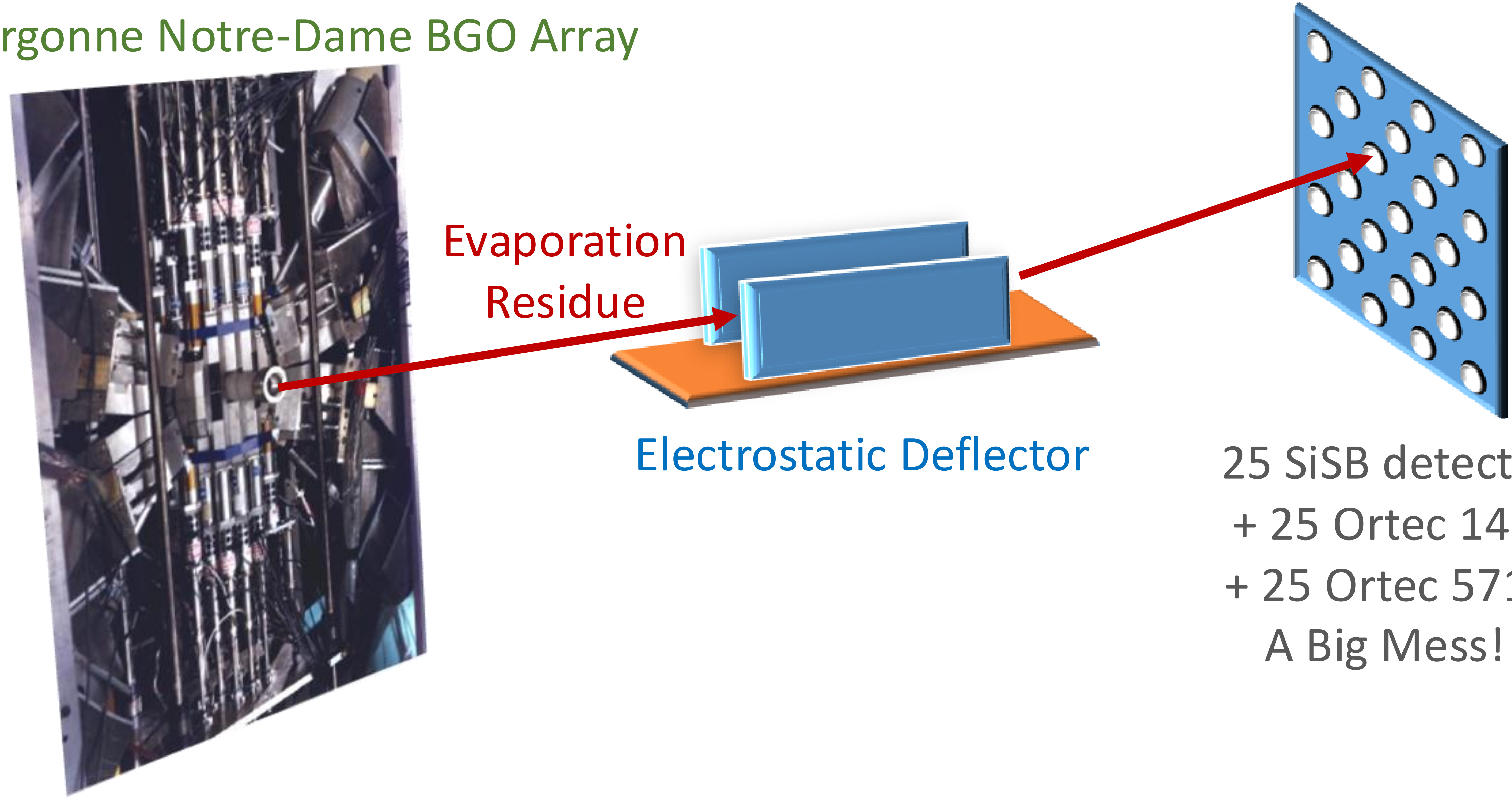
Solenoidal Spectrometers for Nuclear Reaction Studies

Many thanks to Robert for the unwavering support throughout the years

But first: Nothing at all to do with Solenoids, or – When I first met Robert

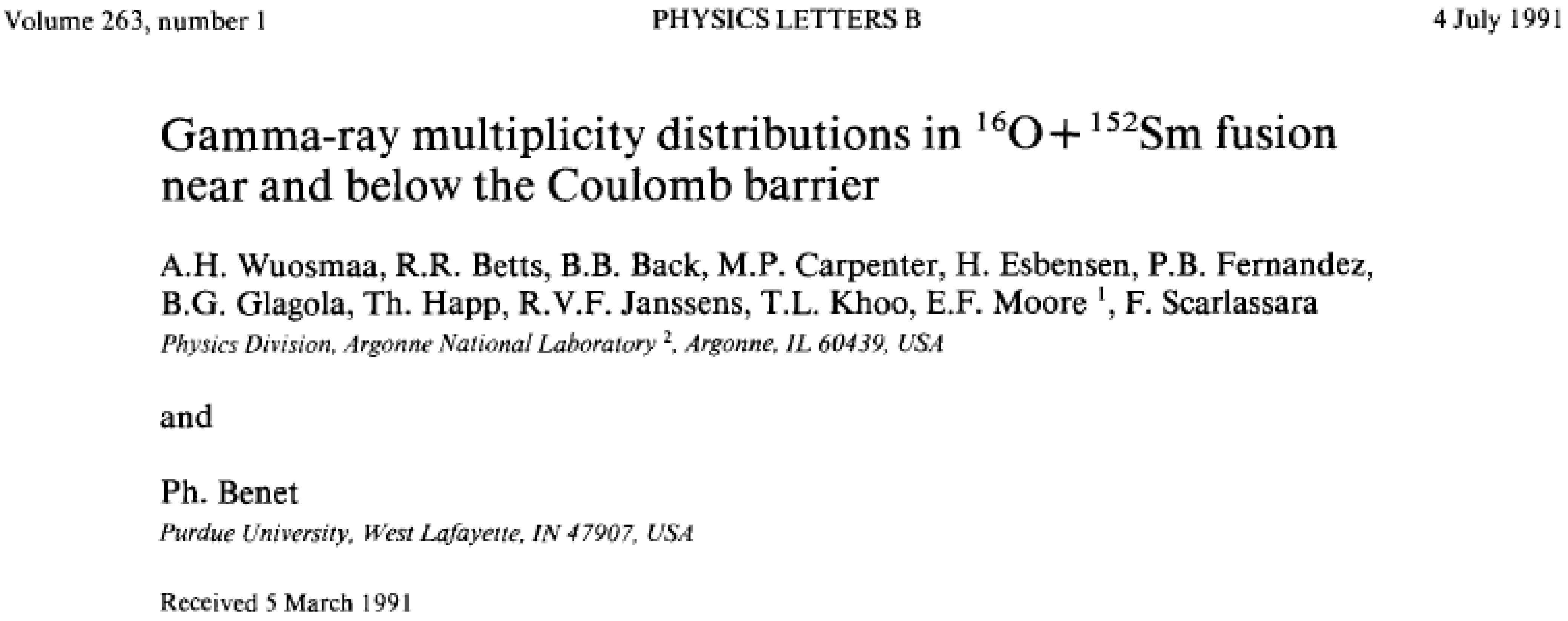
Argonne Notre-Dame BGO Array



Evaporation Residue

Electrostatic Deflector

25 SiSB detectors
+ 25 Ortec 142A
+ 25 Ortec 571/2
A Big Mess!!



Volume 263, number 1 PHYSICS LETTERS B 4 July 1991

Gamma-ray multiplicity distributions in $^{16}O + ^{152}Sm$ fusion near and below the Coulomb barrier

A.H. Wuosmaa, R.R. Betts, B.B. Back, M.P. Carpenter, H. Esbensen, P.B. Fernandez, B.G. Glagola, Th. Happ, R.V.F. Janssens, T.L. Khoo, E.F. Moore [1], F. Scarlassara
Physics Division, Argonne National Laboratory [2], Argonne, IL 60439, USA

and

Ph. Benet
Purdue University, West Lafayette, IN 47907, USA

Received 5 March 1991

My first paper with Robert
Fond Memories!

Genesis: "I don't know John, that sounds a little crazy…"

The conversation took place somewhere around here…

APEX – e^+e^- spectrometer
Transverse solenoid recycled from old MSU K50 cyclotron
B=300 G (.03T)

Why?

Z. Phys. A – Hadrons and Nuclei 340, 339–340 (1991)

Investigation of the (*d*, *p*)-reaction on ^{136,132}Xe in inverse kinematics*

G. Kraus[1], P. Egelhof[1], H. Emling[1], E. Grosse[1], W. Henning[1], R. Holzmann[1], H.J. Körner[2], J.V. Kratz[3], R. Kulessa[4], Ch. Schießl[2], J.P. Schiffer[5], W. Wagner[2], W. Walus[4], and H.J. Wollersheim[1]

[1] GSI Darmstadt, W-6100 Darmstadt, Federal Republic of Germany
[2] Physik-Department TU München, W-8046 Garching, Federal Republic of Germany
[3] Institut für Kernchemie, Universität Mainz, W-6500 Mainz, Federal Republic of Germany
[4] Jagiellonian University, Cracow, Poland
[5] Argonne National Laboratory, Argonne, IL 60439, USA

Received May 14, 1991; revised version July 2, 1991

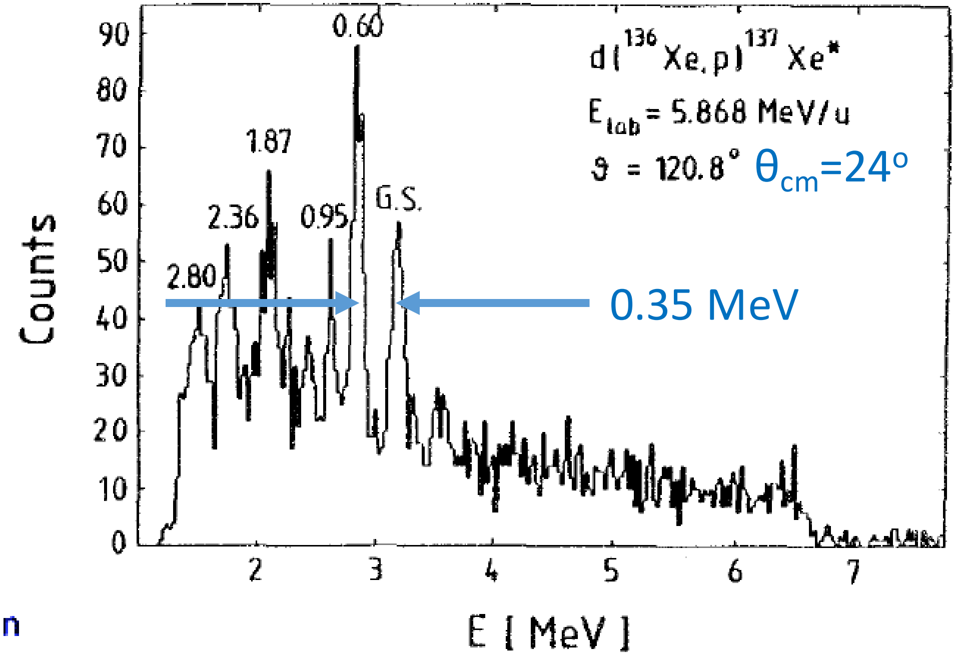
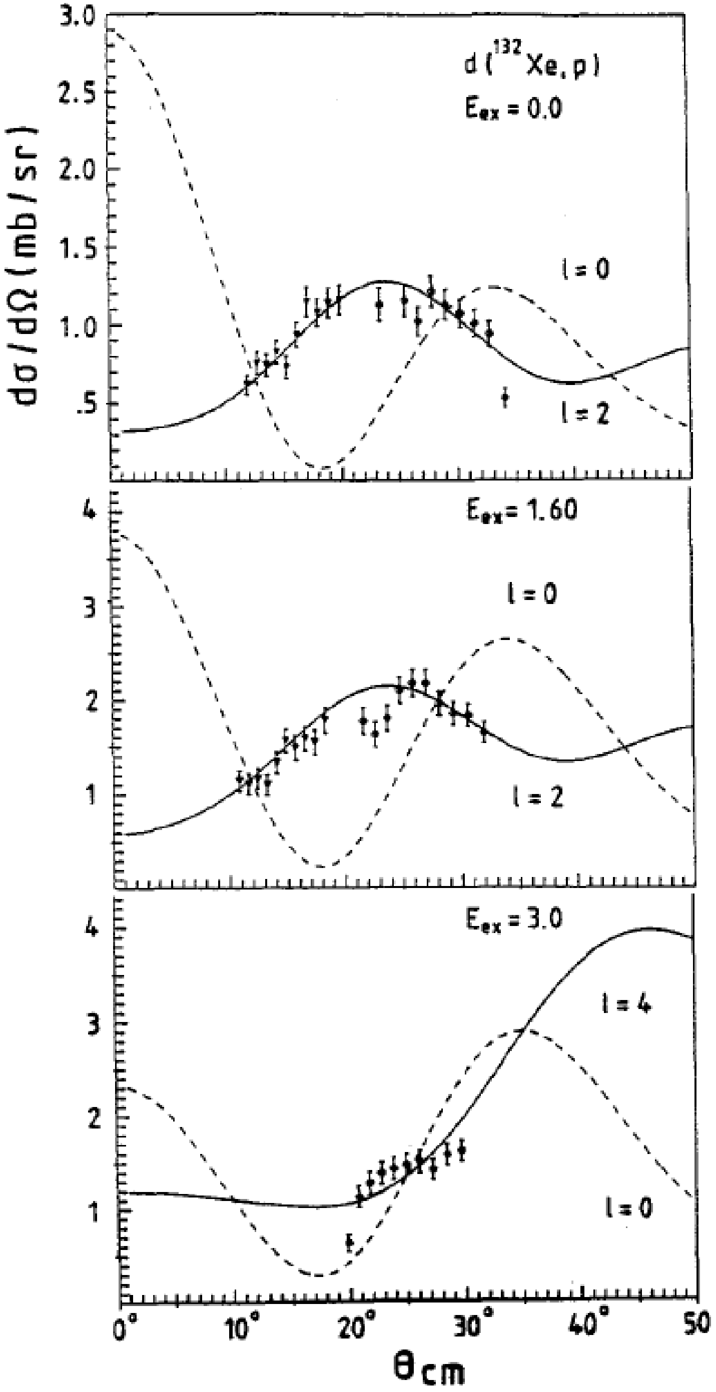


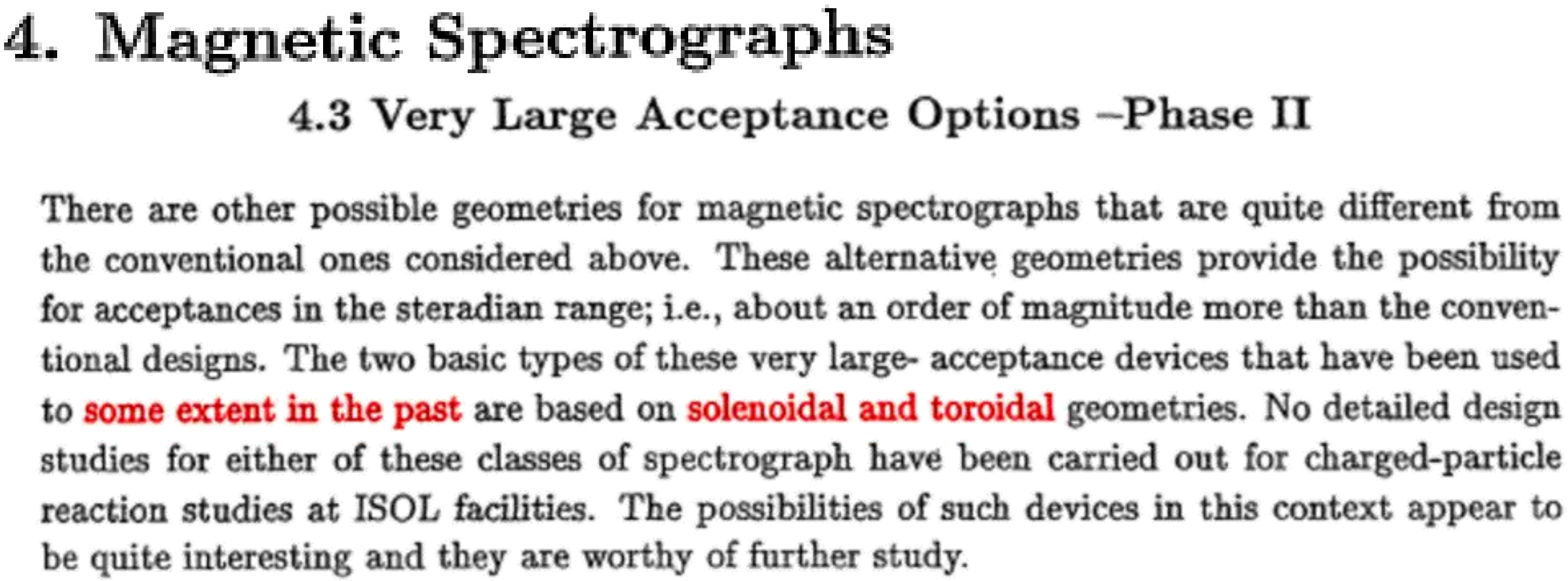
Fig. 2: Energy spectrum of protons emitted in the reaction d(^{136}*Xe*, *p*)^{133}*Xe*. ϑ is the laboratory angle.



