PRODUCT YIELD RATIOS IN PHOTO-FISSION REACTIONS (γ, f), (γ, nf) ON ^{235}U

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Plan

- Aim of the study
- Experimental methods
- Photo-fission spectrum of fragments
- Values of isomeric yield ratios
- Comparison with other results
- Conclusions

Scientific interest and purpose of the study

- Configuration of nuclear system at scission point
- Scientific interest for nuclear science and engineering
- Description of fission process using isomeric yield ratios for ^{235}U
- Effect of (γ, nf) fission channel
- Study of characteristics of nuclei during descent from fission barrier and near the saddle point

Experimental method

- ^{235}U samples (*aluminum liner covered of thin layer of uranium with thickness 100 mkg/sm^2*) were irradiated by bremsstrahlung photons from microtron M-30 IEP NAS, Uzhgorod, Ukraine

- The spectrum of bremsstrahlung gamma rays formed after complete inhibition of the electron beam on Ta-target with 2 mm thickness

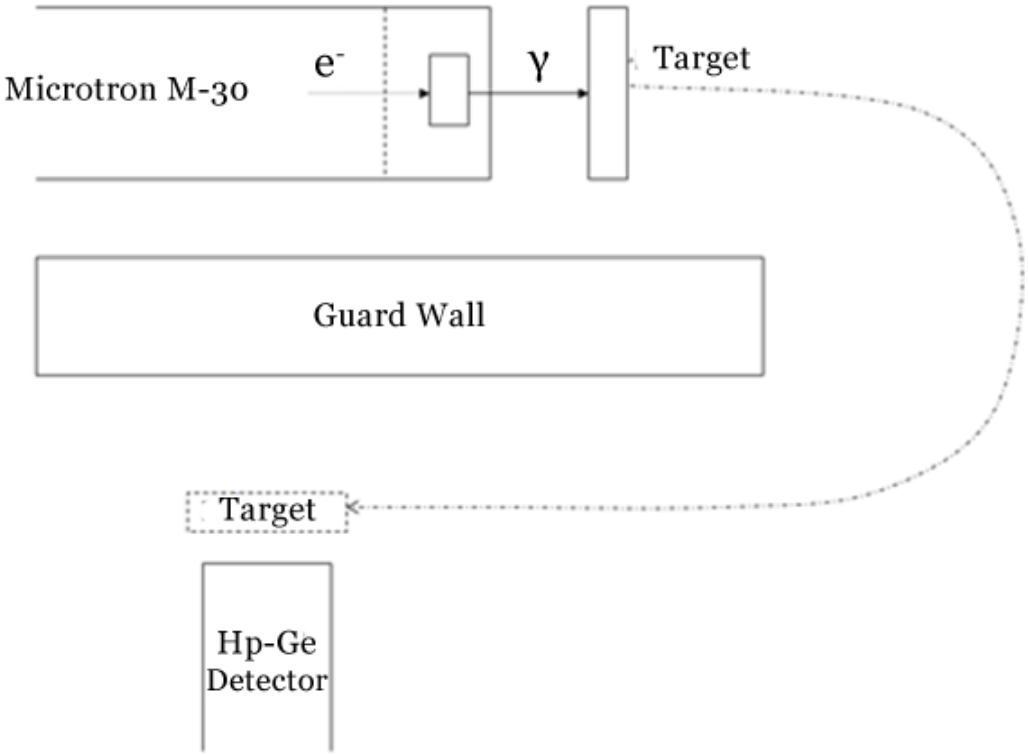
- Maximum energy of gamma-rays - 17 MeV

Measured reactions and thresholds

- **E (γ, f) = 5,5 MeV**
- **E (γ, n) = 5,3 MeV**
- E (γ, 2n) = 12,1 MeV
- E (γ, p) = 6,7 MeV
- E (γ, t) = 10 MeV
- E (γ, ^{3}He) = 9,5 MeV
- E (γ, α) = - 4,7 MeV
- E (γ, np) = 11,9 MeV
- E (γ, 2p) = 12,4 MeV

