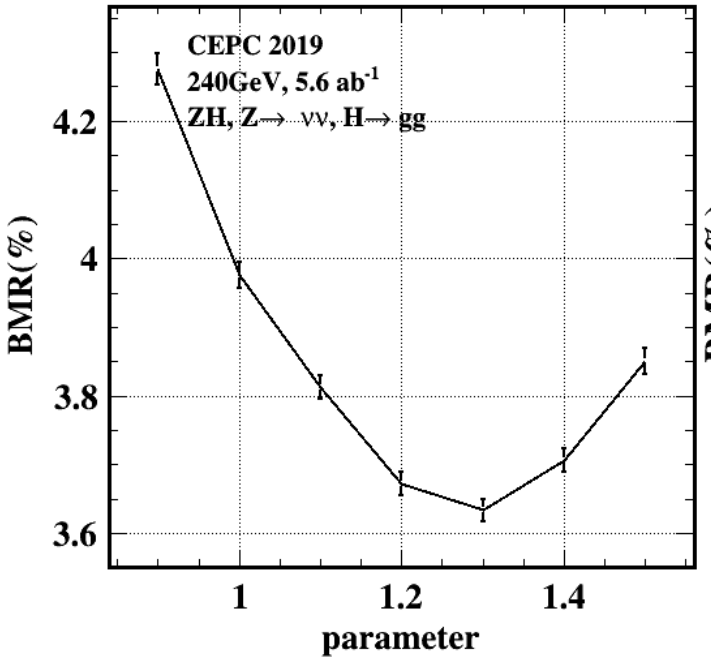


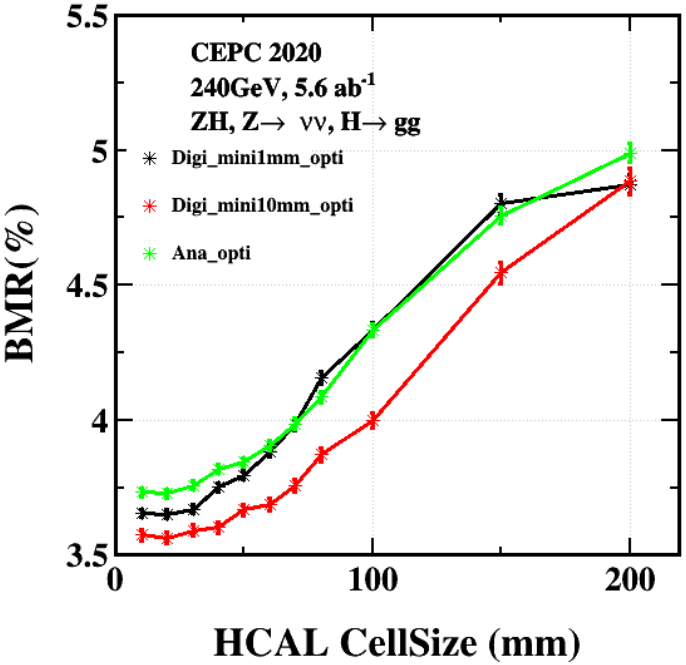
# $b_{Digi}$ optimization



- $b_{Digi}$ is first determined by KL using minimum $\chi^2$ method
- $b_{Digi}$ is then scanned in terms of BMR
- The final Cell Size – BMR curve represents the relation between Cell Size and shower separation power, energy resolution at different point from a single curve should be the same




