

Accelerator based monoenergetical neutron sources

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Why do we need monoenergetic neutrons?

- Measurement carry out with broad neutron spectra (reactor, PuBe source, ^{252}Cf) is important for some applications, but result is impossible to use to predict something for another neutron spectra.
- Using data obtained for monoenergetic neutrons we can predict a reaction rate for any other neutron spectrum.

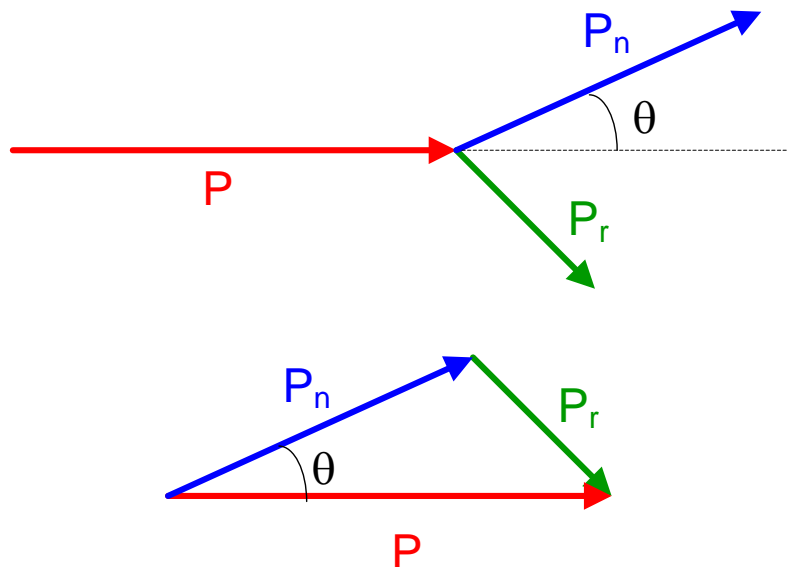
How are monoenergetic neutrons produced by accelerator?

- There are a lot of nuclear reactions with neutron in the output channel proceed by charge particles.
- Energy of neutrons depend on incoming charge particle energy.
- Accelerator can provide a big flux of monoenergetic charge particles (p, d).
- Irradiation of some targets by charge particles can produced you a flux of monoenergetic neutrons.

Main reactions which are used for monoenergetic neutron production

- ${}^7\text{Li} + \text{p} \rightarrow {}^7\text{Be} + \text{n} - 1.644 \text{ MeV}$
- ${}^3\text{H} + \text{p} \rightarrow {}^3\text{He} + \text{n} - 0.764 \text{ MeV}$
- ${}^2\text{H} + {}^2\text{H} \rightarrow {}^3\text{He} + \text{n} + 3.269 \text{ MeV}$
- ${}^2\text{H} + {}^3\text{H} \rightarrow {}^4\text{He} + \text{n} + 17.59 \text{ MeV}$