Possible reactions for maximal bremsstrahlung energy - 17 MeV

Scheme of the experiment



Characteristics of experimental facilities

- Maximal energy of bremsstrahlung photons – 17 MeV
- Average current of electrons – 1,5 mkA
- Time of one impulse – 1 mks
- Frequency of impulses – 1000 Gz
- Outlet size of electron beam – 12x4 mm
- Energy error – 0,5 %

Photo-fission spectrum of ^{235}U for isomeric pair $^{134mg}I$

Nuclide	E, KeV	Q. yield %	$T_{1/2}$	S	δS, %
^{134}Te	767	29	41,8 min	92	12,9
^{134m}I	271	79	3,69 min	243	6,22
^{134g}I	847	95	52,6 min	149	12,5

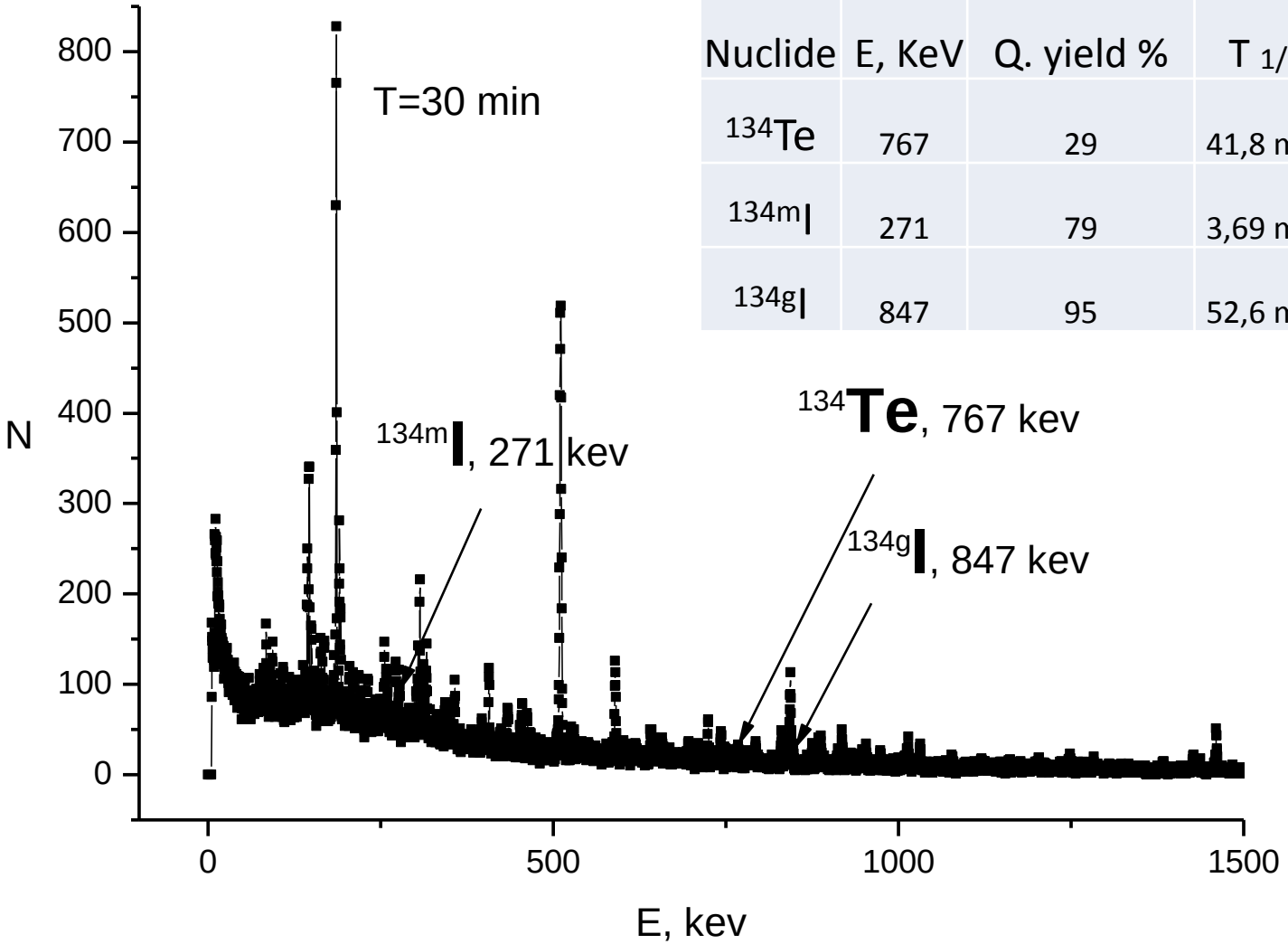
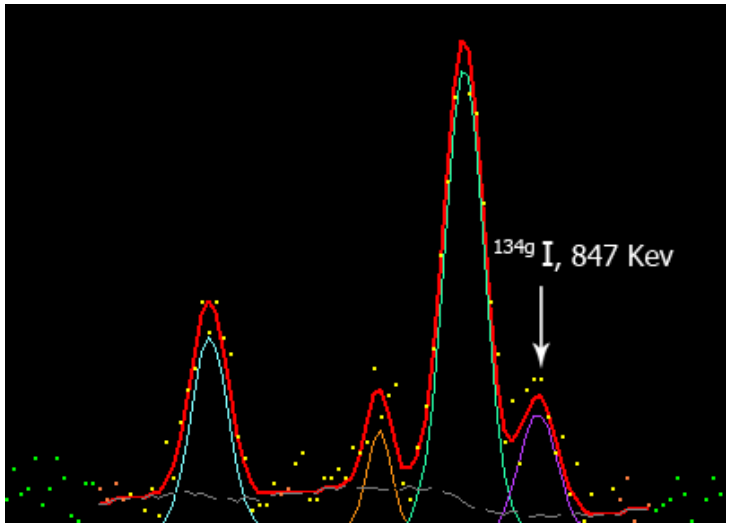
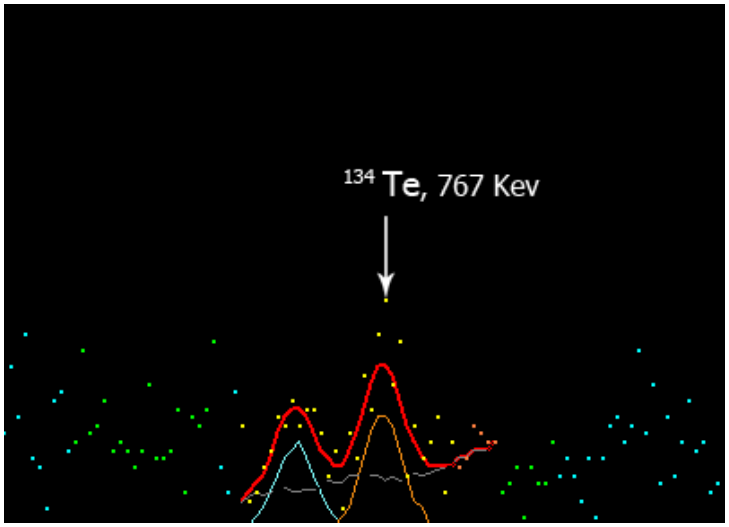