$b_{Digi}$ scanning



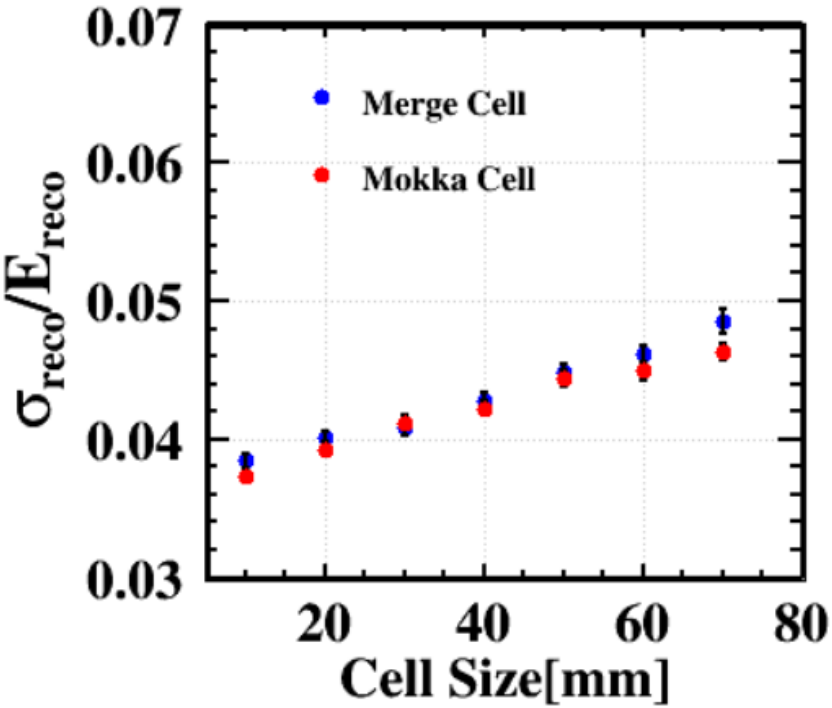

HCAL Cell - BMR

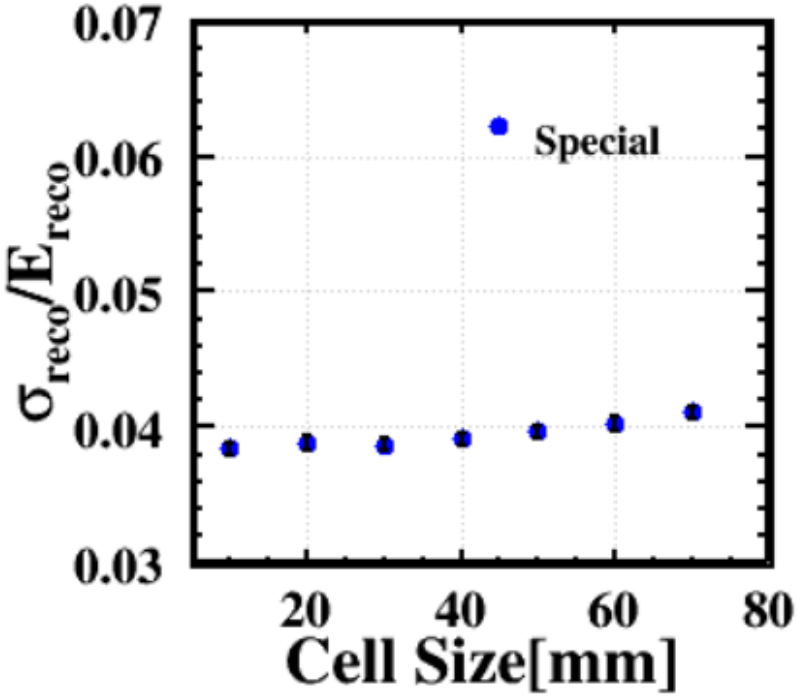
# RPC HCAL



- Special energy reconstruction is used to remove the impact from energy resolution of different cell size
- After special energy reconstruction, the result is in consistent with Steel scintillator HCAL
- Shower separation ability is not sensitive when cell size  under 50mm

Cell size – BMR with different energy reconstruction by Jiechen Jiang

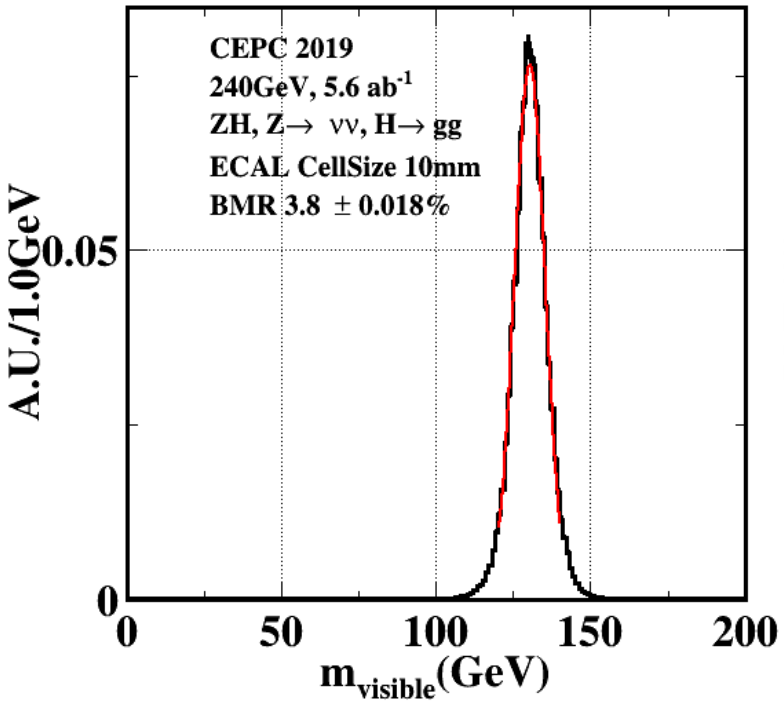


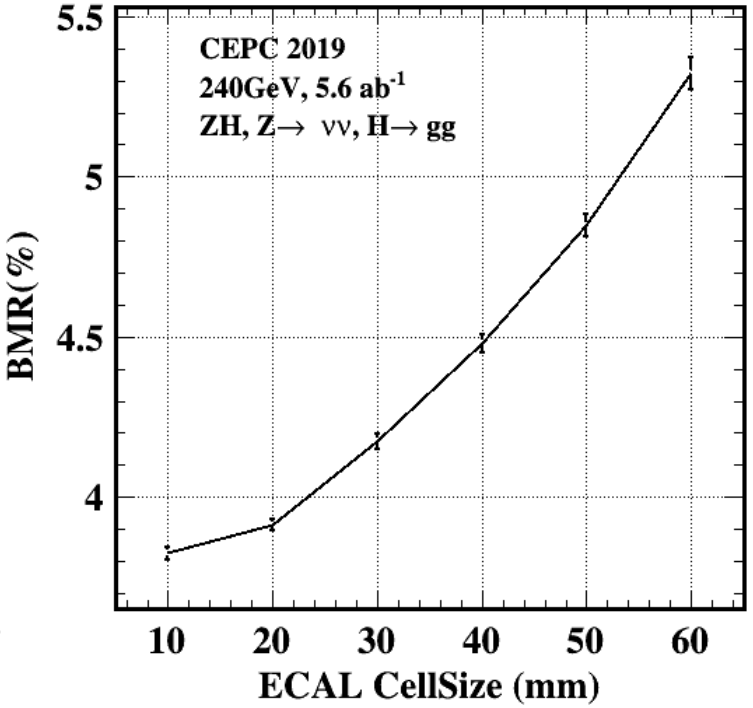
# ECAL Cell



- ECAL only use analog readout
- HCAL is Steel scintillator HCAL
- ECAL Cell is more sensitive than HCAL in terms of BMR




