Observation of a new effect in the ternary fission of ^{252}Cf(sf) with the emission of an alpha particle.

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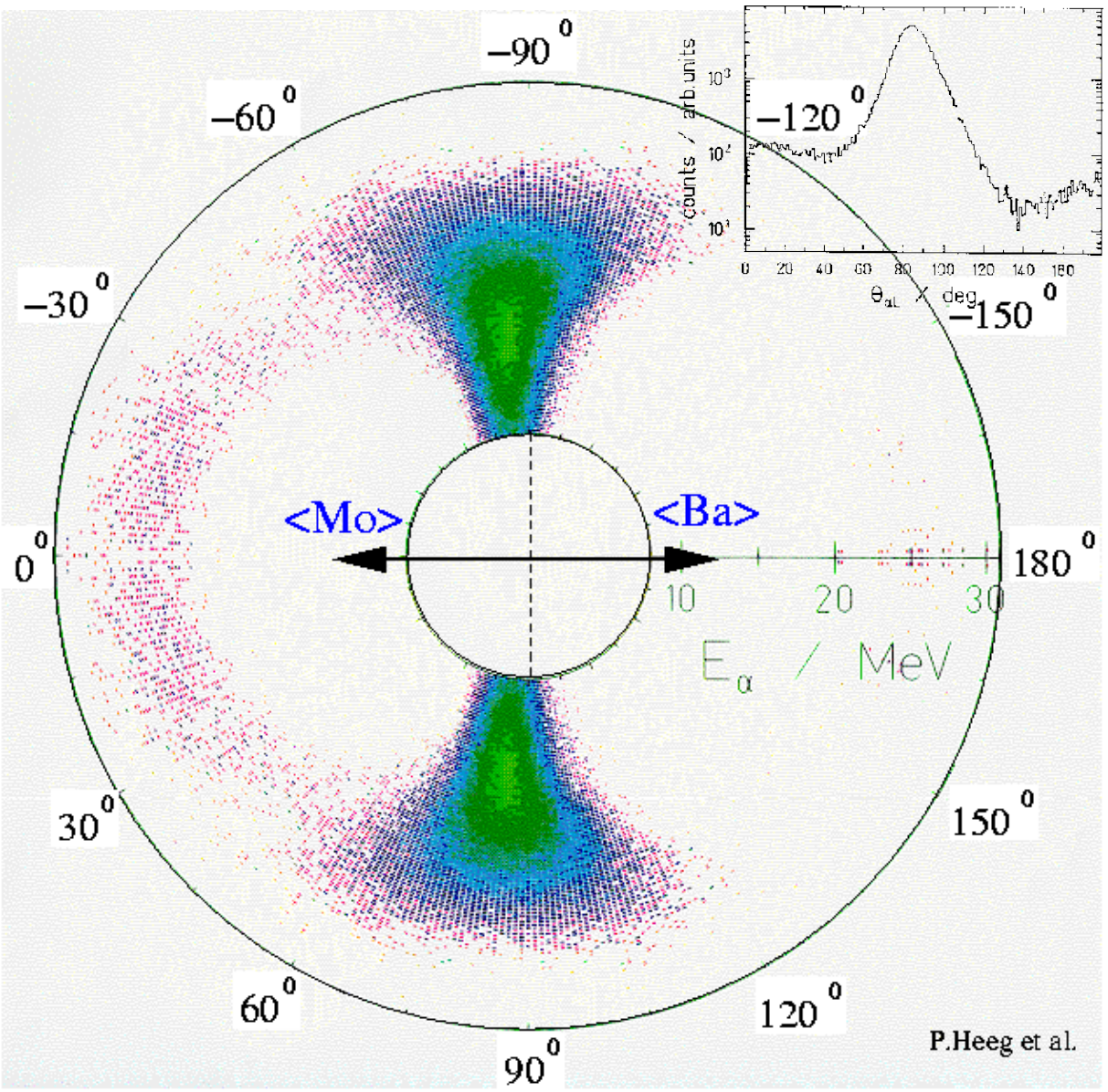
Introduction

Particle accompanied ^{252}Cf fission (conventional ternary fission or equatorial emission)



Polar diagram of alpha-particle energy versus the emission angle with respect to the light fission fragment, for ^{252}Cf.

Tsien San-Tsiang et al.;P hys.Rev.71(1947), 128

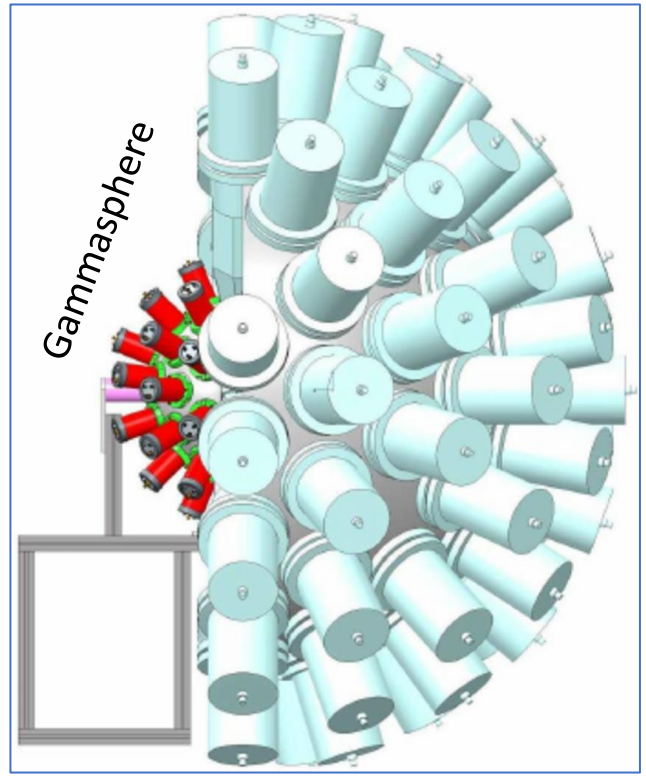
ternary particle	<E> [MeV]	FWHM [MeV]	Yield Particle/ Bin.fission
^{3}H	8.2±0.6	7.2±0.6	3.1E-04
^{4}He	16.4±0.2	10.3±0.3	2.7E-03
^{5}He	12.4±0.3	8.9±0.5	5.6E-04
^{6}He	12.6±0.5	8.9±0.5	7.2E-05
^{7}He	11.0±1.5	8±2	1.5E-05
^{8}He	10.2±1.0	10.2±1.0	8.1E-06
Li	14.3±1.0	14.3±1.0	1.9E-05
Be	17.5±1.0	18±1	5.6E-05
B	21.2±1.0	19.3±1.0	4.4E-06
C	26±1	-	3.1E-04
Sum			**3.73E-03**

