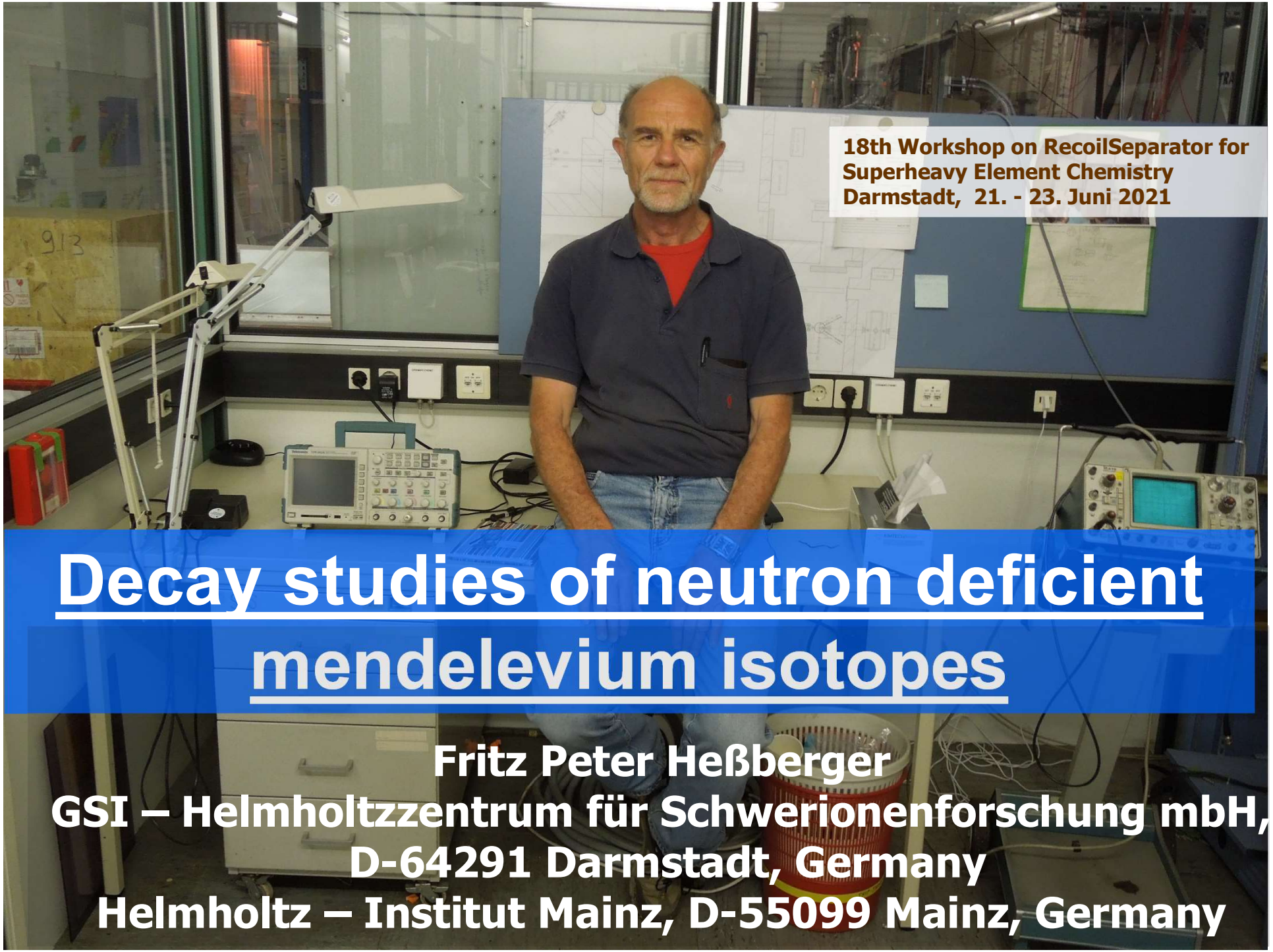


18th Workshop on RecoilSeparator for Superheavy Element Chemistry
Darmstadt, 21. - 23. Juni 2021

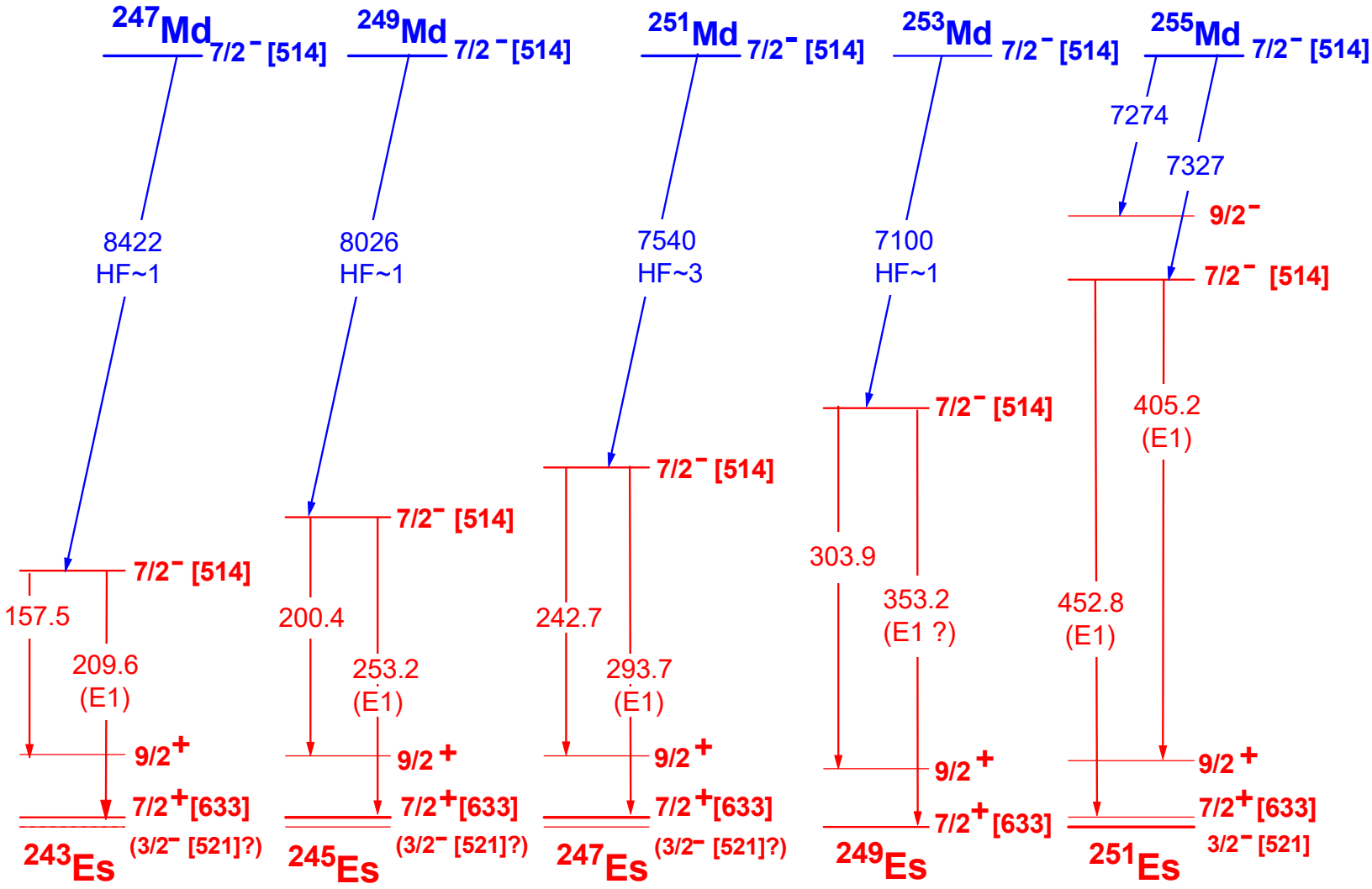
Decay studies of neutron deficient mendelevium isotopes

Fritz Peter Heßberger
GSI – Helmholtzzentrum für Schwerionenforschung mbH,
D-64291 Darmstadt, Germany
Helmholtz – Institut Mainz, D-55099 Mainz, Germany

