DAMSA at PIP-II Beam Dump

- Strategy for Neutron Background Mitigation -

Workshop for Physics Opportunities at Beam Dump Facility in PIP-II and Beyond
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Fermi National Accelerator Laboratory

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Overview

- DAMSA Experiment
- Neutron Background Study
  - Beam Dump and Neutron Moderator
    (Presenter: Wooyoung Jang)
  - Background Mitigation Strategies at Vacuum Chamber
    (Presenter: Jacob Bogenschuetz)

DAMSA Experiment

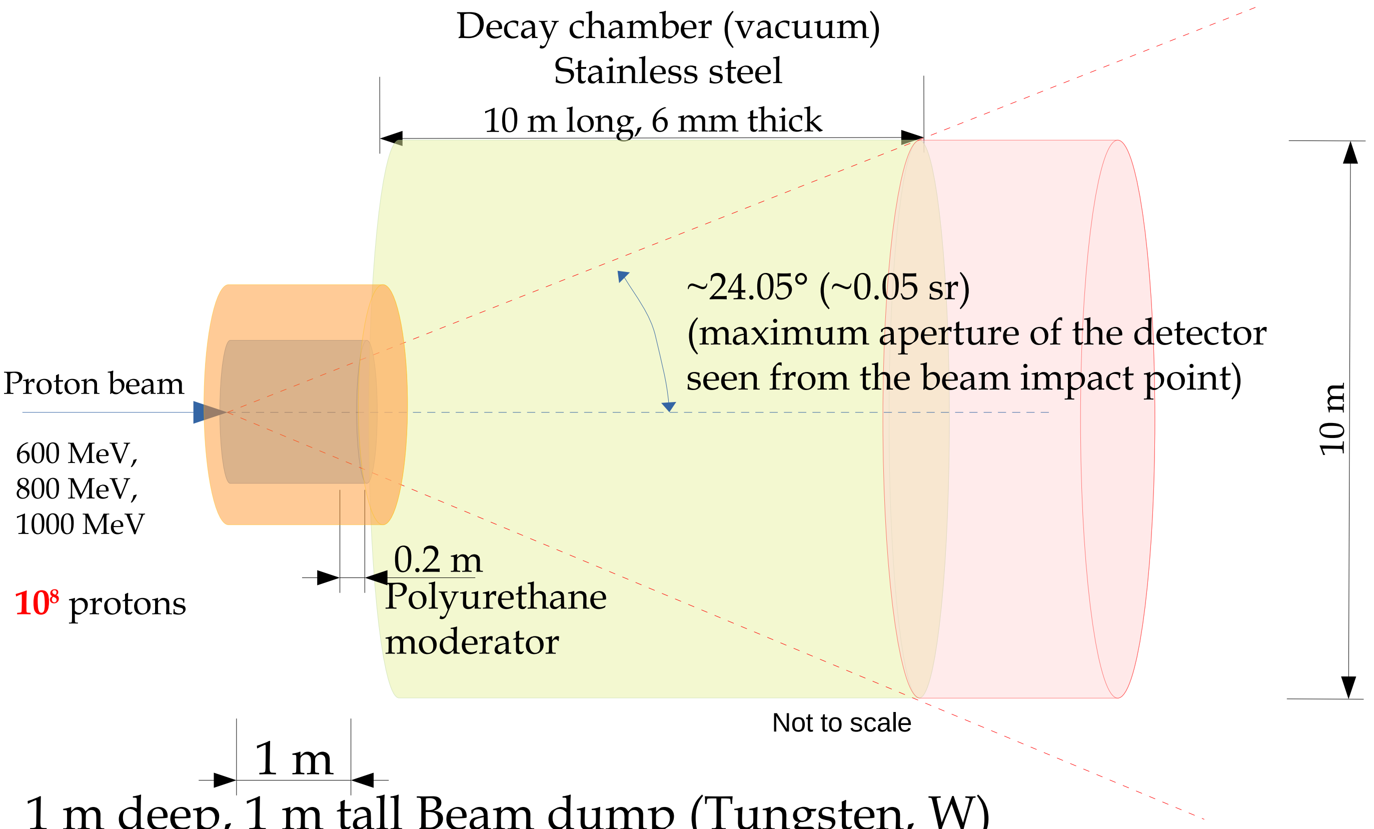
- DAMSA is an experiment that takes advantage of **proximity** of BSM source (beam dump, or target) to the detector.
- A group of people have been studying this concept from few years ago and first result of the study assumed 600 MeV proton beam was published this year.

