Лаборатория ядерных проблем им. В. П. Джелепова
Объединенный институт ядерных исследований

Improvement of the energy resolution of ECal SPD

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Electromagnetic Calorimeter (SPD)

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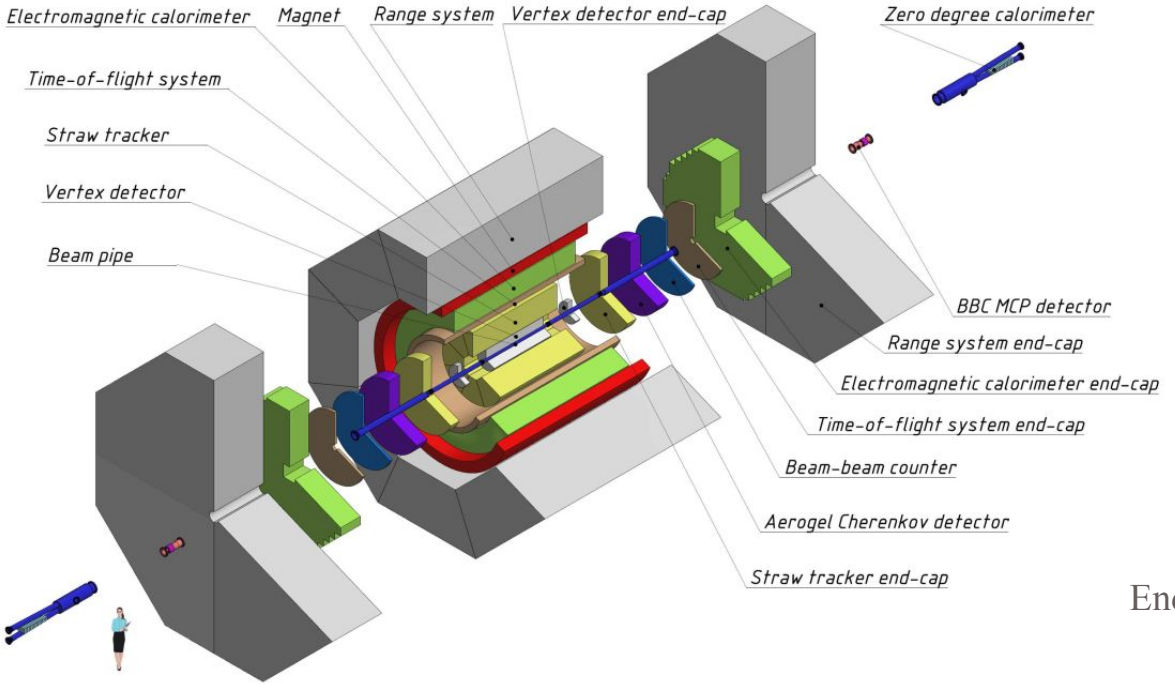
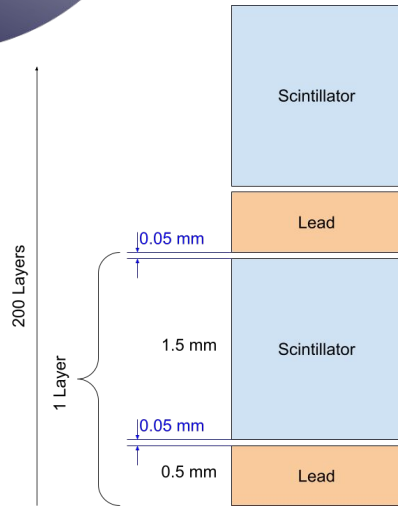




End-cup

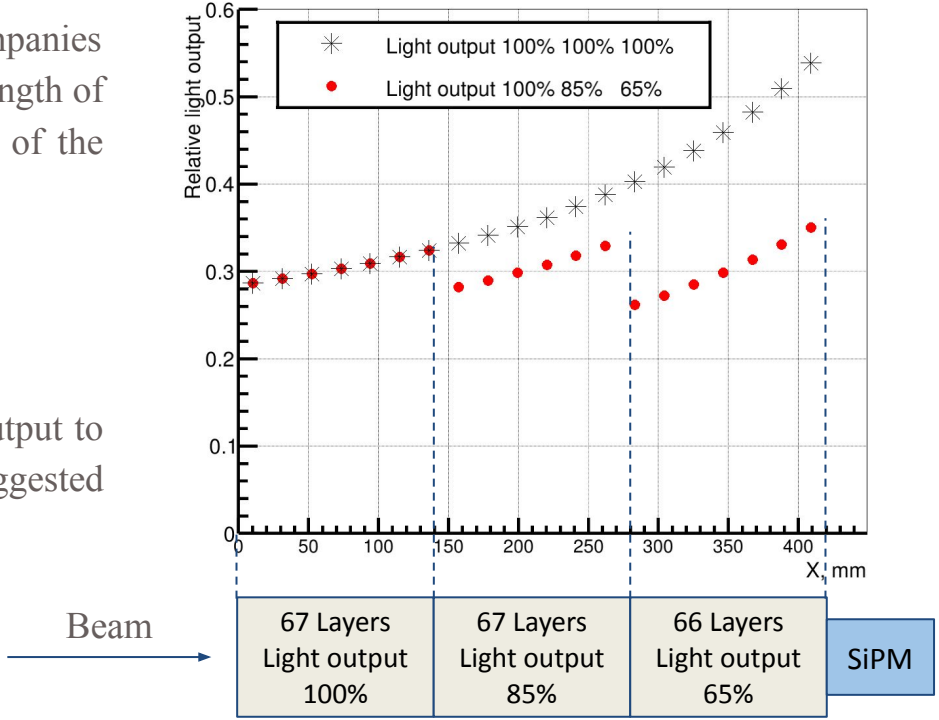
Problem & possible solutions

Now, it is impossible to buy fibers from famous companies for a good price. Russian-made fibers have an attenuation length of 600 mm. This leads to a deterioration in the performance of the detector.

Two possible solutions:

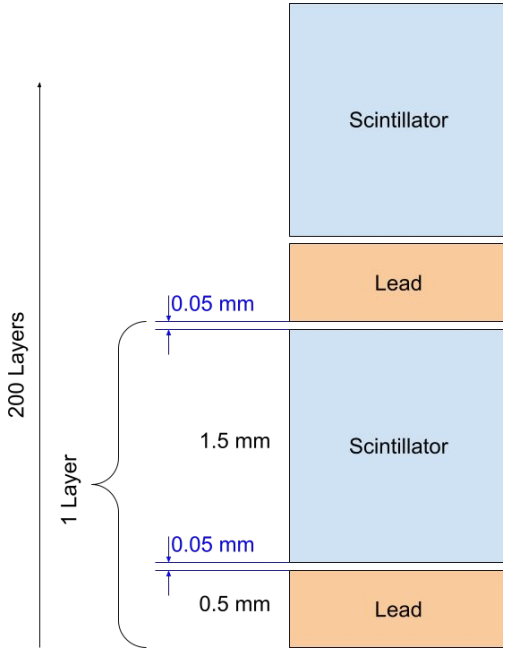
- Improving the characteristics of fibers.
- Using sets of scintillator with different light output to align the light collection from the module (suggested by Oleg Gavrishchuk).

Our goal was to check the second method.

