Optimisation Studies for the BeamCal Design

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The Aim and Content

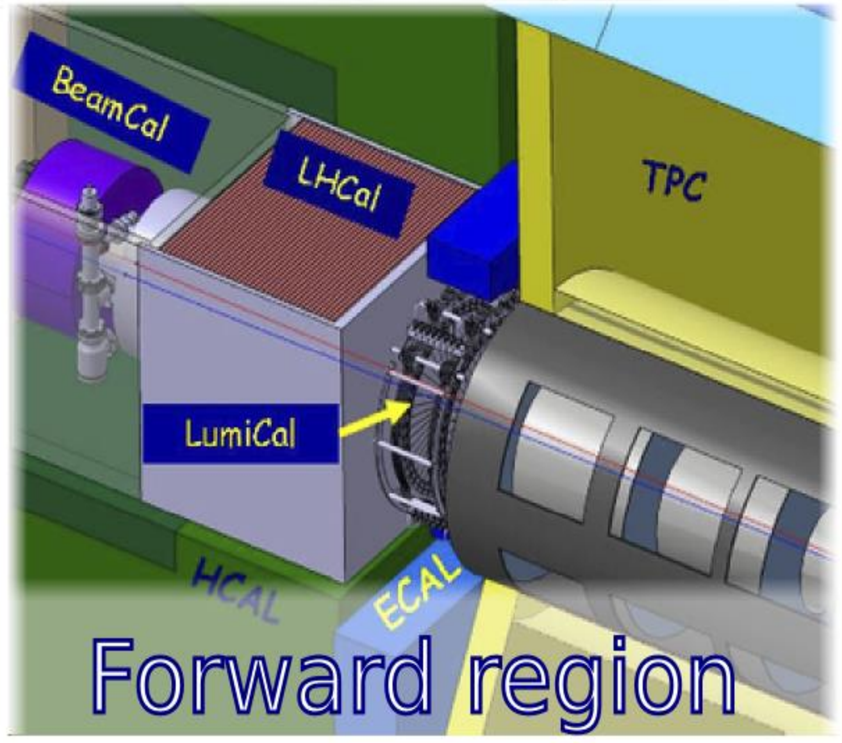
The Aim:

- compare 2 types of segmentation of calorimeter
- investigate the characteristics

Content:

- Introduction
- Simulation studies
  - SNR
  - efficiency
  - CCE
  - dependence E_{dep} vs E_e
  - energy resolution
  - spatial resolution
- Conclusion

Beam Calorimeter for ILC

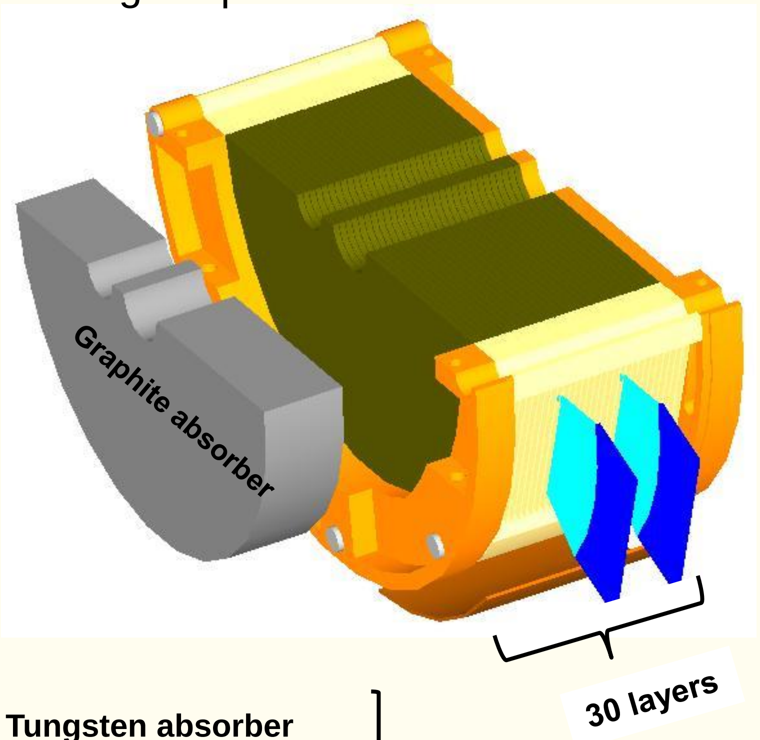


Beam parameters from the ILC Technical Design Report (November 2012)

- Nominal parameter set
- Center-of-mass energy 1 TeV

BeamCal aimed:

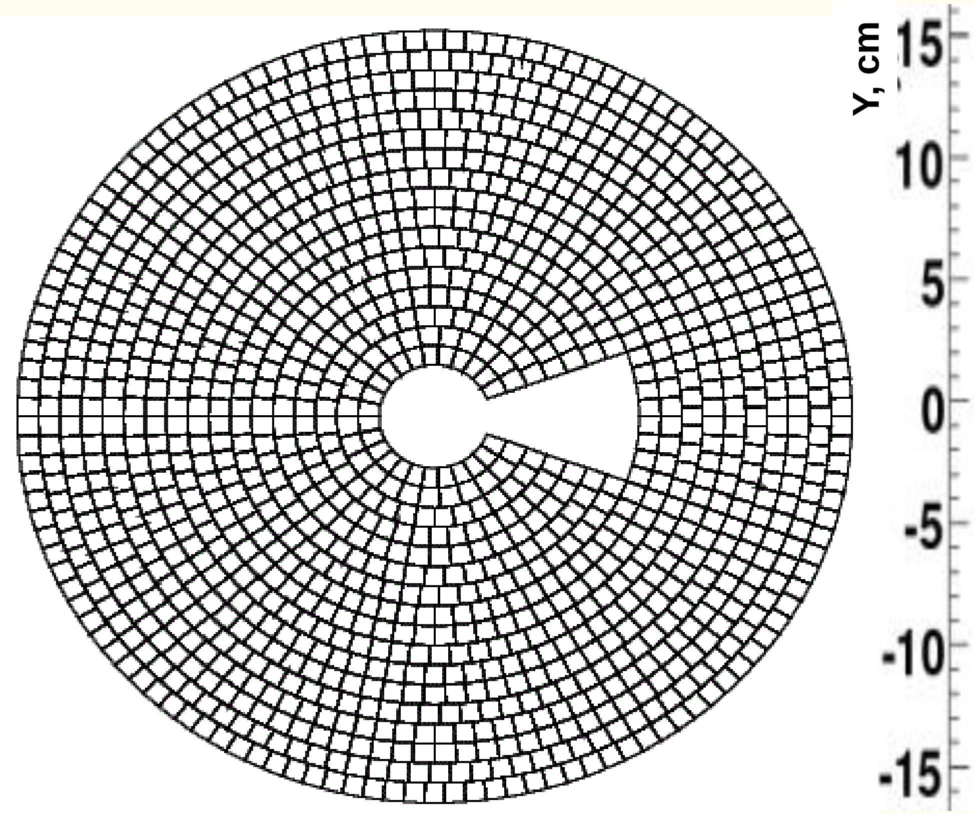
- Detect sHEe
- Determine Beam Parameters
- Masking backscattered low energetic particles



- **Tungsten absorber**
- **Diamond sensor**
- **Readout plane/air gap**

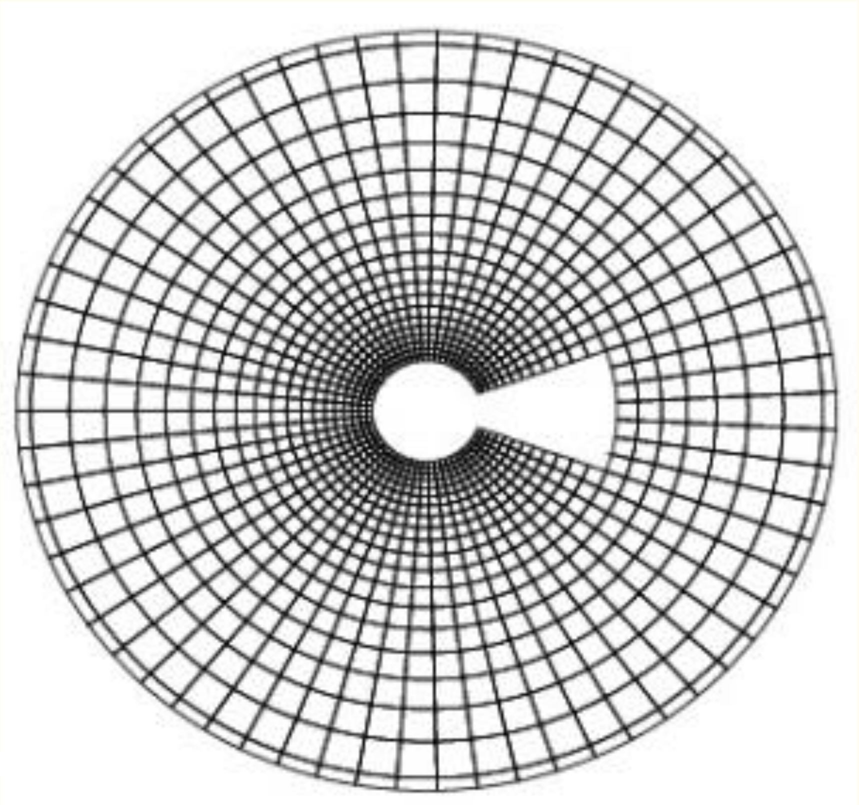
} **1** X_0

BeamCal Segmentation



Uniform Segmentation (US)

pads size are the same



Proportional Segmentation (PS)

