Development of a neutron production facility at the Lawrence Berkeley National Laboratory

May 29, 2013

Lawrence Livermore National Laboratory

LLNL-PRES-XXXXXX

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The UCB/LBNL/LLNL Team! (Well, most of them)

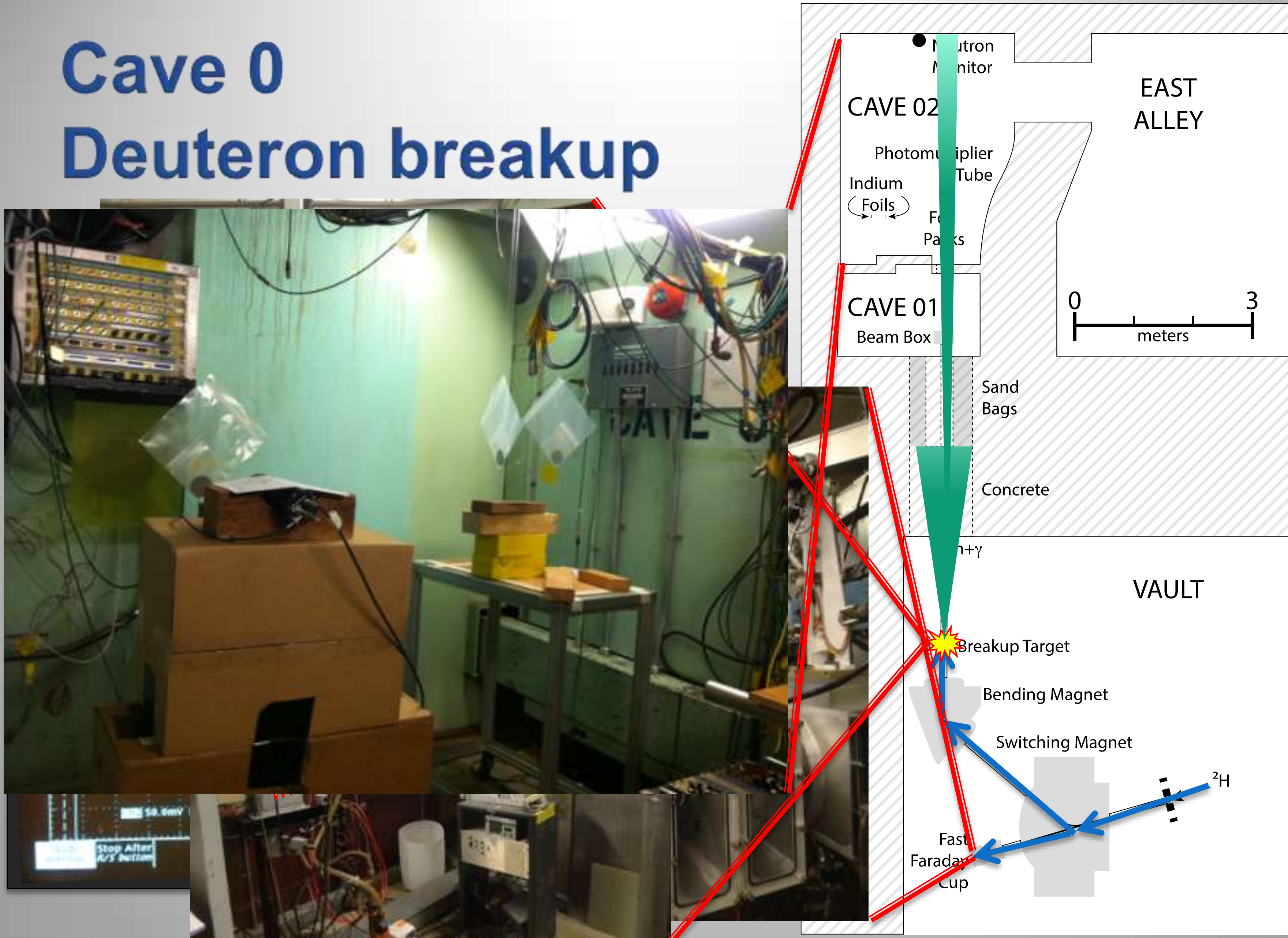
In Oct '12: we kicked off an effort to form a U.C. Berkeley Nuclear Engineering group to pursue nuclear science & diagnostic development for NIF, primarily with funding from a UCOP grant (P.I. – Darren Bleuel) to study nuclear reactions on excited nuclear states at NIF.

Introduction:
We are developing three different neutron sources

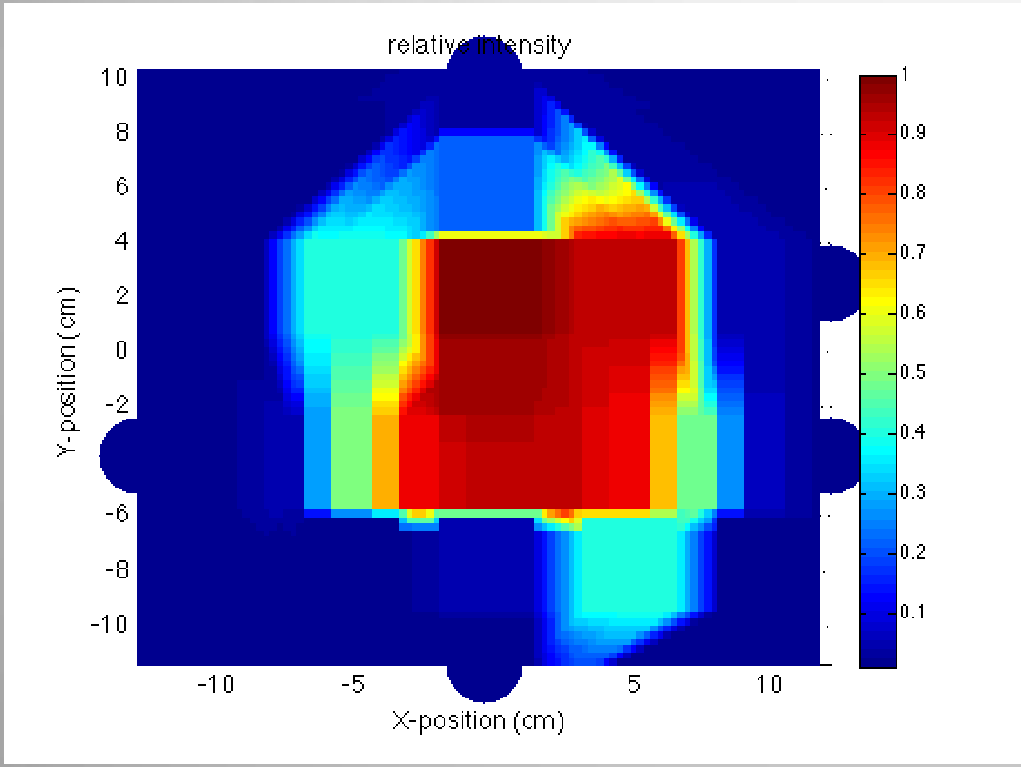
- **Deuteron breakup**
  - “White” neutron source (~1-30 MeV)
- **^{7}Li(p,n) (normal and inverse kinematics)**
  - Monoenergetic (< 1 MeV)
  - Bi-energetic (>1 MeV)
- **High Flux DD Neutron Generator**
  - 2.5 MeV monoenergetic
  - Thermal

