MANCHESTER 1824

The University of Manchester

ISOLDE Solenoidal Spectrometer

Single-particle behaviour towards doubly-magic ^{24}O - $^{27}Na(d,p)^{28}Na$ in inverse kinematics

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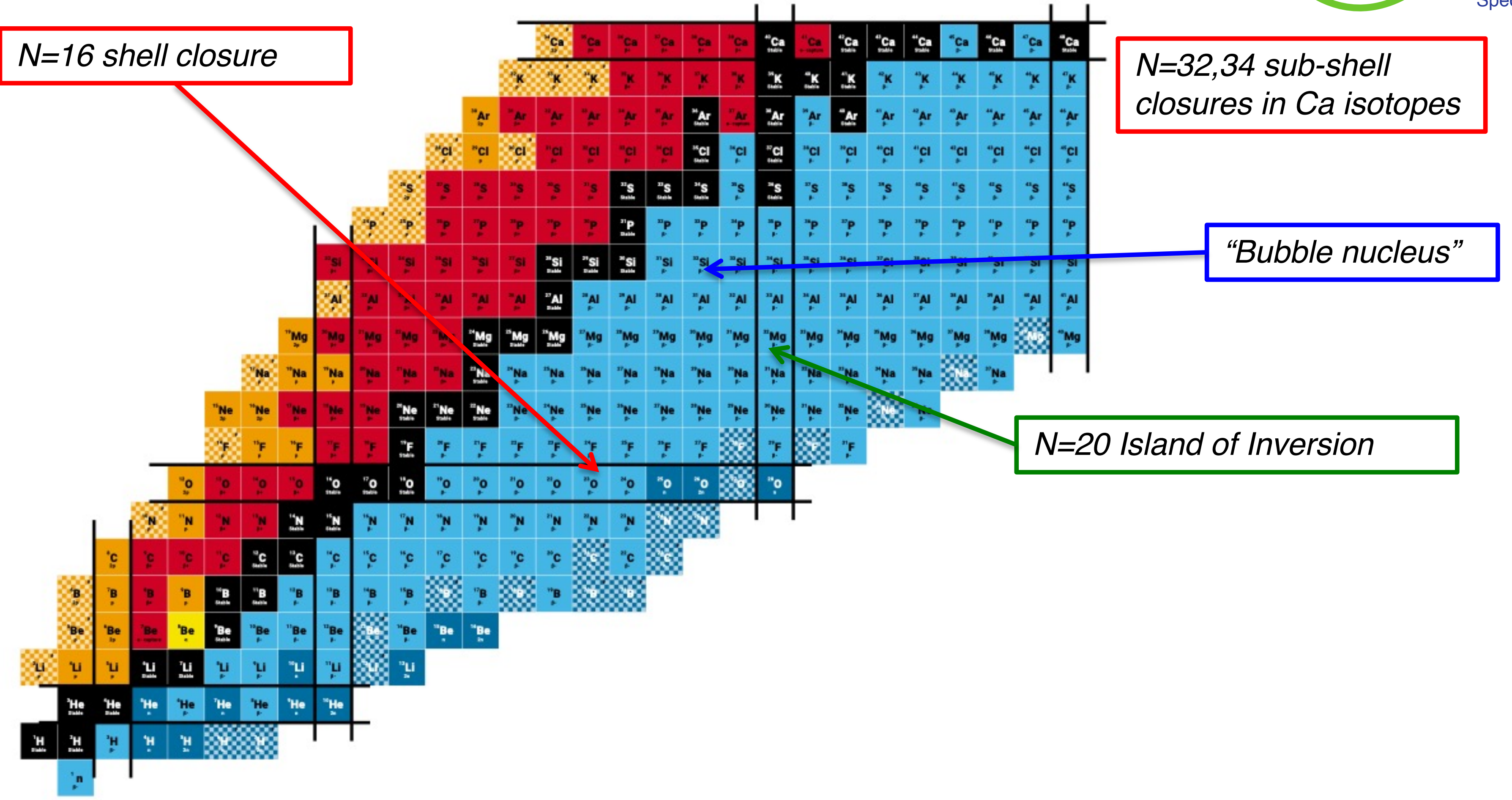
Requested shifts: 15 shifts
Beam: ^{27}**Na** at 10 MeV/u
Target: Deuterated polyethylene $(CD_2)_n$
Installation: ISOLDE Solenoidal Spectrometer

