Alena Kohoutová

Experiment 2019 Autumn
MASHA Separator

Experiment I
Data Analysis

JINR 114 Flerovium FLNR Dubna

ОИЯИ

Univerzita Palackého v Olomouci

KEF Department of Experimental Physics

Outline

1. Introduction
2. MASHA
3. Superheavy elements – production, observation and determination of properties
4. Experiment 2019
    1. $^{40}Ar+^{144}Sm \rightarrow ^{184-xn}Hg$
    2. $^{40}Ar+^{166}Er \rightarrow ^{206-xn}Rn$
5. Time Efficiency of MASHA

Department of Experimental Physics

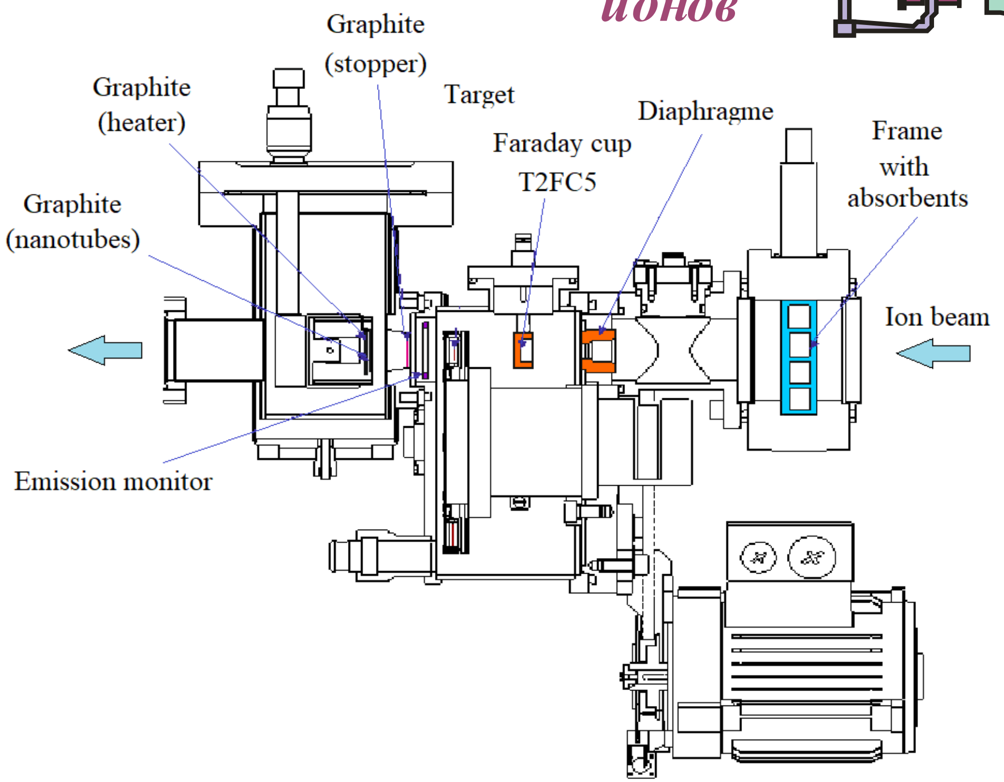
Introduction

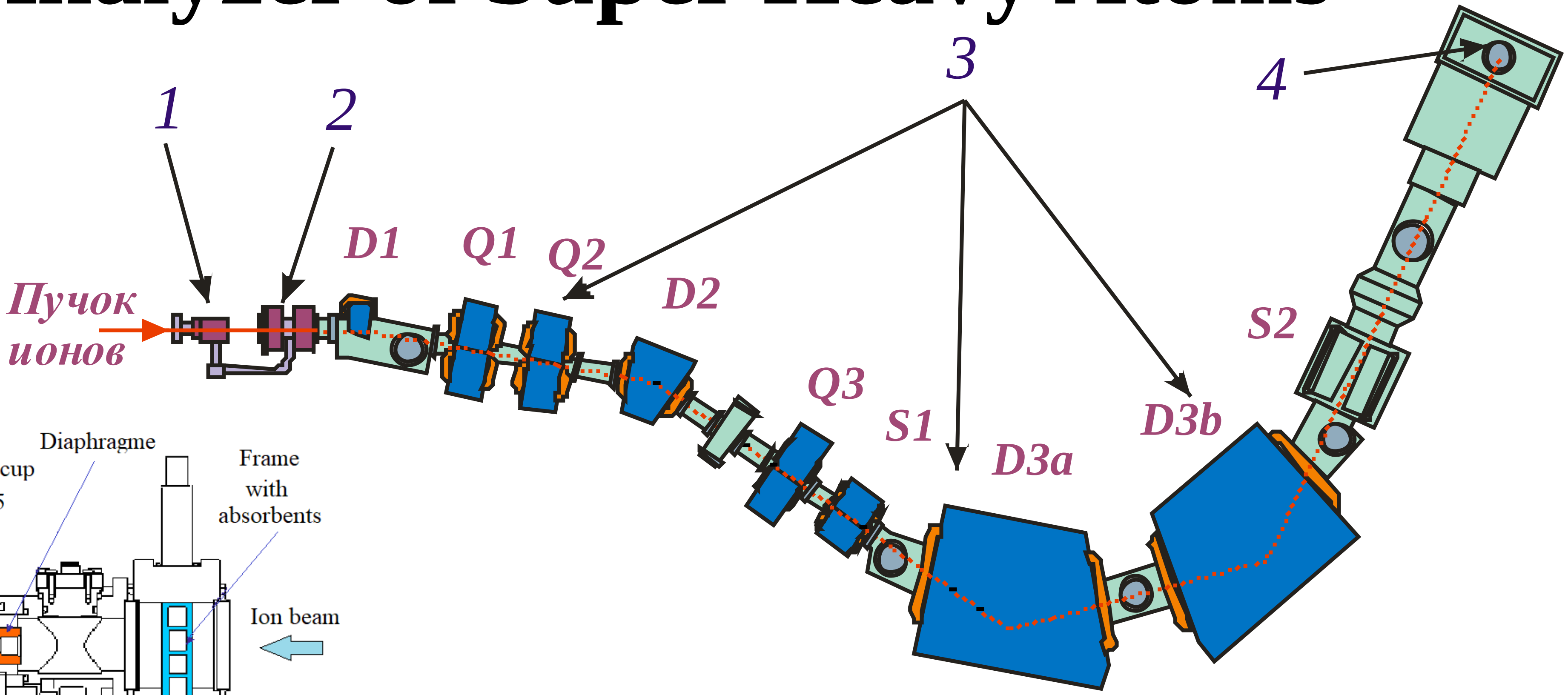
- PhD. Student of Applied physics, Palacky University Olomouc, Czech Republic
- Third year
- Supervisor: assoc. prof. Jiří Pechoušek, Ph.D.
- Joint Institute for Nuclear Research in Dubna, Russia
- Flerov Laboratory
- From February 2020
- Consultant: Mgr. Ľuboš Krupa, Ph.D.
- Head of sector: Aleksandr Mikhailovich Rodin, CSc.
- Thesis theme: **Properties of heavy and super heavy elements studied by mass spectroscopy and ISOL method**

