Neutron production for BNCT

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4 settembre 2023

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01 Introduction

- Thermal Neutron (0.025 eV) react with ^{10}B with 3840 barn of cross section

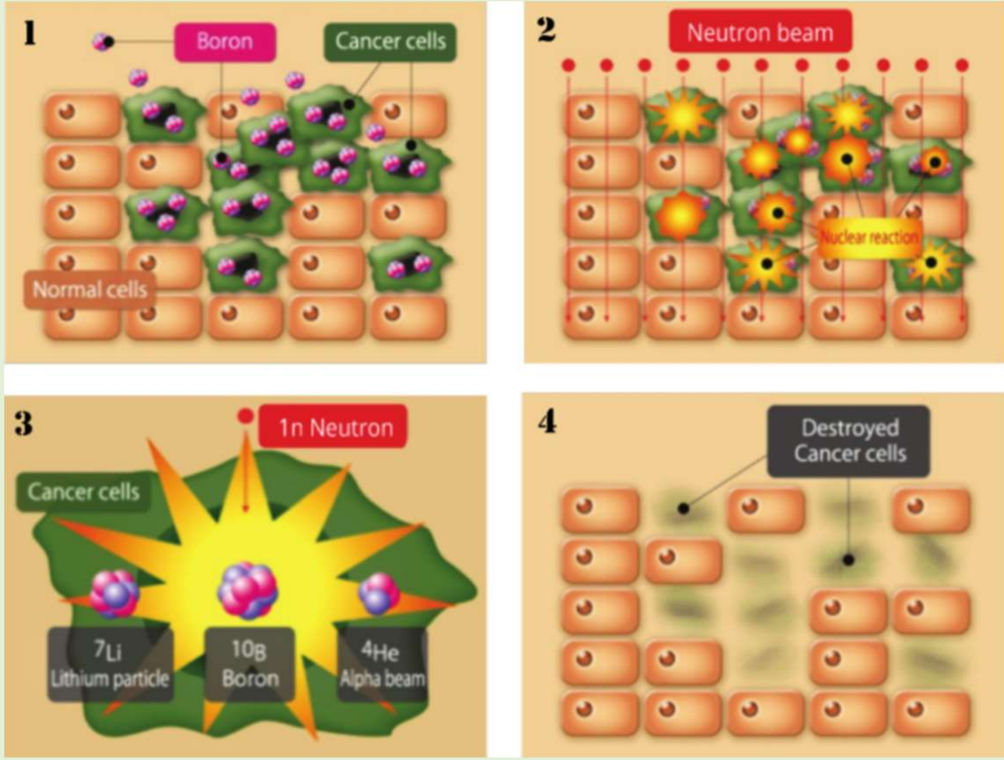
- Boron is fluxed inside tumor zone with drugs

$$^{10}B + n \rightarrow {}^{7}Li + \alpha + 2.79\ MeV \quad (6.1\%)$$

$$\rightarrow {}^{7}Li^{*} + \alpha + 2.31\ MeV \quad (93.9\%)$$

$$\rightarrow {}^{7}Li + \gamma + 0.478\ MeV\,.$$

$$\sigma = 3837\ b$$



Advantages

1. Localized treatment
2. Metastatic lesion terapy

Disadvantages

1. Boron localization not easy
2. Very difficult collimation and selection of epithermal neutrons

01 Introduction

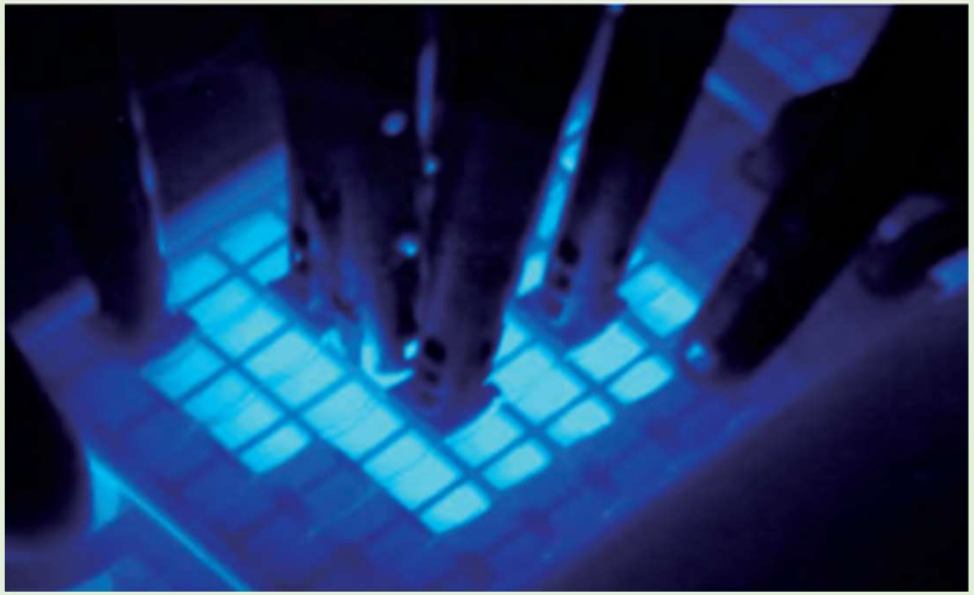
Neutron source for BNCT

1. Nuclear Reactors
2. Accelerators

Neutrons for treatment have energy range from thermal to epithermal, from 25meV to 0.5 eV, and from 0.5 eV to 10 keV.

Use of reactor is not feasible into a hospital centre.

Accelerator could be compact and modular, and very less radiation impactant.



01 Introduction

NEUTRON PRODUCTION

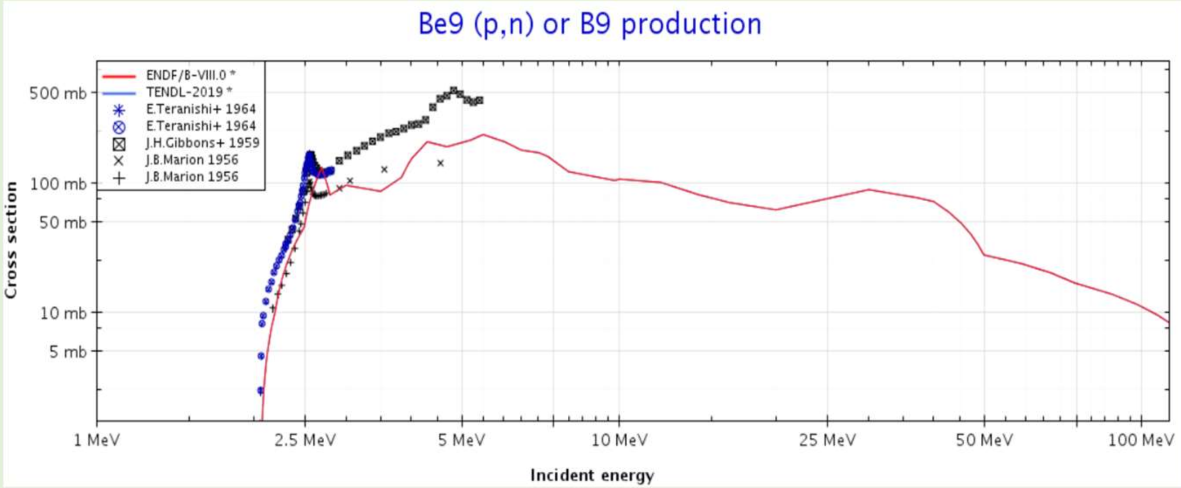
Lithium and Beryllium have highest cross section:

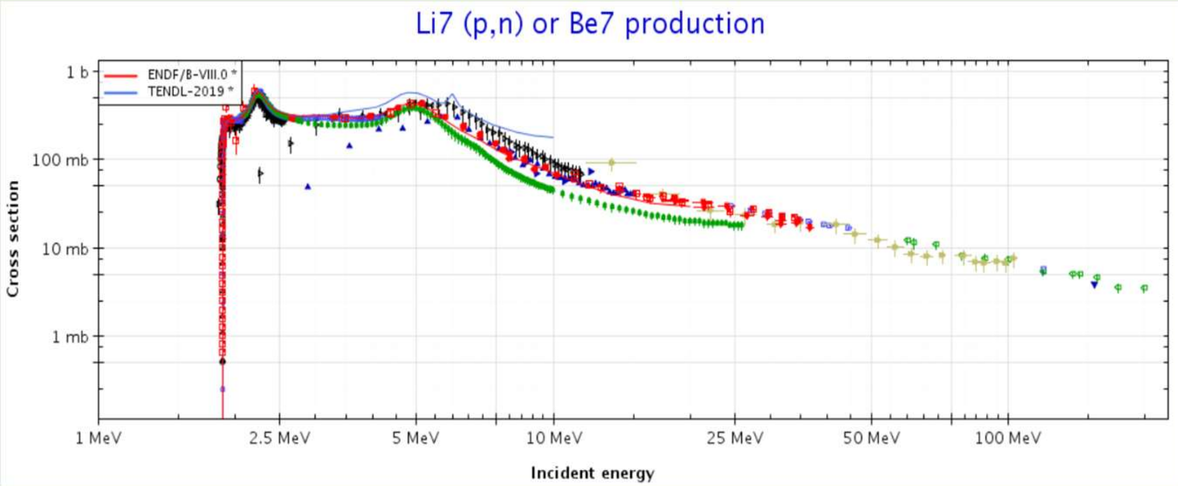
1. p(^{9}Be,^{9}B)n
2. p(^{7}Li,^{7}Be)n

Conversion efficiency:

1. 1*10 12 n*mC-1
2. 9.8 * 10 11 n*mC -1

(2) Juan Esposito





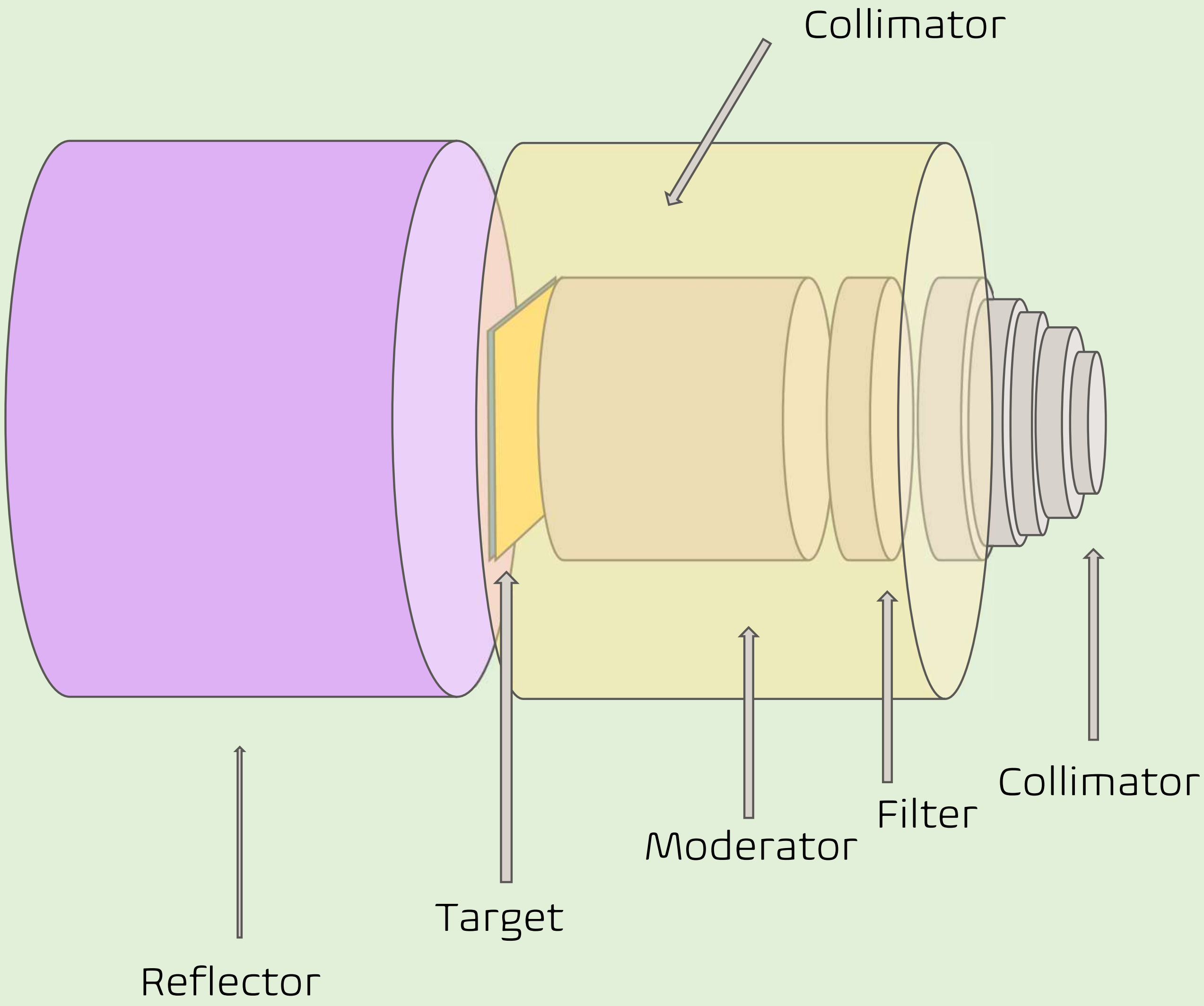
01 Introduction

ACCELERATOR-DRIVEN SYSTEM:

In order to produce thermal neutrons needs to moderate them with a moderator

BSA:

1. Moderator:
   - Thermal: polyethylene
   - Epithermal: AlF_3 , Al, MgF_2, CaF_2
2. Filter:
   - Thermal: Pb
   - Epithermal: ^{7}LiF
3. Collimator: polyethylene (external with boron)
4. Reflector: Pb

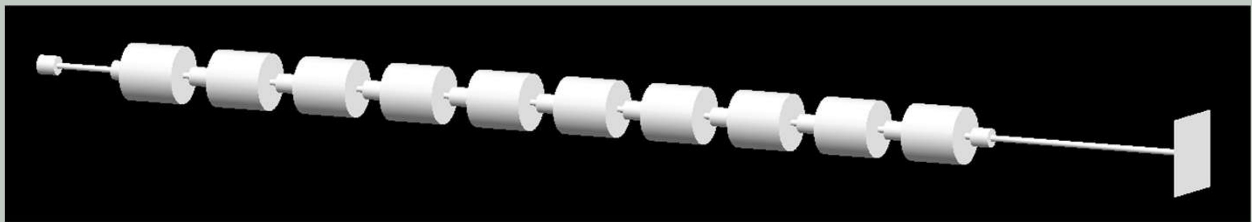


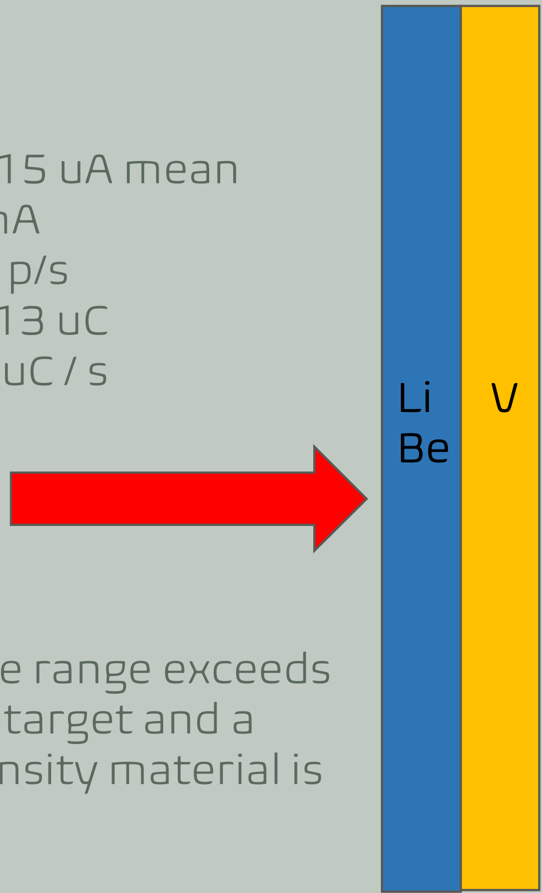
02 Set-up simulation

Linearbeam s.r.l. protonterapy facility

Linac: 4 MeV +/- 50 keV
Radiofrequecy cavity: 15 V/m
Quadrupole: 180 T/m

Current: 15 uA mean
Peak: 2 mA
5 * 10 11 p/s
1,6* 10 -13 uC
8 * 10 -2 uC / s





TARGET
Slice of Lithium or Berillium
Size: 8 cm * 8 cm * 0.04 cm
Slice of Vanadium for stopping protons

At these energies the range exceeds the thickness of the target and a thickness of high density material is postponed.

