Experimental measurement of the level of transmutation and neutron flux density in subcritical nuclear reactors, ADS

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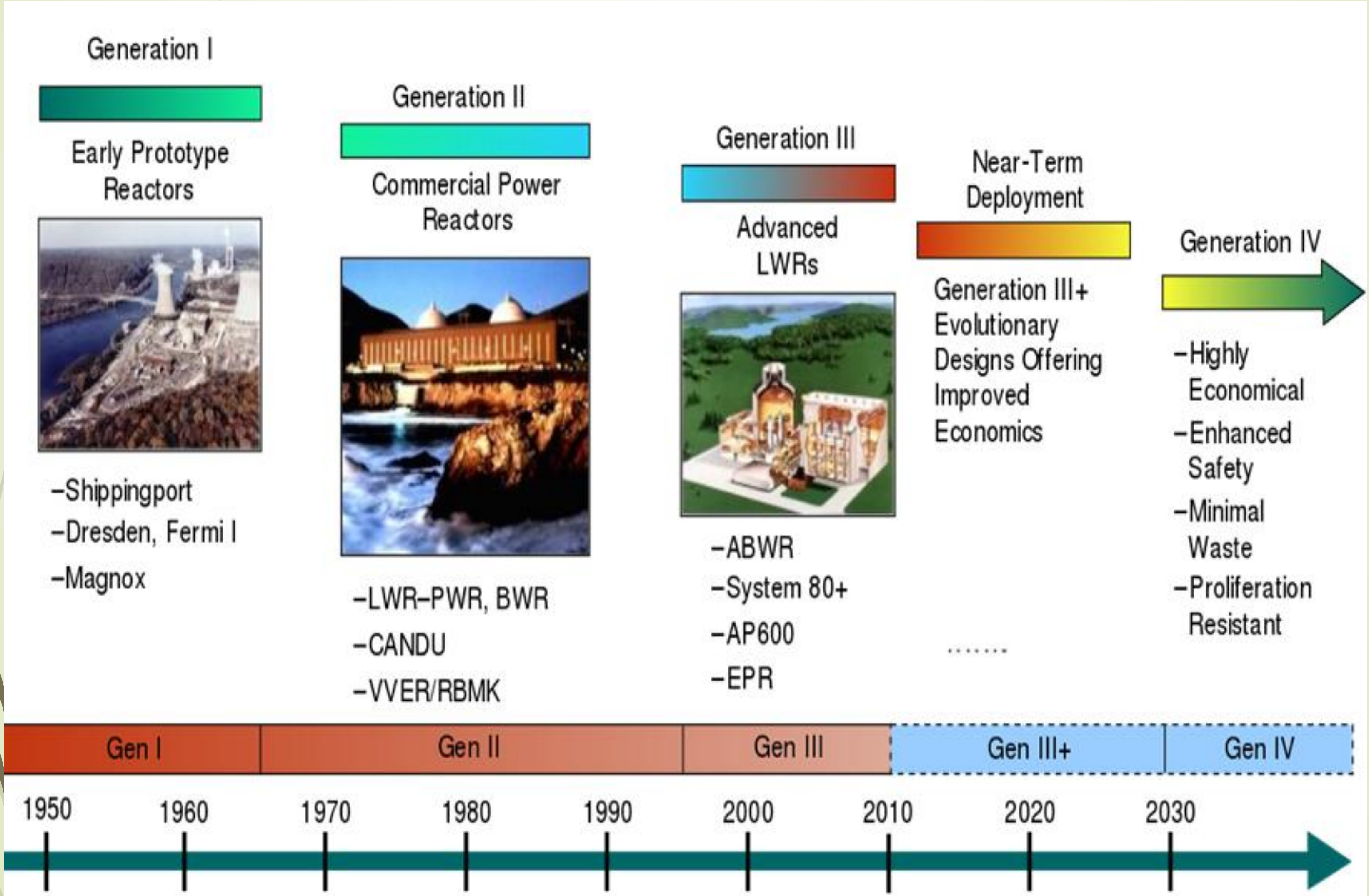
Outline

- What is ADS?
- QUINTA experiment
- Calibration Procedure
- Results
- Conclusion

Types of nuclear reactors



What is an Accelerator Driven System (ADS)?

- ADS is a subcritical fourth (IV) generation reactor that is controlled by a beam from an accelerator.

