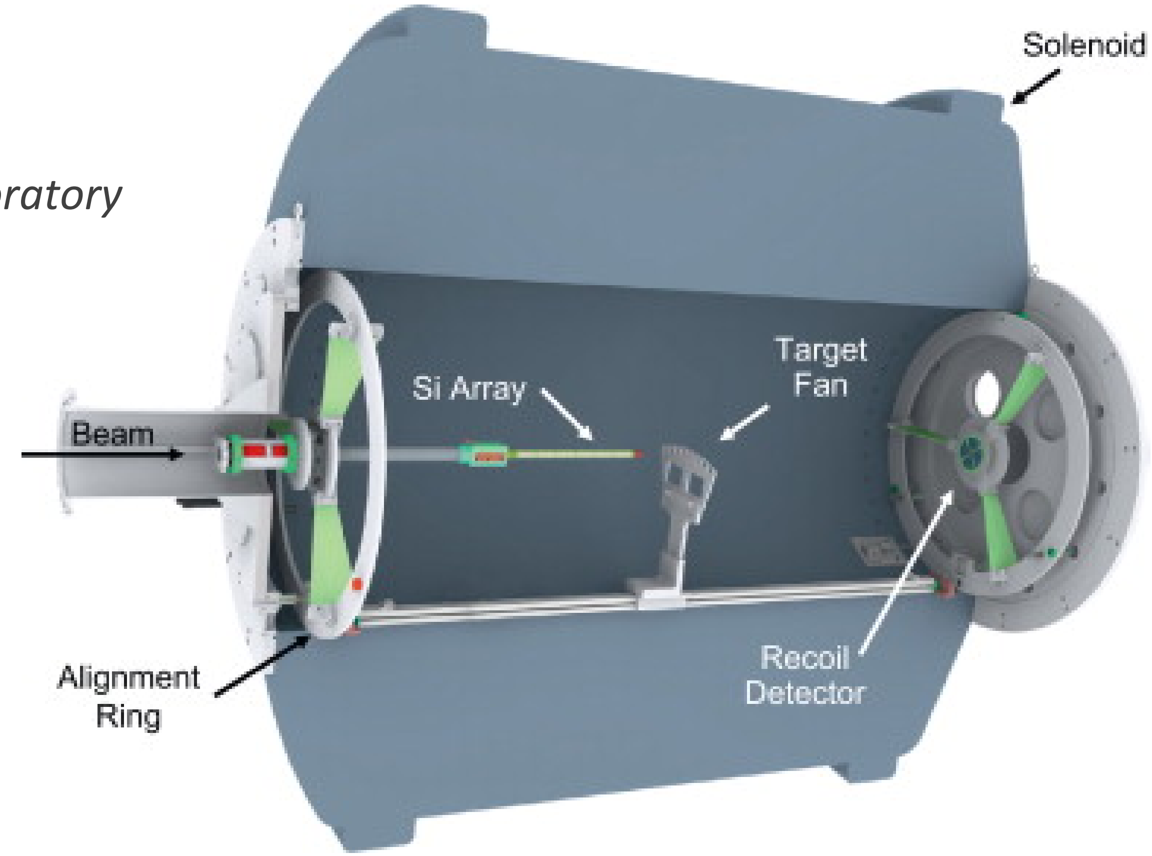
HELIOS: The Helical Orbit Spectrometer at ATLAS

B.B.Back

Argonne National Laboratory



Outline:

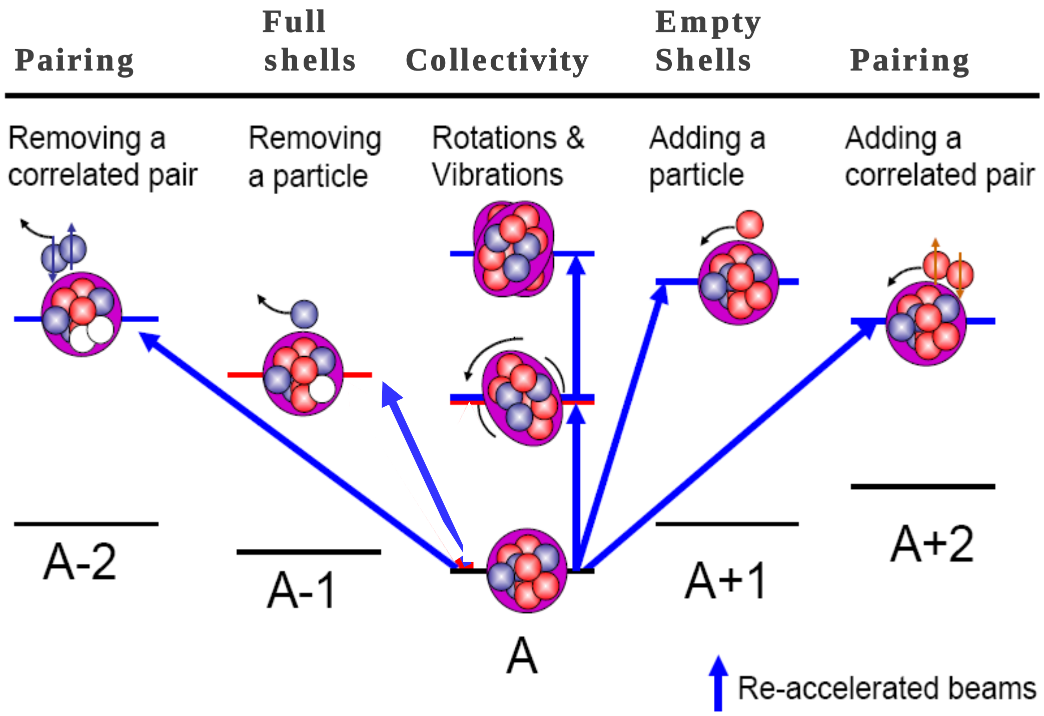
- Motivation for studying light-ion reactions in inverse kinematics
- The HELIOS Spectrometer concept
- The Argonne implementation of HELIOS
- Commissioning experiment
- Planned upgrades
- Helios elsewhere

Motivation for studying light-ion reactions in inverse kinematics

Nuclear structure with re-accelerated beams

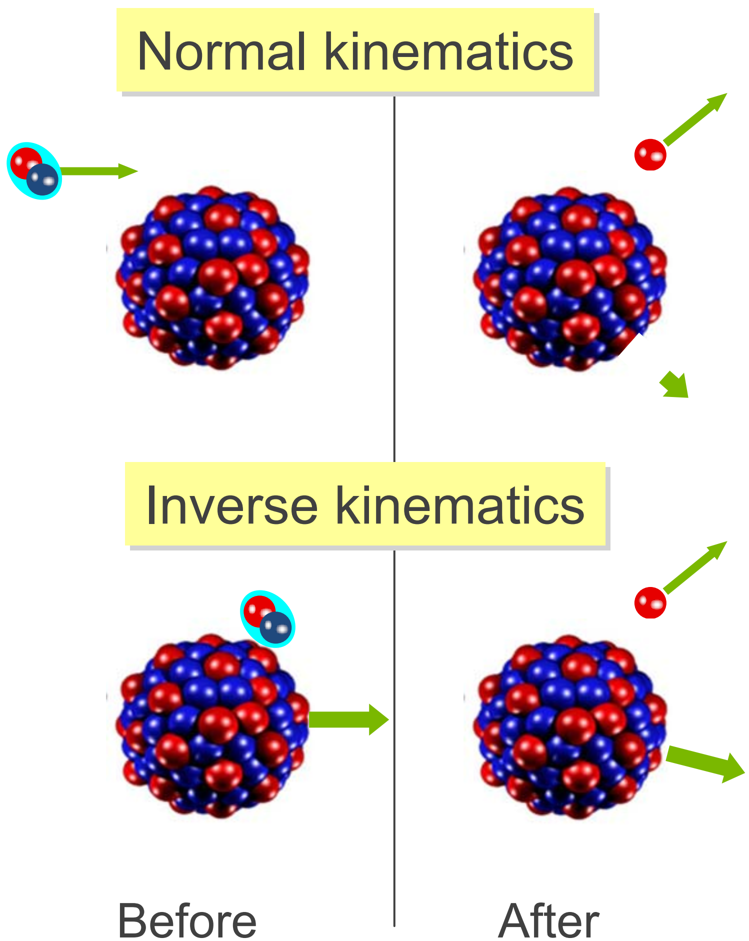
Search for

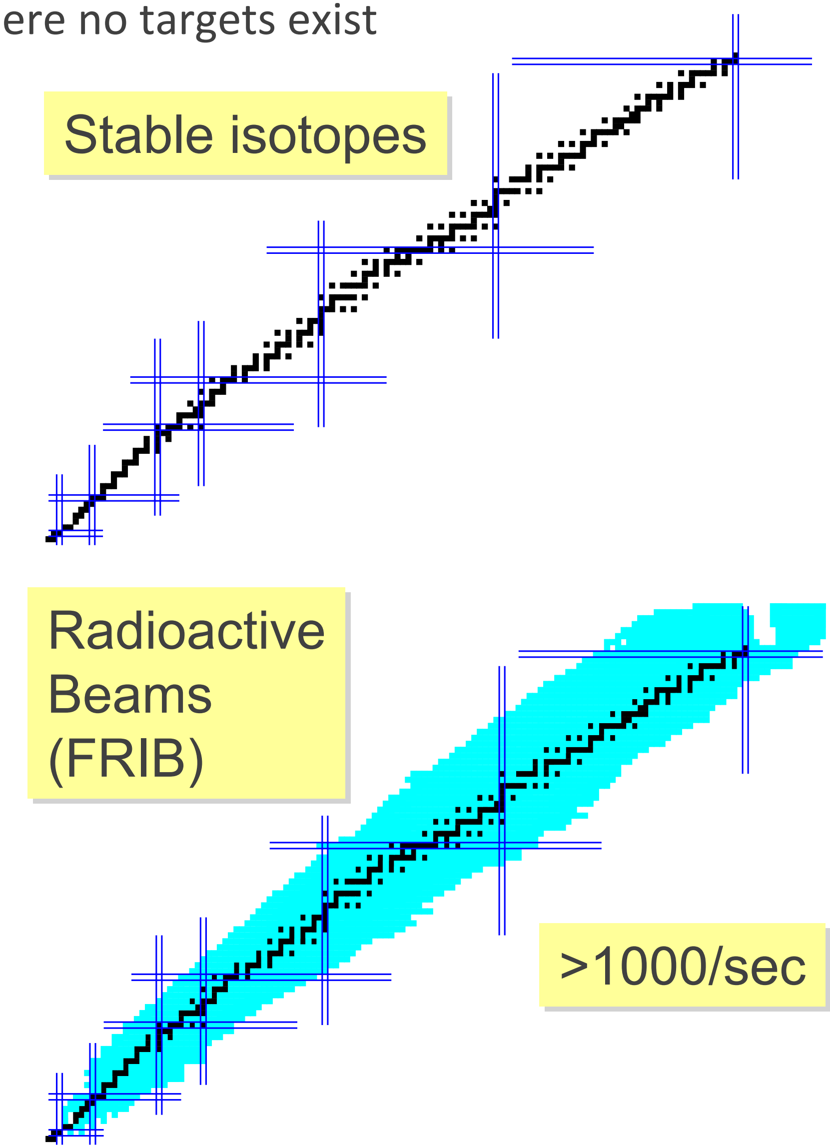
- changes in shell structure with single-nucleon transfer reactions
- pair correlations with transfer of nucleon pairs
- new modes of collectivity with β decay, moments, single or multiple Coulomb excitation
- ....



