Carbon ion beam quality: LET spectra calculated by Geant4 at different positions along and around ion beam

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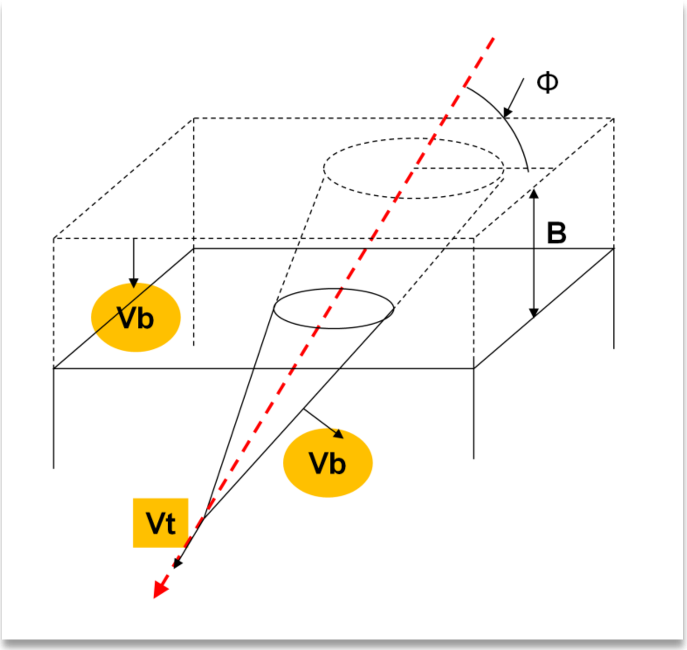
Track etched detectors (TED)



1. **latent track:** material damage of microscopic size after passing of charge particle; more or less stable
2. **track:** enlarged and stabilized due to e.g. etching

V_t > V_b

track etch rate
V_t= f (charge particle)

bulk etch rate
V_b= f (material)

3. **calibration to LET:** LET spectrometer;

$V = V_t / V_b$ = relative track size = f(LET)

Track etched detectors (TED)

- Passive detectors: integral information over time
- Light, thin plastic plates, no built-in electronics, cheap, easy to evaluate
- Applications as LET spectrometers:

On board spacecraft and aircraft

Radon monitoring

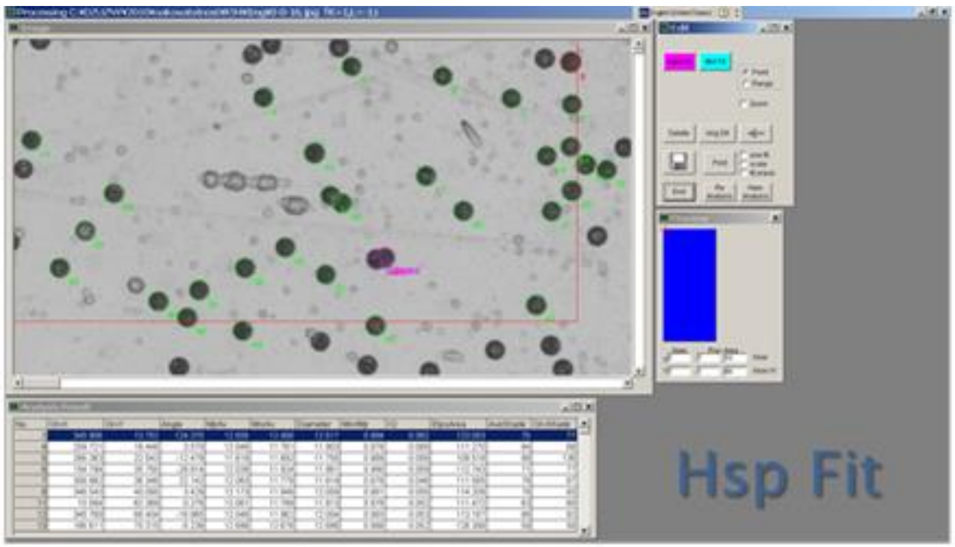
Personal neutron dosimetry

Nuclear fragmentation studies in radiation therapy

Detection of particles with very short ranges

Track etched detectors (TED)

- Etching in sodium hydroxide
- Etching velocity about 0.9 μm/h
- Tracks etches 10 faster than the surroundings
- Measurement of etched track parameters by light microscopic system available in our laboratory: HSP-1000 Seiko Precision

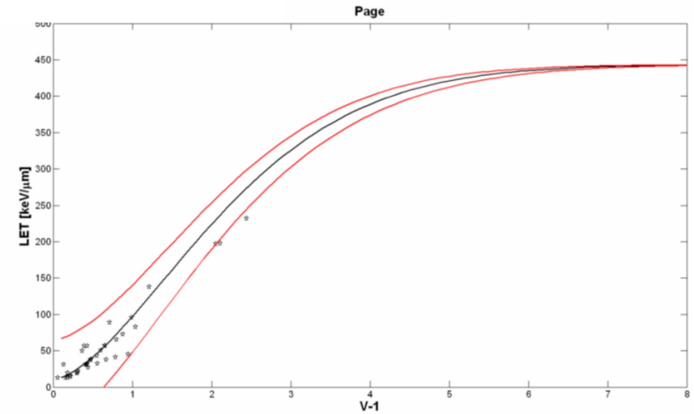


Experiment

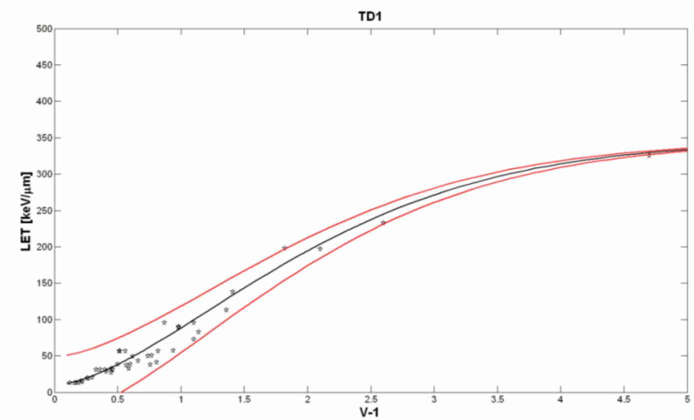
- BIO room at HIMAC (Heavy Ion Medical Accelerator in Chiba)
- C 12, 290 and 400 MeV/n MONO
- behind binary filters (PMMA) with increasing thicknesses

Box with detectors

Page



TD1



F. Spurný, K. Pachnerová Brabcová, O. Ploc, I. Ambrožová, and Z. Mrázová, Radiat. Prot. Dosim. 143, 519–522, 2011
K. Pachnerová Brabcová, I. Ambrožová, and F. Spurný, Radiat. Prot. Dosim. 143 (2–4), 440–444, 2011

Experiment

- BIO room at HIMAC (Heavy Ion Medical Accelerator in Chiba)
- C 12, 290 and 400 MeV/n MONO
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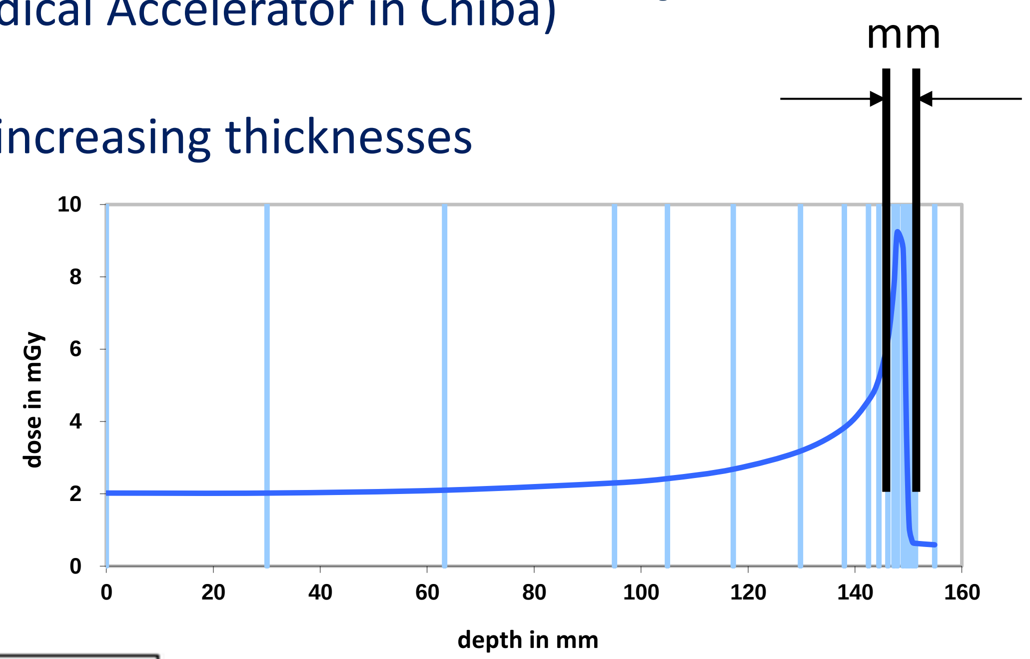
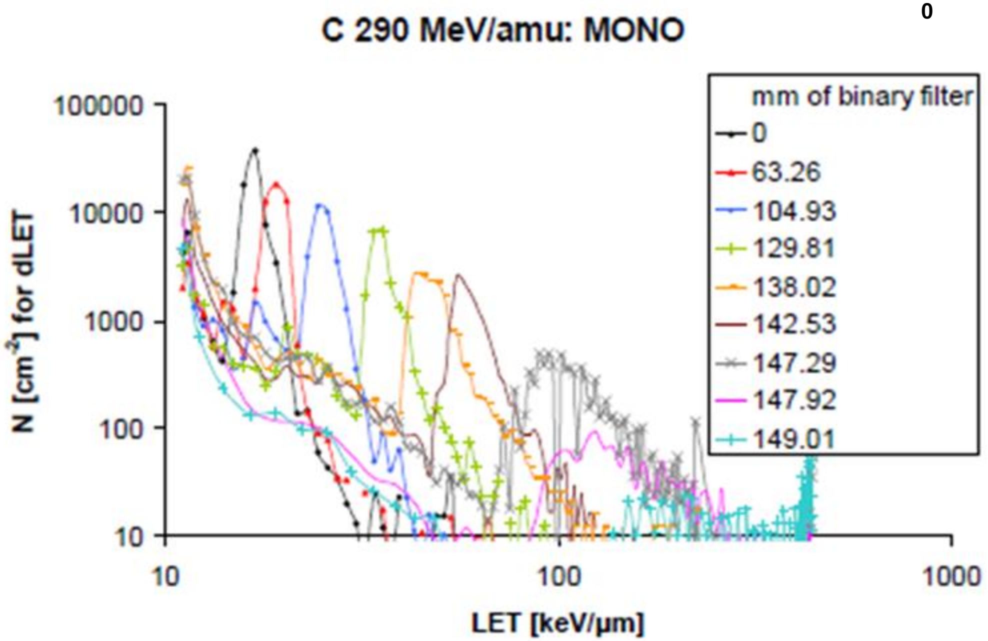
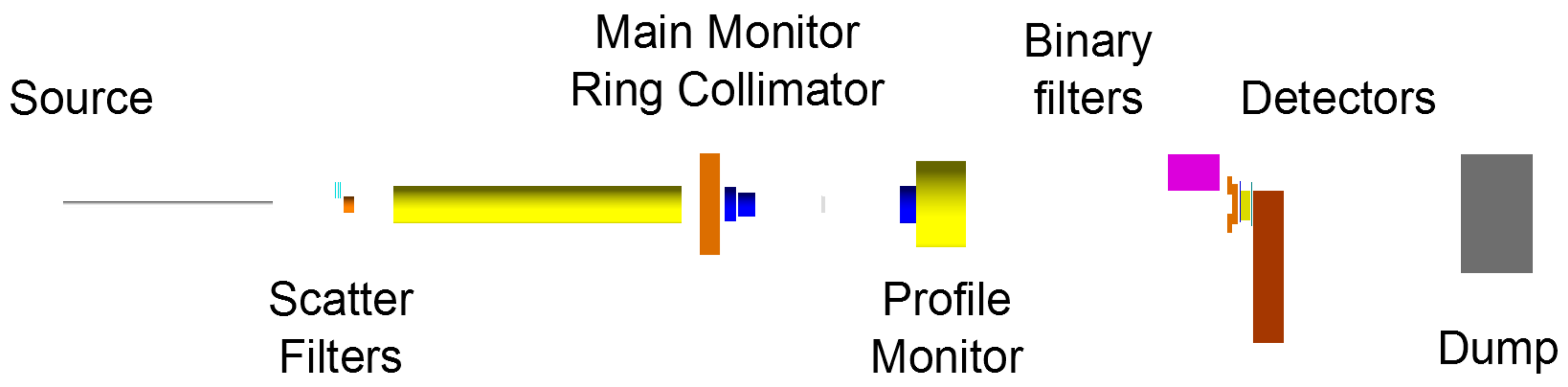




