Quenching Factor Experiments at Queen's

6th NEWS-G Collaboration Meeting in Grenoble

Wednesday June 12th, 2019

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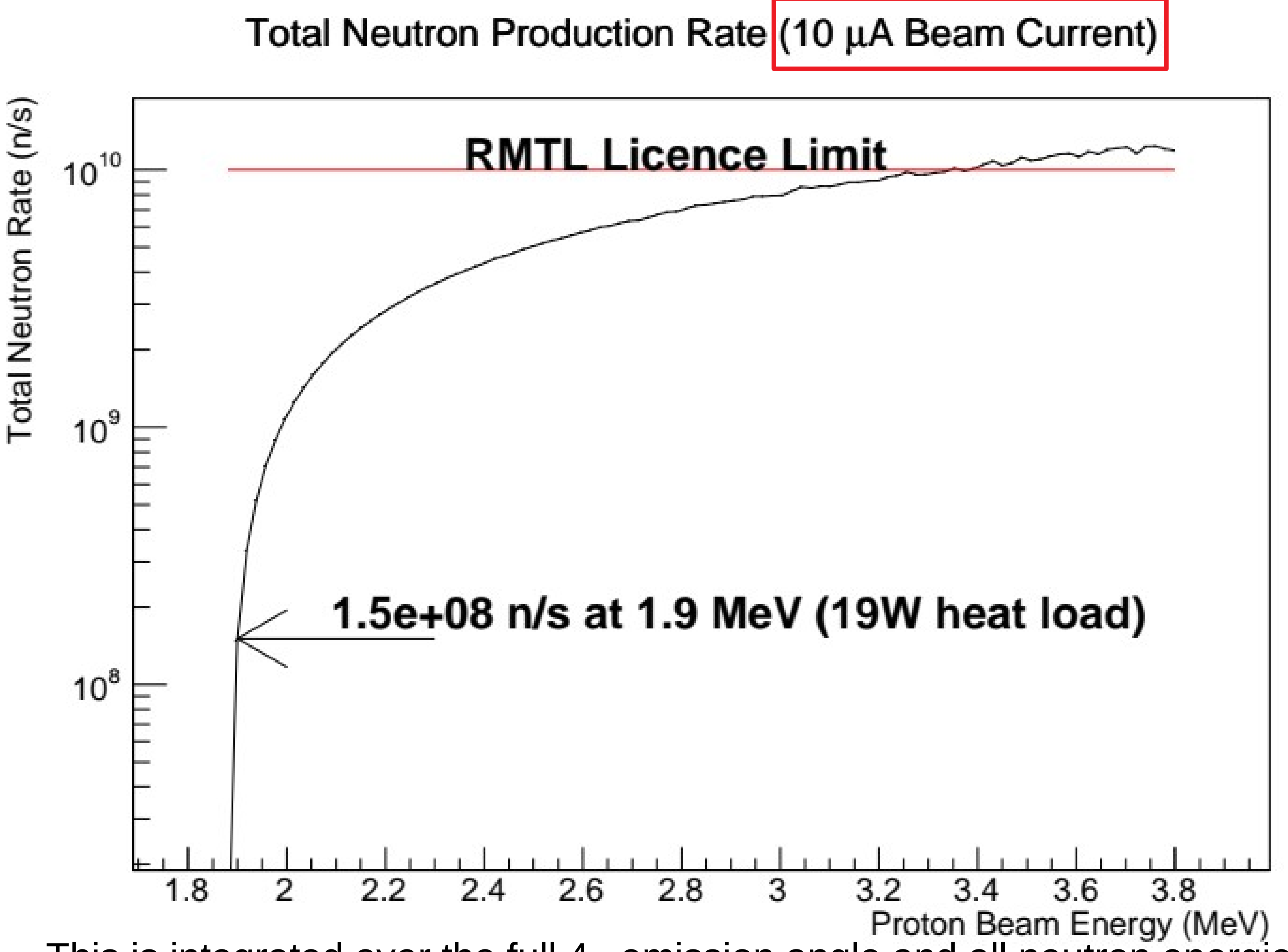
RMTL Proton Beam

- The Reactor Materials Testing Laboratory normally tests materials and devices for radiation damage.
- RMTL has a 1-8 MeV proton beam.
- The precision & stability of accelerator voltage are 0.1% and 100 ppm.
  - 4 keV steps in principle at 2 MeV
  - 100 eV energy spread in principle at 2 MeV
- The beam profile is *not* monitored.
- High beam current of 0.05~45 μA: limiting factor is likely heat load on target!
- If we hit a nuclear target with the beam, we get neutrons to do quenching factor experiments!

