Double-hit experimental approach in study of the ternary decays of ^{252}Cf(sf)

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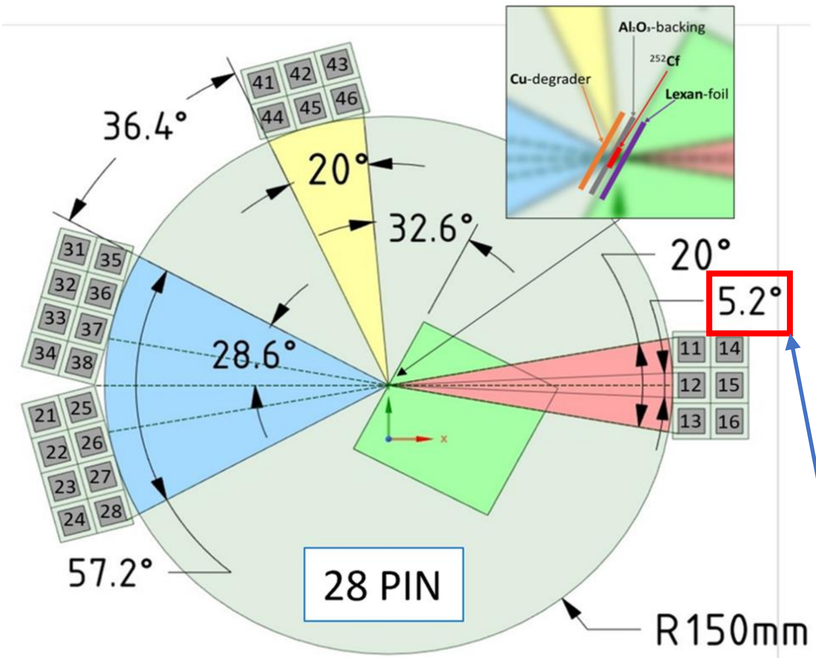
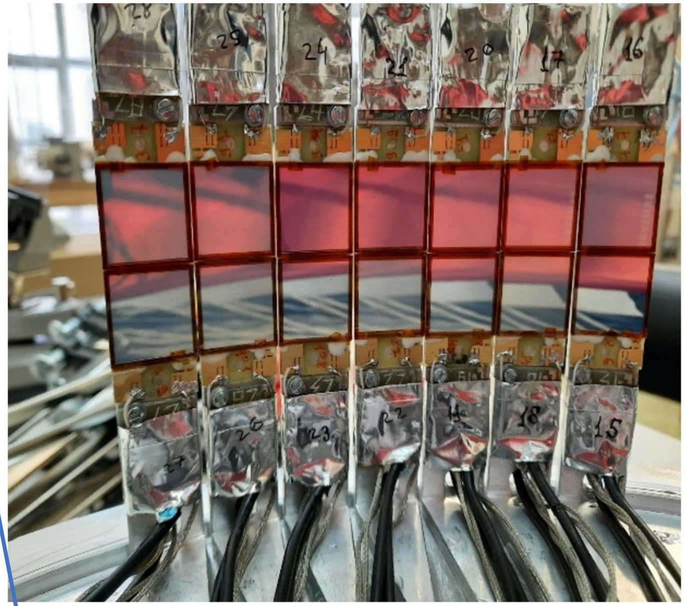
COrrelation M-E-T Array (COMETA) setup



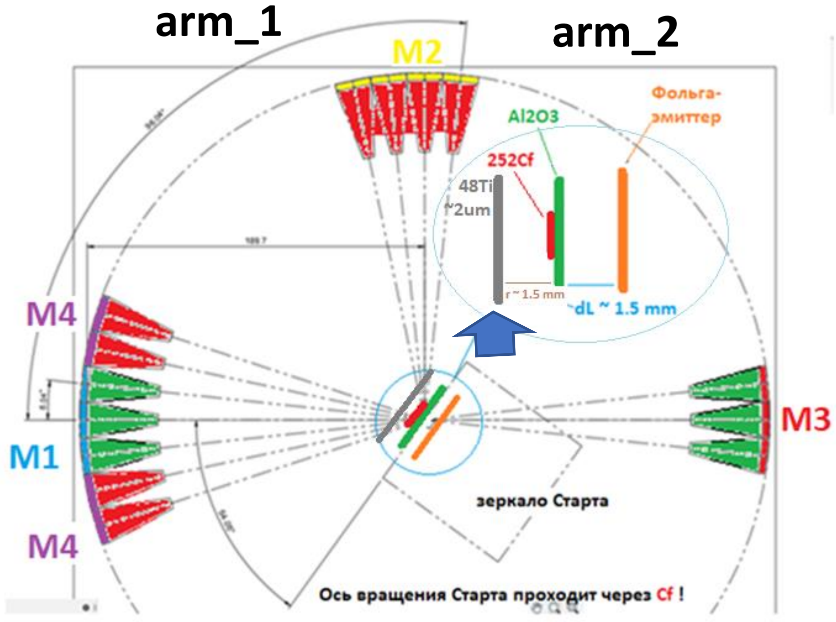


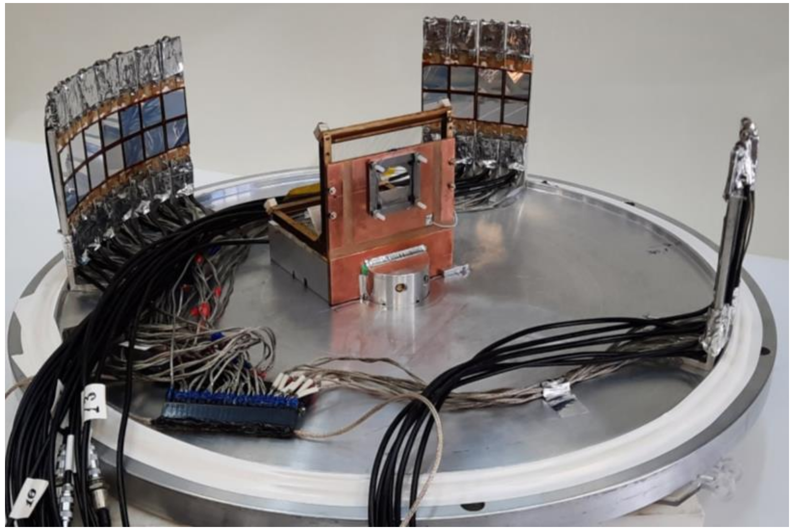
ToF-E method for triple coincidences:

ToF_i & E_i -> M_i

i = 1,2,3

angular uncertainty in 2-hit

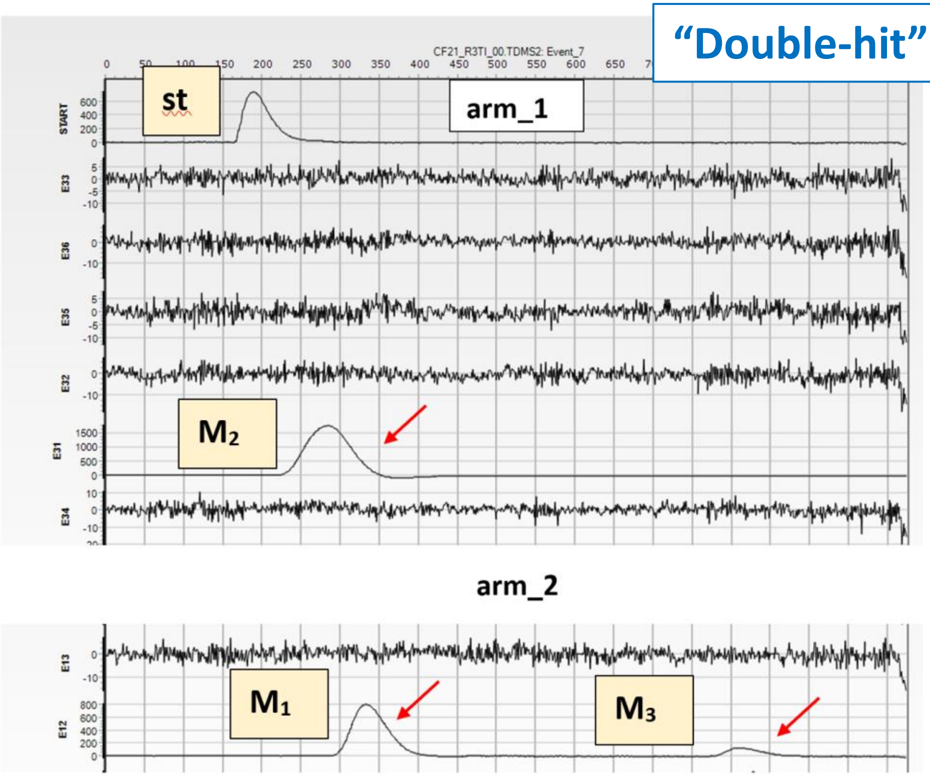


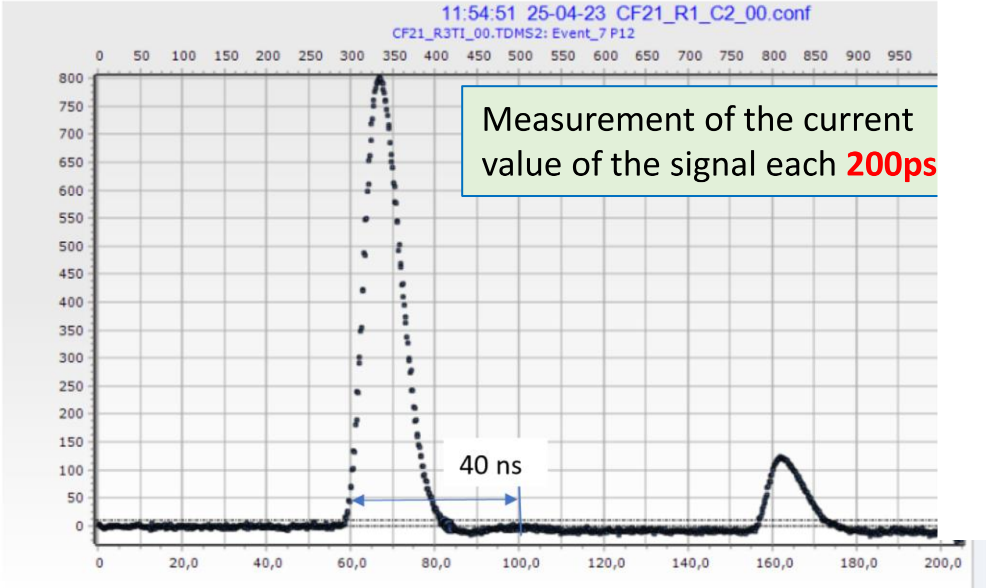


^{252}Cf (45 kBq)
Spot d= 3 mm
on Al_2O_3 65 ug/cm^2

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

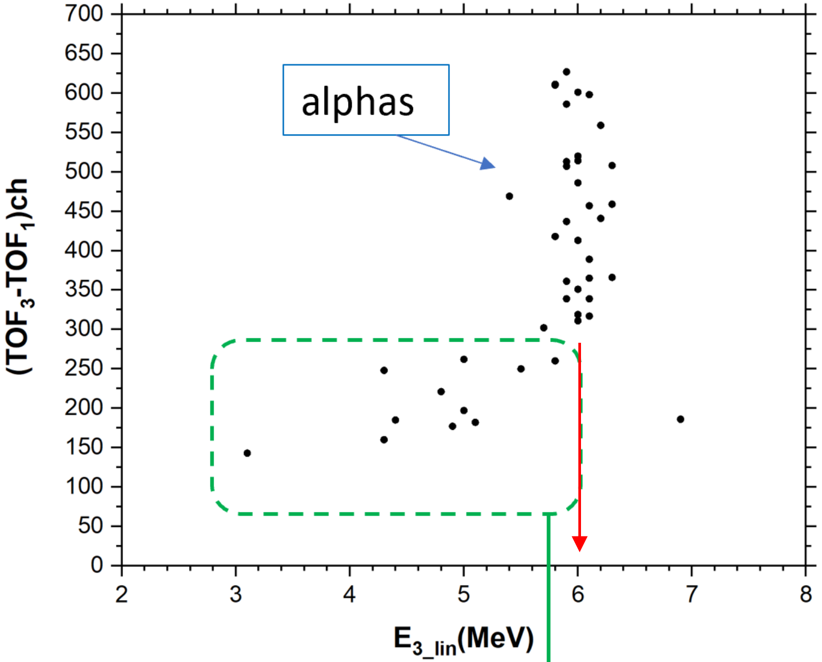
"Double-hit" approach for searching for the multi-body decays

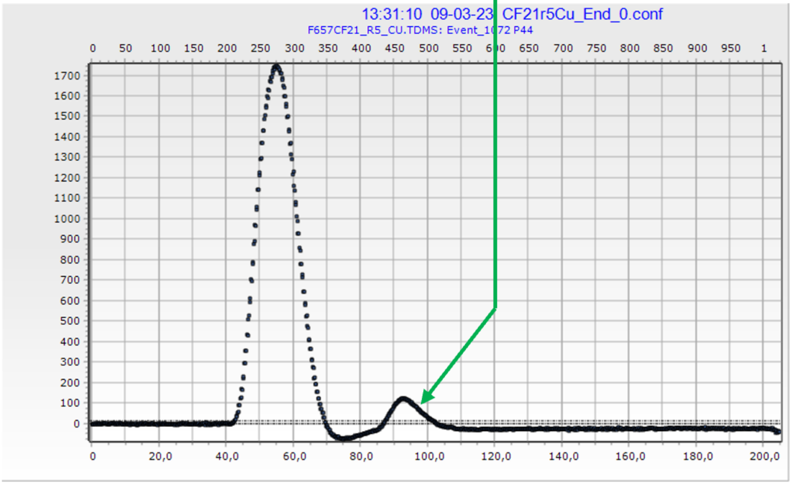


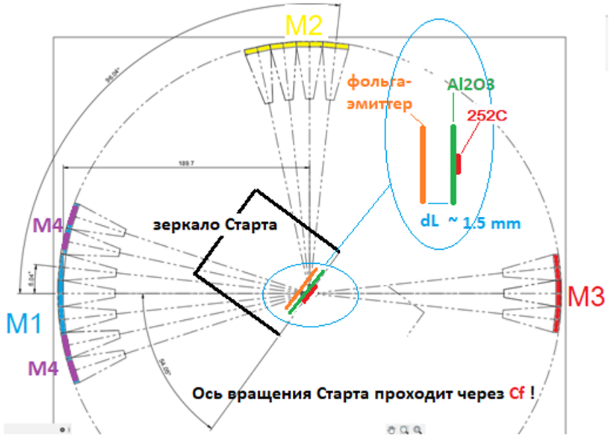


Measurement of the current value of the signal each **200ps**

No foil (test experiment), double –hit events





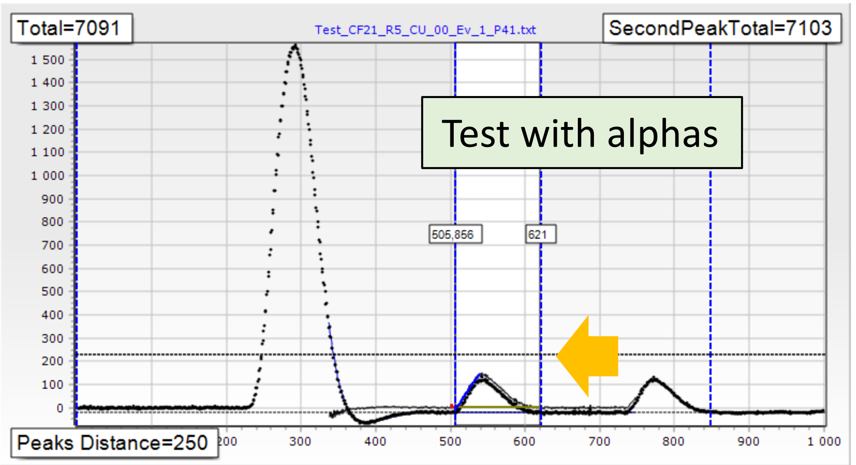


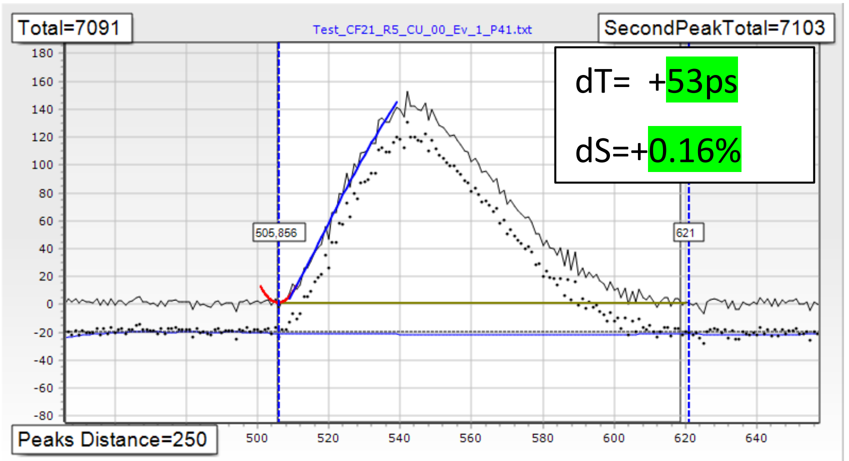
1) Only random coincidences with alphas are seen, what is expected.

