Optimization of Reconstruction Algorithm for BeamCal (ILC)

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The Aim and Content

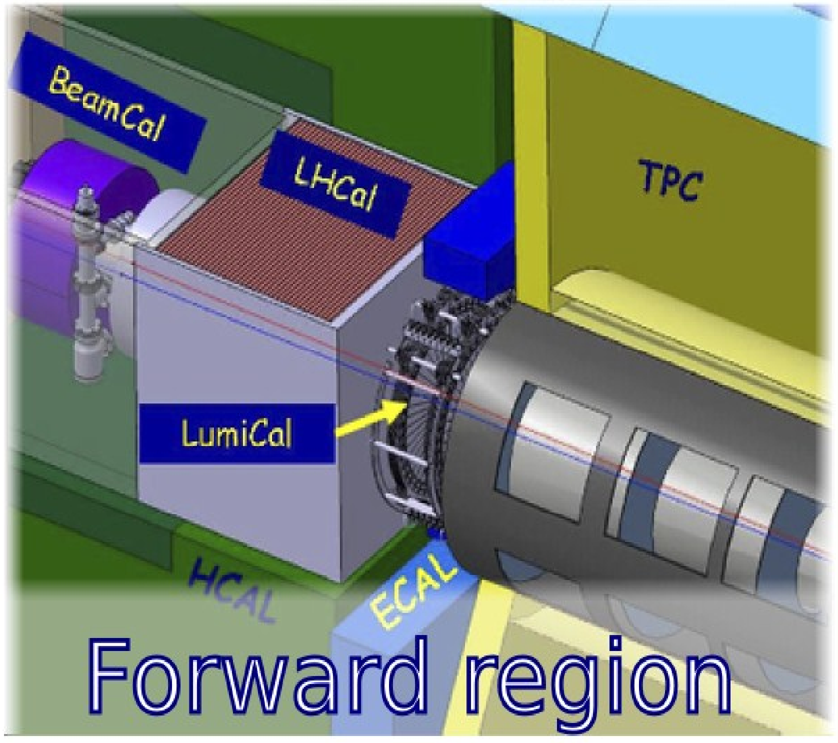
The Aim:

- find optimal parameters for reconstruction algorithm
- investigate and compare characteristics of calorimeter applying this algorithm

Content:

- Introduction
- Searching for algorithm parameters
  - looking into the energy depositions in cells precisely
  - comparing with another algorithms
  - checking with fake rate
- Calorimeter characteristics studies
  - shower reconstruction efficiency
  - energy deposition and resolution
- Conclusion

Beam Calorimeter for ILC

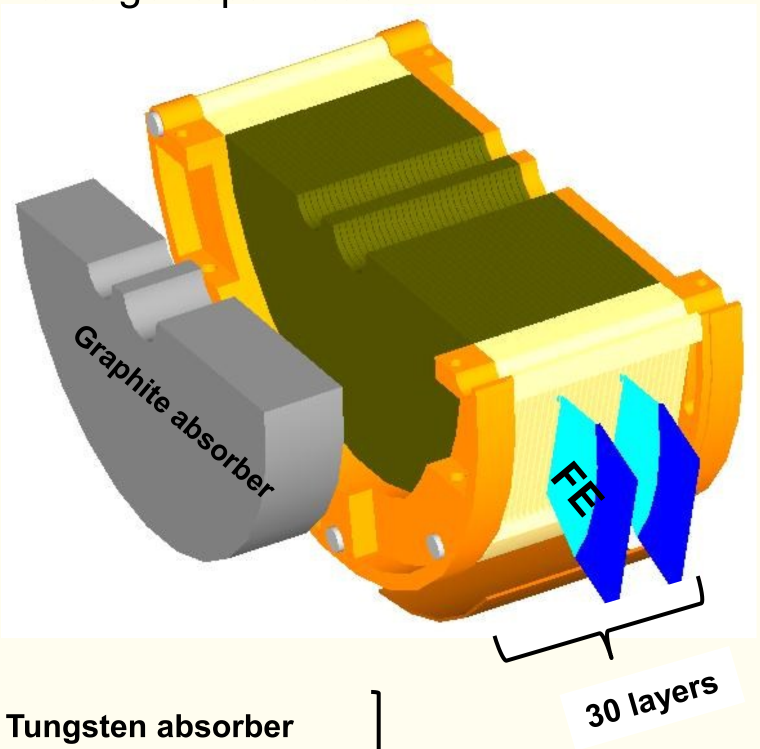


Beam parameters from the ILC Technical Design Report (November 2012)

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

BeamCal aimed:

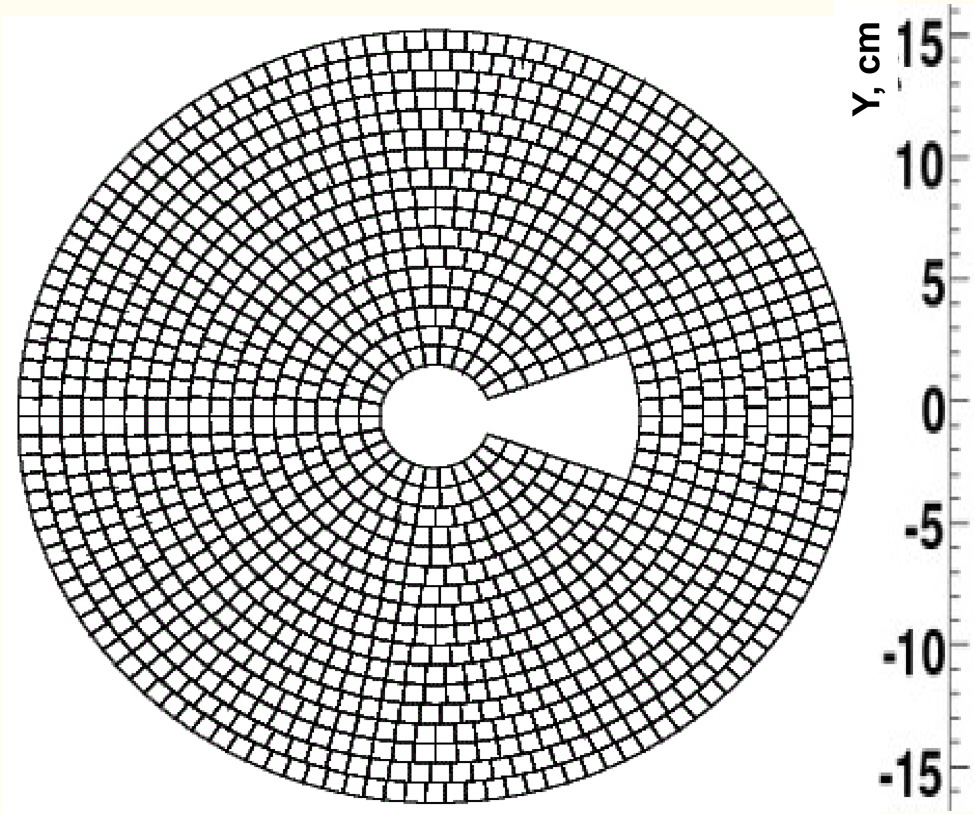
- Detect sHEe
- Determine Beam Parameters
- Masking backscattered low energetic particles