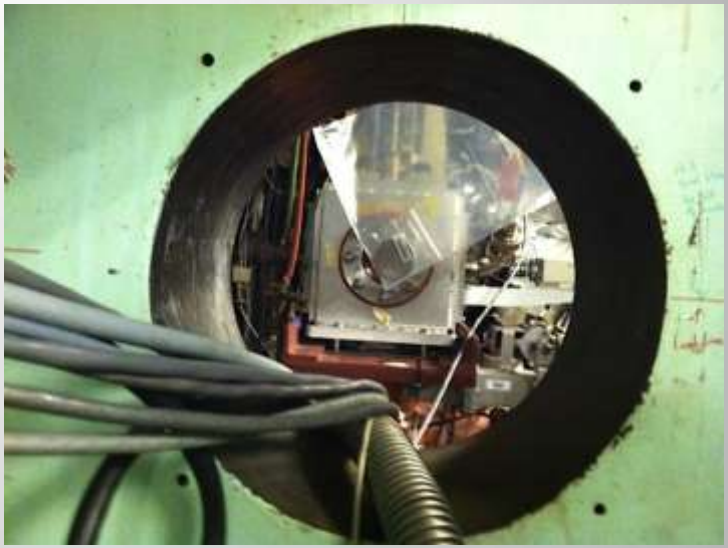
Deuteron breakup

Cave 0
Deuteron breakup



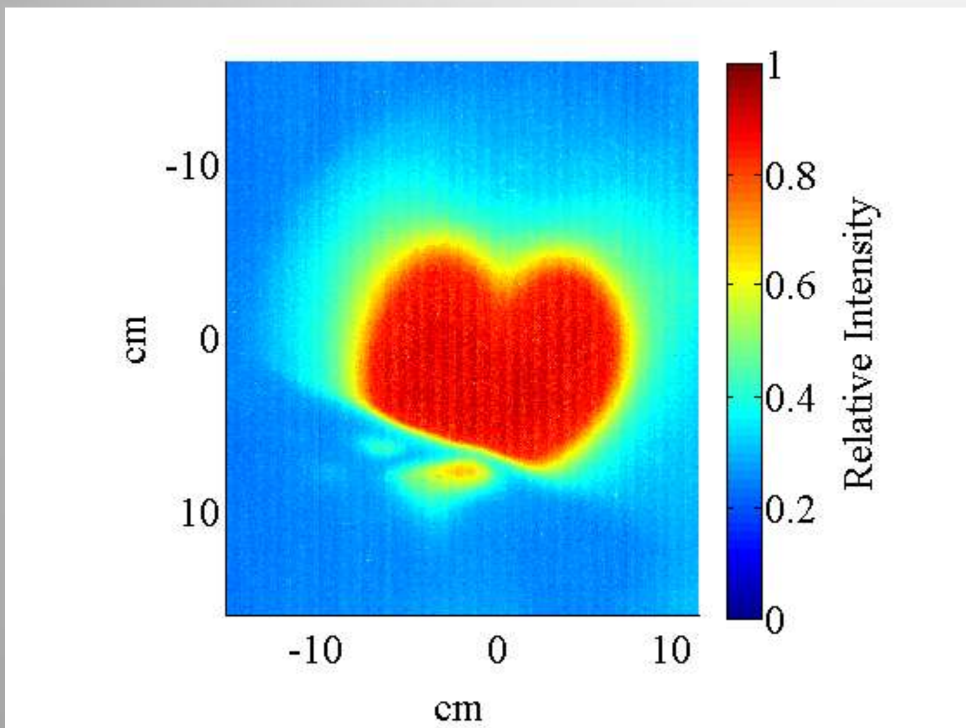
Beam profile characterization
"7 km" technique





1 data point = 2 round trips = 4 * 60 m (10 min)
30 data points = 120 * 60 m = 7200 m
= 120 * 10 min = 5 hours

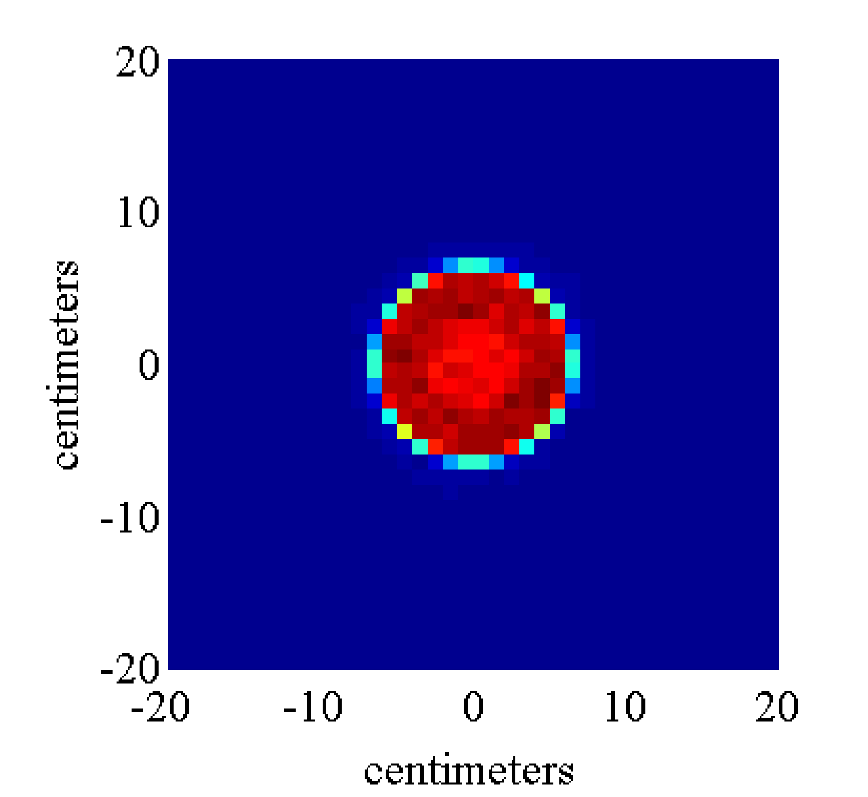
Beam profile characterization
Radiographic film

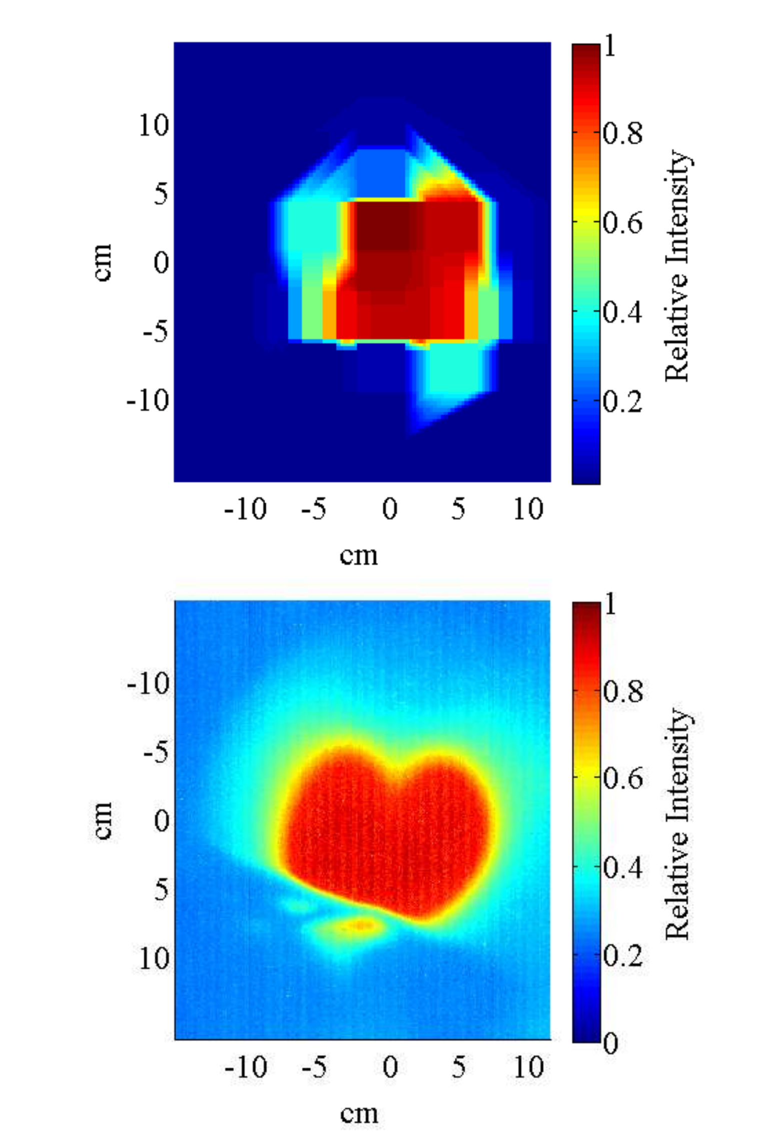


We don’t currently know response function
(Neutrons or photons?)

PS: Our beam ♎’s us!

