New developments in characterizing nuclei using separators

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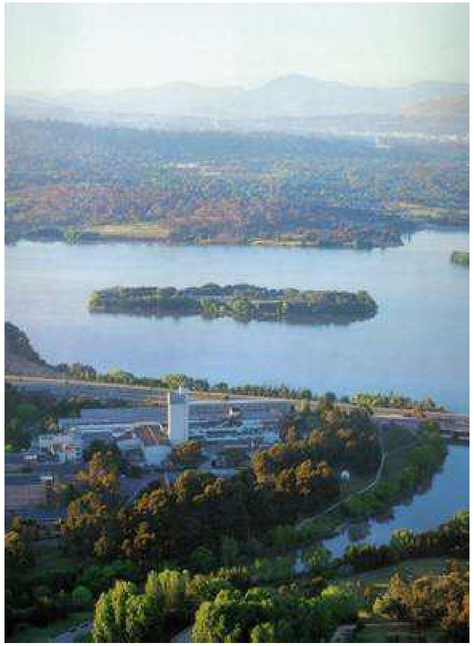


Workshop on "Nuclear Structure and Decay Data: Theory and Evaluation" Trieste, Italy, 2006

Outline:

Lecture II: New developments in characterizing nuclei using separators

- *TRIUMF-ISAC*
- Heavy Element Spectroscopy at JYFL
- New compact recoil separator at the ANU
- Future – radioactive beam facilities

ISAC at TRIUMF

Isotope Separator and ACcelerator

P. G. Bricault, et al.,
Nucl. Instrum. Methods Phys. Res. B126, 231 (1997)

Courtesy of P.E. Garrett

Gamma-Ray Spectroscopy at TRIUMF-ISAC

The 8π Collaboration

- **A. Andreyev, G.C. Ball, R. Churchman, G. Hackman, R.S. Chakrawarthy, C. Morton, C.J. Pearson, M.B. Smith, *TRIUMF***
- **P.E. Garrett, C.E. Svensson, C. Andreoiu, D. Bandyopadhyay, G.F. Grinyer, B. Hyland, E. Illes, M. Schumaker, A. Phillips, J.J. Valiente-Dobon, J. Wong, *University of Guelph***
- **J.C. Waddington, L.M. Watters, *McMaster University***
- **R.A.E. Austin, *St. Mary's University***
- **S. Ashley, P. Regan, S.C. Williams, P.M. Walker, *University of Surrey***
- **J.A. Becker, C.Y. Wu, *Lawrence Livermore National Laboratory***
- **W.D. Kulp, J.L. Wood, *Georgia Tech*.**
- **E. Zganjar, *Louisiana State***
- **J. Schwarzenberg, *Vienna***
- **F. Sarazin, C. Matoon, *Colorado School of Mines***
- **J.J. Ressler, *Simon Fraser University***
- **J.R. Leslie, *Queens University,***

Courtesy of P.E. Garrett

The 8π spectrometer – a versatile tool for nuclear physics

8π Spectrometer at ISAC

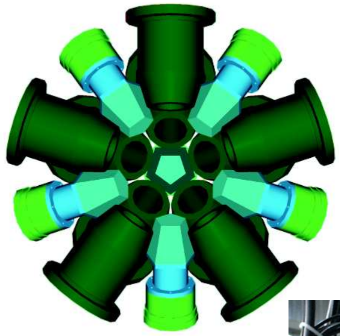
20 Compton-Suppressed HPGe detectors

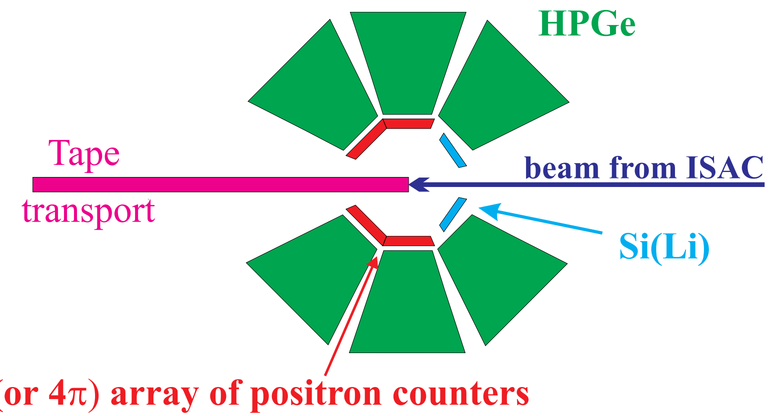
and 10 BaF2 detectors for γ-ray detection

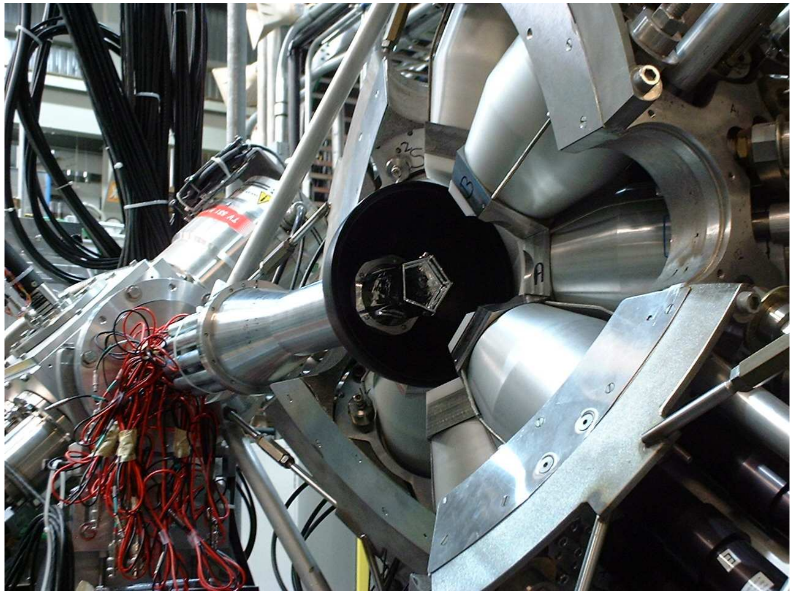
20 plastic scintillators for β detection

5 Si(Li) detectors for conversion electron spectroscopy

Fast, in-vacuum tape transport system







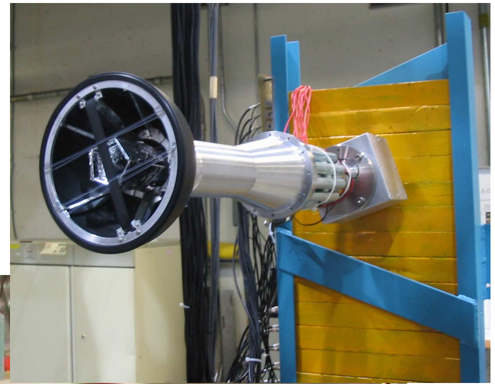
Trigger rate of ~30 kHz; data transfer 5 MB/s

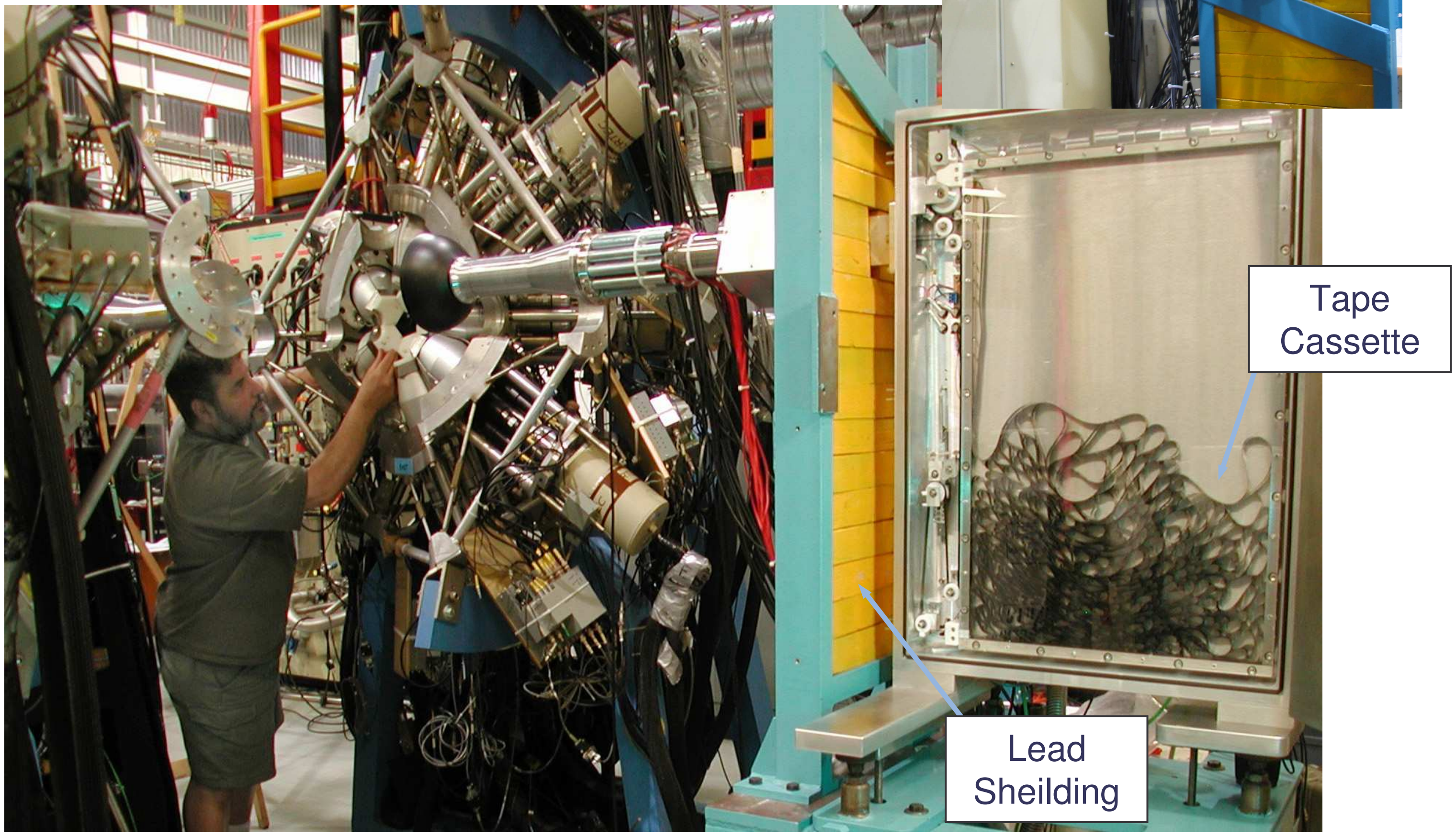
The 8π spectrometer is a world unique device for these types of studies. Simultaneous collection of γ-singles, γγ coincidences, β tagging, conversion electrons, and lifetime measurements

