The neutron production facility at the Lawrence Berkeley National Laboratory

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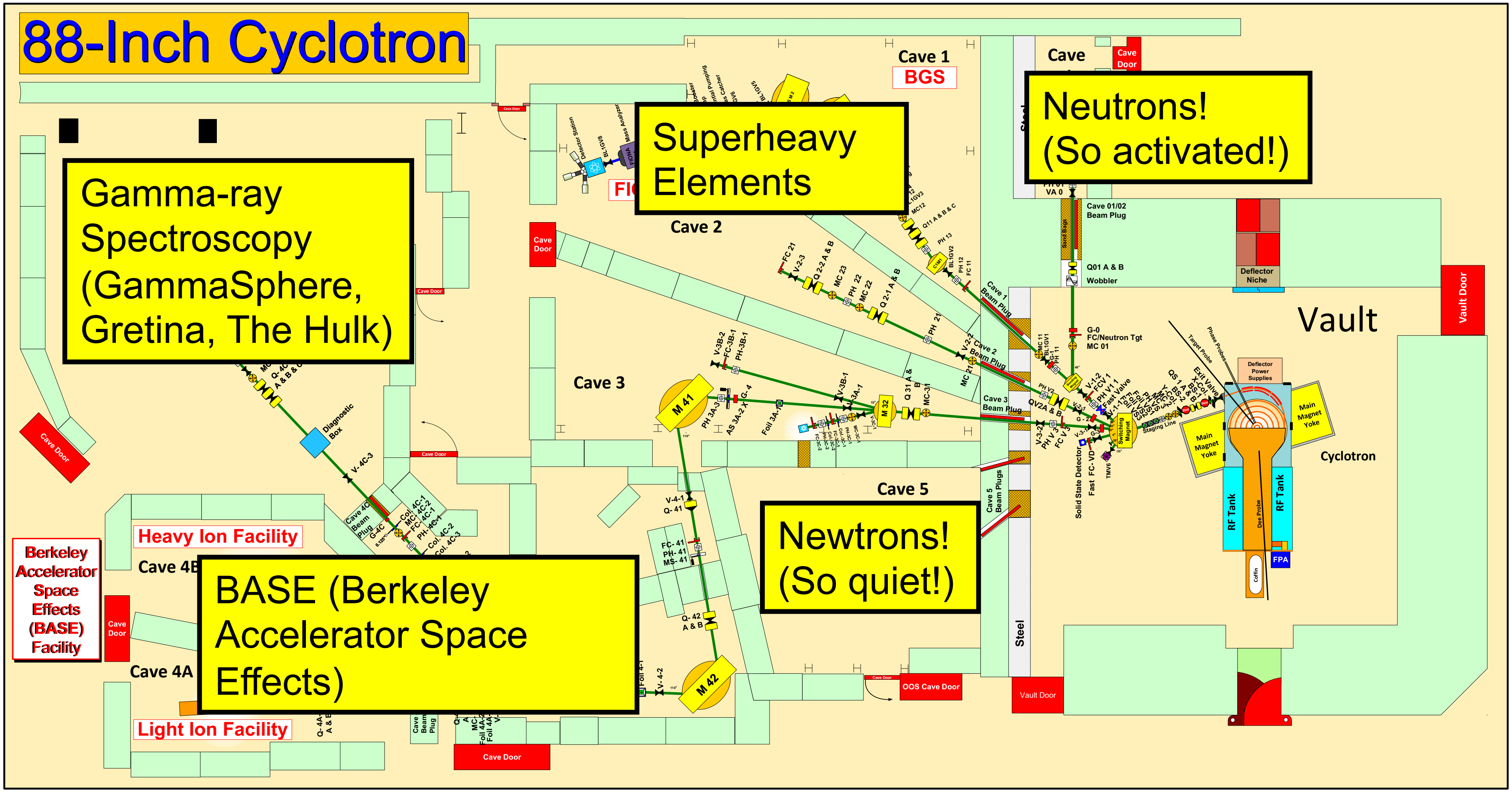
The 88-inch cyclotron is a K140 accelerator producing Z=1-92 beams (up to 65 MeV p,d's), operating since 1961.

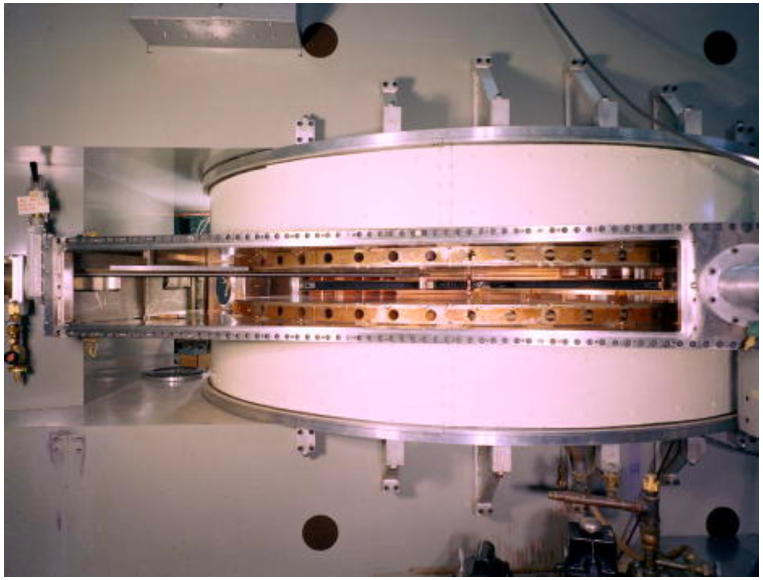


A neutron production facility has been developed at LBNL's 88-inch cyclotron over the past few decades

Sources:
- Deuteron breakup (white)
- $^{7}Li(p,n)$ (quasi-monoenergetic)

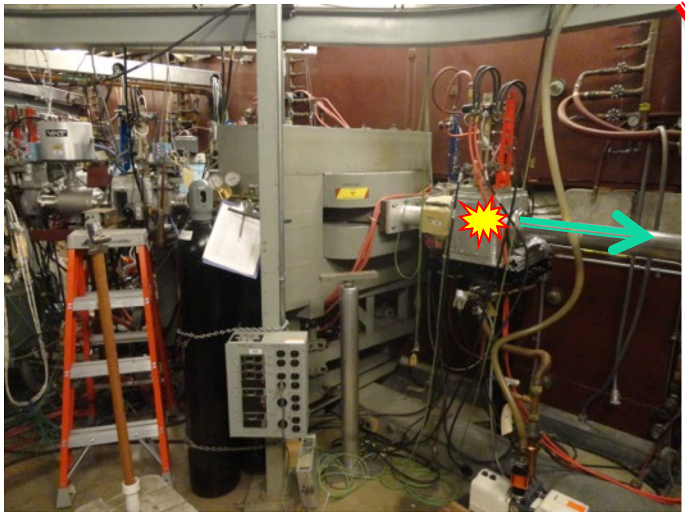
Applications:
- Neutron energy spectral measurements
- Scintillator characterization
    - Timing
    - Light yield
    - Efficiency
- Equipment damage
- Isotope production cross sections