Photo-fission spectrum of ^{235}U for ^{134mg} I and ^{134}Te





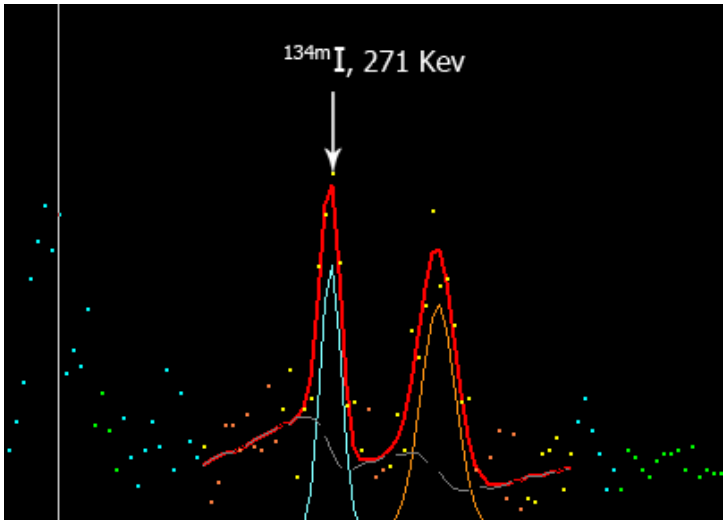


Photo-fission spectrum of ^{235}U for isomeric pair $^{134mg}I$ and ^{134}Te

- The peaks were fitted by Gaussian curves
- Method of least square was used and chi-square value was calculated for each peak
- Intensities of the all peaks with uncertainties were found using Win-Spectrum code