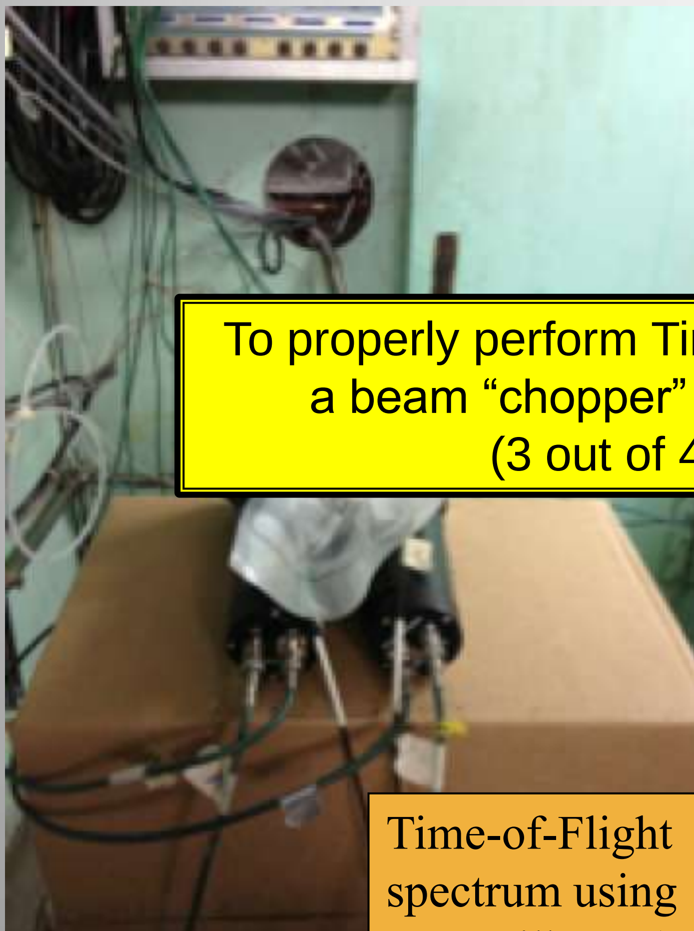
Beam profile characterization
MCNP

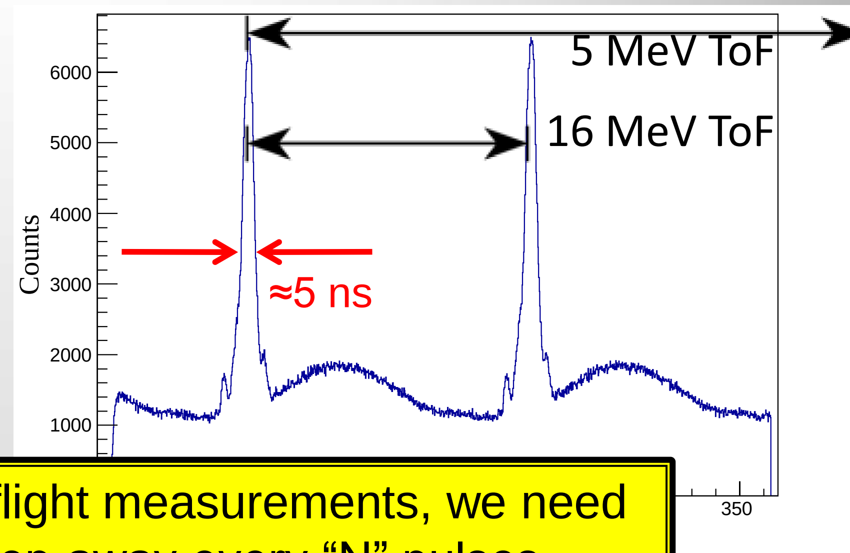




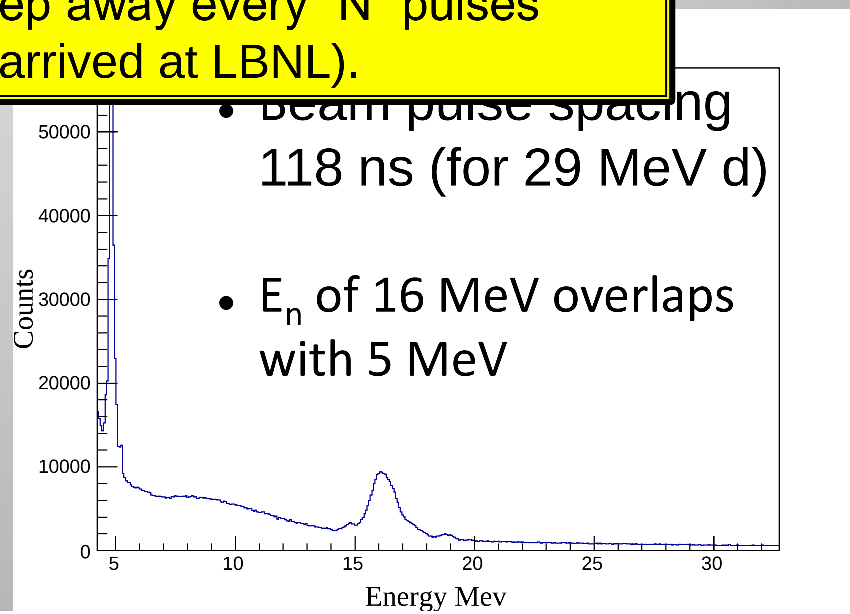
Neutron spectral characterization

Time-of-flight





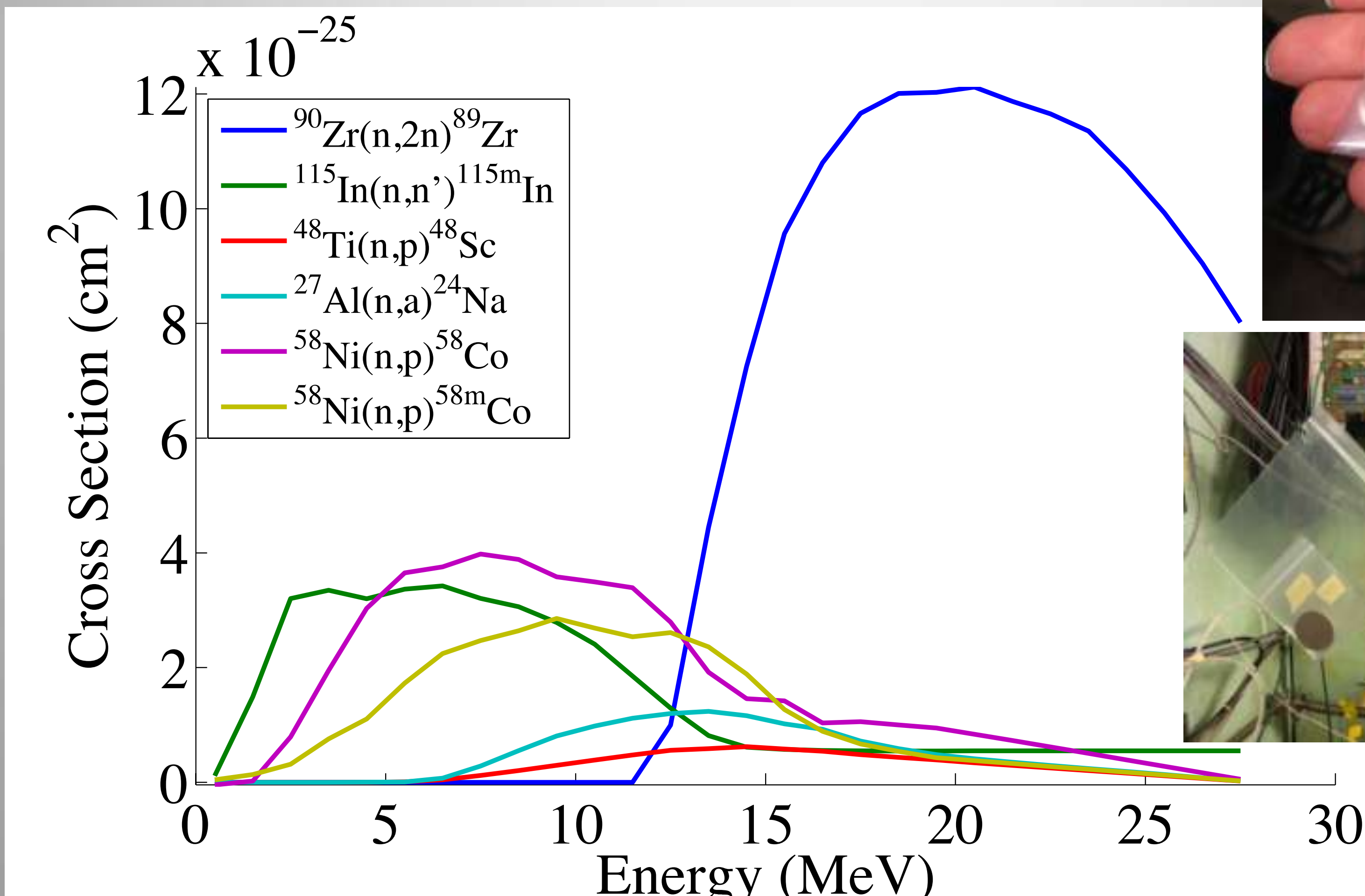
To properly perform Time-of-flight measurements, we need a beam "chopper" to sweep away every "N" pulses (3 out of 4 parts arrived at LBNL).