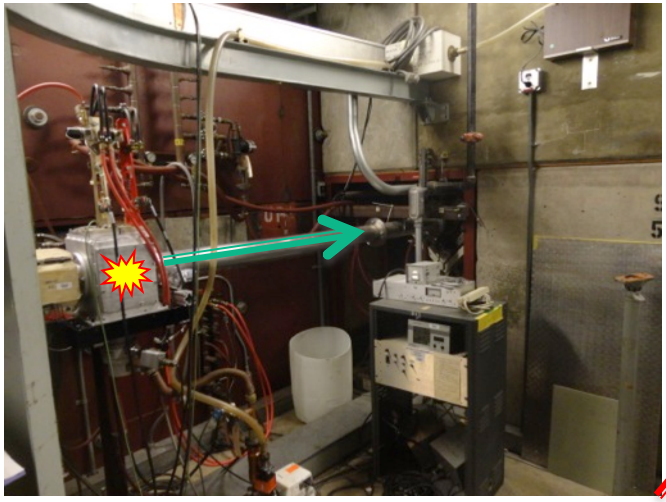
Developing Capabilities (the future!):
- FLUFFY – Short-lifetime fission product yields
- GENESIS – Inelastic scattering

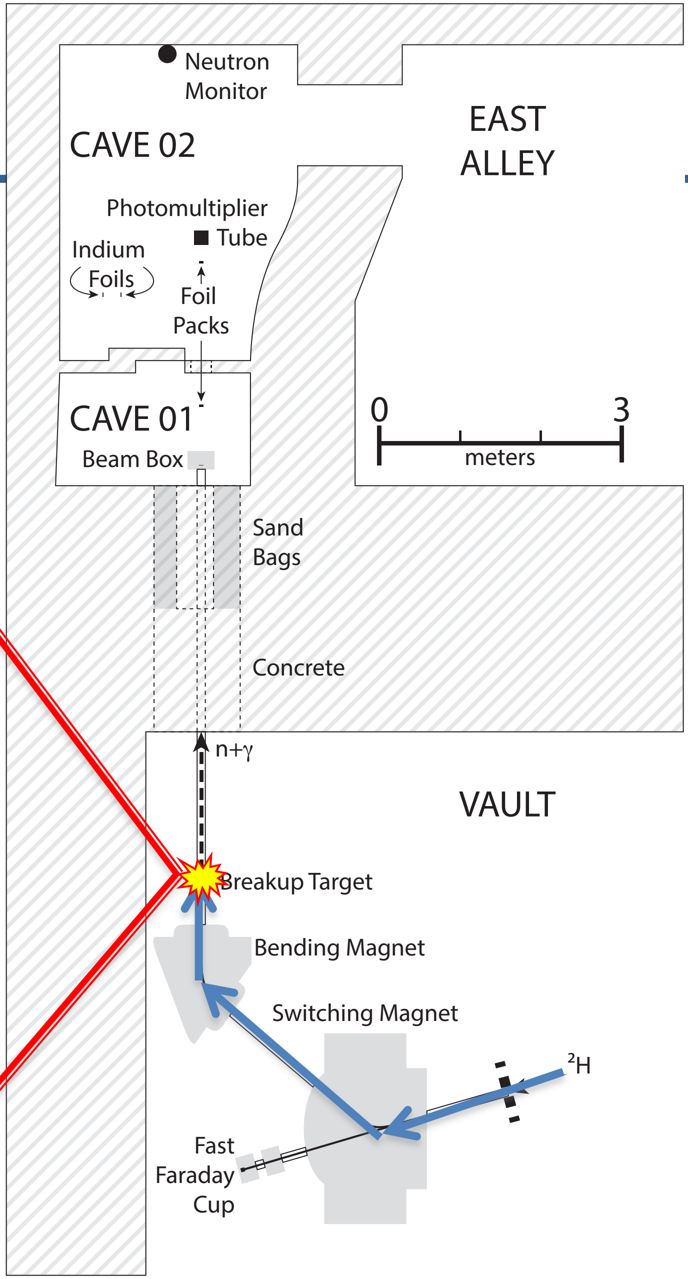


The 88-inch cyclotron

Deuteron breakup in, or into, Cave0 has been our workhorse







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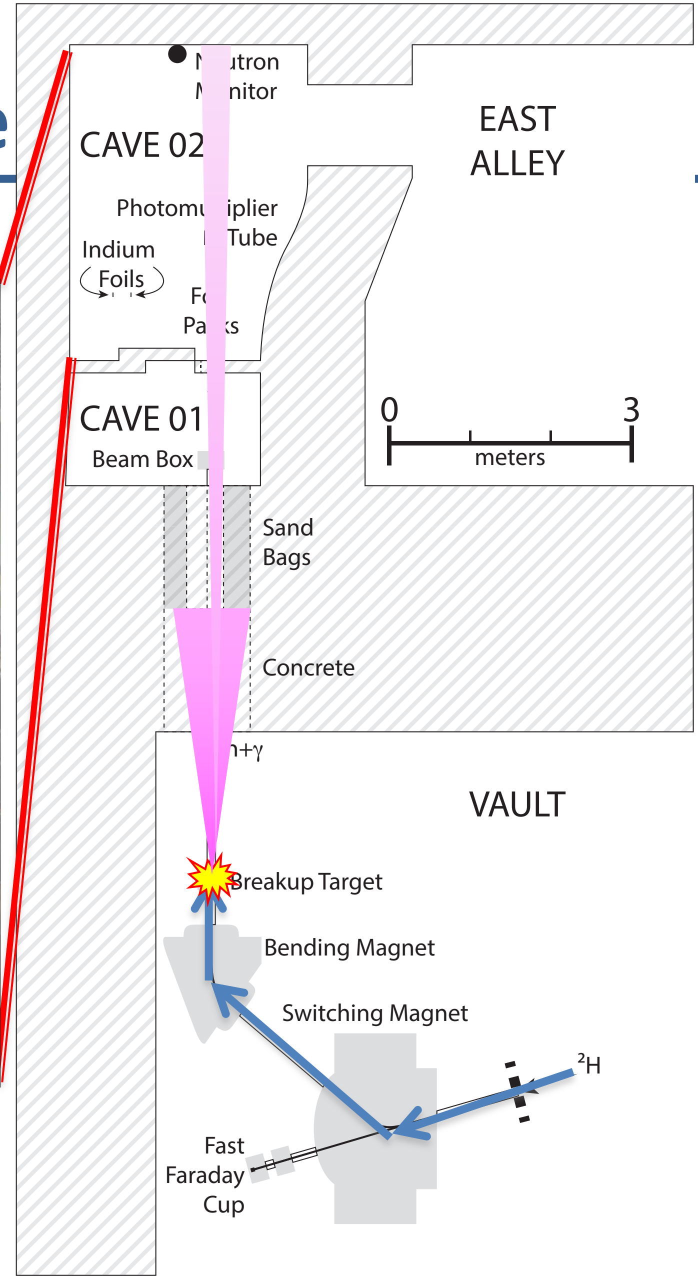

