17th Russbach School on Nuclear Astrophysics

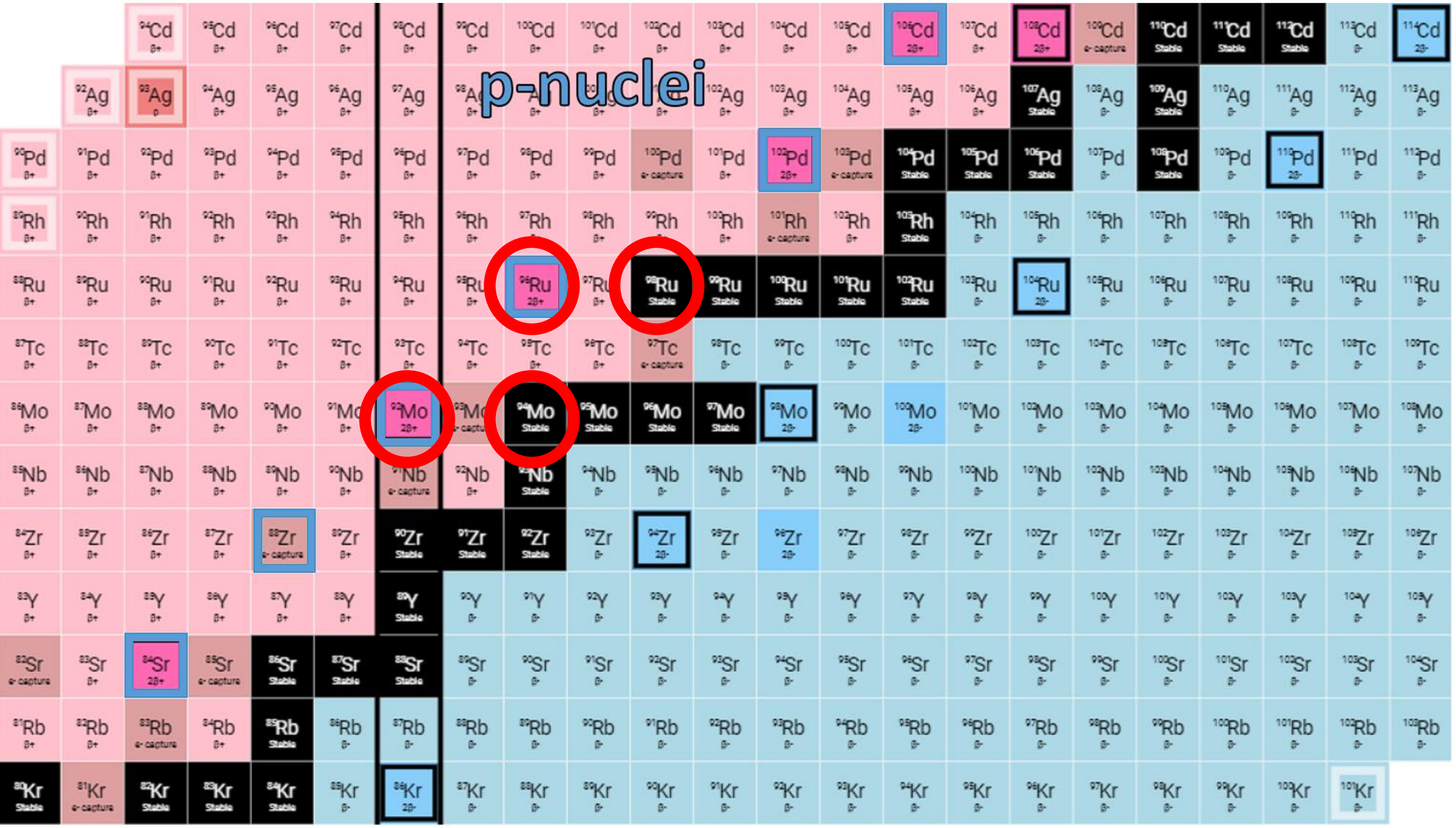
Cross section measurement of the ^{92,94}Mo(α,n) and ^{92}Mo(α,p) reactions by γ-spectroscopy

