Comparative Analysis of Neutron Sources Produced by Low-Energy Electrons and Deuterons for Driving Subcritical Assemblies

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Introduction

- A conceptual design of an accelerator driven subcritical assembly has been developed using the existing accelerators at Kharkov Institute of Physics and Technology (KIPT) in Ukraine.

- Two different external neutron source options were examined for driving the subcritical assembly. Electrons with energies below 200 MeV and deuterons with energies below 100 MeV were considered.

- Comparative analysis of these two options is presented and discussed.

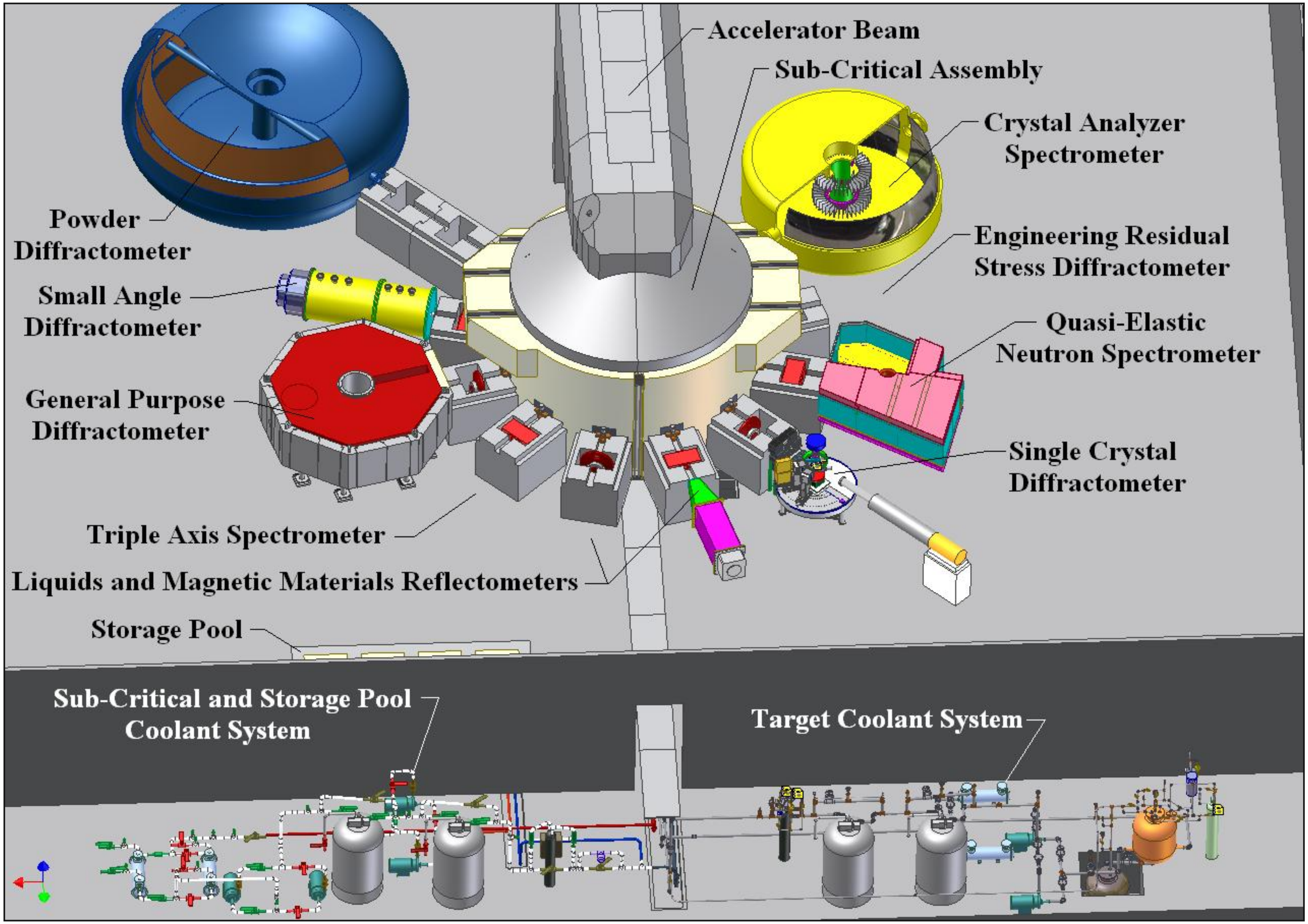
Ukraine Accelerator Driven Subcritical Assembly Facility Mission

- Produce medical isotopes and provide neutron source for performing neutron therapy procedures.

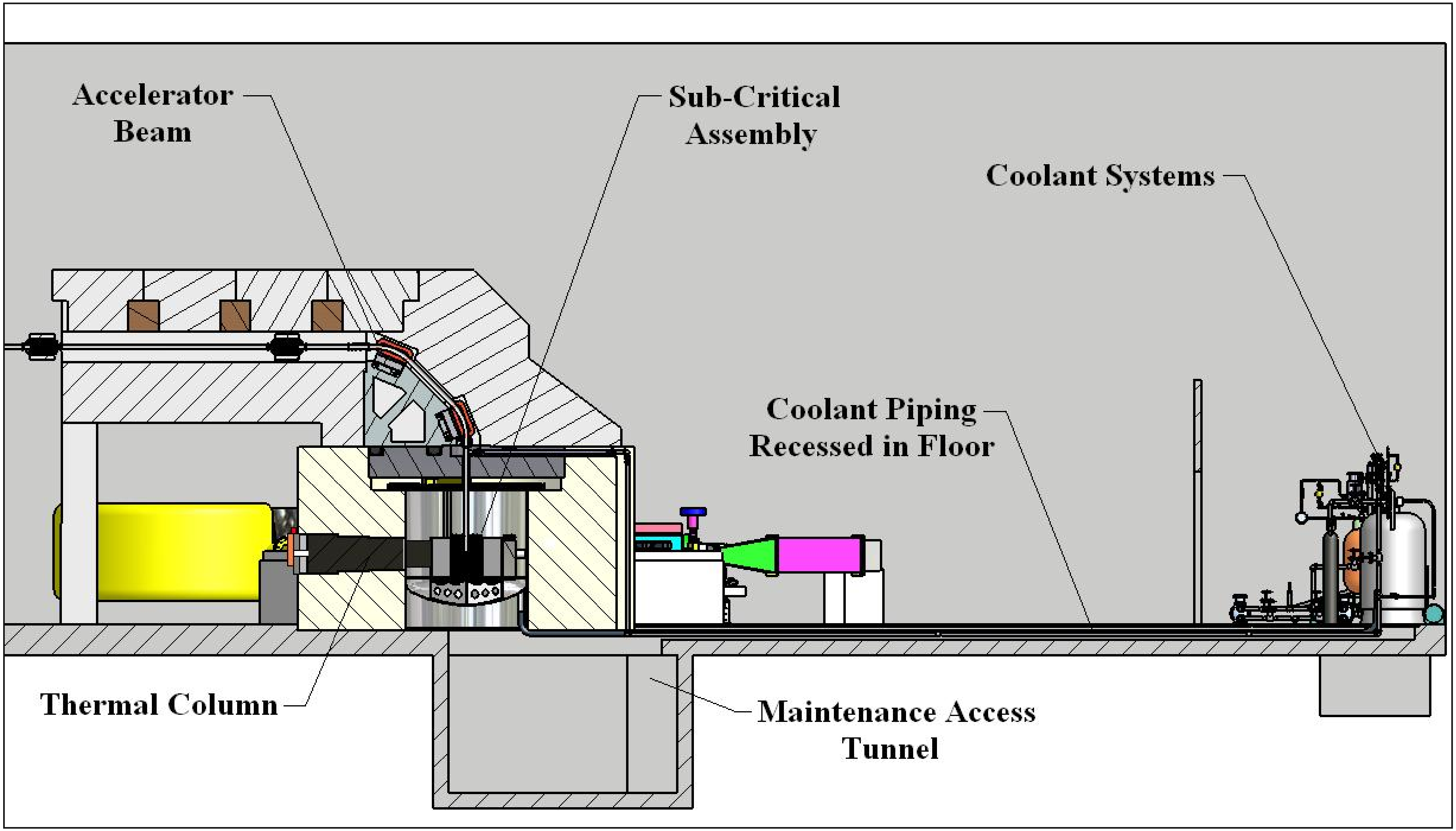
- Provide capabilities for carrying basic and applied research utilizing the radial neutron beam ports around the subcritical assembly.

- Support the Ukraine nuclear power industry by providing the capabilities to perform reactor physics experiments and to train young specialists.