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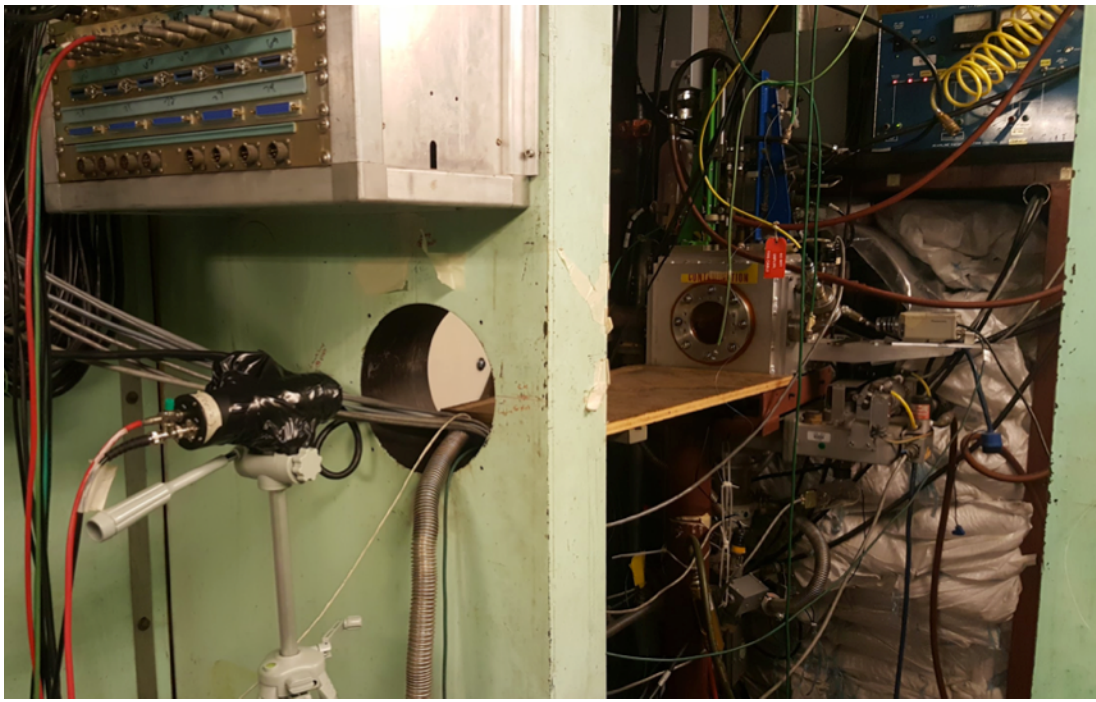

