Facilities, Measurements, and Experimental Verification of (α,n) for Dark Matter

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University of Colorado Denver

- **Position**: Assistant Professor at University of Colorado Denver
- **Collaboration:** SuperCDMS Dark Matter Search
- **Relevant Expertise:** Thesis and Postdoc in Nuclear Physics @ Notre Dame
- **DM Community Planning:** Part of the SNOWMASS process for 10-year community planning for (α,n) backgrounds; specifically organizing white paper section on ***supplemental measurements from nuclear physics.***
- **Contact:** anthony.villano@ucdenver.edu

Who Am I?

The Problem

- TALYS is a great tool to take in evaluations/nuclear data and simulate yields (https://tendl.web.psi.ch/tendl_2019/talys.html)
- **BUT** there are a wide array of nuclei we are interested in, and we heavily rely on evaluations and the final energy distribution of background neutrons depends in complicated ways on the cross section
- **Interesting Note:** sort of similar situation in determining element production in nuclear astrophys.

TABLE I. Isotopes for each (α, n) cross sections are catalogued in the EXFOR and JENDL databases

Isotope	EXFOR	JENDL	Isotope	EXFOR	JENDL	Isotope	EXFOR	JENDL
^{6}Li	Yes	Yes	^{7}Li	Yes	Yes	^{8}Li	Yes	No
^{9}Be	Yes	Yes	^{10}B	Yes	Yes	^{11}B	Yes	Yes
^{12}C	No	Yes	^{13}C	Yes	Yes	^{14}N	Yes	Yes
^{15}N	Yes	Yes	^{16}O	Yes	No	^{17}O	Yes	Yes
^{18}O	Yes	Yes	^{19}F	Yes	Yes	^{20}Ne	Yes	No
^{21}Ne	Yes	No	^{22}Ne	Yes	No	^{23}Na	Yes	Yes
^{24}Mg	Yes	No	^{25}Mg	Yes	No	^{26}Mg	Yes	No
^{27}Al	Yes	Yes	^{28}Si	Yes	Yes	^{29}Si	Yes	Yes
^{30}Si	Yes	Yes	^{31}P	Yes	No	^{34}S	Yes	No
^{35}Cl	Yes	No	^{41}K	Yes	No	^{40}Ca	Yes	No
^{48}Ca	Yes	No	^{45}Sc	Yes	No	^{46}Ti	Yes	No
^{48}Ti	Yes	No	^{51}V	Yes	No	^{50}Cr	Yes	No
^{55}Mn	Yes	No	^{54}Fe	Yes	No	^{59}Co	Yes	No
^{58}Ni	Yes	No	^{60}Ni	Yes	No	^{62}Ni	Yes	No
^{64}Ni	Yes	No	^{63}Cu	Yes	No	^{65}Cu	Yes	No
^{64}Zn	Yes	No	^{66}Zn	Yes	No	^{68}Zn	Yes	No
^{70}Zn	Yes	No	^{69}Ga	Yes	No	^{71}Ga	Yes	No
^{70}Ge	Yes	No	^{72}Ge	Yes	No	^{74}Ge	Yes	No
^{76}Ge	Yes	No	^{75}As	Yes	No	^{76}Se	Yes	No
^{86}Sr	Yes	No	^{89}Y	Yes	No	^{93}Nb	Yes	No
^{92}Mo	Yes	No	^{94}Mo	Yes	No	^{100}Mo	Yes	No
^{98}Ru	Yes	No	^{107}Ag	Yes	No	^{109}Ag	Yes	No
^{115}In	Yes	No	^{121}Sb	Yes	No	^{123}Sb	Yes	No
^{130}Te	Yes	No	^{127}I	Yes	No	^{131}Ta	Yes	No

New Measurements

- There are already some published measurements out there
- ... And also unpublished data on disk in need of analyzers – some of that data less interesting for nuc. astro. but could well make a good dark matter publication

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PHYSICAL REVIEW C **101**, 025808 (2020)

Low-energy cross-section measurement of the $^{10}B(\alpha, n)^{13}N$ reaction and its impact on neutron production in first-generation stars

