Summary of the experimental results on collinear cluster tri-partition studies

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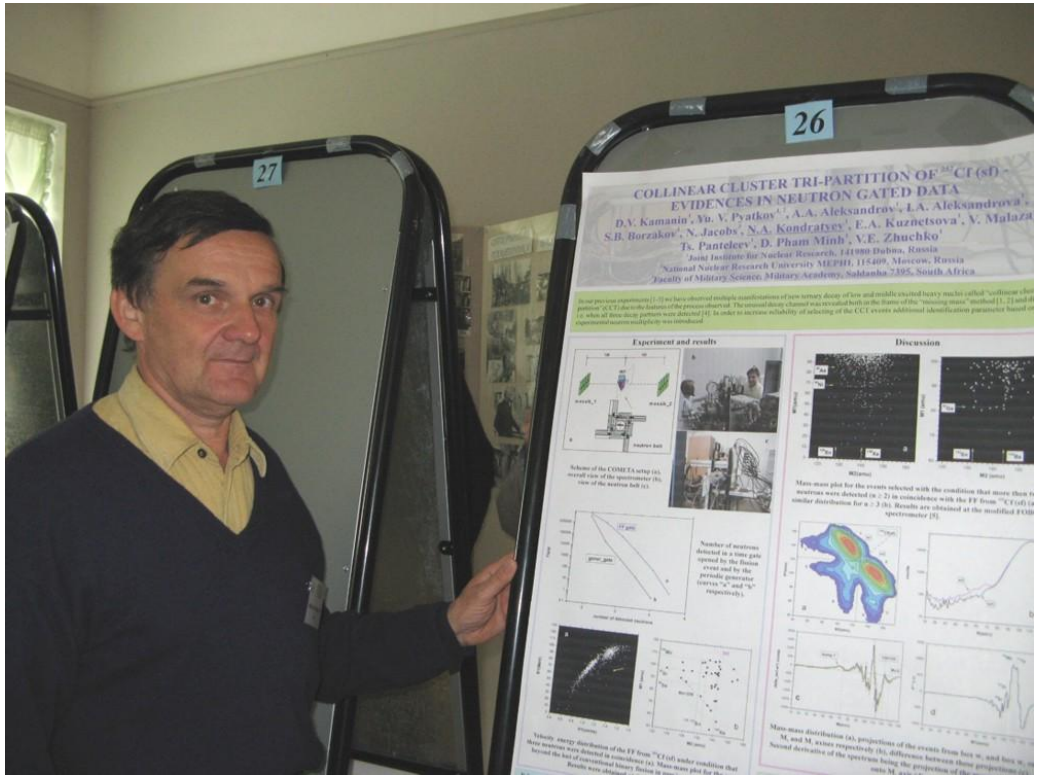
[3]Faculty of Military Science, Military Academy, Saldanha 7395, South Africa
[4]Institute for Nuclear Research RAN, 117312 Moscow, Russia



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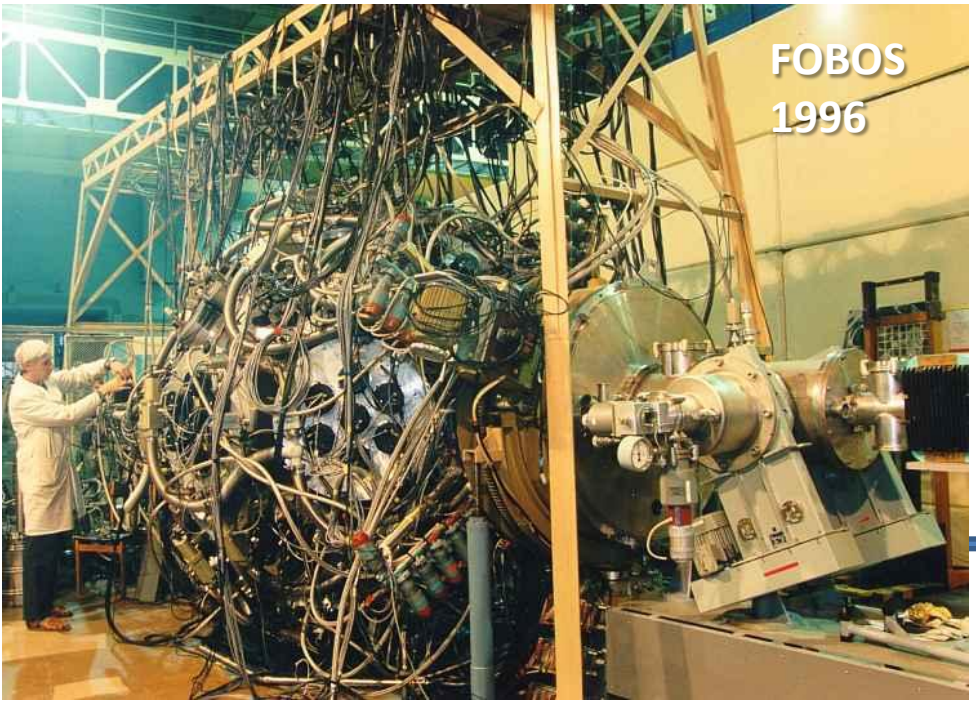
by the grant of the Federal Ministry of Education and Research of Germany

ISINN-20 21-16 May, Dubna@Alushta, JINR



CCT progress from ISINN to ISINN

13 - proposal for the exp @ IBR-2

14 - status of the exp in the cave 6b

15 - preliminary results

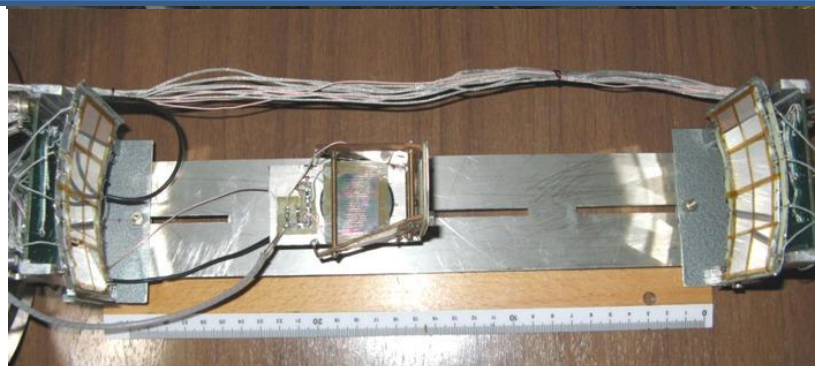
16 - detailed report

17 - triple correlations from ^{232}Th+d

18 - COMETA progress report (posters)

19 - first & interesting COMETA data

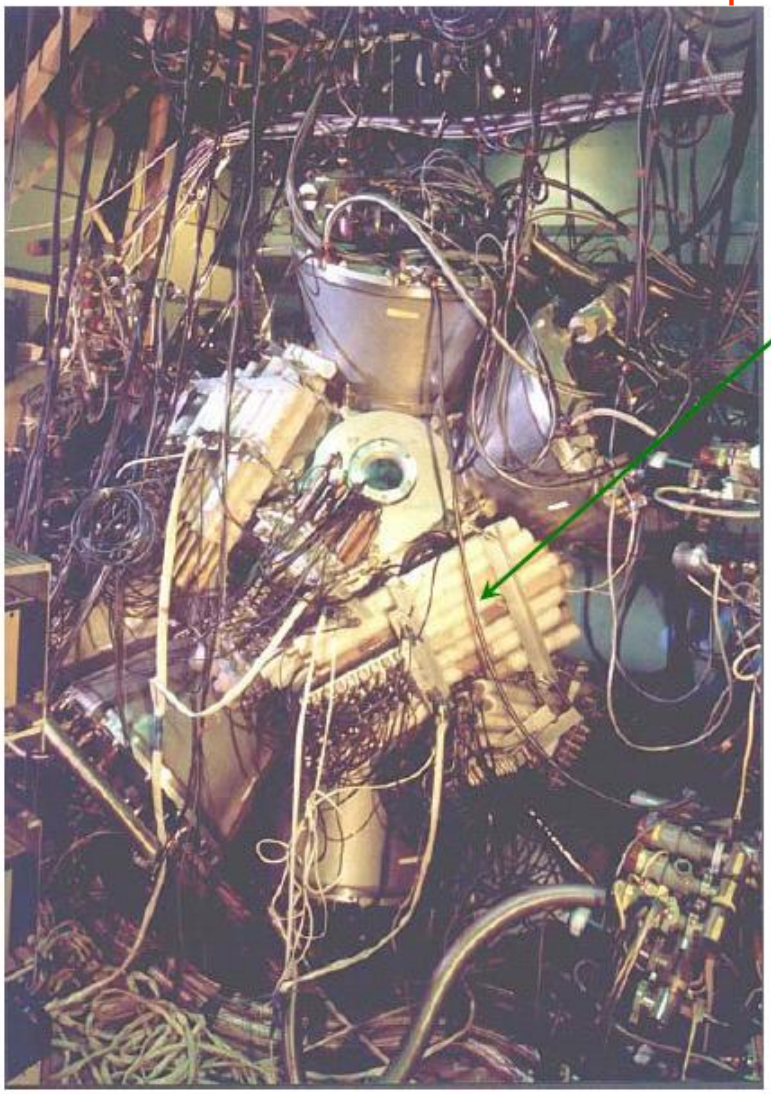
20 – physics and ion guide proposal



Experimental steps: FOBOS →modified FOBOS →mini-FOBOS

missing mass approach, Z -sensitive variables &

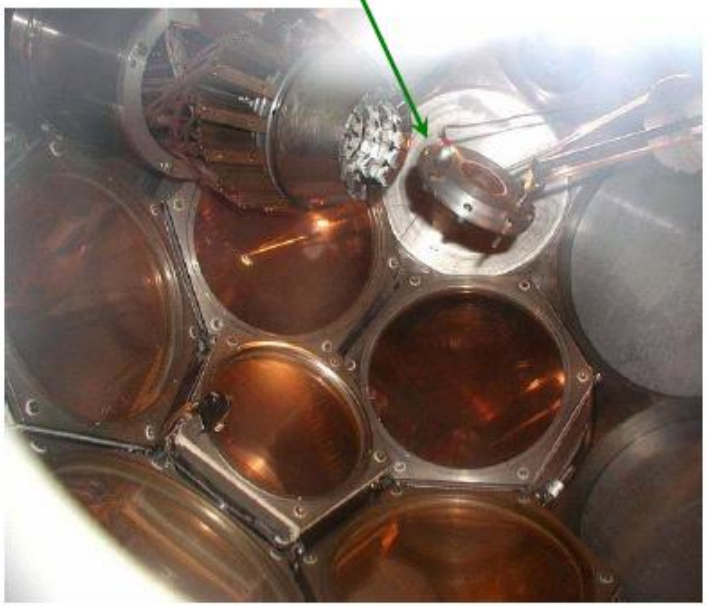
experimental neutron multiplicity ν_{exp} for selection of the CCT events



Double arm spectrometer
6+6 modules

Neutron belt of FOBOS
140 ^{3}He (7 bar) conuters
In PE-moderator

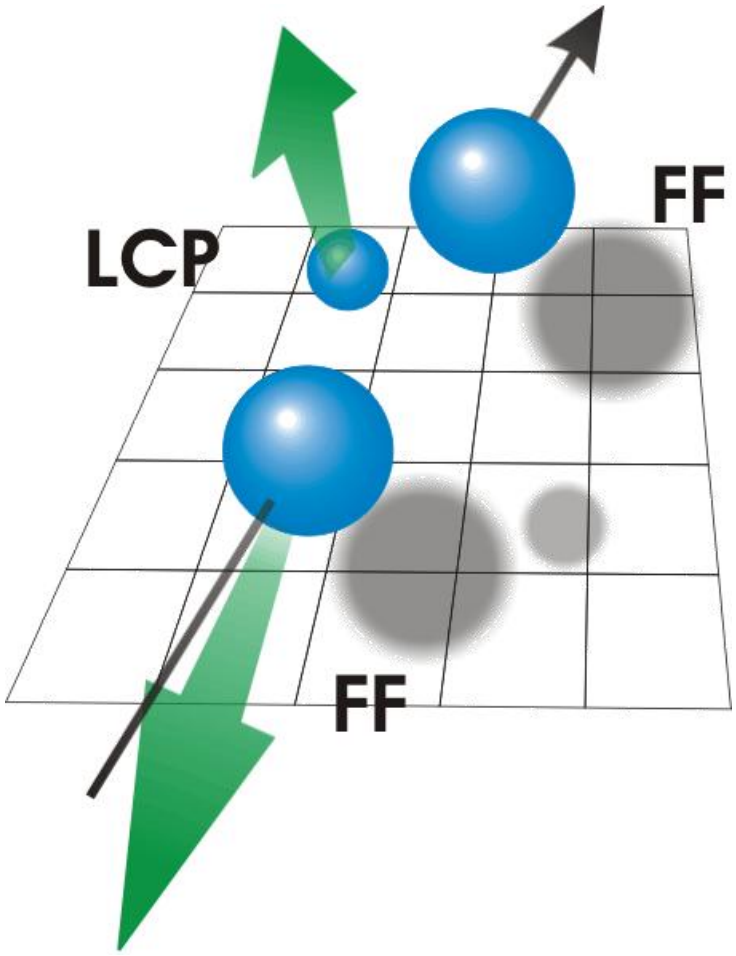
Start PAC
with internal ^{252}Cf source

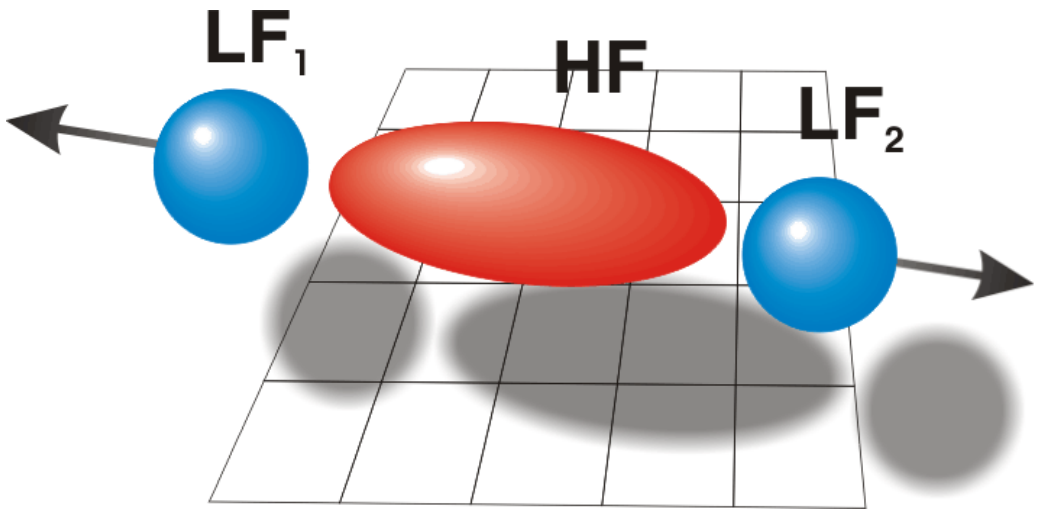


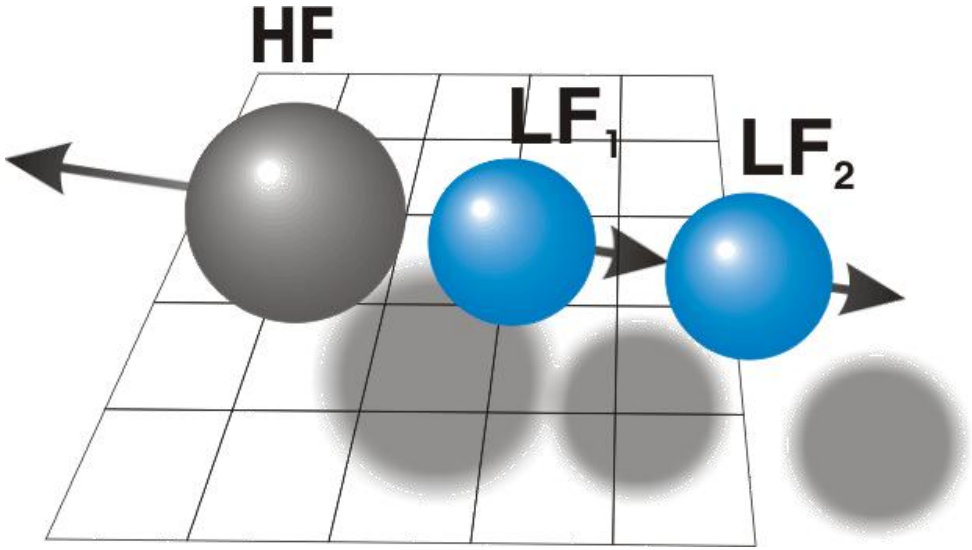
Collinear Cluster Tripartition

(Multy-Cluster Decay)