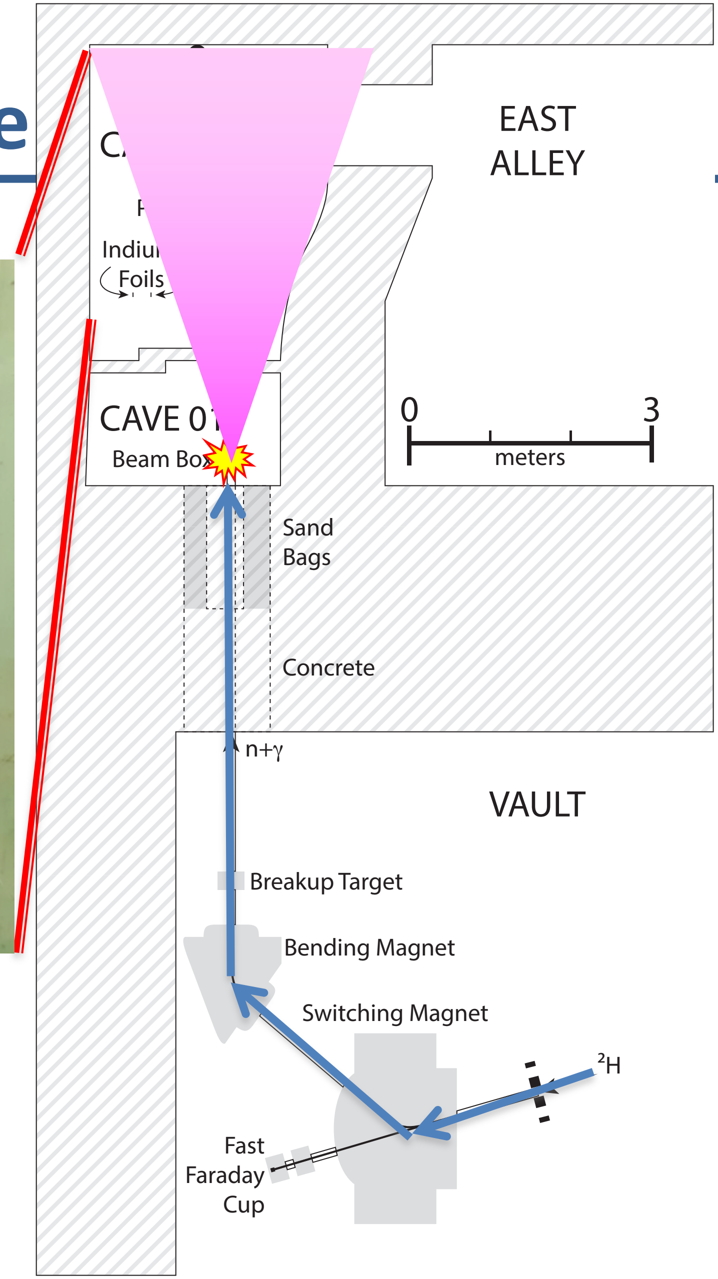

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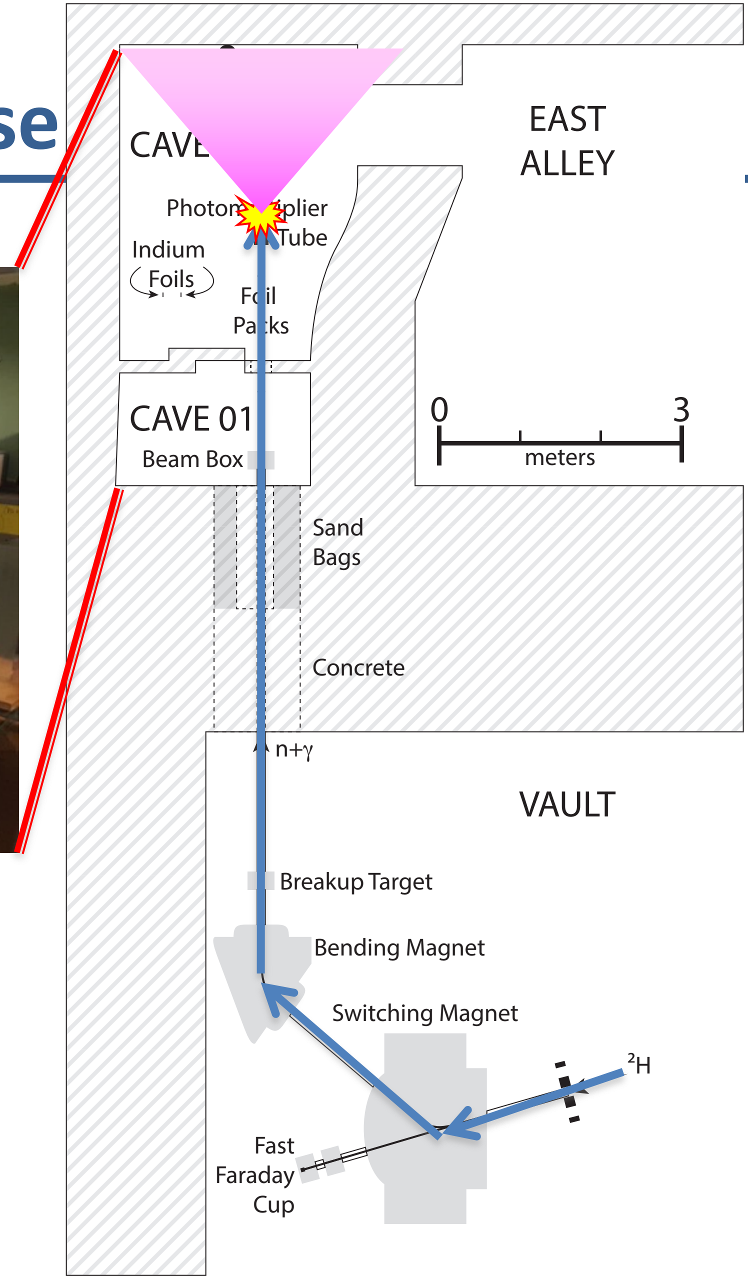
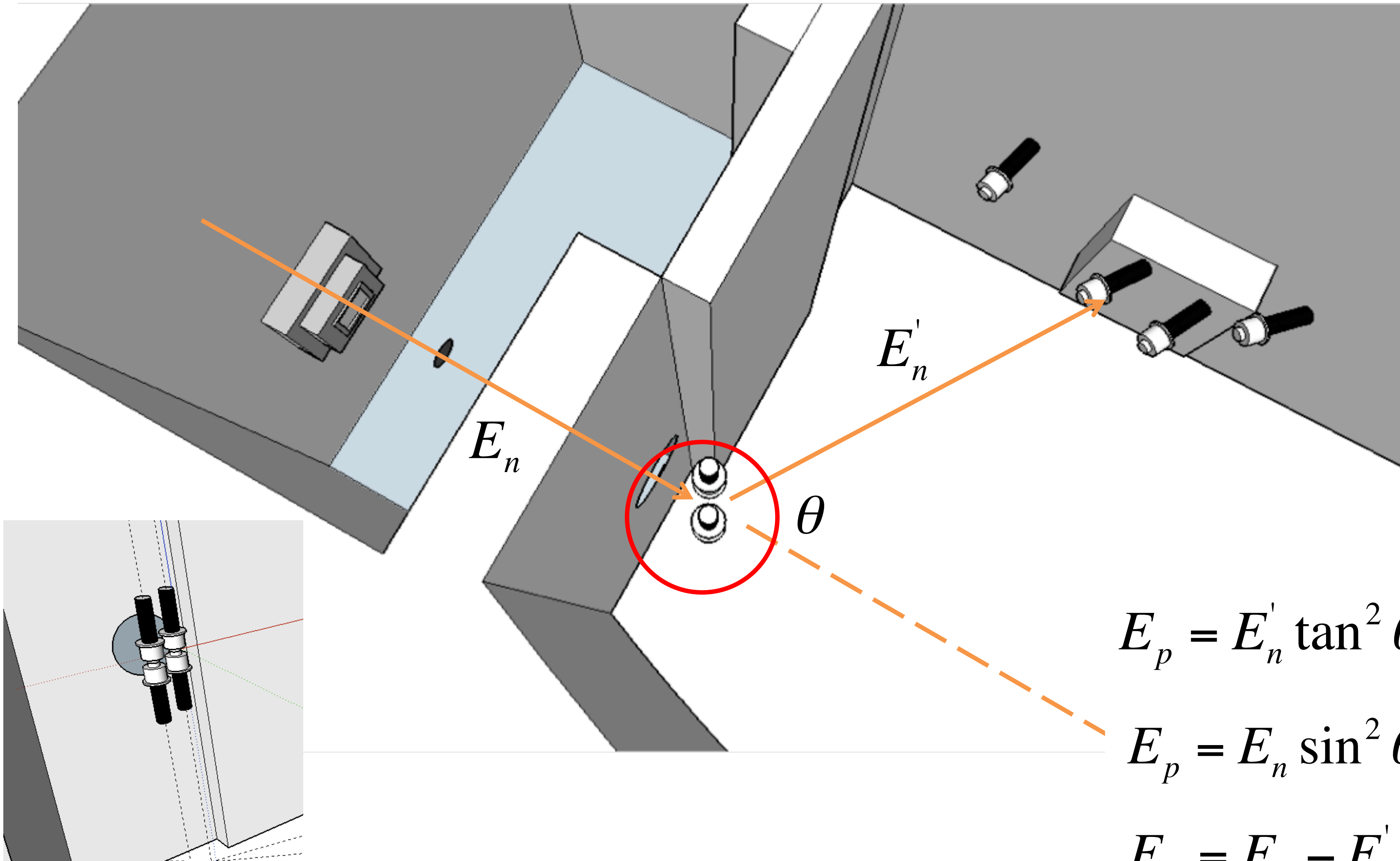


To mitigate frame overlap in energy spectral measurements, we developed a “double time-of-flight” technique