Nuclear Targets

- We have a 1μm LiF target on tantalum backing, from Université de Montréal.
- Neutron production threshold is 1880.57 keV.
- Our target is “semi-thick”: protons lose non-negligible energy in the target.
- Neutrons produced at threshold have 29.68 keV.
- Above threshold, neutrons at a specific emission angle are monochromatic.
- The neutron production rate drops precipitously near threshold => high beam current helps.



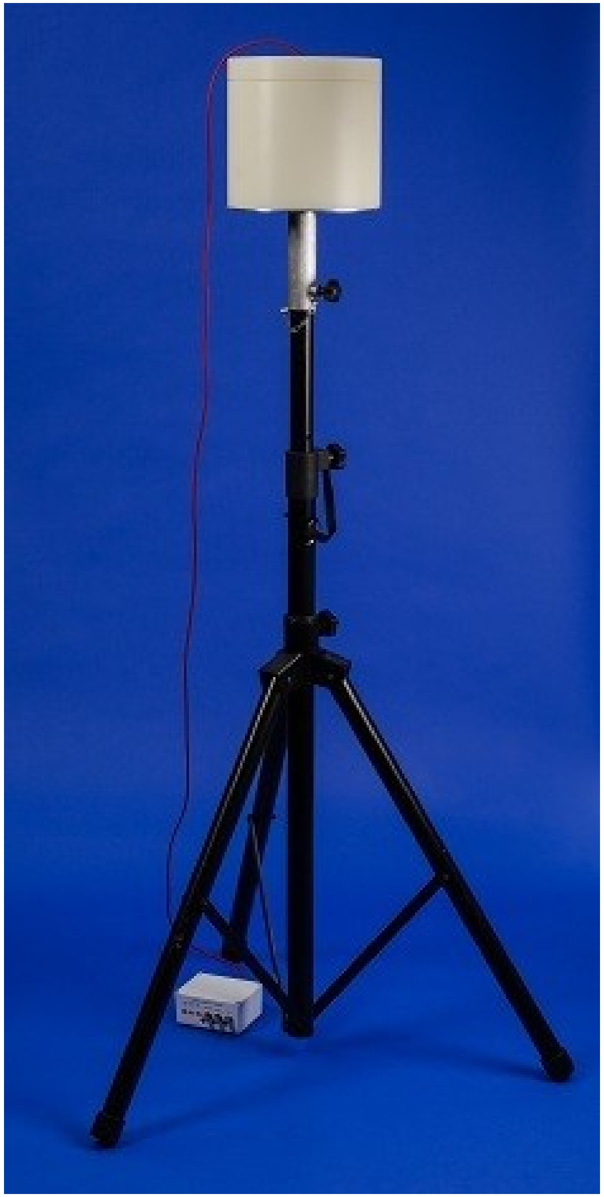
This is integrated over the full 4π emission angle and all neutron energies, for a **monochromatic beam**, with a **thick target**.

