Optimisation Studies for the BeamCal Design

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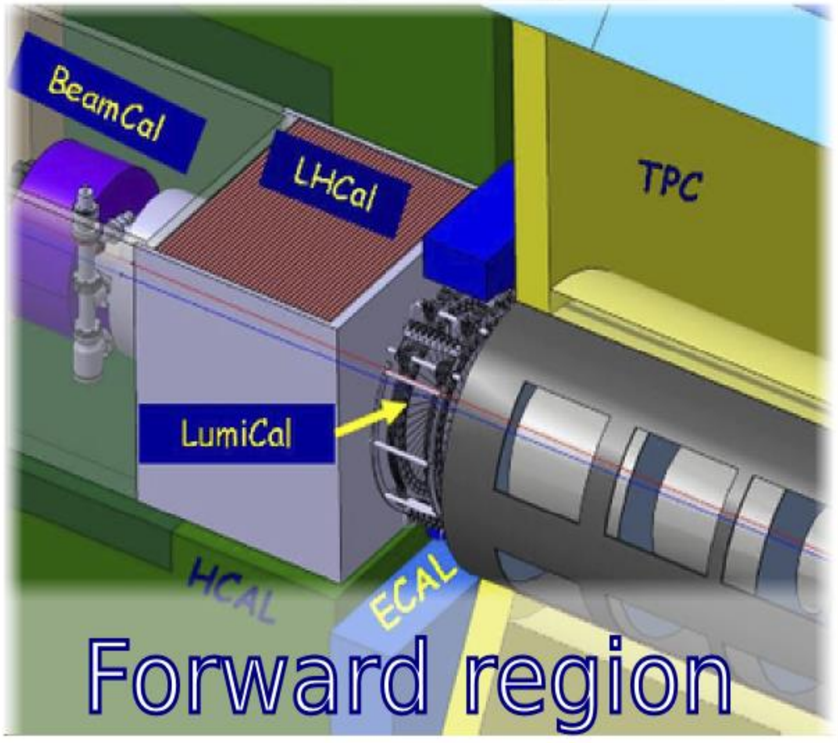
The Aim and Content

The Aim:
- compare 2 types of segmentation of calorimeter
- investigate the characteristics

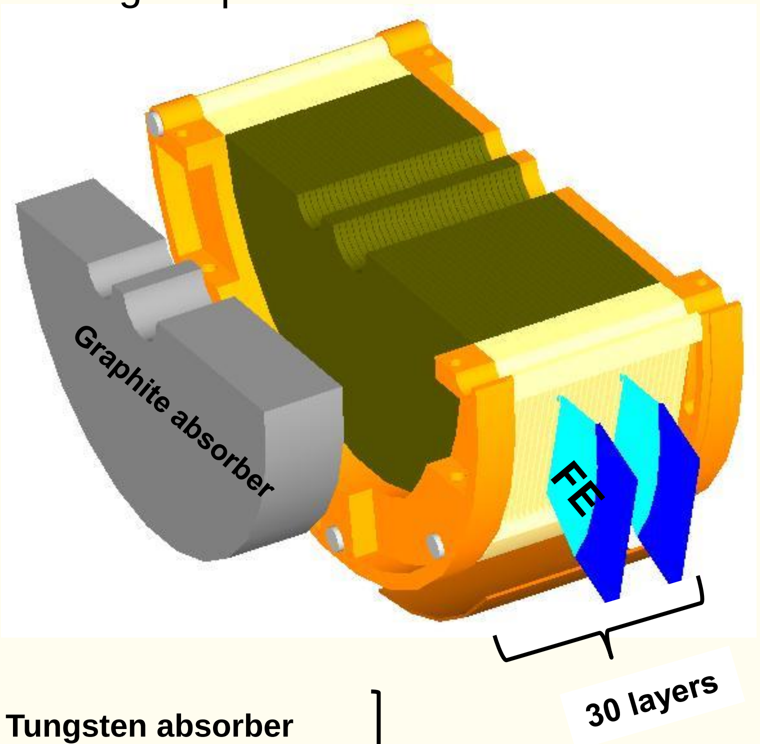
Content:
- Introduction
- Simulation studies
  - SNR
  - efficiency of reconstruction of showers
  - range of charge deposited into the pads
  - dependence E_{dep} vs E_e
  - energy resolution
  - spatial resolution
- Conclusion

Beam Calorimeter for ILC



Beam parameters from the ILC Technical Design Report (November 2012)
- Nominal parameter set
- Center-of-mass energy 1 TeV

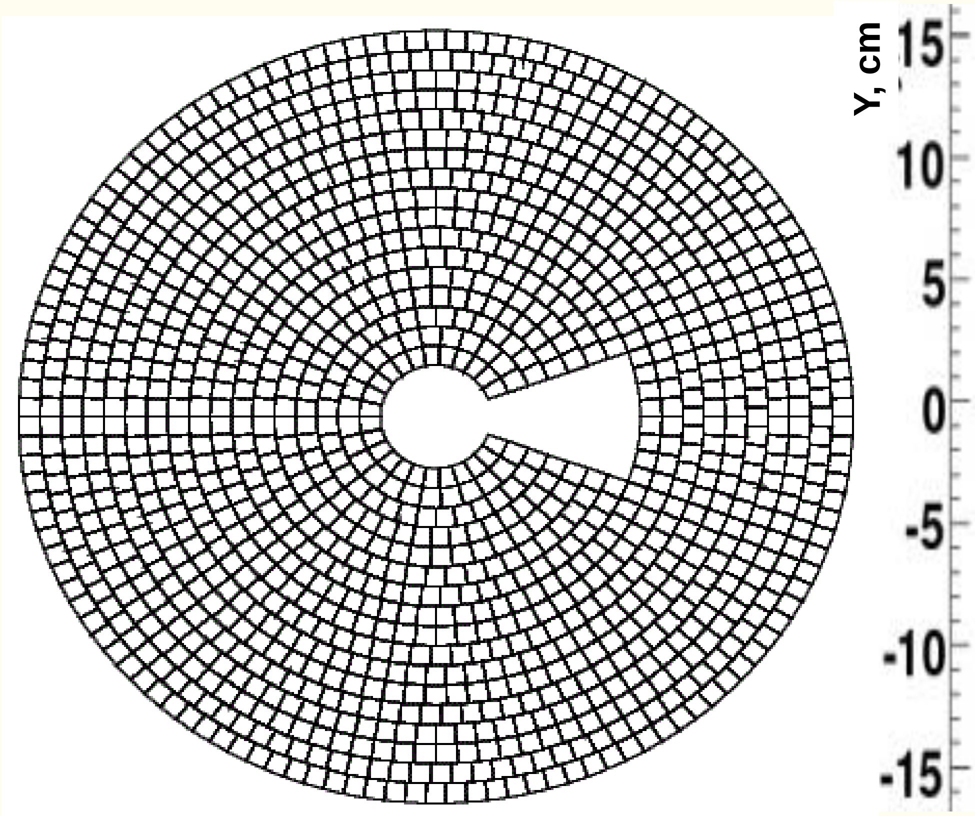
BeamCal aimed:
- Detect sHEe
- Determine Beam Parameters
- Masking backscattered low energetic particles



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

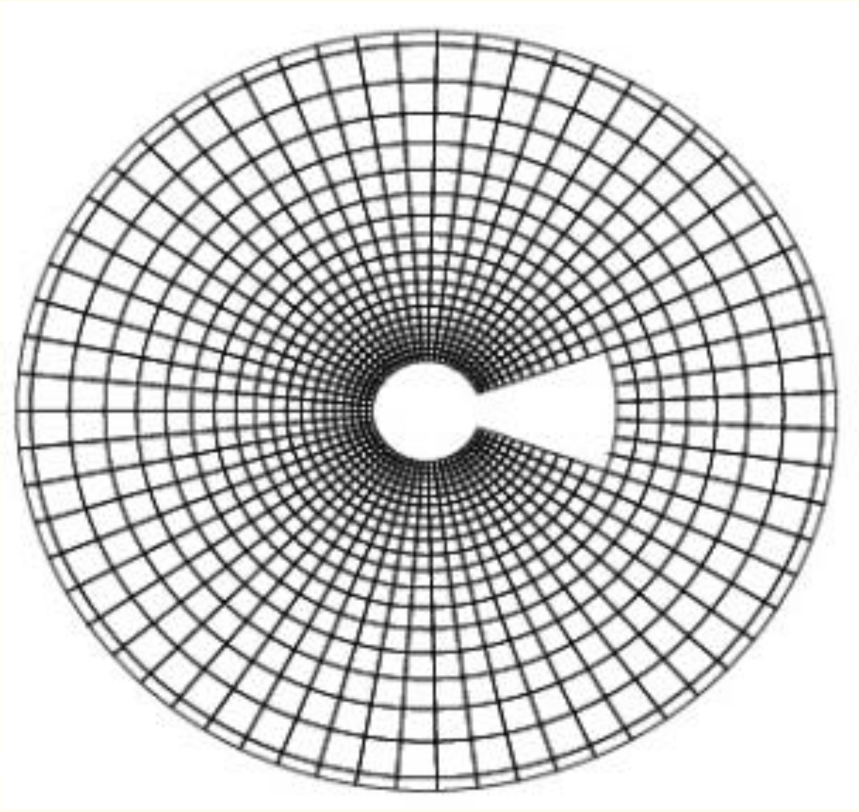
} **1** X_0

BeamCal Segmentation



Uniform Segmentation (US)

pads size are the same



Proportional Segmentation (PS)

pads size are proportional to the radius

<u>Similar number of channels</u>

Energy Deposition due to Beamstrahlung

- **Beamstrahlung (BS) pairs generated with Guinea Pig**

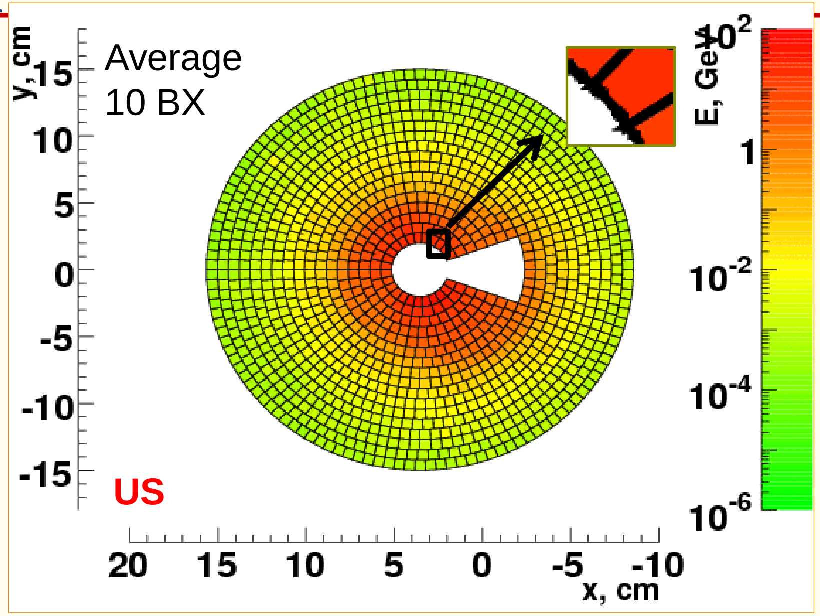
- **Energy deposition in sensors from BS simulated with BeCaS (Geant4)**