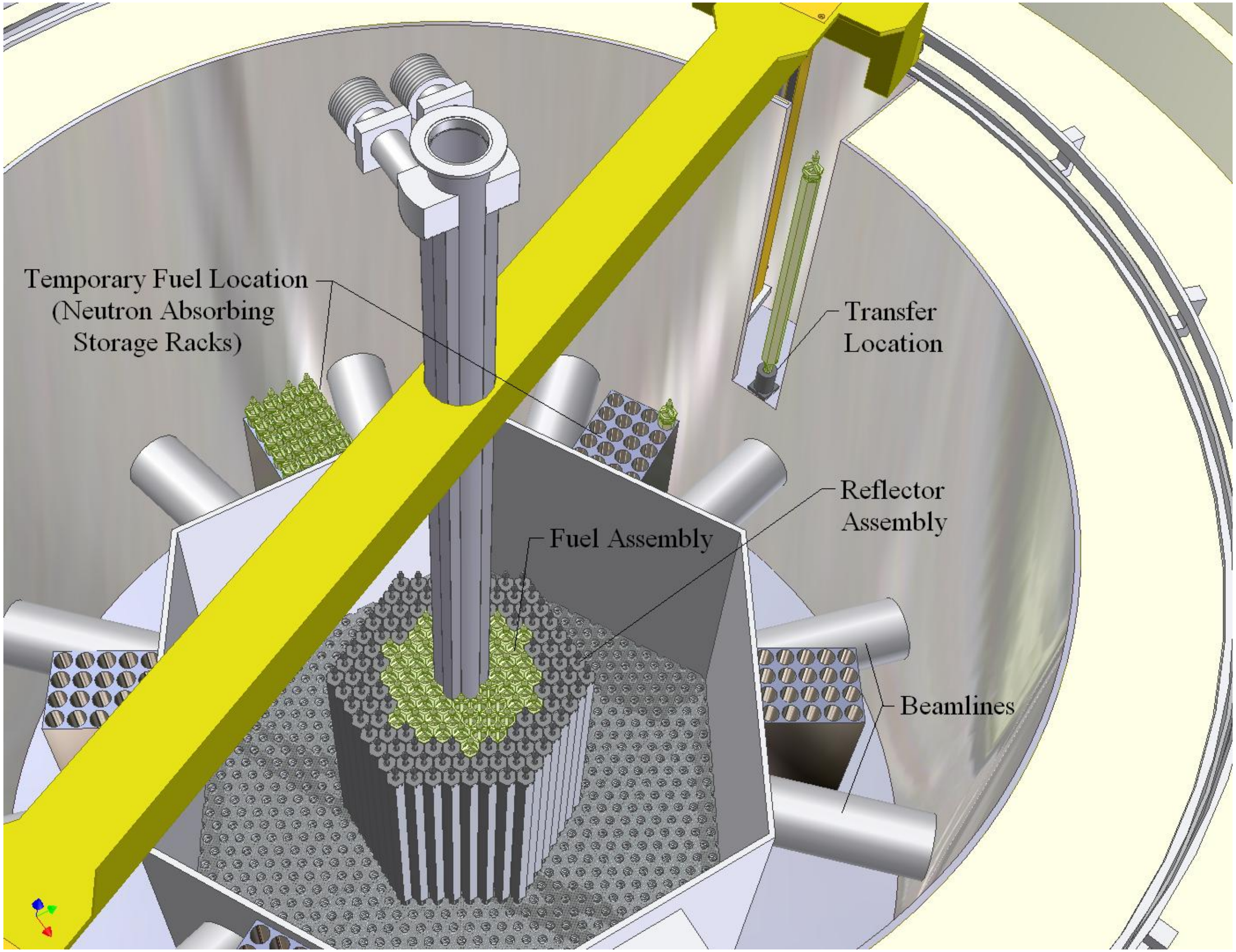
Facility Conceptual Design Overview



Vertical Cross Section Through the Facility



View Inside the Subcritical Assembly Showing Overall Arrangement



Comparative Analysis of Neutron Sources Produced by Low-Energy Electrons and Deuterons for Driving Subcritical Assemblies

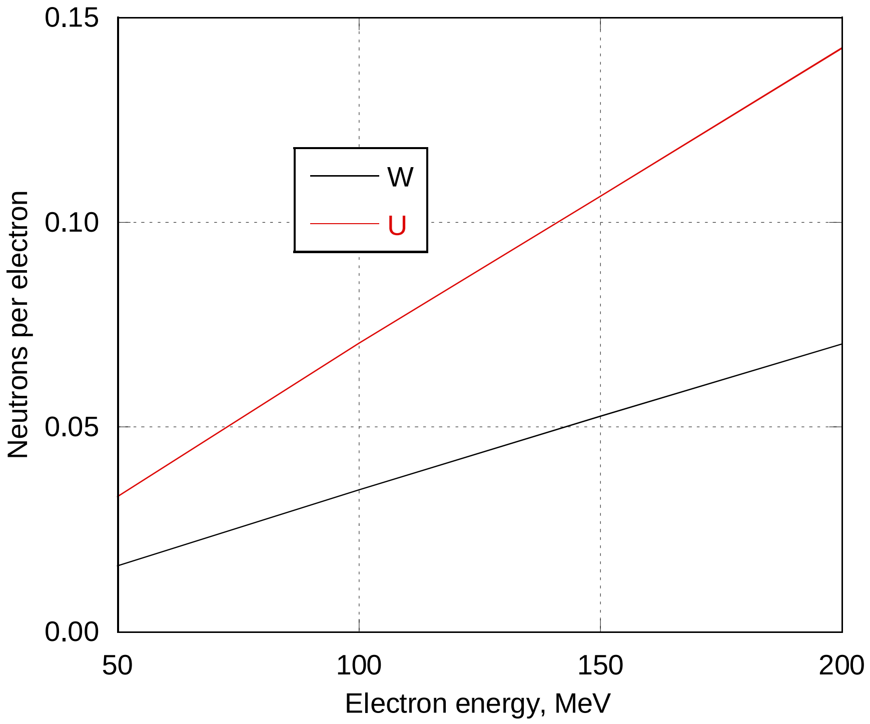
Study Objective:

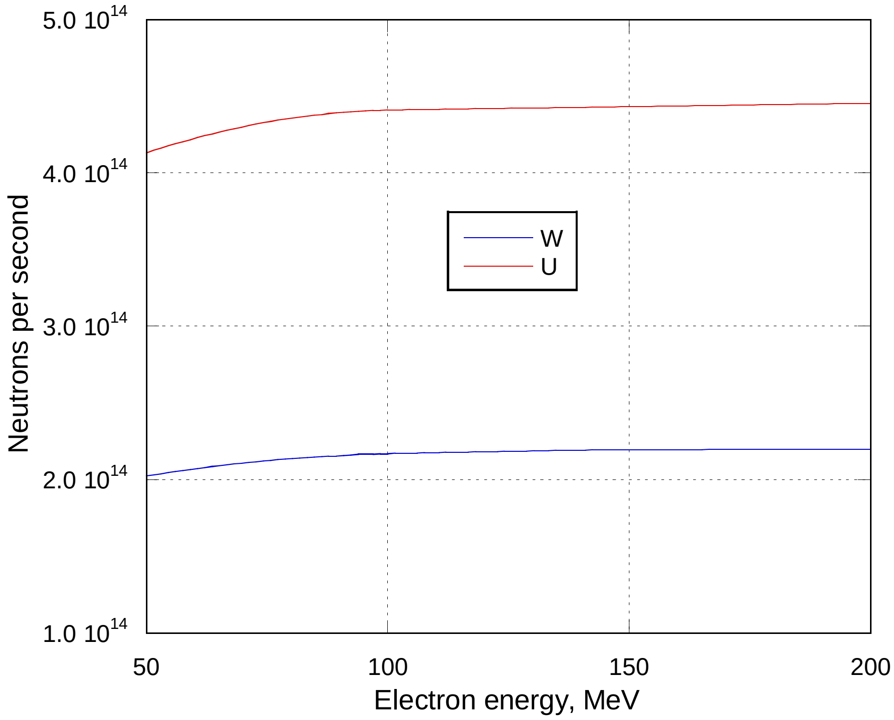
Maximize the neutron production from the available beam power and define the optimal beam parameters.

