LA-UR-15-28XX

New Directions on Nuclear Data Activity at LANSCE

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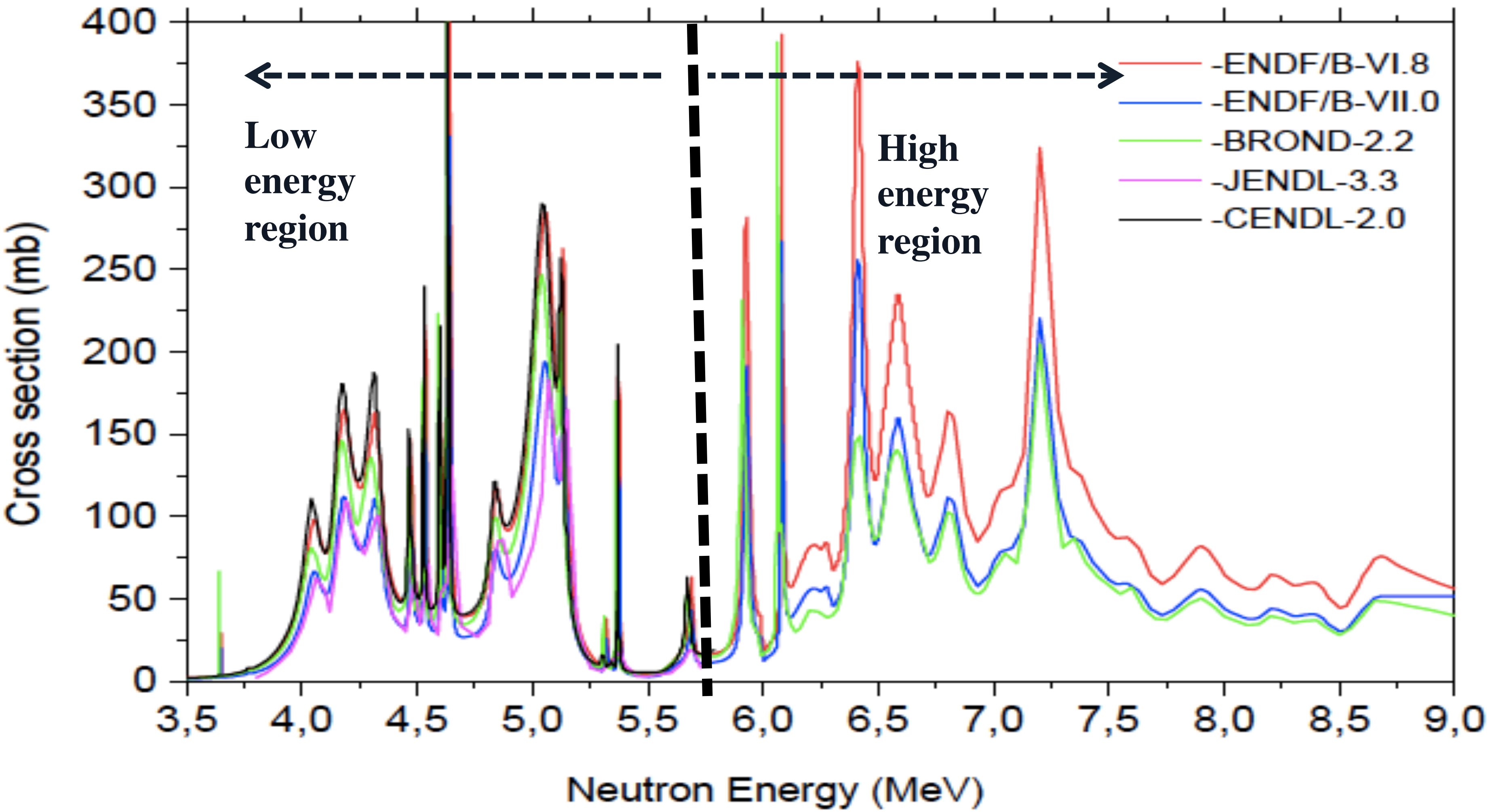
CSEWG Measurement Session
US National Nuclear Data Week 2015

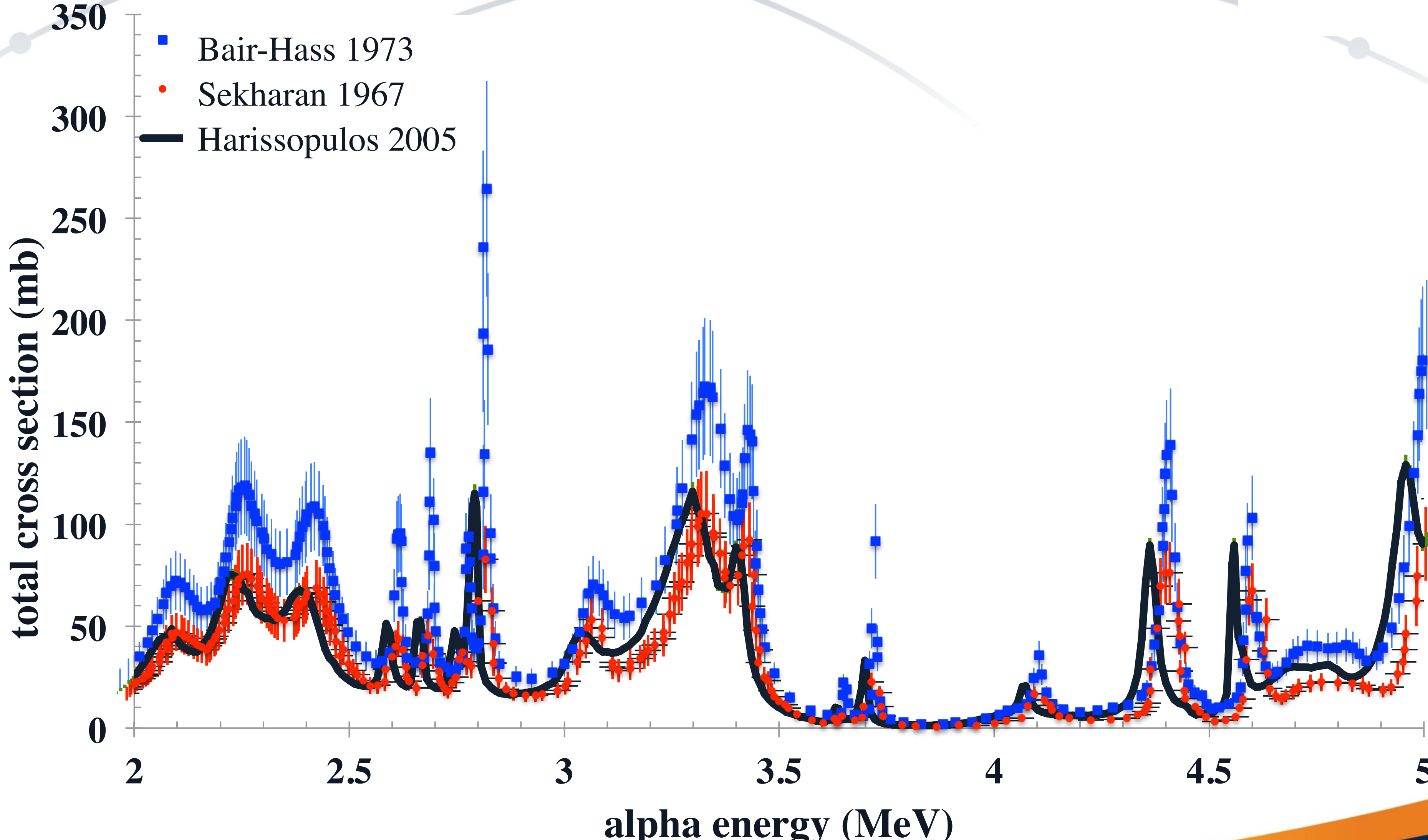
Outline

1. $^{16}O(n,\alpha)$ measurement at LANSCE
   - Status of $^{16}O(n,\alpha)$ cross section evaluation : experimentalist point of view
   - LENZ (Low Energy NZ) capability
   - $^{16}O(n,\alpha)$ measurement at LANSCE
2. Outlook on improving nuclear data quality on (n,p) and (n,α) reactions using LENZ
3. Total Cross Section Measurements
4. Enhanced DANCE Capability
5. Photon Strength Function Study on unstable nuclei

Evaluation of $^{16}O(n,\alpha)$ reaction : differ by up to 30-50 %



Status of $^{13}C(\alpha,n)$ data sets :low energy



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Status of $^{13}C(\alpha,n)$ data sets :low energy-I

- **Discrepancy between Harissopulos, Bair and Hass, and Sakharan**

Reported Uncertainty:

1)Harissopulos – 4%

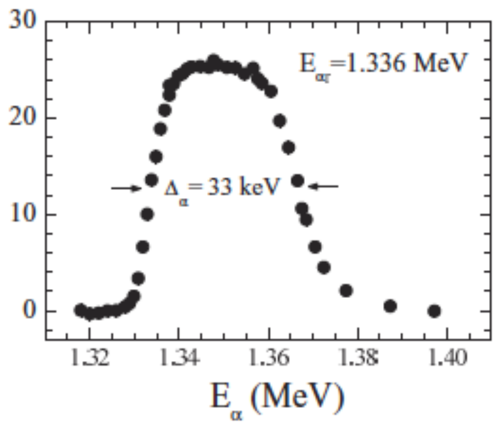
2)Other two measurements – 20 %

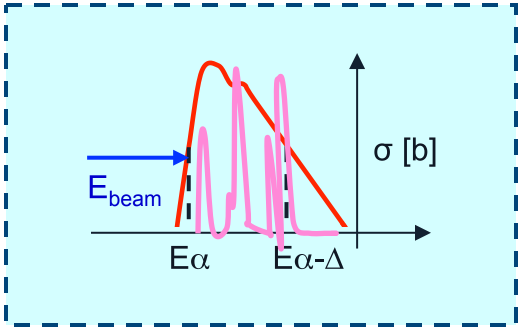
^{13}C target thickness :

