LONGITUDINAL PROFILES AND CORRELATIONS OF ELECTROMAGNETIC CASCADES PRODUCED BY 100-3500 MeV GAMMA QUANTA IN DENSE AMORPHOUS MEDIA

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"Relativistic Nuclear Physics and Quantum Chromodynamics"
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OUTLINE OF THE TALK

- MOTIVATION
- ABSTRACT
- SHORT HISTORY
- RESULTS OF MODELING
- SUMMARY AND CONCLUSION

Motivation

- Longitudinal profiles of electromagnetic cascades (EMC) produced in heavy amorphous media by high enough energy gamma quanta and electrons (or positrons) are the basic characteristics of the phenomenon both from cognitive and application viewpoints.
- The fluctuations determine the energy resolution and accuracy of flight direction of particles initiating EMC.
- A knowledge of correlation enables to measure the energy of EMC in conditions of limited geometry of detectors.
- The information about correlation and fluctuations in EMC is needed for electromagnetic calorimeters under construction as PANDA (GSI), as well for radiation shielding construction and radiation material physics.

Abstract

- We study the average longitudinal and transverse **profiles** of electromagnetic cascades (EC) created in most popular dense amorphous media (liquid xenon, PWO, CdWO4, GaAs, NaI, Pb, lead glass and BGO) by gamma quanta of energy $E\gamma$=100÷3500 MeV at three different cut-off energies (0.6, 1.2 and 3.0 MeV). The work has been performed using the EGS4 & GEANT4 modeling codes.
- Analyzed is the correlation of energy release in longitudinal cascade development in order to estimate the possibility to reconstruct its primary energy when a part of it has been registered.
- The results are compared with available experiment. The ultimate objective of this investigation is to obtain concise information about average profiles, fluctuations and correlation in EC suitable for practical purposes.

Basic steps in the investigation of electromagnetic cascades:

1. Rossi B. Phys. Zs., 1932, vol.33, p.304 - **discovery of the phenomenon.**
2. Rossi B. High-Energy Particles. Prentice-Hall, New York, 1952 - **one-dimensional theory of EMC.**
3. Longo E., Sestili J. Nucl. Instr. Meth., 1975, vol.128, p.283 – **computer model of EMC** *(neither EGS4, nor GEANT)*.
4. De Angelis A. Nucl. Instr. Meth. A., 1988, vol.271, p.455 - **computer model of EMC** *(neither EGS4, nor GEANT)*.
5. Słowiński B. Phys. Part. Nucl. 25 (2), March-April 1994 - **overview of experimental and theoretical description of EMC.**
6. **Modern description of EMC is needed urgently** *(with EGS4 and GEANT confronted with experiment)*.

What is the EMC in short?

$$\gamma \rightarrow e^+ + e^-$$

$$e^+ \rightarrow e^+ + \gamma$$

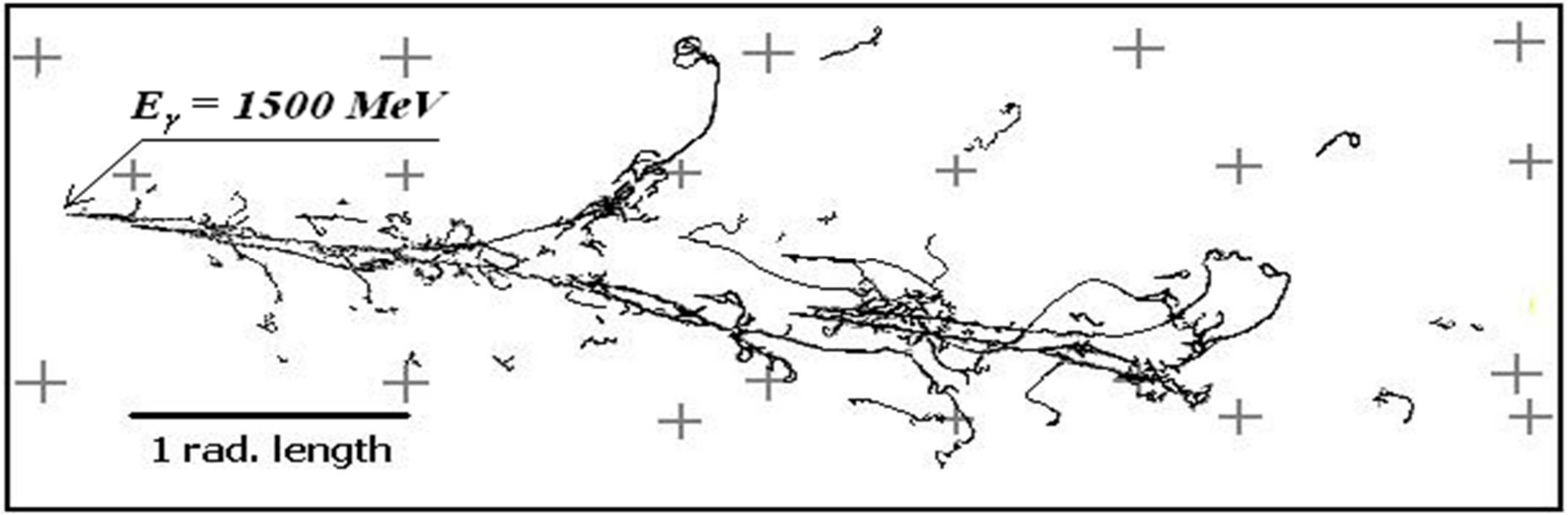
$$e^- \rightarrow e^- + \gamma$$

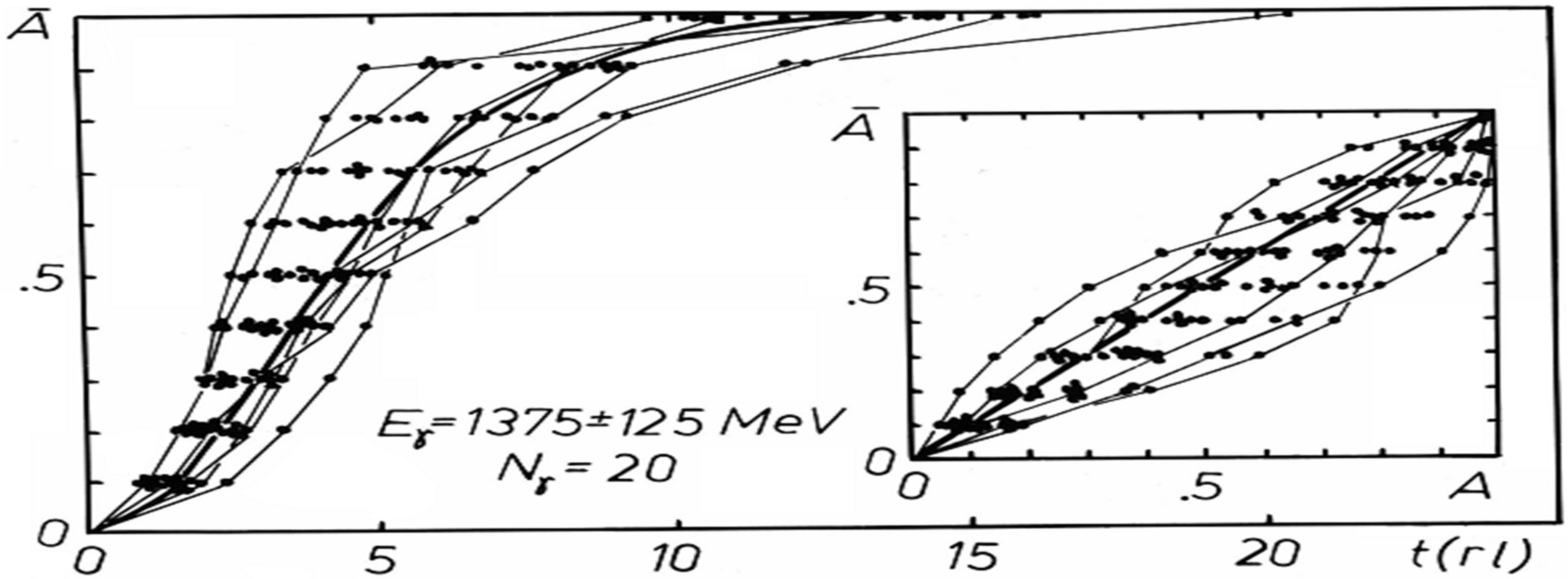
…

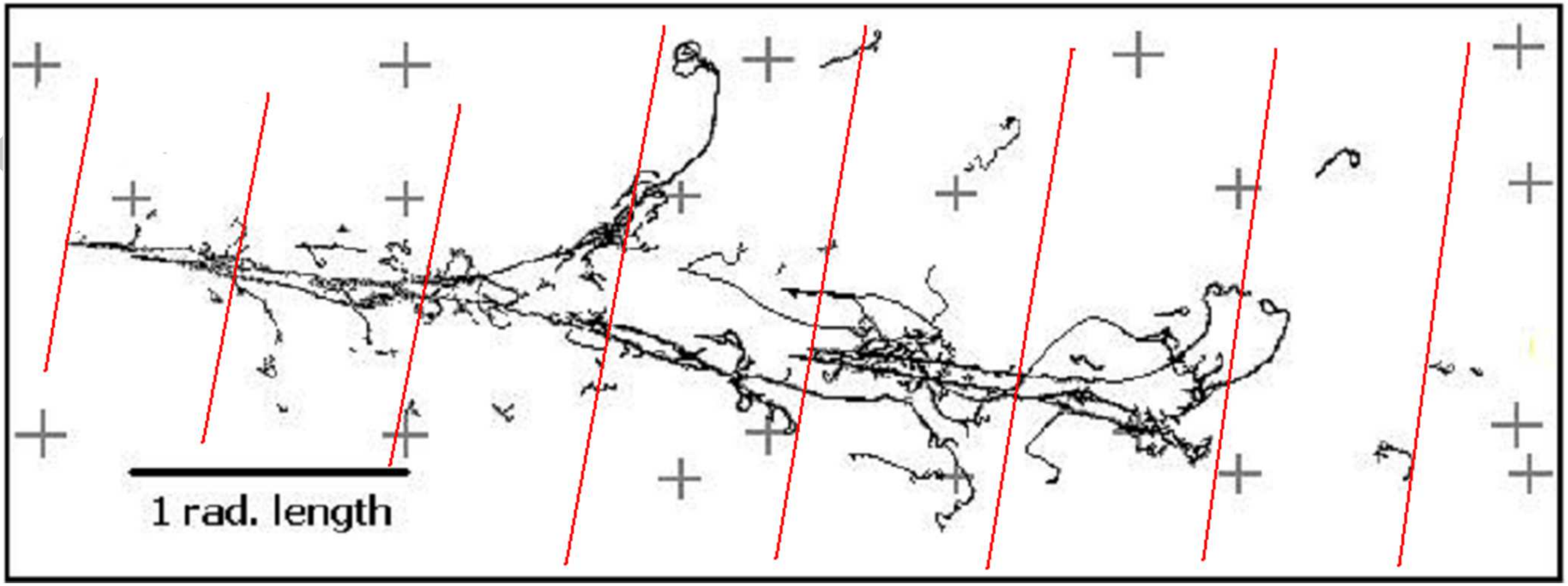
Leading elementary processes:

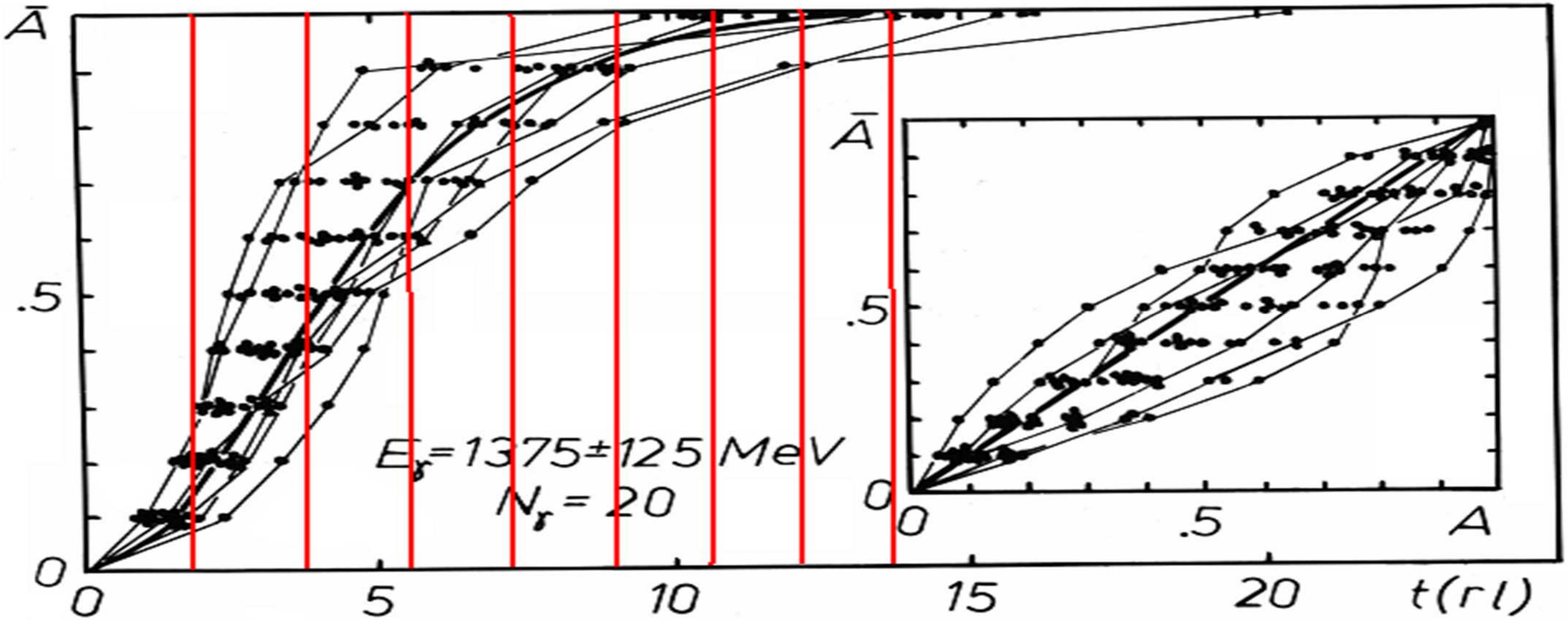
- Pair creation
- Bremstrahlung (radiation emission)
- Ioniztion
- Multiple Coulomb scattering

A picture of EMC from 26 liter Xenon Bubble Chamber (LHE JINR)






1 rad. length


Ā
.5
0
0
5
10
15
20
t(rl)
E_γ=1375±125 MeV
N_γ=20
Ā
.5
0
0
.5
A

Average description of EMC profiles

Profiles

- longitudinal:

$$(-dE/dt) = A \cdot t^{\alpha} \cdot \exp(-bt)$$

- lateral (or radial):

$$(-dE/dr) = B \cdot \exp(-\mu(t) \cdot r)$$

- three-dimensional EMC picture:

$$(-d^2E/dt \cdot dr) = C \cdot t^{\alpha} \cdot \exp\{-[bt + \mu(t) \cdot r]\}$$

and fluctuation

(as an estimation of energy resolution when a cascade totally develops inside a target matrial)

$$\frac{\sigma}{E} \propto \frac{\sqrt{t}}{\sqrt{E}},$$

t is the step of sampling in units of r.l.
(C.Grupen. Particle detectors. Cambridge University Press. 1996)

$$\frac{\sigma_E}{E} = (\frac{a^2}{E^2} + \frac{b^2}{E} + c^2)^{1/2}$$

E is in GeV *(for $PbWO_4$ – PWO; ALICE experiment)*

Modeling of EMC

Programs: EGS4 and GEANT4

GQ energies: E_γ = 210, 555, 875, 1625, 2375, 3125 MeV

Cut-off energies: $E_{c.o.}$= 0.6, 1.2, 2.0, 3.0 MeV

Materials:

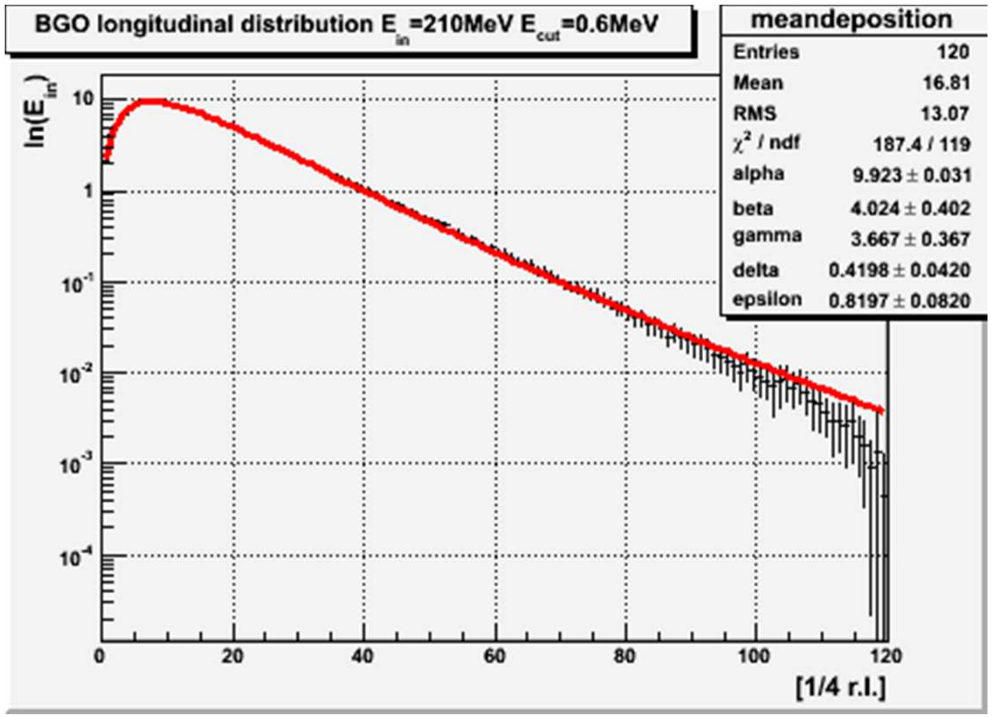
- liquid xenon
- PWO
- $CdWO_4$
- GaAs
- NaI
- Pb
- lead glass
- BGO

For every set of this parameters (E_γ, E_{co} and material) we modeled 20000 events (history).

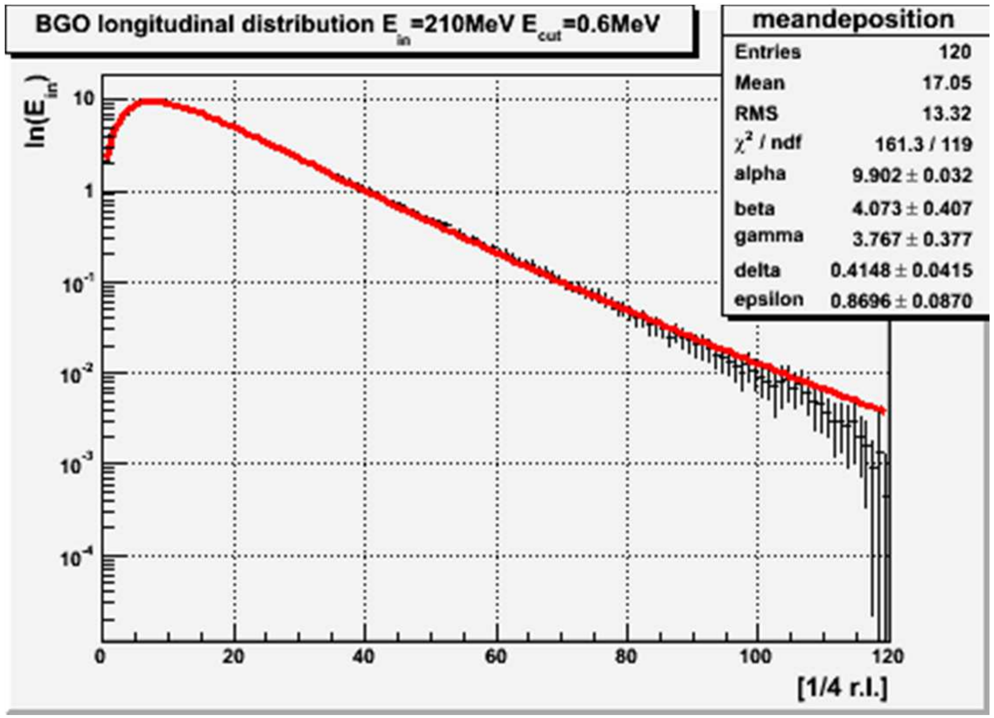
LONGITUDINAL PROFILES

An example for illustration:

Average longitudinal profile of EMC produced in BGO by gammas of energy 210 MeV (E_{co}=0.6 MeV).



EGS4



GEANT4

FITTING LONGITUDINAL PROFILES

to the approximating function:

$$(-dE/dt) = \alpha_t \left(t-\varepsilon_t\right)^{\beta_t} \exp\left(-\gamma_t t^{\delta_t}\right)$$

α_t, β_t, δ_t, γ_t, ,ε_t are the fit parameters depending on cut-off energy $E_{c.o.}$, E_γ and material properties.

$$(-dE/dt) = \alpha_t t^{\beta_t} \exp(-\gamma_t t)$$

Dependence of parameters:

β_t, δ_t, γ_t *and* ε_t

on

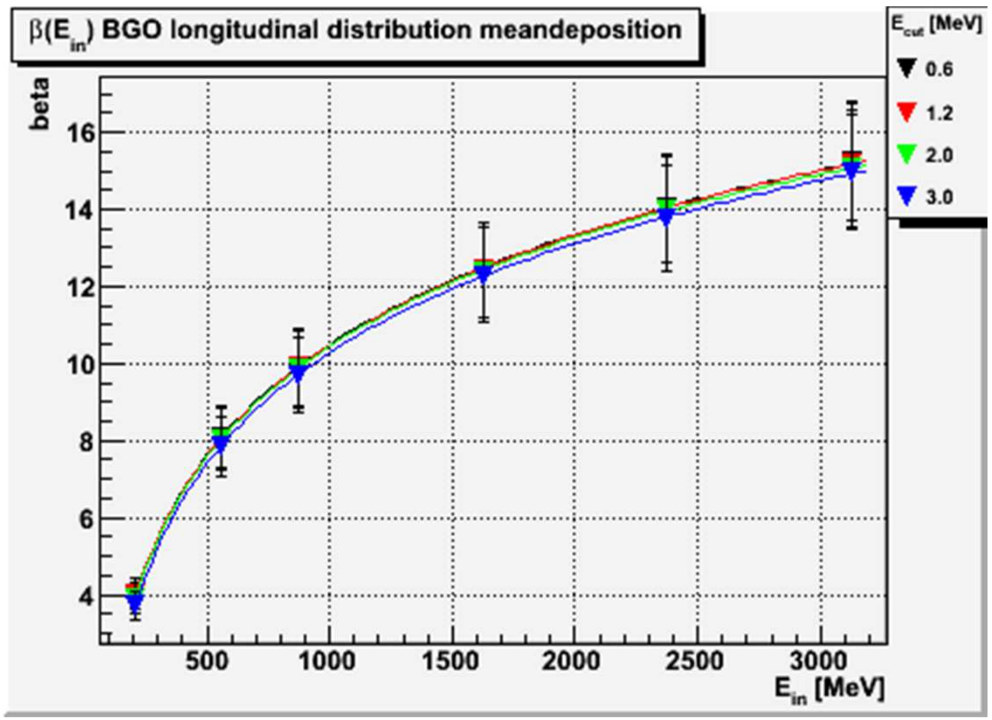
E_γ, $E_{c.o.}$, Z/A.

Parameter

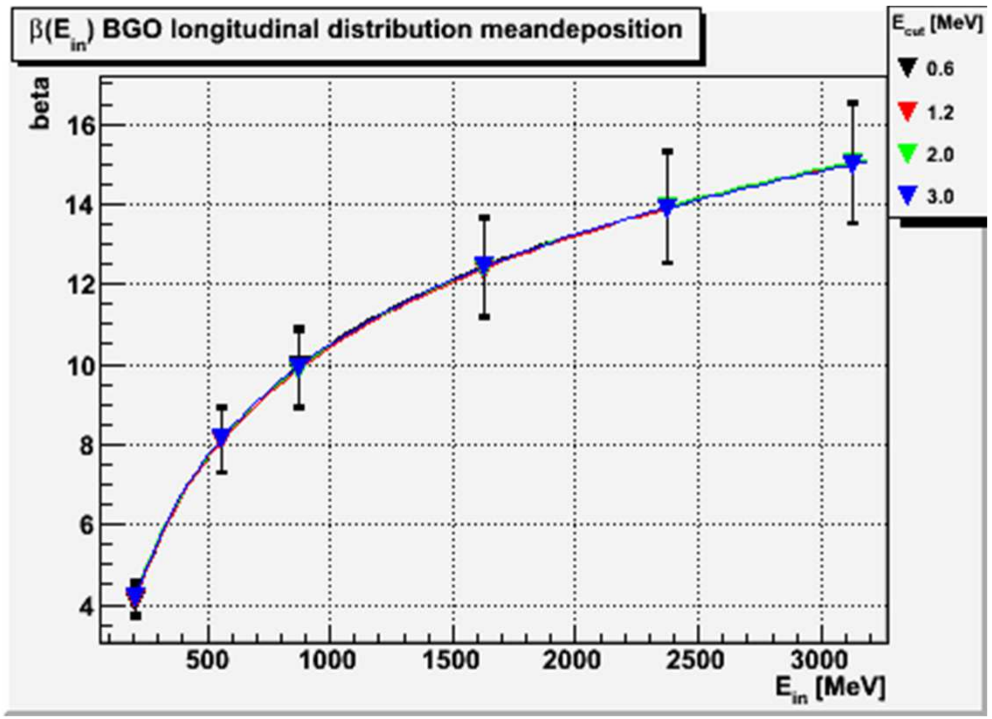
β_t

BGO

$$\beta_t(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$



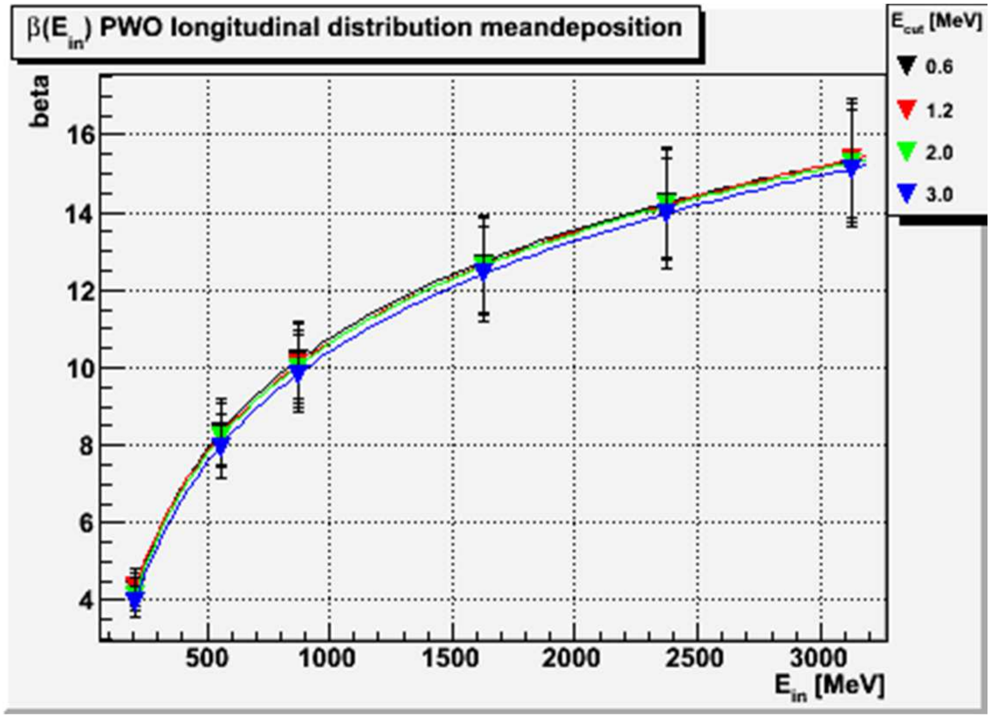
EGS4



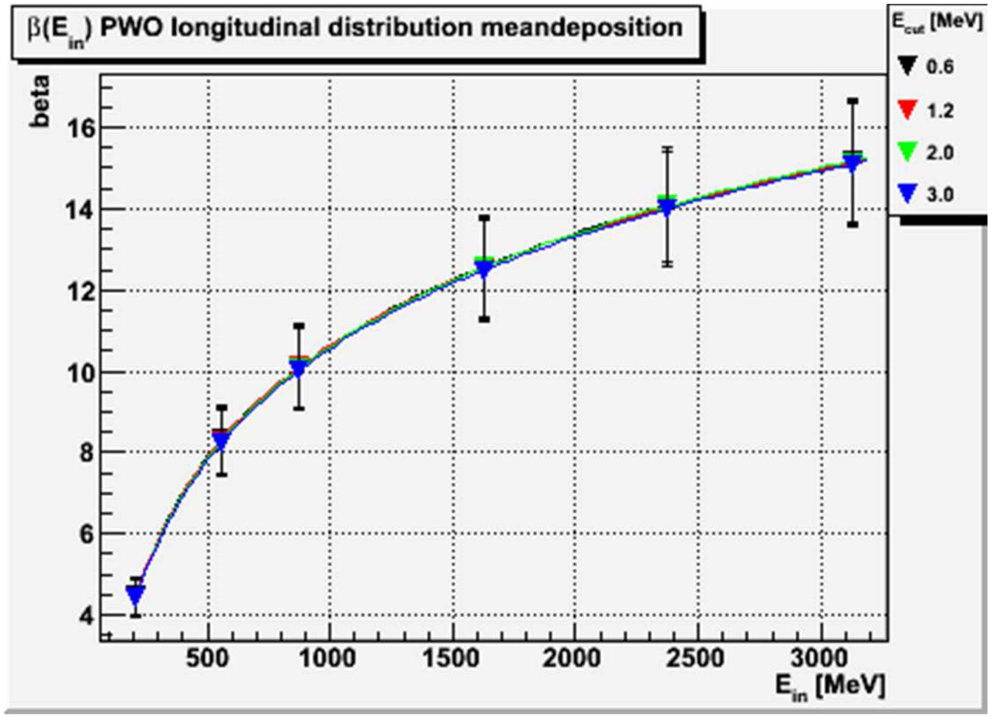
GEANT4

PWO

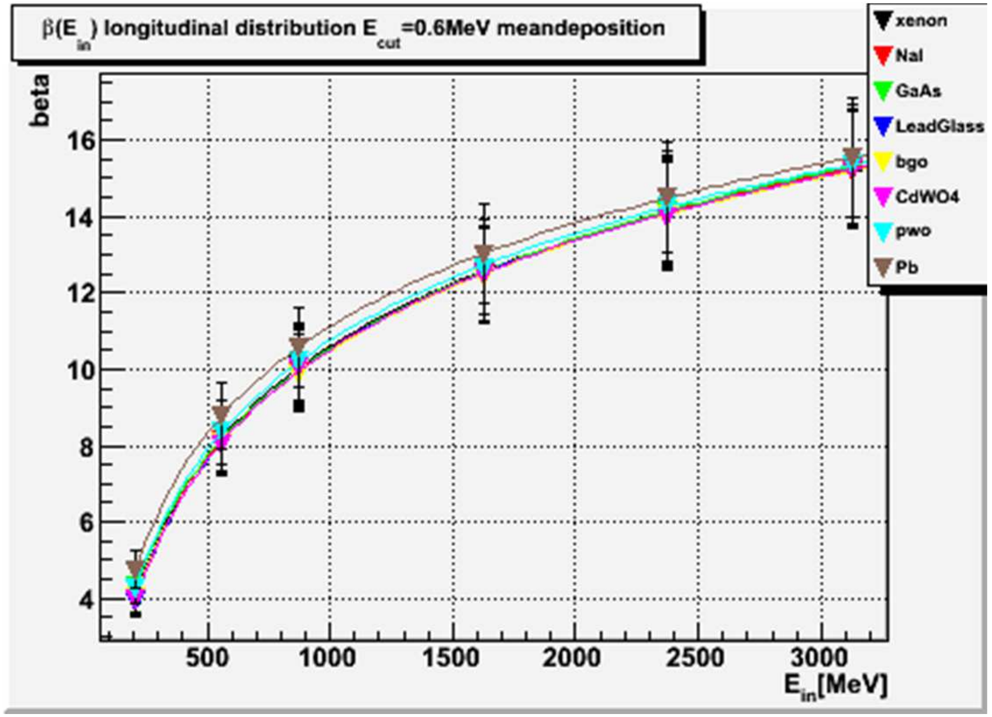
$$\beta_t(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$

