Simulation Status of ScECAL

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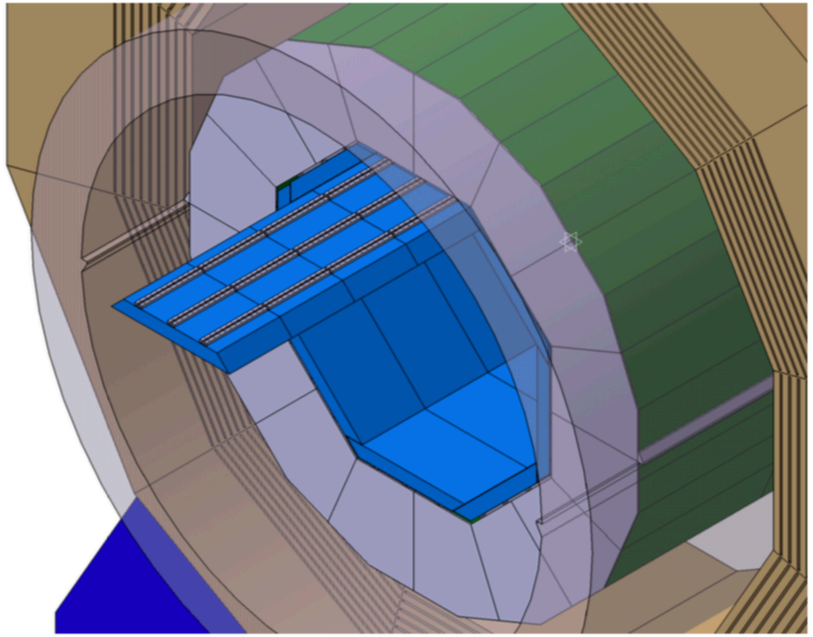
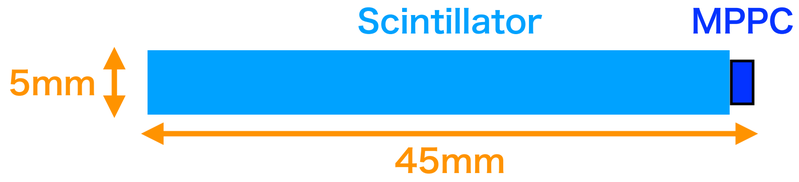
ILD ECAL

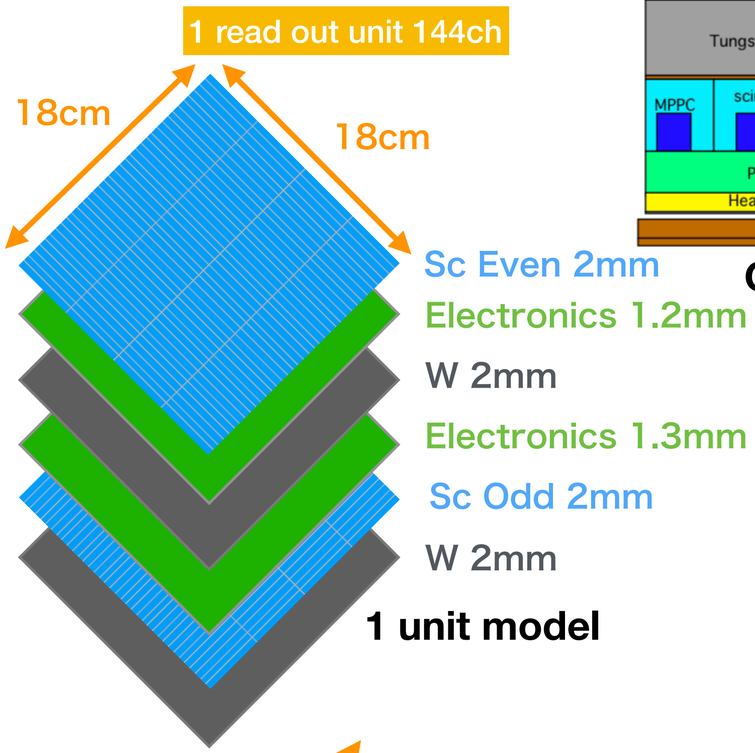
- ECAL
  - 5 x 5 mm^2 segmentation to incorporate with ILC physics requirements
  - Absorber is made of 30 layers of tungsten(W)
    the first 20 layers are 2.1 mm thickness
    the latter 10 layers are 4.2 mm thickness
  - 2 options for as sensor material: Sc(scintillator strip) and Si(silicon pad)

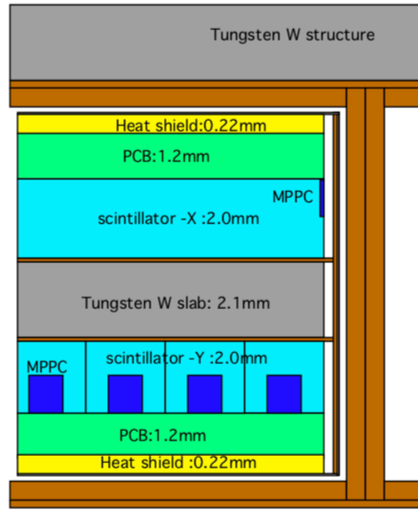


ScECAL

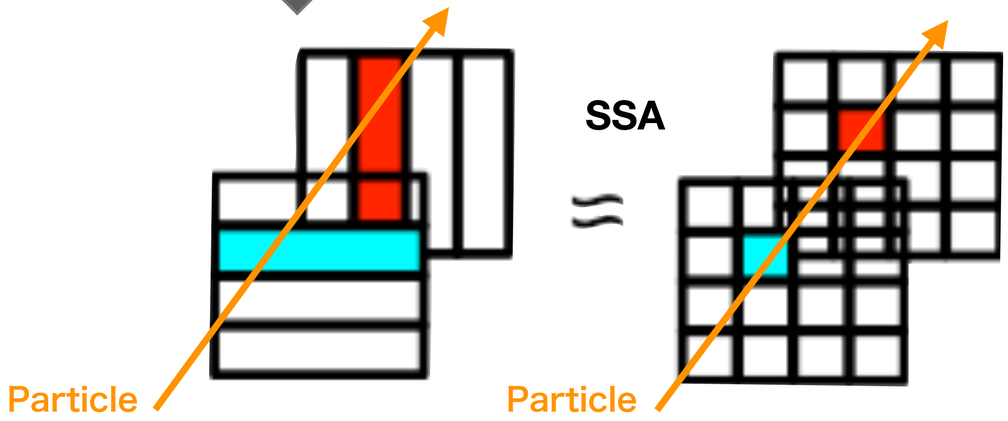
- Detection layer of ScECAL uses plastic scintillators and MPPC as photo sensors
- Scintillator
  - Size is 45 x 5 mm^2
  - Layers are alternately arranged perpendicular to each other
  - 2mm thickness Sc in DBD model
- MPPC
  - 10k pixel (10μm pitch, 1x1 mm^2 sensor area)
- Divide the strip with SSA(Split Splitting Algorithm) software to make a 5 x 5 mm^2 segment





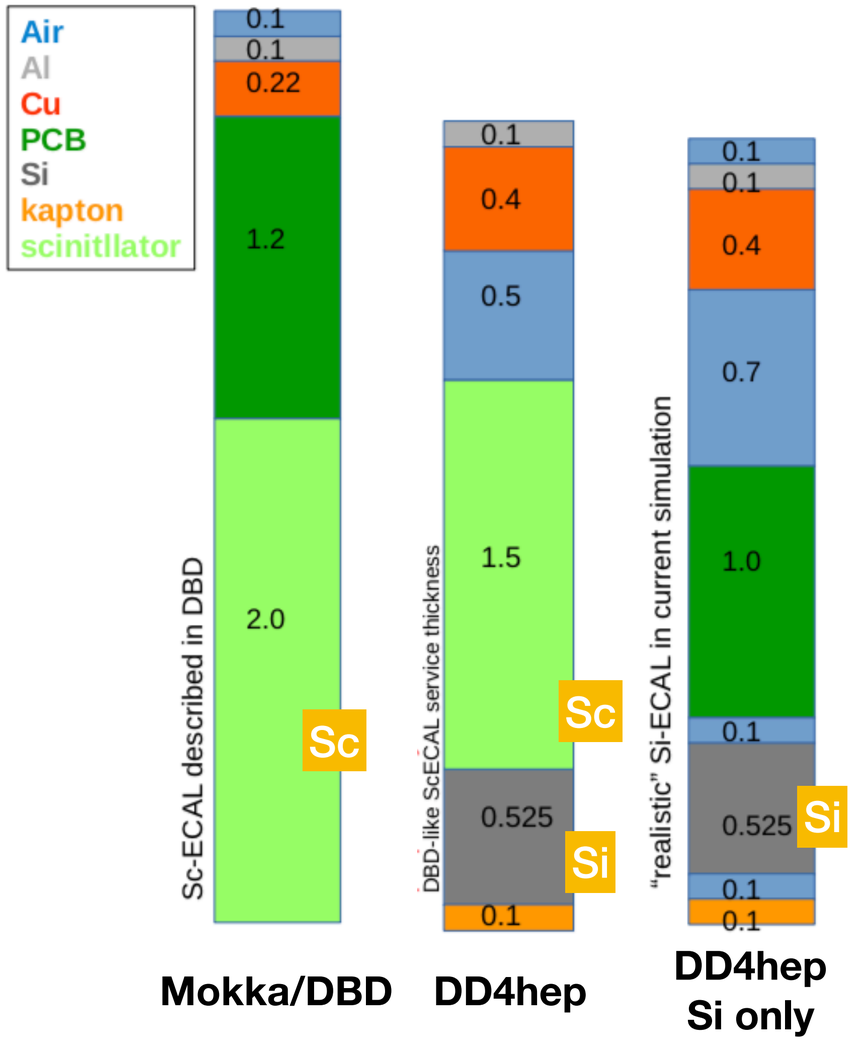


Cut model



DD4hep ScECAL Model

- Mokka (former simulation)
  - DBD geometry
  - Sc thickness is 2mm
  - Differences in thickness, radius and etc. between Sc and Si, so completely different geometry model at part of ECAL
- DD4hep (this simulation)
  - These models include both ScECAL and SiECAL
  - Sc thickness is 1.5mm because of the similar total X0 and lambda at Si only model
  - To compare Sc and Si model with same events
- Parameter of simulation from v01-19-06-p01 & lcgeo_current
- Use default Pandora PFA parameters (for Si, not optimize for Sc)
- SSA is not yet implemented



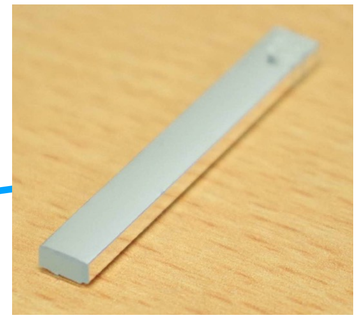
ScECAL Parameters

-Simulation ScECAL Characteristic Parameters

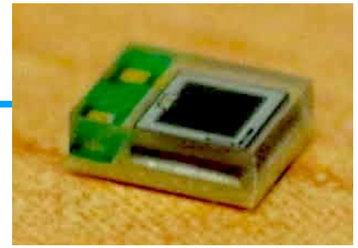
Sensor type	ScECAL	SiECAL
Collection	ECal*ScHits	ECal*SiHits
CaloDigi	RealisticCaloDigiScinPpd	RealisticCaloDigiSilicon
ppd_mipPe (p.e)	7	-
ppd_npix (pixel)	10,000	
calibration_mip (GeV)	?	0.0001575
calibration_factorsMipGev	?	0.00641222630095

Device parameters

Need Calibration



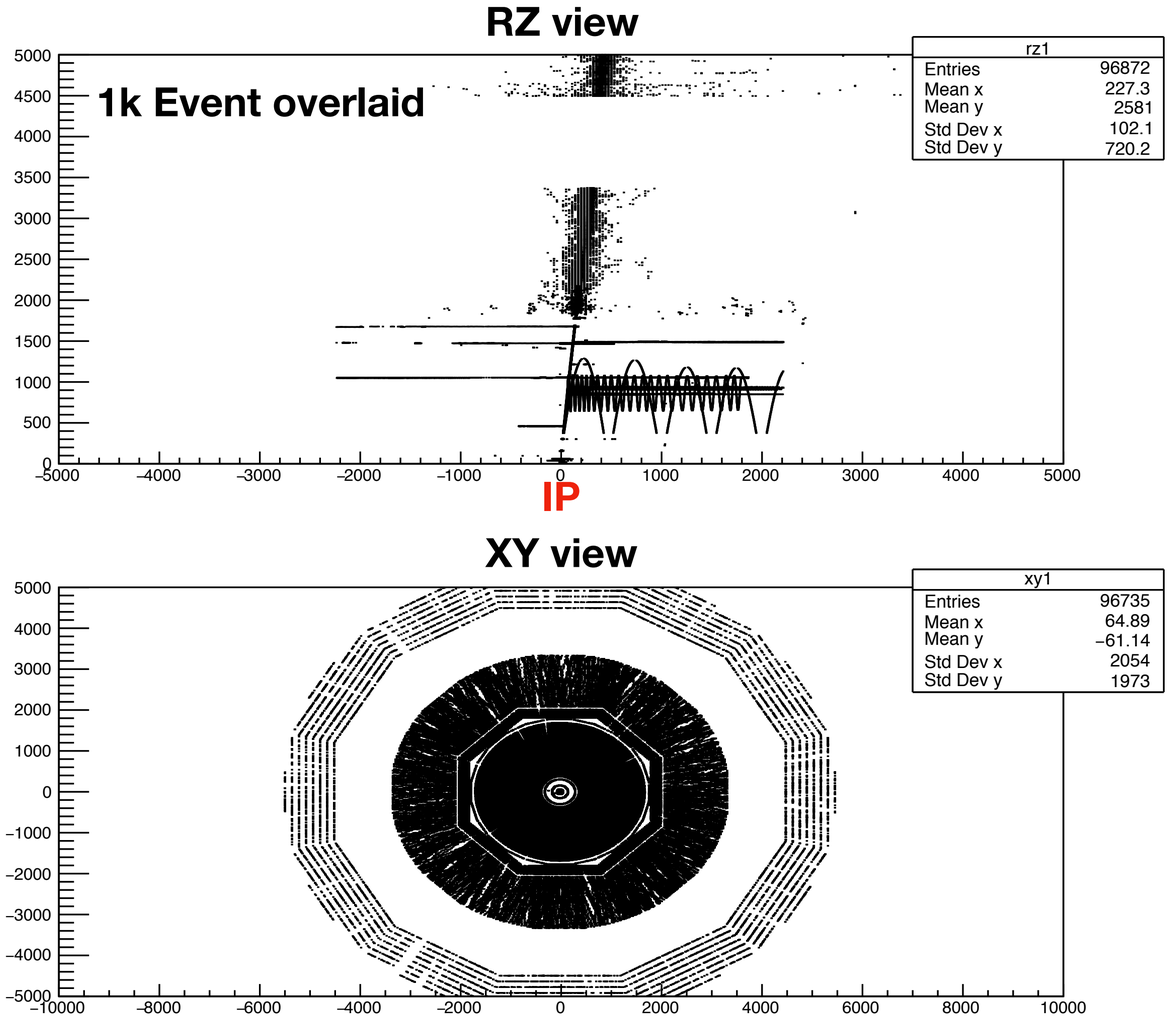
Scintillator (45 x 5 x 2 mm²)



