Nuclear structure studies of neutron rich cobalt isotopes

Dustin P. Scriven

scriven@frib.msu.edu

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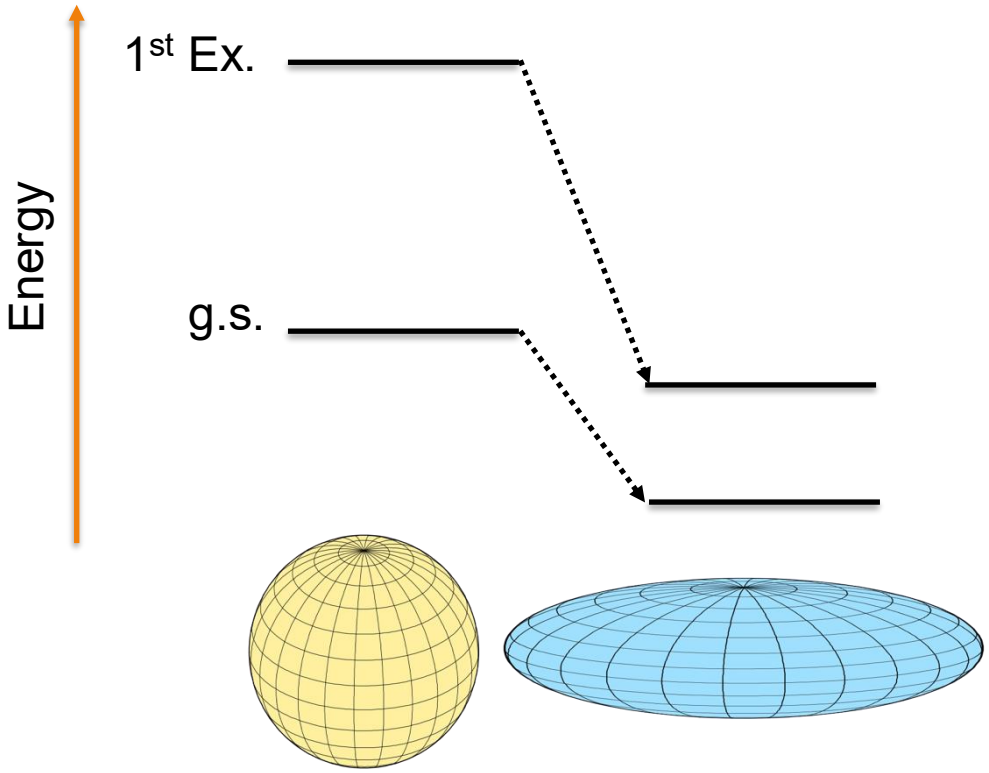
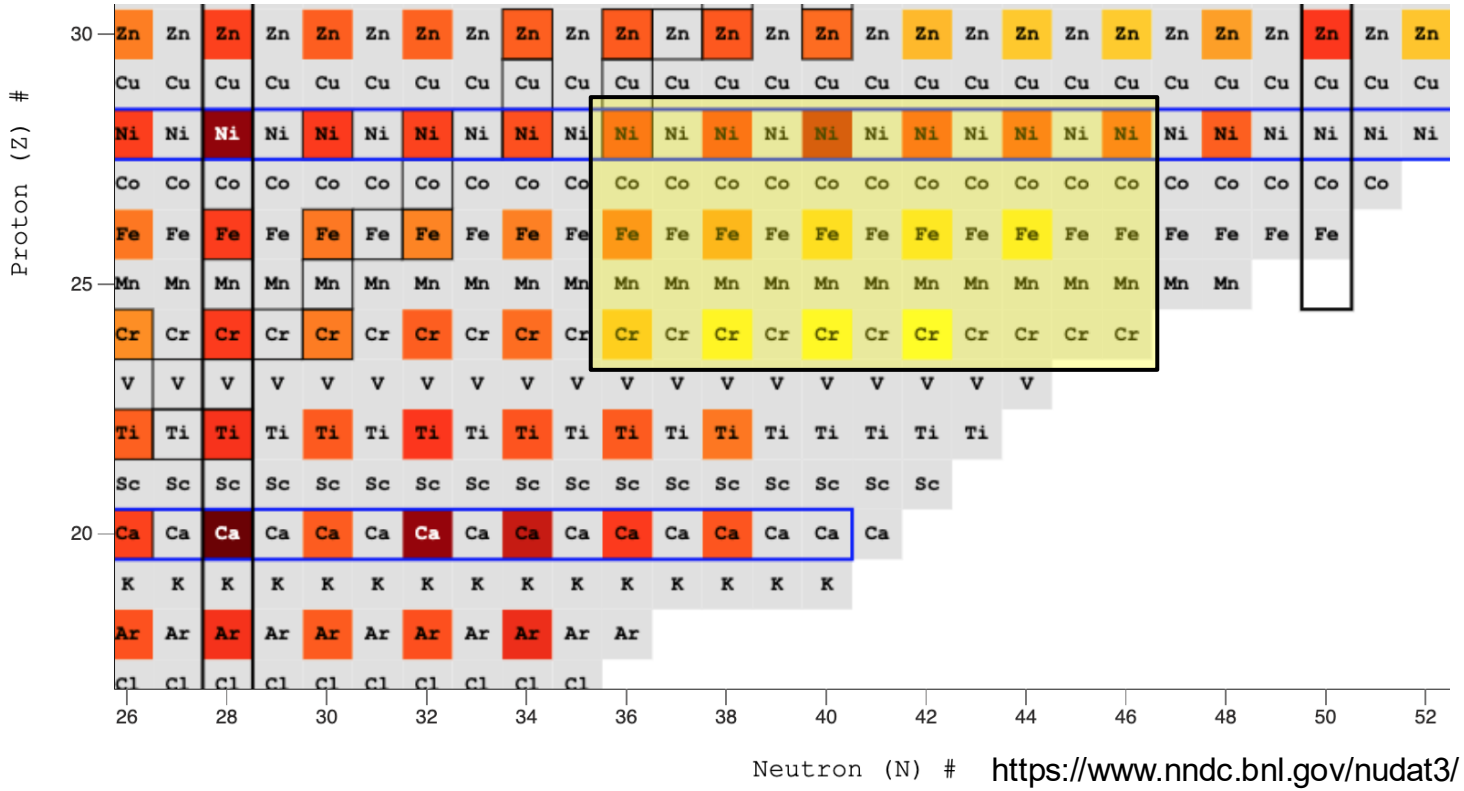
An island of inversion at N=50?

- Understanding this shape and shell evolution far from stability is a central mission of modern radioactive ion beam facilities
- This work focuses beyond the “island of (shape) inversion” at N=40