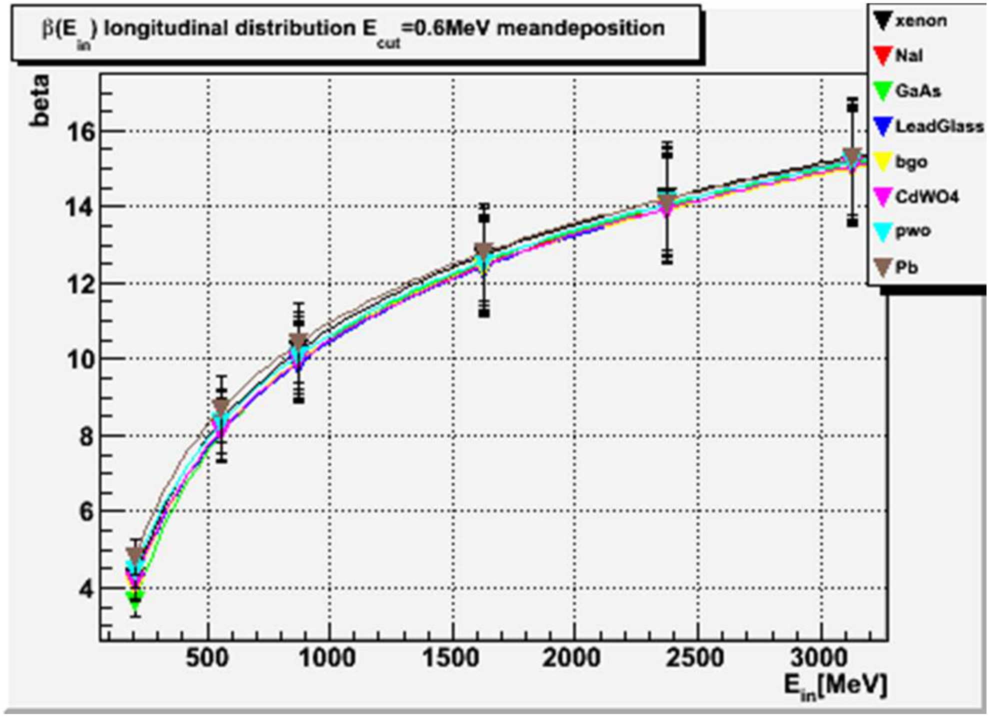


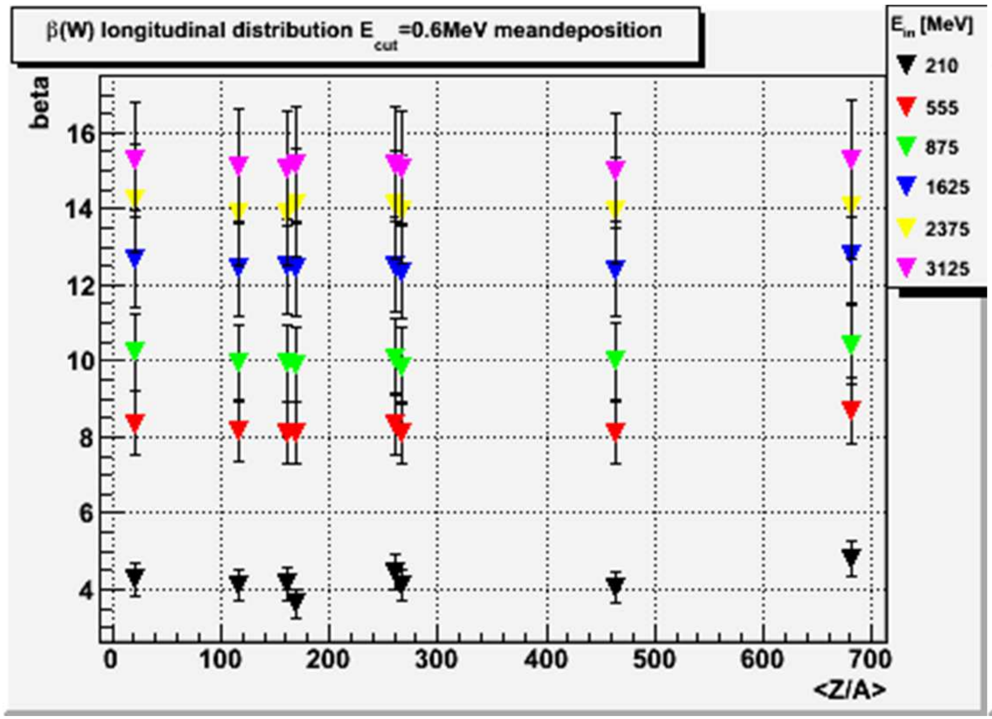
EGS4

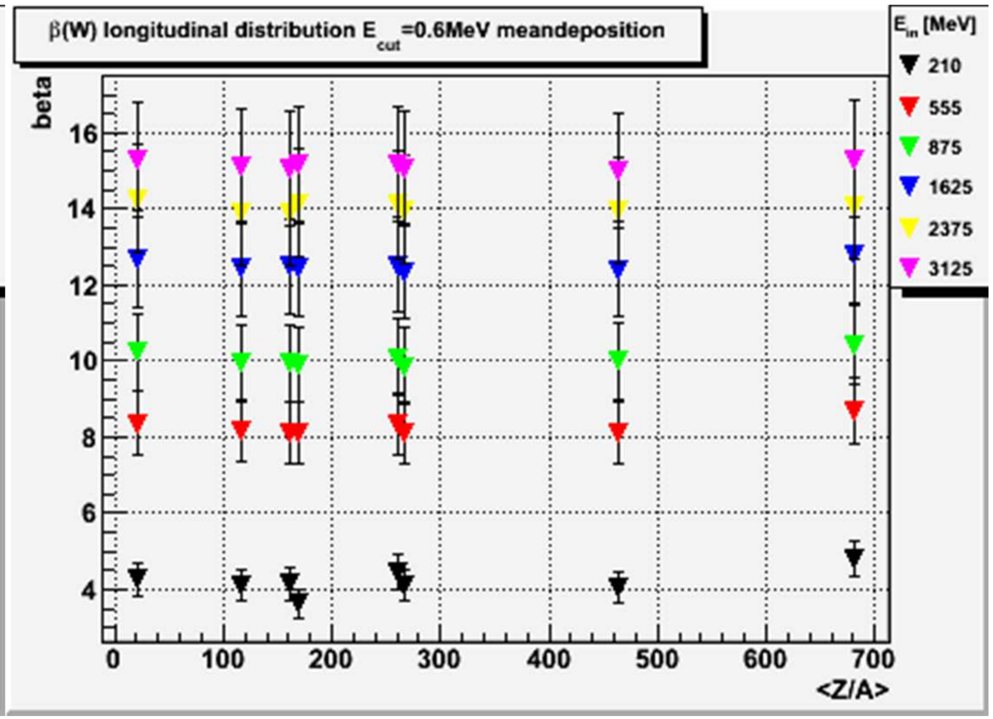


GEANT4


β(E_in) longitudinal distribution E_cut=0.6MeV meandeposition
beta
E_in[MeV]
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb


β(E_in) longitudinal distribution E_cut=0.6MeV meandeposition
beta
E_in[MeV]
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb


β(W) longitudinal distribution E_cut=0.6MeV meandeposition
beta
<Z/A>
E_in [MeV]
210
555
875
1625
2375
3125

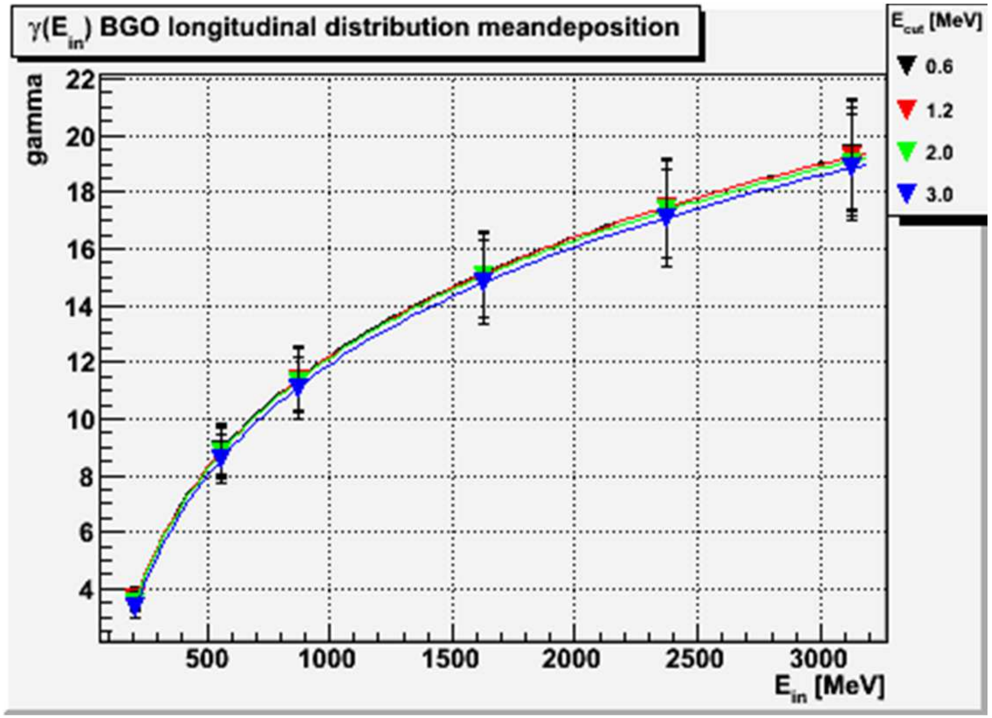

β(W) longitudinal distribution E_cut=0.6MeV meandeposition
beta
<Z/A>
E_in [MeV]
210
555
875
1625
2375
3125

Parameter

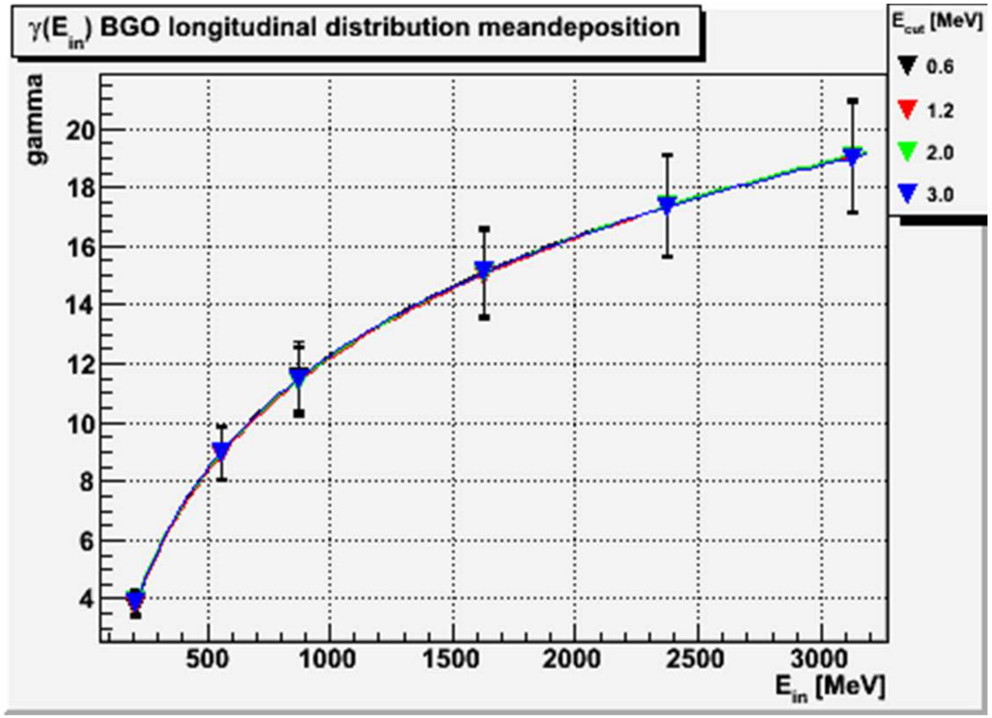
γ_t

BGO

$$\gamma_t(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$



EGS4



GEANT4

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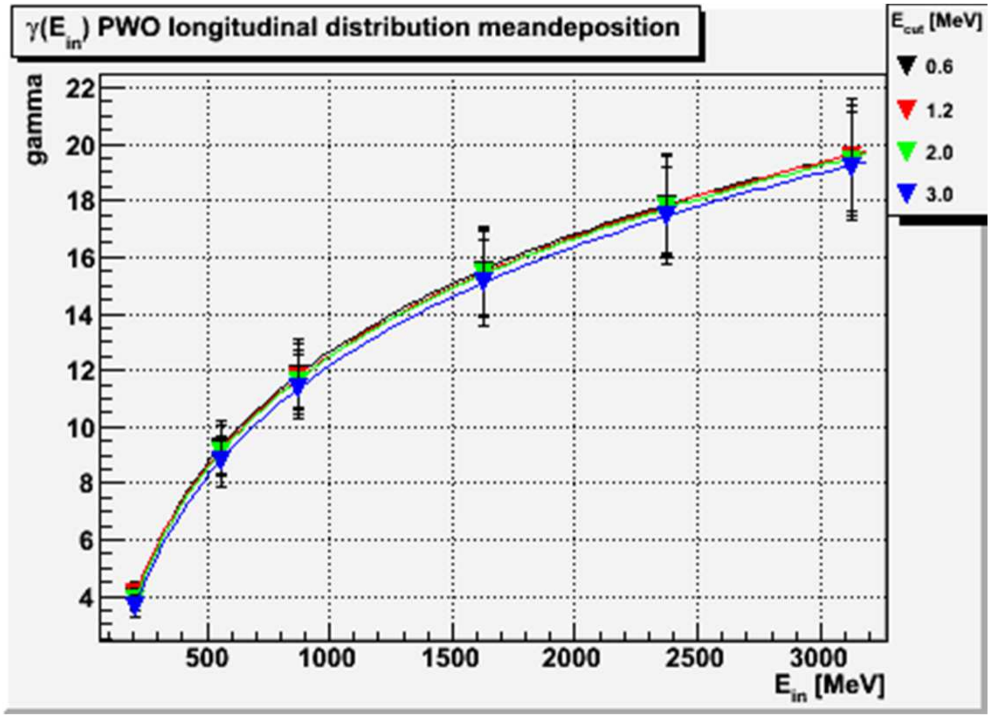
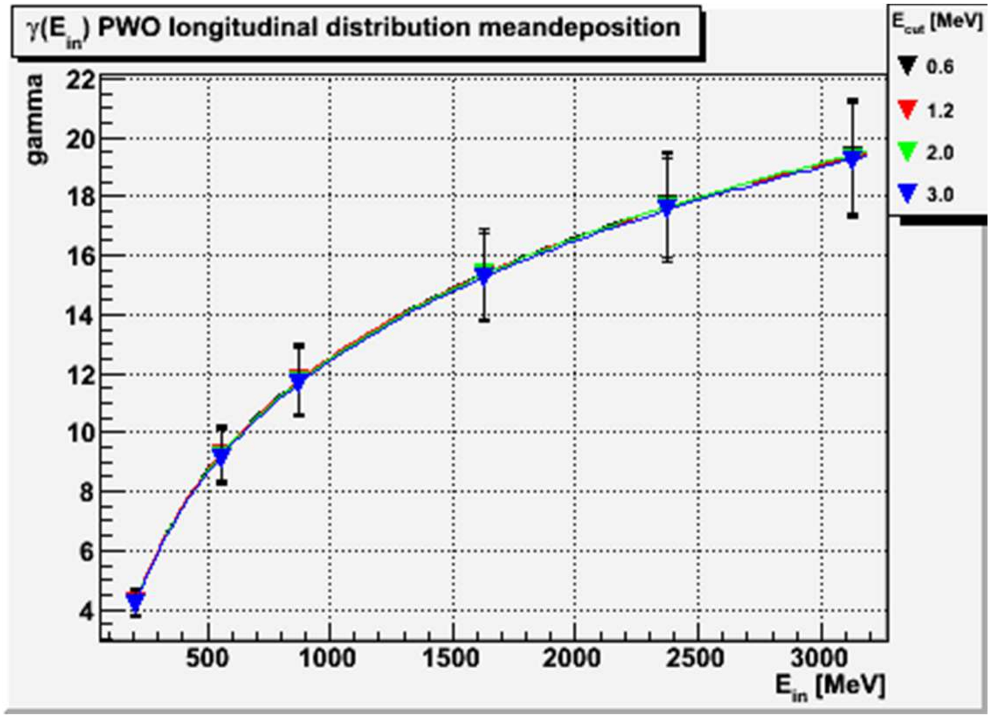
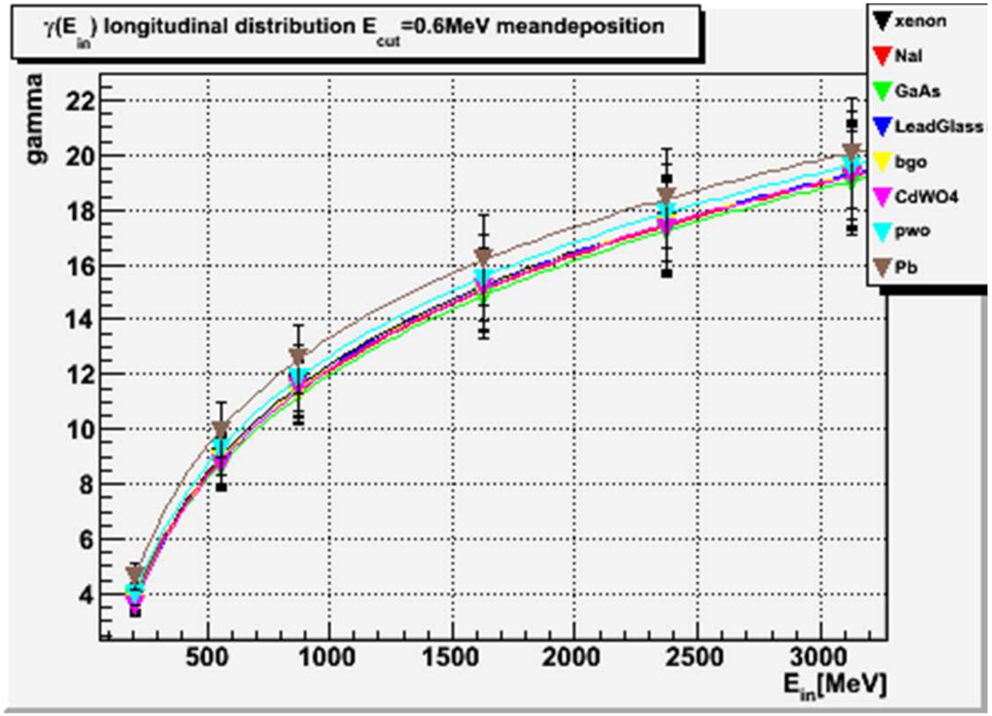
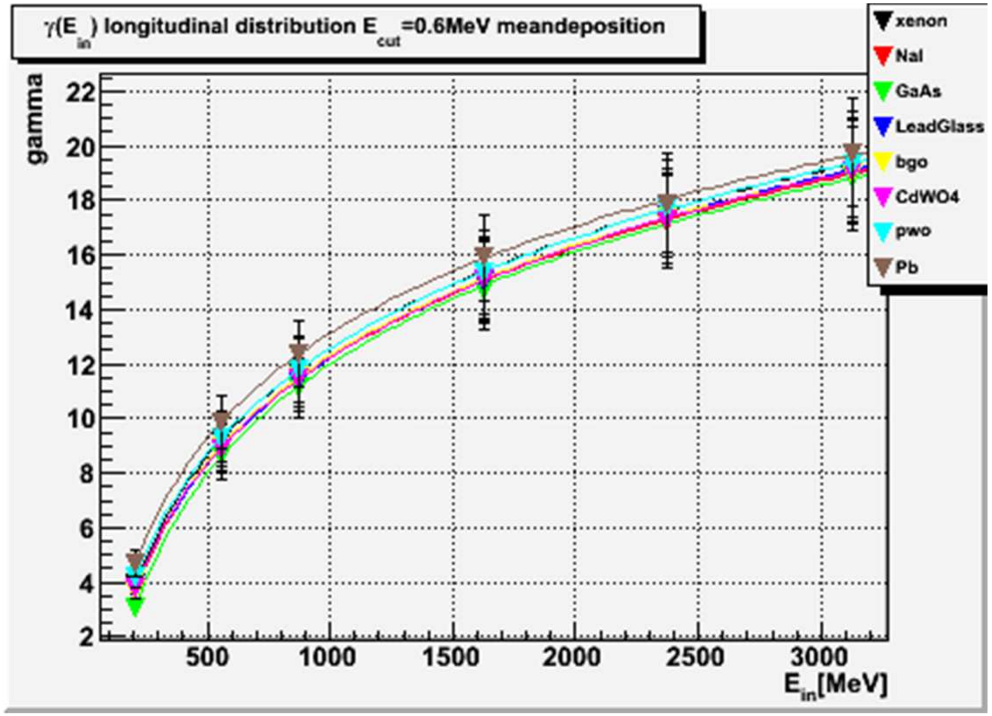


EGS4



GEANT4


γ(E_in) longitudinal distribution E_cut=0.6MeV meandeposition
gamma
E_in[MeV]
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb

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E_in[MeV]
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NaI
GaAs
LeadGlass
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CdWO4
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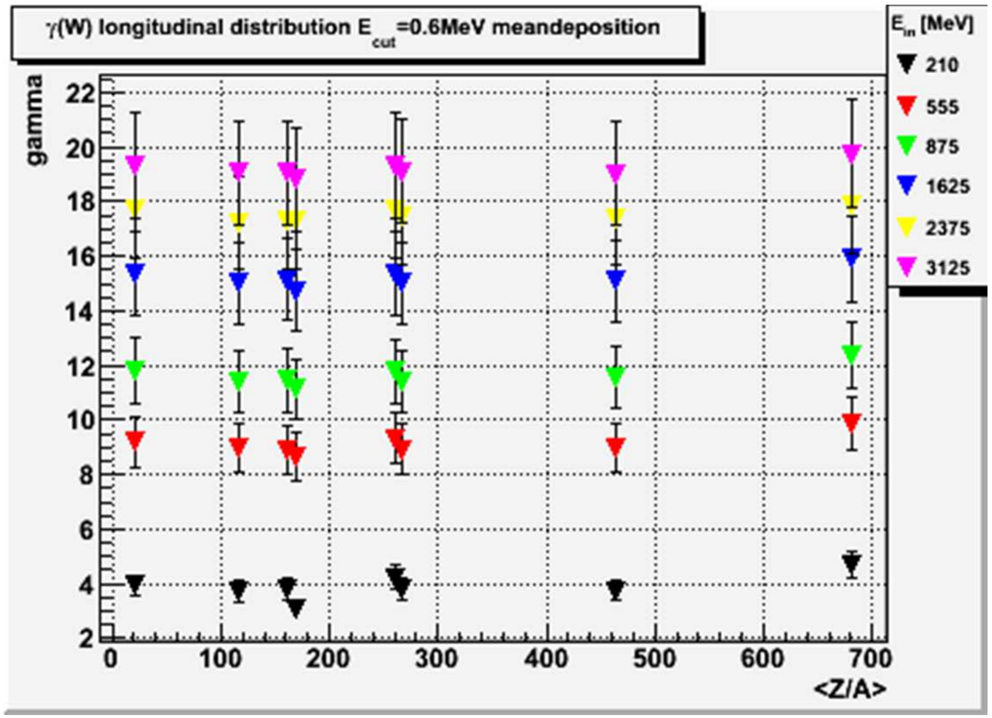
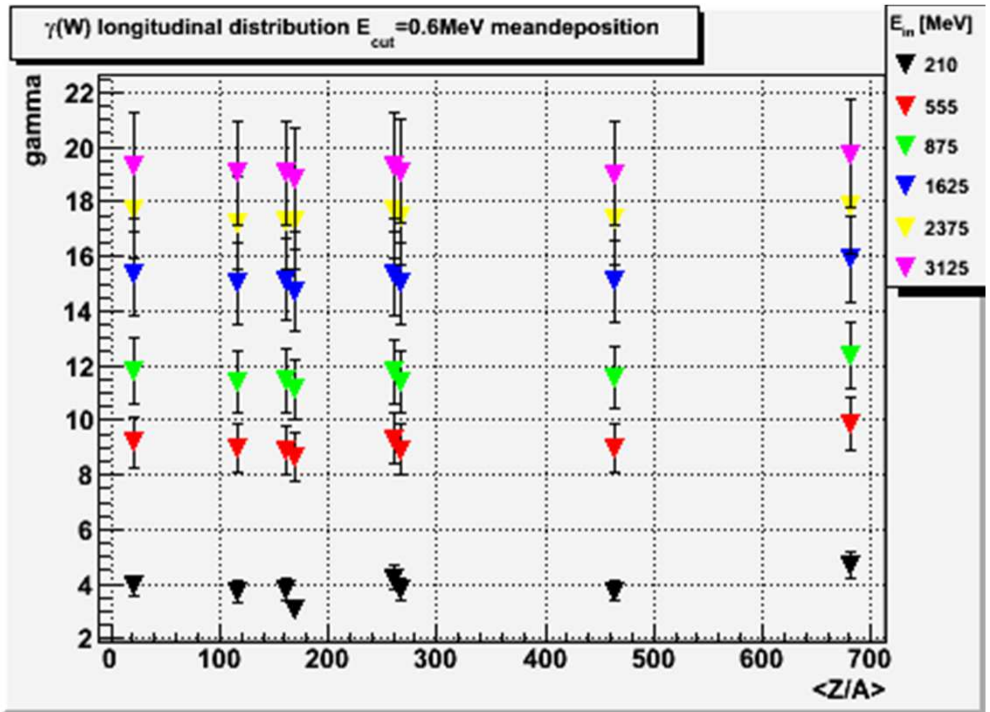
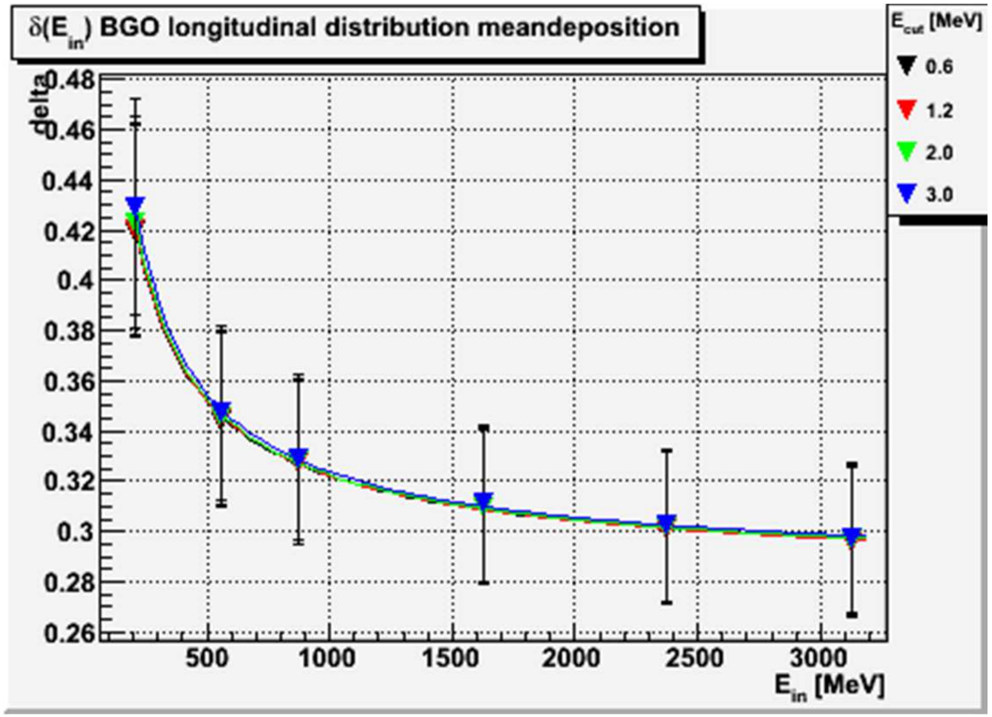
Pb

