Results from ^{140}Sm Coulomb excitation experiment

M. Klintefjord, F.L. Bello-Garrote, A. Görgen, K. Hadyńska-Klęk,
J. Samorajczyk, C. Droste, J. Srebrny,
T. Abraham, F. Giacoppo, E. Grodner, P. Hoff, M. Kisielinski, M. Komorowska, W. Korten,
M. Kowalczyk, J. Kownacki, T. Marchlewski, C. Mihai , I.O. Mitu, P. Napiorkowski,
S. Pascu, T. Renstrom, B. Siebeck, S. Siem, A. Stolarz, R. Szenborn, A. Tucholski, P. Töle,
T. Tornyi, G.M. Tveten, M. Zielińska

Oslo – Warsaw- Łódź

The structure of low-lying states in ^{140}Sm

status of COULEX-IS495, RDDS lifetime and the $\gamma-\gamma$ angular correlation experiments

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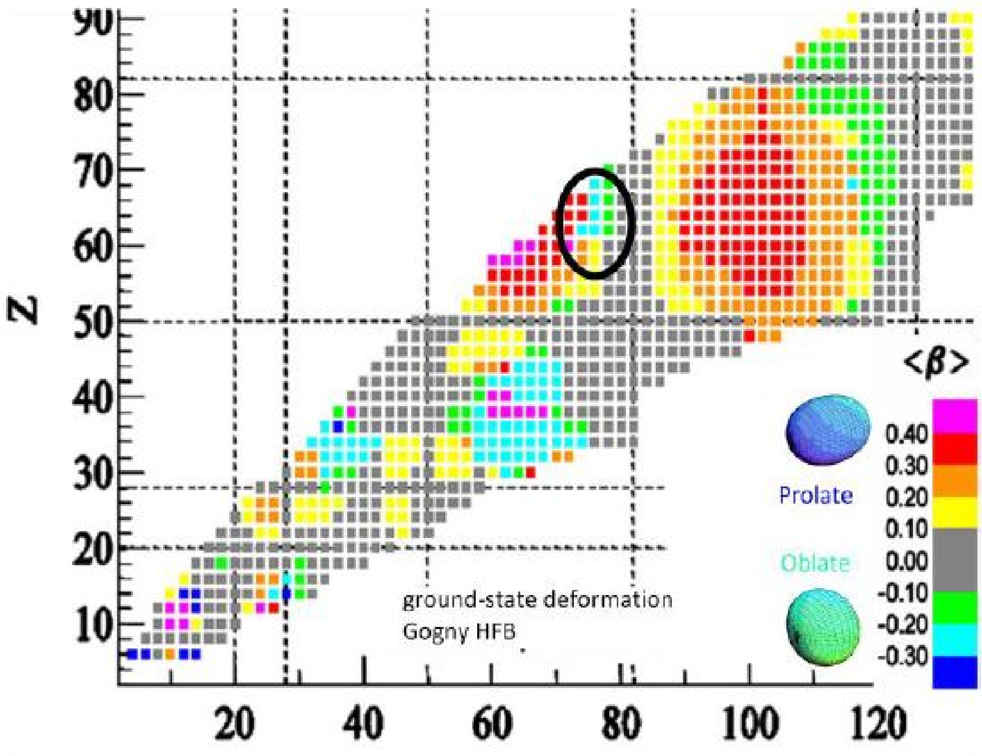
Motivation



The ground-state shapes predicted by a Hartree-Fock-Bogolyubov (HFB) calculation with the Gogny D1S effective interaction.

Rapid GS shape changes in some regions

Nuclear shape can change within the same nucleus - nuclear states of different deformation, close in energy – their wave functions can mix – shape coexistance.

M.Girod, J.-P.Delaroche
CEA Bruyères-le-Châtel

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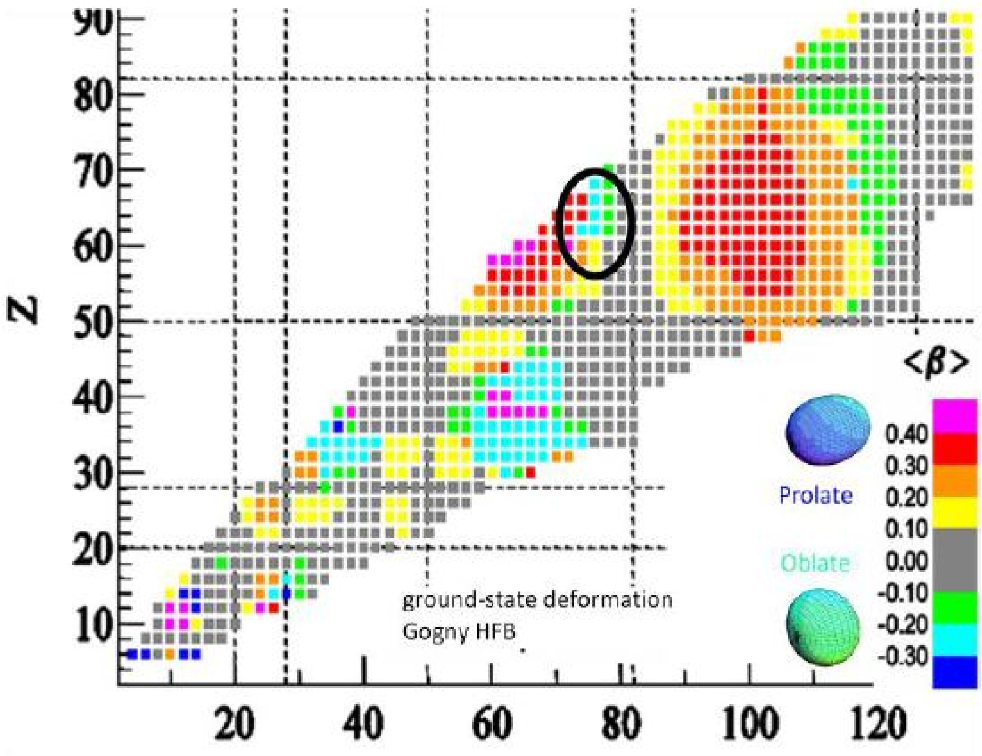

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Measurement of collective properties:
1. Coulomb excitation ⇒ B(E2), Q_s
2. Lifetime measurements ⇒ B(E2)

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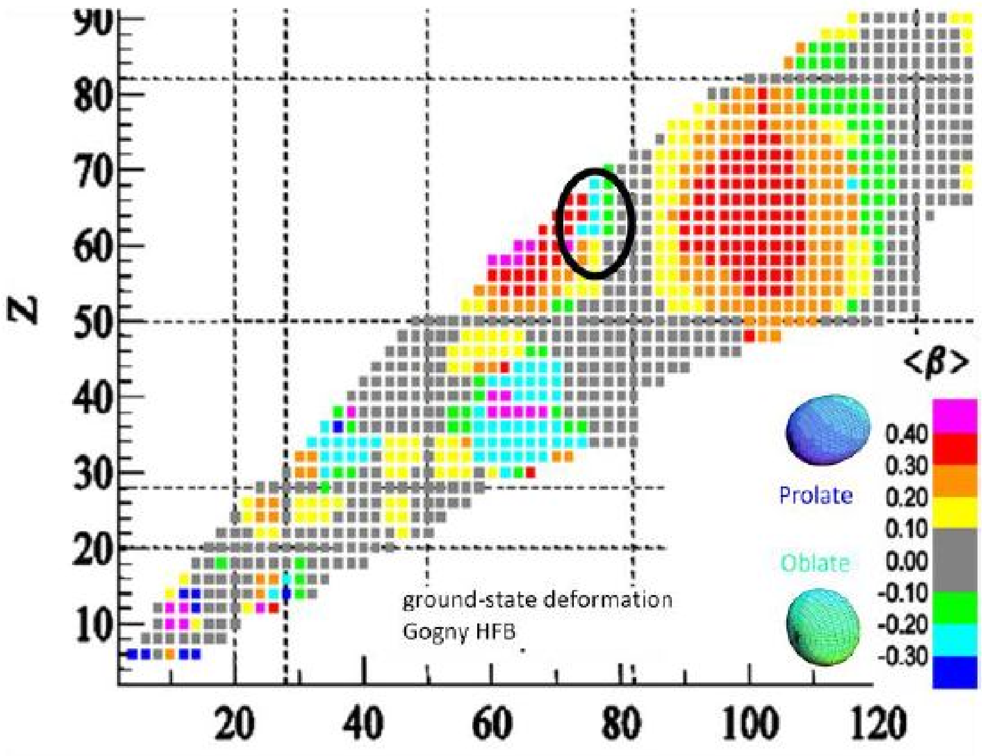

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→ **test of nuclear structure theory**

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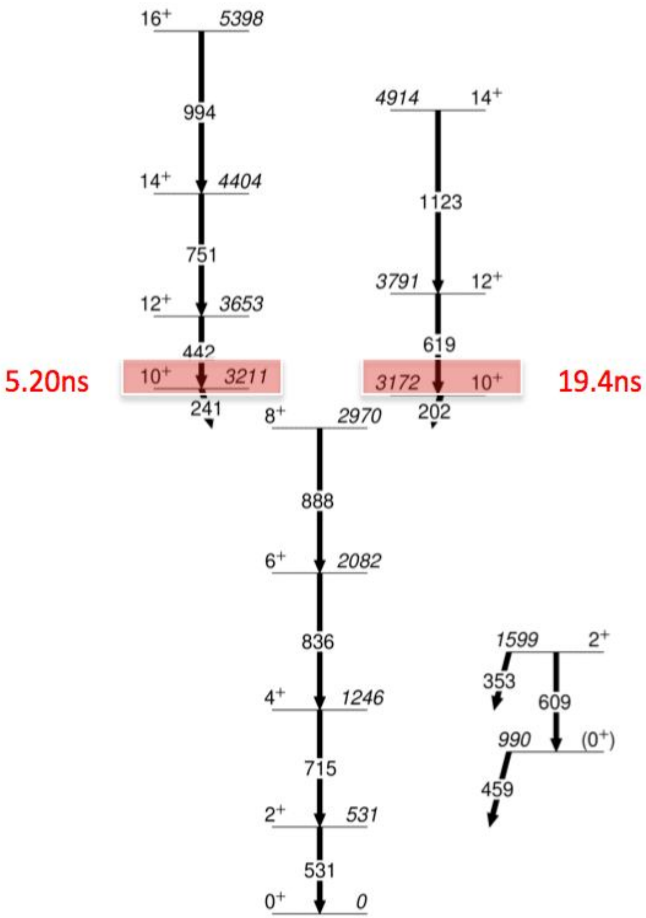
Previous experimental results

fusion evaporation
$^{106}Pd(^{37}Cl,p2n)^{140}Sm$



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Phys. Lett. B 200, 419 (1988)

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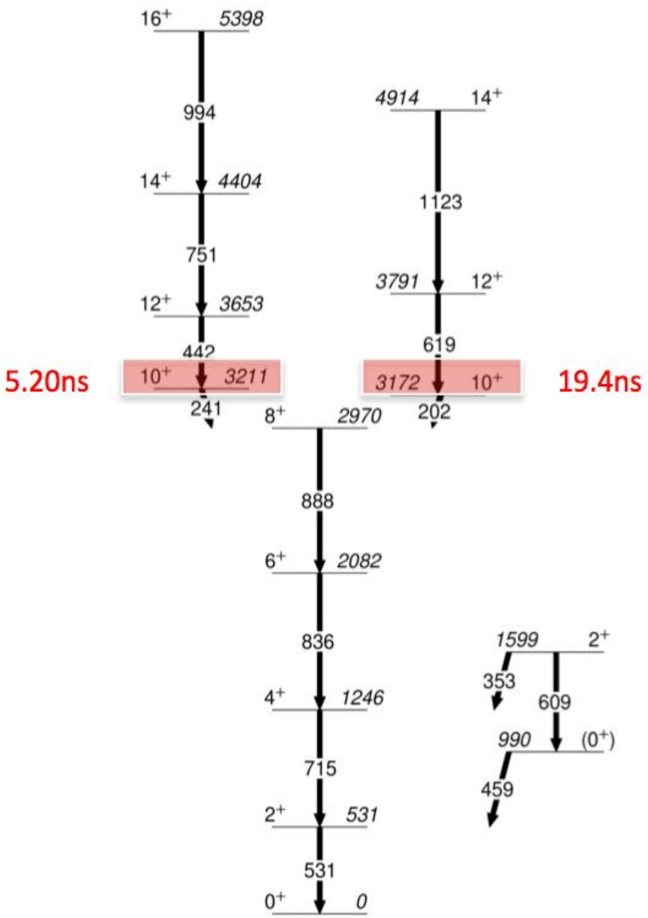

