



THE CeBrA DEMONSTRATOR

Particle- γ coincidence experiments at the FSU Super-Enge Split-Pole Spectrograph

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The CeBr₃ Array (CeBrA) demonstrator was characterized using standard calibration sources and a set of particle- γ coincidence experiments at the FSU Super-Enge Split-Pole Spectrograph (SE-SPS).

I. CeBr₃ Characterization

CeBr₃ Detectors: Four 2"x2" & one 3"x4"

Energy Resolution: 2-3% @ 1.3 MeV (⁶⁰Co)

- Evolution with $1/\sqrt{E_\gamma}$

Timing Resolution (E_γ dependent)

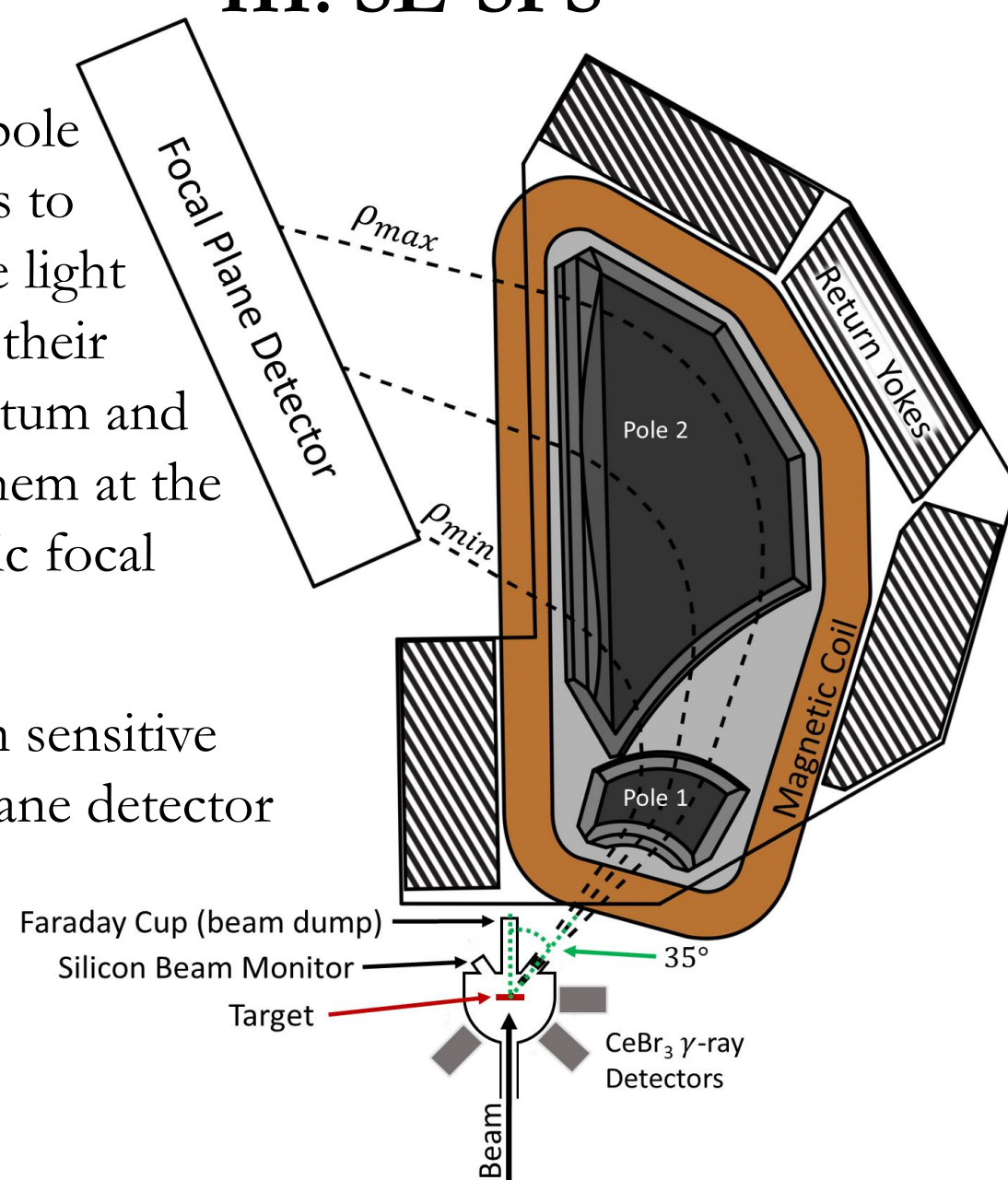
- 500-590 ps for 2"x2" CeBr₃ detectors
- Sufficient for lifetime measurements on the order of a few hundred picoseconds

