Am-241 incineration measurements with activation method in the «QUINTA» neutron field

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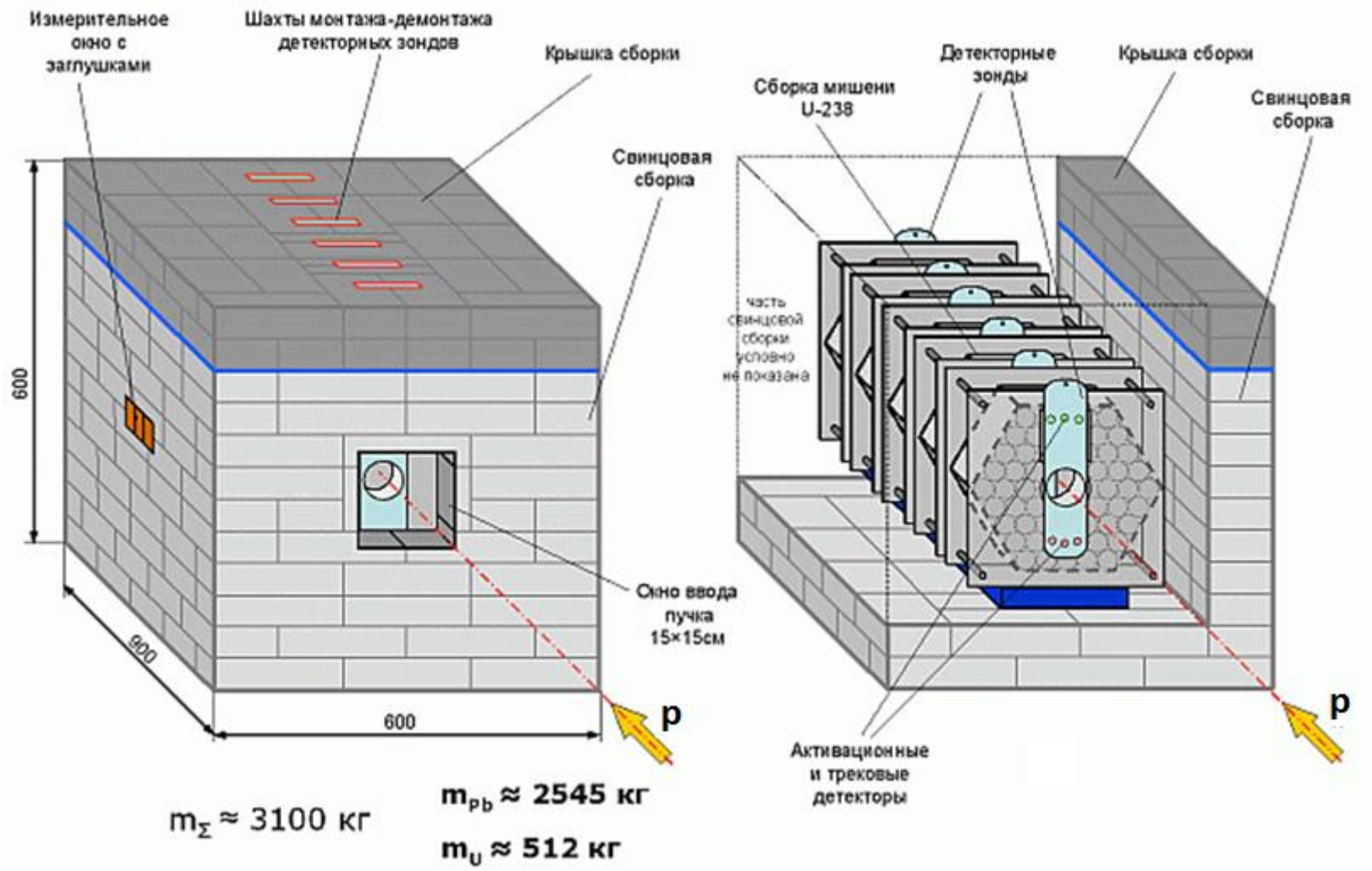
Some Am-241 introductory data

Radioactive, $T_{1/2}$ = 432.2 y, α-active

Produced in a reactor as a nuclear waste.

Difficult to burn in PWRs. It accumulates.

