LIGHT SHAPE ISOMERS IN THE CCT CHANNEL?

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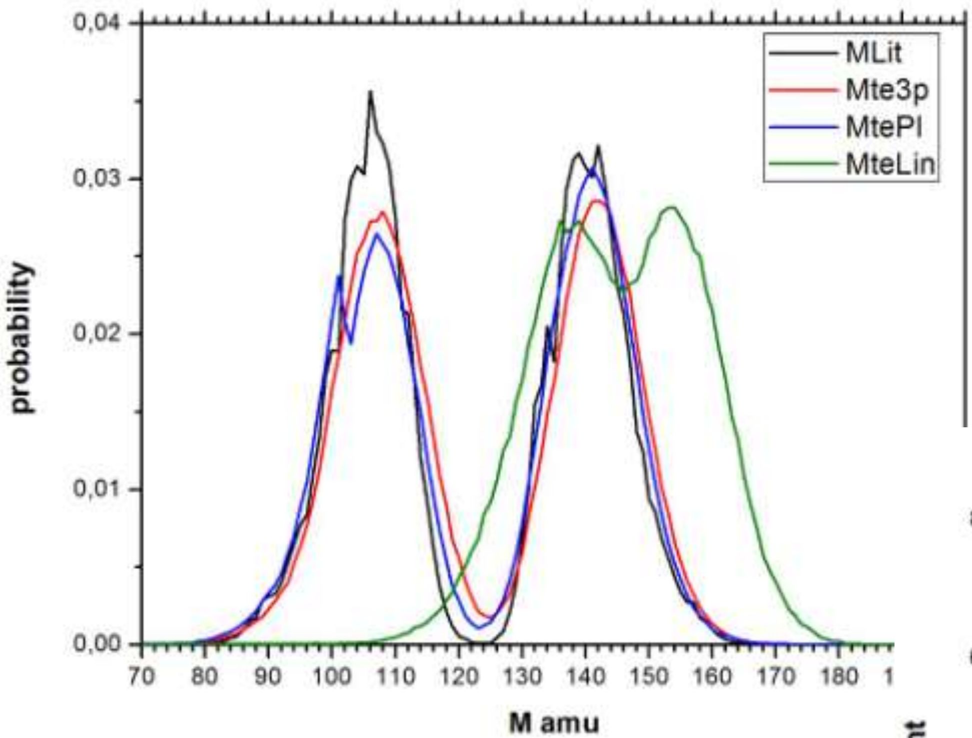
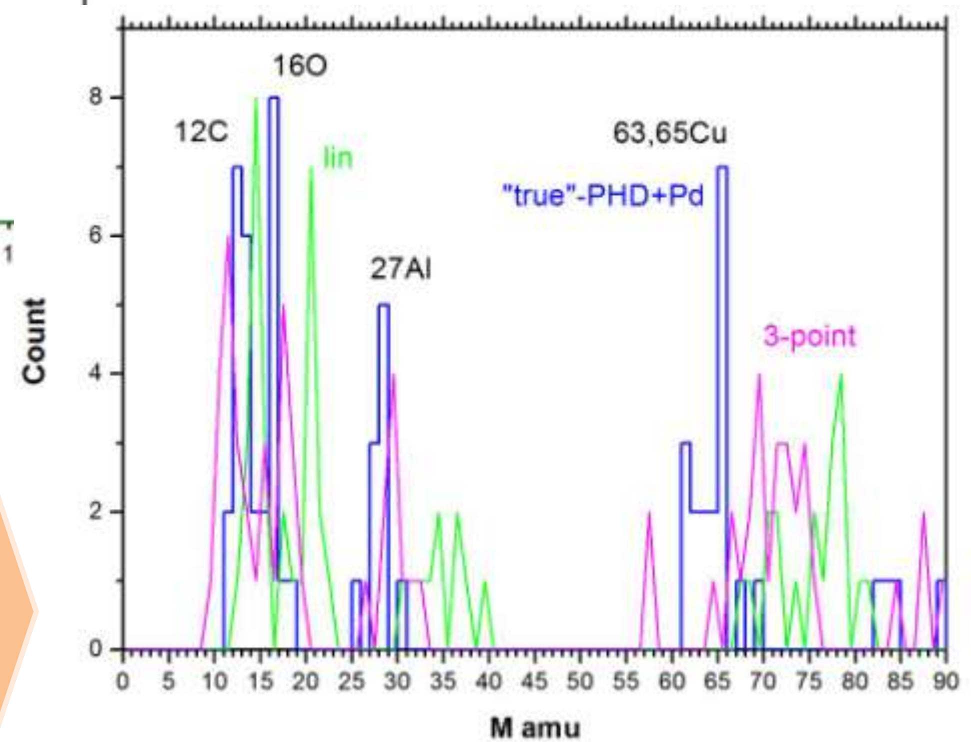
Comparison of different mass reconstruction procedures used at the COMETA setup



Welcome to the poster session!

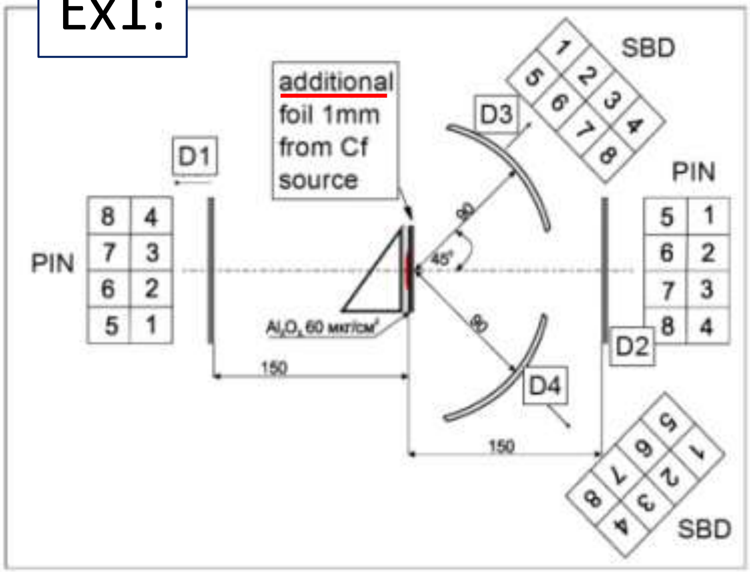


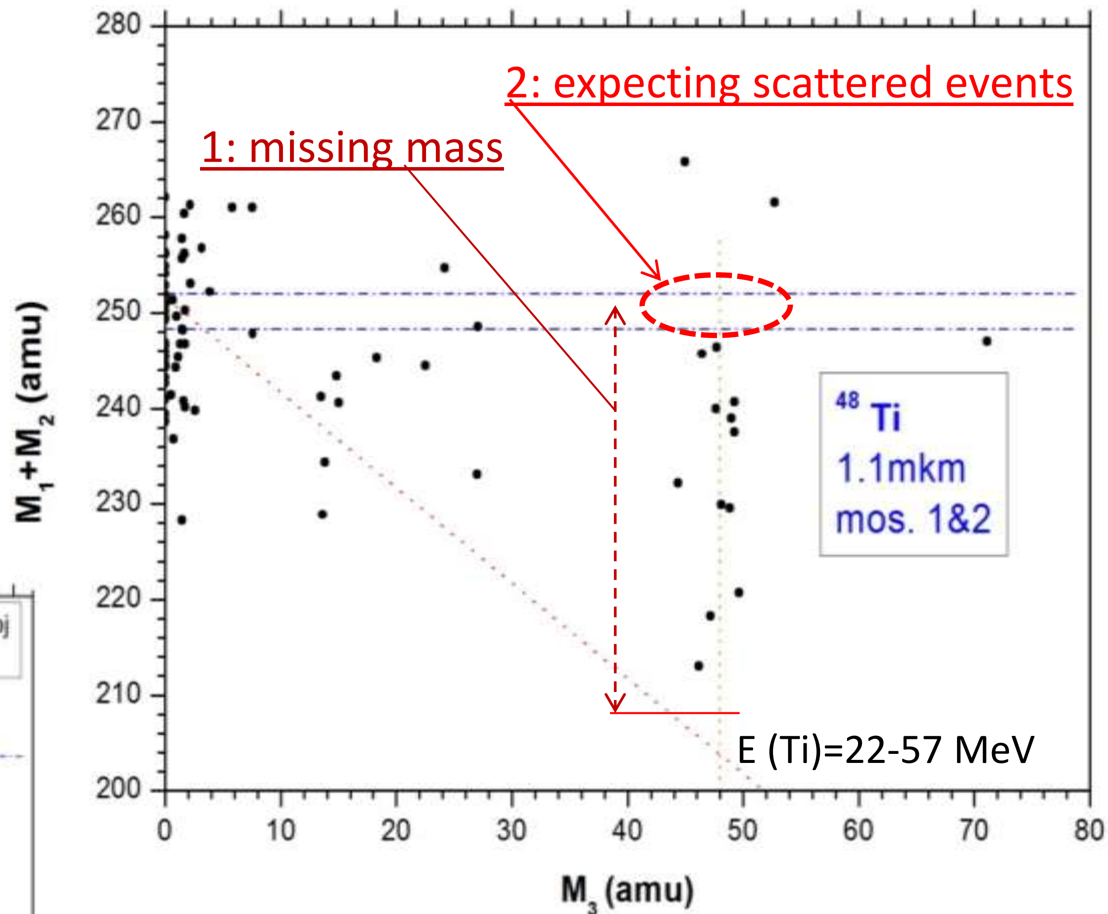
Calibrations compared:
-linear
-3point (suitable for the binary FFs)
-"true"(PHD+PD are taken into account)

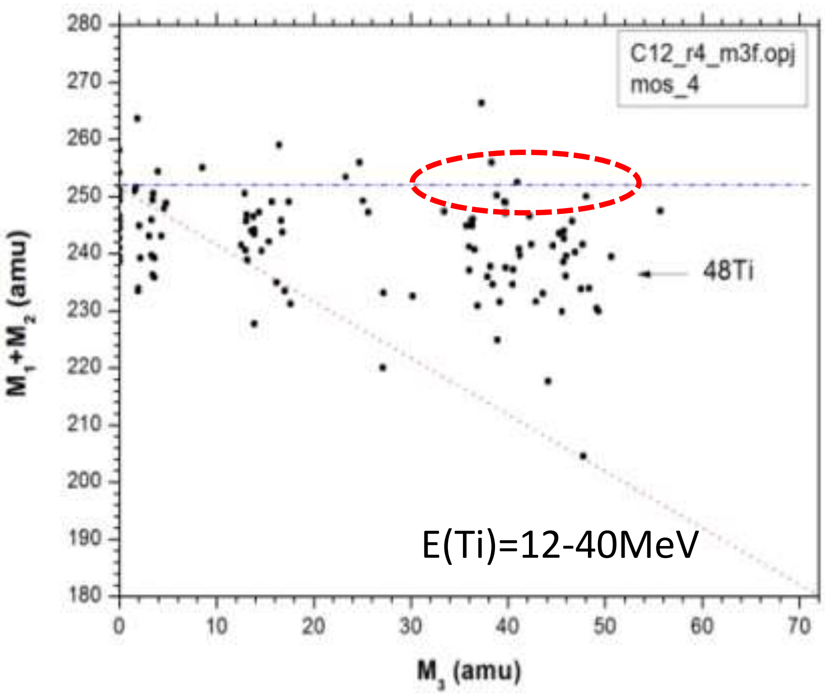
The most adequate in the wide mass range

Experimental results_1

Ex1:

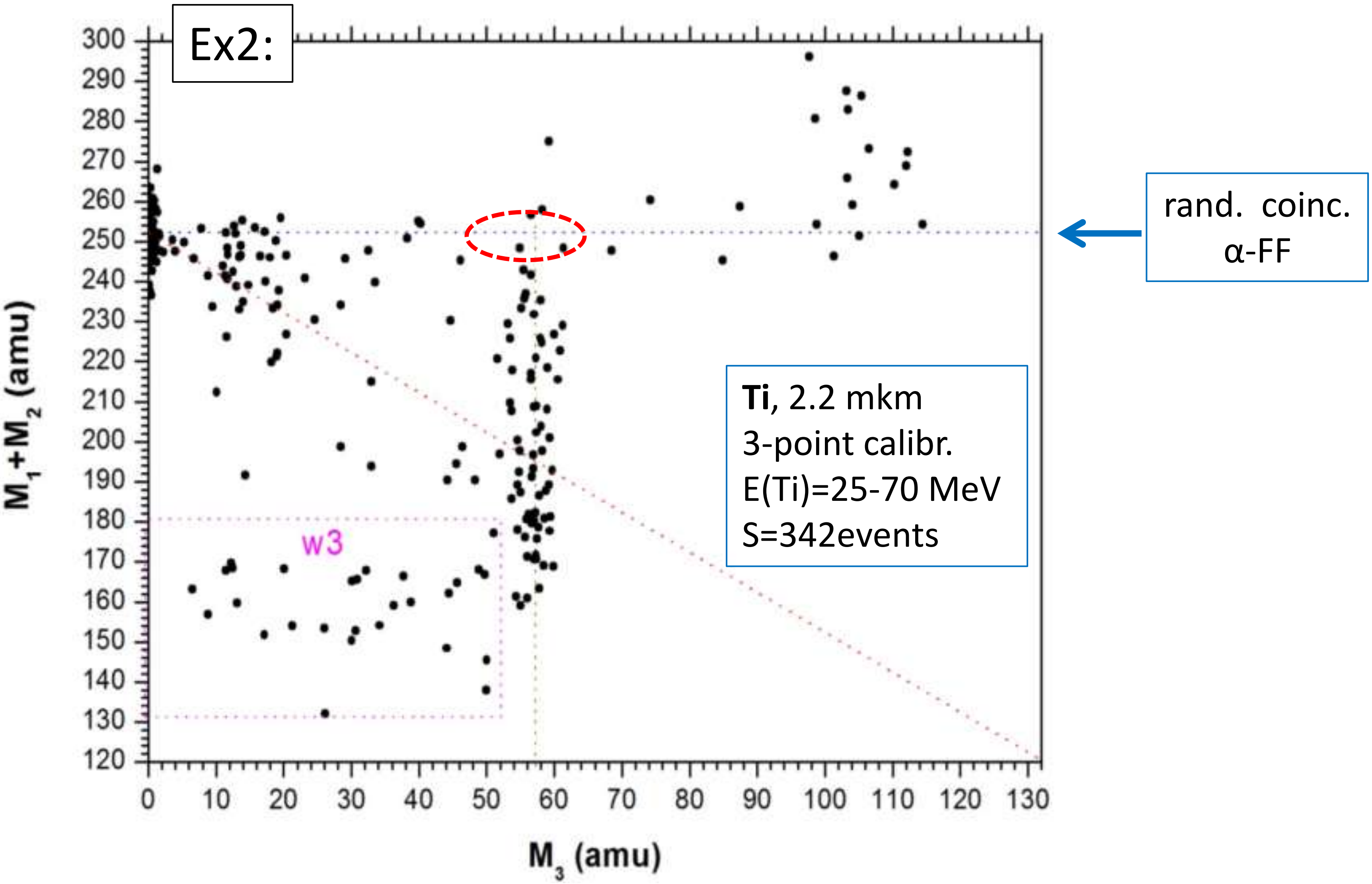






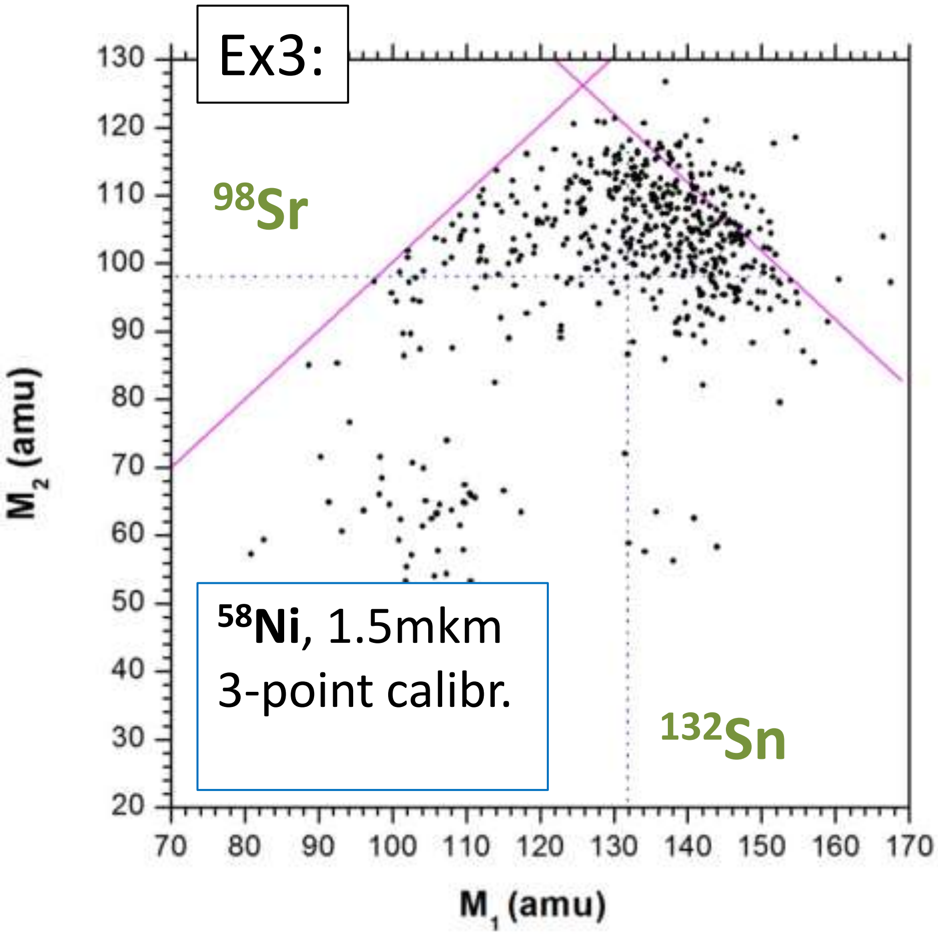
In each ternary event:
$M_1>M_2>M_3$

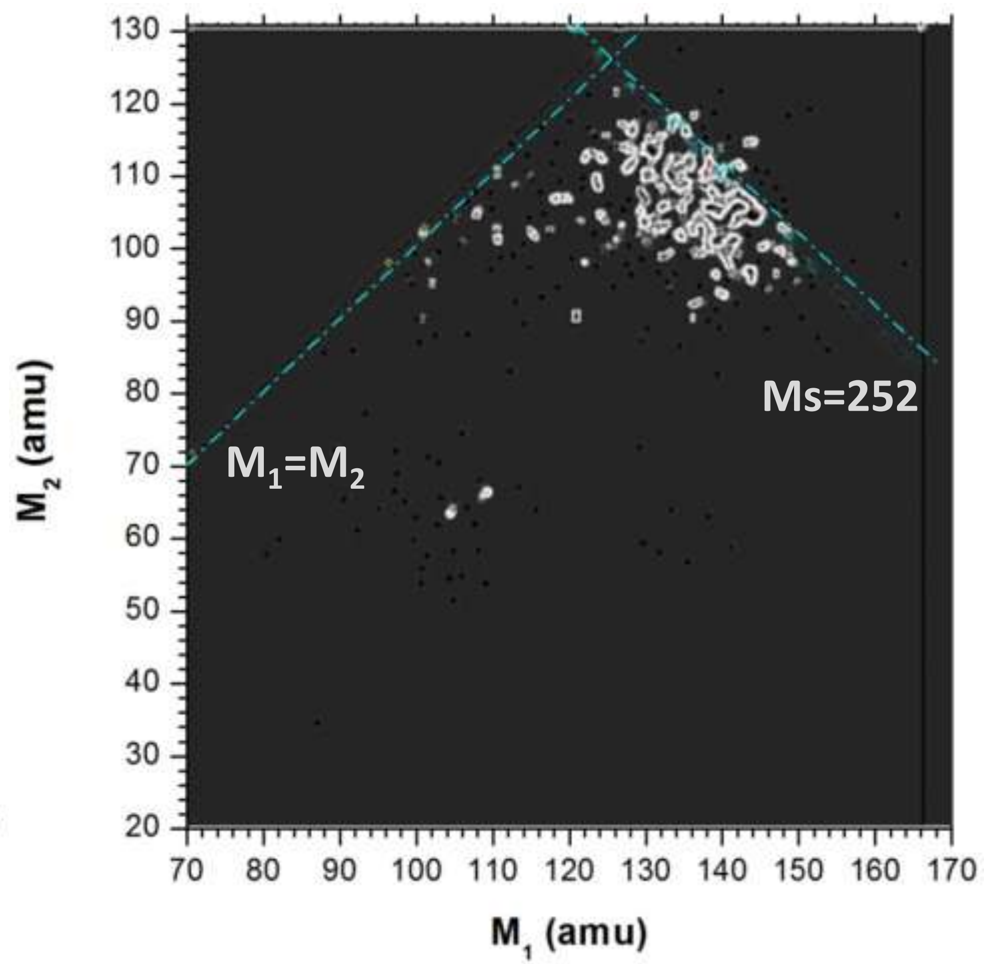
Experimental results_2



C12_r5 w1: n3_p3<30 (t.e. M3_3p in mos1&2) s=342 3p_calibr

Experimental results_3





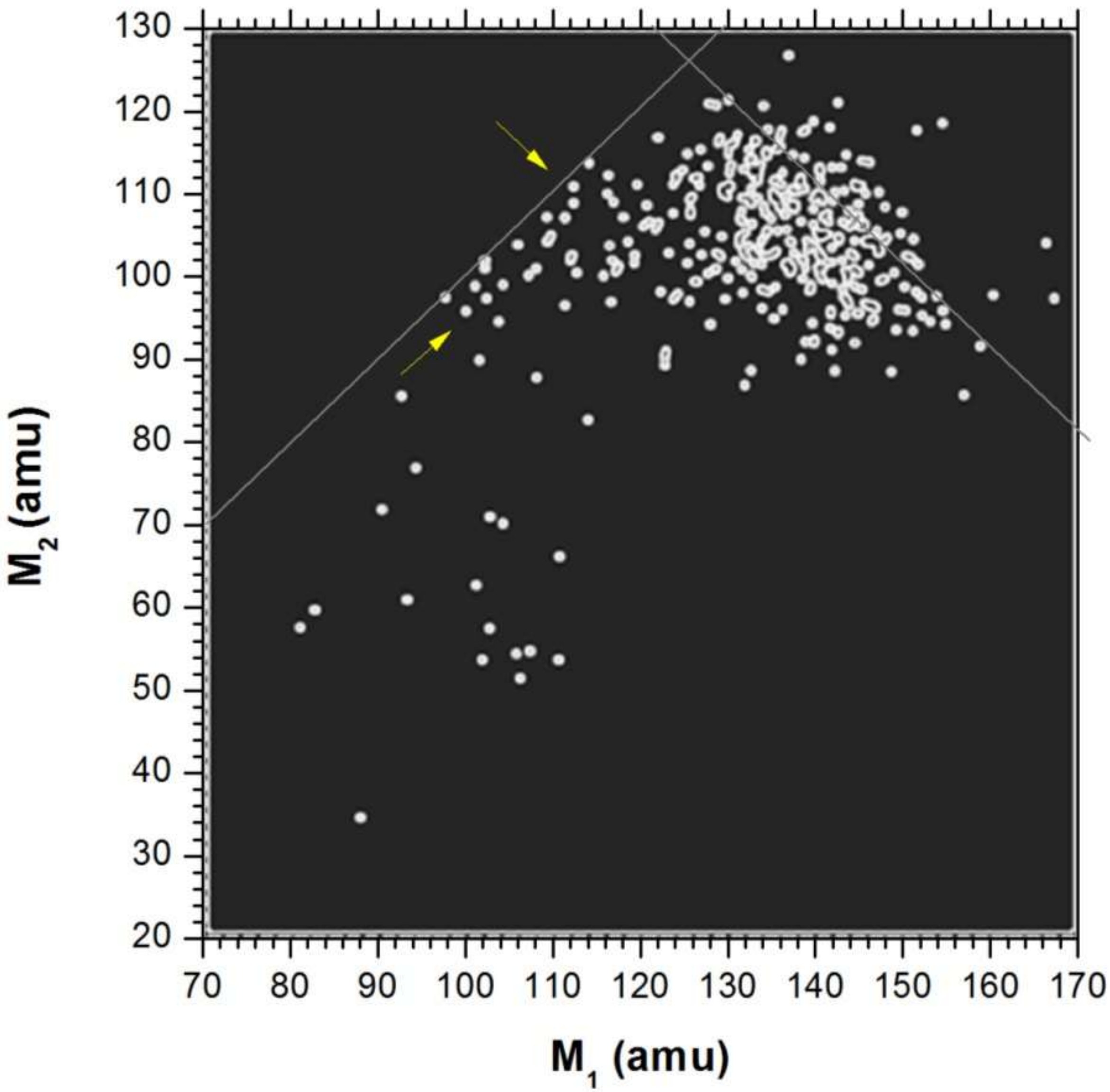
in coincidence with the scattered Ni ions

Special smoothing for revealing global structure

C12_r6_m3w7:M3lin =40-80 (Ni) all mosaics, 3p mass

art eff transper- 15% smoothness- 7%

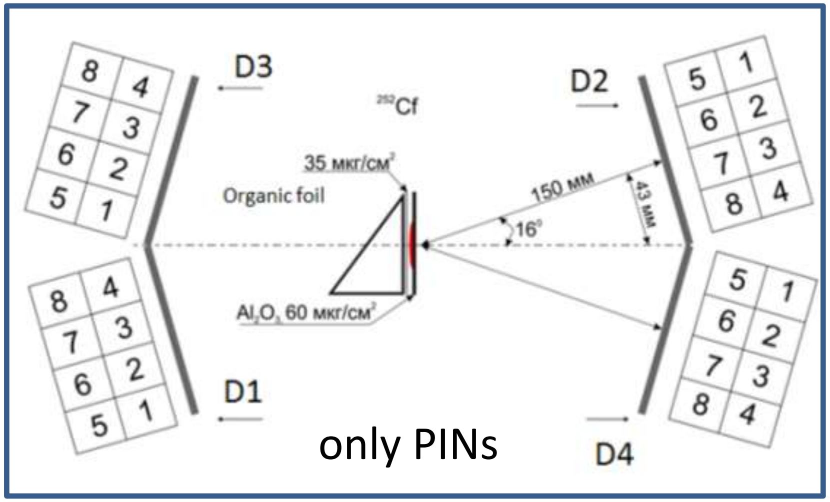
Experimental results_3, part2



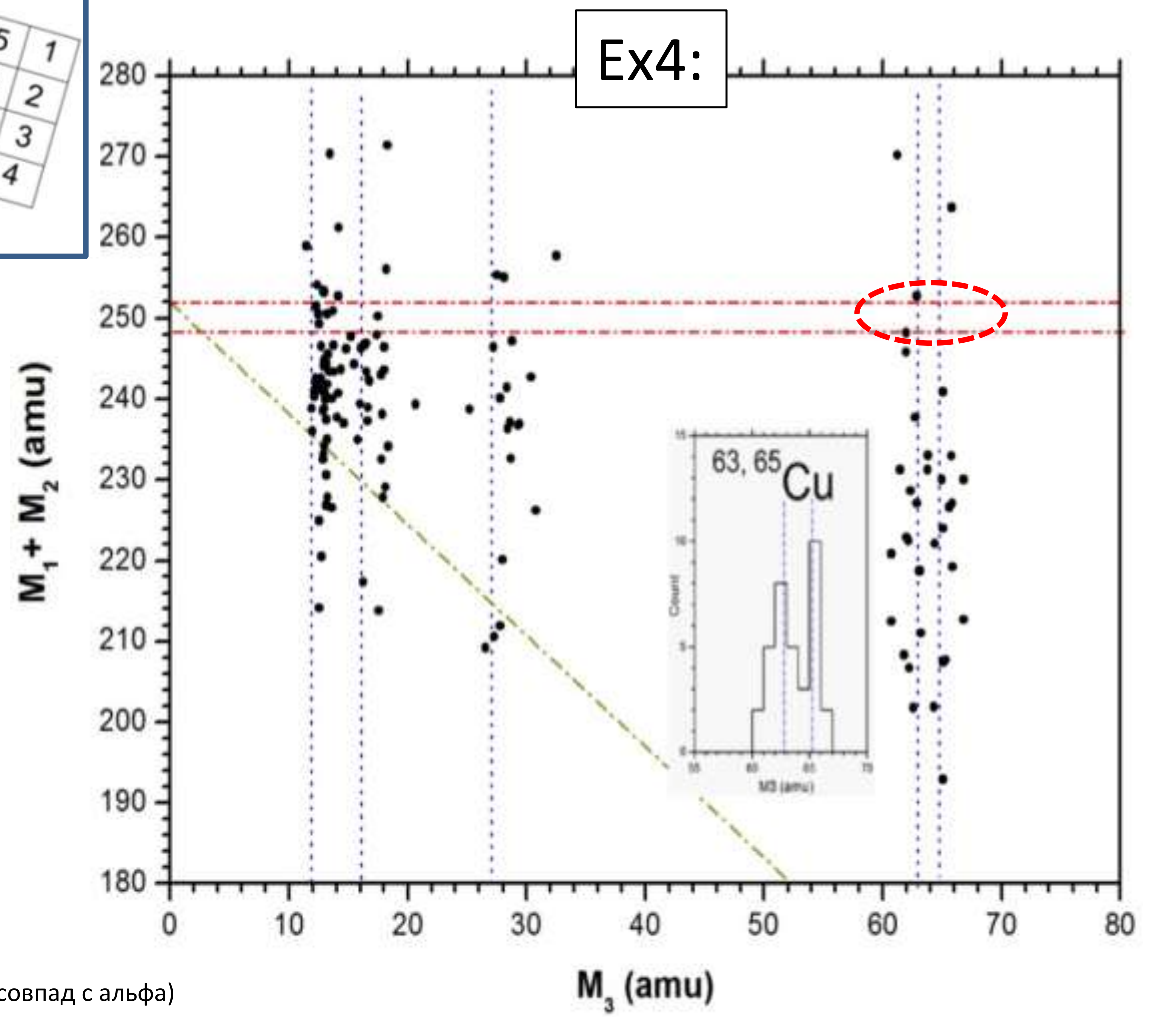
Observation of
regular linear &
rectangular
structures linked
with known magic nuclei-
Is an evidence of unbiased
calibration

