Design Options of External Neutron Source

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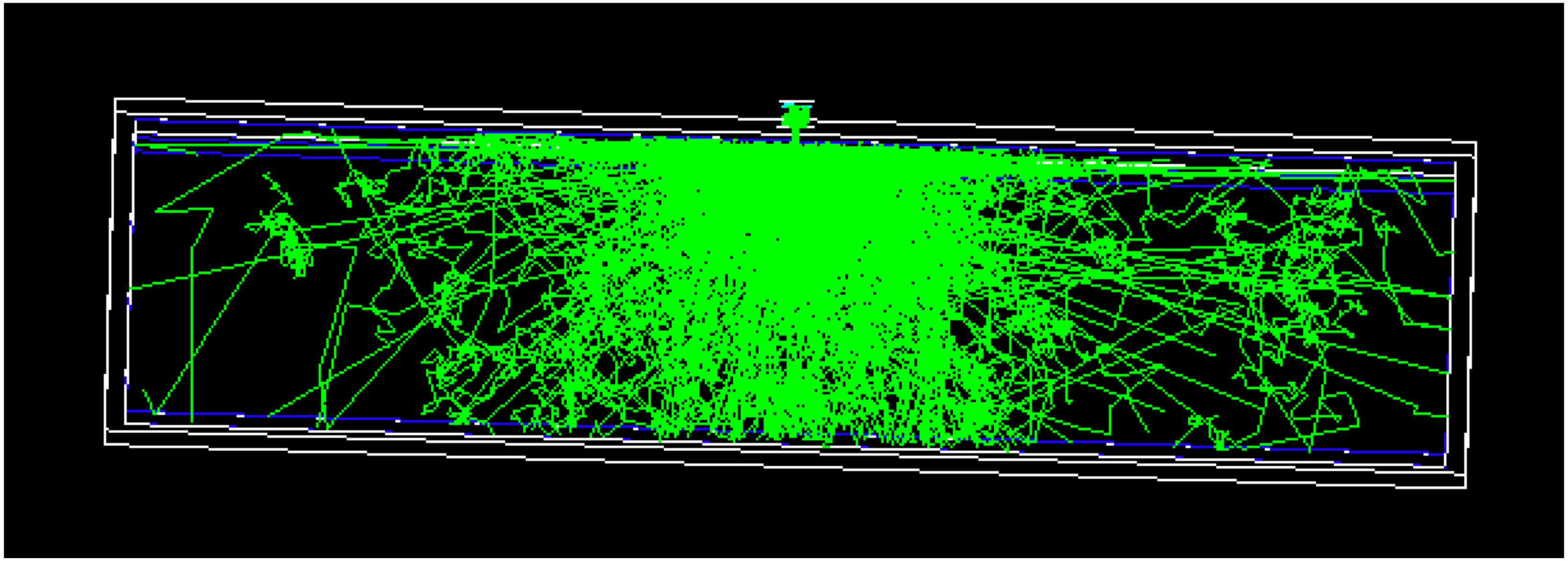
Current Status

- Investigated the DD generator purchase. Got a quote from the StarFire company.
- Studied different moderating materials with different thickness.
- Studied different energy filtering materials.
- Studied three different configurations



Calibration Feedthroughs

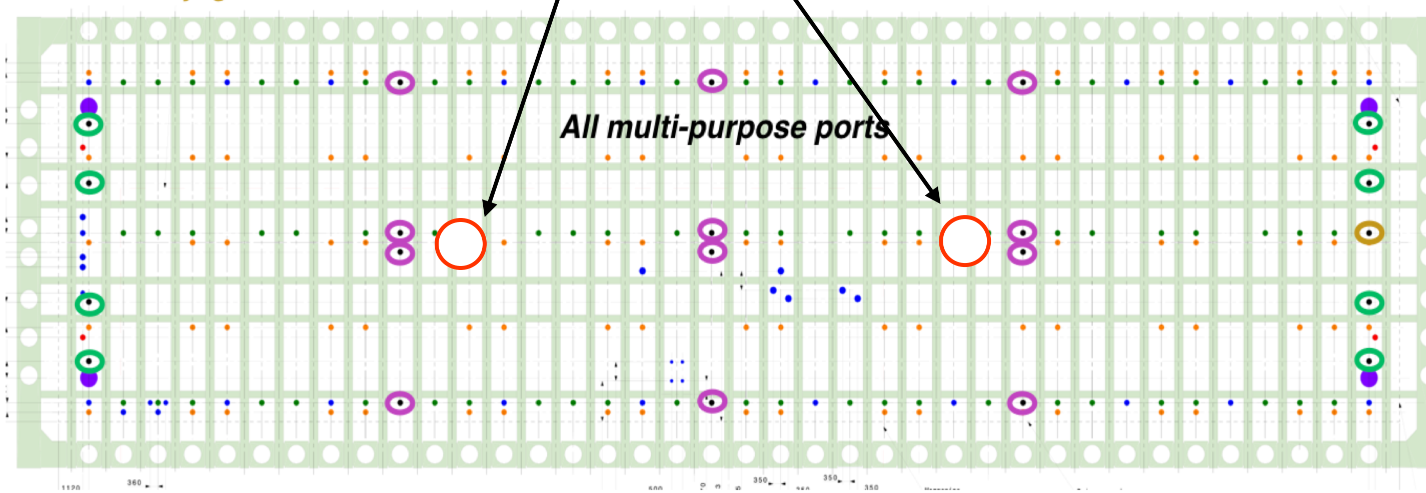
- Ports available: 25 cm feedthrough ports and 80 cm manholes
- Question: can we request to open two more manholes (red)?