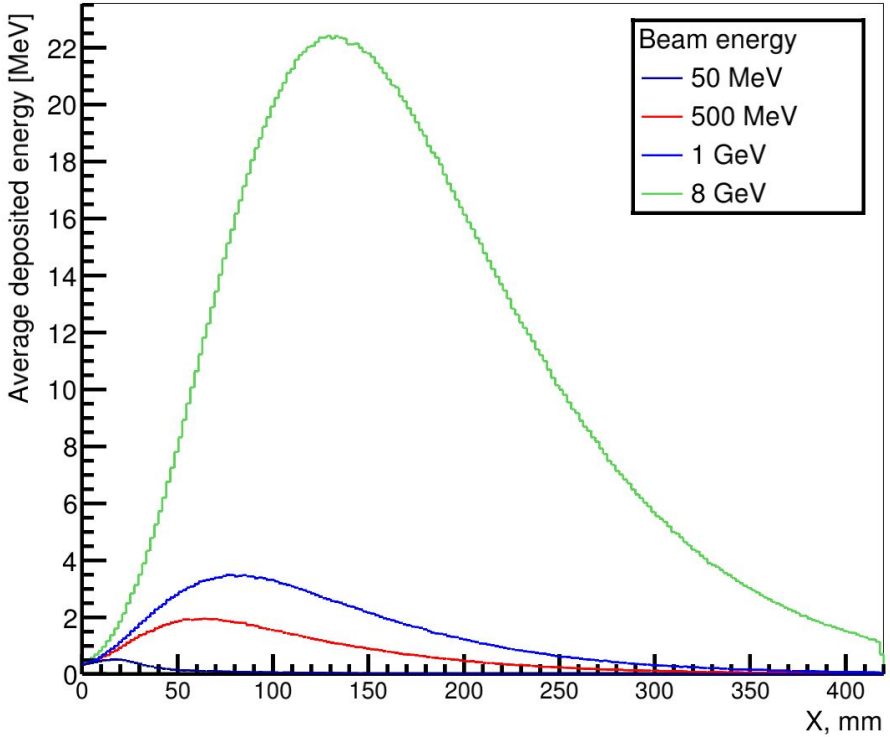


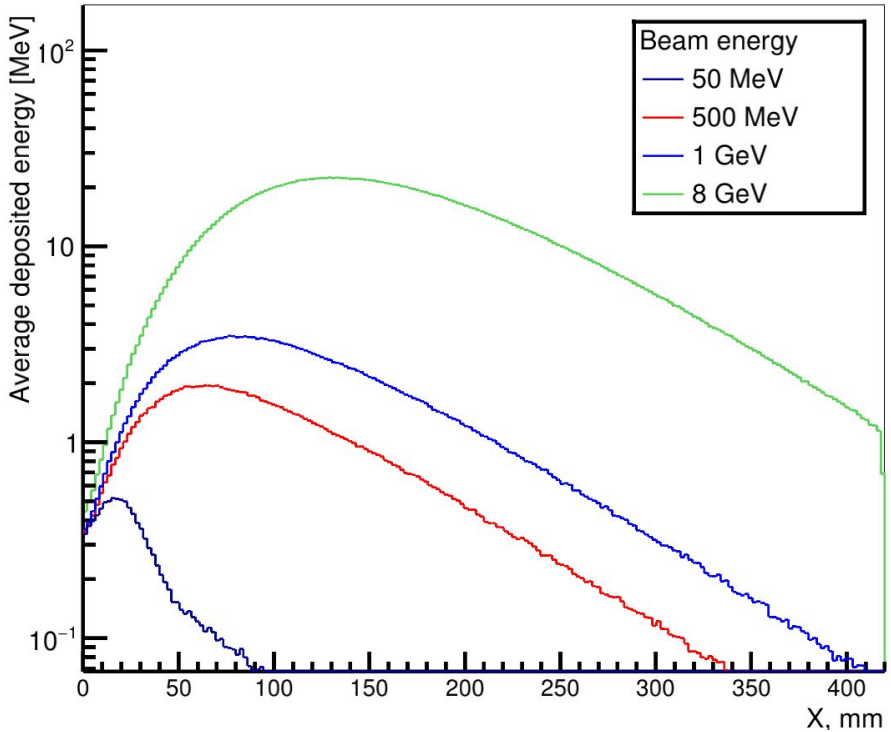
Monte Carlo model

- Monte Carlo model: Geant4 (QGSP_BERT, G4EmStandardPhysics_option4).
- The same geometry as the real module. Except transverse size is 400x400 mm^2.
- Beam: electrons and gamma-ray, energy from 0.05 GeV to 8 GeV.
- The Geant4 simulation is only on the level of particle-material interaction.
- For the estimation of the optical and electronics effect on the module characteristics we used empirical methods.



Longitudinal energy distributions for electrons



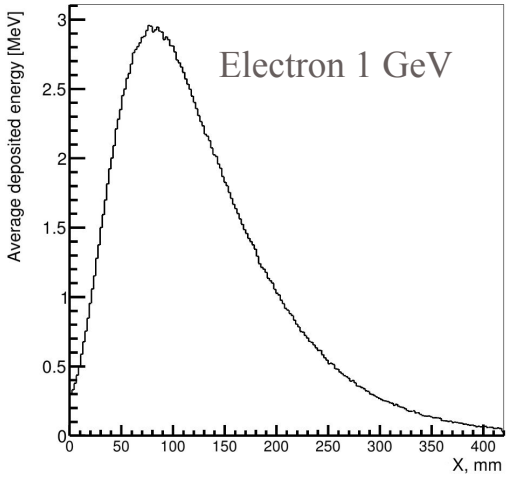


Attenuation of the signal

$$A = 0.5A_0 e^{-(L-x)/\lambda}$$

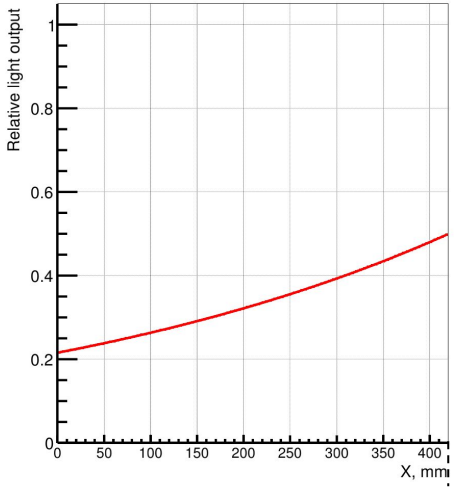
A - number of detected photons, A_0 - number of photons captured at a point x , λ - absorption length, L - WLS fiber length

Longitudinal energy distribution. Beam energy 1 GeV. The light attenuation (L) length = infinity



×

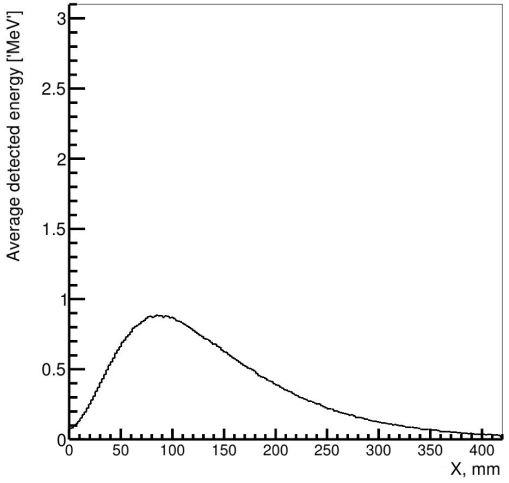
The light attenuation (L) length = 500 mm



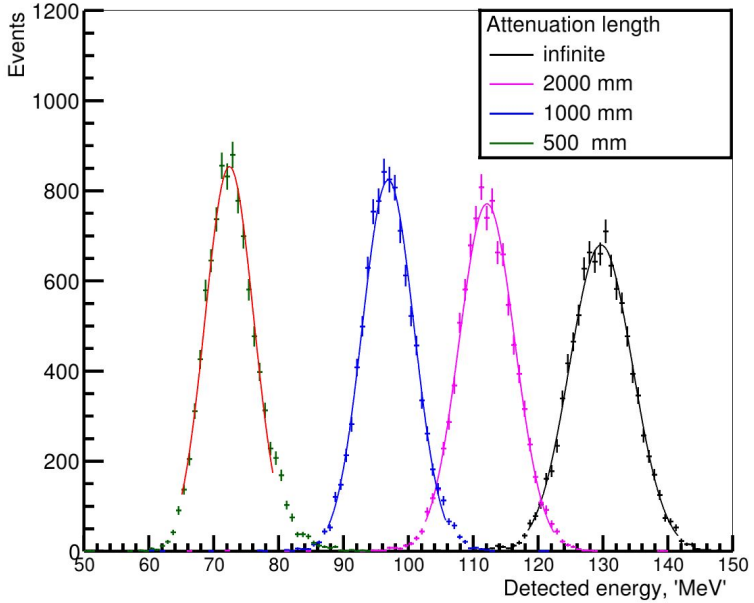
SiPM

=

Longitudinal energy distribution. Beam energy 1 GeV. The light attenuation (L) length = 500 mm