[Jang et al., PRD 107, L031901 (2023)]

- Requirements for DAMSA :
  - Locate the detector as close as possible to the dump.
  - **Sub-GeV beam energy** (not to create pions)
  - **High-intensity** beam.
- PIP-II with Beam Dump fits **ALL** these requirements.
- One things we need to be extra careful is the **beam-related neutrons**.

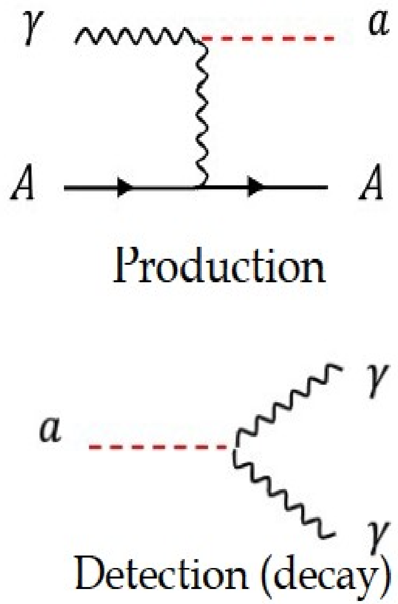
Experimental Layout

- DAMSA = Beam Dump(and moderator) + Decay Chamber + Detector



1 m deep, 1 m tall Beam dump (Tungsten, W)

Physics Goal: ALP



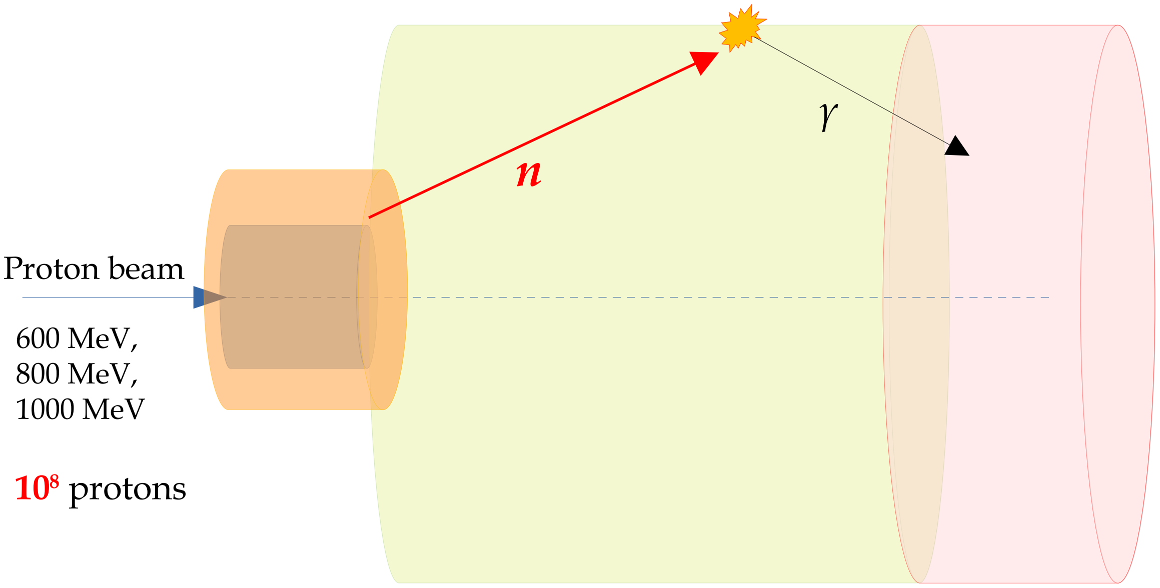
Experimental Layout (cont'd)

- Main concern is beam-induced neutrons that creates photons through interaction with materials in its path:

Proton beam

600 MeV,
800 MeV,
1000 MeV

10^8 protons



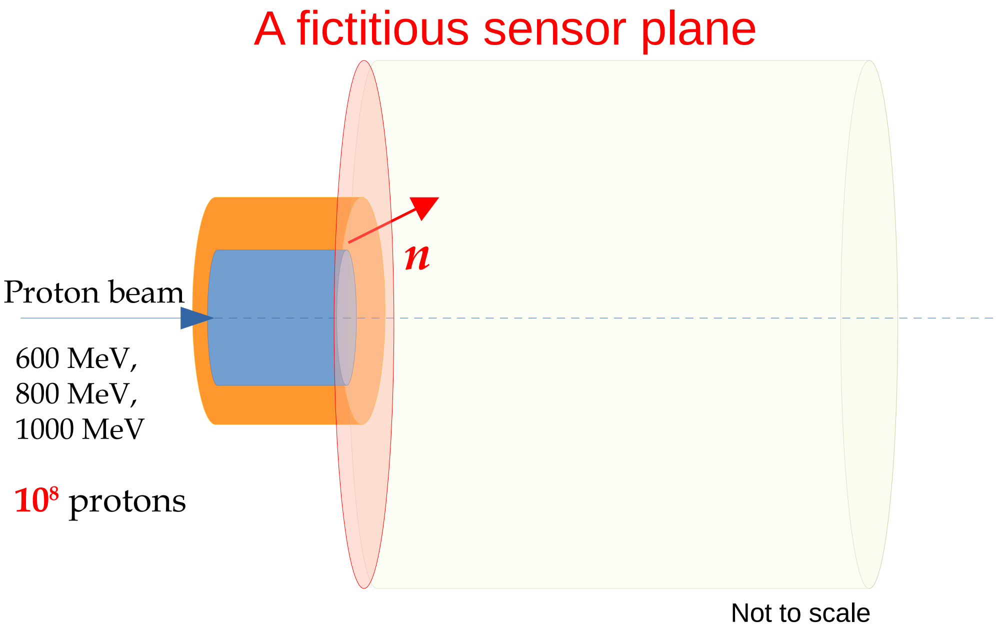
Not to scale

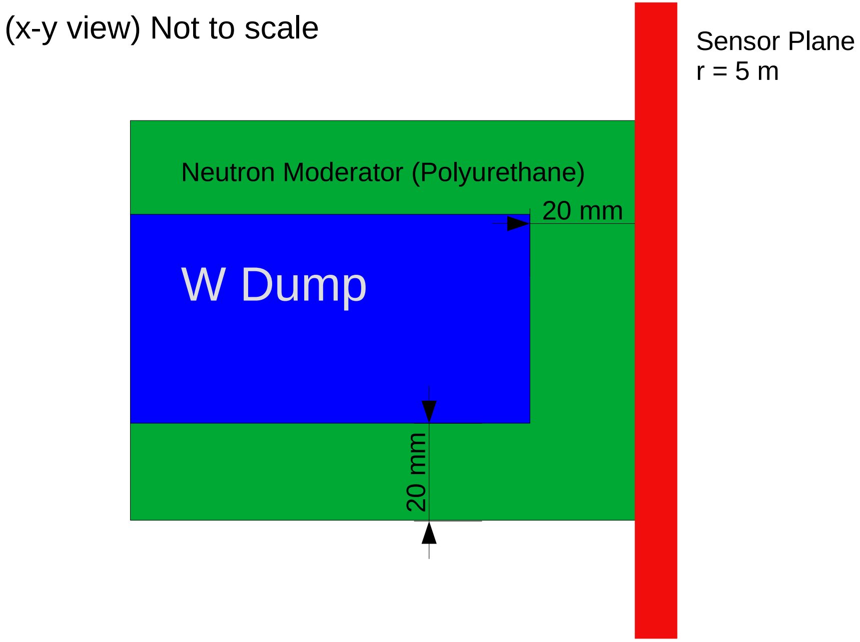
We allow these neutrons to have some spatial and temporal buffer by putting a vacuum decay chamber between the dump and the detector.

After then, by taking advantage of the decay chamber, we collect kinematic information of photons that arrives the detector to distinguish neutron-induced photons from the signals.

