Simulation of showers in SPD ECAL using Geant4

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Goals

Obtain ECAL resolution for different setups (number of layers, thickness of lead layer, etc.)

Estimate impact of light attenuation in light guides and photoelectron statistics

Obtain shower profiles for different values of cell size, energies, angles of incoming particle etc.



particle hitting center of ECAL leakage from sides considered negligible



Input: number of layers, width of scintillator/lead, particle energy/type/angle

Scintillator: Polystyrene/Terphenyl (2.5%)/POPOP (0.01%) Standard EM physics list ³

Resolution of ECAL



Energies ranging from 50 MeV to 10 GeV

SPD ECAL resolution



SPD ECAL resolution

The results are consistent with the results of O.Gavrishchuk 200 layers, 0.5 mm Pb + 1.5 mm Sc was taken for further studies

Corrections for ECAL resolution

• Number of photoelectrons:

~ 3000 per 1 GeV of energy deposition in scintillator \rightarrow additional Poisson error

• Attenuation length: light attenuation depending on distance from PM and reflection coefficient

- mod= 1 Att_len= 163+/- 6 cm NPE_mu=104
 mod= 2 Att_len= 148+/- 5 cm NPE_mu= 99
 mod= 3 Att_len= 182+/- 9 cm NPE_mu= 87
- mod= 4 Att_len= 167+/- 7 cm NPE_mu=110

Result of O.Gavrishchuk on cosmic muons

Corrections for ECAL resolution

SPD ECAL resolution

When taking into account photoelectron statistics, resolution @ 1 GeV changes from 4% to 5-5.5%

Corrections for ECAL resolution

SPD ECAL resolution

Accounting for attenuation length in sensible range (R from (0.9,1.0); L from (1m, 2m)) doesn't have significant impact

Shower profiles

0.0015	0.0038	0.006	0.0037	0.0015	
-0.003	0.018	0.096	0.019	0.0031	
0.0037	0.033	0.71	0.033	0.0037	
0.0023	0.0079	0.017	0.0079	0.0022	
0 .00098	0.0019	0.0025	0.002	0.00096	

- Sum of energy deposition normalized to particle energy
- x indicates particle hit

Shower profiles, electrons E = 1 GeV, angle = 0°

Shower profiles, electrons E = 2 GeV, angle = 0°

0.0016	0.0041	0.0059	0.004	0.0017
0.004	0.019	0.061	0.019	0.004
0.0059	0.06	1.6	0.06	0.0059
-0.004	0.019	0.06	0.019	0.004
- -0.0016	0.004	0.0059	0.004	0.0016

0.16

1.6

0.026

0.0033

0.5

0.027

0.051

0.011

0.0023

-1.5 -1 -0.5 0

E0.0041

0 ₣ 0.005

F0.0028

-2E-0.001

-2

0.5

-0.5 F

-1.5 E-

cell size: 5.5 cm

1.8

1.6

14

1.2

0.8

0.6

0.2

0.0041

0.005

0.0029

0.0011

0.028

0.051

0.011

0.0024

1

1.5

Shower profiles, electrons E = 3 GeV, angle = 0°

-0.002	0.006	0.012	0.0094	0.0036
0.0041	0.024	0.22	0.078	0.0093
-0.0048	0.036	2.3	0.22	0.012
-0.003	0.012	0.036	0.024	0.0061
-0.0012	0.003	0.0047	0.0041	0.002

cell size: 5.5 cm

13

Shower profiles, electrons E = 1 GeV, angle = 10°

-1.5

-1

-0.5 0 0.5

1.5

-2

-1.5 -1 -0.5 0 0.5

1.5

2.5

-2

-1.5

-0.5 0 0.5

1.5

Shower profiles, electrons E = 2 GeV, angle = 10°

0.5

2.5

-0.5

-1.5 E

Shower profiles, electrons E = 3 GeV, angle = 10°

cell size:

4 cm

16

Shower profiles, electrons E = 1 GeV, angle = 20°

1.5

0.5

2.5

1.5

0.5

1.5

0.5

E-0.0017

E0.0027

E0.0017

-1.5

F0.0017

•**E0.0027**

E0.0017

E0.0017

F0.0025

F0.0017

Shower profiles, electrons E = 2 GeV, angle = 20°

2.5

1.5 E

-0.5

2.5

1.5

0.5

1.5

-0.5

-2

⁰**₣0.0041**

Shower profiles, electrons E = 3 GeV, angle = 20°

cell size:

19

5.5 cm

Shower profiles, electrons E = 1 GeV, angle = 30°

0.5

-0.5 F

-2 -1.5 -1

-0.5 0 0.5

1.5

-1.5

-1 -0.5 0 0.5

1.5

-1.5

-

-0.5 0 0.5

1.5

Shower profiles, electrons E = 2 GeV, angle = 30°

25

E-0.0014

F0.0019

E0.0014

0.5

F0.0022

-0.0015

E-0.0015

F0.0023

F0.0015

-1.5

0.5 E

Shower profiles, electrons E = 3 GeV, angle = 30°

Shower profiles, electrons E = 1 GeV, angle = 0°

Đ.00018 0.00049 0.00088 0.00089 0.00054

0.5

1.5

-0.5

23

-1.3

-1.5

0.0012	0.0027	0.0039	0.0026	0.0012
0.0026	0.012	0.036	0.012	0.0027
0.0038	0.036	0775	0.036	0.0038
0.0027	0.012	0.036	0.012	0.0026
0.0012	0.0027	0.0038	0.0027	0.0012

2.5

0.5

2 **-0.0018**

E-0.0034

F0.0035

0.0019

-2 60.00078

2 E-0.0013

-0.0026

•**F0.0027**

0.0014

1.5

0.5

0.0054

0.026

0.026

0.0054

0.0014

0.0043

0.022

0.022

0.0043

0.4

×

0.4

0.00082 -	0.0021	0.003	0.002	0.00083	
-0.002	0.0097	0.031	0.01	0.002	
0.0029	0.03	0.8	0.03	0.0029	
-0.0021	0.0098	0.03	0.0098	0.002	_
0.00086	0.002	0.0029	0.002	0.00086	-

0.00069	0.0018	0.0026	0.0017	0.0007
-0.0017	0.0088	0.028	0.0091	0.0018
-0.0026	0.028	0.82	0.028	0.0026
-0.0018	0.0089	0.028	0.0089	0.0017
-0.0007	0.0017	0.0026	0.0018	0.0007

0.0011	0.0038	0.0072	0.0038	0.0012
0.0023	0.02	0.43	0.02	0.0023
0.0024	0.02	0.43	0.02	0.0023
0.0012	0.0038	0.007	0.0039	0.0011
	0.00069	0.00096	0.00074	0.00035

$nale = 0^{\circ}$ -(10)a

0.0037

0.0069

0.0069

0.0037

0.0015

2.2

0.2

0.011

0.053

0.053

0.011

0.0028

0.0015	0.0049	0.013	0.013	0.0049
0.0025	0.013	0.46	0.46	0.013
0.0024	0.013	0.46	0.46	0.013
0.0015	0.0048	0.013	0.013	0.0049
Ð.00065	0.0014	0.0024	0.0025	0.0015

<mark>ا ا</mark>	0.0042	0.012	0.012	0.0043
5				(
€0.0018	0.012	0.46	0.47	0.012
É		• • •	K	
E0.0018	0.012	0.46	0.47	0.012
Enn	0.0042	0.012	0.012	0.0042
	0.0042	0.012	0.012	0.0043
E 00035	0.001	0.0018	0 0018	0.001

0.0026	0.0086	0.015	0.0085	0.0027	
- -0.0053 -	0.044	0.85	0.044	0.0053	
0.0053	0.043	0.85	0.044	0.0053	
0.0026	0.0084	0.015	0.0084	0.0027	-
- 0.00099	0.002	0.0027	0.002	0.001	

Shower profile, E = 2.00 GeV, cell size = 40.00 cm, intracell: 0.00,0.50

0.019

0.81

×

0.81

0.019

0.0037

Shower profile, E = 2.00 GeV, cell size = 50.00 cm, intracell: 0.00,0.50

-0.5

0.011

0.053

0.052

0.011

0.0028

2.5

1.5

0.5

-0.5

-1.5

-2.525

2.5

2 E-0.0036

E-0.0069

0€0.0069

-1=0.0036

-2**F0.0015**

0.0022	0.0077	0.014	0.0076	0.0023
0.0047	0.04	0.87	0.04	0.0046
0.0046	0.04	0.87	0.04	0.0046
0.0022	0.0075	0.014	0.0076	0.0023
0.00066	0.0014	0.0019	0.0014	0.0007

cell size: **5 cm**

5.5 cm

cell size:

Shower profiles, electrons E = 3 GeV, angle = 0°

cell size:

25

5.5 cm

cell size:

4 cm

0.0015	0.0063	0.017	0.018	0.0064	- 2
0.0027	0.018	0.7	0.7	0.018	- 1. - 1.
0.0027	0.018	0.7	0.7	0.018	= 1.
0.0015	0.0063	0.018	0.018	0.0063	-0.
-0.0005	0.0015	0.0026	0.0026	0.0015	-0.