Critical : Keff =1

Supercritical : Keff > 1

Subcritical: Keff < 1

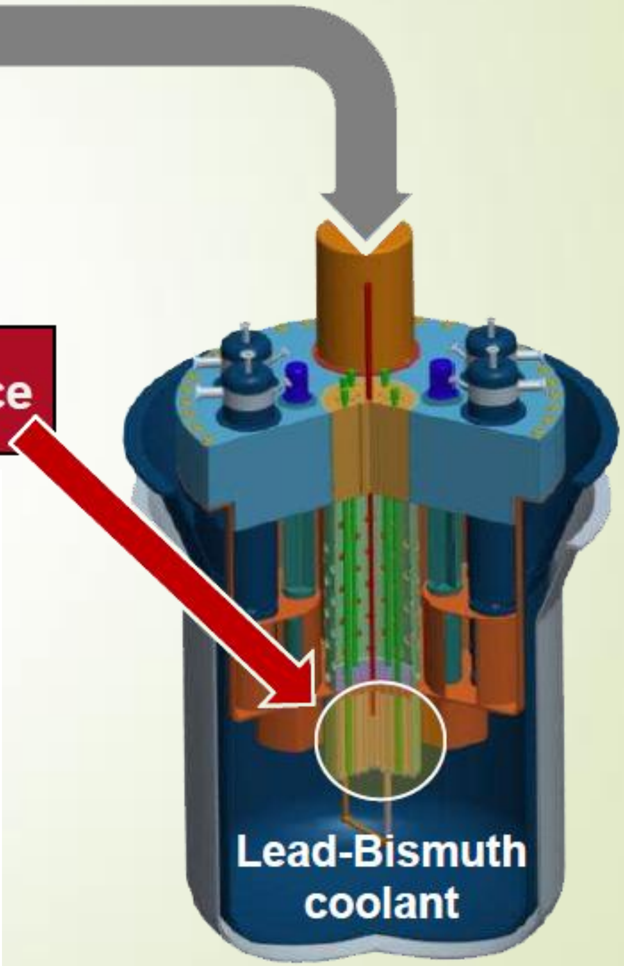
- Additional neutrons are taken from the accelerator.

Accelerator

(600 MeV - 4 mA proton)

