Simulation Status of ScECAL

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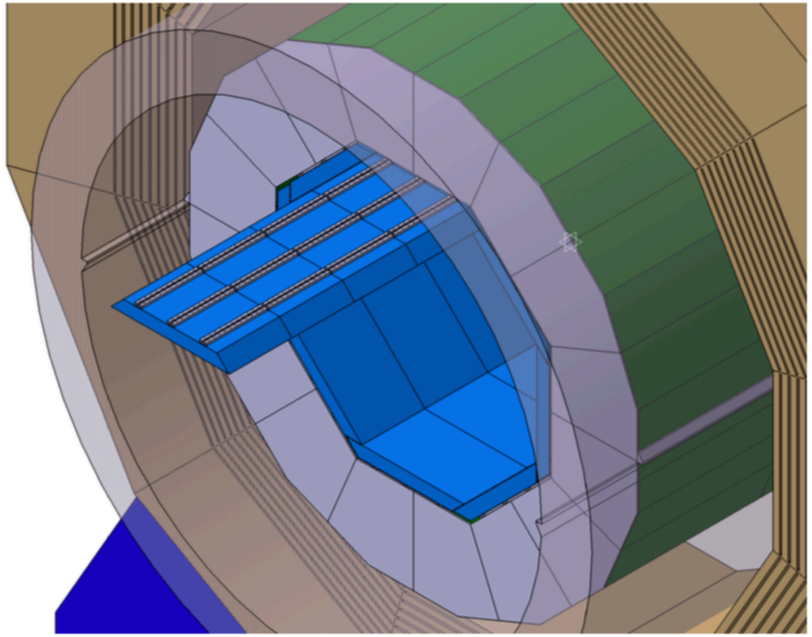
2018/10/12 ILC Seasonal Meeting@KEK

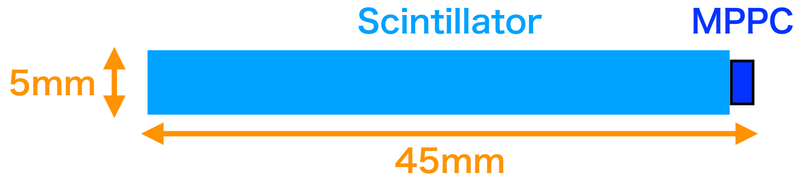
ILD ECAL

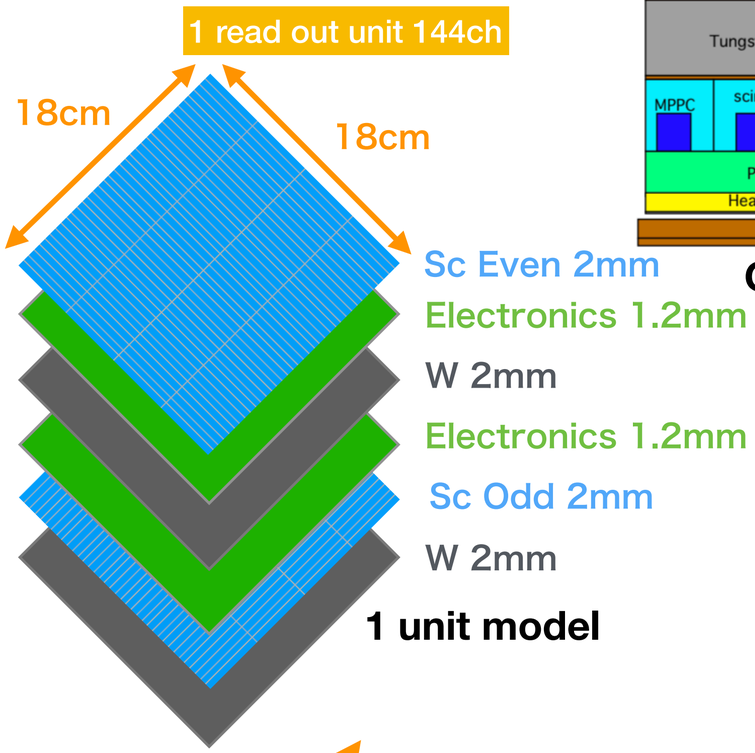
- ECAL
  - 5 x 5 mm^2 segmentation to incorporate with ILC physics requirements
  - Absorber is made of 30 layers of tungsten(W)
    the first 20 layers are 2.1 mm thickness
    the latter 10 layers are 4.2 mm thickness
  - sensor material is 2 options: Sc(scintillator strip) and Si(silicon pad)

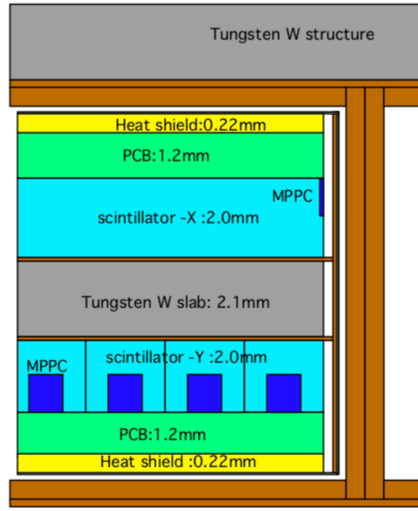


ScECAL

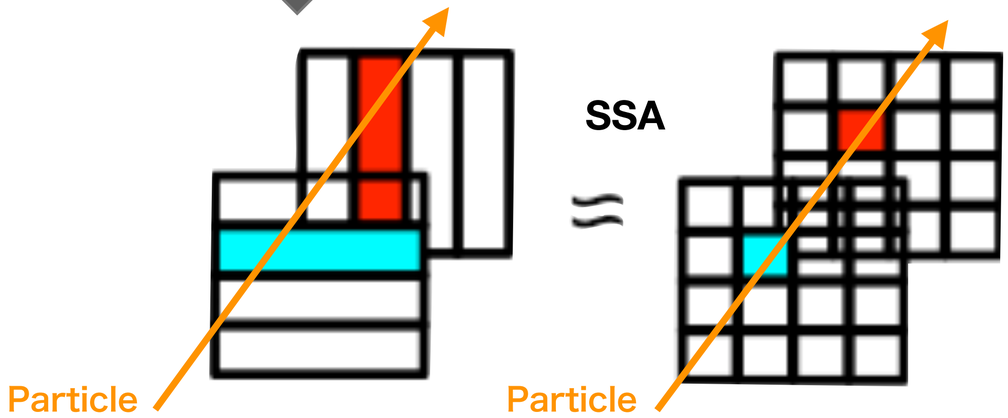
- Detection layer of ScECAL uses plastic scintillators and MPPCs as photo sensor
- Scintillator
  - Size is 45 x 5 mm^2
  - Layers are alternately arranged perpendicular to each other
  - 2mm thickness Sc in DBD model
- MPPC
  - 10k pixel (10μm pitch, 1x1 mm^2 sensor area)
- Divide the strip with SSA(Split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





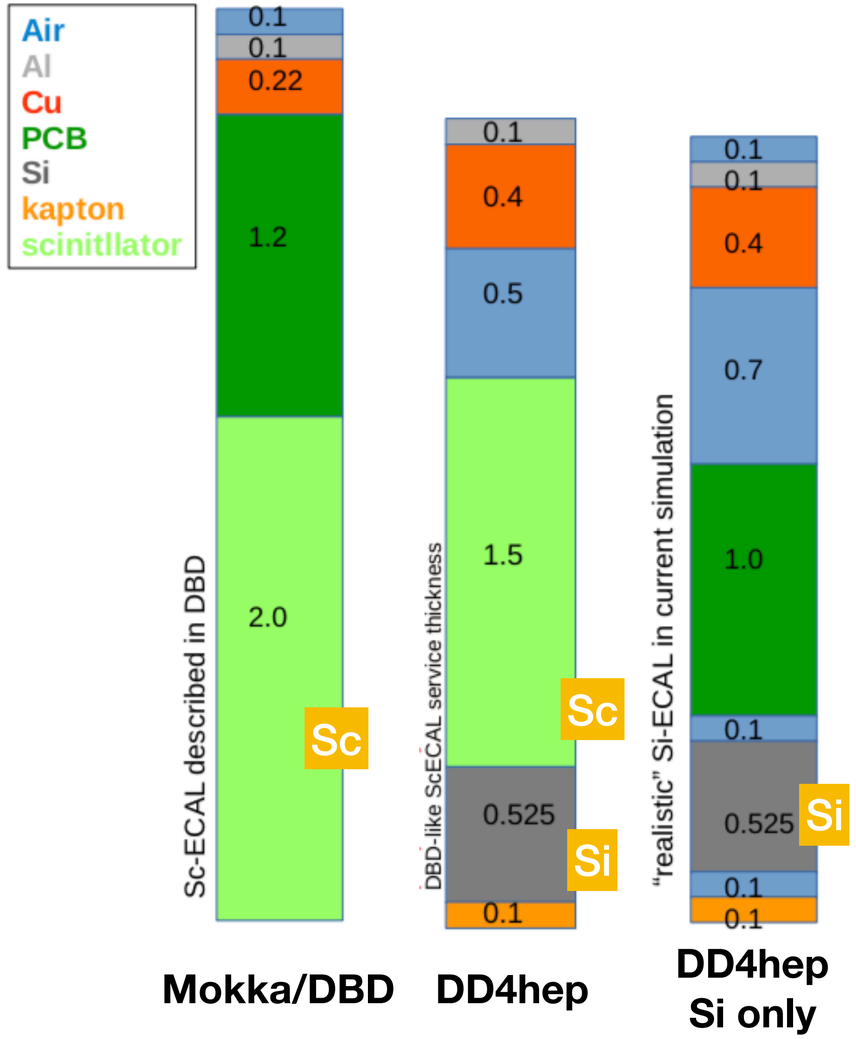


Cut model



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 so as to achieve the same ECAL dimensions in a layer
  - 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 implemented yet



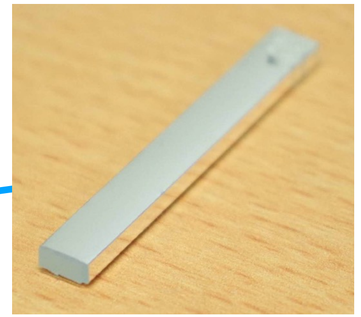
ScECAL Parameters

-Simulation ScECAL Characteristic Parameters

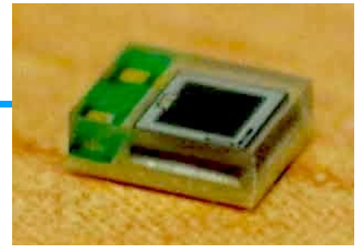
Sensor type	ScECAL	SiECAL
Collection	ECal*ScHits	ECal*SiHits
CaloDigi	RealisticCaloDigiScinPpd	RealisticCaloDigiSilicon
ppd_mipPe (p.e)	7	-
ppd_npix (pixel)	10,000	
calibration_mip (GeV)	?	0.0001575
calibration_factorsMipGev	?	0.00641222630095

Device parameters

Need Calibration



Scintillator (45 x 5 x 2 mm²)



MPPC 10k pixel

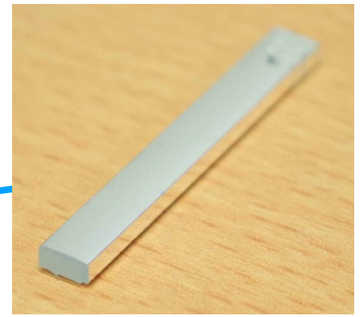
ScECAL Parameters

-Simulation ScECAL Characteristic Parameters

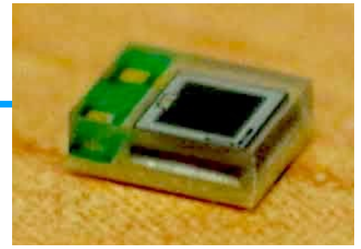
Sensor type	ScECAL	SiECAL
Collection	ECal*ScHits	ECal*SiHits
CaloDigi	RealisticCaloDigiScinPpd	RealisticCaloDigiSilicon
ppd_mipPe (p.e)	7	-
ppd_npix (pixel)	10,000	
calibration_mip (GeV)	0.0002407 (at Barrel) 0.0002472 (at Endcaps)	0.0001575
calibration_factorsMipGev	0.006729 (at Barrel) 0.007256 (at Endcaps)	0.00641222630095

Device parameters

Calibration Data



Scintillator (45 x 5 x 2 mm²)



