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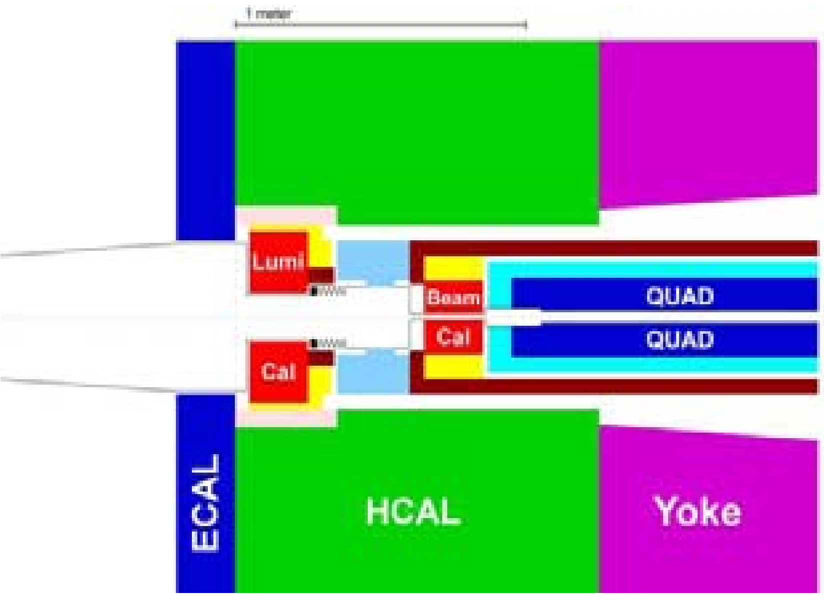
The Optimized Sensor Segmentation for the Very Forward Calorimeter

Andrey Elagin
JINR Dubna

Beam Calorimeter
main parameters

- ✓ beam diagnostic
- ✓ identification and measurement of the high energy particles

Diamond-tungsten	
Distance from the IP, cm	370
$\theta_{min} - \theta_{max}$, mrad	4 – 28
$R_{min} - R_{max}$, cm	1.5 – 10
Sensor thickness, mm	0.5
Absorber thickness, mm	3.5
Number of layers	30
X_0, mm	4
R_{molier}, mm	10

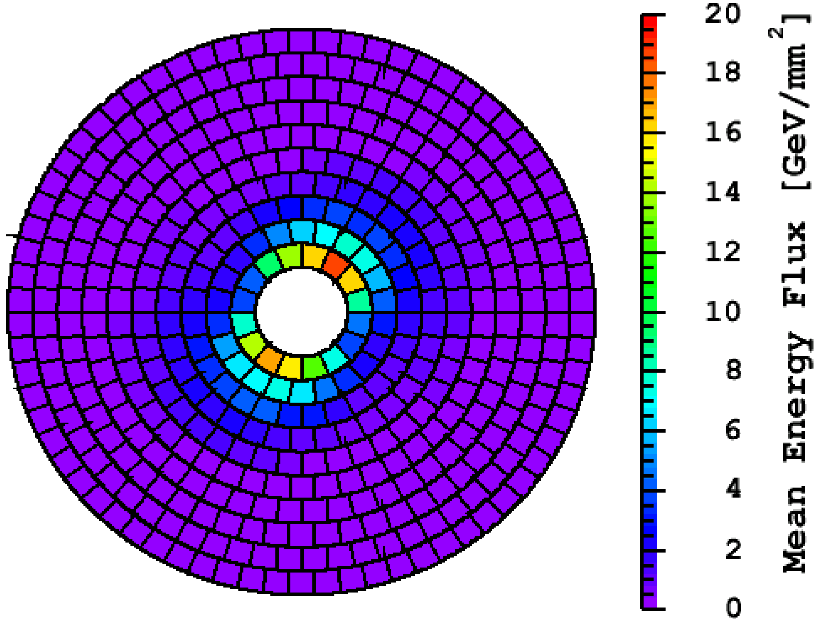


Technologies for the BeamCal:
1) Silicon-tungsten or **diamond-tungsten** sandwich calorimeter
2) PbWO4 crystal

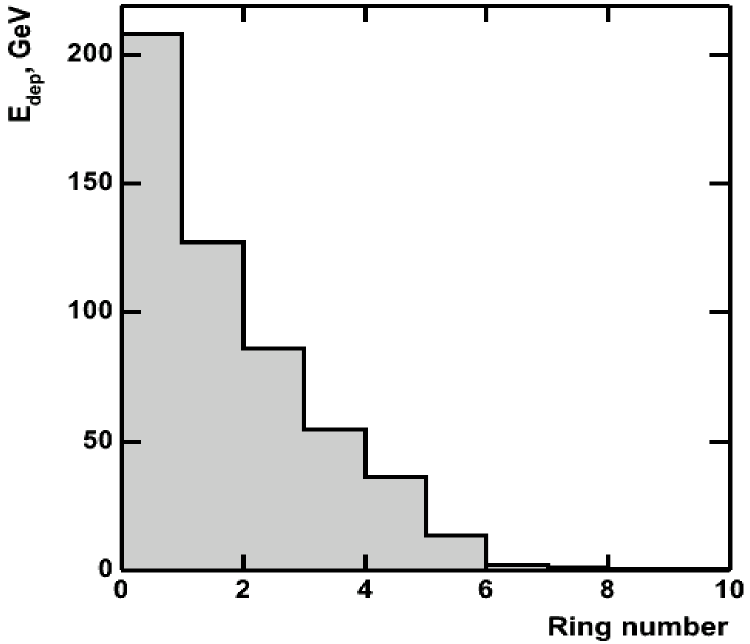
Background from the beamstrahlung

BeamCal will be hit by beamstrahlung remnants carrying about 20 TeV of energy per bunch crossing.

