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.

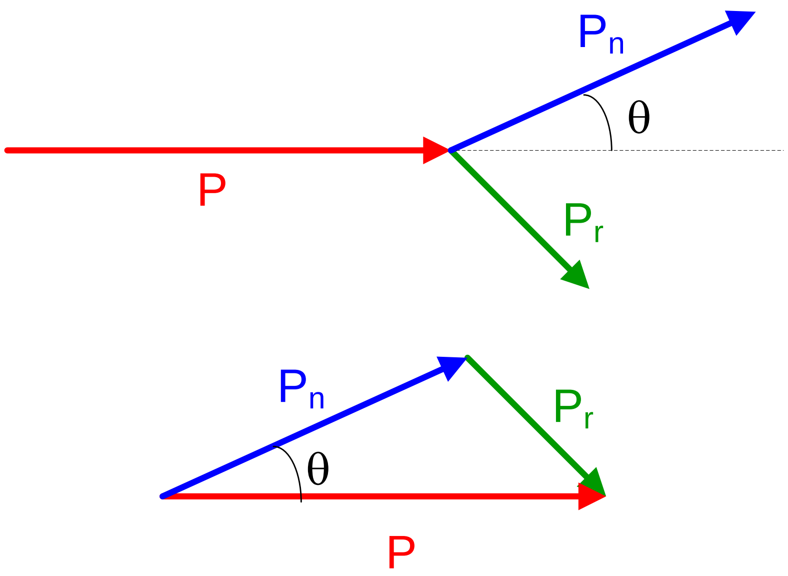
How are monoenergetic neutrons produced by accelerator?

- There are a lot of nuclear reactions with neutron in the output cannel 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 monoenrgetic neutrons.

Main reactions which are used for monoenergetic neutron production

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

Reaction kinematics



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

$E+Q=E_r+E_n$, Energy conservation law

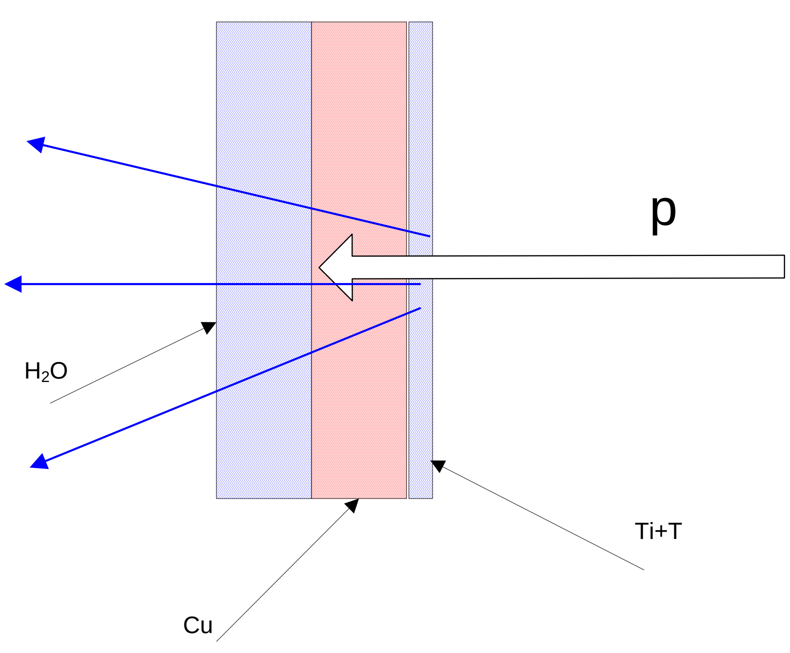
$$p_r^2 = p^2 + p_n^2 - 2pp_n\cos\theta$$ Momentum conservation law