ISOL method

- Isotope Separation On-Line
- Isotopes are produced, separated and analyzed on-line
- Older chemical techniques used to separate radioactive isotopes „off-line“ from irradiated targets

Mass Analyzer of Super Heavy Atoms

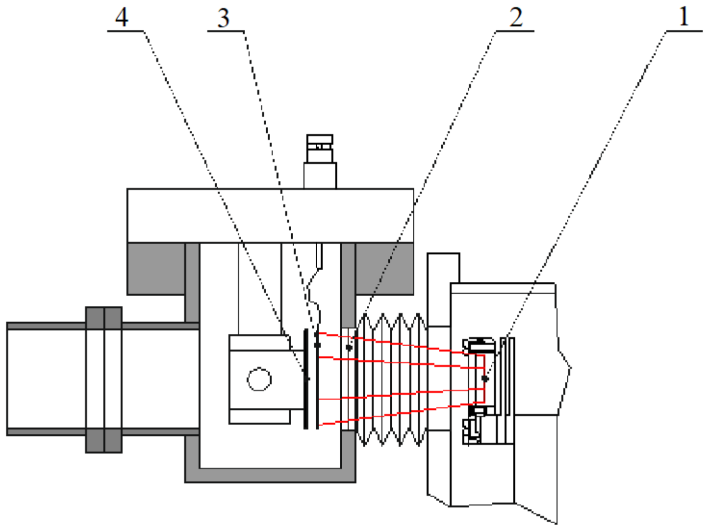




1 – Target block with hot catcher;
2 – Ion source;
3 – Mass separator;
4 – DAQ in the focal plane.

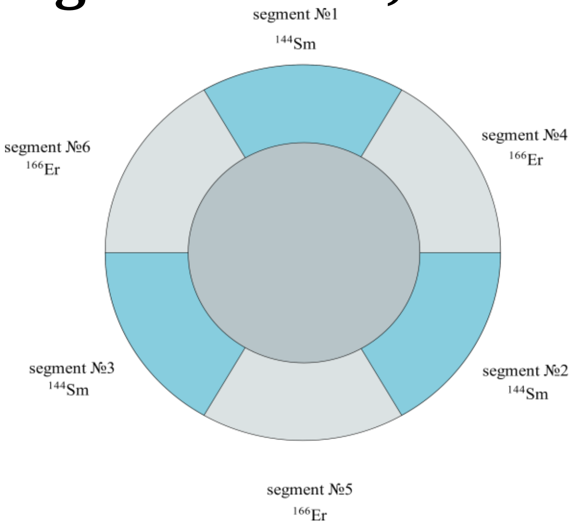
Mass Analyzer of Super Heavy Atoms

Hot cather scheme



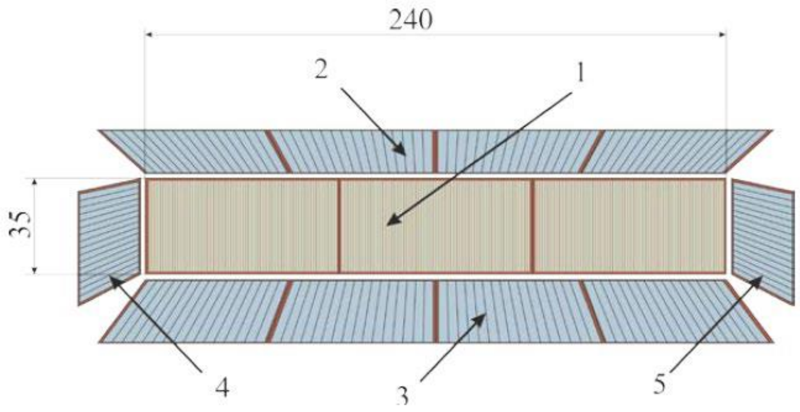
1 - Target sector on Ti foil
2 - Separate foil (graphen) 300 mg·cm^{-2}
3 - Common absorber (nanotubes or graphen) 1,5 mg·cm^{-2}
4 - Graphit foil (heater) 50 mg·cm^{-2}

