Workshop on Advanced Laser and Mass Spectroscopy
ALMAS-1: Innovative Physics Ideas

Study of Superheavy Nuclei

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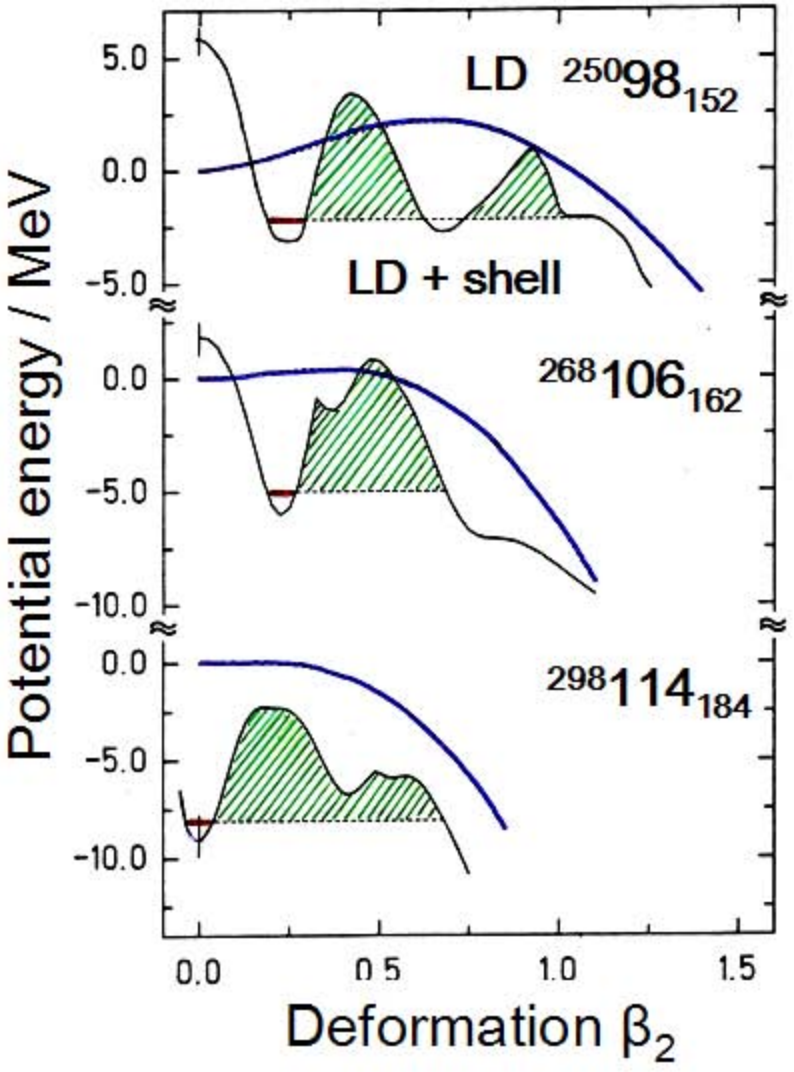
GSI Darmstadt and University Frankfurt
Josef Buchmann-Professor Laureatus

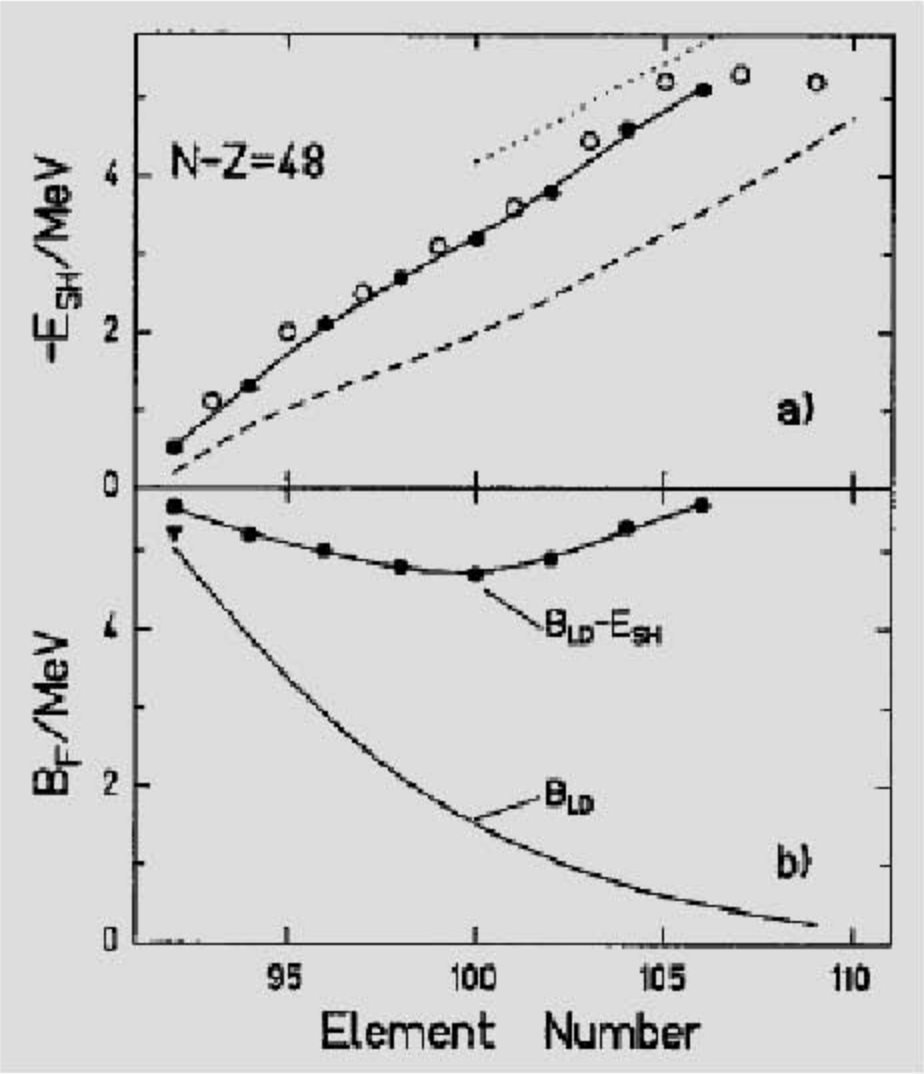
GSI Darmstadt, October 19–20, 2006

The Strutinsky method: Fission barriers



Sobiczewski et al.

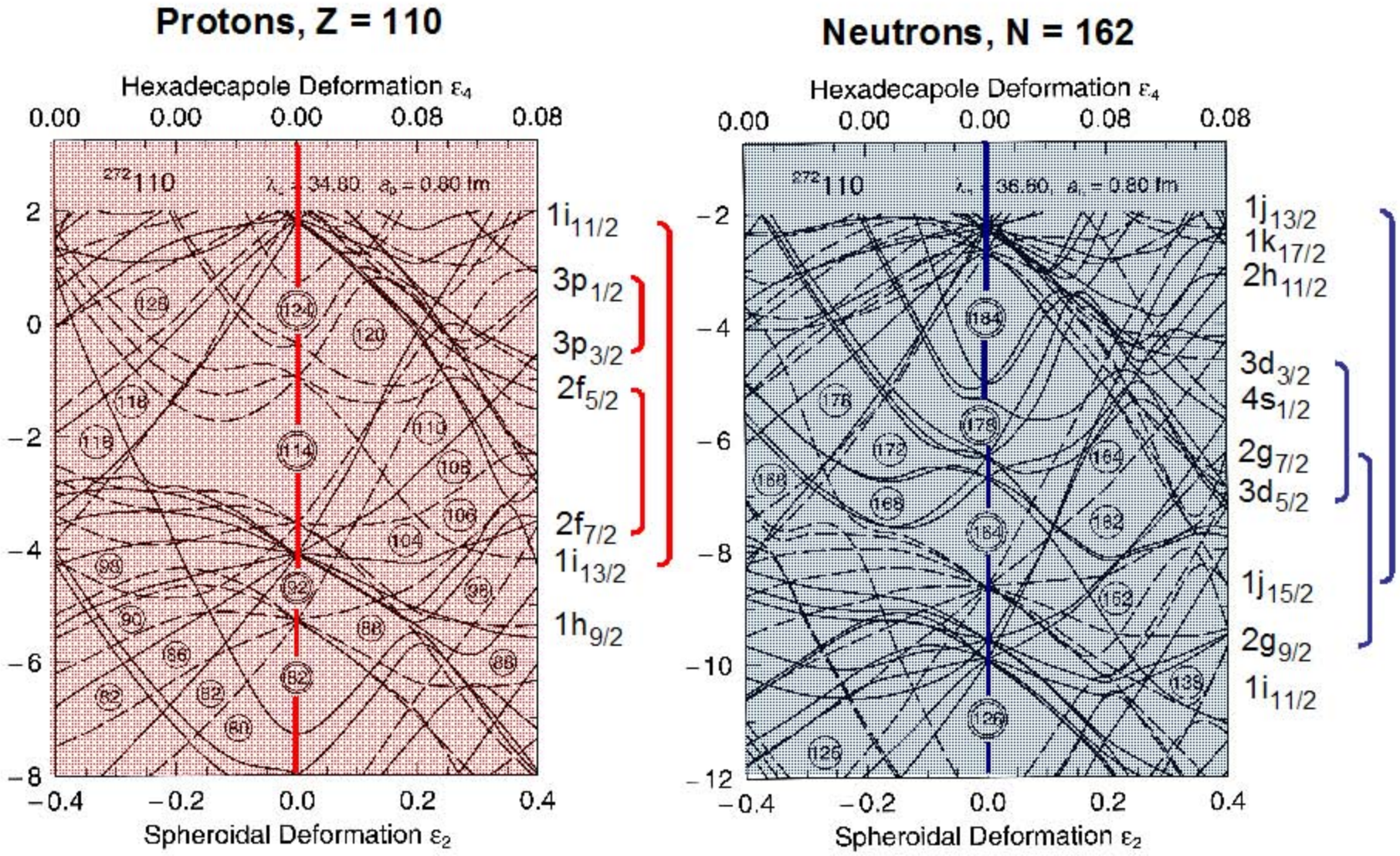
"Experimental" ground-state shell-correction energy



Münzenberg et al., 1985

Liquid drop:
Möller and Nix, 1981

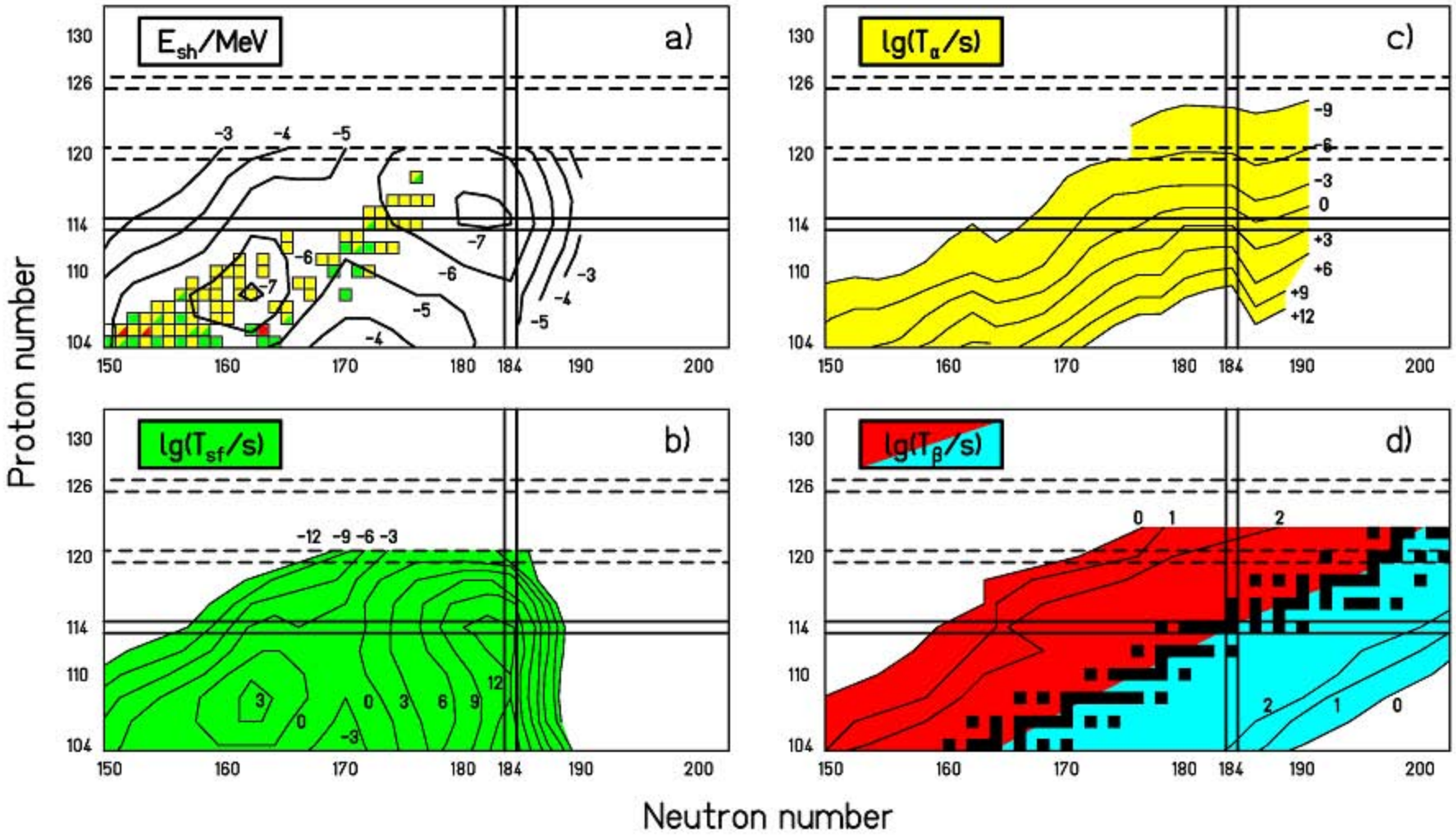
Nilsson single particle energies / MeV



P. Möller et al, 1997

Partial decay half-lives

Calculation: R. Smolanczuk, A. Sobiczewski et al.; P. Möller et al.