TA QUINTA with lead blanket



Experiment data

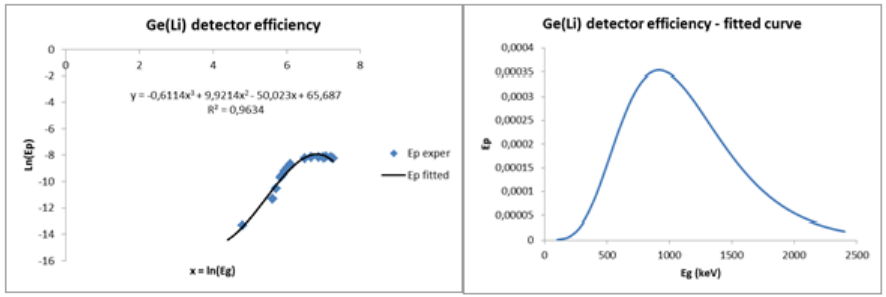
Experiment date	4.12.2015
Experiment place	JINR, Dubna, Russia
QUINTA configuration	5 sections, lead shield
Accelerator	Phasotron
Beam	660 MeV protons
Beam integral	4.5×10^{15}
Method	Am-241 sample activation, gamma spectra measurement

Experimental data work-out details

$$I_{f\gamma} = \frac{S_\gamma}{\gamma_f \cdot m \cdot \varepsilon_p \cdot I_\gamma \cdot \phi \cdot COI} \cdot \frac{\lambda_k \cdot t_{ir}}{\left(1 - e^{-\lambda \cdot t_{ir}}\right)} \cdot \frac{1}{\left(1 - e^{-\lambda t_{real}}\right)} \cdot \frac{t_{real}}{t_{live}} \cdot e^{\lambda t_+}$$

$I_{f\gamma}$ – actinide fission rate, per deuteron and per gram
γ – gamma line index
f – reaction index (f = fission)
S_γ – gamma peak area
γ_f – isotope production yield [%]
m – activation sample mass [g]
ε_p – gamma spectrometer efficiency
I_γ – gamma line intensity [%]

ϕ - deuteron beam integral
COI – correction for gamma quanta coincidence
λ_k – isotope decay constant
t_+ – cooling time
t_{ir} – irradiation time
t_{real} – real time of measurement
t_{live} – live time of measurement

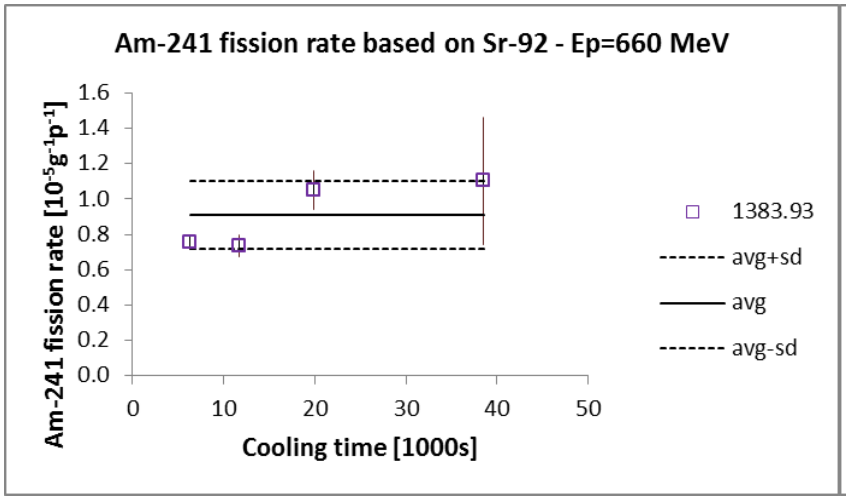


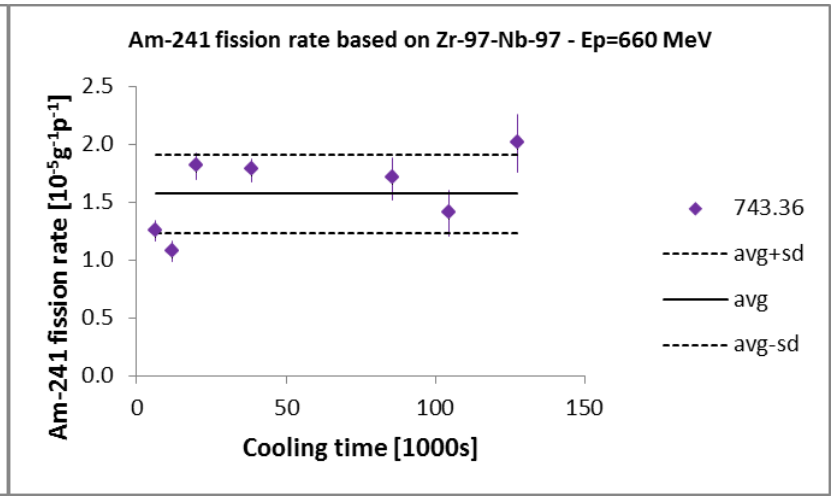
$$\varepsilon_p = -0.6114x^3 + 9.921x^2 - 50.023x + 65.687$$
$$x = \ln(E)$$
$$R^2 = 0.9634$$

