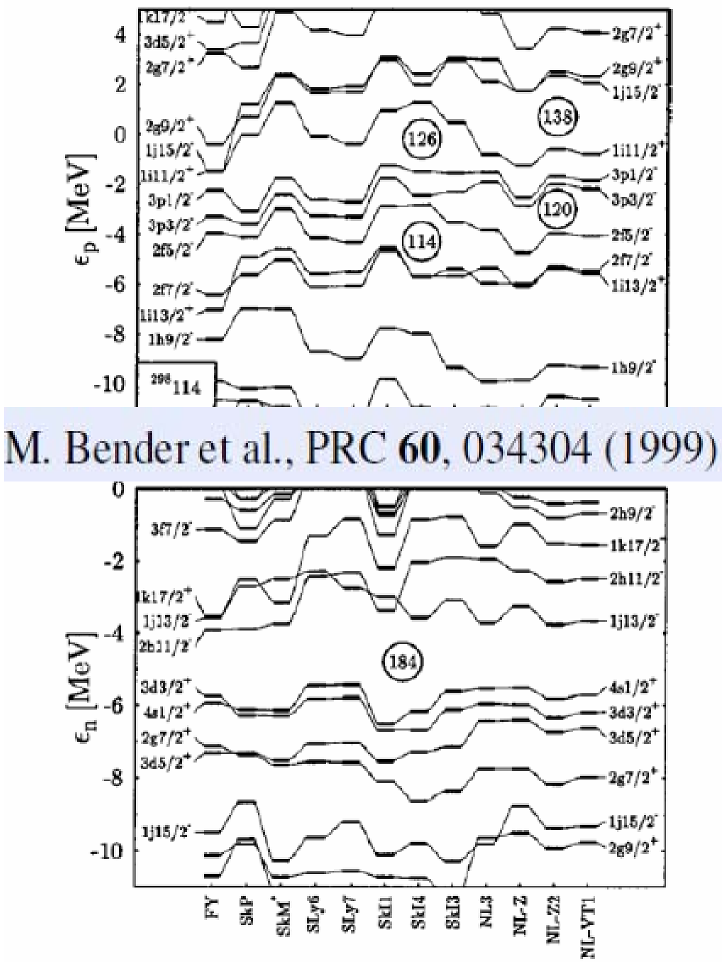
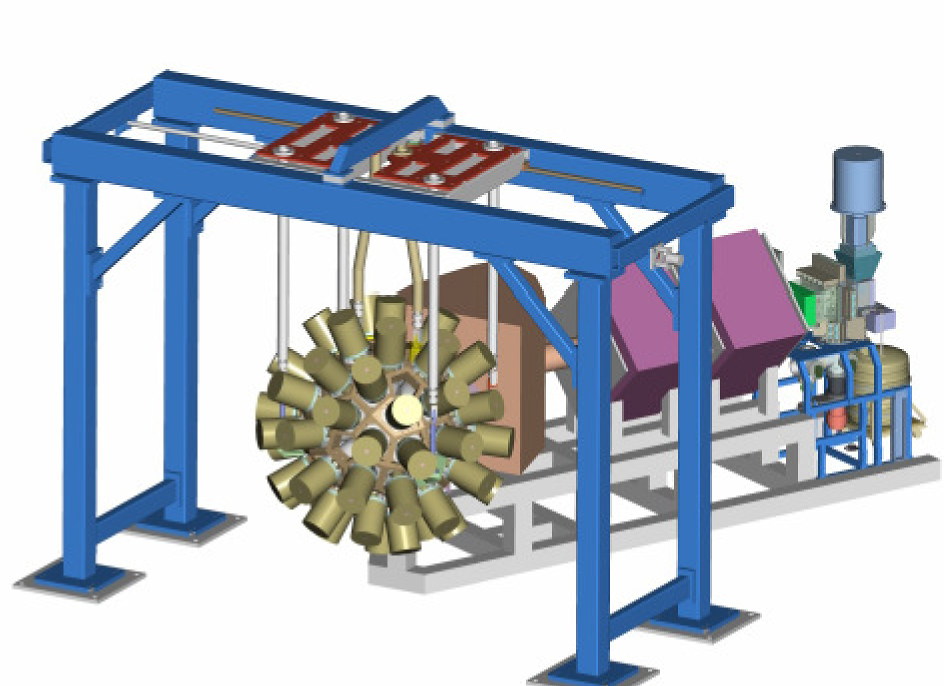
Superheavy Element Research at RITU

J. Uusitalo,
P. Greenlees, R. –D. Herzberg

for the JUROGAMII/SAGE + RITU + GREAT collaboration
University of Jyväskylä, Department of Physics

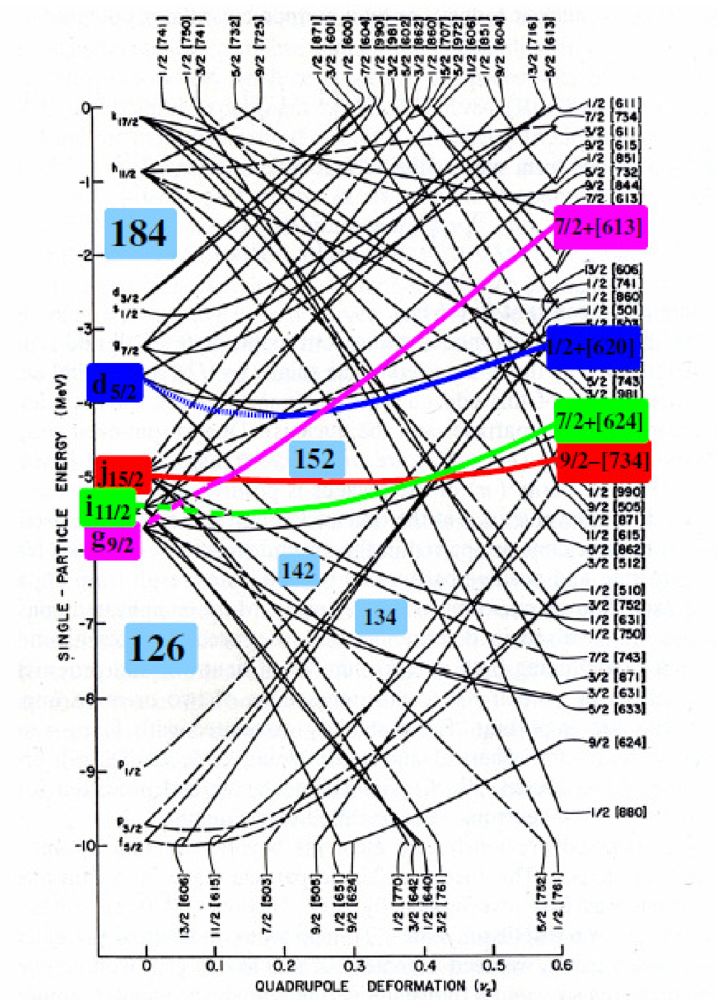


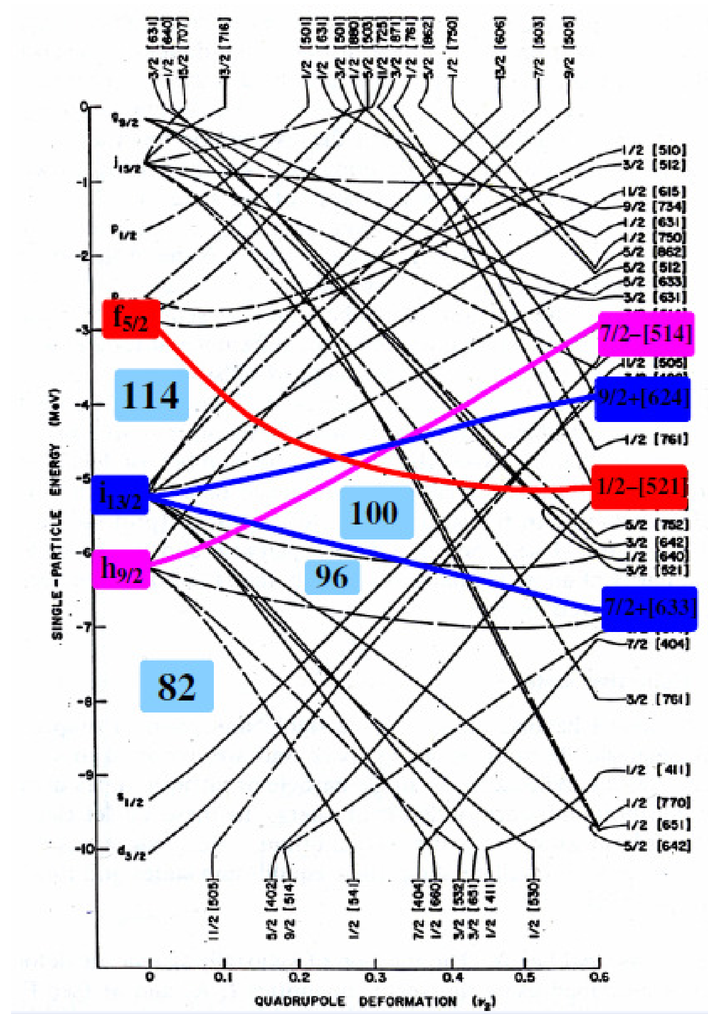
M. Bender et al., PRC **60**, 034304 (1999)



GSI Helmholtzzentrum für Schwerionenforschung GmbH
Darmstadt, November 18, 2010
TASCA 10
9th Workshop on Recoil Separator for Superheavy Element Chemistry

^{252}Fm region





R. R. Chasman et. al.,
Rev. Mod. Phys. 49, 833 (77)

Isomer studies

PHYSICAL REVIEW C VOLUME 7, NUMBER 5 MAY 1973

Isomeric States in ^{250}Fm and ^{254}No†

Albert Ghiorso, Kari Eskola,* Pirkko Eskola,* and Matti Nurmia
Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720
(Received 30 November 1972)

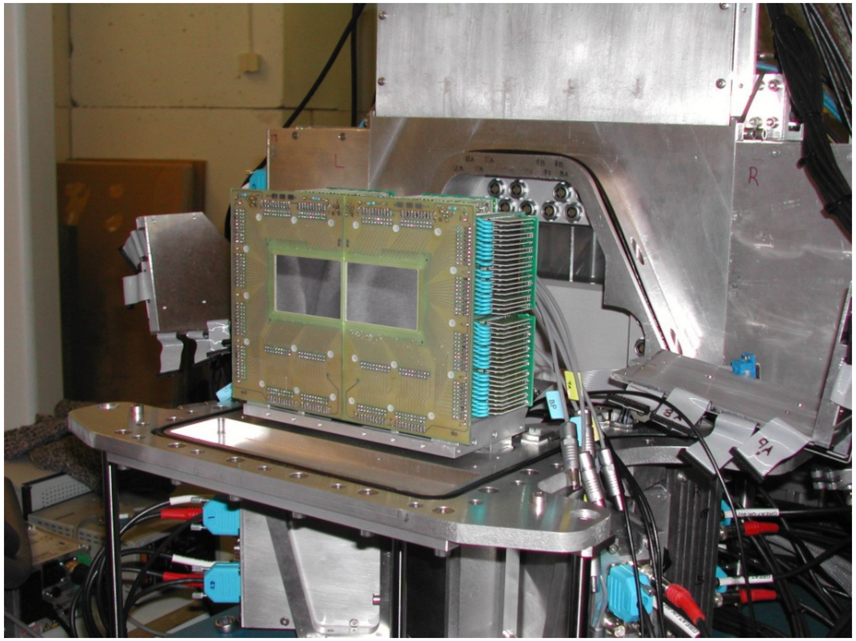
Nature **442**, 896-899 (24 August 2006)