Expected half-lives of SHE and research goals

Location of closed shells:

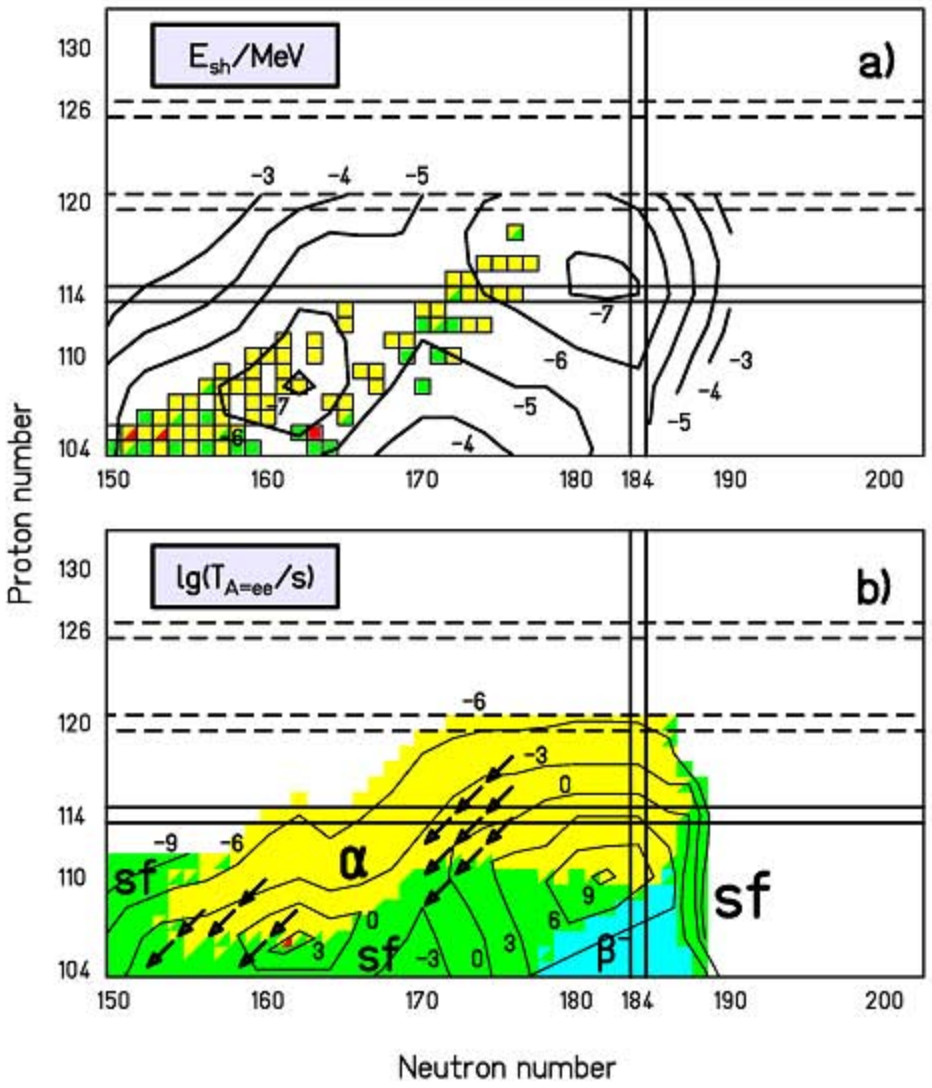
Proton shell:
114, 120 or 126 / 114 – 126 ?
Neutron shell:
172 or 184 ?

Reaction mechanism:

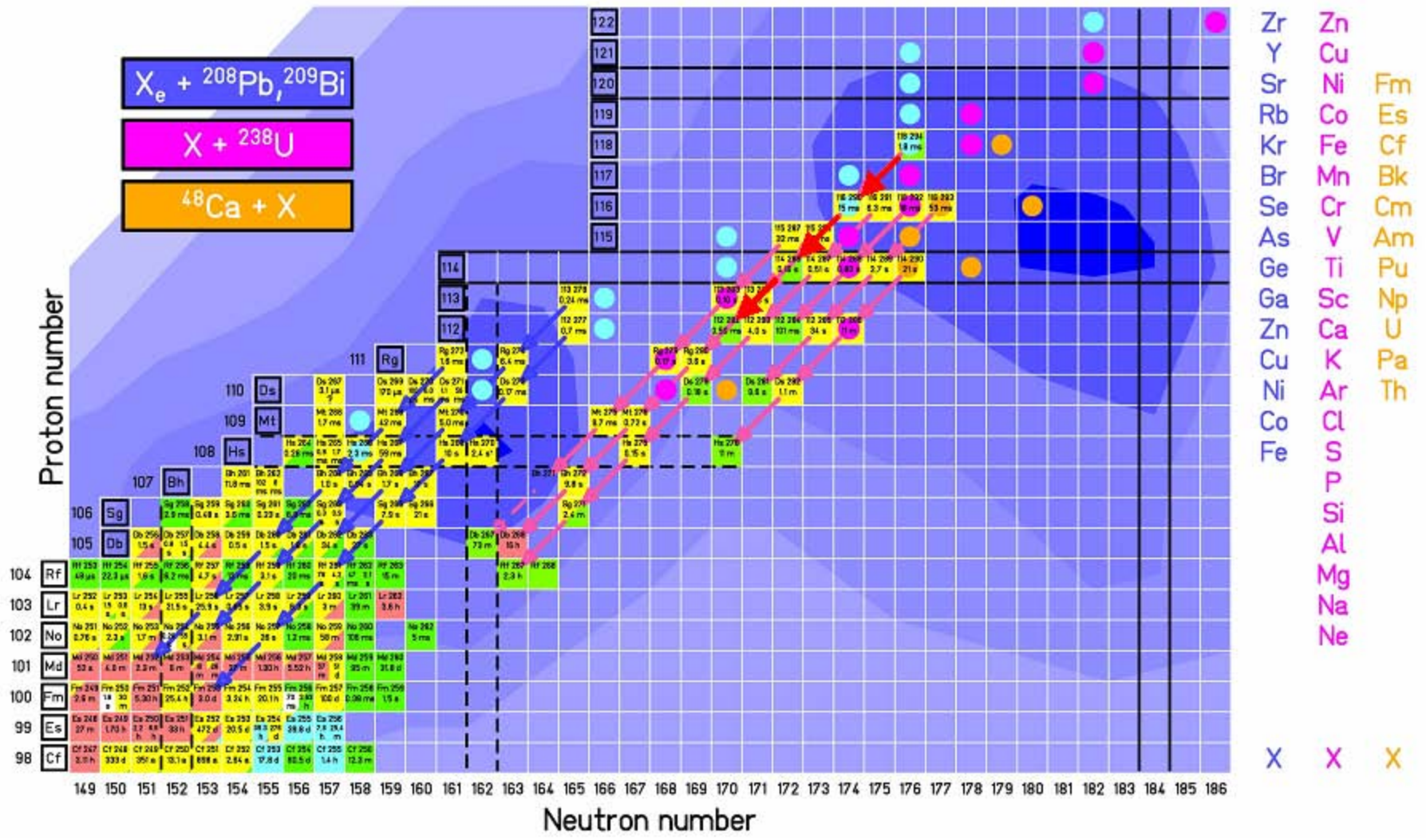
Cross-sections
Excitation functions
Cross bombardments
Mass asymmetry
Fusion and transfer

Nuclear structure:

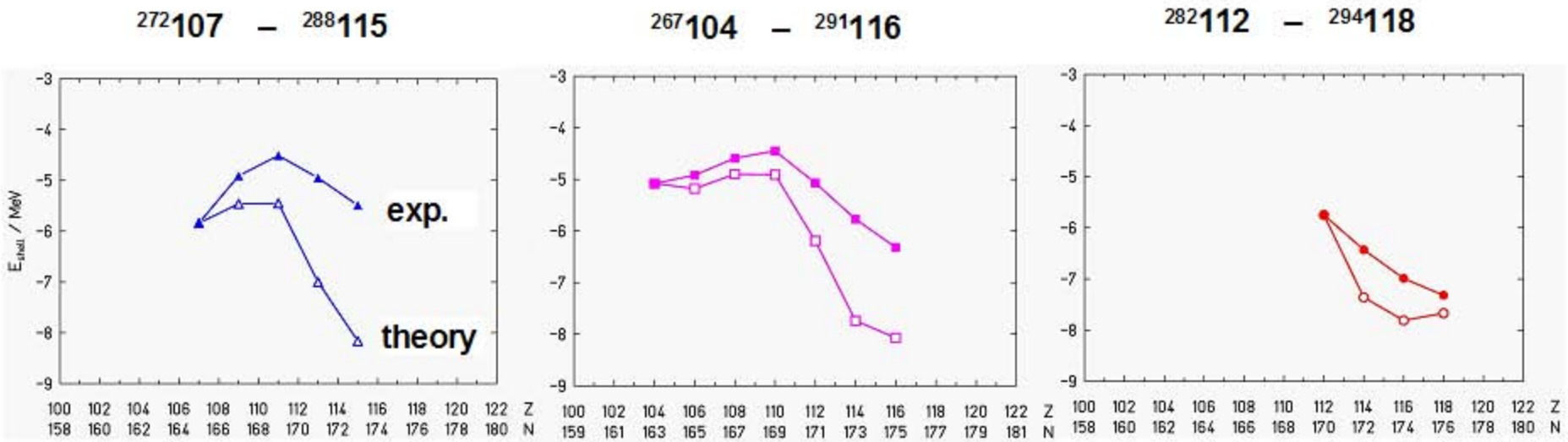
Lifetimes
Decay modes
Isomers



Status of SHE research



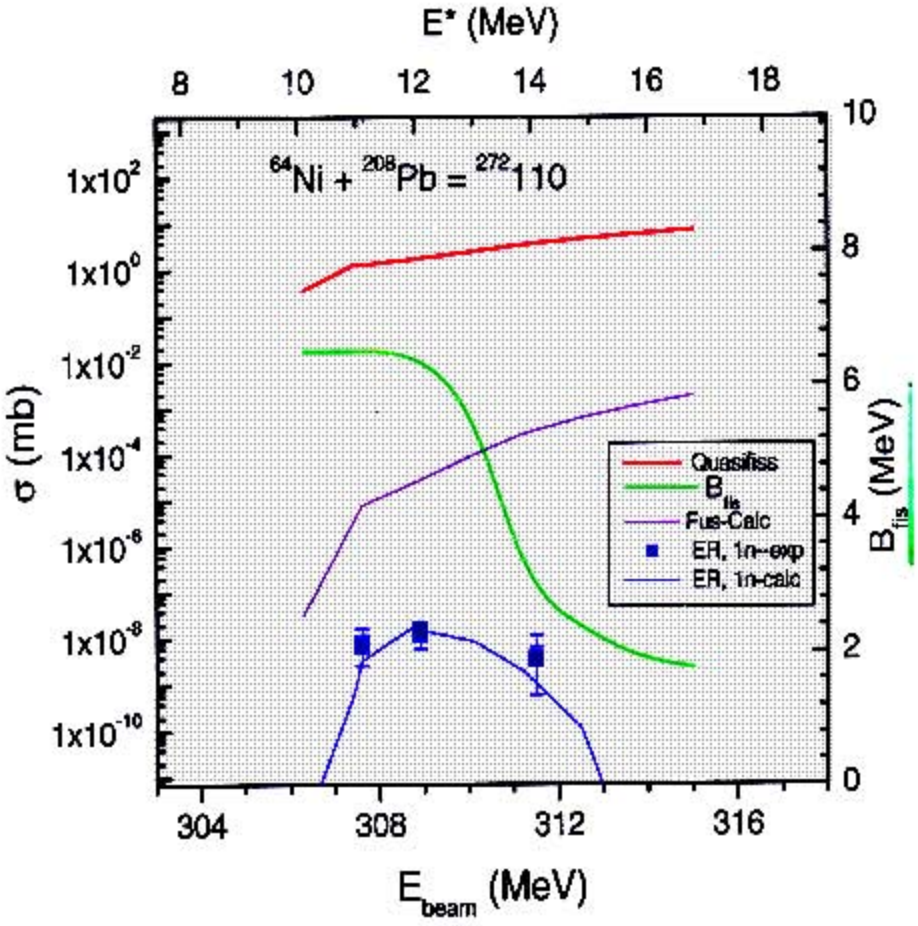
"Experimental" ground-state shell-correction energies

