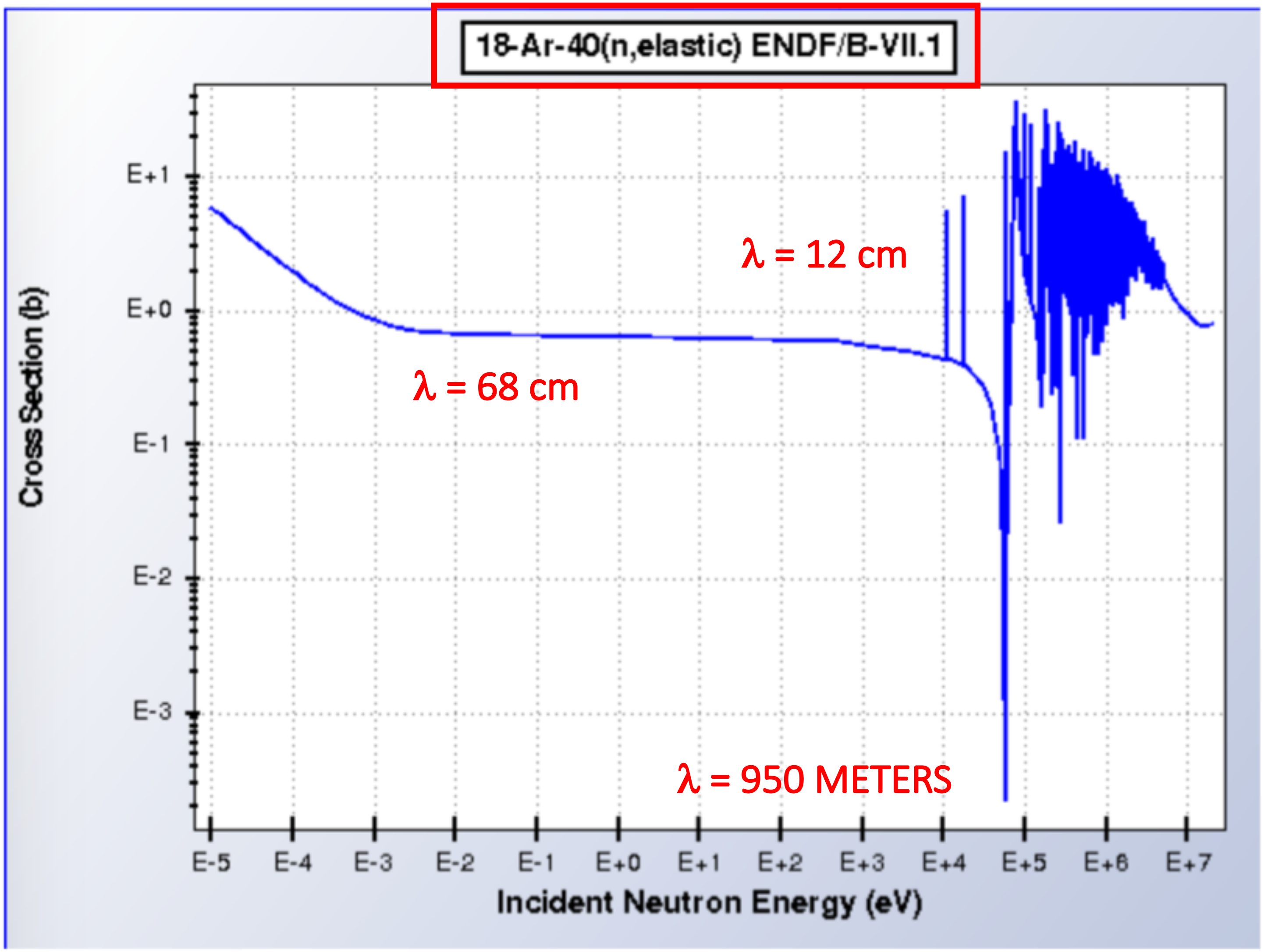
DD Generator Calibration Source for DUNE

