(alpha, n) Cross Section Data Improvement Needs for Next Generation Low-Background Neutrino and Dark Matter Experiments

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(alpha,n) nuclear data evaluation and data needs

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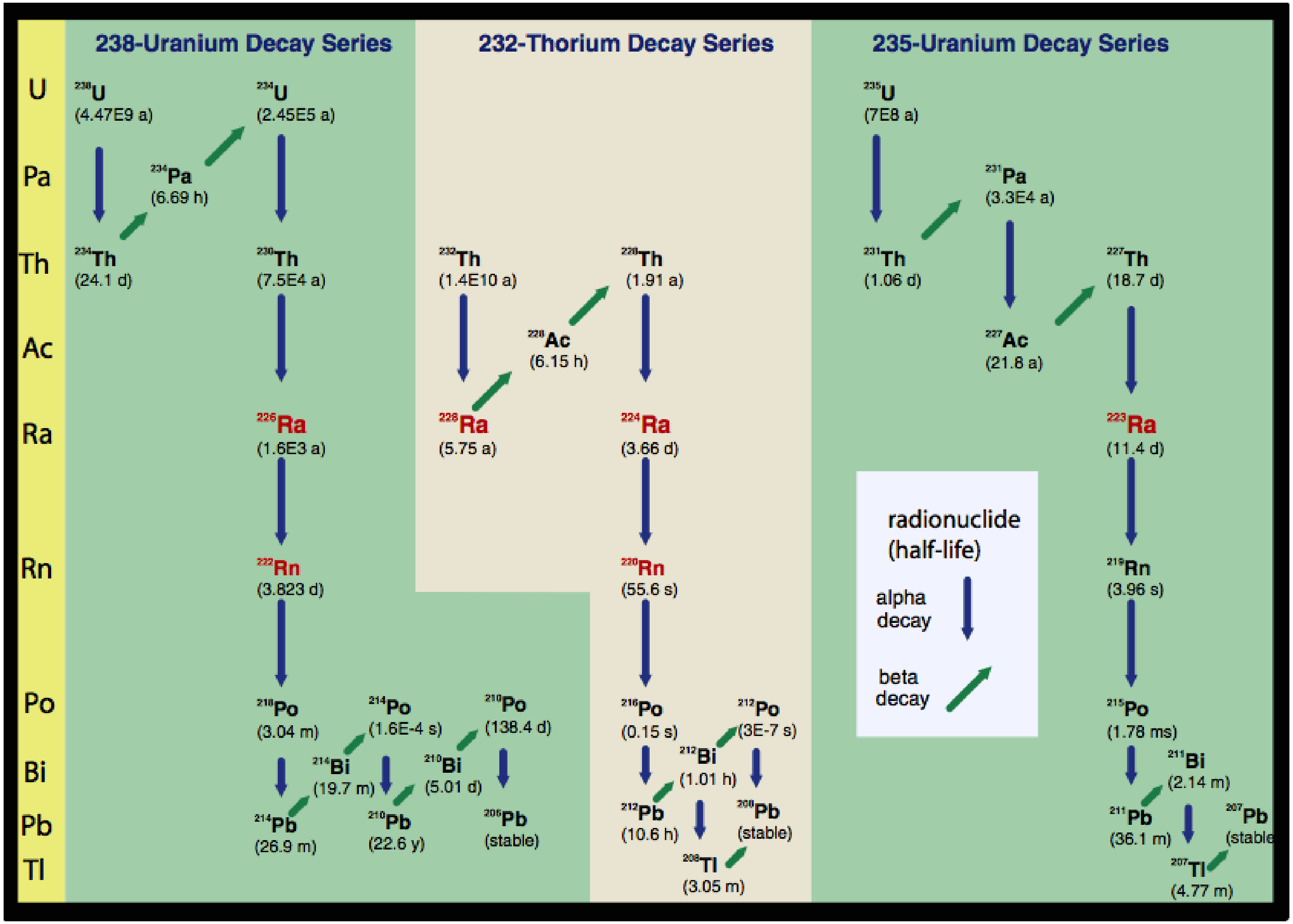
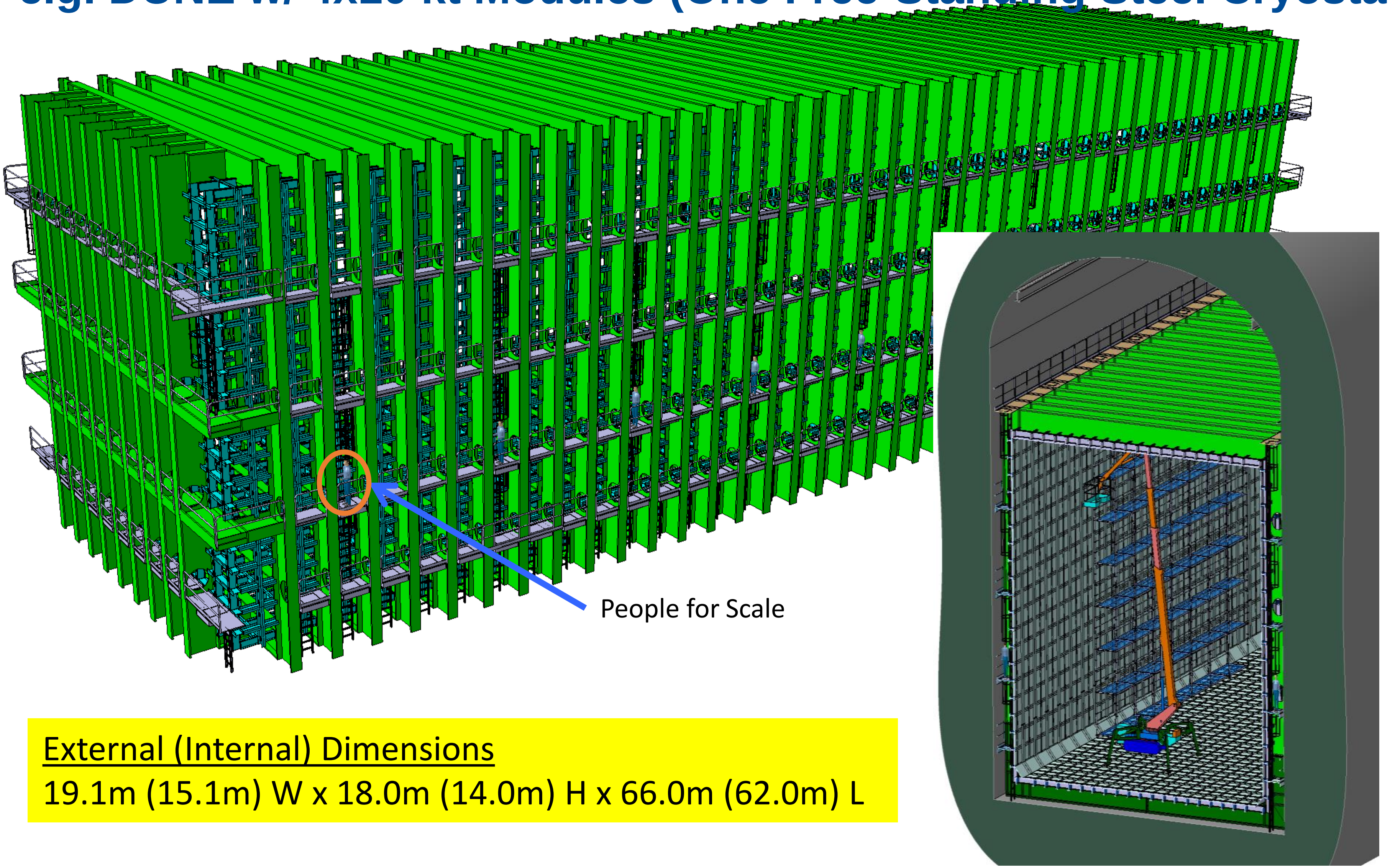
Radiological Neutrons from (alpha,n) Stemming from Early and Late U-238 Decay Chain and Th-232

Alpha energies up to almost 10 MeV



Expensive Large Caverns Needed for Next Generation Neutrino and Dark Matter Experiments:
e.g. DUNE w/ 4x10 kt Modules (One Free-Standing Steel Cryostat)



<u>External (Internal) Dimensions</u>

19.1m (15.1m) W x 18.0m (14.0m) H x 66.0m (62.0m) L

Not always possible to have a very large passive or active veto anymore due to costs!