Shower profiles, electrons E = 1 GeV, angle = 10°

0.00044	0.0012	0.0025	0.0028	0.0016	
0.00084	0.0037	0.021	0.023	0.0058	1
0.0011	0.007	0.62	0.23	0.012	-
0.00088	0.0037	0.02	0.023	0.0058	11- 15-
Ð.00045	0.0012	0.0025	0.0028	0.0016	

-0.0021	0.006	0.0068	0.003	0.00058
0.0059	0.32	0.13	0.0098	0.0012
0.0058	0.32	0.13	0.0098	0.0012
-0.0021	0.006	0.0069	0.003	0.00062
- 0.00065	0.0011	0.0013	0.00087	0.00025

-0.0019	0.0056	0.006	0.0025	0.00023	
0.0058	0.35	0.12	0.0079	0.00052	
0.0057	0.35	0.12	0.008	0.00051	
0.002	0.0056 0	02 0.0056	0.0056 0.0061 0.0025	5 0.00025	5 0.00025
9.00046	0.00085	0.00095	0.00058	7.8e-05	

cell size: 5 cm

26

Shower profiles, electrons E = 2 GeV, angle = 10°

00084	0.0022	0.0048	0.0055	0.0033	
0.0016	0.0068	0.038	0.047	0.012	-
0.0021	0.013	111	0.57	0.027	
0.0016	0.0068	0.038	0.047	0.012	
0.00084	0.0022	0.0048	0.0056	0.0034	

0.0027	0.0048	0.0043	0.002	0.00072 -
0.01	0.042	0.037	0.0066	0.0015
0.022	0.5	1:2	0.013	0.0019
0.01	0.042	0.037	0.0066	0.0014
0.0027	0.0048	0.0043	0.002	Ð.00073

cell size:

4 cm

5.5 cm

27

Shower profiles, electrons E = 3 GeV, angle = 10°

5 cm

cell size:

28

5.5 cm

0.0064	0.019	0.026	0.015	0.0053
-0.015	0.65	0.66	0.061	0.01
-0.015	0.65	0.65	0.061	0.01
- -0.0065 -	0.019	0.027	0.014	0.0053
-0.0024	0.0043	0.0053	0.0041	0.0022

-0.0057	0.017	0.021	0.0097	0.002
- - 0.015 -	0.84 ×	0.53	0.035	0.004
0.015	0.84	0.53	0.035	0.0039
0.0057	0.017	0.021	0.0097	0.002
0.0018	0.0033	0.0038	0.0026	0.00076

0.0053	0.016	0.019	0.008	0.00082
0.015	0.92	0.47	0.028	0.0017
0.015	0.92	0.47	0.028	0.0017
0.0053	0.016	0.019	0.008	0.00081
0.0013	0.0024	0.0027	0.0018	0.00025

Shower profiles, electrons E = 1 GeV, angle = 20°

2.5

E0.00077 0.0018

-260.00076 0.0019

260.00065 0.0016

2 E0.00061 0.0015

F0.0017

⊧**€0.0027**

E0.0017

F0.0017

₽0.0027

F0.0017

E0.00061

-2 -1.5

0.0091

0.21

0.0091

0.0097

0.3

0.0097

0.0099

0.85

0.0099

0.0016

-

E-0.0017

E0.0025

₽0.0017

Shower profiles, electrons E = 2 GeV, angle = 20°

₽ <mark>-0.0012</mark>	0.0031	0.0052	0.0048	0.0016
Ē				
E0.0029	0.017	0.048	0.031	0.0062
Ē		1		
€0.0045	0.46	1.1	0.18	0.016
E	0.047		0.004	
E0.0029	0.017	0.048	0.031	0.006
En 0012	0.003	0.0053	0.005	0.0016

0.5

-1.5

-0.5

1.5

cell size:

30

4 cm

Shower profiles, electrons E = 3 GeV, angle = 20°

cell size:

4 cm

5.5 cm

31

Shower profiles, electrons E = 1 GeV, angle = 30°

0.00086 0.00059 2.2e-06

2 80.00029

0.0006

-0.5

-1.5

32

0.0011	0.0022	0.0032	0.0029	0.00054
0.0042	0.018	0.023	0.014	0.0021
0.1	0.45	0.22	0.065	0.0065
0.0043	0.018	0.023	0.014	0.0021
0.0011	0.0022	0.0032	0.0029	0.00053

Shower profile, E = 1.00 GeV, cell size = 50.00 cm, intracell: -2.00.0.00

0.0026

0.019

0.17

0.019

0.0026

0.5

-0.5

0.0011 1.1e-05

0.0056 6.4e-05

0.0056 6.5e-05

0.0011 1.1e-05

1.5

0.00033

0.024

2**E-0.0011**

F0.0048

- 076

E-0.0049

E-0.0011

1.5

0.0021

0.019

0.53

0.019

0.0021

2.5

F0.0019

-0.056

0.055

€0.0019

Đ.00066

0.0051

0.24

0.24

0.005

0.0011

0.0073

0.13

0.13

0.0073

0.001	0.002	0.0023	0.00041	8.7e-06
0.0051	0.019	0.017	0.0023	6.2e-05
0749	0.55	0.15	0.01	0.00035
0.0052	0.019	0.018	0.0023	5.9e-05
0.001	0.002	0.0023	0.00042	7.3e-06

Shower profiles, electrons E = 2 GeV, angle = 30°

1.8e-05	0.0022	0.0051	0.004	0.0019
0.00016	0.013	0.04	0.034	0.0082
0.00087	0.067	0.44	1	- 0.22
0.00016	0.013	0.041	0.034	-0.008
2.3e-05	0.0022	0.0052	0.0041	0.0019

-0.0019	0.0038	0.0046	0.00084	1.5e-05
0.0087	0.034	0.037	0.0052	0.00014
- 0127	1.1	0.38	0.028	0.00091
0.0085	0.035	0.037	0.0053	0.00014
- -0.0019	0.0039	0.0046	0.00085	1.5e-05

0.0037	0.0094	0.011	0.002	4.2e-05
0.14	0.59	0.22	0.018	0.00055
0.14	0.59	0.22	0.018	0.00059
0.0036	0.0096	0.011	0.018 0.00059 0.0019 4.2e-05	
9.00084	0.0015	0.0018	0.00035	5.8e-06

cell size:

33

5.5 cm

Shower profiles, electrons E = 3 GeV, angle = 30°

Shower profile, E = 3.00 GeV, cell size = 55.00 cm, intracell: -1.50,0.50

0.017

0.67

0.67

0.017

0.0026

0.012

0.16

0.16

0.011

7.1e-05

0.001

0.001

7.1e-05

0.0018 9.7e-06

1 1.5

E0.0028

E-0.0081

0 F0.0082

F0.0028

-2 F0.0008

0.5

-0

-1 4

0.0088

0.61

0.62

0.0092

0.0016

-

-2.5 -2 -2.5 -2 -2.5 -4 -0.5 0 0.5

4

1.2

Shower profile, E = 3.00 GeV, cell size = 40.00 cm, intracell: -2.00,0.50

2.5

0.0049	0.014	0.019	0.0079	8.6e-05
0.14	0.8	0.42	0.077	0.00099
0.14	0.8	0.43	0.076	0.00099
0.0051	0.014	0.019	0.0077	9.1e-05
0.0015	0.0028	0.0037	0.0016	1.4e-05

7.1e-05	0.0032	0.018	0.014	-0.0051
0.001	0.032	0.38	0.87	0.17
0.001	0.032	0.38	0.87	0.17
7.1e-05	0.0031	0.018	0.014	0.0052
9.7e-06	0.00052	0.0026	0.0022	-0.0012

1.6

1.4

1.2

-0.8

0.6

0.2

cell size:

cell size:

5 cm

4 cm

Highlights

Do we know angle before shower reconstruction?

Summary

- Using Geant4 simulation, resolution of SPD ECAL was studied, the results are consistent with O.Gavrishchuk's results
- Additional error from photoelectron statistics increases energy resolution at 1 GeV from 4% to 5%
- Shower profiles, which will be later used for shower reconstruction, were obtained.

BACKUP

SPD ECAL resolution

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