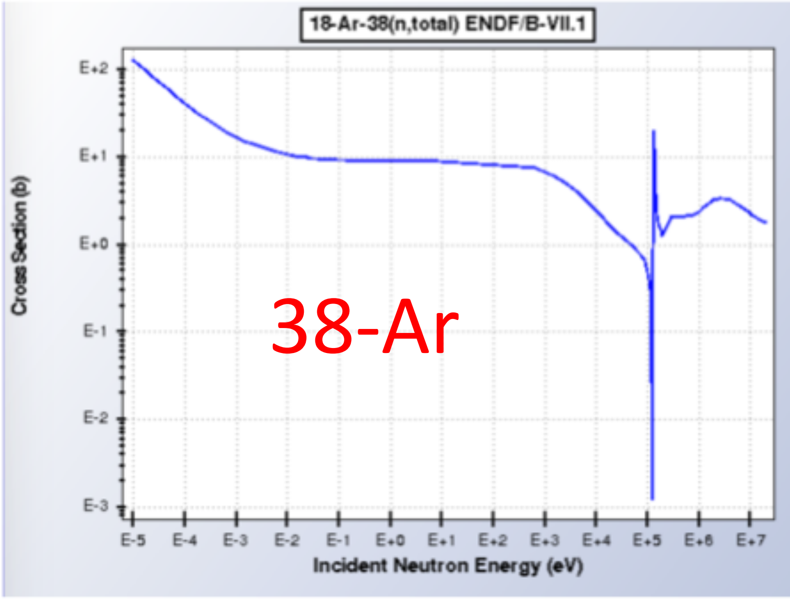
R. Svoboda, FNAL, March 2018

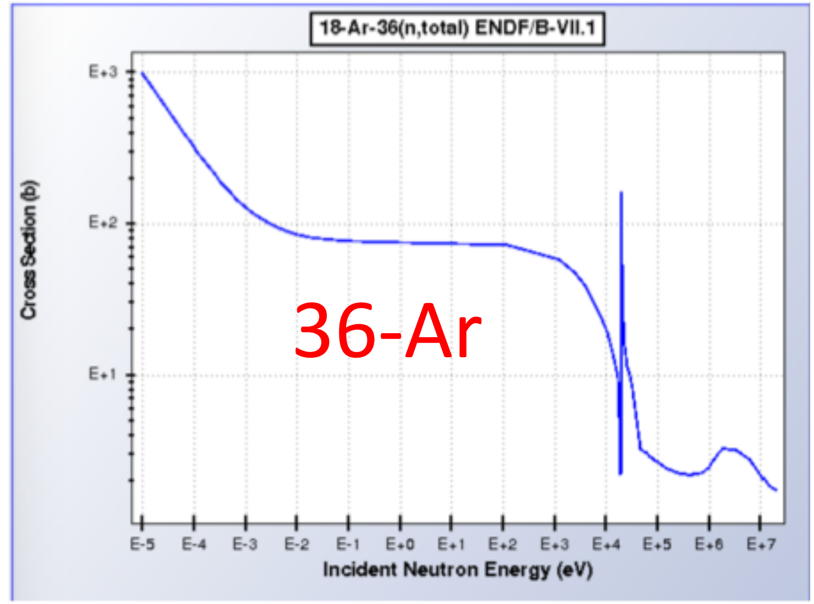
Need for energy calibration over the whole detector

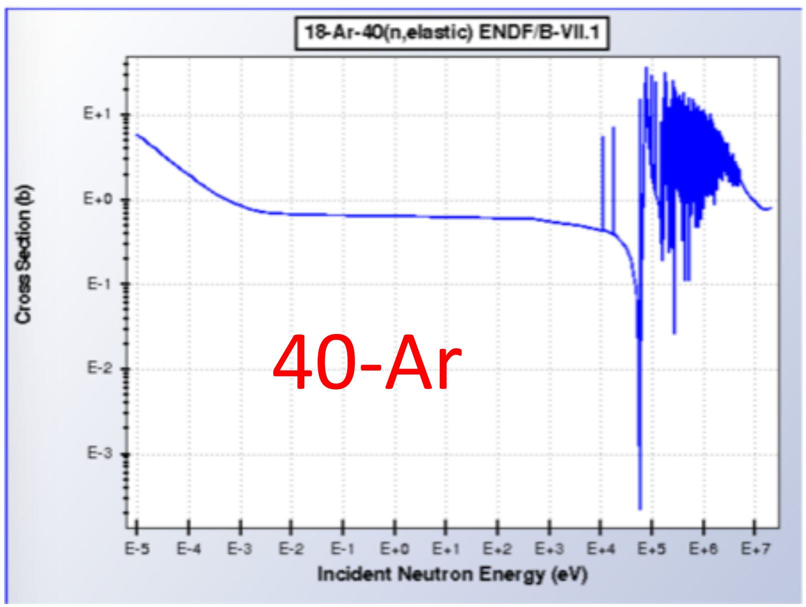
- electron transport and collection may not be uniform everywhere in the active volume – this needs to be calibrated and checked periodically
- this is difficult to do everywhere with calibration sources that test a single point
- very desirable **not** to have to insert devices while running
- DD generators can provide a non-invasive energy calibration source over the full volume of the detector due to a “window” resonance in elastic scattering at 57 keV