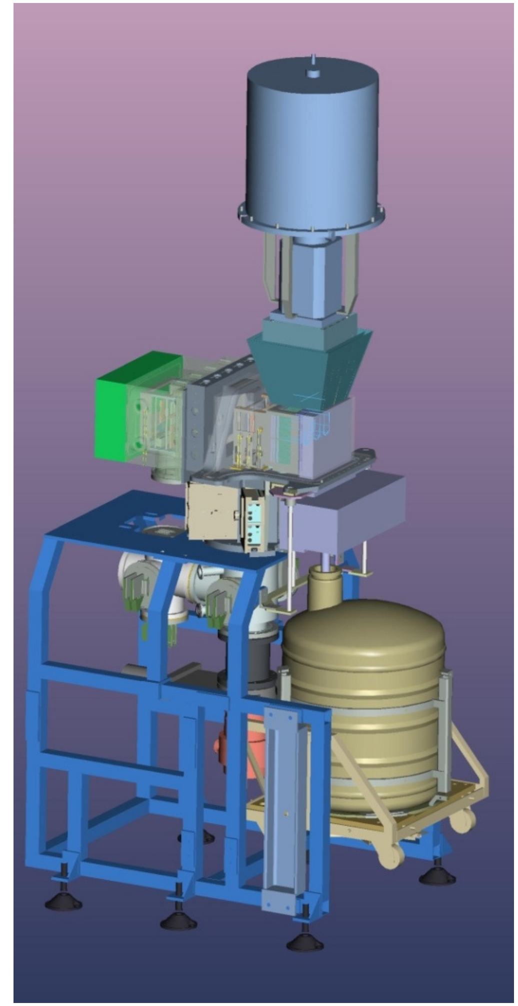
nature Vol 442|24 August 2006|**doi:10.1038/nature05069**

LETTERS

Nuclear isomers in superheavy elements as stepping stones towards the island of stability

R.-D. Herzberg[1], P. T. Greenlees[2], P. A. Butler[1], G. D. Jones[1], M. Venhart[3], I. G. Darby[1], S. Eeckhaudt[2], K. Eskola[4], T. Grahn[2], C. Gray-Jones[1], F. P. Hessberger[5], P. Jones[2], R. Julin[2], S. Juutinen[2], S. Ketelhut[2], W. Korten[6], M. Leino[2], A.-P. Leppänen[2], S. Moon[1], M. Nyman[2], R. D. Page[1], J. Pakarinen[1,2], A. Pritchard[1], P. Rahkila[2], J. Sarén[2], C. Scholey[2], A. Steer[2], Y. Sun[7], Ch. Theisen[6] & J. Uusitalo[2]

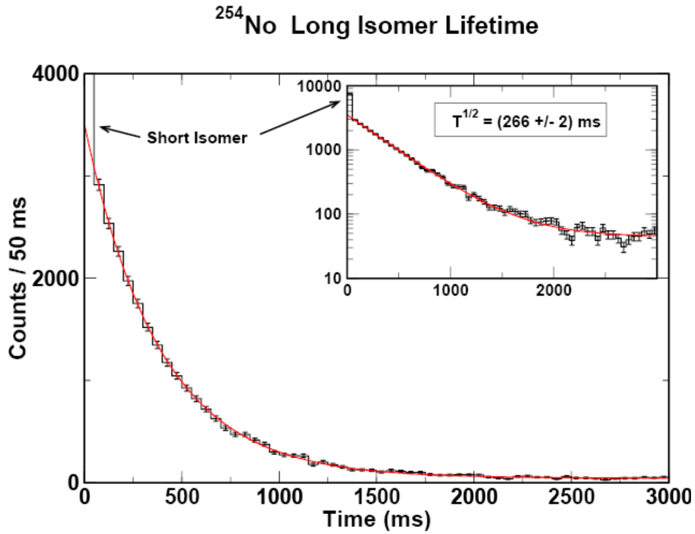





GREAT
ORTEC
ABC
1 2 3 · · ·

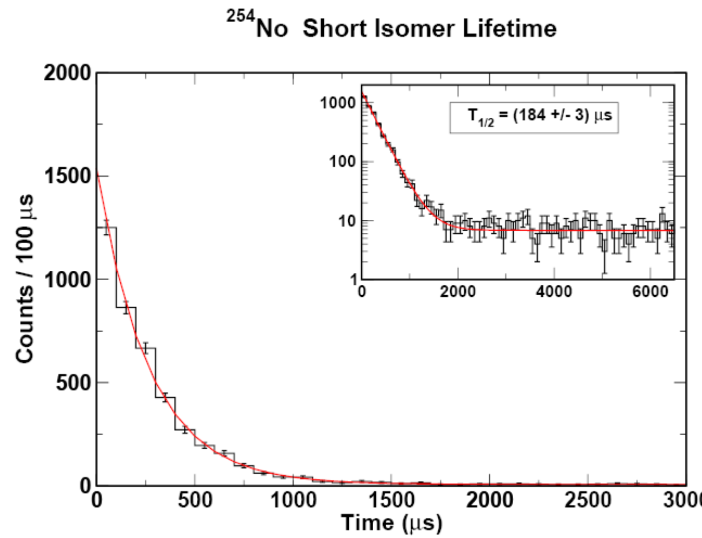
$^{48}Ca + ^{208}Pb \Rightarrow ^{254}No + 2n$, RITU+GREAT, R.-D. Herzberg e

Correlated recoil-electron time differences



$^{48}Ca + ^{208}Pb \Rightarrow ^{254}No + 2n$, RITU+GREAT, R.-D. Herzberg et al.

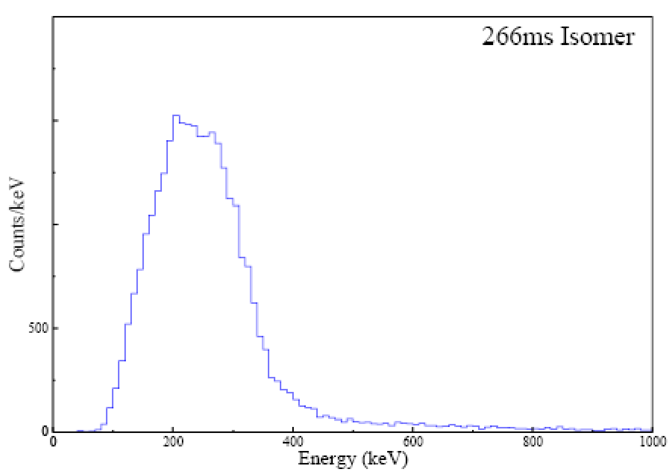
Correlated recoil-electron time differences



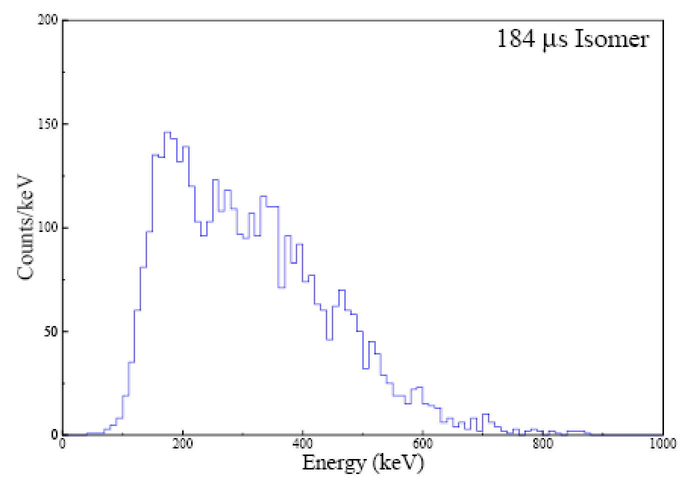
$^{48}Ca + ^{208}Pb \Rightarrow ^{254}No + 2n$, RITU+GREAT, R.-D. Herzberg et al.

Correlated recoil-electron spectra

Slow Isomer



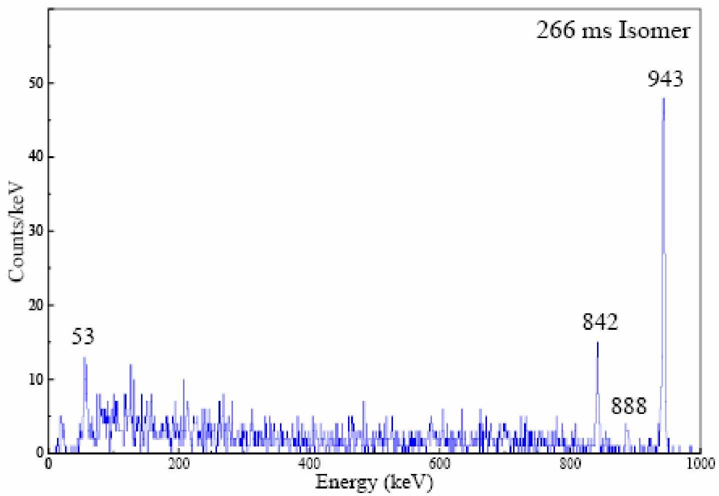
Fast Isomer



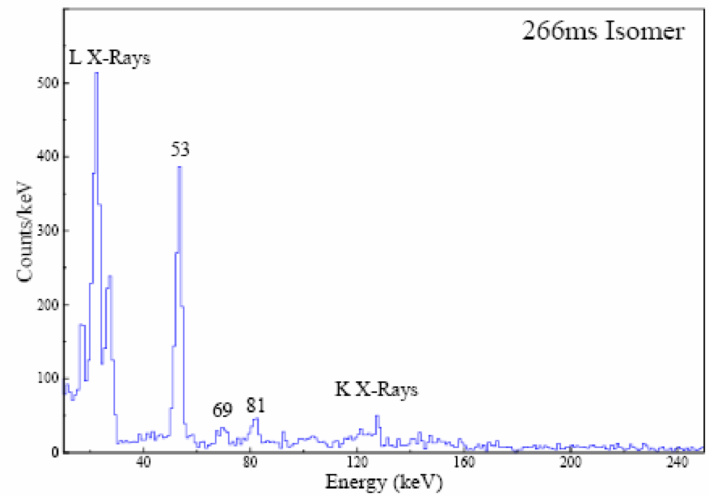
$^{48}Ca + ^{208}Pb \Rightarrow ^{254}No + 2n$, RITU+GREAT, R.-D. Herzberg et al.

