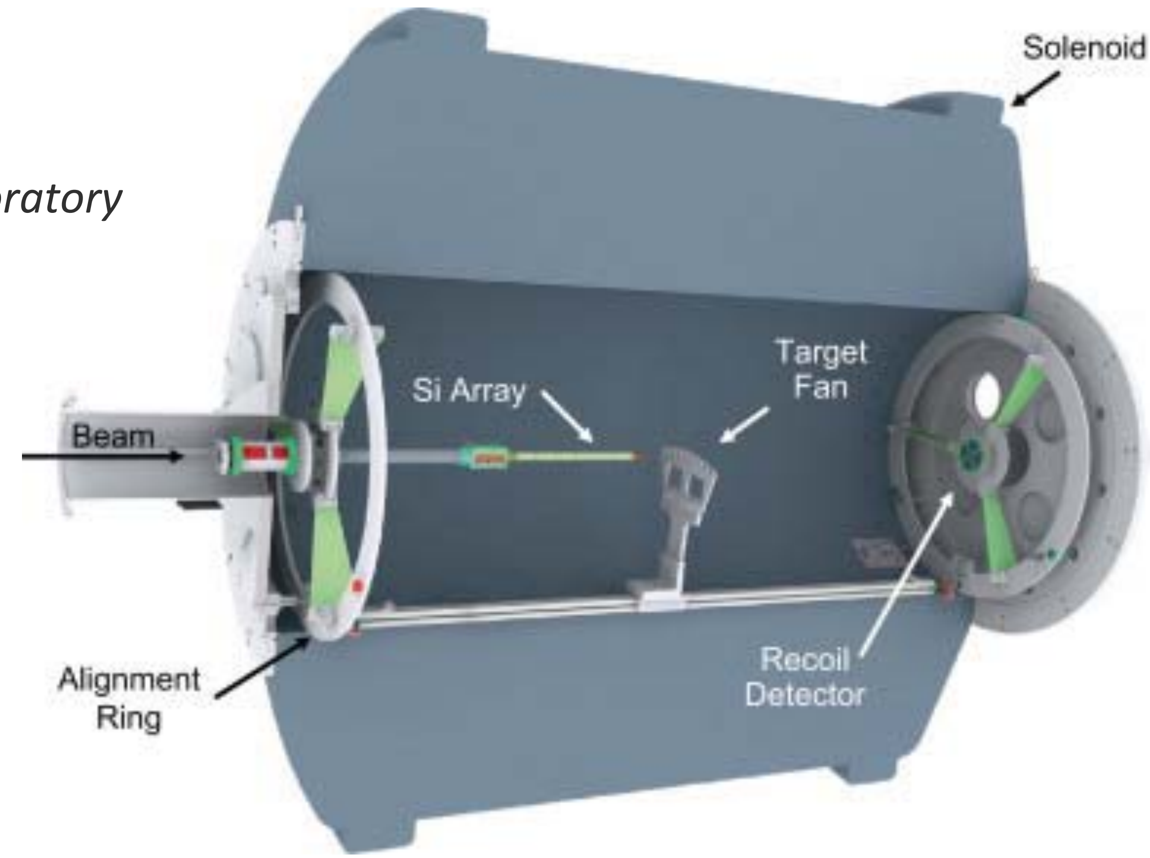
HELIOS

B.B.Back

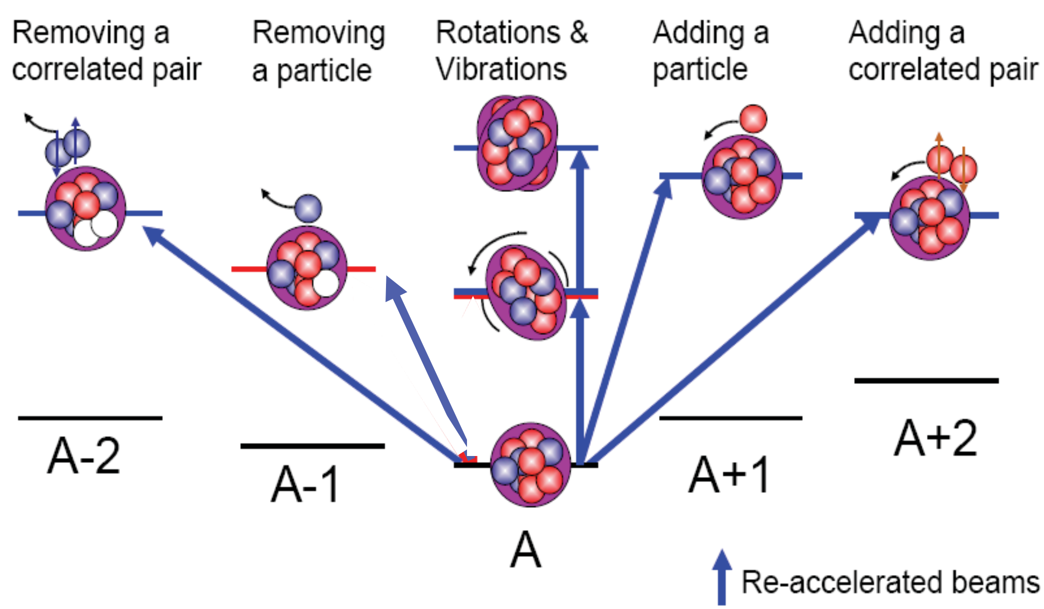
Argonne National Laboratory



Nuclear structure with re-accelerated beams

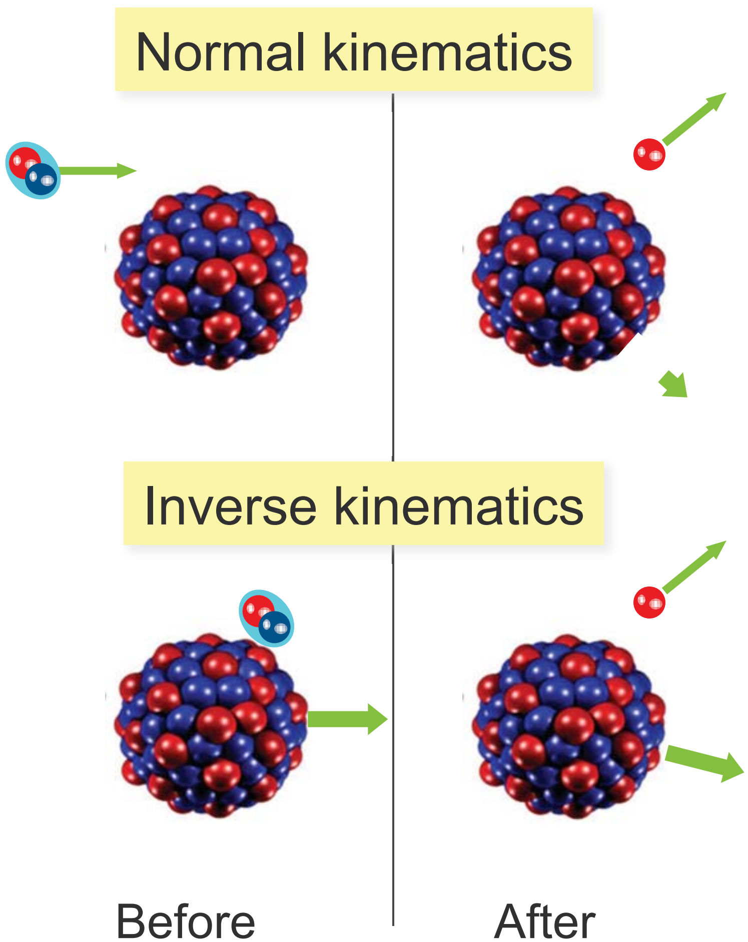
Search for

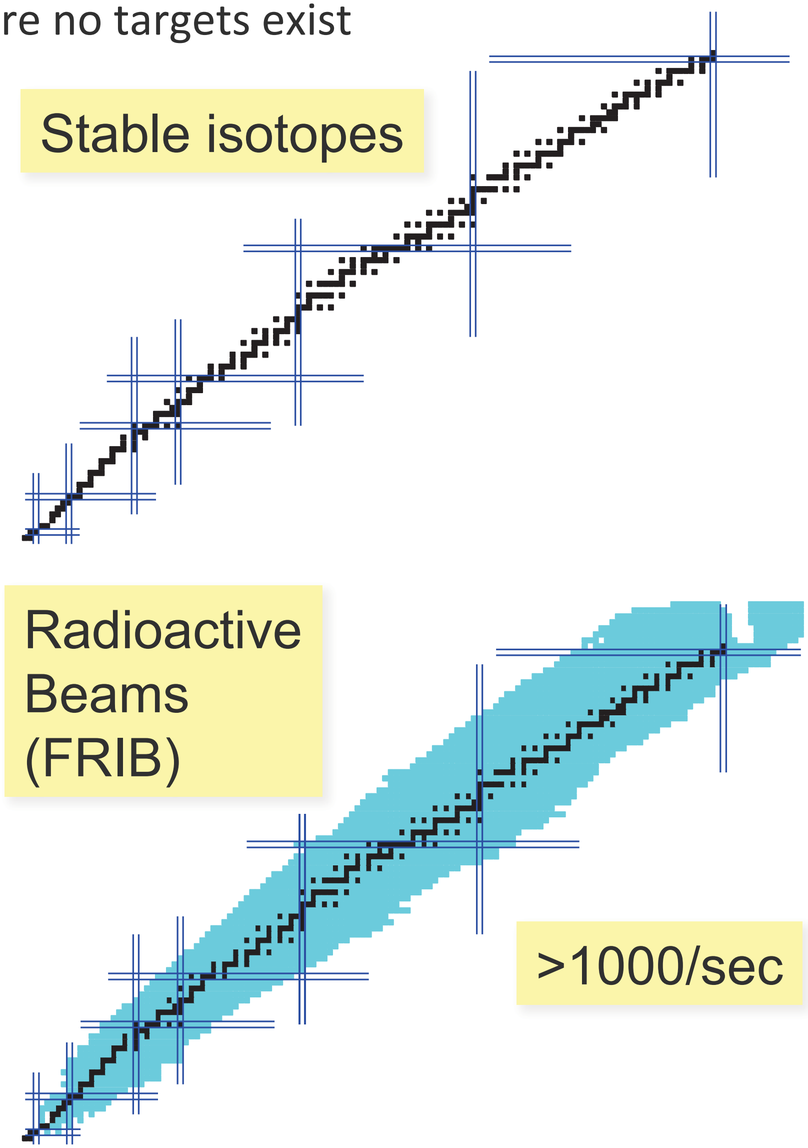
- changes in shell structure with single-nucleon transfer reactions
- pair correlations with transfer of nucleon pairs
- new modes of collectivity with β decay, moments, single or multiple Coulomb excitation
- ….