Study Parameters:

- Neutron source strength
- Neutron spatial and energy distributions
- Energy deposition in the target material
- Beam radius relative to the target radius
- Target geometrical configurations
- Thermal hydraulics results
- Thermal stress results
- Target Fabrication

Neutron Yields from Electron Interactions

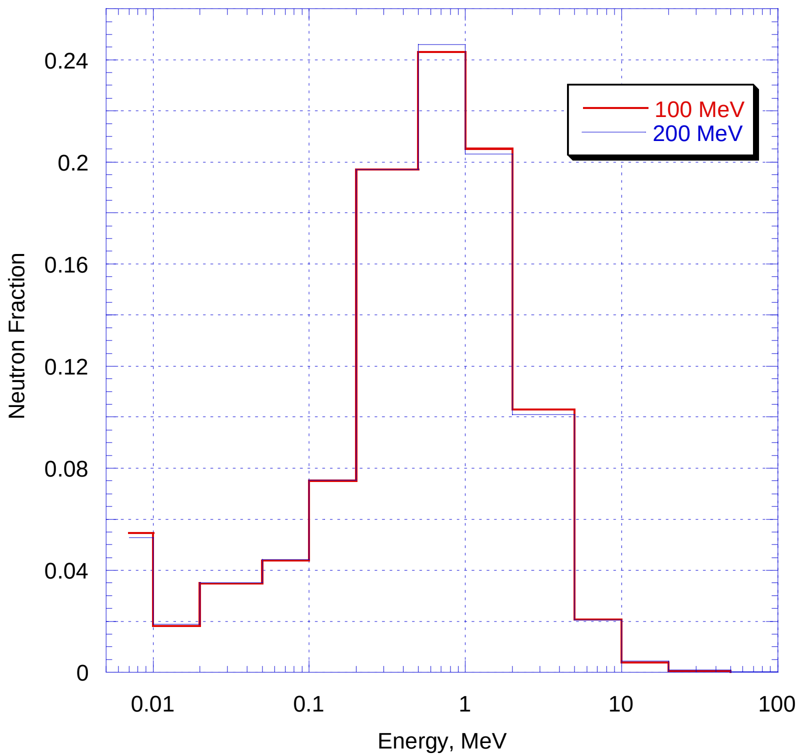




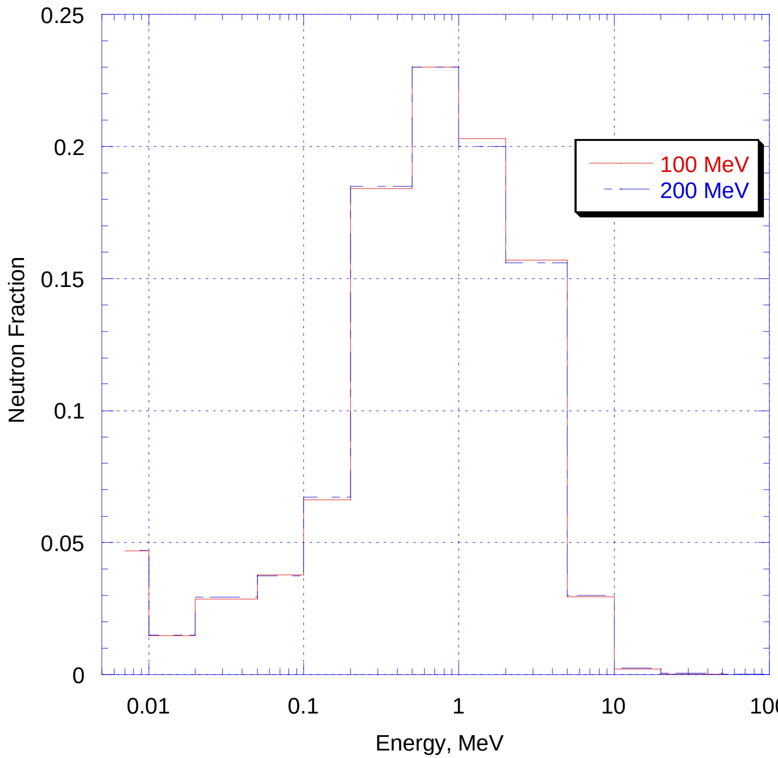
Neutron yield per electron from uranium and tungsten targets as a function of the electron energy

Neutron source strength from tungsten and uranium targets as a function of the electron energy for 100 kW beam power

Neutron Spectrum from Electron Interactions

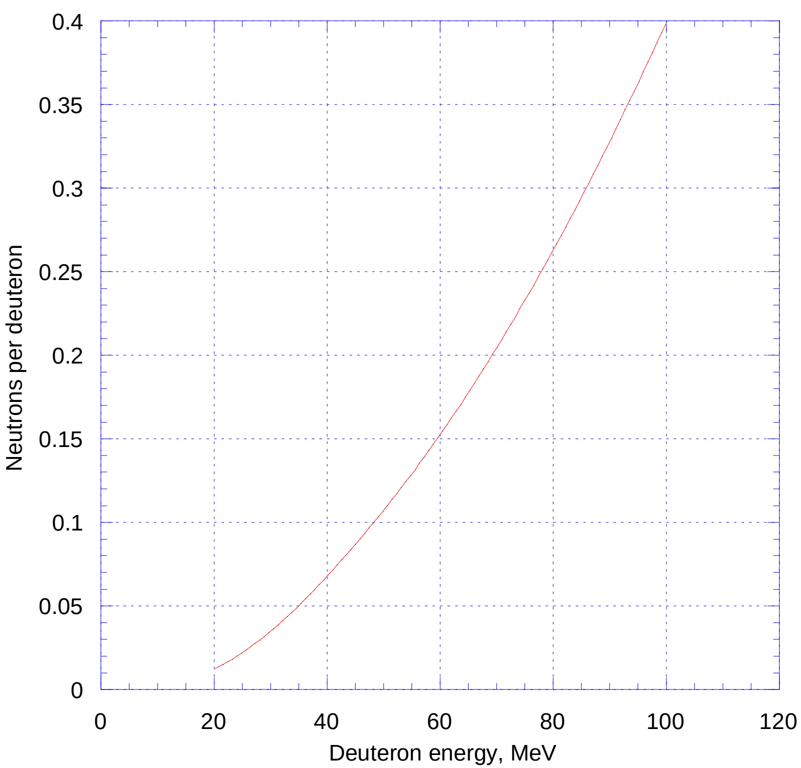


Neutron spectrum from tungsten target material for different electron beam energies

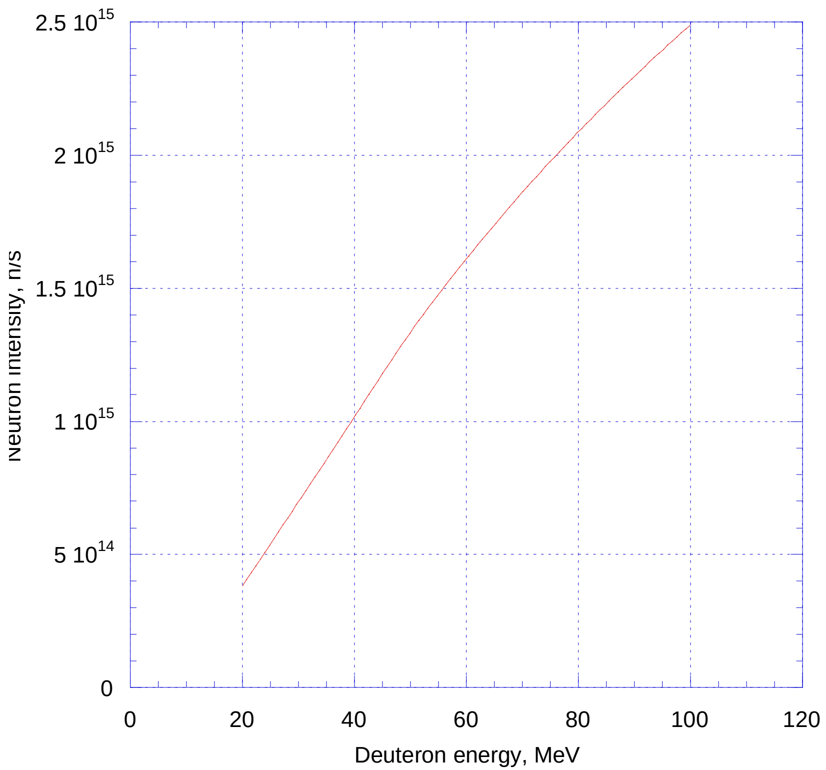


Neutron spectrum from uranium target material for different electron beam energies