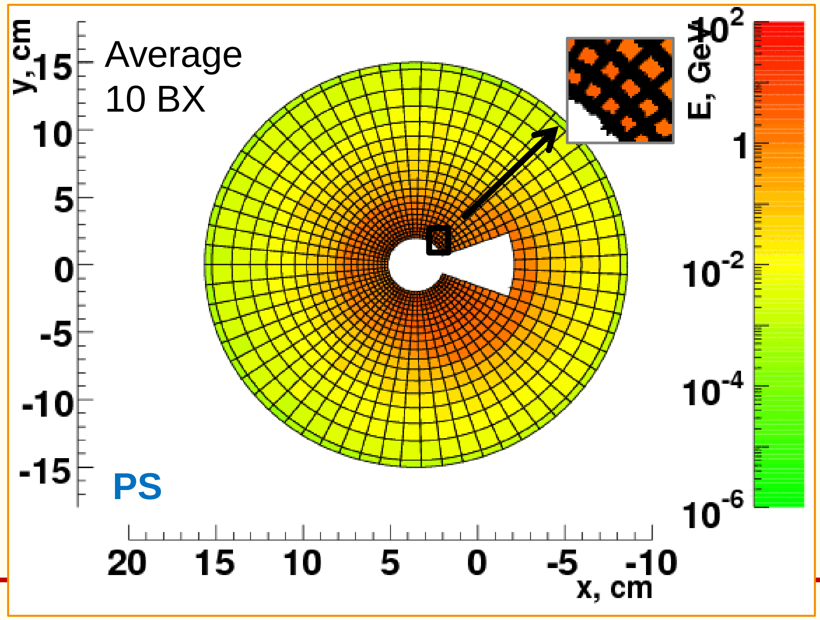
  ⟶ ***considered as Background (BG)***

- **RMS of the averaged BG**

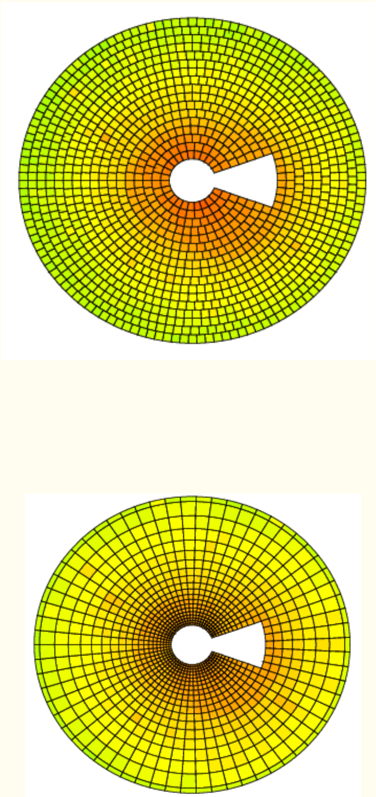
  ⟶ ***considered as noise (for SNR)***

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





RMS

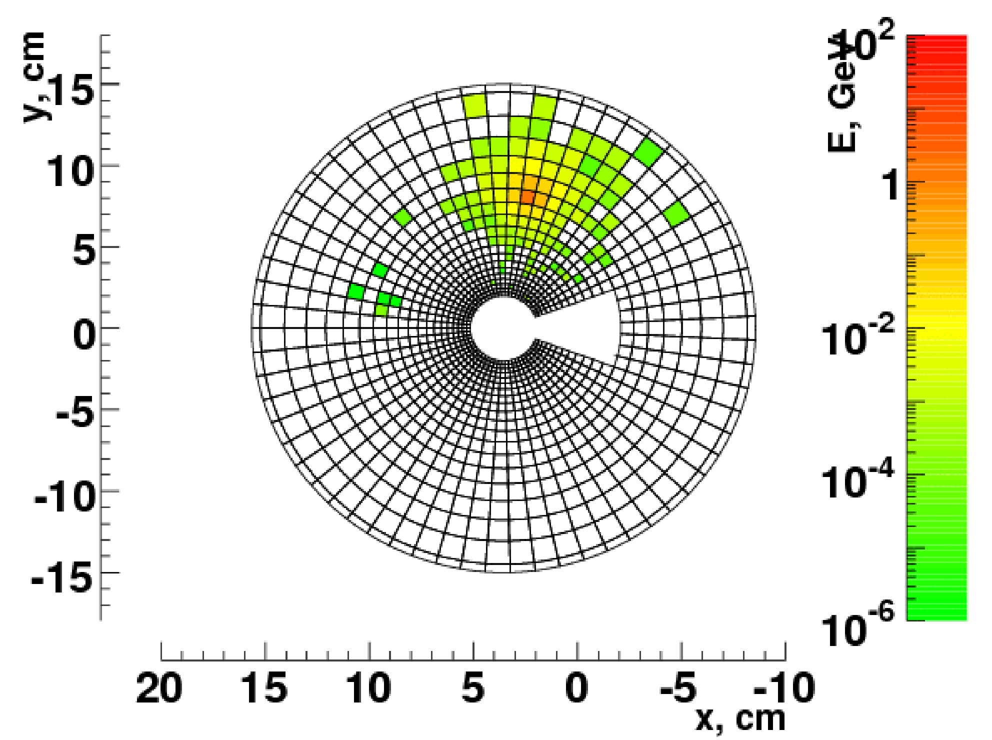


Figures show sum of all layers

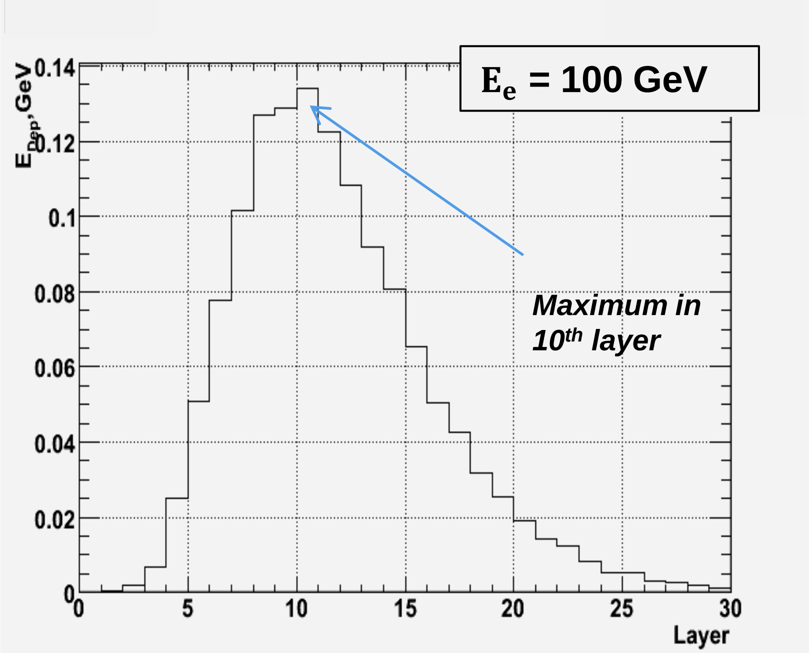
Shower from Single High Energy Electron

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

Shower from 100- GeV electron



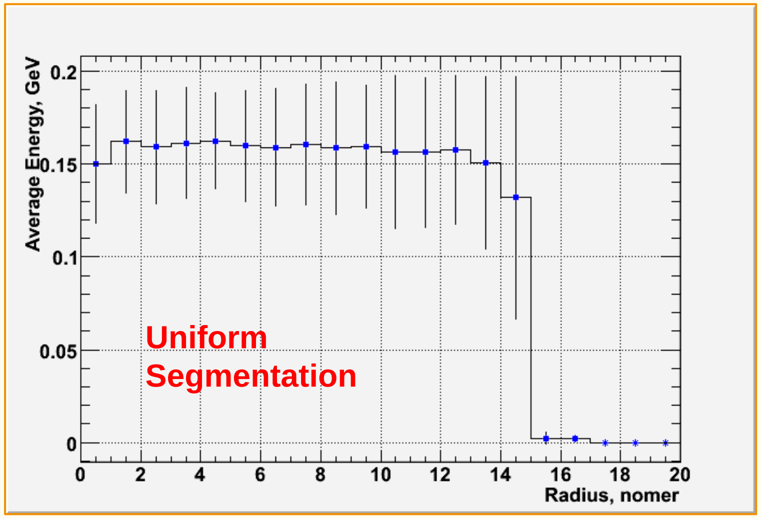
Longitudinal shower profile

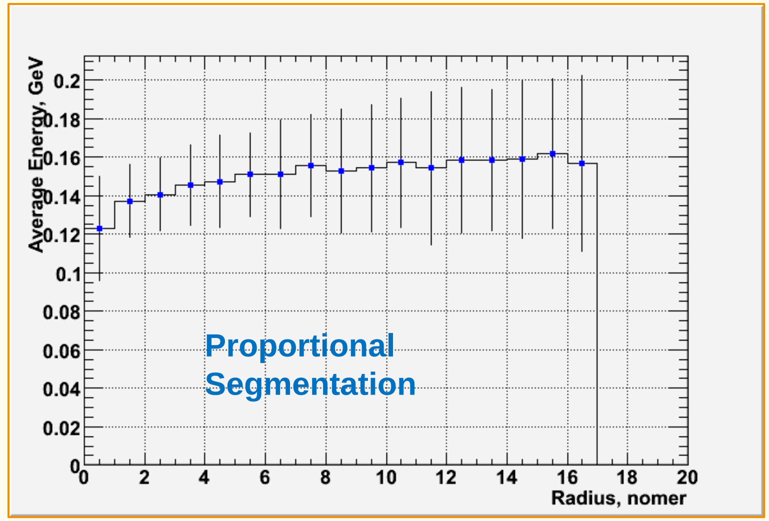


(average over 10 showers)