γ(W) longitudinal distribution E_cut=0.6MeV meandeposition
gamma
<Z/A>
E_in [MeV]
210
555
875
1625
2375
3125

γ(W) longitudinal distribution E_cut=0.6MeV meandeposition
gamma
<Z/A>
E_in [MeV]
210
555
875
1625
2375
3125

Parameter

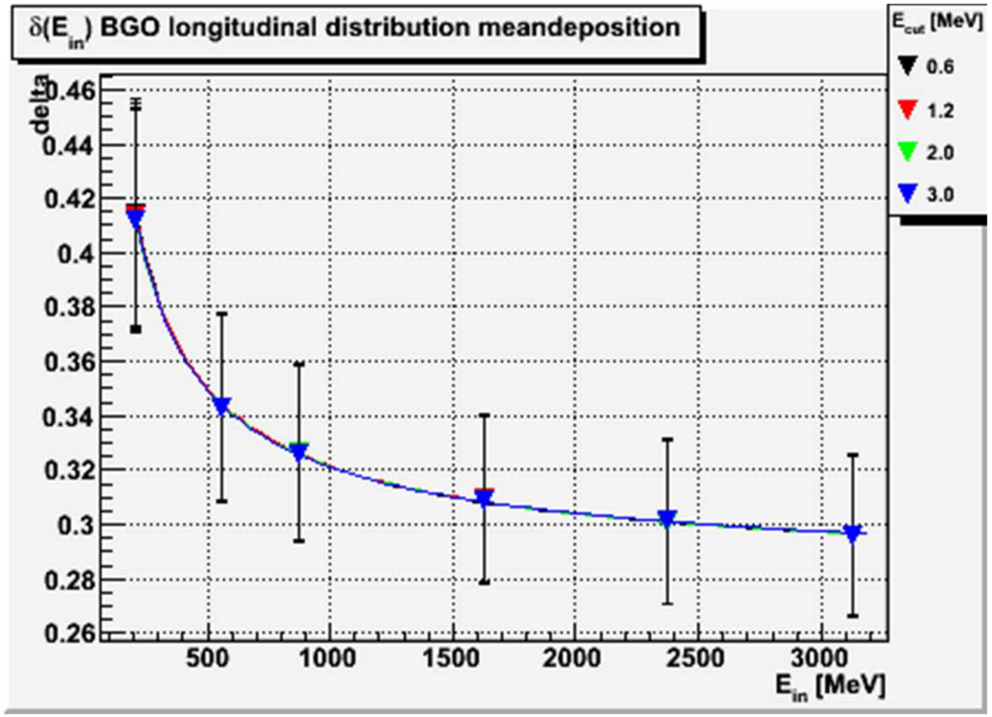
δ_t

BGO

$$\delta_t(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$



EGS4



GEANT4

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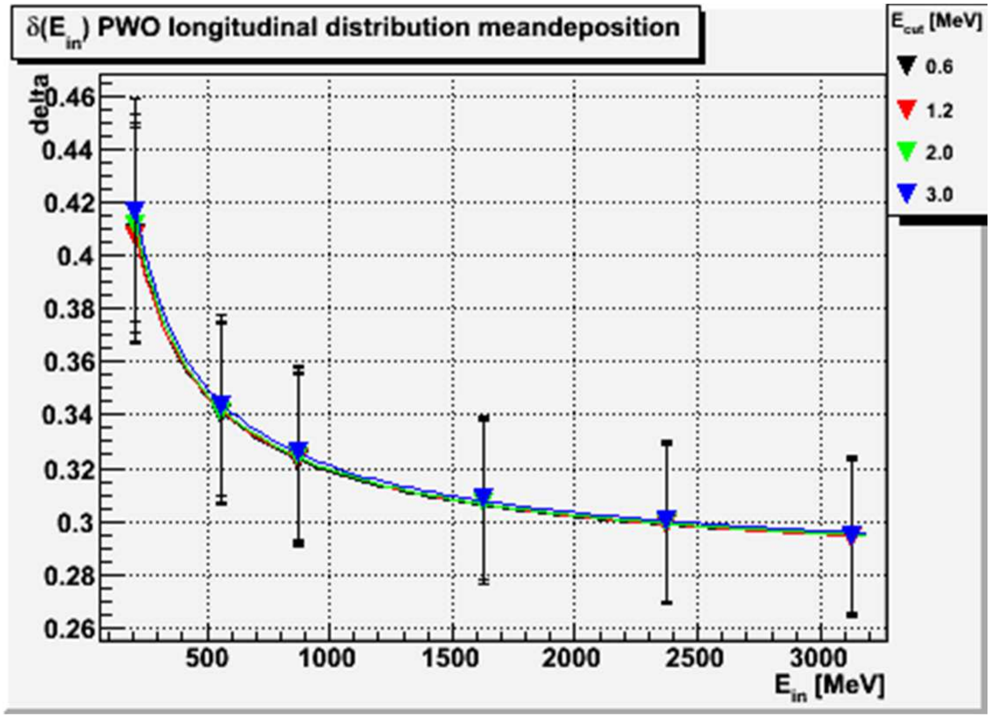
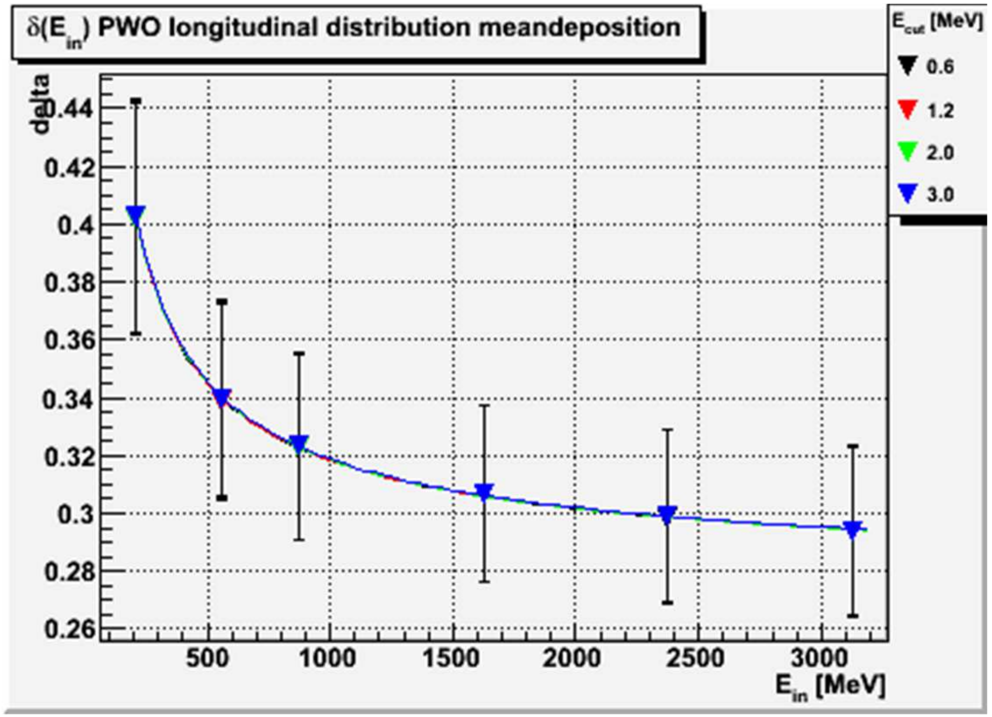
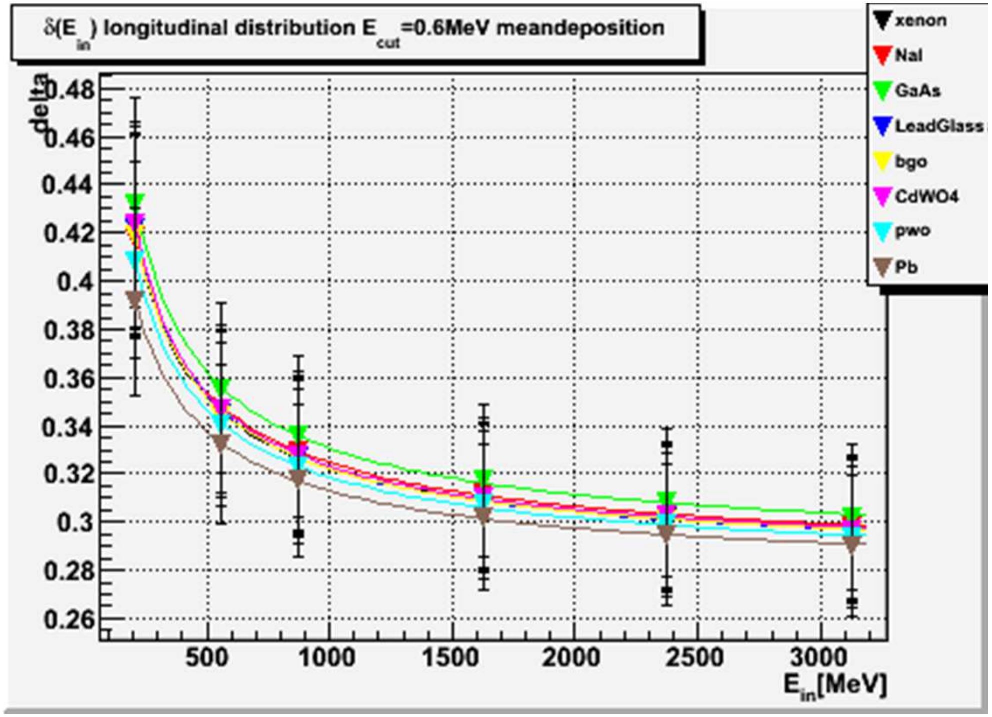
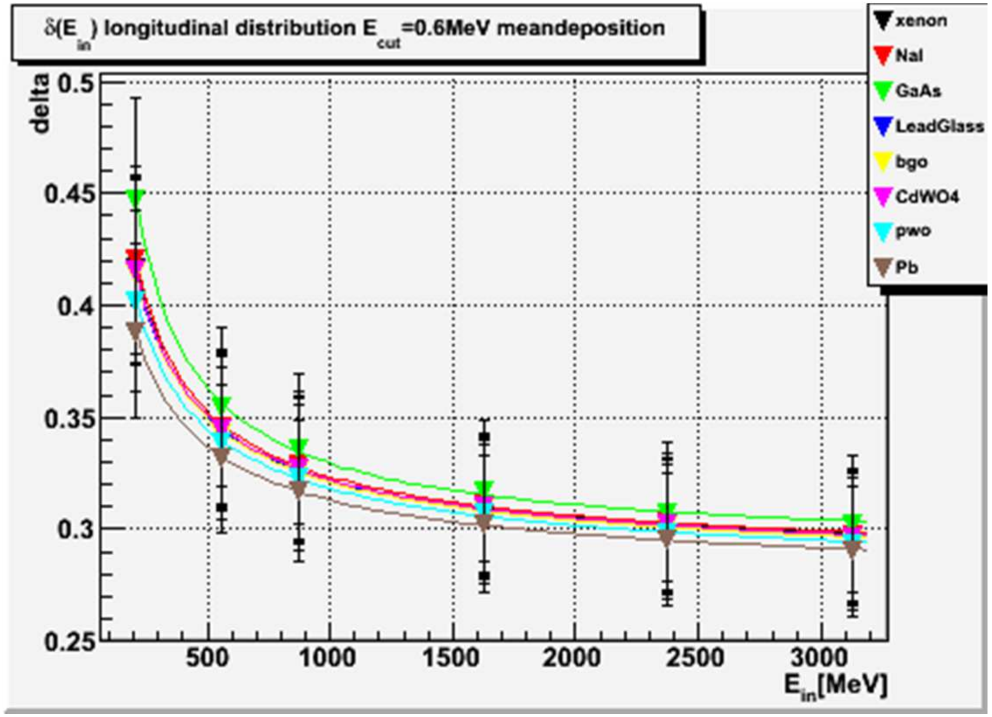


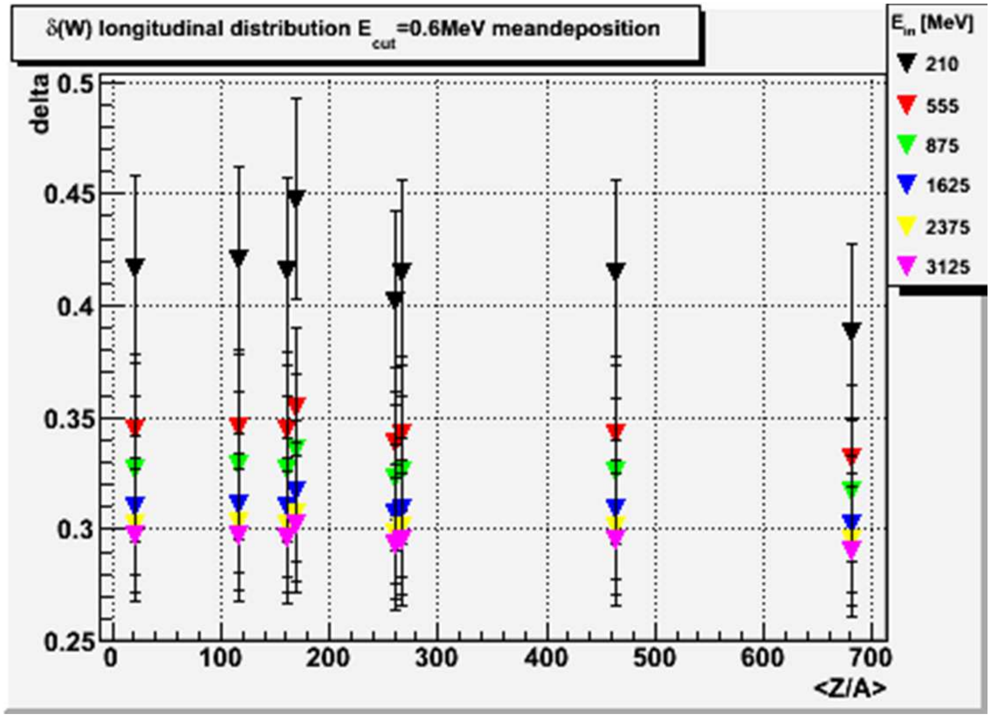


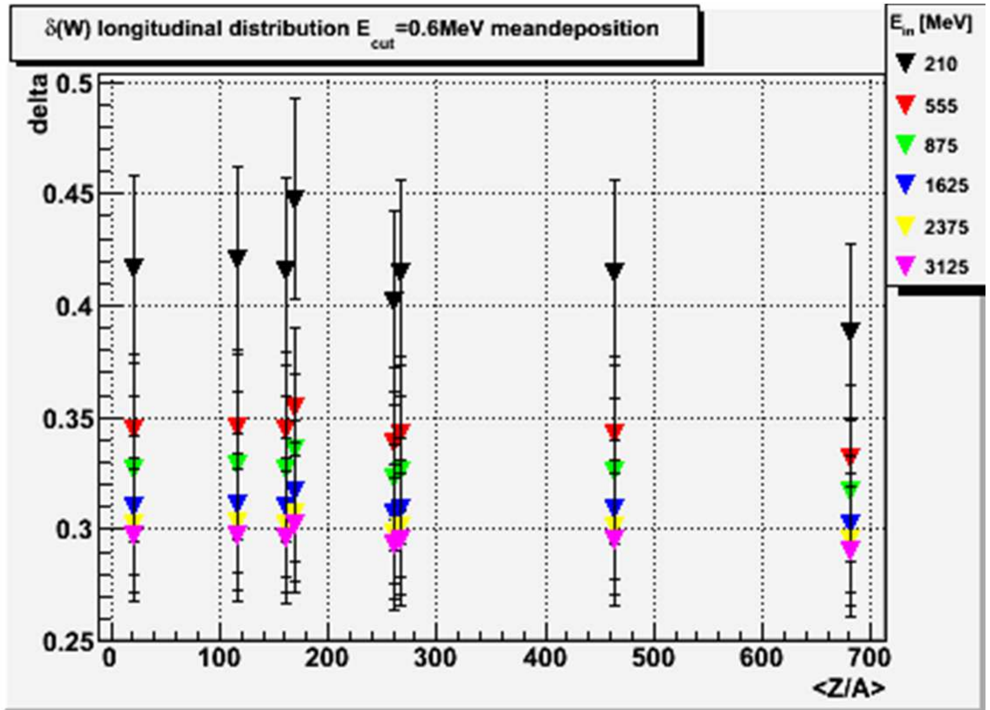
EGS4

GEANT4


δ(E_in) longitudinal distribution E_cut=0.6MeV meandeposition
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb
delta
0.26
0.28
0.3
0.32
0.34
0.36
0.38
0.4
0.42
0.44
0.46
0.48
500
1000
1500
2000
2500
3000
E_in[MeV]


δ(E_in) longitudinal distribution E_cut=0.6MeV meandeposition
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb
delta
0.25
0.3
0.35
0.4
0.45
0.5
500
1000
1500
2000
2500
3000
E_in[MeV]


δ(W) longitudinal distribution E_cut=0.6MeV meandeposition
E_in [MeV]
210
555
875
1625
2375
3125
delta
0.25
0.3
0.35
0.4
0.45
0.5
0
100
200
300
400
500
600
700
<Z/A>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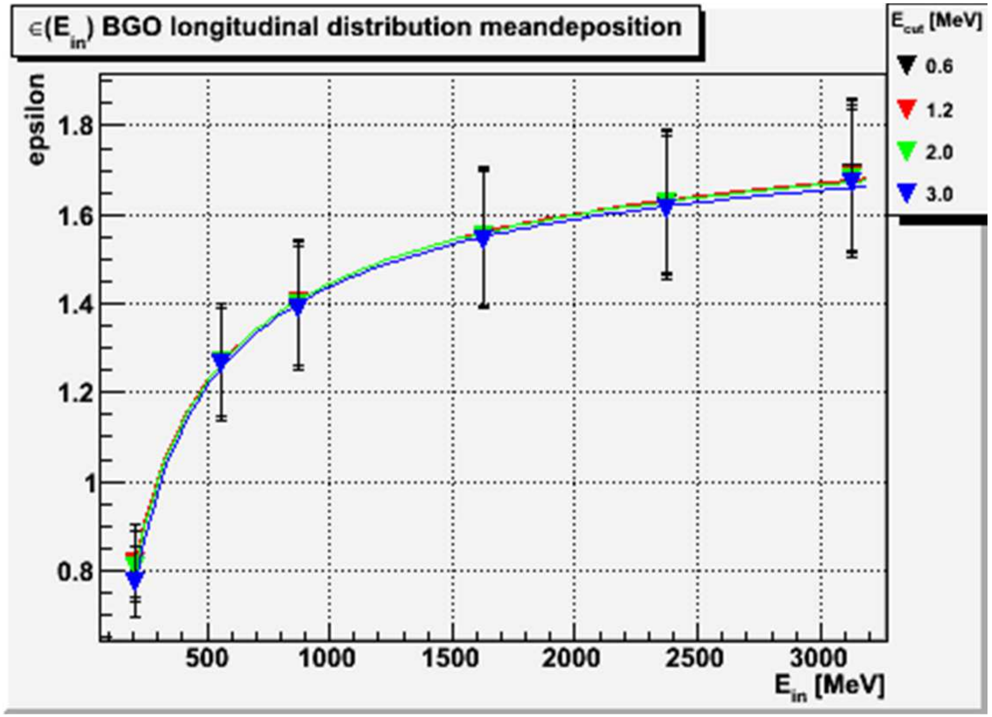
E_in [MeV]
210
555
875
1625
2375
3125
delta
0.25
0.3
0.35
0.4
0.45
0.5
0
100
200
300
400
500
600
700
<Z/A>

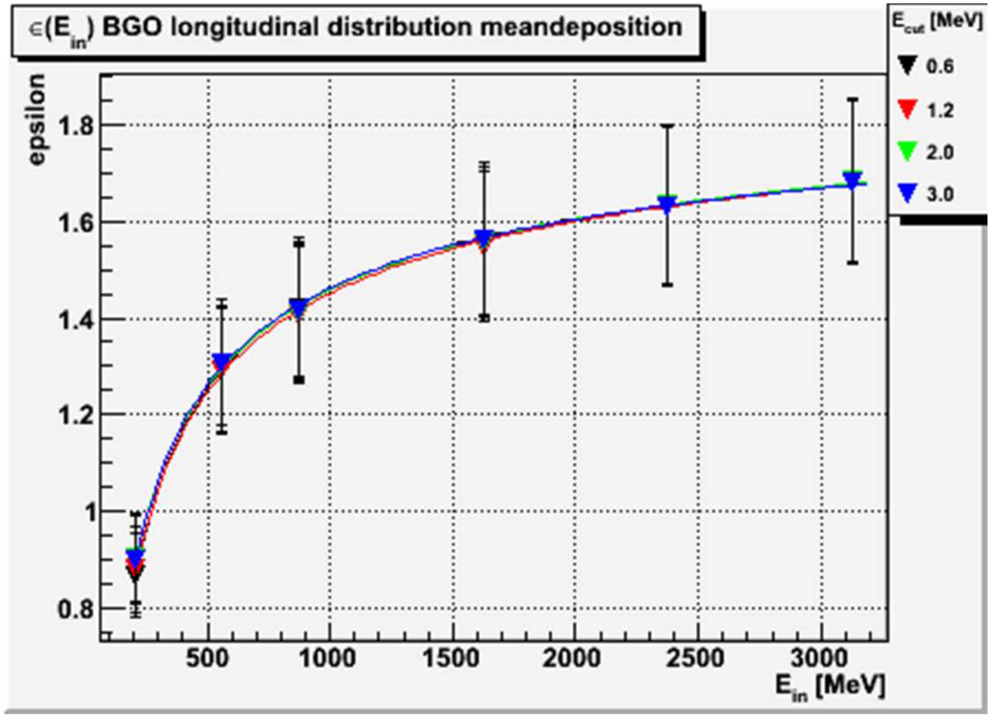
Parameter

ε_t

BGO

$$\varepsilon_t(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$



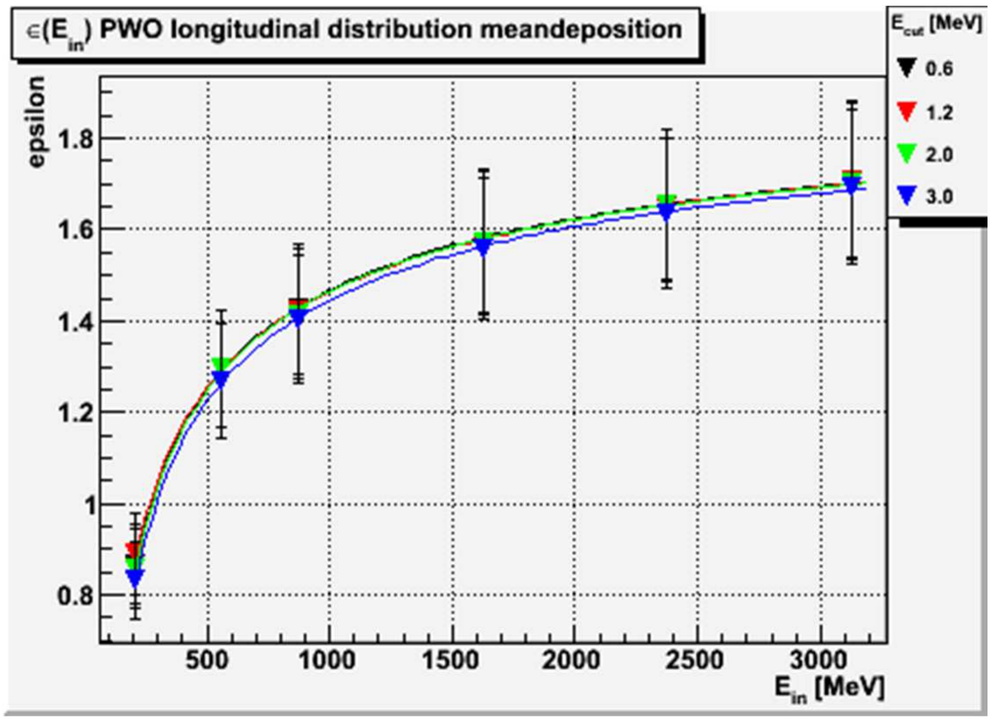


EGS4

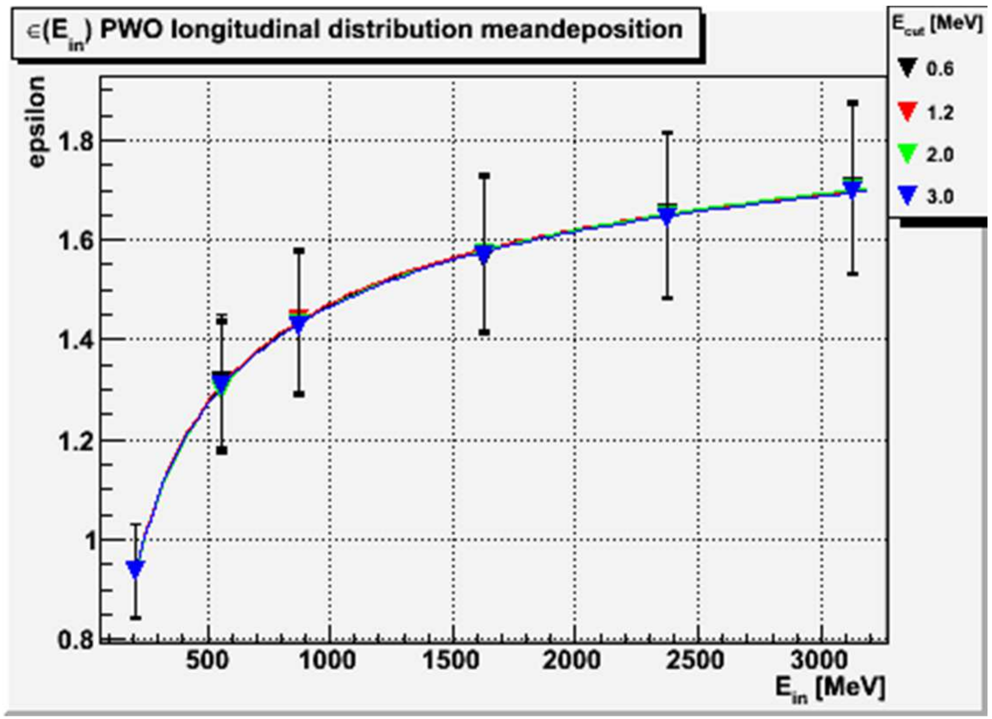
GEANT4

PWO

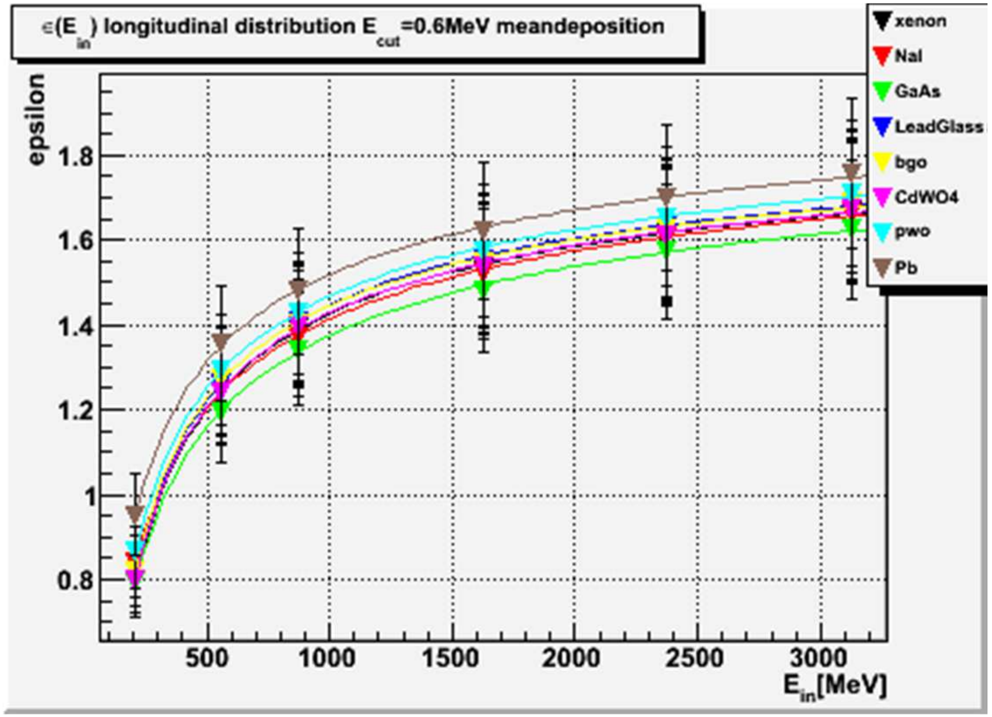
$$\varepsilon_t(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$



