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Design of Target-Moderator-Reflector for a Compact Accelerator-Based Neutron Source for Canada

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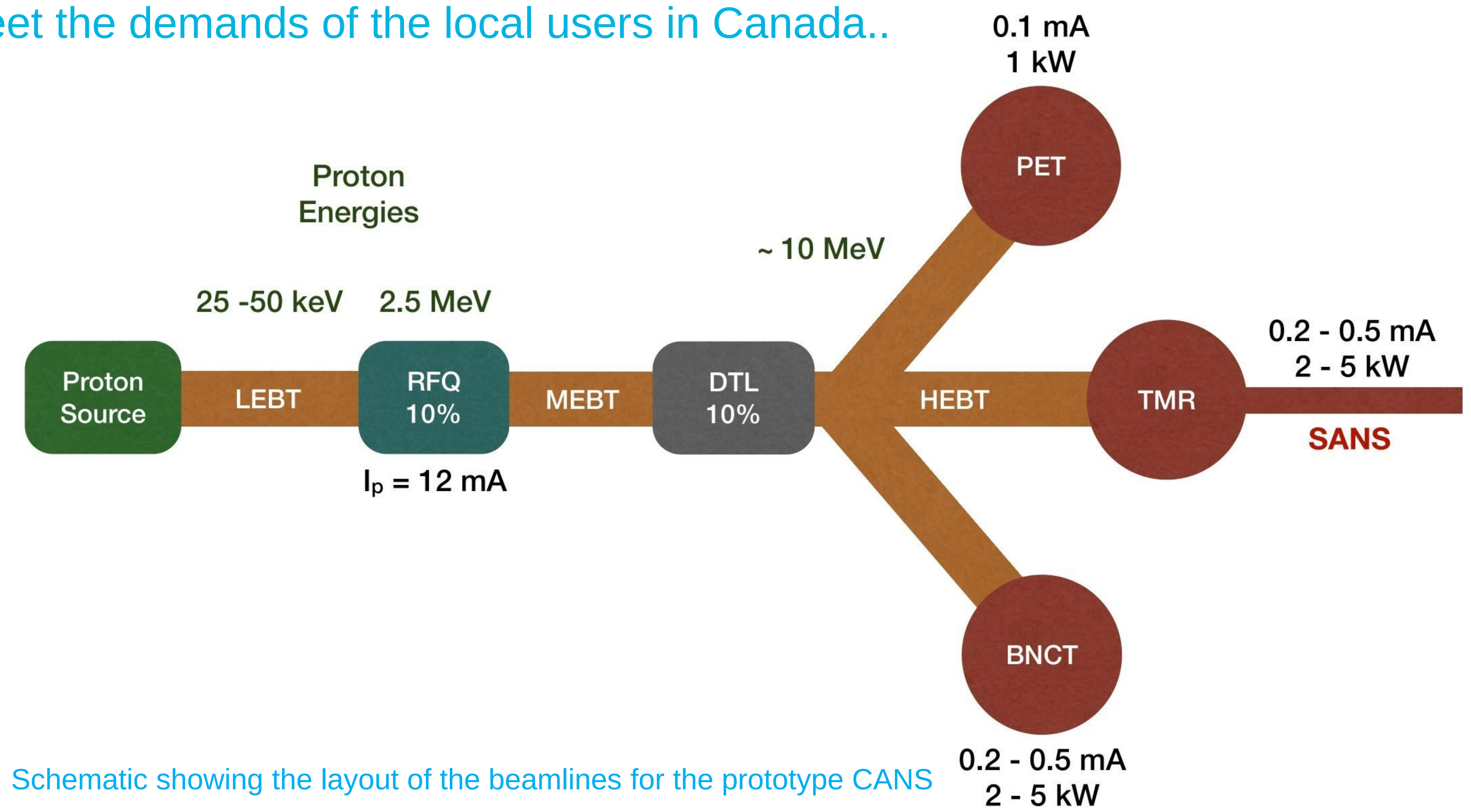
Revitalizing the Neutron Landscape in Canada

Introduction: Canada lost its major source of neutron beams with the closure of the NRU at the end of March 2018. The global neutron supply is under threat as many other major reactors worldwide are scheduled for closure. To address the dwindling supply of neutron beams, an interdisciplinary effort is currently underway to establish a prototype compact accelerator based neutron source meet the demands of the local users in Canada..