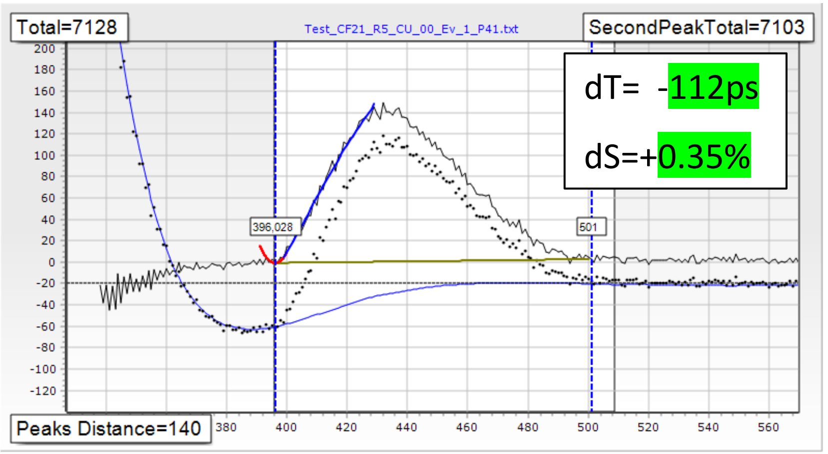
2) Pile-up signals

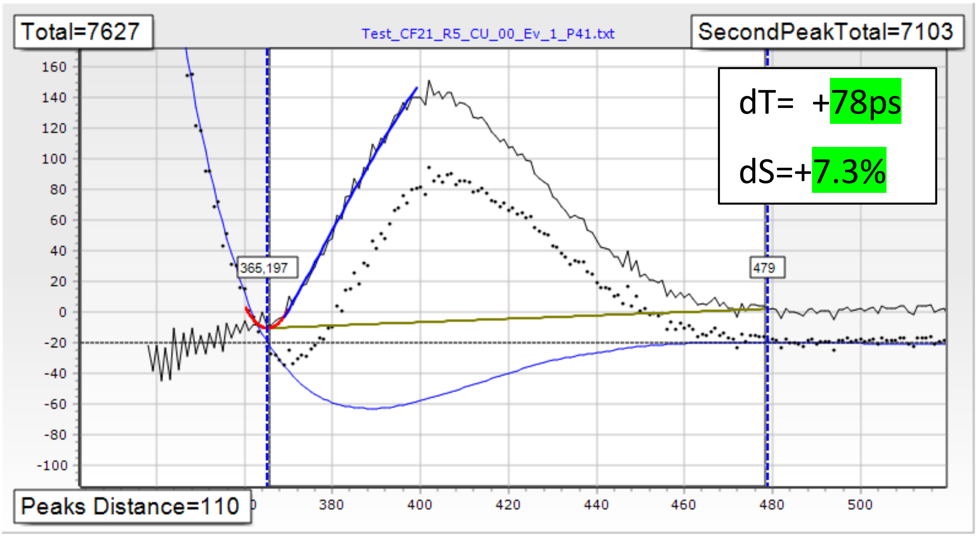
~10^6 binary events

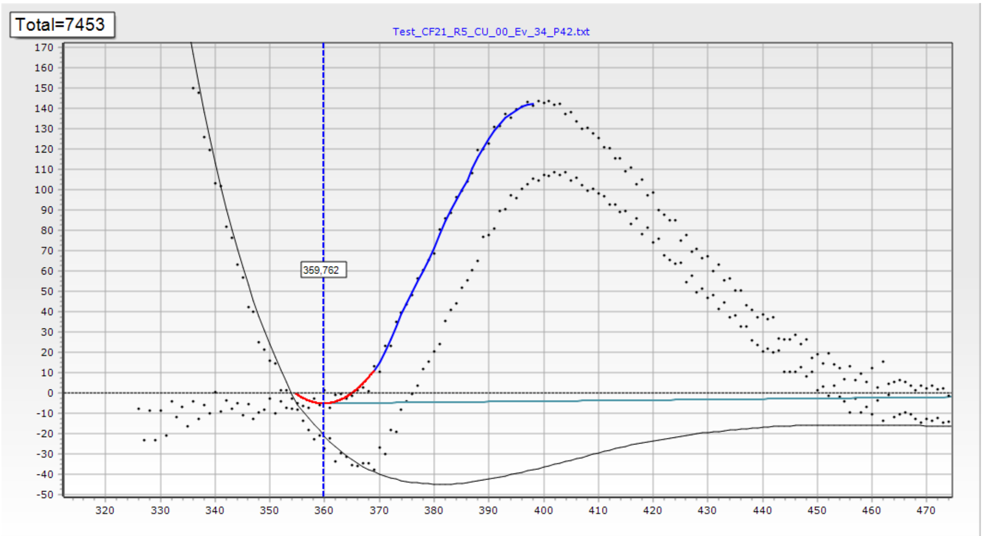
Restoring original signals from pile-up







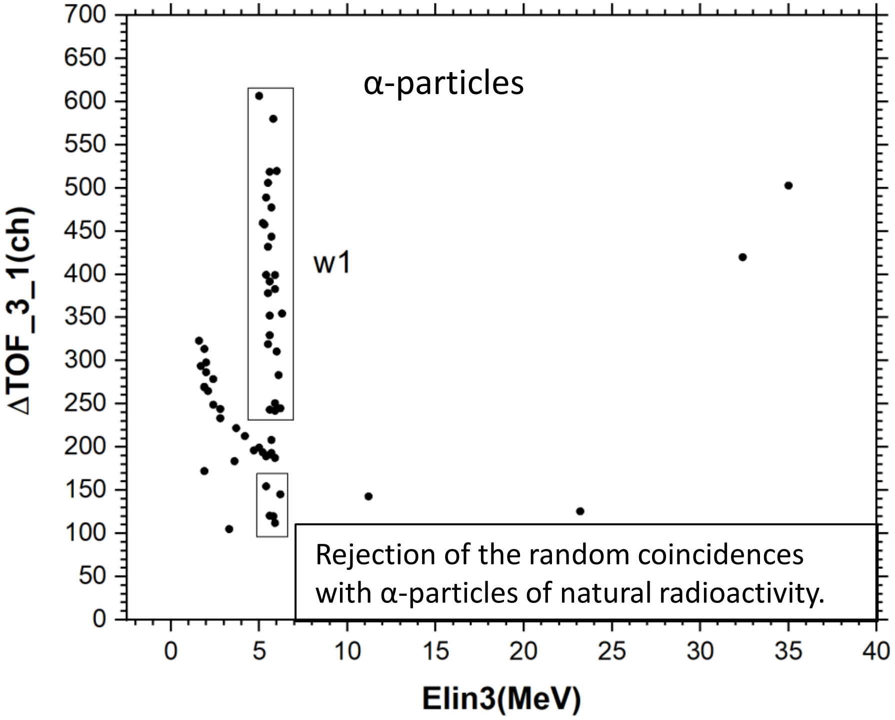


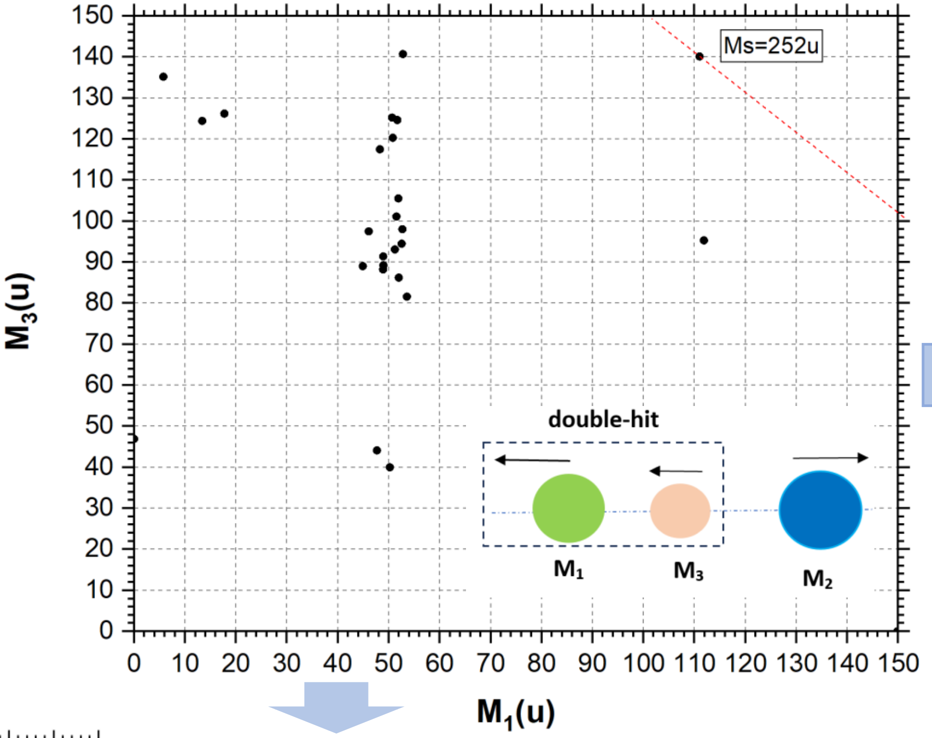


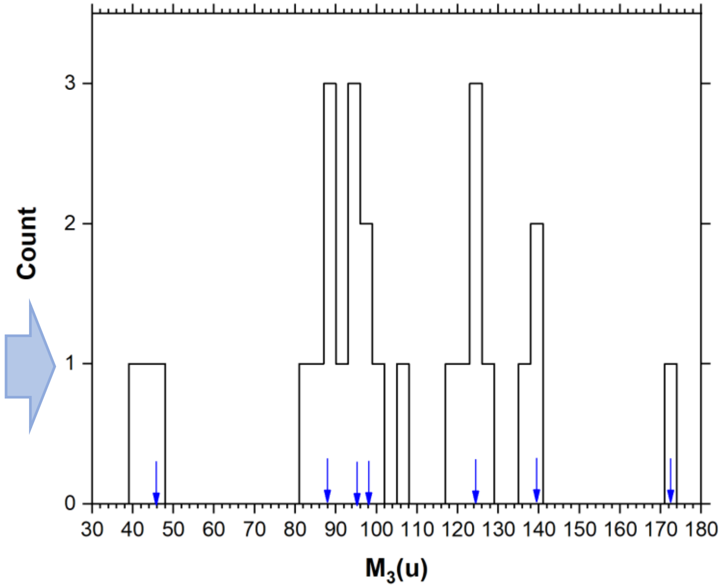
real 2-hit event, restoring original waveform from pile-up