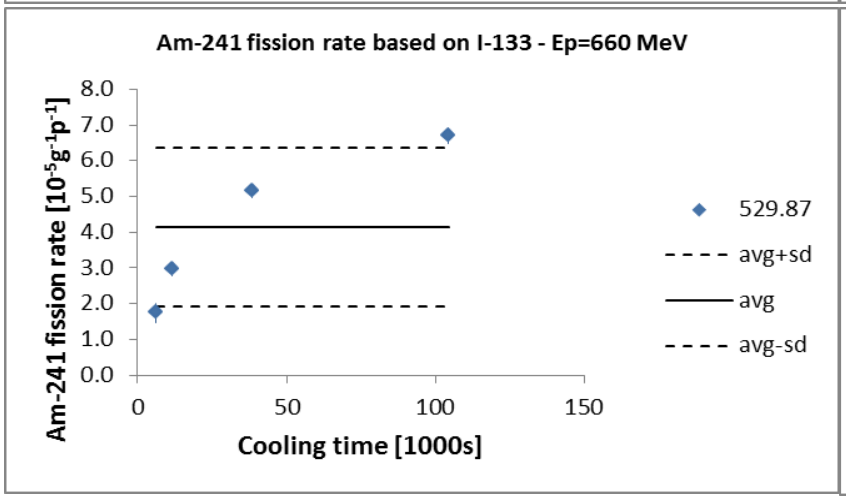
Basic gamma lines and fission product isotopes identified in Am-241 sample

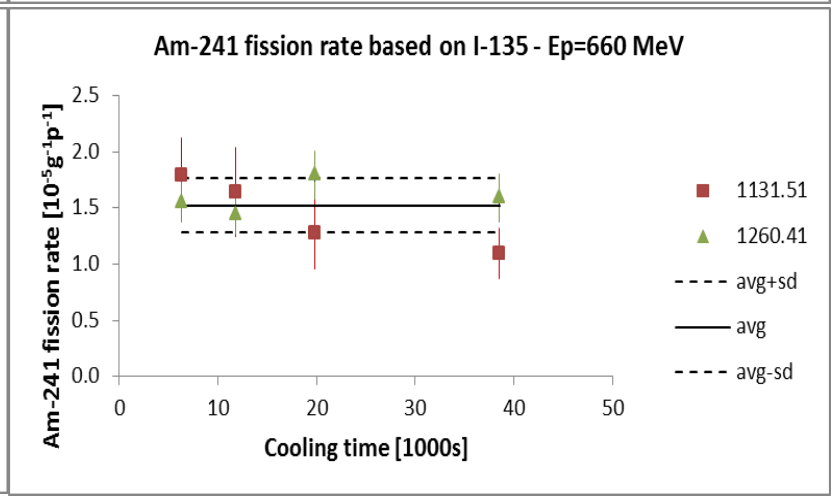
E-gamma [keV]	Isotope 1	Isotope 2	T1/2-1	T1/2-2	I-gamma
529.87	133I		20.87h		87.00%
641.28	142La		91.1 min		47.40%
661.66	137Cs		30.05y		85.10%
722.911	131I		8.02d		1.77%
743.36	97Zr		16.744h		93.00%
847.025	134Te	134I	94m	52.5m	95.40%
884.09	134Te	134I	94m	52.5m	64.90%
1024.3	91Sr		9.63h		33.00%
1072.55	134Te	134I	94m	52.5m	14.90%
1131.51	135I		6.57h		22.60%
1260.41	135I		6.57h		28.70%
1383.93	92Sr		2.66h		90.00%
1435.86	138Cs		33.41m		76.30%
1455.24	134I		52.5m		2.29%