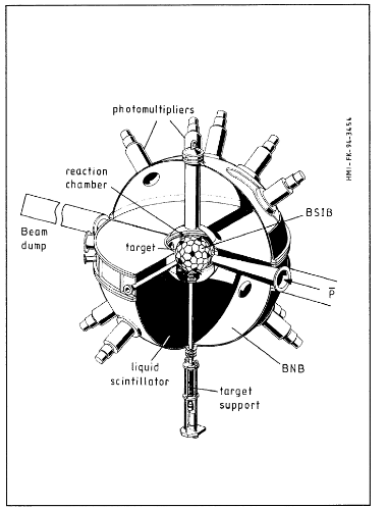
https://web-docs.gsi.de/~wolle/FISSION/ternary/node2.html

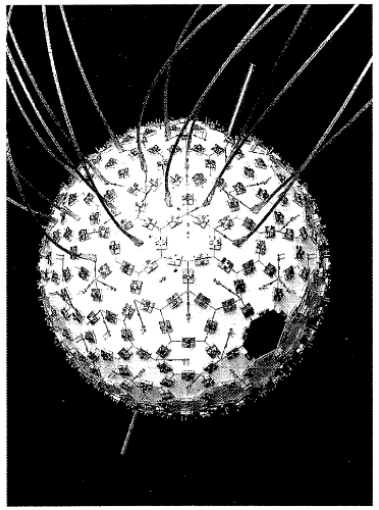
Relative emission probabilities of the various ternary particles and first and second moments of the energy distribution for the spontanous fission of ^{252}Cf.

Particle accompanied ^{252}Cf fission experiments

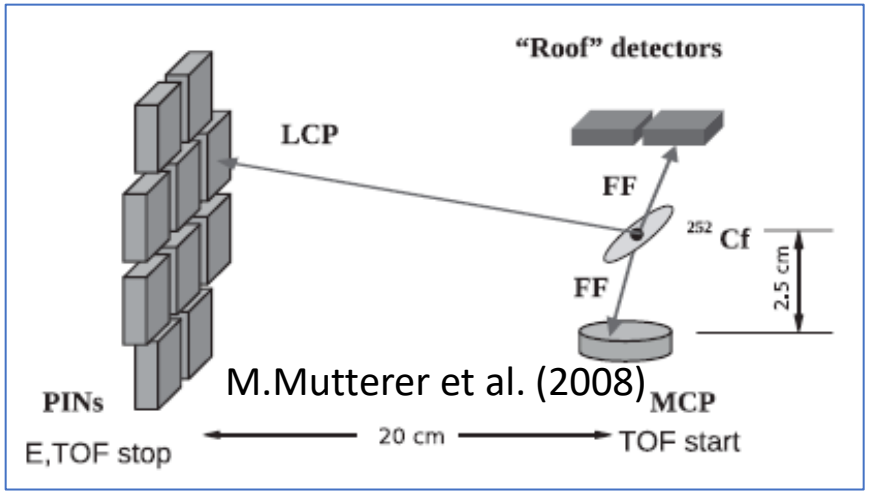
Angular range	**Method (detectors)**	Reference
Equatorial	**TOF-E (MCP-silicon)**	Mutterer et al. (2008)
Full	dE-E (silicon-silicon)	Wagemans et al. (2004)
Full	dE-E (gas-silicon)	Kopatch et al. (2002)
Full	TOF-E (silicon ball)	Tishchenko et al. (2002)
Equatorial	dE-E (gas-silicon)	Grachev et al. (1988)
Full	Eγ (Gammasphere)	Ter-Akopian et al. (2004)







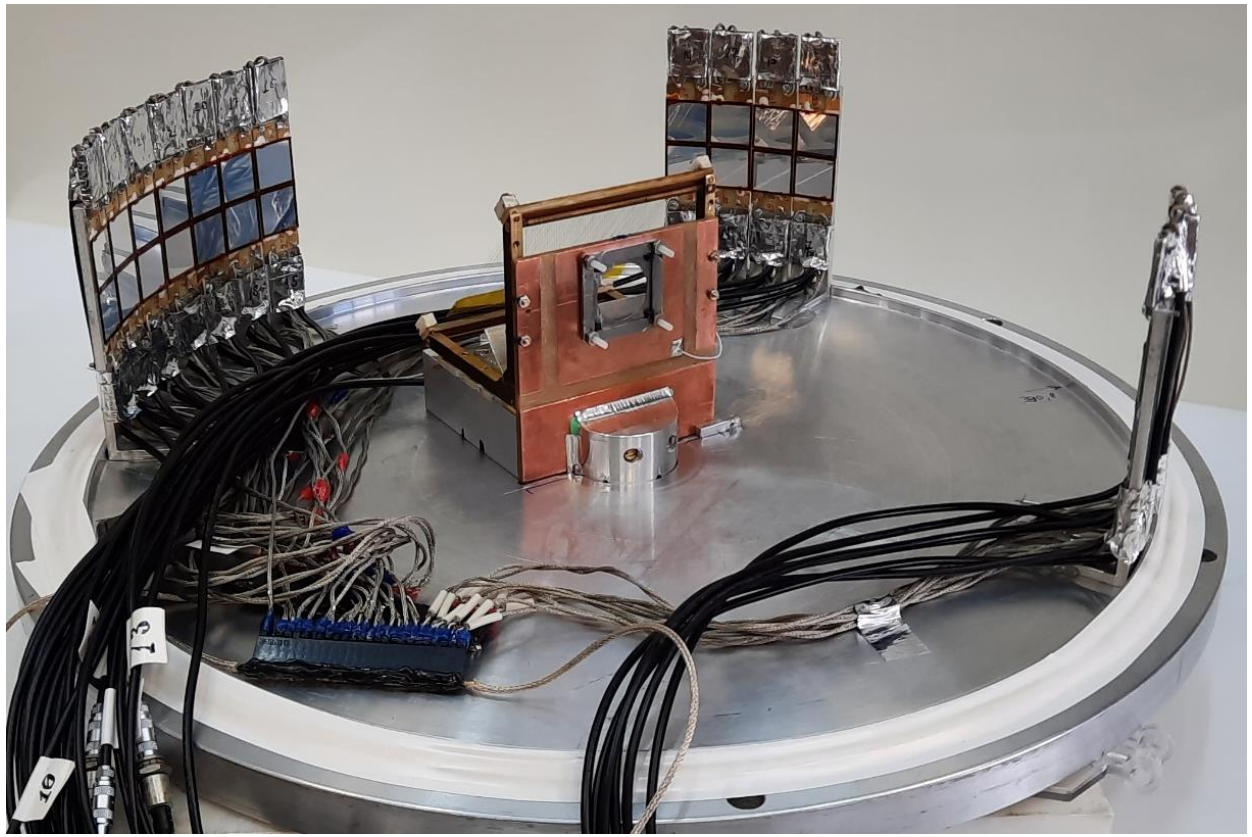
Berlin Silicon Ball
internal radius ~ 10 cm