Results with ^{48}Ti foil as a beak-up medium

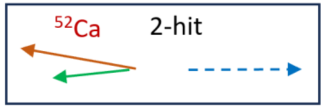
Double-hit events, Ti foil as a break-up medium

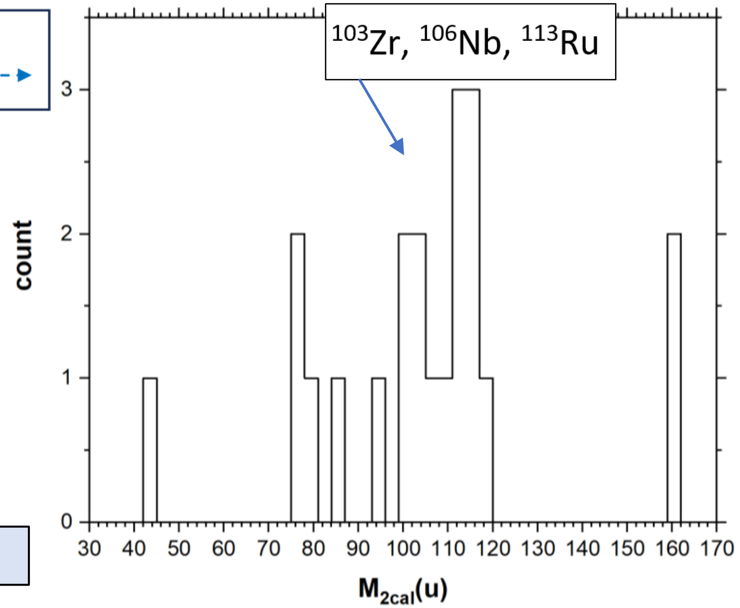




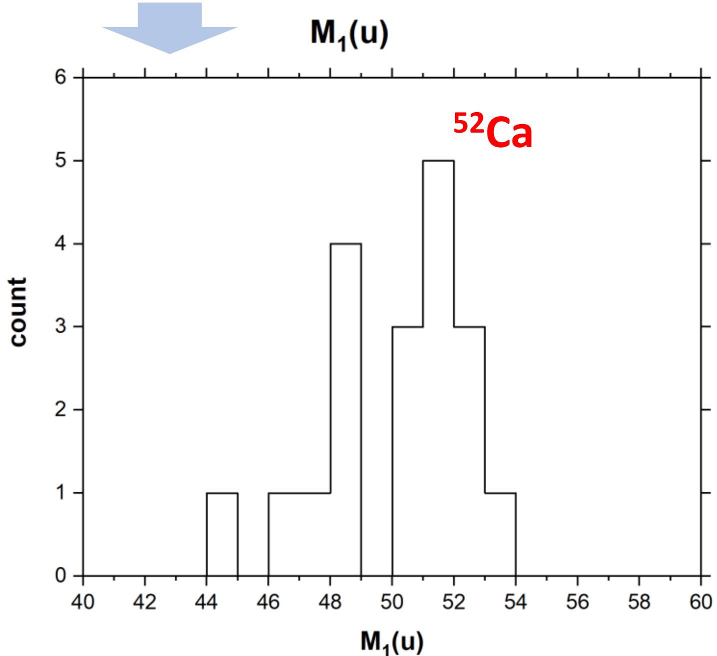


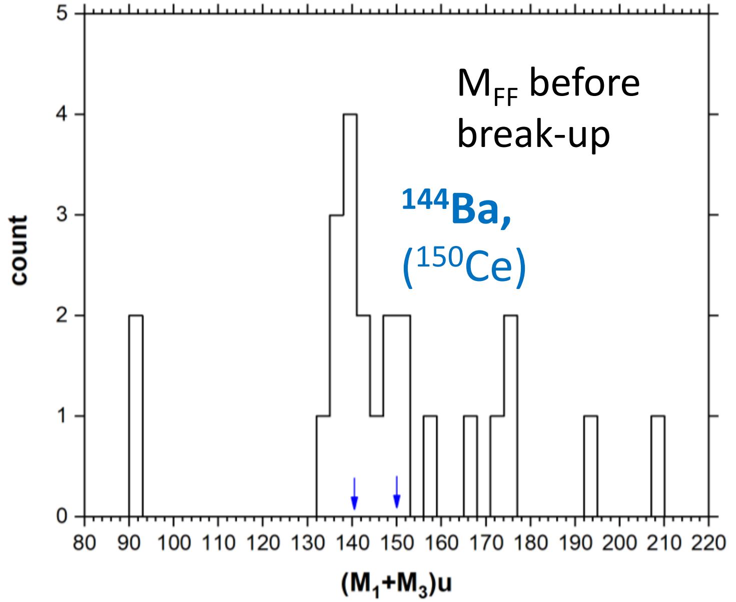
bin. part 144/108



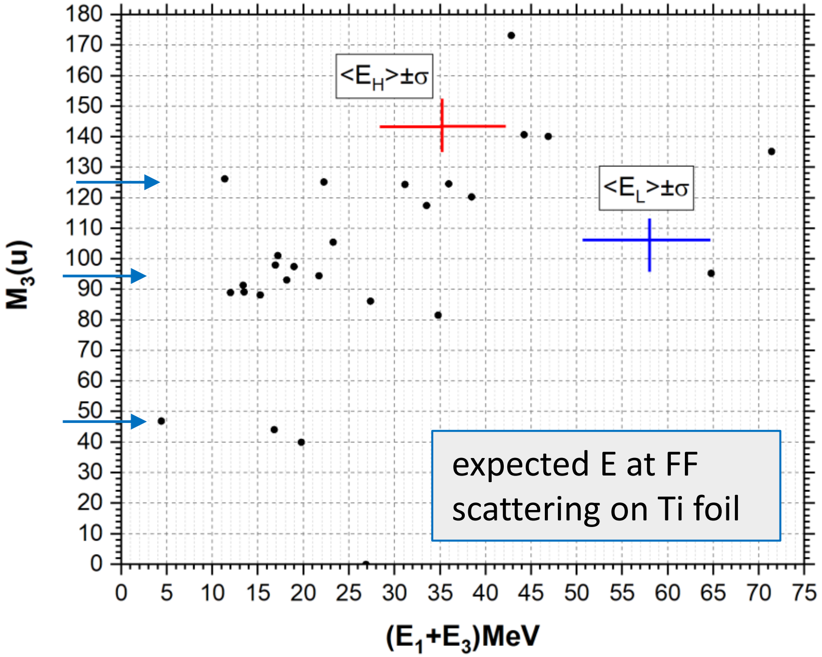


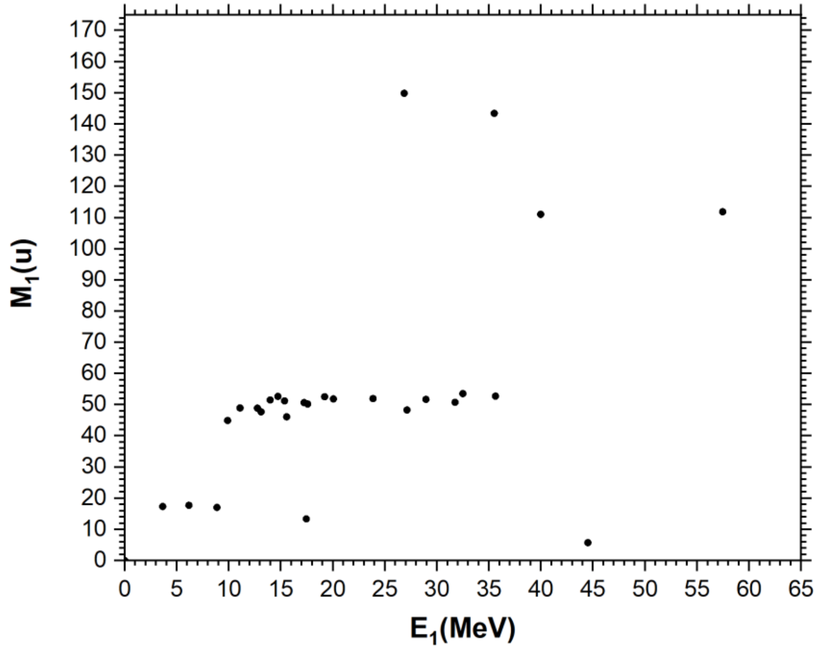
were missed

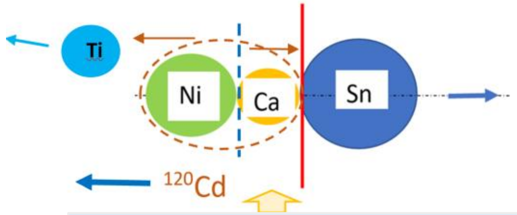




Double-hit events, Ti foil







V(Ca) can be very low

Likely quaternary decays, Zucd is supposed

CF21_r3(Ti)				
	FF1	FF3	FF2	FF4miss
№ 53				
E (MeV)	6.16	5.2	84	
M (u)	17.7	126.2	88.9	19.15
PIN	44	44	35	
	$^{18}_{7}N$ //	$^{126}_{49}In$	$^{20}_{8}O$ //	$^{88}_{34}Se$
	$^{144}_{56}Ba$		$^{108}_{42}Mo$	
	arm_1		**arm_2**	