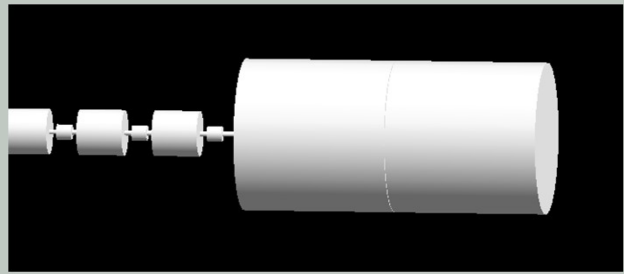
02 Set-up simulation

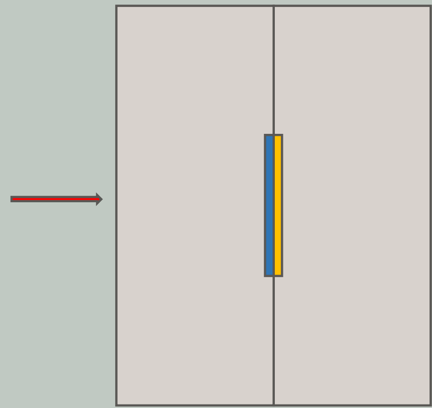
BEAM SHAPING ASSEMBLY for thermal neutrons only with polyethylene as first example
Size: 20 cm * lunghezza 40 cm

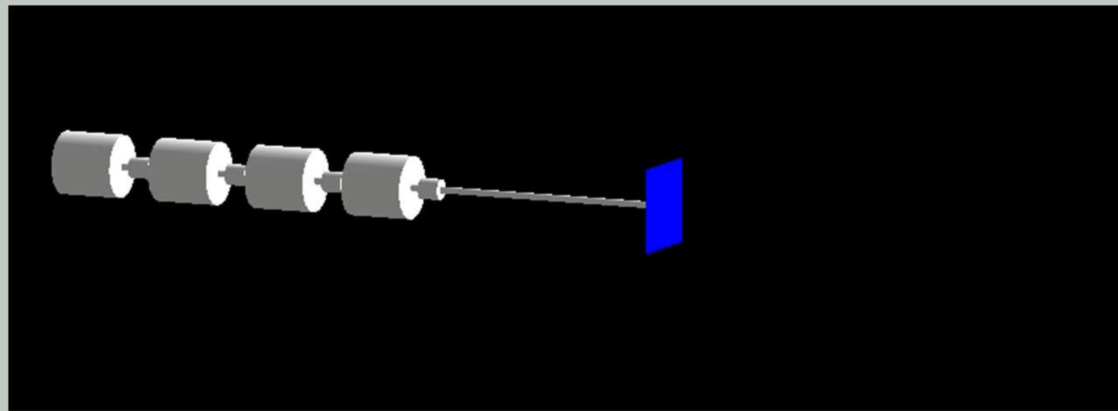
PHYSICS LIST: QGSP_BIC_AllHP – Physics List for neutrons

GEANT4 v10.7
Implementata la classe di Stepping Actions per ottenere neutroni prodotti e uscenti dal target

