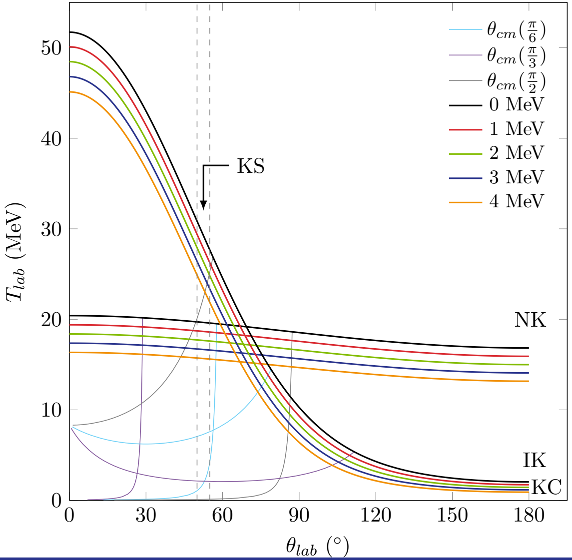
Updates from the ISOLDE Solenoidal Spectrometer

Patrick T. MacGregor

ISOLDE Workshop 2023

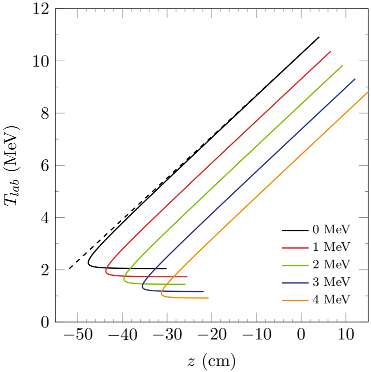


NK: Beam = *d*, Target = ^{A}X
IK: Beam = ^{A}X, Target = *d*

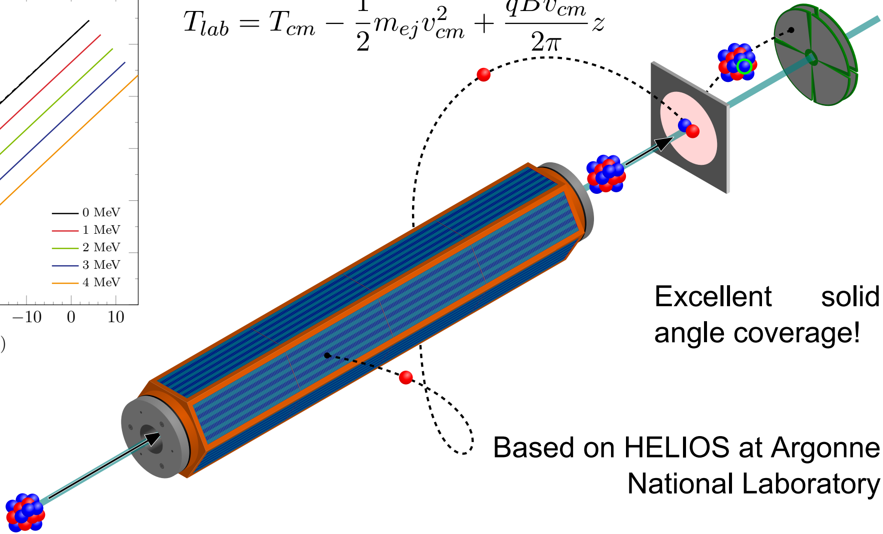
Kinematic shift (KS)
Broadens peaks in energy spectrum.

Kinematic compression (KC)
Reduces spacing between peaks in energy spectrum.

Result: lower-quality information on residual state populated using particle detection *alone*.



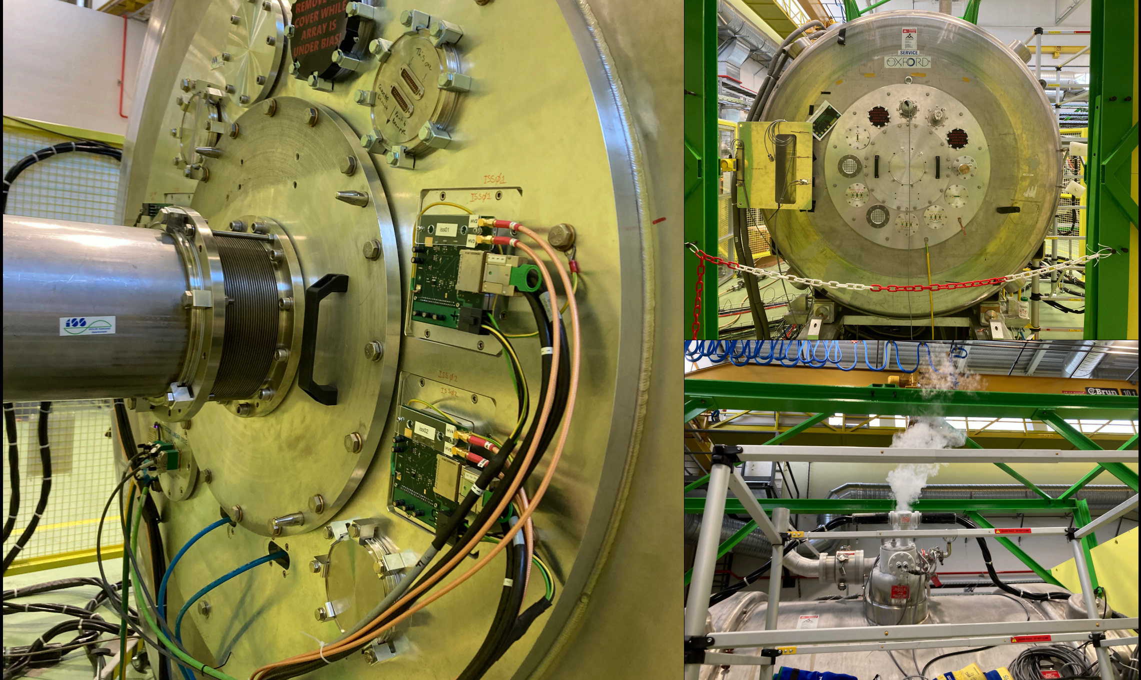
$$T_{lab} = T_{cm} - \frac{1}{2} m_{ej} v_{cm}^2 + \frac{qBv_{cm}}{2\pi} z$$