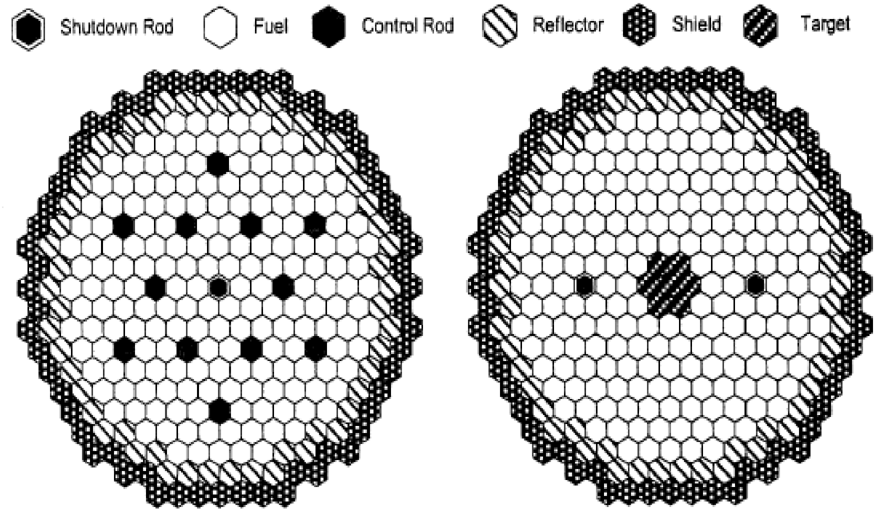
Reactor

- Subcritical mode
- 65 to 100 MWth



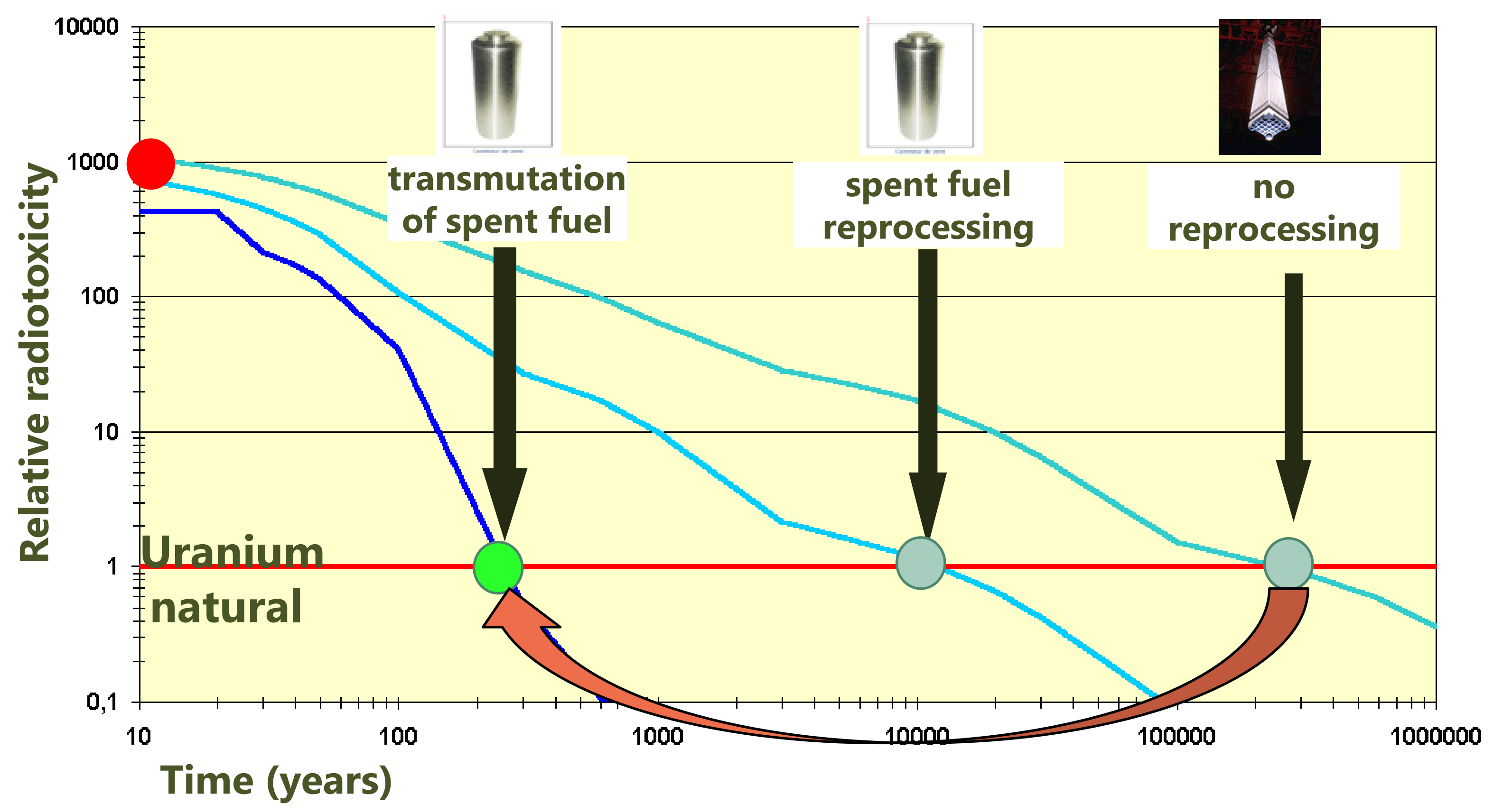
Spallation Source

Lead-Bismuth coolant



(a) CRS Core (b) ADS Core

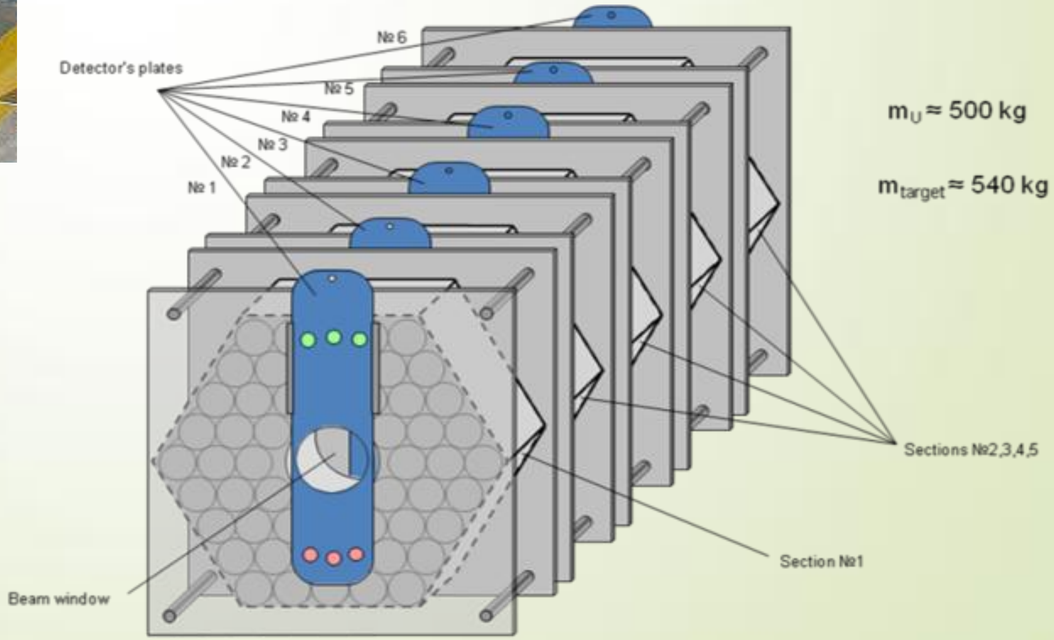
Advantages of ADS



- Enhanced safety.
- Reduced nuclear waste because the system has a closed fuel cycle (fuel can re-used)
- Possibility to transmutate long-lived radioactive waste into short-lived or non-radioactive waste.

The QUINTA experimental set-up

- The Quinta assembly, consists of a total of 512 kg of natural uranium.
- It is composed of five sections and the first section has a hole/beam window which is 80 mm in diameter and serves to reduce the loss of backward emitted/scattered neutrons.



Why do we carry out Quinta experiments?

- The Quinta experiments help to simulate the ADS system.