Layout

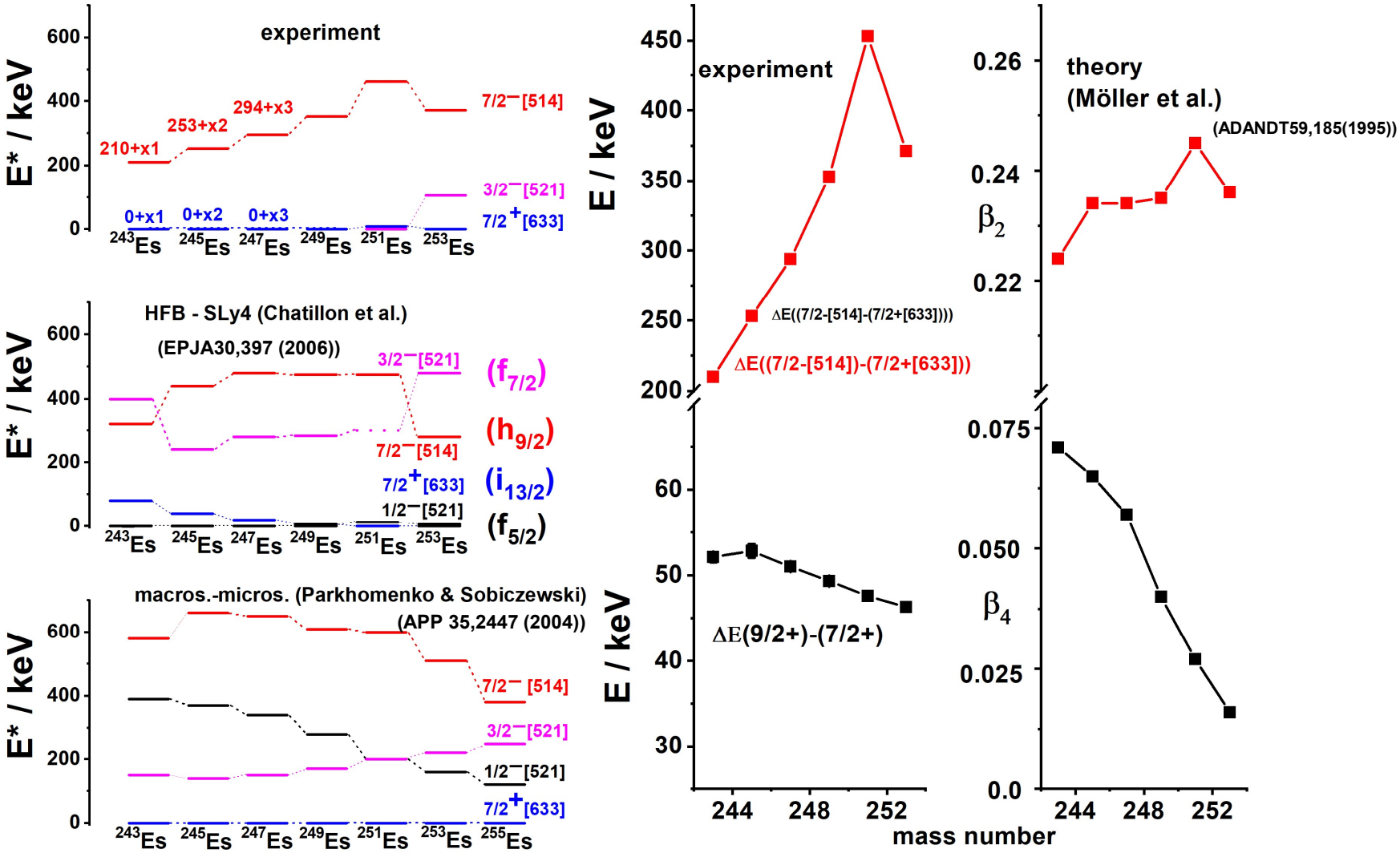
- Motivation
- General considerations
- Decay study of ^{247}Md
- Decay study of ^{250}Md
- Disagreements in the discovery of ^{244}Md
- Summary and conclusions

Decay properties of odd-mass mendelevium isotopes

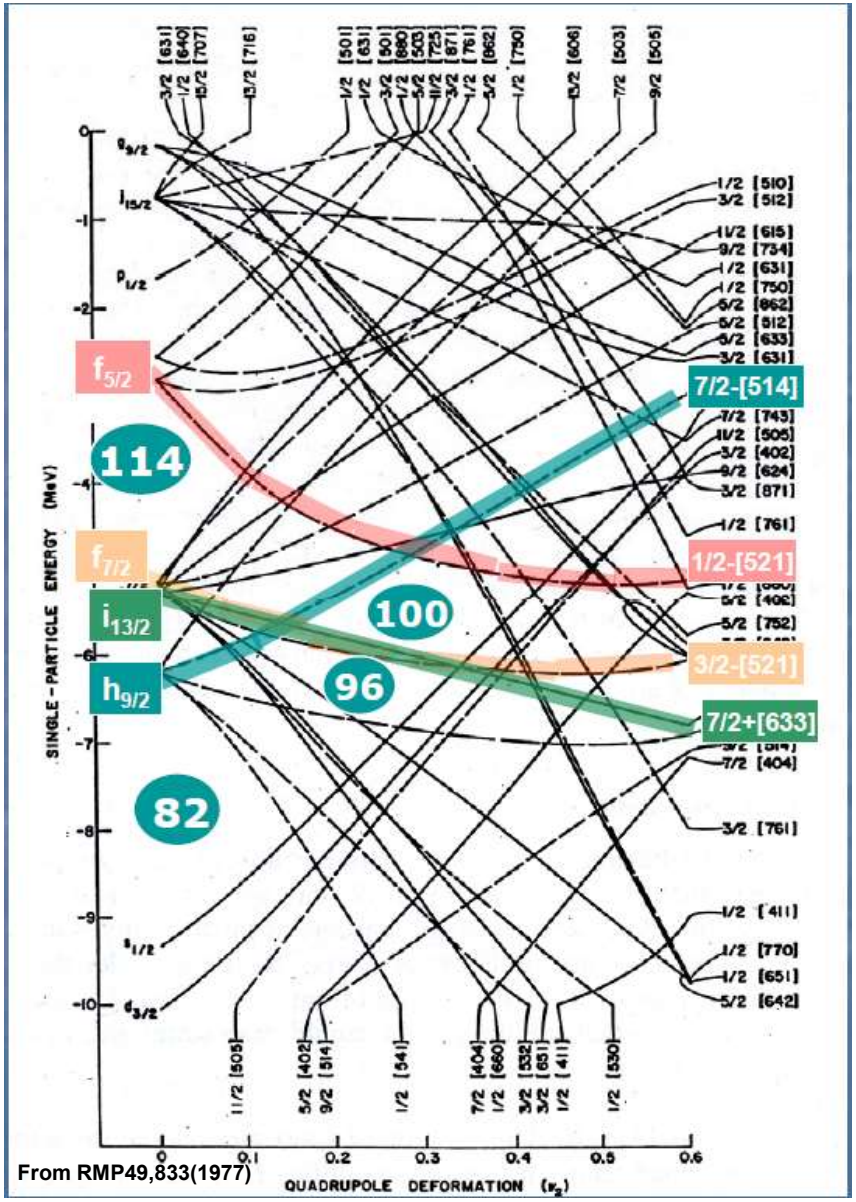


graph/demo/nivmend
F.P.Heßberger 2.6.2006

Low lying levels in einsteinium isotopes experiment and predictions



Structure of odd-mass einsteinium isotopes - some aspects



From RMP49,833(1977)

Motivation for decay studies of odd-mass mendelivium isotopes

- Identify ground-state in daughter isotopes ^{247,245,243}Es
- Obtain more information on low lying levels in odd-mass einsteinuim isotopes

Why ^{247}Md ?