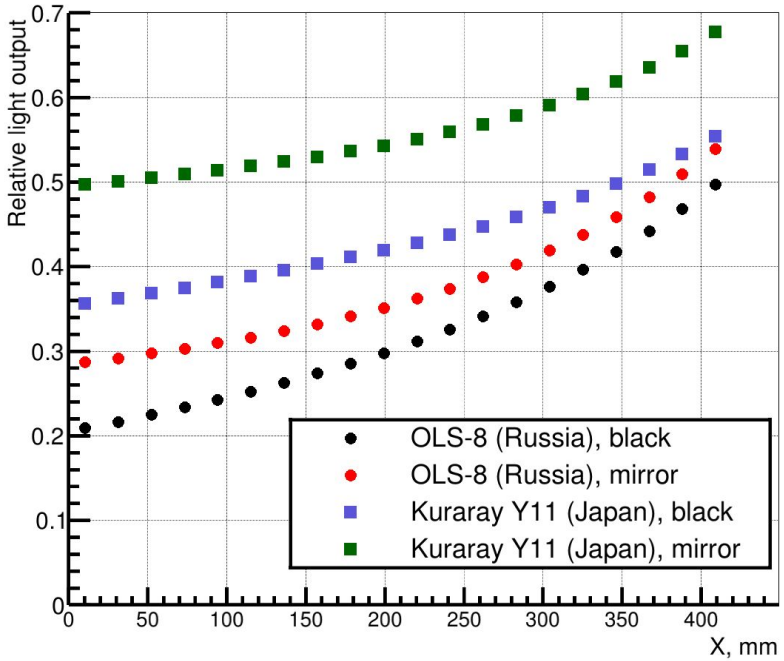
Energy distributions. Electron 1 GeV



	Infinite	2000 mm	1000 mm	500 mm
E, “MeV“	129.66±0.05	112.11±0.05	96.82±0.05	72.37±0.05
σ, “MeV“	4.84±0.04	4.26±0.04	3.97±0.04	3.70±0.05
σ/E	3.73±0.03%	3.80±0.03%	4.10±0.05%	5.12±0.07%
chi2/ndf	22/25	28/20	18/17	17/14

Simulation based on experimental data

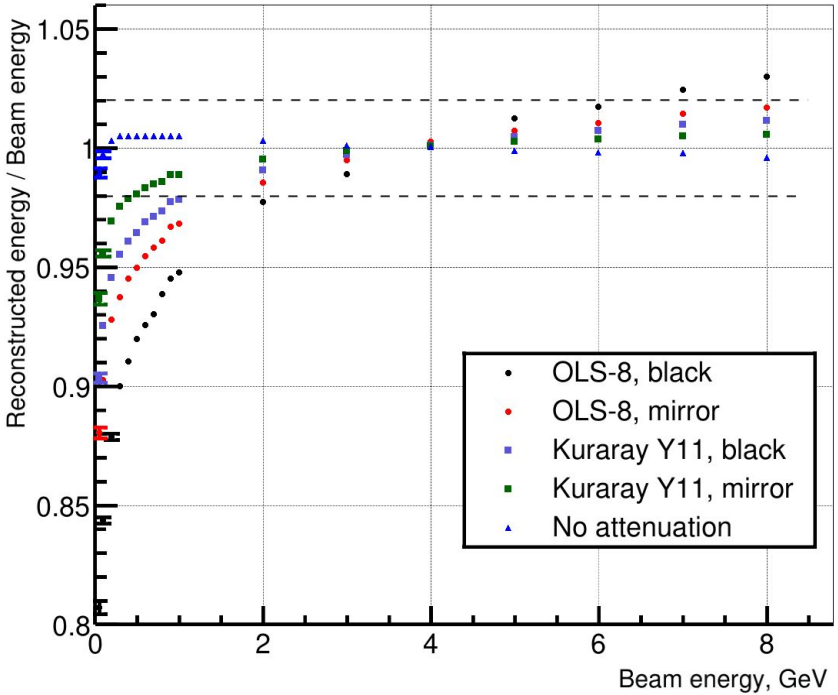
Attenuation of the signal, experimental data



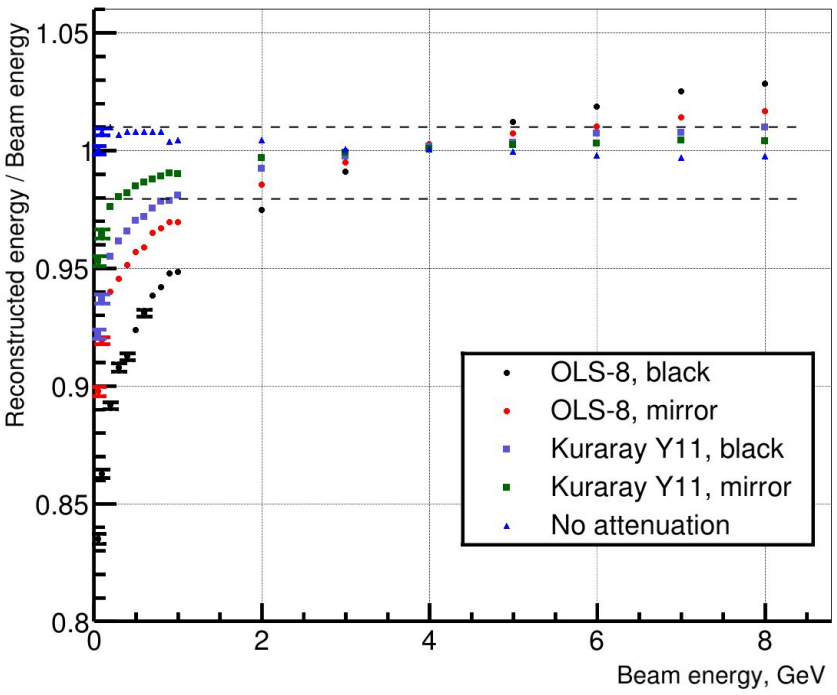
Obtained with data measured by Vladimir Baranov and Eduard Ginya

Linearity. Simulation based on the experimental data.

Electron



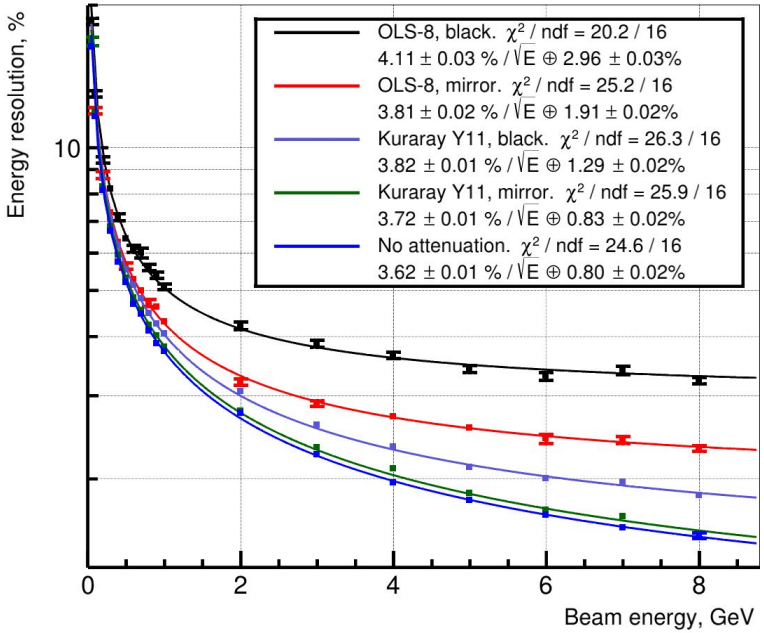
Gamma



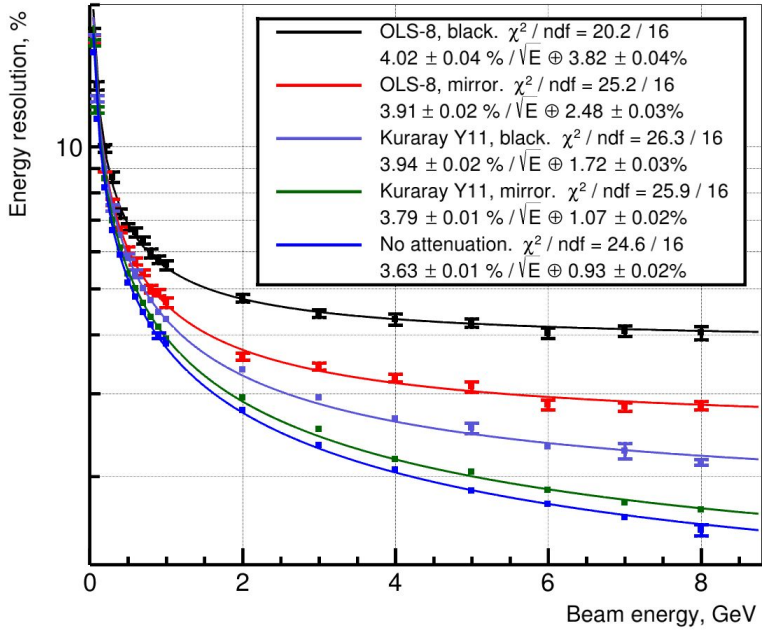
Resolution. Simulation based on the experimental data.