1)the uncertainty in a stopping power could be ~10 % and an effective energy is convolution of target shape & cross section

2) target thickness was 5 keV at Eα = 1MeV (BH) and 31 keV at Eα=3MeV (Sekharan)

Harissopulos et al. PRC (2005)

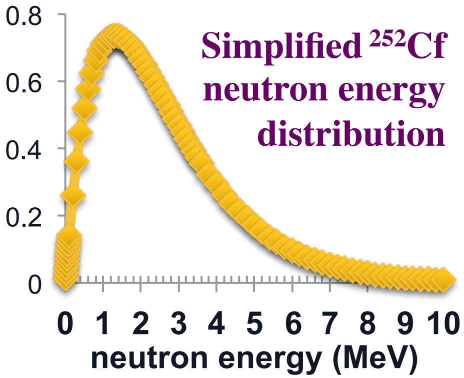




$$\text{Yield\_exp}(E) = \int_{E-\Delta}^{E} \frac{\sigma(E)}{\varepsilon(E)}\, dE$$

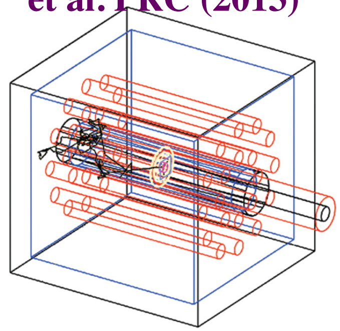
Status of $^{13}C(\alpha,n)$ data sets :low energy-II

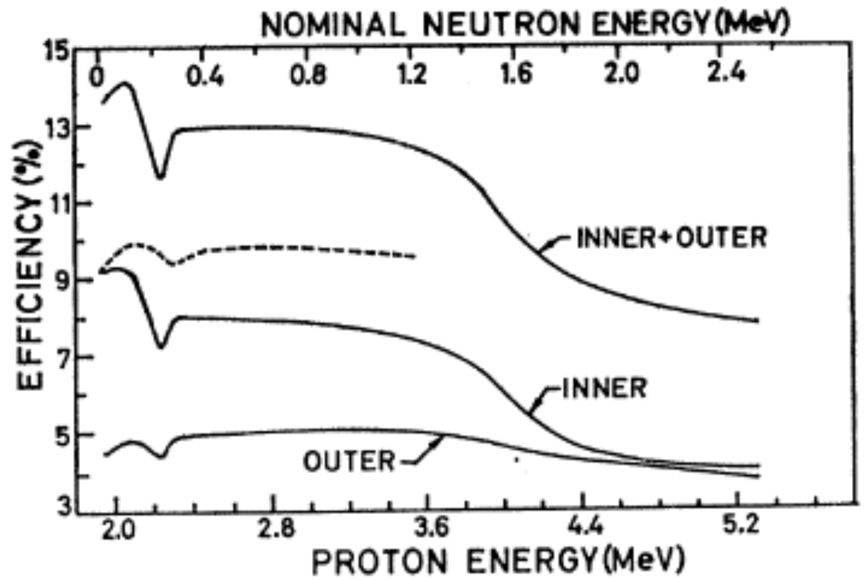
(1) Harissopulos' neutron detector efficiency was calibrated with a ^{252}Cf source at En (mean) =2.3 MeV and the shape is simulated using MCNP.

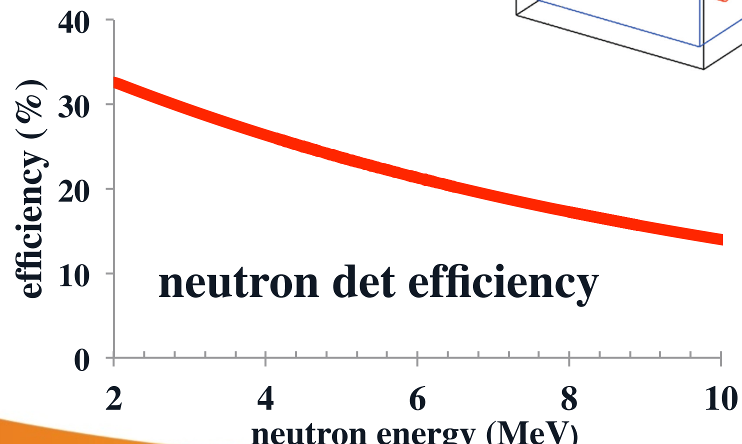


Simplified ^{252}Cf neutron energy distribution

Diagram of similar ^{3}He-tube neutron detectors, from Best et al. PRC (2013)

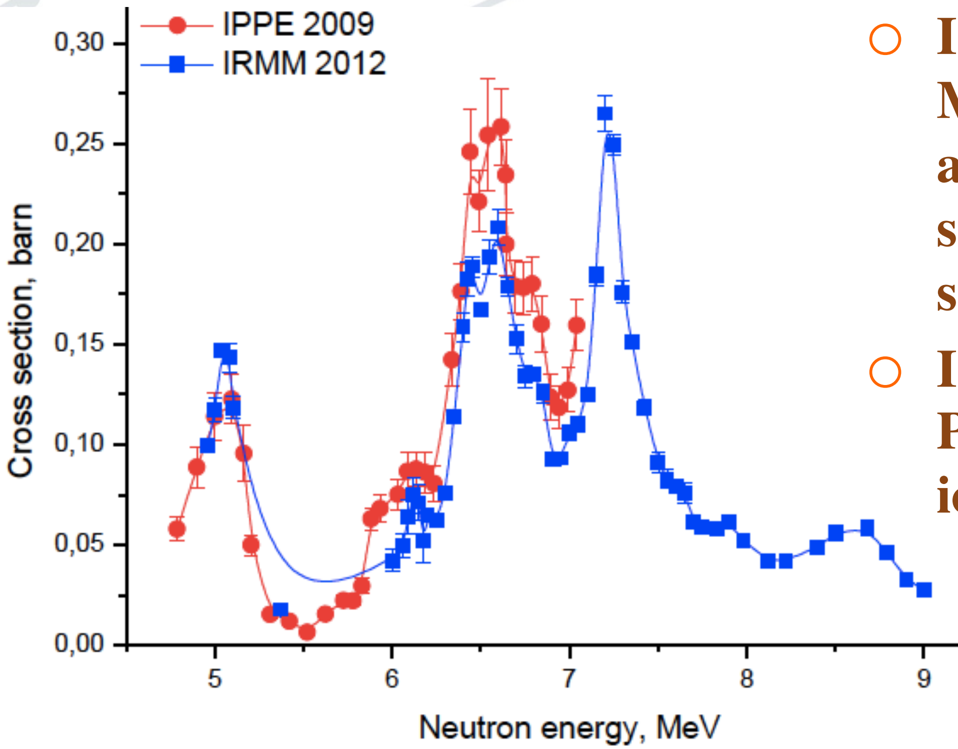






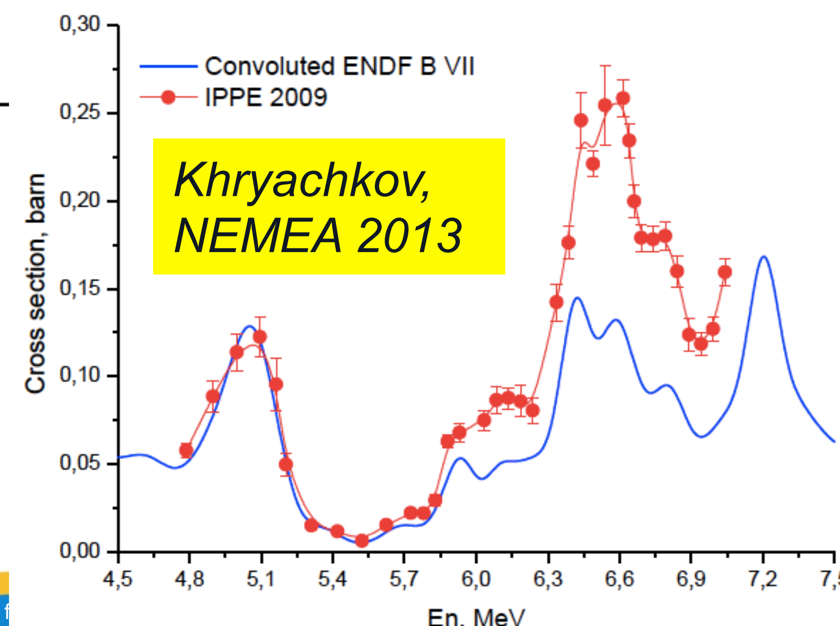
2) Sakharan's neutron detector efficiency was calibrated with multiple energies from the $^{7}Li(p,n)$ reaction and a Ra-α-Be source to extend up to E_n=5 MeV. Reported 12 % of uncertainty in efficiency estimation.