→ ‚high' transmission of SHIP only for ‚heavy' beams

→ Md-isotopes A≥249 can only produced indirectly by α- or EC – decay; background from decay of mother nucleus disturbs search for γ-transitions of low intensity

→ only ^{247}Md can be produced directly; no large area tallium targets available

→ relatively high cross section of ≈6 nb for ^{209}Bi(^{40}Ar,2n)^{247}Md

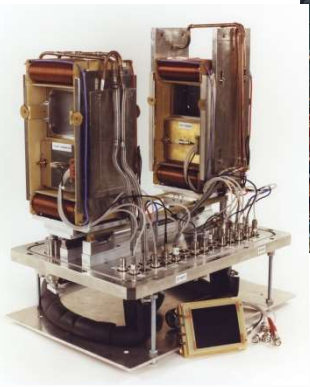
→ ^{40}Ar – beams of high intensity available (>> 1pμA)

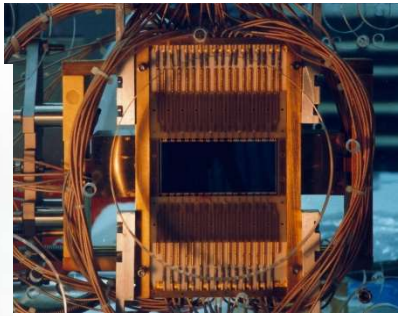
→ detailed investigation of ^{245}Md not accepted by GSI – PAC (2005)

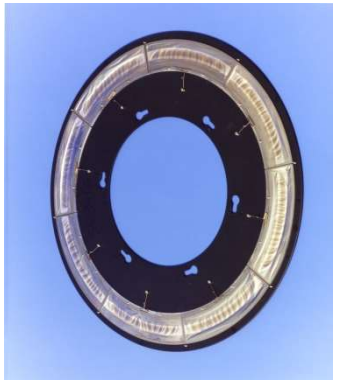
Velocity separator SHIP

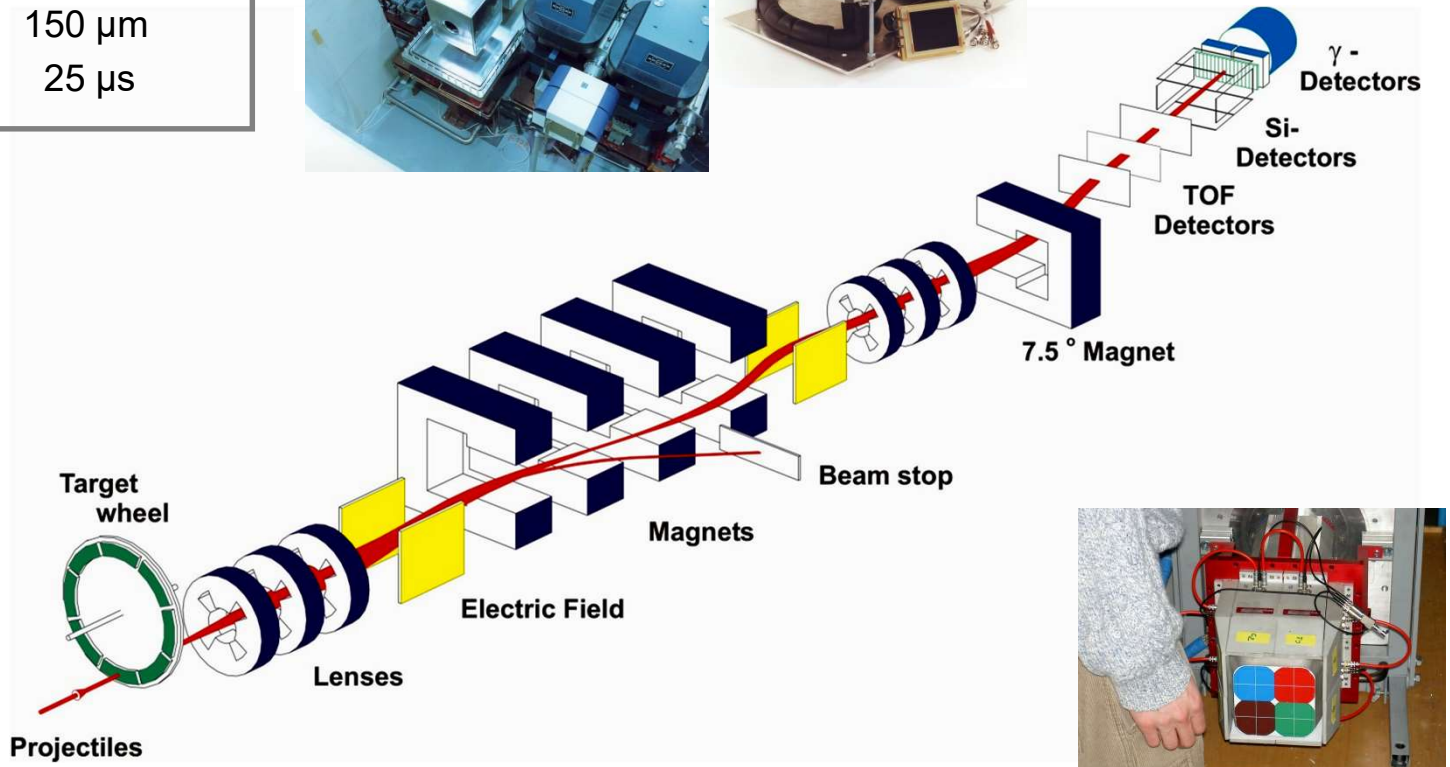
SHIP

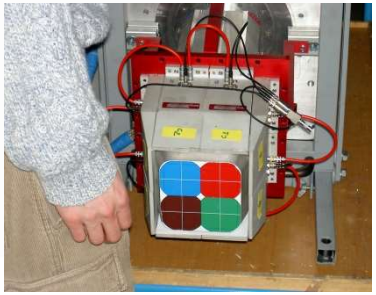
Separation time:	1 – 2 µs
Transmission:	20 – 50 %
Background:	10 – 50 Hz
Det. E. resolution:	18 – 25 keV
Det. Pos. resolution:	150 µm
Dead time:	25 µs