---

*Dedicated to Prof. Dr. P. Kienle on the occasion of his 60th birthday

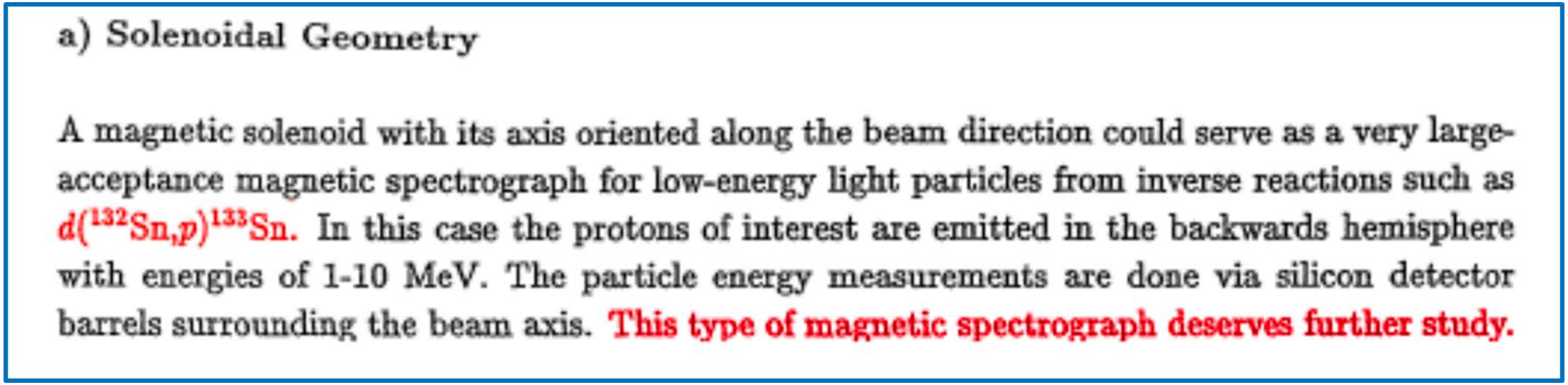
For Something that would become RIA



4. Magnetic Spectrographs

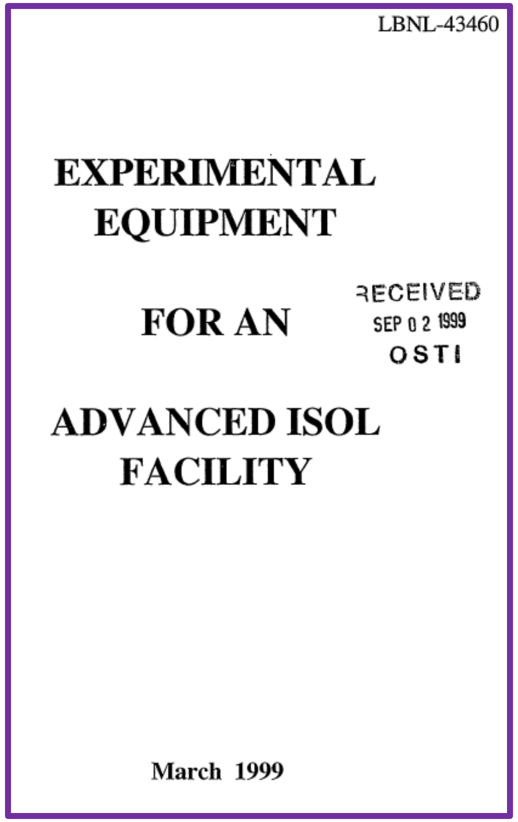
4.3 Very Large Acceptance Options –Phase II

There are other possible geometries for magnetic spectrographs that are quite different from the conventional ones considered above. These alternative geometries provide the possibility for acceptances in the steradian range; i.e., about an order of magnitude more than the conventional designs. The two basic types of these very large- acceptance devices that have been used to some extent in the past are based on solenoidal and toroidal geometries. No detailed design studies for either of these classes of spectrograph have been carried out for charged-particle reaction studies at ISOL facilities. The possibilities of such devices in this context appear to be quite interesting and they are worthy of further study.



a) Solenoidal Geometry

A magnetic solenoid with its axis oriented along the beam direction could serve as a very large-acceptance magnetic spectrograph for low-energy light particles from inverse reactions such as $d(^{132}Sn,p)^{133}Sn$. In this case the protons of interest are emitted in the backwards hemisphere with energies of 1-10 MeV. The particle energy measurements are done via silicon detector barrels surrounding the beam axis. This type of magnetic spectrograph deserves further study.



LBNL-43460

EXPERIMENTAL
EQUIPMENT

FOR AN

ADVANCED ISOL
FACILITY

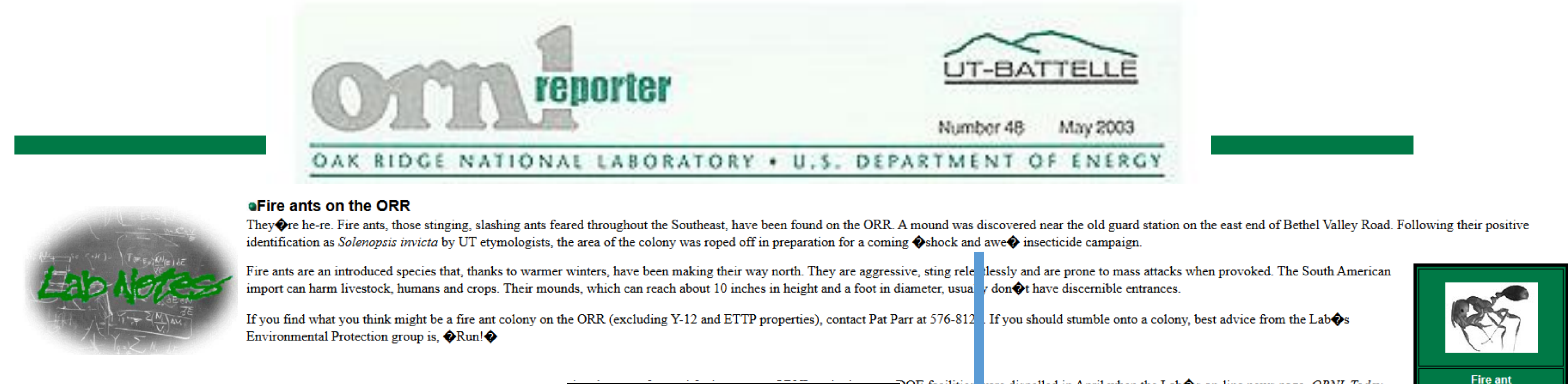
RECEIVED
SEP 0 2 1999
OSTI

March 1999

What do we need to Establish the Single-Particle Structure of Exotic (Neutron-Rich) Nuclei

John Schiffer
Argonne Nat'l. Lab
&
Alan Wuosmaa
Western Michigan University

RIA Equipment Workshop
ORNL March 19, 2003



ornl reporter

UT-BATTELLE

Number 48 May 2003

OAK RIDGE NATIONAL LABORATORY • U.S. DEPARTMENT OF ENERGY

●Fire ants on the ORR

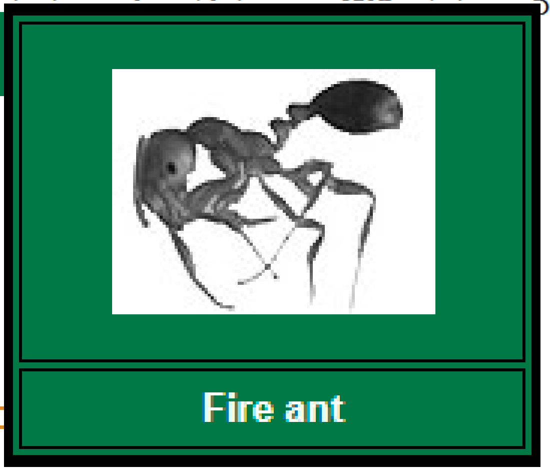
They�re he-re. Fire ants, those stinging, slashing ants feared throughout the Southeast, have been found on the ORR. A mound was discovered near the old guard station on the east end of Bethel Valley Road. Following their positive identification as *Solenopsis invicta* by UT etymologists, the area of the colony was roped off in preparation for a coming �shock and awe� insecticide campaign.

Fire ants are an introduced species that, thanks to warmer winters, have been making their way north. They are aggressive, sting rele tlessly and are prone to mass attacks when provoked. The South American import can harm livestock, humans and crops. Their mounds, which can reach about 10 inches in height and a foot in diameter, usua y don�t have discernible entrances.

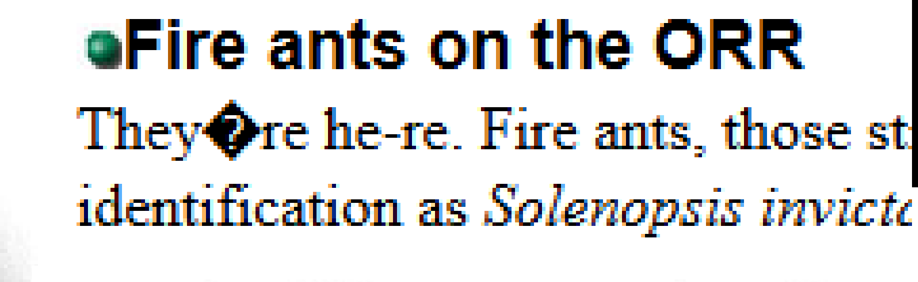
If you find what you think might be a fire ant colony on the ORR (excluding Y-12 and ETTP properties), contact Pat Parr at 576-812 . If you should stumble onto a colony, best advice from the Lab�s Environmental Protection group is, �Run!�

Fire ant

DOE facilities vere dispelled in April when the Lab�s on-line news page, *ORNL Today*,