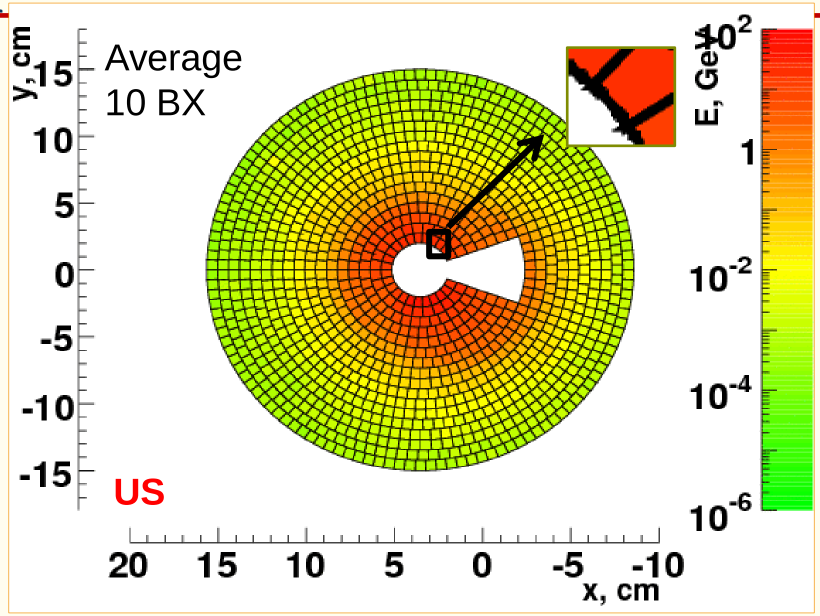
pads size are proportional to the radius

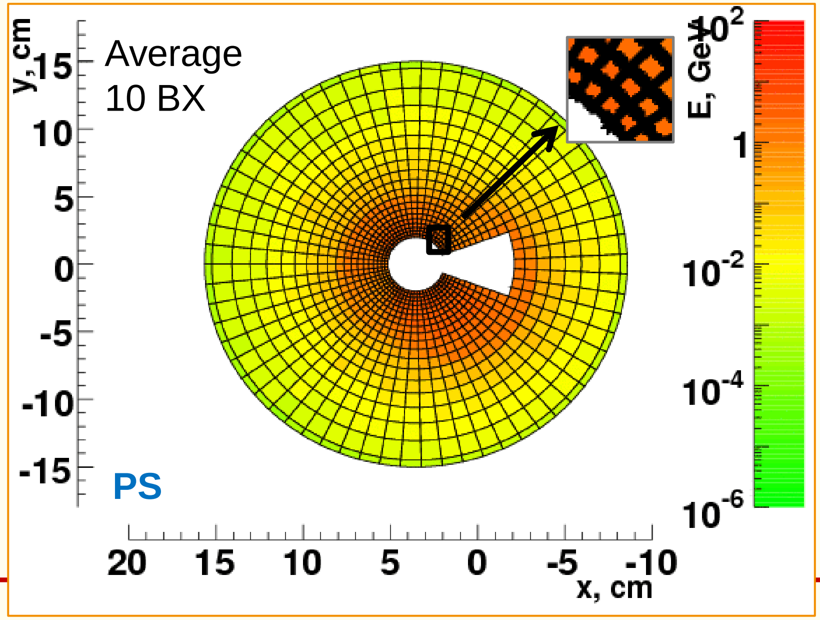
Similar number of channels

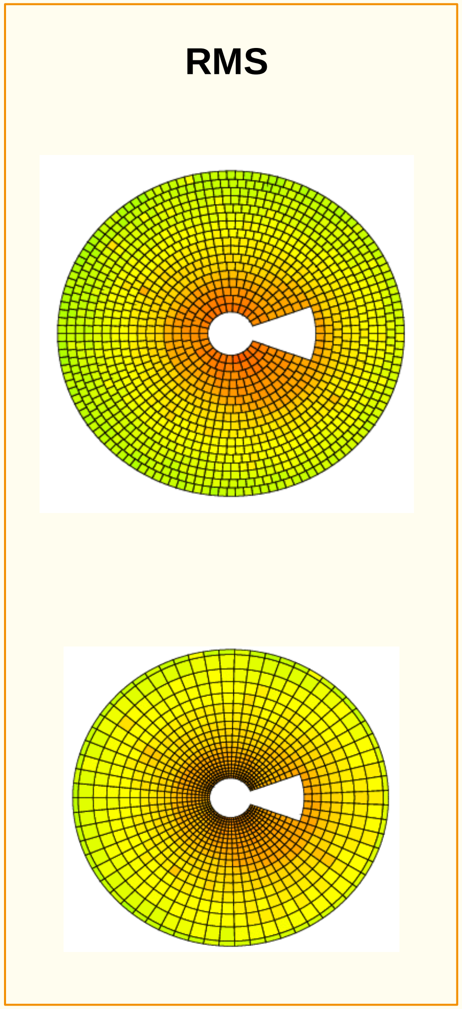
Energy Deposition due to Beamstrahlung

- **Beamstrahlung (BS) pairs generated with Guinea Pig**
- **Energy deposition in sensors from BS simulated with BeCaS (Geant4)**
  ⟶ ***considered as Background (BG)***
- **RMS of the averaged BG**
  ⟶ ***considered as noise (for SNR)***

E_{dep} is the same, but E_{dep}/pad is different!





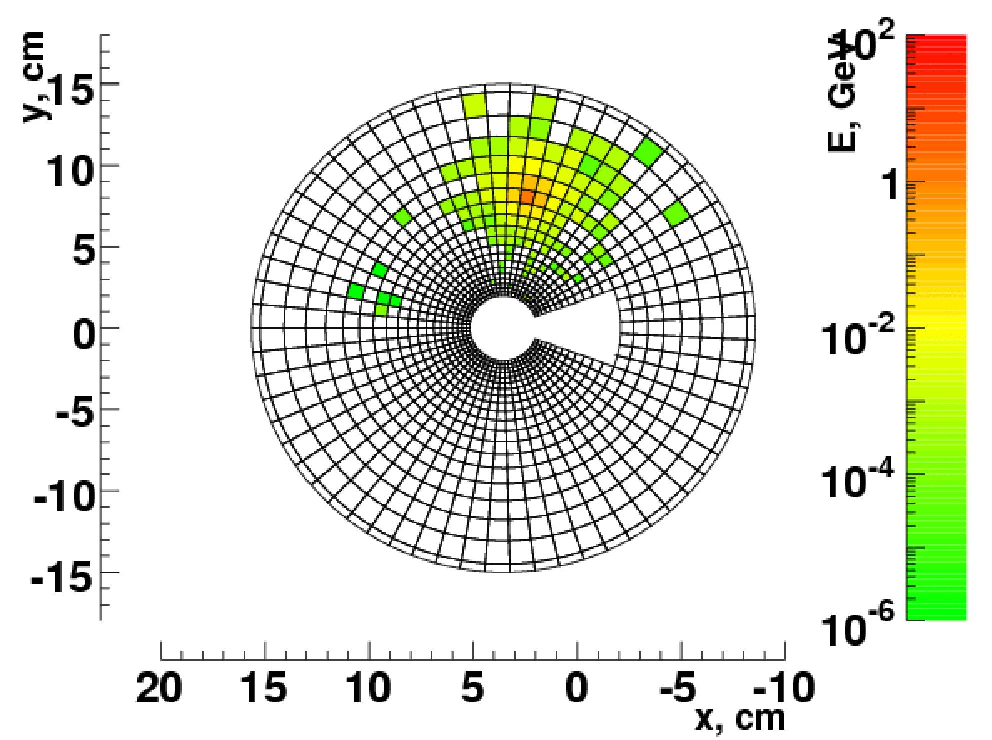


Figures show sum of all layers

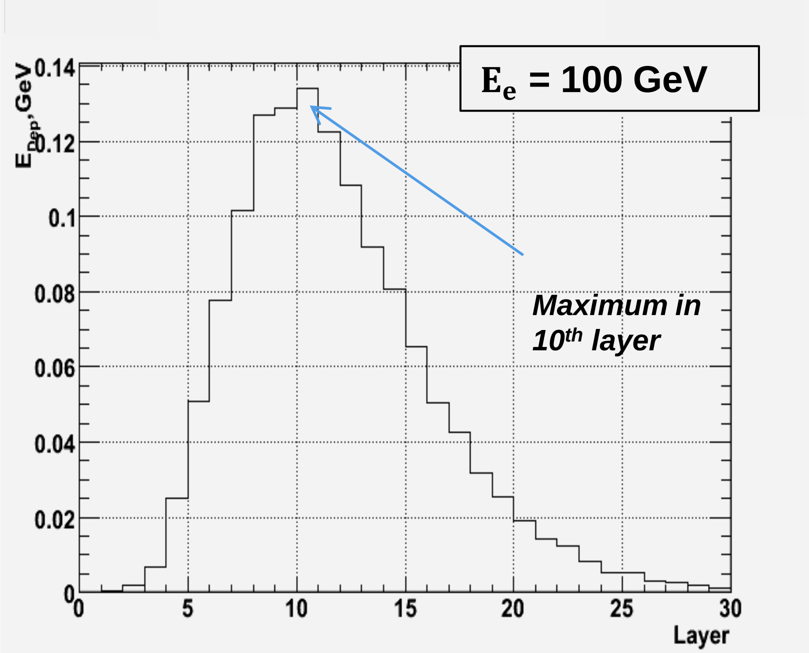
Shower from Single High Energy Electron

- Showers are simulated with BeCaS (Geant4)
- Investigated energies: 10, 20, 50, 100, 200, 500 GeV