Reaction kinematics



No index – projectile ion
 n – index – neutron
 r – index – residual nucleus

$$E + Q = E_r + E_n,$$

Energy conservation law

$$p_r^2 = p^2 + p_n^2 - 2pp_n \cos \theta$$

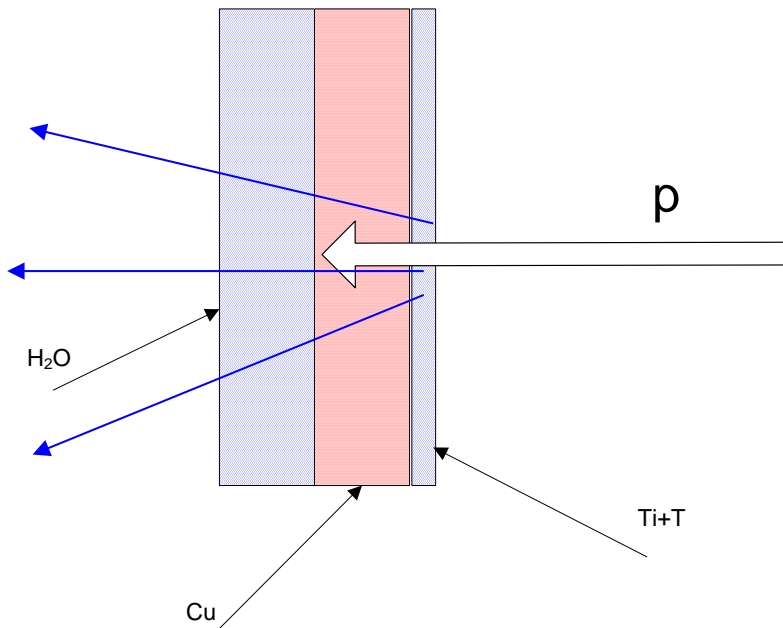
Momentum conservation law

$$E = \frac{P^2}{2M}$$

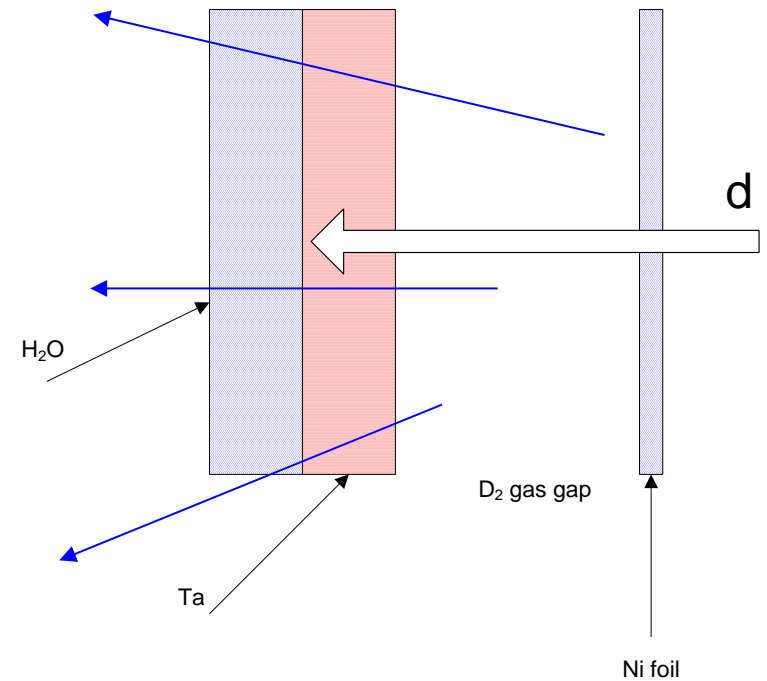
$$Q = \left(1 + \frac{m_n}{M_b}\right) E_n - \left(1 - \frac{m}{M_b}\right) E - \frac{2}{M_b} \sqrt{mm_n EE_n} \cos \theta$$

