Benchmarking an Active Catcher Array for the Study of Multinucleon Transfer Reactions

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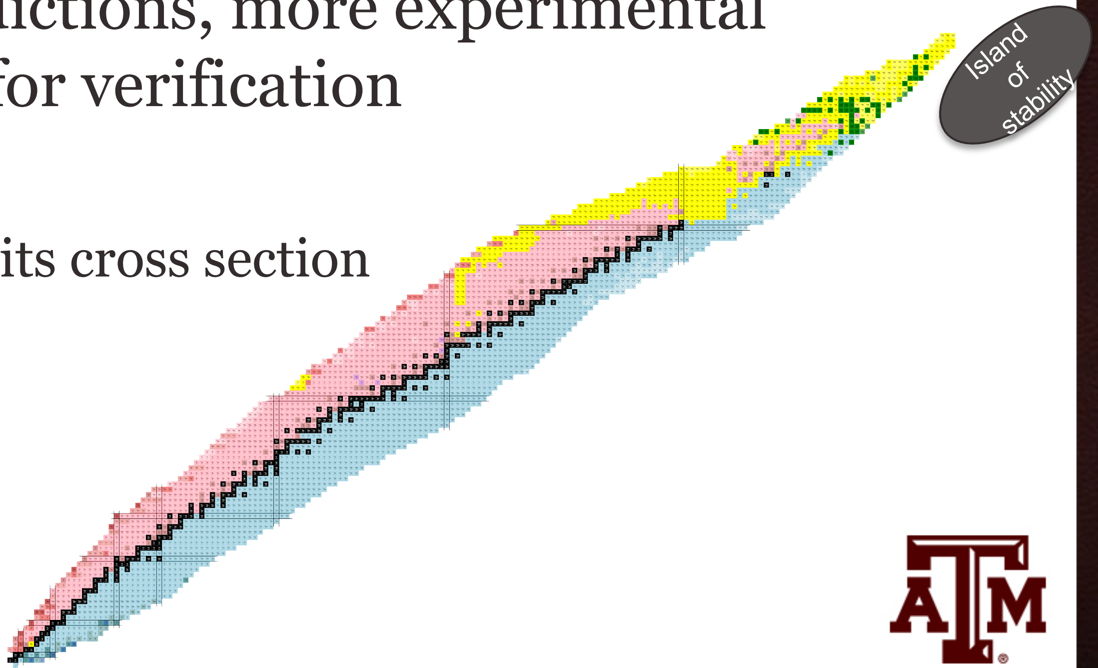
Happy Halloween!

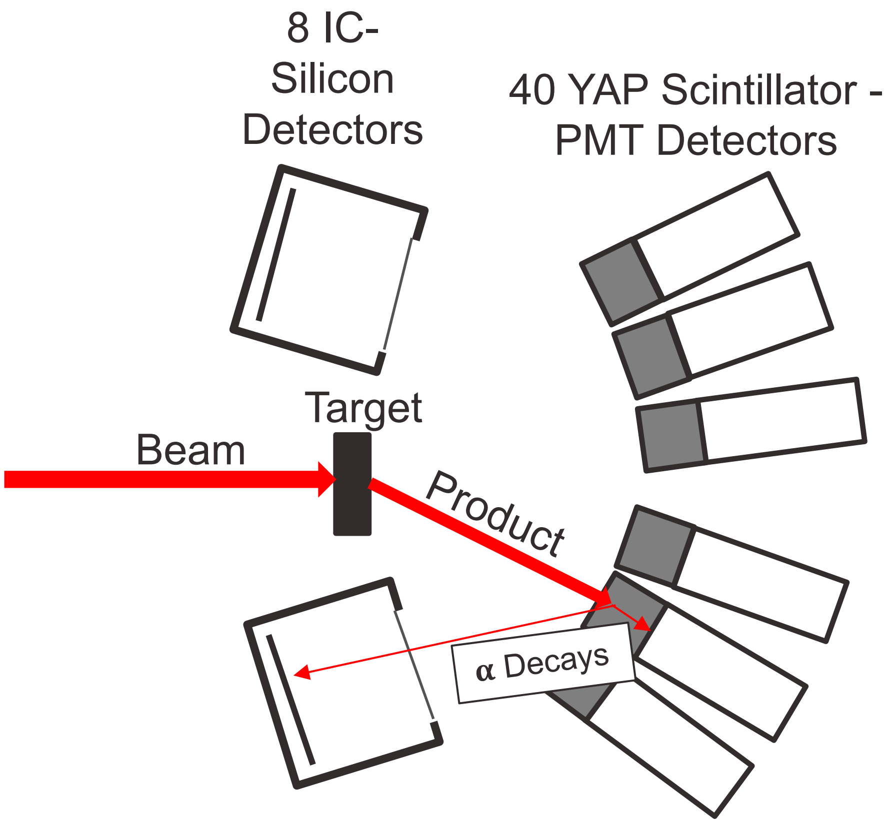
Why Study Multinucleon Transfer Reactions?