INTC meeting, February 9th 2022

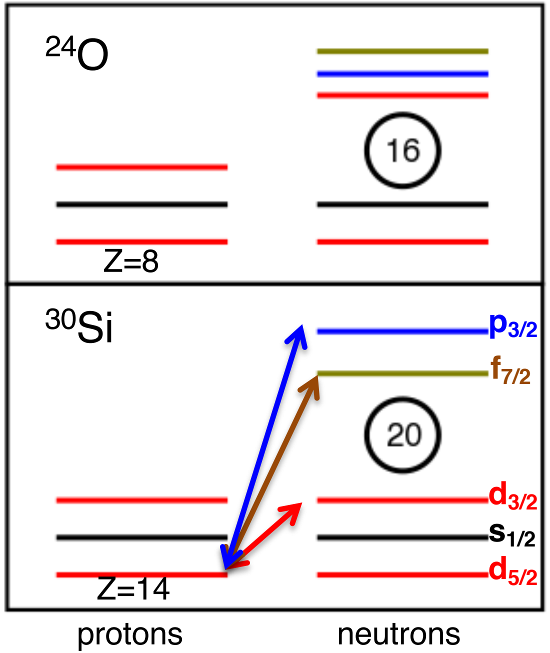
Changing nuclear structure in light neutron-rich nuclei



Changes in shell-closures – NN interaction

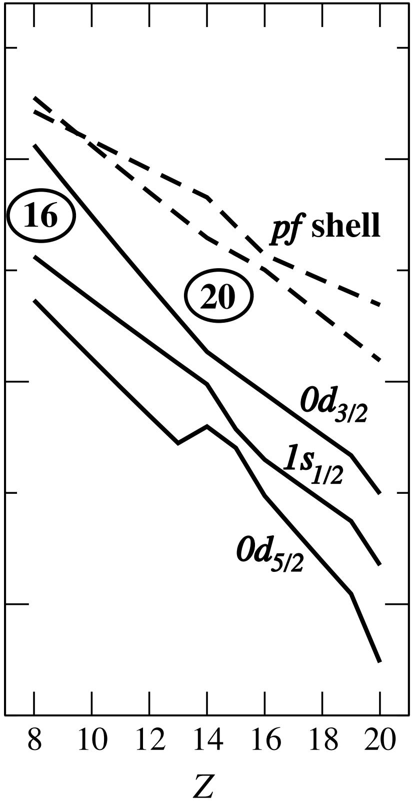
*In the oxygen isotopes, the N=20 shell gap has been shown to disappear with **the emergence of an N=16** shell gap in ^{24}O.*

This weakening shell gap also plays an important role in other regions, such as IOI



*Along N=16, **$\pi d_{5/2}$** is emptying. Different overlaps with **$\nu d_{3/2}$**, **$\nu f_{7/2}$** and **$\nu p_{3/2}$** results in **different monopole shifts**.*

*Changes in ESPE's provide details on **relative strengths of interactions**.*



T. Otsuka *et. al.*, Eur. Phys. J. A 15, 151–155 (2002)

Previous measurements – 28Mg(d,p)