Inverse kinematics - wide applications

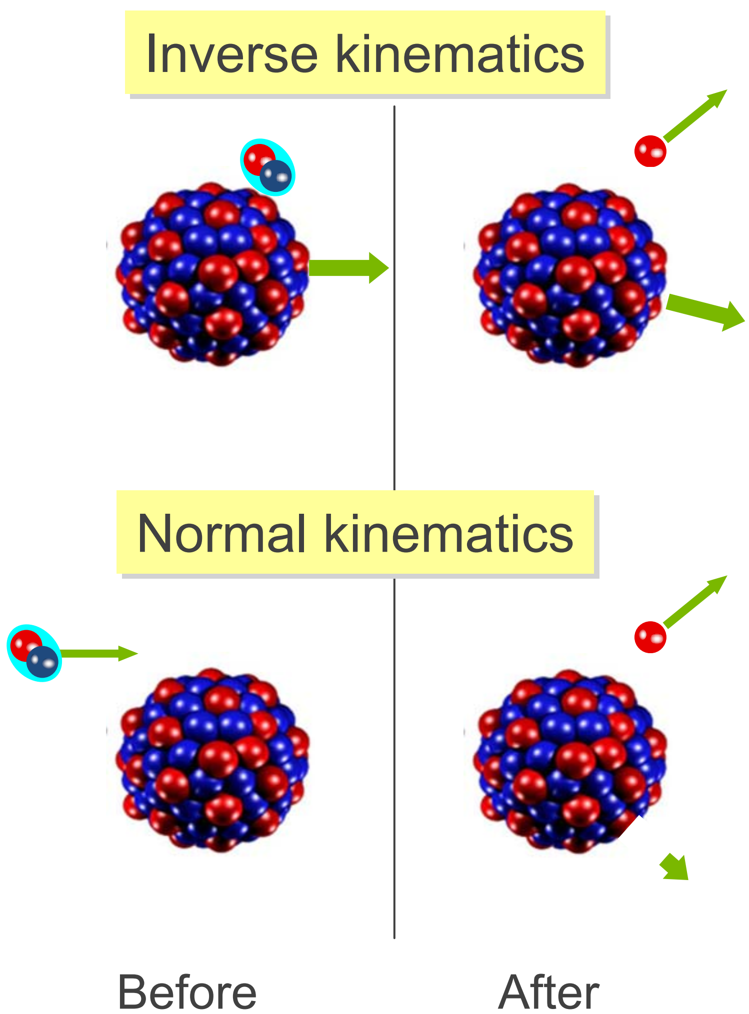
- Precision studies of nuclei in regions where no targets exist

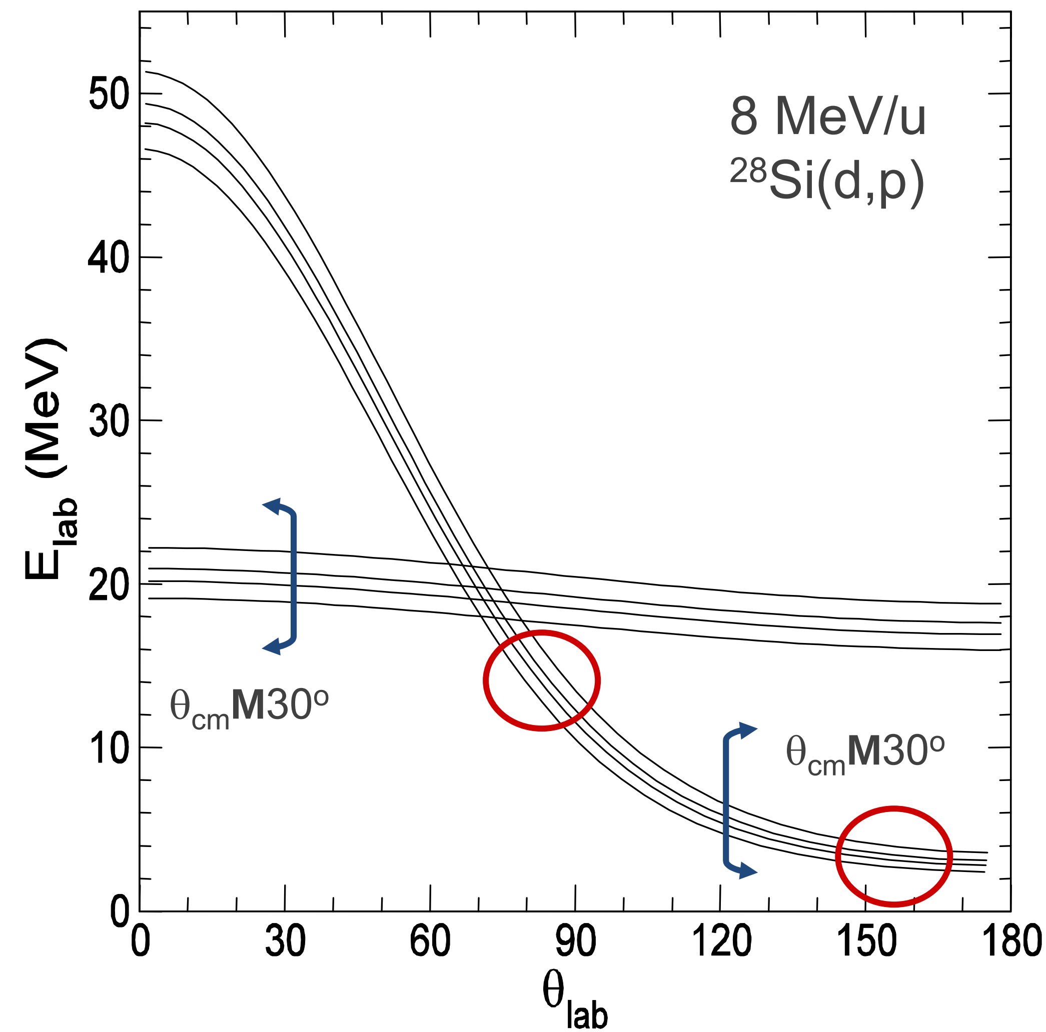




Inverse kinematics problems

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





The solution

HELIOS

Logo by Peter Müller

Principle of operation

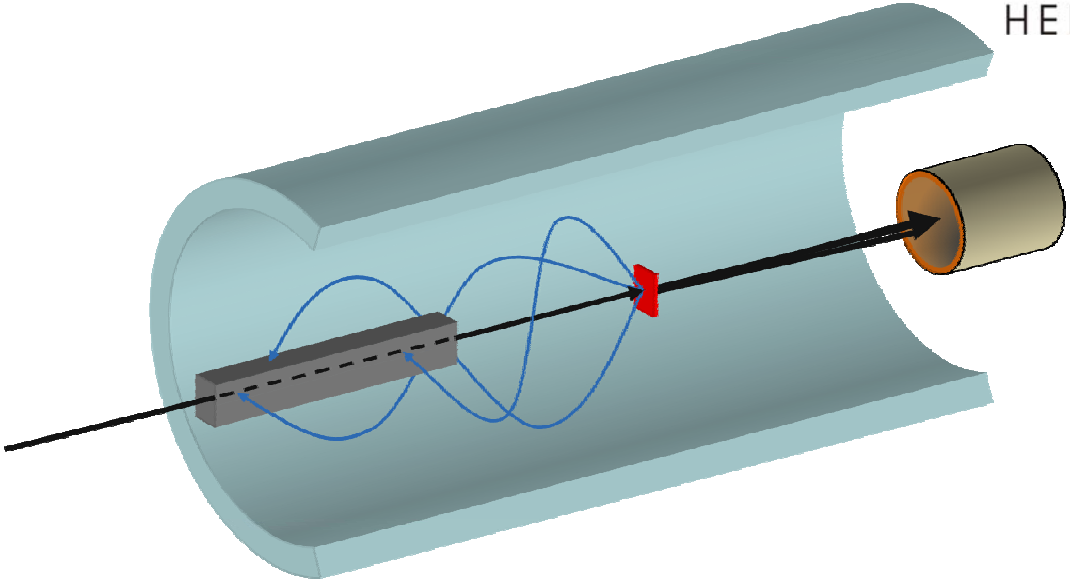
HELIOS

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
$^3He^{2+}$	51.4
d, α	68.5
t	102.7