Shower from 100- GeV electron



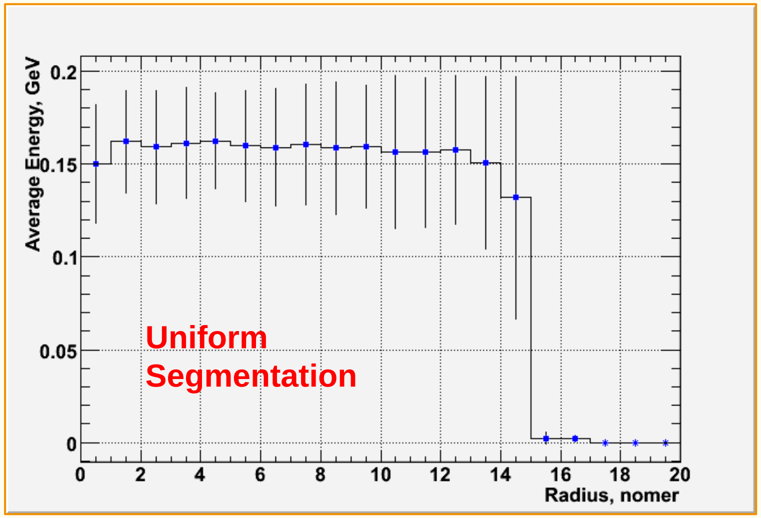
Longitudinal shower profile

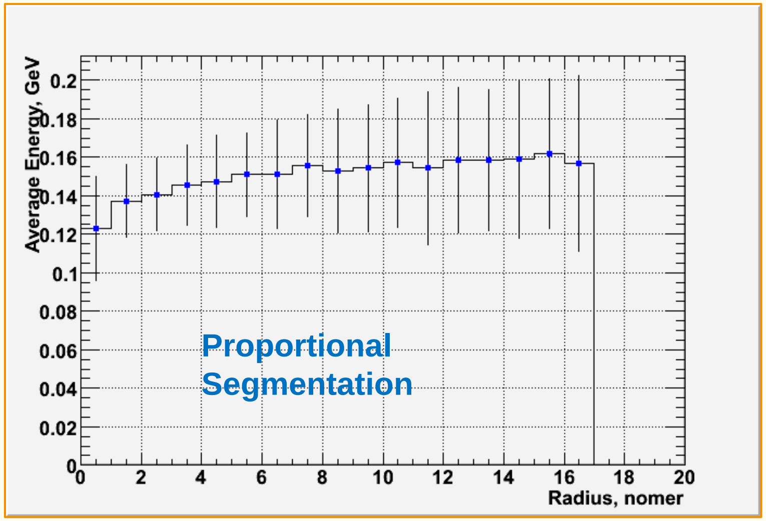


(average over 10 showers)

Signal and RMS for both Segmentations

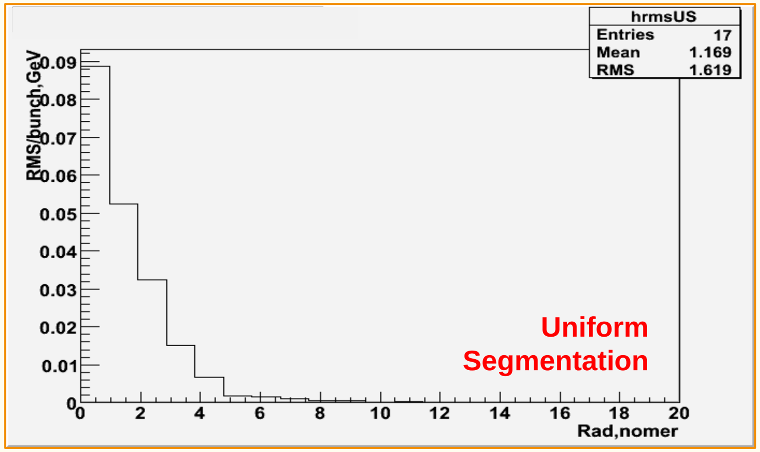
Core signal in layer of shower maximum (10th layer for 100 GeV)

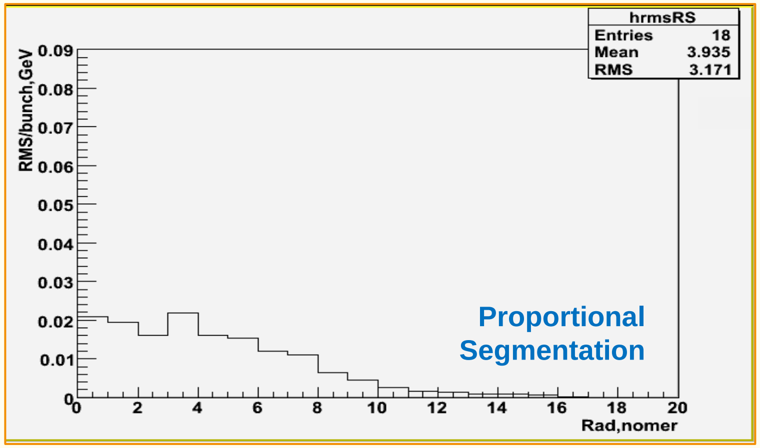




Signal nearly segmentation-independent!

RMS from Background (in 10th layer)





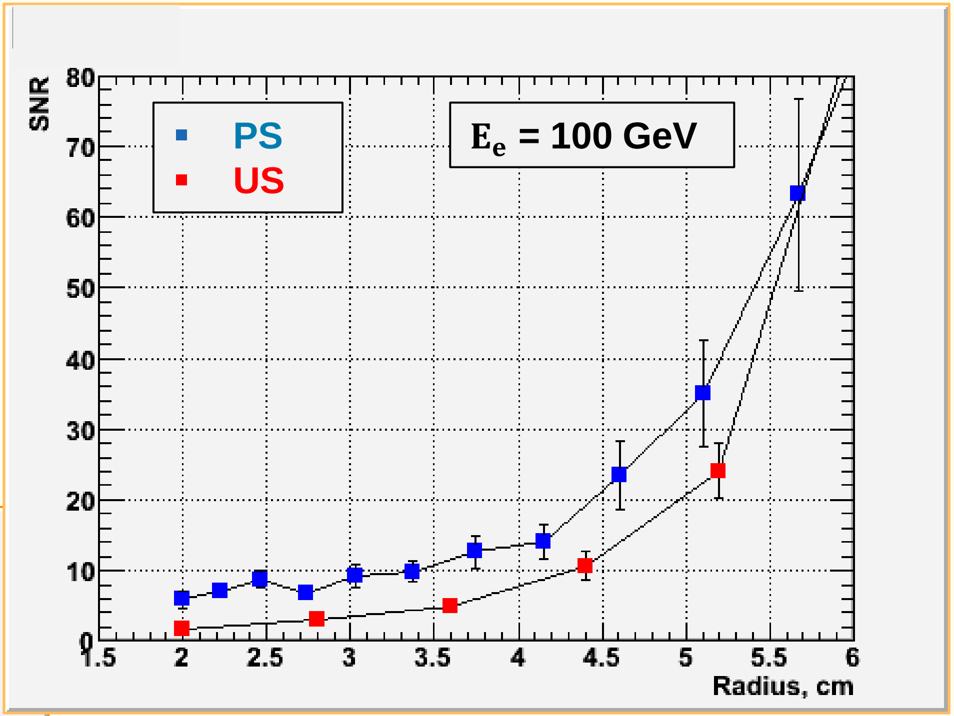
Different distributions!

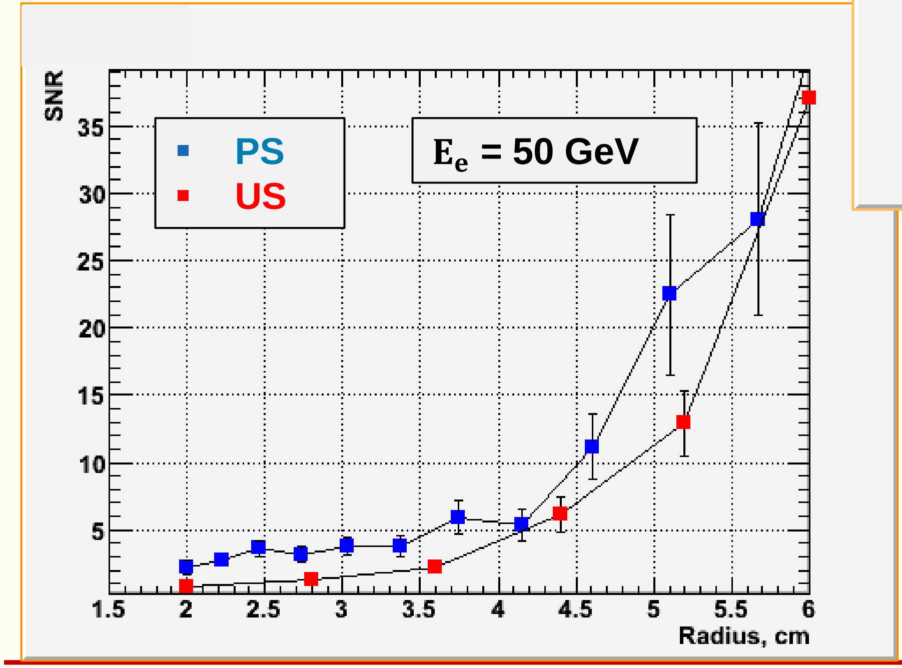
20 bunch crossings were given

SNR in cell with maximum E_dep

- <u>Signal</u> – is maximum energy deposition in cell from sHEe *(in the core of shower and in the maximum energy deposition layer)*