Fire ant



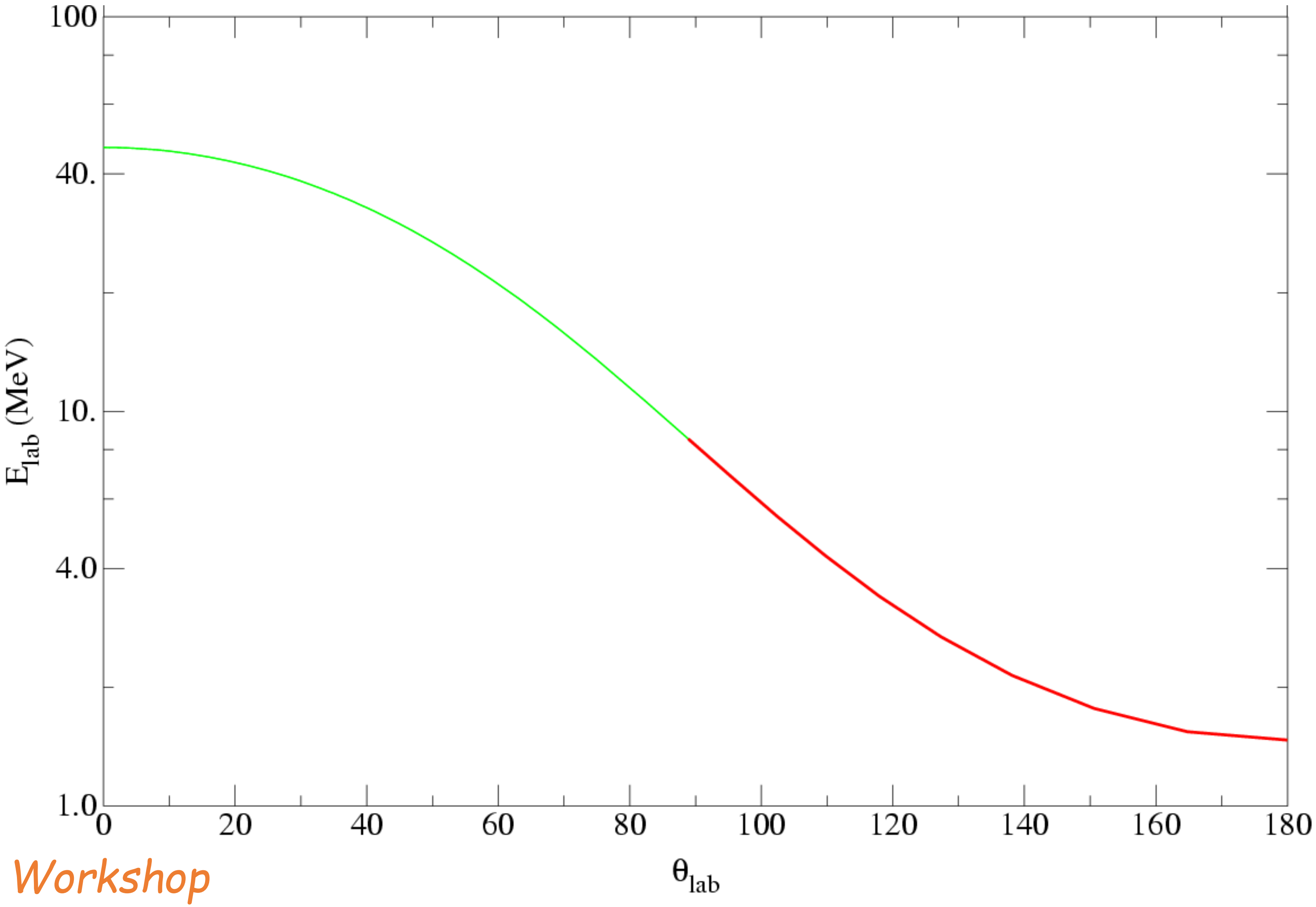
●Fire ants on the ORR

They�re he-re. Fire ants, those st

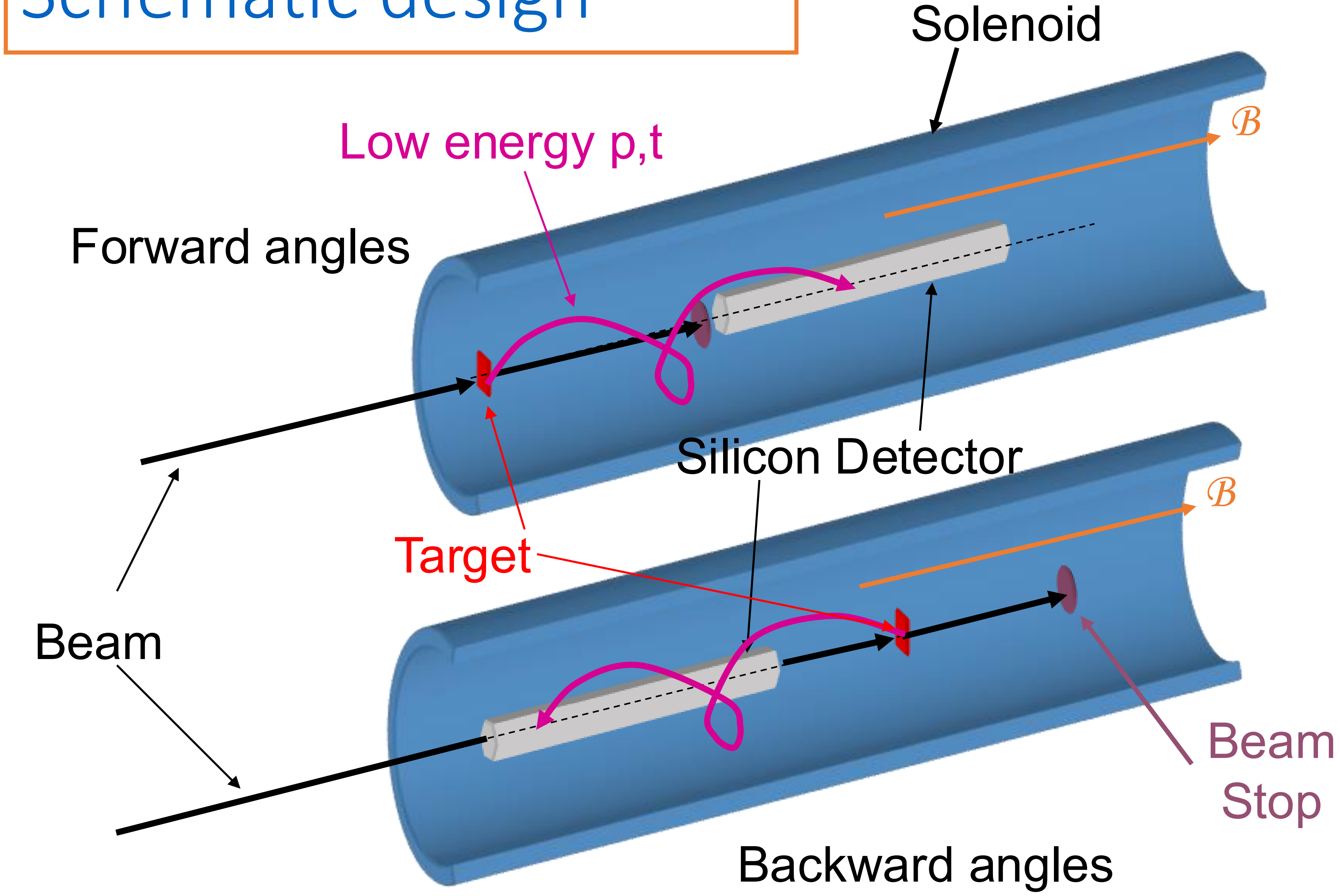
identification as *Solenopsis invict*

roped off in preparation for a coming �shock and awe� insecticide campaign.

d(^{132}Sn,p) kinematics (at 8A MeV)



Schematic design



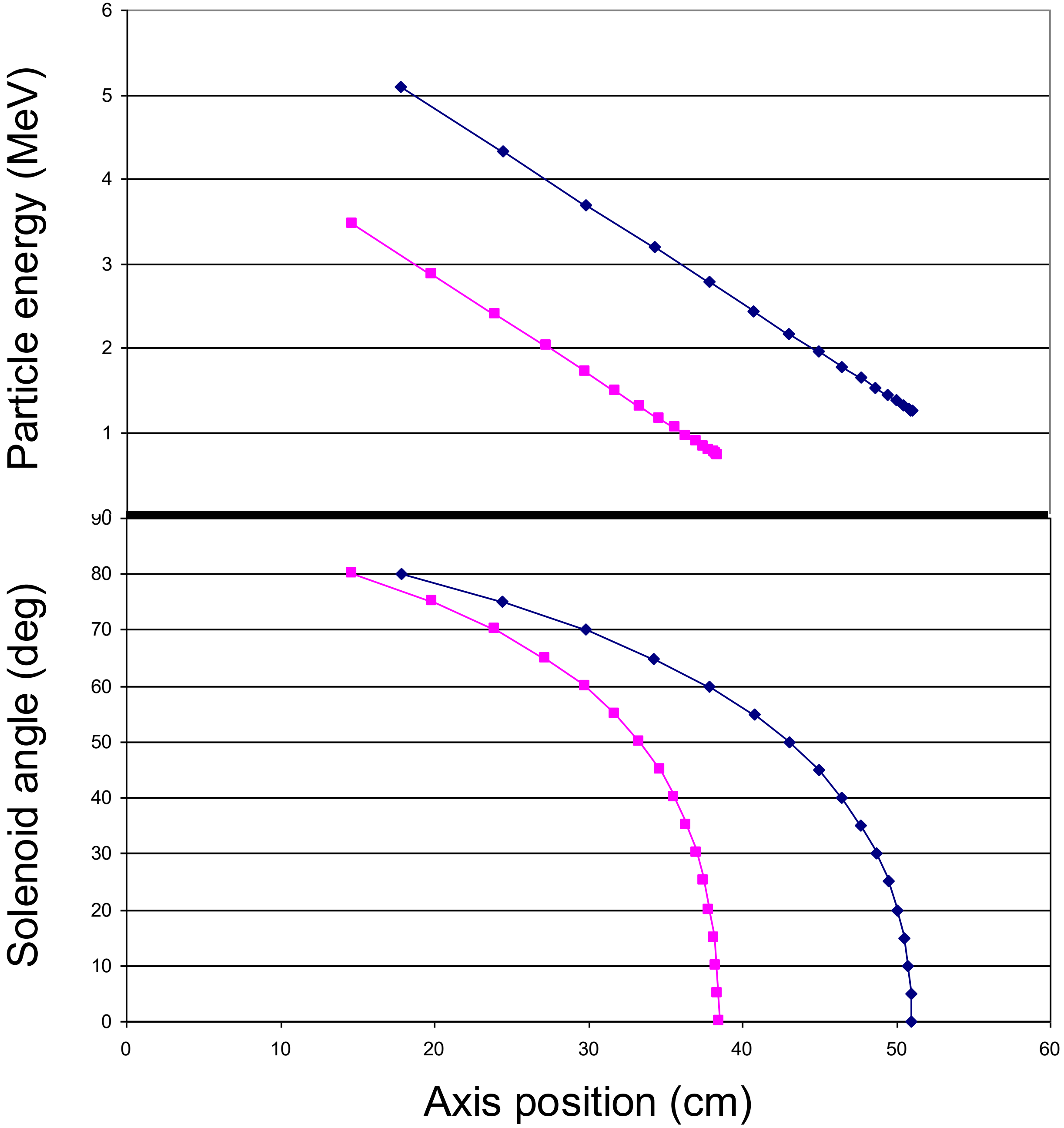
RIA Equipment Workshop
ORNL March 19, 2003

NPA **746** 267c (2004)

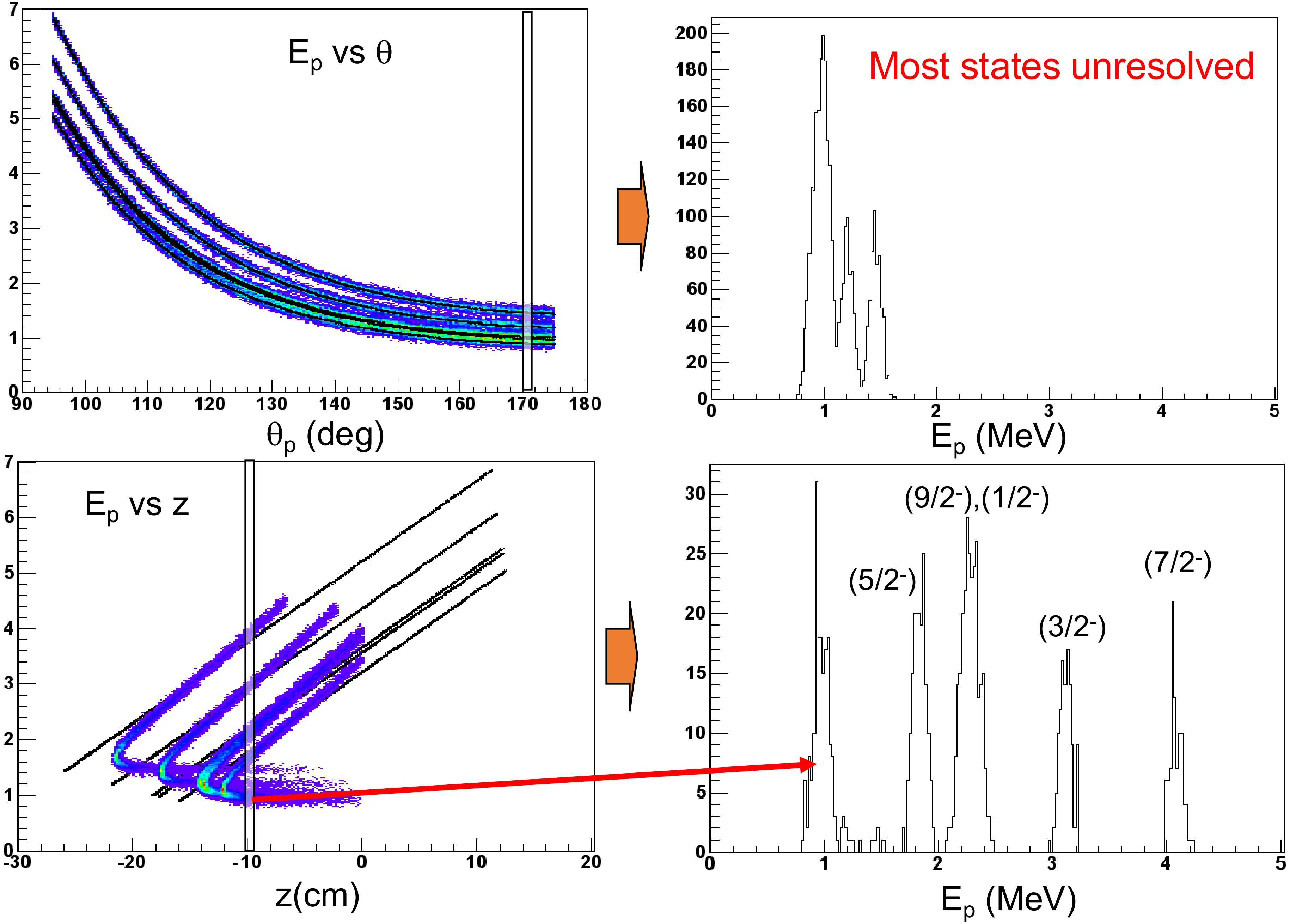
Solenoid transport for d(^{132}Sn,p)

E(^{132}Sn)=7 MeV/u
$\mathcal{B}$=2T

E$_X$=0.0 MeV
E$_X$=2.0 MeV



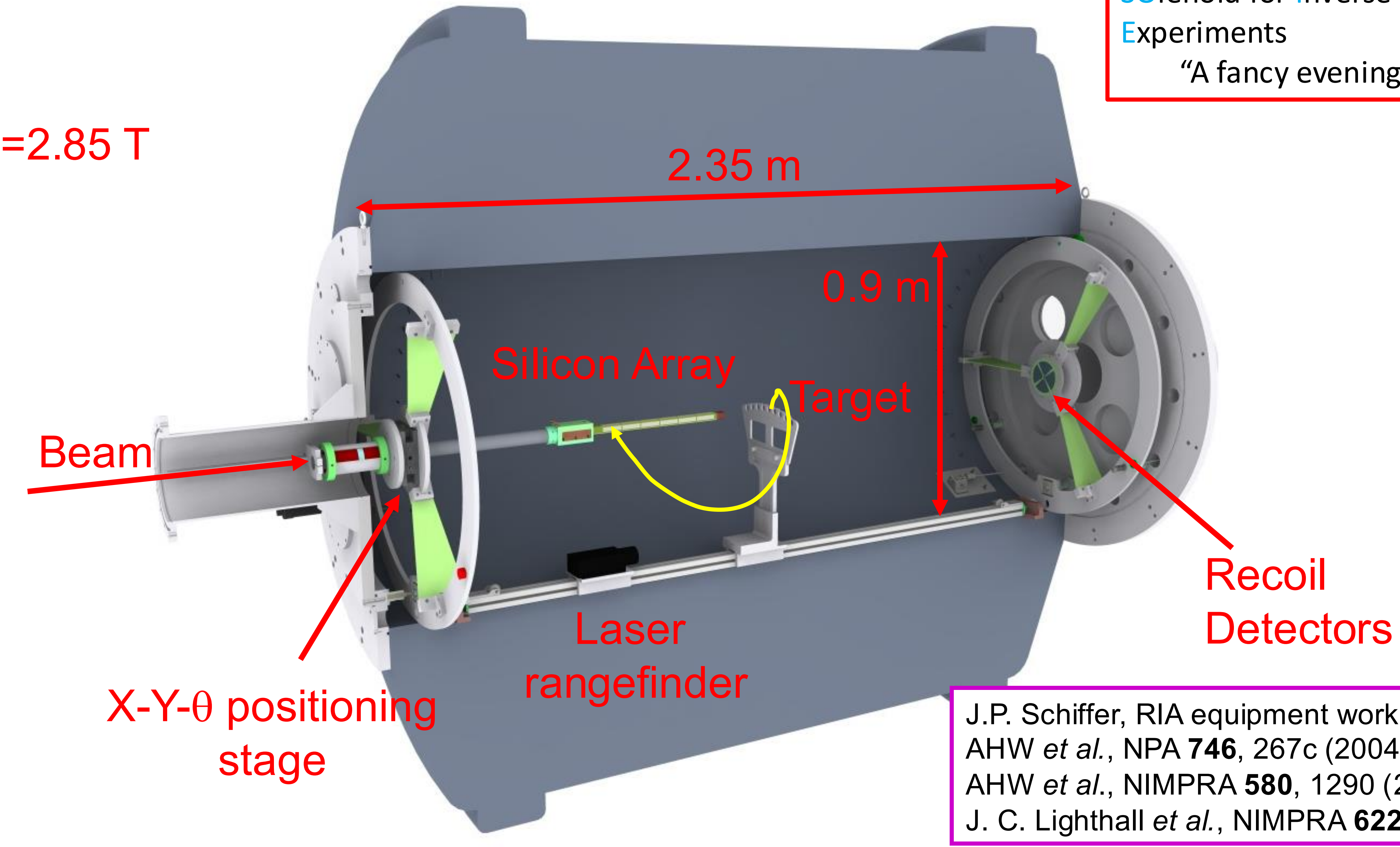
Real states in ^{133}Sn



HELIcal Orbit Spectrometer -HELIOS

John Schiffer's acronym: SOIREE
SOlenoid for Inverse REaction
Experiments
"A fancy evening affair"