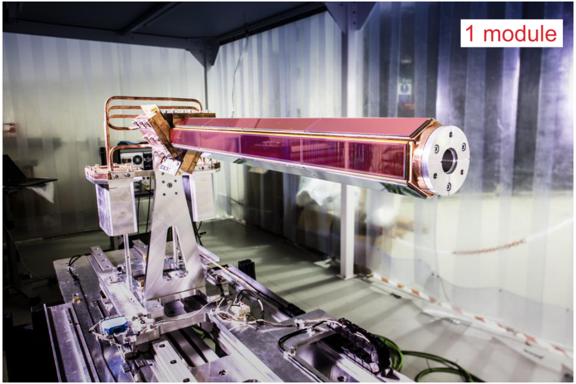
Excellent solid angle coverage!

No kinematic compression!

Based on HELIOS at Argonne National Laboratory

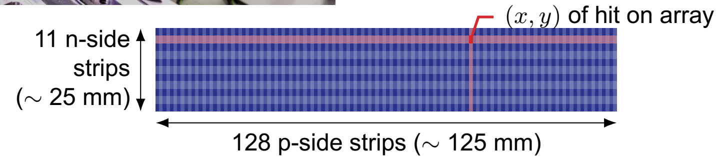

ARRAY IS
UNDER BIAS
ISSØ1
iss01
HV2
HV3
ISSØ2
iss02
HV4
SERVICE
OXFORD

J. M. Ordan. General Photo. (2022). URL: https://cds.cern.ch/record/2800900



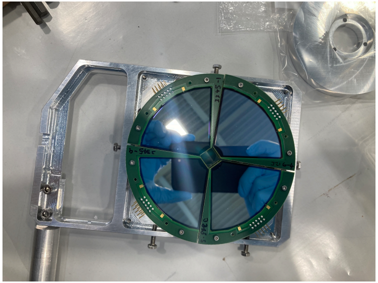
Technical details

- Designed and built in Liverpool during LS2
- 3 modules of DSSDs = 2 sides of hexagonal array each
- Each module has 512 p-side channels and 88 n-side channels: total = 1800!
- Approx. 500 mm active silicon length
- Has ASIC readouts using chips designed for R^3B project
- NIM paper being written



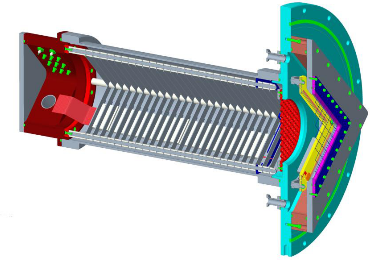
Detectors at ISS: recoil detection

Silicon mode



Used for reactions with lighter beams e.g. ^{49}Ca(*d*,*p*) (2023).

Recoil-gas mode



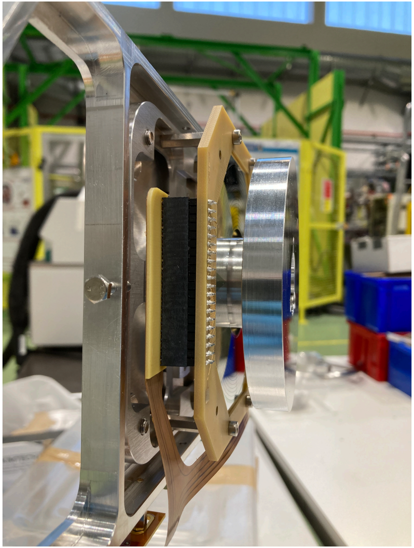
Used for heavier beams, but still being improved (more later) e.g. ^{92,94}Kr(*d*,*p*) (2022)

Singles mode

- No direct recoil detection.
- Use EBIS pulse time, as well as other tricks, to clean the E v.s. z spectrum.
- Used where recoil detection difficult/impossible.