Radon is Potentially a Big Problem for Next Gen Neutrino & DM Experiments (e.g. DUNE)

- **α's have high light yield in LAr (barely quenched)**

- **$^{40}Ar(\alpha, \gamma)$ -> 15 MeV γ's that look like ν's**

- **$^{40}Ar(\alpha,n)$ -> neutron captures in LAr that look like ν's**

- **α surface contamination from:**
  Construction and installation period:
  - radon daughter plate-out in air (^{210}Pb, $T_{1/2}$=22 y)
  Detector operation period:
  - radon daughter migration in LArTPC (-> cathod)

- **^{222}Rn continuously emanating into LAr from materials**

Neutrons ARE a Big Problem

- neutron captures can look like ν's for DAQ
  (-> rate issue, SNB trigger efficiency, solar ν's)

- neutrons are difficult to shield
  (-> simulate large geometry w/ detailed chemical composition)

- external radiological neutron flux is important (rock, shotcrete)

- ^{238}U content of materials for SF

- α emitter content of materials + chemical composition -> (α,n)

- customized (α,n) production yield calculations important!
  (need cross section measurements where uncertainties large)

-> need for entire detector geometry & surrounding environment:
extensive radiological assays + chemical composition assays

Paradigms for Next Gen Rare Event Searches (e.g. DUNE)

radiological assays (γ- and α-spectroscopy, emanation) of materials in DUNE to avoid stupid mistake in building the detector (need extensive assay program)!

Chemical composition of detector materials very important too (different chemical assay methods like XRD, XRF, ICP-MS, FT-IR, CHN etc. needed for each different type of material!):
- insulating foam defines neutron attenuation, but also neutron capture time, even in a 10 kt LAr volume ~half of neutrons will escape!
- aluminium content drives (α, n) production rates
- cryostat is ~10% of mass of detector