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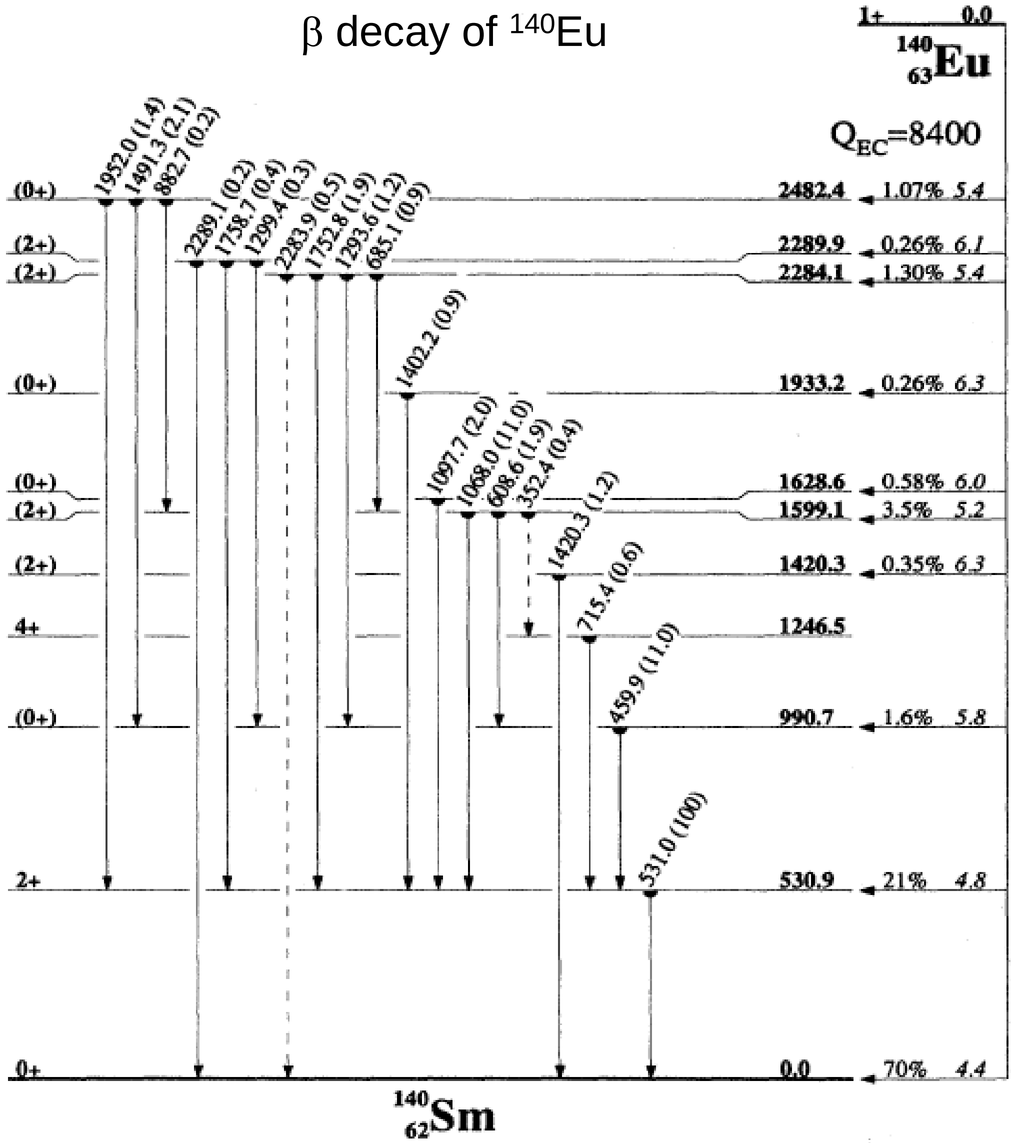
β decay of ^{140}Eu



R.B. Firestone et. al.
PRC 43, 1066 (1991)

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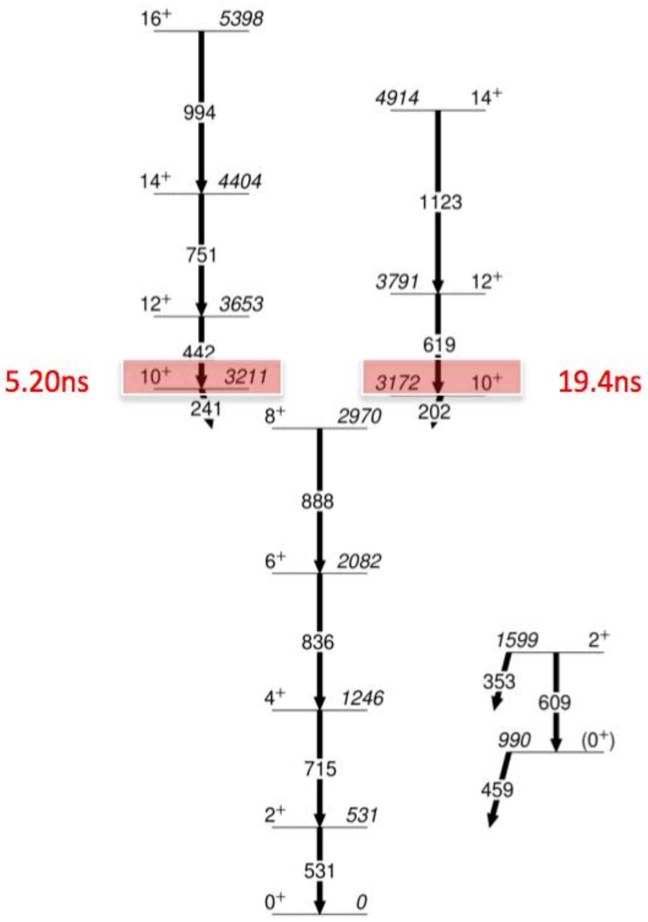

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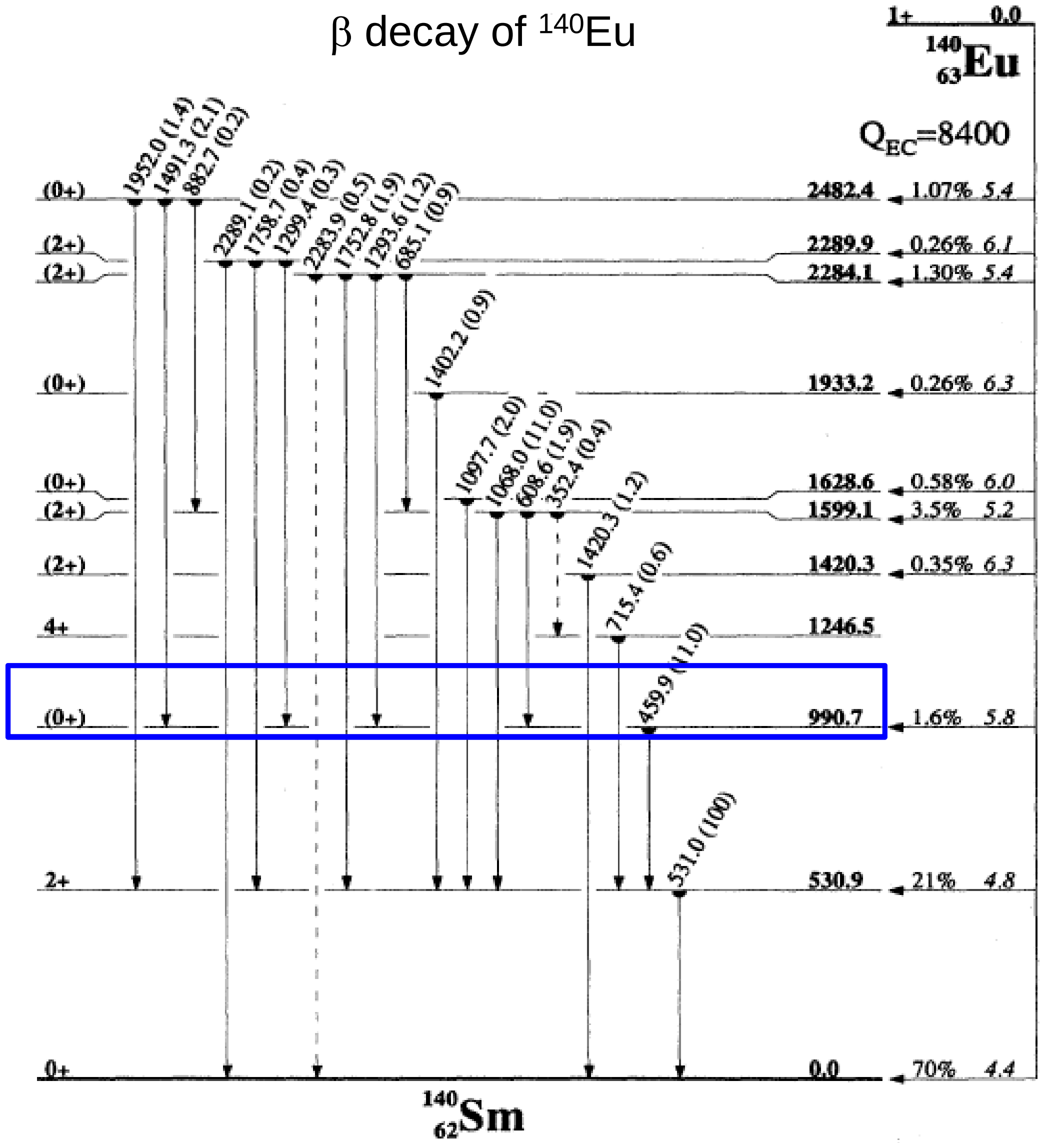
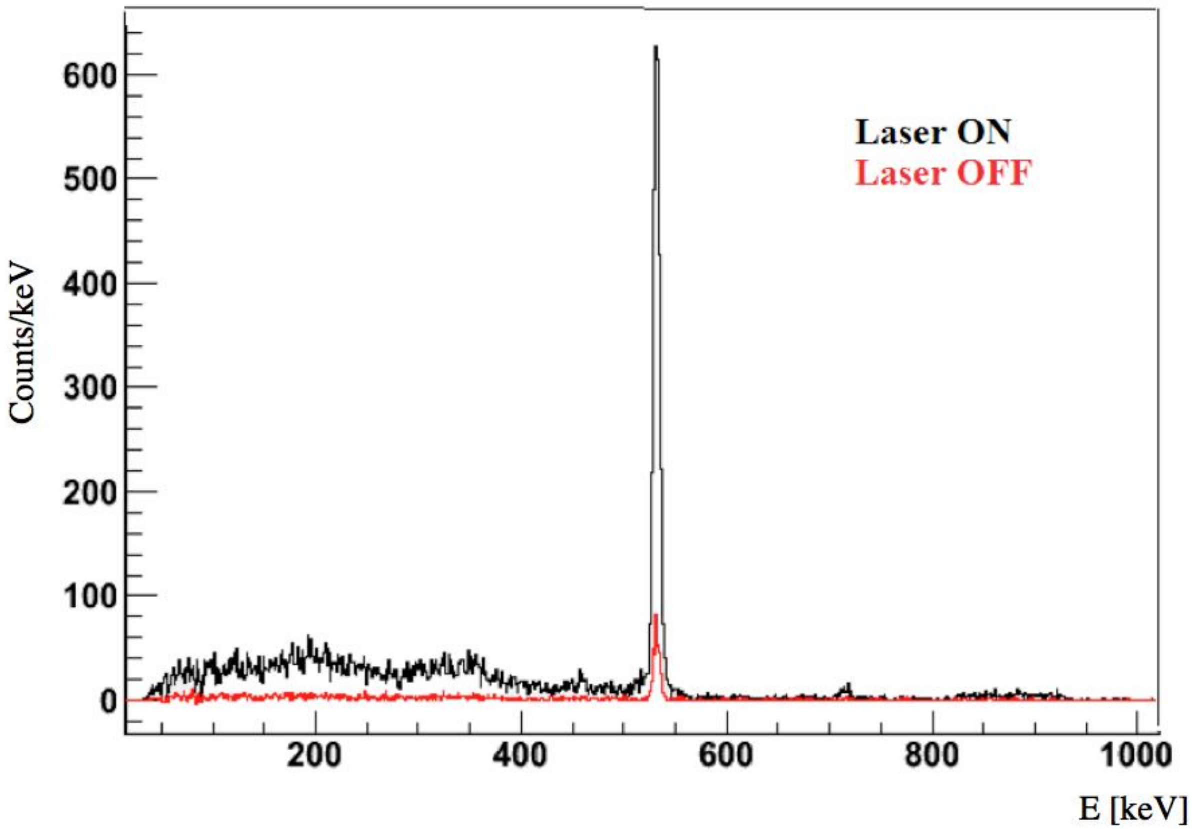


low-lying (0^+) state

R.B. Firestone et. al.
PRC 43, 1066 (1991)