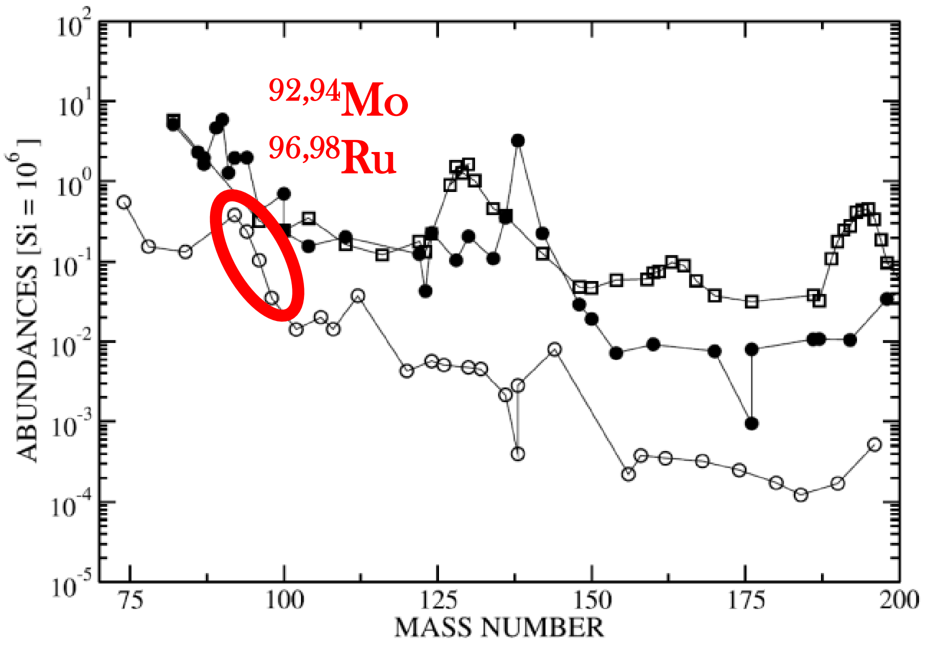
Tibor Norbert Szegedi

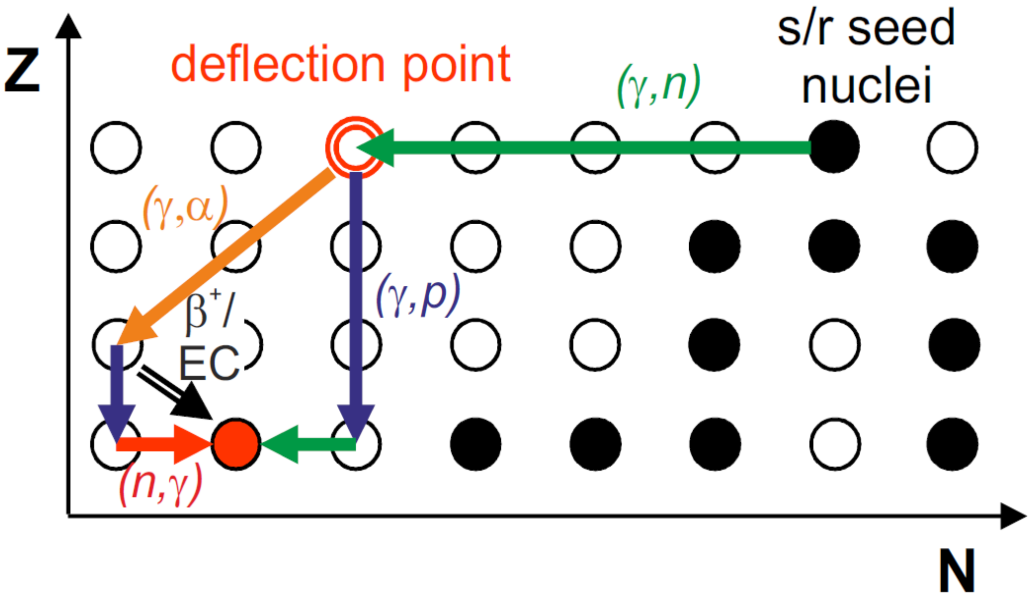
2022

UNIVERSITY of DEBRECEN

γ-process







The p-nuclei mainly synthetized via photodisintegration.
However, the rp- and νp-process can give a contribution to their abundance.

Reaction network calculations

>10 000 reaction on ~ 1 000 (mostly radioactive) nuclei

Astrophysics
- Astrophysical site
- Temperature
- Time scale
- s/r-seed abundance

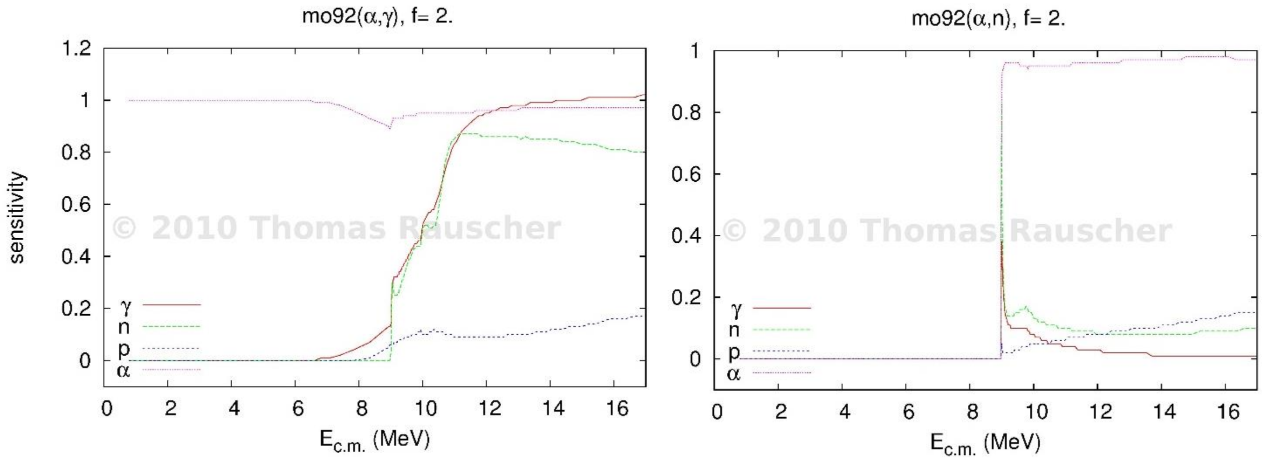
Statistical model
- Optical potential
- Level density
- γ-strength