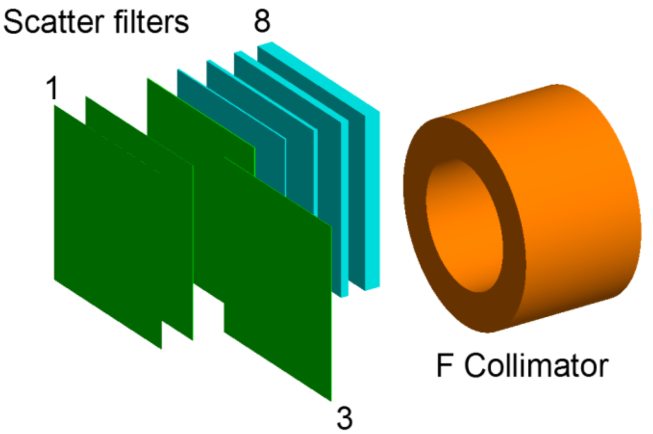
Geant4 modeling

- Transfer of HIMAC beamline geometry from PHITS to Geant4
- Geant4.9.6.-p01
- FTF_BIC 2.0 physics list, production threshold 10 µm (for LET spectra 5 µm)

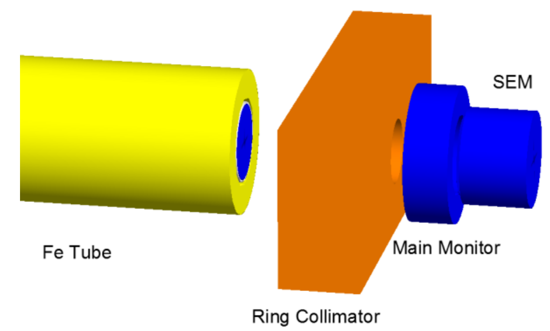


S. Yonai, N. Matsufuji, and S. Kanai, Medical Physics 36, 4830–4839, 2009
M. Torikoshi, et al. Irradiation System for HIMAC., Journal of Radiation Research 48 Suppl A, A15–25, 2007

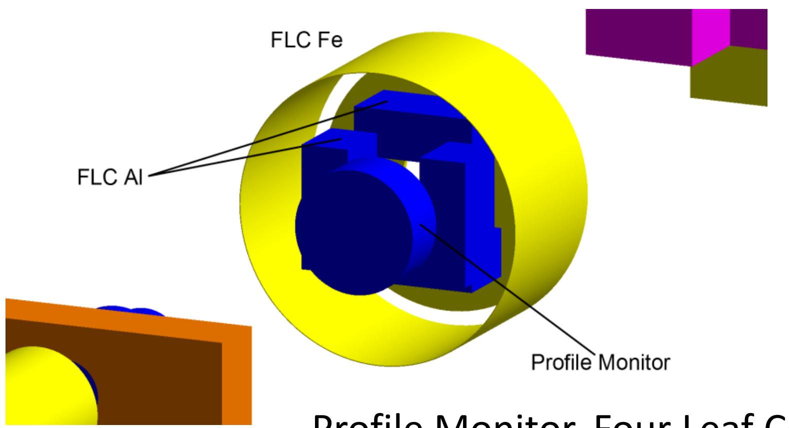
HIMAC BIO room beamline



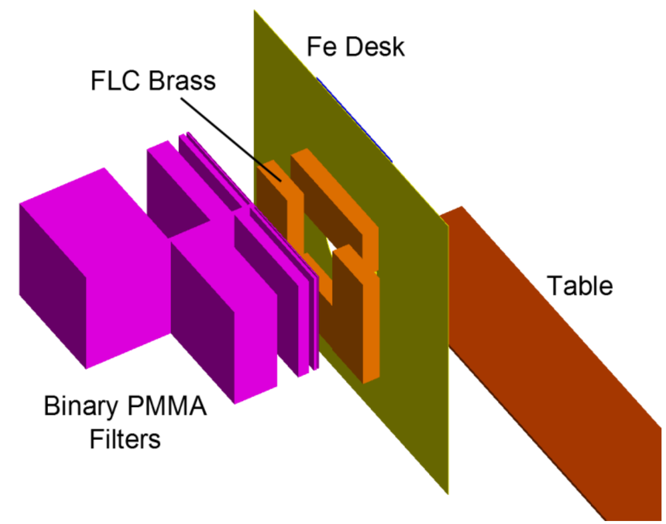
Scatter Filters positions: 1-4 tantalum scatter filters, 5-8 lead scatter filters, cylindrical F collimator made of brass C12 beam 290 MeV/n with 3, 400 MeV/n 1+2+3



Fe Tube, Ring Collimator, Main Monitor and Secondary Emission Monitor

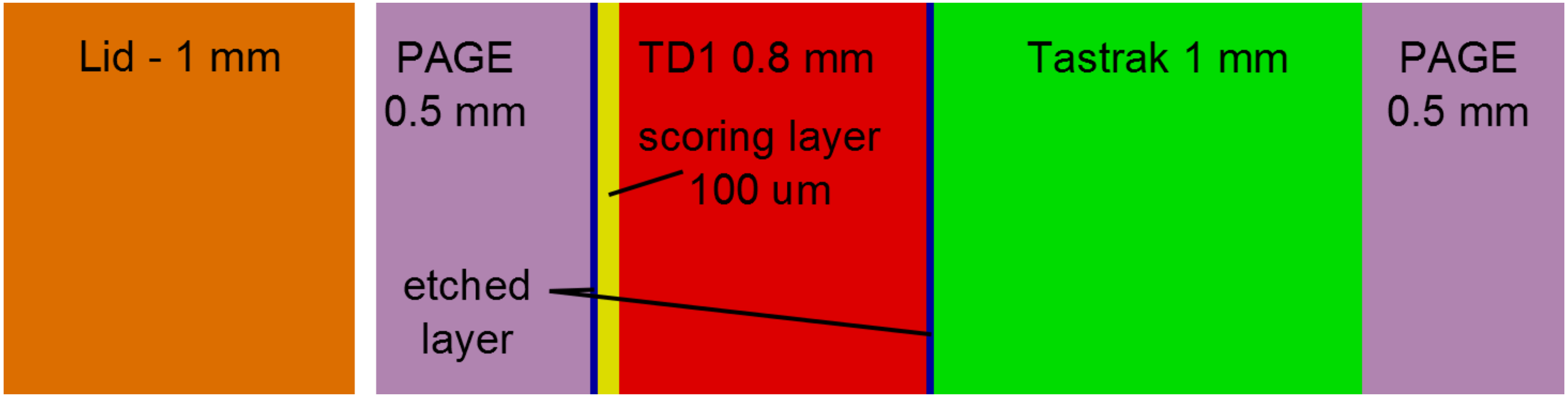


Profile Monitor, Four Leaf Collimatc (FLC Al) and its cover (FLC Fe).

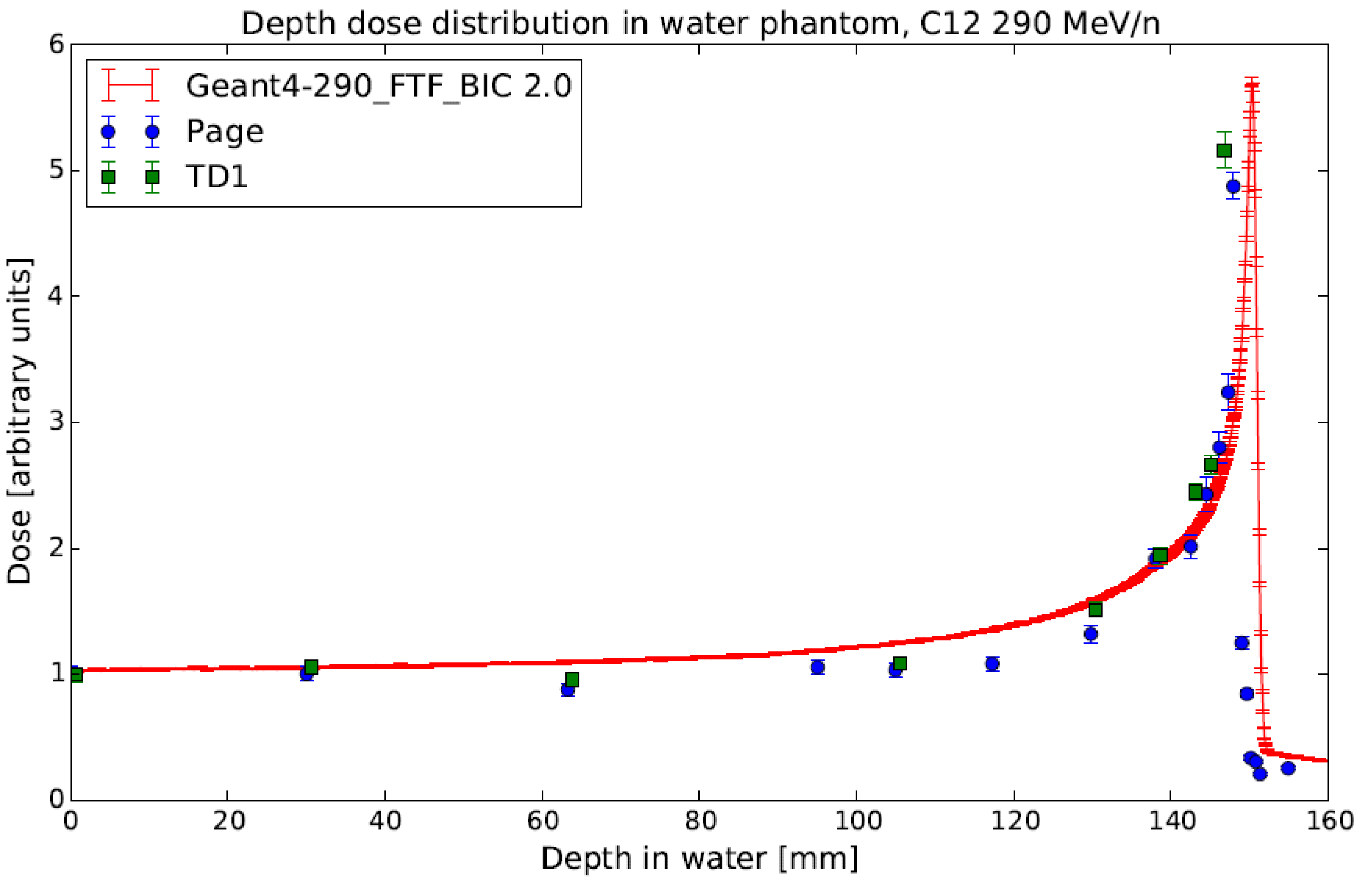


Geant4 modeling

- Positions of detectors:

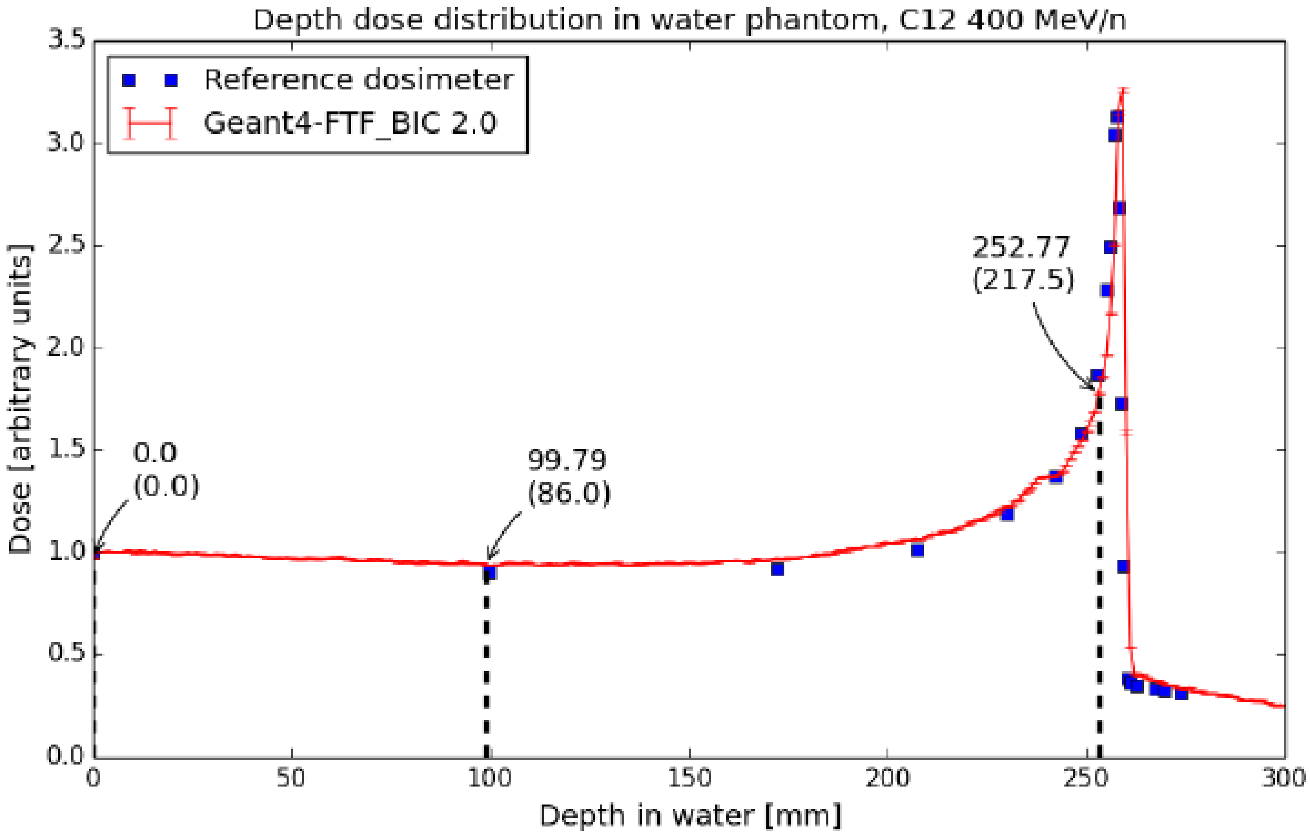


MONO 290 MeV/n C 12 beam in the water phantom



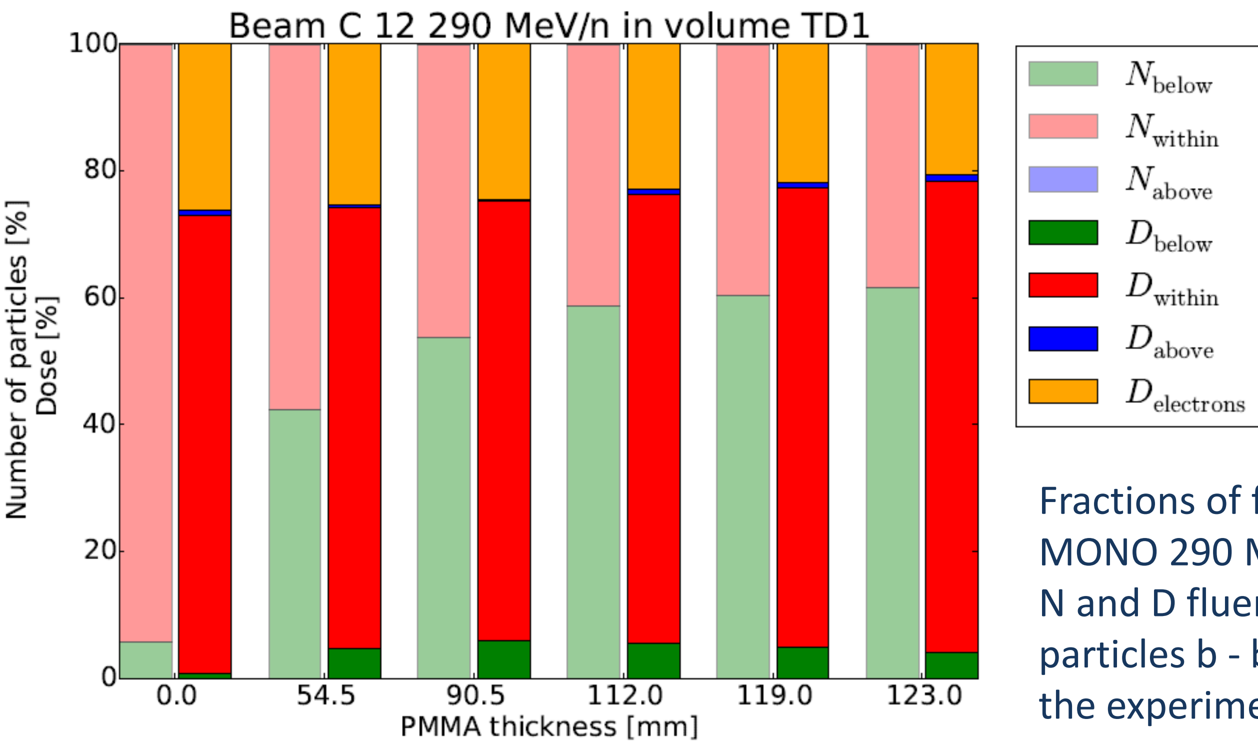
s [mm]	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5
χ^2	9.3	6.3	4.3	2.9	2.3	2.9	3.5	3.5

MONO 400 MeV/n C 12 beam in the water phantom



s [mm]	0.60	0.70	0.72	0.74	0.76	0.77	0.78	0.80	0.90
χ^2	2.80	1.14	0.98	0.87	0.83	0.81	0.83	0.89	1.75

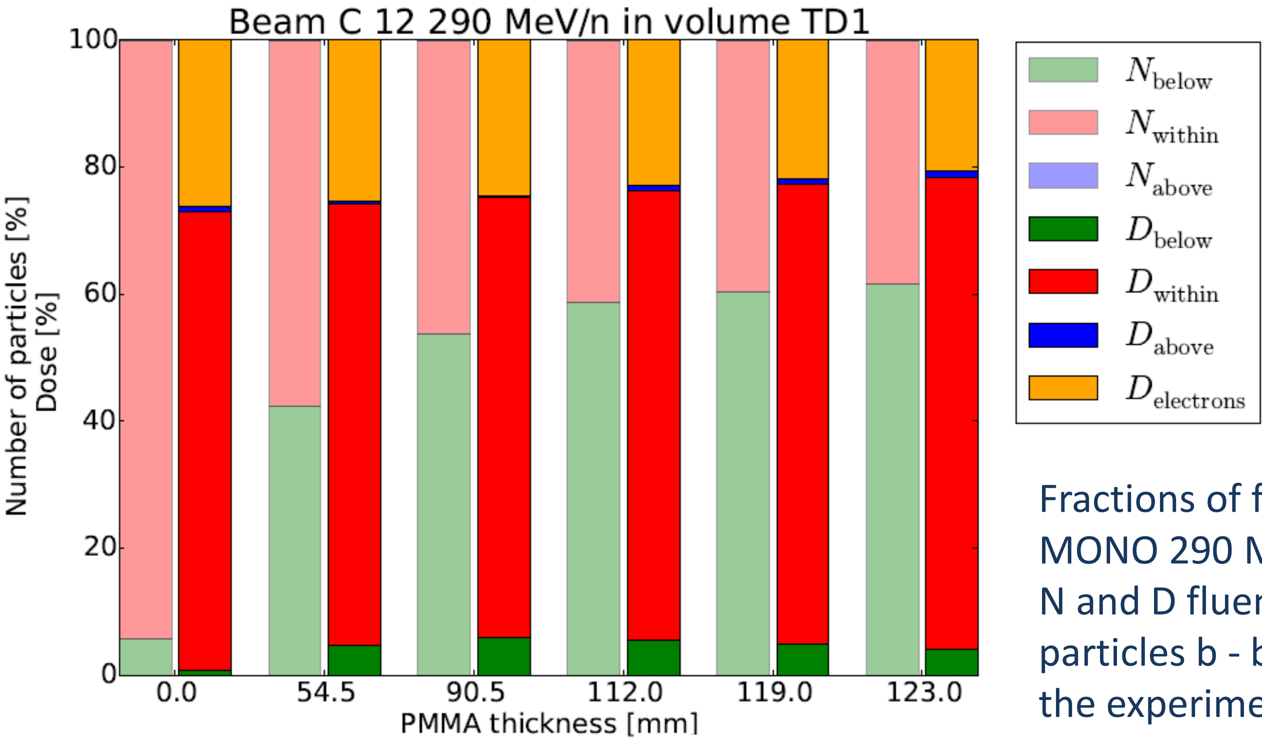
MONO 290 MeV/n C 12 beam in the water phantom



Fractions of fluence and dose for the beam MONO 290 MeV/n for Page detector $\pm 1\sigma$. N and D fluence and dose fractions for particles b - below, w - within and a - above the experimental detection limits.