Courtesy of P.E. Garrett

Moving tape collector for transport of activity

- **Beam implanted onto a moving tape**
- **Allows for movement of long-lived activity out of focus of spectrometer**
- **Beam collection time variable (down to ~ 10 ms)**
- **Tape speeds, dwell times, etc., variable**



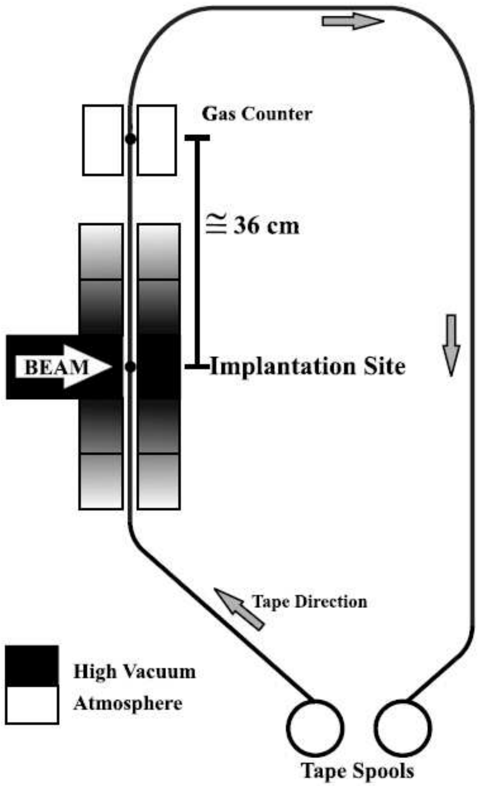


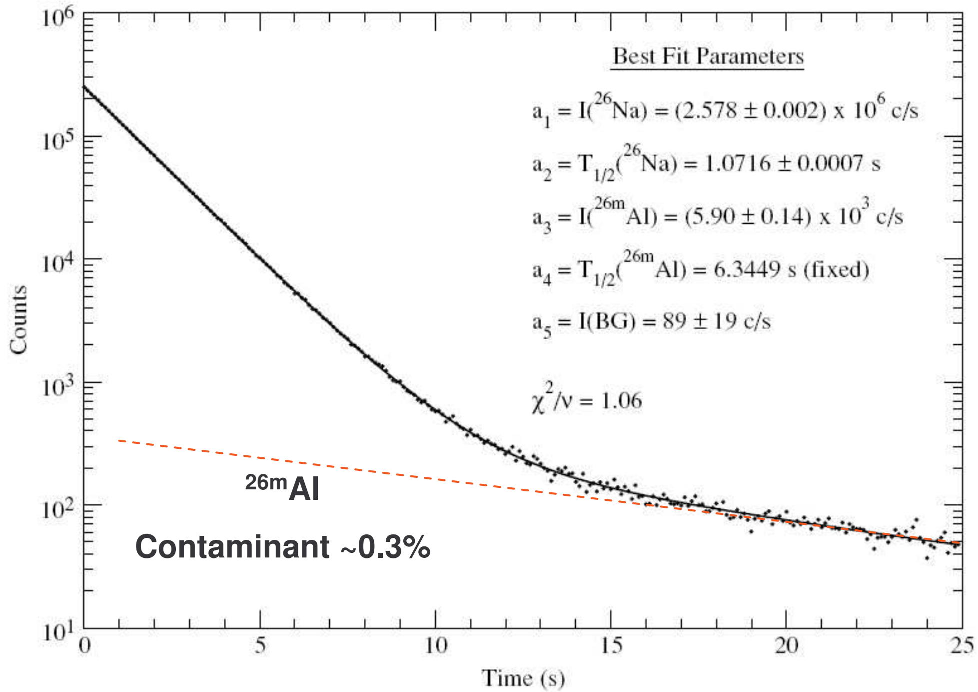
Built by

E. Zganjar, LSU

Courtesy of P.E. Garrett

β decay half-life measurements at a new level





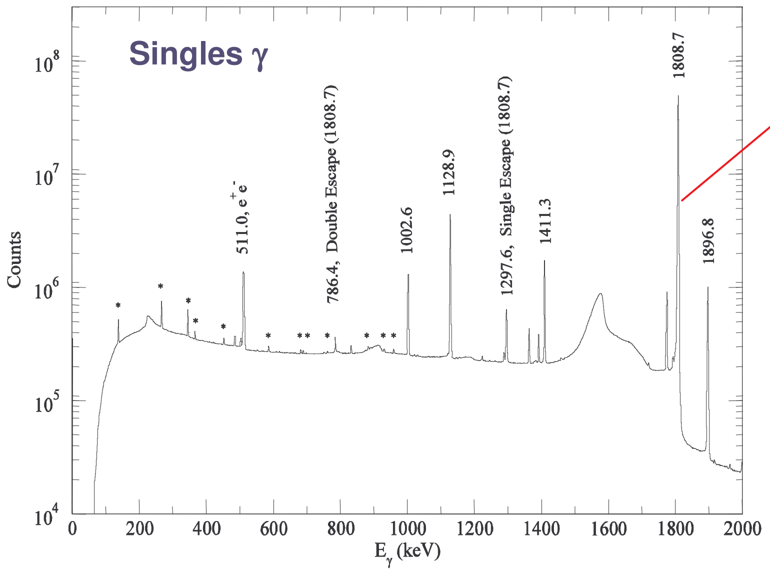
$T_{1/2}$ (^{26}Na) = 1.07128 ± 0.00013 ± 0.00021 s
{Statistical} {Systematic}