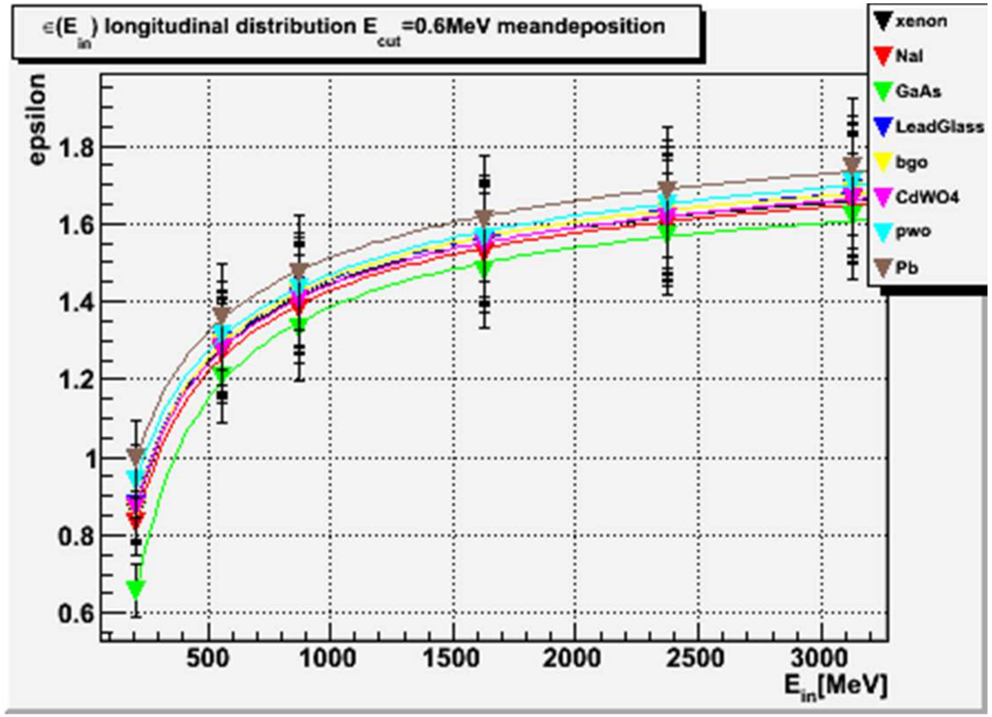
EGS4



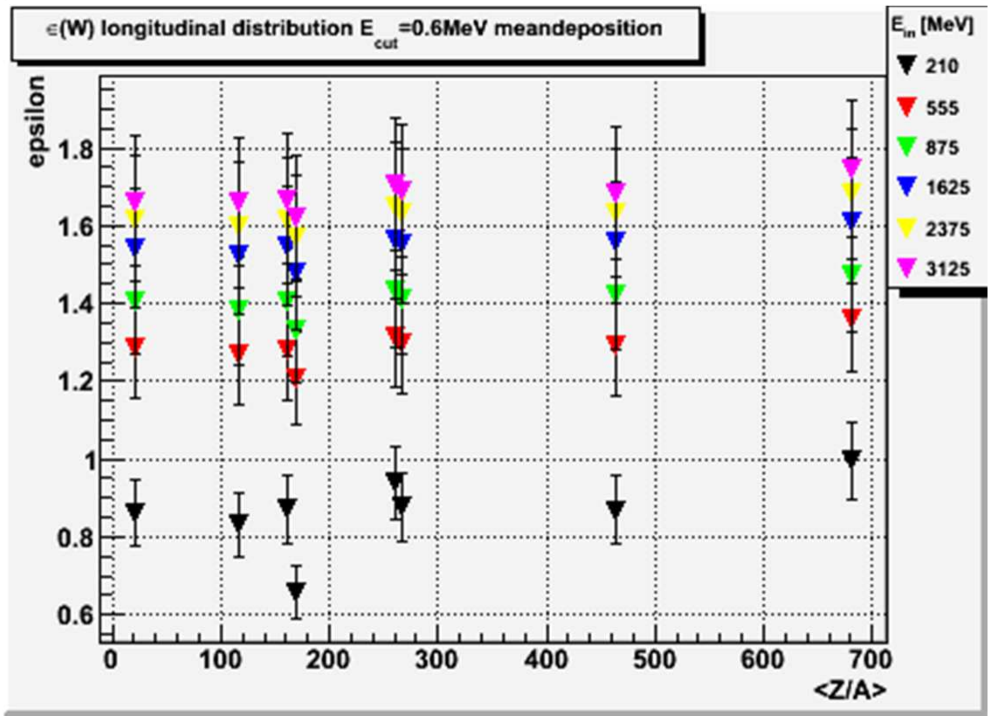
GEANT4



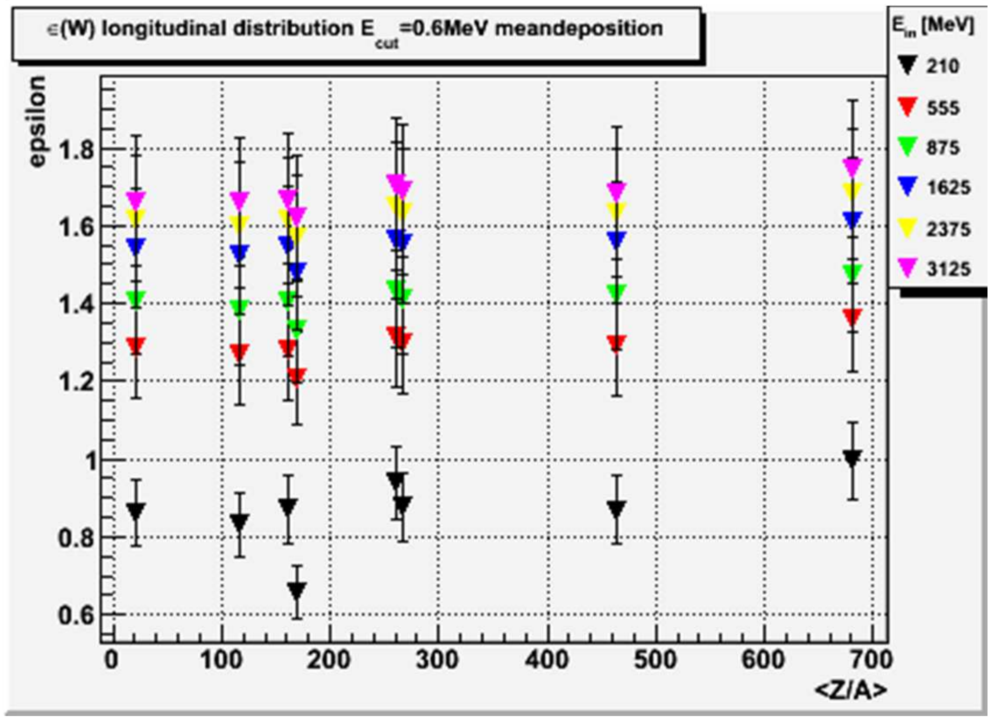
∊(E_in) longitudinal distribution E_cut=0.6MeV meandeposition
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb
epsilon
0.8
1
1.2
1.4
1.6
1.8
500
1000
1500
2000
2500
3000
E_in[MeV]



∊(E_in) longitudinal distribution E_cut=0.6MeV meandeposition
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb
epsilon
0.6
0.8
1
1.2
1.4
1.6
1.8
500
1000
1500
2000
2500
3000
E_in[MeV]



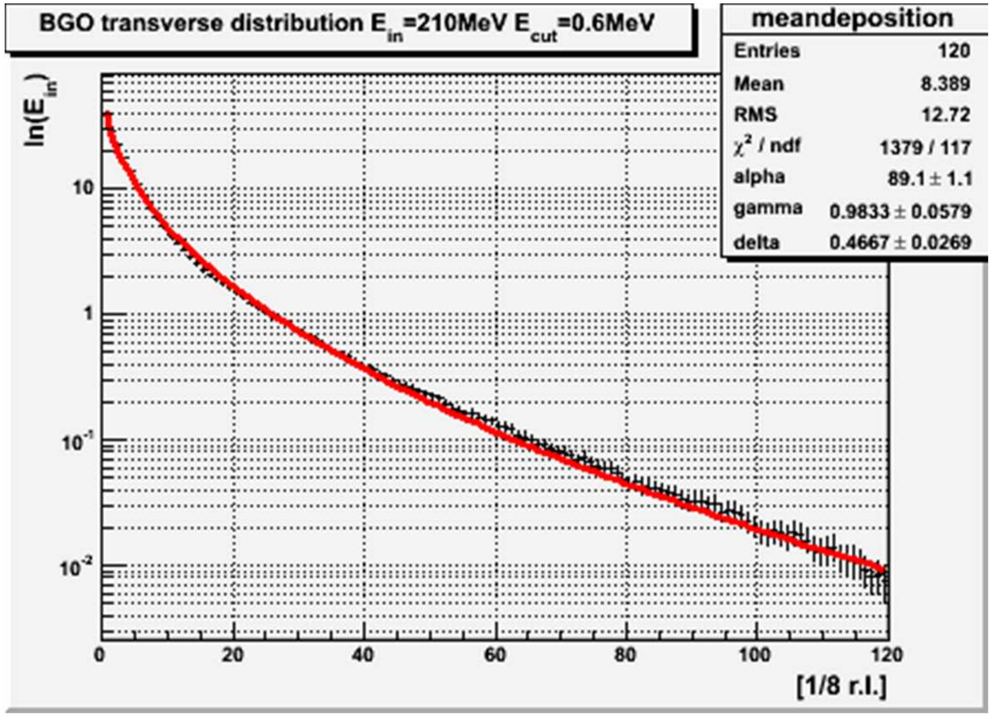
∊(W) longitudinal distribution E_cut=0.6MeV meandeposition
E_in [MeV]
210
555
875
1625
2375
3125
epsilon
0.6
0.8
1
1.2
1.4
1.6
1.8
0
100
200
300
400
500
600
700
<Z/A>



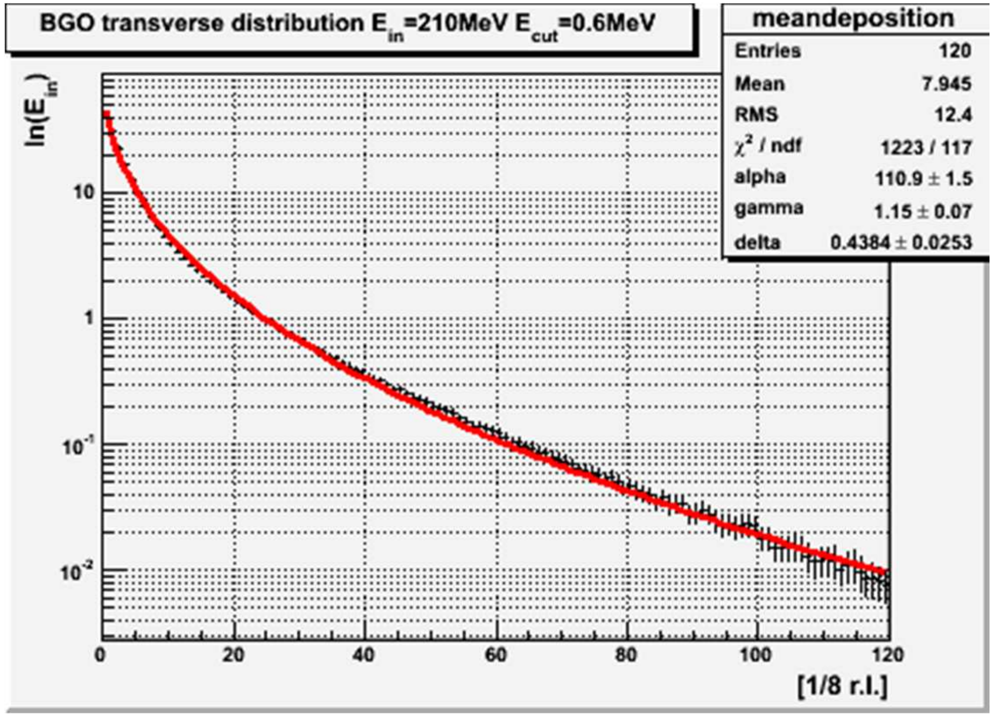
∊(W) longitudinal distribution E_cut=0.6MeV meandeposition
E_in [MeV]
210
555
875
1625
2375
3125
epsilon
0.6
0.8
1
1.2
1.4
1.6
1.8
0
100
200
300
400
500
600
700
<Z/A>

TRANSVERSE PROFILES

Average transverse profile of EMC produced in BGO by gammas of energy 210 MeV (E_{co}=0.6 MeV).



EGS4



GEANT4

APPROXIMATING FUNCTION

$$(-dE/dr) = \alpha_r \exp\left(-\gamma_r\, r^{\delta_r}\right)$$

α_r, δ_r, γ_r, are the fit parameters depending on cut-off energy $E_{c.o.}$, E_γ and material properties Z/A.

Dependence of parameters:

γ_r *and* δ_r

on

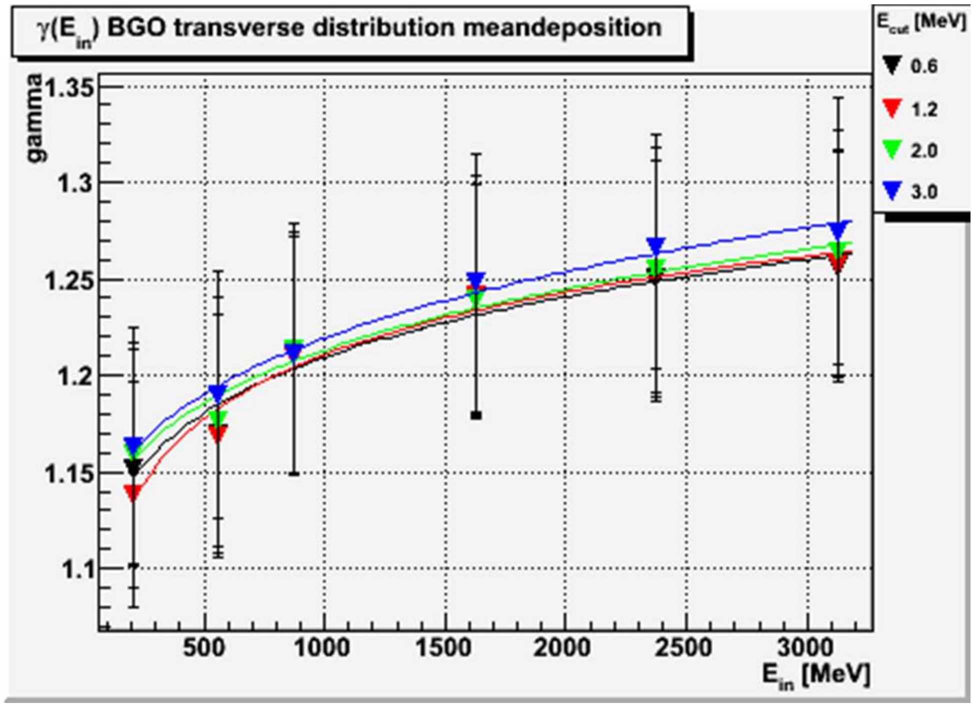
E_γ, $E_{c.o.}$, Z/A.

Parameter

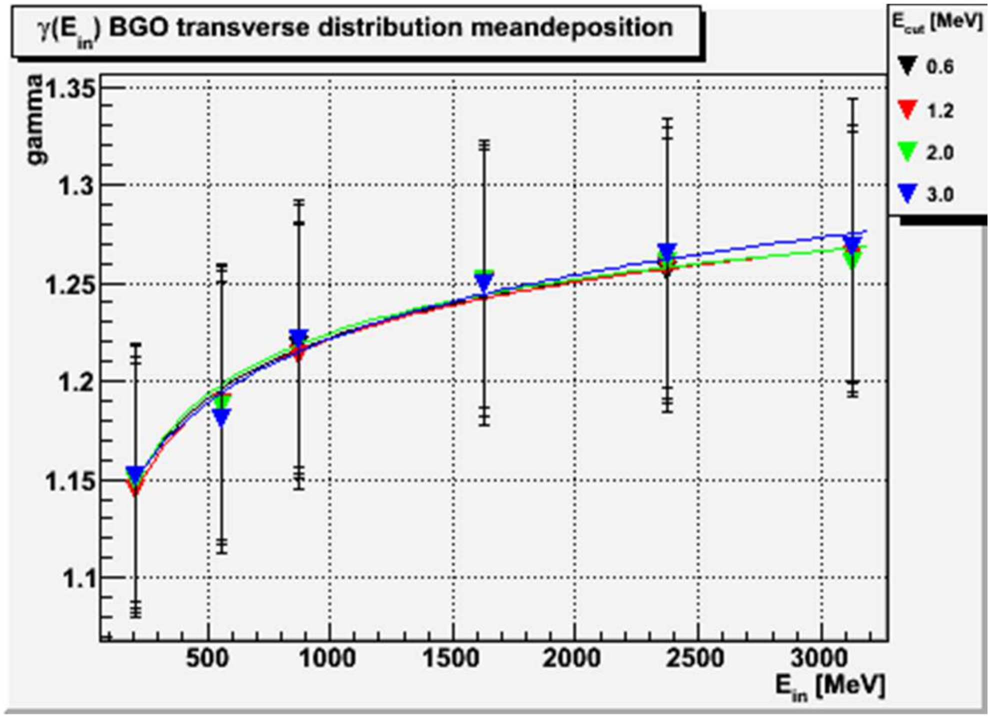
γ_r

BGO

$$\gamma_r(E_\gamma) = a \cdot E_\gamma{}^b + c$$



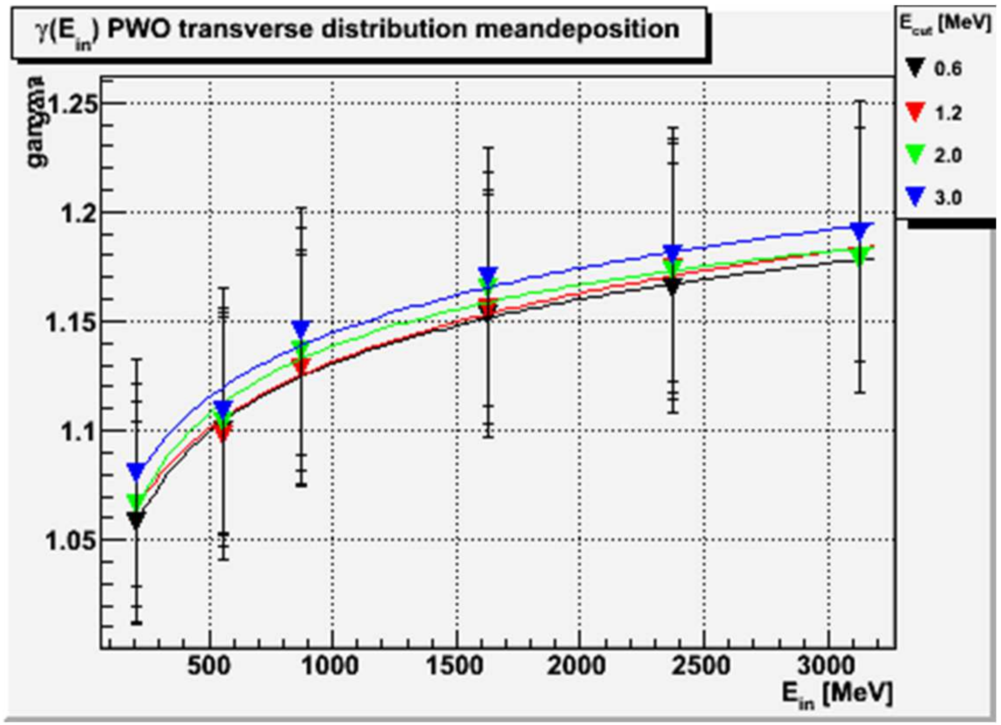
EGS4

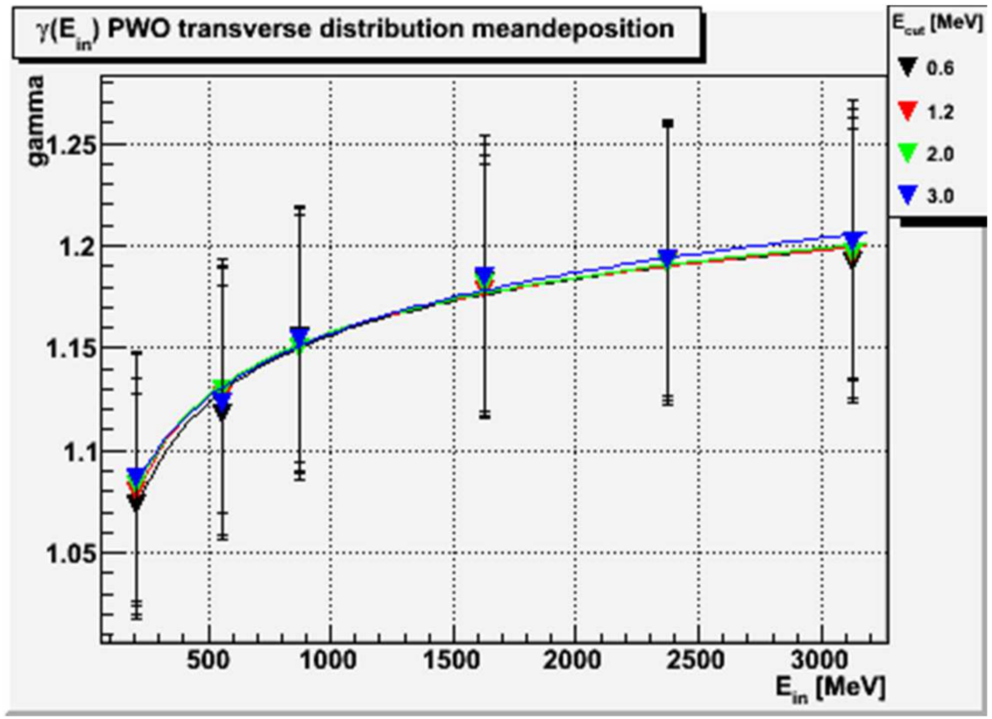


GEANT4

PWO

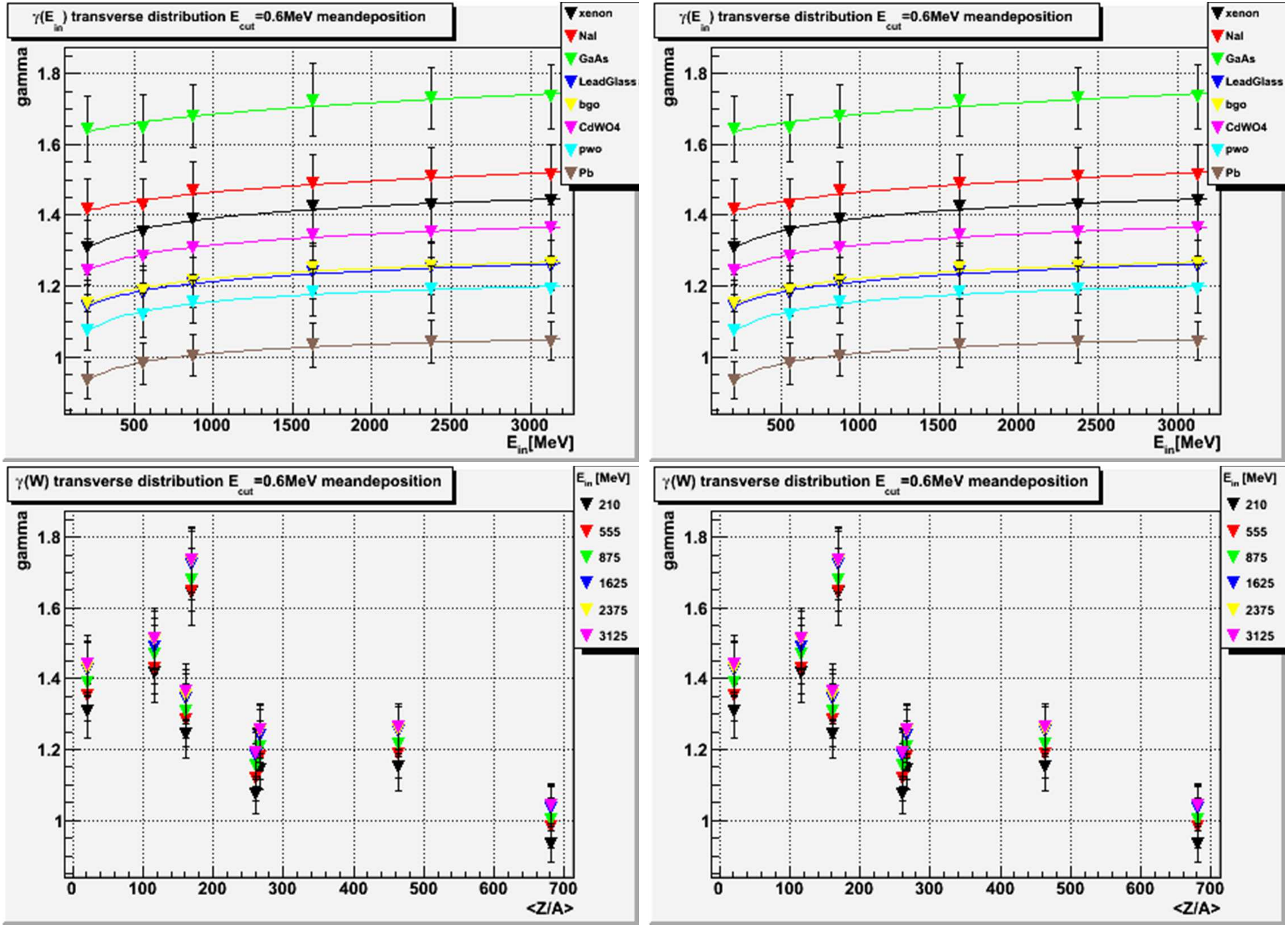
$$\gamma_r(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$