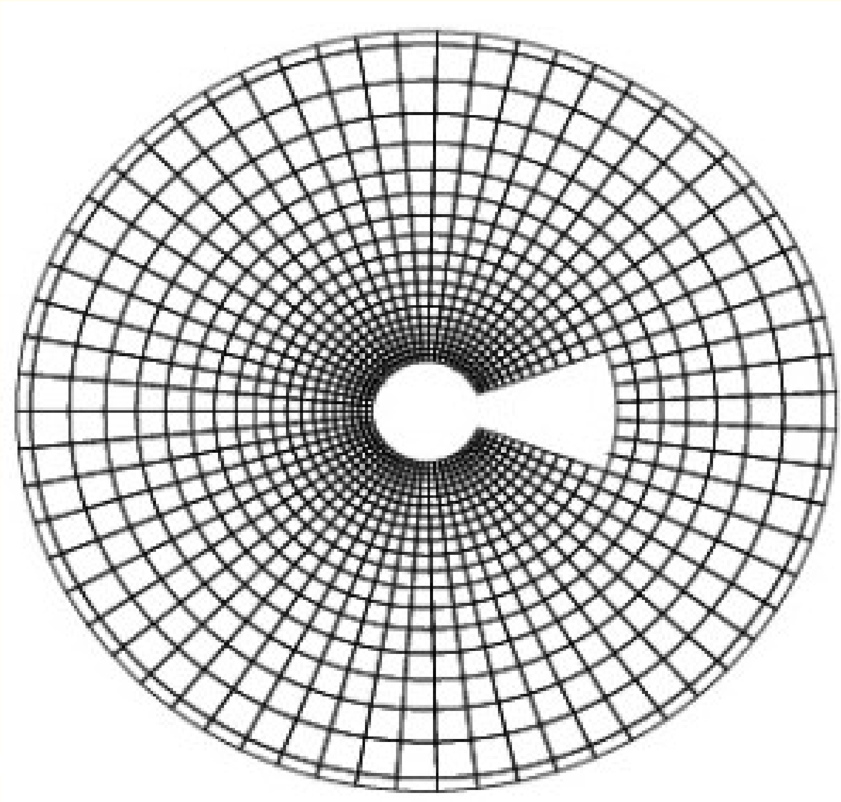


- **Tungsten absorber**
- **Diamond sensor**
- **Readout plane/air gap**

$\Big\}$ **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

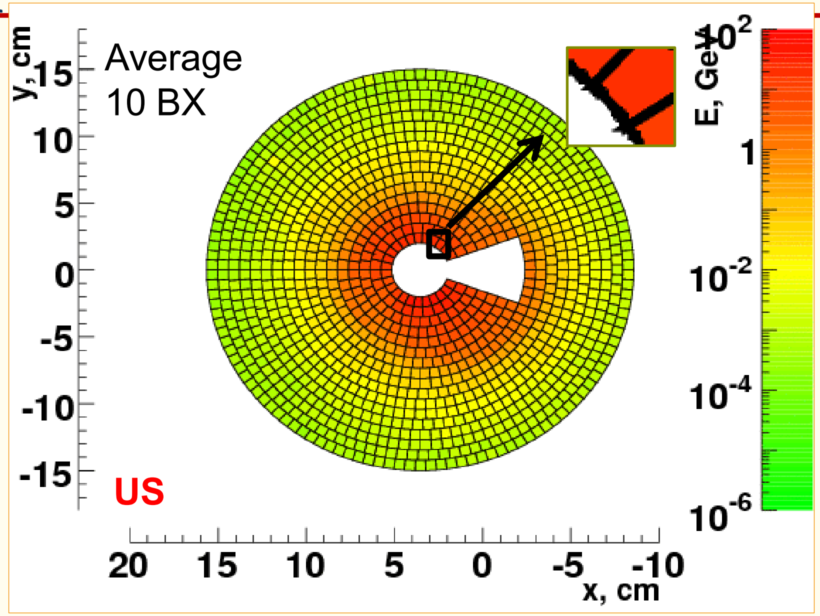
Energy Deposition due to Beamstrahlung

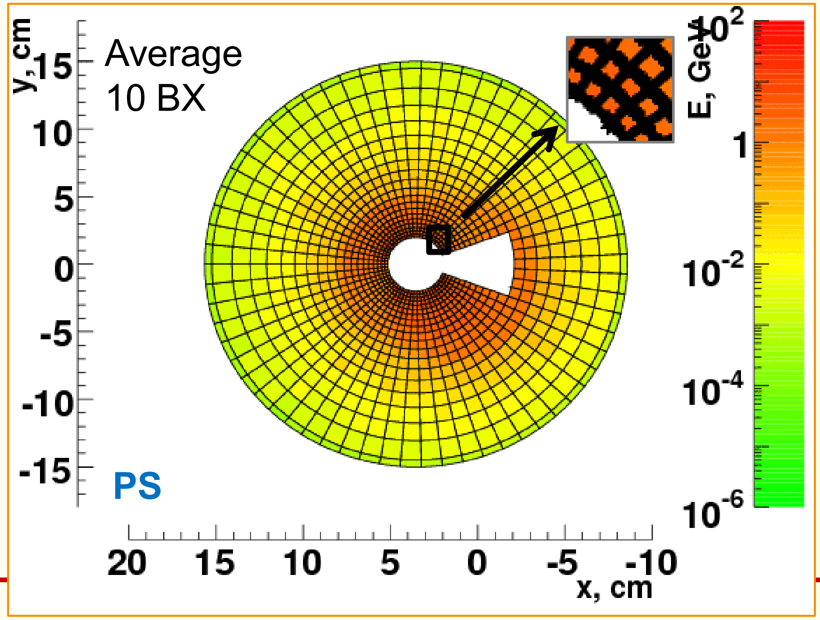
- **Beamstrahlung (BS) pairs generated with Guinea Pig**
- **Energy deposition in sensors from BS simulated with BeCaS (Geant4)**

  → ***considered as Background (BG)***
- **RMS of the averaged BG**

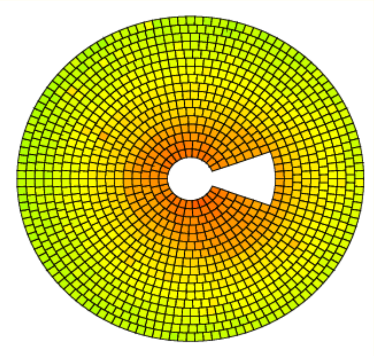
  → ***considered as noise (for SNR)***

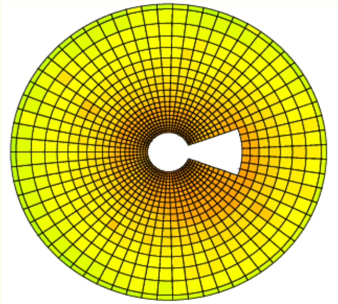
E_{dep} is the same, but E_{dep}/pad is different!





RMS





Figures show sum of all layers

Search parameters for reconstruction Algorithm

The goal: find optimal parameters of reconstruction algorithm

In my hands: deposited energy in each cell of calorimeter from shower and RMS of background(BG)

Parameters to apply:
- how many sigma(RMS) to apply
- which layers should be considered
- how many cells in a row

Requirements:
- fake rate < 2% (strictly!)
- good :
  - --efficiency of reconstruction
  - --energy resolution
  - --spatial resolution

Algorithm

With BG

Without BG

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

2. Select layers from 5th to 20th

3. Applying energy threshold 5 RMS

4. Combine to towers

5. Search 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

   * Consider candidate towers to shower within Rm=1.2 cm or at least 8 pads around max energetic tower

   => shower created

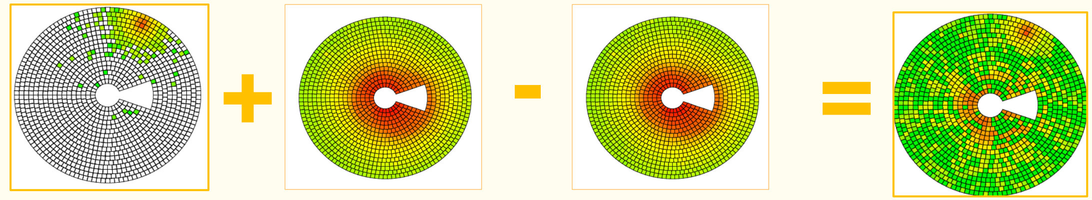
6. Next shower: repeat step 5

7. For each shower calculate

   - R_{COG}, φ_{COG}, E_{sh}

1

SH BG Average BG



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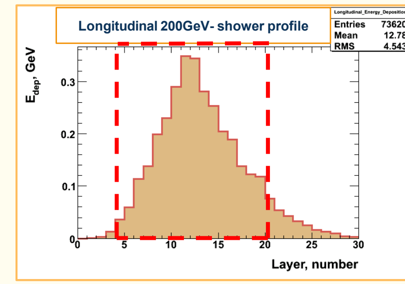
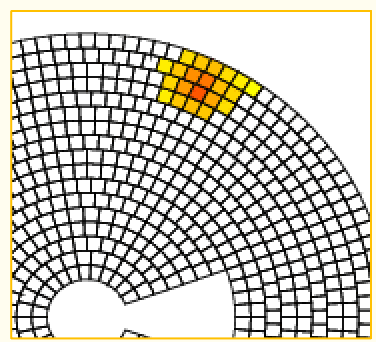


4

Picture with tower

5

Reconstructed SH

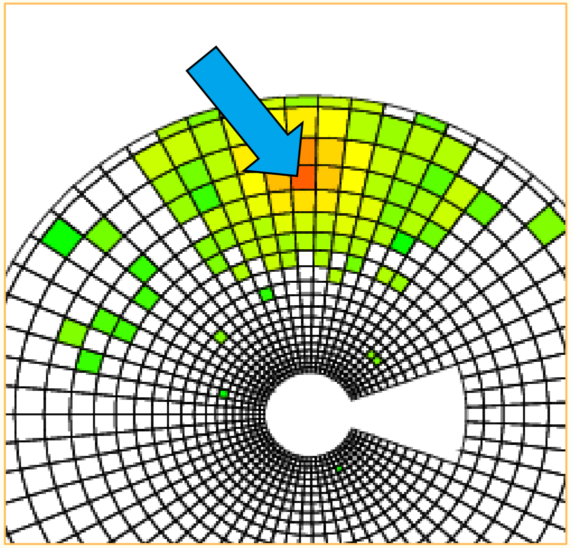


Idea

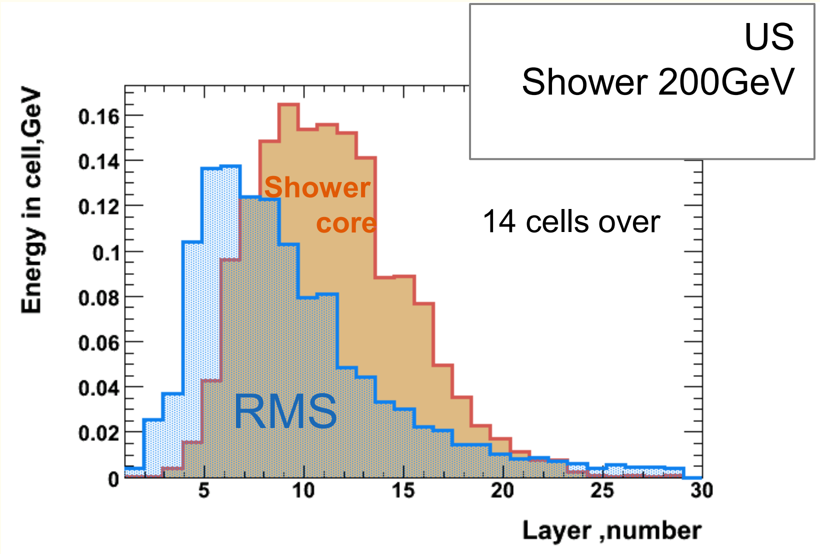
Compare energy deposition <u>on small radii</u> (most problematic area for reconstruction) along Z-axis for:

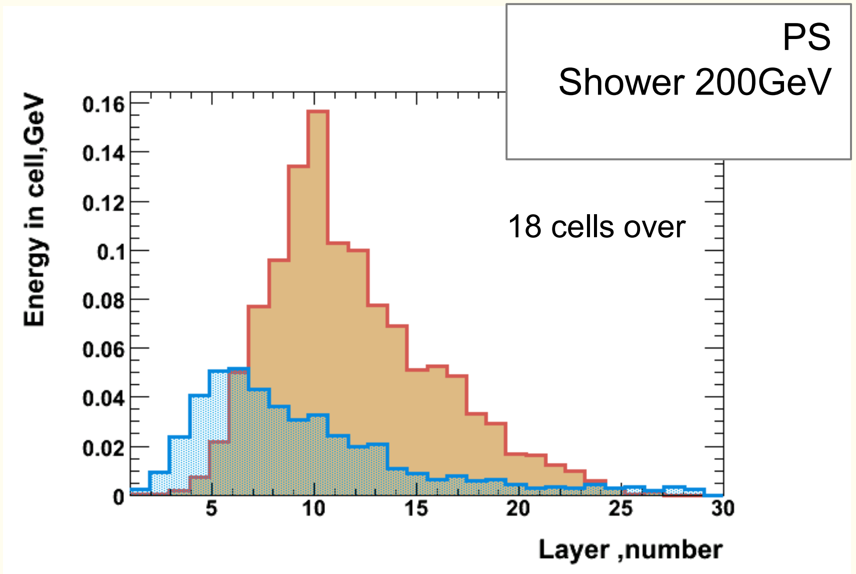
- tower of the shower core and tower of the RMS on small radii
- max energetic tower of (BG – average_BG) and

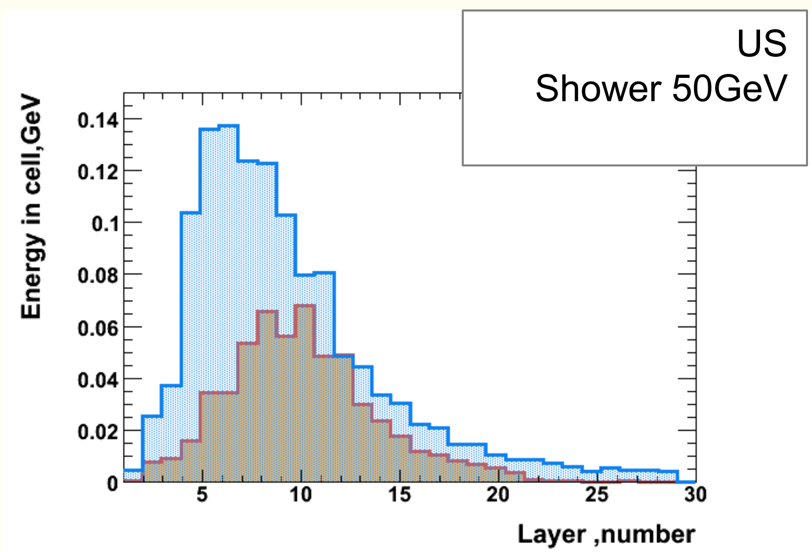
  tower of the RMS

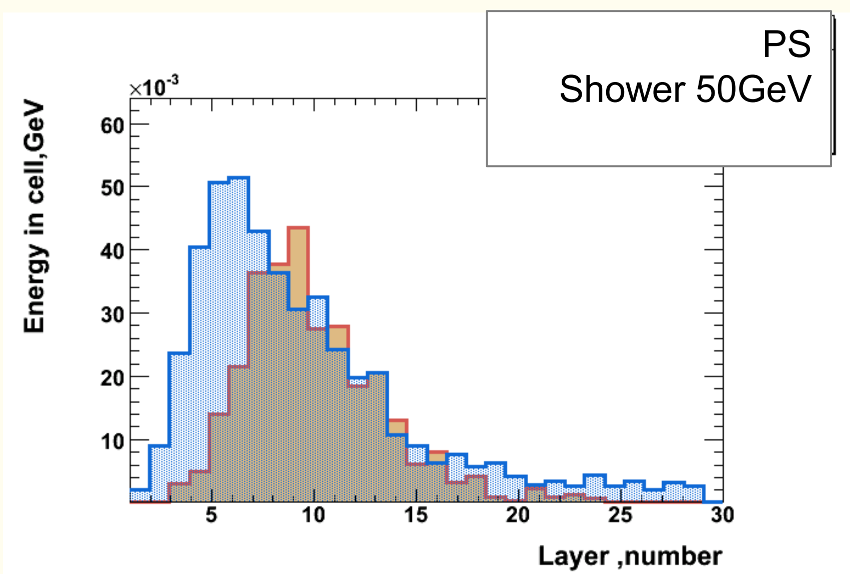


Tower profiles from Shower core and RMS on small R

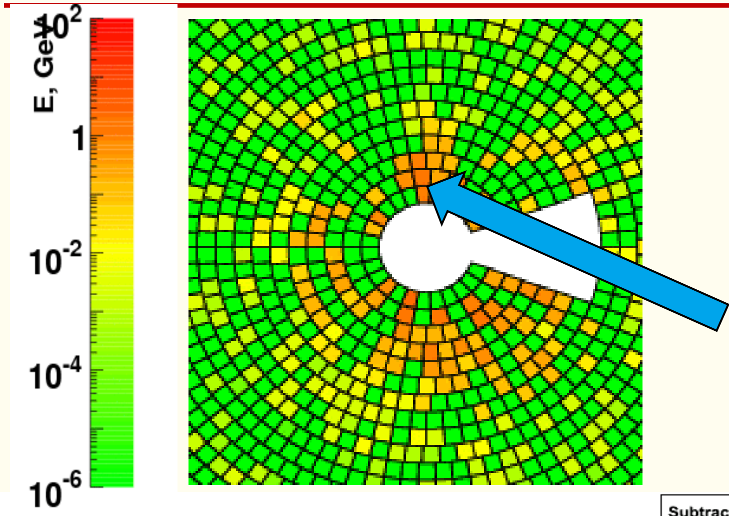




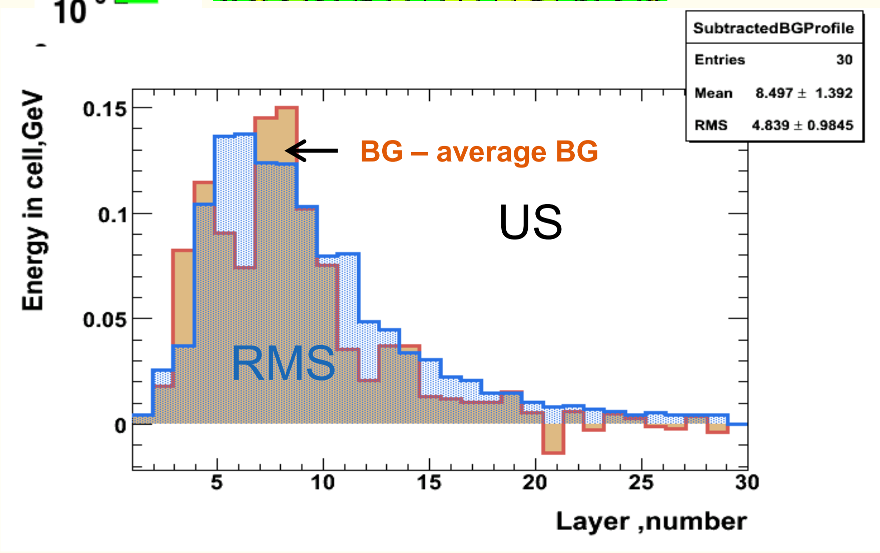


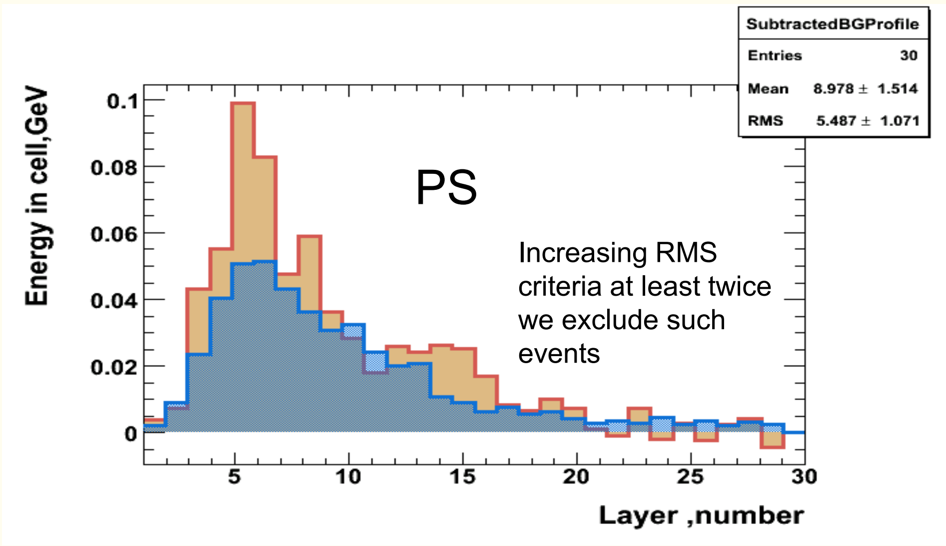


Tower profiles from Subtracted BG and RMS on small R



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 consider ed	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

