RIA Detector workshop: Role of particle detection in nuclear structure studies with GRETA

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Oak Ridge

March 21, 2003

Auxiliary particle-detector systems for Nuclear Structure with arrays like GRETA

- Beam Energies ~ Coulomb Barrier:
  - Charged particle detectors internal to GRETA
  - Fusion and/or transfer reactions, High spin, Far from stability, 4π-channel selection
  - Neutron detectors external to GRETA
  - Evaporation residue counters external to GRETA

- Beam Energies >> Coulomb Barrier:

  Part. detectors downstream to GRETA
  - The HIRA array (Other talks, DeSoussa et al.)
  - A Neutron Wall (Other Talks)

Some possible solutions

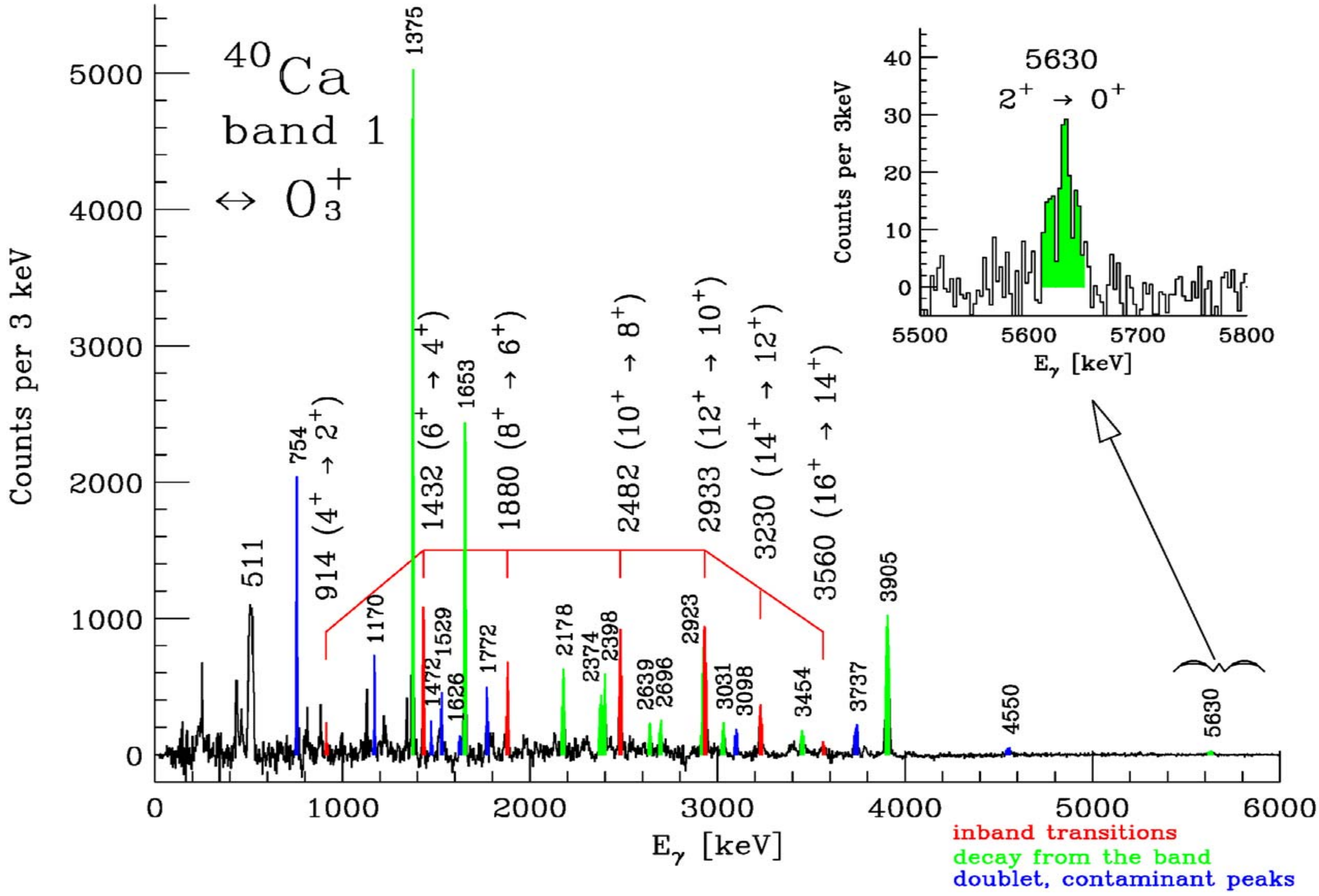
- Beam Energies ~ Coulomb Barrier:
  - Charged particle detectors internal to GRETA
  - Fusion reactions, High spin, Far from stability, 4π-channel selection
    - High intensity, >10^7 particles/s: Tracking difficult if at all possible
    - Moderate to low intensity <10^7 particles /s. Tracking easier but we have to content with very large beam sizes
  - Best channel selection + recoil correction, low resolution Particle spectra

This is clearly seen in the ^{40}Ca SD work. We must have the highest detection efficiency possible

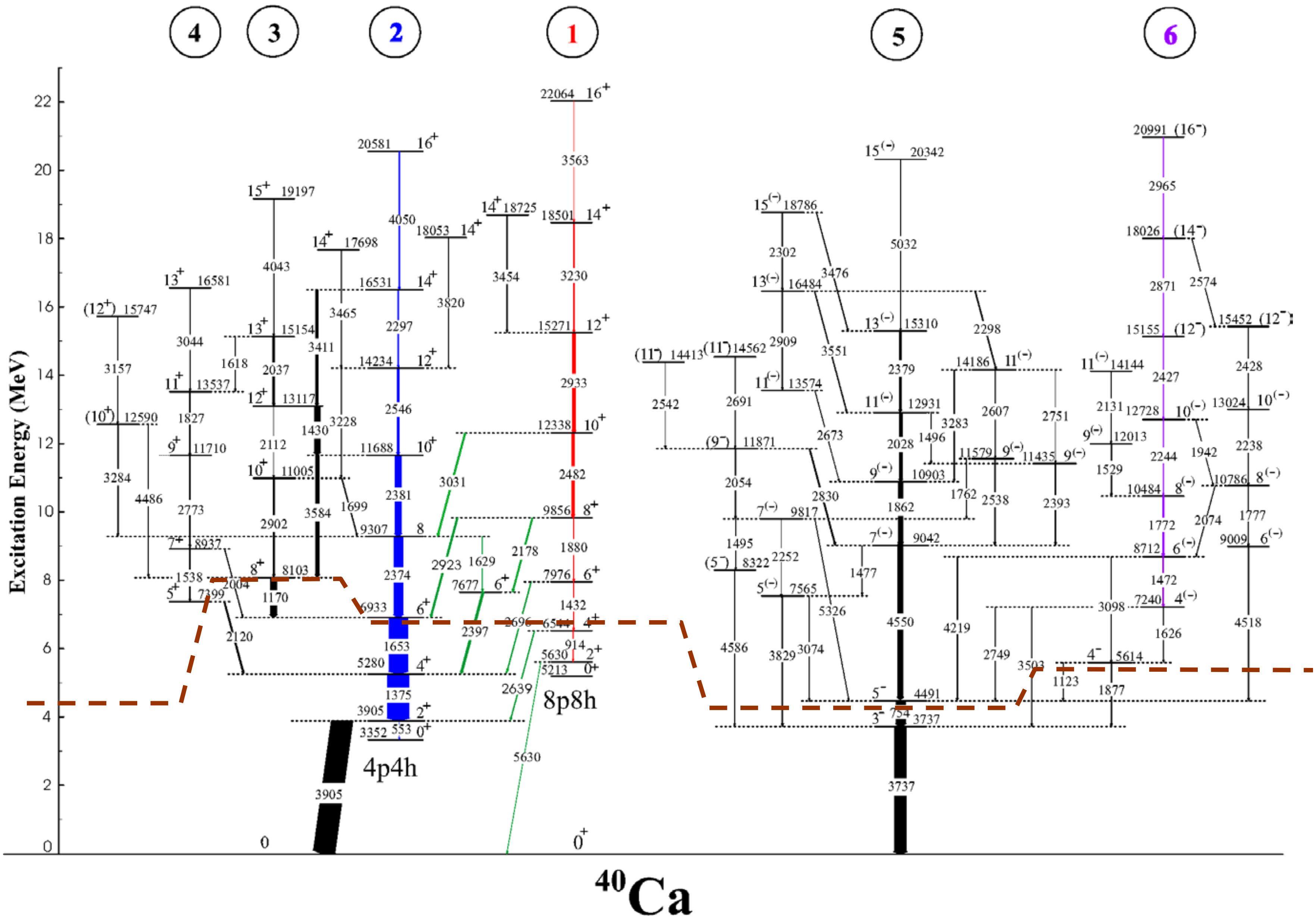
For ^{24}Mg + ^{24}Mg = 2α +^{40}Ca the α-efficiency of the Microball was only 0.52, and the 2α =0.52^2 =0.27!
see next slide:

γ-ray spectrum of the SD band in ^{40}Ca

(84 MeV $^{20}Ne+^{28}Si \rightarrow ^{40}Ca+2\alpha$) , Ideguchi et al., 2001

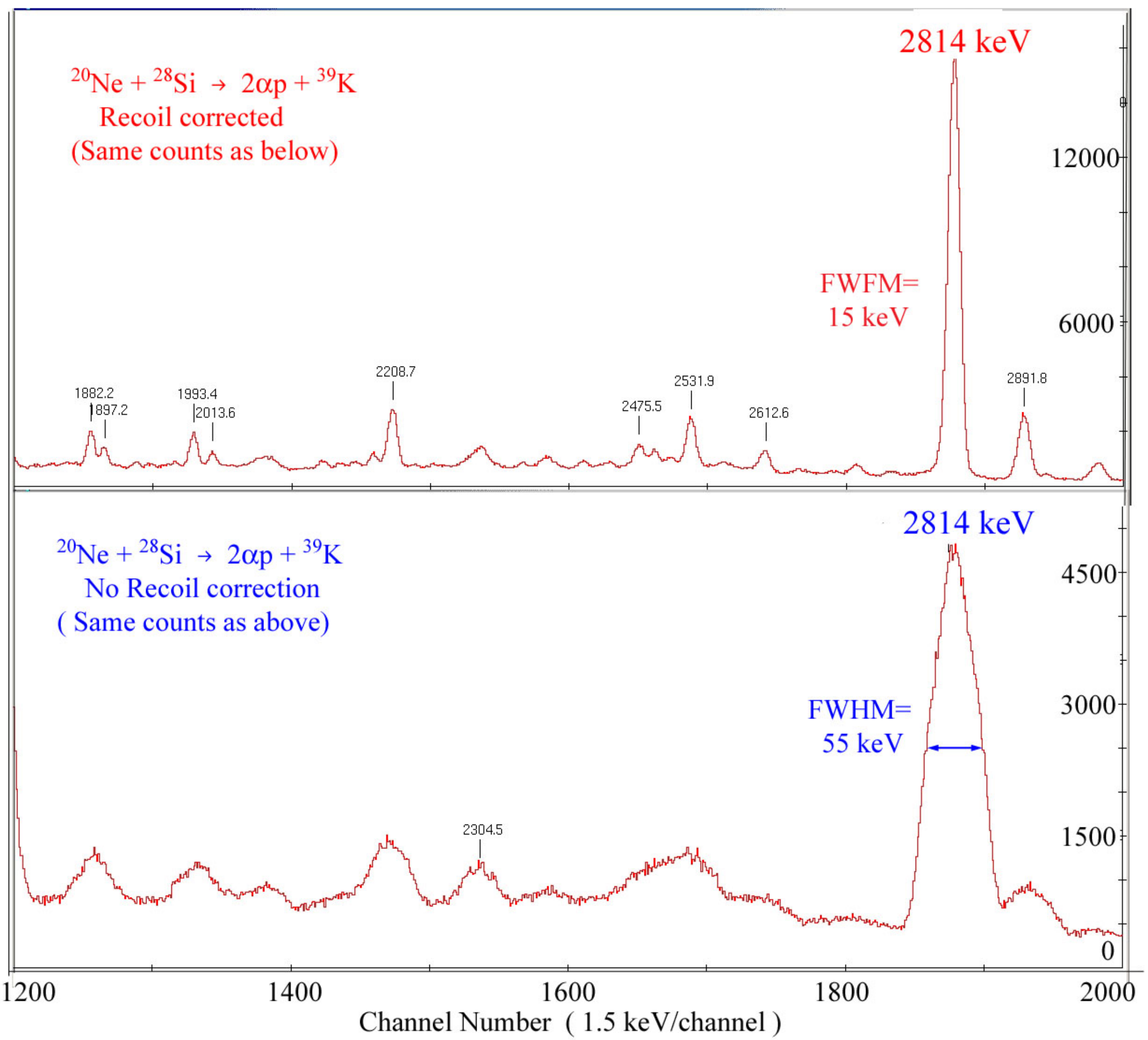


Decay scheme of ^{40}Ca: Both parities, (Ideguci et al.)