Status of $^{16}O(n,\alpha)$ data sets : high energy



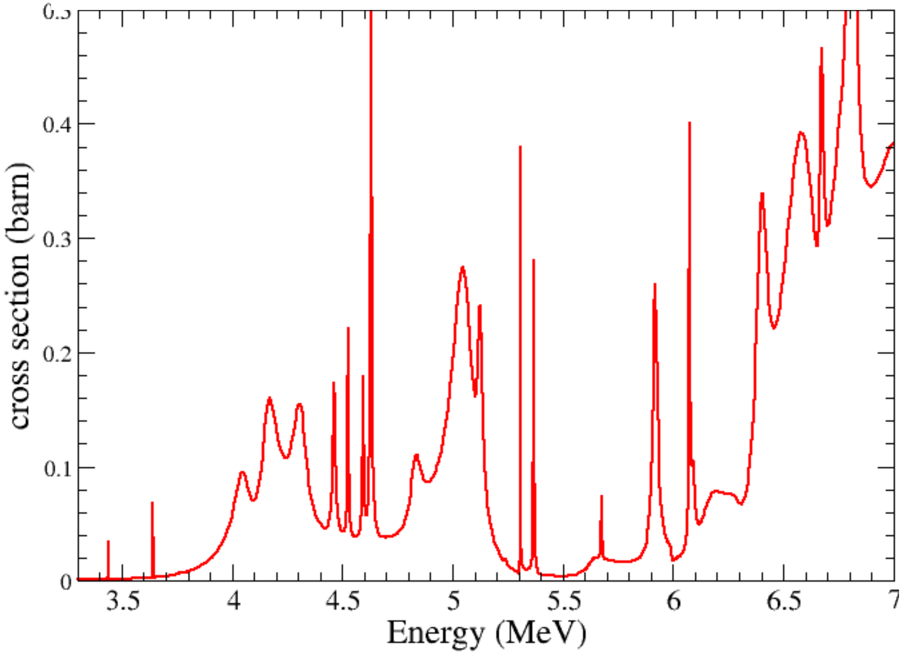
- IRMM 2012 (Institute for Reference Materials and Measurements, Belgium): an ionization chamber, a gas target, signal digitization for better background suppression
- IPPE 2009 (Institute for Physics and Power Engineering, Russia) : an ionization chamber

1. Alpha's self absorption in target
2. Ionization chamber efficiency, esp. potential angular bias
3. Neutron energy resolution



$^{16}O(n,\alpha)$ cross section, angular distributions, kinematics, etc

$^{16}O(n,\alpha)$ reaction cross section, predicted from LANL R-matrix analysis by G. Hale



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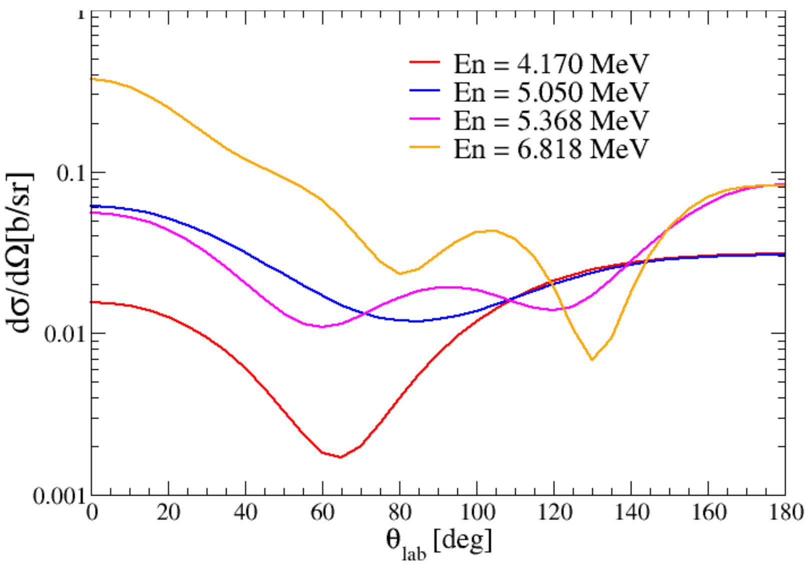
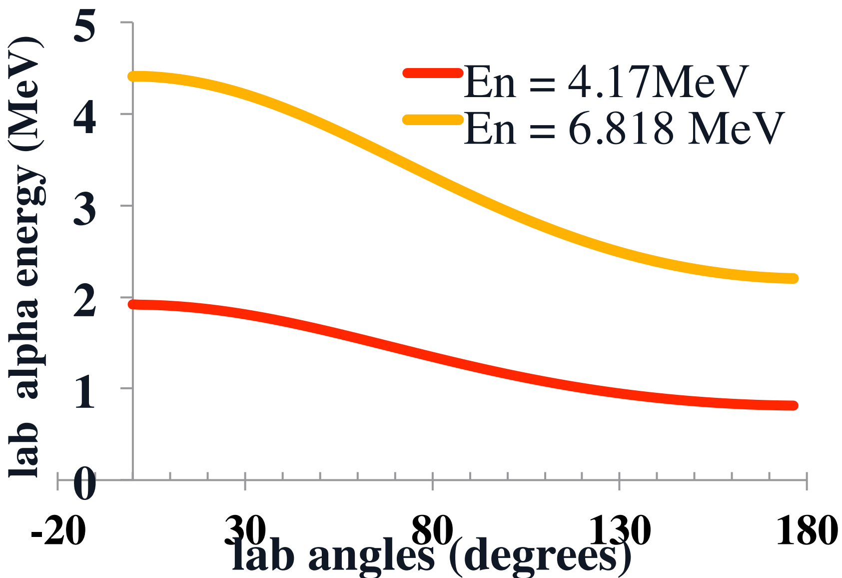


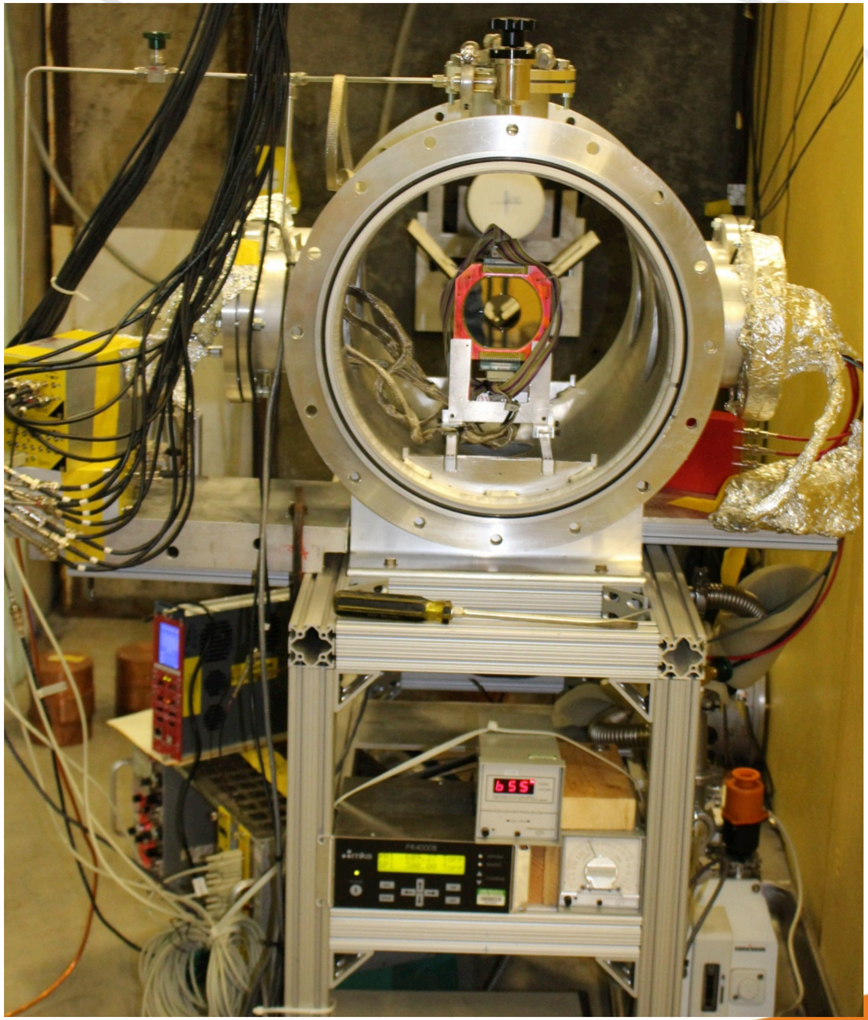


Requirements for a new measurement

- A large number of target atoms and a spectrometer with high detection efficiency, due to low cross sections
- A large signal-to-background ratio and low detection threshold, due to low alpha energies to be detected
- A good energy resolution
- Improved systematic uncertainty in order to distinguish 30 % difference
- Angular distributions to be used in R-matrix studies

