REACTION RATES OF RESIDUAL NUCLEI PRODUCED OF ^{59}Co AT THE TARGET *QUINTA*

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XXII International Baldin Seminar of High Energy Physics Problem, 16 September 2014

Energy and Transmutation- RAW

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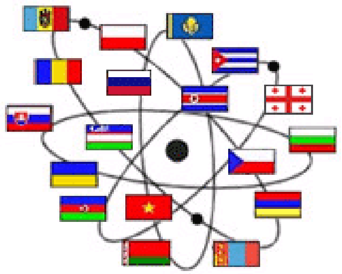
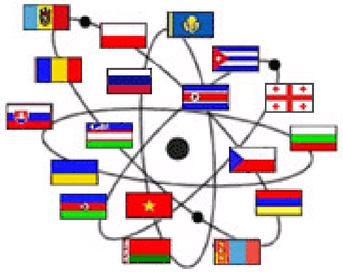




Introduction

- The global problem of nuclear energy is radioactive waste. Each year, nuclear power facilities produce about 10 000 m^3 of high-level waste worldwide. Therefore scientists have investigated transmutation of radioactive waste using ADS since 90`s years.

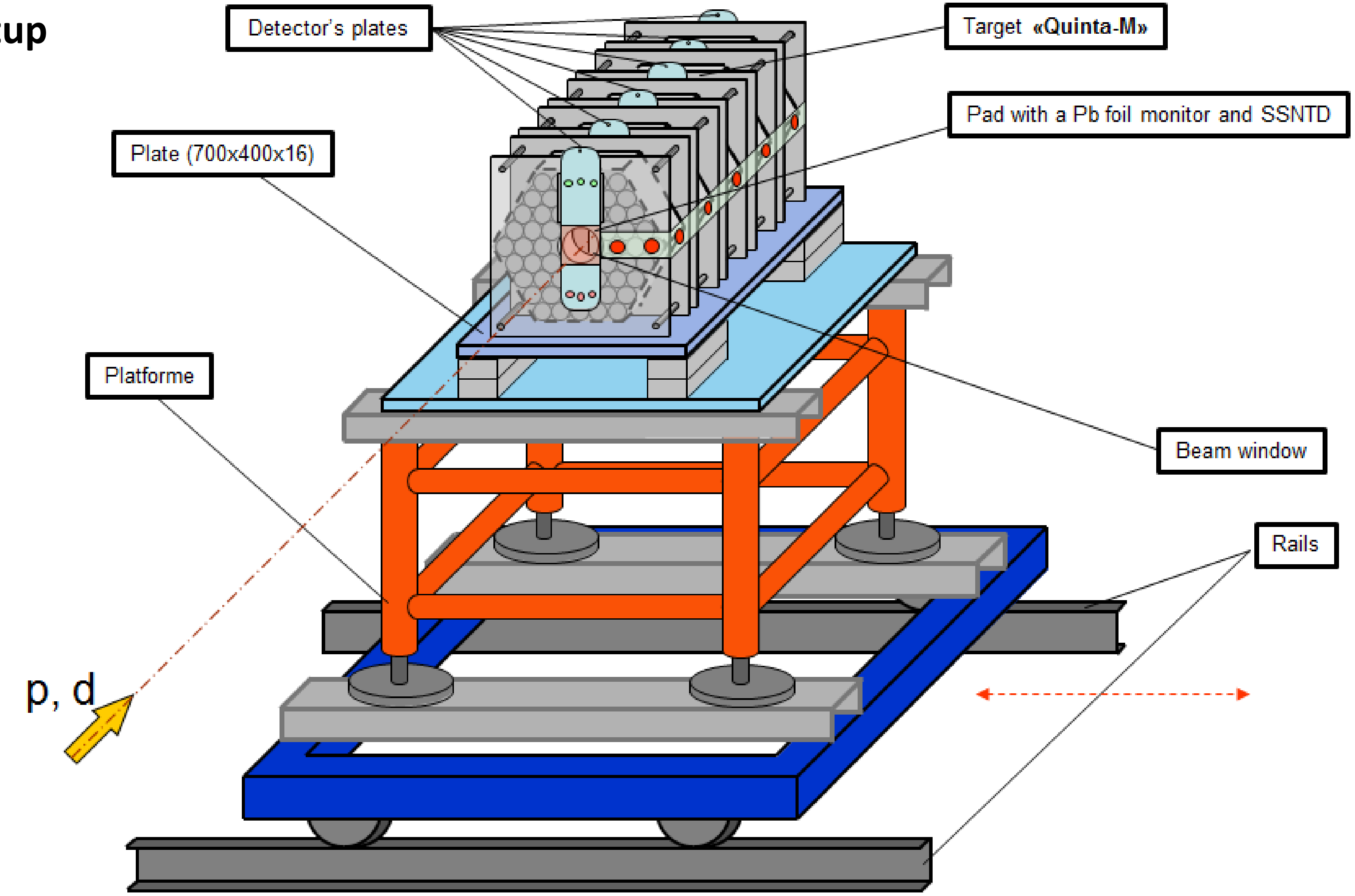
- Worldwide research: MYRRHA(Belgium) E_p = 600 MeV

Topic of presentation

- Samples of ^{59}Co were irradiated in the secondary neutron field of the ***QUINTA*** target generated by the deuteron beam with energy 4 AGeV.
- The experimental reaction rates (R_{exp}) of products in ^{59}Co were obtained with the use of Gamma spectrometry.
- The R_{exp} were compared with calculated reaction rates (R_{cal}) with MCNPX2.7.