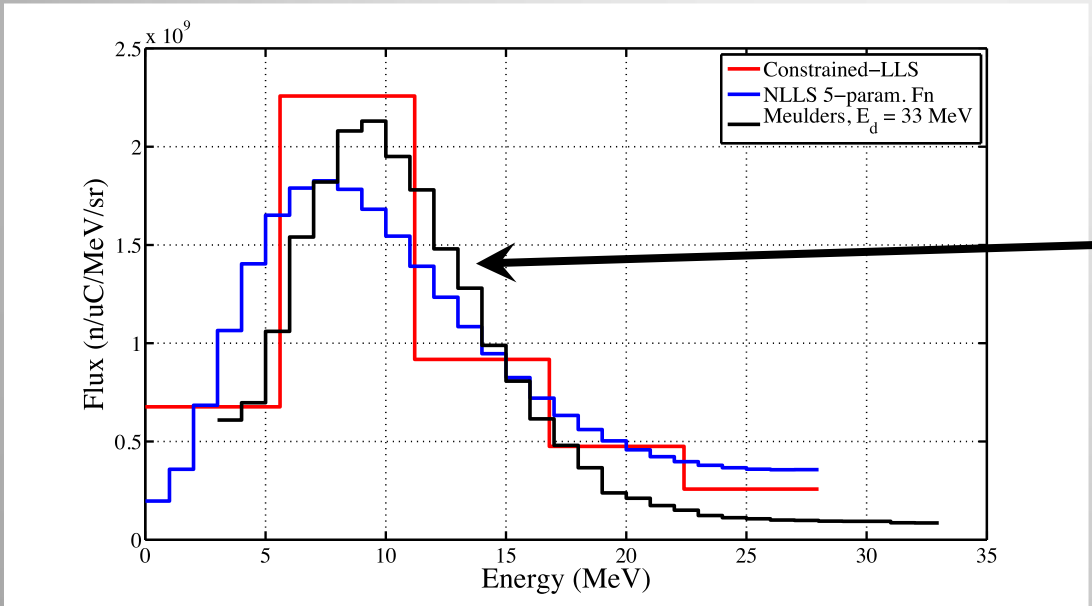
- Beam pulse spacing 118 ns (for 29 MeV d)
- E_n of 16 MeV overlaps with 5 MeV

Time-of-Flight spectrum using BB+Stilbene (0.5%)

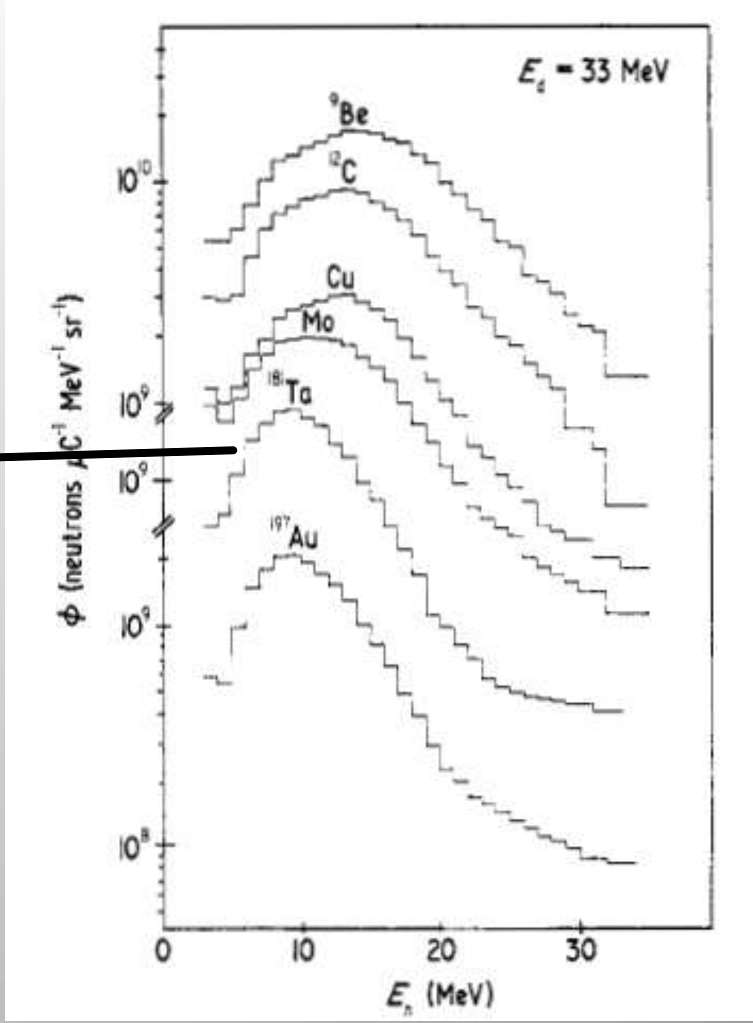
Neutron spectral characterization
Activation foils



Neutron spectral characterization
Activation foils

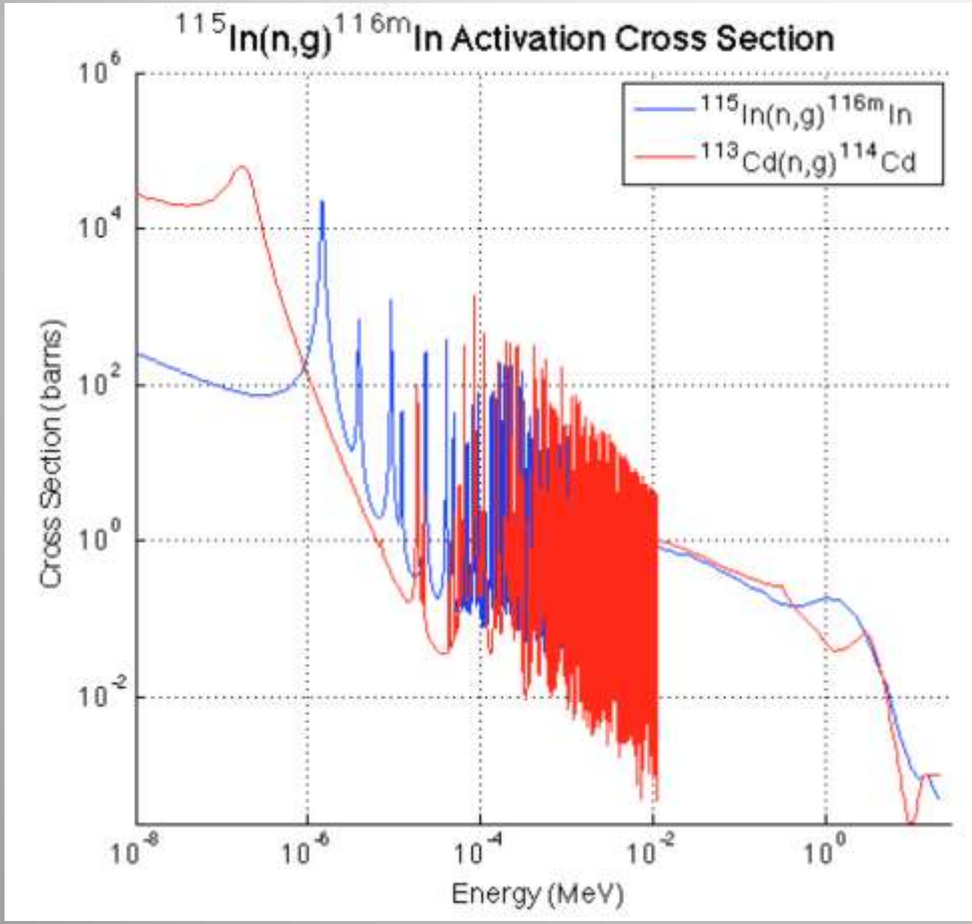


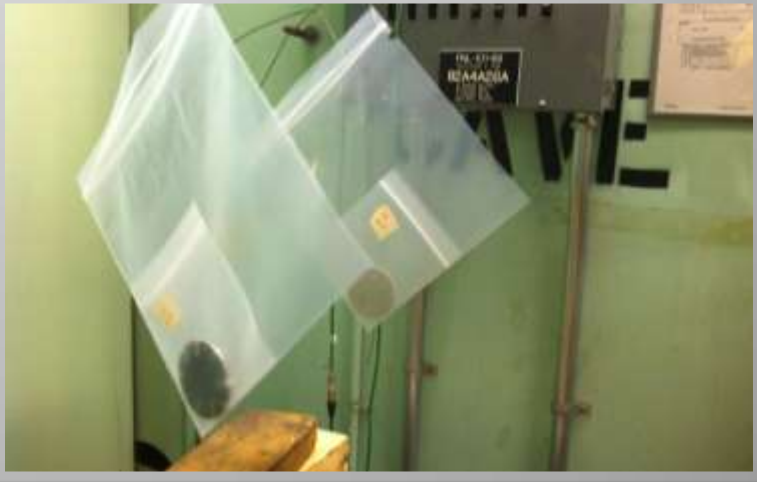
Result of a constrained linear least-squares fit and non-linear 5-parameter functional fit to five thresholding activation reactions.
(29 MeV deuterons on tantalum)