Stepsize implementation for Bragg Peak simulation







Reflector: violet

Barrell collimator: mustard

Moderator: red

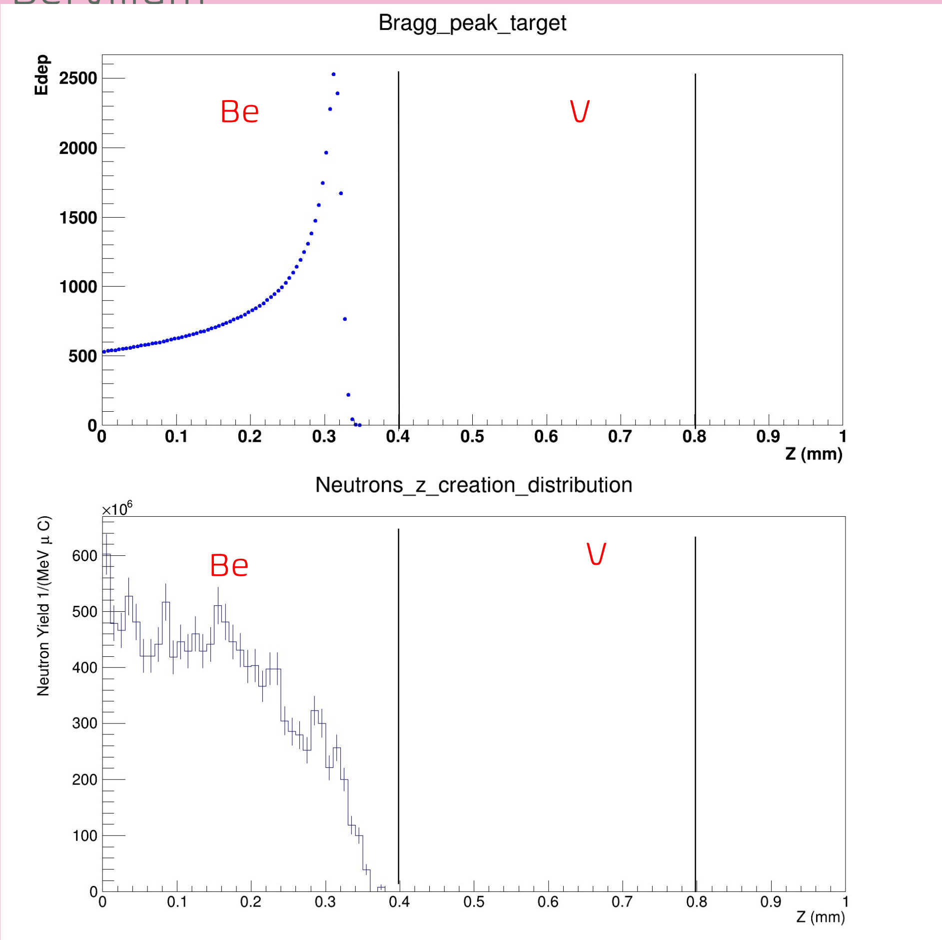
End-cap collimator: cyan

Filter: green

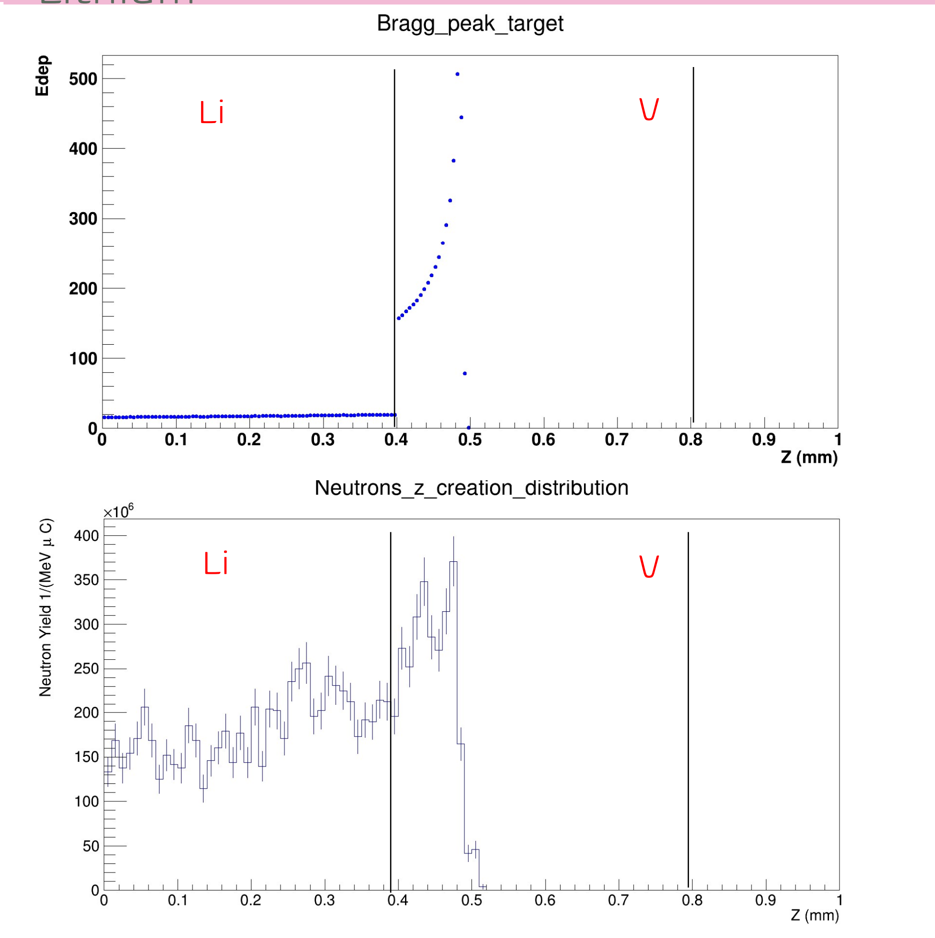
04 Analysis

Analysis at 6 MeV

Beryllium



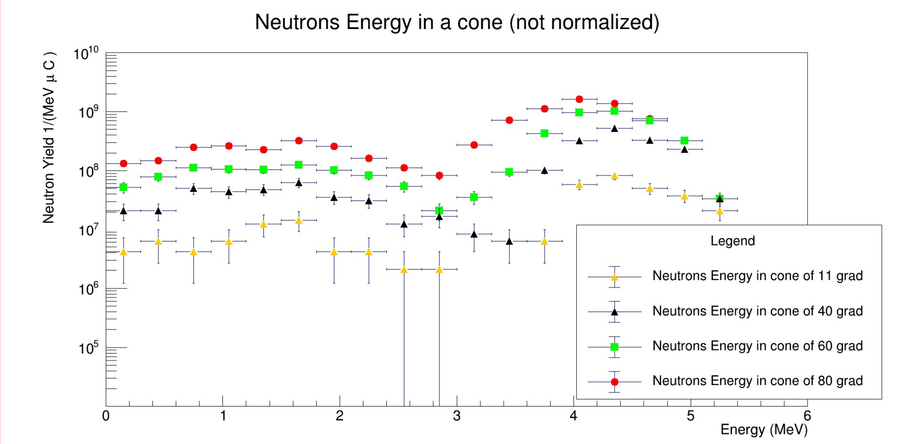
Lithium

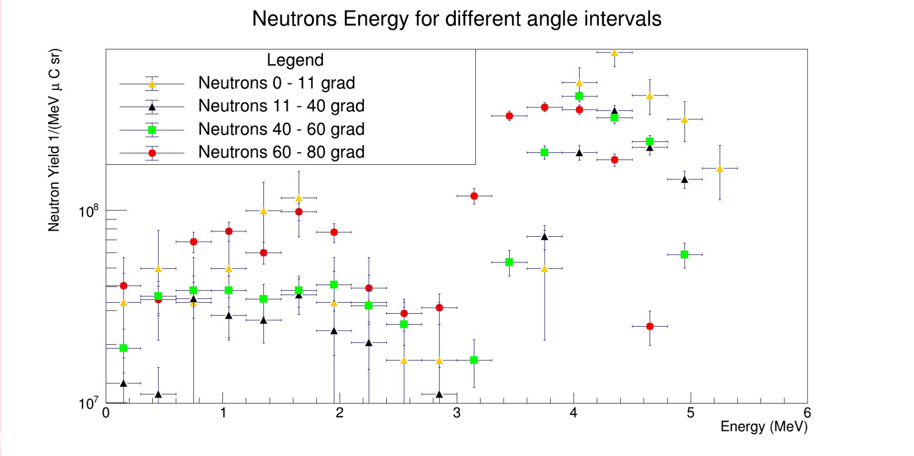


04 Analysis

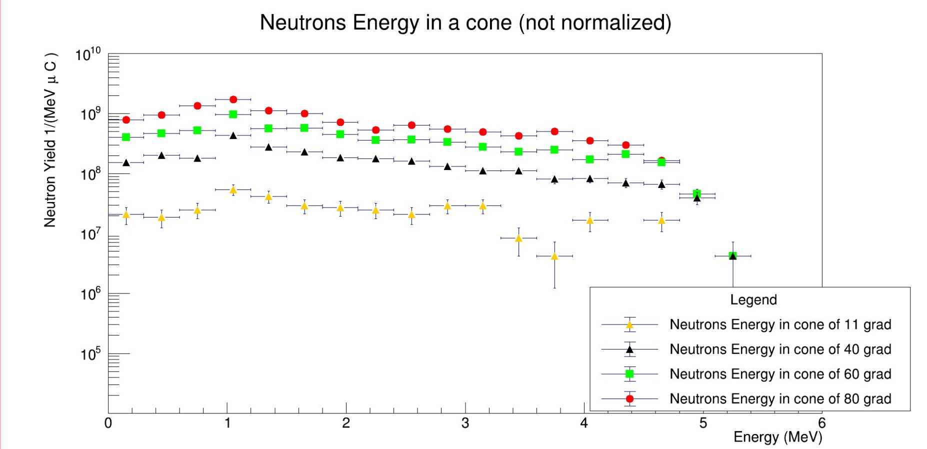
Analysis at 6 MeV

