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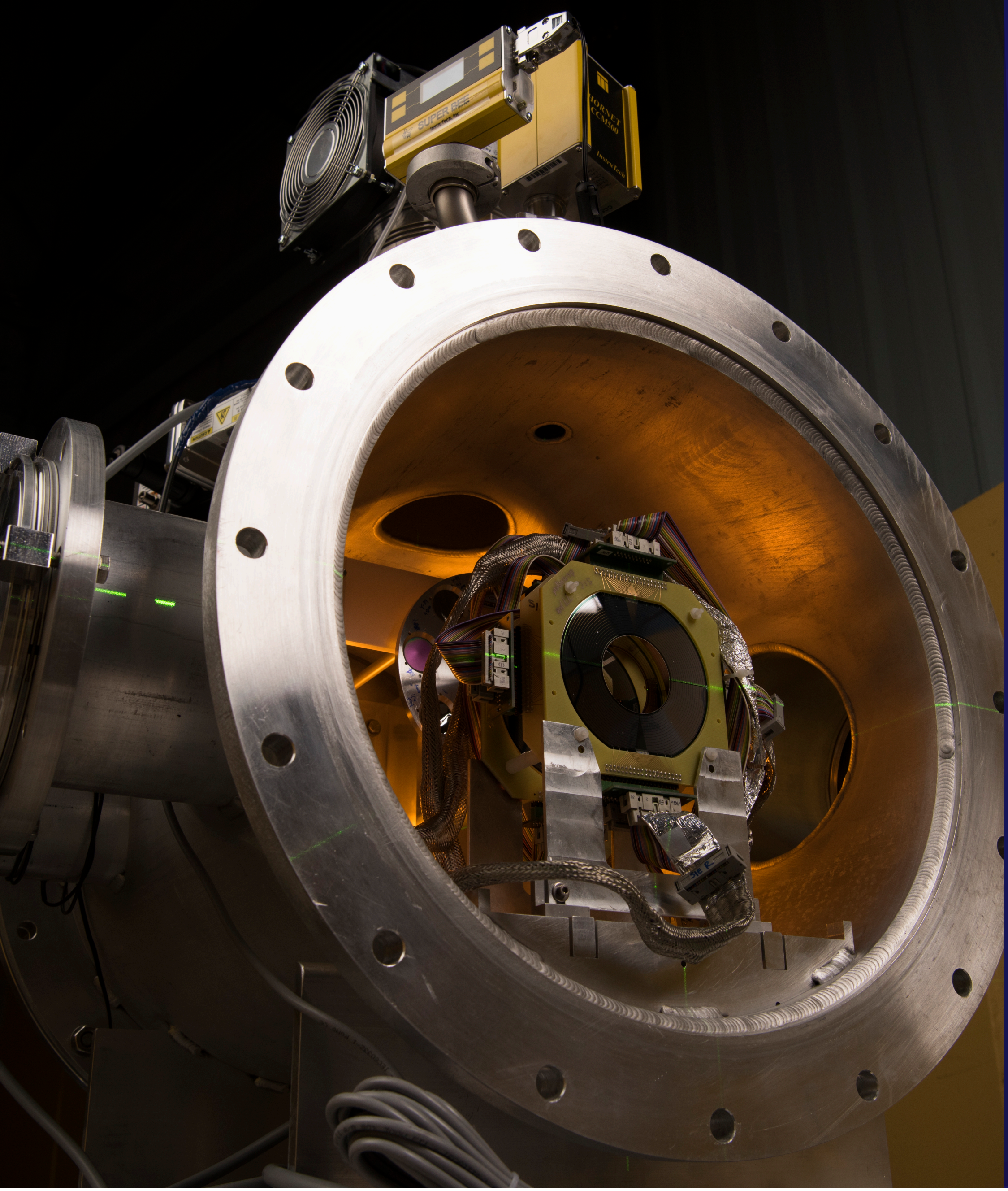

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Measurements of gas production reactions using LENZ at LANSCE.

Status of ^{56}Fe(n,α) and ^{52}Cr(n,α) cross-section measurements

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CSEWG-US National Nuclear Data Week

Brookhaven National Laboratory

November 8, 2017

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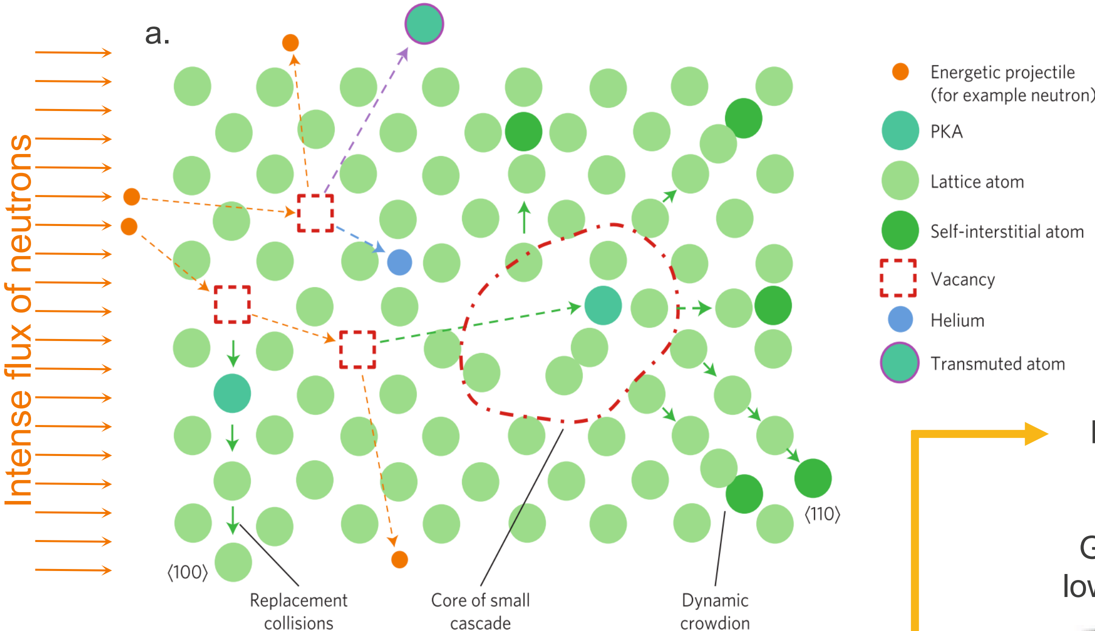
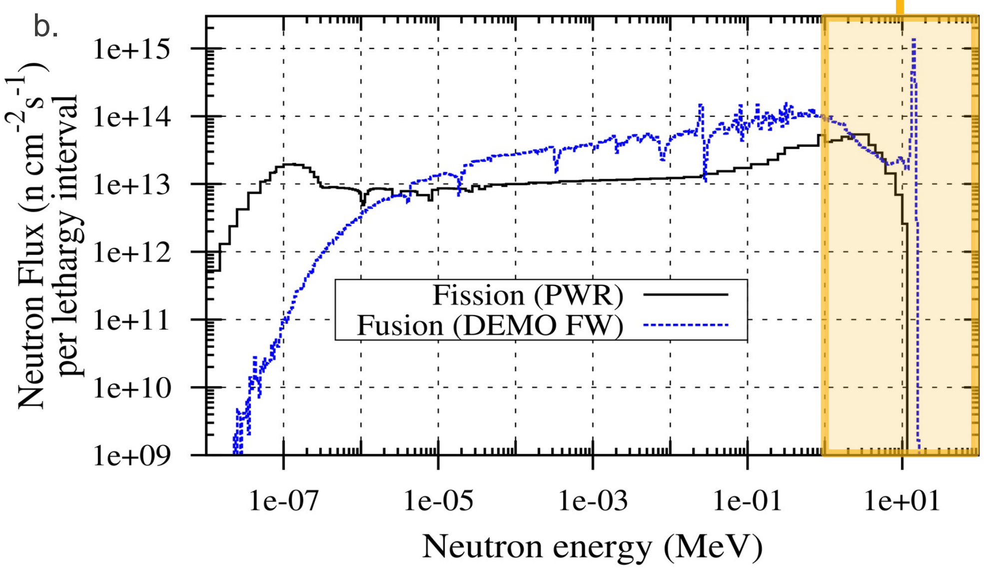
NNSA National Nuclear Security Administration