= Calibration FTs

= Calibration FT (outside the FC)

= Cryogenic Instrumentation FT

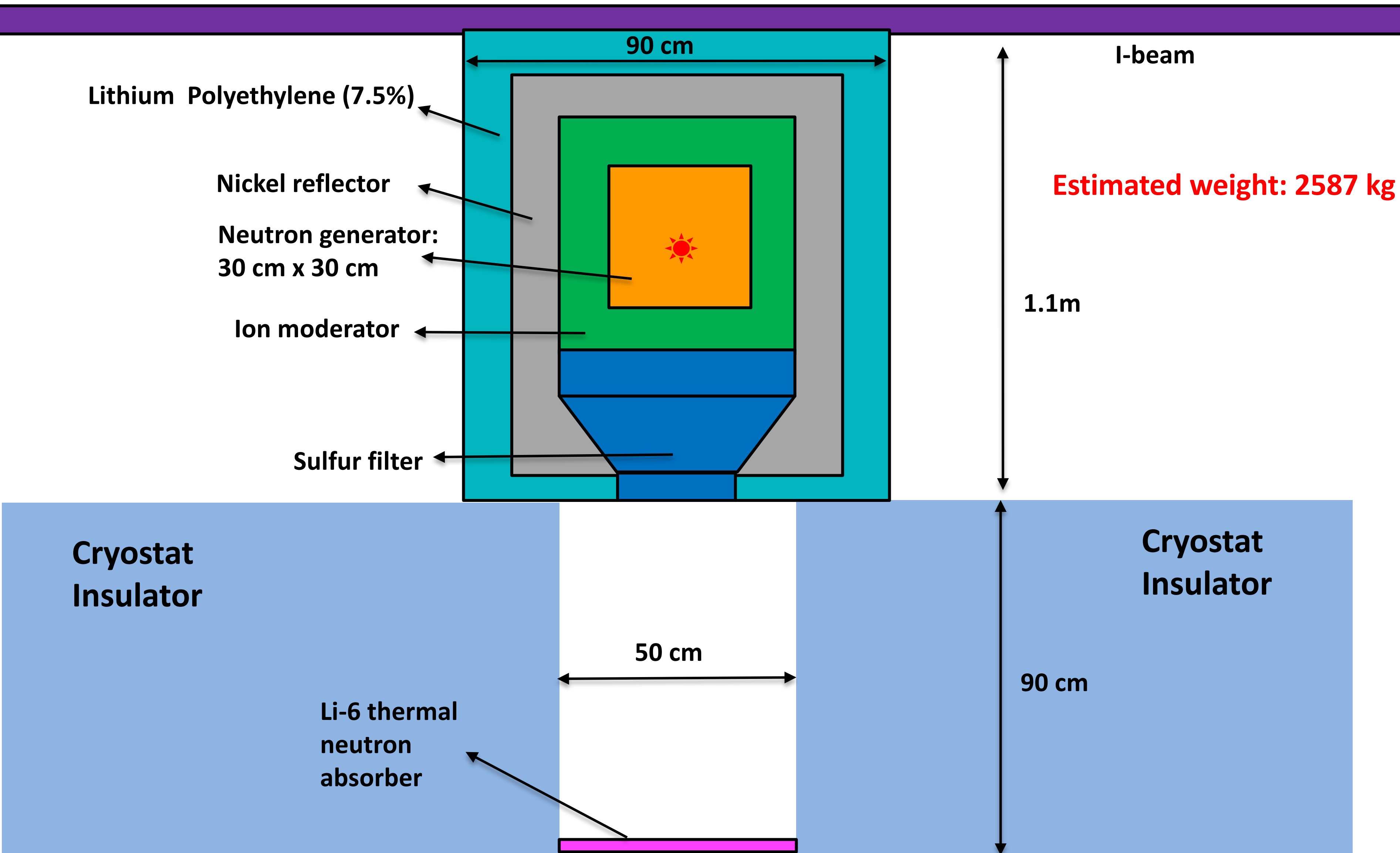
Full volume calibration of E-field map and associated diagnostics (e.g. HV) requires crossing tracks



Pos.	Diameter [mm]	Quantity	Description
1	Ø250	100	Support
2	Ø250	75	Cable
3	Ø250	4	High voltage
4	Ø250	21	Instrumentation
5	Ø800	4	Manholes

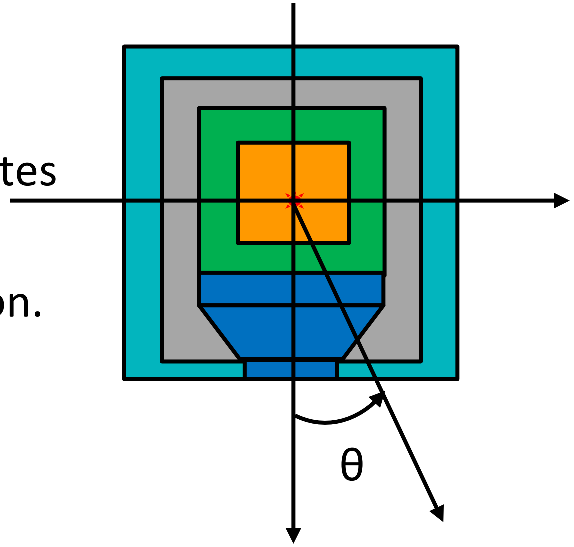
Laser FTs (Magenta & Green) every 14 m or so. 10 m laser range demonstrated in MicroBooNE.