Fast turn-around of assays & simulations to be able to react in time

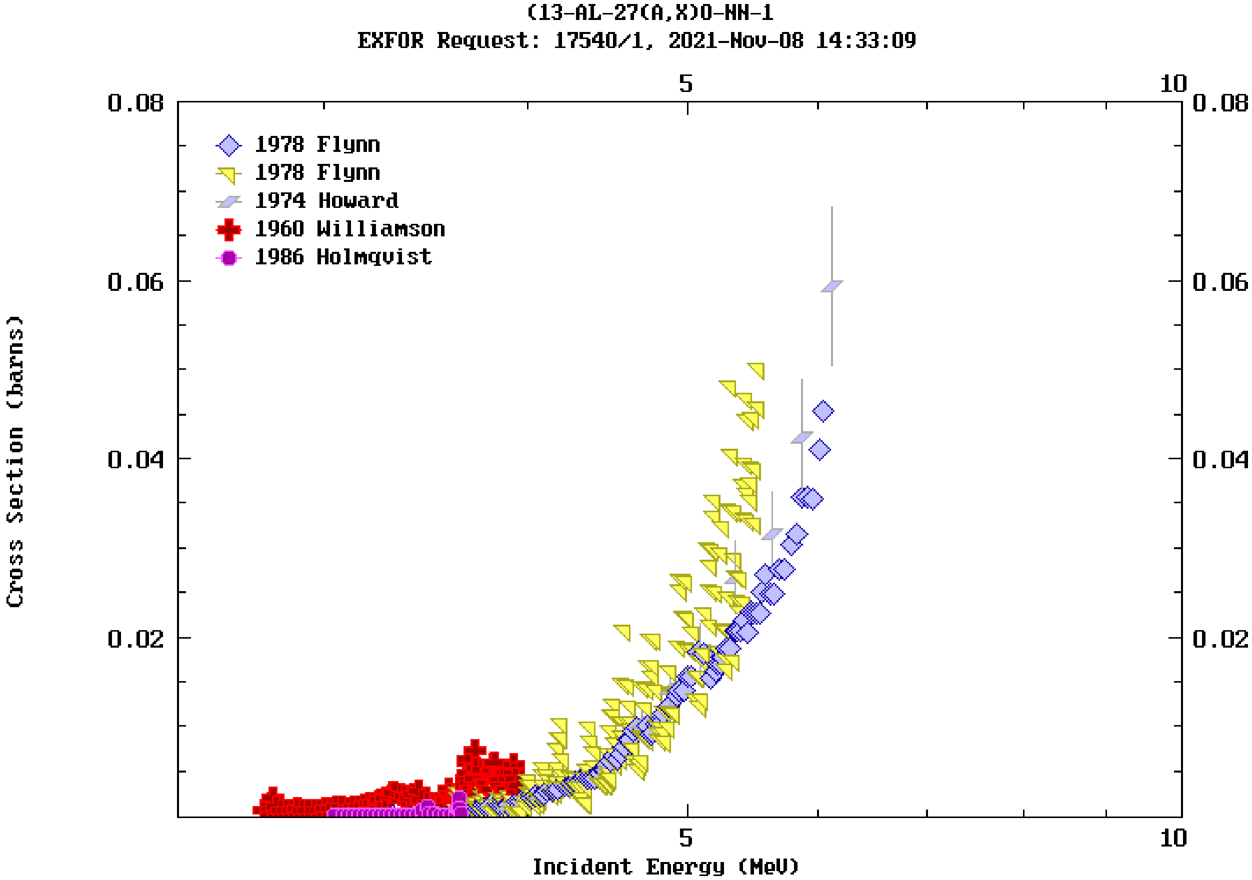
Example Simulation Inputs:
Chemical Composition & Density of Rock and Shotcrete Materials Measured at SDSMT

sample	description	density [g/cm^3]	error	O [a%]	Fe [a%]	Mn [a%]	Ca [a%]	K [a%]	Si [a%]	Al [a%]	Mg [a%]	Na [a%]	N [a%]	C [a%]	H [a%]
#1	DUNE Ross - #6 Winze	2.67	0.05	55.3	2.8	0.0	0.0	0.3	13.9	6.0	6.8	0.2	0.0	0.0	14.8
#2	DUNE Ross - Governor's Corner	2.65	0.10	62.4	0.6	0.1	0.0	2.0	26.2	3.1	1.1	0.5	0.0	0.0	4.0
#3	DUNE Ross - Test Blast Site	2.68	0.10	54.8	2.5	0.0	0.1	0.4	13.3	6.6	6.1	0.1	0.0	0.0	16.0
#4	DUNE Ross - #4 Winze	2.60	0.09	62.8	0.0	0.0	0.4	3.7	26.8	3.9	0.0	2.0	0.0	0.0	0.5
mean	**mean DUNE rock**	**2.65**	**0.04**	**58.742**	**1.501**	**0.030**	**0.112**	**1.554**	**19.854**	**4.940**	**3.580**	**0.692**	**0.000**	**0.000**	**8.996**