Neutron Yields from Deuteron Interactions

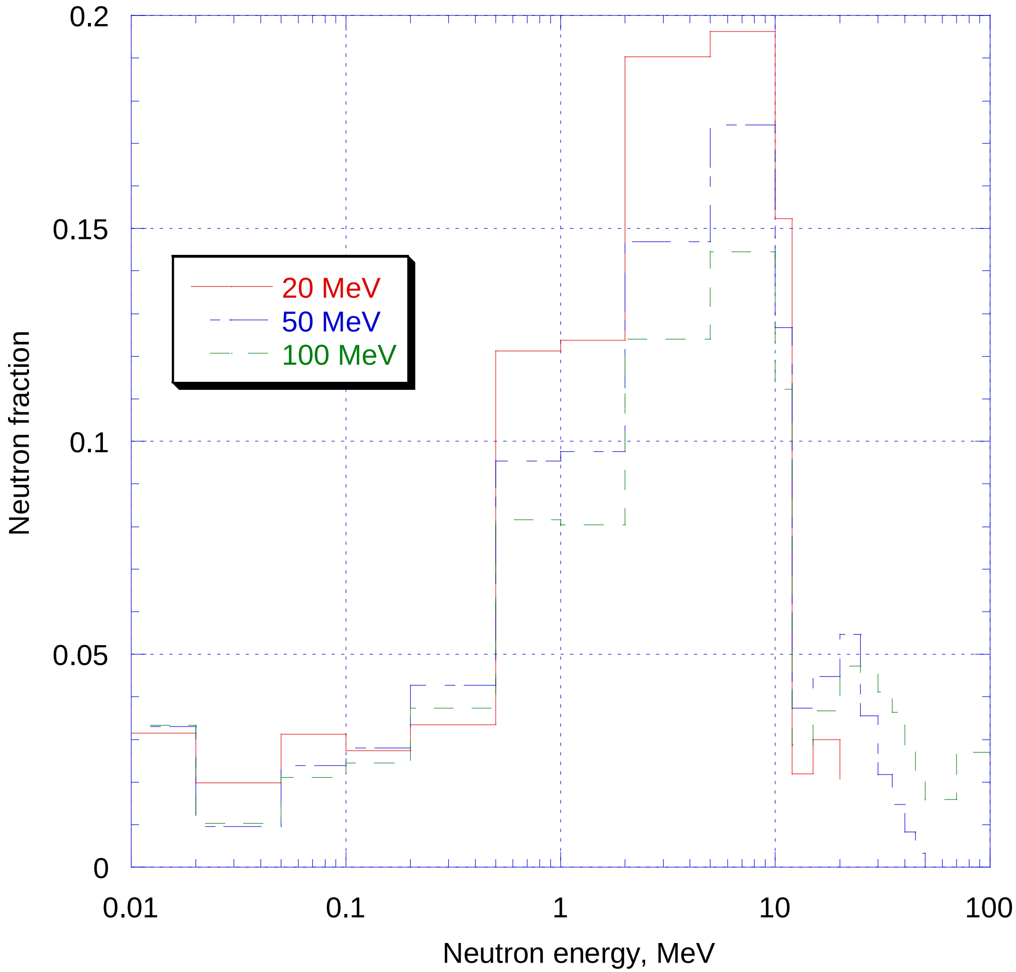


Neutron yields from deuteron interactions with beryllium as a function of the deuteron energy

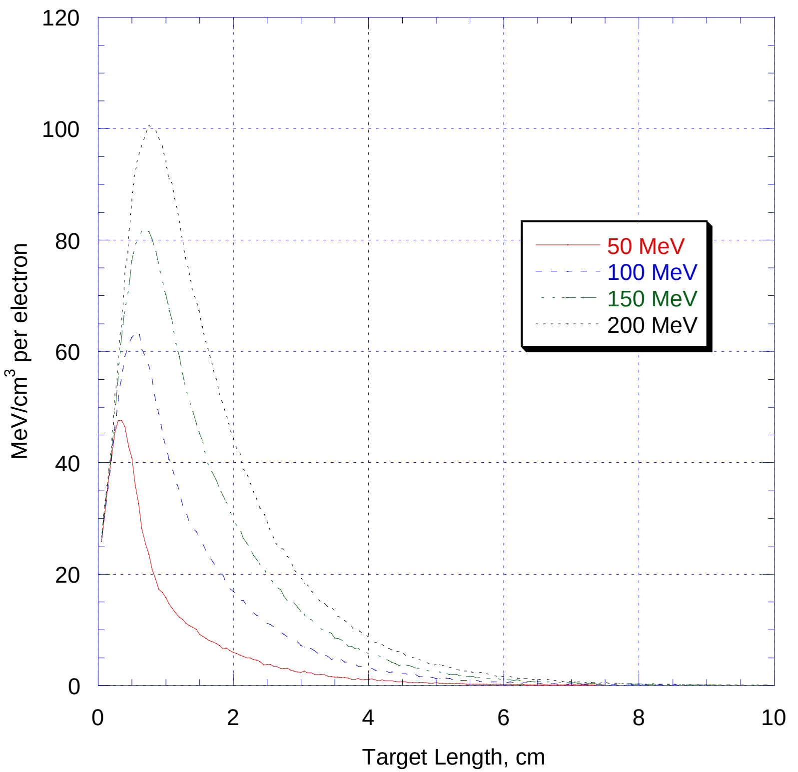


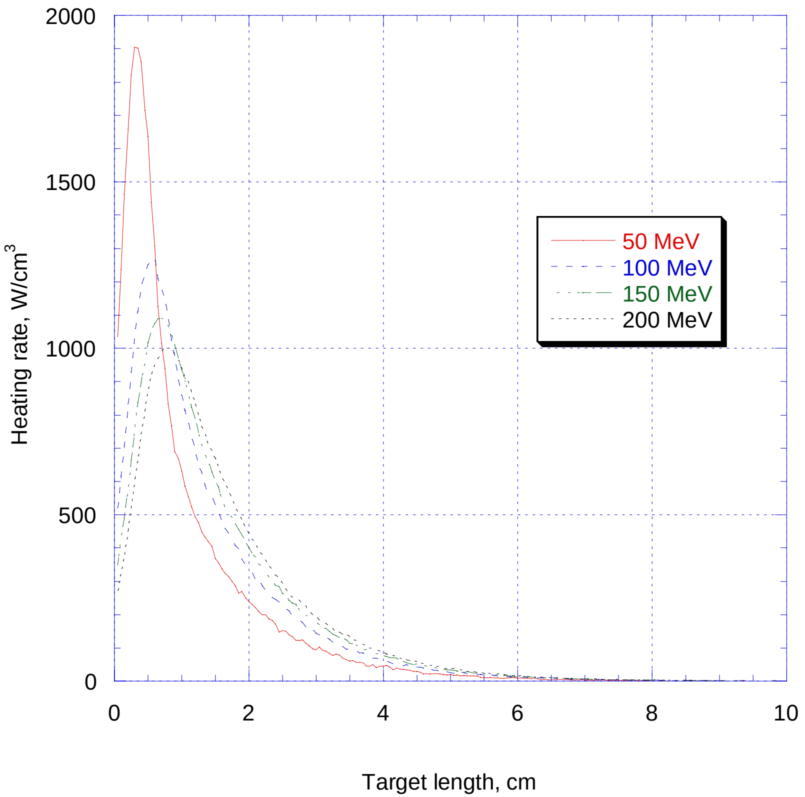
Neutron source intensity from deuteron interactions with beryllium as a function of the deuteron beam energy normalized for 100 KW beam power

Neutron Spectra Generated from Deuteron-Beryllium Interactions for Different Deuteron Energies



