Taras Shevchenko National University of Kyiv

Generation and application of Maxwellian Neutron Spectra for BCNT

V. Basenko, N. Dzysiuk, I. Kadenko

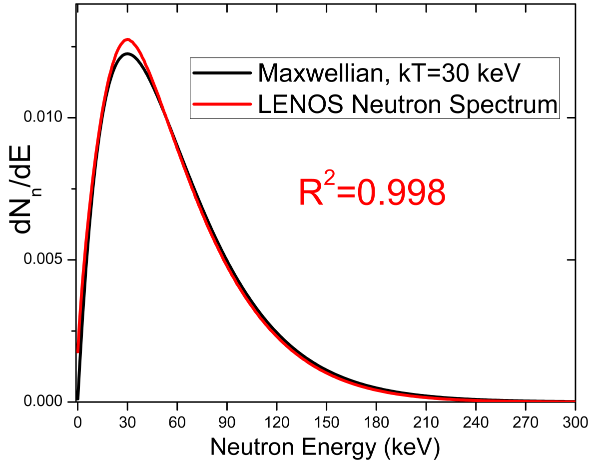
iNSC of Ukraine

Outline

- Objective
- Generation of Maxwell-Boltzmann neutron spectra
- $^{12}C(d,n)^{13}N$ reaction as a neutron source
- Generation of M-B spectra with low-voltage accelerators
- Problematic issues
- A possible BCNT application
- Summary / perspective

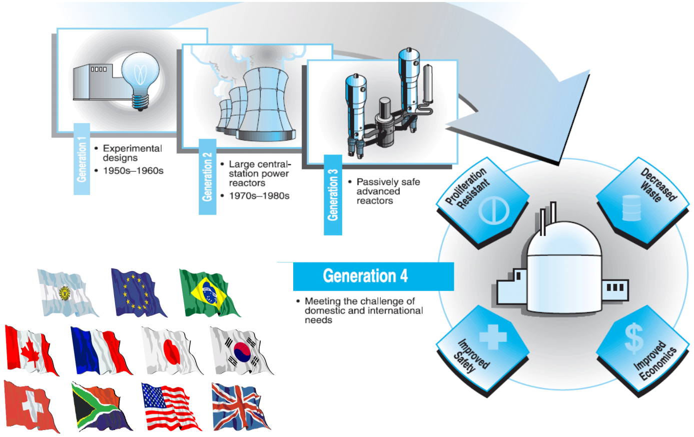
Objective

- Nuclear astrophysics
- Validation of Evaluated Data
- Possibility to perform BNCT



Mastinu P.F. Martin Hernandes G., Praena J. A method to obtain a Maxwell–Boltzmann neutron spectrum at kT=30 keV for nuclear astrophysics studies // Nuclear Instruments and Methods in Physics Research A – 2009 – vol. 601 – p. 333 - 338.

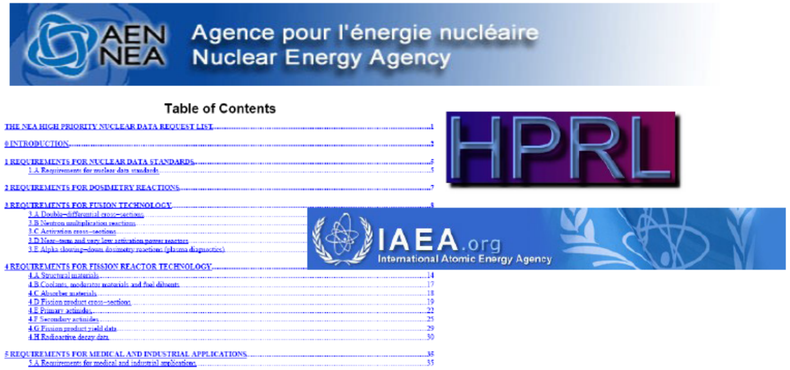
Motivation



Some actinides for Gen-IV:

- Pu-239 fission in 1 keV – 1 MeV
- Pu-241 fission in 1 keV – 1 MeV
- U-238 capture in 2 – 200 keV
- Am-243 capture in fast and thermal energy range
- Am-241fission in fast energy range

P. Oblozinsky, NNDC


AEN NEA Agence pour l'énergie nucléaire Nuclear Energy Agency

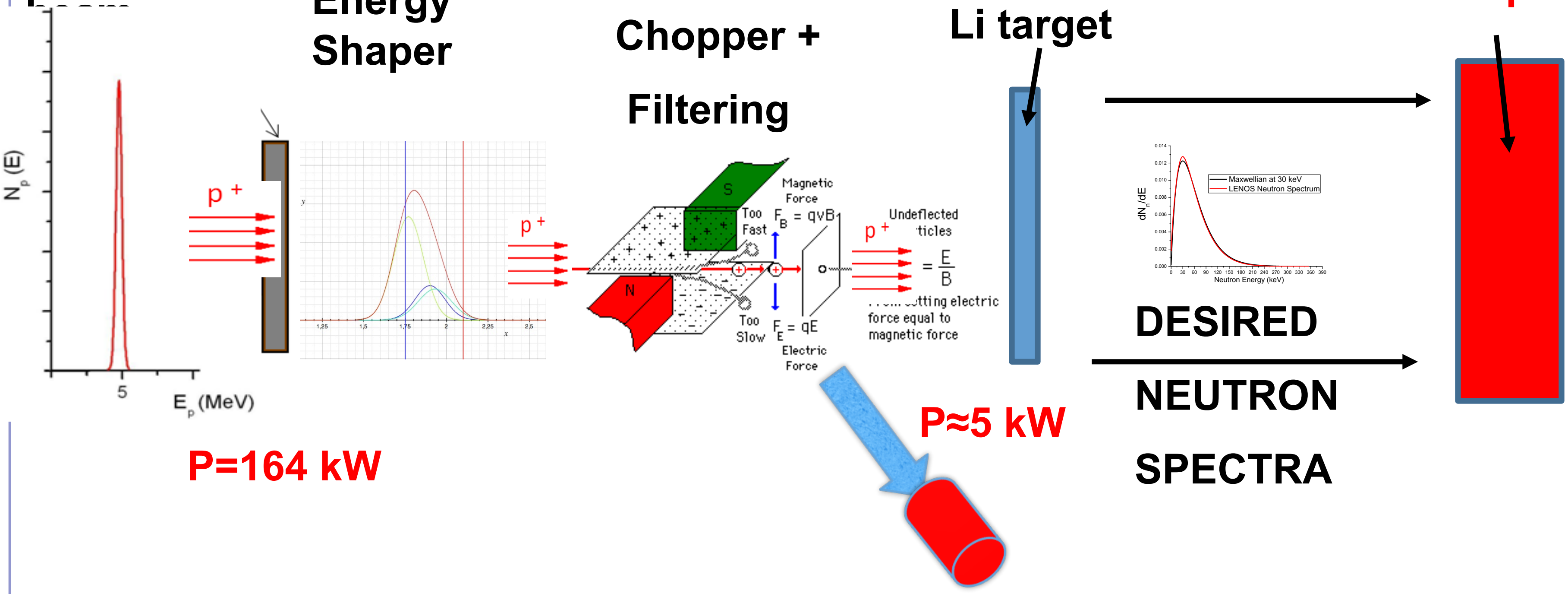
HPRL

IAEA.org International Atomic Energy Agency

Table of Contents

Often large discrepances between data bases (ENDF,JENDL,JEFF,BRONDL) for many already mesured isotopes.
No mesurements for some important isotopes (mainly radioactive)

Generation of M-B neutron spectrum
LENOS: ^{7}Li(p,n)^{7}Be (25-60 keV)