$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus b,$$

Electron



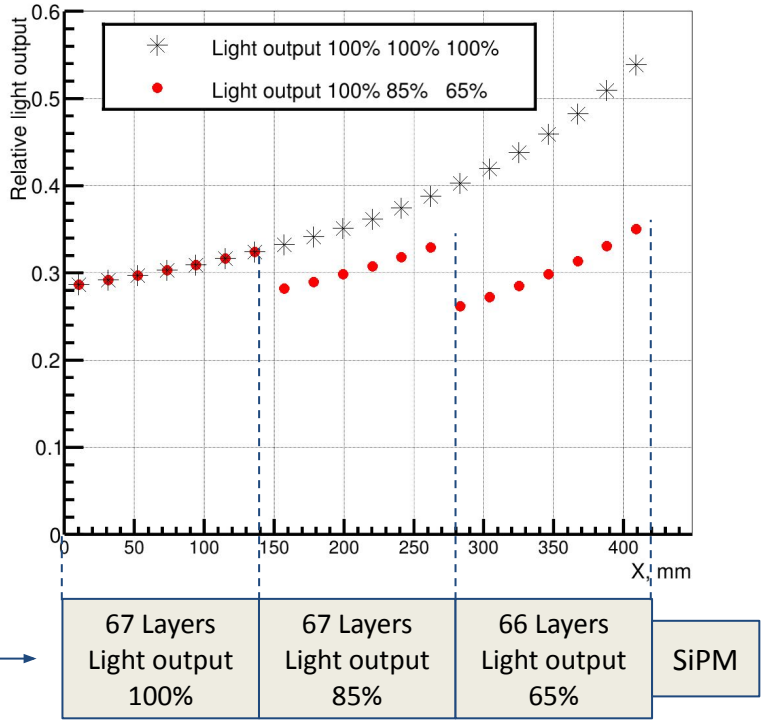
Gamma



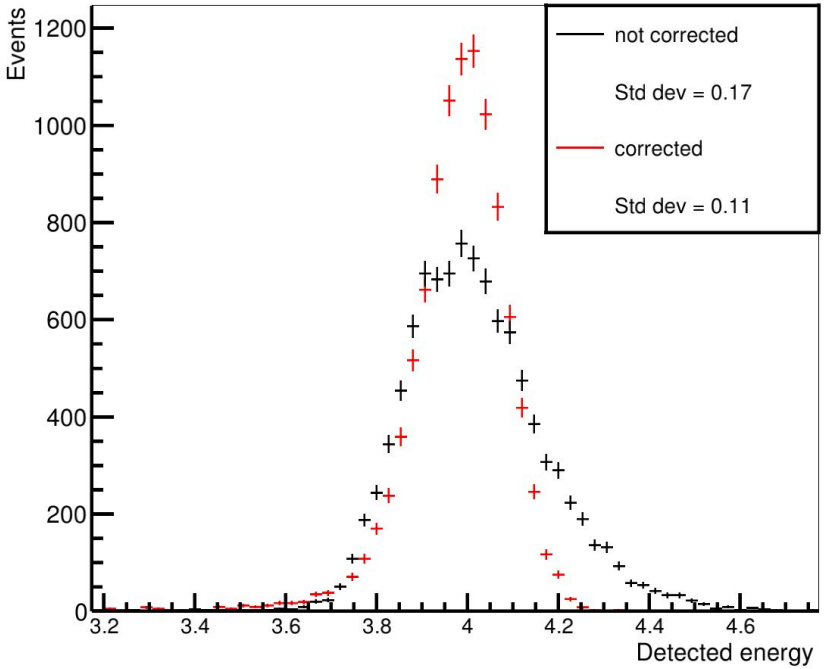
Correction

Correction of the attenuation of the signal

OSL-8 Mirror

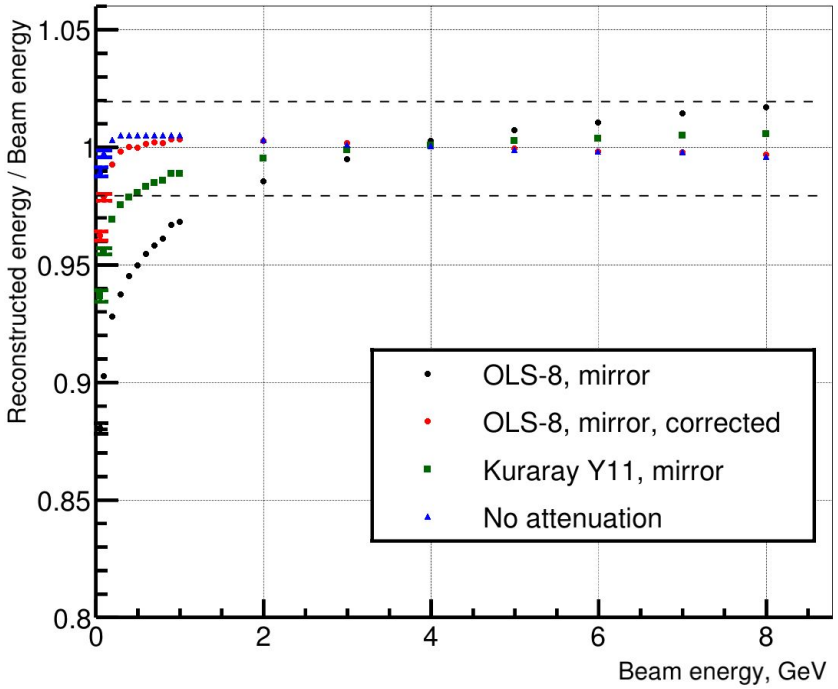


Gamma, 4 GeV

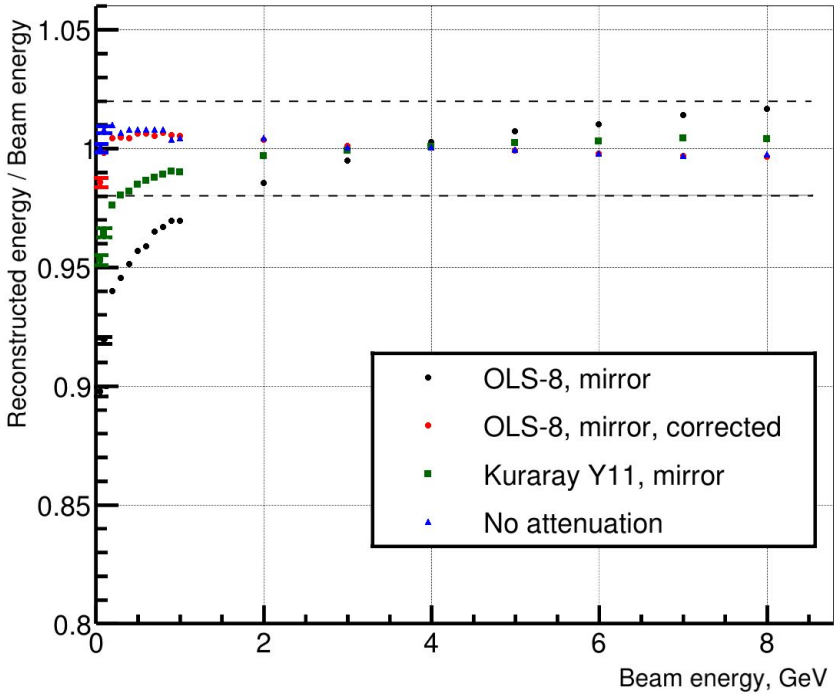


Linearity. Correction.