Full-Energy Peak Efficiency (E_γ dependent)

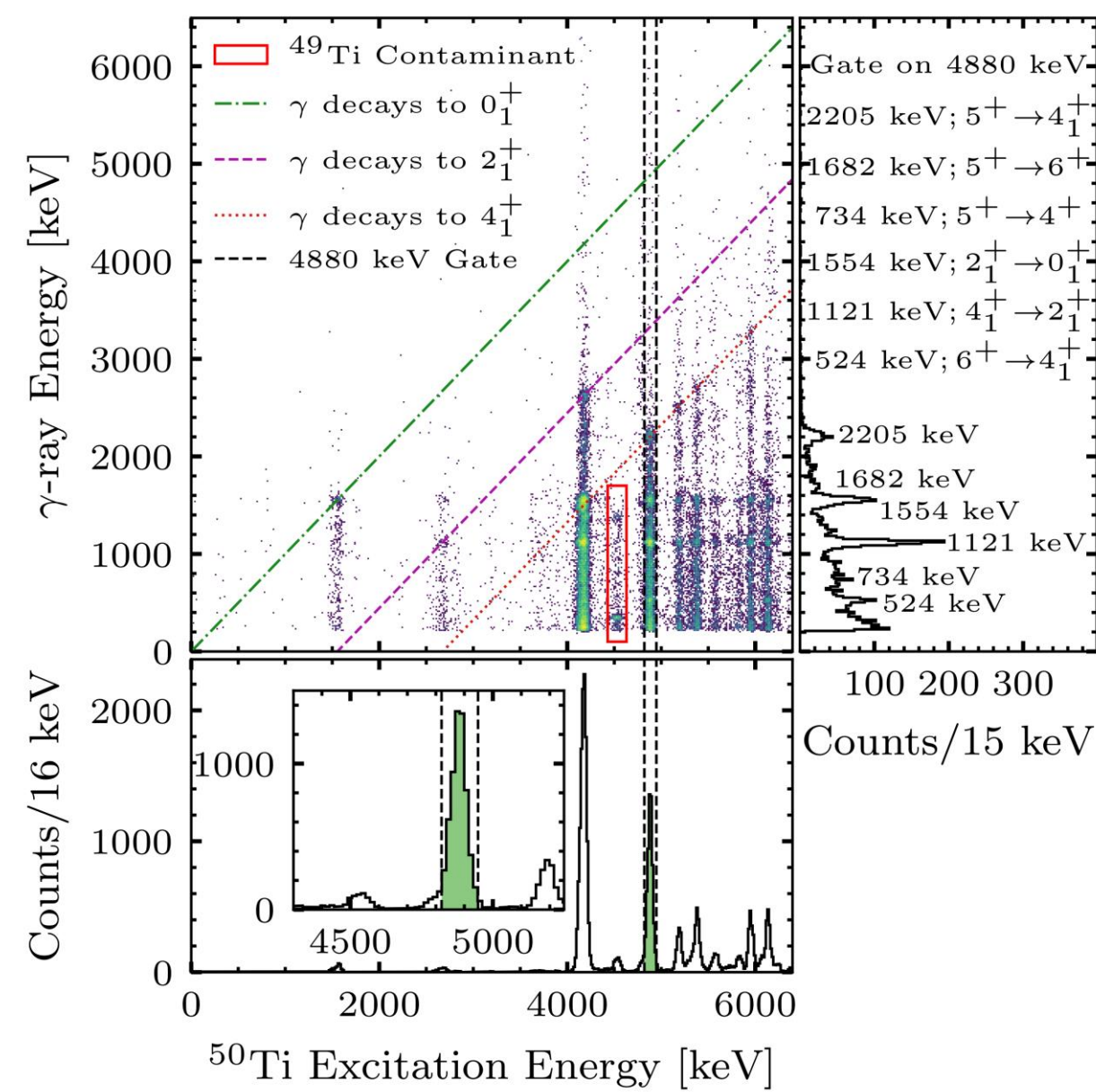
- 2" x 2" CeBr₃: ~ 0.2% @ 1.3 MeV
- 3" x 4" CeBr₃: ~ 0.4% @ 1.3 MeV