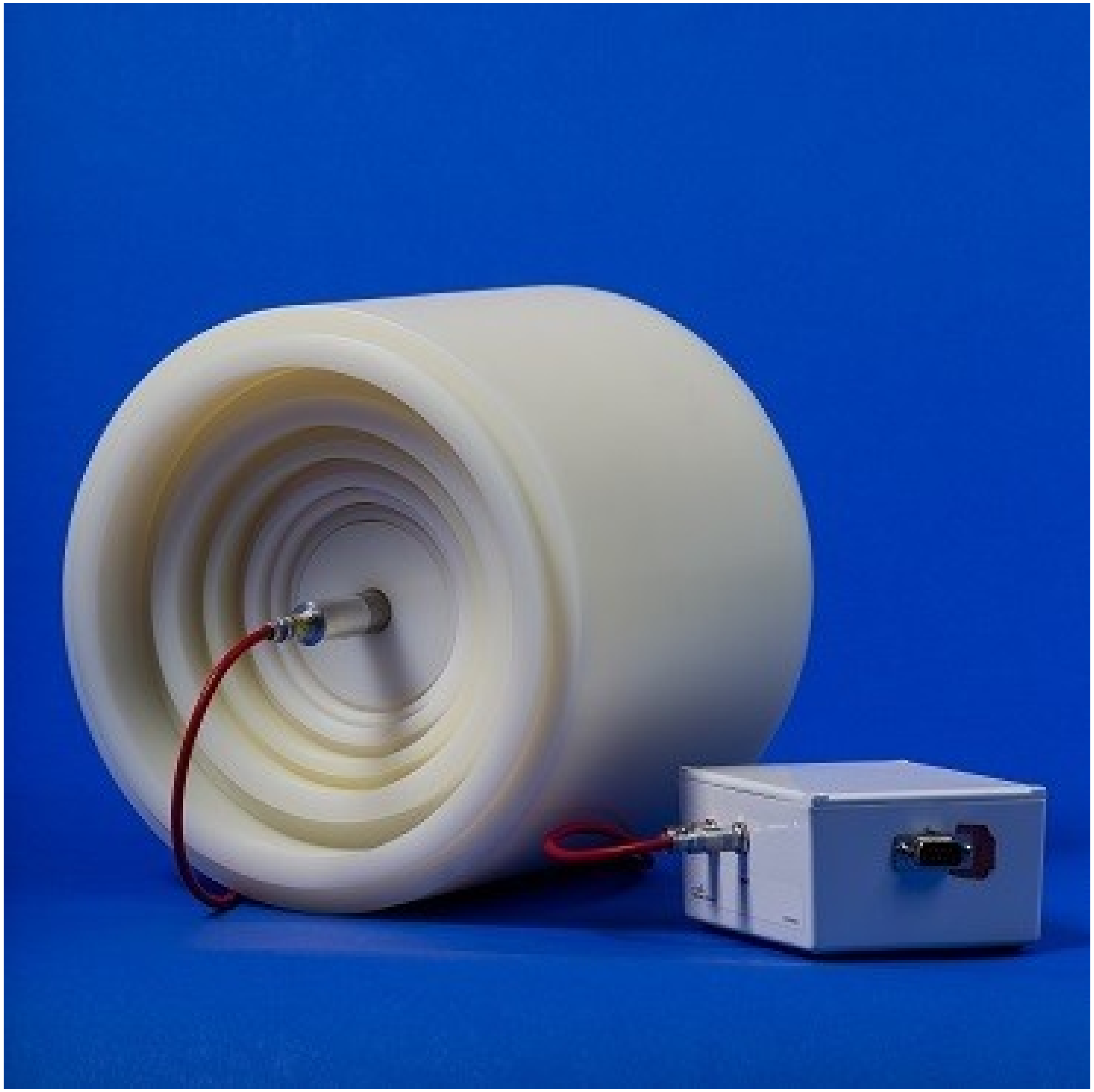
A larger beam current helps us get closer to threshold while maintaining a usable neutron rate. The heat load on the target is a limiting factor.