Radiation Damage to Materials Present in High Neutron Fluence Environments





Displacement per Atom (dpa)

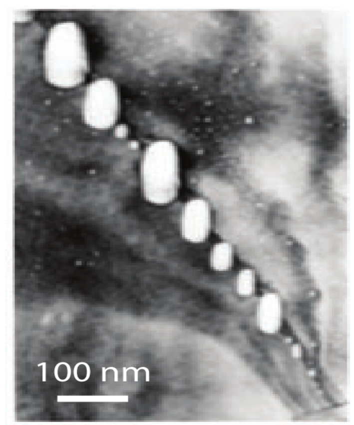
$$dpa = \int_0^t \int_0^\infty \sigma^{dpa}(E_n)\Phi(E_n,t)dE_n dt$$

$$\sigma^{dpa}(E_n) \propto \sum_j \sigma_j(E_n)E_j^{trans}(E_n)$$

More Energetic Neutrons (E_n > 1 MeV) can produce H and He through (n,p) and (n,α) reactions

Given the low solubility of He in most metals & alloys, low concentrations of He can cause significant damage.

c.

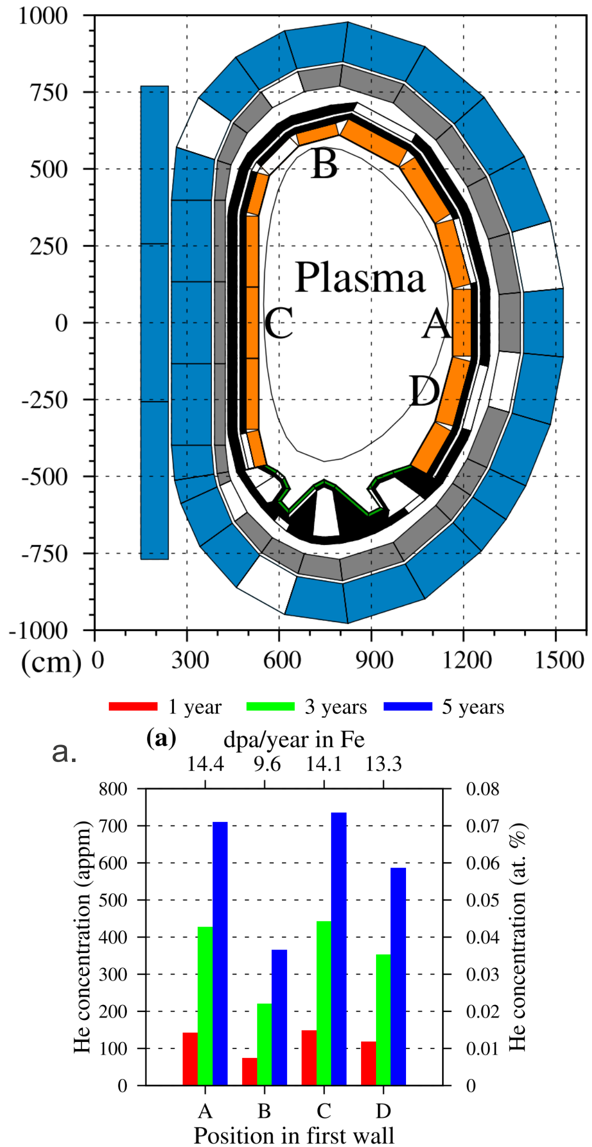


This ratio of ***appm-He/dpa*** defines the phase space of operation for a given material inside a device.

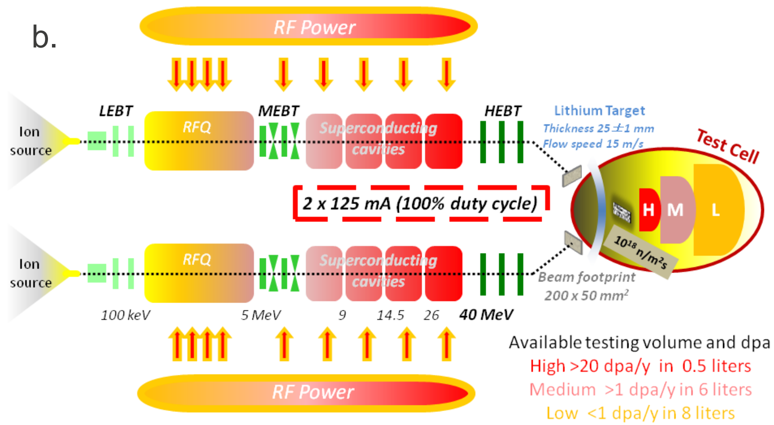
The concentration of He (appm) depends ultimately on the (n,xα) cross-sections over a wide range of neutron bombardment energies.