Q. Liu,[1] M. Febbraro,[2] R. J. deBoer,[1] S. Aguilar,[1] A. Boeltzig,[1,*] Y. Chen,[1] M. Couder,[1] J. Görres,[1] E. Lamere,[1,†] S. Lyons,[1,‡] K. T. Macon,[1,3] K. Manukyan,[1] L. Morales,[1] S. Pain,[2] W. A. Peters,[2] C. Seymour,[1] G. Seymour,[1,§] R. Toomey,[4] B. Vande Kolk,[1] J. Weaver,[5] and M. Wiescher[1]

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[2]*Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, USA*
[3]*Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803, USA*
[4]*Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey 08854, USA*
[5]*Materials Measurement Laboratory, National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA*

PHYSICAL REVIEW LETTERS **125,** 062501 (2020)

New $^{13}C(\alpha,n)^{16}O$ Cross Section with Implications for Neutrino Mixing and Geoneutrino Measurements

M. Febbraro,[1] R. J. deBoer,[2] S. D. Pain,[1] R. Toomey,[3,4] F. D. Becchetti,[5] A. Boeltzig,[2,*] Y. Chen,[2] K. A. Chipps,[1] M. Couder,[2] K. L. Jones,[6] E. Lamere,[2,†] Q. Liu,[2] S. Lyons,[2,‡] K. T. Macon,[2] L. Morales,[2] W. A. Peters,[1,6] D. Robertson,[2] B. C. Rasco,[6,1] K. Smith,[6,‖] C. Seymour,[2] G. Seymour,[2,§] M. S. Smith,[1] E. Stech,[2] B. Vande Kolk,[2] and M. Wiescher[2]

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[5]*University of Michigan, Ann Arbor, Michigan 48109, USA*
[6]*University of Tennessee, Knoxville, Tennessee 37996, USA*

PHYSICAL REVIEW C **100**, 034601 (2019)

Measurement of the $^{10}B(\alpha, n_0)^{13}N$ cross section for $2.2 < E_\alpha < 4.9$ MeV and its application as a diagnostic at the National Ignition Facility

Q. Liu,[1] M. Febbraro,[2] R. J. deBoer,[1] A. Boeltzig,[1,*] Y. Chen,[1] C. Cerjan,[3] M. Couder,[1] B. Frentz,[1] J. Görres,[1] E. A. Henry,[3] E. Lamere,[1,†] K. T. Macon,[1,4] K. V. Manukyan,[1] L. Morales,[1] P. D. O'Malley,[1] S. D. Pain,[2] W. A. Peters,[2] D. Schneider,[3] C. Seymour,[1] G. Seymour,[1,‡] E. Temanson,[2] R. Toomey,[5] B. Vande Kolk,[1] J. Weaver,[6] and M. Wiescher[1]