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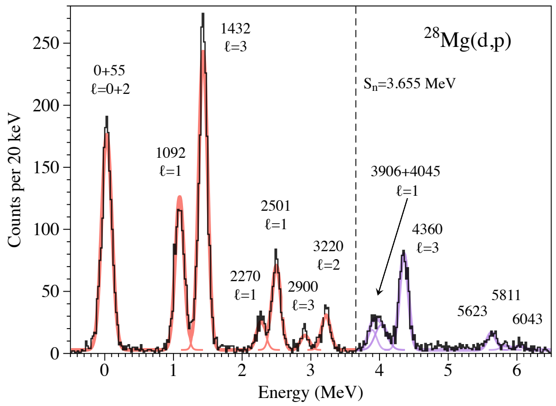
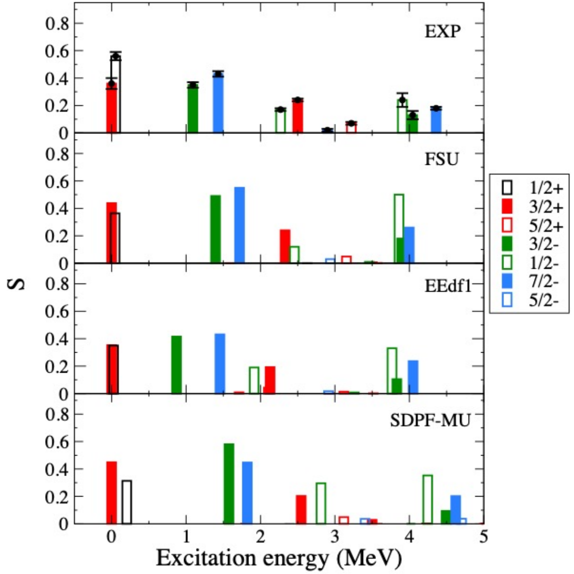
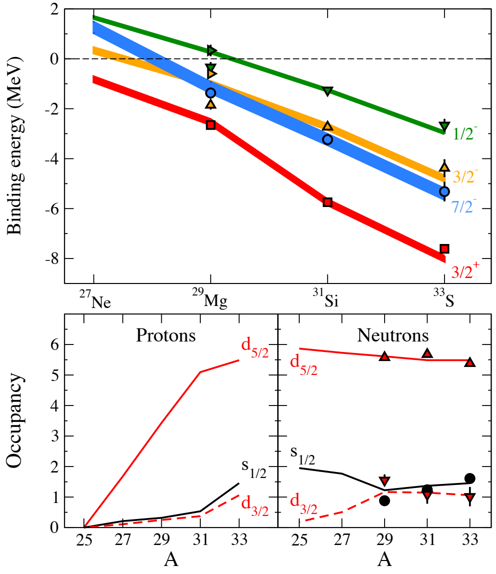
This collaboration has made previous measurements of states in ^{29}Mg (ISS) and ^{30}Al (HELIOS).

Investigated changes in single-particle centroids along N=17 and benchmarked new interactions that have been developed to better describe negative-parity intruder states near and into the IOI.

Data past Z=12 are needed, where changes in neutron occupancies are predicted by calculations, as well as differences in relative energies of orbitals.







PT. MacGregor et al., PRC 104, L051301 (2021).

Probing single-particle properties – transfer reactions

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Whilst nuclei in this region have been characterized by several different probes, details on single-particle properties are lacking.

Measurements of the single-particle properties along N=16 (or one neutron outside) provide details on the behaviour of the orbitals that define the shell gaps.

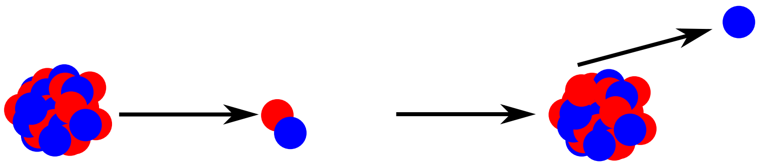
Extracted SFs can impose further constraints on calculations in addition to energies of levels.

Transfer reactions are ideal probe of SP properties.