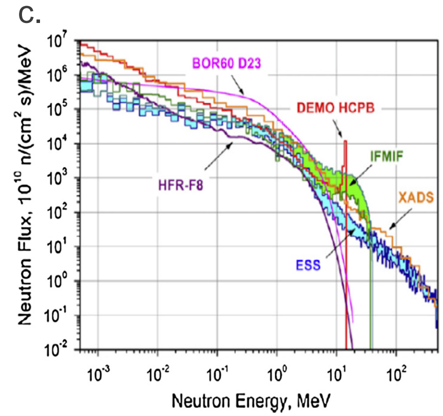
Investigating Material Responses to Neutron Induced Radiation Damage

Modeling DEMO with MCNP



Future Materials Testing with IFMIF (currently in Development)

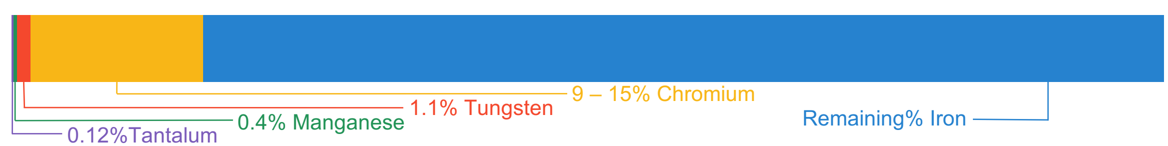




Materials Testing: - Bombard samples with a neutron flux similar to D-T fusion.
- Facilities like IFMIF are still under construction.

Modelling: - Use simulation codes (MCNP/GEANT4) to model materials behavior under various neutron flux conditions.
- Recent simulation studies have investigated the degree of He production in plasma facing materials for fusion devices like DEMO.
- Use evaluated data sets to calculate He production rates these materials. (Gilbert et. al. used 2003 EAF libraries)

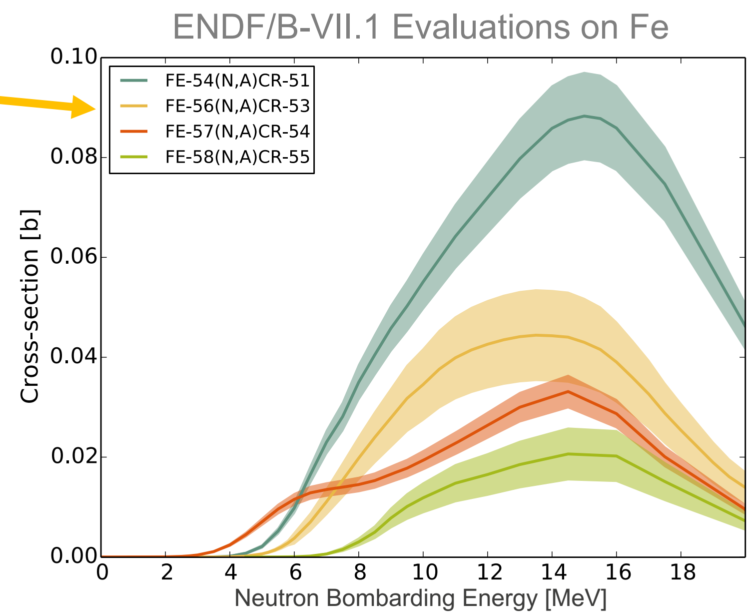
Reduced Activation Ferritic/martensitic (RAFM) steels