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

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

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

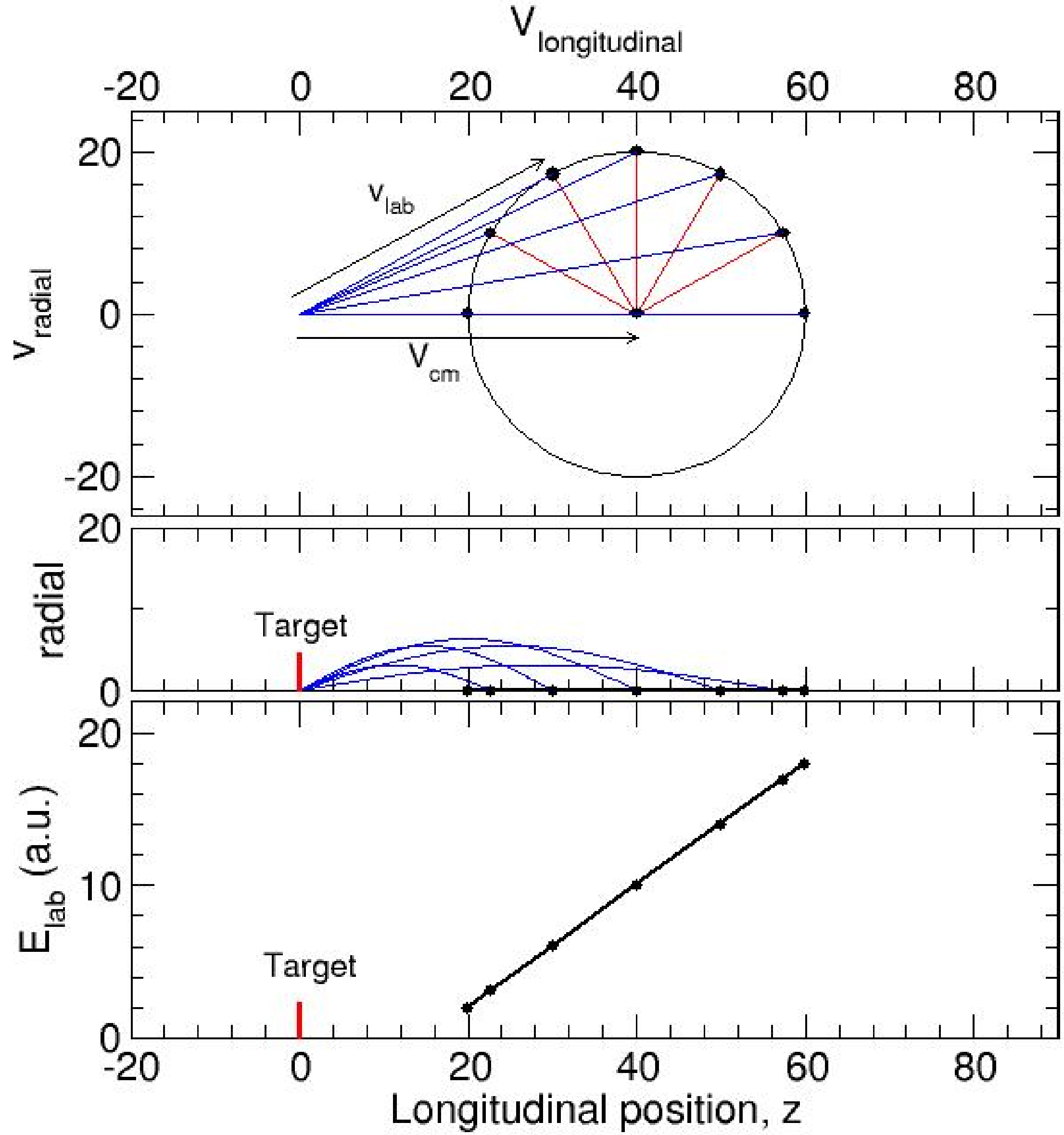
HELIOS kinematics

Return to axis after

$T_{cyc} = 2\pi m/eqB$

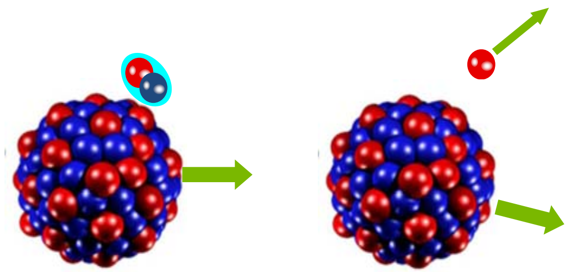
Longitudinal distance

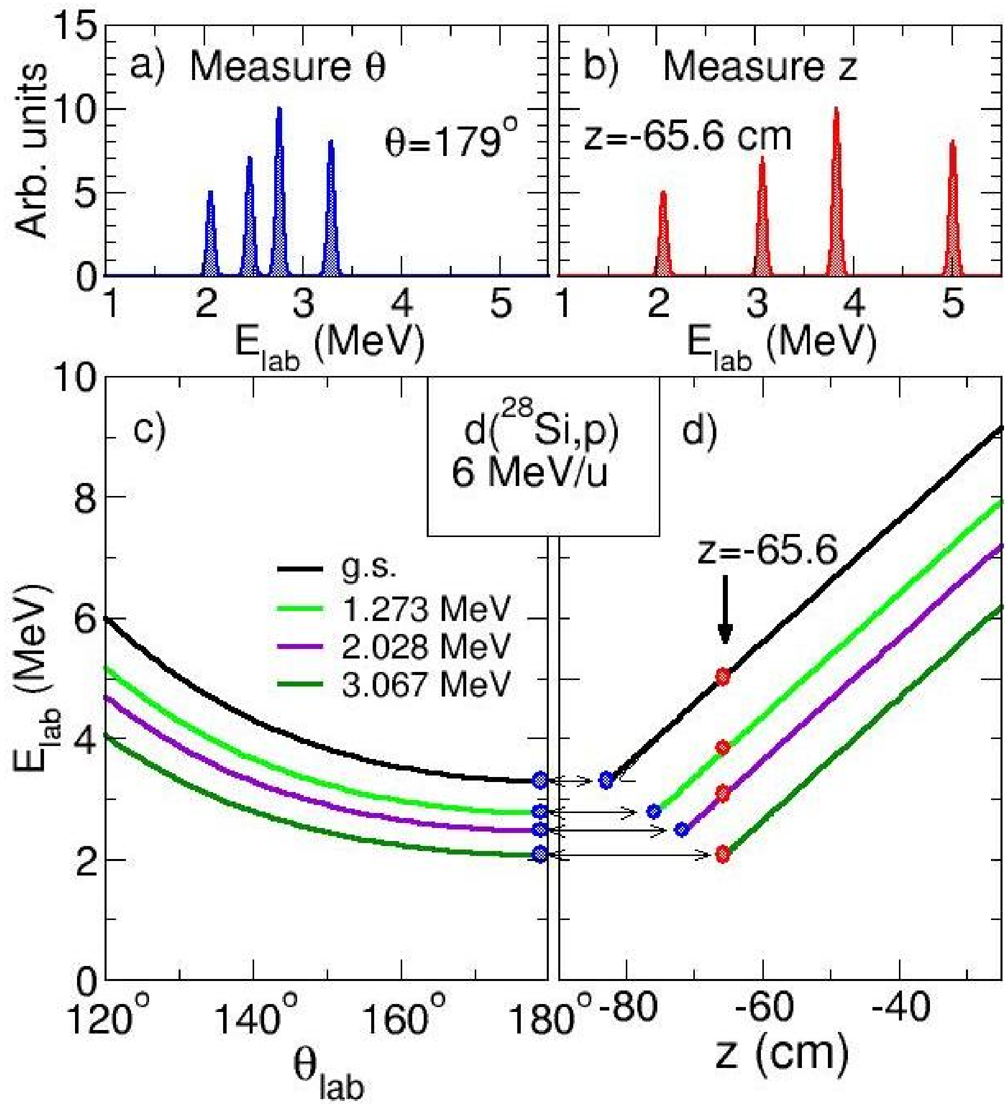
$z = T_{cyc}\, v_{longitudinal}$



Measure Θ or z (in magnetic field)?

Inverse kinematics





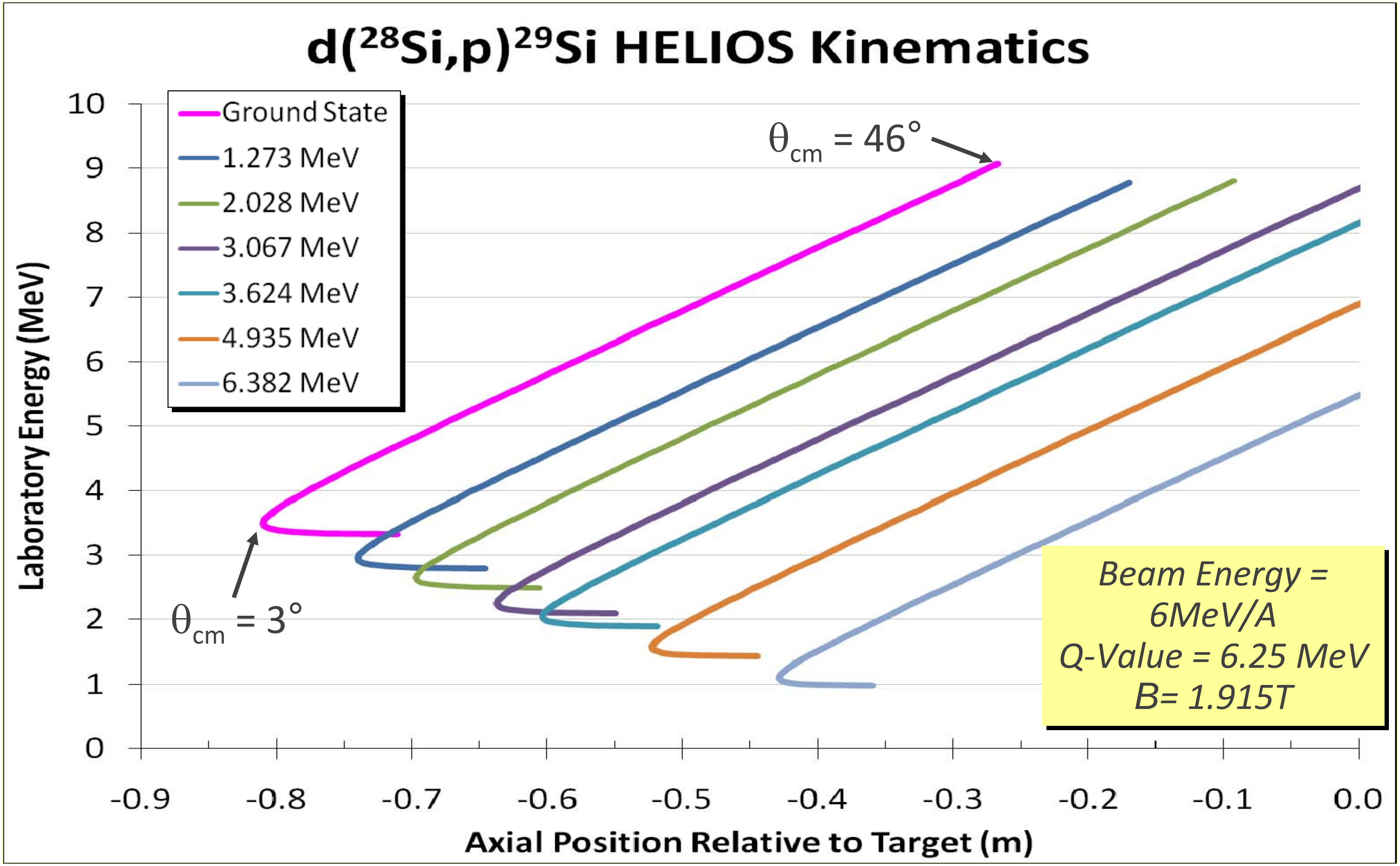
Q-value resolution:

Improvement: 2.4

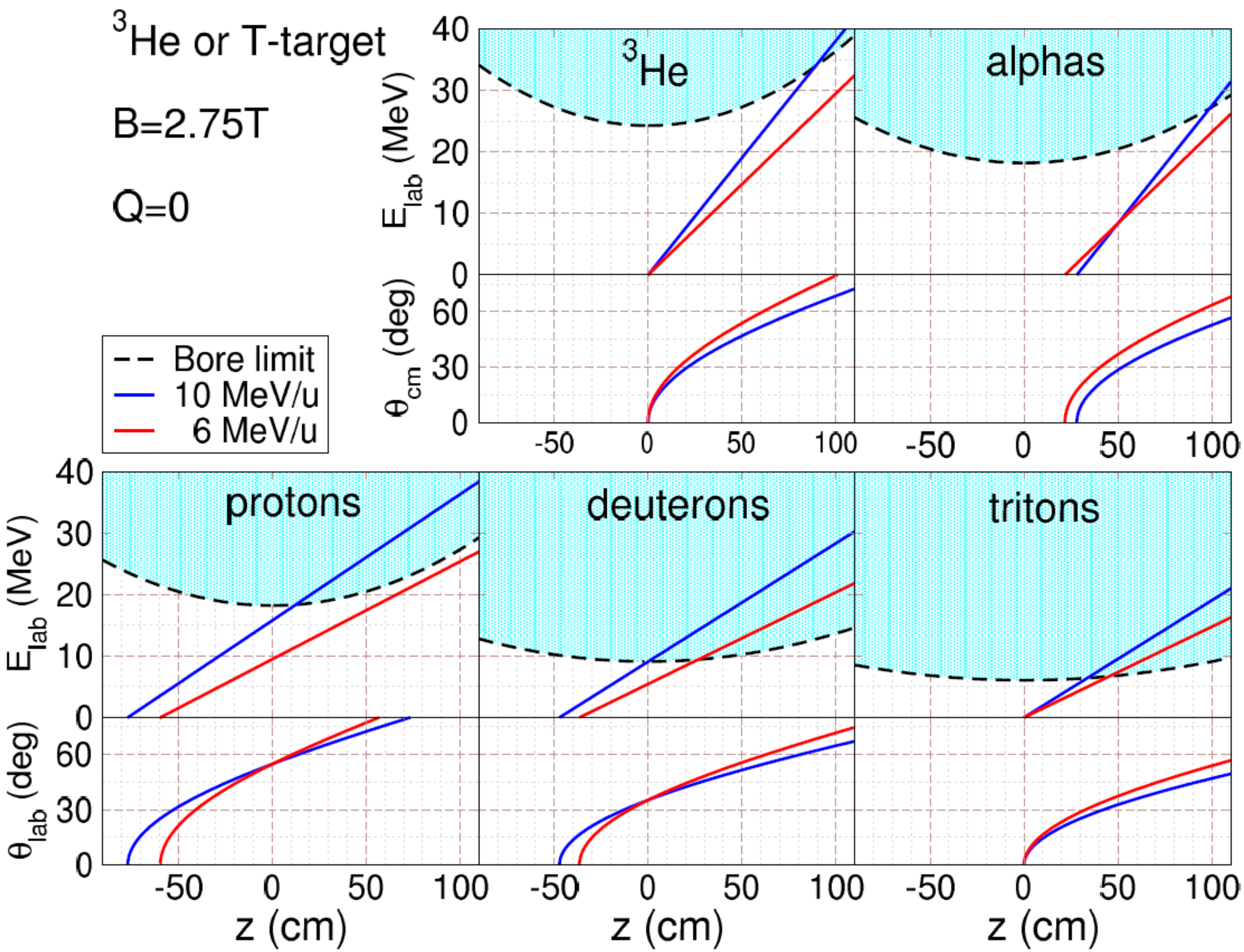
Other contributions:

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

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



Q=0 transfer reactions on ^{3}He or T target



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

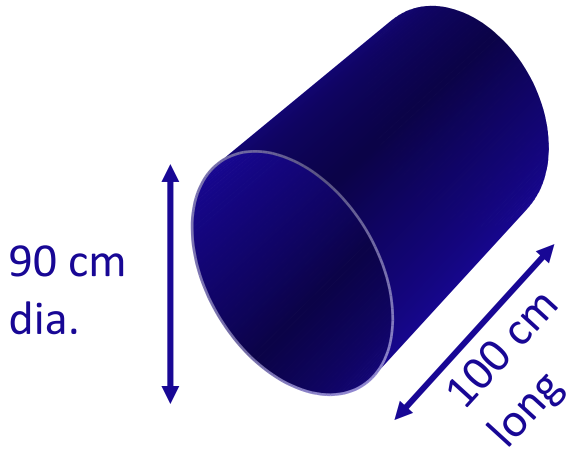
but filled with liquid Helium

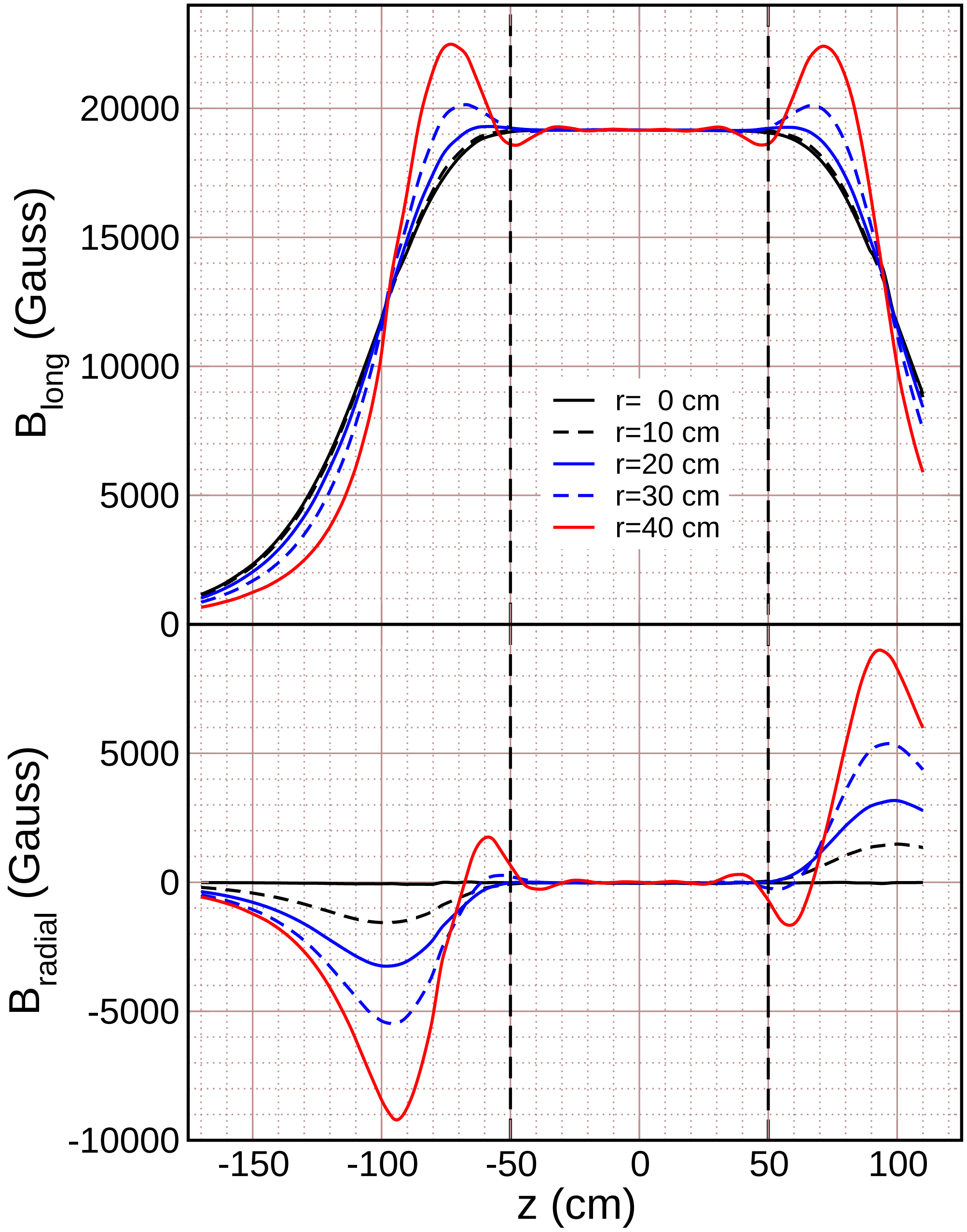
December 8, 2006

HELIOS Field map

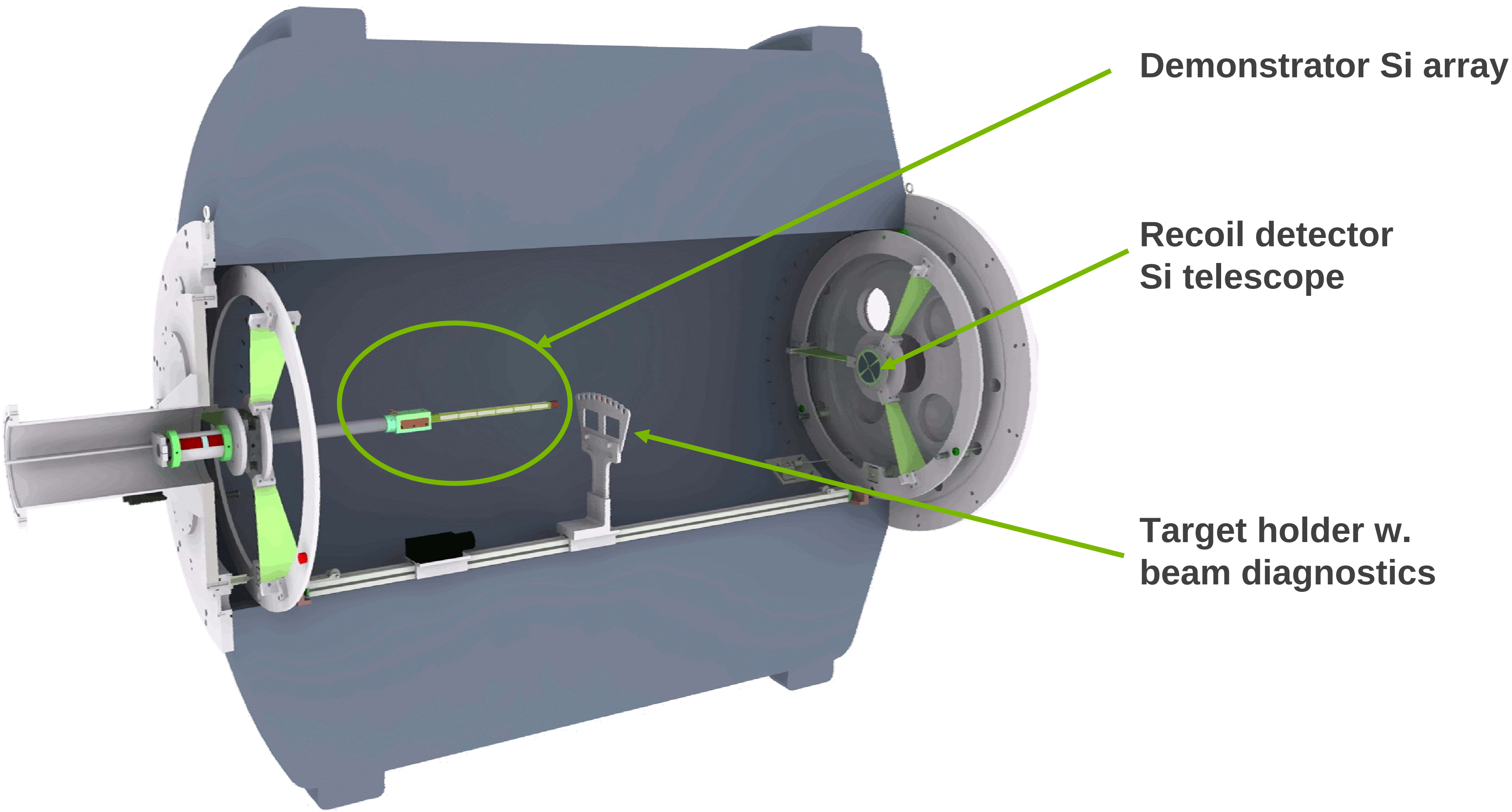
J. Lighthall
J. Winkelbauer
21,240 points