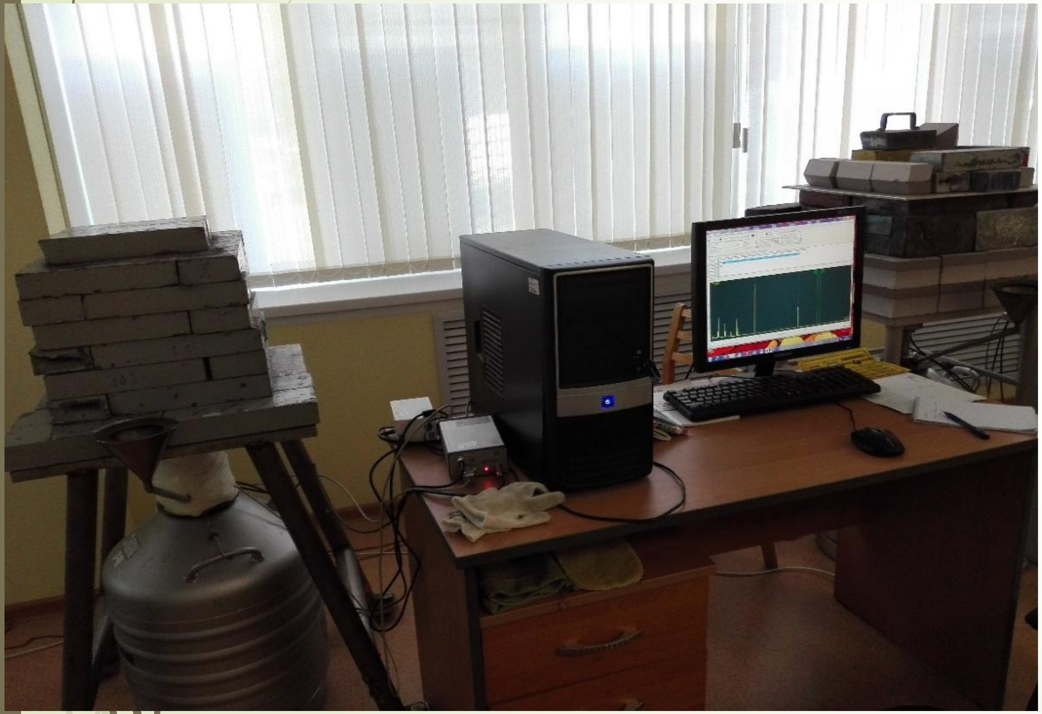
- Comparison of experimental results with results from theoretical calculations.

- Make improvements on simulation codes e.g FLUKA, MCNPX and GEANT.

- Better projection of future nuclear reactors.

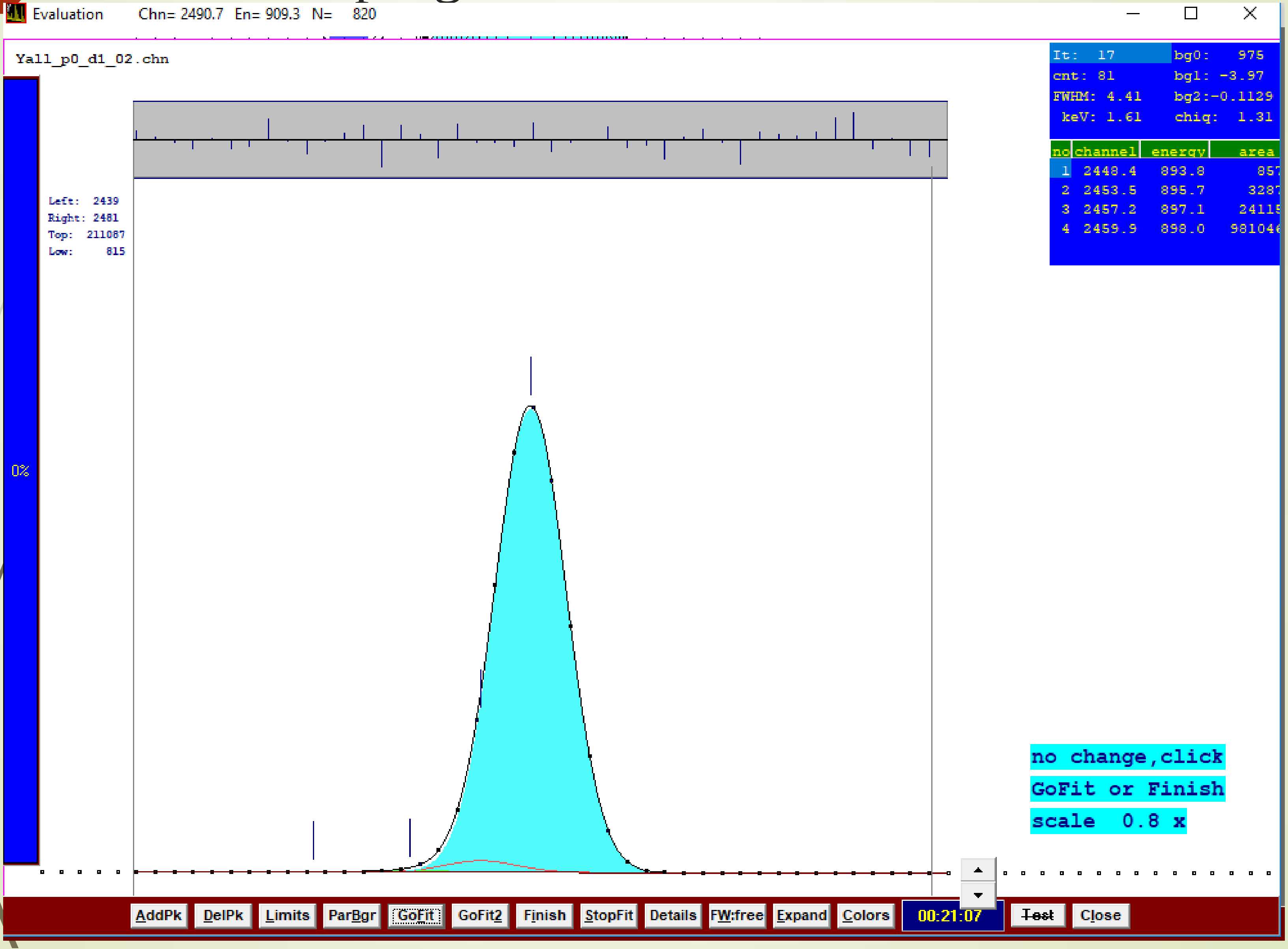
Measurement of gamma-rays using a HPGe detector

Background measurement



Measurement of gamma-rays from the irradiated Y-89 probes.

