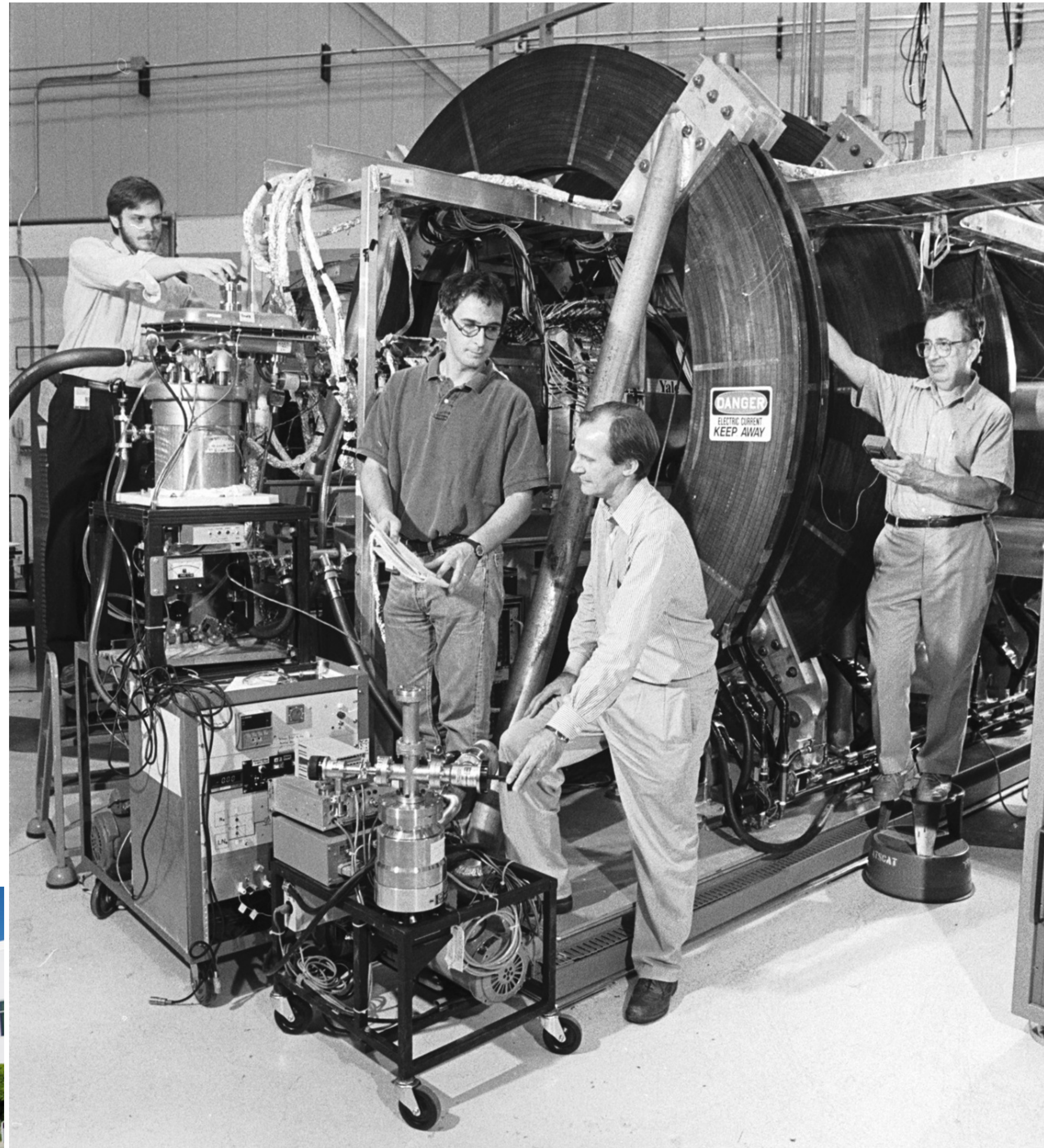
HELIOS

HELIOS at ATLAS

An incomplete retrospective

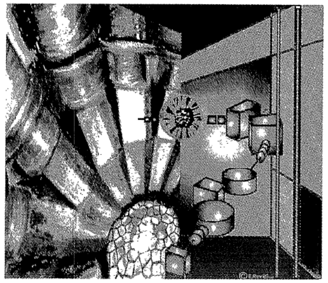
Prehistory: A very different experiment

Circa long, long ago…
(Early 1990s)



Unconventional approaches (JPS, July 1998/March 1999)

Experimental Equipment for an Advanced ISOL Facility



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

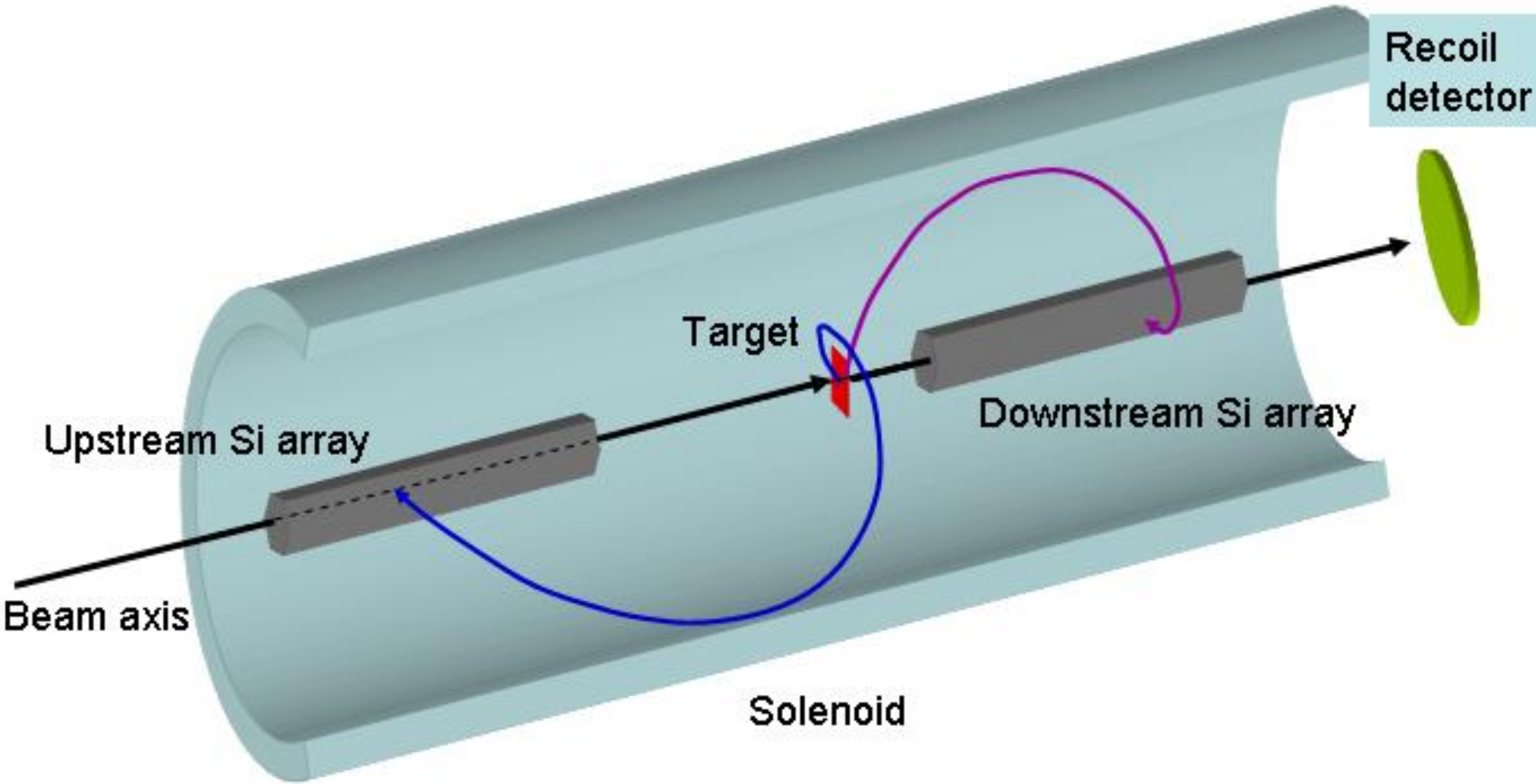
A magnetic solenoid with its axis oriented along the beam direction could serve as a very large-acceptance magnetic spectrograph for low-energy light particles from inverse reactions such as $d(^{132}\mathrm{Sn},p)^{133}\mathrm{Sn}$. In this case the protons of interest are emitted in the backwards hemisphere 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.