CF21_r3(Ti)				
	FF1	FF3	FF2	FF4miss
№9				
E (MeV)	44.5	26.9	90	
M (u)	5.75	135.2	108.12	2.93
PIN	44	44	35	
	$^{6}_{2}He$ //	$^{135}_{53}I$	$^{3}_{1}H$ //	$^{108}_{42}Mo$
	$^{141}_{55}Cs$		$^{111}_{43}Tc$	
	arm_1		**arm_2**	

Ti foil, mul_3: all 3 FFs were detected

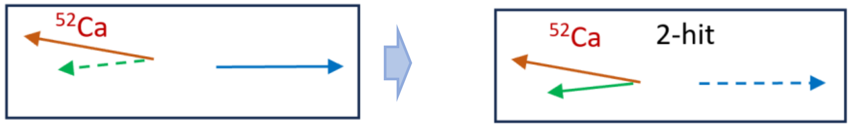
Here : M1>M2>M3

CF21_r3(Ti)_mul_3				
	FF1	FF2	FF3	ΔM=252-Ms
№ 52				0.01
E (MeV)	16.5	80.8	11.02	
M (u)	126.3	112.07	13.62	
PIN	43	33	45	
	← $^{140}_{54}Xe$	/	→ $^{112}_{44}Ru$	
	← $^{13}_{5}B$ ← $^{127}_{49}In$			
	arm_1		arm_2	

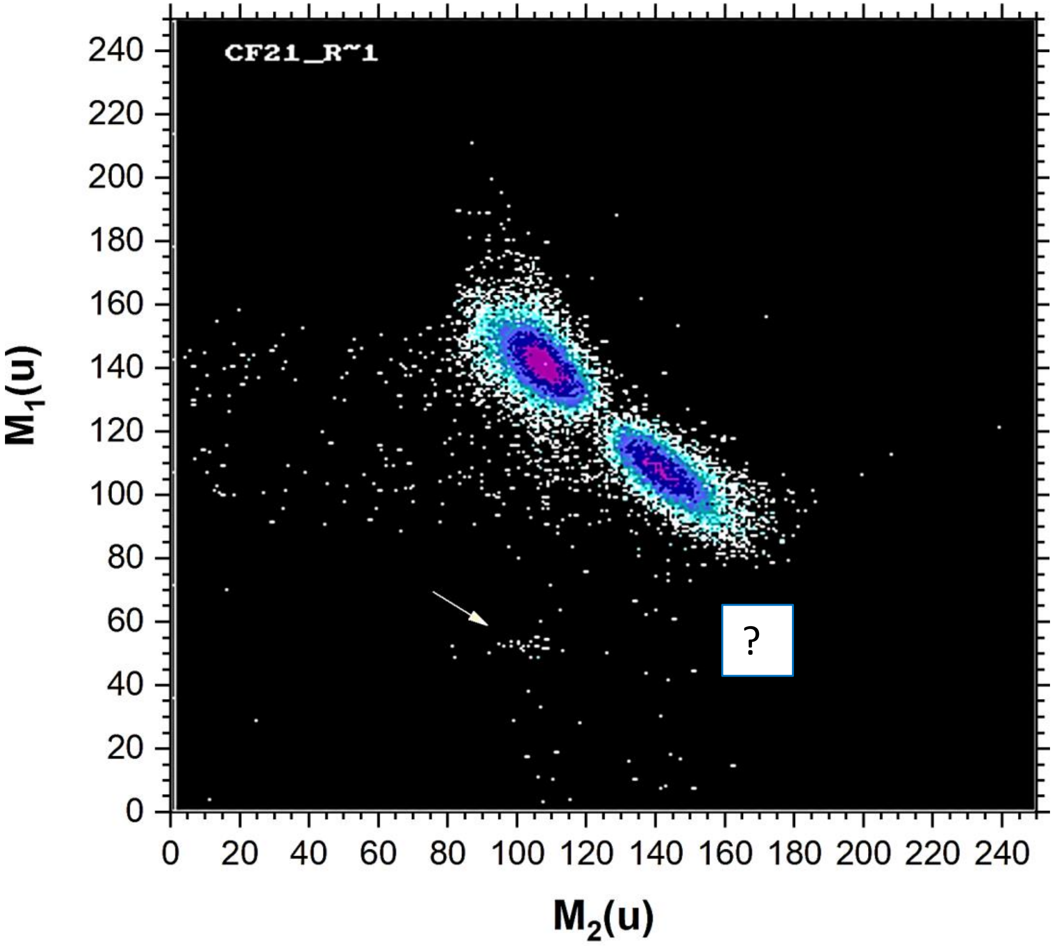
CF21_r3(Ti)_mul_3				
	FF1	FF2	FF3	ΔM=252-Ms
№ 118				-1.36
E (MeV)	103.2	5.34	29.06	
M (u)	103.25	100.97	49.14	
PIN	33	16	43	
	← $^{149}_{58}Ce$	/	→ $^{103}_{40}Zr$	
	← $^{49}_{19}K$ ← $^{100}_{39}Y$			
	arm_1		arm_2	

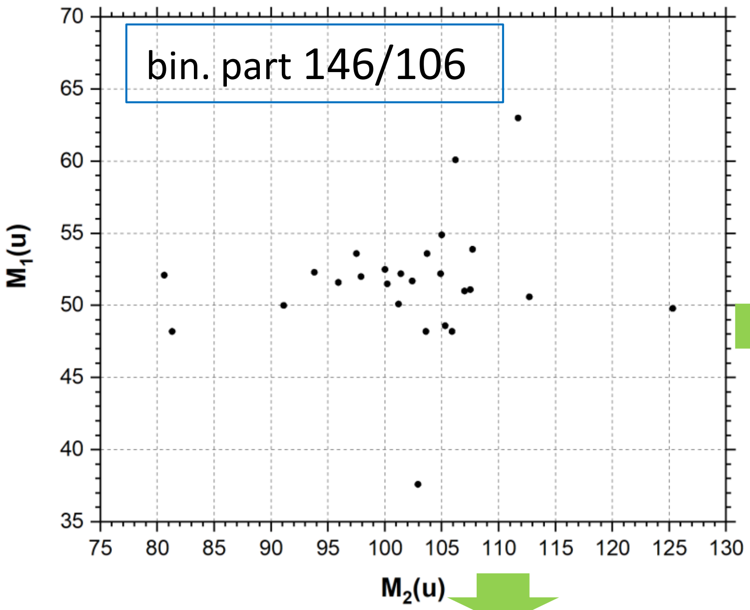
CF21_r3(Ti)_mul_3				
	FF1	FF2	FF3	ΔM=252-Ms
№ 72				2.13
E (MeV)	103.2	5.34	29.06	
M (u)	104.6	92.9	52.3	
PIN	31	16	15	
	← $^{149}_{58}Ce$	/	→ $^{103}_{40}Zr$	
	← $^{52}_{20}Ca$ ← $^{98}_{38}Sr$			
	arm_1		arm_2	