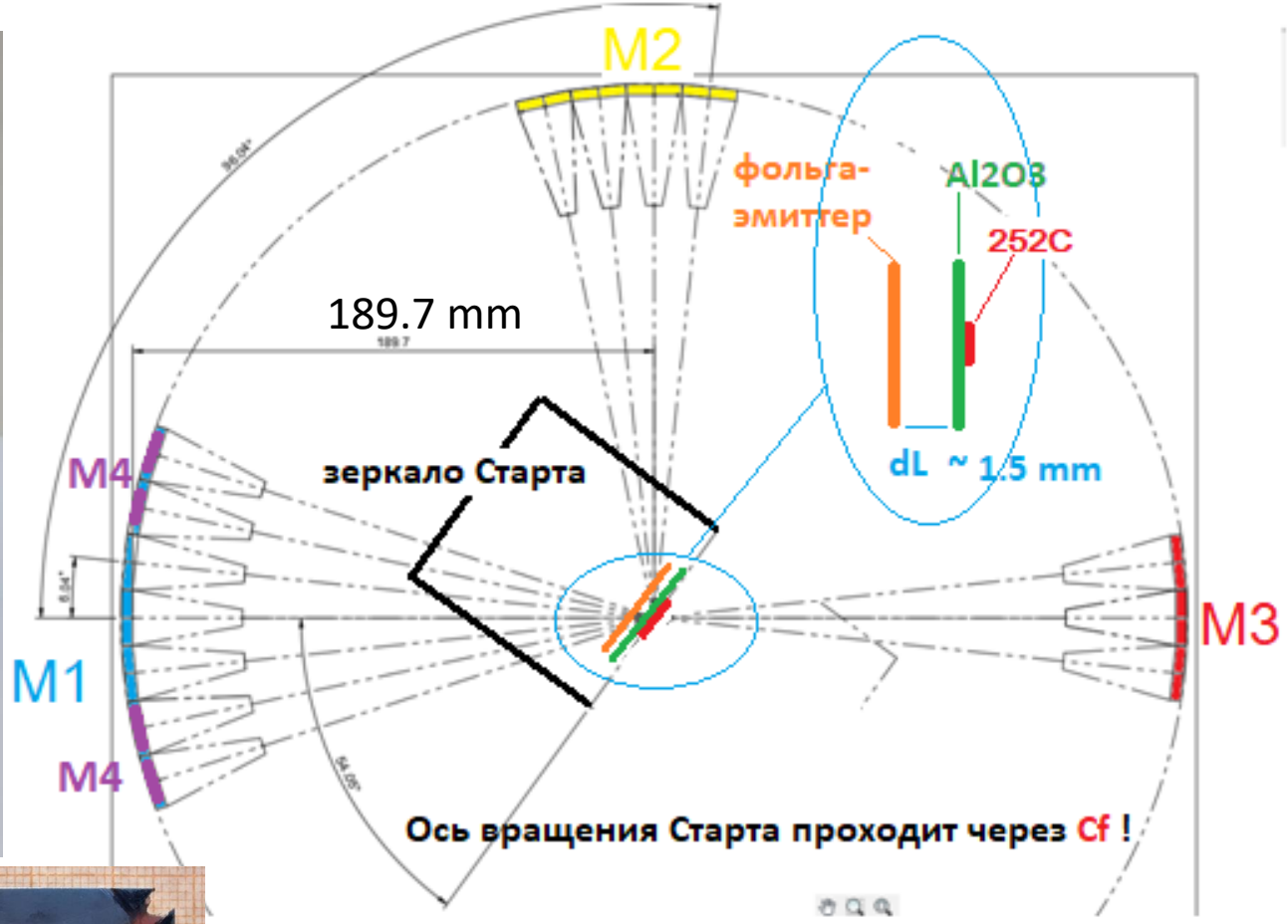


But! **None** of these setups made it possible **to measure** the Time-of-Flight and Energy of **each fragment** in **multiparticle** events independently.

Experiment and results

COrrelation **M-E-T A**rray 2021 **(COMETA) setup - different approach → new data**

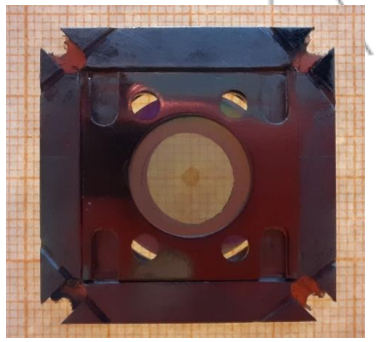




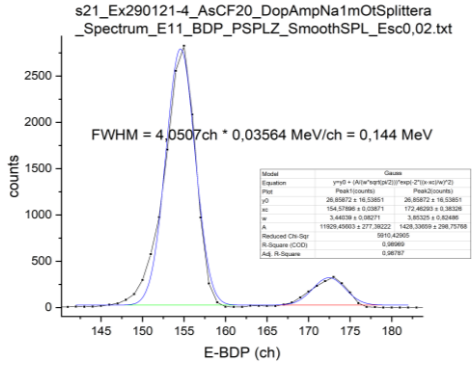
ToF-E method for
triple coincidence:
ToF_i & E_i -> M_i, i = 1,2,3

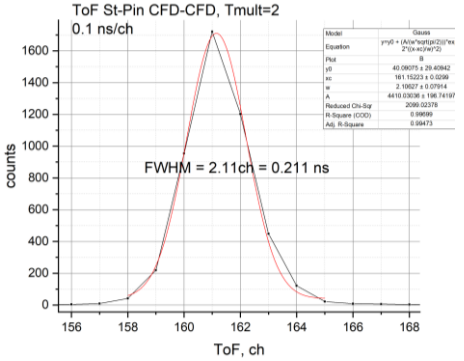
details of methodology:
http://fobos.jinr.ru/