Signal and RMS for both Segmentations

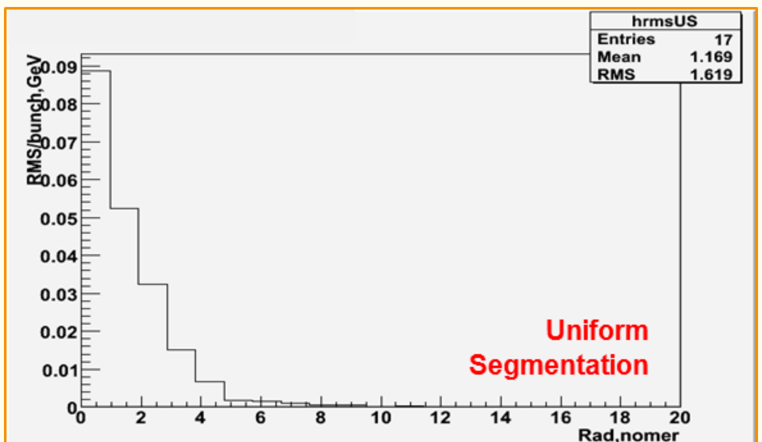
The average energy in the pad of the core of shower

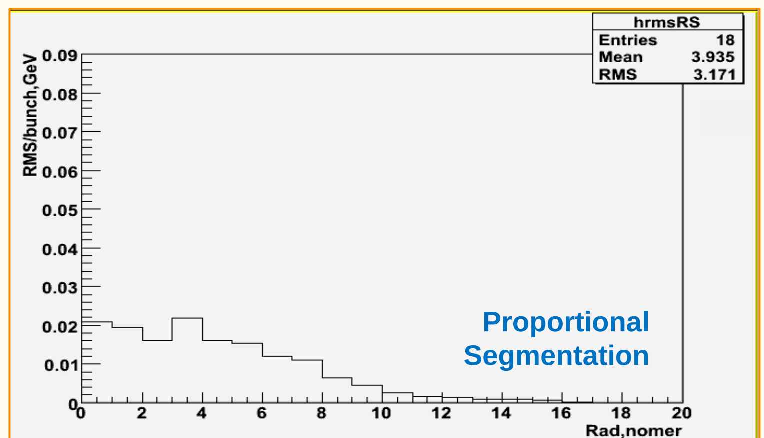




Signal nearly segmentation-independent!

RMS of the averaged Background



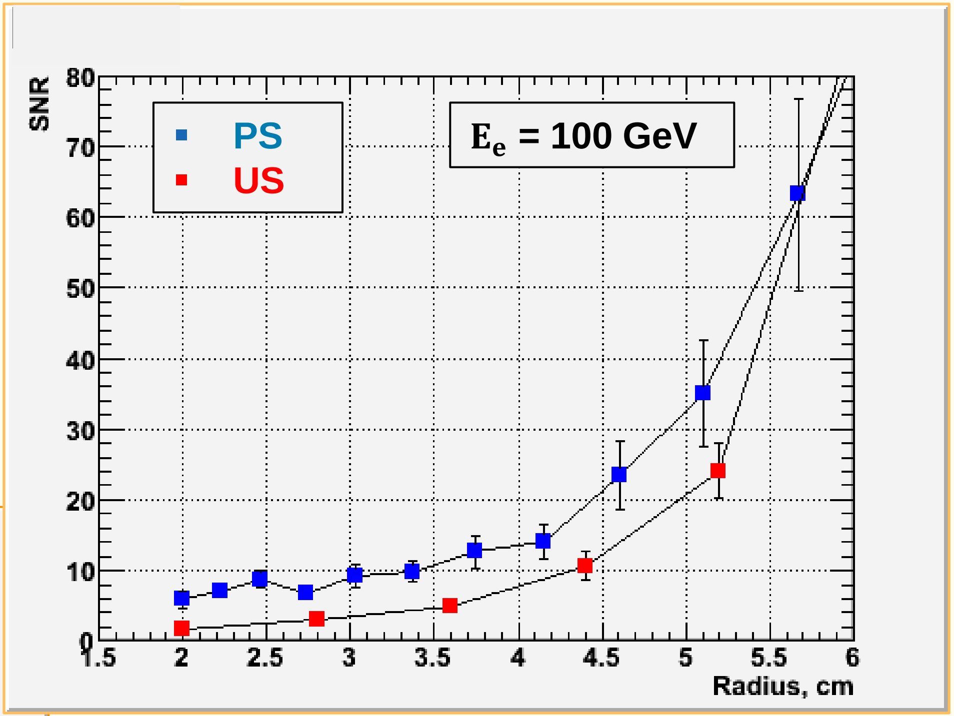


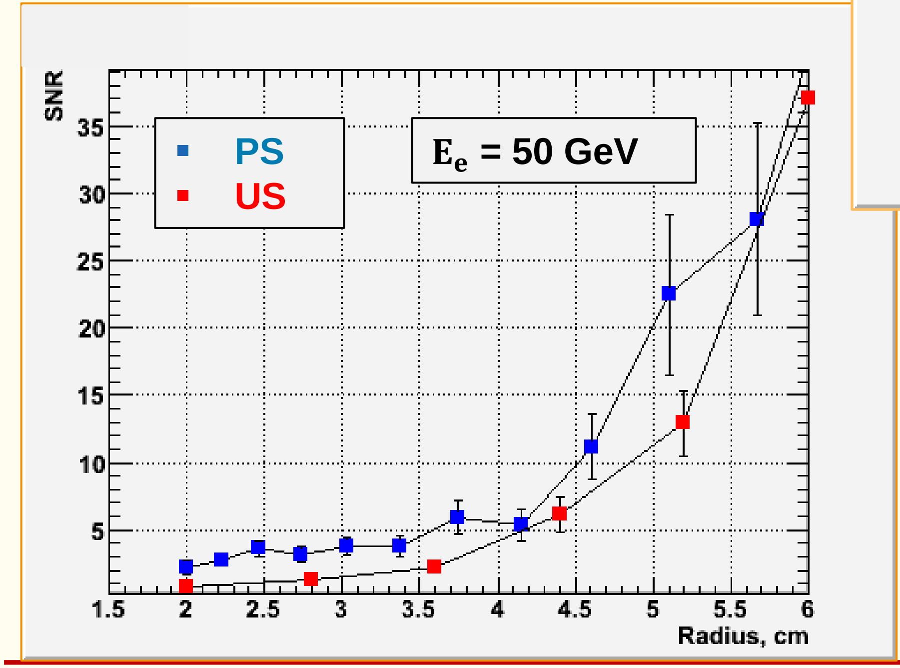
Different distributions!