III. SE-SPS

- Two dipole magnets to separate light ions by their momentum and focus them at the magnetic focal plane
- Position sensitive focal plane detector

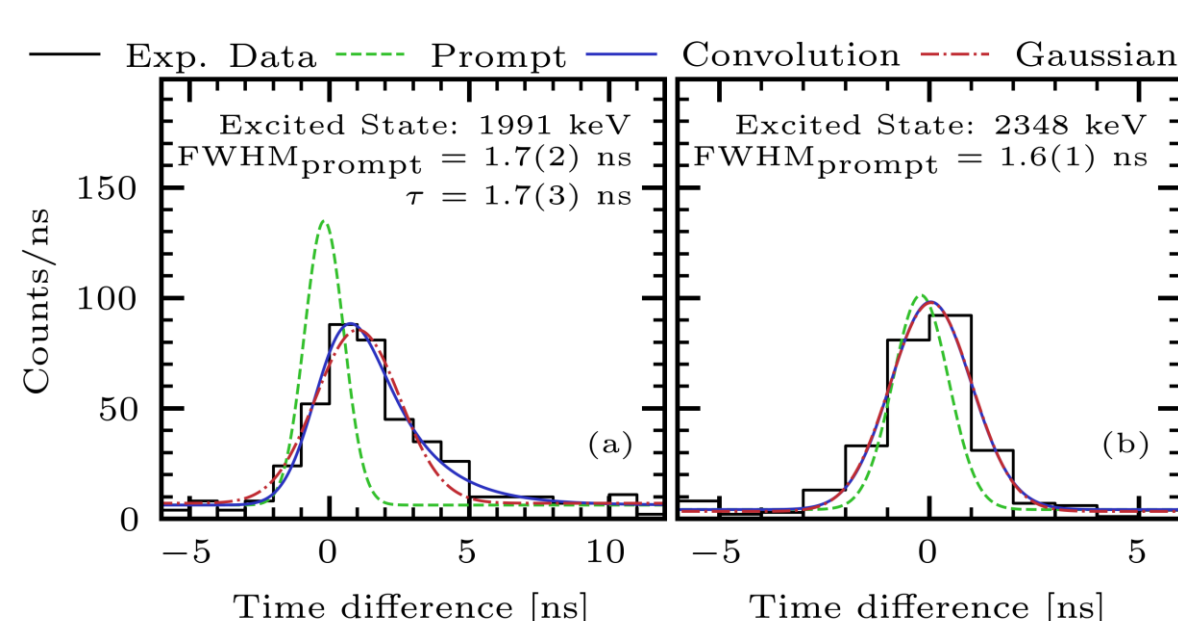


VI. Particle- γ Coincidence Matrix



Particle- γ coincidence matrix for ⁴⁹Ti(d,p)⁵⁰Ti. The γ decays of excited states can be studied by applying selective gates to this matrix.