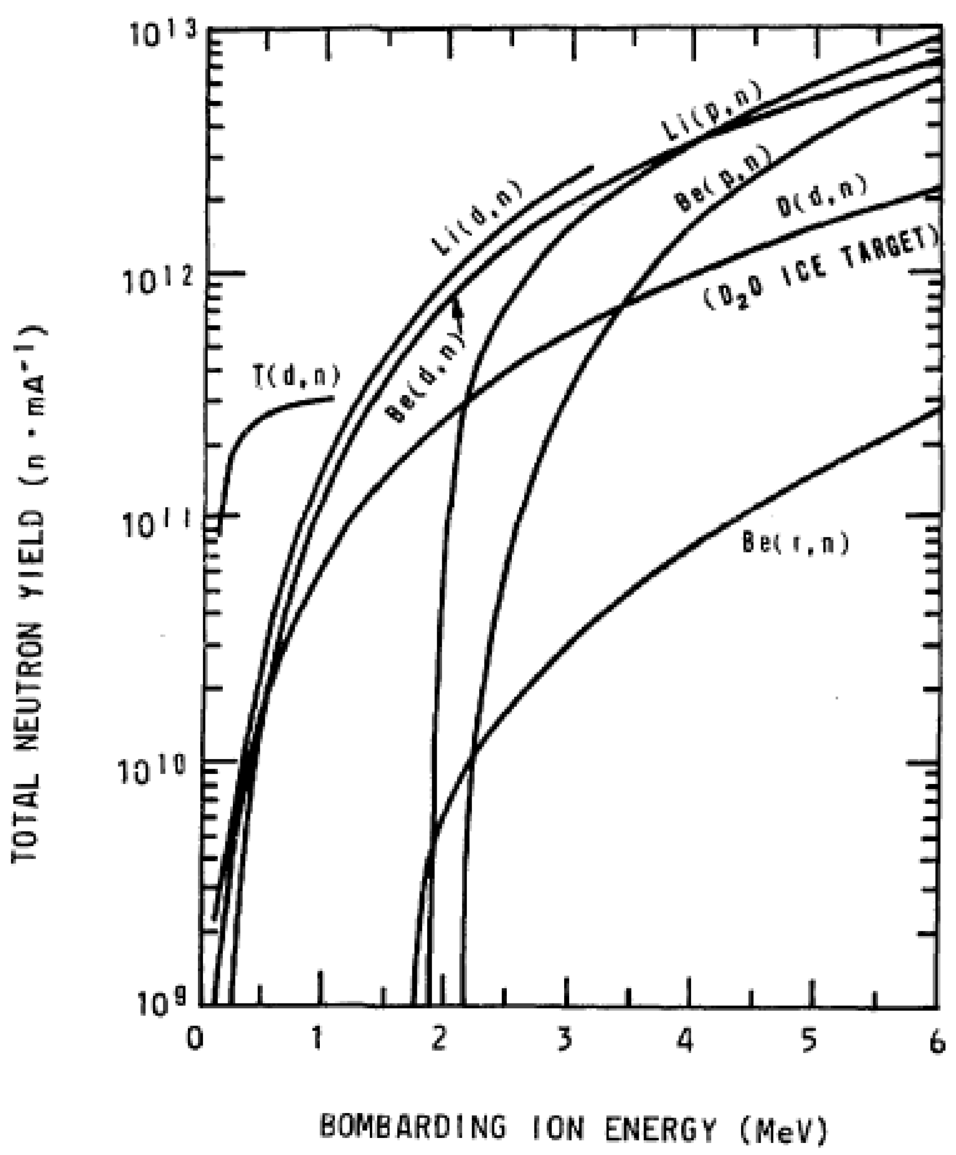
Schematic showing the layout of the beamlines for the prototype CANS

