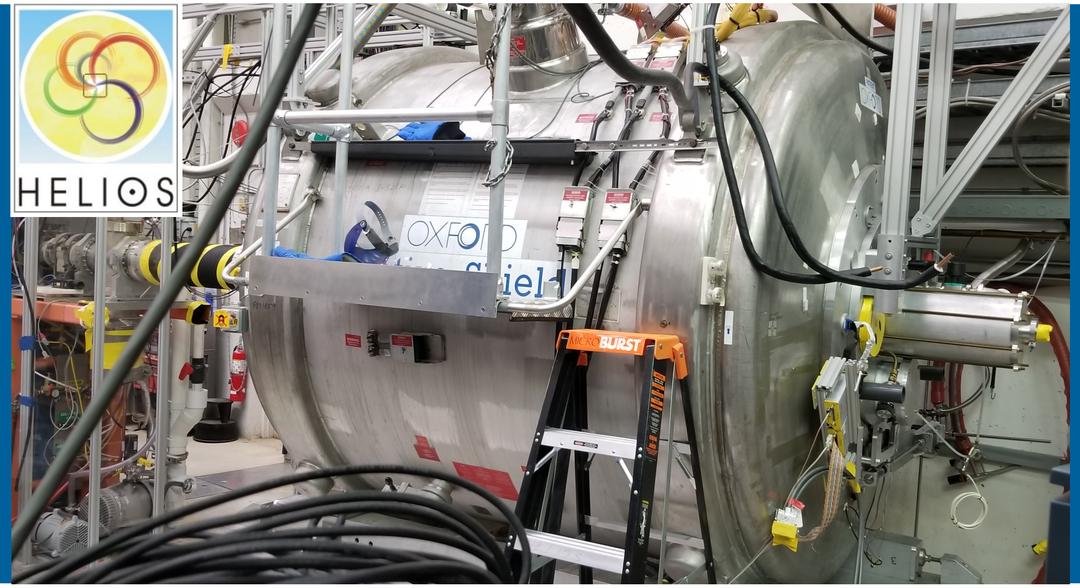


NEW ADVANCES WITH HELIOS

CALEM R HOFFMAN
Physics Division
Argonne National Laboratory
crhoffman@anl.gov

ACKNOWLEDGMENTS

ANL - Ben Kay, Ryan Tang, Jie Chen, John Schiffer, Birger Back, John Rohrer, John Anderson, & many more

UConn - Alan Wuosmaa, Daniel McNeel, & Jeremy Smith

LSU - Catherine Deibel, & Gemma Wilson

Collaborators from around the globe

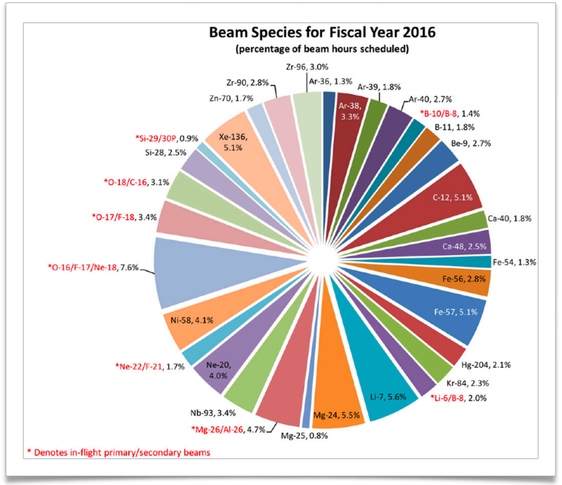
Thanks to the organizers for the invitation to speak

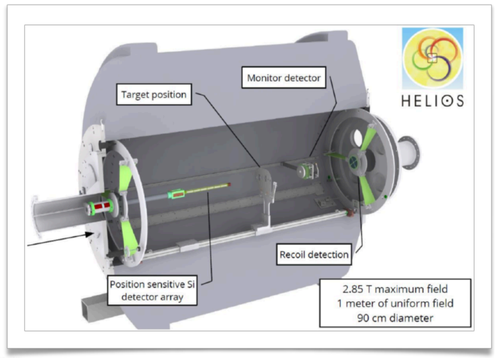
LSU UCONN UNIVERSITY OF CONNECTICUT MANCHESTER 1824 The University of Manchester Argonne NATIONAL LABORATORY

OUTLINE

A little past, mostly present, some future

- HELIOS @ ATLAS
- New Position-sensitive Si Array Upgrade
- Improved monitor, signal & data processing
- Recent “non-standard” reaction measurements
- Future ideas / plans
- Misc. comments along the way



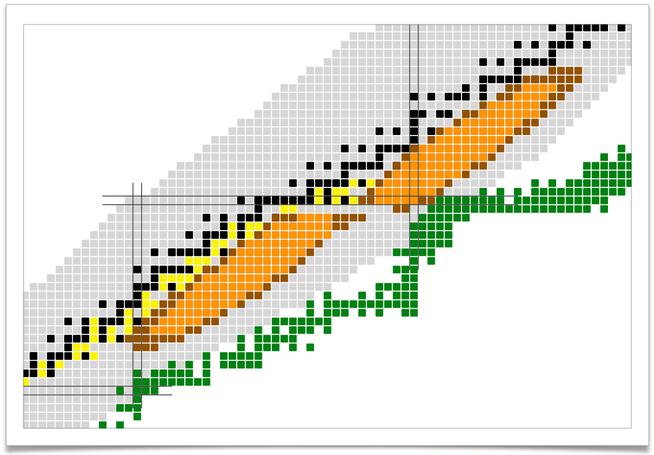


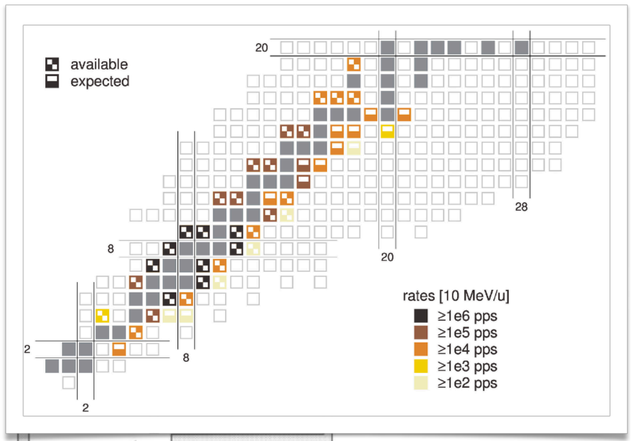
www.anl.gov/atlas

HELIOS @ ATLAS OVERVIEW

- US DOE National User Facility covering a broad range of nuclear science
- Stable & radioactive beams [CARIBU, RAISOR] up to ~15 MeV/u with high intensity
- Few hundred Users per year, >6000 Hrs running time, range of experimental equipment

Argonne NATIONAL LABORATORY





www.anl.gov/atlas/inflight-radioactive-beams
www.anl.gov/atlas/caribu-beams

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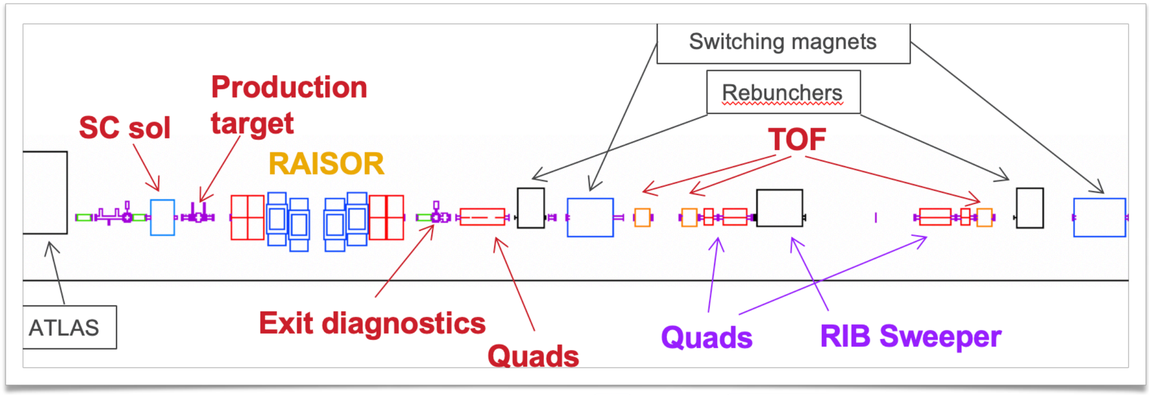
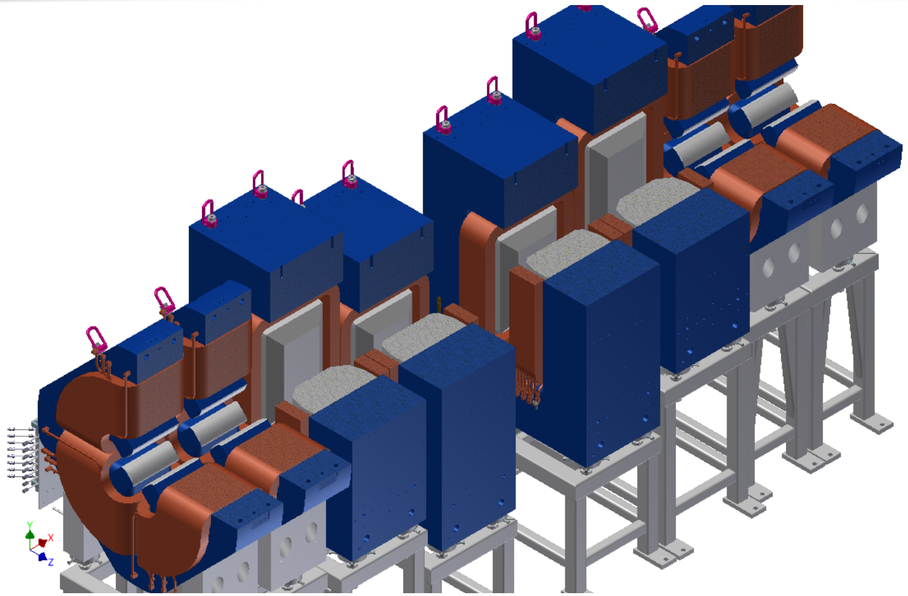
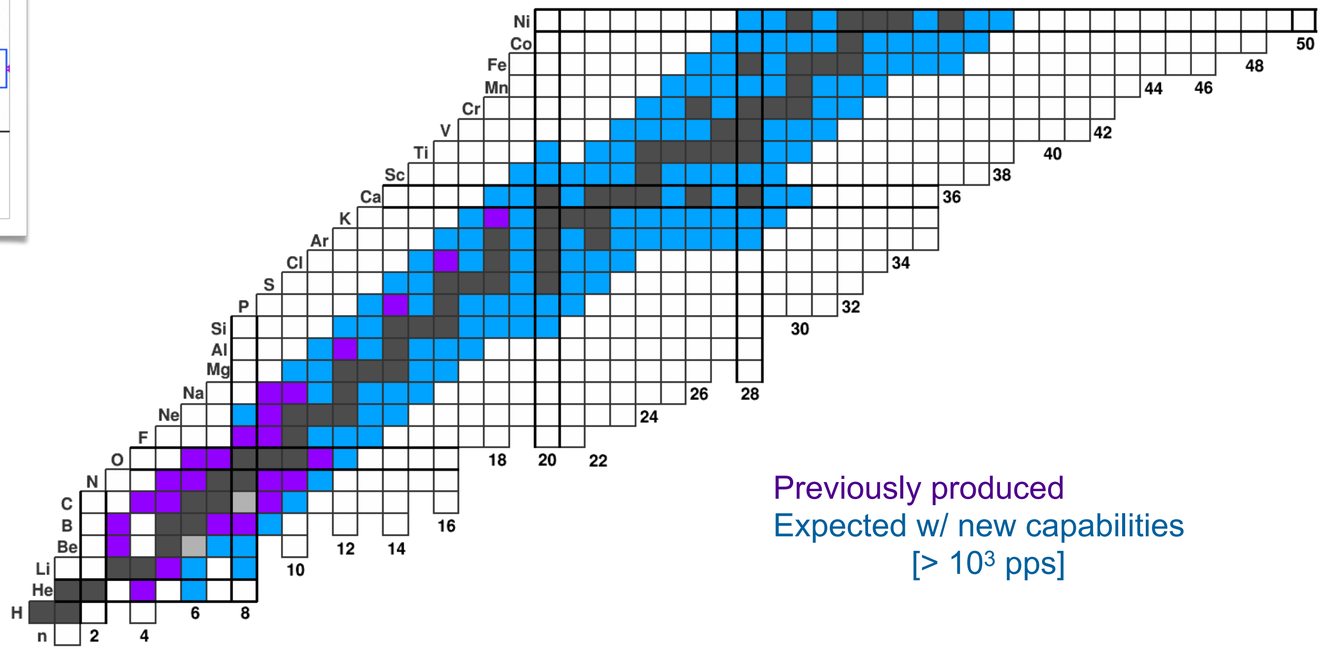