PMMA [mm]	N_b [%]	D_b [%]	N_w [%]	D_w [%]	N_a [%]	D_a [%]	D_e [%]
0.0	5.8 ± 0.1	0.9 ± 0.1	94.0 ± 0.3	72.1 ± 0.2	0.2 ± 0.1	0.9 ± 0.1	26.2 ± 0.2
54.5	42.5 ± 0.2	4.7 ± 0.1	57.5 ± 0.2	69.5 ± 0.2	0.1 ± 0.1	0.3 ± 0.1	25.4 ± 0.1
90.5	53.8 ± 0.2	6.0 ± 0.1	46.2 ± 0.2	69.2 ± 0.2	0.1 ± 0.1	0.4 ± 0.1	24.4 ± 0.1
112.0	58.7 ± 0.2	5.5 ± 0.1	41.3 ± 0.2	70.9 ± 0.3	0.1 ± 0.1	0.7 ± 0.1	22.9 ± 0.1
119.0	60.5 ± 0.2	4.9 ± 0.1	39.4 ± 0.2	72.5 ± 0.3	0.1 ± 0.1	0.9 ± 0.1	21.8 ± 0.1
123.0	61.6 ± 0.2	4.2 ± 0.1	38.2 ± 0.2	74.2 ± 0.3	0.1 ± 0.1	1.1 ± 0.1	20.6 ± 0.1

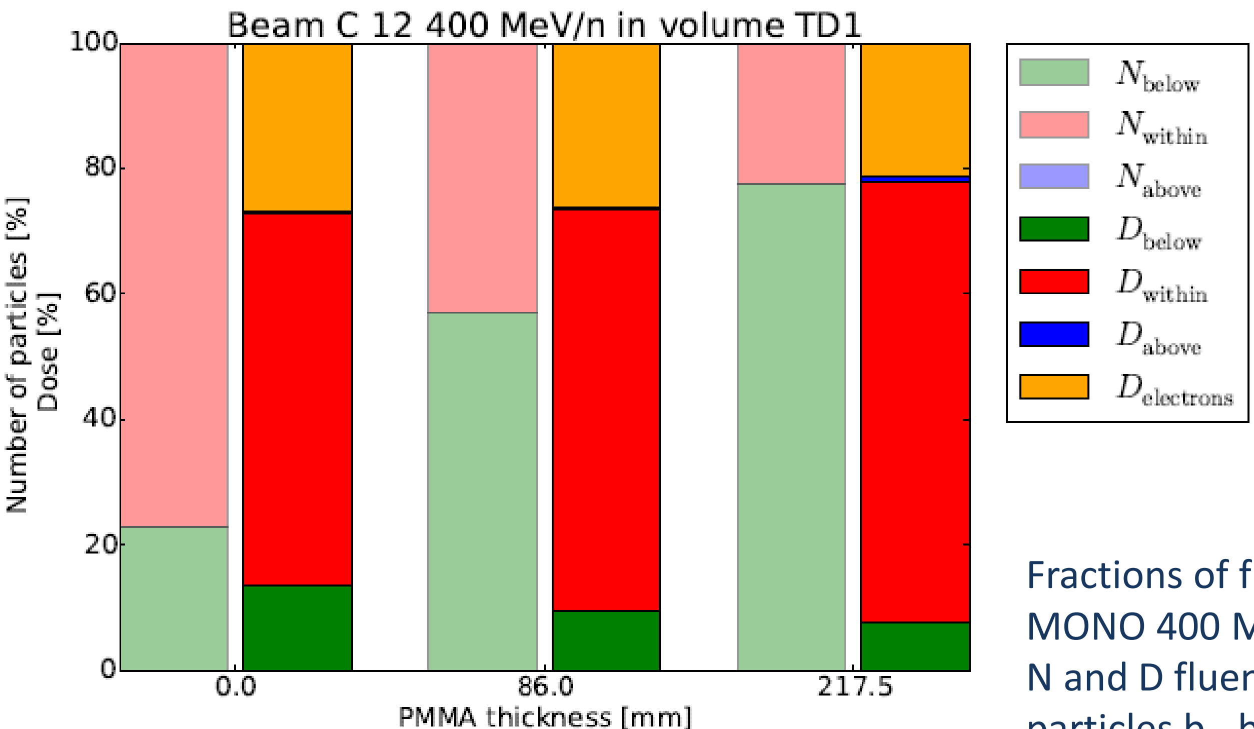
MONO 290 MeV/n C 12 beam in the water phantom



Fractions of fluence and dose for the beam MONO 290 MeV/n for TD1 detector $\pm 1\sigma$. N and D fluence and dose fractions for particles b - below, w - within and a - above the experimental detection limits.

PMMA [mm]	N_b [%]	D_b [%]	N_w [%]	D_w [%]	N_a [%]	D_a [%]	D_e [%]
0.0	5.8±0.1	0.9±0.1	94.0±0.3	72.1±0.2	0.2±0.1	0.9±0.1	26.2±0.2
54.5	42.5±0.2	4.7±0.1	57.5±0.2	69.5±0.2	0.1±0.1	0.3±0.1	25.4±0.1
90.5	53.8±0.2	6.0±0.1	46.2±0.2	69.2±0.2	0.1±0.1	0.4±0.1	24.4±0.1
112.0	58.7±0.2	5.5±0.1	41.3±0.2	70.9±0.3	0.1±0.1	0.7±0.1	22.9±0.1
119.0	60.5±0.2	4.9±0.1	39.4±0.2	72.5±0.3	0.1±0.1	0.9±0.1	21.8±0.1
123.0	61.6±0.2	4.2±0.1	38.2±0.2	74.2±0.3	0.1±0.1	1.1±0.1	20.6±0.1

MONO 400 MeV/n C 12 beam in the water phantom



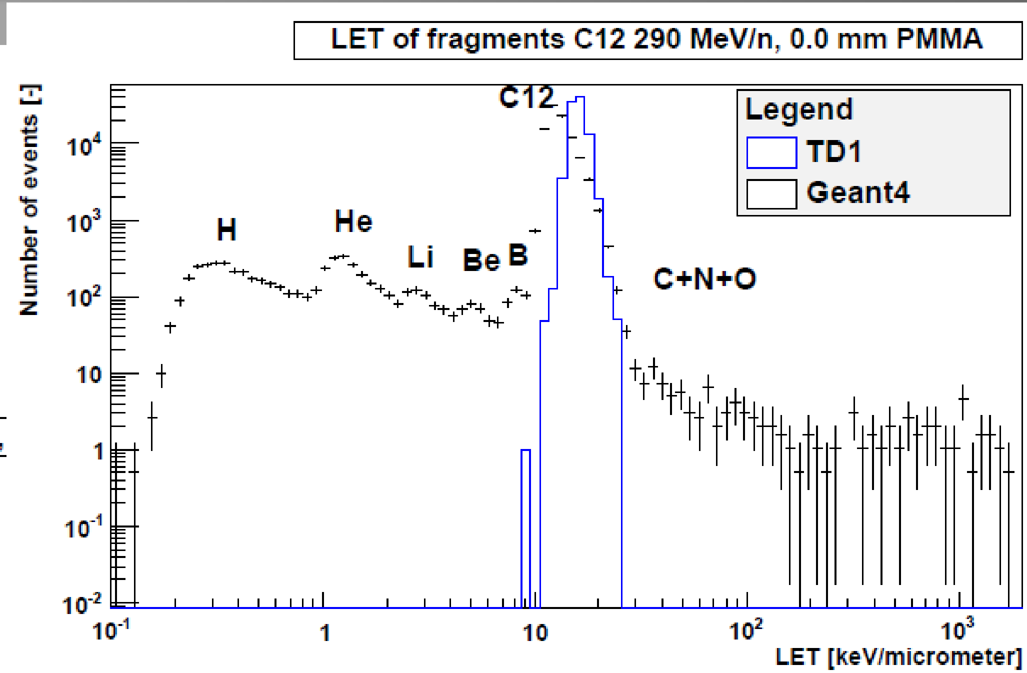
Fractions of fluence and dose for the beam MONO 400 MeV/n for TD1 detector $\pm 1\sigma$. N and D fluence and dose fractions for particles b - below, w - within and a - above the experimental detection limits.

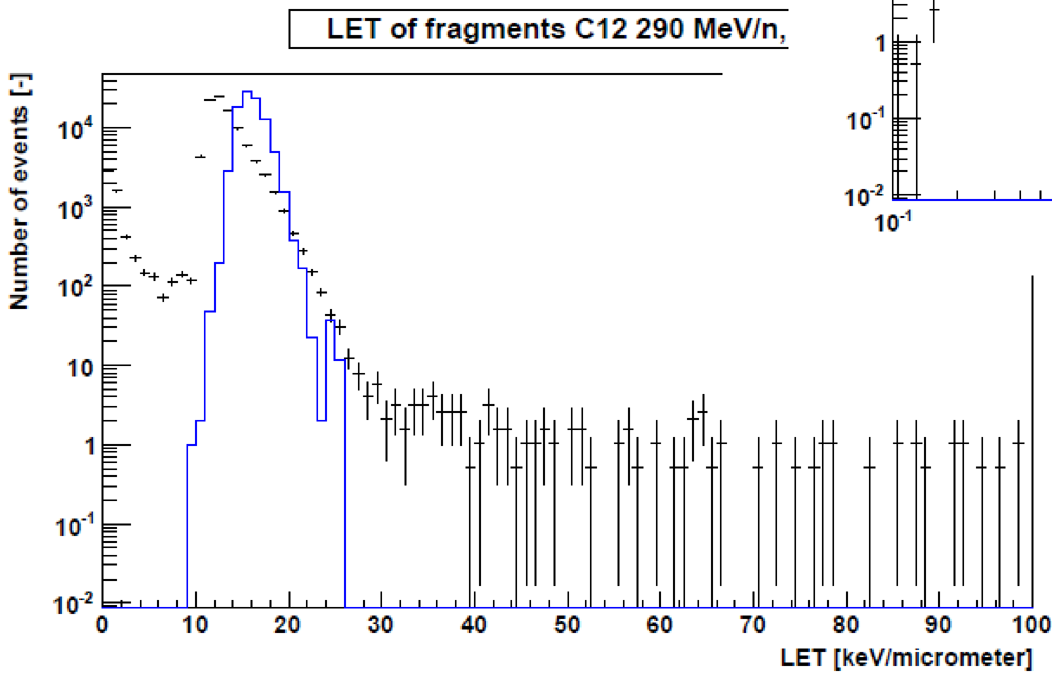
PMMA [mm]	N_b [%]	D_b [%]	N_w [%]	D_w [%]	N_a [%]	D_a [%]	D_e [%]
0.0	22.9 ± 0.2	13.6 ± 0.1	77.1 ± 0.2	59.3 ± 0.2	0.1 ± 0.1	0.4 ± 0.1	26.7 ± 0.2
86.0	56.9 ± 0.2	9.5 ± 0.1	43.1 ± 0.2	63.9 ± 0.2	0.1 ± 0.1	0.3 ± 0.1	26.2 ± 0.2
217.5	77.5 ± 0.2	7.6 ± 0.1	22.5 ± 0.1	70.2 ± 0.3	0.1 ± 0.1	1.0 ± 0.1	21.3 ± 0.1

LET spectra of MONO 290 MeV/n C 12 in TD1

0 mm PMMA

Spectra of unrestricted LET in water of the monoenergetic unshielded C 12 beam 290 MeV/n.