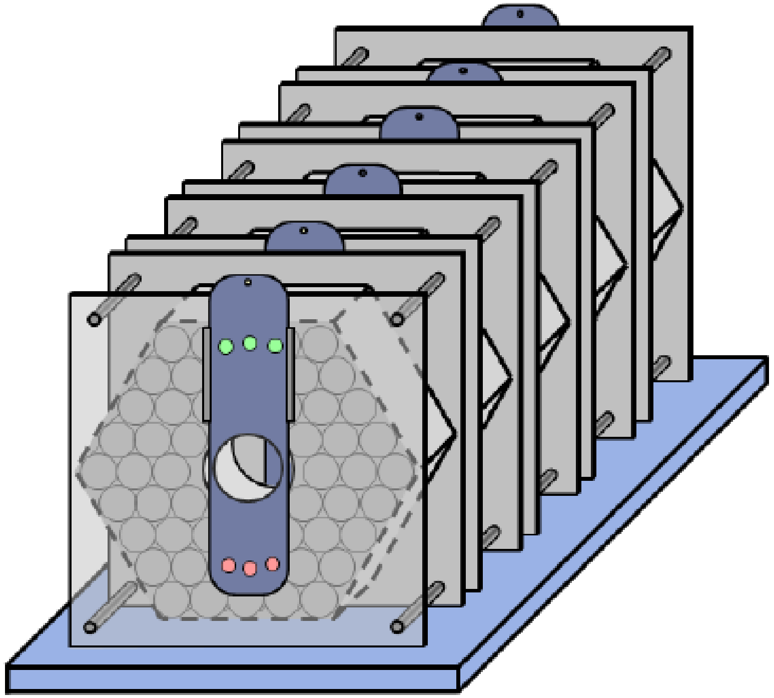
QUINTA-M setup layout at the irradiation position

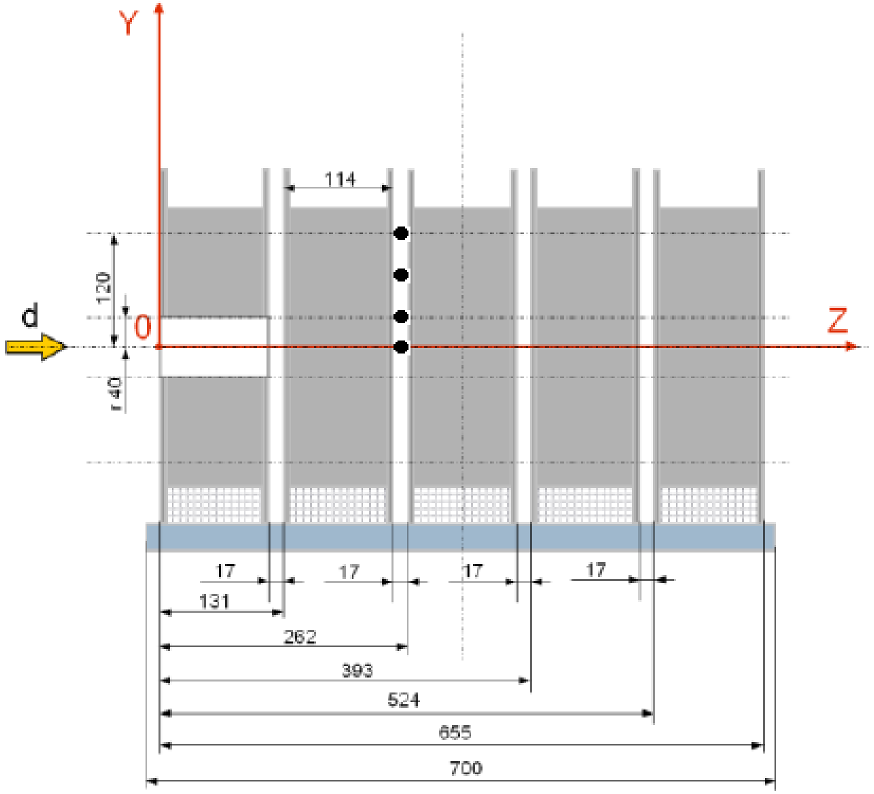
Target *QUINTA* setup



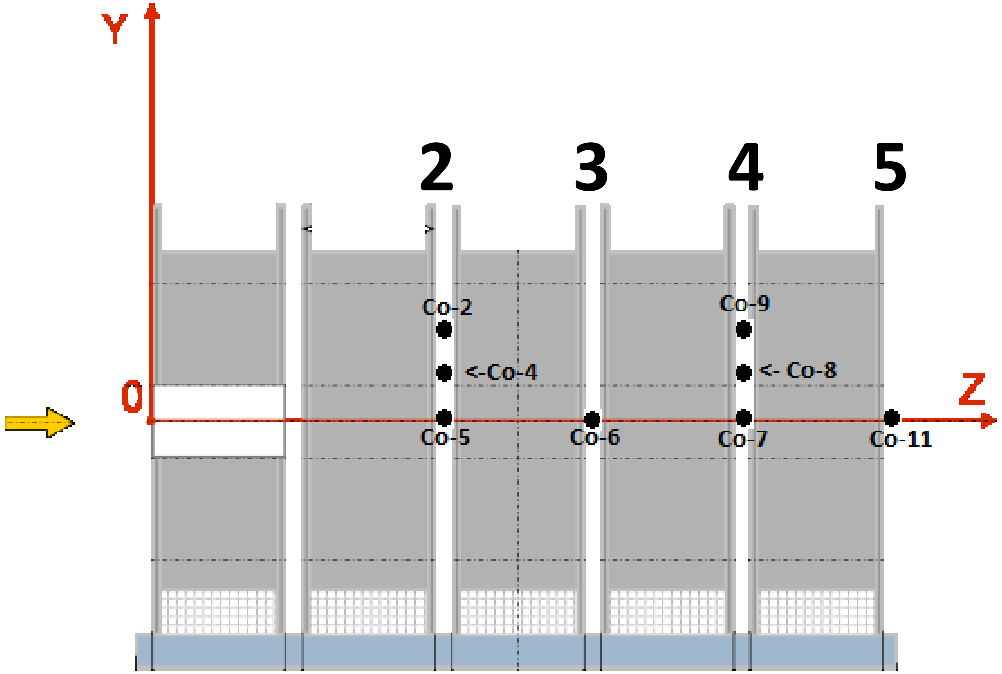
- SSNTD and AD positions at the QUINTA-M target surface