artistic effects: transper- 15%, smoothness- 3%

Experimental results_4

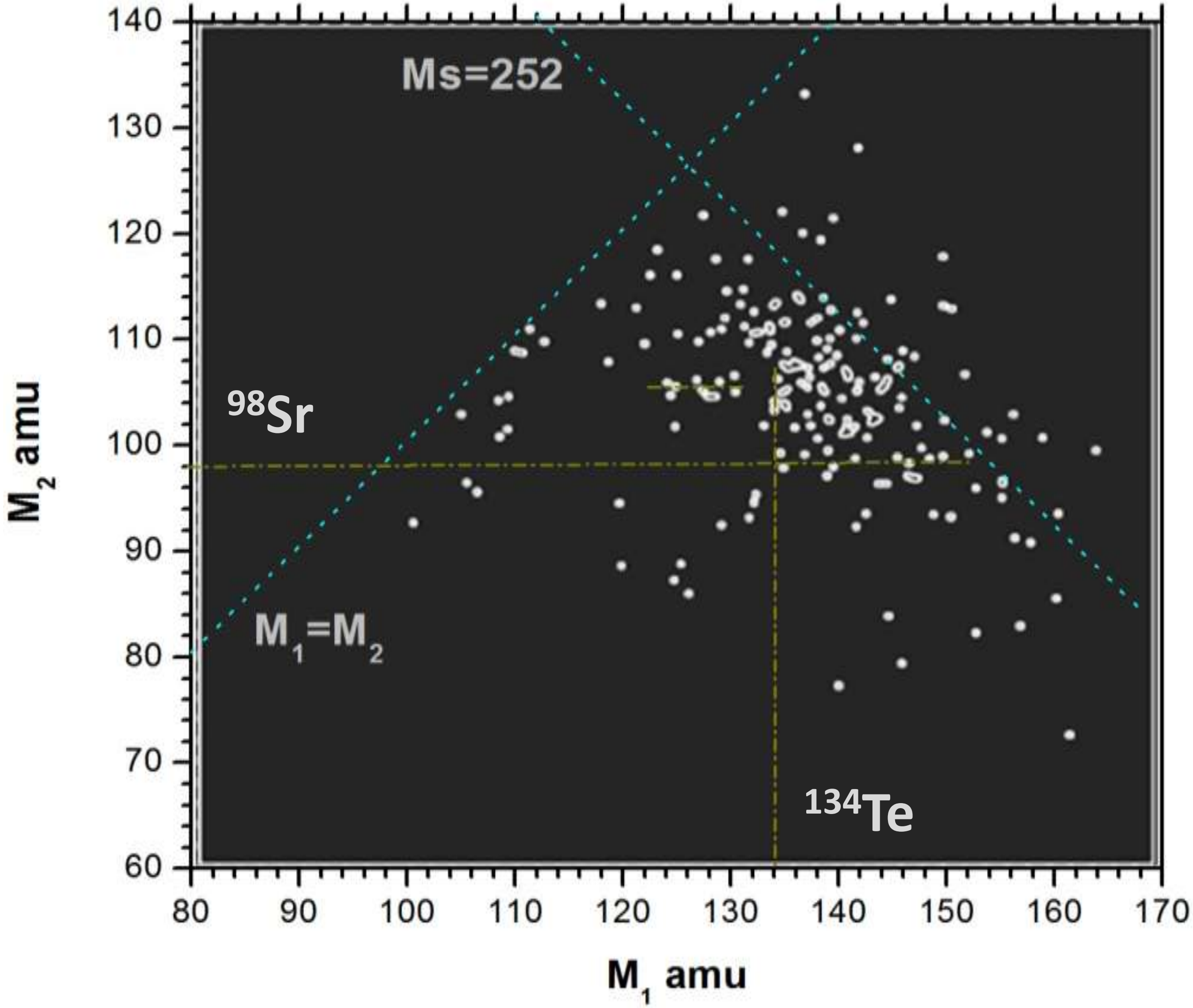


$^{63, 65}$**Cu**, 0.83 mkm
“true” calibr.
W: E3>9MeV



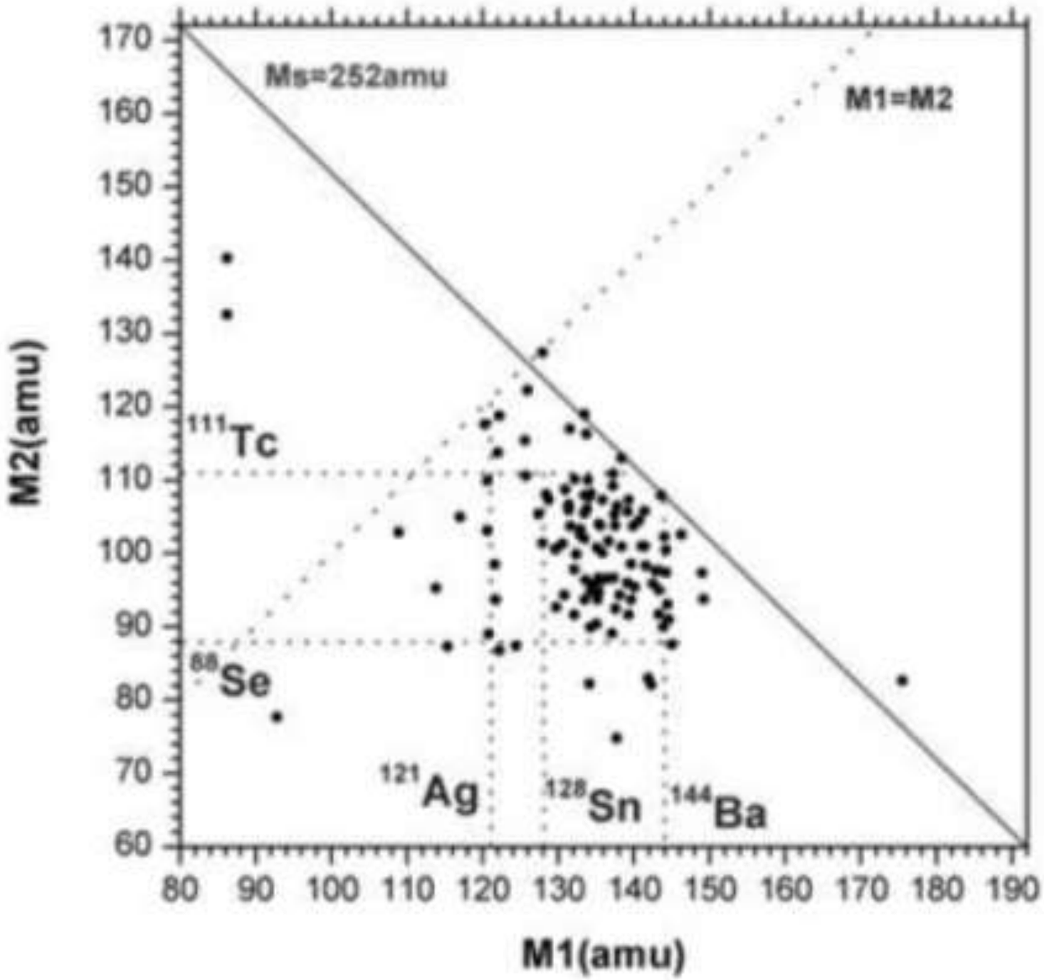
From C13_r2_m3_last.opj & w1: E3plz>9MeV (для устранения случ совпад с альфа)

Experimental results_4, part 2



Good agreement of the results in all 4 experiments with different foils

Previous experiments at the COMETA setup - only thin AL_2O_3 backing was in game

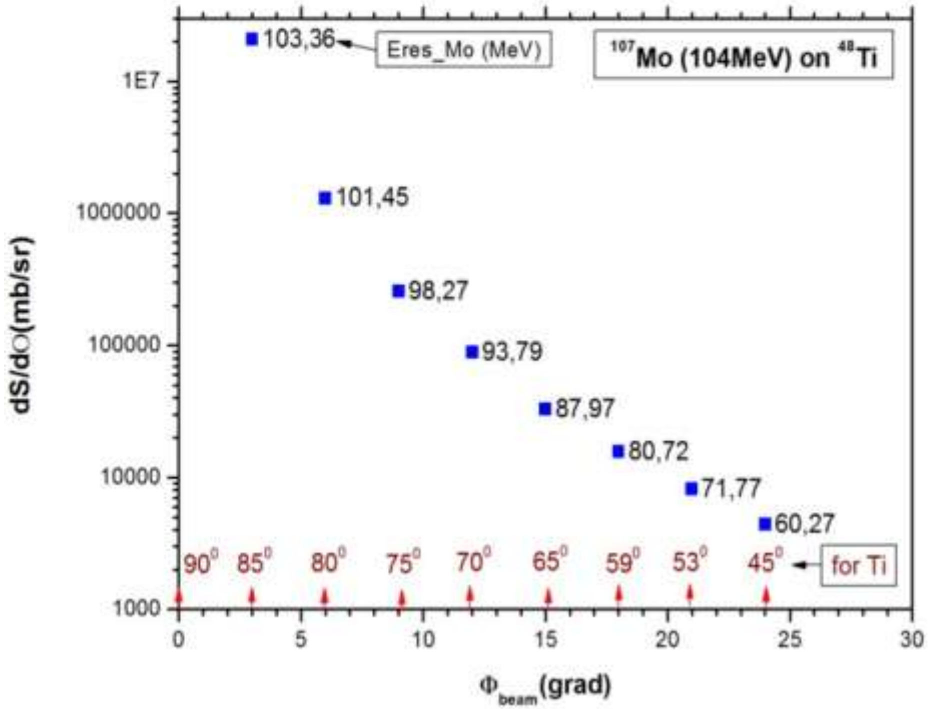


Similar structure of the M_1-M_2 plot for ternary events

Такое получилось в C10_r3_m3f.opj (folder: st_all –c big TOF3 – до этого Ж их резал) на COMETA – просто две мозаики с PINs (впервые использовался новый источник)

Rutherford scattering - L_FF/Ti

2 solutions are possible: the same scattering angle at two different impact parameters



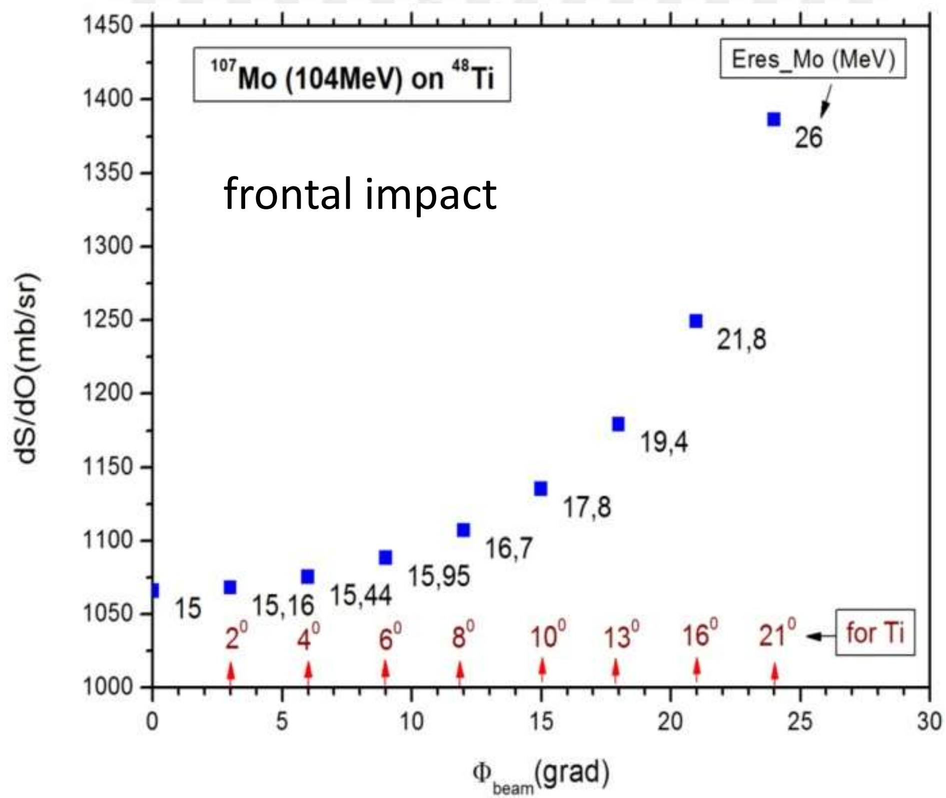
$$\sigma(\theta) = \left(\frac{1}{4\pi\varepsilon_0}\right)^2 \frac{Z^2 e^4}{M^2 v^4} \times \frac{1}{\sin^4(\theta/2)}$$

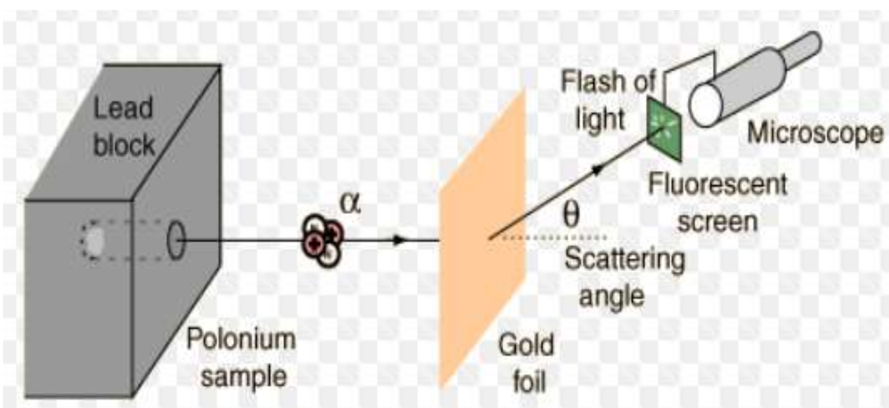
Ze = the positive charge of the target atom,

M = the mass of the α particle,

v = incident speed of the α particle,

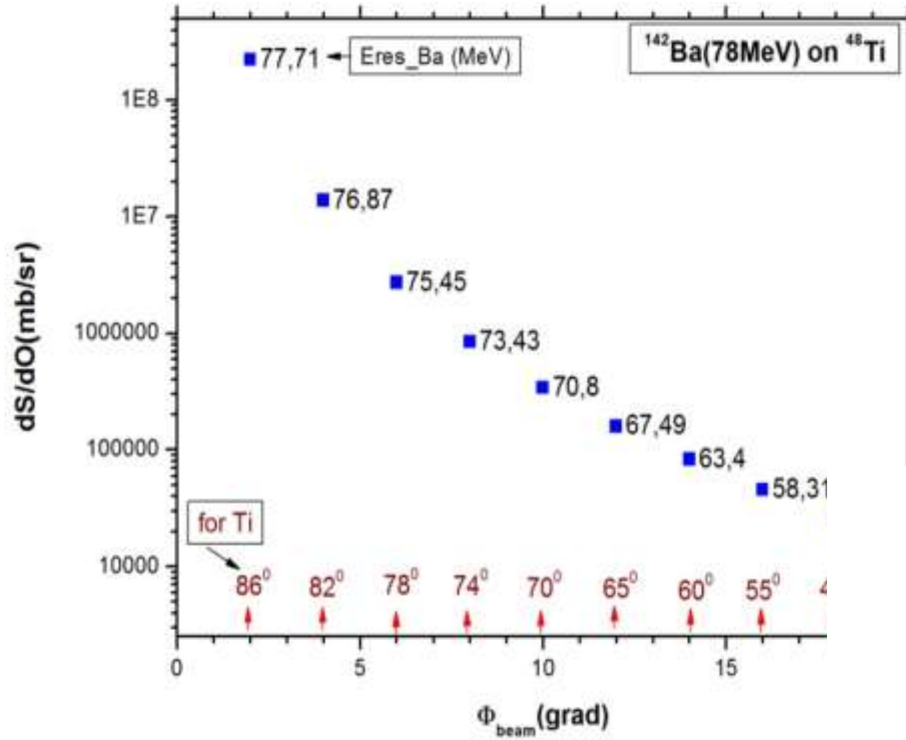
θ = scattering angle,



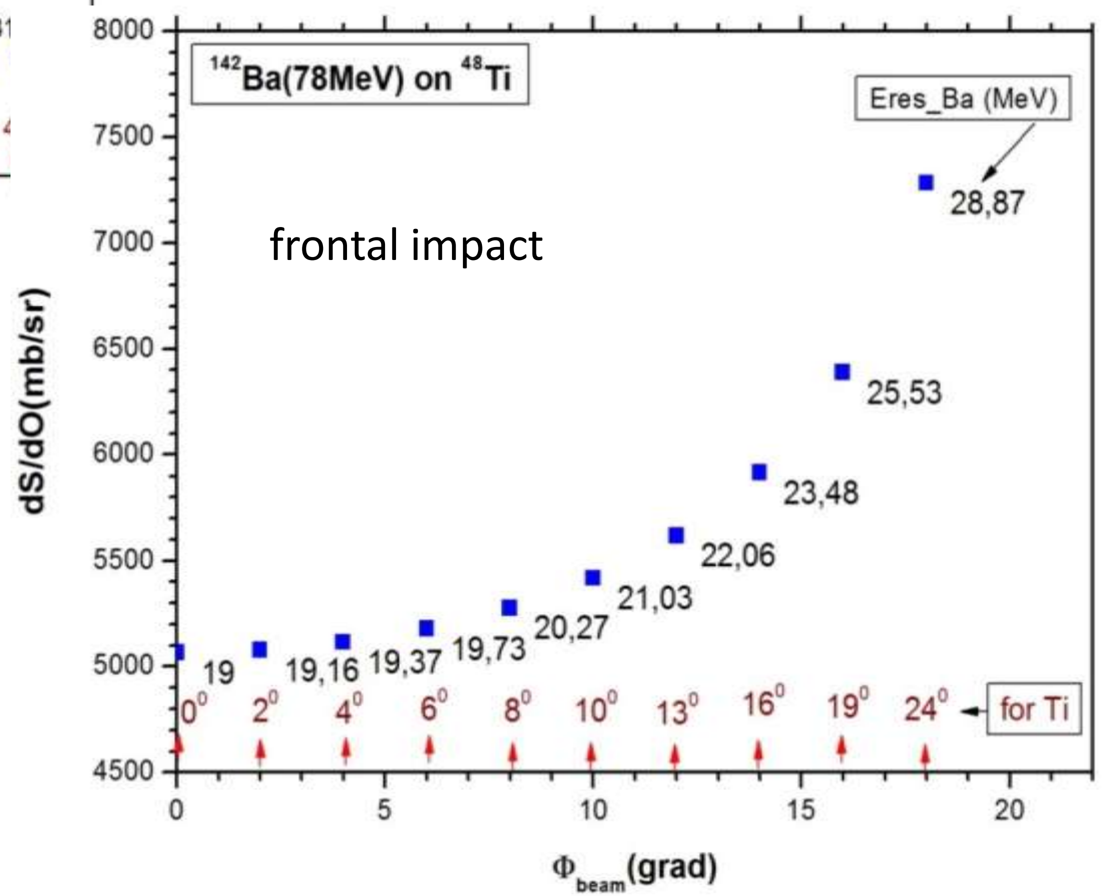


Original Rutherford experiment

Rutherford scattering – H_FF/Ti



Both the experimental geometry and energies of the knocked –out Ions give evidence that we deal with this brunch of the scattering process



Intermediate conclusions.
Presumably:

1. Inelastic impact, at least the frontal one, makes free the constituents of the di-nuclear system (fission fragment) formed in the binary fission .