Inverse kinematics – wide applications

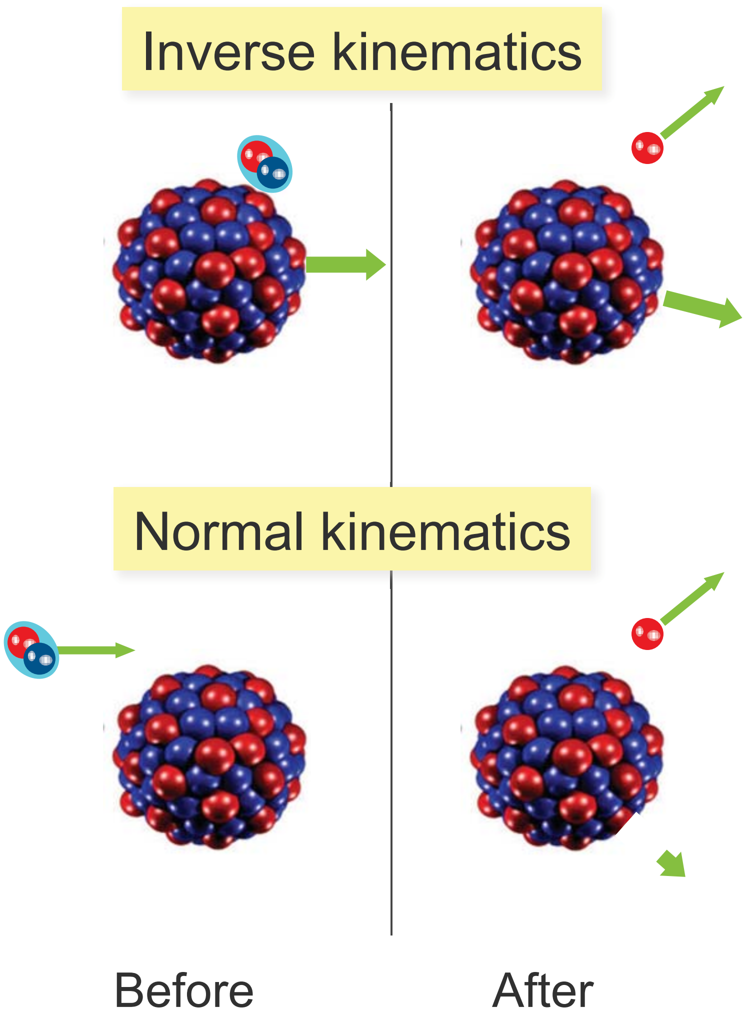
- Precision studies of nuclei in regions where no targets exist

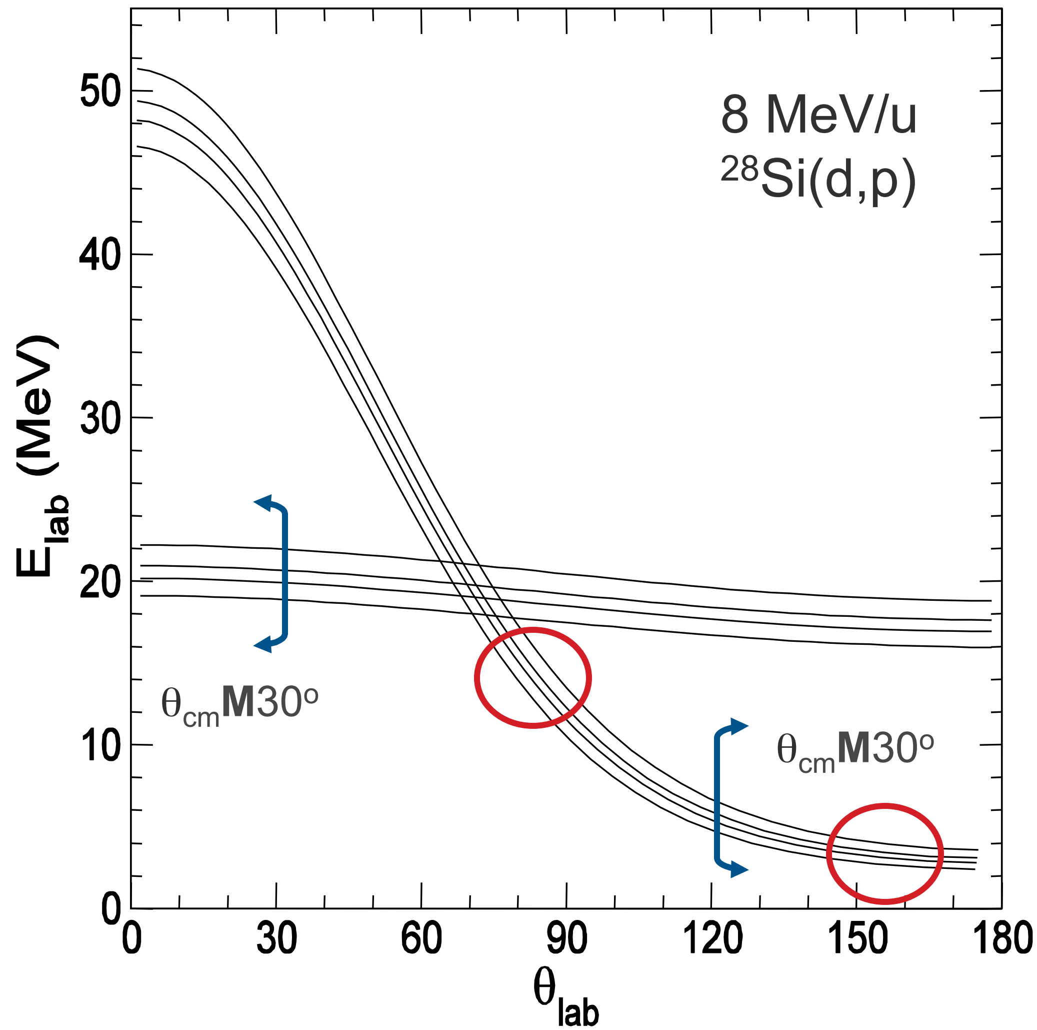




Inverse kinematics problems

1. Low energy – ΔE-E identification
2. Kinematic compression
3. Strong angle dependence





The solution

HELIOS

Logo by Peter Müller

Principle of operation

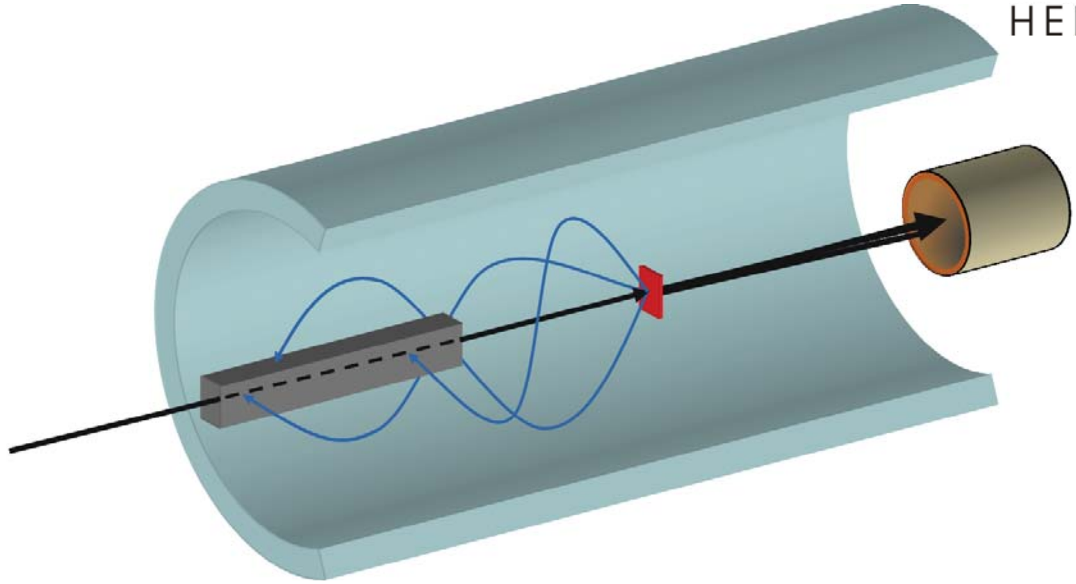
HELIOS

Measured quantities

Flight time:	$T_{flight}=T_{cyc}$
Position:	z
Energy:	E_{lab}

Derived quantities

Part. ID:	m/q
Energy:	E_{cm}
Angle:	θ_{cm}



B=2T

Particle	T_{cyc} (ns)
p	34.2
$^{3}He^{2+}$	51.4
d, α	68.5
t	102.7

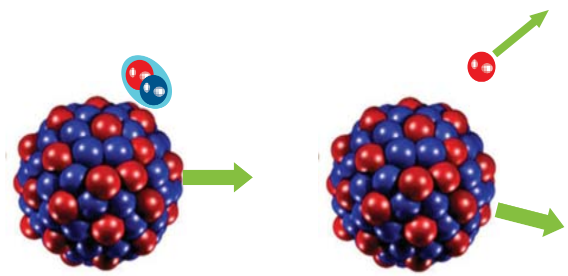
$$\frac{m}{q} = \frac{eB}{2\pi} \times T_{flight}$$