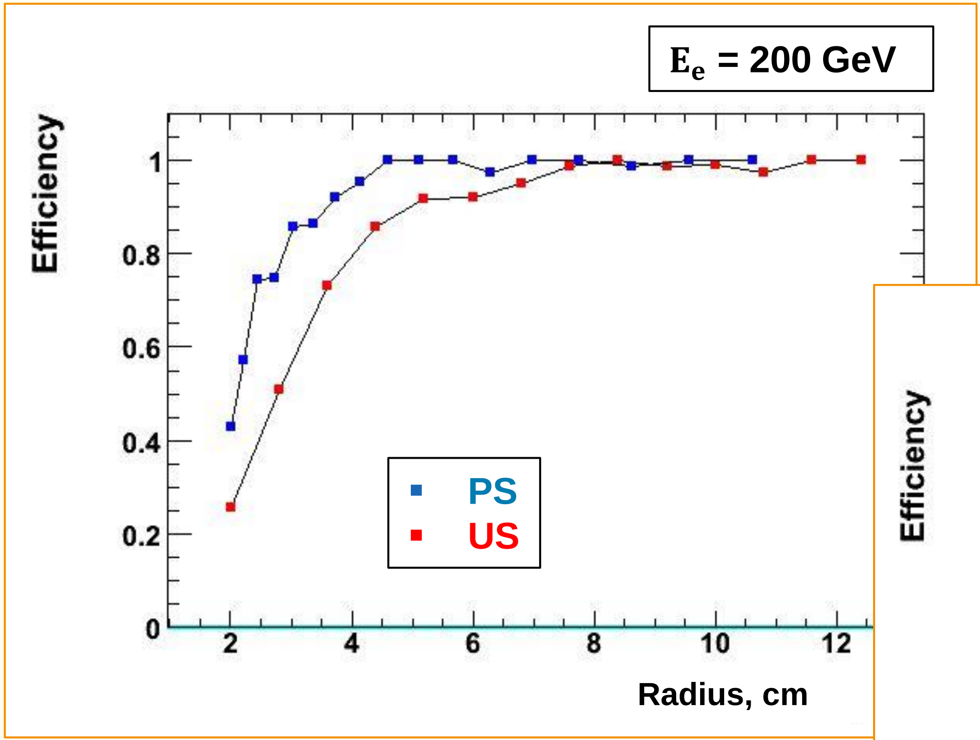
- <u>Noise</u> – is RMS of the averaged BG

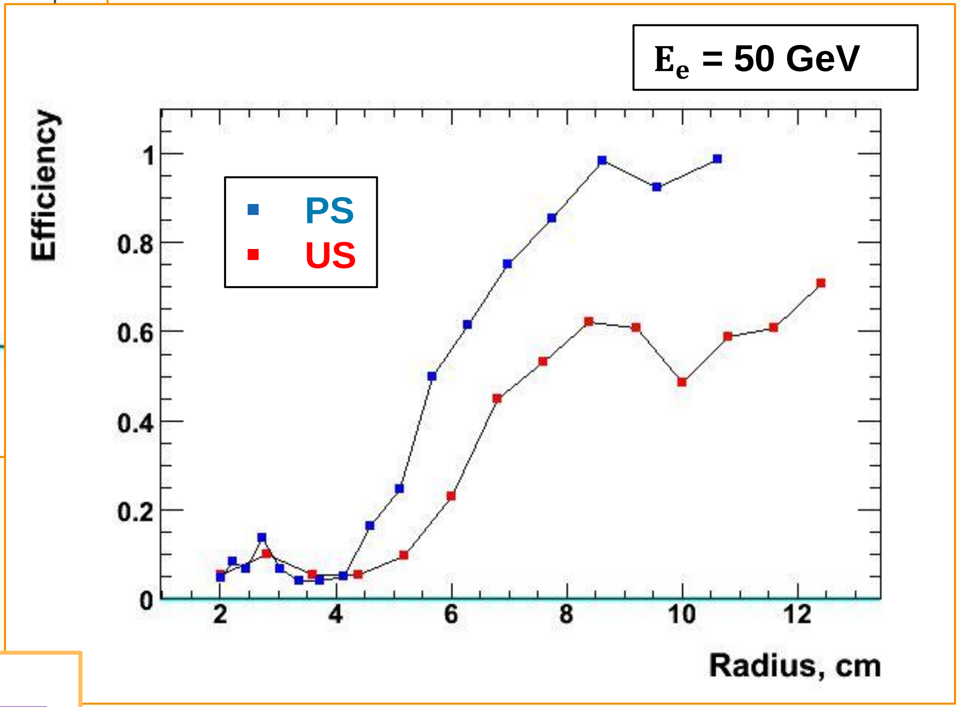




$$SNR = \frac{\text{signal from HE electron}}{\text{RMS from background}}$$

Efficiency of Showers Reconstruction

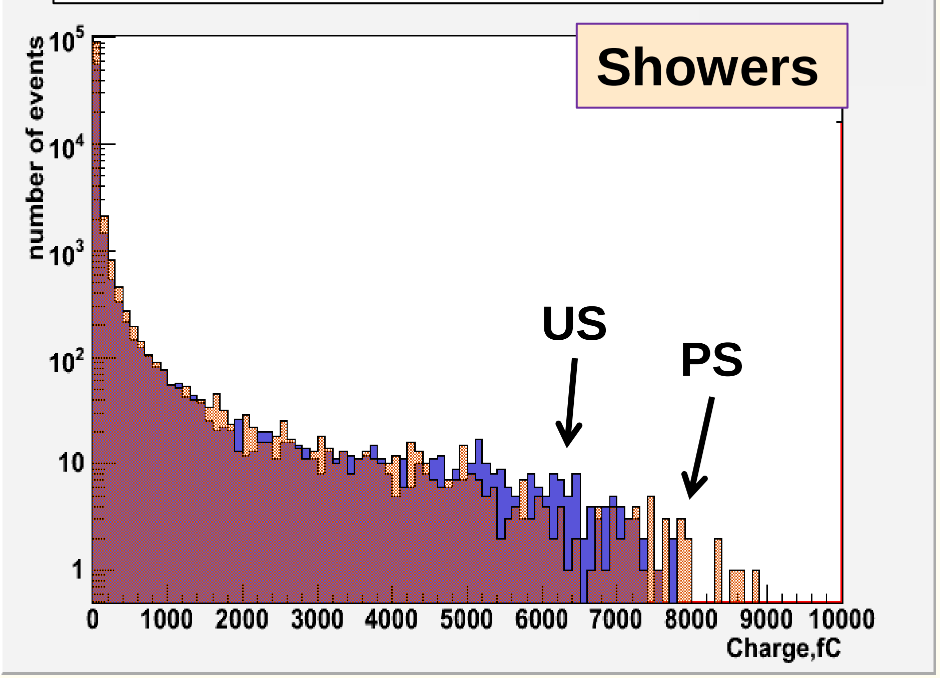




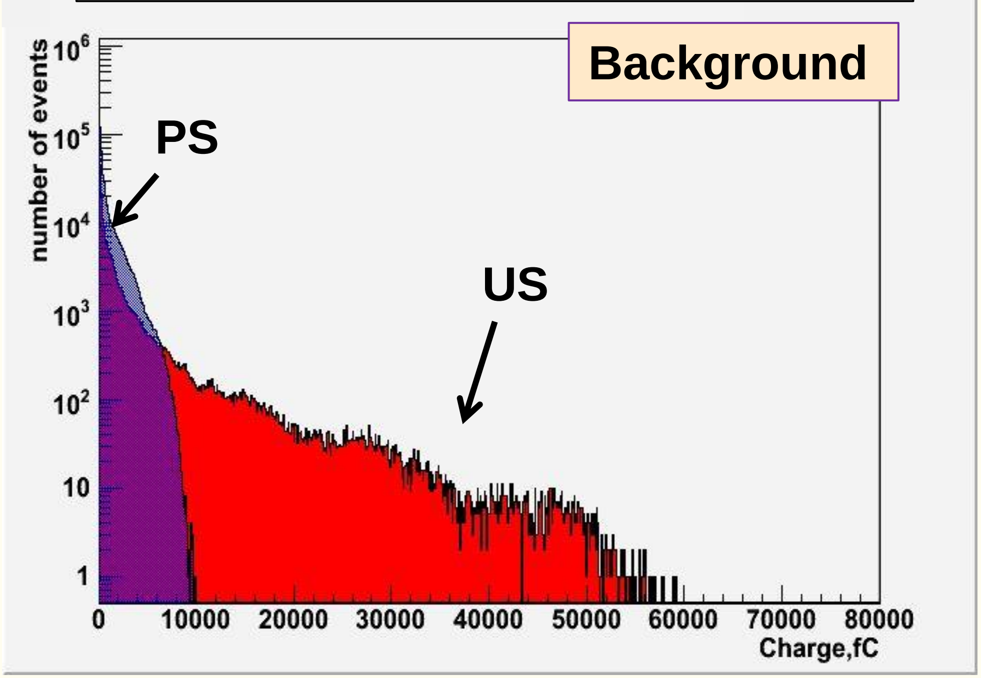
$$\text{Efficiency} = \frac{\text{Reconstructed SH considering BG}}{\text{Reconstructed SH without considering BG}}$$

Charge Range Estimate

Distribution of the collected charge per pad from 500Gev electron showers for Diamond



