



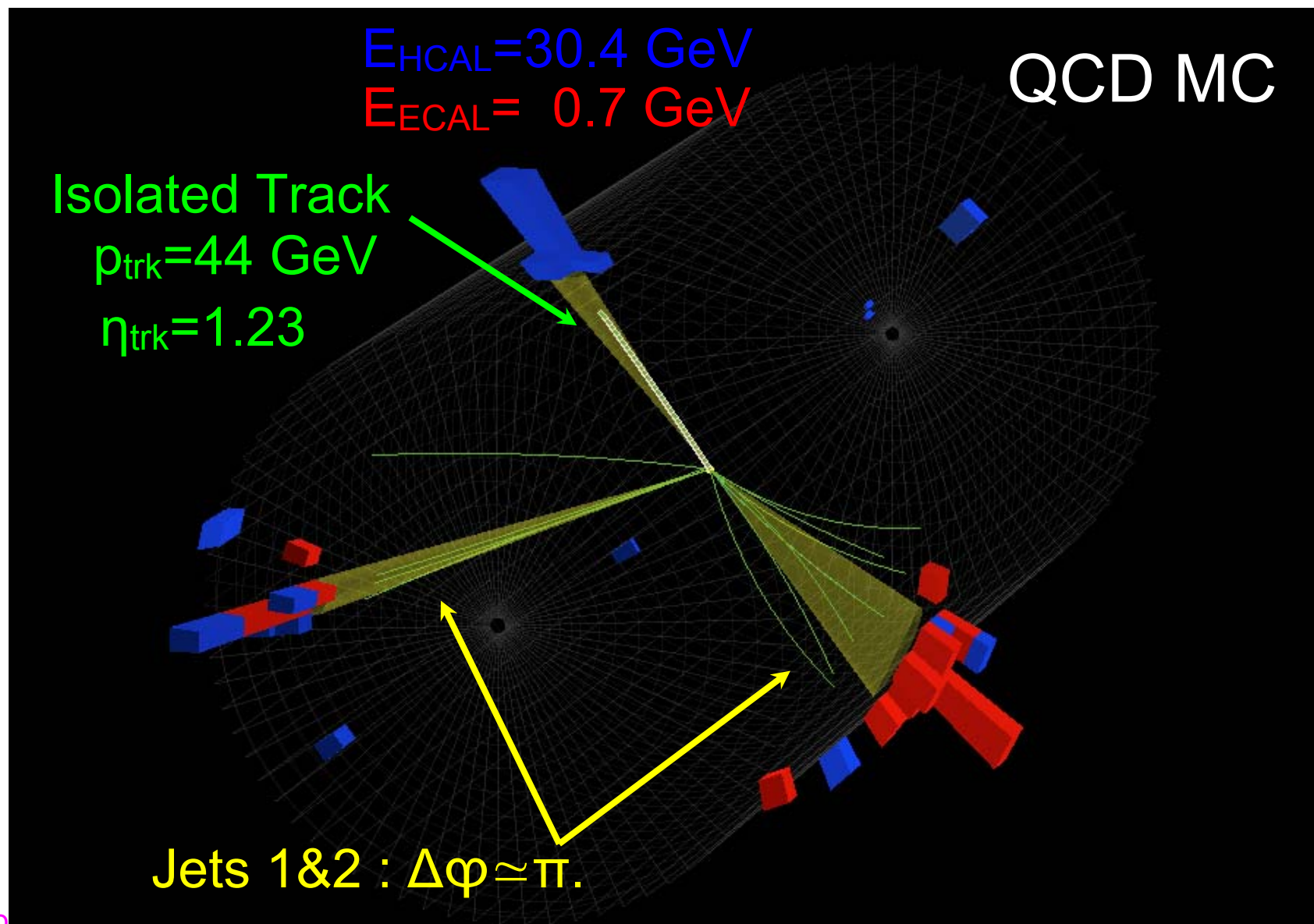
Use Collision Data at CMS to Validate Hadronic Model in Geant4

Outline

- ❑ Isolated single particle
- ❑ Selection procedure
- ❑ Results in different detector regions
- ❑ Summary



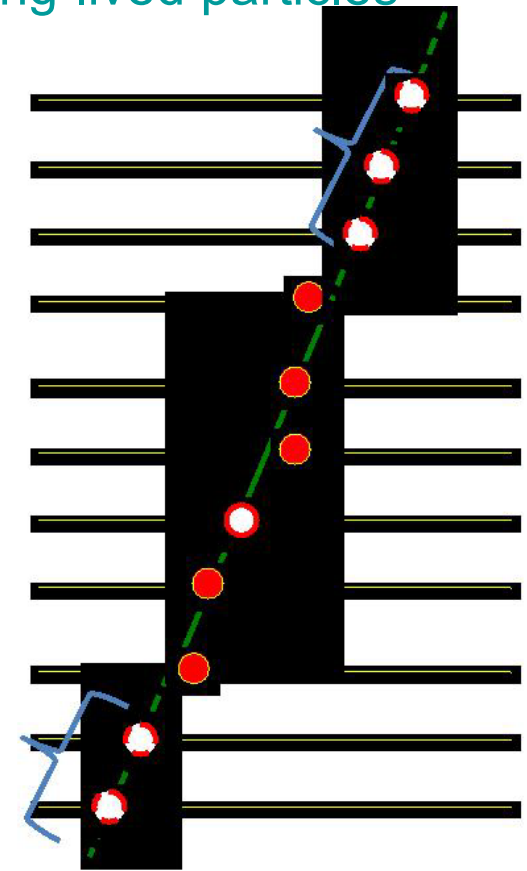
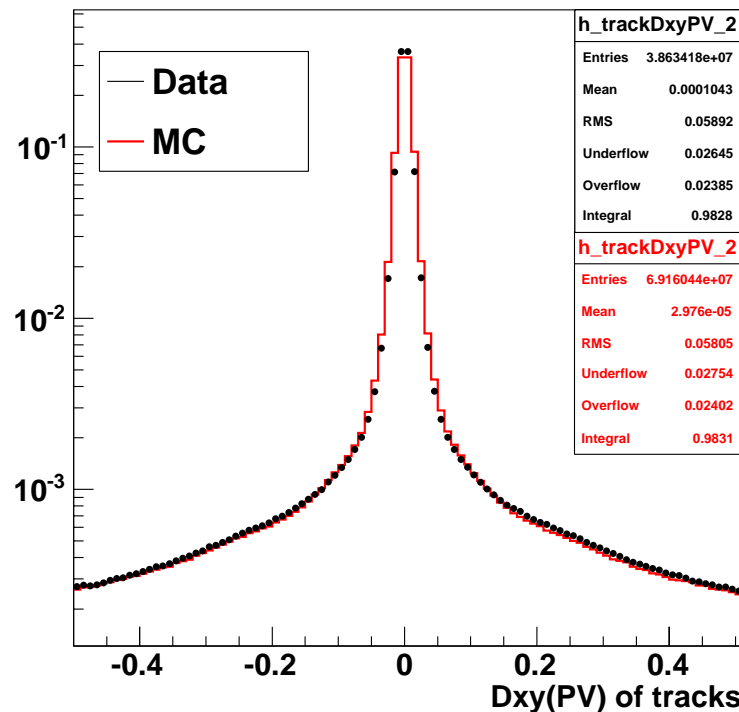
- ❑ Isolated charged particles from LHC collision data can be used to validate the simulation code for shower generation
- ❑ Similar data are useful for other studies where track measurements are used to improve jet or missing E_T measurements.
- ❑ However, each study has its special requirements regarding readout, trigger, etc.
- ❑ CMS uses QGSP_BERT_EML physics list with Geant4 9.3.p01 release for Monte Carlo production