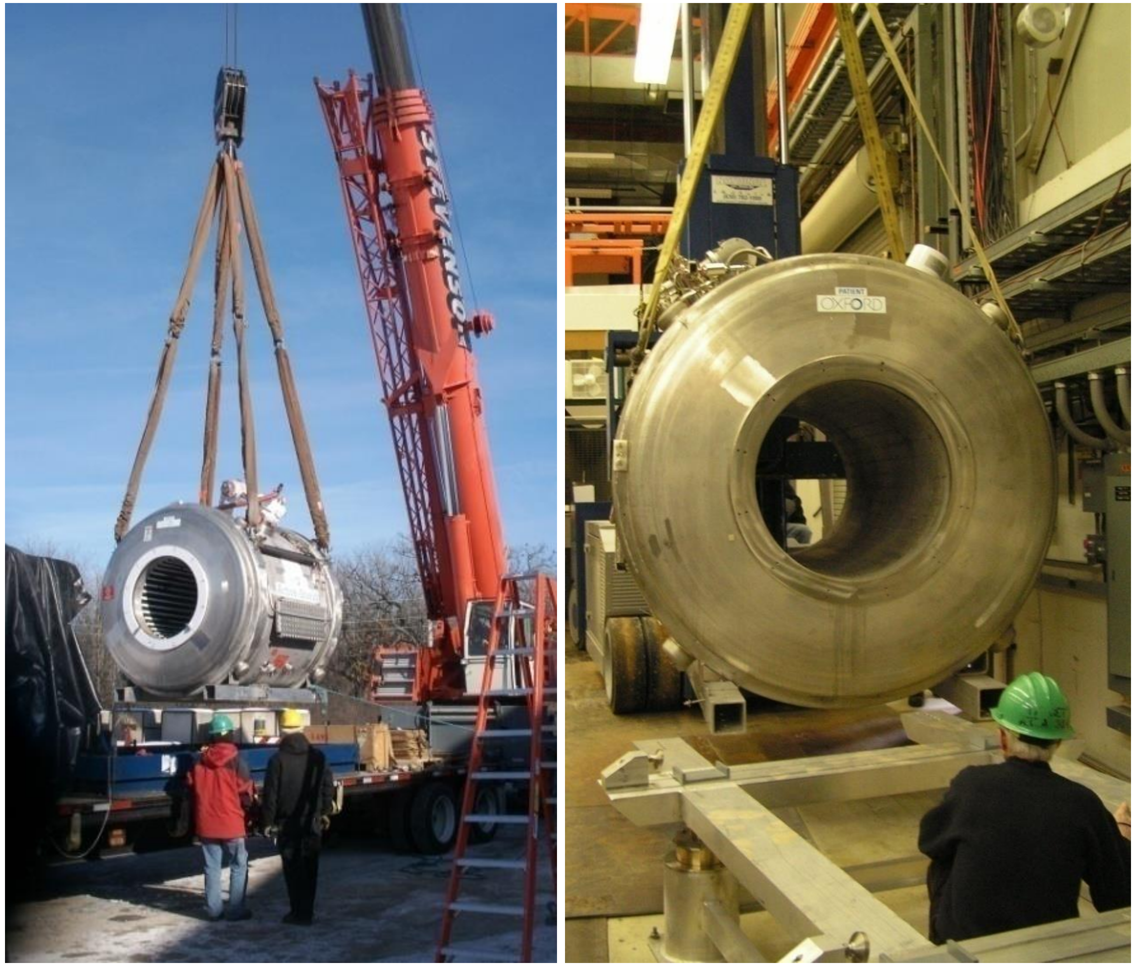
B_{MAX}=2.85 T



J.P. Schiffer, RIA equipment workshop 1999
AHW *et al.*, NPA **746**, 267c (2004)
AHW *et al.*, NIMPRA **580**, 1290 (2007)
J. C. Lighthall *et al.*, NIMPRA **622**, 97 (2010)

HELIOS: From Scanner to Spectrometer

Tübingen, Germany
November 2006



Argonne, USA
December/January 2007

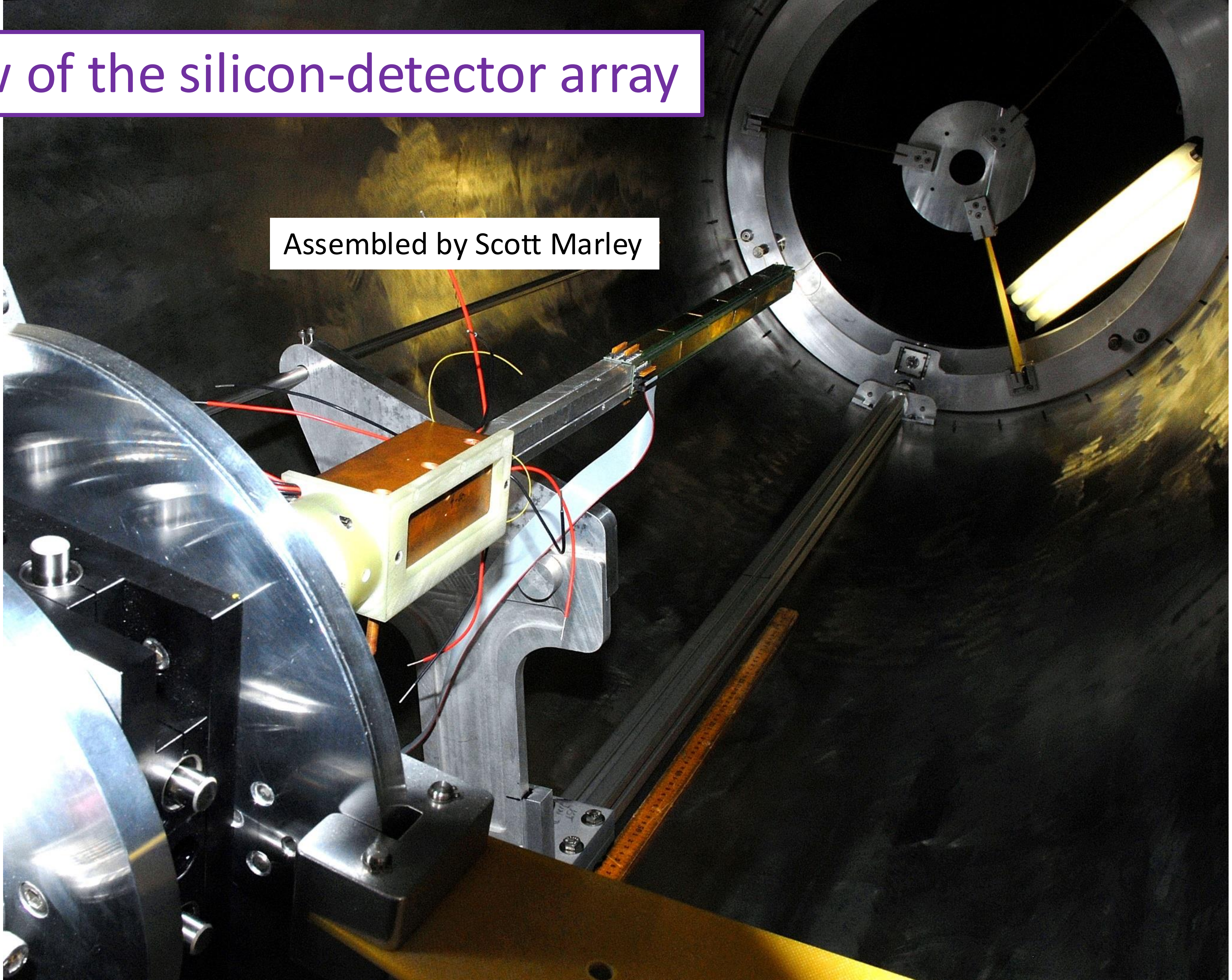
Birger Back managed the project throughout

Students working hard

Jon Lighthall

Jack Winkelbauer

Early view of the silicon-detector array



Assembled by Scott Marley

HELIOS at ATLAS

Revisit ^{136}Xe(d,p)^{137}Xe

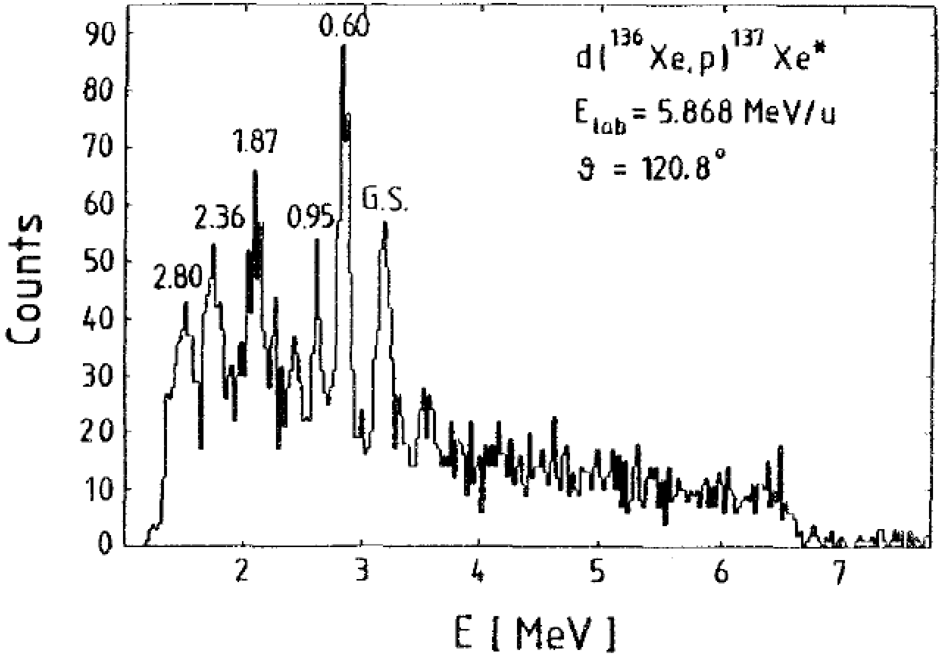
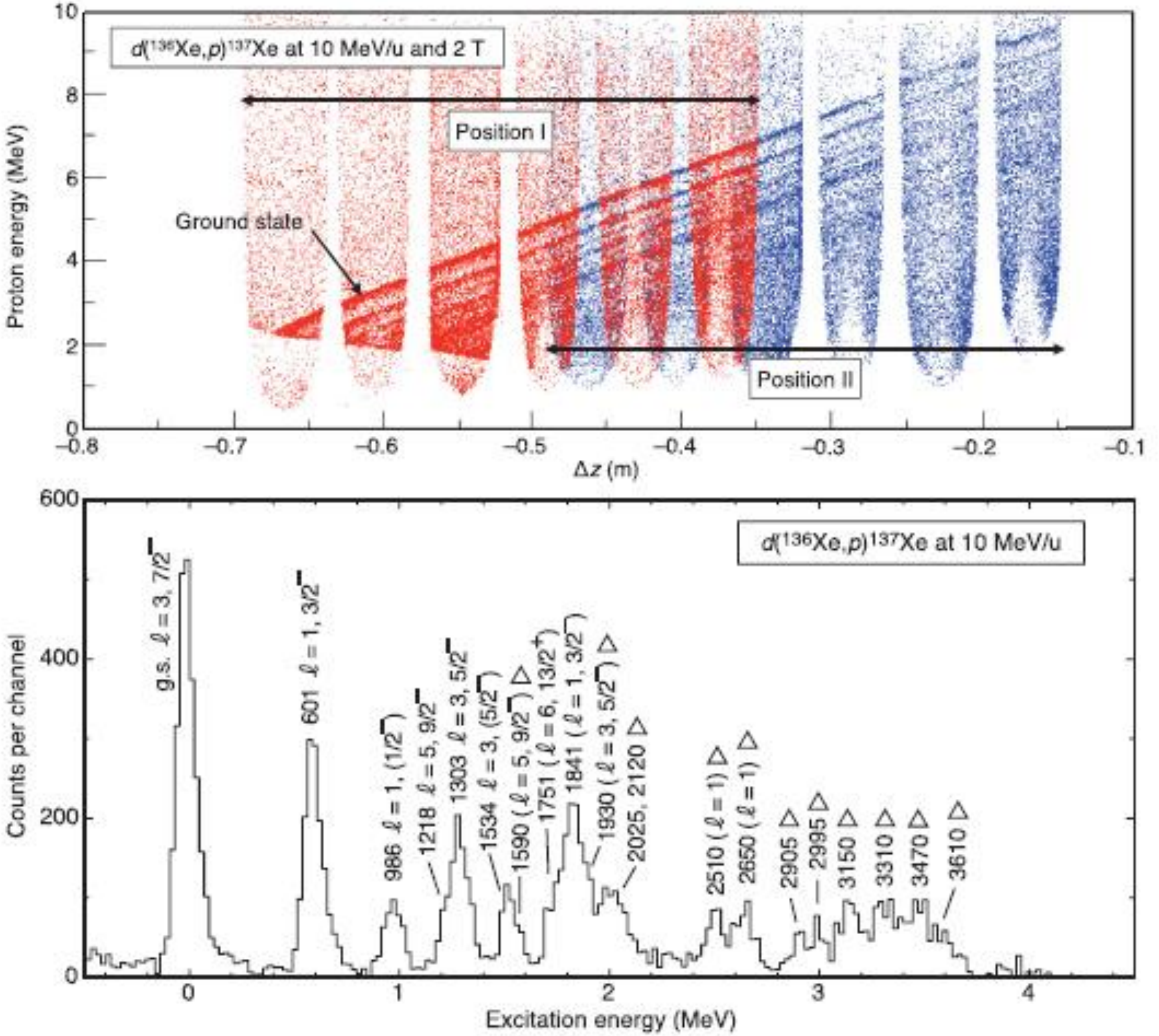


Fig. 2: Energy spectrum of protons emitted in the reaction d(^{136}Xe, p)^{133}Xe. ϑ is the laboratory angle.

