Design of a BSA for Producing Epithermal Neutron for BNCT

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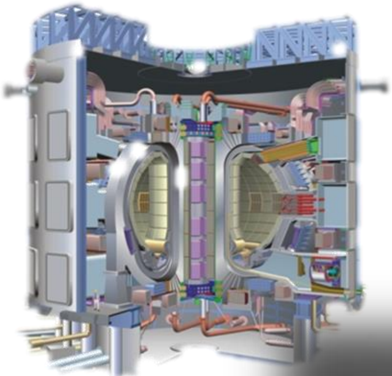
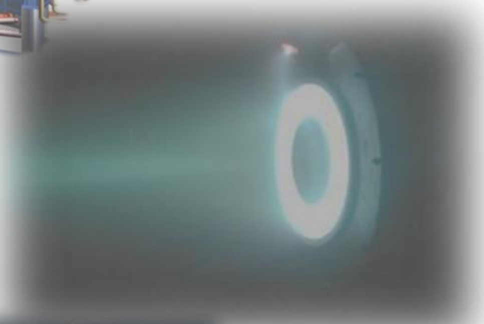
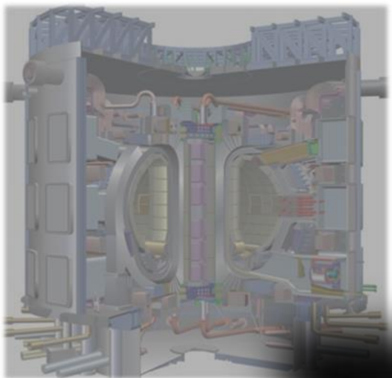
High temperature plasma and nuclear fusion

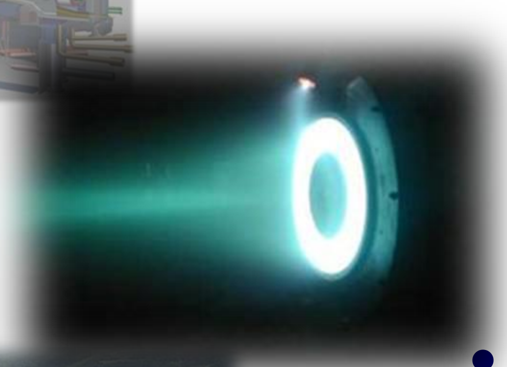




- Magnetic Confinement Fusion (MCF)
  - Basic plasma, transport, MHD instabilities, plasma-wall interactions
  - Fusion reactors
- Dense Plasma Focus (DPF)
  - Radiation sources: X-ray, neutron, proton
  - Radioactive material

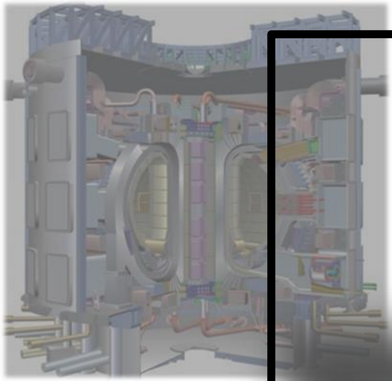
Low temperature & atmospheric pressure plasma

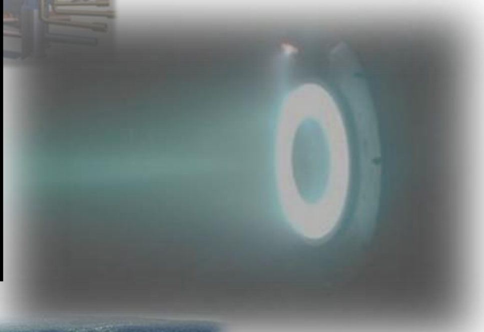




- Atmospheric pressure plasma for agriculture and health
  - Improvement of seed germination and production
  - Sterilization
- Dense Plasma Focus (DPF)
  - Radiation sources: X-ray, neutron, proton

Utilization of nuclear fission technology





- Nuclear reactor technology
  - Nuclear power plants: Conventional and innovative nuclear reactors
  - Siting in Thailand
  - Policy and Roadmap for nuclear development
- Nuclear for health
  - Neutron and proton technology for cancer treatment