Target – rotates, schema

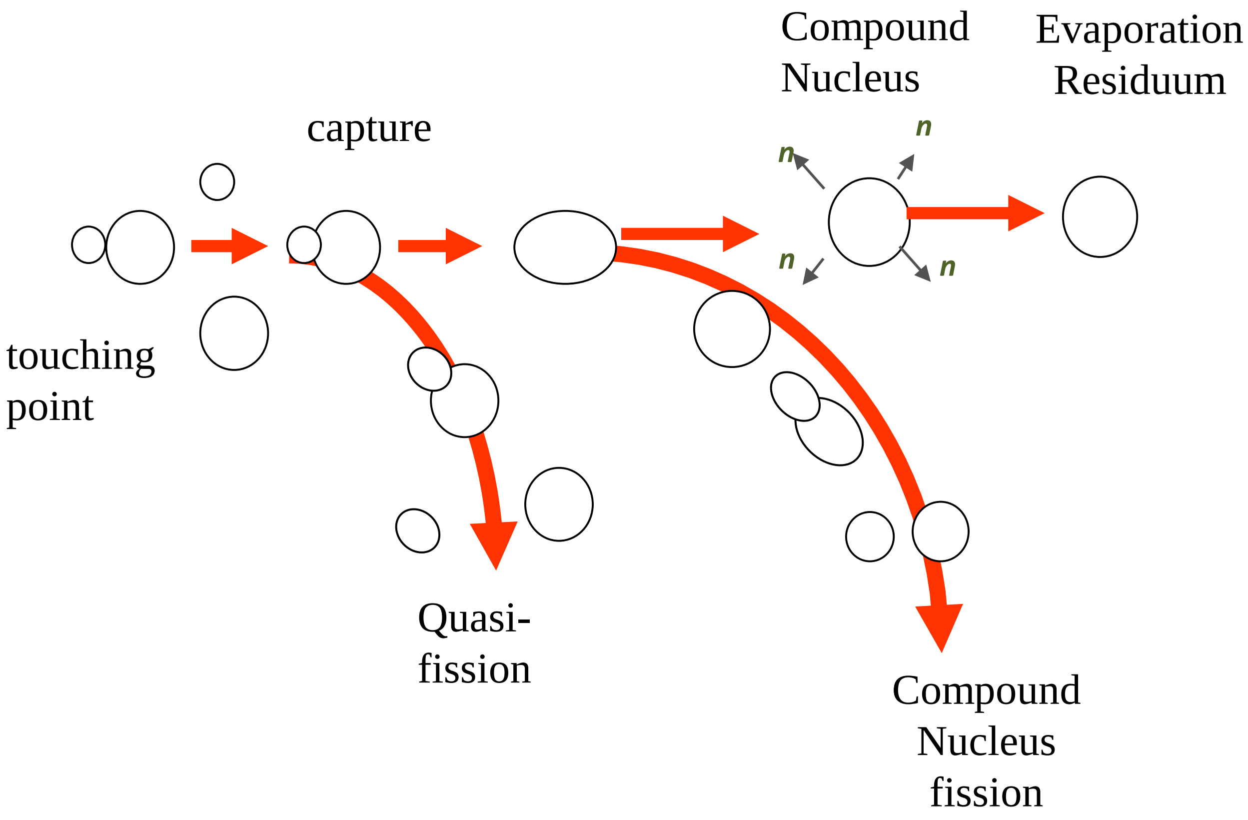


Nanotubes absorbent foil

Detector – schema and picture



More about fusion process

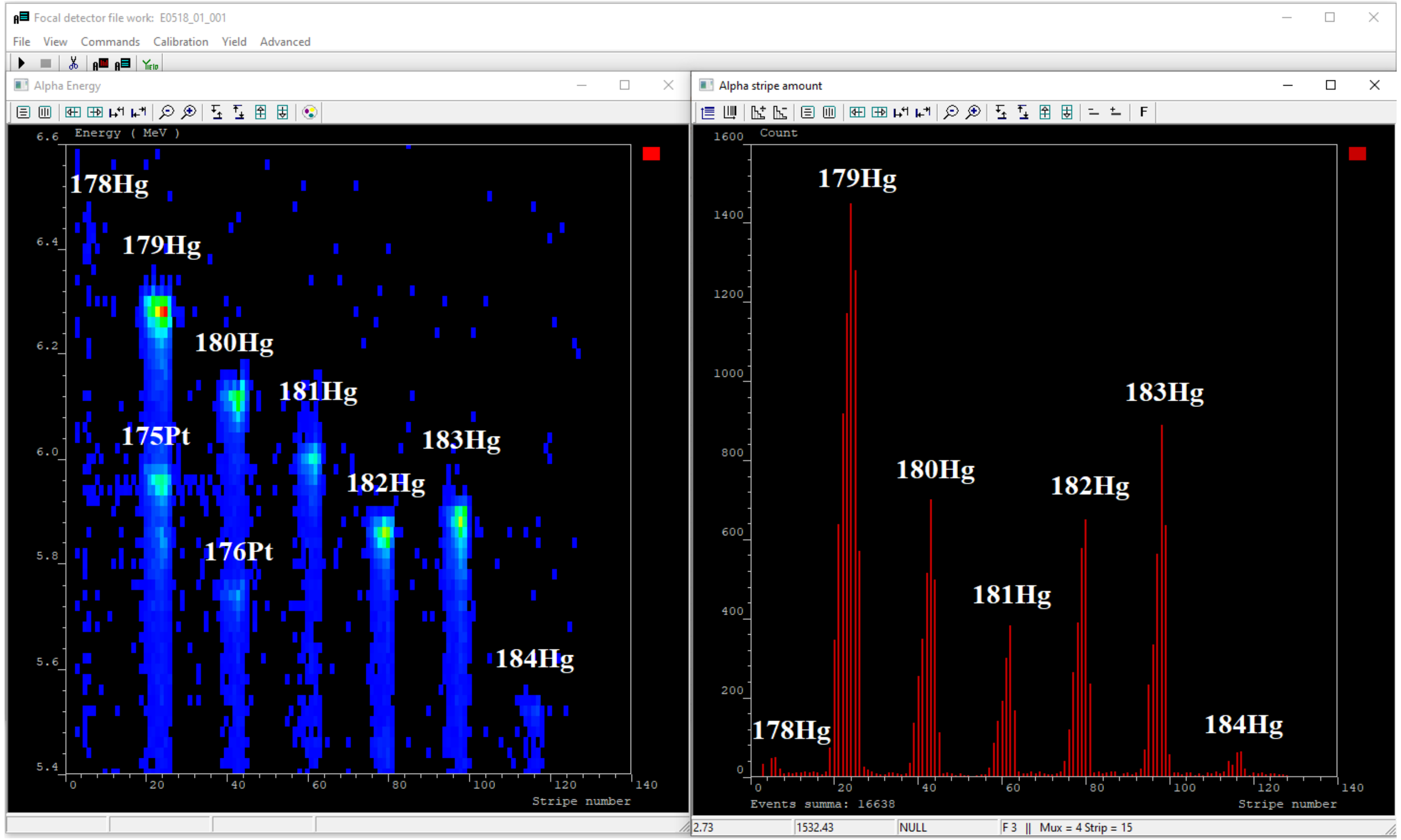


During collision of two nuclei, two cases can happen. Heavier nucleus can capture the lighter one or there can be quasi-fission. After quasi-fission two new nuclei with two new masses are created. In case of capture, one heavier nucleus is created. There are two possibilities again, compound nucleus evaporates neutrons or compound nucleus fissions. After compound nucleus fission, two nuclei of new elements are created. In case of evaporation of compound nucleus, neutron or neutrons are evaporated. As a result, we obtain another isotope of element, not new elements like after compound nucleus fission.

Mass Analyzer of Super Heavy Atoms

- **Experiment I 2019 Autumn, reactions**
  - $^{40}Ar + ^{144}Sm \rightarrow ^{184-xn}Hg$
  - $^{40}Ar + ^{166}Er \rightarrow ^{206-xn}Rn$
- **Experimental parametres**