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

The early concept



NPA **746**, 267 (2004)

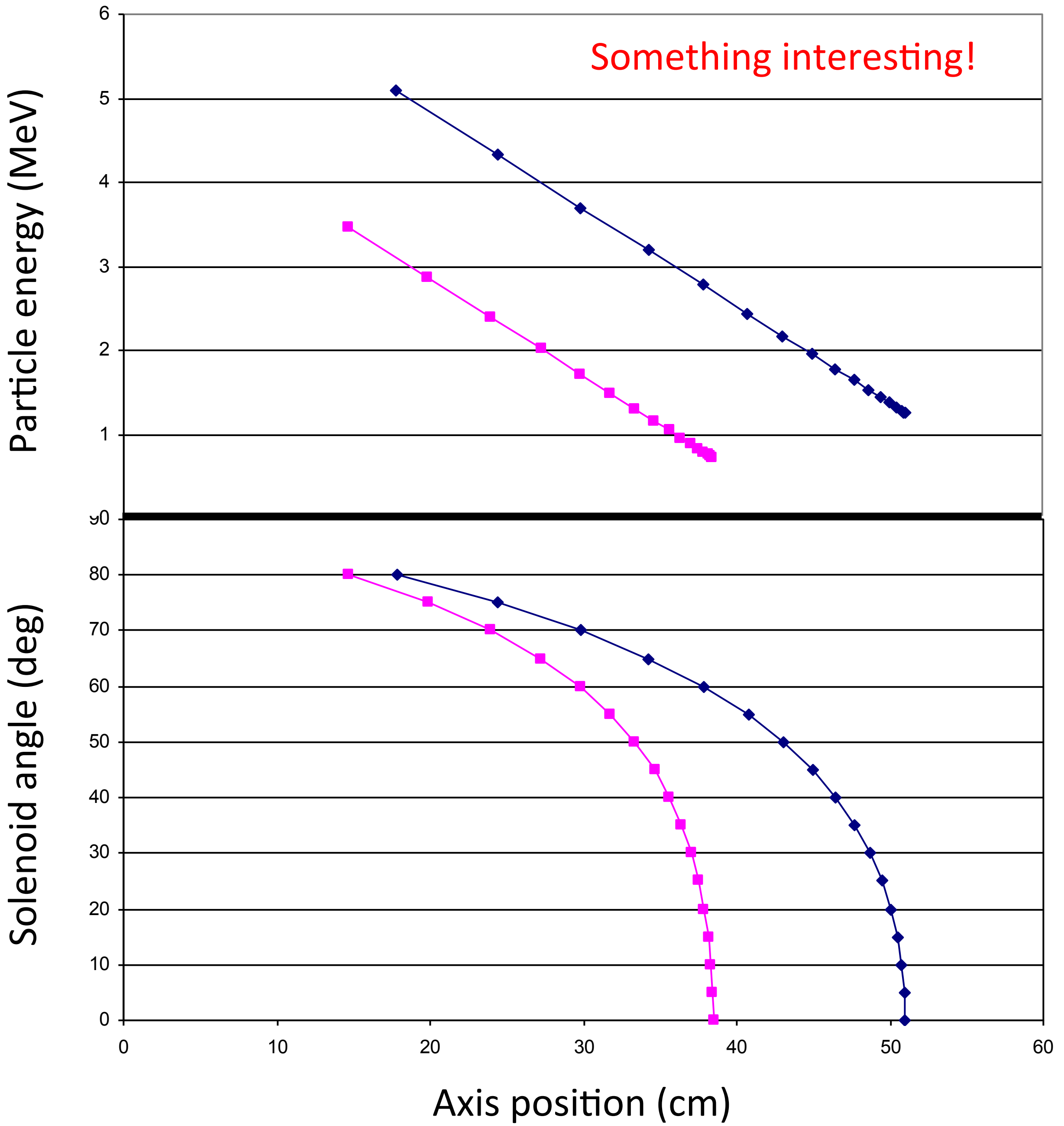
Solenoid transport for d(^{132}Sn,p)

E(^{132}Sn)=7 MeV/u

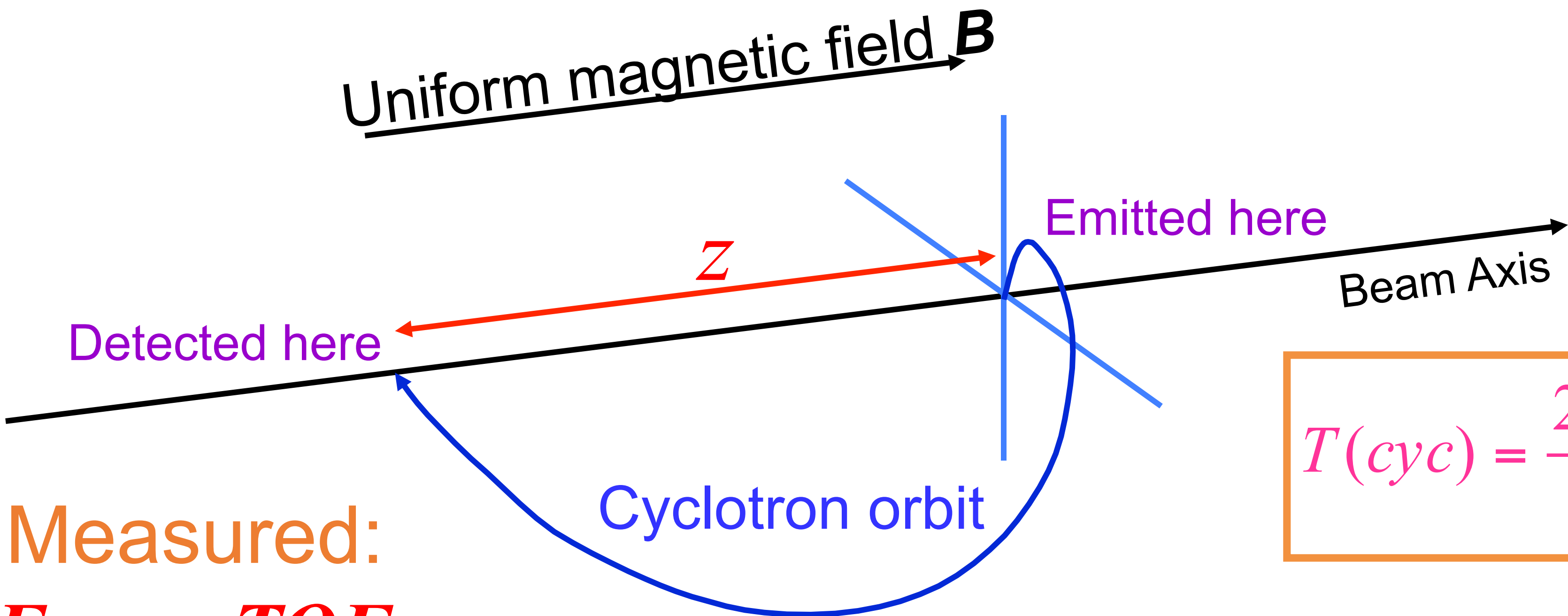
$\mathcal{B}$=2T

E_X=0.0 MeV

E_X=2.0 MeV



Particle transport in a solenoid



$$T(cyc) = \frac{2\pi m}{qB}$$

Measured:

E_{lab}, z, TOF

Deduced:

E_{CM}, θ_{CM}

$$z \propto \cos\theta_{CM}$$

$$E_{lab} = E_{CM} - A + Bz$$

For a given state

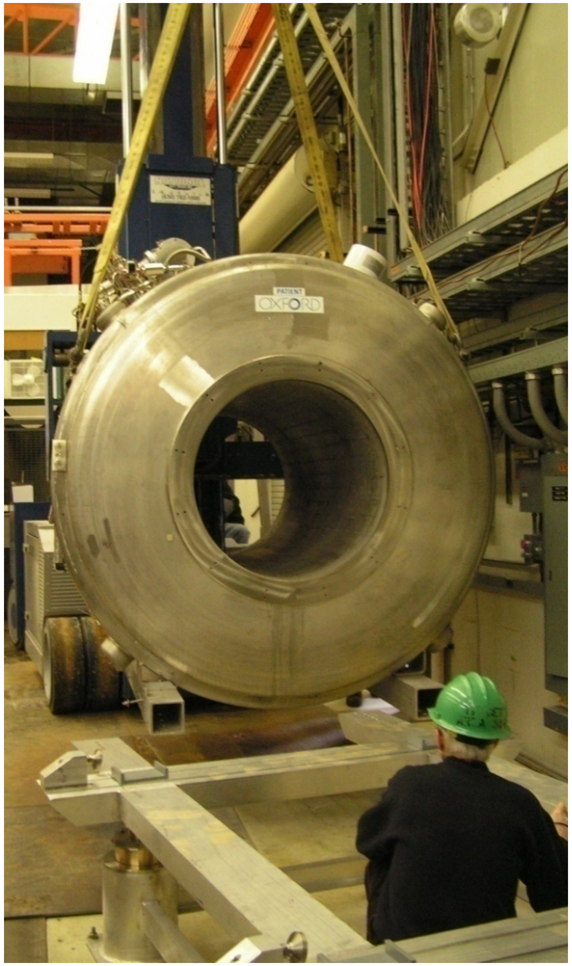
$$\Delta E_{lab} = \Delta E_{CM}$$

For two states at fixed z

Interlude

- ANL Workshop (June 2004)
- Proposal to DOE (October 2004)
- No response from DOE
- ANL LDRD support (2005)
- An acronym is chosen (2006)
- And then…