Types of target for neutron production

Solid target

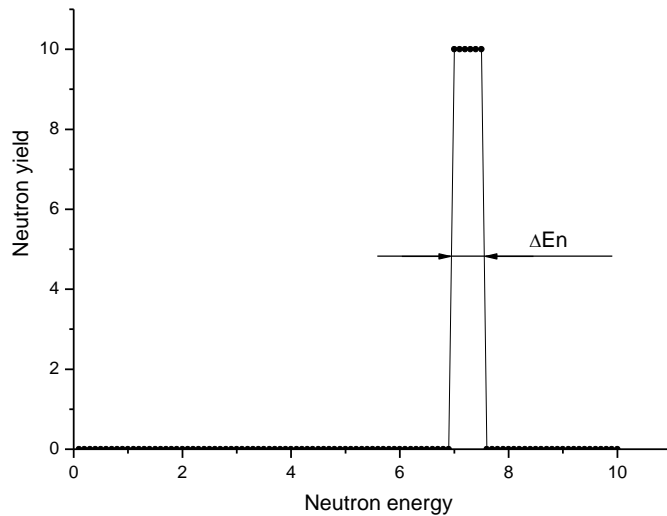
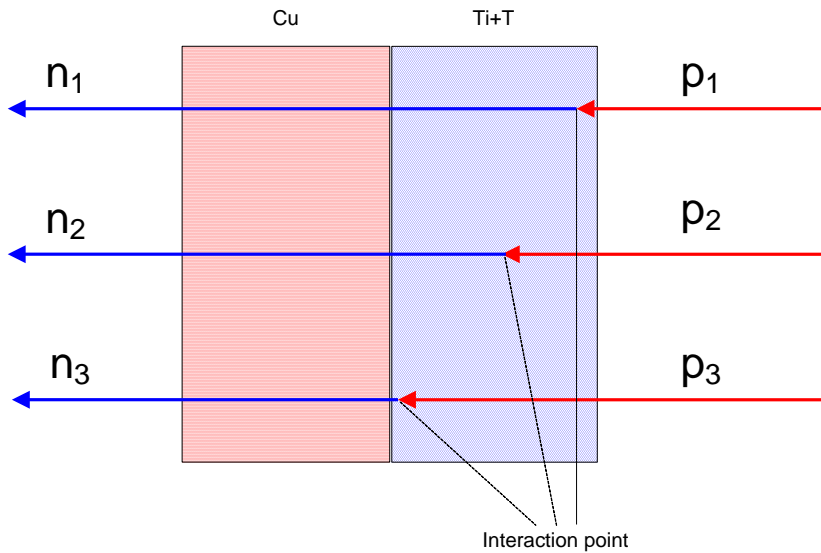