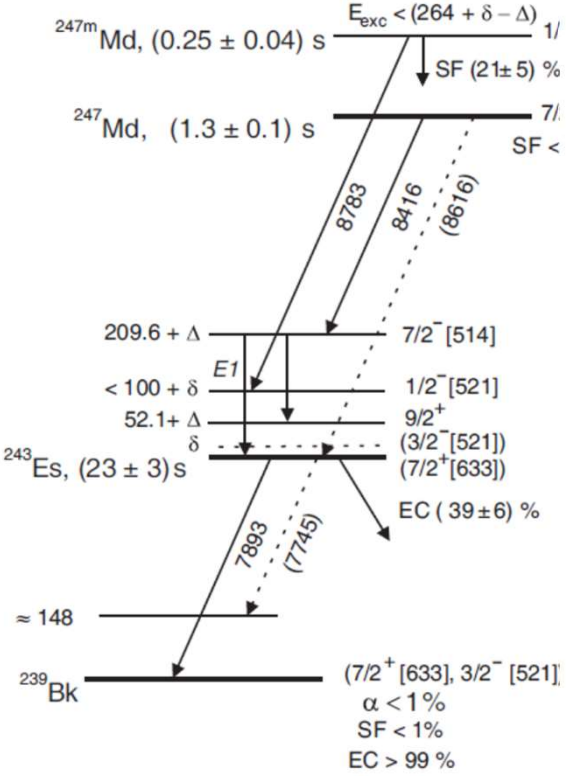




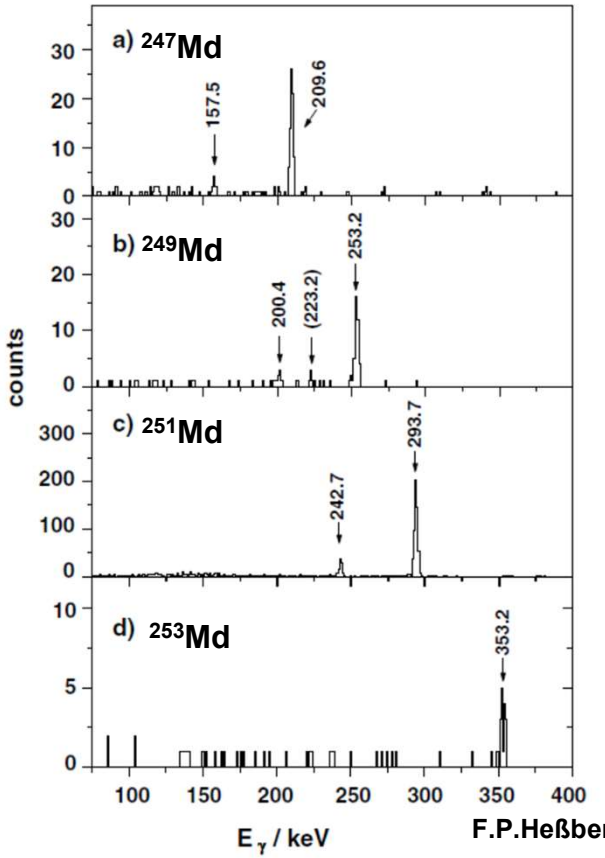
Decay studies of ^{247}Md at SHIP

- 1980: discovery of ^{247}Md (5 α-decays); my first new isotope !!!
  → E_α = 8428±25 keV, $T_{1/2}$ = 2.9 +1.7/-1.2 s (G. Münzenberg et al. ZPA 302,7 (1981))
- 1993: discovery of ^{247m}Md (S. Hofmann et al. GSI Scientific Report 1993, 64 (1994))
  → ^{247}Md: E_α = 8424 keV, $T_{1/2}$ = 1.12±0.22 s; ^{247m}Md: SF, $T_{1/2}$ = 0.23 +0.19/-0.12 s;

2001/2003: α-γ – decay studies of ^{247}Md
(F.P. Heßberger et al. EPJA 26, 233 (2005); S. Antalic et al. EPJA 43,35 (2010)



S. Antalic et al. EPJA 43,35 (2010)



F.P.Heßberger et al. EPJA 26, 233 (2005)

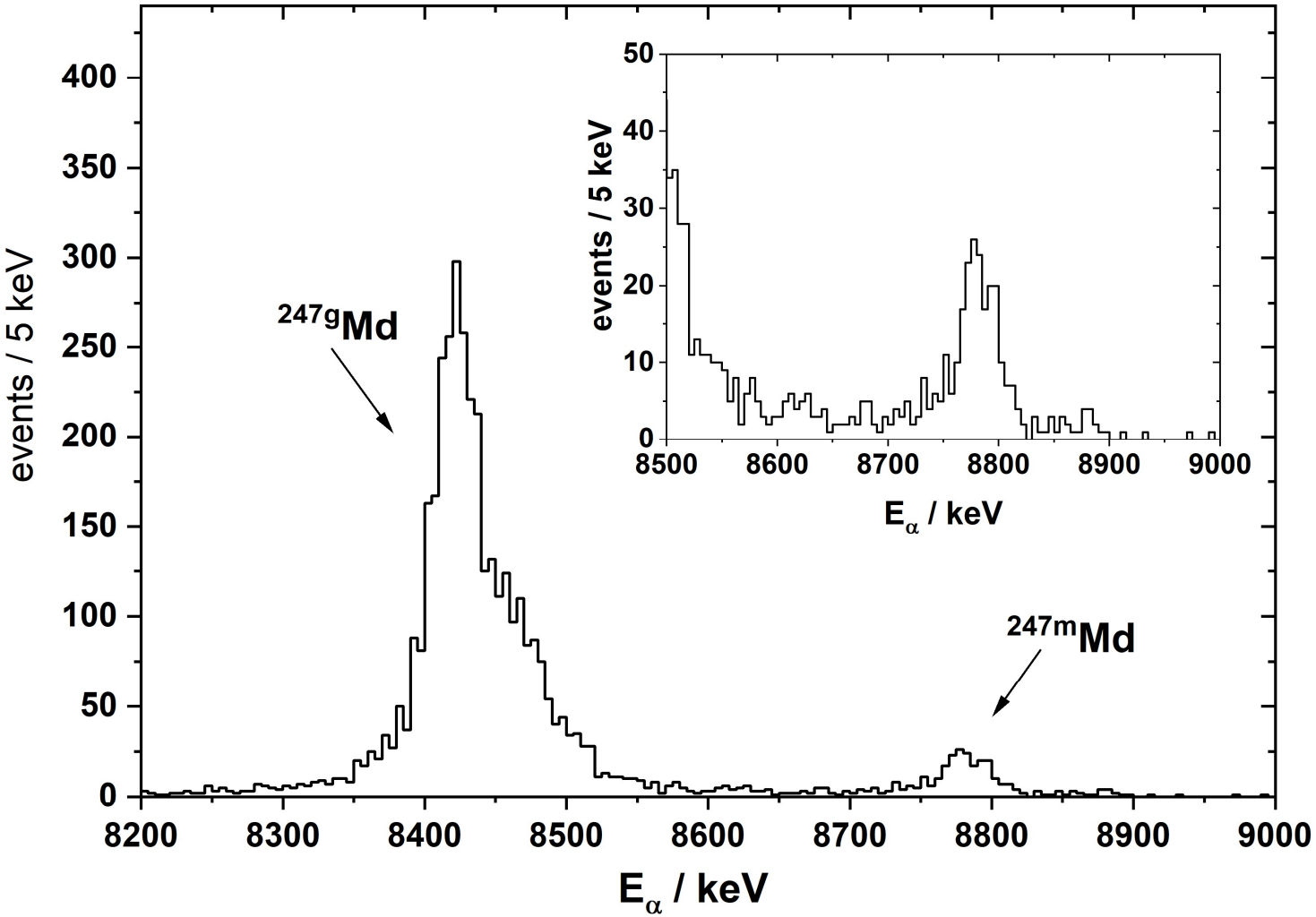
^{243g}Md: :
E_α = 8424 ± 10 keV,
$T_{1/2}$ = 1.2 ± 0.1 s,
b_{SF} < 0.1%

^{247m}Md:
E_α = 8783 ± 40 keV,
$T_{1/2}$ = 0.25 ± 0.04 s,
b_α = 79 ± 5 %
b_{SF} = 21 ± 5 %

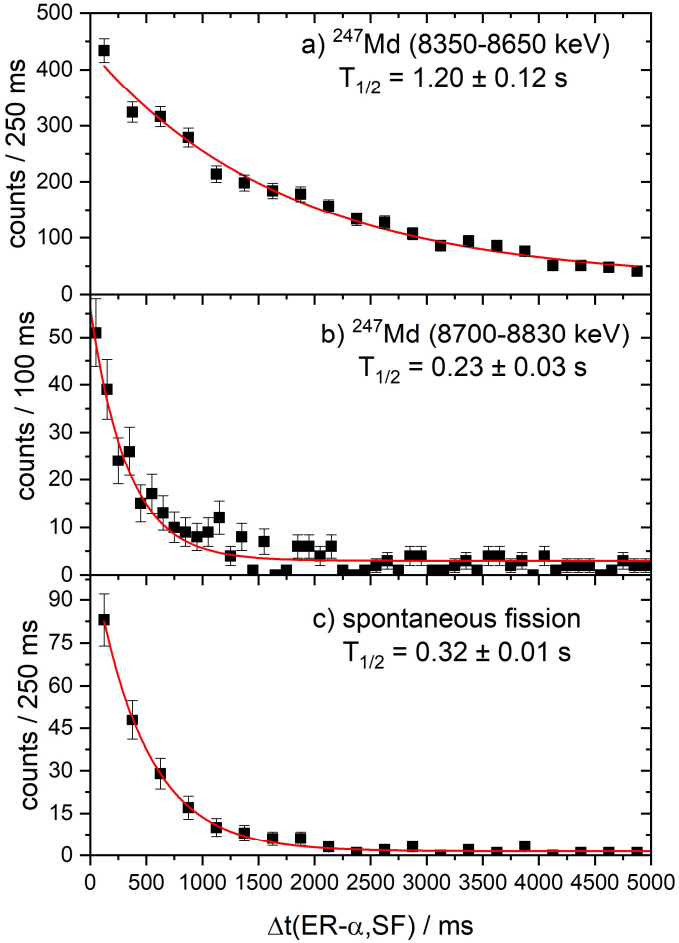
‚New' decay study of ^{247}Md at SHIP (2007)