HELIOS: From Scanner to Spectrometer

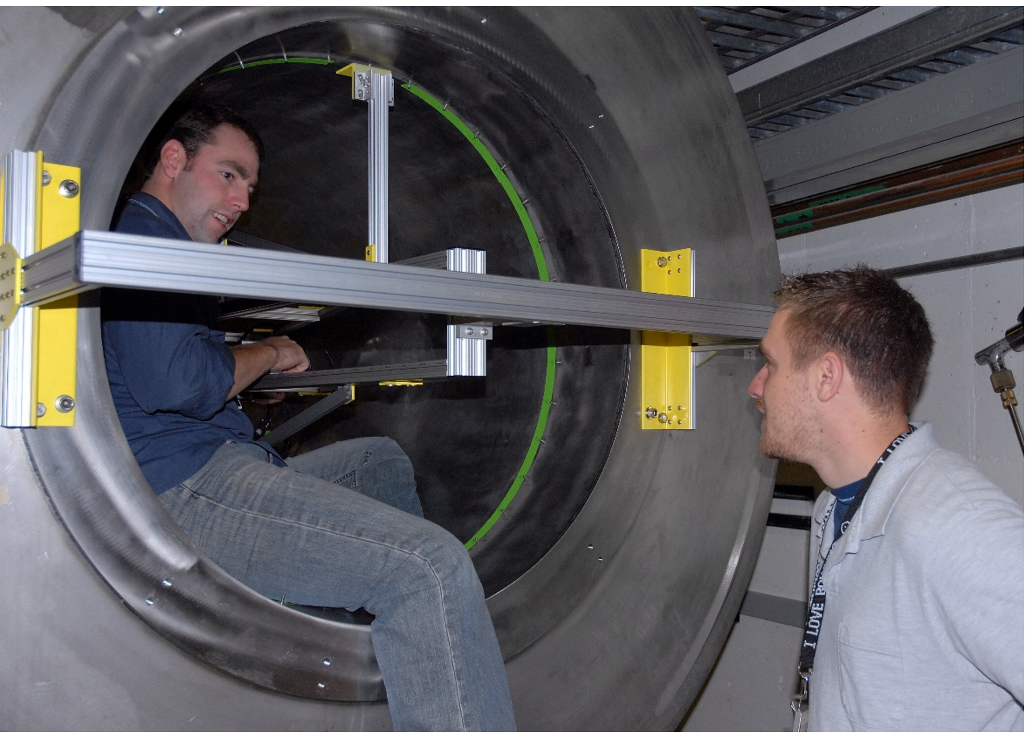


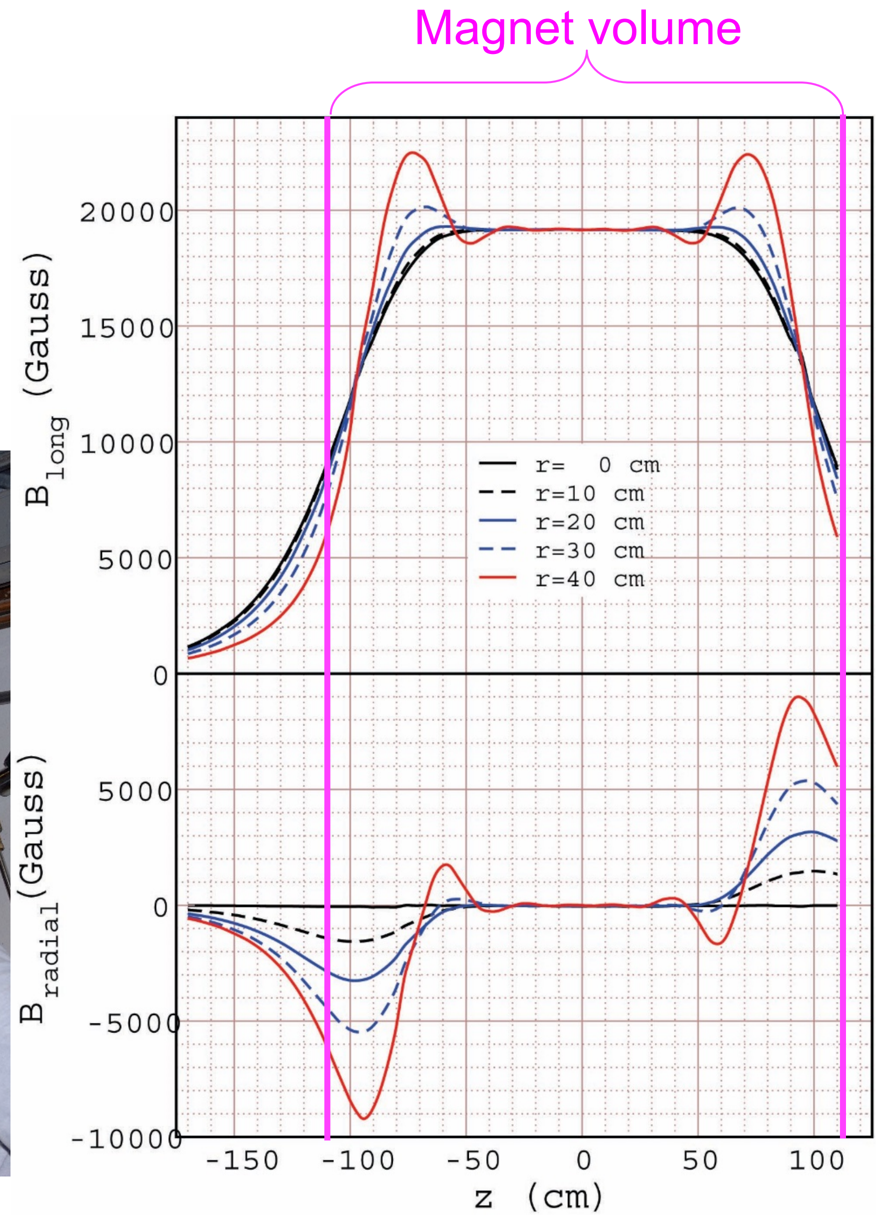
Tübingen, Germany
November 2006

Argonne, USA
December/January 2007

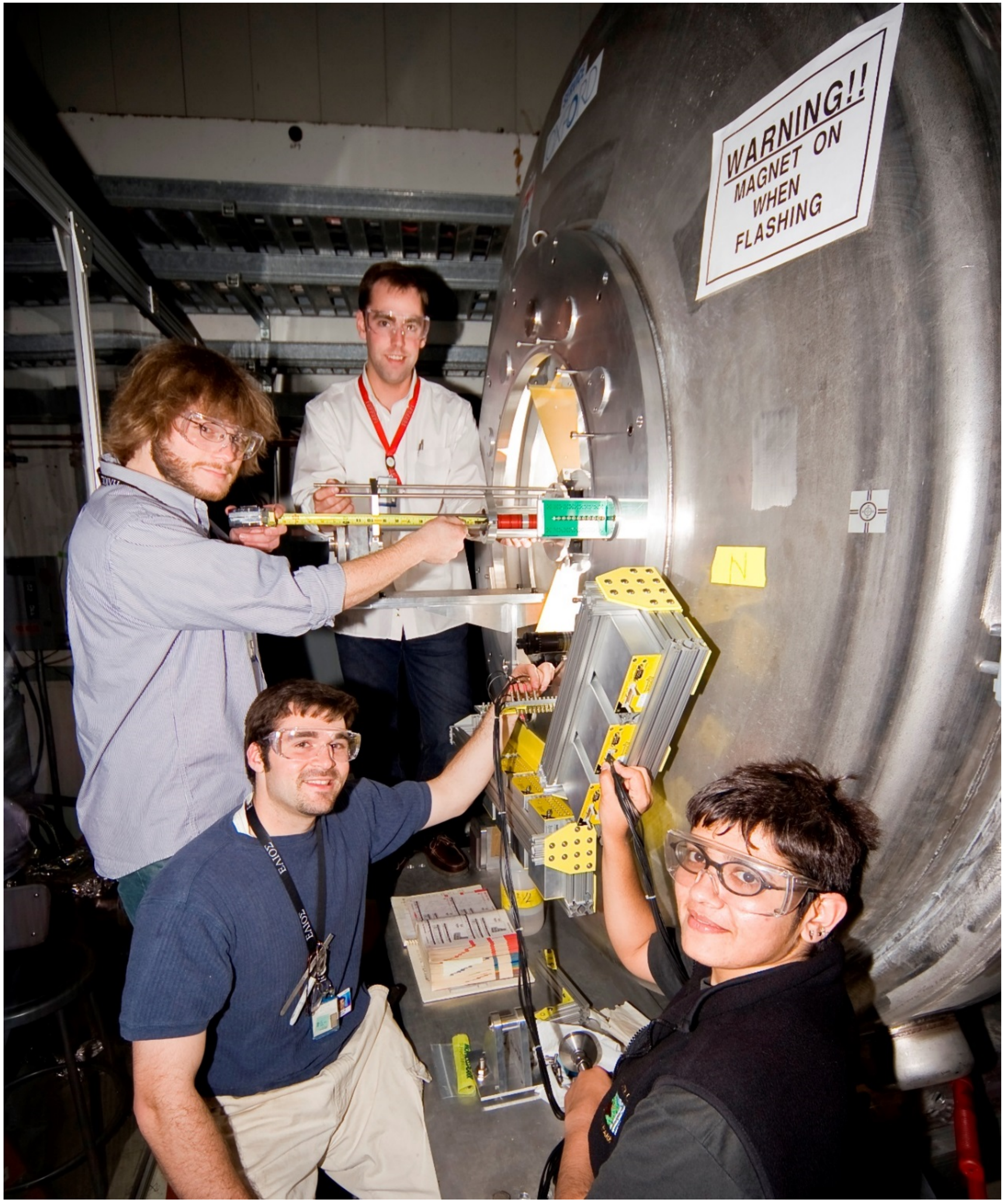
Field mapping

Measurements every 10 degrees, every 5 cm in radius, every 5 cm in axial position – 21,600 points!