Homogeneous region

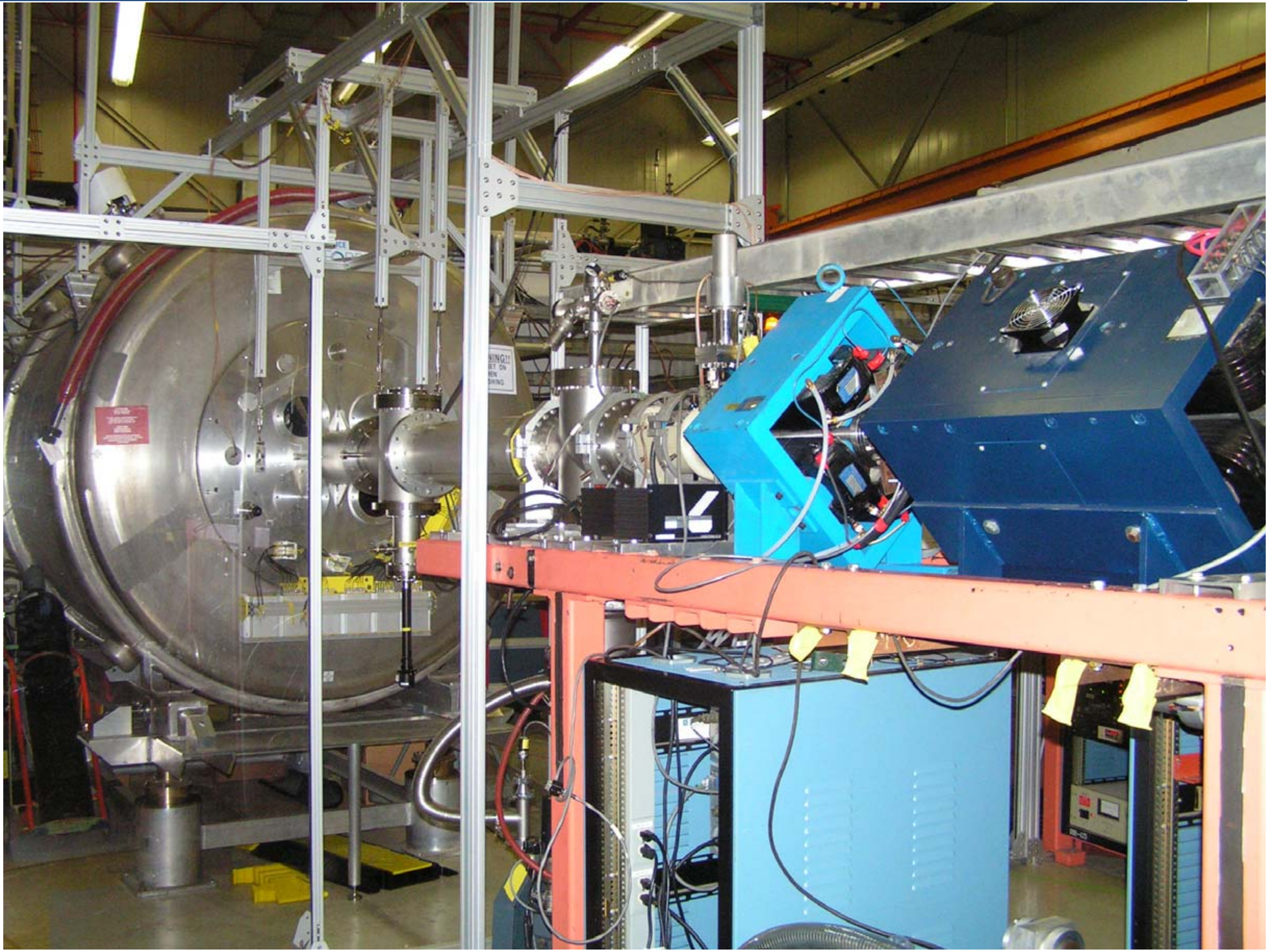




Solenoid → Spectrometer

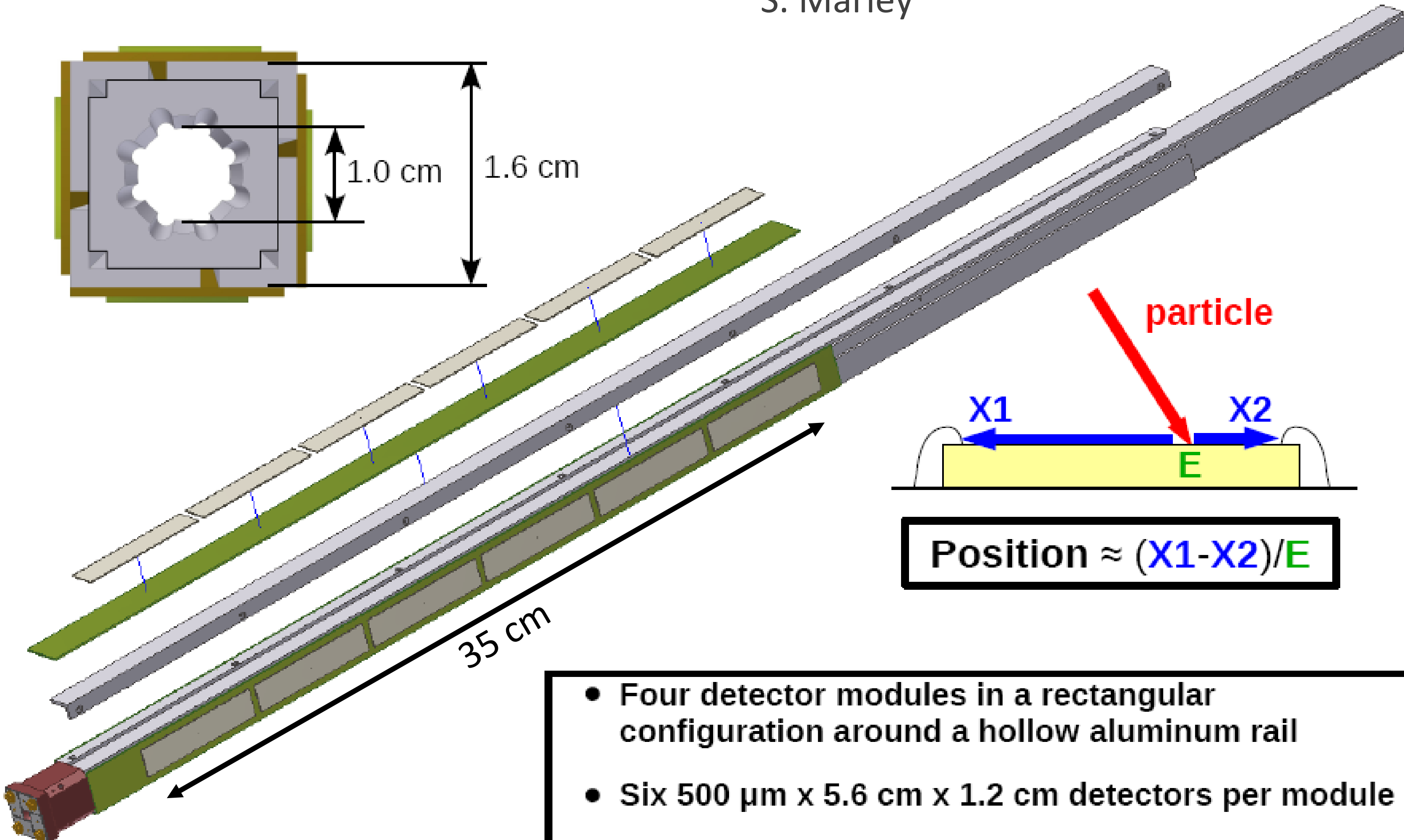


July 2008, Installed – ready to go



Prototype Si-detector array

S. Marley

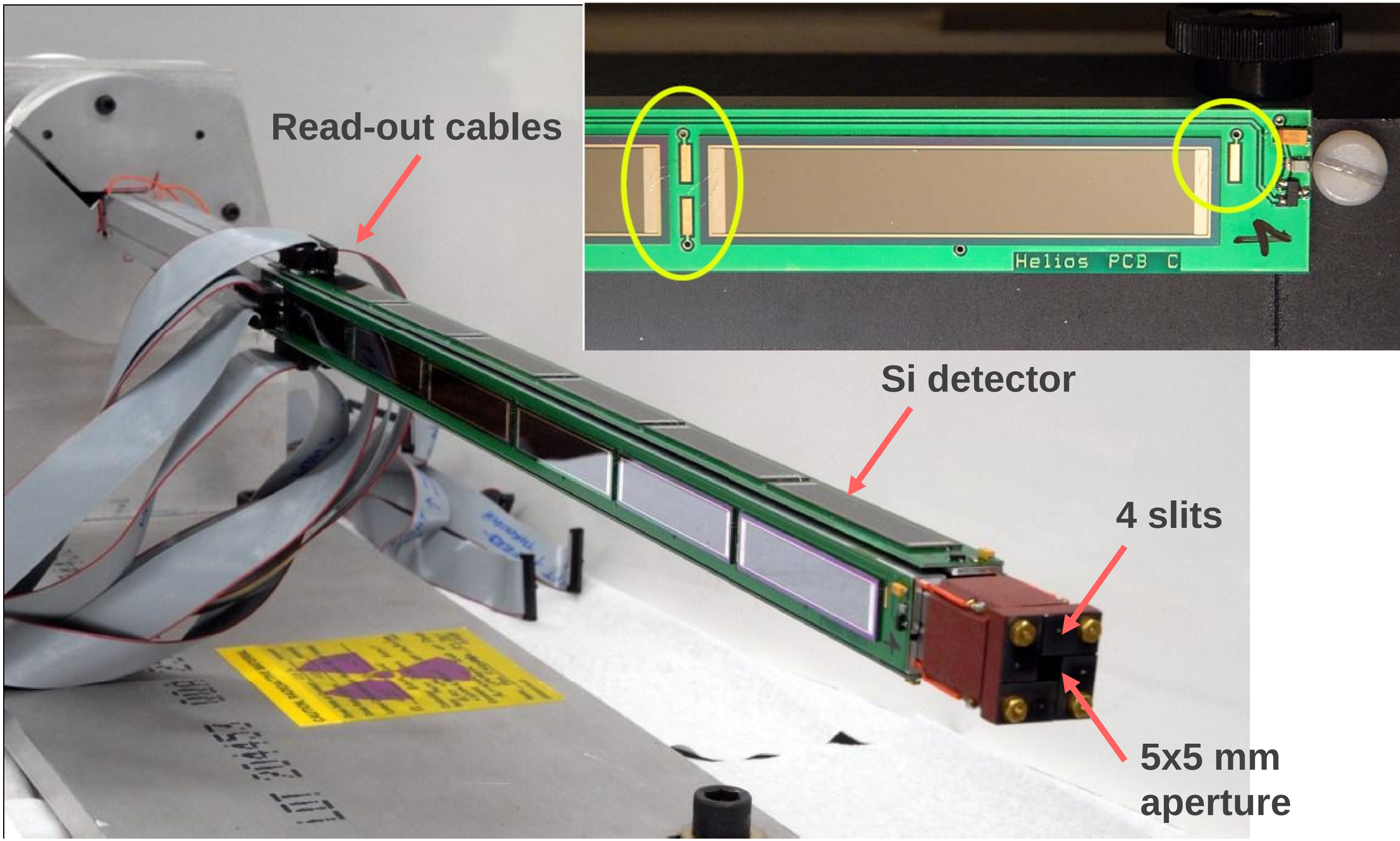


Position ≈ (X1-X2)/E

- Four detector modules in a rectangular configuration around a hollow aluminum rail
- Six 500 µm x 5.6 cm x 1.2 cm detectors per module
- Three channels per detector (72 total)

Isolated slits for beam tuning and collimation (5 x 5 mm^2)

Assembled prototype array



The d(^{28}Si,p)^{29}Si comissioning experiment

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 $1p$ and $2d$ transitions. Additional evidence for $1d$ transitions has also been obtained.