Spatial Energy Deposition in the Tungsten Target Material

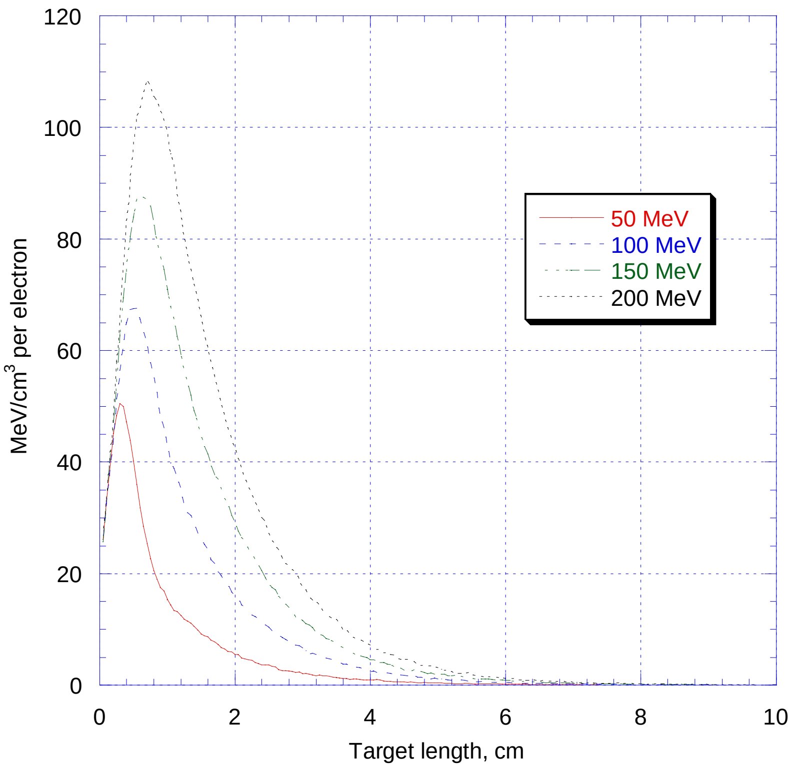




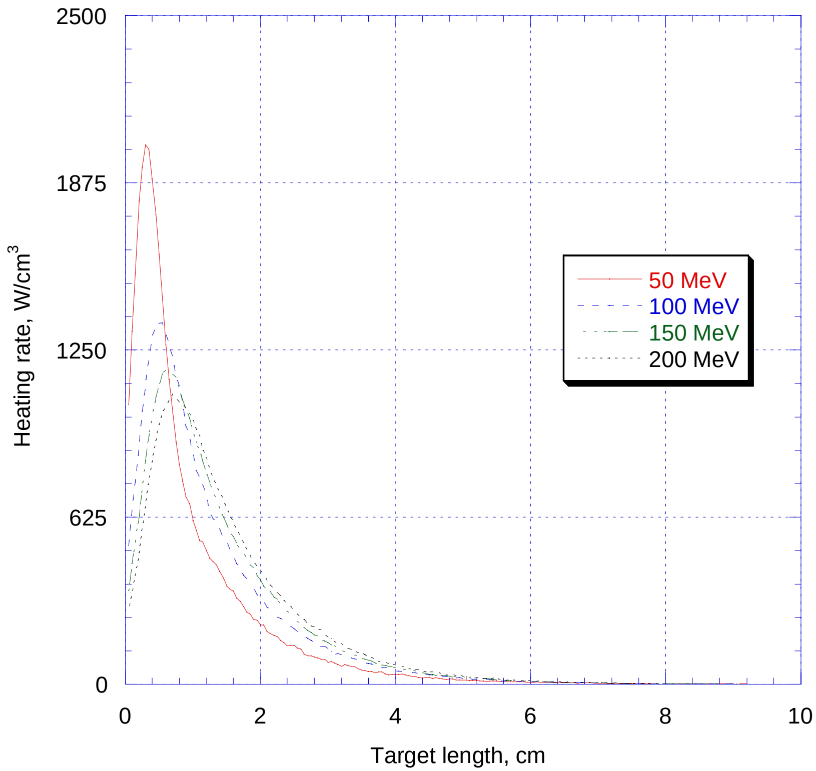
Spatial energy deposition per electron in the tungsten target material for different electron energies

Spatial energy deposition in the tungsten target material normalized to 2 KW/cm^2 on the beam window for different electron energies

Spatial Energy Deposition in the Uranium Target Material

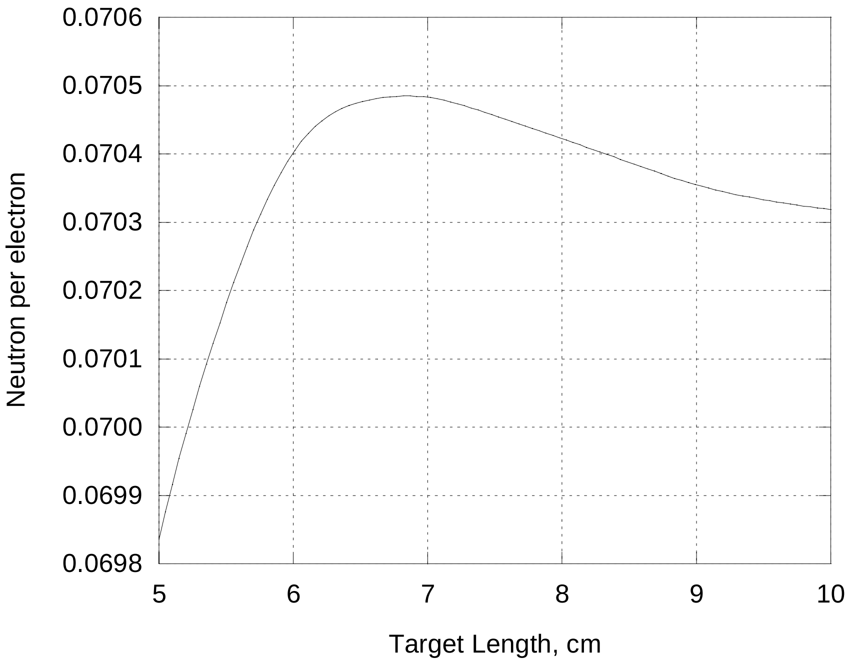


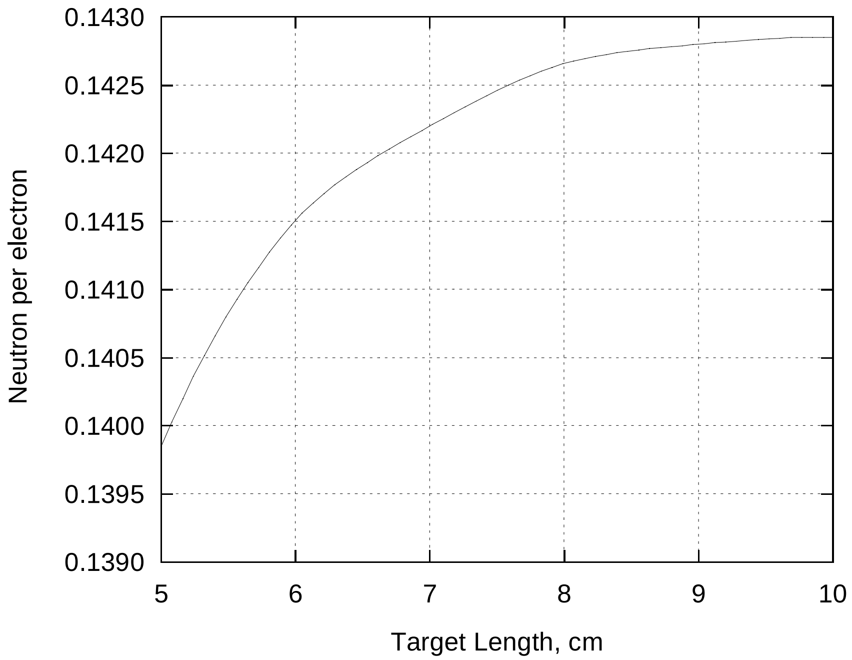
Spatial energy deposition per electron in uranium target material for different electron energies



Spatial energy deposition in uranium target material normalized to 2 KW/cm^2 on the beam window for different electron energies