2. Bearing in mind the distance between the Cf source and the generating foil (~1mm) the lower limit of the life-time of this di-nuclear system (shape isomer) is about 0.1ns.

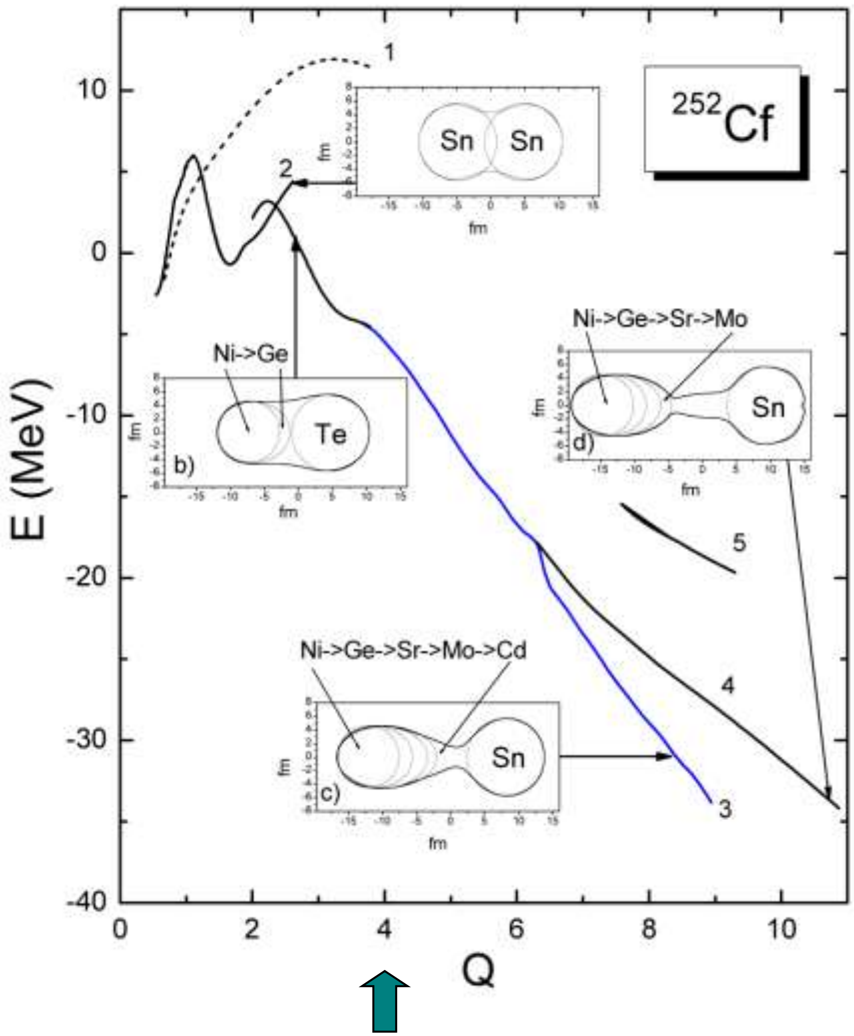
3. Relative probability of elastic Rutherford scattering of fission fragments i.e. taking place without missing mass is much less then those in the inelastic channel. In other words, **the bulk of the fragments from the conventional binary fission are born as shape-isomers .**

Discussion

Fission fragment from the conventional binary fission as a di-nuclear system:

- scenario of forming
- scenario of the decay

FF as a di-nuclear system – possible scenario of forming



Yu.V. Pyatkov, V.V. Pashkevich, Yu.E. Penionzhkevich et al.,
Nucl. Phys. A 624 (1997) 140

Double- magic- cluster structure of the fissioning system:

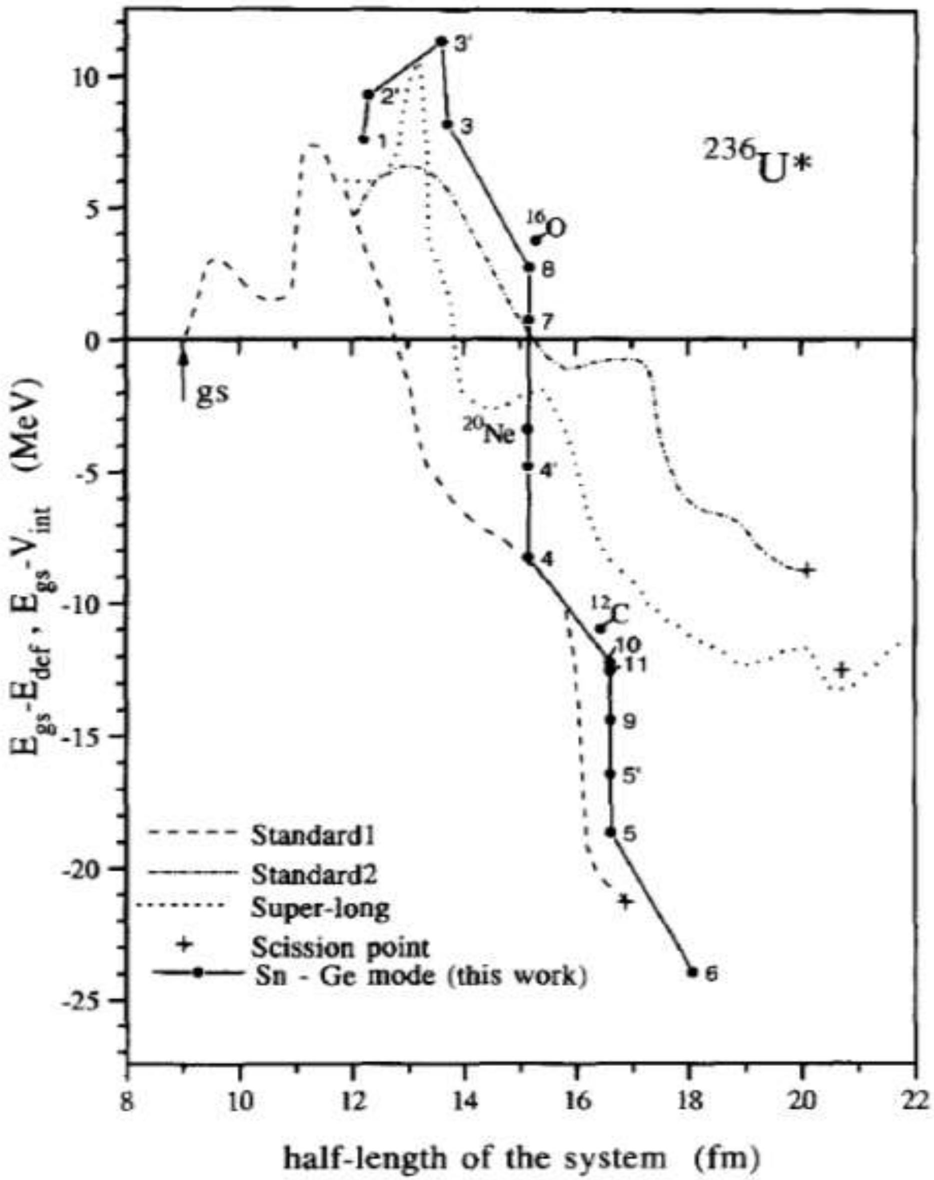
V.V. Vladimirski, JETP (USSR) 5 (1957) 673

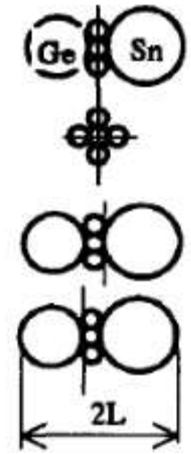
S.L. Whetstone, Phys. Rev. 114 (1959) 581

. . .

I.Tsekanovich,
H.-O.Denschlag, M.Davi,
Z. Büyükmumcu,
F. Gönnenwein, S Oberstedt,
H.R. Faust
Nucl. Phys. A 688 (2001) 633

FF as a di-nuclear system – possible scenario of forming





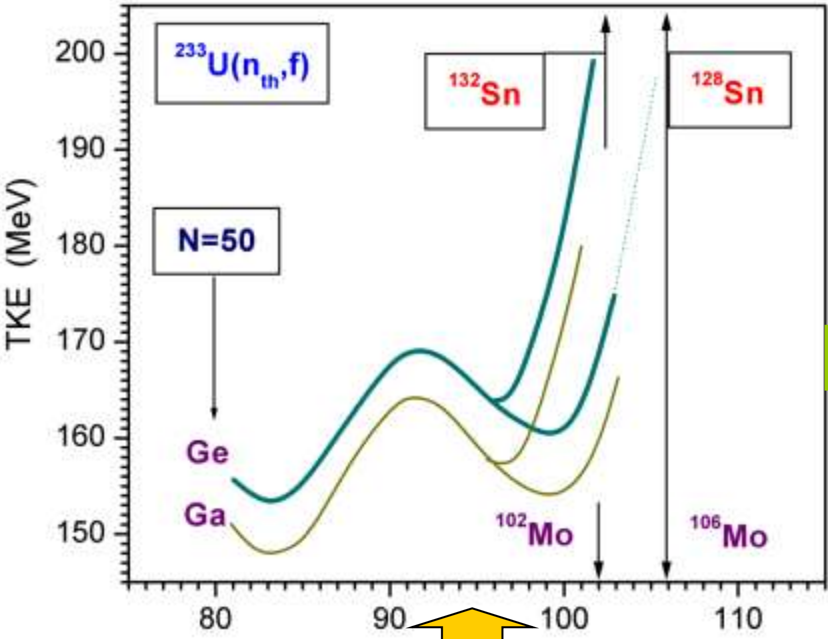
Initial configuration
Of the fission mode
Based on Sn & Ge clusters

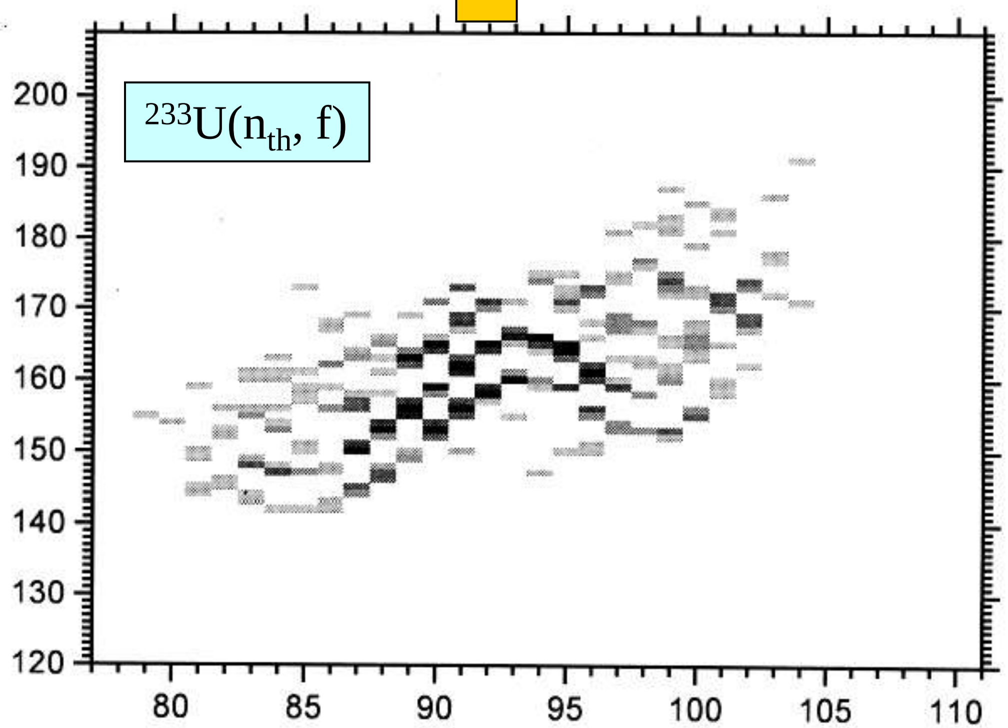
Two magic clusters namely, light & heavy give rise to fission mode while the neck is also clusterised consisting of LCP