Conventional ternary fission

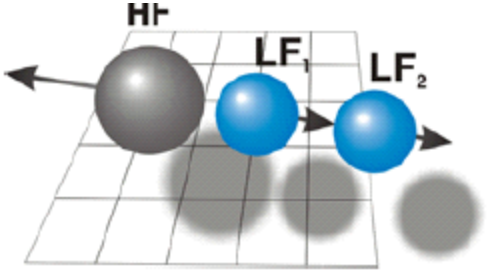


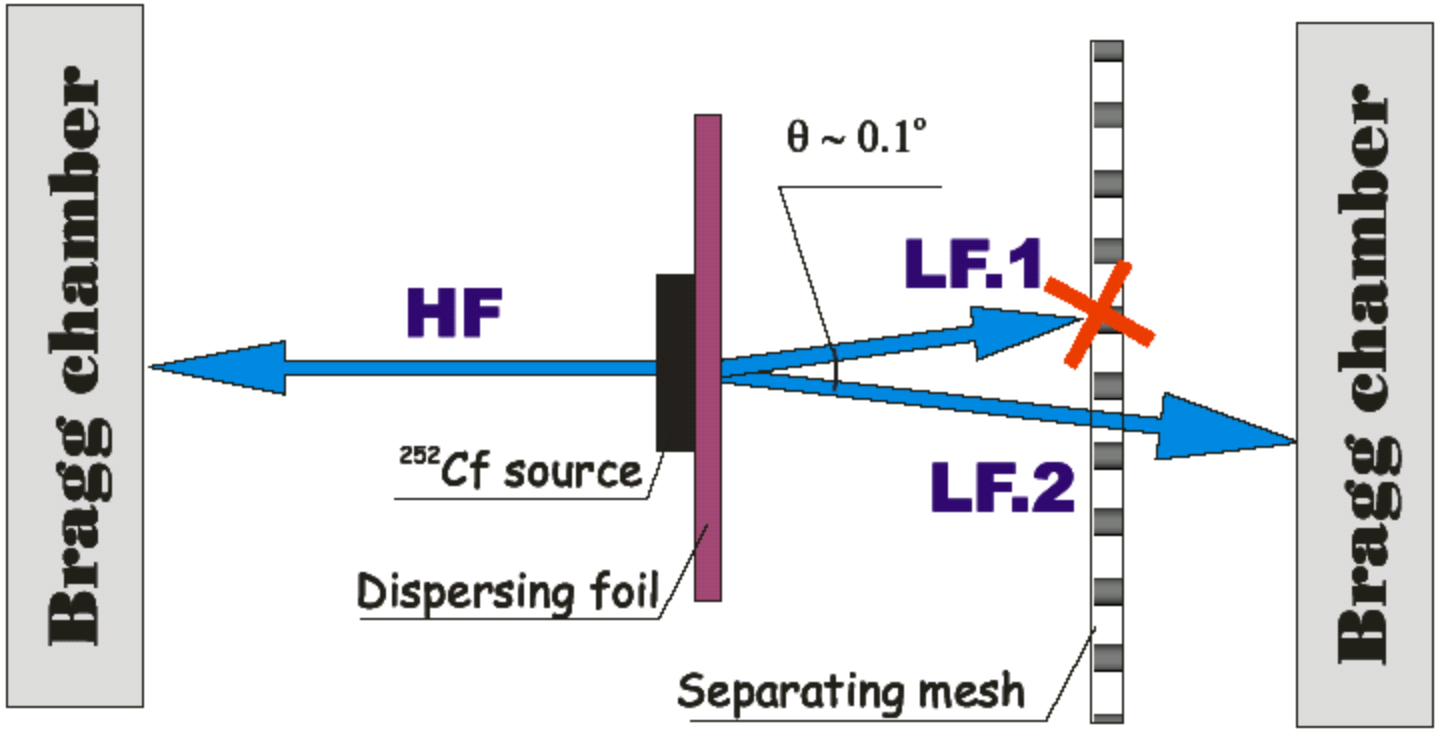




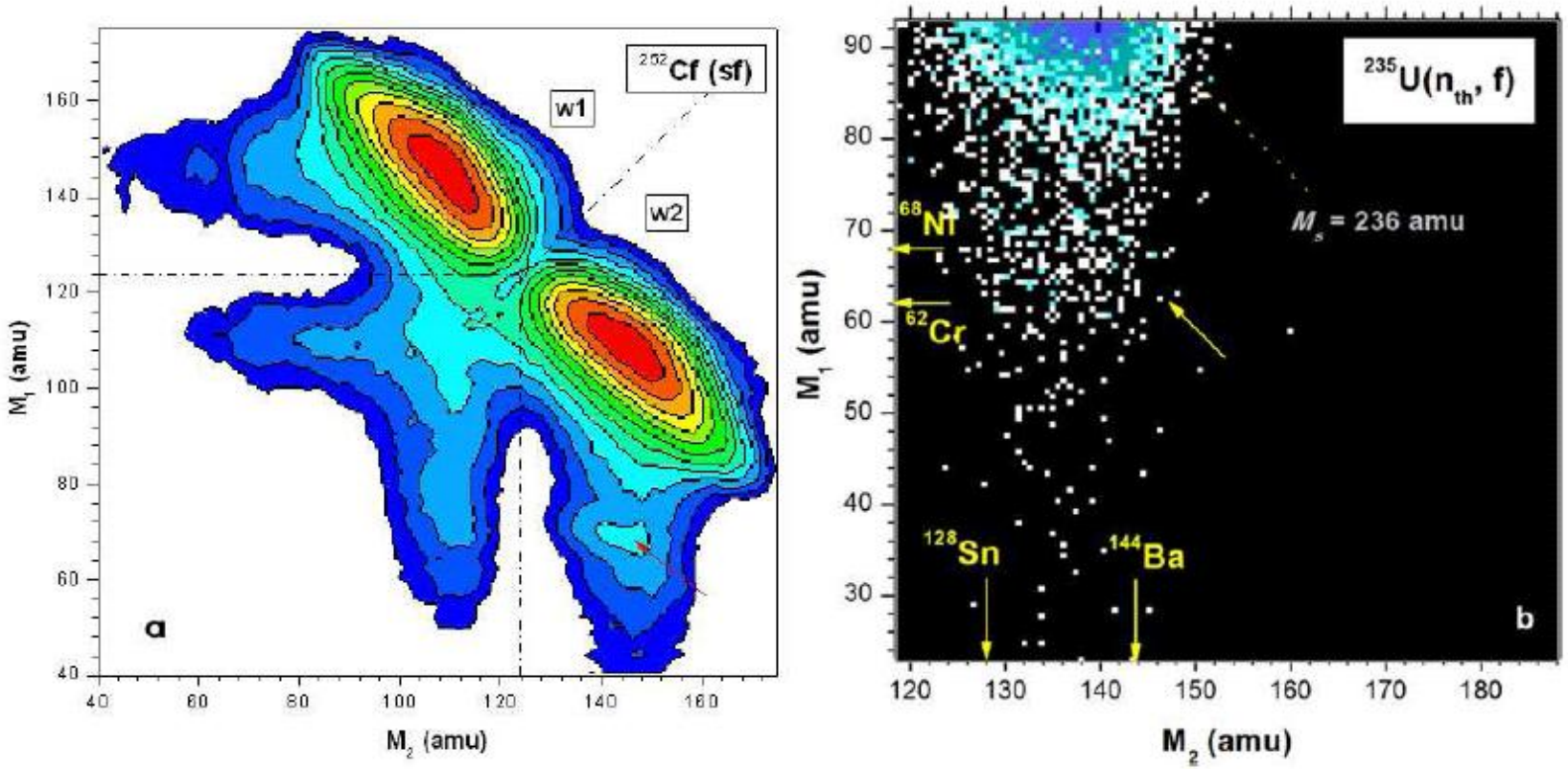
Just to remind:

How to observe CCT @ FOBOS

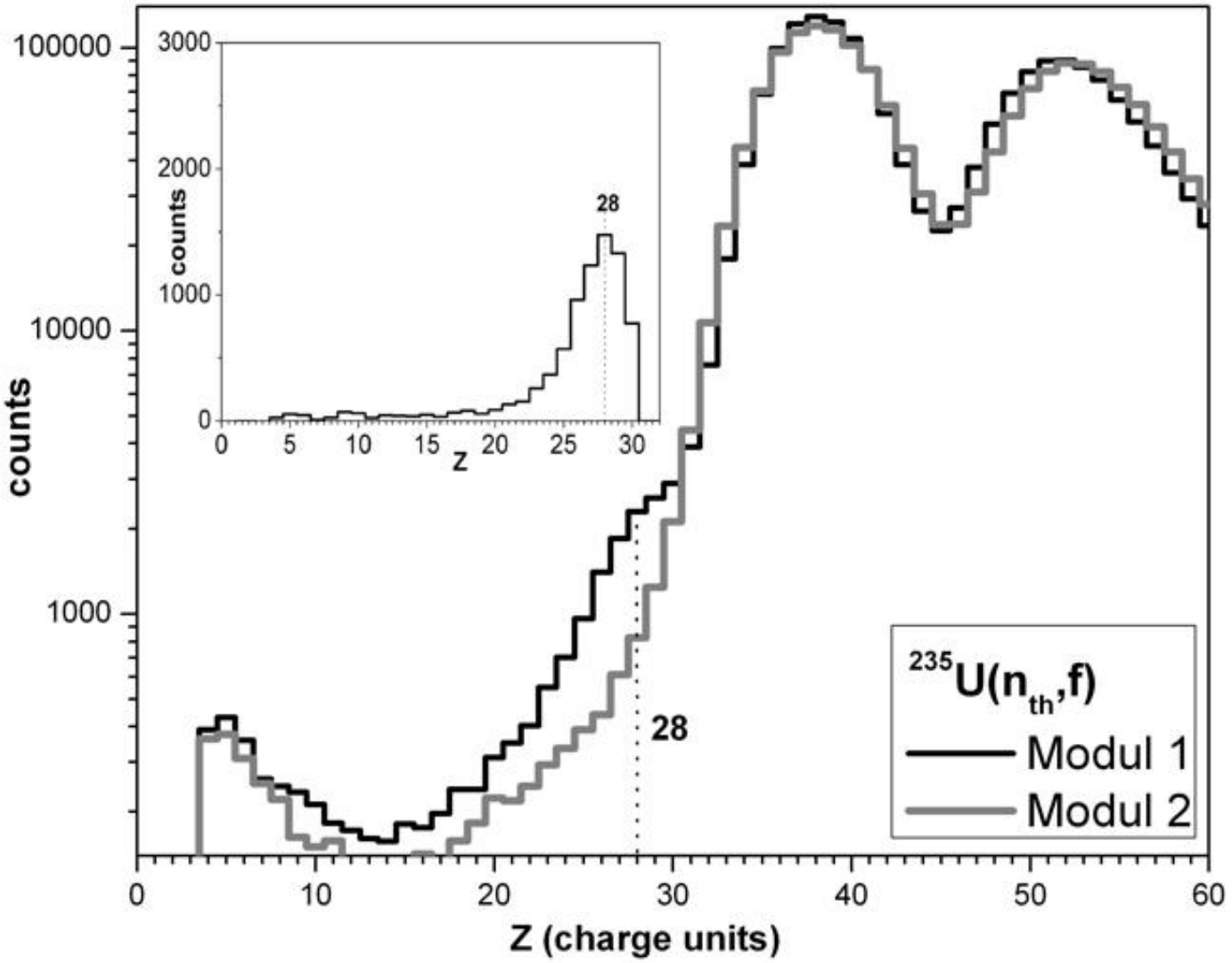




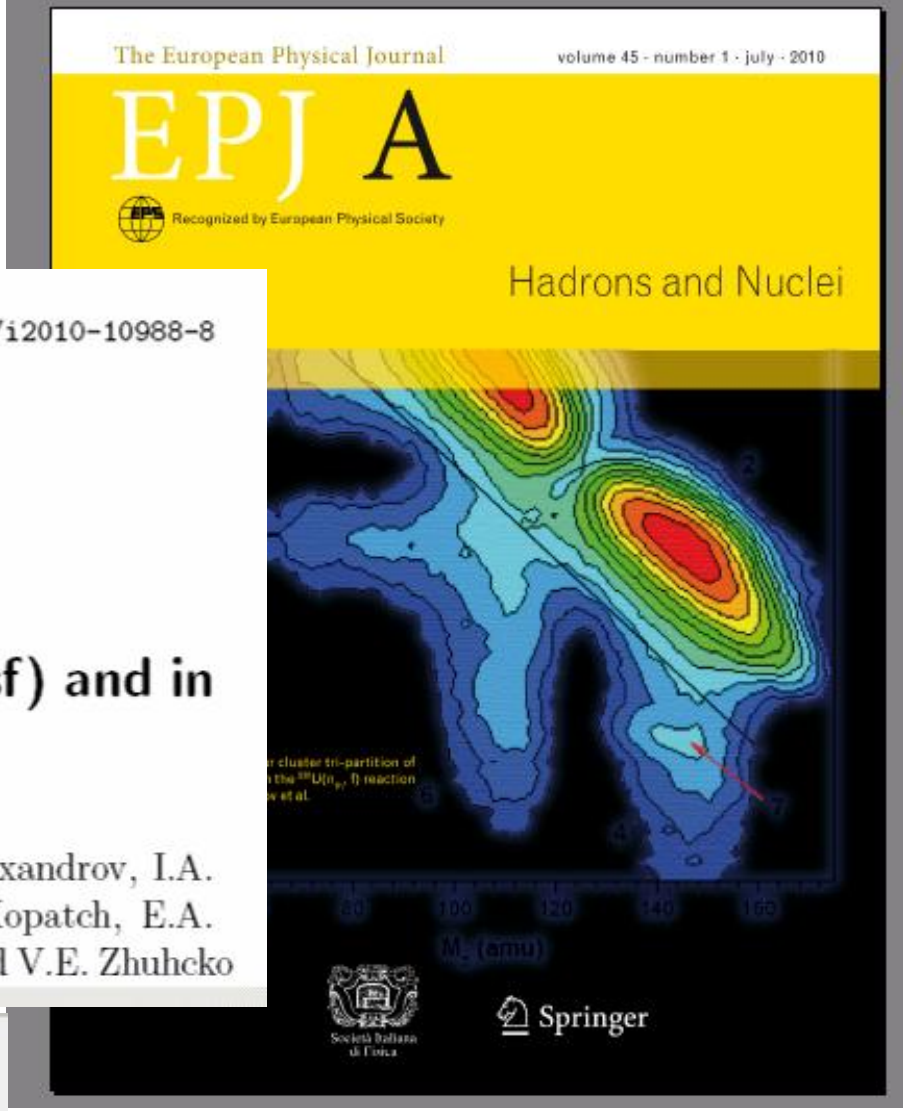
The main results: Ni-bump & its internal structure



Z evidence: it is really Ni-bump



Results were published in:



Eur. Phys. J. A **45**, 29–37 (2010) DOI: 10.1140/epja/i2010-10988-8

Collinear cluster tri-partition of ^{252}Cf (sf) and in the ^{235}U(n_{th}, f) reaction

Yu.V. Pyatkov, D.V. Kamanin, W. von Oertzen, A.A. Alexandrov, I.A. Alexandrova, O.V. Falomkina, N.A. Kondratjev, Yu.N. Kopatch, E.A. Kuznetsova, Yu.E. Lavrova, A.N. Tyukavkin, W. Trzaska and V.E. Zhuhcko

CCT – as a new kind of cluster decay (radioactivity)

H.J. Rose and G.A. Jones, Nature 307 (1984) 245

Yu.V. Pyatkov, D.V. Kamanin et al., EPJ A 45 (2010) 29

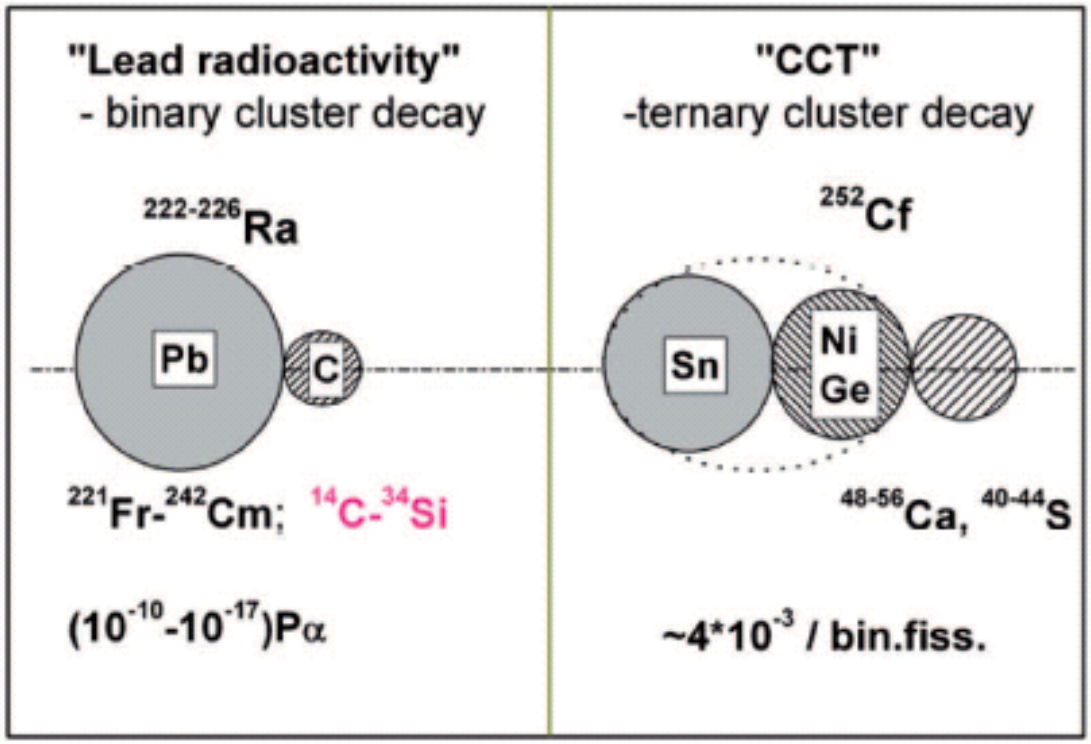
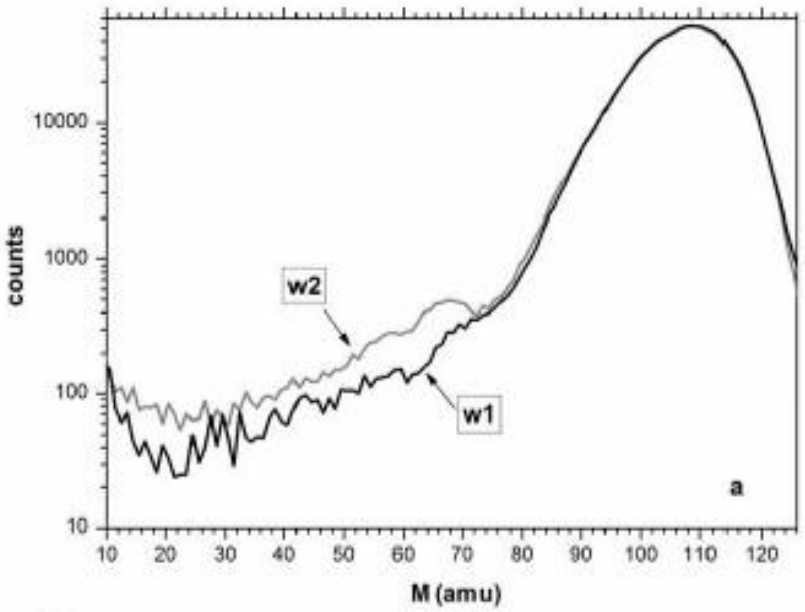
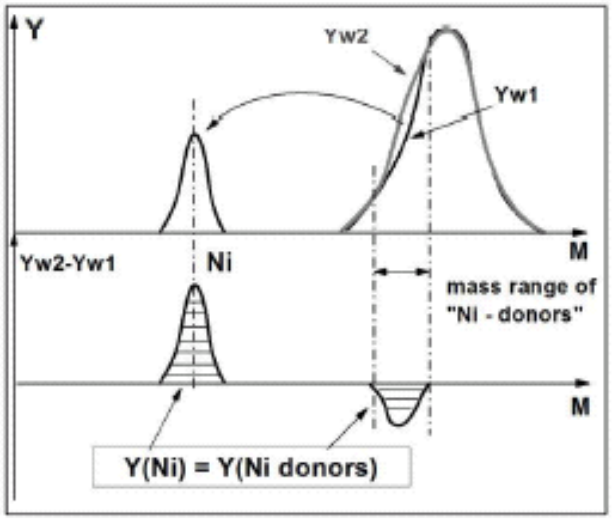
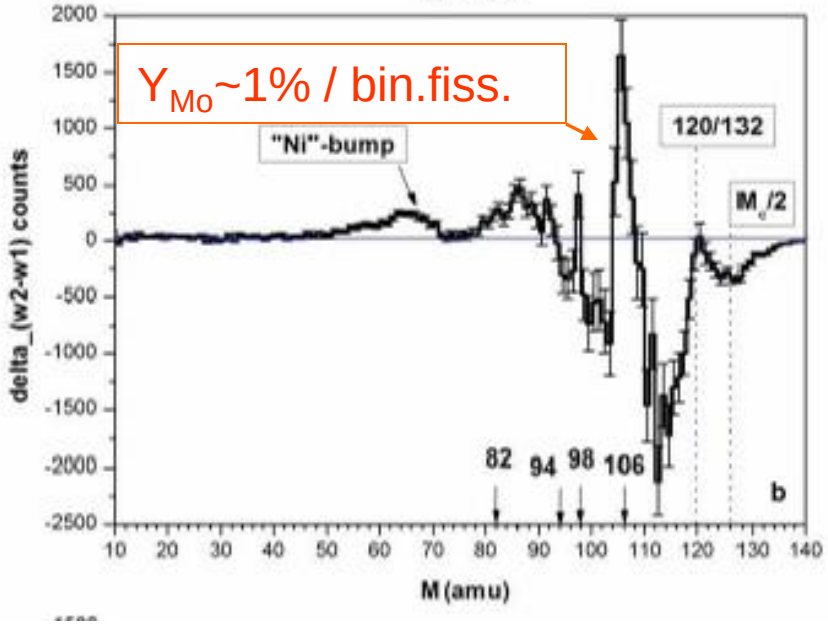