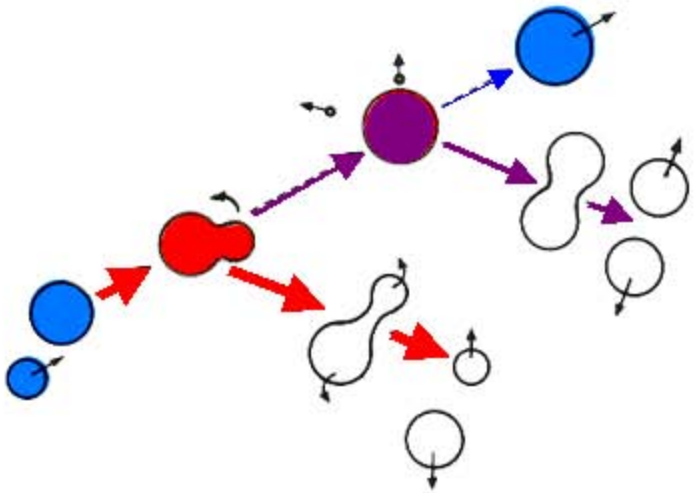


Q-alpha: Oganessian et al., 2006

Theory: Möller et al., FRDM, 1995

Calculation of cross-sections





A.K. Nasirov, G. Giardina et al., (2000)

Experiment SHIP: Fusion without extrapush

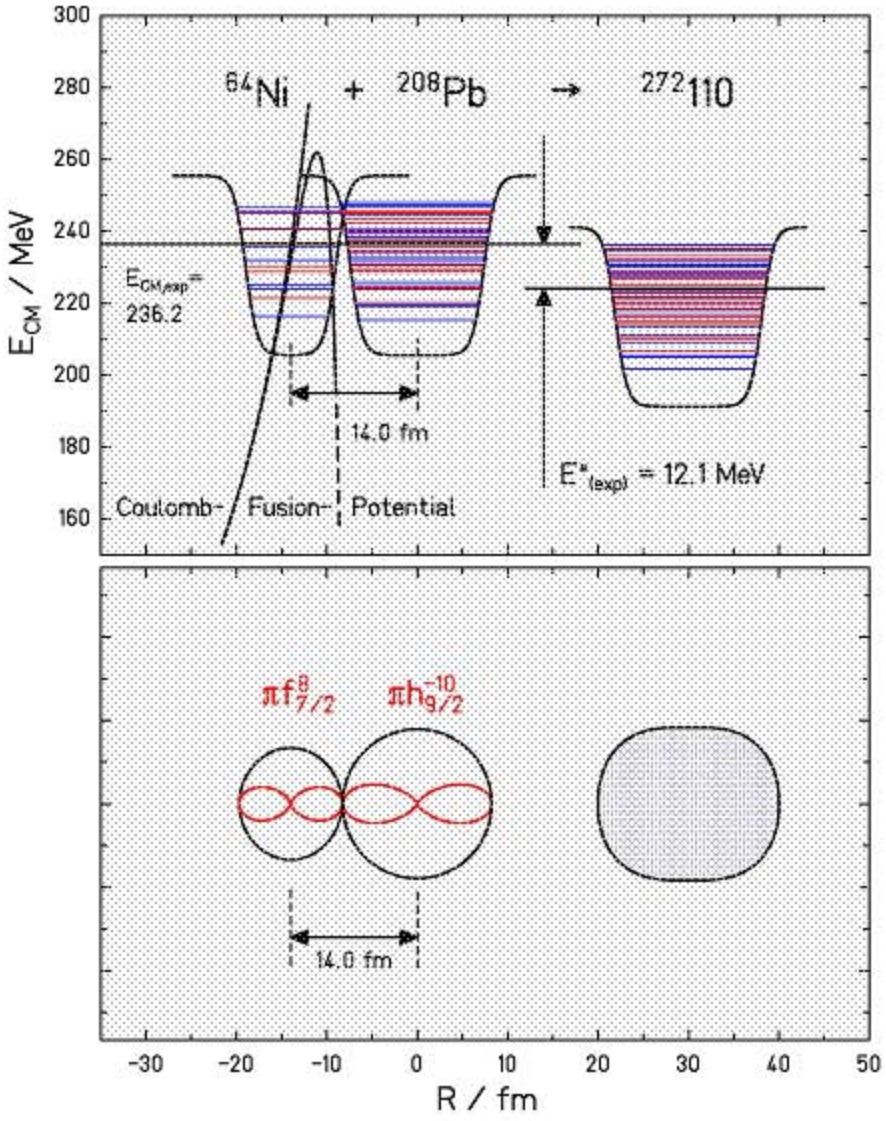
Fusion (initiated) by transfer:

V. Volkov et al.,

W. Von Oertzen et al.

Cold fusion valleys:

W. Greiner et al.



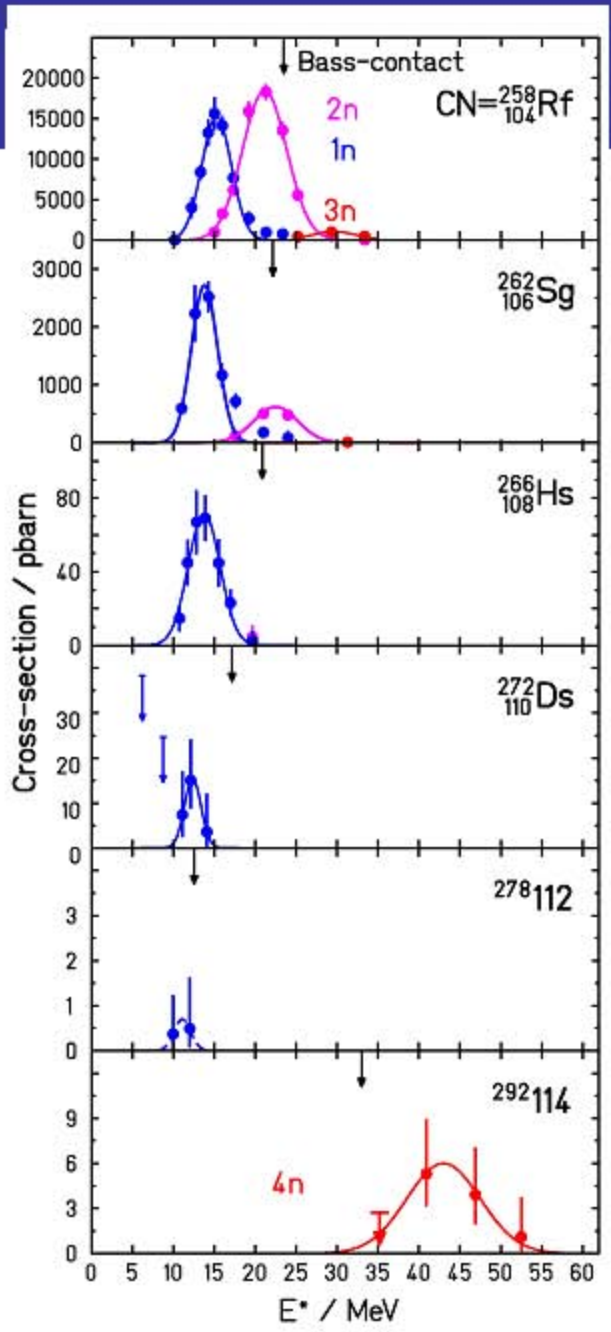
Reaction mechanism

Excitation functions

^{50}Ti, ^{54}Cr, ^{58}Fe, ^{64}Ni, ^{70}Zn

+ ^{208}Pb

^{48}Ca + ^{244}Pu



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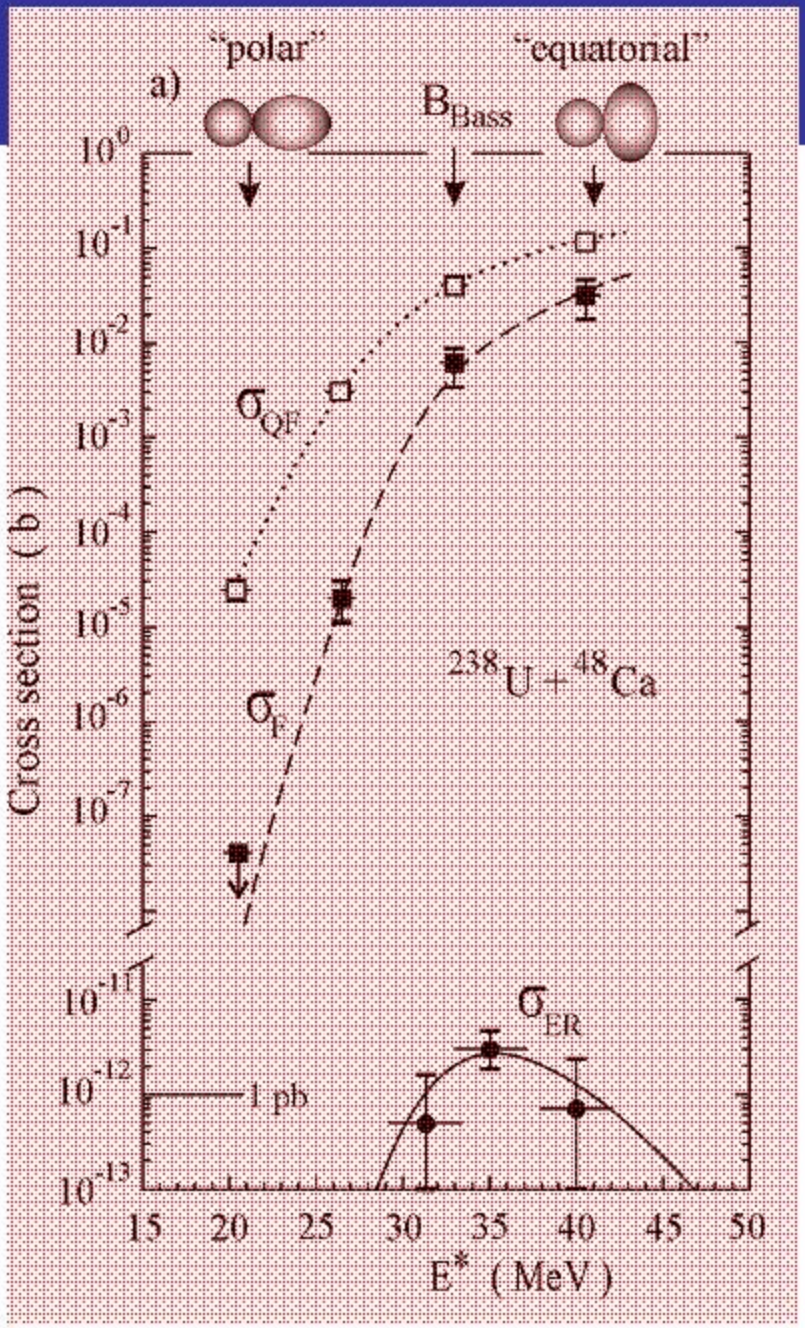
Cold fusion