OVERVIEW

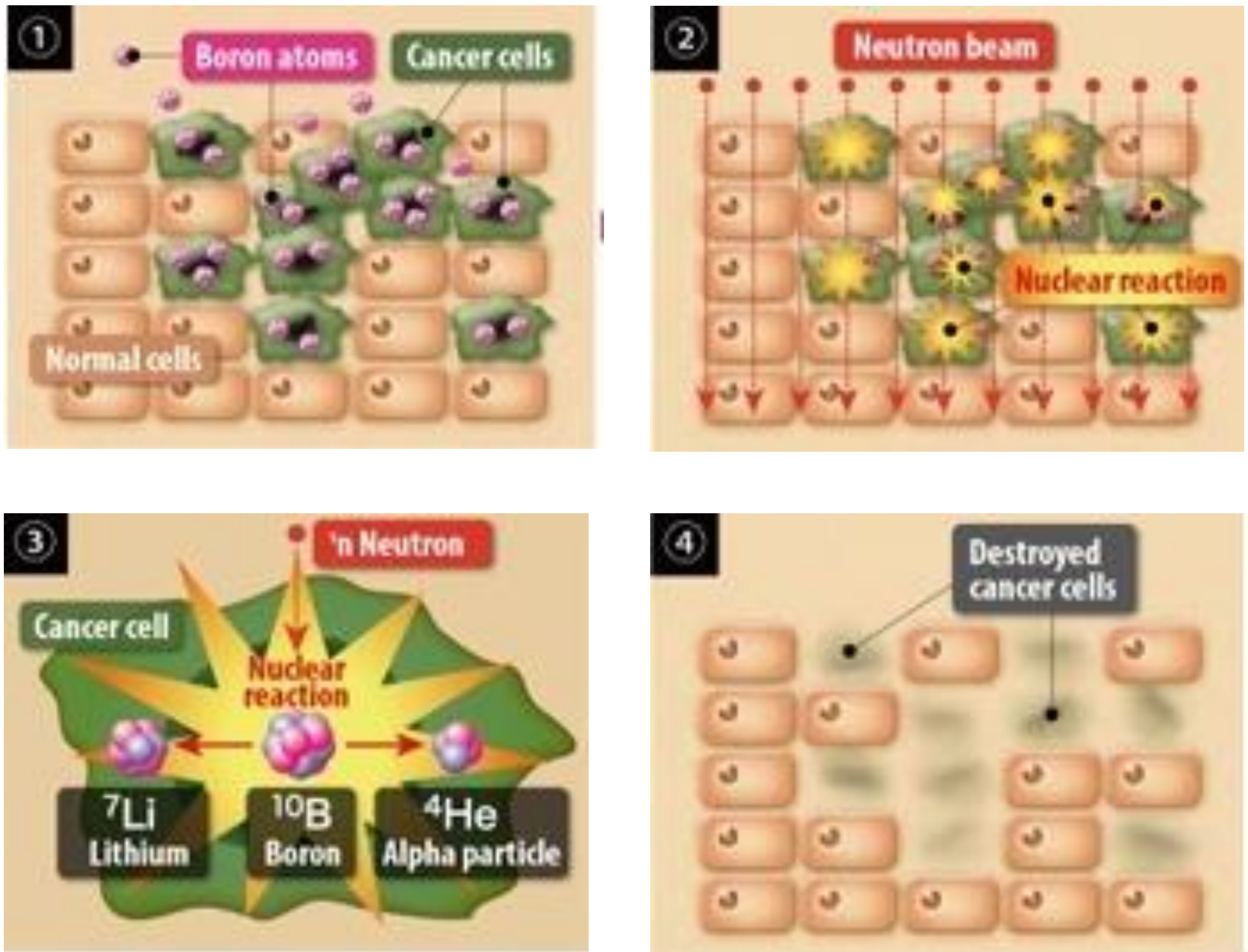
- Boron Neutron Capture Therapy (BNCT)
- Beam Shaping Assembly (BSA)
- Simulation results with D-T neutrons
  - ✓ Multiplier
  - ✓ Moderator
  - ✓ 2nd Moderator
- Conclusion

Background

- The existing treatment methods for brain cancer, such as surgery and chemotherapy, are found to be ineffective
- An ideal therapy for cancer should selectively destroy the cancer without damaging normal tissues
- Boron Neutron Capture Therapy (BNCT) is an indirect radiotherapy for destruction of cancer cells
- BNCT features:
  - ✓ New treatment of refractory cancer
  - ✓ Causes minimal stress to patients
  - ✓ Pinpoint treatment at cell level

Background

- Treatment mechanism of BNCT



http://www.osakafu-u.ac.jp

Background

Advantages and uses of BNCT

1

Only necessary for a small number of these particles to release their energy in order to be effective at killing malignant cells