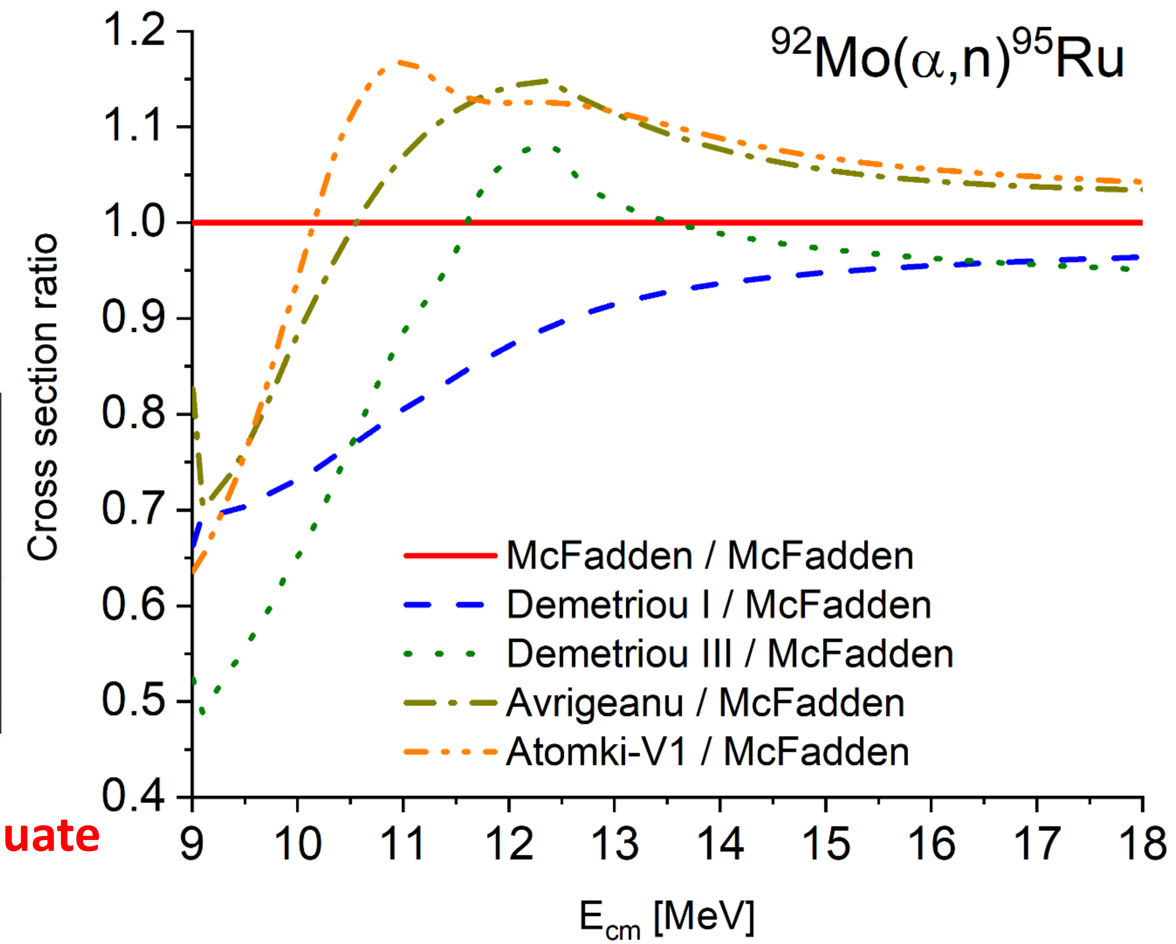
Nuclear physics

Reaction rate

Reaction network calculation → Predicted abundance ↔ Observed abundance

(γ,n), (γ,p) and **(γ,α)** cross sections are required

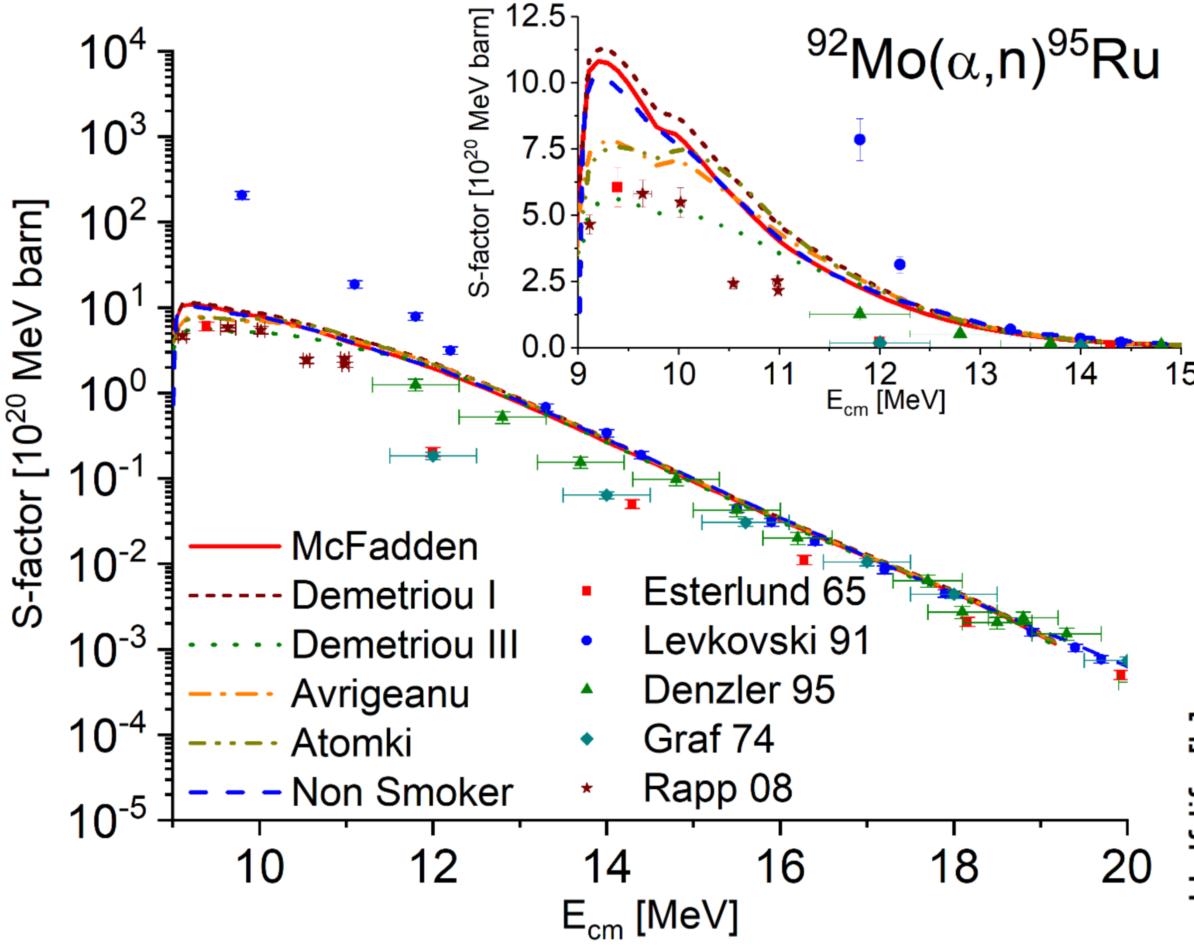


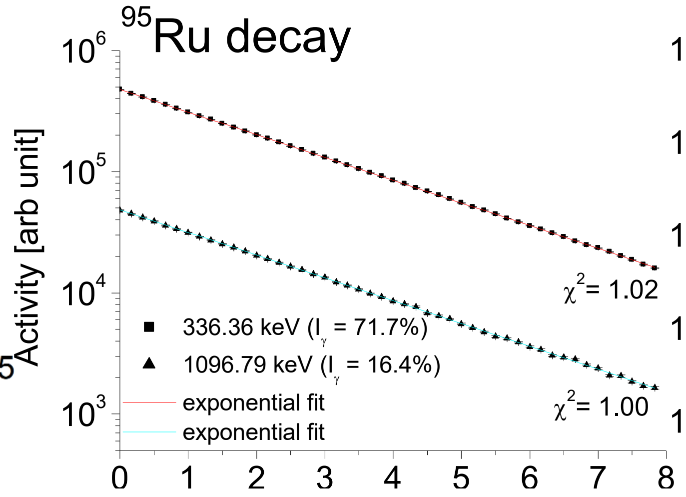


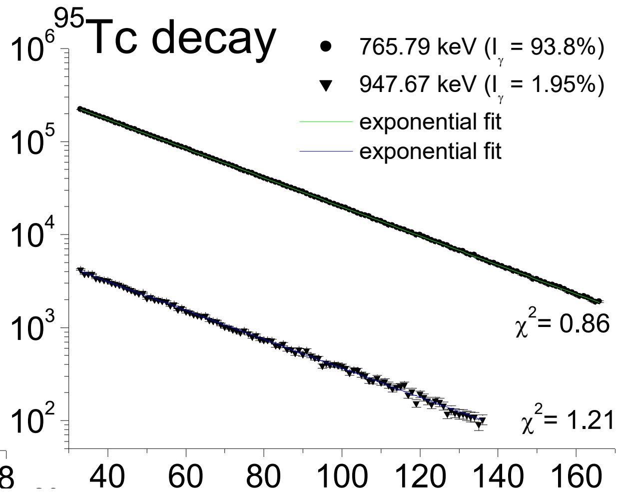
(α,n) cross section measurements can be used to evaluate the α-OMP parameter sets!

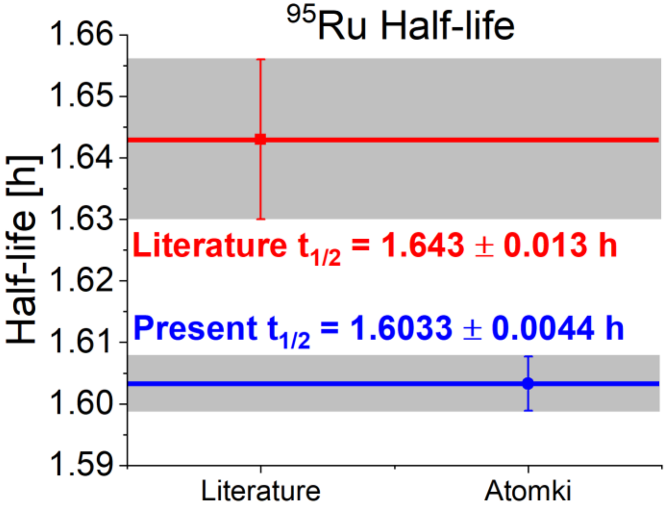
Motivation

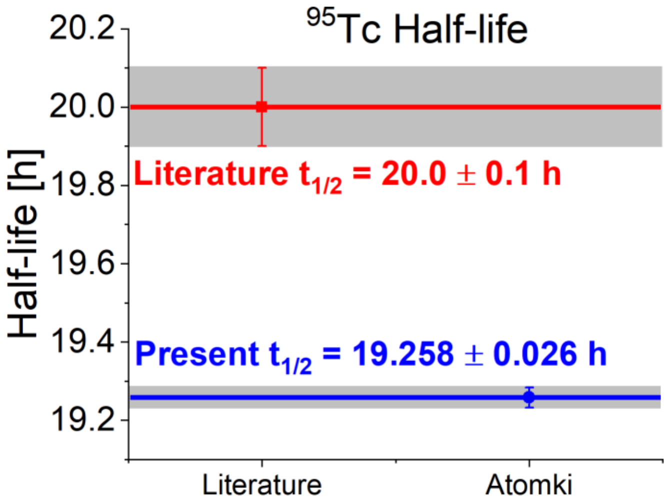
^{92,94}Mo are the most abundant p-isotopes → experimental knowledge on ^{92,94}Mo involved reactions is important











Thick target yield measurement

Radioactive product → Activation technique → Irradiation and counting separately

$$N_{det}(E) = \sigma(E) \cdot \Phi \cdot N_{targ} \cdot \epsilon \cdot I \cdot \frac{\left(1 - e^{-\lambda \cdot t_i}\right)}{\lambda} \cdot e^{-\lambda \cdot t_w} \cdot \left(1 - e^{-\lambda \cdot t_c}\right)$$