BMR at ECAL 10mm Cell




ECAL Cell - BMR

# OutLine

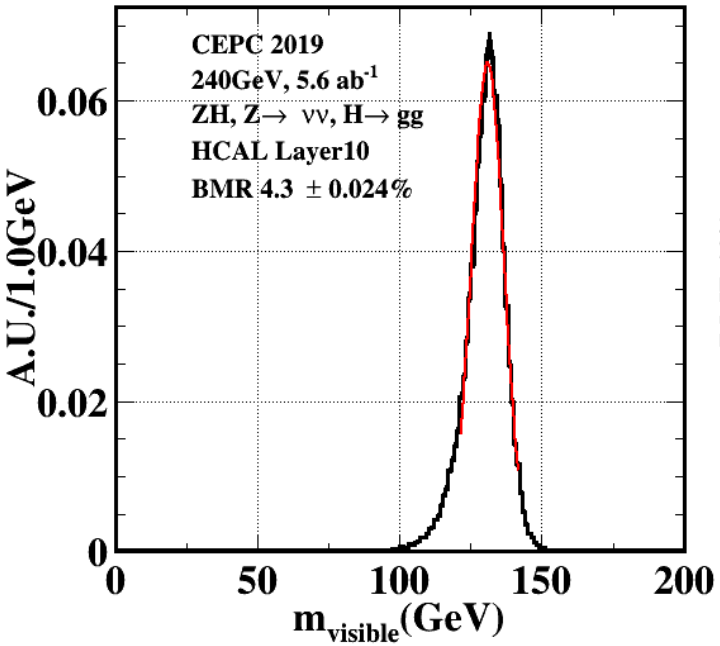


- Background
- Local parameter optimization
  - Calorimeter Cell size
  - Calorimeter Layer
- Global parameter optimization
  - TPC and B field – Hanhua Cui
  - Acceptance and solenoid – Jiechen Jiang
- Conclusion

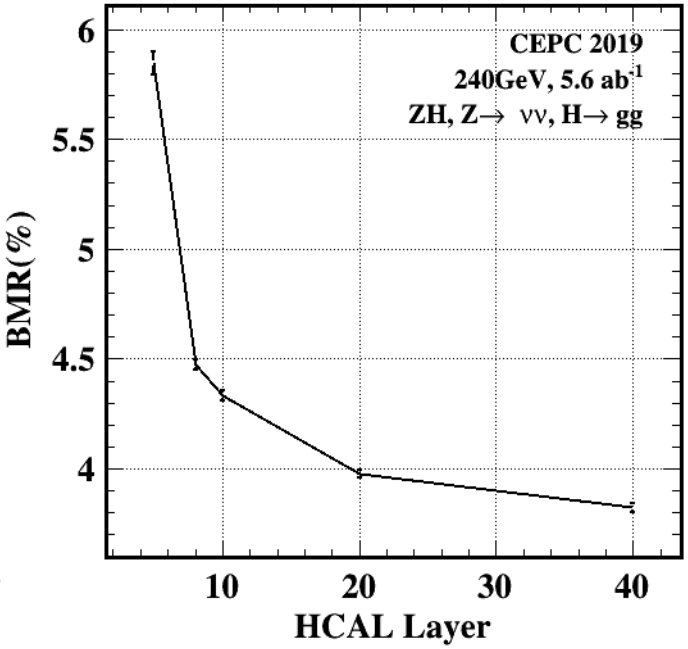
# HCAL Layer



- The number of sampling layers has a strong impact on energy resolution
- The number of sampling layer is fixed, the number of readout layer is changed by merging cell from adjacent layers
- So in this simulation, the energy resolution for HCAL is fixed, but the longitudinal position resolution is changed