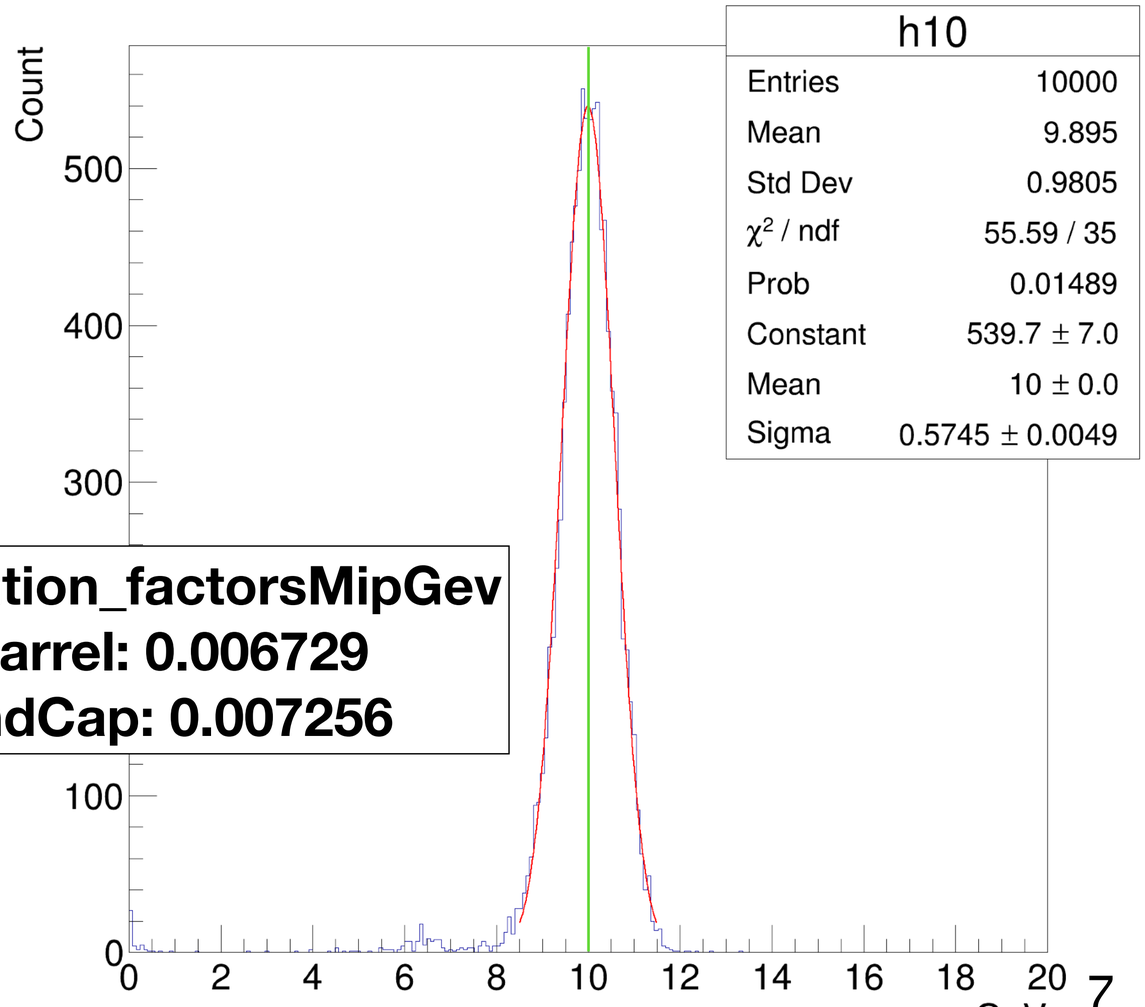
MPPC 10k pixel

Energy Calibration

- Parameter: calibration_factorsMipGev
- After Calibration, Both Barrel and Endcaps
- Fit Gaussian function
- Mean energy is 10GeV

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE
1	Constant	5.39721e+02	6.99160e+00	2.01947e-02
2	Mean	1.00006e+01	6.09029e-03	2.22184e-05
3	Sigma	5.74482e-01	4.91117e-03	8.31537e-06

Ecal calhit energy

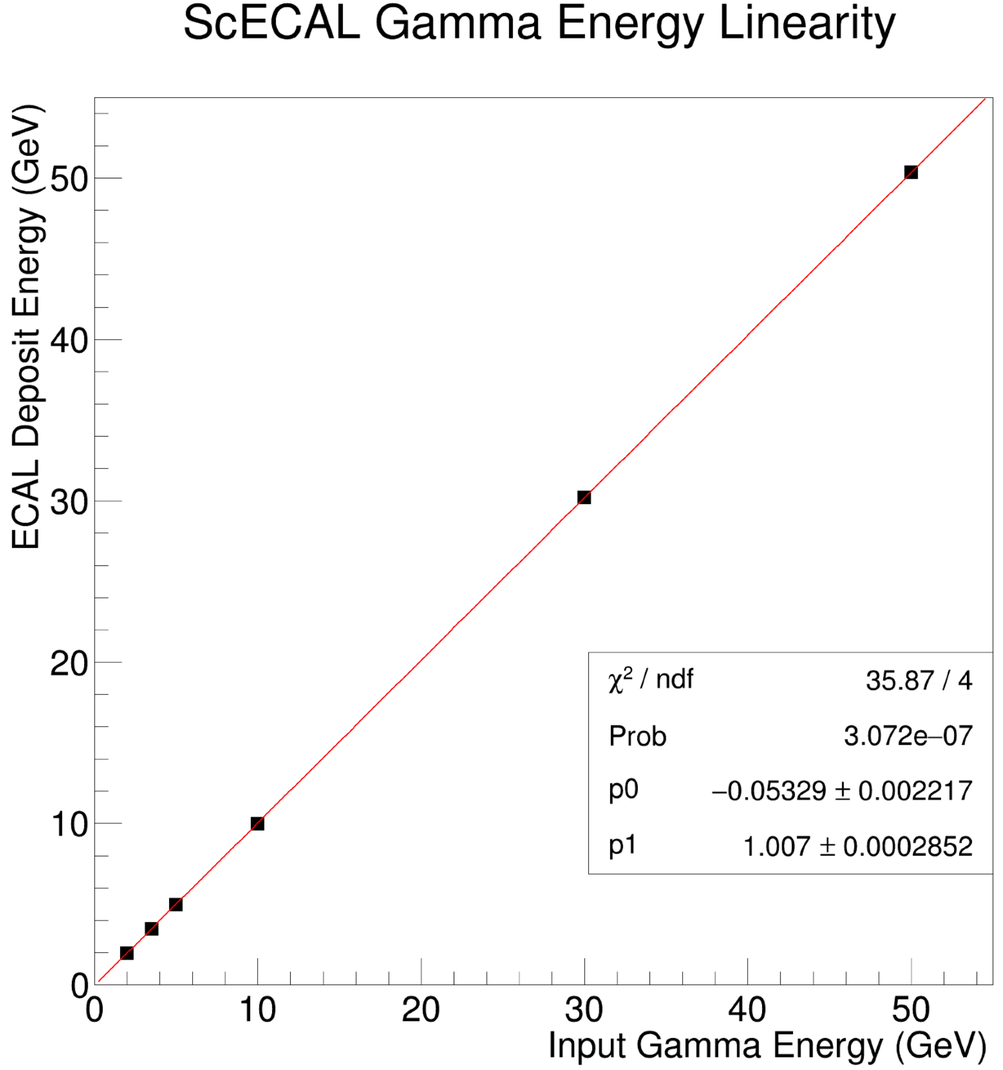


calibration_factorsMipGev
Barrel: 0.006729
EndCap: 0.007256

Energy distribution of totalE at ECAL after calibration

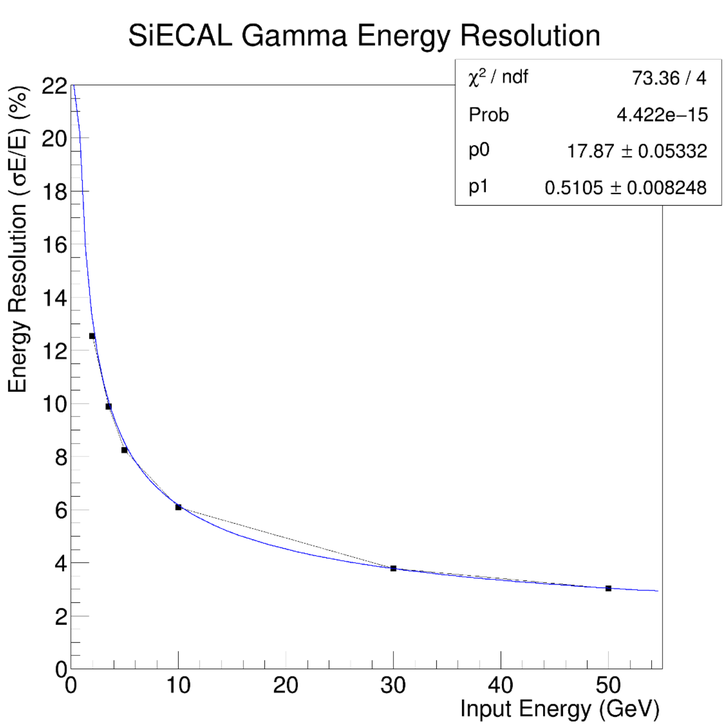
Energy linearity of gamma

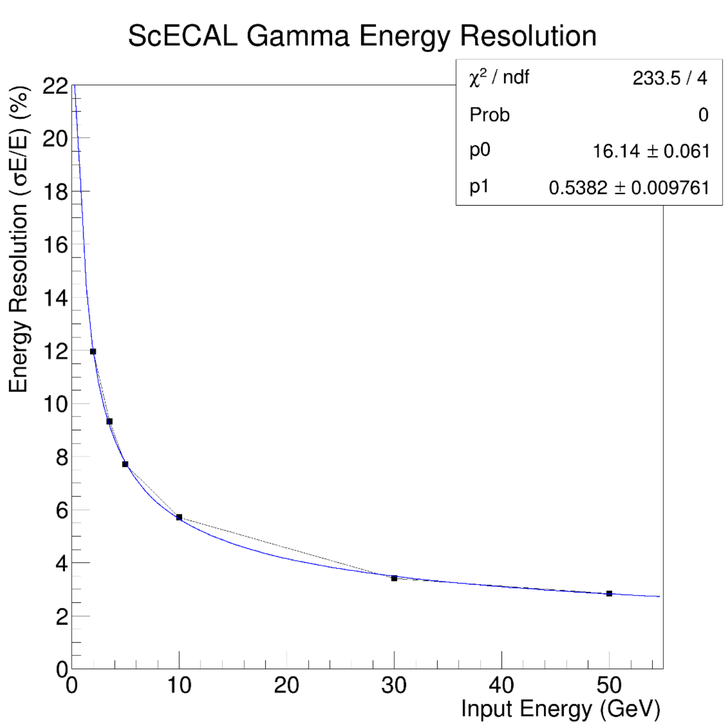
- Linearity of Gamma Energy at ScECAL
  - Gamma 2, 3.5, 5, 10, 30, 50 GeV
  - E1-calib.Ps_22_*Glcio_gun.e0.p0.*.slcio
- Linearity is good
- with almost zero constant term
- Energy calibration at 10GeV is also effective for other energy

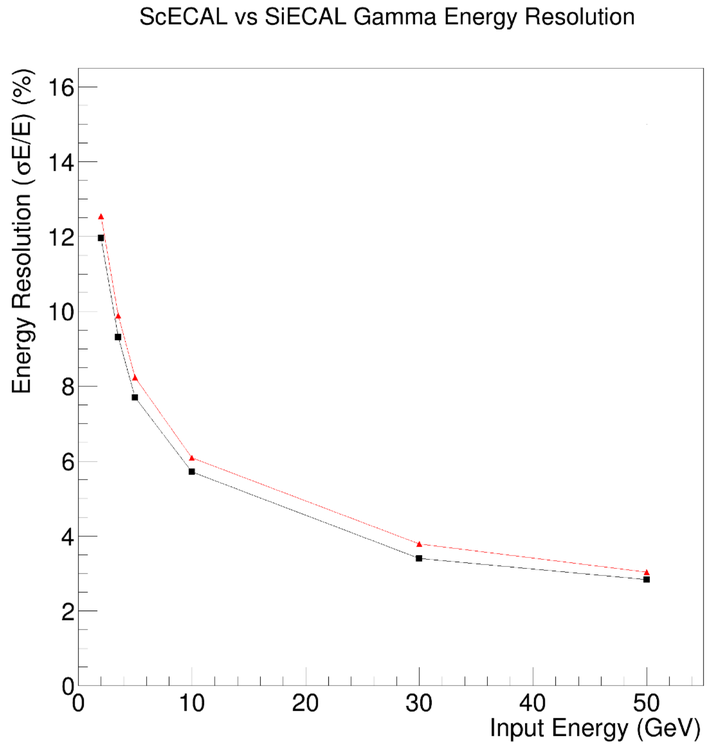


Energy resolution of gamma

- 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 16% at ScECAL
- Energy resolution with single photon is slightly better than silicon due to sampling ratio (at Sc 1.5mm)