^{140}Sm – COULEX (Miniball@ISOLDE)

- Coulomb excitation experiment
- ^{140}Sm + ^{94}Mo
- ^{140}Sm obtained at ISOLDE with Resonant Laser Ionization
- Beam energy: 2.85 MeV/nucleon and intensity: 2*10^5 particles/s



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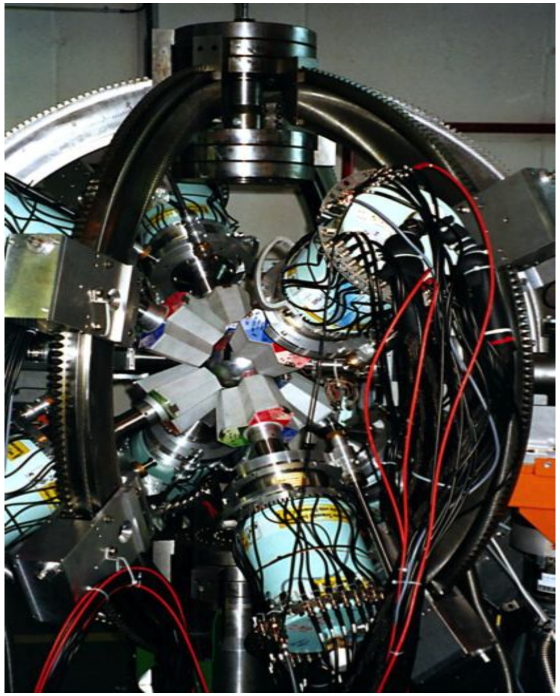
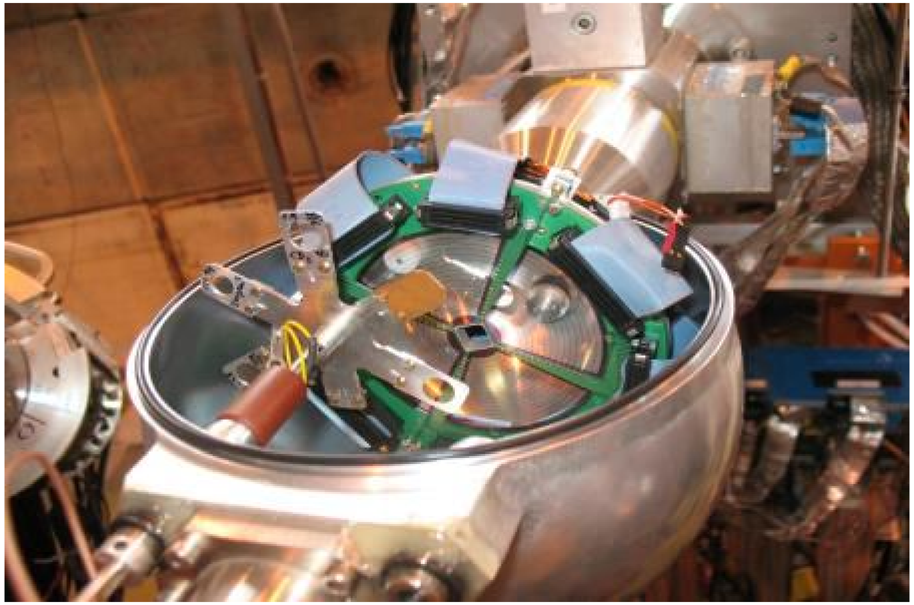
- Particles detected in circular DSSSD - angular range: 20-58^{o}

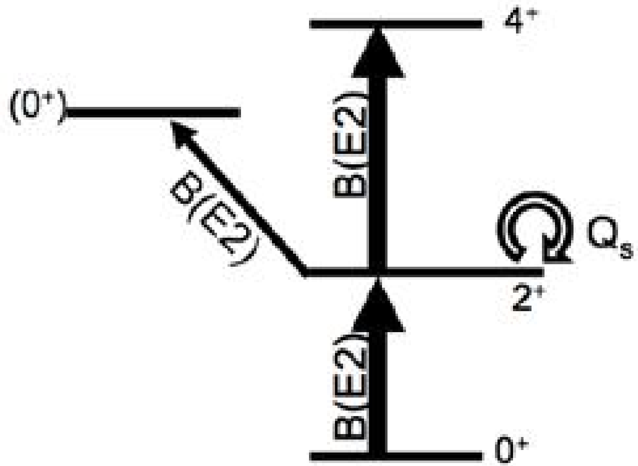


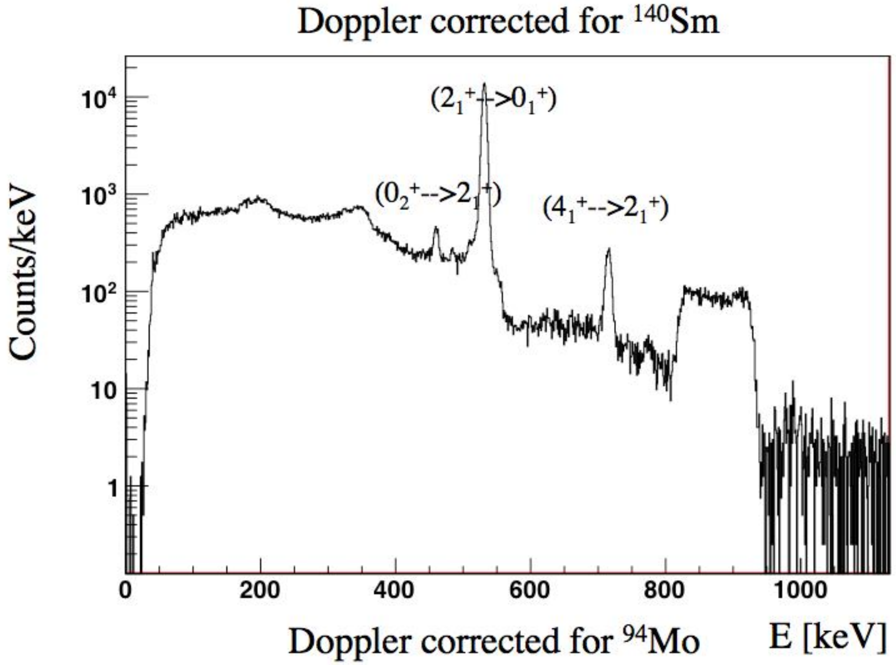


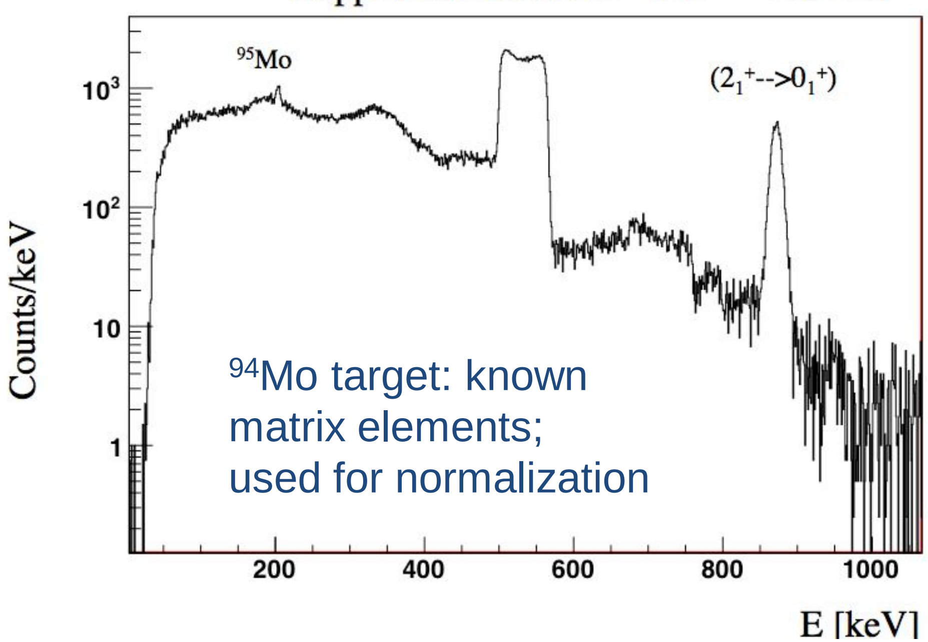
^{140}Sm – COULEX (Miniball@ISOLDE)

Observed:

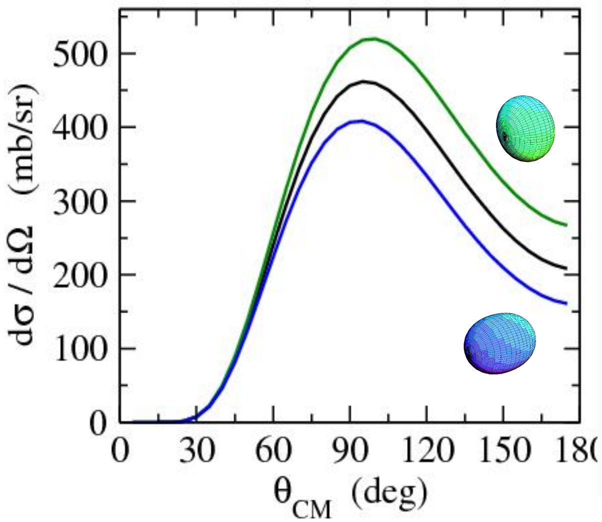
- 2^+, 4^+ and (0^+) states in ^{140}Sm
- 2^+ state in ^{94}Mo
- (+^{95}Mo target contamination)