BMR at 10 HCAL readout layer

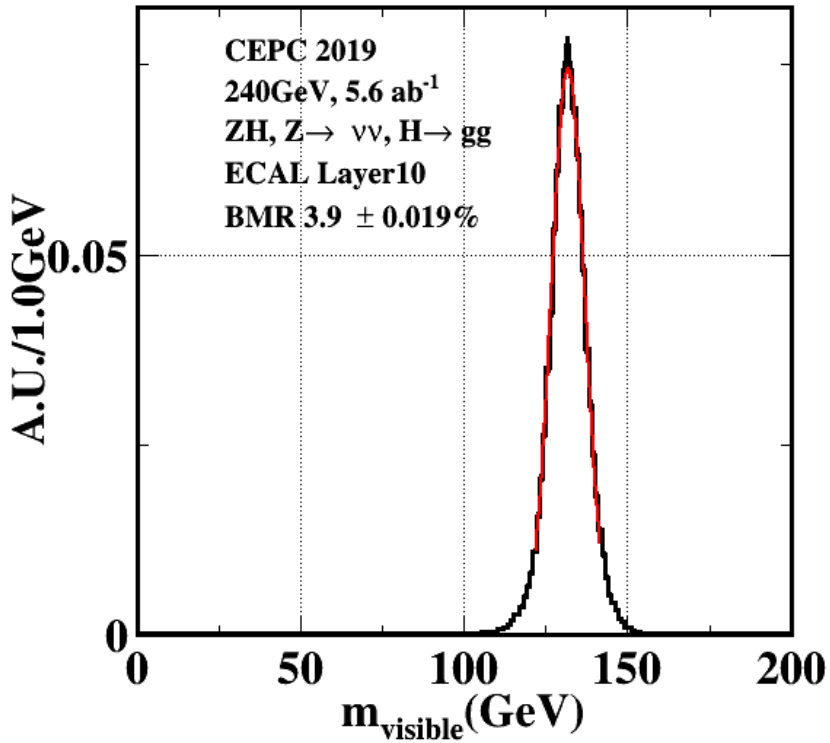



HCAL readout layer- BMR

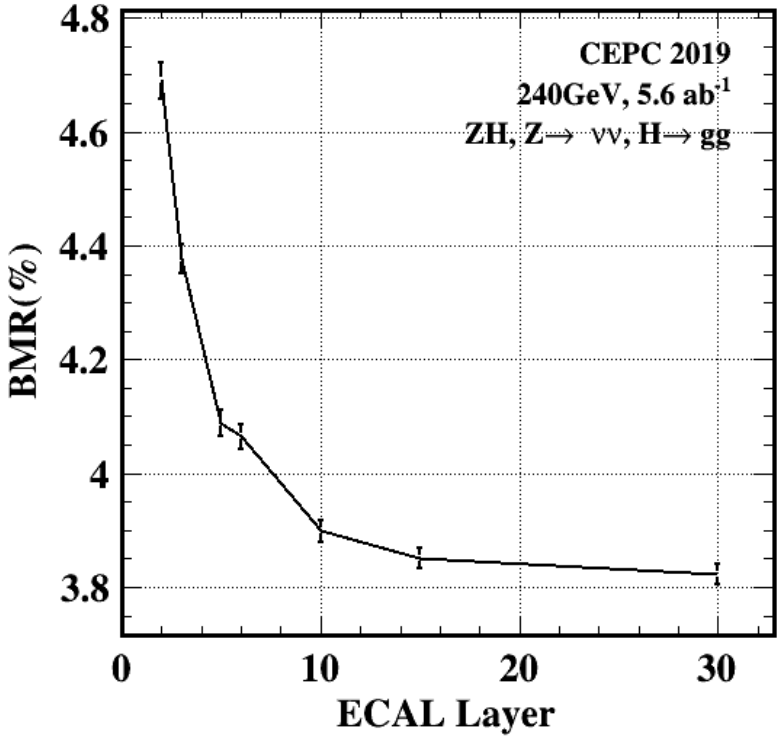
# ECAL Layer



- Similar scanning is done on ECAL
- BMR is less than 4% till 10 readout layer




BMR at 10 ECAL readout layer




ECAL readout layer- BMR

# OutLine

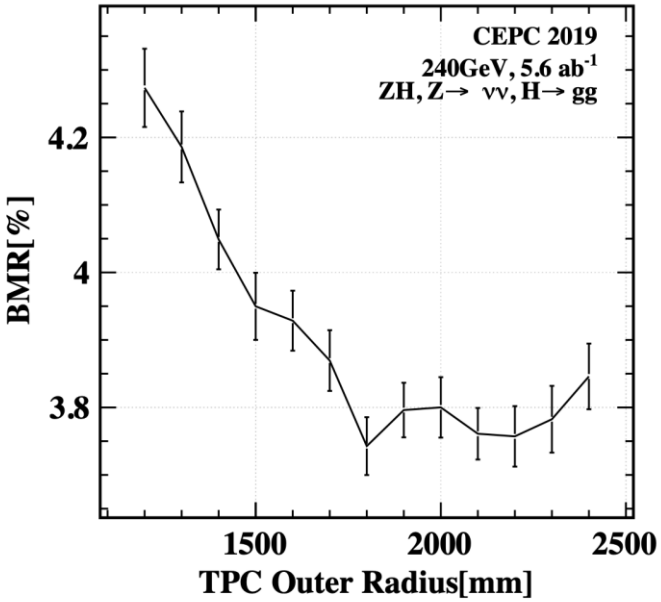


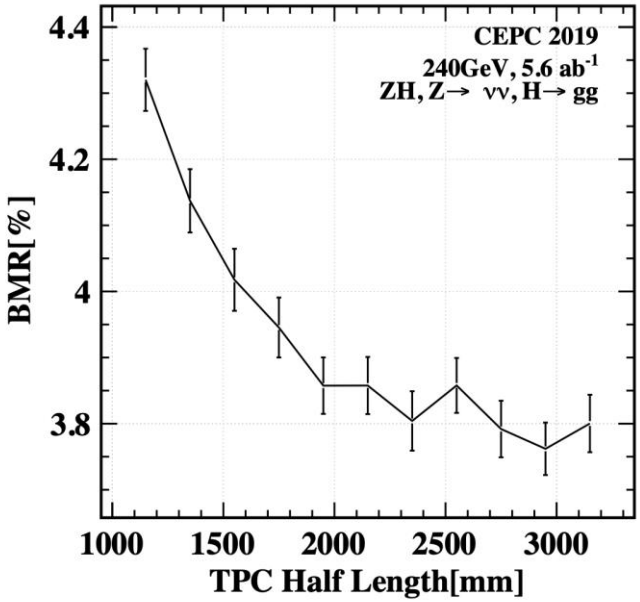
- Background
- Local parameter optimization
  - Calorimeter Cell size
  - Calorimeter Layer
- Global parameter optimization
  - TPC and B field – Hanhua Cui
  - Acceptance and solenoid – Jiechen Jiang
- Conclusion