Dubna

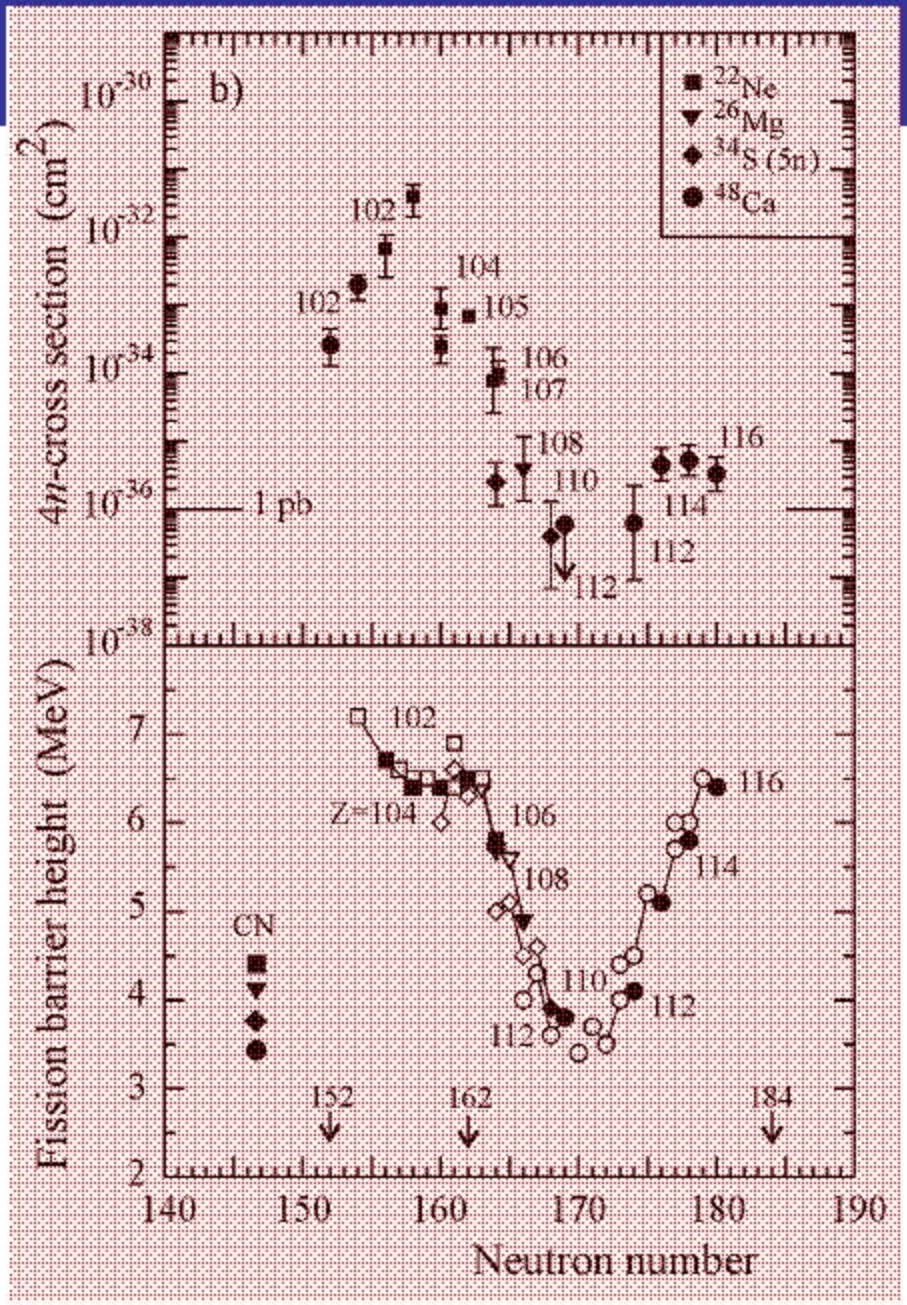
Hot fusion

Hot fusion



Yu.Ts. Oganessian,
M.G. Itkis et al., 2004

Mutual relation



EXPERIMENT:

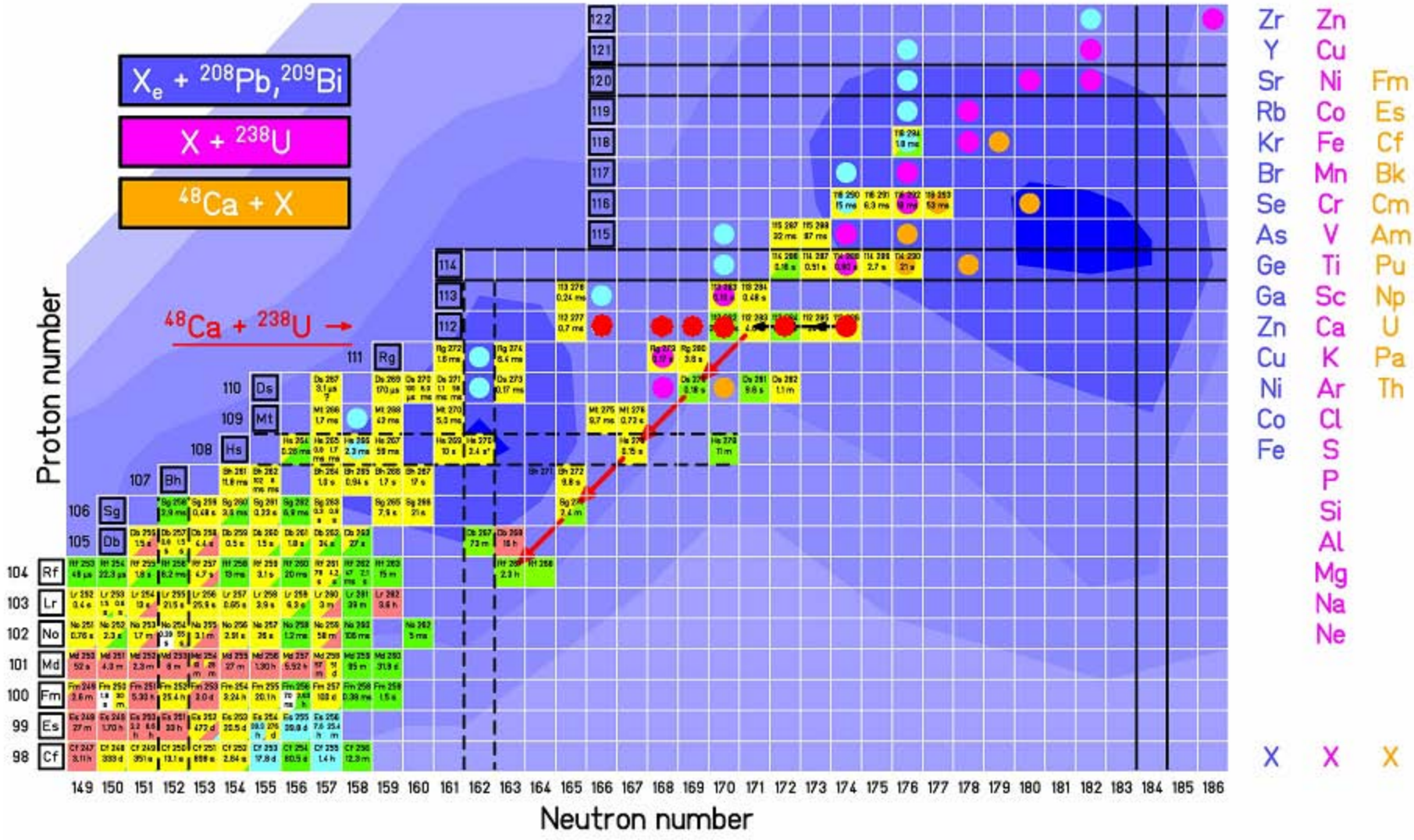
Yu.Ts. Oganessian,

V.K. Utyonkov et al.

THEORY:

A. Sobiczewski et al.

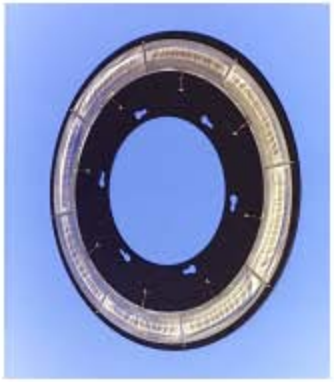
October 2006: $^{48}Ca + {}^{238}U_{metallic}$