Yu.V. Pyatkov, G.G. Adamian,

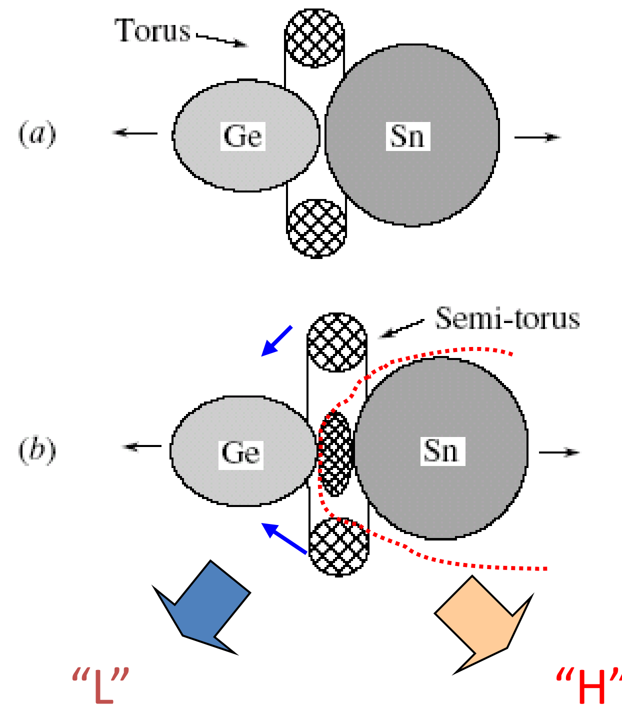
N.V. Antonenko et al.,

Nucl. Phys. A 611 (1996) 355





FF as a di-nuclear system – possible scenario of forming

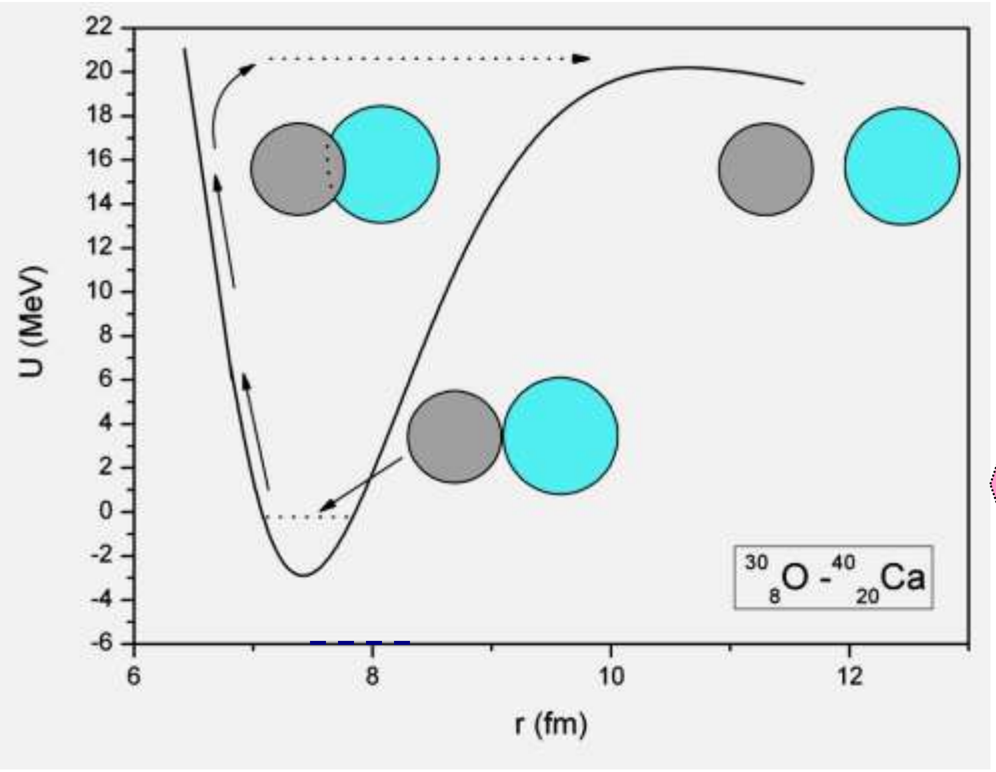


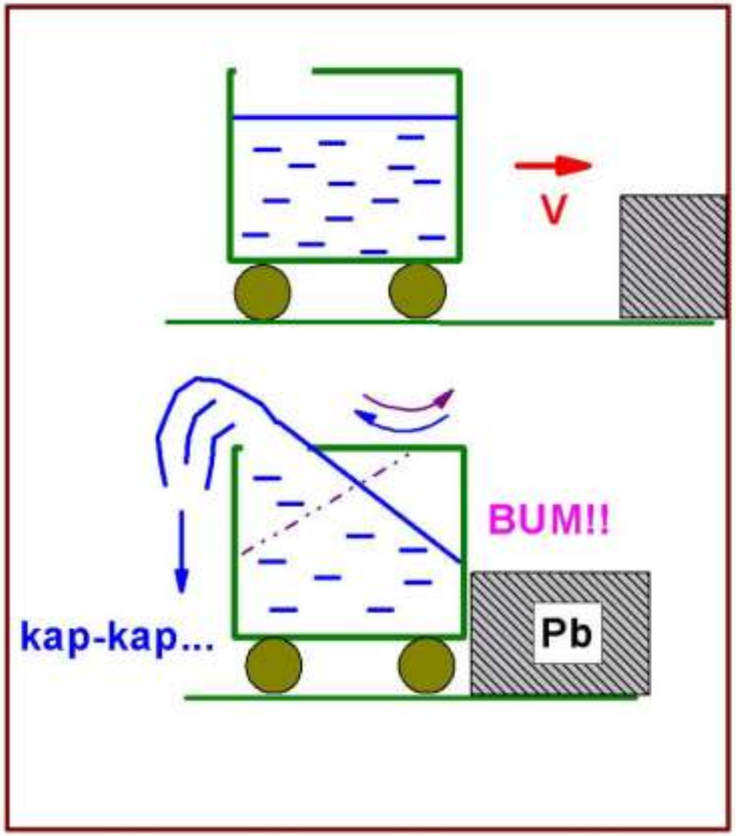
Presumable shapes of the fissioning system in the framework of Ge-Sn fission mode for:

The most compact configuration (a), some grater elongation (b)

Yu. V. Pyatkov, V.V .Pashkevich, W. H. Trzaska et al., ***Physics of Atomic Nuclei, V. 67(2004) 1726***

A possible way of decaying of di-nuclear system





Different inertia of the partners in the frontal impact could be the reason of their scission.

naive illustration of an inertial effect

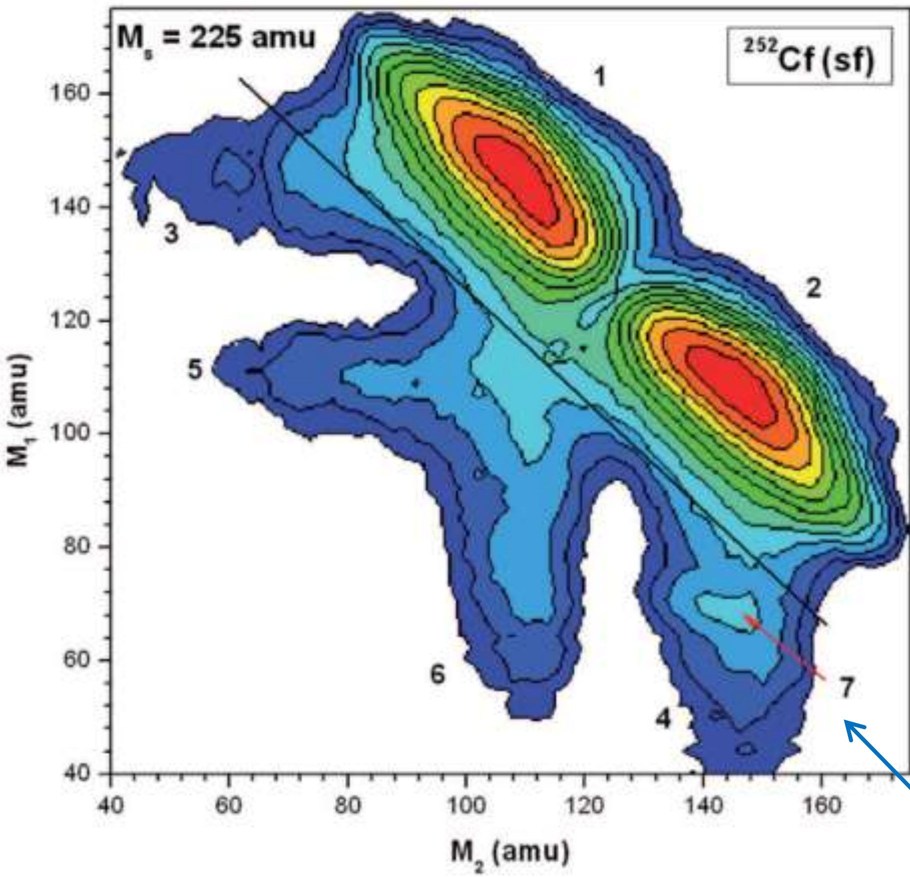
likely to be decisive for decaying of a nuclear molecule

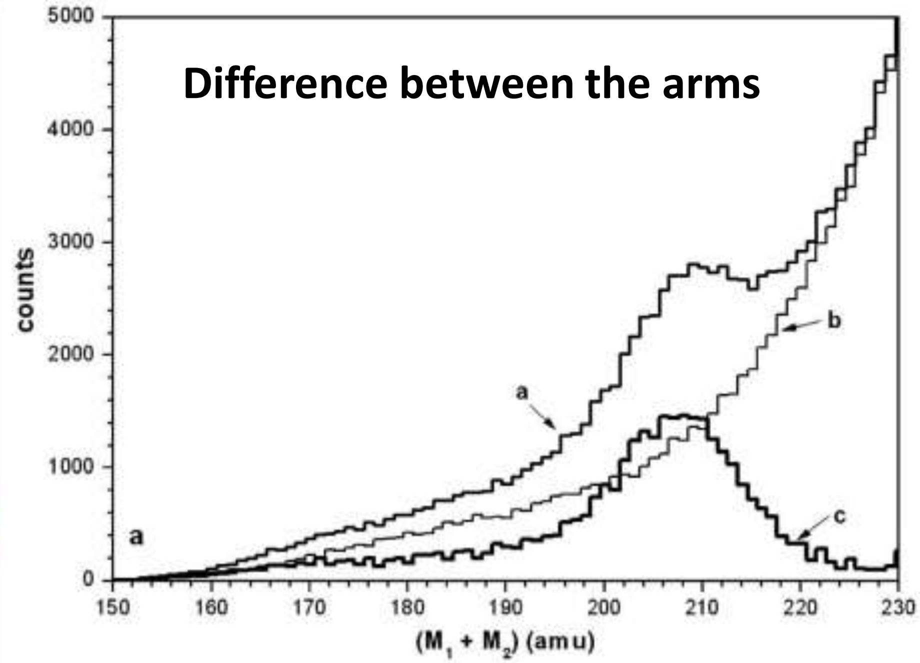
Discussion

CCT mechanism in the light of the results presented above:

inelastic impact is not exclusive channel of producing ternary events!

Initial manifestation of the CCT

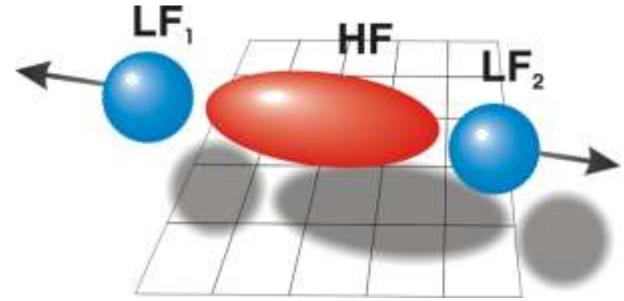




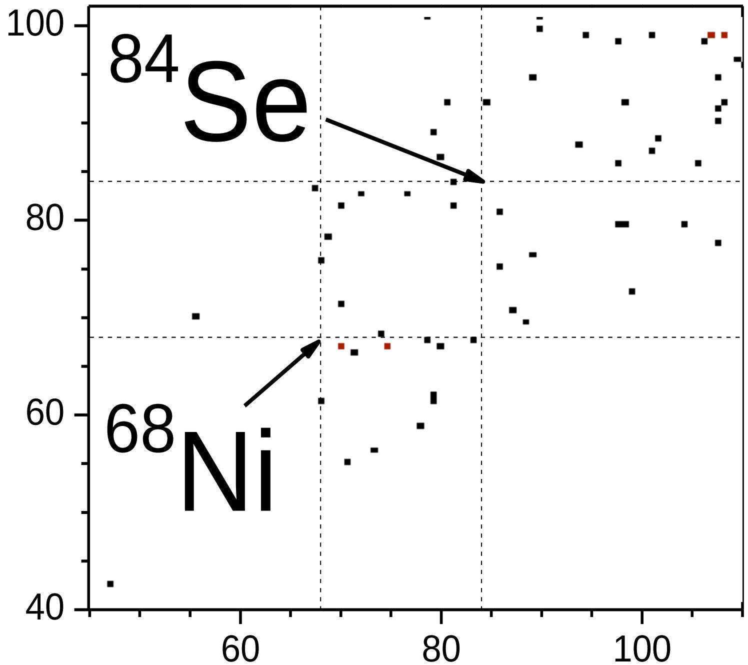
Effect is seen
in the arm from
the side of scattering
foil only.
Thus, it is due to
scattering in any cense

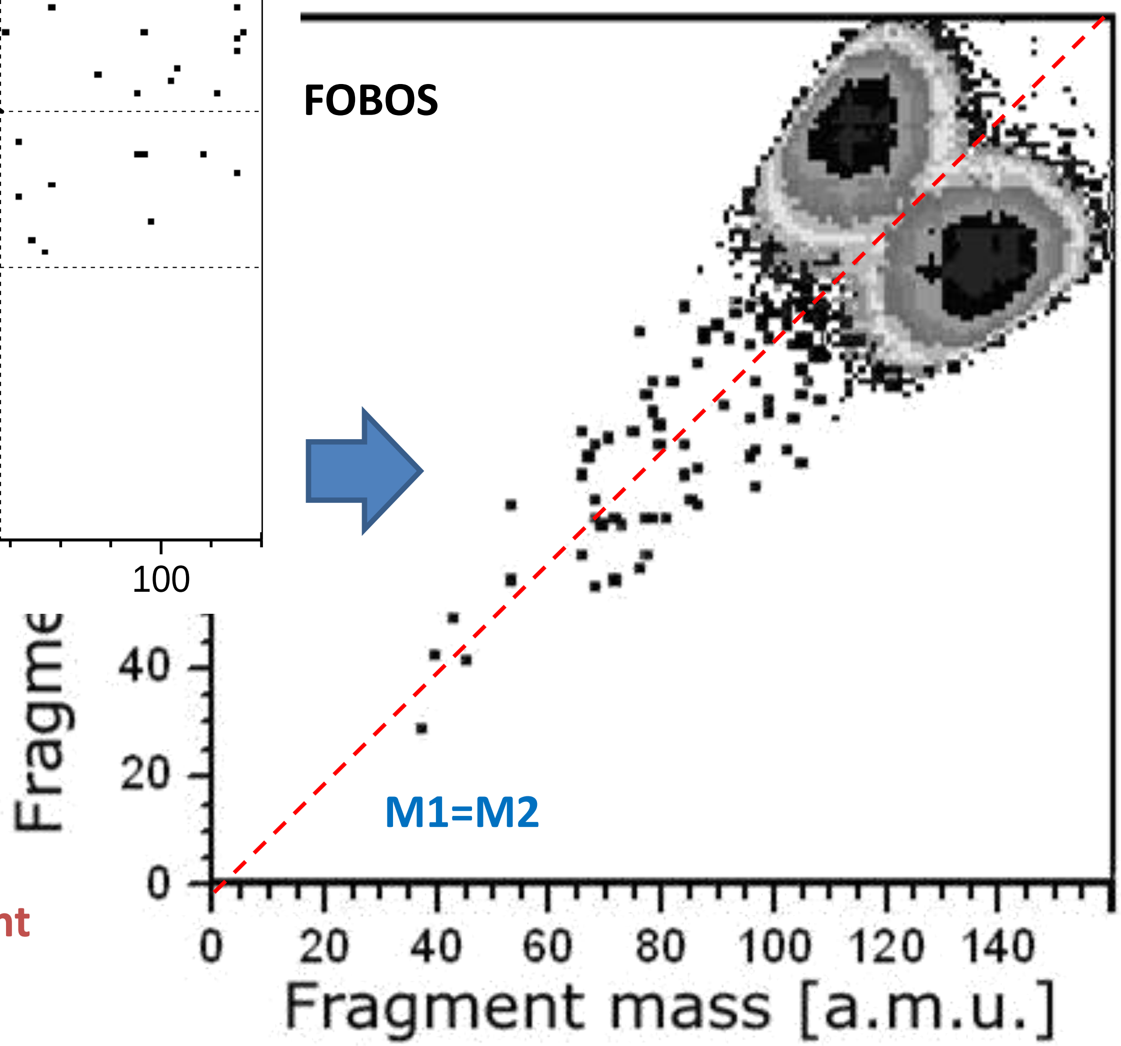
Yu. Pyatkov et al., Eur. Phys. J. A 45, 29–37 (2010)