MPPC 10k pixel

Mip Calibration

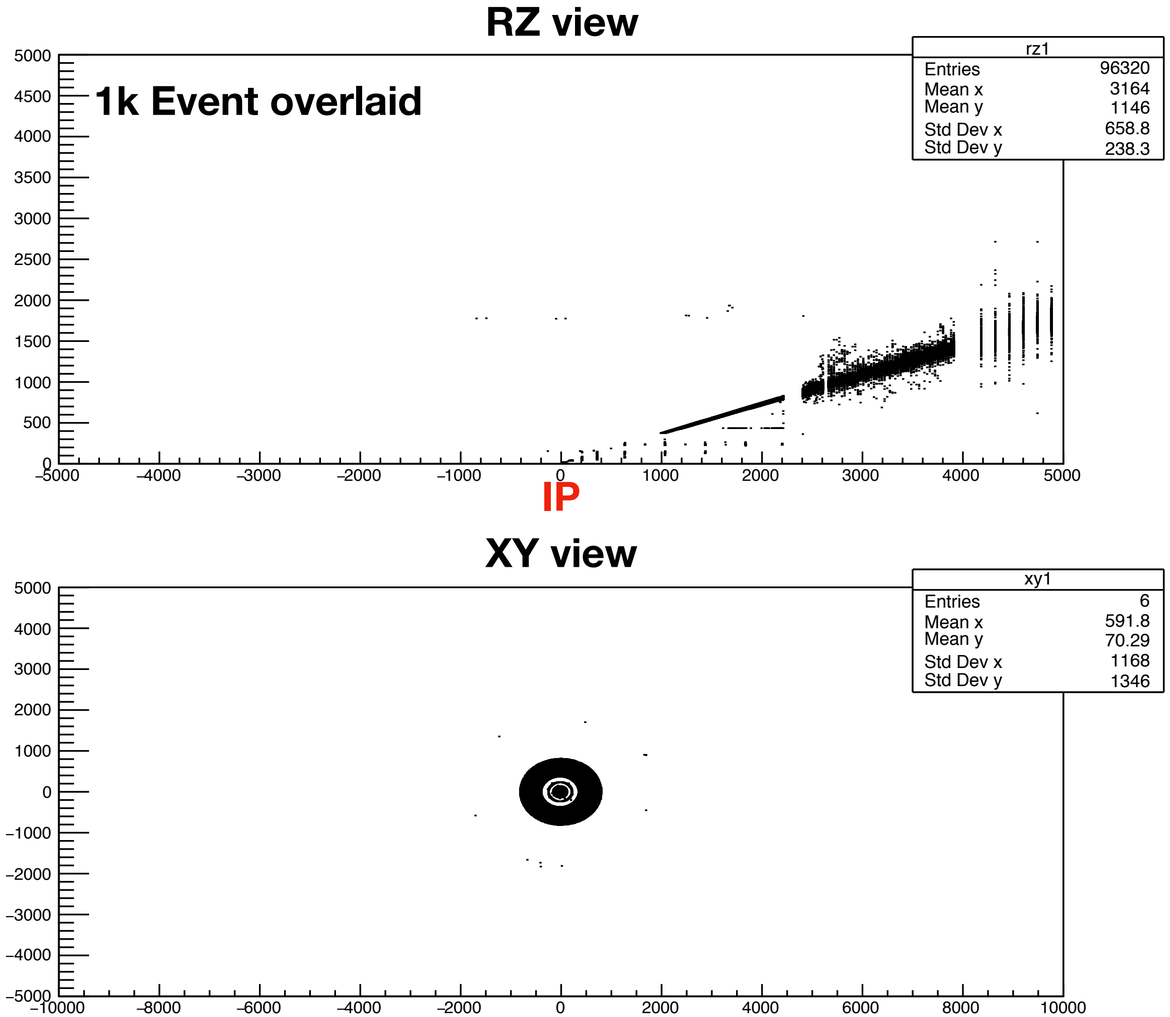
- Parameter: calibration_mip
- Use 10GeV muon 1k Event
- Theta 85 for Barrel (85 deg.)
- Theta 20 for Endcap (20 deg.)
  - E1-calib.Ps_pm13_p010_t20.Glcio_gun.e0.p0.I110107.n1.slcio
  - E1-calib.Ps_pm13_p010_t85.Glcio_gun.e0.p0.I110109.n1.slcio



Hit map of theta 85 muon for barrel calibration

Mip Calibration

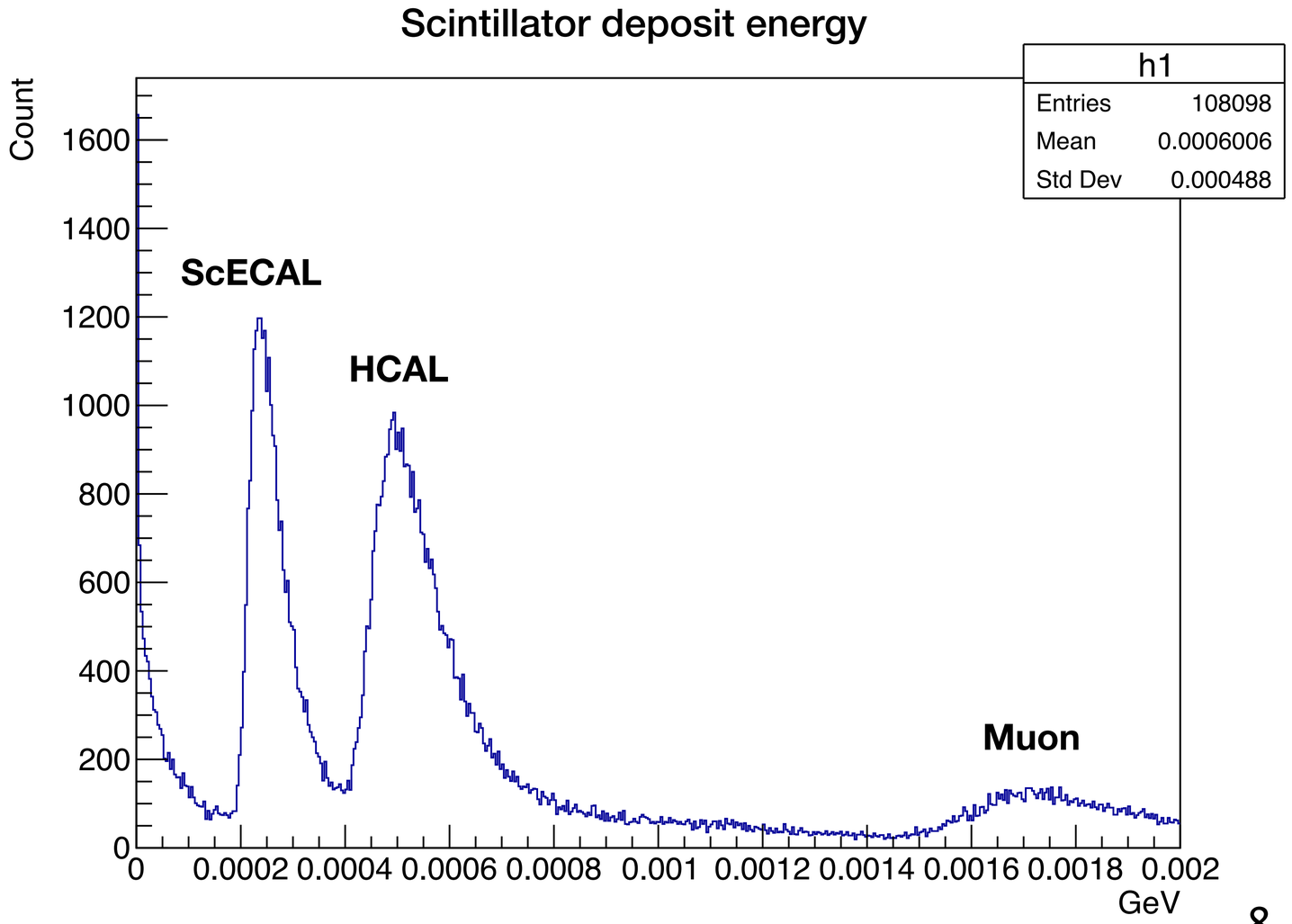
- Parameter: calibration_mip
- Use 10GeV muon 1k Event
- Theta 85 for Barrel (85 deg.)
- Theta 20 for Endcap (20 deg.)
  - E1-calib.Ps_pm13_p010_t20.Glcio_gun.e0.p0.I110107.n1.slcio
  - E1-calib.Ps_pm13_p010_t85.Glcio_gun.e0.p0.I110109.n1.slcio



Hit map of theta 20 muon for barrel calibration

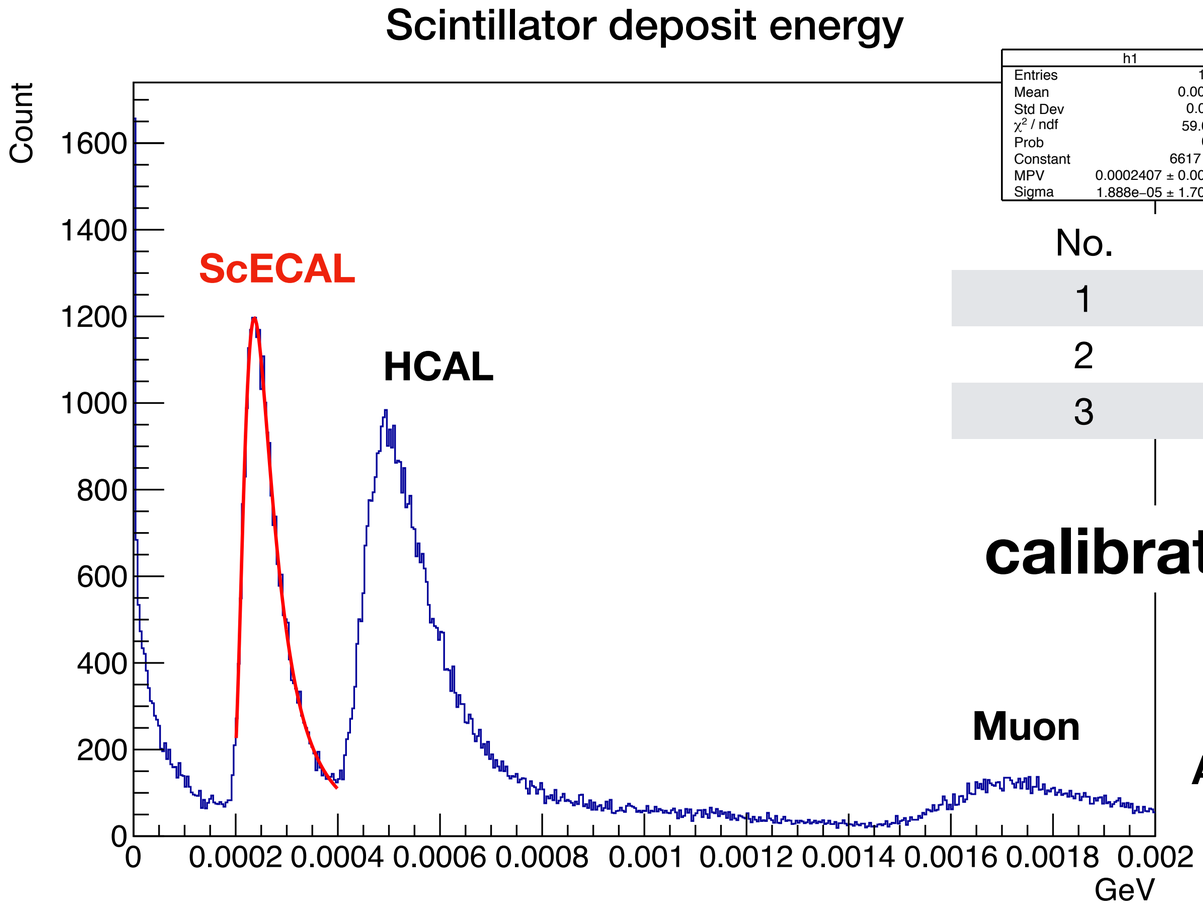
Mip Calibration

- Parameter: calibration_mip
- 10GeV muon
- Plot scintillator deposit energy (from LCTuple
- We have 3 scintillator detectors
  - ScECAL (1.5mm thickness)
  - HCAL (3mm thickness)
  - Muon (10mm thickness)
- Separated 3 detectors
- Energy deposits are locating in proportion to the thickness of scintillator