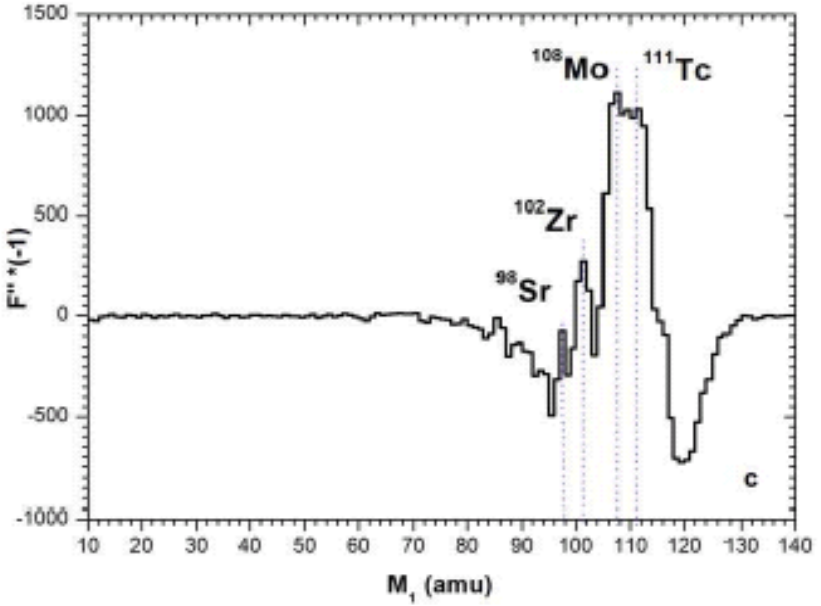
Fig. 10. Cluster scheme for the comparison of the lead radioactivity with collinear cluster tri-partition.

Additional bumps based on deformed magic clusters

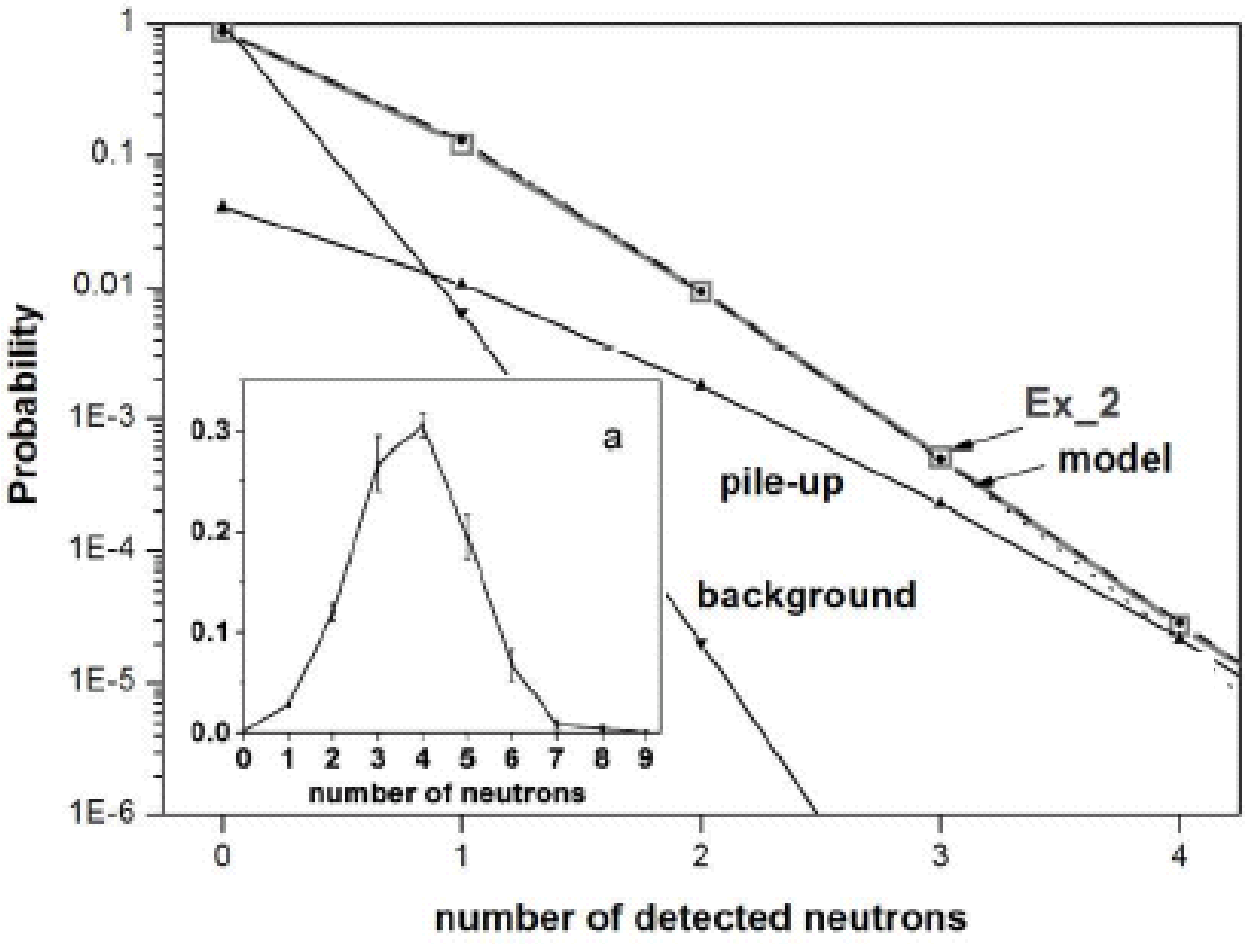


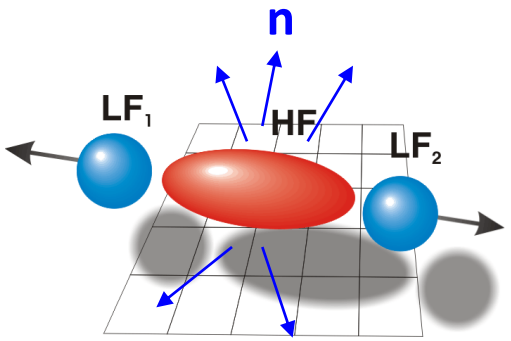


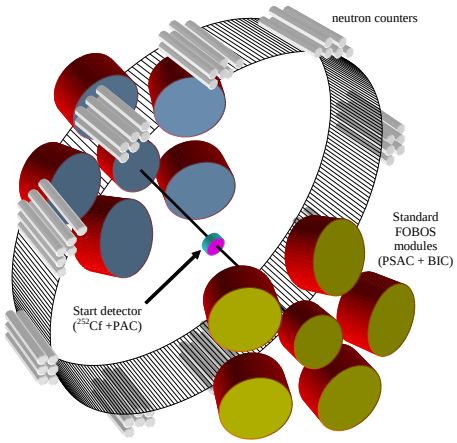




Statistics of neutron registration

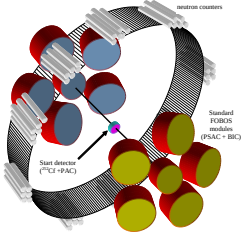




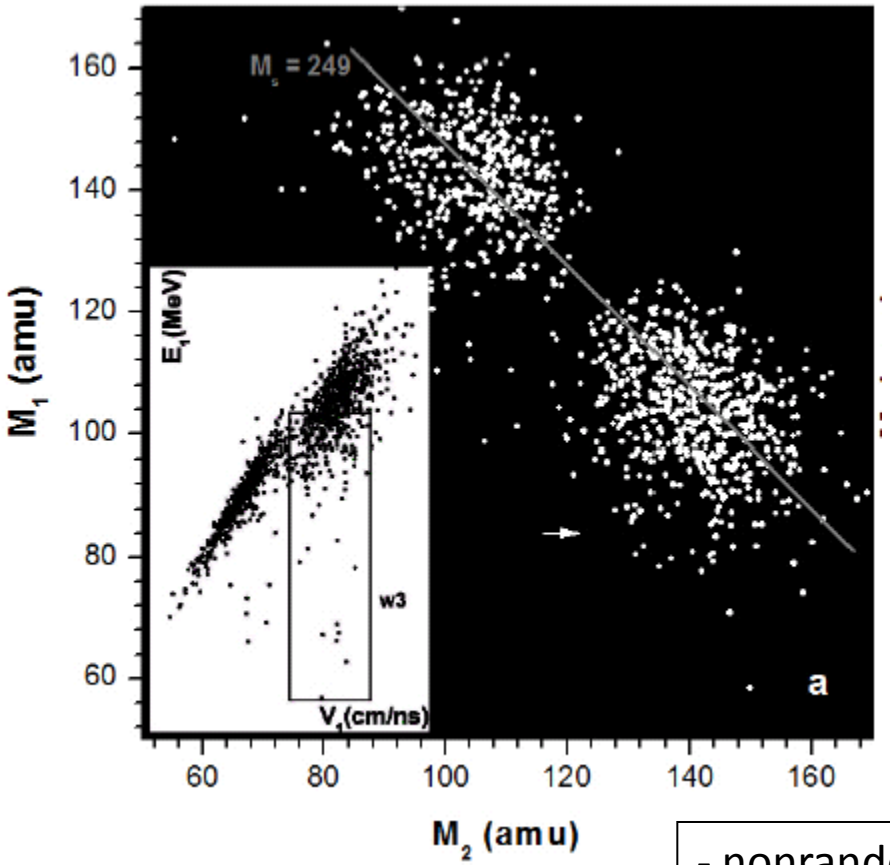


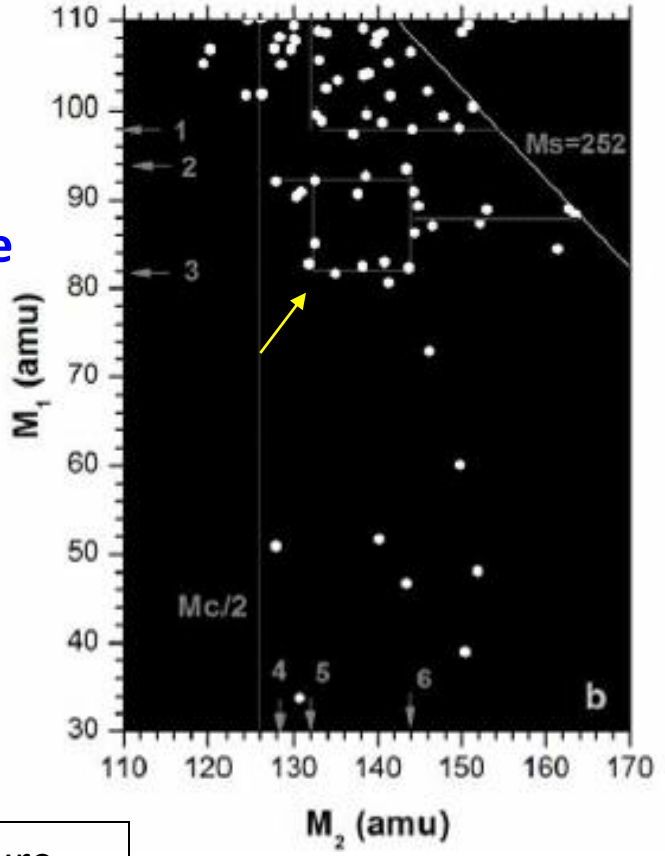
Ex2:

P_{iso}~12%, P_{mov}~5%



Neutron gated data, n=3



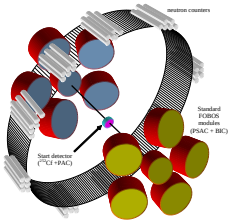


^{94}Kr

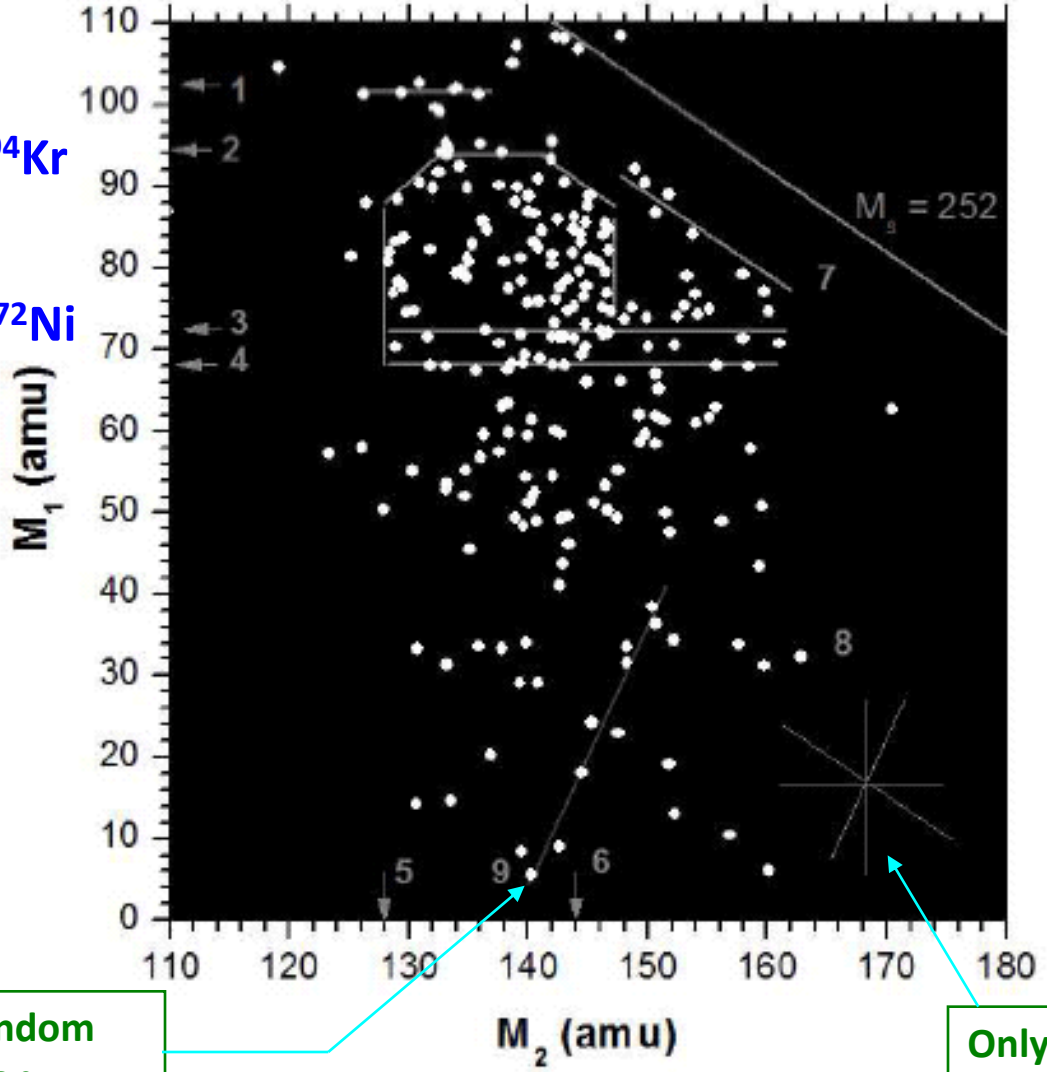
^{80}Ge

$^{128, 132}$Sn ^{144}Ba

- nonrandom nature of the structures observed;
- bright manifestation of clustering