  - Beam energy E_0= 265 MeV
- **Absorbents:** Aluminium
  1. density 1,585 mg.cm^{-2} (thickness **5,87 µm**), foil position 41,5 mm
  2. density 2,516 mg.cm^{-2} (thickness **9,32 µm**), foil position 71,5 mm
  3. density 4,51 mg.cm^{-2} (thickness **16,7 µm**), foil position 101,5 mm
  4. density 1,585+5,55=7,135 mg.cm^{-2} (thickness 5,87+20,5=**26,37 µm**), foil position 131,5 mm
- **No absorbent:** foil position 11,5 mm
- Titan layer of target thickness: **1,5 µm**
- Sm_2O_3 layer of target thickness: **0,33 µm**
- Er_2O_3 layer of target thickness: **0,24 µm**

$^{40}Ar + ^{144}Sm \rightarrow ^{184-xn}Hg$ reaction products

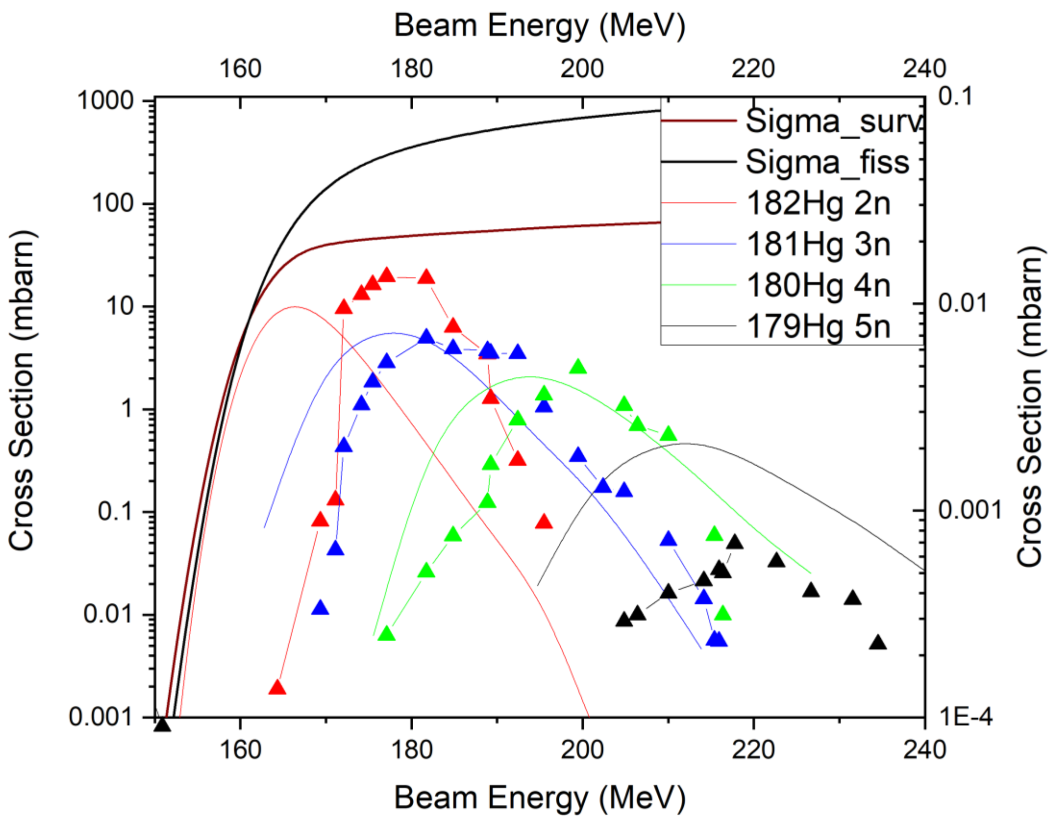


- Screenshots from Focal Detector program.
- On the left side: two dimensional matrix energetic spectrum of parental isotopes Hg and their daughter isotopes Pt (y axis – energy, x axis – mass, z axis – events).
- On the right side: mass spectrum both parental and daughter nuclei (x axis – mass, y axis – energy).