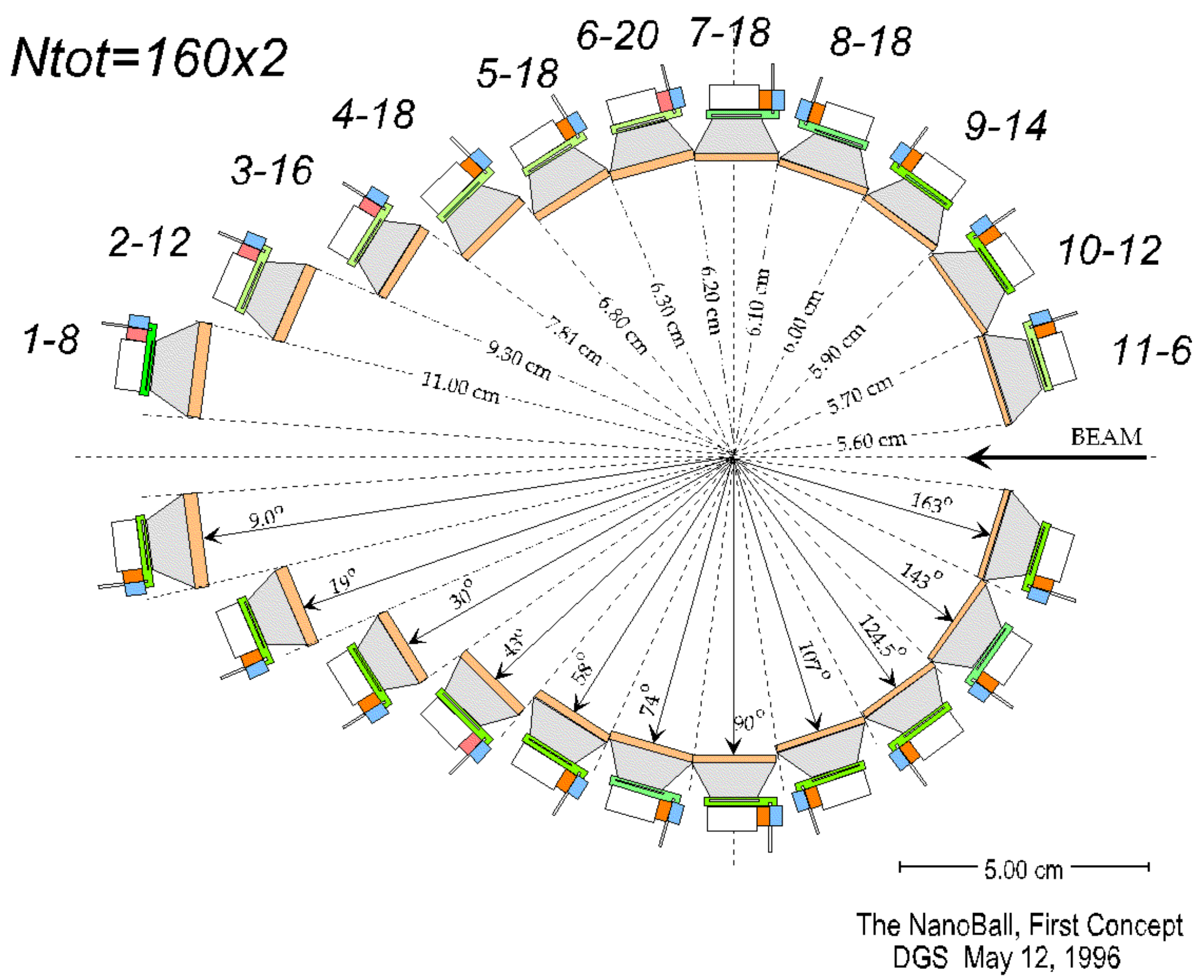
Superdeformation in ^{40}Ca

Possible only because of Recoil Corrected spectra:
The resolution improves by a factor of 3.7 !



One efficient solution for the best 4π coverage: The nanoball

- 320 channels by splitting the CsI(Tl) detectors to half
- 5-point digital signal processing
- Highest rate, minimal pile-up (rates of 5 kHz/split det.)



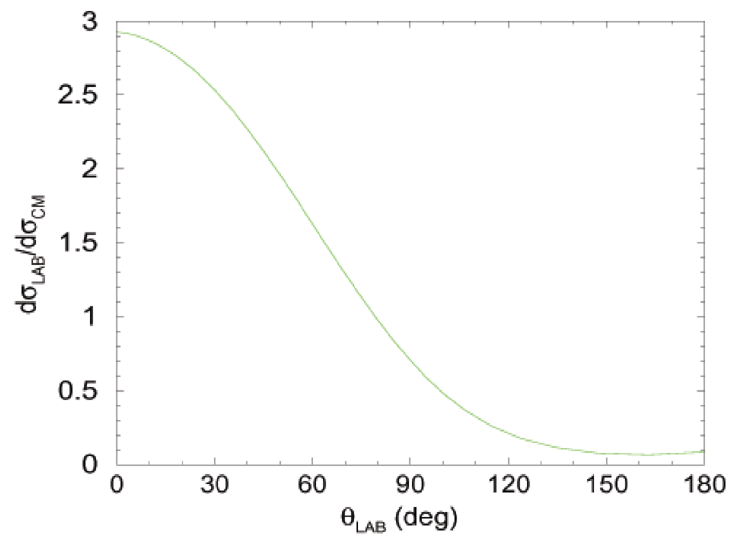
Charged particle detectors internal to GRETA (cont.)

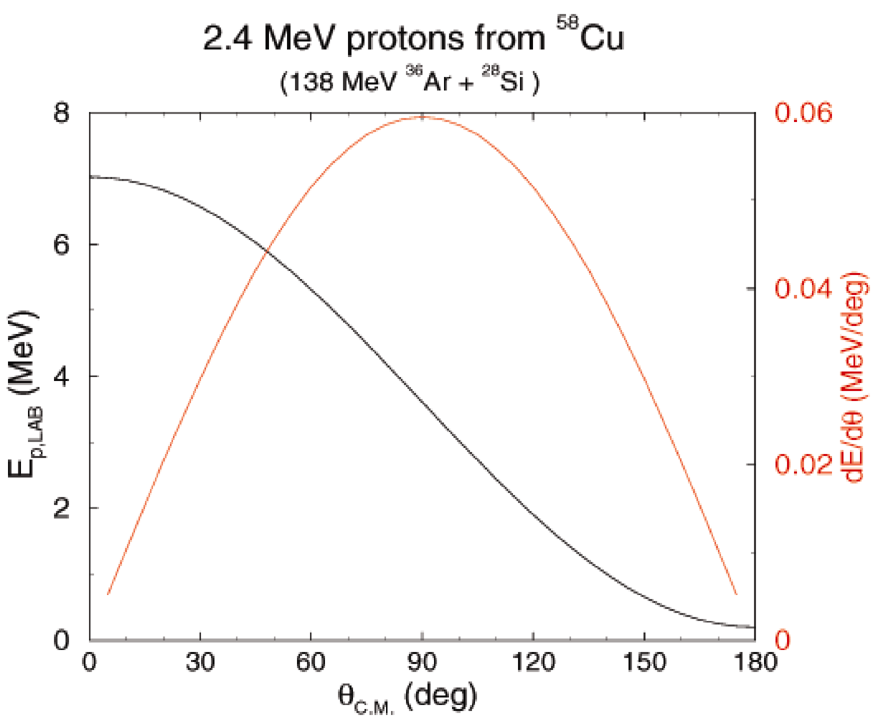
•Fusion reactions, Far from stability, 4π-channel selection
Any intensity.

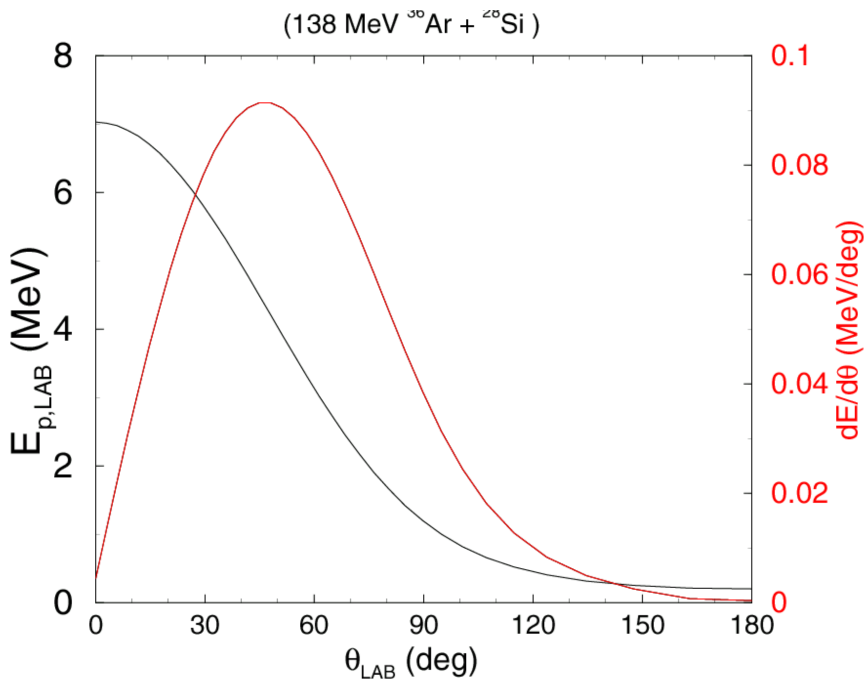
•High efficiency with the Best energy-resolution particle spectra

➢Clear solution: Si strip based 4π system.