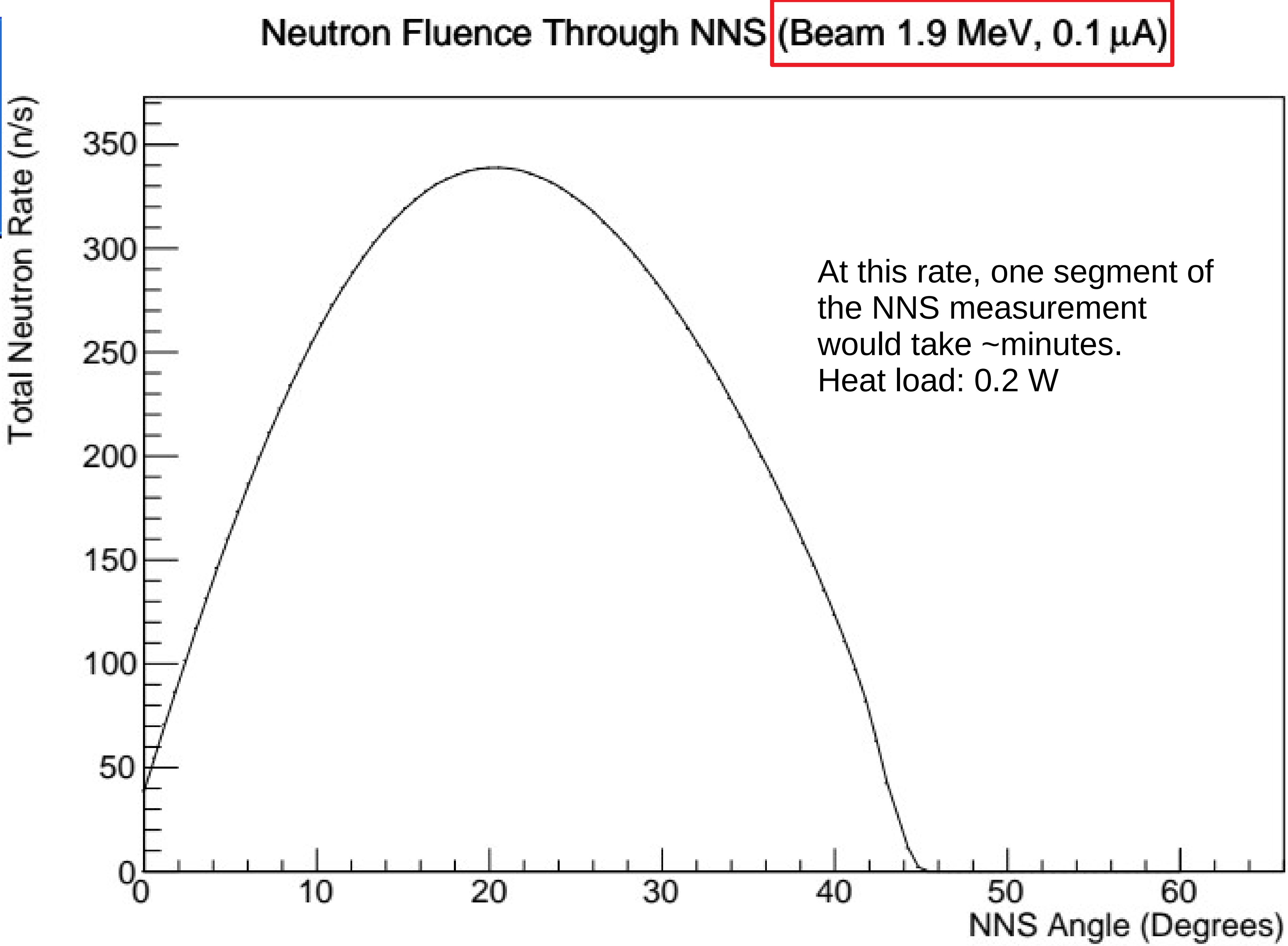
Neutron Detection

- RMTL has a “Nested Neutron Spectromer” (NNS).
- It detects neutrons with 7 layers of moderator to get a spectrum. The response deconvolution returns energies in 52 logarithmically-spaced bins.
- The NNS active region measures 15x25 mm^2 (0.006% solid angle at 1m).
- 10^4 counts per layer are required for a spectrum.
- This is a slow detector, not suitable for coincidence for QF experiments!
- Liquid scintillator used for previous QF experiments are less efficient at ~30 keV.