Neutron Yields as a Function of the Target Length

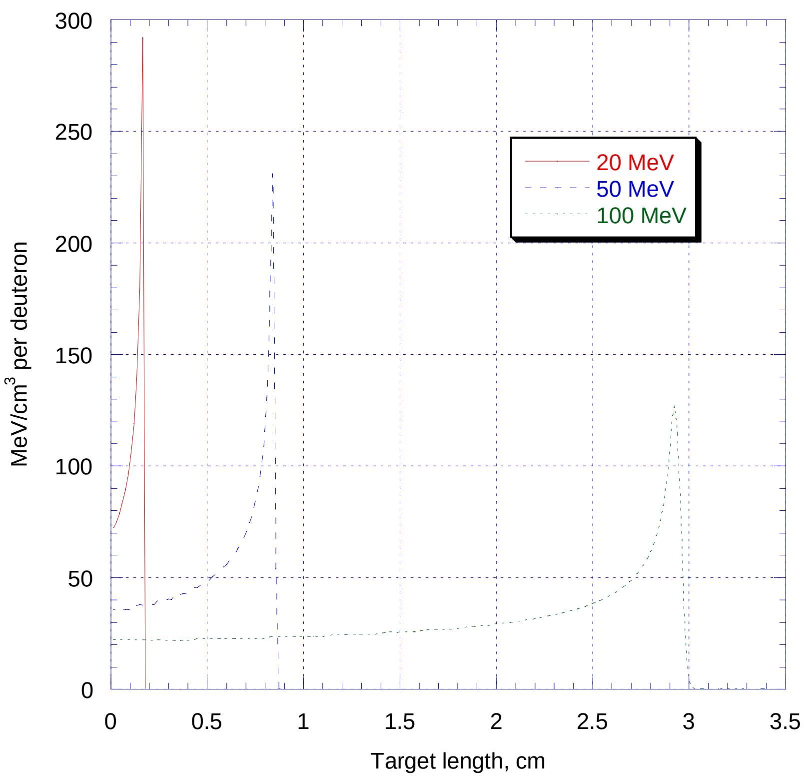




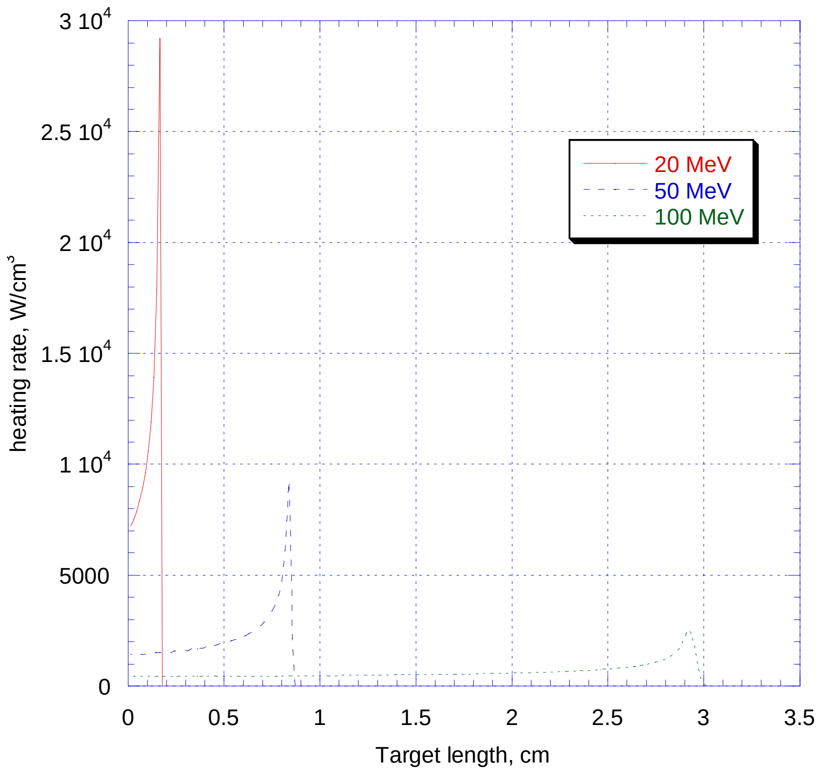
Number of neutrons per electron from pure tungsten material as a function of the target length for the 200 MeV electron energy

Number of neutrons per electron from pure uranium material as a function of the target length for the 200 MeV electron energy

Spatial Energy Deposition in the Beryllium Target Material

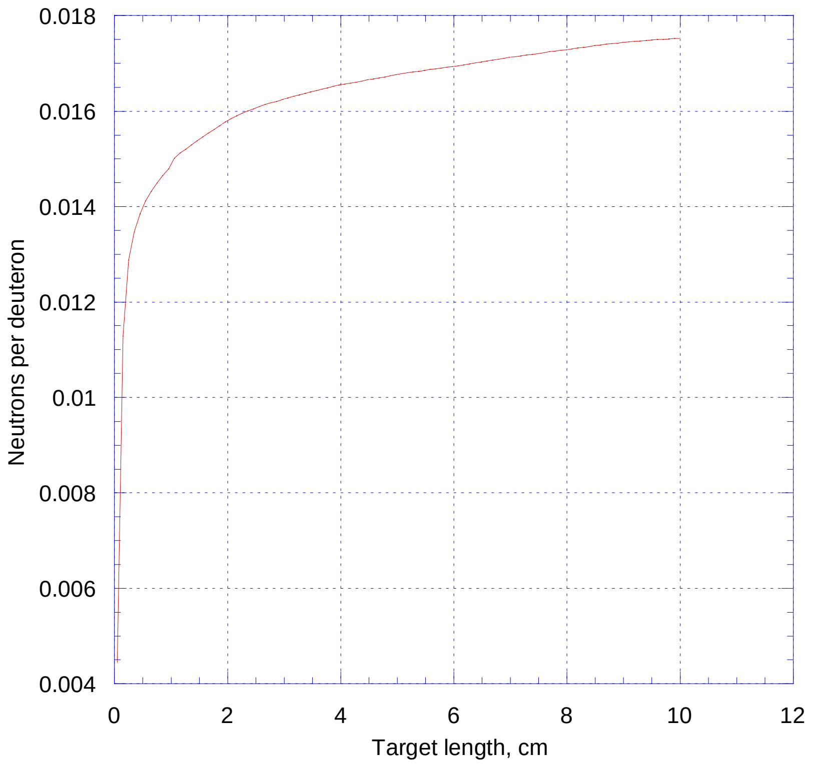


Spatial energy deposition per deuteron in pure beryllium target material for different deuteron energies

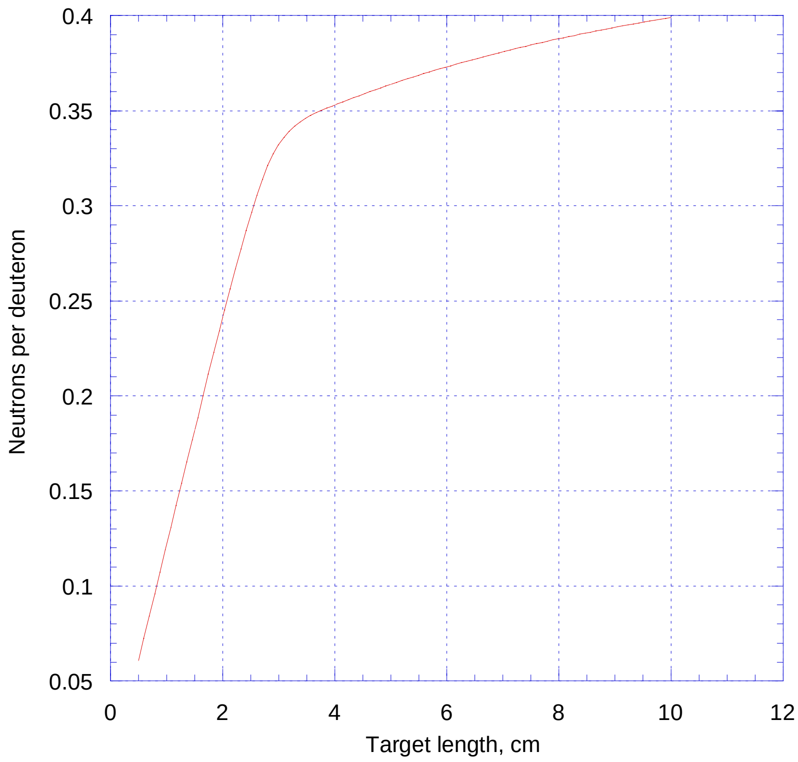


Spatial energy deposition in pure beryllium target material for different deuteron energies normalized to 2 KW/cm^2 on the beam window

Neutron Yields as a Function of the Target Length



Neutron yield as a function of pure beryllium target length from 23 MeV deuteron

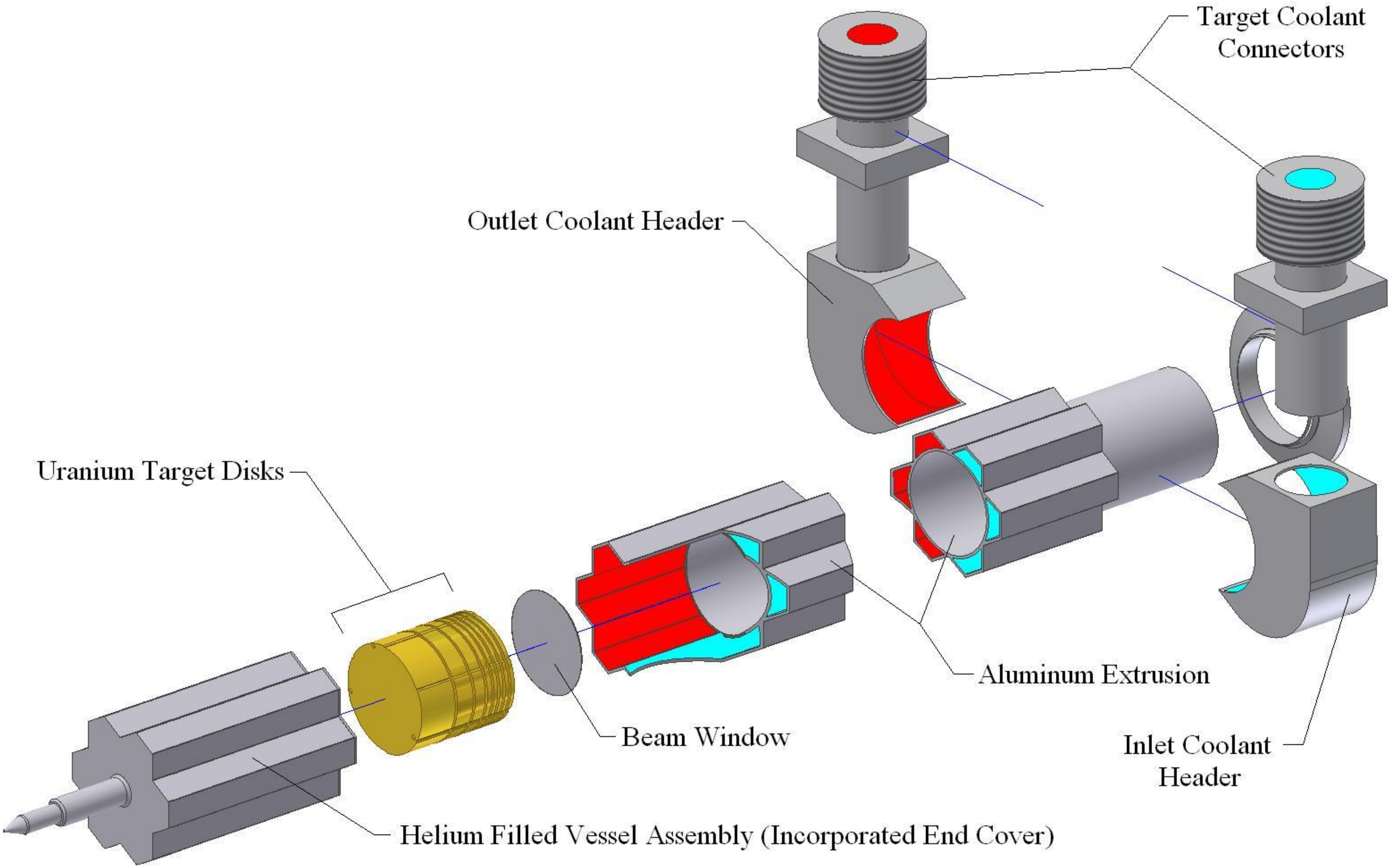


Neutron yield as a function of pure beryllium target length from 100 MeV deuteron