Neutron gated data, n=2

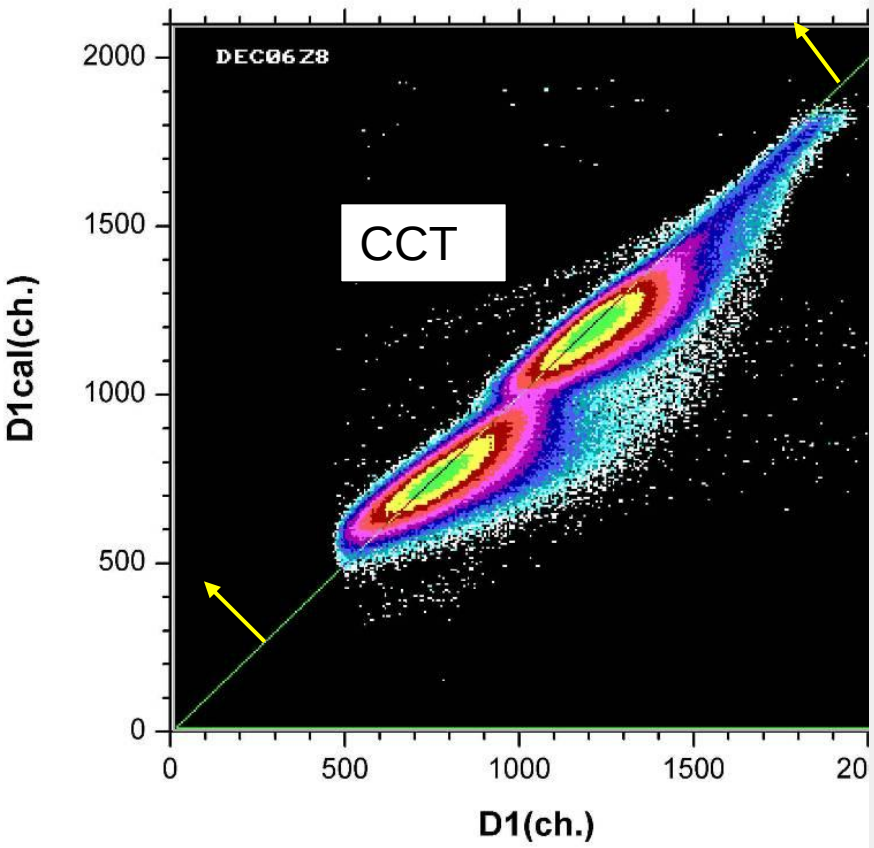


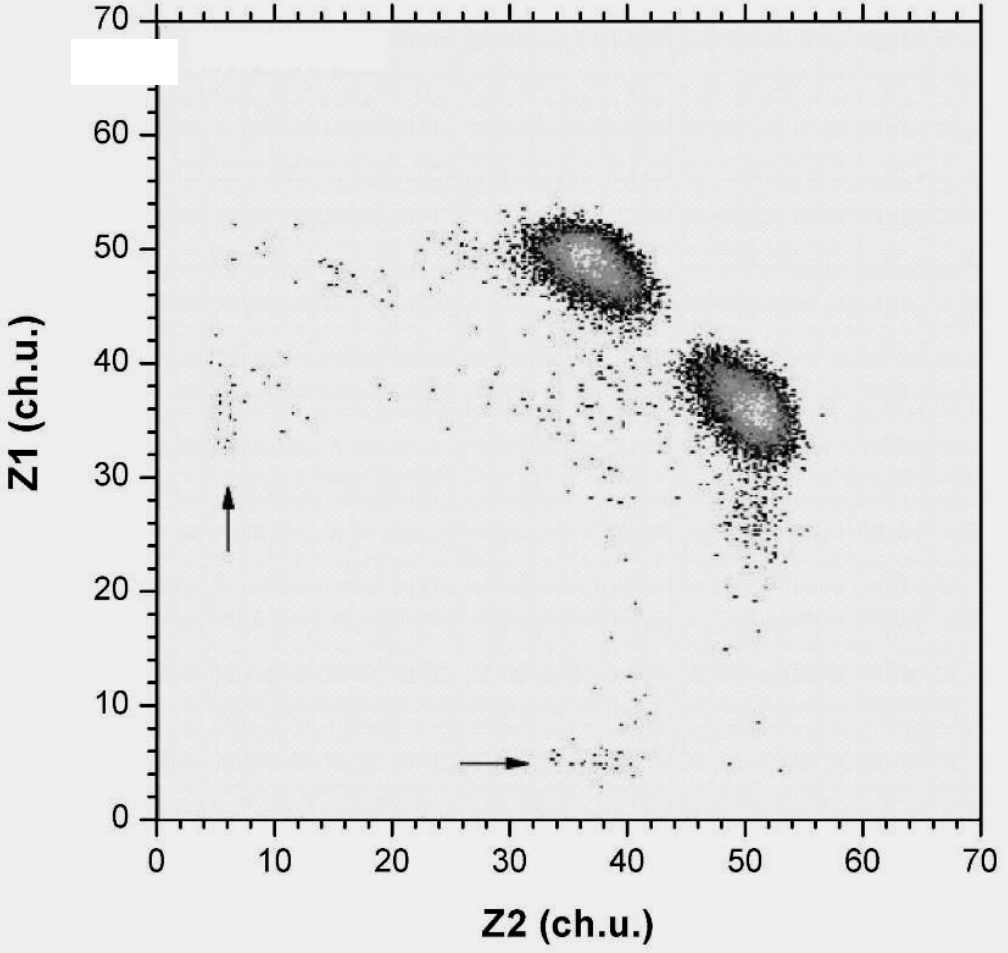
- nonrandom nature of the structures observed;
- bright manifestation of clustering

2% of random realization

Only 4 discreet directions

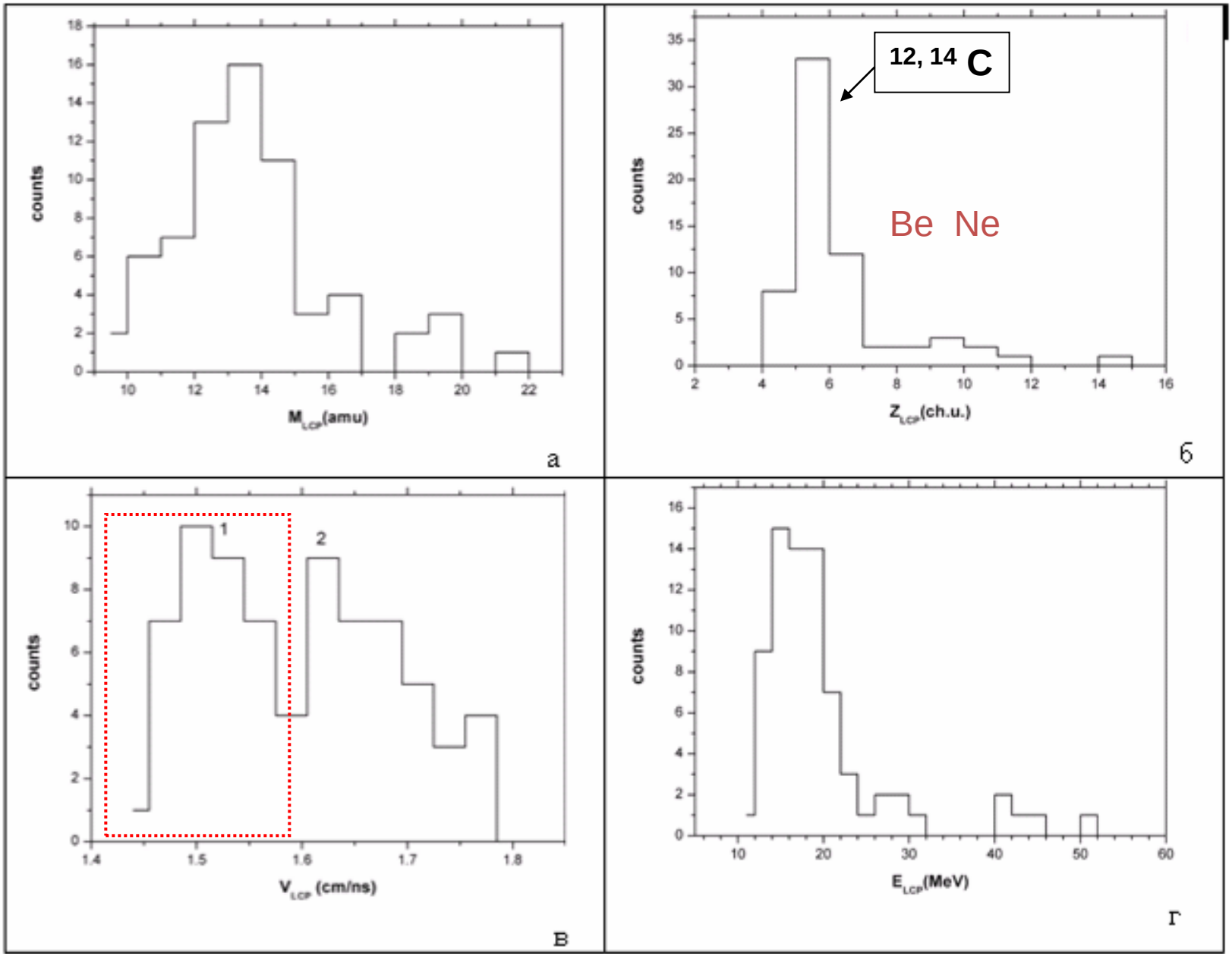
Selection of the CCT events using drift-time





Yu.V. Pyatkov et al., Bulletin of the Russian Academy of Sciences. Physics, 75 (2011) 949

Parameters of the LCP detected



Polar emission : previous experiments –

no chance to detect LCP under discussion

The light charged particles emitted near to the fission axis were identified and their energy was measured using a semiconductor telescope consisting of a surface barrier (SB) 45 μm thick ΔE detector and a 1.7 mm thick Si(Li) drifted E-detector. Simultaneously, both fission fragments were registered in two SB detectors. The

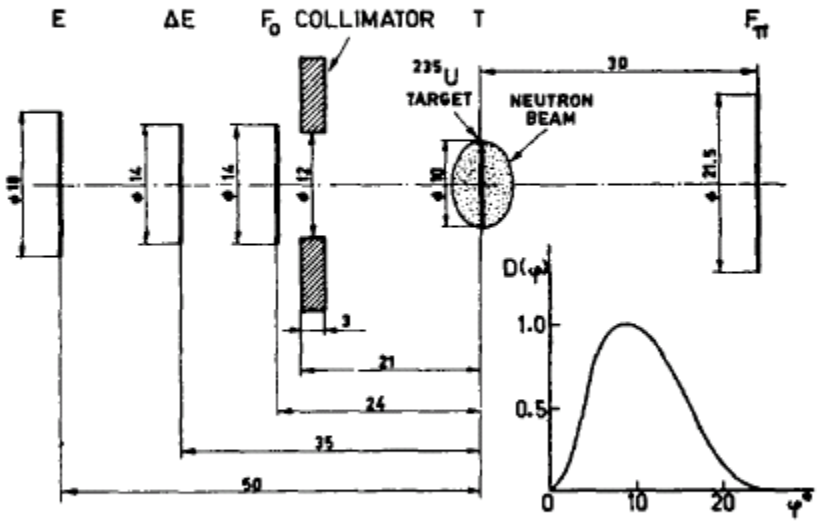


Fig. 1. Geometry of the experiment. The neutron beam passes perpendicularly to the plane of the figure. The symbol Ø denotes diameter. The resolution function $D(\varphi)$ shown in the right corner is the (arbitrarily normalized) probability distribution of registering the $E \wedge \Delta E \wedge F_0 \wedge F_x$ event, when the angle between the polar particle and F_0 fragment is equal to φ degrees.

30 μm detector (denoted F_0) was sufficiently thick to stop and register fission fragments going almost in the same direction as the light particles, protecting at the same time the telescope from fission fragments and α-radioactivity of the target.

The coincident (within 2 μs) pulses from the E, ΔE, F_0 and F_x detectors were analysed and stored event by event on magnetic tape by means of a Nuclear Data

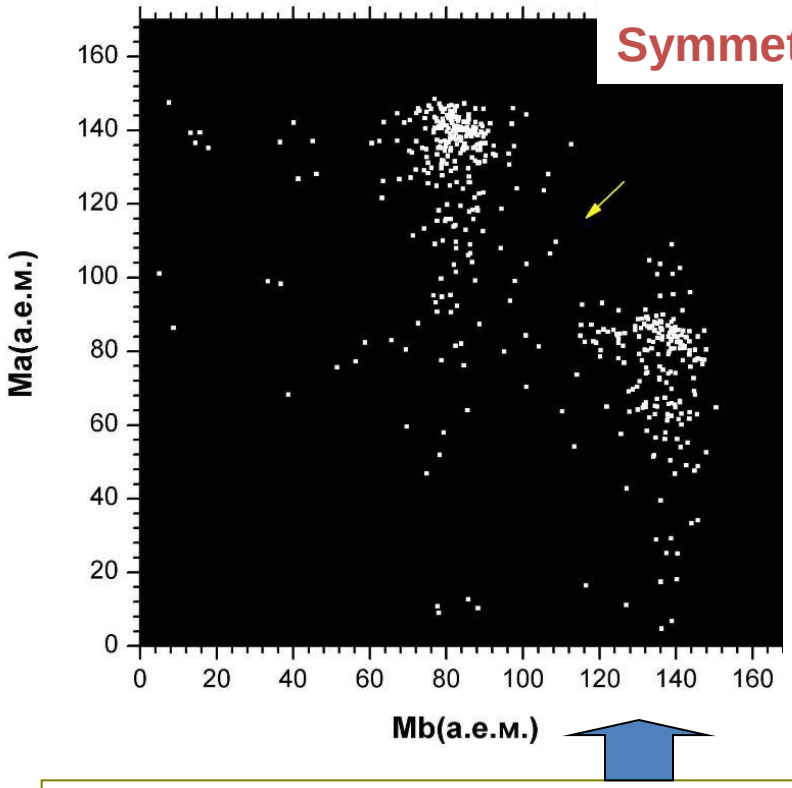
MULTIPARAMETER STUDIES OF POLAR EMISSION IN ^{236}U FISSION

E. PIASECKI, M. SOWIŃSKI, L. NOWICKI, A. KORDYASZ, E. CIEŚLAK and W. CZARNACKI

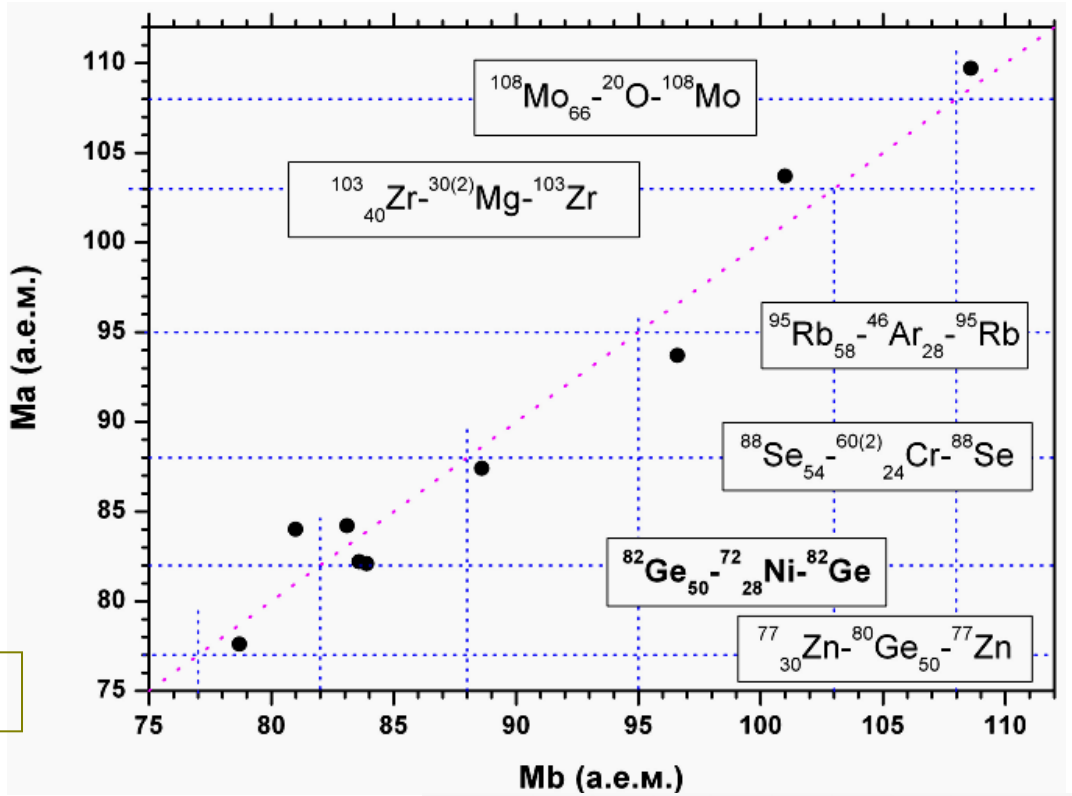
Institute of Nuclear Research, Department IA, 05-400 Świerk, Poland †

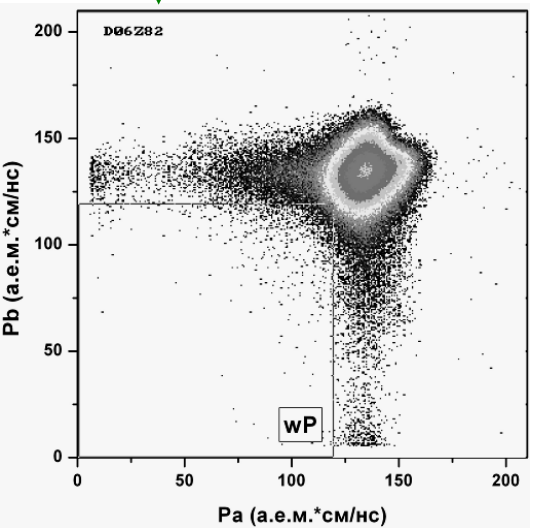
Nuclear Physics **A255** (1975) 387–404

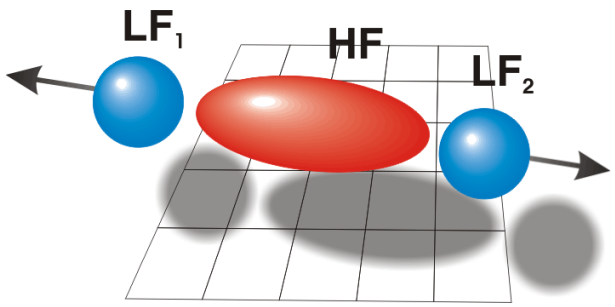
Symmetric cluster configurations in the CCT of $^{236}U^*$