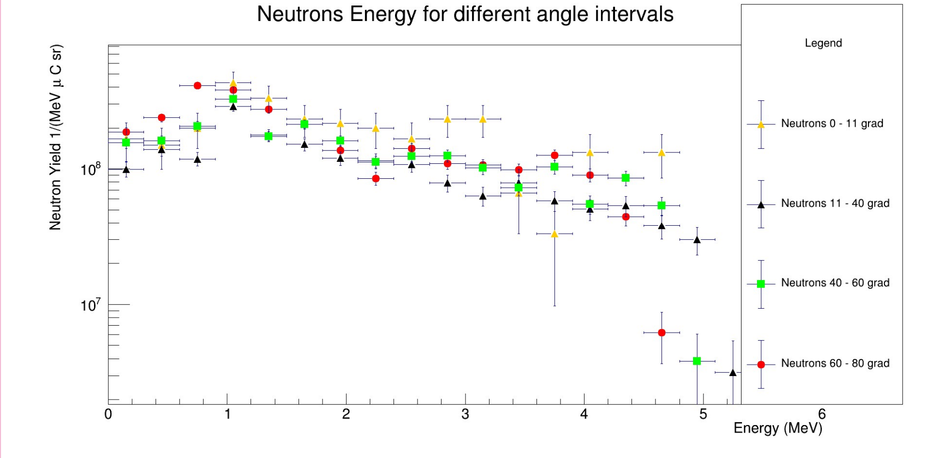
Beryllium





Lithium

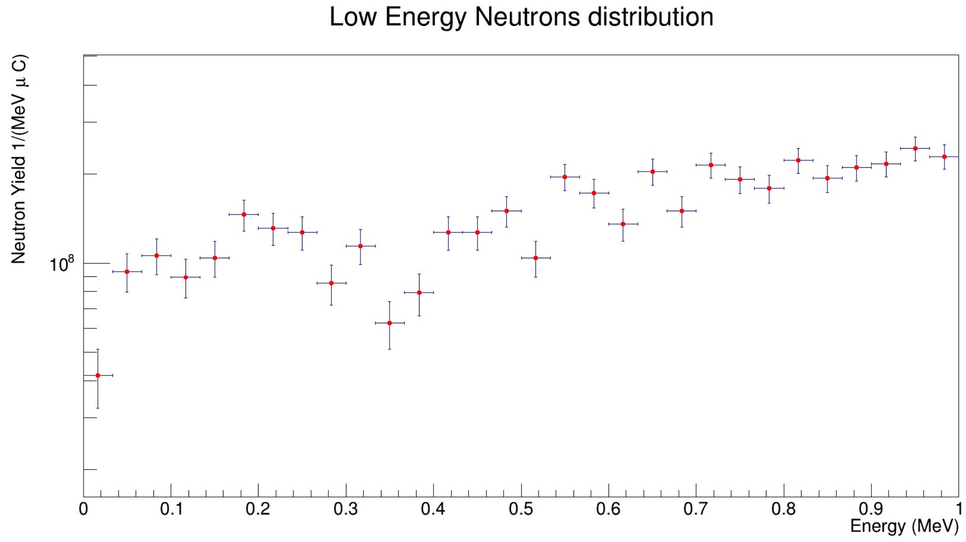




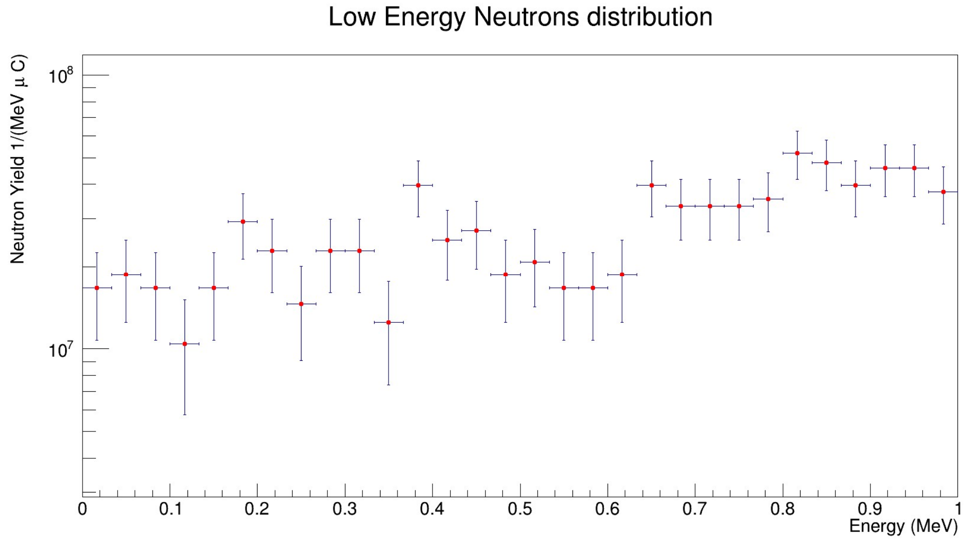
04 Analysis

Analysis at 6 MeV

Beryllium



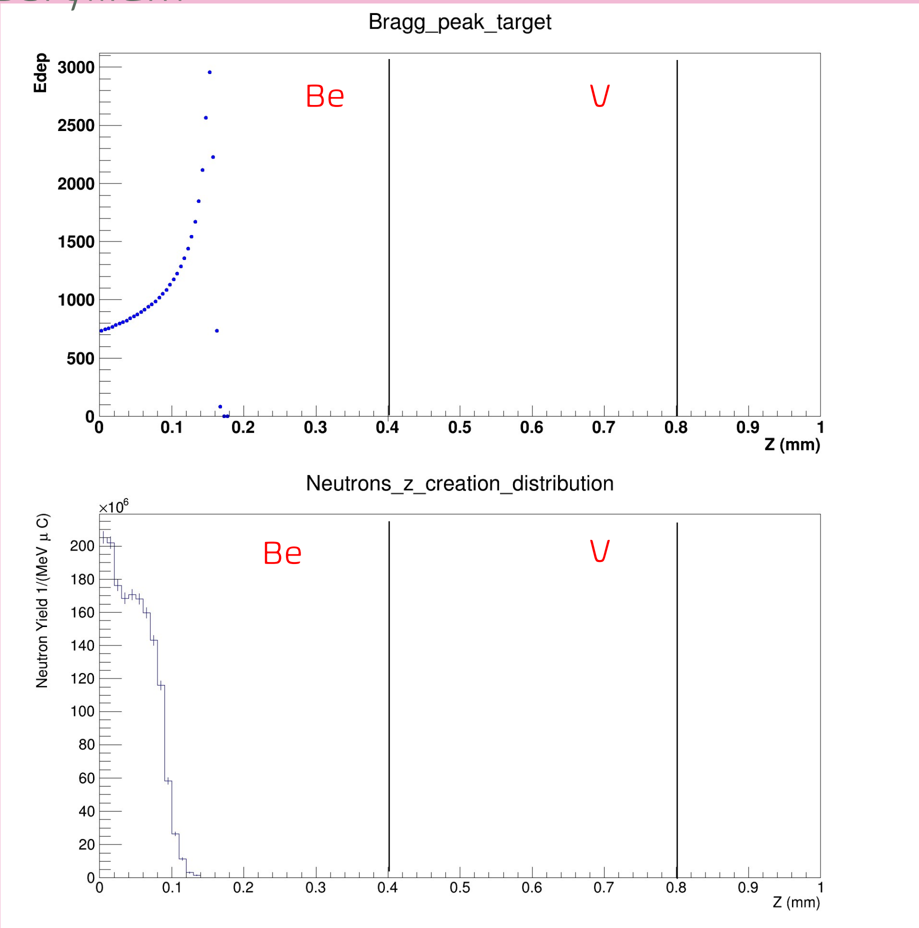
Lithium



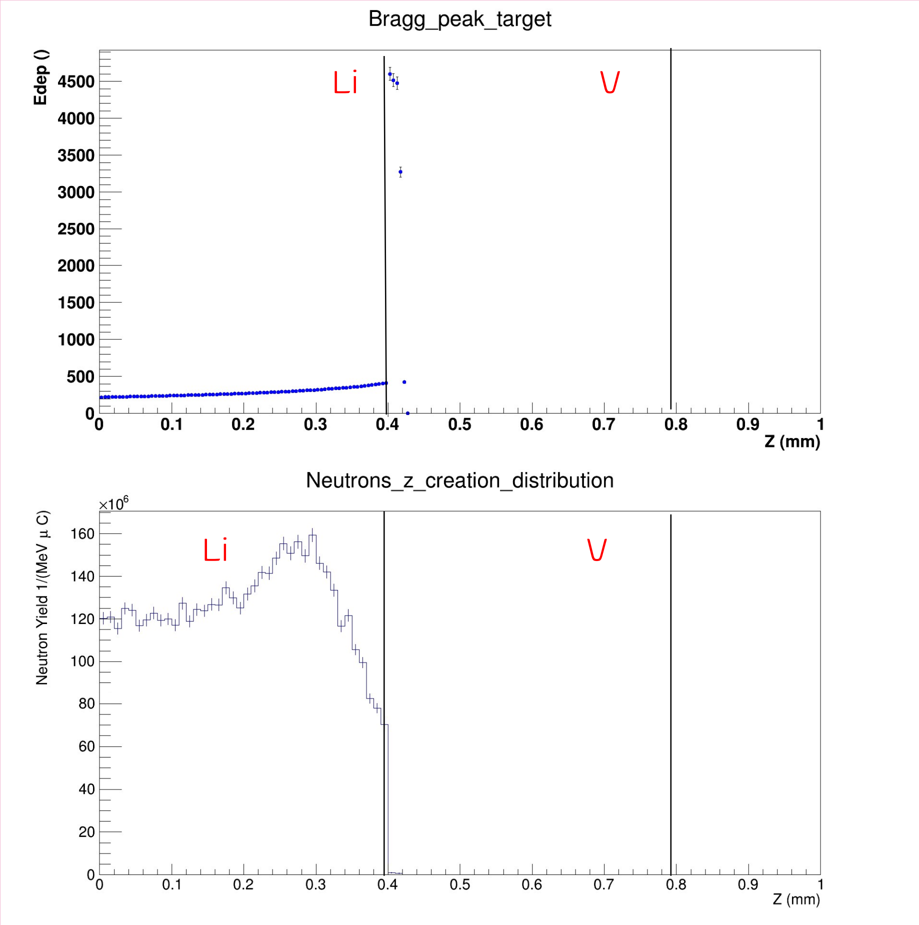
04 Analysis

Analysis at 4 MeV

Beryllium



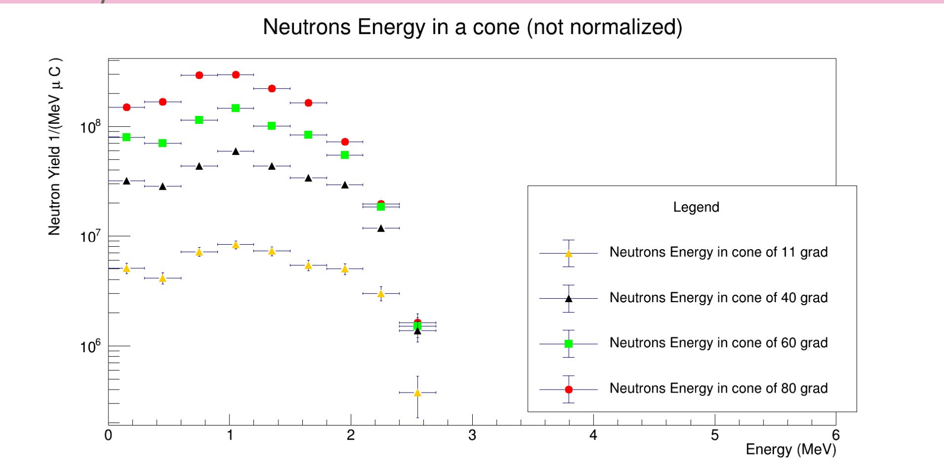
Lithium

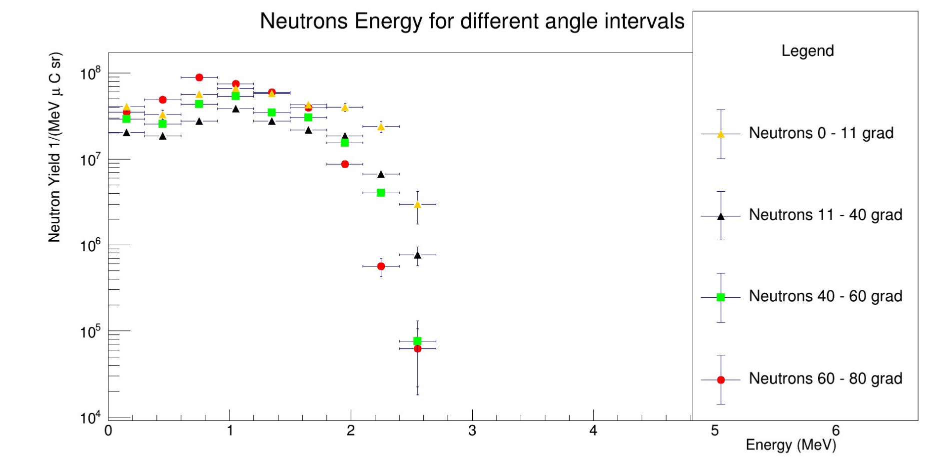


04 Analysis