RFQ

beam

Multilayer
Energy
Shaper

Chopper +

Filtering

Multilayer
Li target

Sample

DESIRED

NEUTRON

SPECTRA

P=164 kW

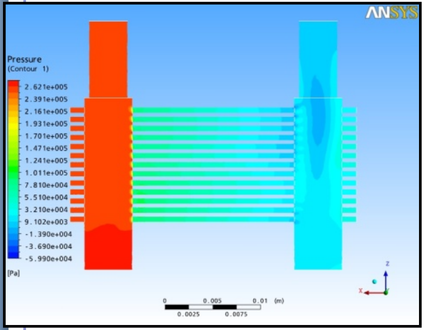
P≈5 kW

Beam Dump and
Faraday Cup

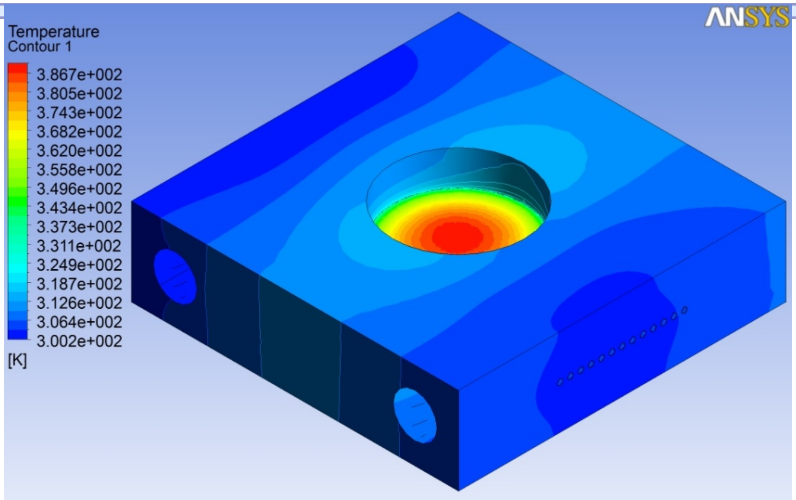
LENOS: Lithium target. ANSYS results

Water cooled

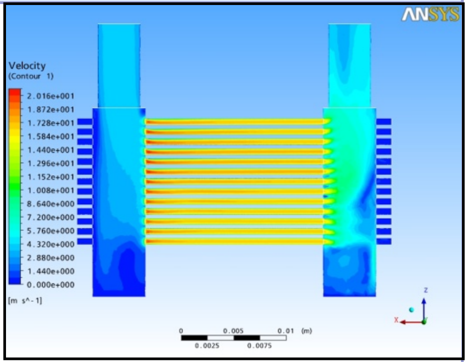
Pressure



P_{in}=2.7 bar
ΔP=2.7 bar