Necessary for reactions using heaviest beams e.g. ^{212}Rn(*d*,*p*) (2021)

Detectors at ISS: ancillary detectors

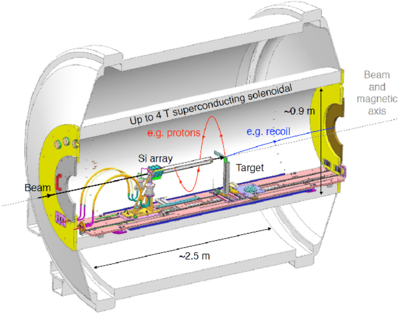


Can use additional ancillary detectors to complement measuring recoil + ejectile from (*d*,*p*) reaction:

- Luminosity detector for measuring elastically scattered deuterons (pictured)
- Zero-degree detector for measuring beam composition

Multiple motors allow different configurations under vacuum.

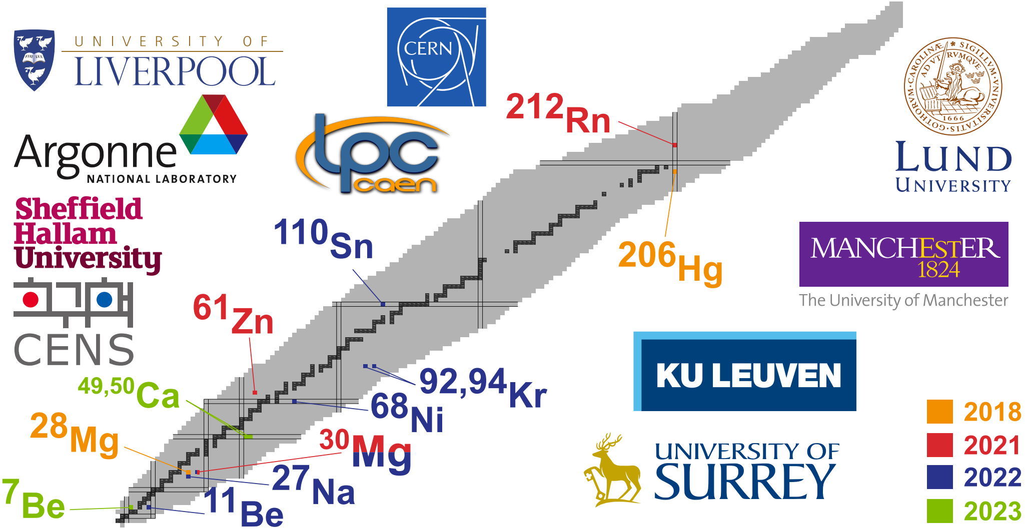
Additional detector designs have been proposed for future experiments...



Beams from ISOLDE

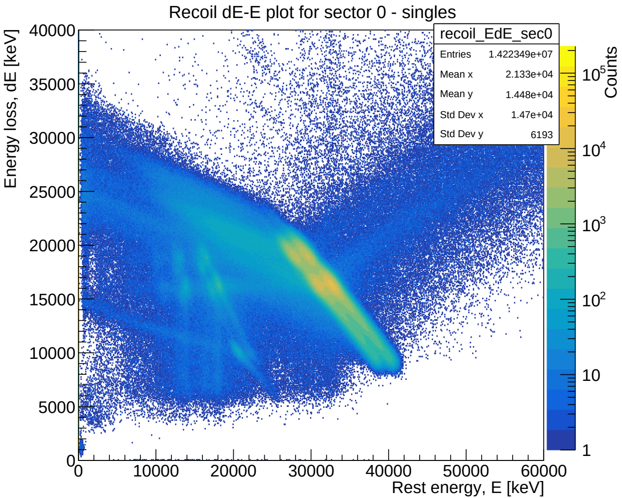
ISOLDE Solenoidal Spectrometer

[1]

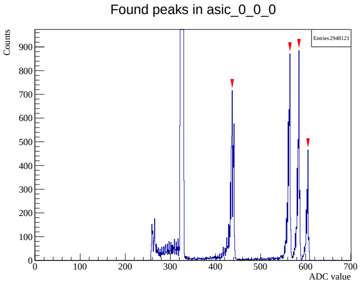


[1] E. Simpson. 2023. URL: https://people.physics.anu.edu.au/~ecs103/chart/ (Date accessed: 05/04/2023).

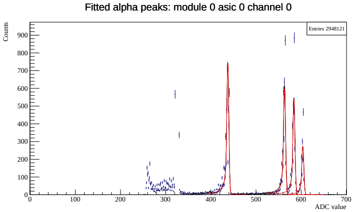
ISSSort



Recoil dE-E plot for sector 0 - singles
recoil_EdE_sec0
Entries 1.422349e+07
Mean x 2.133e+04
Mean y 1.448e+04
Std Dev x 1.47e+04
Std Dev y 6193
Energy loss, dE [keV]
Rest energy, E [keV]
Counts