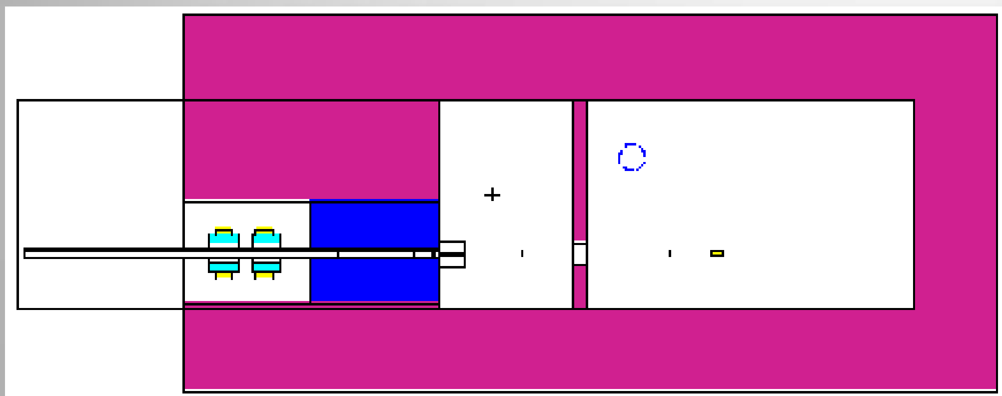
Meulders et al, *Phys. Med. Biol.*, 1975, 20 (2), pp 235-243

Room background characterization Cadmium-difference method





Room background characterization
Cadmium-difference method

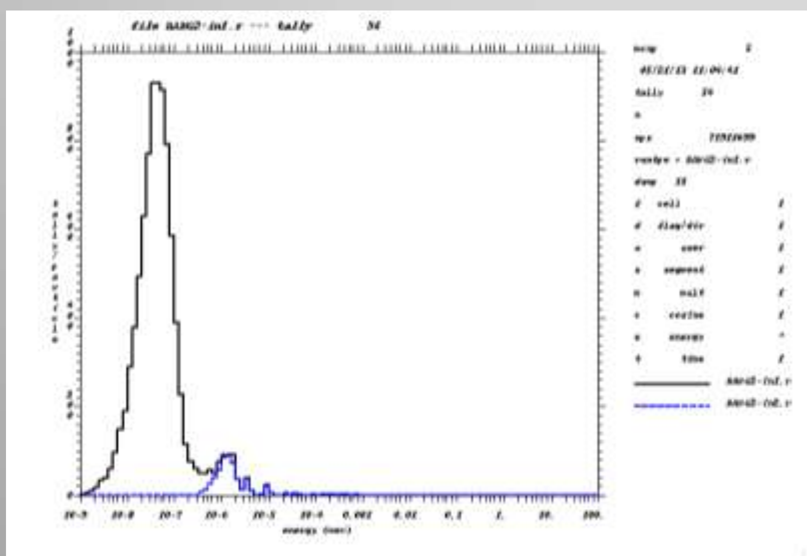


MCNP model of room predicts $A_{bare}/A_{wrap} = 15.$

Measured $A_{bare}/A_{wrap} = 3.$

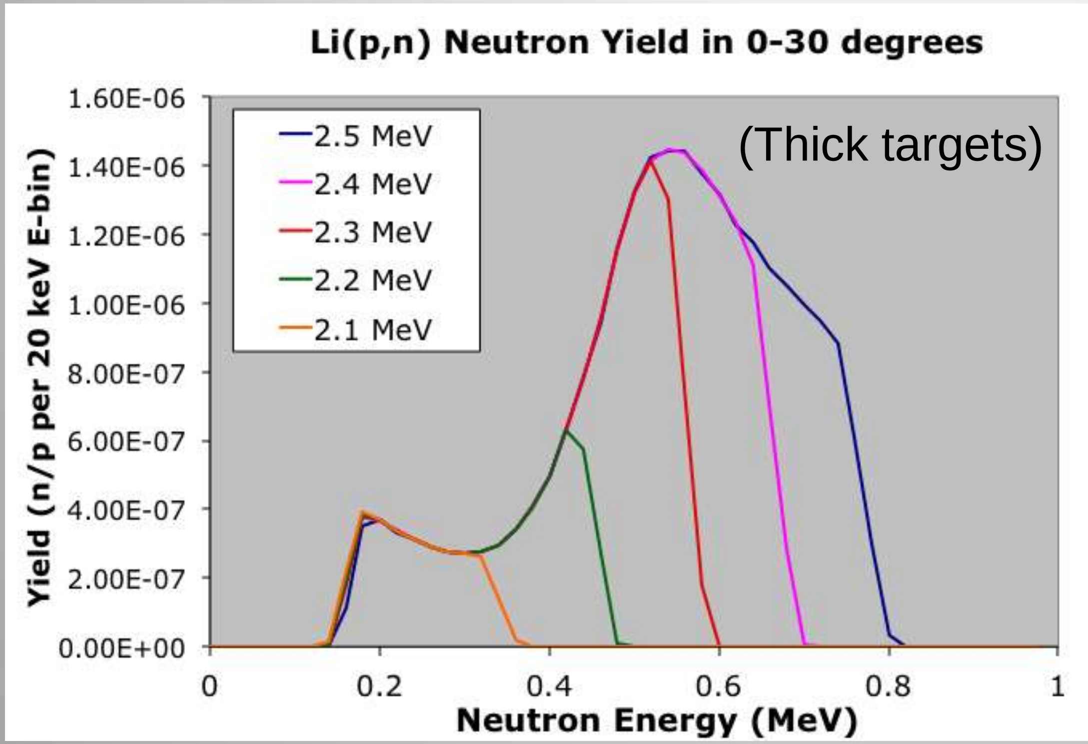
Incomplete Cd wrapping?

More 1eV flux (rel. to thermal) than expected?



$^{7}Li(p,n)$

$^{7}Li(p,n)$ Normal kinematics



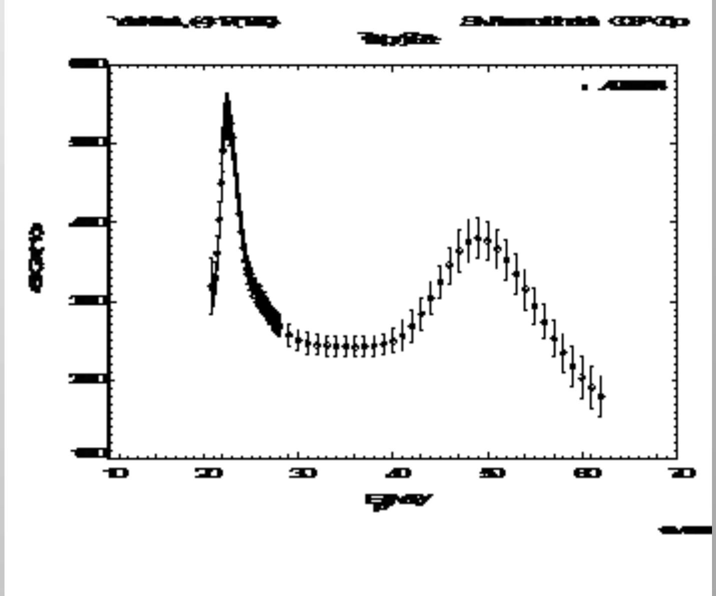
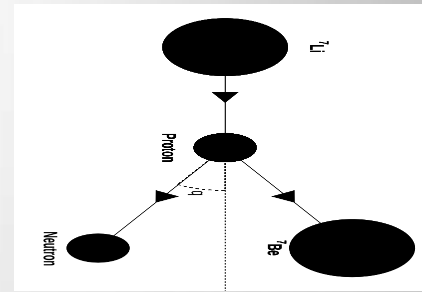


Figure 2.2: Cross section of the $^{7}Li(p,n)^{7}Be$ reaction.[25]