Target *QUINTA* setup

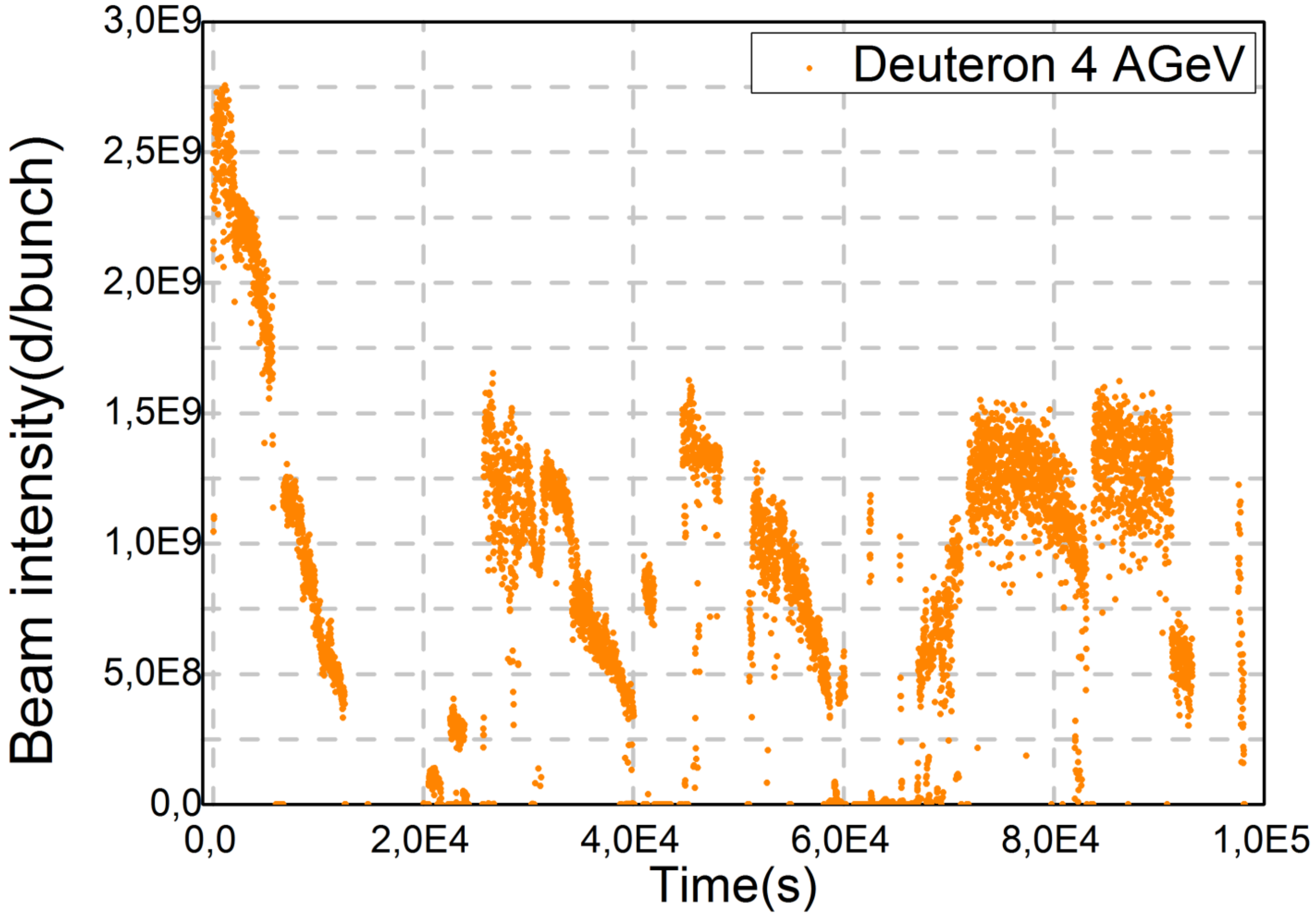




Positions of investigated samples of ^{59}Co



- **Energy of deuterons: 4 AGeV**
- **Total number of deuterons: N_d=(6.11±0.08)E+12**
- **Irradiation time: 27 h and 18 min**

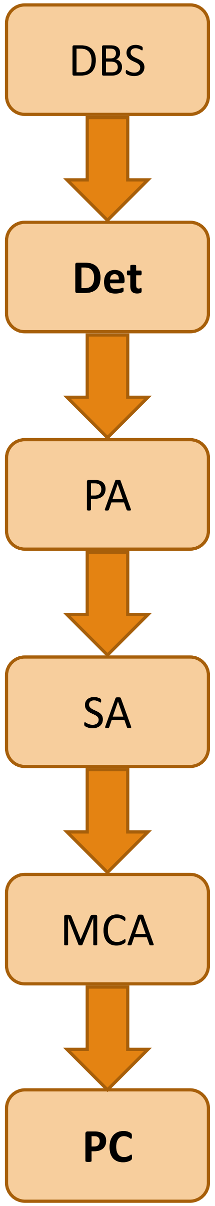


The course of irradiation during 4 AGeV deuteron run on *Quinta* setup.

- After irradiation, the experimental samples were transported to the **YaSNAPP** spectroscopy laboratory and measured with the use of germanium semiconductor detectors.

- Our group has six HPGe semiconductor detectors, four detectors were produced by ORTEC company and two detectors were produced by CANBERRA company.