IX. Nuclear Level Lifetimes



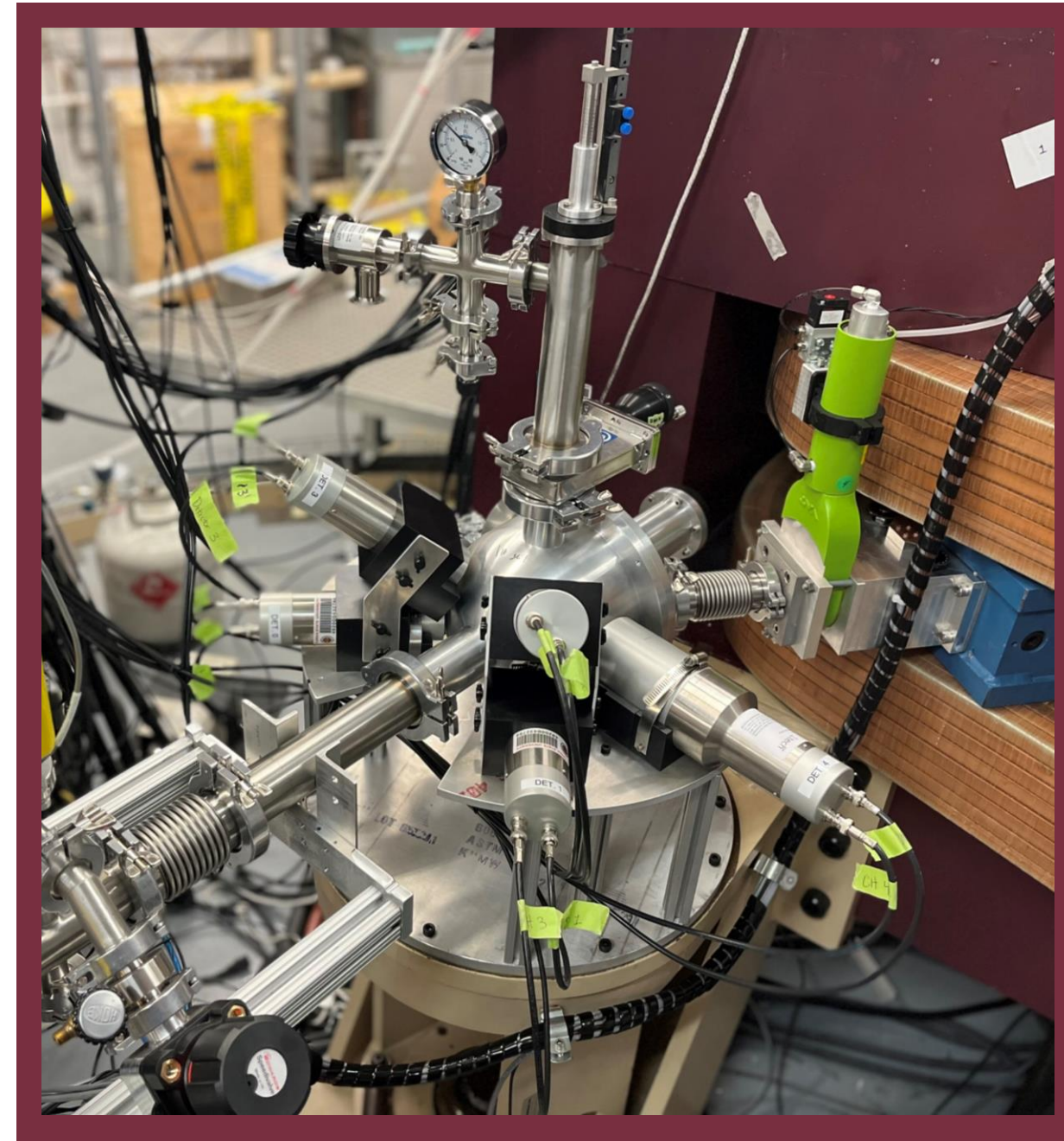
Time-difference spectra of the CeBrA demonstrator and the SE-SPS scintillator for two ³⁵S excited states with an excitation energy gate applied.