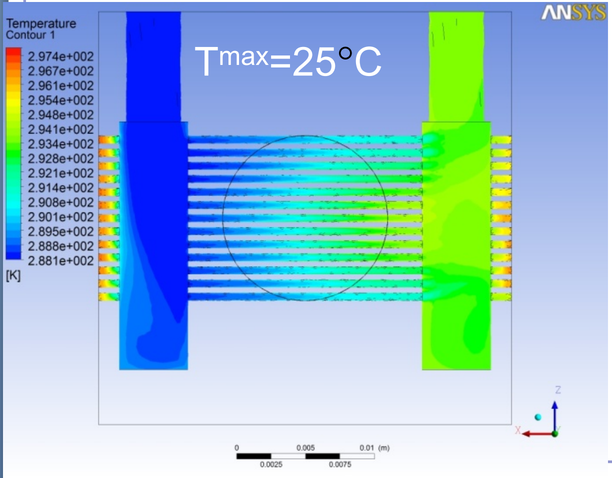


Velocity



μ-channel fluid velocity =15m/s

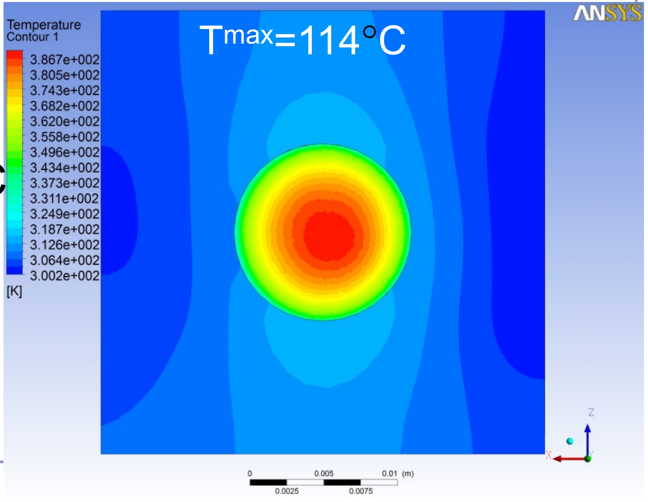
Temperature



T_{max}=25°C

Li - 40 μm
Mass flow=160 l/h
Inlet fluid temperature=15°C
Beam Power=1000 W
Flat beam profile

Melting point Li = 182°C



T_{max}=114°C

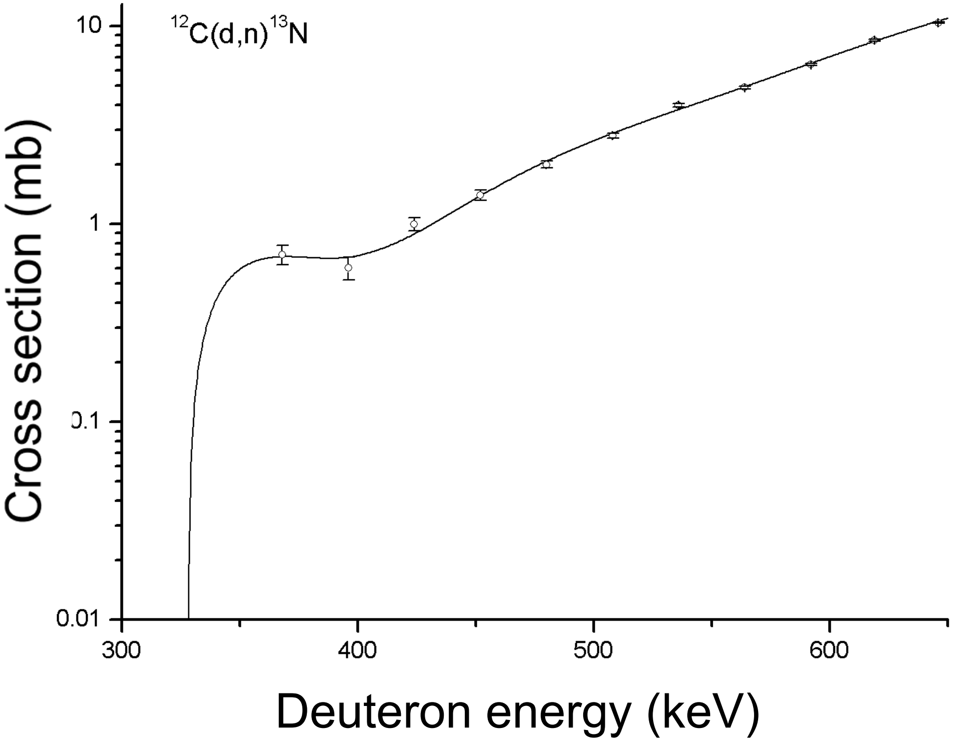
$^{12}C(d,n)^{13}N$ reaction as a neutron source (alternative way)