r-φ distribution per one bunch



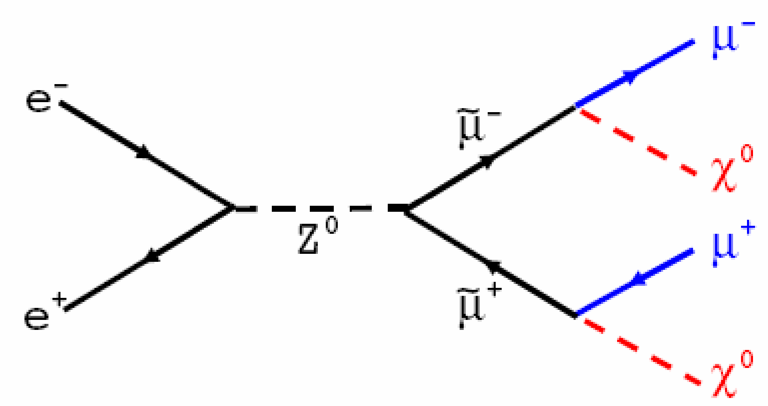
Energy deposition in diamond rings per one bunch



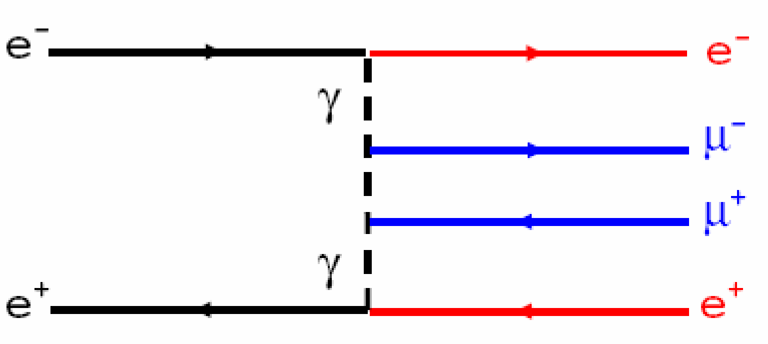
Severe background for electron identification

Particle identification in the BeamCal

Motivation



The Physics:
SUSY particles production **$\sigma \sim 10^2$ fb**
Signature:
$\mu^+ \mu^-$ + missing energy



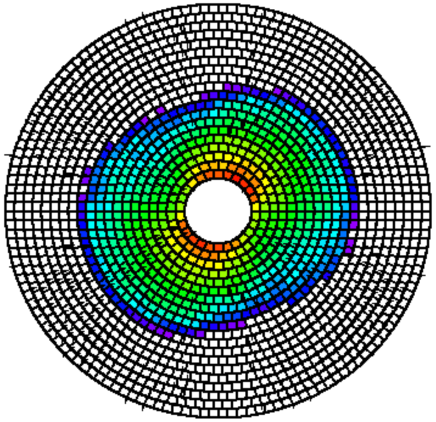
The Background:
two photons event **$\sigma \sim 10^6$ fb**
Signature:
$\mu^+ \mu^-$ + missing energy
(if electrons are not tagged)

Excellent electron identification is needed down to as small angle as possible

Segmentation Optimization Study

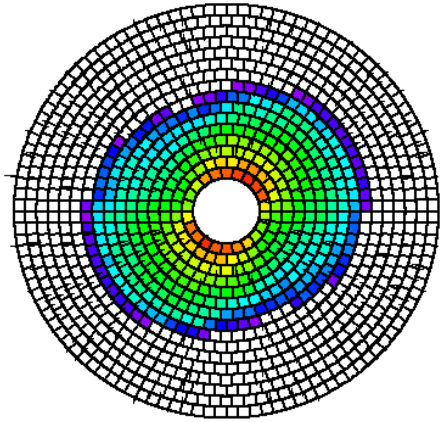
motivation

4 mm



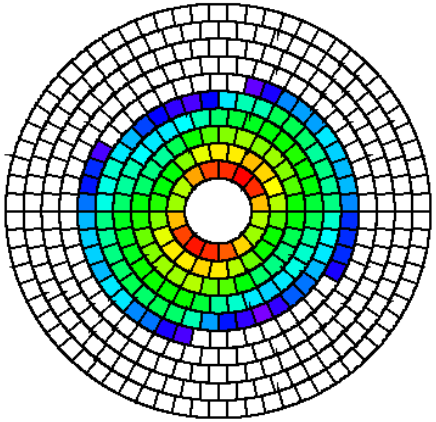
N_{rings}	20
N_{cells}	1660
$N_{channels}$	**49 800**

5 mm



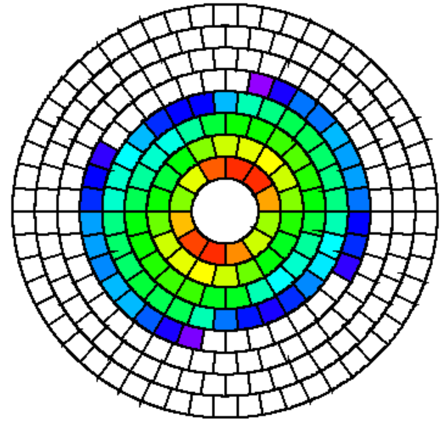
N_{rings}	16
N_{cells}	1072
$N_{channels}$	**32 160**