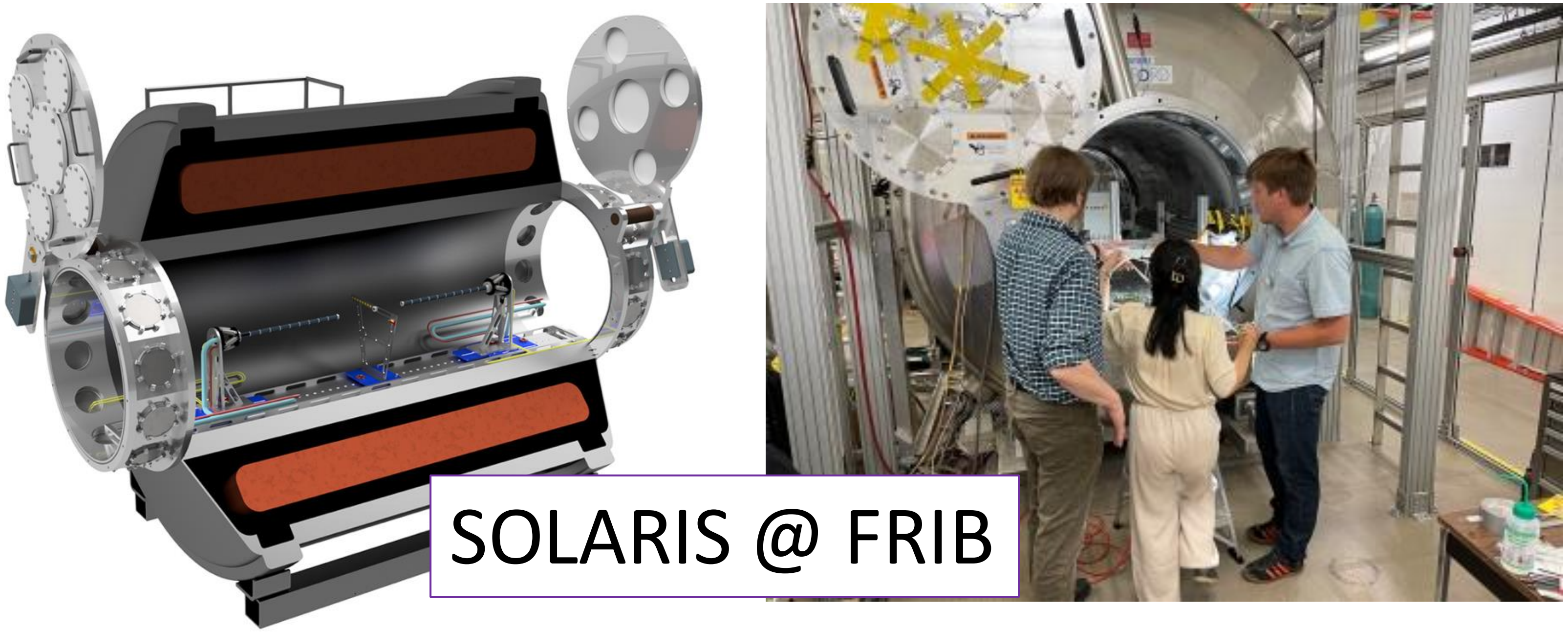
SINGLE-NEUTRON ENERGIES OUTSIDE ^{136}Xe

PHYSICAL REVIEW C **84**, 024325 (2011)

B. P. Kay et al.,



Different Versions



SOLARIS @ FRIB

ISS @ CERN HIE ISOLDE

1,1
milliard d'années après le Big Bang
billion years after the Big Bang

Les scientifiques de l'installation ISOLDE au CERN étudient comment la matière se comporte et se transforme, notamment au cœur des étoiles.

Scientists use experiments at CERN's ISOLDE facility, pictured, to study how matter behaves and transforms, including inside stars.

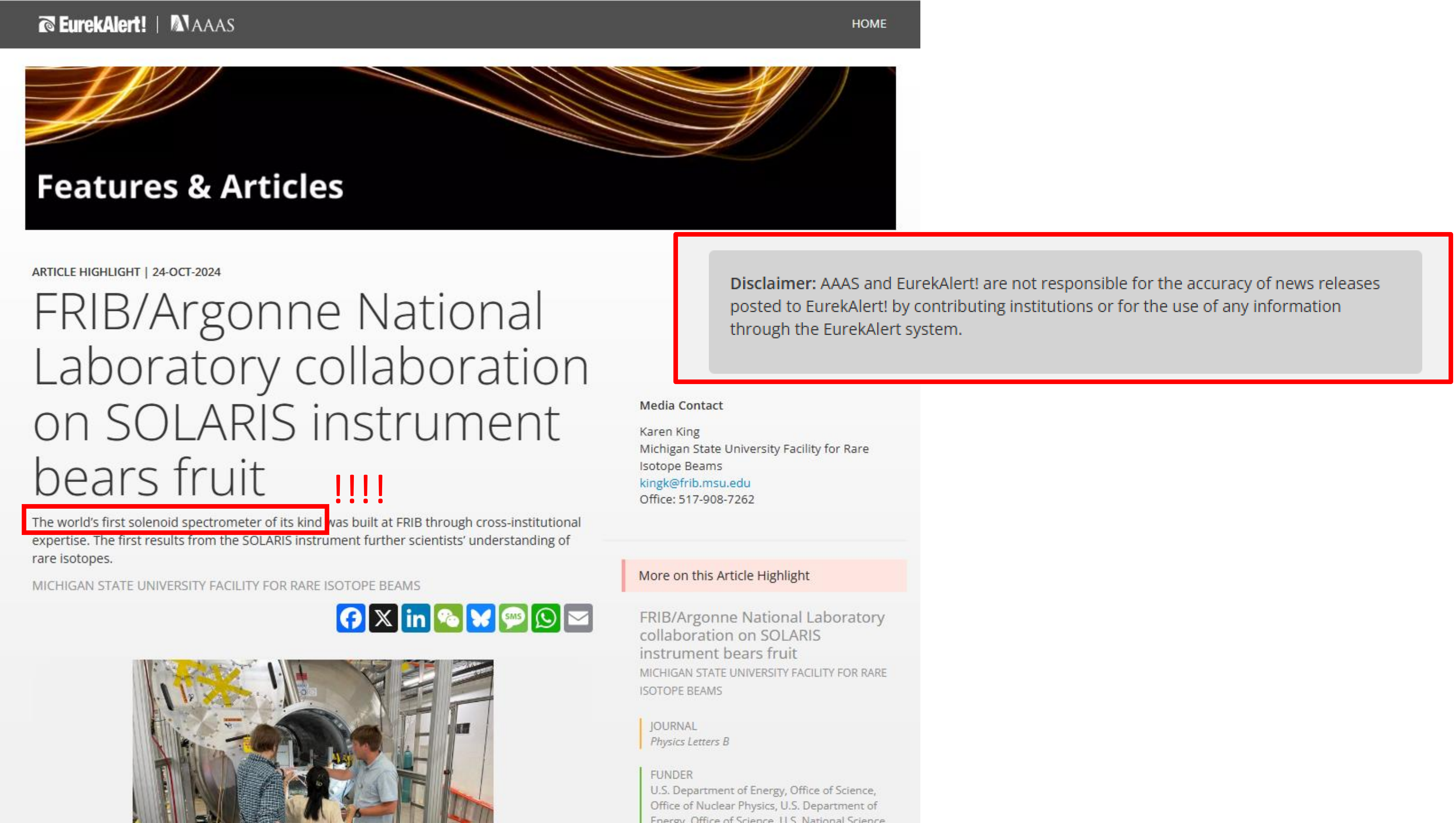
Sommes-nous faits de poussière d'étoiles ?

Lorsque les étoiles brûlent, elles fabriquent des atomes de plus en plus lourds par la fusion d'atomes légers. En fin de vie, les étoiles très massives explosent en supernova, produisant des atomes encore plus lourds et les éjectant dans l'espace pour former la prochaine génération d'étoiles, de planètes et… la vie. La plupart des atomes qui nous constituent ont été produits par les étoiles.

Are we made of stardust?

As stars burn, they produce increasingly heavier atoms through the fusion of lighter atoms. When massive stars run out of fuel, they explode in a supernova, producing yet heavier atoms, ejecting them out into space to eventually form the next generation of stars, planets, ... and life. Most of the atoms in our

ISS in the Geneva Airport



Features & Articles

ARTICLE HIGHLIGHT | 24-OCT-2024

FRIB/Argonne National Laboratory collaboration on SOLARIS instrument bears fruit

!!!!

The world's first solenoid spectrometer of its kind was built at FRIB through cross-institutional expertise. The first results from the SOLARIS instrument further scientists' understanding of rare isotopes.

MICHIGAN STATE UNIVERSITY FACILITY FOR RARE ISOTOPE BEAMS

Disclaimer: AAAS and EurekAlert! are not responsible for the accuracy of news releases posted to EurekAlert! by contributing institutions or for the use of any information through the EurekAlert system.

Media Contact

Karen King
Michigan State University Facility for Rare Isotope Beams
kingk@frib.msu.edu
Office: 517-908-7262

More on this Article Highlight

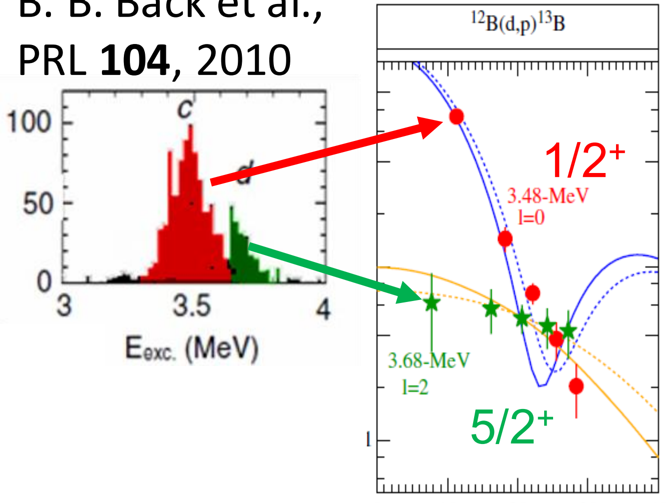
FRIB/Argonne National Laboratory collaboration on SOLARIS instrument bears fruit
MICHIGAN STATE UNIVERSITY FACILITY FOR RARE ISOTOPE BEAMS

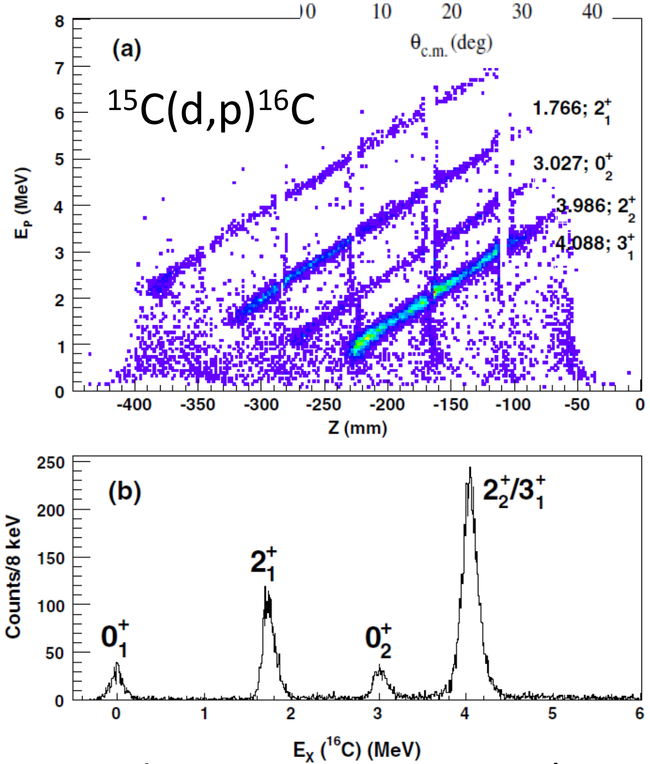
JOURNAL
Physics Letters B

FUNDER
U.S. Department of Energy, Office of Science, Office of Nuclear Physics, U.S. Department of Energy, Office of Science, U.S. National Science

(d,p) light nuclei

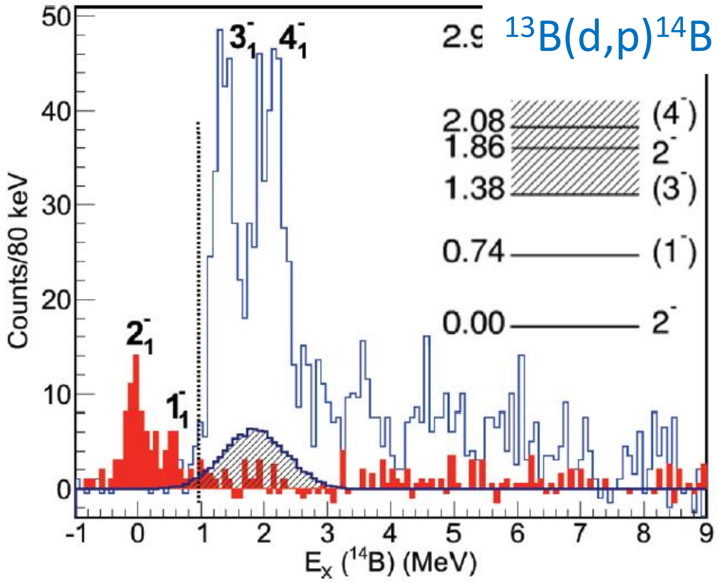
B. B. Back et al., PRL **104**, 2010



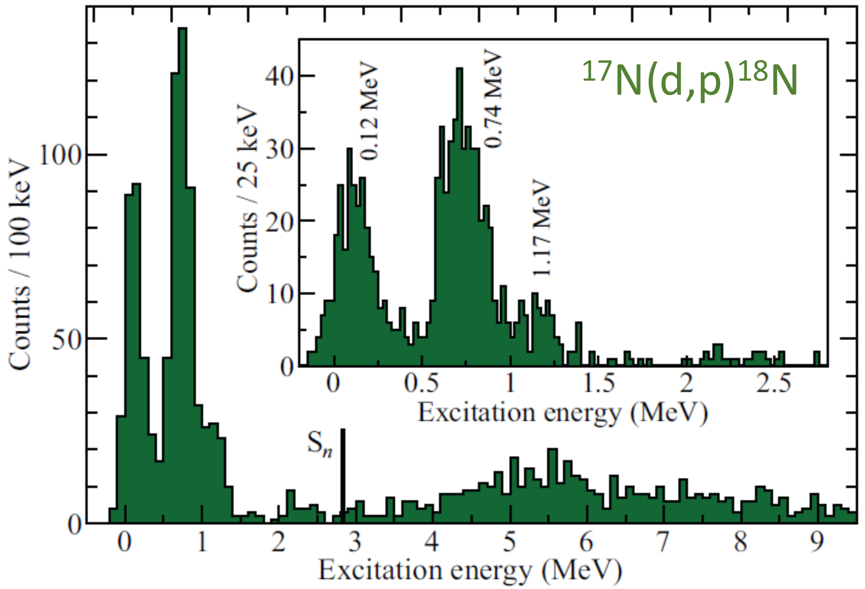


AHW et al., PRL **105**, 0132501 (2010)

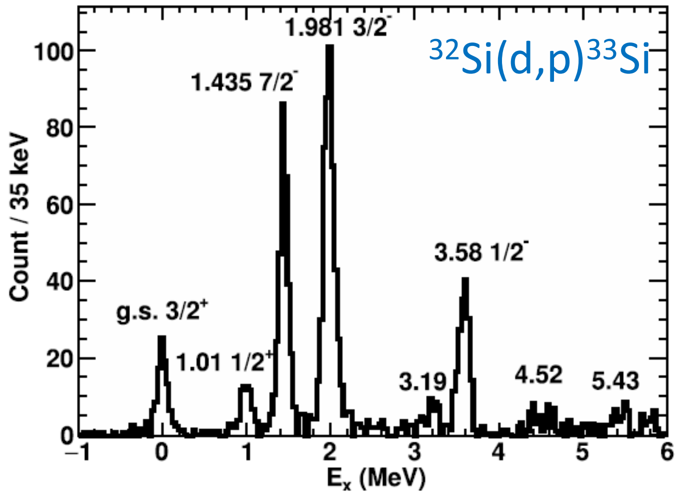
S. Bedoor et al., PRC **88**, 011304(R) (2013)