MB spectrum generation with the voltage modulation

T_n = (10 – 60) keV

Low threshold : 328 keV

Advantage: homogeneous material for target
High melting point



Methodology of calculations

Shape of neutron spectrum

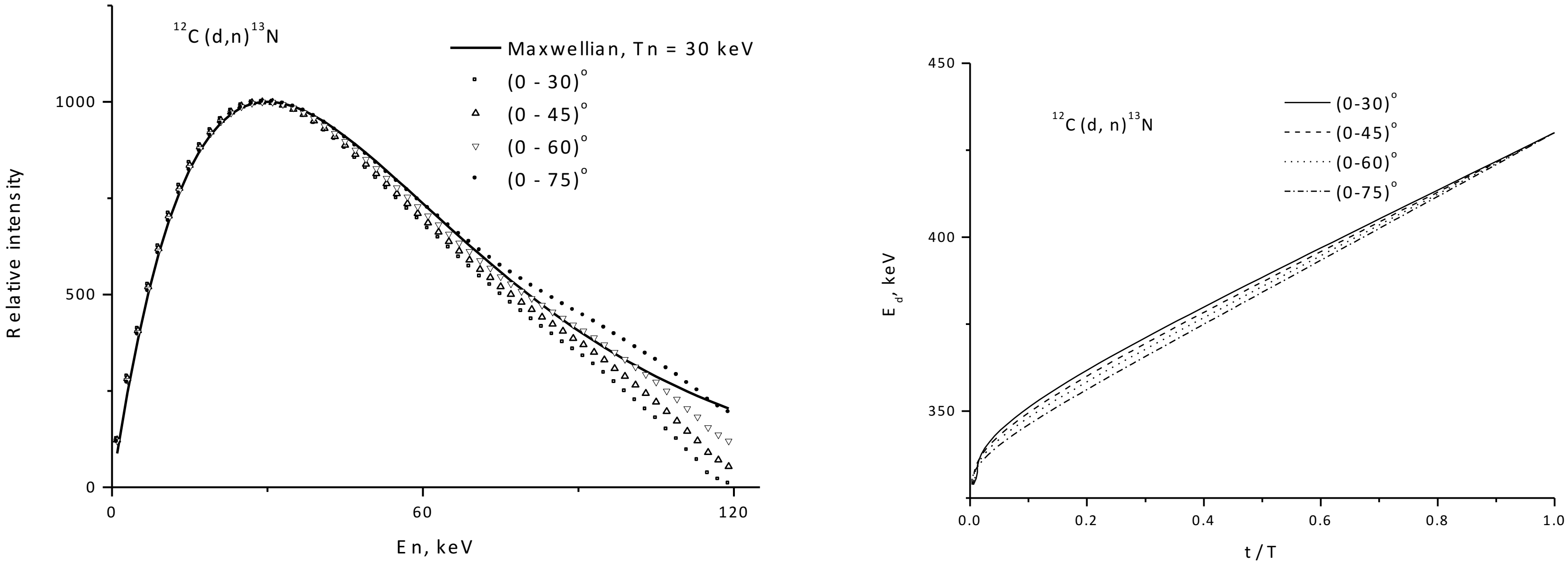
$$N\left(E_n,\theta\right)=\frac{1}{\pi}\int_0^{\pi}d\psi\int_0^{R}C\left(x\right)dx\int_0^{\phi_{\max}}L_x\left(\phi\right)d\phi\int_0^{E_0}\sigma\left(E',\theta\right)G\left(E'-\frac{E_x}{s_x}\right)\delta\left[E_n-f_n\left(E',\omega\right)\right]dE'$$

$$N\left(E_n,\theta\right)=N_0\int_0^{E_0}\sigma\left(E',\theta\right)\delta\left[E_n-f_n\left(E',\omega\right)\right]dE'$$

N_0 – number of nucleai ^{12}C in the target.