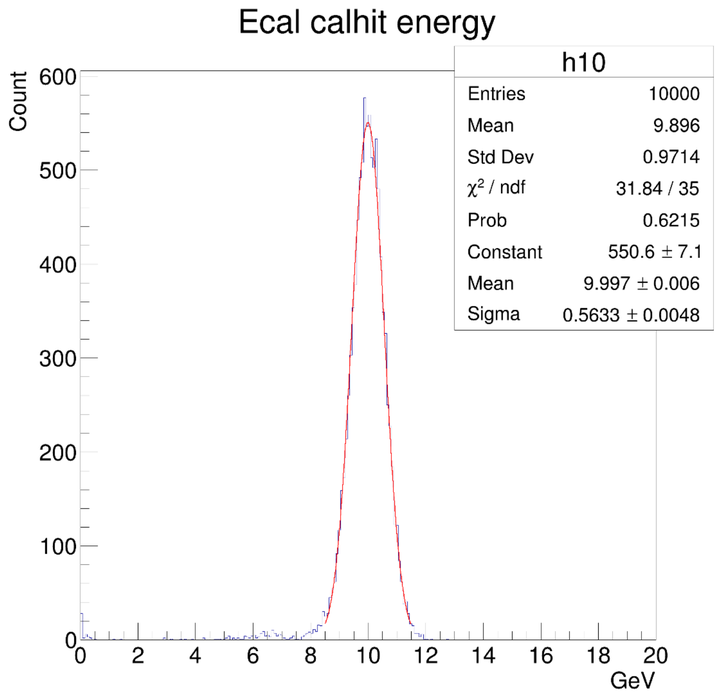


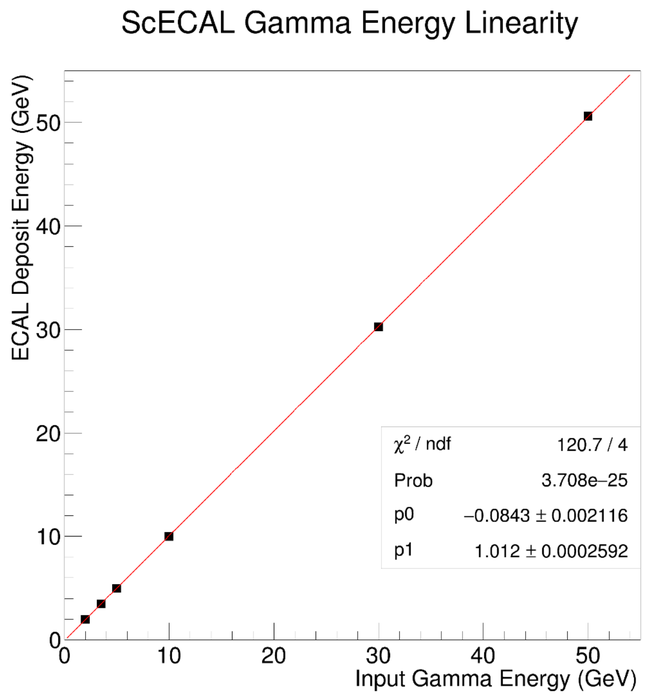


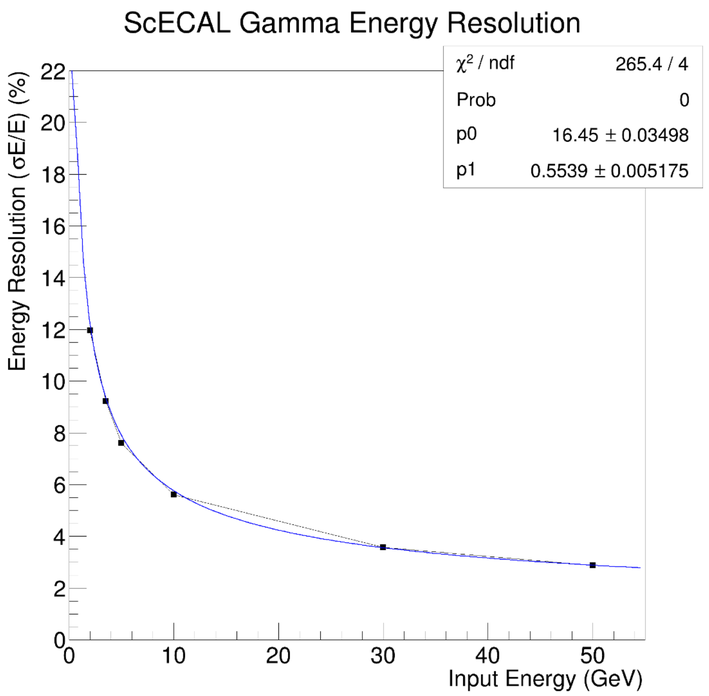


5x5mm² ScECAL

- ScECAL uses SSA to recover 5 x 5 mm resolution
- Because the various parameters are different between Si and Sc, it is necessary to separately consider the calibration of PFA and SSA
- 5 x 5 mm² scintillator introduced in simulation and compared with 45 x 5 mm² scintillator

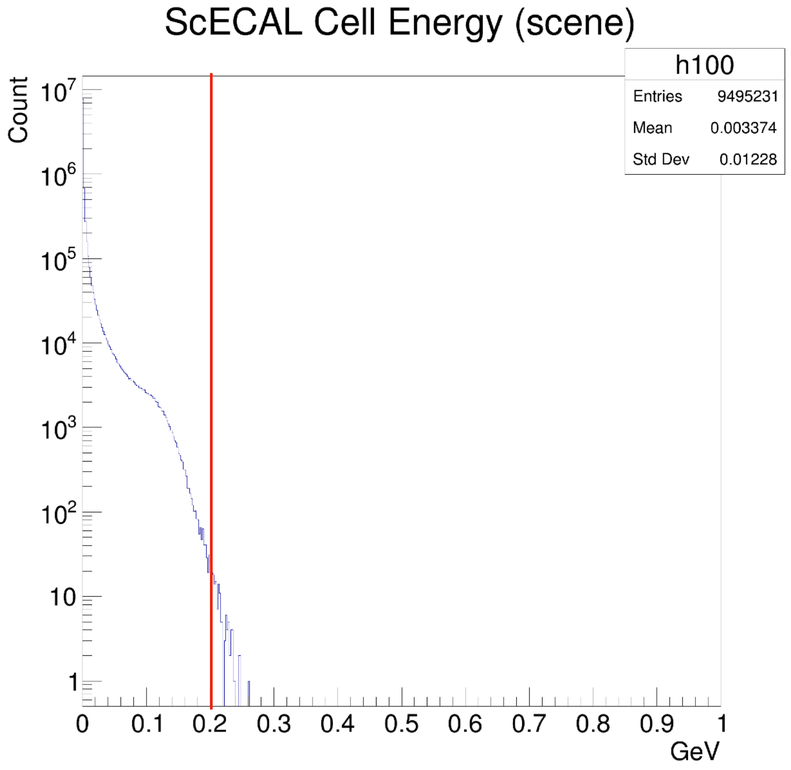






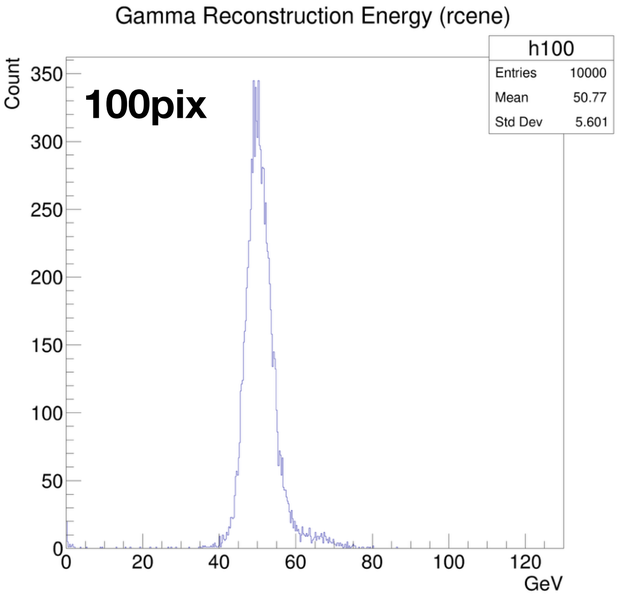
MPPC Saturation Effect

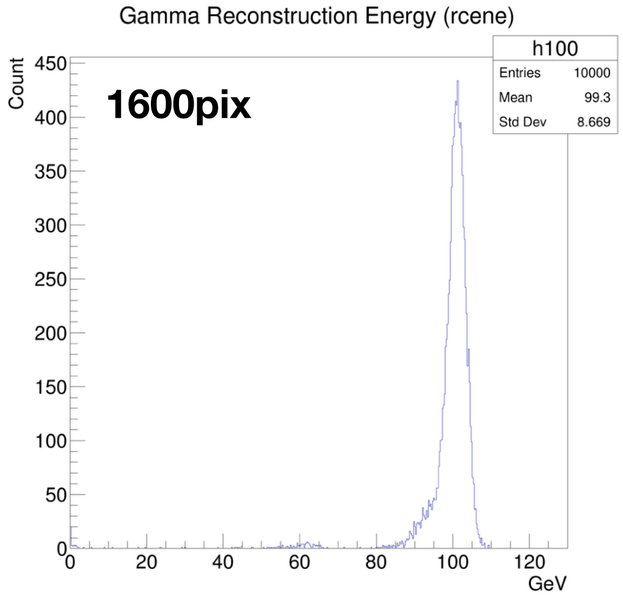
- We will plan to use 10k pix MPPC because of due to dynamic range
- From the noise, gain, etc., we have tested 15 um pitch (4489pix) in the experiment
- It is necessary to check the effect of saturation at high energy by reducing the dynamic range
- At 100GeV gamma, cutoff of one cell is about 0.2 GeV
- The energy dropped by the MIP of the scintillator having a thickness of 1.5 mm is about 0.3 MeV
- At 0.2 GeV, if 1 MIP is 7 p.e., 100 MIP is about 700 photons

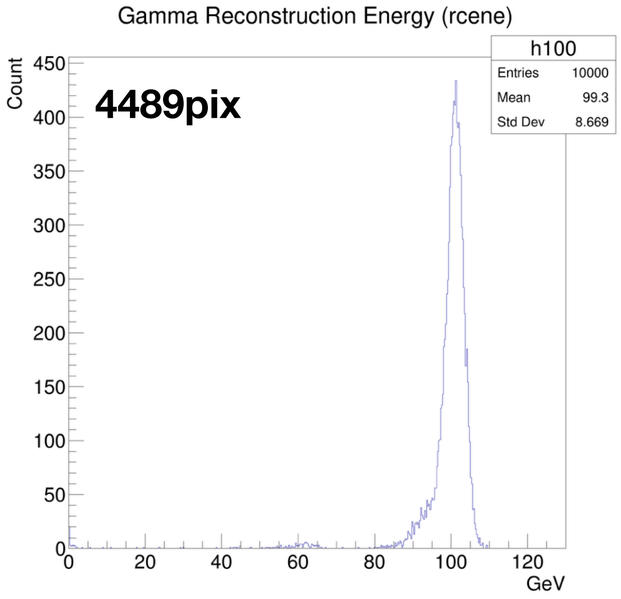


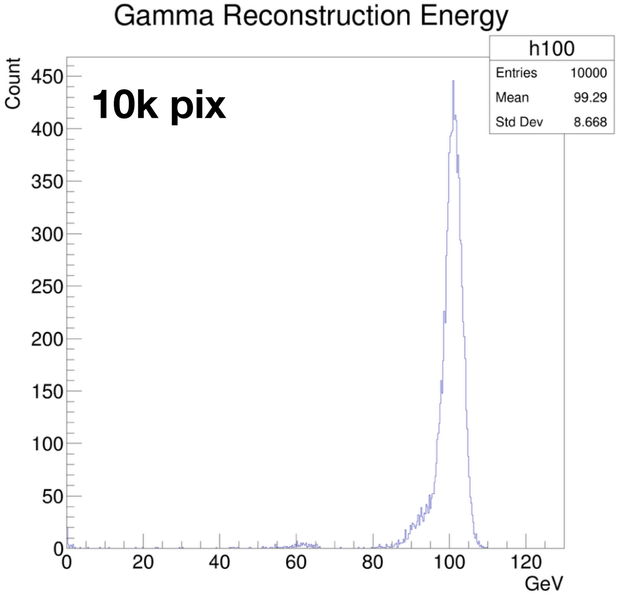
MPPC Saturation Effect

- Compared 100, 1600, 4489 and 10 k pix on Simulation
- Injection 100GeV gamma
- There is no big difference at 1600 pixels or more







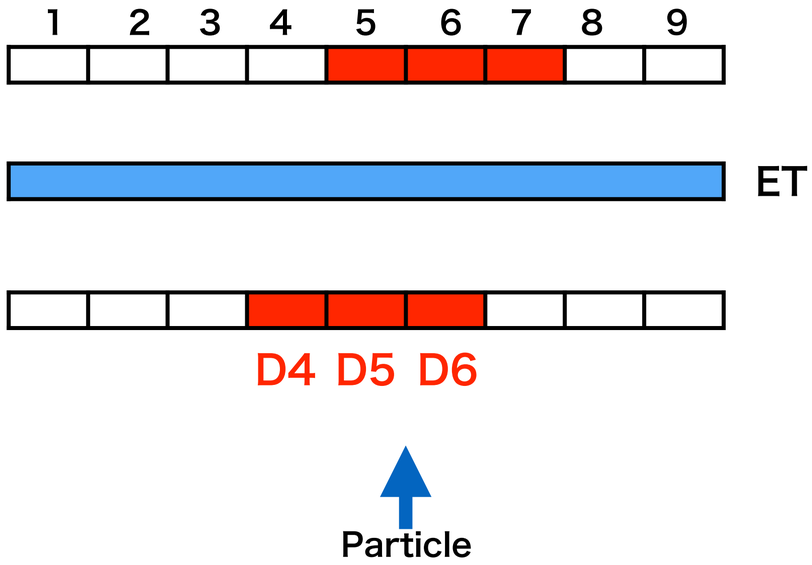


Summary

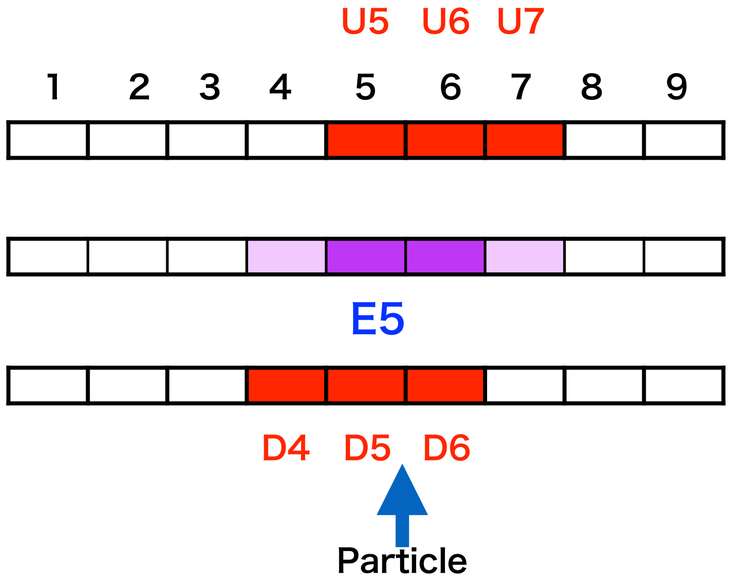
- We are developing and testing Scintillator ECAL
- ScECAL simulation is working
- ScECAL parameters were determined
- Energy linearity is good
- Gamma energy resolution is reasonable
- There is no influence due to MPPC pixel reduction (eg. 4489pix) at 250GeV ILC
- Future Plan
  - Implement SSA into DD4hep for jet energy resolution improvement
  - Calibrate and tune Pandora PFA parameters