Distribution of the collected charge per pad from Background for Diamond

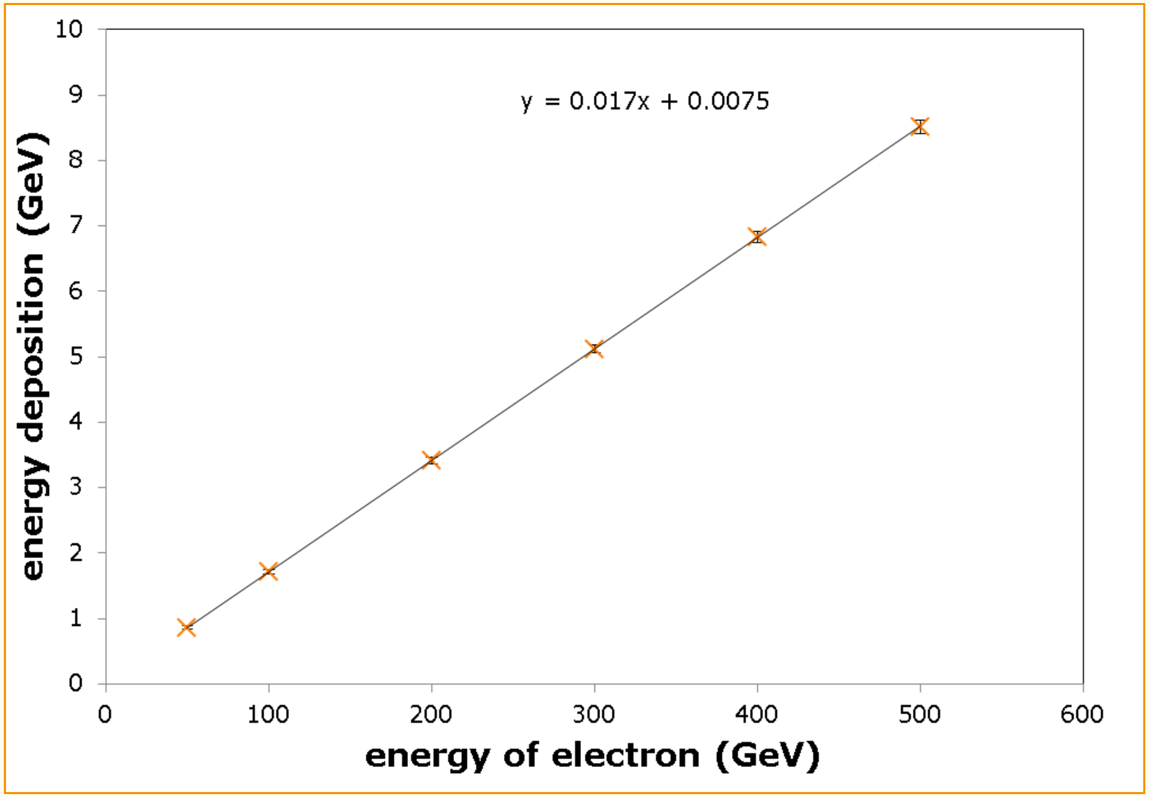


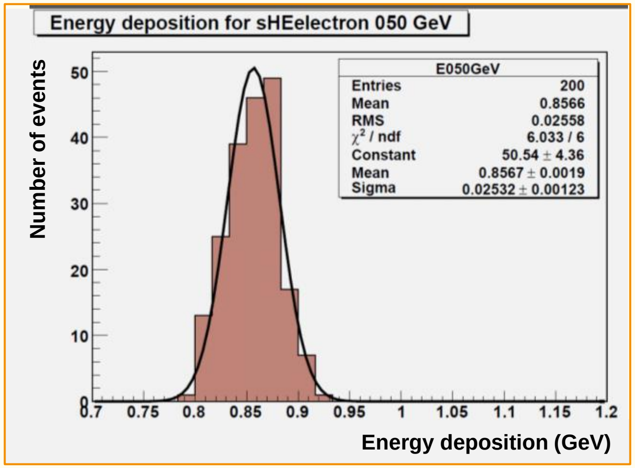
For Diamond sensor pad thickness 300 µm:

- Charge collected from MIP: 2.44 fC

- Maximum charge collected – for shower from 500 GeV electron: 12214 fC (correspond to about 5000 MIPs)

Deposited Energy vs Energy of Electron

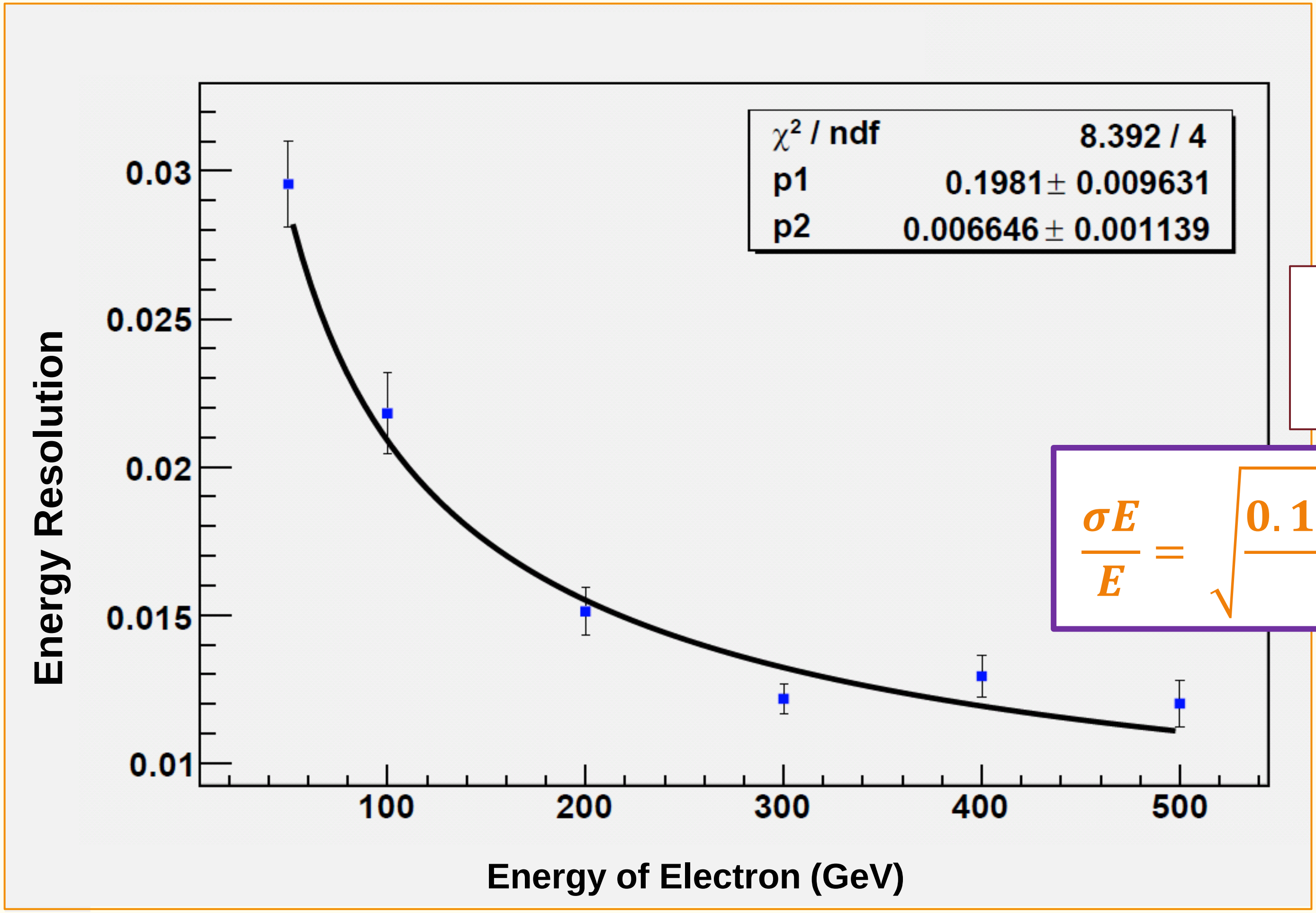




$$E_e = A * E_{dep} - B$$

$$A = 58.66 \pm 0.03974; \quad B = -0.2972 \pm 0.1183$$

Energy Resolution vs Energy of Electron



$$\frac{\sigma E}{E} = \sqrt{\frac{{p_1}^2}{E} + {p_2}^2}$$

$$\frac{\sigma E}{E} = \sqrt{\frac{0.1981^2}{E} + 0.006646^2}$$

Spatial Resolution (In Process)

Estimation

PS

$$\frac{\sigma R}{R} = \frac{\Delta R}{R\sqrt{12}} = 0.029$$

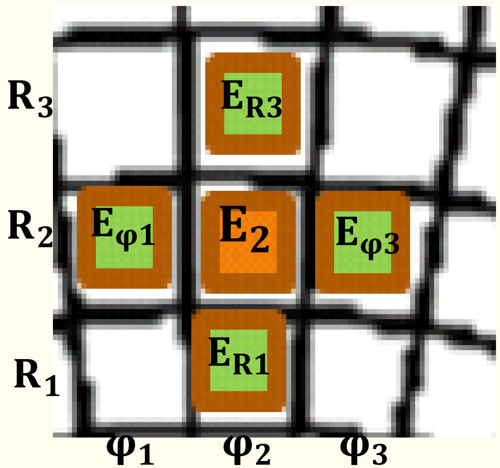
$$\sigma_\varphi = \frac{\Delta\varphi}{\sqrt{12}} = 1.65 \text{ degrees}$$