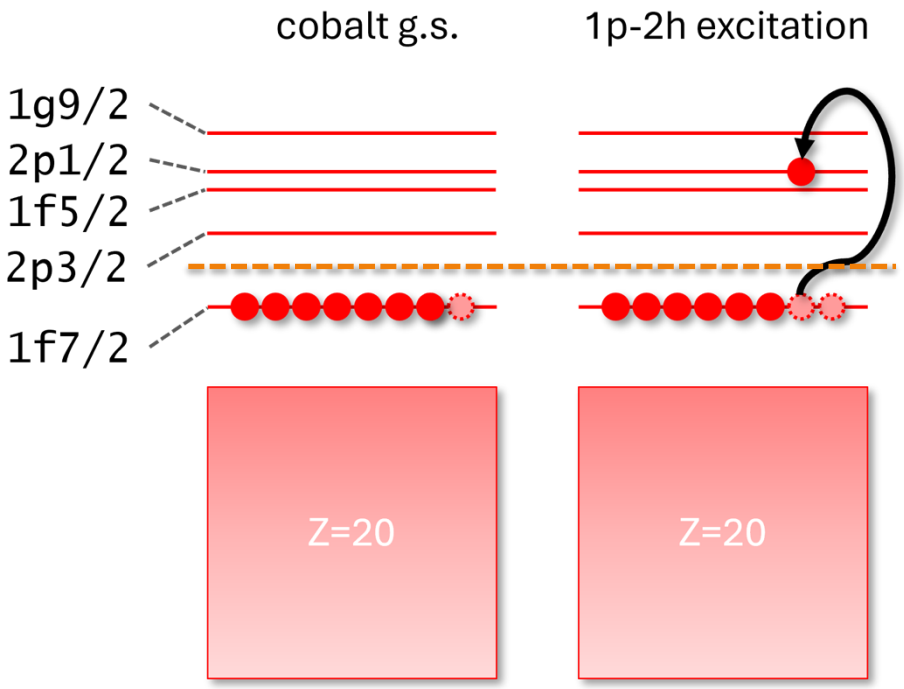


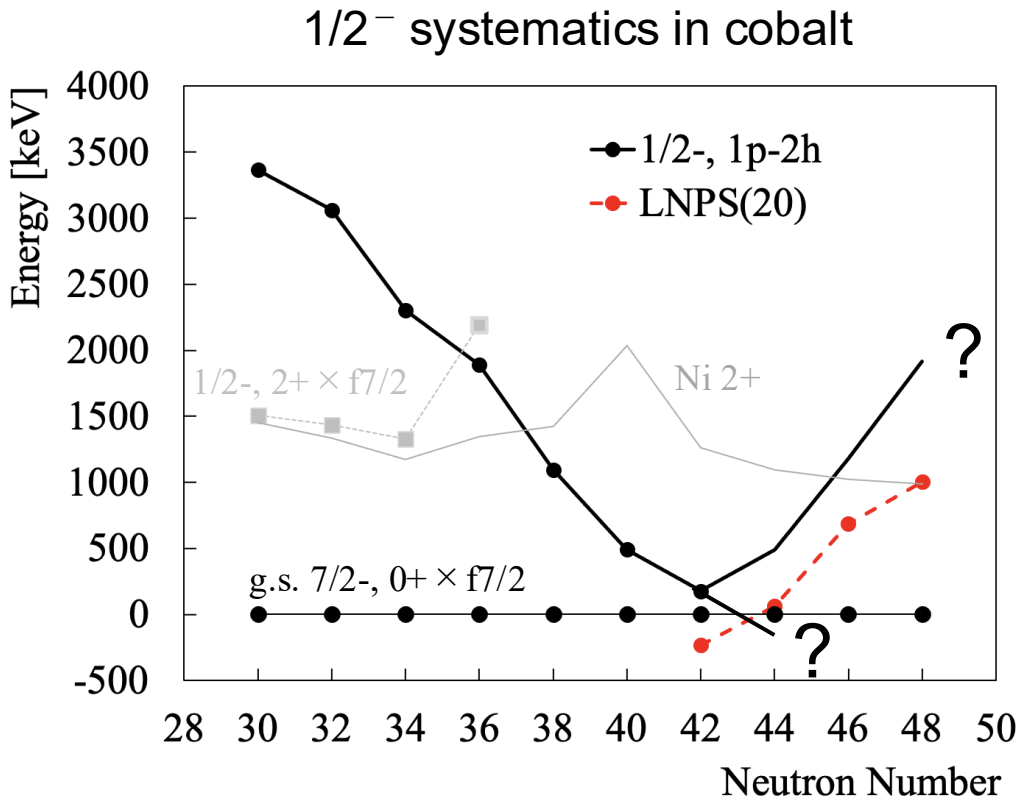


https://www.nndc.bnl.gov/nudat3/

Isomerism of $1/2^-$ intruder toward N=50

- Evolution of proton-driven deformed $1/2^-$ states in cobalt, coexisting with spherical ground states
- A shore of the N=50 island of inversion? Or return to “normal” ordering?

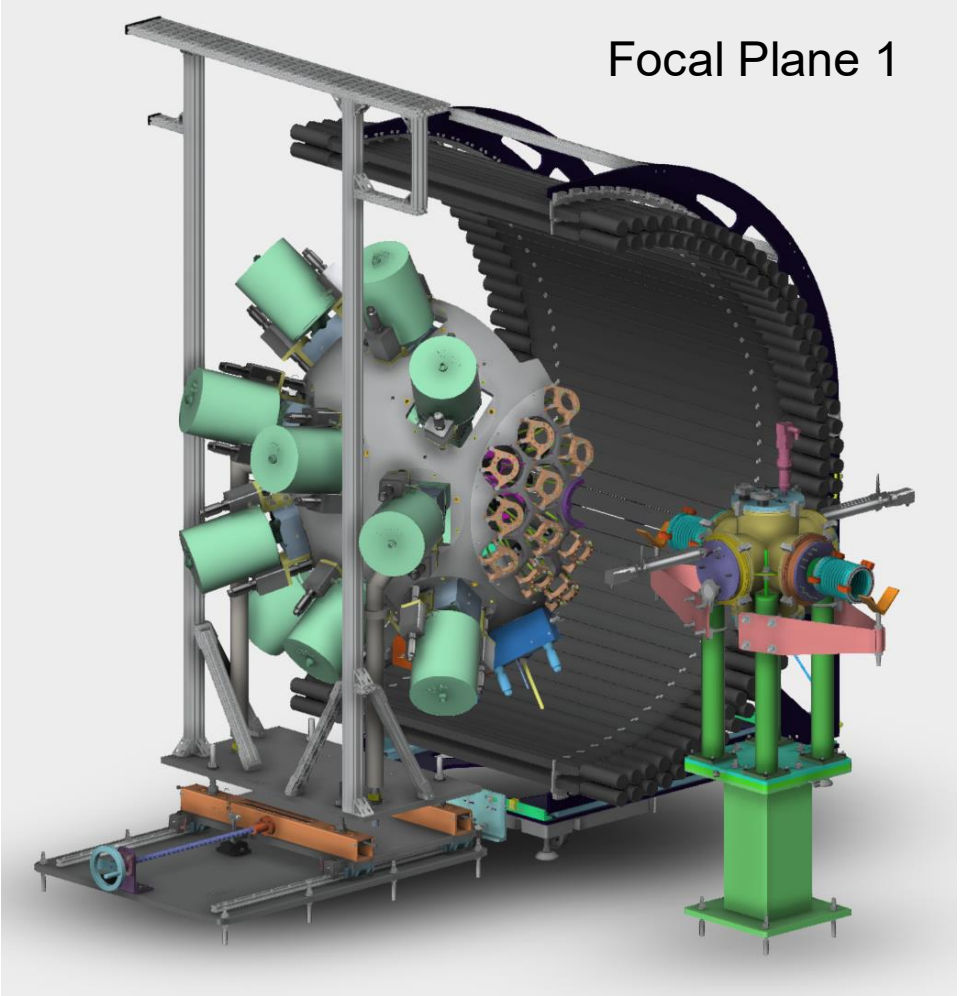




S. M. Lenzi et al., Phys. Rev. C 82, 054301 (2010)
T. Lokotko et al., Phys.Rev.C 101 (2020) 3, 034314

Summary of Experiment Objectives

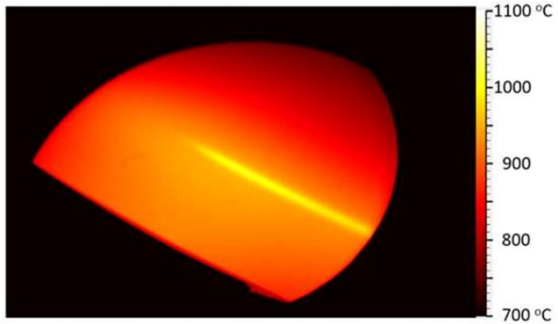
- Decay Spectroscopy Near *N*=40: toward the *N*=50 island of inversion near ^{78}Ni
- Identify excited states, such as excited 0^+ states, near the *N*=40 island of inversion
- Infer shape changes and coexistence
- Use level structures in odd-*Z* nuclei to identify single-particle orbitals and determine shapes
- Identify new isotopes
- Measure new half-lives and spectroscopy
- Measure P(βn), P(β2n)…