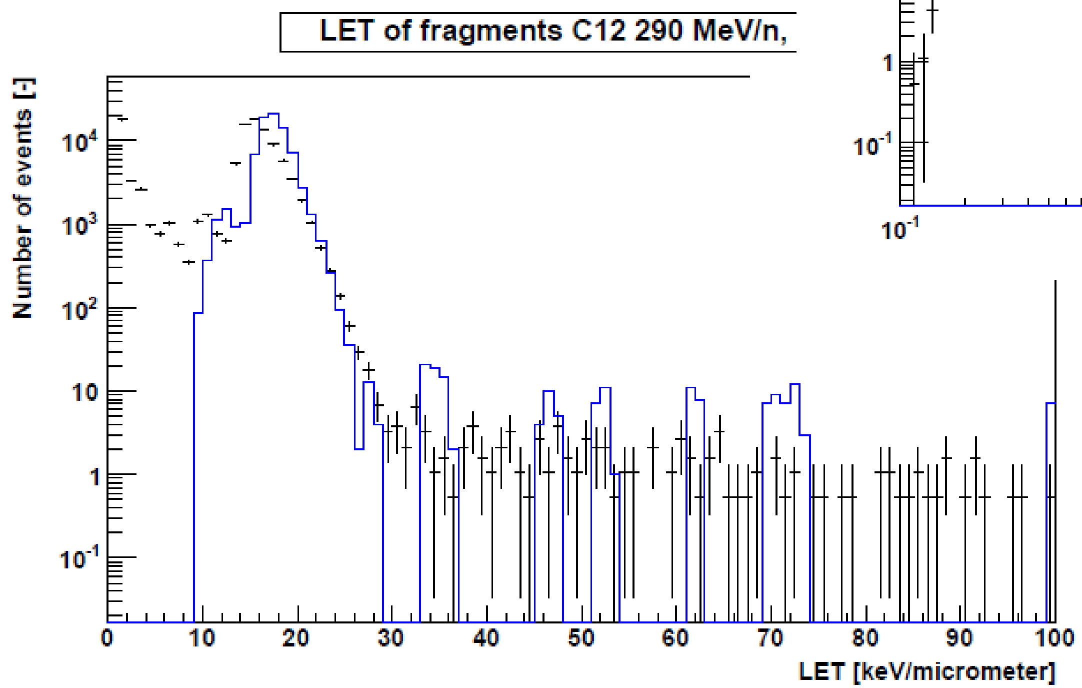


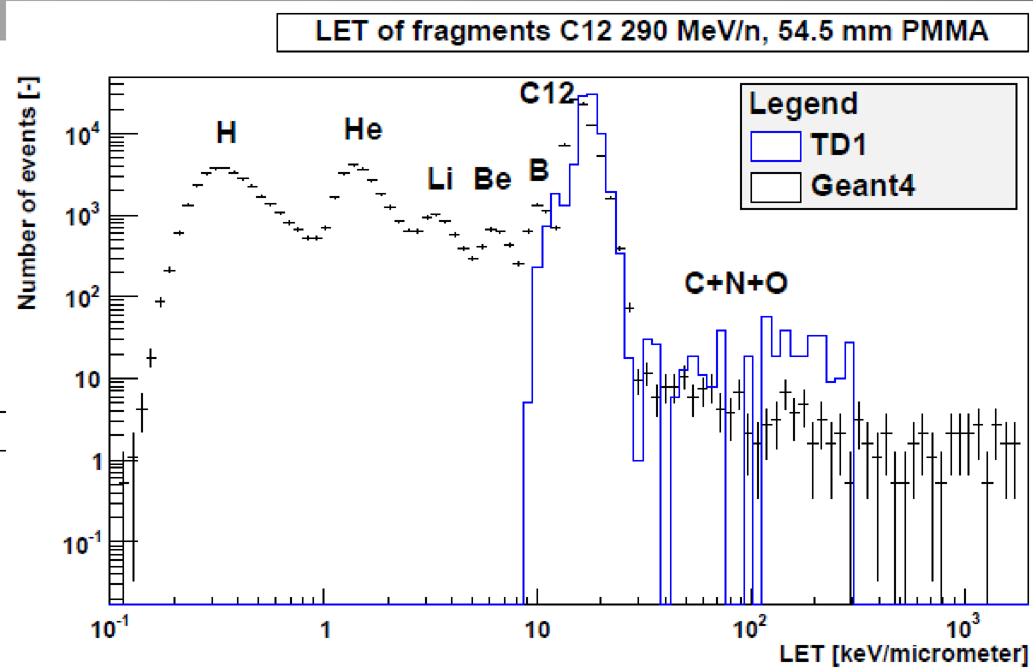


LET spectra of MONO 290 MeV/n C 12 in TD1

54.5 mm PMMA

Spectra of unrestricted LET in water of the monoenergetic unshielded C 12 beam 290 MeV/n.