$^{40}Ar + ^{144}Sm \rightarrow ^{184-xn}Hg$ reaction products

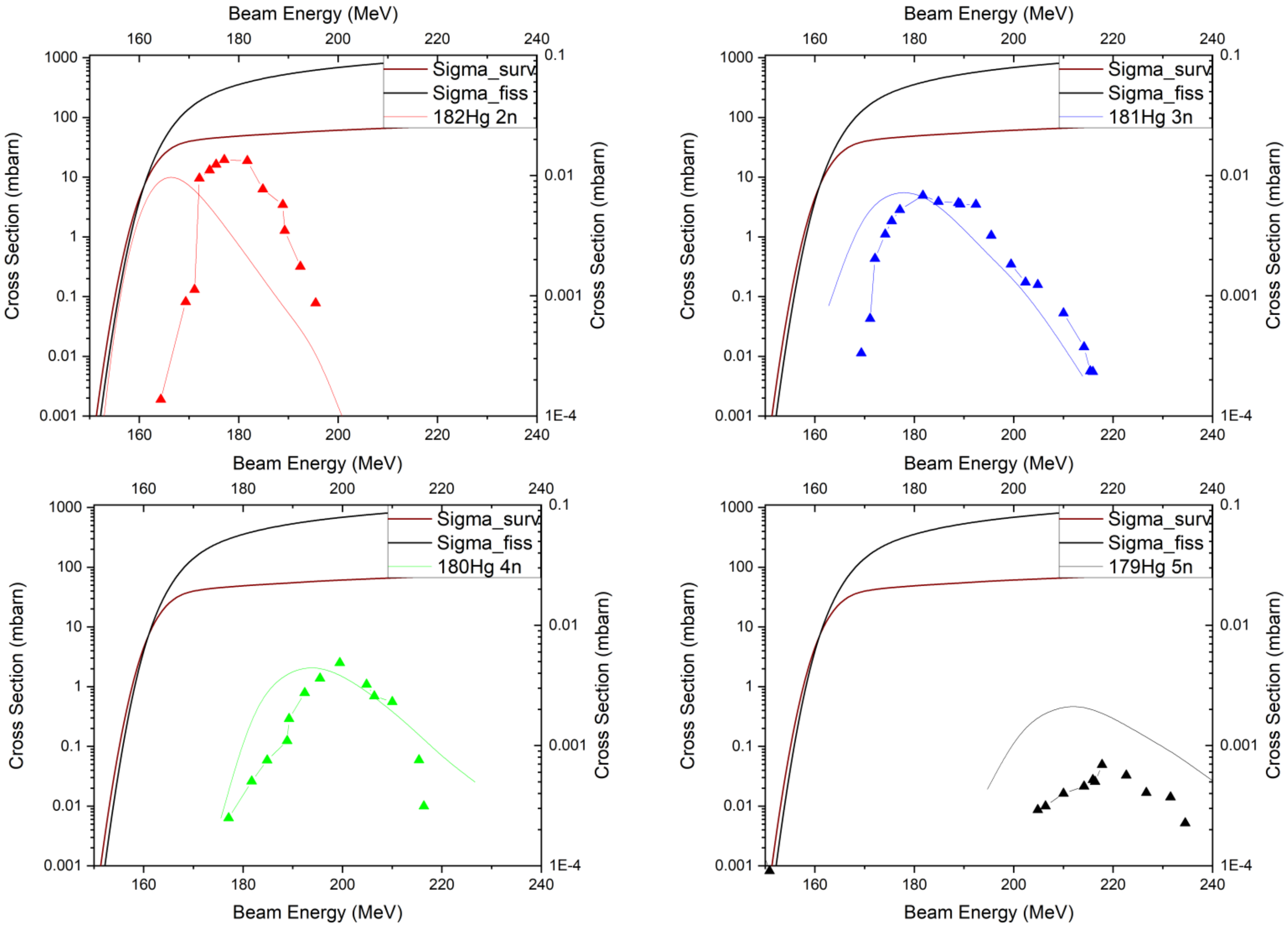
Parental nuclei	Energy [MeV]	Probability α-decay [%]	Half Life [s]	Daughter nuclei	Energy [MeV]	Probability α-decay [%]	Half Life [s]
178Hg	6430	76,38	0,266	174Pt	6039	75	0,891
179Hg	6285	53	1,05	175Pt	6021	64	2,43
180Hg	6119	48	2,58	176Pt	5753	40	6,3
181Hg	6148	30	3,54	177Pt	5517	5,7	10,6
182Hg	5867	15,2	10,83	178Pt	5446	5	21,1
183Hg	5904	11,7	9,4	179Pt	5195	0,24	21,1
184Hg	5539	1,26	30,87	180Pt	5140	0,3	56

$^{40}Ar+^{144}Sm \rightarrow ^{184\text{-}xn}Hg$ reaction, **parental nuclei**



- Dependence of Cross Section on Beam Energy (excitation functions).
- Hg Isotopes which nucleon number is between 179 and 182.
- Black and Brown curves are physical limits which are results of conservation laws.
- Comparison of theoretical (lines) and experimental (triangles) data.