Mip Calibration

- Parameter: calibration_mip
- Fit landau function
- At Barrel



No.	NAME	VALUE	ERROR
1	**Constant**	**3.1498E+03**	**2.97781E+01**
2	**MPV**	**2.40743e-04**	**2.79603E-07**
3	**Sigma**	**1.87398E-05**	**1.83411E-07**

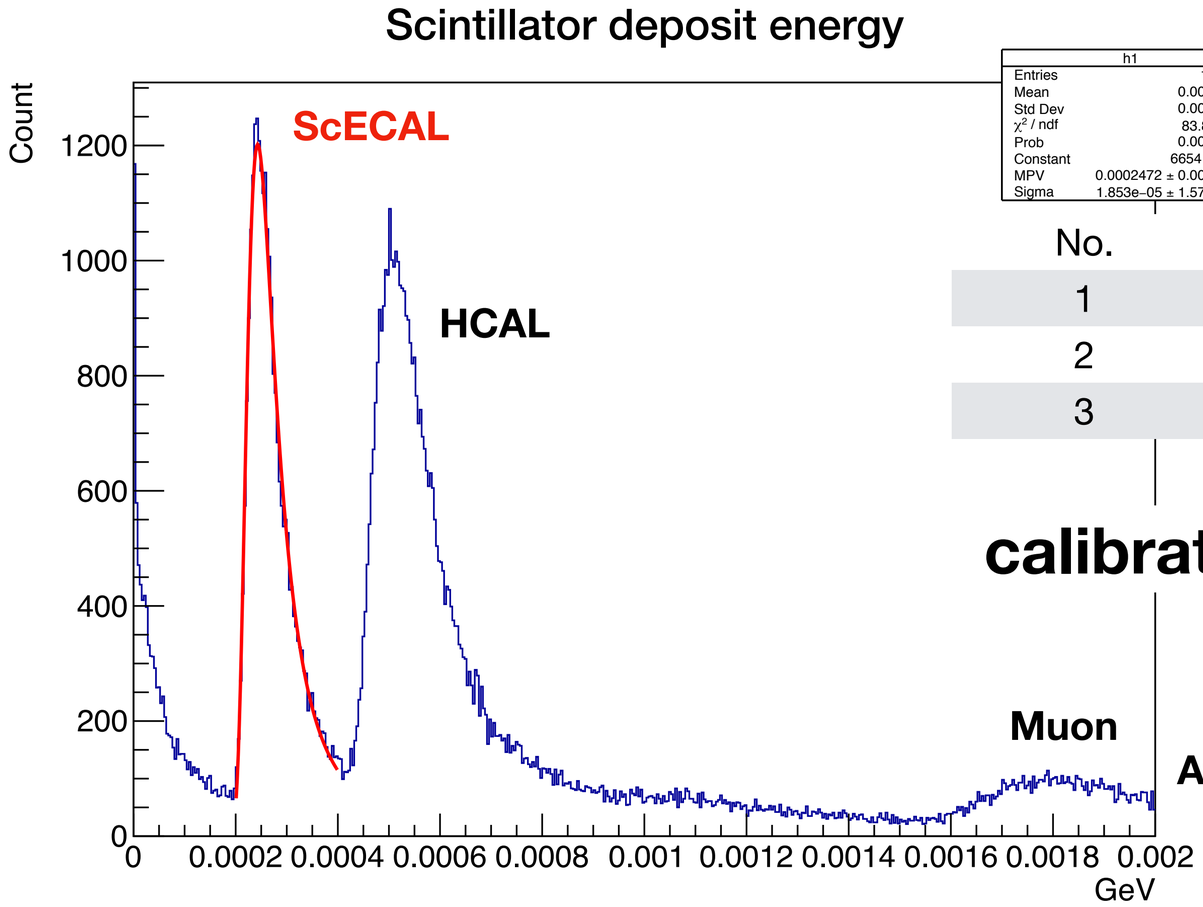
calibration_mip -> 0.000240743 GeV

Sc 1.5mm dE/dx consistent

At 3mm Sc(AHCAL) = 0.4925(MeV) at barrel

Mip Calibration

- Parameter: calibration_mip
- Fit landau function
- At Endcap



h1	
Entries	105871
Mean	0.0005924
Std Dev	0.0004644
χ^2 / ndf	83.82 / 47
Prob	0.0007668
Constant	6654 ± 61.2
MPV	0.0002472 ± 0.0000003
Sigma	1.853e−05 ± 1.579e−07

No.	NAME	VALUE	ERROR
1	**Constant**	**6.65380E+03**	**6.11531E+01**
2	**MPV**	**2.47203e-04**	**2.52573E-07**
3	**Sigma**	**1.85295E-05**	**1.57888E-07**

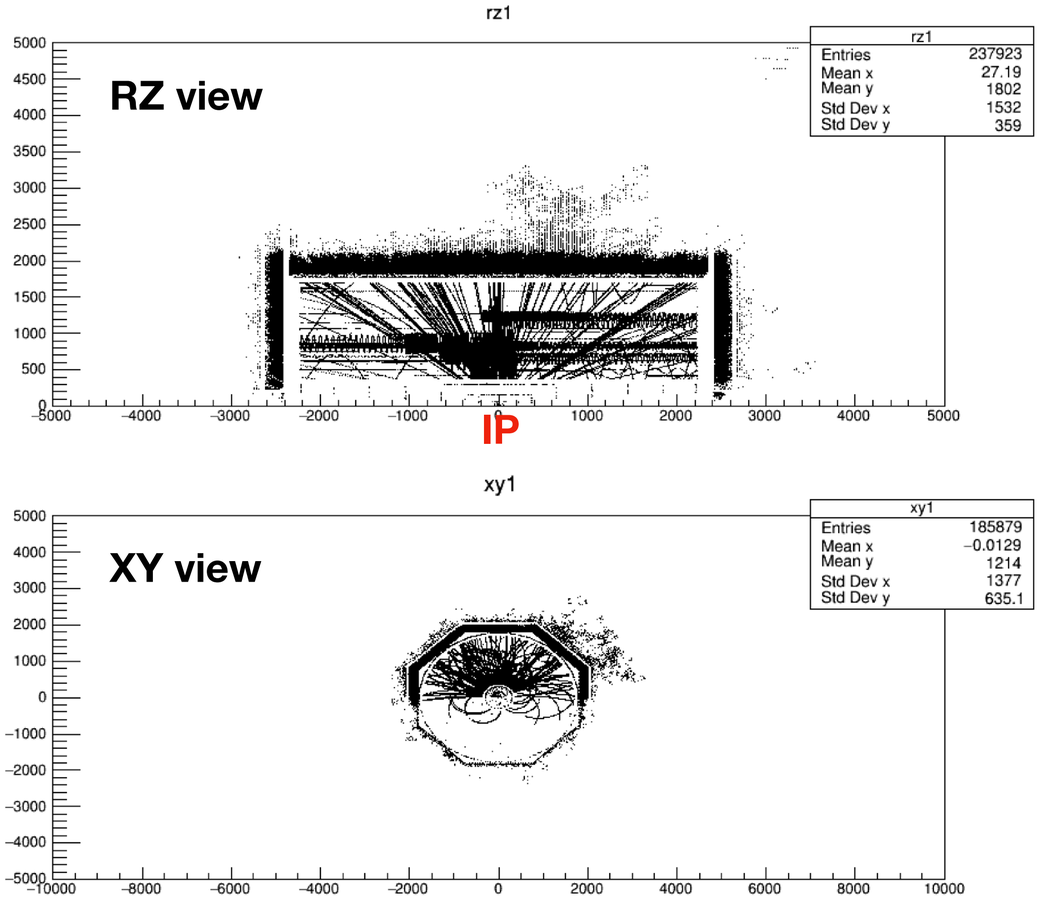
calibration_mip -> 0.000247203 GeV

Sc 1.5mm dE/dx consistent

At 3mm Sc(AHCAL) = 0.4825(MeV) at endcap

Energy Calibration

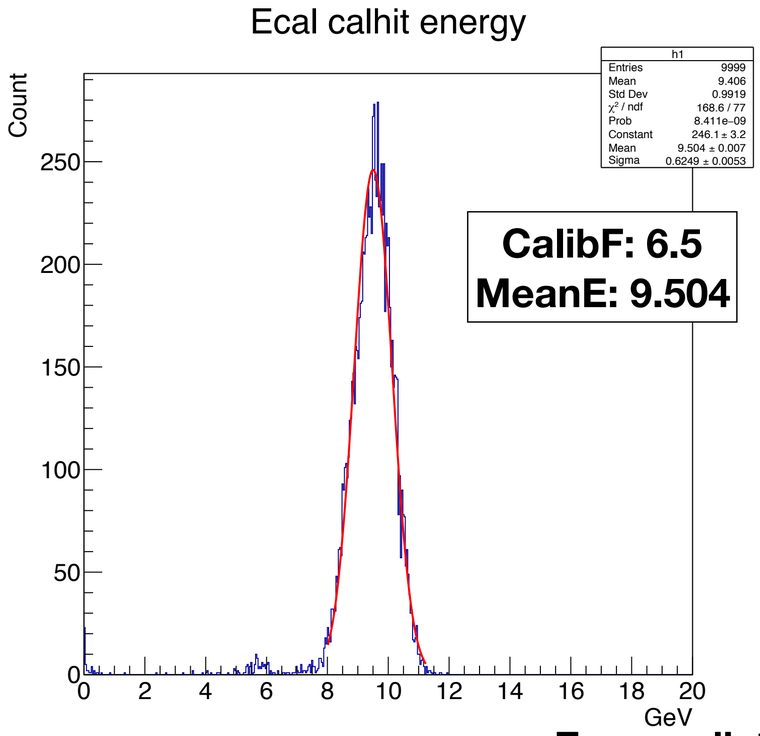
- Parameter: calibration_factorsMipGev
- Use 10GeV gamma
  - E1-calib.Ps_22_p010.Glcio_gun.e0.p0.I110141.n1.slcio
- Injection both barrels and endcaps
- Barrel and endcap are not separately checked

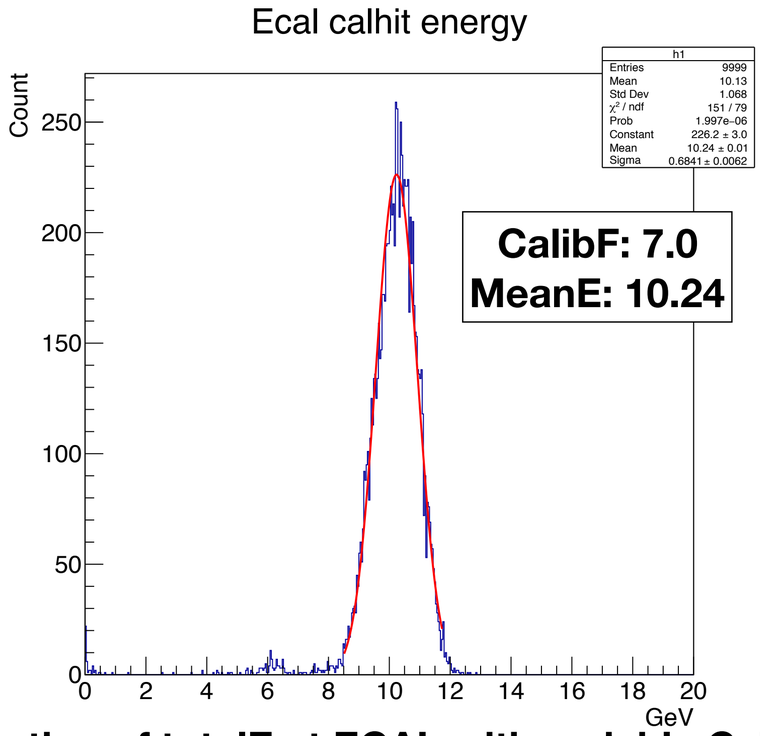


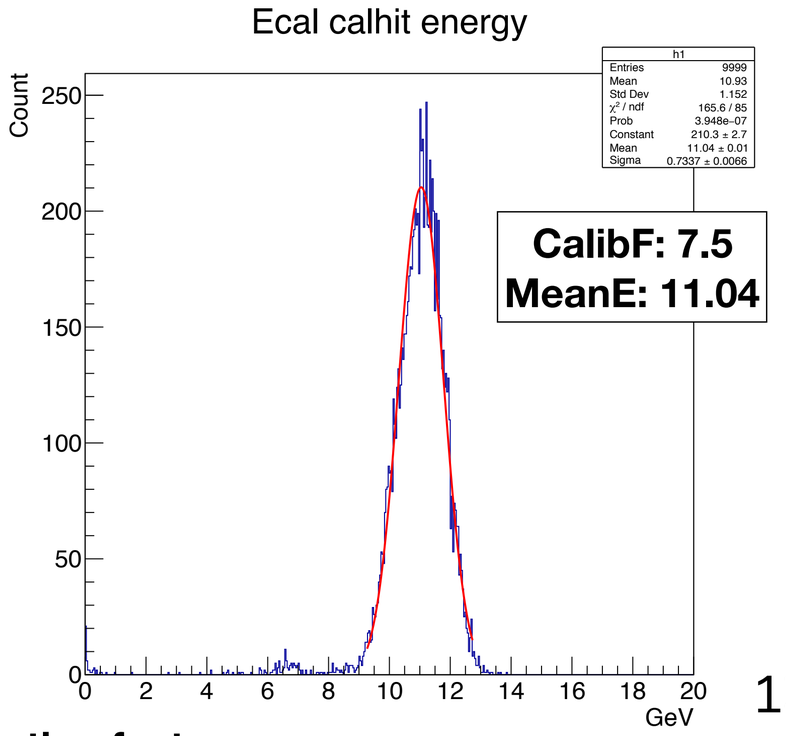
Hit map of gamma 10k Event overlaid

Energy Calibration

- Parameter: calibration_factorsMipGev
- Use 10GeV gamma
- Change calibration_factorsMipGev 6.5, 6.75, 7.0, 7.25, 7.5 (x10^{-3})
- Check ECAL deposit Energy