20 bunch crossings were given

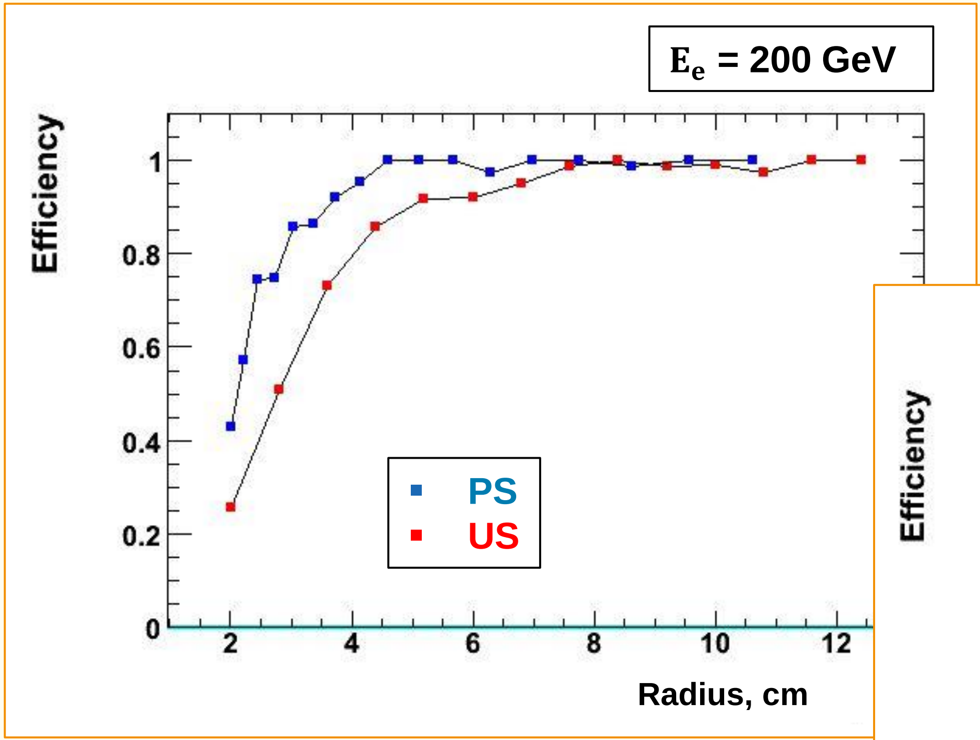
SNR in cell with maximum E_dep

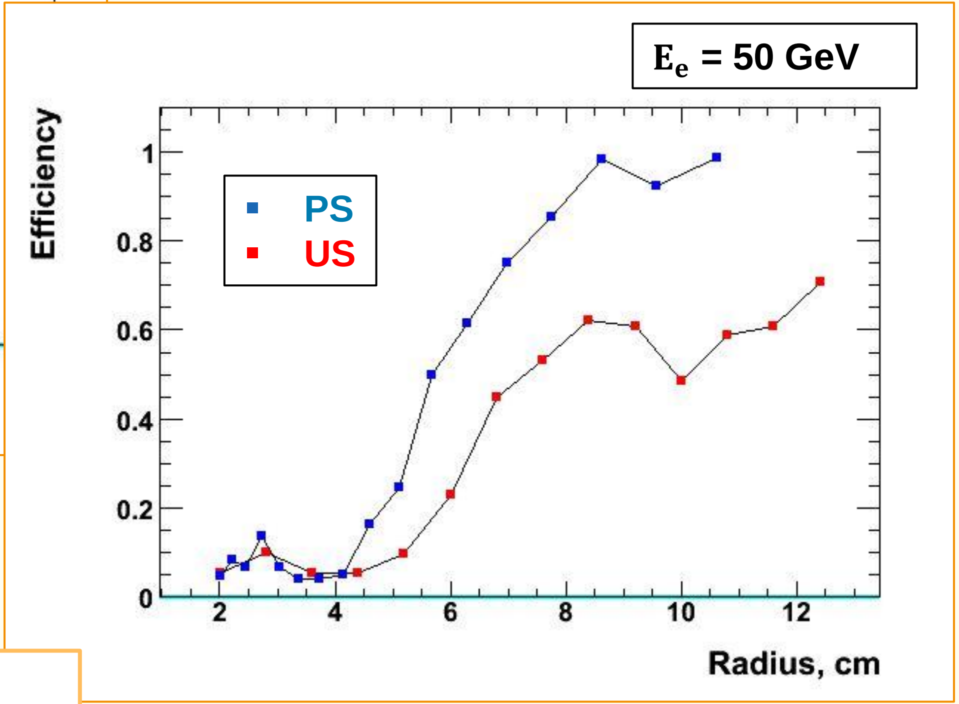
$$SNR = \frac{\text{signal from HE electron}}{\text{RMS from background}}$$





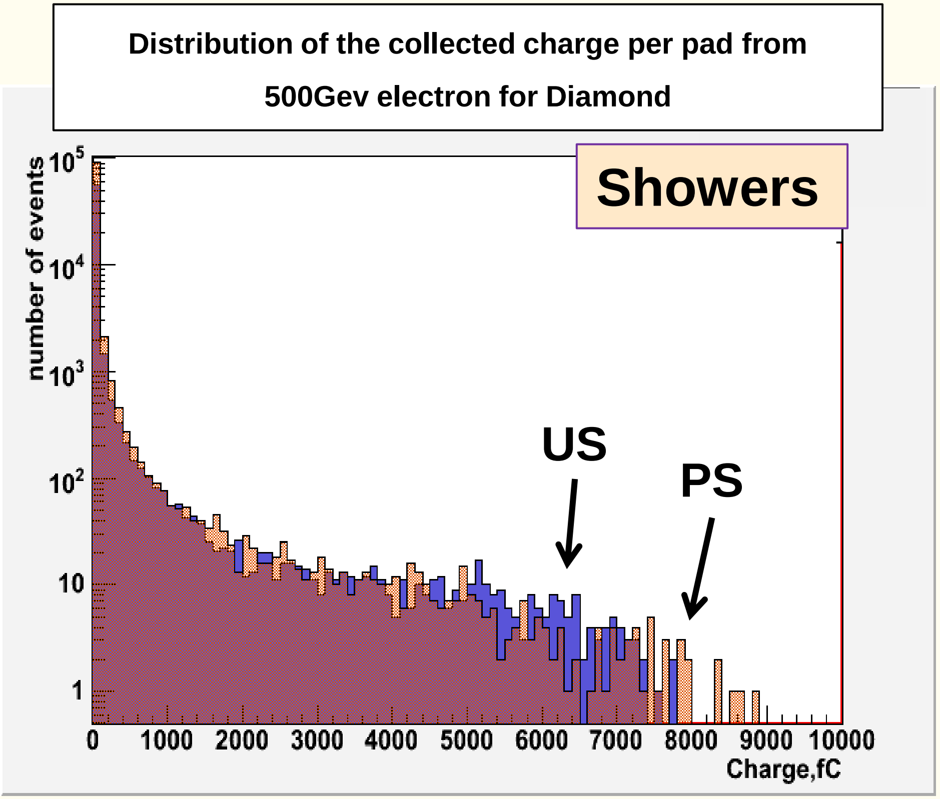
Efficiency of Showers Reconstruction

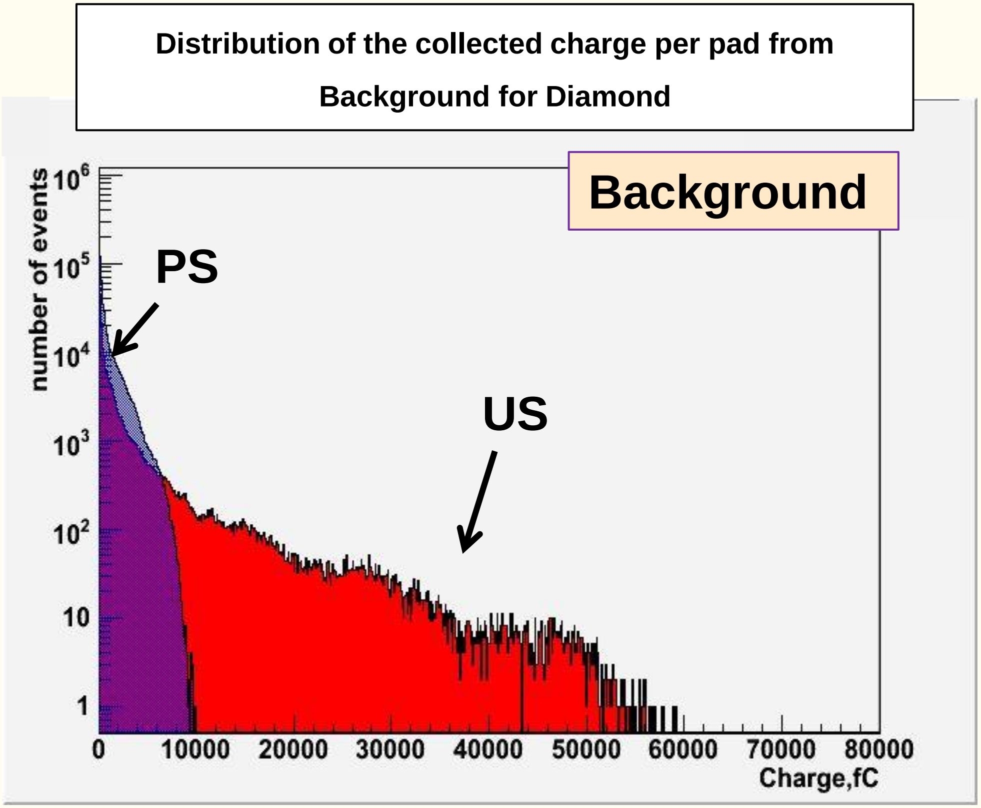




$$\text{Efficiency} = \frac{\text{Reconstructed SH considering BG}}{\text{Reconstructed SH without considering BG}}$$

Charge Range Estimate

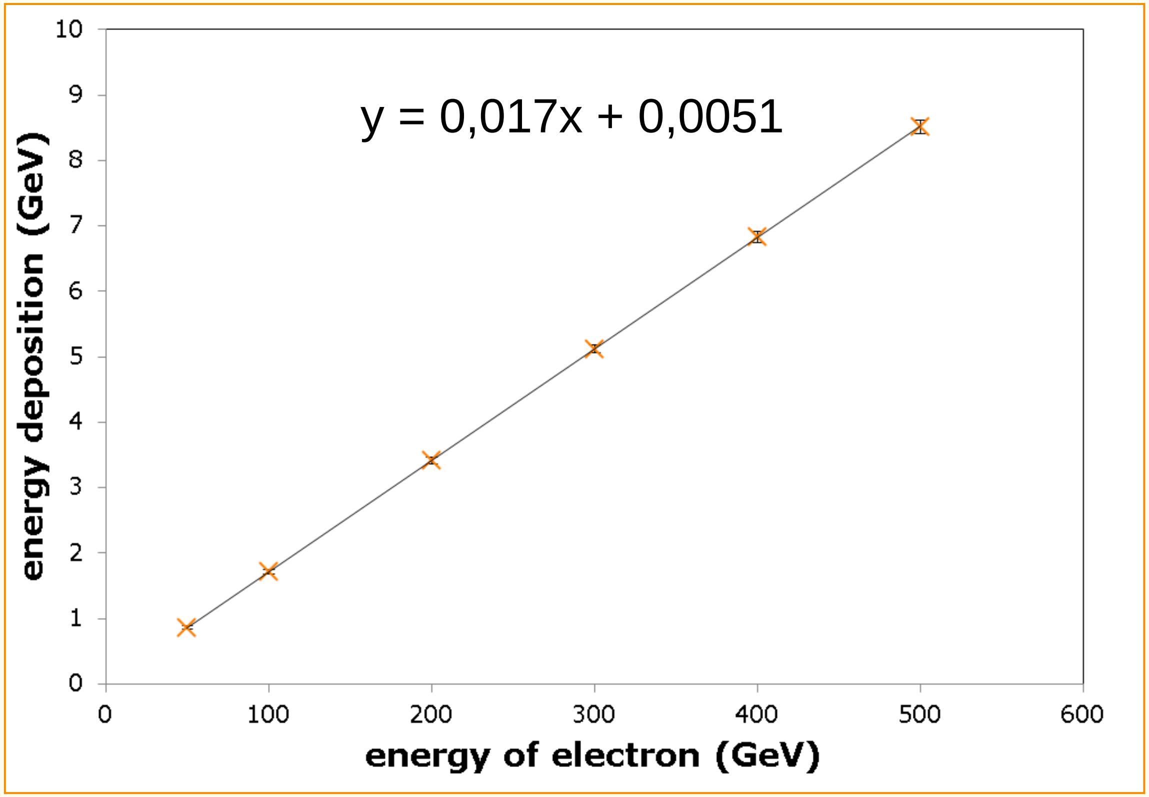


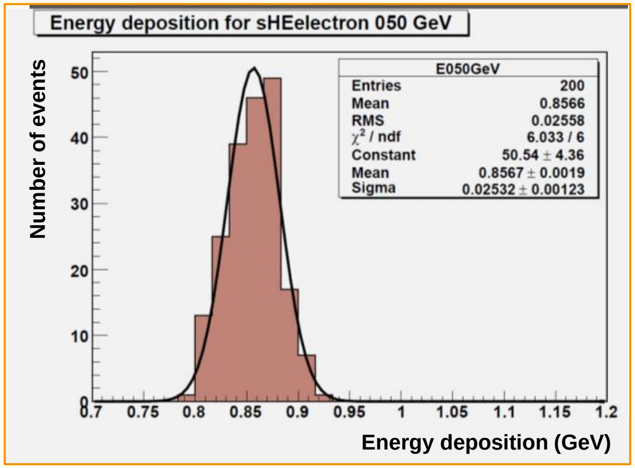


For sensor pad thickness 300 µm:

	Diamond	GaAs
Charge collected from MIP	*2.44 fC*	*4.29 fC*
Maximum collected charge from 500GeV electron	*12 214 fC*	*21 497 fC*
	Correspond to about 5 000 MIPs	

Deposited Energy vs Energy of Electron

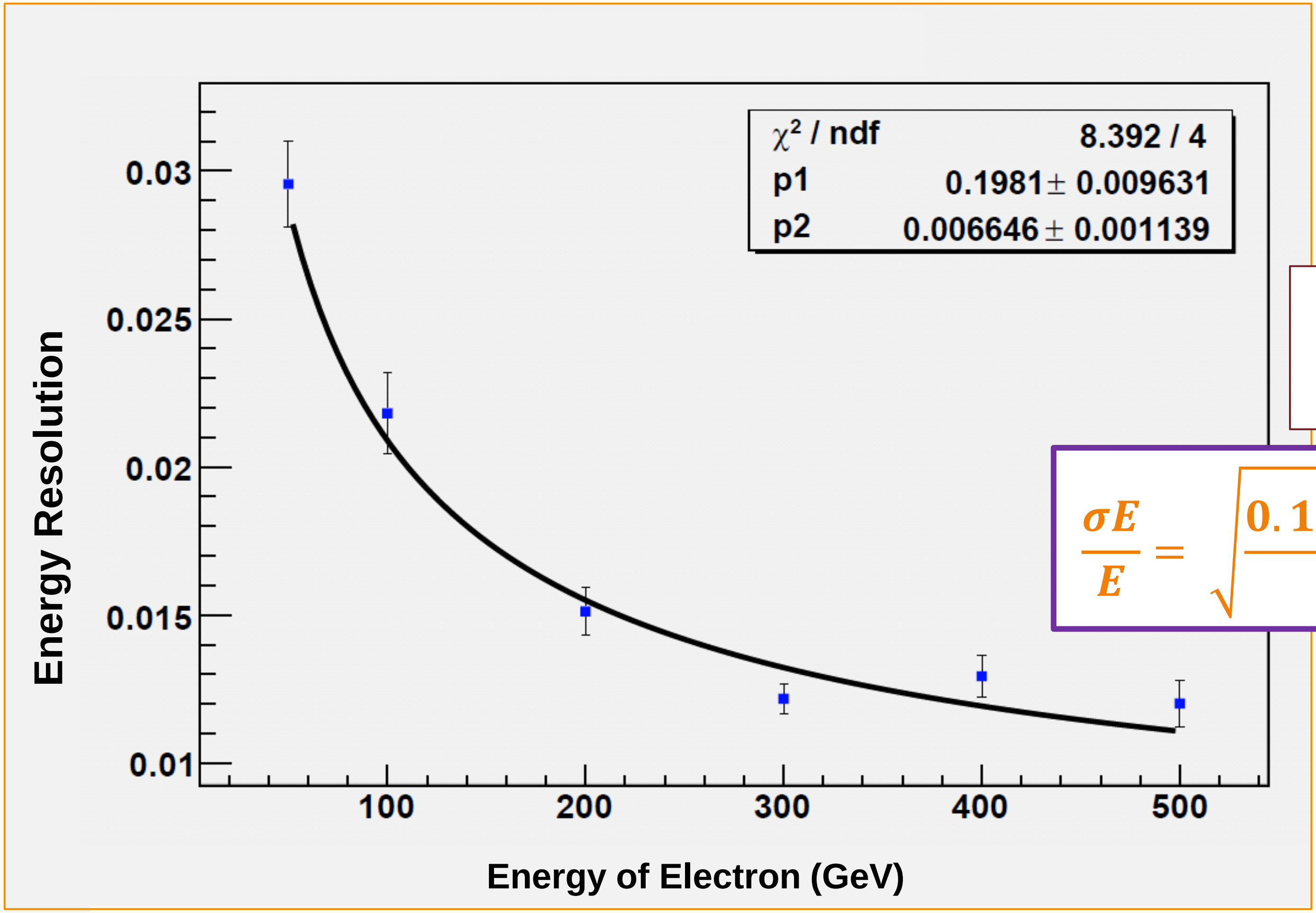




$$E_e = A * E_{dep} - B$$

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

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)

US

PS

Estimation

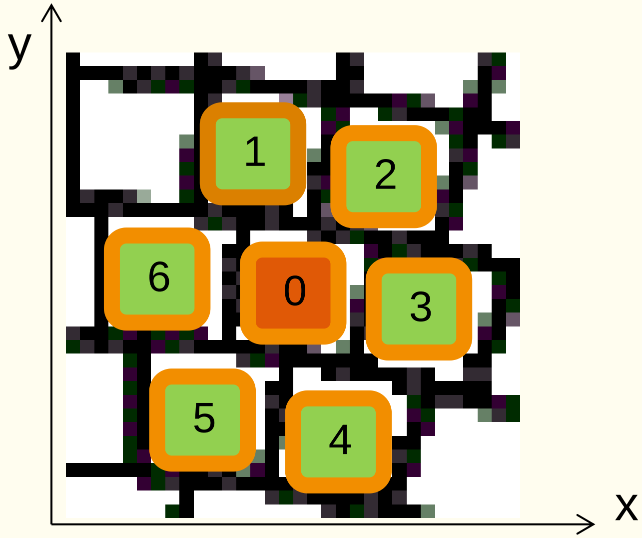
$\sigma d_R = \frac{\Delta d_R}{\sqrt{12}}$ = 2.21 mm

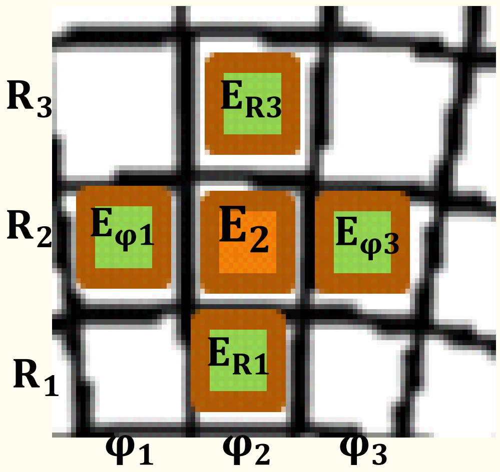
$\sigma d_C = \frac{\Delta d_C}{\sqrt{12}}$ = 2.16 mm → $\sigma\varphi_{in}$ = 5.14 deg → $\sigma\varphi_{out}$ = 0.848 deg

$\frac{\sigma R}{R} = \frac{\Delta R}{R\sqrt{12}}$ = 2.9% → σR_{in} = 0.609 mm → σR_{out} = 3.97 mm

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

COG





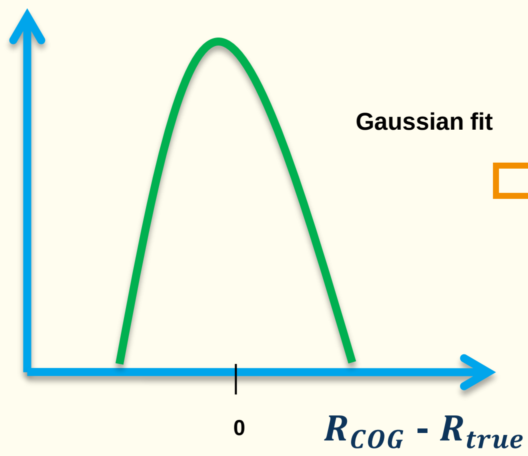
$$X_{COG} = \frac{\sum_{i=0}^{6} X_i E_i}{\sum_{i=0}^{6} E_i}$$

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

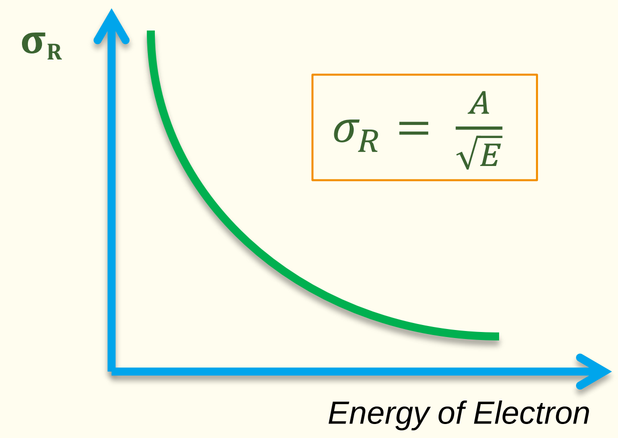
Spatial Resolution (In Process)

R_{COG}

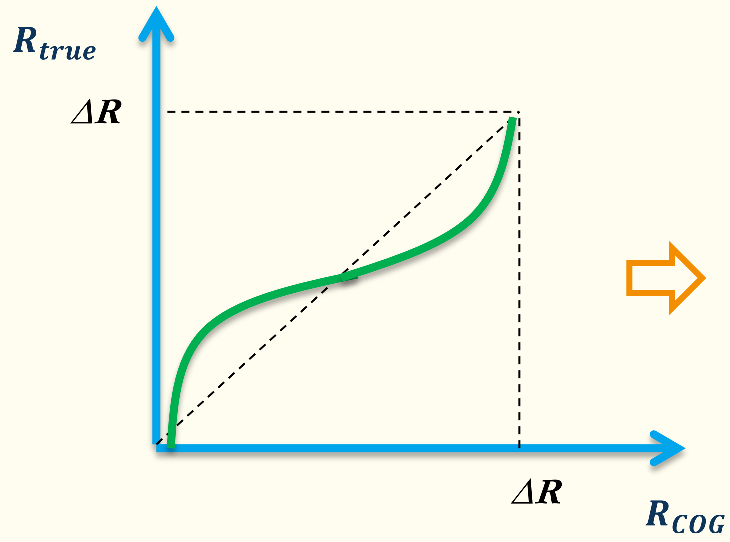
R_{true}



σ_R



Corrected COG



Parameters

Conclusion

- Performance of BeamCal for two different sensor segmentations is 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 bigger than for PS
- Energy deposition was investigated
  - Dependence between energy of electron and deposited in calorimeter energy is linear.