- 0.5 mm thick, natural isotopic composition molybdenum targets.
- The α-beam stops in the target material.
- Reactions takes place with all energies between the initial and threshold energy.
- The cross section can be determined by subtraction:

$$\sigma\left(E_{eff}\right) = \frac{\left[Y_{TT}(E_2) - Y_{TT}(E_1)\right] \cdot \overline{\epsilon_{eff}}\,(E_1;E_2)}{E_2 - E_1}$$

Reaction properties				
Target	^{92}Mo		^{94}Mo	^{100}Mo
Abundance	14.5±0.3%		9.2±0.9%	9.8±0.3%
Reaction	^{92}Mo(α,n)	^{92}Mo(α,p)	^{94}Mo(α,n)	^{100}Mo(α,n) [Sze21]
Product	^{95}Ru	^{95}Tc	^{97}Ru	^{103}Ru
$T_{1/2}$	**1.6033±0.0044 h [Sze20]**	**19.258±0.026 h [Sze20]**	2.84±0.01 d	39.247±0.013d
Gammas	E_γ [keV] (I_γ [%])			
	336.4 (69.9±0.5)	765.8 (93.8±0.3)	215.7 (85.6±1.3)	497.1(91.0±1.2)
	626.8 (17.8±0.5)	947.7 (1.95±0.02)	324.5 (10.79±0.17)	610.3(5.76±0.06)
	1096.8 (20.9±1)	1073.7 (3.74±0.4)		

In progress!