- Produce neutron-rich isotopes of elements in heavy and super-heavy mass regimes
  - Island of stability
  - Astrophysical r-process nucleosynthesis
- Many theoretical predictions, more experimental investigation needed for verification
- Important quantities:
  - What is produced and its cross section
  - Angles of emission
  - Specific isotope ID



The Active Catcher Array (ACA)

- Catcher array
  - 40 YAP scintillators coupled to photomultiplier tubes
  - catches reaction products that leave the target
  - Angular range 7-60°
  - Detects α decays
  - 10% energy resolution
- Silicon array
  - 8 ion chambers with silicon detectors at the back
  - Detect α particles emitted in the backward direction from the products in the catcher array
  - Energy resolution ~ 1%



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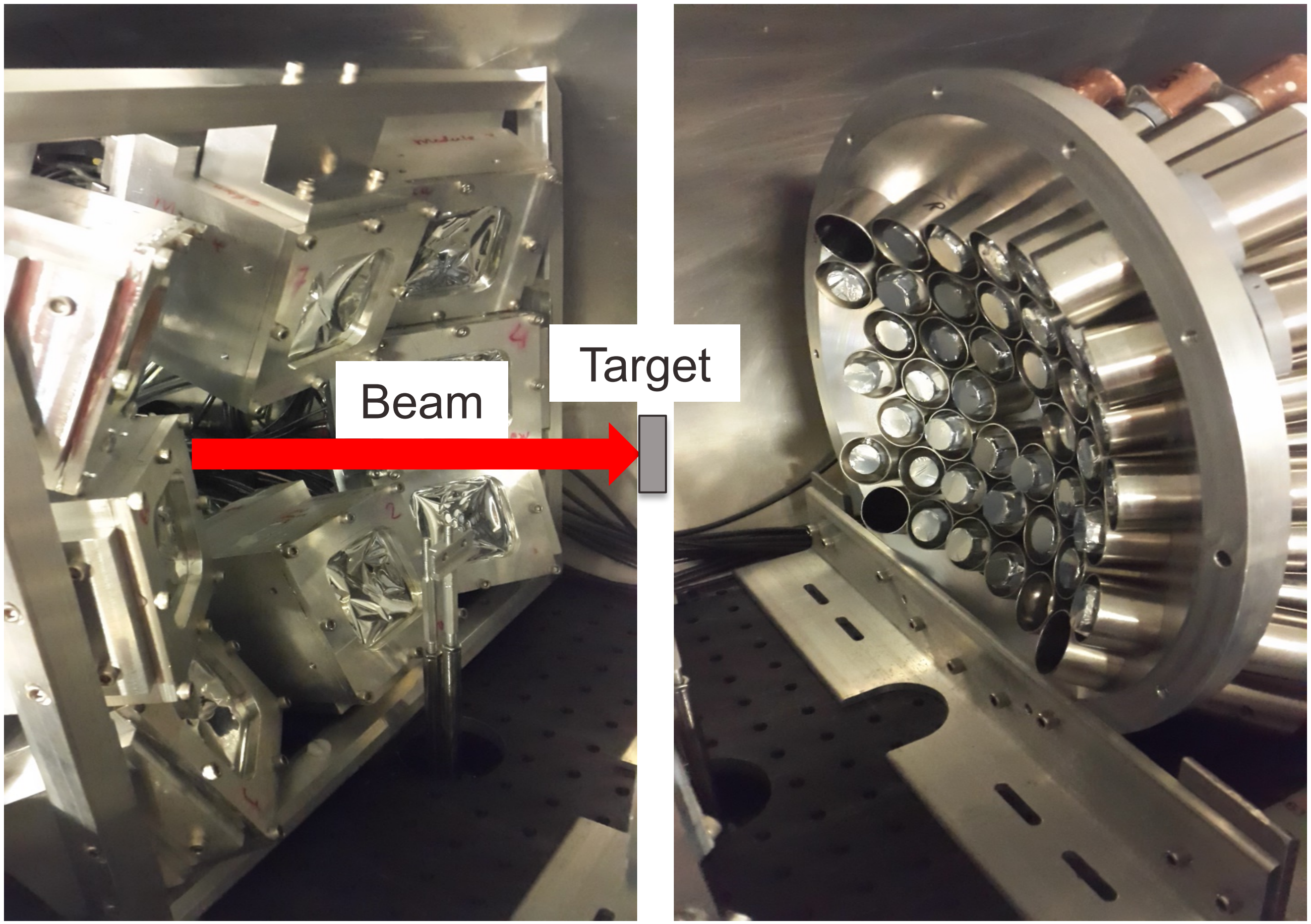
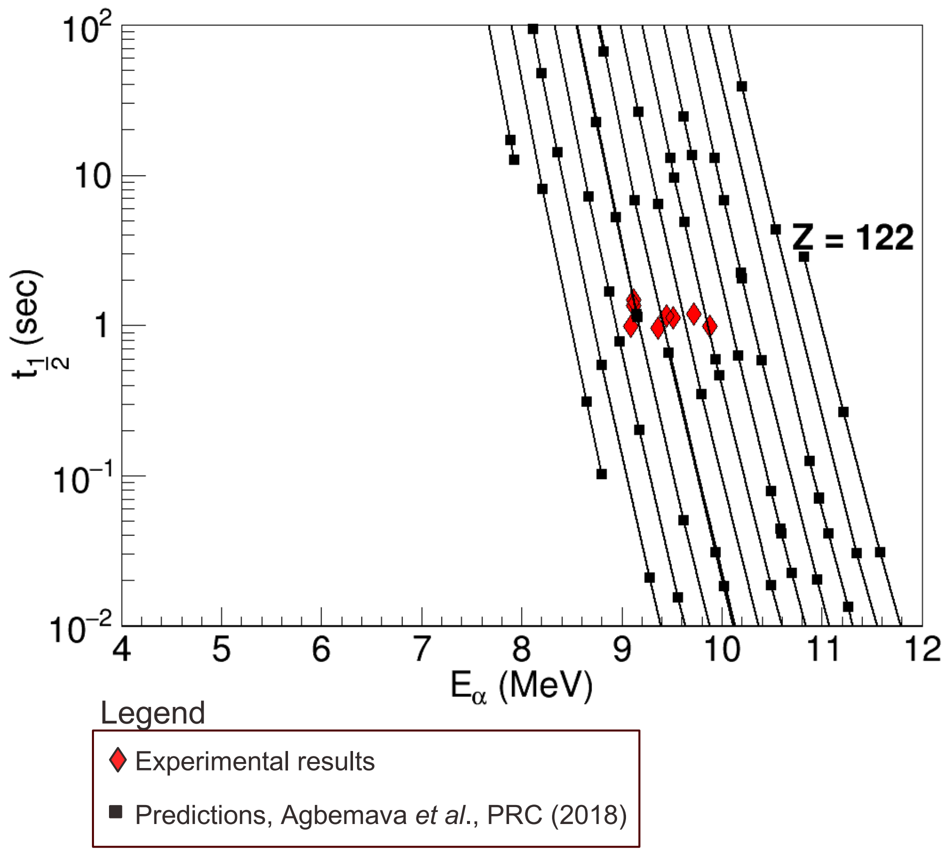


Previous Study of $^{238}U + ^{232}Th$ MNT

- Experiment performed at Texas A&M University using the active catcher array, looking for super-heavy elements
- Results of a correlated pair search show half-life and alpha energy in red diamonds
- Comparison with theoretical predictions made via the Viola-Seaborg approach suggests the identification of nuclei with Z = 112
- Couldn't identify any specific isotopes
  - High Background



Wuenschel, S., et al., PRC 90, 011601 (2014).