G.F. Grinyer et al., Phys. Rev. C ***71****, 044309 (2005)*

Courtesy of P.E. Garrett

Sensitivity to β branches at 10^{-6} level: ^{26}Na → ^{26}Mg

^{26}Na beam: 10^{6} s^{-1} for 12 hours, trigger rate 24 kHz



$2^+_1 \rightarrow 0^+_1$

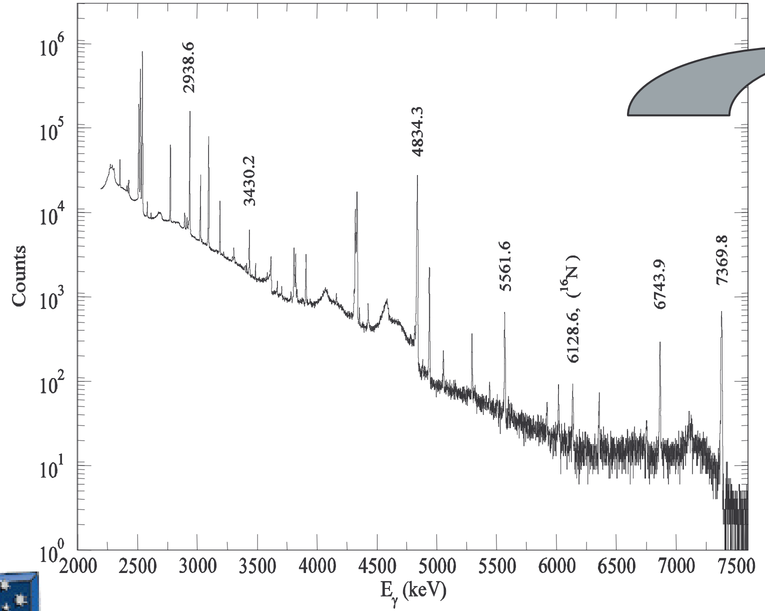
1.54×10^{8} counts

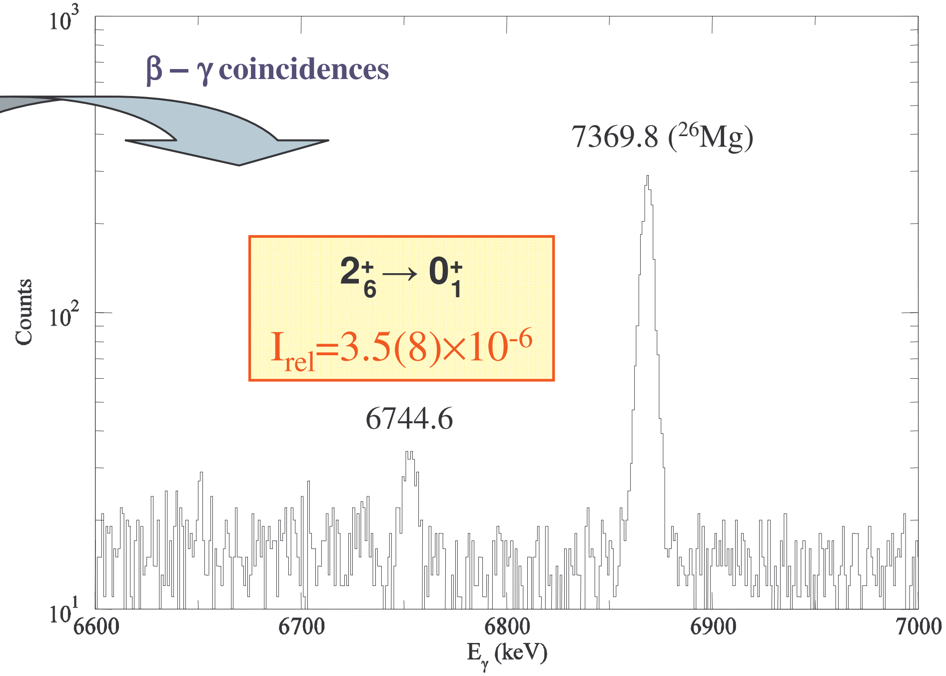
I_{rel}=1.0

8π HPGe array

β – γ coincidences

*G.F. Grinyer et al., Phys. Rev. C **71**, 044309 (2005)*





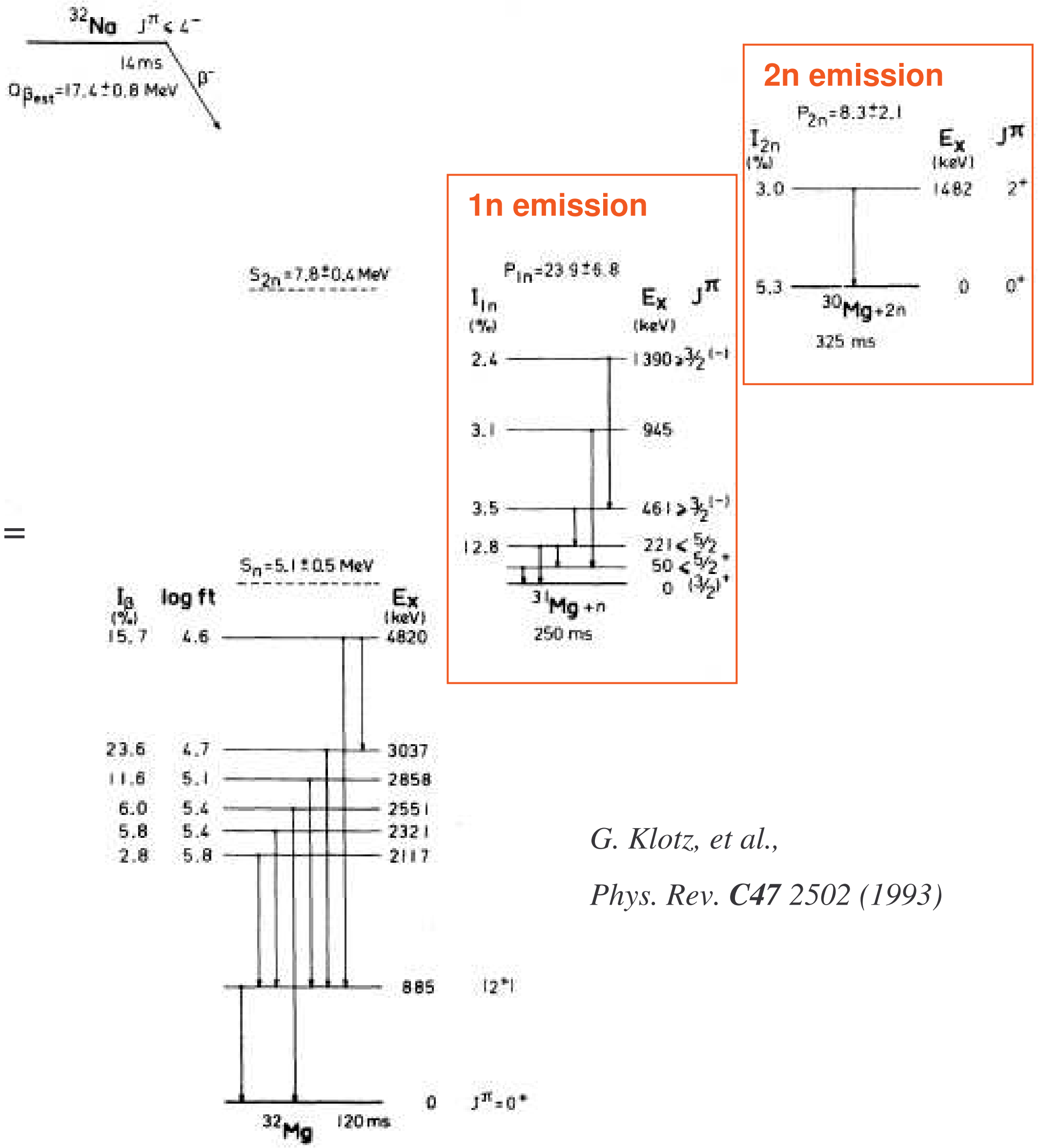
Courtesy of P.E. Garrett

$^{32}Na \rightarrow {}^{32}Mg$ decay – "Island of inversion"

^{32}Na (Z=11, N=21) extra 9 neutrons

N=20 magic number may disappear around Z=11

- ***Large B(E2; $2^+ \rightarrow 0^+$)***
- Large quadrupole moments
- ***Competition of normal and intruder configurations*** (excitations across the N = 20 shell gap)
- ***Call for detailed spectroscopy ($T_{1/2}$, multipolarity, branching ratio)***