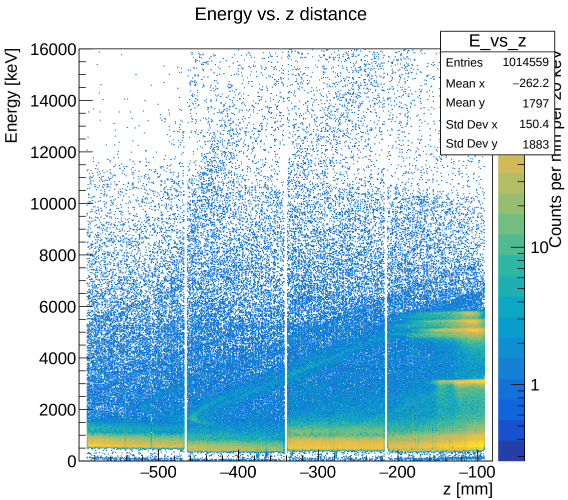
Found peaks in asic_0_0_0
Counts
ADC value
Entries 2948121

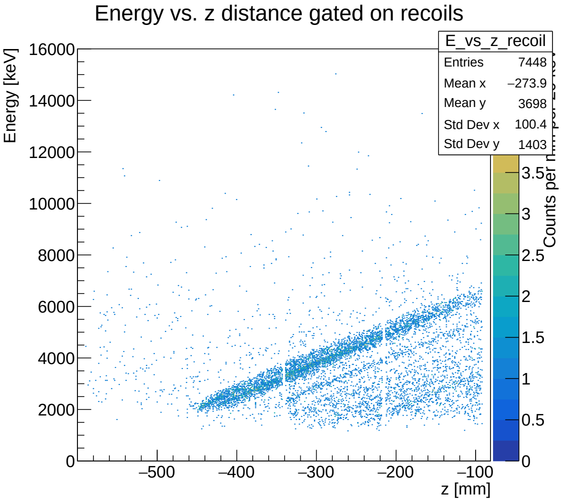


Fitted alpha peaks: module 0 asic 0 channel 0
Counts
ADC value
Entries 2948121

How are data processed - the ^{30}Mg(d,p) reaction

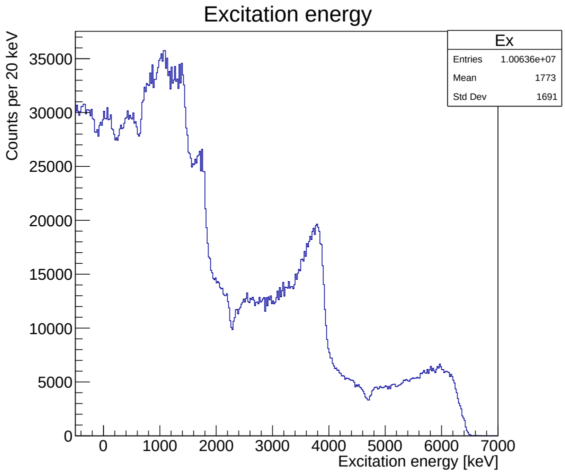
ISSSort

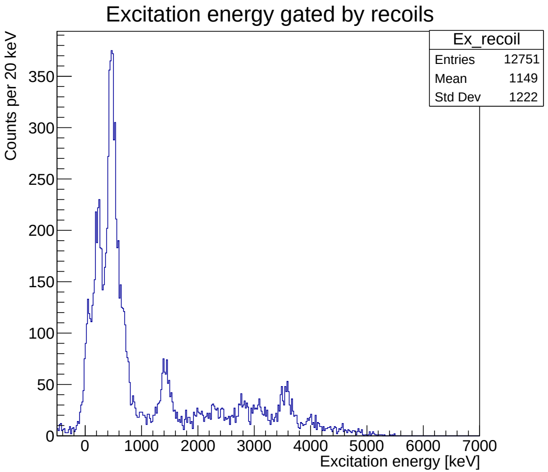




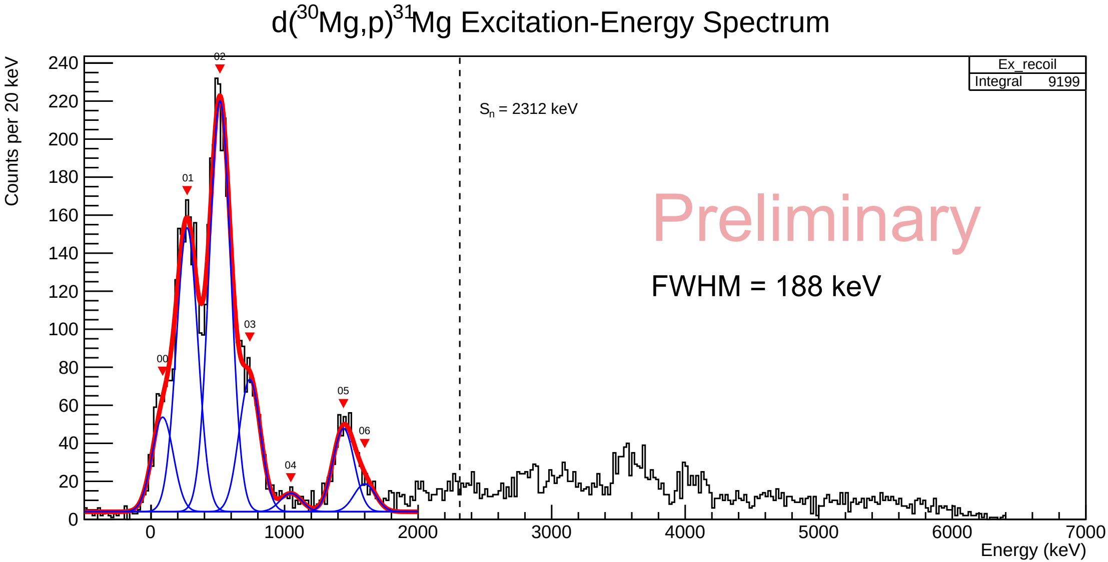
How are data processed - the ^{30}Mg(d,p) reaction