Source above Insulator



DD generator modeling

- The neutron initial direction is modeled with a the experimental measurement in Ref [1].
- The angular distribution in Ref [1] is adapted the coordinates in our GEANT4 simulation.
- Forward neutrons follow the measured angular distribution.
- Set a flat distribution for backward neutrons. We lack measurements for backward emission angles.



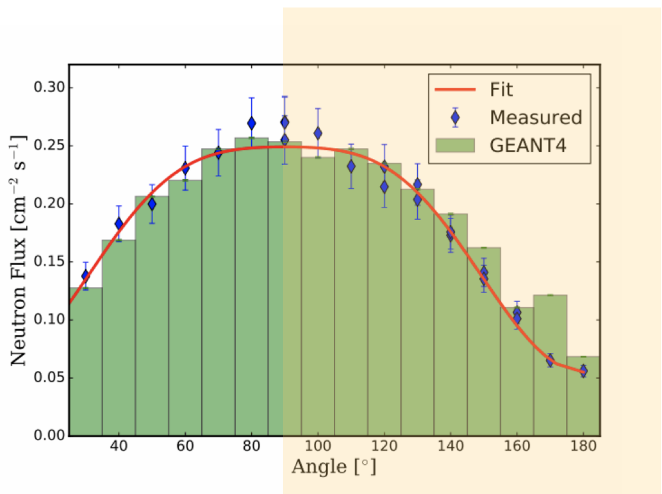
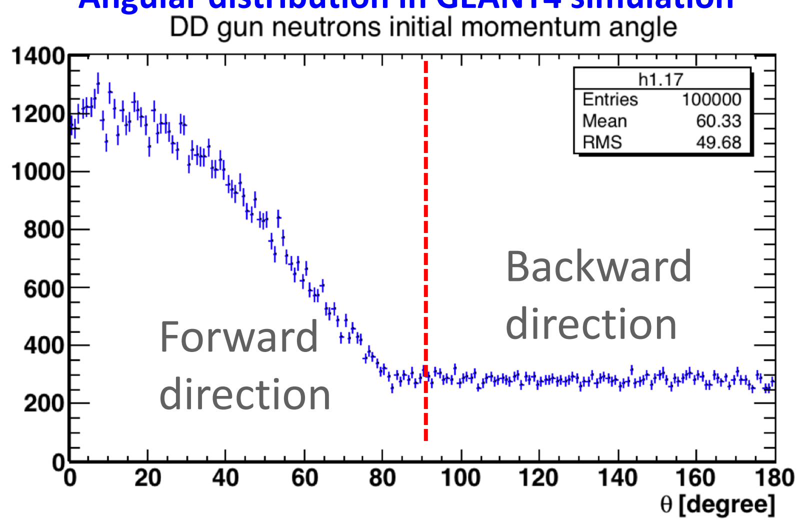