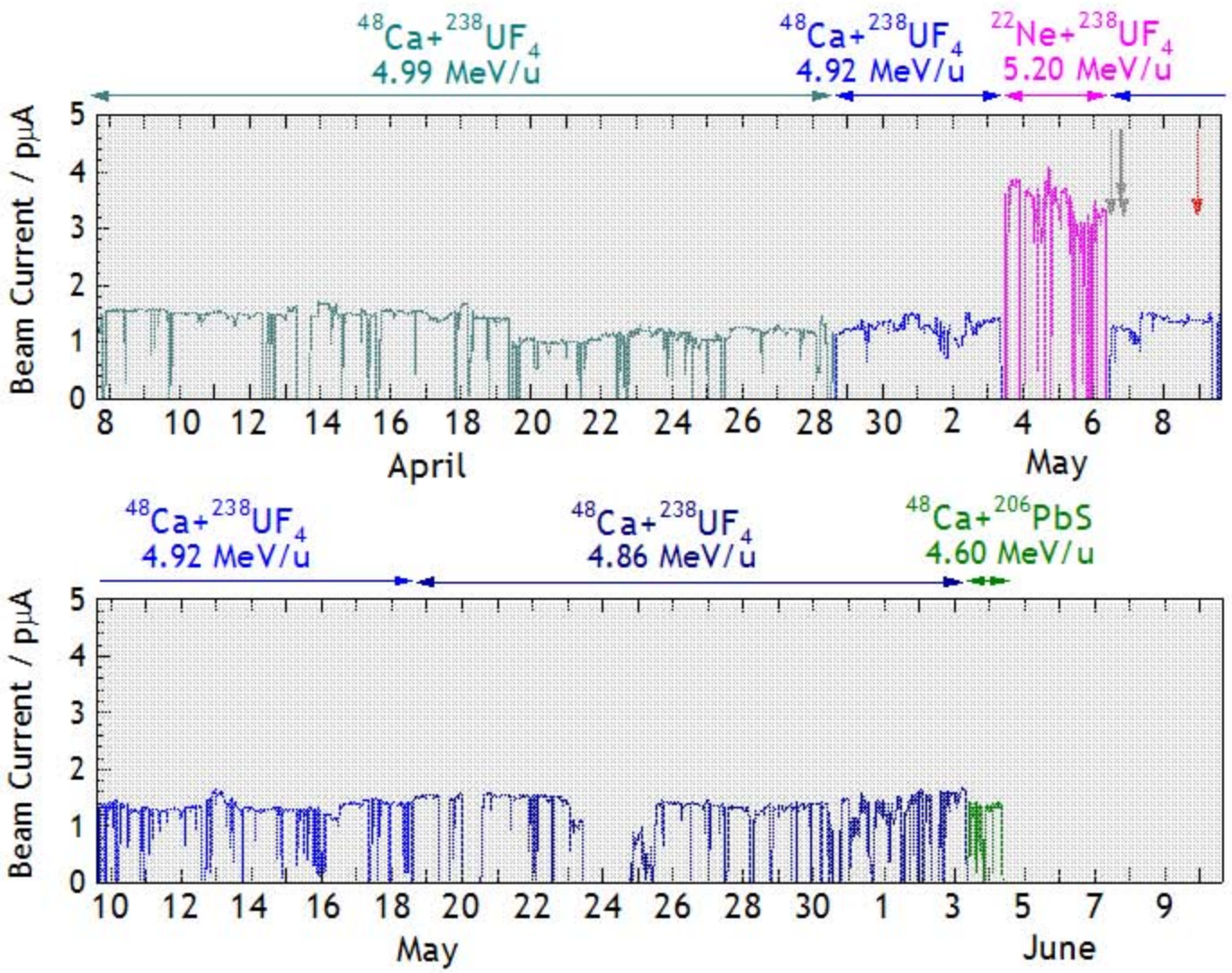
Velocity separator SHIP

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:	3 – 25 μs

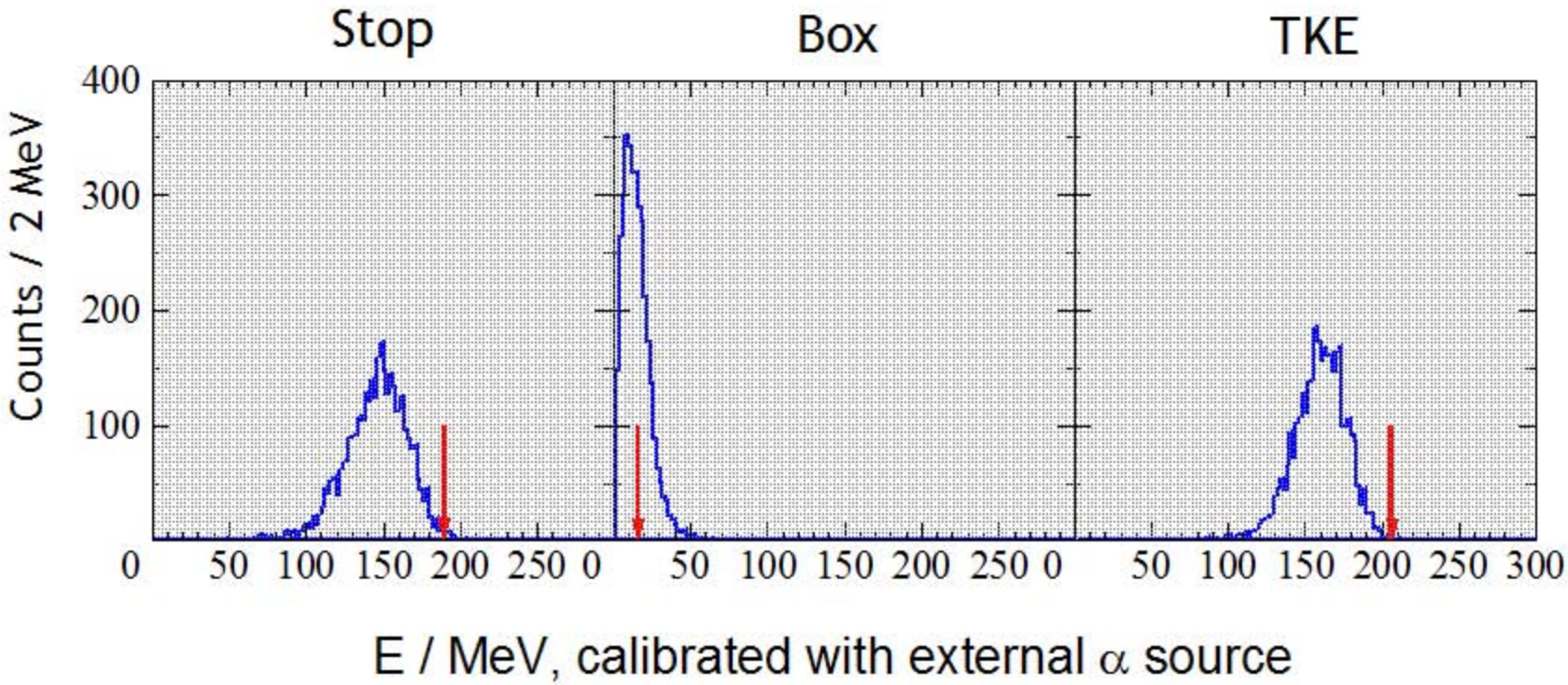


Experiment at SHIP: April 8 – June 4, 2005



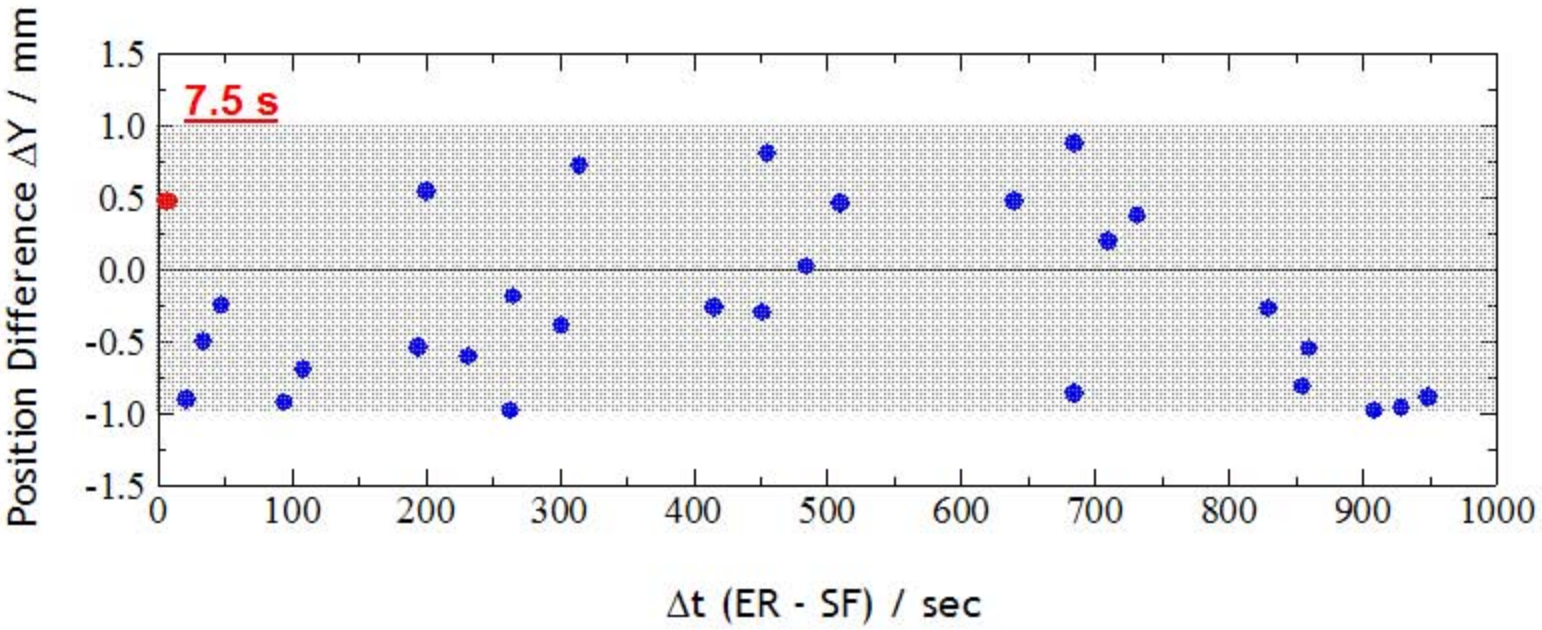
Spont. fission from $^{48}Ca + ^{206}PbS$ and $^{48}Ca + ^{238}UF_4$

sf detected 08.05.2005, 22:45 h; TKE = 206 + 36 = 242 ± 15 MeV



fission calibration: + 36 MeV from TKE (^{252}No) = 195 MeV

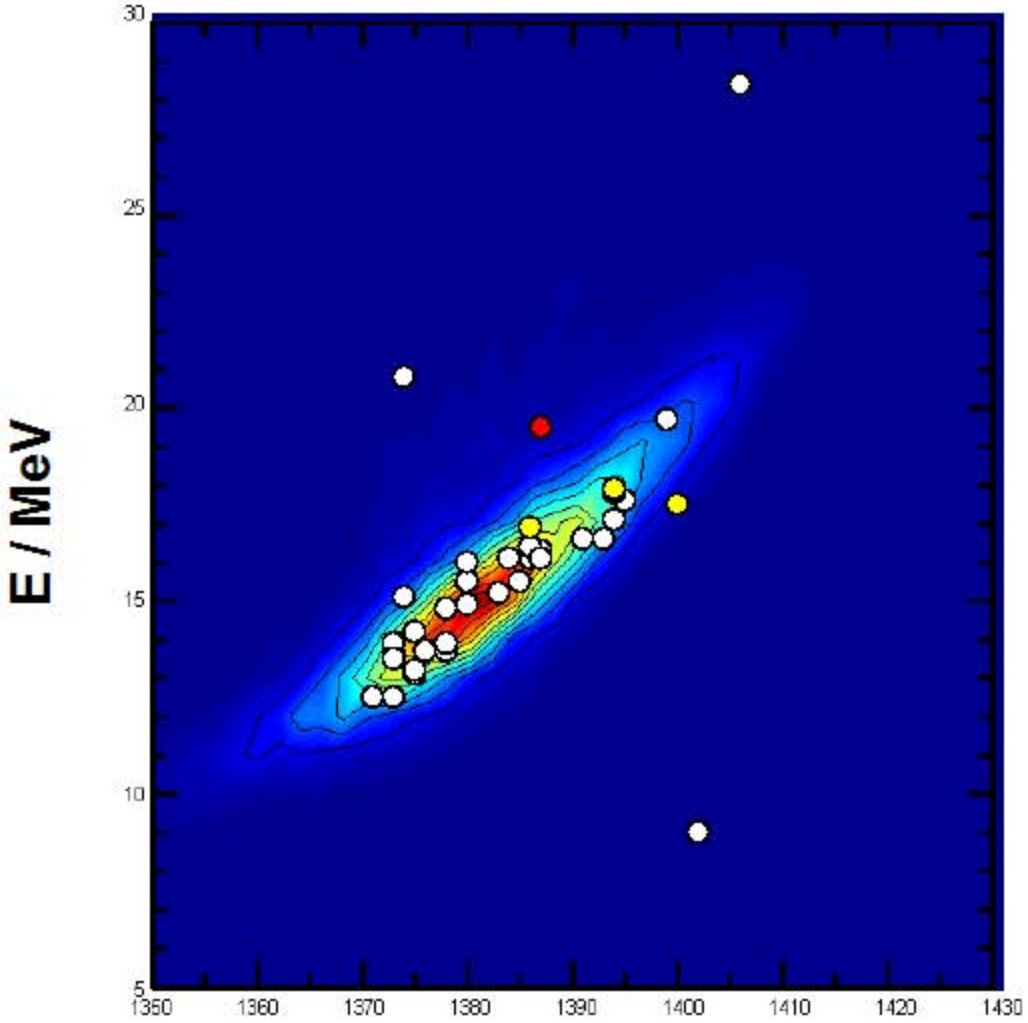
Search for implanted ER's

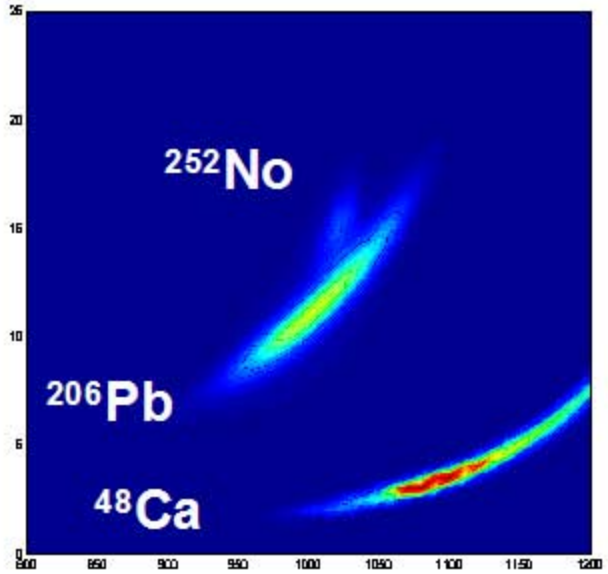


29 ER candidates

within Δy= ±1.0 mm
and Δt = 1000 s

Energy versus time-of-flight plots





$^{48}Ca + {}^{206}PbS \Rightarrow {}^{254}No^*$

$^{48}Ca + {}^{238}U \Rightarrow {}^{286}112^*$

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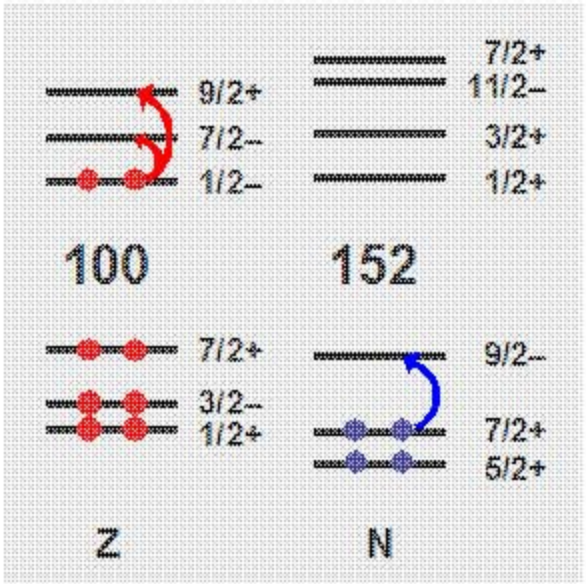
$^{48}Ca + ^{238}U$? $^{286-x}112 + xn$ at DGFRS, SHIP, and BGS