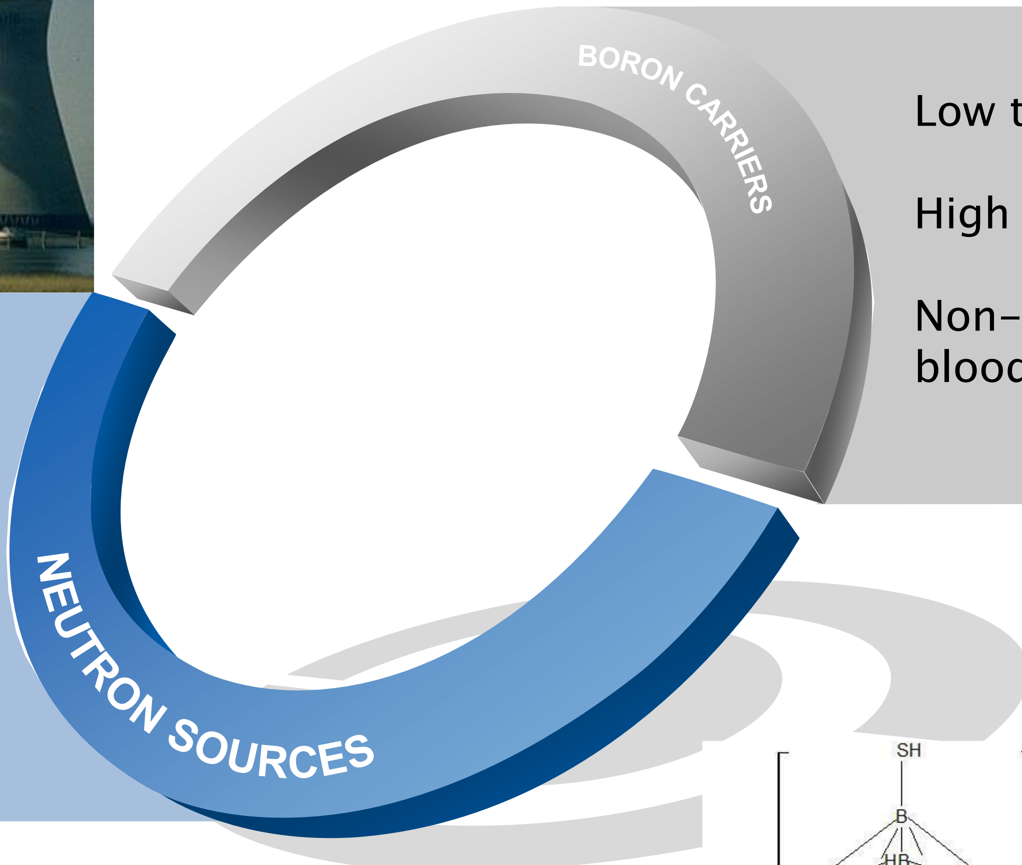
2

BNCT does not result in the destruction of surrounding, healthy tissue.

<u>SOURCES</u>: Clinical Cancer Research, 2005, 11:2, 3987; Radiation Research, 1999, 151, 1-18

Background

- Difficulties for BNCT applications



Low toxicity

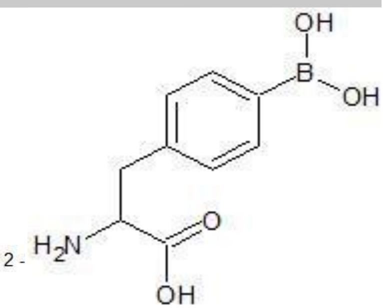
High specificity

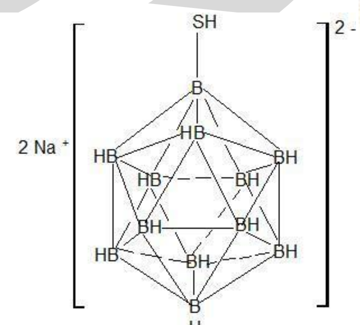
Non-persistence in the bloodstream

High intensity thermal-epithermal neutron beam ($5 \cdot 10^{8}$ n/cm^{2} s^{1})