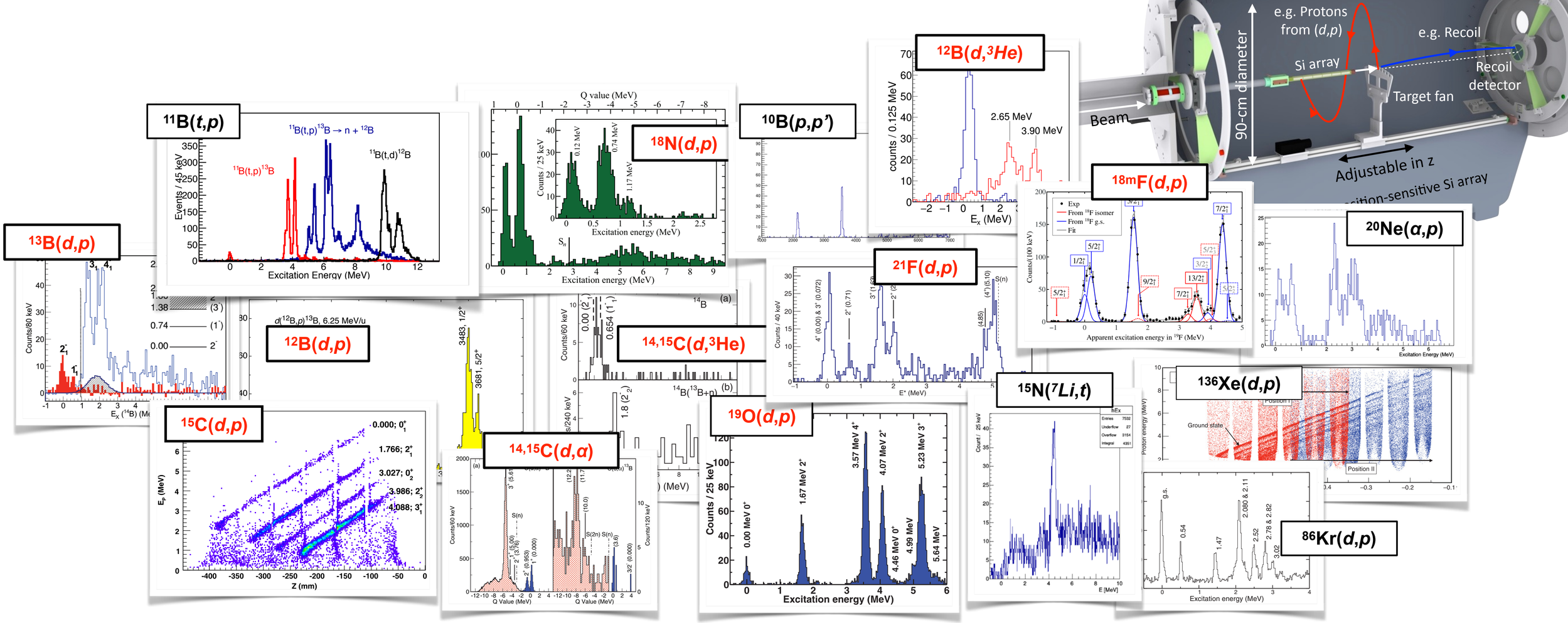


Previously produced
Expected w/ new capabilities
[> 10^3 pps]

www.anl.gov/atlas/inflight-radioactive-beams

RAISOR: UPGRADE TO ATLAS IN-FLIGHT PROGRAM

- Expand reach, intensity, & accessibility of the ATLAS in-flight beam program
- In-use for ~1 year: 6 completed experiments, 4 with HELIOS



HELIOS PROGRAM OVERVIEW

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- (*d*,*p*) workhorse, followed by (*d*,^{3}He), (*d*,*alpha*) & (*t*,*p*)
- Scattering reactions (*p*,*p*'), (*d*,*d*') picking up steam
  - along with investigations into more exotic transfer reaction types, e.g., (^{12}C,*alpha*), (^{7}Li,t), …

HELIOS SCIENCE PROGRAM: 2008 - PRESENT

12 papers, 3 letters, 3 rapid communications, 2 editors suggestions, ~120 citations

PRL Featured in Physics Editors' Suggestion — 22 citations

First Experiment with HELIOS: The Structure of ^{13}B

B. B. Back, S. I. Baker, B. A. Brown, C. M. Deibel, S. J. Freeman, B. J. DiGiovine, C. R. Hoffman, B. P. Kay, H. Y. Lee, J. C. Lighthall, S. T. Marley, R. C. Pardo, K. E. Rehm, J. P. Schiffer, D. V. Shetty, A. W. Vann, J. Winkelbauer, and A. H. Wuosmaa

Phys. Rev. Lett. **104**, 132501 (2010) - Published 31 March 2010

Physics Synopsis : Results from HELIOS

PRL — 33 citations

^{15}C$(d,p)^{16}$C Reaction and Exotic Behavior in ^{16}C

A. H. Wuosmaa, B. B. Back, S. Baker, B. A. Brown, C. M. Deibel, P. Fallon, C. R. Hoffman, B. P. Kay, H. Y. Lee, J. C. Lighthall, A. O. Macchiavelli, S. T. Marley, R. C. Pardo, K. E. Rehm, J. P. Schiffer, D. V. Shetty, and M. Wiedeking

Phys. Rev. Lett. **105**, 132501 (2010) - Published 23 September 2010

Show Abstract +

PRC — 19 citations

Single-neutron energies outside ^{136}Xe

B. P. Kay, J. P. Schiffer, S. J. Freeman, C. R. Hoffman, B. B. Back, S. I. Baker, S. Bedoor, T. Bloxham, J. A. Clark, C. M. Deibel, A. M. Howard, J. C. Lighthall, S. T. Marley, K. E. Rehm, D. K. Sharp, D. V. Shetty, J. S. Thomas, and A. H. Wuosmaa

Phys. Rev. C **84**, 024325 (2011) - Published 29 August 2011

Show Abstract +

PRC — 10 citations

Experimental study of the ^{19}O$(d,p)^{20}$O reaction in inverse kinematics

C. R. Hoffman, B. B. Back, B. P. Kay, J. P. Schiffer, M. Alcorta, S. I. Baker, S. Bedoor, P. F. Bertone, J. A. Clark, C. M. Deibel, B. DiGiovine, S. J. Freeman, J. P. Greene, J. C. Lighthall, S. T. Marley, R. C. Pardo, K. E. Rehm, A. Rojas, D. Santiago-Gonzalez, D. K. Sharp, D. V. Shetty, J. S. Thomas, I. Wiedenhöver, and A. H. Wuosmaa

Phys. Rev. C **85**, 054318 (2012) - Published 29 May 2012

Show Abstract +

PRC Editors' Suggestion — 14 citations

Neutron single-particle strength outside the $\mathbf{N = 50}$ core

D. K. Sharp, B. P. Kay, J. S. Thomas, S. J. Freeman, J. P. Schiffer, B. B. Back, S. Bedoor, T. Bloxham, J. A. Clark, C. M. Deibel, C. R. Hoffman, A. M. Howard, J. C. Lighthall, S. T. Marley, A. J. Mitchell, T. Otsuka, P. D. Parker, K. E. Rehm, D. V. Shetty, and A. H. Wuosmaa

Phys. Rev. C **87**, 014312 (2013) - Published 10 January 2013

Show Abstract +

PRC Rapid Communication — 12 citations

Structure of ^{14}B and the evolution of $N = 9$ single-neutron isotones

S. Bedoor, A. H. Wuosmaa, J. C. Lighthall, M. Alcorta, B. B. Back, P. F. Bertone, B. A. Brown, C. M. Deibel, C. R. Hoffman, S. T. Marley, R. C. Pardo, K. E. Rehm, A. M. Rogers, J. P. Schiffer, and D. V. Shetty

Phys. Rev. C **88**, 011304(R) (2013) - Published 29 July 2013

Show Abstract +

PRL — 3 citations

Probing the Single-Particle Character of Rotational States in ^{19}F Using a Short-Lived Isomeric Beam

D. Santiago-Gonzalez, K. Auranen, M. L. Avila, A. D. Ayangeakaa, B. B. Back, S. Bottoni, M. P. Carpenter, J. Chen, C. M. Deibel, A. A. Hood, C. R. Hoffman, R. V. F. Janssens, C. L. Jiang, B. P. Kay, S. A. Kuvin, A. Lauer, J. P. Schiffer, J. Sethi, R. Talwar, I. Wiedenhöver, J. Winkelbauer, and S. Zhu

Phys. Rev. Lett. **120**, 122503 (2018) - Published 23 March 2018

Show Abstract +

PRC

Experimental study of the effective nucleon-nucleon interaction using the ^{21}F$(d,p)^{22}$F reaction

J. Chen, C. R. Hoffman, T. Ahn, K. Auranen, M. L. Avila, B. B. Back, D. W. Bardayan, D. Blankstein, P. Copp, D. Gorelov, B. P. Kay, S. A. Kuvin, J. P. Lai, D. G. McNeel, P. D. O'Malley, A. M. Rogers, D. Santiago-Gonzalez, J. P. Schiffer, J. Sethi, R. Talwar, and J. R. Winkelbauer

Phys. Rev. C **98**, 014325 (2018) - Published 25 July 2018

Show Abstract +

PRC — 4 citations

Structure of ^{14}C and ^{14}B from the ^{14,15}C$\left(d, {}^{3}\mathrm{He}\right)^{13,14}$B reactions

S. Bedoor, A. H. Wuosmaa, M. Albers, M. Alcorta, Sergio Almaraz-Calderon, B. B. Back, P. F. Bertone, C. M. Deibel, C. R. Hoffman, J. C. Lighthall, S. T. Marley, D. G. Mcneel, R. C. Pardo, K. E. Rehm, J. P. Schiffer, and D. V. Shetty

Phys. Rev. C **93**, 044323 (2016) - Published 21 April 2016

Show Abstract +

PRC — 1 citation

Single-neutron excitations in ^{18}N

C. R. Hoffman, M. Albers, M. Alcorta, S. Almaraz-Calderon, B. B. Back, S. I. Baker, S. Bedoor, P. F. Bertone, B. P. Kay, J. C. Lighthall, T. Palchan, R. C. Pardo, G. Perdikakis, K. E. Rehm, A. M. Rogers, D. Santiago-Gonzalez, Cenxi Yuan, and J. P. Schiffer

Phys. Rev. C **88**, 044317 (2013) - Published 15 October 2013

Show Abstract +

PRC Rapid Communication

α decay of the $T = 1,\ 2^+$ state in ^{10}B and isospin symmetry breaking in the $A = 10$ triplet

S. A. Kuvin, A. H. Wuosmaa, C. J. Lister, M. L. Avila, C. R. Hoffman, B. P. Kay, D. G. McNeel, C. Morse, E. A. McCutchan, D. Santiago-Gonzalez, and J. R. Winkelbauer

Phys. Rev. C **96**, 041301(R) (2017) - Published 3 October 2017

Show Abstract +

PRC Rapid Communication — 3 citations

Stretched states in ^{12,13}B with the (d,α) reaction

A. H. Wuosmaa, J. P. Schiffer, S. Bedoor, M. Albers, M. Alcorta, S. Almaraz-Calderon, B. B. Back, P. F. Bertone, C. M. Deibel, C. R. Hoffman, J. C. Lighthall, S. T. Marley, R. C. Pardo, K. E. Rehm, and D. V. Shetty

Phys. Rev. C **90**, 061301(R) (2014) - Published 8 December 2014

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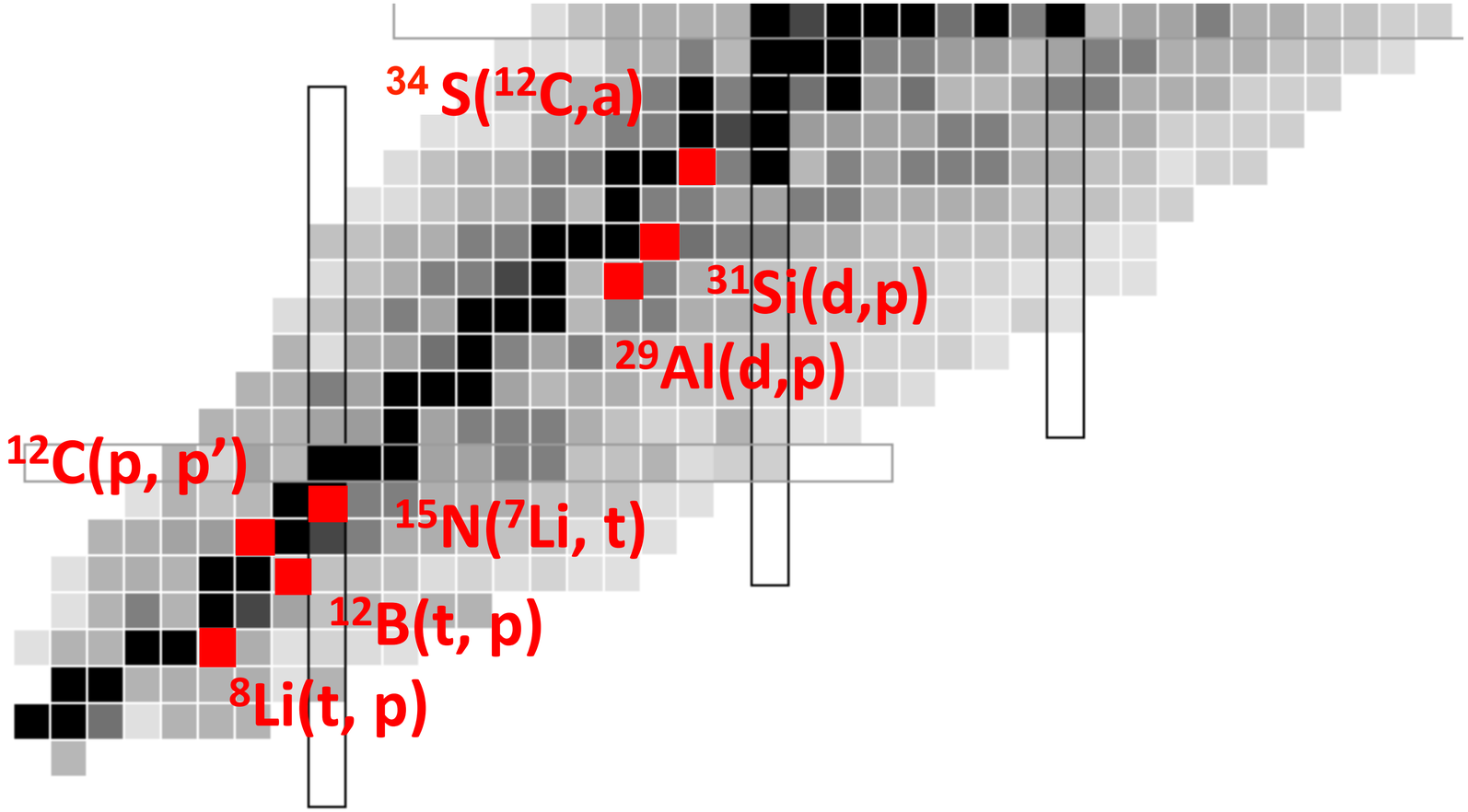
Experiments run in calendar year 2019