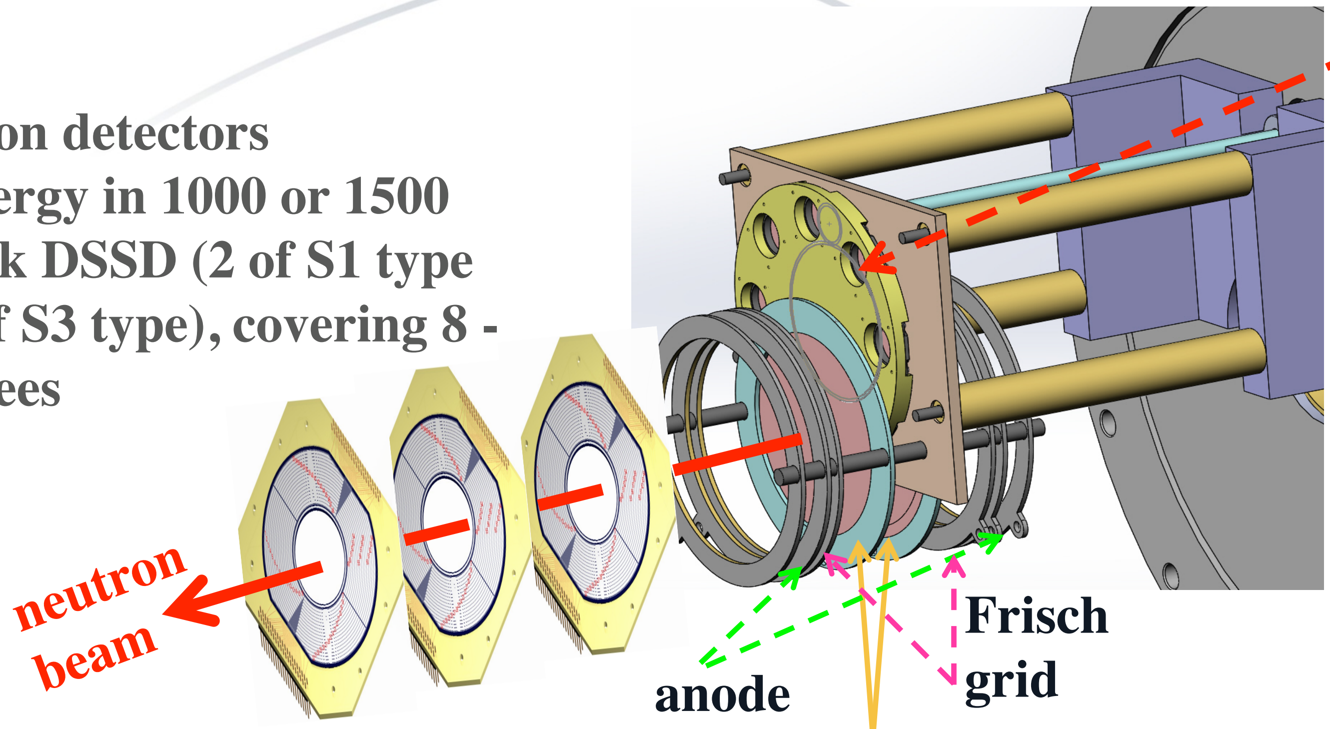
LENZ : upgrade of NZ chamber

- Designed for measuring (n,z) reactions with a large solid angle and low detection threshold for especially alphas
- Twin Frisch grid ionization chamber
- Multi-target wheel system
- At forward angles, silicon strip detectors measures angles and charged particles as a telescope
- Digitizers provide wavelet information as post processing for improving signal-to-noise ratio and timing resolution with no dead time



LENZ configuration for $^{16}O(n,\alpha)$ reaction

E : silicon detectors
rest energy in 1000 or 1500 μm thick DSSD (2 of S1 type and 1 of S3 type), covering 8 - 60 degrees



Multi target system

1. $Ta_2{}^{16}O_5$
2. Li_2CO_3 on Ta backing
3. Th α-source
4. ^{6}LiF calibration target
5. Ta backing

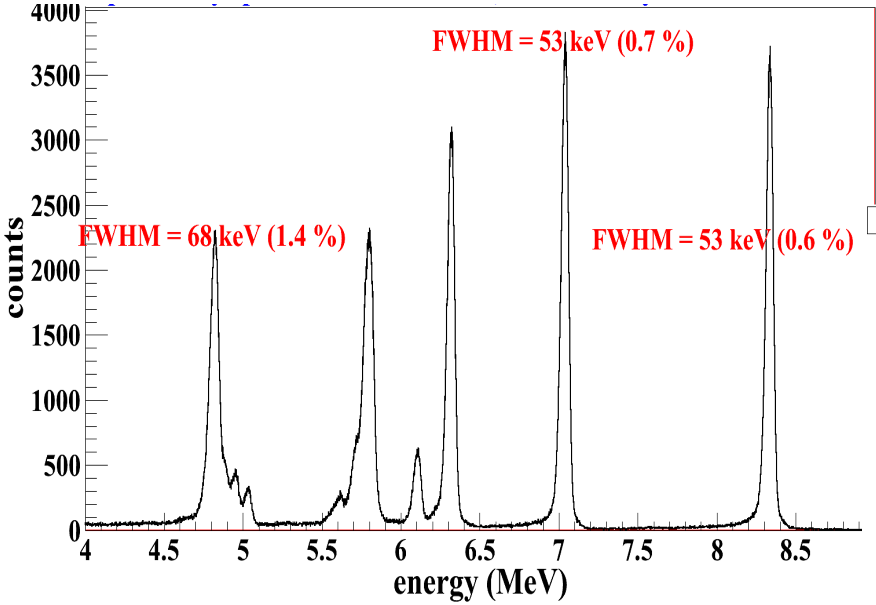
ΔE : ionization chamber
energy loss in 97% Xe + 3%CO2 or in P10 gas mixture

○Maximize the solid angle and minimize the low energy alpha's energy loss

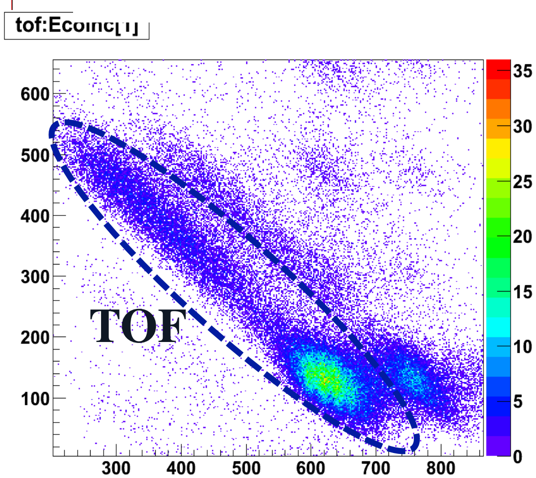
○Minimize the detection thresholds in anodes and timing resolution in cathodes

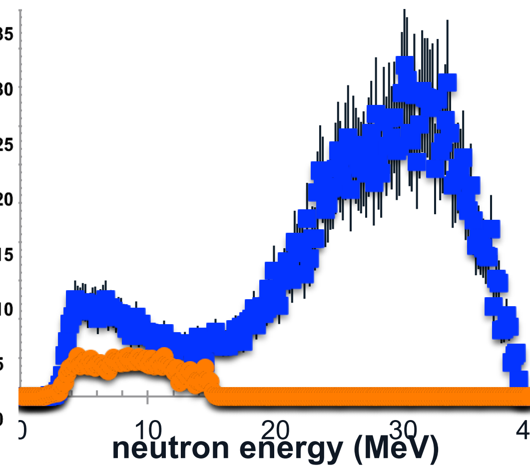
^{59}Co(n,α) and ^{59}Co(n,p) reactions as in-beam commissioning at LANSCE

DSSD energy calibration using Th-228 source



TOF (T0-cathode) vs. TOF (cathode-DSSD) shows groups in time correlations. Based on these gates, the yields normalized to the calculated neutron flux are shown below.