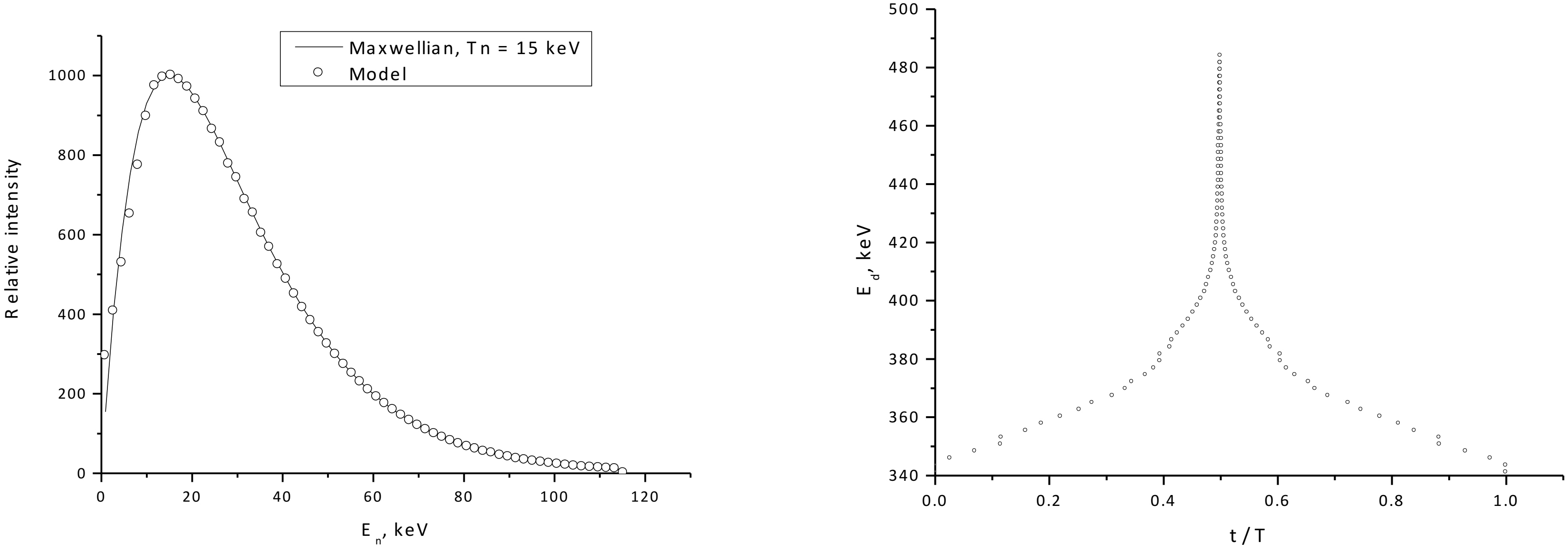
$$E_n\left(\theta\right)=\frac{m_d m_{^{12}C}}{\left(m_n+m_{^{13}N}\right)^2}\left\{\cos\theta\pm\sqrt{\cos^2\theta+\frac{\left(m_n+m_{^{13}N}\right)\left[\left(m_{^{13}N}-m_d\right)E_d+m_{^{13}N}Q\right]}{m_d m_{^{12}C}E_d}}\right\}$$

$^{12}C(d,n)^{13}N$ reaction as a neutron source



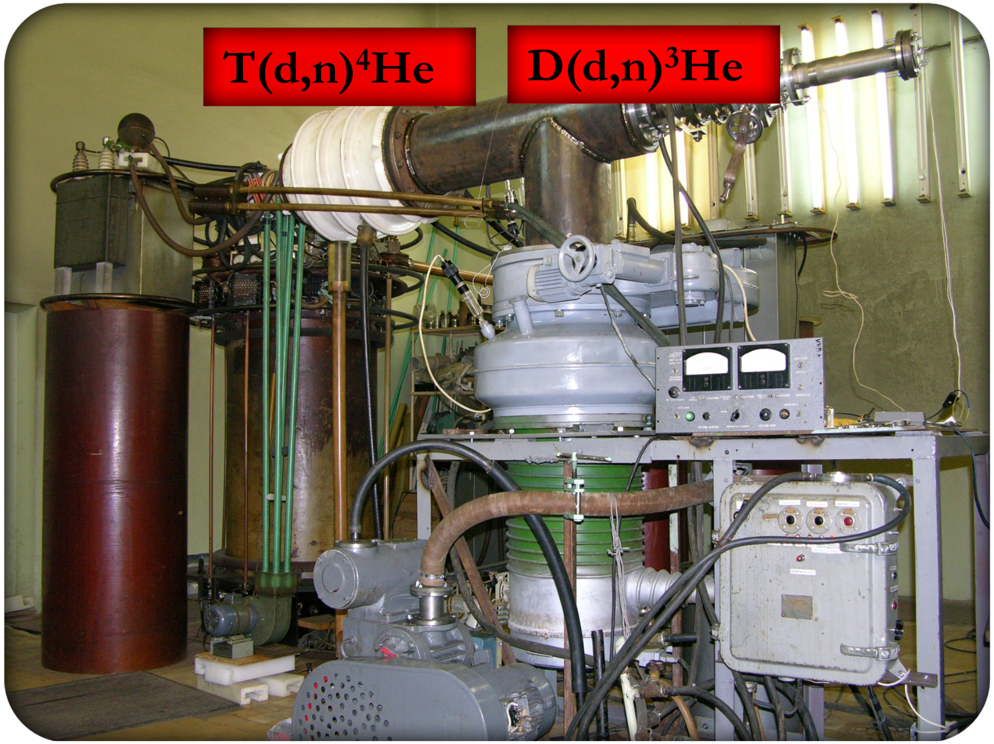
Neutron spectra and the law of voltage modulation in time