Electron

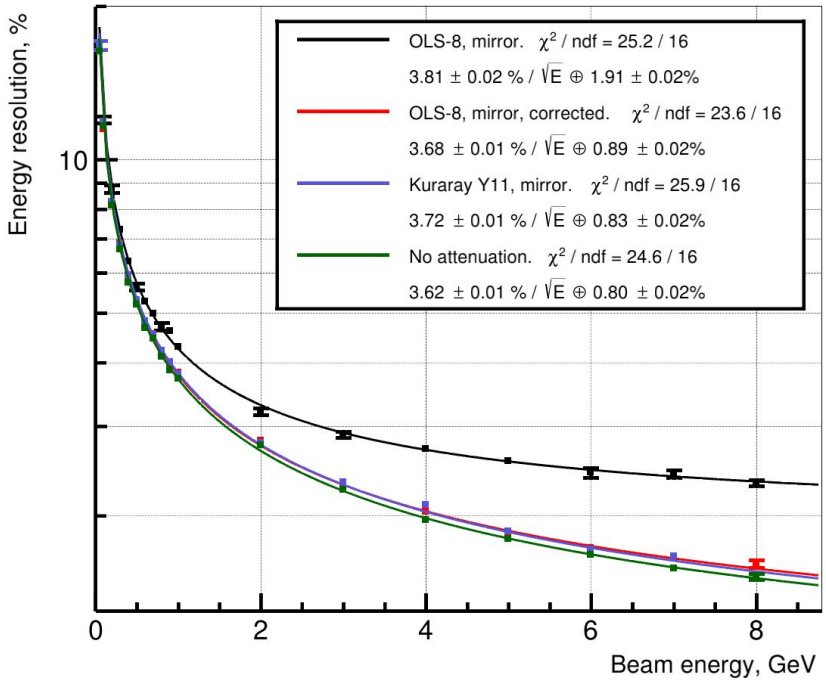


Gamma

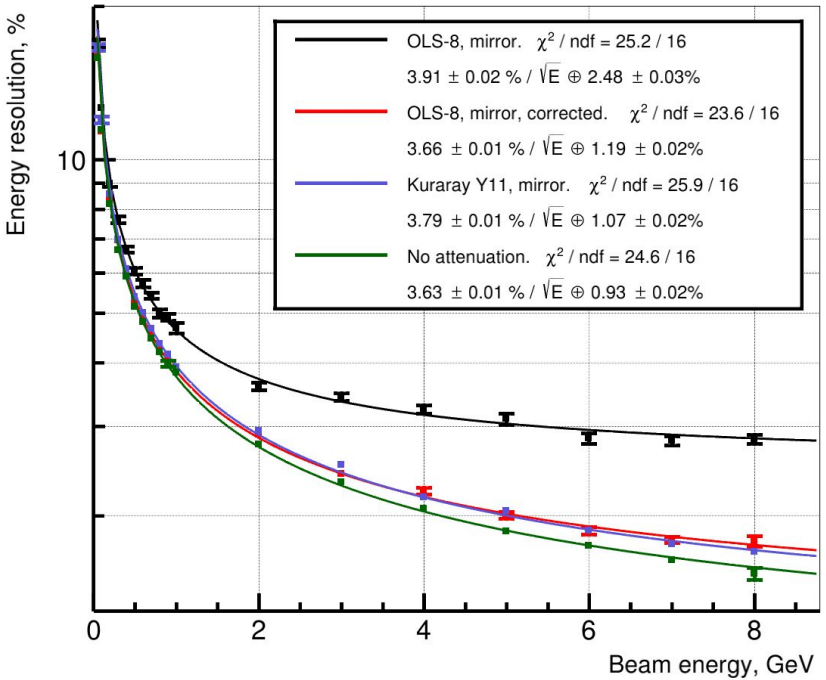


Resolution. Correction.

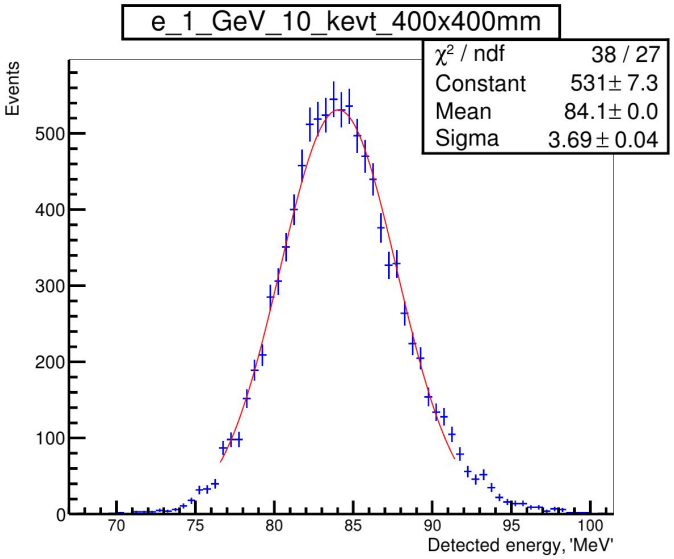
Electron



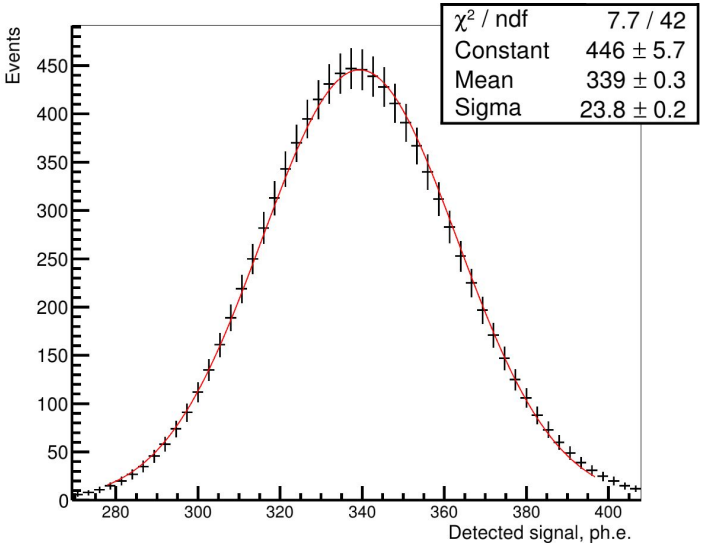
Gamma



Optical and electronics effects

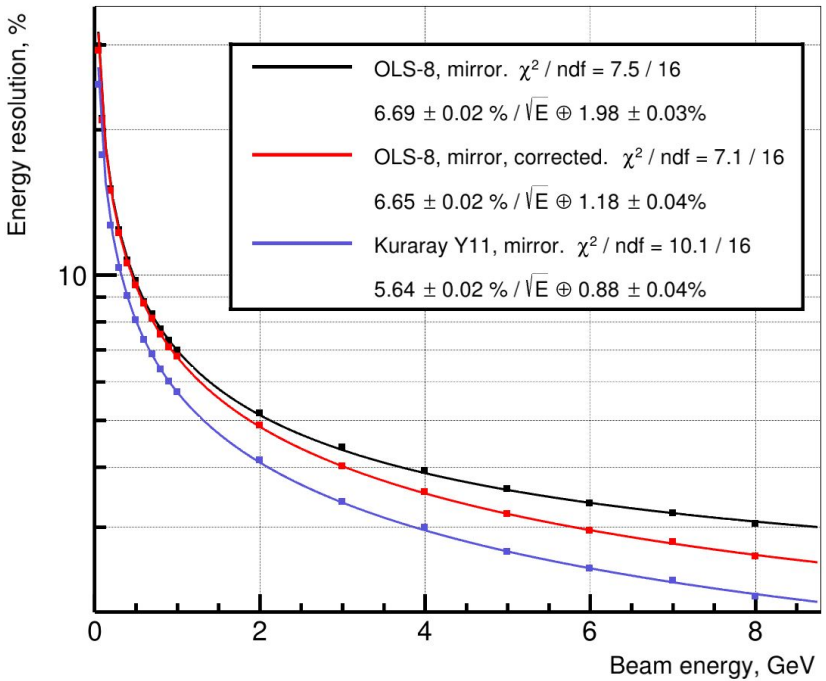


Convolution of this distribution and Poisson distribution (1 GeV = 4000 ph.e. Data provided by Oleg Gavrishchuk)