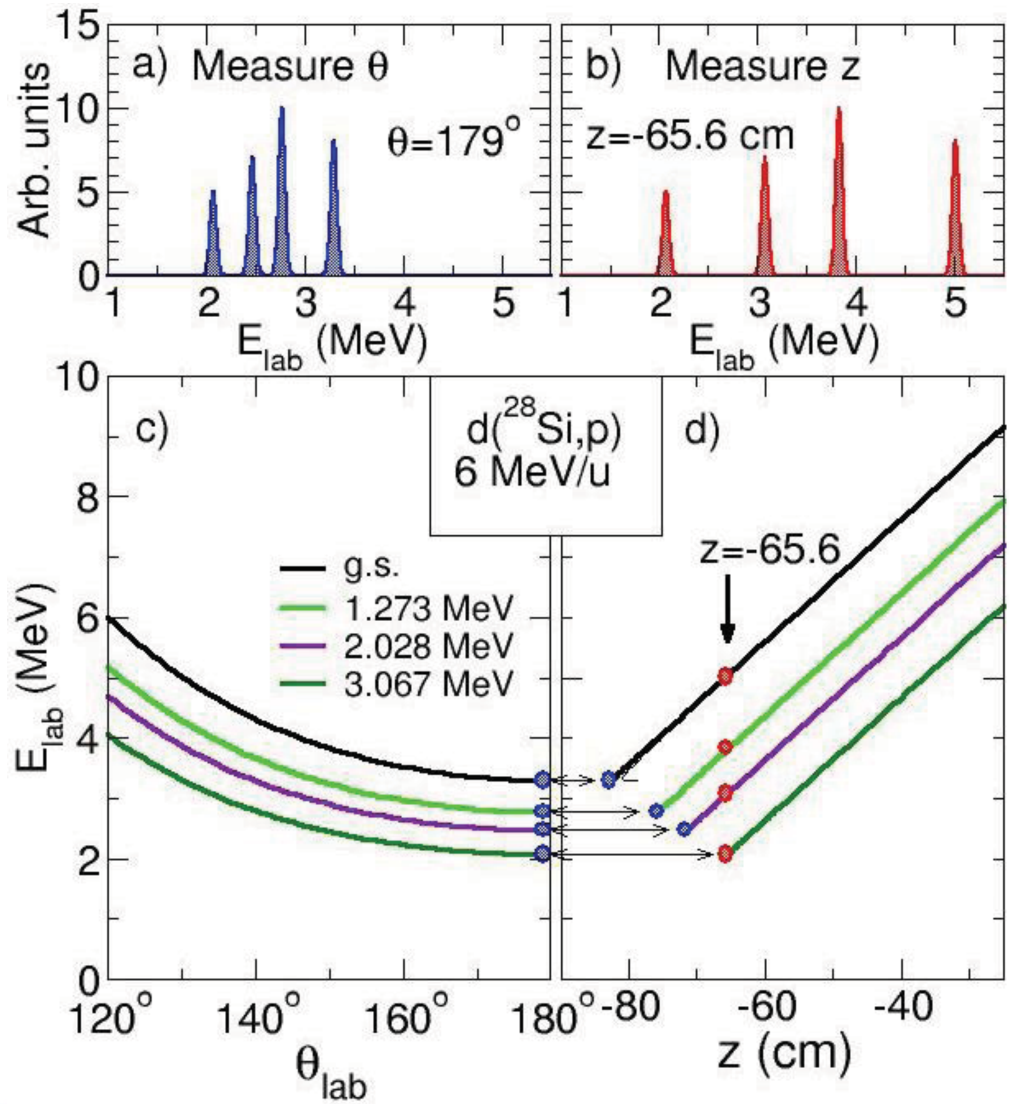
$$E_{cm} = E_{lab} + \tfrac{1}{2} m V_{cm}^2 - \frac{V_{cm} qeB}{2\pi} z$$

$$\theta_{cm} = \arccos\left(\frac{1}{2\pi} \frac{qeBz - 2\pi m V_{cm}}{\sqrt{2mE_{lab} + m^2 V_{cm}^2 - m V_{cm} qeBz/\pi}} \right)$$

Measure Θ or z (in magnetic field)?

Inverse kinematics





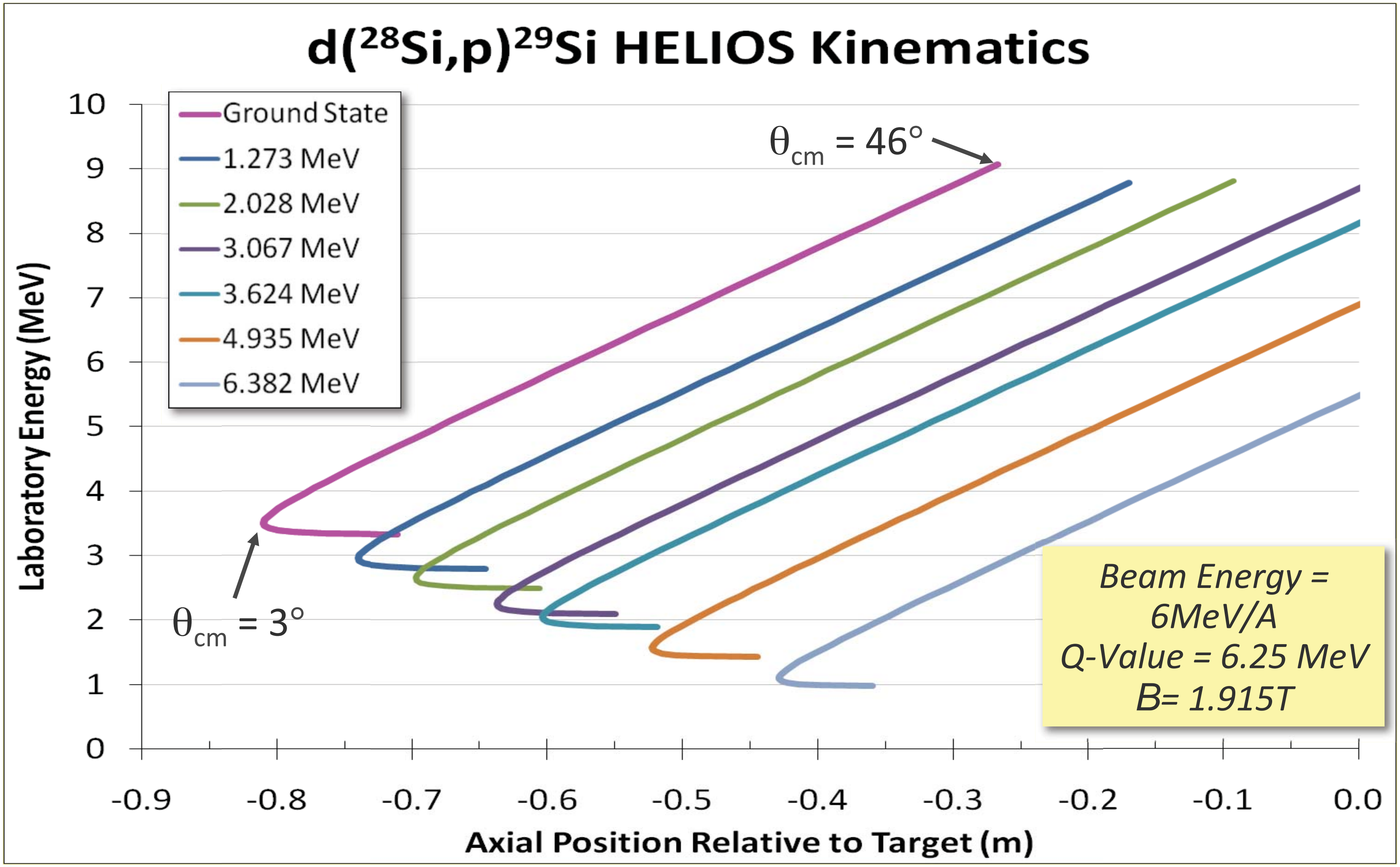
Q-value resolution:

Improvement: 2.4

Other contributions:

1. Detector resolution
2. Target thickness
3. Beam quality

Kinematics for the reaction d(^{28}Si,p)^{29}Si



The Argonne implementation of HELIOS

The Siemens Magnet

MRI Scanner in Tübingen, Monday, Nov 6, 2006

Ernst Rehm

Two days later

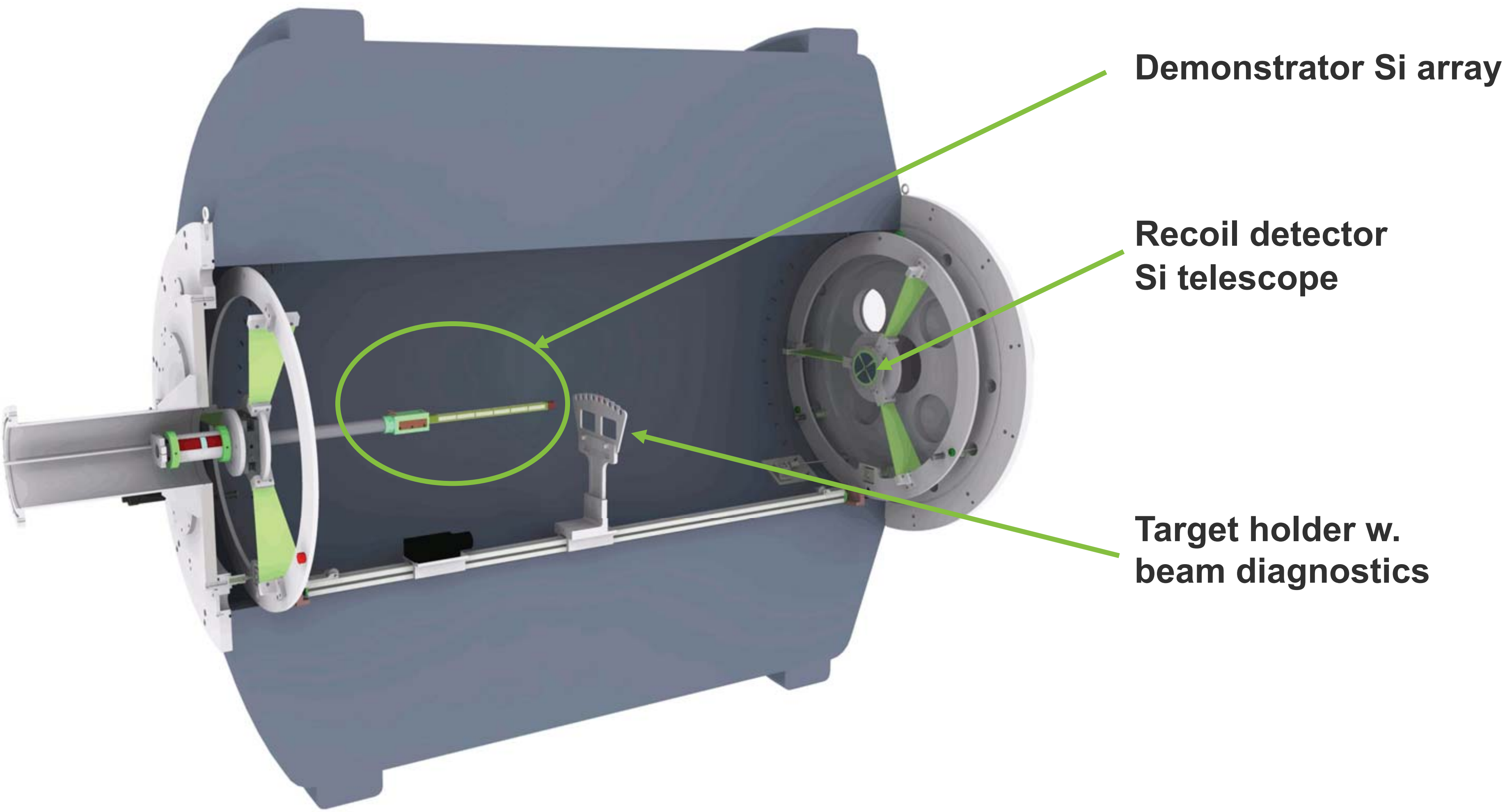
onto the truck

Arrival at ANL on the coldest day of the year

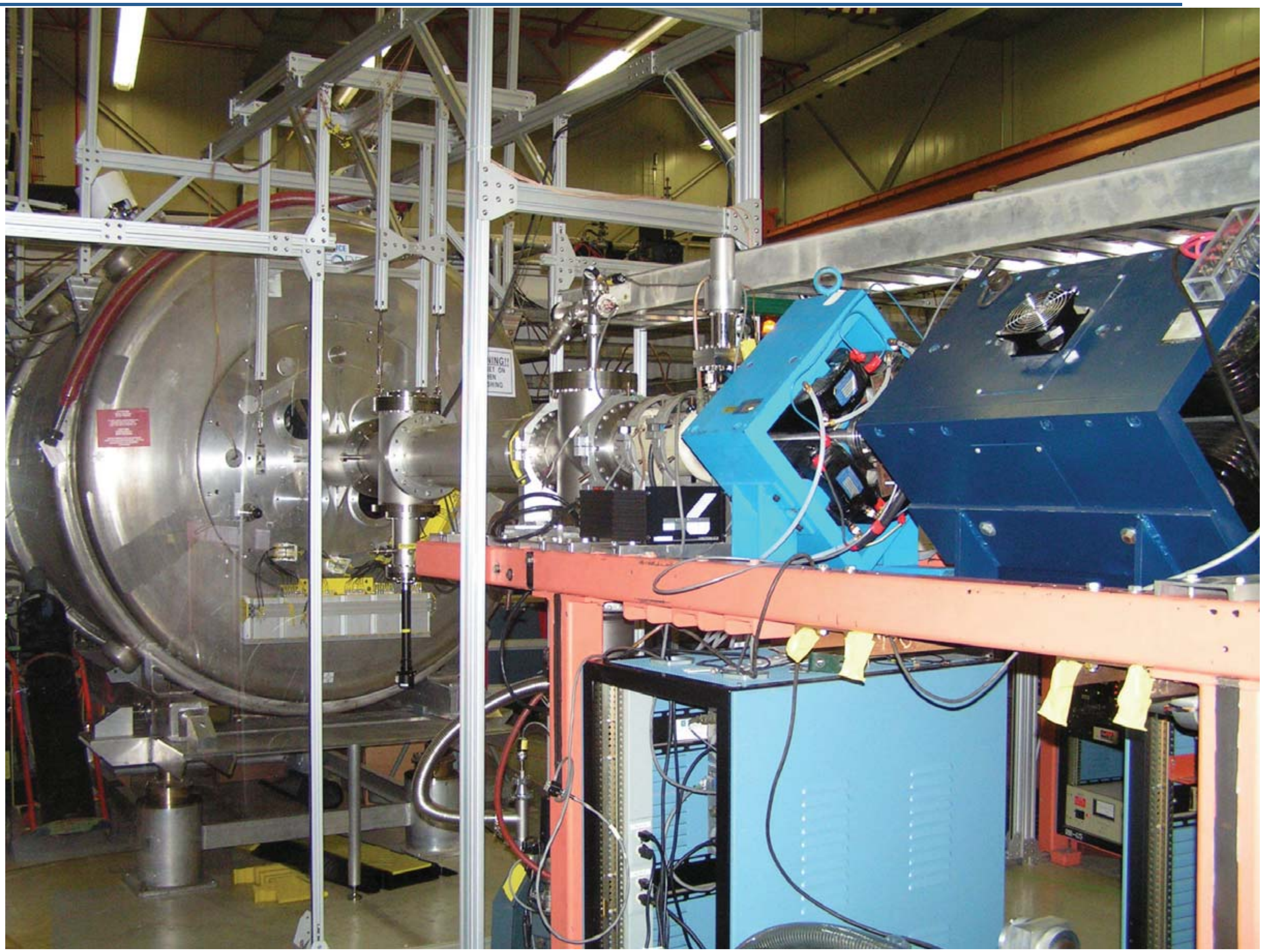
but filled with liquid Helium

December 8, 2006

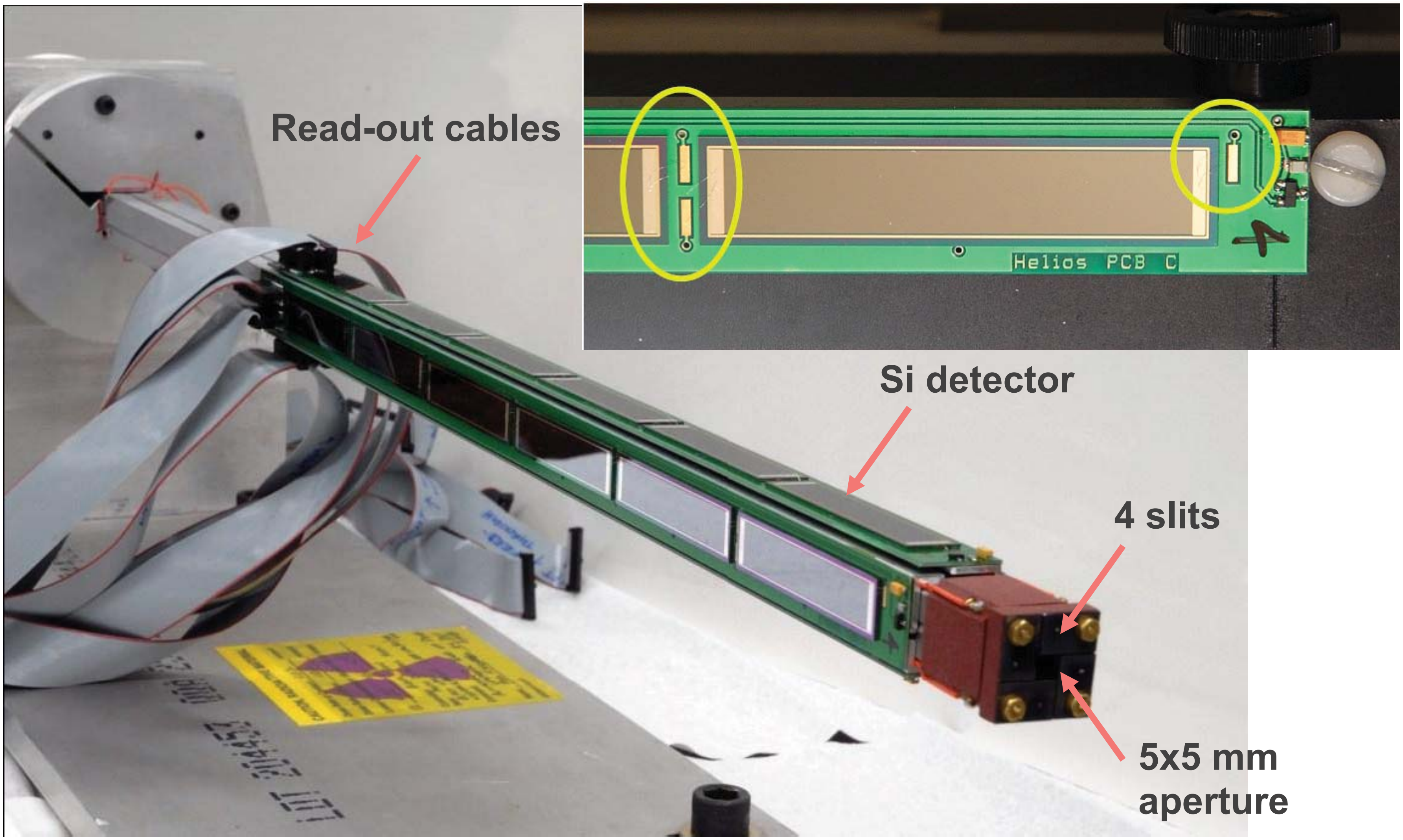
Solenoid → Spectrometer



July 2008, Installed – ready to go



Assembled prototype array



Commissioning experiment: ^{28}Si(d,p)

We're not the first to measure this

PHYSICAL REVIEW VOLUME 147, NUMBER 3 22 JULY 1966

Dependence of the Angular Distribution of the (*d,p*) Reaction on the Total Angular-Momentum Transfer. II*

J. P. SCHIFFER, L. L. LEE, JR.,† A. MARINOV,‡ AND C. MAYER-BÖRICKE§
Argonne National Laboratory, Argonne, Illinois

(Received 25 January 1966)