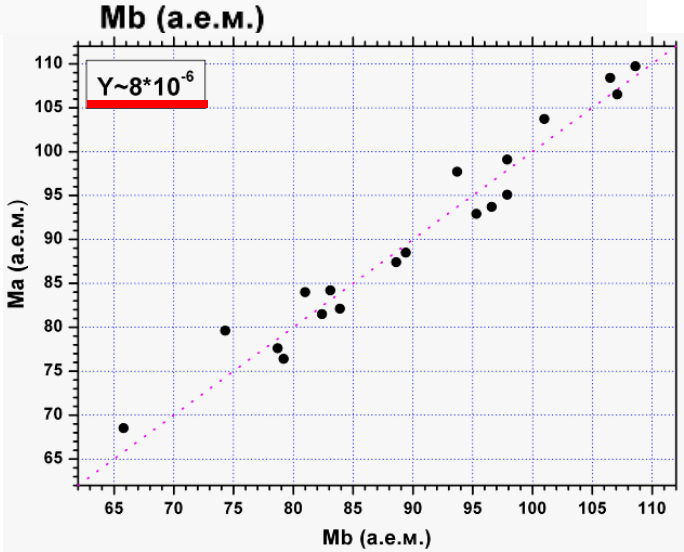


Momentum & Drift_time selection









Selection of symmetric decays

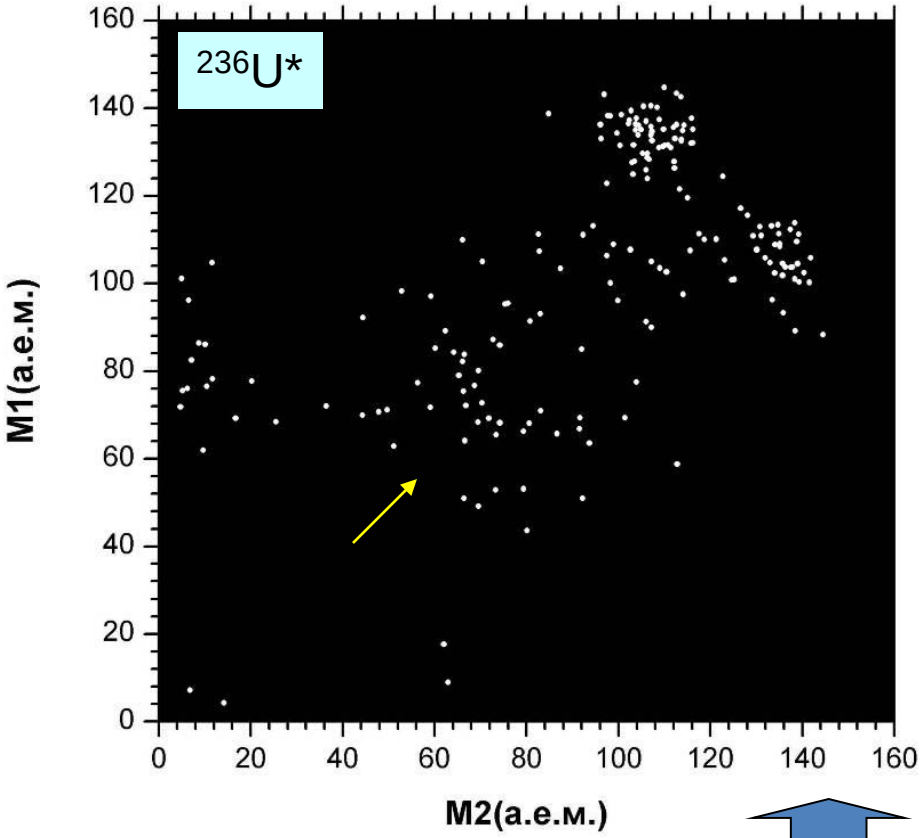
Each point:

6 independent experimental parameters

V1≈ V2

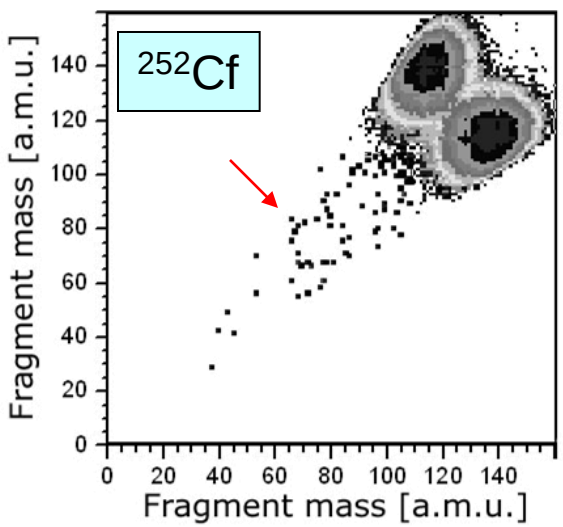
P1 ≈ P2

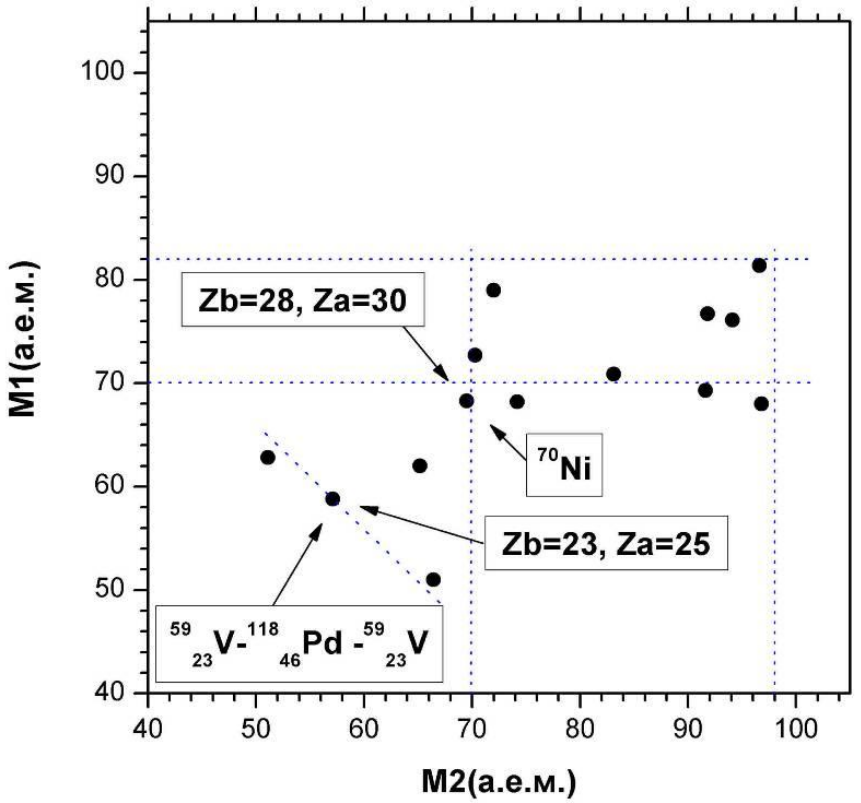
Z1 ≈ Z2



V1≈ V2

P1 ≈ P2

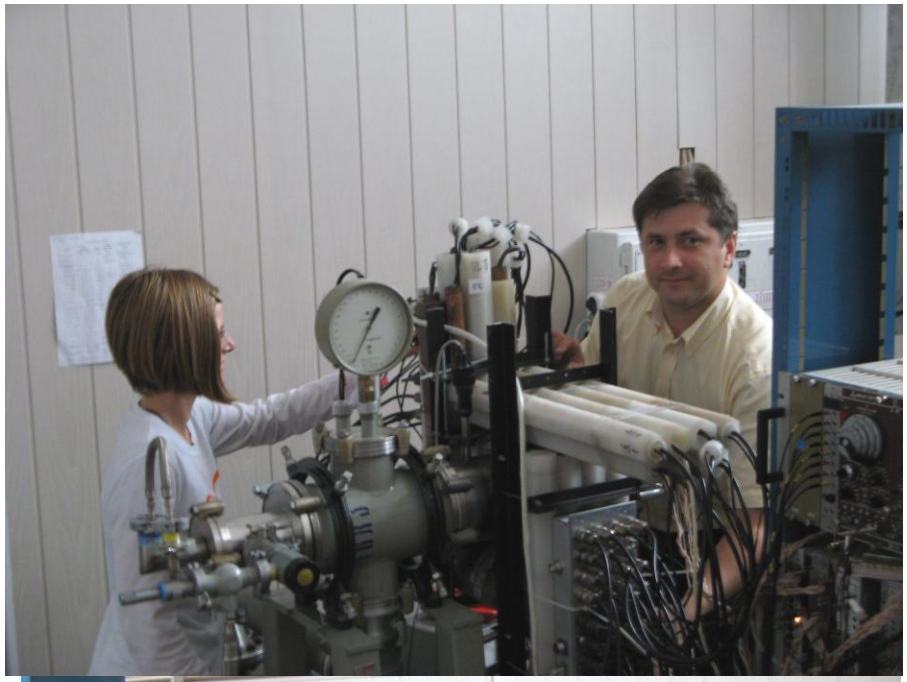


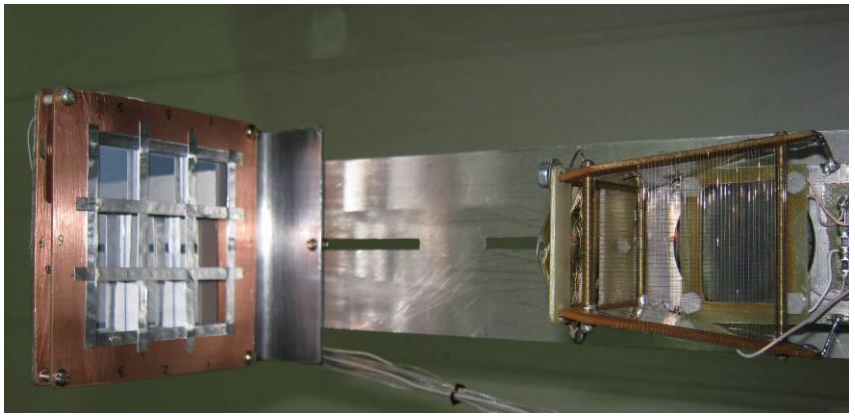


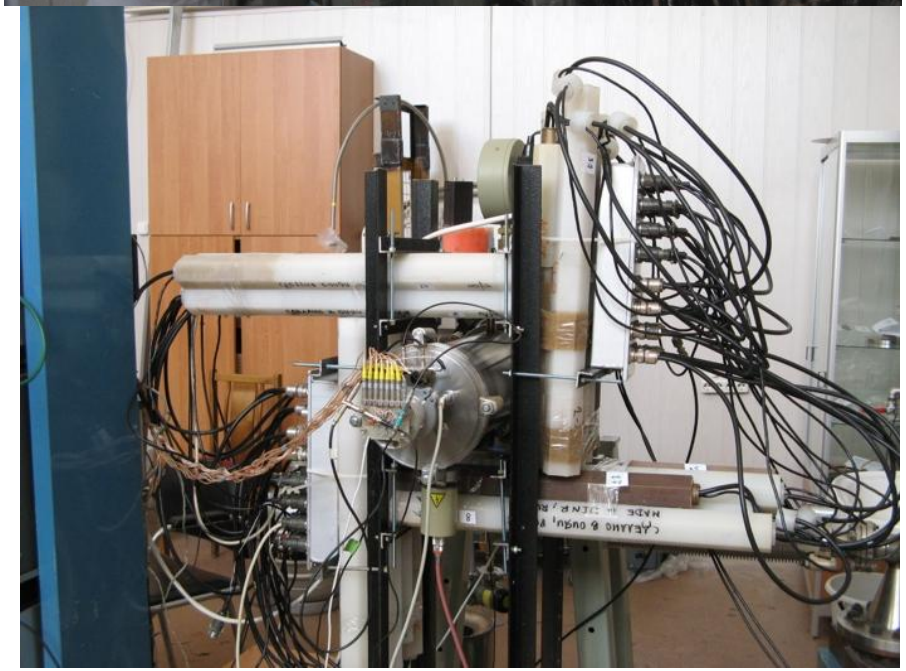
The “missing mass” approach was wary fruitful, however a direct observation of three fragment was still desirable

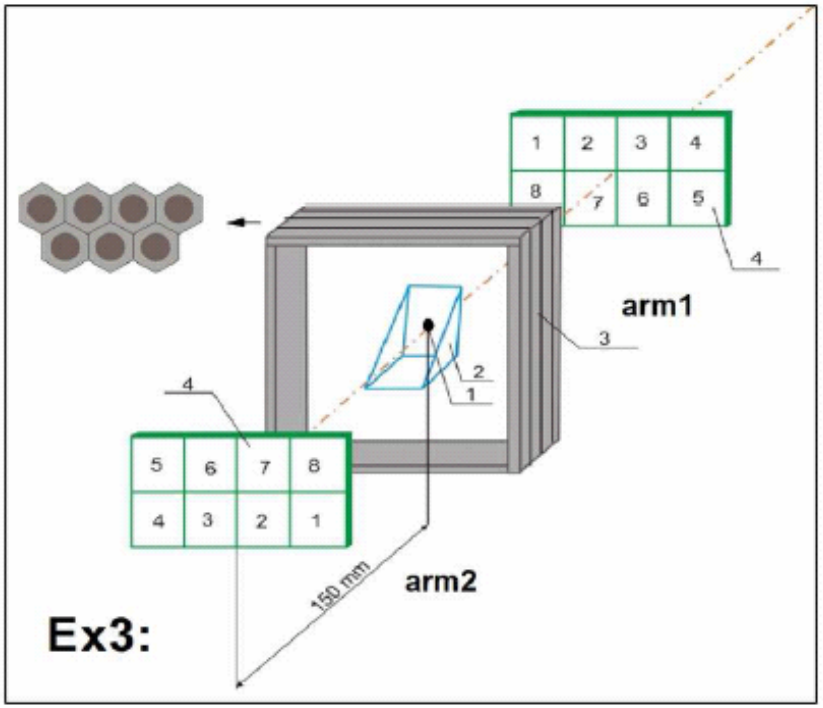
Next steps to be done with the mosaic system: Correlation Mosaic E-TOF Array (COMETA)