8 mm



N_{rings}	10
N_{cells}	430
$N_{channels}$	**12 900**

10 mm



N_{rings}	8
N_{cells}	264
$N_{channels}$	**7 920**

Particle identification in the BeamCal

simulation chain

Generator:

GuineaPig
for e+e- from beamstrahlung
or
"Rndm"
for electrons to be reconstructed

→ ASCII-file or ROOT-file
- 4-momentum
- vertex position

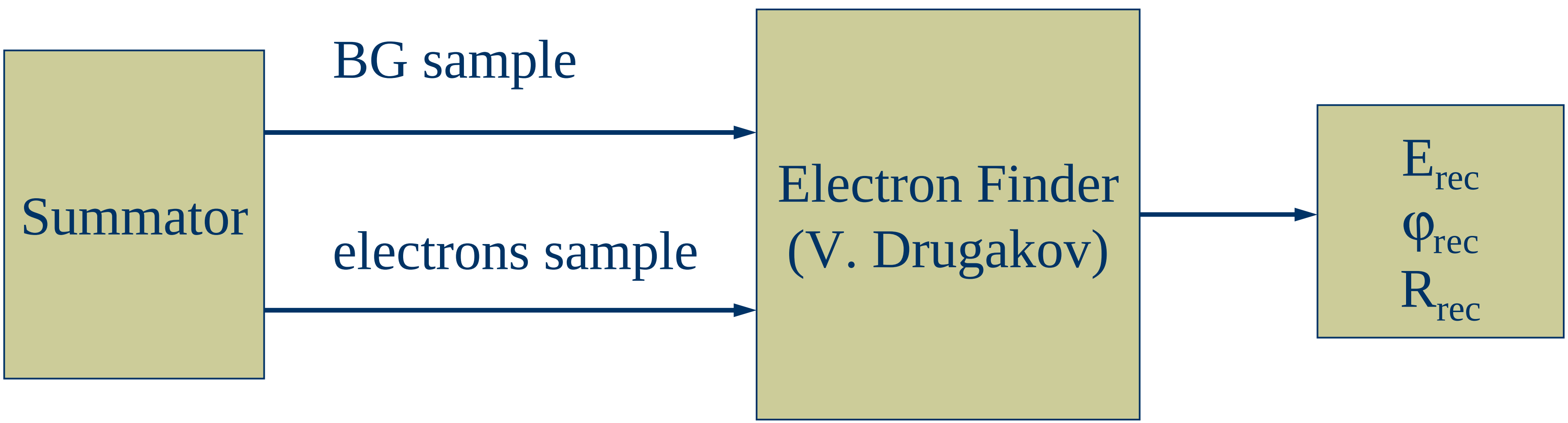
→ **GEANT4 BeamCal simulation**

→ ROOT-file for hits (G4Step)
- side ID
- layer ID
- X,Y position
- energy deposition

→ **Summator**
C++ code
to sum E_{dep} per cell
according to the r-φ segmentation

Particle identification in the BeamCal

simulation chain



Since actual parameters (E_{sim}, φ_{sim}, R_{sim}) of the electrons are known from the simulation one can extract efficiency of the electron identification from the **eFiner** output.

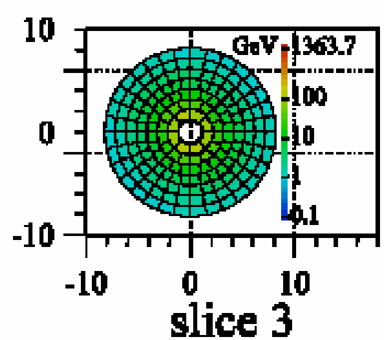
Particle identification in the BeamCal

Electron Finder from V. Drugakov

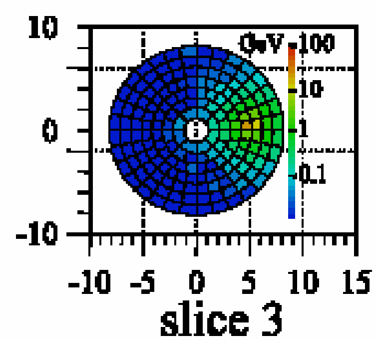
1. Use 10 events to define $\langle \mathbf{E}_{\mathbf{bg}} \rangle$ and $\mathbf{RMS}_{\mathbf{Ebg}}$ for each pad.
2. For signal event subtract $\langle \mathbf{E}_{\mathbf{bg}} \rangle$ from $\mathbf{E}_{\mathbf{dep}}$ for each pad.
3. Keep pads with remaining $\mathbf{E}_{\mathbf{dep}}$ larger than $\mathbf{5 \cdot RMS}_{\mathbf{Ebg}}$.
4. Search along each segment:

   cluster is found if there are more than **7** pads in the segment and more than **4** pads within at least one neighbor segment.