*Extract **excitation energies** of states, **angular momentum** of state, **spectroscopic factor**.*

***Centroid of SP strength** – related to effective SPE's.*

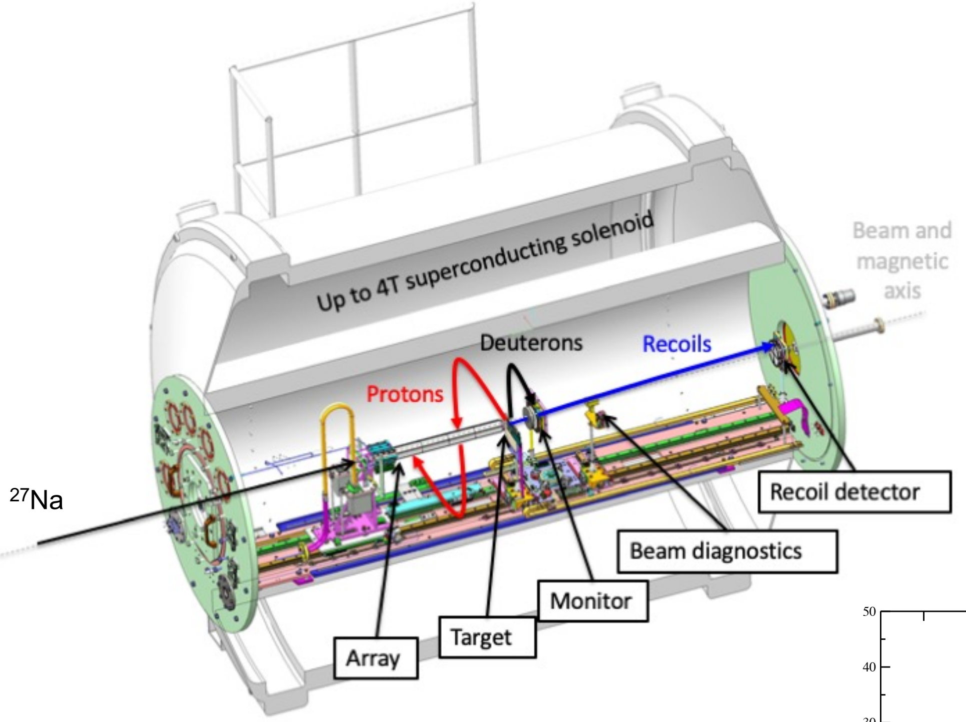
*Relative **occupancies/vacancies** of relevant orbitals.*



Use of solenoid technique results in clean identification of populated states and study fragmentation of SP strength in ^{28}Na up to and beyond S_n.

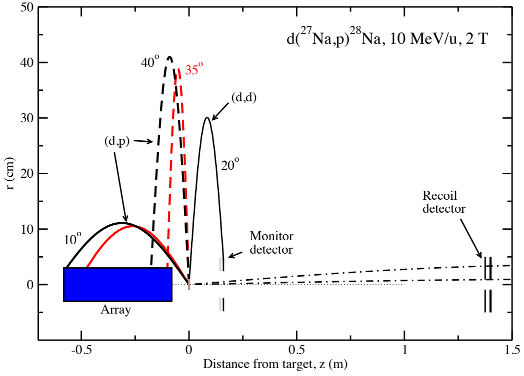
ISOLDE Solenoidal Spectrometer set up

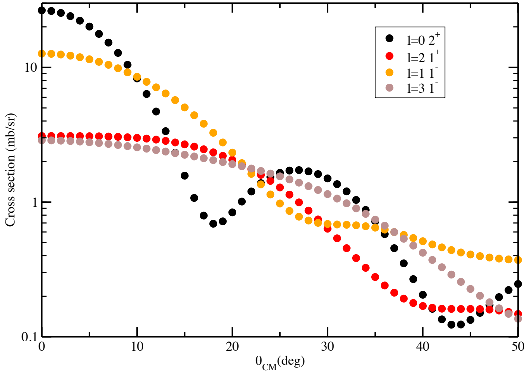
ISOLDE Solenoidal Spectrometer



- *2T field. Array-to-target 10cm.*
- *Silicon recoil detectors at rear of magnet.*
- *Annular silicon detector – monitor for absolute normalization.*
- *Beam diagnostics – FC and zero-degree detector.*