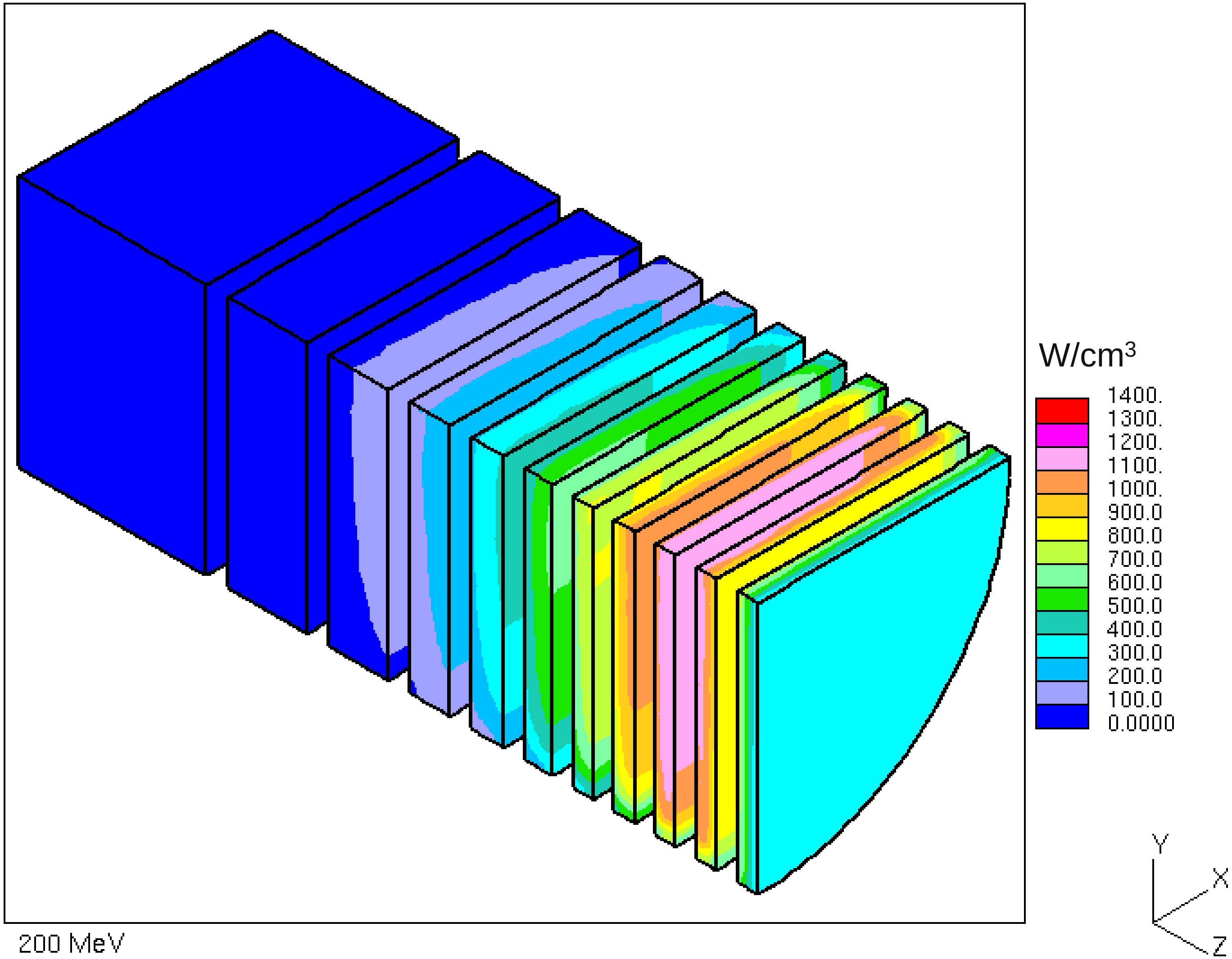
Comparison of different options for producing neutron source

Target Concept	Beam Power, KW	Particle Energy, MeV	Beam Current, mA	Neutron Source Strength, n/s
Uranium with Electrons	100	200	0.5	3.28×10^{14}
Tungsten with Electrons	100	200	0.5	1.91×10^{14}
Beryllium with Deuterons	100 100 11.5	100 23 23	1.0 4.35 0.5	1.90×10^{15} 4.03×10^{14} 4.63×10^{13}

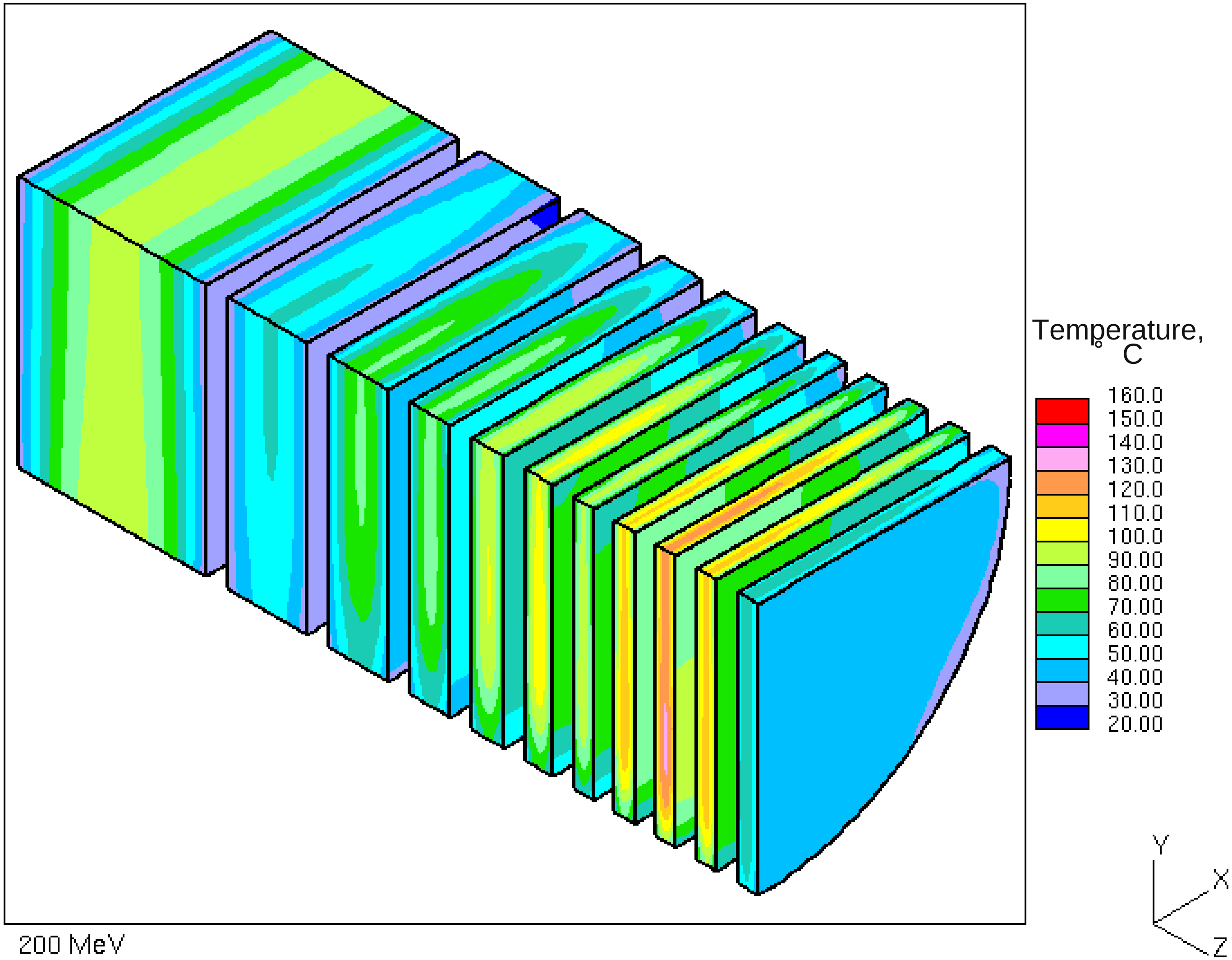
Exploded Assembly View of the Updated Uranium Target Design