The (*d,p*) reaction has been studied with targets of C^{12}, O^{16}, F^{19}, Si^{28}, $S^{32,34}$, and $Zr^{90,92,94}$. New evidence on the *J* dependence of the (*d,p*) angular distribution has been obtained in 1*p* and 2*d* transitions. Additional evidence for 1*d* transitions has also been obtained.

"Proton spectra were recorded in multi-channel analyzers and punched on IBM cards for further data processing"

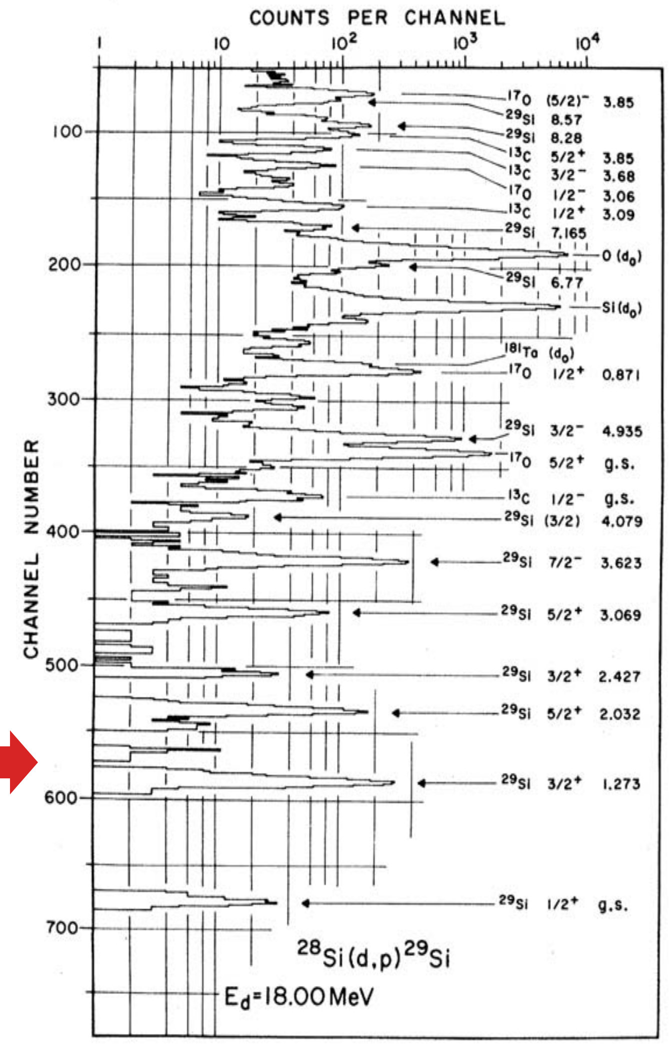
PHYSICAL REVIEW C VOLUME 4, NUMBER 5 NOVEMBER 1971

Study of the (*d, p*) Reaction on ^{28}Si, ^{32}S, and ^{36}Ar at E_d = 18.00 MeV*

M. C. Mermaz,† C. A. Whitten, Jr.,‡ J. W. Champlin, A. J. Howard,§ and D. A. Bromley
Wright Nuclear Structure Laboratory, Yale University, New Haven, Connecticut 06520

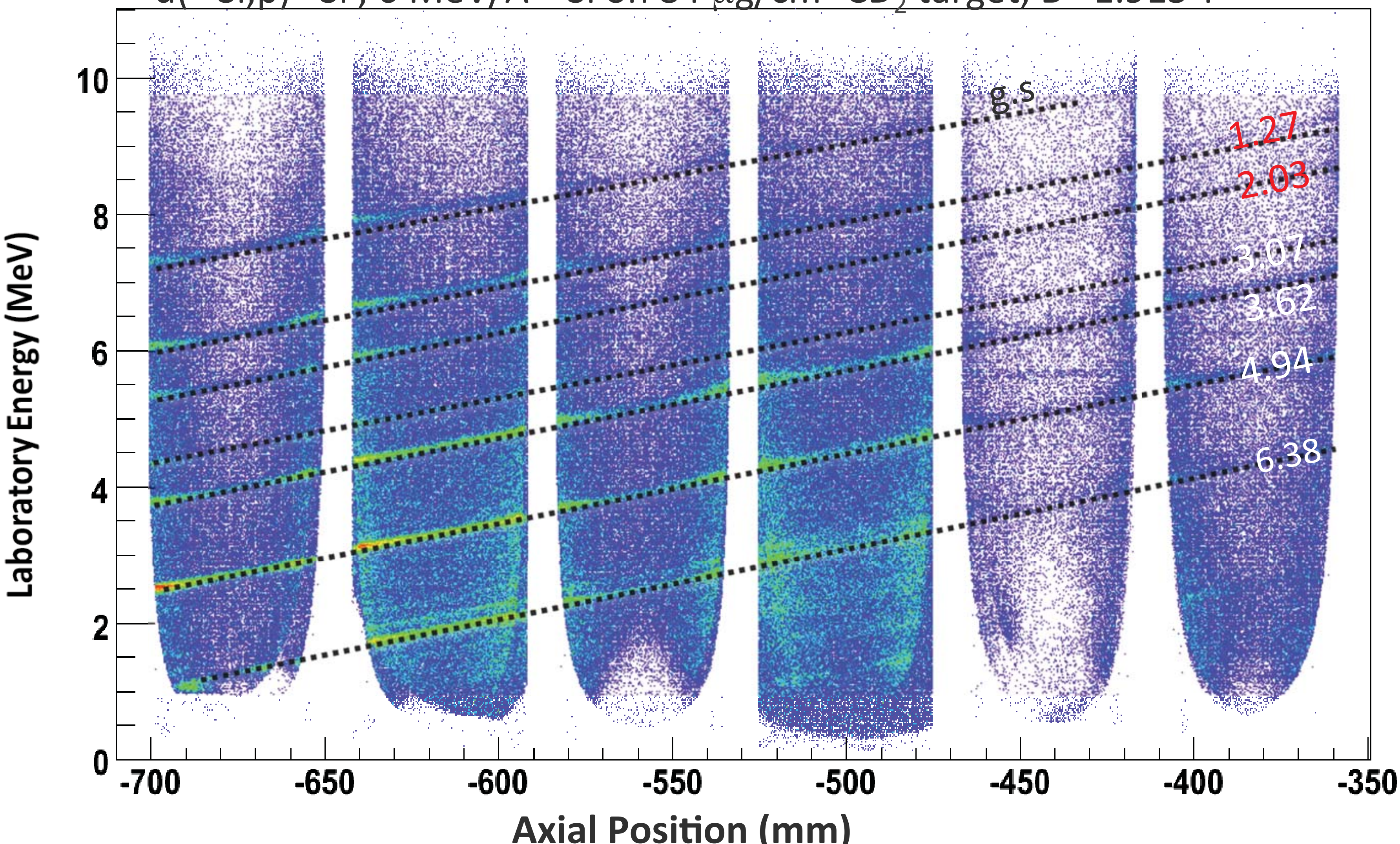
(Received 22 July 1971)

"The proton spectra were stored in a standard 1024-channel analyzer" … " The total energy resolution in ^{28}Si … was ~ 60 keV."