HELIOS PROGRAM OVERVIEW

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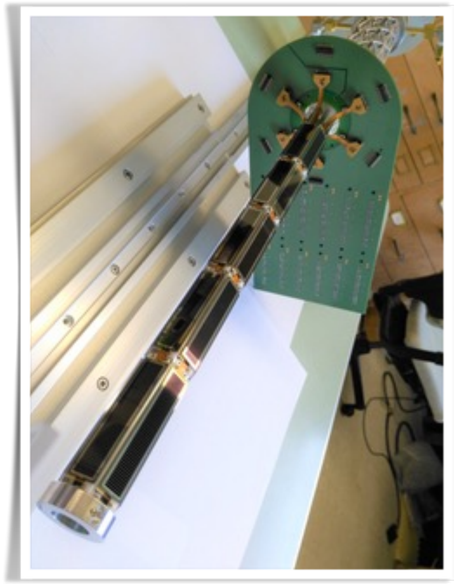
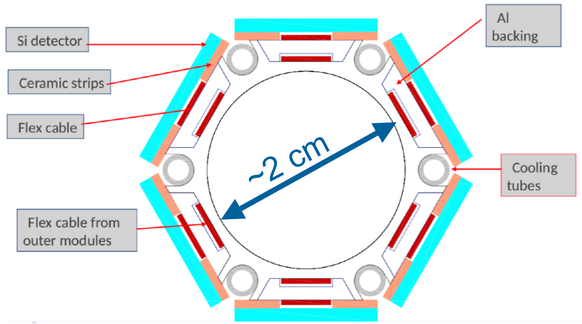
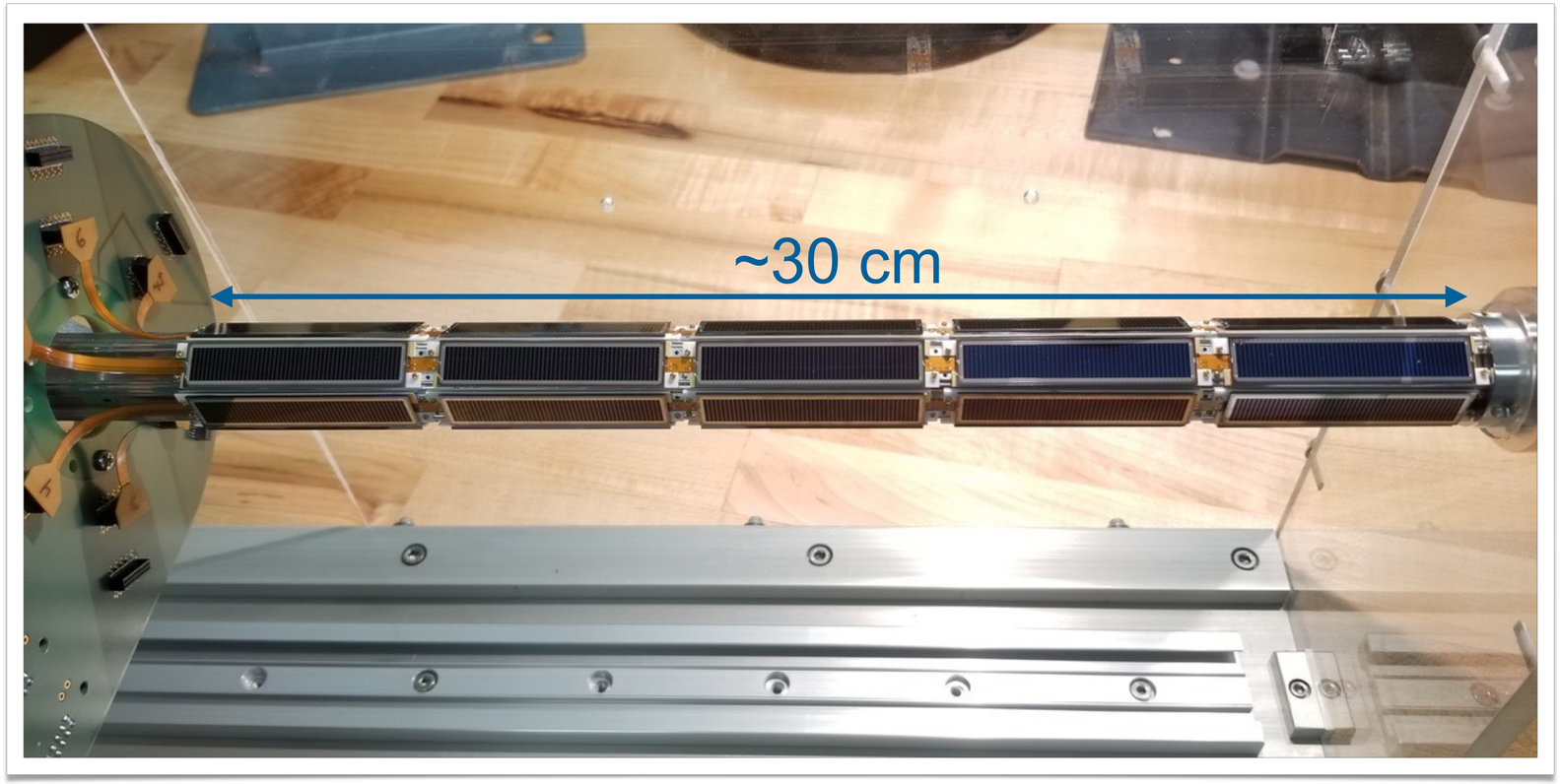
  - along with investigations into more exotic transfer reaction types, e.g., (^{12}C,*alpha*), (^{7}Li,t), …

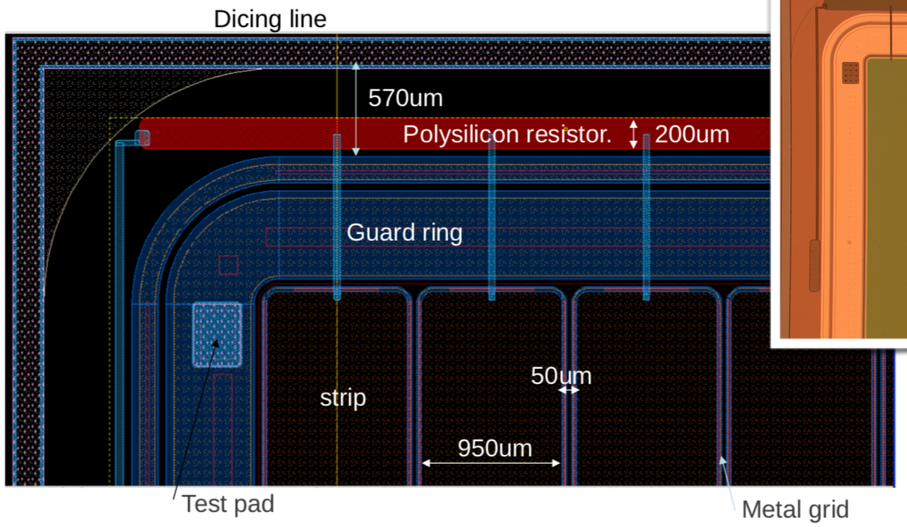


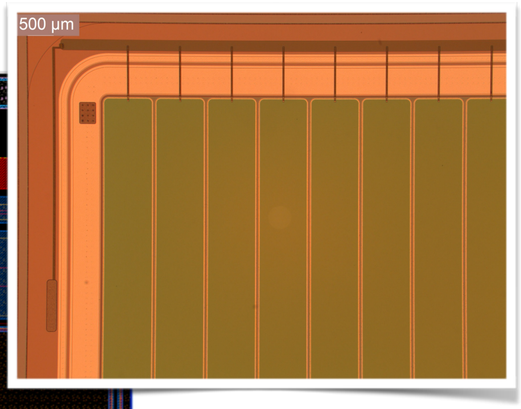


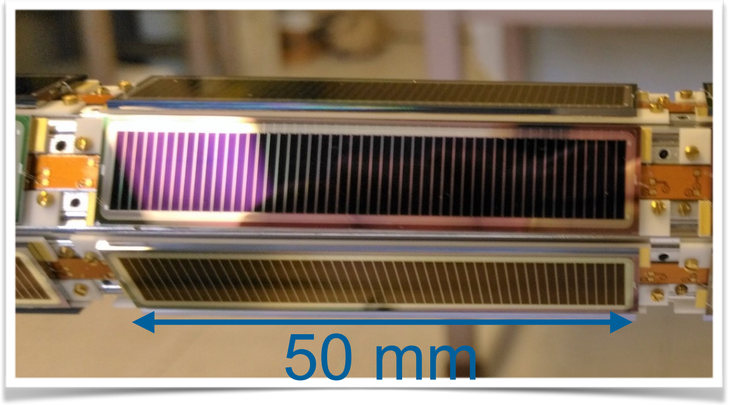


NEW POSITION SENSITIVE SI DETECTOR ARRAY

- Improved phi angle coverage & a larger support tube ID
- In use with custom preamps & digital data acquisition since spring 2019
- Modular design in principle, e.g., 4, 6 or 10 sided array could be constructed







D+T Microelectrónica, A.I.E.

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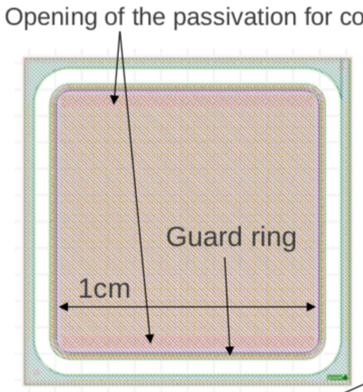
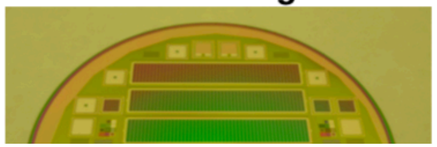
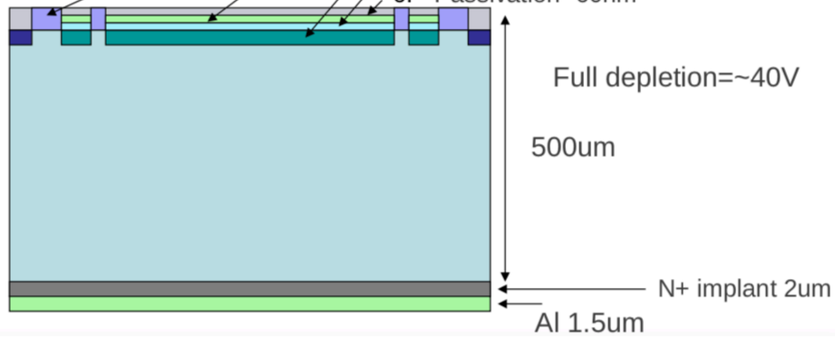
Tel.: +34 93 594 77 00 ext. 2122
Fax: +34 93 580 94 62
E-mail: Humberto.Mata@cnm.es
www.dtm.es



Giulio Pellegrini





POSITION SENSITIVE RESISTIVE & SEGMENTED HYBRID SI DETECTORS

- developed by Microelectronica / Barcelona
- ~x50 800 *u*m thick detectors delivered (some variations in performance)
- 4 signal readouts from each individual detector (total energy, x2 positions, guard ring)
- Assembly & wire bonding done in-house at ANL/PHY