ISSSort

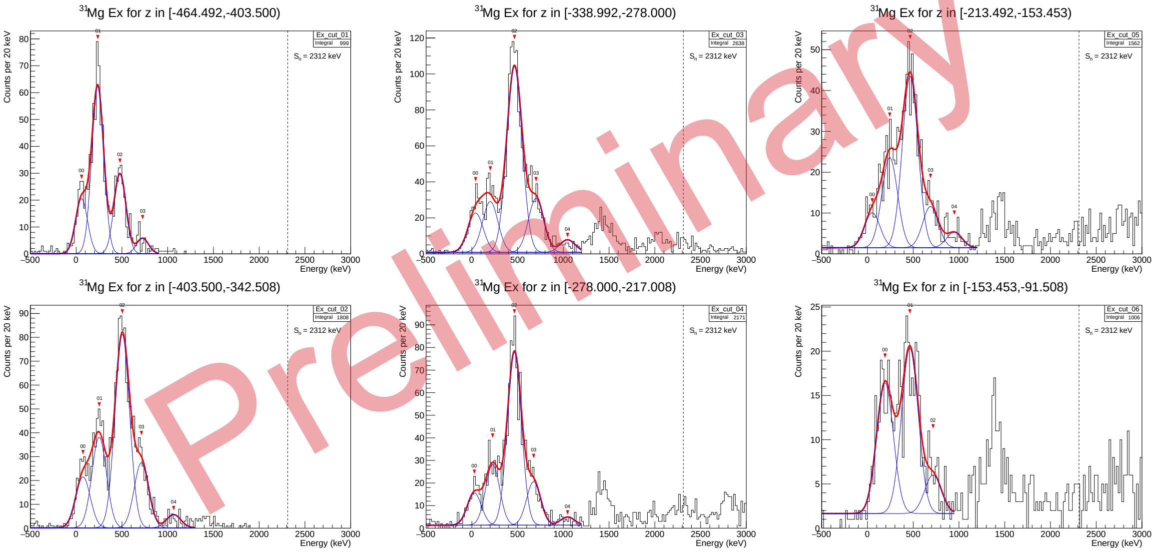




How are data processed - the $^{30}Mg(d,p)$ reaction



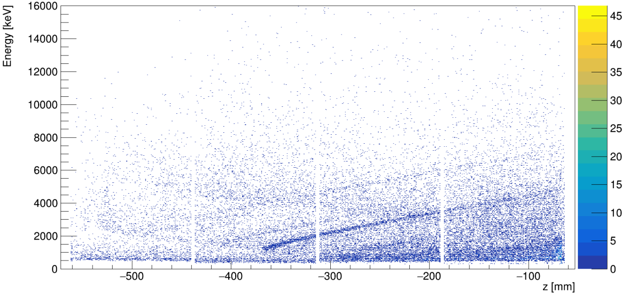
How are data processed - the $^{30}Mg(d,p)$ reaction

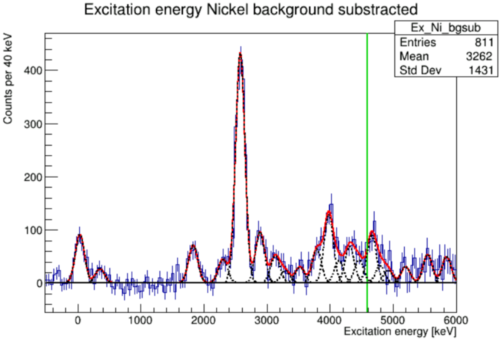


2022 physics

Single-neutron transfer on 68Ni
503/1-001 - Council Chamber, CERN

Andreas Ceulemans
Wed 29/11 15:15-15:27





[2]

Identified states corresponding to $\nu d_{5/2}$ orbital e.g. large state at $\sim$ 2.6 MeV. In preparation for publication...

[2] A. Ceulemans. Private communication.

2022 physics

ISOLDE Solenoidal Spectrometer

Onset of deformation in the neutron-rich krypton isotopes via transfer reactions with the ISOLDE Solenoidal Spectrometer *503/1-001 - Council Chamber, CERN*	*Annie Dolan*
Evolution of Single Particle Trends Outside the N = 16 Isotones: The ^{27}Na(*d*,*p*) Reaction at ISS. *503/1-001 - Council Chamber, CERN*	*Samuel Boyd Reeve* Fri 01/12 15:30-15:42
The (*d*,*p*) reaction on ^{11}Be using ISS: Bringing clarity to the structure of ^{12}Be *503/1-001 - Council Chamber, CERN*	*Jie Chen* Fri 01/12 15:45-15:57

2022 also had ^{30}Mg(*d*,*p*) and ^{110}Sn(*d*,*p*) reactions, as well as...