- 1991-keV state: $\tau_{\text{CeBrA}} = 1.7(3)$ ns using the convolution method. This value agrees with the adopted value of 1.47(7) ns [1, 2].
- 2348-keV state: Short lifetime = no tail ($\tau_{\text{Lit}} = 1.2(2)$ ps [1])

[1] ENSDF, NNDC Online Data Service, ENSDF database (2023).
[2] F. W. Prosser and G. I. Harris, Phys. Rev. C 4, 1611 (1971).

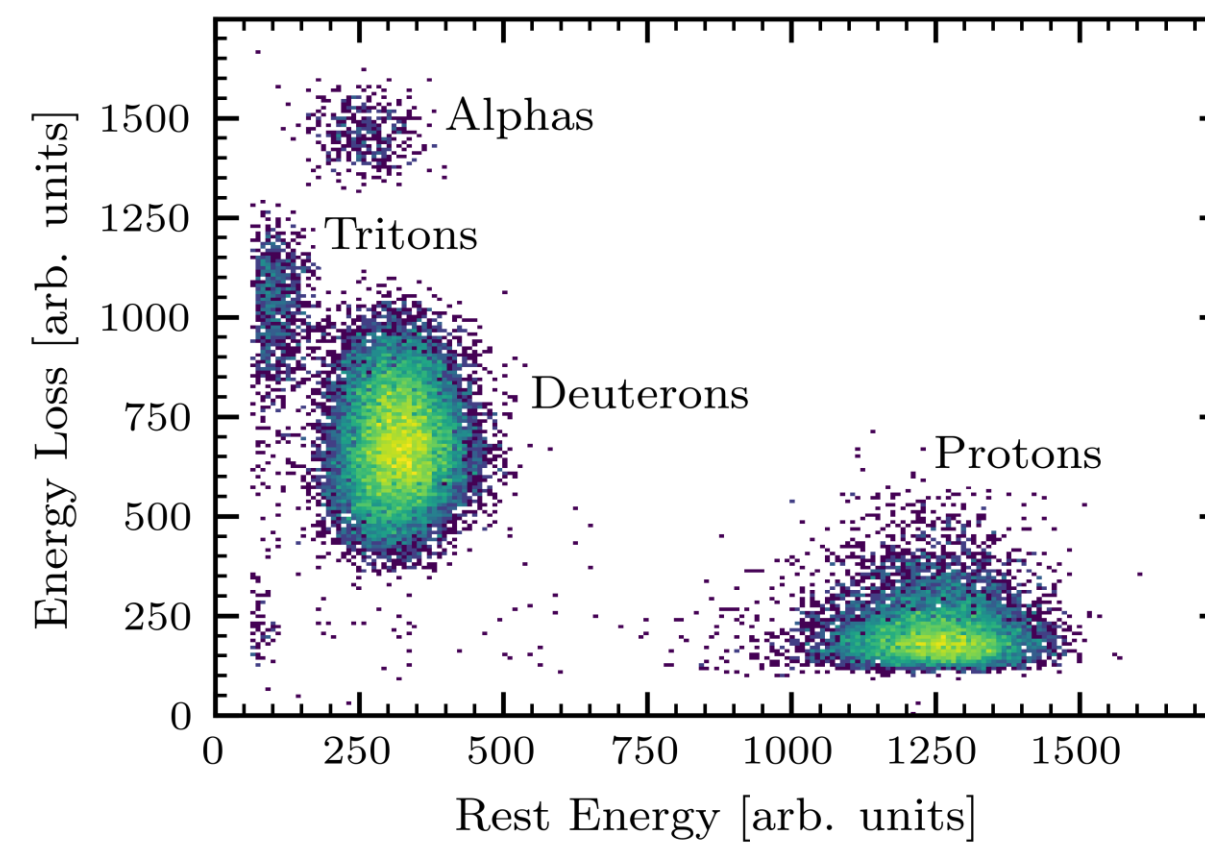
For more details and discussion view: A. L. Conley, B. Kelly, M. Spieker, *et al.* NIM A **1058**, 168827 (2024).