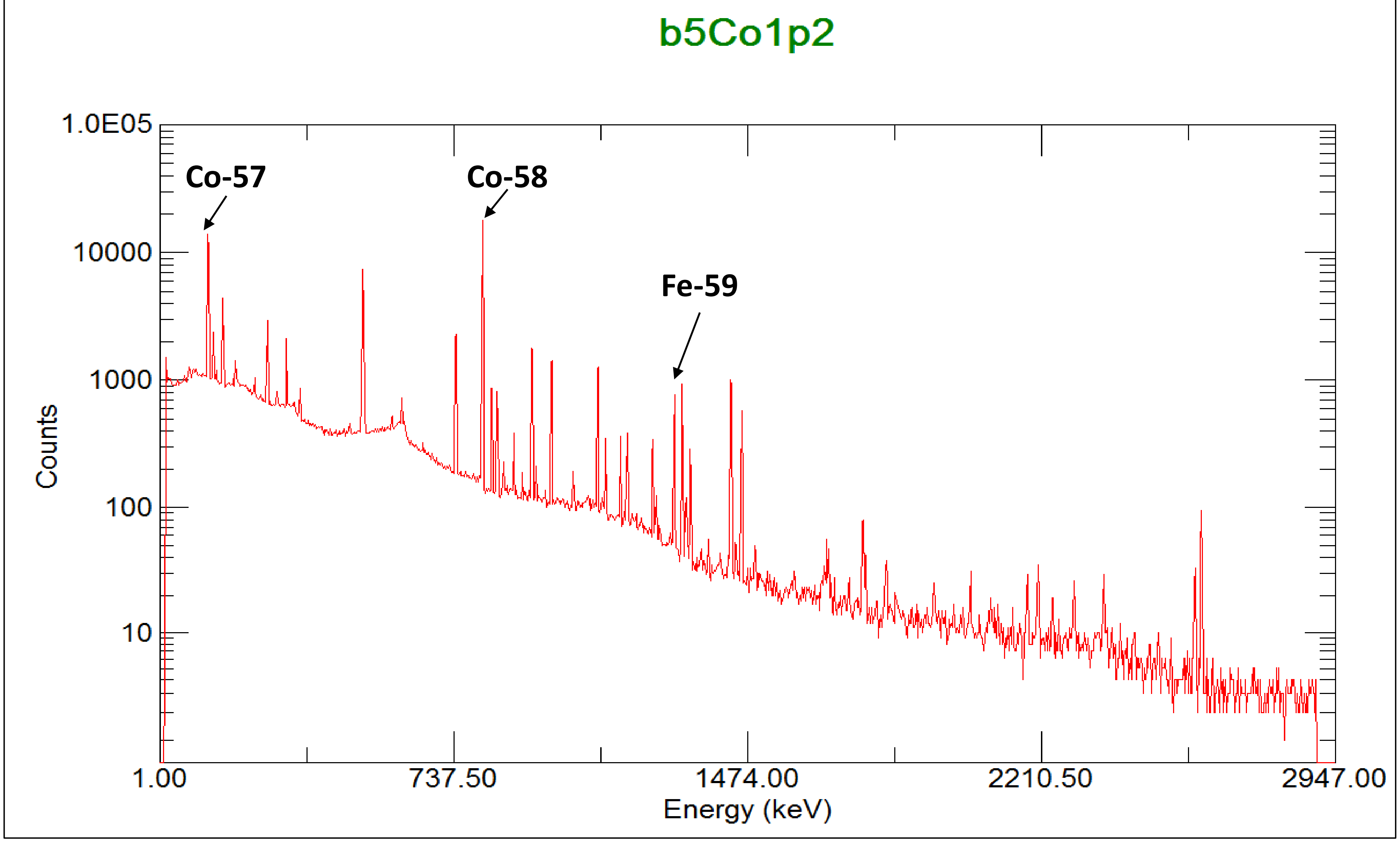
- Experimental samples were measured with two HPGe detectors(Det B, Det C)

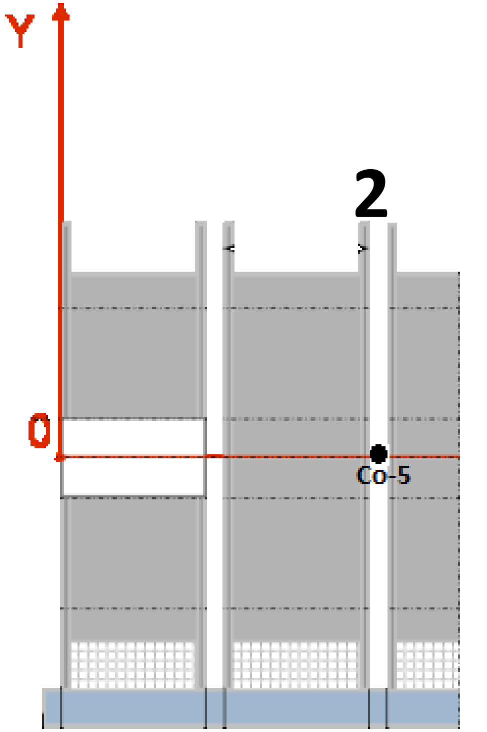


DBS-> Detector Bias Supply
PA-> Preamplifiers and HV filters
SA-> Spectroscopy Amplifier
MCA-> Multichannel analyzer

Label	Denomination	Company, model	Relative efficiency(%)
Det B	HPGe detector	ORTEC, GMX-23200	26
Det C	HPGe detector	ORTEC, GMX-20190	32,9

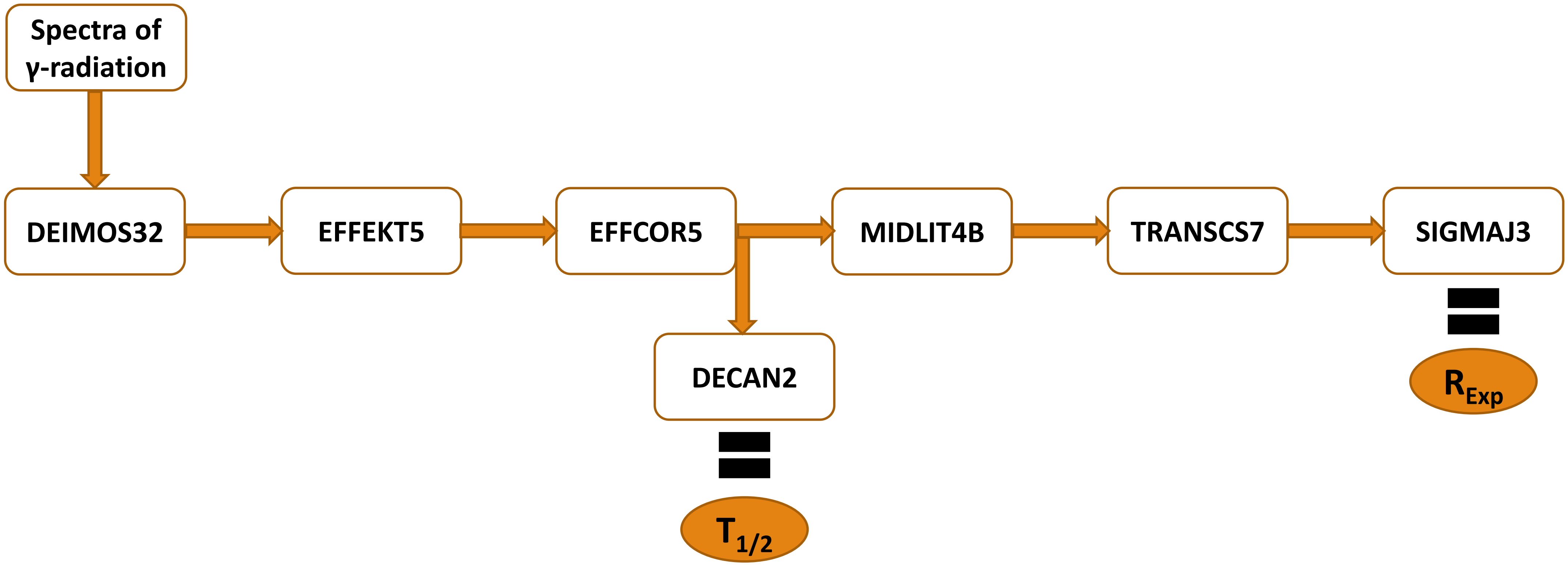
Label	Denomination	Company, model
Det B	HPGe detector	ORTEC, GMX-23200
Det C	HPGe detector	ORTEC, GMX-20190
DBS	Detector Bias Supply	ORTEC
PA	Preamplifiers and HV filters	ORTEC
SA	Spectroscopy Amplifier	CAEN, 968
MCA	Multichannel analyzer	ORTEC ASPEC 927