EGS4

GEANT4

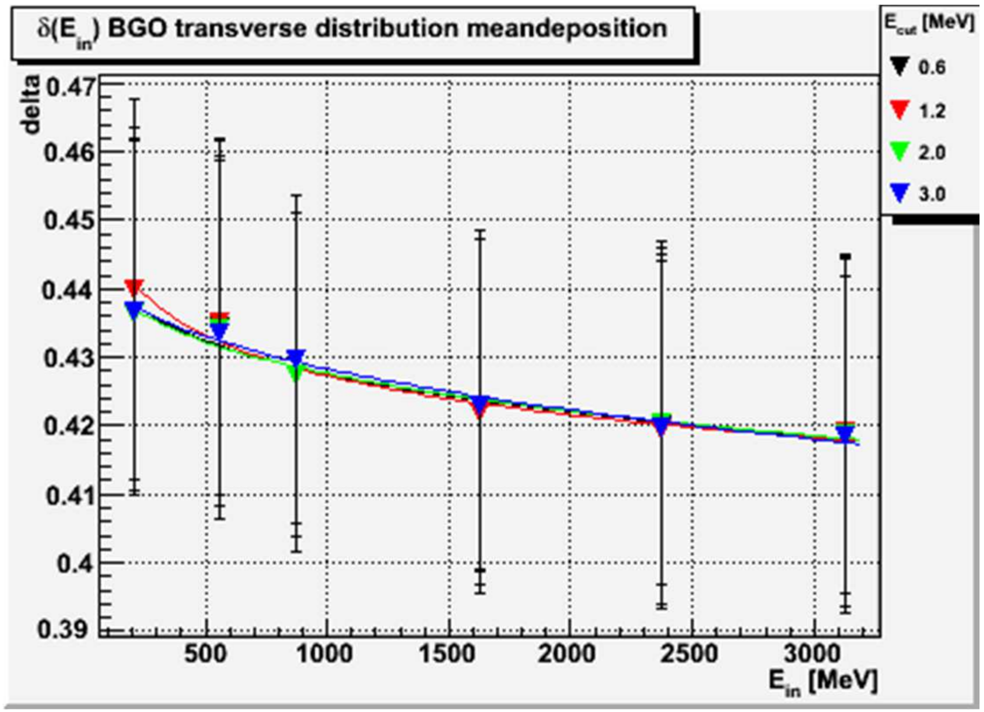

γ(E_in) transverse distribution E_cut=0.6MeV meandeposition
gamma
E_in[MeV]
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb
γ(W) transverse distribution E_cut=0.6MeV meandeposition
<Z/A>
E_in [MeV]
210
555
875
1625
2375
3125

Parameter

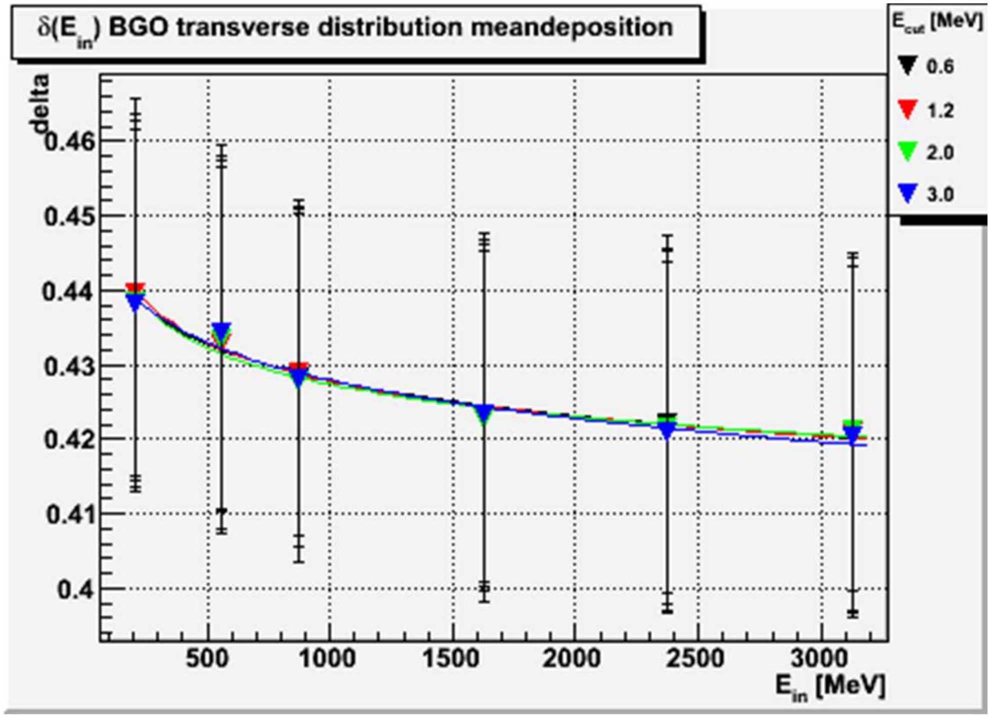
δ_t

BGO

$$\delta_r(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$



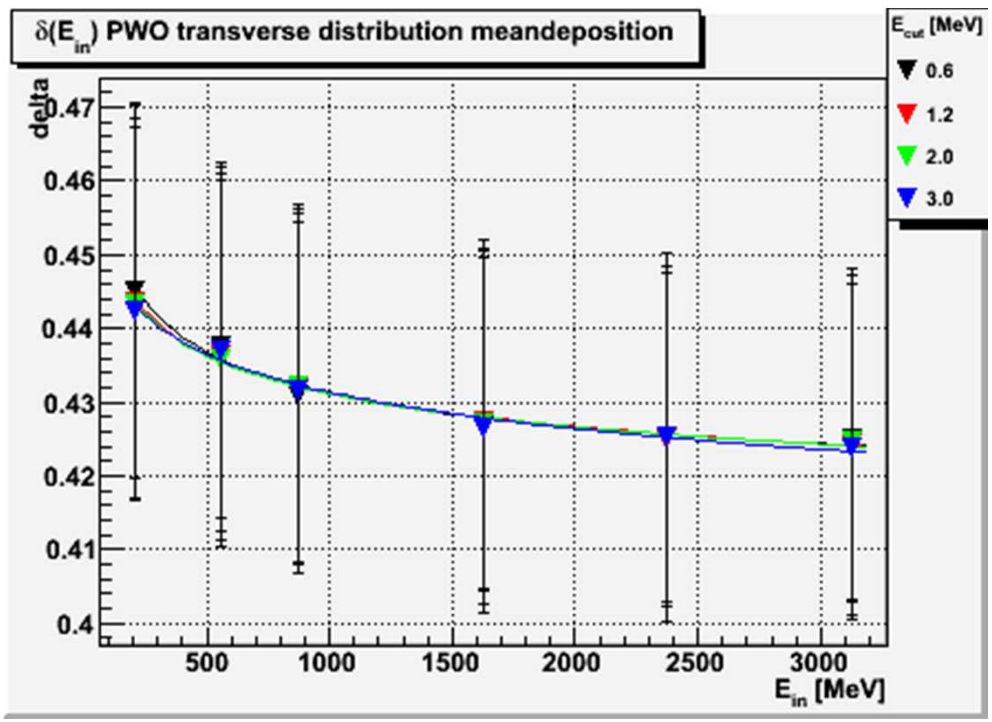
EGS4

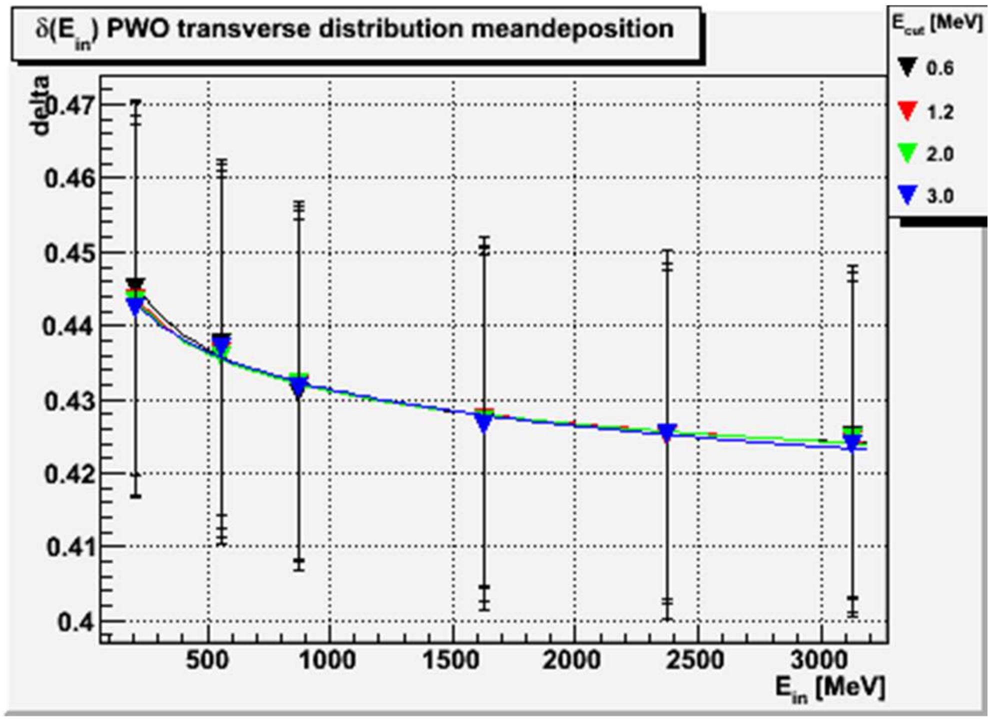


GEANT4

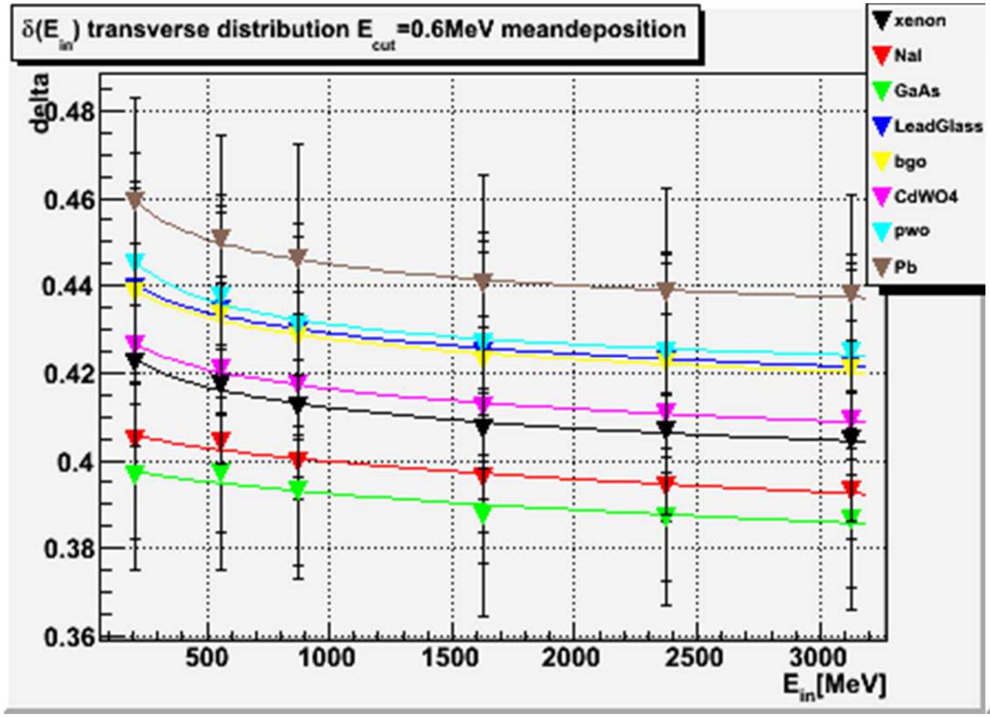
PWO

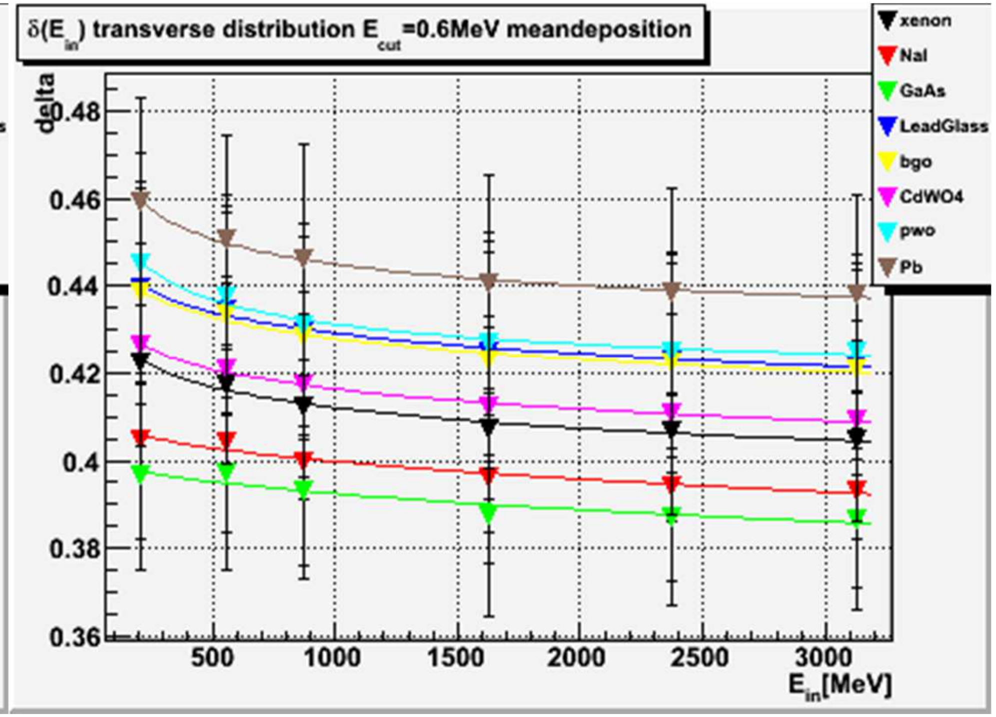
$$\delta_r(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$

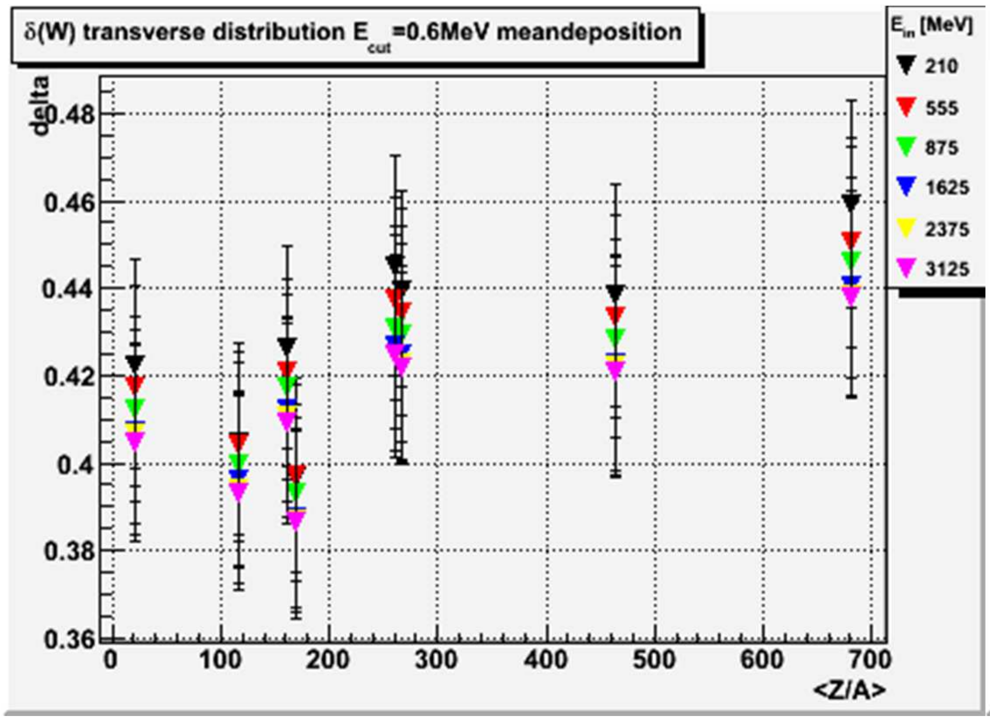


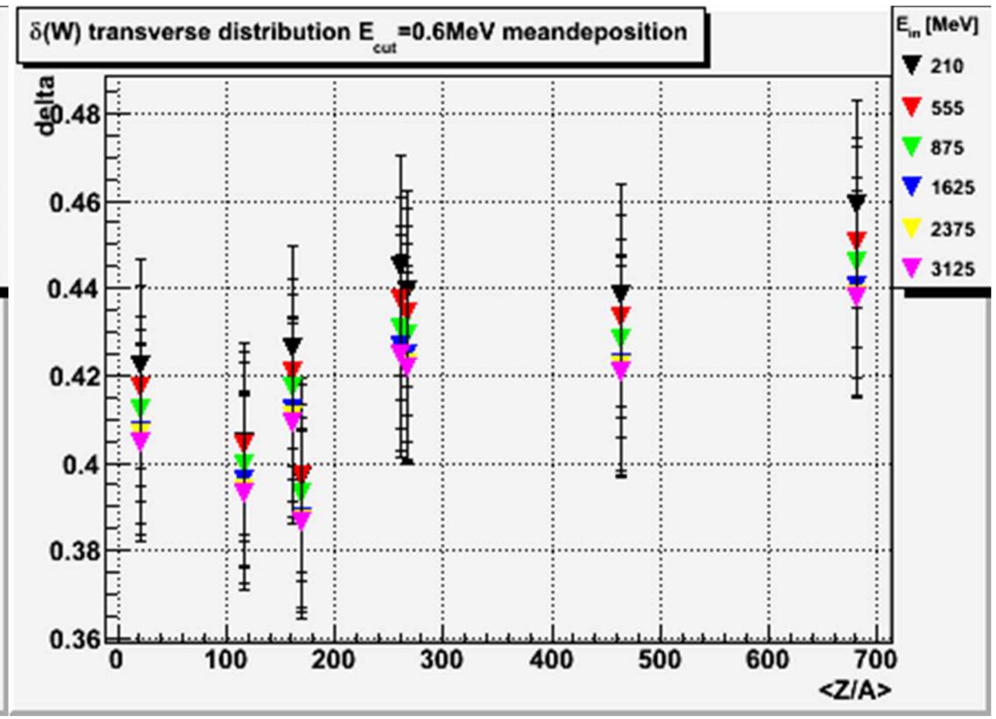


EGS4 *GEANT4*


δ(E_in) transverse distribution E_cut=0.6MeV meandeposition
delta
E_in[MeV]
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb


δ(E_in) transverse distribution E_cut=0.6MeV meandeposition
delta
E_in[MeV]
xenon
NaI
GaAs
LeadGlass
bgo
CdWO4
pwo
Pb


δ(W) transverse distribution E_cut=0.6MeV meandeposition
delta
<Z/A>
E_in [MeV]
210
555
875
1625
2375
3125


δ(W) transverse distribution E_cut=0.6MeV meandeposition
delta
<Z/A>
E_in [MeV]
210
555
875
1625
2375
3125

FLUCTUATIONS

Distributions of the depth t at which a fraction A of the total EMC energy is deposited

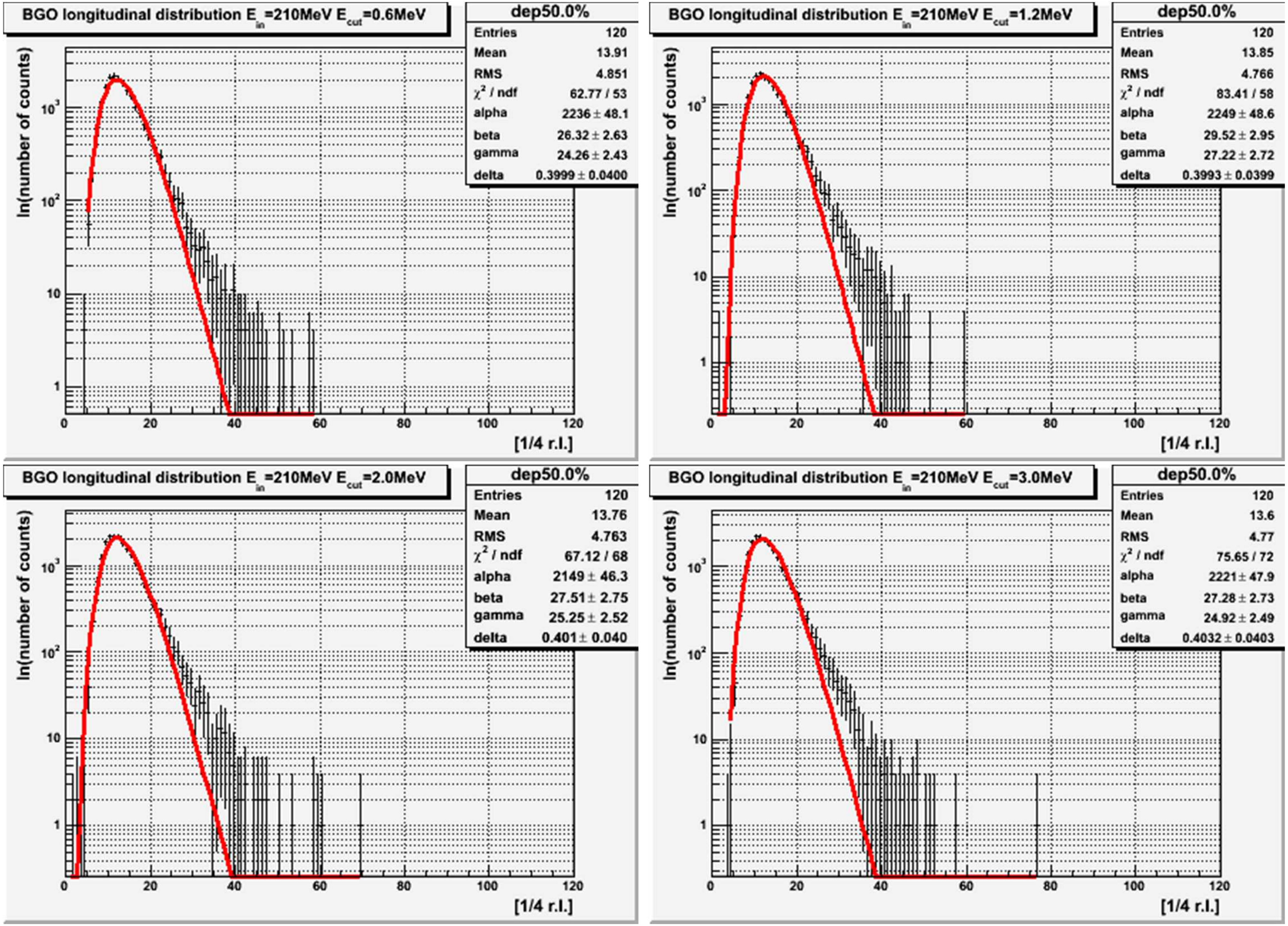
Fitting function for longitudinal and transverse fluctuation of EMC:

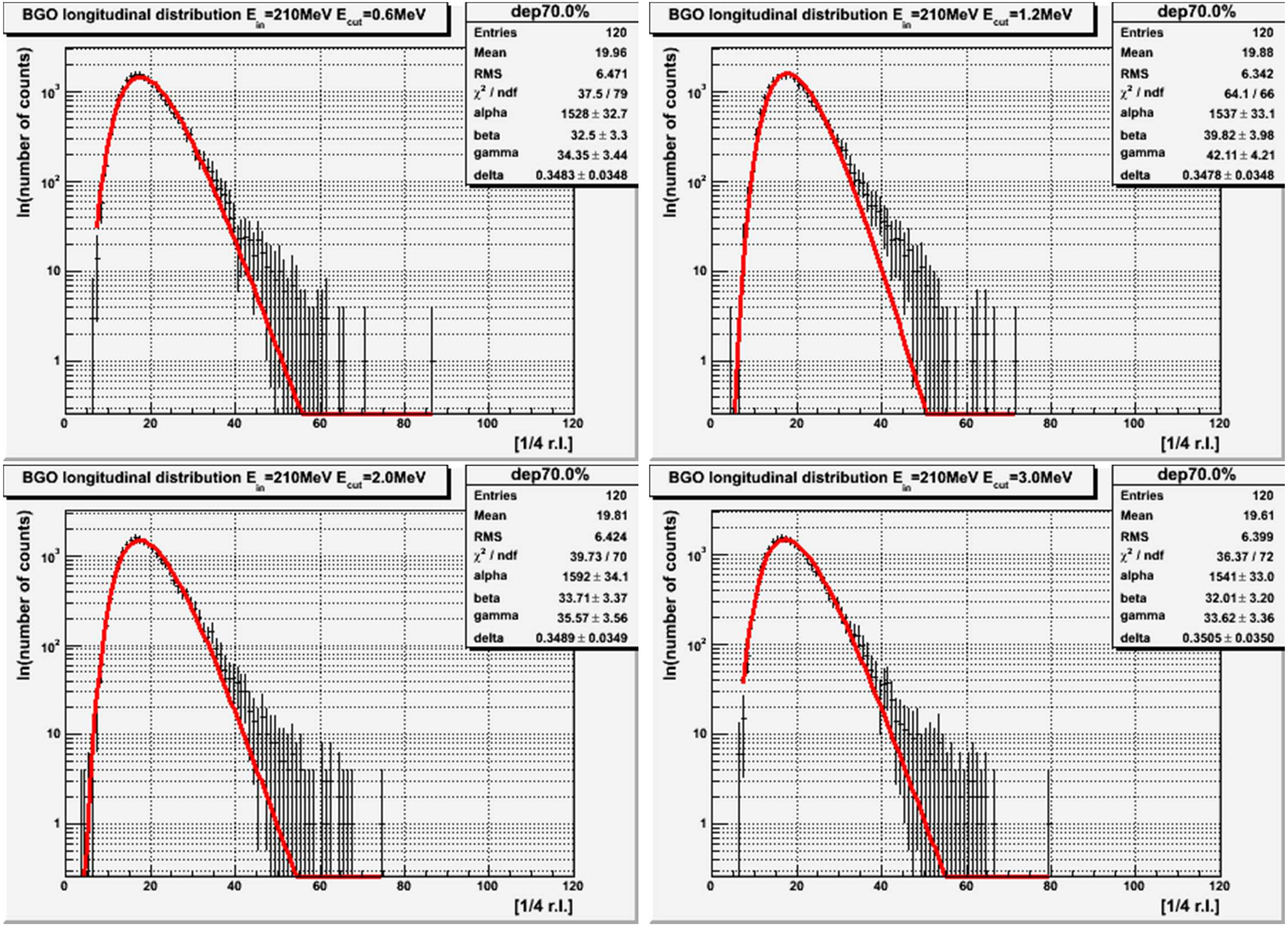
$$P(t_A) = \alpha\, t_A{}^{\beta} \exp\left(-\gamma\, t_A{}^{\delta}\right)$$

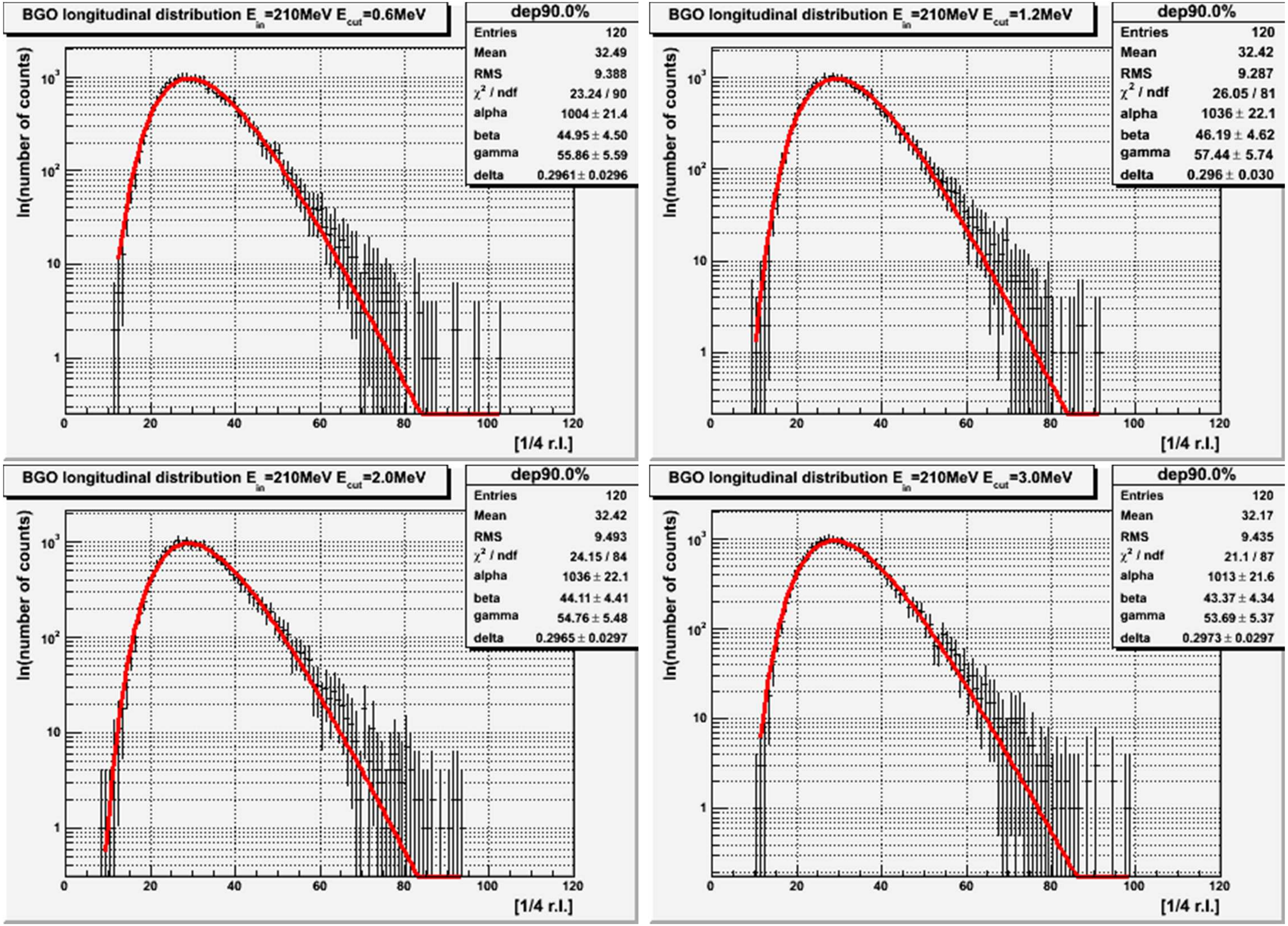
LONGITUDINAL

Illustration for Eγ = 210 MeV in BGO

Distributions of the shower depth t_A at which a fixed part A of average cascade energy is released when the cascade is initiated by gamma quanta of energy E_γ = 1625 MeV and detected with the cut-off energies $E_{c.o.}$ = 0.6, 1.2, 2.0 and 3.0 MeV (histograms).