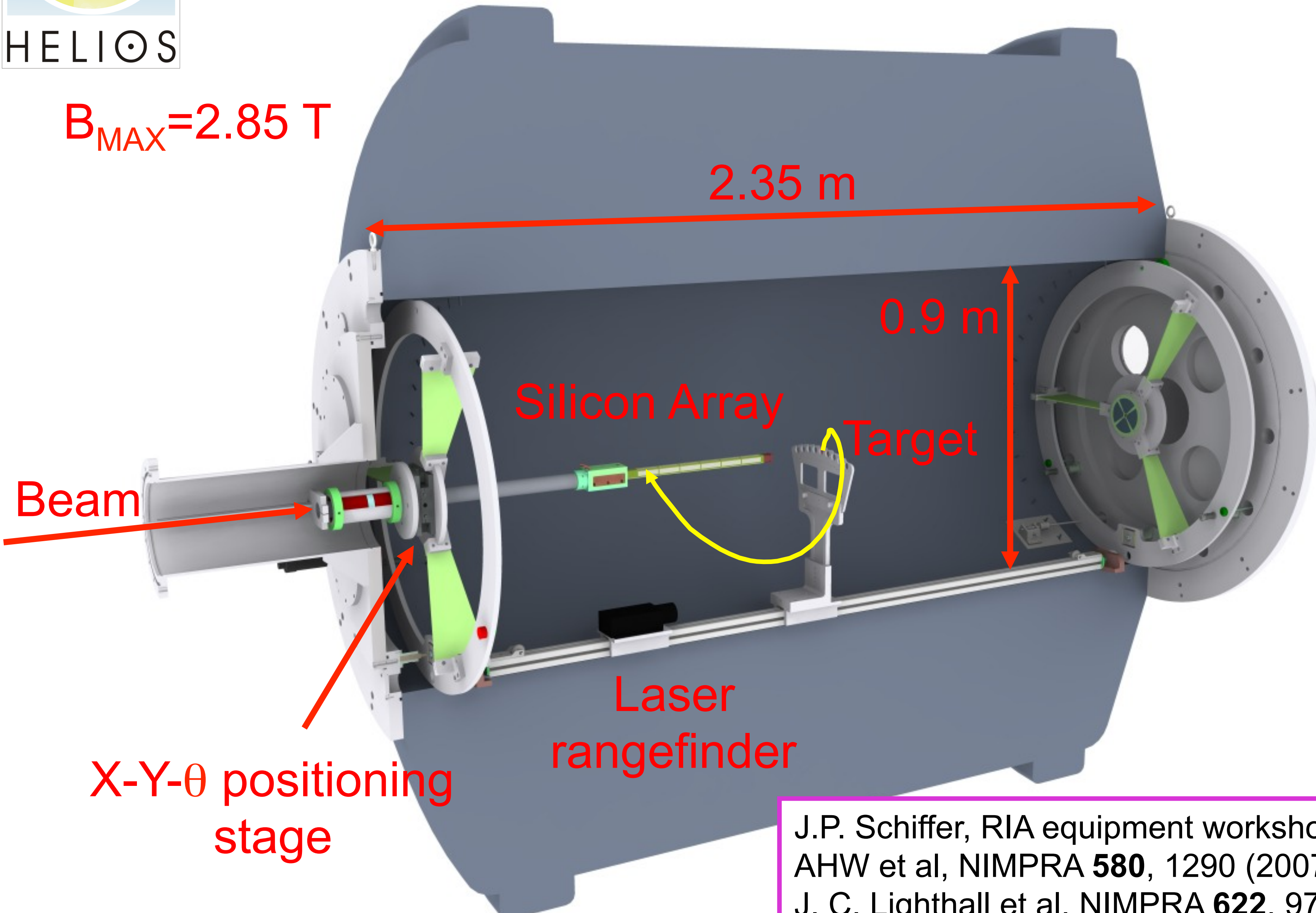




Students hard at work…



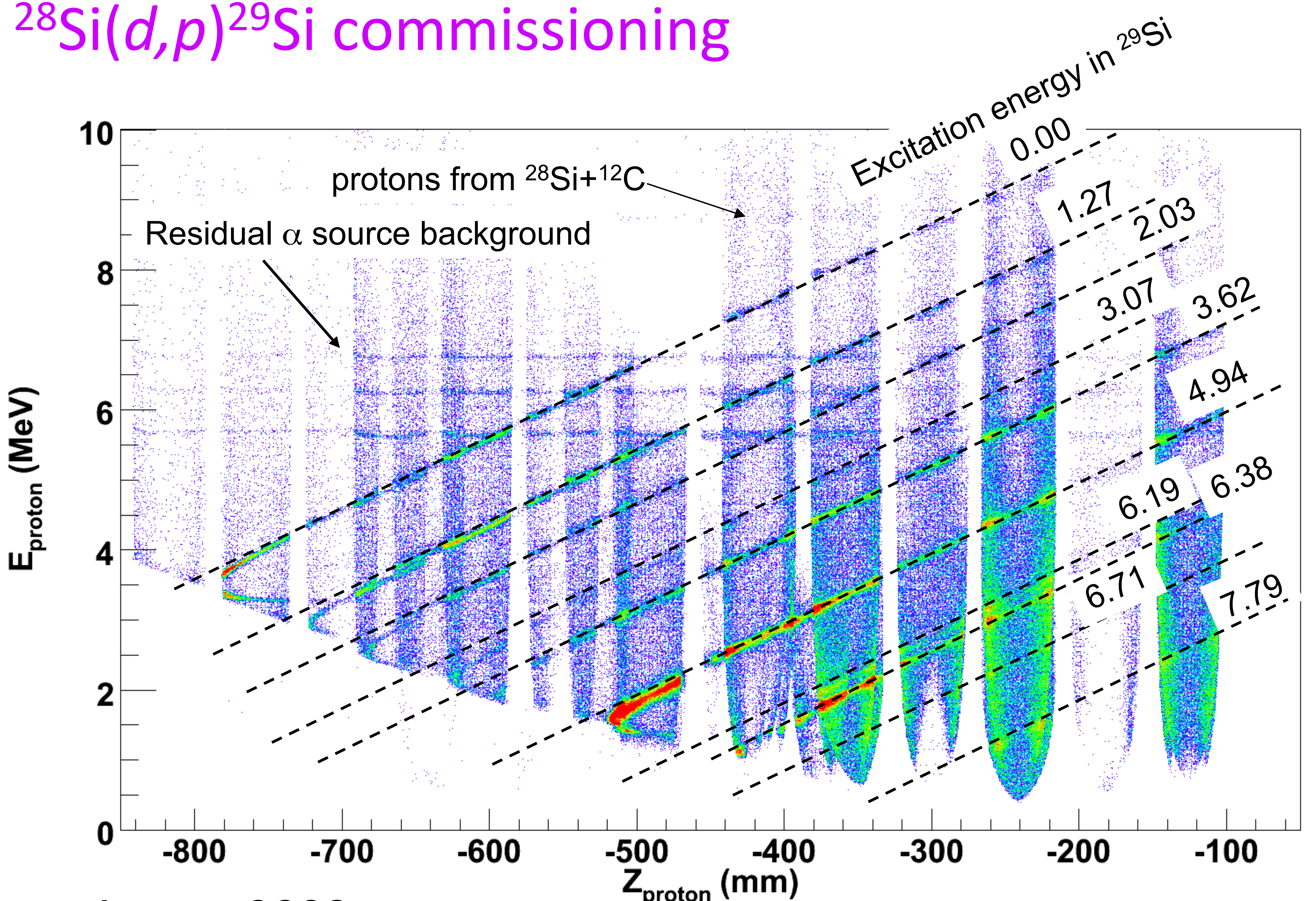
HELIcal Orbit Spectrometer -HELIOS



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

HELIOS at ATLAS/ANL (August 2008)

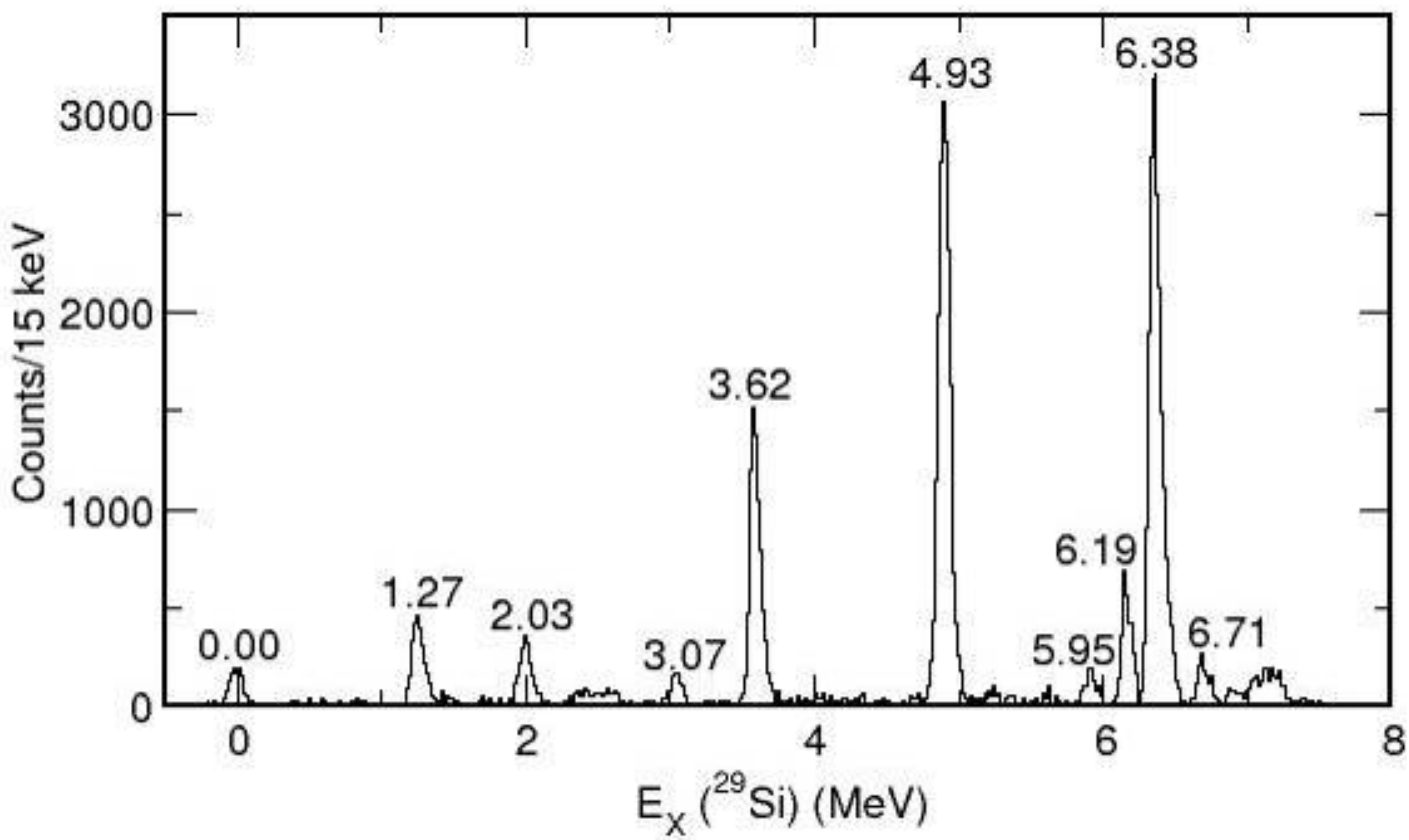
$^{28}Si(d,p)^{29}Si$ commissioning



August 2008

J. C. Lighthall et al, NIMPRA **622**, 97 (2010)

^{28}Si(*d,p*)^{29}Si Excitation-energy spectrum



Typical resolution ~ 120 keV FWHM
Best resolution ~ 80 keV FWHM

J. C. Lighthall et al,
NIMPRA **622**, 97 (2010)

What *was* the physics?

- Experiment #1: $^{132}Sn(d,p)^{133}Sn$
- High-resolution measurements of single-particle states outside doubly-magic ^{132}Sn