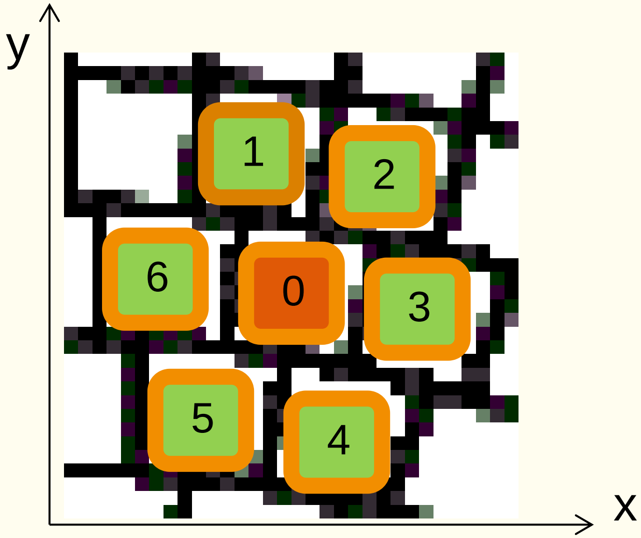
US

$$\sigma d_R = \frac{\Delta d_R}{\sqrt{12}} = 2.21 \text{ mm}$$

$$\sigma d_C = \frac{\Delta d_C}{\sqrt{12}} = 2.16 \text{ mm}$$

COG

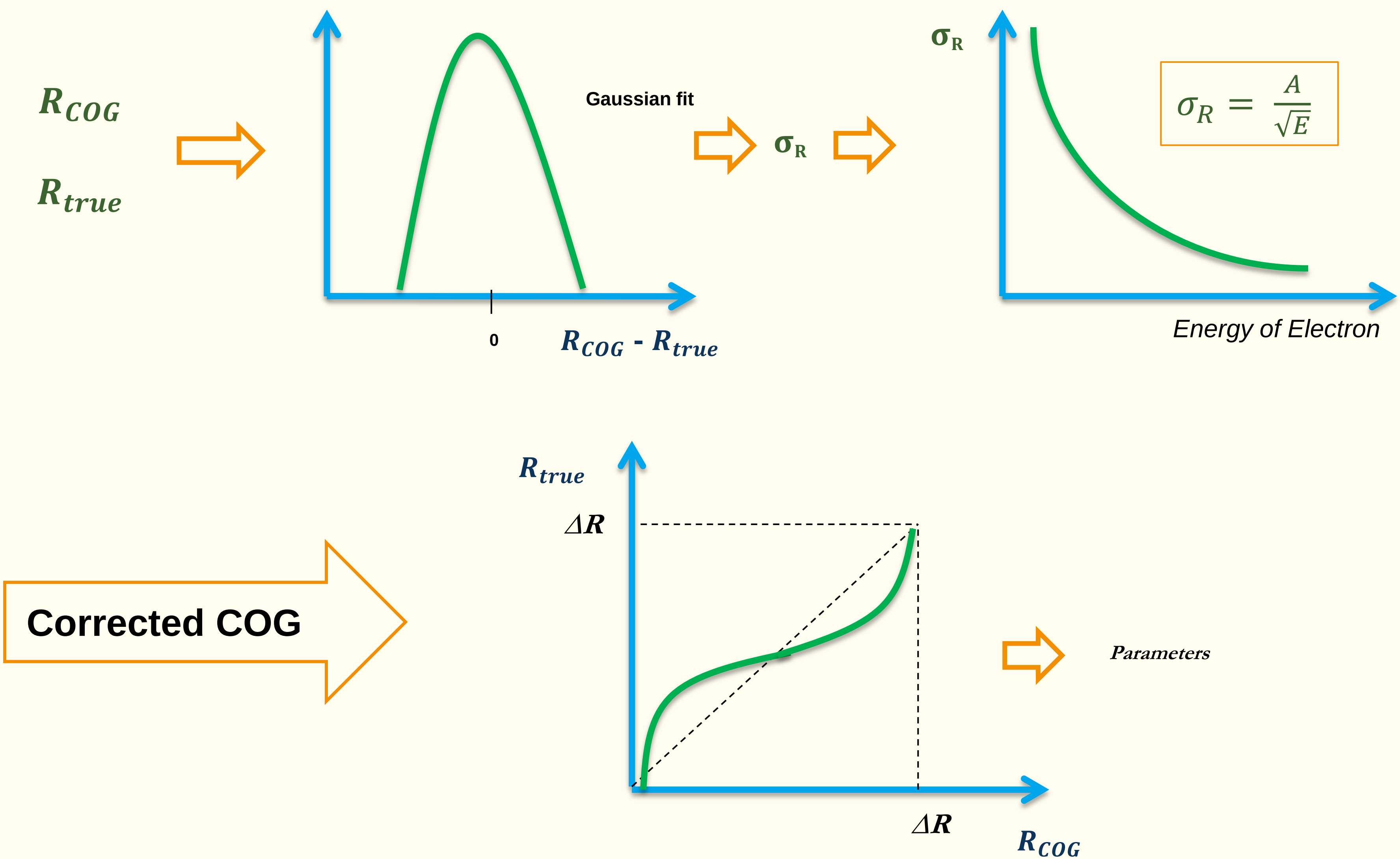




$$R_{COG} = \frac{R_1 E_{R1} + R_2 E_2 + R_3 E_{R3}}{E_{R1} + E_2 + E_{R3}}$$

$$X_{COG} = \frac{\sum_{i=0}^{6} X_i E_i}{\sum_{i=0}^{6} E_i}$$

Spatial Resolution (In Process)



Conclusion

- Performance of BeamCal for two different sensor segmentations was compared
  - Number of readout channels is kept similar
  - Signal from sHEe nearly independent of the segmentation
  - Energy deposition per pad from Beamstrahlung differs significantly
  - Proportional segmentation improves the signal-to-noise ratio
  - Proportional segmentation gives better reconstruction efficiency
- The charge range has been estimated
  - Collected charge per pad from sHEe nearly independent of the segmentation
  - Collected charge per pad from BS for US in 6 times more than for PS
- Energy deposition was investigated
  - Dependence between energy of electron and deposited in calorimeter energy is good linear

    Coefficient of linearity 59.
  - Dependence energy resolution vs energy of electron is calculated and parameterized.

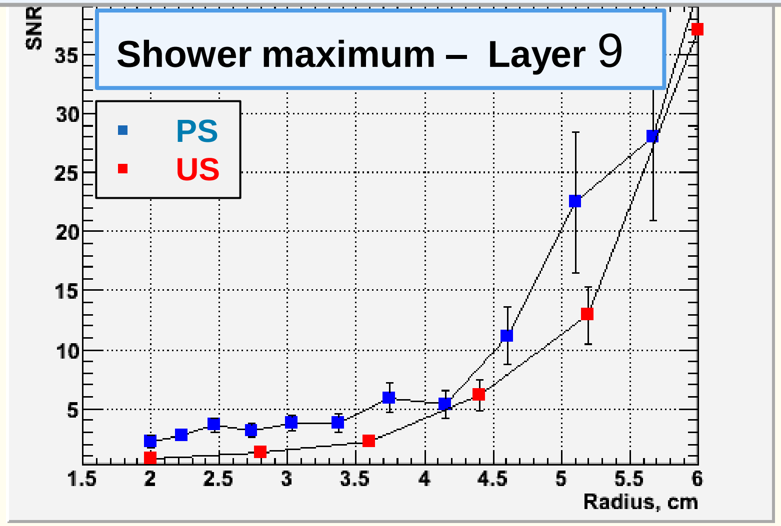
    Calorimeter gives good energy resolution: 3% (for 50GeV HEe); 1,1% (500GeV)

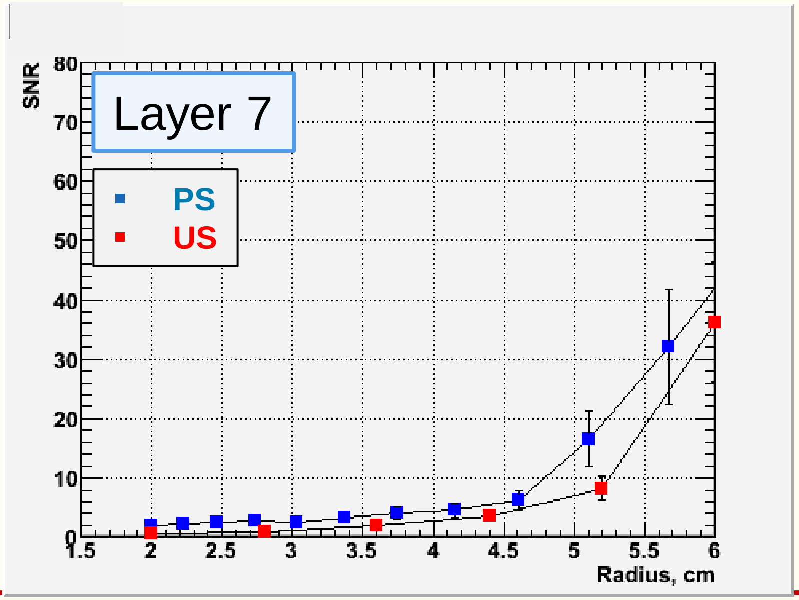
Thank you for your attention!