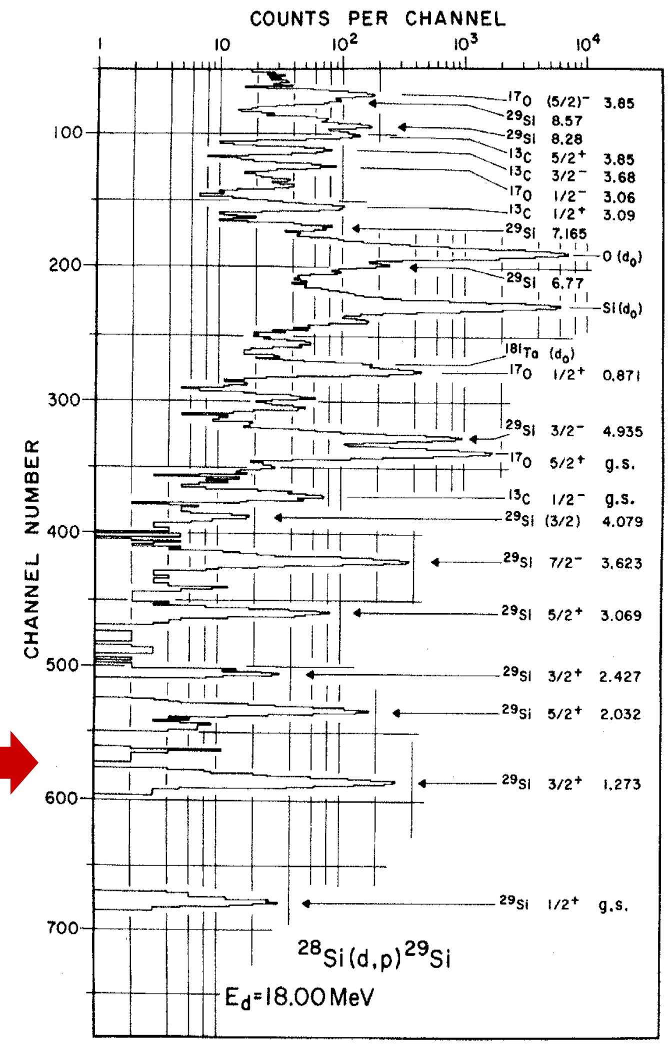
"Proton spectra were recorded in multi-channel analyzers and punched on IBM cards for further data processing "

PHYSICAL REVIEW C VOLUME 4, NUMBER 5 NOVEMBER 1971

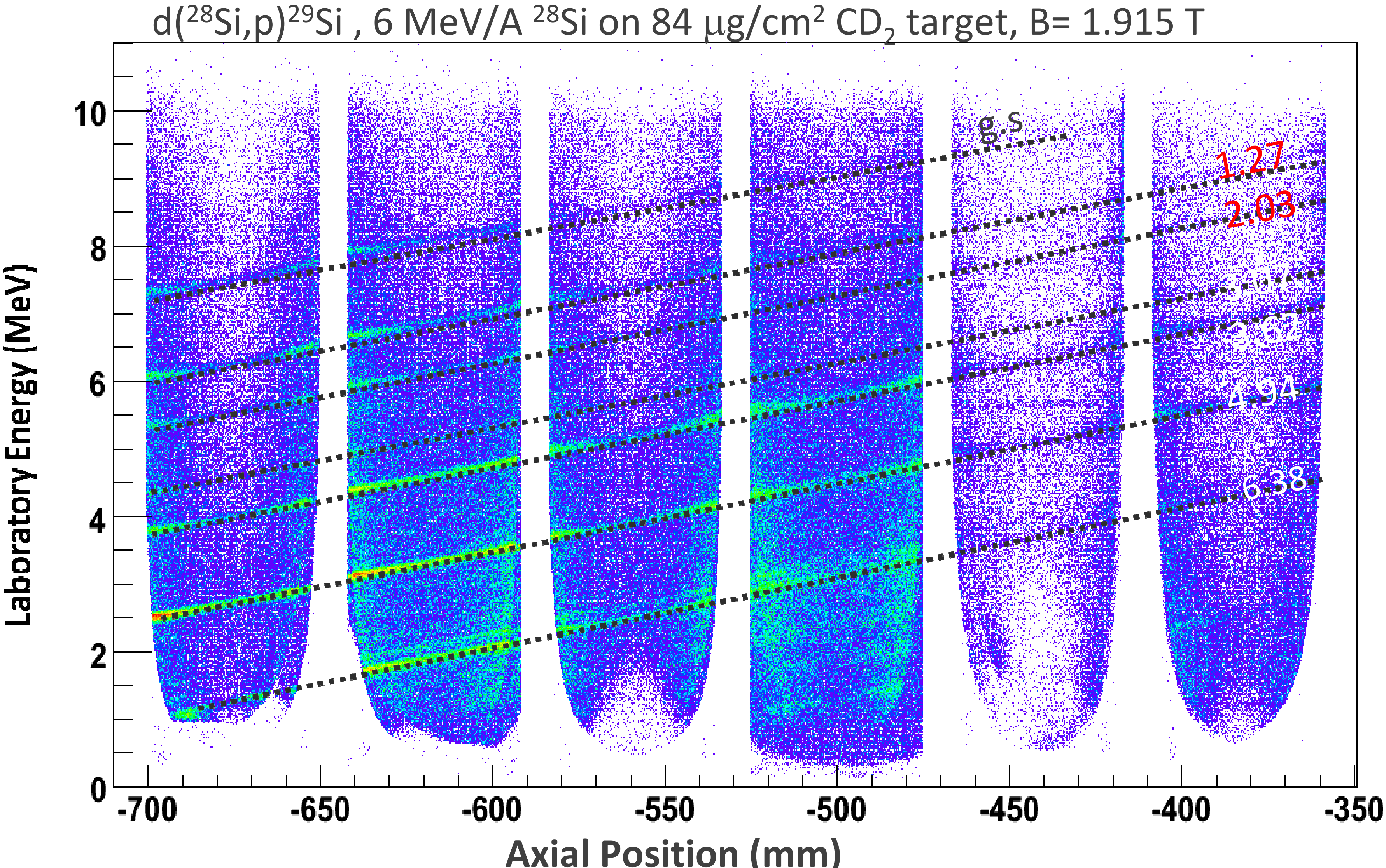
Study of the (d, p) Reaction on ^{28}Si, ^{32}S, and ^{36}Ar at $E_d = 18.00$ MeV*

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



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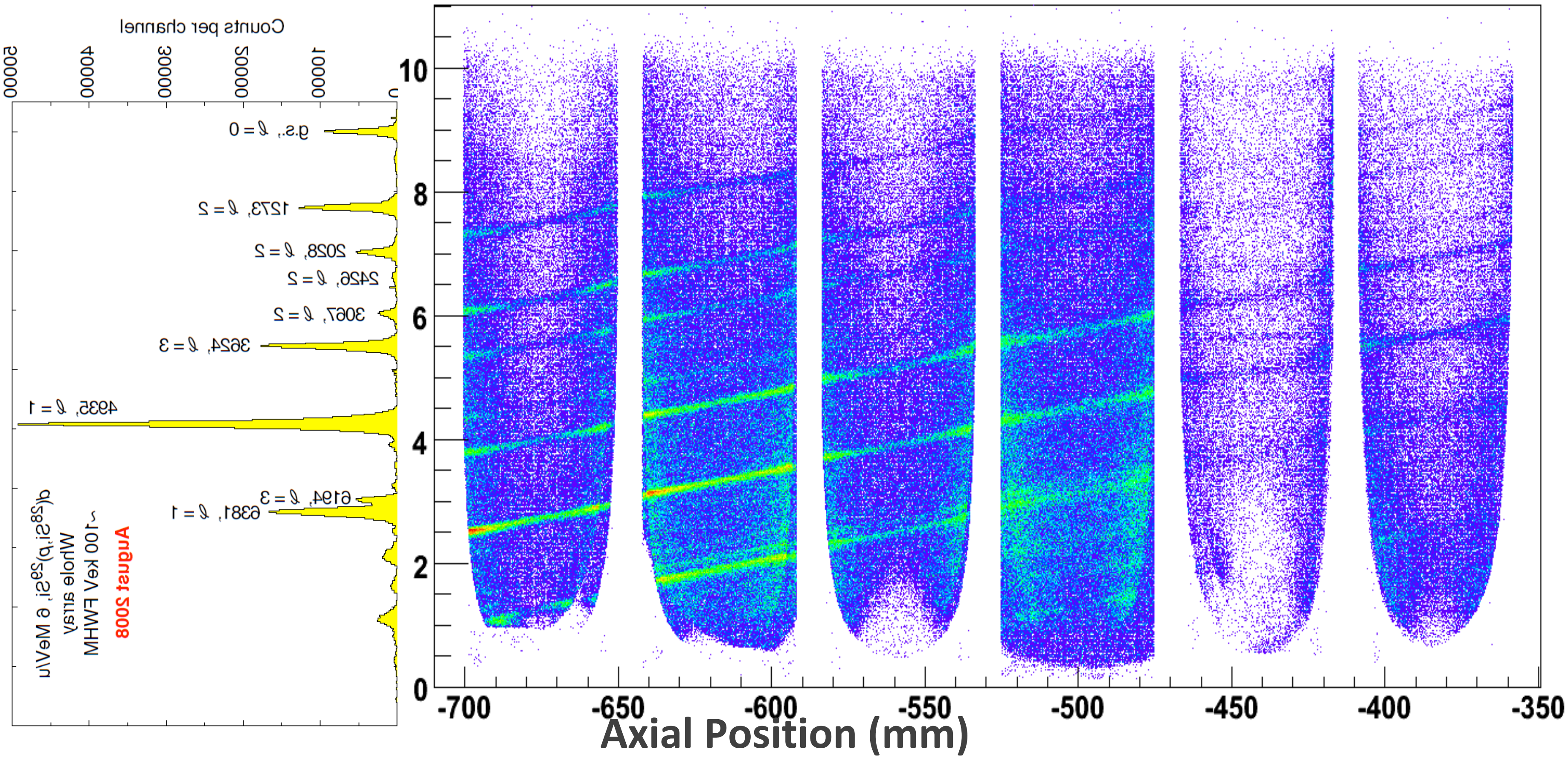
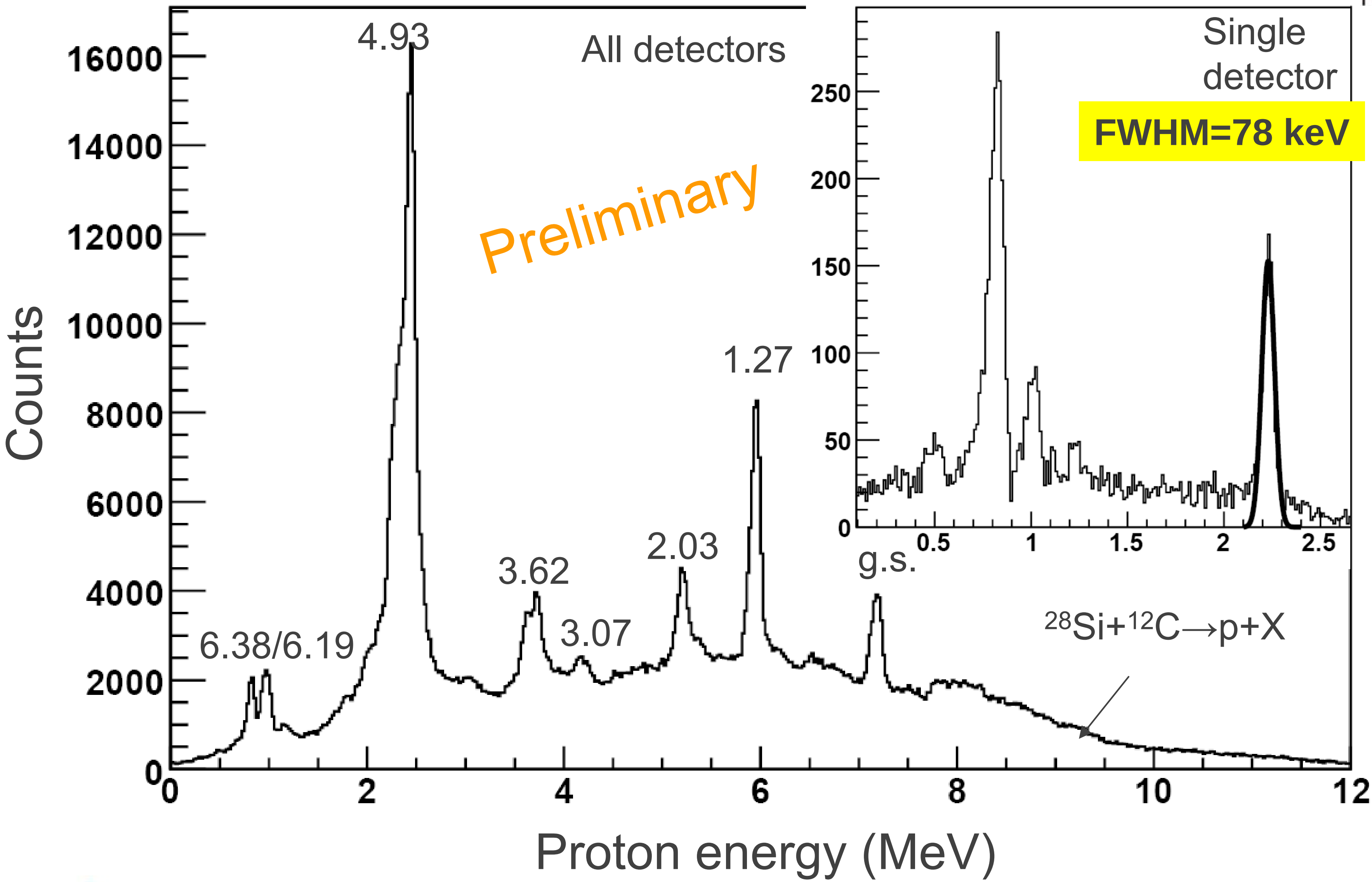
Energy vs. position - it works as expected