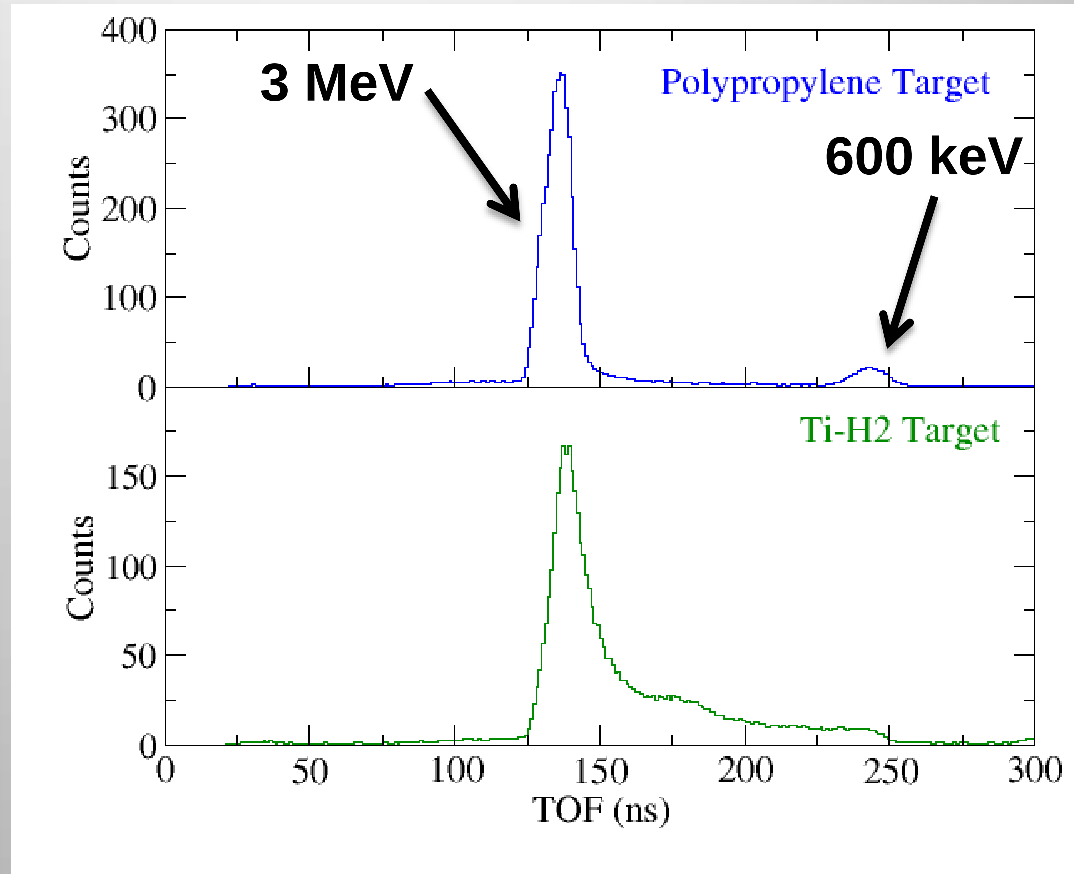
Below ~2.6 MeV protons on a thin target, a unique, epithermal, monoenergetic kinematic solution exists at any particular angle

$^{7}Li(p,n)^{7}Be^{*}$ and $^{7}Li(p,n)^{7}Be^{**}$ begin to contribute above ~2.7 MeV

$^7Li(p,n)$ Inverse kinematics

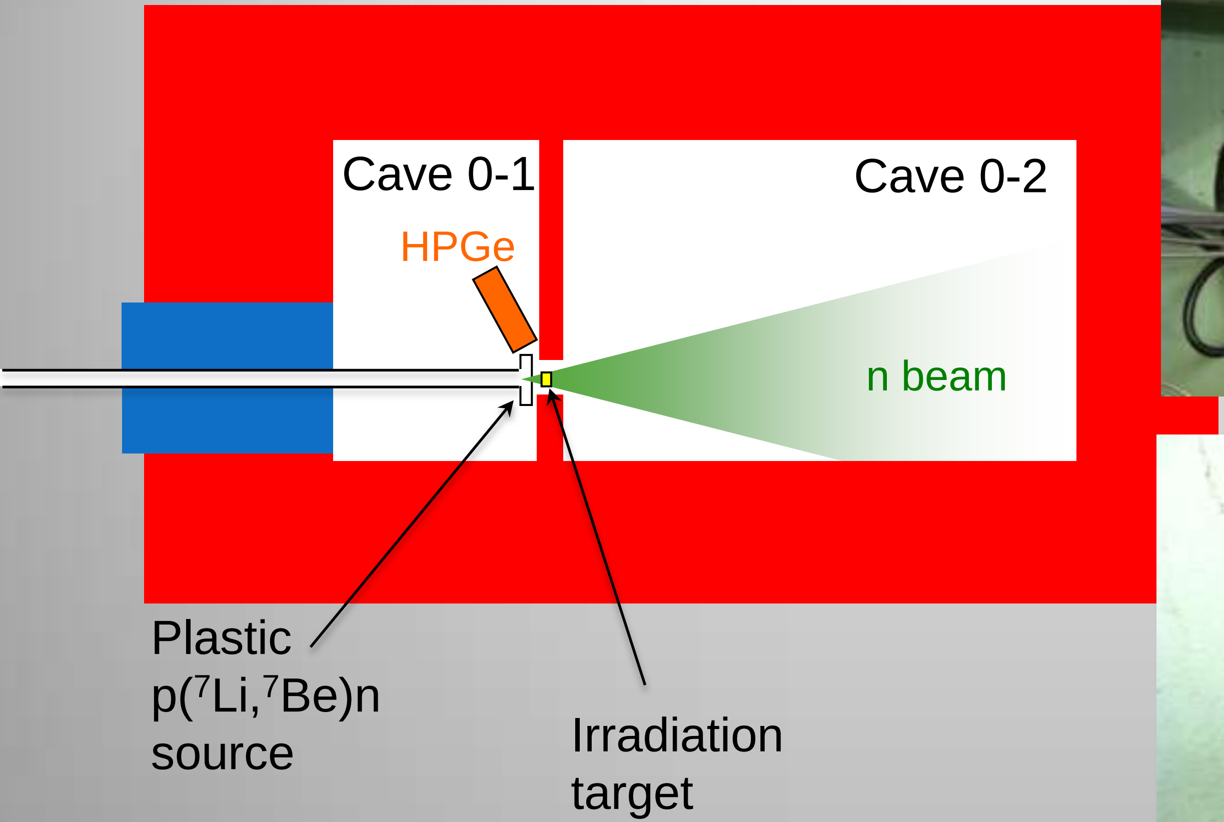


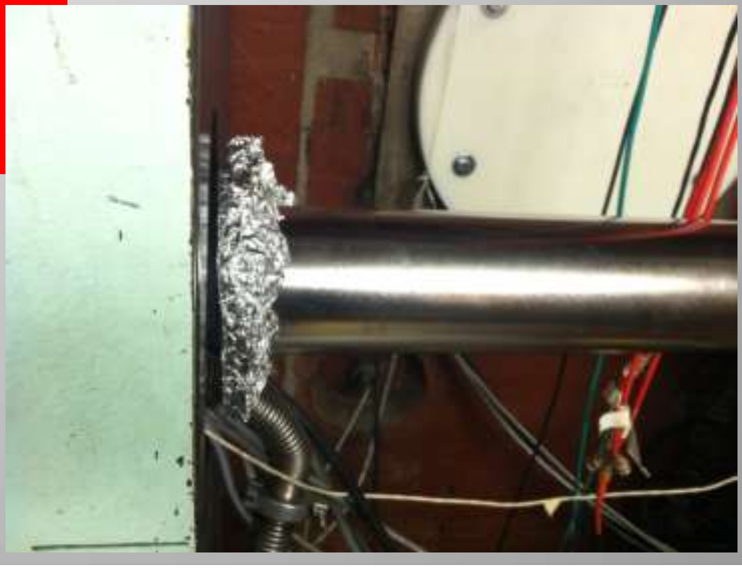
- Technique has been used at LICORNE (**Lithium Inverse Cinematiques ORsay NEutron source).**
- Time of flight plots show peaks for bi-energetic solution.
- For Ti-H_2 target, can see significant background of neutrons due to Li-Ti Fusion



Thanks to Jon Wilson from IPN.