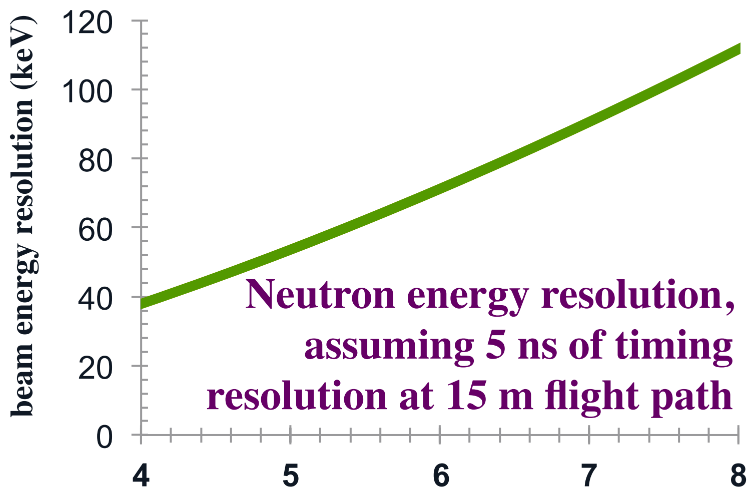


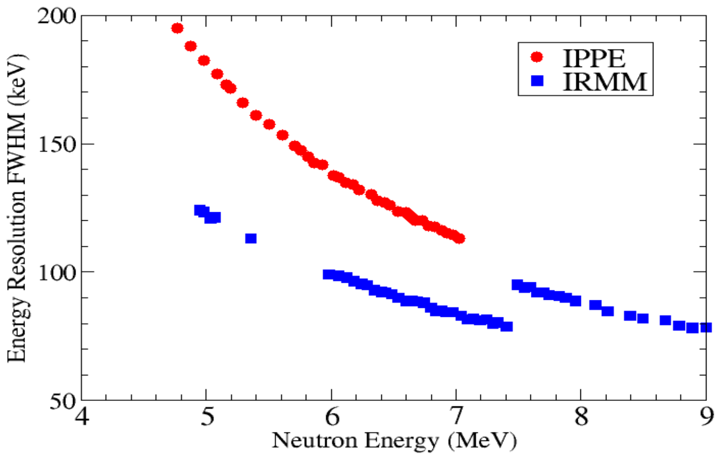


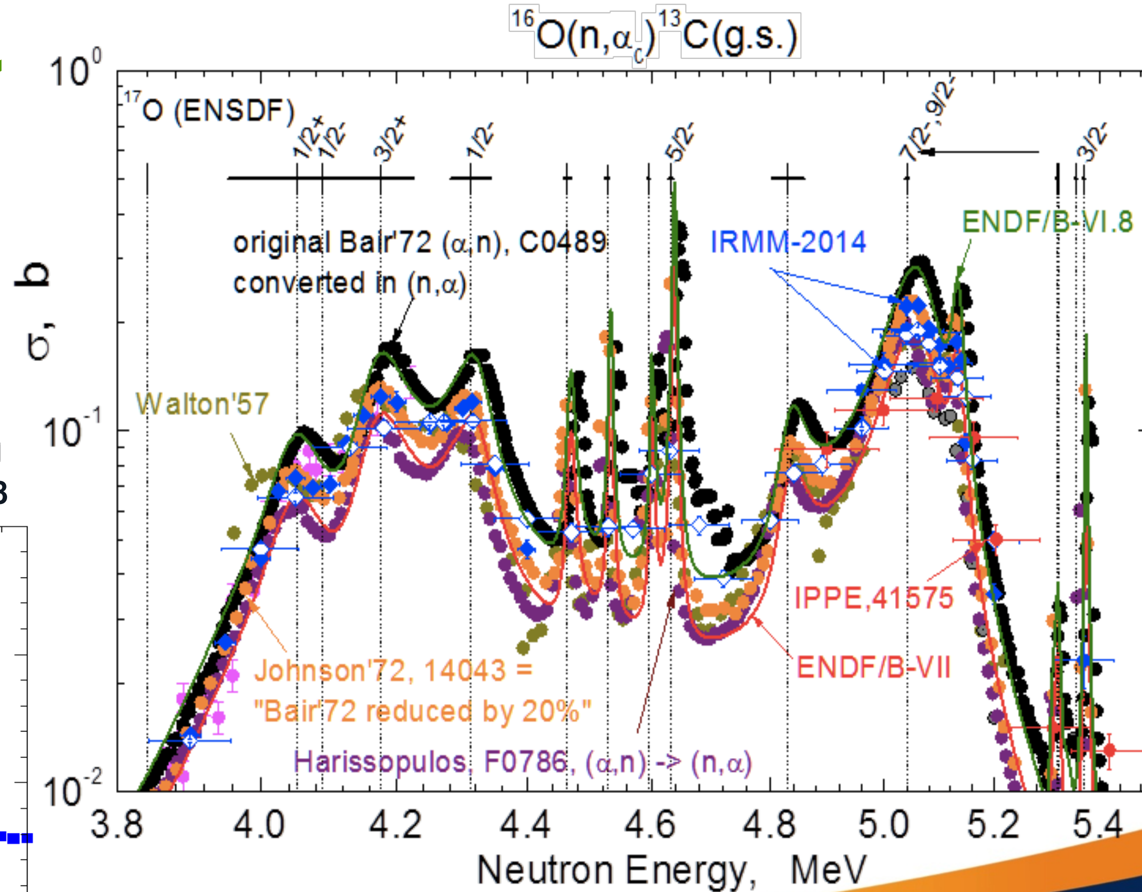
- Different particles were identified
- Not yet optimized preamplifier for ΔE silicon detector to extract the best timing resolution
- Beam induced background was measured
- Analysis is in progress

Estimated energy resolution at LANSCE

- IPPE and IRMM used D(d,n), 3H(p,n) reactions to generate neutrons
- LANSCE provides a white neutron source

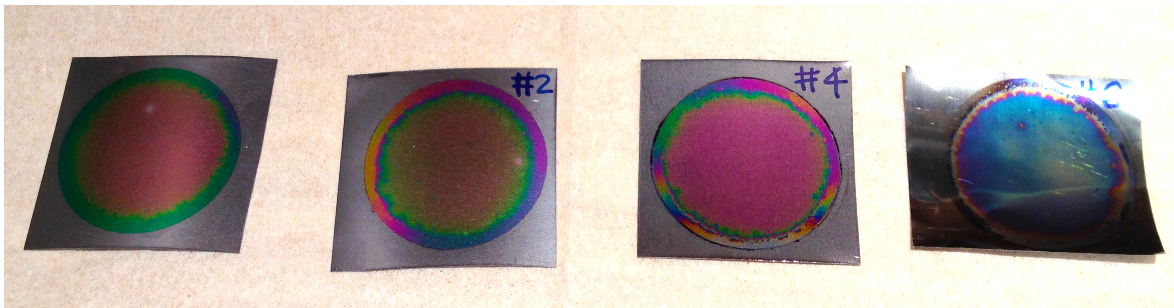






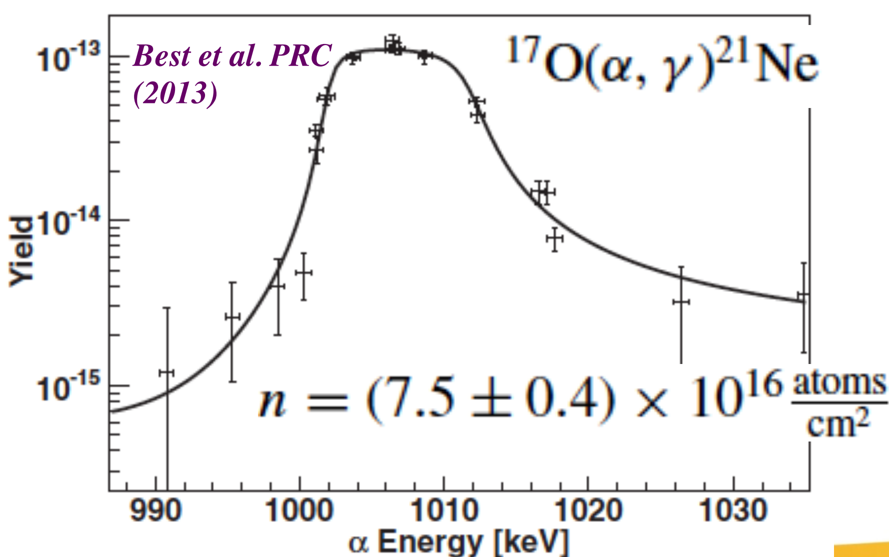
Solid ^{16}O target for LANSCE measurements

- For better control of the target amount and ease of manufacturing in house, we plan to use a solid oxygen target
- Tantalum backing was anodized to produce Ta_2O_5 with ~ 4000 Å

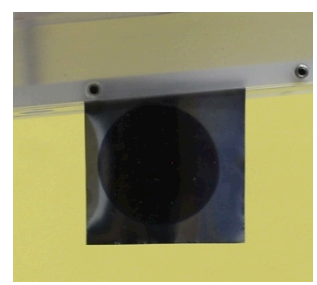


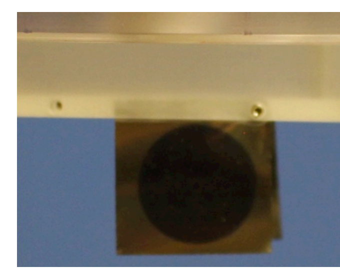
Vermilyea, Acta Metallurgica (1953)

Thickness (Å)	Error (Å)
200-500	1
500-2500	5
2500-5000	8



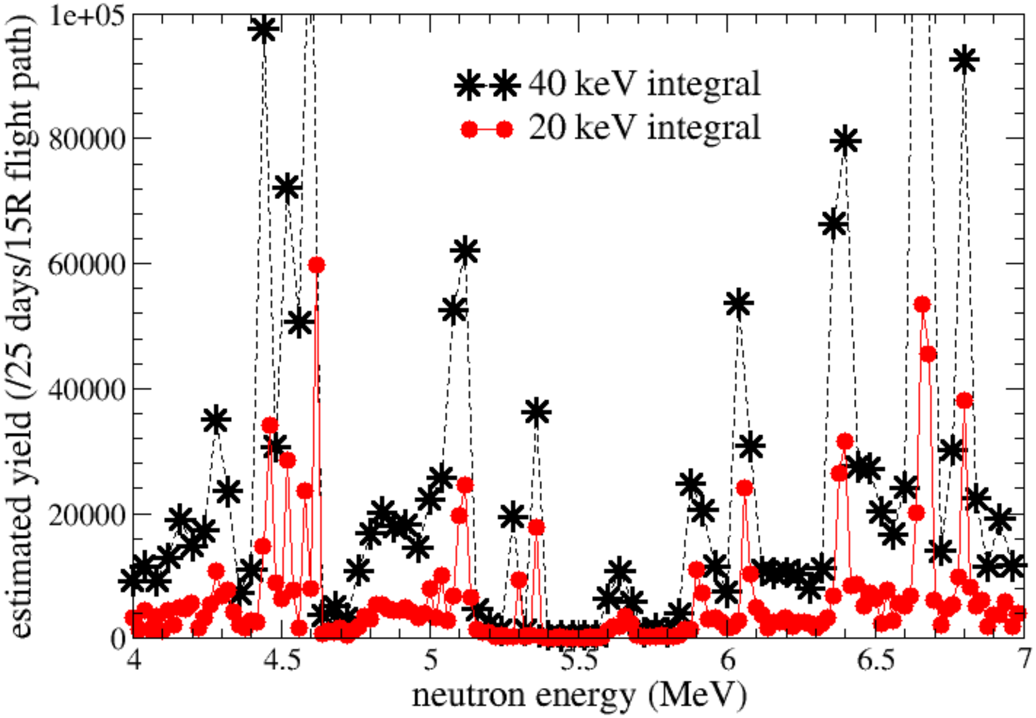
- For the ratio measurement, Li_2CO_3 targets were made