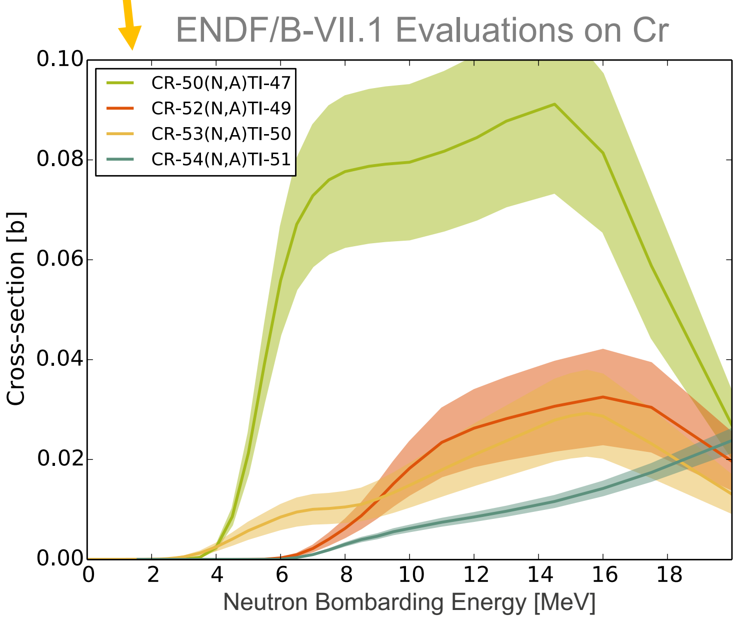


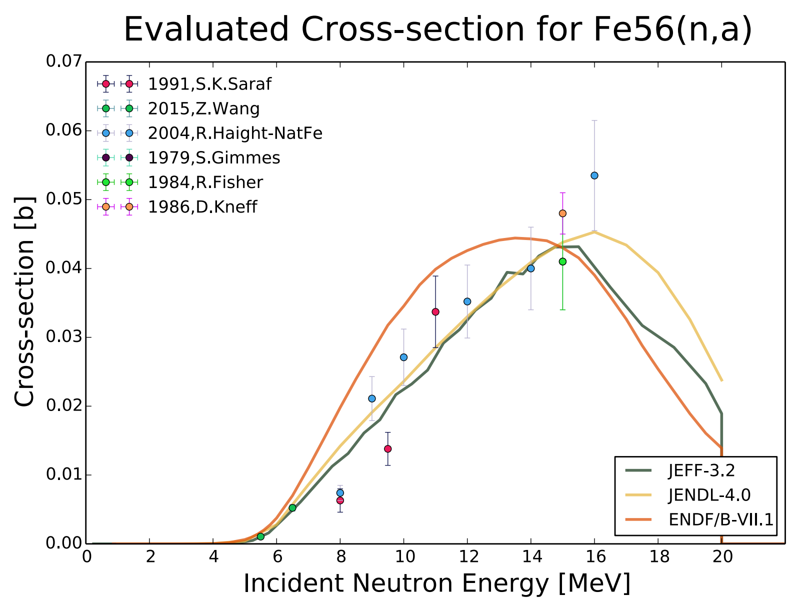
a. Gilbert *et al.* Nucl. Fusion 52 (2012) 083019 (12pp)
b. Knaster *et al.* Nature Physcis Vol. 12 May 2016
c. Knaster *et al.* Journal of Nuclear Materials 453 (2014) 115–119

Current Evaluations of (n,α) on Iron and Chromium Isotopes

^{52}Fe	^{53}Fe	^{54}Fe 5.8	^{55}Fe	^{56}Fe **91.7**	^{57}Fe 2.2	^{58}Fe 0.28	^{59}Fe
^{51}Mn	^{52}Mn	^{53}Mn	^{54}Mn	^{55}Mn 100	^{56}Mn	^{57}Mn	^{58}Mn
^{50}Cr 4.3	^{51}Cr	^{52}Cr **83.8**	^{53}Cr 9.5	^{54}Cr 2.4	^{55}Cr	^{56}Cr	^{57}Cr

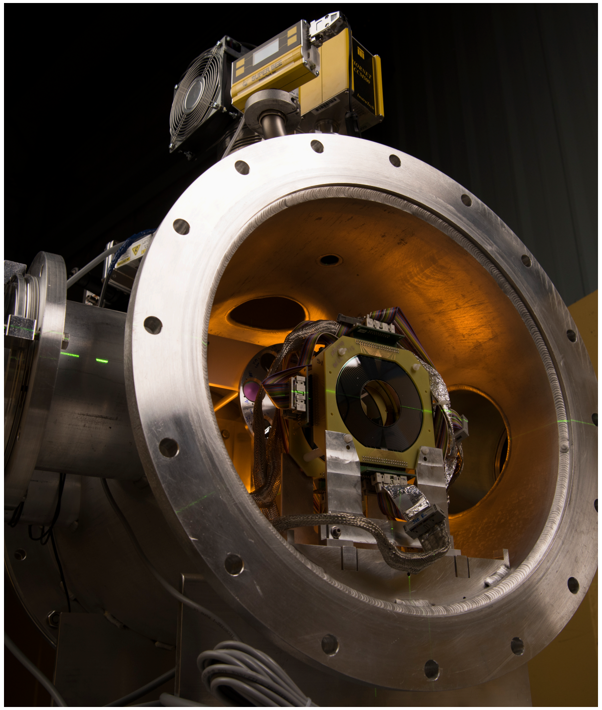


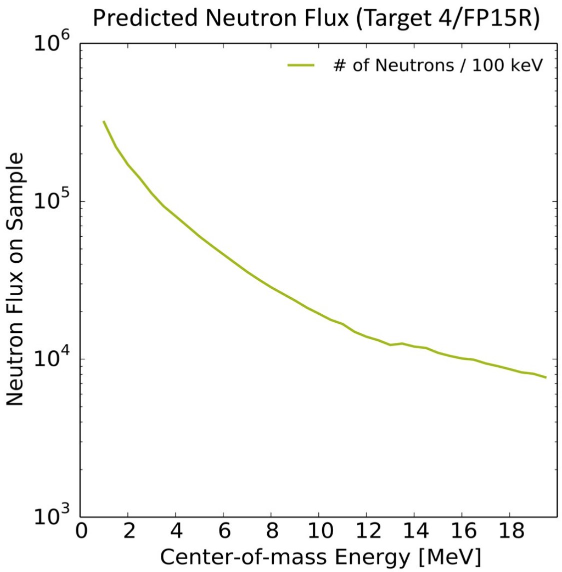




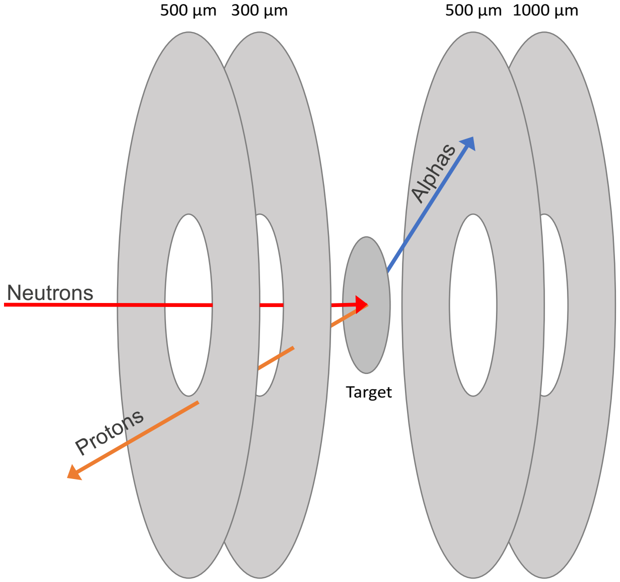
Taking abundances into account most important individual isotopes to focus on are **^{56}Fe** and **^{52}Cr**.