Am-241 FP specific fission rates

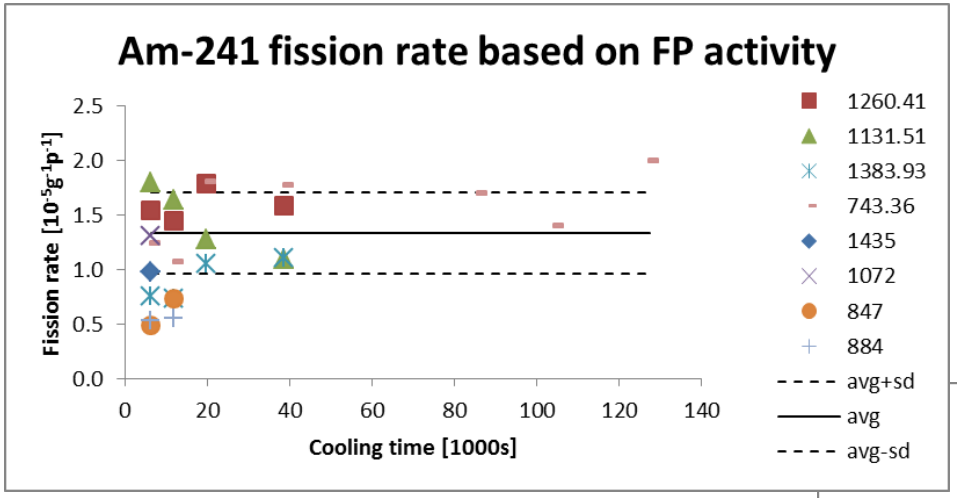


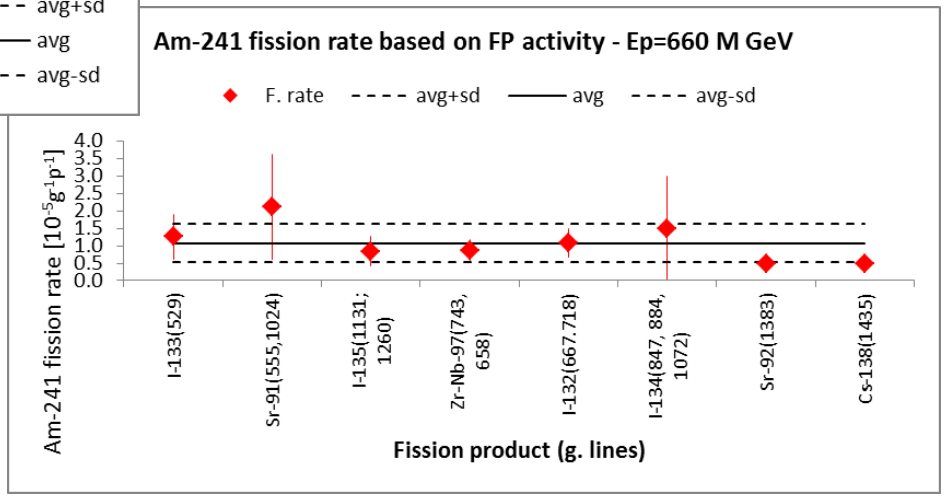






Am-241 fission rate summary based on FP activities



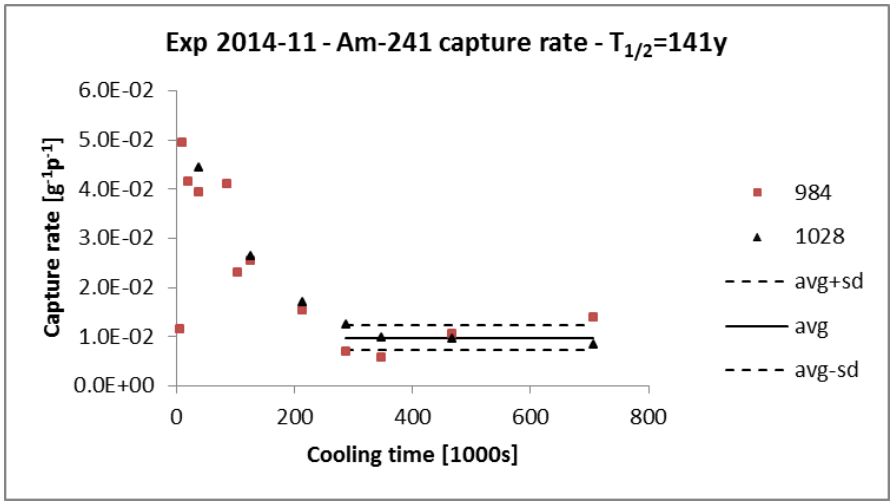


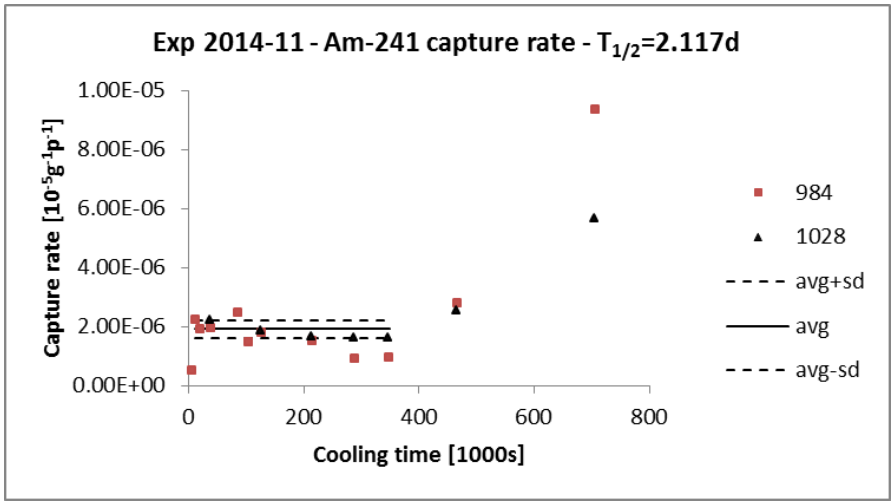
$I_f = 1.34(37)\times10^{-5}$ fissions/g/beam particle