Simulation Workflow (1)

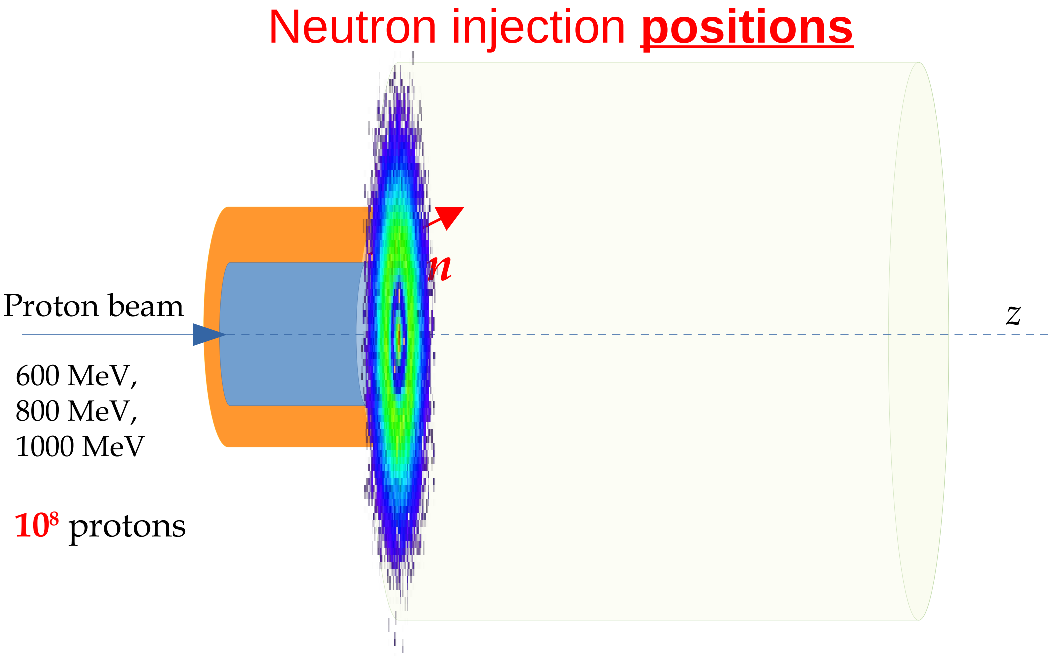
- We implemented multiple stages of Monte Carlo simulations to study the behavior of those beam-related neutrons in the experiment using `Geant4` with `QGSP_BIC_AllHP` physics list.
- First stage of the simulation is to produce neutrons that we're concerning.

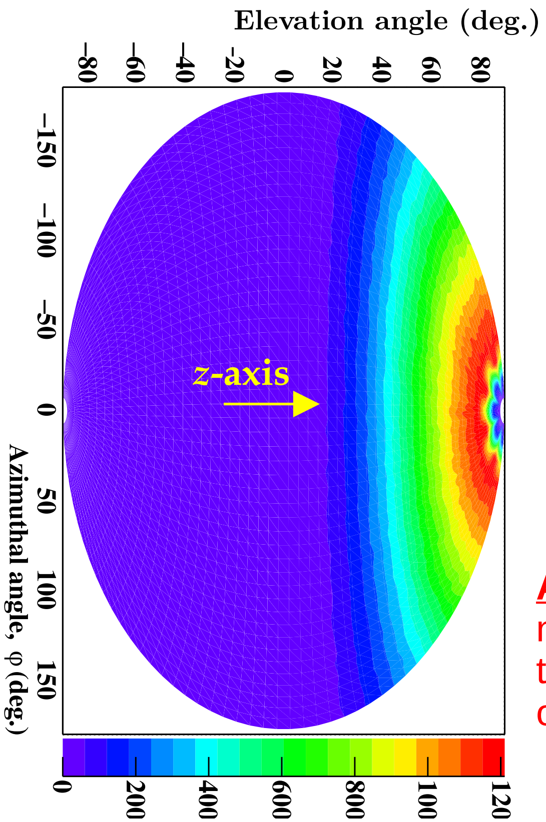




Simulation Workflow (2)

- In the first part of the simulation called ‘`DumpSim`’, we record positions and 4-momentum of neutrons passing this plane.