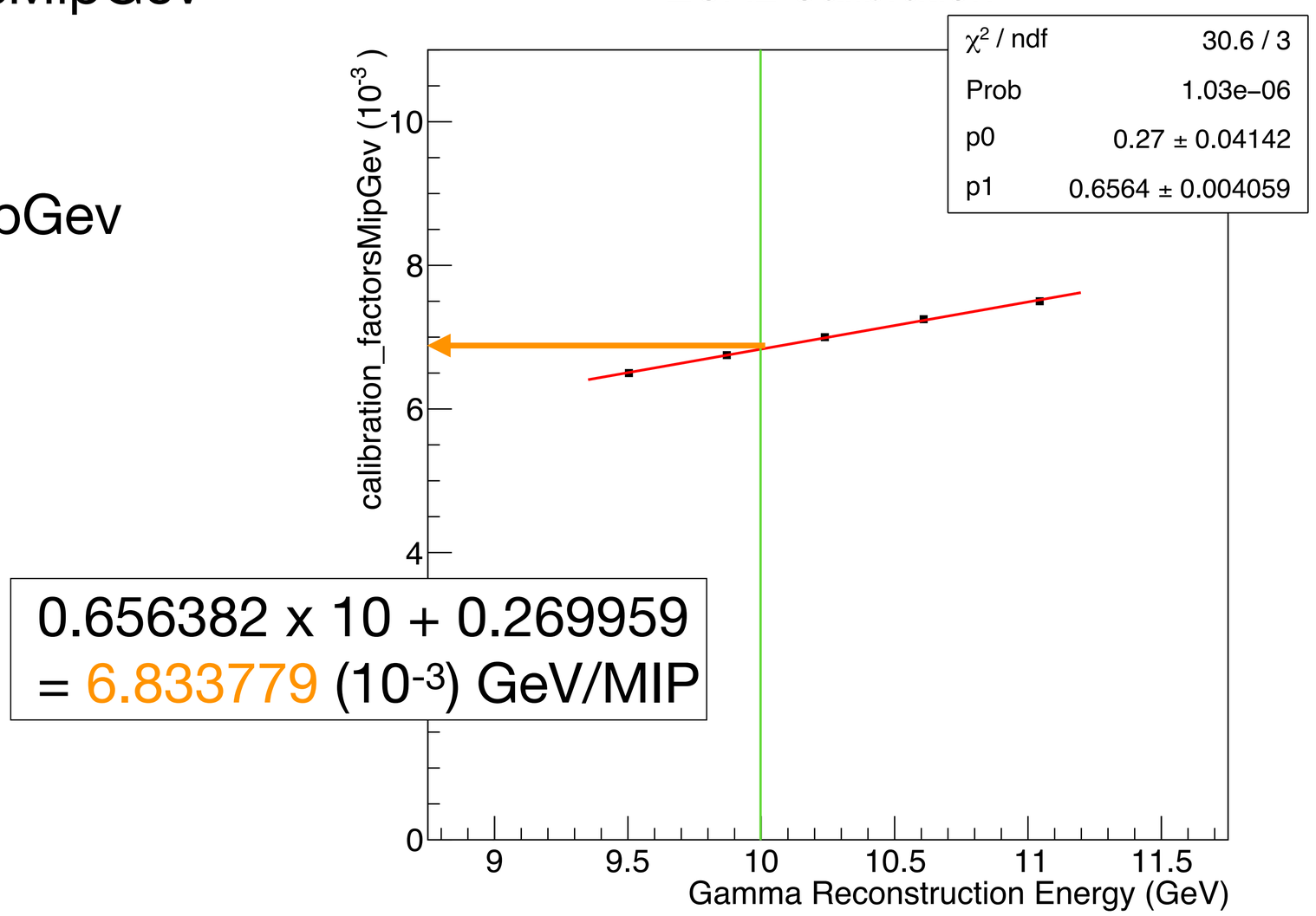




Energy distribution of totalE at ECAL with variable Calibration factor

Energy Calibration

- Parameter: calibration_factorsMipGev
- Use 10GeV gamma
- Change calibration_factorsMipGev
  6.5, 6.75, 7.0, 7.25, 7.5 (x10^{-3})
- Check ECAL deposit Energy



0.656382 x 10 + 0.269959
= 6.833779 (10^{-3}) GeV/MIP

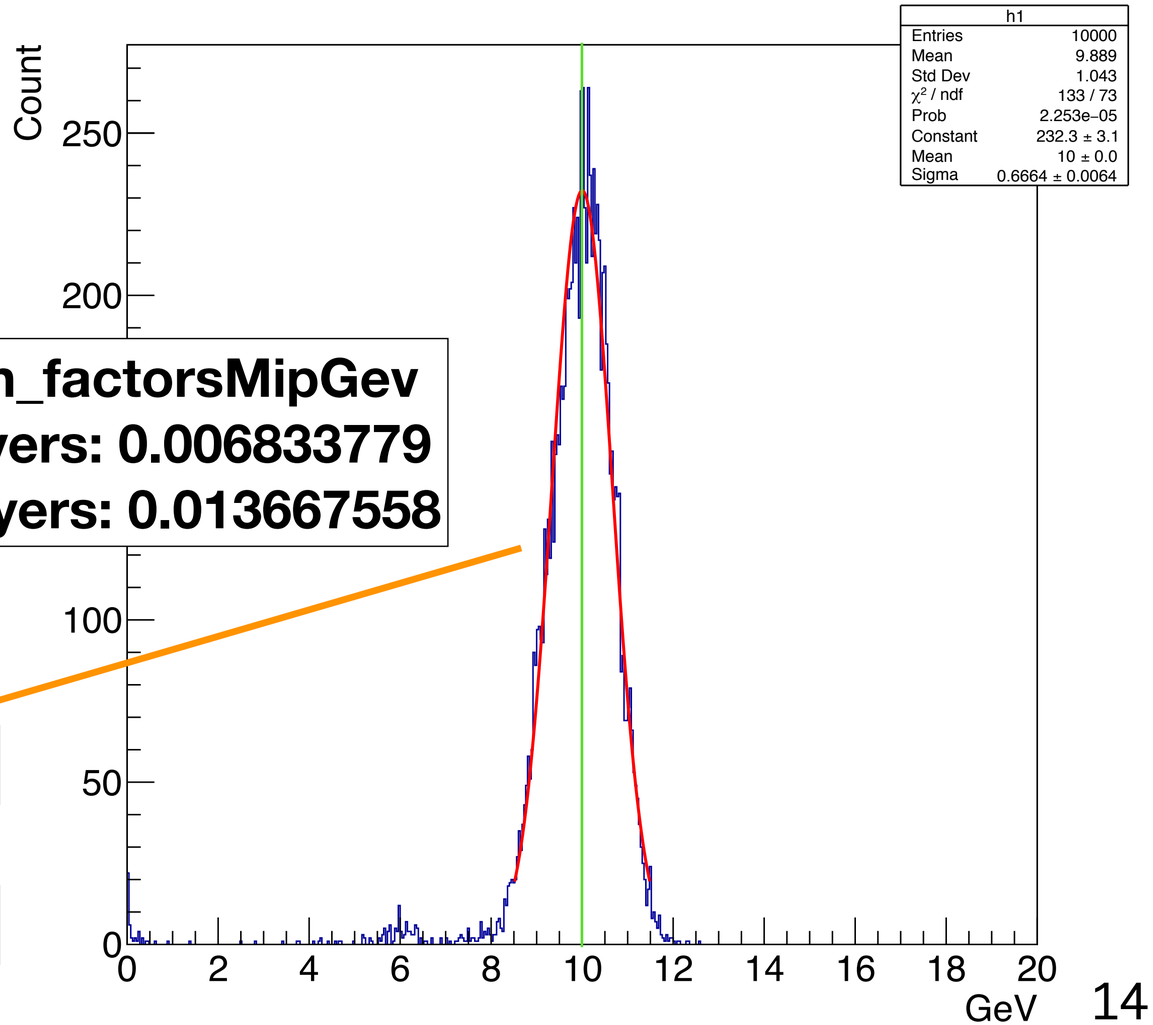
Energy Calibration

- Parameter: calibration_factorsMipGev
- Use 10GeV gamma
- Calculated calibration_factorsMipGev (p13)
- Check ECal deposit Energy
- At 10GeV result is good

No.	NAME	VALUE	ERROR
1	**Constant**	**2.32310E+02**	**3.05684E+00**
2	**Mean**	**1.00008e+01**	**7.44538E-03**
3	**Sigma**	**6.66415E-01**	**6.36020E-03**

calibration_factorsMipGev
First 20 layers: 0.006833779
Later 11 layers: 0.013667558

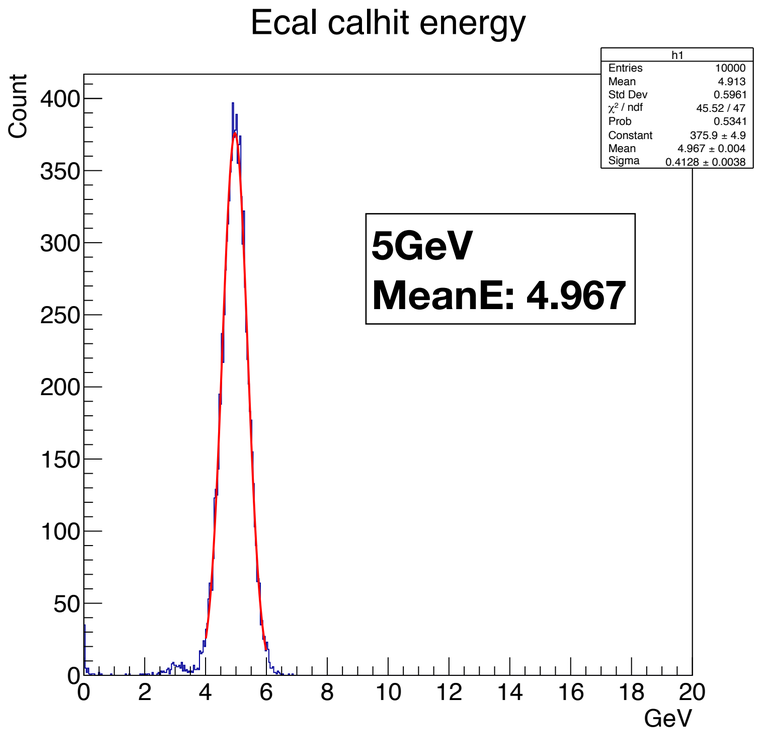
Ecal calhit energy

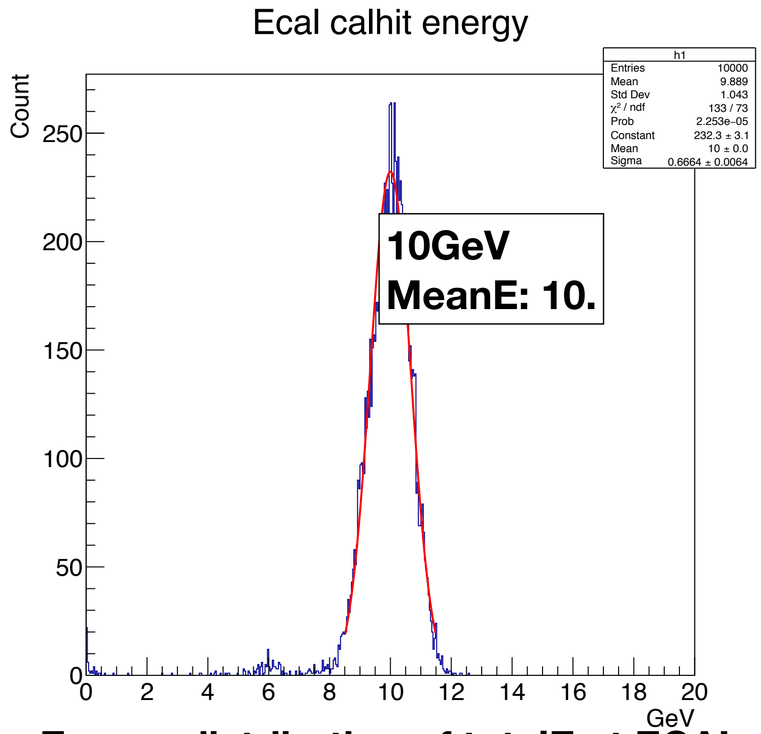


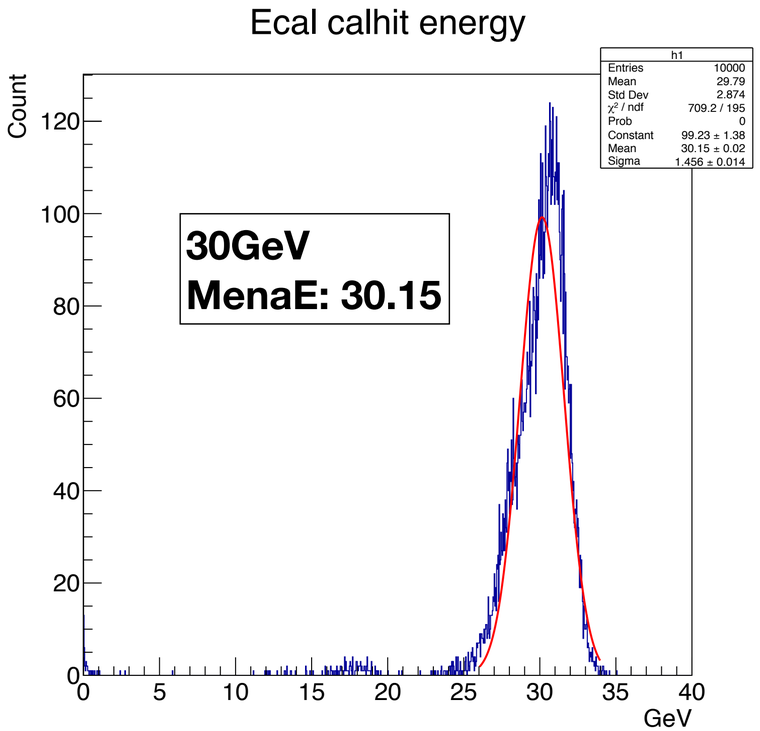
Energy distribution of totalE at ECAL after calibration