COMETA setup – overall view

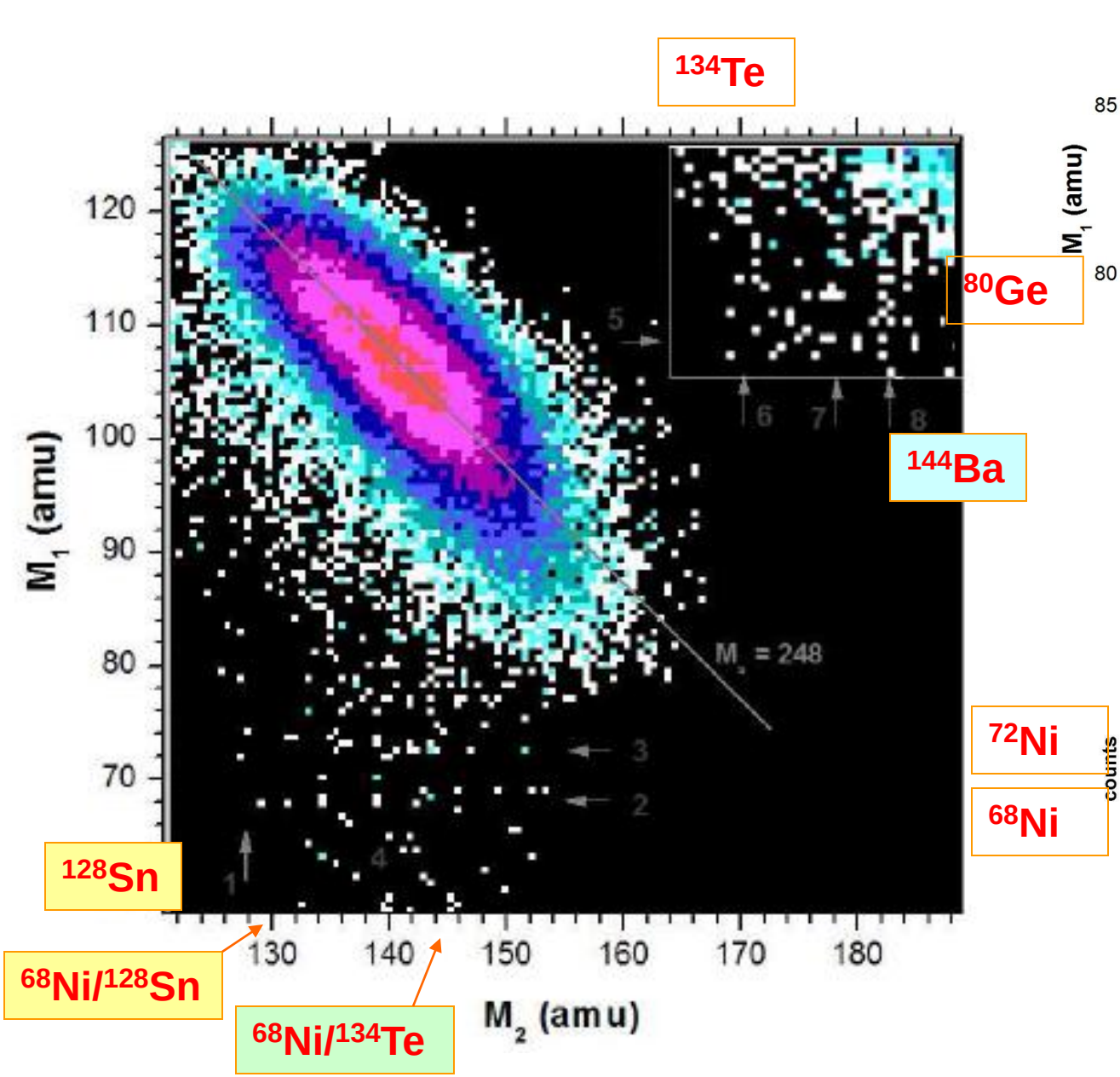


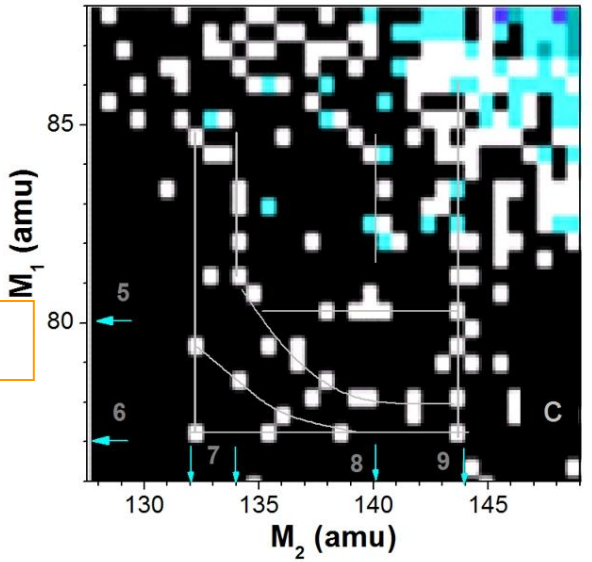


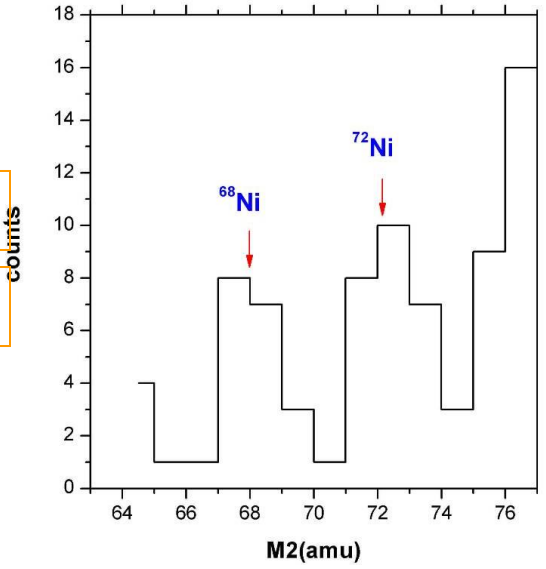


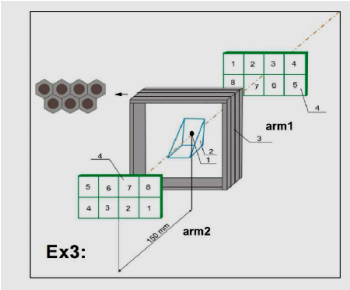


COMETA data: Ni-bump & Ge-bump without any gating

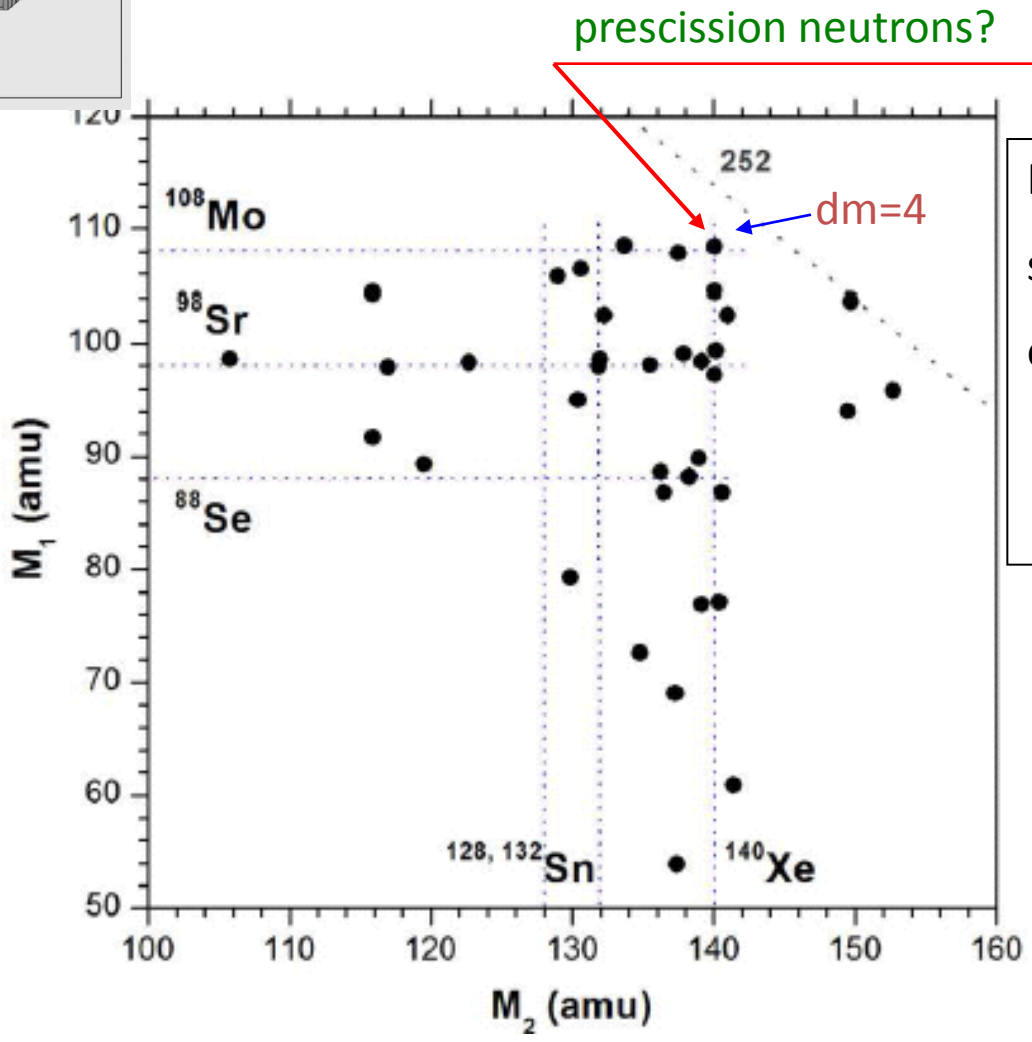








Neutron gated data, n=3 & V-E gate

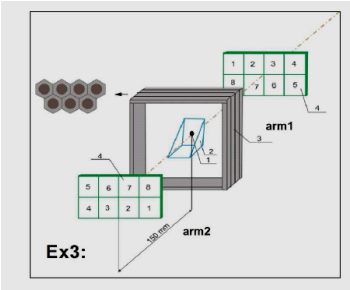


Rectangular structure similar to these observed earlier but:

- based on deformed magic clusters

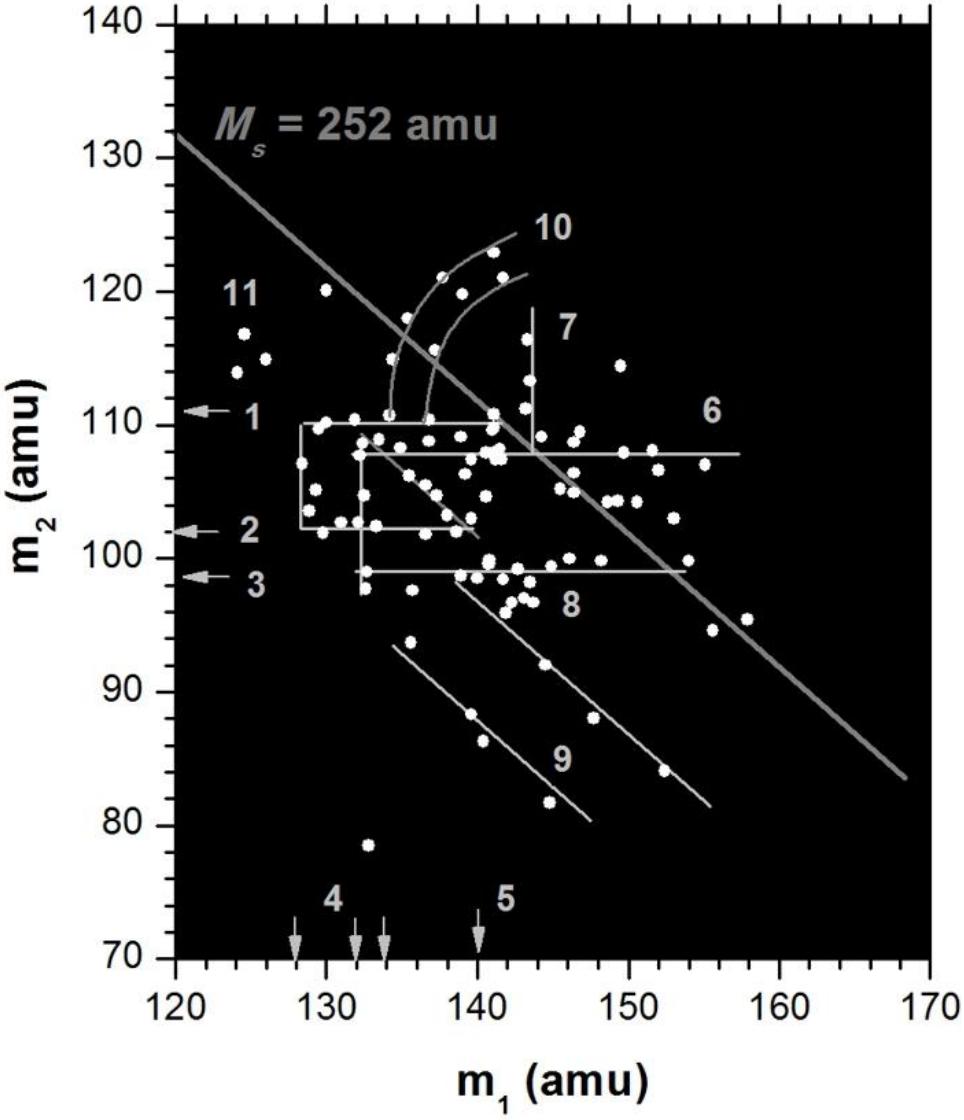
1. Neutron source being at rest;
2. Low missing mass;

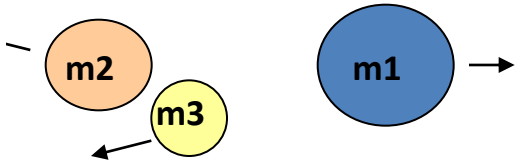
prescission neutrons?



Ternary events,

3 fragments were really detected





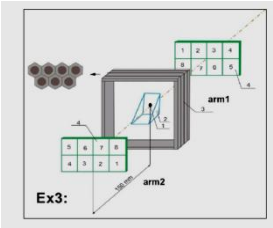
m1>m2>m3

m3: low velocity after 2-nd rupture.

Isotropic n-source?

V3~0.55cm/ns

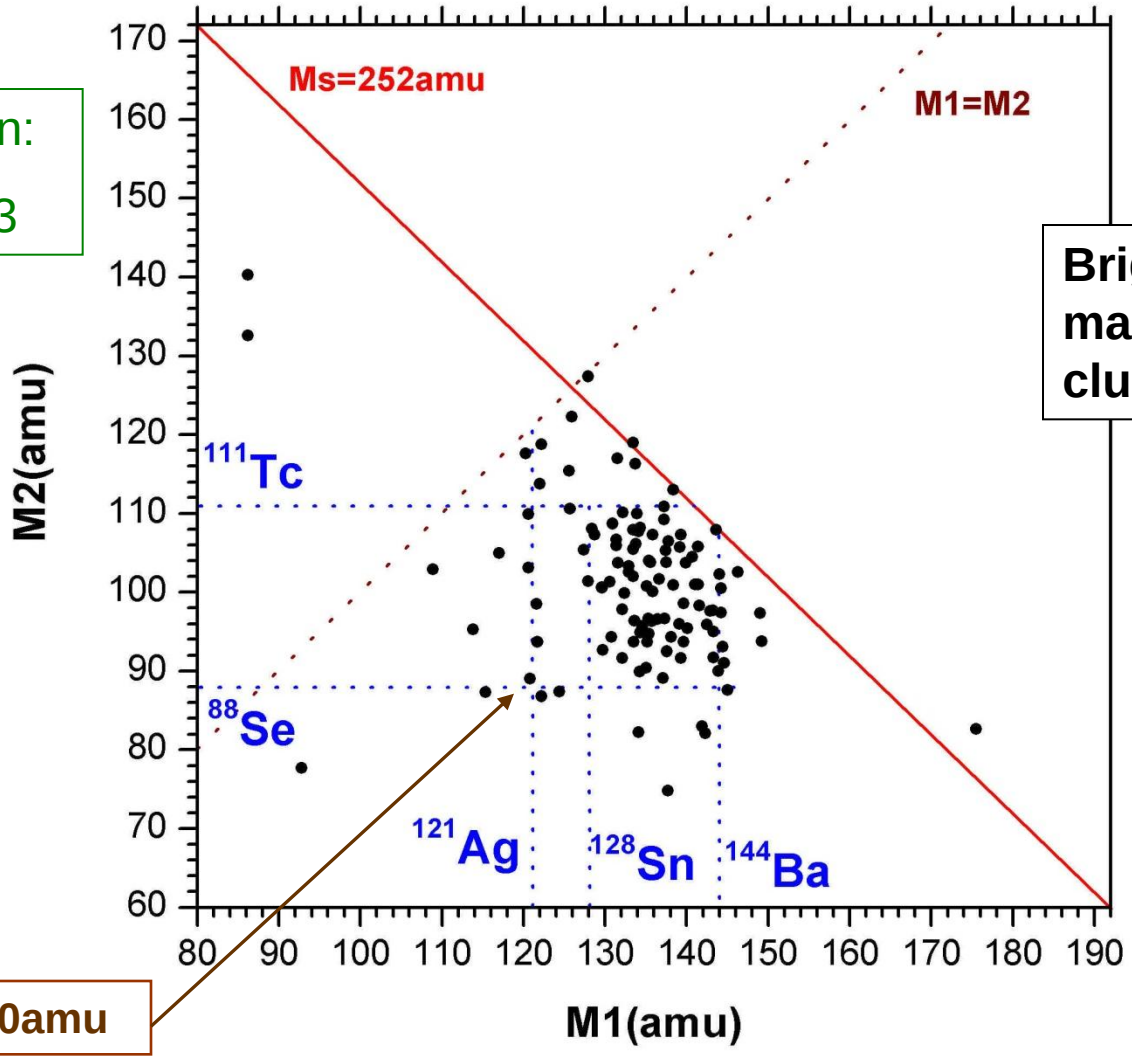
E3<2MeV



Ternary decays, all 3 fragments were detected

By definition:

m1>m2>m3



Bright manifestation of clustering

dM12s ~ 40amu

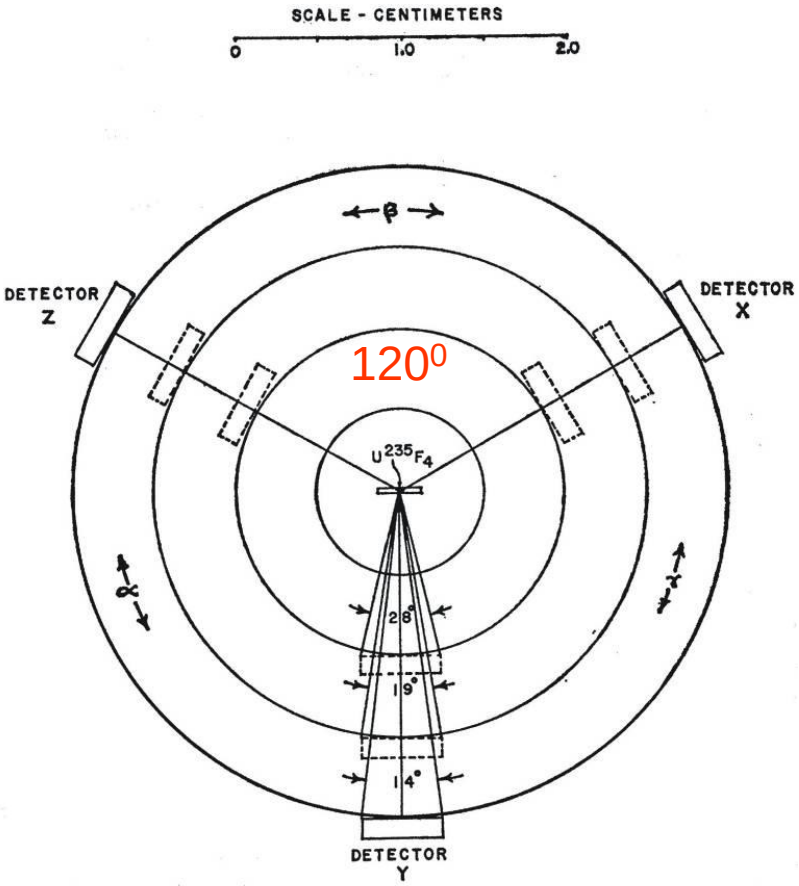
&Ms12<258

The new important data obtained, three correlated CCT partner are directly observed, but the most (perhaps) intriguing collinear CCT mode is still available only in “missing mass”

Next steps of the development:
- Expanding the number of the detectors
- Applying the new acquisition method
- Physical de-collinearization