Elastic Scattering from ENDF



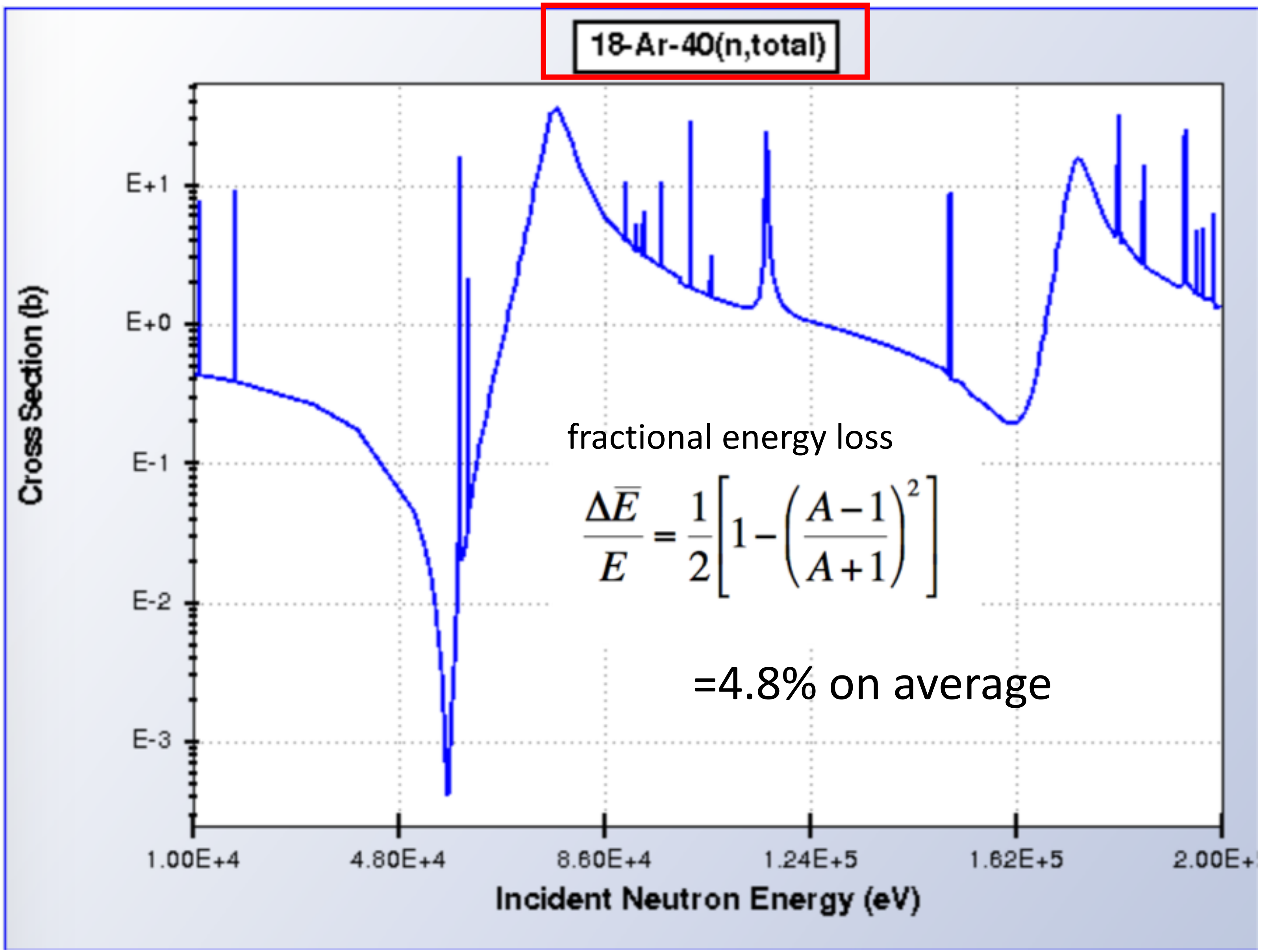






Fortunately, 38-Ar and 36-Ar have different resonance structure that keep the argon from being totally transparent at the 40-Ar resonance.