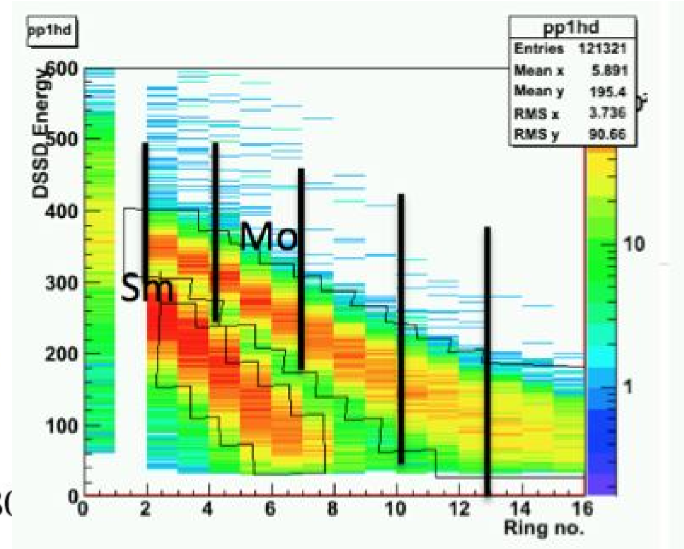


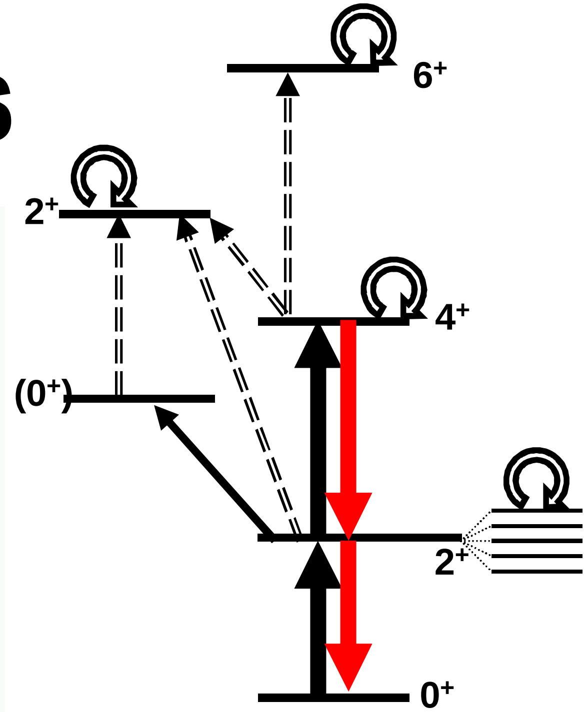


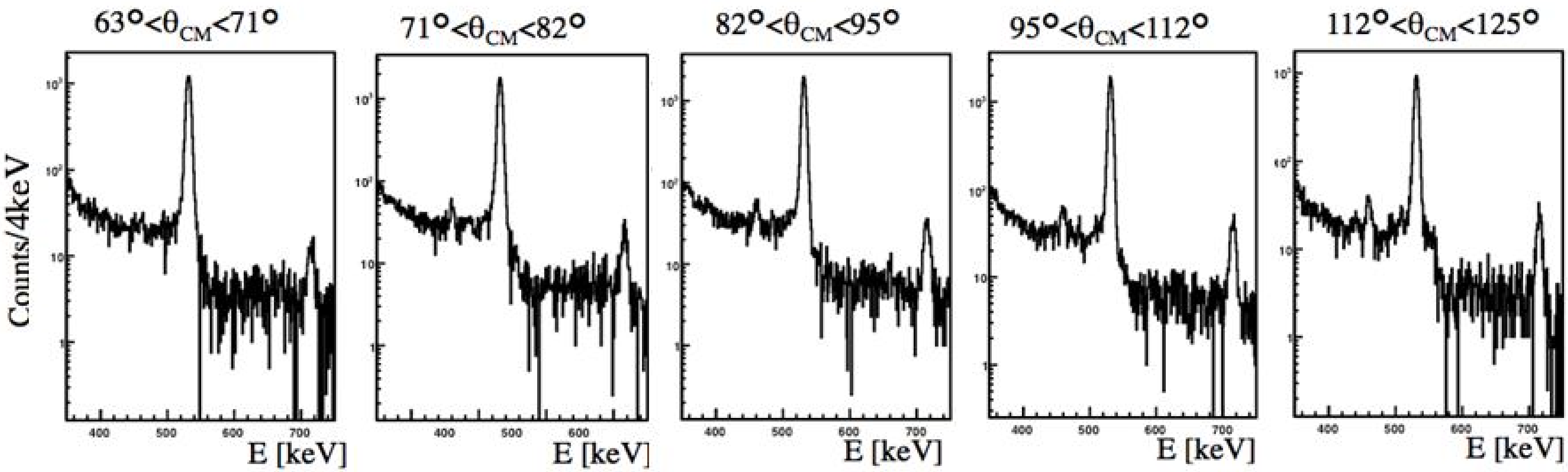


Differential cross sections



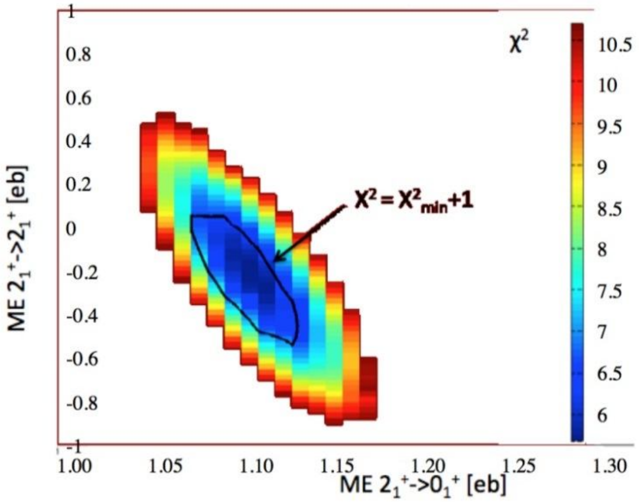


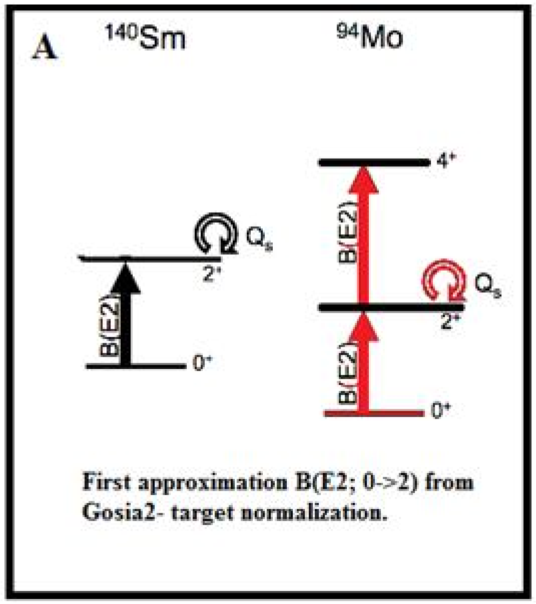


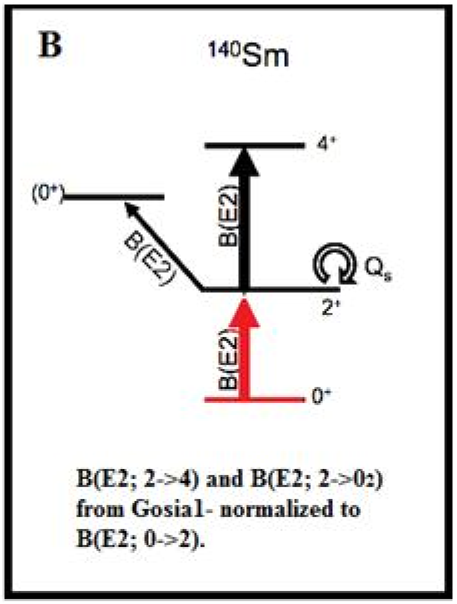


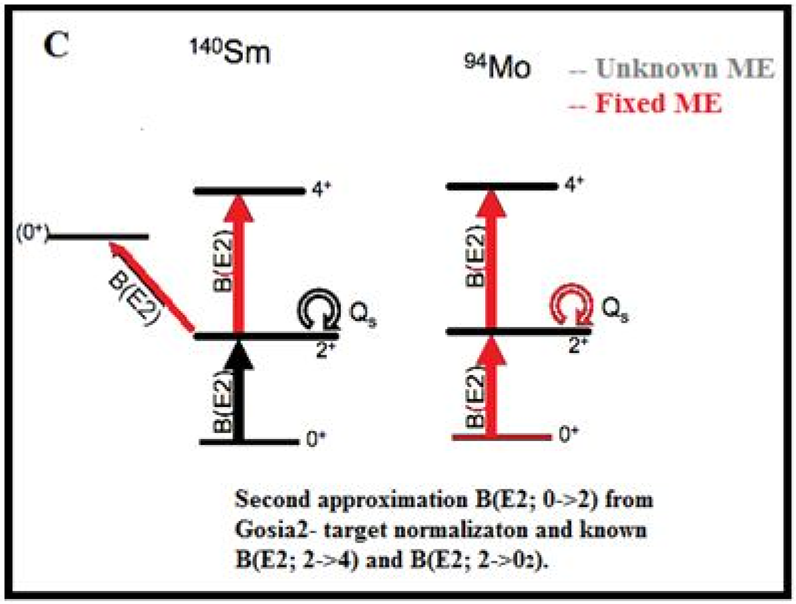
^{140}Sm – COULEX

GOSIA2 analysis,
target normalization approach









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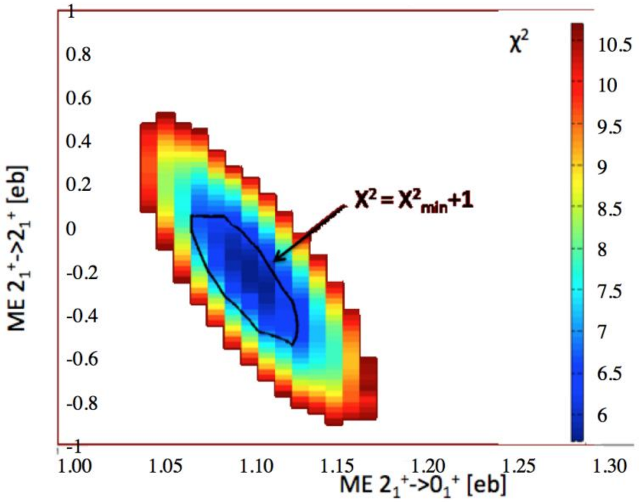

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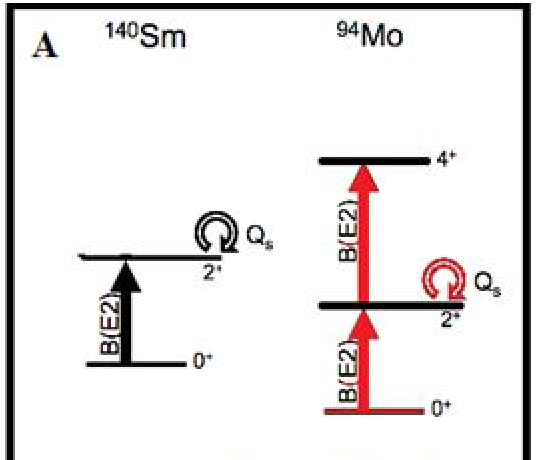
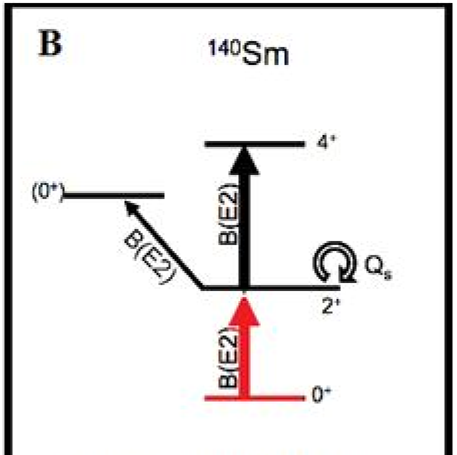
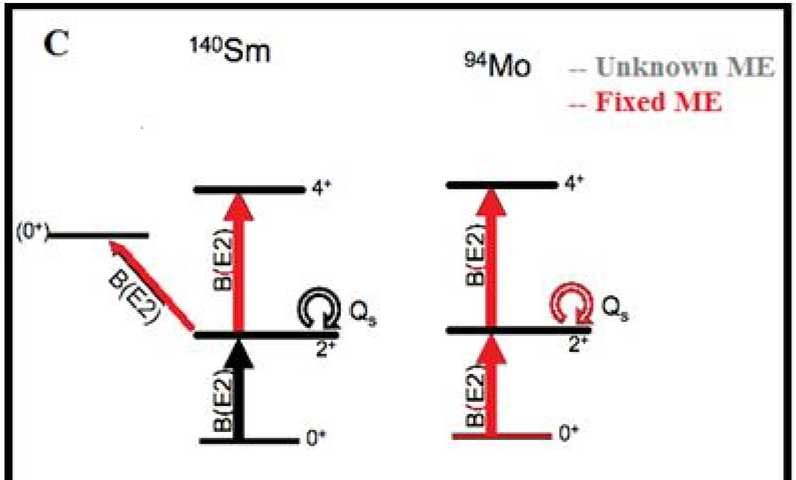
2_1^+	0_1^+	$1.12^{+0.05}_{-0.05}$	$0.25^{+0.02}_{-0.02}$	58^{+5}_{-5}
2_1^+	2_1^+	$-0.18^{+0.43}_{-0.29}$	-	-
4_1^+	2_1^+	$1.64^{+0.05}_{-0.05}$	$0.30^{+0.02}_{-0.02}$	70^{+5}_{-5}
(0_2^+)	2_1^+	$1.01^{+0.07}_{-0.07}$	$1.02^{+0.15}_{-0.15}$	236^{+35}_{-35}



First approximation B(E2; 0->2) from Gosia2- target normalization.



B(E2; 2->4) and B(E2; 2->0₂) from Gosia1- normalized to B(E2; 0->2).



Second approximation B(E2; 0->2) from Gosia2- target normalizaton and known B(E2; 2->4) and B(E2; 2->0₂).

