Optimization of Reconstruction Algorithm for BeamCal (ILC)

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The Aim and Content

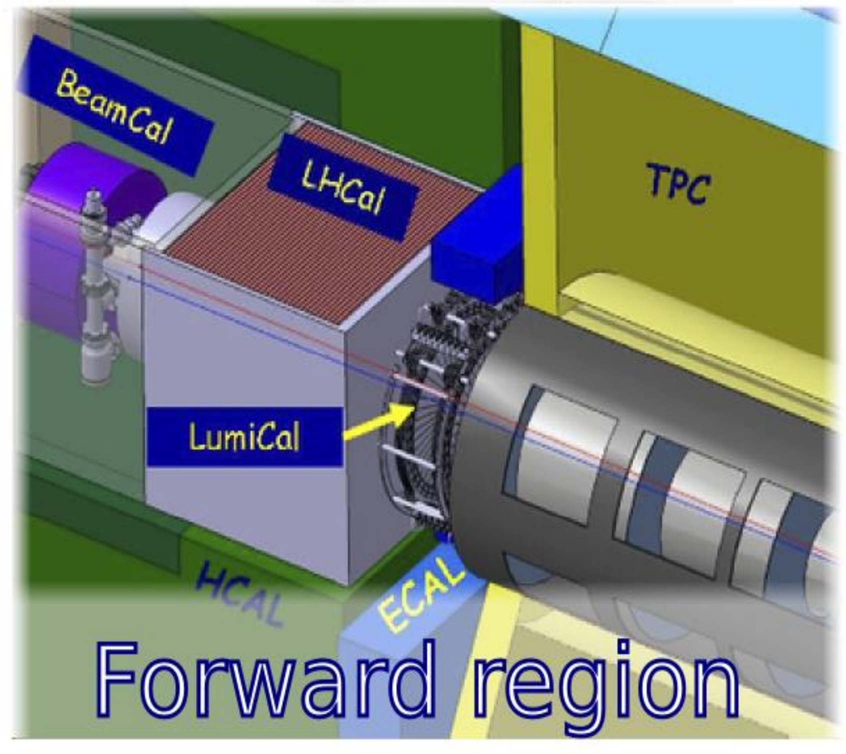
Aim:

- find optimal parameters for reconstruction algorithm
- compare the performance of two segmentations

Content:

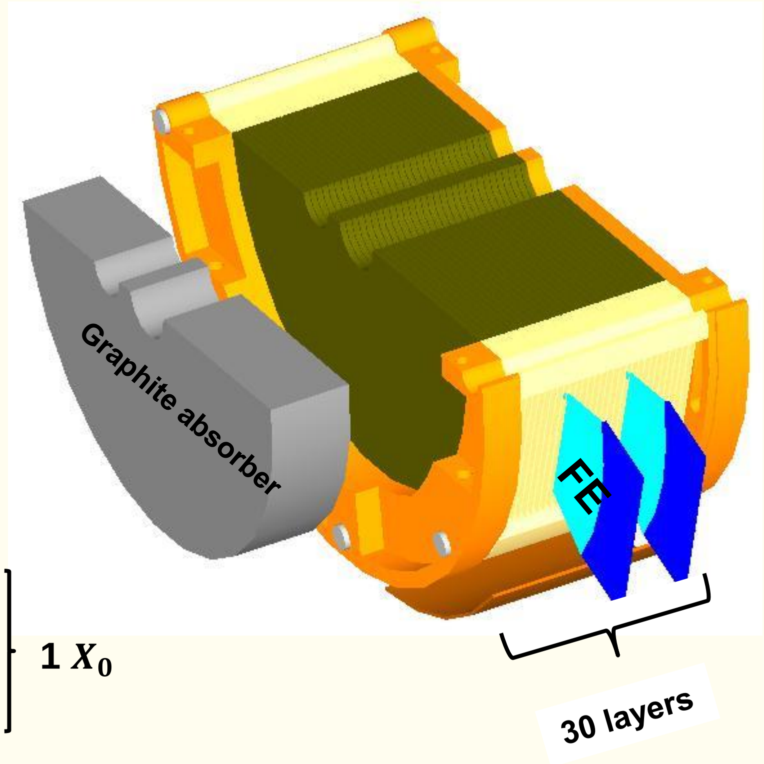
- Introduction
- Algorithm parameters adjustment
- Calorimeter characteristics studies
- Conclusion

Beam Calorimeter for ILC



BeamCal aimed:

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



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

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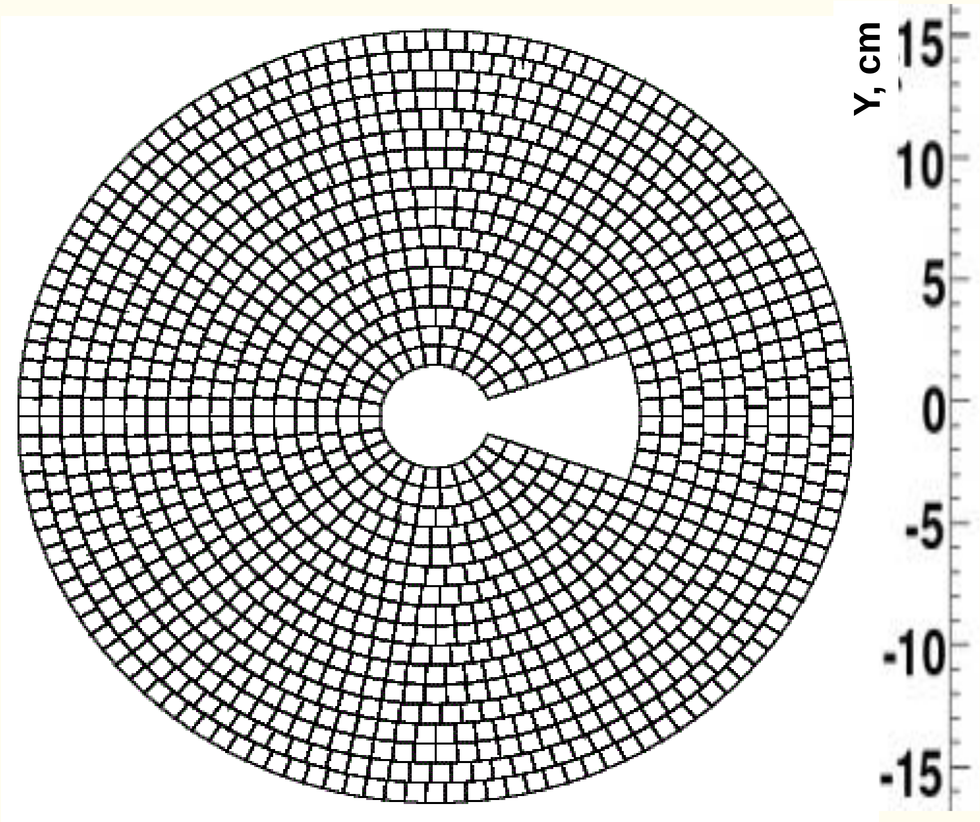
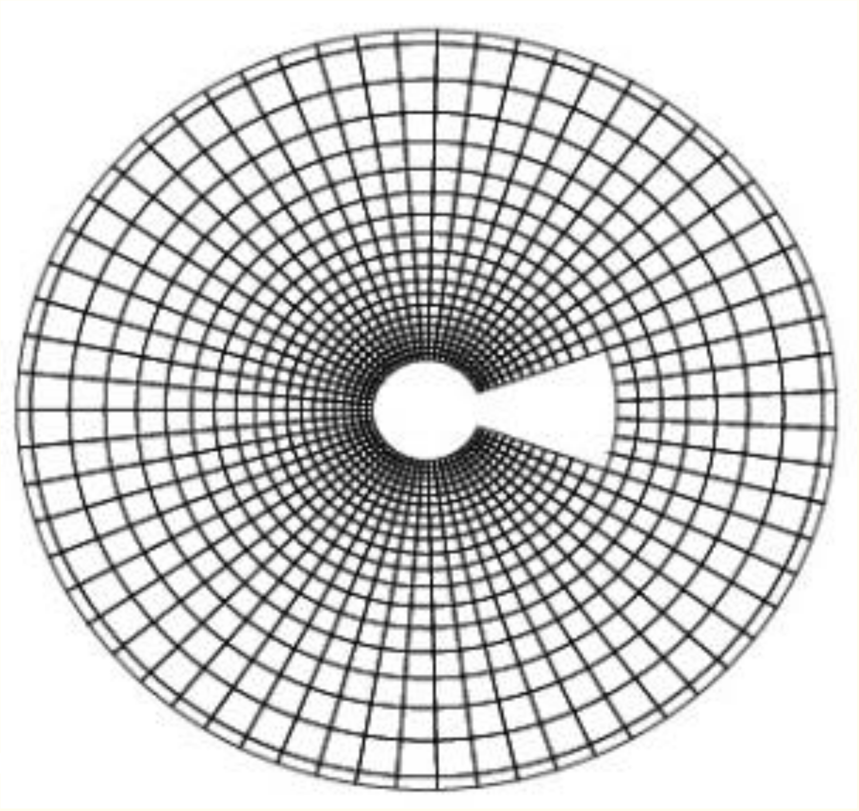
BeamCal Segmentation