Structures symmetric to the arms



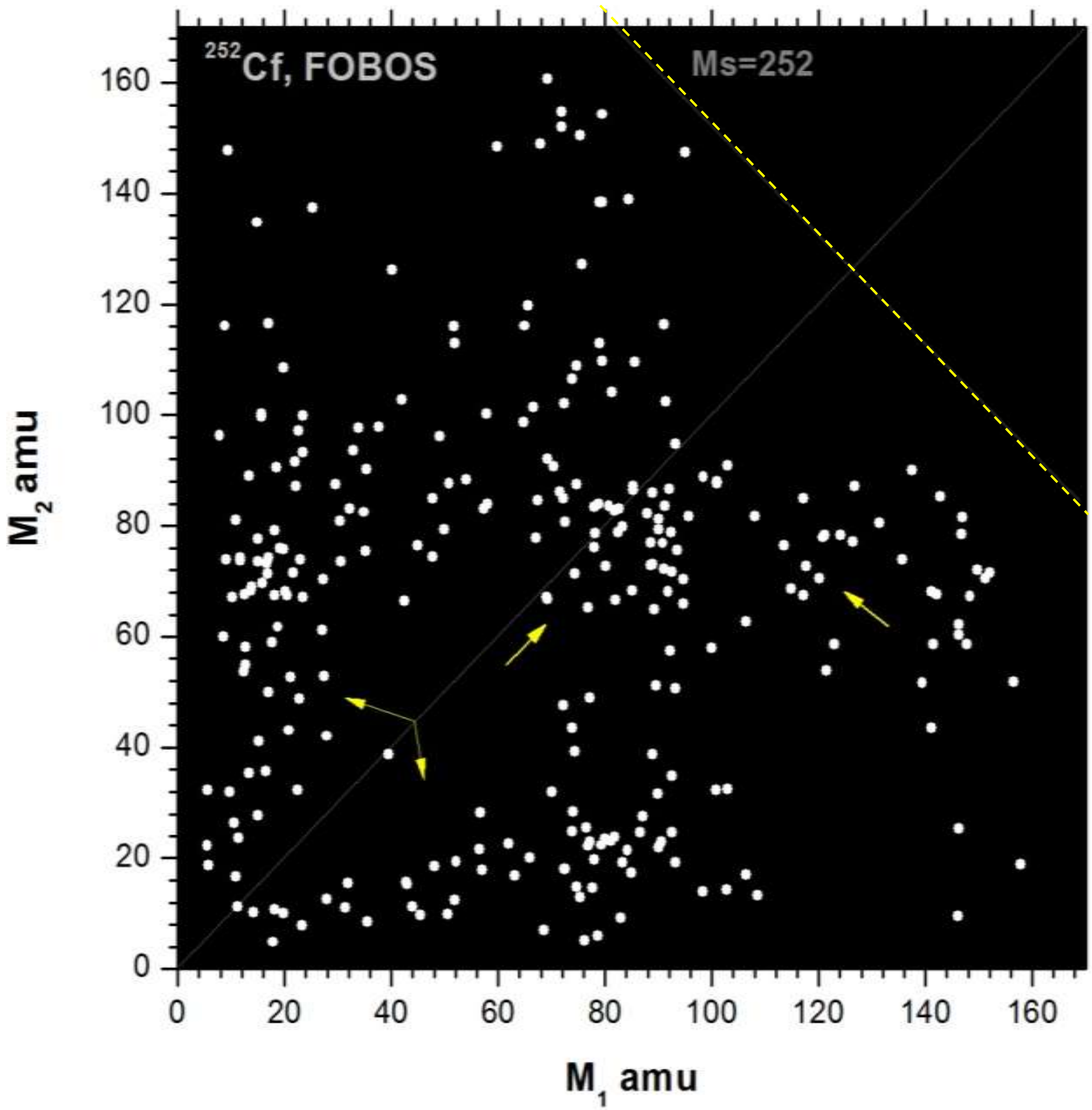
Individual modes / structures
with equal velocity/momentum window





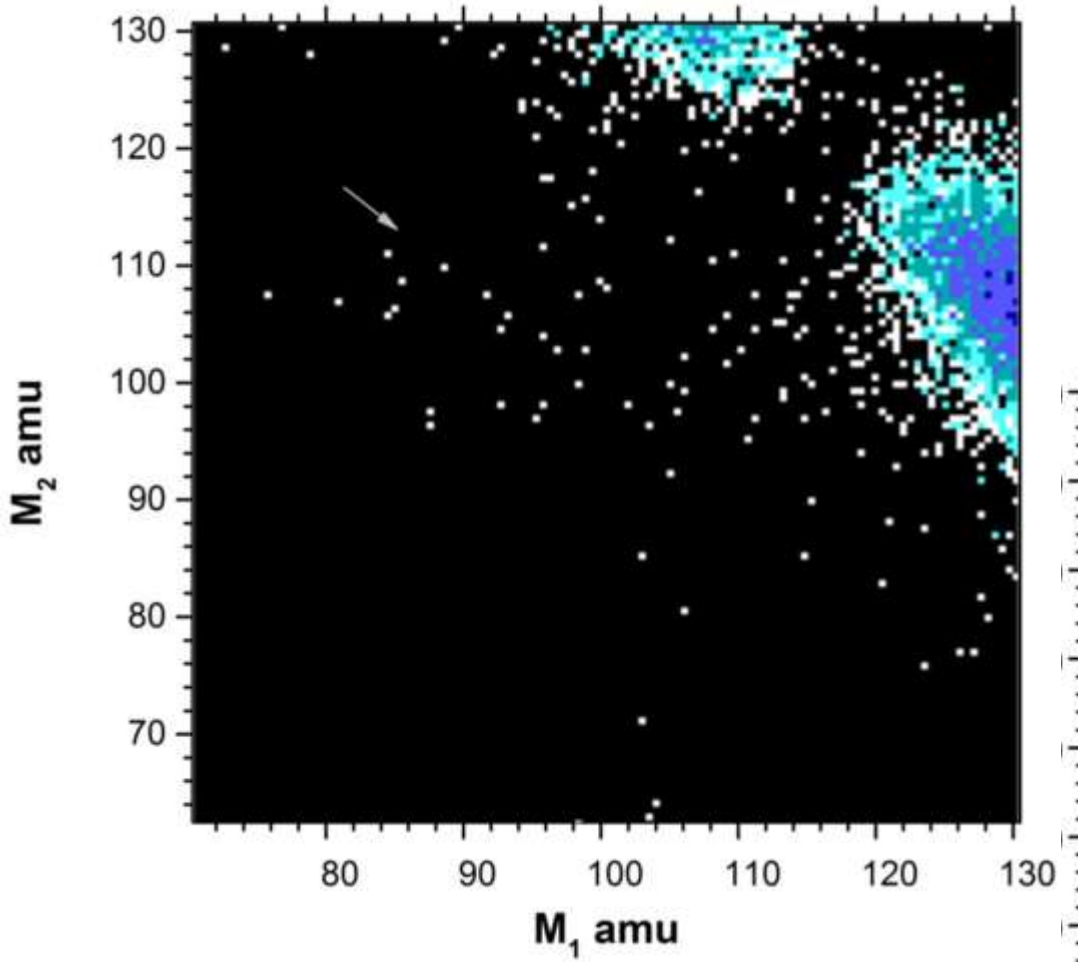
Vice versa:
structures symmetric
to the arms are independent
from the scattering

Structures symmetric to the arms

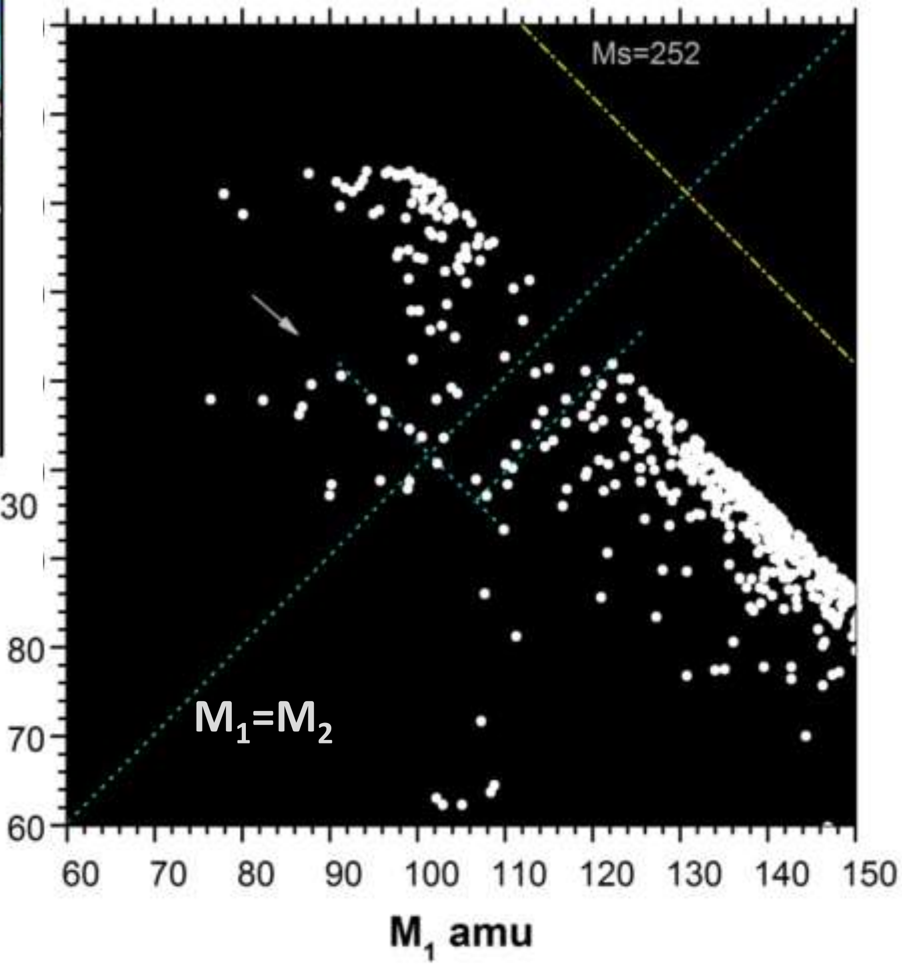


n=1
&
momentum
box

Structures symmetric to the arms



COMETA, Cu foil, n=1

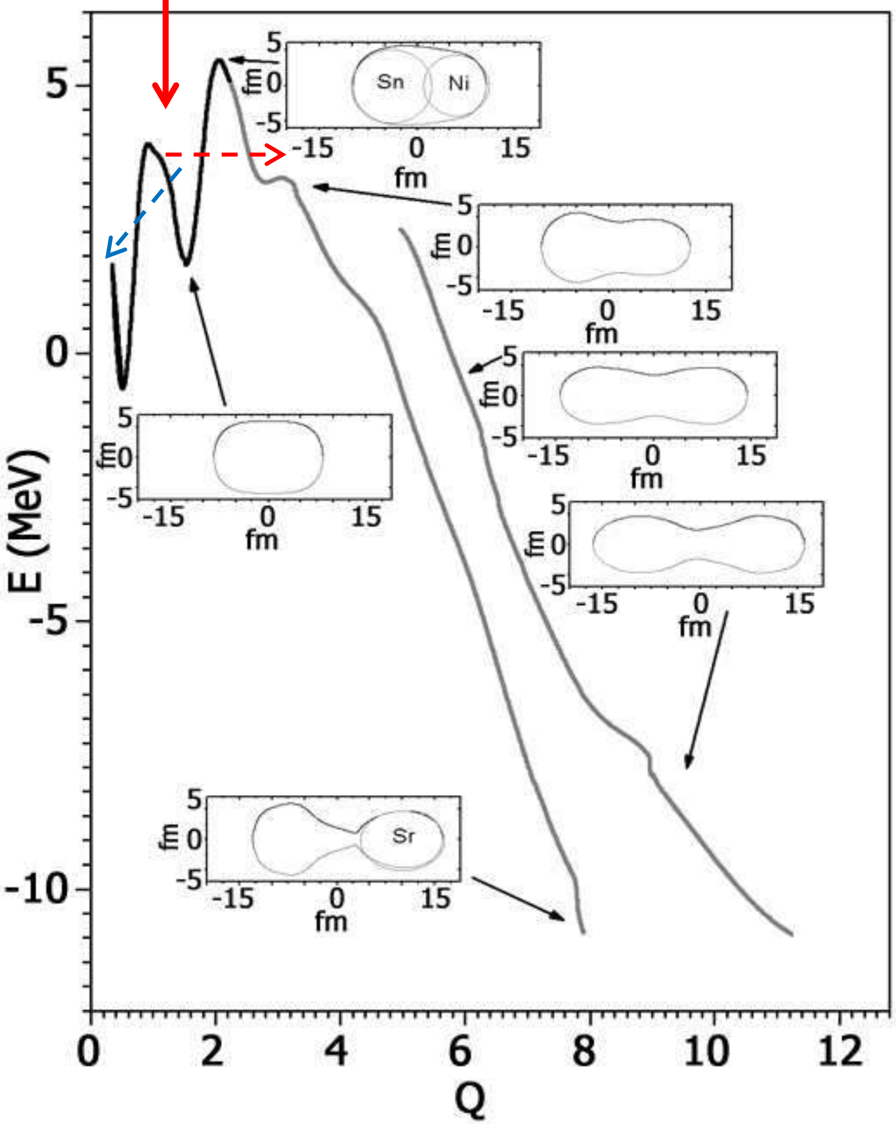


Missing mass ~50amu

Shape isomers: short review

SIS in heavy nuclei

Shape isomer state (**SIS**) in the second potential well



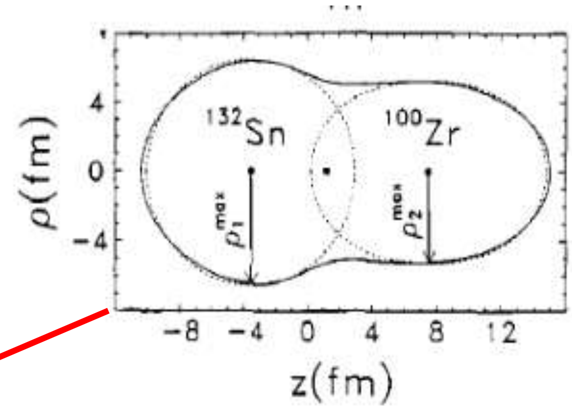
Discovery of fission (shape) isomers: FLNR (JINR) 1961
242Am, τ =0.014sec

More then 30 fission isomers of heavy nuclei, namely, isotopes of
U, Np, Pu, Am, Cm, Bk
are known including short lived in the ns range.
(Flerov, Polikanov)

The bottoms of the fission valleys as a function of parameter Q (proportional to the quadrupole moment) for 234U.
V. Pashkevich et al.

S. Ċwiok et al.,
Phys. Lett. B 322 (1994) 304

SIS in heavy nuclei



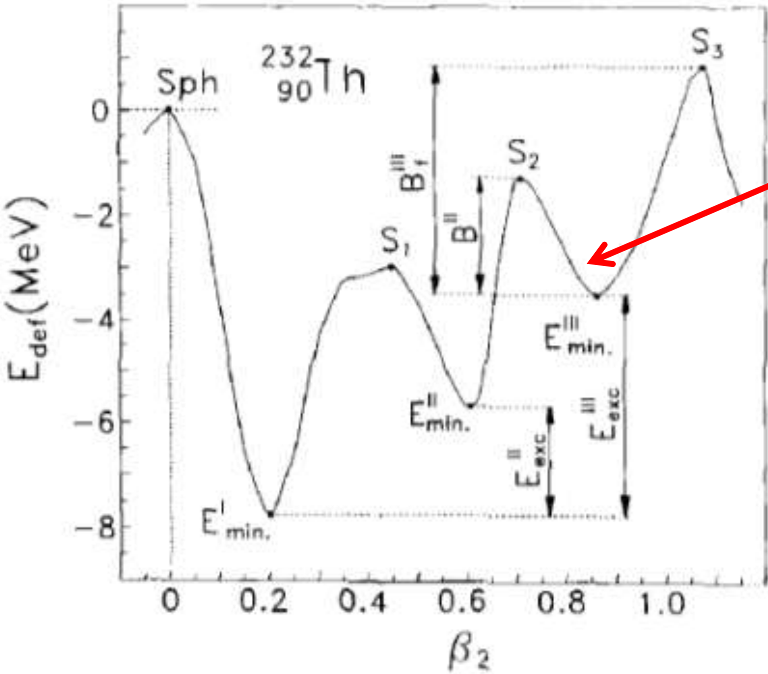


Fig. 1. Potential energy curve for ^{232}Th as a function of quadrupole deformation β_2 along the shorter static fission path of fig. 2.