Photo-fission spectrum of ^{235}U, for isomeric pair $^{133mg}Te$

Nuclide	E, KeV	Q. yield %	$T_{1/2}$	S	δS, %
^{133}Sb	1306	43	2,5 min	30	11,1
^{133m}Te	913	55	55,4 min	78	17,7
^{133g}Te	312	62	12,5 min	367	8,8

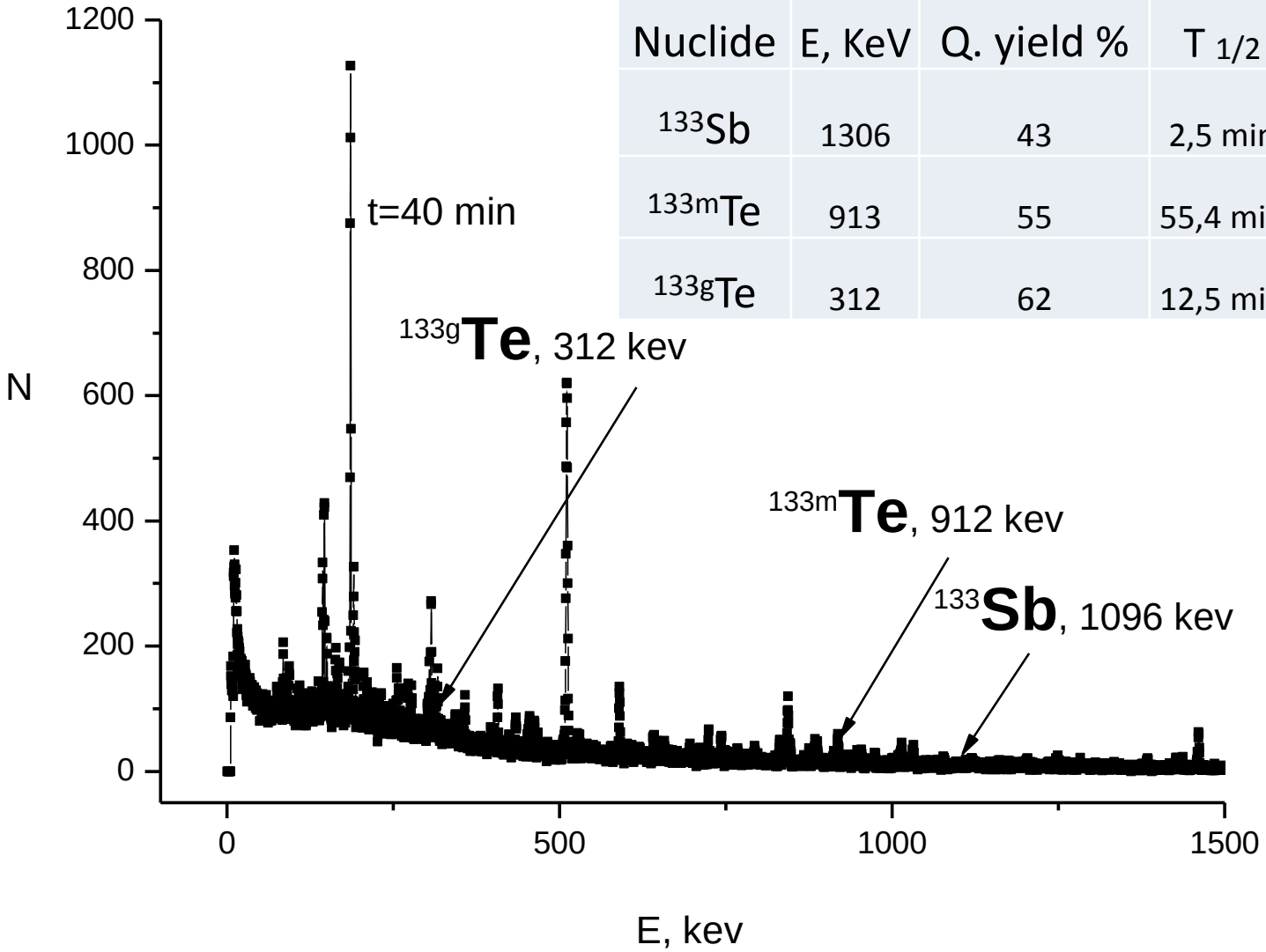