^{140}Sm – COULEX

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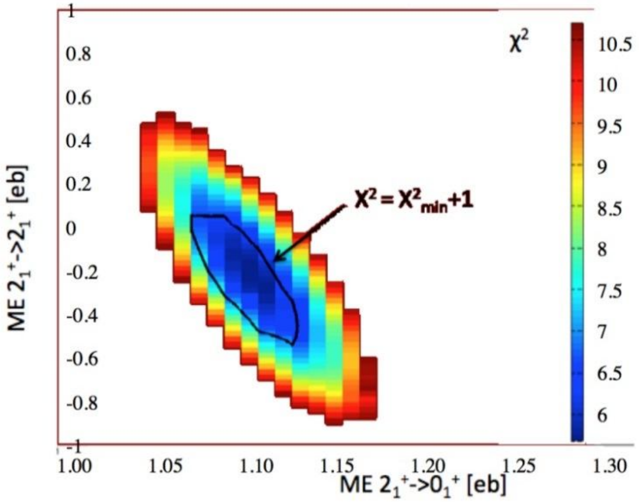

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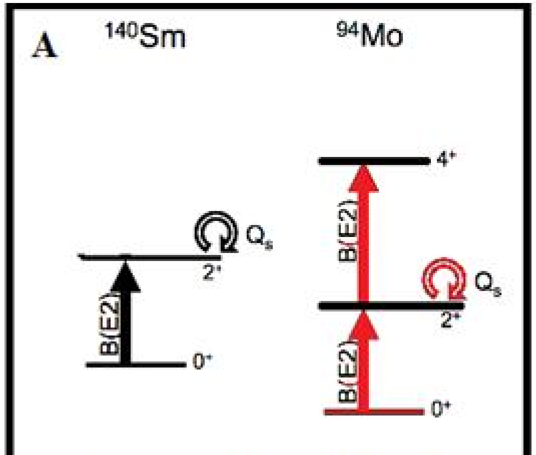

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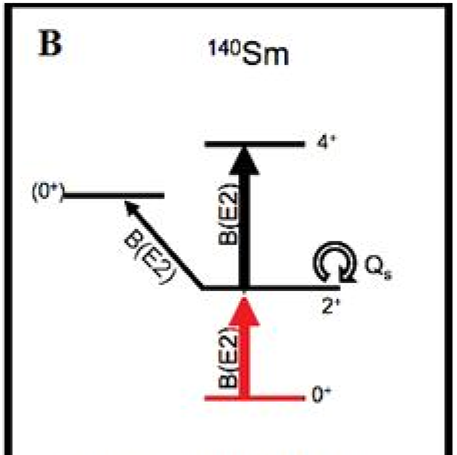

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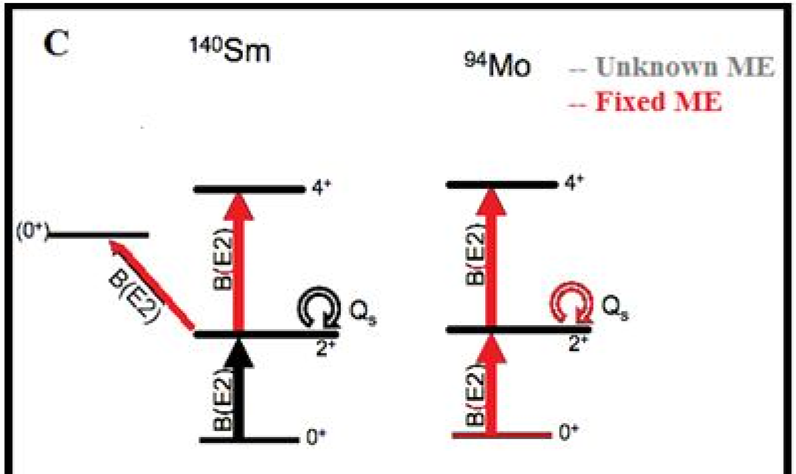

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^{140}Sm - RDDS measurement
EAGLE+Köln-Bucharest plunger@HIL Warsaw

Analysis: F.L. Bello Garrote, Univ. of Oslo (to be published)

Goal: liteftime of 2$^+$ state in ^{140}Sm

Reaction: ^{124}Te(^{20}Ne,4n)^{140}Sm at 82 MeV (just above the Coulomb barrier!) – very difficult experiment

EAGLE array:
GAMMAPOOL HPGe detectors in ACS
- 4 detectors at 37 deg. (forwards)
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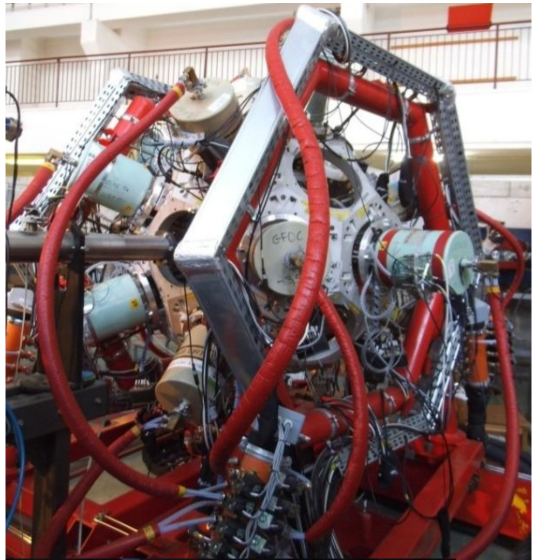
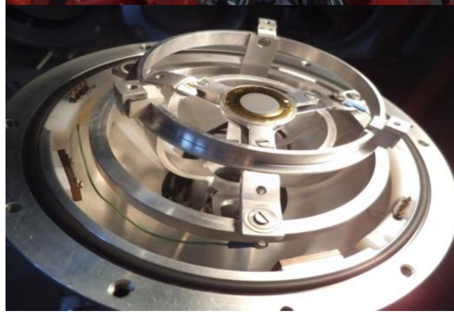
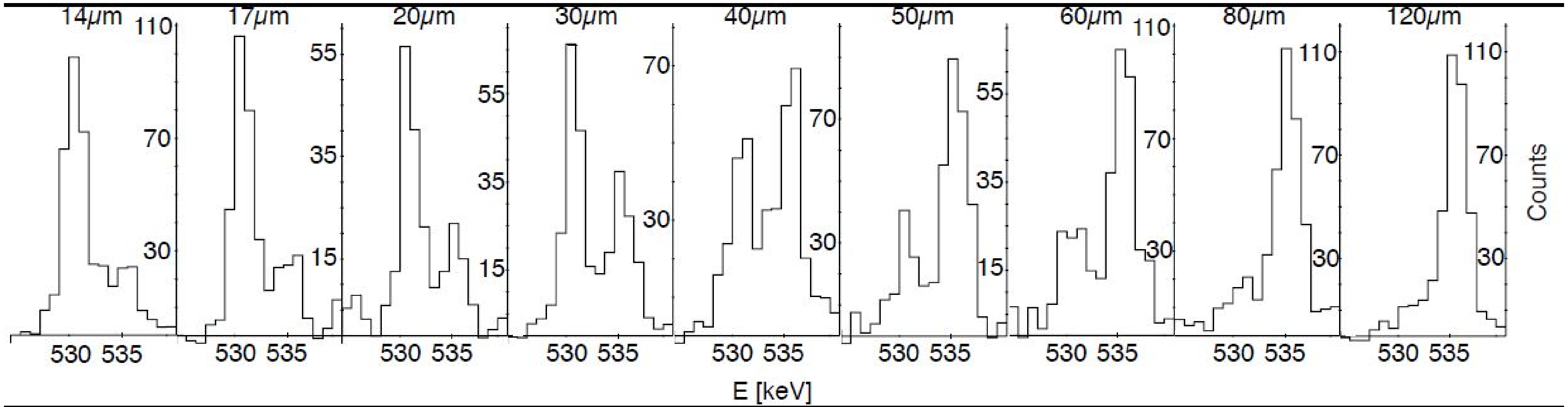




Bucharest Plunger
C. Mihai et al.

gate on flying component of 715 keV [4$^+$ $\rightarrow$ 2$^+$ transition]



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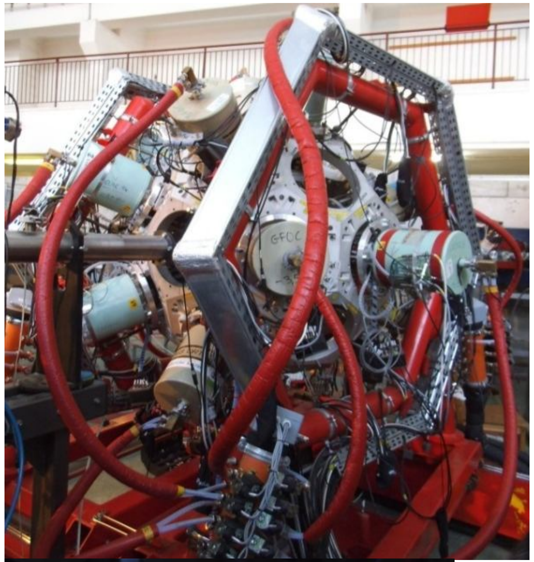

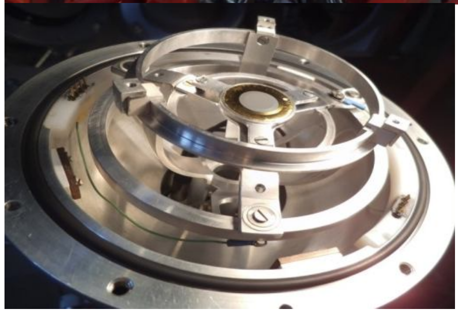

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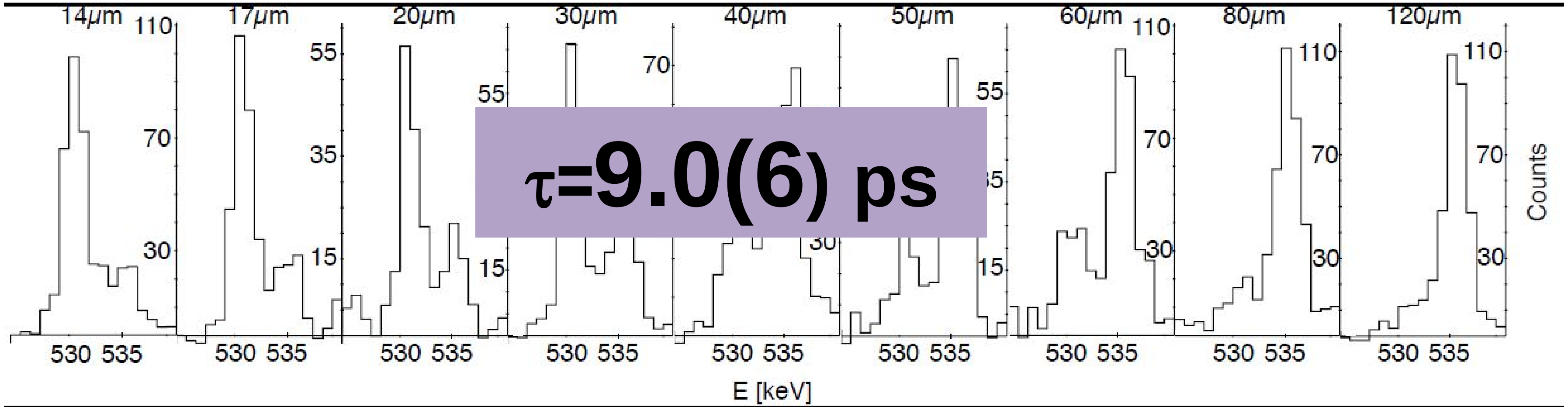

τ=9.0(6) ps

^{140}Sm – COULEX – 2nd approach

Standard GOSIA analysis - matrix elements in ^{140}Sm with correlated errors obtained with lifetime normalization approach.