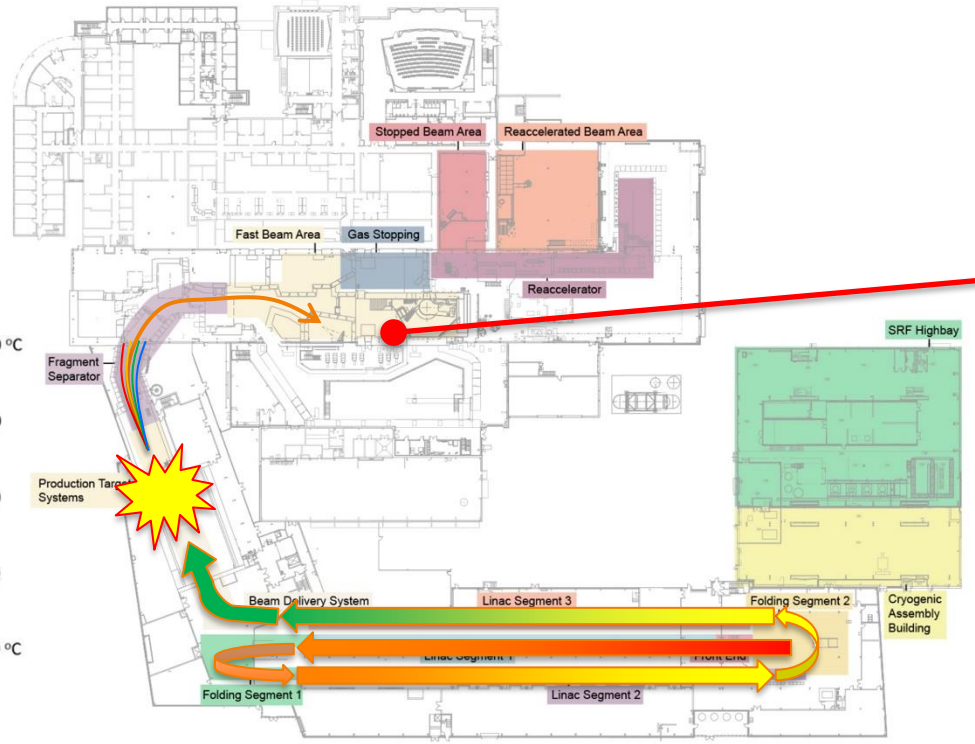


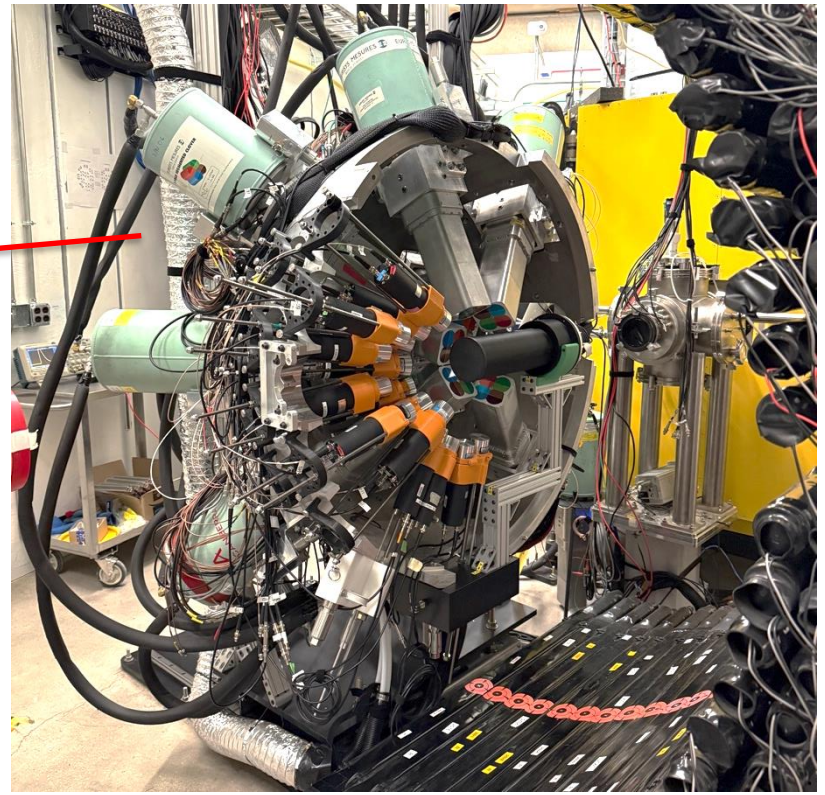
Experiment e23055 with FRIB Decay Station Initiator

- A 225 MeV/u ^{82}Se primary beam impinged on ^{12}C fragmentation target, producing a cocktail secondary beam, separated by the Advanced Radioactive Isotope Separator (ARIS)

Rotating ^{12}C target

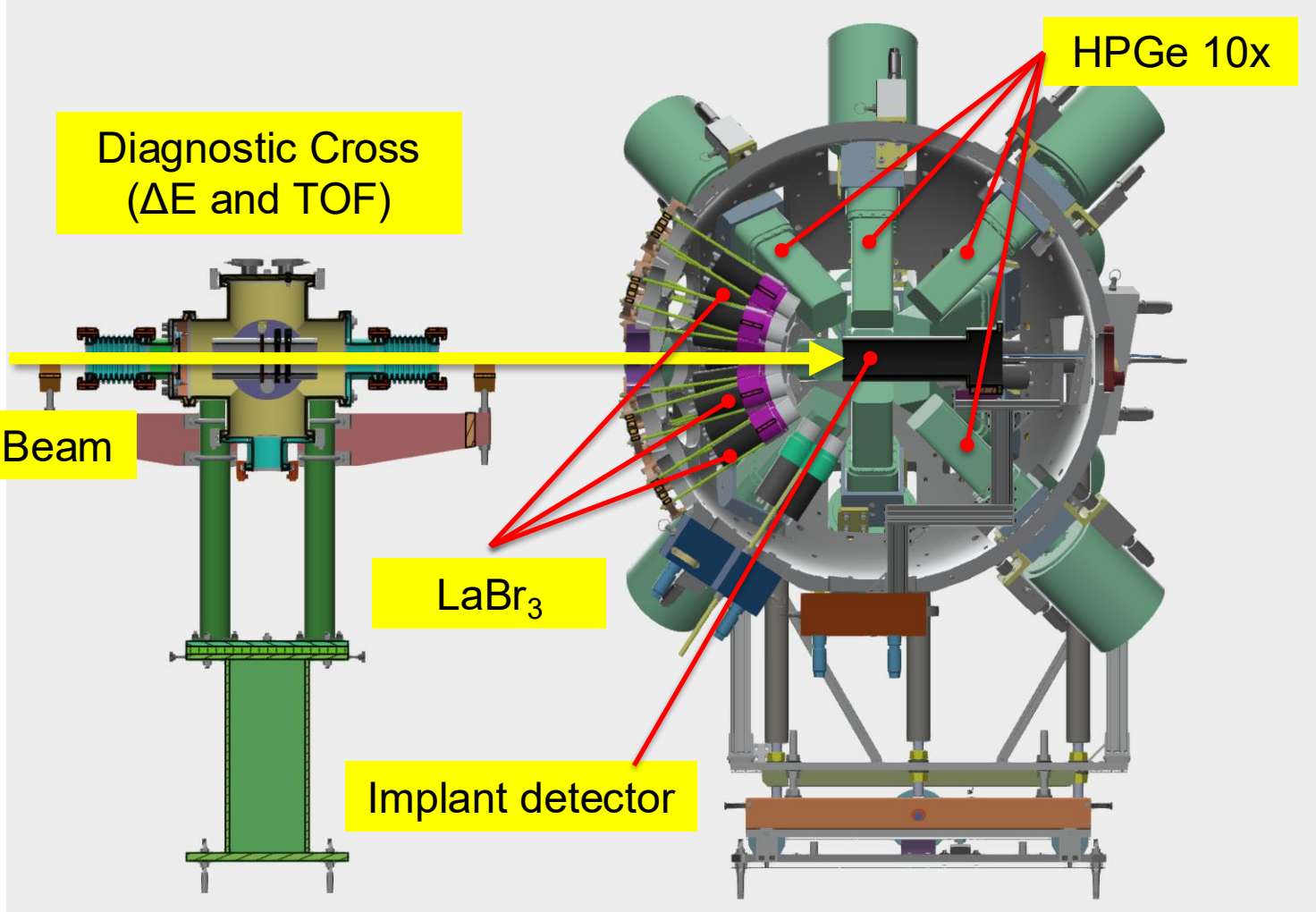






Glasmacher, T., Gade, A., Bollen, G., & Wei, J. (2024). *Nuclear Physics News*, *34*(3), 5–12.

