LA-UR-22-xxxxx

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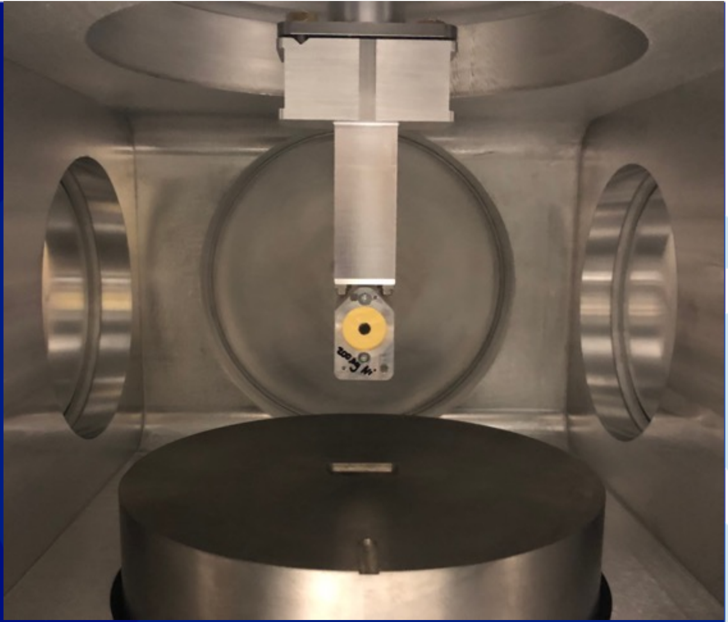

LANL result on the $^{16}O(n,\alpha)$ reaction

H.Y. Lee, S. Kuvin, B. DiGiovine, G. Hale, S. Mosby, M. Paris, D.Votaw[a], M. White, L. Zavorka[b]

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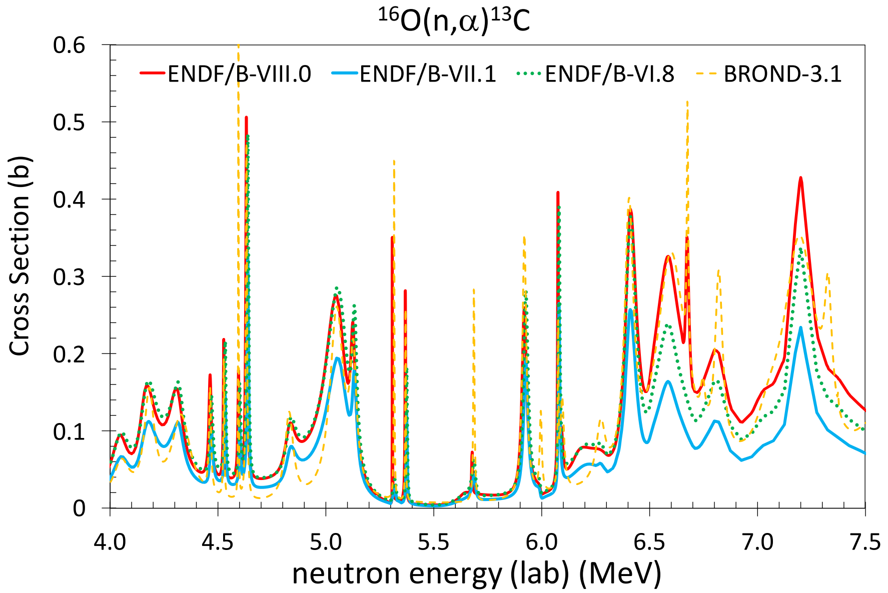
Nuclear Data Week: Cross Section Evaluation Working Group (CSEWG)

Oct. 31- Nov. 4, 2022

Current status of ^{16}O(n,α) -- evaluation of ^{17}O system



Available evaluations for ^{16}O(n,α):

JEFF-3.1 and JENDL-4.0 are very similar to ENDF/B-VII.1

Channel configuration (top) and data summary (bottom) for the ^{17}O analysis at LANL (Paris and Hale, at IAEA 2020)

Channel	a_c (fm)	l_{max}
$n+^{16}$O	4.4	4
$\alpha+^{13}$C	5.4	5
$\gamma+^{17}$O	10.	1