< 10 keV energy range

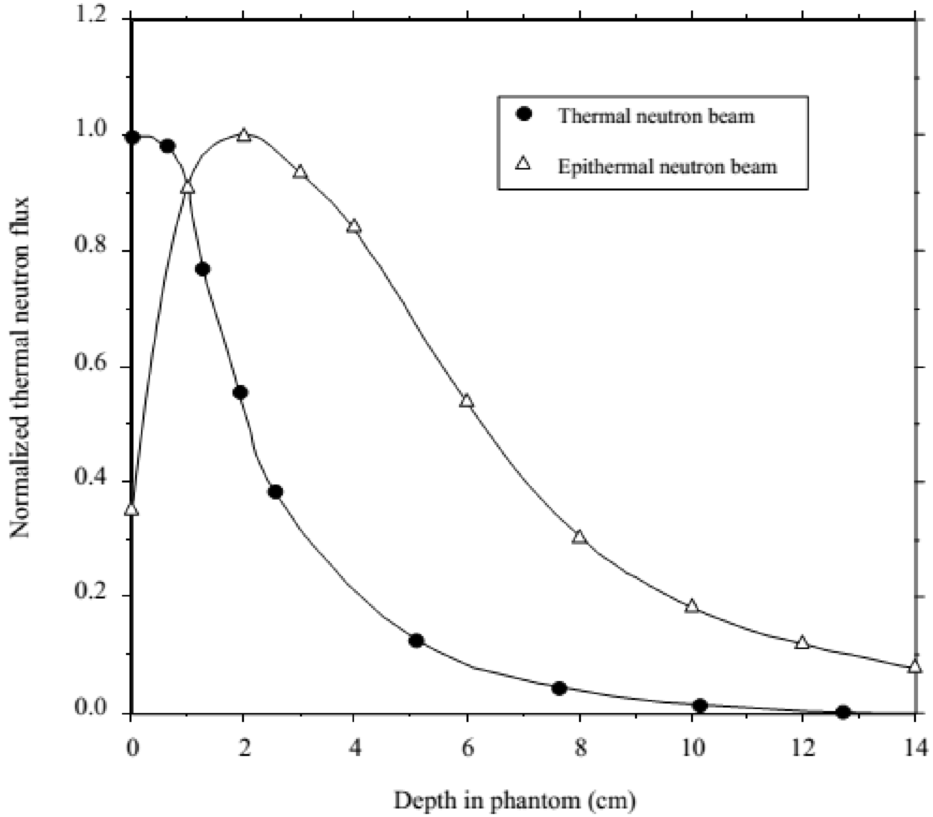
Gamma contamination $< 2 \cdot 10^{-13}$ Gy cm^{2}/n





Background

General beam properties



Comparison of flux-depth distributions for thermal and epithermal neutrons.

IAEA-TECDOC-1223, 2001

Background

Beam characteristic

Intensity

- determines treatment time

Quality

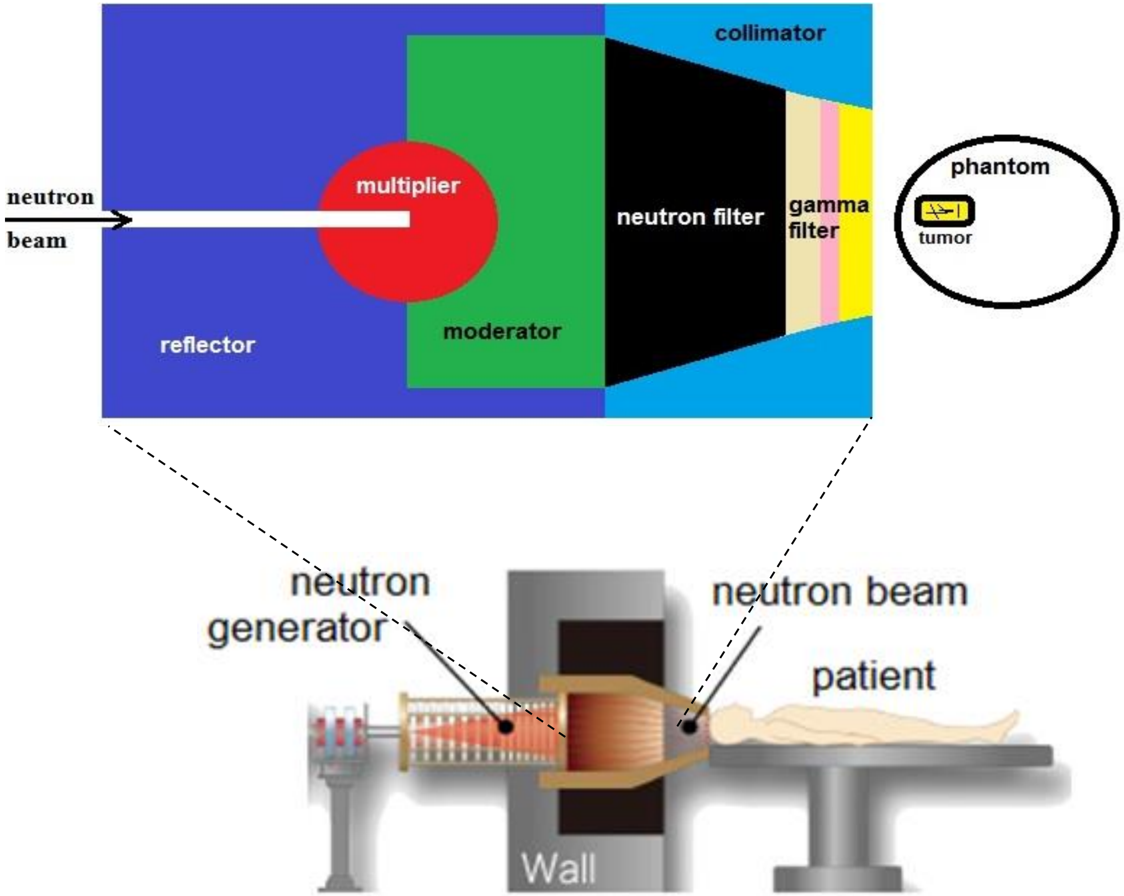
- relates to the types, energies, and relative intensities of all the radiations present