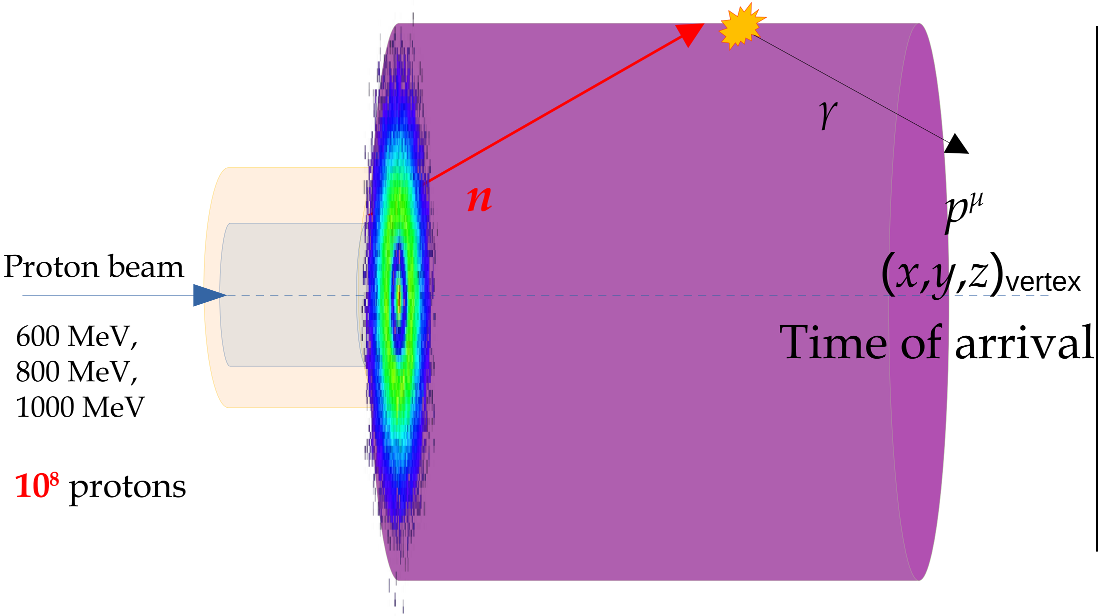


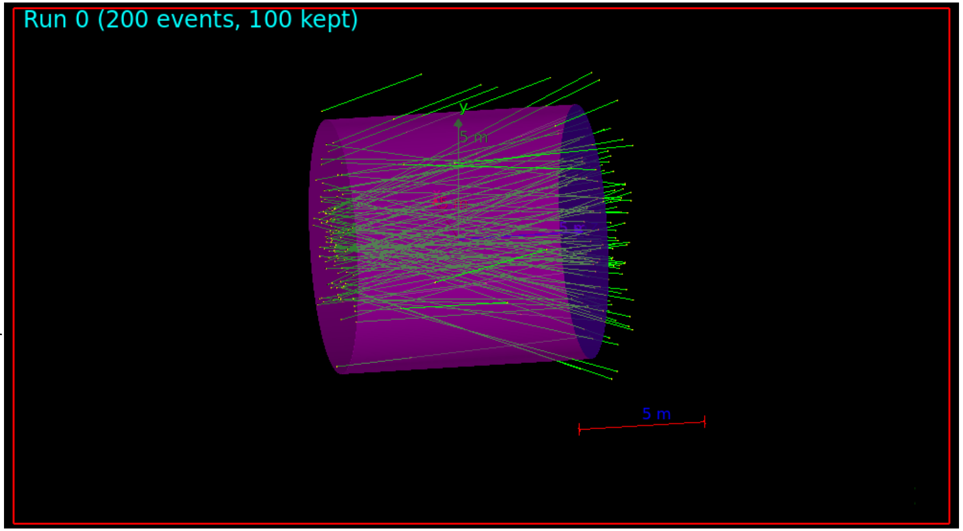


Angular distribution of neutrons that comes into the vacuum chamber on a skymap coordinates.

Simulation Workflow (3)

- For the final stage of the simulation, we use p.d.f.s of incident neutron kinematics to implement neutron random generator at the upstream surface of the decay chamber.
- Then, for the photon that arrives to the detector, we record its 4-momentum, its position, and its time of arrival. Based on this data, we apply some series of cuts against photon pair combinations to select diphoton events and to reject random photons. (Jacob will discuss details of it)