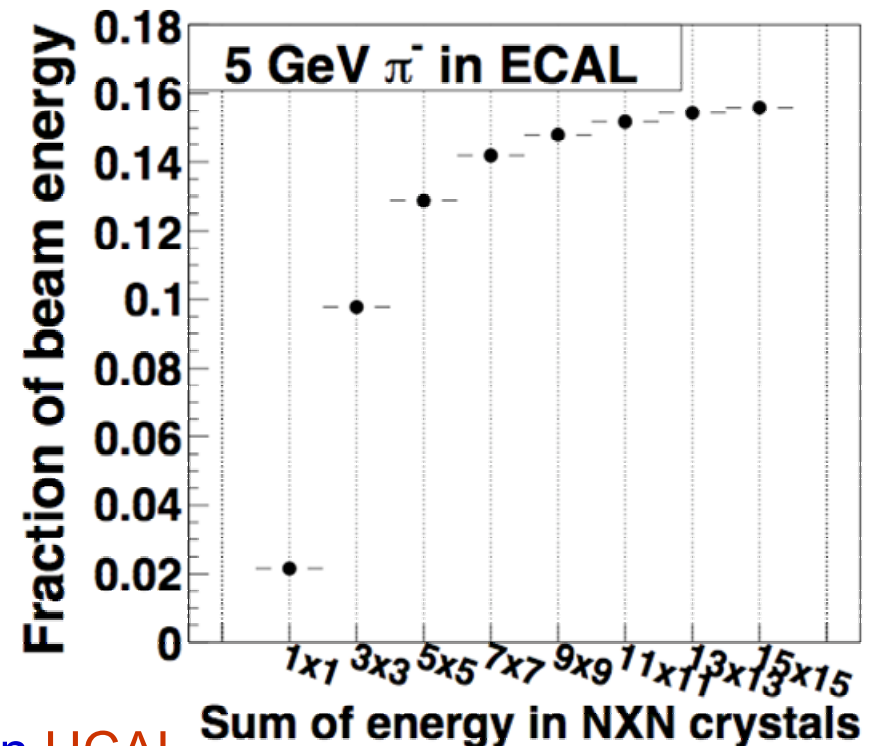
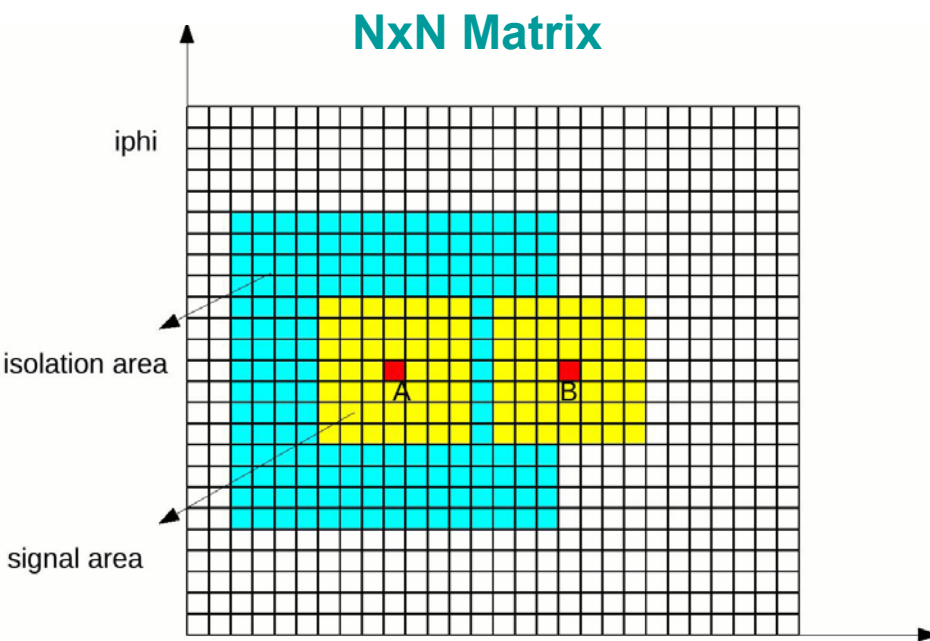
- Use High purity tracks coming from the primary vertex:
 - Distance from primary vertex < 0.2 mm in xy -plane & along z
- Well measured tracks
 - $\chi^2/\text{d.o.f.} < 5$
 - Number of planes crossed ≥ 8

Use of missed hit information is important for rejection of interacting tracks in the tracker material or selection of long-lived particles





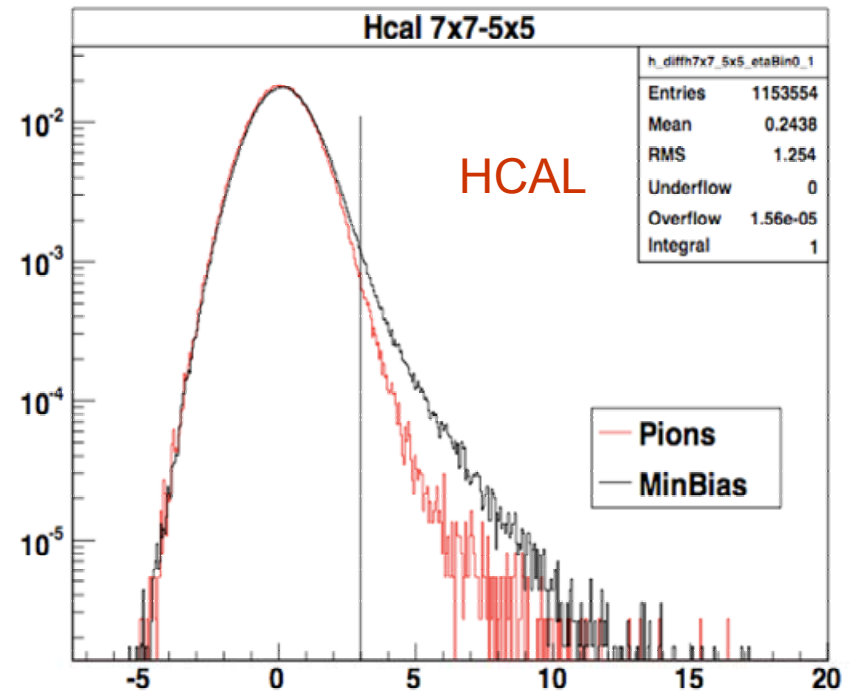
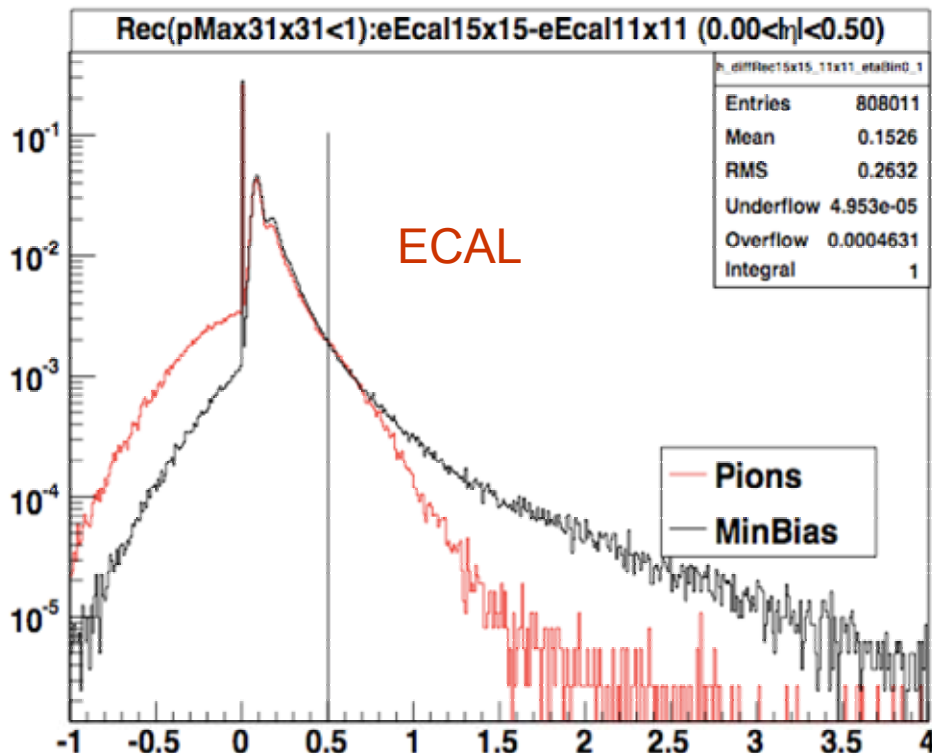
- ❑ Propagate the track to the calorimeter surface (ECAL as well as HCAL)
- ❑ Use granularity of calorimeter → NxN matrix
- ❑ Use test beam and simulation to decide signal zone size
- ❑ Balance between containment and contamination