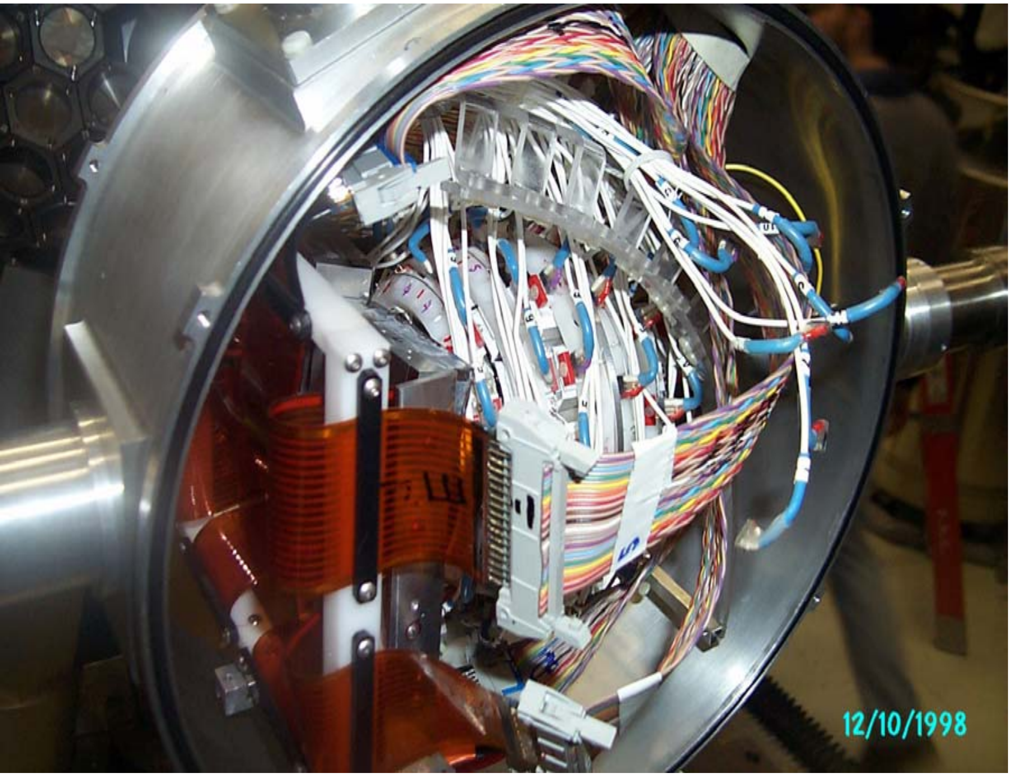
➢Now we must look at the kinematics:







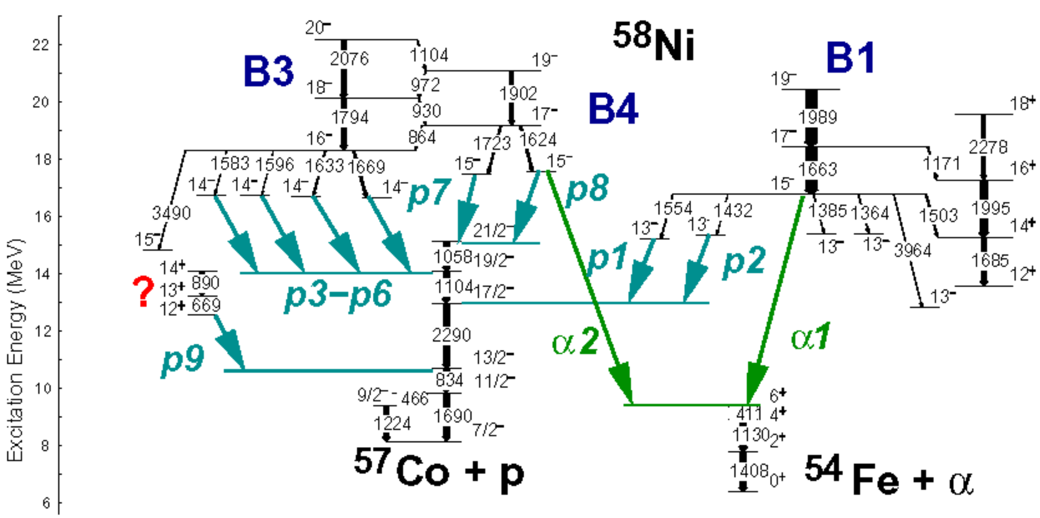
The Wash. U. Si-Wall + Microball in Gammasphere



1024 pixels (3.1x3.1 mm^2)
Within $\theta_{\text{lab}} < 45^o$

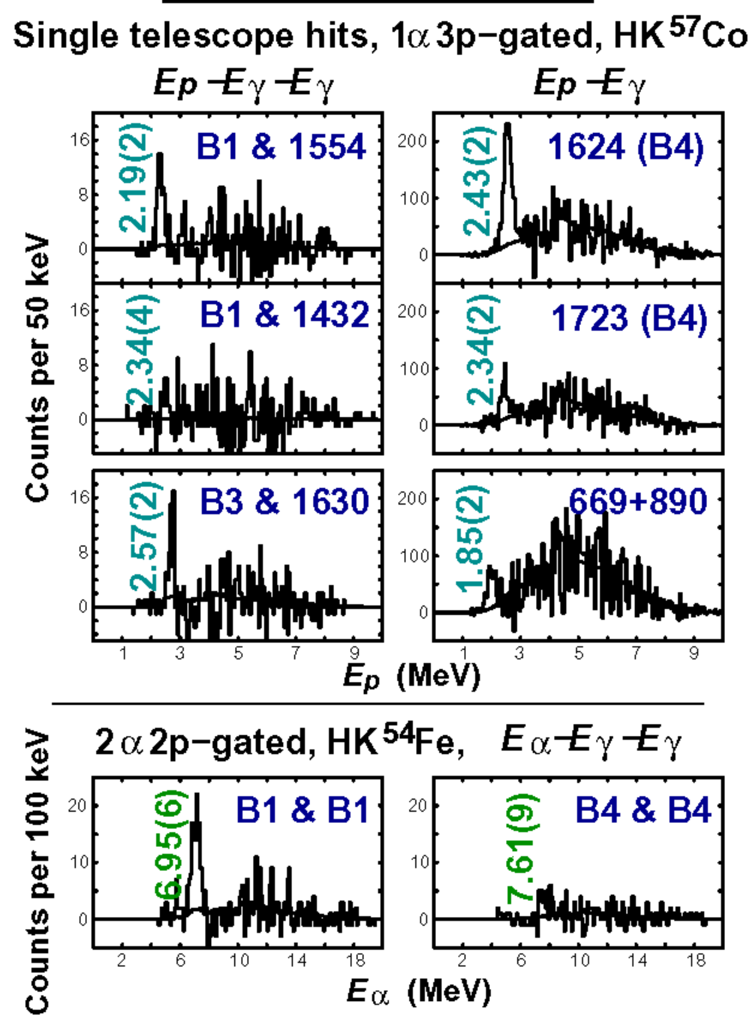
From GSFMA42, ^{36}Ar+^{28}Si, Rudolph et al.

Particle Decay Scheme of ^{58}Ni



No.	*p1*	*p5*	*p7*	*p8*	*p9*	*α1*	*α2*
Q (MeV)	2.259	2.624	2.336	2.437	1.876	7.445	8.231
E (MeV)	2.19(2)	2.57(2)	2.34(2)	2.43(2)	1.85(2)	6.95(6)	7.61(9)
b (%)	>80	~70	~25	~60	~2	3.9(3)	~5