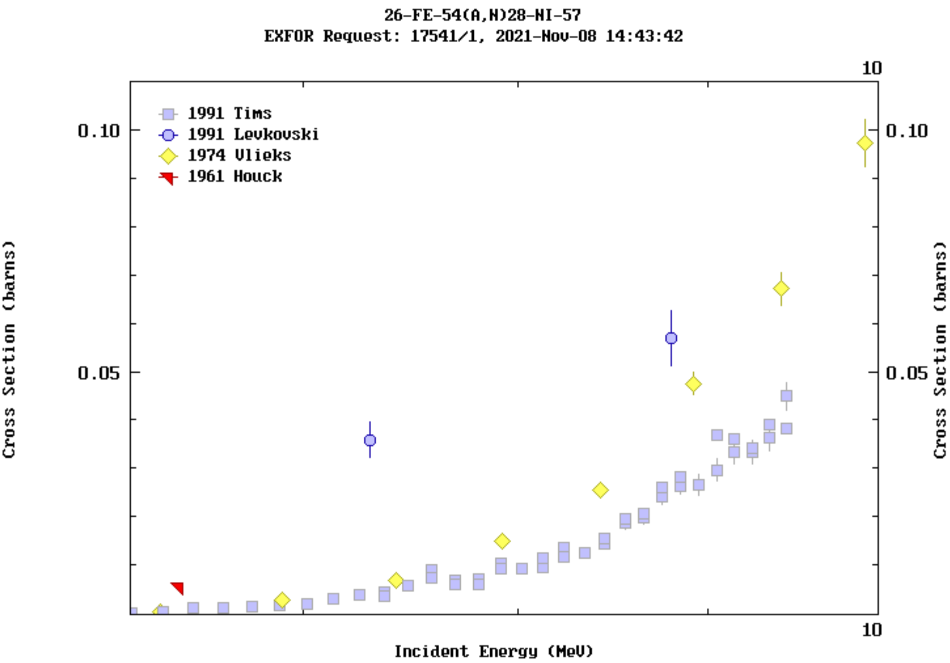
(to be published for DUNE including radioactivity content and neutron production and energy spectra)

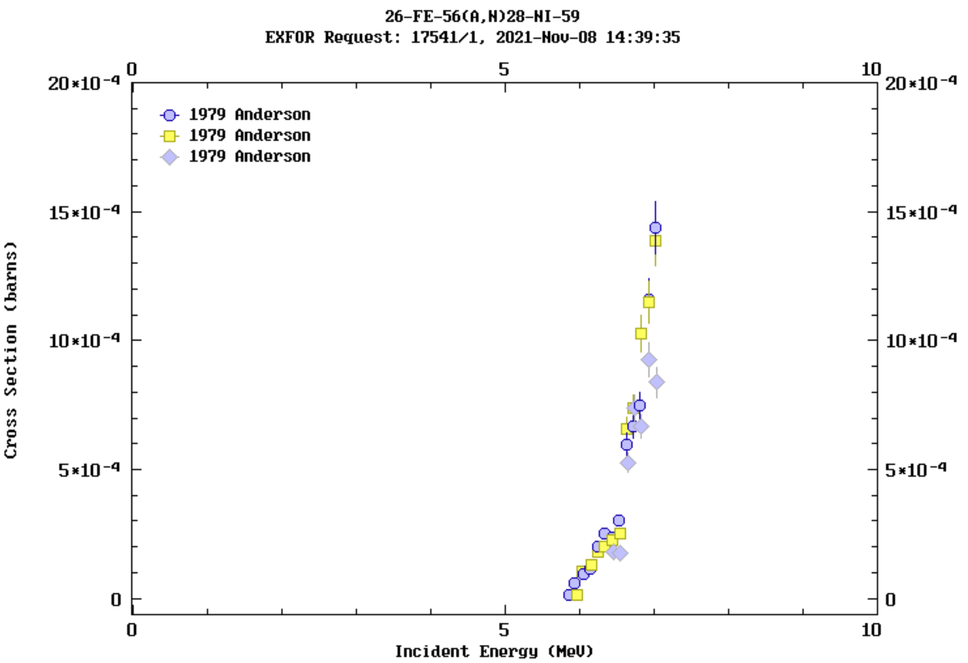
Precise (alpha, n) Cross Section Data Needed: Aluminium in Rock/Shotcrete

Aluminium in materials is critical for (alpha, n) production of radiological neutrons (verbal comm. V. Kudryavtsev)