Energy linearity of gamma

- Linearity of Gamma Energy at ScECAL
  - Gamma 2, 3.5, 5, 10, 30, 50 GeV
  - E1-calib.Ps_22_*Glcio_gun.e0.p0.*.slcio



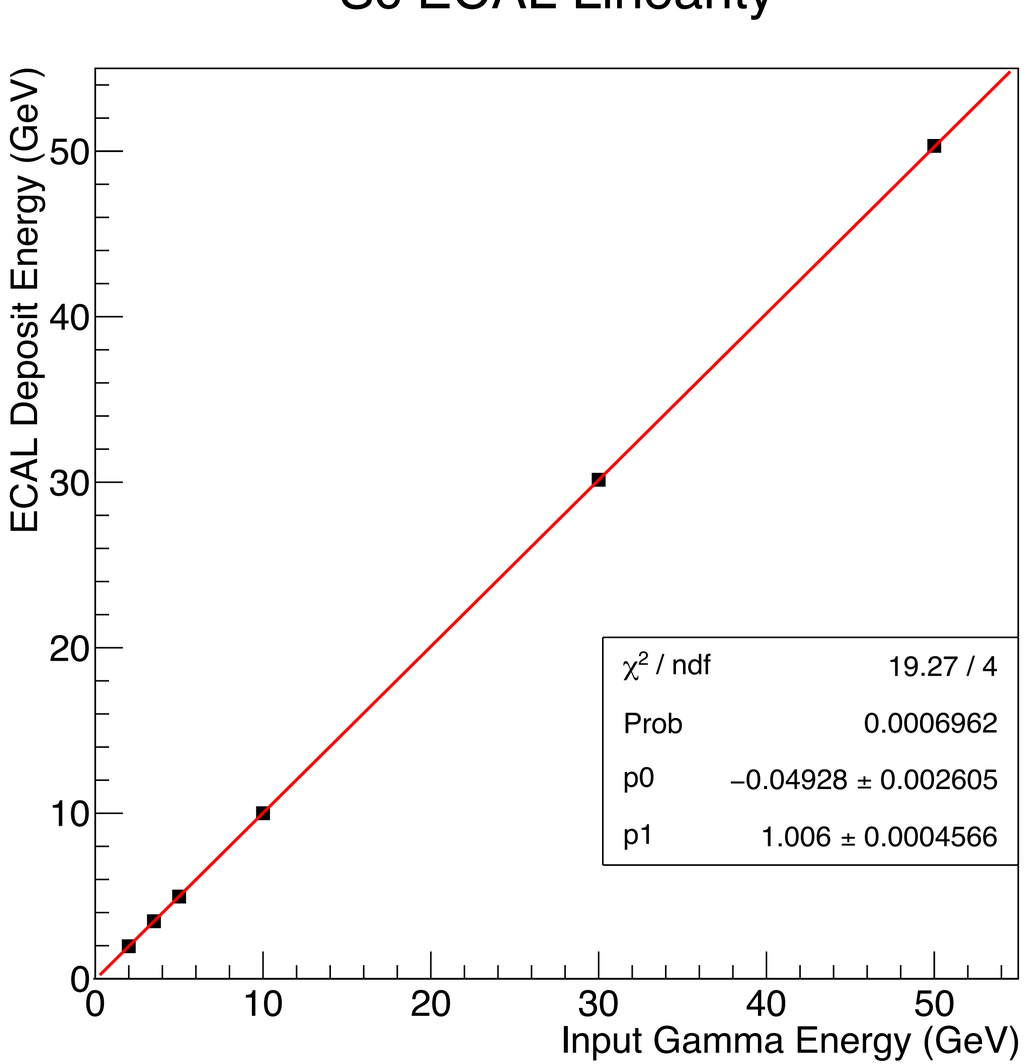




Energy distribution of totalE at ECAL

Energy linearity of gamma

- Linearity of Gamma Energy at ScECAL
  - Gamma 2, 3.5, 5, 10, 30, 50 GeV
  - E1-calib.Ps_22_*Glcio_gun.e0.p0.*.slcio
- Linearity is good
- with almost zero constant term

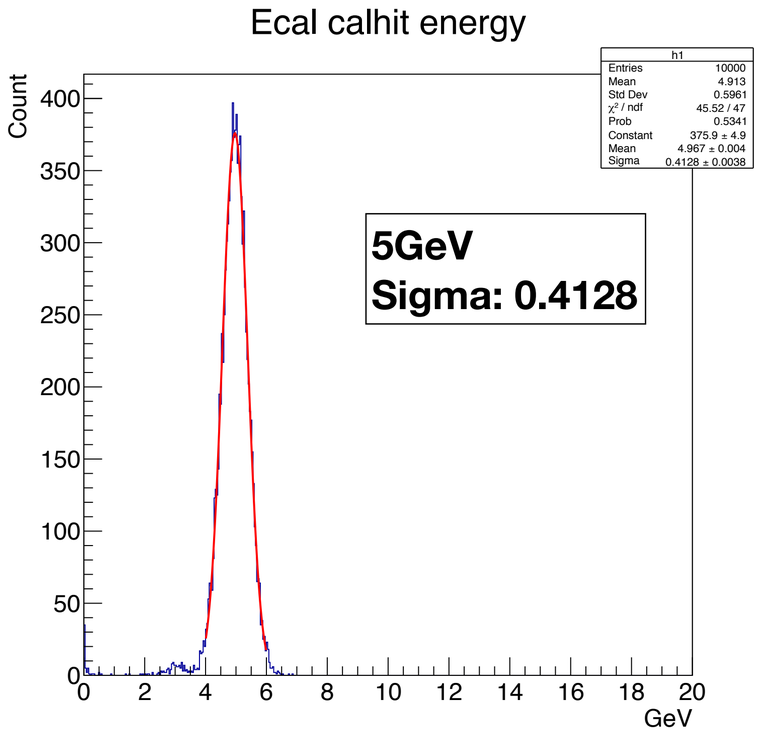


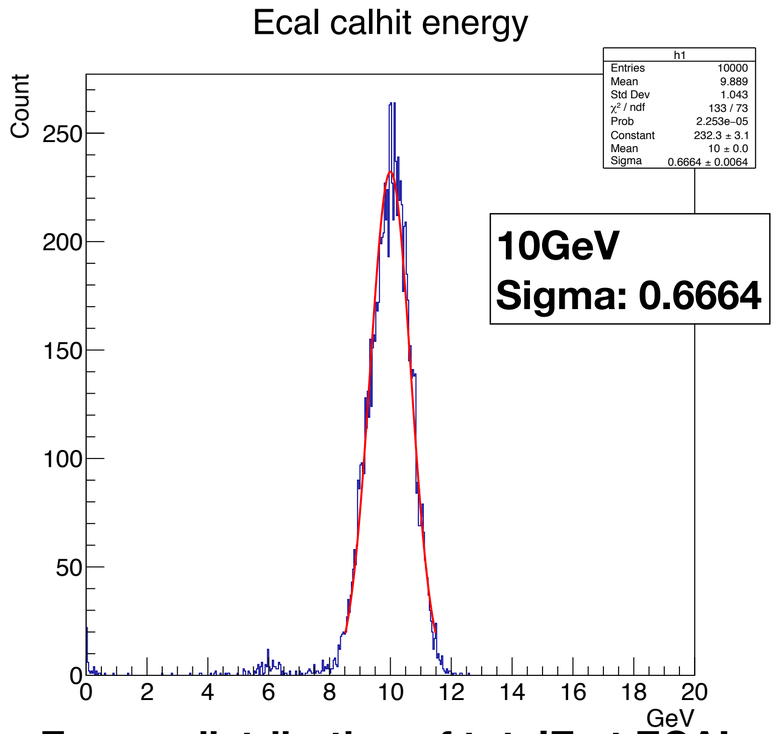
ScECAL calibration results

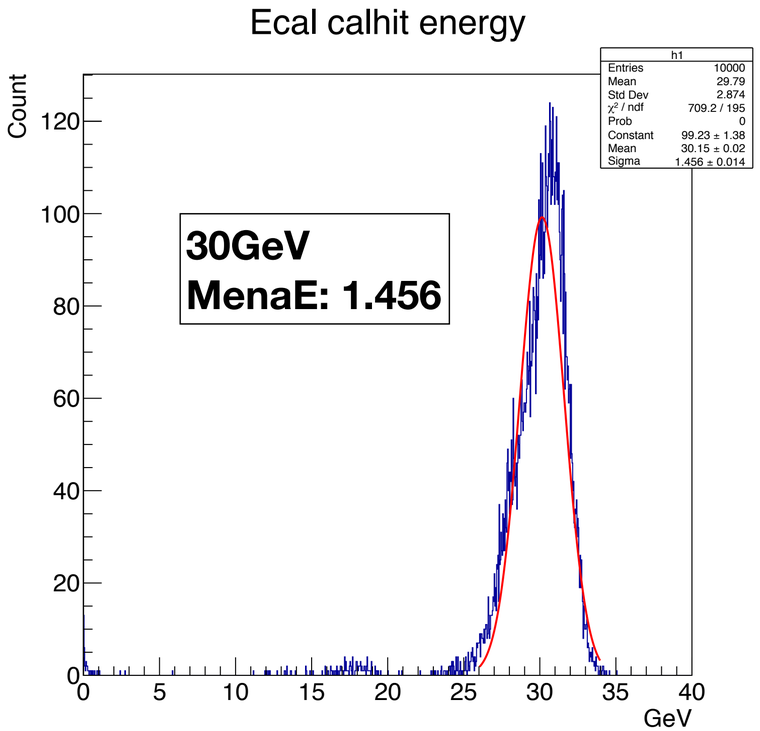
Sensor type	ScECAL	SiECAL	AHCAL
Collection	ECal*ScHits	ECal*SiHits	Hcal*RegCollection
CaloDigi	RealisticCaloDigiScinPpd	RealisticCaloDigiSilicon	RealisticCaloDigiScinPpd
ppd_mipPe (p.e)	7	-	15
ppd_npix (pixel)	10,000	-	2000
calibration_mip (GeV)	0.000240743 (at Barrel) 0.000247203 (at Endcap)	0.0001575	0.0004875 (at Barrel) 0.0004825 (at Endcap)
calibration_factorsMipGev	0.006787437	0.00641222630095 (at Barrel) 0.0066862777075 (at Endcap)	0.0289008640628 (at Barrel) 0.0231348530678 (at Endcap)

Energy resolution of gamma

- Energy resolution of gamma Energy at ScECAL
  - Gamma 2, 3.5, 5, 10, 30, 50 GeV
  - E1-calib.Ps_22_*Glcio_gun.e0.p0.*.slcio