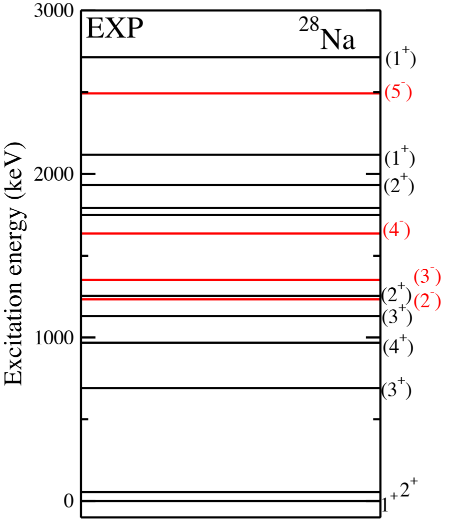
- *Beam energy of 10 MeV/u.*
- *CoM angular coverage for protons 10-40 degrees.*
- *Expect <50% ^{27}Al contamination – reaction of interest selected using recoil detectors.*



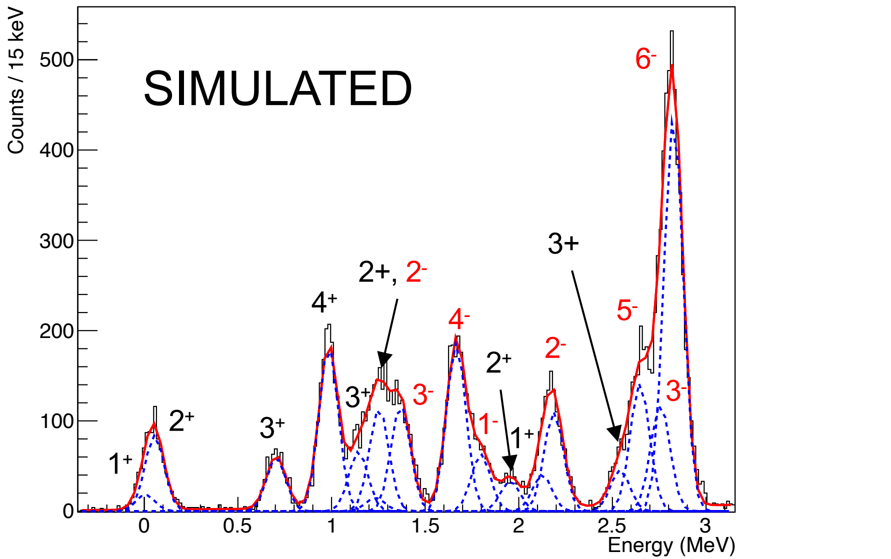


Simulations

ISOLDE Solenoidal Spectrometer

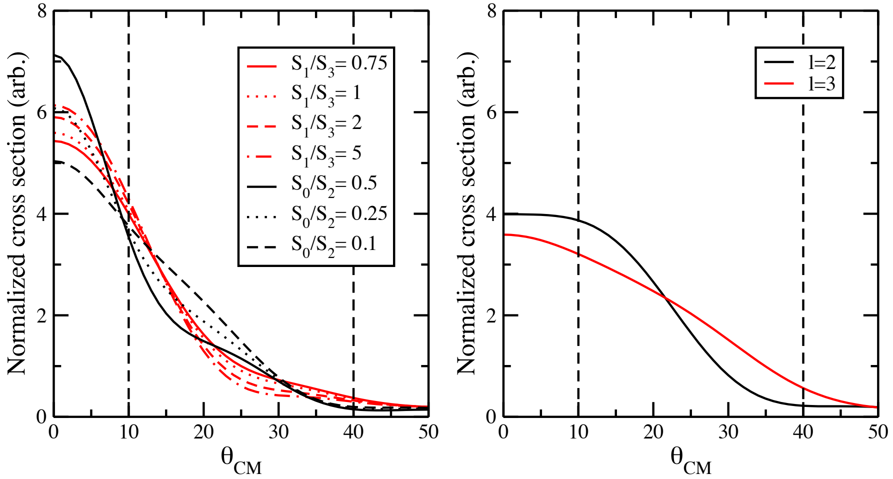


A. Pepailleur, et al., PRC. 92 054309 (2015).

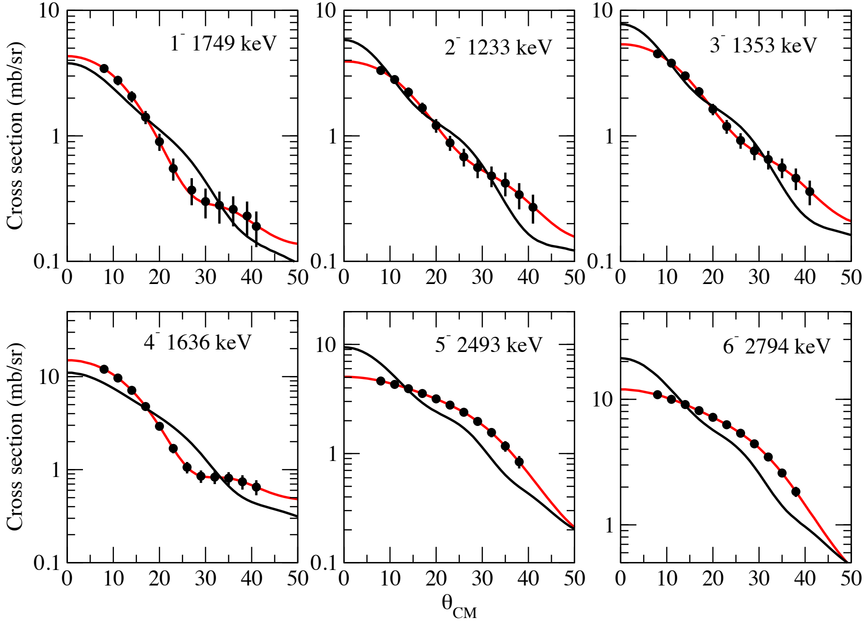


- ^{28}Na has been studied through a combination of beta-decay and in-beam gamma-ray spectroscopy.
- This data combined with SM calculations using FSU interaction has been used to simulate expected excitation energy.
- Simulated spectrum shown given a proton current of 1.3uA. FWHM 120 keV.
- Yields for most negative-parity states should be sufficient for measurement.

Angular distributions



Simulated



- *Primary goal is to identify negative-parity states from even-parity ones.*
  - *Negative-parity are populated by either ℓ=1 or 3 transfer.*
  - *Positive-parity ℓ=0 or 2.*
  - *Distributions are therefore a linear combination of up to two distributions.*
- *With expected level of statistics, parities of states can be differentiated from even-parity.*
- *Contributions of each ℓ determined at ~5% level.*

Proposed measurements

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Propose measurement of $^{27}Na(d,p)^{28}Na$ reaction at 10.0 MeV/u using the ISOLDE Solenoidal Spectrometer (ISS)

- *States of interest are intruder states from above the valence shell. Neutron-adding reactions ideal probe for studying single-particle properties of these states.*
- *Combined with existing data on ^{30}Al and ^{29}Mg provides systematic picture of evolution of single-particle structure in N=17 isotones.*
- *Request a total of **15 shifts** for $^{27}Na(d,p)$ at 10.0 MeV/u preferred option – using stripping foils to remove $^{12}C^{4+}$.*
- *Assuming $3x10^5$pps expect >115 counts a day in the whole array for states of interest. Aim is for <8% statistical error on absolute cross sections for negative-parity states.*
- *Whilst maximum expected Al contamination is within acceptable limits there are ways of reducing this.*

Goals

- *Confirm parity of states and obtain centroids of SP strength.*
- *Investigate changes in neutron occupancies and centroids along N=17.*
- *Probe changes in SP behaviour along N=17 isotones in odd and even nuclei.*
- *Benchmark new interactions.*