VX1742
32+2 Channel
12bit 5 GS/s
Digitizer



New 252Cf (45 kBq)
Spot d 3 mm on Al2O3 65 ug/cm2





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

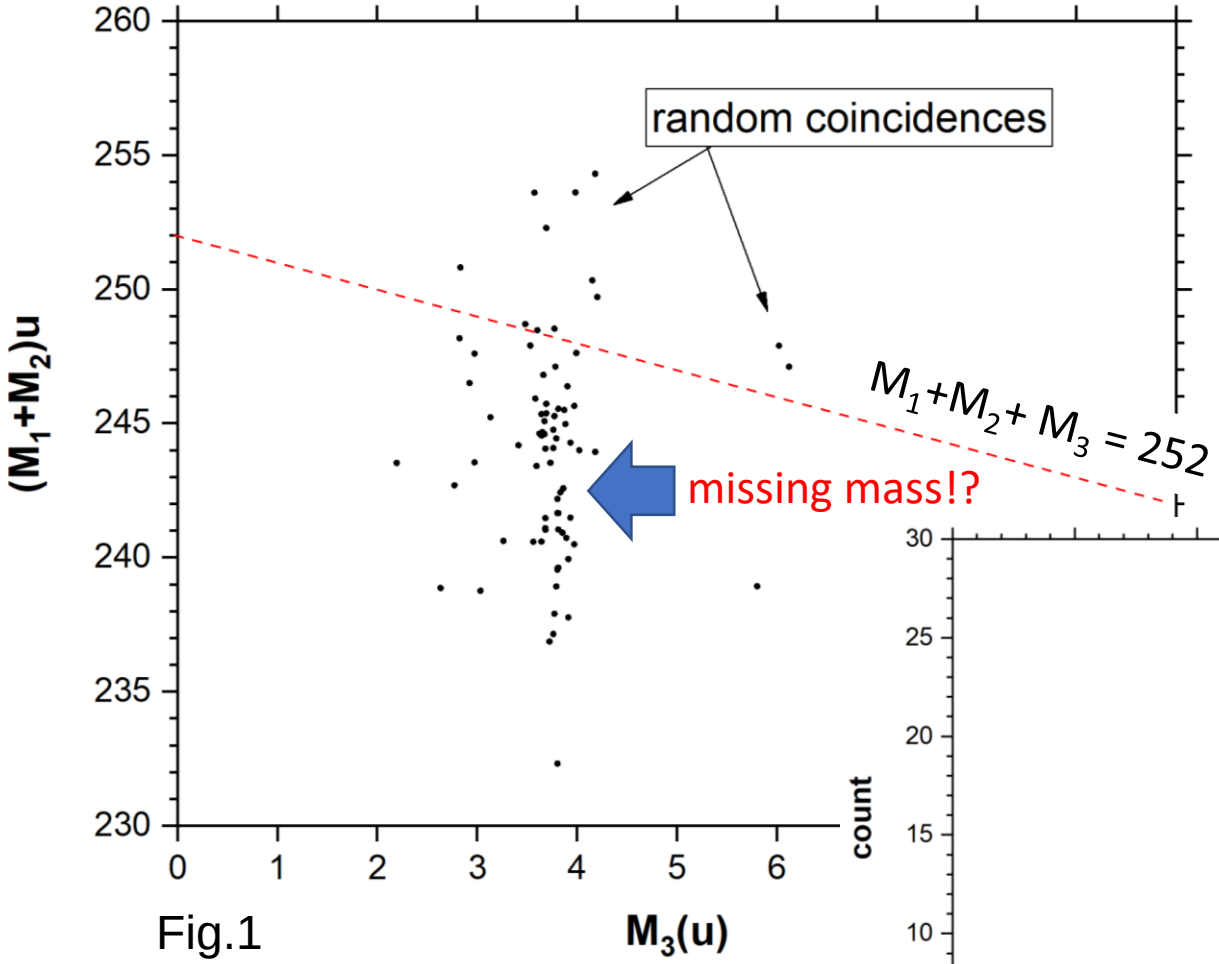


Fig.1

(M1+M2) vs M3 distribution,
all M_3 are in mosaic_2
& Energy-filter for M3: >7MeV

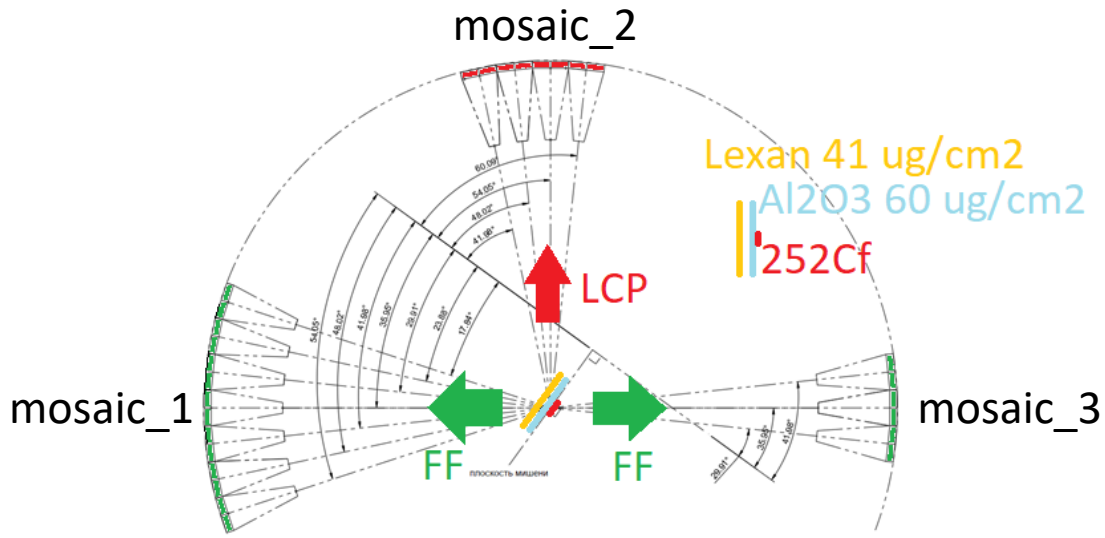
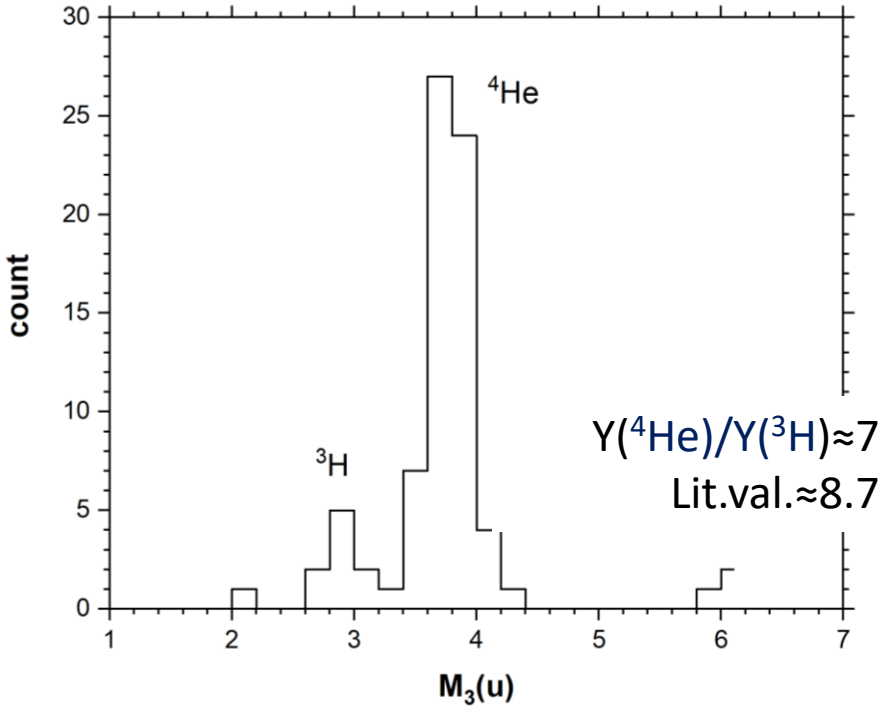