BGO longitudinal distribution E_in=210MeV E_cut=0.6MeV
dep50.0%
Entries 120
Mean 13.91
RMS 4.851
χ² / ndf 62.77 / 53
alpha 2236 ± 48.1
beta 26.32 ± 2.63
gamma 24.26 ± 2.43
delta 0.3999 ± 0.0400
ln(number of counts)
[1/4 r.l.]
BGO longitudinal distribution E_in=210MeV E_cut=1.2MeV
dep50.0%
Entries 120
Mean 13.85
RMS 4.766
χ² / ndf 83.41 / 58
alpha 2249 ± 48.6
beta 29.52 ± 2.95
gamma 27.22 ± 2.72
delta 0.3993 ± 0.0399
ln(number of counts)
[1/4 r.l.]
BGO longitudinal distribution E_in=210MeV E_cut=2.0MeV
dep50.0%
Entries 120
Mean 13.76
RMS 4.763
χ² / ndf 67.12 / 68
alpha 2149 ± 46.3
beta 27.51 ± 2.75
gamma 25.25 ± 2.52
delta 0.401 ± 0.040
ln(number of counts)
[1/4 r.l.]
BGO longitudinal distribution E_in=210MeV E_cut=3.0MeV
dep50.0%
Entries 120
Mean 13.6
RMS 4.77
χ² / ndf 75.65 / 72
alpha 2221 ± 47.9
beta 27.28 ± 2.73
gamma 24.92 ± 2.49
delta 0.4032 ± 0.0403
ln(number of counts)
[1/4 r.l.]

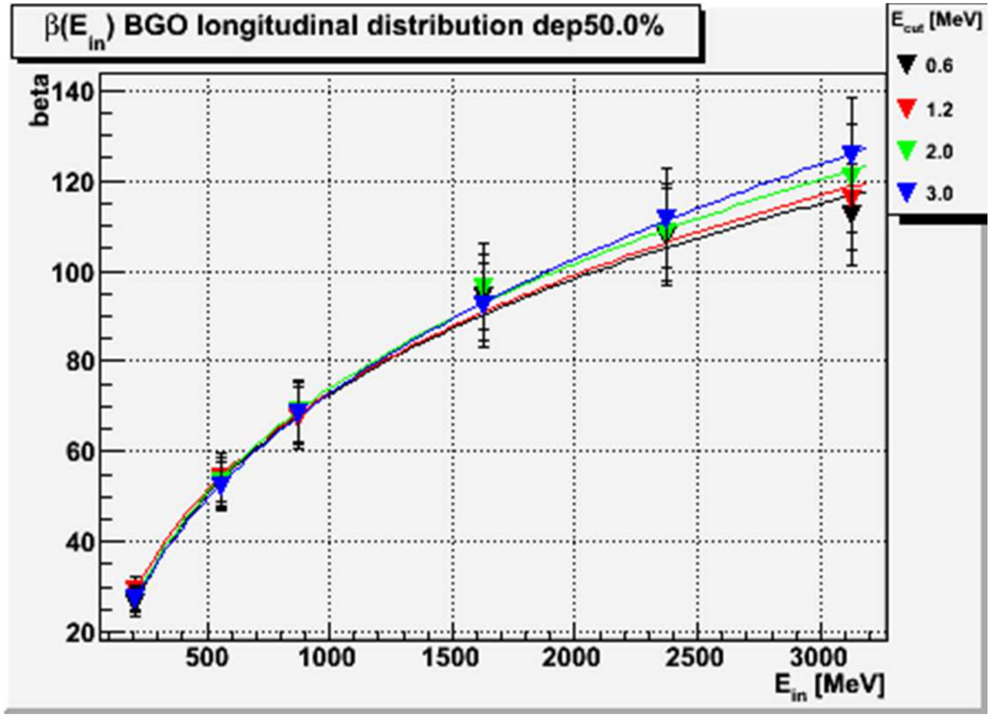

BGO longitudinal distribution E_in=210MeV E_cut=0.6MeV
dep70.0%
Entries 120
Mean 19.96
RMS 6.471
χ² / ndf 37.5 / 79
alpha 1528 ± 32.7
beta 32.5 ± 3.3
gamma 34.35 ± 3.44
delta 0.3483 ± 0.0348
ln(number of counts)
[1/4 r.l.]
BGO longitudinal distribution E_in=210MeV E_cut=1.2MeV
dep70.0%
Entries 120
Mean 19.88
RMS 6.342
χ² / ndf 64.1 / 66
alpha 1537 ± 33.1
beta 39.82 ± 3.98
gamma 42.11 ± 4.21
delta 0.3478 ± 0.0348
ln(number of counts)
[1/4 r.l.]
BGO longitudinal distribution E_in=210MeV E_cut=2.0MeV
dep70.0%
Entries 120
Mean 19.81
RMS 6.424
χ² / ndf 39.73 / 70
alpha 1592 ± 34.1
beta 33.71 ± 3.37
gamma 35.57 ± 3.56
delta 0.3489 ± 0.0349
ln(number of counts)
[1/4 r.l.]
BGO longitudinal distribution E_in=210MeV E_cut=3.0MeV
dep70.0%
Entries 120
Mean 19.61
RMS 6.399
χ² / ndf 36.37 / 72
alpha 1541 ± 33.0
beta 32.01 ± 3.20
gamma 33.62 ± 3.36
delta 0.3505 ± 0.0350
ln(number of counts)
[1/4 r.l.]

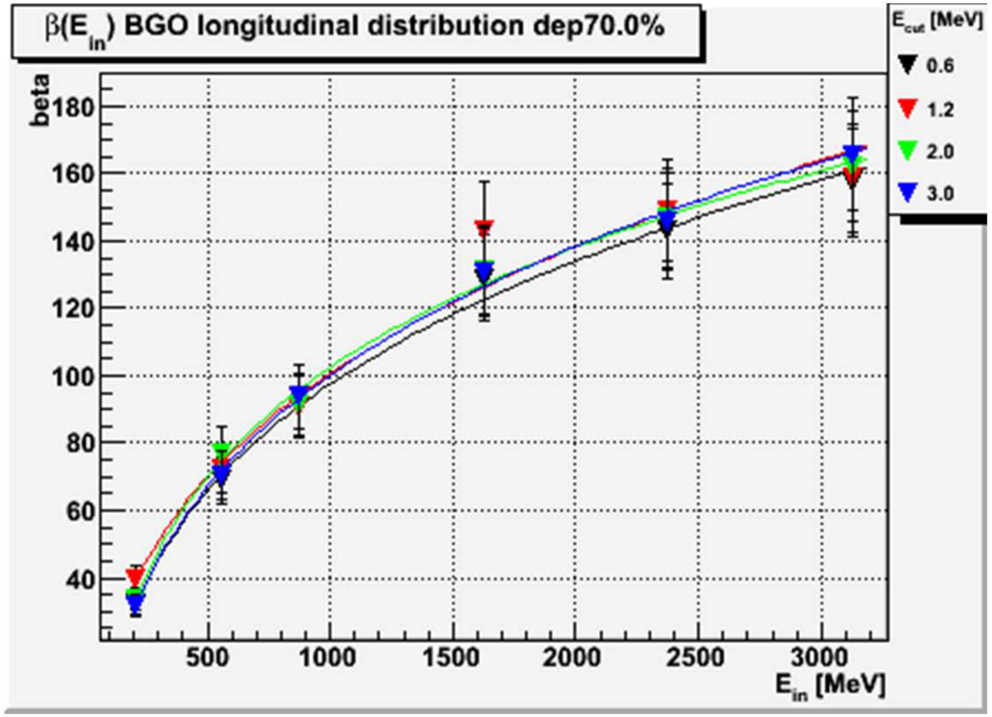

BGO longitudinal distribution E_in=210MeV E_cut=0.6MeV
dep90.0%
Entries 120
Mean 32.49
RMS 9.388
χ² / ndf 23.24 / 90
alpha 1004 ± 21.4
beta 44.95 ± 4.50
gamma 55.86 ± 5.59
delta 0.2961 ± 0.0296
ln(number of counts)
[1/4 r.l.]
BGO longitudinal distribution E_in=210MeV E_cut=1.2MeV
dep90.0%
Entries 120
Mean 32.42
RMS 9.287
χ² / ndf 26.05 / 81
alpha 1036 ± 22.1
beta 46.19 ± 4.62
gamma 57.44 ± 5.74
delta 0.296 ± 0.030
ln(number of counts)
[1/4 r.l.]
BGO longitudinal distribution E_in=210MeV E_cut=2.0MeV
dep90.0%
Entries 120
Mean 32.42
RMS 9.493
χ² / ndf 24.15 / 84
alpha 1036 ± 22.1
beta 44.11 ± 4.41
gamma 54.76 ± 5.48
delta 0.2965 ± 0.0297
ln(number of counts)
[1/4 r.l.]
BGO longitudinal distribution E_in=210MeV E_cut=3.0MeV
dep90.0%
Entries 120
Mean 32.17
RMS 9.435
χ² / ndf 21.1 / 87
alpha 1013 ± 21.6
beta 43.37 ± 4.34
gamma 53.69 ± 5.37
delta 0.2973 ± 0.0297
ln(number of counts)
[1/4 r.l.]