Backup

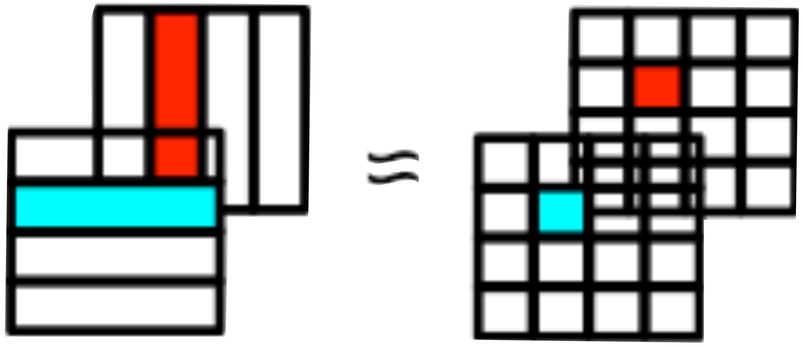
Strip Splitting Algorithm(SSA)



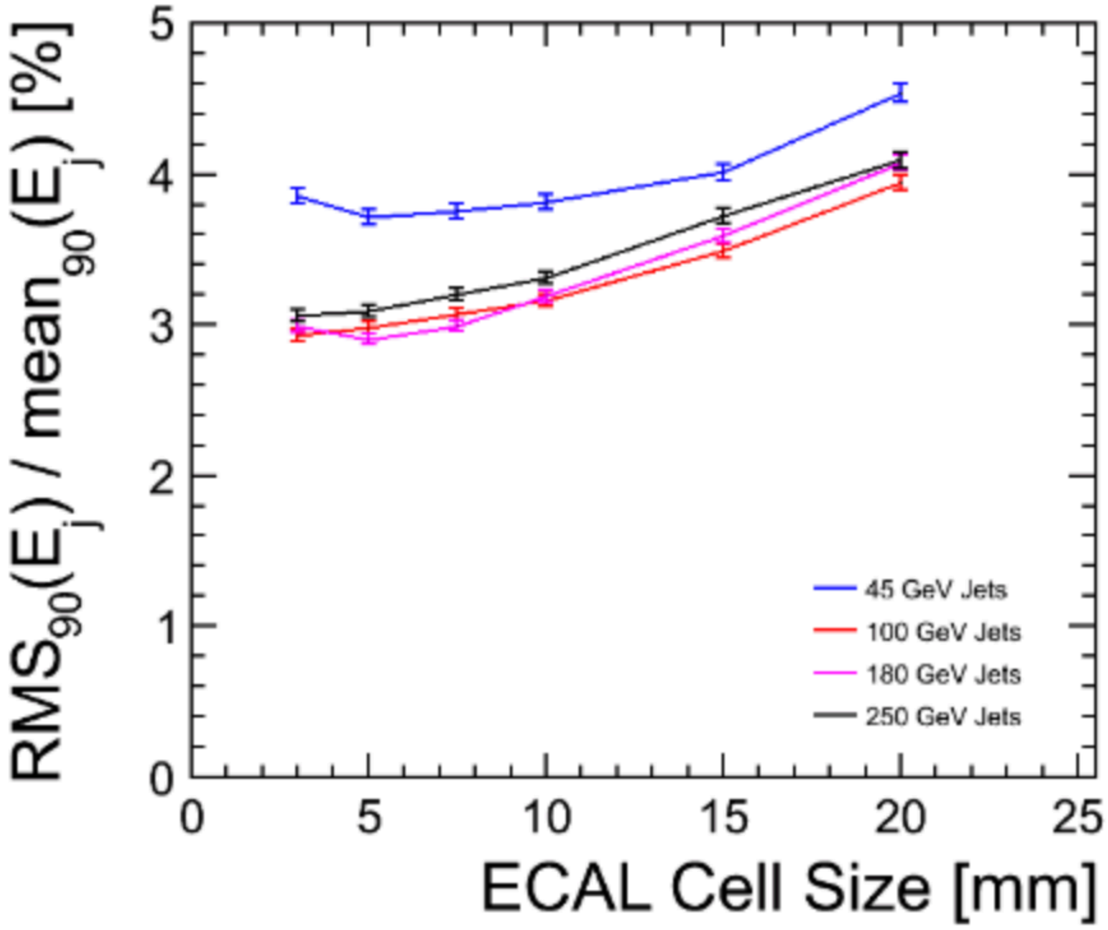
deposited energy is distributed into 9 virtual cells



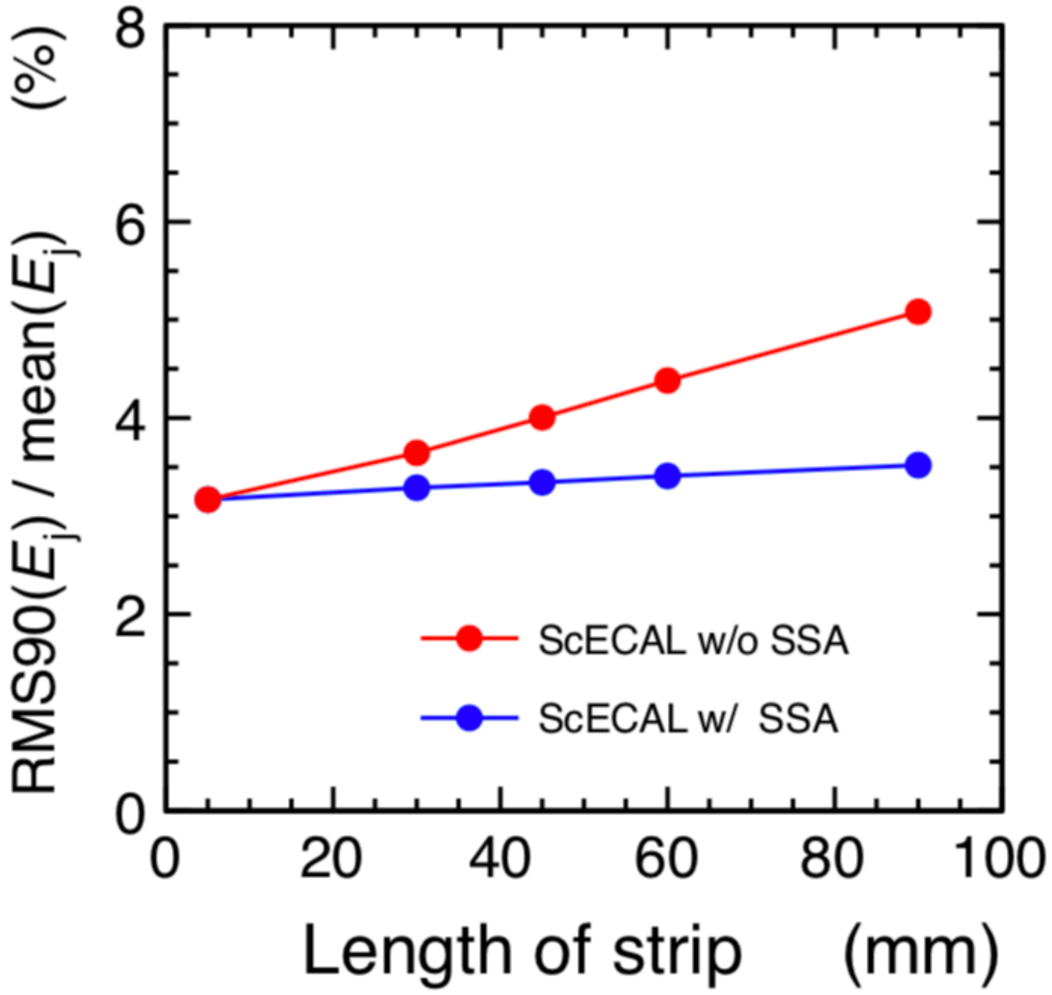
energy distributed in #cell5 $E5 = ET \times \frac{U5 + D5}{\sum_{9} Uj + \sum_{9} Dj}$