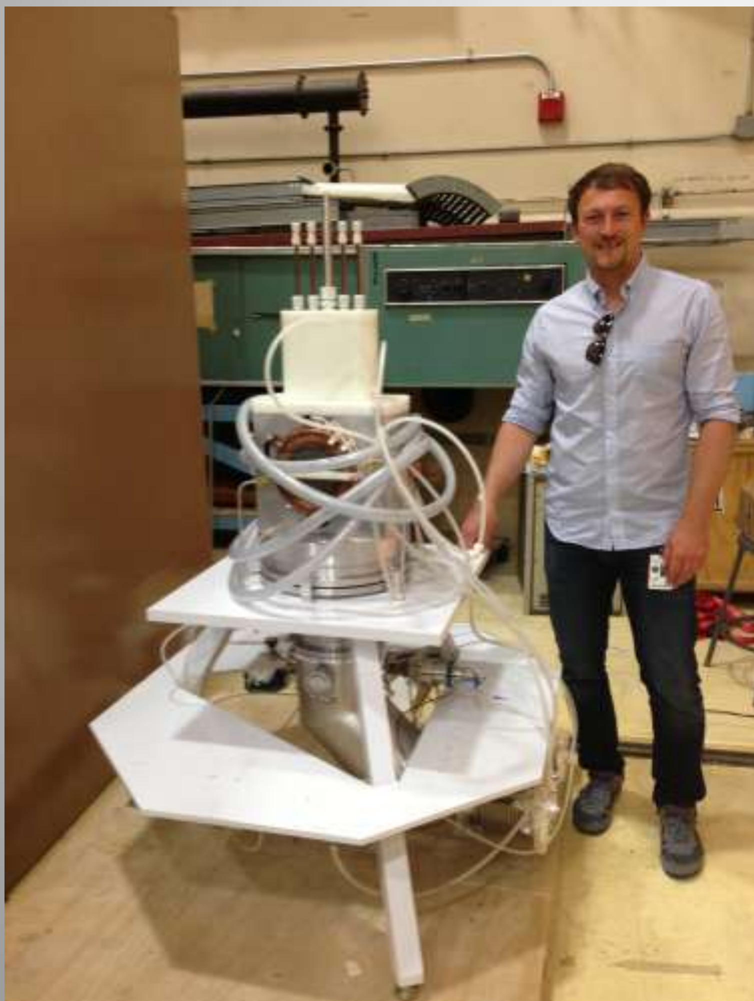
^{7}Li(p,n) Inverse kinematics
High flux, low bg





High Flux Neutron Generator
$d(d,{}^{3}He)n$

High Flux Neutron Generator Now being installed



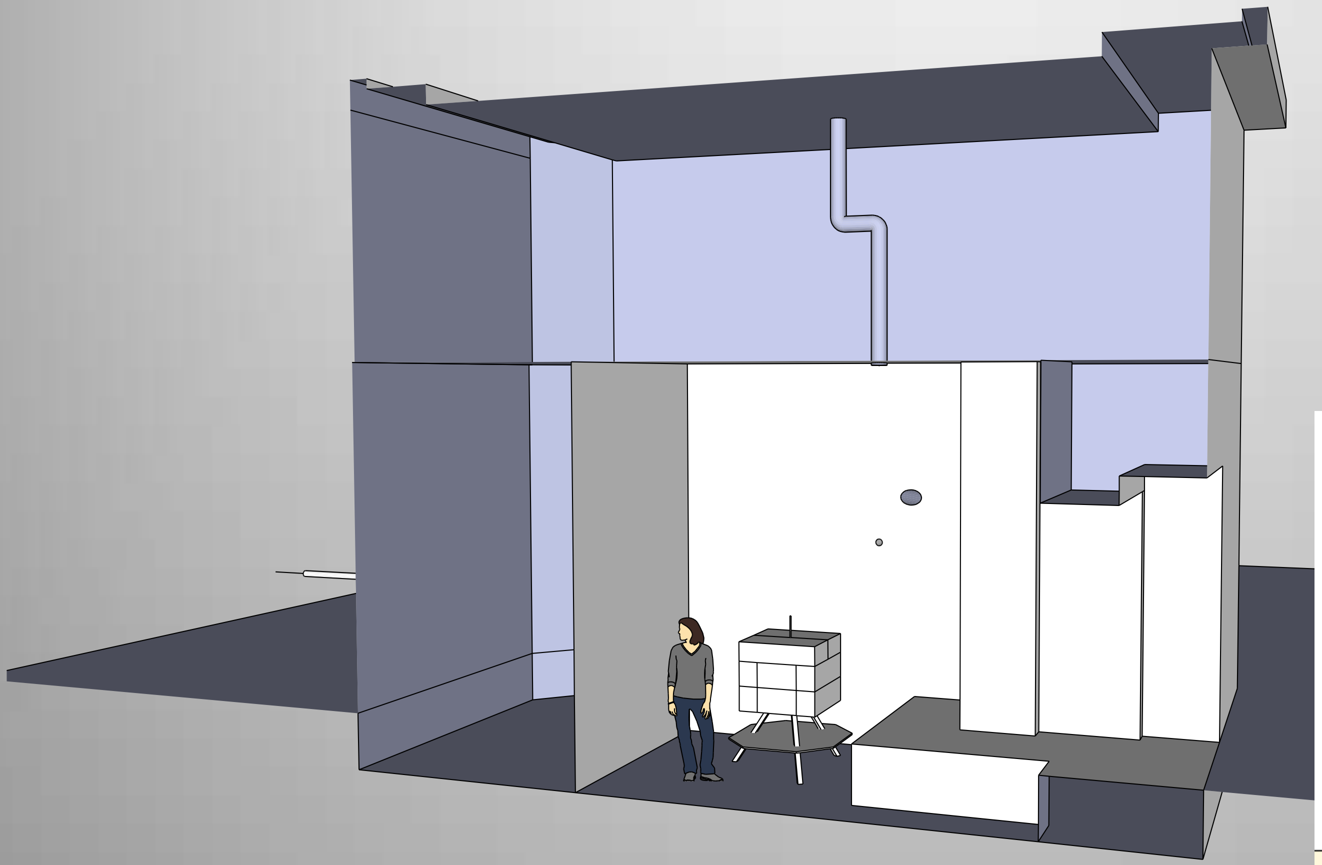
1. Nominal yield of 10^{10} to 10^{11} neutrons/s.
2. Beam self-loading neutron production target.
3. Utilizes dual RF-driven multicusp ion sources developed at LBNL.
4. Uniform sample irradiation.
5. 100 kV nominal operating voltage.

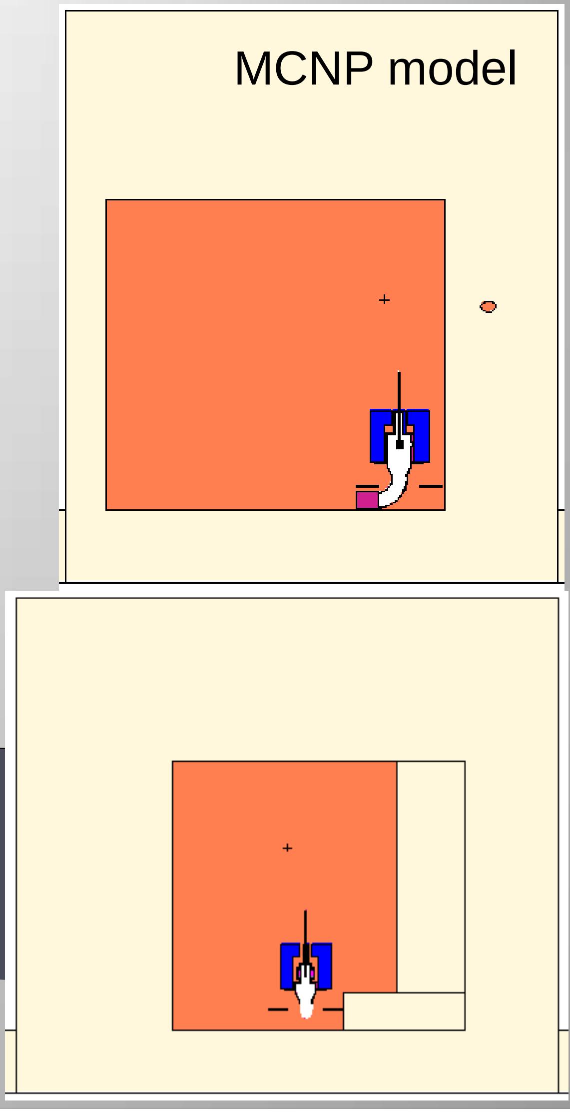
High Flux Neutron Generator
The "reactor room"