Fig.4 scheme of the detector part of the spectrometer



Y(^{4}He)/Y(^{3}H)≈7
Lit.val.≈8.7

Fig.2 Projection to M3 axis

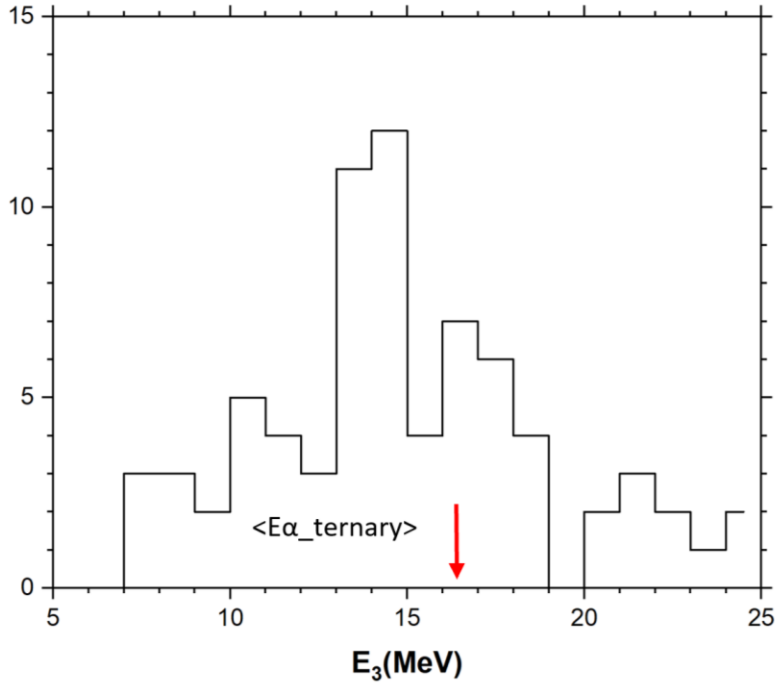


Fig.3 Energy of M3

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

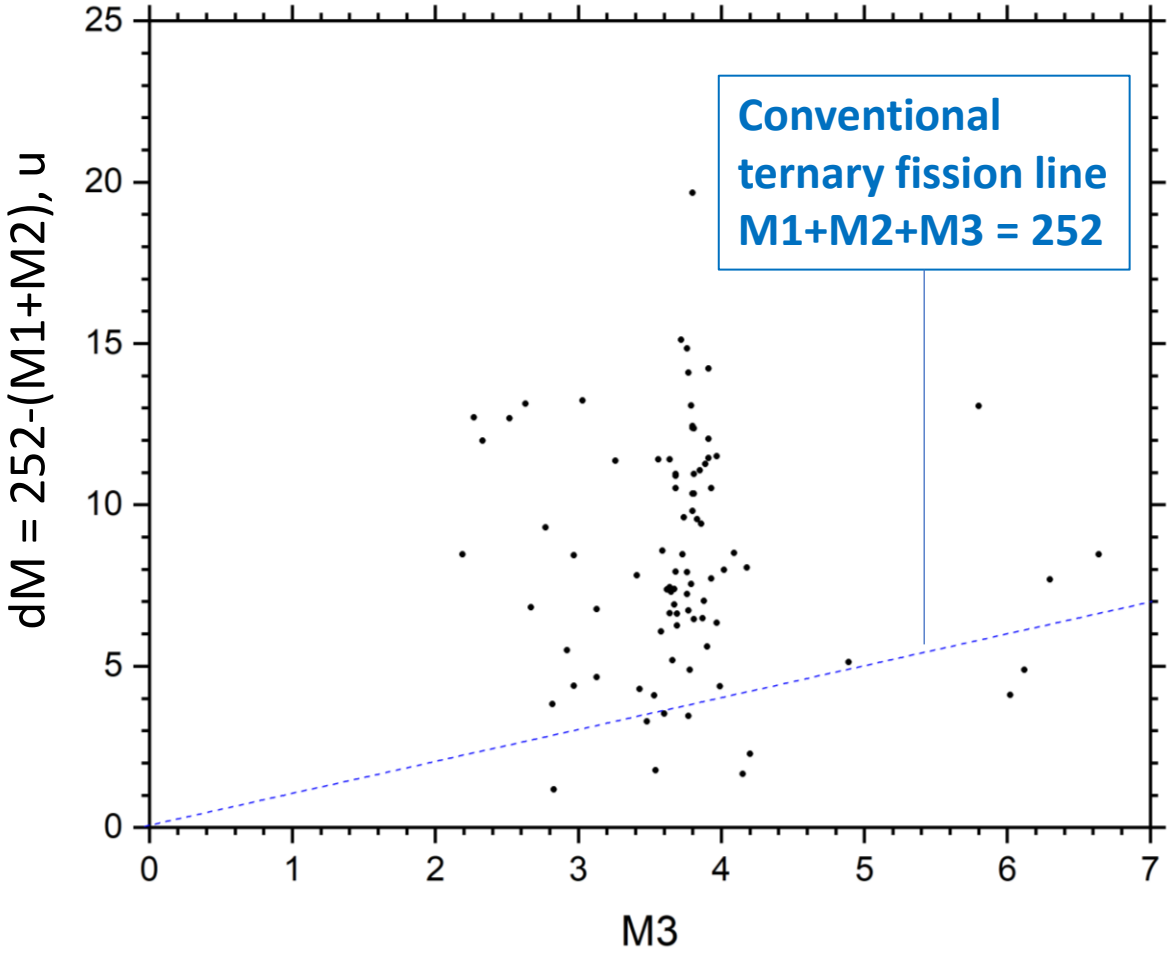


Fig.5 (the redone fig.1) dM = 252-(M1+M2) vs M3 distribution, all M_3 are in mosaic_2 & Energy-filter for M3: >7MeV.