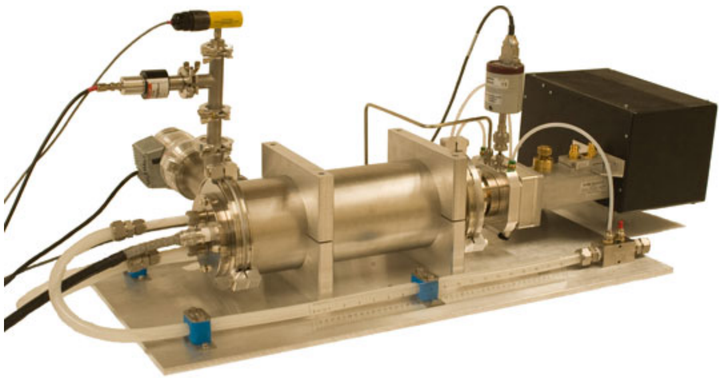
Still expect λ>10 meters



fractional energy loss

$$\frac{\Delta\overline{E}}{E} = \frac{1}{2}\left[1-\left(\frac{A-1}{A+1}\right)^2\right]$$

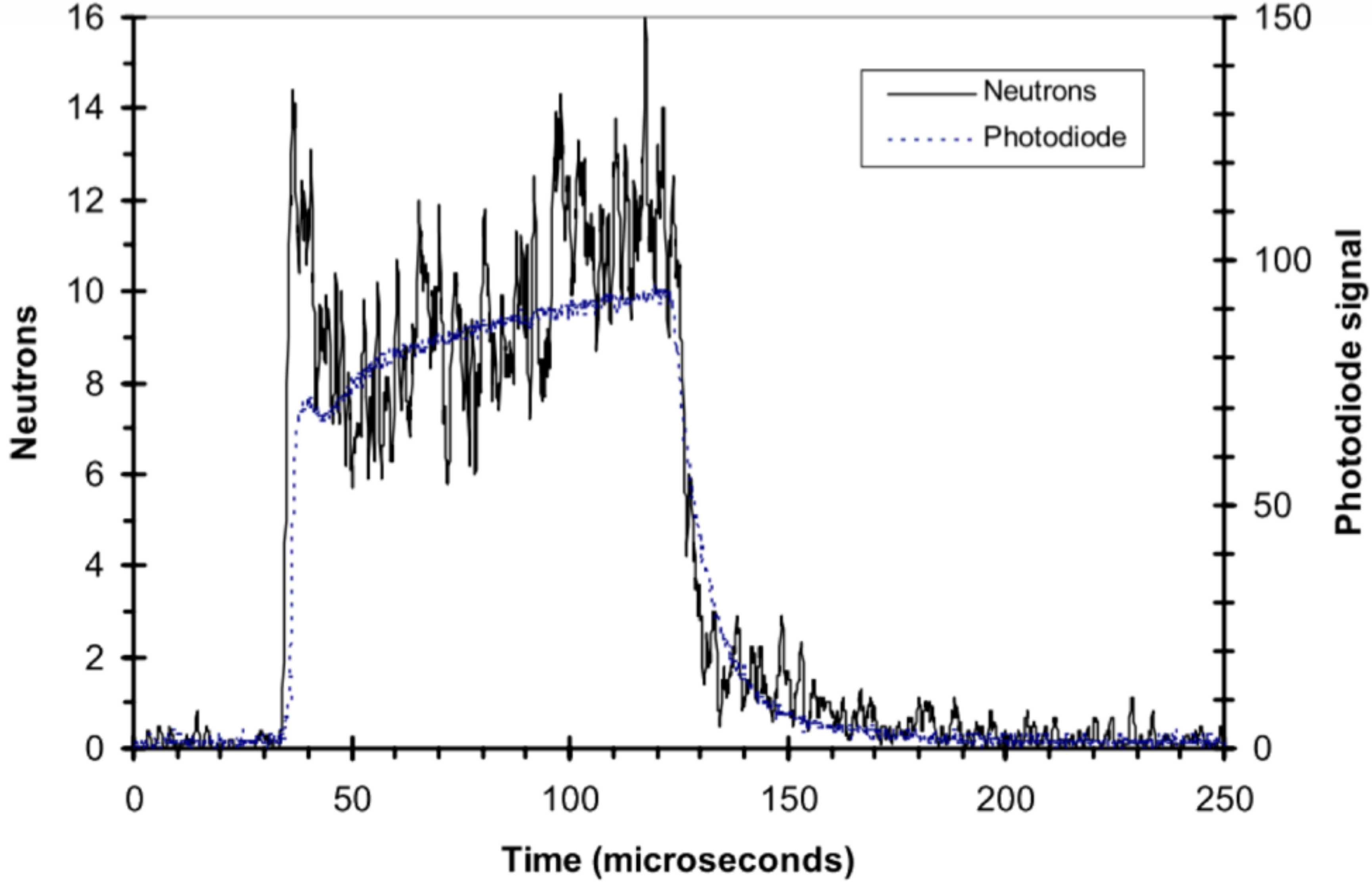
=4.8% on average



DD Generators are commercial devices that could provide a source of low energy (2.45 MeV) neutrons. Costs are low (~$100k) and they can be operated in pulse mode to give a trigger signal

General Specifications	
DD Neutron Yield	1 x 10^8 neutrons/sec
Neutron Energy	2.5 MeV
Standard Neutron Source Size	≤ 8mm diameter
Small Source Size (option)	≤ 2 mm diameter
Simple scheduled maintenance	≥ 2000 hrs, replacement of some internal parts
Standard operating mode	Continuous
Pulse on demand (option)	≥ 50 μS, to 100% duty factor