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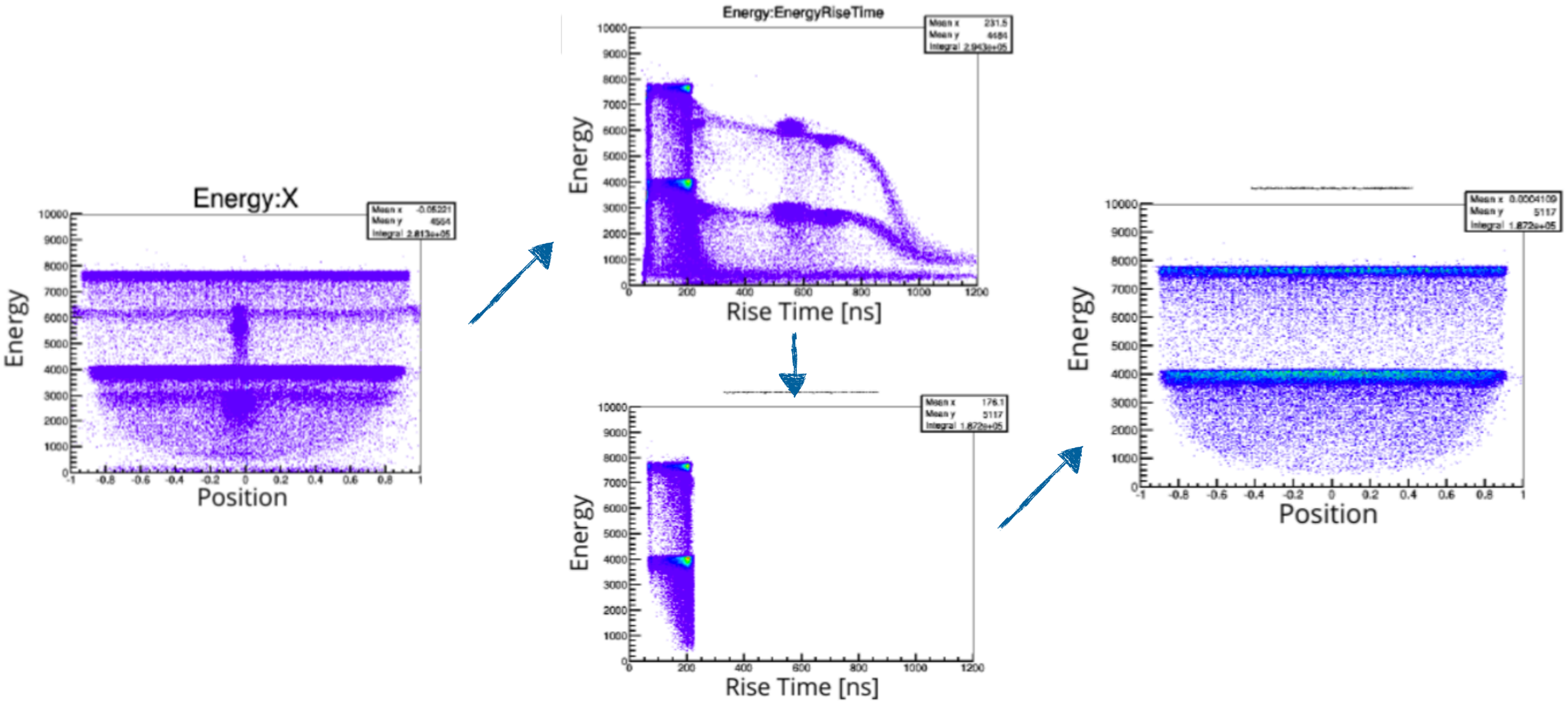
PSD PERFORMANCE

Requirement of rise time &/or ring information



PSD SIGNAL PROCESSING

Custom preamplifiers, digital data acquisition, & advanced sorting algorithms

Preamplifier

- Mesytec 4-channel preamplifier board
- Motherboard to combine 4x5 per Si array side
- x2 10 channel outputs matched to digitizer inputs

Digital DAQ

- 200 channels of 100 MHz sampling
- Flexible triggering / data collection / inputs
- Data throughput limited to ~10-12 MB/s per 40 channels

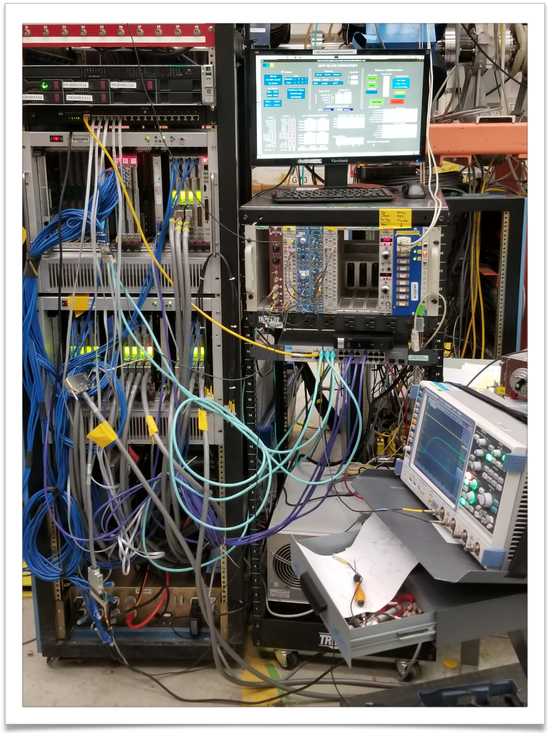
Local Data Processing

- 1 Gb direct link to data acquisition
- “real-time” processing of data with single “click”
- Git repository for each experiment

Offline / Trace / Large Data Processing

- Transfer data to LCRC via GLOBUS [slow still at present]
- Access to >10 cores on login nodes
- Large amount of free computing power / space through HELIOS project
- Full trace analysis of collected data straight forward on this platform

Motherboard and 5 preamp cards.



LABORATORY COMPUTING RESOURCE CENTER

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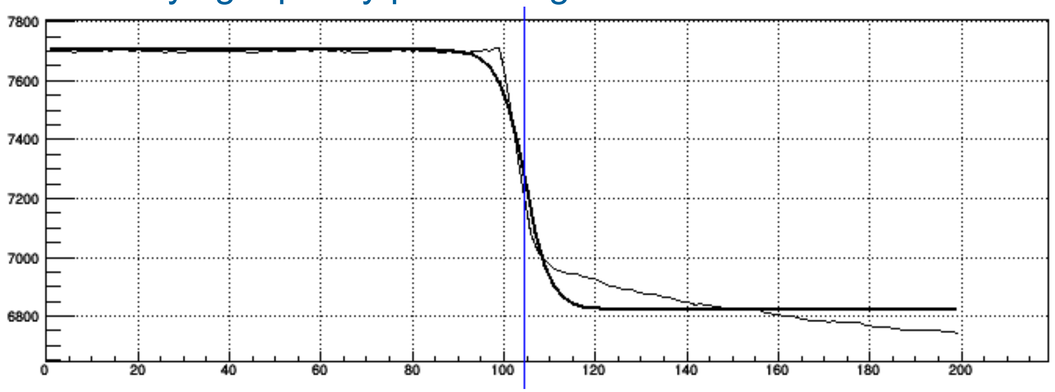
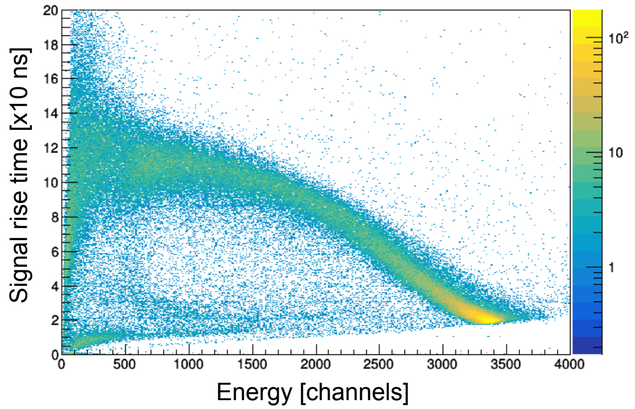
PSD SIGNAL PROCESSING

Example of trace analysis on in-beam recoil detector signals

Identifying a poorly performing detector





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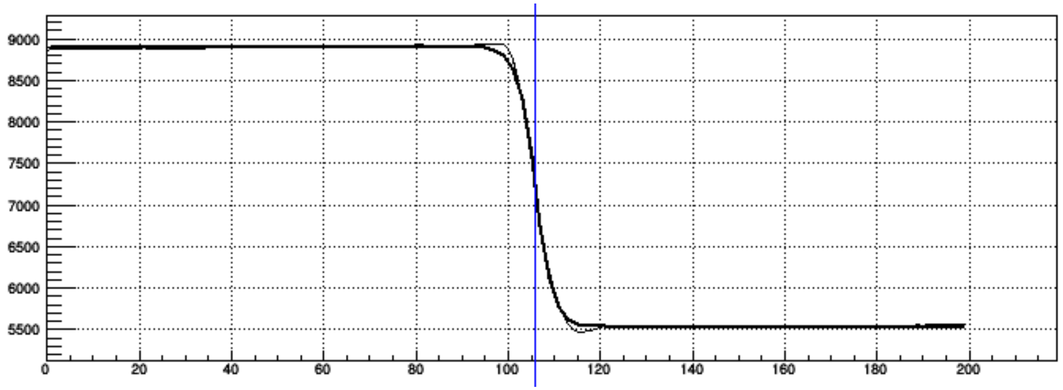
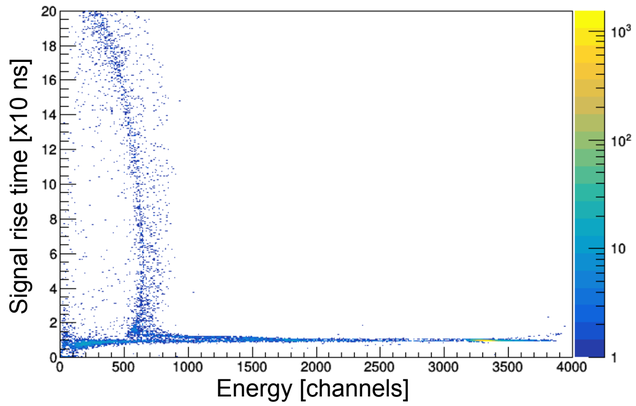
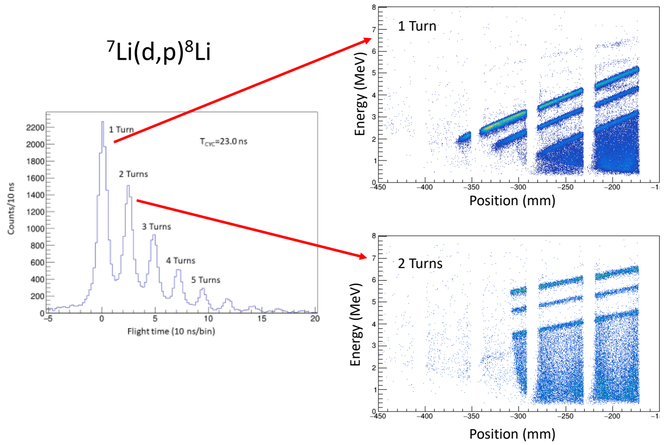
LABORATORY COMPUTING RESOURCE CENTER

Excellent detector performance







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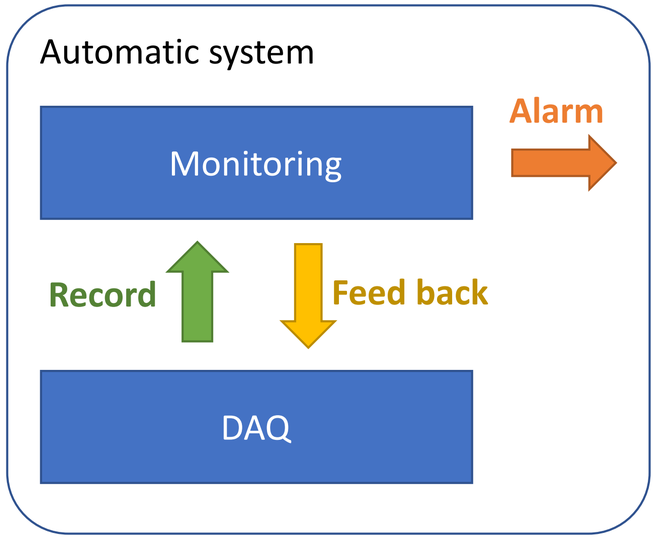
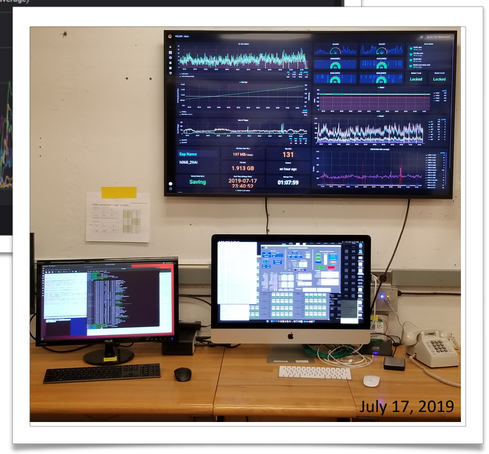