Uniform Segmentation (US)

pads size are the same



Proportional Segmentation (PS)

pads size are proportional to the radius

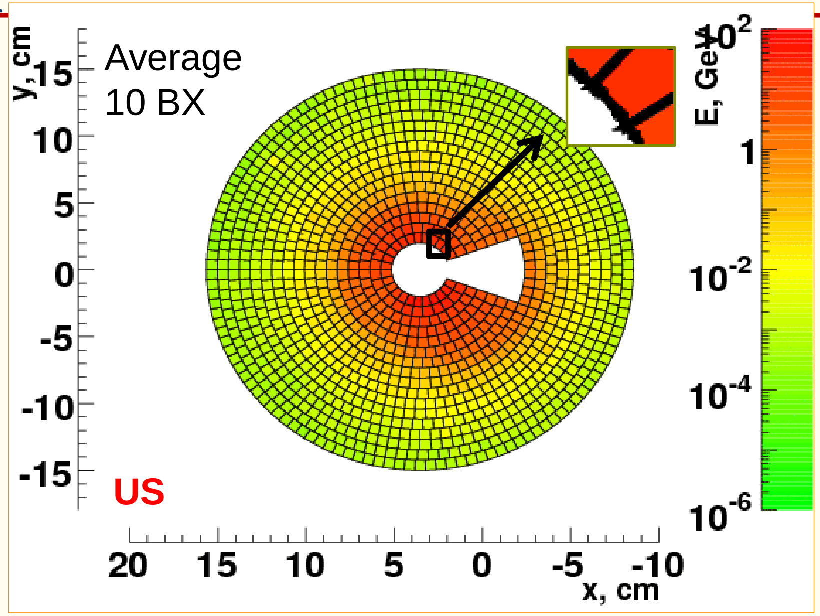
Similar number of channels

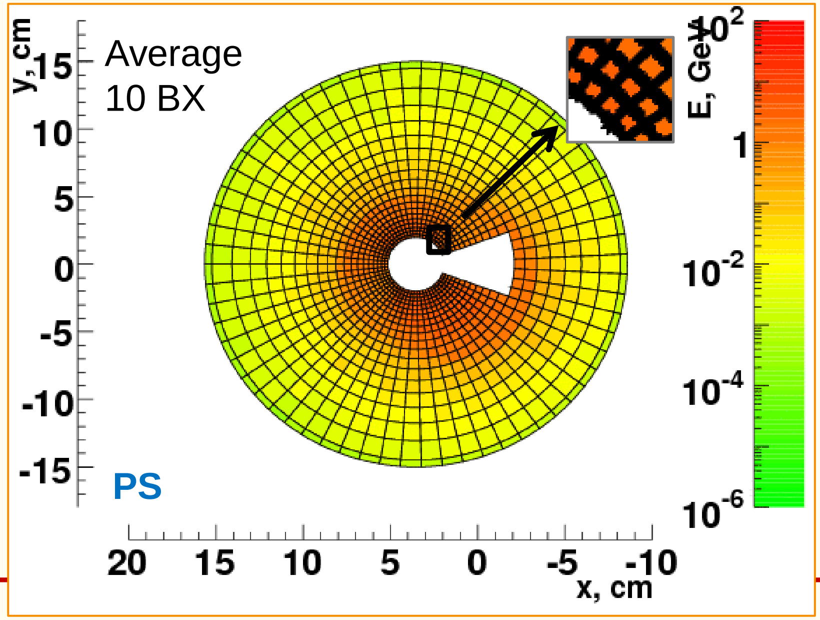
Energy Deposition due to Beamstrahlung

- **Beamstrahlung pairs generated with Guinea Pig**
- **Beam parameters taken from the ILC TDR Nov 2012**
  - ***Nominal parameter set***
  - ***Center-of-mass energy 1 TeV***
- **Energy deposition in sensors from beamstrahlung simulated with BeCaS (Geant4)**

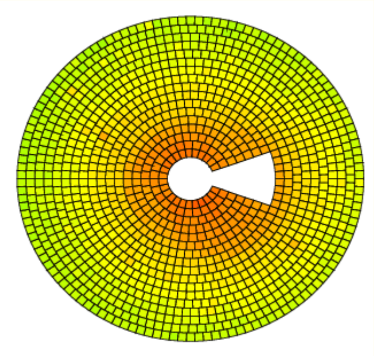
  → *considered as Background (BG)*

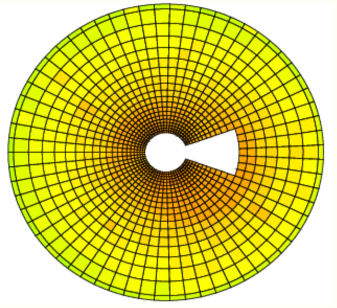
PS decrease deposited energy per pad in a high BG area





RMS of the averaged BG





Figures show sum by all layers

Search parameters for reconstruction Algorithm

On top of this BG single high energetic electrons (sHEe) produce showers, and to recognize their energy deposition reconstruction algorithm is using.

The goal is to find optimal parameters of reconstruction algorithm

Parameters to adjust:
- threshold in terms of background standard deviations
- layers to be considered
- how many layers in a tower

Requirements:
- fake rate a few percent (e.g. 2%)
- good :
  - --efficiency of reconstruction
  - --energy resolution
  - --spatial resolution

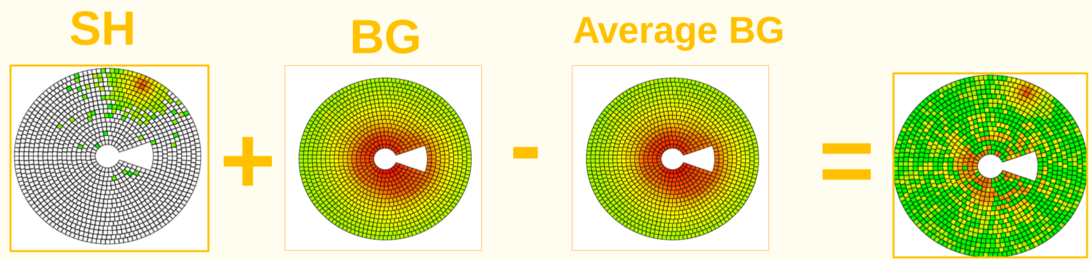
Algorithm

With BG

Without BG

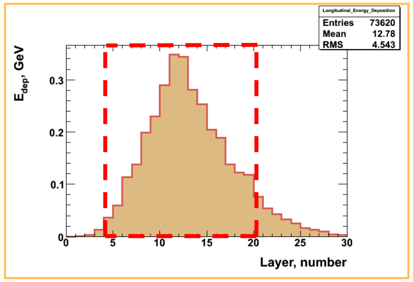
1. SH + BG – average by 10th previous BXs BG

1



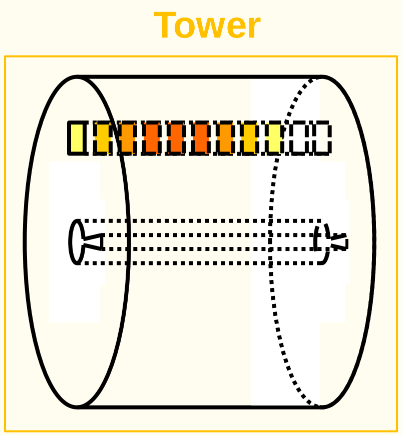
2. Select layers from **5th** to **20th**

2



3. Applying energy threshold **5** RMS
4. Combine to towers

4



5. Search shower core (max energetic tower)

   * if there ≥ **13** cells (not necessarily sequent), search for neighbor towers

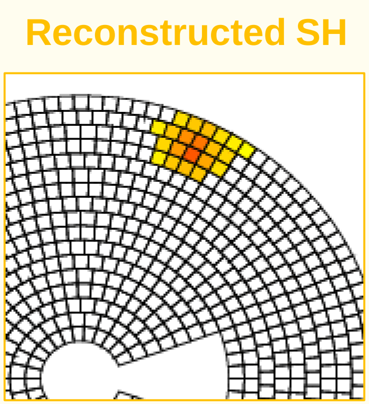
     * if in neighbor ≥ **9** cells & at least 1 neighbor

   => shower defined

   * Candidate towers are considered to shower within Rm=1.2 cm or at least 8 pads around shower core

   => shower created

5



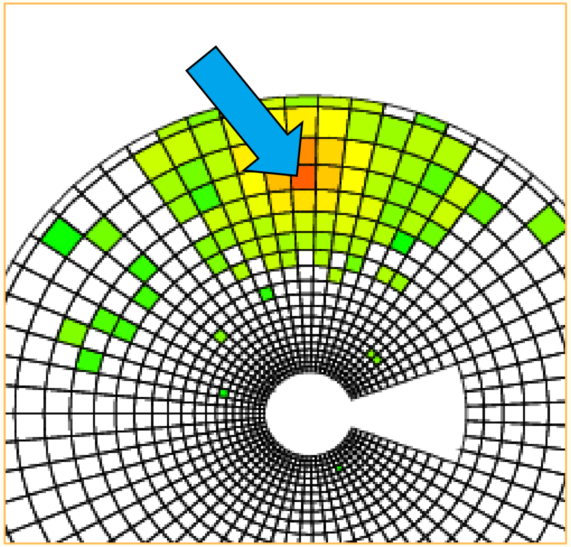
6. Next shower: repeat step 5
7. For each shower calculating

   - $R_{COG}, \varphi_{COG}, E_{sh}$

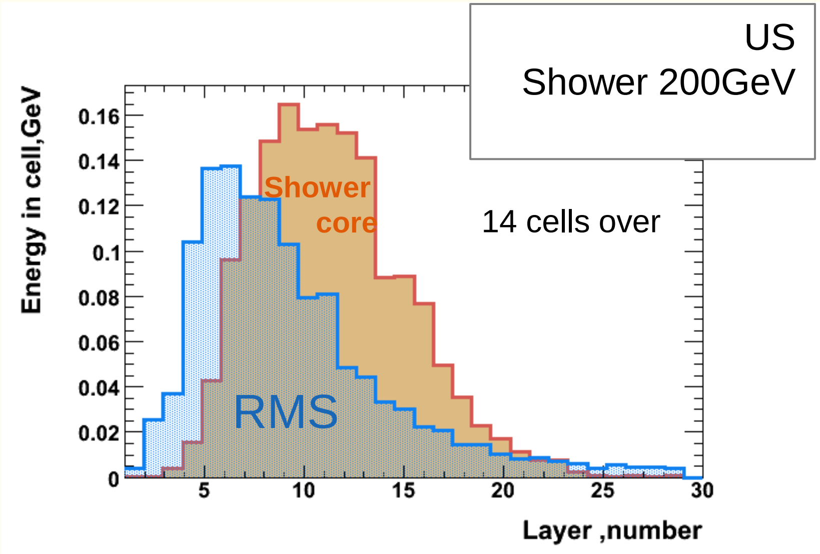
Idea

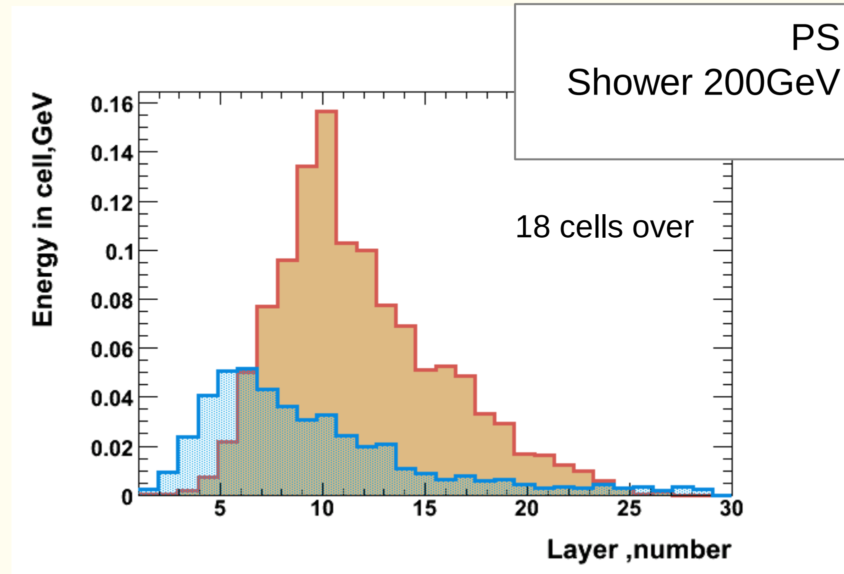
Compare energy deposition in high BG area along calorimeter layers for:

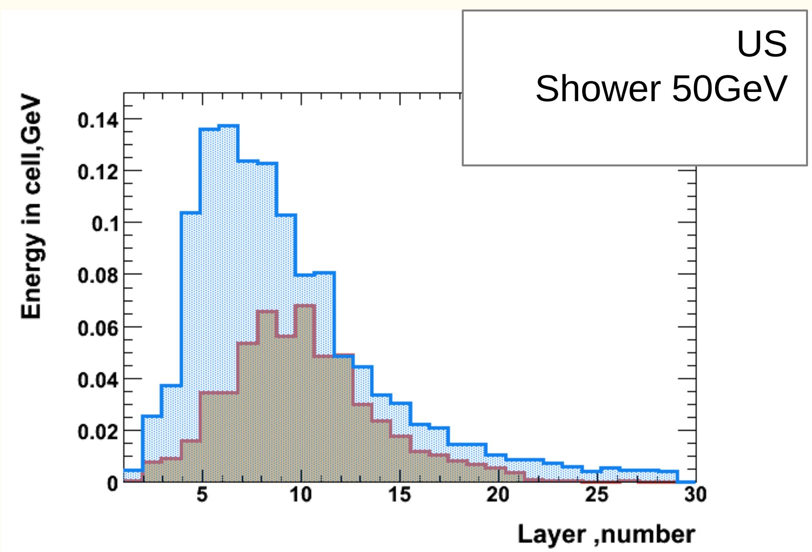
1) tower of the shower core and tower of the RMS
2) max energetic tower of <BG – average_BG> and tower of the RMS (for excluding fake showers criteria)

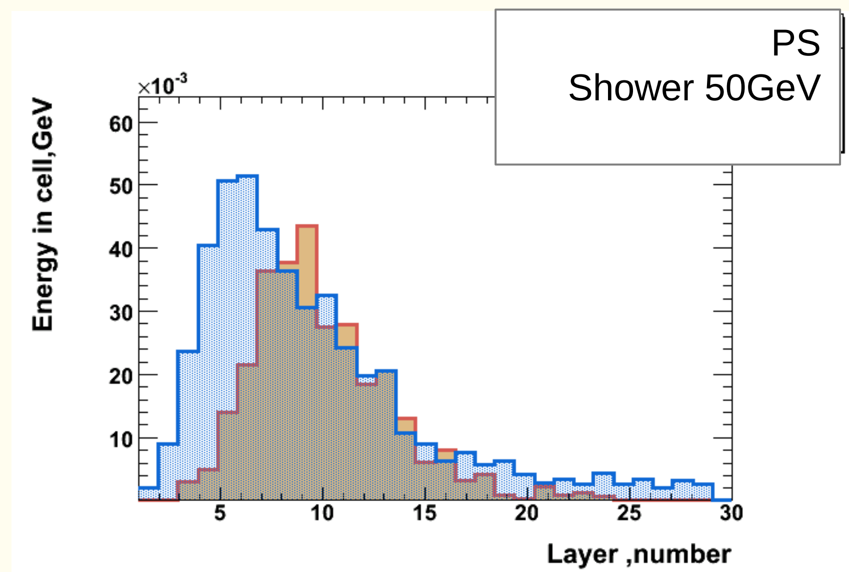


Tower profiles from Shower core and RMS on high BG area

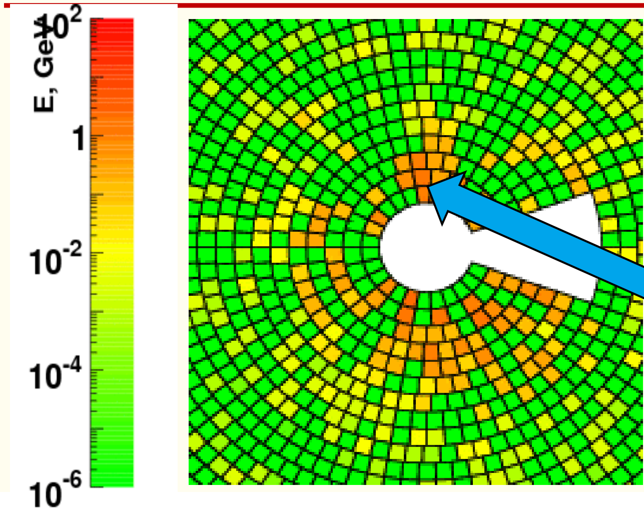






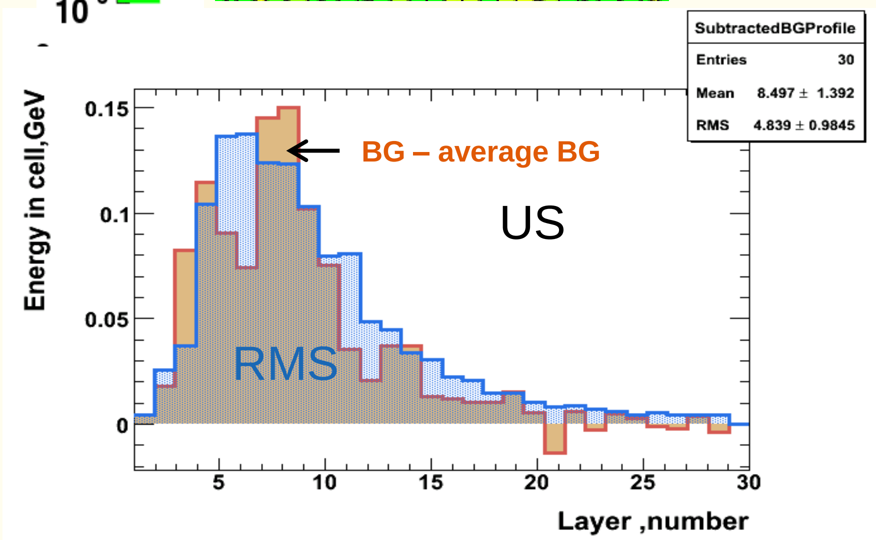


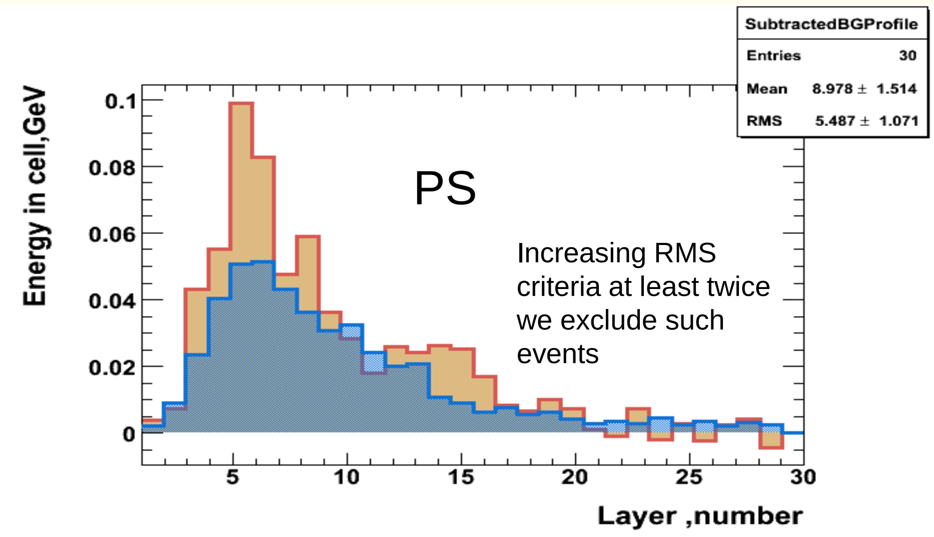
Tower profiles from Subtracted BG and RMS in high BG area



Current BG – average BG

The tower with maximal energy deposition was chosen(the worst case)





But for showers(previous slide) we still have possibility to reconstruct, especially going further with radius

Choosing parameters. Fake Rate.