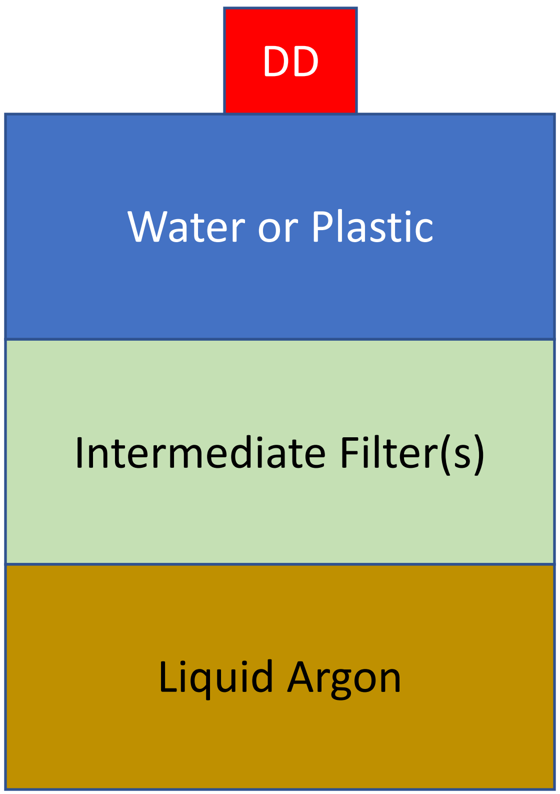
Time structure of single pulse

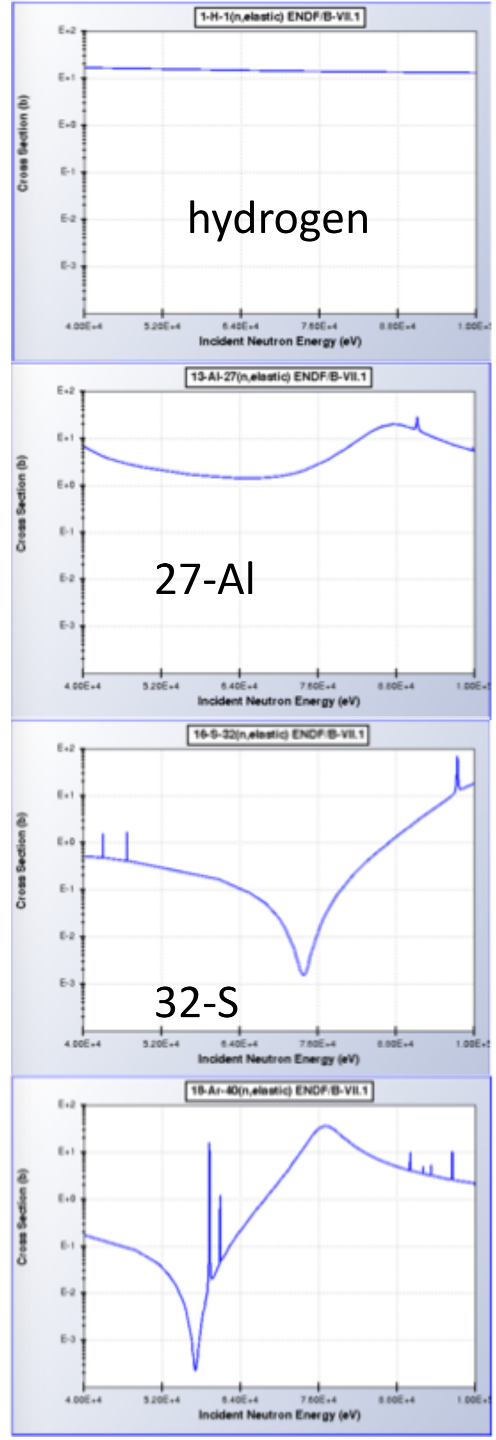


Why DD?

- No tritium used – makes import/export and compliance with local rules much less difficult than DT or TT generators
- Low energy (2.45 MeV) is well below the neutron and proton separation energy of most elements – little activation expected.
- Monoenergetic spectrum (unlike TT) which will simplify neutron degrader design and shielding

How to create a 57 keV neutron beam?