Recoil detection

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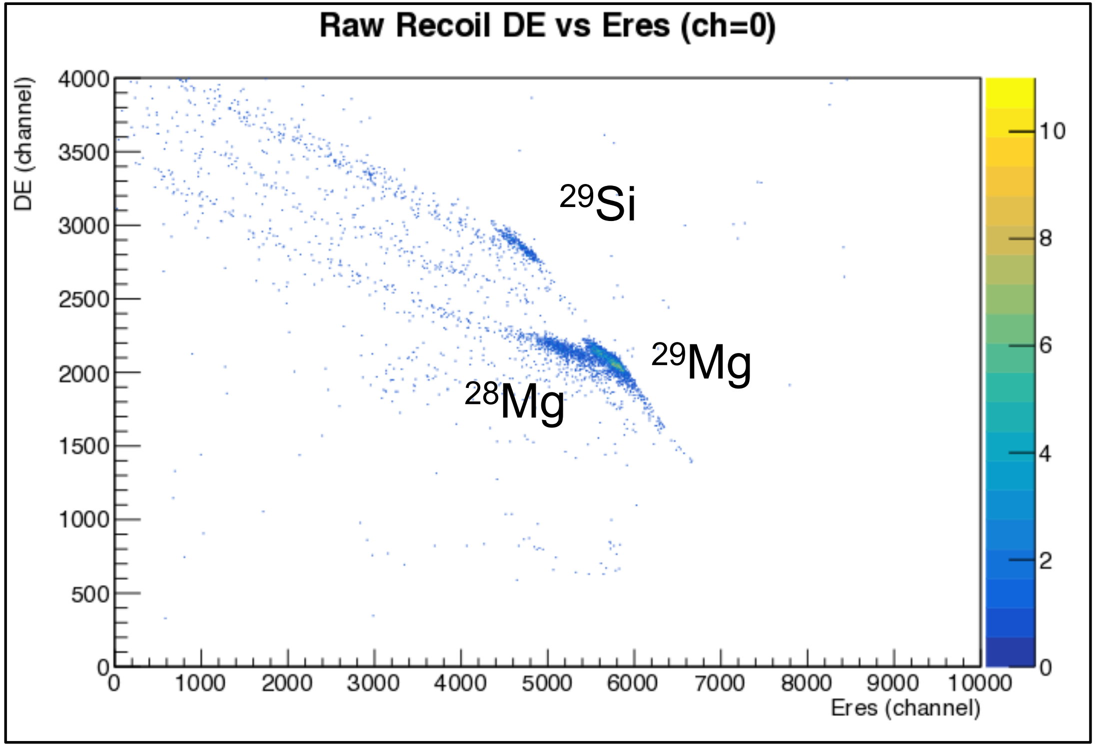
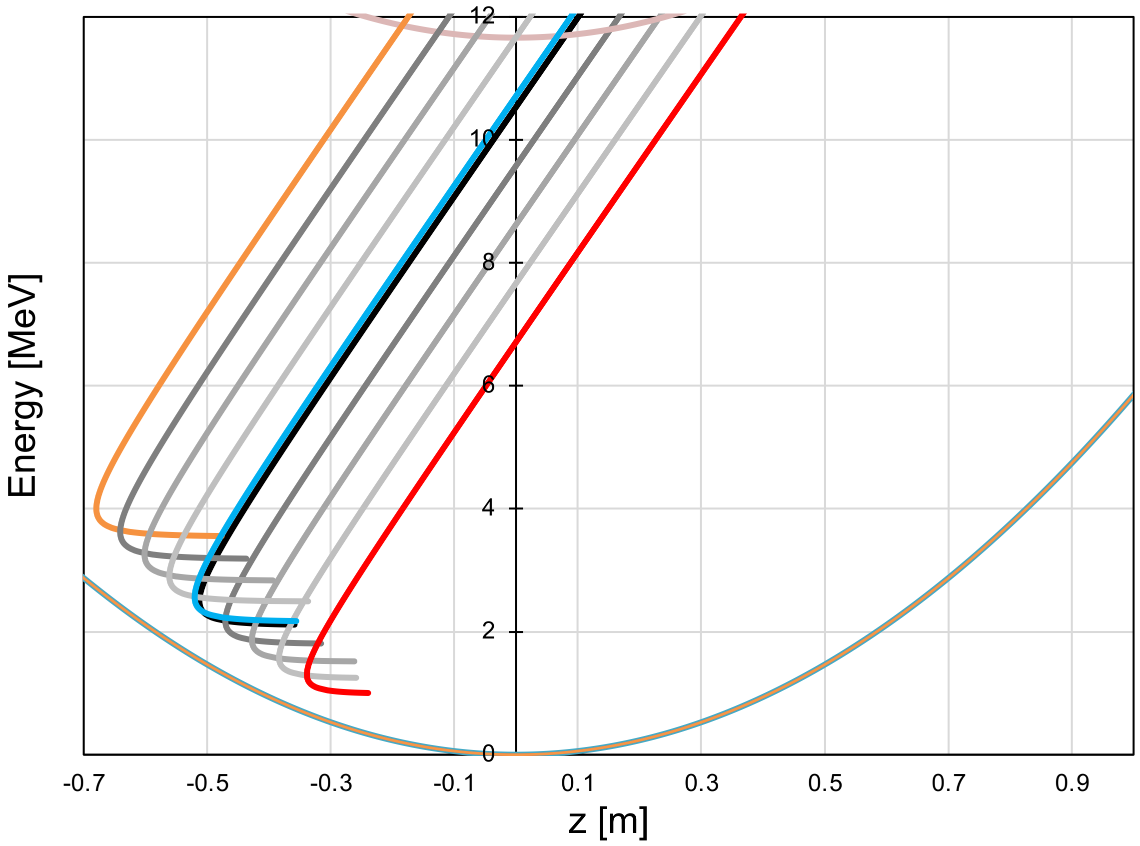