$^{40}Ar+^{144}Sm \rightarrow ^{184-xn}Hg$ reaction, **parental nuclei**



- Dependence of Cross Section on Beam Energy.
- Hg Isotopes which nucleon number is between 179 and 182.
- Black and Brown curves are physical limits which are results of conservation laws.
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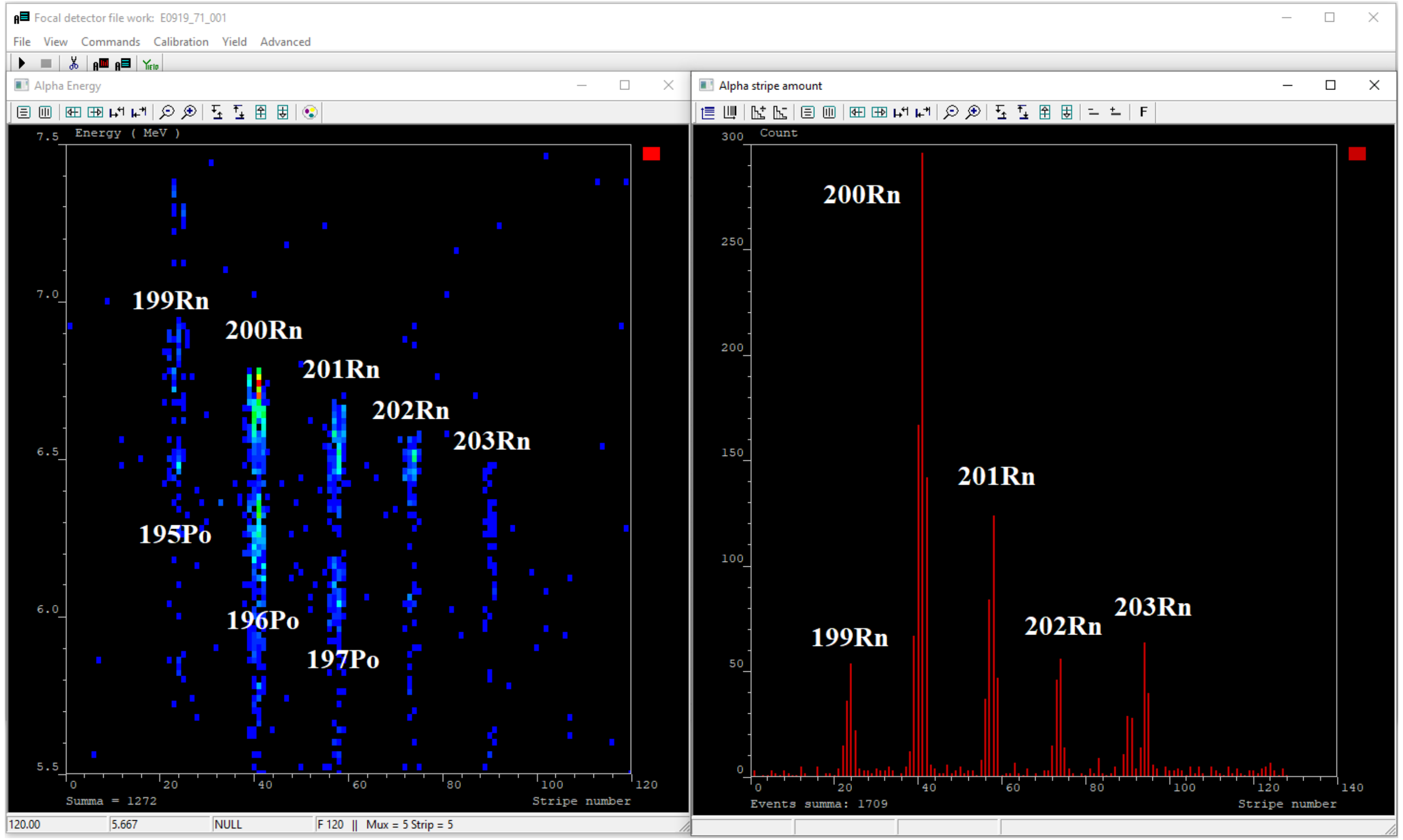
$^{40}Ar+^{166}Er \rightarrow {}^{206\text{-}xn}Rn$ reaction products