Estimated LENZ ^{16}O(n,α) yield and target uncertainty for the ratio measurement to ^{6}Li(n,α)

Assuming 100 Hz macro pulses at WNR 15R with 15 m flight path, integrating over the detected solid angles,

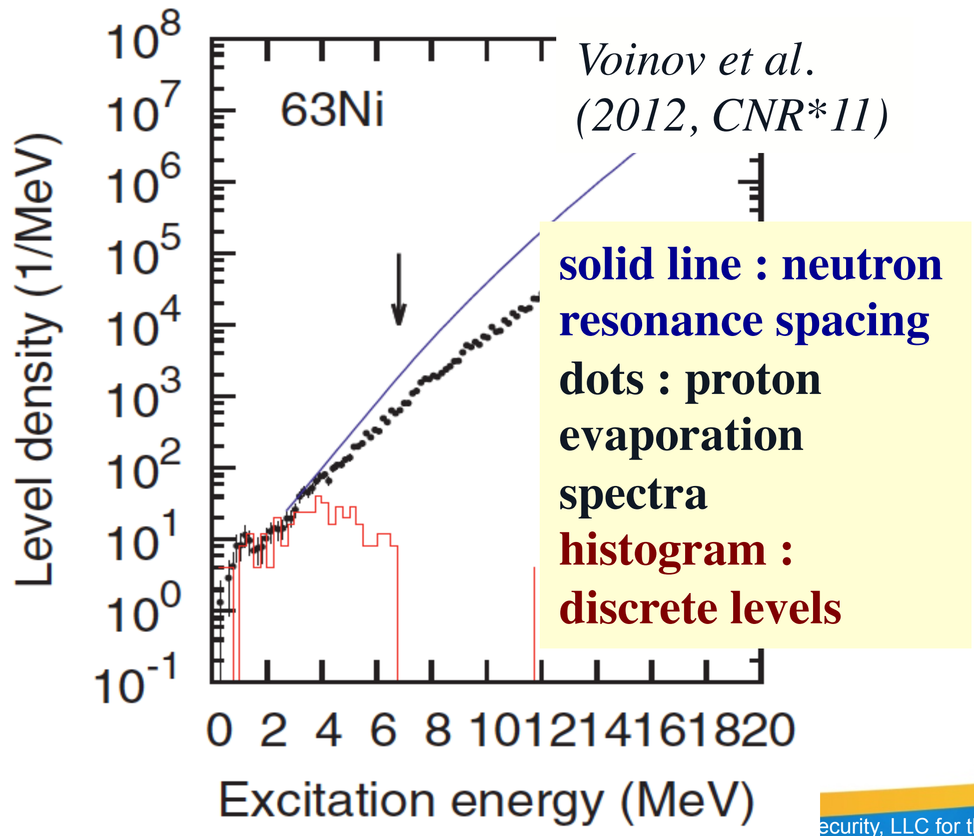


estimated systematic uncertainty for O/Li ratio measurement

target thickness	5	%
stoichiometry	5	%
(neutron flux)	(10)	%
timing resolution	1	%
Li cross section	10	%
total sys unc	12.3	%
total stat. unc	0.7-2.5	%
total unc.	12.3-12.7	%

Experimental effort for level density study

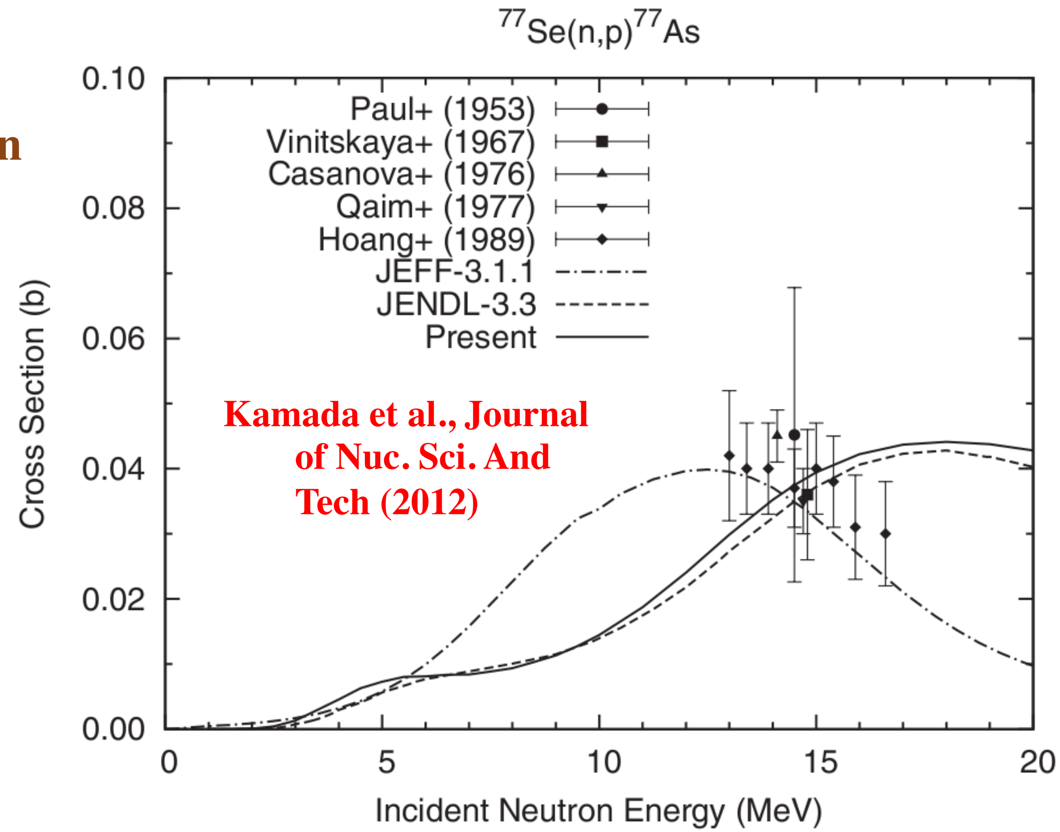
- Traditionally, for most of stable nuclei, the level density is estimated on the basis of experimental information from low-lying discrete levels and neutron resonance spacing
- Evaporation spectra from (n,p) (n,α), (α,n) and (p,n) reactions and with beams like d, ^{3}He, ^{6,7}Li, ^{12}C up to 15 MeV of beam energy



Level density parameters obtained from neutron resonance spacing measurements need to be validated by a different experimental approach such as (n,p) and (n,α) reactions for better predictive power in reaction cross sections, especially for unstable nuclei

For better understanding of HF nuclear inputs via studying ^{77}Se(n,p) reactions

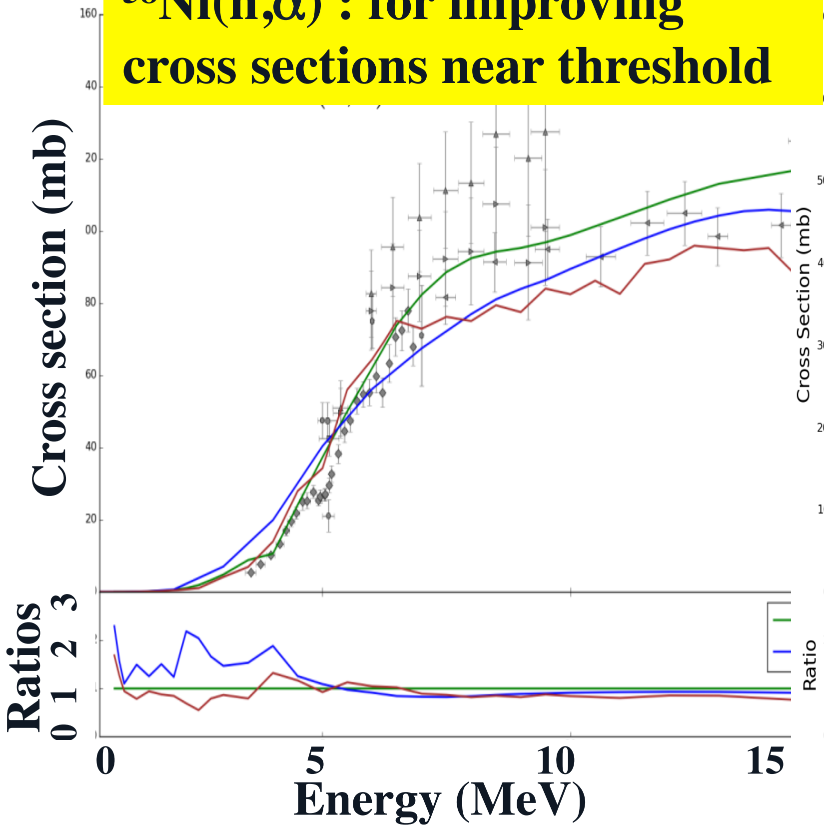
- Various Hauser-Feshbach calculations show different shapes on (n,p) cross section for ^{77}Se and ^{76}As, questioning nuclear input parameters at this mass range
- Currently available data sets were measured only near 14 MeV, so LENZ will measure (n,p) cross sections at E_n = 1-20 MeV at LANSCE