Photo-fission spectrum of ^{235}U, for isomeric pair $^{133mg}Te$ and ^{133}Sb

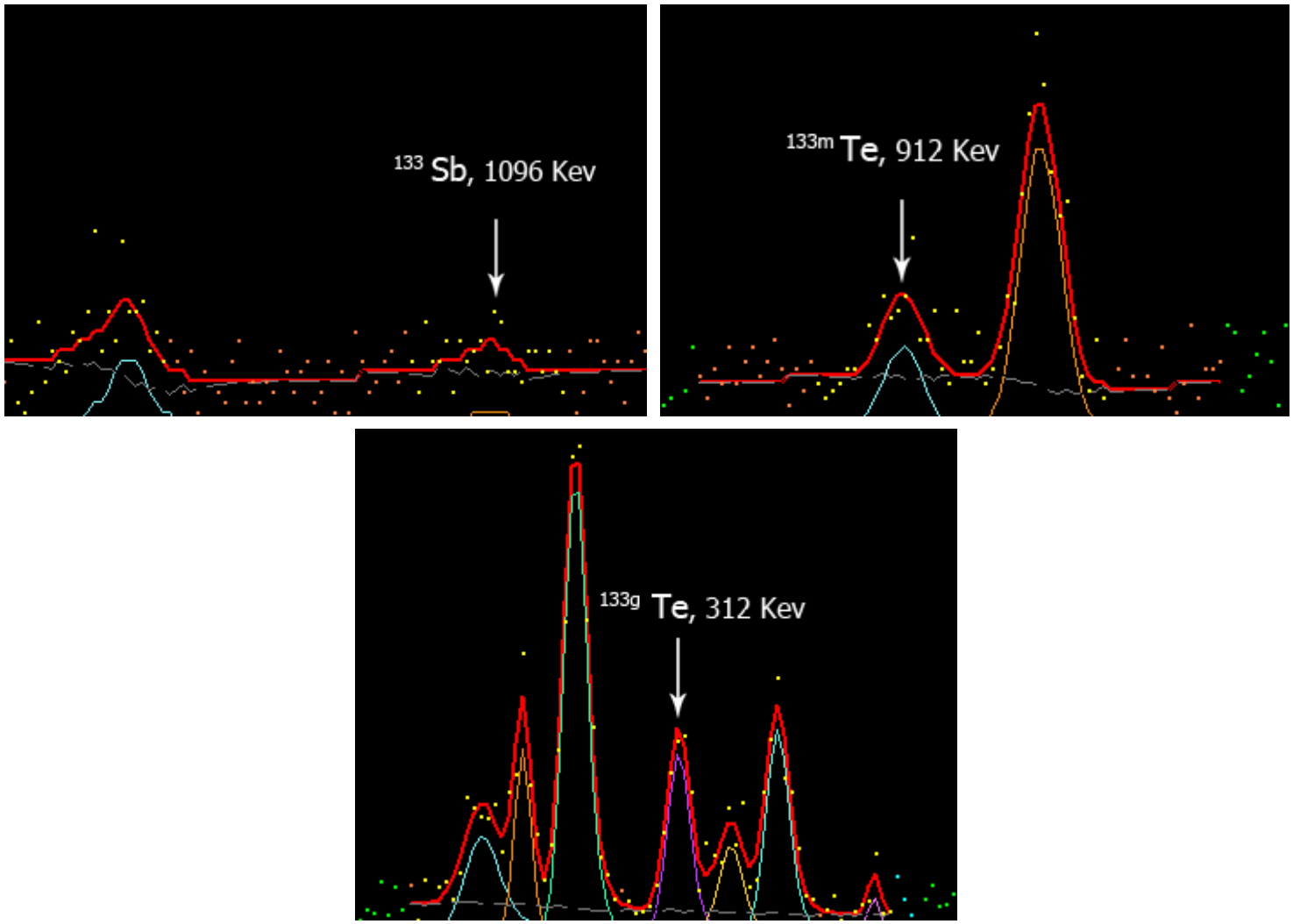


Photo-fission spectrum of ^{235}U for isomeric pair $^{135mg}Xe$

Nuclide	E, KeV	Q. yield %	$T_{1/2}$	S	δS, %
^{135}I	546	7,2	6,57 h	42	10,2
^{135m}Xe	527	81	15,29 min	133	11,7
^{135g}Xe	250	90	9,14 h	120	16,7