Source	Difference in conditions	Layers to be considered	RMS applyed	Min number of cells in a row	
				In SH max	In neighbor
Max SH Tower and RMS along Z comparison (previous slides)	**1 Tev**	**5-20** (25?)	**>2 RMS** (chosen 5 RMS)	**13**	**9**
Thesis of Katharina Kuznetsova, 2006	**500GeV ,** diff size of pads, type of segmentation - US	**4-17**	**3 RMS**	**10**	**6**
FCAL Paper, 2004	**500 GeV**	**2-20**	**5 RMS**	**9**	**6**

Checking fake rate (100 files were used)

	Layers to be considered	RMS applyed	Min number of cells in a row		Fake rate	
			SH max	Neighbor	US	PS
Case 1 (suitable)	5-20	5 RMS	13	9	2 %	0 %
Case 2 (relaxed)	5-20	5 RMS	10	6	3%	3%

Efficiency of Shower Reconstruction

If *rTrue, phiTrue - original coordinates of electron*

rReco, phiReco – COG coordinates from reconstructed showers on top of BG

then If | rTrue - rReco| < Rm
and |phiTrue – phiReco| < Rm } => shower reconstructed correctly

$$\text{Efficiency} = \frac{\text{rReco}}{\text{rTrue}}$$

4. Else (| Rtrue- Rreco| > Rm) - fake shower

Efficiency of shower reconstruction for 500 GeV electron

PS

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 89.2%

NUMBER FAKE SHOWERS = 1.2%