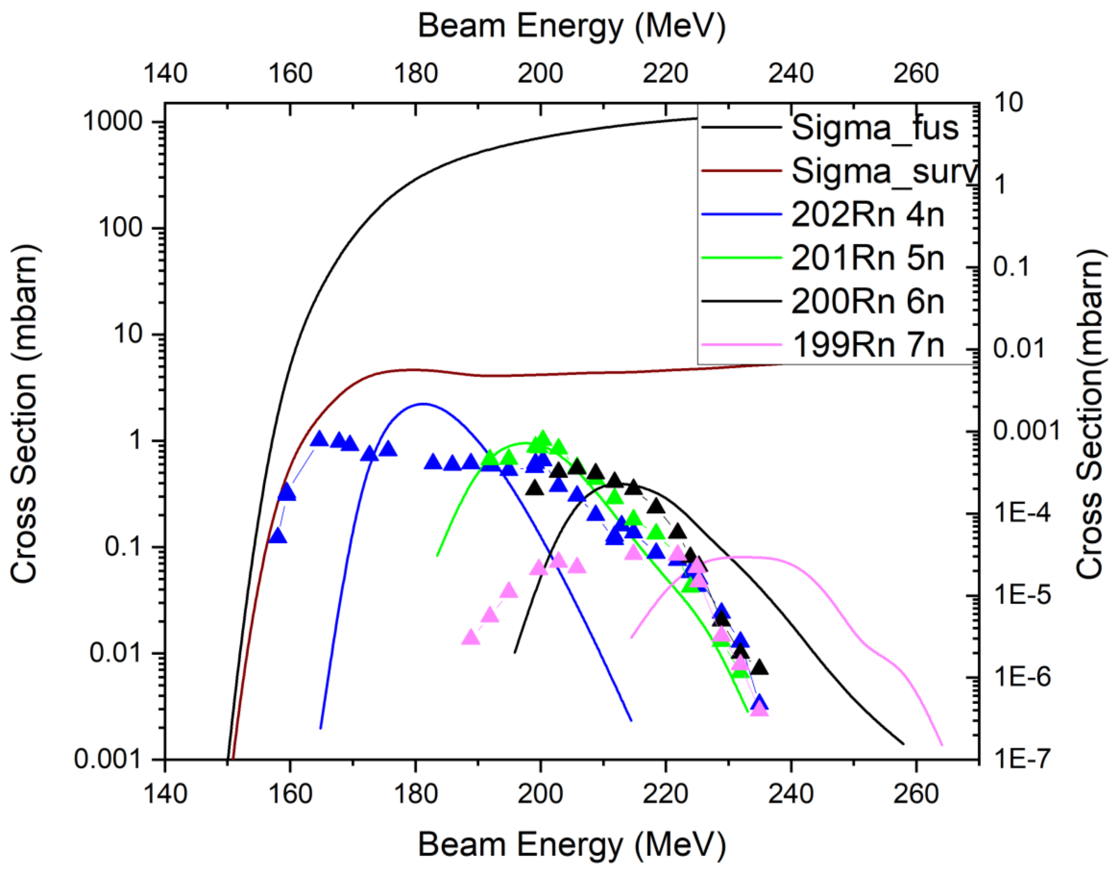


- Screenshots from Focal Detector program
- On the left side: two dimesional matrix energetic spectrum of parental isotopes Rn and their daughter isotopes Po.
- On the right side: spectrum of counts both parental and daughter nuclei (y axis – energy, x axis – mass, z axis – events).
- On the right side: mass spectrum both parental and daughter nuclei (x axis – mass, y axis – energy).

$^{40}Ar+^{166}Er \rightarrow\ ^{206-xn}Rn$ reaction products

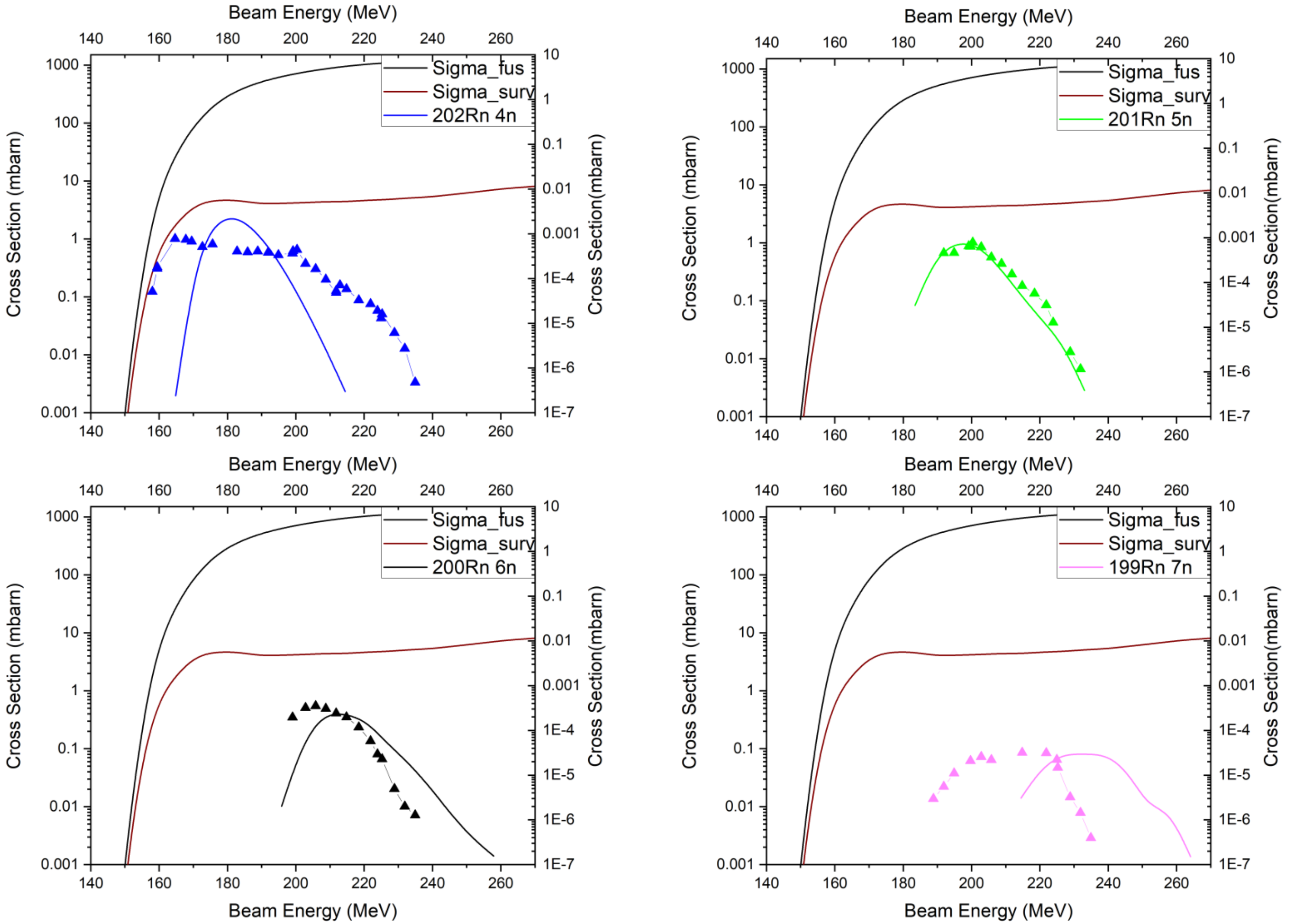
Parental nuclei	Energy [MeV]	Probability α-decay [%]	Half Life [s]	Daughter nuclei	Energy [MeV]	Probability α-decay [%]	Half Life [s]
199Rn	6989	94	0,59	195Po	6606	75	4,64
200Rn	6902	98	0,96	196Po	6522	94	5,6
201Rn	6725	80	7,1	197Po	6281	44	53,6
202Rn	6639	78	9,7	198Po	6182	57	106,2 s = 1,77min
203Rn	6499	66	44	199Po	5952	12	328,2 s = 5,47 min
204Rn	6418	72,4	73,8 s = 1,23 min	200Po	5861,9	11,1	690,6 s = 11,5 min
205Rn	6255	24,6	170 s = 2,83 min	201Po	5683	1,6	918 s = 15,3 min

$^{40}Ar+^{166}Er \rightarrow \ ^{206-xn}Rn$ reaction products



- Dependence of Cross Section on Beam Energy.
- Rn Isotopes which nucleon number is between 199 and 202.
- Black and Brown curves are physical limits which are results of conservation laws.
- Comparison of theoretical (lines) and experimental (dots) data.