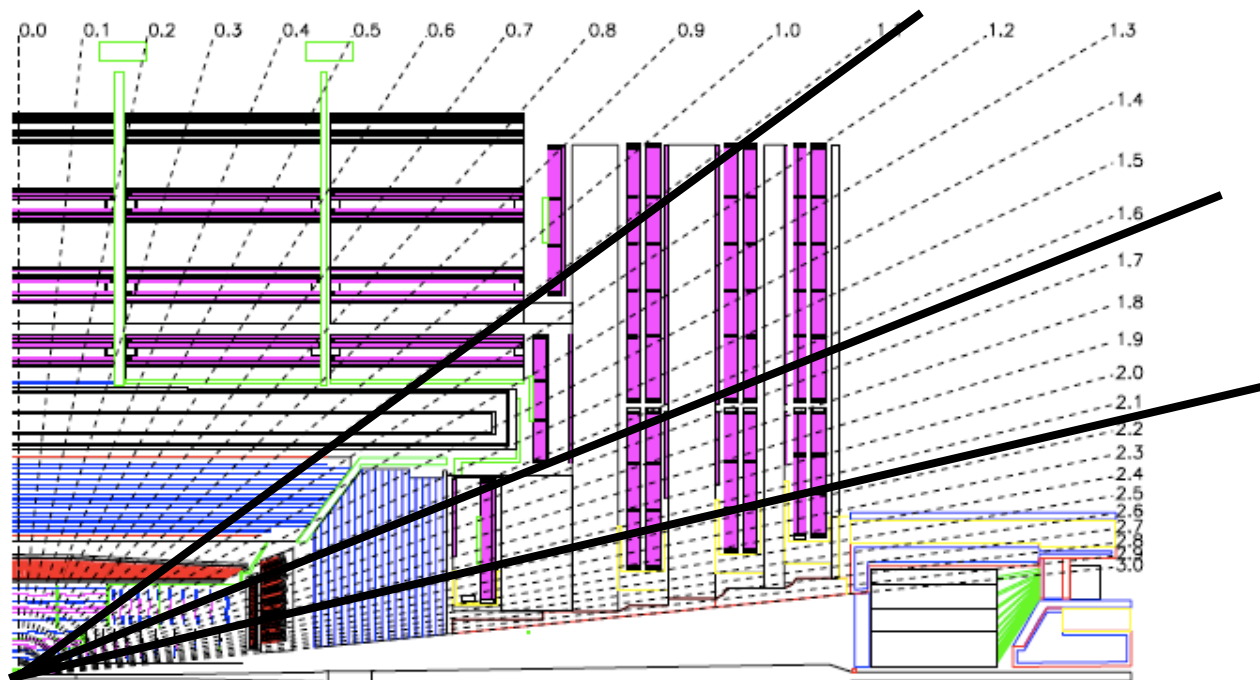
Final choice: 11x11 in ECAL and 3x3 in HCAL



- Isolate from other charged particles by extrapolating all charged particles to ECAL/HCAL surface and see they are not within the isolation zone
- Neutral isolation demanded by looking into energy deposit in an annulus region in ECAL (HCAL)

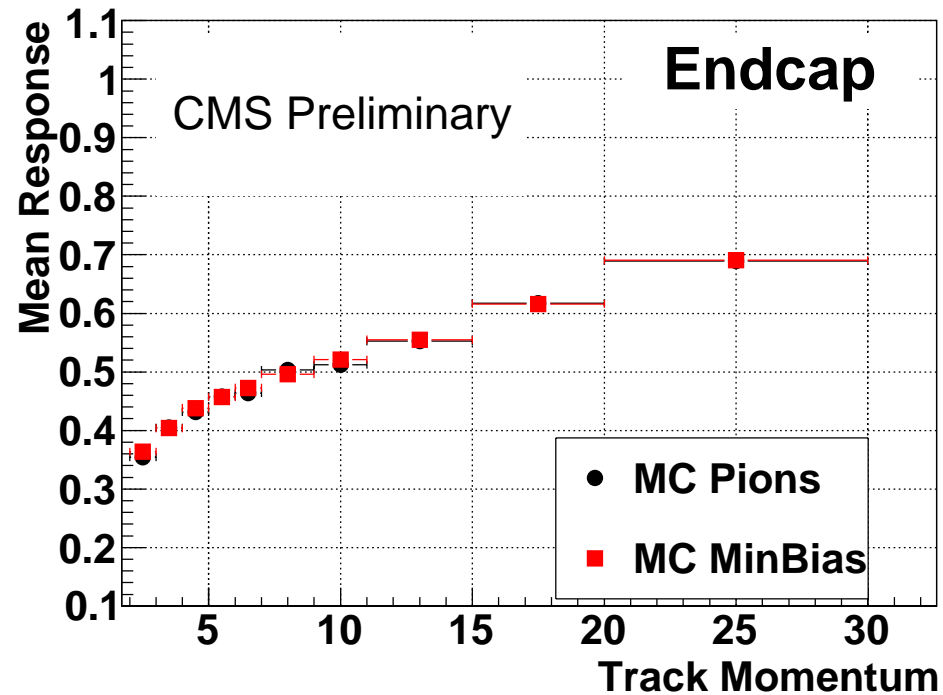
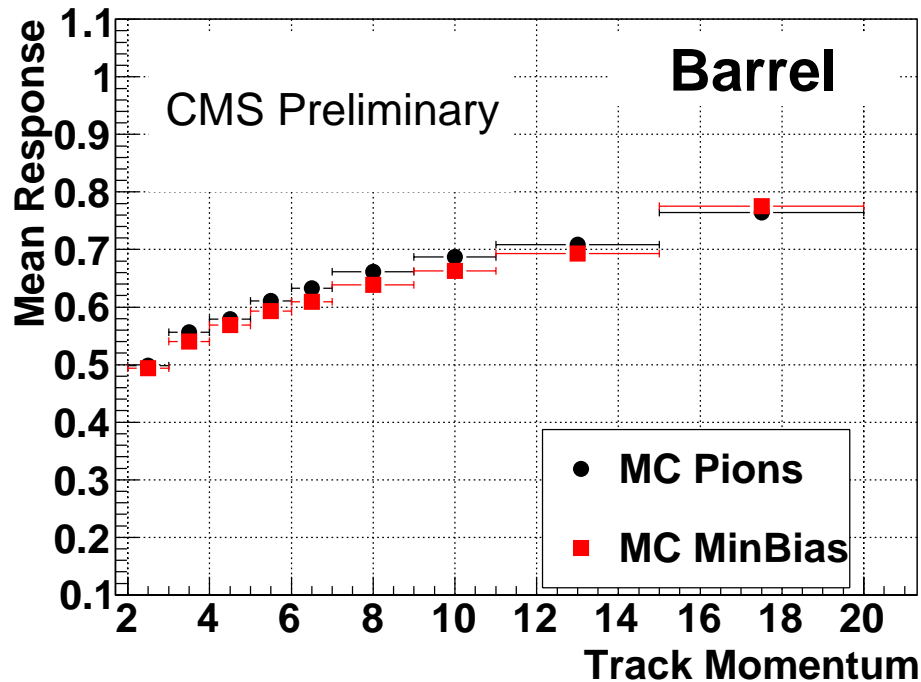