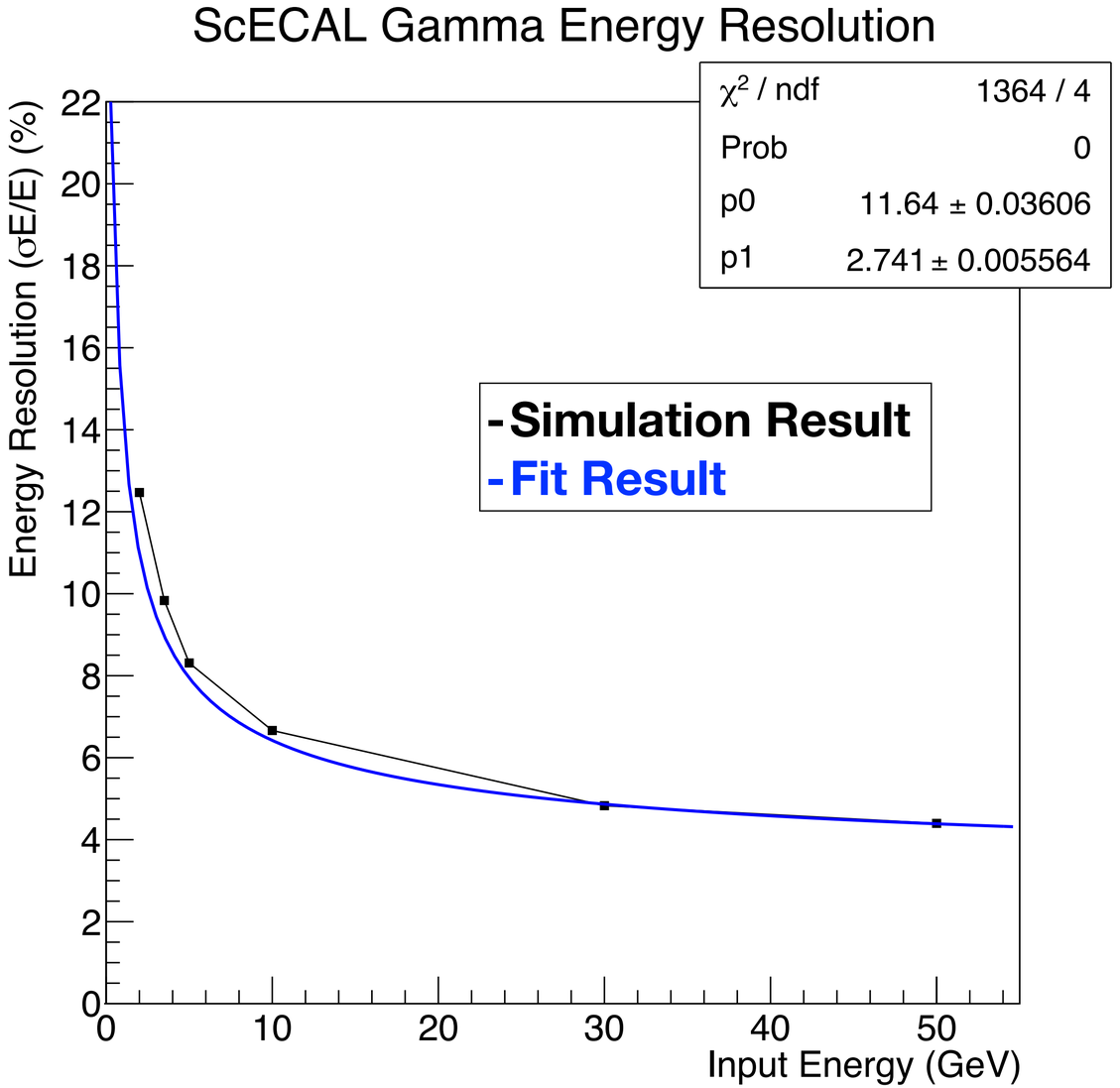




Energy distribution of totalE at ECAL

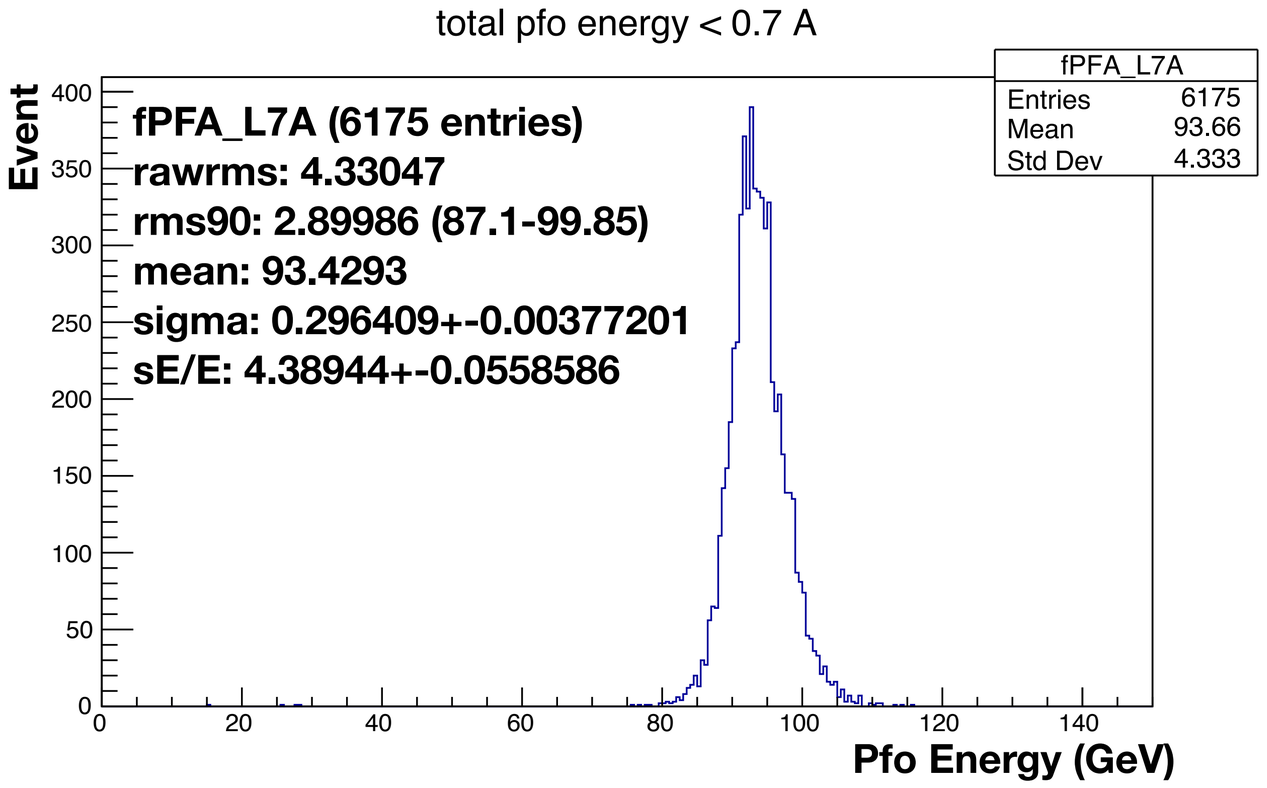
Energy resolution of gamma

- Energy Resolution
  - 2 3.5, 5, 10, 30, 50GeV gamma
  - E1-calib.Ps_22_*.Glcio_gun.e0.p0.*.slcio
- No SSA
- Fit result (σE/√E) is 11.64%
- But constant term 2.8% exists
- we will examine further more



Jet Energy Resolution

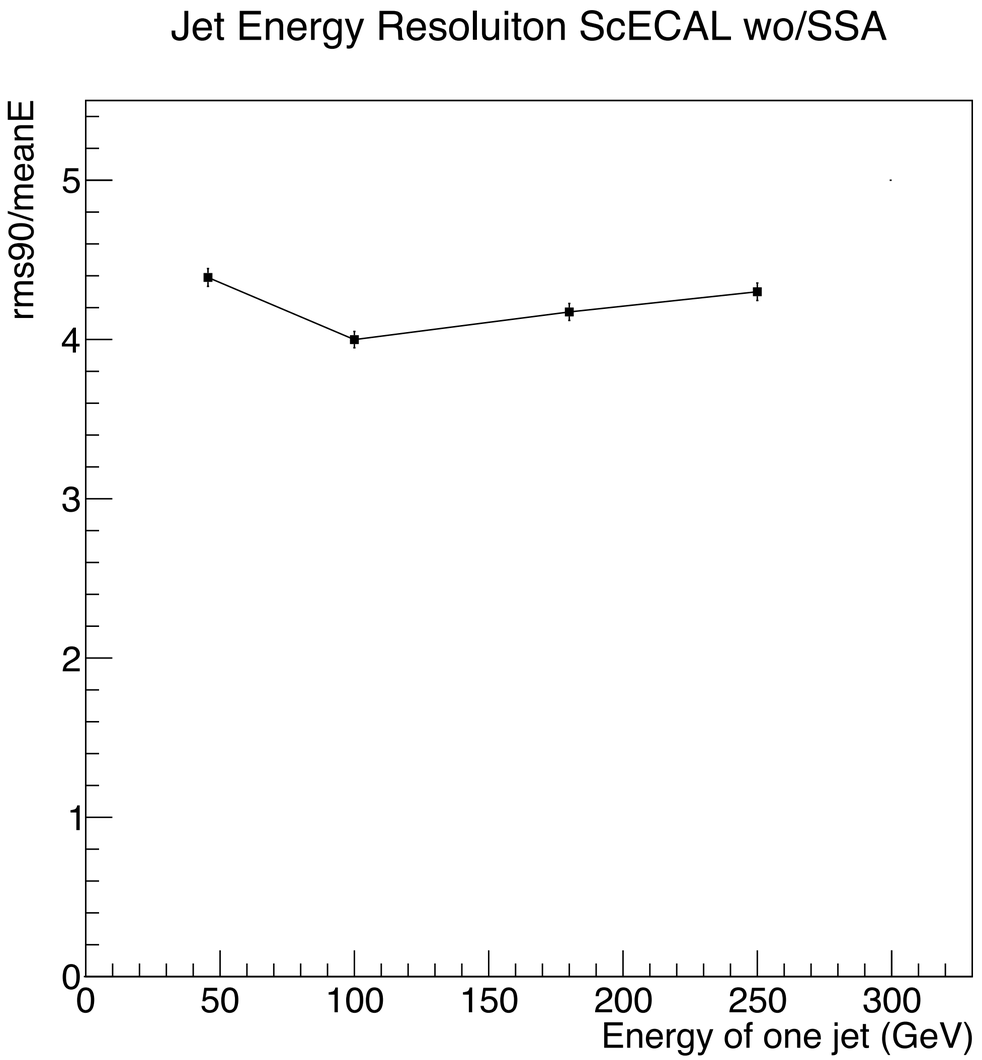
- Uds jet energy resolution
  - 91, 200, 360, 500GeV
  - E1-calib.Puds*.Gsgreen.e0.p0.*.stdhep
- No SSA
- Calculate rms90



Pro energy distribution at 91GeV udsjet

Jet Energy Resolution

- Uds jet energy resolution
  - 91, 200, 360, 500GeV
  - E1-calib.Puds*.Gsgreen.e0.p0.*.stdhep
- No SSA
- Not far from Mokka simulation result



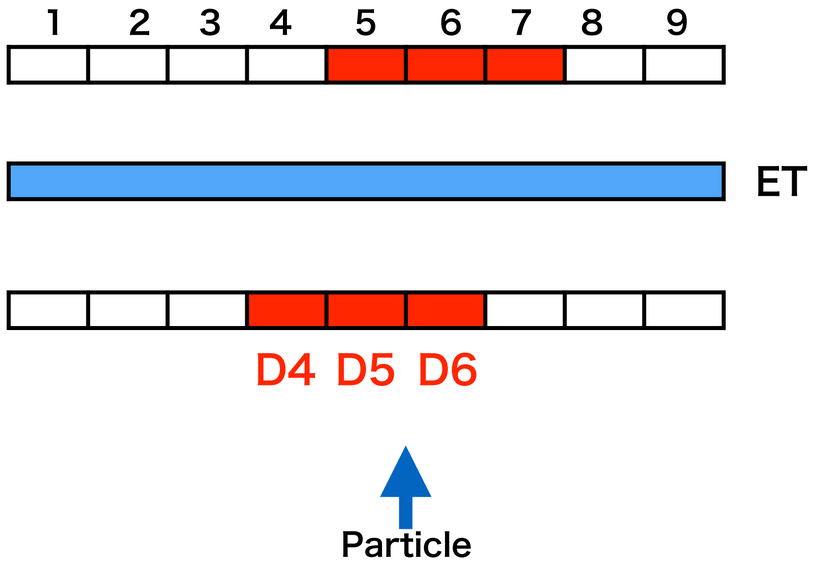
Summary

- We are developing and testing Scintillator ECAL
- ScECAL simulation is working
- ScECAL parameters were determined
- Energy linearity is good
- Gamma energy resolution is reasonable but need more study

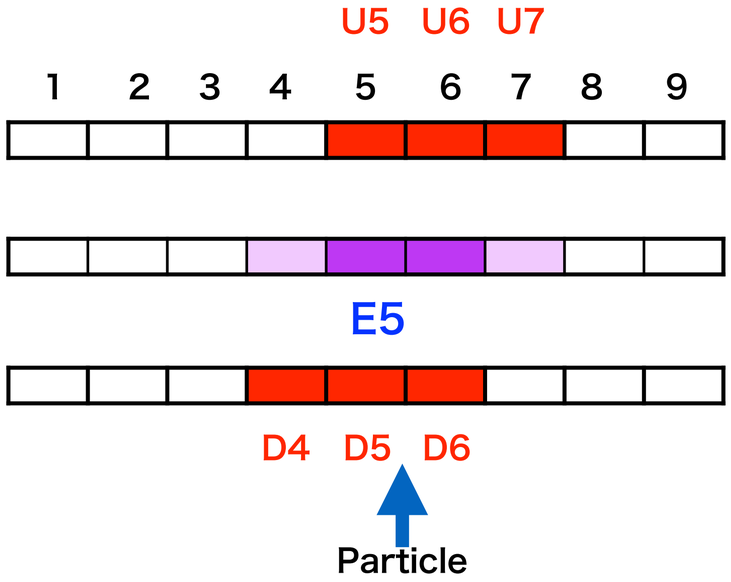
- Future Plan
  - Check energy calibration barrels and endcaps separately
  - Implement SSA into DD4hep for jet energy resolution improvement
  - Calibrate and tune Pandora PFA parameters

Backup

Strip Splitting Algorithm(SSA)