E*/MeV	dose/10^{19}	events	$T_{1/2}$ (parent)	x	σ/pb (1 ev. limits)
31.4	0.58	1 (ER?[α]?sf)*	(3.4 s)	3	0.5 +1.2 ?0.4
32.0	0.7	0	--		< 0.8
31.9	0.23	0	--		< 0.8
35.0	0.71	2 (ER?[α]?sf) (1.4 s) 3 (ER? α ?sf) 2.7 s 1 (ER?4α?sf) 6.1 s		3	2.5 +1.8 ?1.1
34.5	1.0	1 (ER ? sf)	5.2 s	?	0.7 +1.6 ?0.6
36.3	0.18	0	--		< 0.96
39.8	0.52	1 (ER ? sf)	0.14 ms	4	0.6 +1.6 ?0.5
37.0	1.2	0	--		< 0.6

* Dubna work: $T_{1/2}(^{279}Ds) = 0.18$ s, $b_{sf} = 0.9$

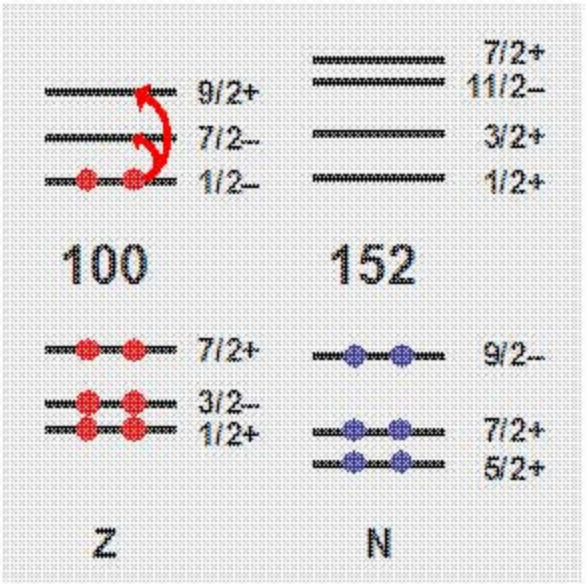
4+, 5?, 8?

8?



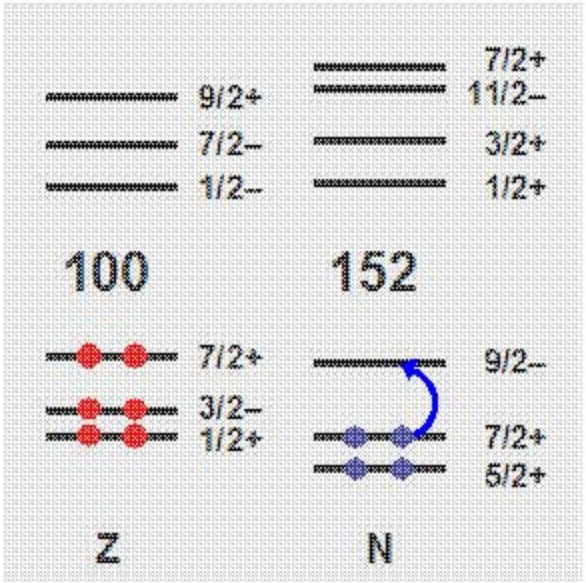
^{252}No

4+, 5?, 8?

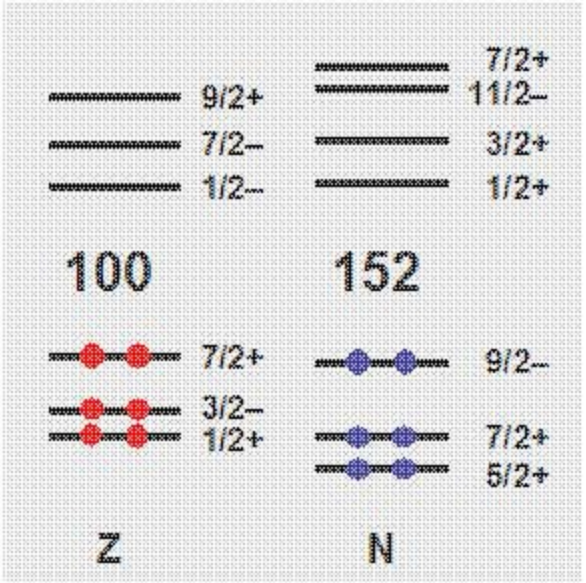


^{254}No

8?

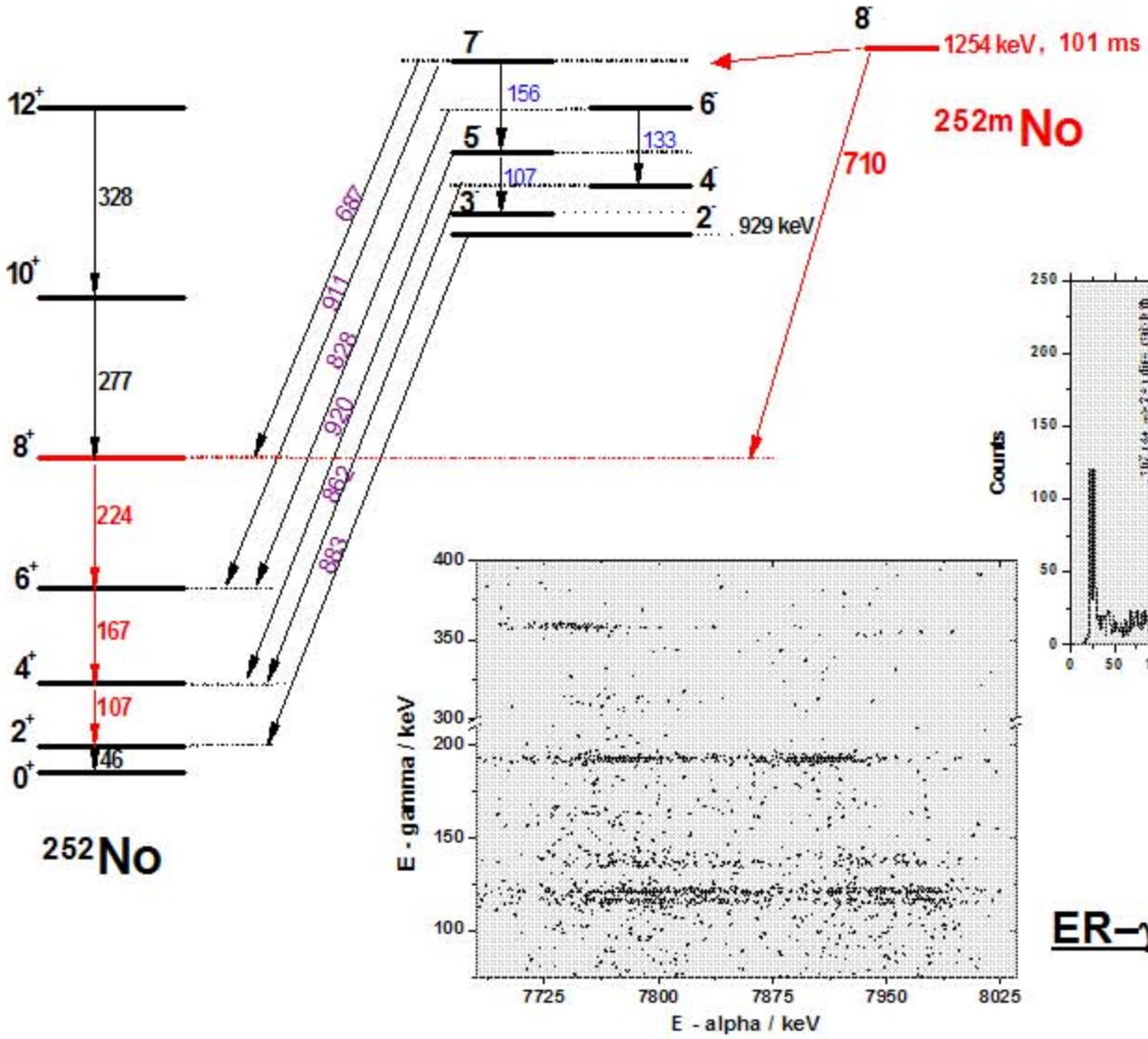


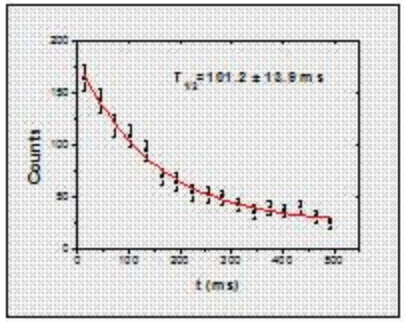
^{250}Fm

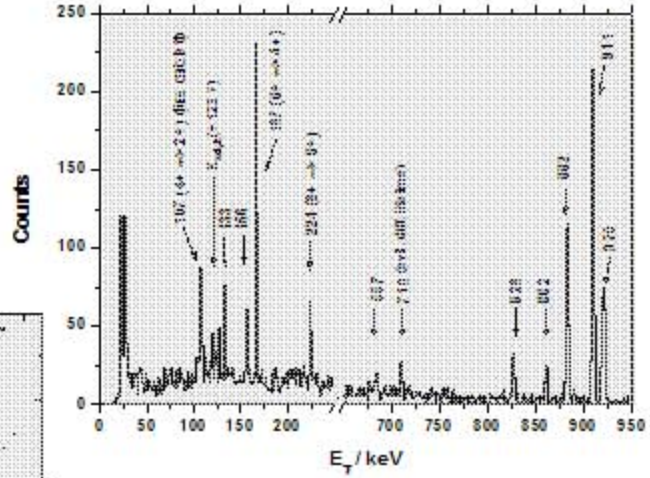


^{252}Fm

New K isomers in ^{252}No





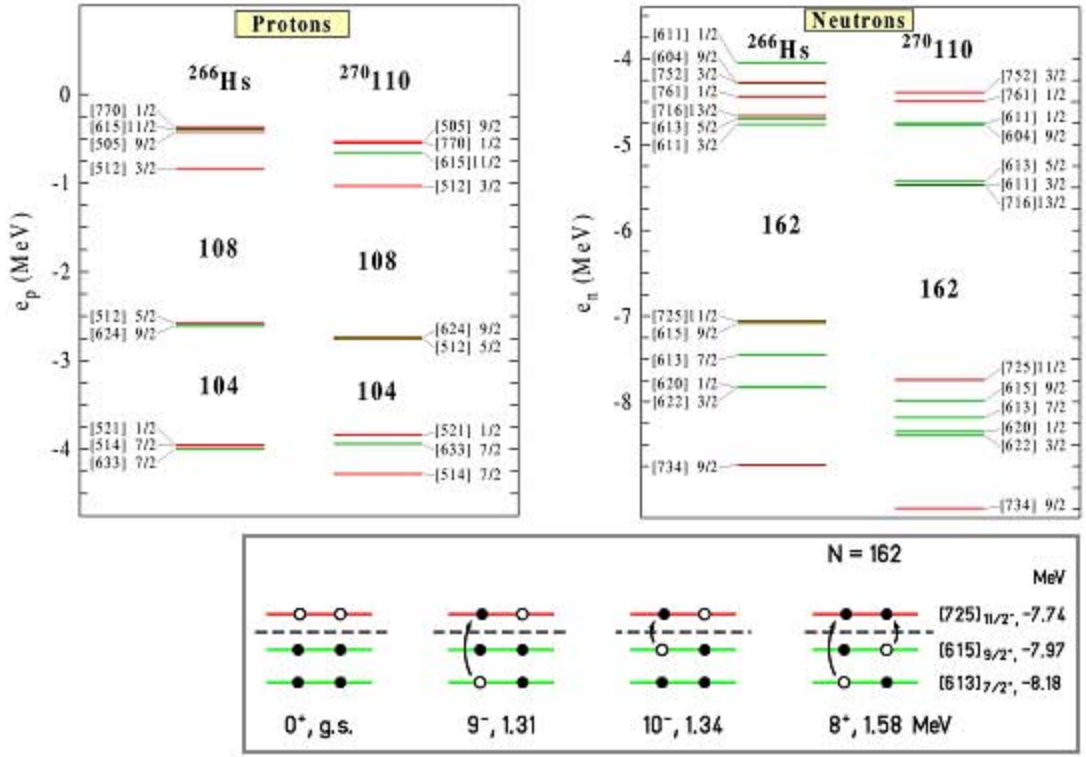


ER–γ, ER–α–γ/e correlation

Spectroscopy on a pb–level

Single particle energies:

Energy gaps at Z = 108 and N=162



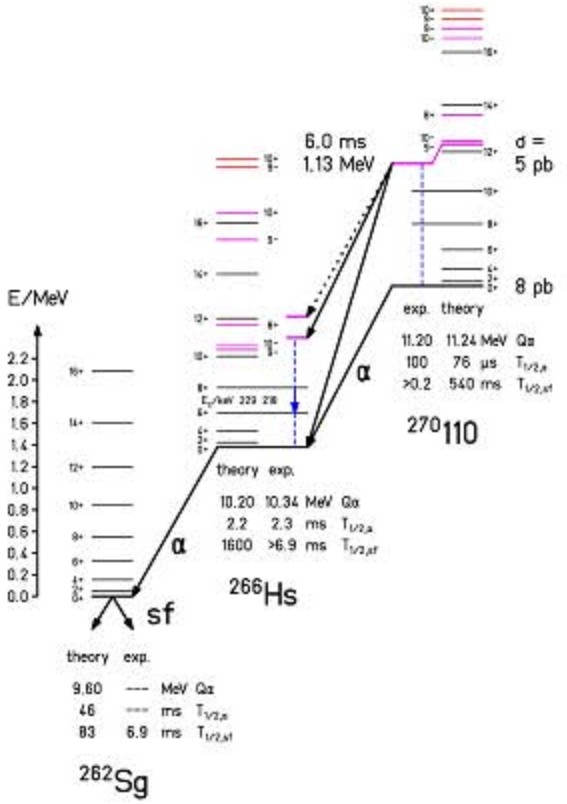
Theory:

S. Cwiok and P. Heenen

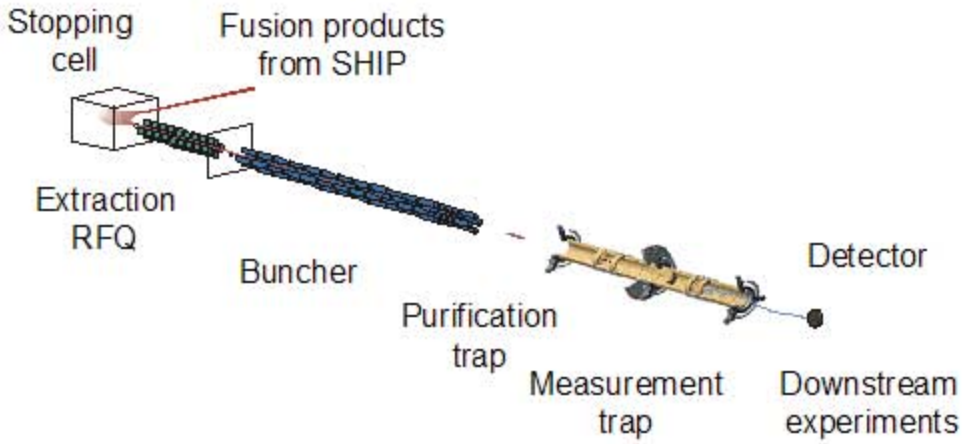
A. Sobiczewski et al.

Example: ^{270}Ds

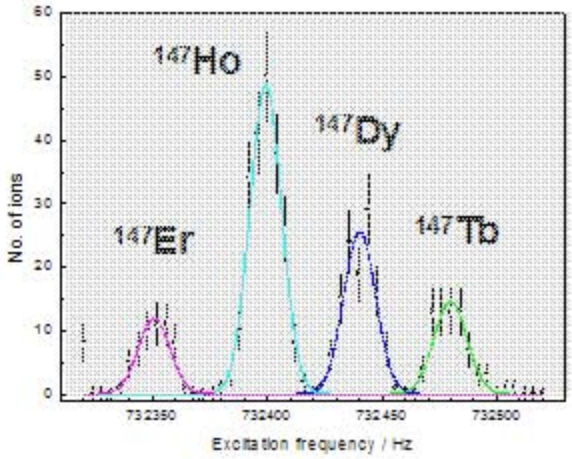
Ground-state and K isomer



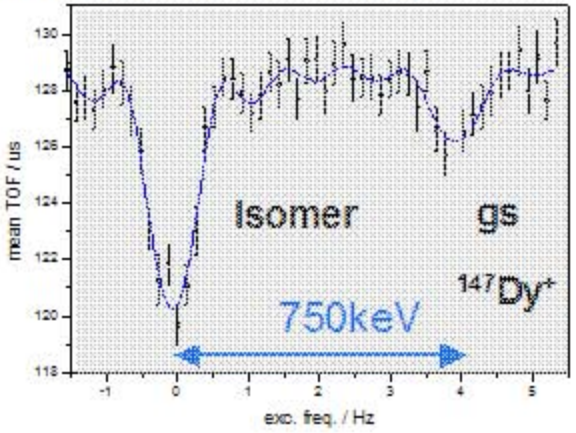
New methods: SHIPtrap



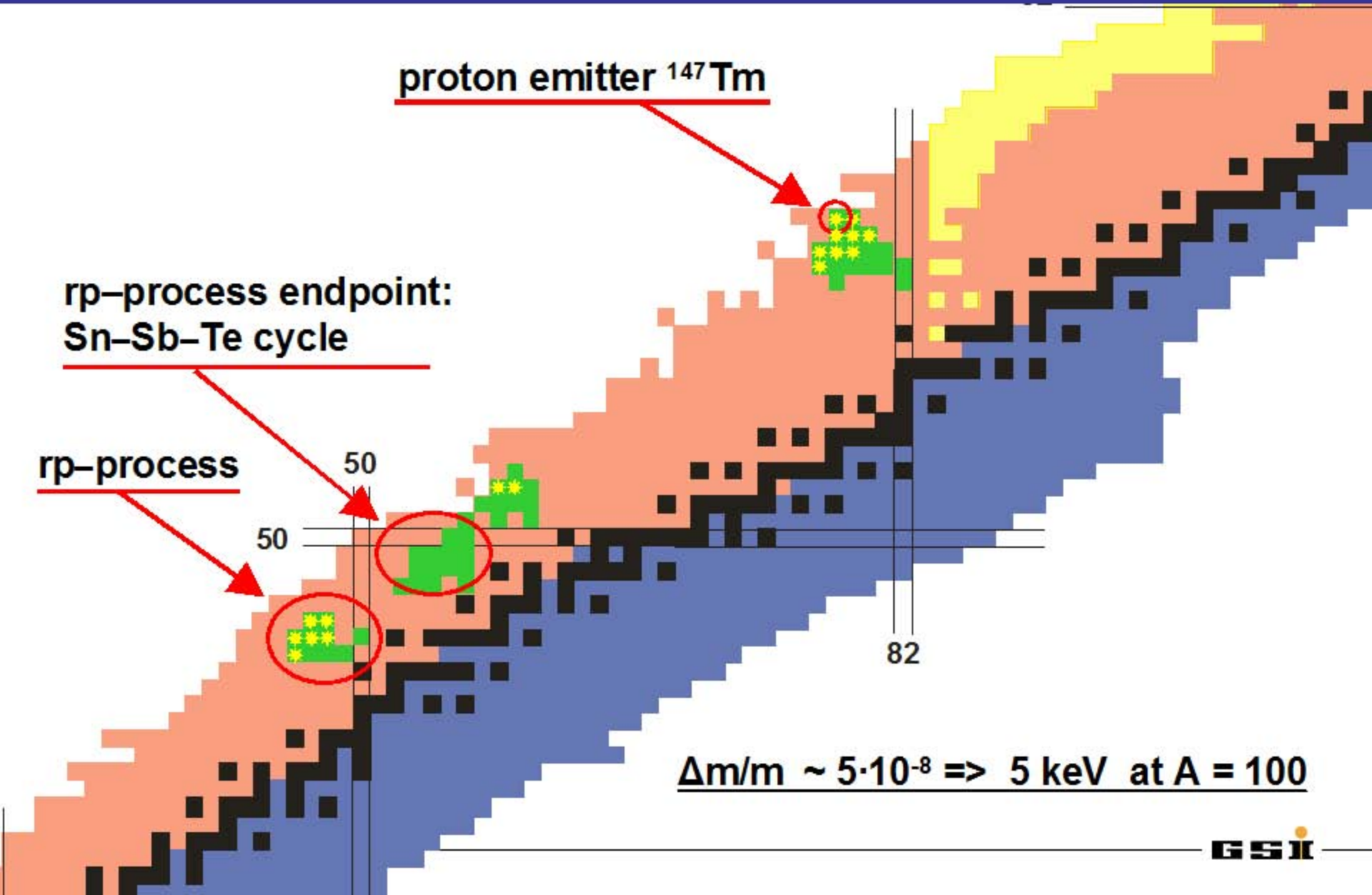
Isobar separation at A=147 in the purification trap



Isomeric state identification in the measurement trap



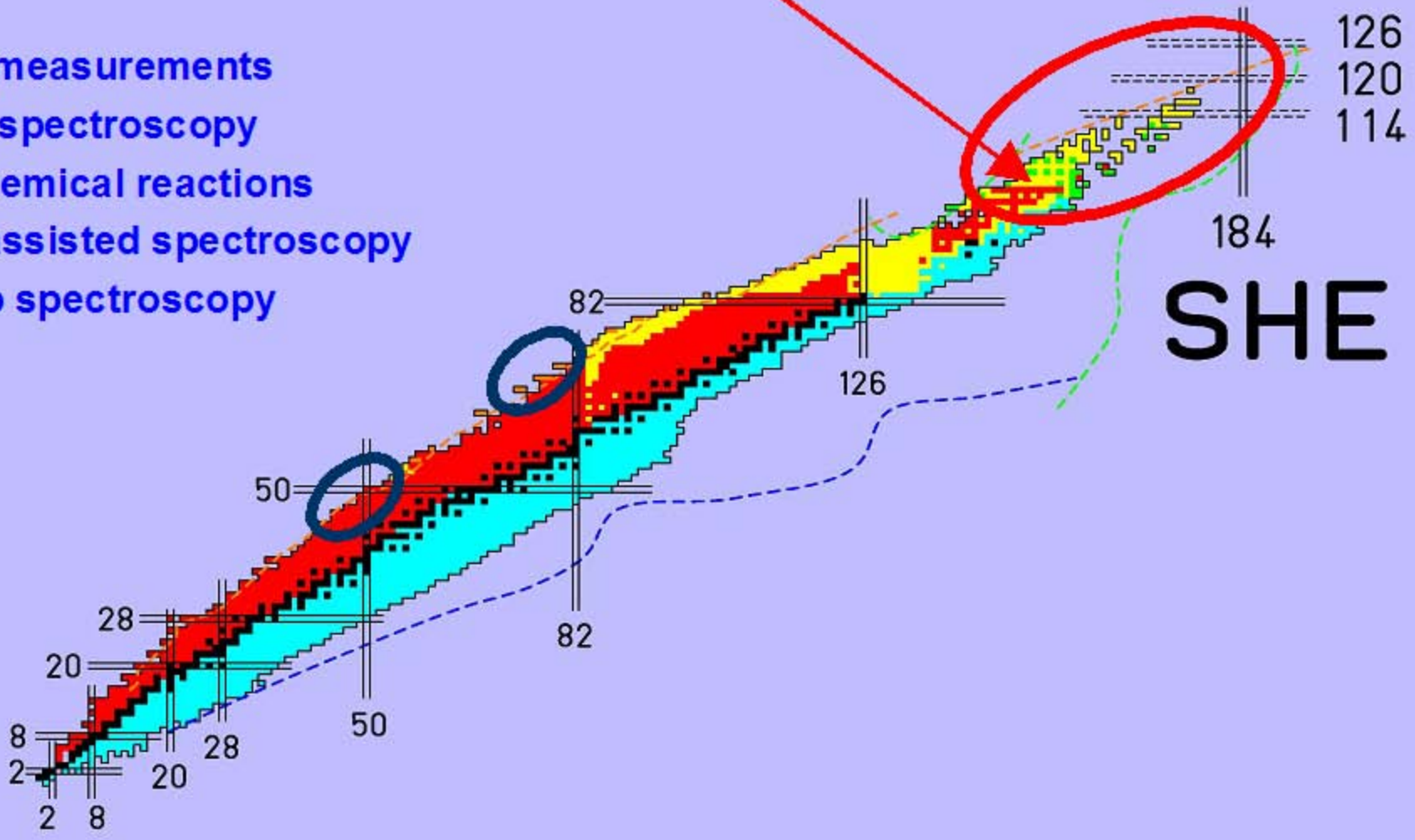
Recent results: 17 new masses (✳)