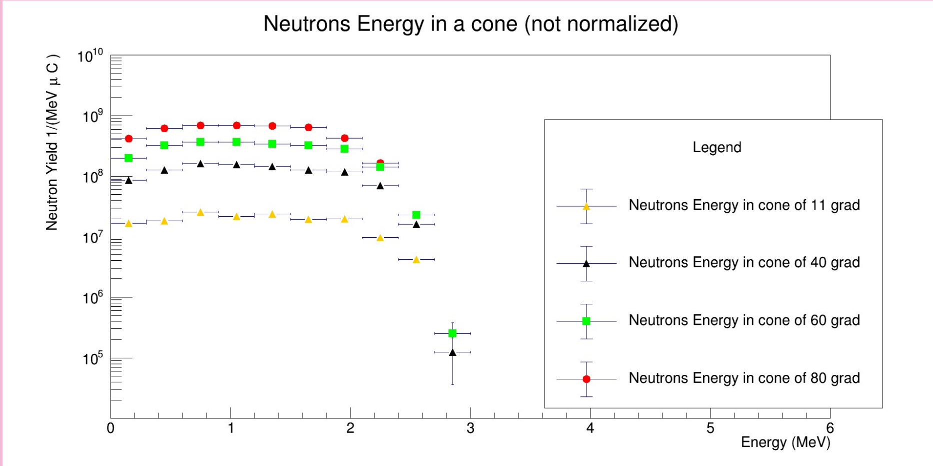
Analisi per target con 4 MeV

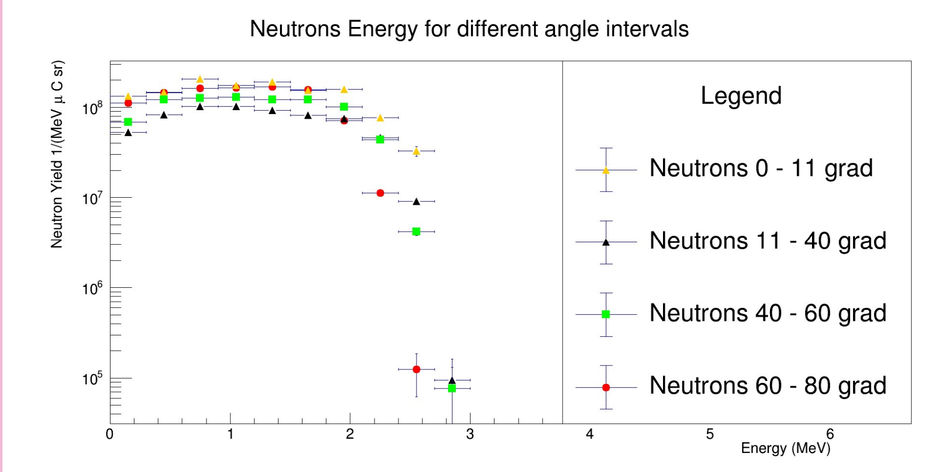
Beryllium





Lithiutm

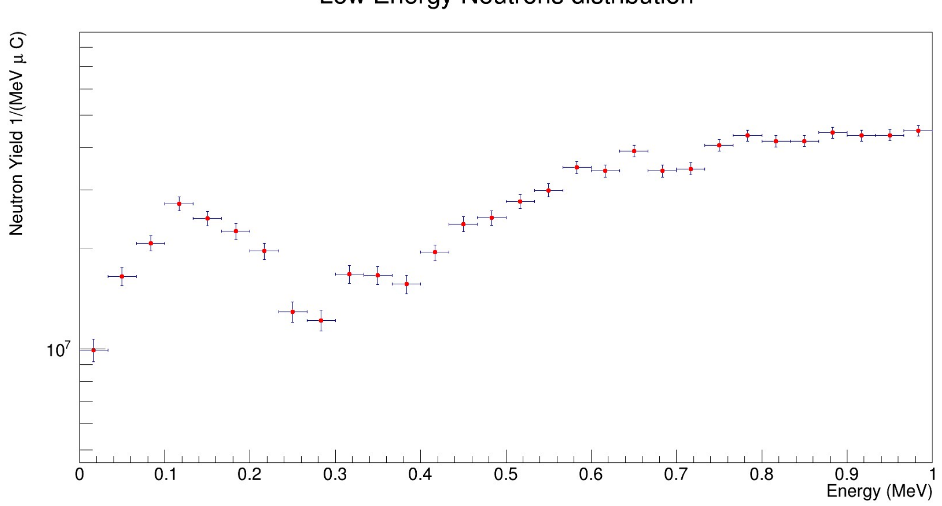




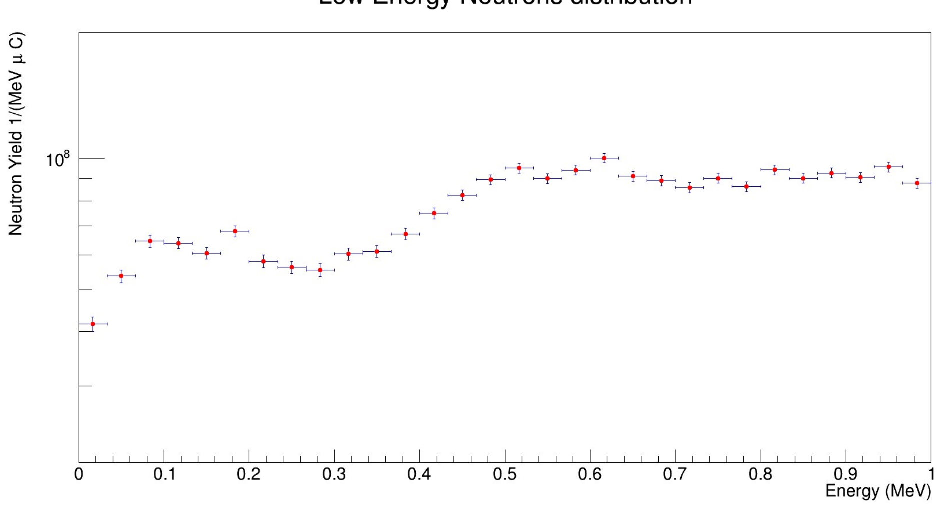
04 Analysis

Analysis for Lithium at 4 MeV

Beryllium



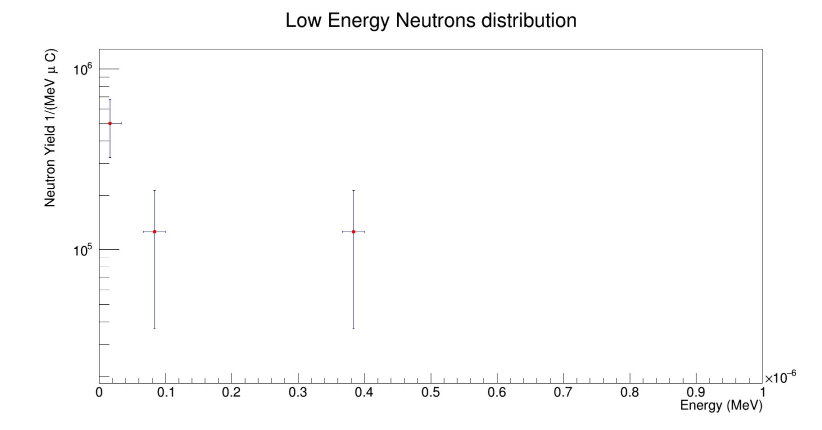
Lithium

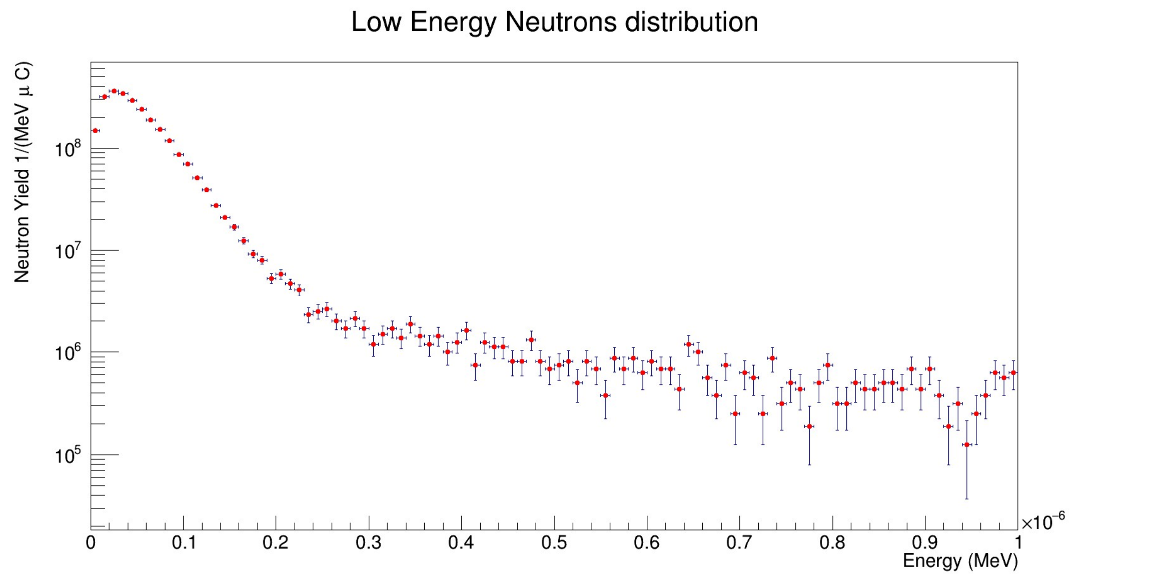


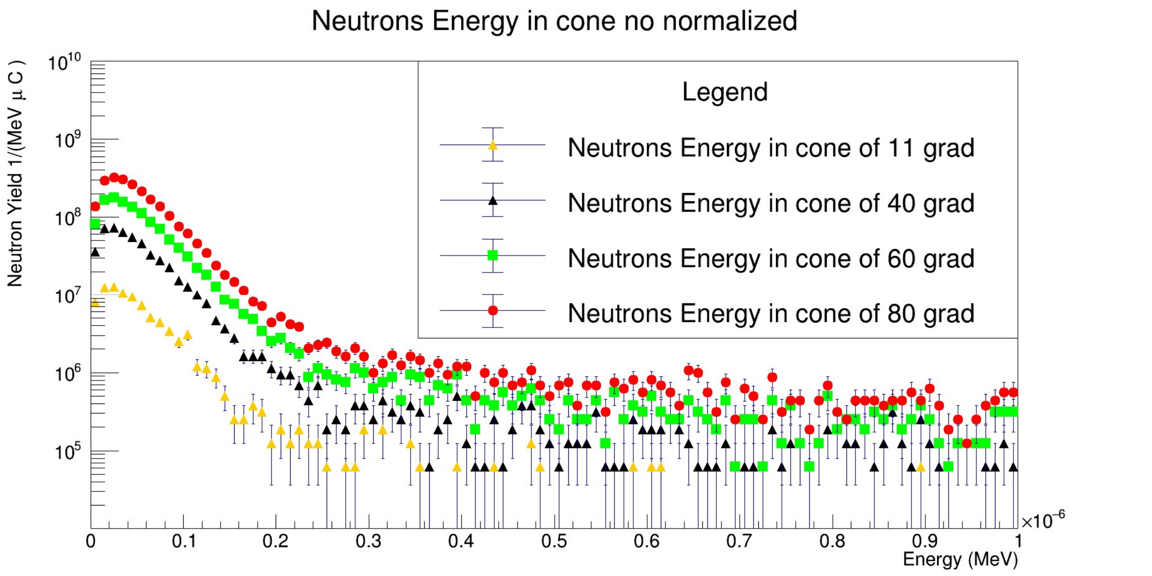
Lithium target better than Beryllium

04 Analysis

THERMAL BSA