Analysis of gamma spectra using the DEIMOS program.



Evaluation Chn= 2490.7 En= 909.3 N= 820

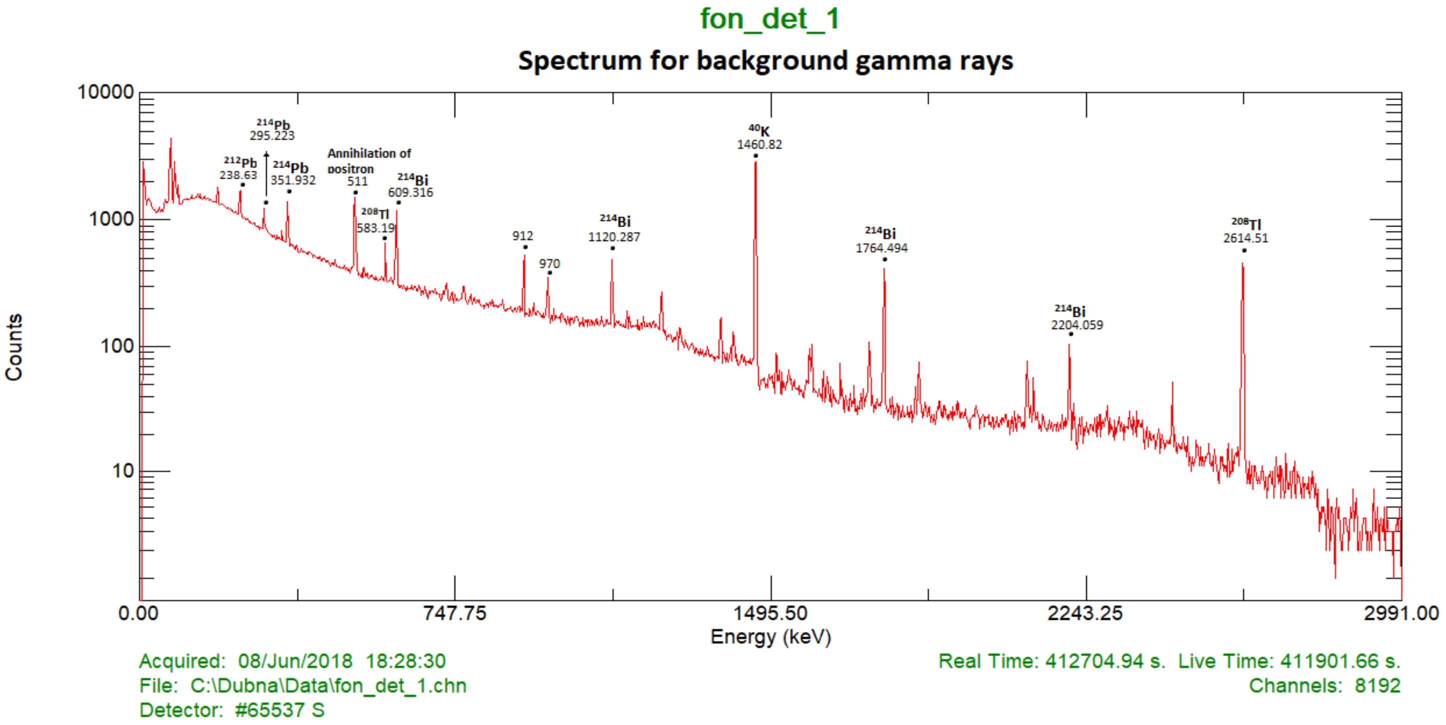
Yall_p0_d1_02.chn

Left: 2439
Right: 2481
Top: 211087
Low: 815

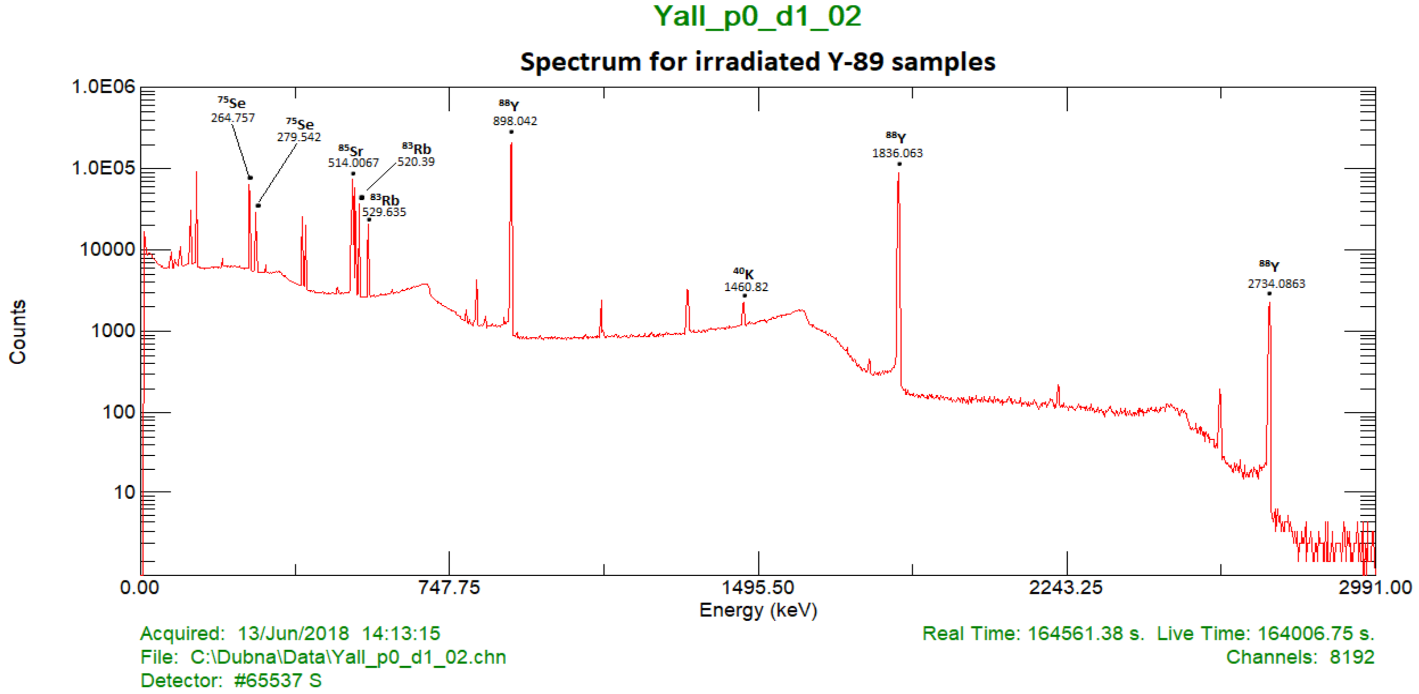
It: 17
cnt: 81
FWHM: 4.41
keV: 1.61
bg0: 975
bg1: -3.97
bg2:-0.1129
chiq: 1.31