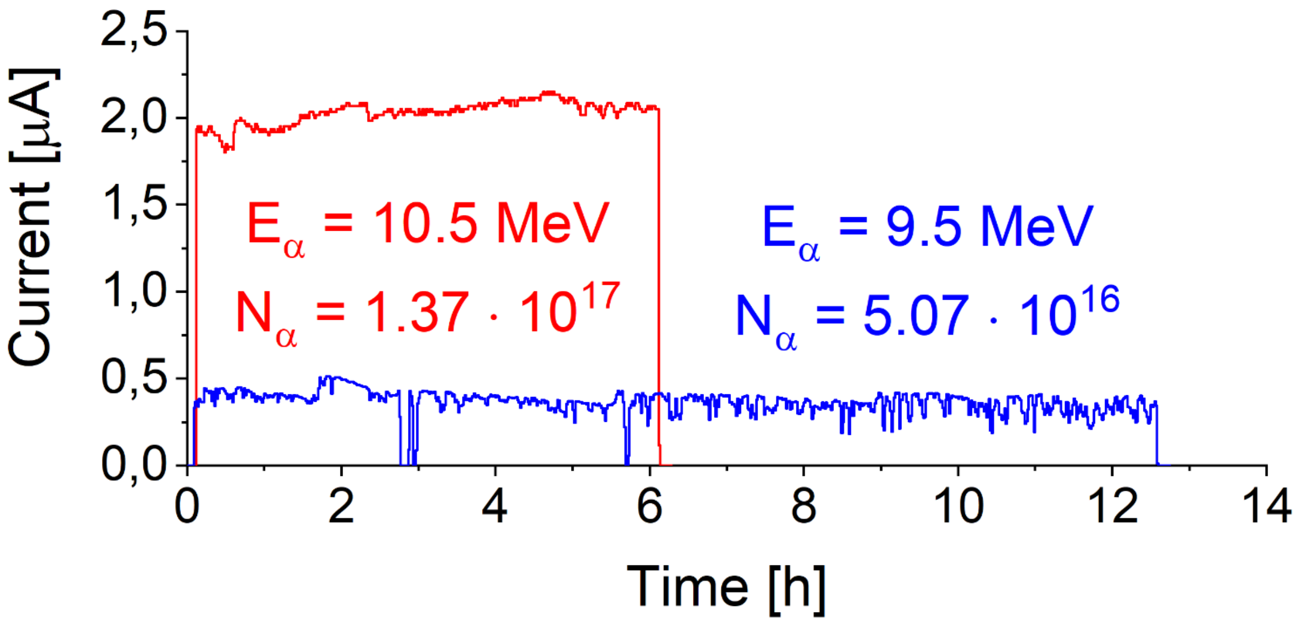
Published!

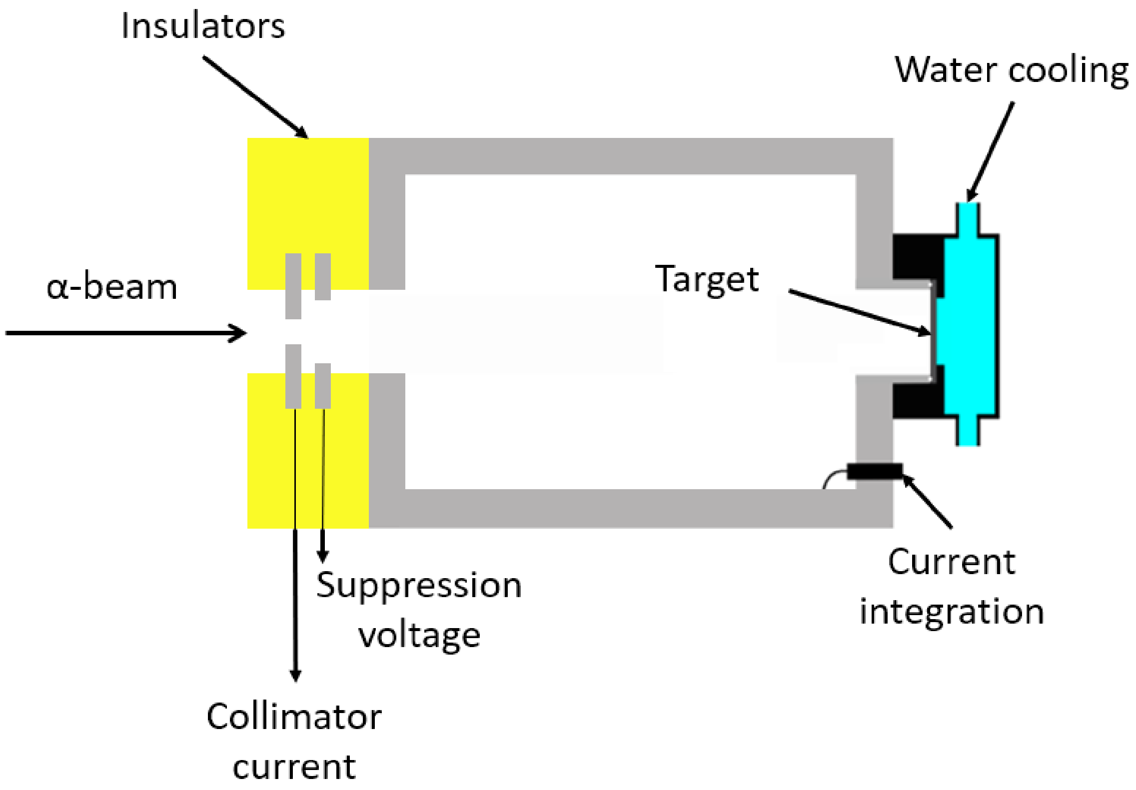
[Sze20] T.N. Szegedi et al., Eur. Phys. J. A **56**, 182 (2020).