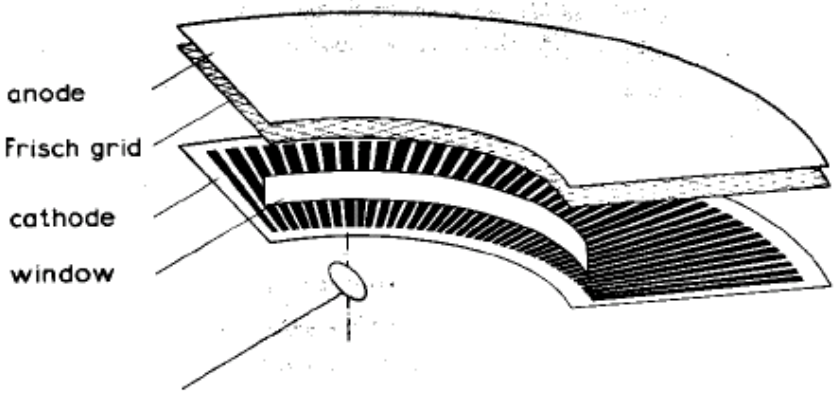
The goal is a common approach to physics of
- conventional ternary fission
- polar emission
- heavy ion radioactivity
- CCT

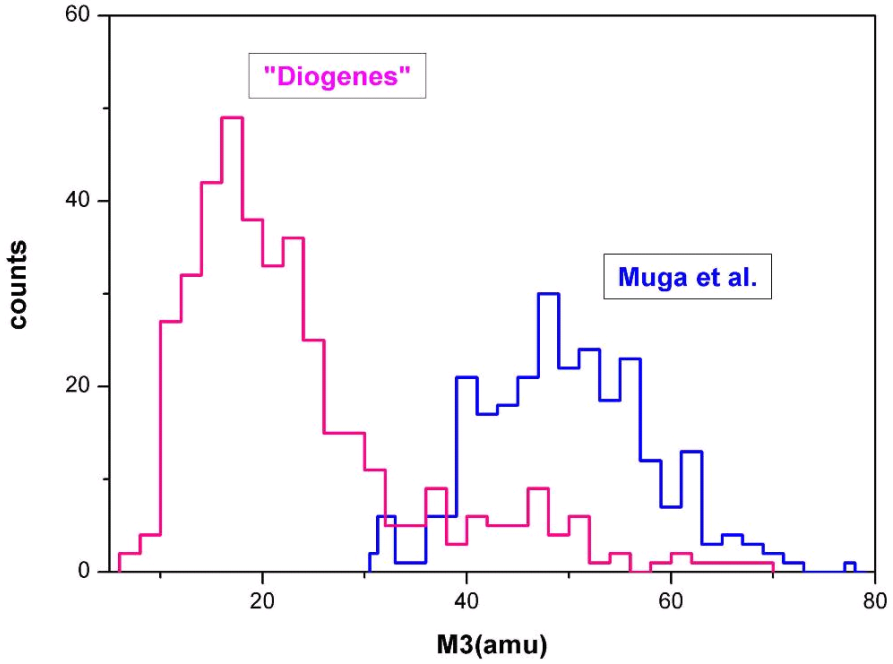
True ternary fission studies: contradictive results



Muga et al. Phys. Rev. Lett. 1967. v.161. p.1266 1283

Diogenes

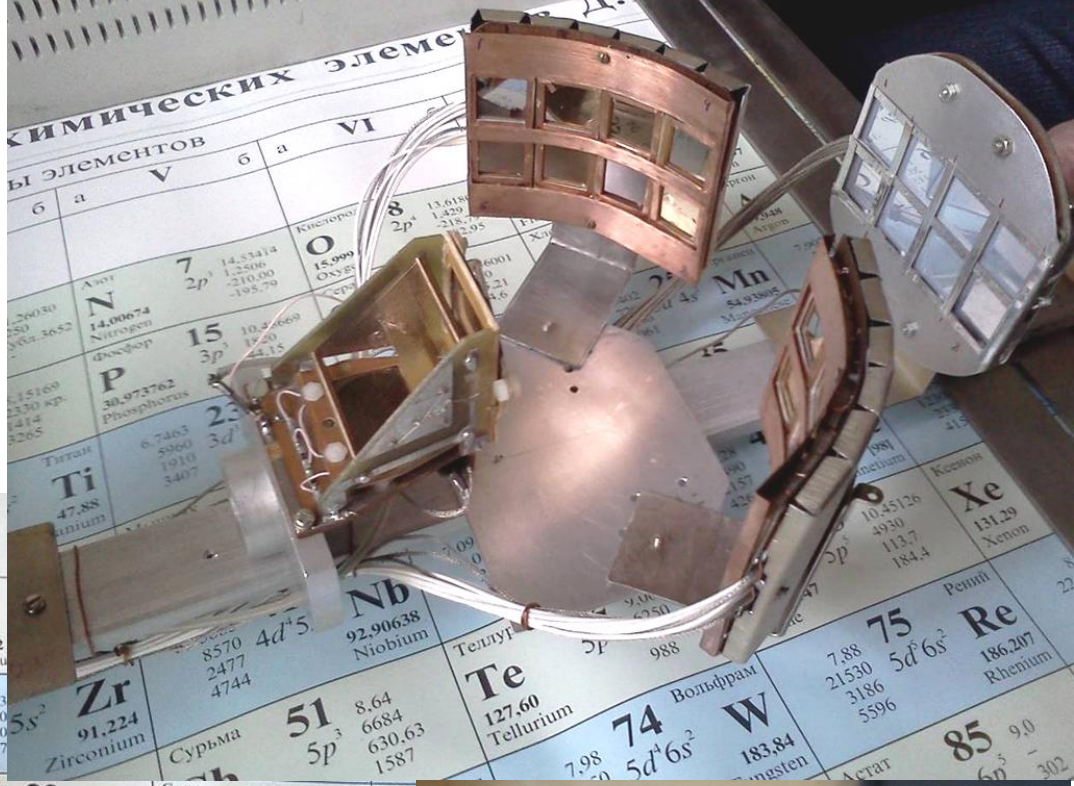


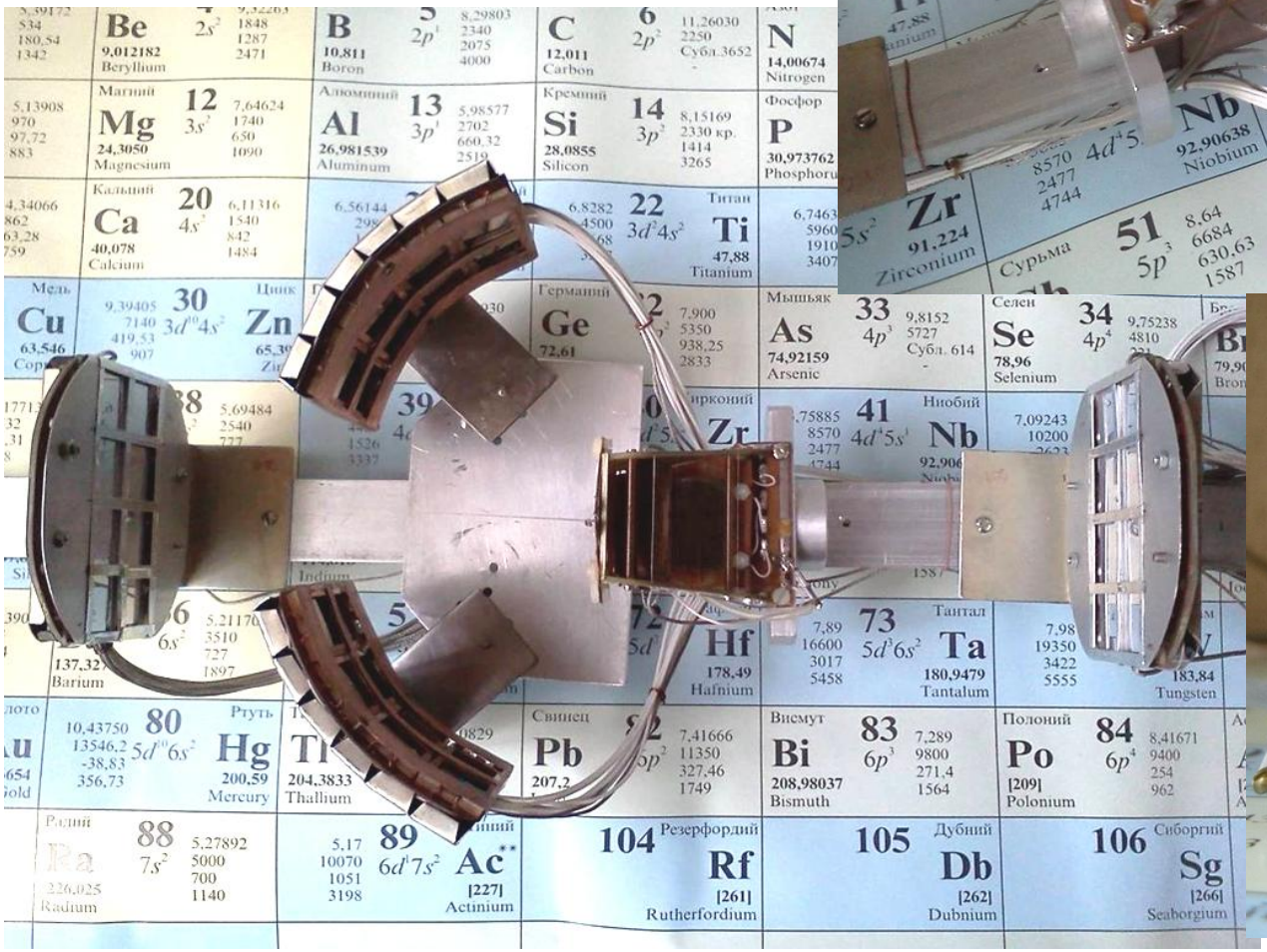


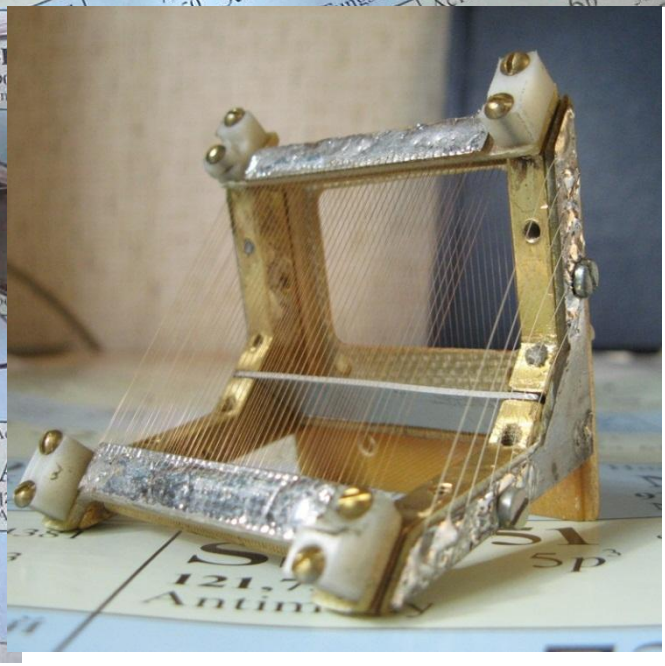
COMETA-2 setup, time-of-flight part

PIN-diodes 120˚& MCP

neutron belt 28 ^{3}He counters



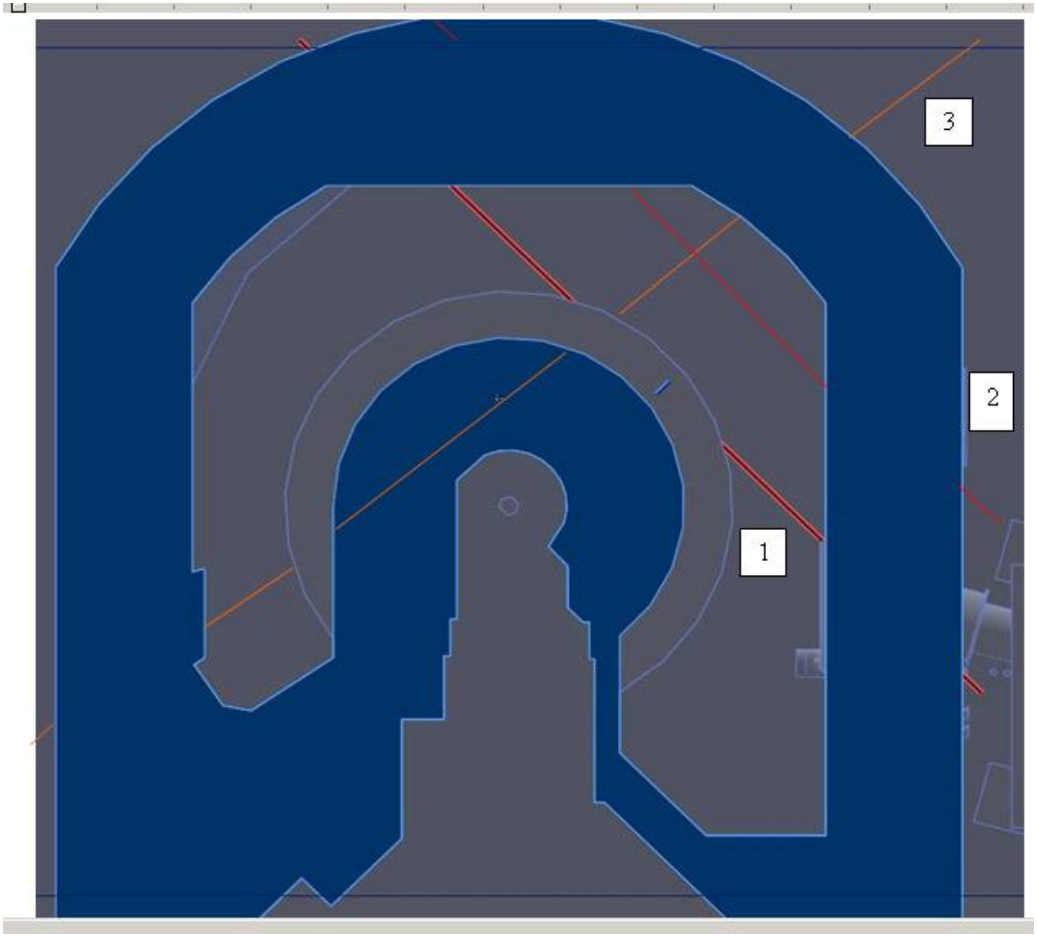


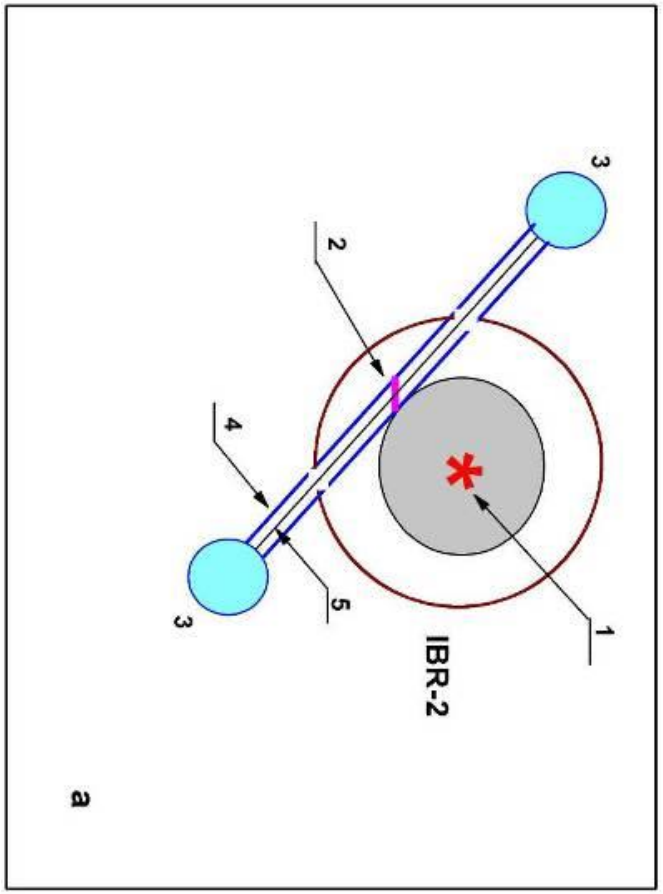


Perspective approach to electronics

- 16+1 channel
- 12 bit 5 GS/s Switched Capacitor ADC
- 1 Vpp input dynamics, single ended, 50 Ohm, MCX coaxial connectors
- Based on DRS4 chip (Paul Scherrer Institute design)
- 1024 storage cells per channels (200 ns recorded time per event @ 5GSample/s)
- Memory buffer: 128 events/ch (optional: 1024 events/ch)
- Trigger Time stamps