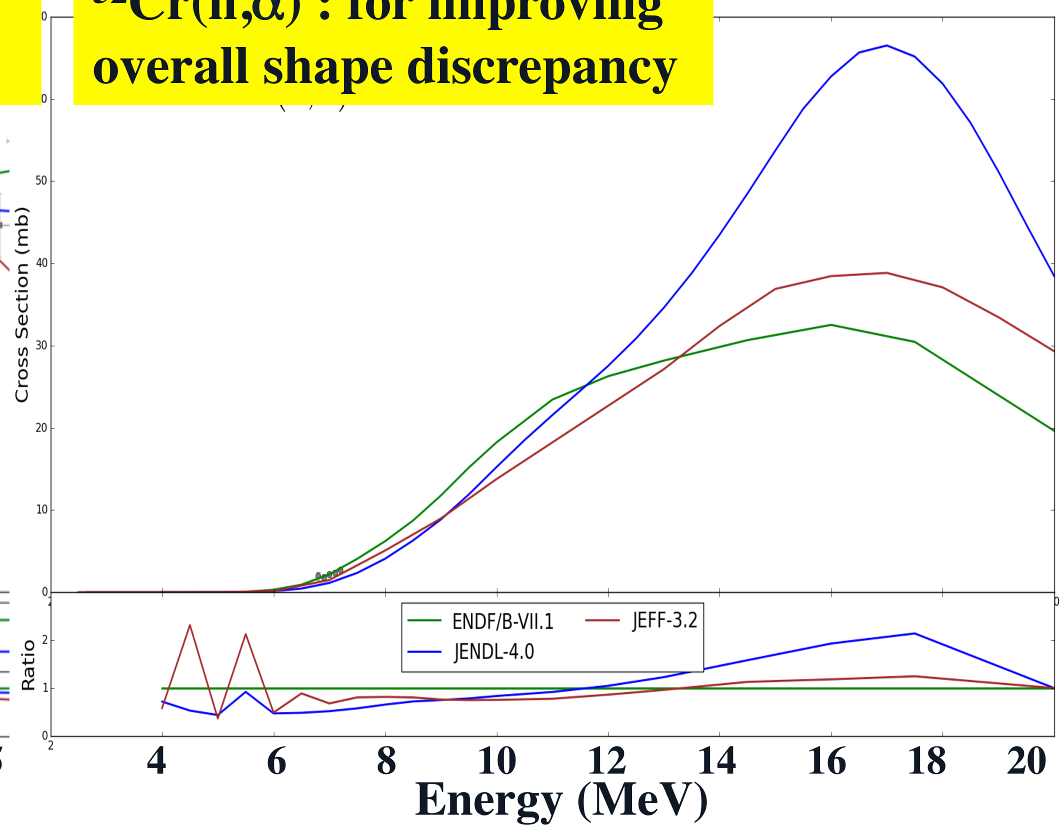
Kamada et al., Journal of Nuc. Sci. And Tech (2012)

For improving data evaluation, we plan to provide better quality (n,α) cross section data on structure materials

^{58}Ni(n,α) : for improving cross sections near threshold

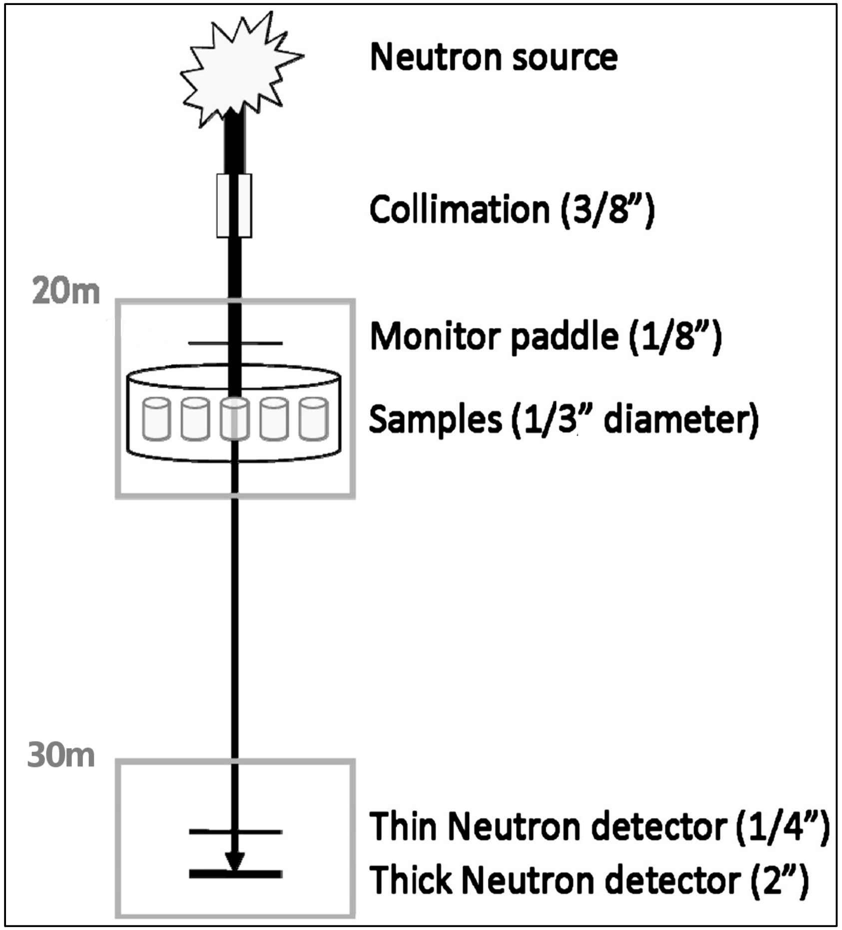


^{52}Cr(n,α) : for improving overall shape discrepancy



ENDF/B-VII.1 JEFF-3.2 JENDL-4.0

3. Total cross section measurement capability at LANSCE - I

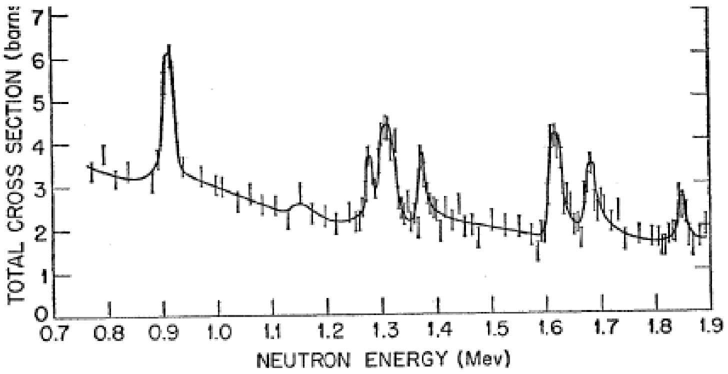


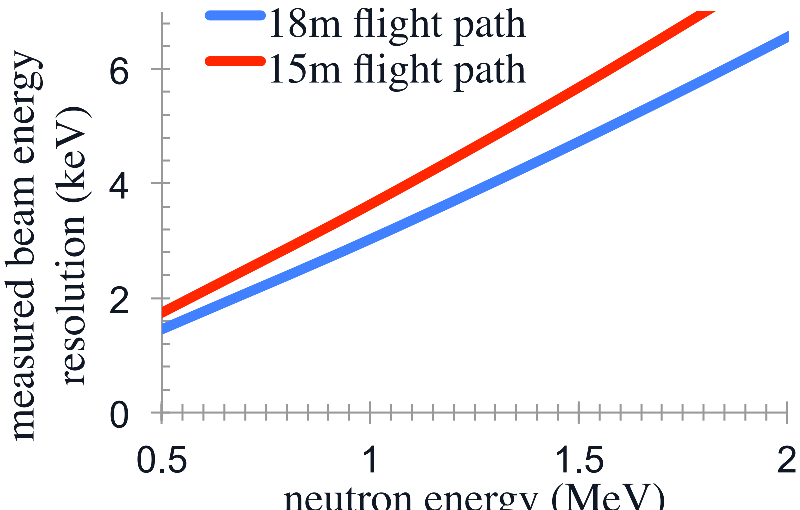
Expanding Dispersive Optical Model(DOM) predictive power :

- DOM connects reaction data (σ_{tot}(n), elastic scattering) to structure (rms radii, spectroscopic factors) via fitting a complex optical potential
- Data from along closed-shells provide a natural, chart-wide data scaffold for DOM fitting, improving extrapolation away from stability
- Wash. U. group has performed successful measurements on Ca isotopes and now are taking data with Sn isotopes (Sn-112 & Sn-124) in the 2015 Run cycle

3. Total cross section measurement capability at LANSCE - II

Previous (n,n) measurement with 13 keV resolution and 10 keV uncertainty didn't observe weak resonances