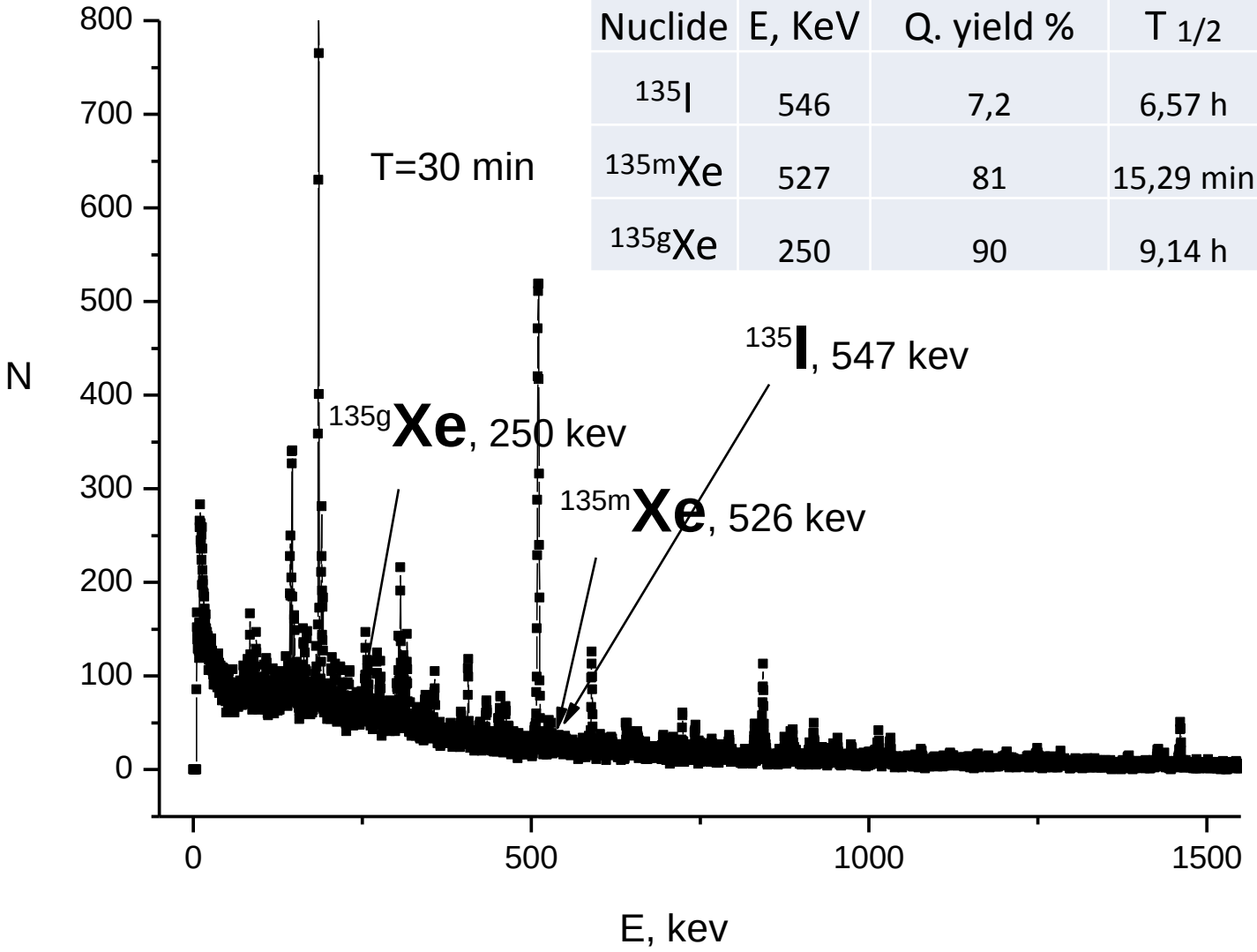
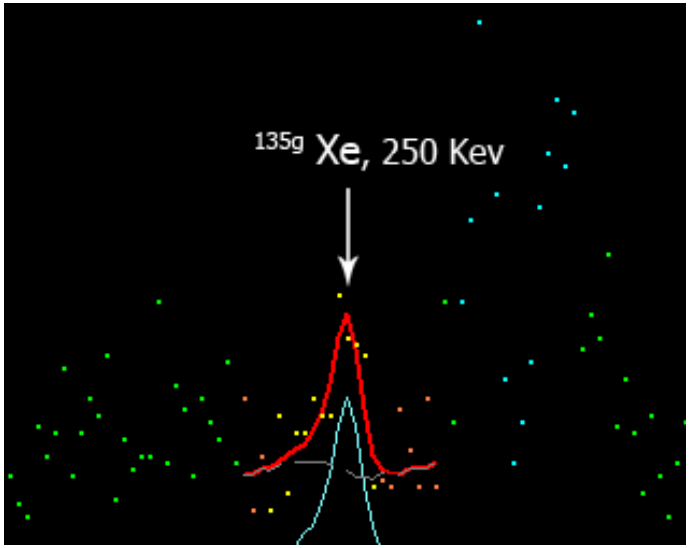