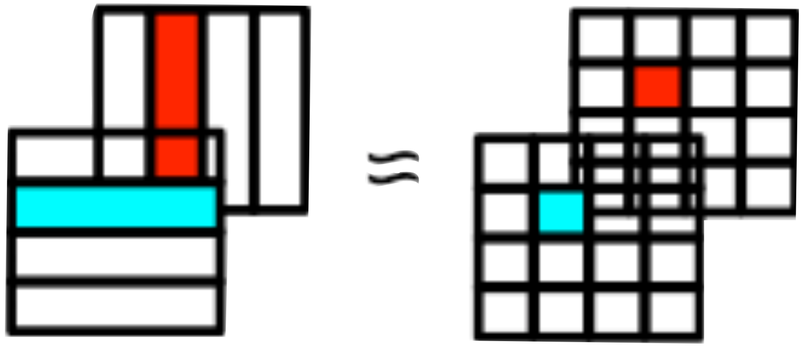


deposited energy is distributed into 9 virtual cells

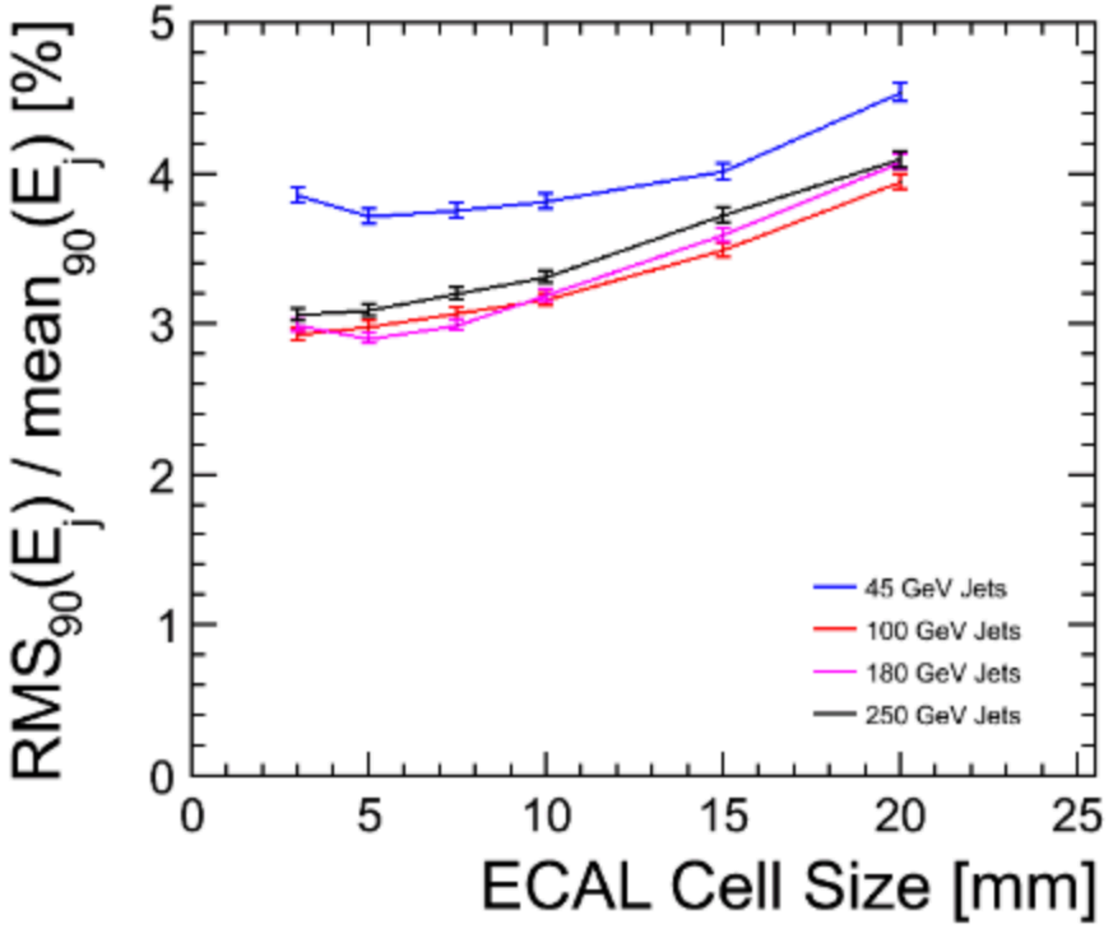


energy distributed in #cell5

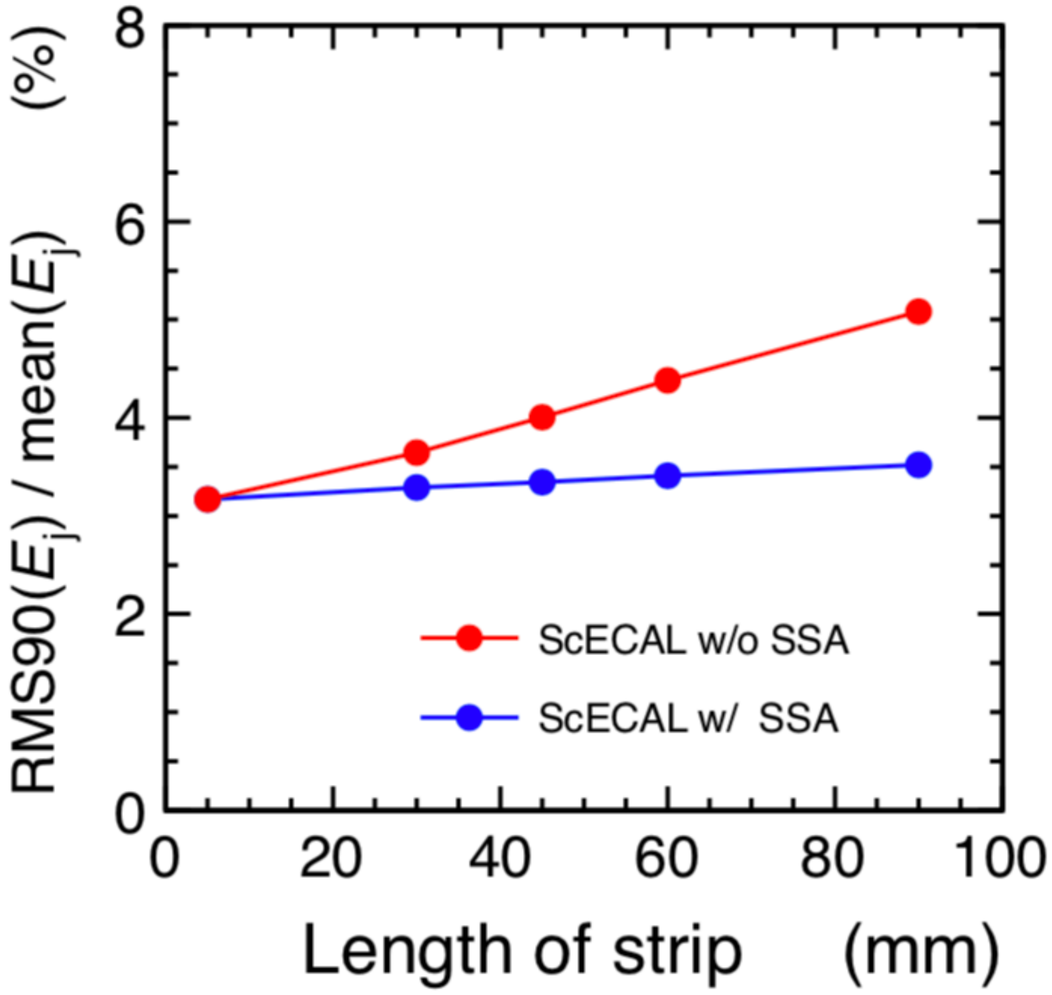
$$E5 = ET \times \frac{U5 + D5}{\sum_{9} Uj + \sum_{9} Dj}$$