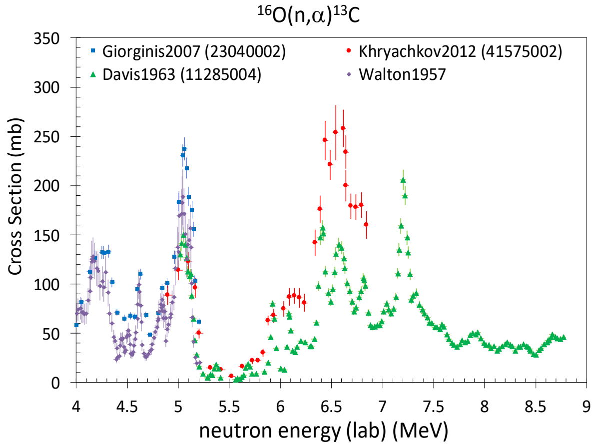
Reaction	Energy Range (MeV)	# Data Points	Observables
^{16}O$(n,n)^{16}$O	$E_n = 0 - 7$	2540	$\sigma_T, \sigma(\theta), P_n(\theta)$
^{16}O$(n,\alpha)^{13}$C	$E_n = 2.35 - 5$	672	$\sigma_{int}, \sigma(\theta), P_n(\theta)$
^{16}O$(n,\gamma)^{17}$O	$E_n = 0.02 - 0.56$	12	σ_{int}
^{13}C$(\alpha,n)^{16}$O	$E_\alpha = 0 - 5.4$	870	σ_{int}
^{13}C$(\alpha,\alpha)^{13}$C	$E_\alpha = 2 - 5.7$	1168	$\sigma(\theta)$
^{17}O$(\gamma,n_0)^{16}$O	$E_\gamma = 4.4 - 6.7$	186	$\sigma(90°)$
	Total:	5448	10

Current status of $^{16}O(n,\alpha)$ --measurements

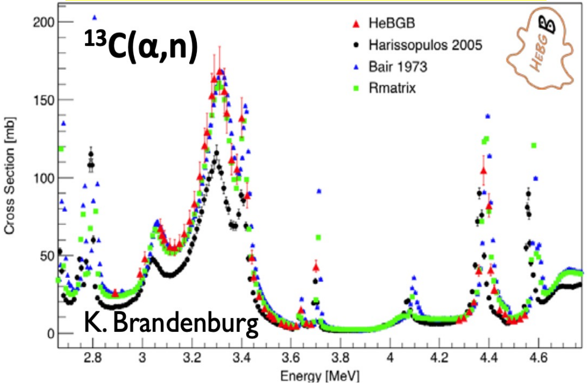
Courtesy Mark Paris

Author	Channel	Obs.
Walton'57, Robb'70, Spear'63	$^{13}C(\alpha,n)^{16}O$	$d\sigma/d\Omega$
Sekheran'67, Davids'68, Bair and Haas'73, Harissopulos	$^{13}C(\alpha,n)^{16}O$	σ
Giorginis-2007 (EXFOR)	$^{16}O(n,\alpha)^{13}C$	σ

Recent meetings about new measurements:
-IAEA INDEN Consultants' Meeting on Light Elements. 2021
-IAEA Technical Meeting on (alpha,n) nuclear data evaluation and data needs, 2021

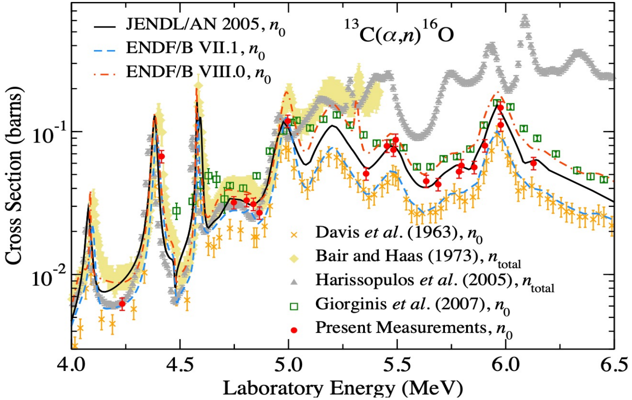


HeBGB at Ohio: σ measurement

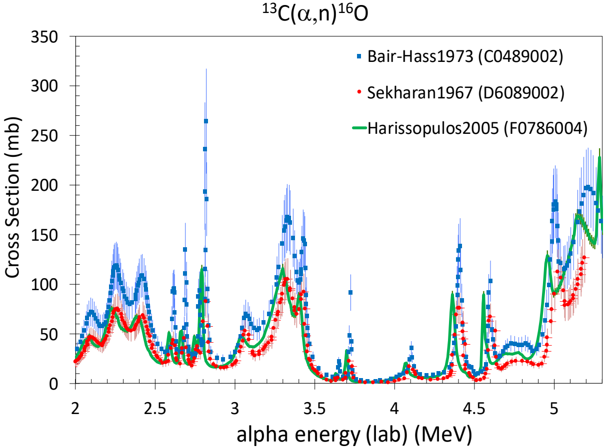


Meisel/ Brandenburg (Ohio U. 2021)