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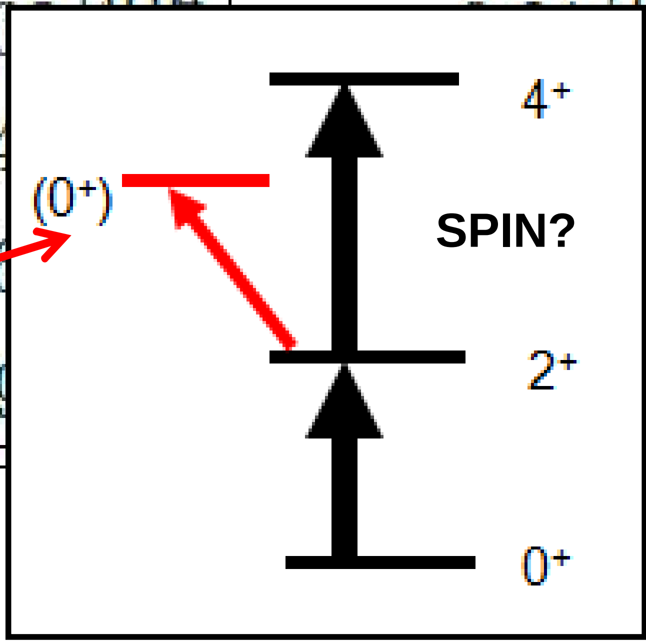
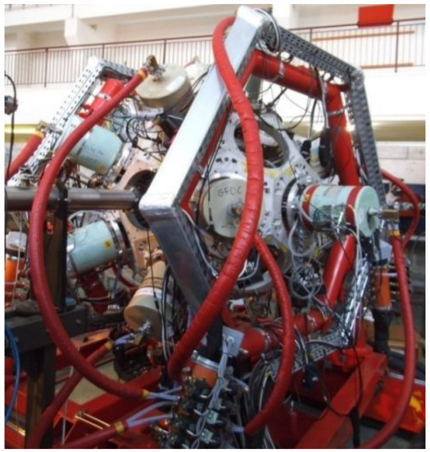


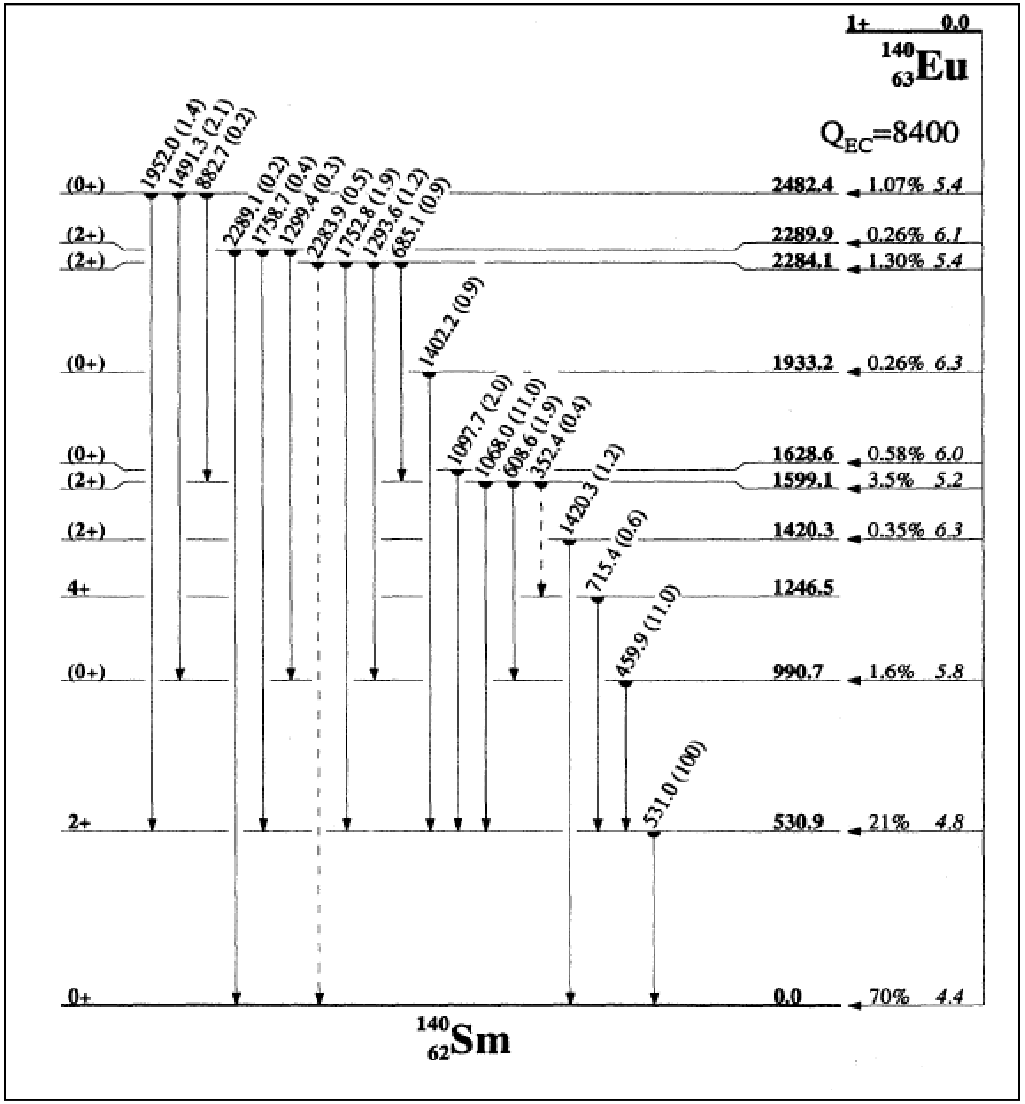
^{140}Sm – γ-γ angular correlation @ HIL Warsaw

Analysis:
Malin Klintefjord, Univ. of Oslo
Justyna Samorajczyk, Univ. of Lodz

^{112}Cd(^{32}S,p3n)^{140}Eu

- off-beam experiment using macrostructure of U200P: 2 ms on – 4 ms off
- EAGLE: 12 HPGe detectors at 42, 70, 110, 140, 180 degrees
- The ^{140}Eu recoils were stopped with a Au foil





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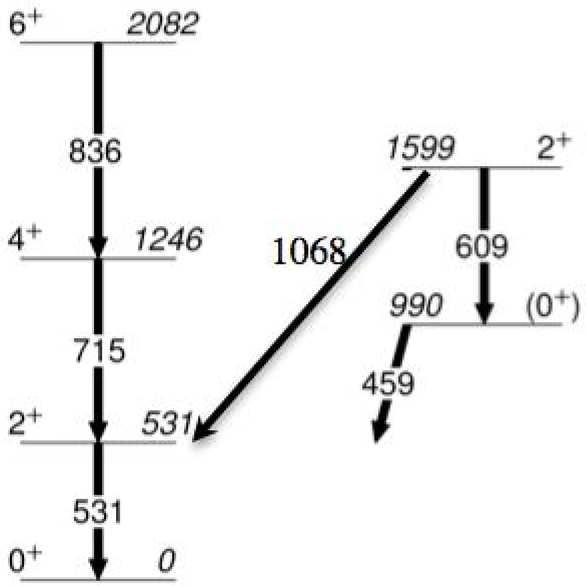
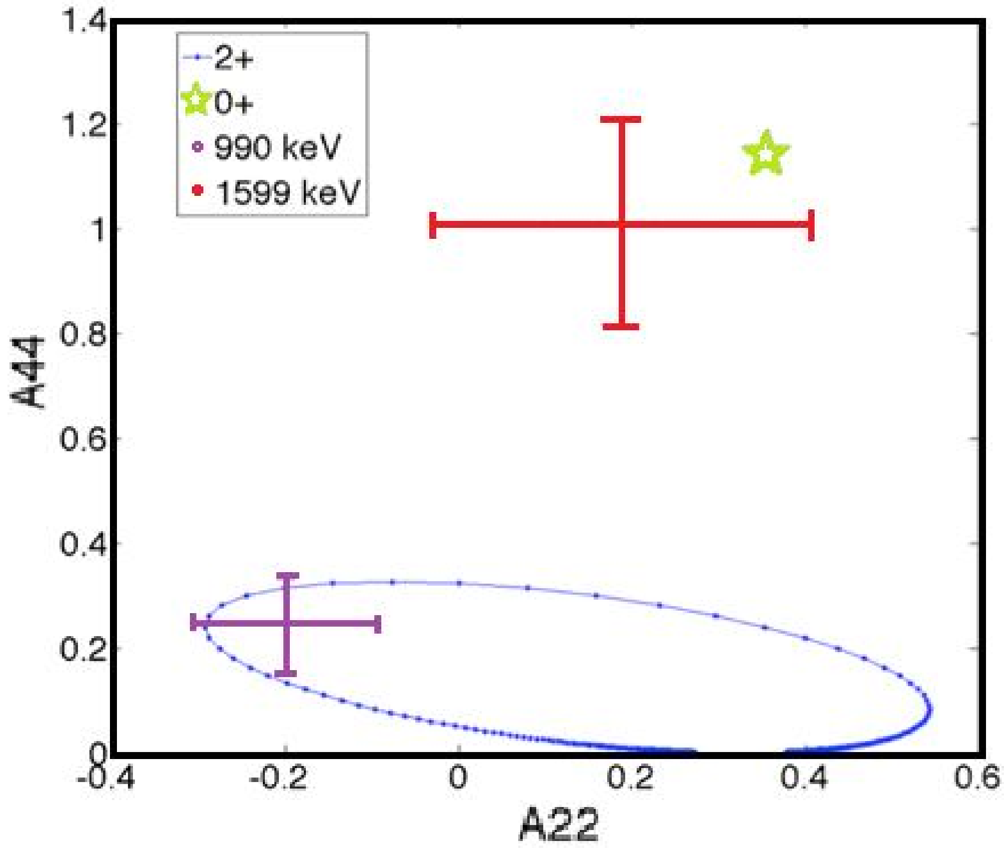
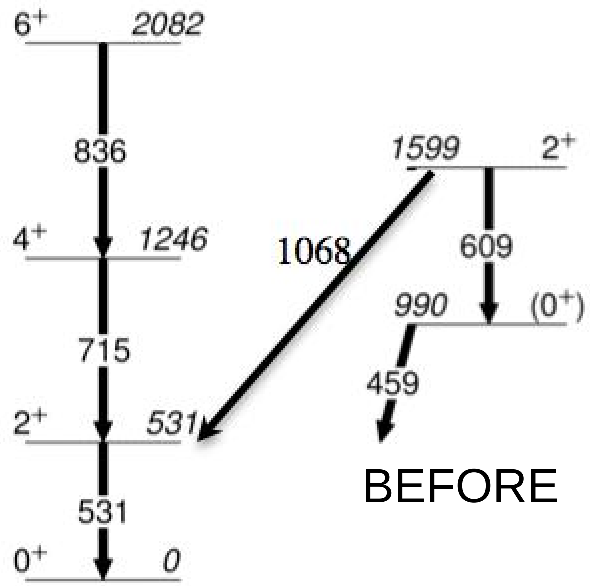
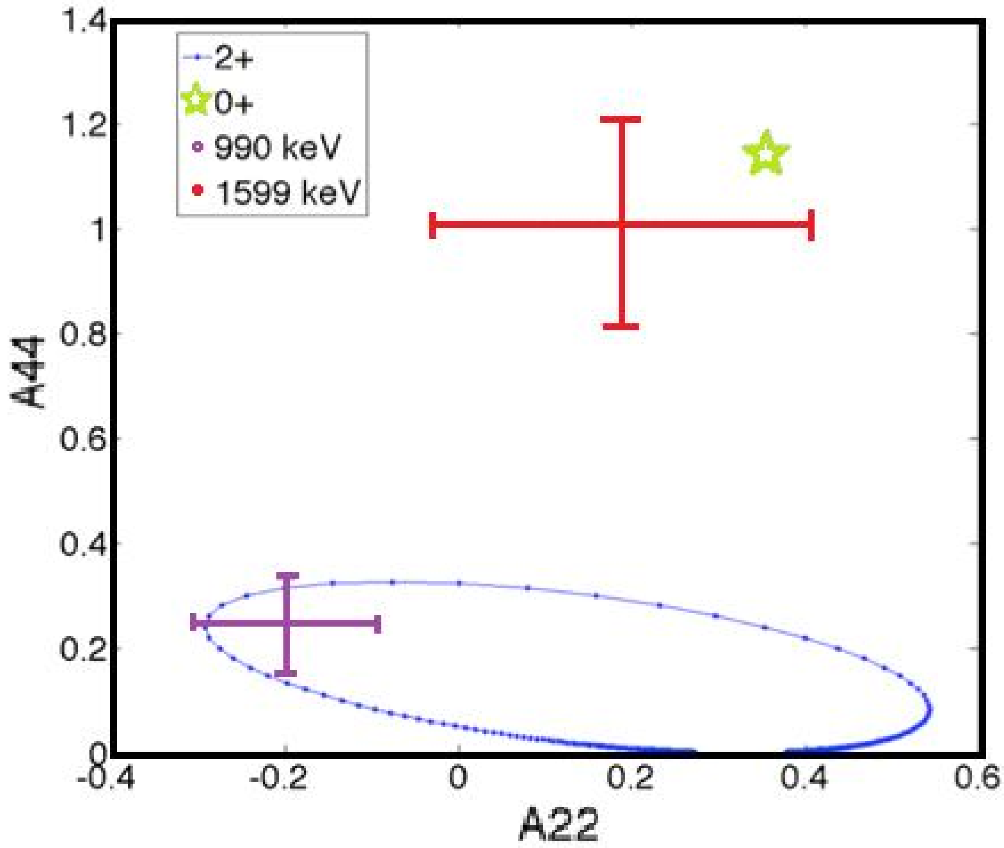