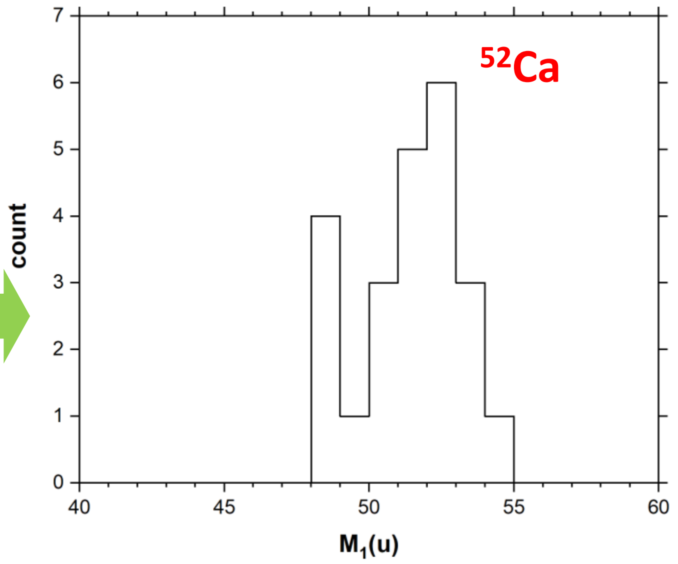
Ti foil , multiplicity-two events



^{103}Zr, ^{106}Nb, ^{113}Ru



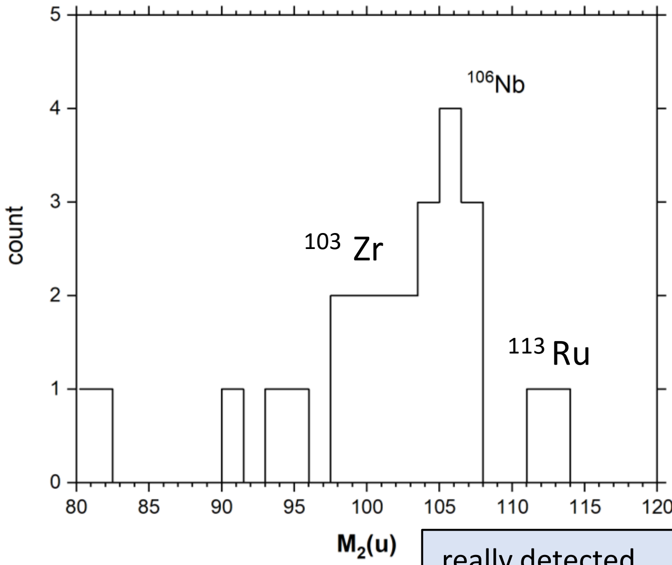




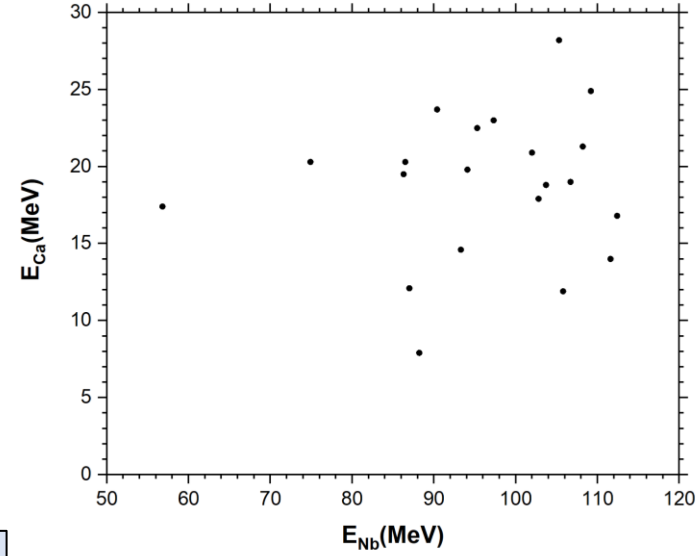
only mosaics 4 &3 are in game

Effect is <u>only for the heavy FFs</u>

$Y \sim 2 \cdot 10^{-5}$/bin. fiss

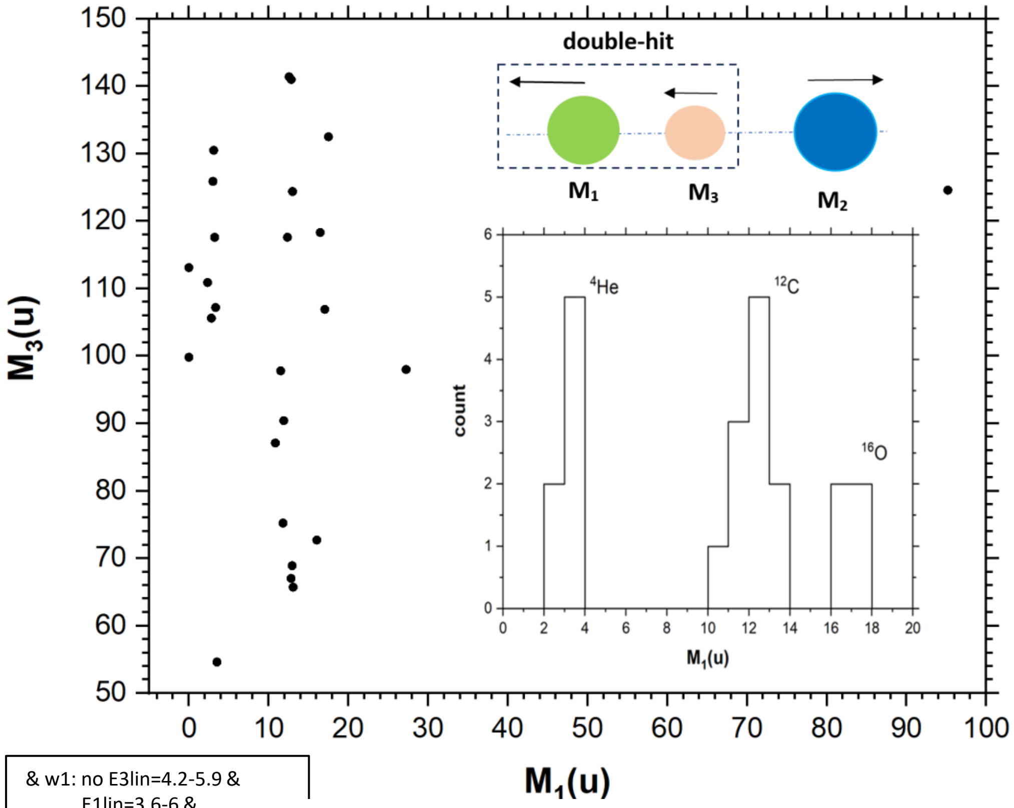


really detected

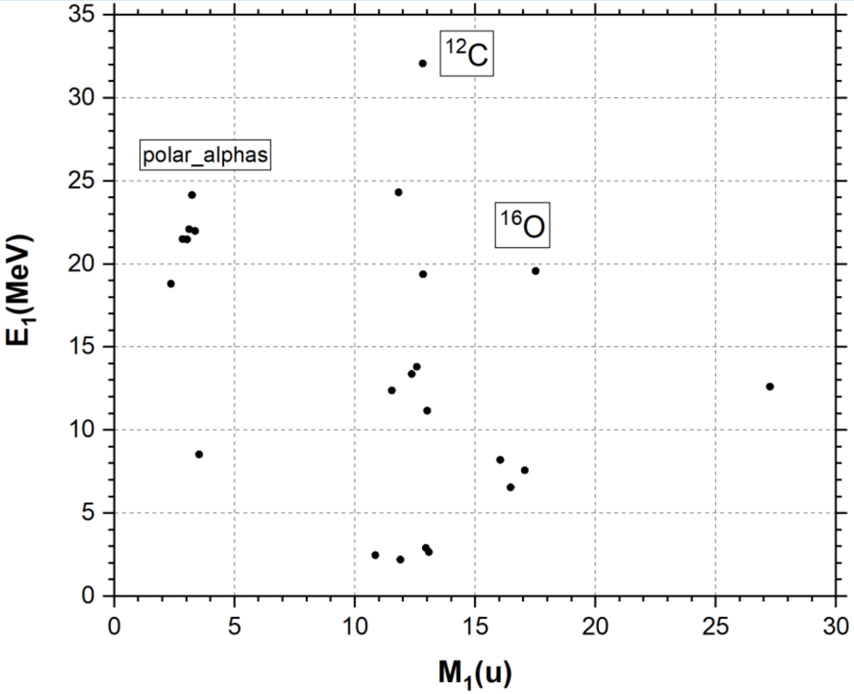


Results with ^{181}Ta foil as a beak-up medium

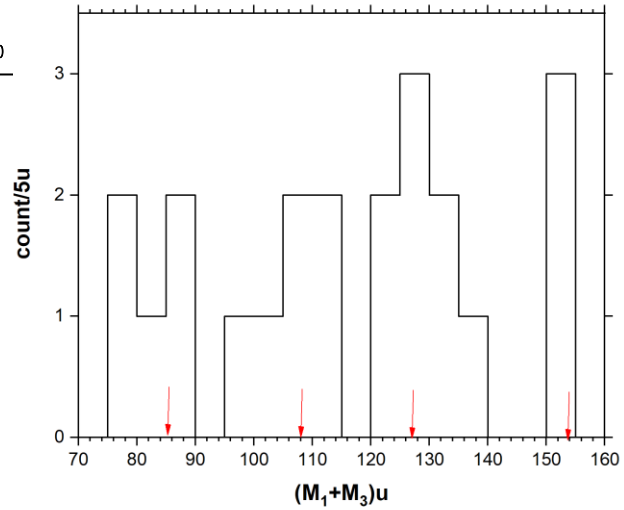
Double-hit events, $^{181}_{73}Ta$ foil as a break-up medium



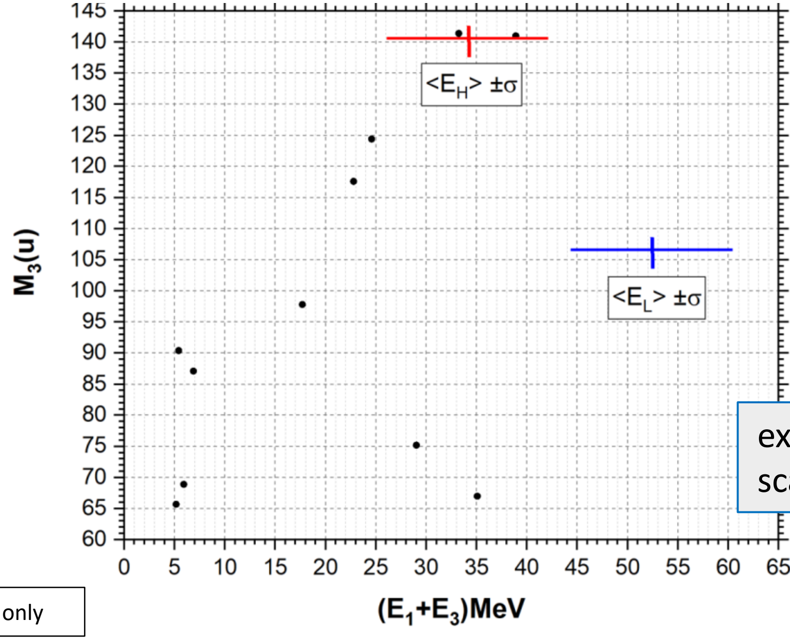
& w1: no E3lin=4.2-5.9 &
E1lin=3.6-6 &
M3<200 &
M123<25 & no M3=0



&w3: w1& M1<40, all alphas in arm_1



Ta, M1- 12C only



expected E at FF scattering on Ta foil

Double-hit events, Ta foil

Likely quaternary decays

CF23_r1(Ta), 2hit				
	FF1	FF3	FF2	FF4miss
№ 36				
E (MeV)	51.09	4.2	2.15	
M (u)	95.19	124.6	12.88	19.33
PIN	44	44	35	
	${}^{95}_{37}Rb$ // ${}^{13}_{5}B$ →		${}^{124}_{48}Cd$ // ${}^{20}_{8}O$	
	${}^{108}_{42}Mo$		${}^{144}_{56}Ba$	
	arm_1		**arm_2**	