ODeSA at Notre Dame: $d\sigma/d\Omega$ measurement



Febbraro et al. Phys. Rev. Lett. (2020)



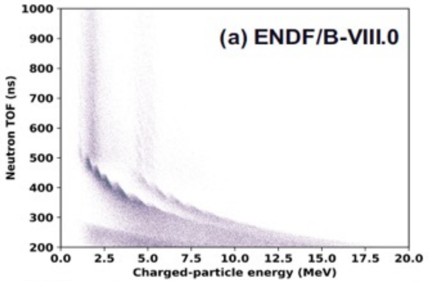
Validating MCNP simulations with LENZ data

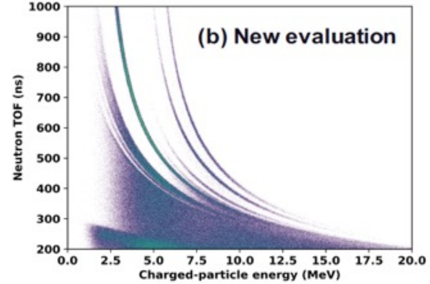
Votaw, Zavorka, Lee, et al. NIMA (soon to be submitted)

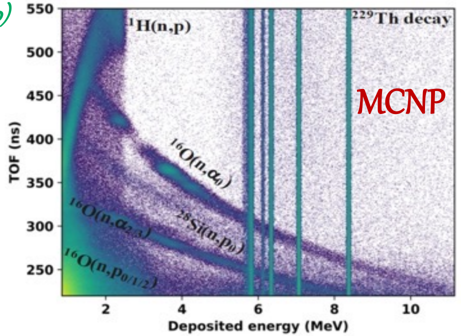
1. Testing if nuclear library is adequate for charged particle transport
2. Optimizing experimental timing and energy resolutions in LENZ configuration
3. Reducing neutron beam induced backgrounds in detecting charged particles in TOF facility

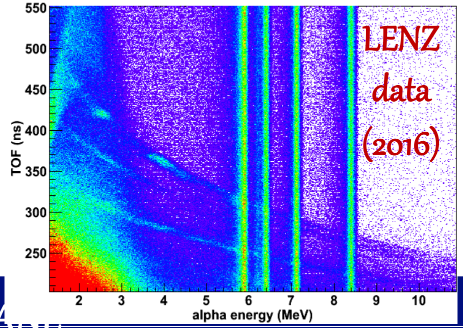
Kim, Lee, Kawano et al. NIMA 964, 163699 (2020)