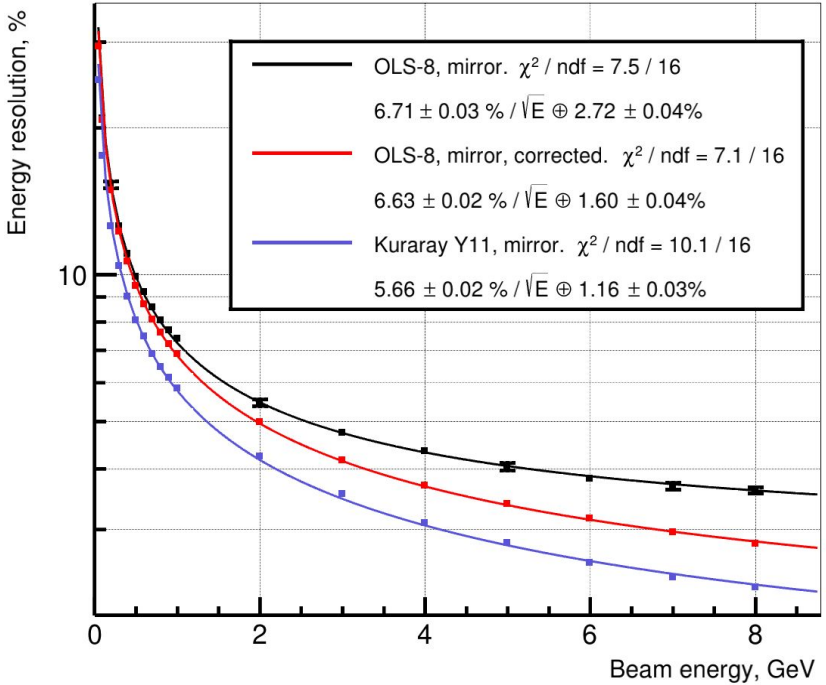


Resolution. Correction. Scintillation.

Electron



Gamma



Results

Linearity

WLS shifter	Electron		Gamma	
	from	to	from	to
OSL-8 (Not corrected)	2 GeV	8 GeV	2 GeV	8 GeV
OSL-8 (Corrected)	0.1 GeV	8 GeV	0.05 GeV	8 GeV
Kuraray Y11 (Not corrected)	0.4 GeV	8 GeV	0.3 GeV	8 GeV

Resolution

WLS shifter	Electron		Gamma	
	a, %	b, %	a, %	b, %
OSL-8 (Not corrected)	6.63±0.02	2.06±0.02	6.71±0.03	2.72±0.04
OSL-8 (Corrected)	6.66±0.02	1.12±0.04	6.63±0.02	1.60±0.04
Kuraray Y11 (Not corrected)	5.64±0.02	0.88±0.04	5.66±0.02	1.16±0.03

Verification of the Monte Carlo model

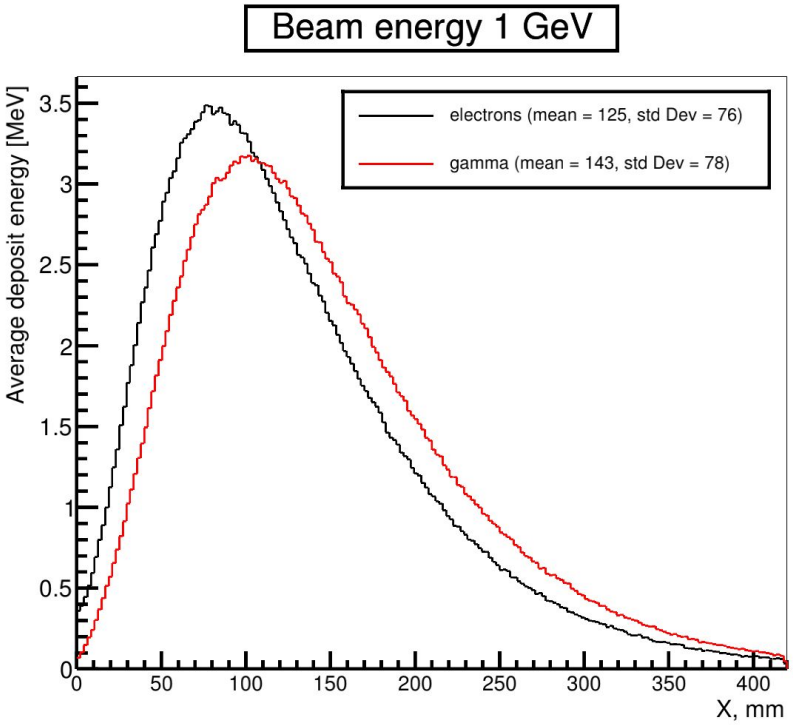
Verification

Conclusions

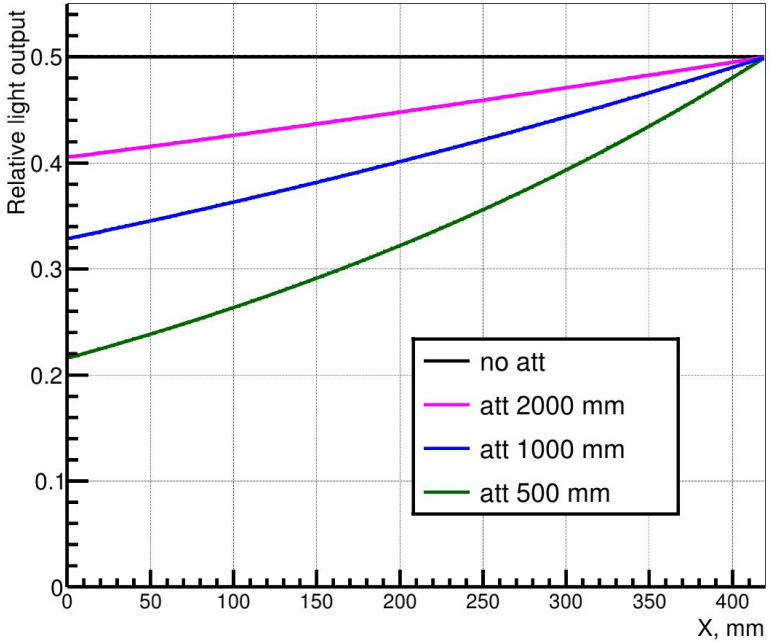
- A Monte Carlo model of the ECal was made (Geant4).
- Calculated linearity and energy resolution of the ECal with Kuraray Y11 and OSL-8 WLS fibers. Showed that the characteristics of the ECal module with Kuraray Y11 is better than with OSL-8.
- Checked the method when using sets of scintillation plates with different light output.
- Showed that the method provides the linearity of the ECal module with fiber OSL-8 and plate sets 100, 85, 65% from 0.1 GeV to 8 GeV.
- Showed that the method improves the energy resolution of the ECal module with fiber OSL-8 and plate sets 100, 85, 65%. For electrons a = 6.66±0.02, b = 1.12±0.04 and for gamma a = 6.63±0.02, b = 1.60 ±0.04. Constant members have decreased about 45%.

Thank you for your attention!

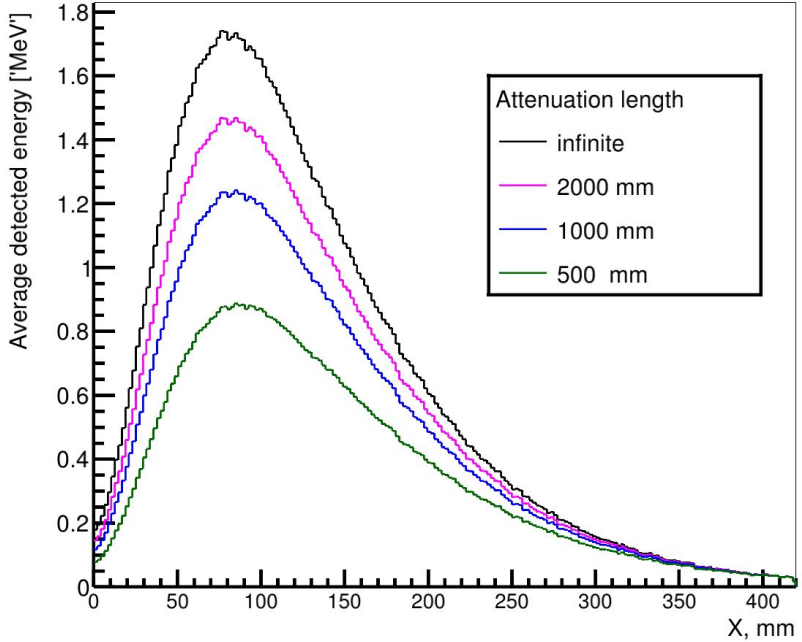
Longitudinal energy distributions, electrons vs gamma