Measure as a Function of η

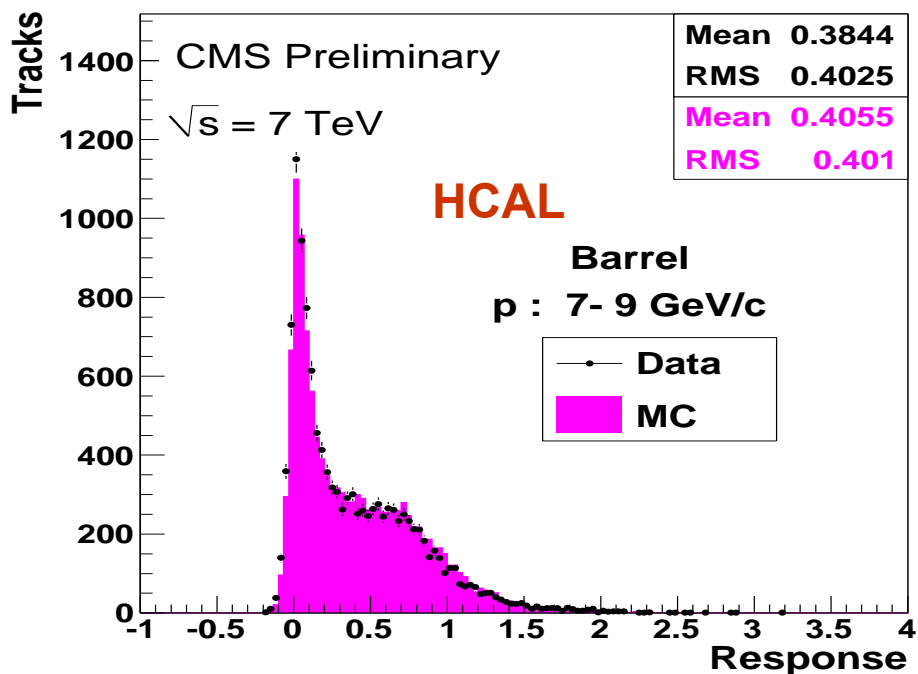
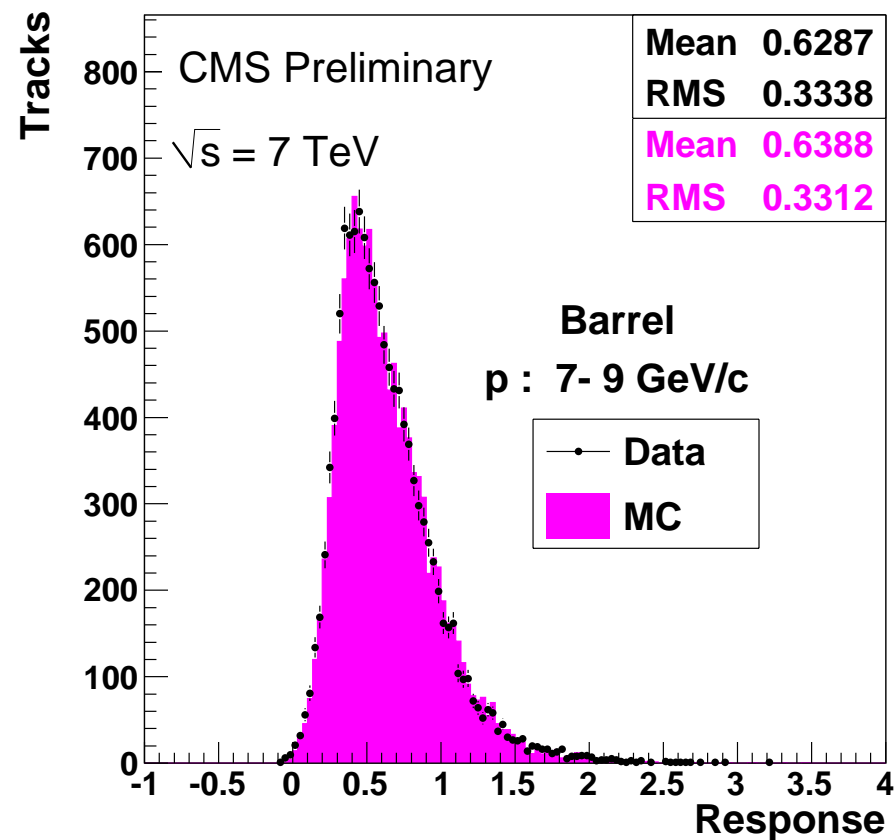
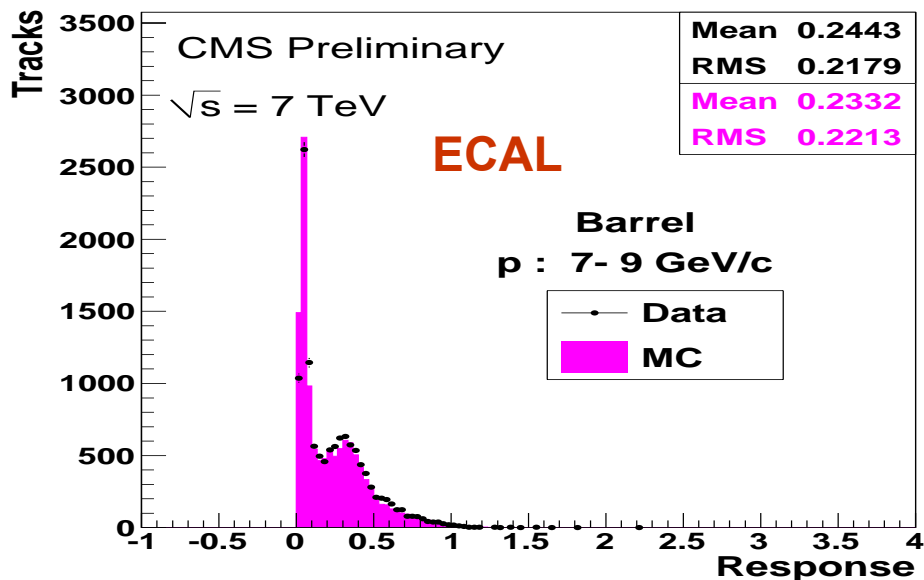


Divide the phase space in 3 angular regions:

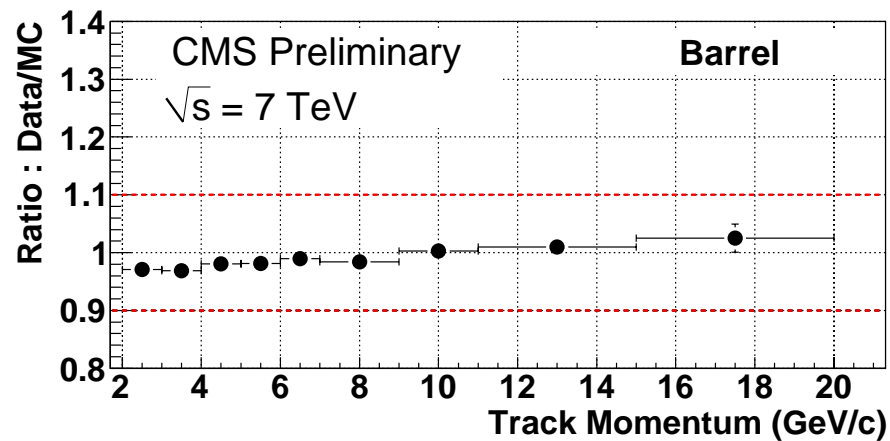
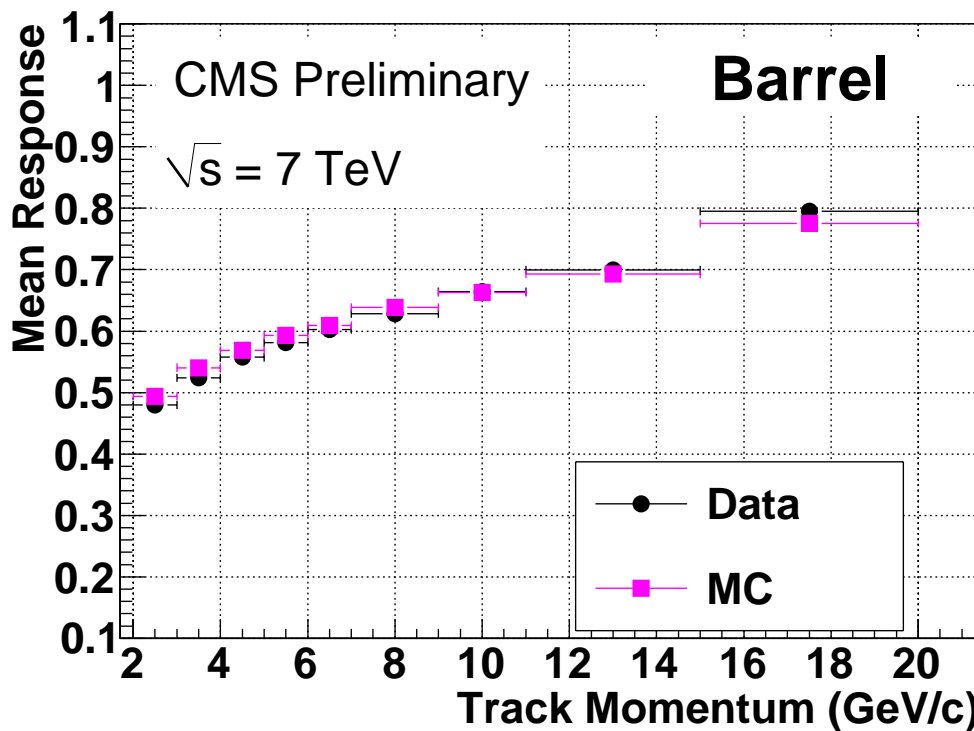
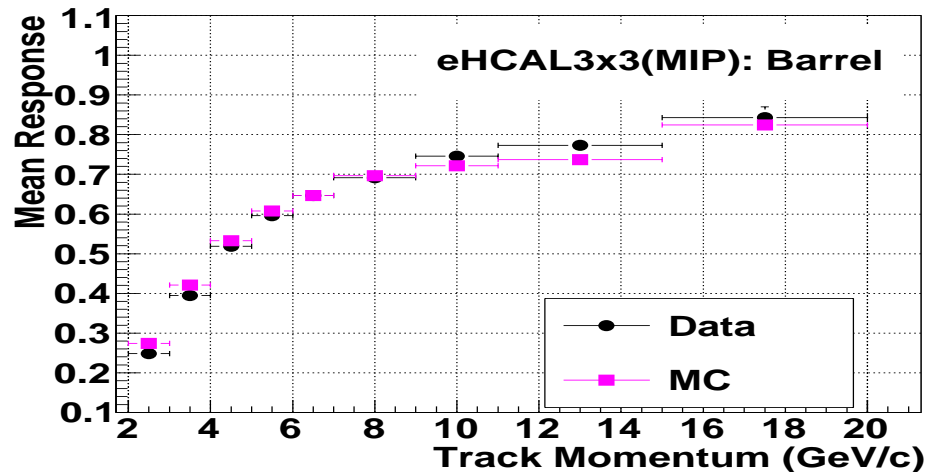
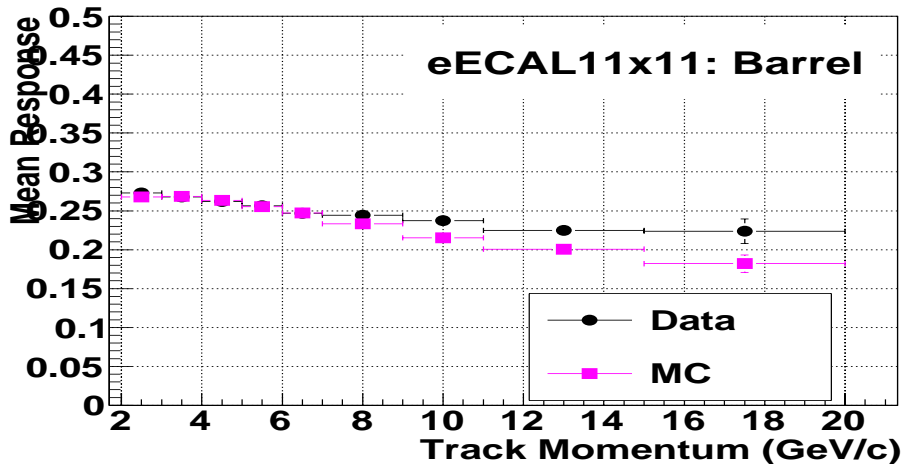
- $0.000 < |\eta| < 1.131$ (Barrel)
- $1.131 < |\eta| < 1.653$ (Transition)
- $1.653 < |\eta| < 2.172$ (Endcap)



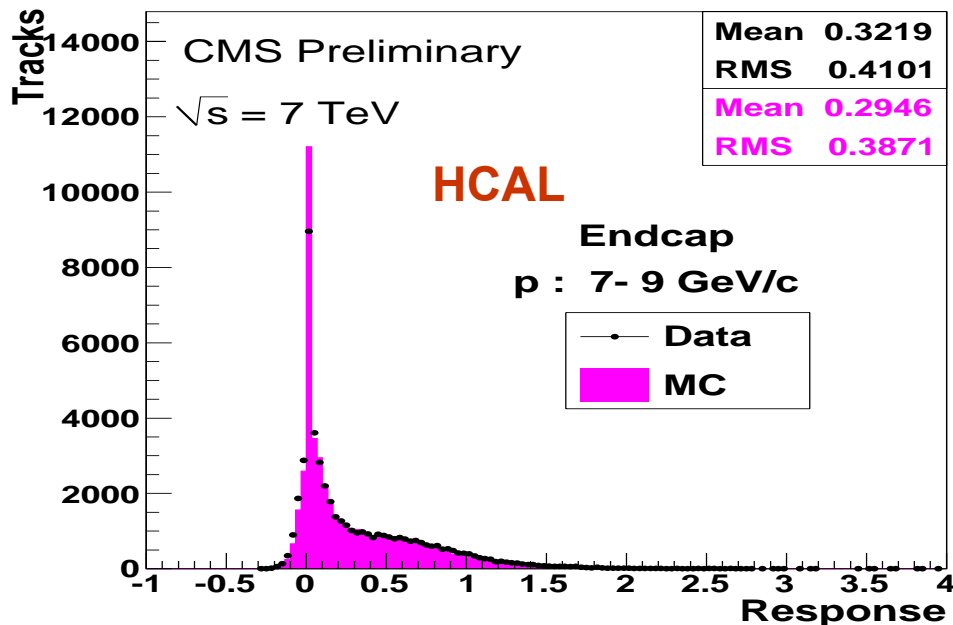
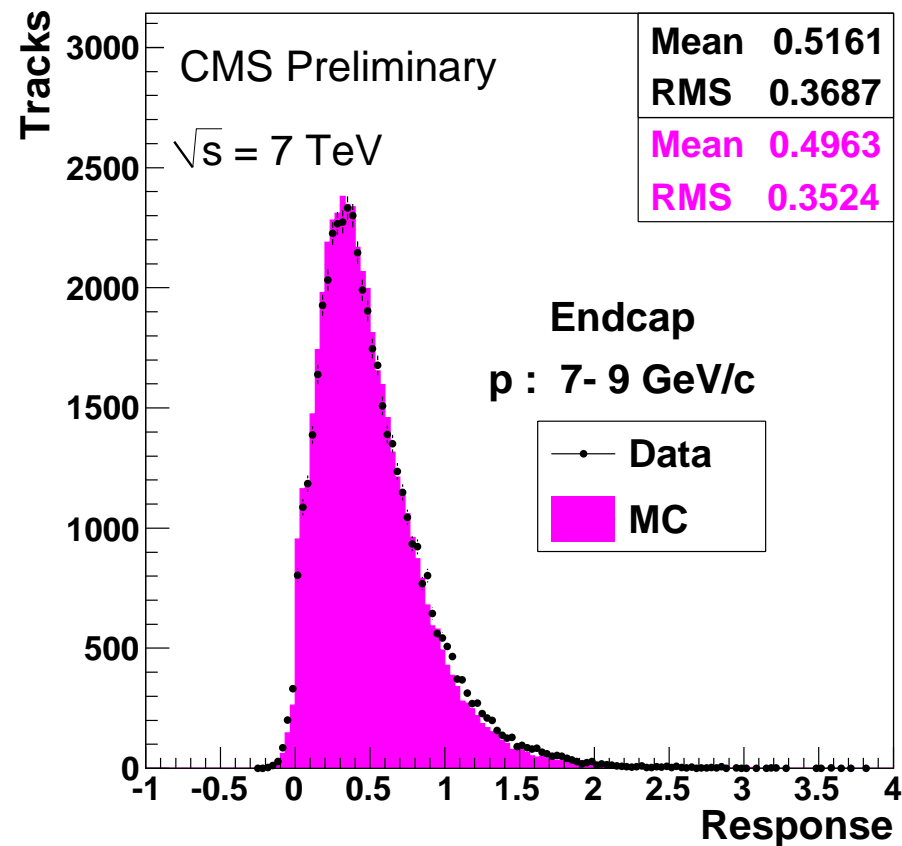
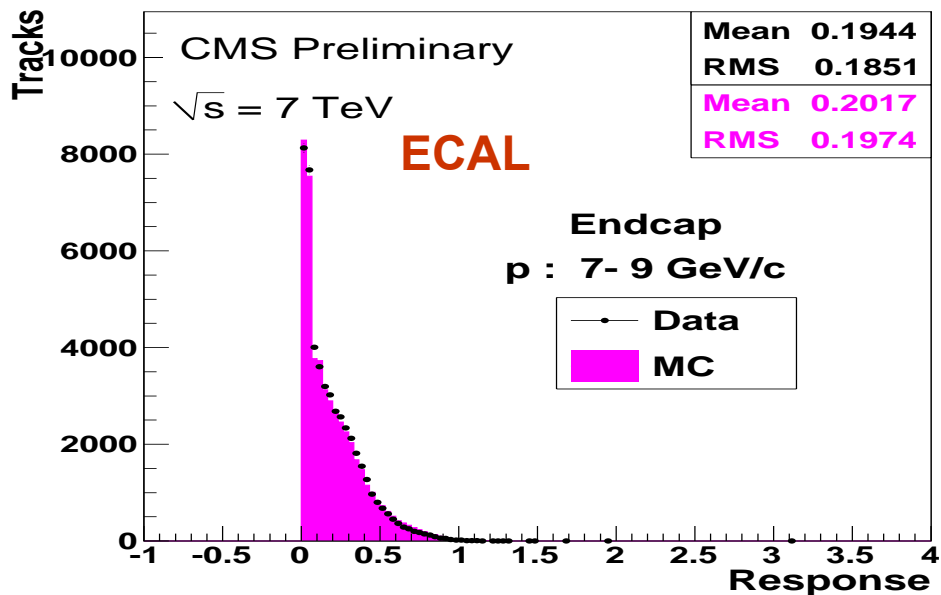
- ❑ Check isolation criteria by repeating the same measurements with minimum-bias and single particle Monte Carlo
- ❑ Very similar measurements observed – justifies choice of signal and isolation zones