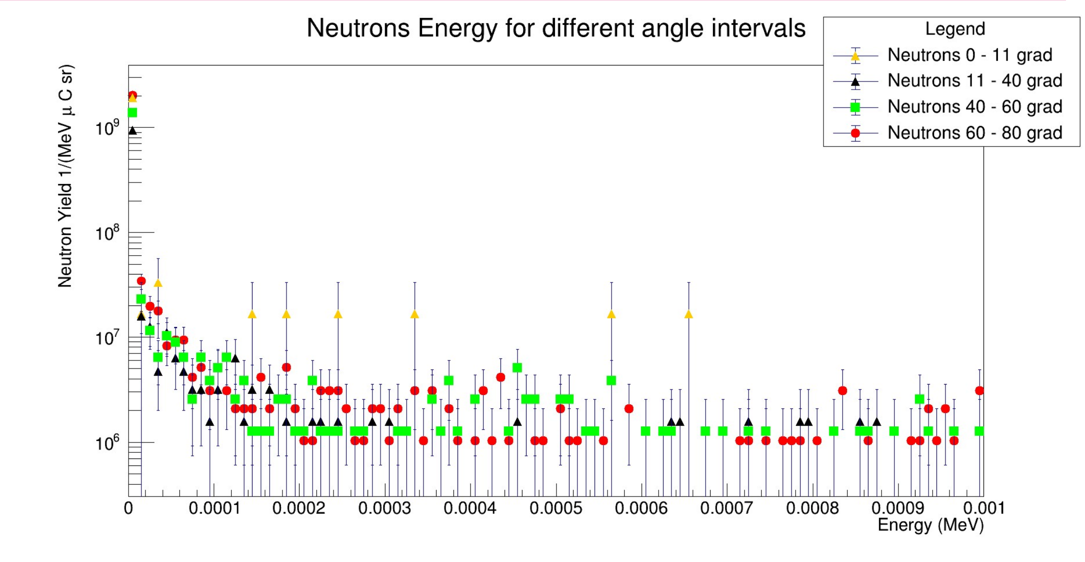


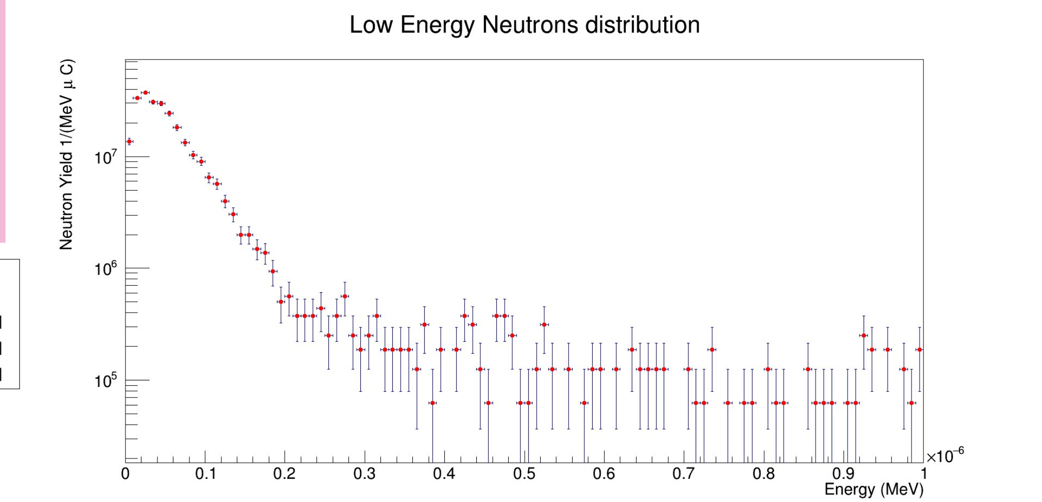


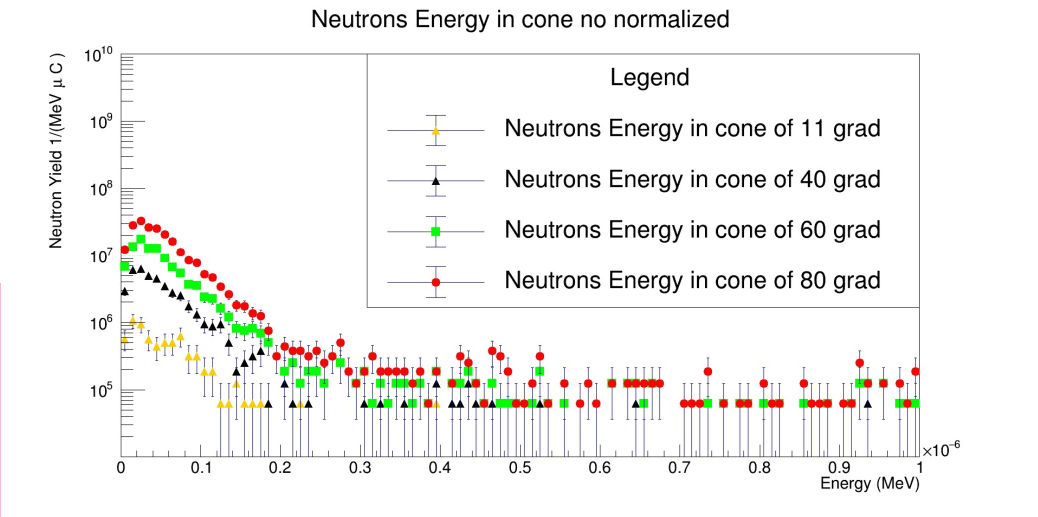
Polyethylene BSA with 4 MeV for thermal neutrons: left, thermal neutrons produced without BSA, right upper shift properties of Polyethylene BSA for thermal neutrons, right bottom, angle spectral properties

04 Analysis

EPITHERMAL BSA







Yield is an order of magnitude smaller, but BSA collimation works well in forward direction