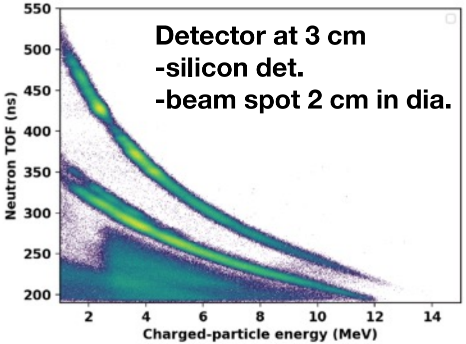
^{59}Ni(n,z) reaction

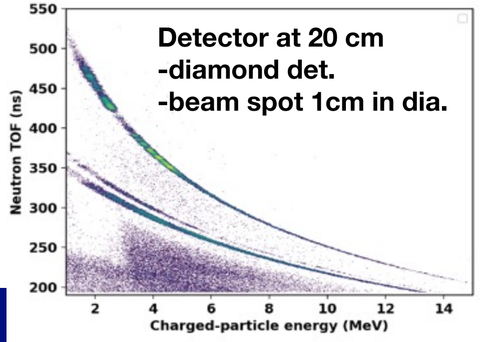


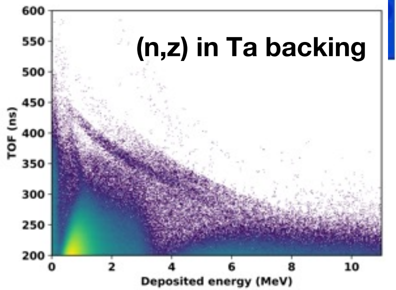


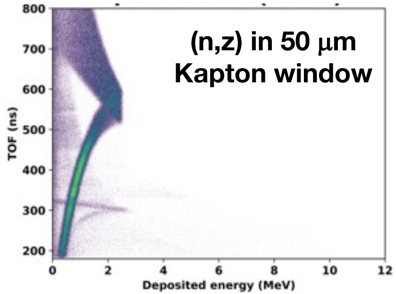


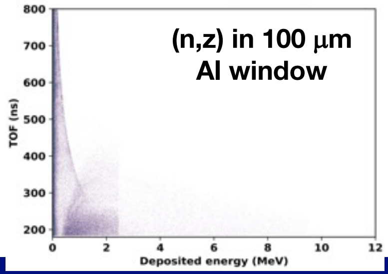






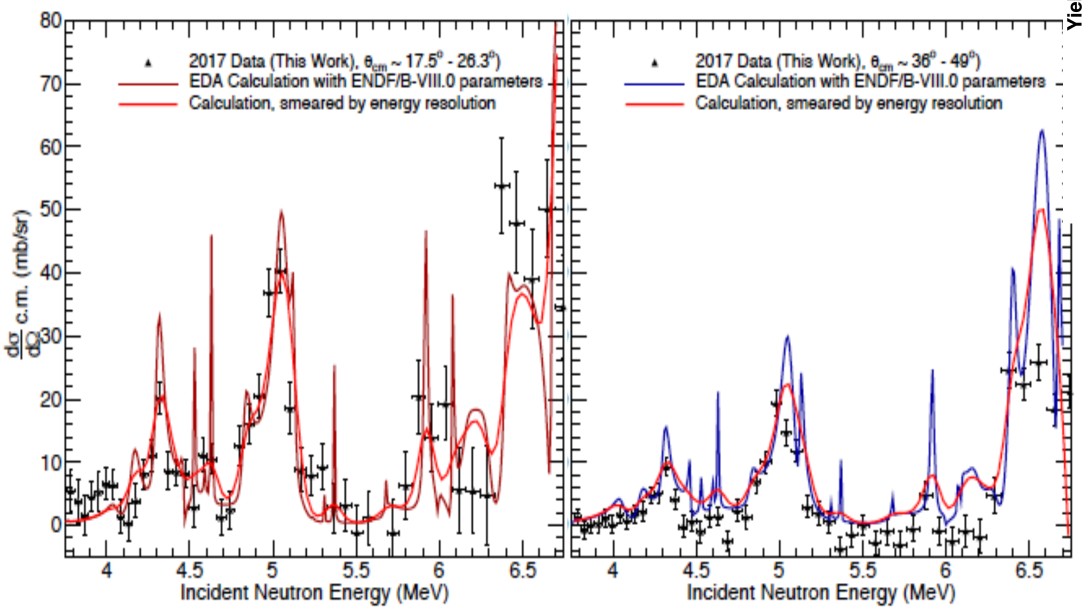


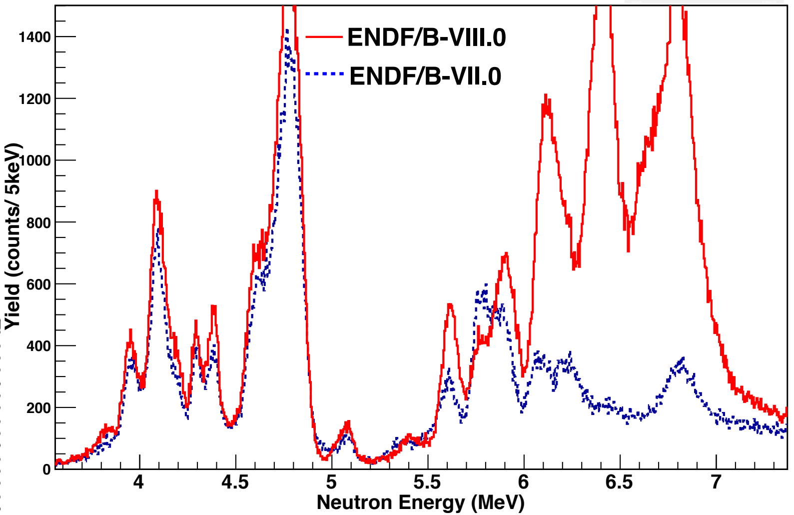




2017 LENZ $^{16}O(n,\alpha)$ differential cross sections

1. Angular response functions are provided by MCNP simulations
2. (n,α_0) and $(n,\alpha_2+\alpha_3)$ angular distributions are deduced from this work
3. LENZ (n,α_0) angular distributions well agree with ENDF/B-VIII.0





MCNP calculations show the sensitivity of LENZ @ LANSCE, when used with different releases of ENDF