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

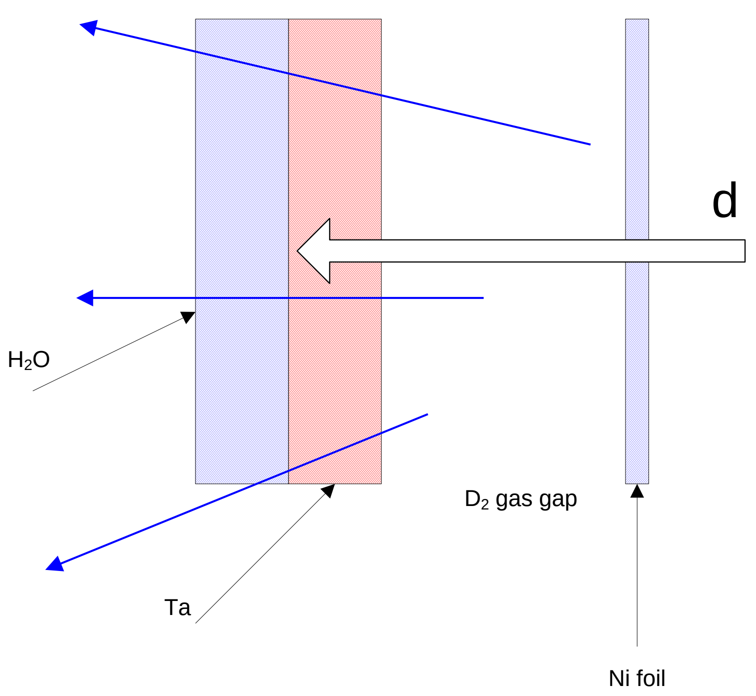
$$Q = \left(1+\frac{m_n}{M_b}\right)E_n - \left(1-\frac{m}{M_b}\right)E - \frac{2}{M_b}\sqrt{mm_nEE_n}\cos\theta$$