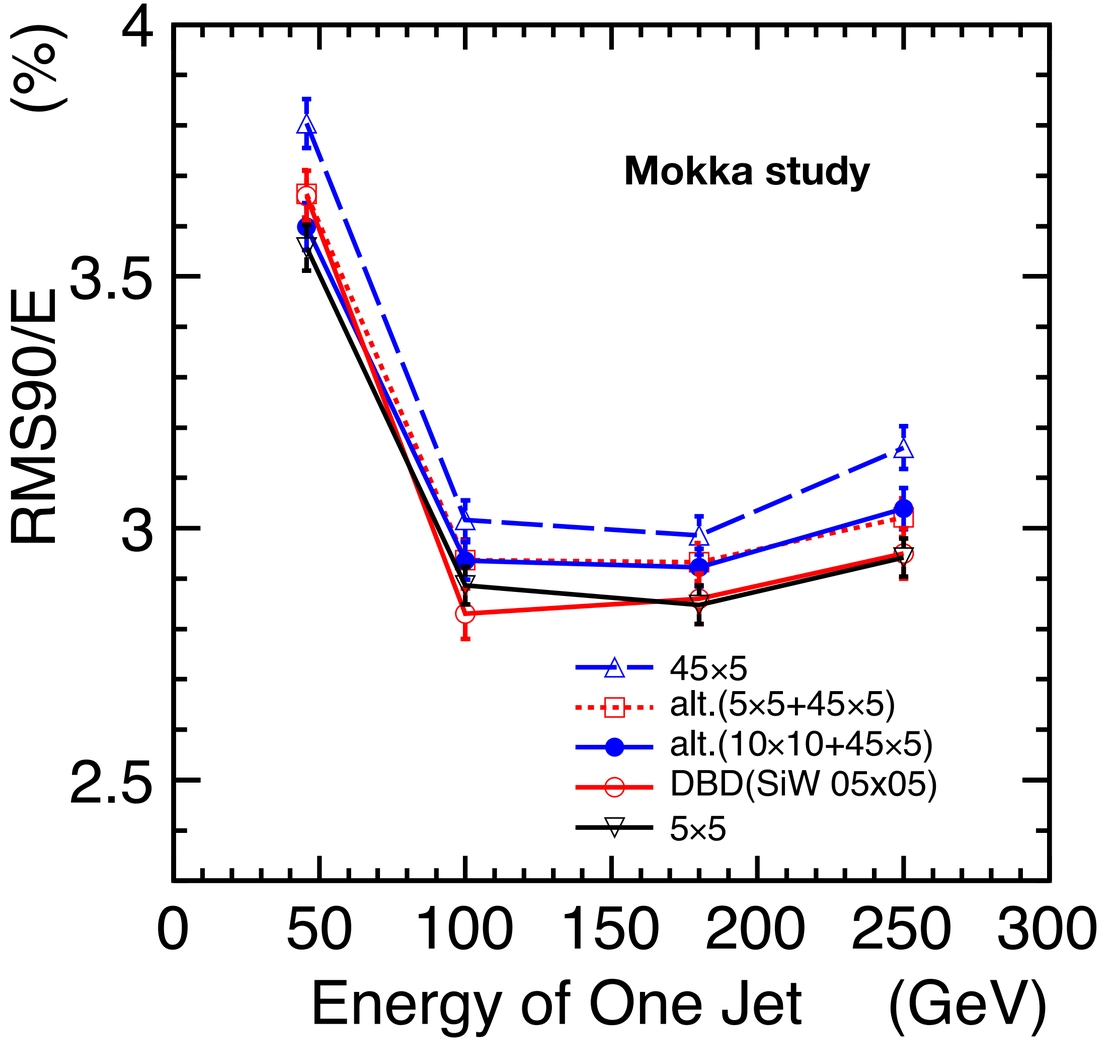
ECAL Cell Size

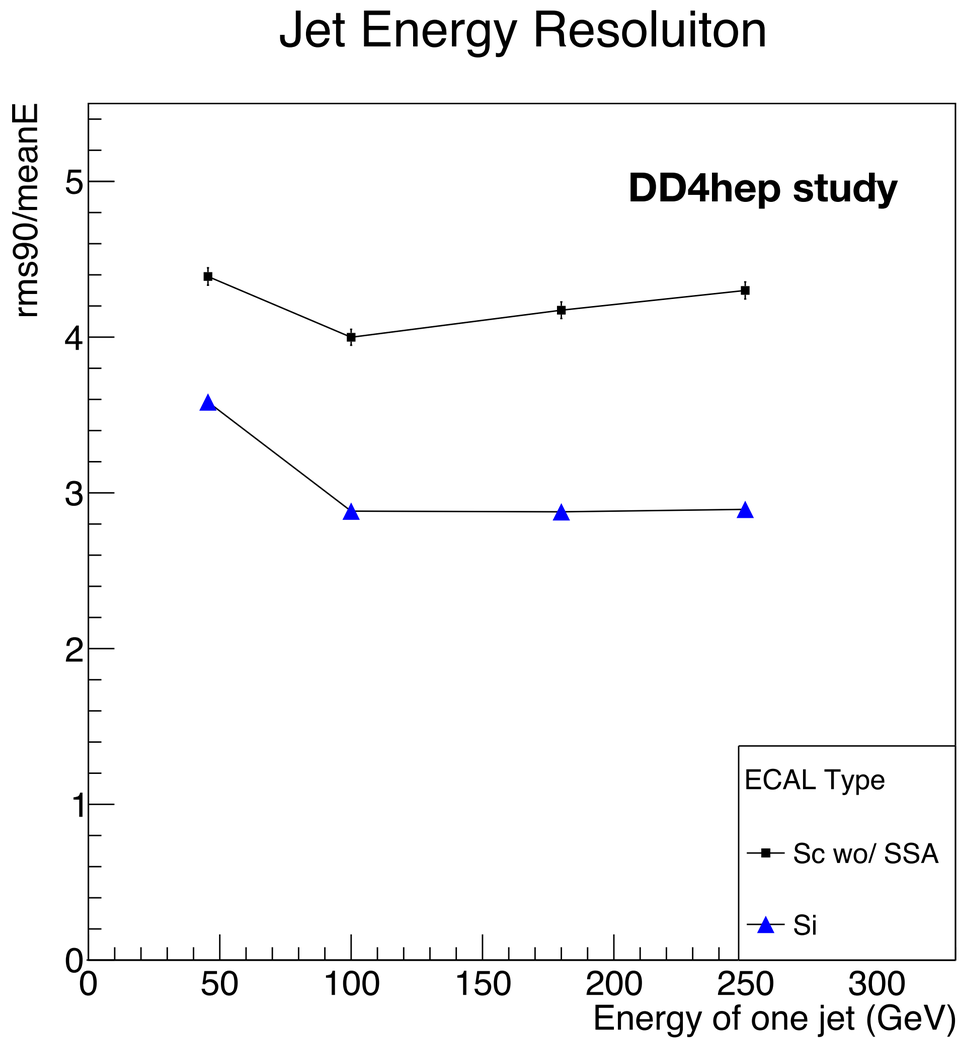


Energy Resolution vs Strip Length

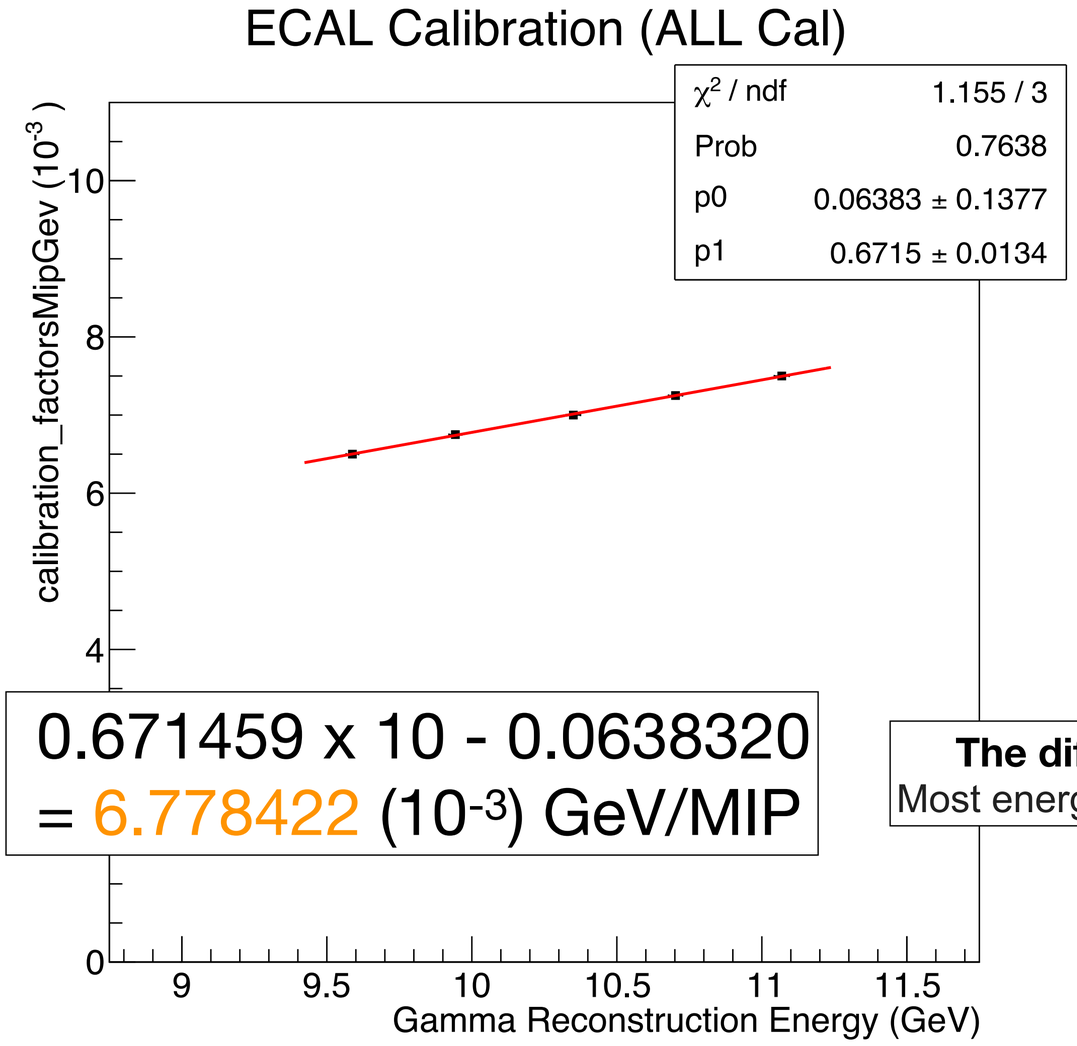


Jet Energy Resolution

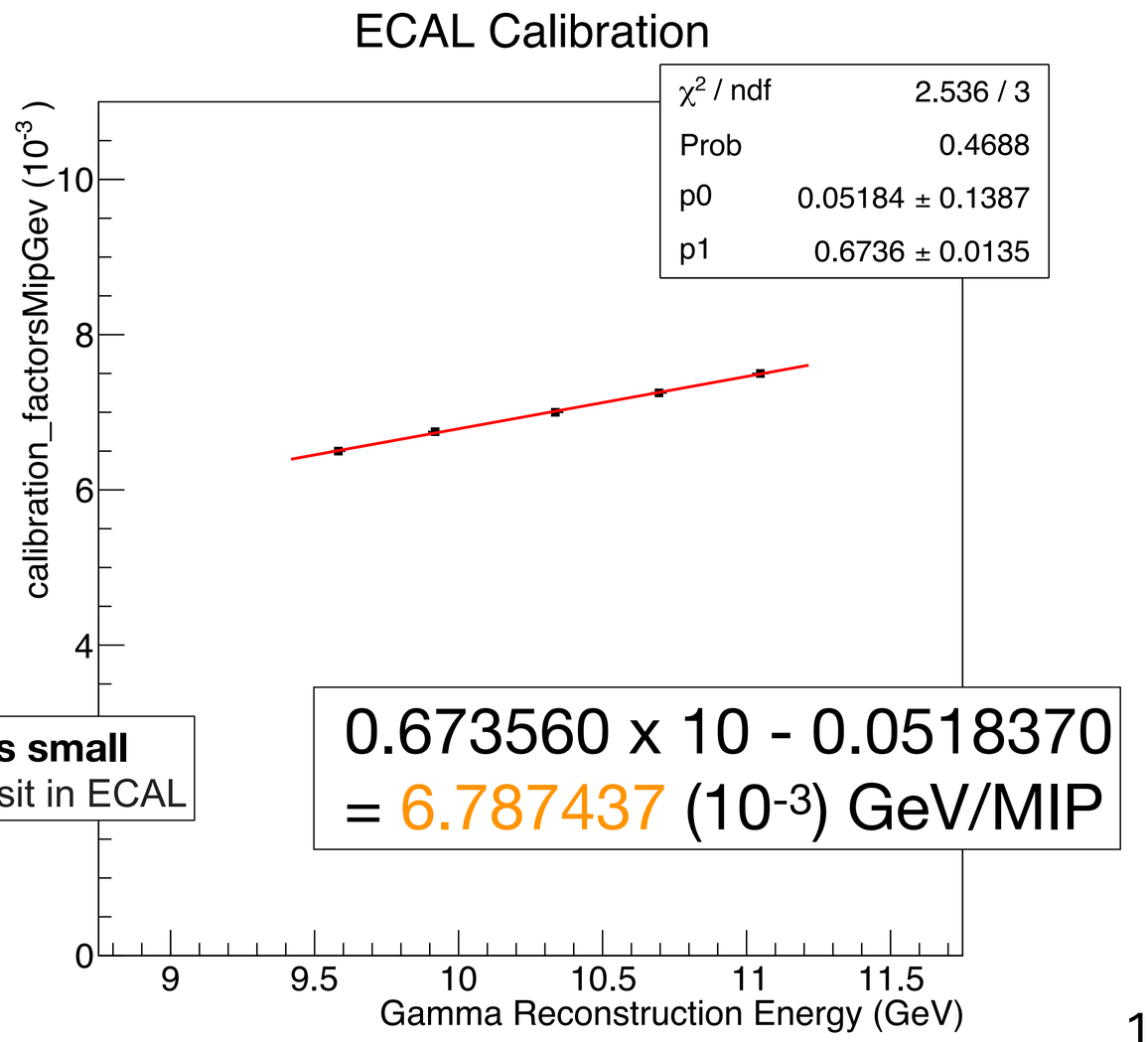




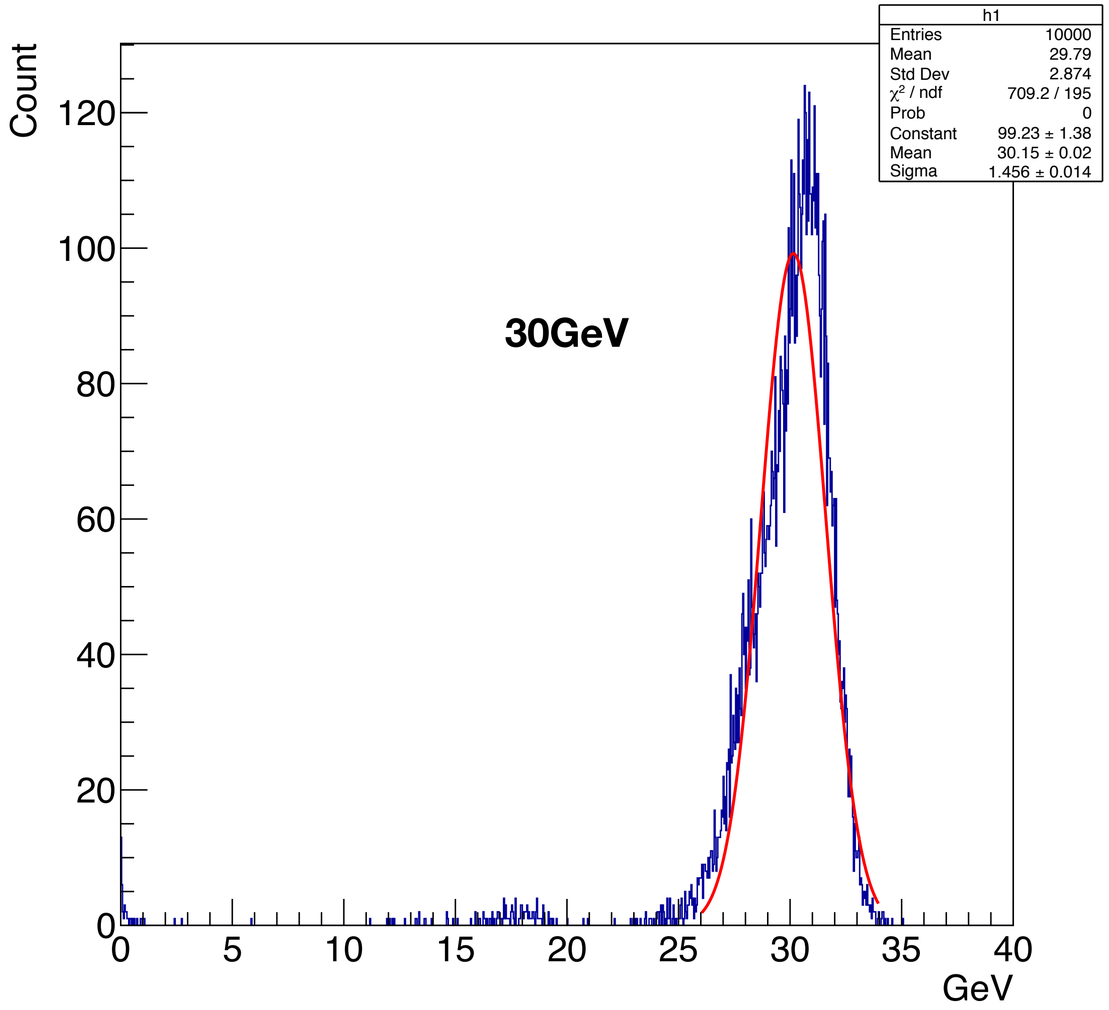
Calib use all cal



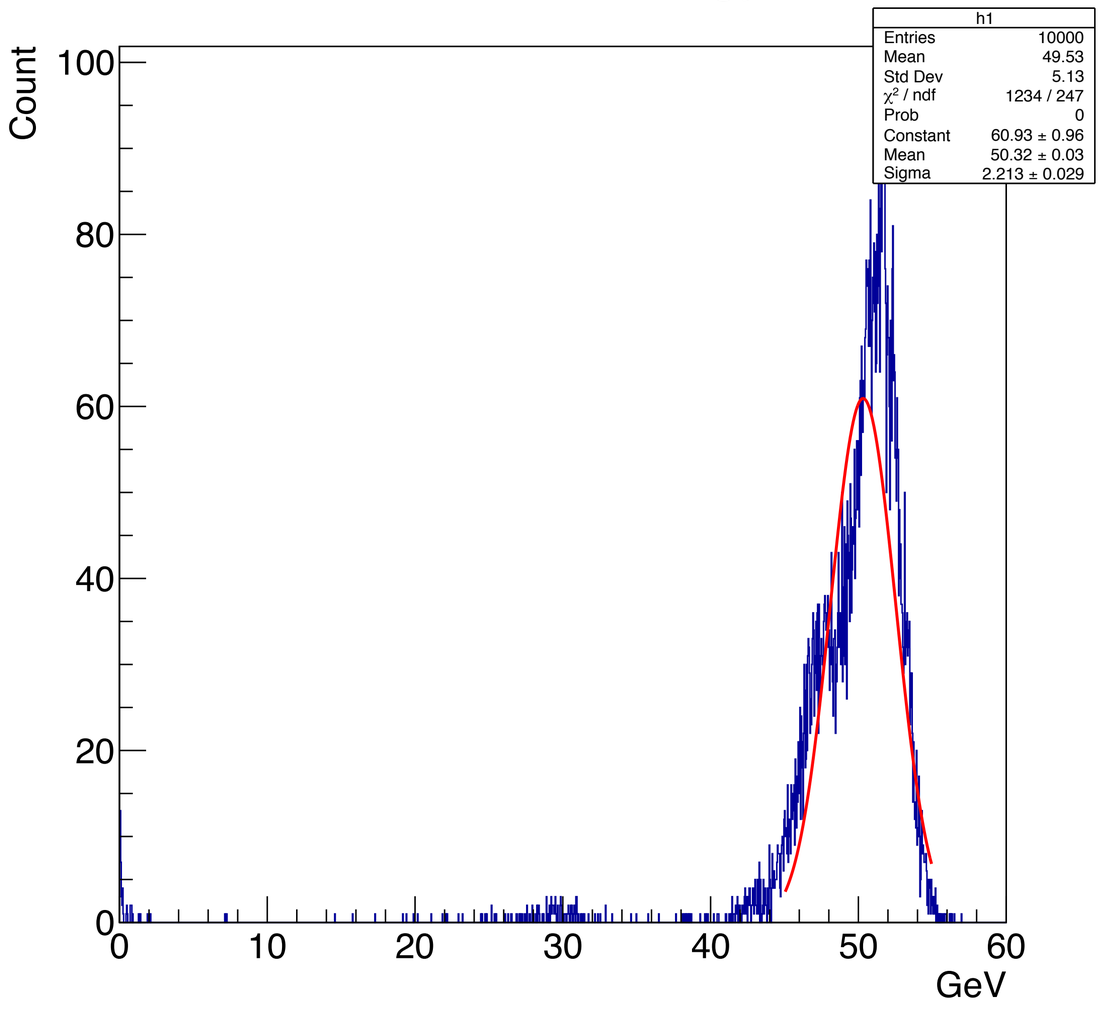
The difference is small