Particle Spectra ^{58}Ni

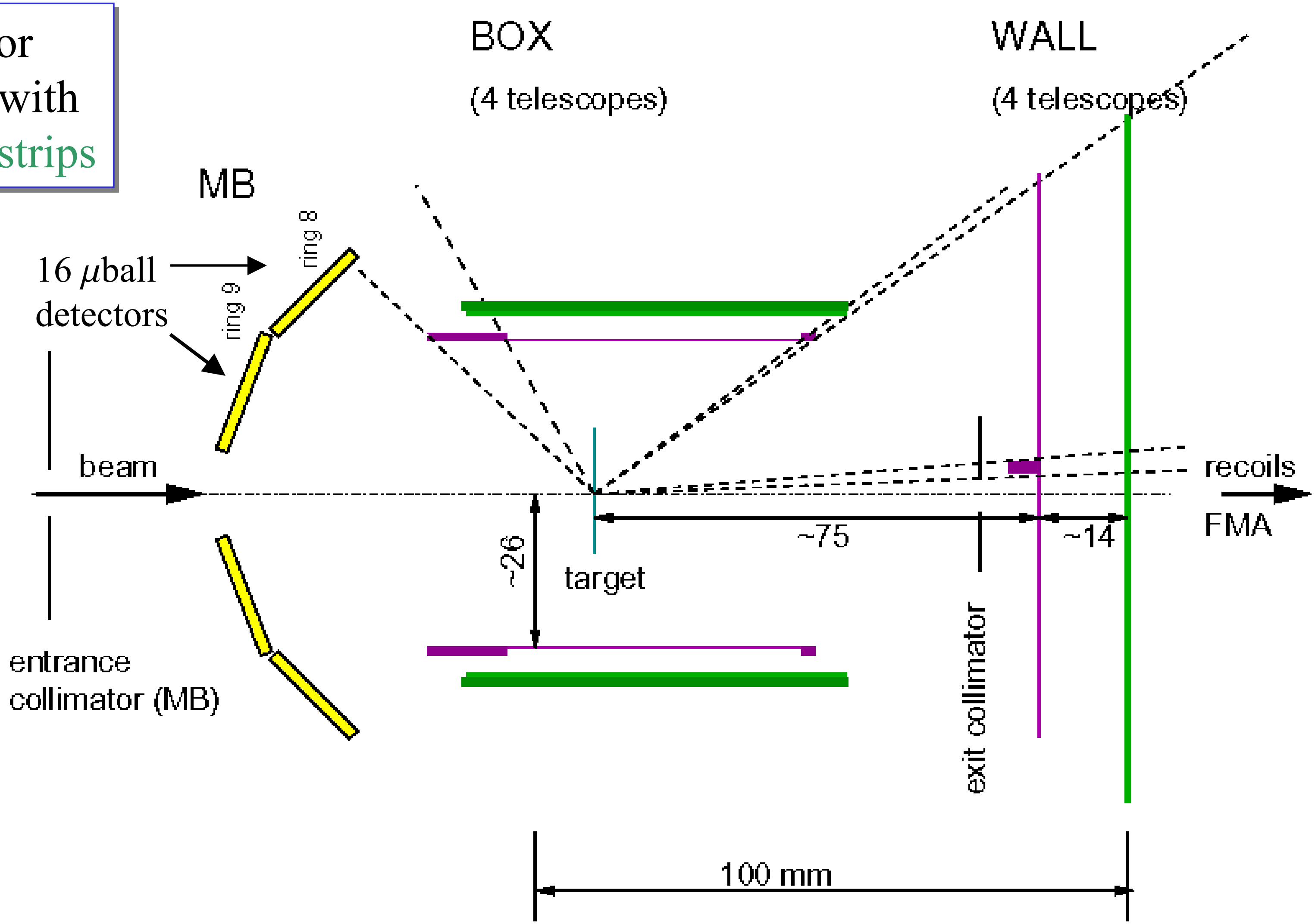


What makes the particle resolution in the last experiment bad, or 230 keV at 2.3 MeV c.of m from 6 MeV lab. ?

- Biggest effect: Target thickness (it was 500 μg/cm^2)
- Next, the beam spot size: diameter about 1 mm !
- Next, the Si strip size: 3.1 mm, pixel size 3.1x3.1 mm^2
- Last, the Si intrinsic resolution: 35 keV at 5.8 MeV E_α

Lund + Wash.U.
Wall+Box+Mball to run in GS late in this summer

Optimized for $^{40}Ca+^{24}Mg$ with 256 total Si strips



Transfer reactions

- All problems listed earlier present but they become worse
- Good particle energy resolution is hopeless even with Si strip detectors

Neutron detectors external to GRETA

For Fusion reactions and channel selection The Neutron Shell for Gammasphere

Why? ^{100}Sn spectroscopy of course! The reaction:

$$^{48}\mathrm{Cr} + {}^{58}\mathrm{Ni} = {}^{106}\mathrm{Te}^* \rightarrow {}^{100}\mathrm{Sn} + \alpha 2n \quad \text{OR}$$