CF23_r1(Ta), 2hit				
	FF1	FF3	FF2	FF4miss
№ 37				
E (MeV)	11.17	13.4	96.38	
M (u)	13	124.4	97.95	16.65
PIN	44	44	35	
Stage 1	${}^{14}_{6}C$// ${}^{140}_{54}Xe$		${}^{98}_{38}Sr$	
Stage 2	${}^{16}_{6}C$ // ${}^{124}_{48}Cd$			
	${}^{154}_{60}Nd$		${}^{98}_{38}Sr$	
	arm_1		**arm_2**	

Confirmation from our previous experiments

Cu foil , LIS spectrometer, missing light ions

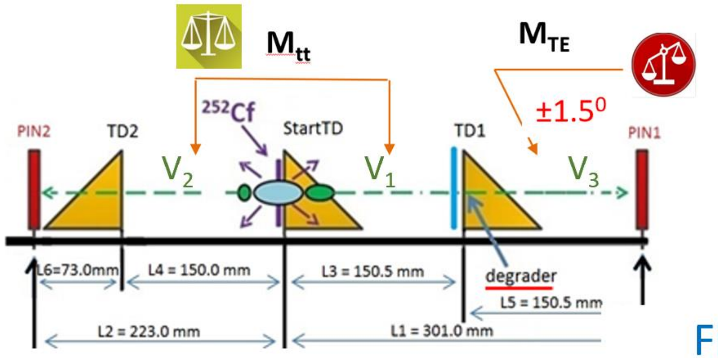


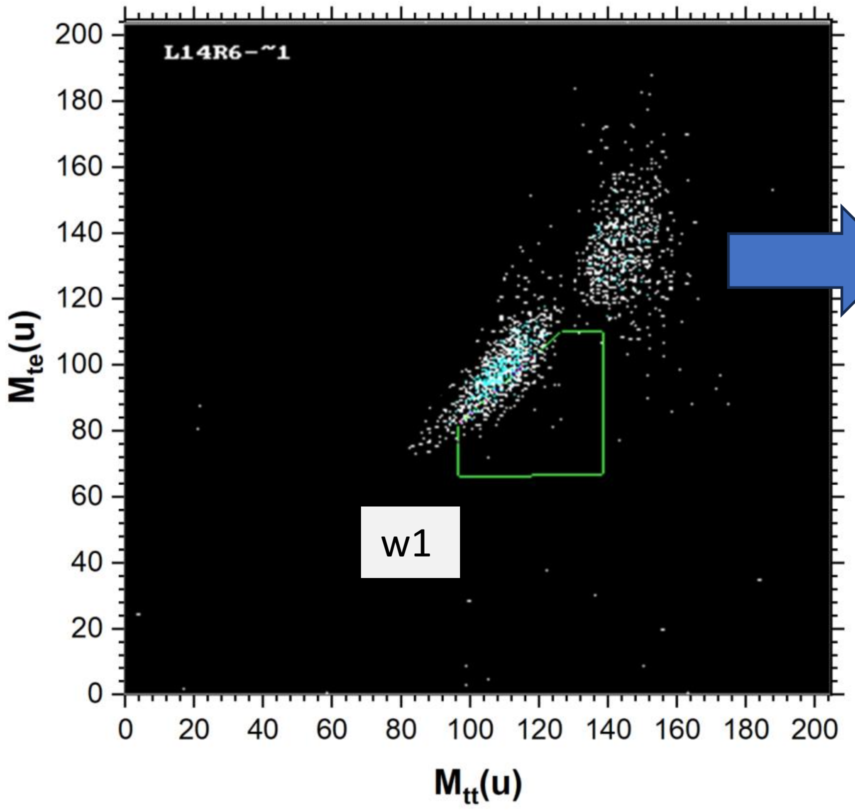
Fig.1

$M_{tt} = Mc/(1+V_1/V_2)$ - ”initial” FF mass

$M_{TE}=2E/(V_3^2)$ - “resultant” FF mass

$\tau_{\ life} > 15\text{ns}$

Fig.2



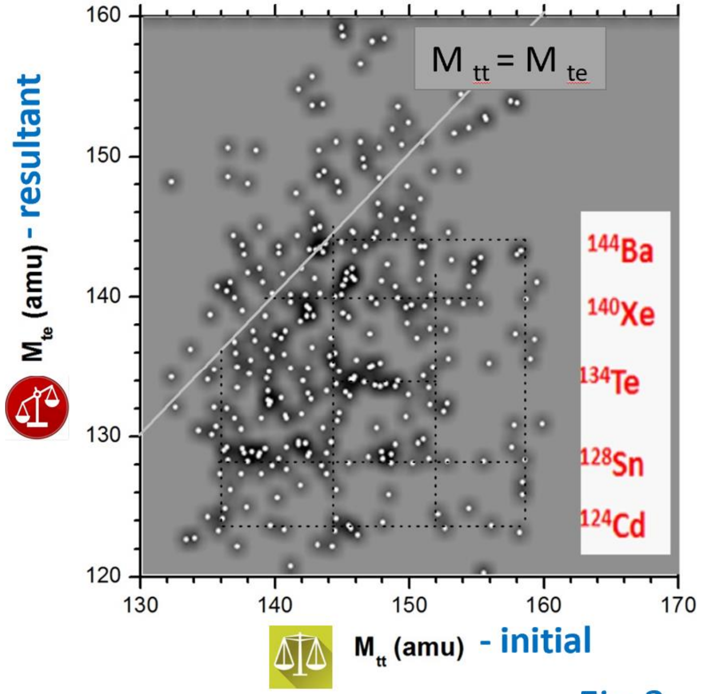


Fig.3

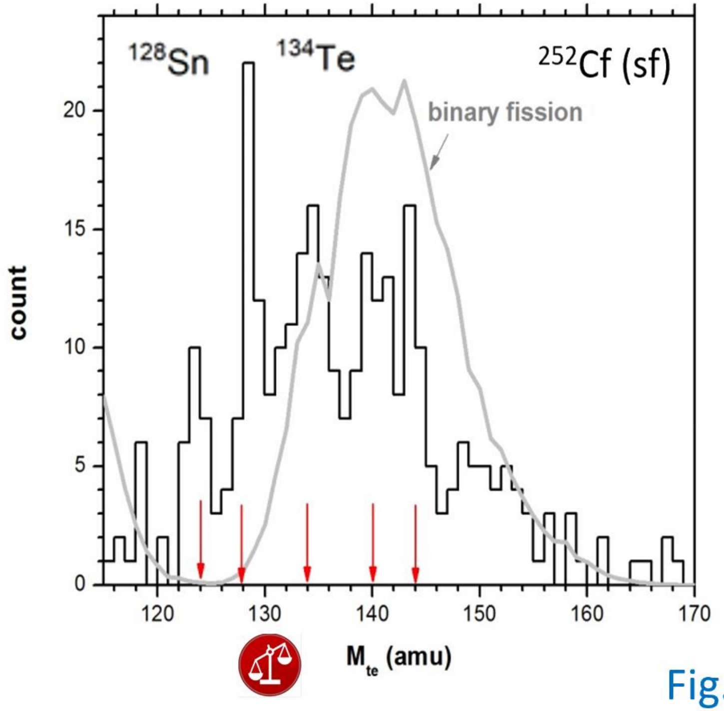
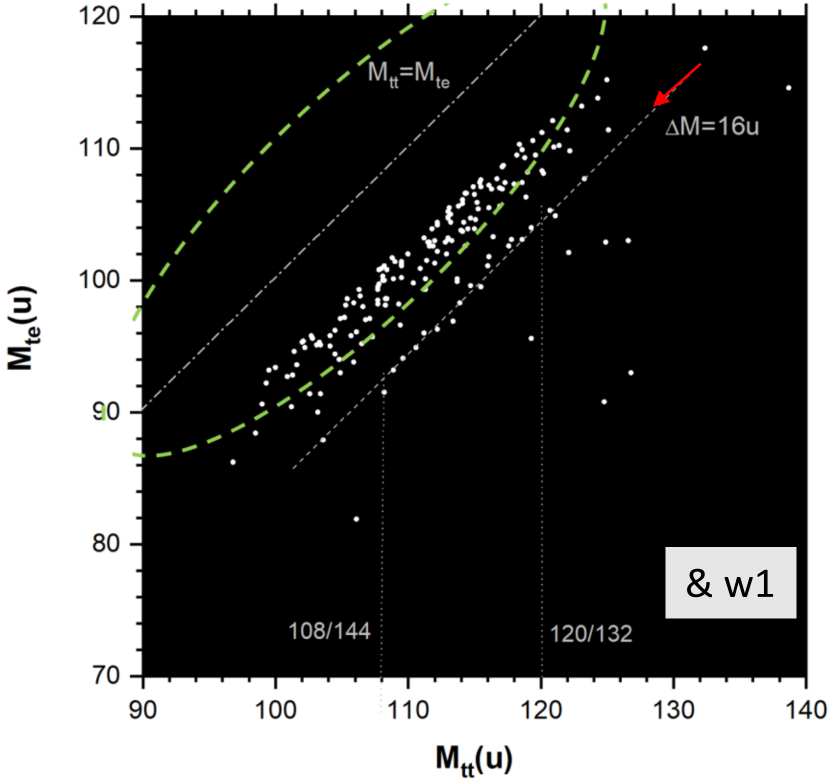
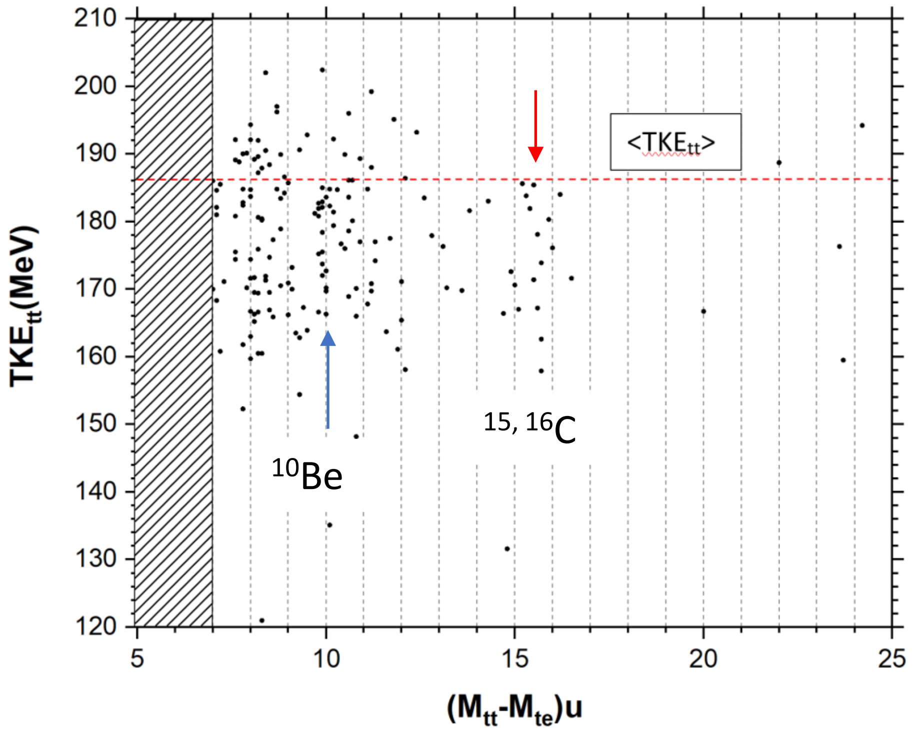
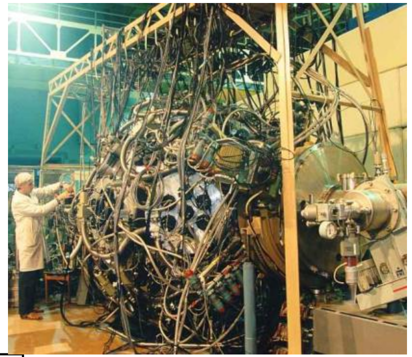