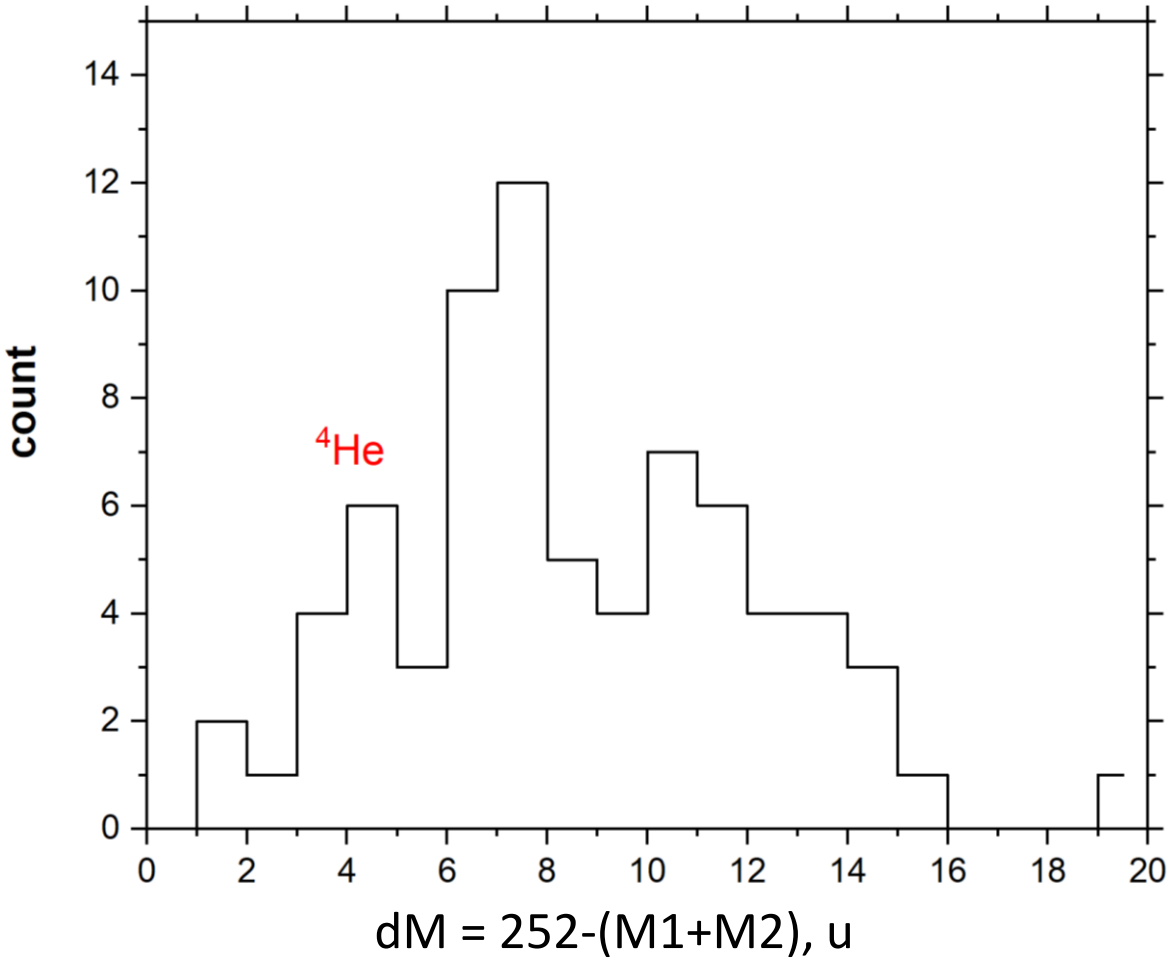


Fig.6 Projection to dM = 252-(M1+M2) axis.
M1 and M2 are measured independently.

Discussion and conclusion

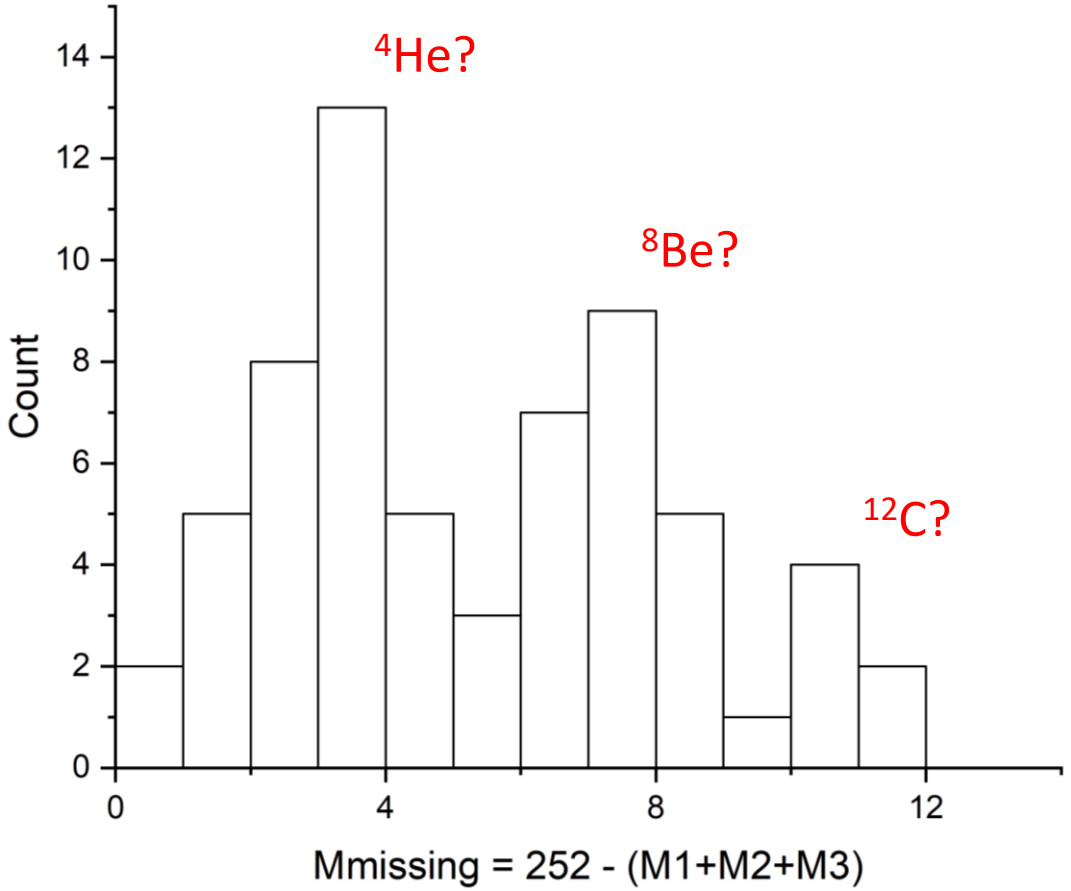


Fig.7 Mmissing = 252-(M1+M2+M3) distribution, all masses were measured independently.