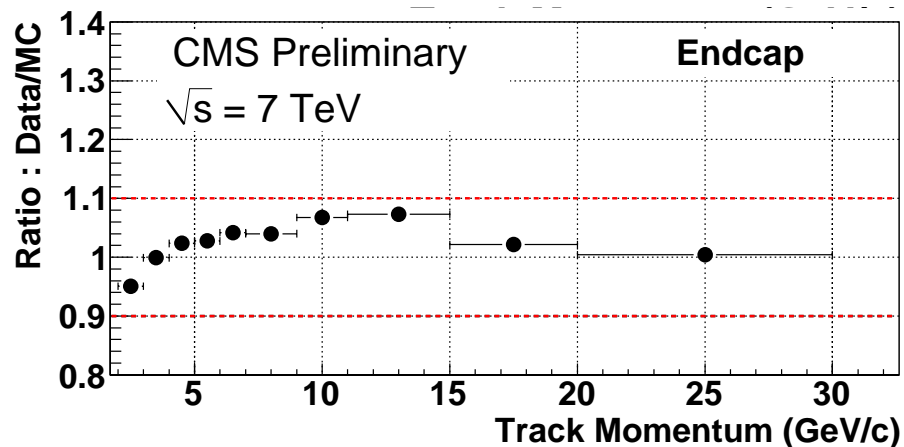
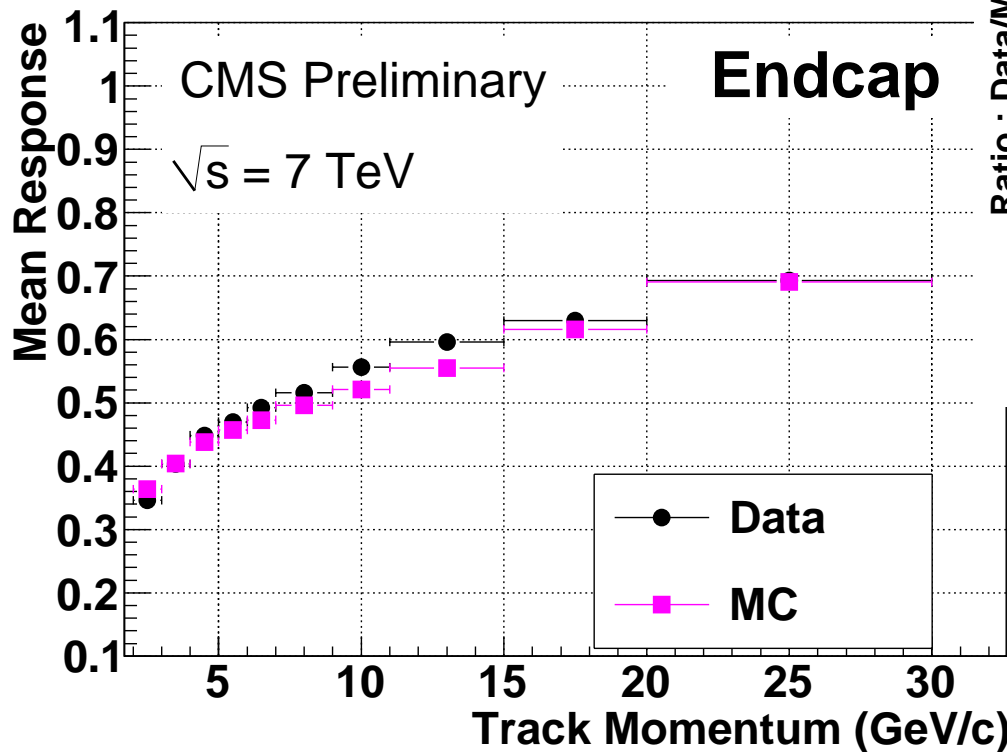
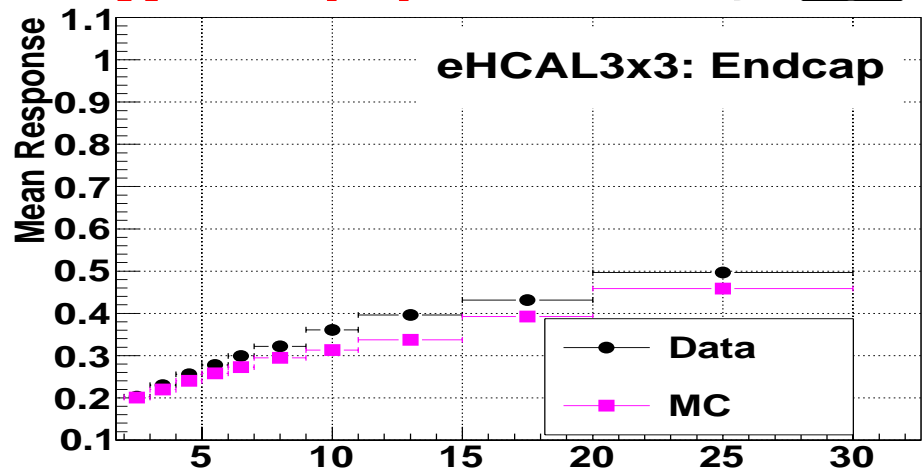
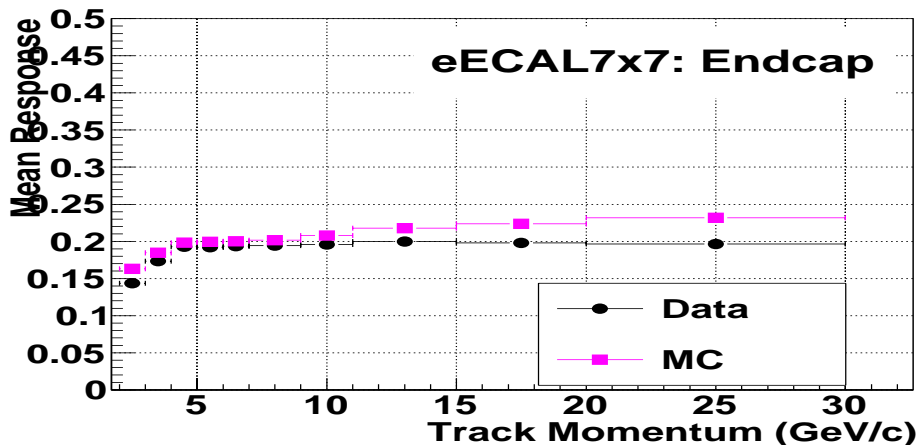
Overall agreement is quite reasonable: small difference in individual contributions