An example of γ-ray spectrum in the sample ^{59}Co.

Yasnapp spectrometry software package



A set of computer codes has been used for the energy calibration, subtraction of background gamma-ray lines, efficiency calibration and determination of experimental half-lives for the identification of gamma-ray lines. Various isotopes are assigned only when energy, half-life and intensity of peaks match with the values available in the literature.

$$R_{Exp} = \frac{S_p \cdot C_{abs}(E) \cdot B_a}{I_\gamma \cdot \varepsilon_p(E)} \frac{t_{real}}{t_{live}} \frac{1}{N_A} \frac{1}{N_D} \frac{e^{(\lambda \cdot t_0)}}{1 - e^{(-\lambda \cdot t_{real})}} \frac{\lambda \cdot t_{irr}}{1 - e^{(-\lambda \cdot t_{irr})}}$$

Reaction rate

Peak area

Self-absorption correction

Beam correction

Real measurement time

Correction for decay during cooling time

Decay constant

Irradiation time

Correction for decay during irradiation

Correction for decay during measurement

Number of deuterons

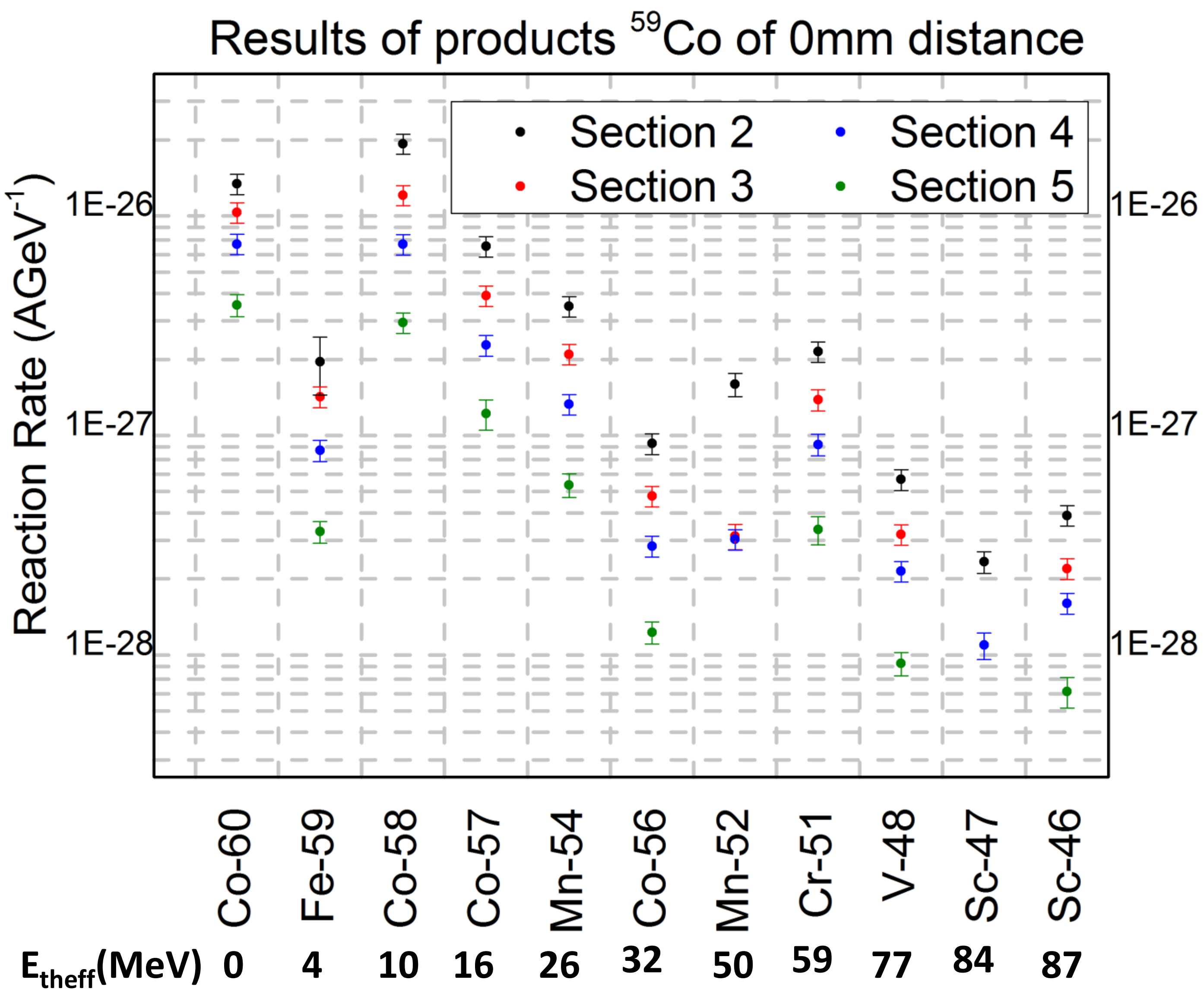
Number of atoms in the sample

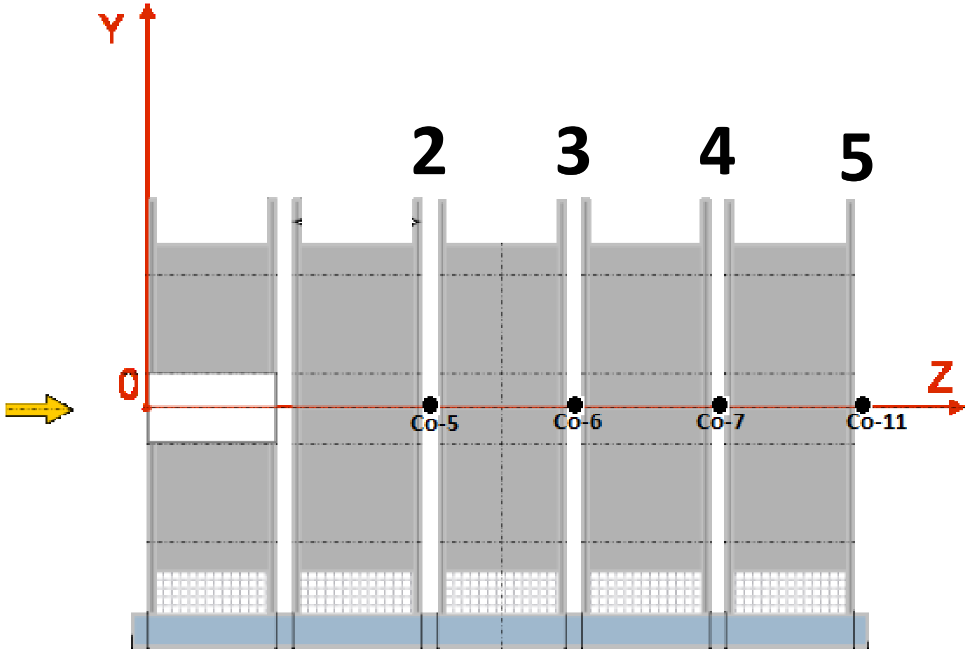
Live time of the measurement

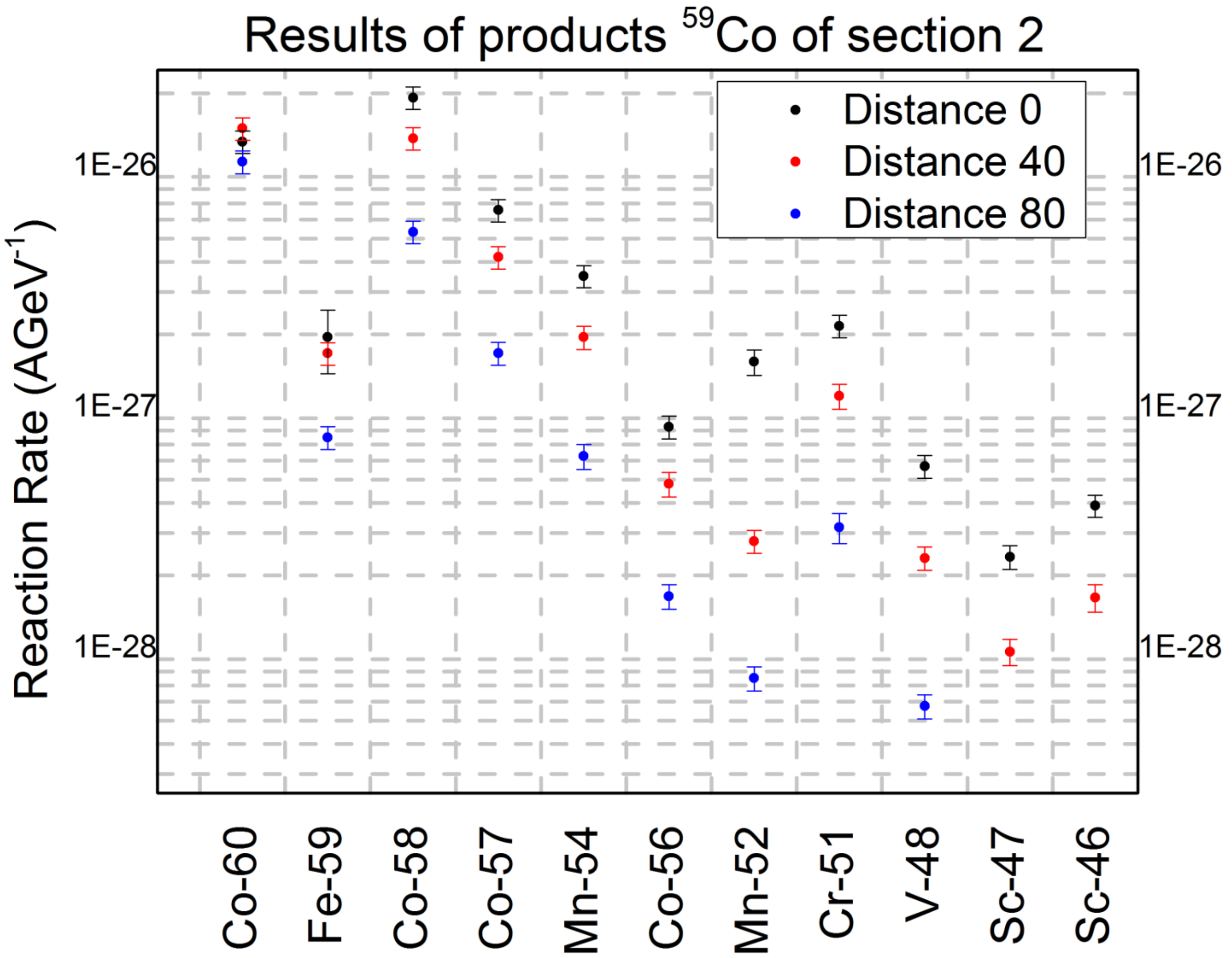