Types of target for neutron production

Solid target

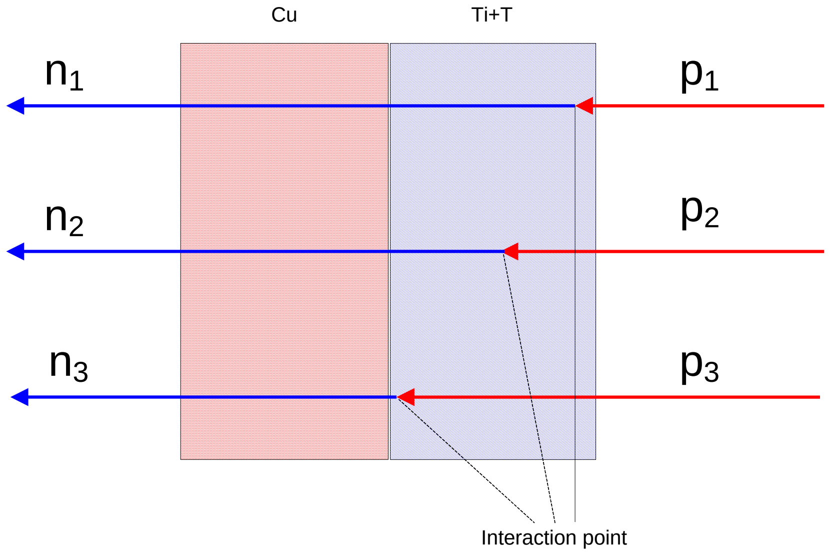


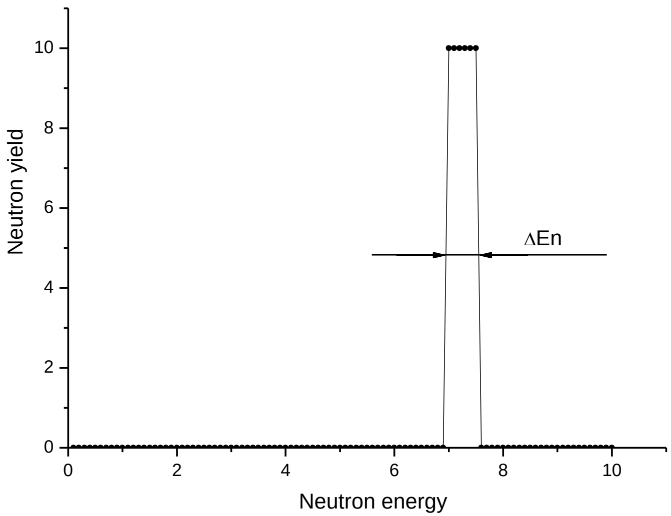
Gas target



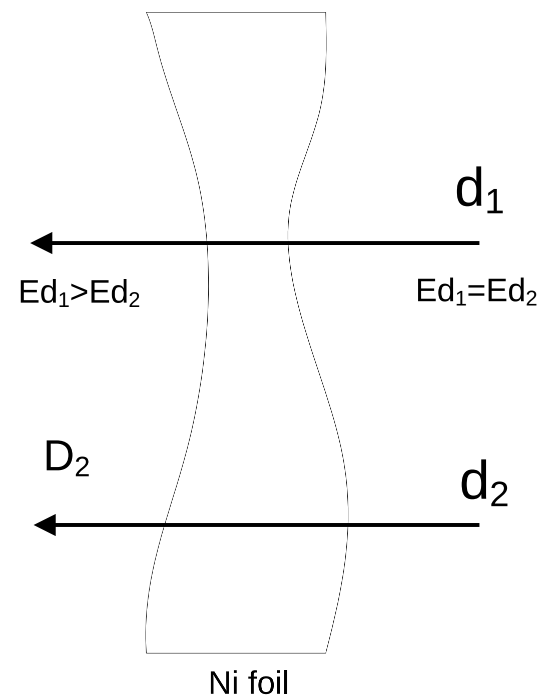
The nature of neutron energy spread

Solid target