Gas target

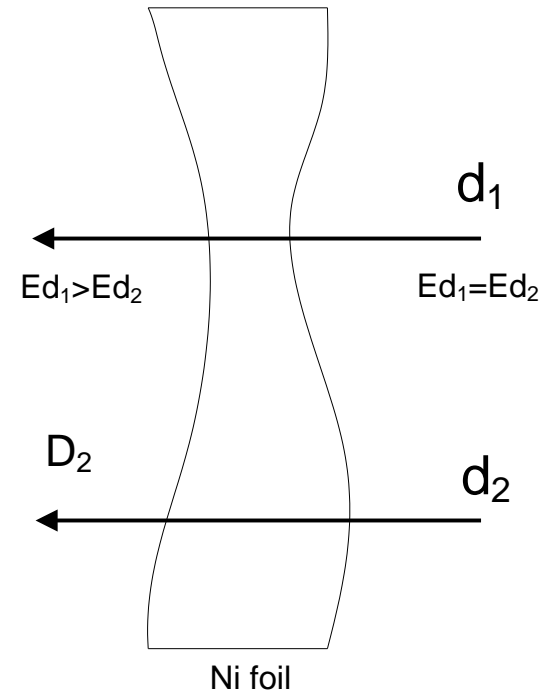


The nature of neutron energy spread

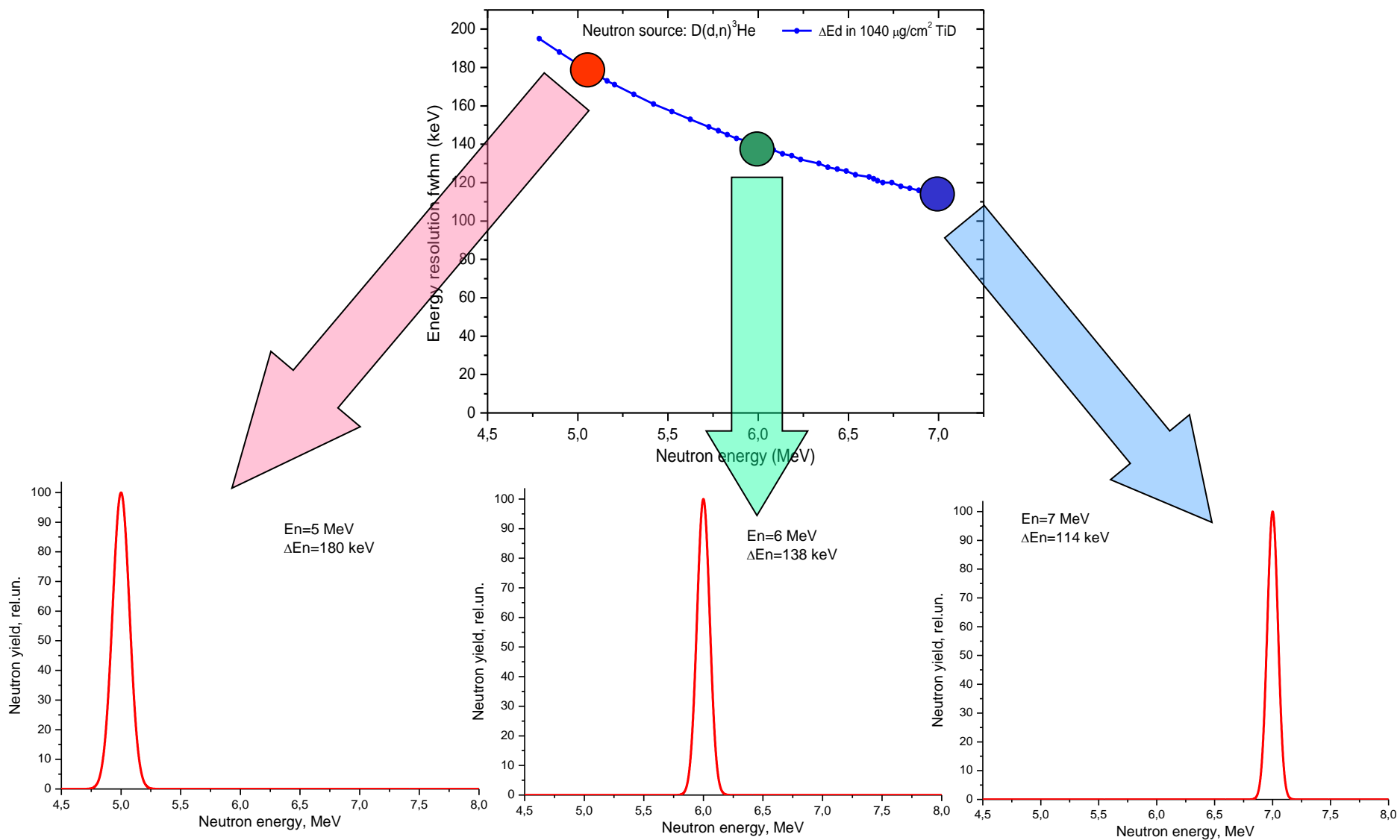
Solid target



Gas target



Neutron source - EG-1 accelerator (d,D) reaction $E_n=4-7$ MeV

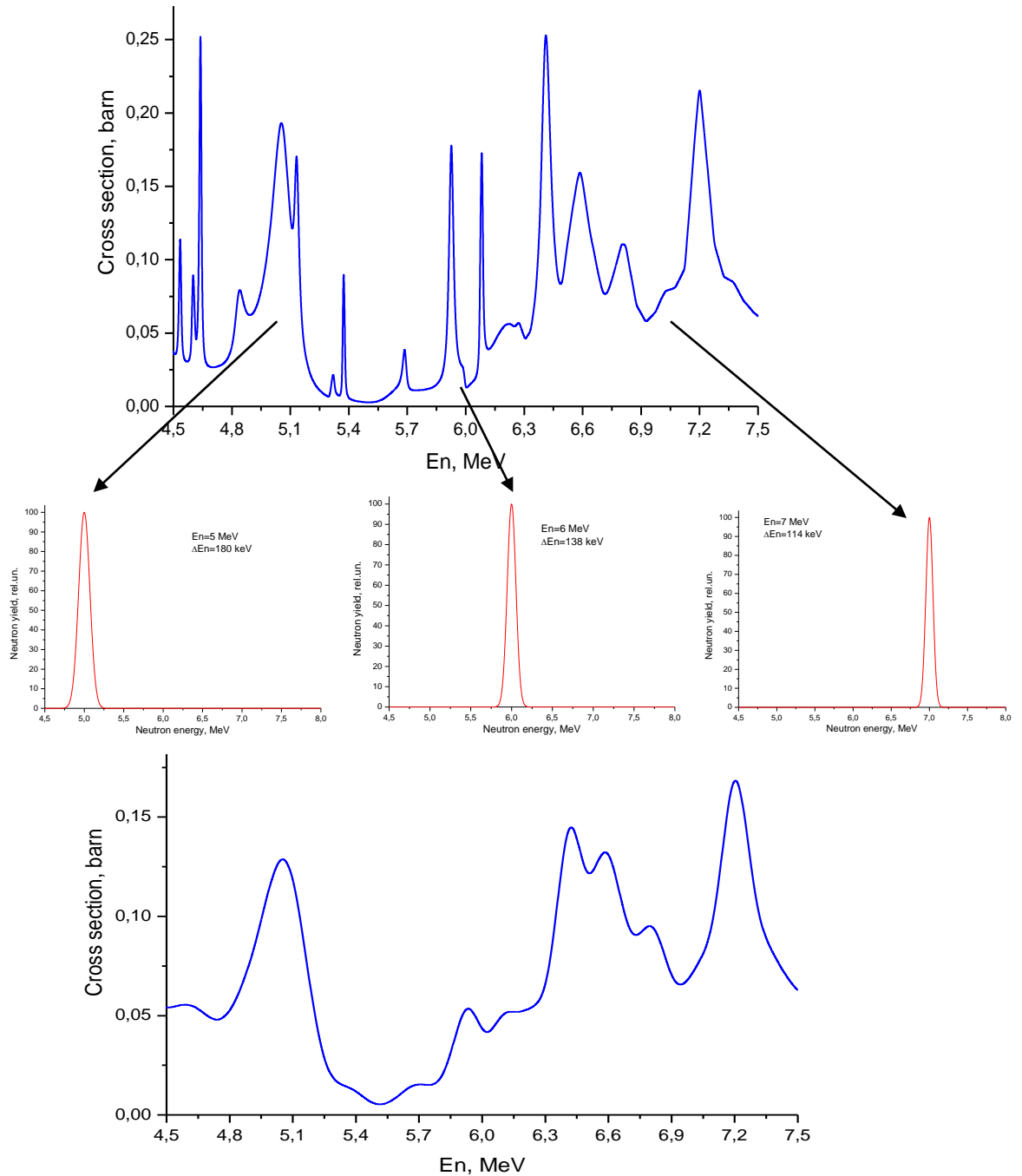


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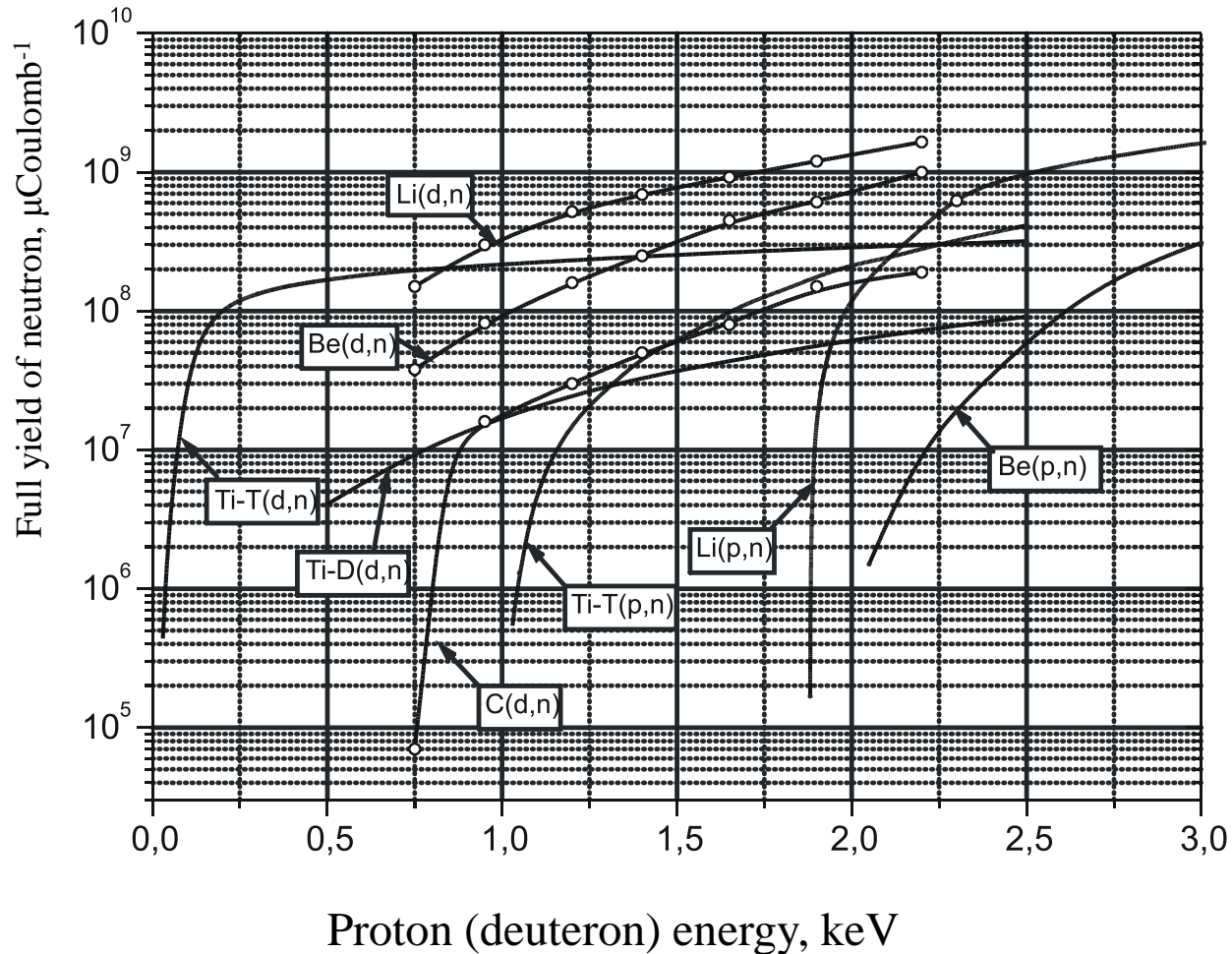
Energy spread

Convolution

Convolutated
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Yield of neutrons from different reaction vs incoming particle energy (normalized to 1 $\mu\text{Coulomb}$).



EnergySet program

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EnergySet program

13 KE - Research Microsc... 11.00.2015 10:17
EnergySet ver.3, EC-JRC-IRMM, March-2006

EXIT

About

Save spectrum

List for angles

List for energies

Time stamp update

2015-09-29 12:10:21

Ions and neutrons

Reaction: 7Li(p,n)7Be, LiF target

Ion energy (keV): 3000 Neutron emission angle: 0

Target thickness (ug/cm2): 2000

H/Ti or D/Ti ratio: 1.00

Gas pressure (kPa): 100

Gas cell length (mm): 40

Ion en. loss in target (keV): 188.420

Ion en. loss in target (%): 6.3 TOF (ns) neutron / gamma: 0.7 / 0.0

Entrance foil and thickness: 0 ug/cm2 D-TOF (ns): 0.1

Molybdenum

Ion en. loss in foil (keV): 0.