Parameters for the quality:

1. The fast neutron component
2. The gamma ray component
3. The ratio between the thermal flux and the epithermal flux
4. The ratio between the total neutron current and the total neutron flux

Beam Shaping Assembly (BSA)

To moderate high energy neutrons to the ones of lower energies and to remove fast and thermal neutrons and gamma contaminations, Beam Shaping Assembly (BSA) is used



BNCT treatment apparatus

Brief Explanation of the BSA Design

Simulation method: Monte Carlo

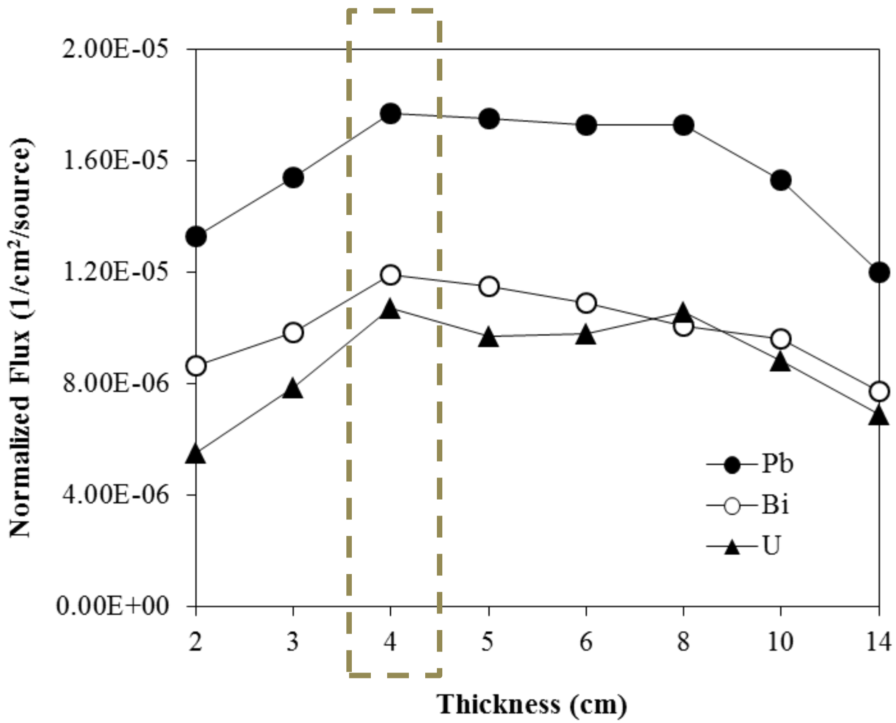
Code: Particle and Heavy Ion Transport code System (PHITS)

Neutron source:

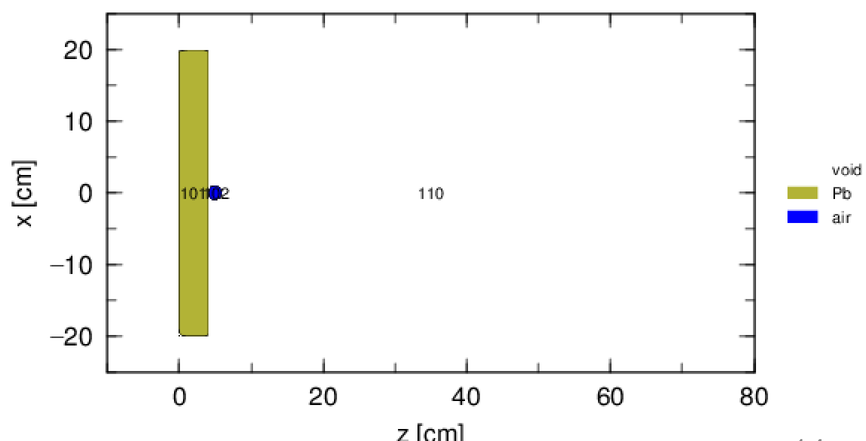
- neutron yield = 1.45 x 10^{14} n/s

  Rasouli FS, Masoudi SF, Kasesaz Y. Annals of Nuclear Energy. 2012;39:18-25
- mono-energetic
- energy = 14 MeV
- r_0 = 1.7 cm