Benchmarking the ACA

- Two experiments conducted:
  - Ne + Th
  - Au + Pb
- Pulsed beam 30 ms On/Off
  - On: MNT products made and lodged in catcher detectors
  - Off: Detect α decays of products
- Pulse timing: multiple half-lives of nuclides of interest

Identifying an Isotope of Interest Au + Pb

Correlate 2-3 α-decays:

220Ra, 217Rn, 219Fr,
219 Ra, 220Ac, 221Ac

^{220}Ra: $T_{1/2}$ = 17.9 ms, E_α = 7.59 MeV

↓

^{216}Rn: $T_{1/2}$ = 45 μs, E_α = 8.20 MeV

↓

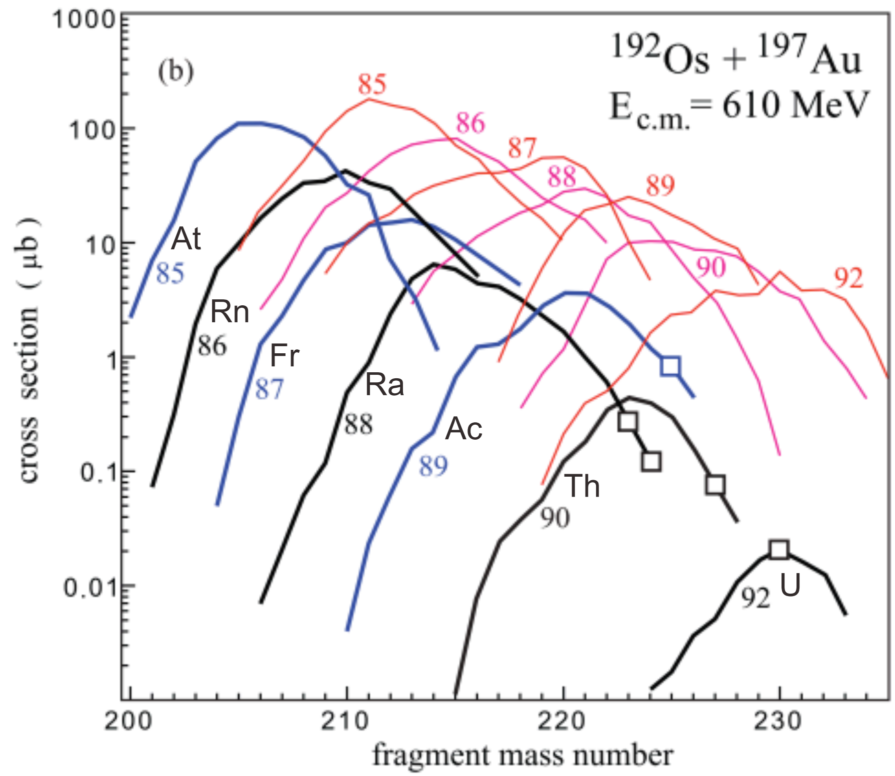
^{212}Po: $T_{1/2}$ = 294 ns, E_α = 8.95 MeV

1. Search all beam-off events for α detection of correct energy
2. Search for α detection of daughter's energy within time window of 3-5*$t_{1/2}$
3. Repeat for granddaughter nucleus (^{212}Po)

- Minimize random correlations
  - Position, energy window, time searched

Future Experiment: $^{192}Os + ^{197}Au$

- Plans to conduct experiment in spring 2021
  - Good theoretical prediction for comparison
  - Low α background
- Beam test produced 10^9 pps ^{192}Os



Zagrebaev, V. & Greiner, W. PRC **87**, 034608 (2013).

^{197}Au + ^{192}Os Products Predicted

Future Work: Detector Improvements

- Improve ACA by lowering possible random correlations
  - Better position Resolution
    - Position-sensitive Photomultiplier Tubes
  - Better energy resolution
    - Must be radiation hard
    - Investigated using diamond detectors, not radiation hard

Acknowledgements

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