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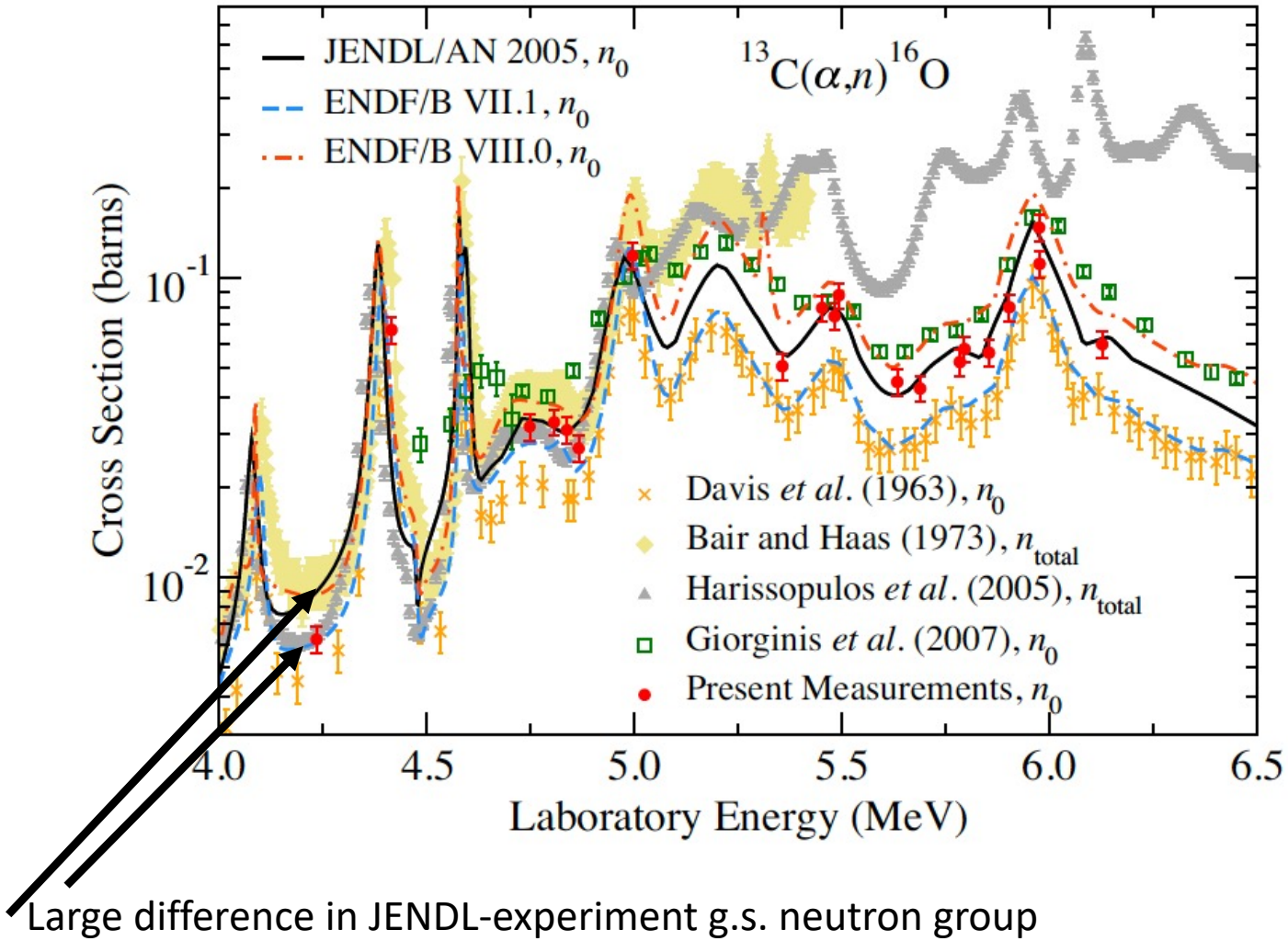
[5]*Department of Physics and Astronomy, Rutgers University, New Brunswick, New Jersey 08901, USA*
[6]*Material Measurement Laboratory, National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA*