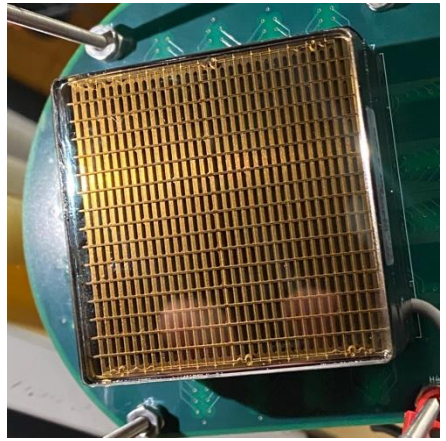
Experiment e23055 with FRIB Decay Station Initiator



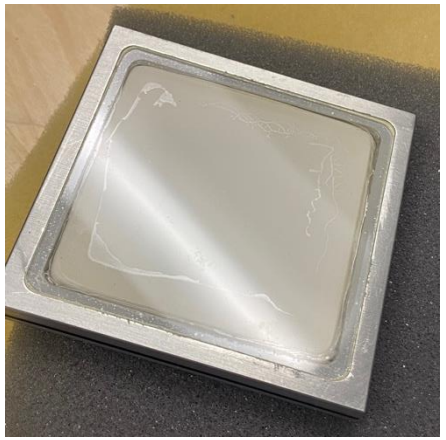
- Silicon and plastic scintillator for dE-TOF
- $CeBr_3$ central implant detector
- The first focal plane used 2π γ array
  - 10 clover HPGe – high-res spectroscopy
  - 12 $LaBr_3$ - fast timing
- 2π VANDLE neutron detector array

New $CeBr_3$ Implantation Detector

- Fielded new $CeBr_3$ implantation detector
  - 3 x 51 x 51 mm^3 $CeBr_3$ crystal coupled to 16x16 PSPMT (256+1 ch)
  - Excellent position resolution and fast timing (~550 ps)
  - Unique double-pulse analysis for decay gammas and E0 electrons

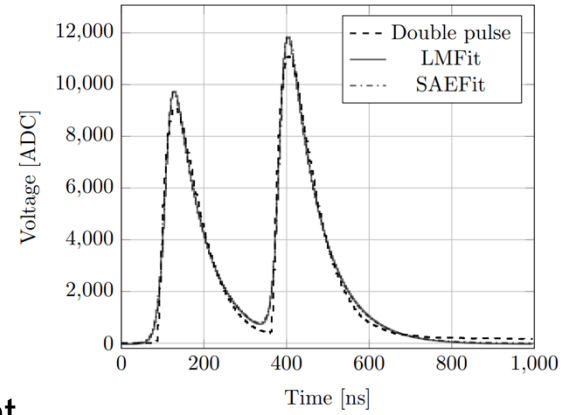


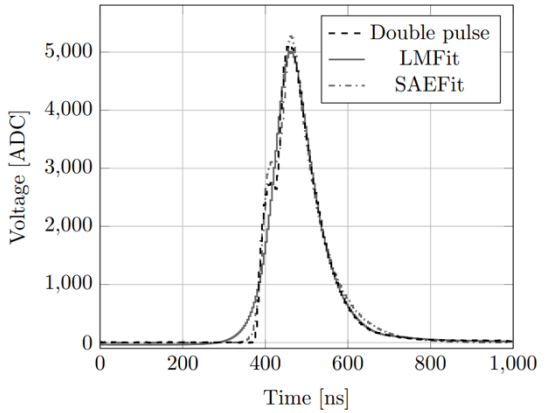
Hamamatsu H13700 PSPMT



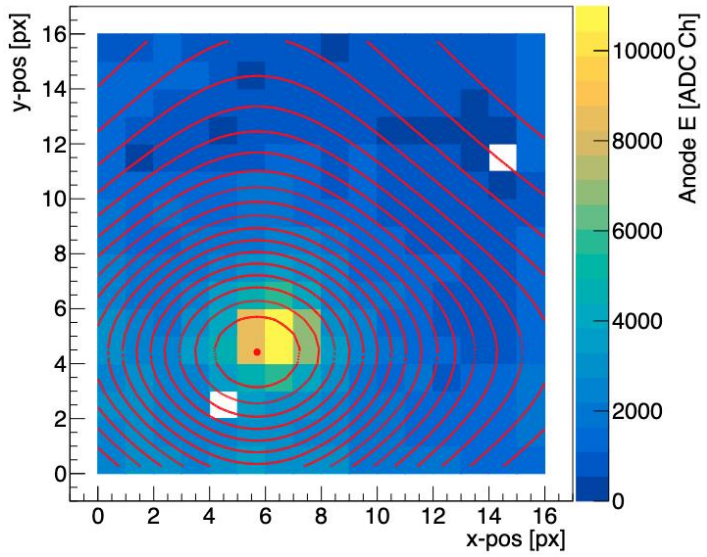
Monolithic Scionix $CeBr_3$ Crystal Assembly

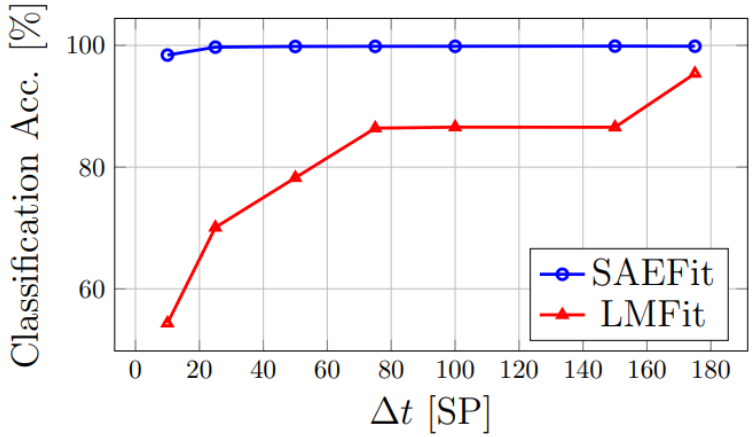
Characterization of a $CeBr_3$ Implantation Detector manuscript is in prep.