05

Conclusion

The ideal target for the facility is Lithium with a thickness of 400um. For BSA the ideal moderator for a beam of thermal neutrons is polyethylene, while for epithermal beam is MgF_2, but an order of magnitude of yield is lost.

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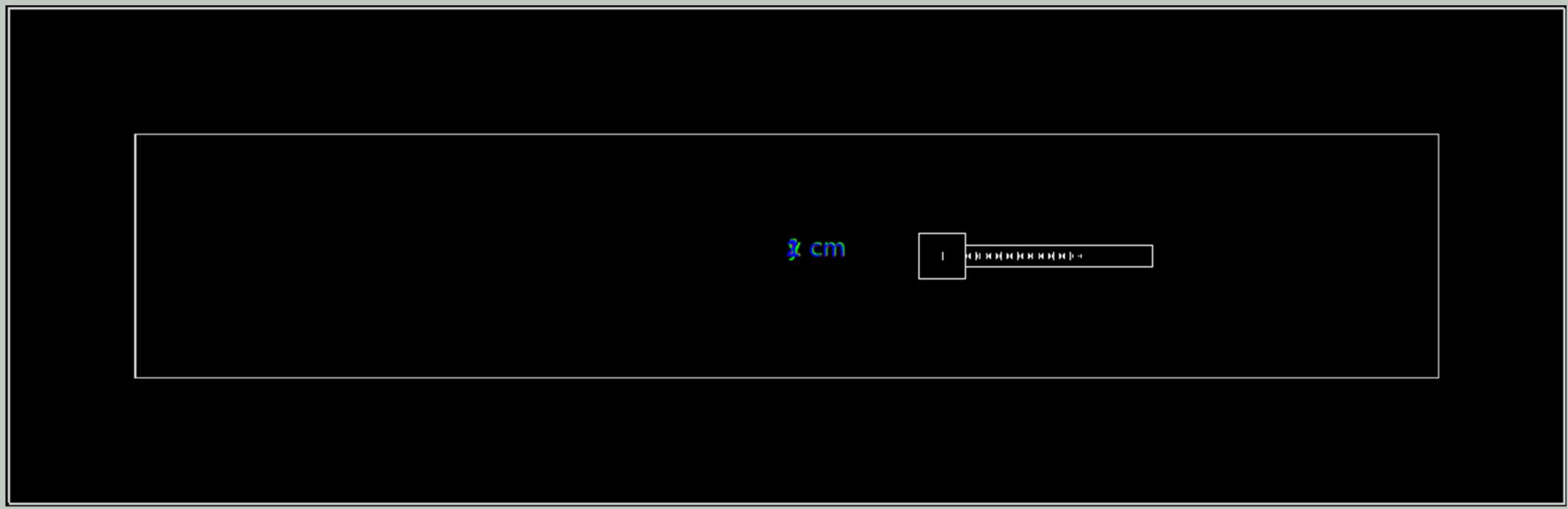
Backup

Geometry of the simulation

1. Accelerator
2. Target
3. BSA
4. Bunker



Backup

Berillio 4 MeV Litio