Energy vs. position – it works as expected

d(^{28}Si,p)^{29}Si , 6 MeV/A ^{28}Si on 84 μg/cm^2 CD_2 target, B= 1.915 T



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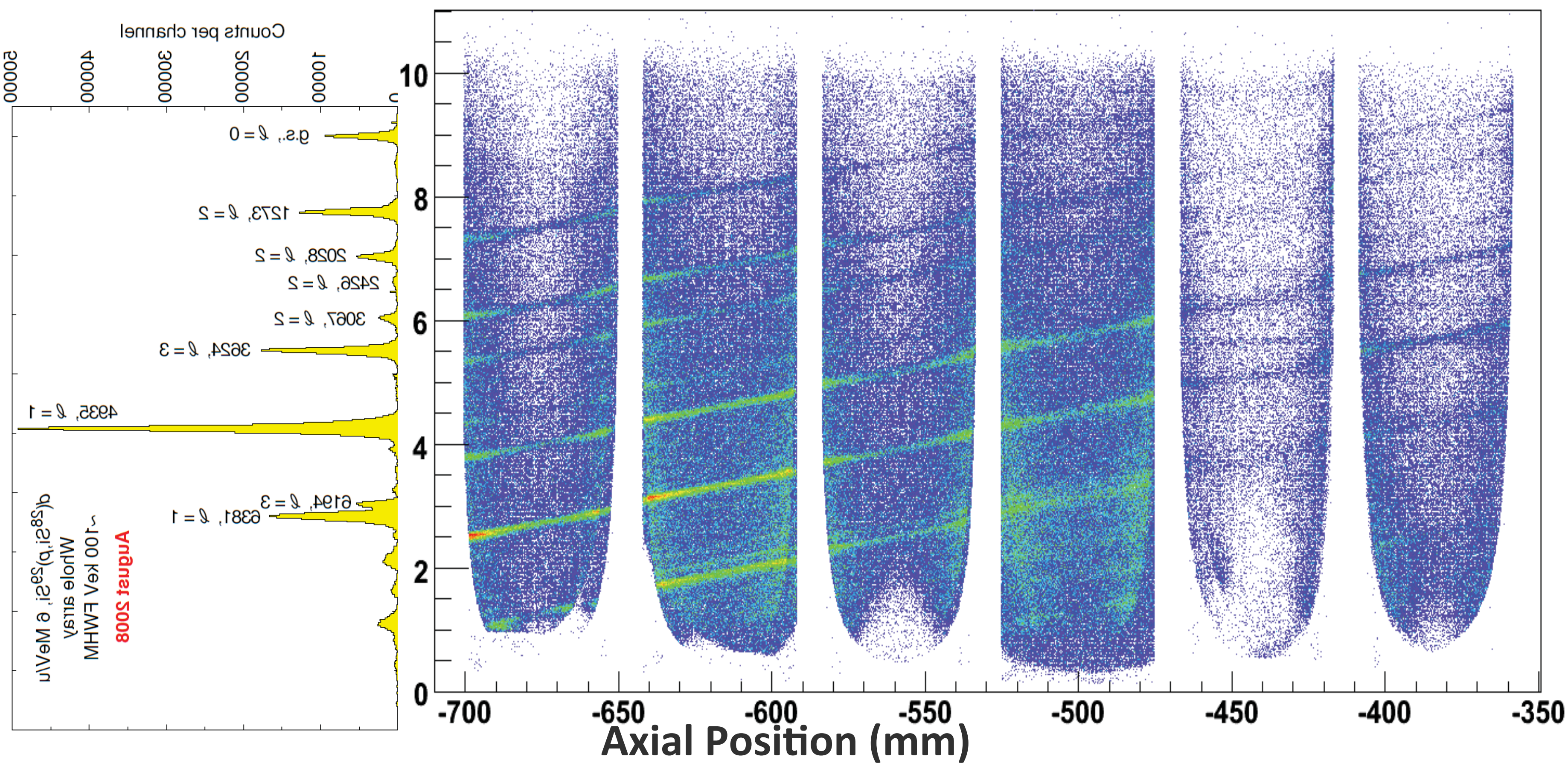
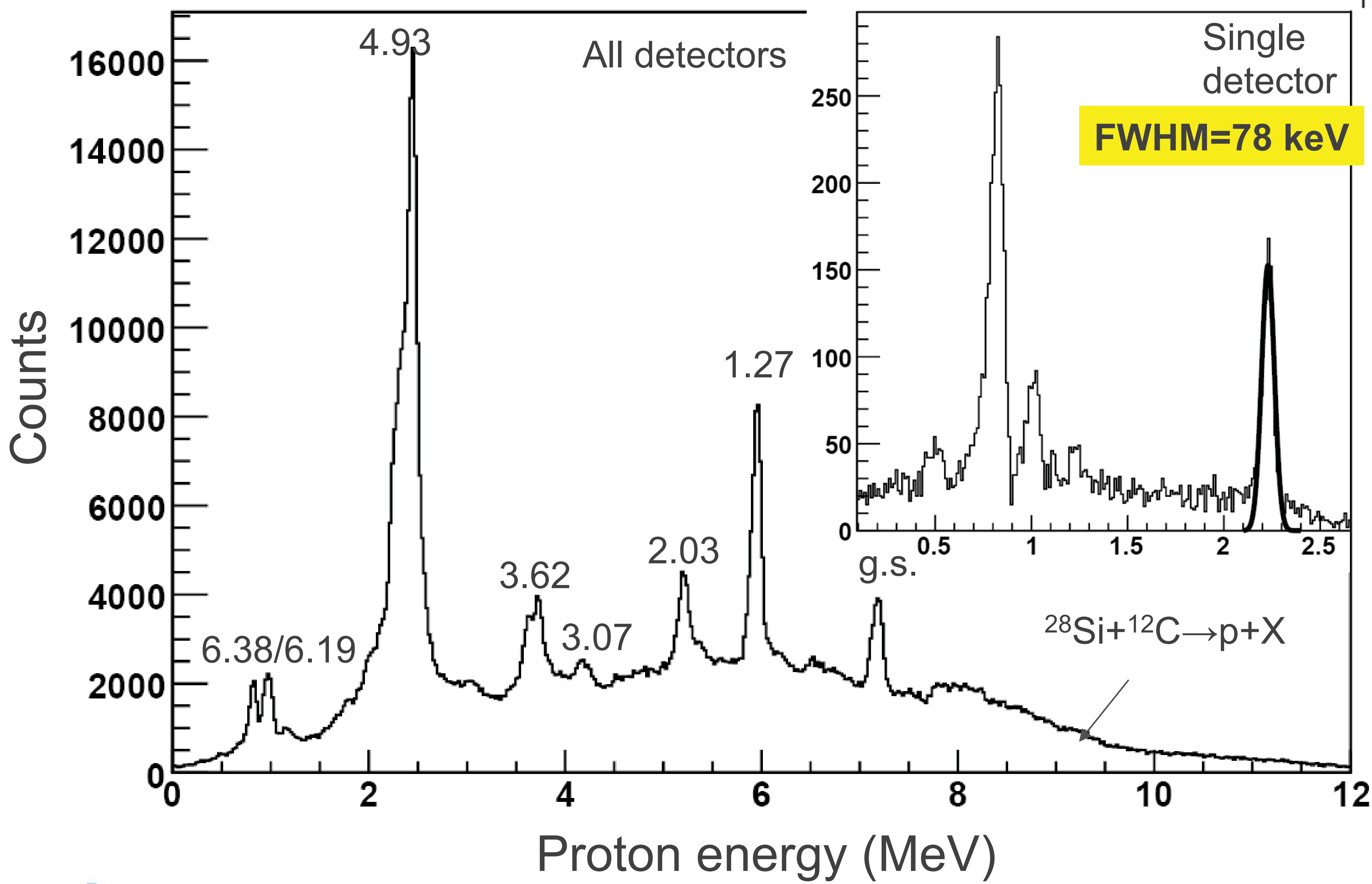
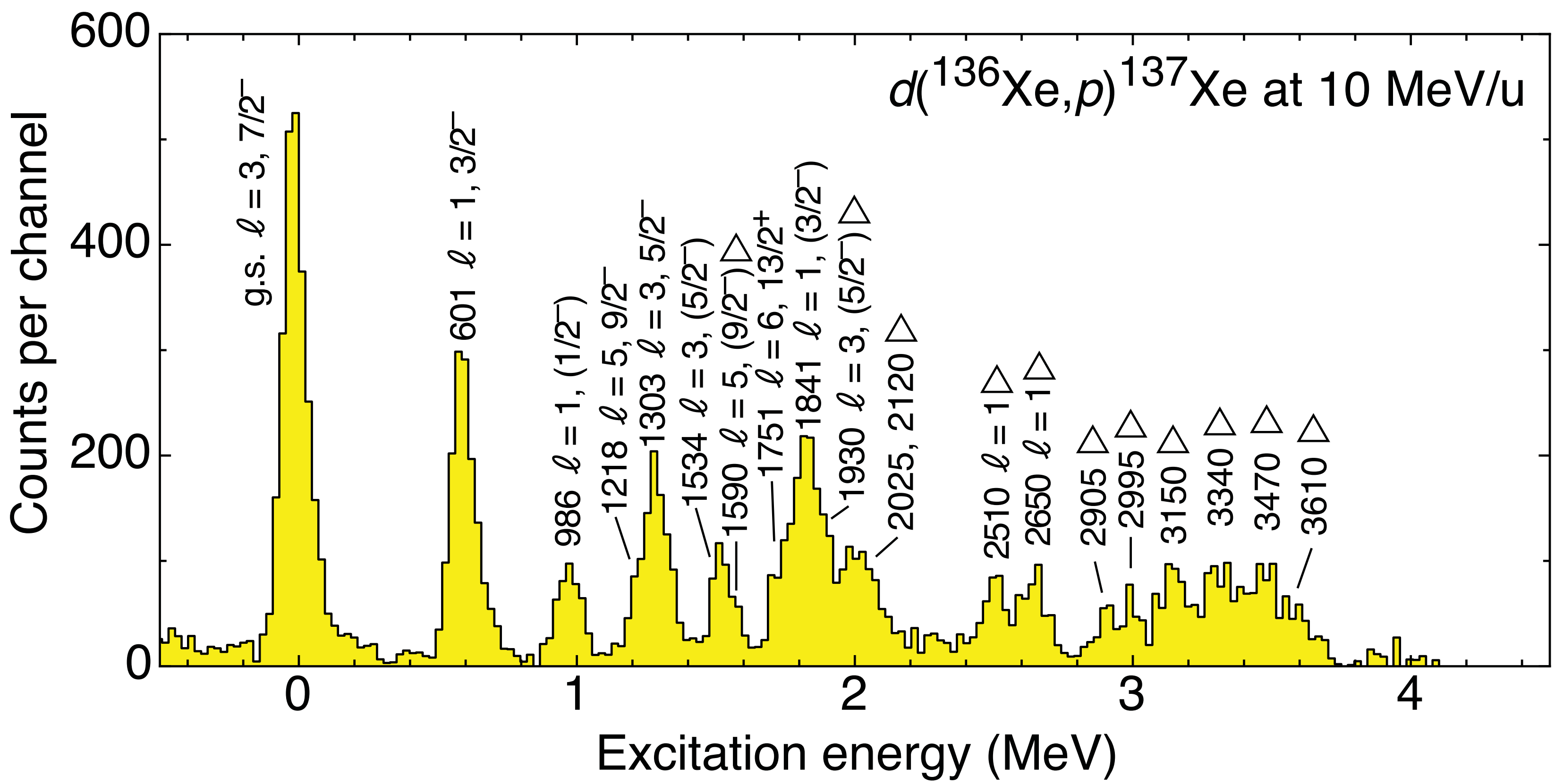