Detector efficiency

Gamma-line intensity

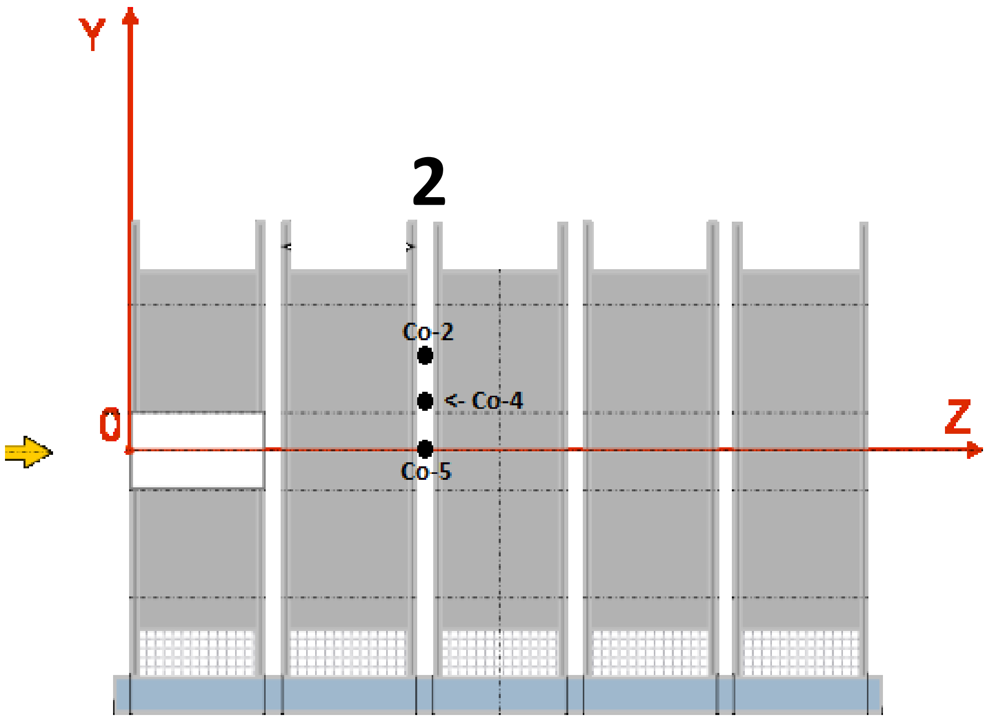
Reaction rate - is defined as the number of produced residual nuclei $Q(A_r, Z_r)$ per one atom in the sample N_t and one incident deuteron per second N_d according to the following equation.

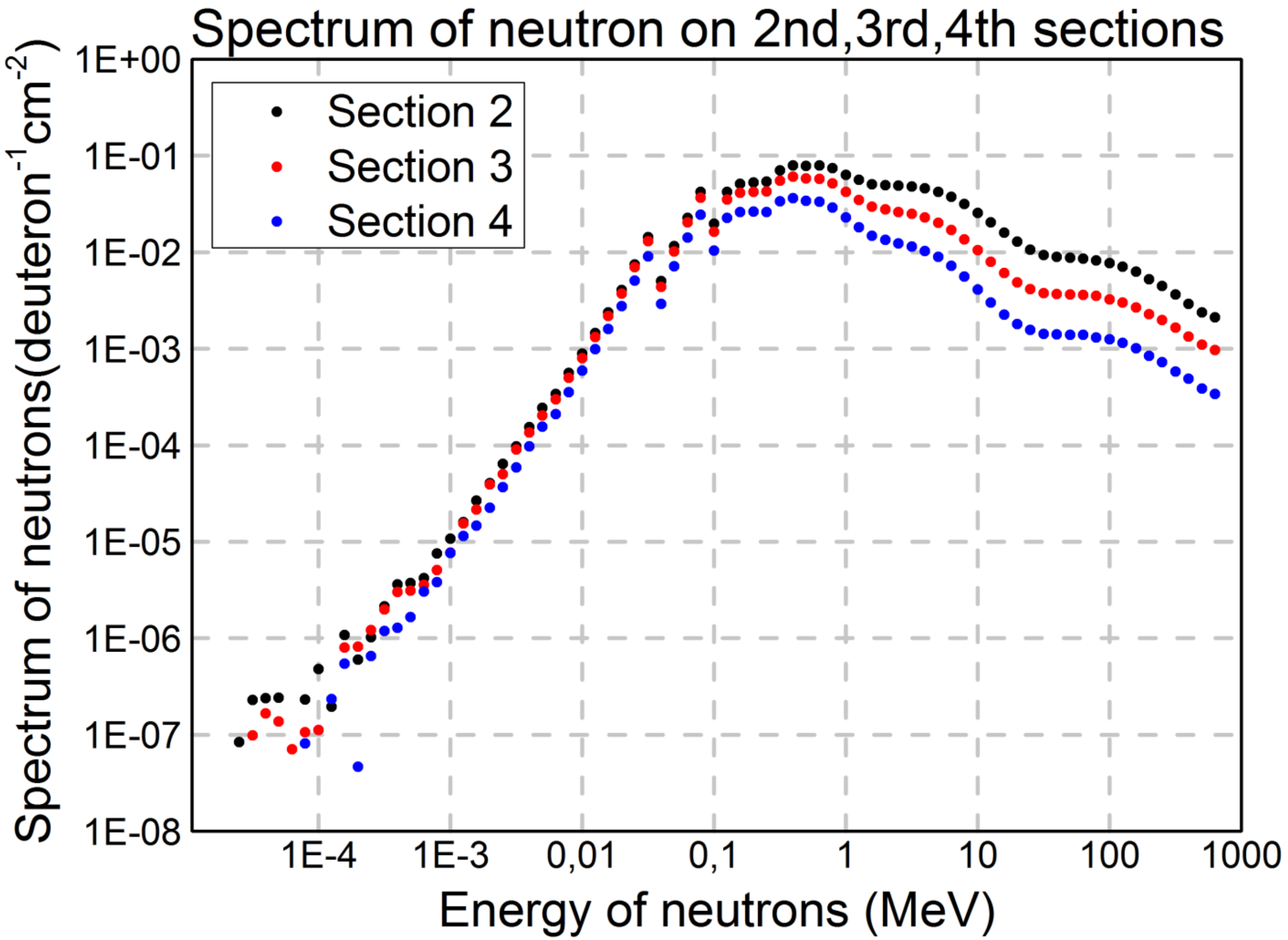

Results of products ^{59}Co of 0mm distance
Section 2
Section 3
Section 4
Section 5
Reaction Rate (AGeV^{-1})
1E-26
1E-27
1E-28
Co-60
Fe-59
Co-58
Co-57
Mn-54
Co-56
Mn-52
Cr-51
V-48
Sc-47
Sc-46
E_{theff}(MeV) 0 4 10 16 26 32 50 59 77 84 87