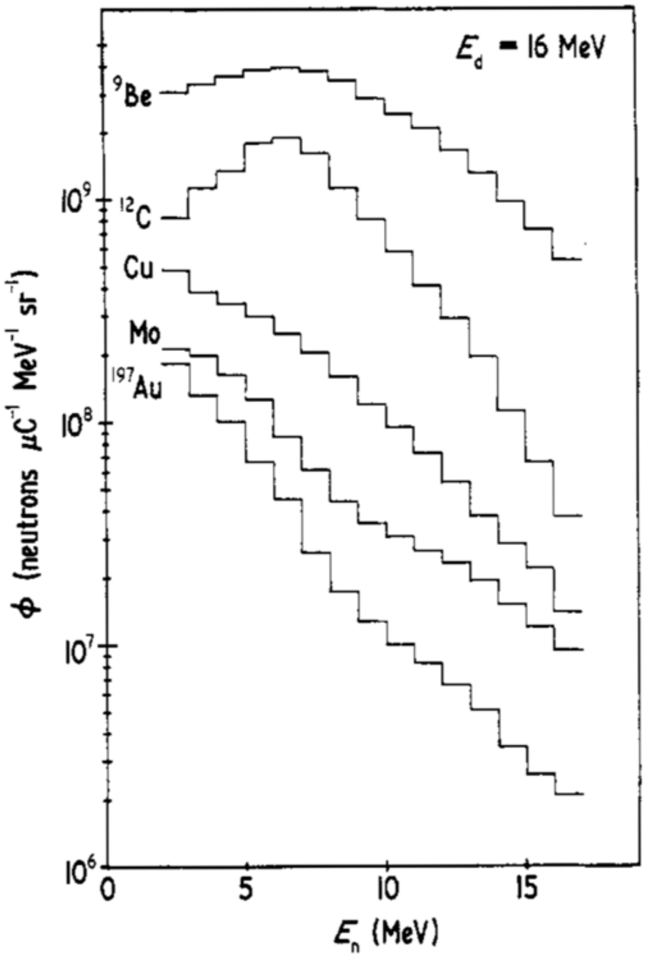
$$E_p = E_n^{'} \tan^2 \theta$$

$$E_p = E_n \sin^2 \theta$$

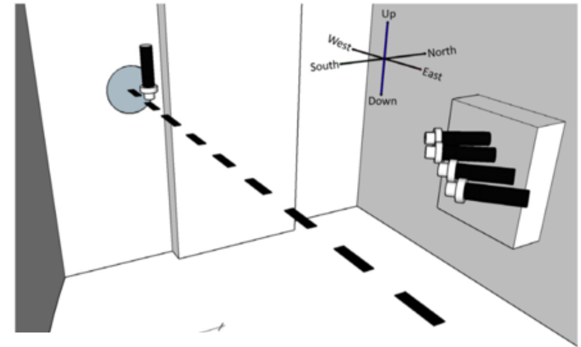
$$E_p = E_n - E_n^{'}$$

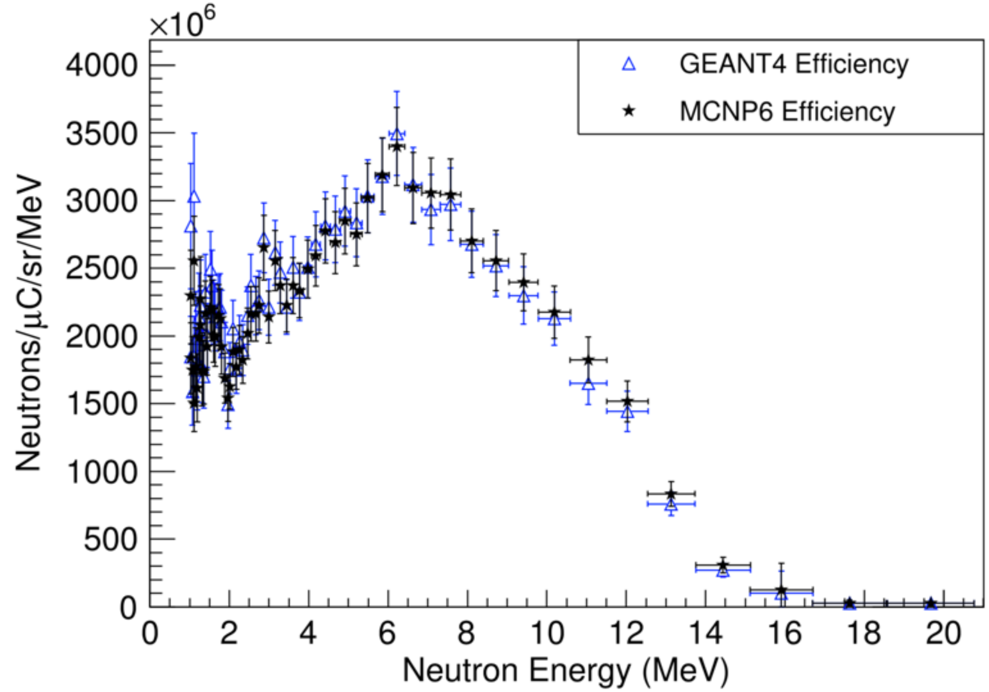
Harrig et. al, NIM A 877 (2018) 359.

Using this "dToF" method, we were able to improve the 16 MeV $^{9}Be(d,n)$ deuteron breakup spectral measurement



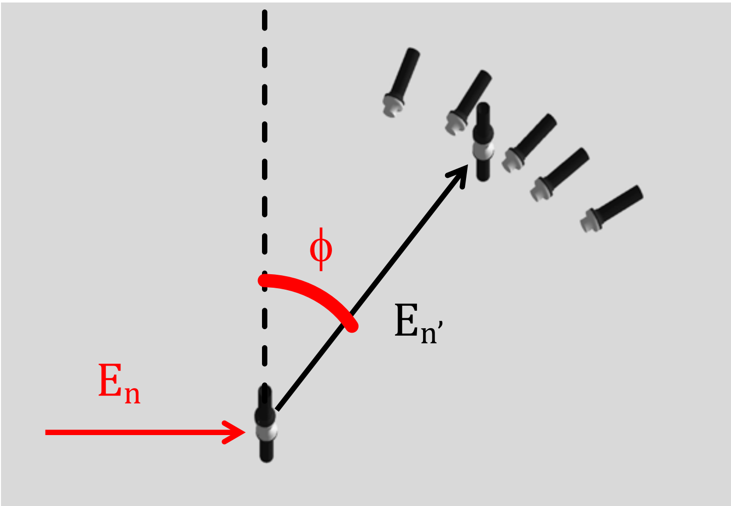
Meulders et. al, Phys. Med. Biol., **20(2)**, 235 (1975).