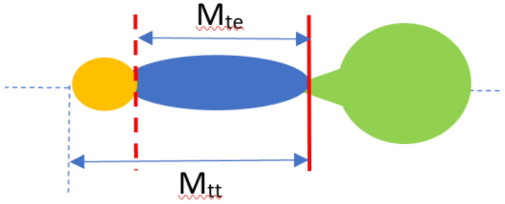
Fig.4

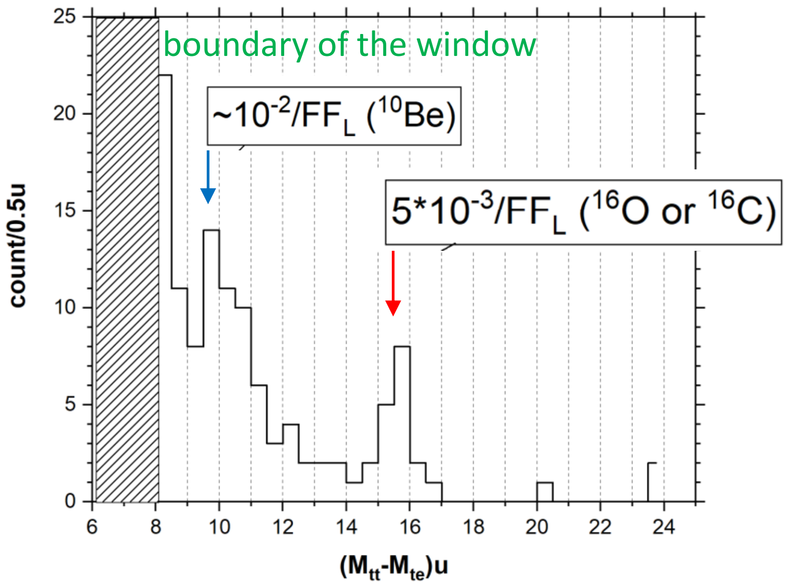
Cu foil , LIS spectrometer, missing light ions

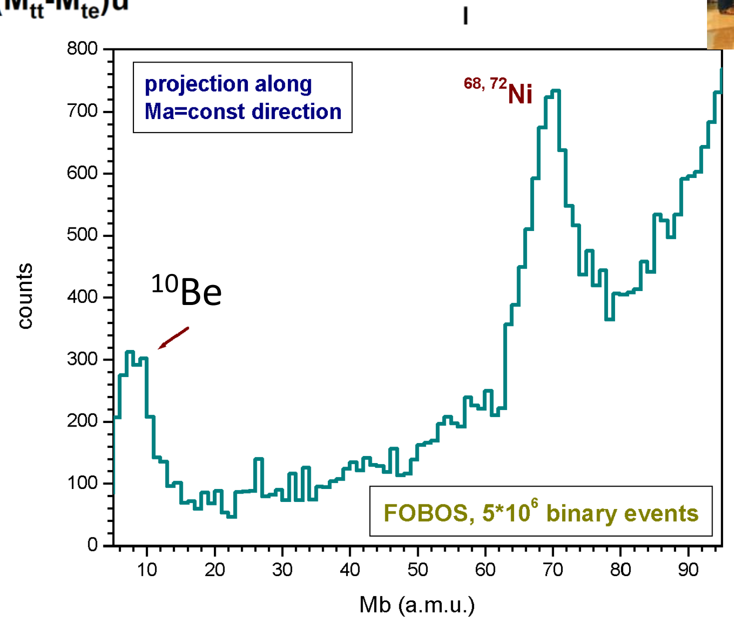




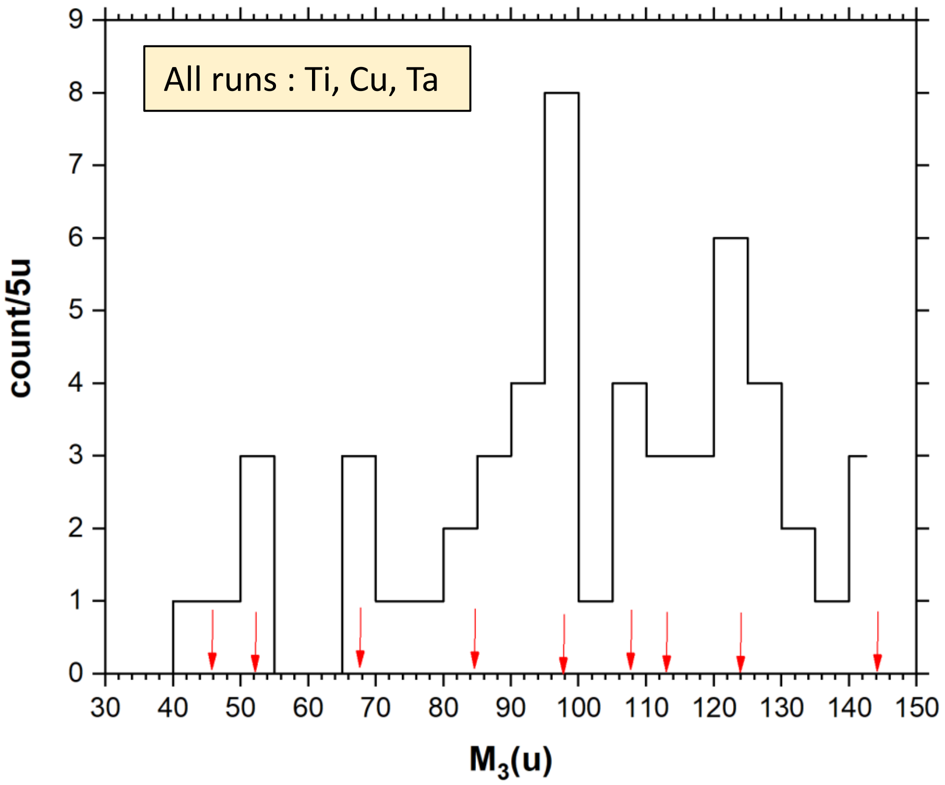








L14_r6_analys16.opj



Conclusions

1. It is shown experimentally the possibility of quite satisfactory mass-spectrometry of pair of heavy ions with minimal time interval between them ≈ 25ns and open angle < 5^0 using "double-hit" approach.
2. A reliable direct confirmation is obtained of the delayed break-up of fission fragments from binary fission of ^{252}Cf(sf) while a fragment passes through a solid-state foil. The fact which was established by us earlier using "missing mass" experimental approach.
3. Strong indication is obtained of clustering of the mother system at the stage of binary fission and clustering of the intermediate fragment which undergoes further break-up. Deformed magic and semi-magic nuclei play a role of clusters.

Thanks for attention.