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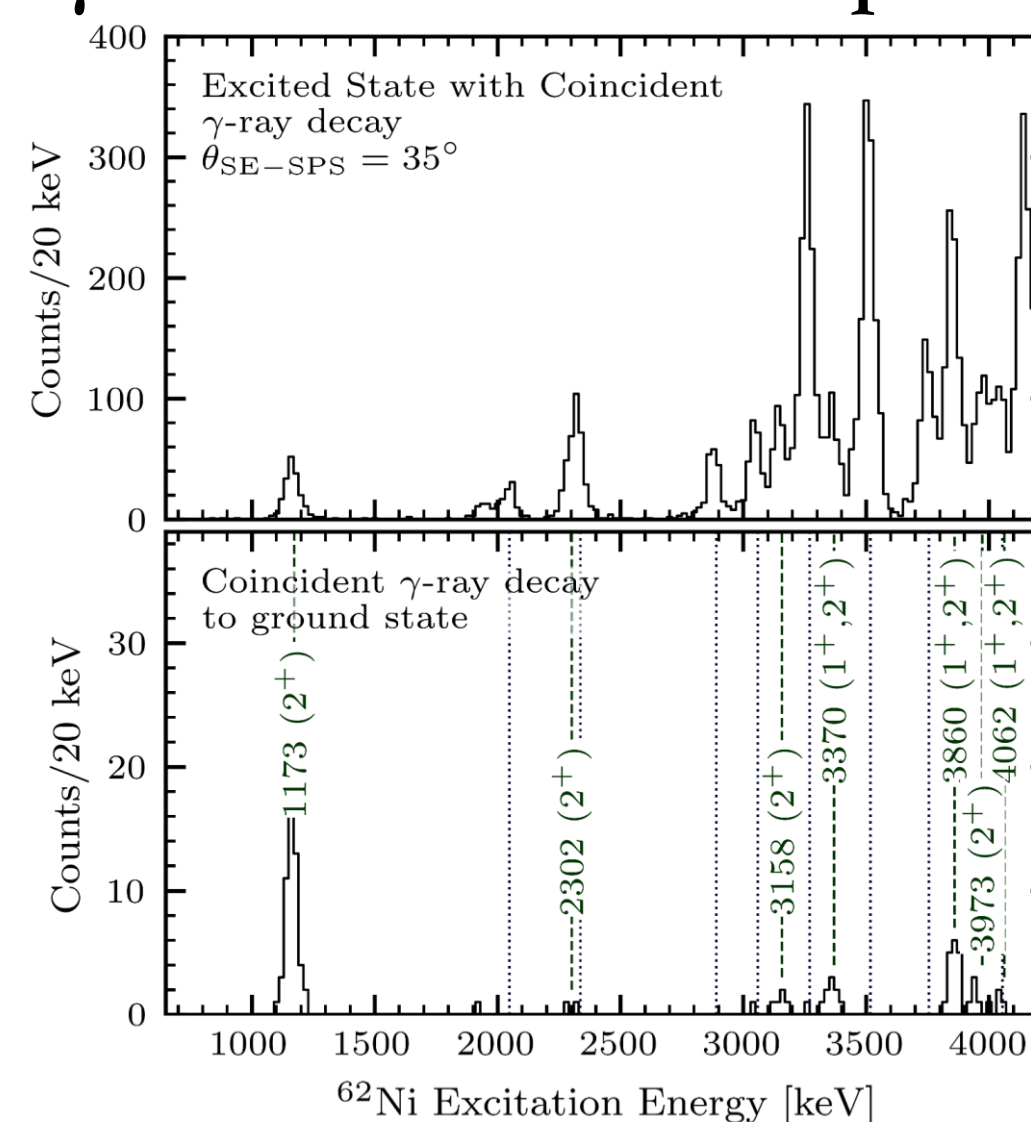
CeBrA demonstrator at the SE-SPS

IV. Particle and Reaction Identification



Particle identification (PID) with the SE-SPS focal plane detector. Anode wires are used to measure the energy loss and a large plastic scintillator is used to measure the rest energy of the particles.