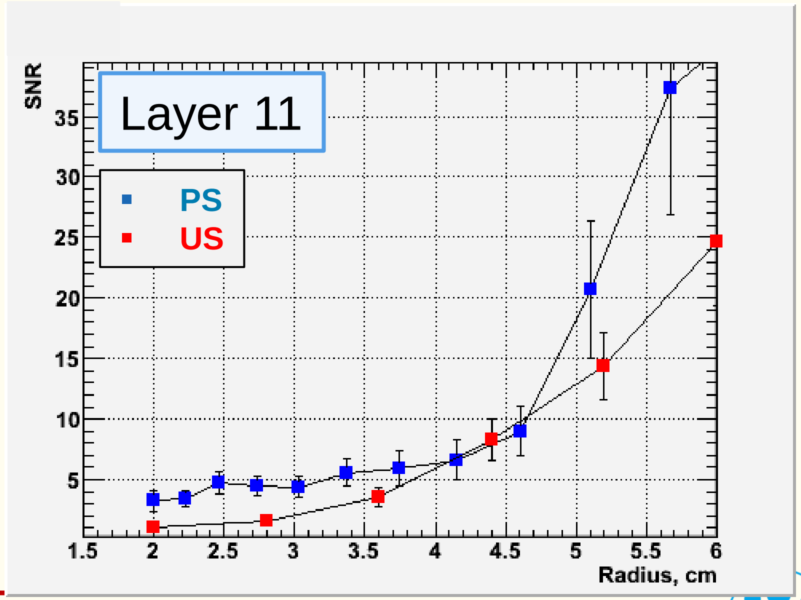
Backup slides

SNR for 50 GeV Electron

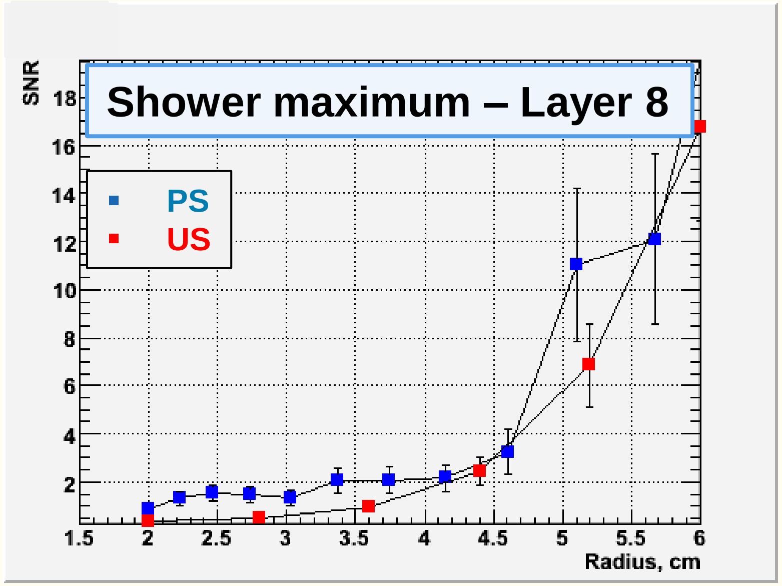
SNR in cell with maximum E_{dep}

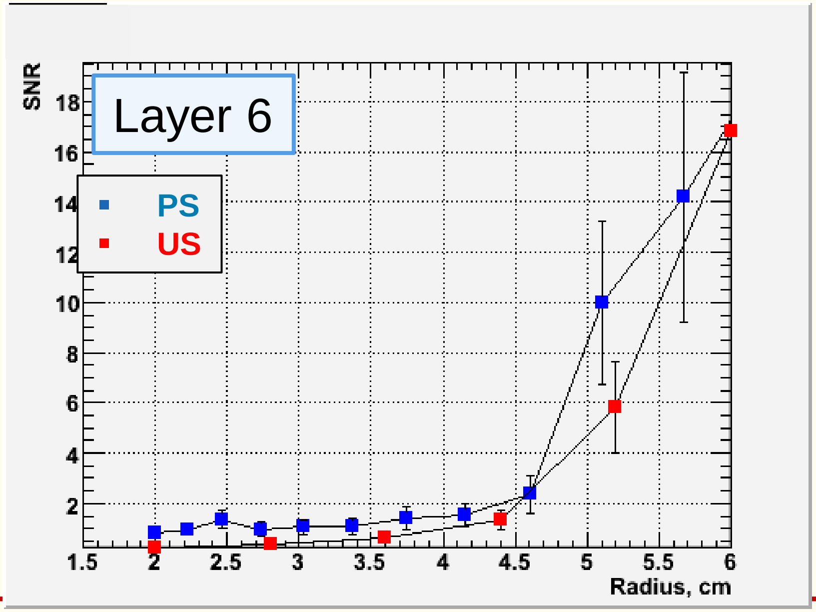


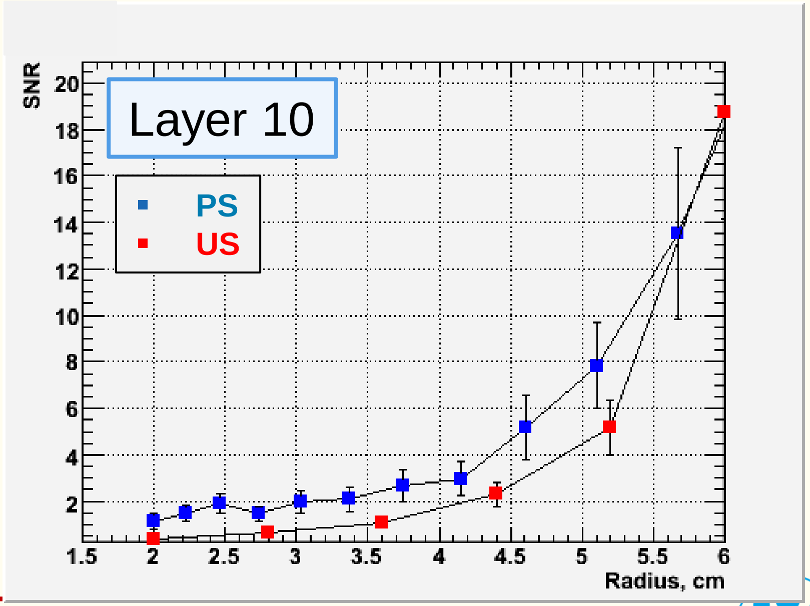




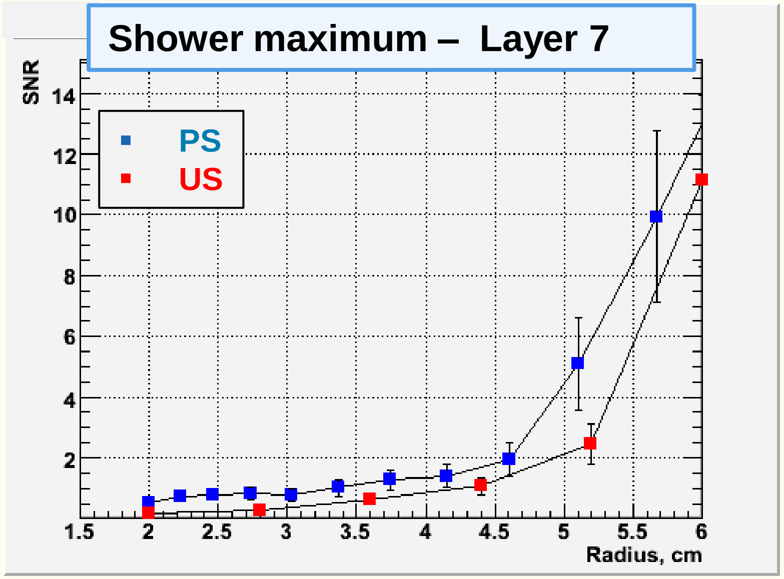
SNR for 20 GeV Electron

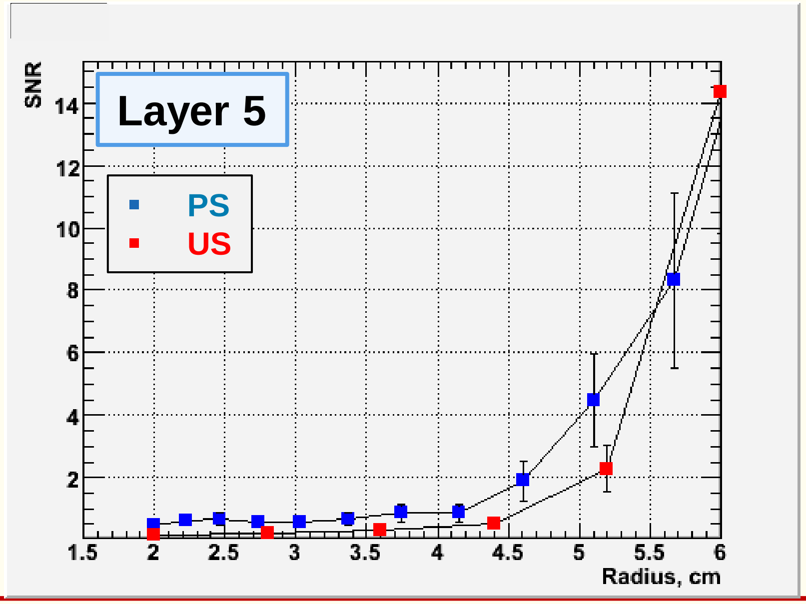


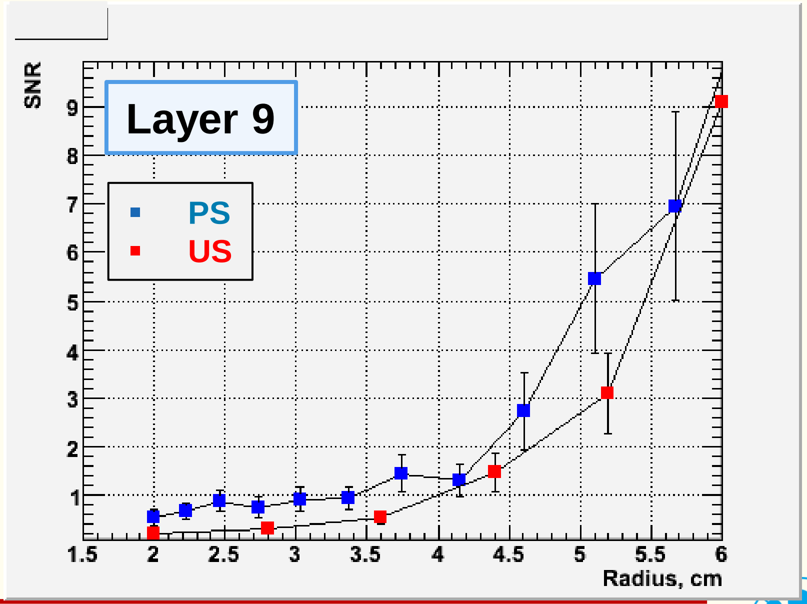




SNR for 10 GeV Electron







Charge range estimate

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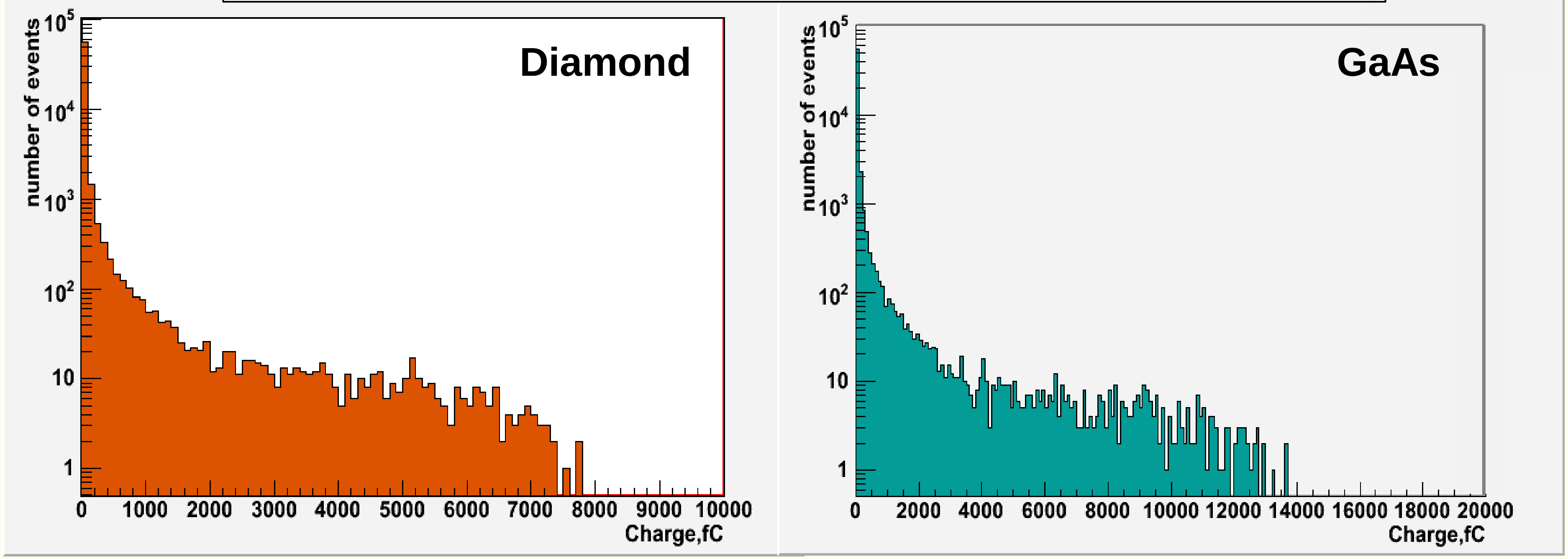