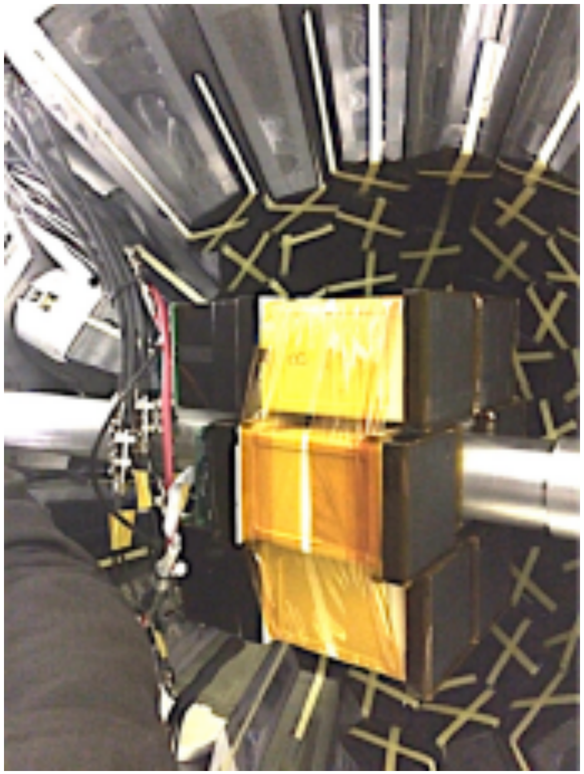




High resolution study of $^{20}Ne(n,n)$ at neutron energies below 2 MeV

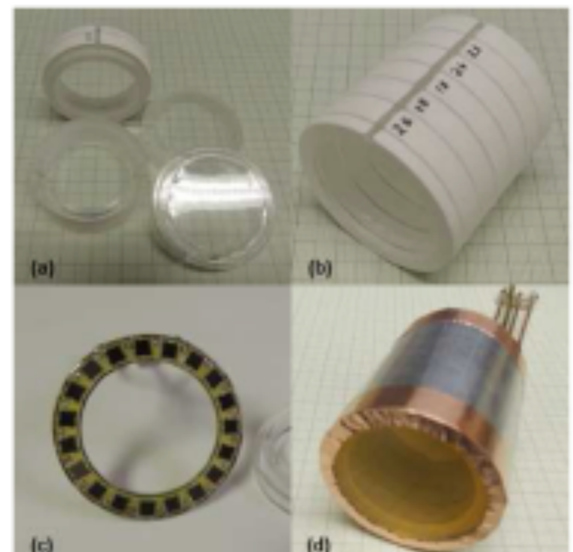
- $^{22}Ne(\alpha,n)^{25}Mg$ is the main neutron source for the s process in massive stars, however most abundance ^{16}O acts as the strongest neutron absorber via $^{16}O(n,\gamma)^{17}O$, which could recover "lost" neutron flux by the subsequent $^{17}O(\alpha,n)^{20}Ne$ reaction
- However, the efficiency of this recovery strongly depends on the relative strength of the competing reaction channel $^{17}O(\alpha,\gamma)^{21}Ne$
- Current limitation is poorly known level information on ^{21}Ne at Ex = 7.4 – 8.4, therefore improved total cross section measurement is needed

4. Enhanced DANCE Capability at LANSCE, led by M. Jandel (DOE-Early Career)



DANCE hardware upgrade, NEUANCE (Neutron Array at DANCE), provides new measurements on correlated data between neutrons and gammas in neutron-induced fissions with high efficiency

Fission fragment tagging with thin scintillator foils is composed of multiples films from a solution of liquid scintillator, for the studies of gamma-ray cascades leading to the isomeric states in U-236



5. Photon strength function studies on unstable nuclei in inverse kinematics at ANL

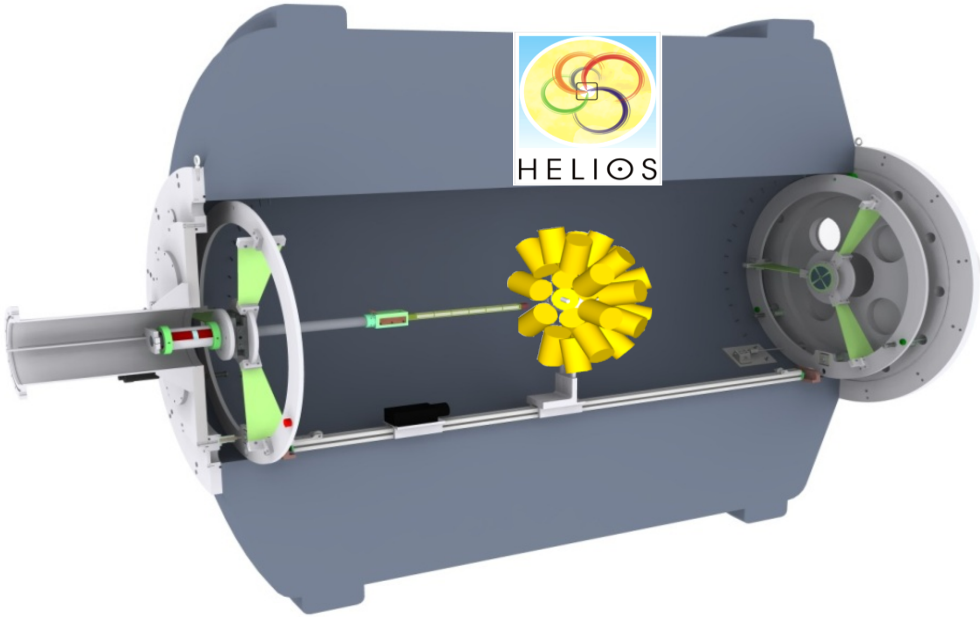
What can we obtain by combining HELIOS (Helical Spectrometer) & APOLLO (LANL developed γ-ray array)?

(d,p) reactions can deduce :

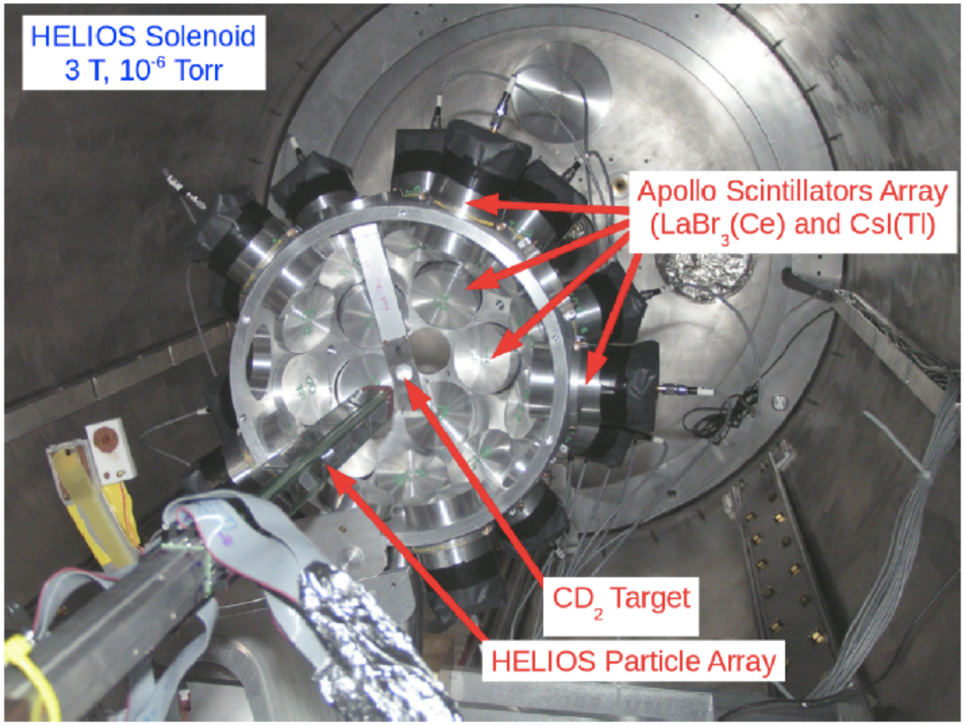
- Properties in excited states
- Angular momentum transfers
- Single-particle strengths

Coincident γ detection can add:

- Level densities
- γ-ray decay schemes & multiplicities
- Photon strength function



5. Planned experiments on ^{97}Zr photon strength function (PSF) led by S. Mosby



- Measure ^{96}Zr(n,γ) at DANCE (Dec. 2015) and ^{96}Zr(d,p)^{97}Zr using Apollo at ANL (spring 2016) to constrain PSF, verify consistency of direct, indirect methods
- Many fission fragments could be studied using CARIBU, and potentially more at FRIB

Summary

- Feasibility to study the $^{16}O(n,\alpha)$ has been established at LANSCE and currently performing a proof-of-principle measurement in the run cycle 2015
- Many more exciting and new initiatives are being developed to contribute US Nuclear Data Program
- Close collaboration at LANL among experiment, theory, and evaluation :

  R. Haight, A. Couture, M. Devlin, S. Mosby, F. Tovesson
  J. Ullmann. J. Winkelbauer (P-27)
  M. Jandel, T. Bredeweg, G. Rusev, B. Baramsai, C. Walker (C-NR)
  T. Kawano, G. Hale, M. Paris, P. Talou (T-2)
  M. White, M. Chadwick (XCP, ADX)