[Sze21] T.N. Szegedi et al., Phys. Rev. C, **104**, 035804 (2021).

Irradiation

- α-beam was provided by the cyclotron accelerator of Atomki between 9.5 – 13 MeV energy range
- Length of irradiation varied between 30 min and 12.5 hours
- Current measurement
  - Faraday-cup → Determination of the number of incident α-particles
  - Multichannel analyzer
  - Secondary electron suppression voltage U = - 300 V
  - Water cooling
  - Typical beam current: 0.3 - 2 μA



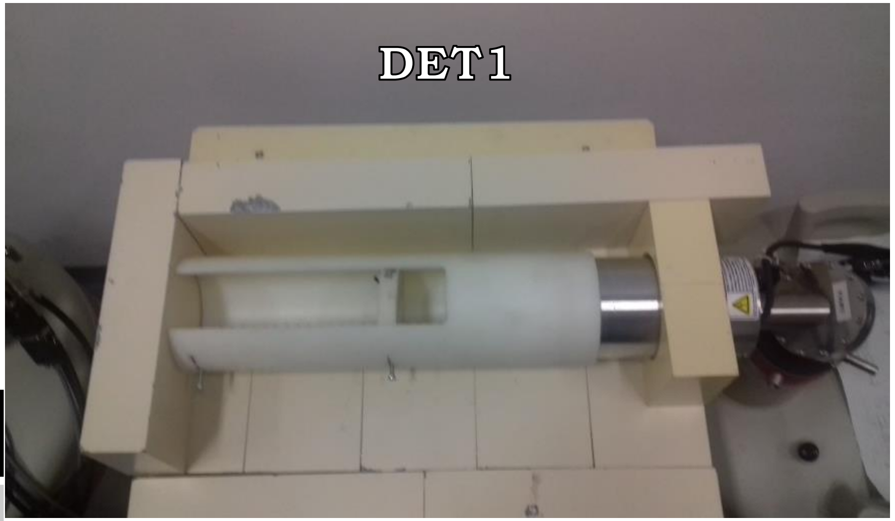


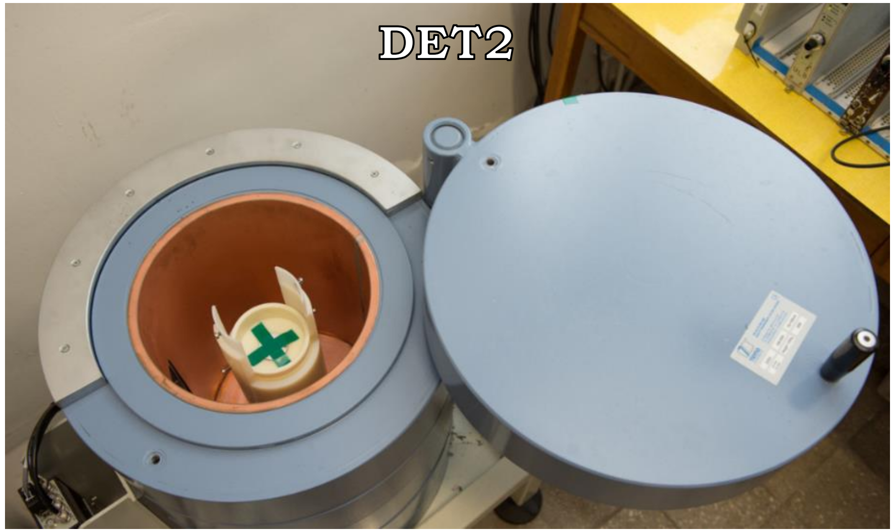
γ-counting setup

- Cross section measurement is based on measuring the yield of γ-radiation following the β-decay of the radioactive isotopes → HPGe detectors
- Absolute detection efficiency was measured by calibration γ-sources (^{60}Co, ^{133}Ba, ^{137}Cs, ^{152}Eu)

Parameters	Detector	
	DET1	DET2
Relative efficiency*	50 %	100 %
Shielding	Pb (50 mm)	Cu-Cd-Pb (1-1-100 mm)
Far counting geometry	21 cm	27 cm
Close counting geometry	5 cm	1 cm

* Absolute efficiency of a 3” diameter, 3” high cylindrical NaI detector.