# TPC



- Reducing the outer radius R or the half length Z leads to lower construction cost and power consumption
- the BMR is mainly affected by the Barrel&EndCap performance and the Barrel/EndCap ratio

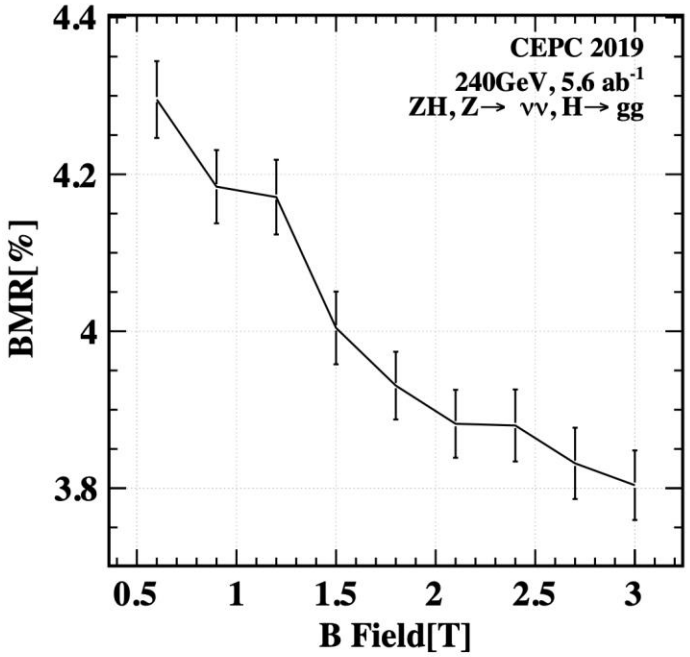


# B field



- B field can affect the physics performance and total cost greatly
- Compared with baseline option of 3T, the energy resolution degrades by 13.16% at 0.6T.
- 1.5T is acceptable for B field in terms of the 4% BMR physical requirement.