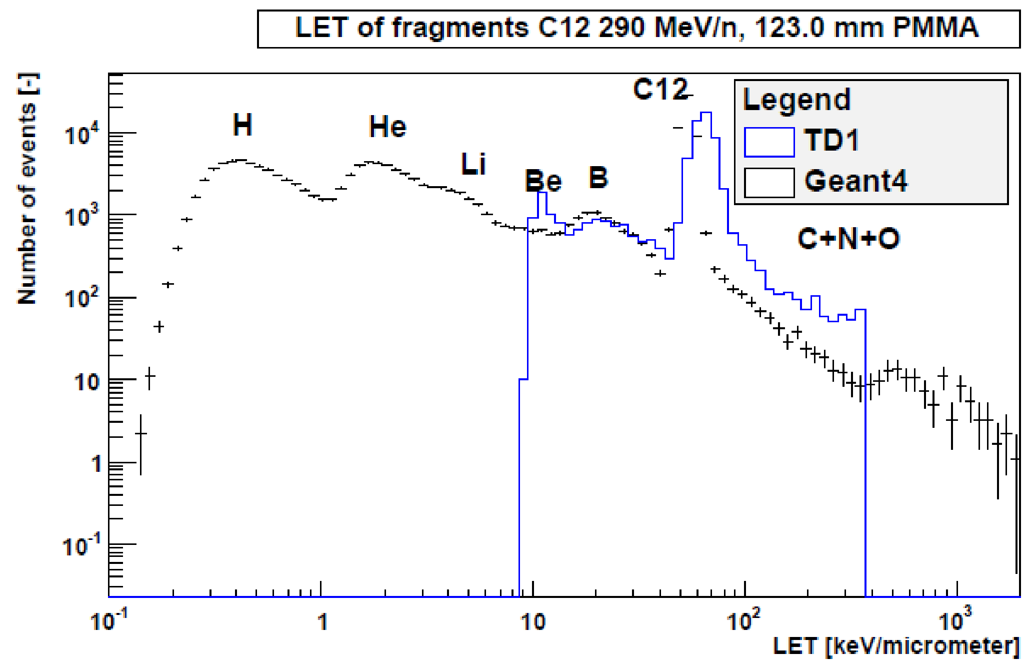


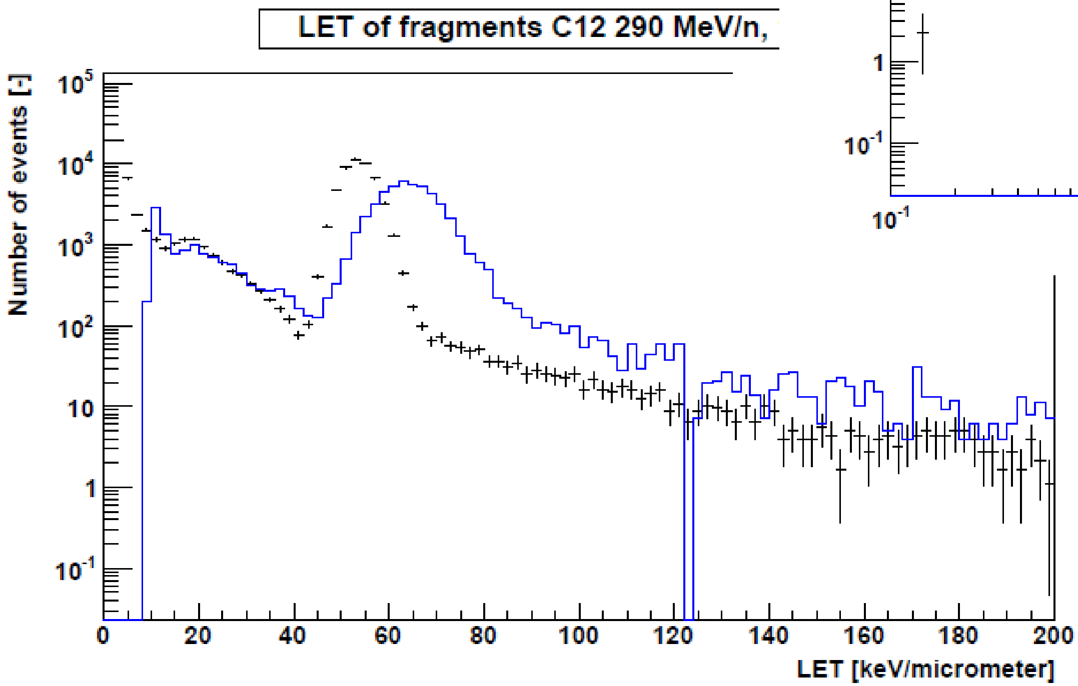


LET spectra of MONO 290 MeV/n C 12 in TD1

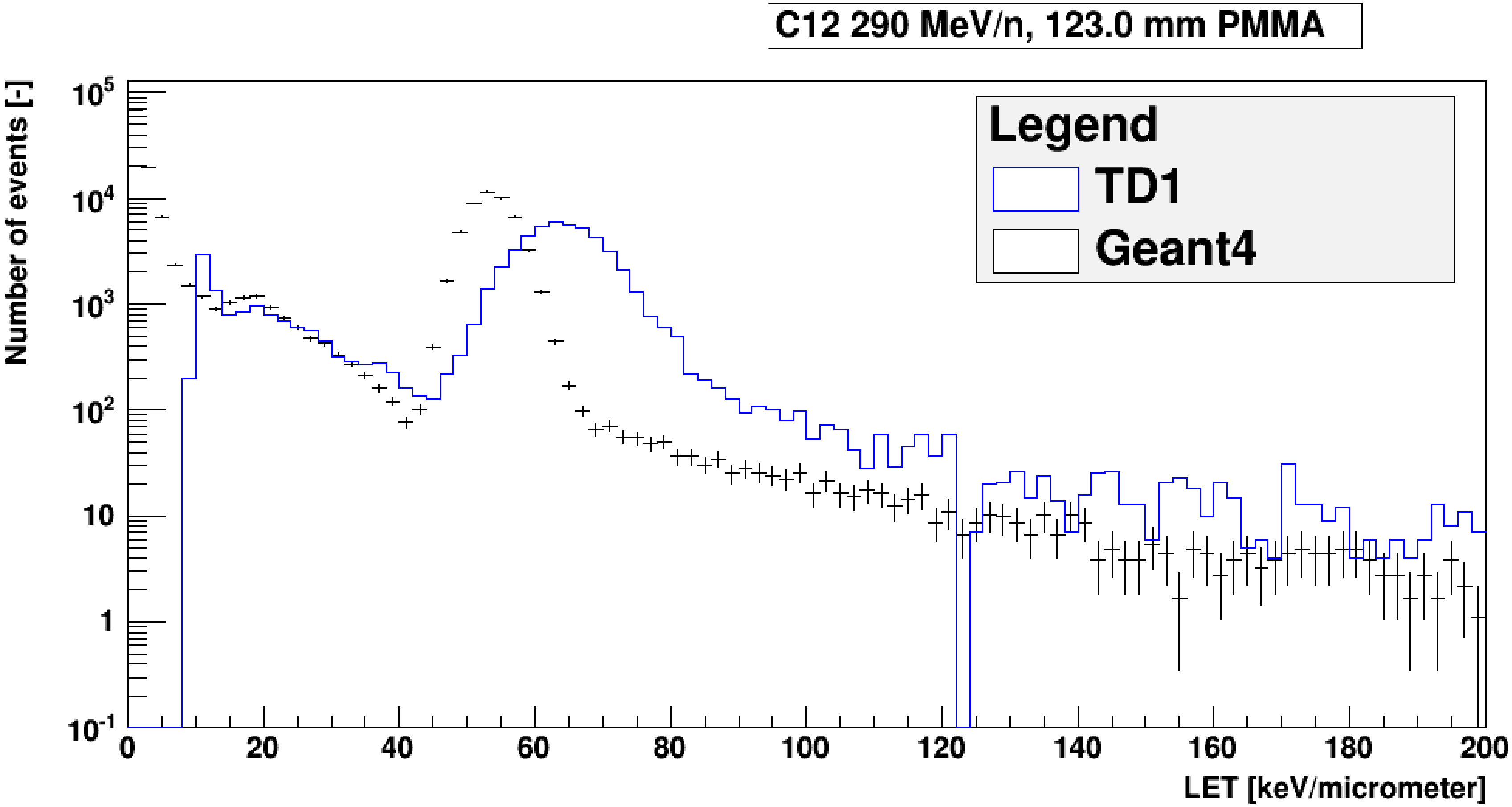
123.0 mm PMMA

Spectra of unrestricted LET in water
of the monoenergetic unshielded
C 12 beam 290 MeV/n.