Most energy is Deposit in ECAL



Ecal calhit energy



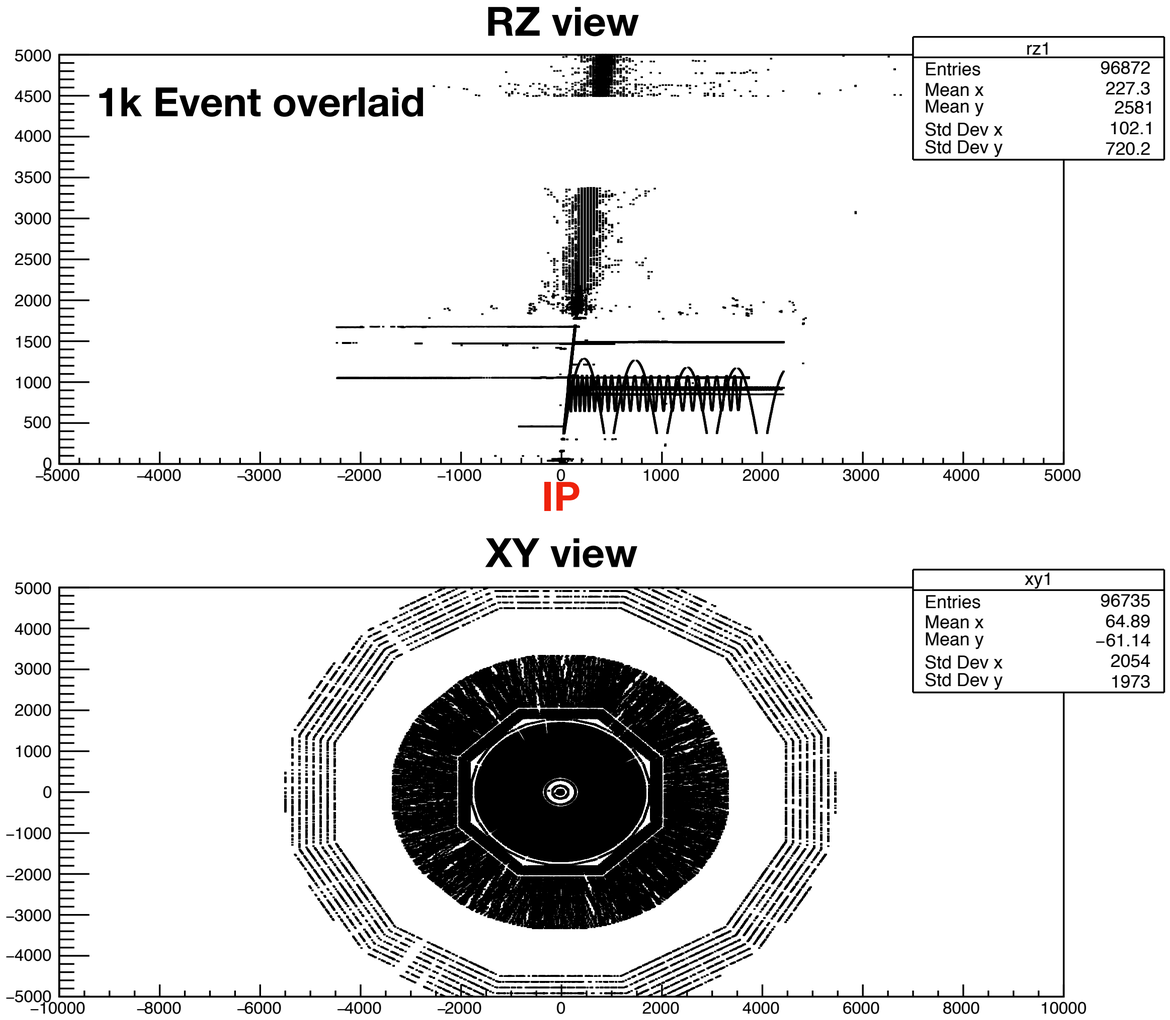
Ecal calhit energy



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

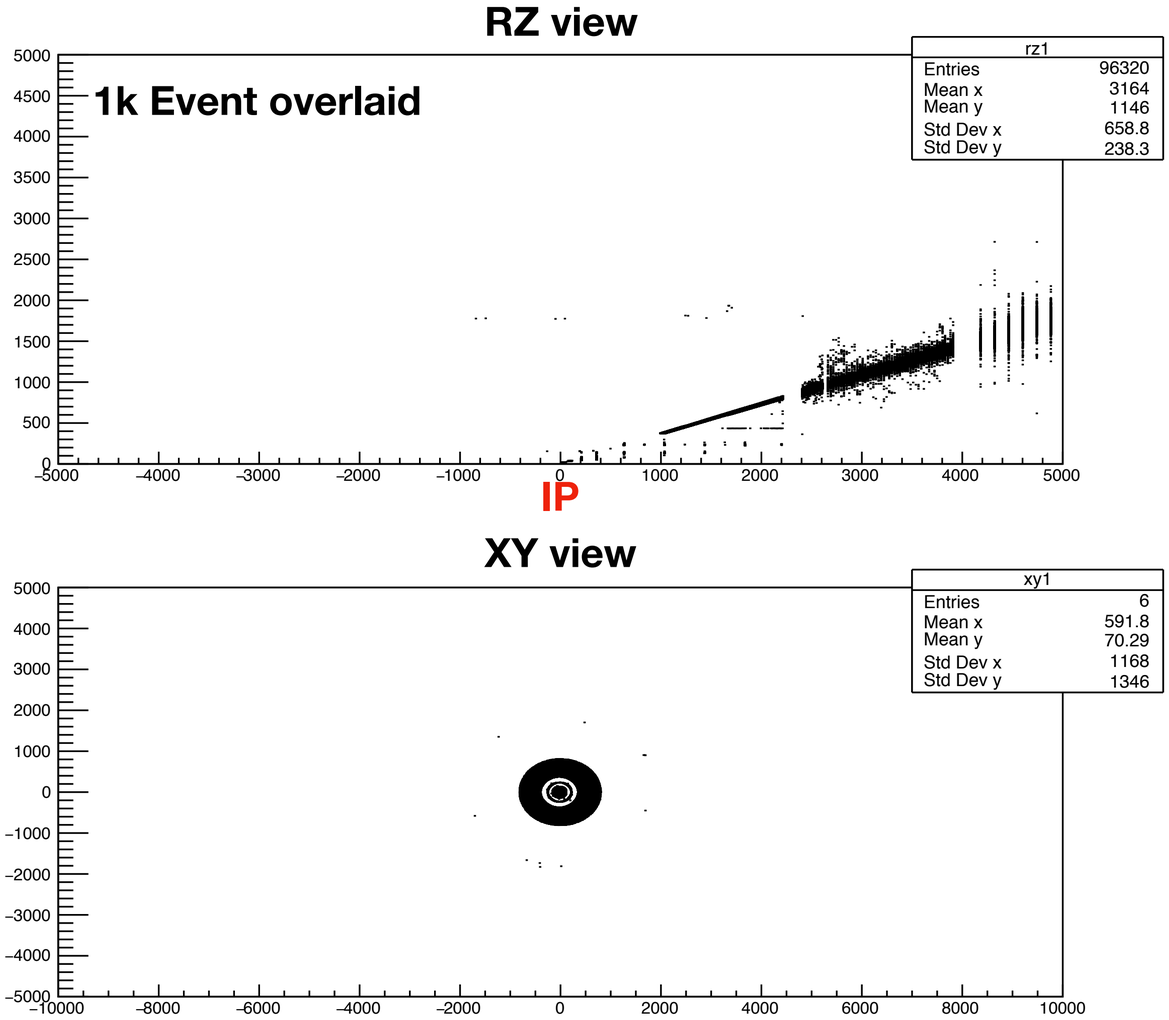


Hit map of theta 85 muon for barrel calibration

Mip Calibration

- Parameter: calibration_mip
- Use 10GeV muon 1k Event
- Theta 85 for Barrel (85 deg.)
- Theta 20 for Endcap (20 deg.)