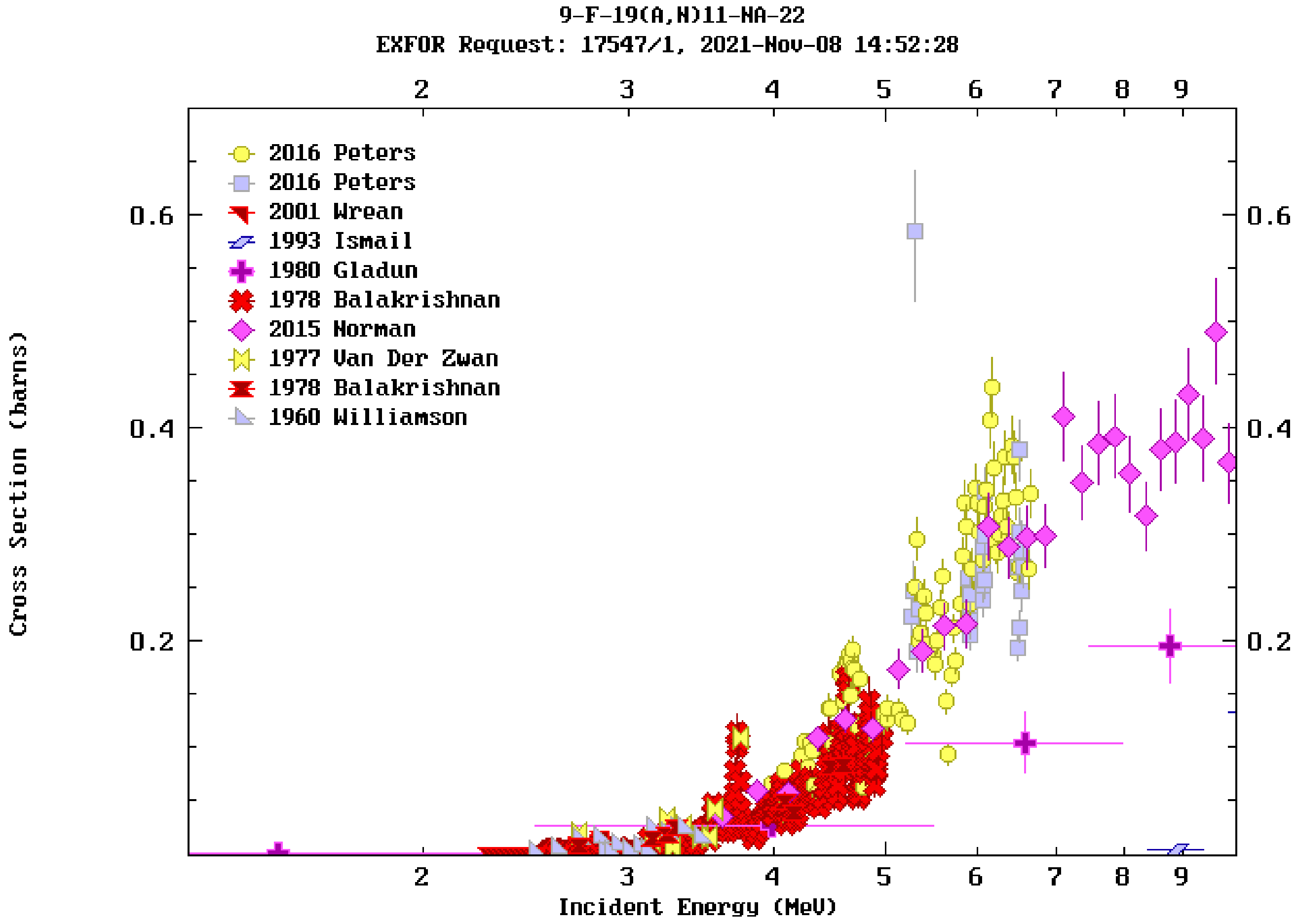


Precise (alpha, n) Cross Section Data Needed:
Iron in Cryostat/Detector

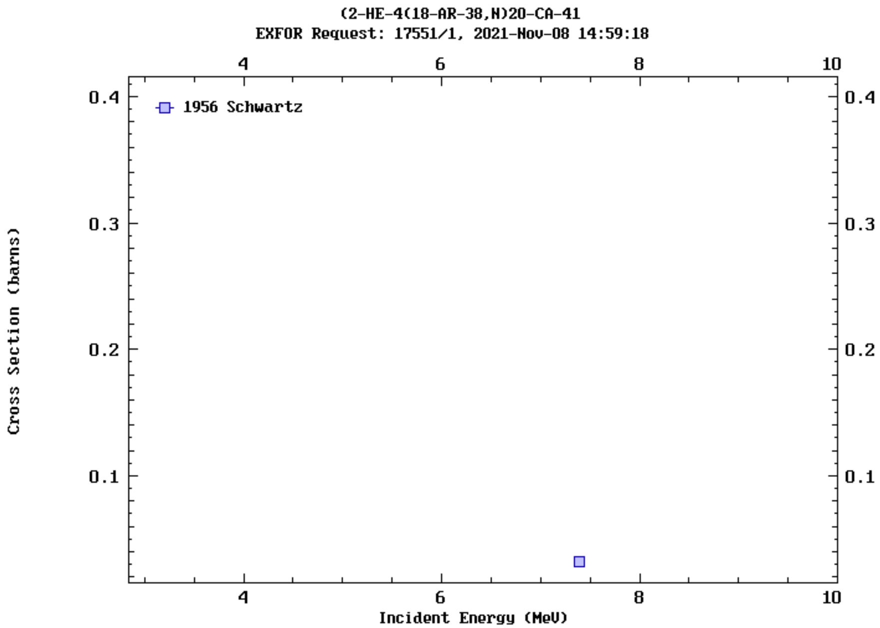


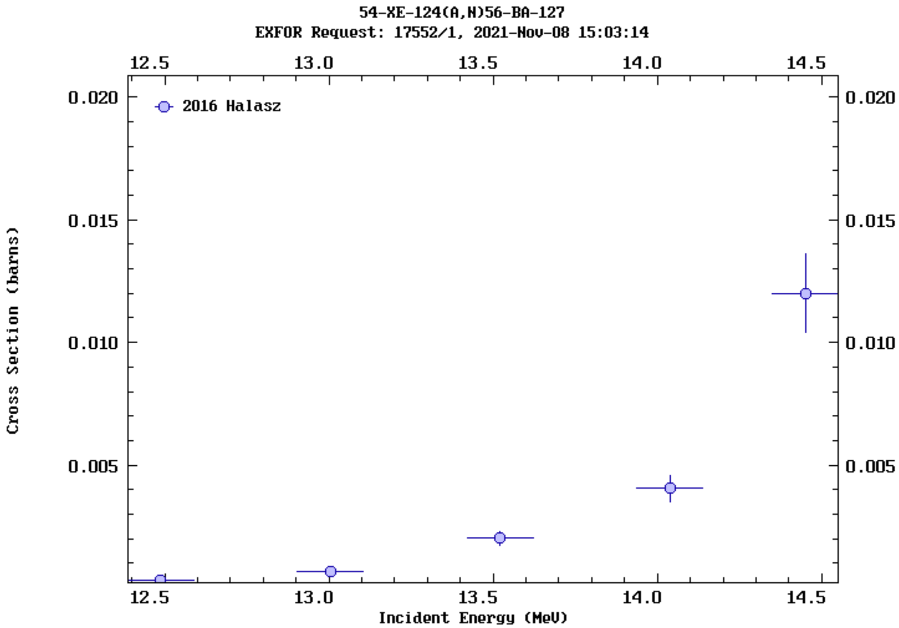


Precise (alpha, n) Cross Section Data Needed: Fluor in Teflon



Precise (alpha, n) Cross Section Data Needed: Argon and Xenon Targets





Precise (alpha, n) Cross Section Data Needed: Lithium Targets (e.g. for AmLi Calibration Sources)