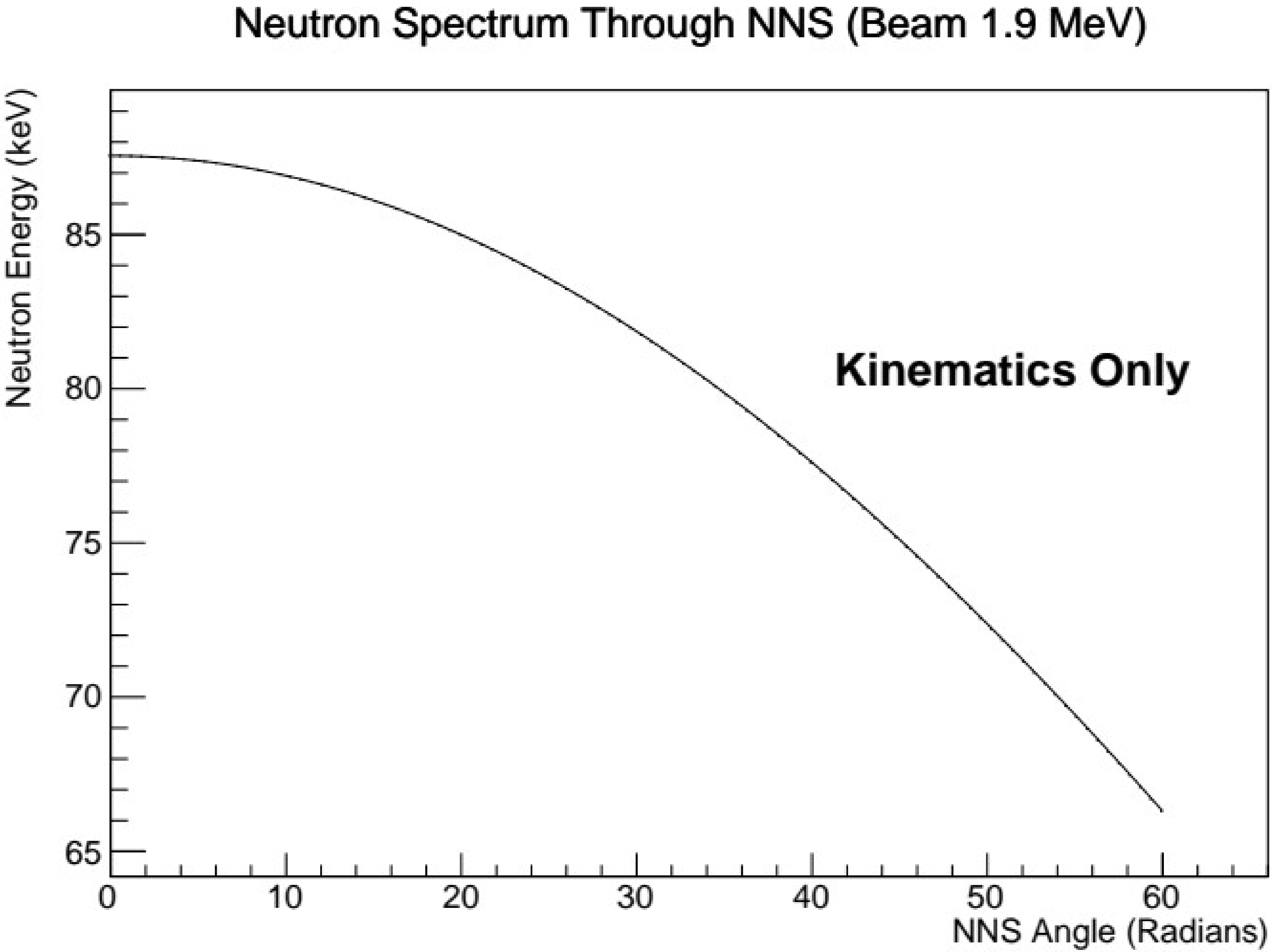
Nested Neutron Spectrometer







The rate and spectrum depends on the angle from the proton beam axis. At low proton energies, the neutrons are only emitted forwards.



At the maximum emission angle (20°), the neutron energy is ~85 keV.

Nuclear Targets II

- Al can be used to characterize the proton beam.
- Gamma resonance at 1799.75 keV.
- With a thin (few keV) target, the width will be dominated by the proton beam energy spread.
- Al is isotopically pure, target can be cheap.
- A copper substrate will not make neutrons.
- We will need to buy or borrow a γ-detector.
- Vanadium is another target material that has neutron resonances near the energies we want.
- Local spinoff can make targets: NanoFabrication Kingston — People. Ideas. Technologies.

Considerations

- Passive target cooling:
  - There is less material to block neutrons.
  - The heat load will severely limit the maximum sustainable beam current, which is the main strength of RMTL.
  - We can maybe use the target backing material as vacuum flange for better cooling through the air.
- Active cooling:
  - Allows us to run at higher current.
  - The coolant will moderate neutrons, broadening their energy spectrum.
  - The equipment will be more complex and less portable.

Considerations II

- Experiment rooms:
  - These are heavily shielded and can likely handle the maximum beam current.
  - They are shared with other RMTL users (*i.e.*, our equipment must be portable).
  - The rooms are small, which means the neutrons may bounce off the walls, requiring additional interior shielding.
- Accelerator hall:
  - There are two currently unused beam lines, so our setup can be made permanent.
  - The large hall means neutron that reflection is less significant.
  - It is less well-shielded than the experiment rooms, so possibly we cannot run at maximum current there.

Immediate Goals

- To determine the proton beam width and profile, and the impact of slits at ion source.
- To confirm the neutron production threshold, rate and energy-dependence on proton beam energy.
- To confirm the angular dependence.
- To gain experience with the LiF target, especially with heat tolerance.
- Ultimately, to deliver a neutron beam at ~30±10 keV.

We are recruiting!

For more information contact Prof. Levente Balogh at levente.balogh@queensu.ca

- PhD student: background/interest in experimental particle physics, detector instrumentation and data evaluation.
- MSc student: background/interest in engineering design of structural components needed to set up the beam line, the proton target holder, and neutron shielding.