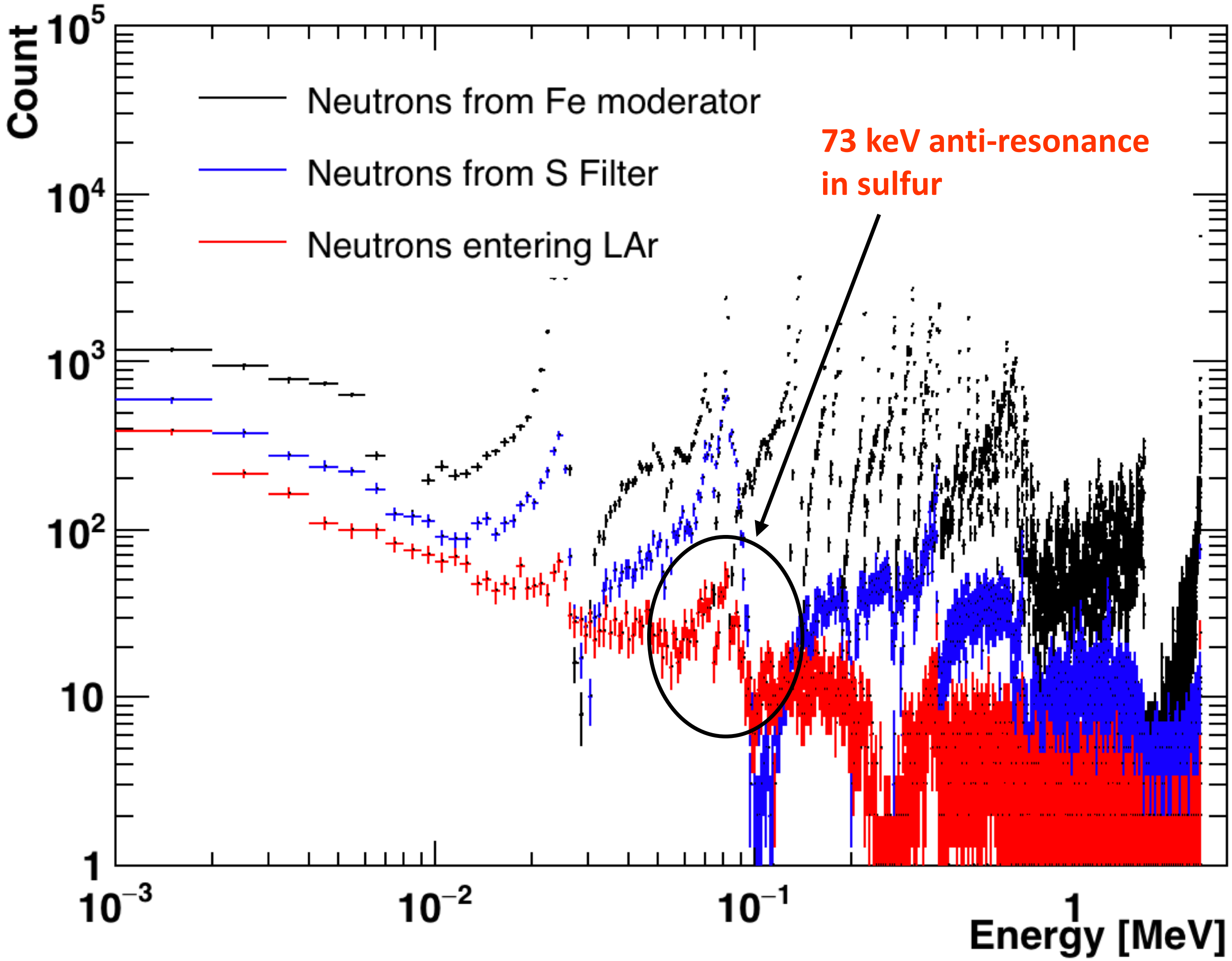
Figure 9: Measured neutron flux as function of polar angle. Data taken with the the Long Counter is shown (blue diamonds) together with the angular neutron flux dependence predicted by a detailed GEANT4 simulation of the neutron generator (green bars). A fourth order polynomial fit to the data is shown as well (red line), parametrizing the measured dependence.