Note 1: this is Forward Propagation Analysis

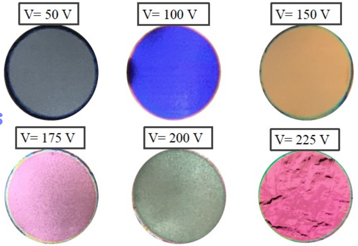
Note 2: 2017 LENZ setup was not yet optimized

Note 3: angular coverage is at 30-44 degrees in LAB

$^{16}O(n,\alpha)$ LANSCE dedicated run in 2021, to reduce systematic uncertainties

Run Cycle (year)	Beam size radius (cm)	Target (thickness) (Ta_2O_5/Ta backing)	Detector thickness (μm)	Detector's distance from target (cm)	Nominal Angles (degrees)	Vac. Window material
2016	1	Ta_2O_5 (400 nm/ 125 μm)	71 & 1000	3.9 & 7.0	$19° - 51°$	Kapton
2017	1	Ta_2O_5 (400 nm/ 125 μm)	300 & 500	4.1 & 9.1	$15° - 50°$	Kapton
2021	0.5	Mylar: $C_{10}H_8O_4$ (1.6 μm)	300, 300	20 &12.5, -2.5	$7° - 21°$, $124° - 142°$	Al. alloy
2021	0.5	Ta_2O_5 (350 & 500 nm/ 3 μm)	300, 300	12.5 & 2.5	$11° - 21°$, $44° - 63°$	Al. alloy

Anodized Ta_2O_5 targets

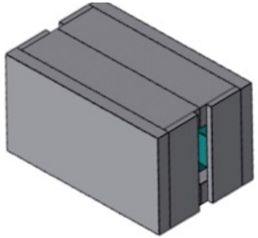


1. Reduce neutron scattering at a sample: new oxidized samples (Ta2O5) will be made in order to reduce the Ta backing thickness from 125 μm to 3 μm.
2. Utilize the secondary sweeper magnet right after the collimation: this reduces any secondary charged particles entering to silicon detectors immensely.
3. Replace the vacuum window from Kapton to a thin Al foil: this removes any additional protons produced from (n,p) scattering on hydrogens in the window.
4. Increase the distance between the sample and DSSDs and reduce the beam spot to be 1 cm in diameter, in order to improve angular resolutions