1. Reconstruction showers on top of BG -> Number of ring rReco and phiReco
2. Reconstruct showers, no threshold applied (0*RMS,

   cause not all SH on small radii reconstructing) -> rTrue, phiTrue
3. If | rTrue - rReco| < Rm and |phiTrue – phiReco| < Rm,

   then shower reconstructed correctly

   and ratio rReco/rTrue = efficiency
4. Else (| Rtrue- Rreco| > Rm) - fake shower

Efficiency 500 GeV

PS

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 89.2%

NUMBER FAKE SHOWERS = 1.2%

NUMBER NOT RECONSTRUCTED SHOWERS = 9.6%

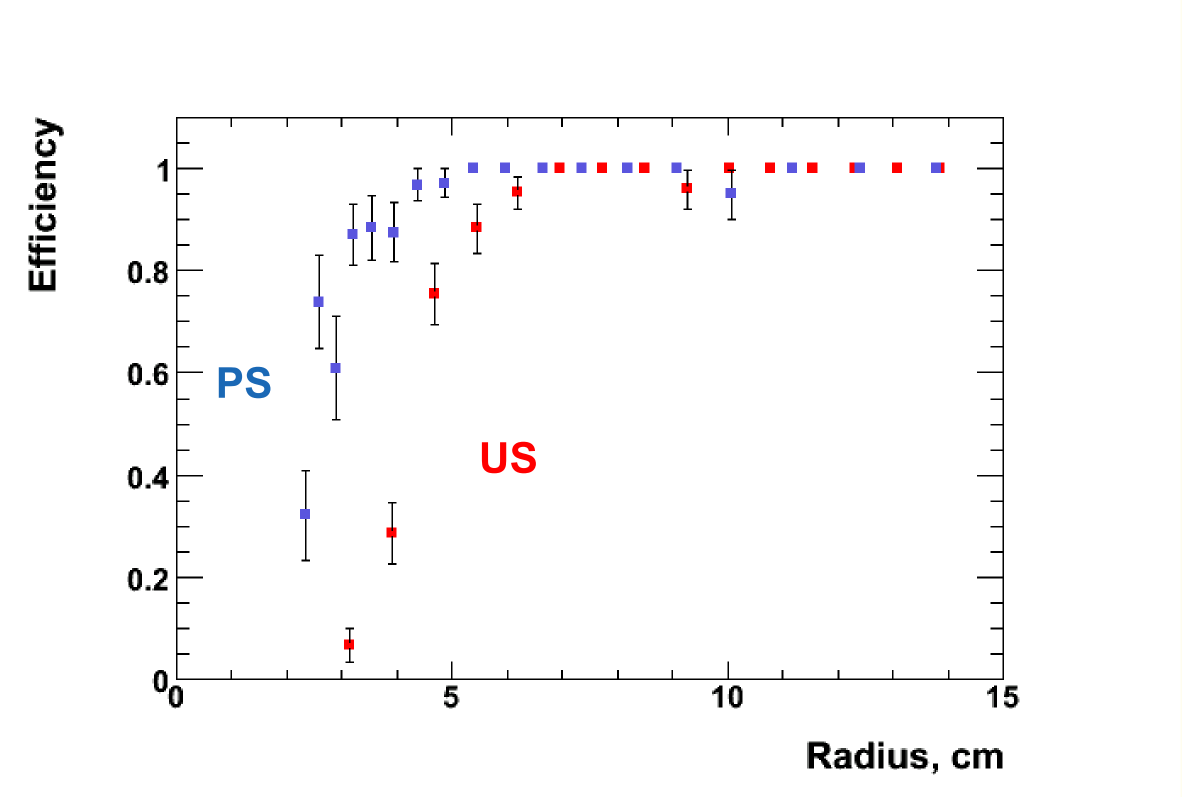
US

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 64.9%

NUMBER FAKE SHOWERS = 0.6%

NUMBER NOT RECONSTRUCTED SHOWERS = 34.5%



Efficiency 200 GeV

PS

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 55.1%