$$^{56}\mathrm{Ni} + {}^{50}\mathrm{Cr}$$

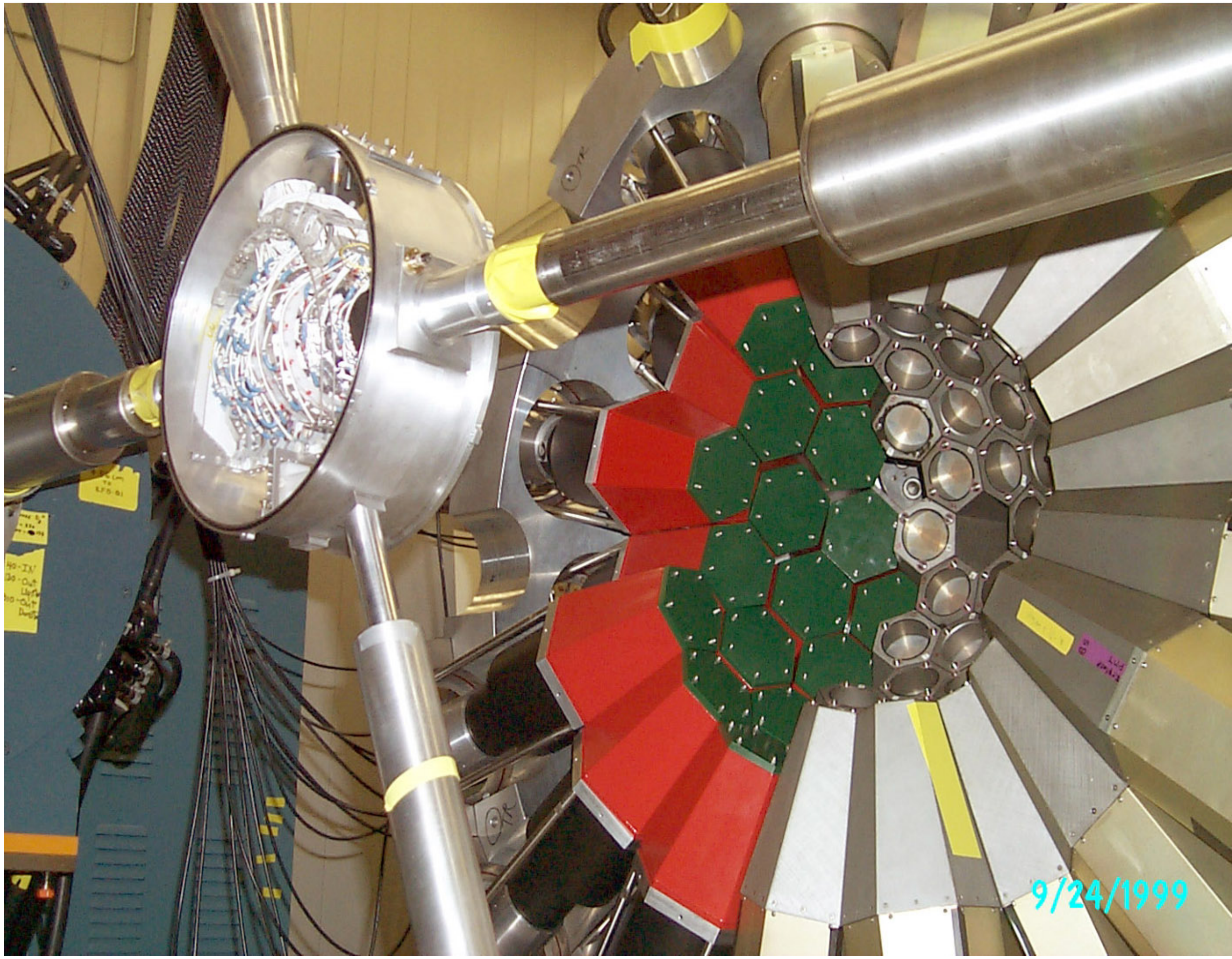
RIA

The Neutron Shell in Gammasphere with the Microball

30 regular tapered hexagons
30 % 1-neutron efficiency

Only half of the Neutron detectors are visible

The Neutron Shell with the Microball in Gammasphere

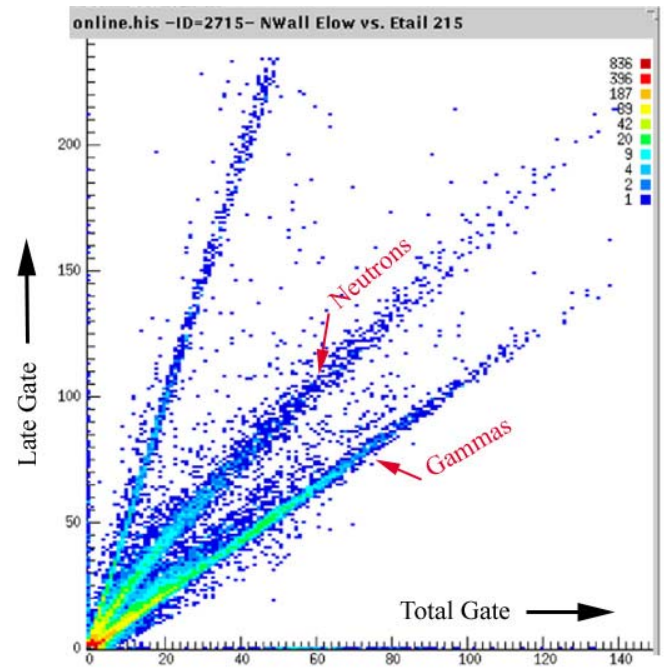


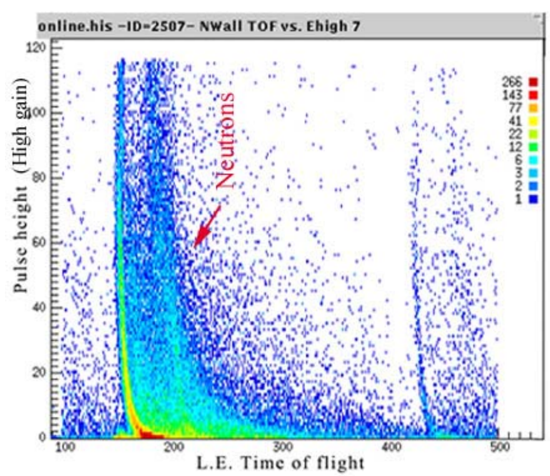
On Line Response of the Neutron array

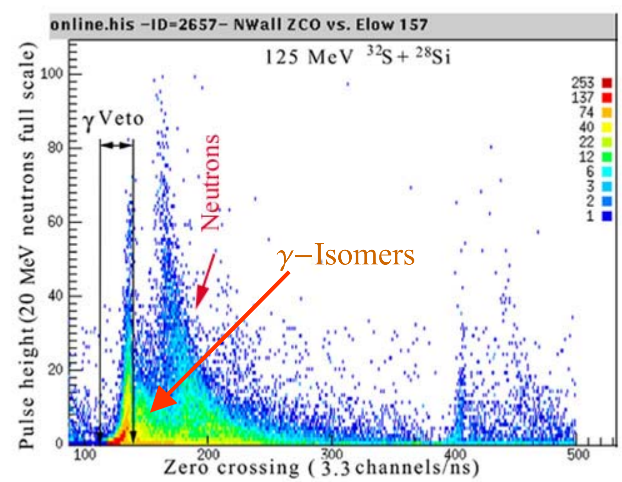
- $\nu\!-\!\gamma$ Separation:
  - By ToF
  - By Pulse shape discrimination
  - By Zero-crossing

- Hardware γ–ray Veto

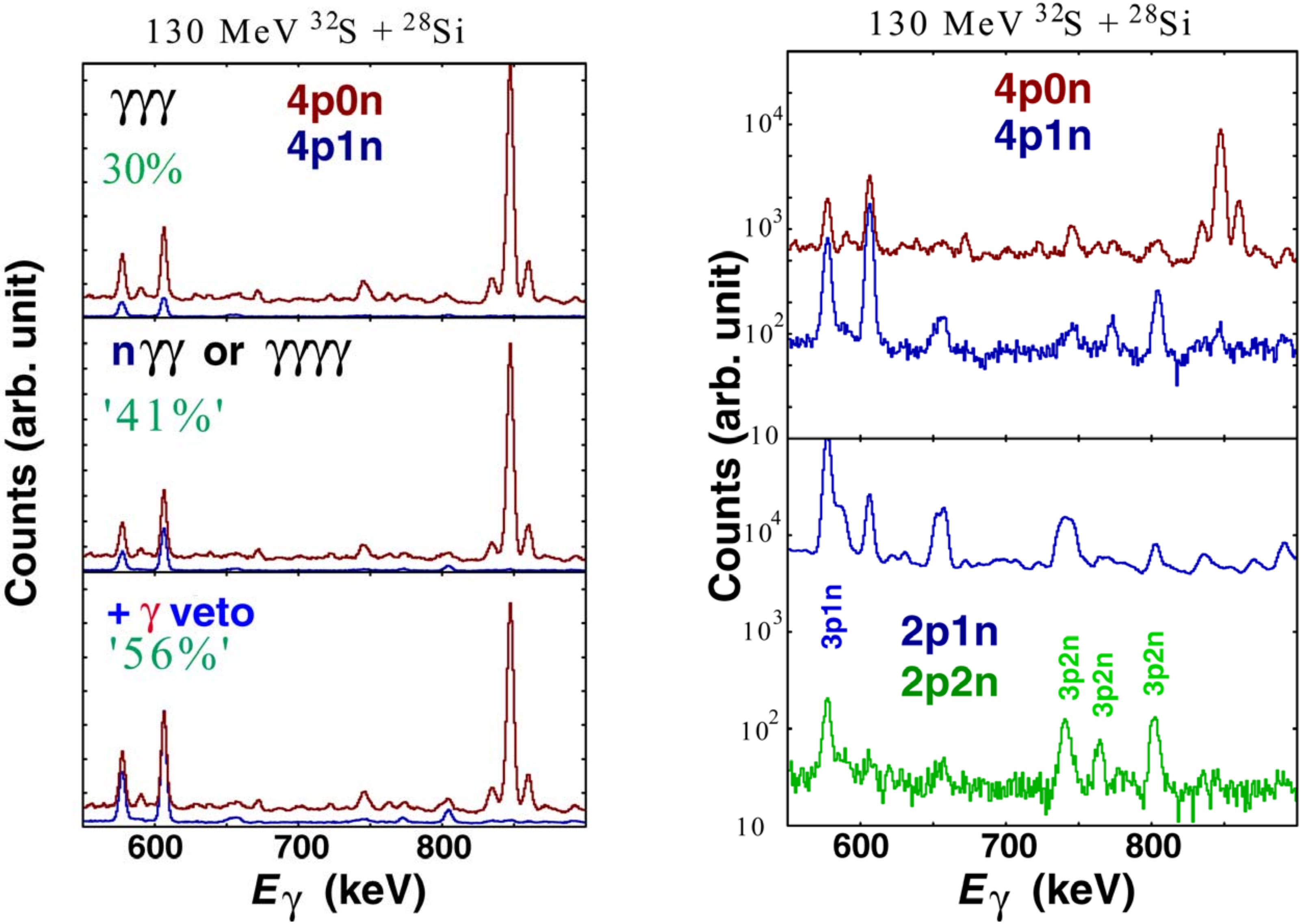
- 2-neutron channel ID
  - Reject nearest neighbors
  - Subtract ~2% of the 1-neutron spectrum from the 2-neutrons
    ID the 2-neutron γ–rays
    Gate with Gammasphere