Search for neutron capture product gamma lines

Neutron capture line candidates

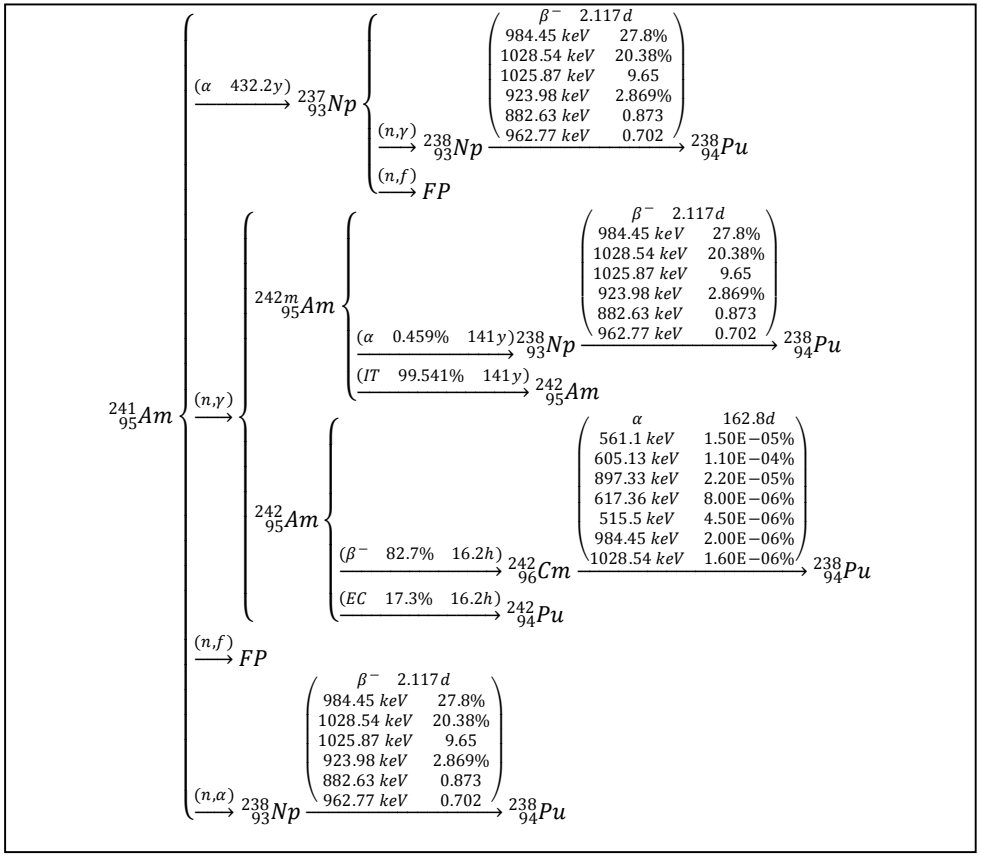
923.98 keV
962.77 keV
984.45 keV
1028.54 keV





Surprising effect of correction for cooling time – the lines 984 and 1028 keV stem from more than one reaction.