$^{12}C(d,n)^{13}N$ reaction as a neutron source



Neutron spectra and the law of voltage change in time with a small step adjustment

Generation of M-B spectra with low-voltage accelerators



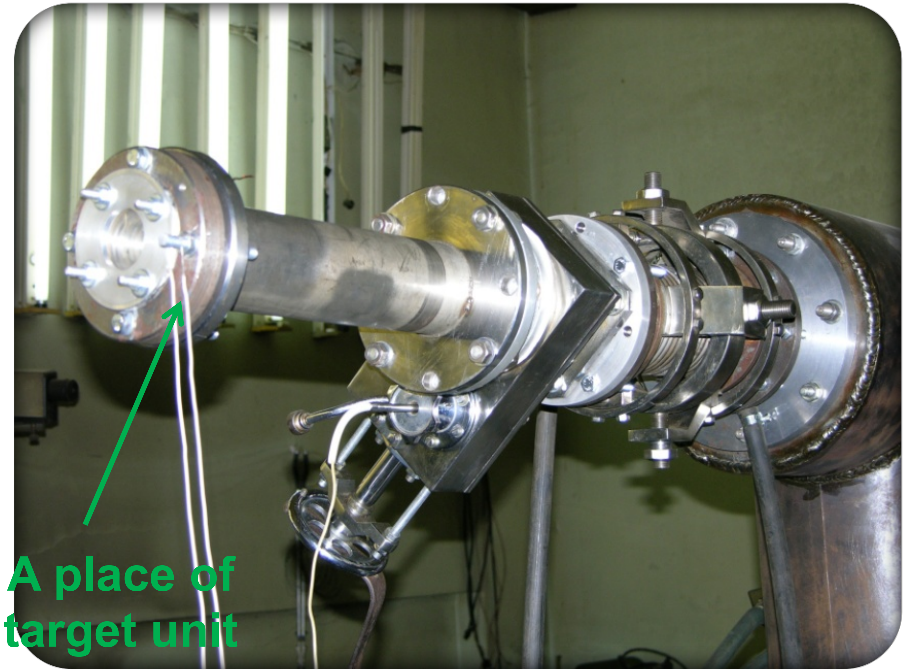
Main characteristics:

- Neutrons are generated in reactions $T(d,n)^4He$ and $D(d,n)^3He$
- Average neutron energy E = 14.7 MeV and 2.8 MeV
- Average neutron flux density $1.8 \cdot 10^9$ and $3 \cdot 10^8$ $n/(s \cdot cm^2)$

Generation of M-B spectra with low-voltage accelerators

- Algorithm of MB spectra generation by high-voltage modulation
- Advantage - much higher beam current
- Thick target (higher yield)

Carbon neutron production target



Heading time, hour	Temperature of heating, ºC	Neutron flux, relative units
Before heating	20	8500
1	150	1600
1	200	1200
1	250	700
1	300	700
Background		700

Atomic and molecular component could be obtained by means of magnet separation

Target dimension: d= 45 mm, water cooling system.