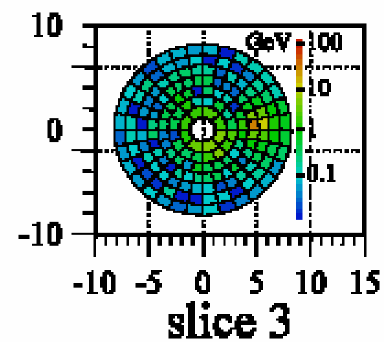
BG



particle



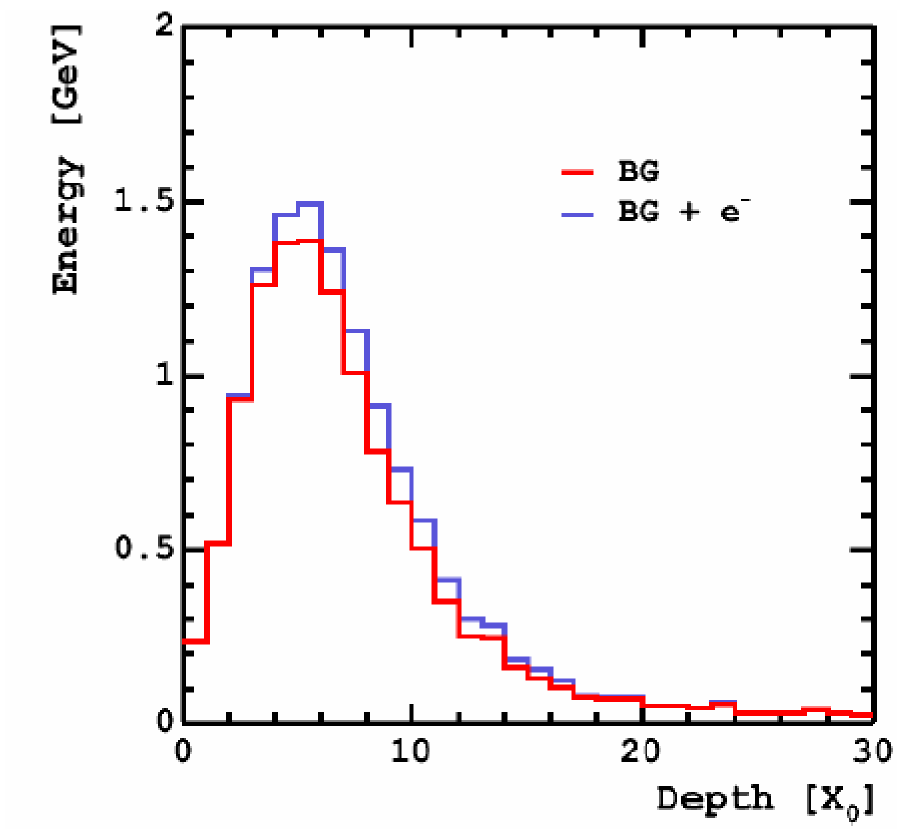
“event”