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



First HELIOS spectra



Upgrades to HELIOS

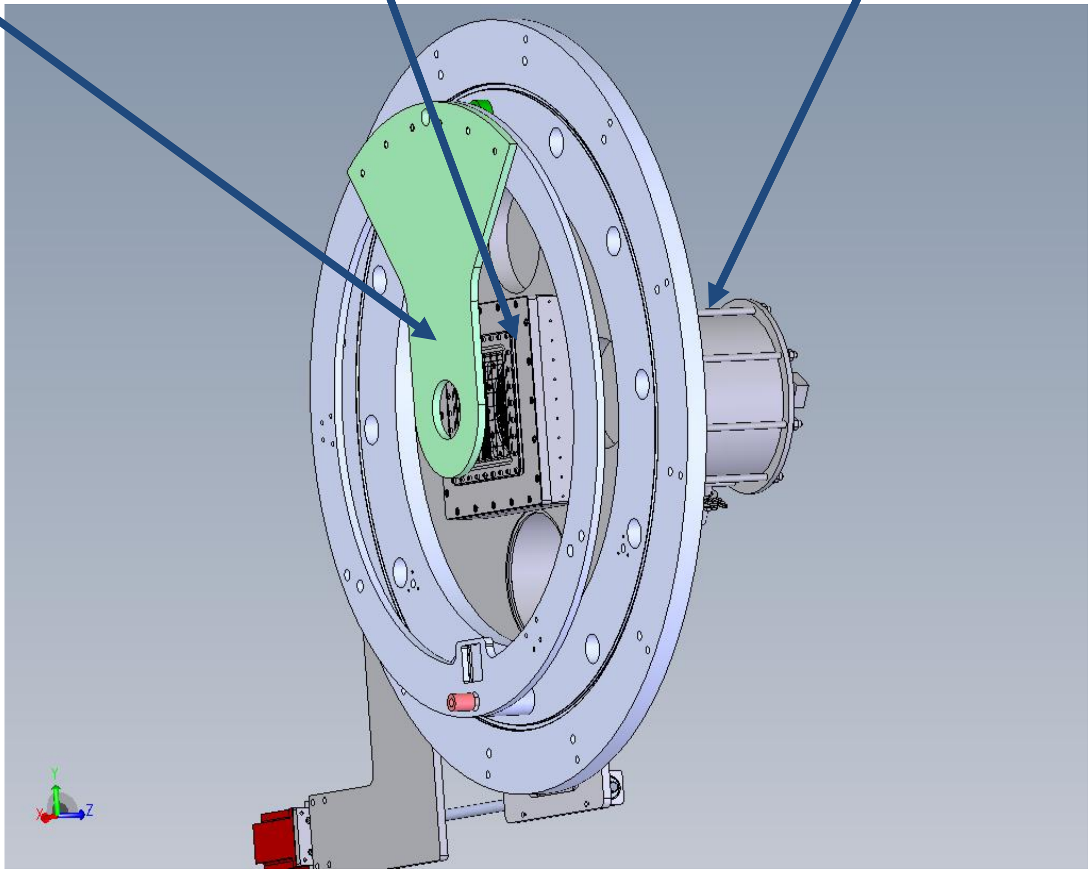
- PPAC+Bragg Recoil detector (Manchester University)
- Gas target to allow for (^{3}He,p), (^{3}He,d), (^{3}He,α) reactions etc.
- Full efficiency backward array (2 cm wide Si wafers)
- Forward Si detector array
- Etc.
- Etc.

Manchester recoil detector

Support for new forward array

PPAC

Bragg curve detector



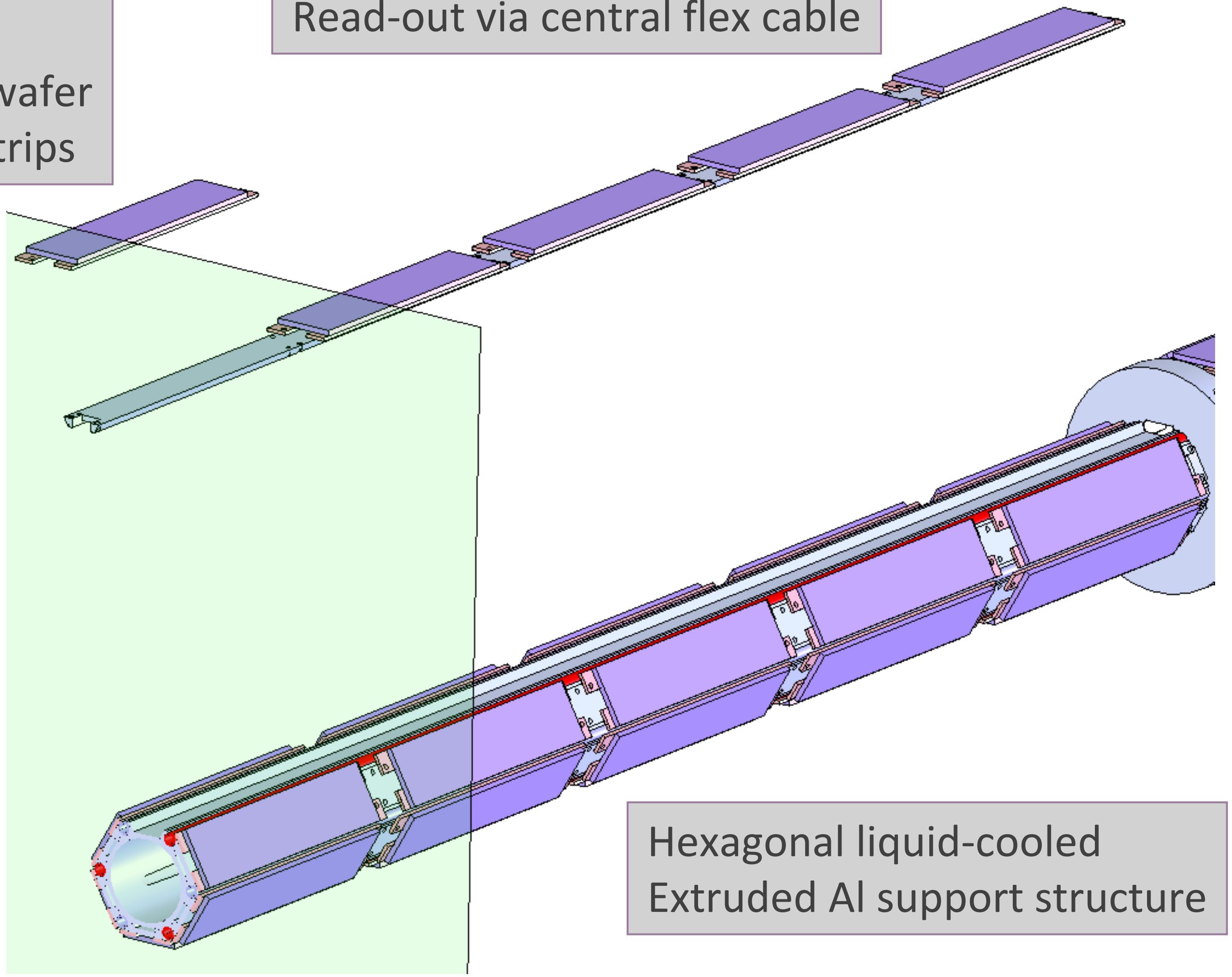
Cryogenic Gas target for ^{3}He and ^{4}He

(Brad DiGiovine)