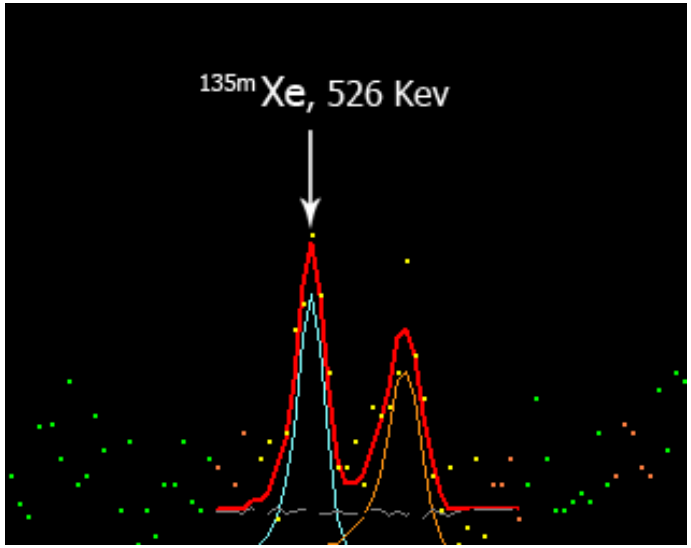
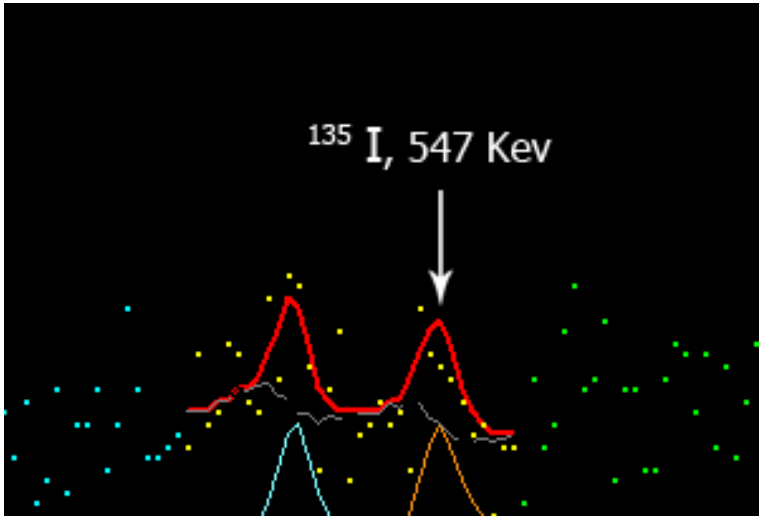