50% average energy loss/scatter

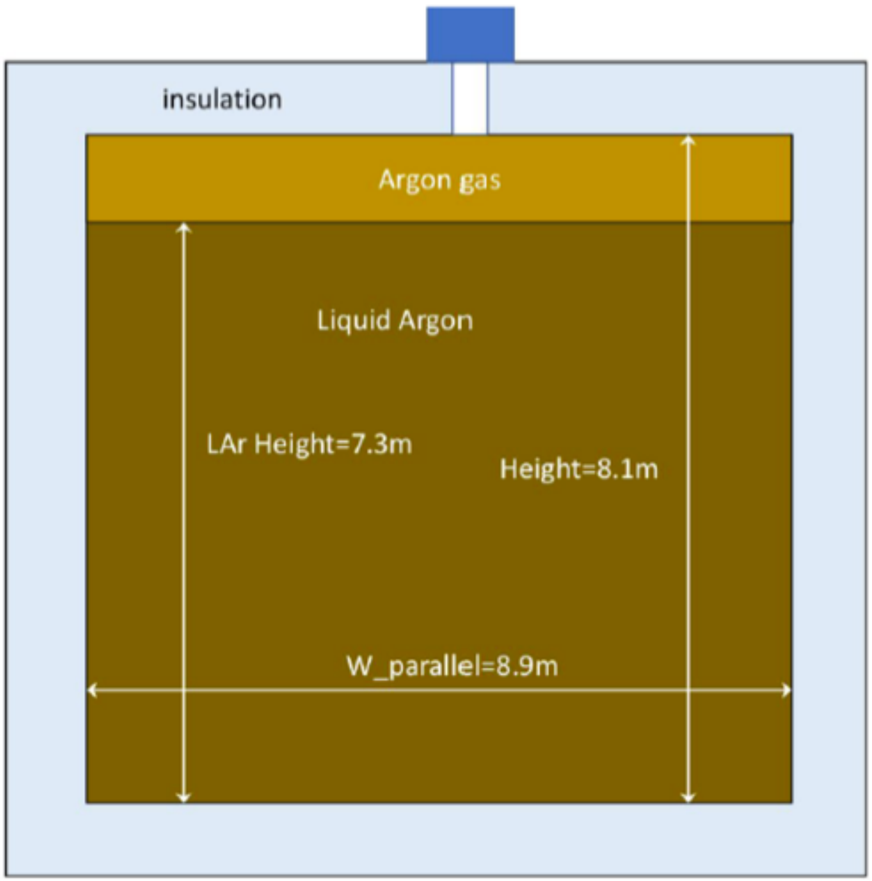
7% average energy loss/scatter

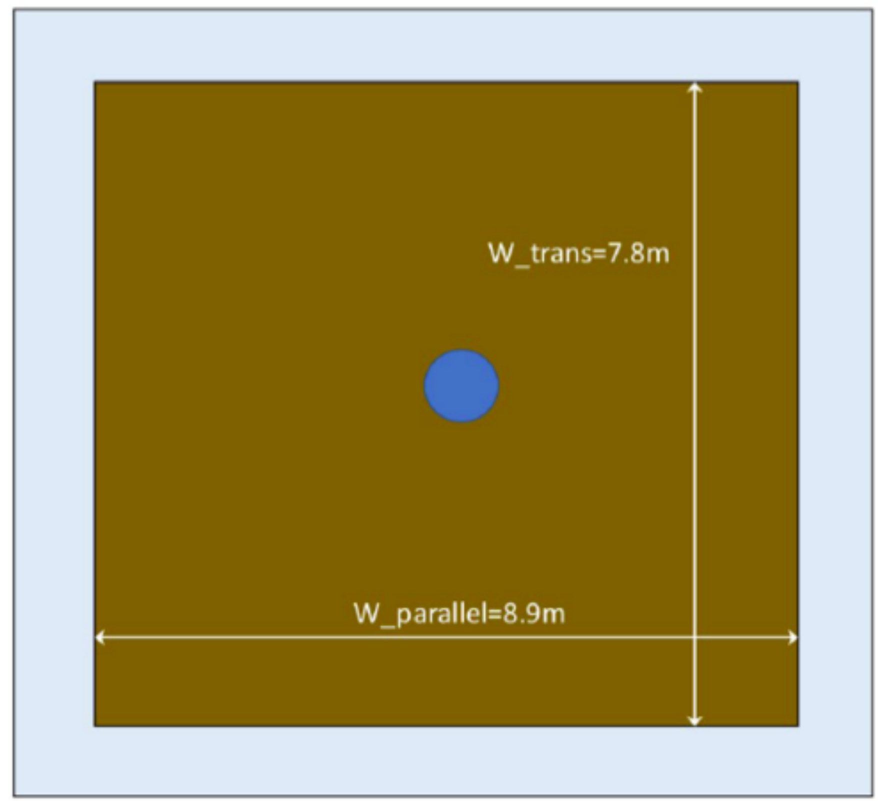
Resonance window just above 40-Ar window

40-Ar

Simulation of 57 keV source on top of the protoDUNE-SP detector

(Vincent Fischer)