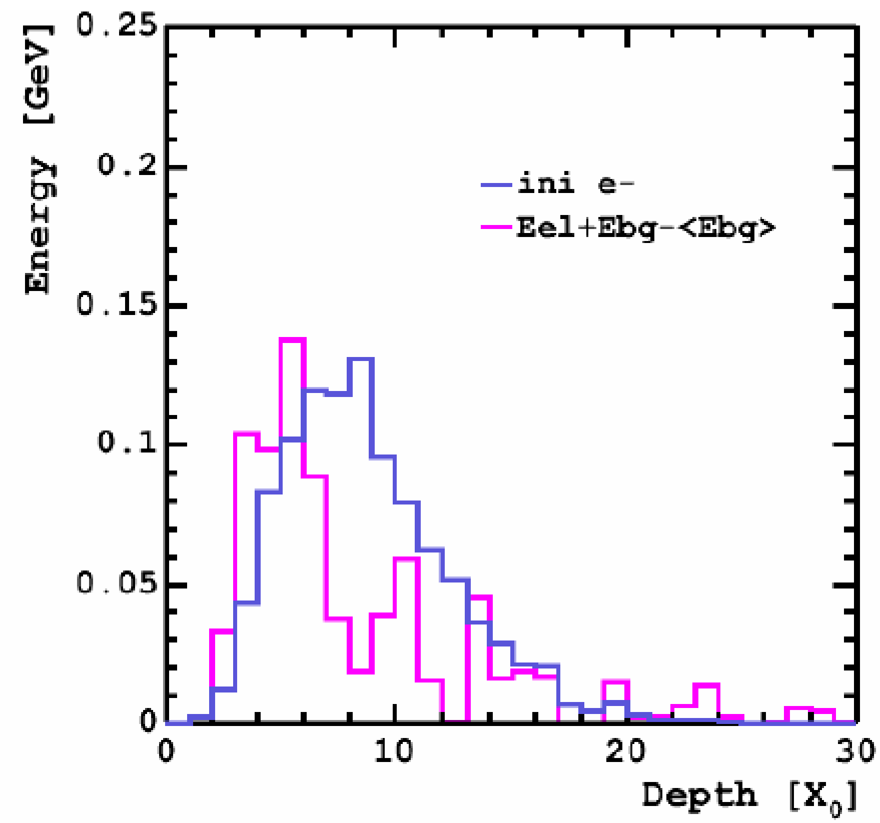
Particle identification in the BeamCal

Electron Finder from V. Drugakov

100 GeV electron on top of the beamstrahlung



Subtraction of average background

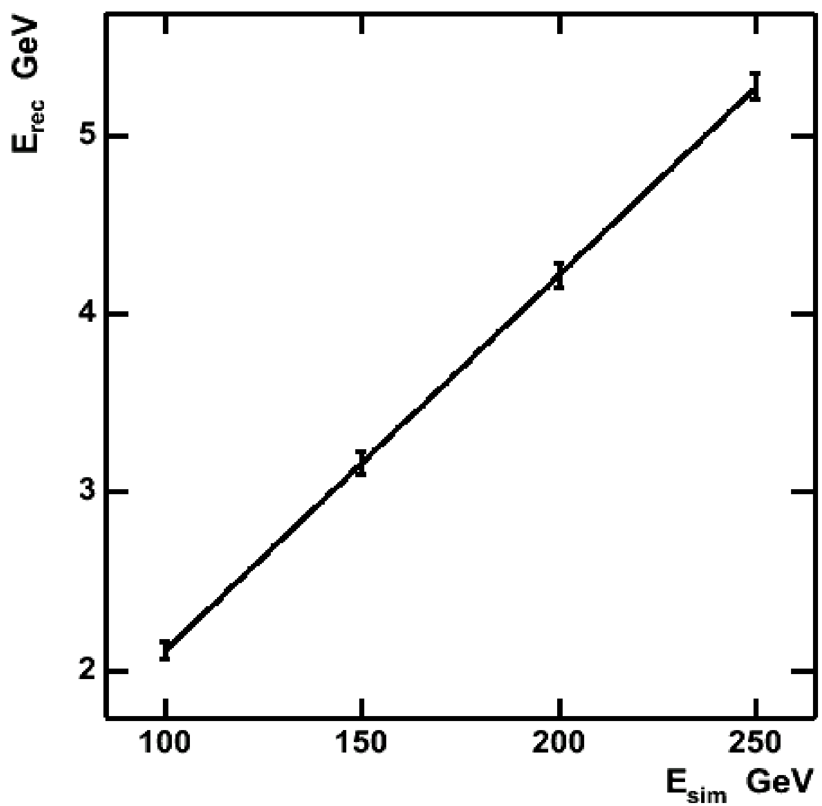


Energy reconstruction

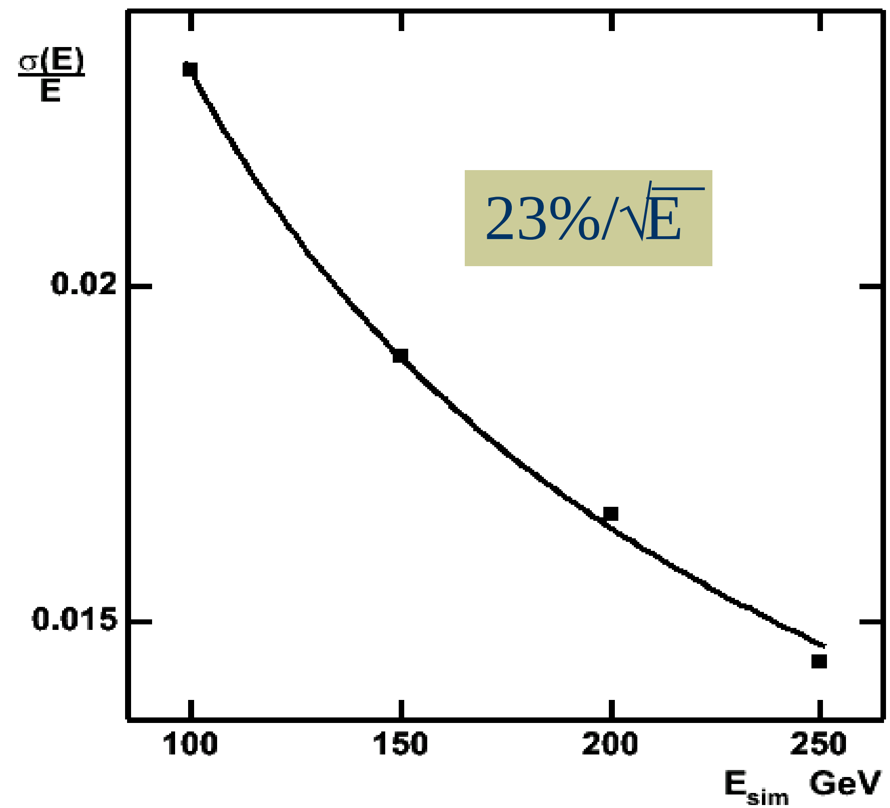
No background

5 mm

calibration