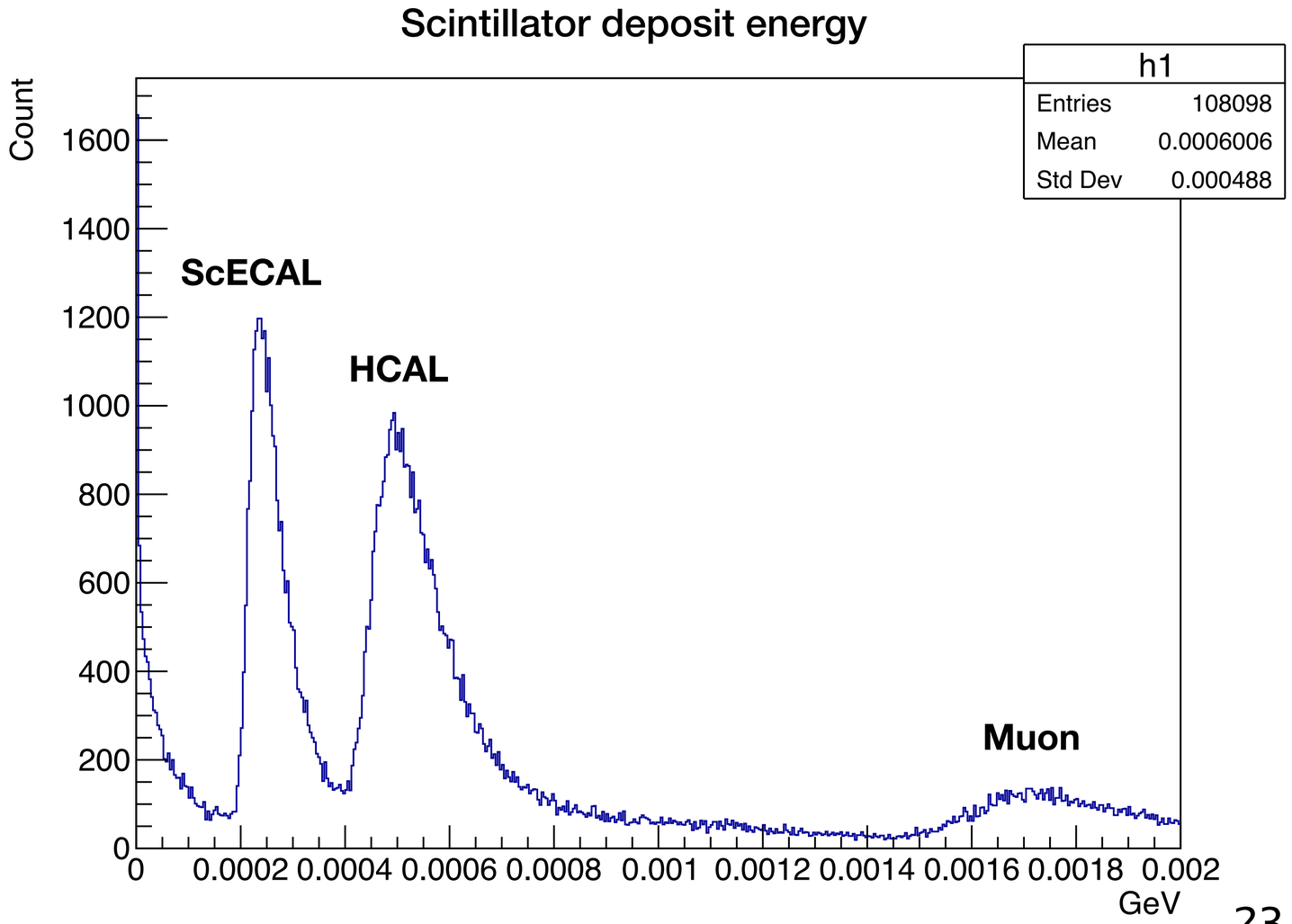
- E1-calib.Ps_pm13_p010_t20.Glcio_gun.e0.p0.I110107.n1.slcio
- E1-calib.Ps_pm13_p010_t85.Glcio_gun.e0.p0.I110109.n1.slcio



Hit map of theta 20 muon for barrel calibration

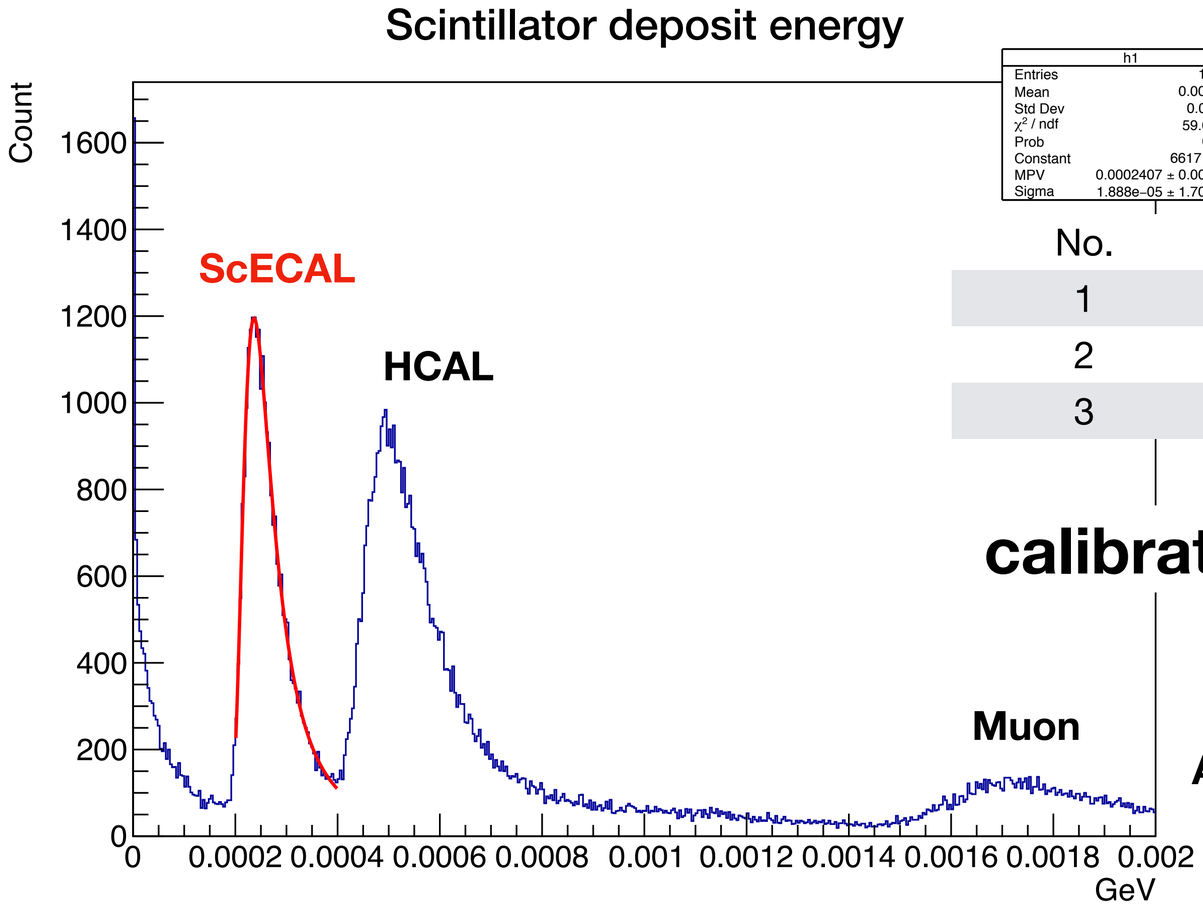
Mip Calibration

- 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**

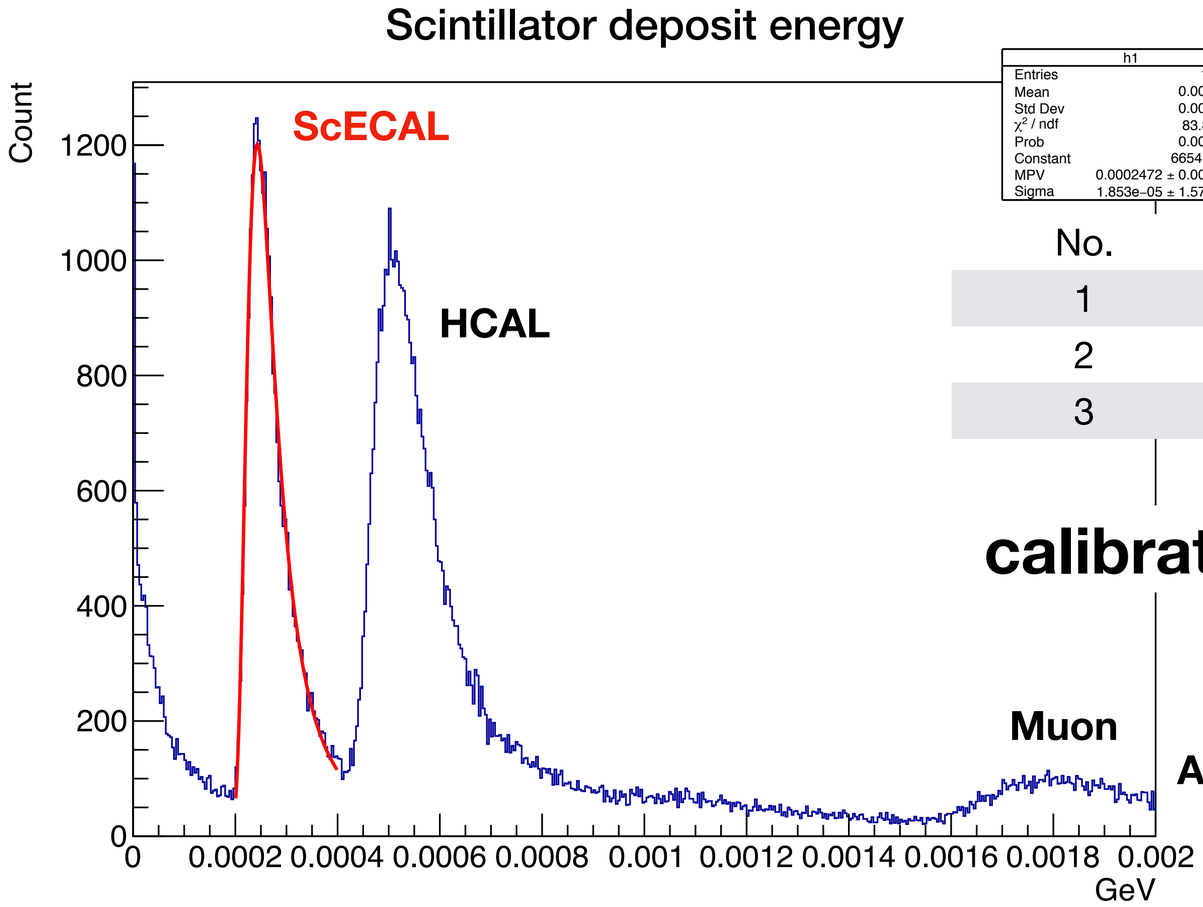
calibration_mip -> 0.000240743 GeV

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**

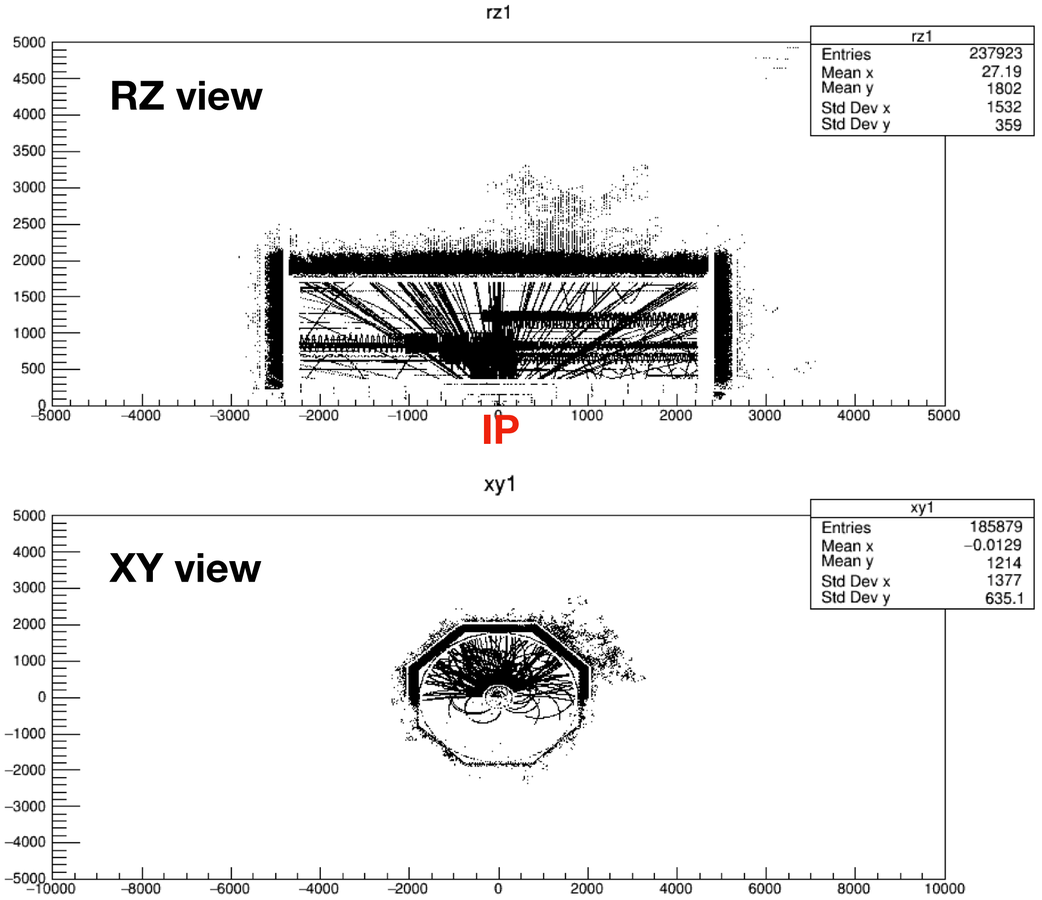
calibration_mip -> 0.000247203 GeV

Sc 1.5mm dE/dx consistent

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

Energy Calibration

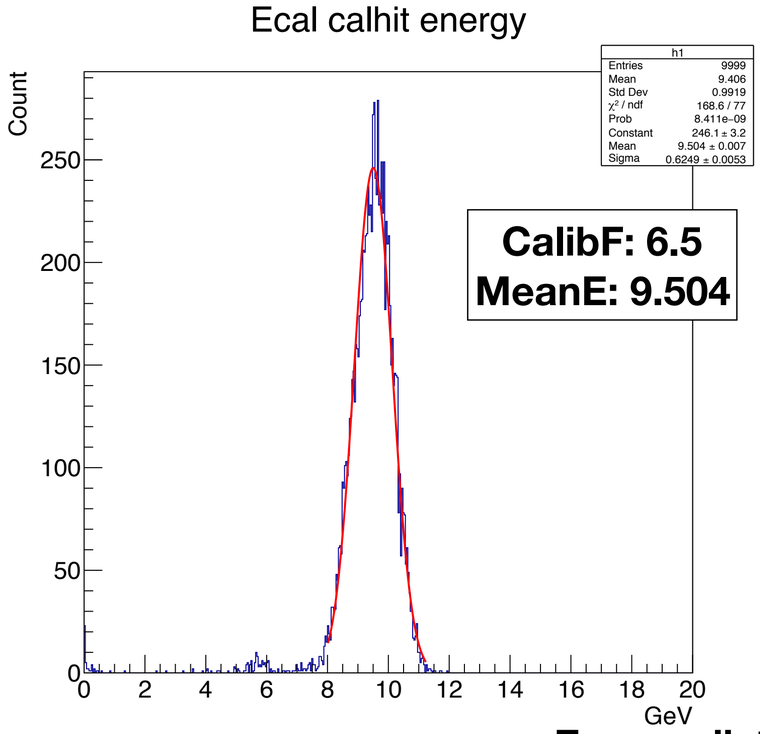
- Parameter: calibration_factorsMipGev
- Use 10GeV gamma
  - E1-calib.Ps_22_p010.Glcio_gun.e0.p0.I110141.n1.slcio
- Injection both barrels and endcaps
- Barrel and endcap are not separately checked