NUMBER FAKE SHOWERS = 0.8%

NUMBER NOT RECONSTRUCTED SHOWERS = 44.1%

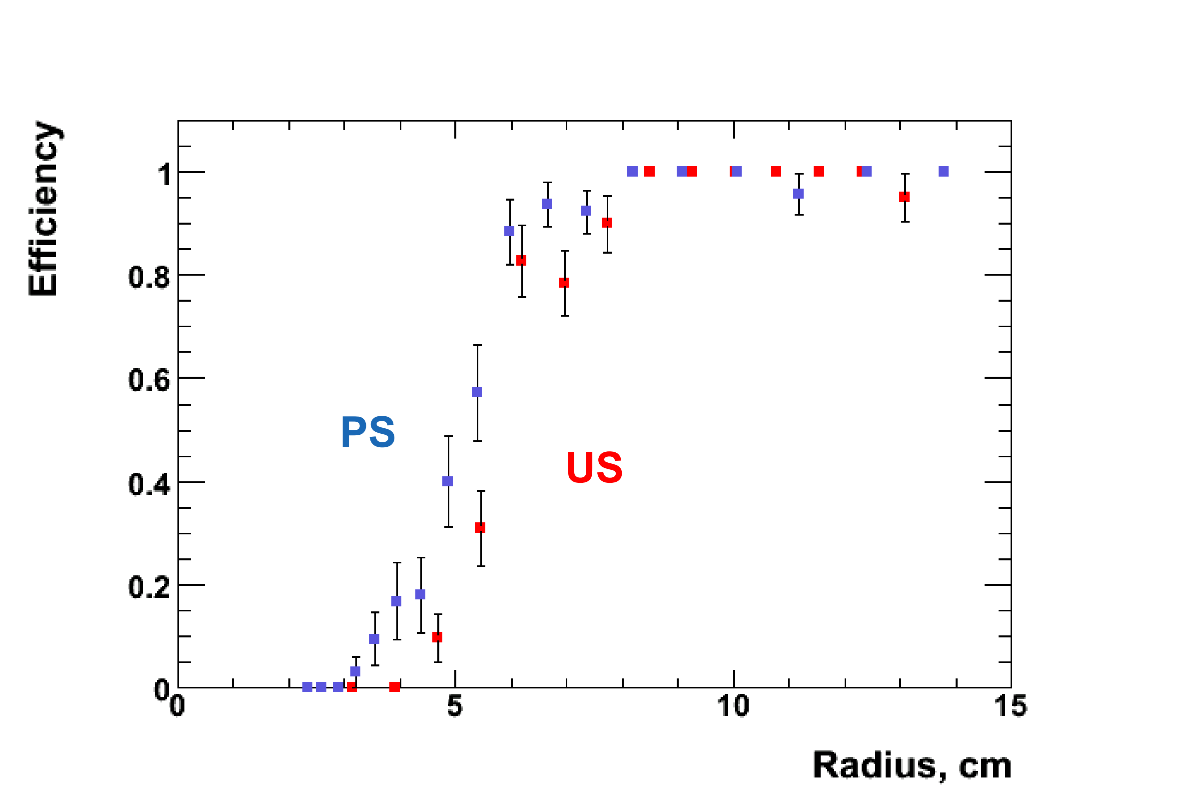
US

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 46.0%

NUMBER FAKE SHOWERS = 1.4%

NUMBER NOT RECONSTRUCTED SHOWERS = 52.6%



Efficiency 50 GeV

PS

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 29.5%

NUMBER FAKE SHOWERS = 0.4%

NUMBER NOT RECONSTRUCTED SHOWERS = 70.1%

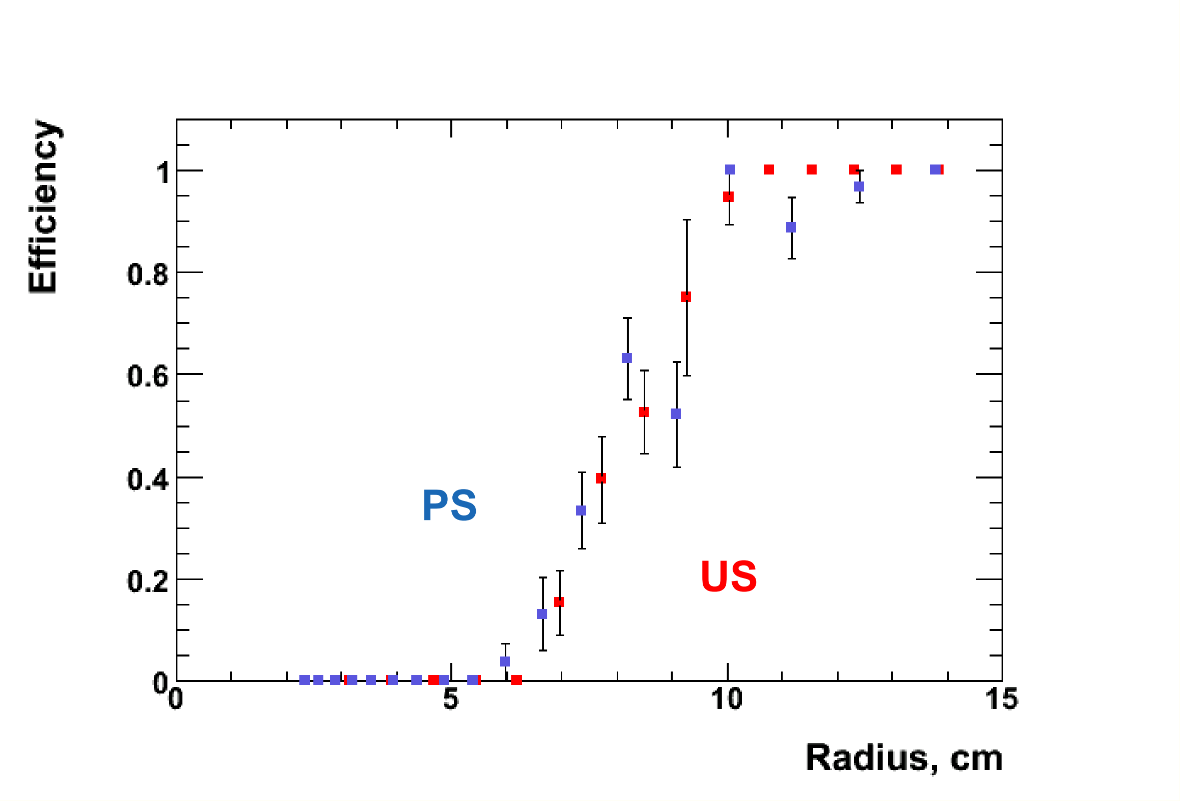
US

TOTAL EVENTS≈500

NUMBER RECONSTRUCTED WITHIN R_MOLIERE SHOWERS = 27.9%

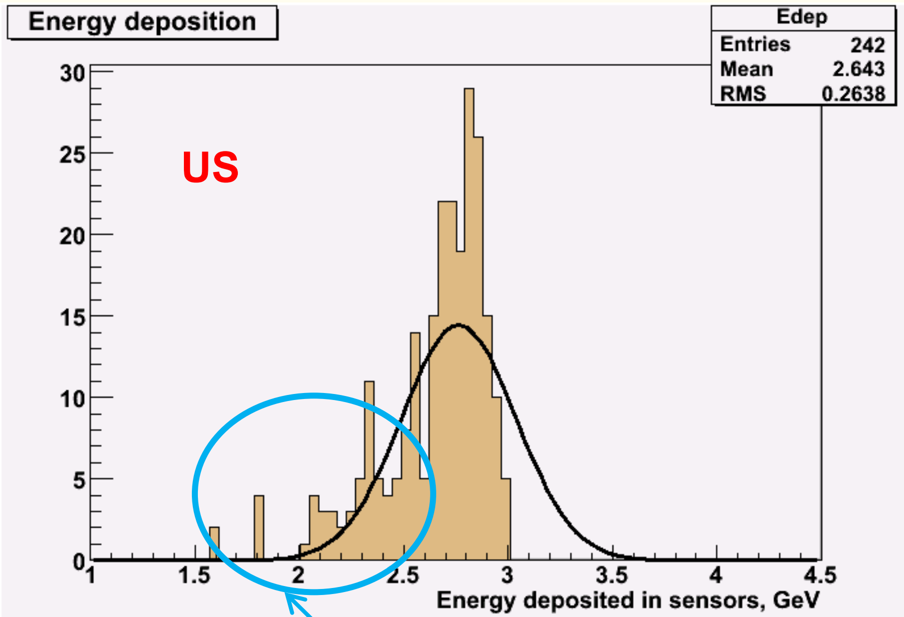
NUMBER FAKE SHOWERS = 1.6%

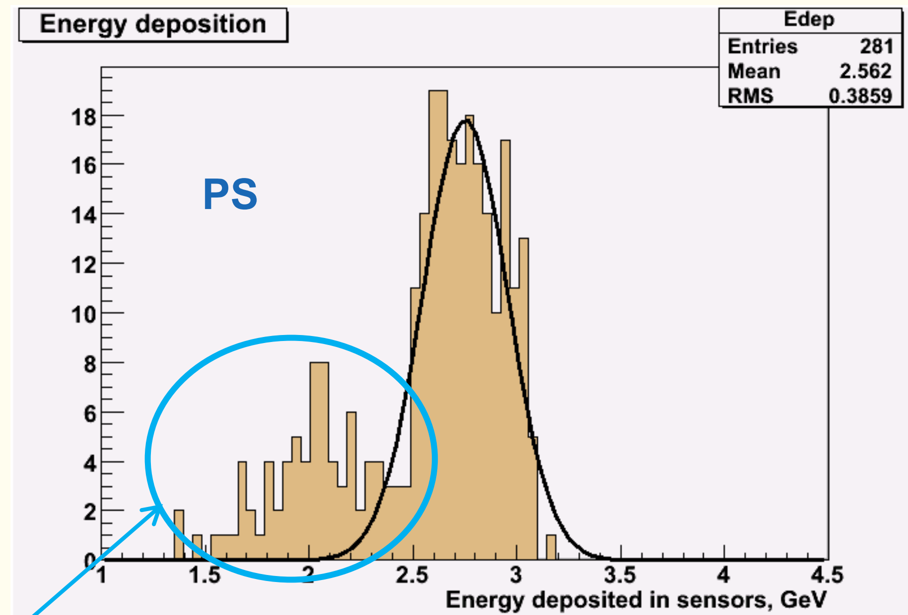
NUMBER NOT RECONSTRUCTED SHOWERS = 70.5%



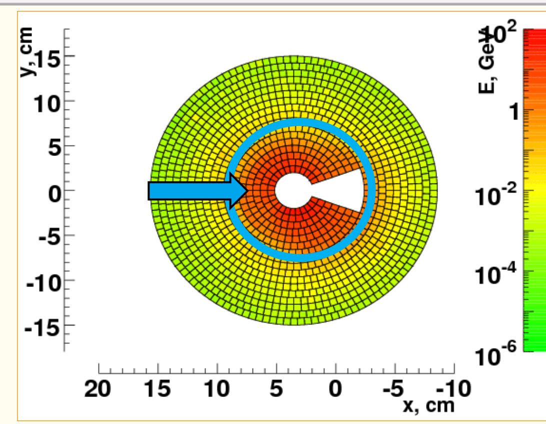
Energy deposition from 200 GeV electrons

Deposited energy over the all radii of calorimeter:



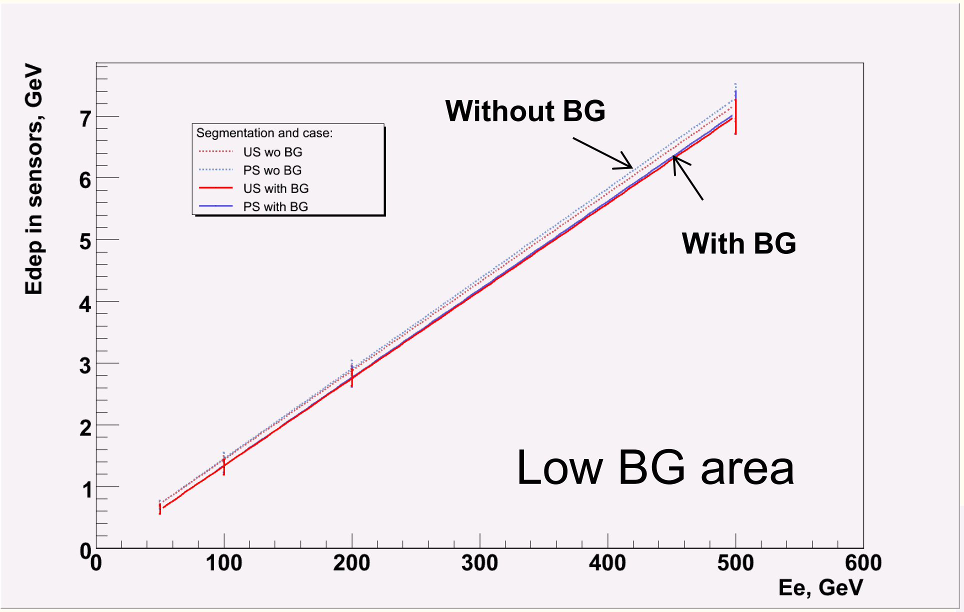


Events from high BG area

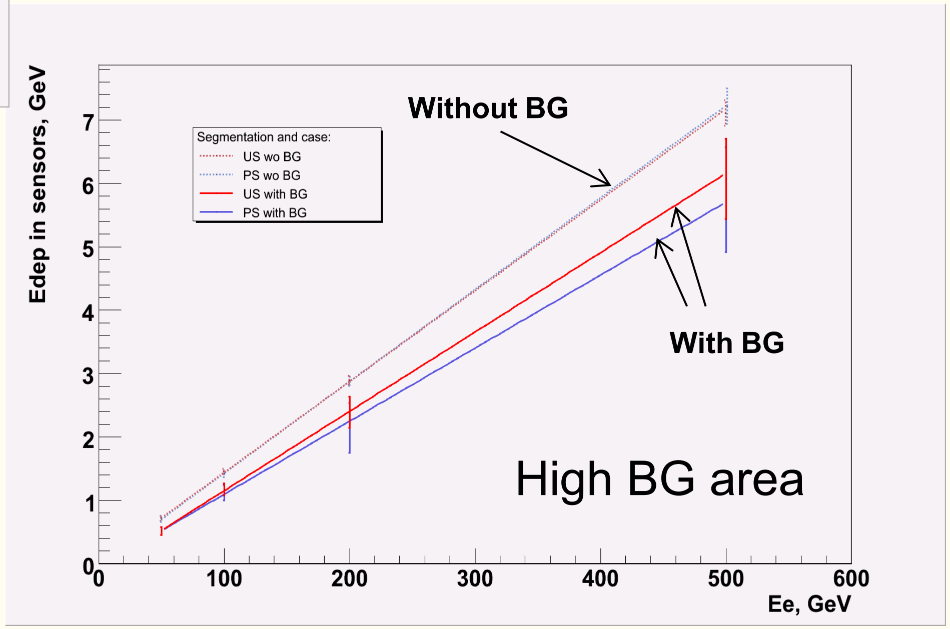


$\Rightarrow$ Consider separately 2 areas:
Low BG and High BG

Energy deposited in sensors vs Energy of electron

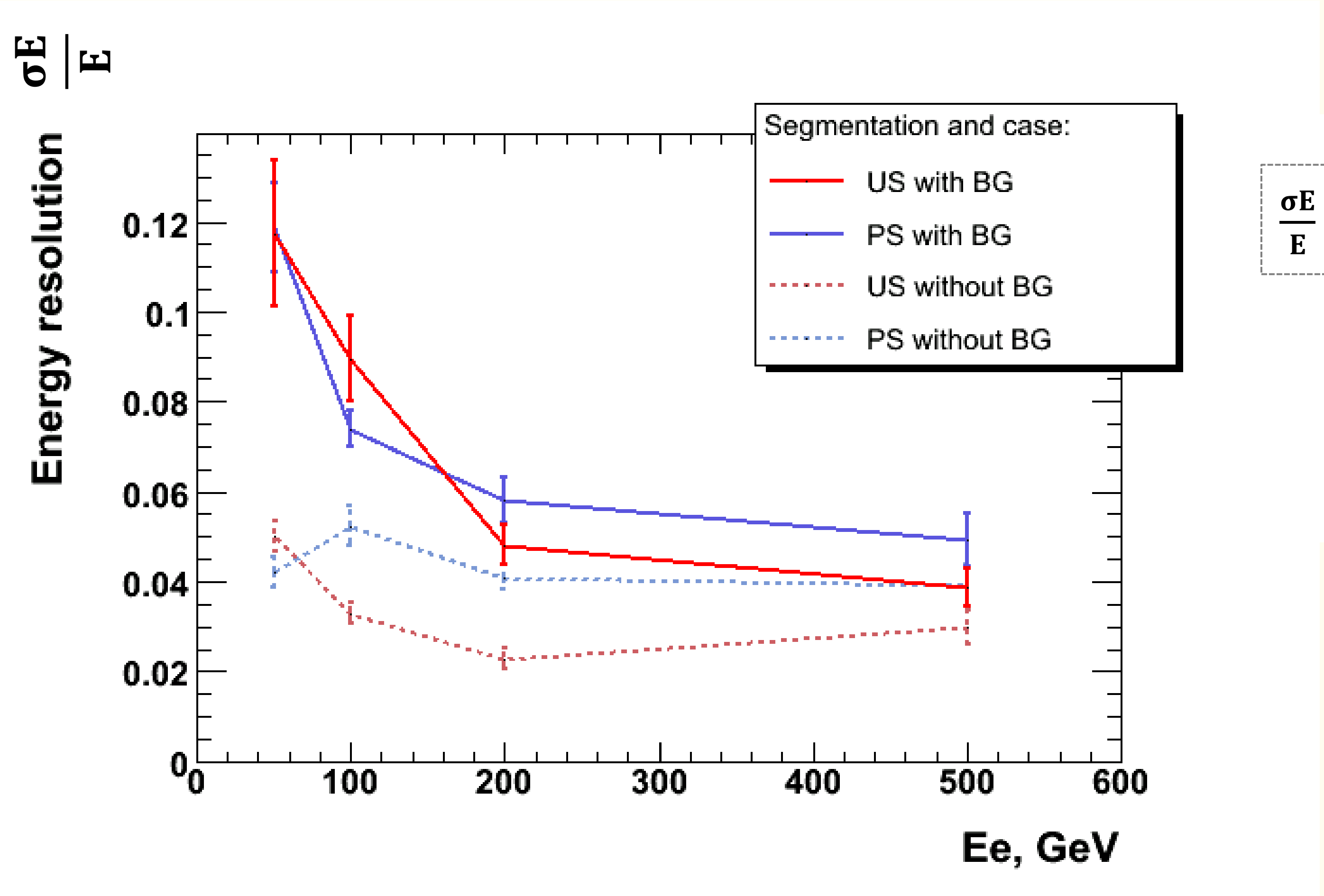


Without BG:
- no background
- sigma criteria is zero



Energy resolution vs Energy of Electron for low BG area

7<R<12 [cm]



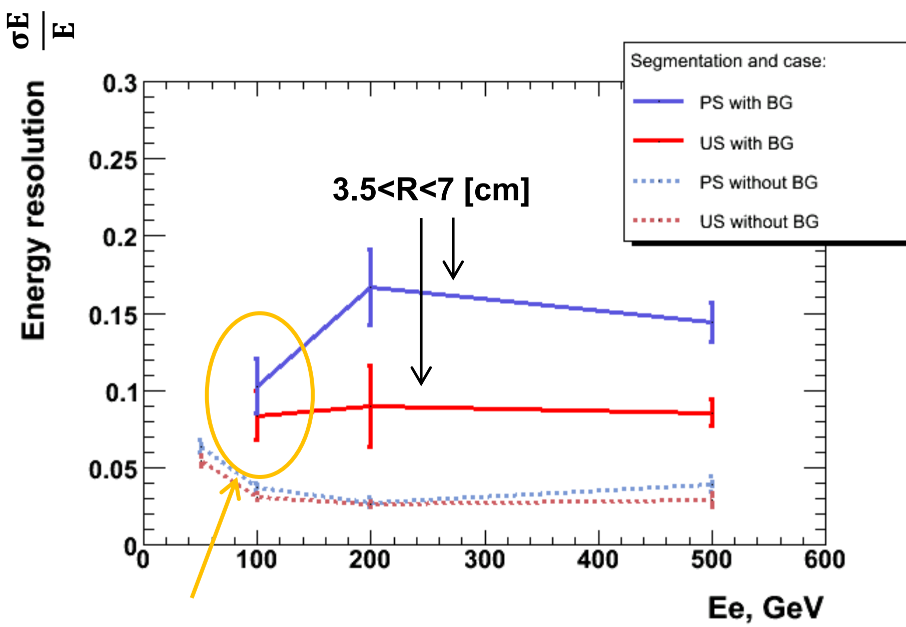
$$\boxed{\frac{\sigma E}{E} = \frac{p_0}{\sqrt{E}}} \oplus \frac{p_1}{\sqrt{E}} \oplus p_2$$

$$\Downarrow$$

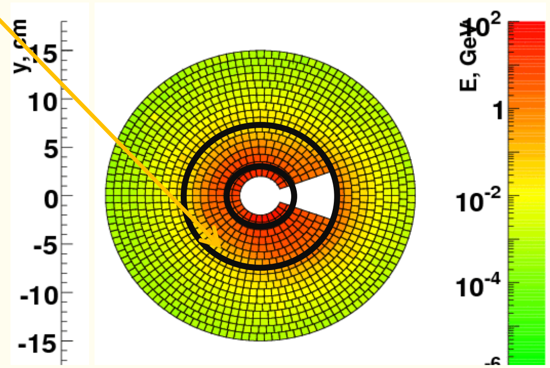
$$\frac{\sigma E}{E} > \frac{40\%}{\sqrt{E}}$$

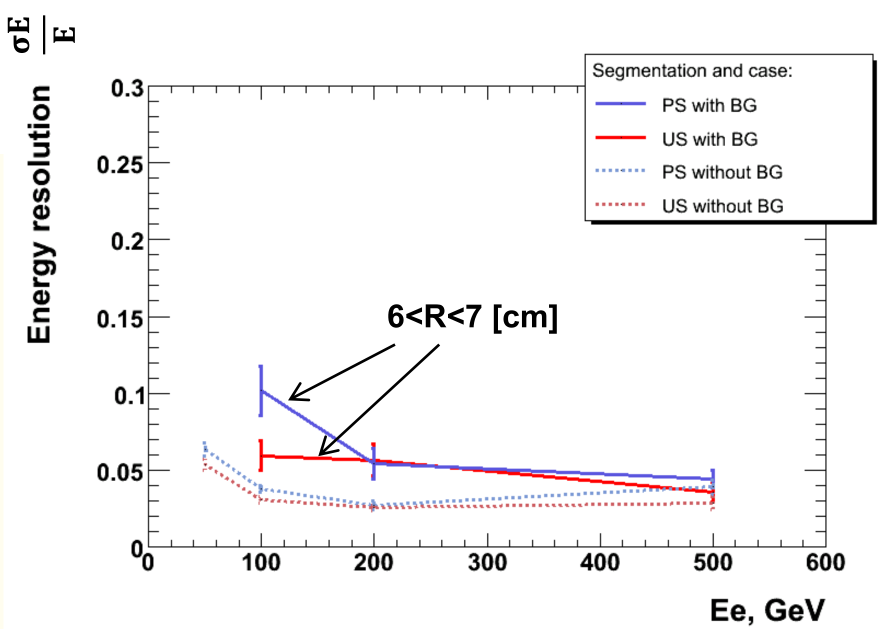
Energy resolution vs Energy of Electron for high BG area

3.5<R<7 [cm]