0.5 Tesla permanent magnet to sweep off any secondary charged particles

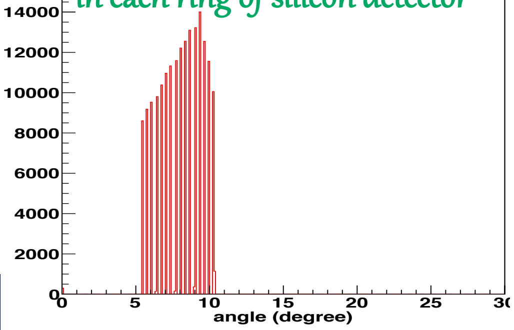
-dimensions: 55 X 35 X 30 cm^3

-bore size: 5 X 10 cm^2

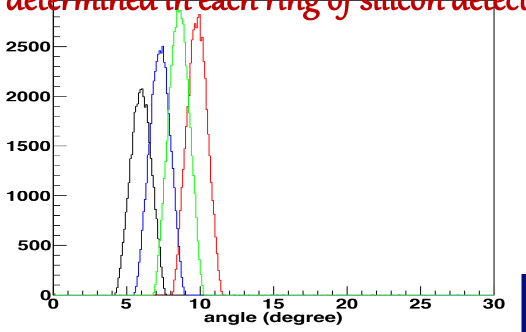


MCNP simulation for the optimized LENZ data

Emitted charged particle's angles in each ring of silicon detector

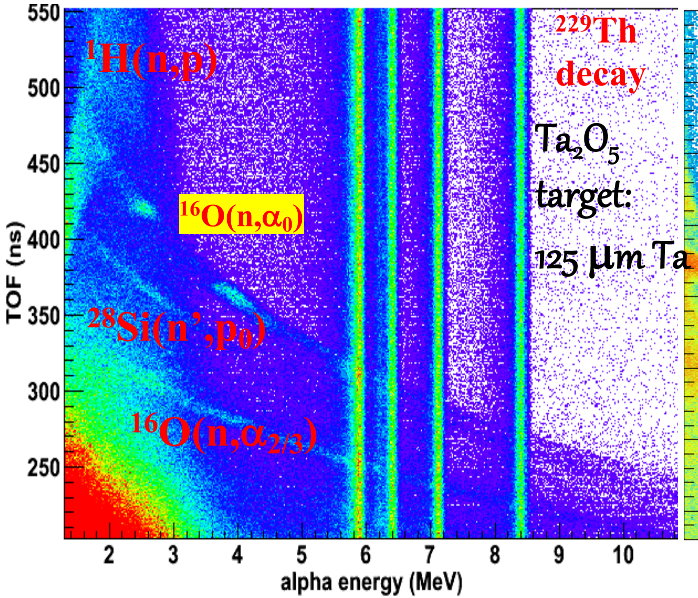


detected charged particle's angles determined in each ring of silicon detector

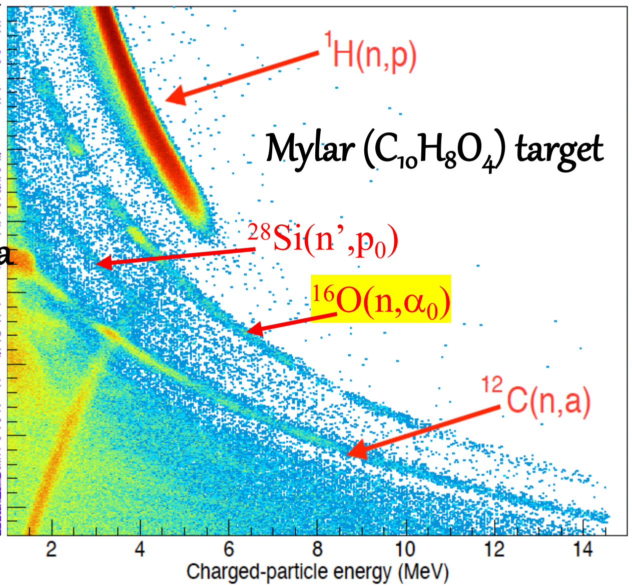


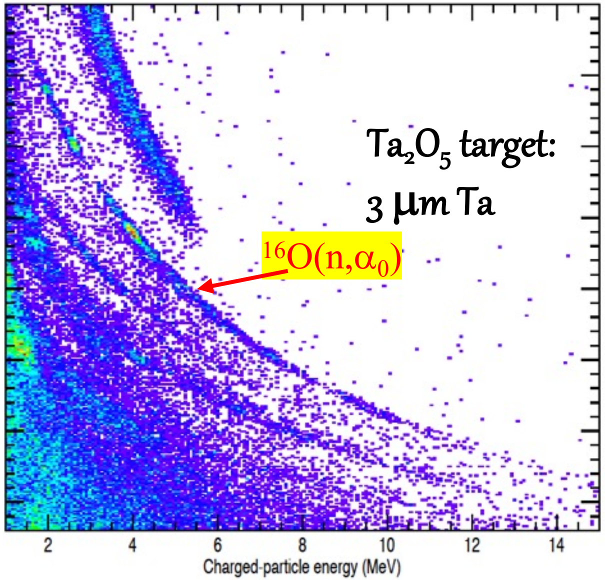
$^{16}O(n,\alpha)$ yield comparison with different experimental configurations