    Deposited in sensors energy is 1,7% from the original energy of electron.
  - Dependence energy resolution vs energy of electron is calculated and parameterized.

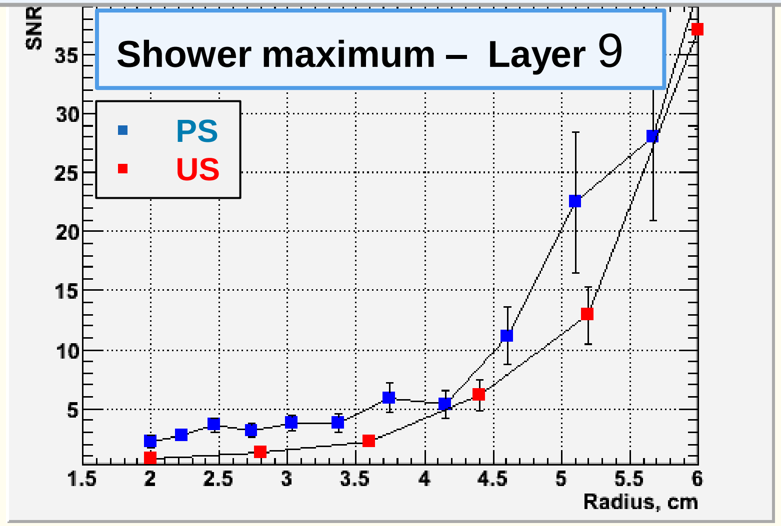
    Calorimeter gives good energy resolution: $\frac{\sigma E}{E} \approx \frac{0.2}{\sqrt{E_e}}$ → 2% for 100GeV electron.

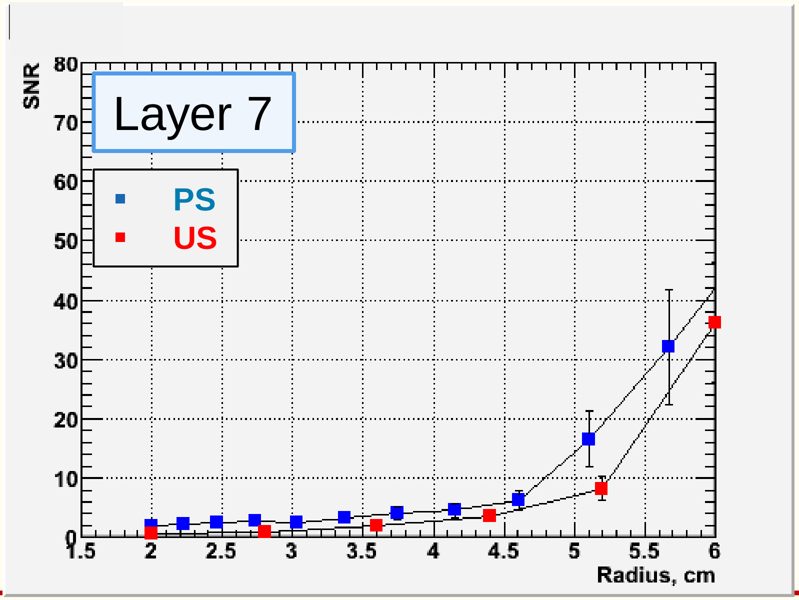
Thank you for your attention!