Campaign of LENZ Measurements at the WNR





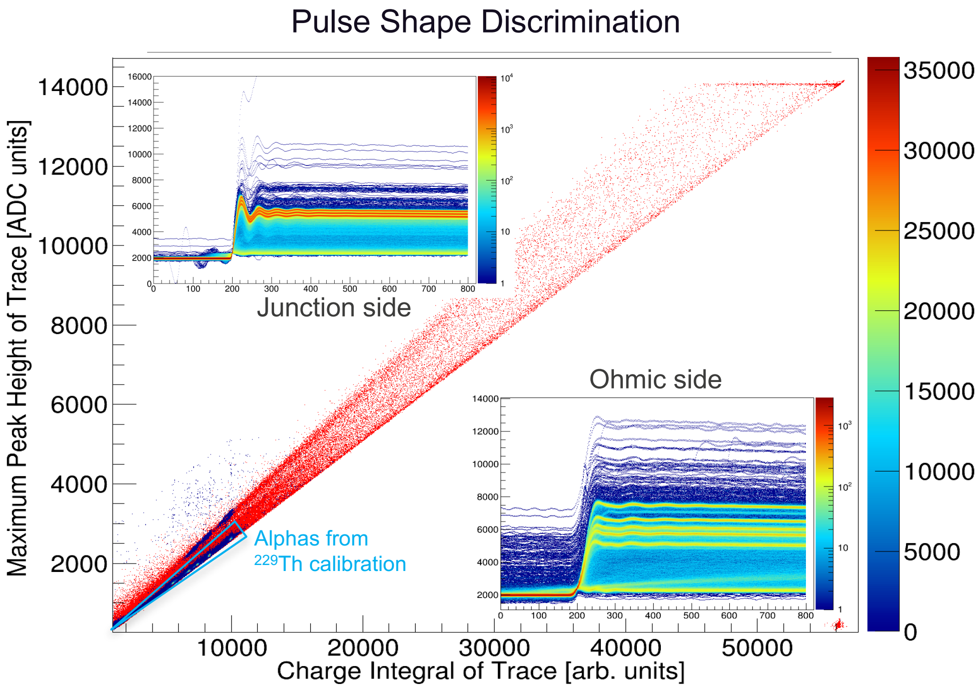
Cartoon Setup from ^{56}Fe(n,$x\alpha$) Measurement

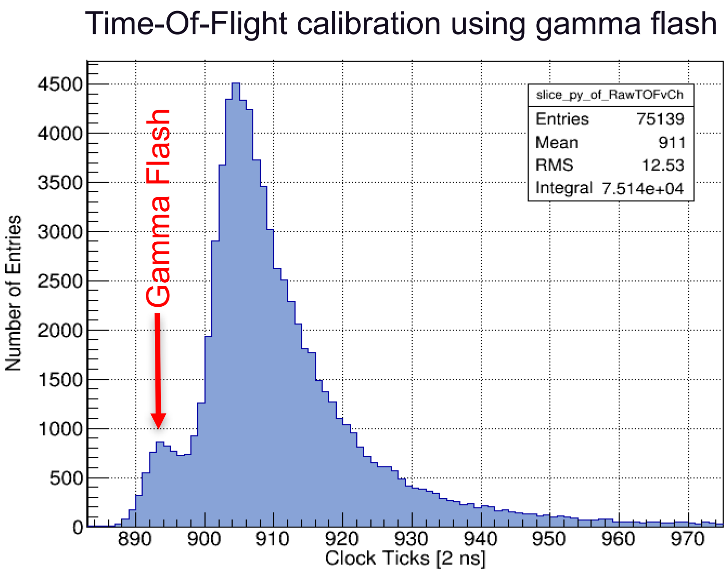


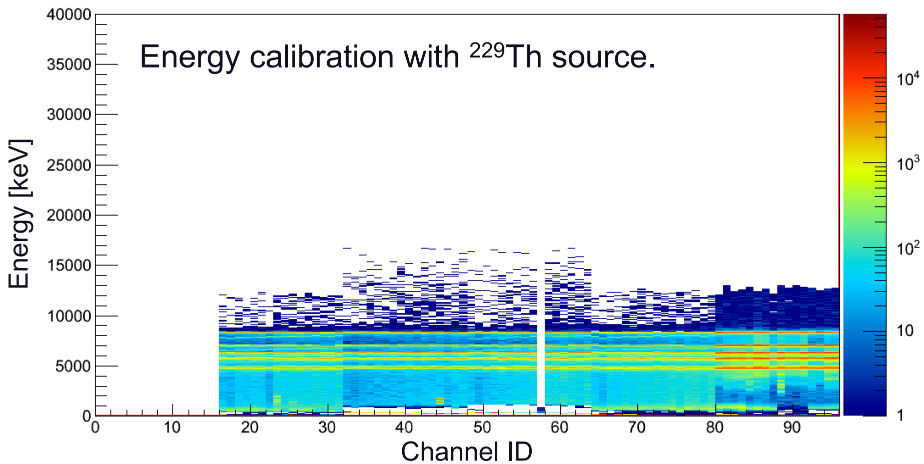
Reaction	Target	Beam Time	Comments on setup.
^{56}Fe(n,α)	1.1 mg/cm^2	Oct 2017	• Used four DSSD's in a two telescope setup. One up stream and one down stream. • Thickness were chosen such that most alpha's up to 30 MeV stop in the first detector while most protons (E > 6 MeV) punch through. This allows for clean veto signals.
^{52}Cr(n,α)	975 µg/cm^2 *	Nov 2017 **	• Plan to four DSSD's in a two telescope setup. Both would be down stream. • Thickness were chosen such that most alpha's up to 30 MeV stop in the first detector while most protons (E > 6 MeV) punch through. This allows for clean veto signals.

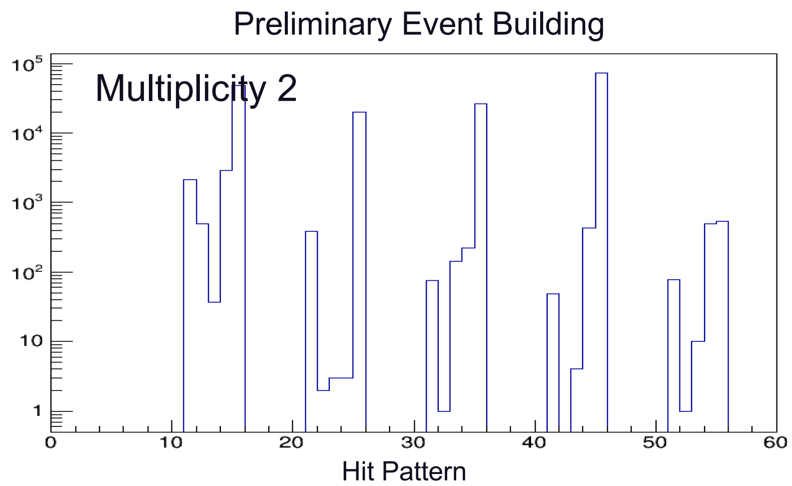
* Target was fabricated by evaporation onto a 6µm gold foil.
** Target fabrication at CINT has been delayed significantly.