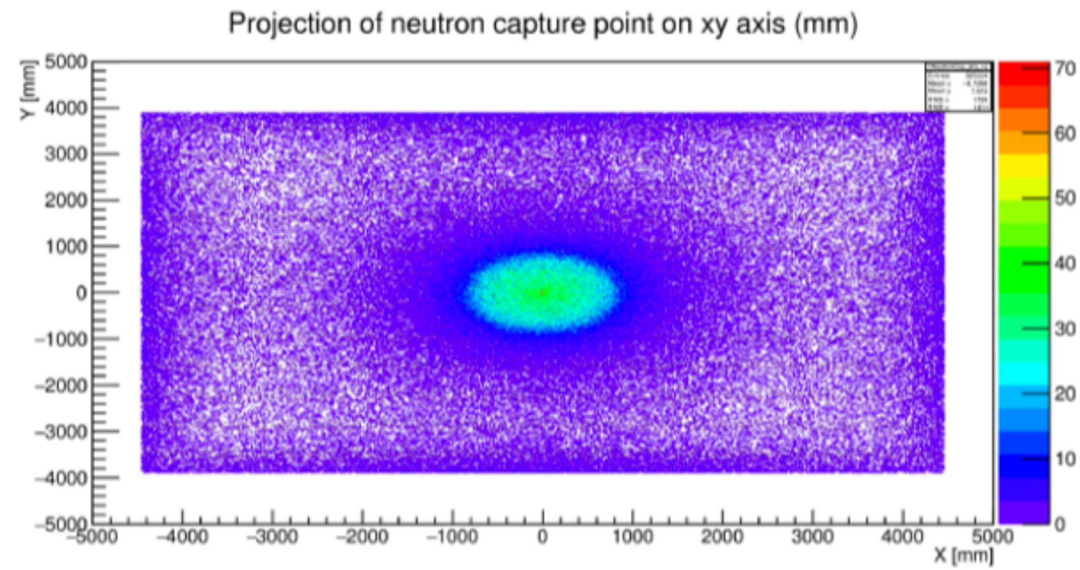


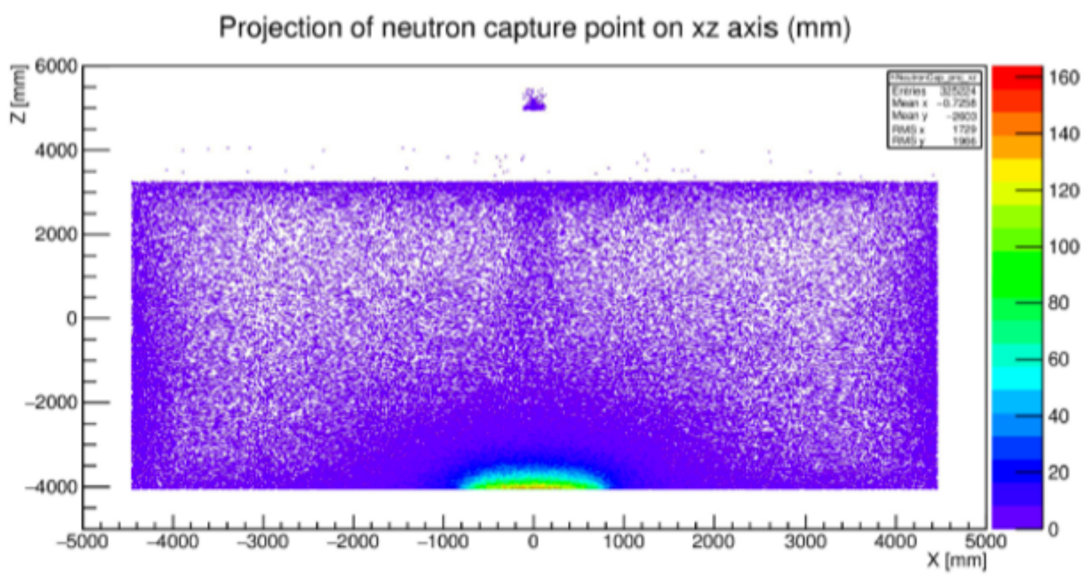


Simplified protoDUNE concept

- Simulation performed with rat-pac
- 57 keV neutrons (anti-resonance) shot from the liquid argon “neutron filter” downwards in protoDUNE

Neutrons populate the whole Lar volume





- 1 million neutrons shot in a 5-degree half aperture cone downwards

How well do we know the neutron capture energy?

- Last November the ACED Collaboration (UC Davis and Boston University) took several hundred thousand neutron capture events at the DANCE facility at LANSCE
- These are now being analyzed to reconstruct individual gammas on an event-by-event basis. Looking to have results by this summer.
- This will provide LArSoft with a database of gamma cascades to use
- Note: easy to get more data if needed – the gas target and peripheral equipment now stored at LANL

Argon capture gammas

Eγ (keV)	ΔEγ (keV)	Iγ/Iγ(max) (%)
167.30	0.20	100.00
348.70	0.30	8.29
516.00	0.30	31.78
837.70	0.30	12.06
867.30	0.60	1.38
1044.30	0.40	7.54
1186.80	0.30	65.58
1354.00	0.40	2.89
1828.80	1.20	1.26
1881.50	1.00	1.76
1972.70	1.20	0.68
2130.80	0.80	5.52
2229.50	2.00	0.36
2291.70	2.00	0.26
2432.50	0.80	1.05
2566.10	0.80	3.51
2614.40	0.80	3.65
2668.20	2.00	0.63