First HELIOS spectra



Outgoing proton spectrum: ^{137}Xe



A subset of the data from Position II. A smooth background has been subtracted. Those marked with a triangle have been deduced in this work. The state at 1751 keV previously observed by Radford et al., (unpublished).

Upgrades to HELIOS

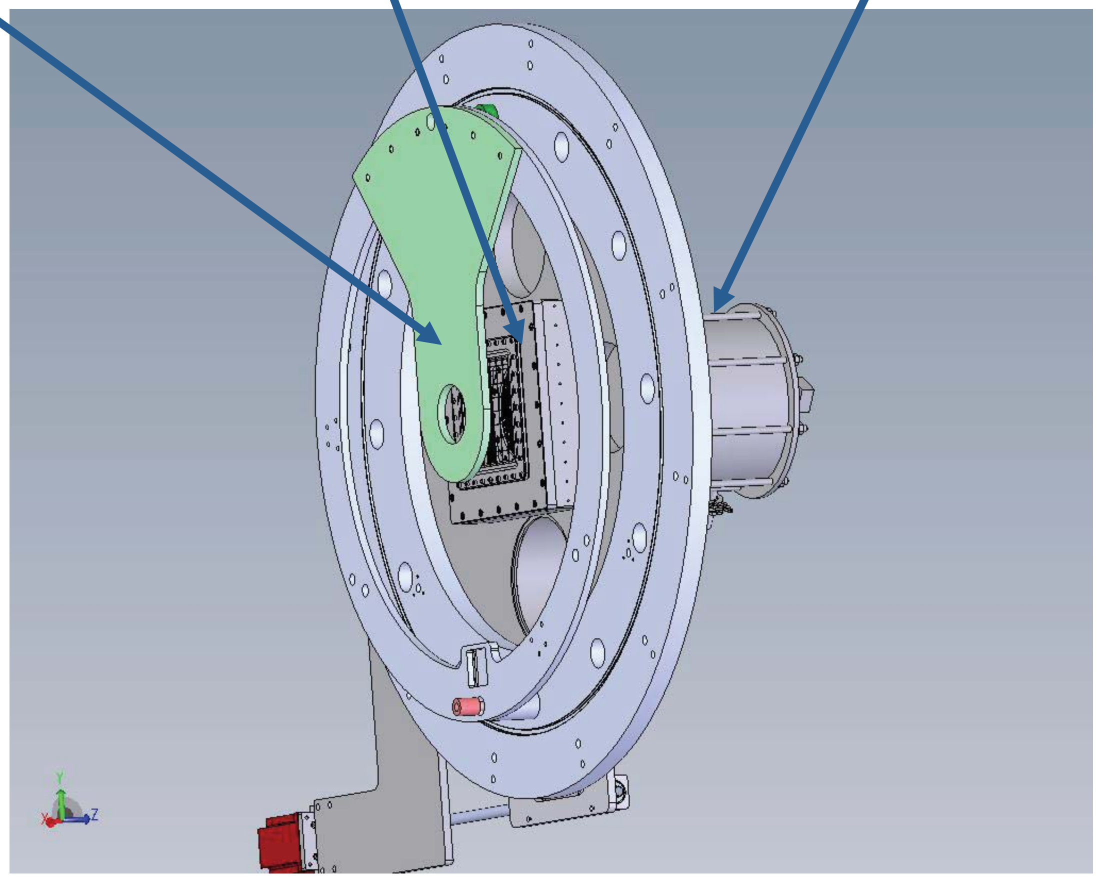
- PPAC+Bragg Recoil detector (Manchester University)
- Gas target to allow for (^{3}He,p), (^{3}He,d), (^{3}He,α) reactions etc.
- Full efficiency backward array (2 cm wide Si wafers)
- Forward Si detector array
- Etc.
- Etc.

Manchester recoil detector

Support for new forward array

PPAC

Bragg curve detector



Status:
Ready to install

Cryogenic Gas target for ^{3}He and ^{4}He

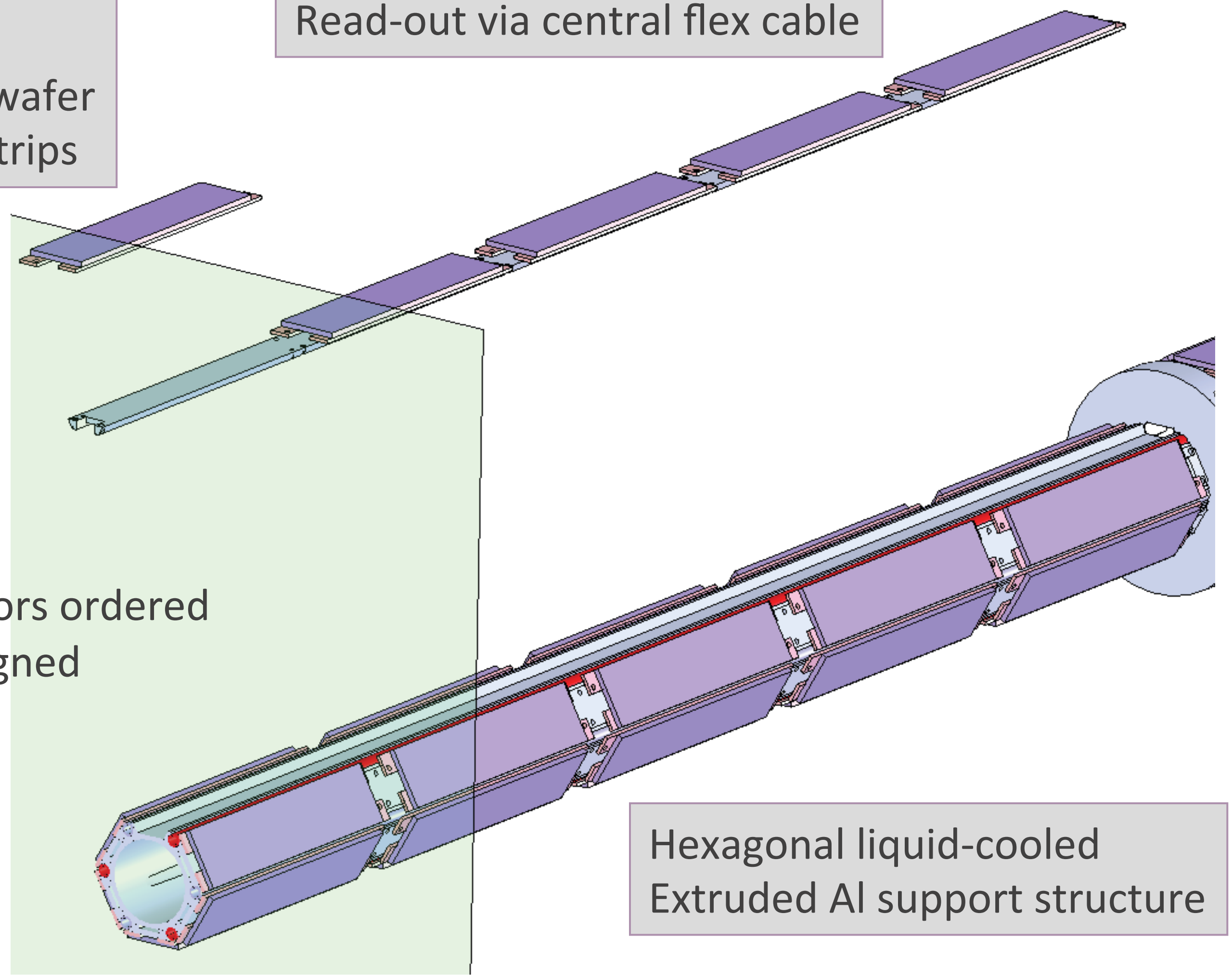
(Brad DiGiovine)