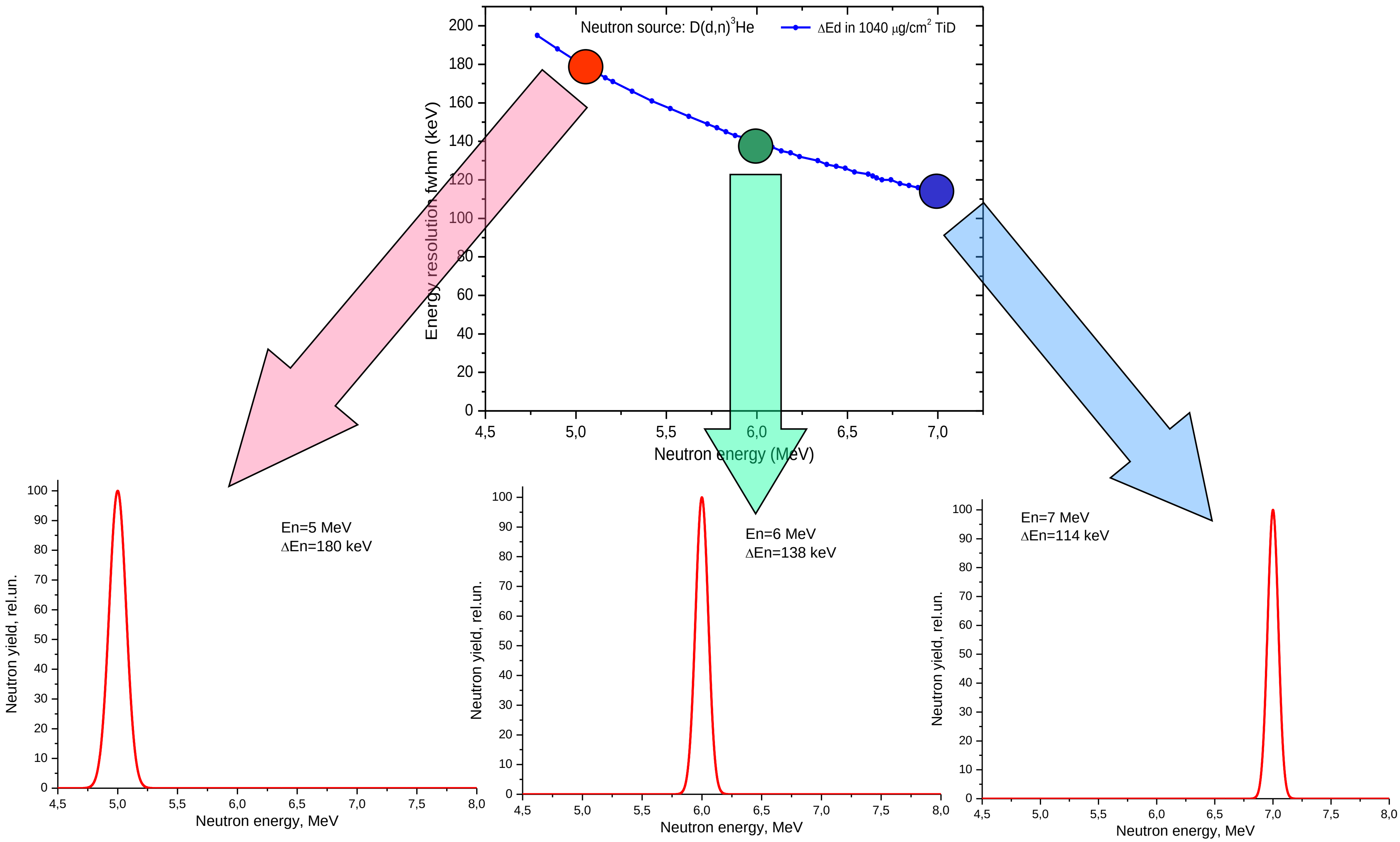


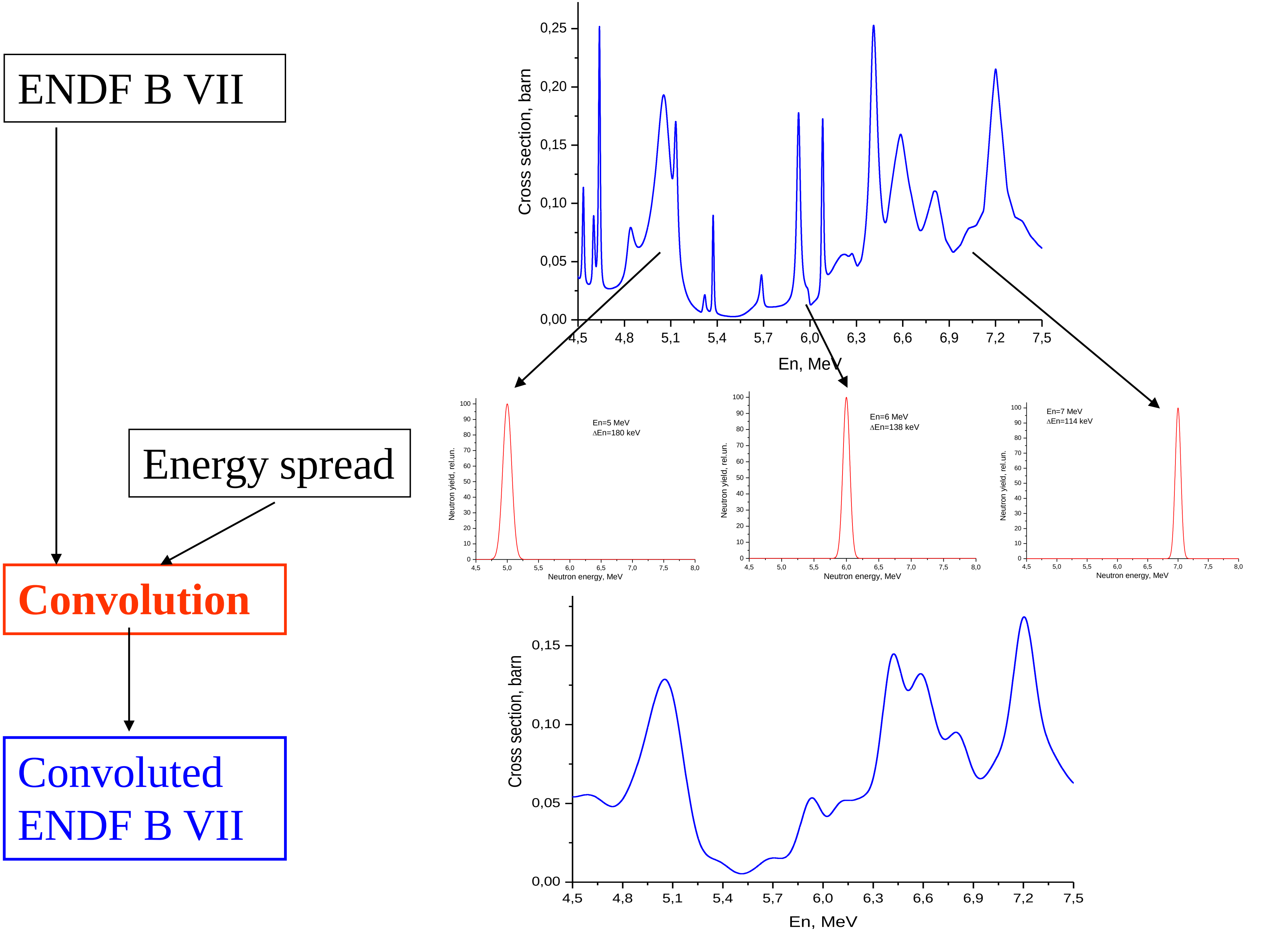


Gas target



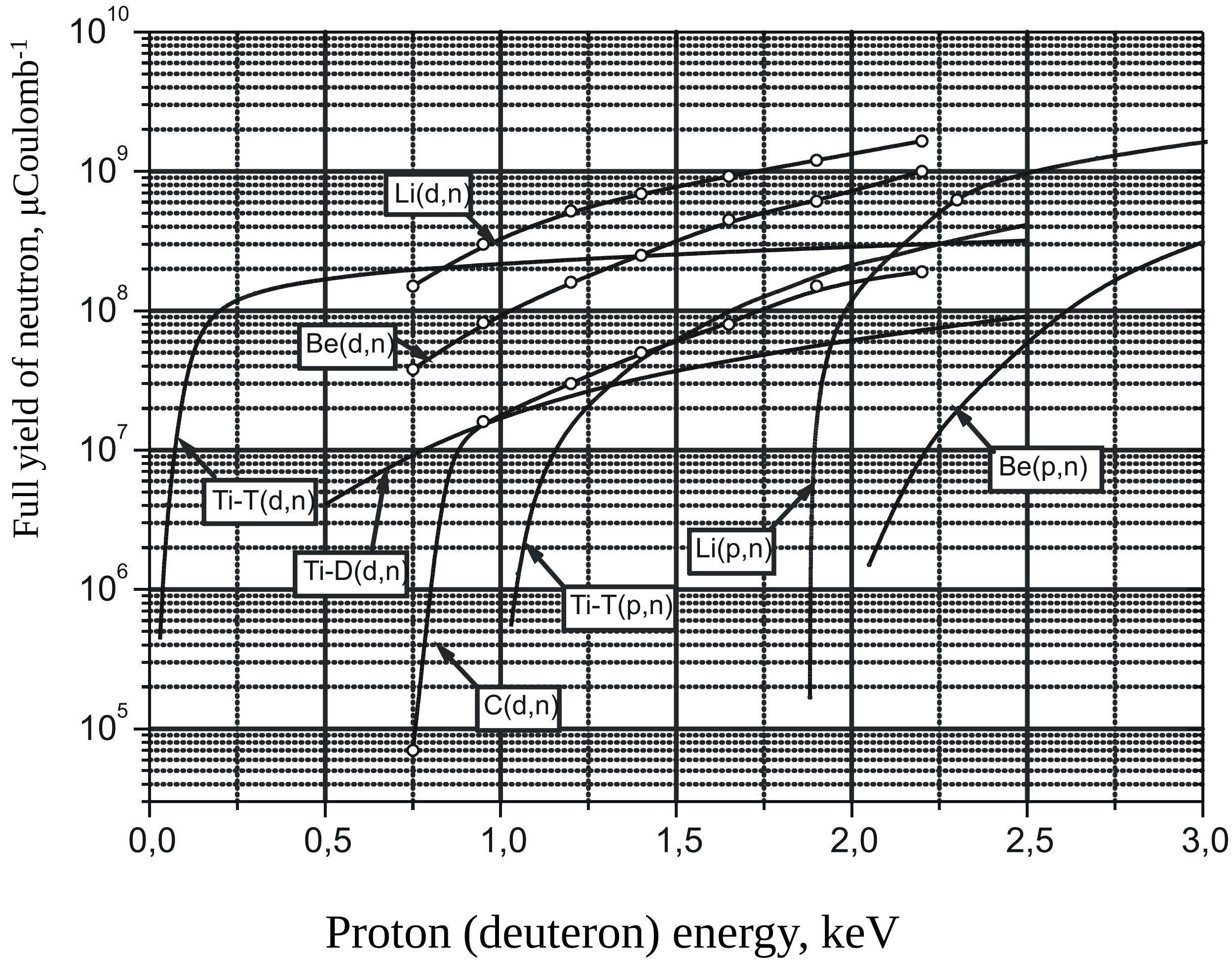
Neutron source - EG-1 accelerator (d,D) reaction En=4-7 MeV





ENDF B VII
Energy spread
Convolution
Convoluted ENDF B VII
Cross section, barn
En, MeV
Neutron yield, rel.un.
Neutron energy, MeV
En=5 MeV
ΔEn=180 keV
En=6 MeV
ΔEn=138 keV
En=7 MeV
ΔEn=114 keV

Yield of neutrons from different reaction vs incoming particle energy (normalized to 1 μCoulomb).