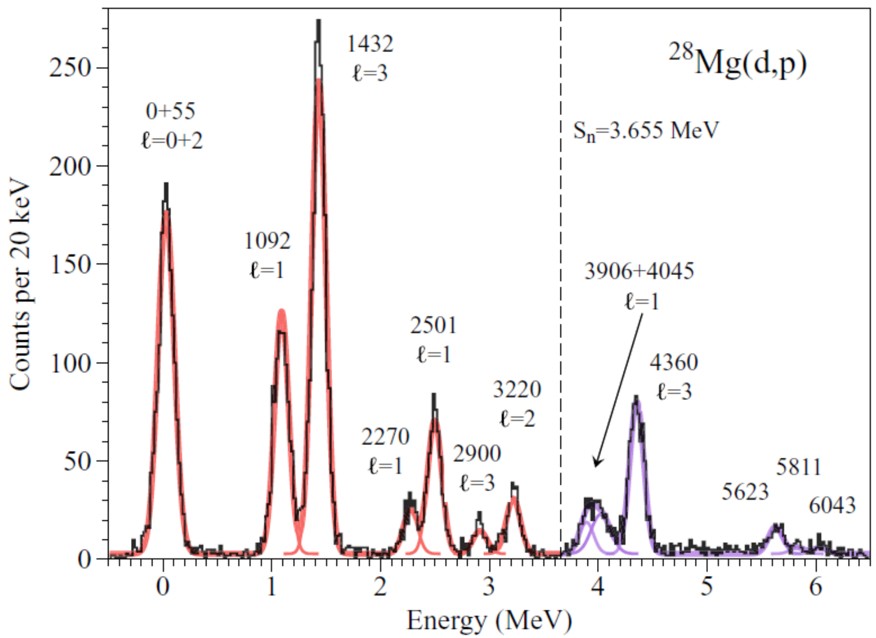
C. R. Hoffman et al., PRC **88**, 044317 (2013)



J. Chen et al., PLB **853**, (2024)
(SOLARIS measurement)

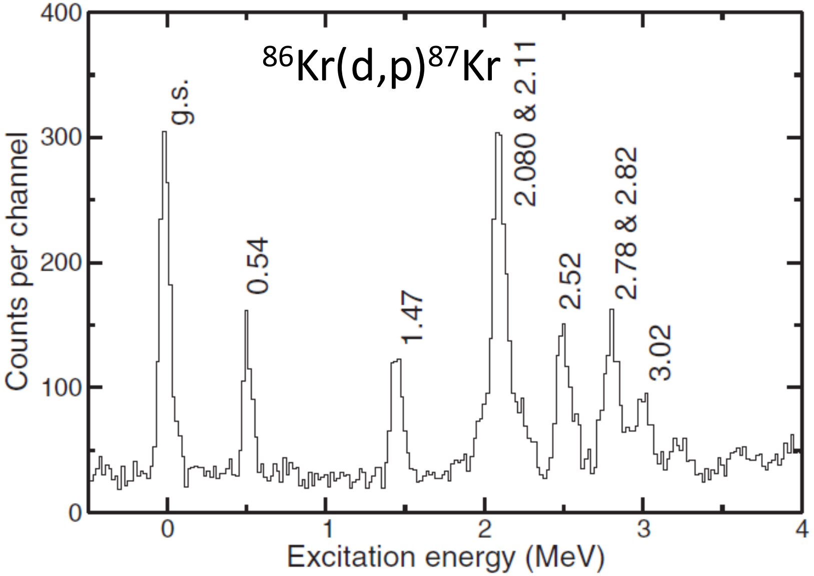


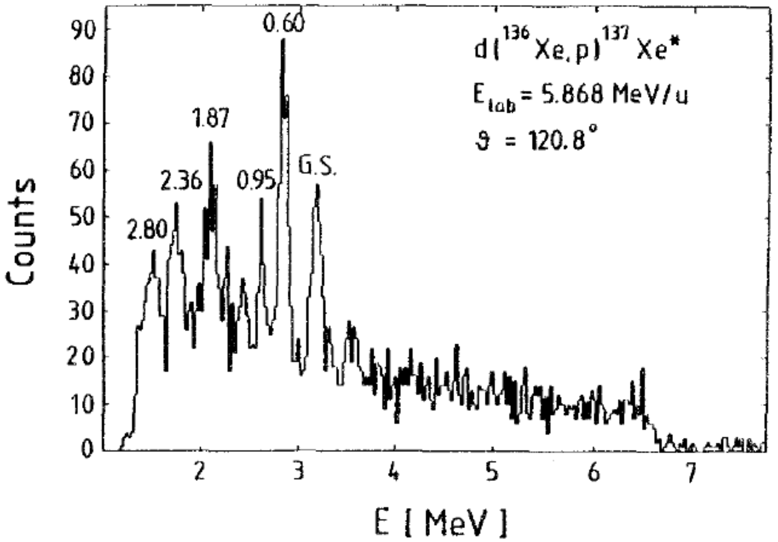
P. T. MacGregor et al., PRC **104**, L051301 (2021)
(ISS Measurement)



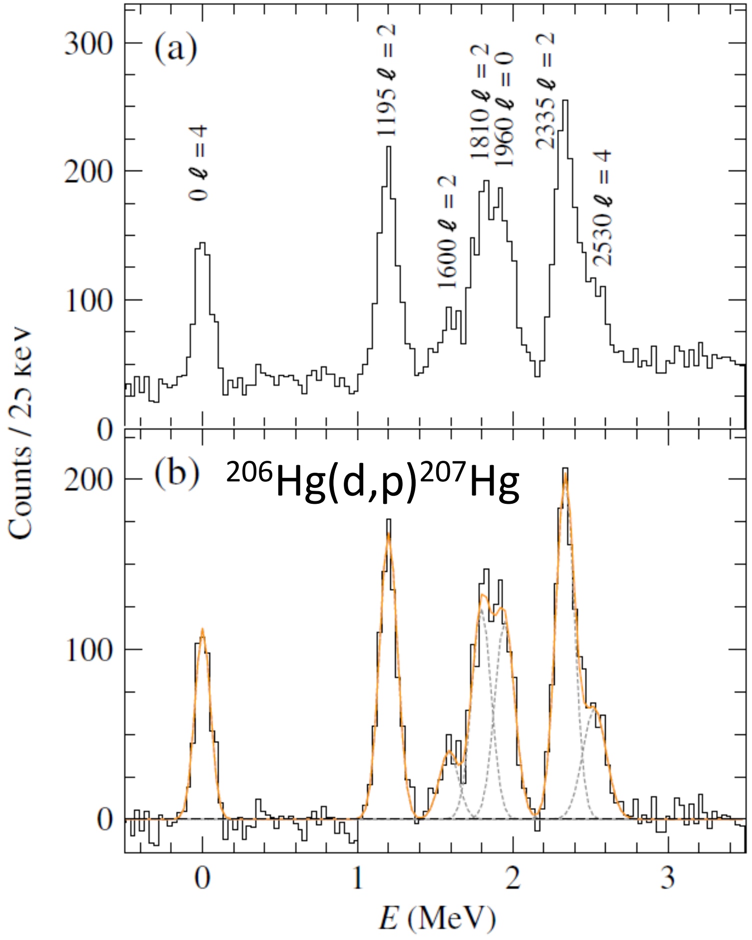
(d,p) heavy nuclei

D. K. Sharp et al., PRC **87**, 014312 (2013)

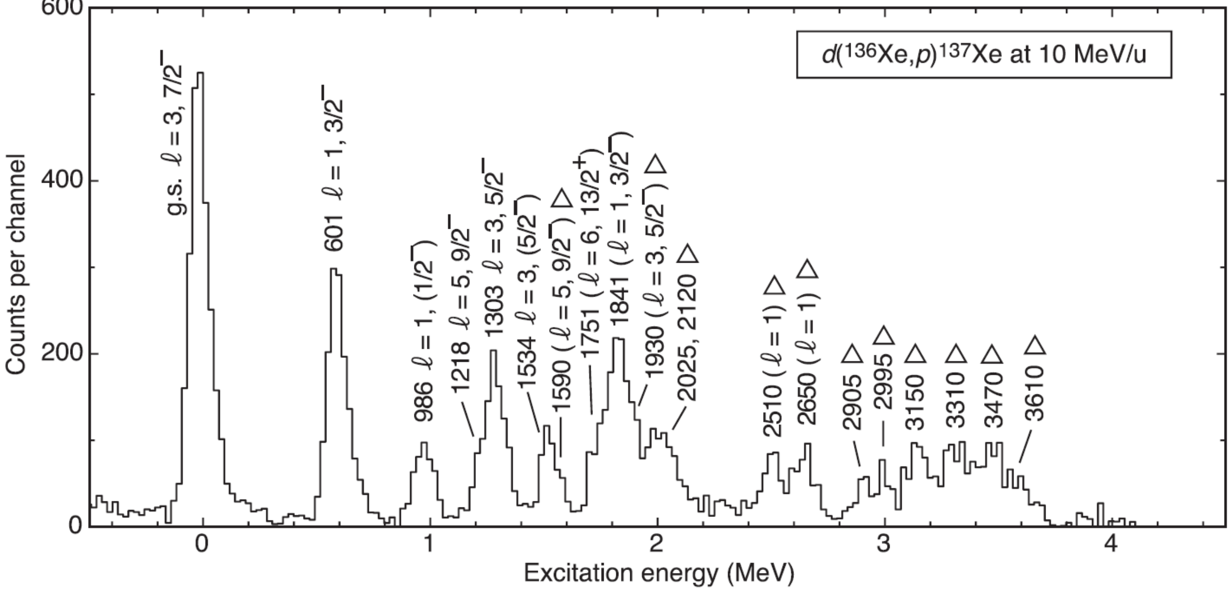




T. L. Tang et al., PRL **124**, 062502 (2020)
(ISS measurement)

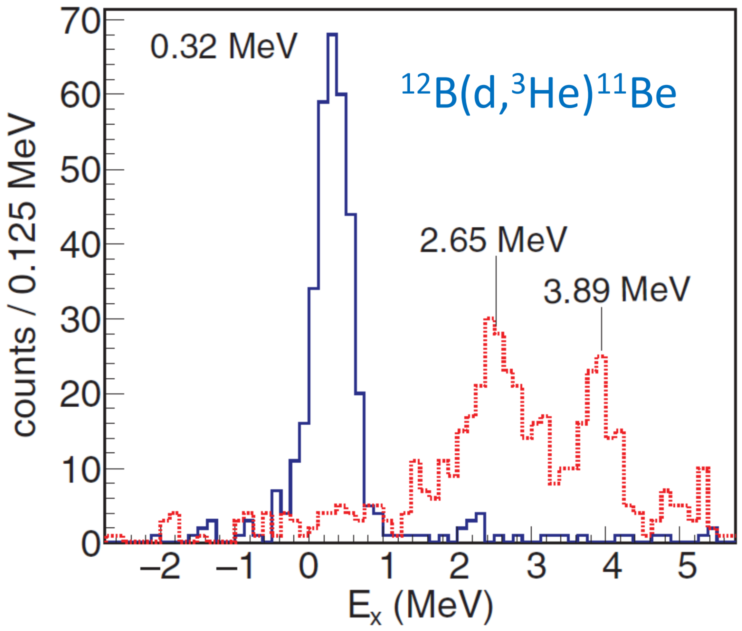


B. P. Kay et al., PRC **84**, 024325 (2011)

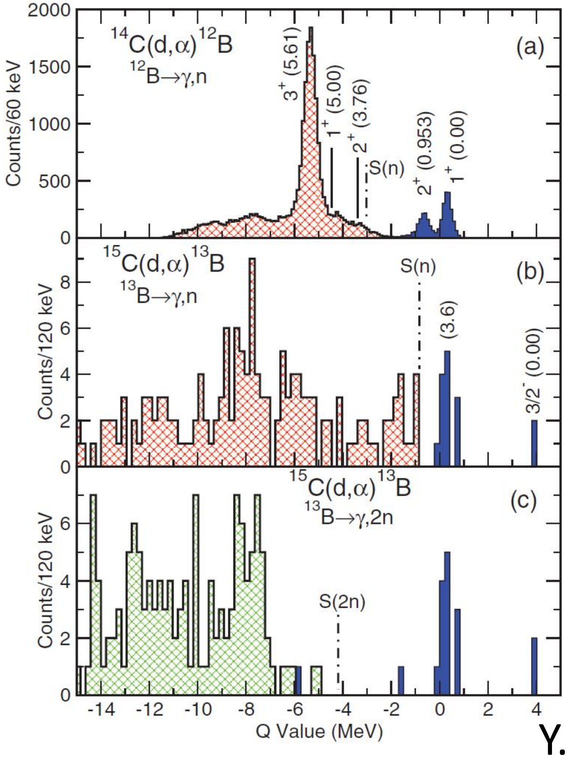


Nucleon Removal

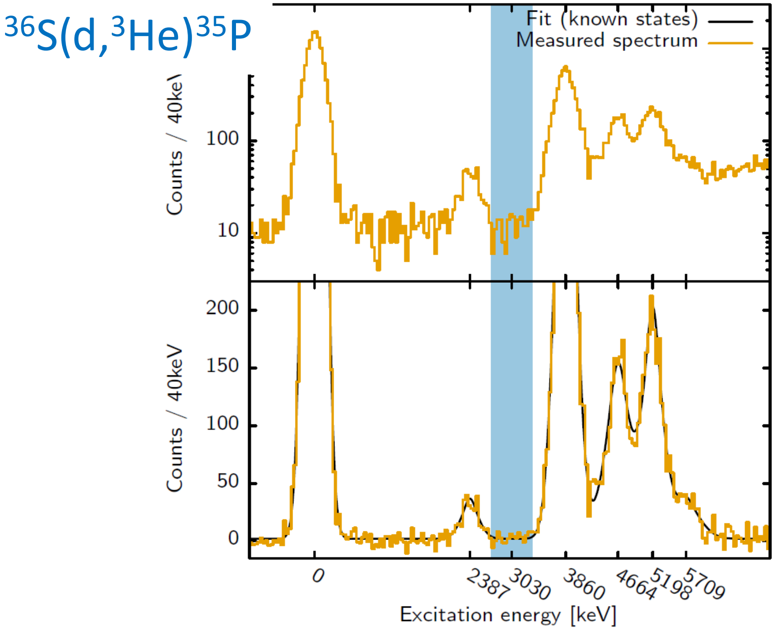
J. Chen et al., PRC **100**, 061314 (2019)



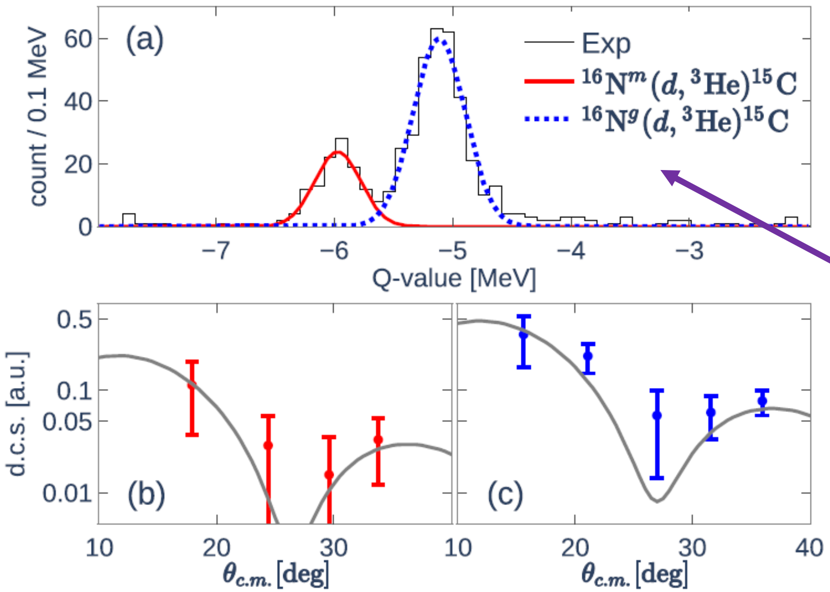
AHW et al., PRC **90**, 061301(R) (2014)