- Populate with (*d*,*p*) (small *L* transfer); (α,^{3}He) or (α,*t*) (large *L* transfer)
- We still want to do this!!
- Other transfer studies to nuclei where the density of states makes it challenging to work in inverse kinematics.

What *is* the physics?

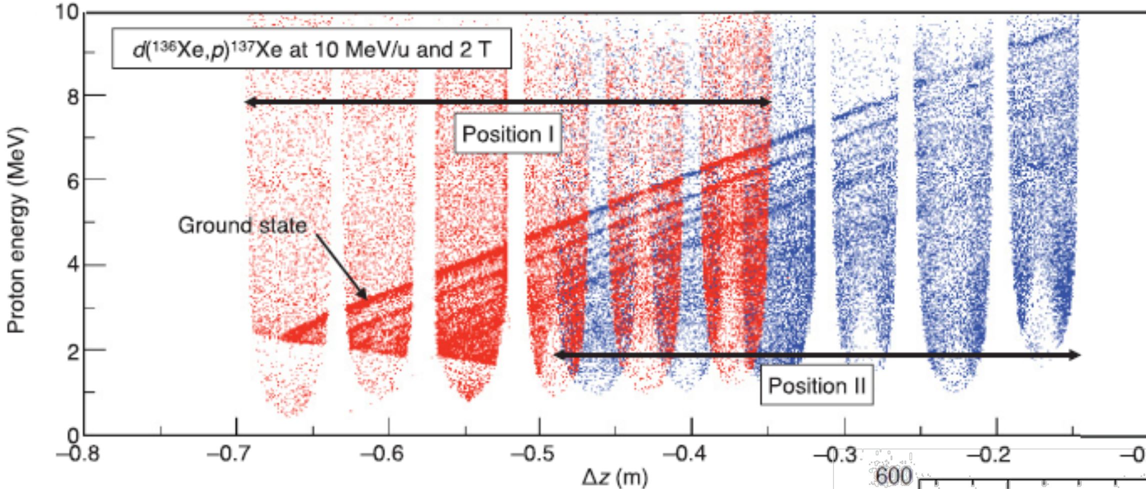
- Have done some stable-beam (*d,p*) near N=50 (^{86}Kr) and Z=50, N=82 (^{136}Xe)
- Much more done with light RIBs produced "In-Flight"
- Single-particle states in *p-sd* shell nuclei – evolution of shell-model orbitals, configuration mixing, residual interactions, etc.
- Multi-nucleon correlations in light nuclei
- Astrophysics
- Ab-Initio calculations

Reactions studied to date (a partial list)