□ Data/MC agreement is better than $\pm 3\%$ between 2-20 GeV/c



□ Data give somewhat larger response in HCAL – but overall response still within 5%



□ Agreement in overall response is still within $\pm 8\%$ - understanding the calibration issues



- ❑ Isolated charged particles are used in CMS to measure calorimeter response as a function of particle energy
- ❑ Single particle response measurements are used to compare data with Monte Carlo predictions
- ❑ There is an impressive agreement between Geant4 predictions and data in the barrel region. The agreement worsens in the endcap region – this is currently under investigation.



Backup Slides



- ❑ Minimum bias triggers are used right now
 - To start with use BSC (beam scintillators) technical bits
 - Use HLT_BSC trigger path with later runs
- ❑ Low momentum end: Need HCAL to be read out without zero suppression (ZS)
- ❑ Higher momentum side needs dedicated HLT (just commissioned)



Collision Data

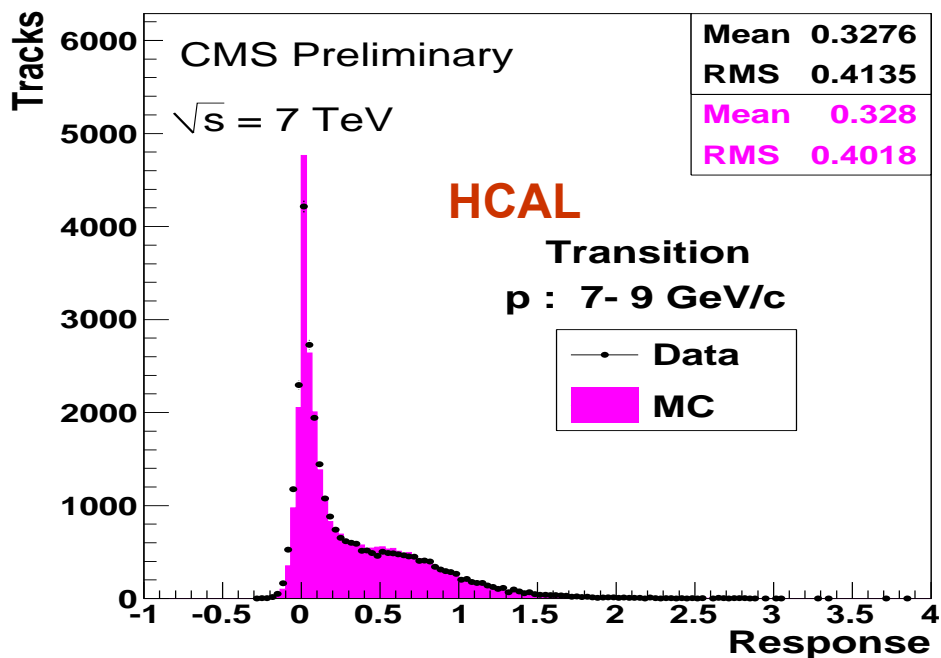
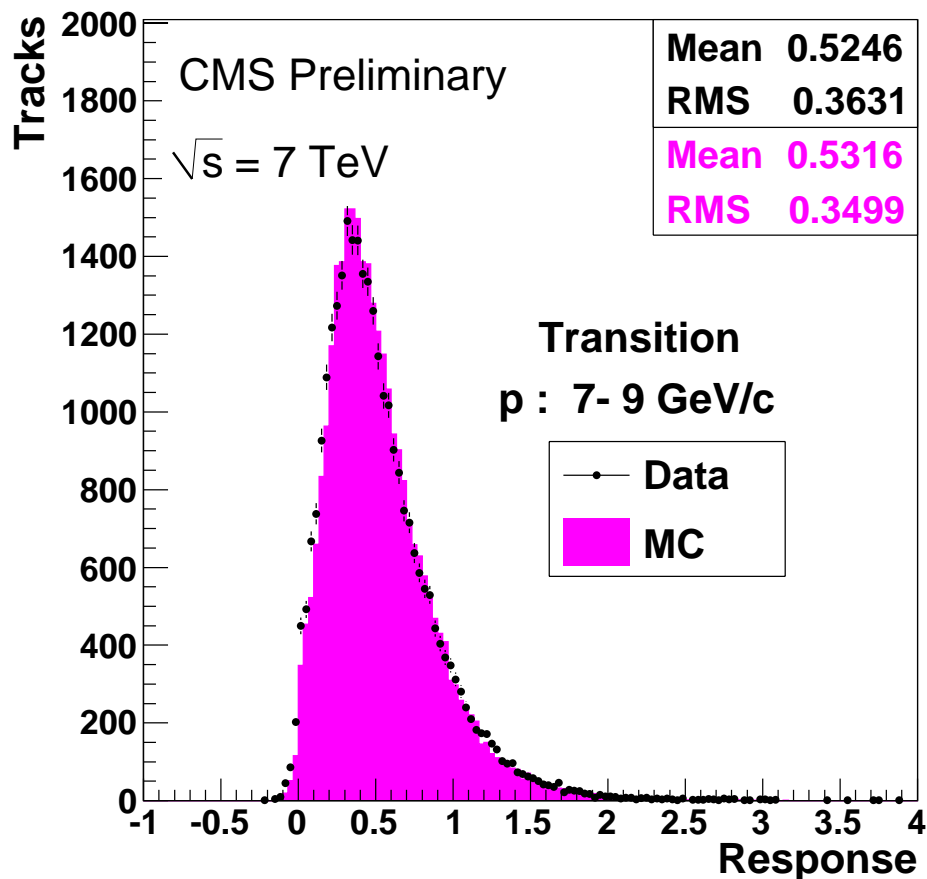
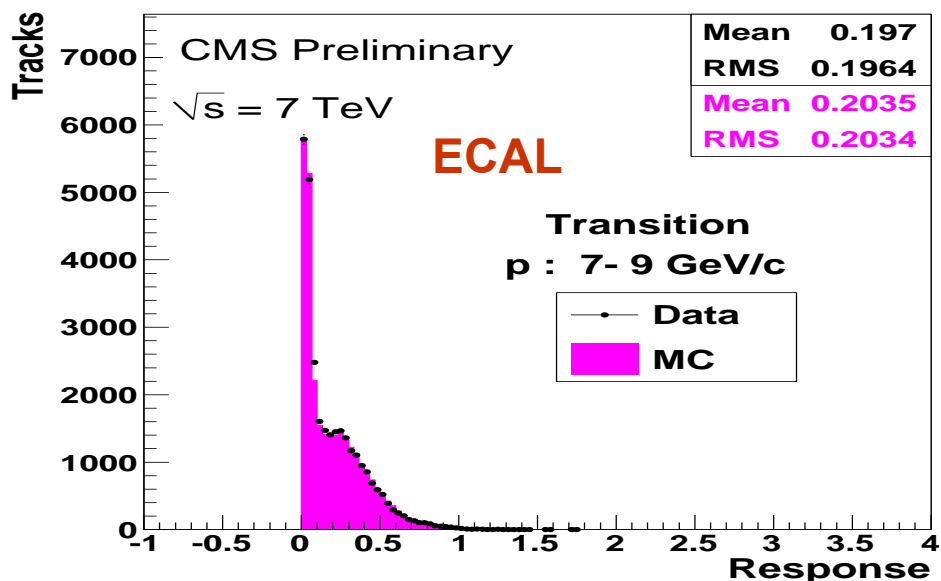
- /MinimumBias/Commissioning10-GOODCOLL-May27thSkim_v5/RAW-RECO
- ReReco using CMSSW_3_6_1_patch3 , 'GR10_P_V4::All'
- Using runs & lumi sections from official json files