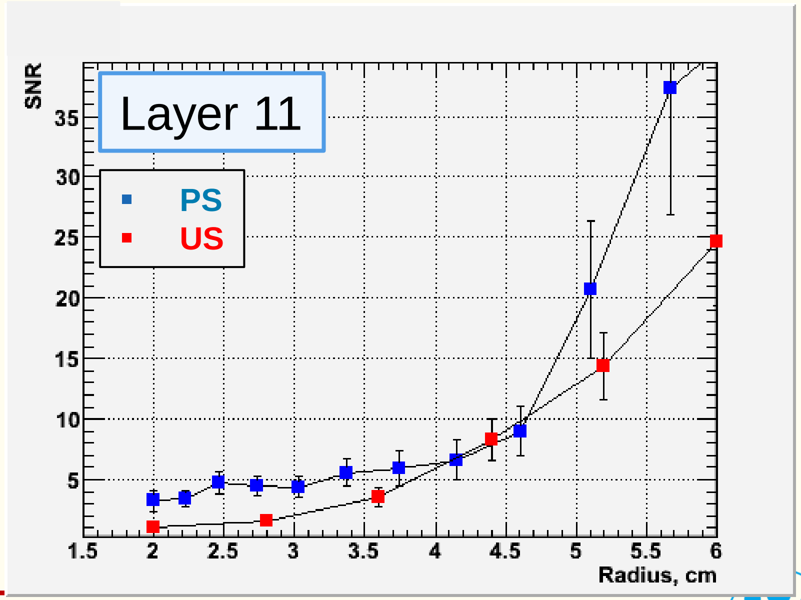
Backup slides

SNR for 50 GeV Electron

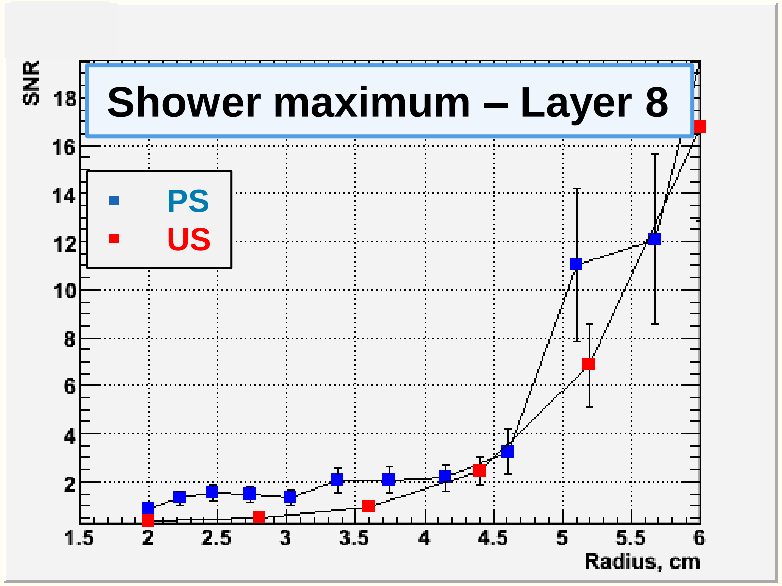
SNR in cell with maximum E_{dep}

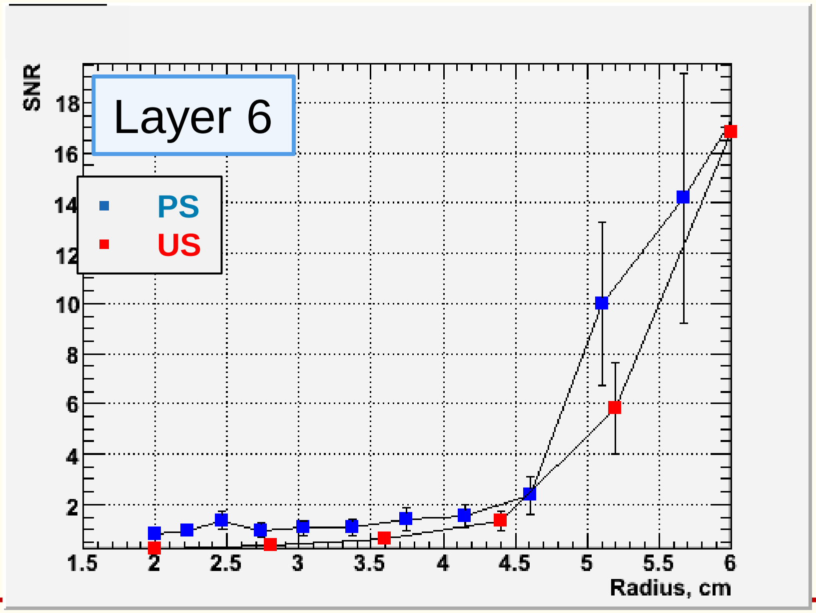


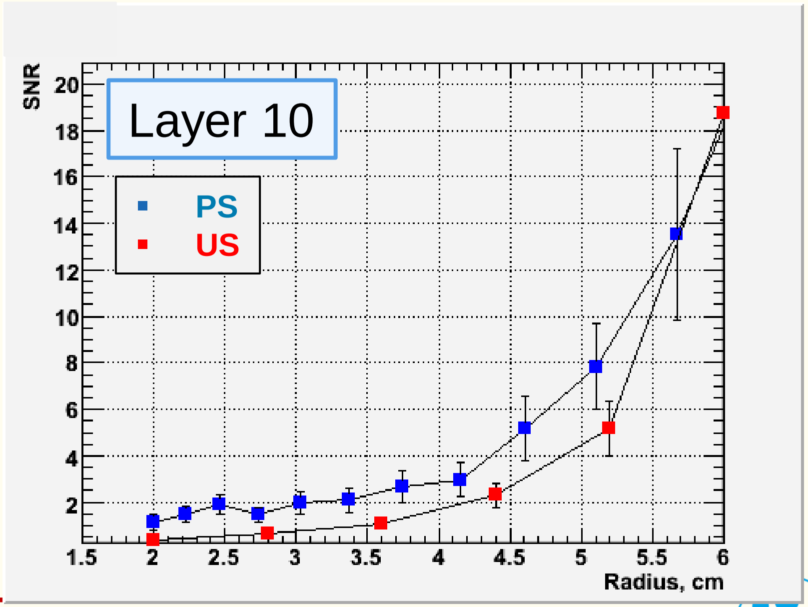




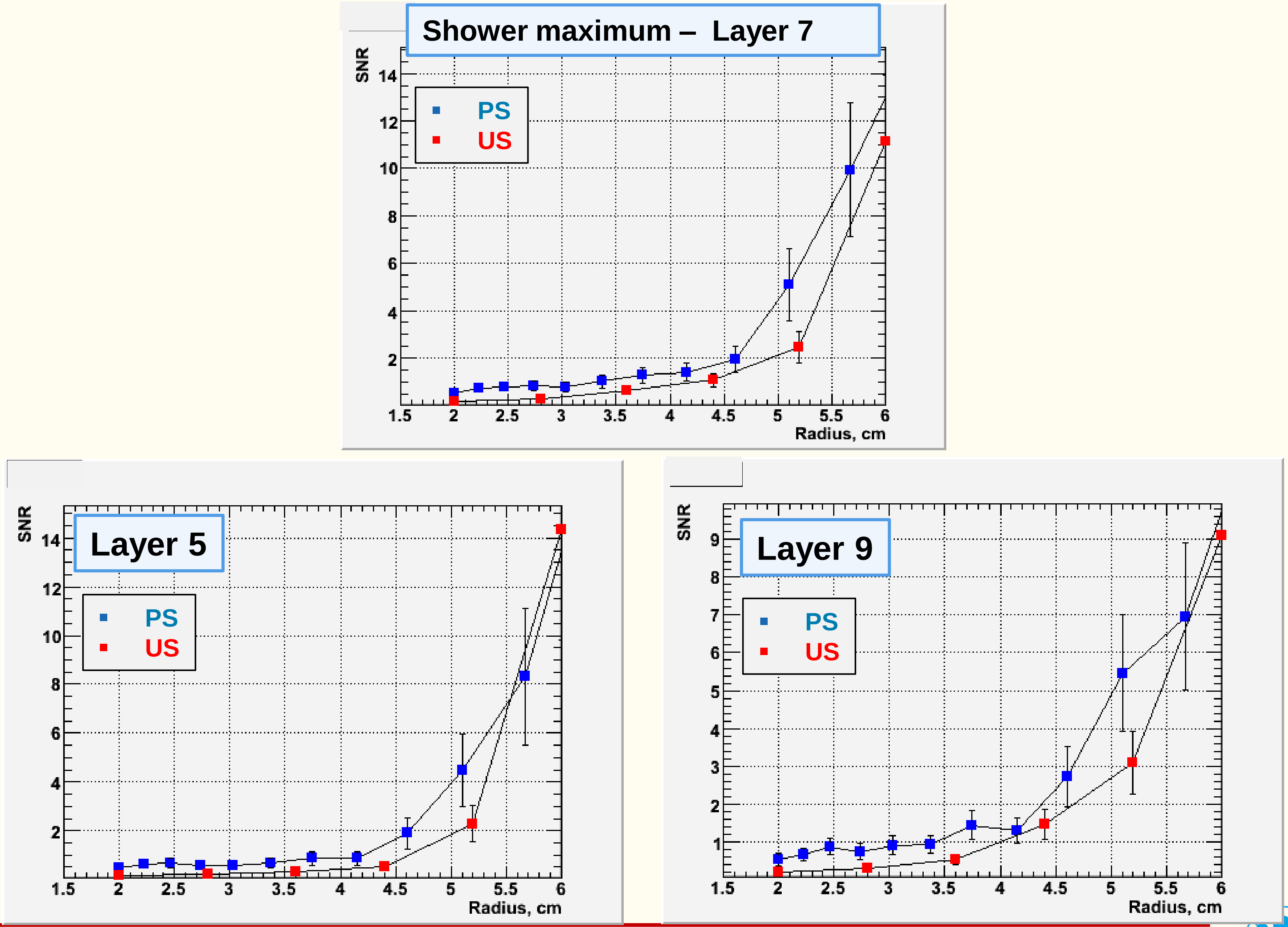
SNR for 20 GeV Electron





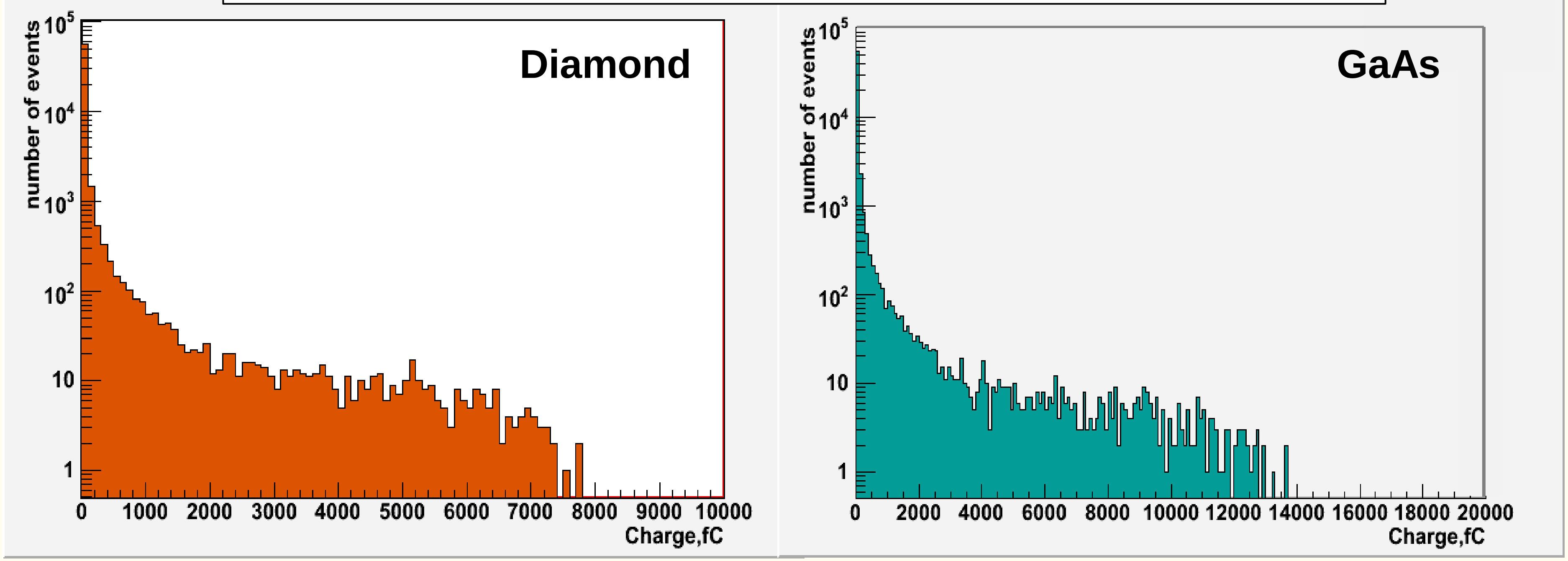


SNR for 10 GeV Electron



Charge range estimate

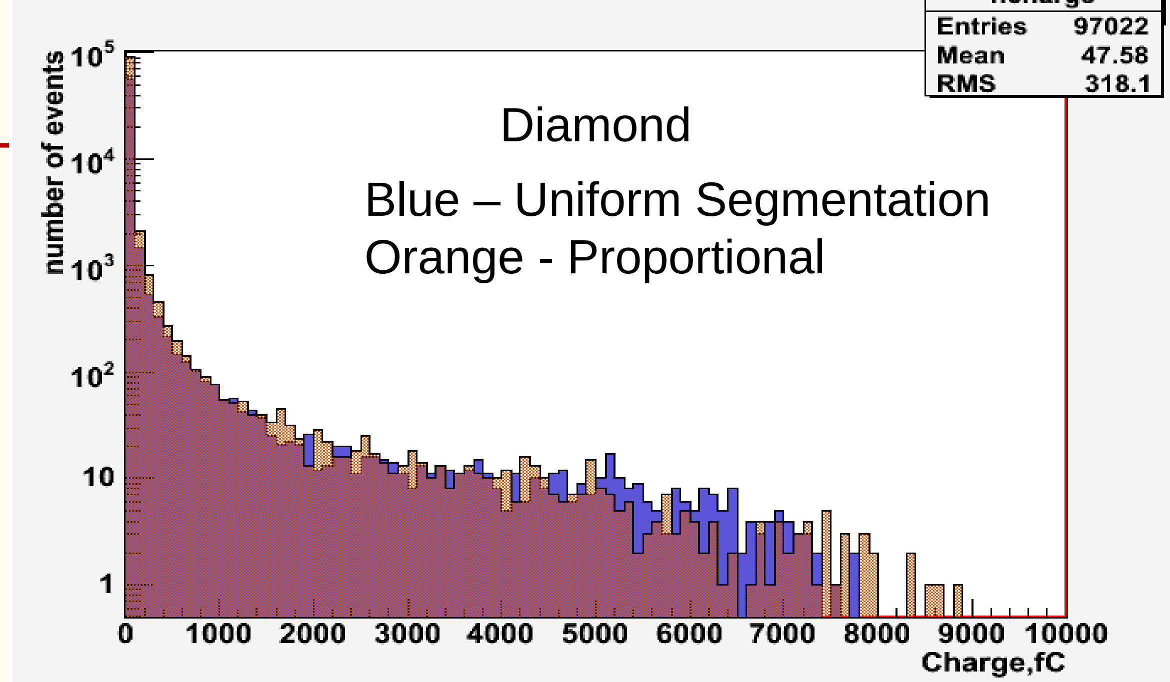
Distribution of the collected charge per pad for 500Gev electron showers