- ^{10}B(p,p')^{10}B* — (*ab-initio* calculations for ^{10}B)
- (*d*,*p*) — (many beams A=12-136, single-particle structure)
- ^{14,15}C(*d*,^{3}He)^{13,14}B — (nucl. structure ^{14,15}C,^{13,14}B)
- ^{27}Al(*d*,*t*)^{26}Al — (test/demonstration)
- ^{14,15}C(*d*,α)^{12,13}B — ("stretched" states in ^{12,13}B)
- (α,*p*) — (gas target – various beams, nuclear astrophysics)
- (^{3}He,*d*) — (gas target – various beams, nuclear astrophysics)
- (^{6}Li,*d*) — (various, cluster structure and nuclear astrophysics)
- ^{15}C,^{12}B(*t*,*p*)^{17}C,^{14}B — (coming soon with ^{3}H target)

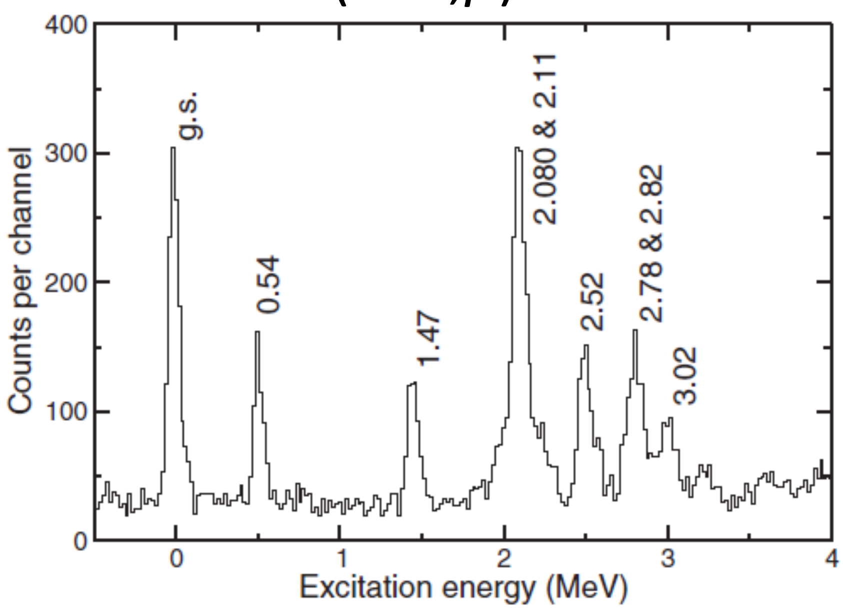
(13 journal publications to date)

Heavy stable beams: ^{86}Kr and ^{136}Xe



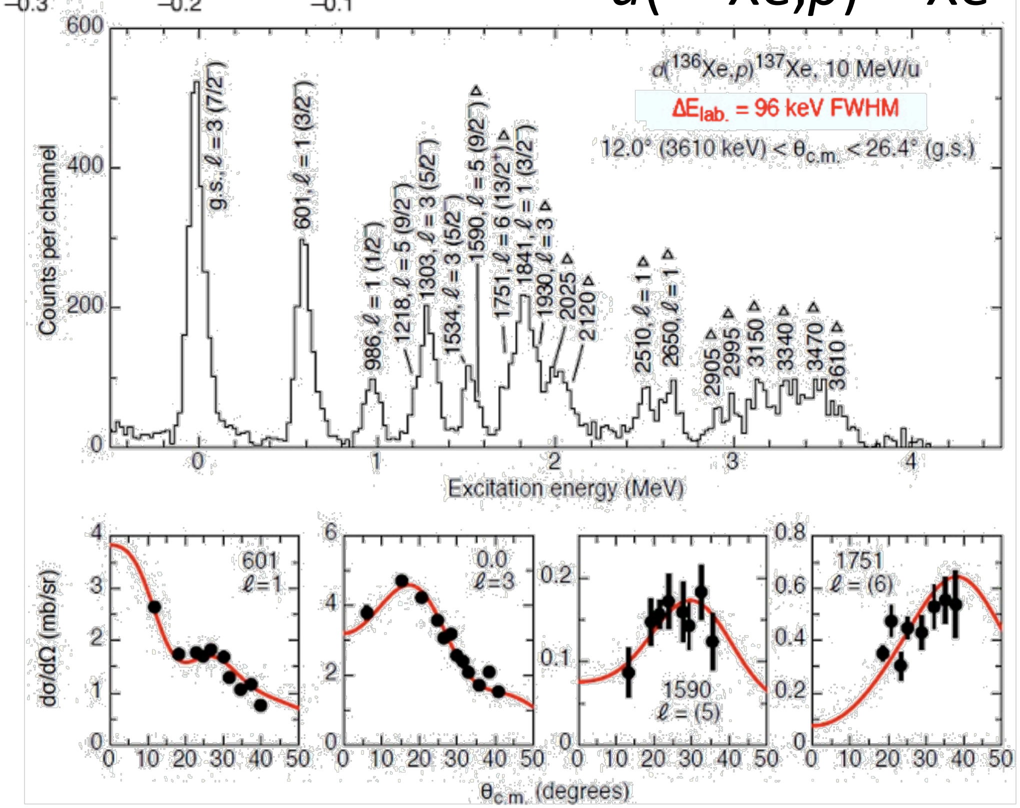
Particle energy versus position for $d(^{136}\text{Xe},p)^{137}\text{Xe}$

$d(^{86}\text{Kr},p)^{87}\text{Kr}$



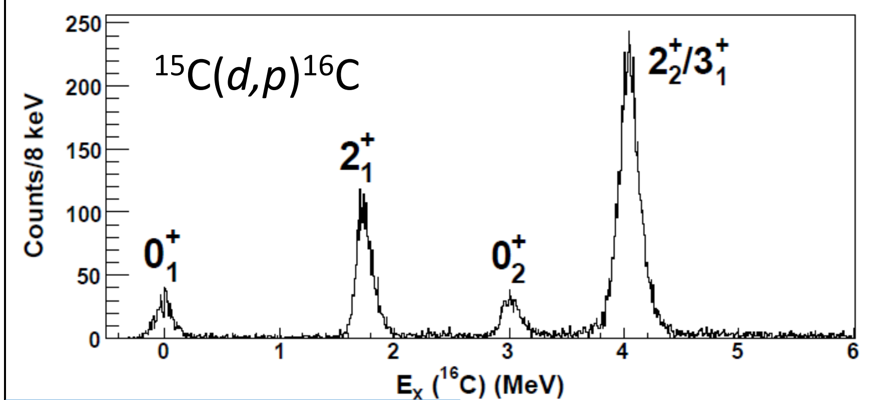
D. K. Sharp et al, PRC **87**, 014312 (2013)