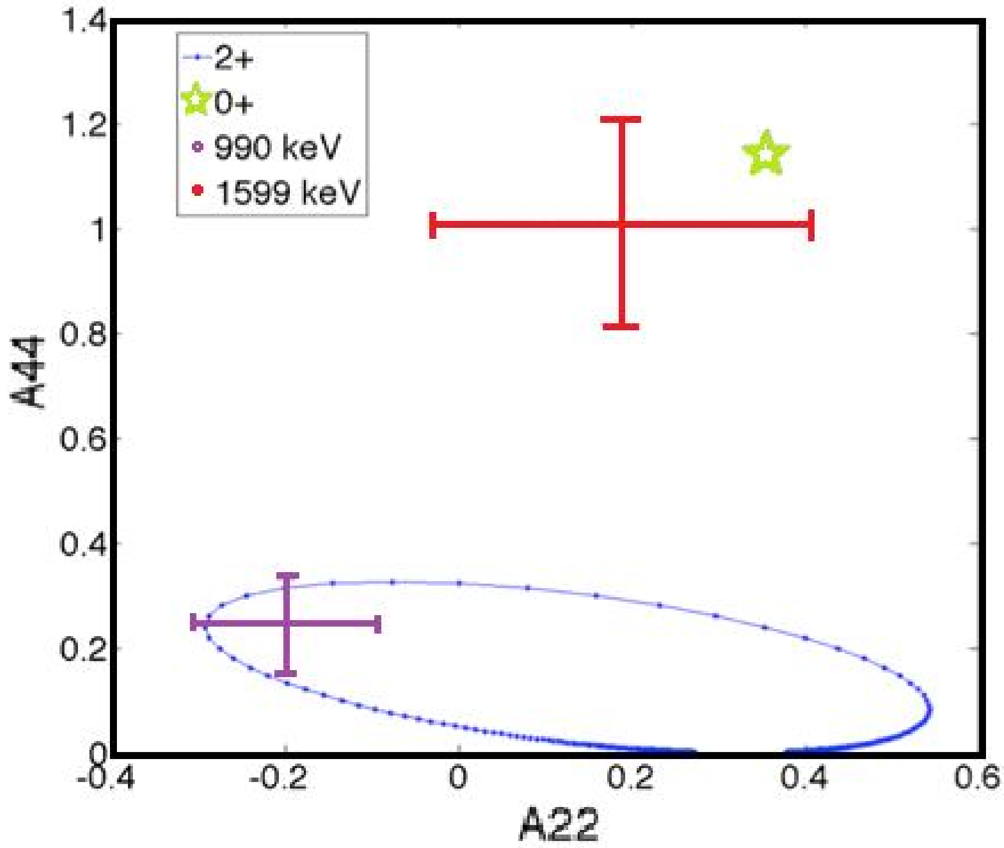
^{140}Sm – γ-γ angular correlation @ HIL Warsaw

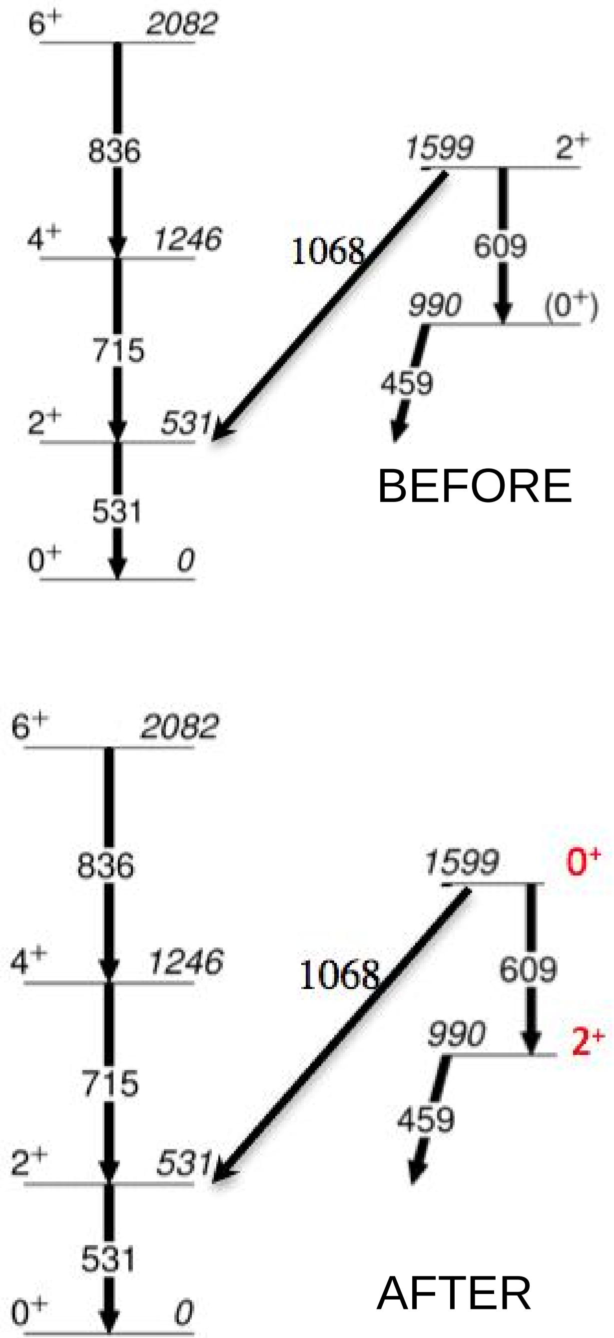




^{140}Sm – γ-γ angular correlation @ HIL Warsaw

New spin assignment!





(to be published)

^{140}Sm – COULEX – 3rd (final) approach

Matrix elements and B(E2) values in ^{140}Sm with correlated errors obtained assuming (2^+_2) state at 990keV.

I_i	I_f	Without lifetime M(E2) eb	Without lifetime B(E2) e^2b^2	Without lifetime B(E2) W.U.	With lifetime M(E2) eb	With lifetime B(E2) e^2b^2	With lifetime B(E2) W.U.
2^+_1	0^+_1	$1.12^{+0.03}_{-0.02}$	$0.25^{+0.01}_{-0.01}$	58^{+7}_{-5}	$1.03^{+0.04}_{-0.03}$	$0.21^{+0.02}_{-0.01}$	49^{+4}_{-3}
2^+_1	2^+_1	$+0.06^{+0.54}_{-0.20}$	-	-	$-0.19^{+0.48}_{-0.19}$	-	-
4^+_1	2^+_1	$1.64^{+0.05}_{-0.05}$	$0.30^{+0.03}_{-0.02}$	70^{+5}_{-5}	$1.61^{+0.05}_{-0.05}$	$0.29^{+0.02}_{-0.02}$	67^{+5}_{-5}
2^+_2	2^+_1	$1.32^{+0.08}_{-0.09}$	$0.36^{+0.05}_{-0.05}$	83^{+12}_{-12}	$1.34^{+0.08}_{-0.09}$	$0.36^{+0.05}_{-0.05}$	81^{+12}_{-12}

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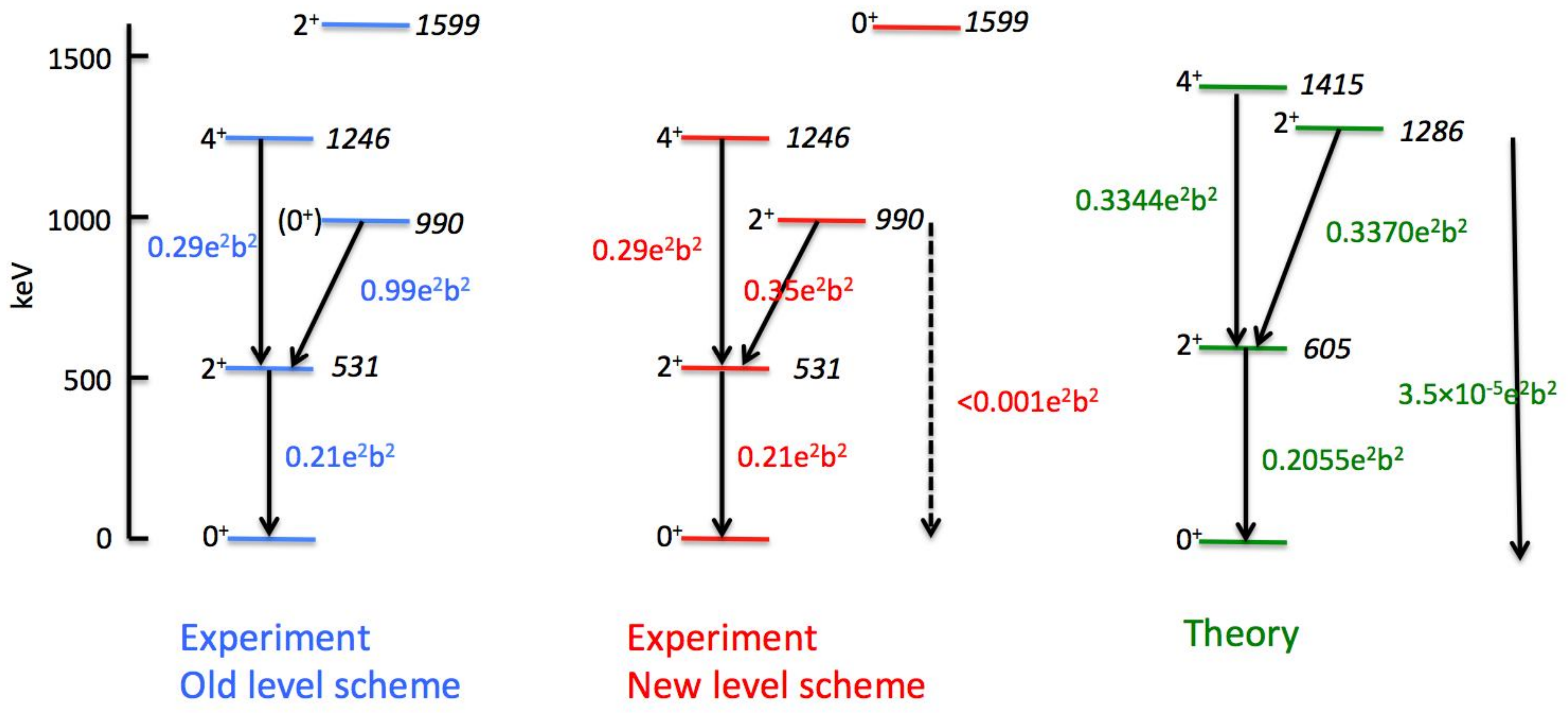
Comparison with theory