Problematic issue

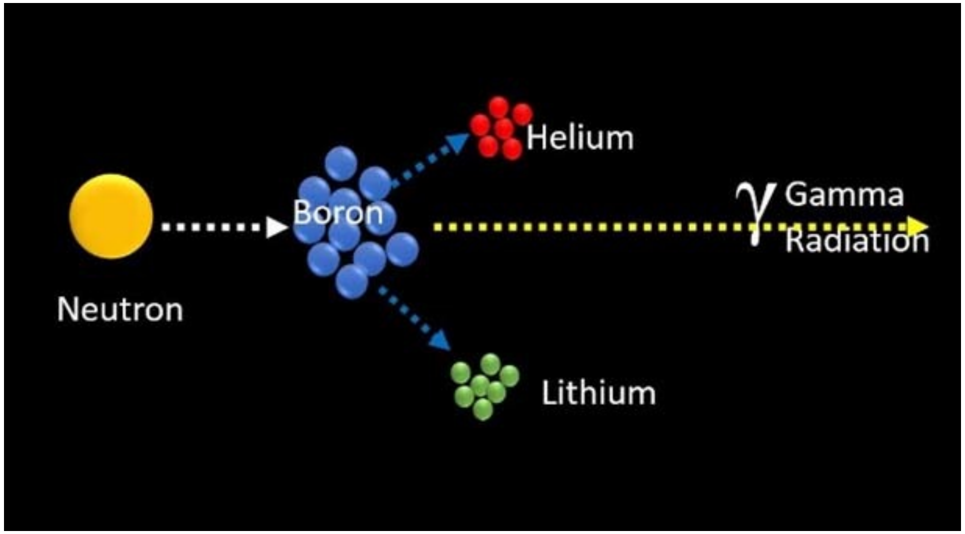
- No reliable data for the $^{12}C(d,n)$ reaction CS

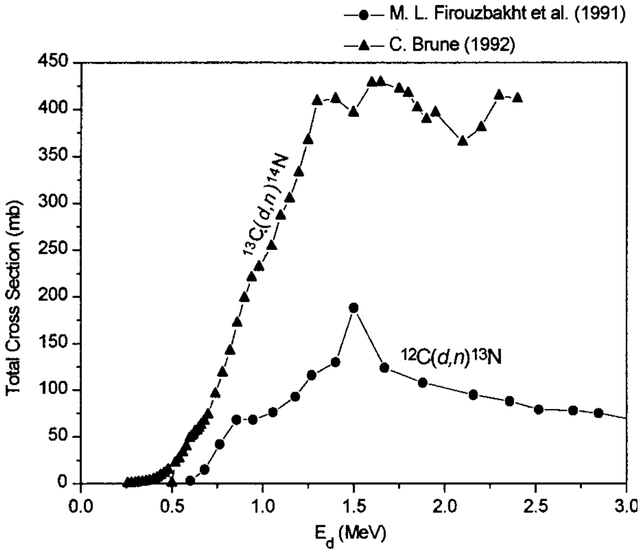
The only option is theoretical calculations (TENDL)

- Algorithm to make simulation of this neutron spectrum

Using TALYS + the code that can do a transport calculations. Collaboration with Spain is ongoing …

BCNT possible application





$^{10}B(n,\alpha)^{7}Li$ + MBNS (10 - 60 keV):

I=10 mA, σ = 1.14 b ⇨

$\varphi = 1.2*10^{6}$ n/cm^2/s

^{13}C is low abundance therefore
^{12}C is a possible alternative way !

Summary

- A possibility to generate a well characterized neutron spectrum was studied
- ^{12}C is an alternative way to ^{7}Li and could be used for performing BCNT
- Carbon target was developed
- Advantage : simplicity and accuracy
- Estimated production of alpha particles can be performed

Thanks for your attention!