# OutLine

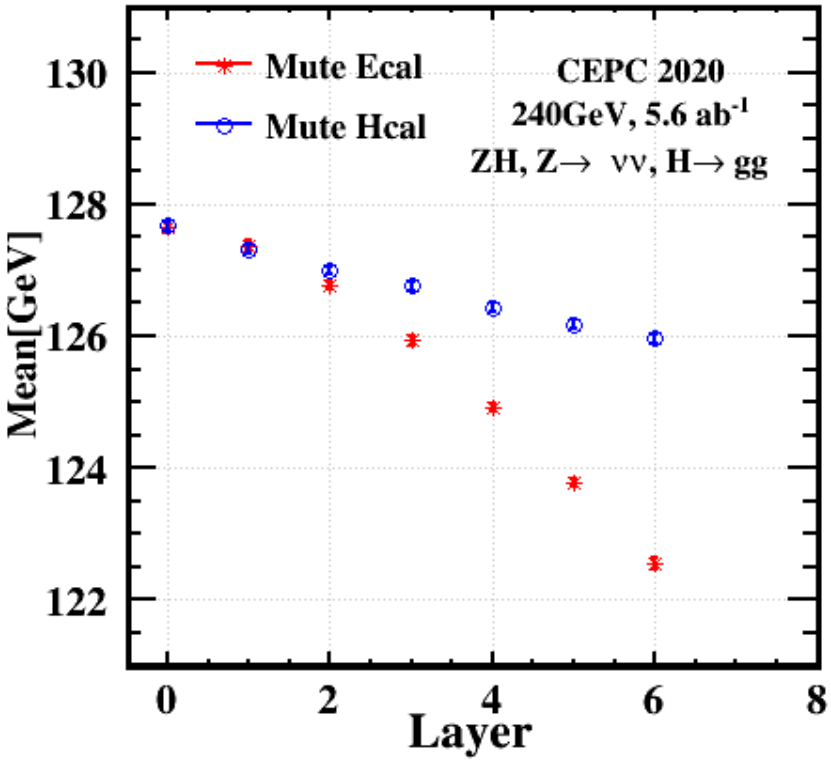


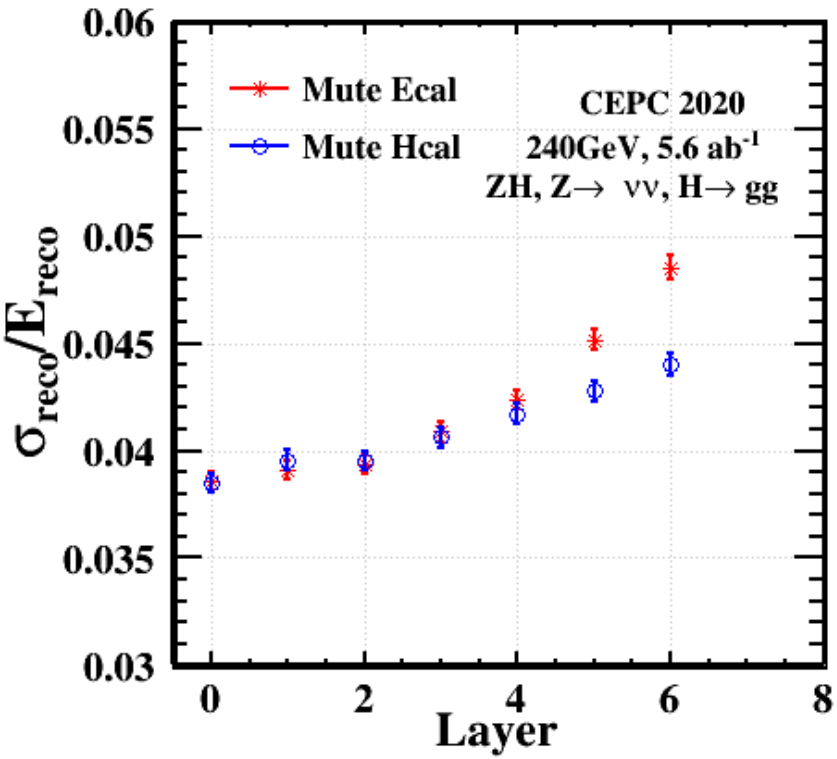
- Background
- Local parameter optimization
  - Calorimeter Cell size
  - Calorimeter Layer
- Global parameter optimization
  - TPC and B field – Hanhua Cui
  - Acceptance and solenoid – Jiechen Jiang
- Conclusion

# Solenoid



- The solenoid is considered to be put between ECAL and HCAL or even before ECAL to save cost
- Some of the ECAL or HCAL layers are muted to see the feasibility of this option

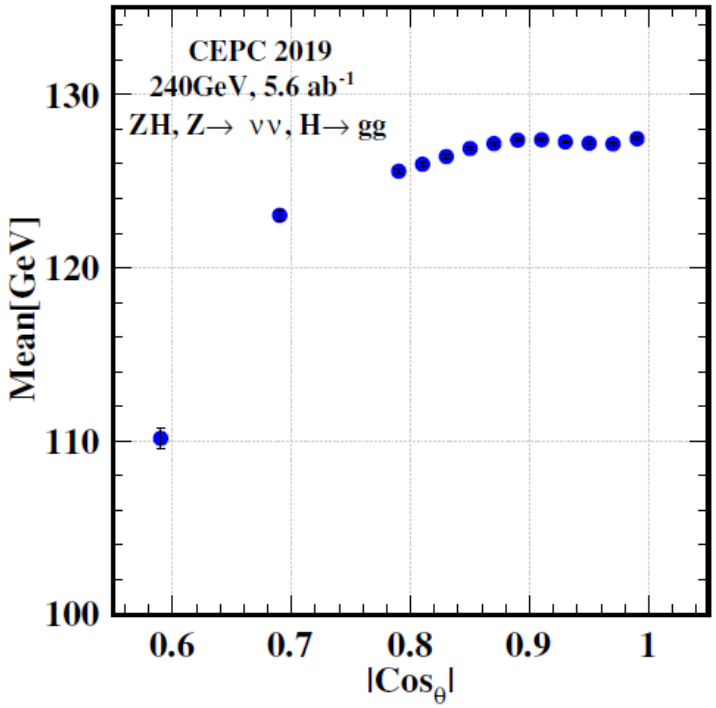


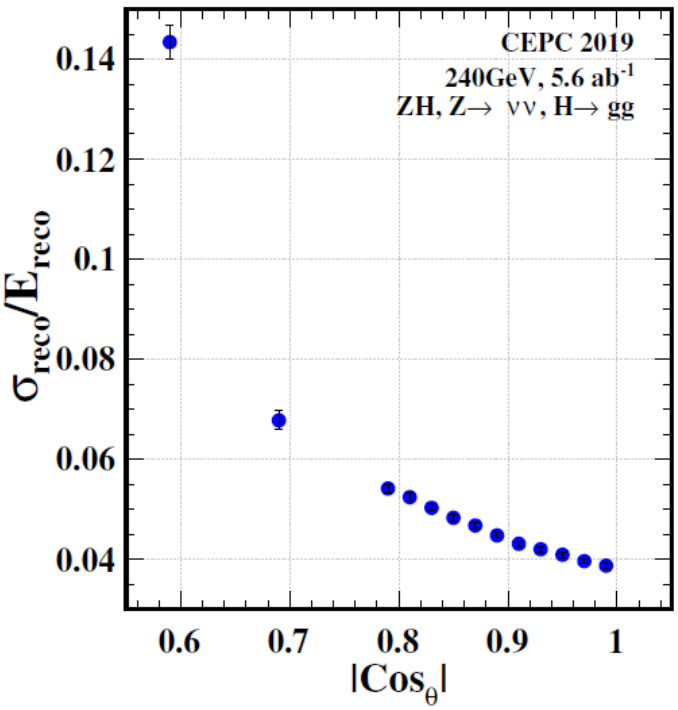



# acceptance



- Acceptance is a very important parameter concerning the cost and performance
- Acceptance is 0.996 in CDR



# OutLine



- Background
- Local parameter optimization
  - Calorimeter Cell size
  - Calorimeter Layer
- Global parameter optimization
  - TPC and B field – Hanhua Cui
  - Acceptance and solenoid – Jiechen Jiang
- Conclusion