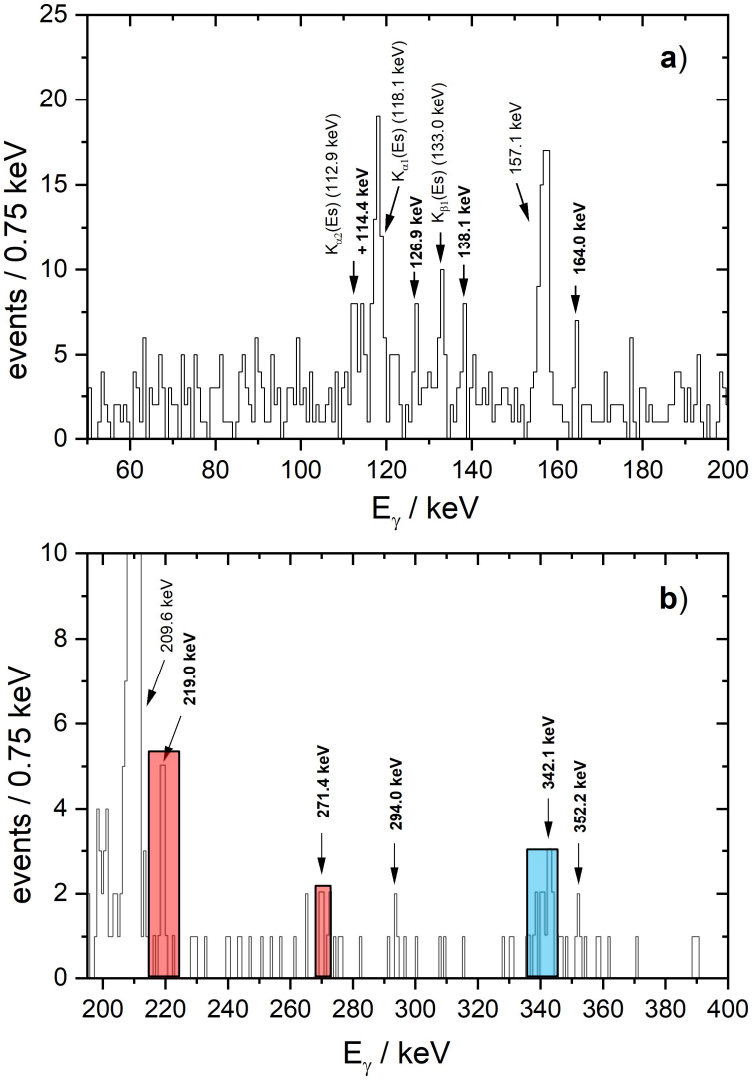
Irradiation time: 157 h
Beam intensity: 1.5 – 2 pμA
(0.93 – 1.24) x 10^{13} part./s

Σα(full energy events (stop detector) in pause)
^{247g}Md: 3428
^{247m}Md: 299
ΣSF: 227



‚New' decay study of ^{247}Md at SHIP (2007)





$T_{1/2}$ (SF) > $T_{1/2}$ (α, ^{247m}Md)
→ interpreted as mixture of SF from ^{247m}Md and ^{247}Md;
→ f(t) = A x exp(-ln2 x t/$T_{1/2}$(^{247m}Md)) + B x exp(-ln2 x t/$T_{1/2}$(^{247g}Md))
with A ≈ 0.7 and B ≈ 0.3

→ b_{SF}(^{247m}Md) = 0.20 ± 0.02, b_{SF}(^{247g}Md) = 0.0086 ± 0.0010

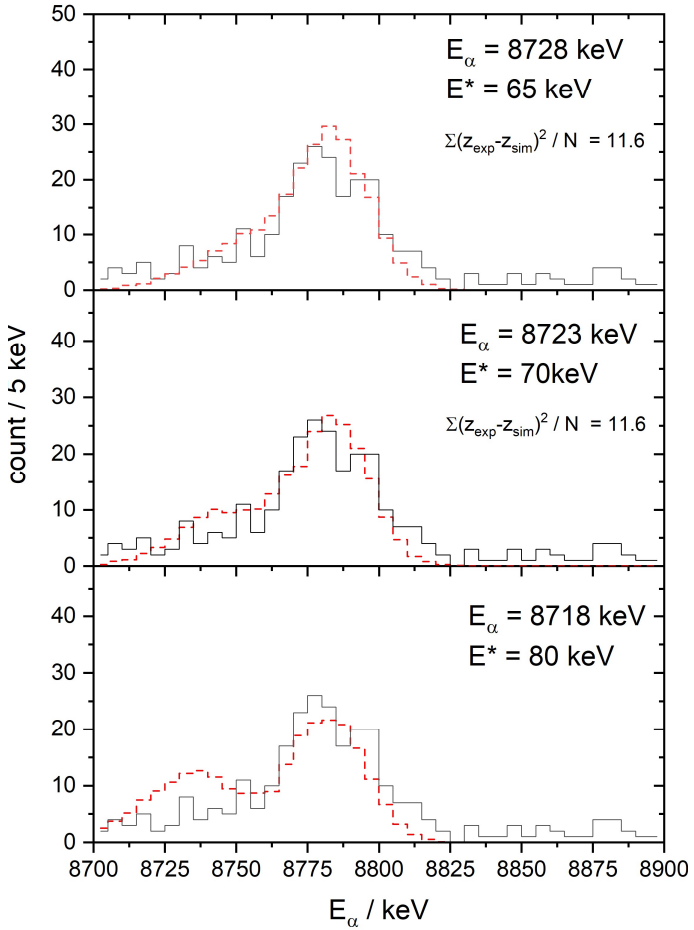
Sum of γ – events from 2001, 2003, and 2007 studies

Proposed decay scheme of ^{247}Md

GEANT simulations for α – peak of ^{247m}Md

Basis: $E_\alpha + E_\gamma$ = 8451 keV + 342.1 keV transition represents transition into the ground-state

Performed by B. Andel

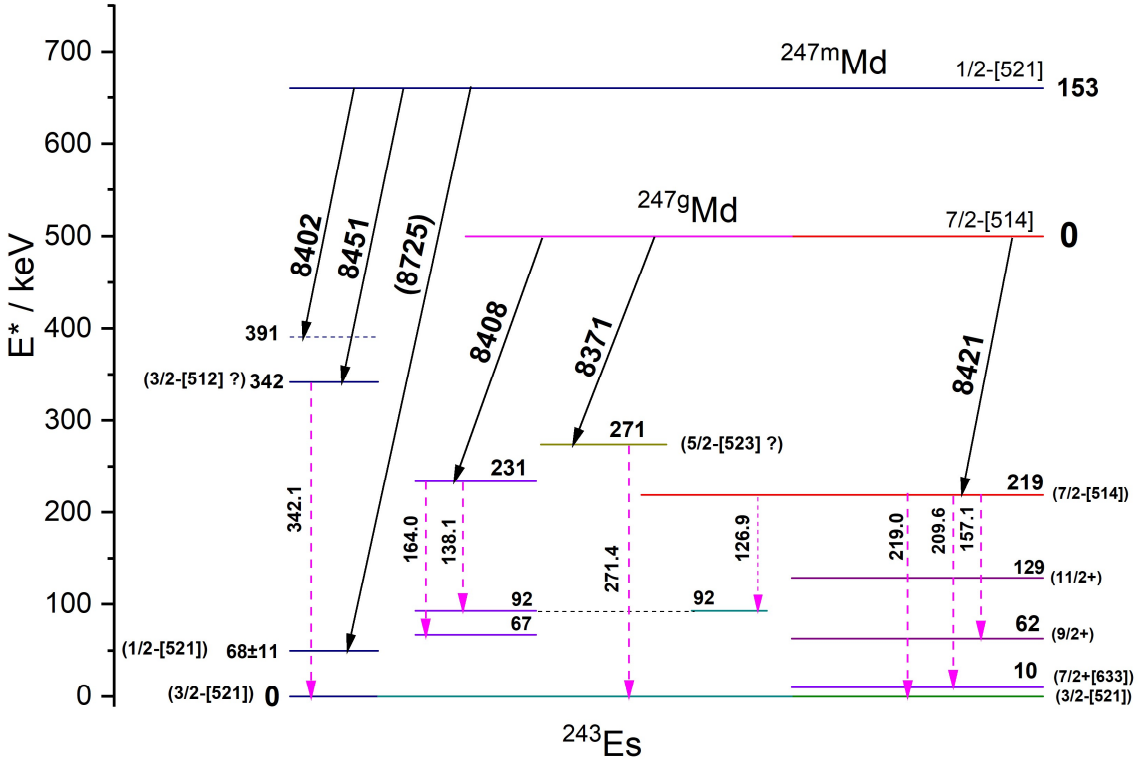


Assignments:

a) **E_γ = 219.6 keV → E_α = 8421 keV → decay from 7/2-[514] – level into the ground-state**