no	channel	energy	area
1	2448.4	893.8	857
2	2453.5	895.7	3287
3	2457.2	897.1	24115
4	2459.9	898.0	981046

no change,click
GoFit or Finish
scale 0.8 x


fon_det_1

Spectrum for background gamma rays


Yall_p0_d1_02

Spectrum for irradiated Y-89 samples

From shielding material

^{208}Tl

^{212}Bi

^{212}Pb

^{214}Bi

^{214}Pb

From the ground

^{220}Rn

^{224}Ra

^{228}Th

^{40}K

Identified radionuclides

^{88}Y

^{75}Se

^{83}Rb

^{85}Sr

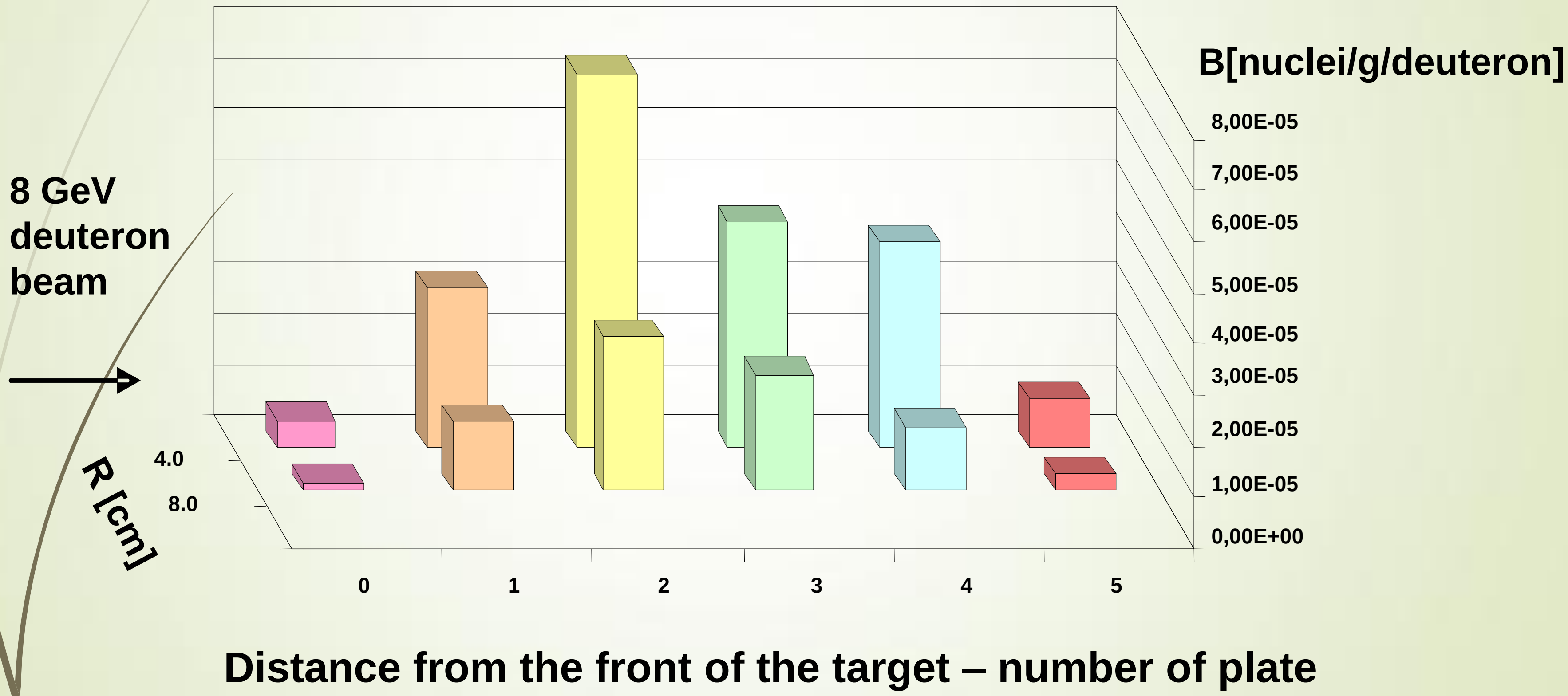
Calibration and normalization of measured results