NUMBER NOT RECONSTRUCTED SHOWERS = 9.6%

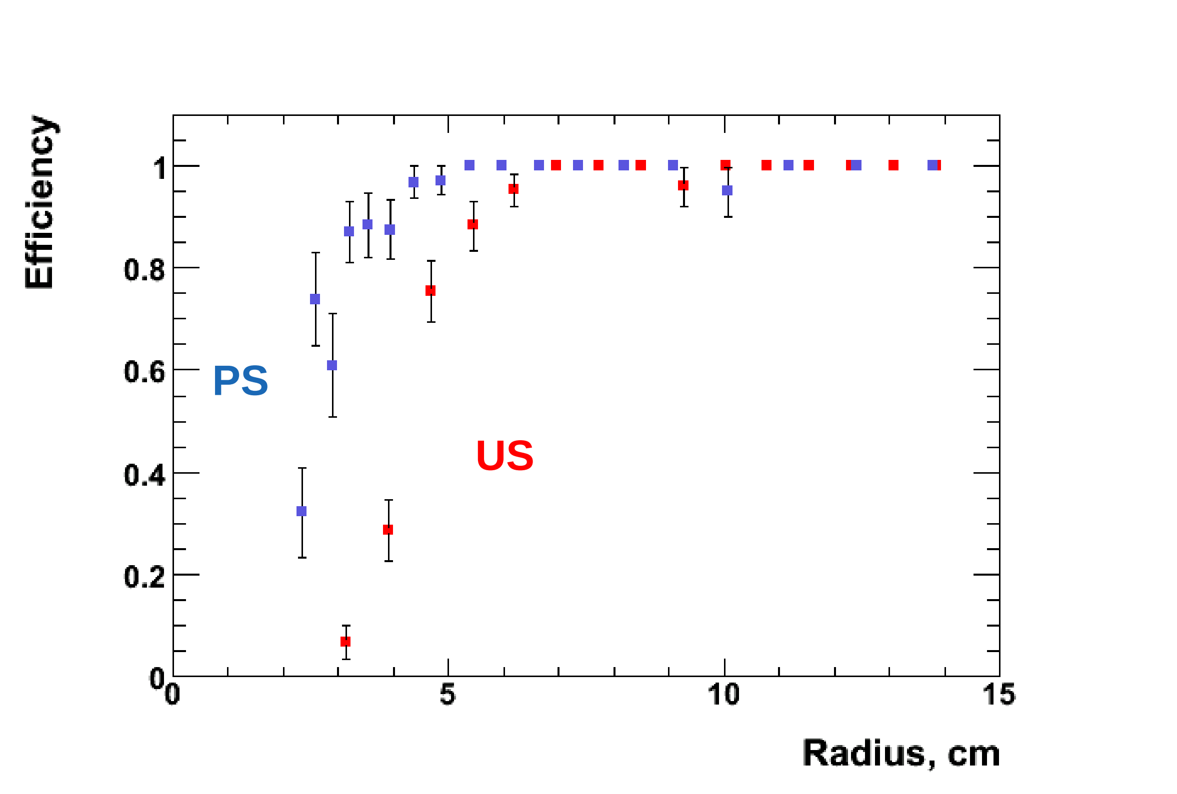
US

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 64.9%

NUMBER FAKE SHOWERS = 0.6%

NUMBER NOT RECONSTRUCTED SHOWERS = 34.5%



Efficiency of shower reconstruction for 200 GeV electron

PS

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 55.1%

NUMBER FAKE SHOWERS = 0.8%

NUMBER NOT RECONSTRUCTED SHOWERS = 44.1%

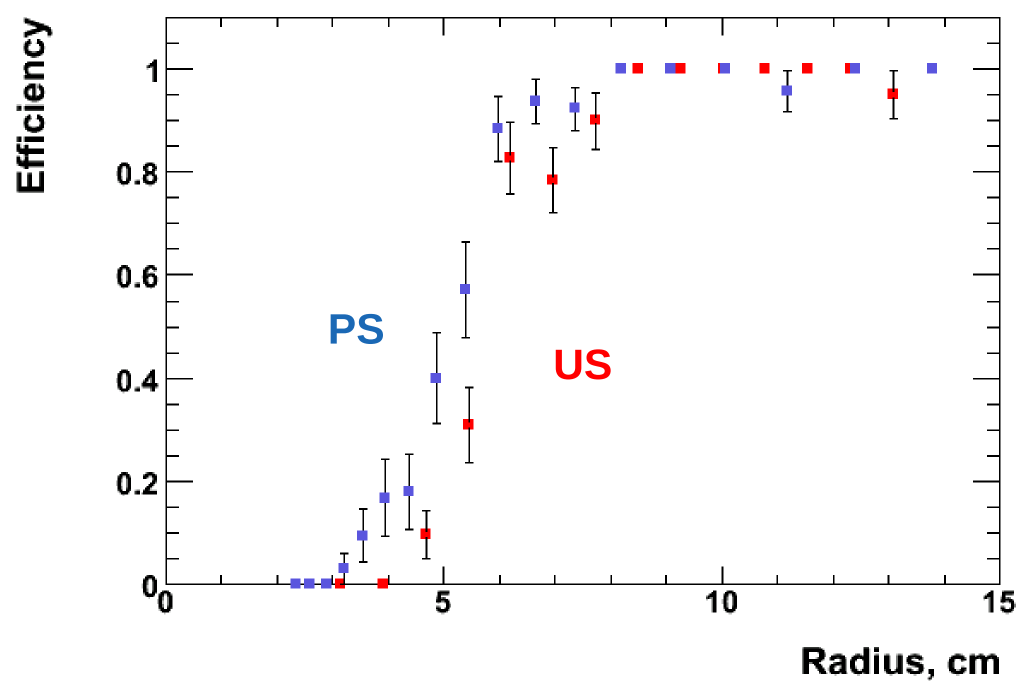
US

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 46.0%

NUMBER FAKE SHOWERS = 1.4%

NUMBER NOT RECONSTRUCTED SHOWERS = 52.6%



Efficiency of shower reconstruction for 50 GeV electron

PS

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 29.5%

NUMBER FAKE SHOWERS = 0.4%

NUMBER NOT RECONSTRUCTED SHOWERS = 70.1%

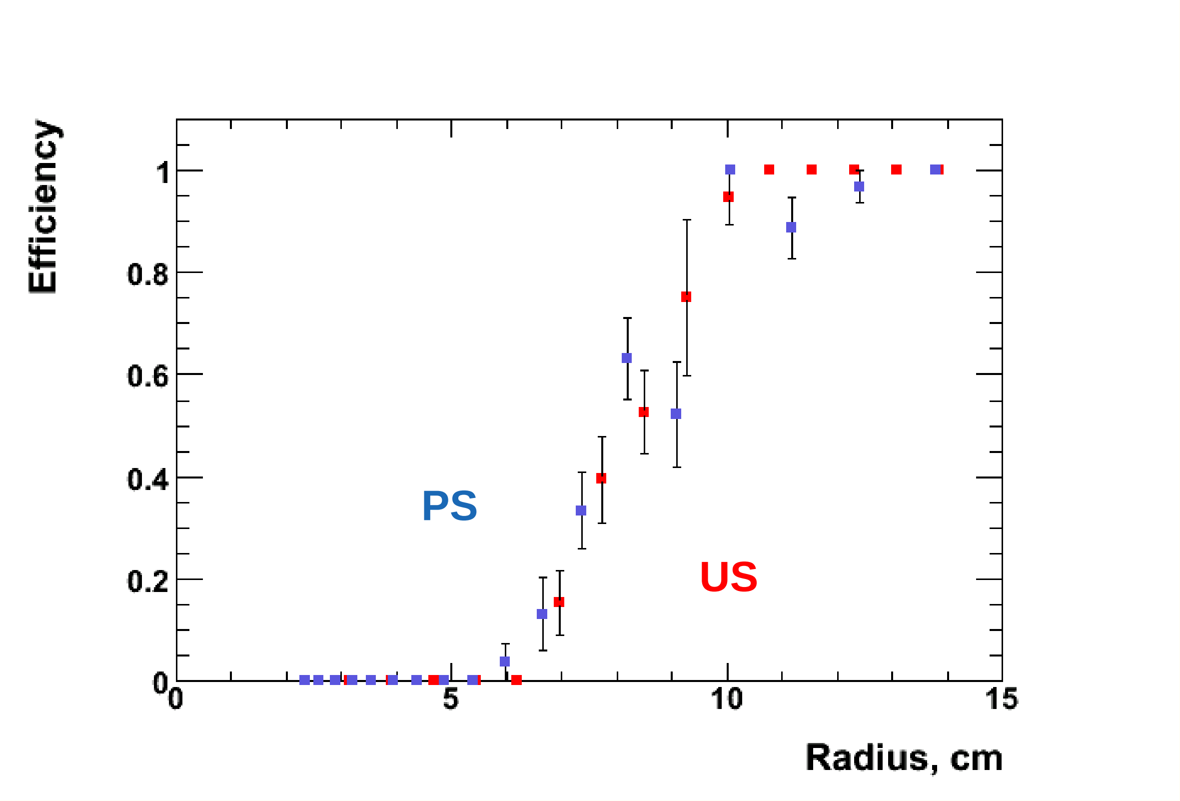
US

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 27.9%

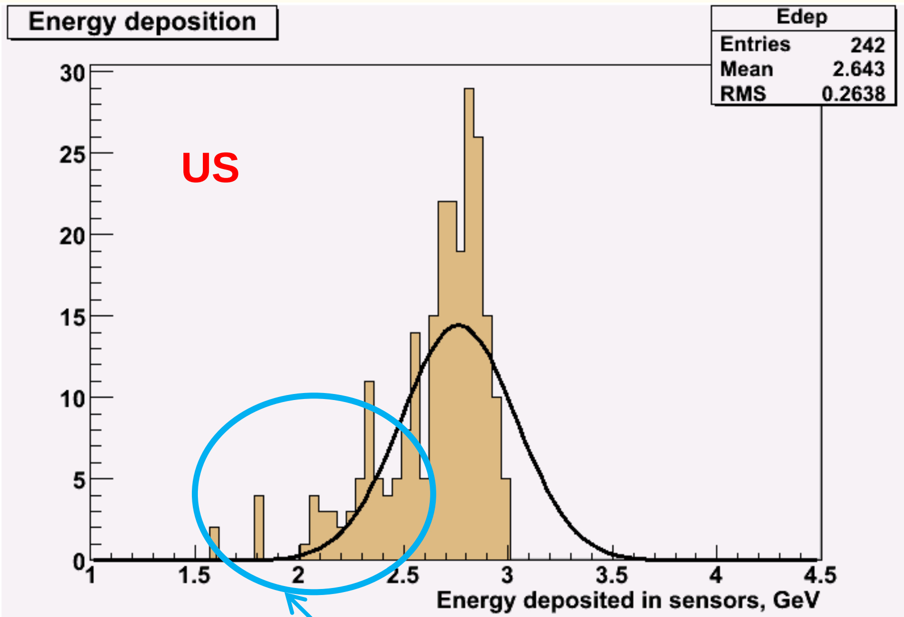
NUMBER FAKE SHOWERS = 1.6%

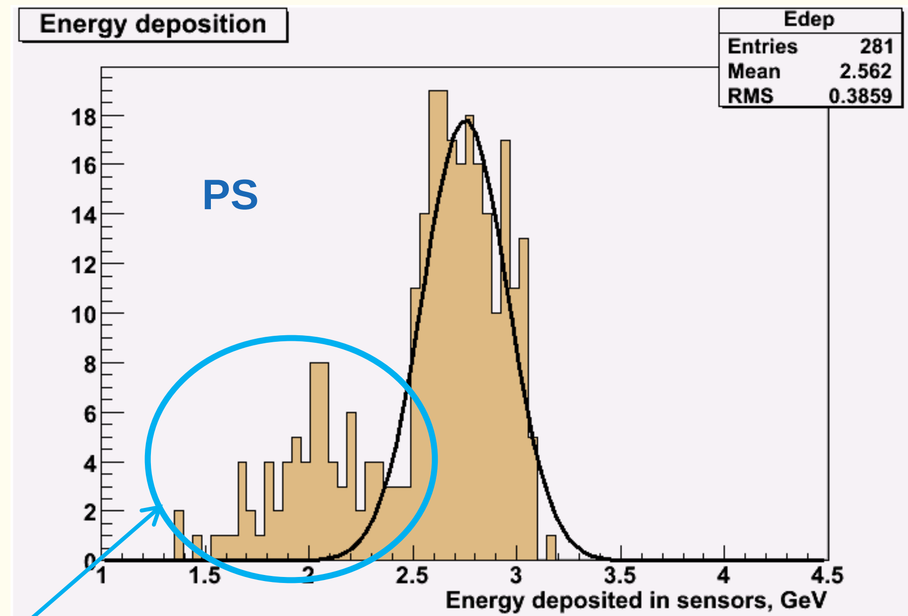
NUMBER NOT RECONSTRUCTED SHOWERS = 70.5%



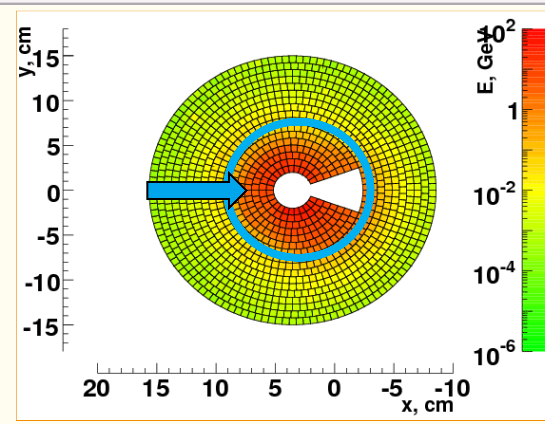
Energy deposition from 200 GeV electrons

Deposited energy over the all radii of calorimeter:



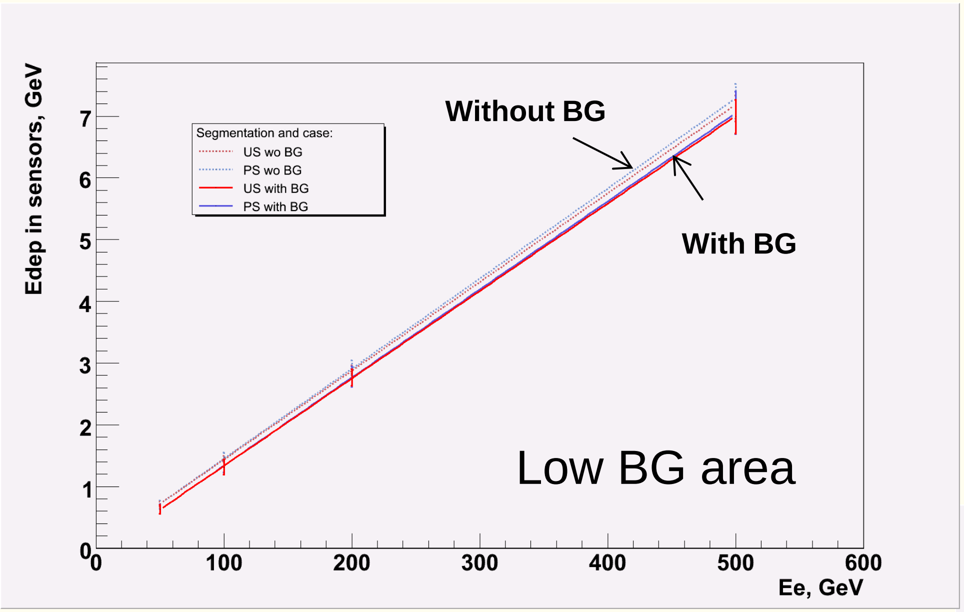


Events from high BG area

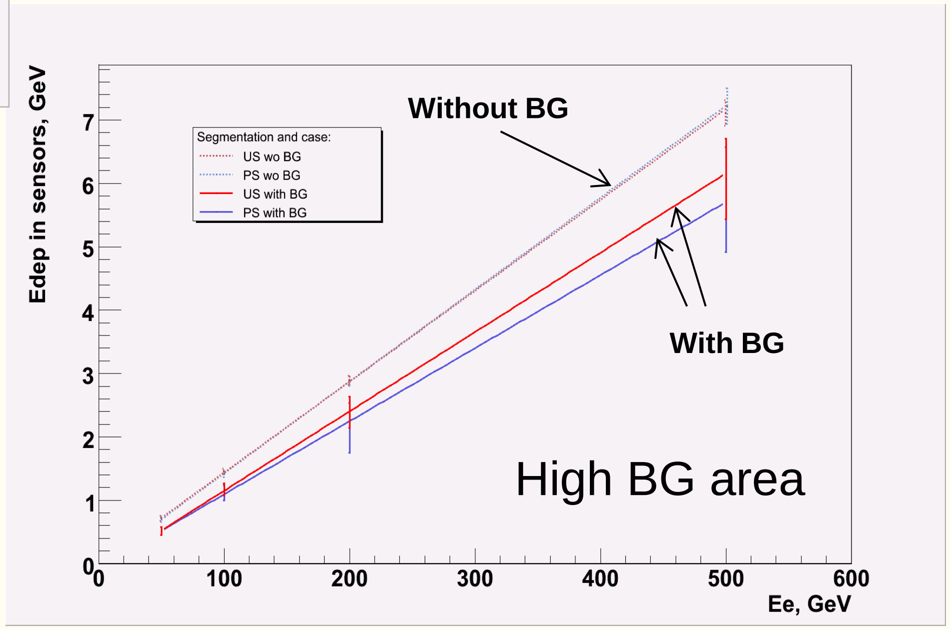


⇒ Consider separately 2 areas:
Low BG and High BG

Energy deposited in sensors vs Energy of electron

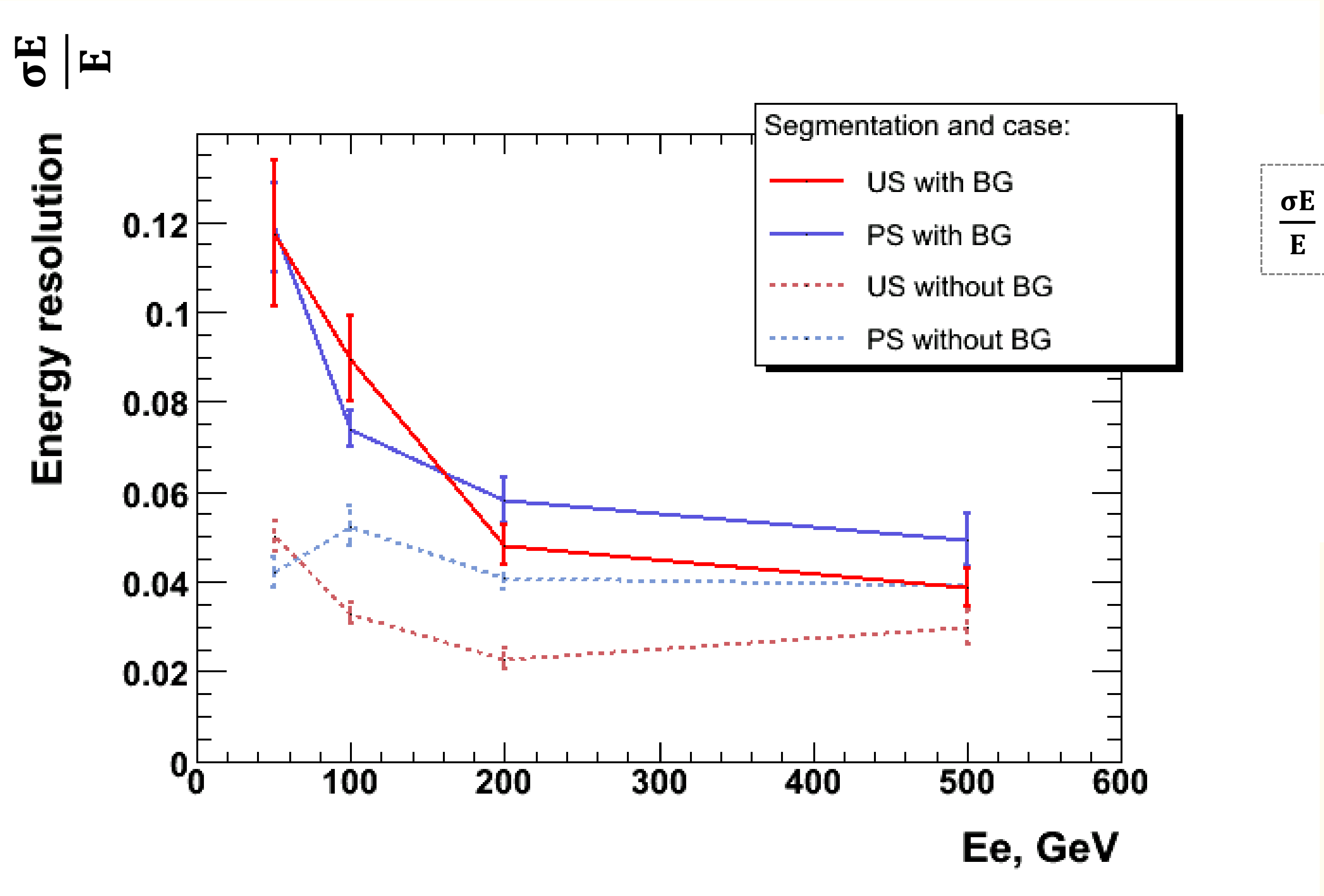


Without BG:
- no background
- sigma criteria is zero



Energy resolution vs Energy of Electron for low BG area

7<R<12 [cm]

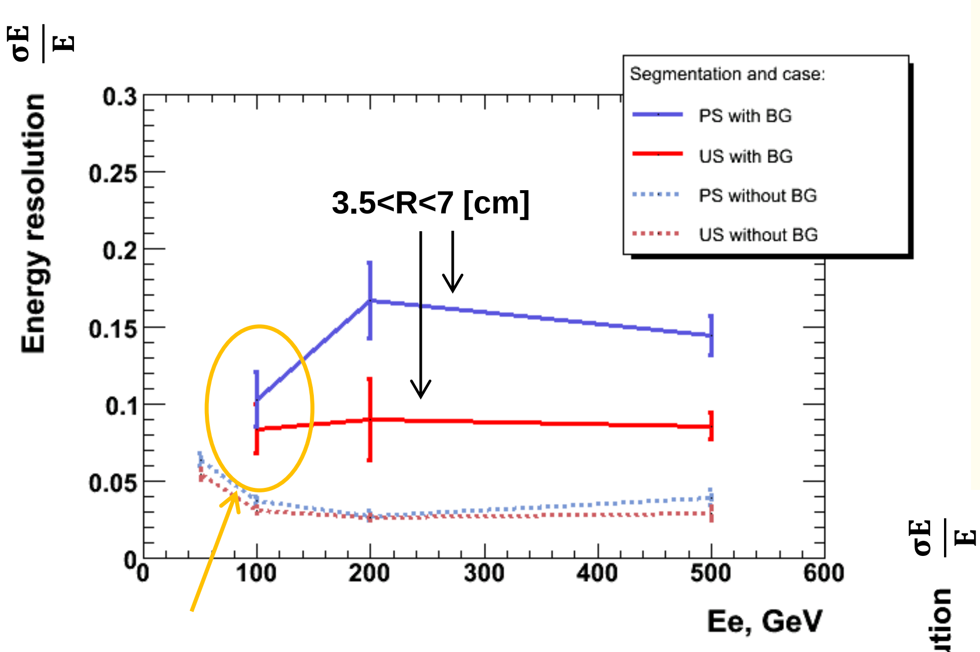


$$\frac{\sigma E}{E} = \frac{p_0}{\sqrt{E}} \oplus \frac{p_1}{\sqrt{E}} \oplus p_2$$

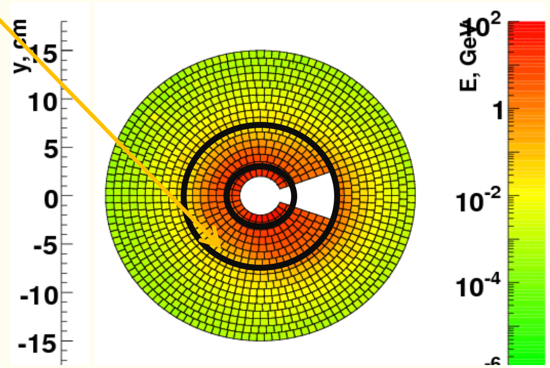
$$\frac{\sigma E}{E} > \frac{40\%}{\sqrt{E}}$$

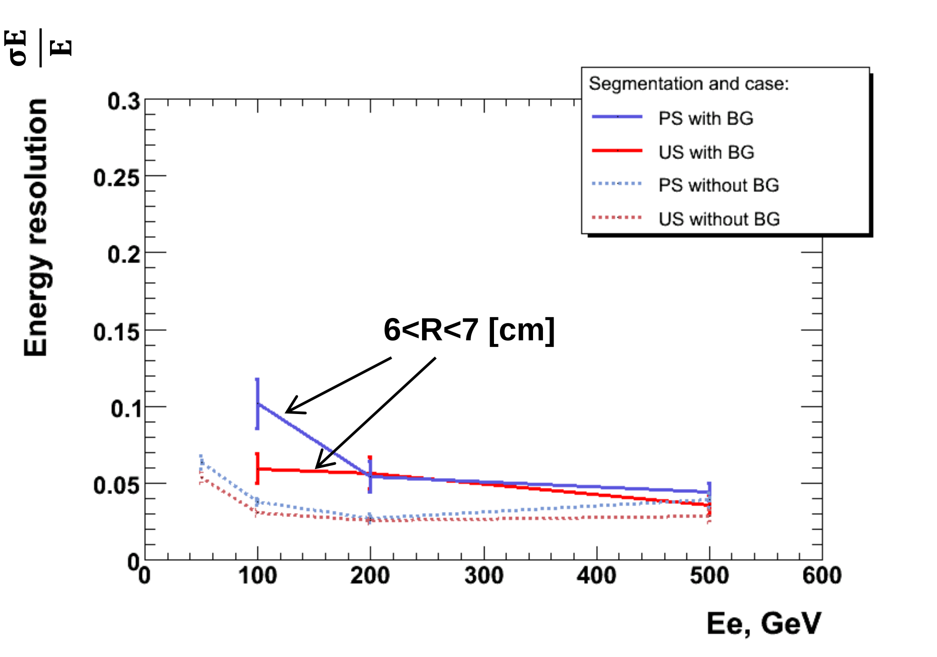
Energy resolution vs Energy of Electron for high BG area

3.5<R<7 [cm]