Ion energy is below threshold:

Ion energy in doubled value region:

Not in mono-energetic region:

Neutron yield data. Note, x-sections for neutron centroid energy!

Neutron energies (MeV)	Mean fluence rate (n/(cm2 s)):	0.147E+08
Max: 1.306	Mean yield (n/(sr s)):	0.147E+08
Centroid: 1.209	Total cross section (mb):	239.8
Min: 1.111	Diff. cross section (mb):	50.790
% width: 14.9	dEn/dEion:	1.031
	dEn/dTH:	0.000

Distance (mm): 10 Current (uA): 1

Beam line and magnets settings

Ion beam: Protons

NMR probe frequency: 15.942901

Magnetic field (T): 0.374445

Analysing magnet ADC: 187209 Magnet: level 4.6

Switching magnet 4.6 ADC: 352730 Polarity: -

NMR probe: B C D E

NMR probe data

Probe	Frequency range (MHz)	Magnetic field range (T)
B (2)	3.832 - 11.070	0.09 - 0.26
C (3)	7.238 - 22.140	0.17 - 0.52
D (4)	14.902 - 44.706	0.35 - 1.05
E (5)	29.804 - 89.413	0.70 - 2.10

Calibration factors (MeV/MHz²): level 4.6 = 0.011822
level 0 = 0.030293

Problem 1

Problem specification:

In an experiment a solid D/Ti target with thickness of 2 mg/cm^2 is used. The target was irradiated by deuterons with energy 3 MeV .

Question:

What average neutron energy will be released for an angle of 0 degrees?

Problem 2

Problem specification:

In an experiment a solid T/Ti target with thickness of 1 mg/cm^2 is used. The target was irradiated by protons with energy 4 MeV.

Question:

What average neutron energy will be released for an angle of 60 degrees?

Problem 3

Problem specification:

In an experiment a solid D/Ti target with thickness of 2 mg/cm^2 is used. The target was irradiated by deuterons with energy of 2,5 MeV.

Question:

Obtain minimal and maximal energy of neutrons for an angle of 0 degree.

Problem 4

Problem specification:

The ${}^7\text{Li}(p,n)$ reaction is used. The thickness of a metallic target is $500 \mu\text{g}/\text{cm}^2$.

Question:

What proton energy do we need to obtain 3,33 MeV neutron at 0 degree?

Problem 5

Problem specification:

Gas target fulfilled with deuterium at 0,5 atm pressure. The thickness of the target is 2 cm. The thickness of the entrance molybdenum foil is 500 mg/cm². The target is irradiated by 3,5 MeV deuterons. Beam current is 10 μA.

Question:

What mean neutron energy is released at 30 degrees? What is the neutron energy spread? What is the neutron fluence rate at 1 m distance from the target at this angle?

Problem 6

Problem specification:

The D/Ti target with thickness of 2 mg/cm^2 is used. The target is irradiated by 3,5 MeV deuterons. Beam current is $10 \text{ }\mu\text{A}$.

Question:

What is the mean neutron energy released at 30 degrees? What is the neutron energy spread? What is the neutron flux at 1 m distance from the target at this angle? Compare result with Problem 5 result. Make a conclusion.

Problem 7

Problem specification:

The T/Ti target with thickness of 5 mg/cm^2 is used. The target is irradiated by $0,3 \text{ MeV}$ deuterons. Beam current is $100 \mu\text{A}$.

Question:

What is the mean neutron energy released at 90 degrees? What is the neutron flux at 1 m distance from the target at this angle?

Problem 8

Problem specification:

You have an accelerator which is able to produce only 5 MeV deuterons. You have only one D/Ti target with 5 mg/cm² thickness.

Question:

What neutron energy region can you cover in your experiment?