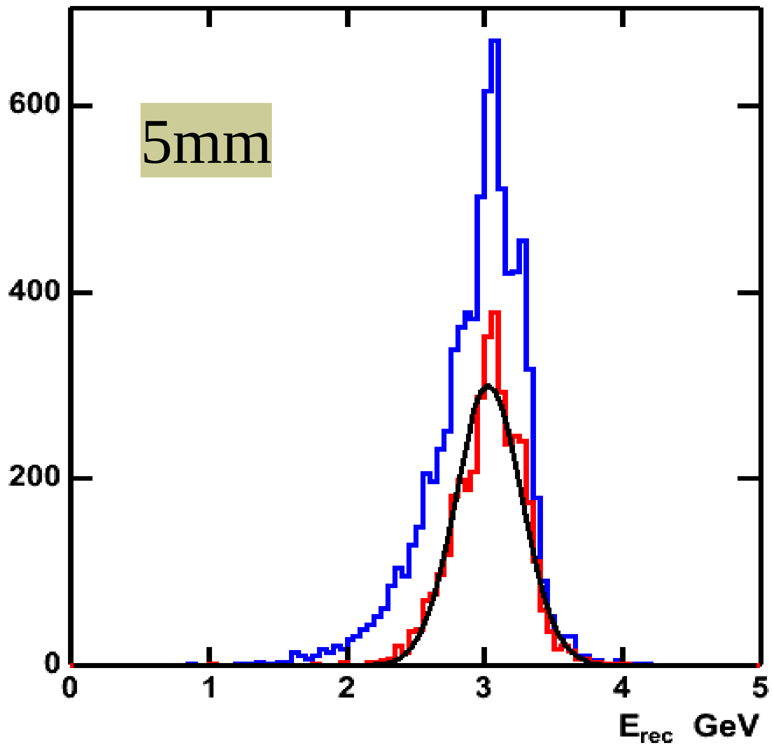
intrinsic resolution

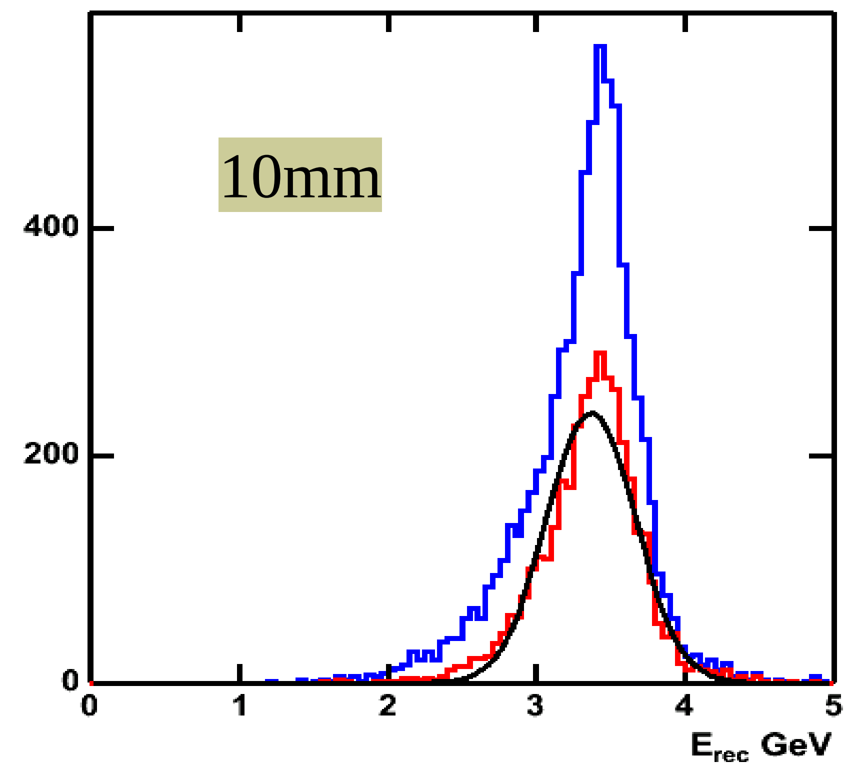


Energy reconstruction

electrons on top of the background

Energy deposited in diamond for 200 GeV electrons
low BG region (φ ~ 0°)





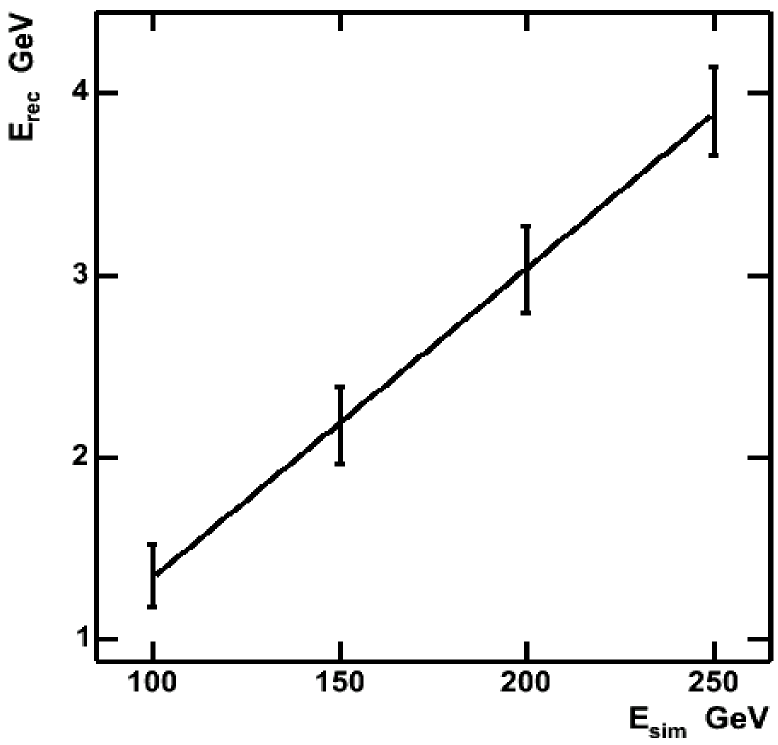
Blue – all events, red – 2·R_{molier} from edges