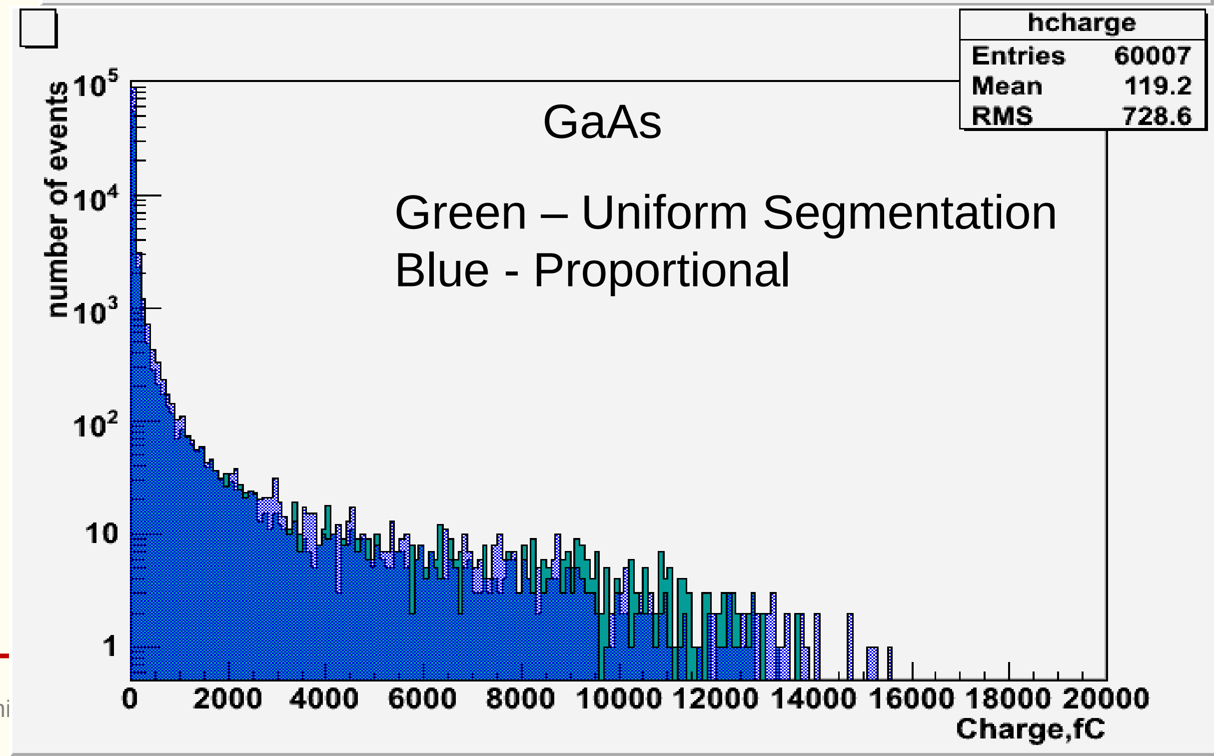


For Diamond sensor pad thickness 300 µm:

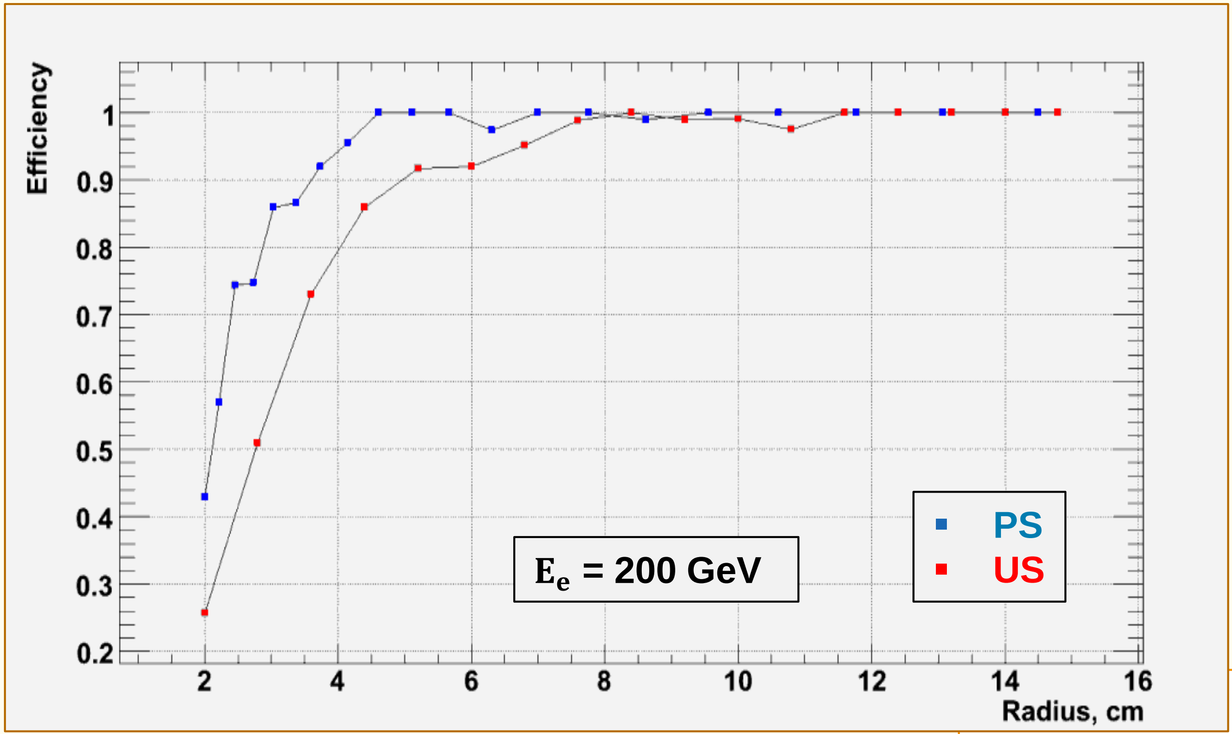
- Charge collected from MIP: 2.44 fC
- Maximum charge collected – for shower from 500 GeV electron: 12214 fC (correspond to about 5000 MIPs)

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





Efficiency of Showers Reconstruction

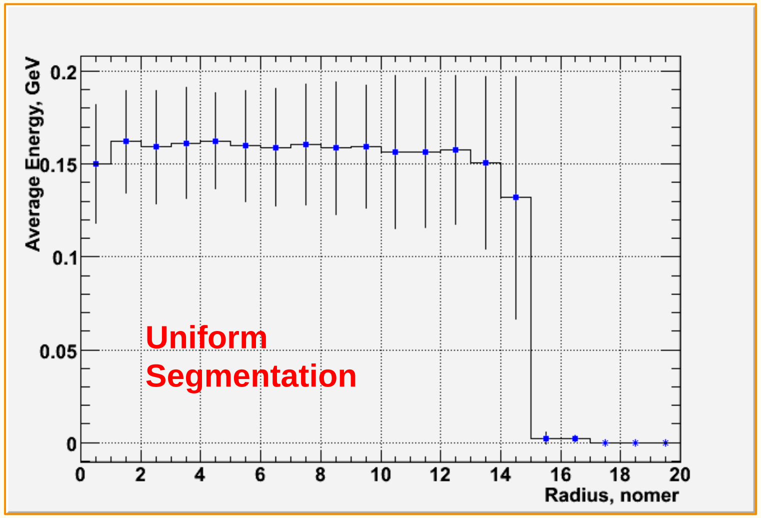


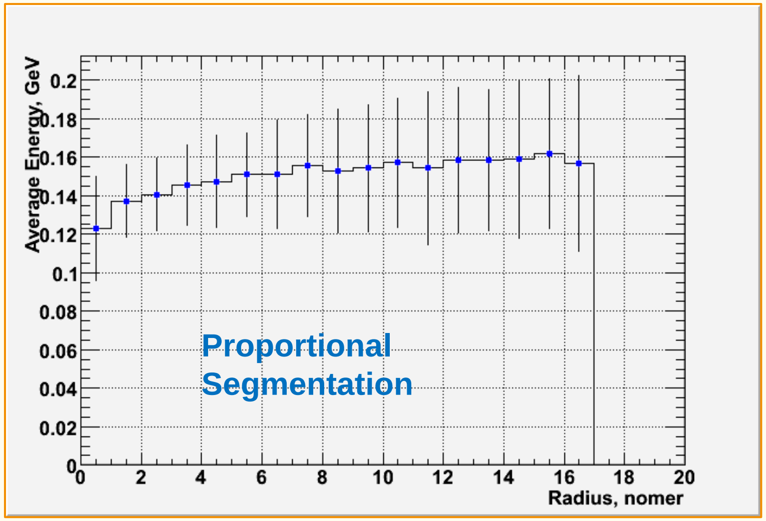
Efficiency for 50 GeV

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

Signal and RMS for both Segmentations

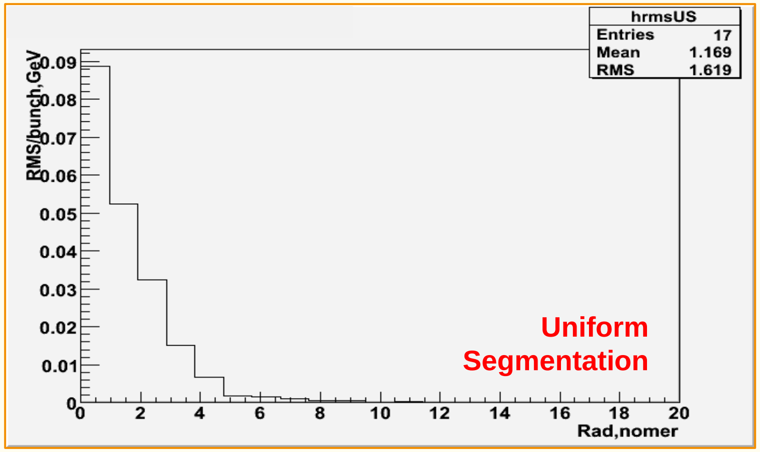
The average energy in the pad of the core of shower

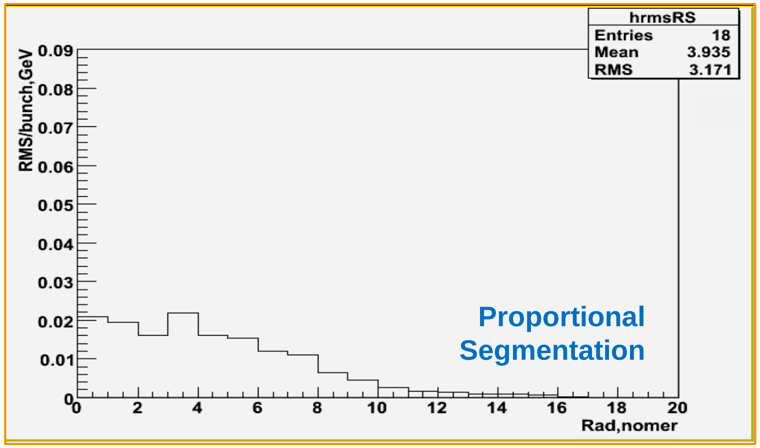




Signal nearly segmentation-independent!

RMS of the averaged Background





Different distributions!

20 bunch crossings were given