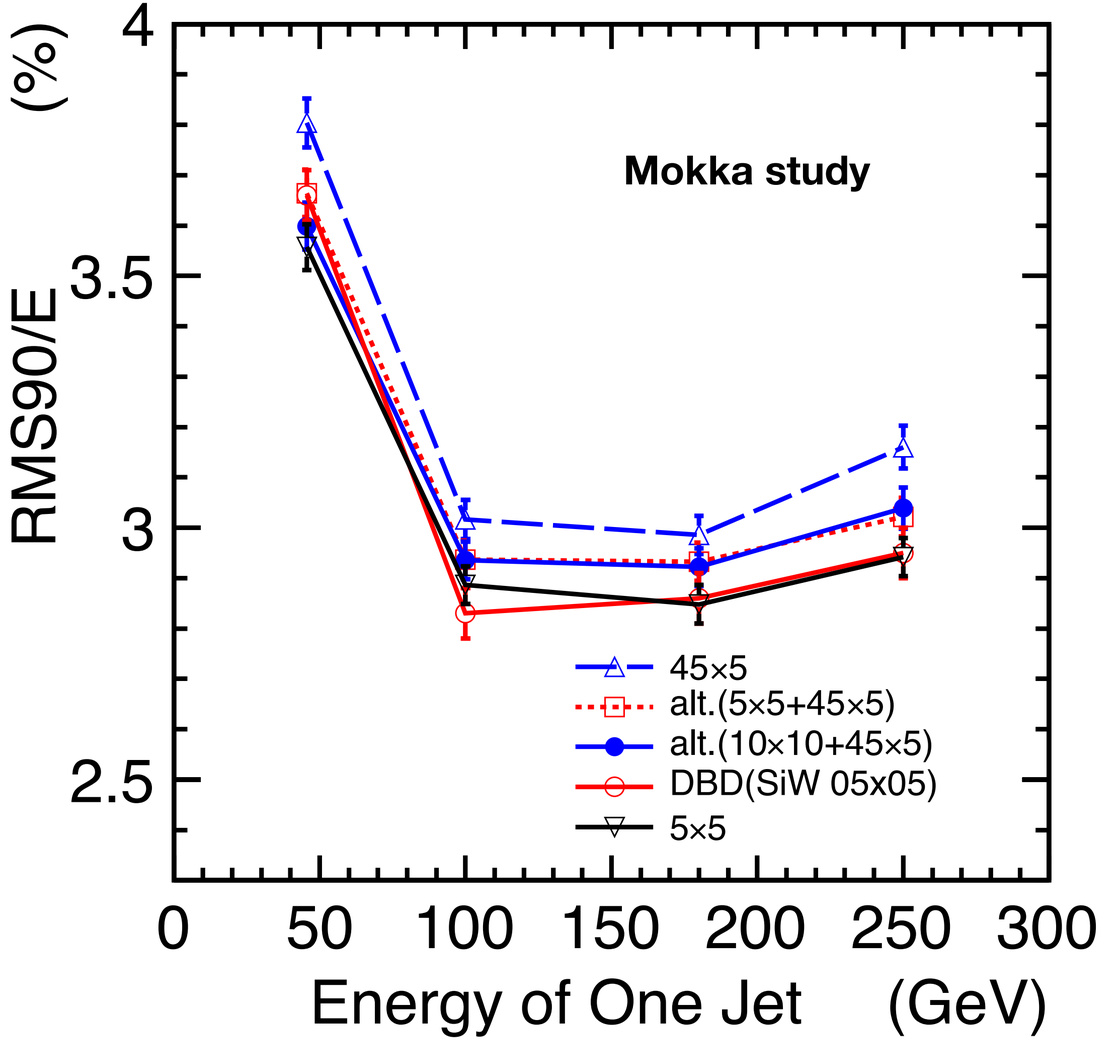
ECAL Cell Size

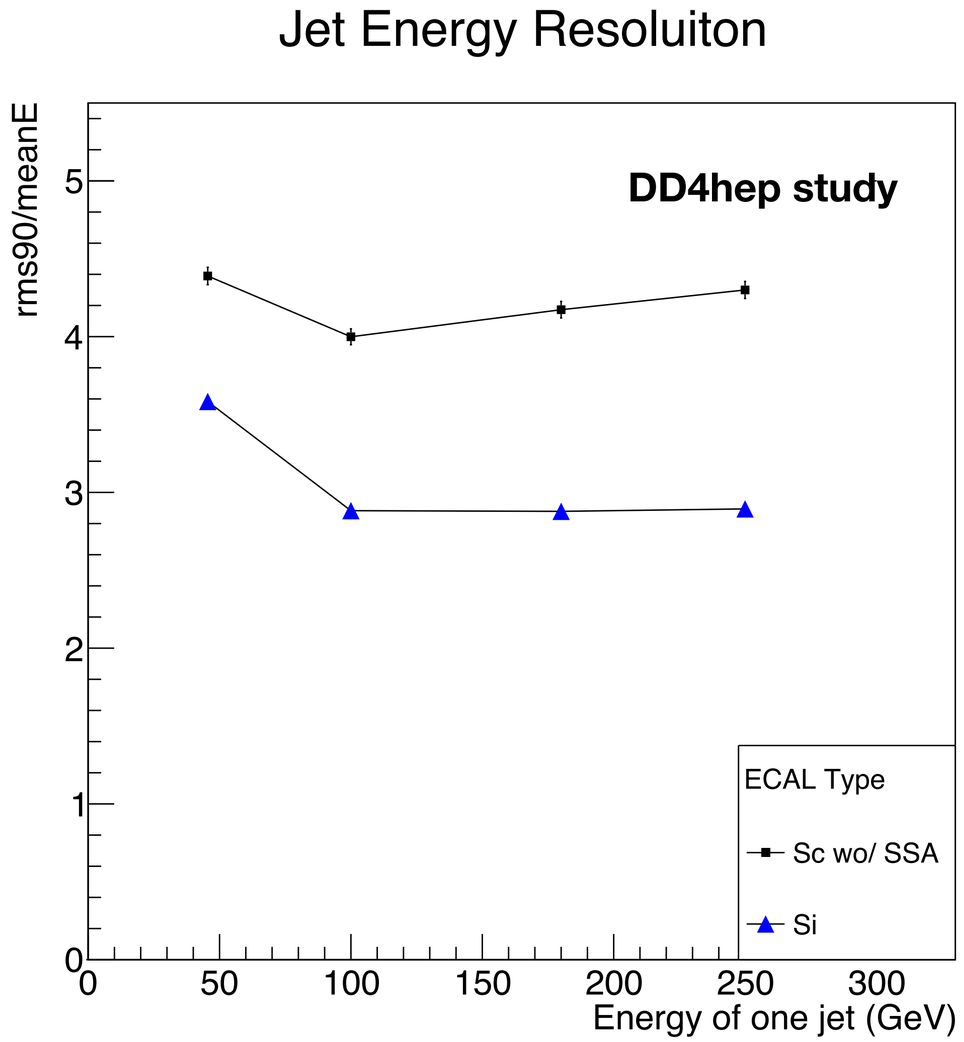


Energy Resolution vs Strip Length

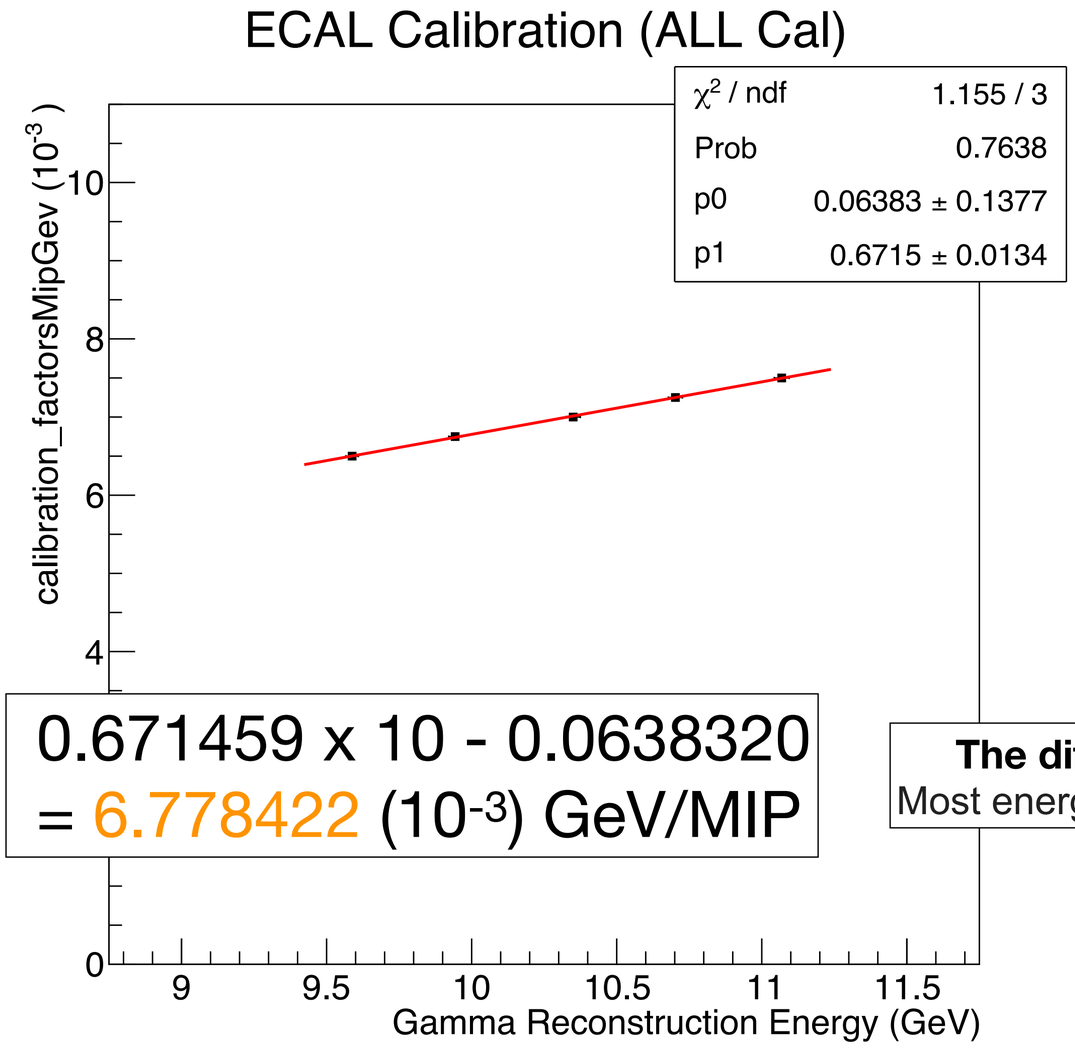


Jet Energy Resolution

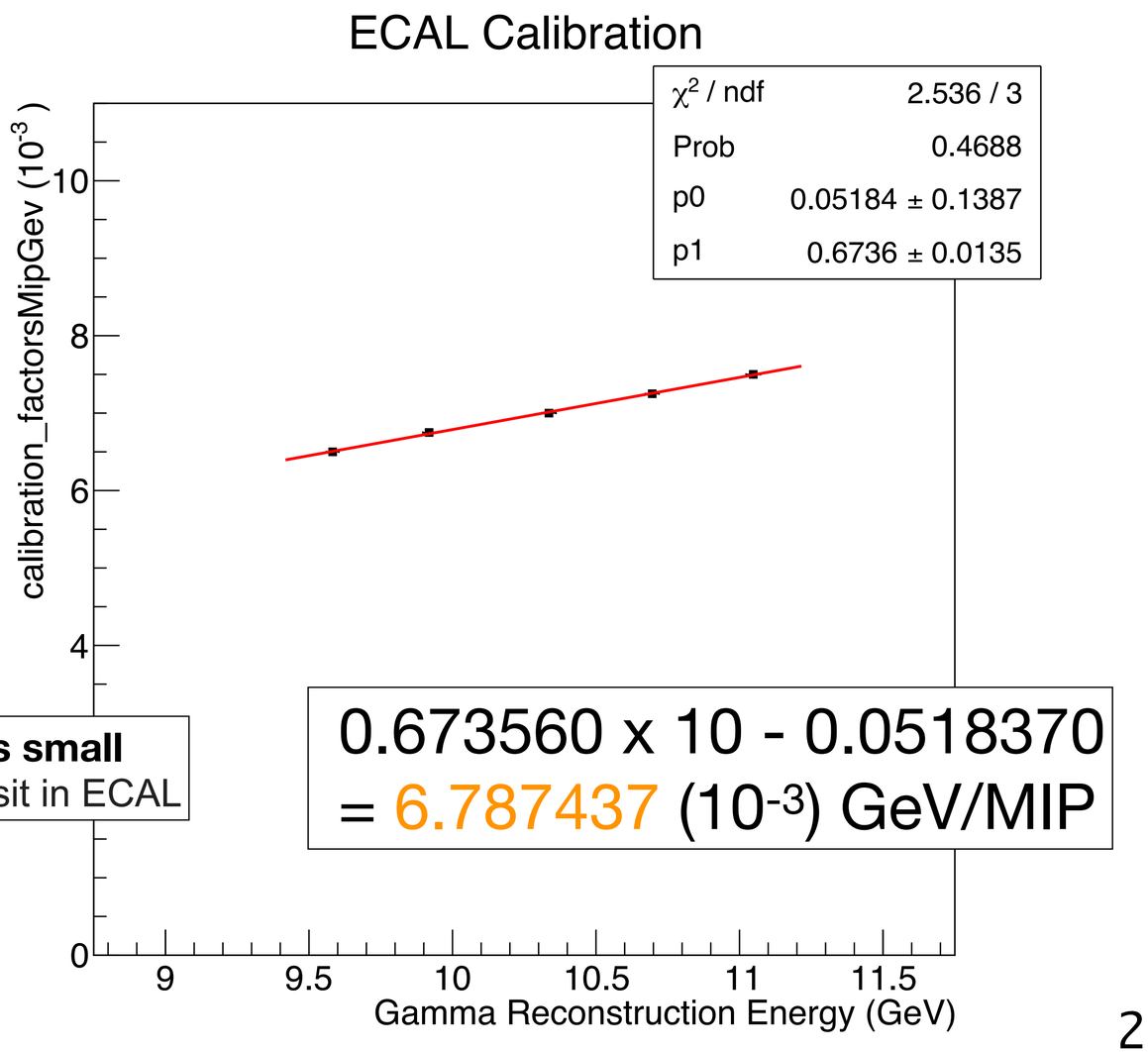




Calib use all cal



The difference is small
Most energy is Deposit in ECAL



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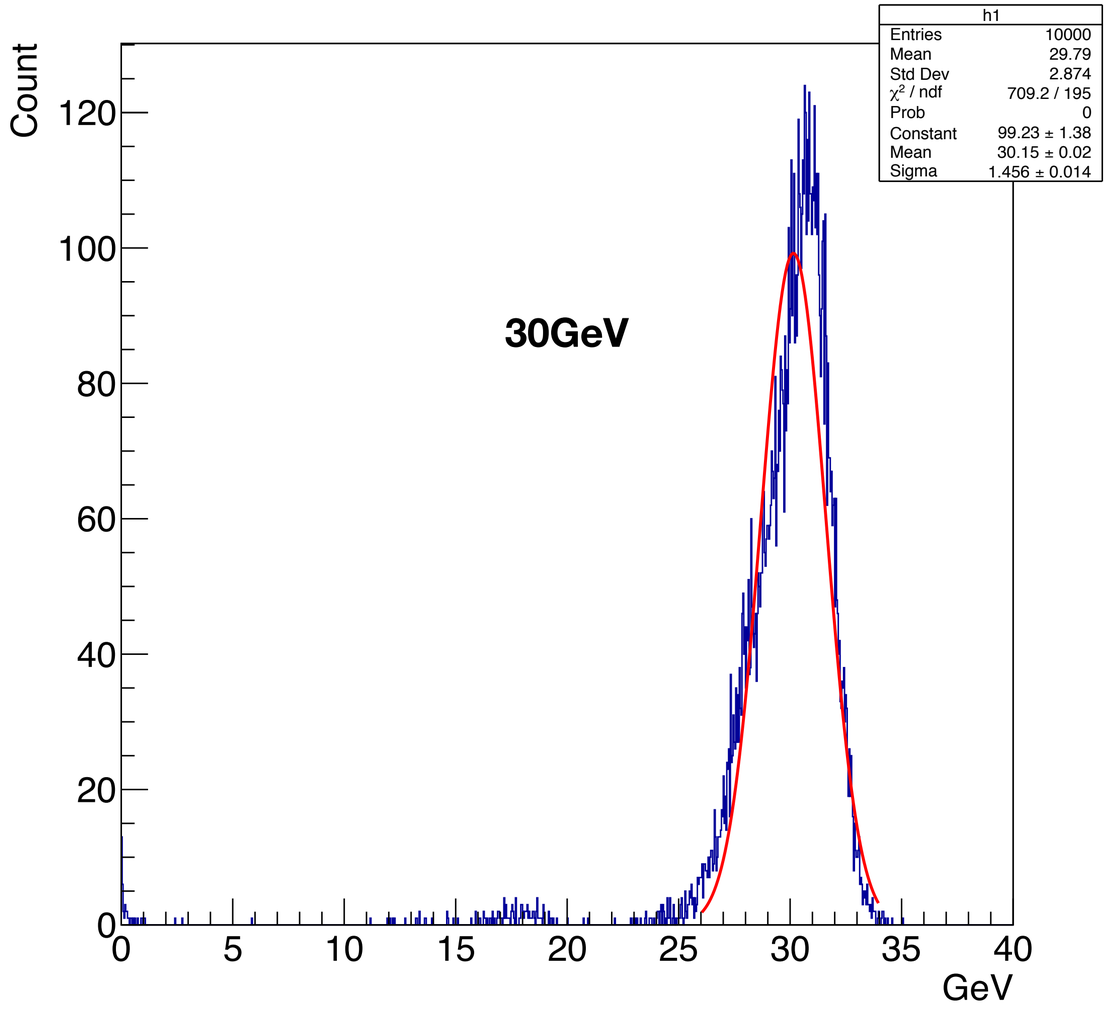
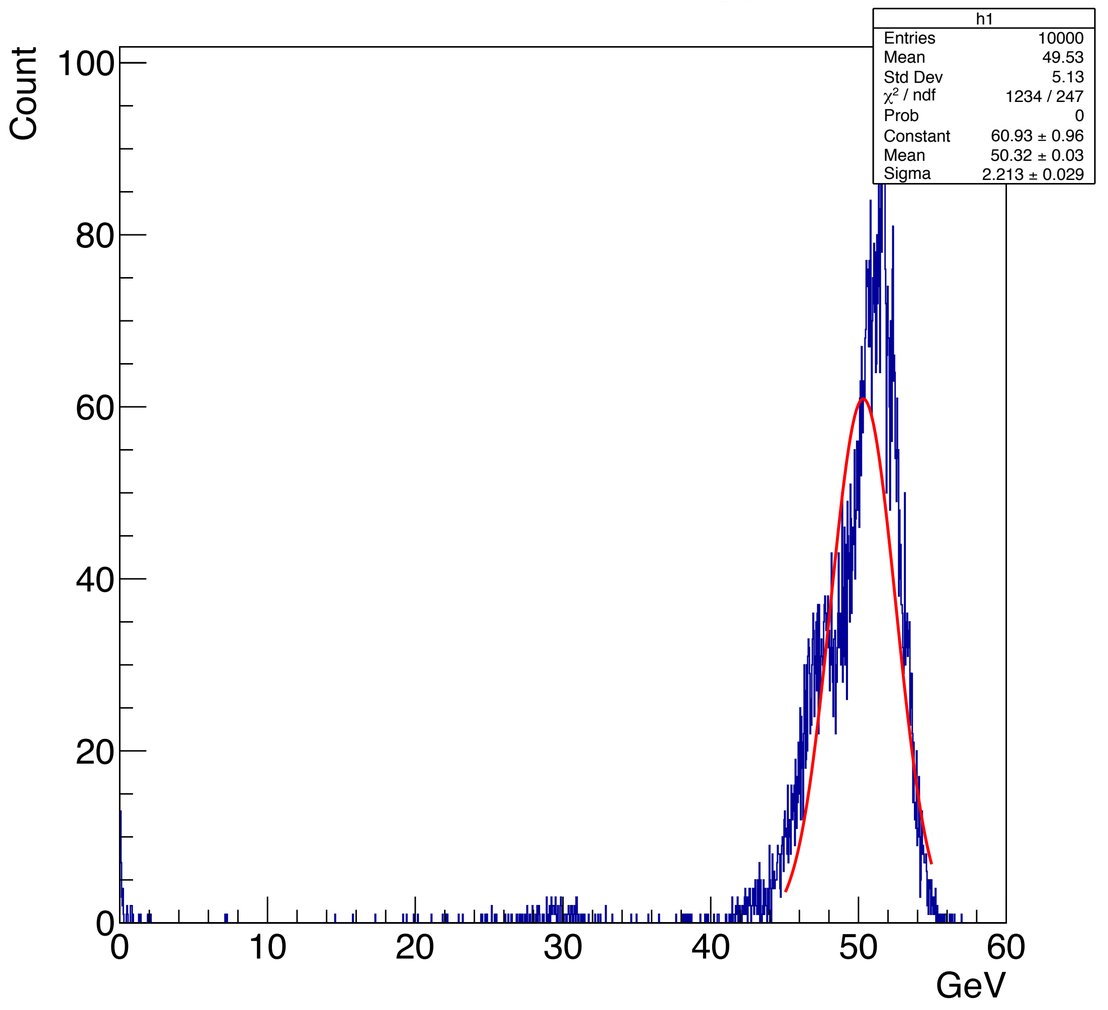
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