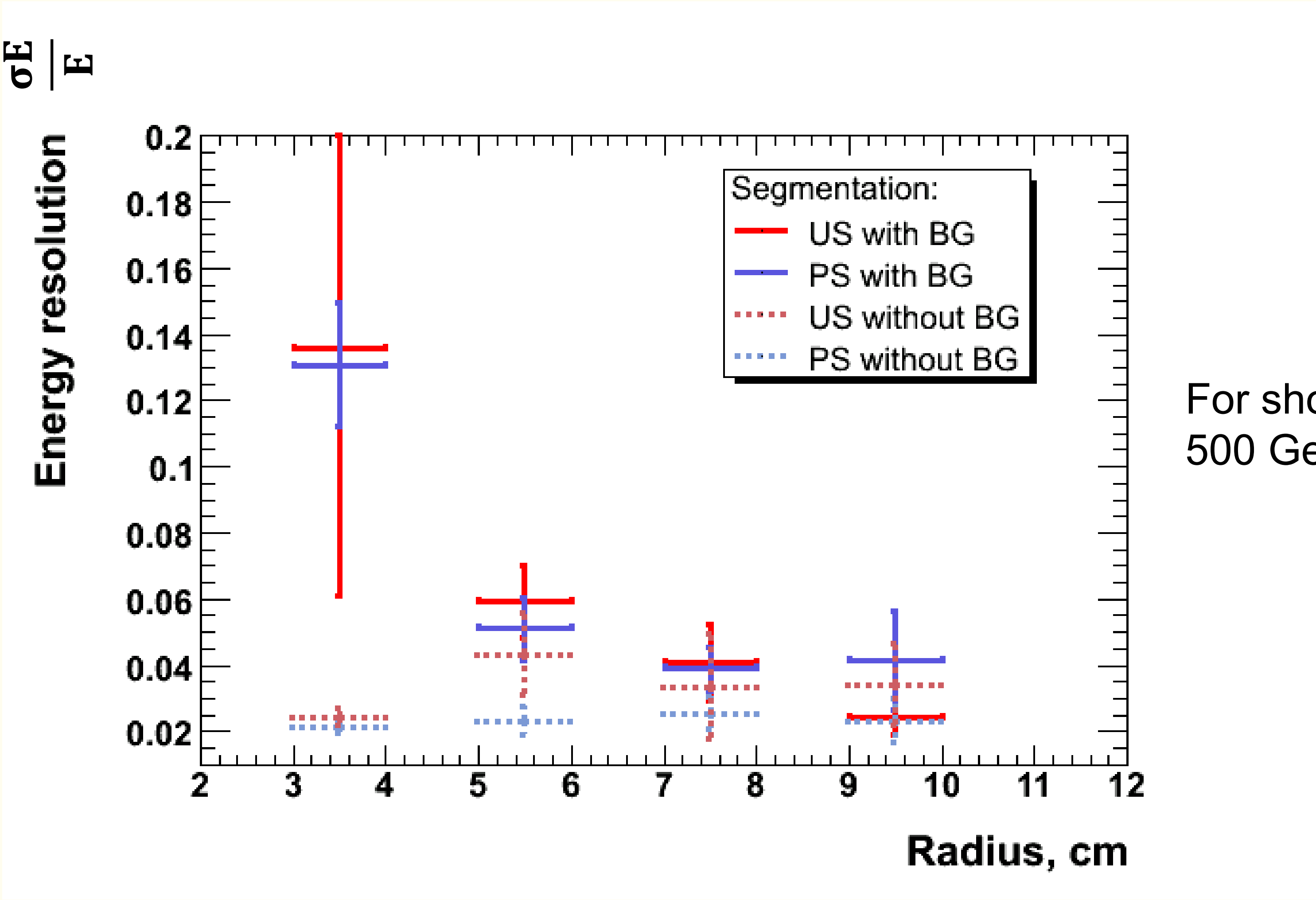


100 GeV electrons reconstruct only
on outer part of range 3.5-7 cm, i.e. only on 6-7 cm





E resolution vs Radius



For showers from 500 GeV electrons

Conclusion

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

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

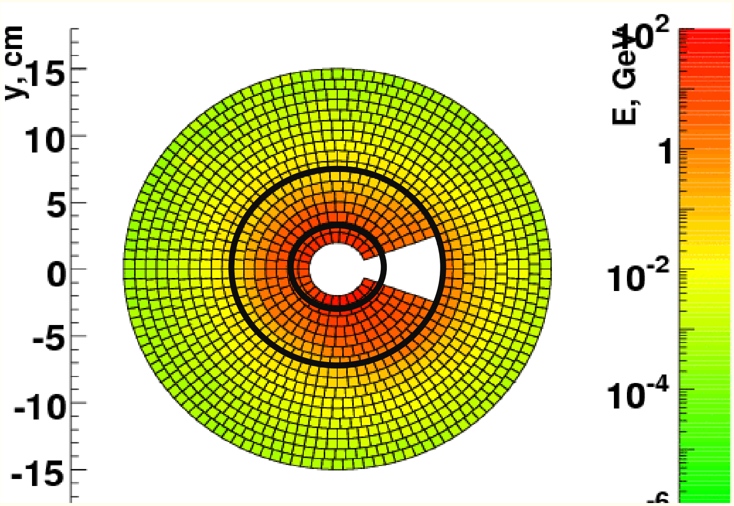
- Algorithm was applied for studying calorimeter characteristics
  - Shower reconstruction efficiency is better for proportional segmentation for energies starting approximately from 200 GeV. For energies 200 GeV and below it is almost impossible to reconstruct showers in area of high background(up to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

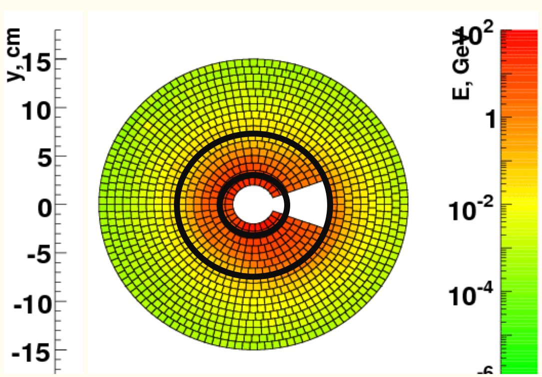
    And energy resolution vs radius worse significantly in high background area – 3 times worse then in low background area

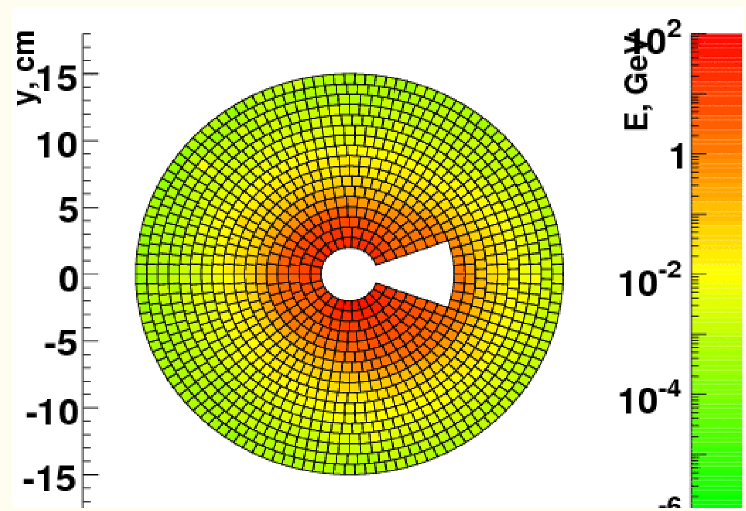
- Presented algorithm has quit strict criteria. By relaxing them it is expecting to get a little better characteristics of BeamCal, but nevertheless the high background area stays problematic for shower reconstructions with these beam parameters

Thank you for your attention!

Back up

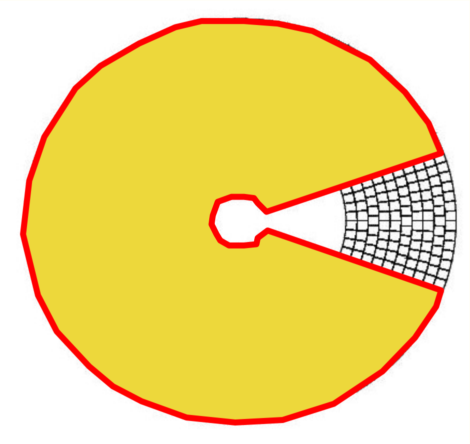

y, cm
15
10
5
0
-5
-10
-15
E, GeV
10^2
1
10^{-2}
10^{-4}


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

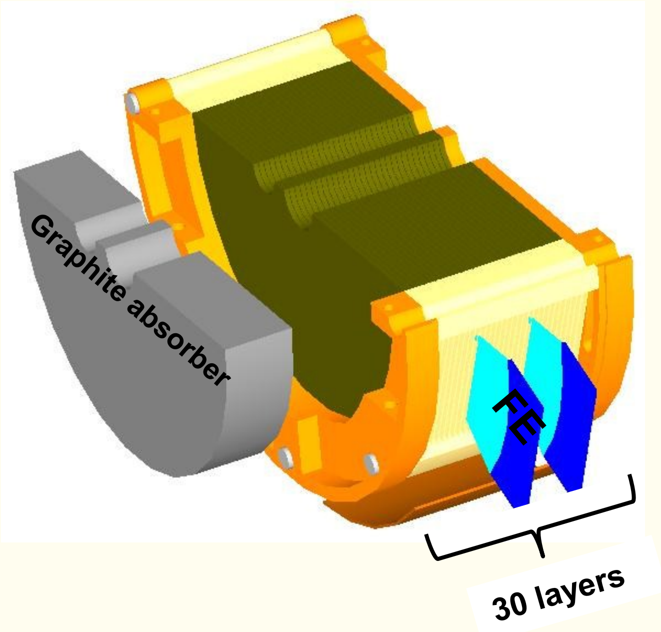
- Sector area
- Distribution: RD



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 калориметра.
 - 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

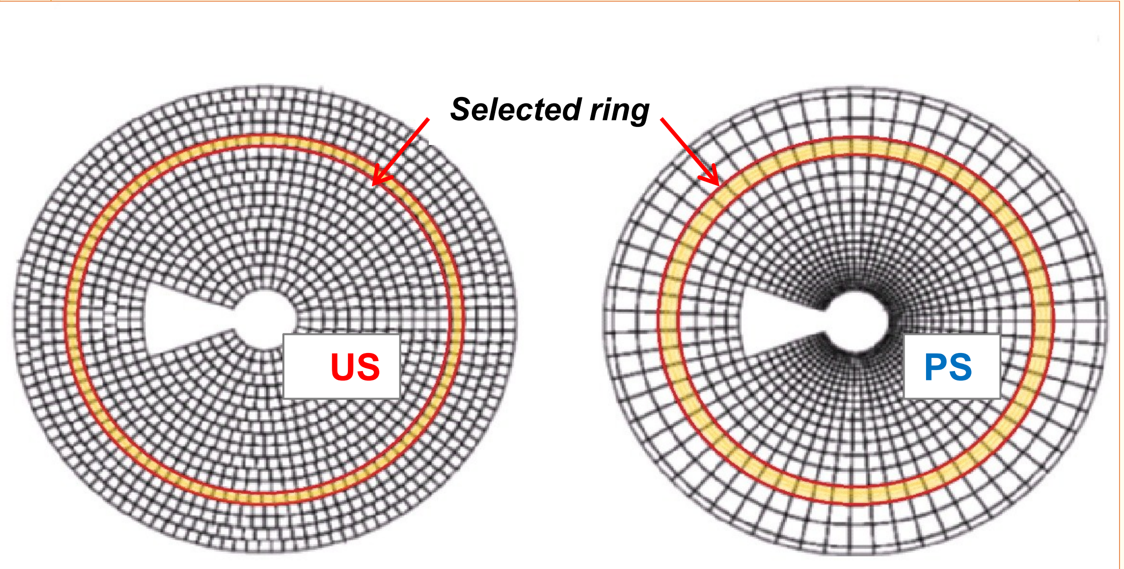
$\Big\}$ 1 X_0

Size of pads:

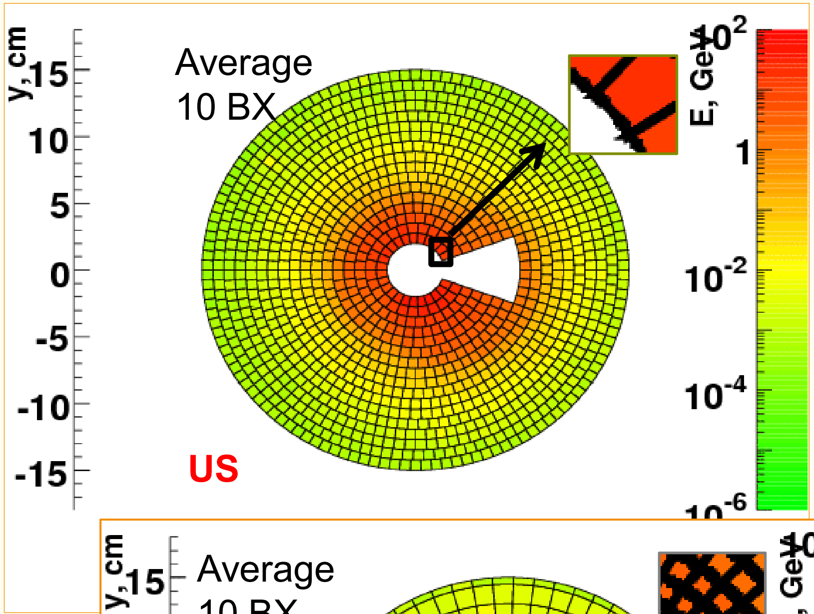
- US - similar, ≈7.65x7.65 mm
- PS - ~R, min 2.2x2.2, max 14.4x14.4mm

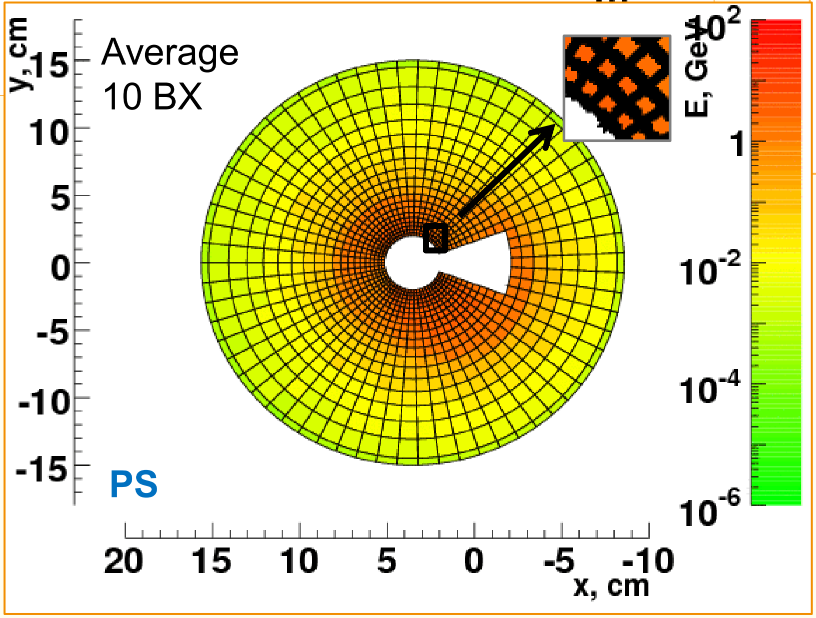
Number of pads:

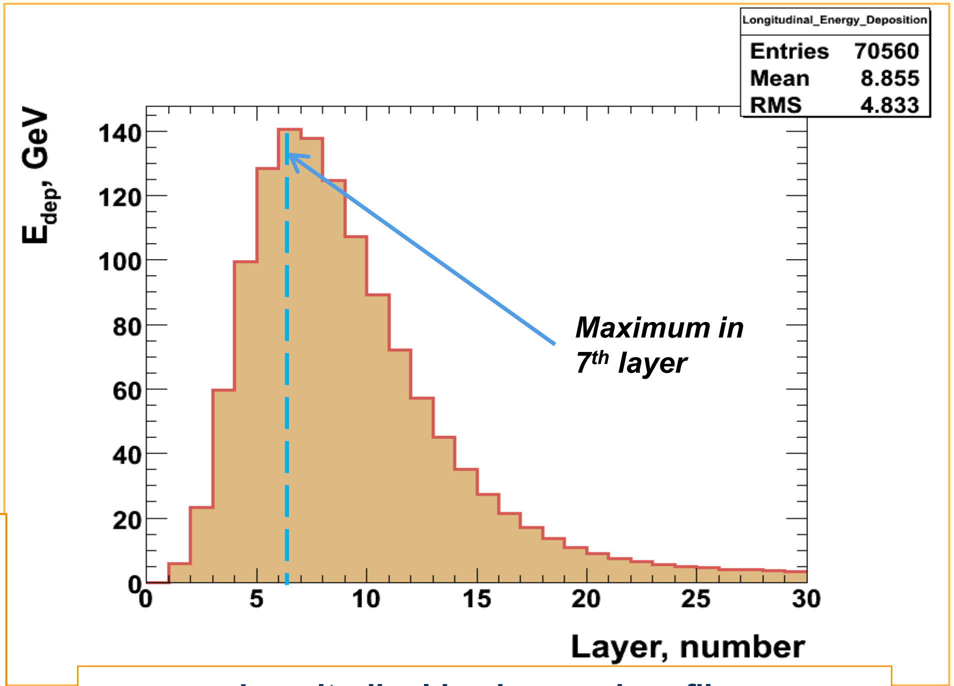
- For US and PS similar



Energy Deposition due to Beamstrahlung





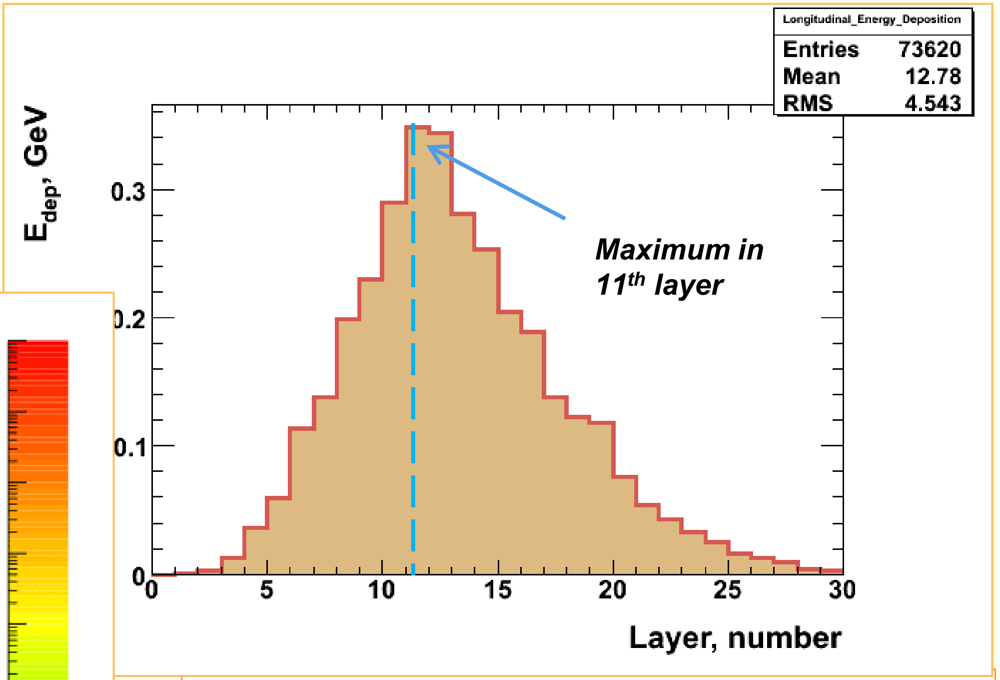


Longitudinal background profile

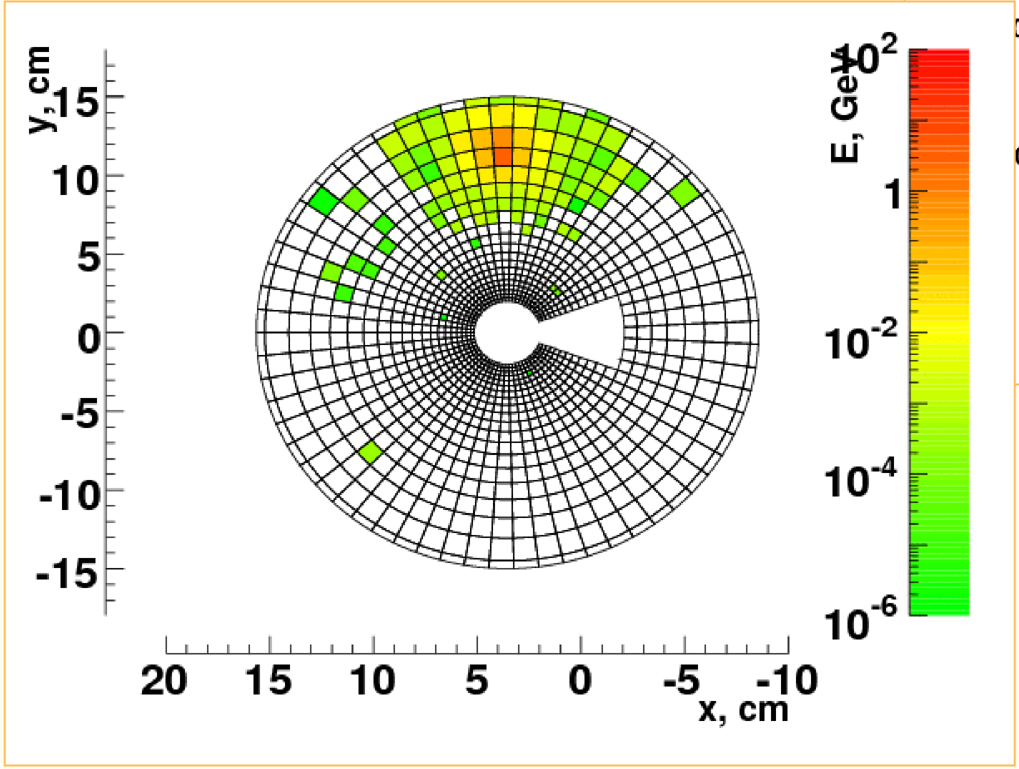
- Beamstrahlung (BS) pairs generated with Guinea Pig
- Energy deposition in sensors from BS simulated with BeCaS (Geant4) ⟶ *considered as background (BG)*

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