$d(^{136}\text{Xe},p)^{137}\text{Xe}$

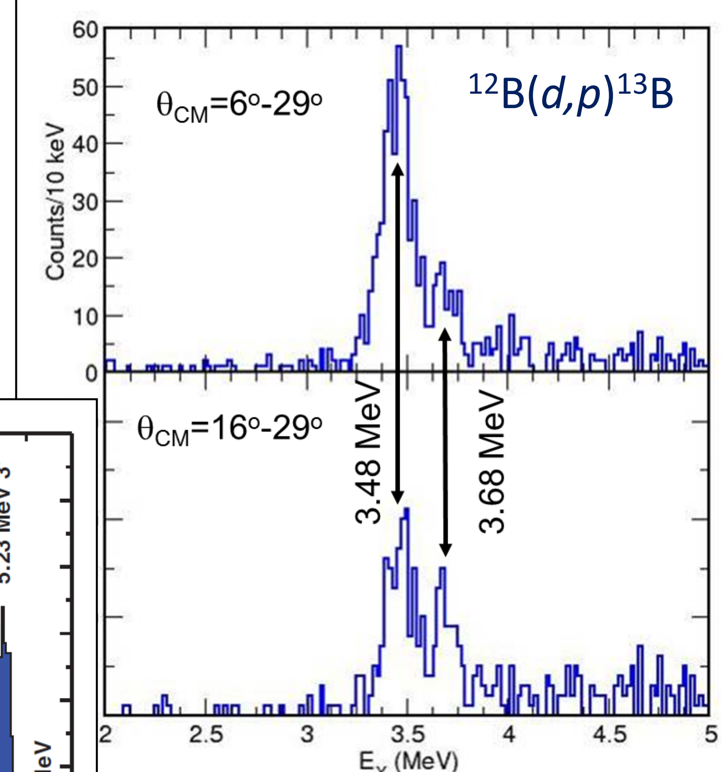


B. P. Kay et al, PRC **84**, 024325 (2011)

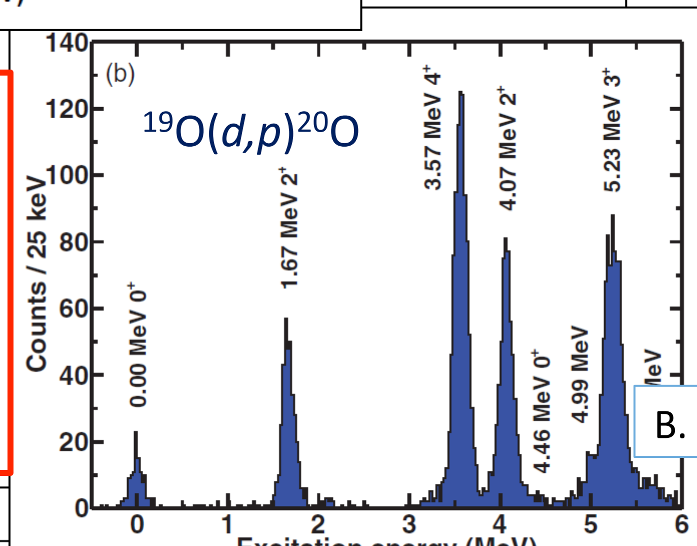
(d,p) with in-flight ATLAS RIBs



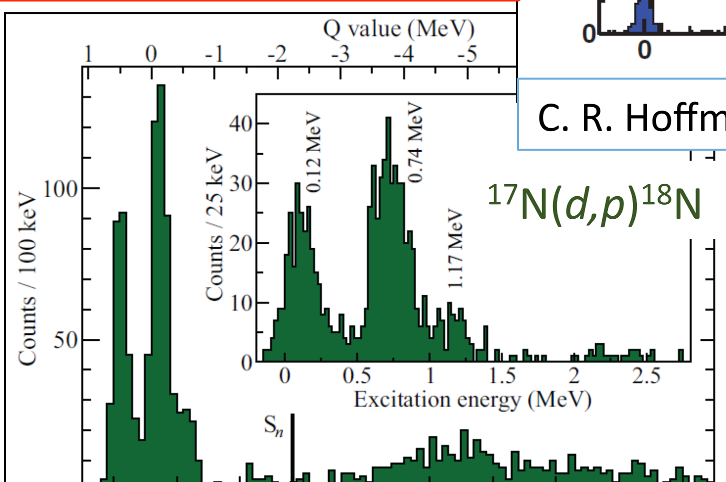
PRL **105**, 132501 (2010)



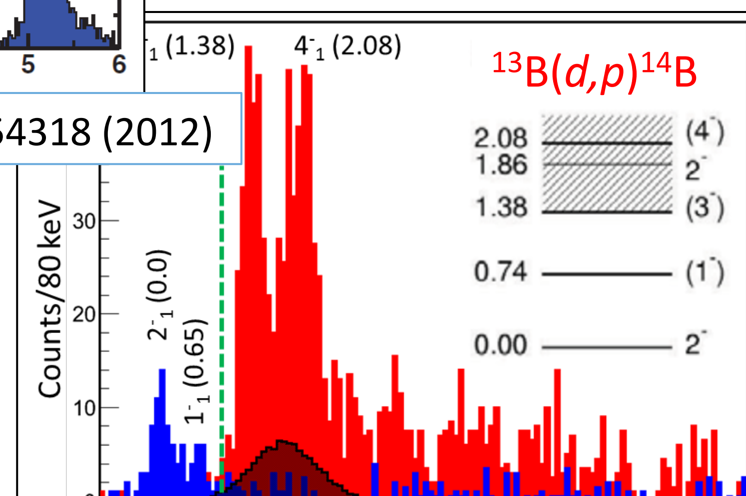
B. B. Back et al., PRL **104**, 132501 (2010)



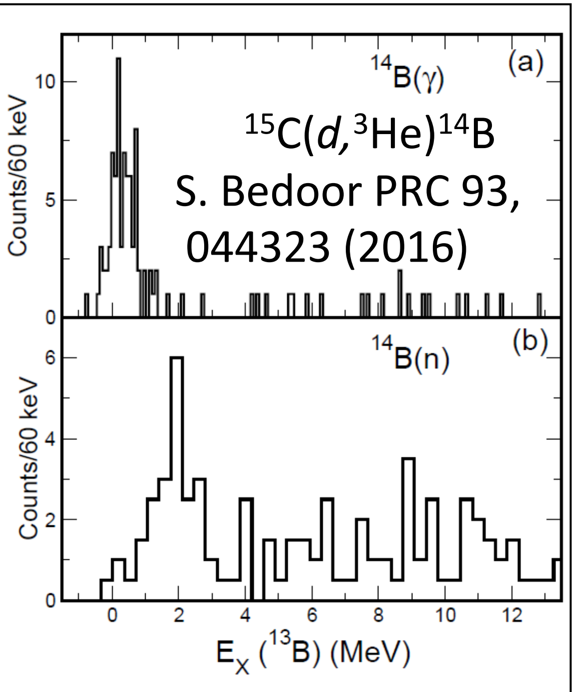
C. R. Hoffman et al., PRC **85**, 054318 (2012)

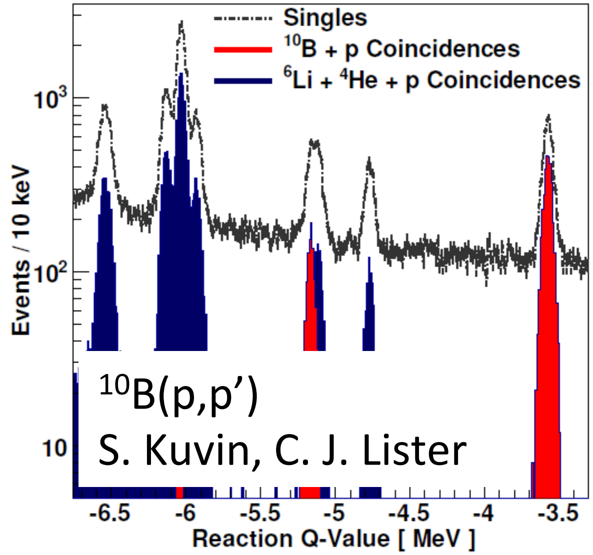


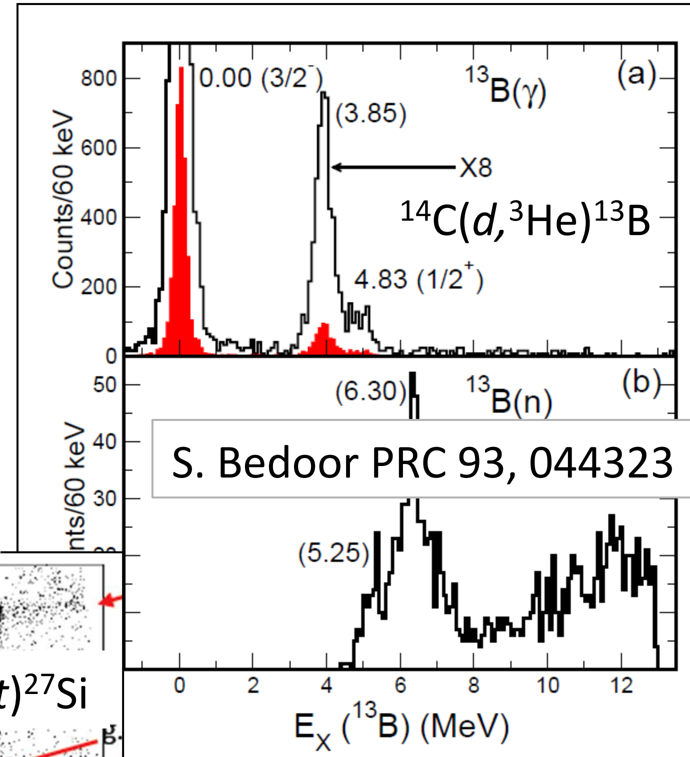
C. R. Hoffman et al., PRC **88**, 044317 (2013)