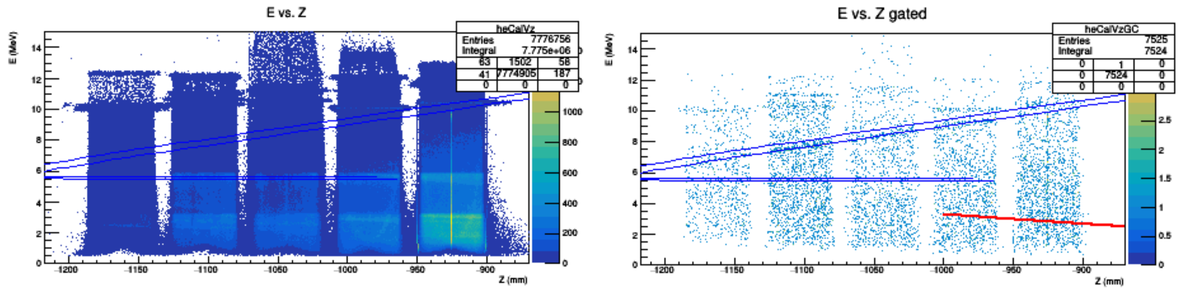
EXPERIMENT MONITORING

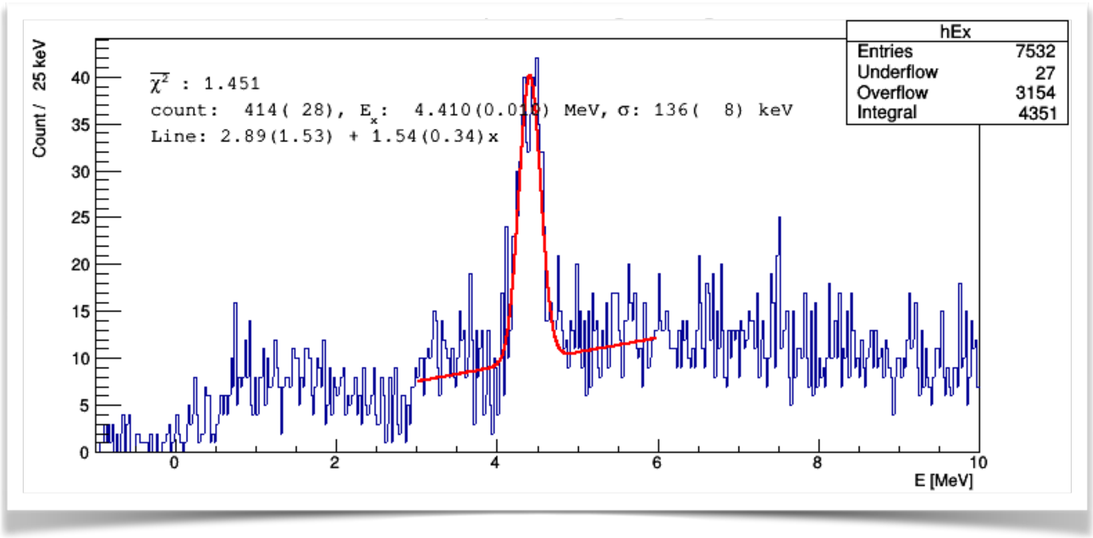
- Gaining improvements in:
  - Information flow, Reliability, Automation
- Information can be stored in database, displayed in real-time through Grafana
- Critical rates / items can be set with alarms / alerts & notifications
  - Also can trigger automated adjustments / fixes to experiment, i.e. thresholds, low-buffers
- Transparency for Users with dedicated set of modern analysis software

ALPHA(-LIKE) TRANSFER REACTIONS

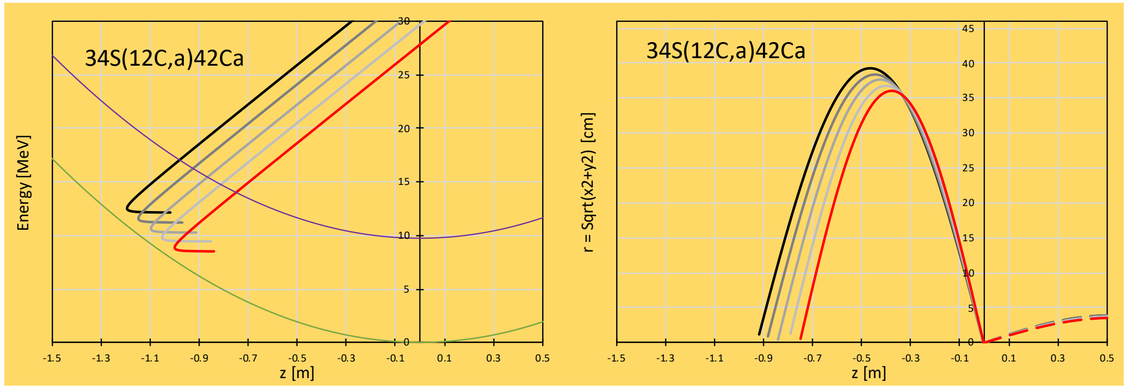
Spectroscopy of key states in nuclear astrophysics & np-nh excitations

(^{6}Li,*d*) & (^{7}Li,*t*) Reaction on ^{15}N [Deibel - LSU]





- Limited / no success in other alpha-like transfer measurements using ^{14}C [Lee - LANL], ^{22}Ne [Almaraz - FSU], & ^{32}S [Avila - ANL]
- Analysis underway to explore possibility for identifying (^{12}C,*alpha*) transfer in inverse kinematics ^{34}S->^{42}Ca [Henderson - LLNL]



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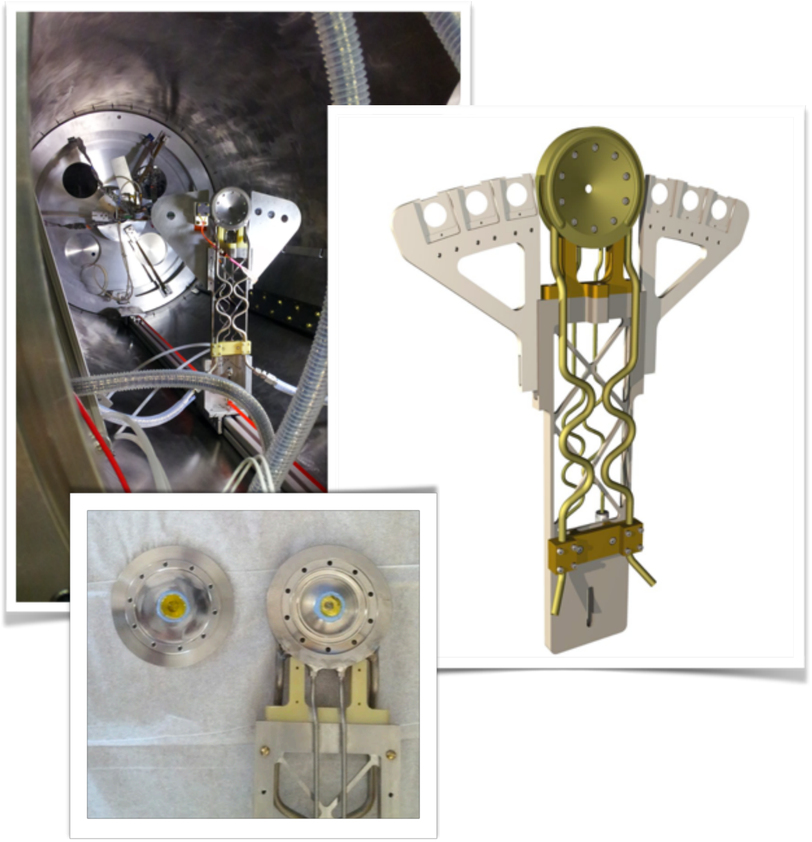
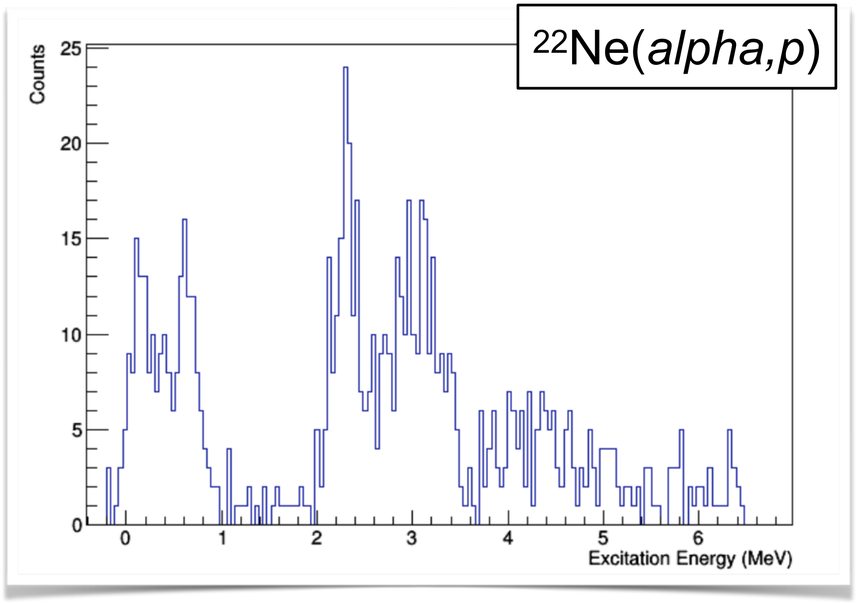




- Gas volume (1mm, 2mm or 3mm)
- Cooled to liquid nitrogen temperatures (~80 K)
- Particles between $0<\theta<72$ and $94<\theta<180$
- Kapton windows (1.1 – 1.8 mg/cm^2)
  - Originally used Ti windows
- ^{4,3}He direct reactions
  - Astrophysics
  - High momentum matching reactions

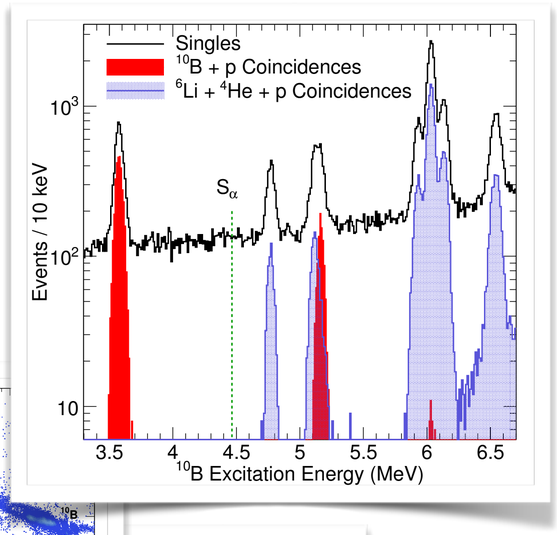
USE OF THE HELIOS CYRO-COOLD GAS TARGET

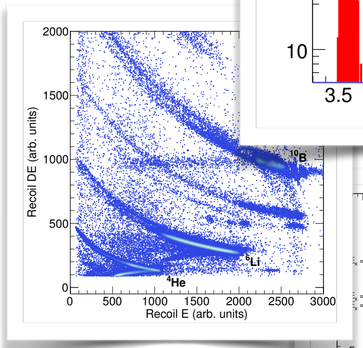
- Tested with (d,p) & (^{3}He,d) reactions - Resolution equivalent to ~300-400 *u*g/cm2 CD_2 target
- Physics measurement led by LSU group to measure ^{22}Ne(*alpha,p*)
- Stronger / thinner windows being investigated by LSU group

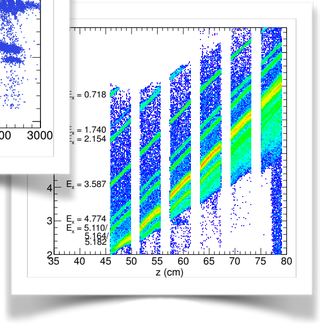
COINCIDENCE TAGGING WITHIN HELIOS

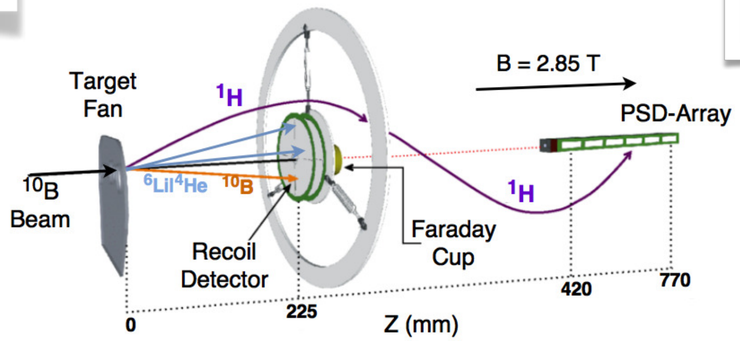
Advantages of inverse kinematics

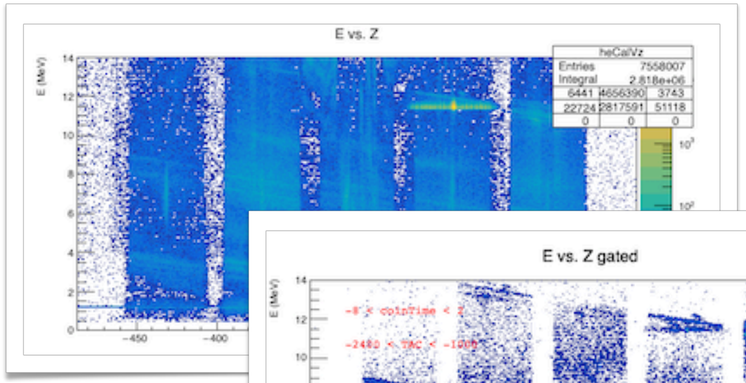
- Precise determination of particle decay branches
  - ^{10}B(*p*,***p'***) -> **^{10}B** vs. **^{6}Li** + **alpha** branch [Kuvin - UConn]
- Triple coincidence from ^{12}C 0+ state
  - ^{12}C(*p*,***p'***) -> **^{12}C** + **e+e-** [Smith - UConn]
  - PSD Array + DE-E Recoil + Si(Li)