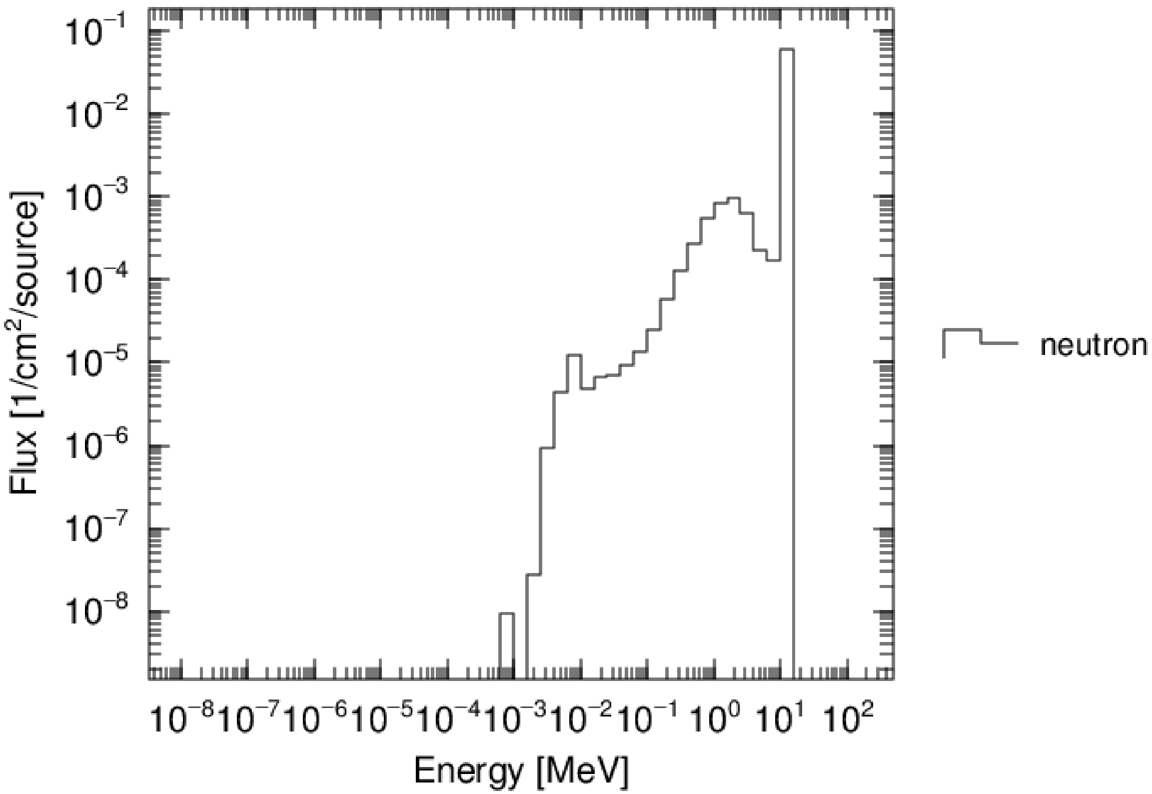
Multiplier



- Materials for multiplier must be able to effectively increase the number of neutron flux.
- Based on the graph, Pb of 4 cm thickness is the best choice for multiplier region