Decay event



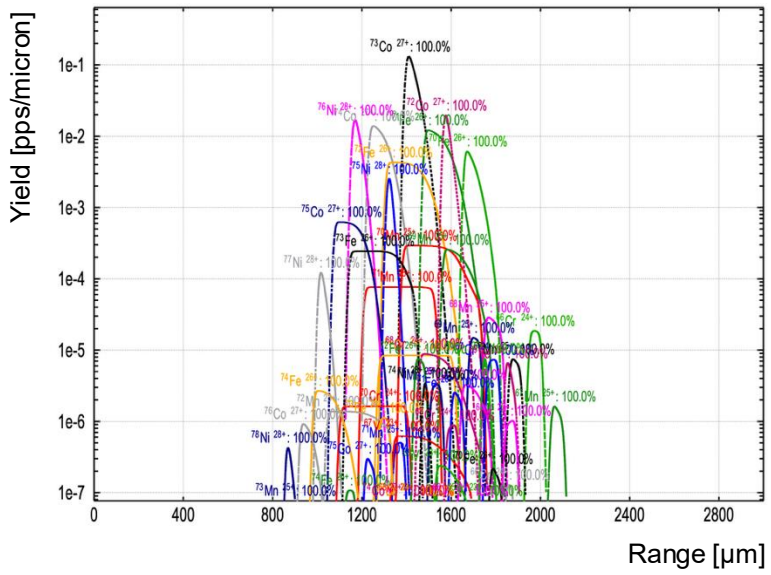


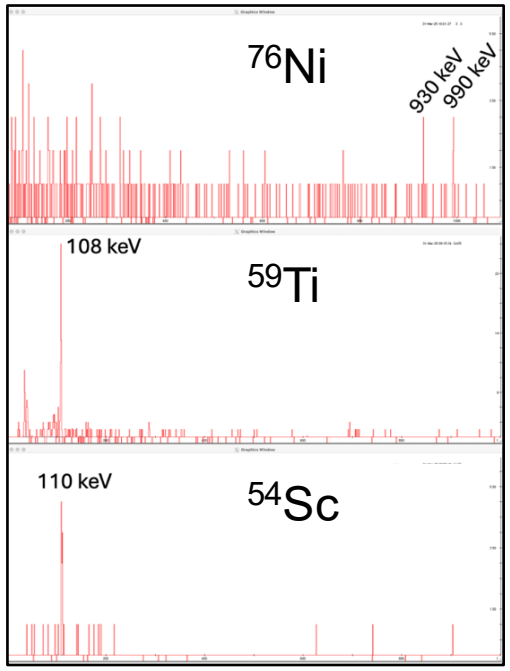
B. Sadeghi, D. P. Scriven, A. Chester, R. Fox, S. N. Liddick, G. Cerizza *NIM A 1082 (2026)*

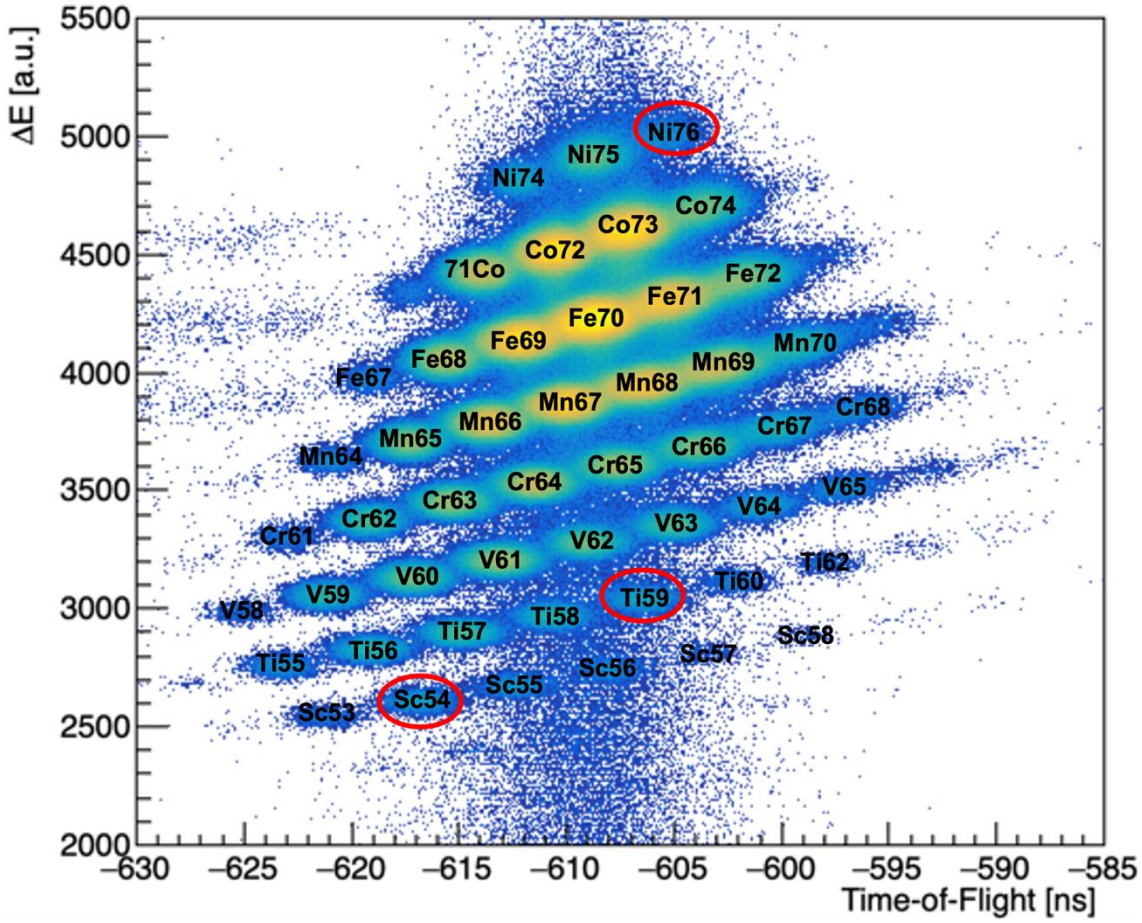
Experiment e23055 with FRIB Decay Station Initiator

- Produced over 50 isotopes in cocktail beam (~100 pps)
- Secondary beam ions were identified using dE-TOF method
- PID validated by known isomer decays

Range distributions in $CeBr_3$







Facility for Rare Isotope Beams
U.S. Department of Energy Office of Science | Michigan State University
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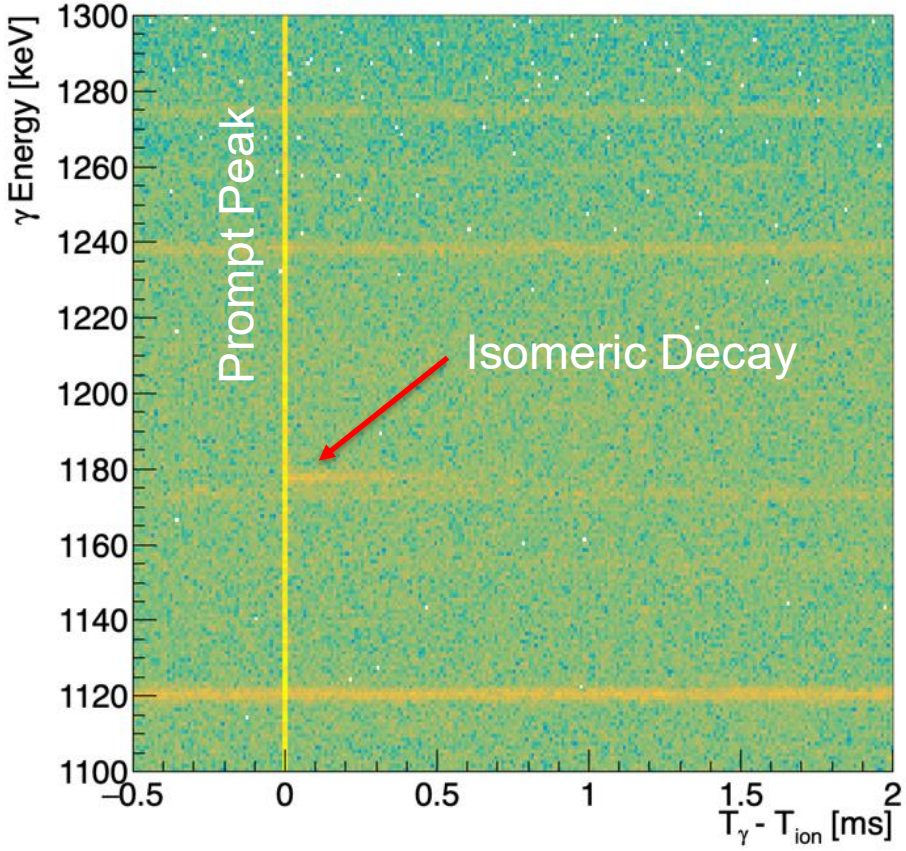
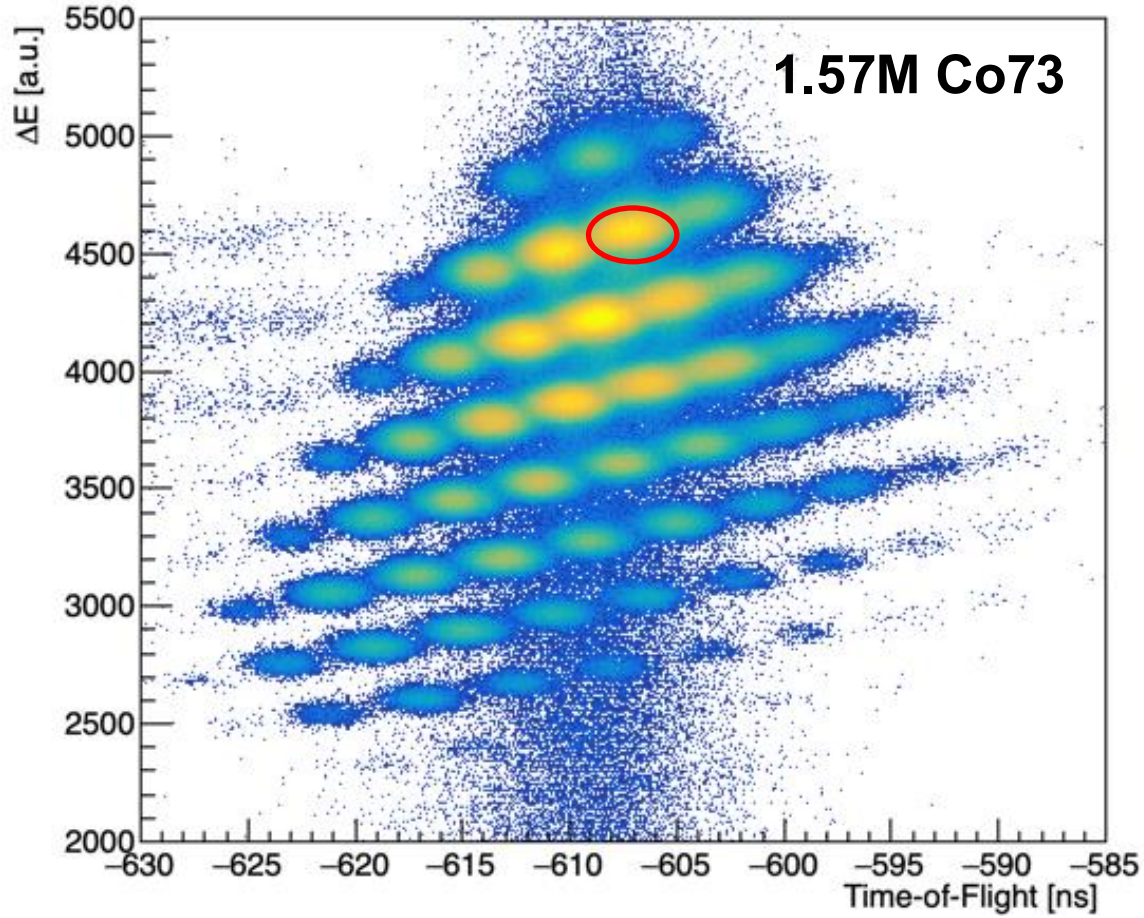
Experimental Results