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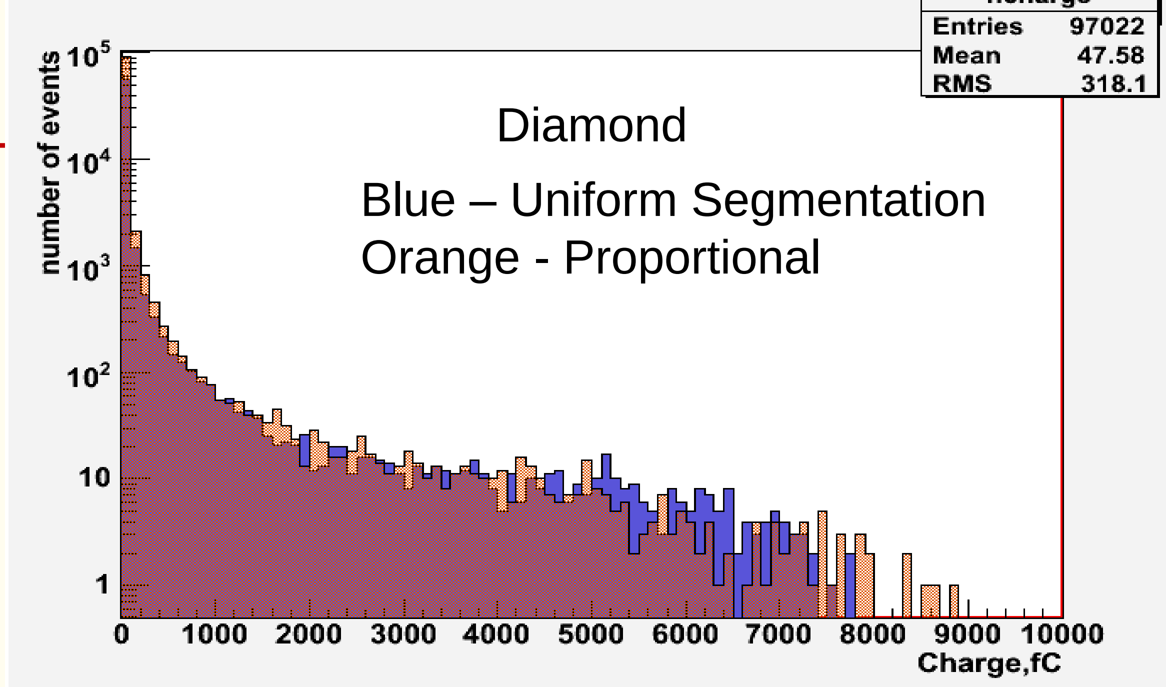
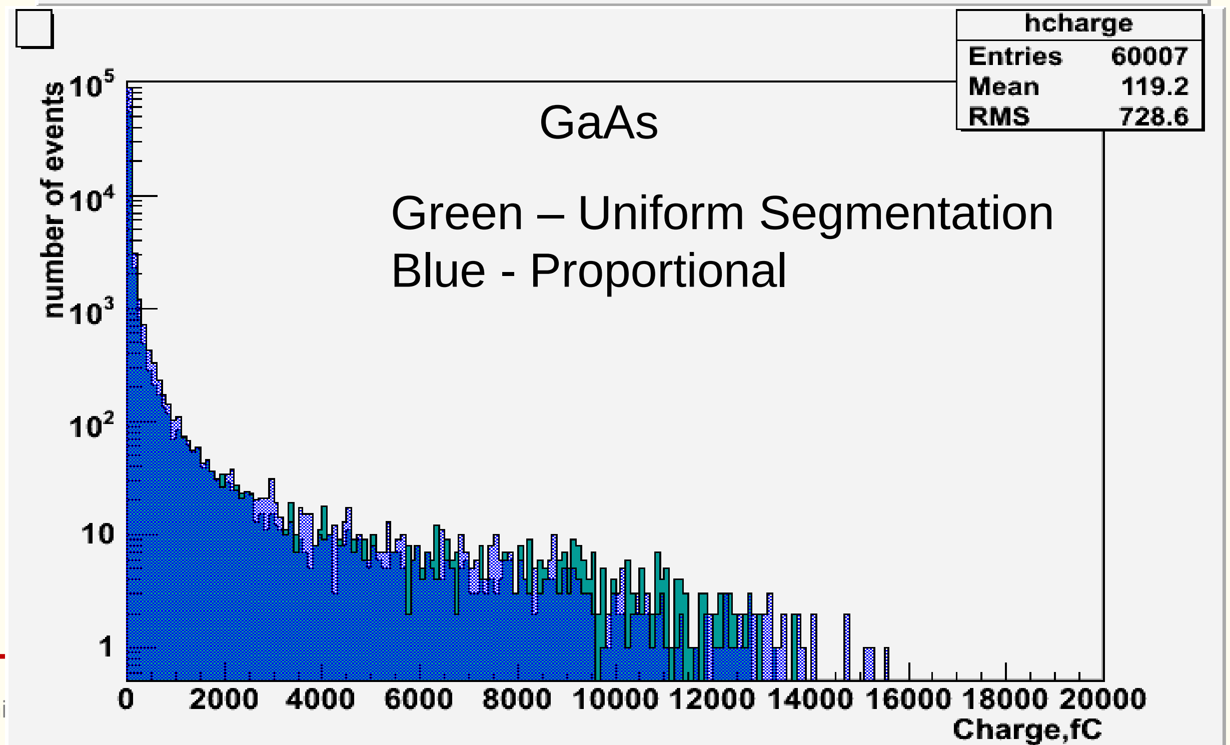
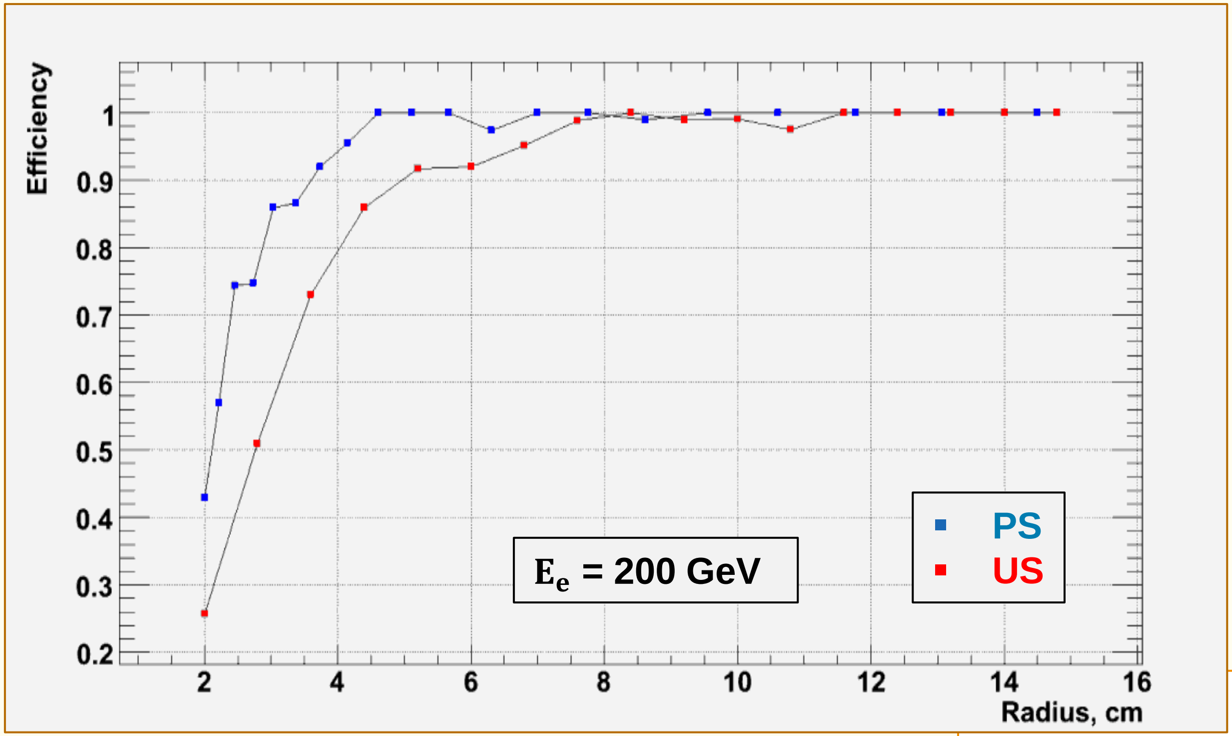




Efficiency of Showers Reconstruction



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Efficiency for 50 GeV