LENZ 2016 data



LENZ 2021 data



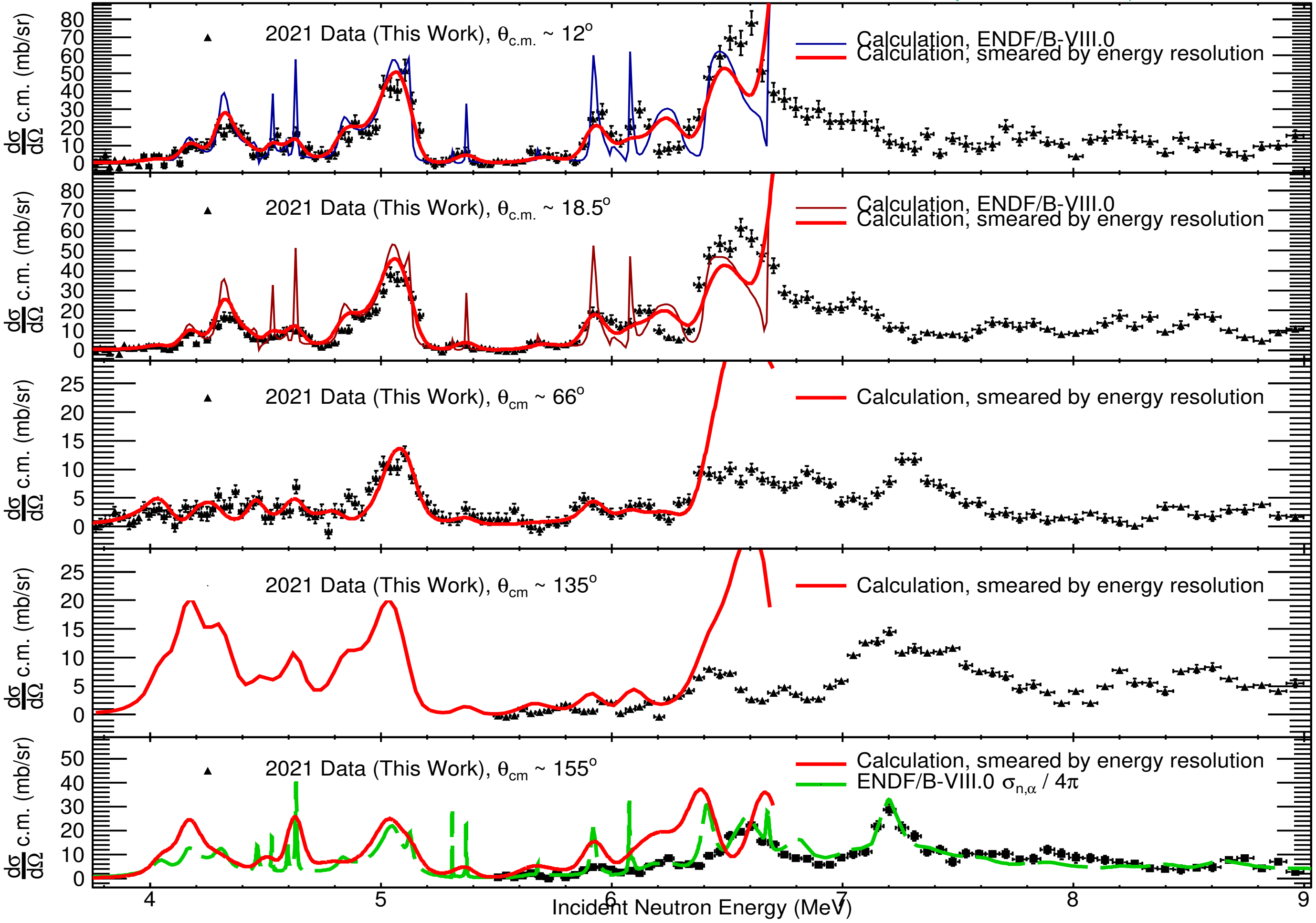


- LENZ 2016 data was taken using a 65 micron thick silicon strip detector and LENZ 2021 using a 300 micron DSSD
- LENZ 2021 data was taken using optimized experimental configurations and a thinner Ta backing
- Ta_2O_5 targets with different thicknesses & Mylar ($C_{10}H_8O_4$) target for the ratio method

2021 LENZ $^{16}O(n,\alpha_0)$ differential cross sections

Lee, Kuvin, et al
(soon to be submitted)

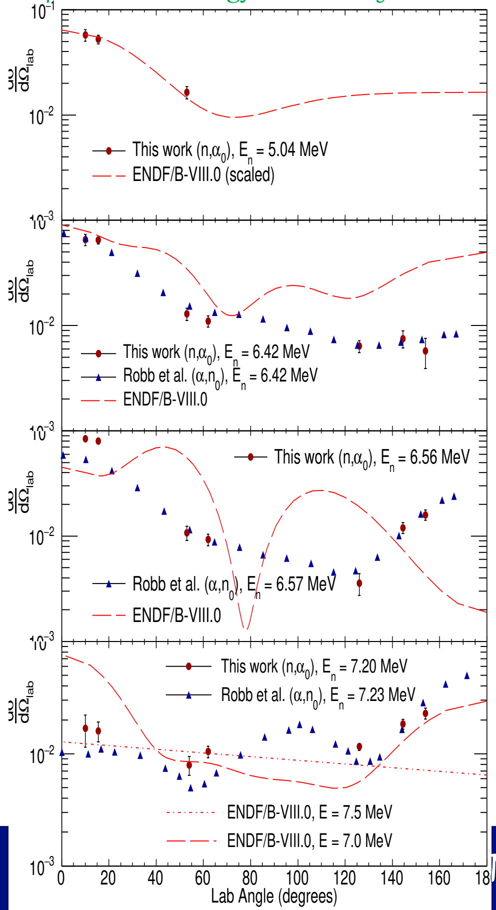
1. Differential data can be directly used for R-matrix fits, using experimentally estimated energy resolution functions
2. LENZ data consistently agrees well with ENDF/B-VIII.0
3. Above 6 MeV, a new evaluation of angular distributions is needed with differential data sets
4. Differential cross sections are obtained up to 12 MeV in the neutron energy