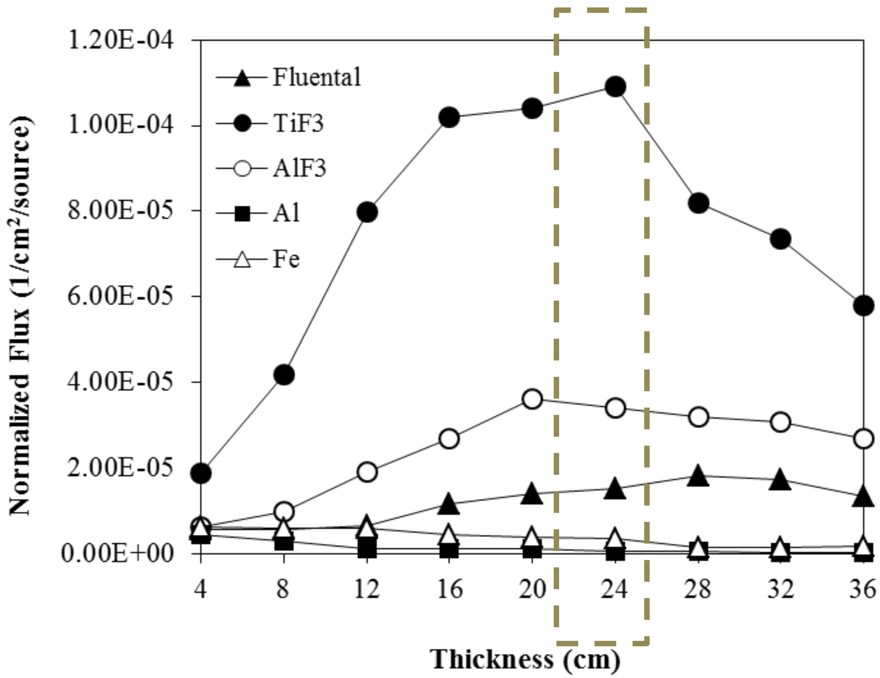


Multiplier

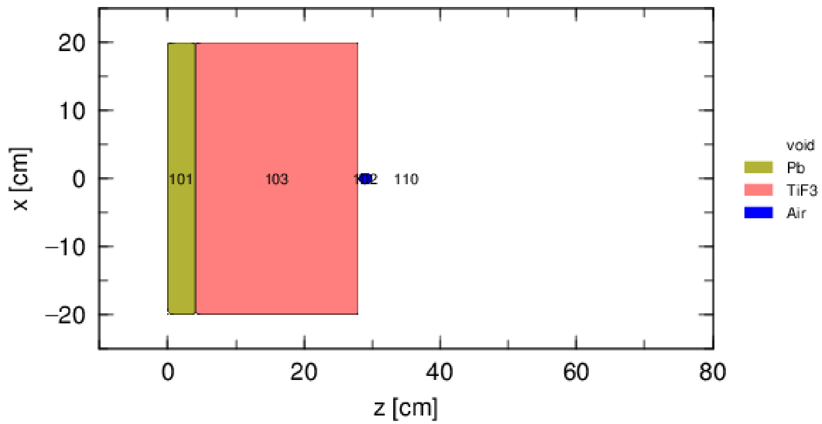


Normalized neutron flux versus energy of Pb as neutron multiplier,

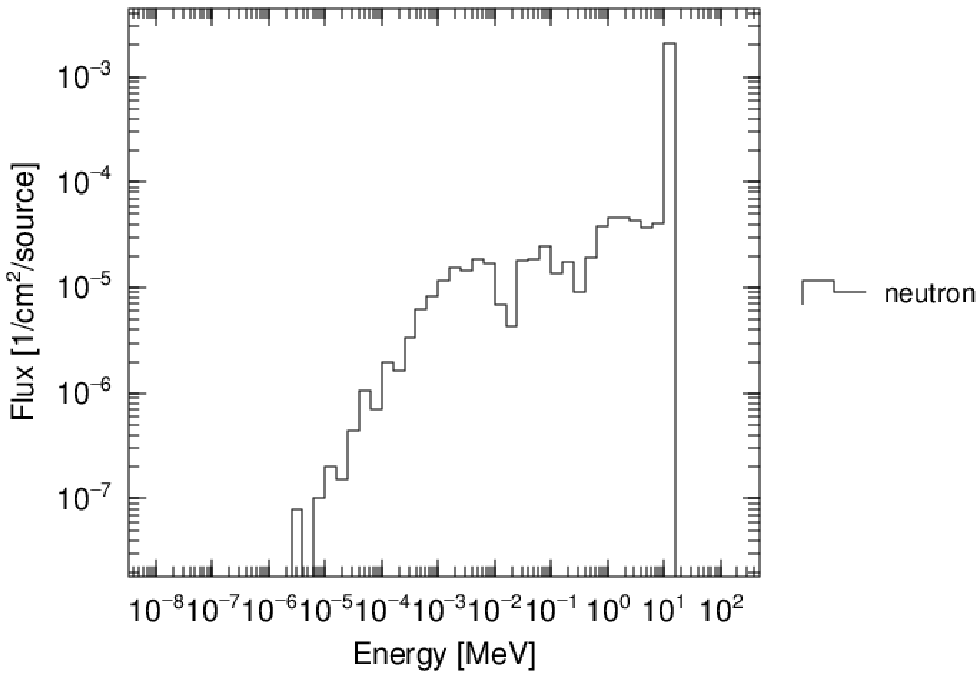
Moderator



- Materials for moderator must be able to moderate the fast neutron into thermal and epithermal neutron
- It is shown that the best thickness for moderator is 24 cm TiF_3. Multiplication is done with 4 cm of Pb