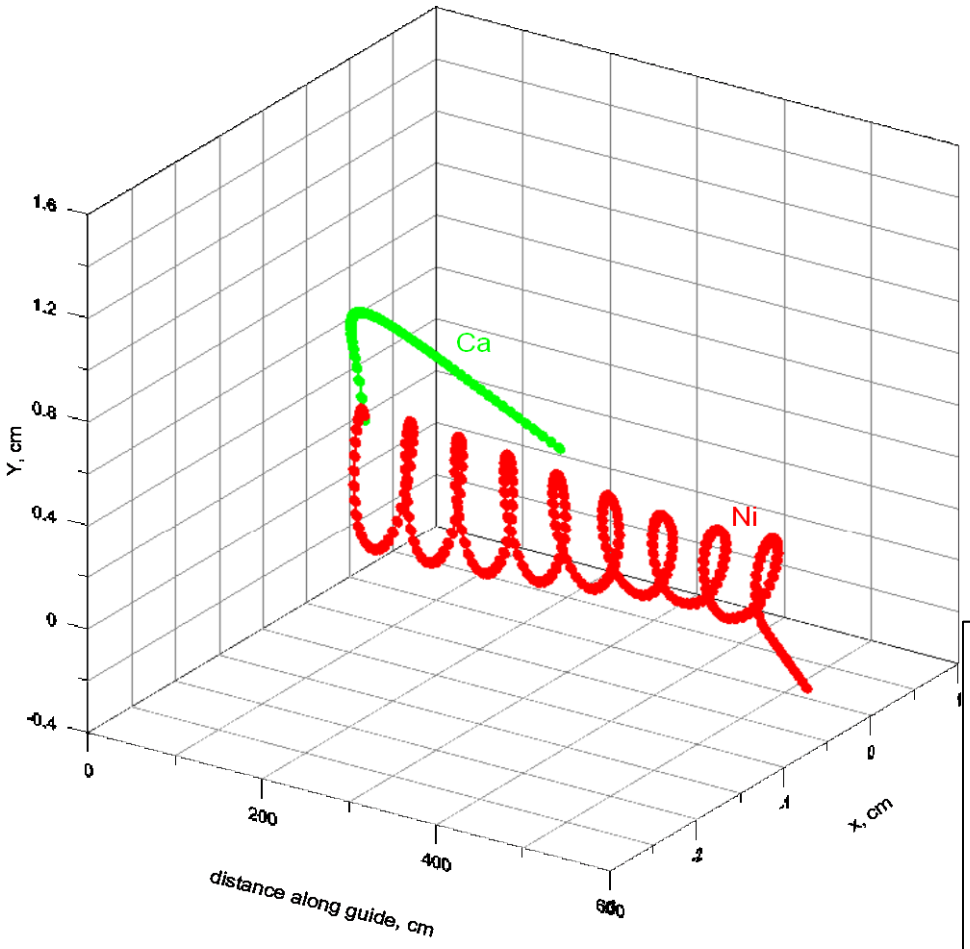
Electrostatic guide system



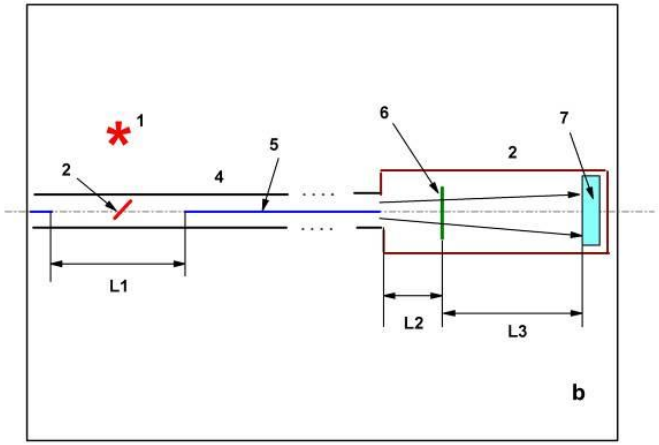


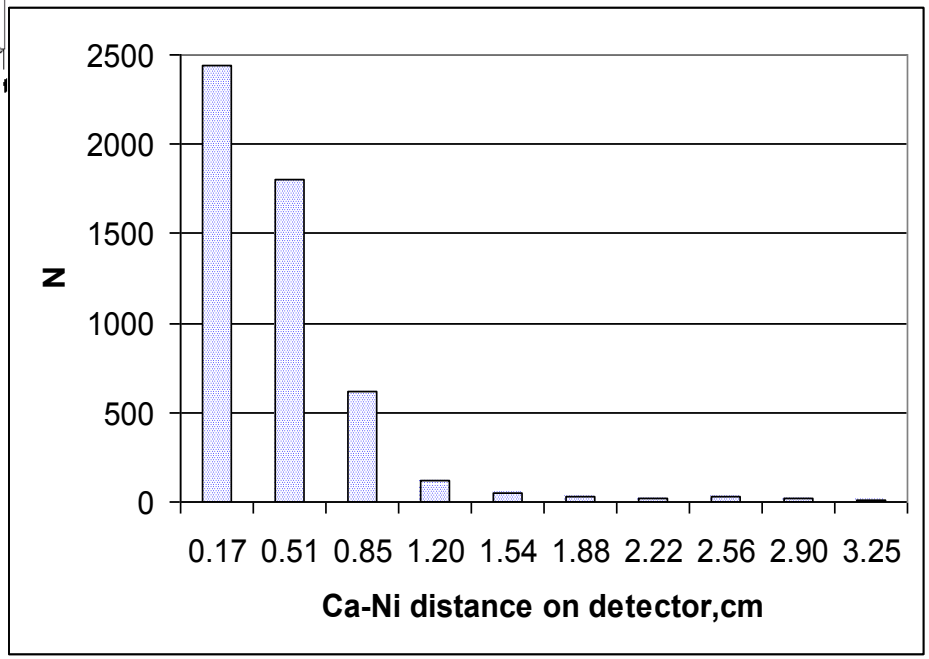
Poster of A. Alexandrov

Ion guide performance simulations

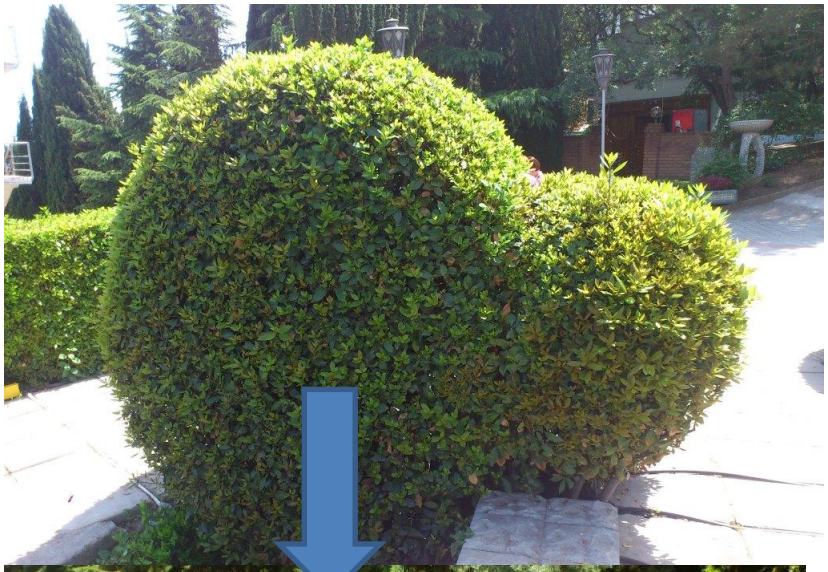


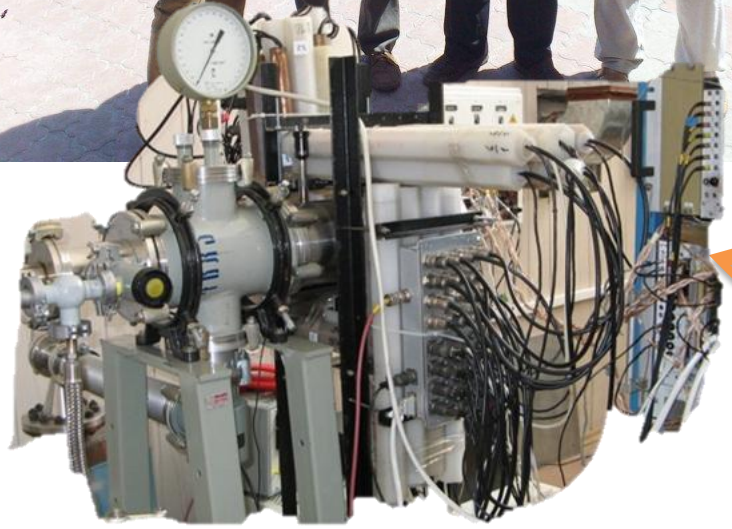
3D trajectories of the initially collinear ions of Ca and Ni



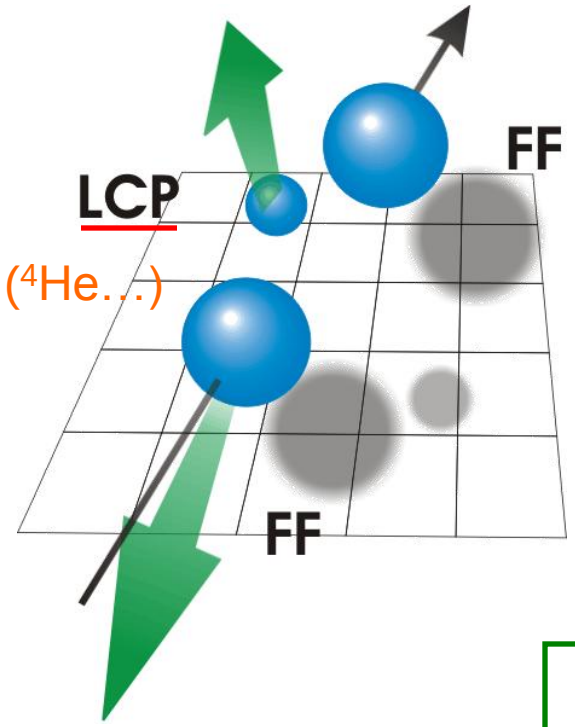


CCT @ DUBNA (ALUSHTA)





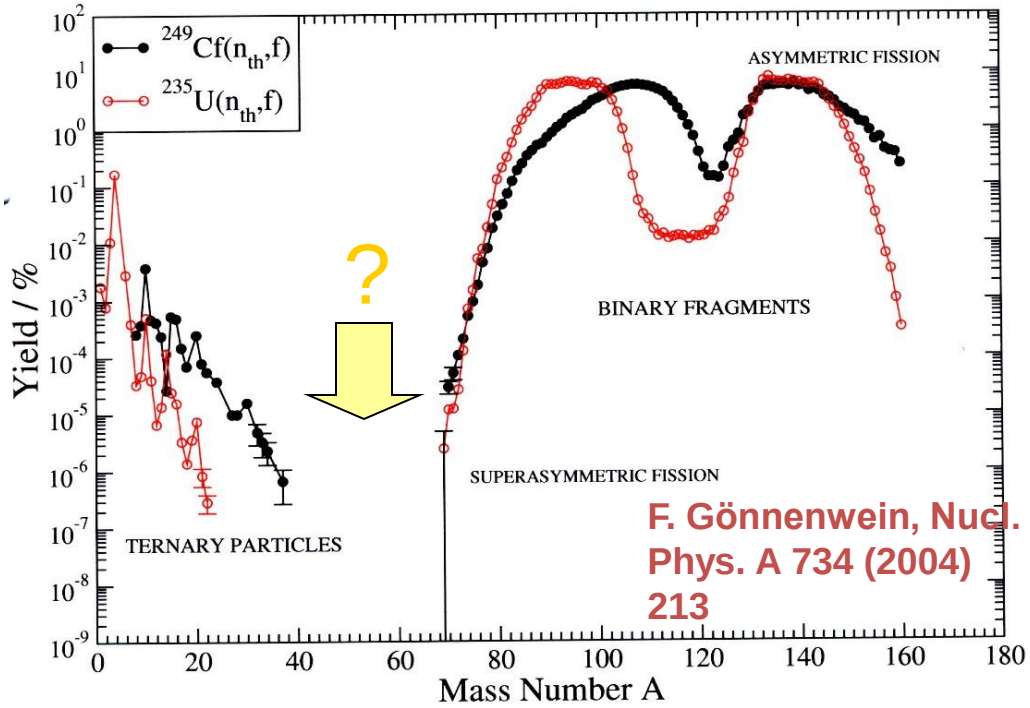
Conventional ternary fission ~10^{-3}/bin.fiss.



"Polar emission"

~10^{-5}/bin. fiss.

Ternary fission of low excited nuclear systems - **status quo at the start:**



F. Gönnenwein, Nucl. Phys. A 734 (2004) 213

True ternary fission - <u>contradictory</u> results:

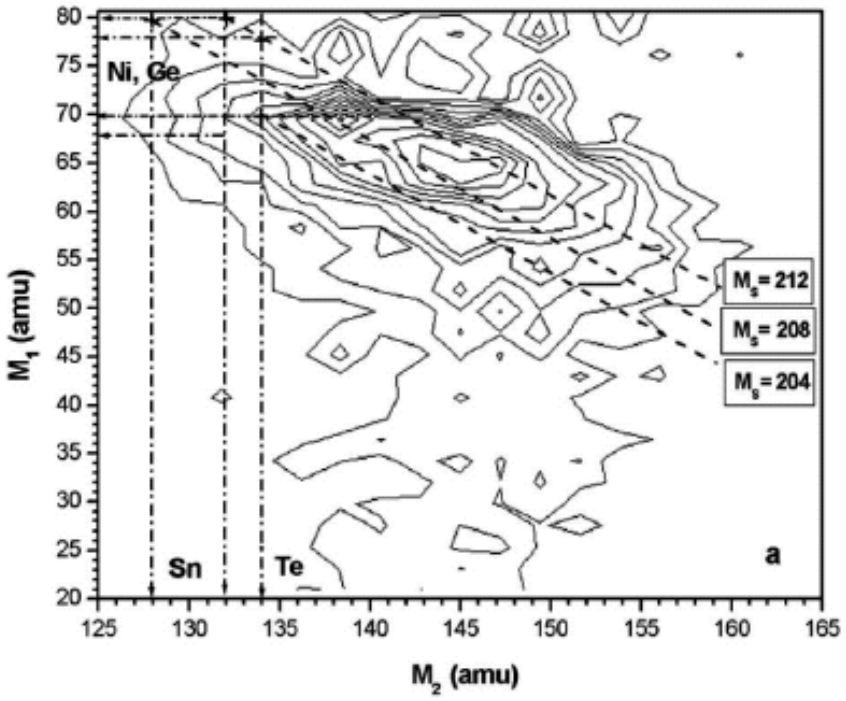
M.L. Muga et al., (1967) - Y_3 ~10^{-6}/bin. fiss.,

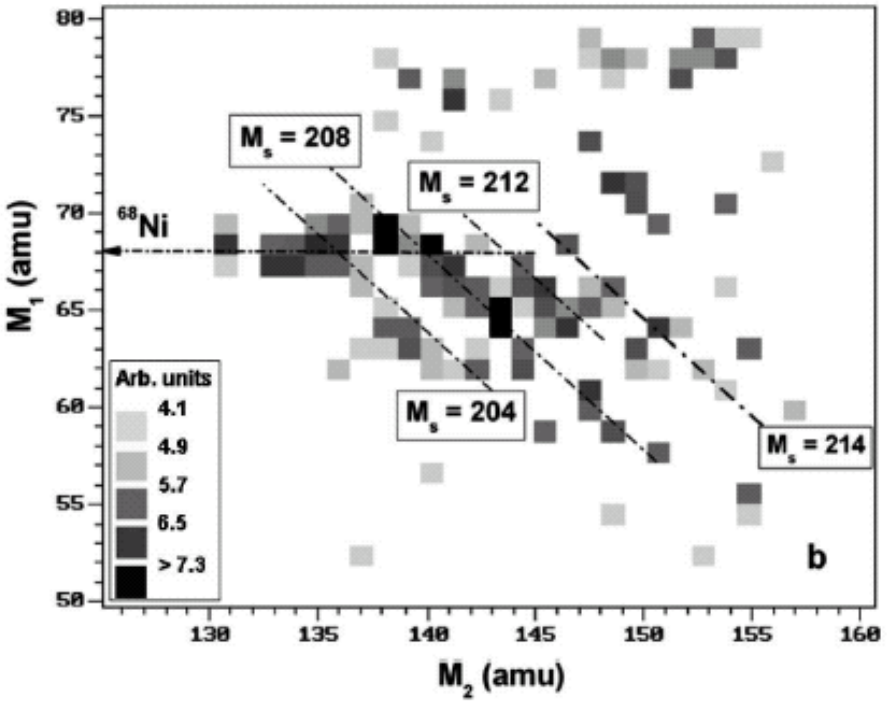
but it was strongly criticized ;

P. Schall, P. Heeg,

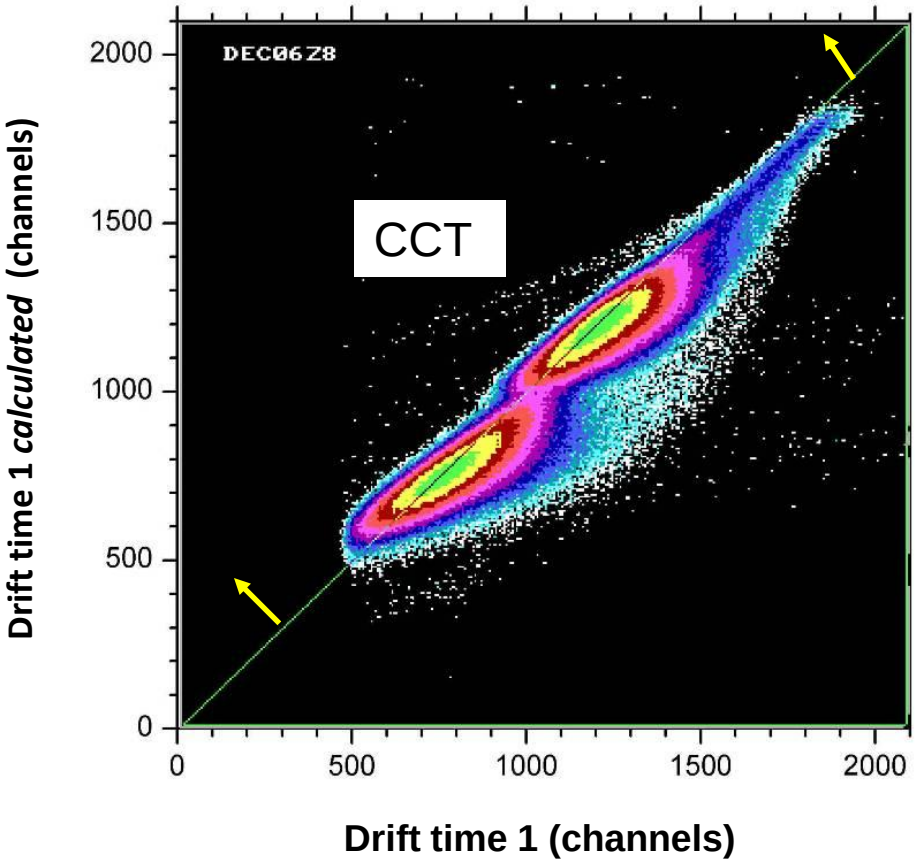
M. Mutterer, J.P. Theobald (1987) - Y3 <10^{-8}/bin.fiss.

Internal structure of the Ni-bump: the ridges M1+M2=const





Drift time application



$$D\_{calc} = \alpha - \beta\sqrt{E_{BHX} M_{TT}^{\bullet}}\; Z^{-2/3} + \gamma M_{TT}^{\bullet}$$

True drift time D even for scattered fragments

Yu.V. Pyatkov et al.,
Phys. Of Atomic Nuclei
73 (2010) 1309