Current Progress on (n,α) Measurements



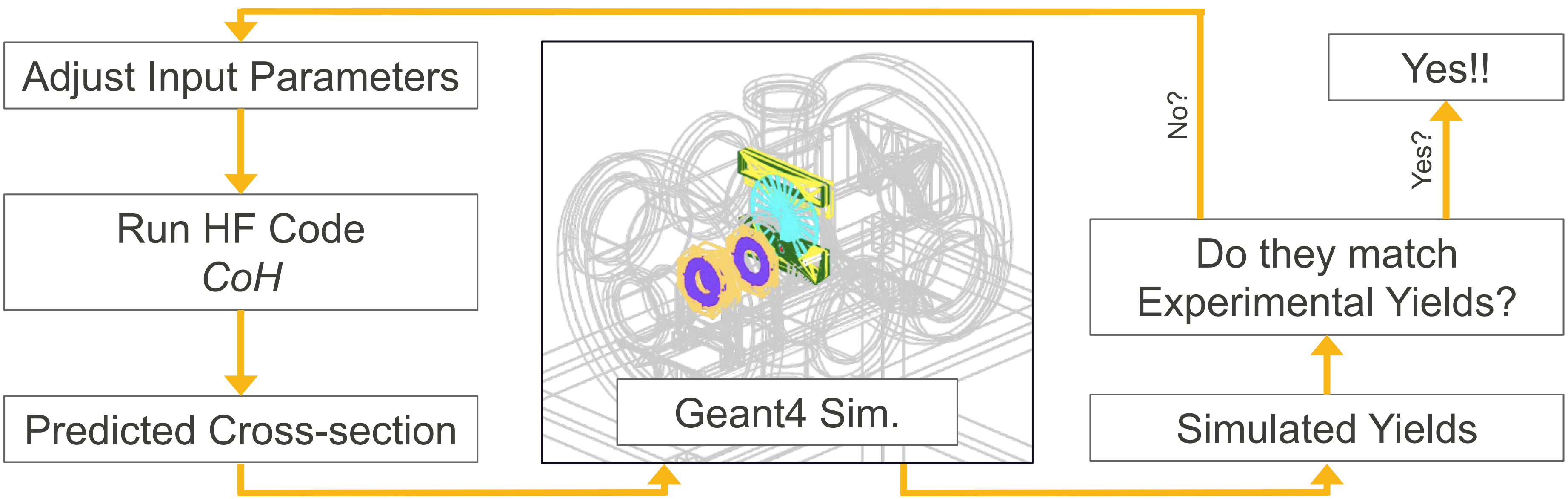




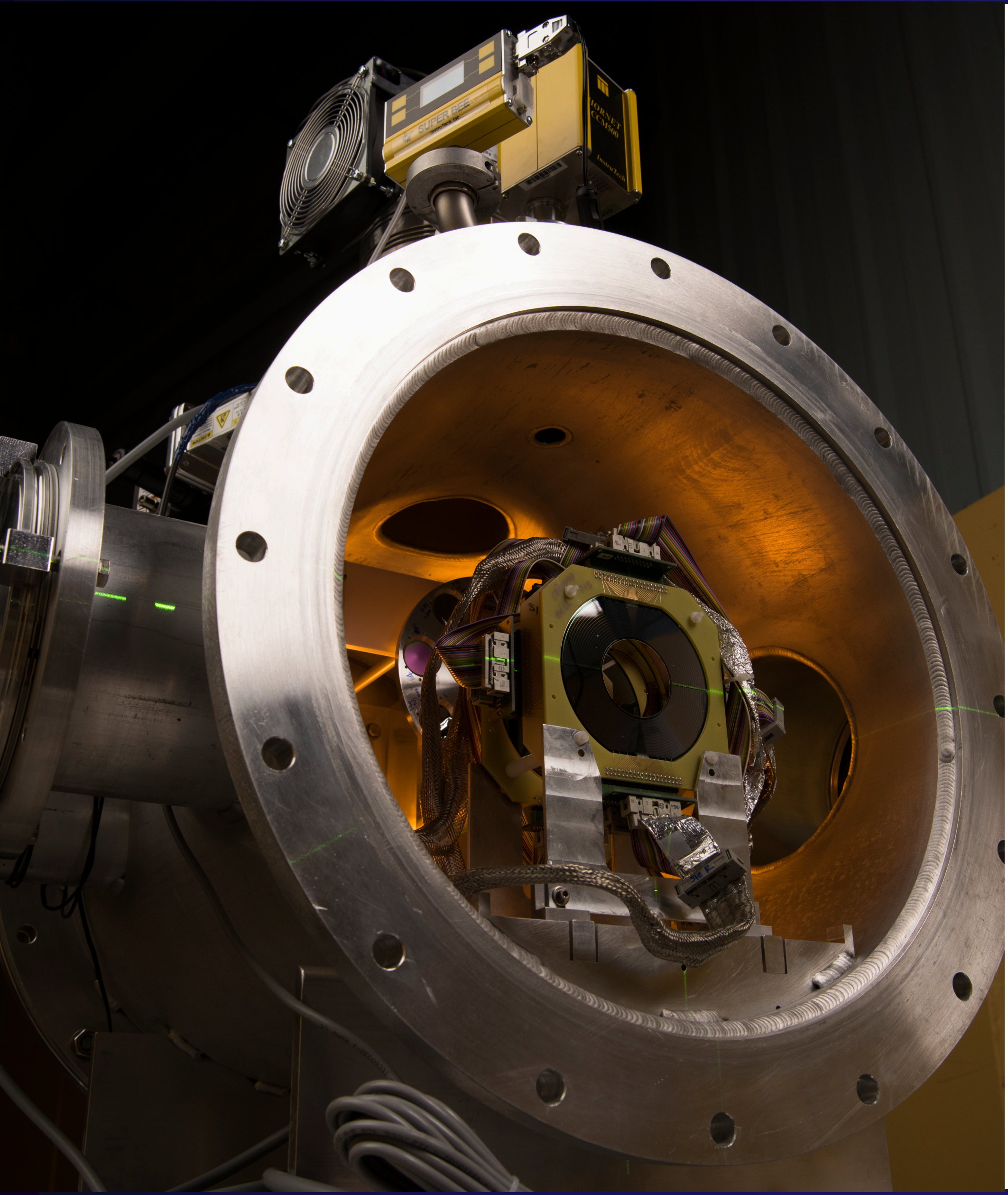


A *Very General* Overview of My To-Do List:

1. Get a ^{52}Cr target from CINT @ LANL
2. Perform ^{52}Cr(n,α) experiment at WNR
3. Finalize our MIDAS unpacker and event builder.
   - Optimize PSD gates (also generate dE-E plots to benchmark PSD capabilities)
   - Optimize coincidence time windows
   - Determine incoming neutron flux
   - … (Things that I'm forgetting)
4. Extract (n,α) yields as a function of angle.
5. ... (More things that I'm forgetting.)
6. Finally, Use a forward analysis techniques with extracted (n,α) yields to determine a (n,α) cross-section with respective uncertainties.