Longitudinal energy distributions for different attenuation lengths

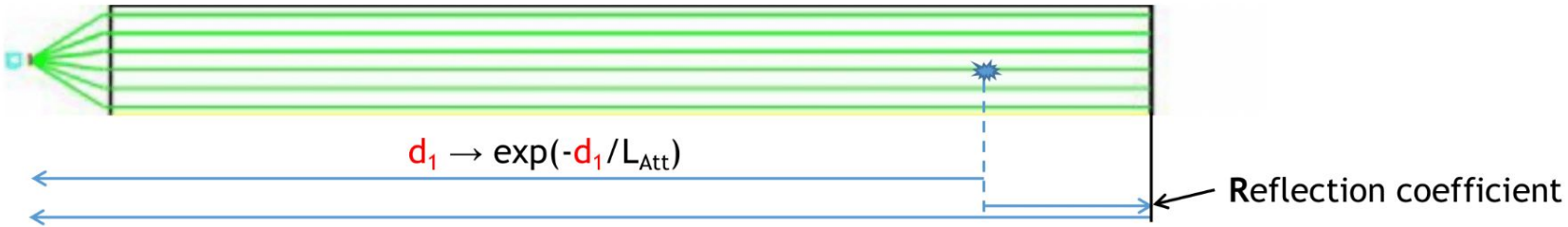


Electron 1 GeV

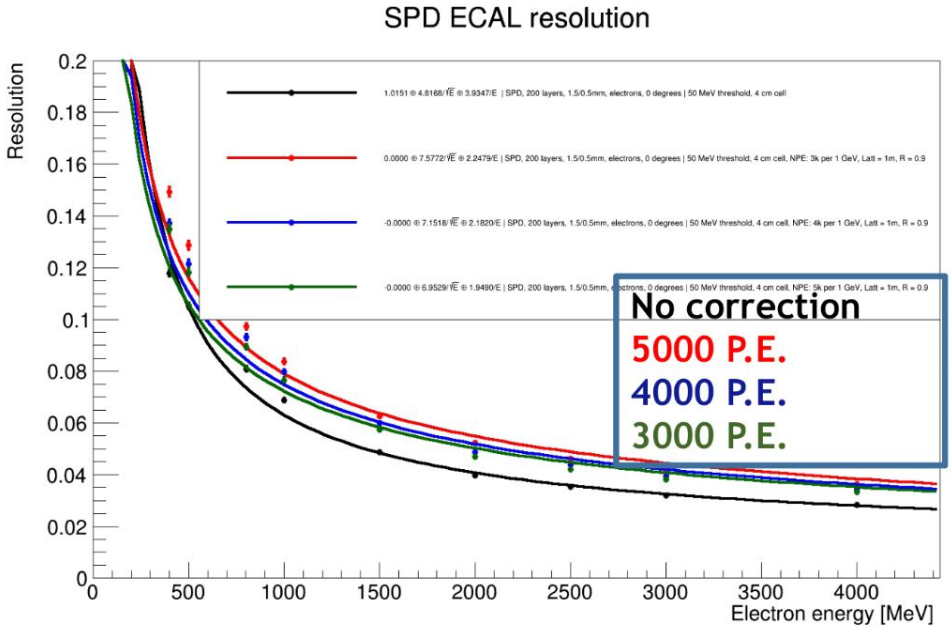


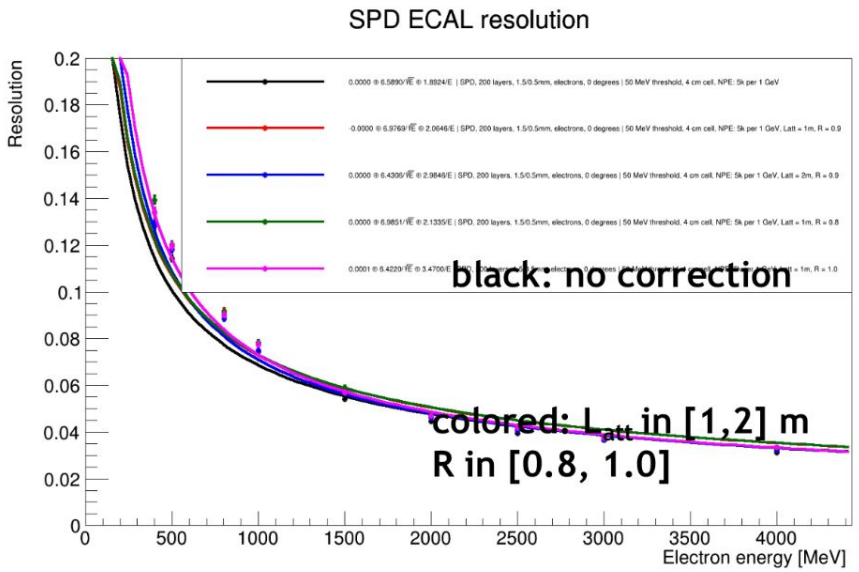
Setup details

- 200 layers of shashlyk: 0.5 mm Pb/1.5 mm scintillator
- 50 MeV cell energy threshold, 4x4 cm cell
- L_{Att}= 1.0 m, R = 0.9, 5000 photoelectrons per 1 GeV in scintillator



Effect of corrections on ECAL resolution





All other corrections are also applied

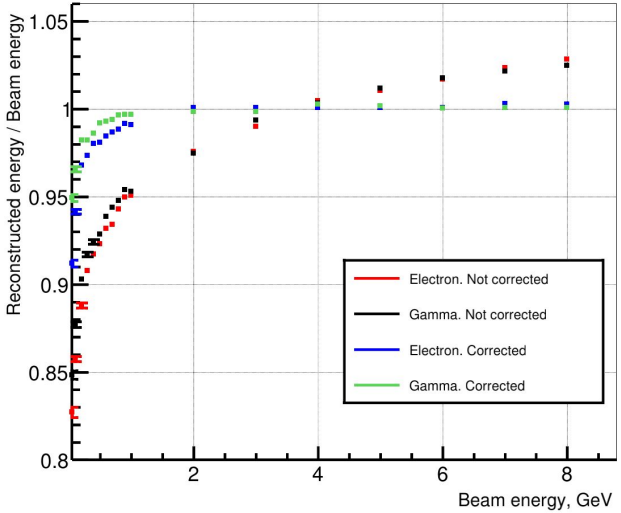
Bigger contribution is from photoelectron statistics

Значения χ^2 для разных степеней свободы

Число степеней свободы *k*	Уровень значимости a					
	0,01	0,025	**0.05**	0,95	0,975	0.99
1	6.6	5.0	**3.8**	0.0039	0.00098	0.00016
2	9.2	7.4	**6.0**	0.103	0.051	0.020
3	11.3	9.4	**7.8**	0.352	0.216	0.115
4	13.3	11.1	**9.5**	0.711	0.484	0.297
5	15.1	12.8	**11.1**	1.15	0.831	0.554
6	16.8	14.4	**12.6**	1.64	1.24	0.872
7	18.5	16.0	**14.1**	2.17	1.69	1.24
8	20.1	17.5	**15.5**	2.73	2.18	1.65
9	21.7	19.0	**16.9**	3.33	2.70	2.09
10	23.2	20.5	**18.3**	3.94	3.25	2.56
…	…	…	**…**	…	…	…

Linearity. Correction. Electron vs gamma.