Correlated recoil-electron γ coincidences

Clover Ge Spectra

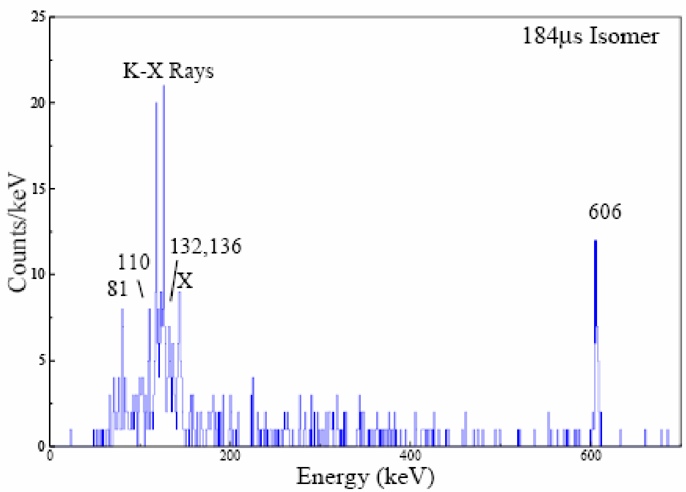


Planar Ge Spectra

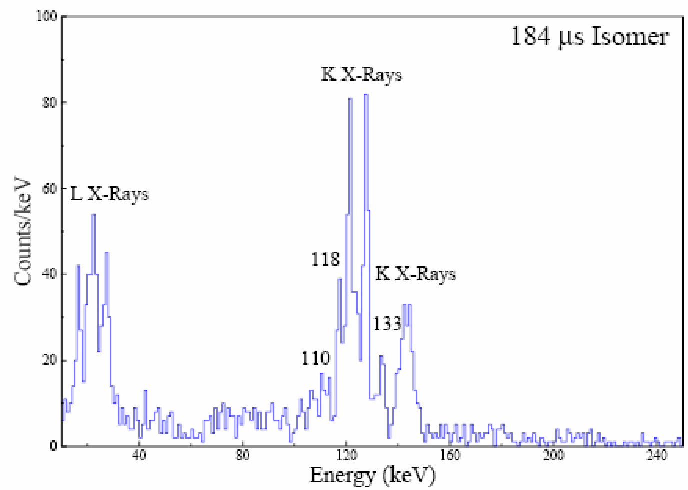


Correlated recoil-electron γ coincidences

Clover Ge Spectra



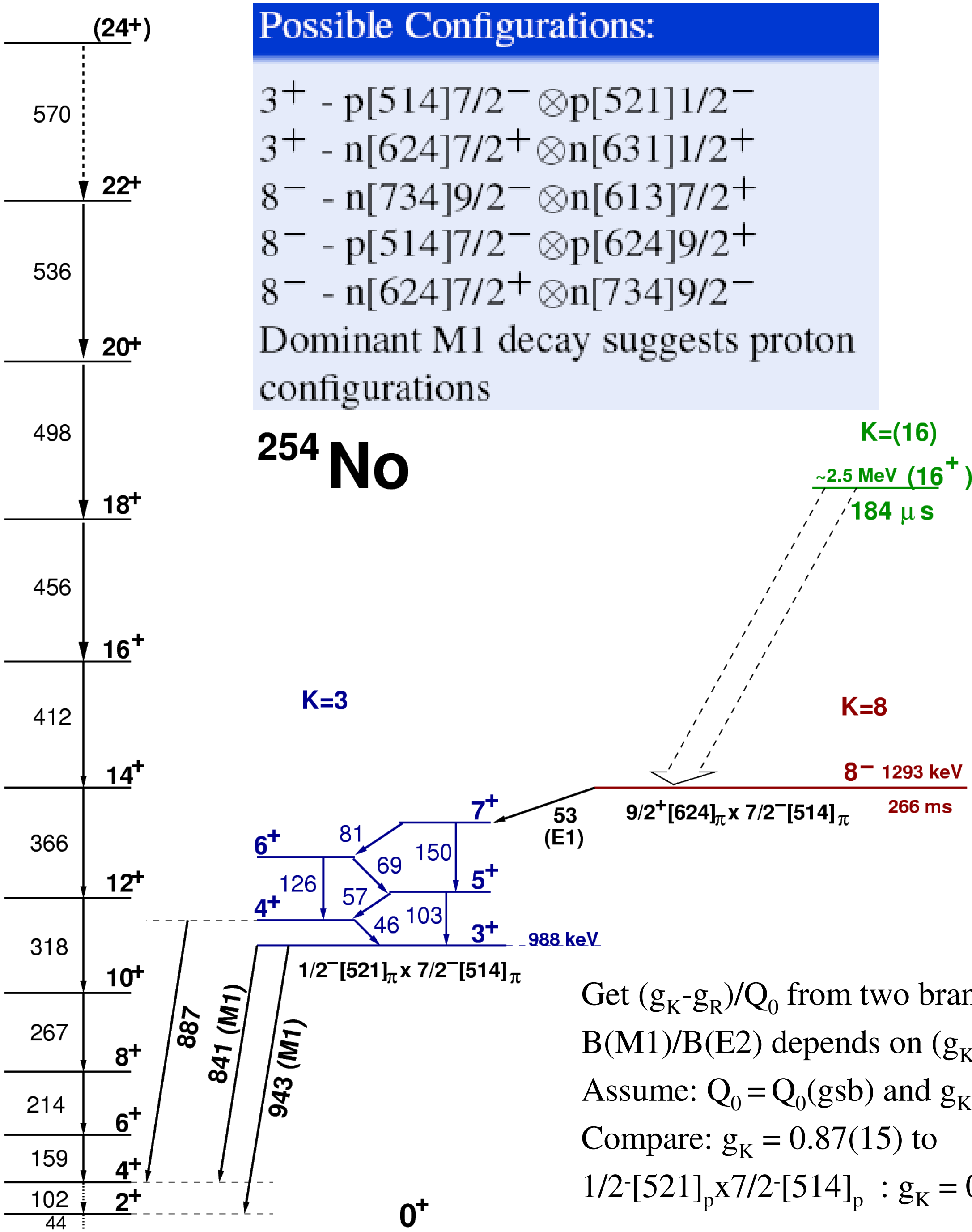
Planar Ge Spectra

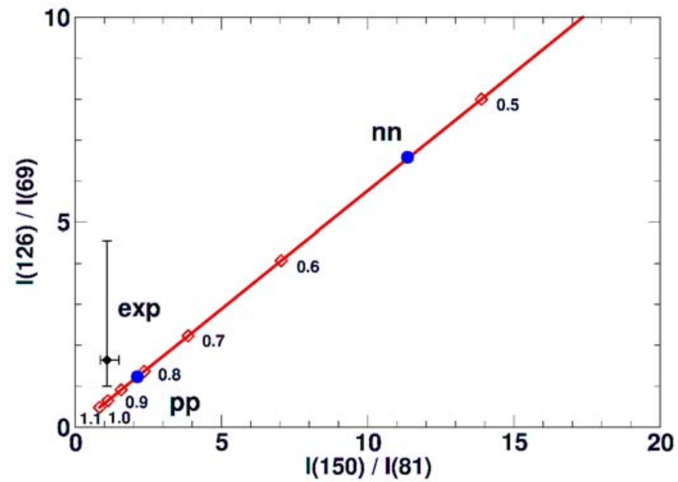


Possible Configurations:

3^+ - $p[514]7/2^- \otimes p[521]1/2^-$
3^+ - $n[624]7/2^+ \otimes n[631]1/2^+$
8^- - $n[734]9/2^- \otimes n[613]7/2^+$
8^- - $p[514]7/2^- \otimes p[624]9/2^+$
8^- - $n[624]7/2^+ \otimes n[734]9/2^-$

Dominant M1 decay suggests proton configurations





Get $(g_K - g_R)/Q_0$ from two branching ratios

$B(M1)/B(E2)$ depends on $(g_K - g_R) / Q_0$

Assume: $Q_0 = Q_0(\text{gsb})$ and $g_K = Z/A$

Compare: $g_K = 0.87(15)$ to

$1/2^-[521]_p x 7/2^-[514]_p$: $g_K = 0.824$ or $7/2^+[624]_n x 1/2^+[620]_n$: $g_K = 0.53$

PHYSICAL REVIEW C **78**, 021303(R) (2008)

High-K structure in ^{250}Fm and the deformed shell gaps at $N = 152$ and $Z = 100$

P. T. Greenlees,[1,*] R.-D. Herzberg,[2] S. Ketelhut,[1] P. A. Butler,[2] P. Chowdhury,[3] T. Grahn,[1] C. Gray-Jones,[2] G. D. Jones,[2] P. Jones,[1] R. Julin,[1] S. Juutinen,[1] T.-L. Khoo,[4] M. Leino,[1] S. Moon,[2] M. Nyman,[1] J. Pakarinen,[2] P. Rahkila,[1] D. Rostron,[2] J. Sarén,[1] C. Scholey,[1] J. Sorri,[1] S. K. Tandel,[3] J. Uusitalo,[1] and M. Venhart[5]

^{204}Hgs(^{48}Ca,2n)^{250}Fm, 510μg/cm^2 target, 8 pnA beam

13000 full-energy 7.43 MeV α's after 170 hour (7 days) collection time

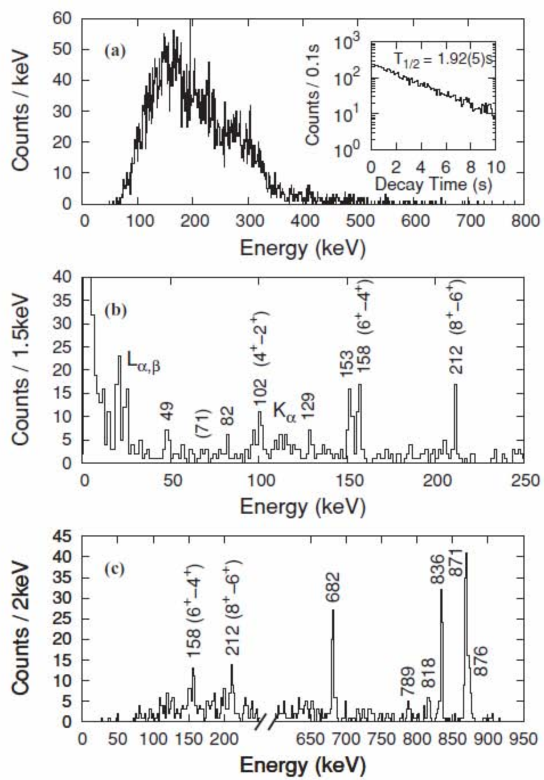


FIG. 1. (a) Spectrum of "sum energy" electrons observed within 10 s of a fusion-evaporation residue at the same position in the DSSD. (b) Gamma rays detected in prompt coincidence with the electrons of part (a) in the planar germanium detector. (c) As in (b), but in the array of clover detectors.

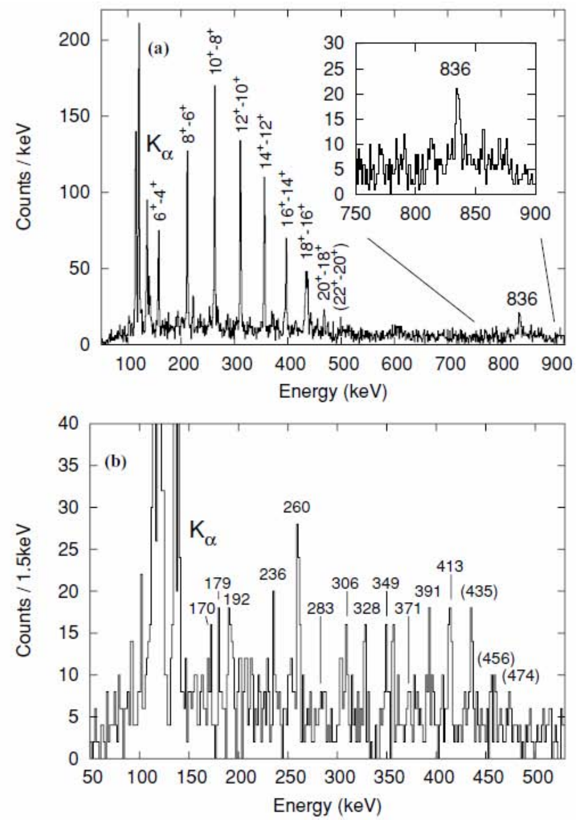


FIG. 2. (a) Spectrum of γ rays detected in the JUROGAM array when a fusion-evaporation residue is observed at the focal plane of RITU. (b) As in (a), with the additional requirement that an electron sum event is observed within 10 s of the recoil at the same position in the DSSD.