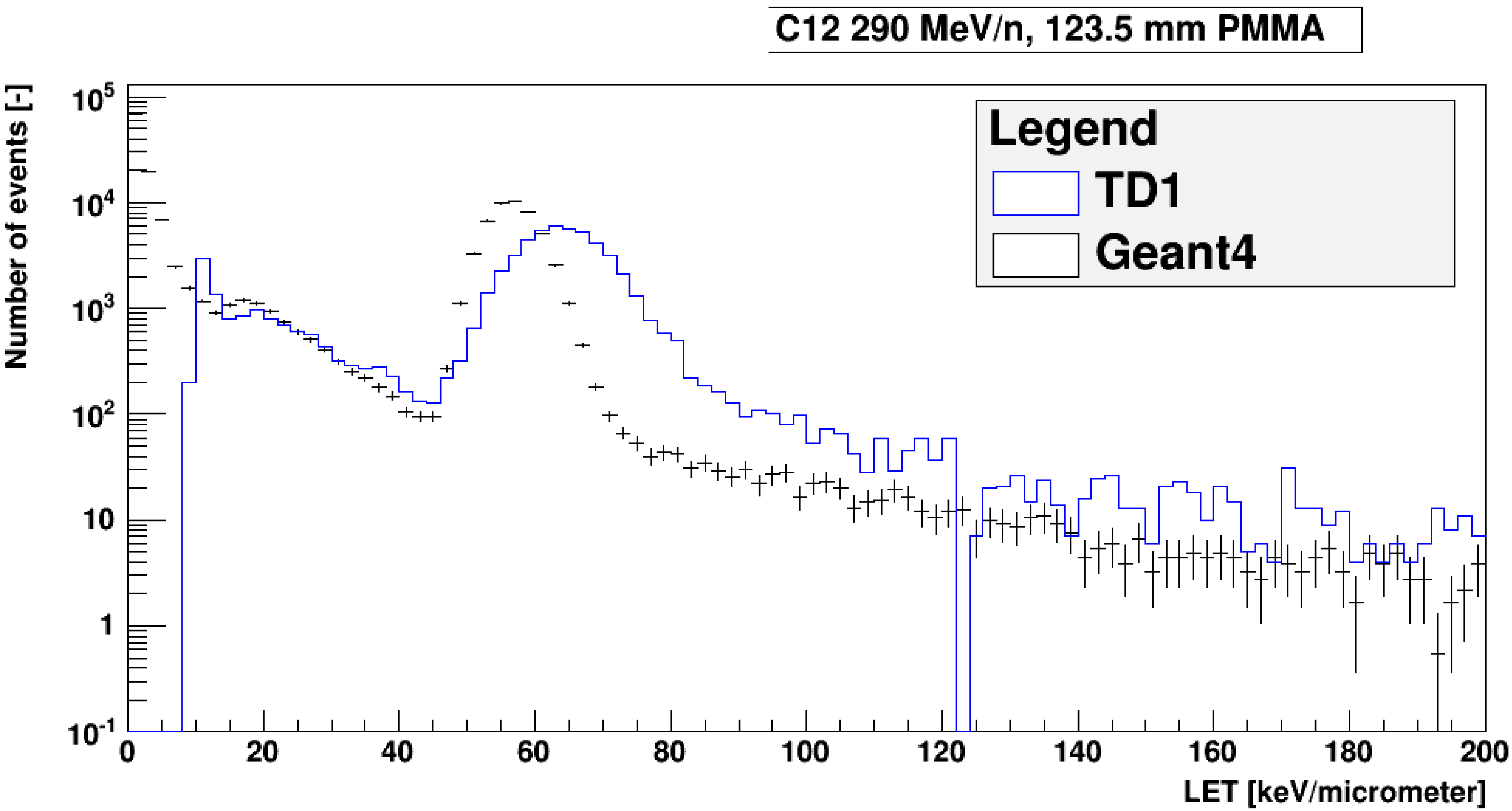




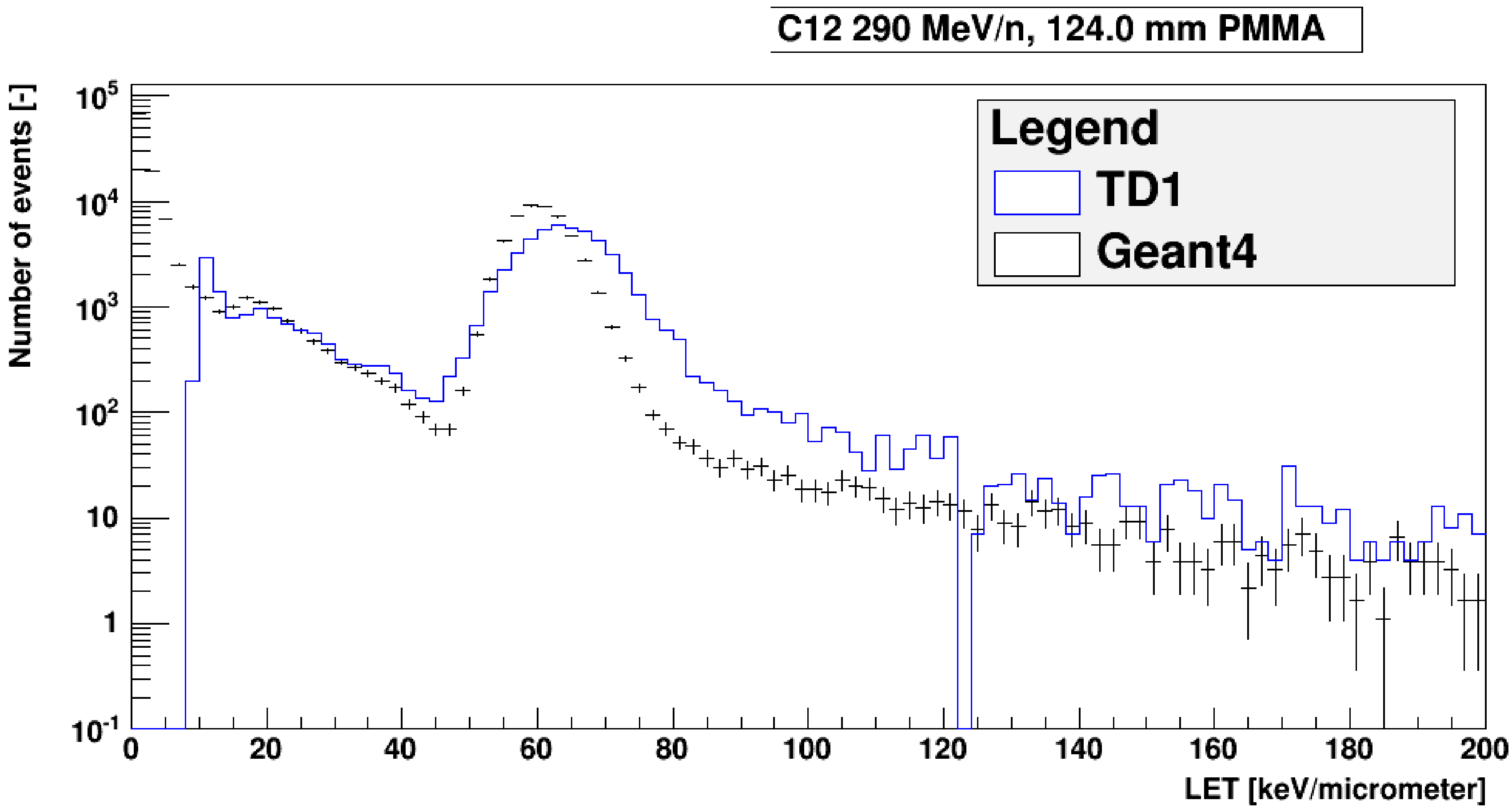
Shift of the peak



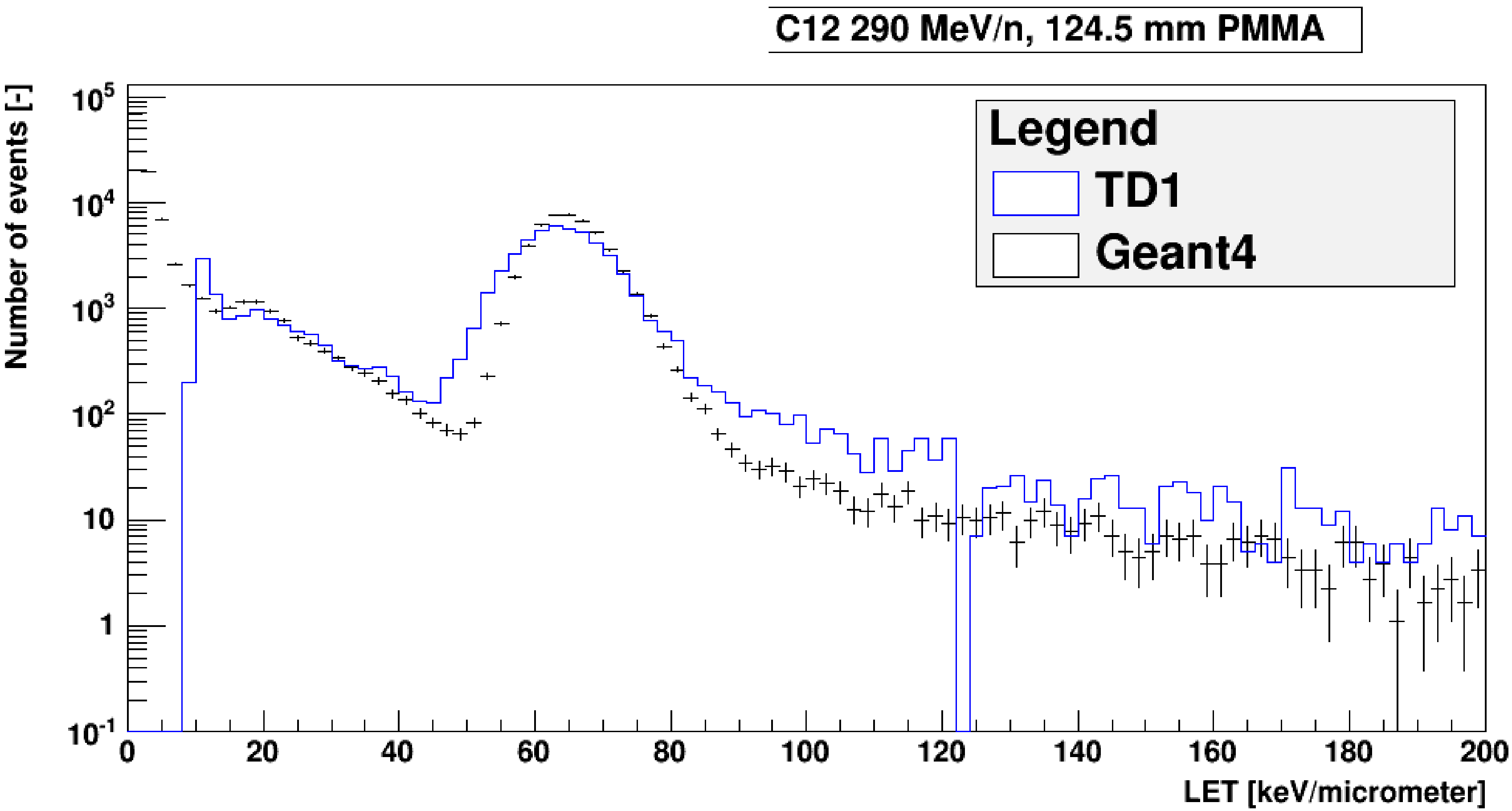
Shift of the peak



Shift of the peak



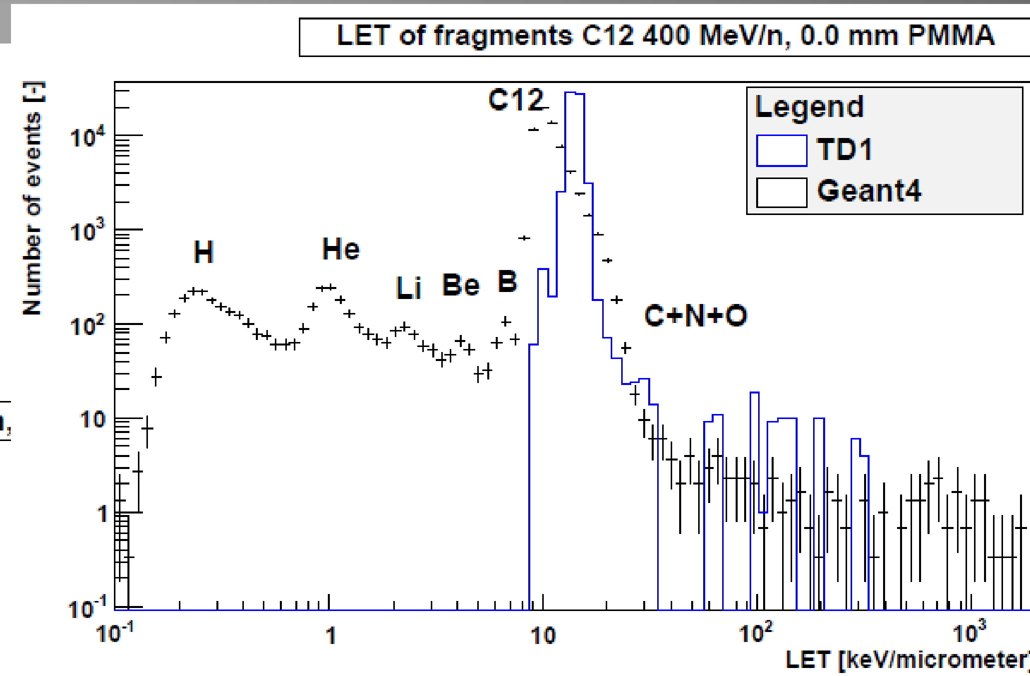
Shift of the peak

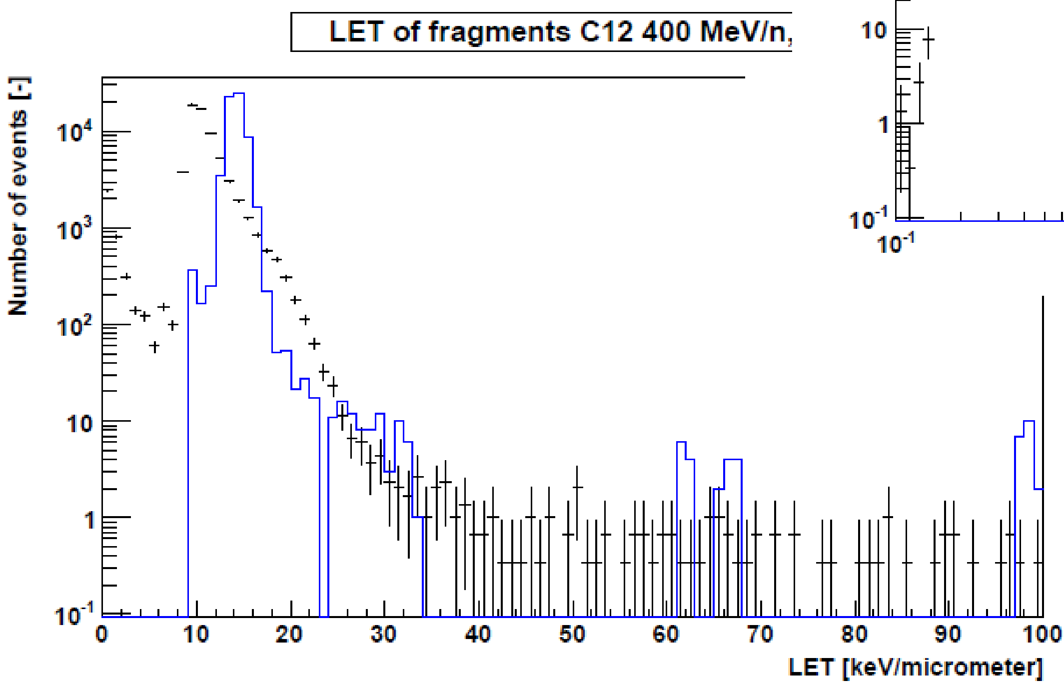


LET spectra of MONO 400 MeV/n C 12 in TD1

0 mm PMMA

Spectra of unrestricted LET in water of the monoenergetic unshielded C 12 beam 400 MeV/n.