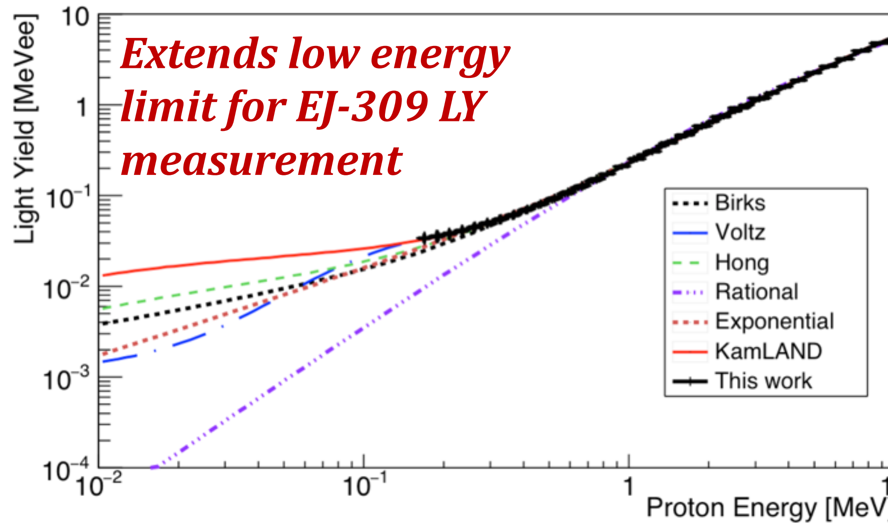


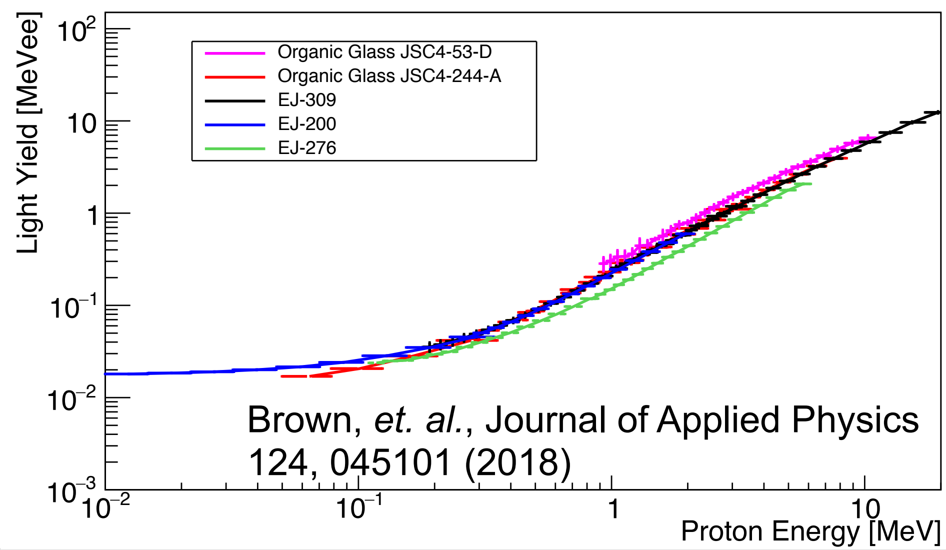


Harrig et. al, NIM A 877 (2018) 359.

Using the same "dToF" method, we have characterized scintillator light yield lower in energy than ever before

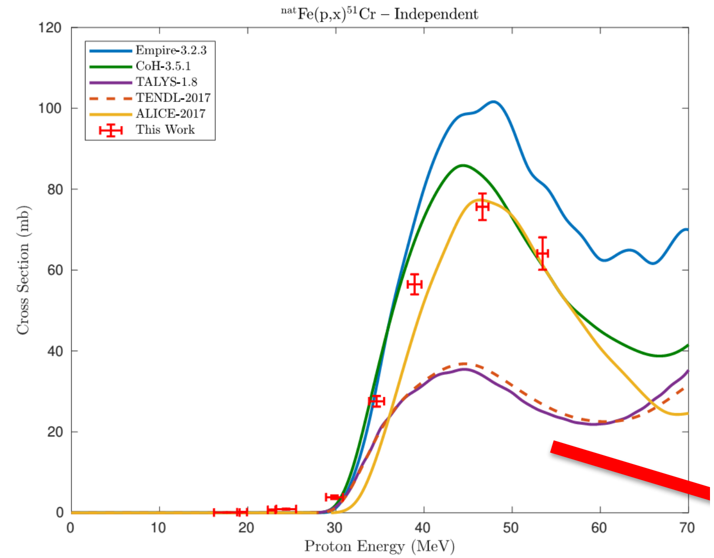




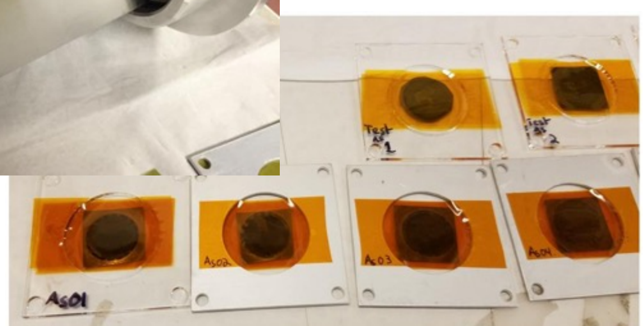


Thanks to Thibault Laplace, Bethany Goldblum…

The Berkeley Nuclear Data group has begun a program to measure cross sections important to isotope production



Foil packs use degrader layers to measure full excitation function in one experiment



Developing target-plating capabilities

Each Rx is a thesis:

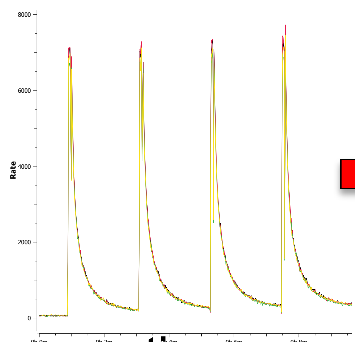
- $Fe(p,x)^{51,52m/g}Mn$
- $Zn(n,x)^{64,67}Cu$
- $Ir(d,x)^{193m}Pt$
- $La(p,x)^{134}Ce$
- $^{235}U(d,x)^{236m}Np$
  $Tm(d,x)^{169}Yb$
- $As(p,x)^{72}Se, ^{68}Ge$
- $^{86}Sr(d/p,x)^{86}Y$

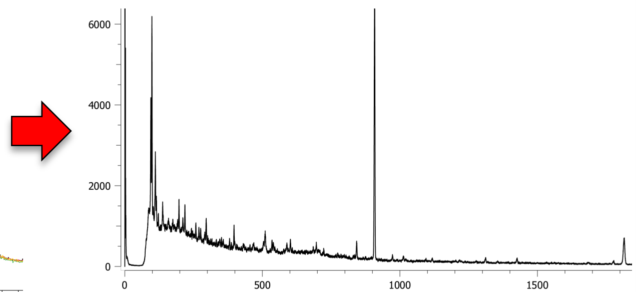
Aiming towards simultaneous production using breakup neutrons from production target!

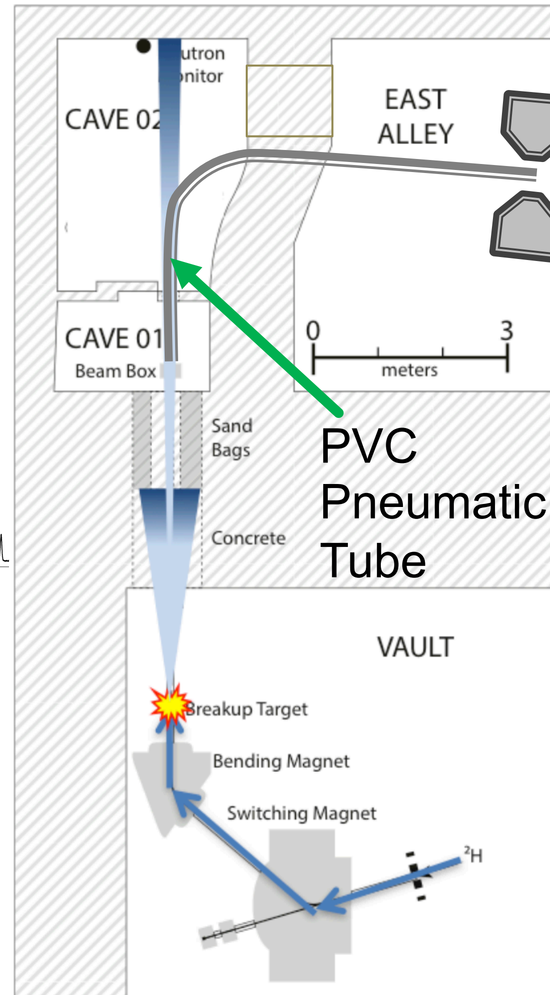
Thanks to Andrew Voyles

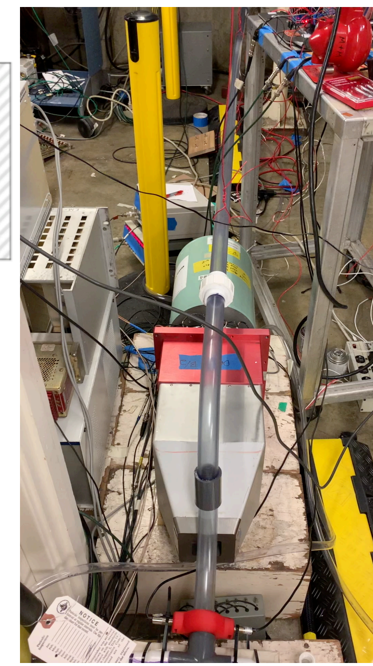
We were part of a successful NDIWG grant to assemble FLUFFY to measure short-lived fission product yields