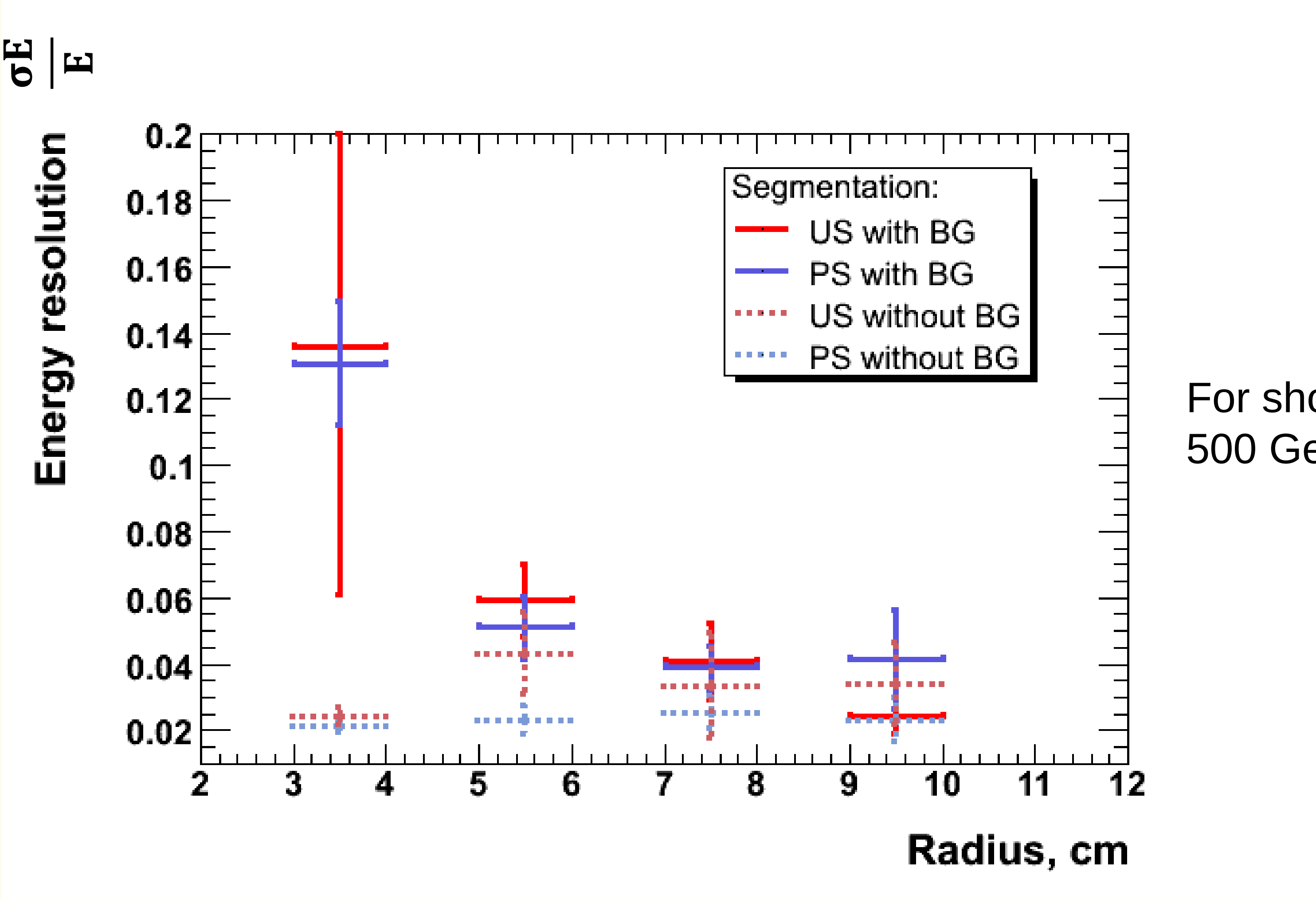


100 GeV electrons reconstruct only
on outer part of range 3.5-7 cm, i.e. only on 6-7 cm





E resolution vs Radius



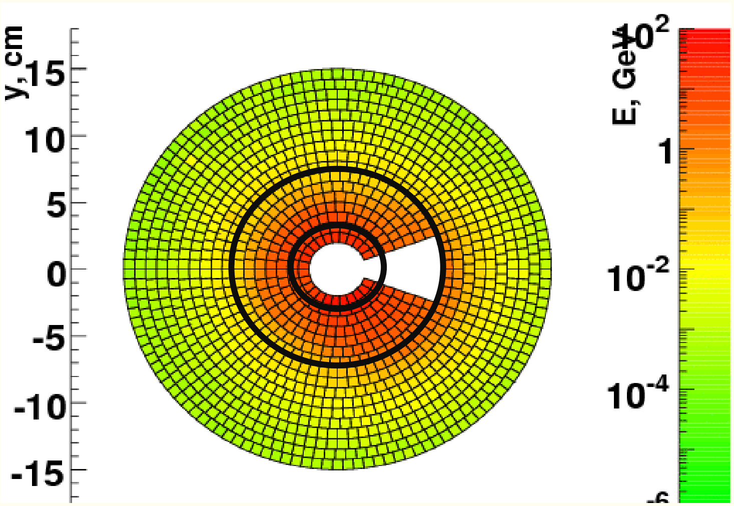
For showers from 500 GeV electrons

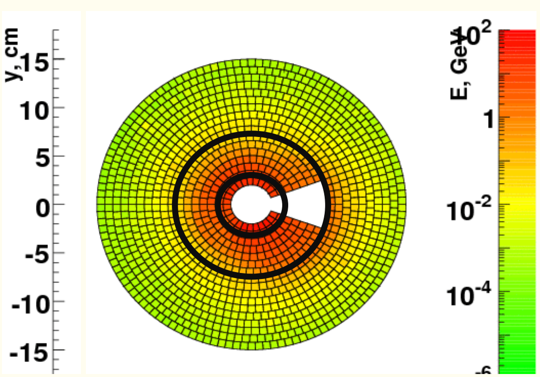
Conclusion

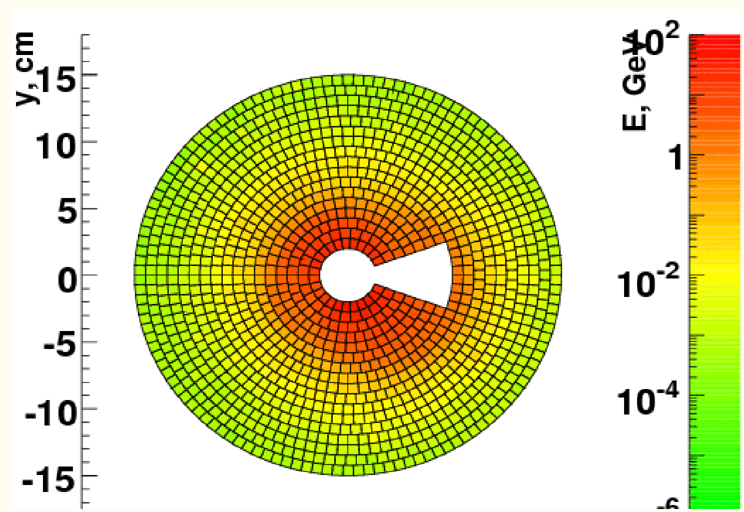
- According available data the optimal parameters of reconstruction algorithm were chosen and BeamCal performance was studied for 1 TeV center-of-mass energy
- A shower reconstruction algorithm was compared for two different segmentations
- The shower reconstruction efficiency is higher using proportional segmentation for electrons with energies above 200GeV
- For lower energy electrons the efficiencies are similar and showers are not reconstructing on a high background area

Thank you for your attention!

Back up

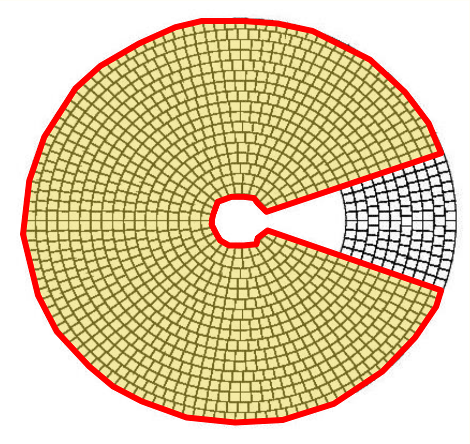

y, cm
15
10
5
0
-5
-10
-15
E, GeV
10^2
1
10^-2
10^-4


y, cm
15
10
5
0
-5
-10
-15
E, GeV
10^2
1
10^-2
10^-4


y, cm
15
10
5
0
-5
-10
-15
E, GeV
10^2
1
10^-2
10^-4

Simulation Showers

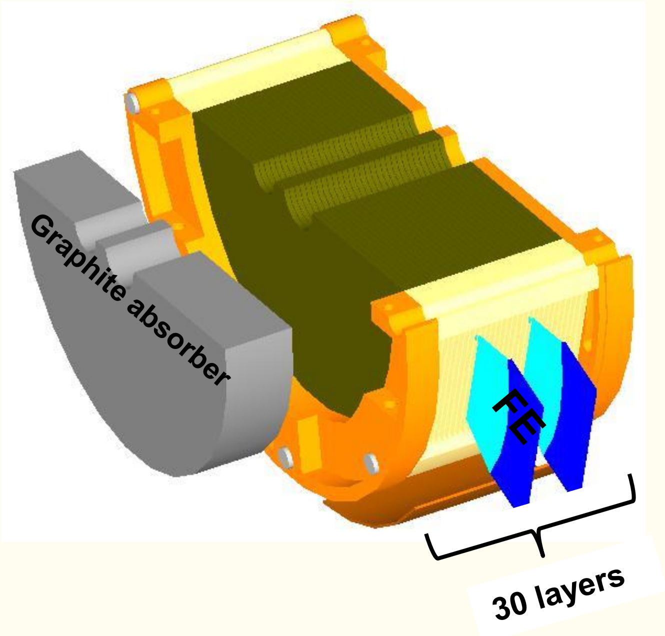
- Sector area
- Distribution: RD



в соответствии с имеющимися данными оптимальные параметры реконструкционного алгоритма были подобраны. Но для более точной оценки правильности работы алгоритма требуется набрать большую статистику по файлам фона.

Алгоритм был применен для изучения характеристик kалориметра.
- эффиктивность восстановления ливней лучше с пропорциональной сегментацией для энергий начиная примерно от 200 Гев.для энергий 200 GeV и ниже ливни практически невозможно восстановить в области высокого фона (до 5-7цм) у обоих сегментации.

Beam Calorimeter for ILC



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

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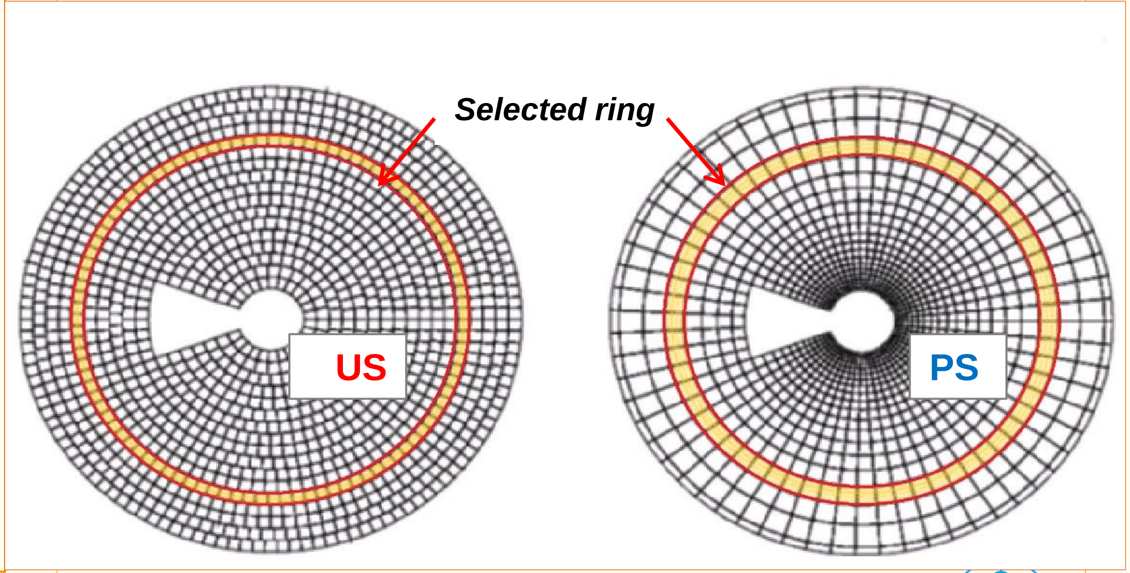
Size of pads:

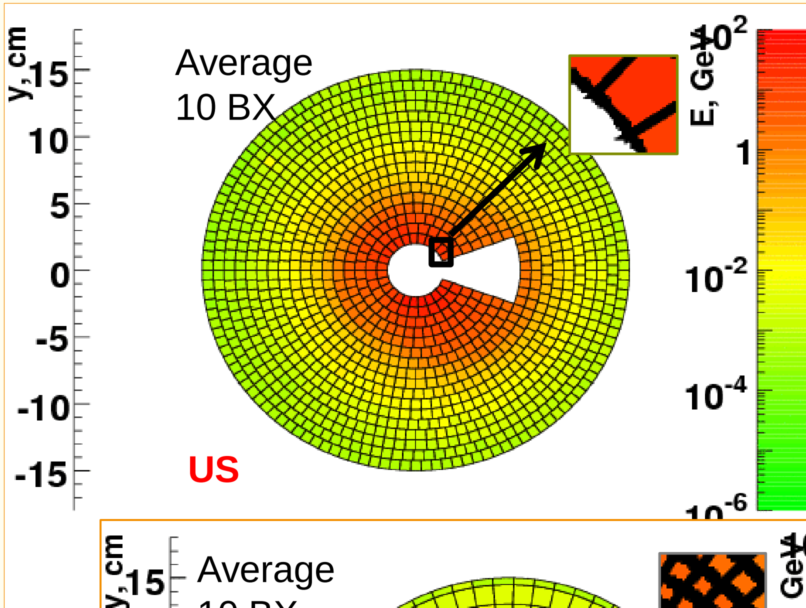
- US - similar, ≈7.65x7.65 mm
- PS - ~R, min 2.2x2.2, max 14.4x14.4mm