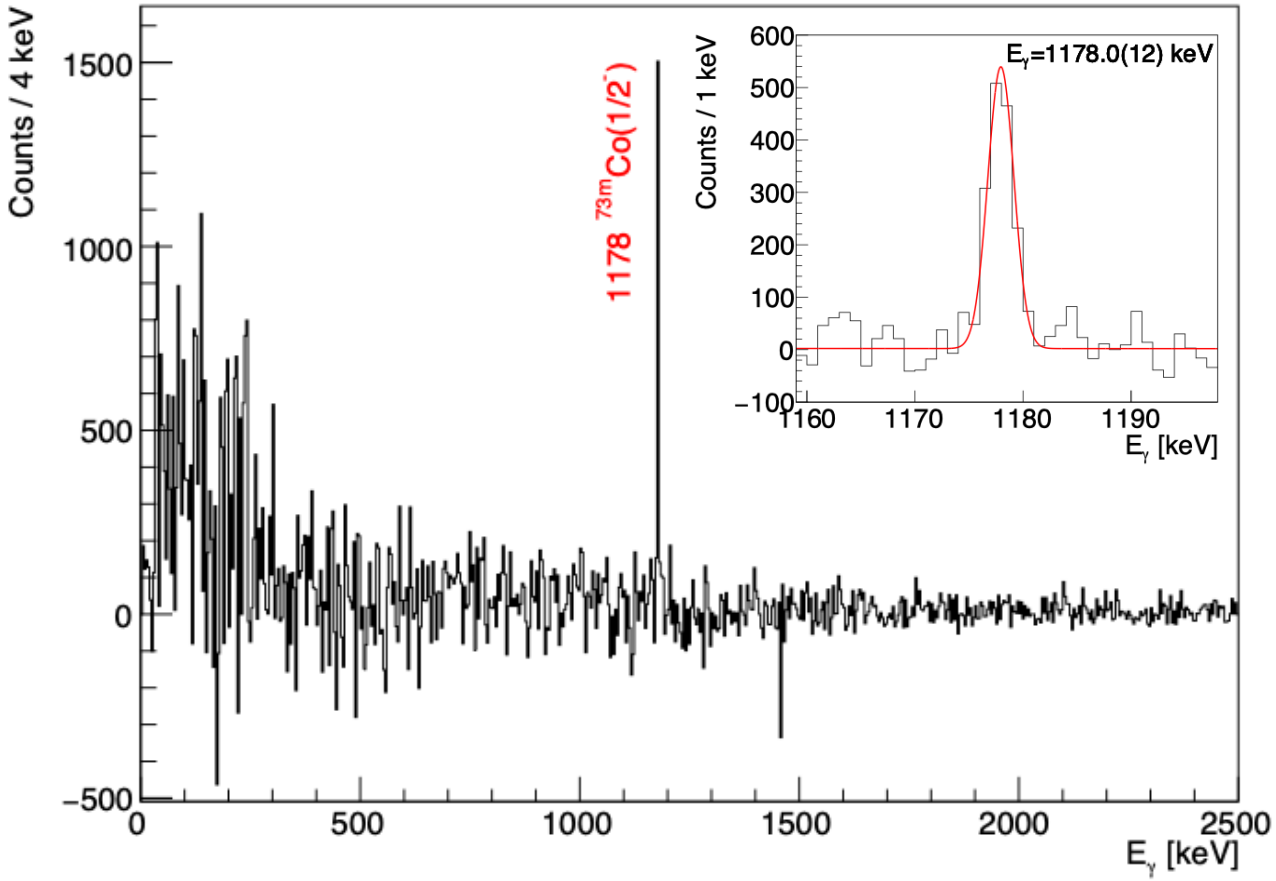
- Position + ^{73}Co PID validated ions correlated to γ rays up to 2 ms