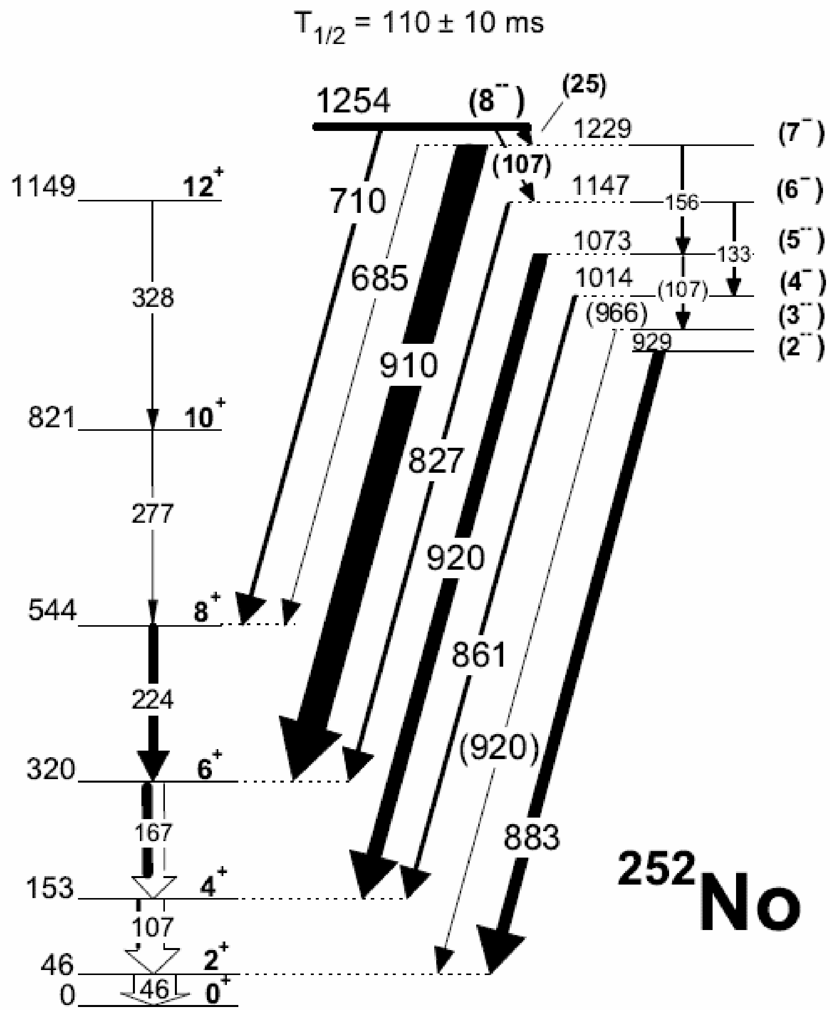
Eur. Phys. J. A 33, 327–331 (2007)
DOI 10.1140/epja/i2007-10469-3

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Experimental Physics

Identification of a K isomer in ^{252}No

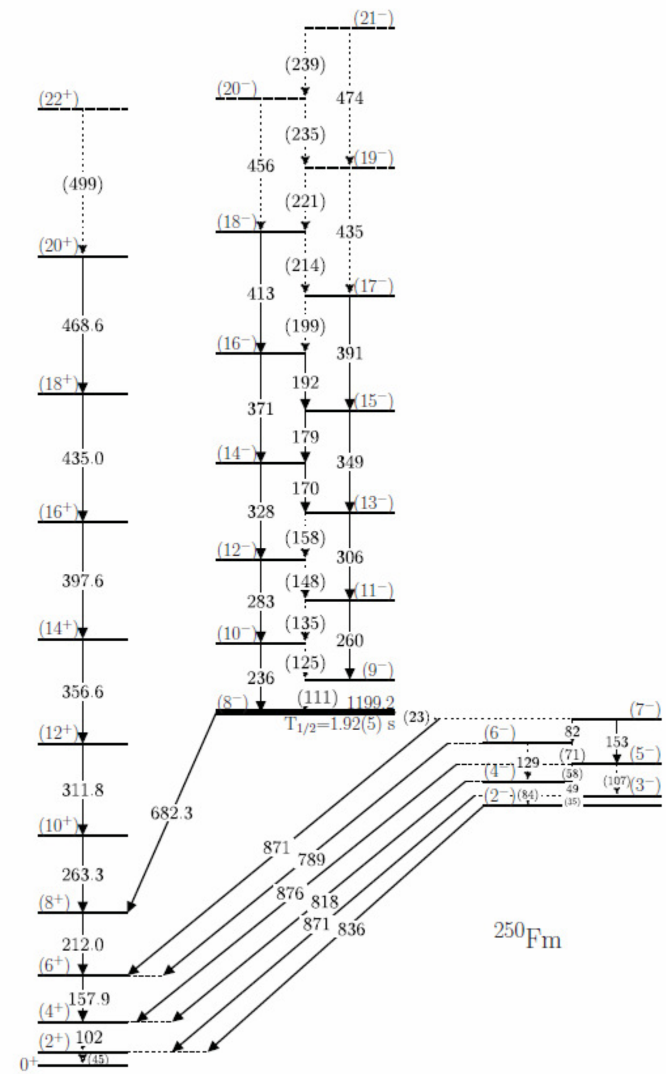
B. Sulignano[1], S. Heinz[1], F.P. Heßberger[1,a], S. Hofmann[1,2], D. Ackermann[1], S. Antalic[3], B. Kindler[1], I. Kojouharov[1], P. Kuusiniemi[4], B. Lommel[1], R. Mann[1], K. Nishio[5], A.G. Popeko[6], S. Saro[3], B. Streicher[3], M. Venhart[3], and A.V. Yeremin[6]



PHYSICAL REVIEW C 78, 021303(R) (2008)

High-K structure in ^{250}Fm and the deformed shell gaps at $N = 152$ and $Z = 100$

P. T. Greenlees,[1,*] R.-D. Herzberg,[2] S. Ketelhut,[1] P. A. Butler,[2] P. Chowdhury,[3] T. Grahn,[1] C. Gray-Jones,[2] G. D. Jones,[2] P. Jones,[1] R. Julin,[1] S. Juutinen,[1] T.-L. Khoo,[4] M. Leino,[1] S. Moon,[2] M. Nyman,[1] J. Pakarinen,[2] P. Rahkila,[1] D. Rostron,[2] J. Sarén,[1] C. Scholey,[1] J. Sorri,[1] S. K. Tandel,[3] J. Uusitalo,[1] and M. Venhart[5]



Eur. Phys. J. A **30**, 397–411 (2006)
DOI 10.1140/epja/i2006-10134-5

THE EUROPEAN PHYSICAL JOURNAL A

Spectroscopy and single-particle structure of the odd-Z heavy elements ^{255}Lr, ^{251}Md and ^{247}Es

A. Chatillon[1,a], Ch. Theisen[1,b], P.T. Greenlees[2], G. Auger[3,c], J.E. Bastin[4], E. Bouchez[1], B. Bouriquet[3], J.M. Casandjian[3,d], R. Cee[3], E. Clément[1], R. Dayras[1], G. de France[3], R. de Toureil[3], S. Eeckhaudt[2], A. Görgen[1], T. Grahn[2], S. Grévy[6,e], K. Hauschild[7], R.-D. Herzberg[4], P.J.C. Ikin[4], G.D. Jones[4], P. Jones[2], R. Julin[2], S. Juutinen[2], H. Kettunen[2], A. Korichi[7], W. Korten[1], Y. Le Coz[1,f], M. Leino[2], A. Lopez-Martens[7], S.M. Lukyanov[9], Yu.E. Penionzhkevich[9], J. Perkowski[2,g], A. Pritchard[4], P. Rahkila[2], M. Rejmund[3], J. Saren[2], C. Scholey[2], S. Siem[7,h], M.G. Saint-Laurent[3], C. Simenel[1], Yu.G. Sobolev[9], Ch. Stodel[3], J. Uusitalo[2], A. Villari[3], M. Bender[1,i], P. Bonche[5], and P.-H. Heenen[8]

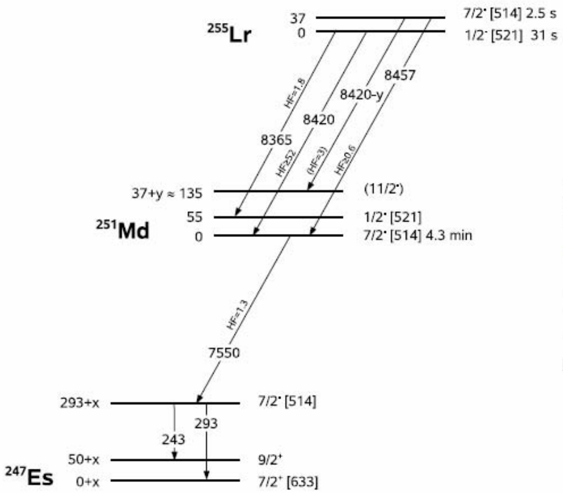
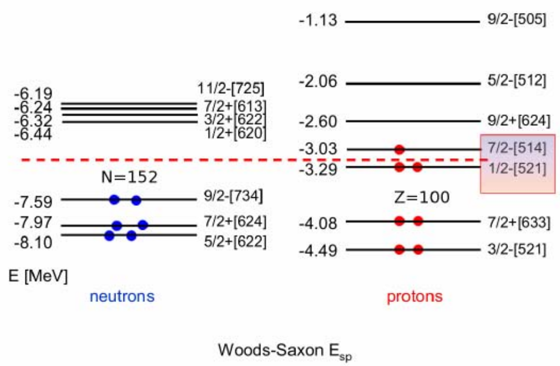


Fig. 13. Level scheme of ^{247}Es ^{251}Md and ^{255}Lr deduced from experimental data. The tentative 8290 keV line from ^{255}Lr is not shown.