No mirror



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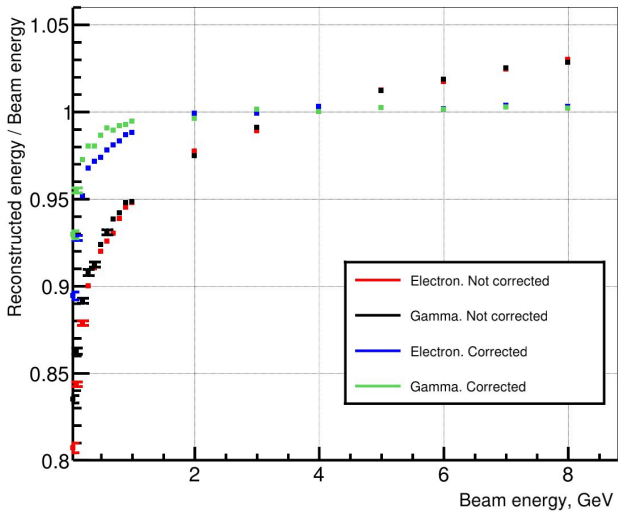
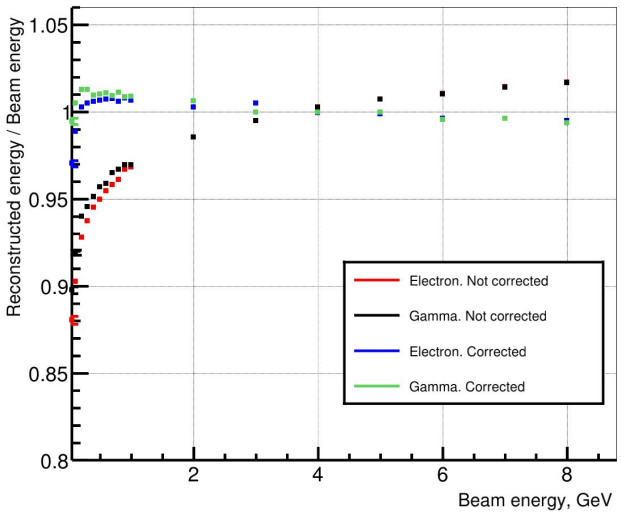
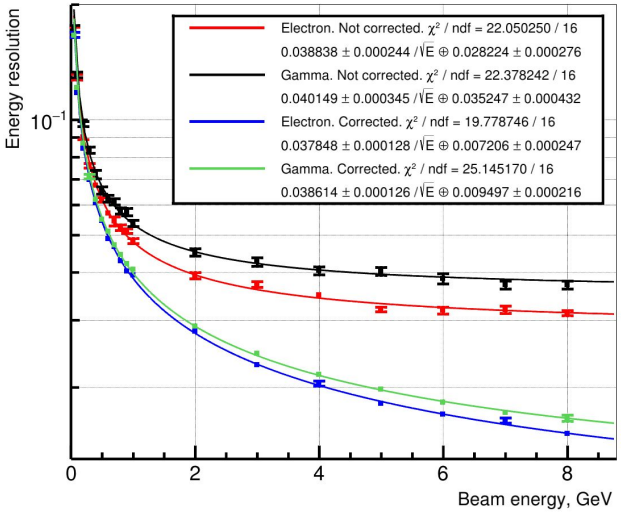


Mirror



Resolution. Correction. Electron vs gamma

No mirror



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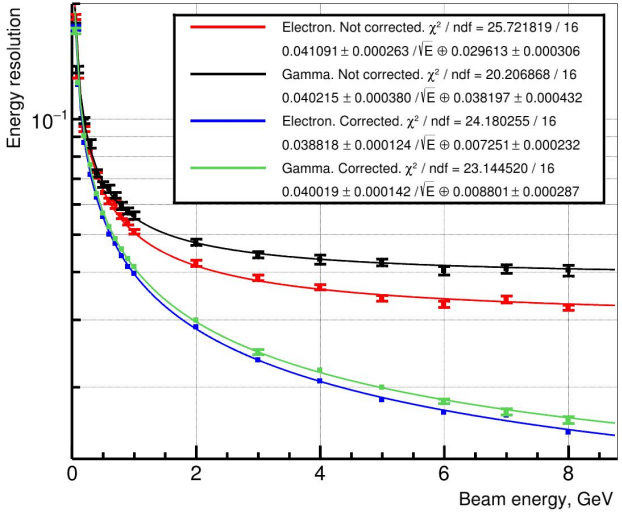
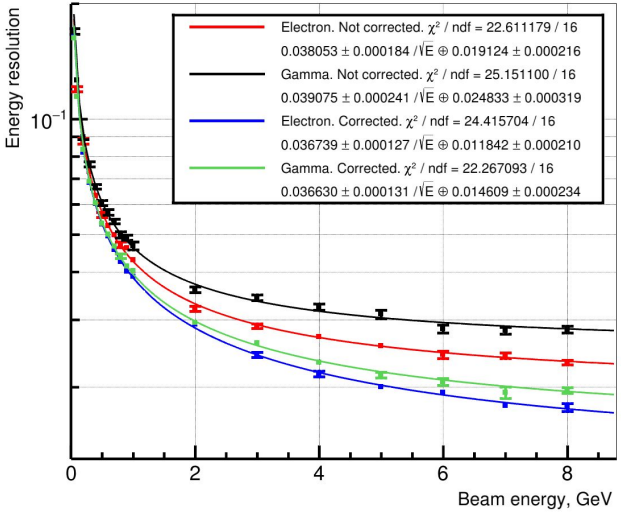
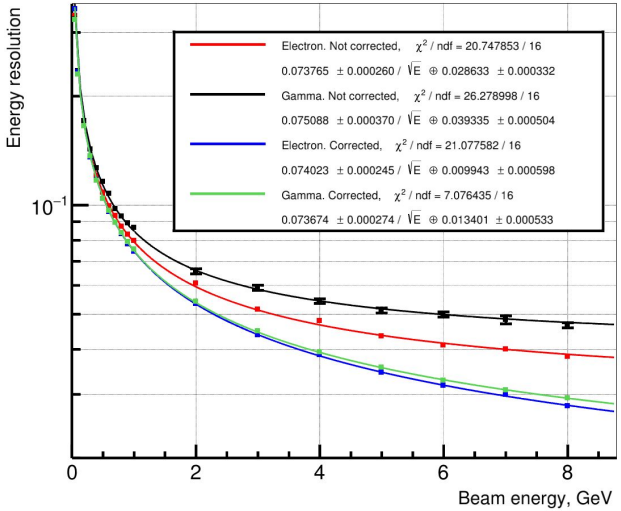


Mirror



Resolution. Correction. Electron vs gamma + scintillation

No mirror



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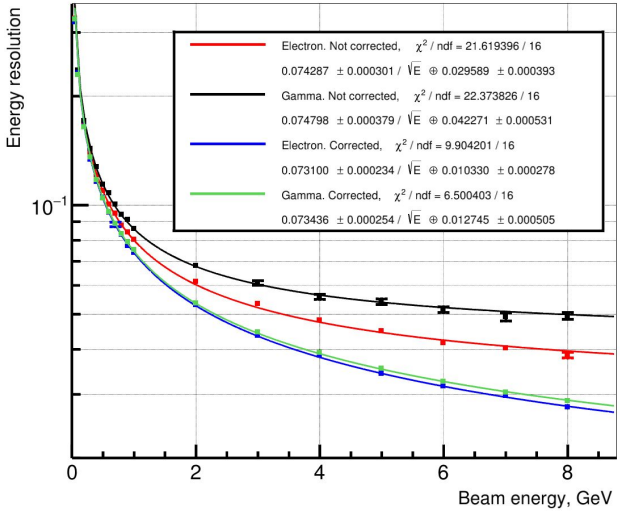

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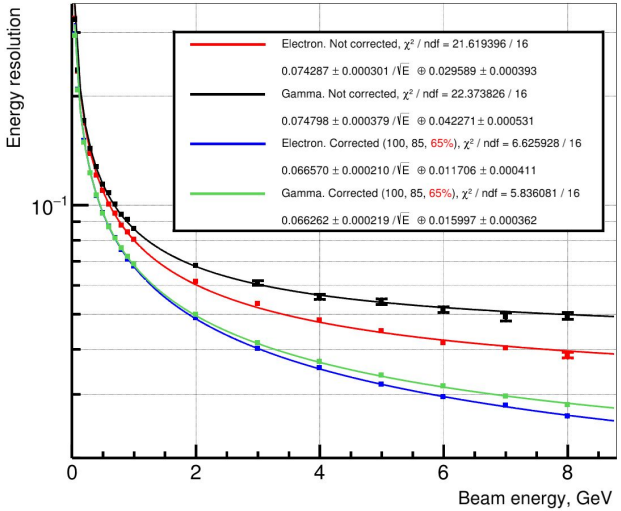

Correction of the attenuation of the signal