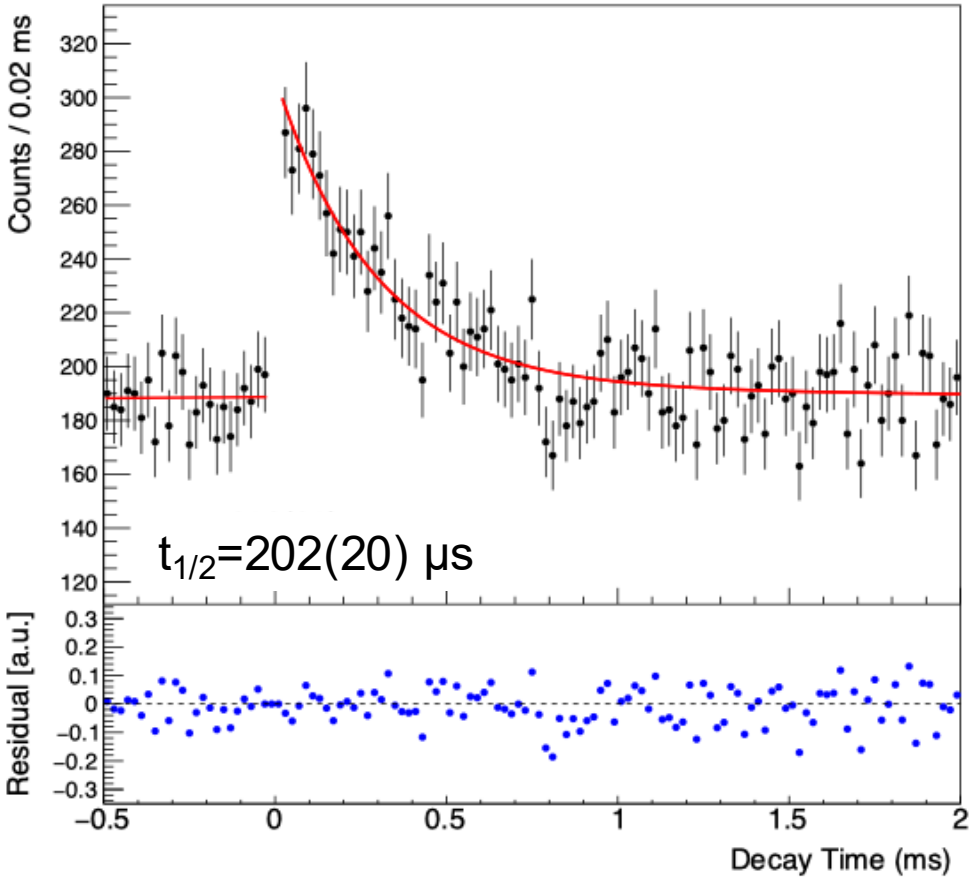


Experimental Results

Background subtracted HPGe Spectrum 0-1 ms

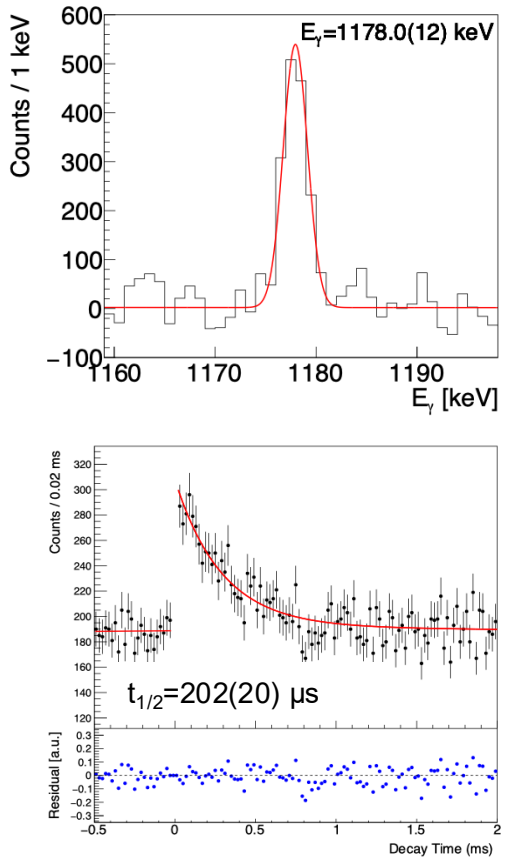


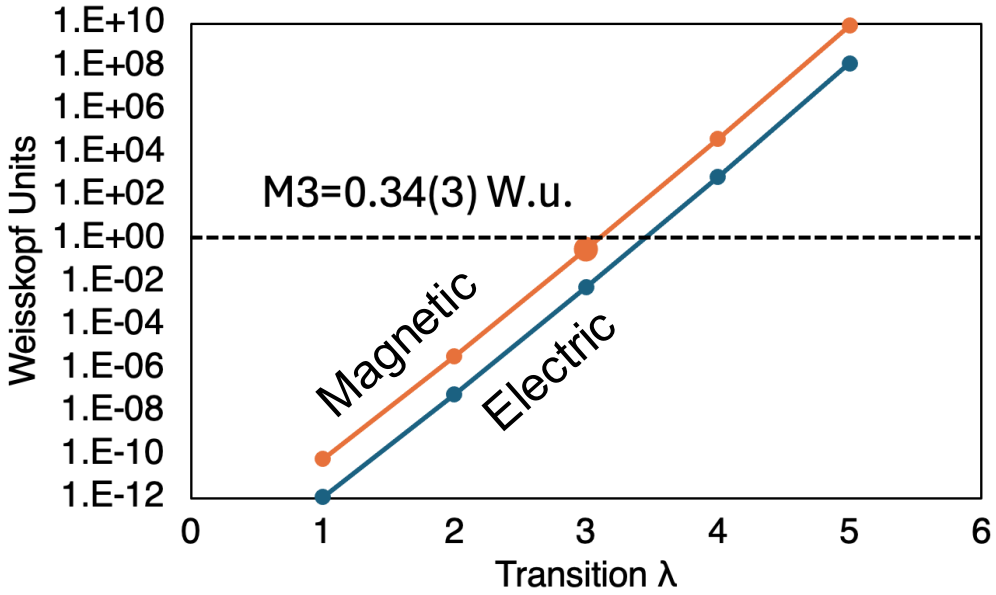
Decay time gated on E_γ=1178 keV



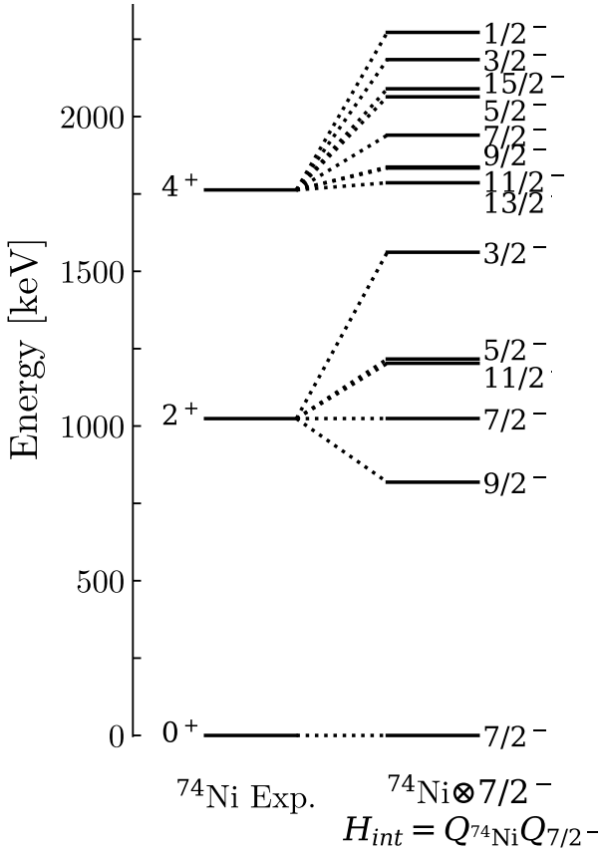
Interpretation

- Half-life and energy suggests decay of M3 nature, indicative of $1/2^- \rightarrow 7/2^-$ transition