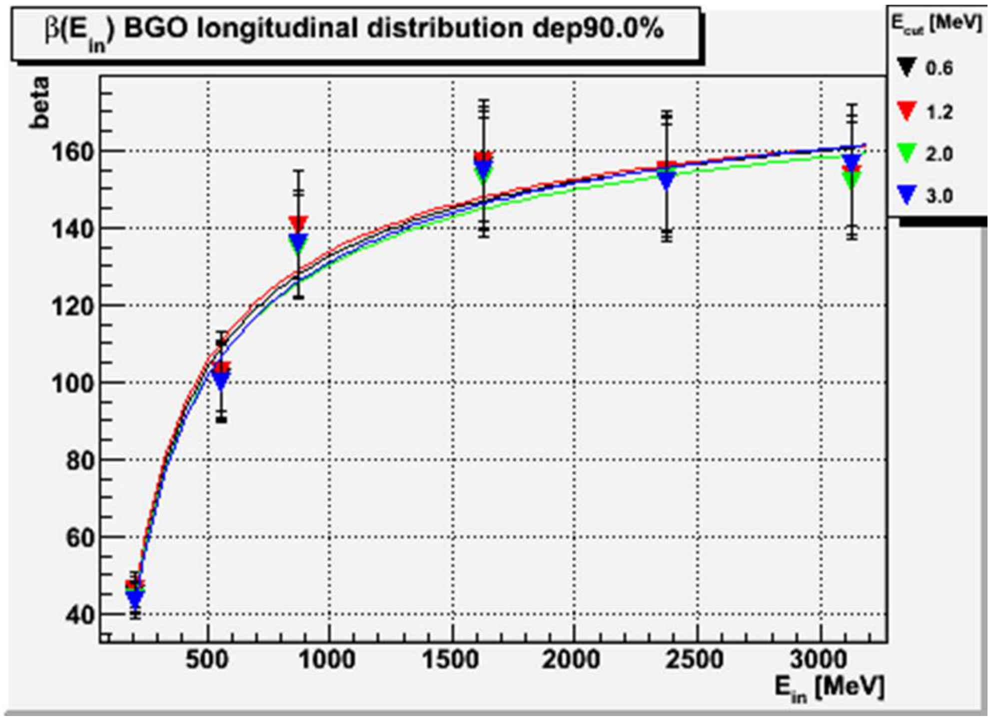
Dependence of fit parameters

β, γ, δ

on E_{γ}, $E_{c.o.}$ *and Z/A*

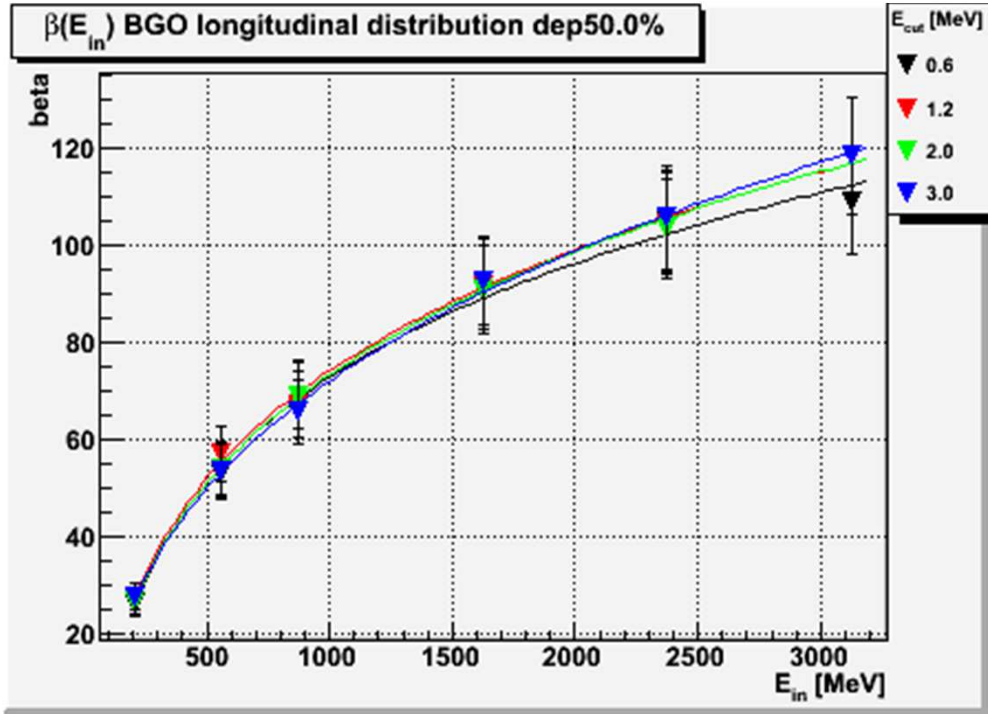


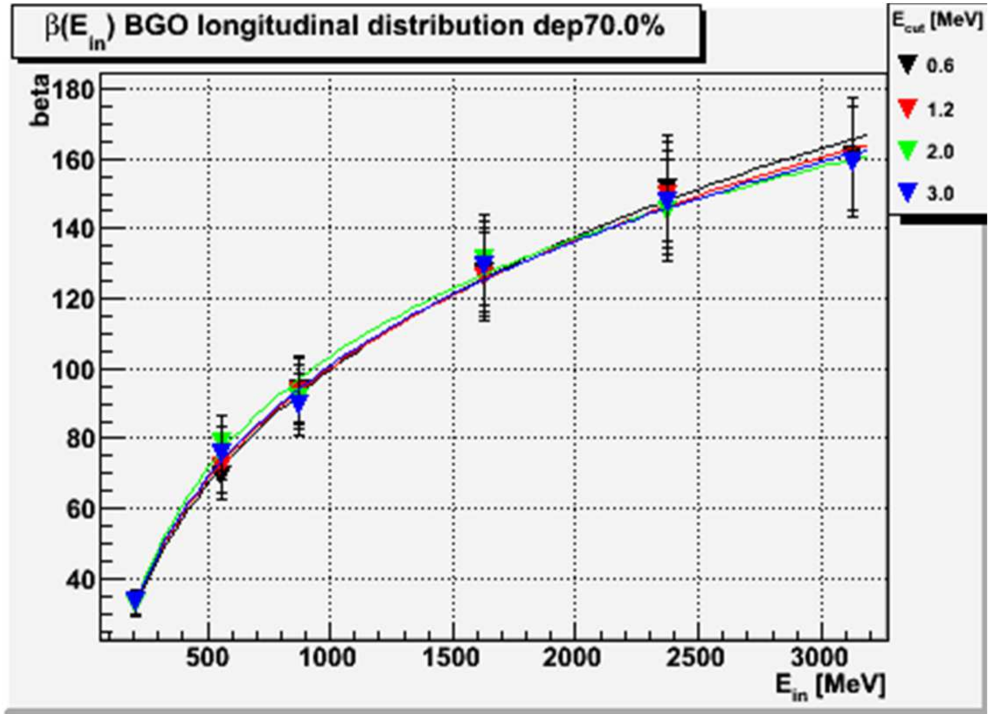


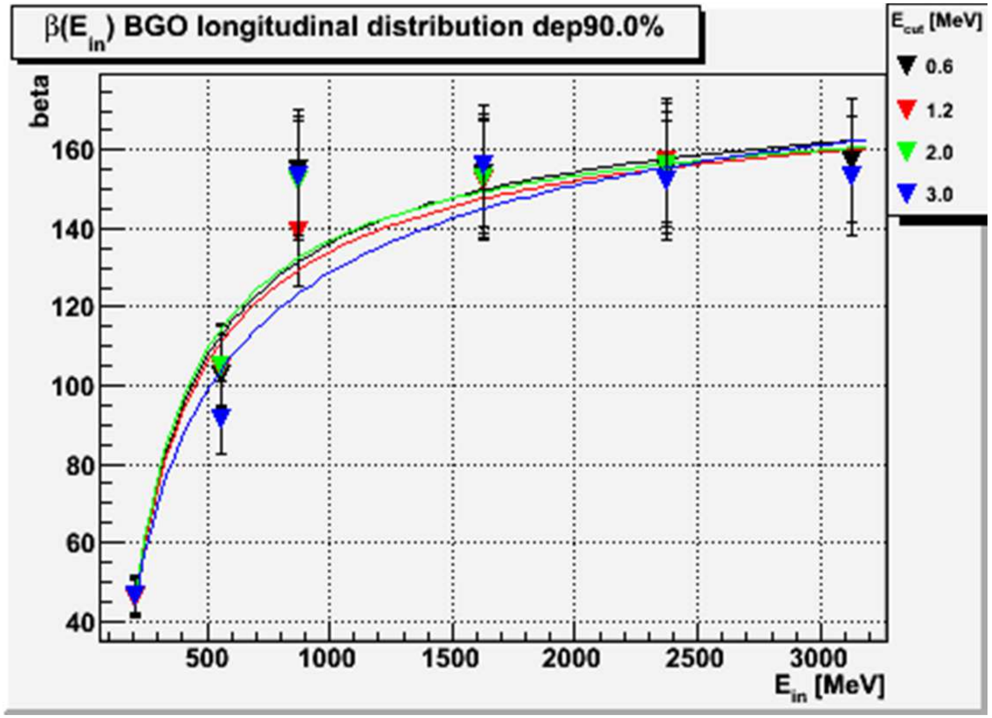


$$\beta(E_\gamma) = a \cdot E_\gamma{}^{b} + c$$

EGS4

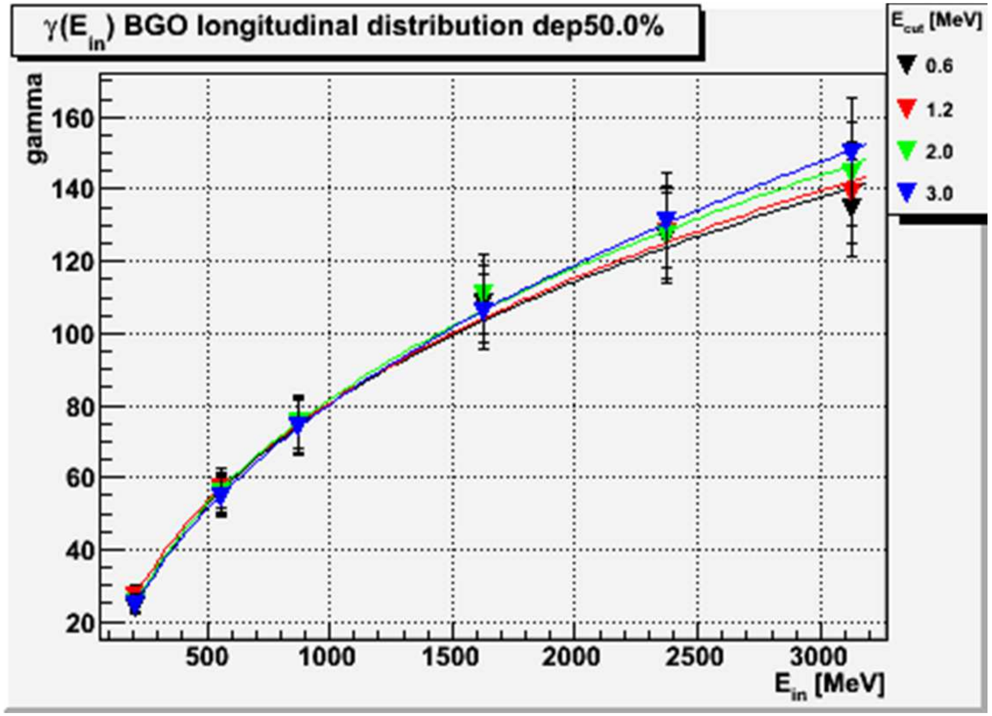


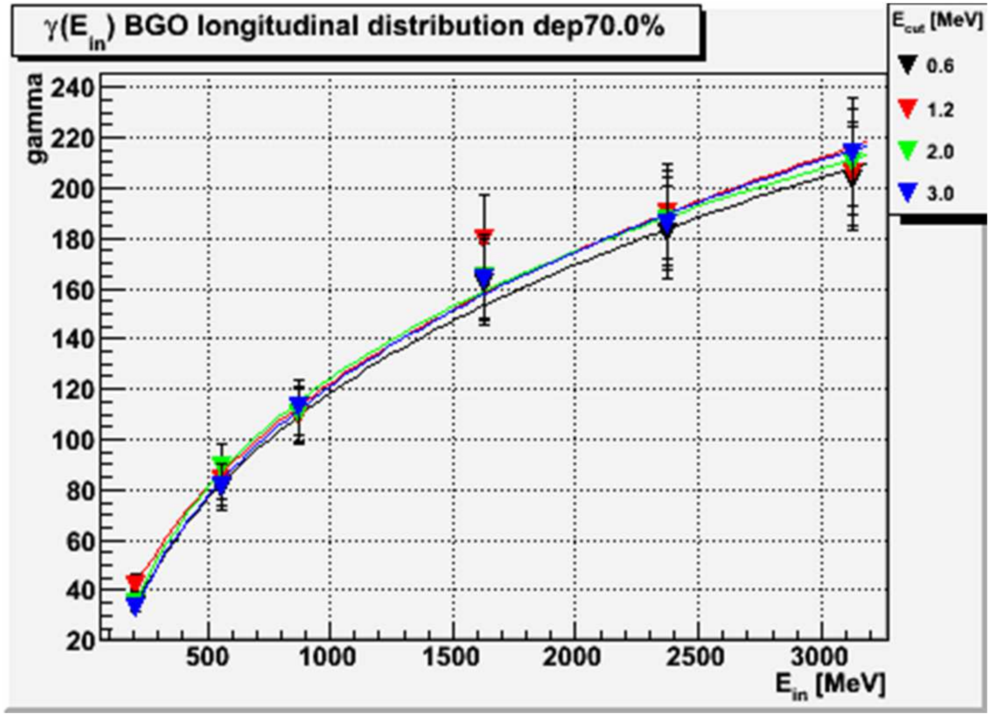


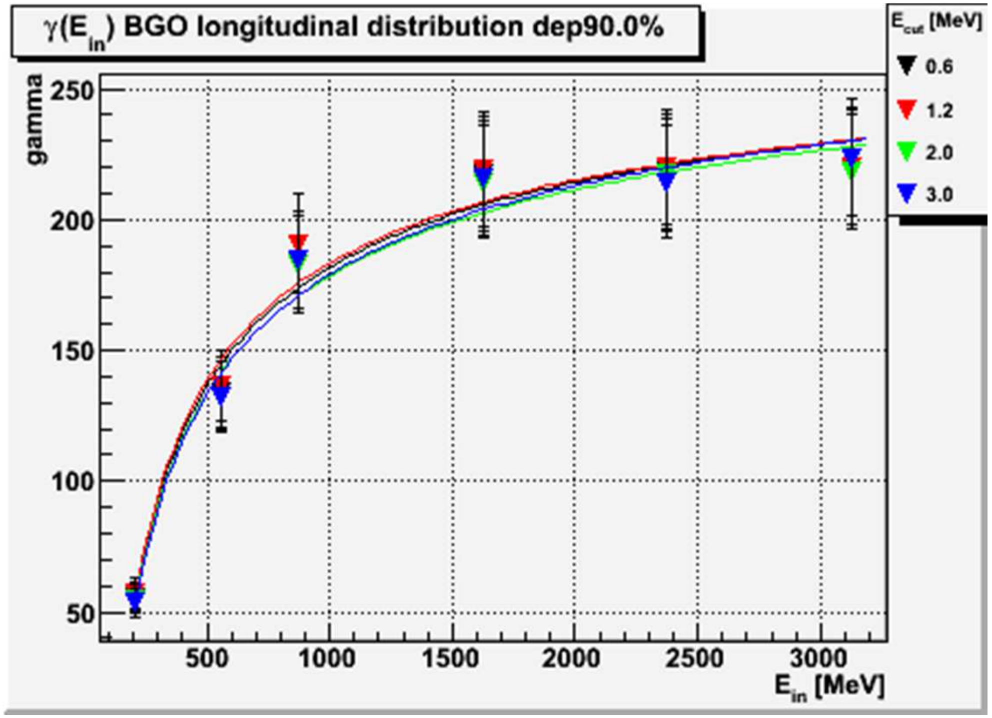


$$\beta(E_\gamma) = a \cdot E_\gamma^{\;b} + c$$

GEANT4

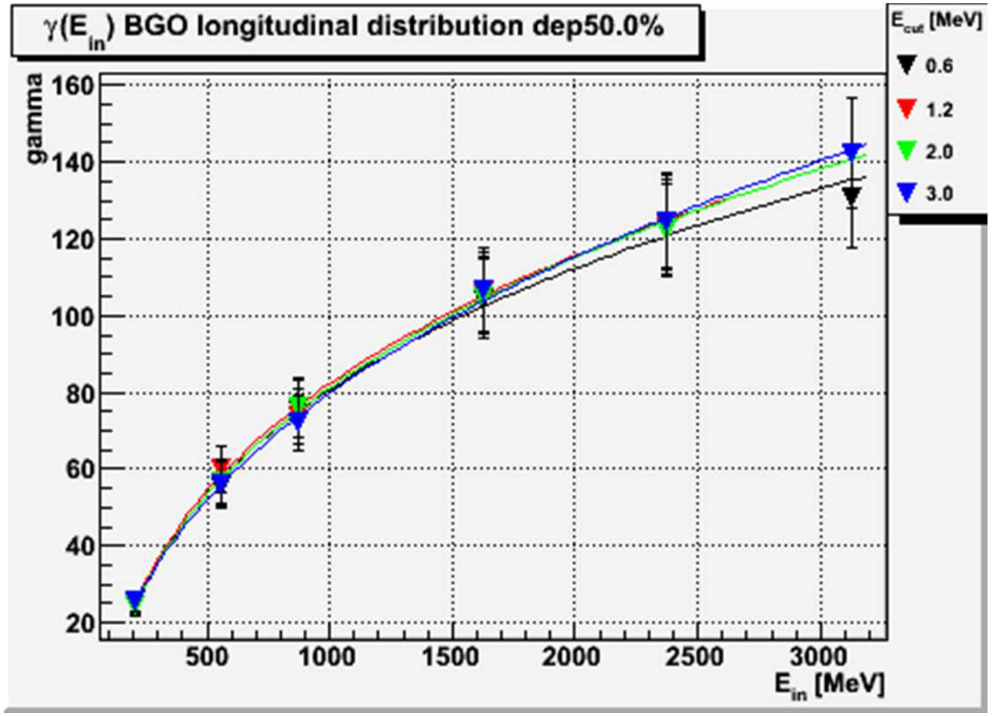


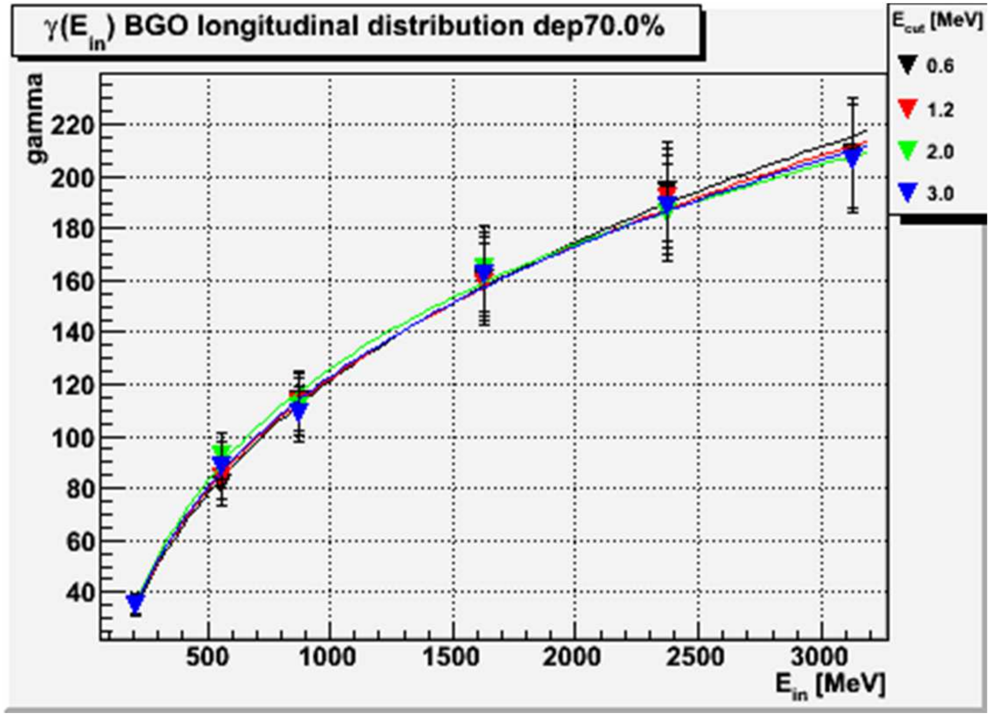


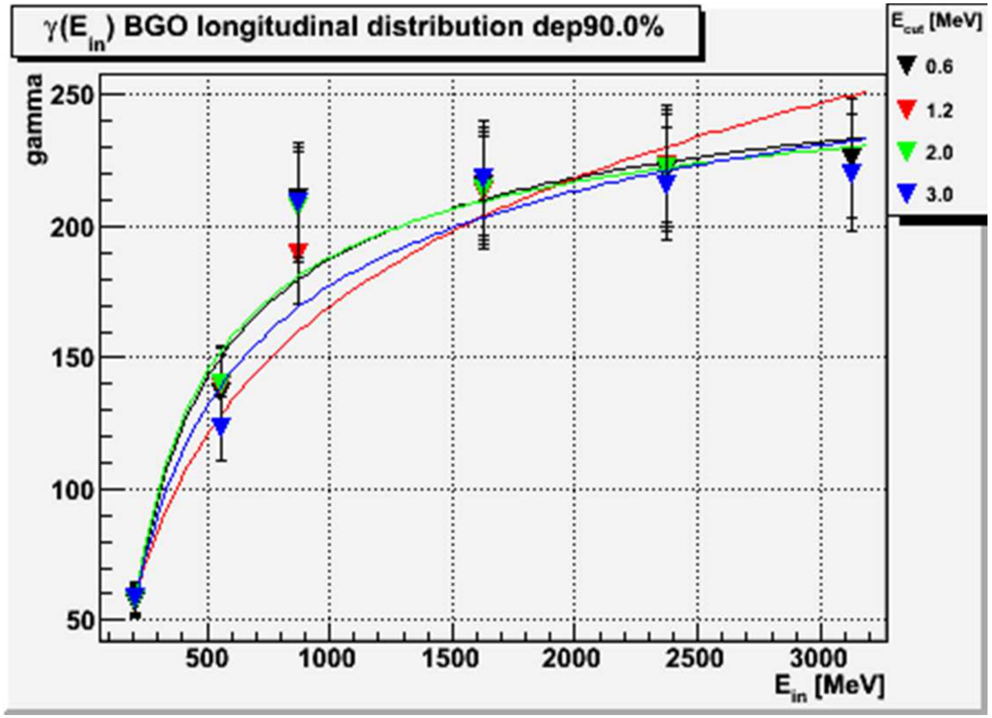


$$\gamma(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$

EGS4

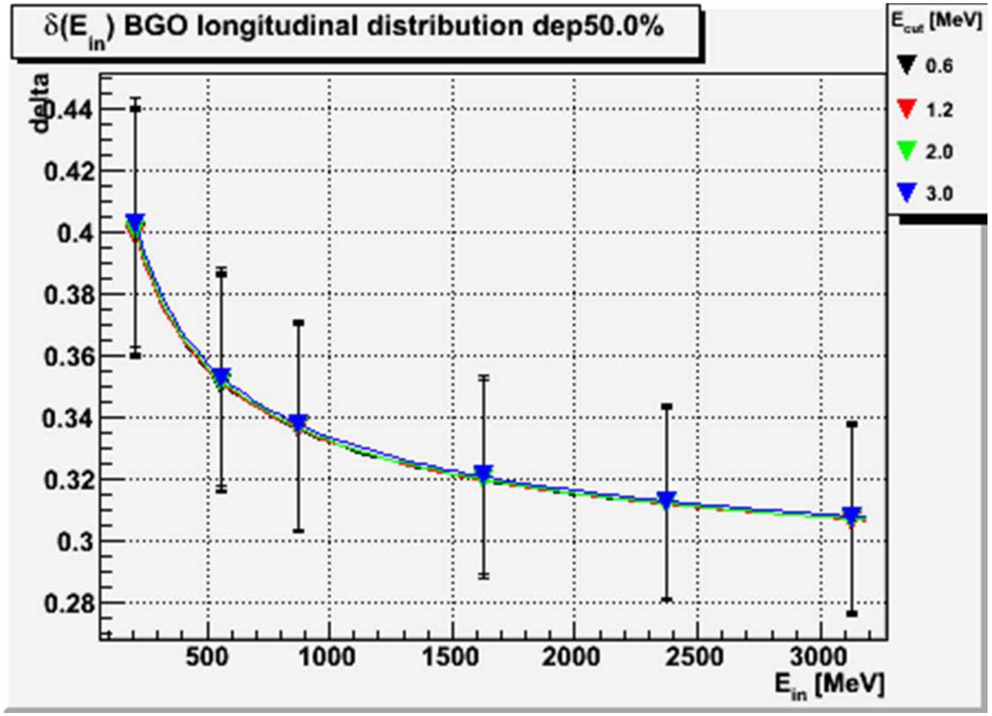


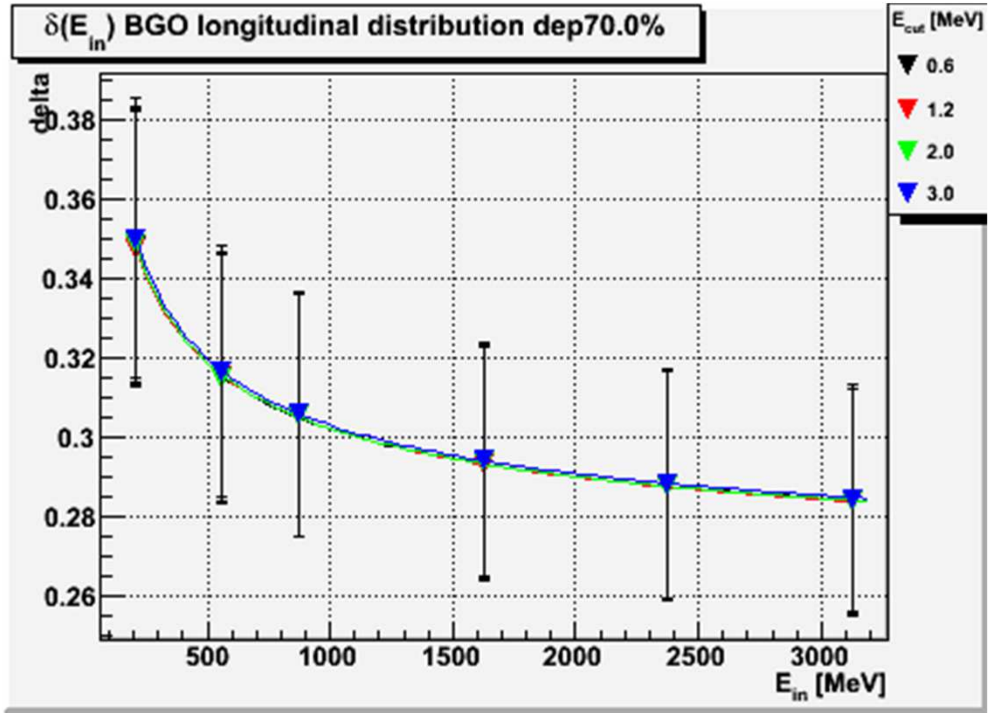


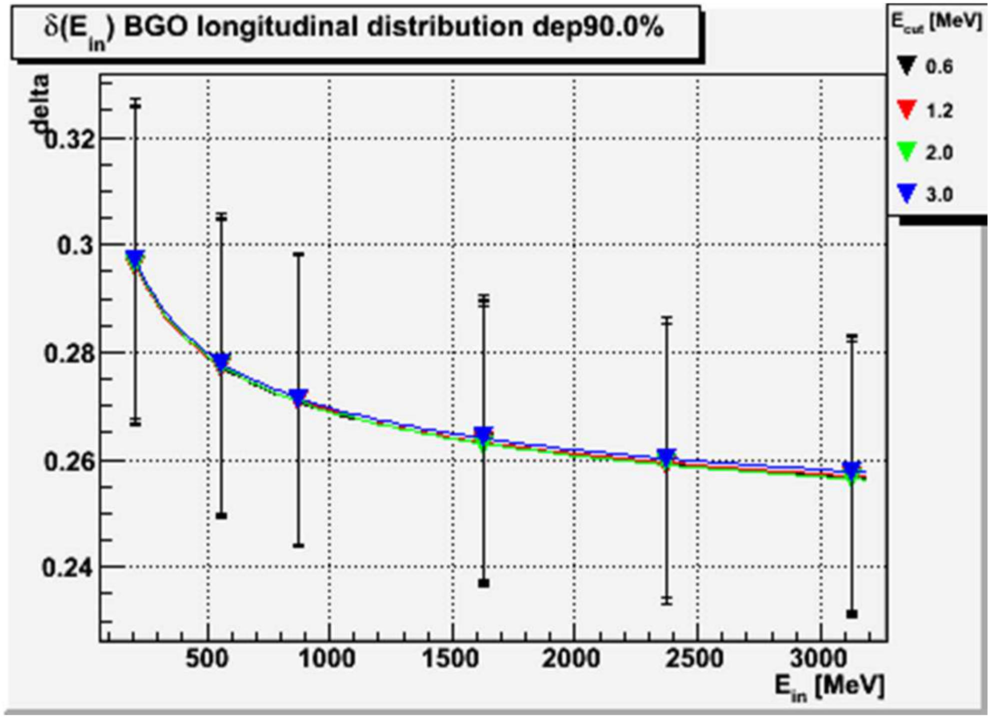


$$\gamma(E_\gamma) = a \cdot E_\gamma{}^{b} + c$$

GEANT4

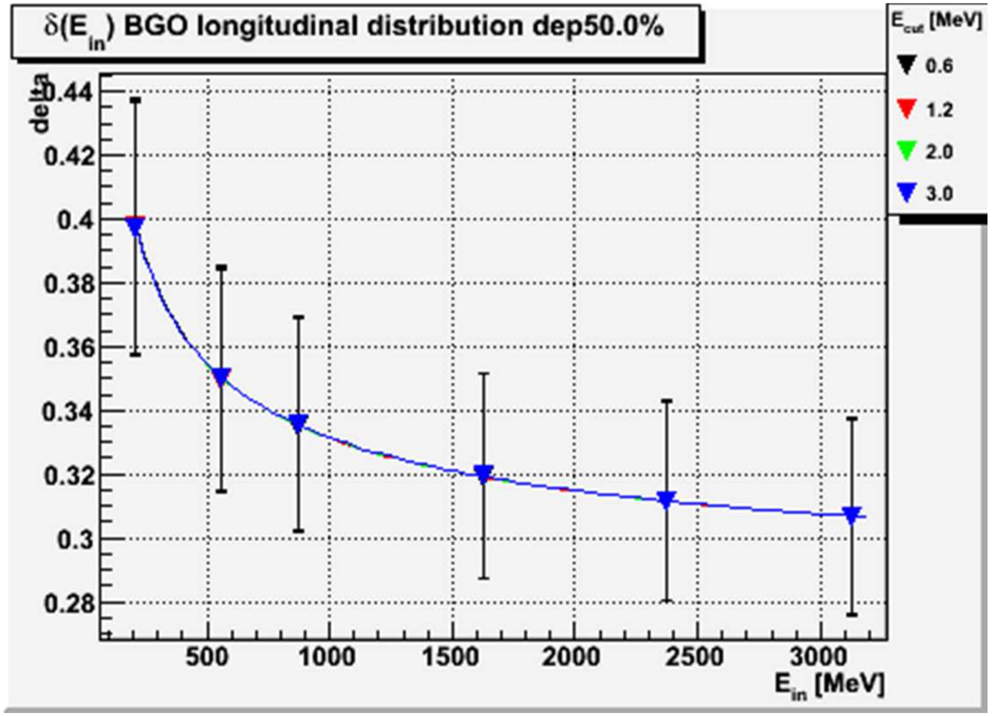


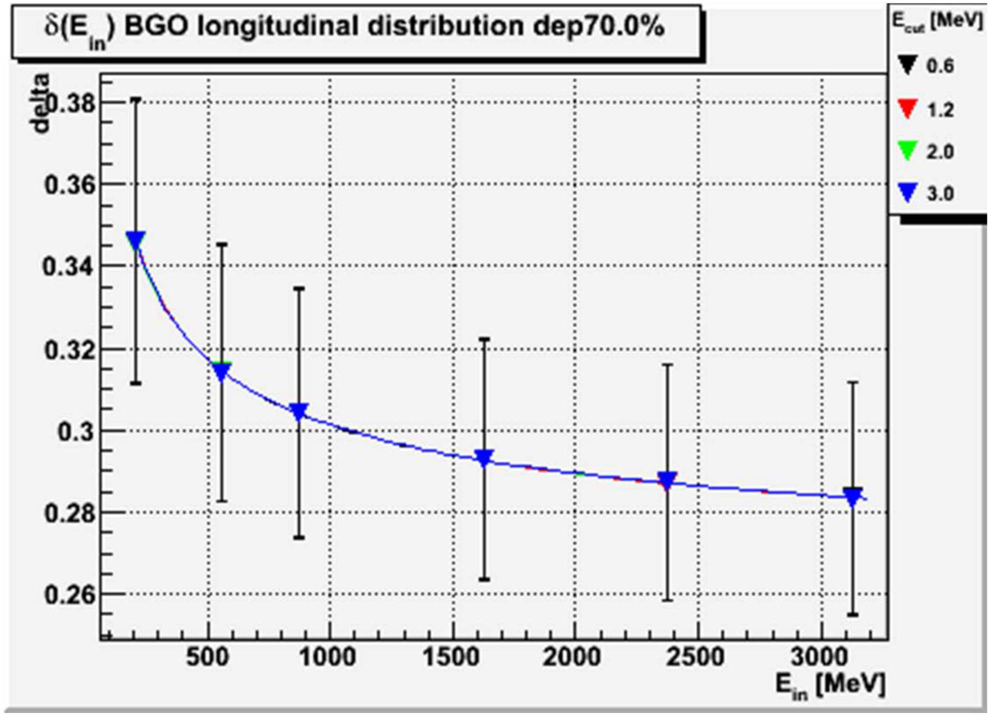


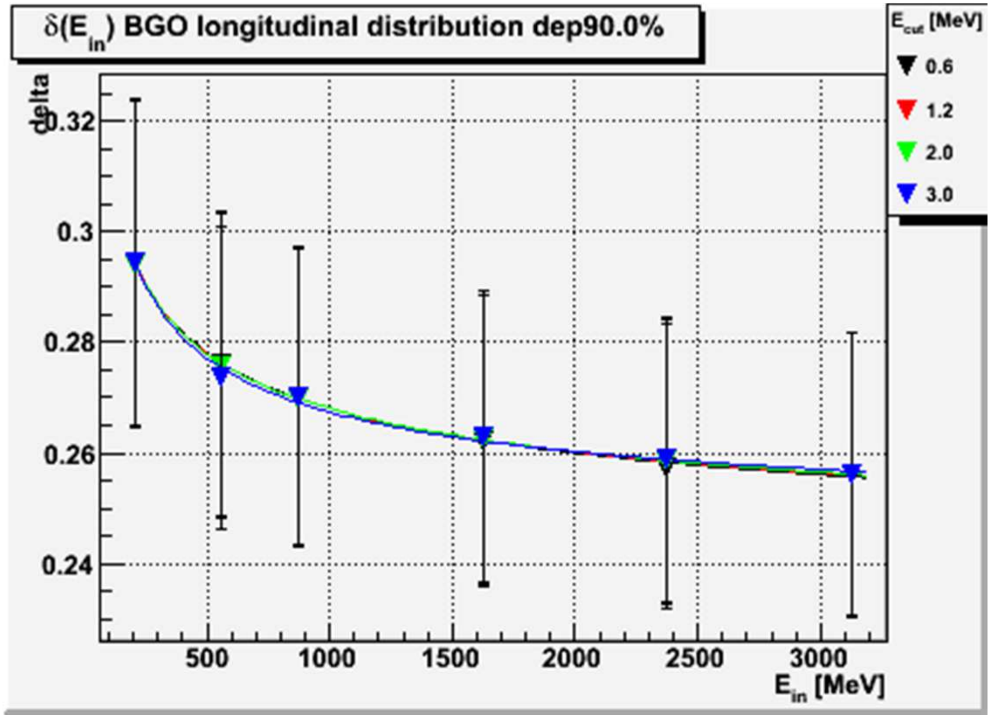


$$\delta(E_\gamma) = a \cdot E_\gamma^{\ b} + c$$

EGS4



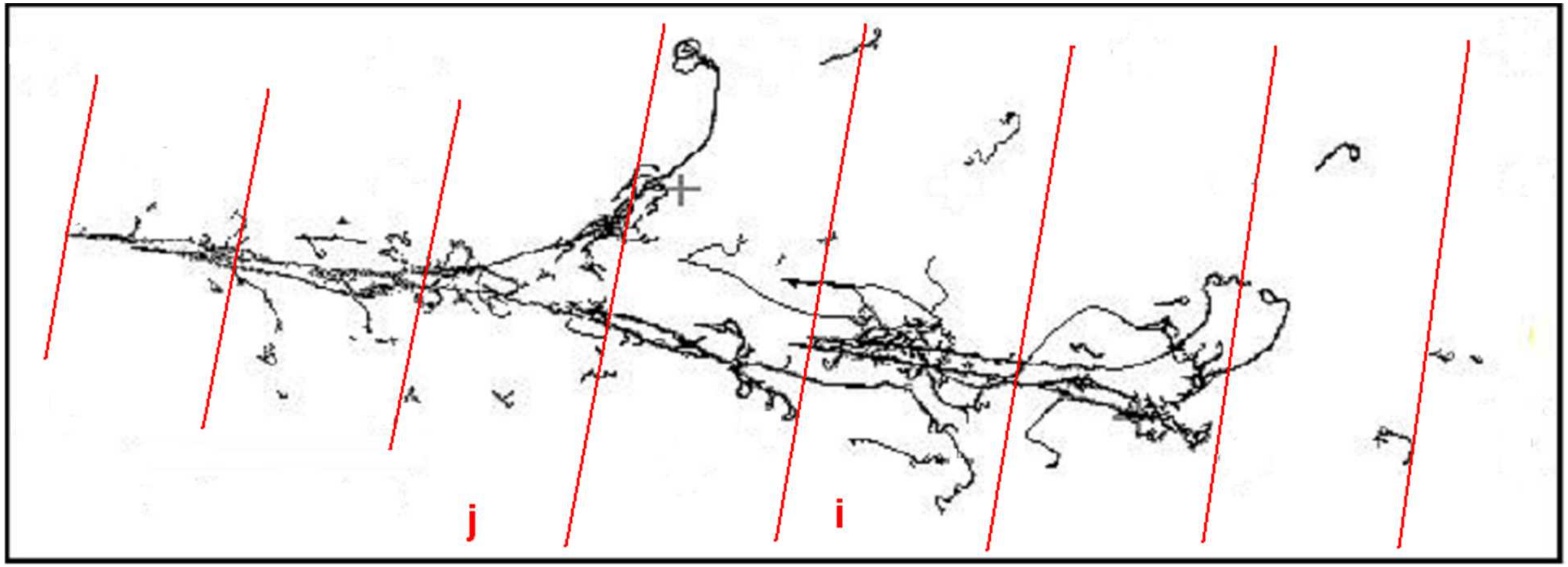


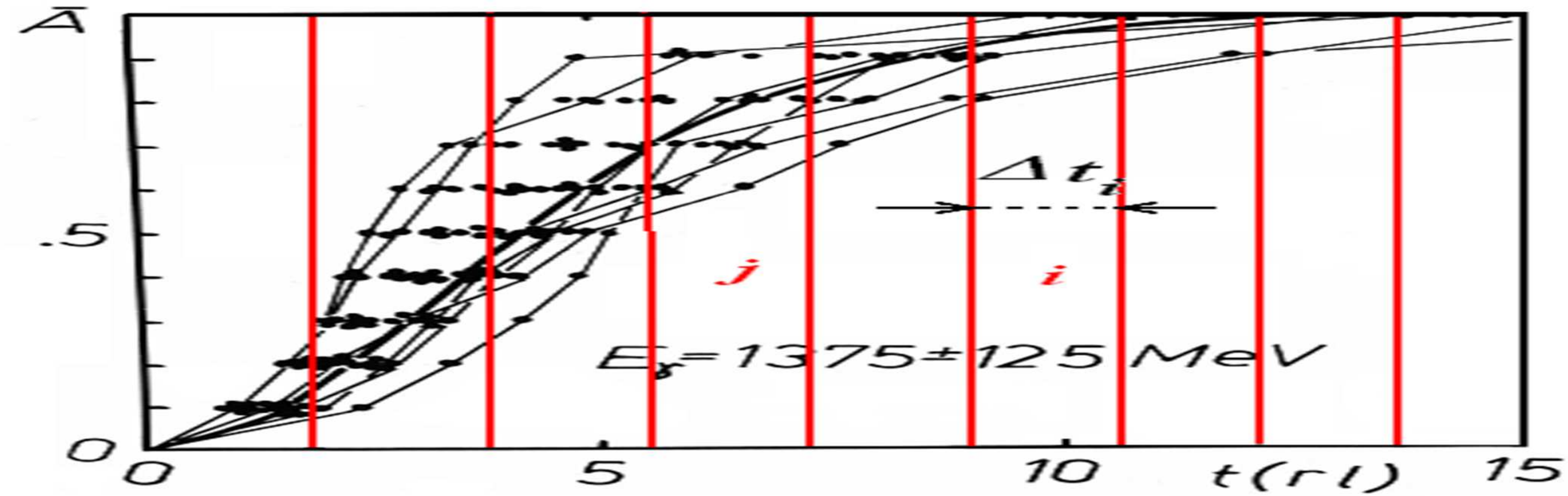


$$\delta(E_\gamma) = a \cdot E_\gamma{}^b + c$$

GEANT4

LONGITUDINAL CORRELATION





Correlation coefficient

$$r_{ij} = \mathrm{cov}(X_i, X_j)/[\sigma(X_i)\sigma(X_j)]$$

$$X_i = \Delta\bar{A} / \Delta t_i$$

is the slope of the cumulative longitudinal profile at the depth t_i at which on the average i/10 of the total shower energy is absorbed

$E_\gamma = 210$ MeV, XeC_2H_4, $E_{cut} = 1$MeV

i/j	3	4	5	6	7	8	9	10
2	0,29 ± 0,03	0,10 ± 0,03	0,04 ± 0,03	0,02 ± 0,03	0,01 ± 0,03	0,00 ± 0,03	-0,02 ± 0,03	0,01 ± 0,03
3	0,32 ± 0,03	0,13 ± 0,03	0,06 ± 0,03	0,02 ± 0,03	-0,01 ± 0,03	-0,02 ± 0,03	-0,01 ± 0,03	
4	0,35 ± 0,03	0,10 ± 0,03	0,02 ± 0,03	-0,02 ± 0,03	-0,02 ± 0,03	-0,02 ± 0,03		
5	0,33 ± 0,03	0,07 ± 0,03	-0,02 ± 0,03	-0,04 ± 0,03	-0,02 ± 0,03			
6	0,29 ± 0,03	0,02 ± 0,03	-0,06 ± 0,03	-0,03 ± 0,03				
7	0,20 ± 0,03	-0,07 ± 0,03	-0,05 ± 0,03					
8	0,06 ± 0,03	-0,06 ± 0,03						
9	-0,08 ± 0,03							

E_γ = 555 MeV, XeC_2H_4, E_{cut} = 1 MeV

i/j	3	4	5	6	7	8	9	10
2	0,38 ± 0,03	0,16 ± 0,03	0,08 ± 0,03	0,04 ± 0,03	0,00 ± 0,03	-0,01 ± 0,03	-0,01 ± 0,03	-0,02 ± 0,03
3	0,42 ± 0,03	0,19 ± 0,03	0,08 ± 0,03	0,03 ± 0,03	0,00 ± 0,03	-0,02 ± 0,03	-0,02 ± 0,03	
4	0,41 ± 0,03	0,15 ± 0,03	0,05 ± 0,03	0,00 ± 0,03	-0,02 ± 0,03	-0,02 ± 0,03		
5	0,39 ± 0,03	0,12 ± 0,03	0,00 ± 0,03	-0,02 ± 0,03	-0,01 ± 0,03			
6	0,32 ± 0,03	0,03 ± 0,03	-0,03 ± 0,03	-0,04 ± 0,03				
7	0,23 ± 0,03	-0,02 ± 0,03	-0,05 ± 0,03					
8	0,11 ± 0,03	-0,05 ± 0,03						
9	-0,04 ± 0,03							

E_γ = 1125 MeV, XeC_2H_4, E_{cut} = 1MeV

i/j	3	4	5	6	7	8	9	10
2	0,45 ± 0,03	0,22 ± 0,03	0,12 ± 0,03	0,07 ± 0,03	0,04 ± 0,03	0,02 ± 0,03	0,00 ± 0,03	-0,03 ± 0,03
3	0,48 ± 0,03	0,26 ± 0,03	0,14 ± 0,03	0,05 ± 0,03	0,02 ± 0,03	-0,01 ± 0,03	-0,03 ± 0,03	
4	0,49 ± 0,03	0,23 ± 0,03	0,11 ± 0,03	0,03 ± 0,03	-0,02 ± 0,03	-0,04 ± 0,03		
5	0,45 ± 0,03	0,18 ± 0,03	0,06 ± 0,03	-0,02 ± 0,03	-0,05 ± 0,03			
6	0,39 ± 0,03	0,12 ± 0,03	0,00 ± 0,03	-0,06 ± 0,03				
7	0,30 ± 0,03	0,00 ± 0,03	-0,06 ± 0,03					
8	0,12 ± 0,03	-0,05 ± 0,03						
9	-0,05 ± 0,03							