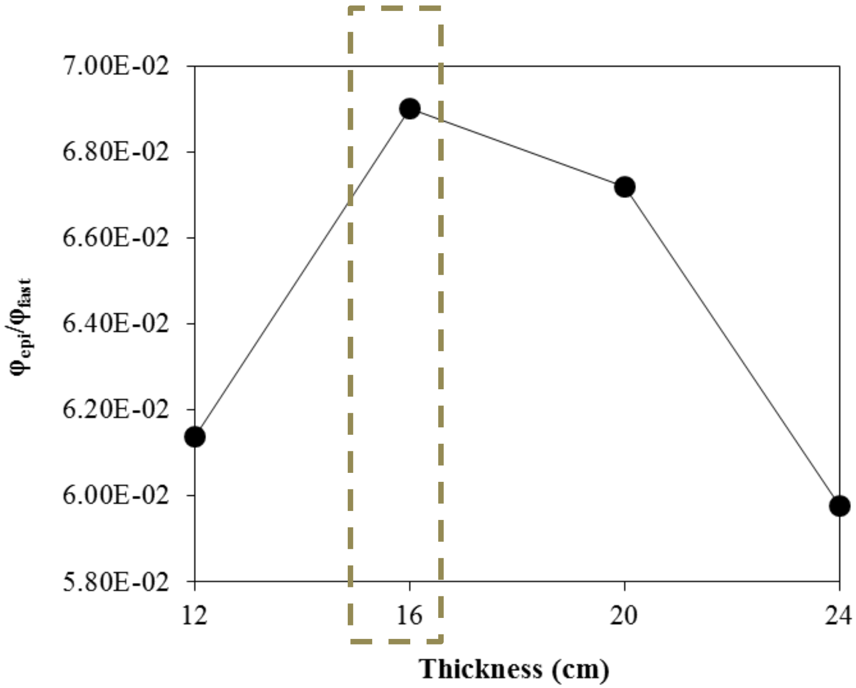
Moderator



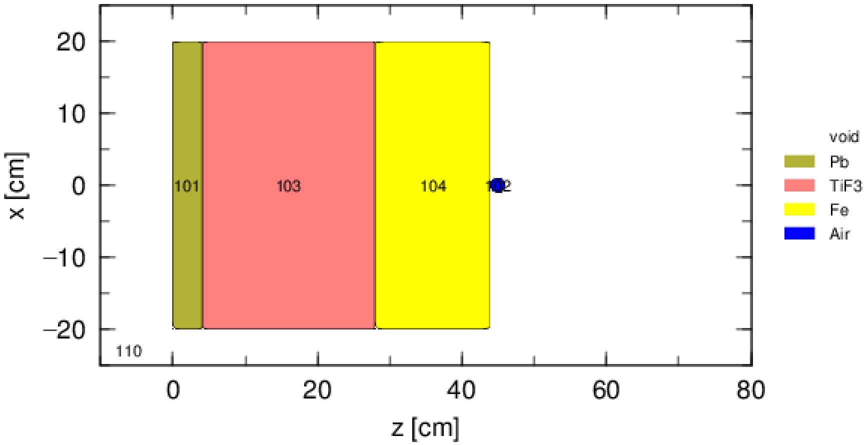
Normalized neutron flux versus energy of TiF3 as moderator

Although the epithermal flux for 24 cm TiF_3 satisfy IAEA recommended value (1.58×10^{10} n/cm^{2}s). its fast neutron flux is significantly high. As a result, the value of $\varphi_{epi}/\varphi_{fast}$ is very low and does not satisfy the IAEA recommended value (4.46×10^{-2}).

2^{nd} Moderator



- 2^{nd} moderator is adopted to increase the epithermal flux and decrease the fast neutron flux.
- the ϕ_{epi}/ϕ_{fast} values are still very far from that recommended by the IAEA.



Conclusion

Adopting multiplier, first moderator, and second moderator still cannot satisfy one of the IAEA criteria; thus more BSA components are needed.

Materials selection and size optimization are required to obtain BSA design which is suitable for BNCT applications

THANK YOU