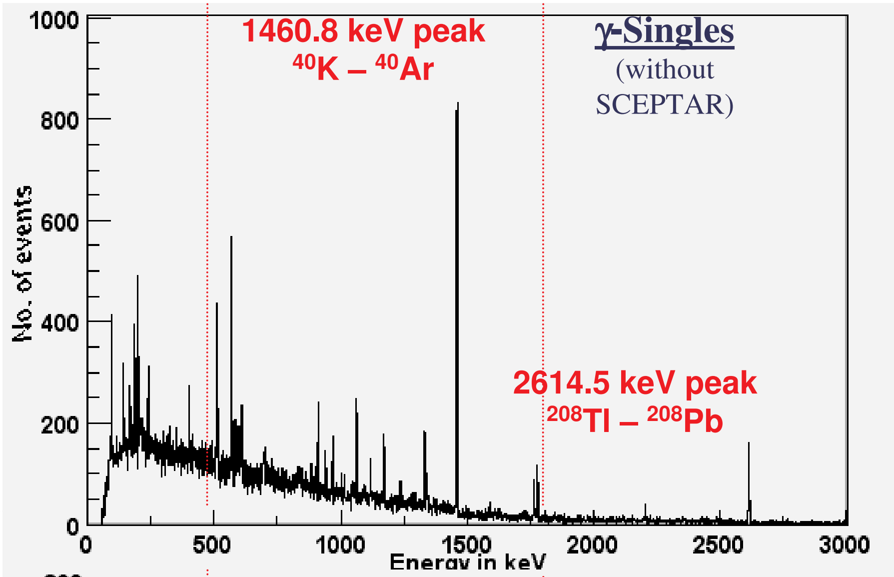
G. Klotz, et al.,

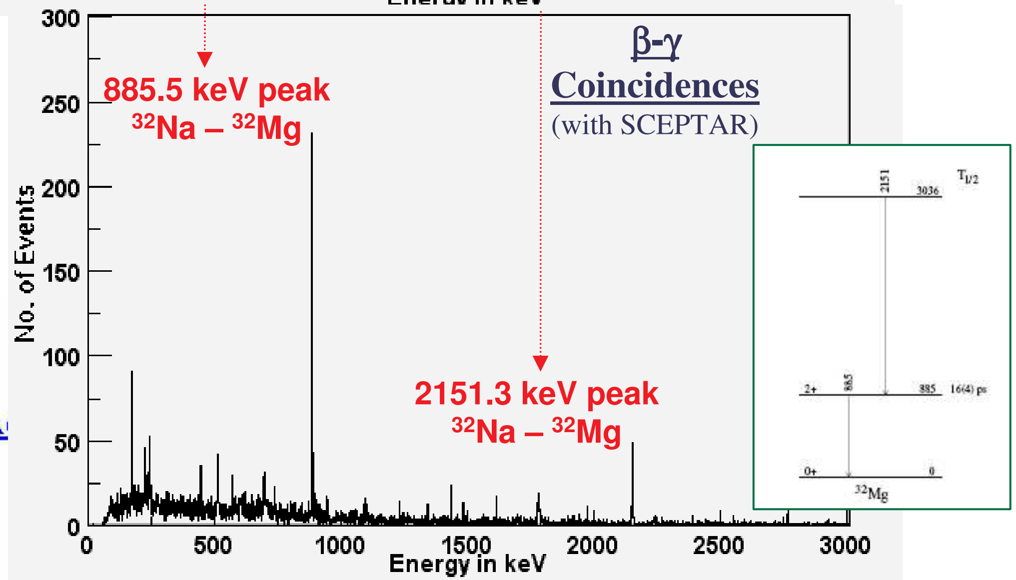
Phys. Rev. ***C47*** *2502 (1993)*

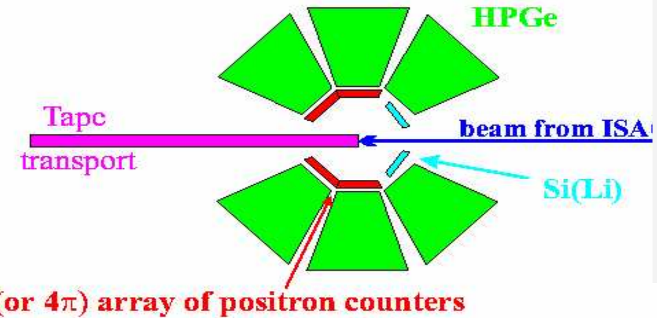
Courtesy of P.E. Garrett

Preliminary experiment to examine ^{32}Na decay

- **^{32}Na decay investigated as a means to study the excited nuclear states of ^{32}Mg (Z=12, N=20).**
- **Investigate the breakdown of shell closures far from stability.**
- **β-γ coincidences measured with 8π and SCEPTAR.**
- **Reduce background and allow weak ^{32}Na decay spectrum to be measured. (^{32}Na beam rate at ~2 ions/s).**
- **Beam production with Ta target insufficient for detailed study, but expect boost of 2-3 orders of magnitude with actinide target**



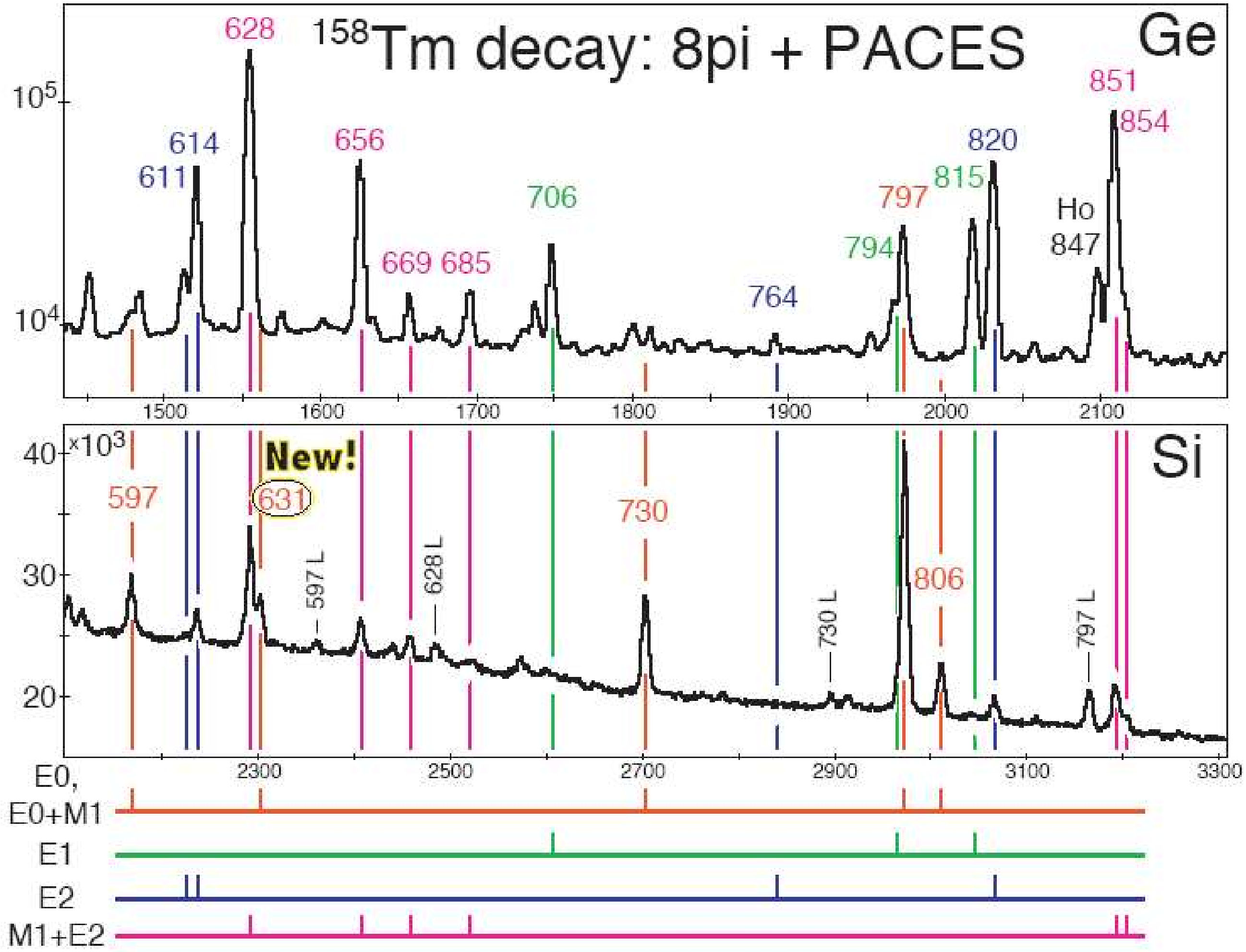




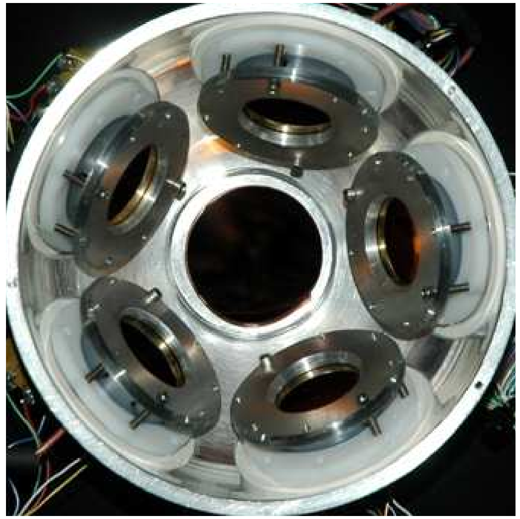
T. Kibèdi, NSDD Workshop, Trieste 2006

Courtesy of P.E. Garrett

Preliminary experiment on ^{158}Er



W.D. Kulp, et al.