Search for neutron capture lines in Am-241 – cont.

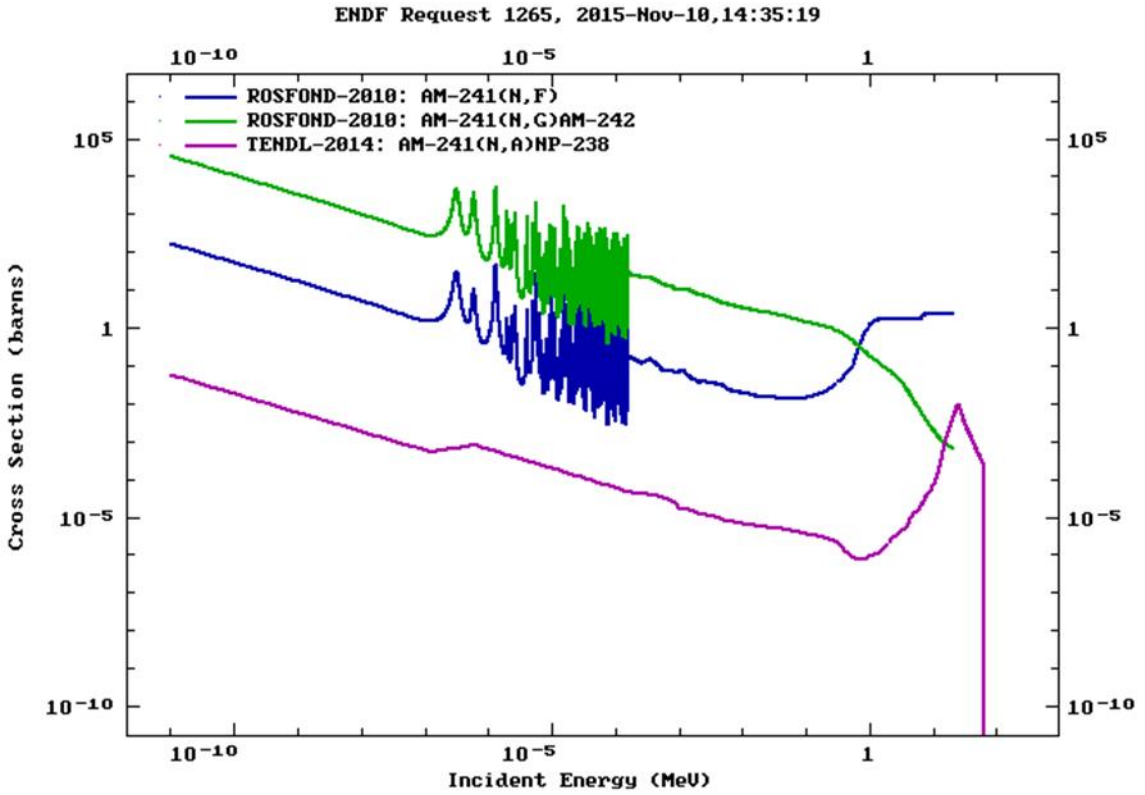


Am-241 spontaneous α-decay and reaction (n,γ), (n,f), (n,α) channel data.

Comments to the above scheme

1. Neutron capture products long lived and therefore emitted gammas are of weak intensity.
2. Spontaneous Am-241 alpha decay emits gammas making high background.
3. Spontaneous Am-241 alpha decay product (Np-237) cumulates so intensively that after years its neutron capture product overlaps Am-241 neutron capture products.

Am-241 cross sections for interaction with neutrons



Conclusions

1. Am-241 sample was irradiated in spallation neutron field produced in JINR Dubna's ADS setup QUINTA to determine Am-241 incineration rate with activation method. The incineration goes in two competitive channels, either by fission or neutron capture. A gamma spectrometry method was used then to identify fission products and neutron capture products.
2. Three fission products were identified and based on them Am-241 fission rate. Am-241 sample activation method is good enough for Am-241 fission rate determination.
3. Nevertheless the expected lines stemming from neutron captures are either so weak that do not stack above background or are covered by Np-237 neutron capture product lines. To get rid of Np-238 decay lines problem one has to use fresh Am-241 sample or apply completely different method, not the activation one.