# Conclusion

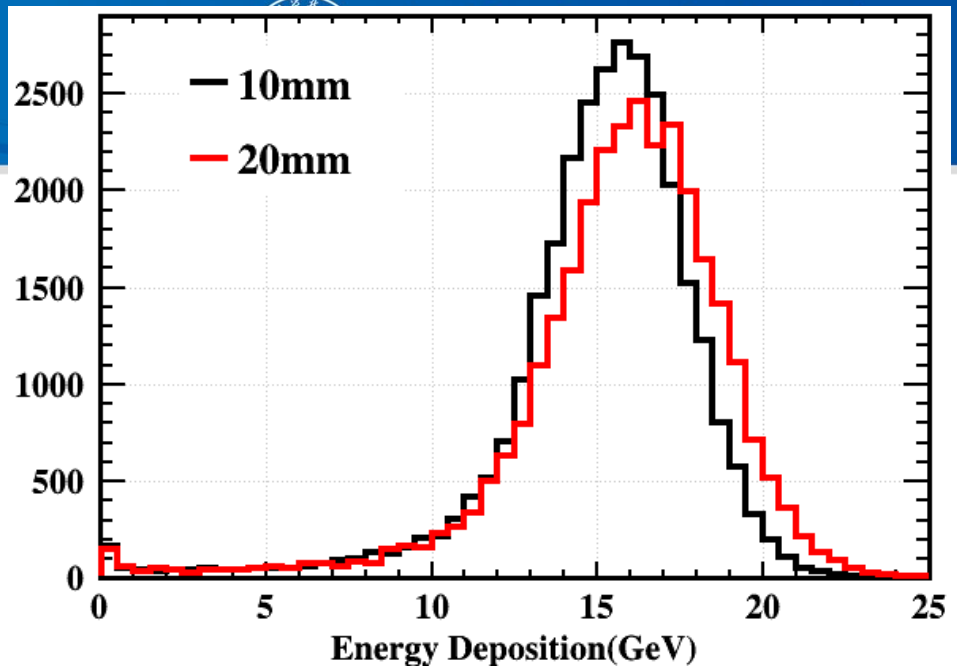


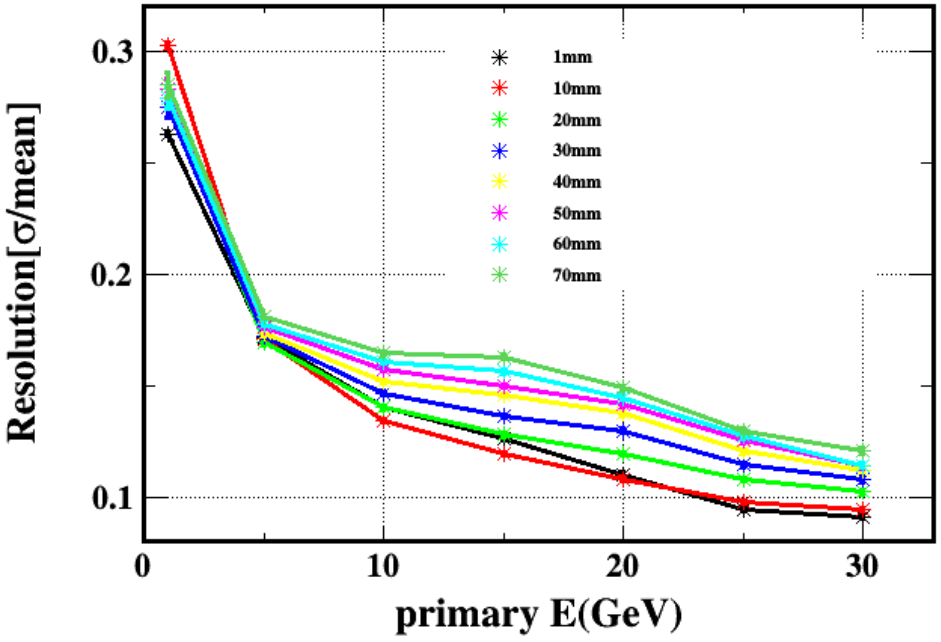
- Local parameter
  - Calorimeter Cell Size
    - BMR is not sensitive to HCAL cell till 50mm
    - ECAL cell should be less than 20mm in terms of BMR
  - Calorimeter Readout layer
    - BMR doesn’t rely on longitudinal segmentation obviously according to the readout layer scanning results
- Global parameter
    - TPC should have a R no smaller than 1600mm and a half length Z no smaller than 1450mm
    - 1.5T is acceptable for B field
    - Solenoid is not suitable between ECAL and HCAL nor before ECAL
    - Acceptance in CDR is enough in terms of BMR