Differences from Evaluations

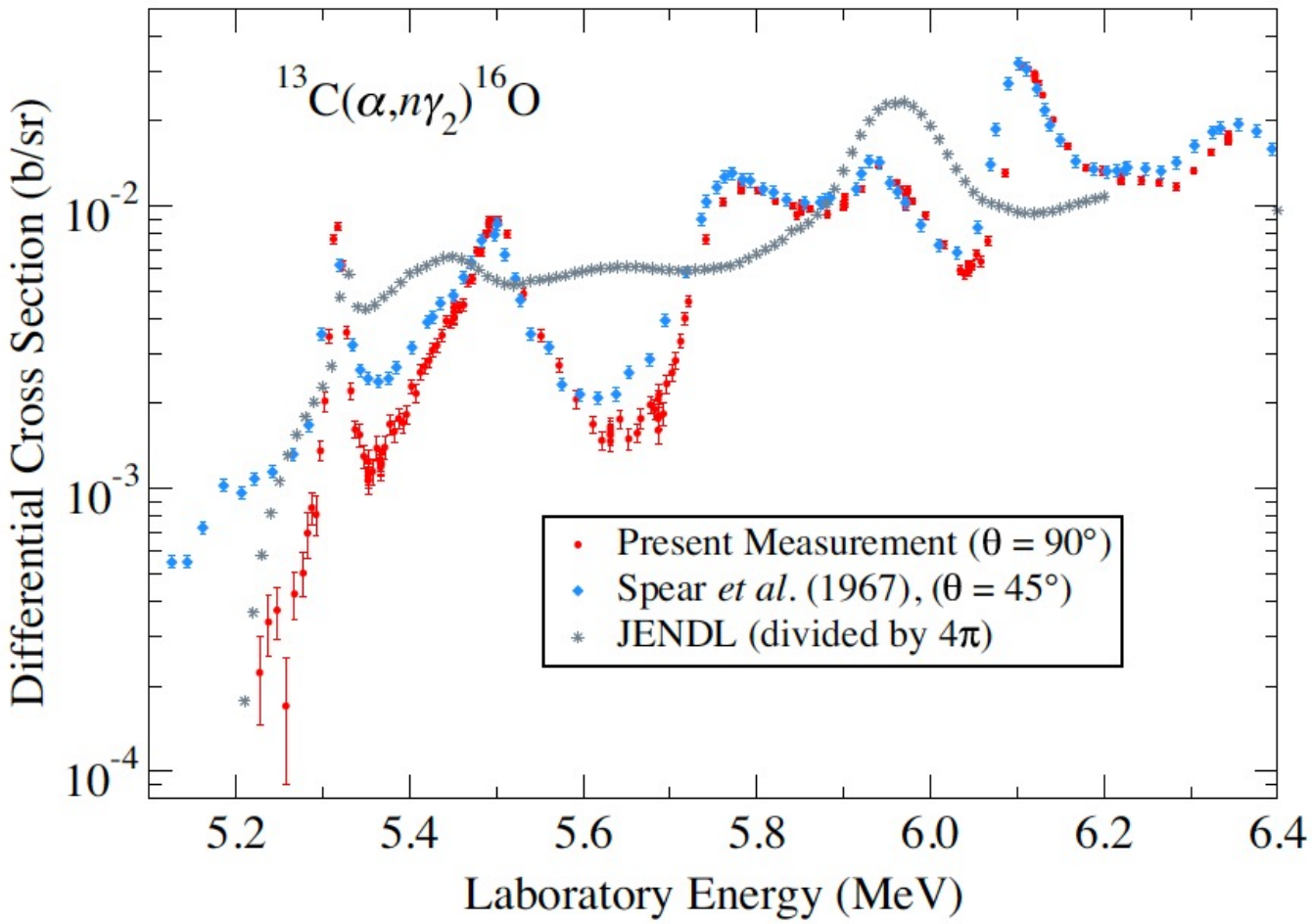
- From **Febbraro, deBoer, et al.**
- Excellent new measurements using neutron spectral unfolding
- Evaluations not perfect (log scale)



Large difference in JENDL-experiment g.s. neutron group

Worse for $^{13}C(\alpha,n\gamma)$

- Also from **Febbraro, deBoer, et al.**
- This process is important for DM as well, especially if gamma can escape veto



North American Facilities I have contacts at

Montreal: 6 MV Tandem (https://ion.lps.umontreal.ca/facilities.html)

Montreal vs. TUNL – neutron scattering facilities

Parameter	TUNL	Montreal
Target used	^{7}Li(p,n)	^{51}V(p,n) or ^{7}Li(p,n)
Minimum usable neutron speed (energy)	3100 km/s (50 keV)	960 km/s (4,8 keV)
Typical beam current on target	0.5 μA	3.5 μA
Neutron flux at target station at lowest speed	2.5 n/cm^2/s/keV	0.4 n/cm^2/s on < 1 keV resonance
Scattered neutron detectors	26 2" x 2" cylindrical liquid scintillator cells	Proposed boron-10 loaded scintillator

North American Facilities I have contacts at

- Notre Dame: 10 MV Tandem (https://isnap.nd.edu/research/facility/)

So What Do I Propose?

- Work together with the Nuclear Physics community!!

USER MEASUREMENTS IN COLLABORATION

1. have a workshop on best candidate reactions for new measurements
2. put together a team to propose said measurements and execute

SNOWMASS WHITE PAPER

1. carefully reference new relevant measurements and techniques
2. Spell out the possibilities of shared data analysis
3. Make it clear the value of building up one or two “standard” setups at various facilities

SHARED ANALYSIS

1. get relevant parties in contact and catalog what data is on disk and where
2. make agreements and seek funding for grad students through DM funding to work on those analyses
3. Publish cross-disciplinary papers where possible