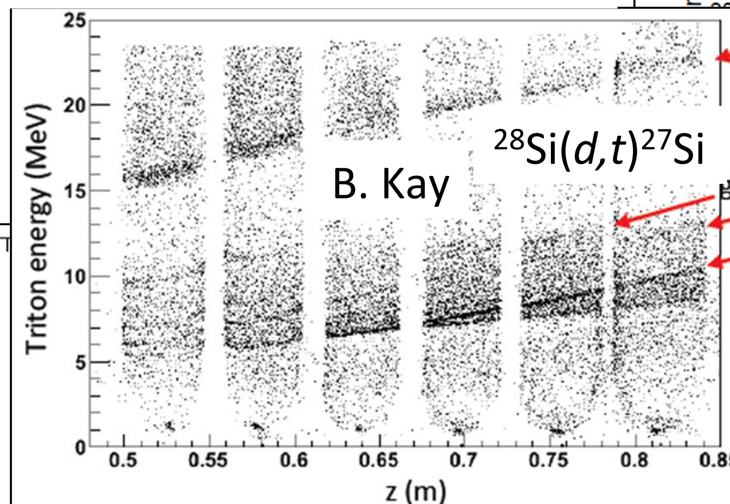


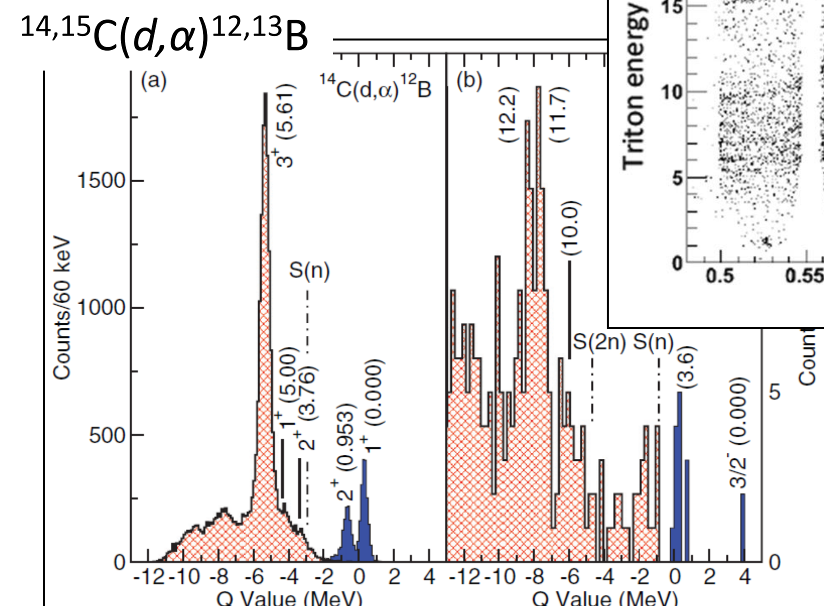
S. Bedoor et al., PRC **88**, 011304 (2013)

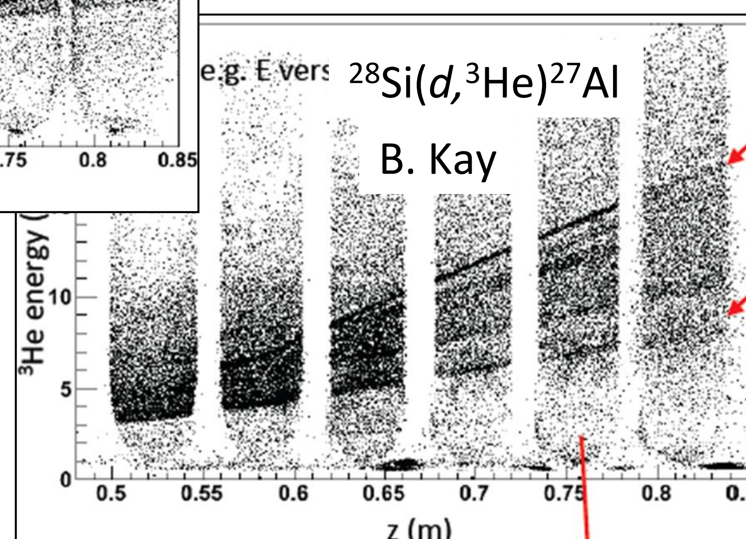








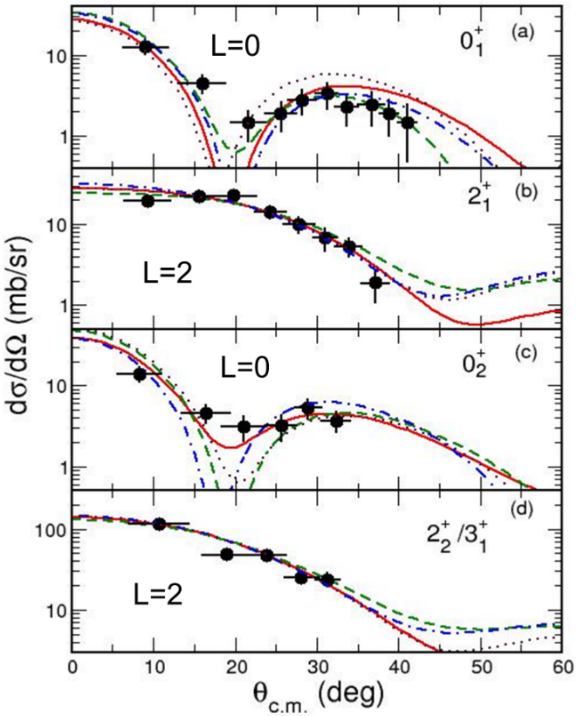




PRC **90**, 061301 (2014)

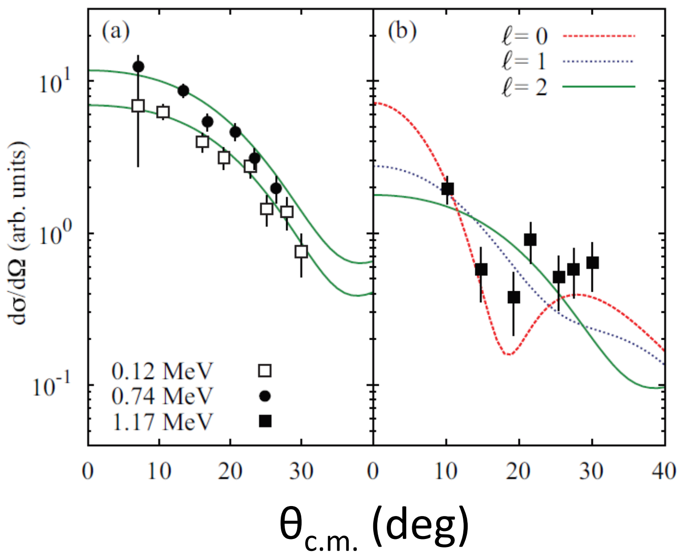
Angular distributions with light RIBs

$^{15}C(d,p)^{16}C$
10^6 pps



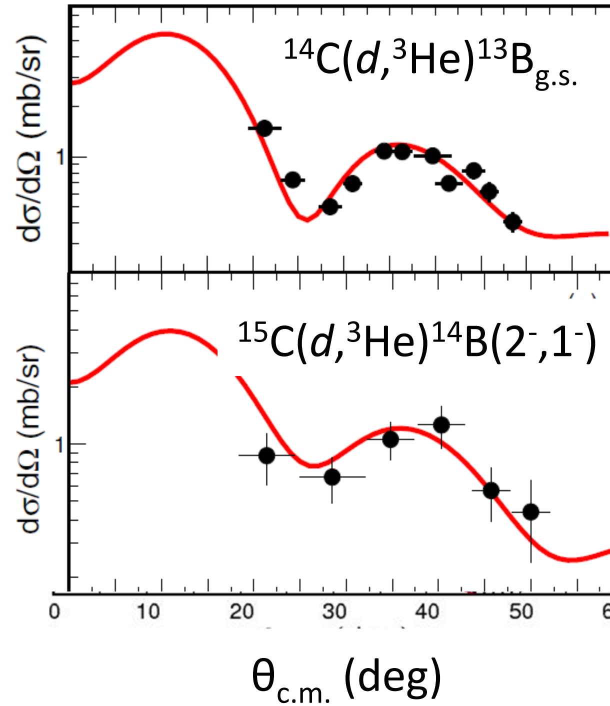
PRL **105**, 132501 (2010)

$^{17}N(d,p)^{18}N$
$2x10^4$ pps



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

$^{14,\,15}C(d,{}^3He)^{13,14}B$
$5x10^5$ pps ^{15}C



S. Bedoor et al, PRC **93**,
044323 (2016)

Additions and upgrades

See Later Talks!

Conclusions

- HELIOS has proved to be a very useful device and serves an active and growing physics program.
- The approach is versatile and the applications have grown far beyond the original motivating physics.
- You will hear about recent developments in other physics and instrumentation.
- Prospects for new physics at FRIB with reaccelerated beams are promising – that is what we are here to discuss!

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And …

The HELIOS Collaboration

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