SpecMAT overview

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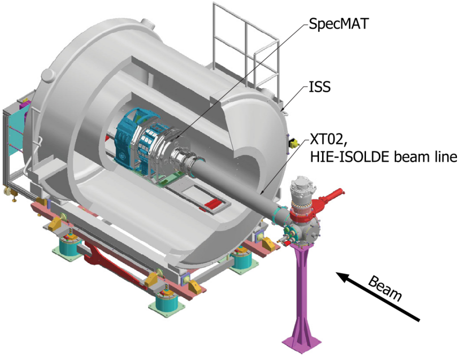
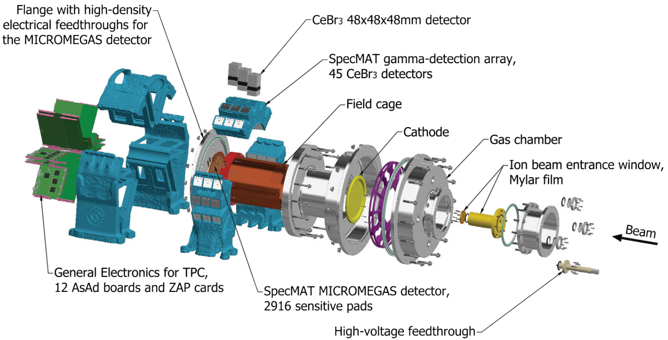
SpecMAT





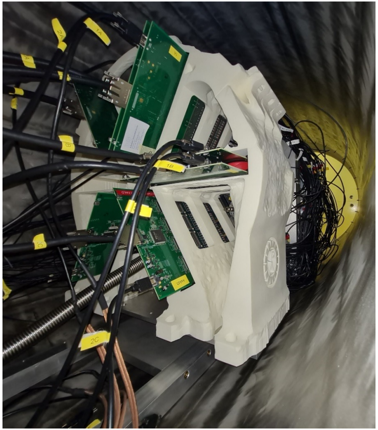
[3]

Active target within ISS combined with a time-projection chamber and CeBr detectors. Led by team from KU Leuven

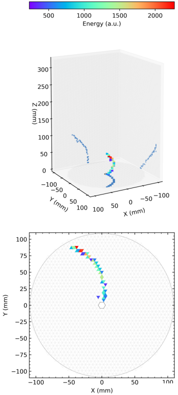
[3] O. Poleshchuk et al. Nucl. Instrum. Methods Phys. Res., Sect. A **1015**, 165765. (2021) .

Commissioning of the detector at HIE-ISOLDE 2022, offline

Slide courtesy of O. Poleshchuk



SpecMAT installed in the ISS solenoid at ISOLDE



α-particle track measured in B=2.5T (offline)

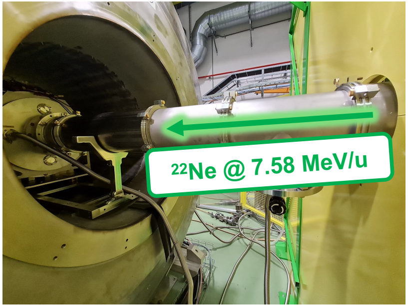
Commissioning of the detector at HIE-ISOLDE 2023, online

^{22}Ne @ 7.58 MeV/u on **D_2 @ 800 mbar**

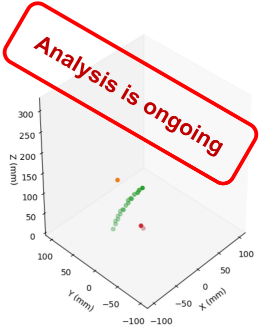
8 μm Mylar window → Beamline 8×10^{-8} mbar | Detector 800 mbar

Main reaction branches expected to observe:
- $^{22}Ne(d,d)$
- $^{22}Ne(d,p)$
- $^{22}Ne(d,^{3}He)$
- $^{22}Ne(d,t)$

Online



D_2



Slide courtesy of O. Poleshchuk

ISOLDE Solenoidal Spectrometer

SPECMAT

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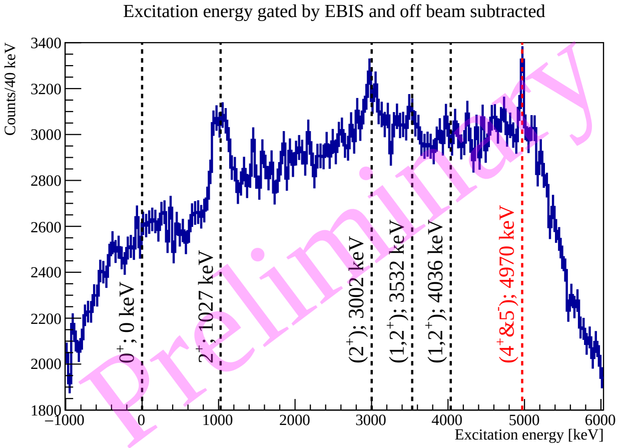
KERN- EN STRALINGSFYSICA