Status: Being built

New efficient Si detector array

De-mountable
Resistive wire
11x53 mm^2 Si wafer
on 2 ceramic strips

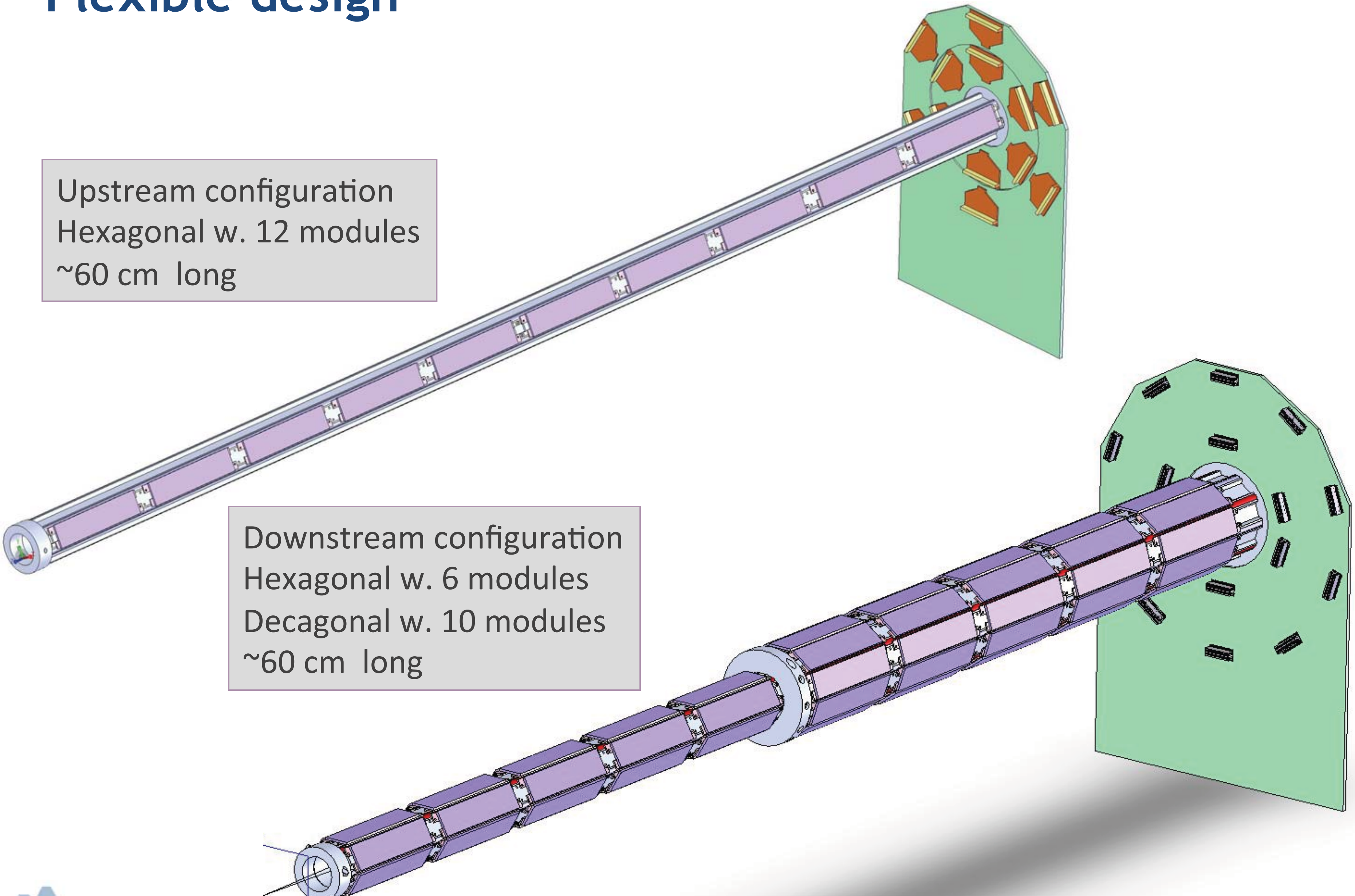
Standard 5 detector module
Read-out via central flex cable



Status:
Prototype Si detectors ordered
Support frame designed

Hexagonal liquid-cooled
Extruded Al support structure

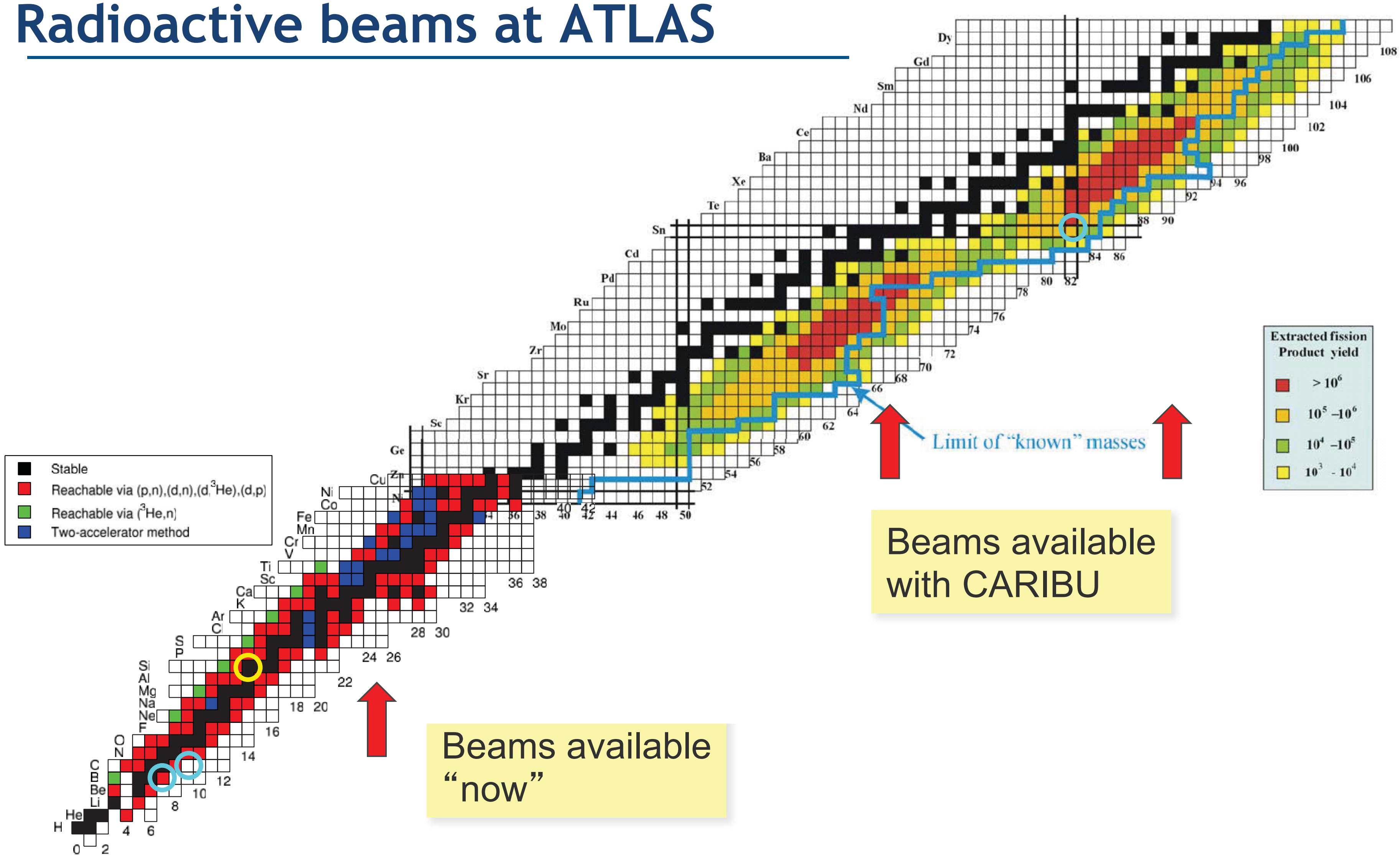
Flexible design



Upstream configuration
Hexagonal w. 12 modules
~60 cm long

Downstream configuration
Hexagonal w. 6 modules
Decagonal w. 10 modules
~60 cm long

Radioactive beams at ATLAS



Beams available with CARIBU

Beams available "now"

Yields for Representative Species

Calculated maximum beam intensities for a 1 Ci ^{252}Cf fission source using expected efficiencies.

Isotope	Half-life (s)	Low-Energy Beam Yield (s^{-1})	Accelerated Beam Yield (s^{-1})
^{104}Zr	1.2	6.0×10^5	2.1×10^4
^{143}Ba	14.3	1.2×10^7	4.3×10^5
^{145}Ba	4.0	5.5×10^6	2.0×10^5
^{130}Sn	222.	9.8×10^5	3.6×10^4
^{132}Sn	40.	3.7×10^5	1.4×10^4
^{138}Xe	846.	9.8×10^6	7.2×10^5
^{110}Mo	2.8	6.2×10^4	2.3×10^3
^{111}Mo	0.5	3.3×10^3	1.2×10^2

HELIOS Collaboration

N.Antler[1], B B.Back[1], S.Baker[1], J.Clark[1], C. Deibel[1], .J.DiGiovine[1], S.J.Freeman[3], N.J.Goodman[2], Z.Grelewicz[1], S.Heimsath[1], C.Hoffman[1], B.Kay[1], H.Y.Lee[1], C.J.Lister[1], S. T. Marley[1,2], P.Mueller[1], R.Pardo[1], K.E.Rehm[1], A.Rogers[1], J.Rohrer[1], J.P.Schiffer[1], D. Shetty[2], J. Snyder[2], M.Syrion[1], J.C.Lighthall[1,2], A.Vann[1], J.R.Winkelbauer[1,2], A.Woodard[1], A.H.Wuosmaa[2]

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[1]***Argonne National Laboratory***
[2]***Western Michigan University***
[3]***University of Manchester***

The (partial) HELIOS Collaboration, August 2009

Thank you