$^{40}Ar+^{166}Er \rightarrow {}^{206\text{-}xn}Rn$ reaction products



- Dependence of Cross Section on Beam Energy.
- Rn Isotopes which nucleon number is between 202 and 199.
- Black and Brown curves are physical limits which are results of conservation laws.
- Comparison of theoretical (lines) and experimental (triangles) data.

Cross section calculation of parental isotopes and daughter isotopes

$$\sigma = \frac{N\,M_{tg} Z\,e}{\rho\,N_A\,I\varepsilon_{parent}\varepsilon_d\,\varepsilon_{hc}\varepsilon_{tg}}, \text{ [barn]}$$

σ … cross section, [mbarn]

N … number of events(measured yield)

N_{corr} … corrected number of events (corrected yield)

$$N_{corr} = \frac{N}{\varepsilon_{parent}\varepsilon_d\,\varepsilon_{hc}\varepsilon_{tg}},\quad N_{corr\ daughter} = \frac{N}{\varepsilon_{parent}\varepsilon_{daughter}\varepsilon_d\,\varepsilon_{hc}\varepsilon_{tg}}$$

ε_{parent} … α decay fork, unique for parent isotope

$\varepsilon_{daughter}$ … α decay fork, unique for daughter isotope

ε_d … detector construction efficiency, correction ε_d =0,45

ε_{hc} … honey comb transparency, correction ε_{hc} = 0,85

ε_{tg} … target construction, correction ε_{tg} = 0,5

M_{tg} … target mass number

Z … charge of ^{40}Ar ion, Z = 16

e … elementary charge, $e = 1{,}6\cdot10^{-19}$C

ρ … target area density,

$\rho = 0{,}004$ kg $\cdot m^{-2}$

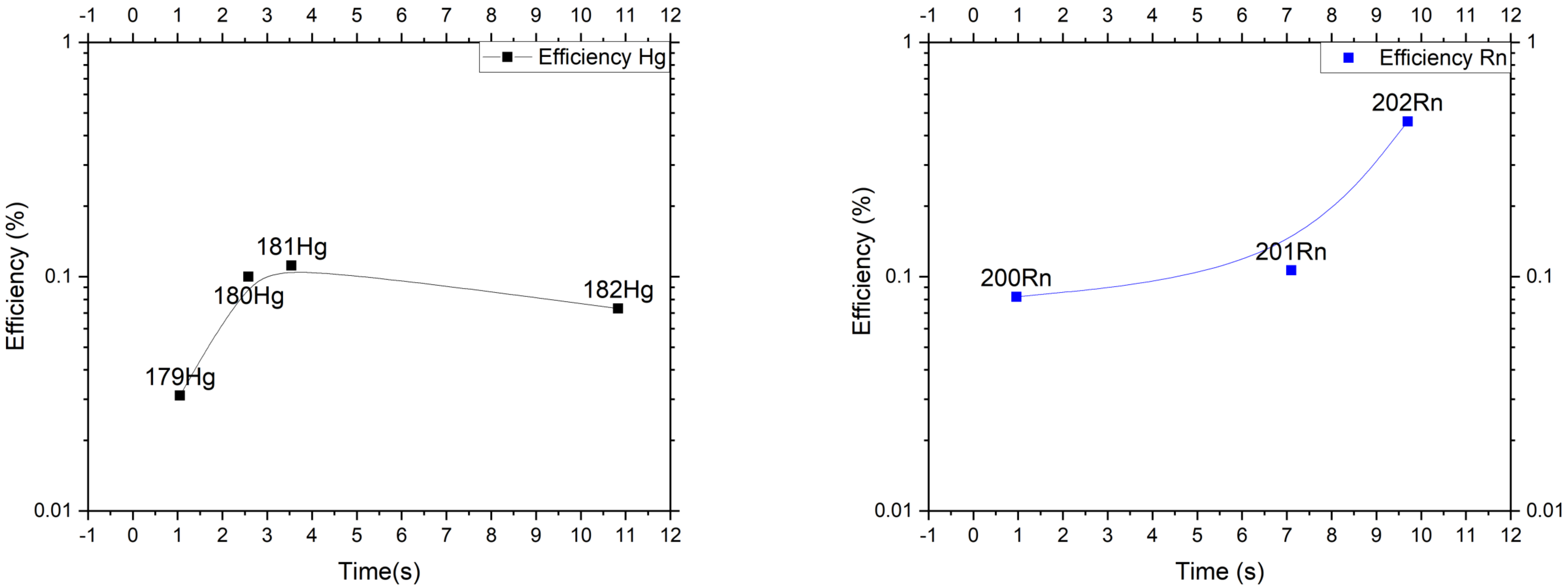
N_A … Avogadro constant, $N_A = 6{,}02\cdot10^{23}mol^{-1}$

I … beam integral, [μC]

Time Efficiency

σ	2n (182Hg)	3n (181Hg)	4n (180Hg)	5n (179Hg)
Time (s) for Hg	10,83	3,54	2,58	1,05
Efficiency (%) for Hg	0,07314	0,11157	0,1	0,31069
σ	**4n (202Rn)**	**5n (201Rn)**	**6n (200Rn)**	
Time (s) for Rn	9,7	7,1	0,96	
Efficiency (%) for Rn	0,24131	0,01098	0,06387	

Separation efficiency of MASHA



Separation efficiency of MASHA setup for mercury (left figure) and radon (right figure) isotopes.

Used programs and databases

- Number of events (measured yield) … Focal Detector
- α decay fork … database ITab and NNDC ENSDF

- Cross section … programs Focal Detector, Itab, Origin

- Reaction energy (is going to be calculated by using SRIM)
- Graphs of Reaction Energy and corrected yield for each of isotopes … Origin

Thank you for your attention.