European Research Council

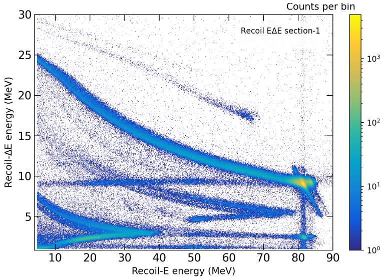
2023 physics: summer Ca runs

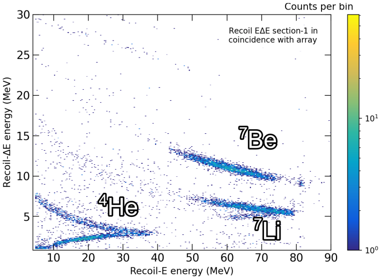


[4]

Reactions: ^{49,50}Ca(d,p)
Motivation: Measure single-particle structure of neutron-rich calcium nuclei to better understand magicity of N = 32,34 shell closure.
Progress: Experiments in early stages on analysis. Image here is of theory predictions matched to experiment in the ^{49}Ca(d,p) reaction.

4 F. Browne. Private communication.





[5]


[6]

Reaction: ^{7}Be(d,p)

Motivation: Measure single-particle structure at high-excitation energy $\rightarrow$ low-energy protons in weaker (1.42 T) magnetic field.

Progress: Finished less than a month ago...

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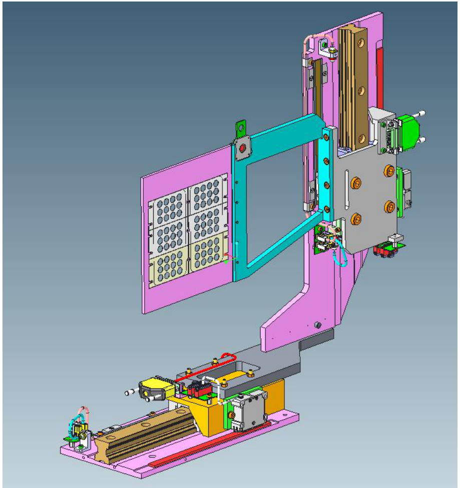
5 K. Haverson. Private communication.

6 M. Gai. Private communication.

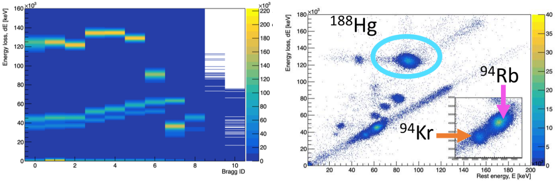


Detector bed upgrade

- Additional motor for target ladder in vertical axis: 2D movement
- More targets available for use: good for heavy beams

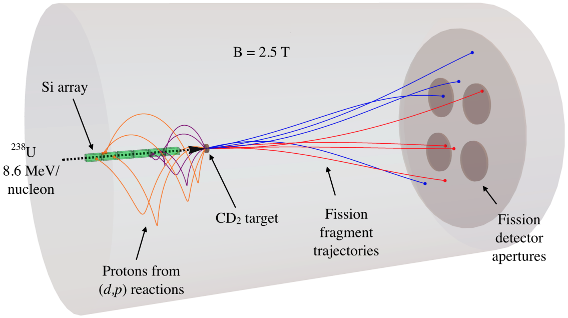
Gas recoil detector upgrade

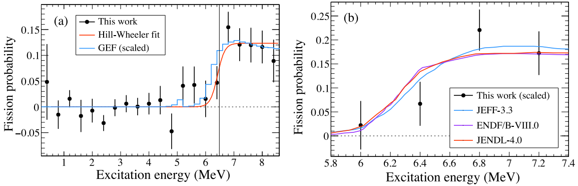
- Beam blocker gaining similar 2D mechanism
- Faster preamps



Looking to the future: transfer-induced fission

MANCHESTER 1824 The University of Manchester · Argonne NATIONAL LABORATORY · KU LEUVEN · CHALMERS UNIVERSITY OF TECHNOLOGY





(d,pf) surrogate reaction has advantages over traditional fission measurements:

- Fission fragments focussed into small solid angle $\Rightarrow$ efficient detection
- Full Bragg peak spectroscopy possible at these energies
- ISOLDE gives access to short-lived actinides

Can combine with scintillator array for (n,γ)/(n,f)…

Successful proof-of-principle ^{238}U(d,pf) experiment at HELIOS!

[7] S. A. Bennett et al. Phys. Rev. Lett. **130**, 202501. (May 2023) .