THEN

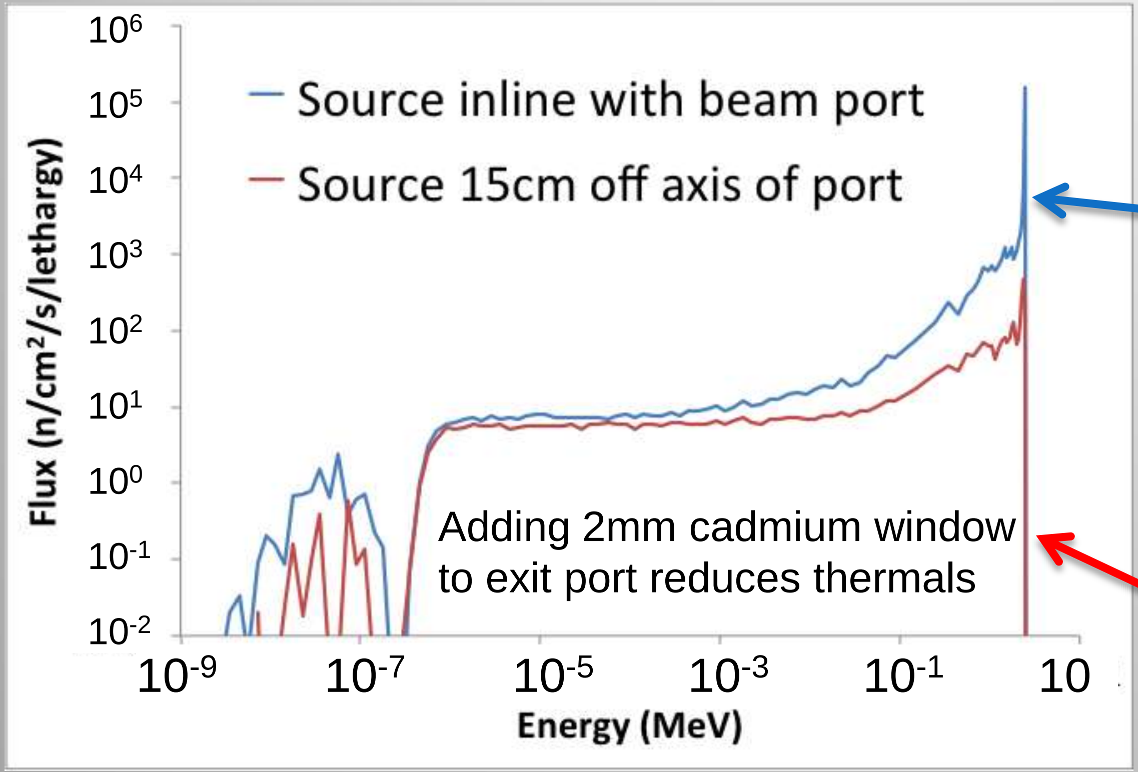
NOW

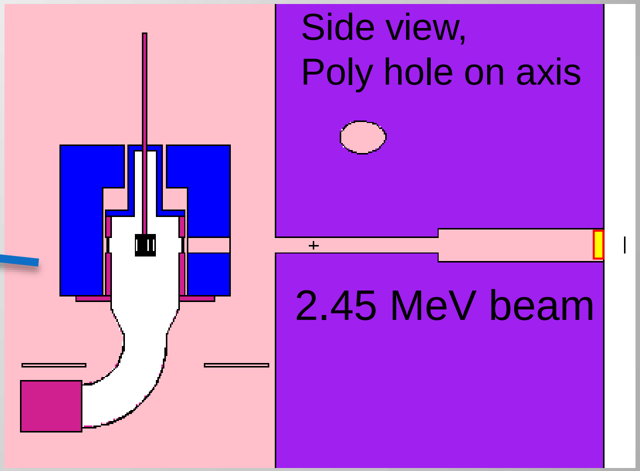
High Flux Neutron Generator Shielded irradiation room

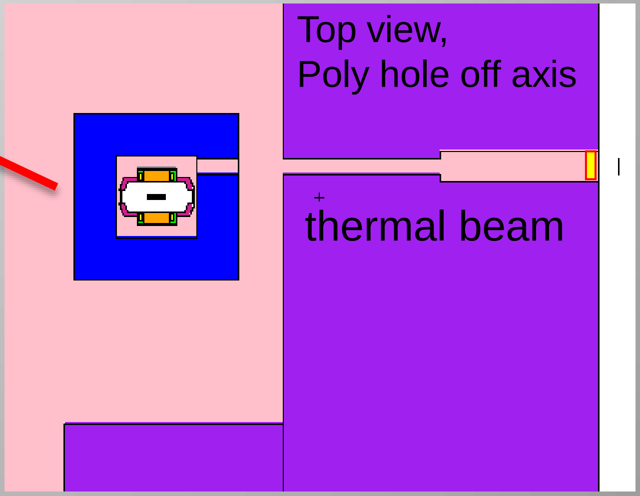




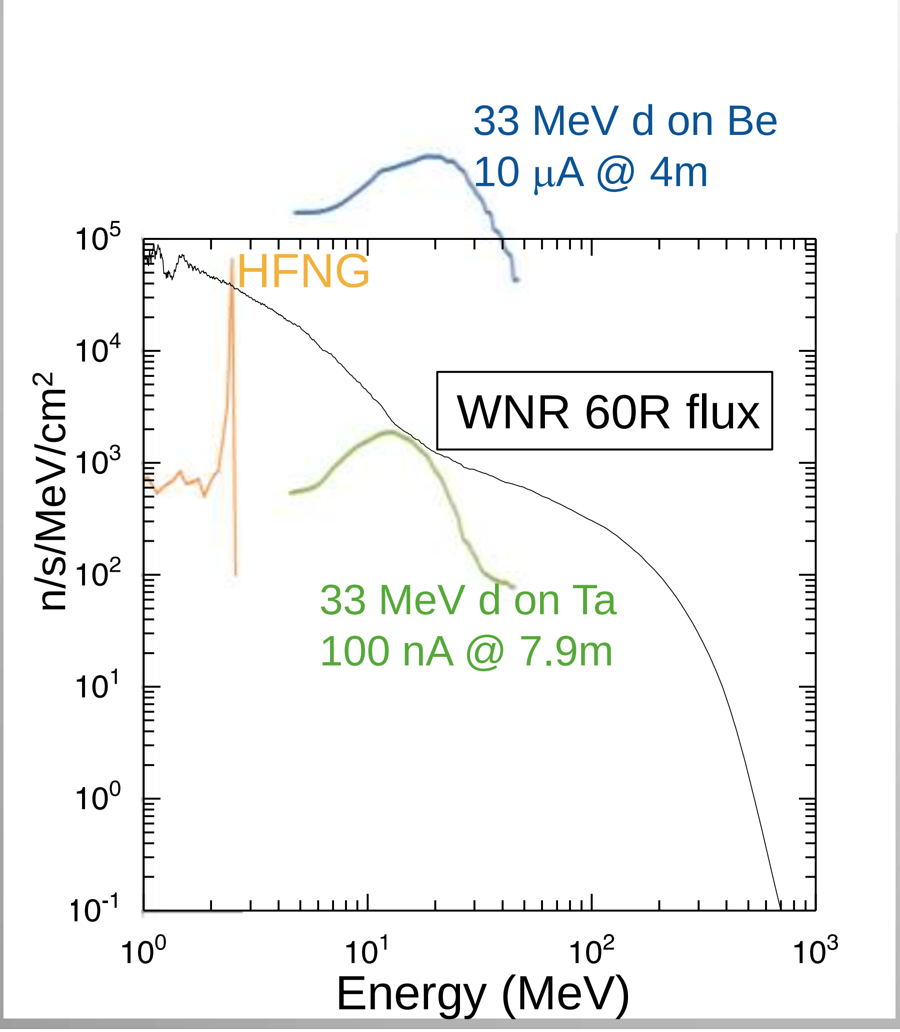
High Flux Neutron Generator Collimated 2.45MeV/thermal source







Summary of Berkeley Neutrons Comparison with WNR?



Source	Total Flux (n/cm2/s)
WNR	10^6 ?
HFNG (2.27m)	10^4
33 MeV d on Ta (100nA @ 7.9m)	$3x10^3$
33 MeV d on Be (10μA @ 4m)	$2x10^7$
Kentucky T(p,n) (@ 2m)	$2x10^3$

High Flux Neutron Generator RSF/ρ_{level} physics?

Stay tuned for Bethany Goldblum! (Friday morning)

<u>HFNG unique capabilities:</u>

- High flux (10^4 n/cm^2/s outside port)
- High availability (months)
- Excellent collimation (Detector sees ~1 n/cm^2/s)

- Compare RSF from (n,γ) at different E/J (test of Brink)?
- Measure Ericsson σ fluctuations around 2.45 MeV?

Thanks!

Lawrence Livermore National Laboratory

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- Jac Caggiano
- Robert Hatarik
- Dieter Schneider
- Charles Yeamans

Lawrence Berkeley National Laboratory

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- Andy Rogers
- The entire operations staff

University of California at Berkeley

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- Lucia Crespo
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- Paul Davis
- Bethany Goldblum
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