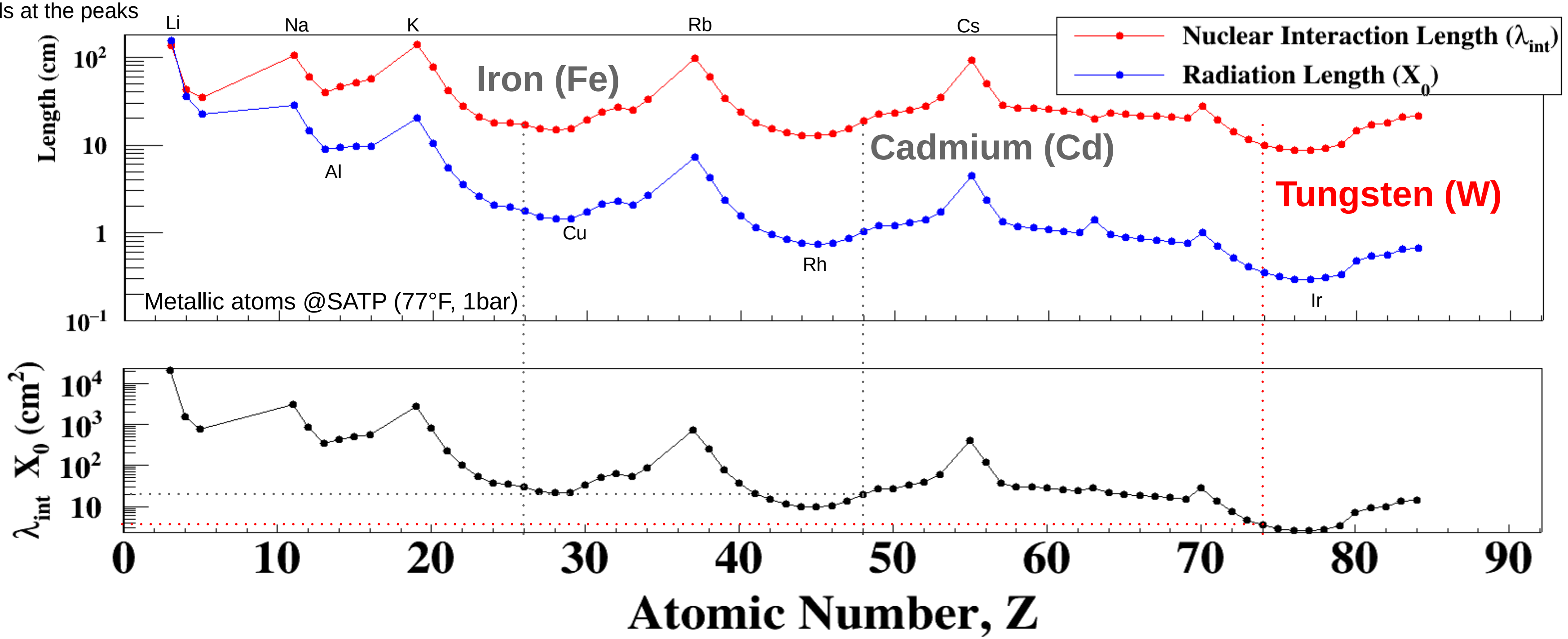


Dump Simulation
- Neutron Moderator -

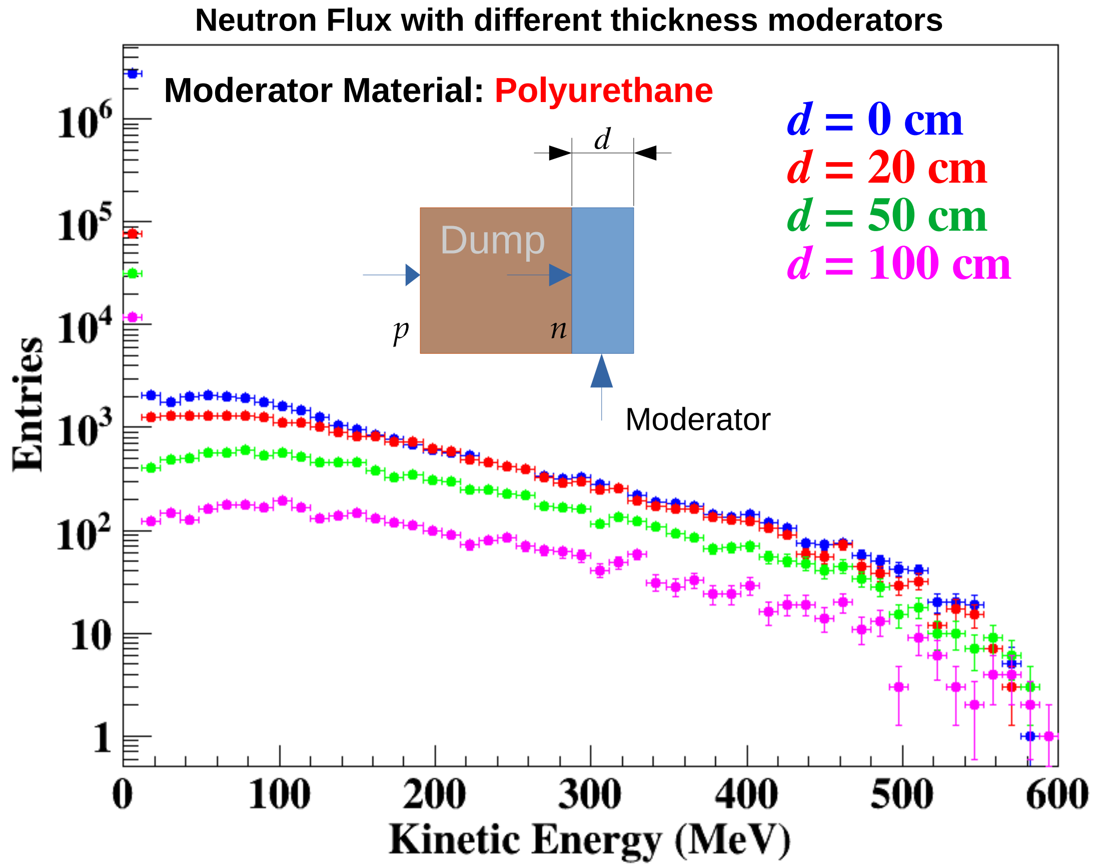
Dump Material

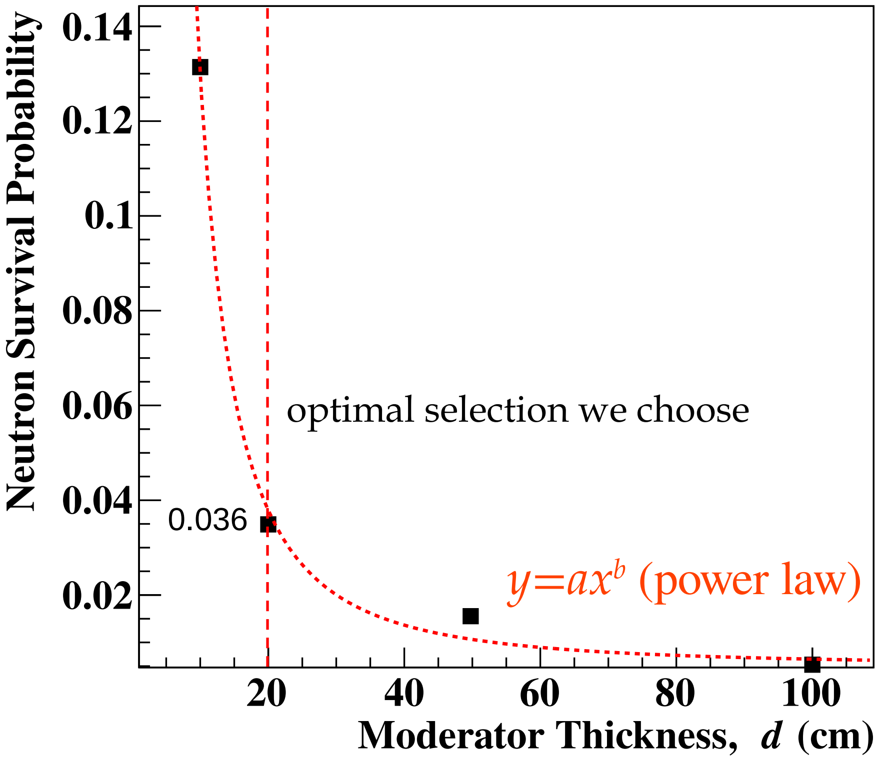
- **Short radiation length (X^0)** and thick enough material → **more signals!**
- **Short nuclear interaction length (λ_{int})** with deep enough dump → **less neutrons!**
  - Long nuclear interaction length → lower neutron production? → beam spill