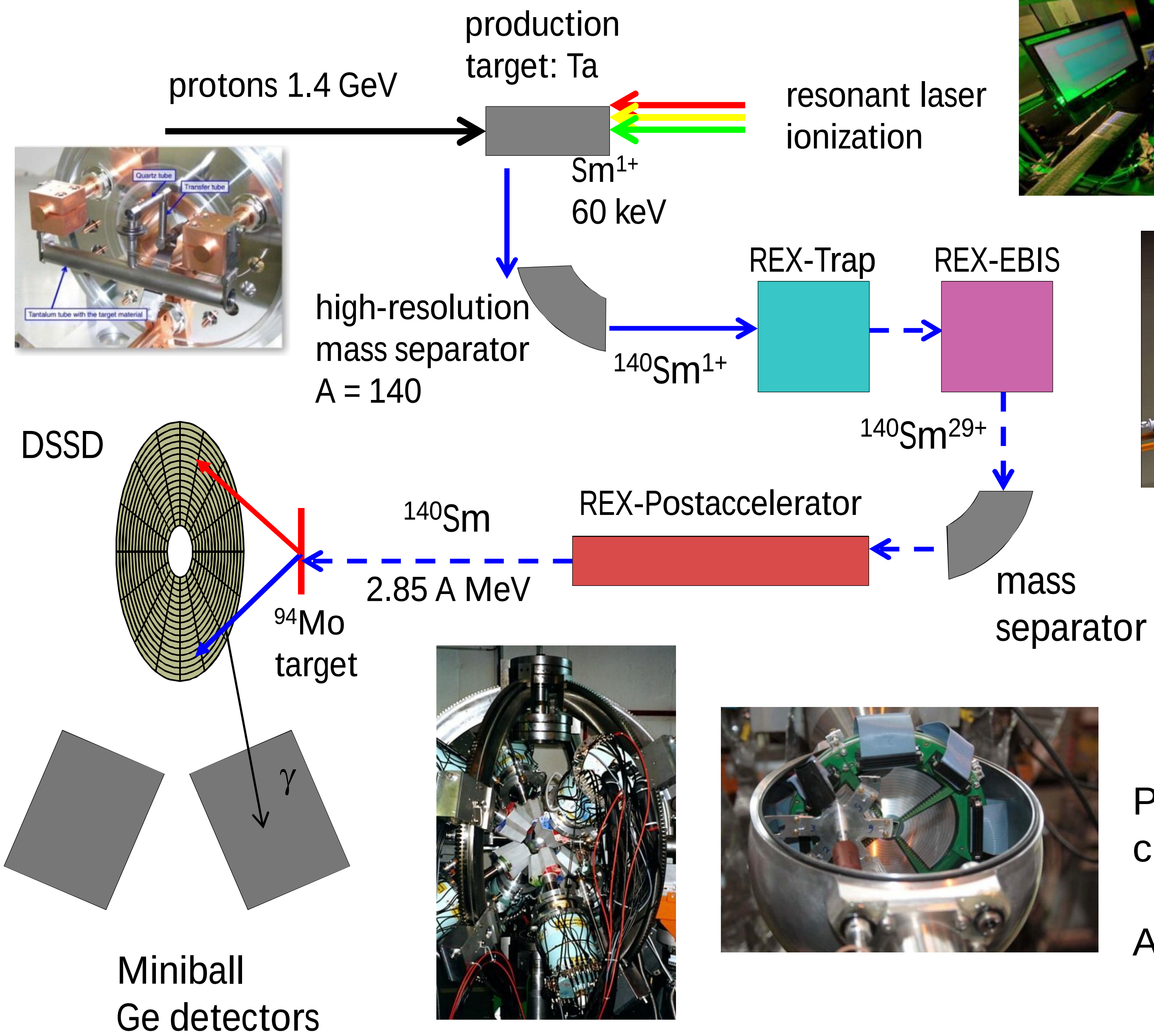


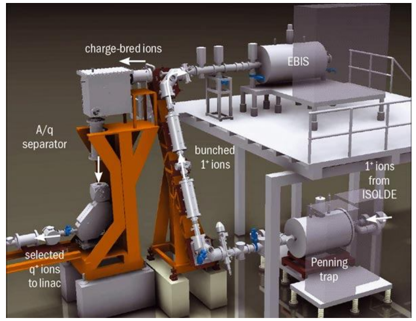
Theory from Gogny D1S calculations from M.Girod and J.-P.Delaroche, CEA Bruyeres-le-Chatel (priv. comm.)

Summary

- Coulomb excitation $^{140}Sm + ^{94}Mo$ at CERN, ISOLDE
- Lifetime investigation at HIL, Warsaw
- Spin-state assignment from angular correlation at HIL, Warsaw
- Probably no shape coexistence
- The analysis of the Coulomb excitation data is presently being finalized
- <u>Future:</u> accepted proposal at High ISOLDE

Isotope separation on-line and postacceleraation at ISOLDE



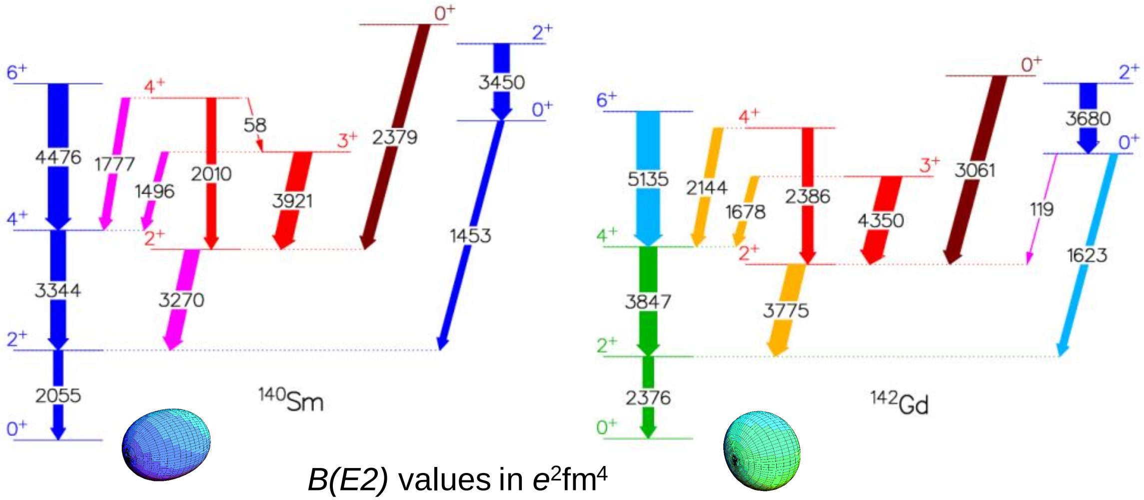


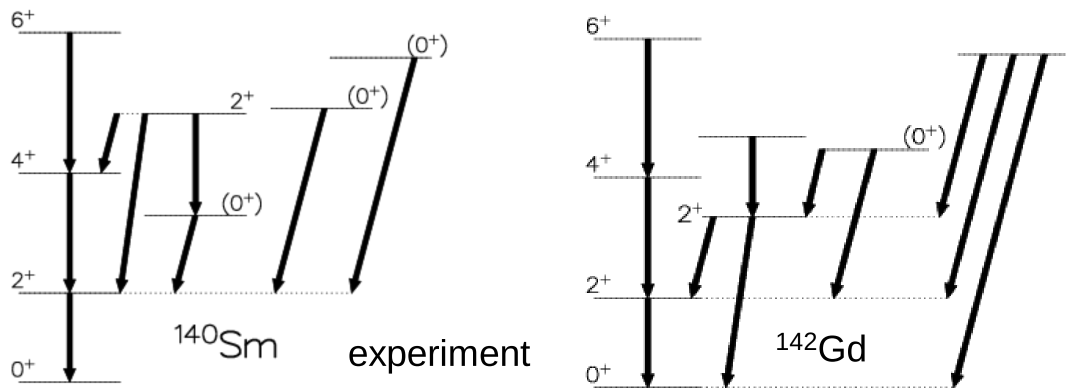
Particles detected in circular DSSSD

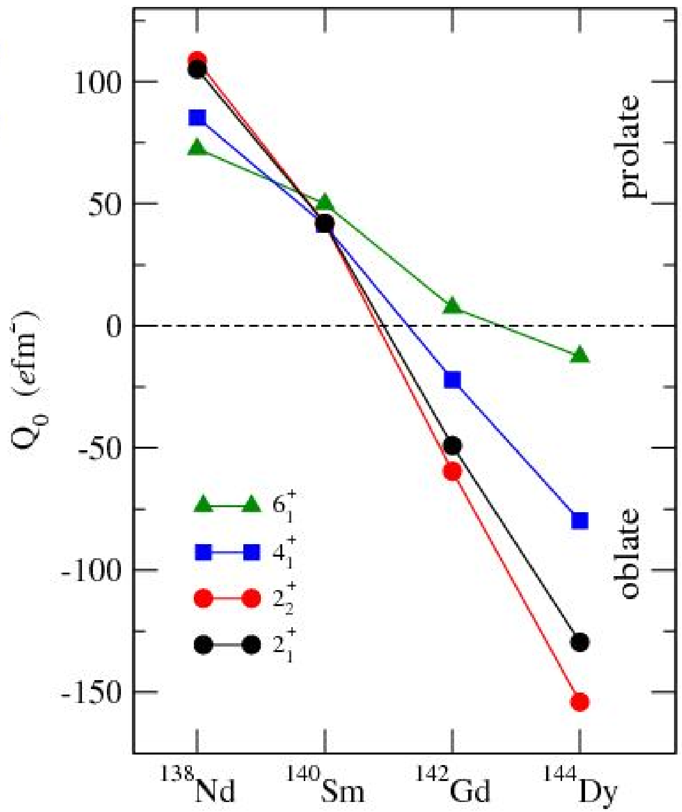
Angular range: [20 58]

Theory vs experiment

Calculations predict transition from prolate to oblate shape with increasing proton number along N=78







no experimental B(E2) values
low-lying (0^+) state
⇒ indication for
shape coexistence ?

no experimental B(E2) values
1. low-lying excited 0^+ state ?
2. γ-vibrational band built on oblate shape ?

configuration mixing calculation
GCM(GOA)
5-dimensional $(q_{20},q_{22},\alpha,\beta,\gamma)$
Gogny D1S interaction

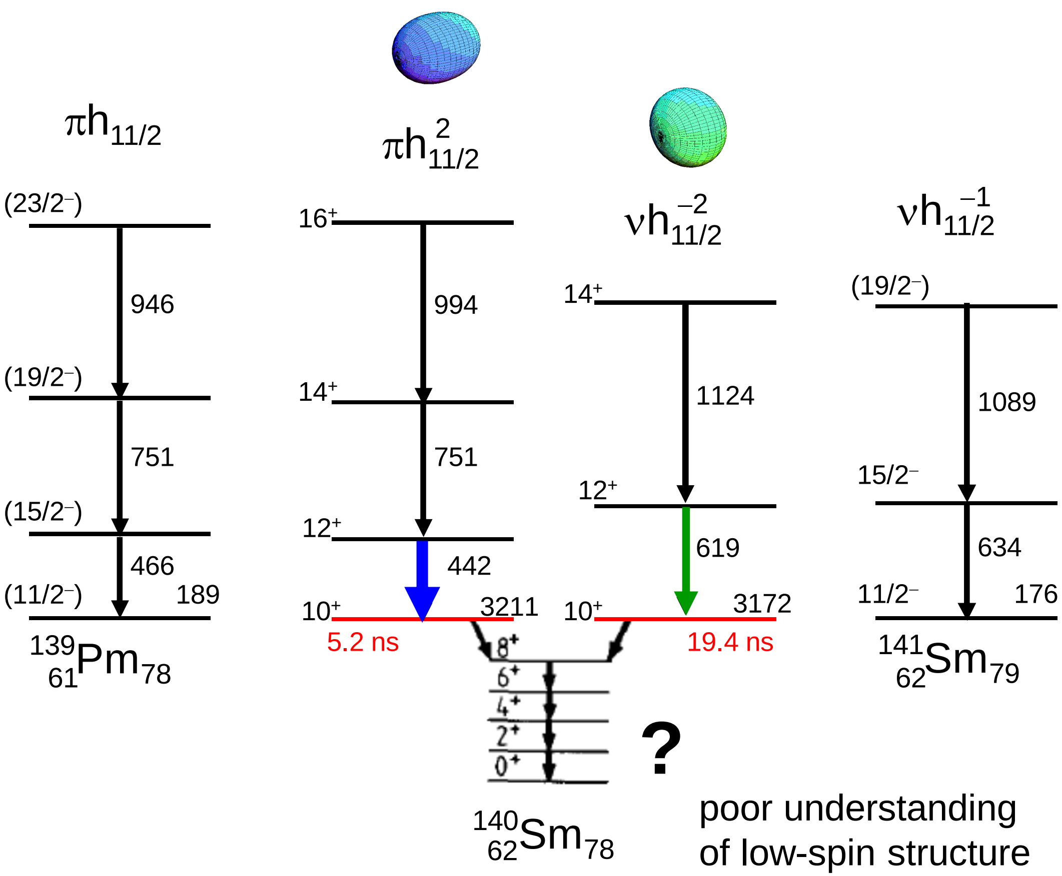
M.Girod, J.-P.Delaroche
CEA Bruyères-le-Châtel

Shapes above the isomers

M.A. Cardona et al.
PRC 44, 891 (1991)

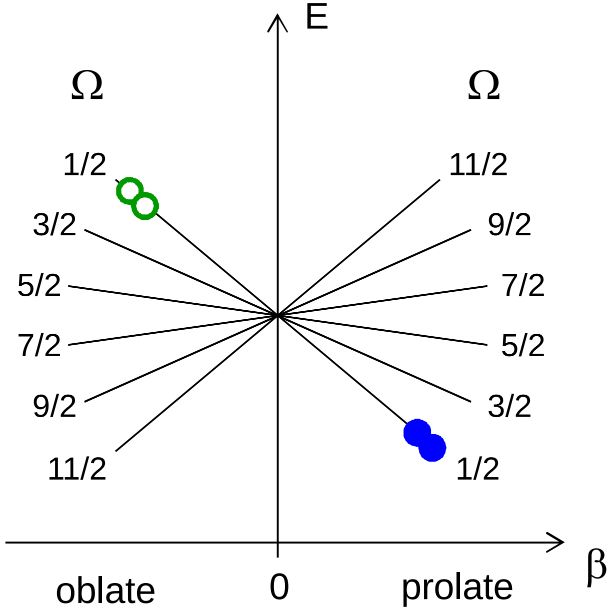
B(E2;12⁺→10⁺) [W.u.]

50(7) **19(5)**



poor understanding
of low-spin structure

need B(E2) and Q_s



rotationally aligned 2qp bands
built on $\pi(h_{11/2})^2$ and $\nu(h_{11/2})^{-2}$

indirect evidence for
shape coexistence
at higher spins