Data analysis

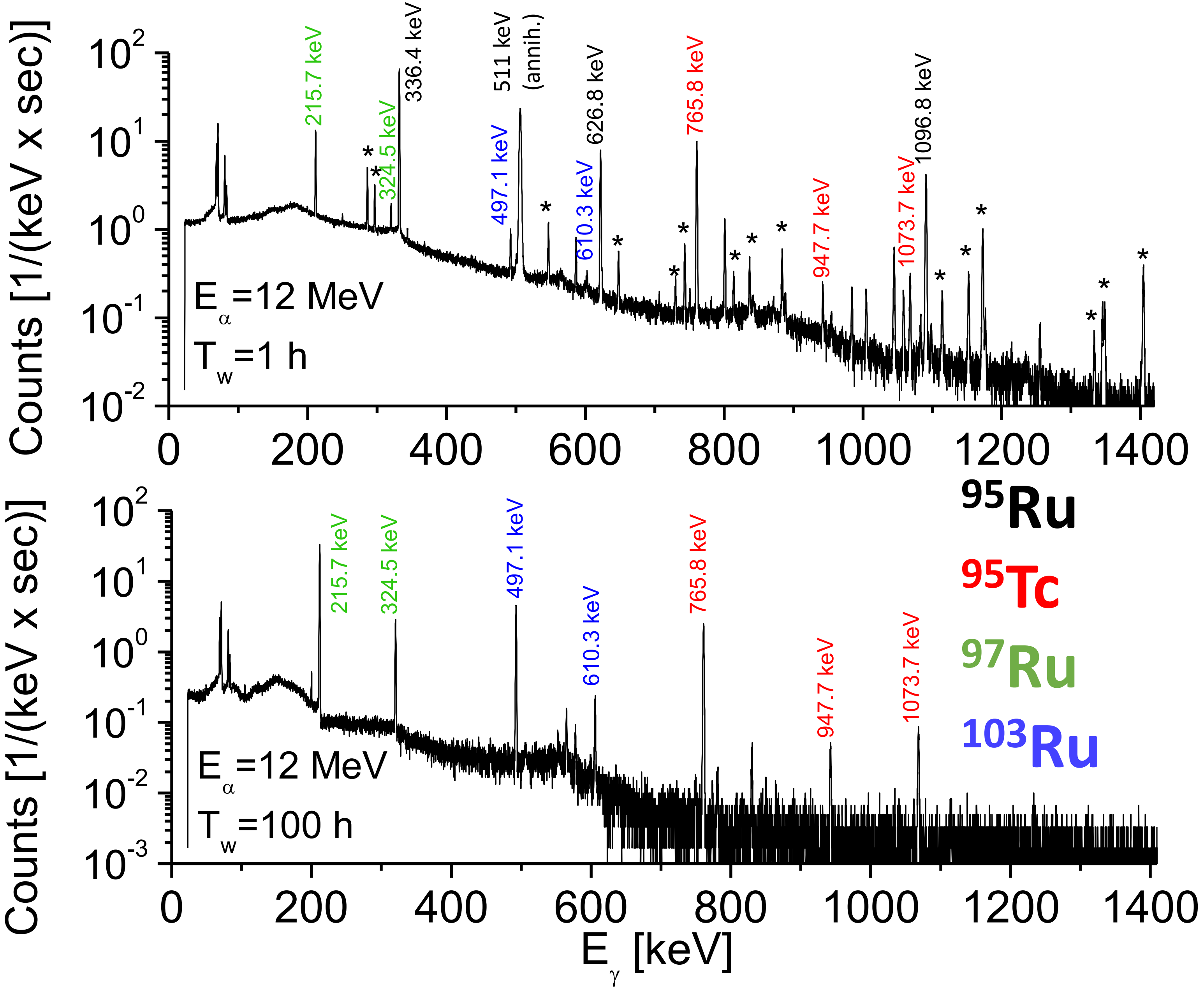
1. γ-counting

2. Peak area

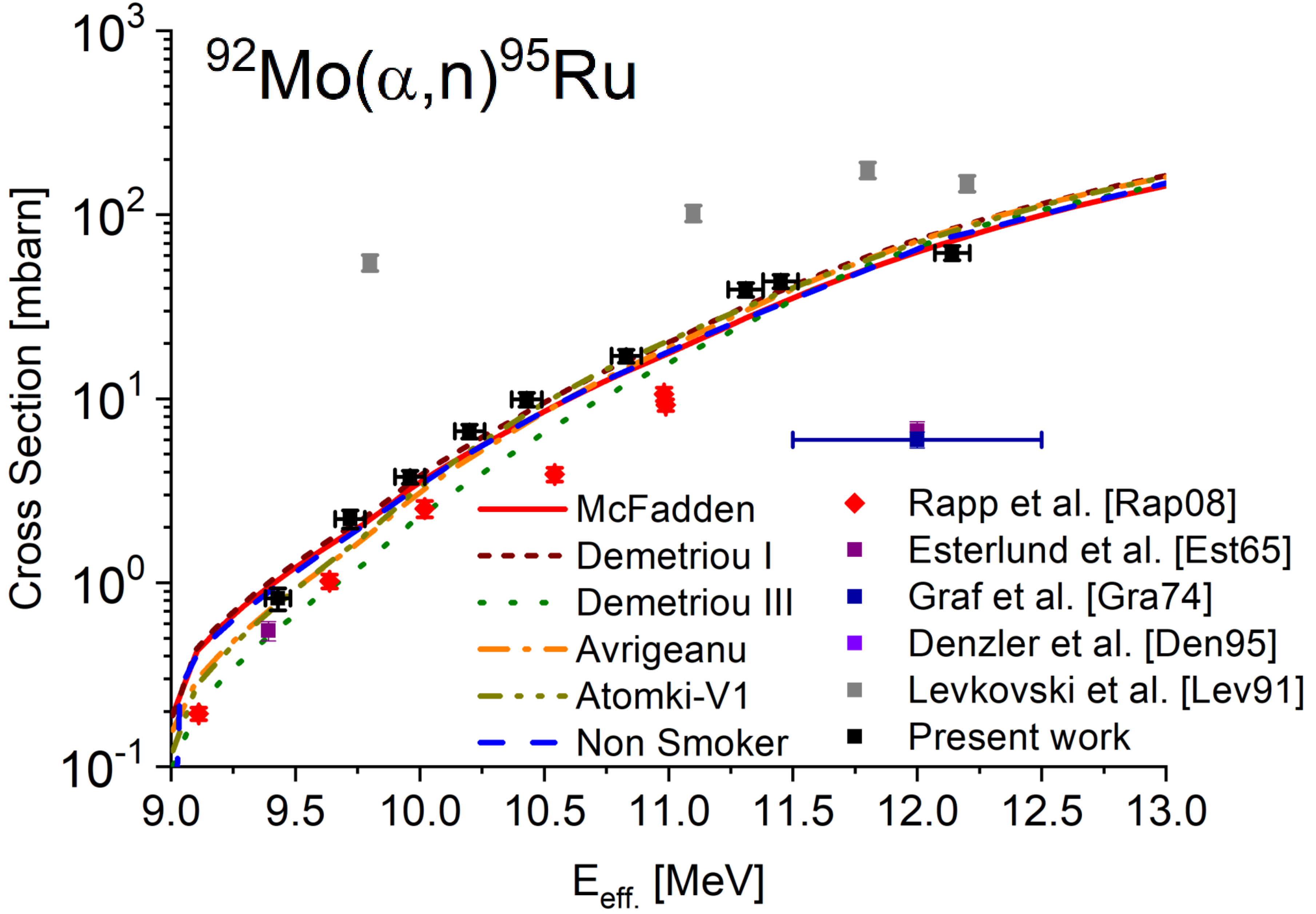
3. Thick target yield ($Y_{TT}(E)$)