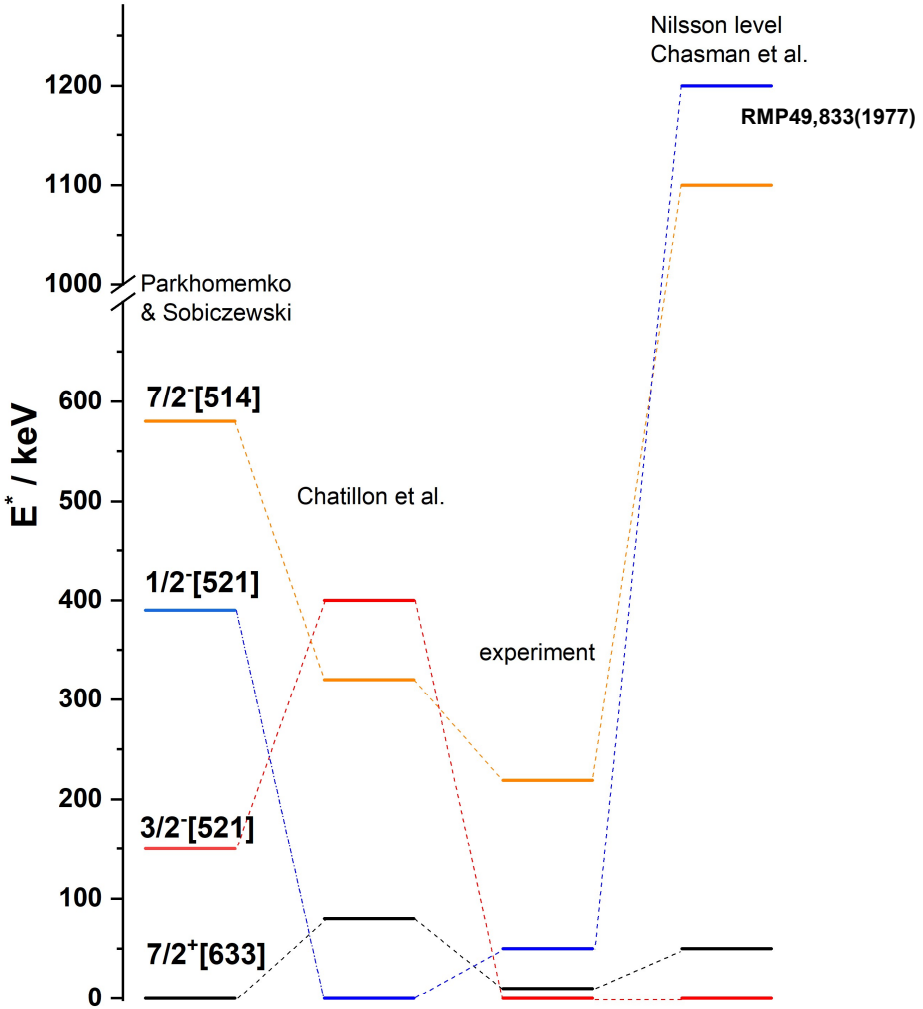
b) **E_γ = 271.4 keV, E_α = 8371 keV → decay into the gound-state due to Q-value**

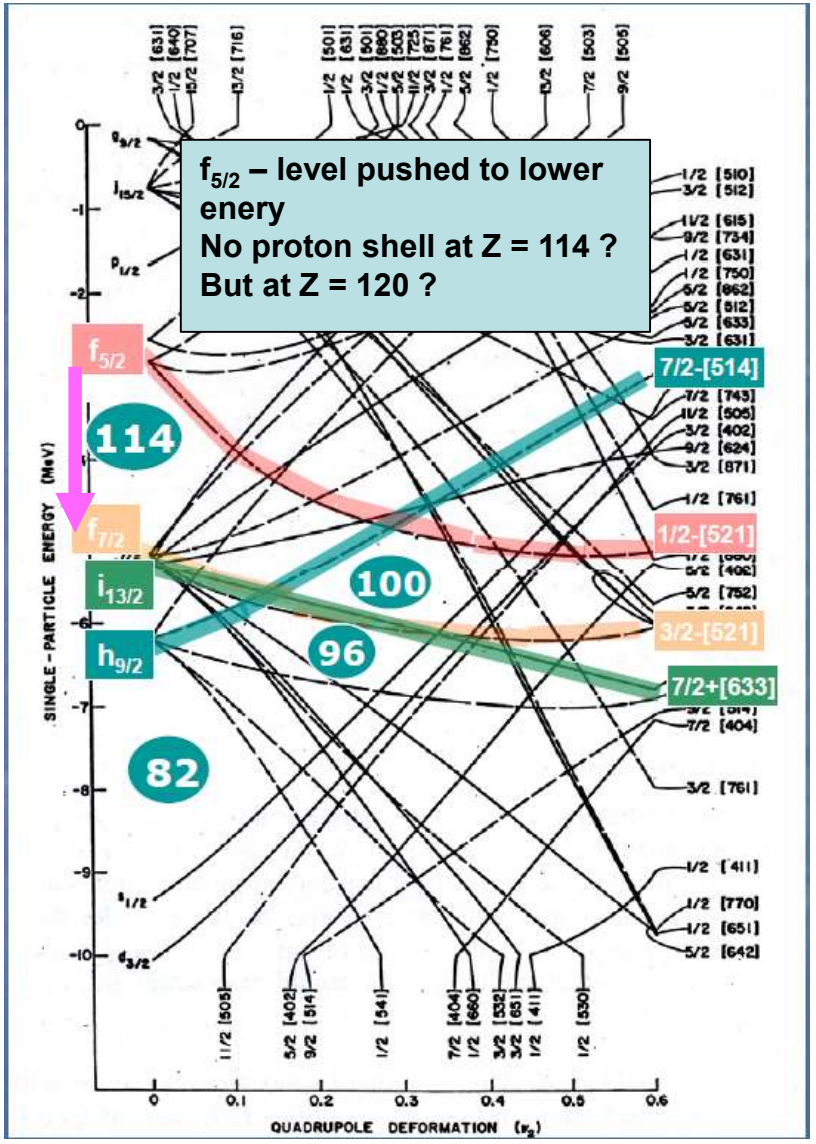
c) **E_γ = 342.1 keV line assigned to isomer due to half-life: 0.36 +0.27/-0.15 s**



F.P. Heßberger et al., to be submitted to EPJA

^{247}Md – levels – comparison with theory

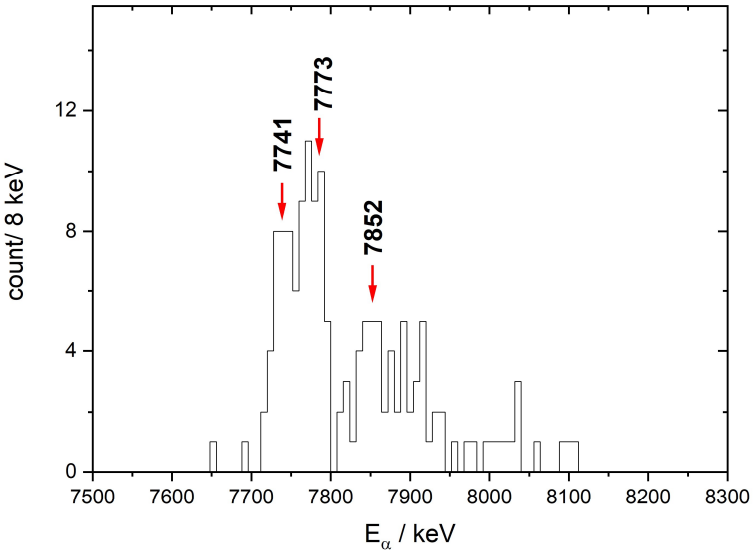


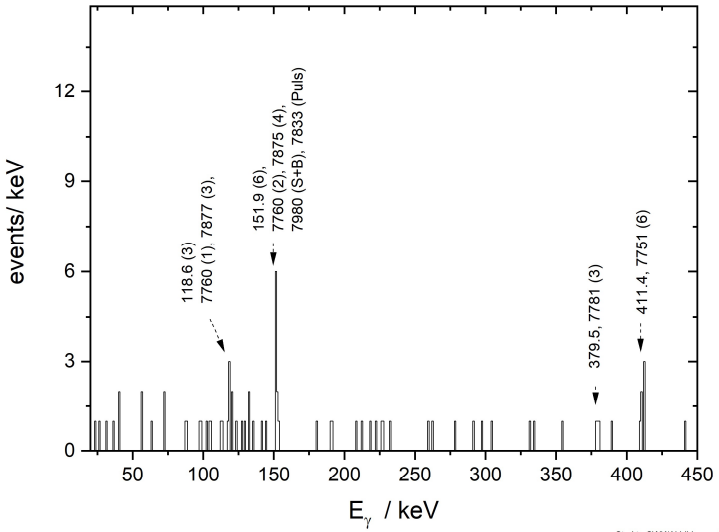


From RMP49,833(1977)