- High-intensity, short-burst neutron irradiations of ^{235}U, ^{238}U, ^{239}Pu targets
- Goal is to measure independent fission product yields with $t_{1/2}<1s$



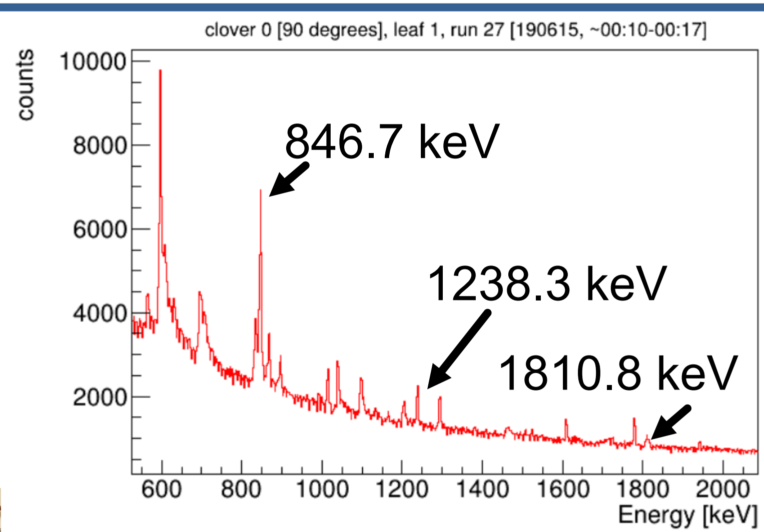


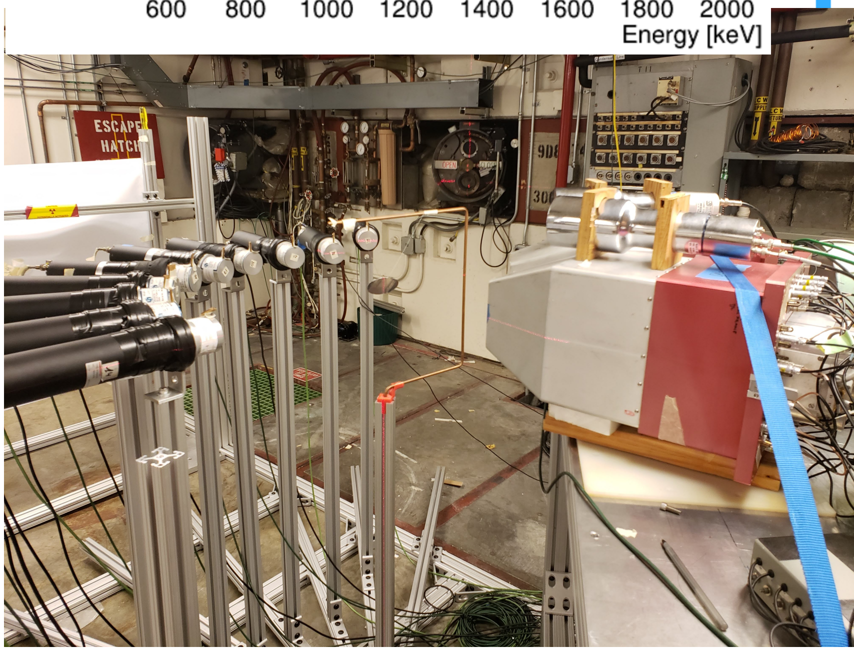


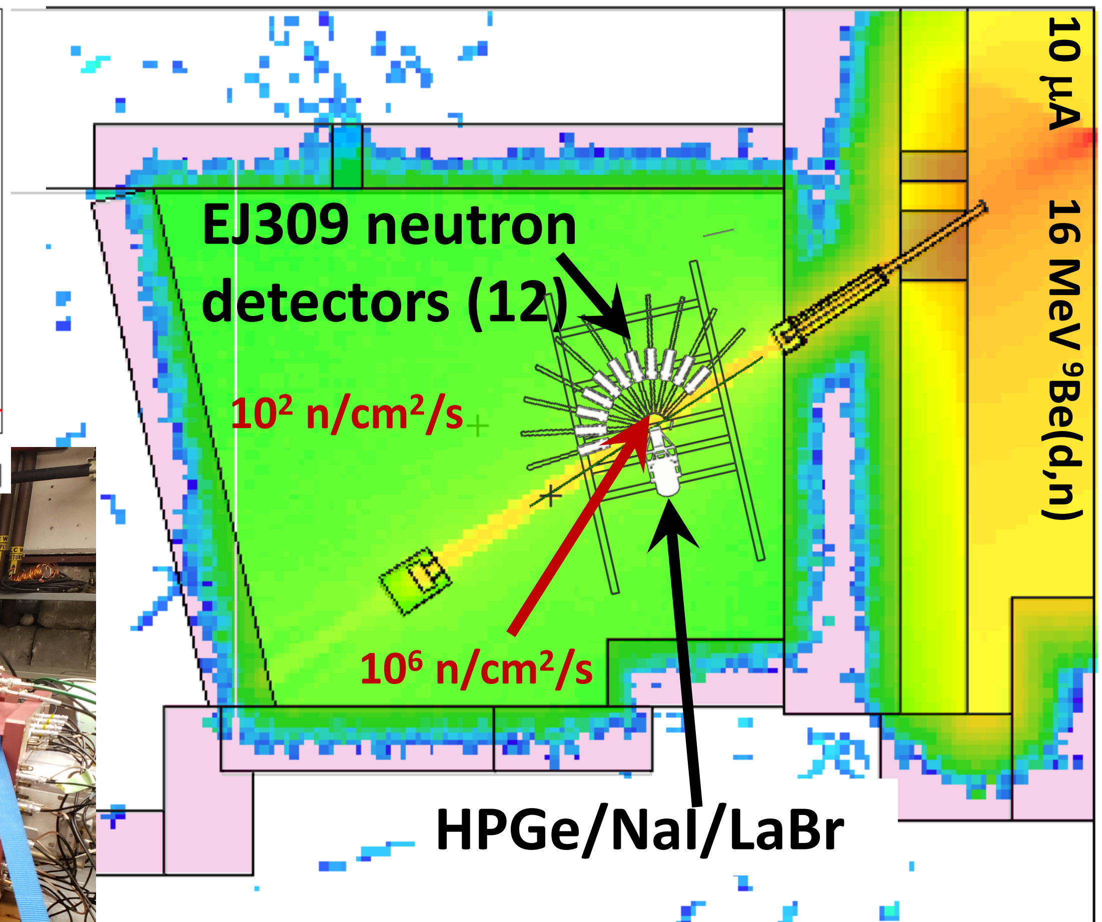


FLUFFY: Fast-Loading User Facility for Fission Yields

We just commissioned GENESIS in Cave 5, a new capability to measure triple-differential (E_n,$E_{n'}$,Ω) inelastic cross sections