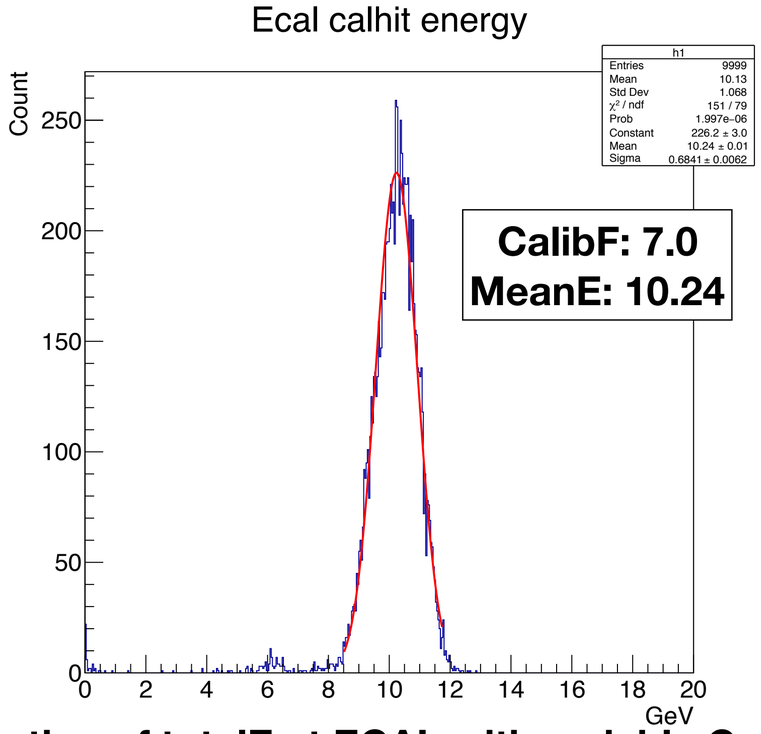


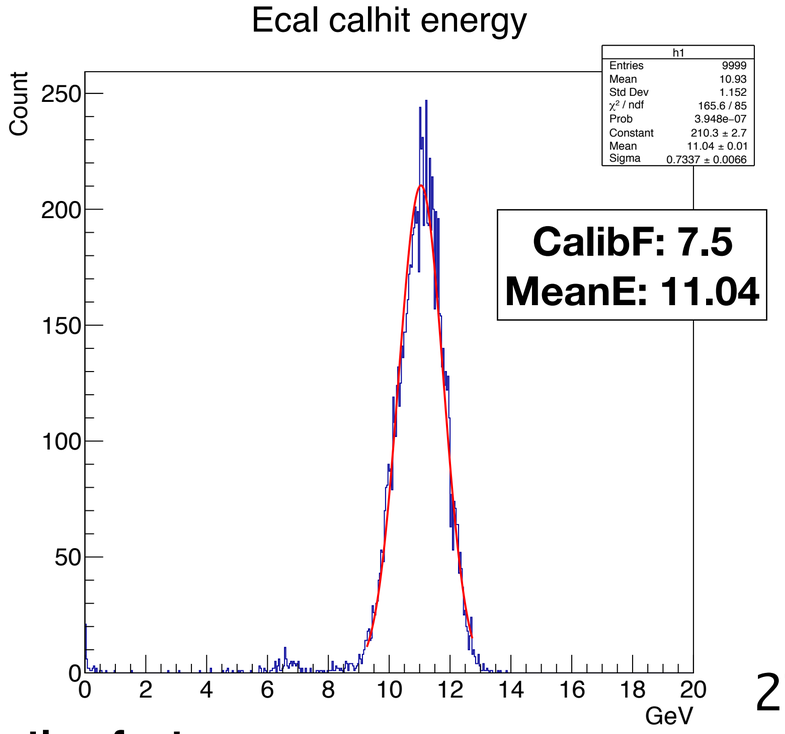
Hit map of gamma 10k Event overlaid

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



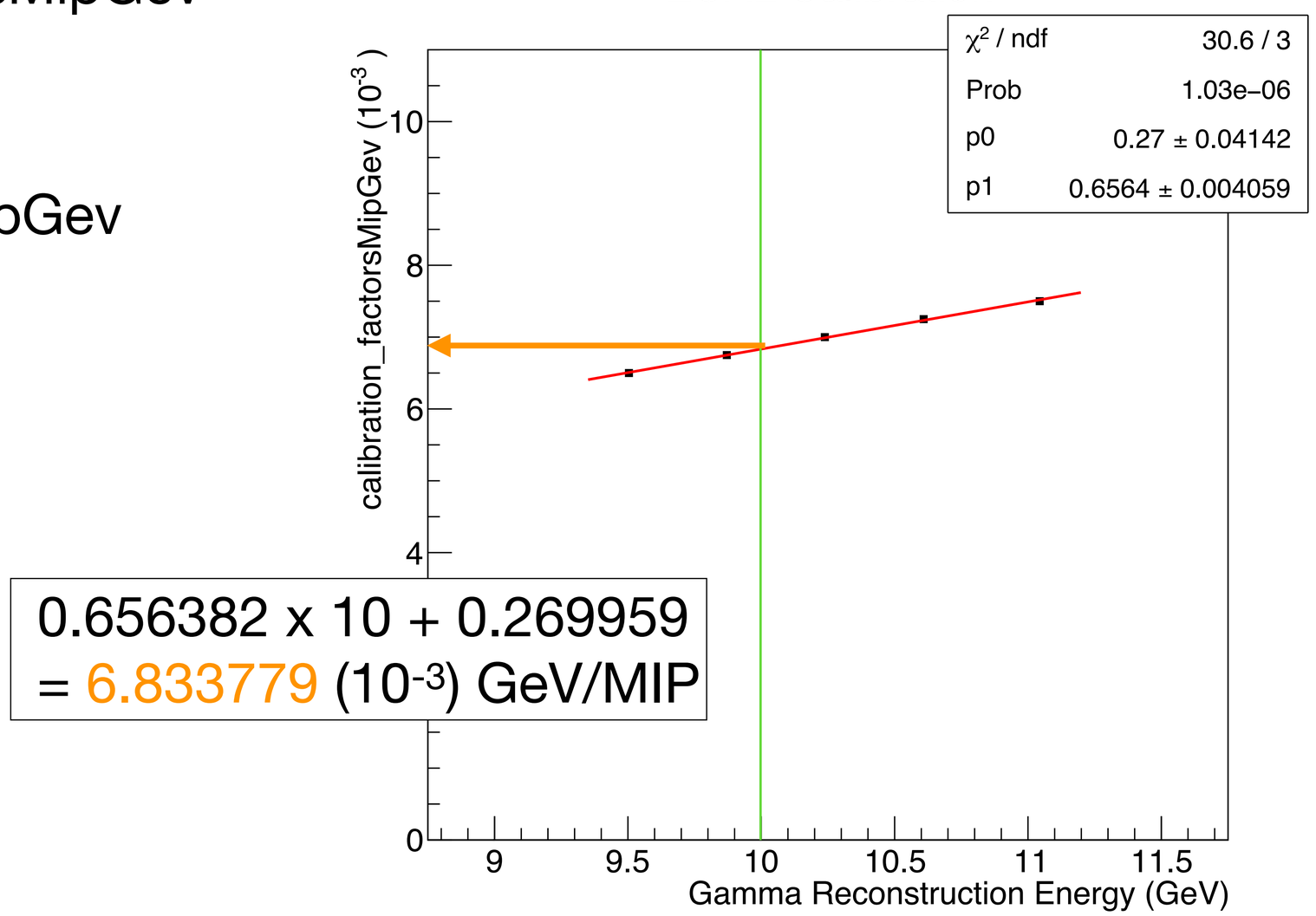




Energy distribution of totalE at ECAL with variable Calibration factor

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

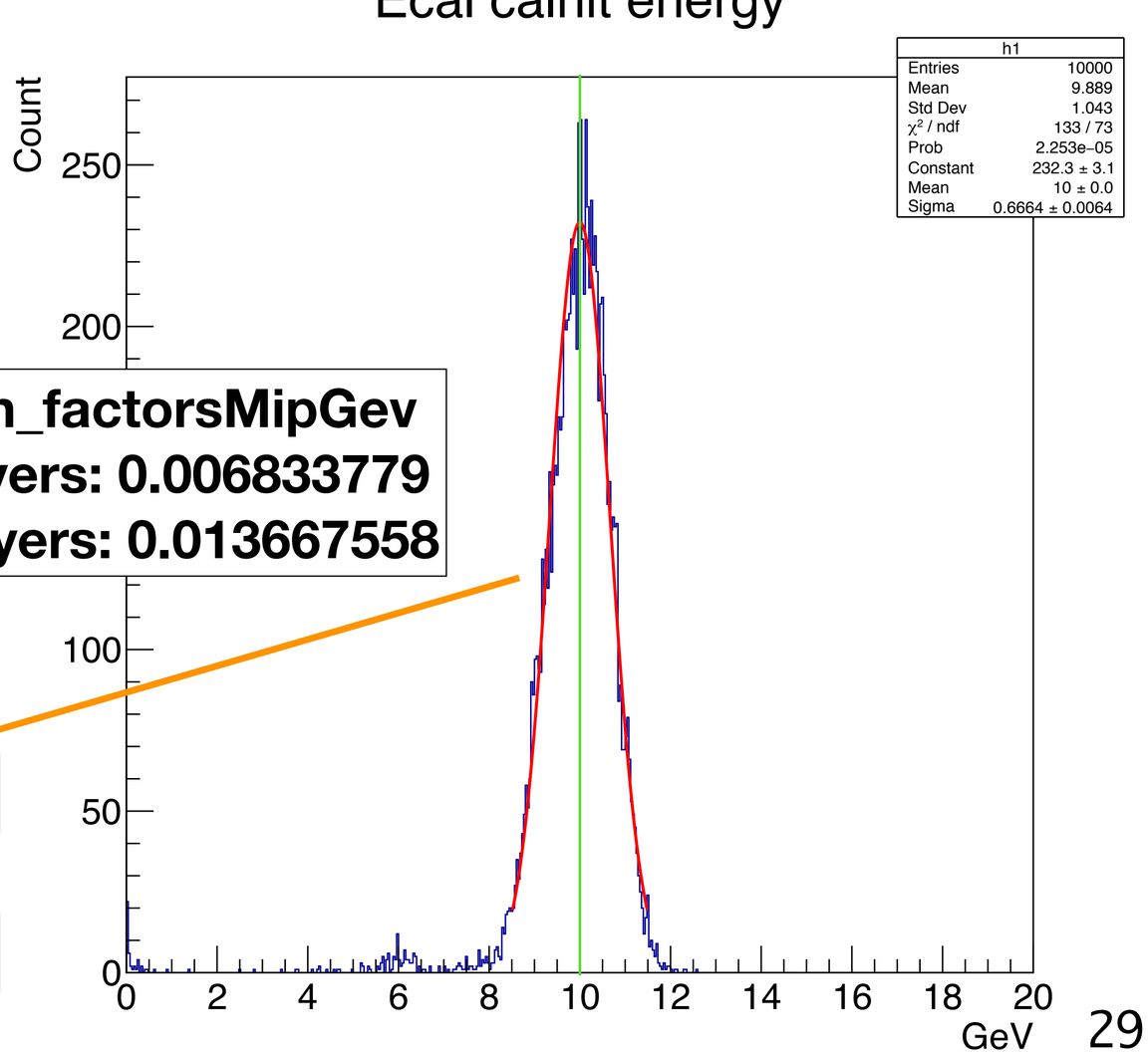


Energy Calibration

- 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



Energy distribution of totalE at ECAL after calibration