4. Cross section

$$\sigma(E_{eff}) = \frac{[Y_{TT}(E_2) - Y_{TT}(E_1)] \cdot \overline{\epsilon_{eff}}\,(E_1;E_2)}{E_2 - E_1}$$



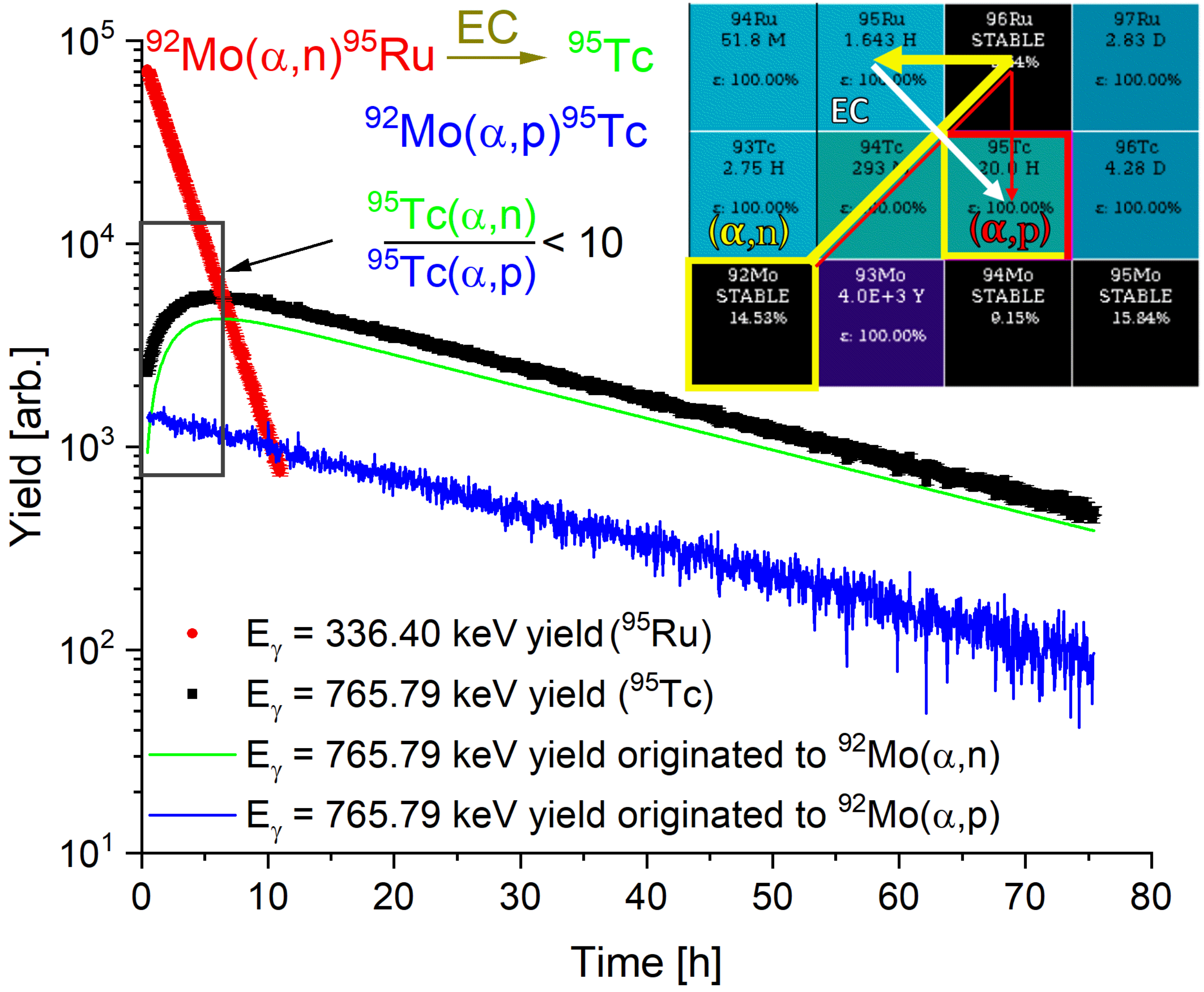
Preliminary results



^{92}Mo(α,p)^{95}Tc method

- ^{92}Mo(α,n) and ^{92}Mo(α,p) channels are open
- σ(α,n) ≈ 10 · σ(α,p), but different half-lives
- By applying the Bateman equation the counts corresponding to the (α,n) channel can be subtracted from the measured yield

Data Analysis Is In Progress!



Új Nemzeti Kiválóság Program

NEMZETI KUTATÁSI, FEJLESZTÉSI ÉS INNOVÁCIÓS HIVATAL

Thank you for your attention!

Nuclear Astrophysics group of Atomki: G.G. Kiss, Gy. Gyürky, T. Szücs, Z. Halász, Z. Elekes, Á. Tóth

Supported by the ÚNKP-21-4-I-DE-243 New National Excellence Program of the Ministry for Innovation and Technology from the source of National Research, Development and Innovation fund.