EnergySet program

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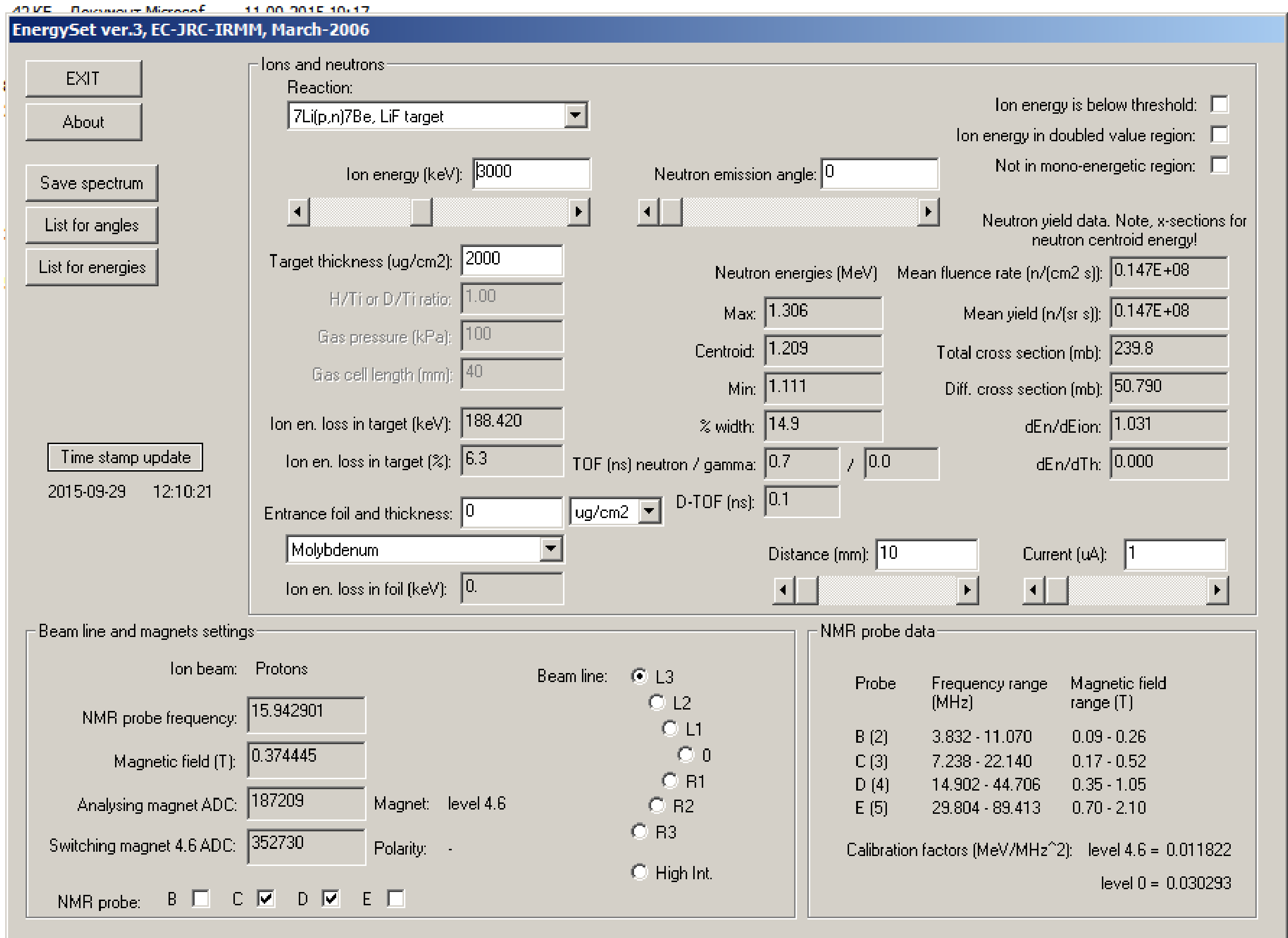
EnergySet program



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

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 MeV deuterons. Beam current is 100 μA.

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 accelerator which is able to produce only 5 MeV deuterons. You have only one D/Ti target with 5 mg/cm^2 thickness.

Question:

What neutron energy region can you cover in your experiment?