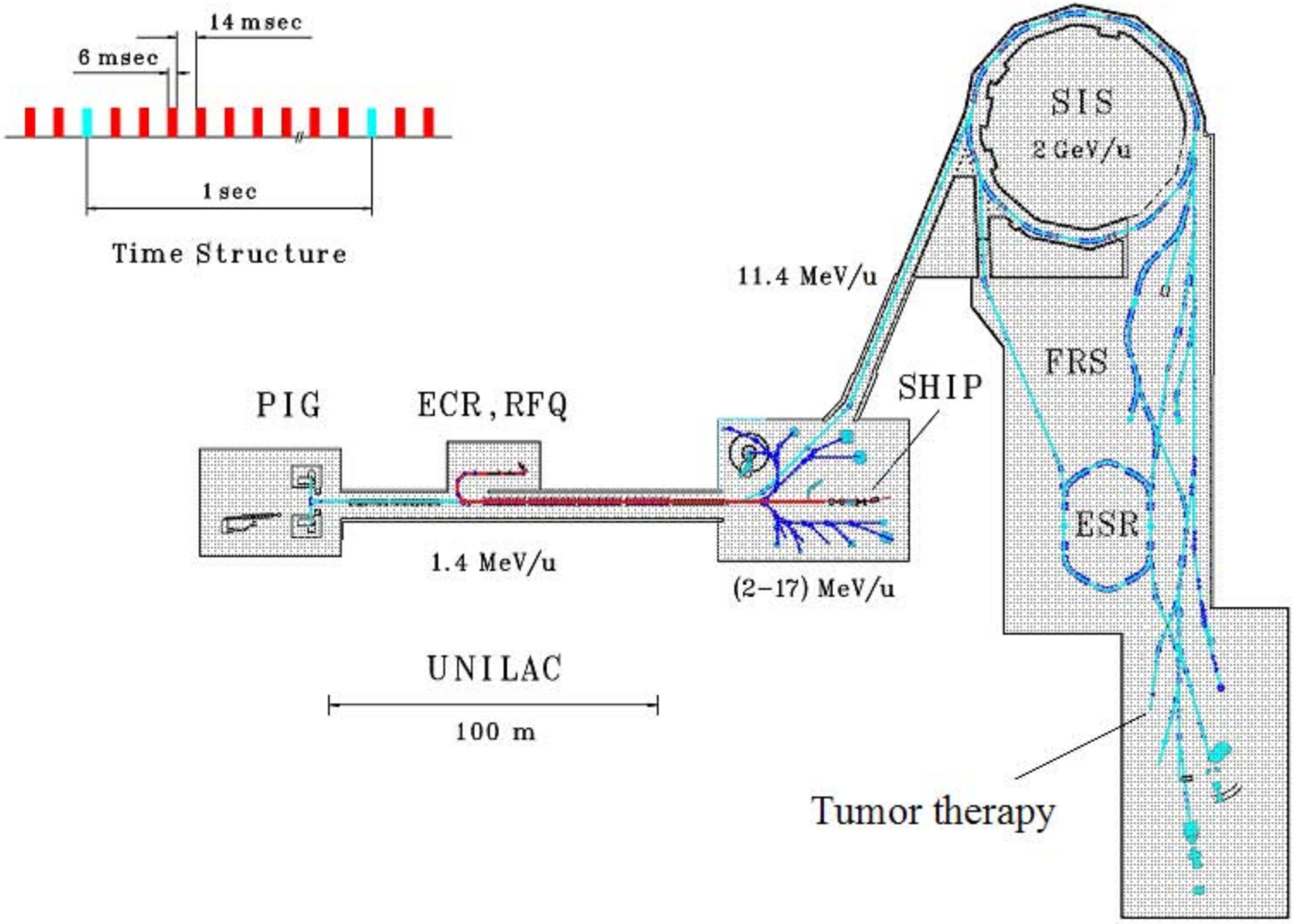
Near and mid term plans at SHIPtrap

$^{48}Ca + {}^{208}Pb \Rightarrow {}^{254}No + 2n \quad (\sigma = 3\ \mu b)$

- Mass measurements
- Laser spectroscopy
- Ion-chemical reactions
- Trap-assisted spectroscopy
- In-trap spectroscopy



UNILAC and SHIP



Technical developments: UNILAC upgrade

New 28-GHz ECR Ion-Source:

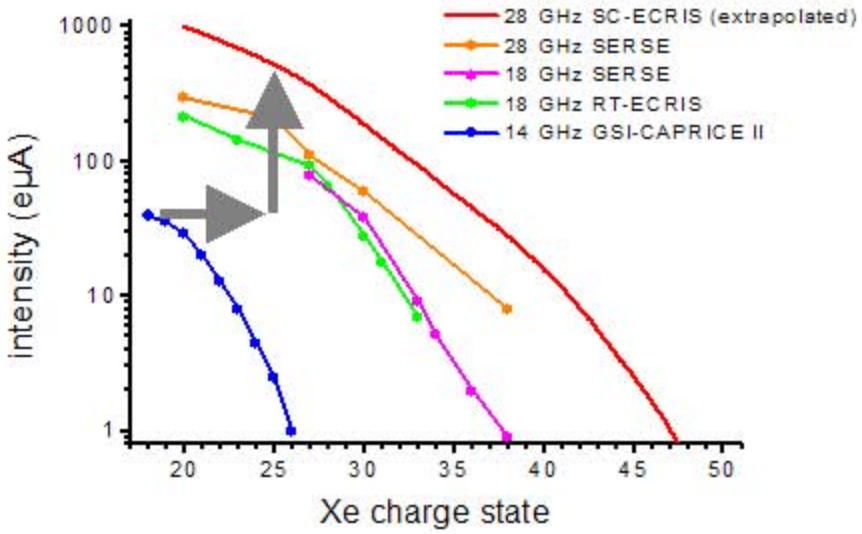
higher charge state
higher intensity

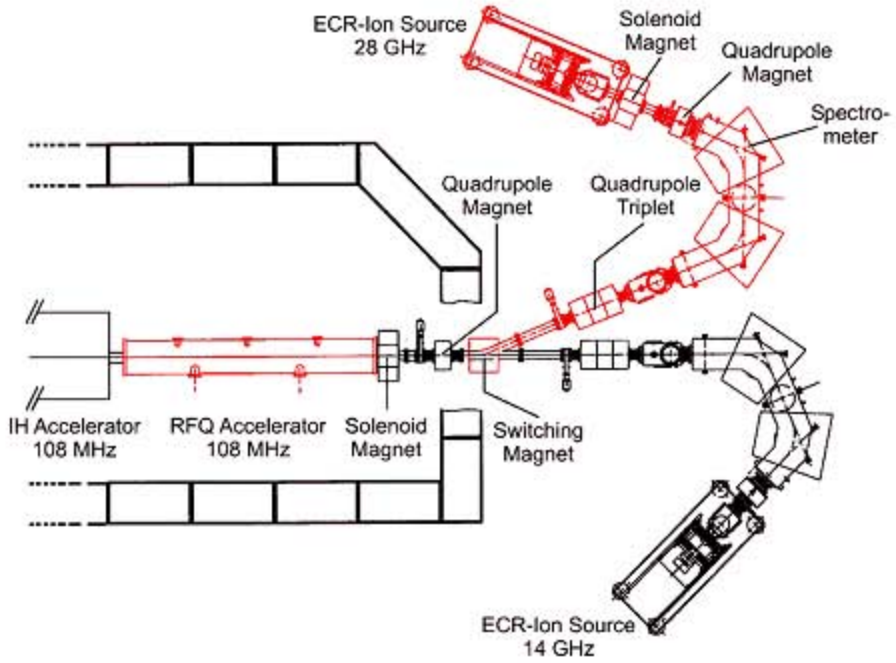
GAIN factor: 2 – 5

New RFQ Accelerator:

duty factor 25 % => 50 %
higher injection energy
higher acceptance

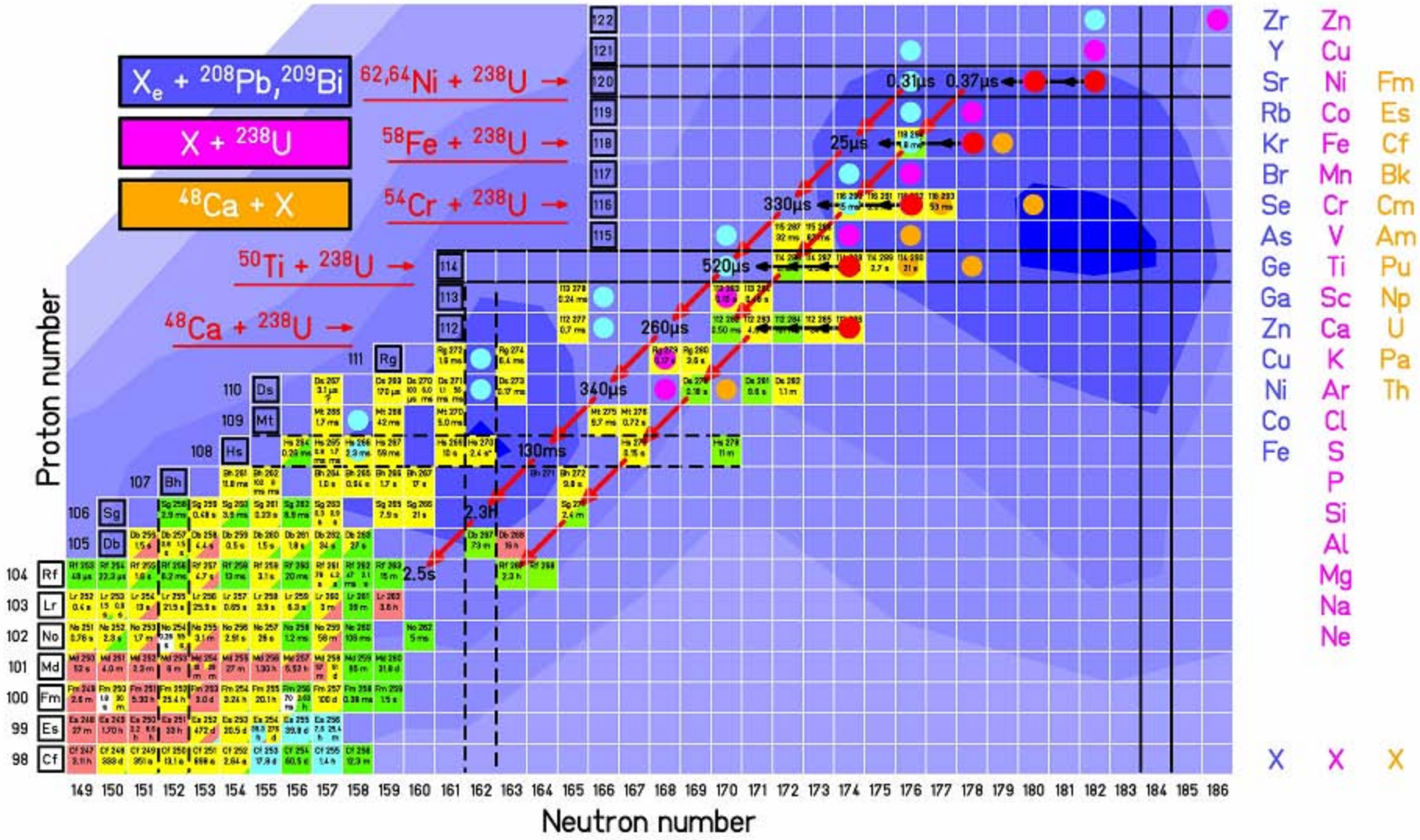
GAIN factor: ? 2





U. Ratzinger, K. Tinschert et al., 2004

Research plan and reactions to be studied



SHE Collaboration

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SHIP Spectroscopy Collaboration

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University of Leuven, Leuven (Belgium)
University of Manchester, Manchester (United Kingdom)
Institut de Physique Nucléaire d'Orsay, Orsay (France)
Japan Atomic Energy Agency, Tokai (Japan)
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Plus SHIPtrap collaboration