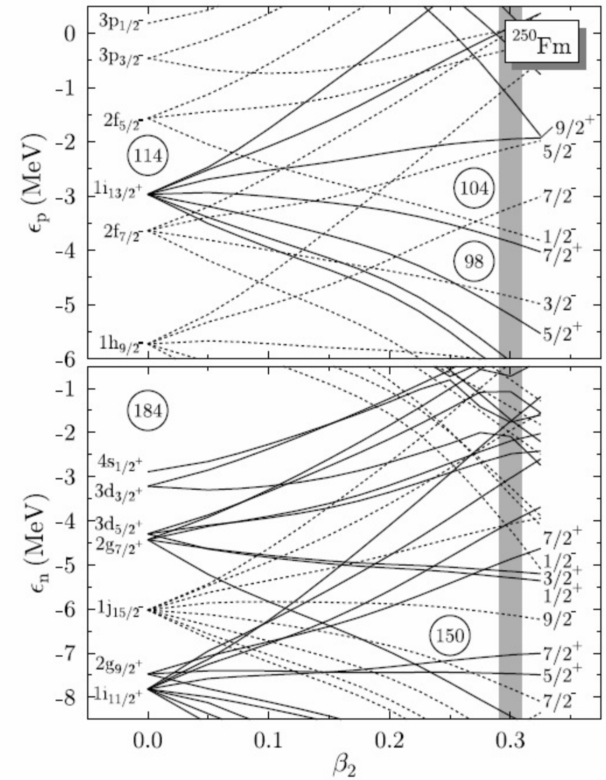
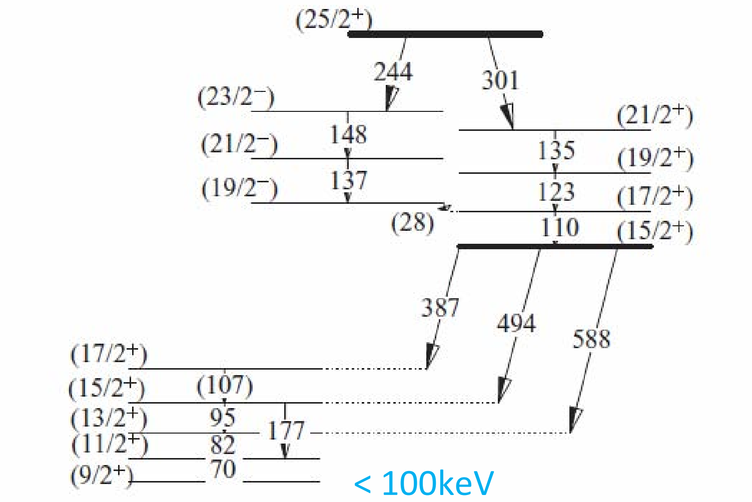
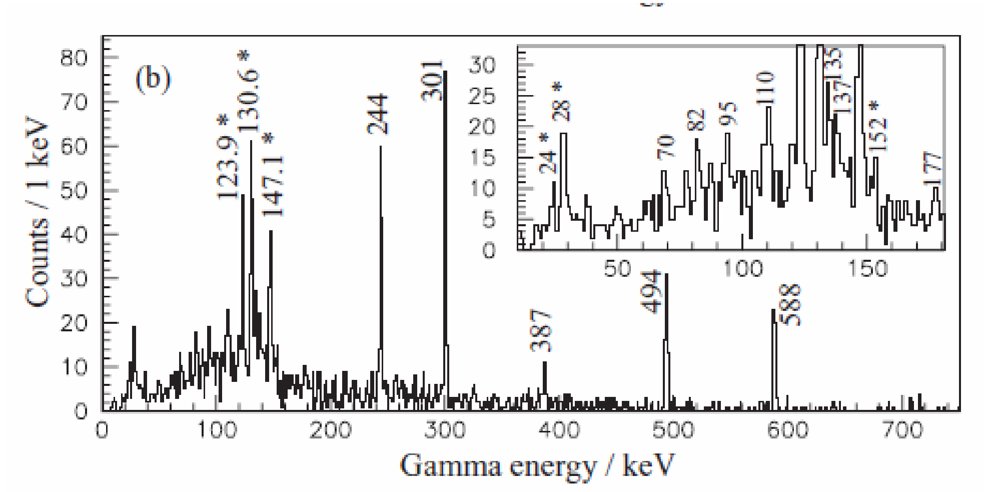


Fig. 14. Single-particle spectra of ^{250}Fm for protons (top) and neutrons (bottom) obtained with the SLy4 interaction. The vertical grey bar indicates the range of ground-state deformations predicted for this and neighboring nuclei.

H. B. Jeppesen et. al., PRC 80, 034324 (09)

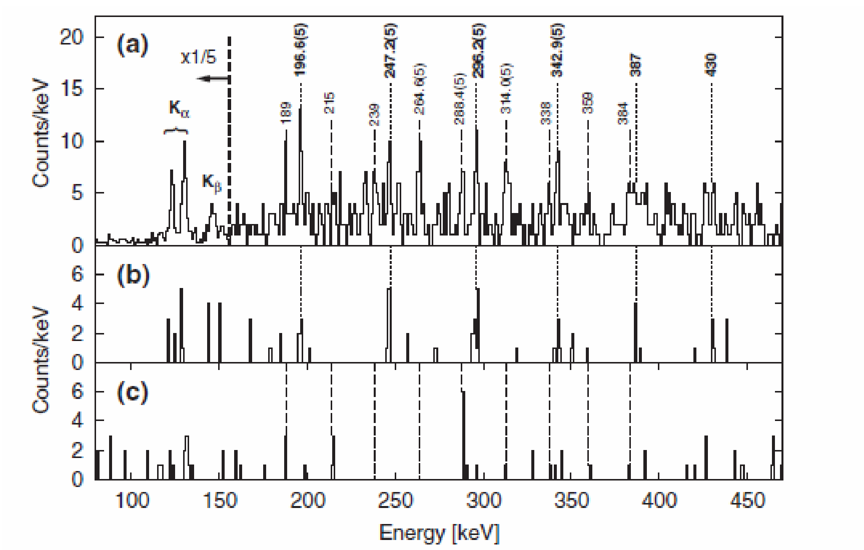


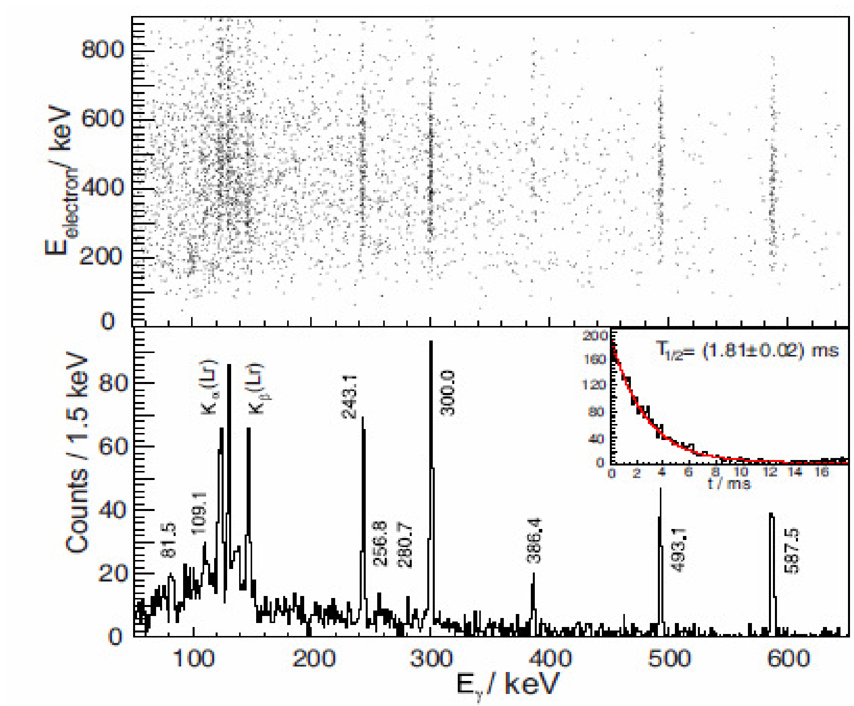
< 100keV



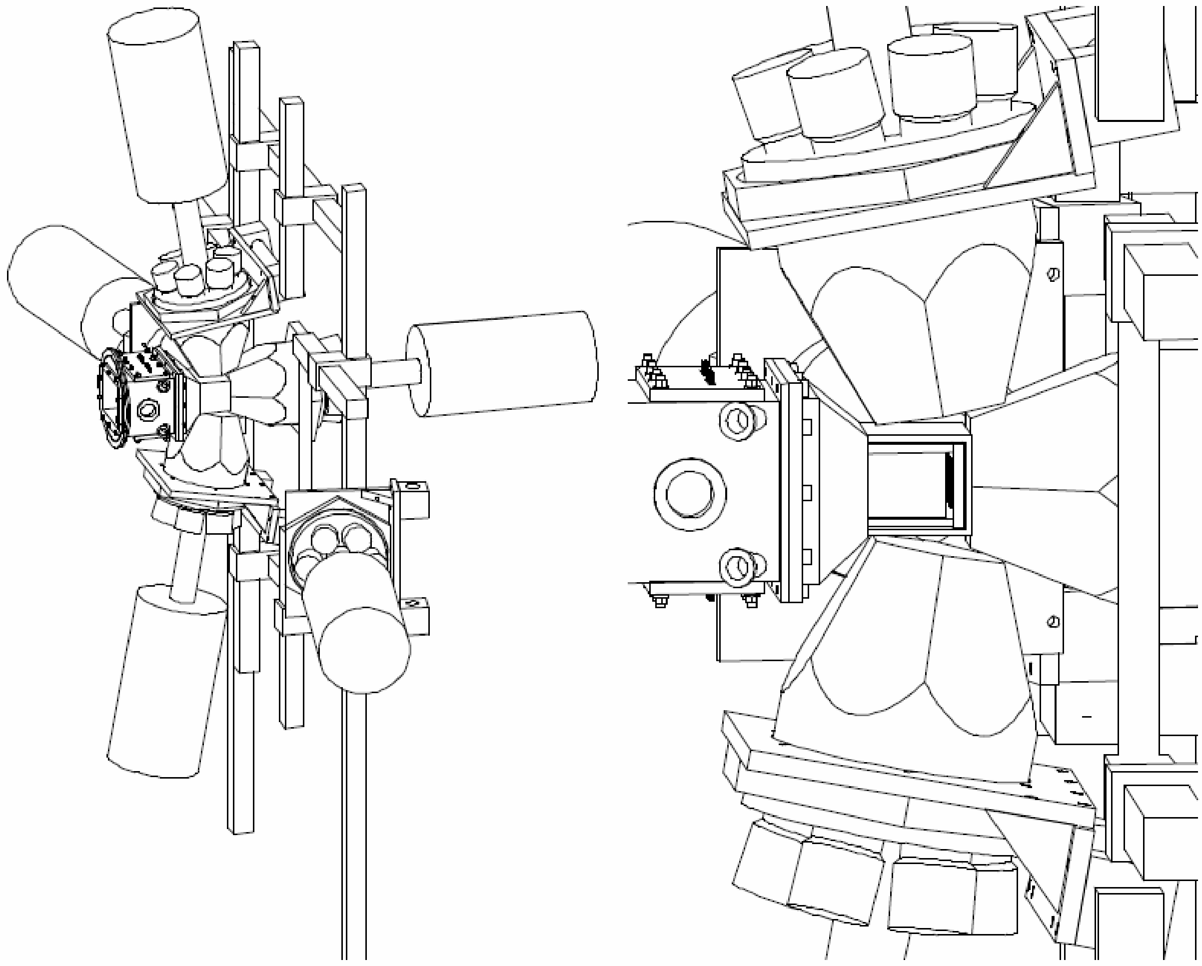
S. Antalic et. al., EPJ A 38, 219 (08)