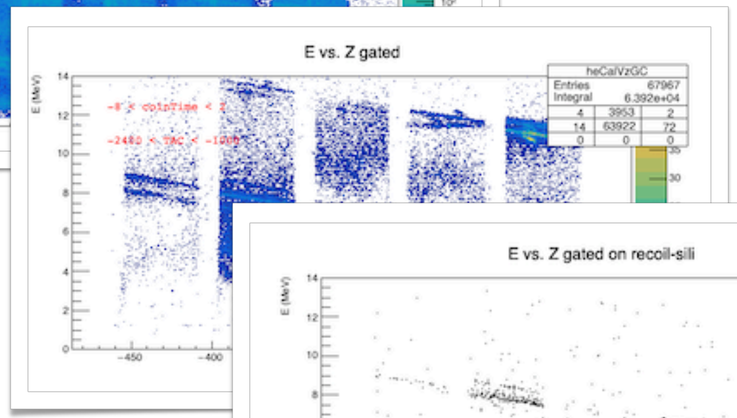


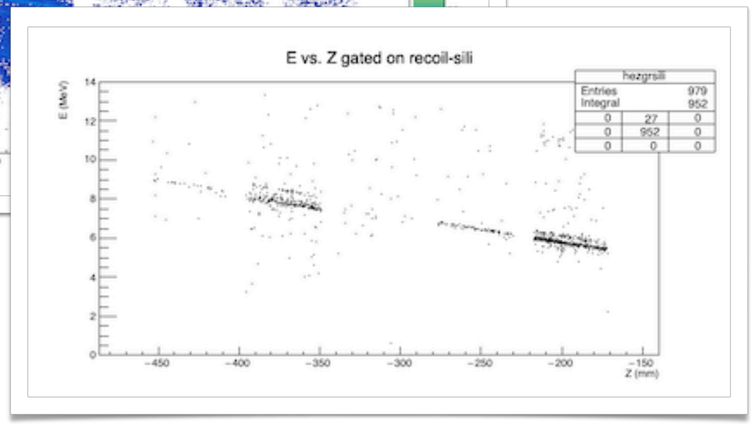






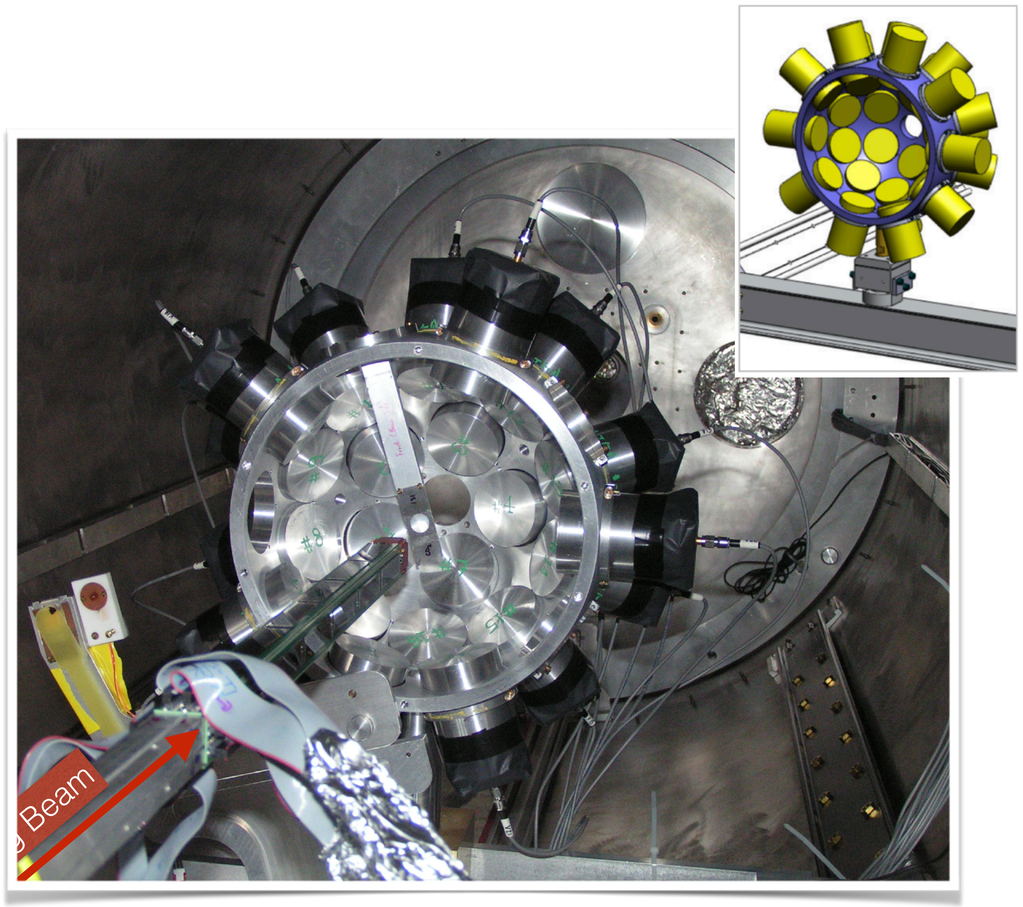


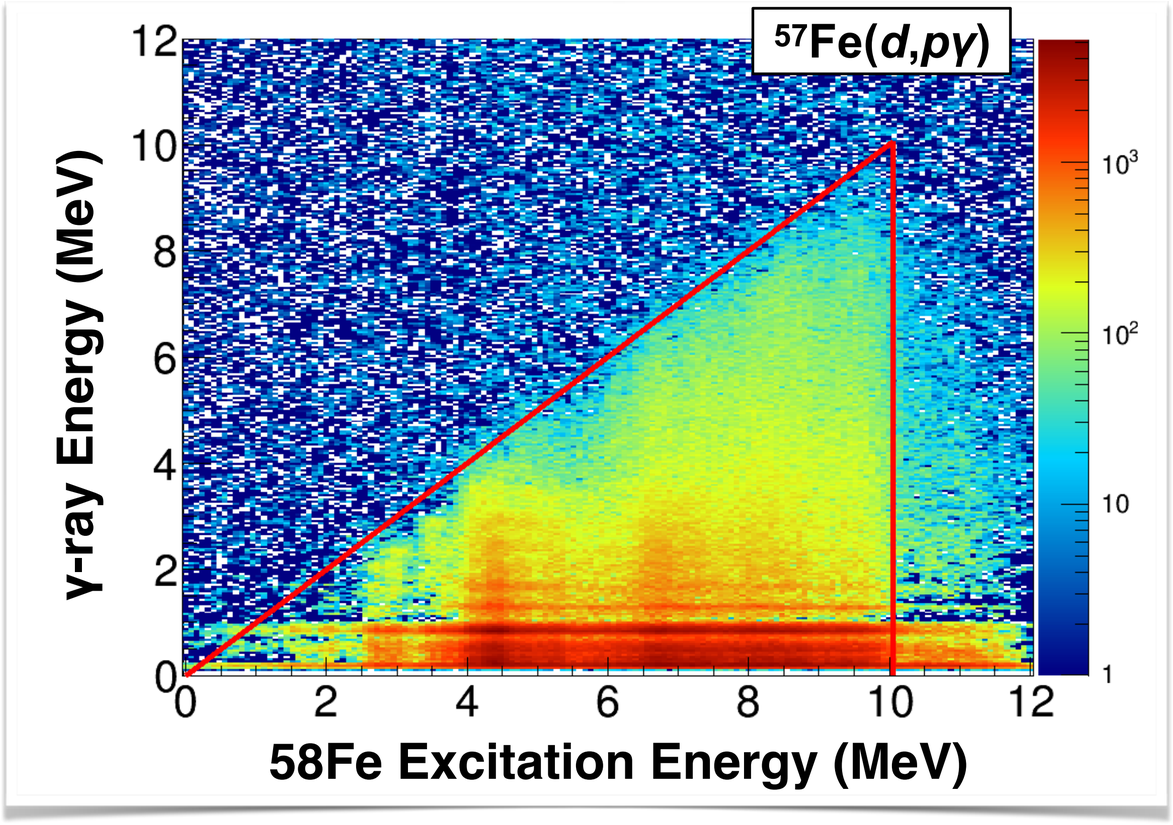




APOLLO: GAMMA-RAY DETECTION WITHIN HELIOS

CsI & $LaBr_3$ Array for (*d,p*gamma) measurements [Couture, Lee, Mosby - LANL]





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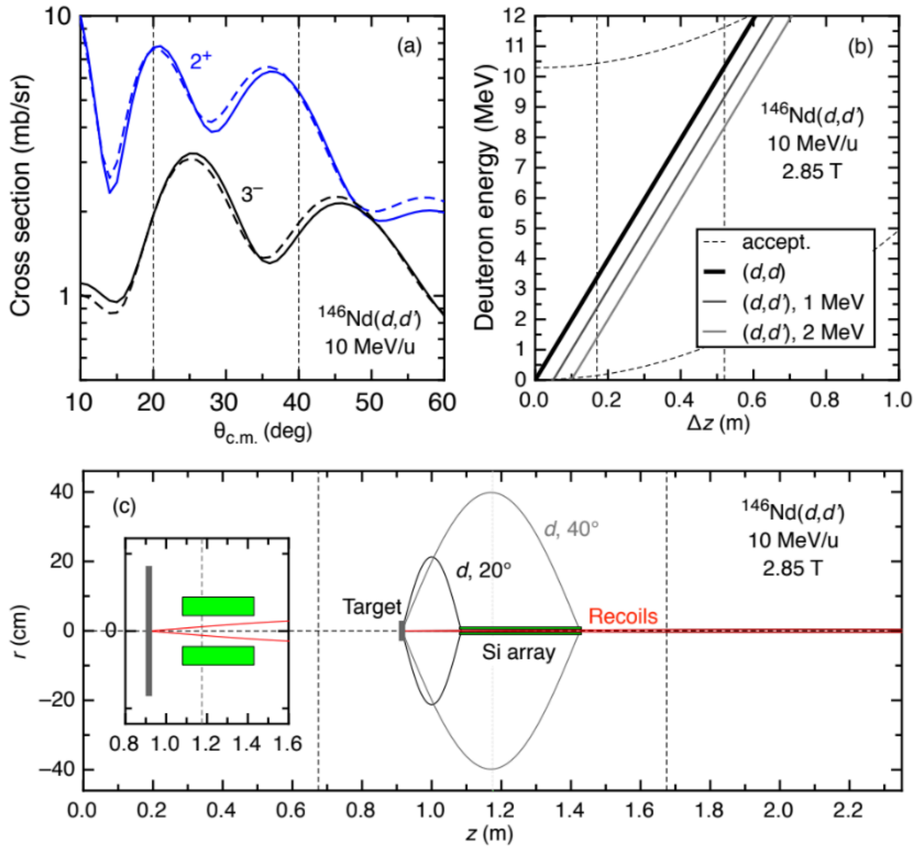