M. Salathe et al., PRC **102**, 064317 (2020)

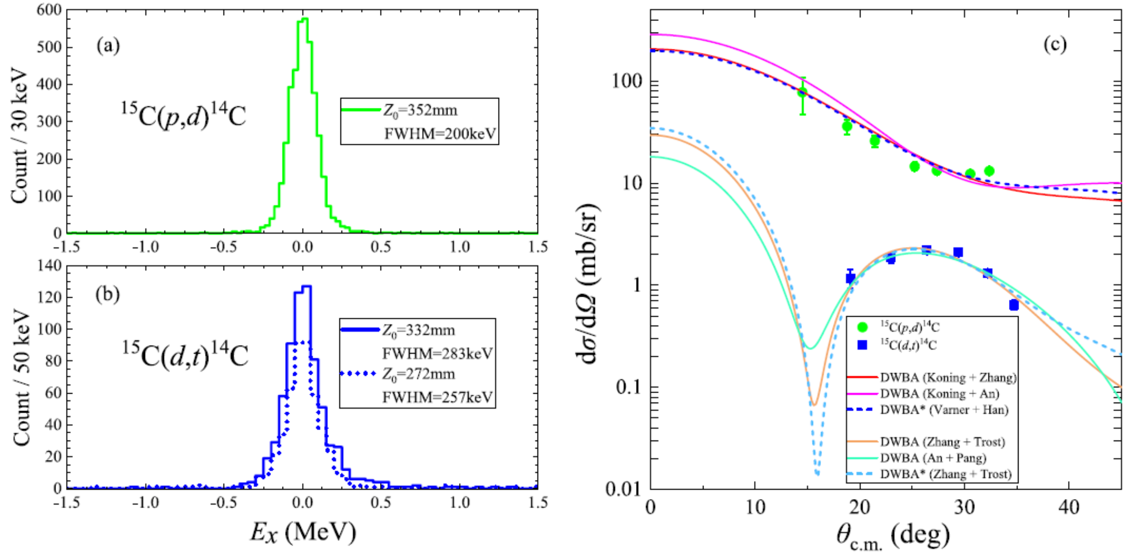


T. L. Tang et al., PRC **105**, 064307 (2022)



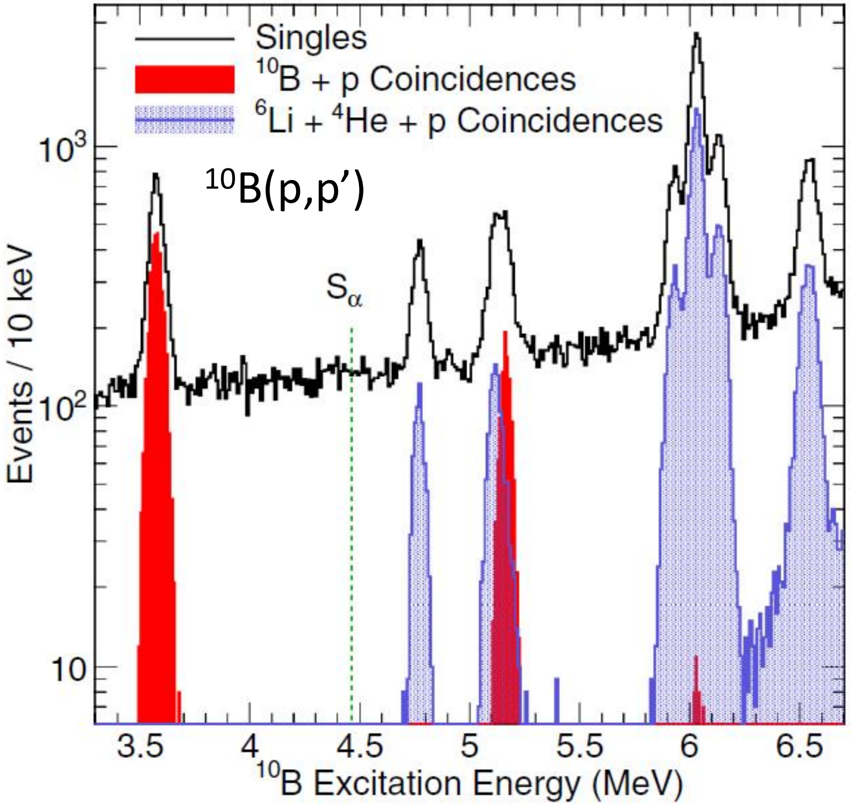
Isomeric beam!

Y. C. Jiang et al., PLB **868** (2025)

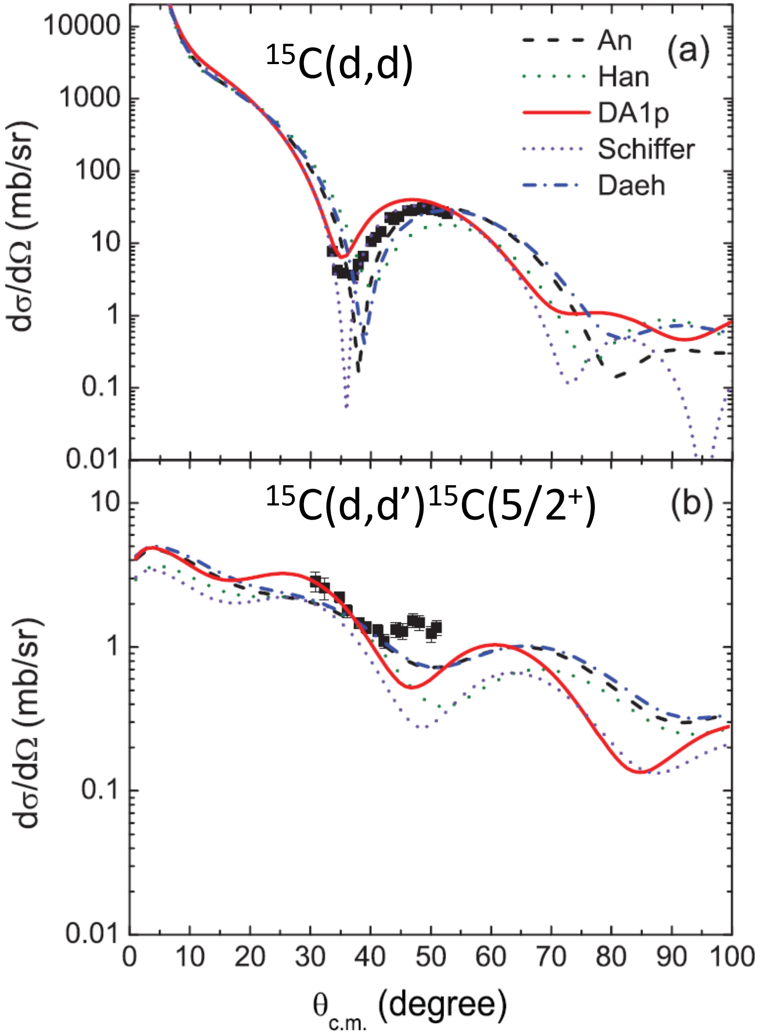


(In)elastic scattering

S. A. Kuvin et al., PRC **96**, 041301(R) (2017)



J. Chen et al., PRC **106**, 064312 (2022)

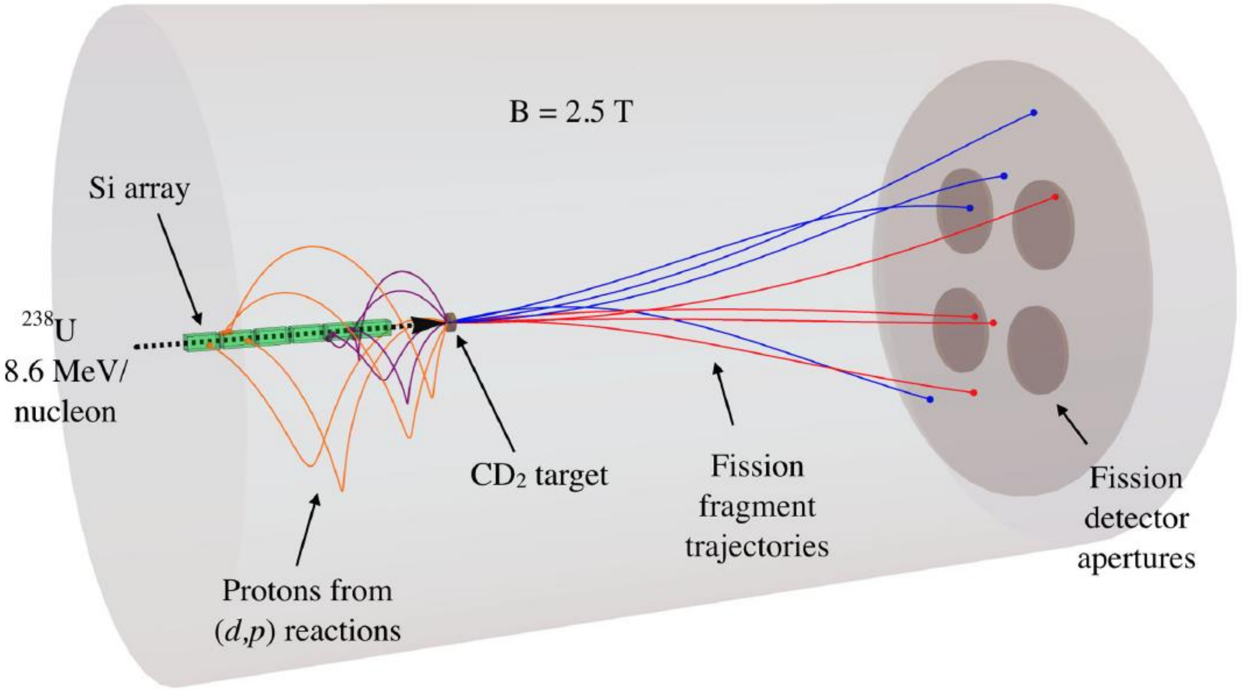


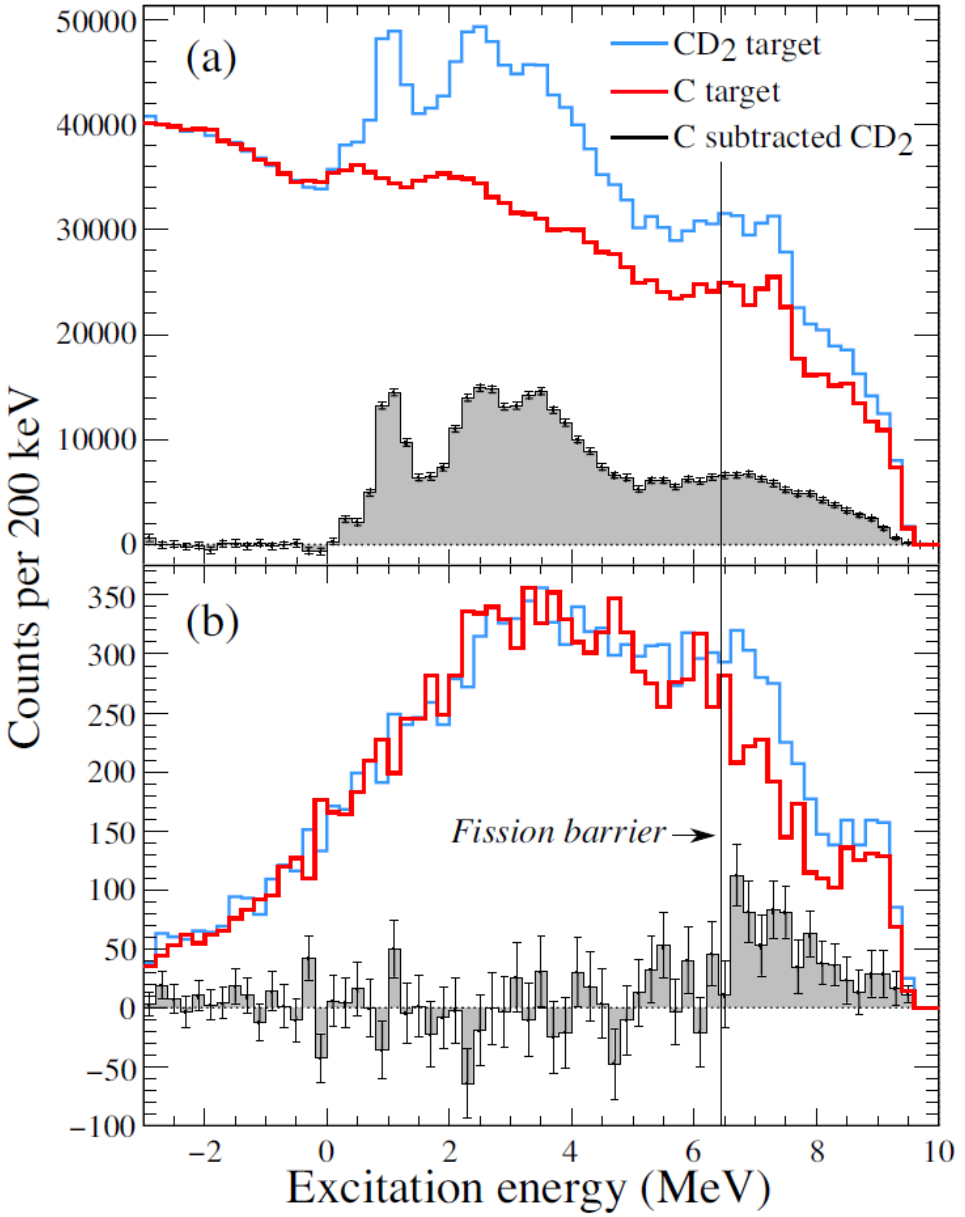
Fission!