Angular distribution in GEANT4 simulation

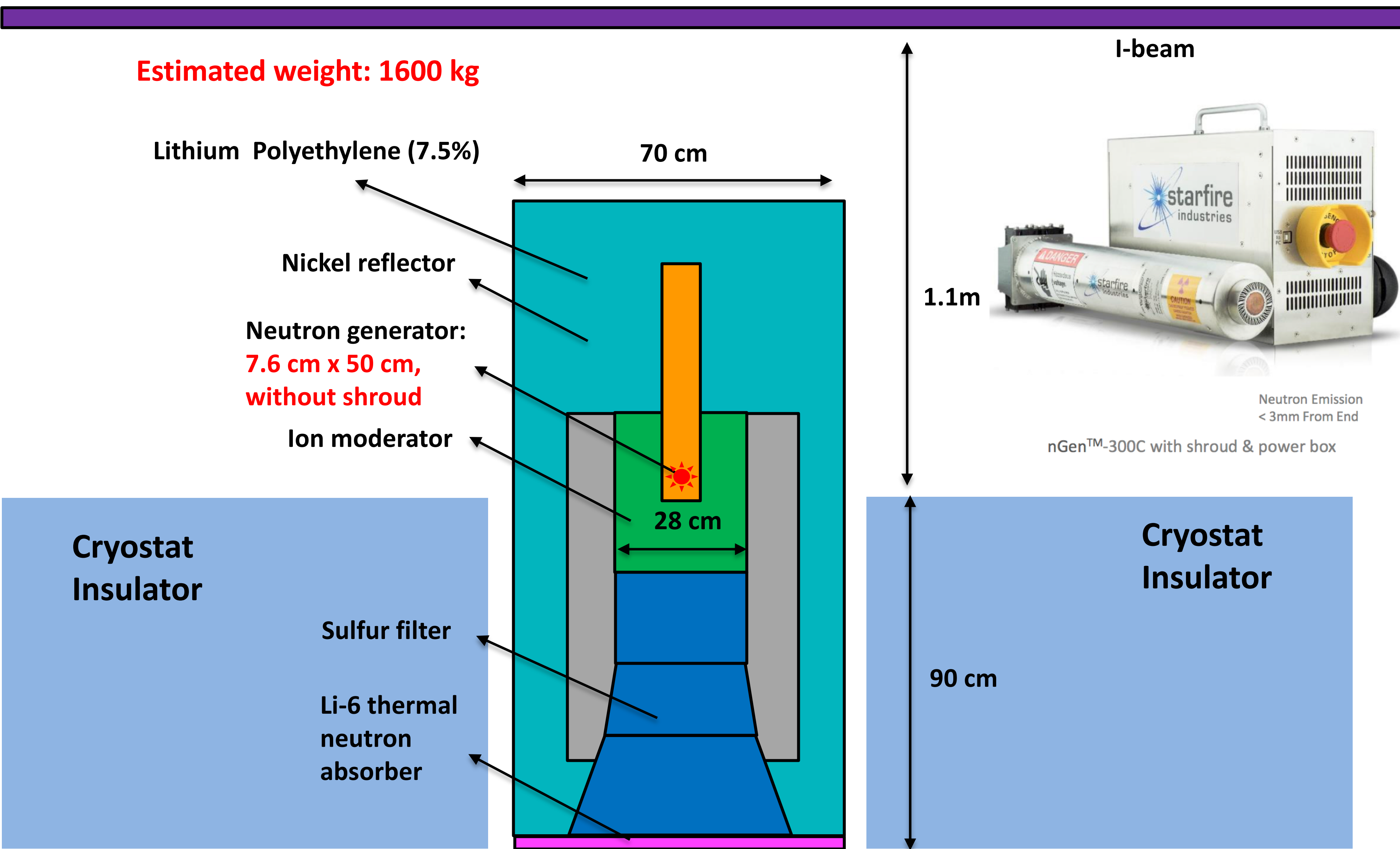


[1] R.F. Lang, et. al., Nucl. Instrum. Methods, 879 (2018), P. 31-38

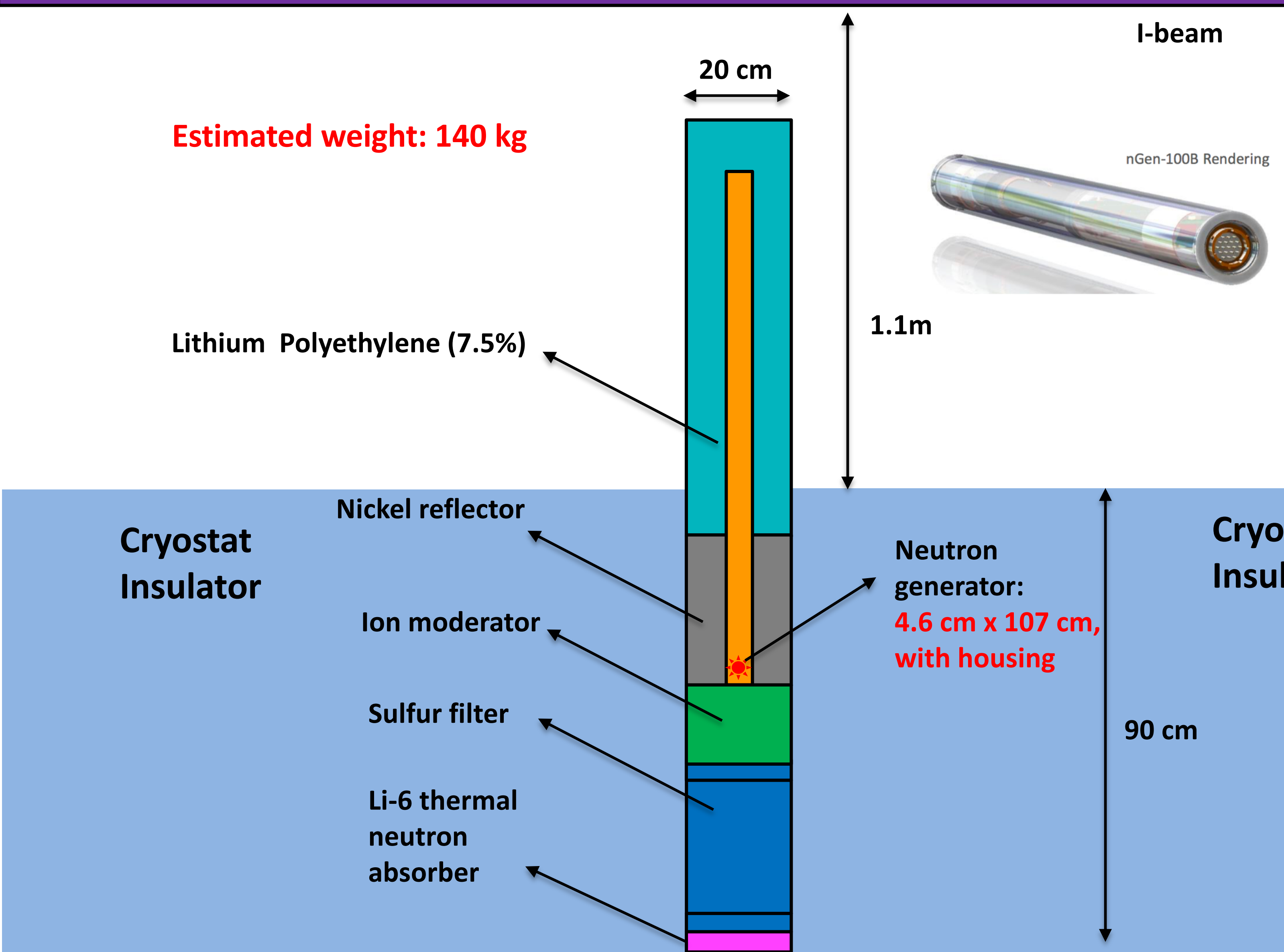
Neutron Energy Spectrum

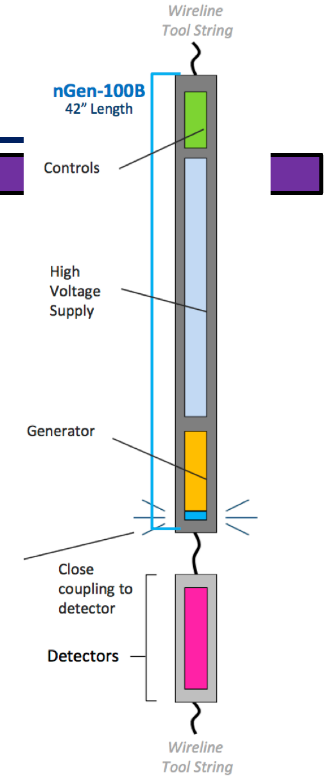


Source in Manhole

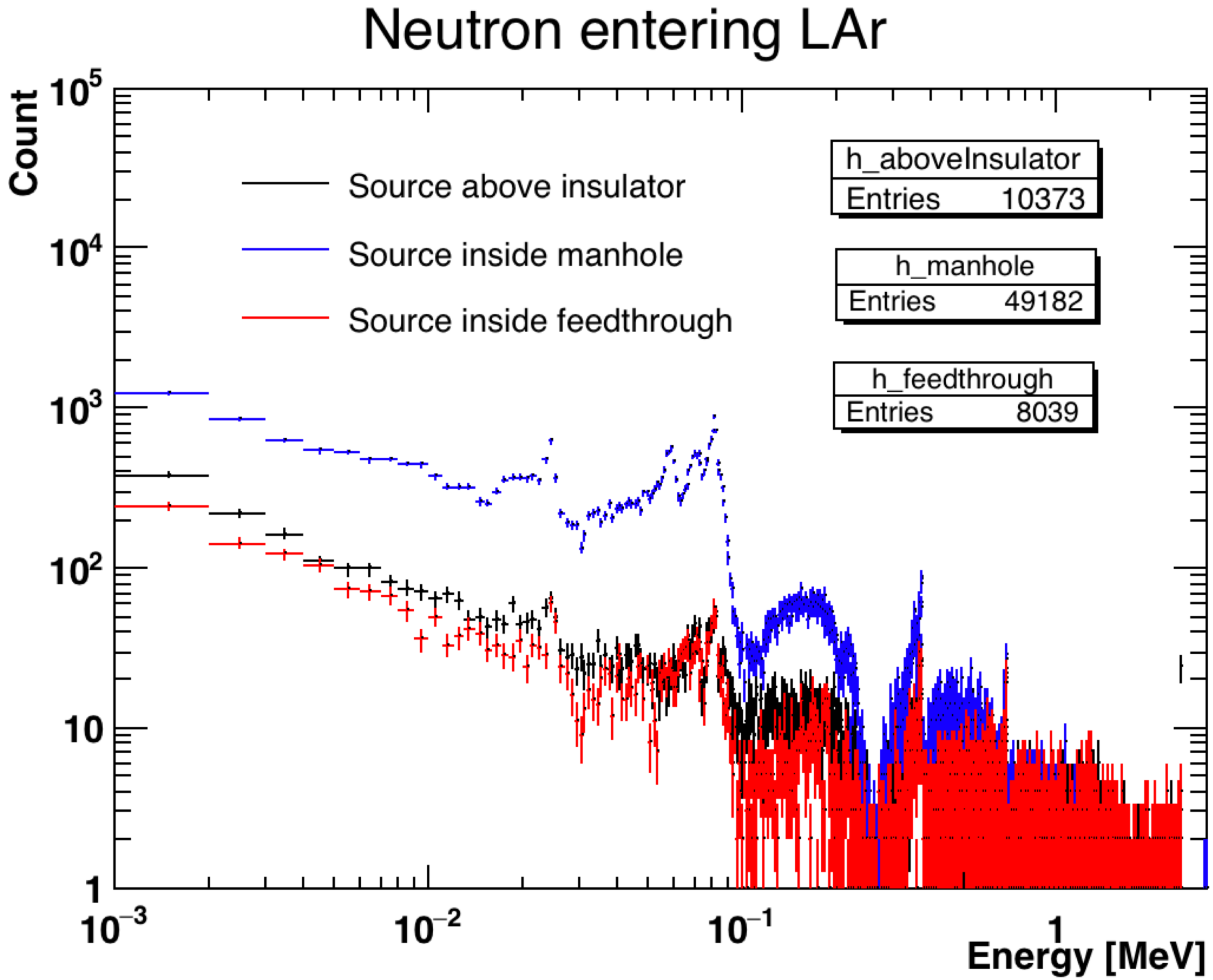


Source in Feedthrough





Neutron Energy Spectrum

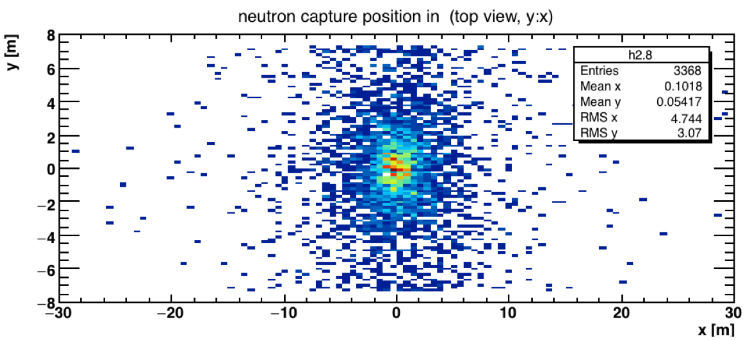


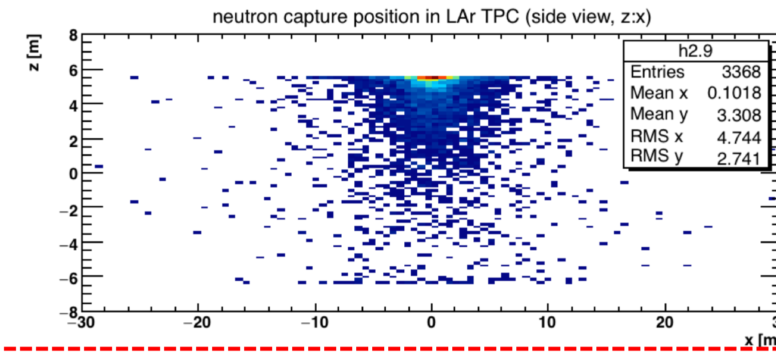
Neutron Capture Position

Top View

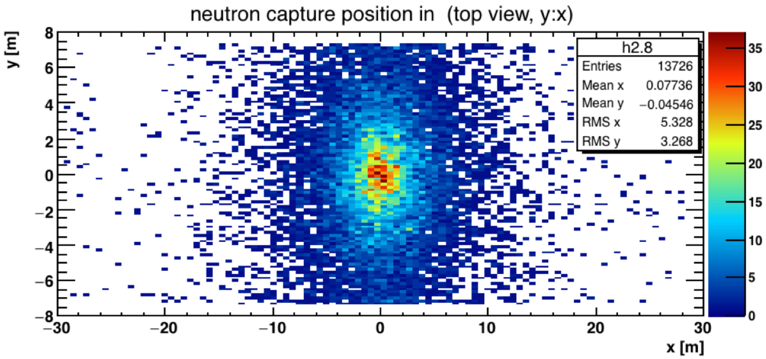
Side View

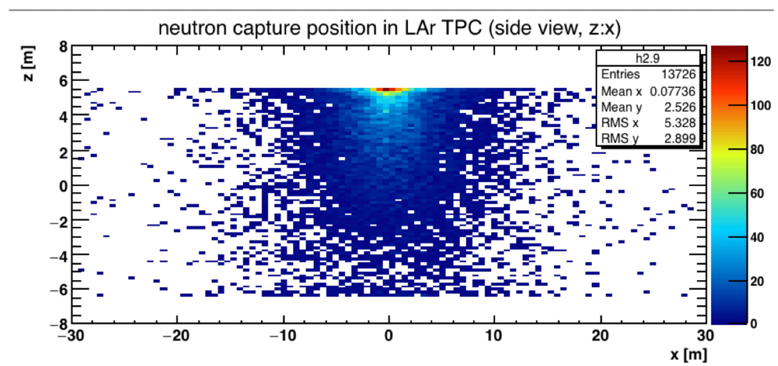
Source Above insulator



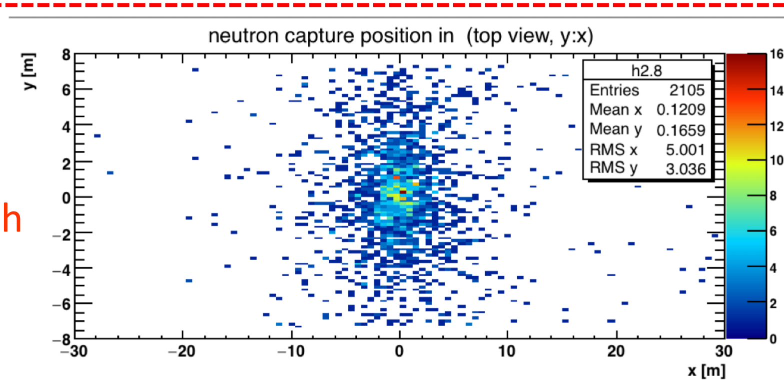


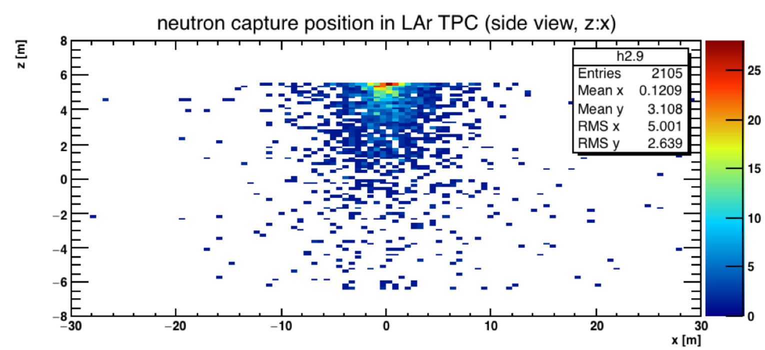
Source Inside Manhole





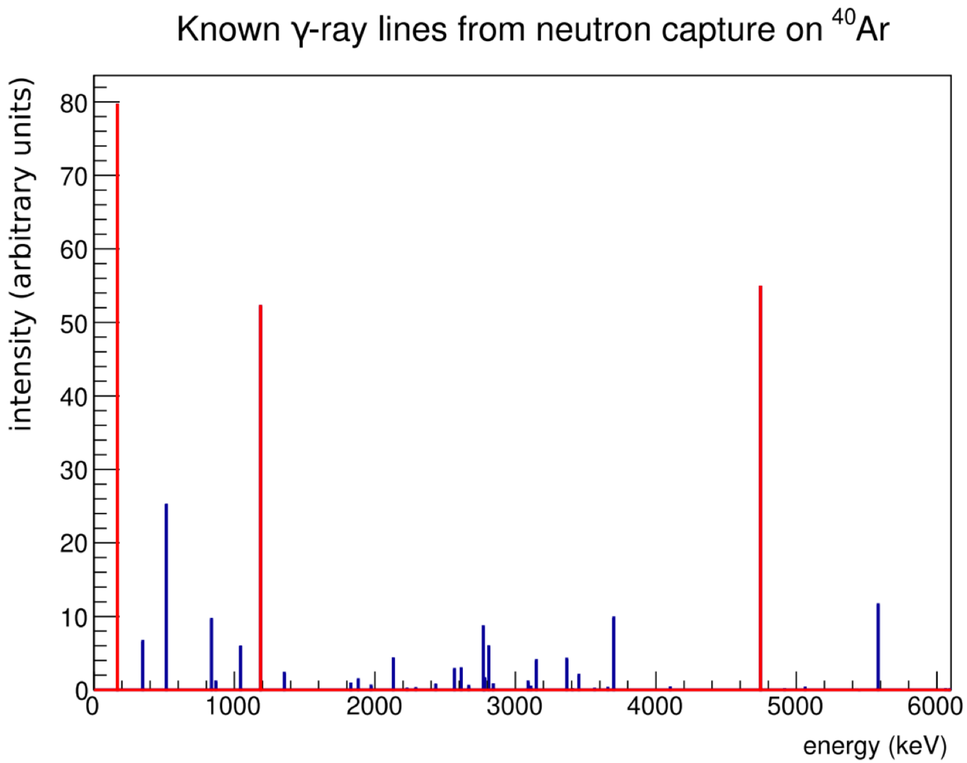
Source Inside Feedthrough





Expected Gamma Cascade