S. Ketelhut et. al., PRL 102, 212501 (09)





Old RITU focal plane system

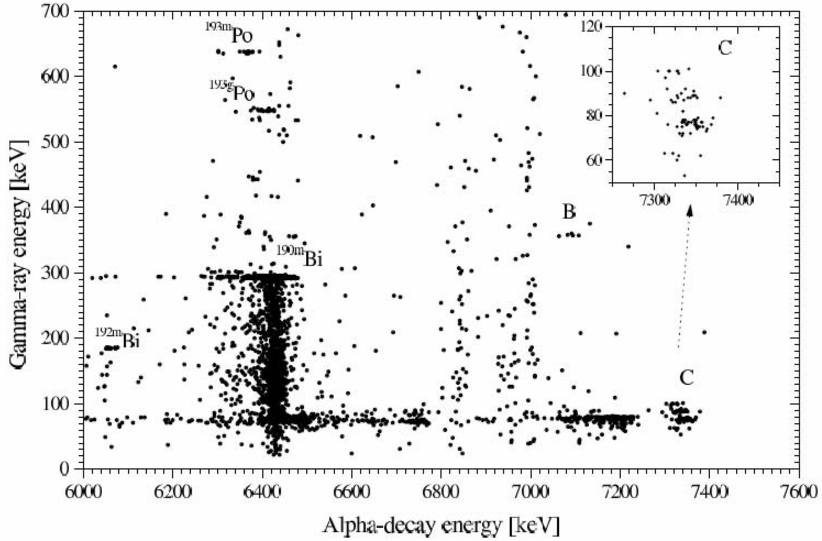


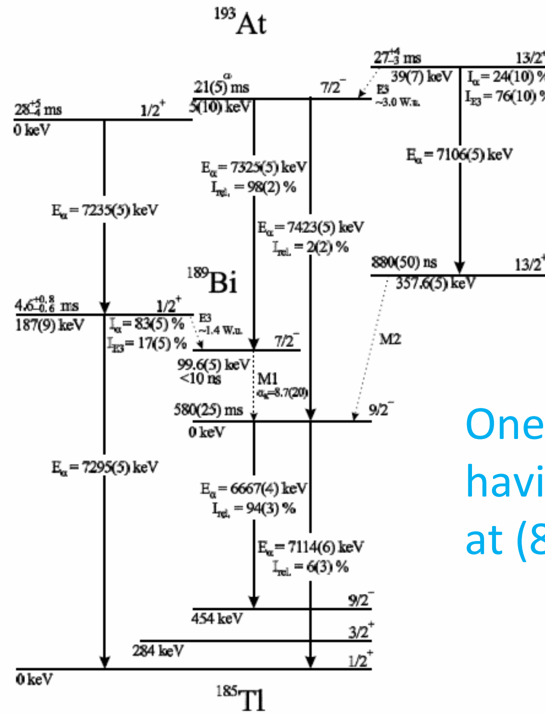
$^{56}Fe(^{141}Pr,4n)^{193}At$

750 μg/cm² target,70 pnA for 56 h

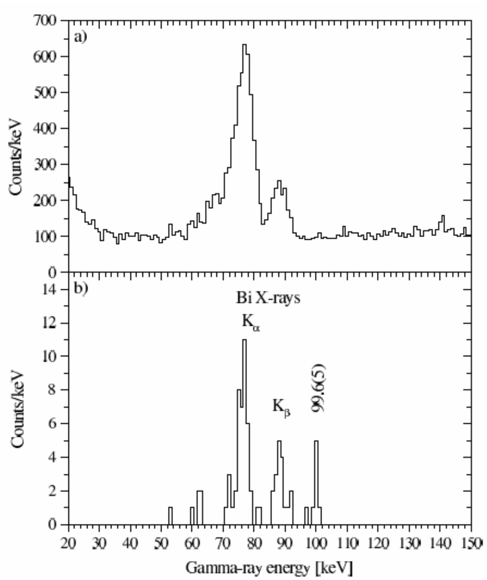
σ = 40 nb

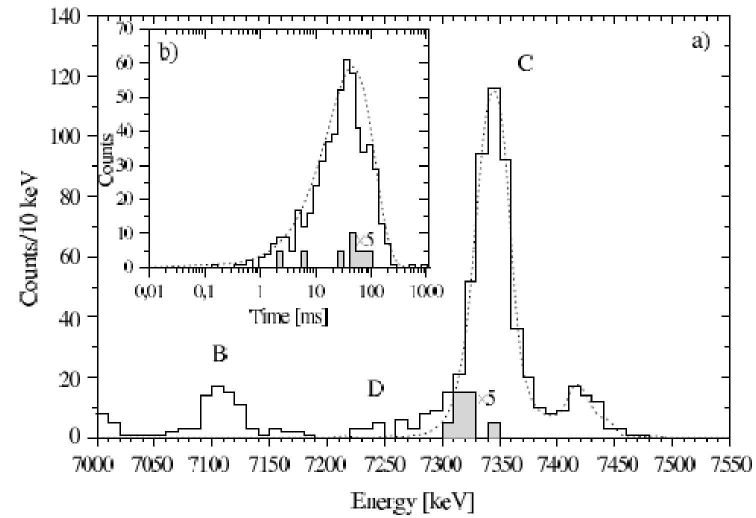
H. Kettunen *et al.*: Alpha-decay studies of the new isotopes ^{191}At and ^{193}At

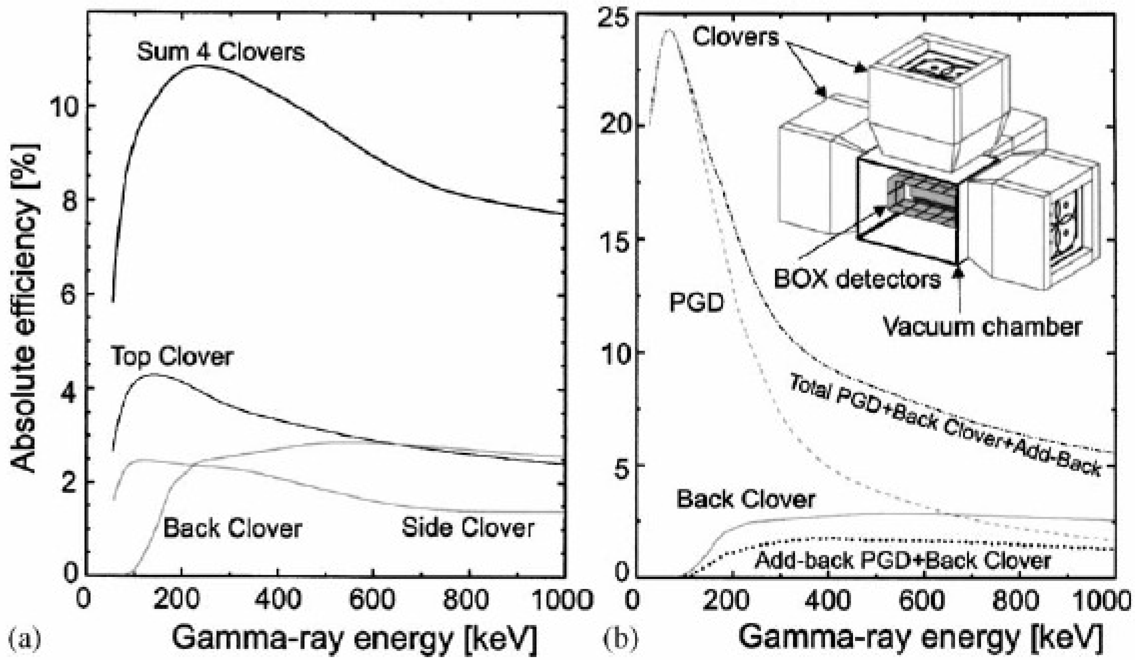




One Nordball type Ge having about 5 % eff. at (80-200) keV range







Sum 4 Clovers
Top Clover
Back Clover
Side Clover
Absolute efficiency [%]
Gamma-ray energy [keV]
(a)
Clovers
BOX detectors
Vacuum chamber
PGD
Total PGD+Back Clover+Add-Back
Back Clover
Add-back PGD+Back Clover
Gamma-ray energy [keV]
(b)

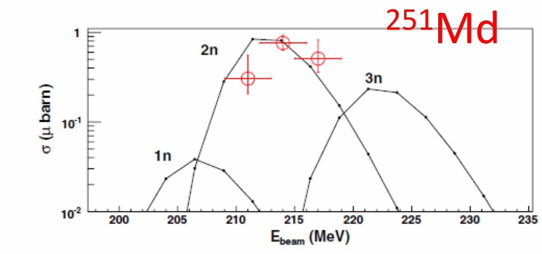
GREAT
ORTEC

100 pnA
^{48}Ca
40 % transmission
400 µg/cm2 ^{208}Pb target
1 µb
~ 25000 recoils collected/day
10 nb ~ 250 recoils/day

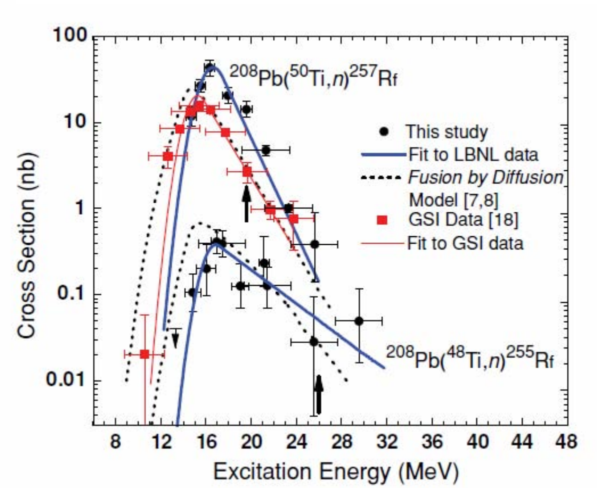
Future ?
200 pnA
3 weeks experiments
In total
1 µb 1x10^6 recoils
1 nb 1x10^3 recoils

^{254}No 2 µb
^{255}Lr 300 nb
^{257}Rf 40 nb, ^{256}Rf 15 nb
^{258}Db 5 nb, ^{257} Db 1 nb
^{259}Sg 300 pb, ^{259}Sg 150 pb

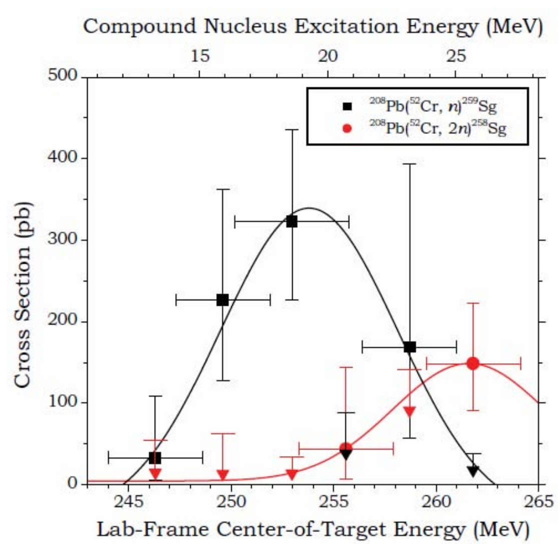
A. Chatillon et. al.,
PRL 98, 132503 (07)



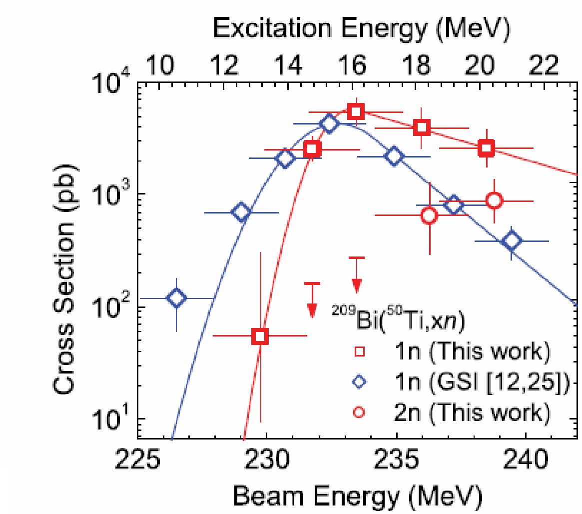
I. Dragojevic et al.,
PRC 78, 024605 (08)