PHYSICAL REVIEW LETTERS **130**, 202501 (2023)

Direct Determination of Fission-Barrier Heights Using Light-Ion Transfer in Inverse Kinematics

S. A. Bennett,[1] K. Garrett,[1] D. K. Sharp,[1,*] S. J. Freeman,[1,2] A. G. Smith,[1] T. J. Wright,[1] B. P. Kay,
T. L. Tang,[3,†] I. A. Tolstukhin,[3] Y. Ayyad,[4] J. Chen,[3] P. J. Davies,[5] A. Dolan,[6] L. P. Gaffney,[6] A. Heinz
C. R. Hoffman,[3] C. Müller-Gatermann,[3] R. D. Page,[6] and G. L. Wilson[8,3]





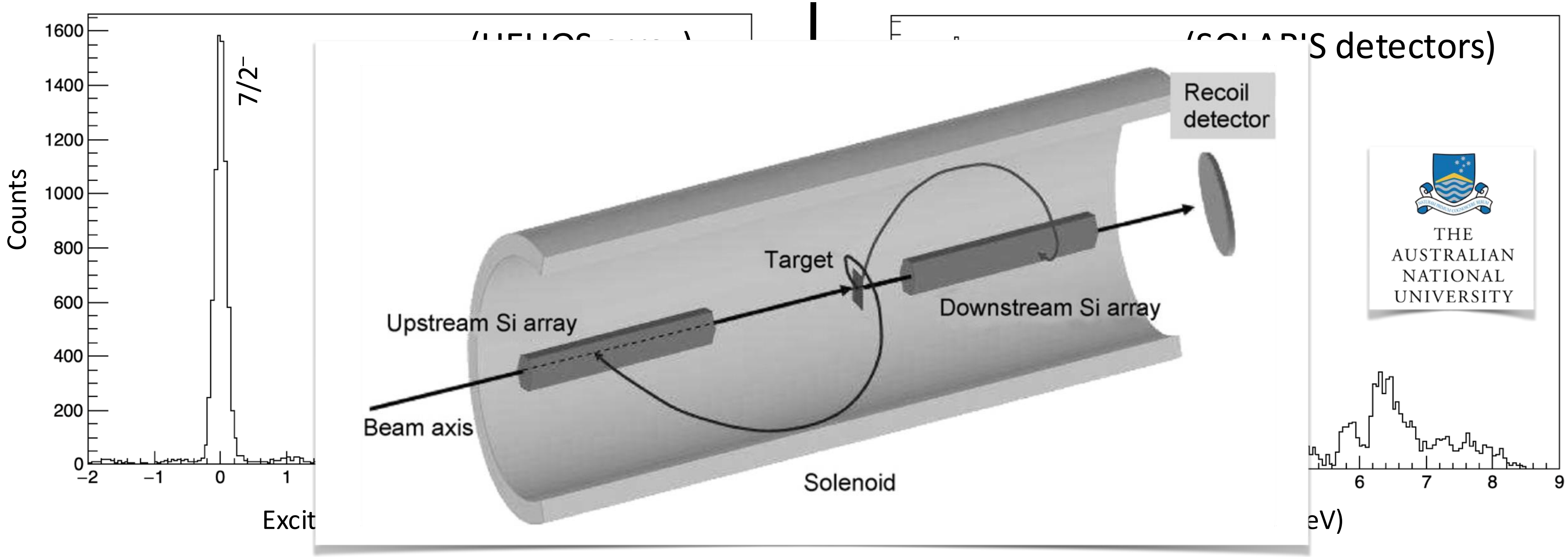
HELIOS: Dual array mode — a long time coming

A cartoon of the dual-array mode was used in the 2007 NIM*, and is the foundation of the SOLARIS proposal; however, the dual-array mode had never been used in practice … until now (proposals accepted at FRIB for SOLARIS)

^{48}Ca(d,t)^{47}Ca, Q = –3.7 MeV

N = 28

^{48}Ca(d,p)^{49}Ca, Q = 2.9 MeV

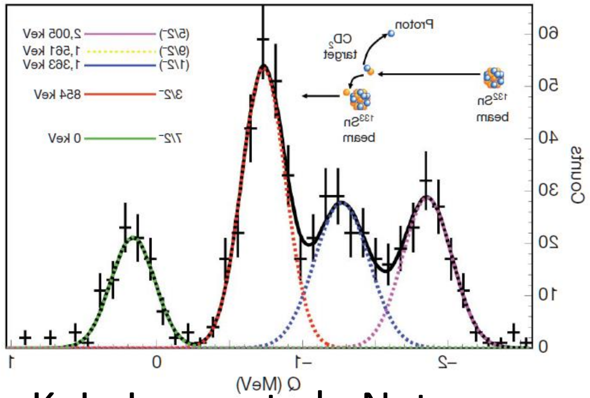


*A. H. Wuosmaa *et al.*, NIMA 580, 1290 (2007)

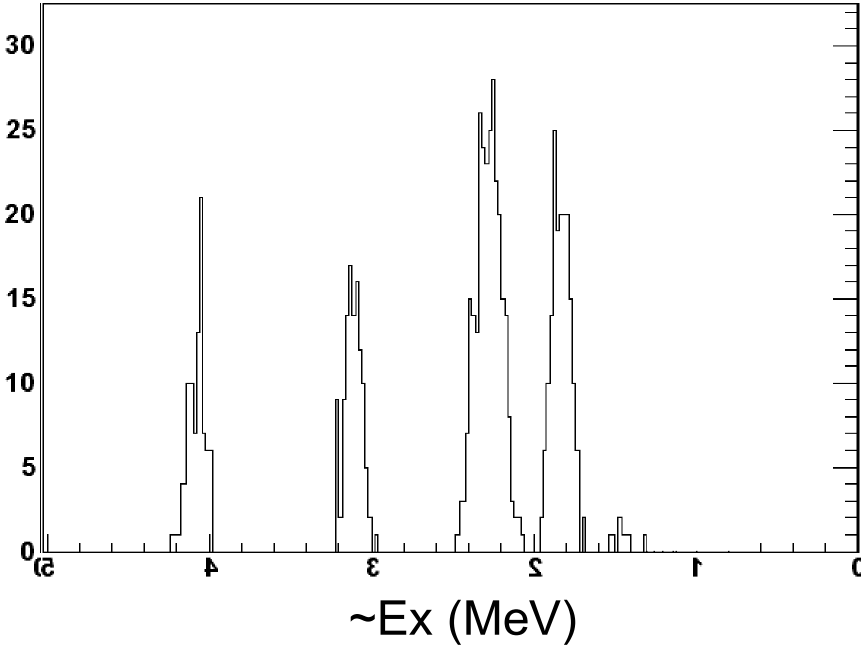
A. Babu, A. J. Mitchell *et al.*, under analysis

Courtesy B. Kay

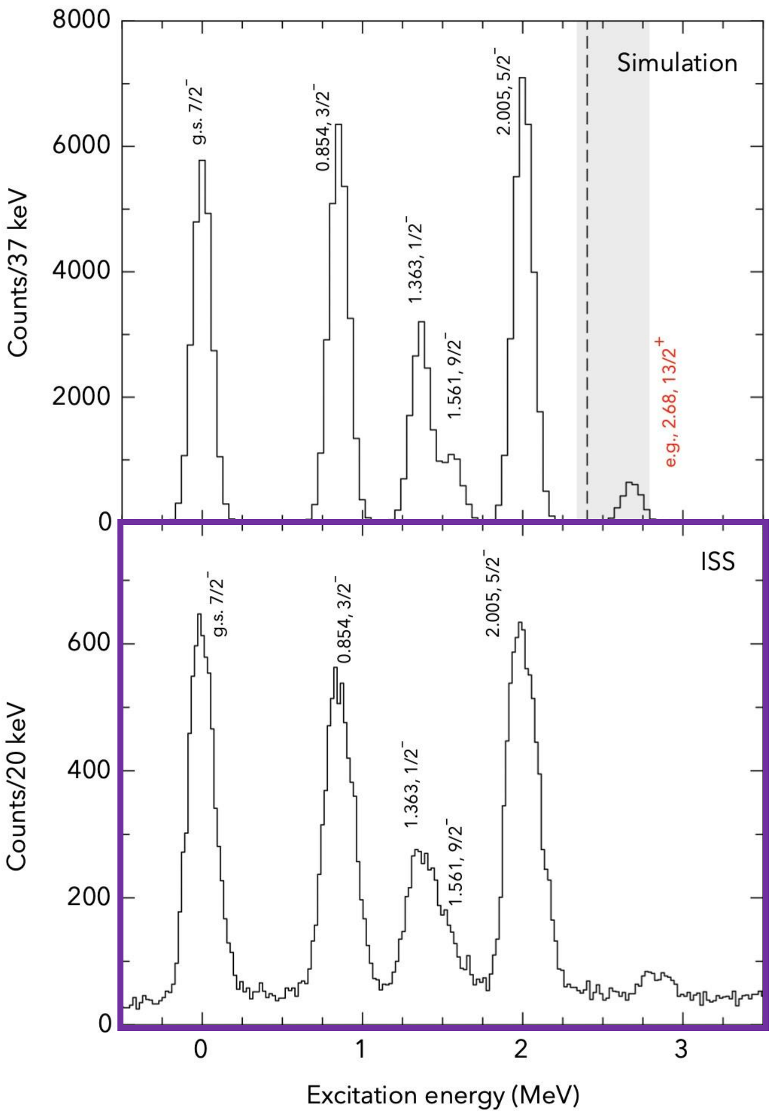
The Poster Child: ^{132}Sn(d,p)^{133}Sn



K. L. Jones et al., Nature, **465**, 454 (2010)



(Fantasy from 2007)



B. Kay et. al.
Online spectrum
from CERN-ISOLDE
ISS… July 2024

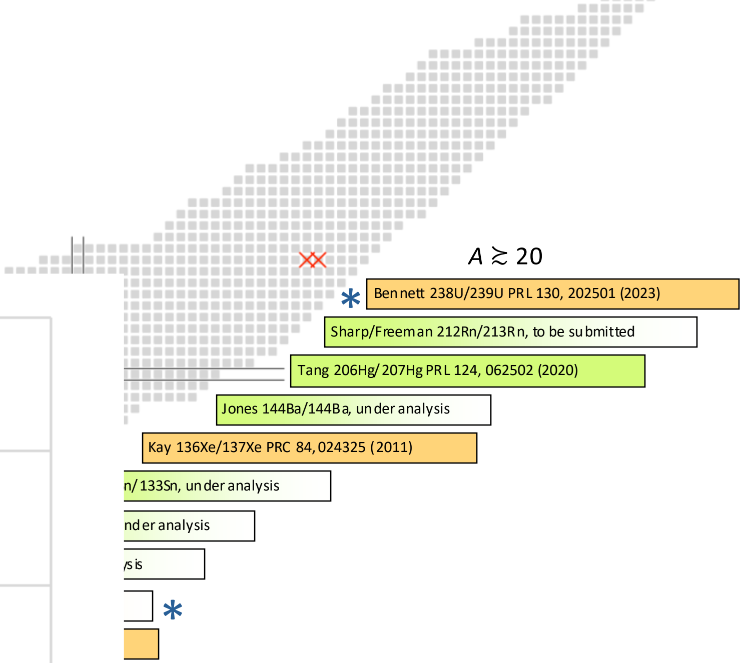
email received at AMS…

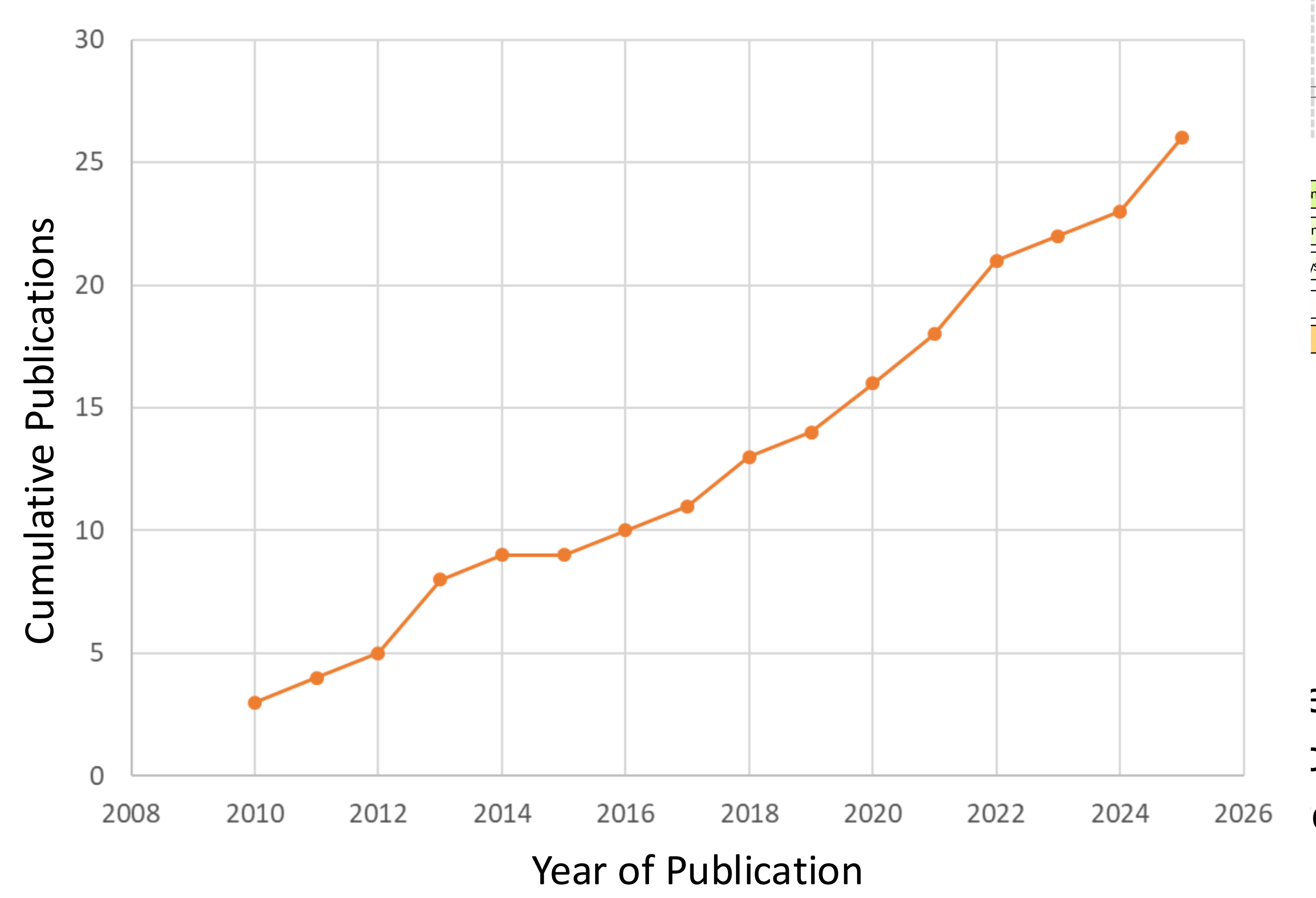
Very preliminary: From 1st day of beam!

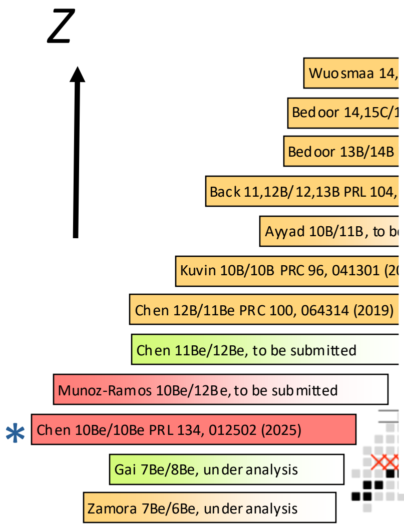
Solenoidal spectrometers, past 15 yrs

Solenoidal spectrometers have proven to be a highly versatile approach to studying nuclear reactions for structure, astrophysics and applications

🟧 HELIOS
🟥 SOLARIS
🟩 ISS
(Not a complete list, but clos







er (stripping and pickup),
omer beams, tritium targets,
on-capture surrogates,
and long-lived beams,
active targets, etc.

Courtesy Ben Kay

Merci beaucoup, et à la prochaine, nos amis!


Welcome to
The Sun Room
Home of HELIOS
SERVICE
OXFORD
CAUTION
CAUTION