New efficient Si detector array

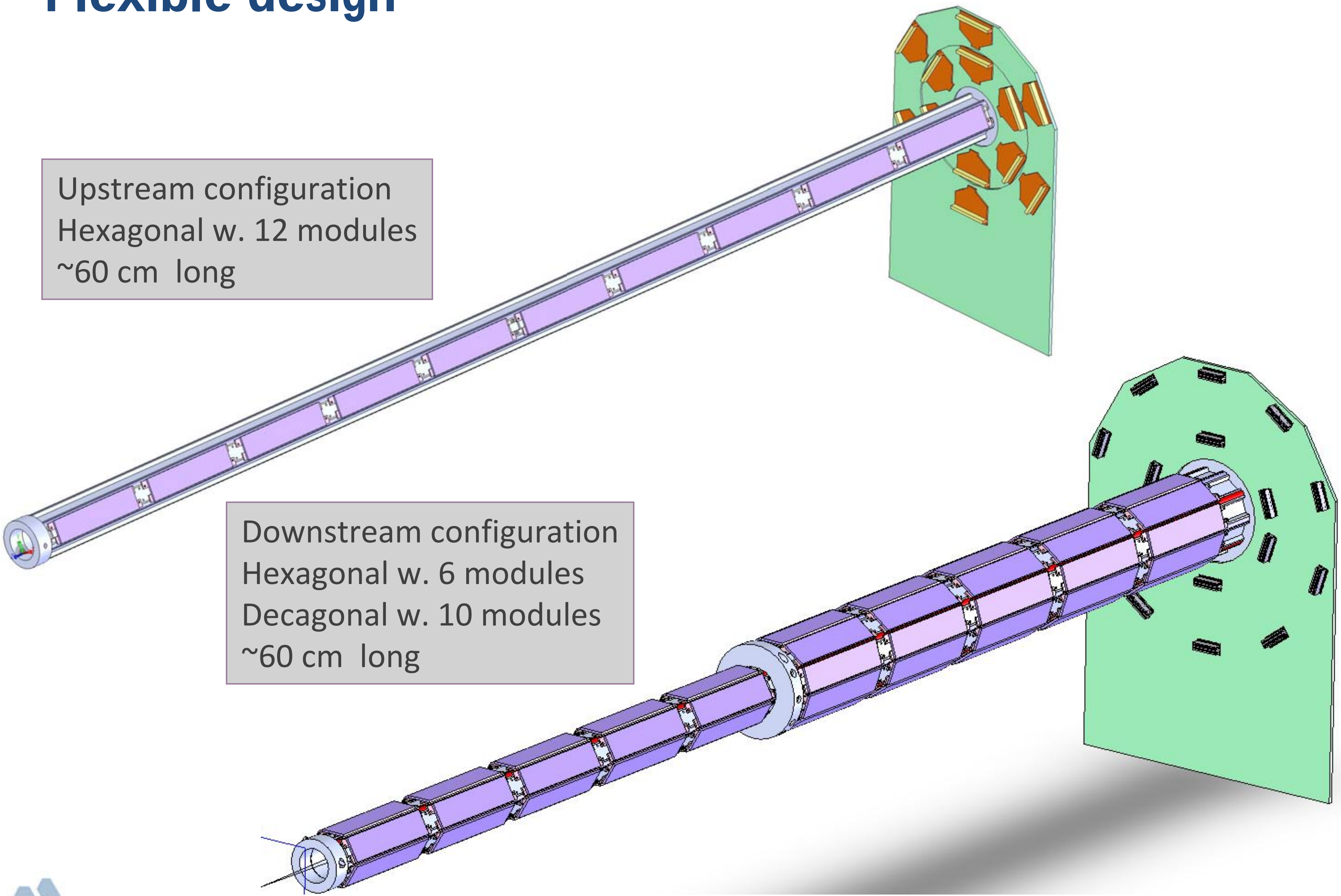
De-mountable
Resistive wire
11x53 mm^2 Si wafer
on 2 ceramic strips

Standard 5 detector module
Read-out via central flex cable



Hexagonal liquid-cooled
Extruded Al support structure

Flexible design

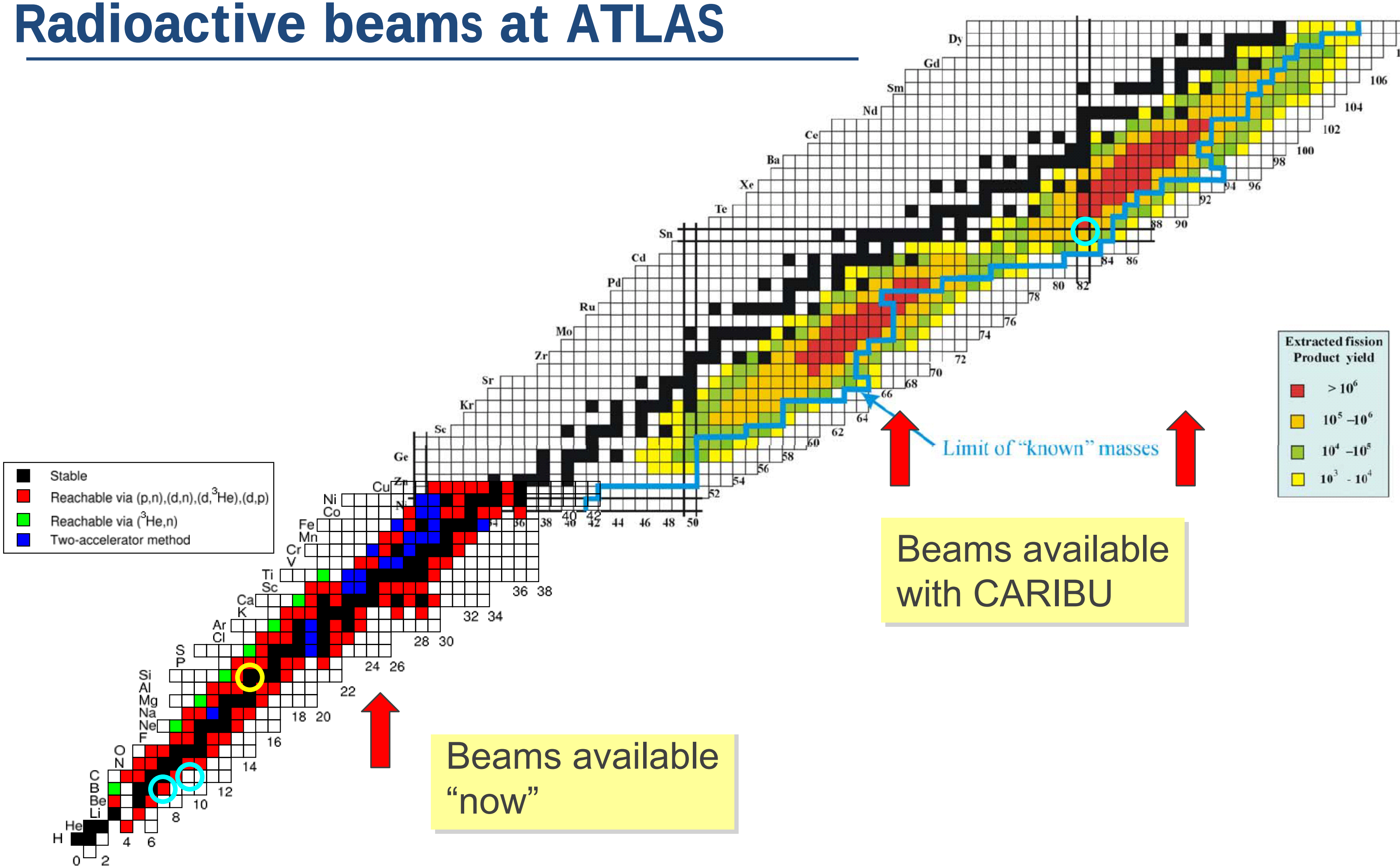


Upstream configuration
Hexagonal w. 12 modules
~60 cm long

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

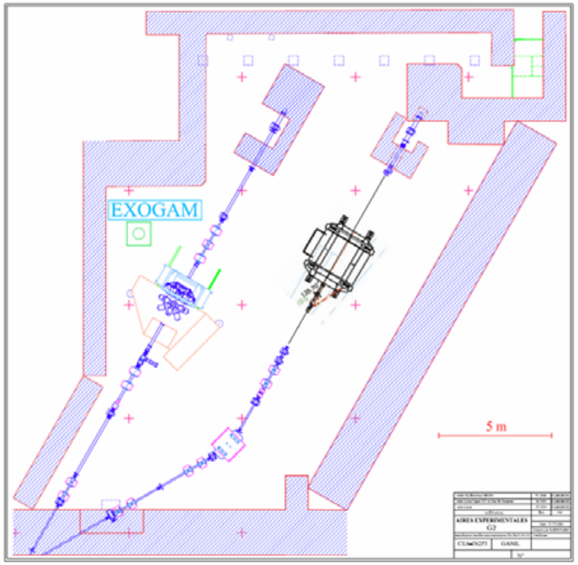
Radioactive beams at ATLAS and elsewhere

Radioactive beams at ATLAS

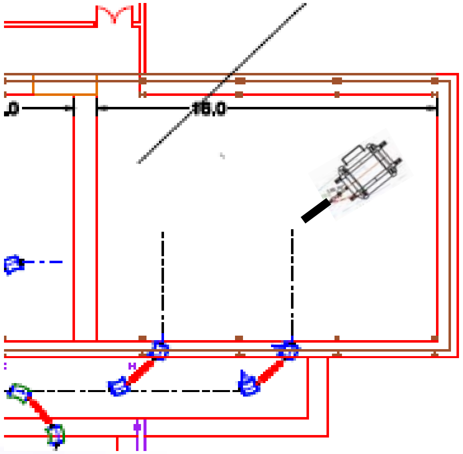


HELIOS-like spectrometers elsewhere

- HELIOS spectrometer at Spiral-2 (2013/14)
  - Proposal presented at Spiral-2 week, January 28, 2010
  - DOE funding proposal accepted
  - Recently put on hold by DOE



- HELIOS spectrometer at FRIB
  - Proposal presented at FRIB Instrumentation Workshop, February 20, 2010
  - Well received by FRIB Science Advisory Committee
  - No funding yet – collaboration in process of forming.



HELIOS at HIE-ISOLDE

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the
ISOLDE and Neutron Time-of-Flight Experiments Committee
for experiments with HIE-ISOLDE

A HELIcal Orbit Spectrometer (HELIOS) for HIE-ISOLDE

S.J. Freeman[1], A. Andreyev[2], B.B. Back[3], V. Bildstein[4], P.A. Butler[5], W.N. Catford[6], J. Cederkall[7], R. Chapman[2], D. Di Julio[7], M. Huyse[8], D. Jenkins[9], B.P. Kay[3], T.Kröll[10], R.Krücken[4], D. Müncher[4], N. Nowak[4], R. Raabe[8], J.P.Schiffer[3], J.S. Thomas[1], P. Van Duppen[8], R. Wadsworth[9], N. Warr[11], K. Wimmer[4] and A.H.Wuosmaa[12]

[1] University of Manchester, UK; [2] University of the West of Scotland, [3]Argonne National Laboratory, USA; [4] Technischen Universität München, Germany; [5]University of Liverpool, UK; [6] University of Surrey, UK; [7] Lund University, Sweden, [8]Katholieke Universiteit Leuven, Belgium, [9]University of York, UK; [10]Technischen Universität Darmstadt, Germany; [11] Universität zu Köln, Germany; and [12]Western Michigan University, USA

Spokesperson: Sean.Freeman@manchester.ac.uk

Abstract
The potential for a HELIcal Orbit Spectrometer at ISOLDE is discussed.

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