Photo-fission spectrum of ^{235}U, for ^{135mg} Xe and ^{135}I







Data processing

- Set time (2 hour) was divided on 5 individual intervals according to half-live times

- Data set from individual intervals was used for every fragments to determine their yields

Results of measurements

Nuclide	E, KeV	Q. yield %	δQ. yield %	ε	δε	T 1/2	**S**	δS
135I	546,0	7,2	0,1	6,6	0,1	6,57 h	**42,0**	4,3
135mXe	527,0	81,0	0,5	6,8	0,1	15,29 min	**133,0**	15,6
135gXe	250,0	90,0	0,2	10,5	0,2	9,14 h	**120,0**	20,0
133Sb	1306,0	43,0	1,3	3,3	0,1	2,5 min	**30,0**	3,3
133mTe	913,0	55,0	3,0	4,1	0,2	55,4 min	**78,0**	13,8
133gTe	312,0	62,0	1,8	9,4	0,1	12,5 min	**367,0**	32,3
134Te	767,0	29,0	1,2	4,8	0,1	41,8 min	**92,0**	11,9
134mI	272,0	79,0	3,0	10,4	0,1	3,69 min	**243,0**	15,1
134gI	847,0	95,0	1,9	4,4	0,1	52,6 min	**149,0**	18,6

- The results were used to calculate the isomeric yield ratios of fragments of photo-fission of ^{235}U by Isomer code

Isomeric yield ratios of photo-fission fragments

	σ_m/σ_g	$\delta(\sigma_m/\sigma_g)$	$\delta(\sigma_m/\sigma_g)$,%
^{134mg} I	2,8	0,6	21,6
^{133mg} Te	2,8	0,7	25,2
^{135mg} Xe	0,15	0,03	24,4

- The uncertainties correspond to statistical ones
- The rules of indirect measurements were applied
- Previously obtained values of isomeric ratios for maximum energy of irradiation - 9.6 and 20 MeV allow us to do comparative analysis for considered elements

Comparisons with previous measurements

Nuclide	^{241}Am E_{max} = **9.8 MeV**	^{241}Am E_{max} = **17 MeV**	^{233}U E_{max} = **10.5 MeV**	^{233}U E_{max} = **17 MeV**	^{235}U E_{max} = **17 MeV**	^{235}U E_{max} = **9.6 MeV**
$^{90mg}Rb_{37}$	1.1(3)	0.6(1)	0.9(3)	0.7(3)	-	0.53(8)
$^{133mg}Te_{52}$	1.6(2)	1.3(2)	3.2(8)	3.2(9)	2.8(6)	2.3(3)
$^{134mg}I_{53}$	3.0(5)	2.0(4)	1.33(14)	1.8(5)	2.8(7)	0.65(5)
$^{135mg}Xe_{54}$	0.18(1)	0.84(8)	0.14(2)	0.38(4)	0.150(36)	0.142(14)

	σm/σg	δ	E_{max} = 20MeV
$^{133mg}Te_{52}$	2,4	0,3	Gent Belgium "82
$^{134mg}I_{53}$	1,13	0,06	Gent Belgium "84

Conclusions

- Isomeric yield ratios for ^{235}U photo-fission products for maximal energy of bremsstrahlung photons – 17 MeV were measured for the first time

- Possible influence of (γ, nf) – fission channel on experimental results (isomeric pair $^{134mg}I_{53}$)

- The average angular moments of the fission fragments are under consideration and comparison with theoretical predictions in the Talys 1.4 code

Thank you for your attention!