Neutron Production at a CANS

- Relatively inefficient process for neutron production when compared with spallation – 4 neutrons per 10^3 protons and 200 MeV of heat per neutron
- Low levels of induced activity imply that the instruments can be built closer to source
- Less biological shielding is needed therefore CANS is less costly to build

$$^{9}\mathrm{Be} + \mathrm{p} \rightarrow {}^{9}\mathrm{B} + \mathrm{n} - 2.1\,\mathrm{MeV}$$

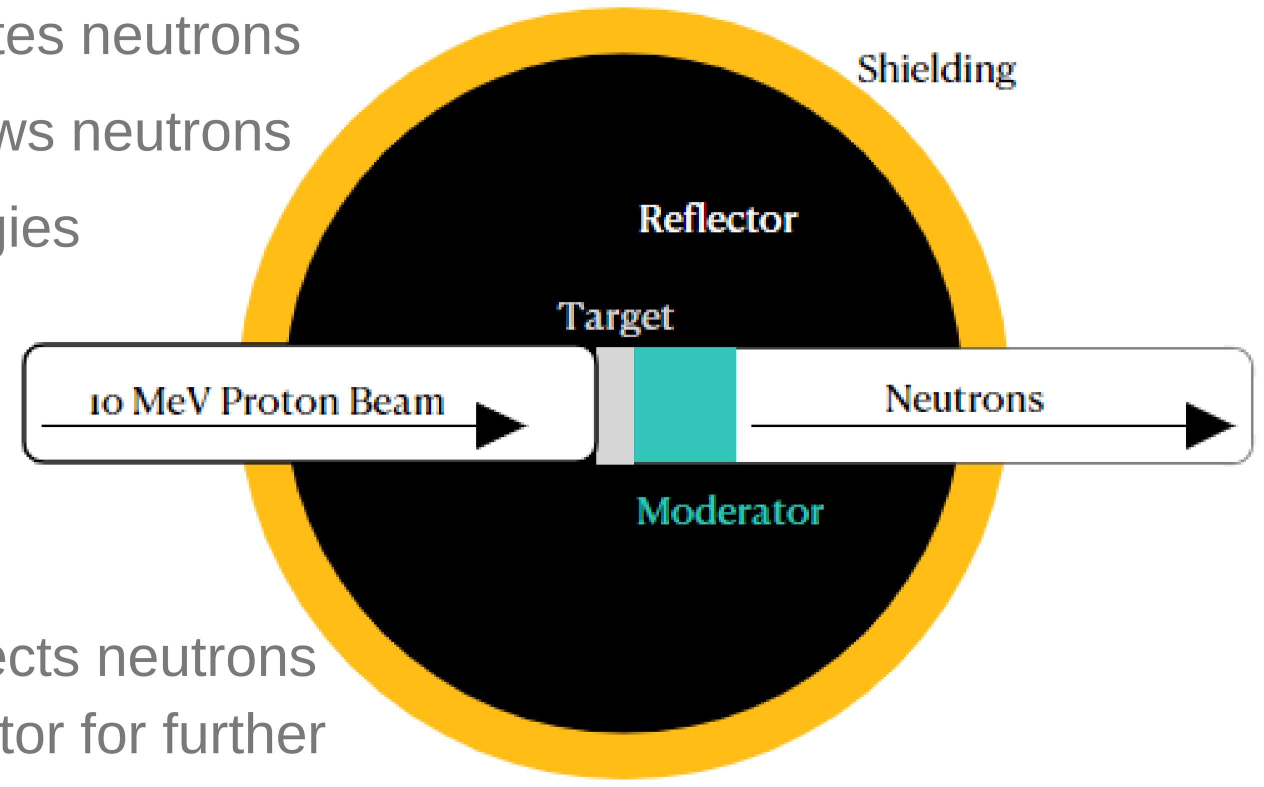
$$^{7}\mathrm{Li} + \mathrm{p} \rightarrow {}^{7}\mathrm{Be} + \mathrm{n} - 1.9\,\mathrm{MeV}$$



Schematic showing neutron yield curves for beryllium and lithium. Figure reproduced from ***Lone et al AECL-7413***.