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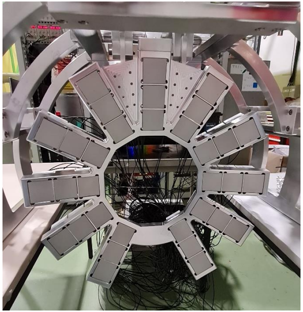
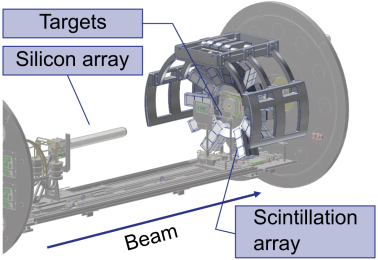
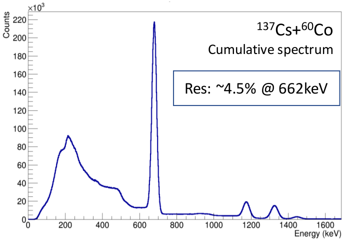
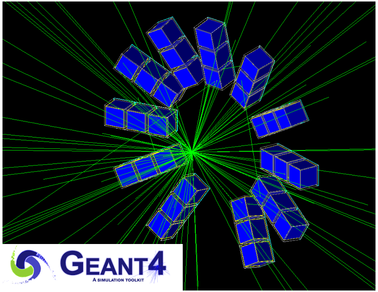
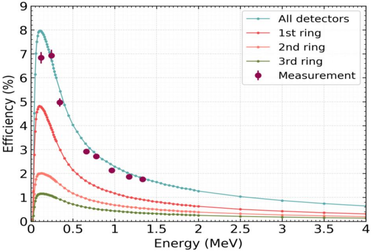


3 rings of 11 CeBr detectors from SpecMAT. Commissioned in Oct. 2022. Can be used for (d,$p\gamma$) experiments for astrophysics[8].









8 D. K. Sharp. Private communication.

Transfer-induced fission with scintillator array!

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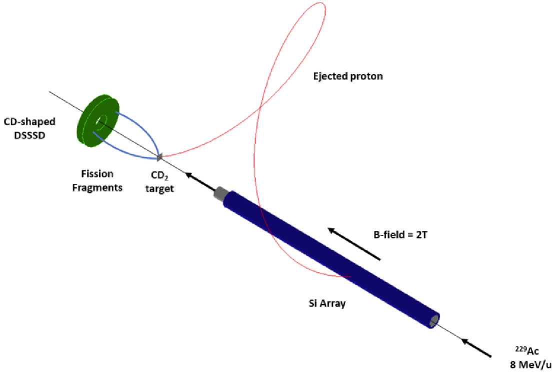
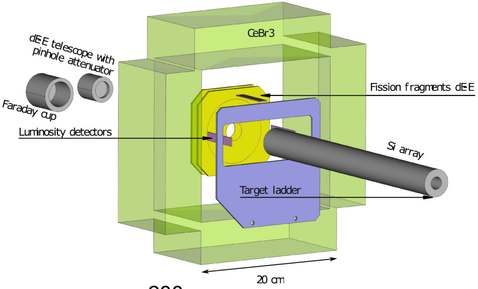




[9]

INTC P-668 ^{230}Ac(*d*,*pf*) proposal combines scintillator array with (*d*,*pf*) measurement. Detect fission fragments with CD detector. Geometrical efficiency of 82% for detecting both fission fragments.

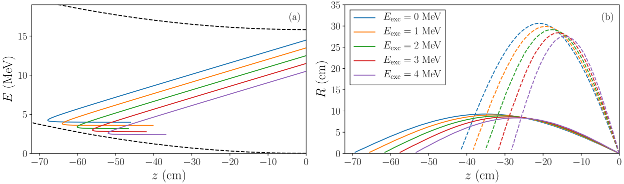
9 A. Kawęcka, M. V. Managlia, and A. Heinz. Tech. rep. Geneva: CERN, 2023. URL: https://cds.cern.ch/record/2872247.

Looking to the future: new reactions

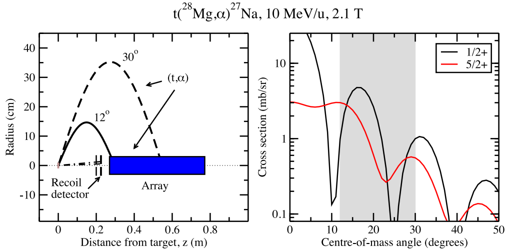
	INTC	Beam	Reaction	Spokesperson(s)
✓	P-582	^{9}Li	(*t*,*p*)	Y. Ayyad and E. Vigezzi
✓	P-599	^{134,136,138,140}Xe	(*t*,*p*)	A. O. Macchiavelli and K. Wimmer
?	P-679	^{78}Zn	(*t*,*p*)	S. Bottoni, F. Galtarossa
✓	P-609	^{146}Ce	(*d*,*d*′)	L. P. Gaffney
?	P-660	^{28,30}Mg	(*t*,α)	D. K. Sharp and P. T. MacGregor

N.B. tritium target purchased for SEC and Miniball experiments

(*t*,*p*): protons travel backwards[10]



(*t*,α) + (*d*,*d*′): protons travel forwards[11]



[10] K. Wimmer and A. O. Macchiavelli. Tech. rep. Geneva: CERN, 2021. URL: https://cds.cern.ch/record/2766315.

[11] D. K. Sharp and P. T. MacGregor. Tech. rep. Geneva: CERN, 2023. URL: https://cds.cern.ch/record/2845991.

Thanks to all collaborators on experiments!