C. M. Folden III et. al.,
PRC 79, 027602 (09)



J. M. Gates et. al.,
PRC 78, 034604 (08)



Recoil shadow method

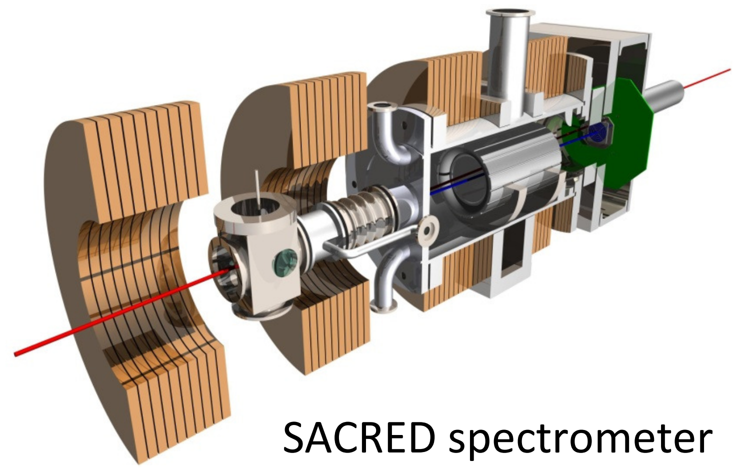
Z. Physik A 285, 159 – 169 (1978)

Zeitschrift für Physik A

In-Beam Spectroscopy of Low Energy Conversion Electrons with a Recoil Shadow Method – A New Possibility for Subnanosecond Lifetime Measurements

H. Backe, L. Richter, R. Willwater, E. Kankeleit, E. Kuphal*, and Y. Nakayama**
Institut für Kernphysik der TH Darmstadt, Darmstadt, Germany

B. Martin
Max-Planck-Institut für Kernphysik, Heidelberg, Germany



SACRED spectrometer

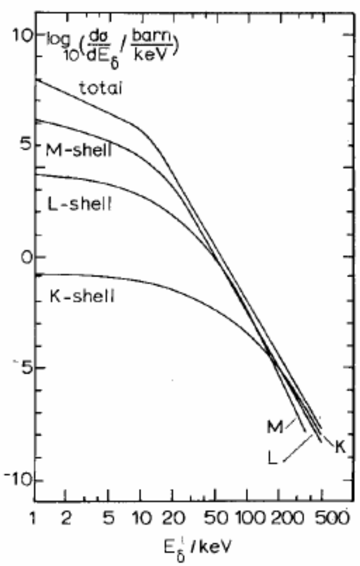


Fig. 1. The δ-electron spectrum as calculated from the binary encounter theory for 90 MeV ^{16}O on ^{208}Pb [1]

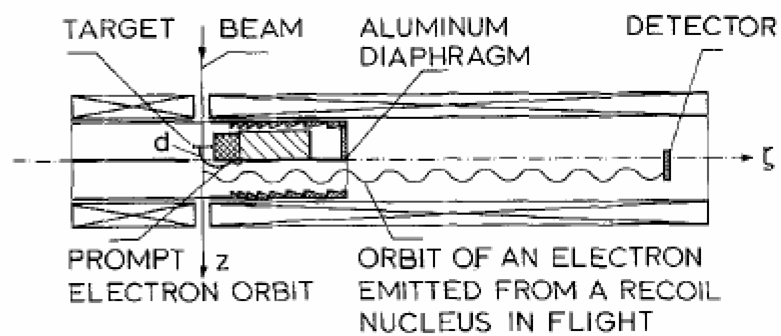


Fig. 8. The recoil shadow method. It is shown a cut through the electron transport system containing the beam and solenoid symmetry axis. The longitudinal baffle avoids detection of prompt electrons but allows very efficiently passage of delayed electrons emitted in flight

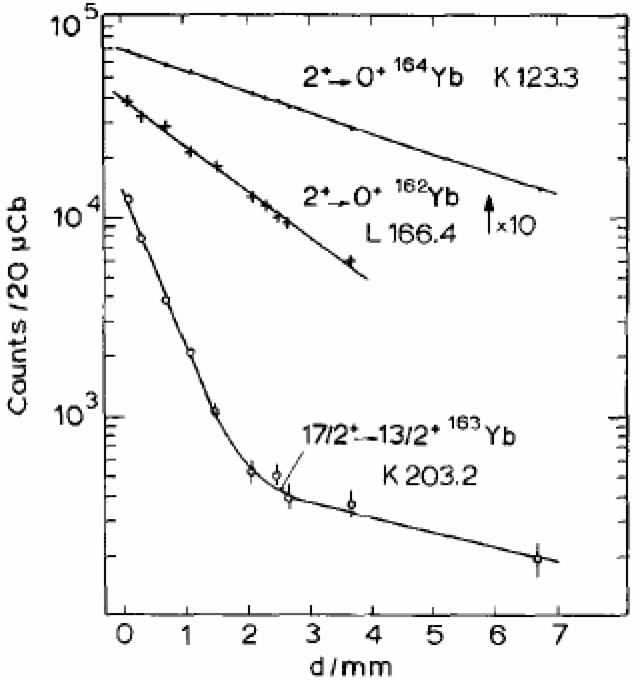
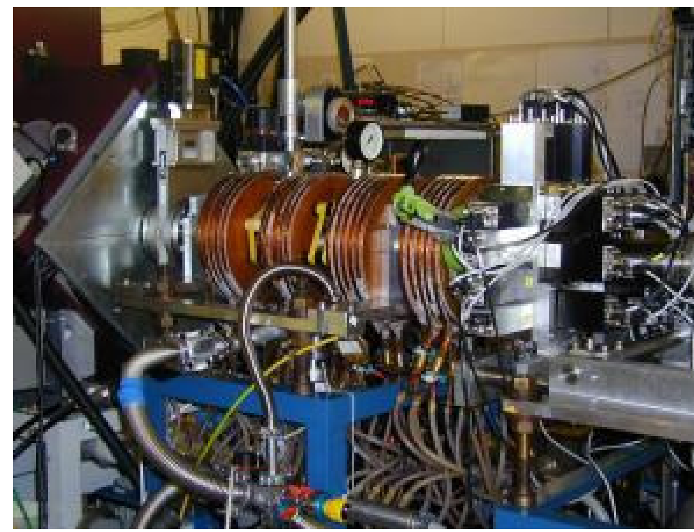


Fig. 12. Life time measurements on certain levels in $^{162,163,164}Yb$ with the recoil shadow method by variation of the target position d relative to the edge of the semicylindrical baffle. The results are $T_{1/2} = (971 \pm 31)$ ps and $T_{1/2} = (439 \pm 37)$ ps for the $2^+ \rightarrow 0^+$ transitions in ^{164}Yb and ^{162}Yb, respectively. For the 203.2 keV transition in ^{163}Yb the two half life components are $T_{1/2}^{(1)} = (108 \pm 7)$ ps and $T_{1/2}^{(2)} = (1.2 \pm 0.3)$ ns

$^{208}Pb(^{48}Ca,2n)^{254}No$

V = 0.017c = 5.1 mm/ns

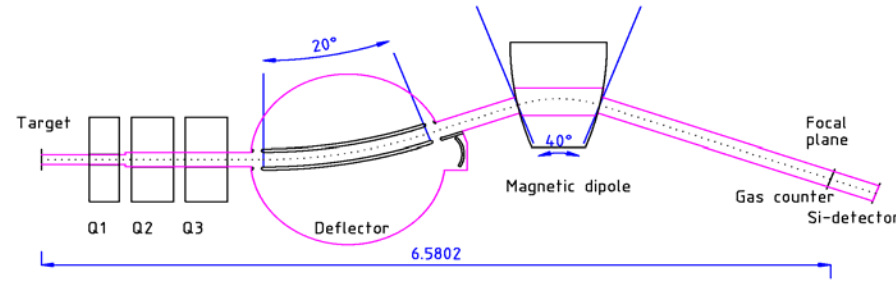
SACRED spectrometer



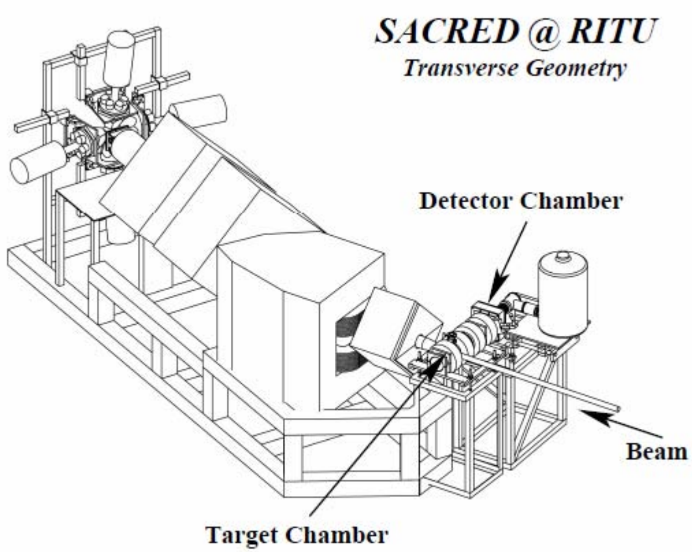
d > 0.3 mm

In the present paper

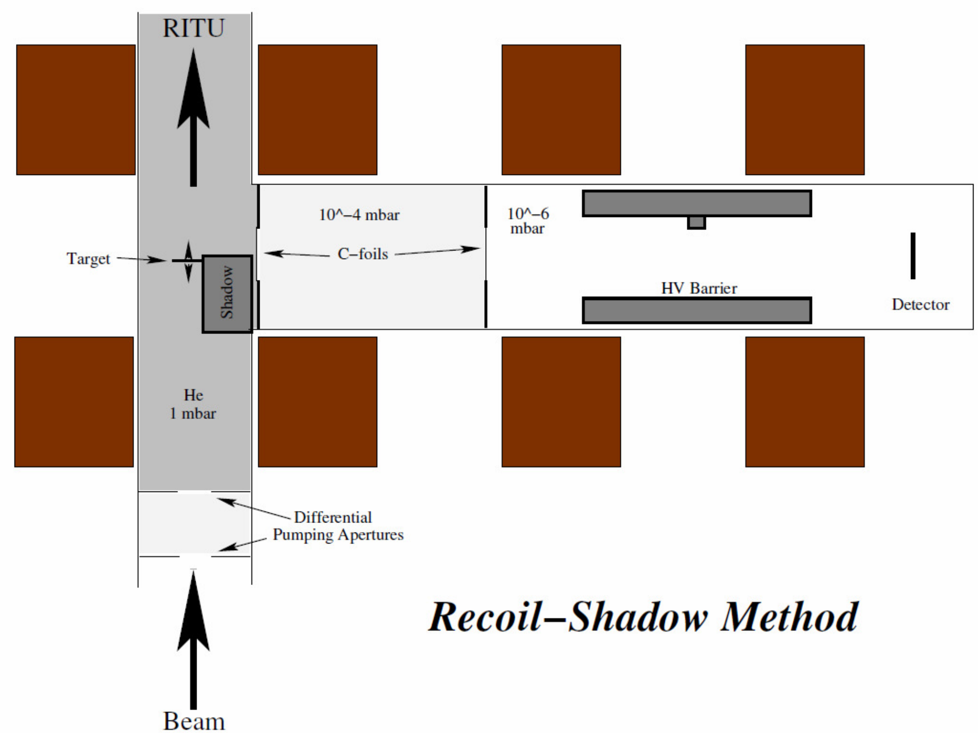
d < 0.3 mm δ-electron background too high