$$B = N_1 \cdot \frac{1}{m \cdot I} \cdot \frac{\Delta S(G) \cdot \Delta D(E)}{\frac{N_{abs}}{100} \cdot \varepsilon_p(E) \cdot COI(E,G)} \cdot \frac{(\lambda \cdot t_{ira})}{\left(1 - \exp(-\lambda \cdot t_{ira})\right)} \cdot \exp(\lambda \cdot t_+) \cdot \frac{\frac{t_{real}}{t_{live}}}{\left(1 - \exp(-\lambda \cdot t_{real})\right)}$$

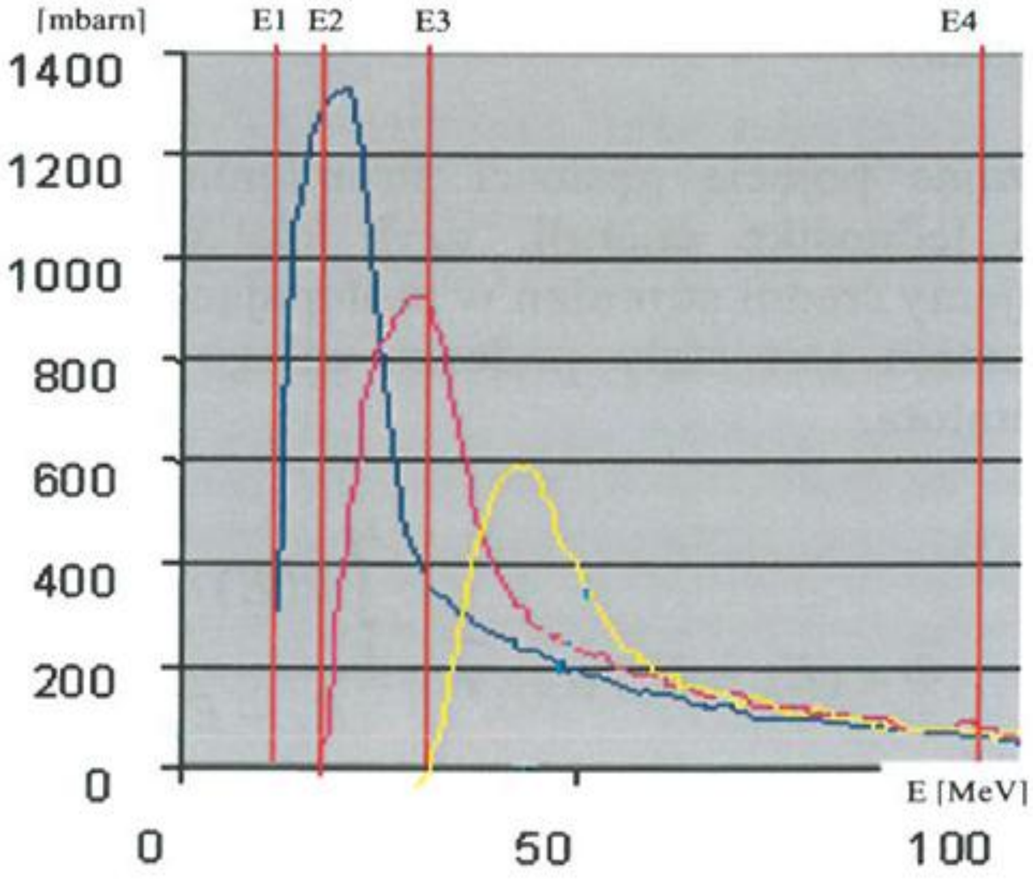
where	**B**	**number of nuclei per 1 gram of a sample material per 1 primary deuteron [nuclei/g/deuteron]**
	N_1	peak area (line) – number of counts
	N_{abs}	the absolute intensity of given line in percent [%]
	$\varepsilon_p(E)$	detector efficiency function of energy (polynomial)
	COI(E,G)	cascade effect coefficient function of energy and geometry
	$\Delta S(G)$	calibrations function for thickness and shape of detectors
	$\Delta D(E)$	calibrations function for self absorption inside the detectors
	I	total number of primary deuterons
	$t_{1/2}$	half life time [s]
	t_{ira}	elapsed time of irradiation [s]
	t_+	elapsed time from the end of irradiation to the beginning of measurement [s]
	t_{real}	elapsed time of the measurement [s]
	t_{live}	“live” time of measurement [s]
	m	mass of the sample (target) in grams [g]