E_γ = 2625 MeV, XeC_2H_4, E_{cut}= 1MeV

i/j	3	4	5	6	7	8	9	10
2	0,53 ± 0,02	0,32 ± 0,03	0,22 ± 0,03	0,12 ± 0,03	0,07 ± 0,03	0,04 ± 0,03	0,01 ± 0,03	-0,10 ± 0,03
3	0,57 ± 0,02	0,35 ± 0,03	0,21 ± 0,03	0,11 ± 0,03	0,04 ± 0,03	0,02 ± 0,03	-0,11 ± 0,03	
4	0,56 ± 0,02	0,31 ± 0,03	0,17 ± 0,03	0,08 ± 0,03	0,02 ± 0,03	-0,09 ± 0,03		
5	0,52 ± 0,02	0,28 ± 0,03	0,12 ± 0,03	0,02 ± 0,03	-0,11 ± 0,03			
6	0,46 ± 0,03	0,18 ± 0,03	0,04 ± 0,03	-0,09 ± 0,03				
7	0,37 ± 0,03	0,08 ± 0,03	-0,09 ± 0,03					
8	0,22 ± 0,03	-0,09 ± 0,03						
9	-0,09 ± 0,03							

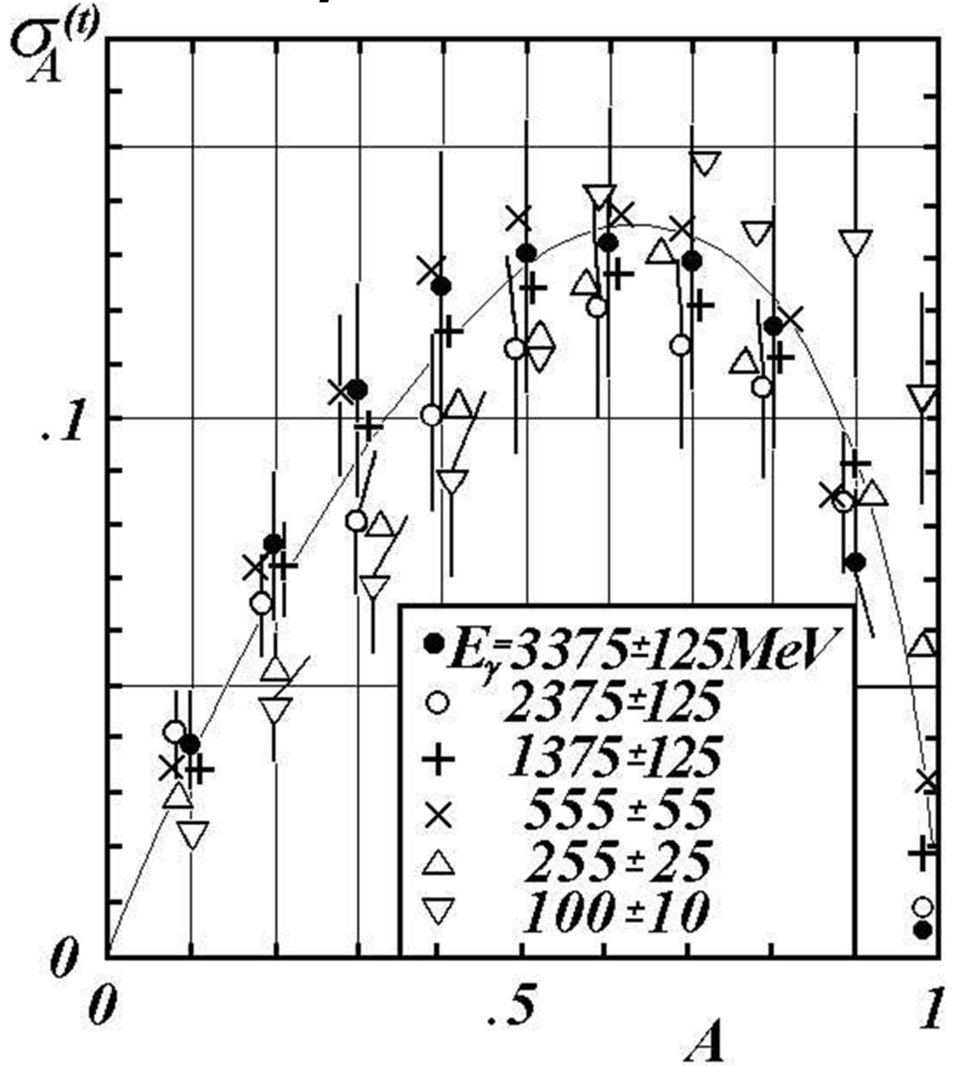
E_γ = 3375 MeV, XeC_2H_4, E_{cut} = 1MeV

i/j	3	4	5	6	7	8	9	10
2	0,55 ± 0,02	0,35 ± 0,03	0,23 ± 0,03	0,16 ± 0,03	0,07 ± 0,03	0,02 ± 0,03	0,00 ± 0,03	-0,11 ± 0,03
3	0,59 ± 0,02	0,37 ± 0,03	0,25 ± 0,03	0,13 ± 0,03	0,06 ± 0,03	0,02 ± 0,03	-0,13 ± 0,03	
4	0,59 ± 0,02	0,36 ± 0,03	0,20 ± 0,03	0,08 ± 0,03	0,04 ± 0,03	-0,13 ± 0,03		
5	0,56 ± 0,02	0,29 ± 0,03	0,12 ± 0,03	0,05 ± 0,03	-0,13 ± 0,03			
6	0,48 ± 0,03	0,20 ± 0,03	0,07 ± 0,03	-0,13 ± 0,03				
7	0,38 ± 0,03	0,10 ± 0,03	-0,13 ± 0,03					
8	0,24 ± 0,03	-0,11 ± 0,03						
9	-0,10 ± 0,03							

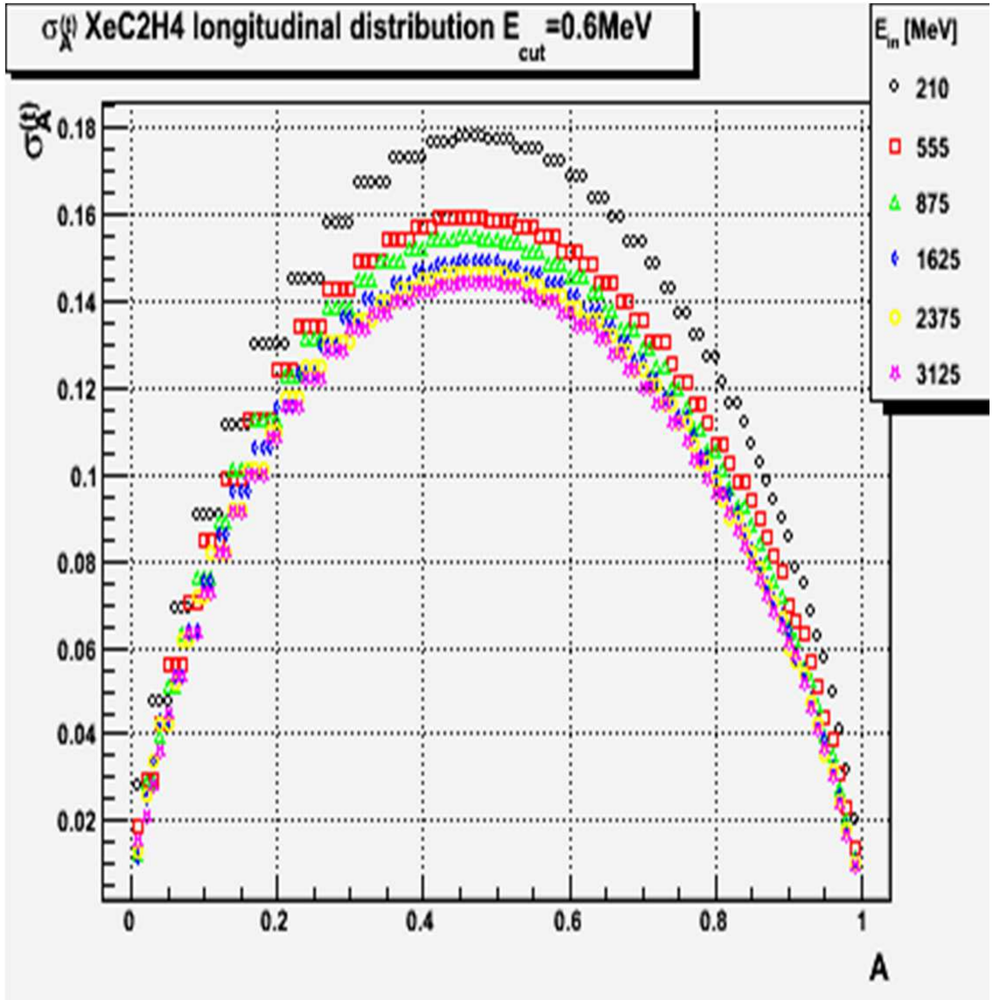
COMPARISON EGS4 & GEANT4 WITH EXPERIMENT

(material: liquid xenon)

Longitudinal fluctuation [EGS4]

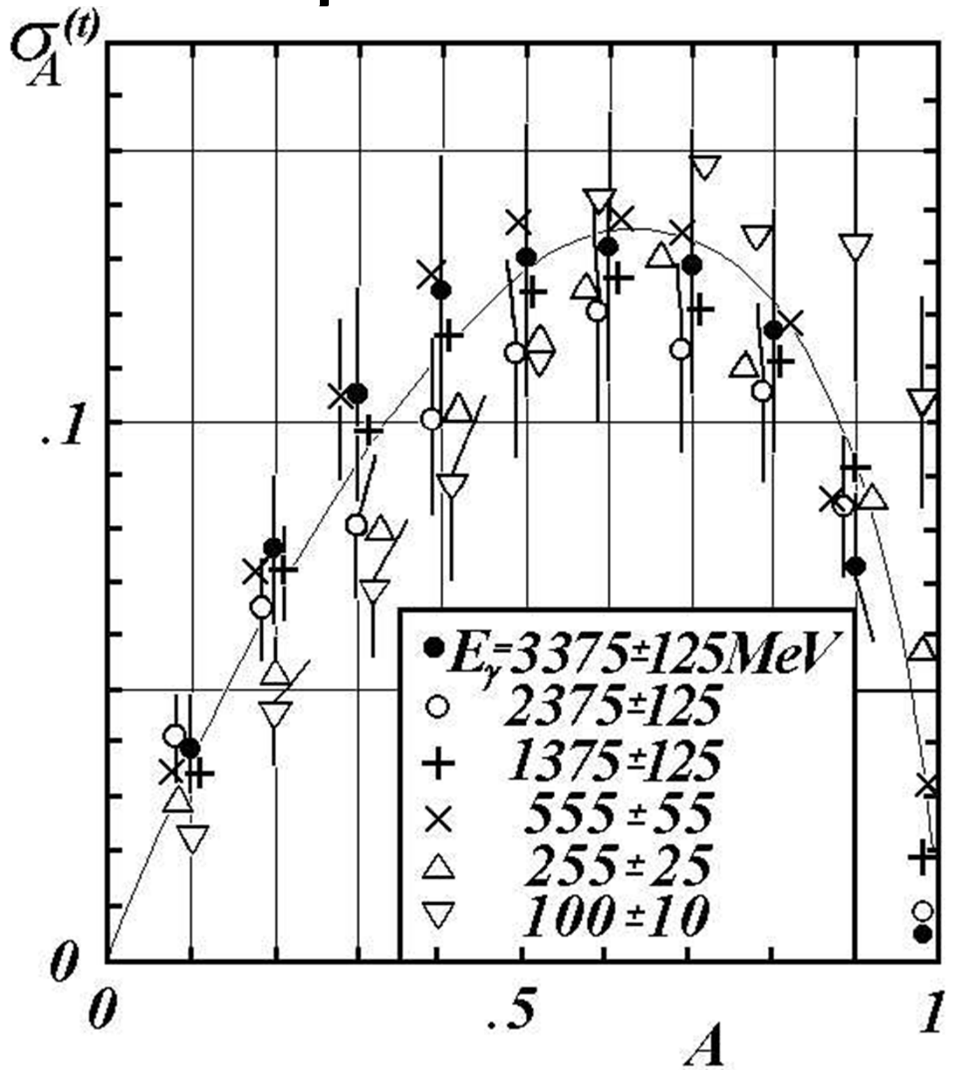


Experiment

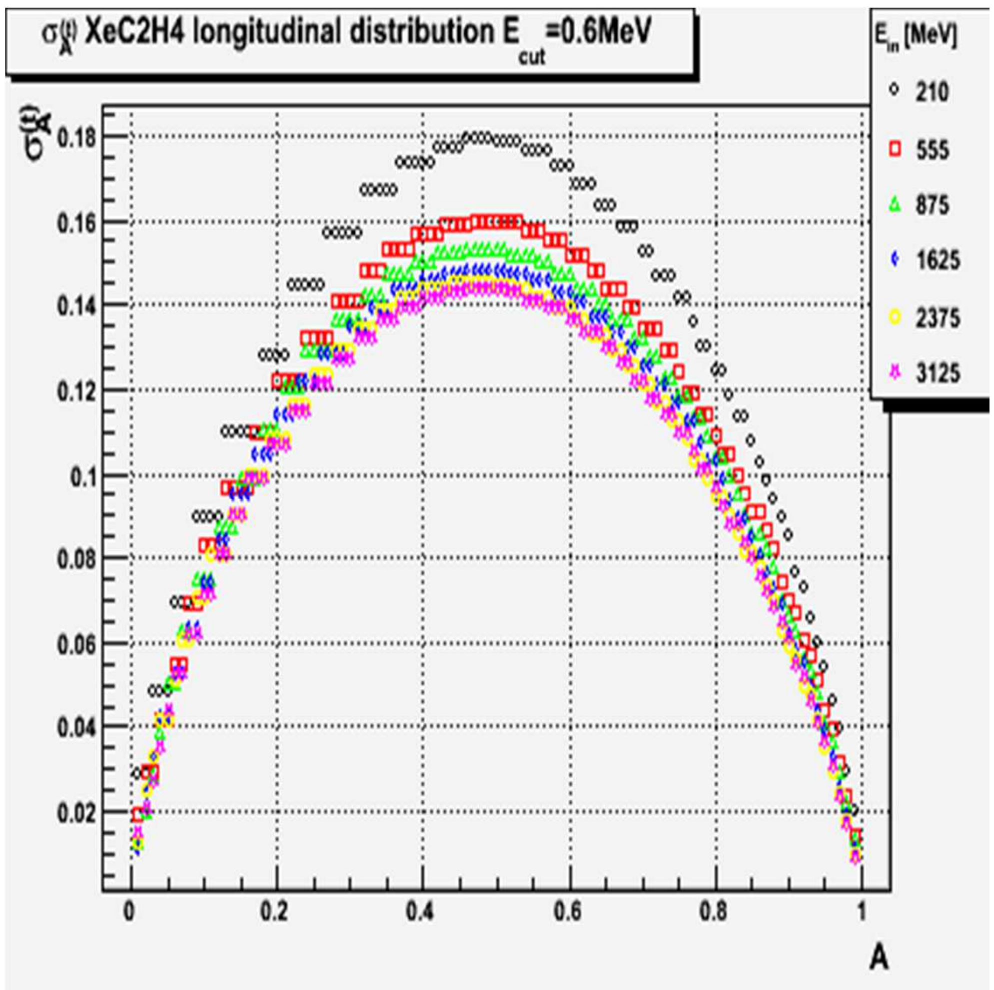


Simulation

Longitudinal fluctuation [GEANT4]

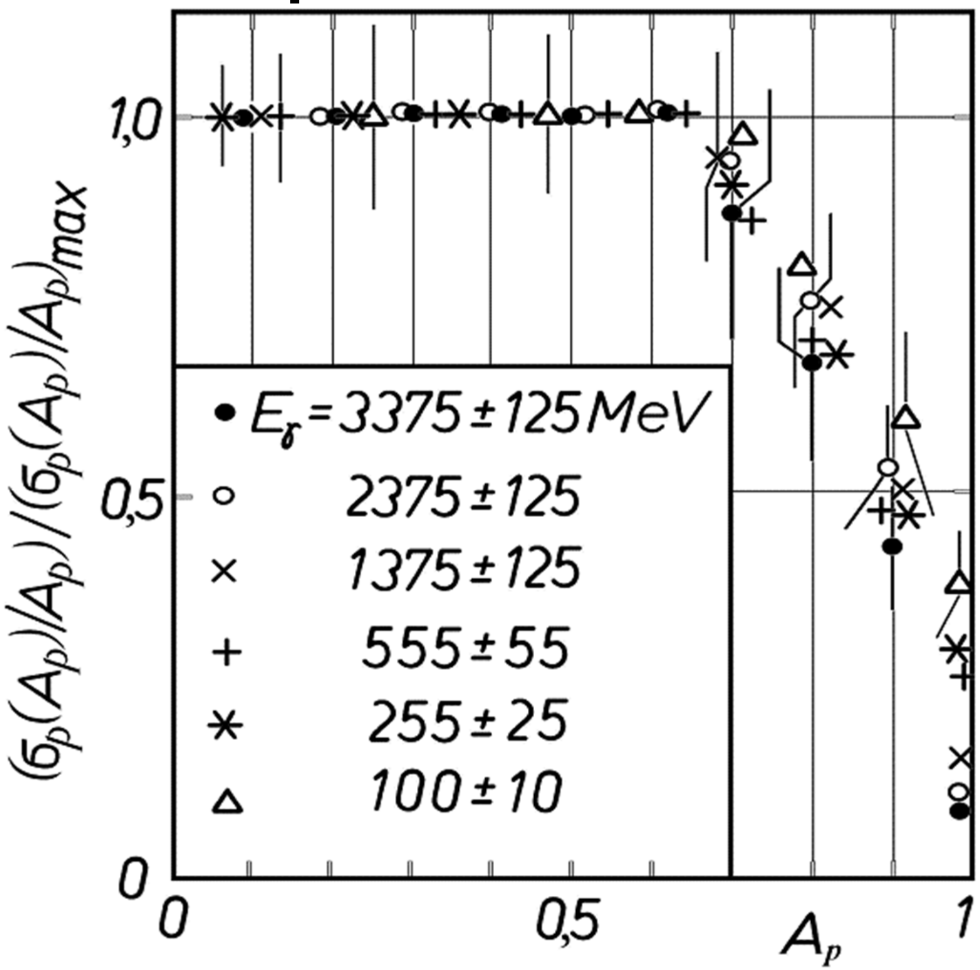


Experiment



Simulation

Transverse fluctuation [EGS4]



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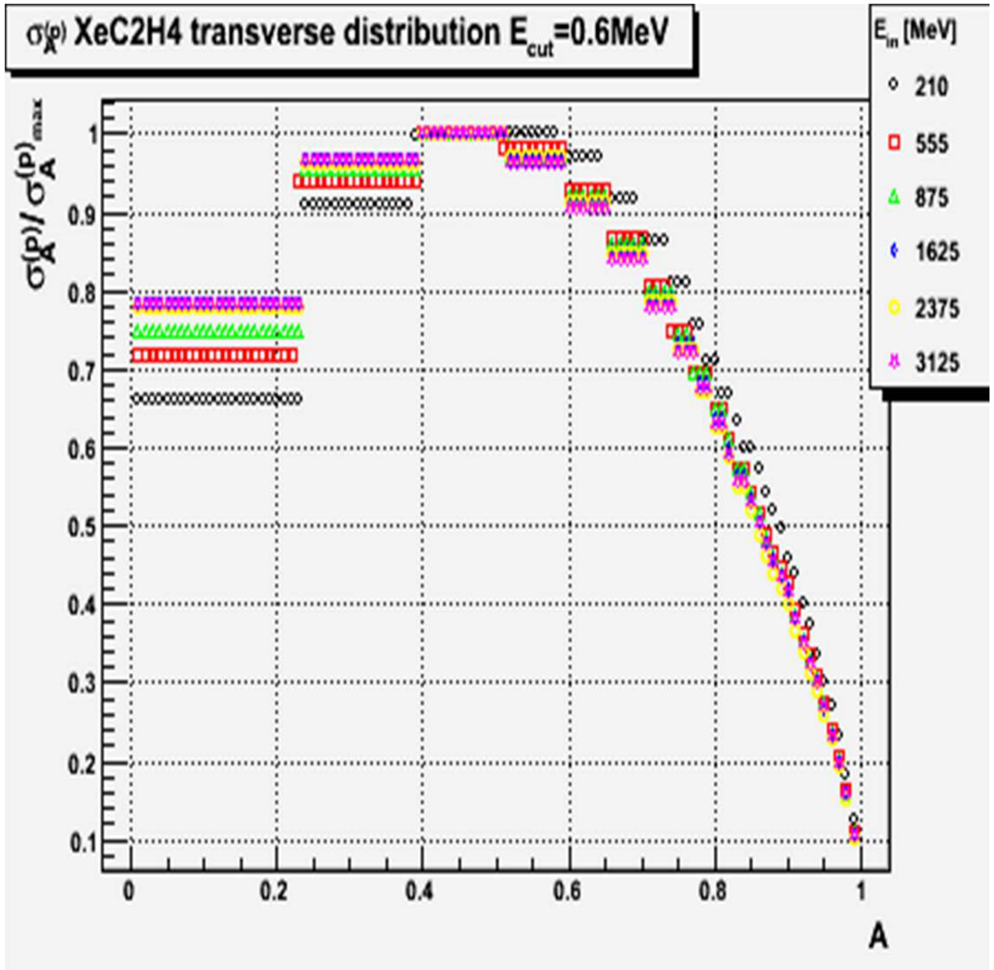
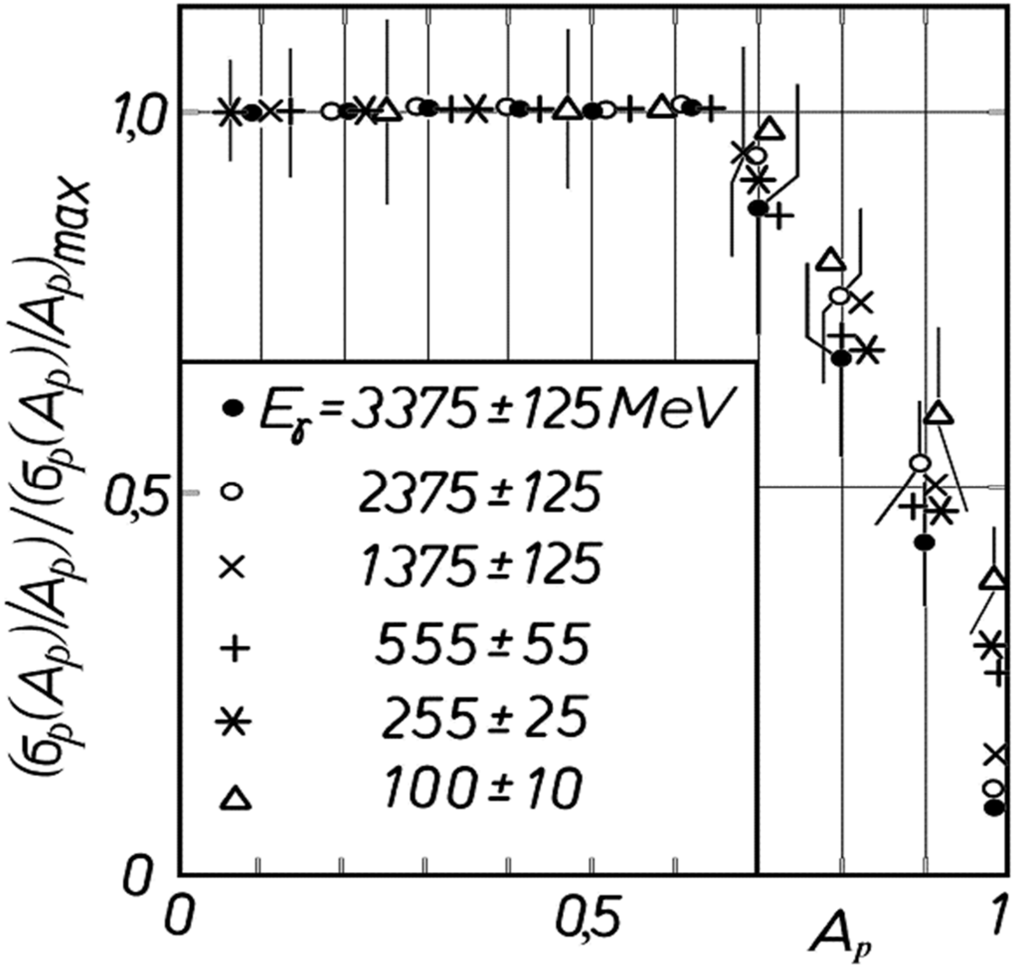
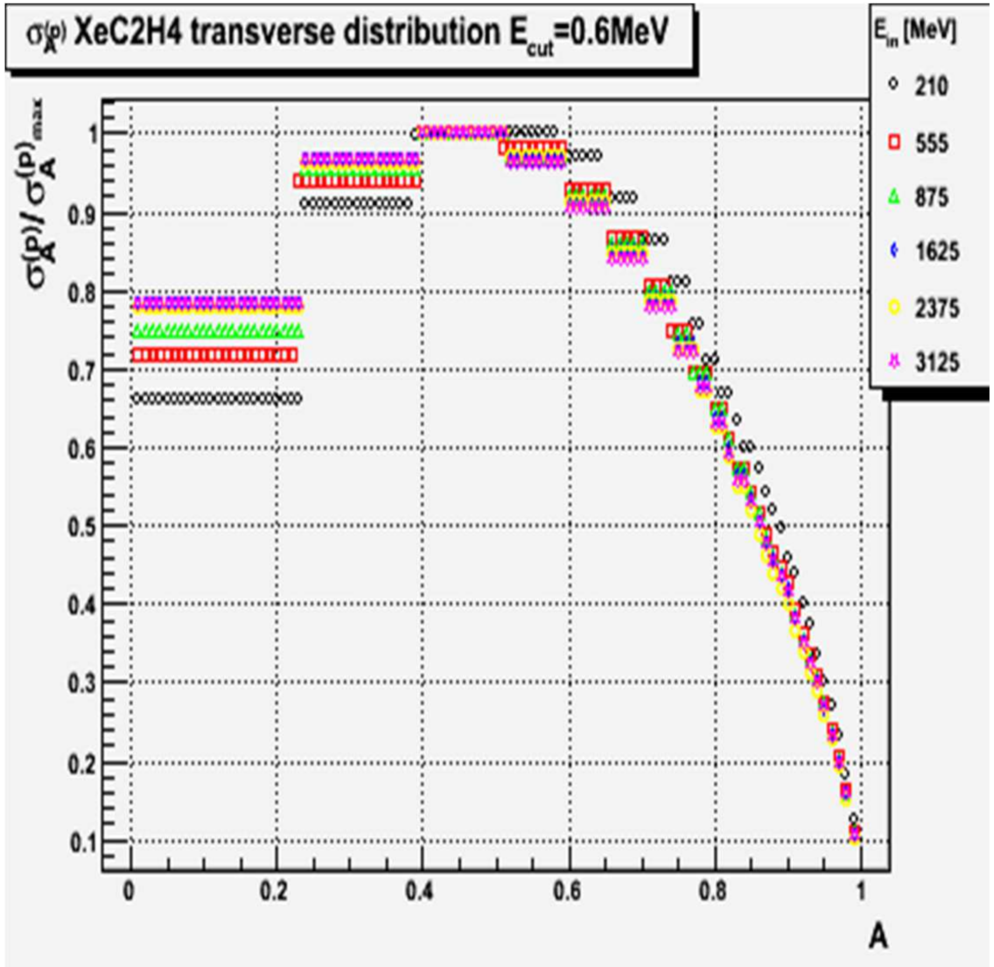


Simulation

Transverse fluctuation [GEANT4]





Experiment

Simulation

SUMMARY AND CONCLUSION

- The comprehensive analysis of the longitudinal and transverse profiles of EMC initiated in 8 various amorphous materials by qamma quanta of energy E_{γ}= 210, 555, 875, 1625, 2375 and 3125 MeV has been performed by using EGS4 and GEANT4 code at four values of cut-off energy $E_{c.o.}$= 0.6, 1.2, 2.0 and 3.0 MeV.
- All the obtained approximating formulas in the form of simple functions reveal a quite acceptable scaling description of the electromagnetic cascade process initiated by gamma quanta of transitional energy interval 100÷3500 MeV in the most often used dense materials. They can be applied both for hard gamma detection and radiation shielding construction.

- In the range $E\gamma$ = 100-3375 MeV of energies of gamma quanta producing cascades in liquid xenon mainly short-range correlation of the longitudinal energy release in the vicinity of the cascade maximum (i.e., for *i* = 3-7) takes place.