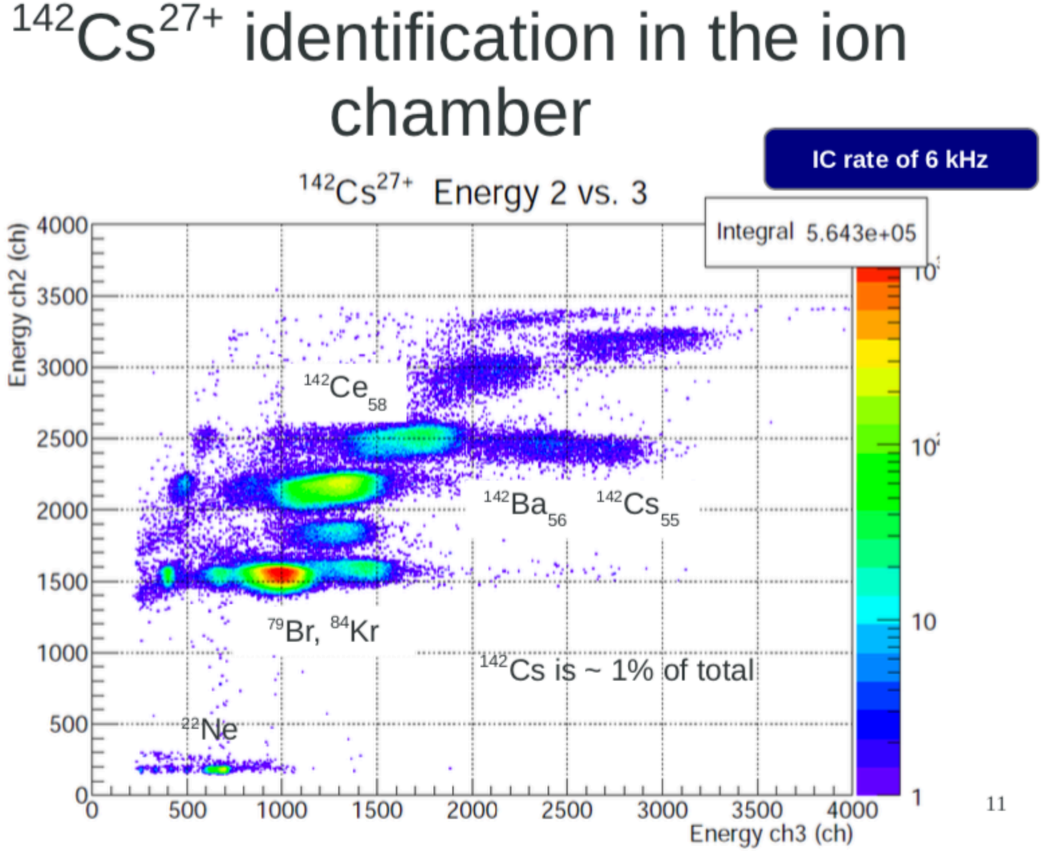

TAGGING ON RECOILS “THRU” PSD ARRAY

- Suppression of recoils needed in (*d,d'*) reactions with heavy beams
- Plan to discriminate recoils / suppress background via an ionization chamber at zero degrees after the downstream array
- ^{146}Nd(*d,d'*) test happening in September 2019 [Kay]

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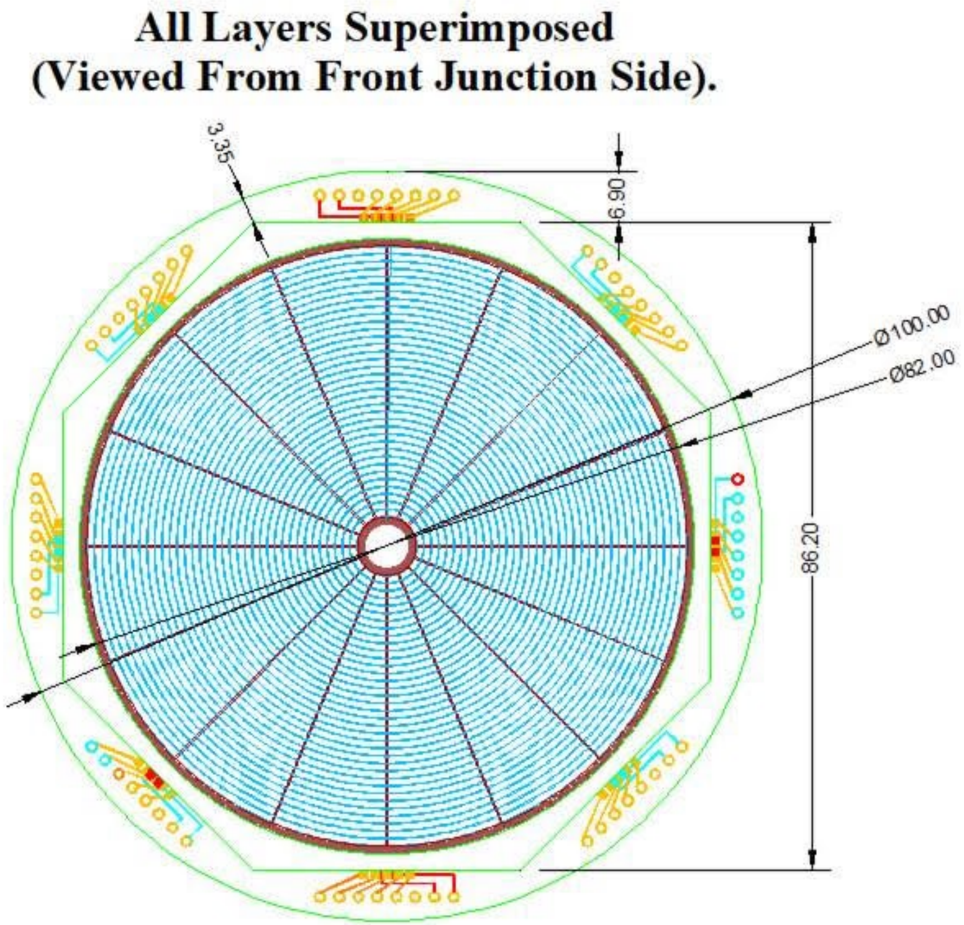
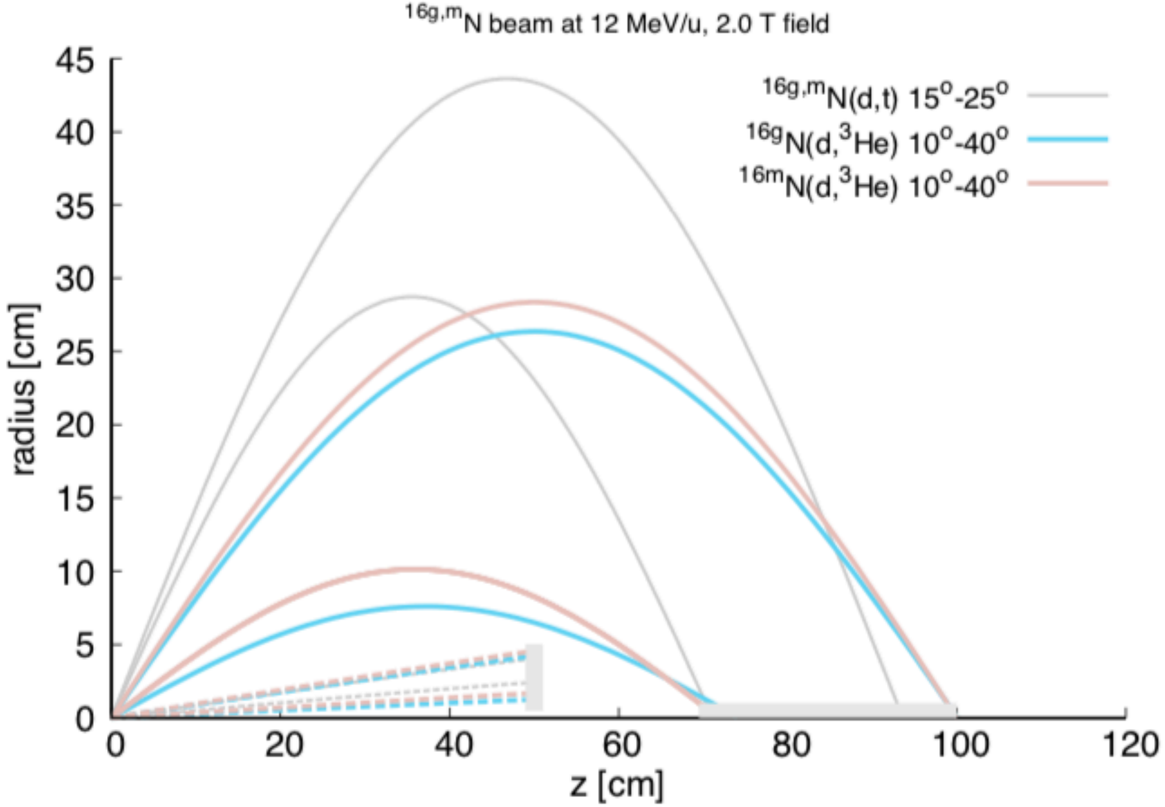
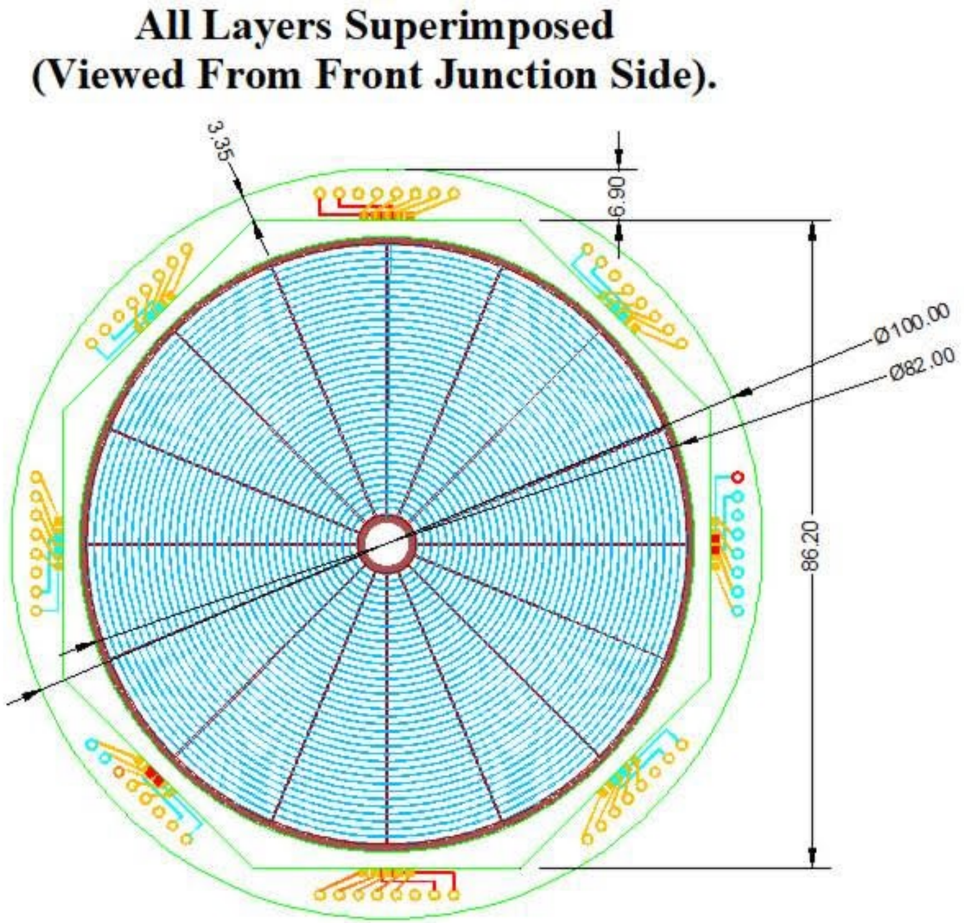
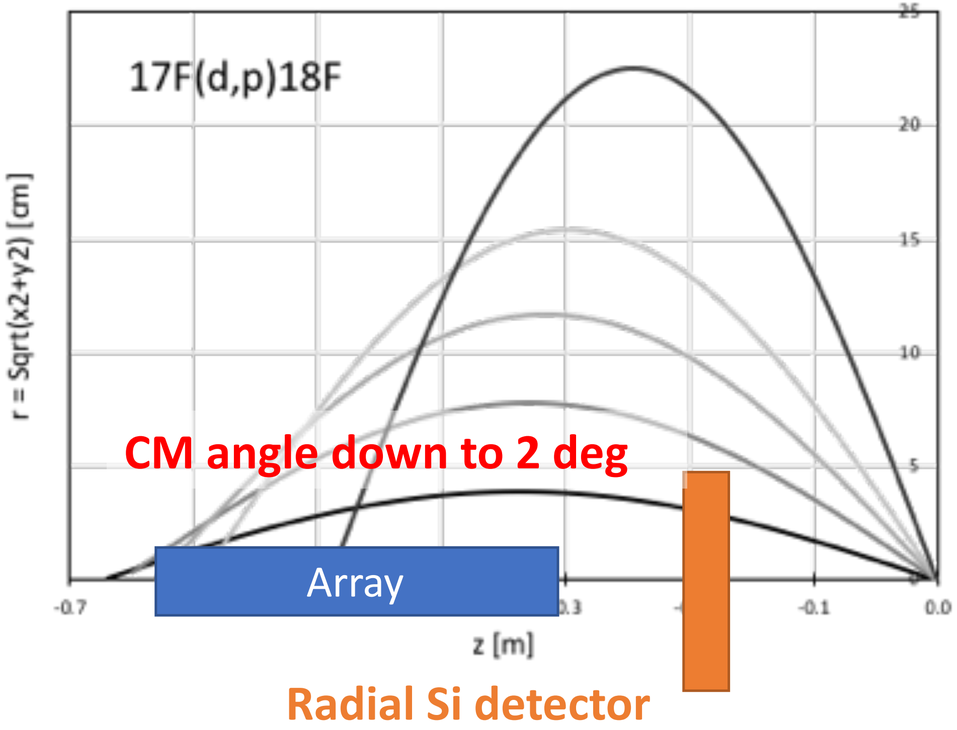




OPTIMIZED / MULTIPURPOSE RECOIL DETECTORS

- “restricted” geometry for some forward reactions & (*d,p*) on heavier systems
- Recording radial positions allows for extraction of spectra at small lab angles
- ~$35k / 5-6 months for custom design & two detectors [micron semiconductor ltd]