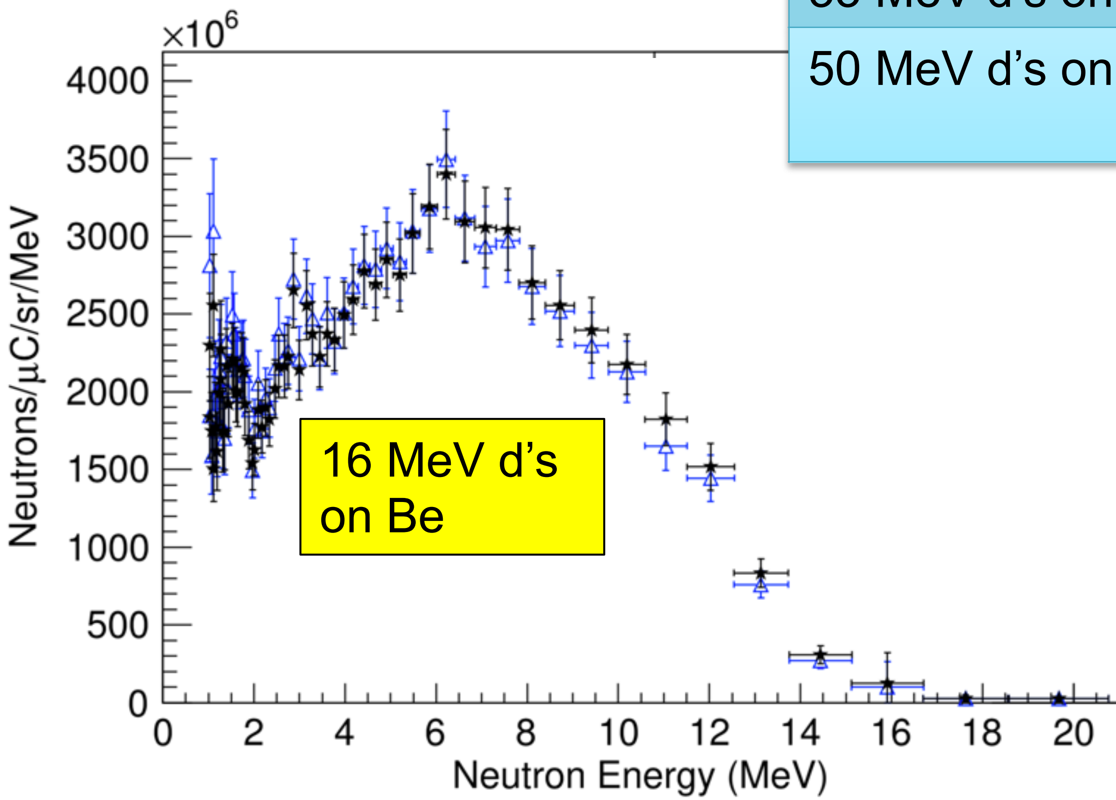


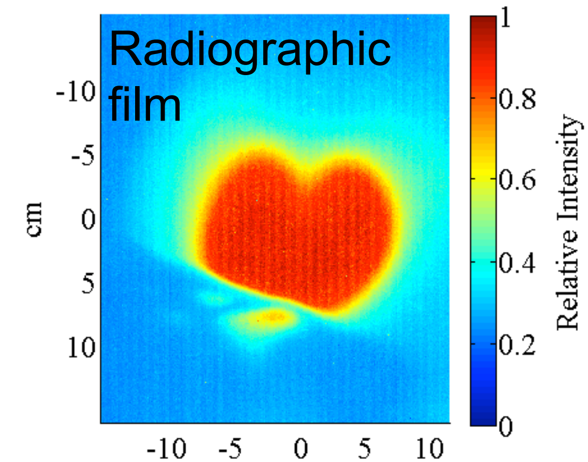
GENESIS: Gamma-Energy Neutron-Energy Spectrometer for Inelastic Scattering

Summary: Berkeley "neuterons" are intense, tunable, well-collimated, and have an adjustable endpoint at 16-50 MeV

- Perfect for low-energy neutron cross section measurements needing high statistics

Breakup E/tgt	Flux* @ 5m (10 μA)
16 MeV d's on Ta	10^5 n/cm^2/s
16 MeV d's on Be	10^6 n/cm^2/s
33 MeV d's on Be	10^7 n/cm^2/s
50 MeV d's on Be	2×10^7 n/cm^2/s (10^{11} n/cm^2/s @7.5cm)





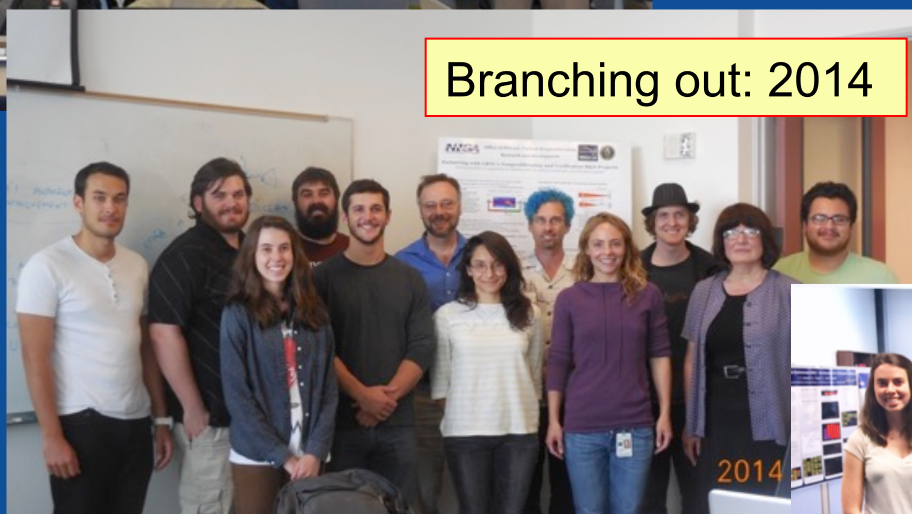
Berkeley ♥'s neutrons. And our neutrons ♥ us!

*Meulders, et. al., Phys. Med. Biol., 1975, 20(2), 235, (1975)

Thanks!

UC Fee NPI@NIF grant launches UCB/LLNL collaboration: 2012

Branching out: 2014



This vast variety of neutron capabilities are the result of many dozens of students’ and postdocs’ efforts through a very successful collaboration (BANG) between LBNL, LLNL, and UCB over the past seven years.

Realizing we need to take group photos more often: 2018

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