ternary particle	<E> [MeV]	FWHM [MeV]	Yield Particle/ Bin.fission
^{3}H	8.2±0.6	7.2±0.6	3.1E-04
^{4}He	16.4±0.2	10.3±0.3	2.7E-03
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Sum			**3.73E-03**

<- only "part of the truth"

- Ternary LCP Yields ↑
- Quaternary ^{4}He Yield is ≈ 2.0E-06 Particle/Bin.fission [V.G.Tishenko_thesis_2002]

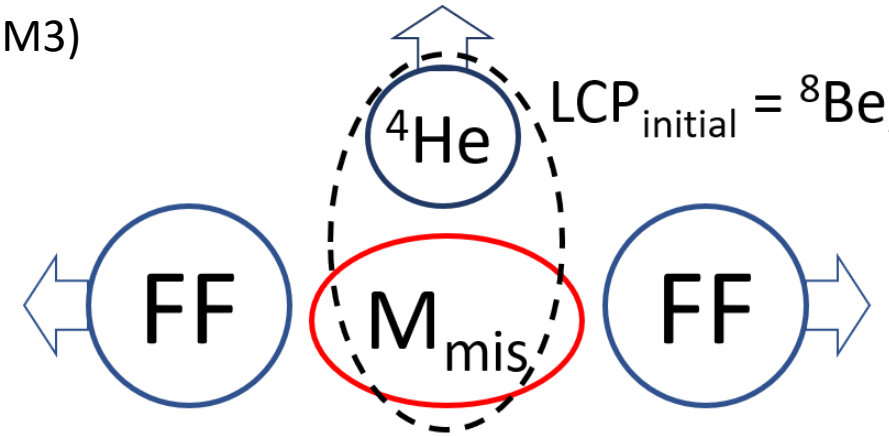


Fig.8 The figure is given to demonstrate the distribution of masses between the decay products.

Fig.9 An analogy with known Collinear Cluster Tri-partition (CCT) process can be used to explain the experimental results.
CCT: break-up of the FF while its passing through the foil.

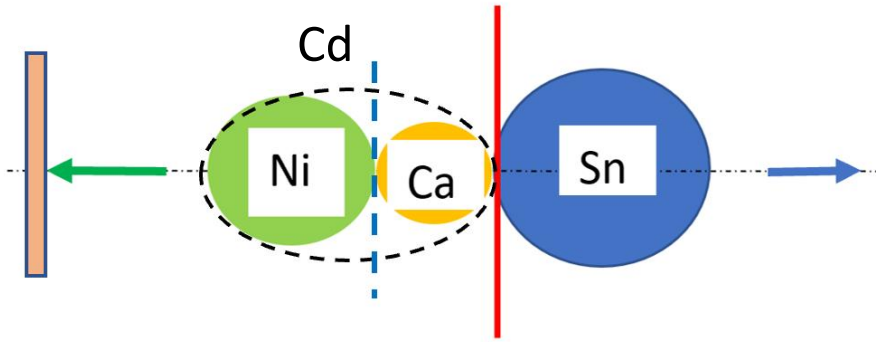
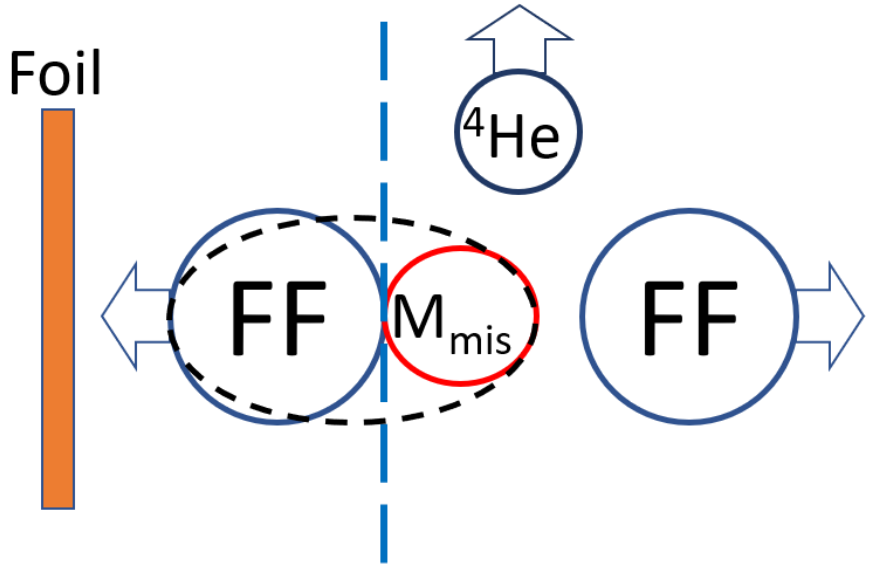


Fig.10 Hypothetical scenario:



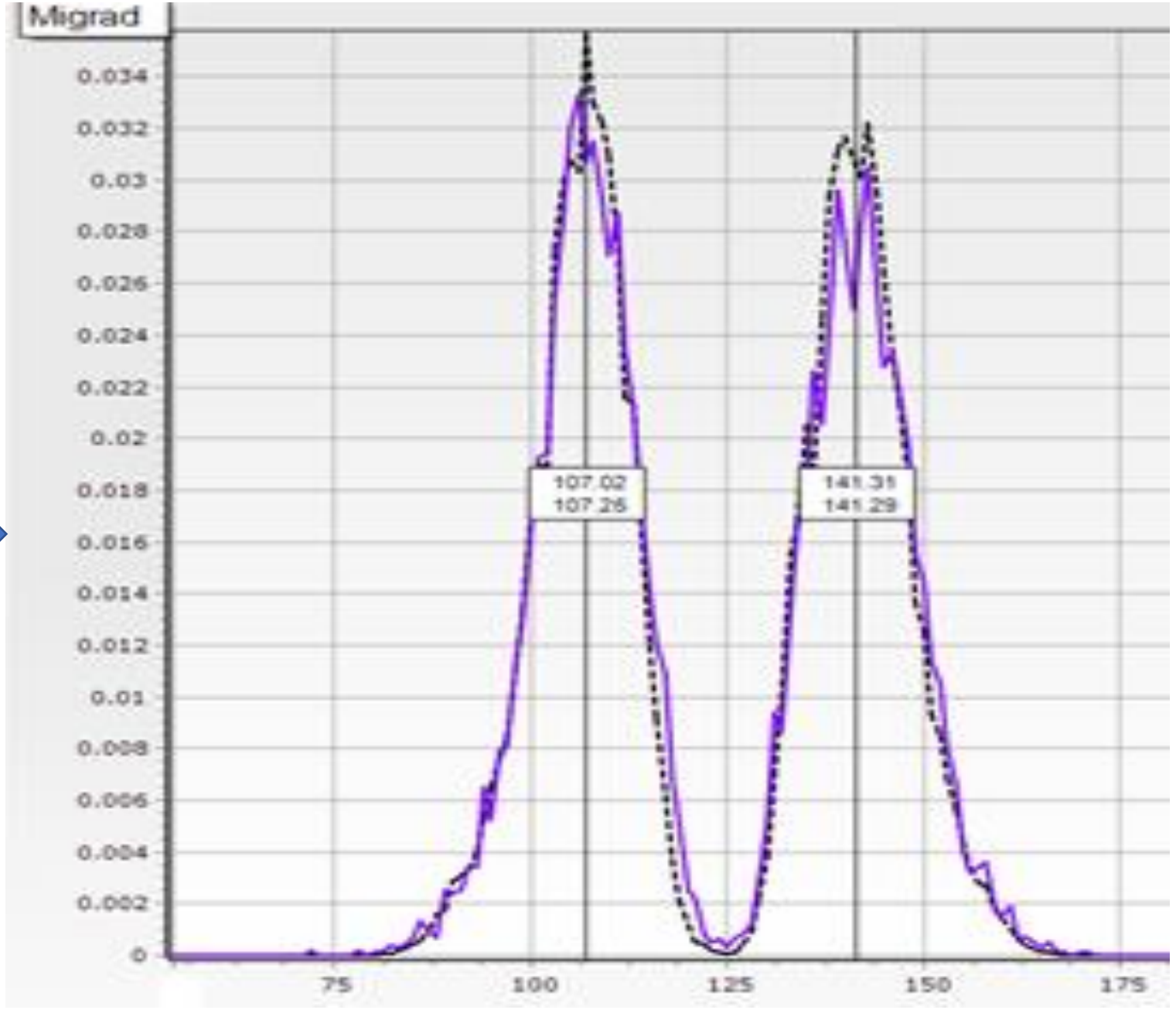
Conclusion

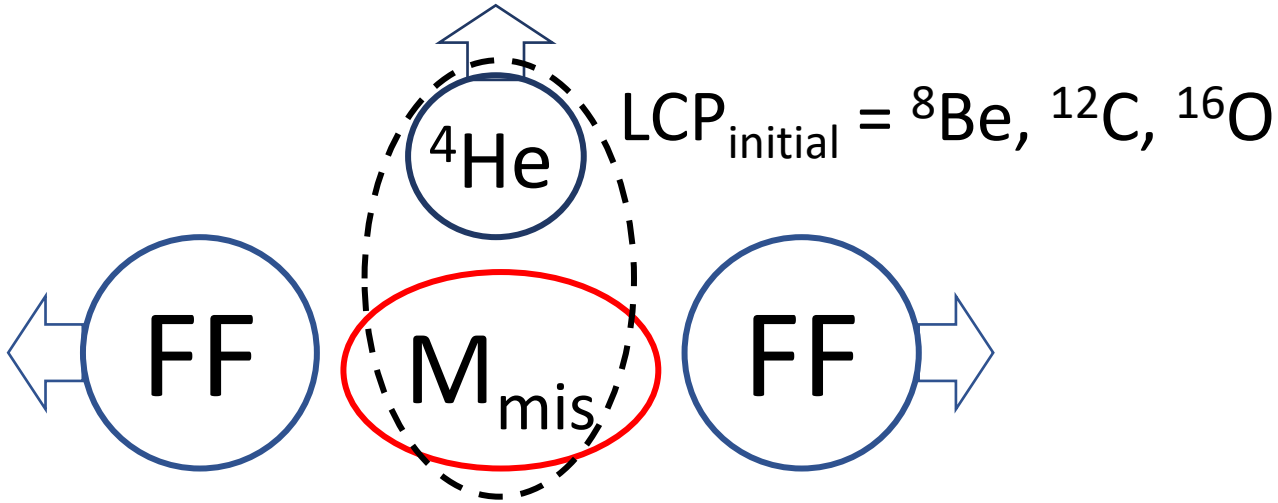
For the first time the missing mass is experimentally observed in triple coincidences with the emission of an alpha particle. This observation may indicate that at least some part of the α-accompanied ternary fission events are realized according to the following scenario:

1. Preformation of a di-nuclear system in the scission point consisting of the LCP in the range of ^{8}Be-^{16}O and much heavier core-nucleus;
2. At scission the LCP can emit the α-particle in the direction perpendicular to the fission axis;
3. The rest of the LCP does not fuse with the core-nucleus and this system breaks-up when passing through the foil.

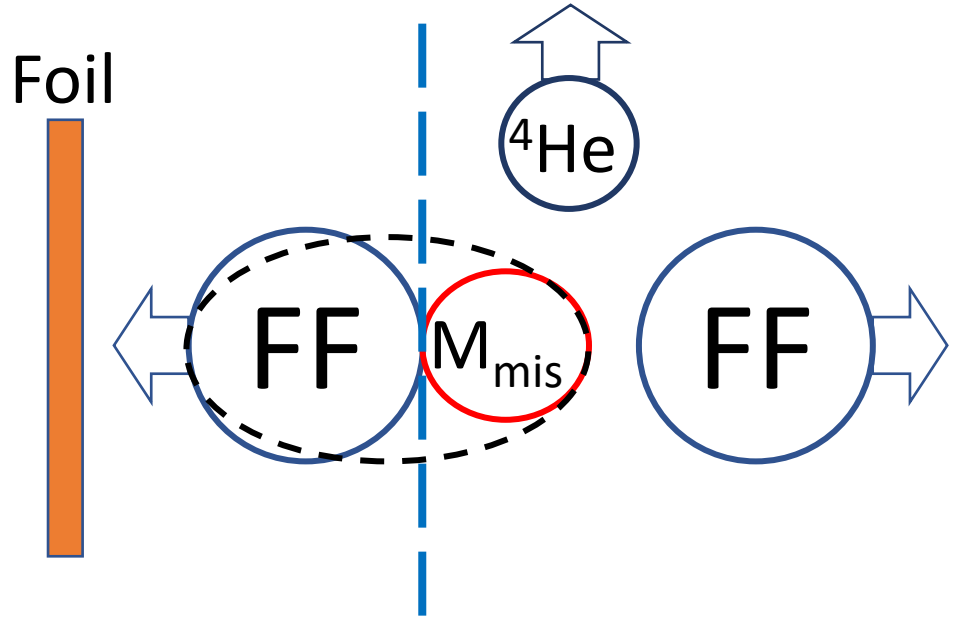
Thank you for your attention!

Mass spectrum of 252Cf fission fragments obtained by the method described above. Black denotes the reference mass spectrum from [3].





На 4пи системах типа силиконБола:
Для 2E – очень тонкие источники, но вопрос порога и разрешения, т.к. 4я частица может иметь очень маленькую E (от 0ля)



M-miss In each TERNARY event