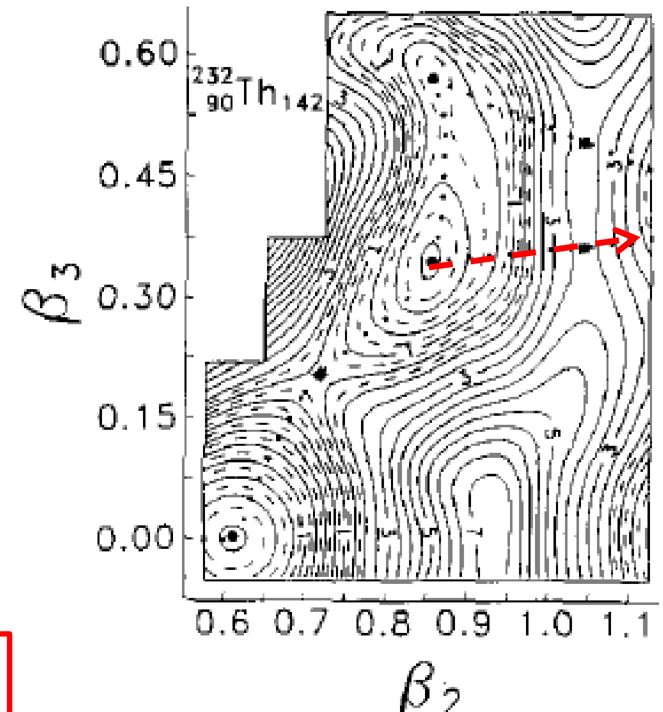
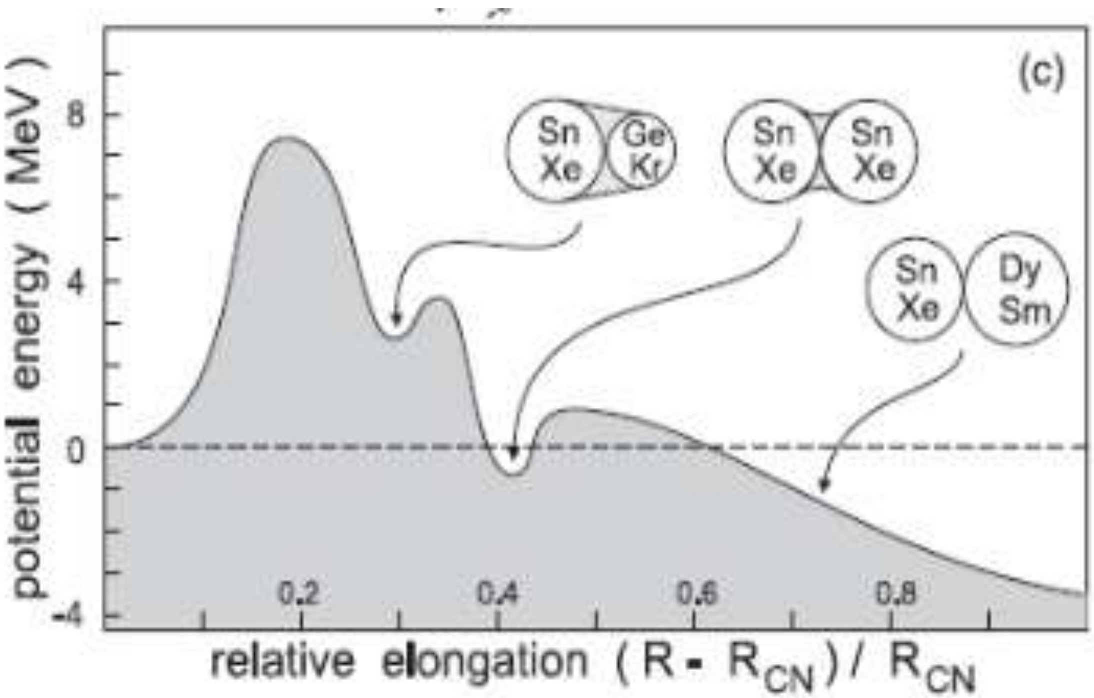


Fig. 2. The Woods–Saxon–Strutinsky total potential energy (relative to the spherical macroscopic energy) for ^{220}Rn, ^{222}Ra, ^{232}Th, and ^{234}U, as a function of β_2 and β_3. At each (β_2, β_3) point the energy was minimized with respect to β_4–β_7. The distance between the solid contour lines is 0.5

density distribution at the third minimum looks like a di-nucleus consisting of a nearly-spherical heavier fragment (around doubly-magic ^{132}Sn) and a well-deformed lighter fragment (from the neutron-rich $A \sim 100$ region).

SIS in super-heavy nuclei



Three-humped barrier calculated along the fission path of $^{296}_{116}$Lv (Livermorium).

V. ZAGREBAEV, W. GREINER

Proc. Int. Symp. on Atomic Cluster Collisions (ISACC07), GSI
Darmstadt, 2007, (Imperial College Press, London, 2008), Eds. J.-P.
Connerade and A. V. Solov'yov, p. 23

"These intermediate minima correspond to the <u>shape isomer states.</u>
From analysis of the driving potential we may definitely conclude that these <u>isomeric states</u> are nothing else but <u>the two-cluster configurations with magic or semi-magic cores</u> surrounded with a certain amount of shared nucleons."

Shape isomers at high spin

SIS at high spin

Sven Åberg et al., Z. Phys. A 358 (1997) 269

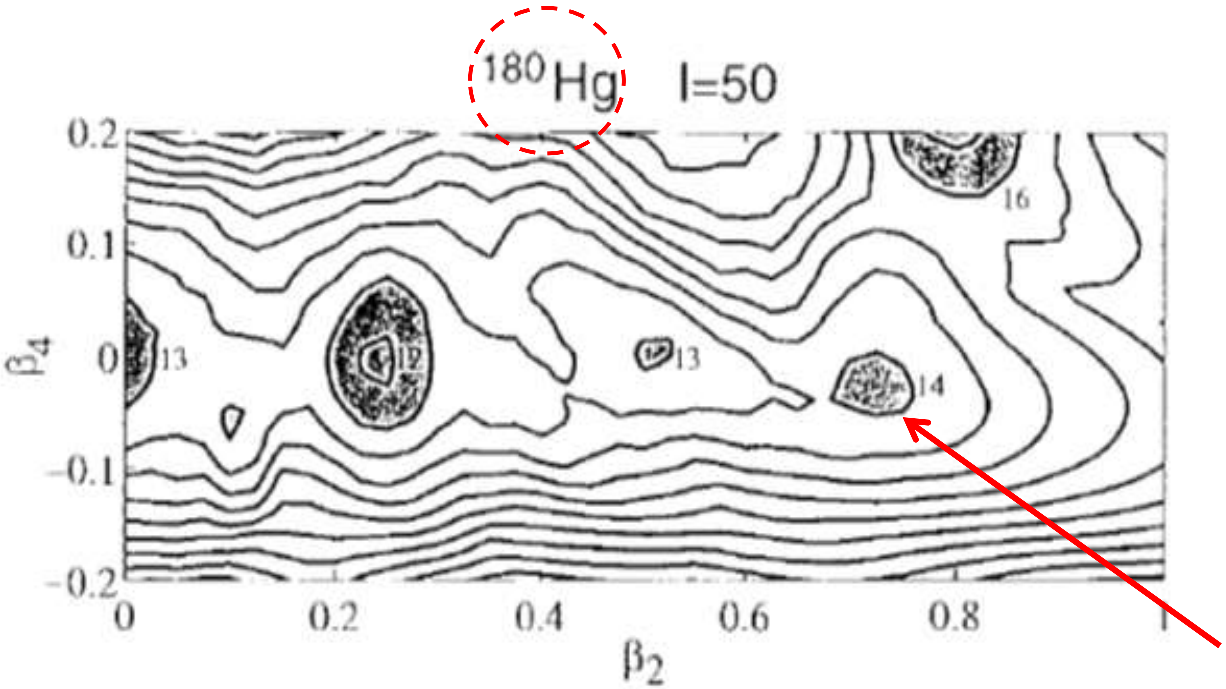


Fig. 5. Potential-energy surface valid for ^{180}Hg at I=50. The calculation has been performed within the cranked Nilsson-Strutinsky formalism using the Woods-Saxon potential. Local minima are shaded, and the line separartion is 1 MeV. Notice the minimum at β_2=0.75, β_4=0 that corresponds to a necked-in superdeformed shape

"Superdeformed (or hyperdeformed) nuclei with necking was calculated to exist, e.g. in 180Hg. The exotic configuration was similar in shape as well as in single-particle structure to **two partly overlapping spherical 90Zr nuclei.**"

SIS of light nuclei

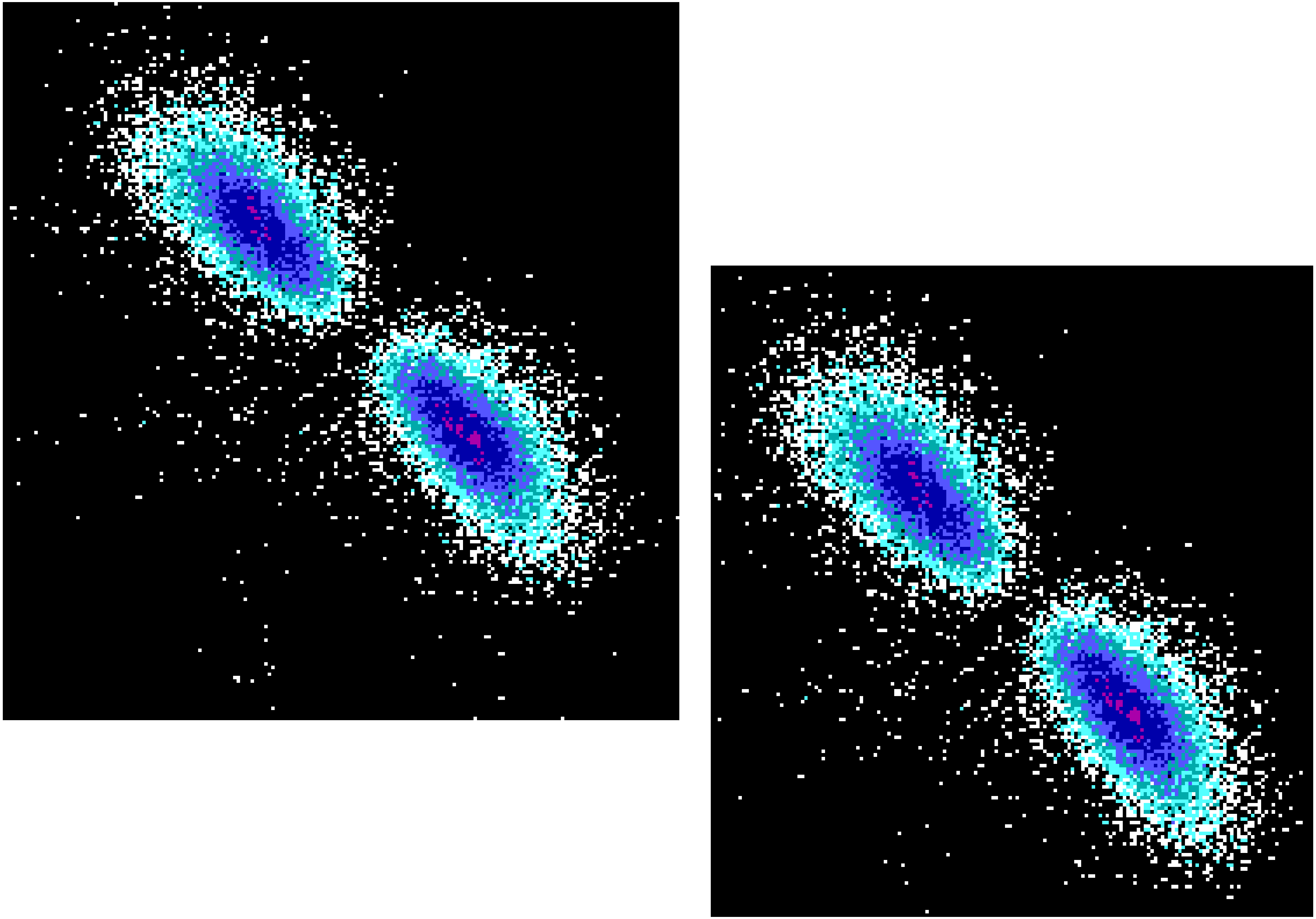
The *cluster states of light nuclei* and the possible existence of the *necked-in shaped nuclei* were considered in:

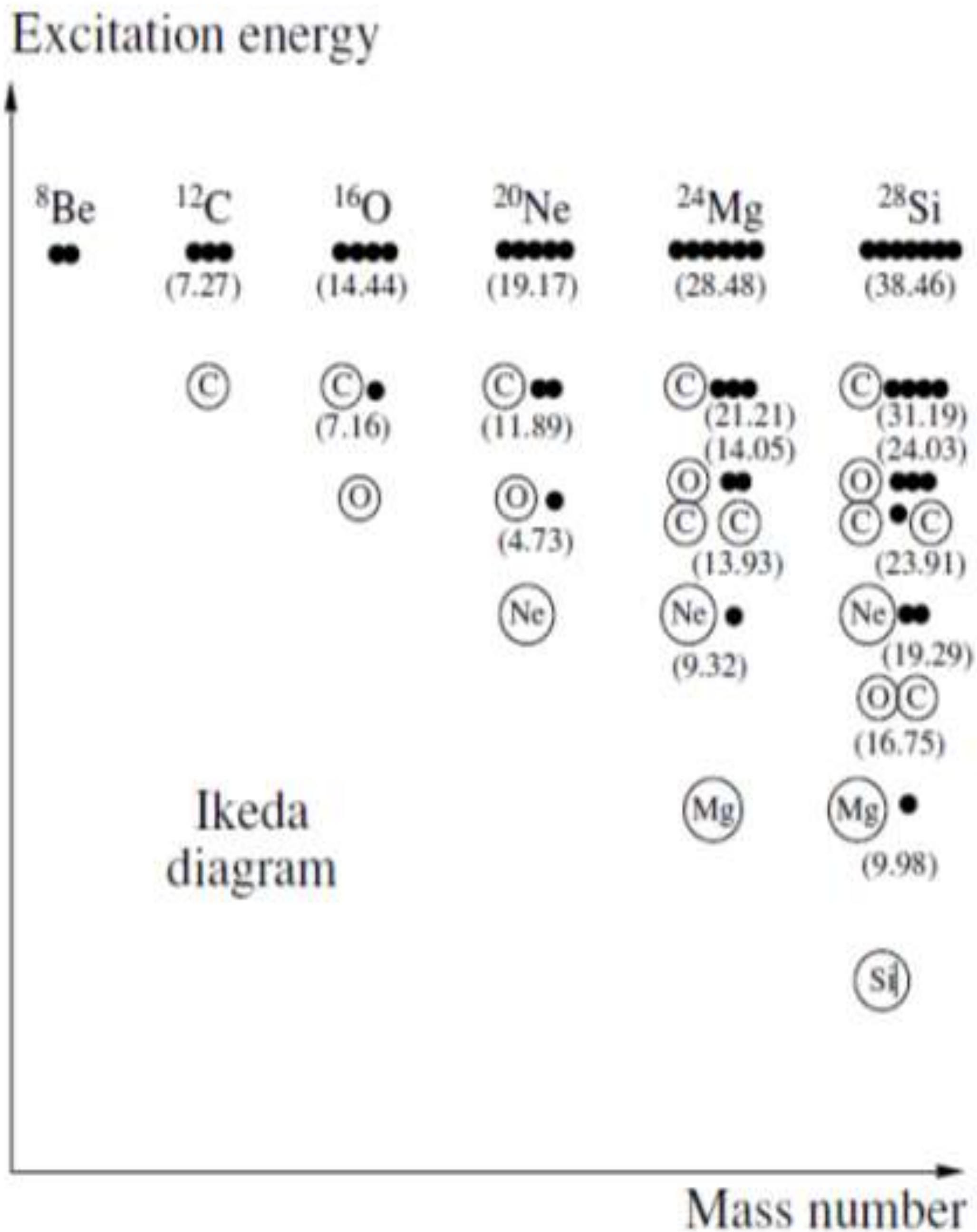
Cseh, J., Scheid, W. J.: Phys. G 18 (1992) 1478
Cseh, J. et al.,: Phys. Rev.C 48 (1993) 1724
Sanders S.J. et al.,: Phys. Rep. 311 (1999) 487
Freer, M : Prog. Phys. 70 (2007) 2149
Sciani, W et al., : Phys. Rev. C80 (2009) 034319
Cseh, J. et al.,: Phys. Re v. C 80 (2009) 034320
Beck, C. et al.,: Phys. Rev. C 80 (2009) 034604
Von Oertzen W. et al.,; Phys. Rev. C 78 (2008) 044615

We likely deal with shape-isomers in the new mass rang typical for the fission fragments of the conventional binary fission

Conclusions.