Alkali metals at the peaks

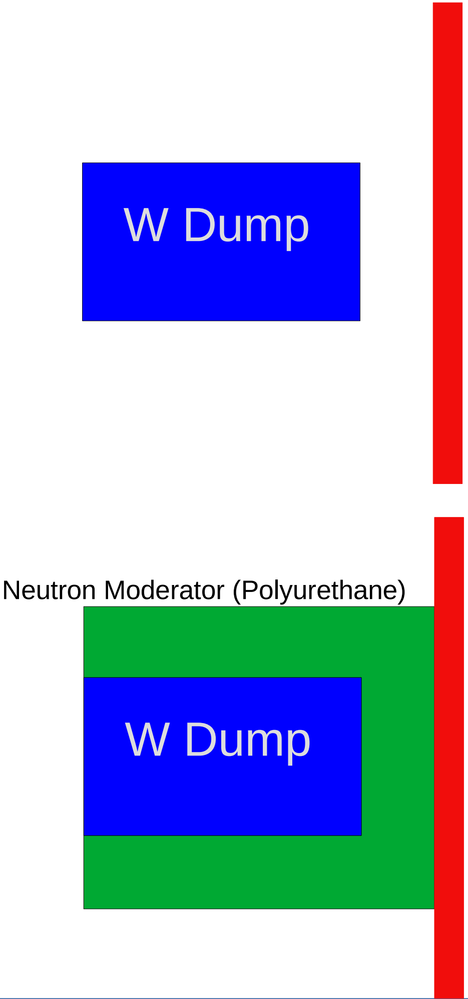


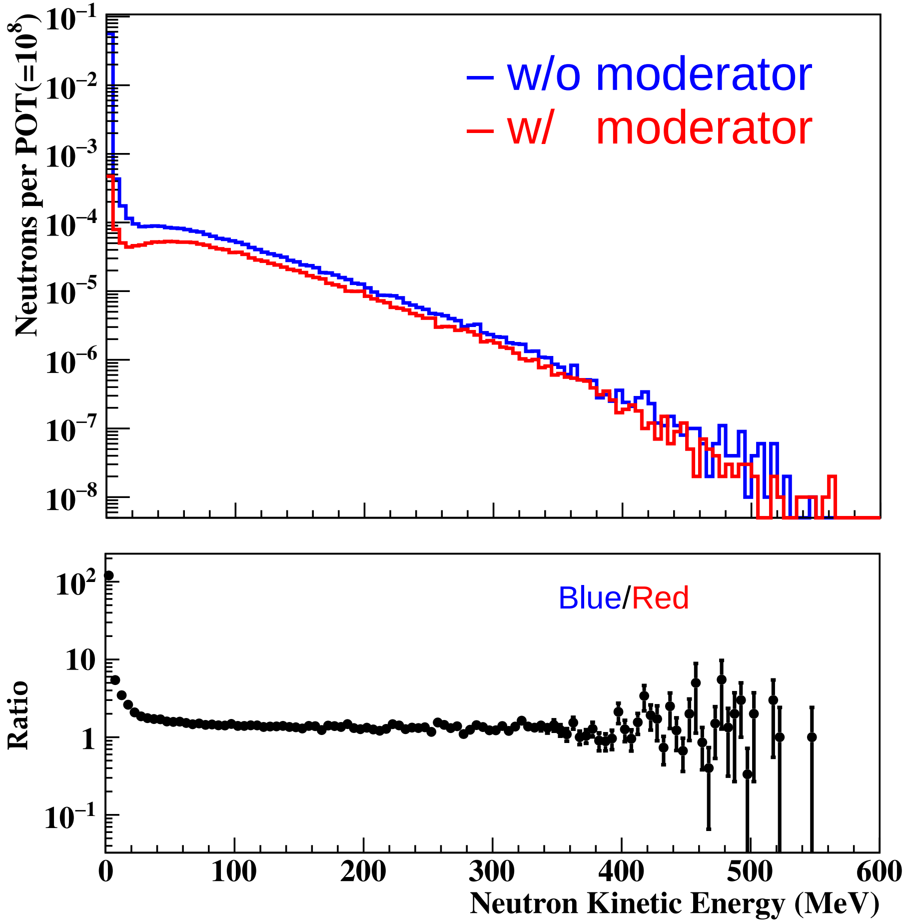
Neutron Moderator Simulation (1)





Neutron Moderator Simulation (2)





Neutrons Jumping into the Decay Chamber

- We counted all the neutrons entering into the vacuum chamber.
- The interactions between beam particle and dump material creates lots of neutrons, about 0.2% of neutrons (per proton) actually jumps into the decay chamber.
- Considering the beam intensity, this is still a big number. Therefore we need a strategy to mitigate backgrounds that will be induced by these neutrons.