Target
Q1
Q2
Q3
20°
Deflector
40°
Magnetic dipole
Focal plane
Gas counter
Si-detector
6.5802



SACRED @ RITU
Transverse Geometry
Detector Chamber
Beam
Target Chamber



RITU
10^−4 mbar
10^−6 mbar
Target
C−foils
Shadow
HV Barrier
Detector
He
1 mbar
Differential
Pumping Apertures
Beam
Recoil−Shadow Method

Charge plunger technique

NUCLEAR INSTRUMENTS AND METHODS 148 (1978) 369-379 ;

LIFETIME MEASUREMENTS OF NUCLEAR LEVELS WITH THE CHARGE PLUNGER TECHNIQUE

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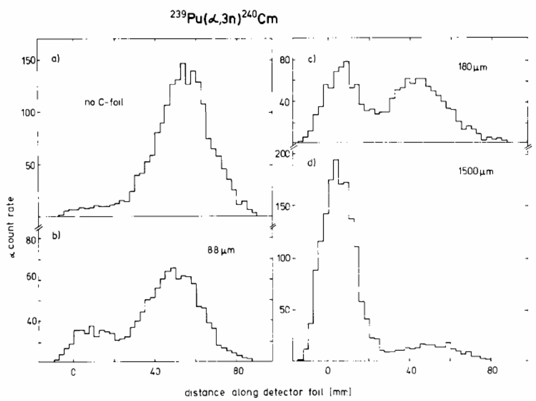


Fig. 6. Distribution of ^{240}Cm ions from the ^{239}Pu(α, 3n) reaction at 33 MeV, measured along the recoil collector for various distances between target and carbon foil.

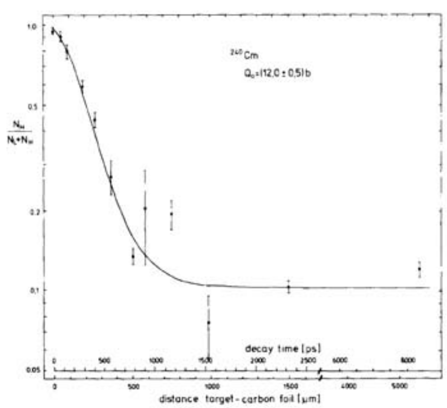
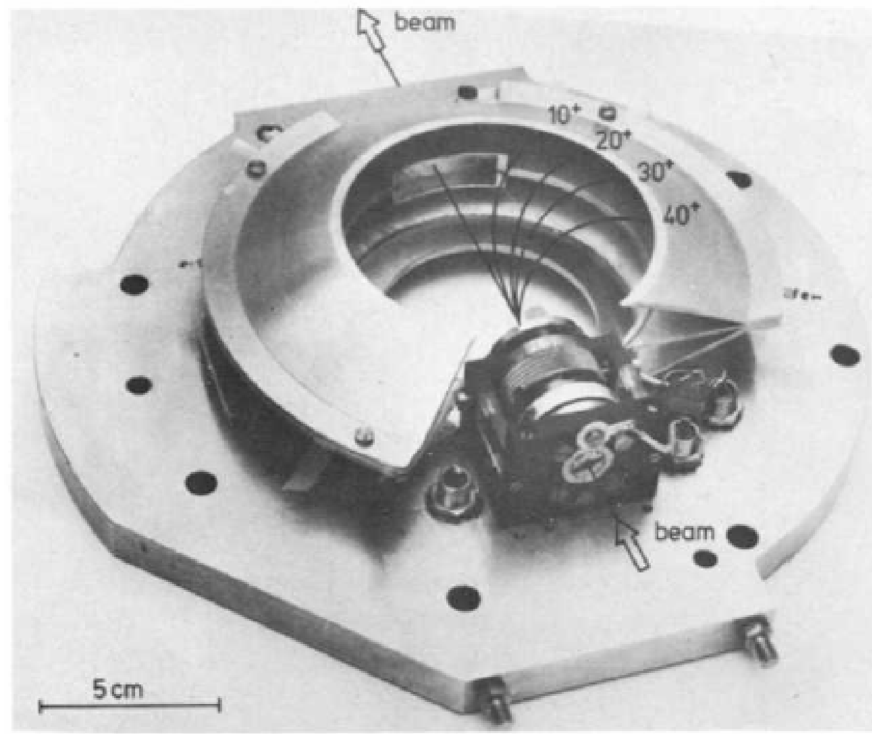


Fig. 9. Percentage of highly charged ^{240}Cm recoil ions as a function of the distance between the target and the carbon foil. The curve is a least-squares fit of a cascade calculation to the data points yielding a quadrupole moment of (12.0±0.5)b and allowing in addition for a contribution from a long-lived isomeric state.

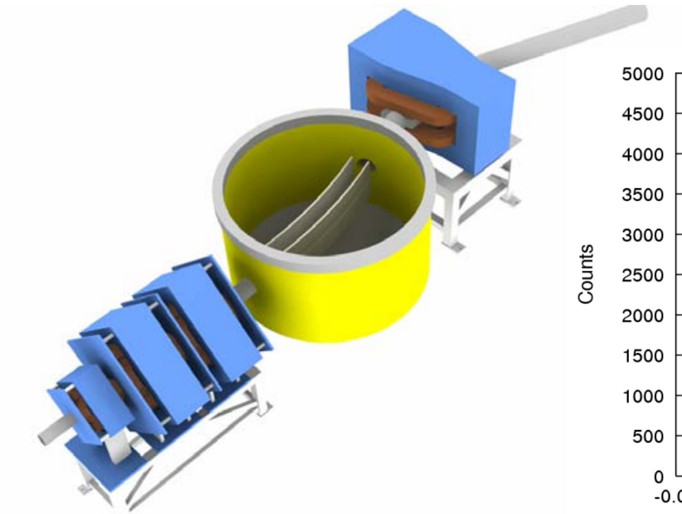


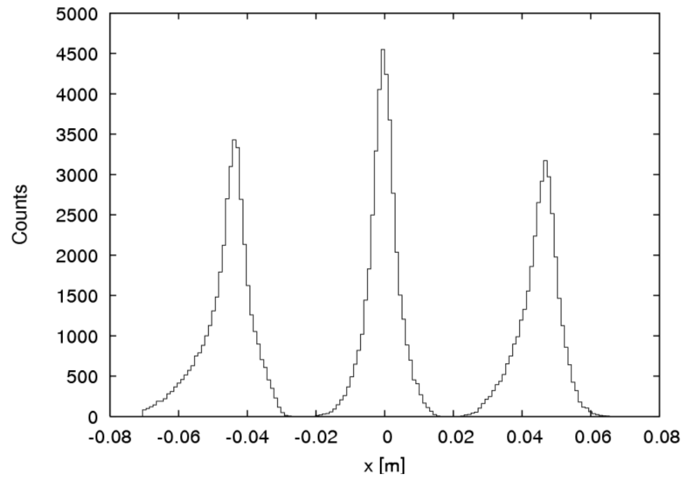
$^{48}Ca + ^{208}Pb \rightarrow ^{256}No^{*} \rightarrow ^{254}No + 2n$

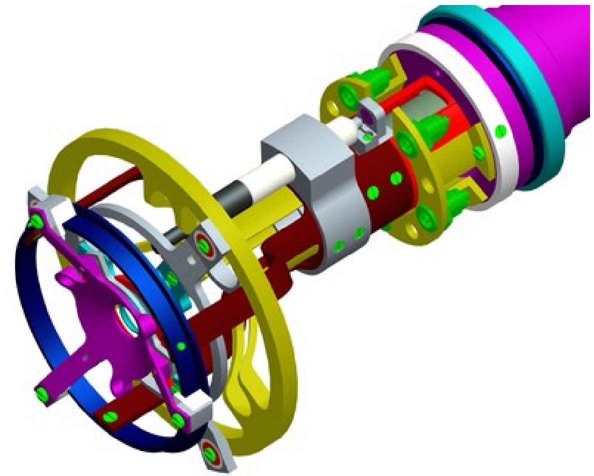
E_{lab} = 215 MeV (MOT)

Target 400 μg/cm^2

M = 254, Q = 17, 18, 19, E = 35(5) MeV, $\sigma_{x,y}$ = ± 50 mrad







DPUNS plunger
University of Manchester

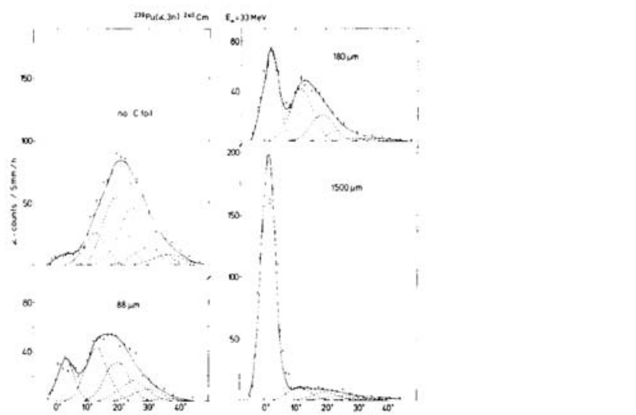


Fig. 10. Charge distributions of ^{240}Cm recoil ions from fig. 6, decomposed into the contributions from several consecutive converted transitions.

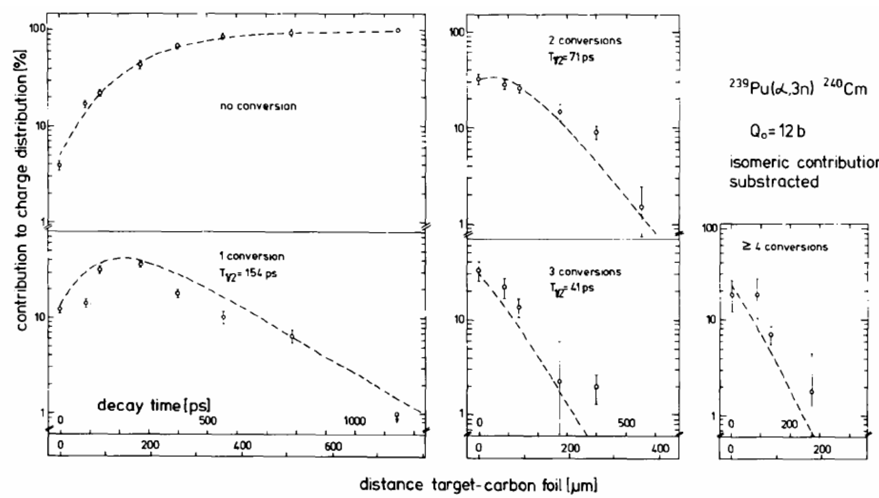


Fig. 11. Decay curves for the contributions of individual rotational levels to the charge distribution of ^{240}Cm recoil ions.

Thank you for your attention

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