- We did the ACED experiment to measure the neutron capture cross-section and the correlated gamma cascade
- One 3-gamma cascade from the thermal neutron capture state is fully known (red lines): 167 keV, 1186 keV, 4745 keV
- Roughly 33% of all captures will produce those 3 gammas



Questions

- **How many calibration sources will there be?** Two fixed sources if we open two manholes; One movable source if we use feedthroughs
- **Can they be run with detector "live" to other physics?** Yes
- **Can the source be triggered, or will it provide a trigger?** Yes. The DD generator pulse duration is tunable from 5 to 1000 μs
- **What is rate of source?** 0 - 200 kHz pulse rate with up to 2×10^7 neutrons/pulse
- **What is rate of events to be recorded?** <0.5 Hz
- **What is the total number of events/year needed?** Assuming the calibration needs 1000 neutron captures per m^3 and the neutron captures are evenly distributed, we need roughly 6×10^6 neutron captures
- **Will it provide a timestamp and if not, is latency known and constant? And how will it be synchronized?** The DD generator provides t0. The neutron life time is 120 μs on average and about 1 ms at most.
- **How much of the detector will be illuminated? (Can we localize events?)** The whole TPC can be illuminated. Need studies on how well the TPC can localize the neutron capture gammas.

Questions:

- **How many neutron captures in LAr are expected for one DD generator pulse with 10^7 neutrons:**
  - Source above insulator: 16,000 (0.16%)
  - Source in 80 cm manhole: 137,260 (1.33%)
  - Source in 20 cm feedthrough: 21,050 (0.21%)
- **How many neutron pulses are needed for calibration (assume 10^7 neutrons/pulse)?** <400 pulses.
- **How much operation time per run is need in total?** 400 pulses/0.5 Hz = 14 minutes. We may want to reduce the neutron pulse duration time or the intensity but turn on the source for a longer time.
- **How many 2.5 MeV neutrons can be generated within a short pulse duration (5-1000μs tunable) ?** Need to check with vendors. This number determines how long time we need to turn on the neutron source.
- **What's the total data size per run?**

  <400 pulses x 1.5 Bytes x 2MHz x 5.4 ms x 384000 channels = 2.5 TB
- **How many runs are expected for one year?** To be decided

Summary

- There are two kinds of ports: 80 cm manhole and 25 cm feedthrough
- Compared three neutron source configurations
  - Neutron source on top of the insulator
  - Neutron source inside manhole
  - Neutron source inside feedthrough
- Question: which configuration is the best? What would be the technical challenge ?
- Need some discussions with the cryostat engineer