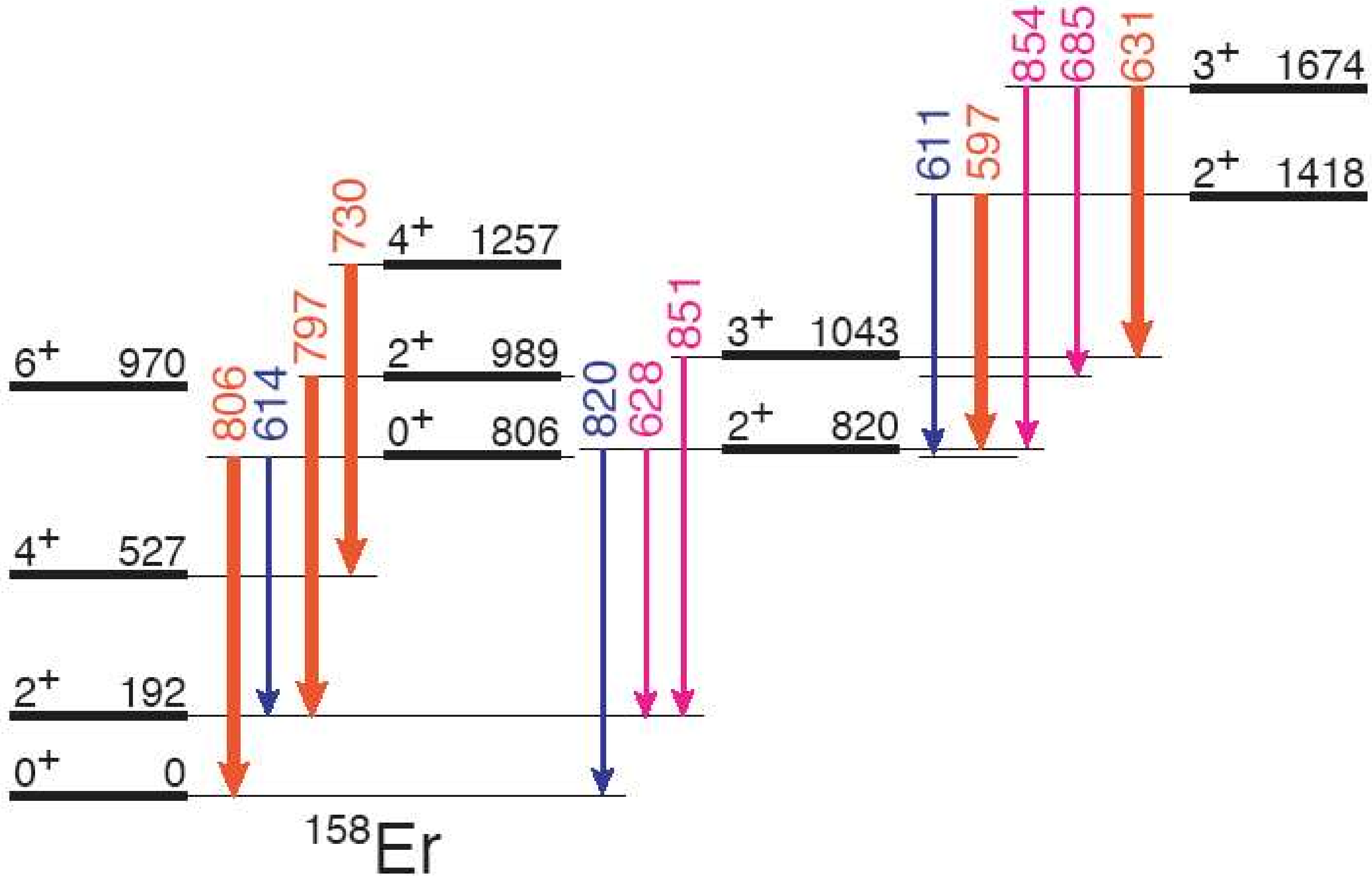
Data are for 1/3 of the sample, 1 detector

- Part of study of N=90 isotopes examining shape transition
- Goal is to search for vital $E0$ transitions
- 7d run collected 1 TB of data with 8π, SCEPTAR, and PACES

Courtesy of P.E. Garrett

Enhanced E0 transitions observed

E0 transitions: mixing between coexisting shapes of different deformation

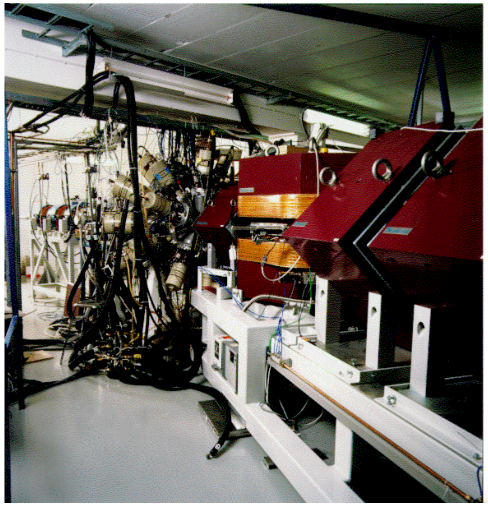


Must await lifetime measurements for $\rho^2(E0)$

Courtesy of P.E. Garrett

Heavy Element Spectroscopy at JYFL

RITU



Next predicted closed shells

Nilsson/Woods Saxon:

Z = … 50, 82, *114*

N =… 50, 82, 126, *184*

Skyrme-Hartree-Fock:

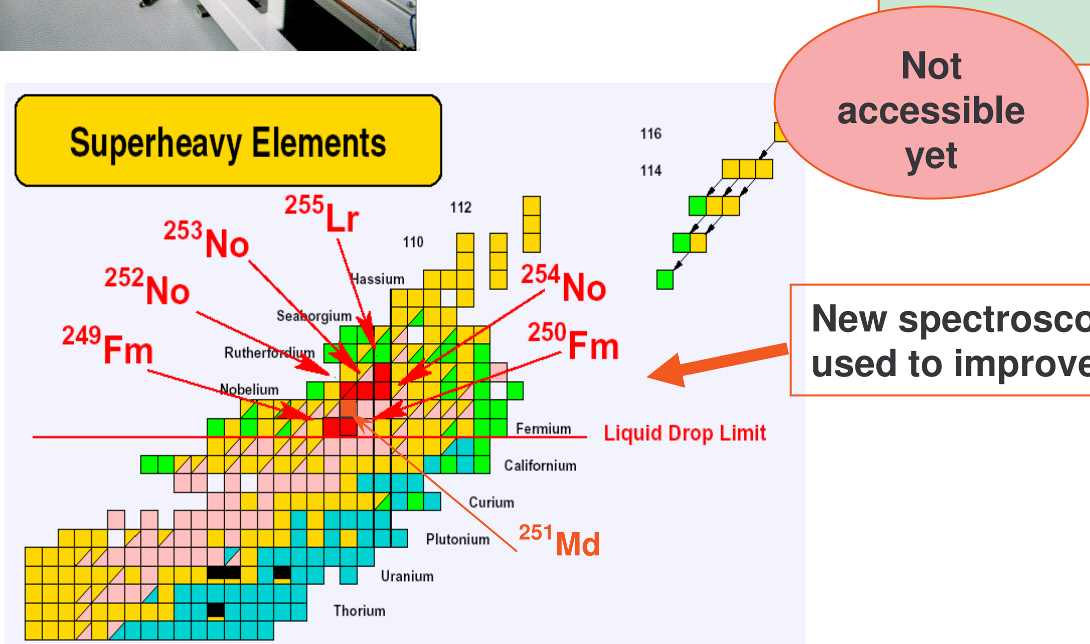
Z = … 50, 82, *126*

N = … 50, 82, 126, *184*

Relativistic mean-field:

Z = … 50, 82, *120*

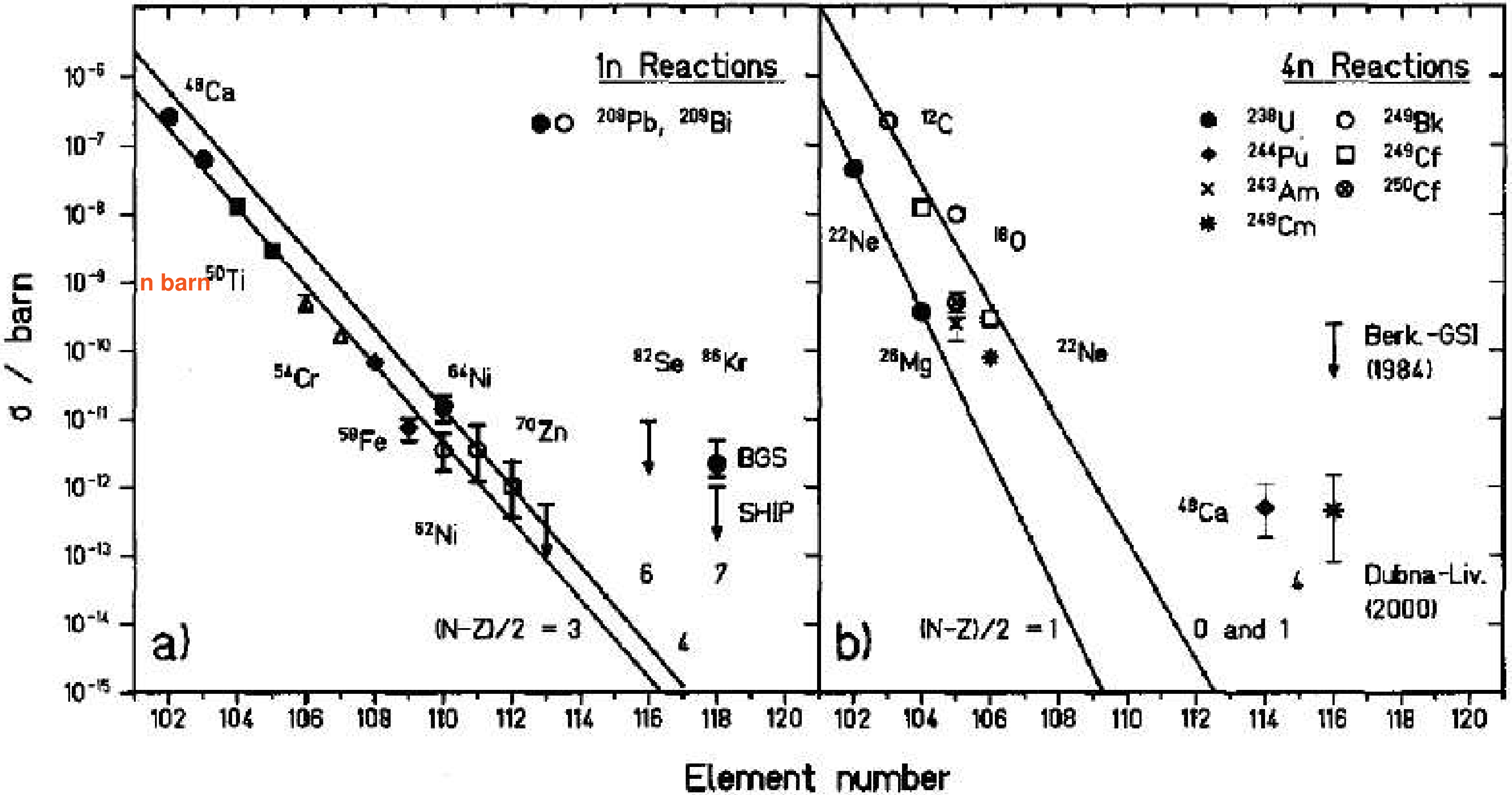
N = … 50, 82, 126, *172*



New spectroscopic data can be used to improve predictions

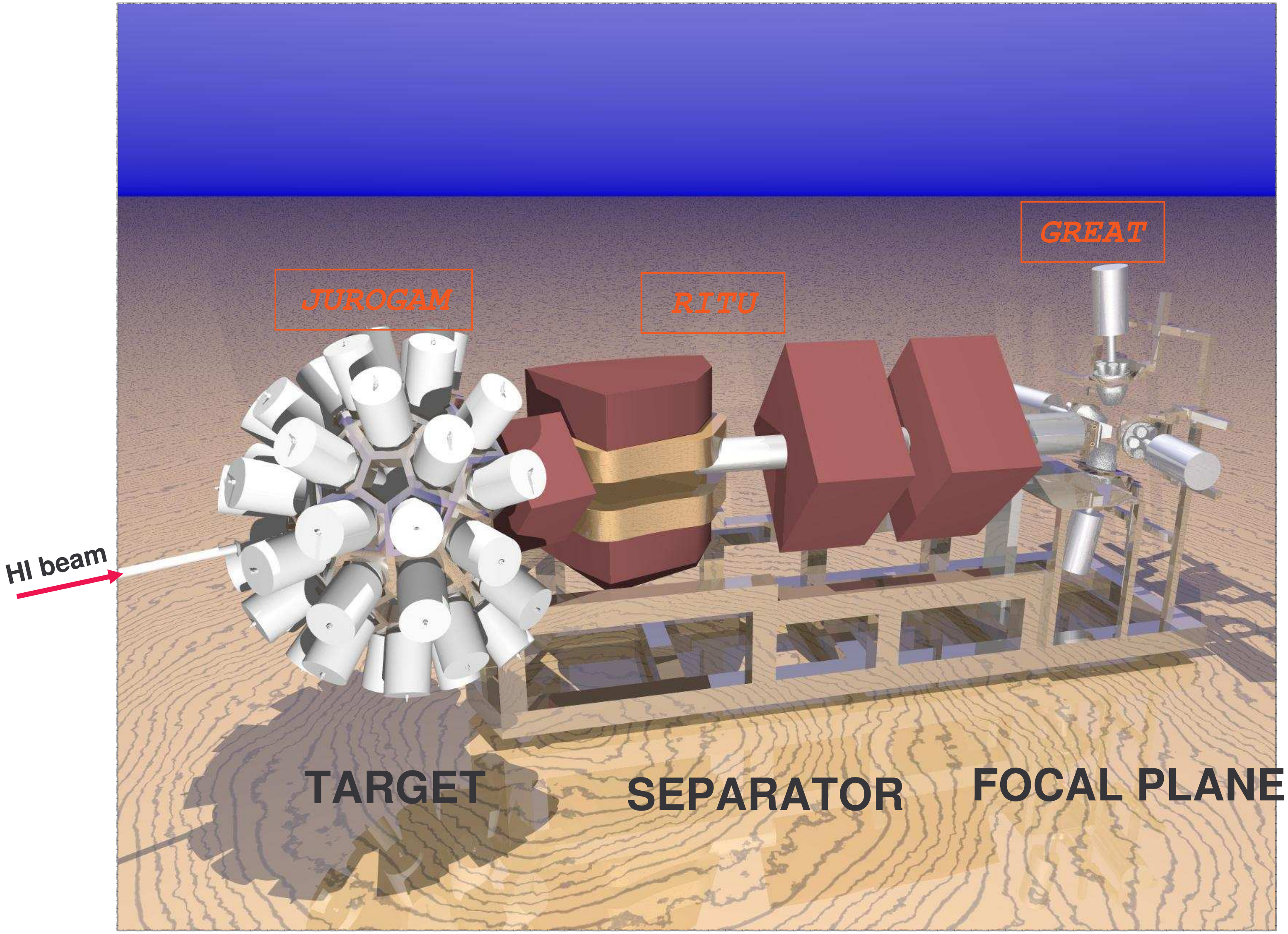
Courtesy of P. Greenlees

Decay pectroscopy at the limits



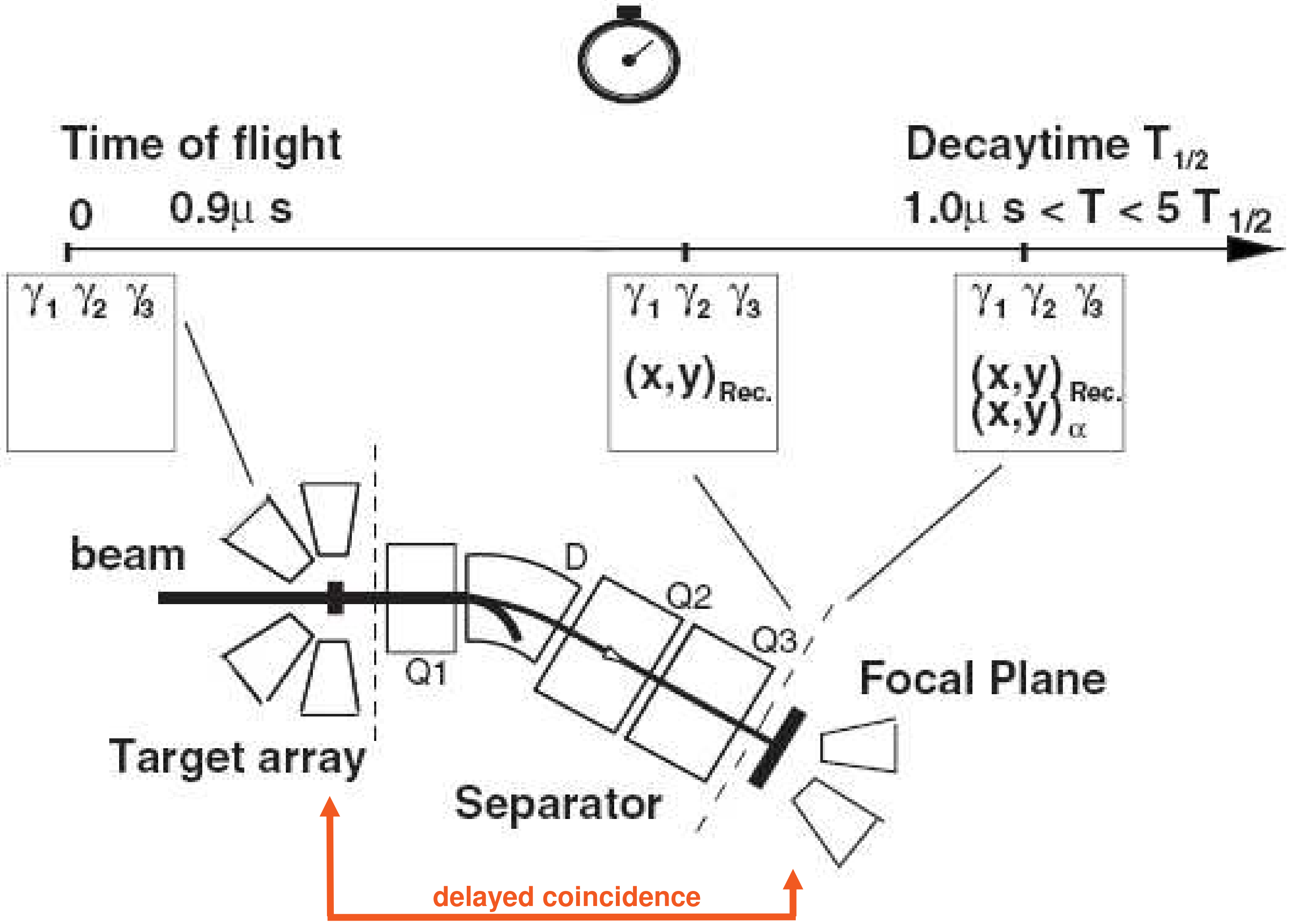
S. Hofmann / Prog. Part. Nucl. Phys. 46 (2001) 293.