Thank you for your time



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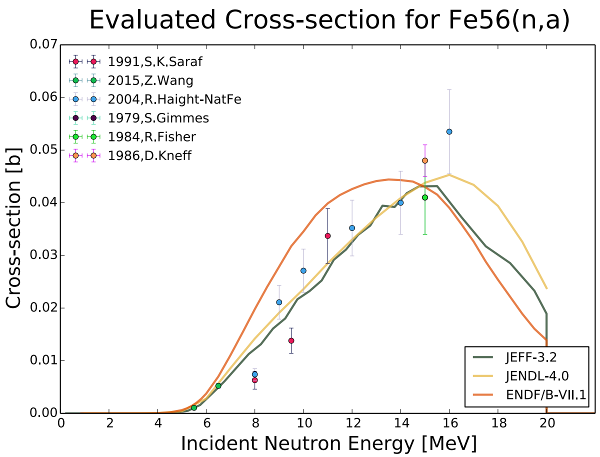
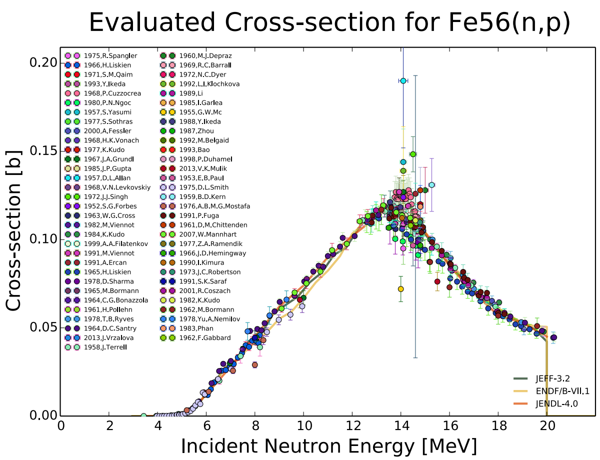
Chris Prokop

Any questions or comments?

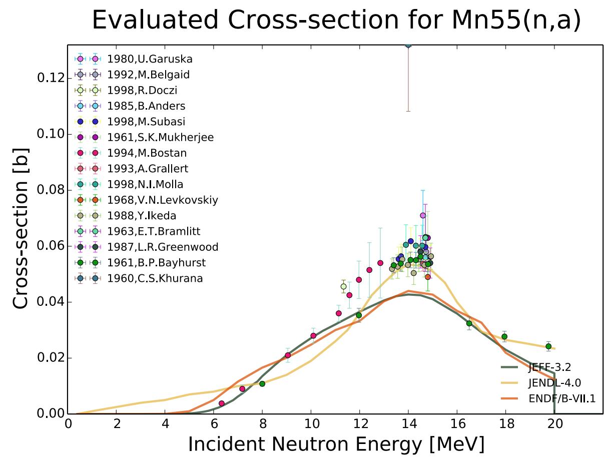
Previous Works with Current Evaluations.