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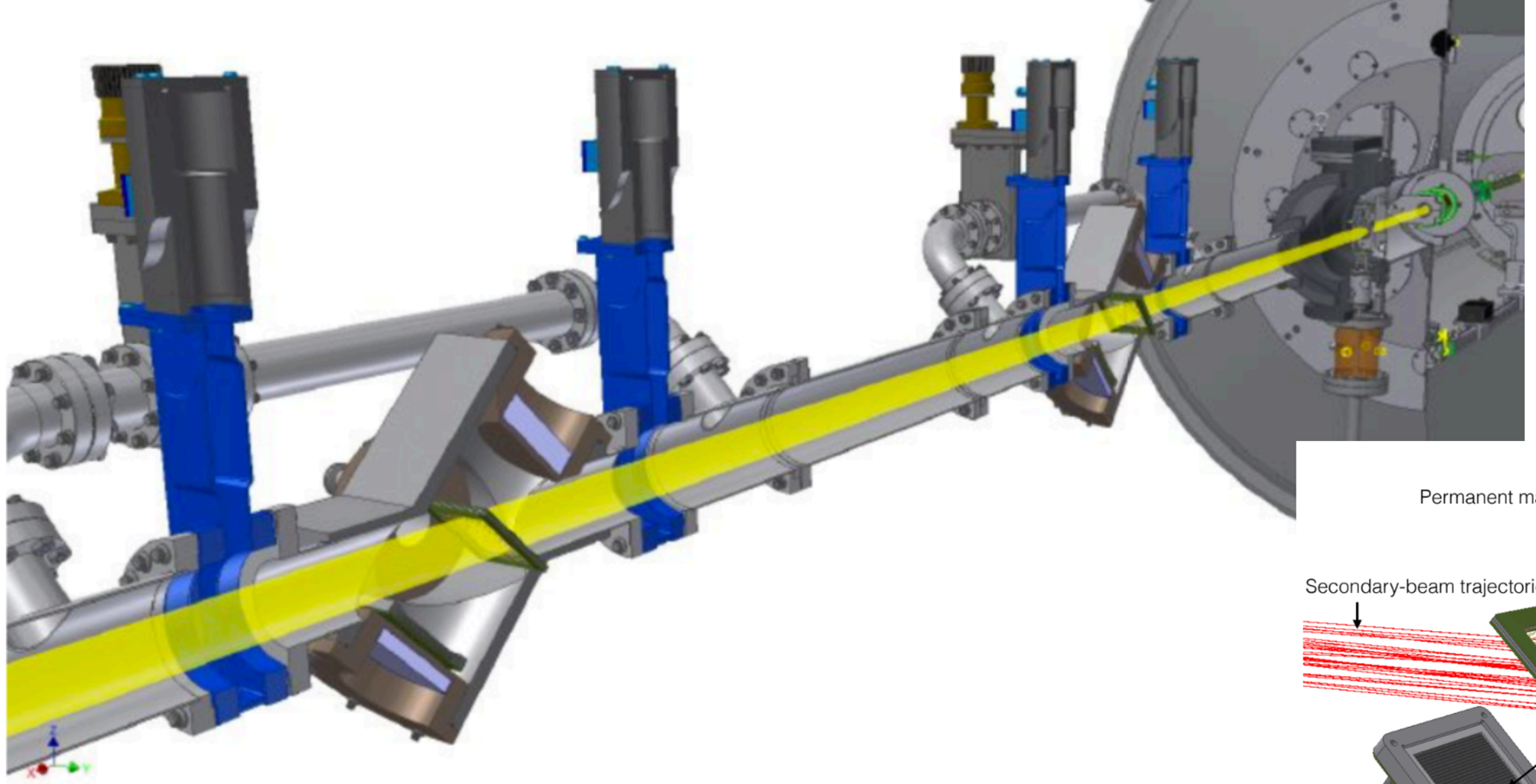

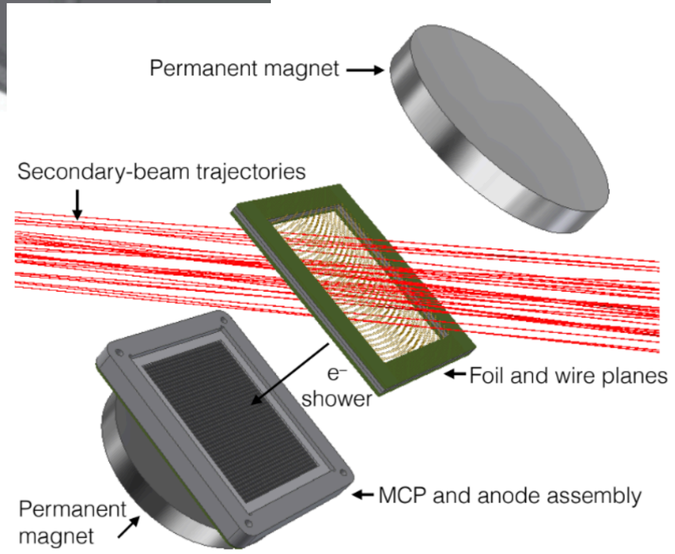

EVENT-BY-EVENT BEAM TRACKING

- Leading contribution to the Q-value resolution for in-flight beams
- Utilize secondary electron emission & Micro Channel Plate to extract time & positions
- Multiple stations for track reconstruction & time-of-flight on target
- Demonstrator unit under construction for Fall 2019 / Early 2020 deployment [tolstukhin]

ACKNOWLEDGMENTS

ANL - Ben Kay, Ryan Tang, Jie Chen, John Schiffer, Birger Back, John Rohrer, John Anderson, & many more

UConn - Alan Wuosmaa, Daniel McNeel, & Jeremy Smith

LSU - Catherine Deibel, & Gemma Wilson

Collaborators from around the globe

Thanks to the organizers for the invitation to speak & for your attention!!
Happy to entertain any questions

LSU UCONN UNIVERSITY OF CONNECTICUT MANCHESTER 1824 The University of Manchester Argonne NATIONAL LABORATORY

HELIOS SCIENCE PROGRAM: 2008 - PRESENT

12 papers, 3 letters, 3 rapid communications, 2 editors suggestions, ~120 citations

PRL Featured in Physics Editors' Suggestion — 22 citations

First Experiment with HELIOS: The Structure of ^{13}B

B. B. Back, S. I. Baker, B. A. Brown, C. M. Deibel, S. J. Freeman, B. J. DiGiovine, C. R. Hoffman, B. P. Kay, H. Y. Lee, J. C. Lighthall, S. T. Marley, R. C. Pardo, K. E. Rehm, J. P. Schiffer, D. V. Shetty, A. W. Vann, J. Winkelbauer, and A. H. Wuosmaa

Phys. Rev. Lett. **104**, 132501 (2010) - Published 31 March 2010

Physics Synopsis : Results from HELIOS

PRL — 33 citations

^{15}C$(d,p)^{16}$C Reaction and Exotic Behavior in ^{16}C

A. H. Wuosmaa, B. B. Back, S. Baker, B. A. Brown, C. M. Deibel, P. Fallon, C. R. Hoffman, B. P. Kay, H. Y. Lee, J. C. Lighthall, A. O. Macchiavelli, S. T. Marley, R. C. Pardo, K. E. Rehm, J. P. Schiffer, D. V. Shetty, and M. Wiedeking

Phys. Rev. Lett. **105**, 132501 (2010) - Published 23 September 2010

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PRC — 19 citations

Single-neutron energies outside ^{136}Xe

B. P. Kay, J. P. Schiffer, S. J. Freeman, C. R. Hoffman, B. B. Back, S. I. Baker, S. Bedoor, T. Bloxham, J. A. Clark, C. M. Deibel, A. M. Howard, J. C. Lighthall, S. T. Marley, K. E. Rehm, D. K. Sharp, D. V. Shetty, J. S. Thomas, and A. H. Wuosmaa

Phys. Rev. C **84**, 024325 (2011) - Published 29 August 2011

Show Abstract +

PRC — 10 citations

Experimental study of the ^{19}O$(d,p)^{20}$O reaction in inverse kinematics

C. R. Hoffman, B. B. Back, B. P. Kay, J. P. Schiffer, M. Alcorta, S. I. Baker, S. Bedoor, P. F. Bertone, J. A. Clark, C. M. Deibel, B. DiGiovine, S. J. Freeman, J. P. Greene, J. C. Lighthall, S. T. Marley, R. C. Pardo, K. E. Rehm, A. Rojas, D. Santiago-Gonzalez, D. K. Sharp, D. V. Shetty, J. S. Thomas, I. Wiedenhöver, and A. H. Wuosmaa

Phys. Rev. C **85**, 054318 (2012) - Published 29 May 2012

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PRC Editors' Suggestion — 14 citations

Neutron single-particle strength outside the $\mathbf{N = 50}$ core

D. K. Sharp, B. P. Kay, J. S. Thomas, S. J. Freeman, J. P. Schiffer, B. B. Back, S. Bedoor, T. Bloxham, J. A. Clark, C. M. Deibel, C. R. Hoffman, A. M. Howard, J. C. Lighthall, S. T. Marley, A. J. Mitchell, T. Otsuka, P. D. Parker, K. E. Rehm, D. V. Shetty, and A. H. Wuosmaa

Phys. Rev. C **87**, 014312 (2013) - Published 10 January 2013

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PRC Rapid Communication — 12 citations

Structure of ^{14}B and the evolution of $N = 9$ single-neutron isotones

S. Bedoor, A. H. Wuosmaa, J. C. Lighthall, M. Alcorta, B. B. Back, P. F. Bertone, B. A. Brown, C. M. Deibel, C. R. Hoffman, S. T. Marley, R. C. Pardo, K. E. Rehm, A. M. Rogers, J. P. Schiffer, and D. V. Shetty

Phys. Rev. C **88**, 011304(R) (2013) - Published 29 July 2013

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PRL — 3 citations

Probing the Single-Particle Character of Rotational States in ^{19}F Using a Short-Lived Isomeric Beam

D. Santiago-Gonzalez, K. Auranen, M. L. Avila, A. D. Ayangeakaa, B. B. Back, S. Bottoni, M. P. Carpenter, J. Chen, C. M. Deibel, A. A. Hood, C. R. Hoffman, R. V. F. Janssens, C. L. Jiang, B. P. Kay, S. A. Kuvin, A. Lauer, J. P. Schiffer, J. Sethi, R. Talwar, I. Wiedenhöver, J. Winkelbauer, and S. Zhu

Phys. Rev. Lett. **120**, 122503 (2018) - Published 23 March 2018

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PRC

Experimental study of the effective nucleon-nucleon interaction using the ^{21}F$(d,p)^{22}$F reaction

J. Chen, C. R. Hoffman, T. Ahn, K. Auranen, M. L. Avila, B. B. Back, D. W. Bardayan, D. Blankstein, P. Copp, D. Gorelov, B. P. Kay, S. A. Kuvin, J. P. Lai, D. G. McNeel, P. D. O'Malley, A. M. Rogers, D. Santiago-Gonzalez, J. P. Schiffer, J. Sethi, R. Talwar, and J. R. Winkelbauer

Phys. Rev. C **98**, 014325 (2018) - Published 25 July 2018

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PRC — 4 citations

Structure of ^{14}C and ^{14}B from the ^{14,15}C$\left(d, {}^{3}\mathrm{He}\right)^{13,14}$B reactions

S. Bedoor, A. H. Wuosmaa, M. Albers, M. Alcorta, Sergio Almaraz-Calderon, B. B. Back, P. F. Bertone, C. M. Deibel, C. R. Hoffman, J. C. Lighthall, S. T. Marley, D. G. Mcneel, R. C. Pardo, K. E. Rehm, J. P. Schiffer, and D. V. Shetty

Phys. Rev. C **93**, 044323 (2016) - Published 21 April 2016

Show Abstract +

PRC — 1 citation

Single-neutron excitations in ^{18}N

C. R. Hoffman, M. Albers, M. Alcorta, S. Almaraz-Calderon, B. B. Back, S. I. Baker, S. Bedoor, P. F. Bertone, B. P. Kay, J. C. Lighthall, T. Palchan, R. C. Pardo, G. Perdikakis, K. E. Rehm, A. M. Rogers, D. Santiago-Gonzalez, Cenxi Yuan, and J. P. Schiffer

Phys. Rev. C **88**, 044317 (2013) - Published 15 October 2013

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PRC Rapid Communication

α decay of the $T = 1,\ 2^+$ state in ^{10}B and isospin symmetry breaking in the $A = 10$ triplet

S. A. Kuvin, A. H. Wuosmaa, C. J. Lister, M. L. Avila, C. R. Hoffman, B. P. Kay, D. G. McNeel, C. Morse, E. A. McCutchan, D. Santiago-Gonzalez, and J. R. Winkelbauer

Phys. Rev. C **96**, 041301(R) (2017) - Published 3 October 2017

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PRC Rapid Communication — 3 citations

Stretched states in ^{12,13}B with the (d,α) reaction

A. H. Wuosmaa, J. P. Schiffer, S. Bedoor, M. Albers, M. Alcorta, S. Almaraz-Calderon, B. B. Back, P. F. Bertone, C. M. Deibel, C. R. Hoffman, J. C. Lighthall, S. T. Marley, R. C. Pardo, K. E. Rehm, and D. V. Shetty

Phys. Rev. C **90**, 061301(R) (2014) - Published 8 December 2014

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