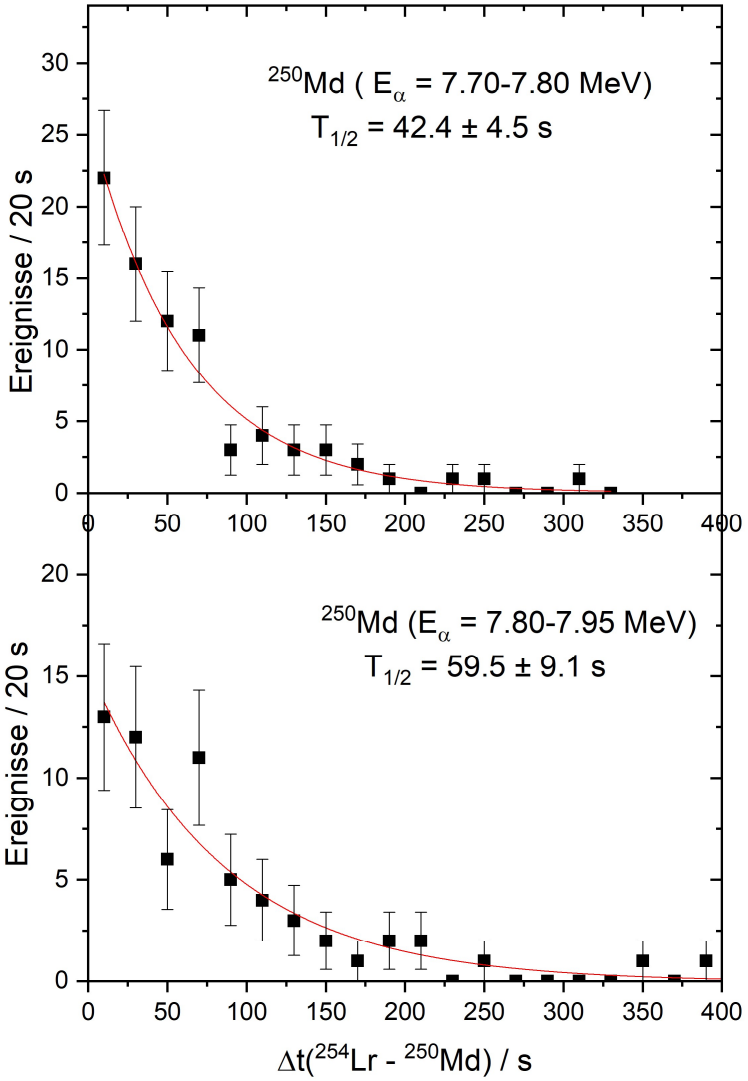
Decay study of ^{250}Md

(M.Vostinar et al. EPJA 55:17 (2019))





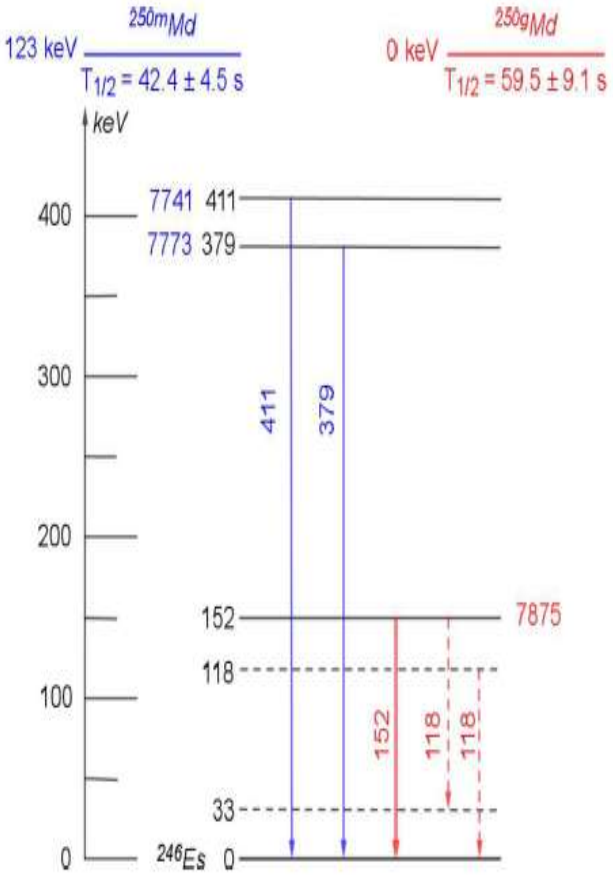
StrukturSWK/Abbildungen/Md250_alga
F.P. Heßberger 6.11.2017