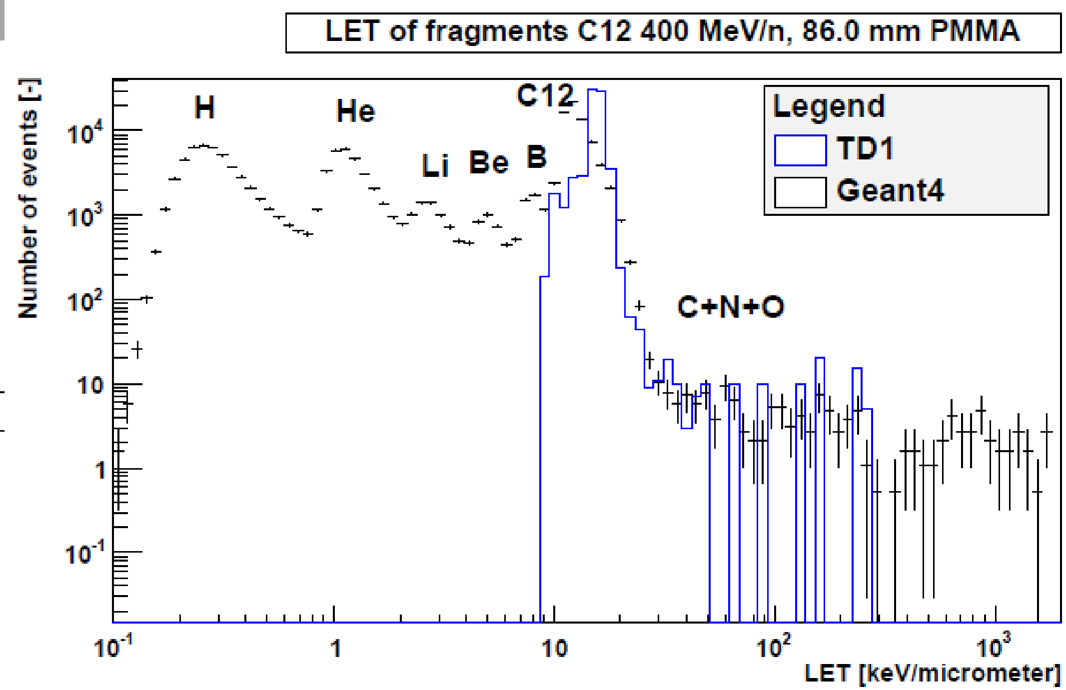


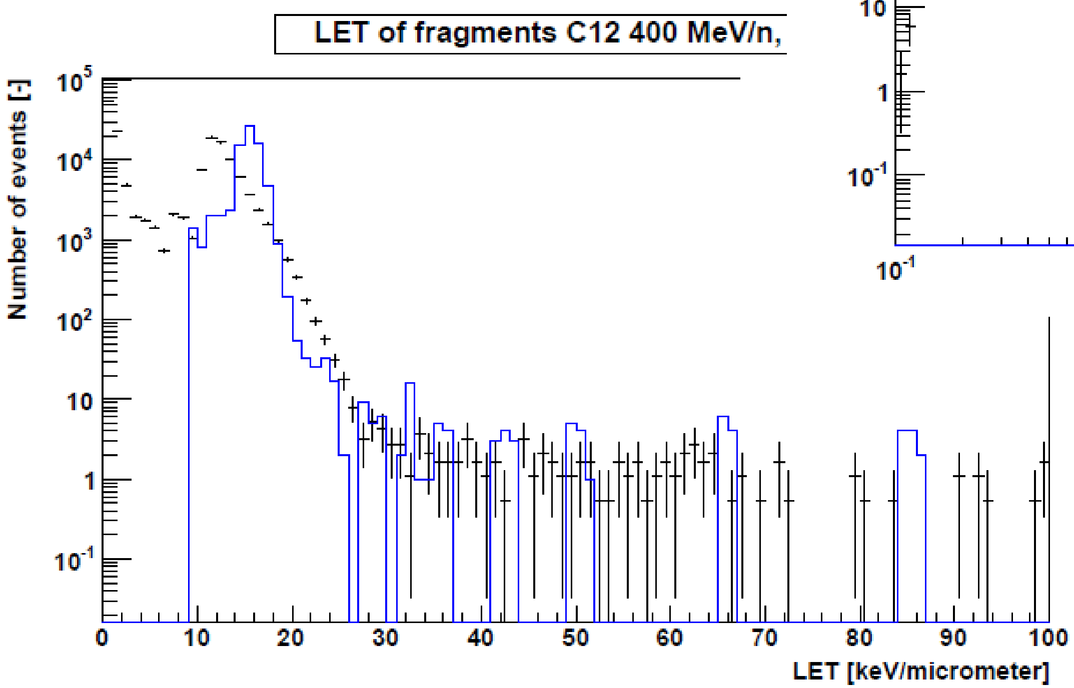


LET spectra of MONO 400 MeV/n C 12 in TD1

86 mm PMMA

Spectra of unrestricted LET in water of the monoenergetic unshielded C 12 beam 400 MeV/n.

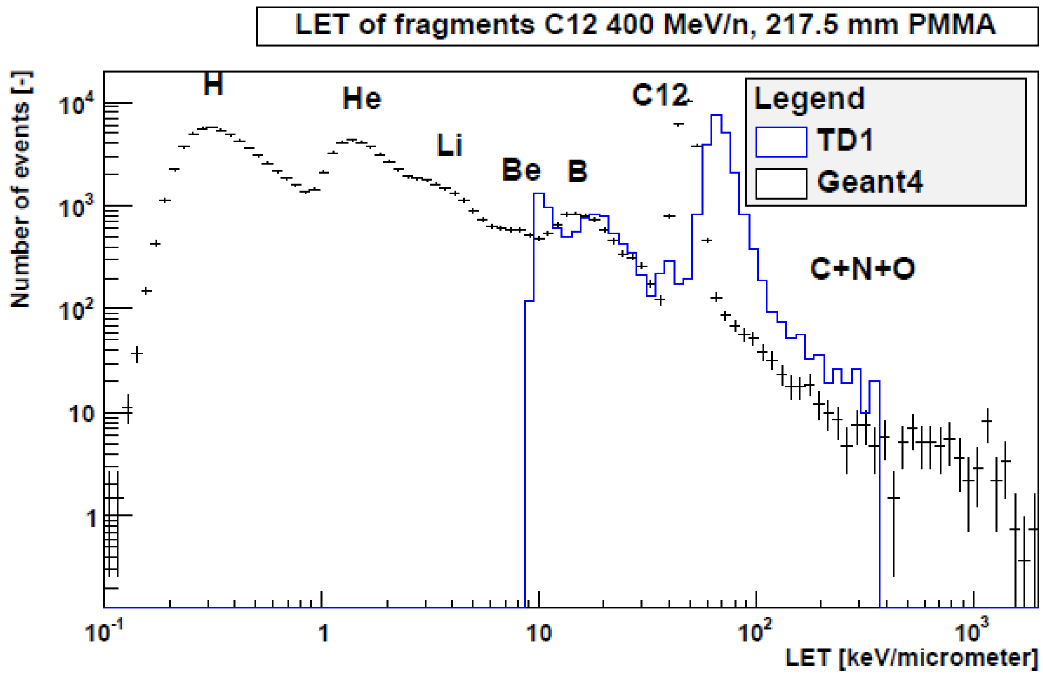


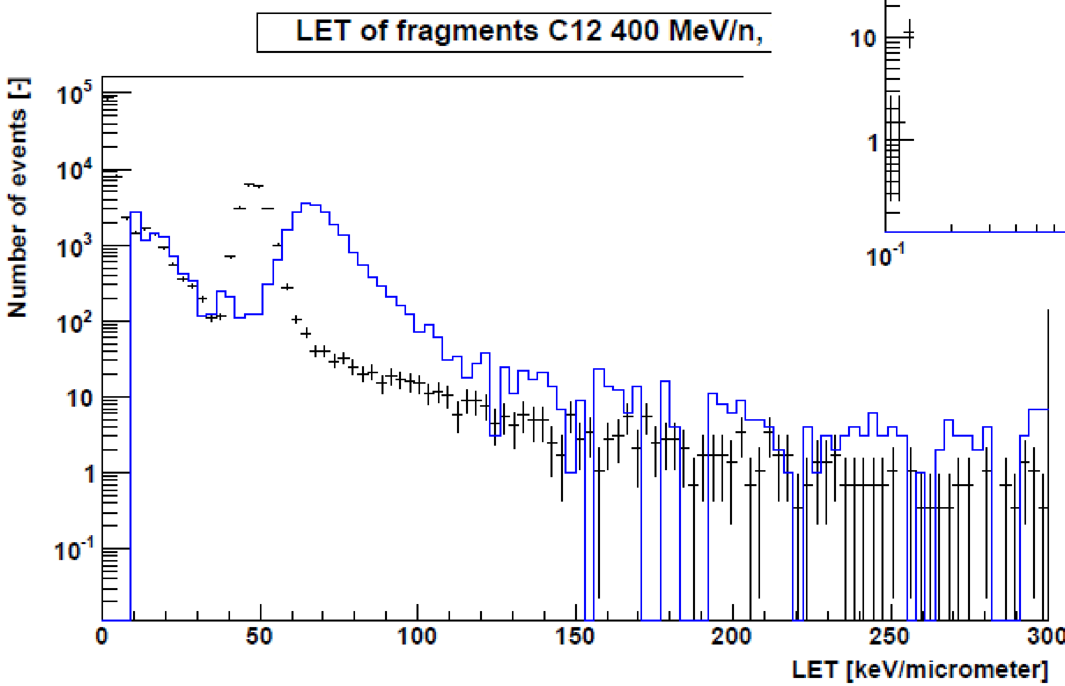


LET spectra of MONO 400 MeV/n C 12 in TD1

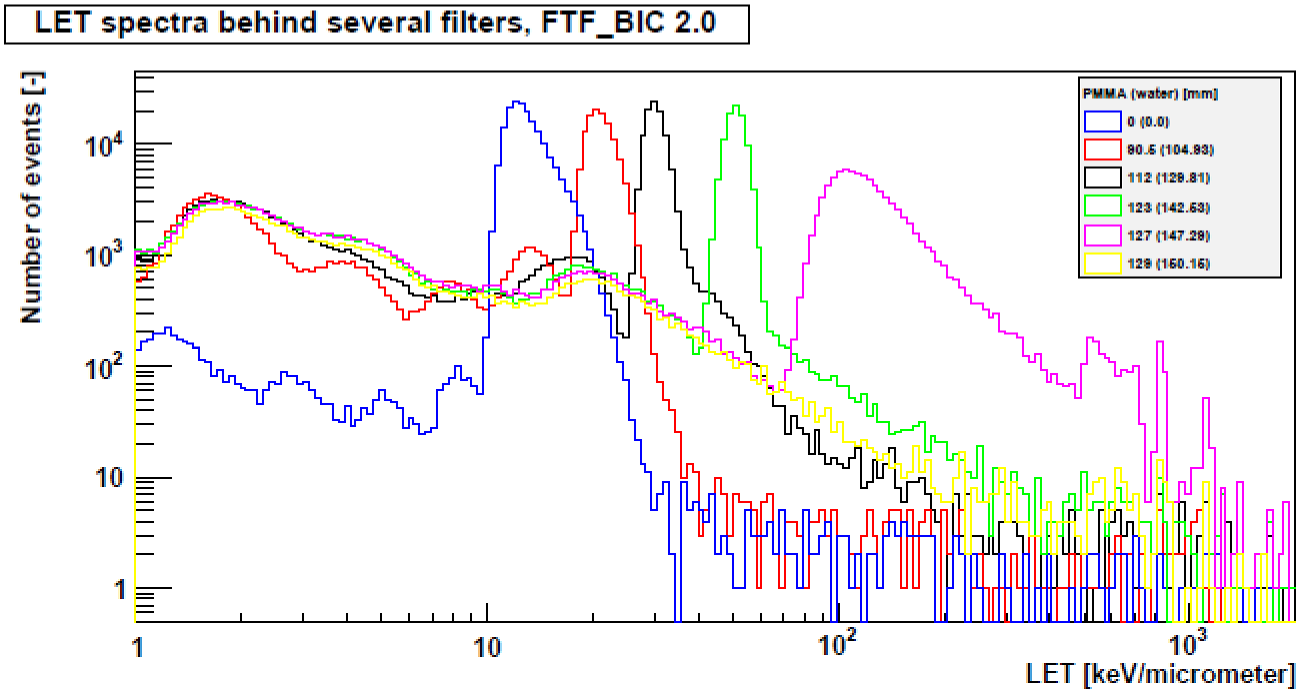
217.5 mm PMMA

Spectra of unrestricted LET in water of the monoenergetic unshielded C 12 beam 400 MeV/n.





LET dependence on depth



PMMA thickness [mm]	0.0	54.5	90.5	112.0	119.0	123.0	127.0
Water equivalent [mm]	0.0	63.26	104.93	129.81	138.02	142.53	147.29
Peak maximum [keV/μm]	12.06	15.14	20.52	30.01	39.16	51.09	105.19

Experiments

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Reference

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DEPARTMENT OF DOSIMETRY AND APPLICATION OF IONIZING RADIATION

http://dx.doi.org/10.6084/m9.figshare.1050072

DIPLOMA THESIS

Calculation of solid-state track etched detectors response in 290 MeV/n and 400 MeV/n carbon ion beams using Geant4

Author: Bc. Martin Šefl

Supervisor: Ing. Václav Štěpán, Ph.D.

Prague, 2014