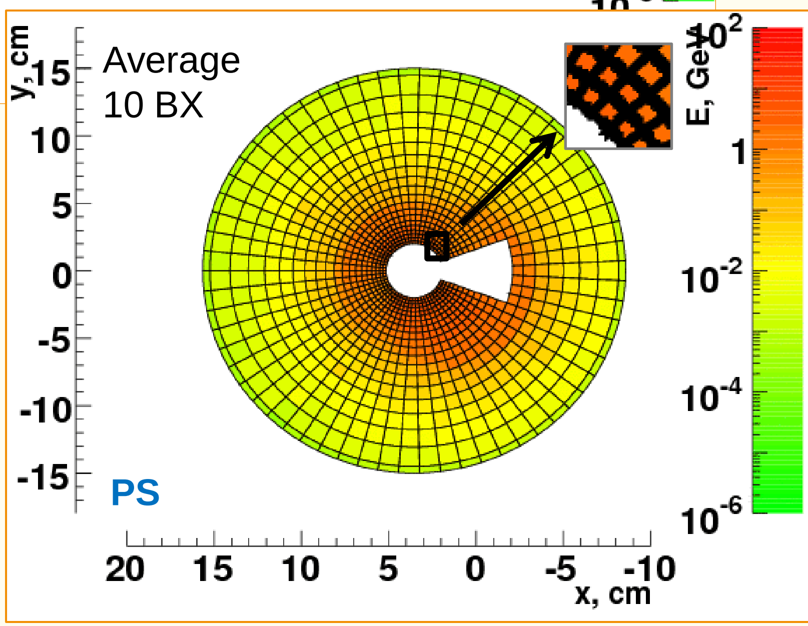
Number of pads:

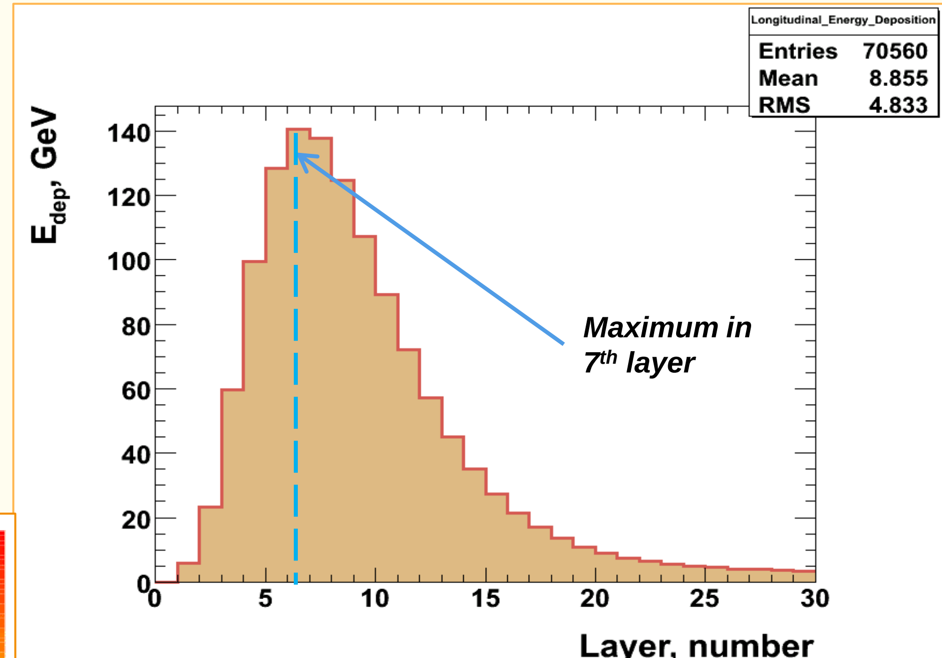
- For US and PS similar



Energy Deposition due to Beamstrahlung





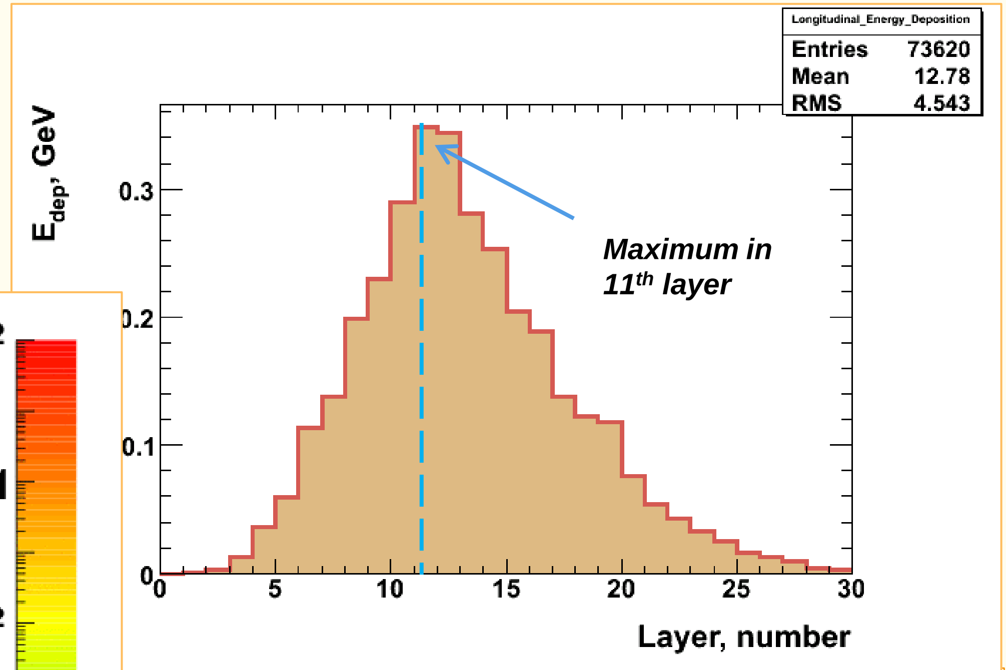


Longitudinal background profile

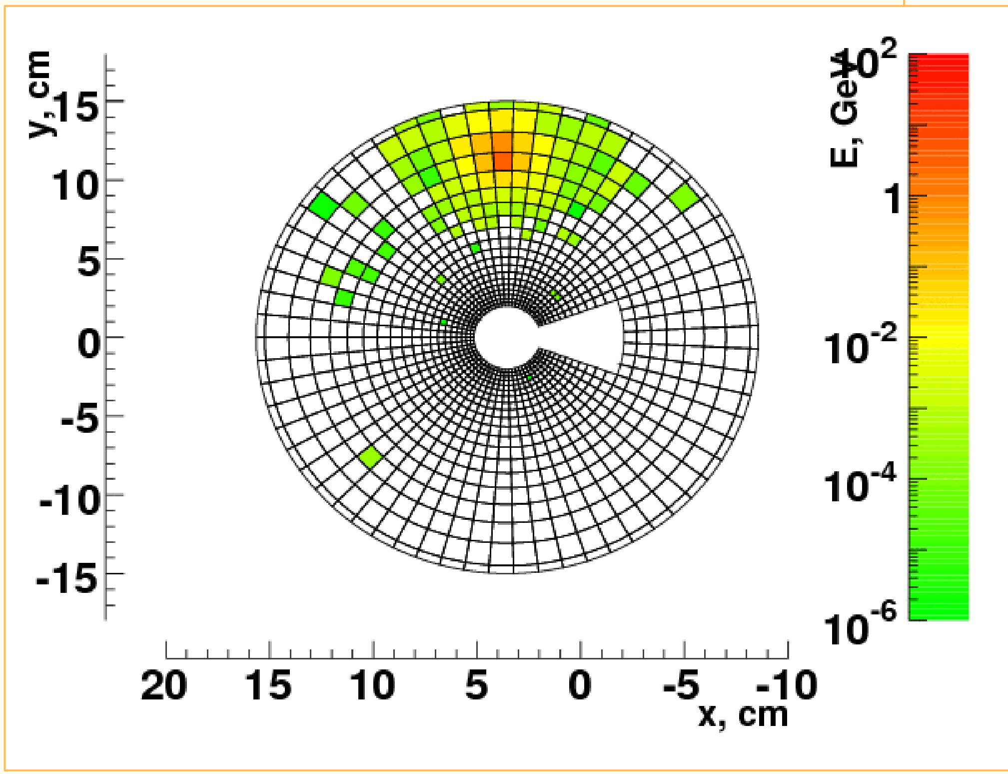
- Beamstrahlung (BS) pairs generated with Guinea Pig
- Energy deposition in sensors from BS simulated with BeCaS (Geant4) ⟶ *considered as background (BG)*

Shower from Single High Energy Electron

Example for 200 GeV electron:



Longitudinal shower profile



Shower from 200- GeV electron

Electron energy	Shower maximum
10 GeV	7 layer
20 GeV	8 layer
50 GeV	9 layer
100 GeV	10 layer

Conclusion

- According available data the optimal parameters of reconstruction algorithm were chosen.

For more precise algorithm correctness estimation more statistics by background files is required

- Algorithm was applied for studying calorimeter characteristics
  - Shower reconstruction efficiency is better for proportional segmentation for energies starting approximately from 200 GeV. For energies 200 GeV and below it is almost impossible to reconstruct showers in area of high background(up to 5-7 cm) for both segmentations
  - The relative energy resolution for the case of background absence is more then $\frac{40\%}{\sqrt{E}}$

  And energy resolution vs radius worse significantly in high background area – 3 times worse then in low background area

- Presented algorithm has quit strict criteria. By relaxing them it is expecting to get a little better characteristics of BeamCal, but nevertheless the high background area stays problematic for shower reconstructions with these beam parameters