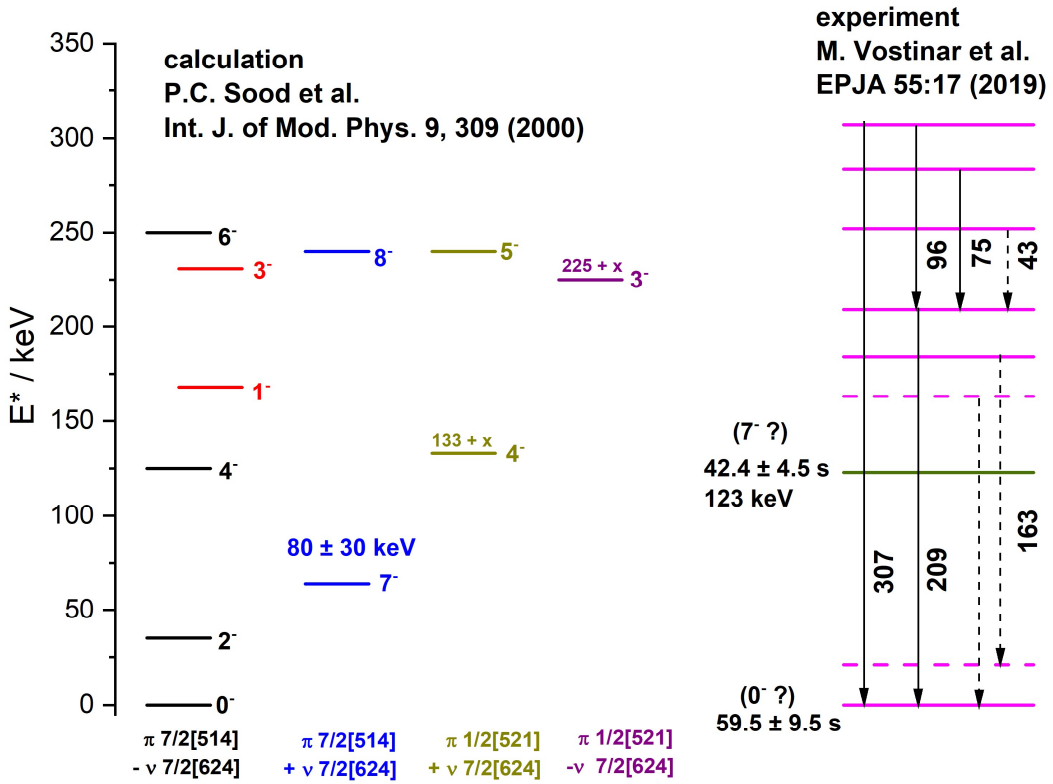
Decay study of ^{250}Md

Decay scheme of ^{250g,250m}Md

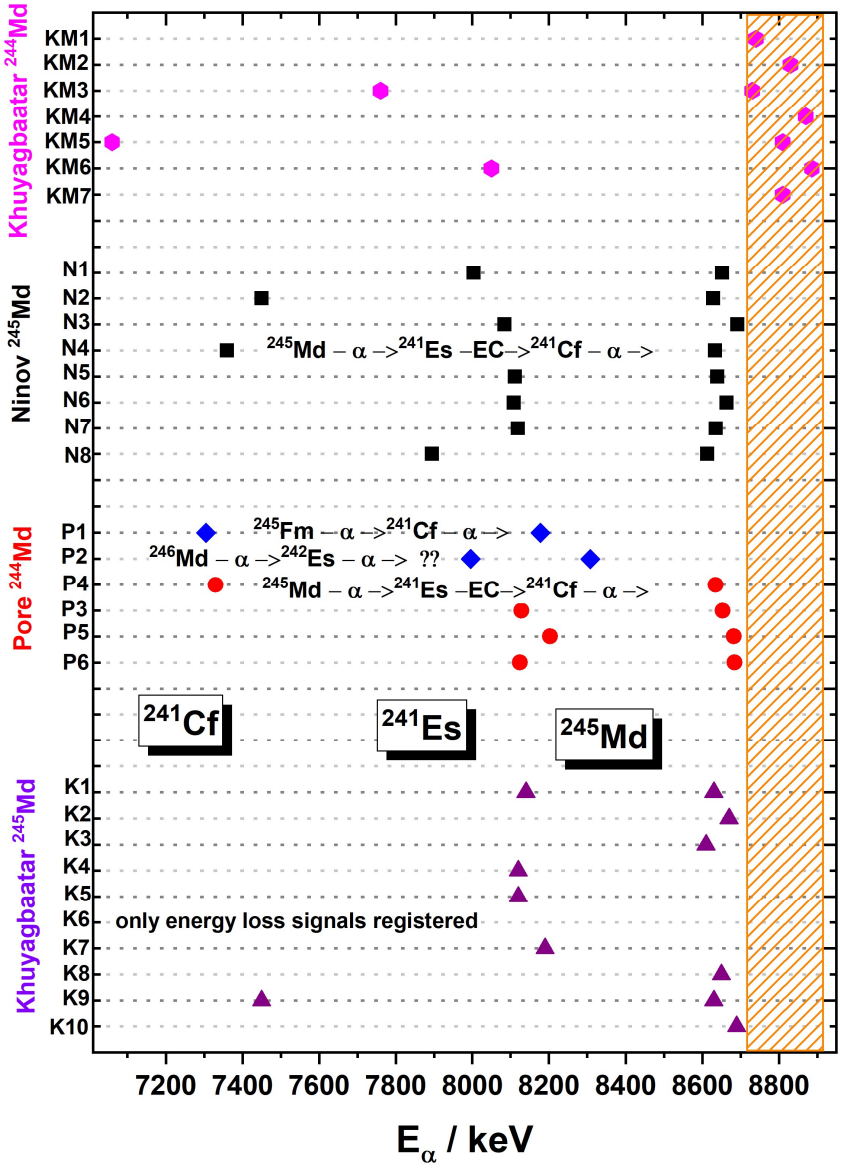
(M.Vostinar et al. EPJA 55:17 (2019))



Existence of isomeric state at E* = 80±30 keV of $I^{\pi} = 7^-$ predicted by theory; spin and parity experimentally not established so far



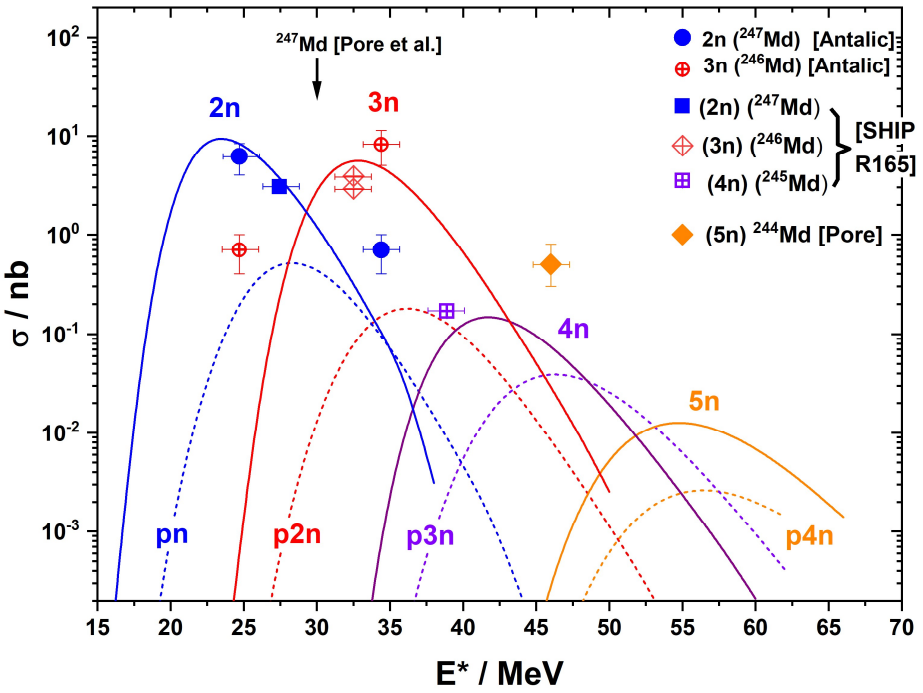
Disagreements in the discovery of ^{244}Md



Publications:

^{245}Md: V.Ninov, F.P.Heßberger et al. Z.Phys. A356,11 (1996)
^{244}Md: J.L.Pore et al. PRL 124, 252502 (2020)
^{244,245}Md: J.Khuyagbaatar et al. PRL 125, 142504 (2020)
Comment on discovery: F.P.Heßberger et al. PRL 126, 182501 (2021)

Comparison of published data and excitation function indicate that events attributed to ^{244}Md rather have to be attributed to ^{245}Md



Summary and Outlook

- ☺ New decay study provides an enhanced decay scheme of ^{247}Md; ground-state configuration of ^{243}Es established; energy of ^{247m}Md was determined
- ☺ Long-lived isomeric state in ^{250}Md, predicted by theory, was identified

- ☺ Confusion about conflicting data on ^{244}Md was solved; Berkeley data rather have to be attributed to ^{245}Md

Collaborations

^{247}Md: S. Antalic (1), F. Giacoppo (2), B. Andel (1), D. Ackermann (2*), M. Block (2,3,4), S. Heinz (2), J.Khuyagbaatar (2), I. Kojouharov (2), M. Venhart (1)
(1) Comenius University, Bratislava (Slovakia), (2) GSI, Darmstadt (Germany), (3) HIM Mainz (Germany), (4) Johannes Gutenberg Universität, Mainz (Germany), *now at GANIL

^{250}Md: M. Vostinar (1), D.Ackermann (2*), B. Andel (3), S. Antalic (3), M. Block (2,4,5), Ch. Droese (6), J. Even (4), S. Heinz (2), Z. Kalaninova (3), I. Kojouharov (2), M. Laatiaoui (2,4,5), A.K. Mistry (2,4), J. Piot (1), H. Savajols (1)
(1) GANIL, Caen (France), (2) GSI, Darmstadt (Germany), (3) Comenius University Bratislava (Slovakia), (4) HIM Mainz (Germany), (5) Johannes Gutenberg Universität Mainz (Germany), (6) Ernst-Moritz-Arndt – Universität, Greifswald (Germany), * now at GANIL

^{244}Md: M. Block (1,2,3), Ch. E. Düllmann (1,2,3), A. Yakushev (1), M. Leino (4), J. Uusitalo (4)
(1) GSI, Darmstadt (Germany), (2) HIM, Mainz (Germany), (3) Johannes Gutenberg Universität, Mainz (Germany), (4) University of Jyväskylä, Jyväskylä (Finland)