Energy reconstruction

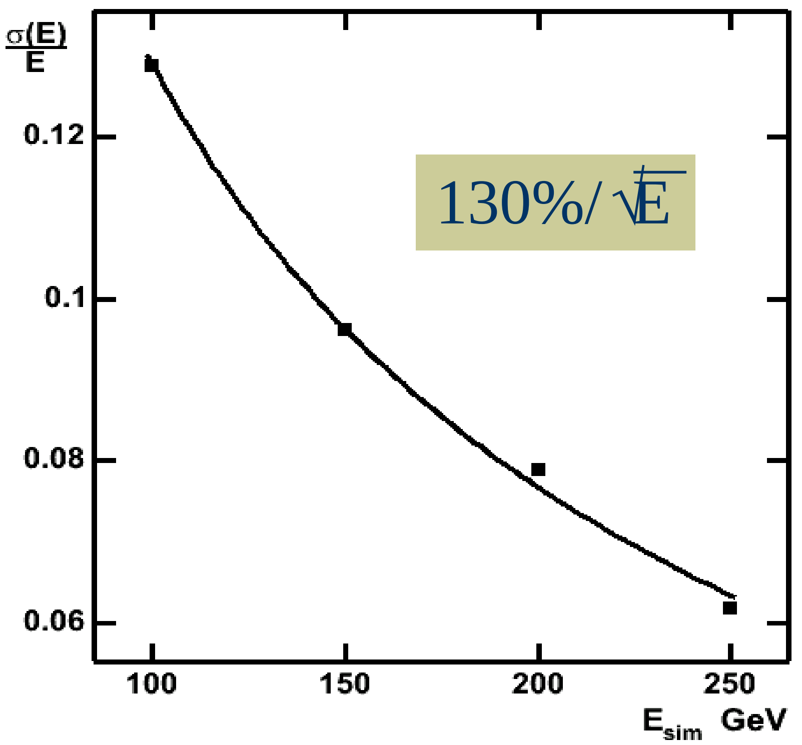
electrons on top of the background

Low BG region (φ ~ 0°)
5 mm

calibration



resolution



Cuts for reconstructed particles

Electrons are considered as reconstructed if:

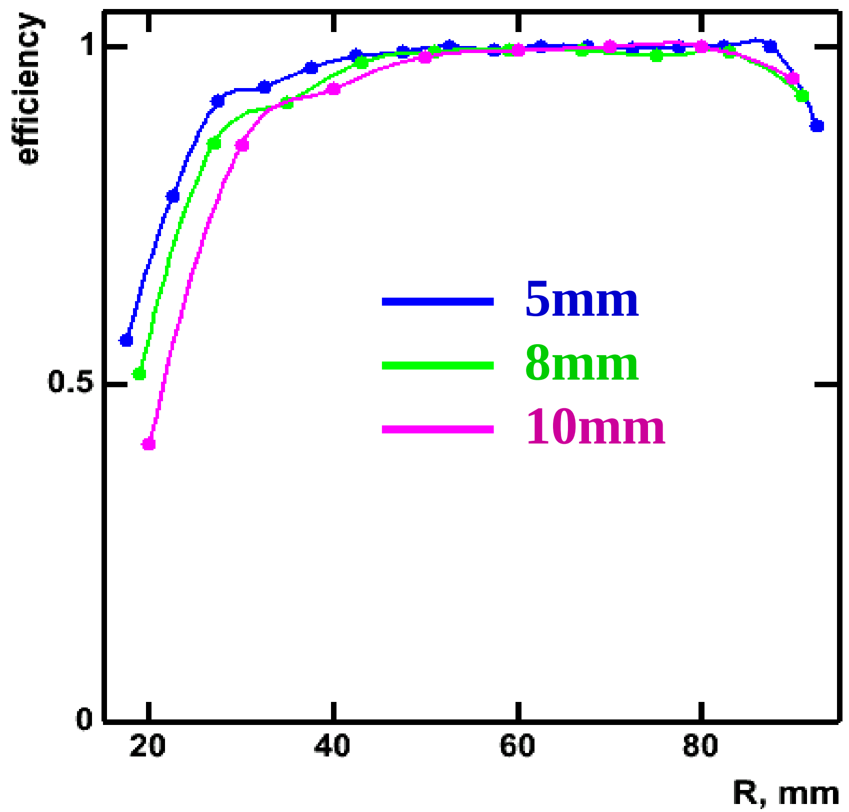
1. $E_{fit} - 3\sigma_{fit} < \mathbf{E_{rec}} < E_{fit} + 3\sigma_{fit}$
2. $R_{sim} - CellSize/2 < \mathbf{R_{rec}} < R_{sim} + CellSize/2$
3. $\varphi_{sim} \bullet R_{sim} - CellSize/2 < \boldsymbol{\varphi_{rec}} \bullet R_{rec} < \varphi_{sim} \bullet R_{sim} + CellSize/2$

E_{fit} and σ_{fit} are defined from the distribution of the reconstructed energy for events in the middle of the BeamCal