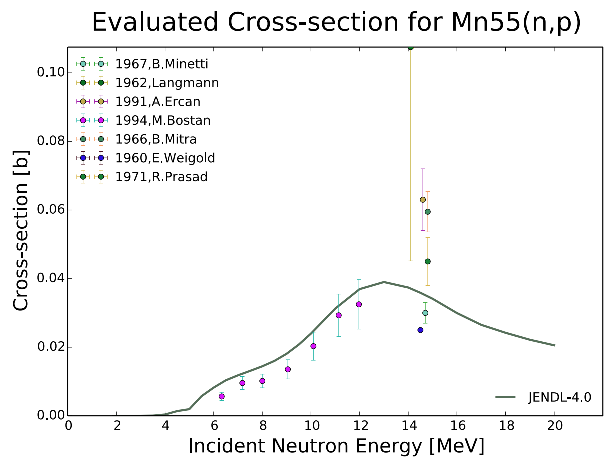
^{56}Fe



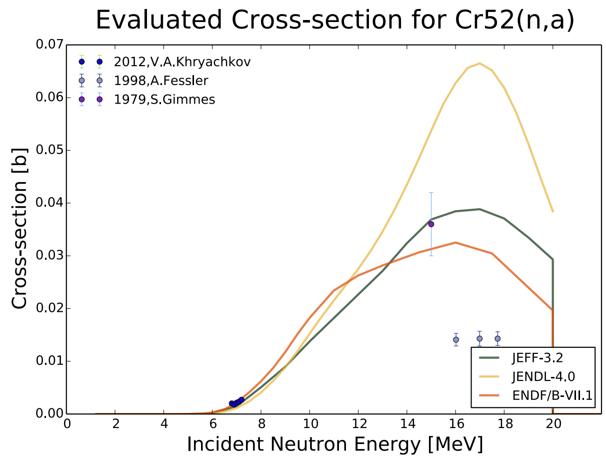


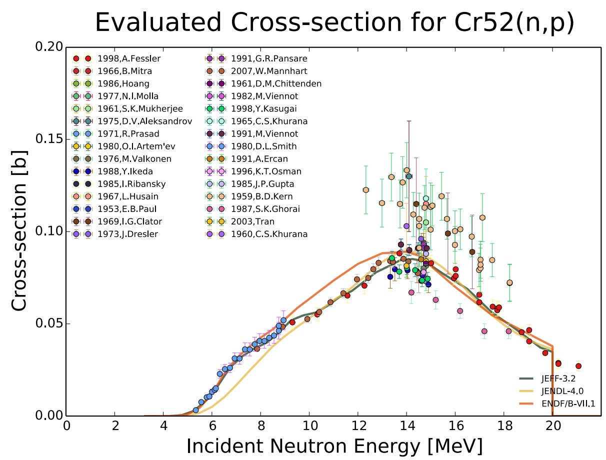
^{55}Mn





^{52}Cr

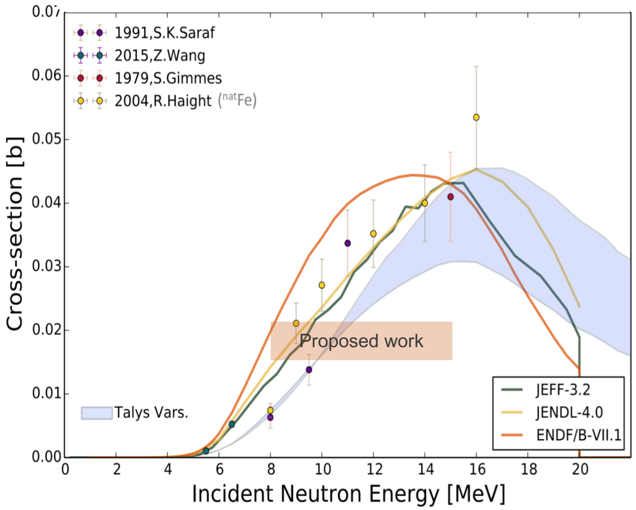




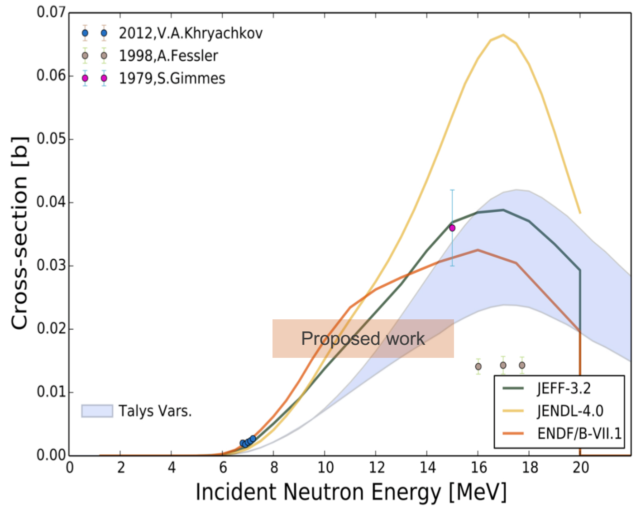
^{56}Fe(n,α) and ^{52}Cr(n,α) Measurements with LENZ

Current experimental cross section data

^{56}Fe(n,α)



^{52}Cr(n,α)



Evaluation depends on fitting HF models to experimental data.

Most influential input parameters in HF models for these (n,α) reactions are:

Level Densities

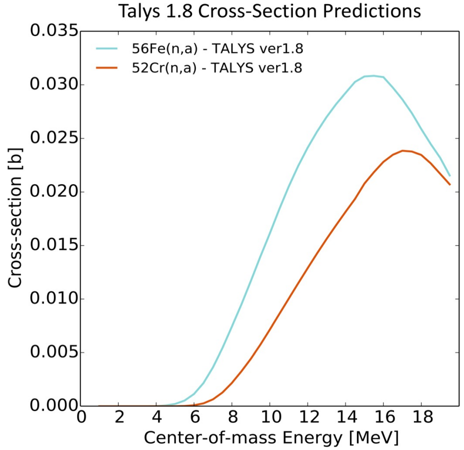
- *Fermi Gas Model*
- *Constant Fraction Model*
- *Spin Cutoff Parameter*

Alpha Optical Model Parameters

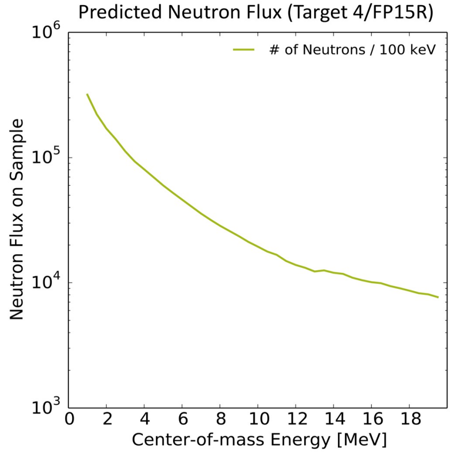
- *McFadden & Shatchler*
- *"Normal" alpha potential*

There is a definite need for accurate exp. data (within the 8-15 MeV energy region) to constrain HF models for these two reactions.

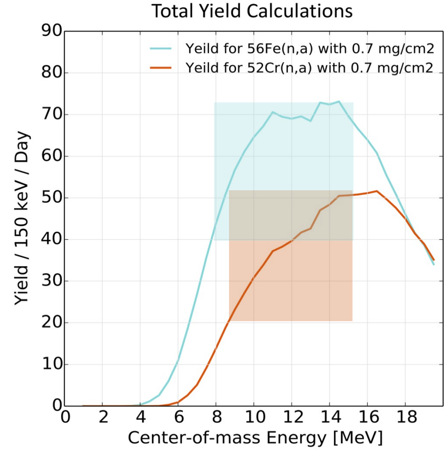
Talys 1.8 Cross-Section Predictions



Predicted Neutron Flux (Target 4/FP15R)



Total Yield Calculations



Yield Prediction:

- Conservative Talys Cross Sec.
- Proton beam flux (4 μA)
- Detector solid angle (20° – 52°)
- Target area (2.835 cm^2)
- Target Thickness (0.7 mg/cm^2)

^{56}Fe(n,α):
~ 40 - 70 events / Day / **150 keV**

^{52}Cr(n,α):
~ 20 - 50 events / Day / **150 keV**

Got **~ 21 days of beam time** to get statistical uncertainties ≲ 5% for each 150 keV energy bin between E_n ~ 8 - 15 MeV

Main Reactions Contributing to α-Production

Used Talys 1.8: **Level Density Model** = Constant temperature + Fermi gas model
Alpha OMP = McFadden and Satchler