Key Components for Neutron Production at a CANS

- Target – generates neutrons
- Moderator – slows neutrons to desired energies
- Reflector – reflects neutrons back to moderator for further moderation



Simplified schematic showing a target-moderator-reflector arrangement.

Performance Requirements for Planned Beamlines

Application	P_{avg} (kW)	P_{pk} (kW)	Beamline Requirements	Desired Neutron Spectrum
Neutrons for Science	2	40	4 x 10^7 n/cm²/mA	Cold (< 127 meV)
BNCT	2	40	1 x 10^9 n/cm²/s^{-1}	Epithermal 0.5 eV to 10 keV
F-18 Production	1	20	Maximize proton energy	N/A

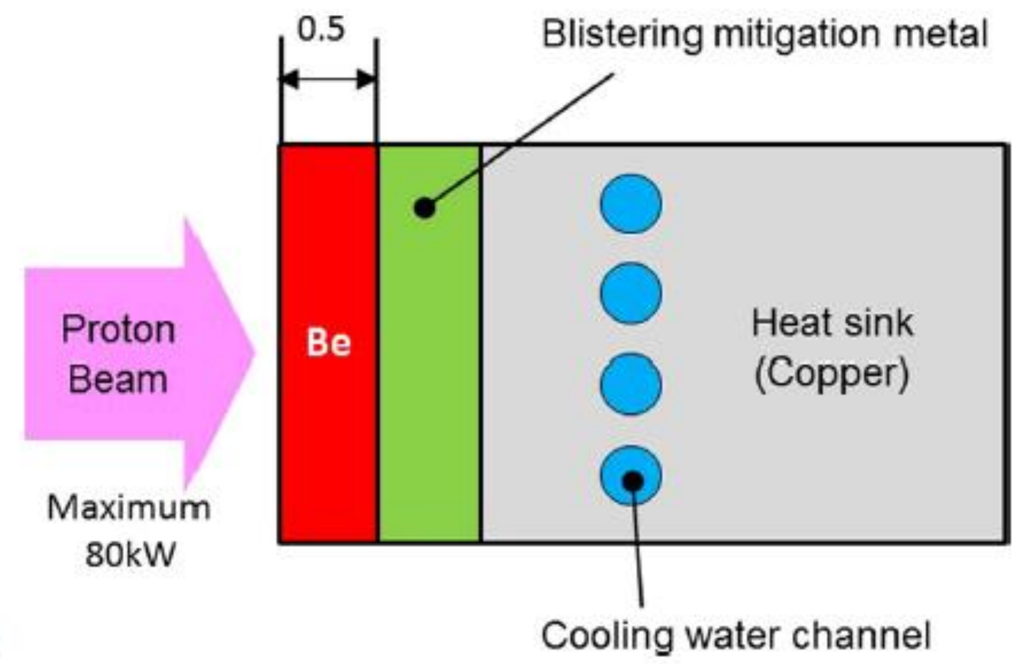
Optimization of Target-Moderator-Reflector

- **Target** – beryllium possesses higher melting point, (1287 °C) higher thermal conductivity and chemical stability when compared with lithium. Produces no radioactive by-product below 13.4MeV.
- **Moderator**
  - Cold neutrons – mesitylene, polyethylene, methane
  - Epithermal neutrons – Fluental™, CaF_2, LiF_2 and MgF_2
- **Reflector** – lead, graphite, light water, beryllium

Major Target Design Challenges

- Management of power density and thermal cycling on target
- Prevention of hydrogen formation and blistering of beryllium

Triple-Layer Target Design



Schematic showing a triple-layer target design. Reproduced from ***Kumada et al App. Radiat. Isot.106 (2015) 78–83***.

- Blister mitigation materials – palladium, vanadium, niobium, tantalum, aluminum, copper
- Explore sputtering and electroplating for bonding layers
- Perform ANSYS simulations to determine efficacy of designs in managing heat load on target
- Perform test using TR13 cyclotron to determine lifetime of target

Summary

Fluka is being utilized to test different target-moderator-reflector geometries to optimize the neutron yield for the different end uses being planned for the CANS at the University of Windsor. Key challenges which need to be addressed are heat management and blistering of the target.

Discovery, accelerated