Radioisotope production level

^{88}Y spatial distribution based on lines 898.042 and 1836.063 keV



Average neutron flux density calculation for the three energy regions

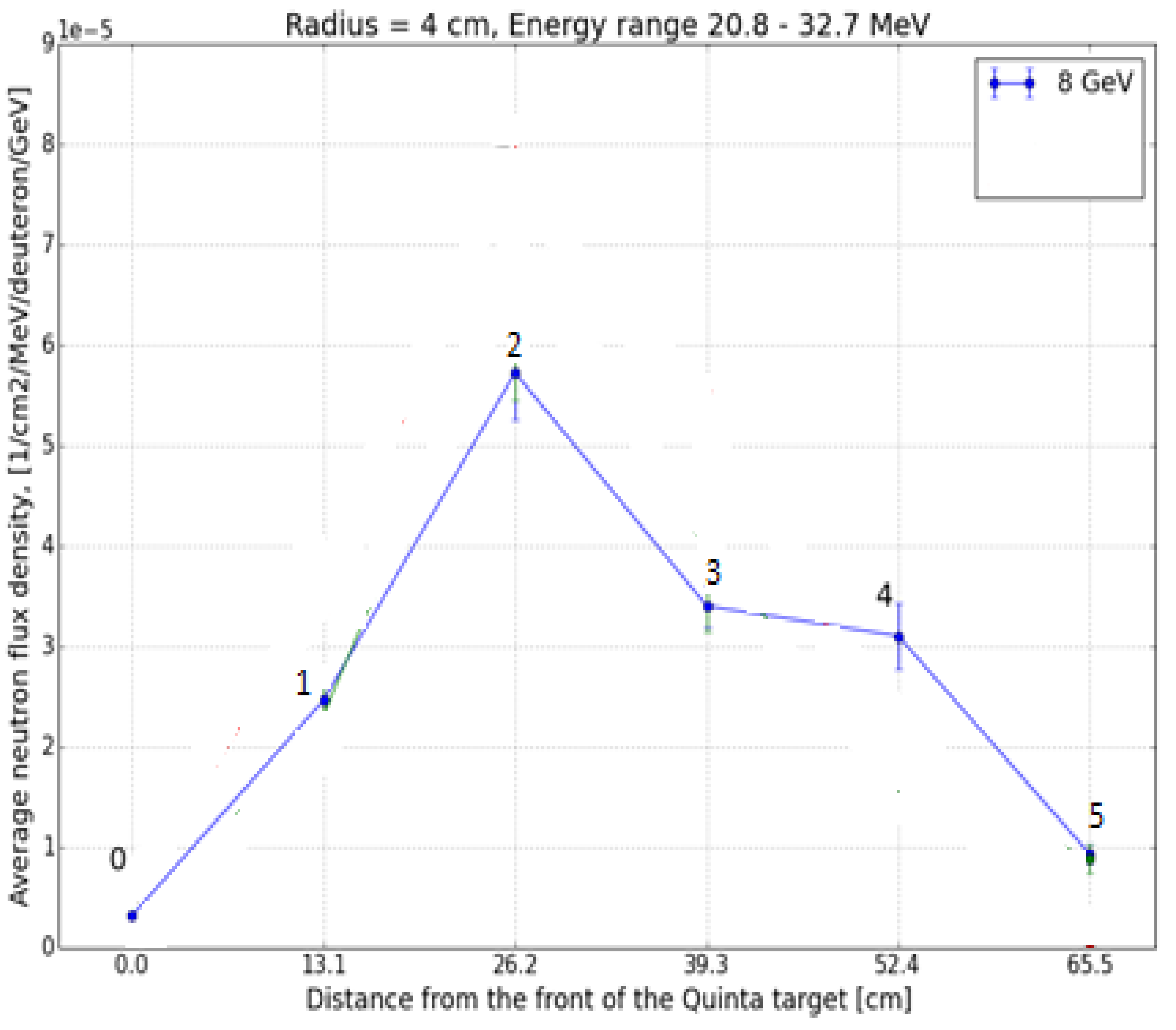


E1 = 11.5 MeV
E2 = 20.8 MeV
E3 = 32.7 MeV
E4 = 100 MeV

Energy range divided into 3 parts because of threshold reactions.

11,5 – 20,8 MeV	*(**n,2n**)*
20,8 – 32,7 MeV	*(**n,3n**)*
32,7 – 100 MeV	*(**n,4n**)*

We need the microscopic cross section for (n, xn) reactions


Radius = 4 cm, Energy range 20.8 - 32.7 MeV
1e−5
Average neutron flux density, [1/cm2/MeV/deuteron/GeV]
0
1
2
3
4
5
6
7
8
9
8 GeV
0
1
2
3
4
5
0.0
13.1
26.2
39.3
52.4
65.5
Distance from the front of the Quinta target [cm]

Conclusion

- Knowledge on the neutron flux density will be useful in the construction of fourth generation ADS subcritical nuclear reactors.
- The radioisotope production level will help determine where to position the transuranic isotopes in the reactor for better transmutation efficiency.
- The point of maximum neutron flux density is about 13 cm from the beginning of target
- We can see that Y-89 is a very good material for creating activation detectors.

References

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[3] A.J. Koning, S. Hilaire, M.C. Duijvestijn – "TALYS: Comprehensive Nuclear Reaction Modeling, International Conference on Nuclear Data for Science and Technology 2004, Santa Fe, New Mexico, 26th September-1st October 2004. AIP Conference Proceedings, Volume 769, pp.1154-9.

[4] M. Majerle - TALYS Calculation http://ojs.ujf.cas.cz/~mitja/download/poland

[5] L.R.Veesel et al. – "Cross sections for (n,2n) and (n,3n) reaction above 14 MeV", Physical Review, Part C - Nuclear Physics, Vol. 16, pp. 1792

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Спасибо

Thank you!

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