2668.20	2.00	0.63
2771.90	0.80	10.81
2781.80	1.50	2.13
2810.60	0.80	7.42
2842.60	1.00	1.11
3089.50	1.00	1.38
3111.40	2.20	0.50
3111.40	2.20	0.50
3150.30	1.00	5.02
3365.60	1.00	5.28
3405.50	2.50	0.09
3405.50	2.50	0.09
3452.00	1.00	2.51
3564.70	2.50	0.16
3564.70	2.50	0.16
3658.70	1.80	0.31
3700.60	0.80	12.31
4102.70	1.50	0.38
4745.30	0.80	69.09
4917.10	2.00	0.09
5064.00	1.00	0.32
5449.00	2.50	0.07
5582.40	0.80	14.58
5960.70	2.50	0.01
6063.10	2.50	0.05
6082.80	2.50	0.03
6093.30	2.50	0.04
6142.50	2.50	0.03

Binding Energy 6.1 MeV (monoenergetic)

Here are the major gammas - ACED will measure the correlated cascades

How to verify the neutron anti-resonance

- The LANSCE facility at LANL has a TOF beamline set up to make these kinds of measurements
- Would need a liquid argon target and perhaps some beam halo counters and associated electronics
- Recommend a proposal to LANL in February 2019 for a beam run in late 2019 or early 2020
- Costs should be <$100k total, as LANL provides beam monitors and does not charge users for beam time

Interested Groups

- UC Davis
- Boston University
- Illinois Institute of Technology
- Lisbon (LIP) – potential DUNE collaborators

We have had one meeting and would like to form a Working group specifically for this source