Neutron efficiencies

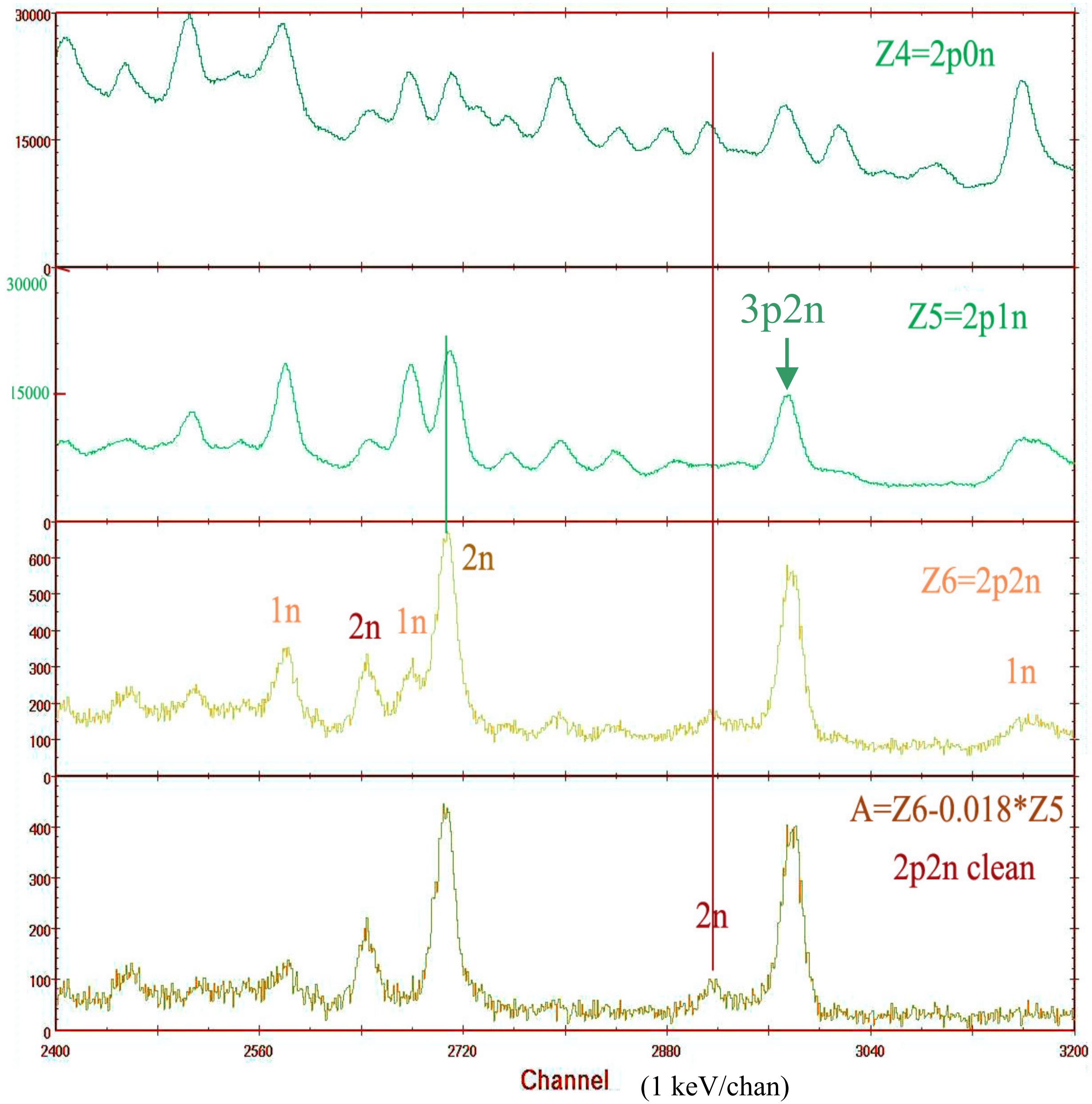


Elaborate false double neutron rejection
Gives 4.6% efficiency for 2 neutrons

130 MeV $^{32}S + ^{28}Si = ^{60}Zn^* \longrightarrow$

$\epsilon_{1n} = 30\% \rightarrow$

$\epsilon_{2n} = 8\% \rightarrow$



Conclusion: The Gammasphere Neutron Shell is adequate for fusion reactions to reach very neutron deficient isotopes like ^{100}Sn.

- No change needed for this purpose with GRETA and RIA
- Fancier inexpensive electronics possible but not necessary.

An Evaporation residue counter external to GRETA

Residue counters with very high efficiency (no spectrographs) :

Nuclei of interest:

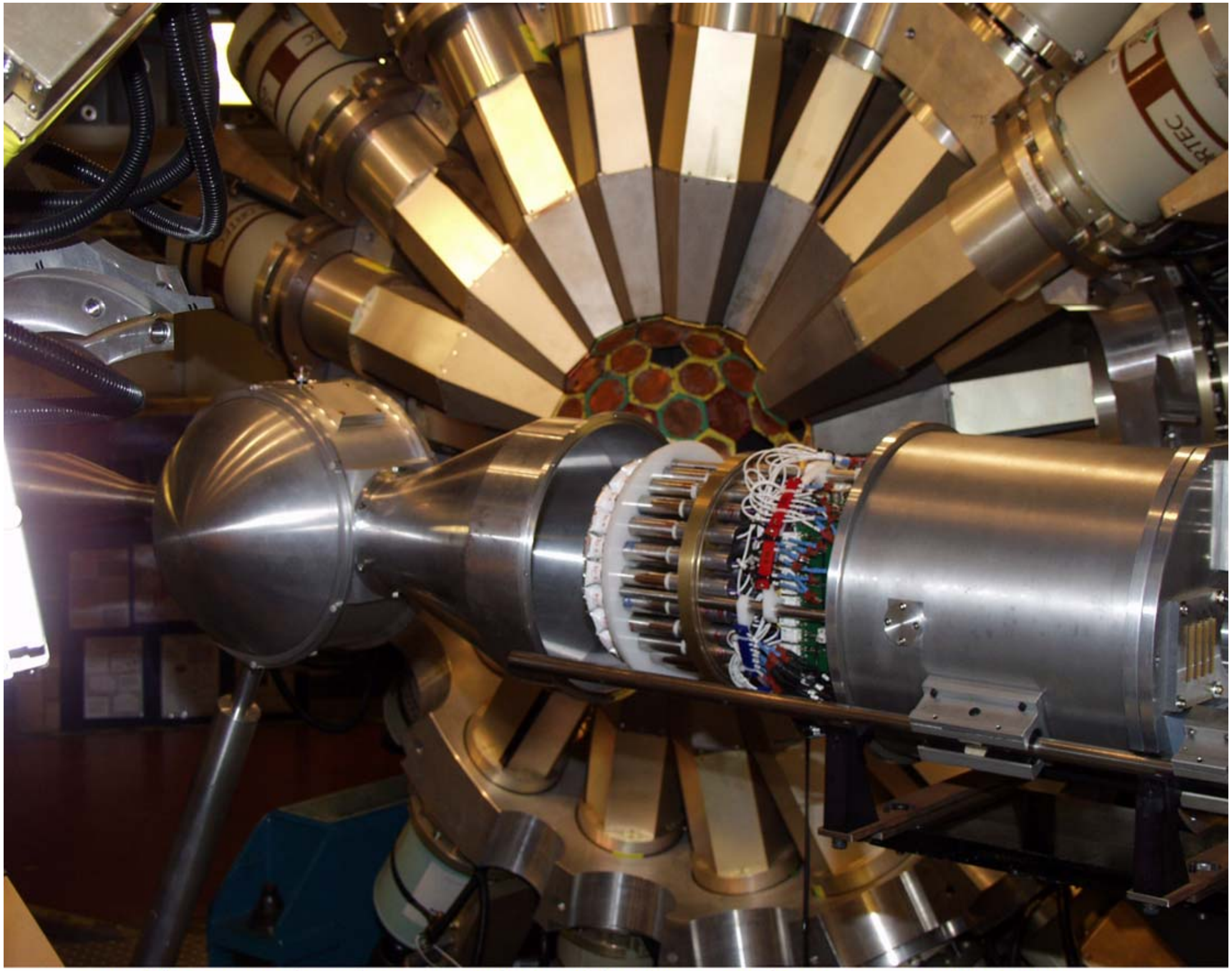
–Spectroscopy in the trans-lead nuclei

–Trans-uranium nuclei and beyond with rare beams and/or weaker exit channels (αxn)