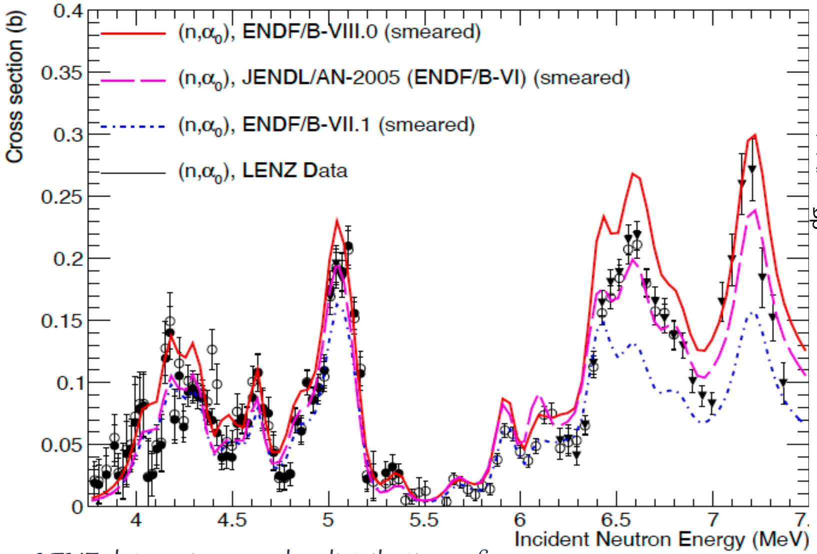
Double differential cross sections on the $^{16}O(n,\alpha)$ reaction at neutron energies from 3.8 MeV to 15 MeV

H.Y. Lee,* S. Kuvin, B. DiGiovine, G. Hale, S. Mosby, M. Paris, D. Votaw,† M. White, and L. Zavorka‡
Los Alamos National Laboratory, Los Alamos, NM 87545

Angular distributions compared with energy-averaged ENDF/B-VIII.0 using the experimental energy resolution function

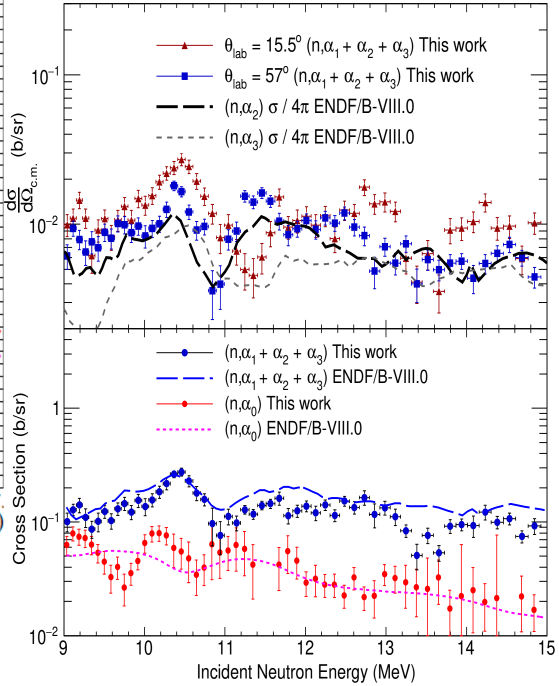


Angular integrated partial cross sections, compared with different ENDF releases using the experimental energy resolution function



LENZ data: using angular distributions of
filled circles - ENDF/B-VIII up to 5.2 MeV
open circles – Notre Dame data (private comm.) up to 6.8 MeV,
filled triangles – Prusachenko data (PRC 2022) up to 7.6 MeV

Partial differential cross section populating first three excited states in ^{13}C, compared with total ENDF/B-VIII.0 cross sections assuming isotropic distributions



Summary of $^{16}O(n,\alpha)$ reaction measurement at LANSCE

- With better understanding of systematic uncertainties associated with (n,z) reaction measurements at LANSCE through multiple reaction studies and validations with MCNP/GEANT simulations, we provided differential cross sections on the $^{16}O(n,\alpha)$ reaction, with experimental resolution functions.
- To reduce uncertainties for LANSCE measurements, we investigated;

  a. direct measurements of reaction cross sections

  b. ratio method with reference cross sections

  c. Forward Propagation Analysis by validating available libraries in MCNP
- Outlook on potential future measurements at LANSCE:

  - Diamond mosaic array for better neutron energy resolution and around 90 deg detectioin

  - TPC detector for better neutron energy/angular resolution
- Outlook on improving evaluations:

  -Suggests the need of full evaluation including old and new data sets and differential/total cross sections, with realistic uncertainties in absolute normalizations from measurements

  -More effort of performing consistent evaluation including high energy, break up channels