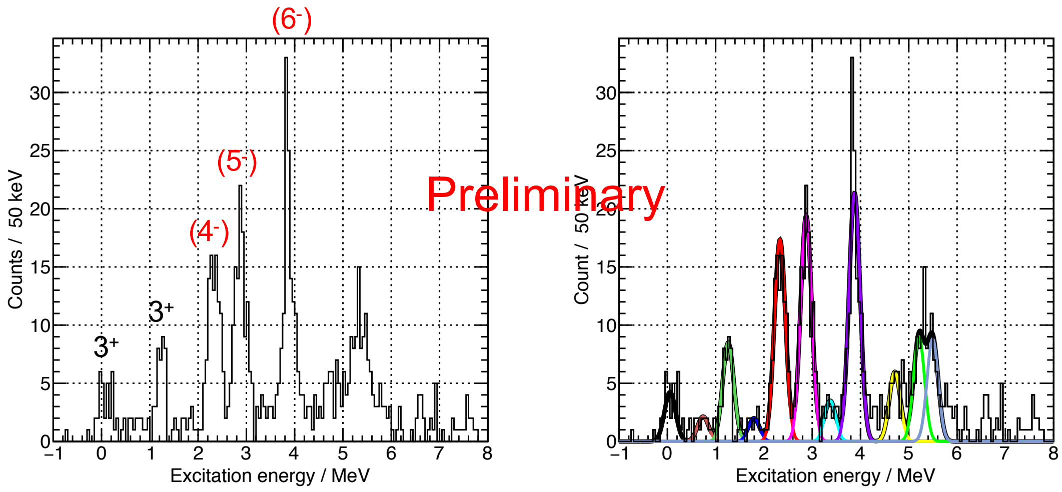
Silicon recoil detectors used for $^{28}Mg(d,p)^{29}Mg$

Resolution sufficient to identify ^{28}Mg and ^{29}Mg – as well as reactions on ^{28}Si.



Energy [MeV]
12
10
8
6
4
2
0
-0.7
-0.5
-0.3
-0.1
0.1
0.3
0.5
0.7
0.9
z [m]

$^{29}Al(d,p)^{30}Al$ - preliminary



- *Few 10^4pps.*
- *Low statistics but resolution sufficient to identify suspected negative-parity states.*
- *Angular distributions for strongest states – currently under analysis*