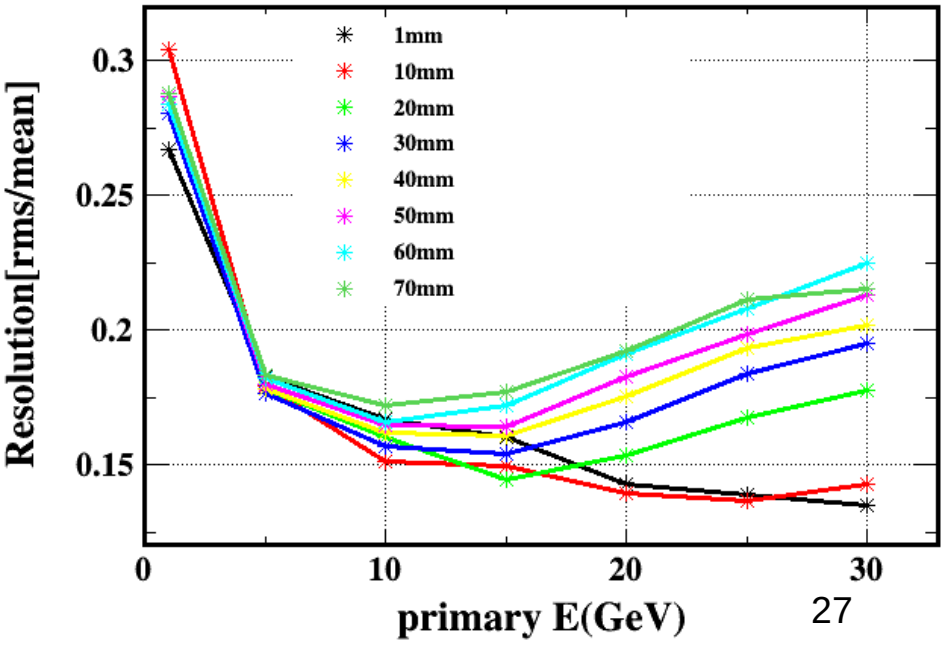
# backup

# Digital readout

- CEPC V4 Geometry
- KL Resolution
  - Sigma/mean
  - Rms/mean



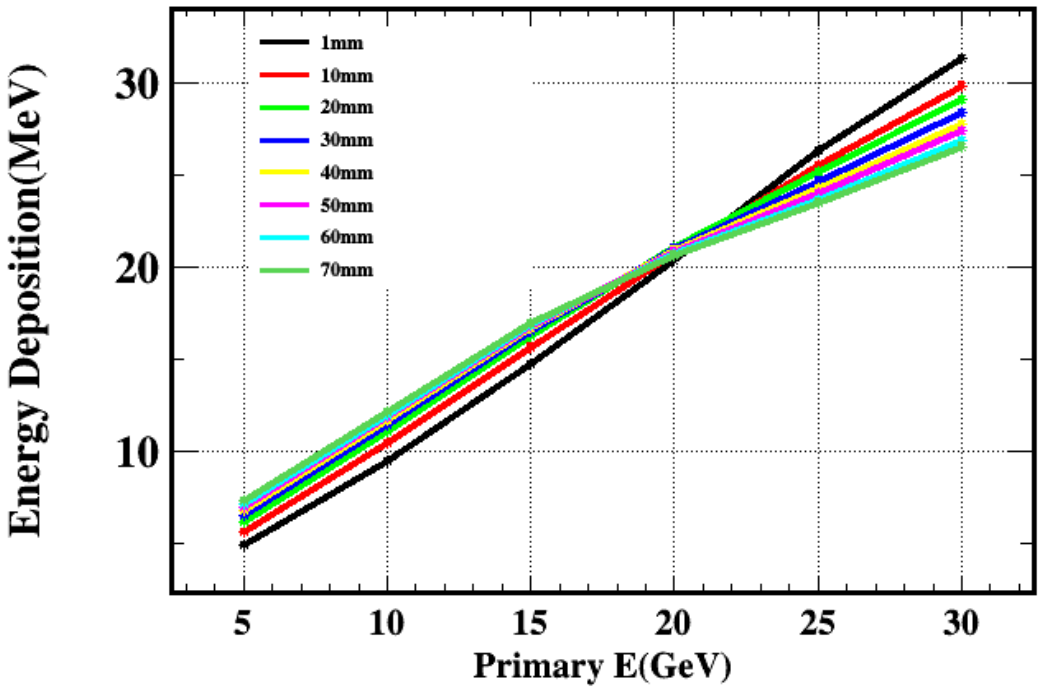



# Digital mode

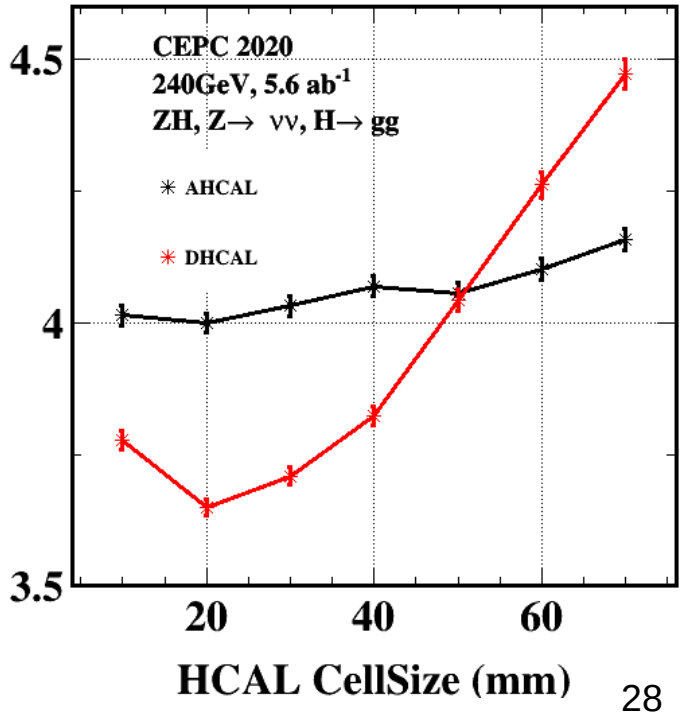


- Cell size influences both PFA separation ability and hadron resolution in digital mode
- Bigger Cells are easier to saturate

KL Linearity of different cell size




Analog and Digital mode



# Motivation



- The HCAL geometry in this report is fixed as the scintillator Steel option
- Why analog mode and digital mode have such big difference in BMR?

Analog and Digital readout mode KL resolution(10mm Cell Size) and BMR