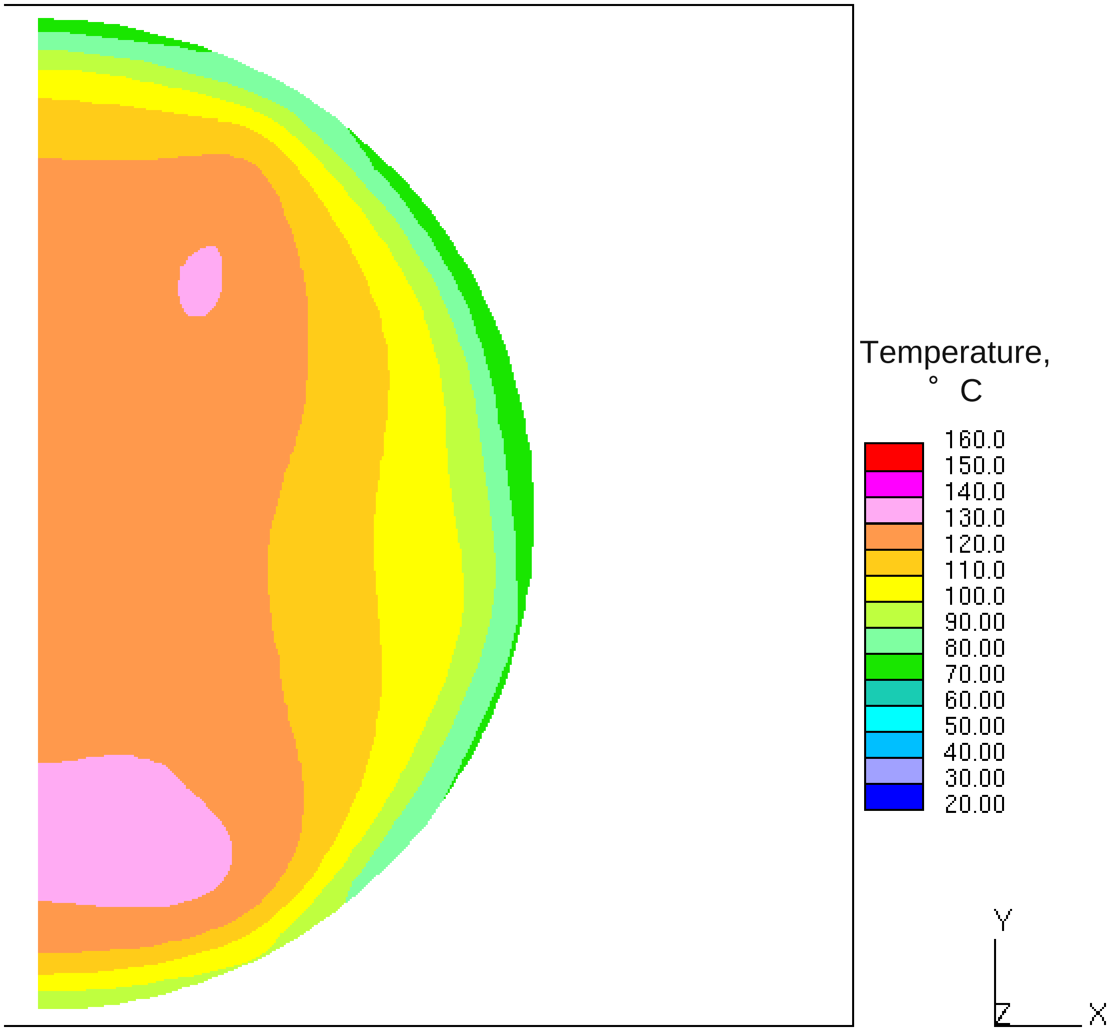
Spatial Energy Deposition Distribution in the Uranium Target Disks



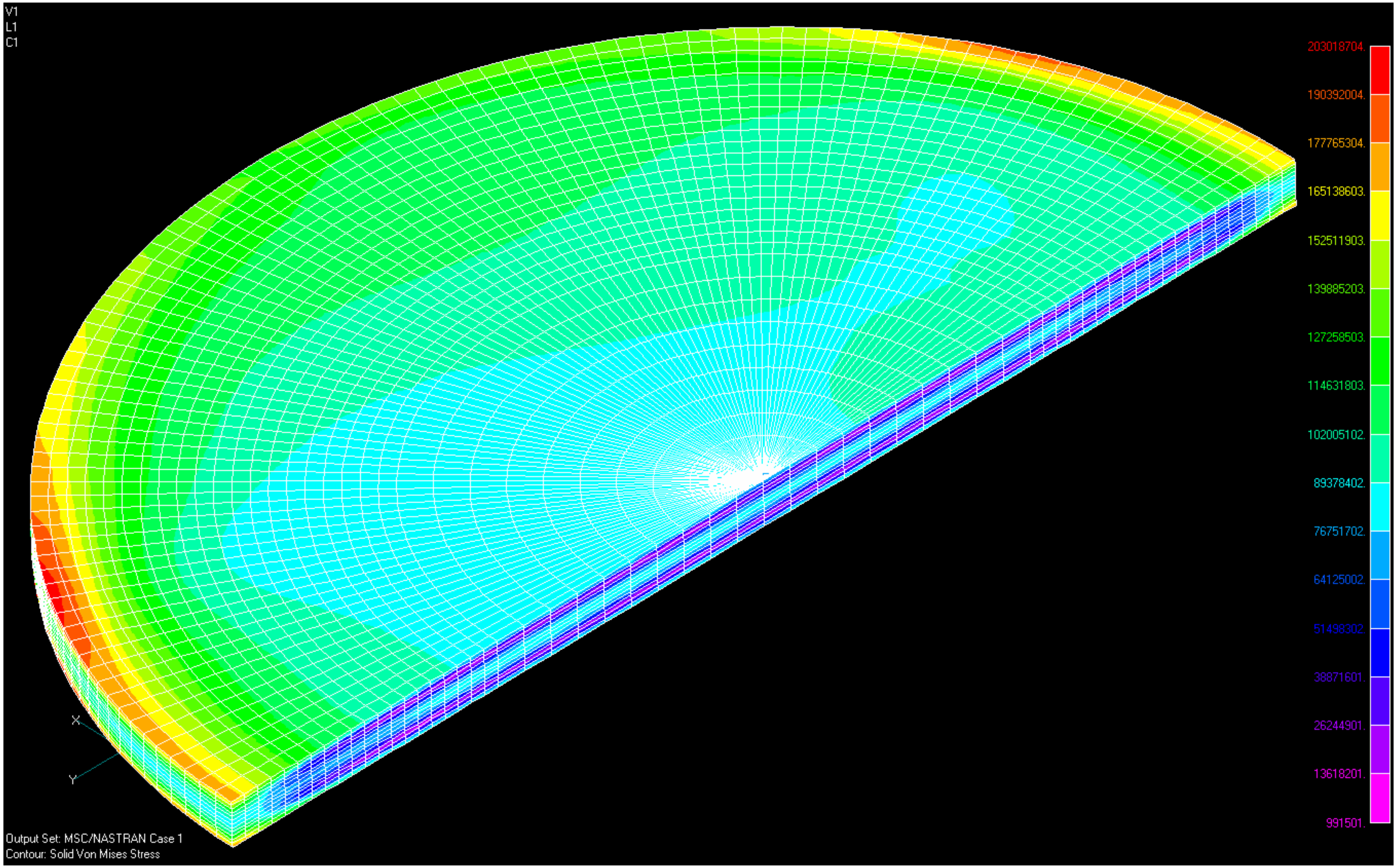
Temperature Distribution in the Uranium Target Disks



Third Disk Midplane Temperature Distribution (The Highest Disk Temperature)



Third Disk Thermal Stress (The Disk with Highest Thermal Stress)



Conclusions

The Comparative analysis of neutron sources produced by low-energy electrons and deuterons show that:

- **An electron accelerator with electron energy in the range of 150 to 200 MeV is preferred for producing neutron source.**
- **The uranium target material produces the highest neutron yield per electron.**
- **The uranium target with 100 KW electron beam produces 3.3×10^{14} n/s.**
- **The thermal hydraulics analyses of the uranium target operating with the 100 KW electron beam power satisfy the engineering design requirements.**
- **The peak thermal stresses (secondary stress) is less than the yield strength of the uranium target material.**