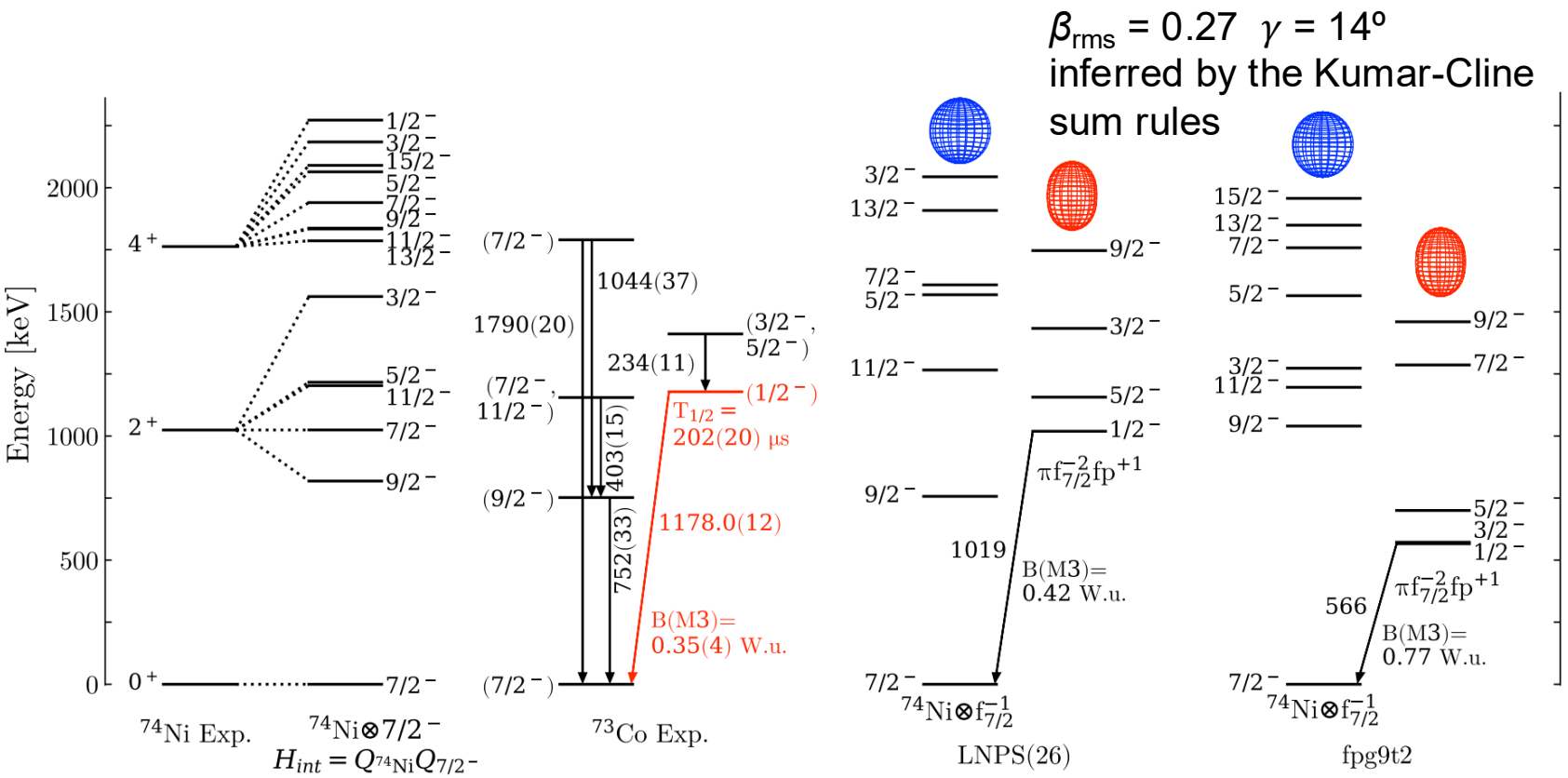


- Core + Single-Particle Coupling Model
- No low-spin states at low energy to decay to



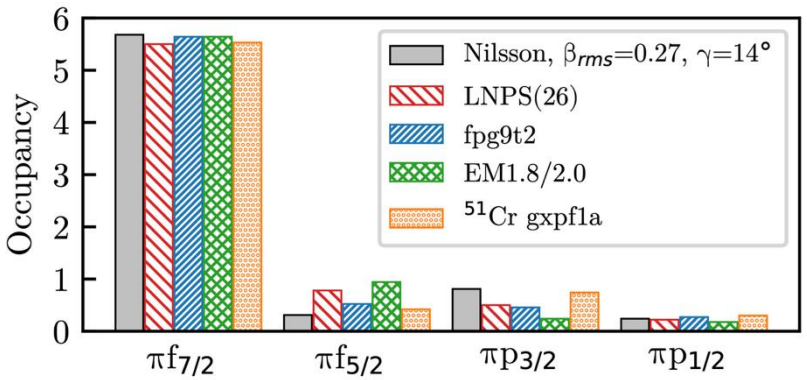
Interpretation

- Known levels from (*p*,2*p*) at RIKEN can be interpreted in the core + SP framework
- Semi-empirical shell model calculations give rise to a prolate deformed 1/2⁻ isomer



β_{rms} = 0.27 γ = 14°
inferred by the Kumar-Cline sum rules

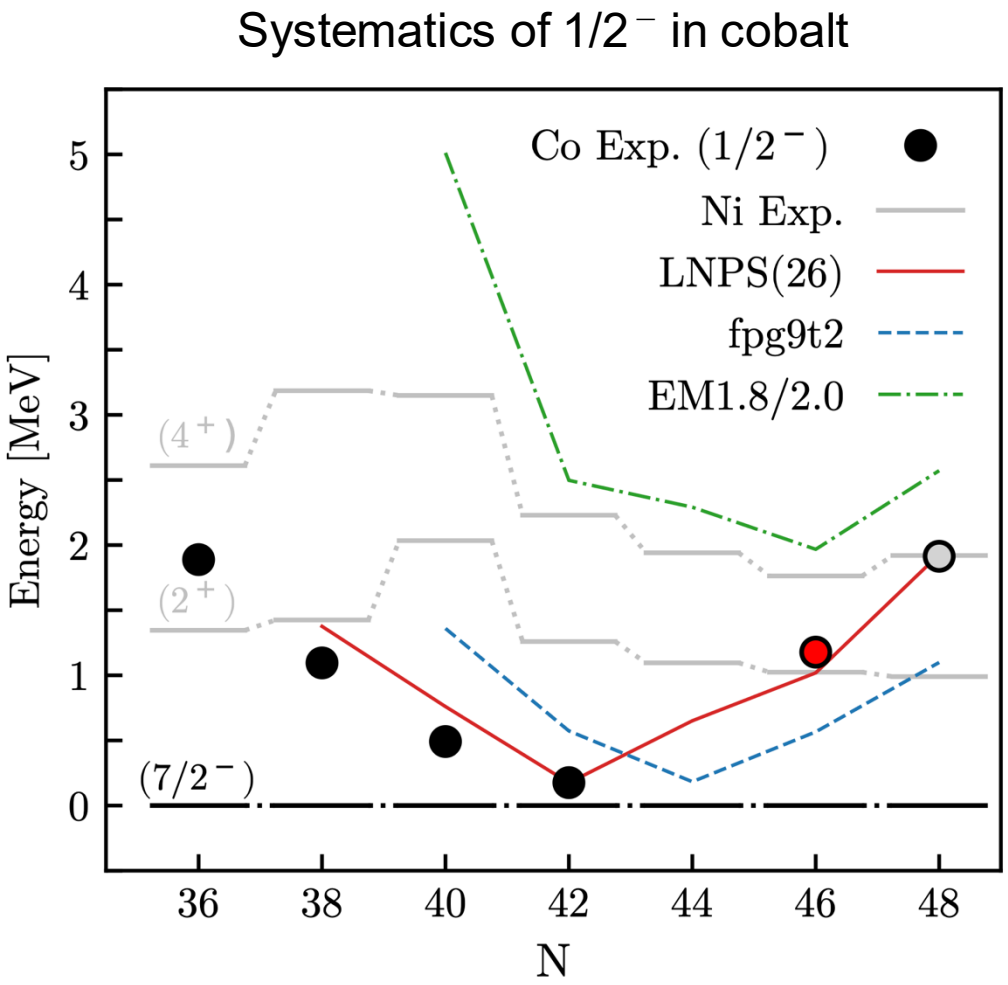
pf shell occupancies of 1/2⁻ intruder



S. M. Lenzi et al., Phys. Rev. C 82, 054301 (2010)
T. Lokotko et al., Phys.Rev.C 101 (2020) 3, 034314
C. Dembski et al., Communications Physics 8, 77 (2025)

Discussion

- The observation confirms the upward trend of the $1/2^-$ proton-driven intruder
- The deformed proton-driven intruder does not lead to a shape inversion in the cobalt isotopes as *N*=50 is approached
- The updated LNPS(26) should lead to better prediction in the region
- Currently exploring how the 1 MeV ESPE effects the structures in the region
- Where is the shore of the *N*=50 island of inversion?



THANK YOU FOR YOUR ATTENTION!

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^{71}Co Isomer Signature