Monte Carlo

- /MinBias_TuneD6T_7TeV-pythia6/Spring10-START3X_V26B-v2/GEN-SIM-RECO
- ReDigi-ReReco : CMSSW_3_5_8_patch4, 'START3X_V26B::All'

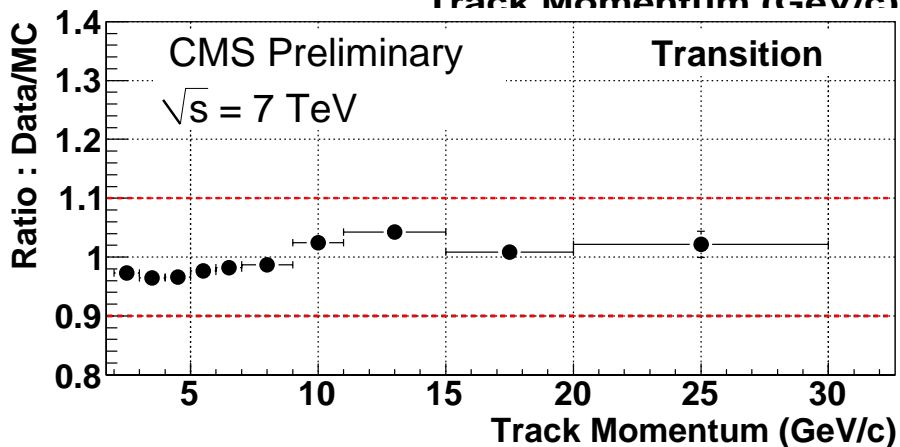
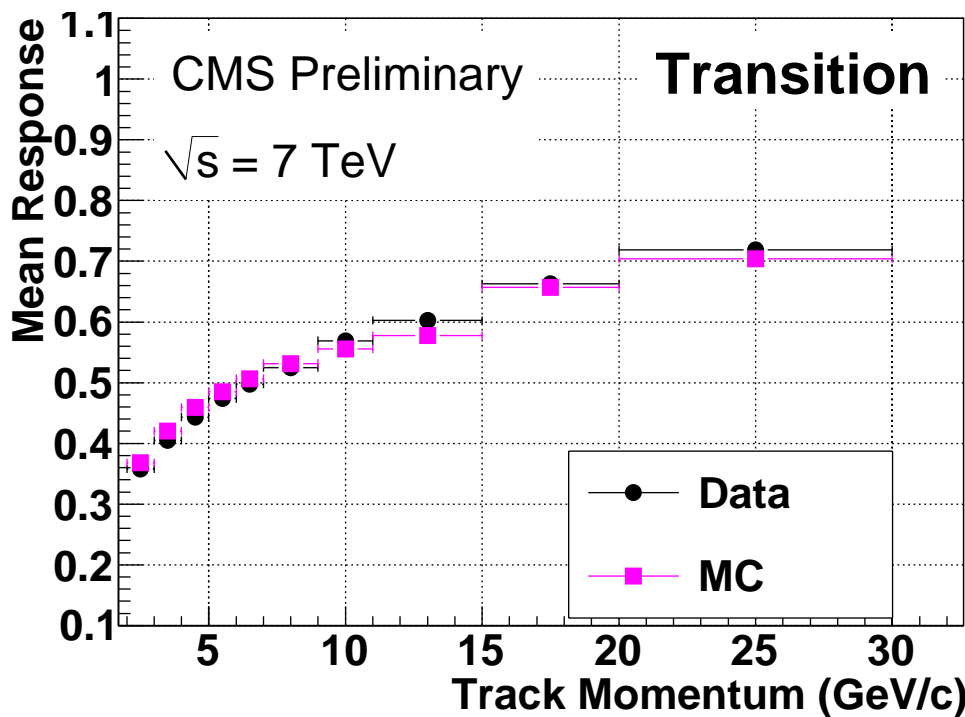
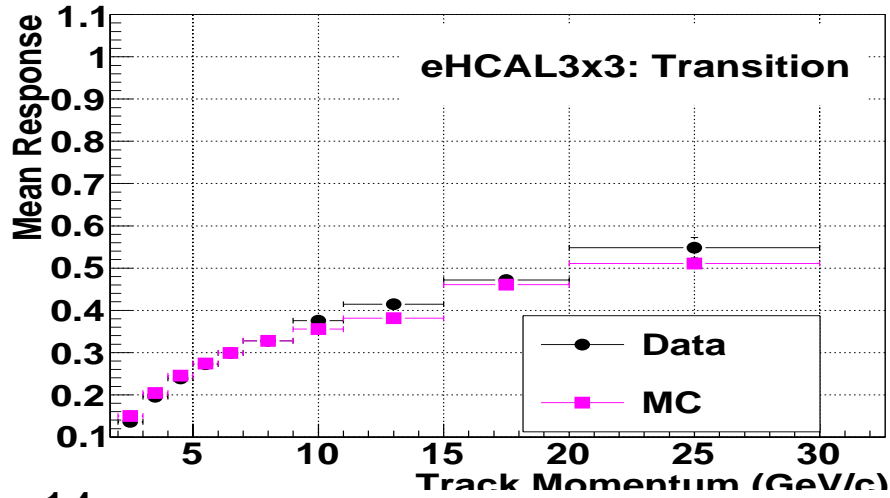
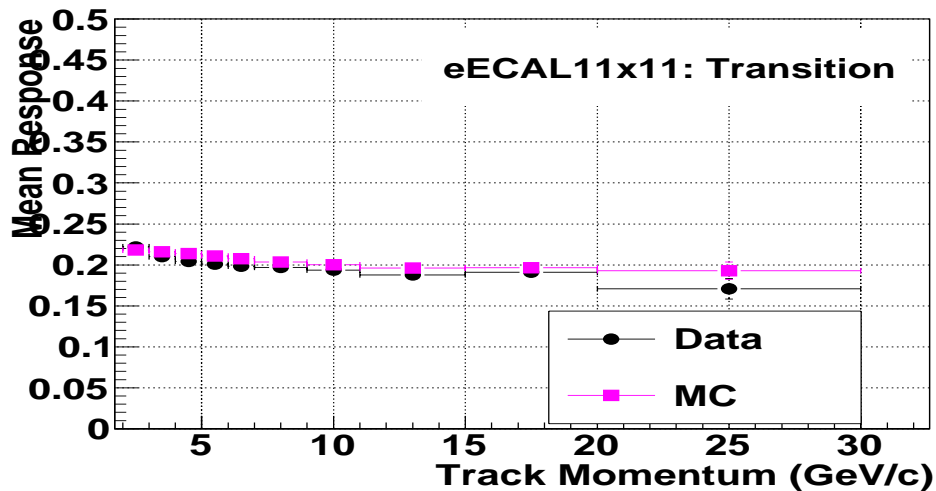
Event Selection	Data	MC
Technical Trigger Bits [0 AND (40 OR 41) AND NOT (36 OR 37 OR 38 OR 39)]	✓	
GoodVertexFilter [NDOF>4, z < 15 cm ρ < 2.0 cm]	✓	✓
Remove monster events [numtrack>10, thresh>0.25]	✓	
Trigger [HLT_MinBiasBSC]	✓	✓

Officially quoted Lumi : 8.44 nb⁻¹: 14.5 M Events in Data and 30 M Events in MC



Overall response matches well between data and MC – so does the individual contributions

Transition Region (II)



☐ Agreement in overall response is within $\pm 5\%$