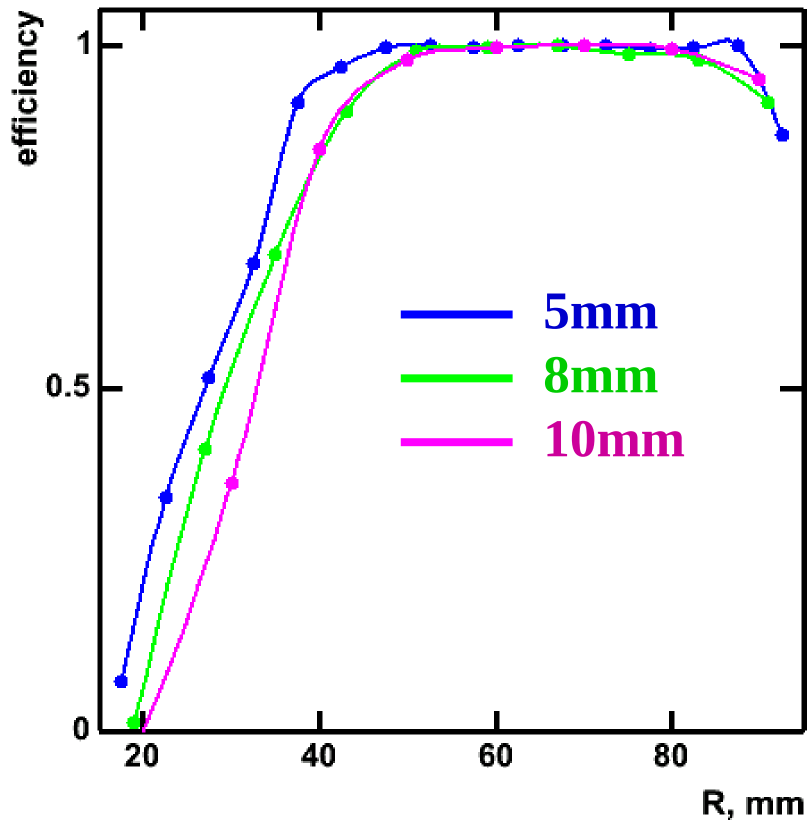
Particle identification efficiency

electrons 200 GeV

Low BG (φ ~ 0°)



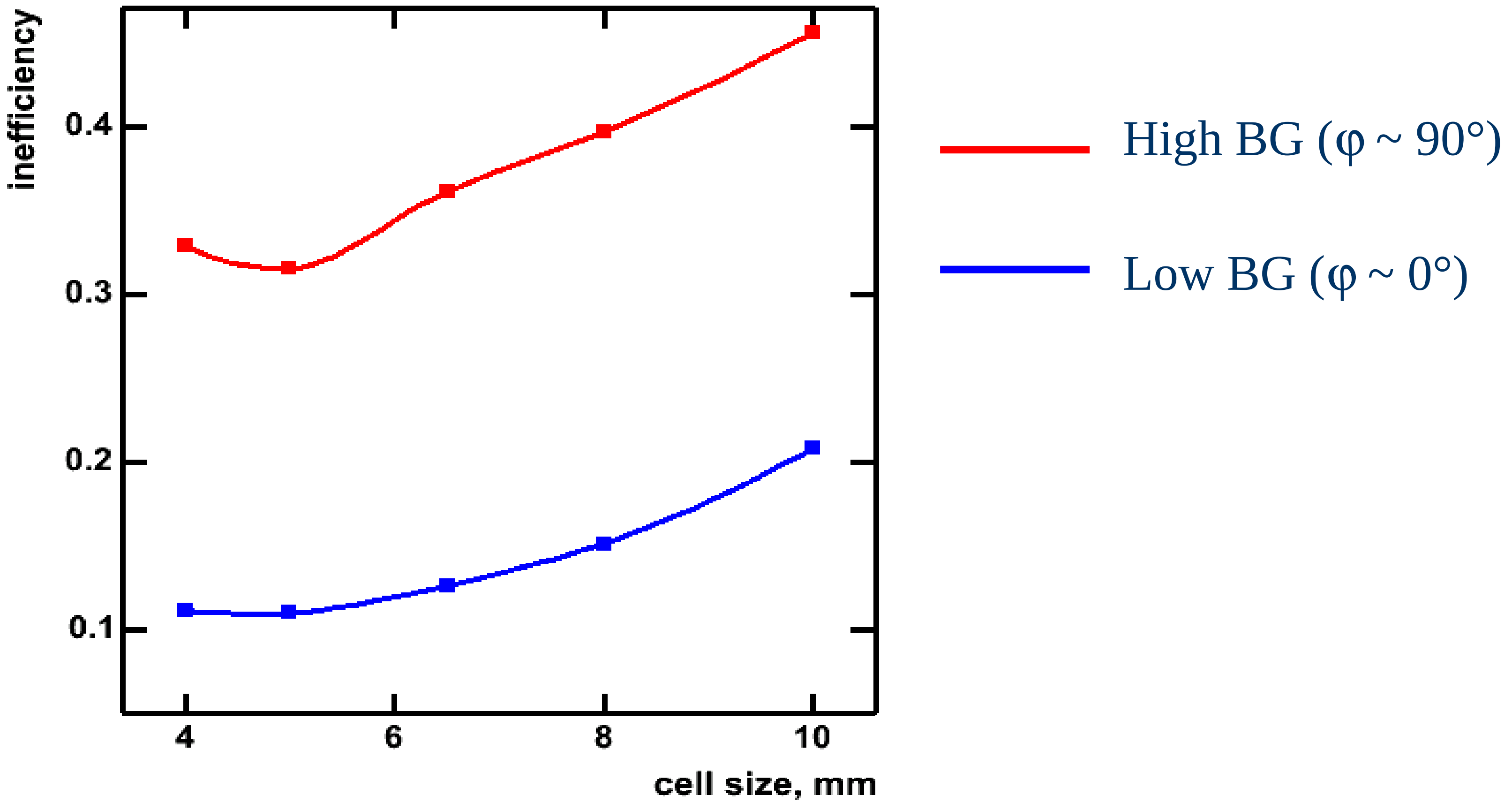
High BG (φ ~ 90°)



Inefficiency in particle identification

Lost particles for R < 55 mm

Inefficiency to identify 200 GeV electrons



Summary

- Complete simulation chain for BeamCal exist:
  – GEANT4 based simulation (A. Elagin)
  (**crossing angle options are available, implemented by V.Drugakov)**
  – eFinder for electron identification (V. Drugakov)
- **5 mm** segmentation is the best for electron identification at small radii
- **8 mm** – is not too bad
- **10 mm** segmentation gives 100% efficiency for R > 55 mm