VII. γ Gated Focal-Plane Spectrum



(Top) Focal-plane spectrum for ⁶¹Ni(d,p)⁶²Ni if any coincident γ ray was detected. (Bottom) Focal-plane spectrum if γ -ray transition led directly to ground state. This gating technique can provide important complementary information for better constraining spin-parity assignments and identifying which states were populated in a specific nuclear reaction.



II. Commissioning Experiments

a) ⁴⁹Ti(d,p)⁵⁰Ti and ⁶¹Ni(d,p)⁶²Ni

- Selectively study γ decays of excited states to different final states
- Determine γ -decay branching ratios
- Contaminant identification

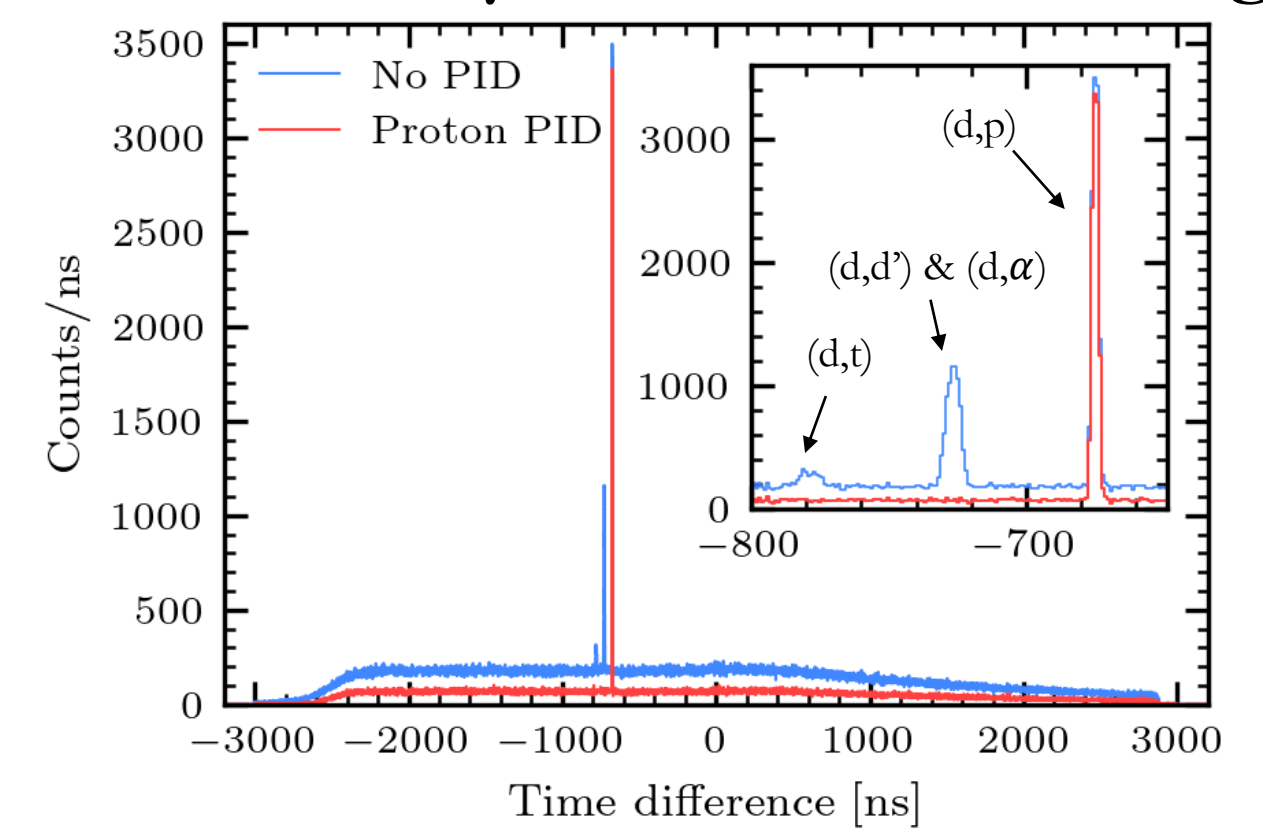
b) ⁵²Cr(d,p)⁵³Cr

- Particle- γ angular correlations for spin-parity assignments

c) ³⁴S(d,p)³⁵S

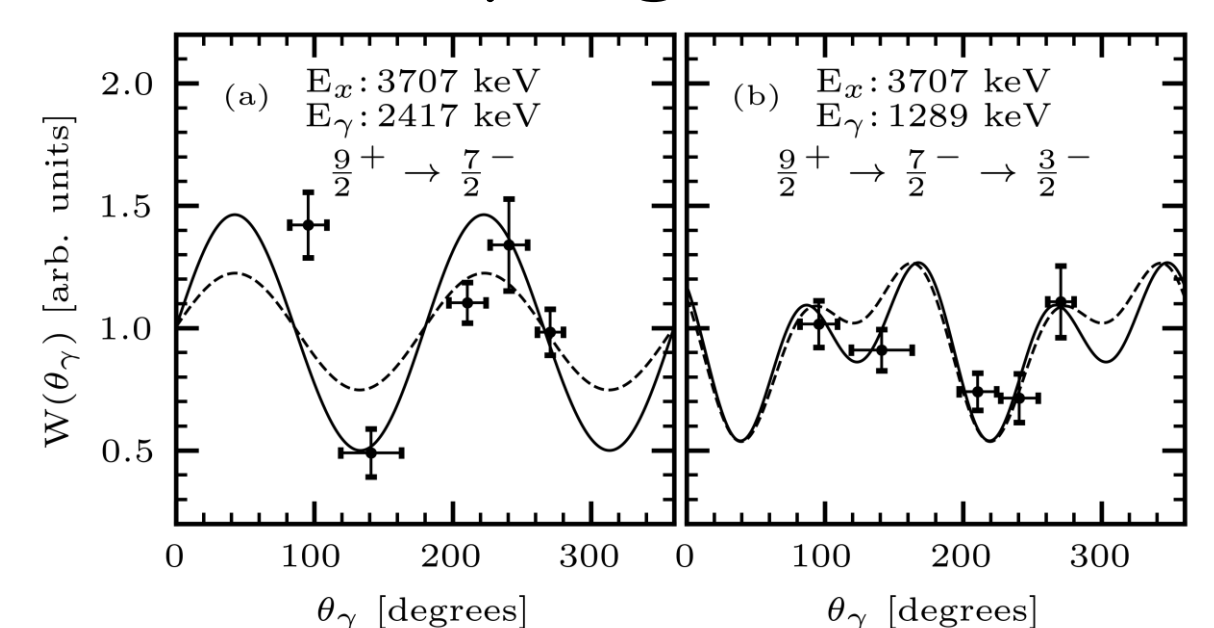
- Nuclear level lifetimes via fast-timing techniques

V. Particle- γ Coincidence Timing



Time-difference spectrum between one 2"x2" CeBr₃ detector and the SE-SPS focal-plane scintillator.

VIII. Proton- γ Angular Correlations



Proton- γ angular correlations for the primary and secondary transitions depopulating the 3707-keV state of ⁵³Cr populated via ⁵²Cr(d,p)⁵³Cr (symbols). The dashed lines correspond to predictions when using the adopted multipole mixing ratios [1], while solid lines used different multipole mixing ratios. Dominant (a) dipole (E1) and (b) quadrupole (E2) character of the transition are clearly observed.

X. Future of CeBrA

- Construction of full 14 detector array
 - Complementing the array with 3"x6" CeBr₃ detectors.
- Use CeBrA+SE-SPS for selective nuclear structure studies via different nuclear reactions also informing nuclear astrophysics.
- Complement setup with additional ancillary detectors for internal conversion electron and fission fragment spectroscopy.