–Complementary to RDT experiments

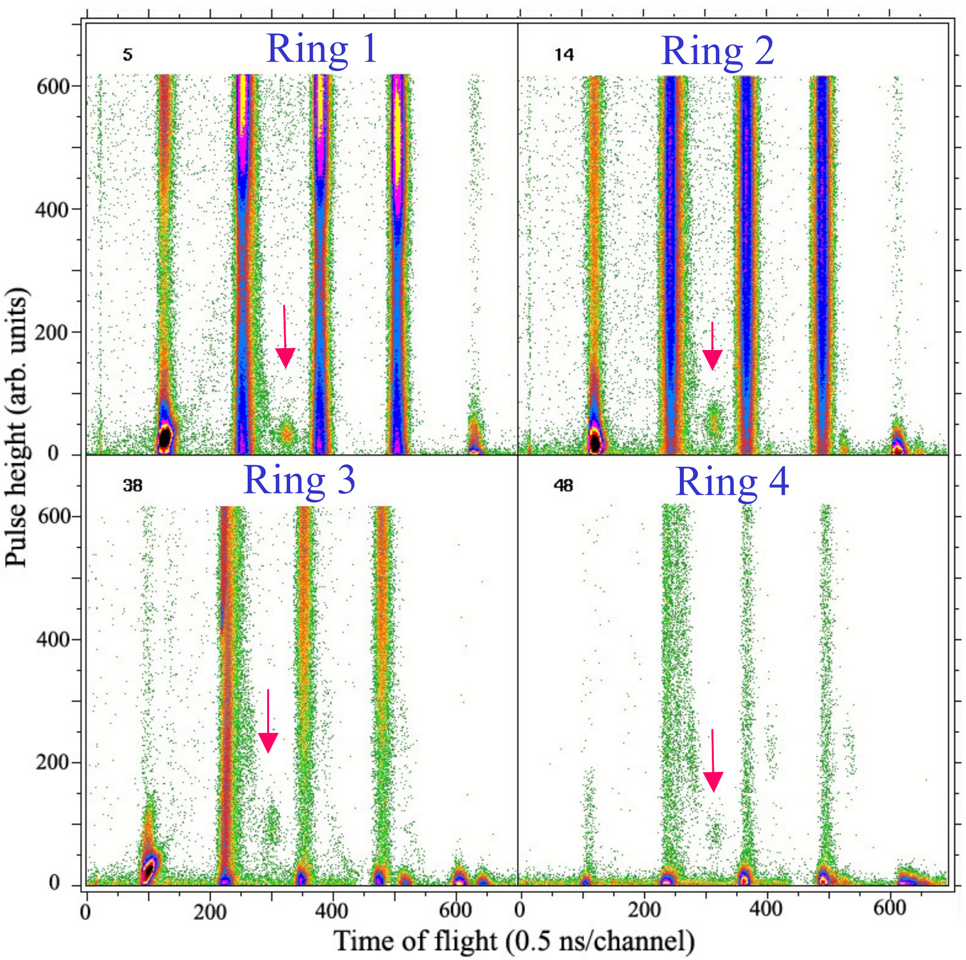
–A fine tuned version of HERCULES with 60-70% residue efficiency **coupled with the nearly full GRETA** (or Gammasphere)

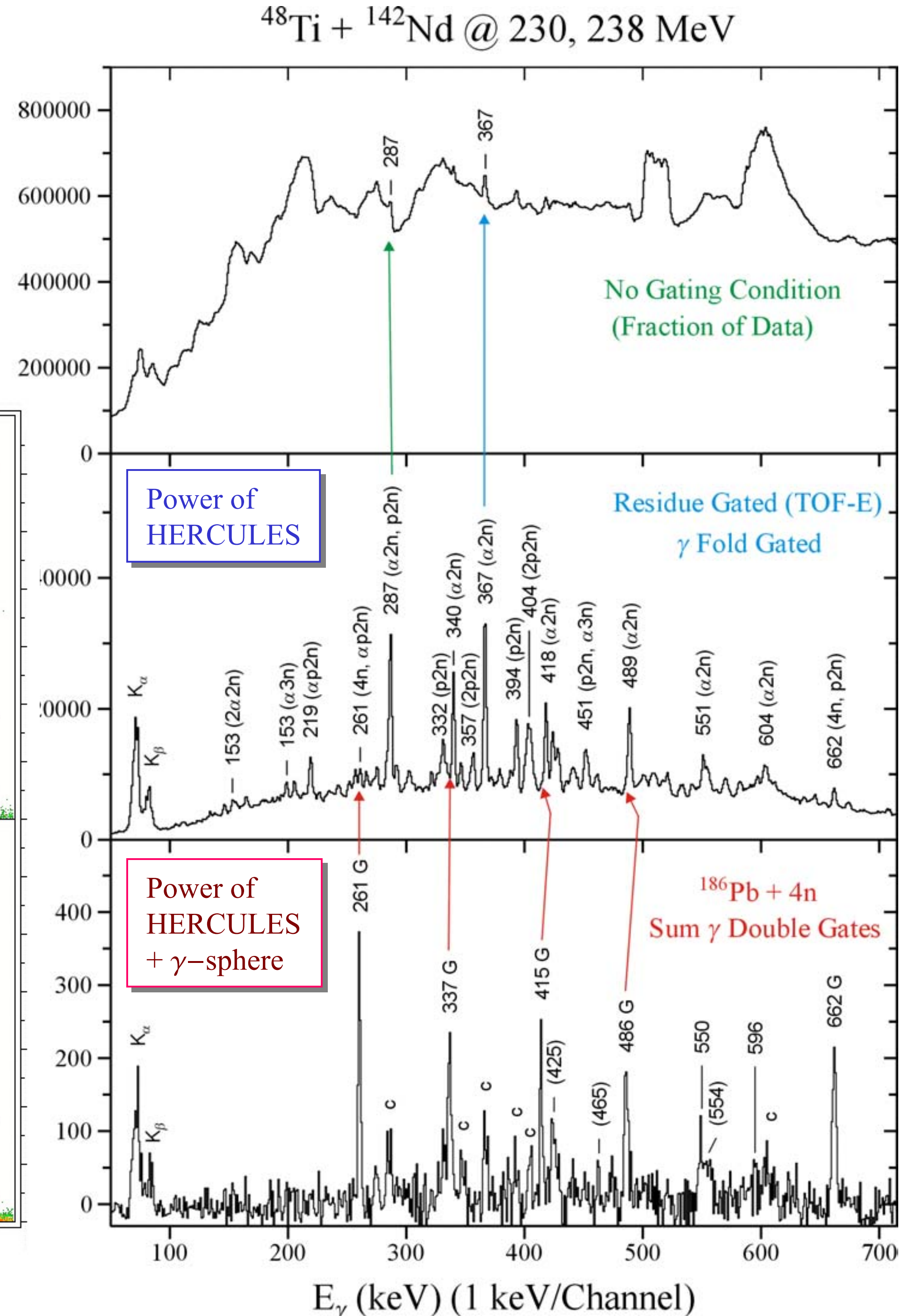
Last but not Least: HERCULES
(High Efficiency Residue Counter Under Lots of Elastic Scattering)



Washington University: HERCULES in Gammasphere, August 20, 2002

Sample Residue gating and γ–ray spectra





That's all Folks,

Thanks