RITU + JUROGAM + GREAT



M. Leino et al., Nucl. Instr. and Meth. B 99 (1995) 653.

Recoil Decay Tagging (RDT)



R-D Herzberg, J. Phys. G 30 (2004) R123.

JuroGam

43 Phase I and GASP-type detectors – Ex. EUROBALL and UK-France loan pool

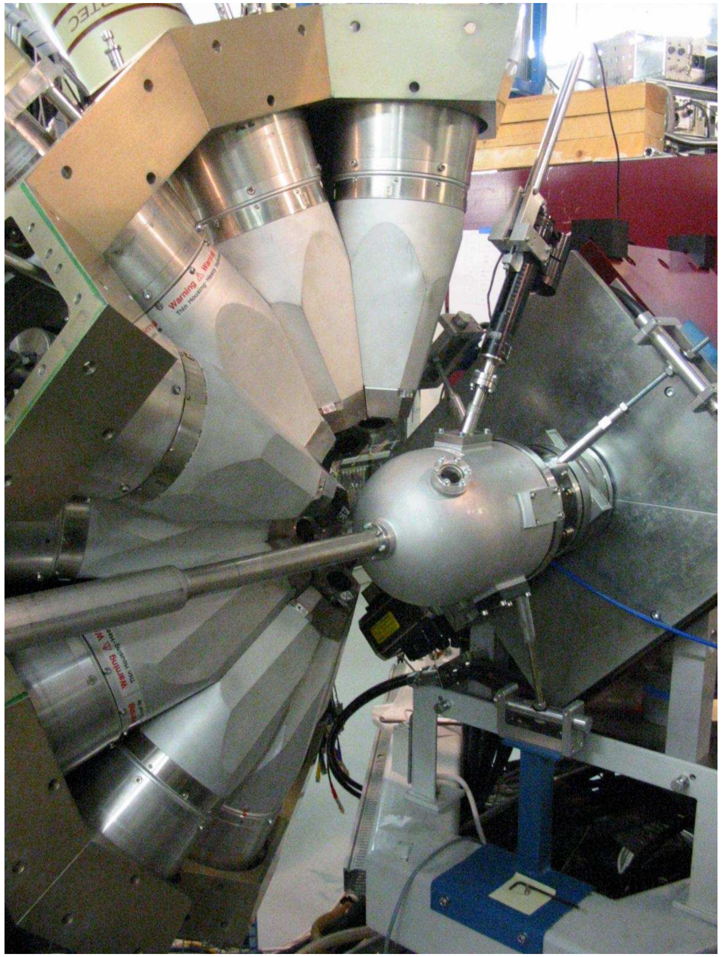
Efficiency ~ 4.2% @ 1.3 MeV

TDR data acquisition system – Data rate ~ 5 MB/s @ 10 kHz

Software BGO suppression

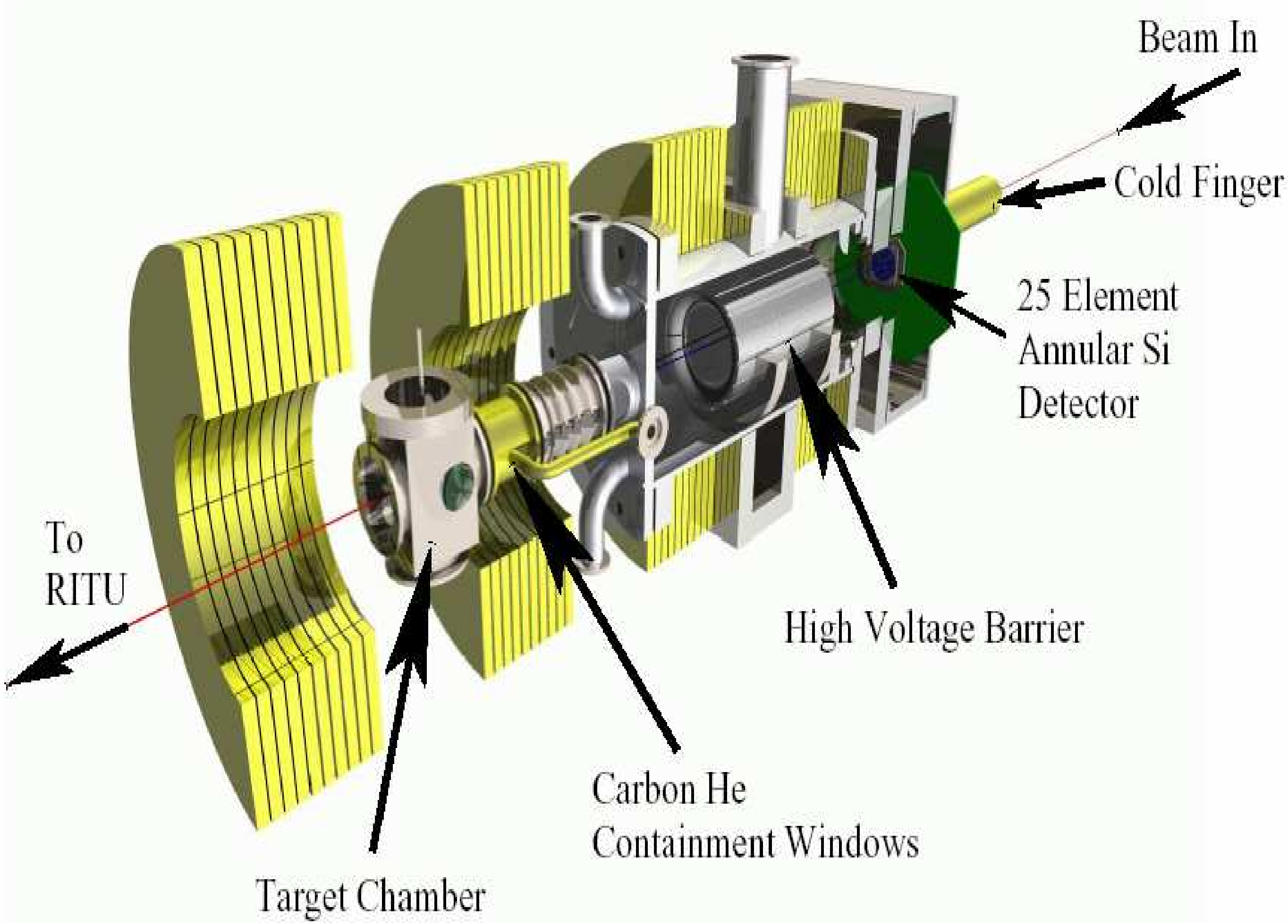
Auto fill system built by University of York, part of GREAT Project

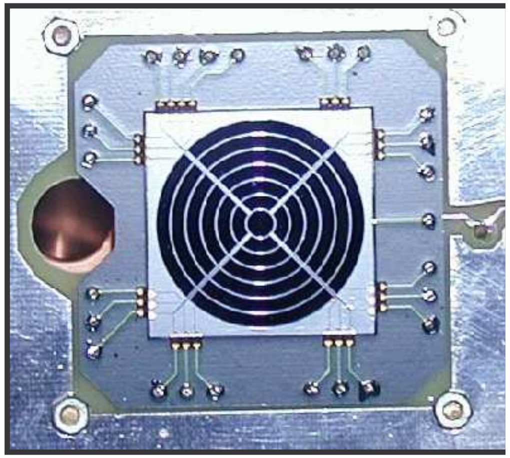
Online/Offline Sorting – Grain developed by P. Rahkila



Courtesy of P. Greenlees

The SACRED Electron Spectrometer





THE UNIVERSITY of LIVERPOOL

UNIVERSITY OF JYVÄSKYLÄ

H. Kankaanpää, et al., Nucl. Instr. and Meth. ***A534*** *(2004) 503*

see also P.A. Butler, et al., Nucl. Instr. and Meth. ***A381*** *(1996) 433*

Courtesy of P. Greenlees

The GREAT Spectrometer

High energy γ-ray detection

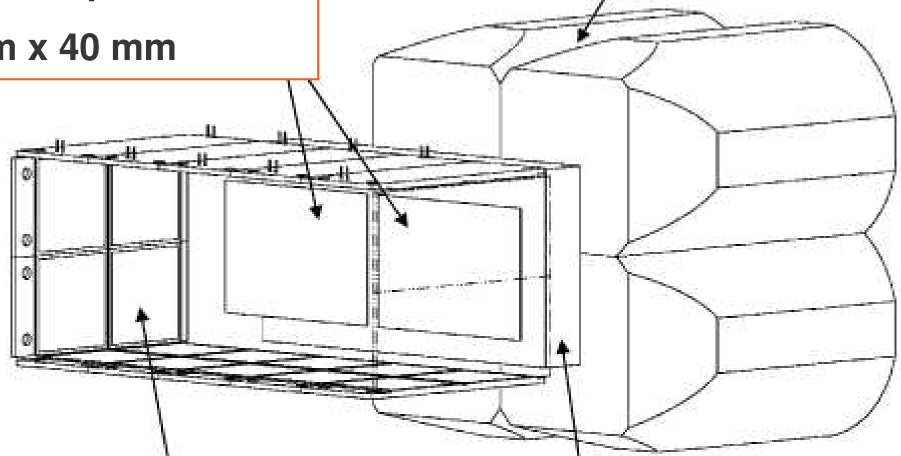
Planar germanium strip detector

120 mm x 60 mm x 15 mm

α-detection

Double-sided Si strip detector

2 x 60 mm x 40 mm



CE-detection

Si PIN diode array

28 x 28 mm x 28 mm

X– and γ-ray detection

Clover detector

Total Data Readout (TDR) Acquisiton System

R.D. Page, et al.,
Nucl. Instr. and Meth. B 204 (2003) 634.