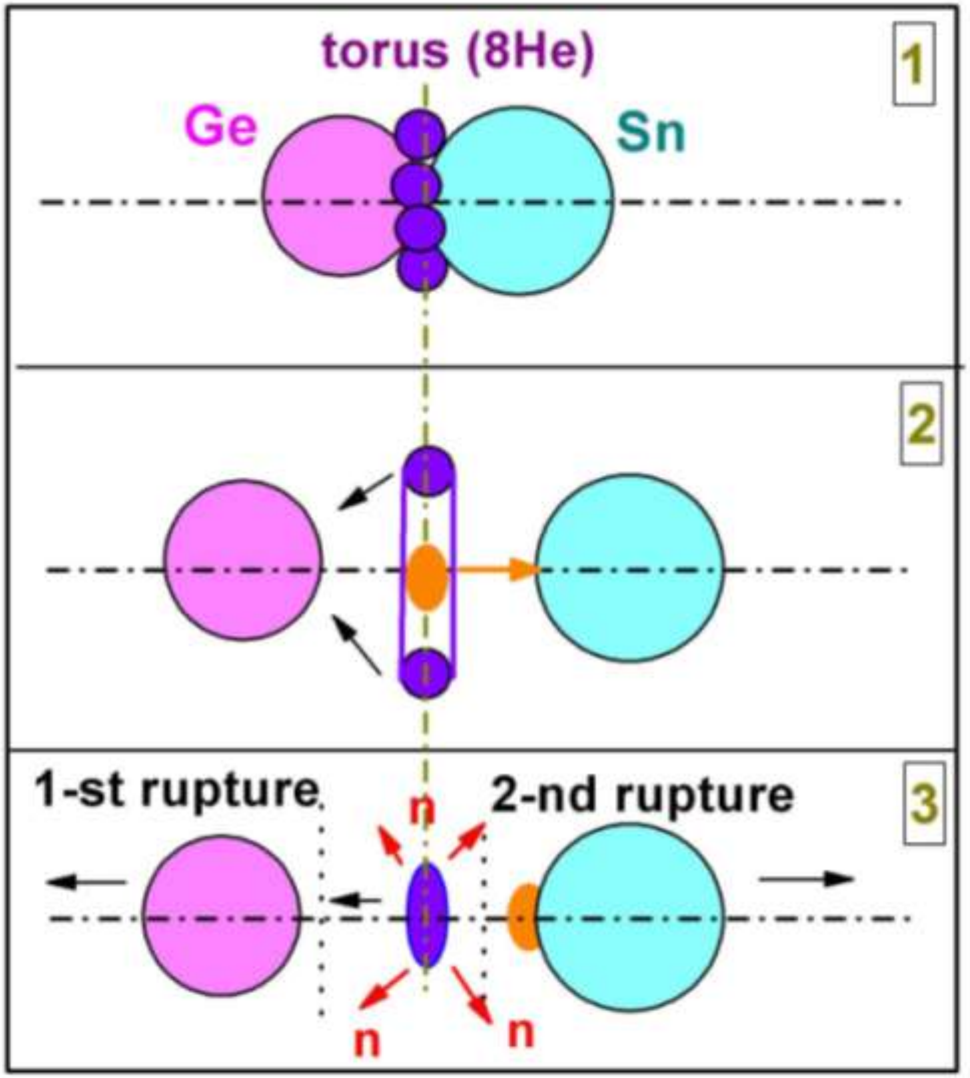
1. **New mechanism of ternary decay based presumably on the Rutherford break-up of the fragment in the shape-isomeric state is observed.**
2. **Break-up is only one of the different ways leading to the CCT.**
3. **The results obtained let us to suppose that the bulk of the fragments from the conventional binary fission are born in the shape-isomeric states.**
4. **The conclusions above can be regarded as the preliminary ones till further estimation of the life times of the shape isomers under discussion will be obtained.**



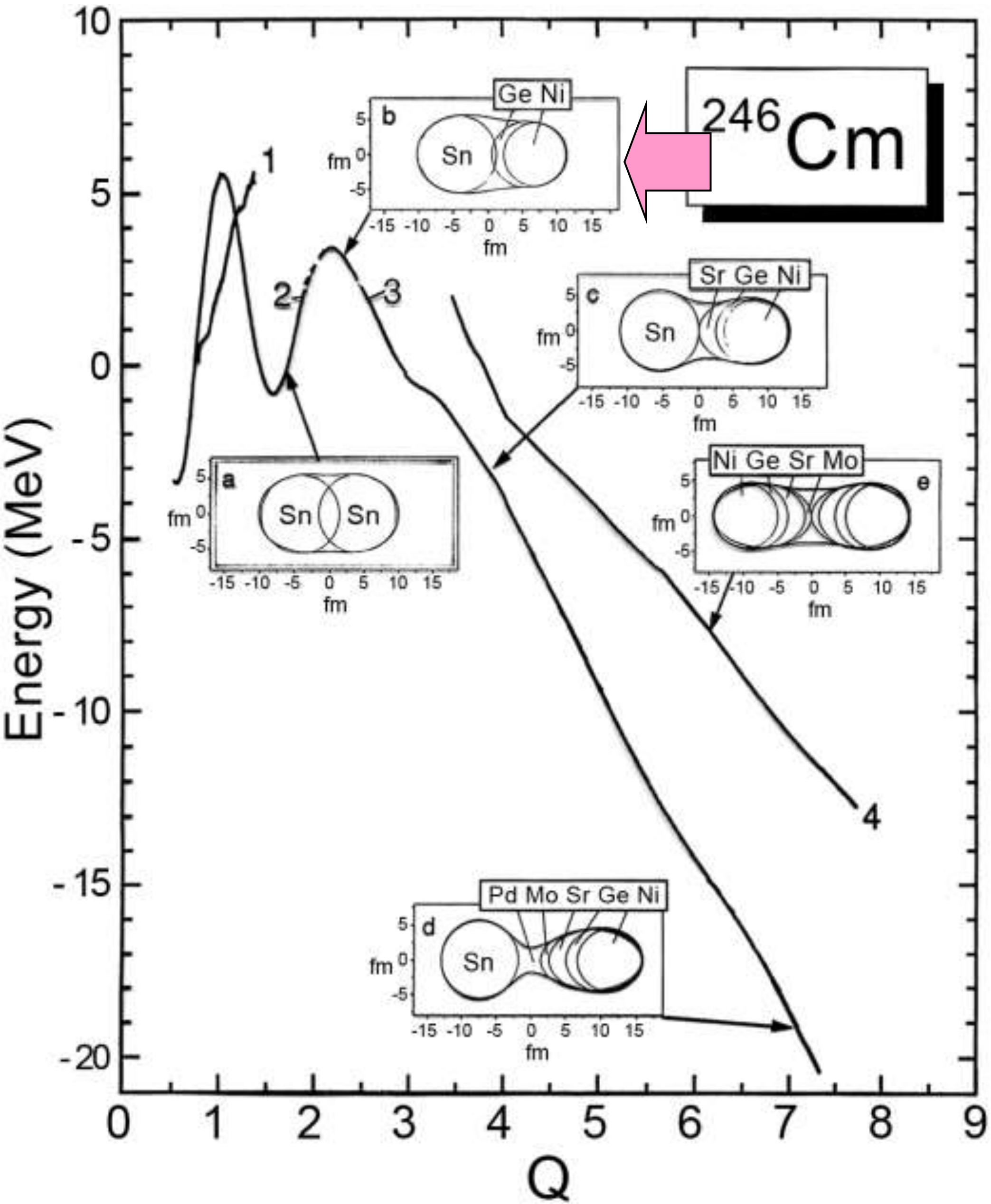


Excitation energy
⁸Be
¹²C
(7.27)
¹⁶O
(14.44)
²⁰Ne
(19.17)
²⁴Mg
(28.48)
²⁸Si
(38.46)
C
(7.16)
(11.89)
(21.21)
(14.05)
(31.19)
(24.03)
O
(4.73)
(13.93)
(23.91)
Ne
(9.32)
(19.29)
(16.75)
Mg
(9.98)
Si
Ikeda
diagram
Mass number

Scenario of the collinear cluster tripartition



Calculated Fission Valleys (^{246}Cm)



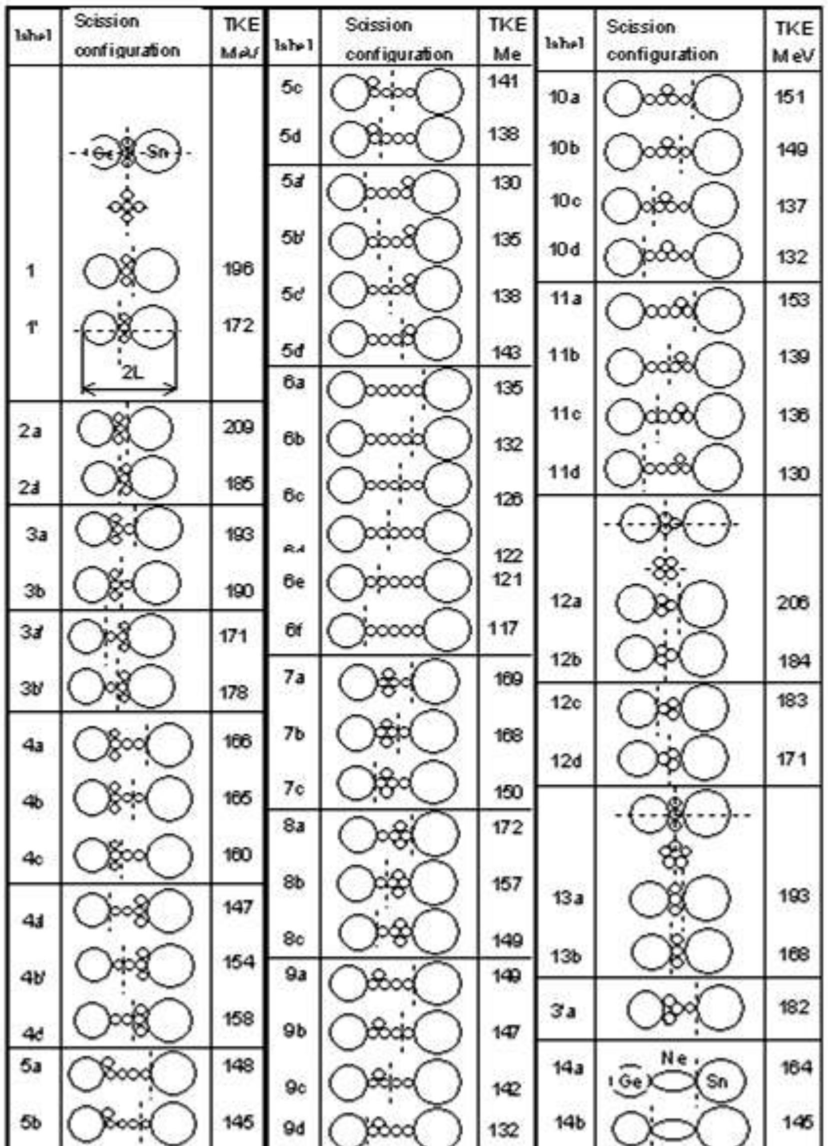
Valley of the mass-asymmetrical shapes

Valley of the mass-symmetrical shapes

V. V. Pashkevich et al.

Known calculations

Table1: TKE for some configurations of the fissioning system $^{236}U^{*}$



label	Scission configuration	TKE MeV
1		196
1'		172
2a		209
2a'		185
3a		193
3b		190
3a'		171
3b'		178
4a		166
4b		165
4c		160
4a'		147
4b'		154
4c'		158
5a		148
5b		145
5c		141
5d		138
5a'		130
5b'		135
5c'		138
5d'		143
6a		135
6b		132
6c		126
6d		122
6e		121
6f		117
7a		169
7b		168
7c		150
8a		172
8b		157
8c		149
9a		149
9b		147
9c		142
9d		132
10a		151
10b		149
10c		137
10d		132
11a		153
11b		139
11c		136
11d		130
12a		206
12b		184
12c		183
12d		171
13a		193
13b		168
3'a		182
14a		164
14b		146

α-cluster configurations analyzed in:

Yu.V. Pyatkov, G.G. Adamian,

N.V. Antonenko, V.G. Tishchenko

Nucl. Phys. A 611 (1996) 355

Thus pre-formation of light clusters in the neck region and just forming of two and three-neck shapes are energetically possible. At the same time nothing is known from theory about probability of the decay modes discussed here.

Known calculations

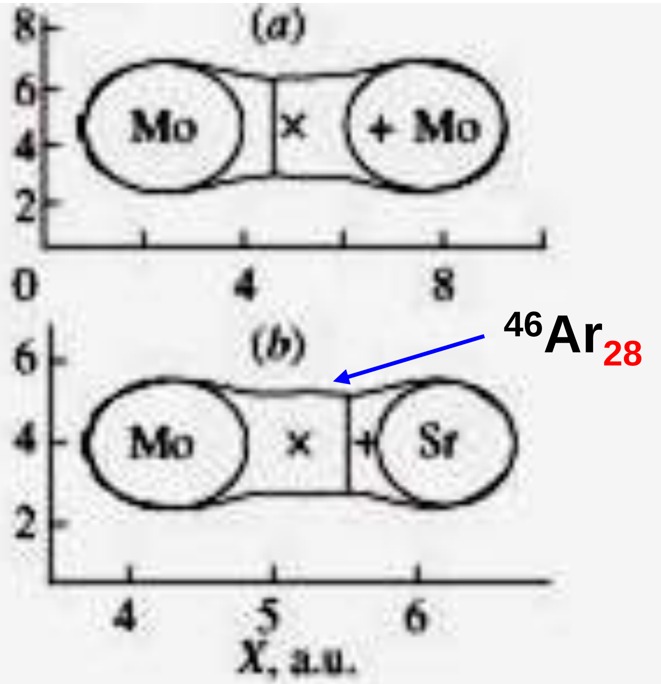
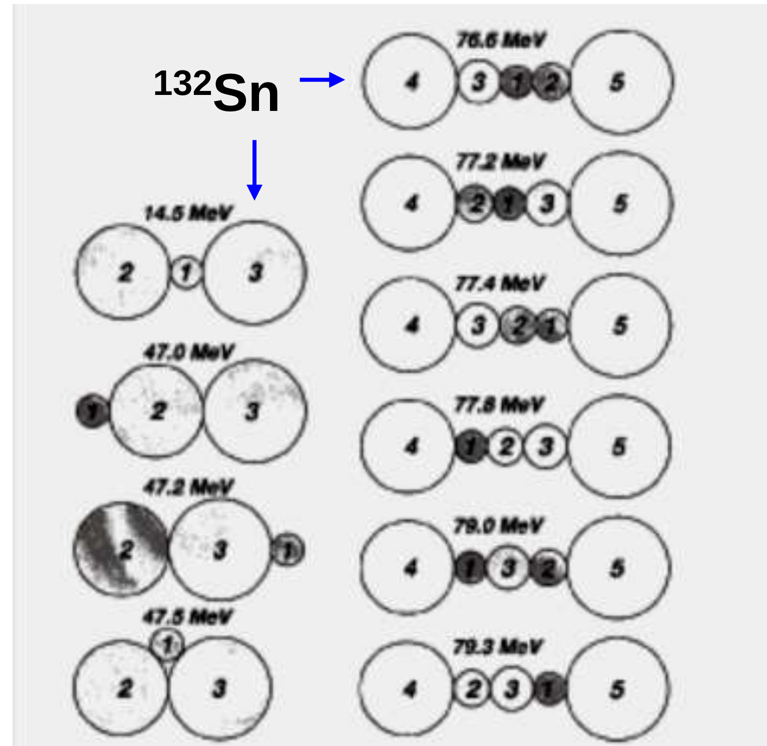


Fig. 7. The shape of the nucleus at the bottom of the "symmetric" valley ($Q_2 = 7.52$ a.u., $\eta = 0.074$) (a); the same system at the point $Q_2 = 7.52$ a.u., $\eta = -0.208$ (b).

Yu.V. Pyatkov, V.V. Pashkevich, A.V. Unzhakova et al., Physics of Atomic Nuclei 66 (2003) 1631



Aligned and compact configurations for α-accompanied and α+^{6}He+^{10}Be accompanied cold fission of ^{252}Cf

D.N. Poenaru et al., Phys. Rev. C 59 (1999) 3457