The SACRED – example (Liverpool-JYFL)

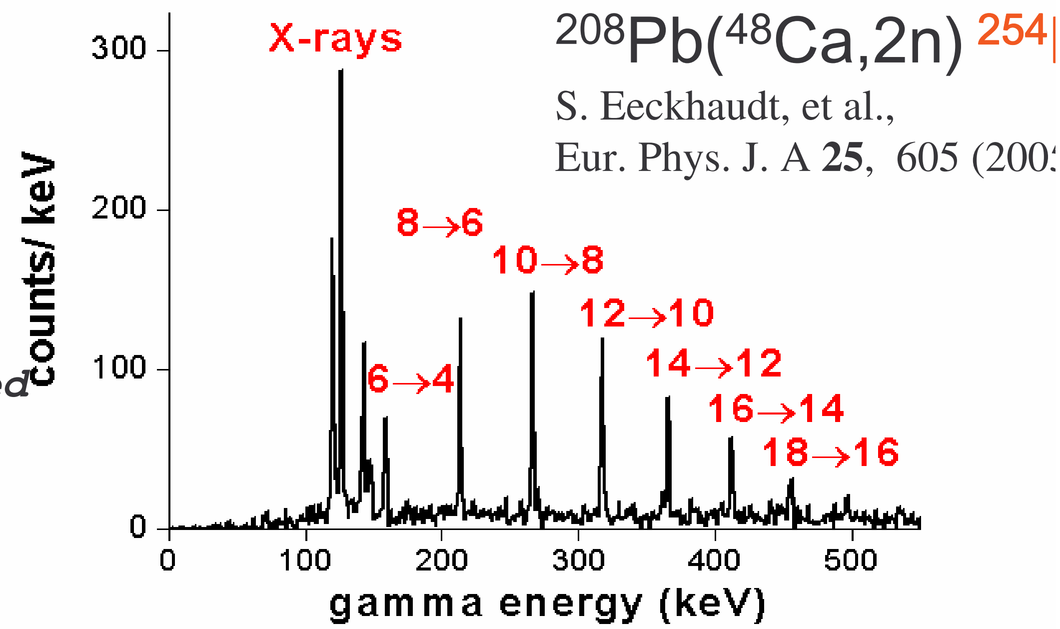
Z=102

BE_K=149.2 keV

Lowest transitions fully converted

	E_γ(keV)	α_K(E2)	α_L(E2)	α_T(E2)
$2^+ \rightarrow 0^+$(*)	44(1)	N/A	1100	1540
$4^+ \rightarrow 2^+$(*)	102(1)	N/A	20.6	28.8
$6^+ \rightarrow 4^+$	159.5(2)	0.108	2.74	3.93
$8^+ \rightarrow 6^+$	214.1(1)	0.122	0.772	1.20

(*) transition not seen; from extrapolation using the Harris formulae



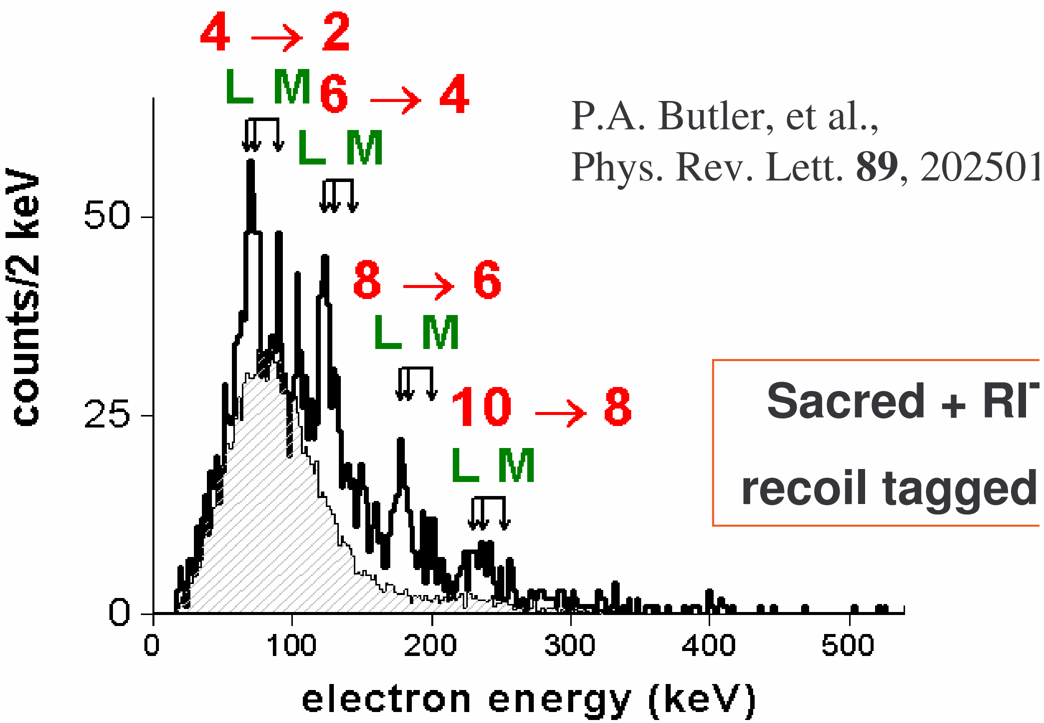


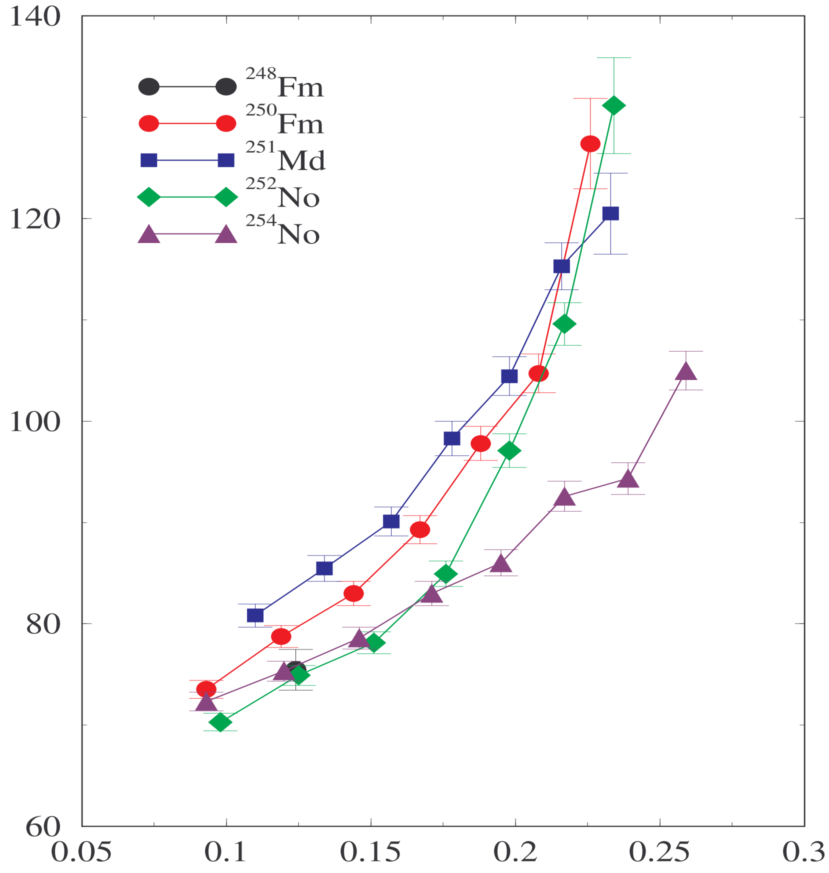
Figure courtesy of P. Greenlees

Dynamic Moments of Inertia

^{250}Fm
Experiment: J.E. Bastin et al.,
Phys. Rev. C73 (2006) 024308

β_2 = 0.28(2)

Raman, et al.,
Atomic Data and Nuclear Data Tables **78,** 1–128 (2001)
GLOBAL FIT to data:



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