Y
Z
0
2
3
4
5
Co-5
Co-6
Co-7
Co-11

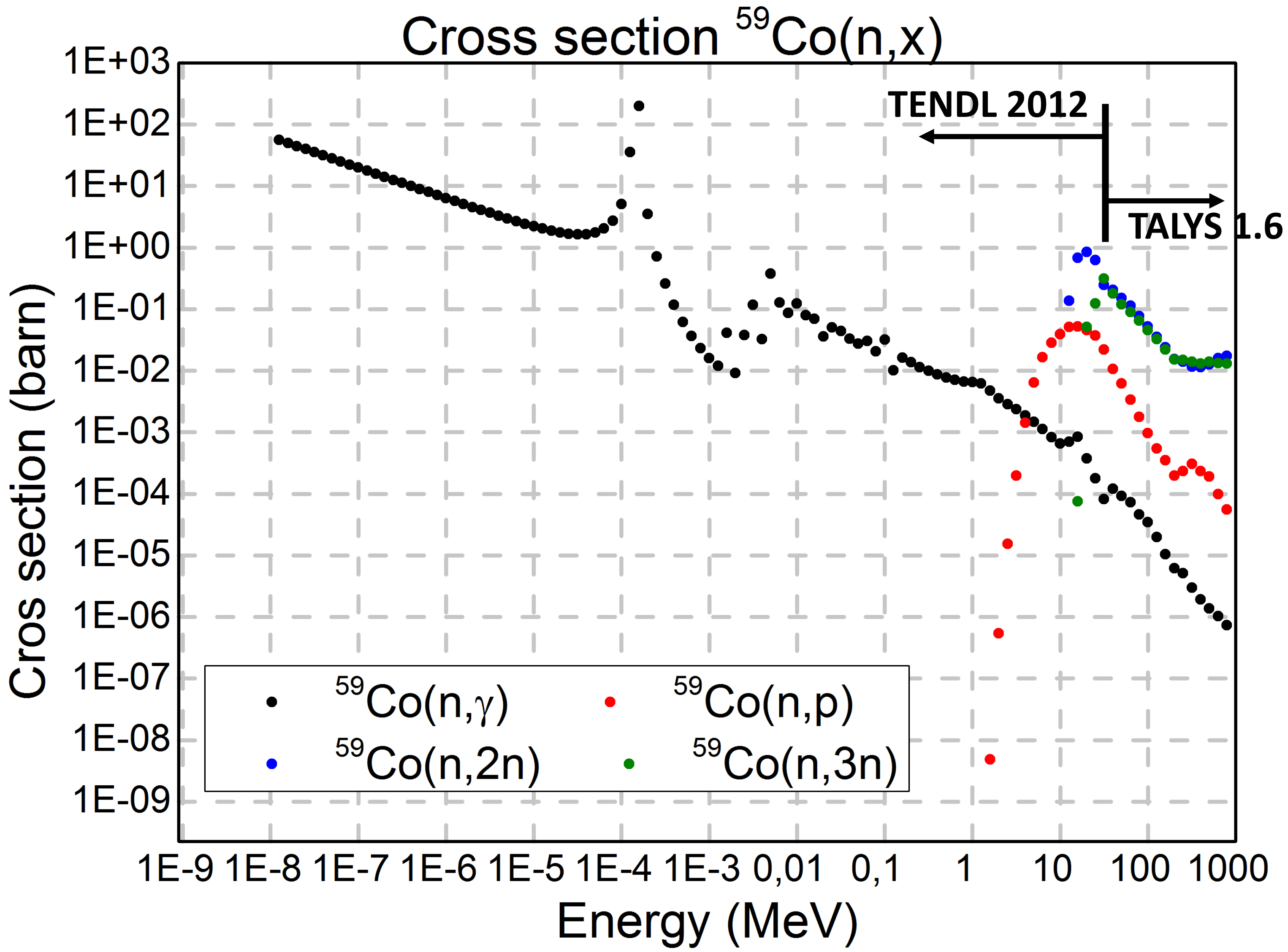


E_{theff}(MeV) 0 4 10 16 26 32 50 59 77 84 87

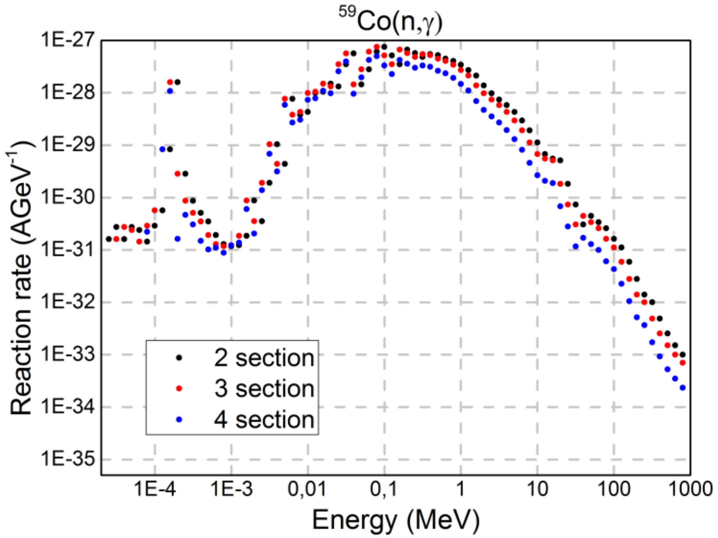


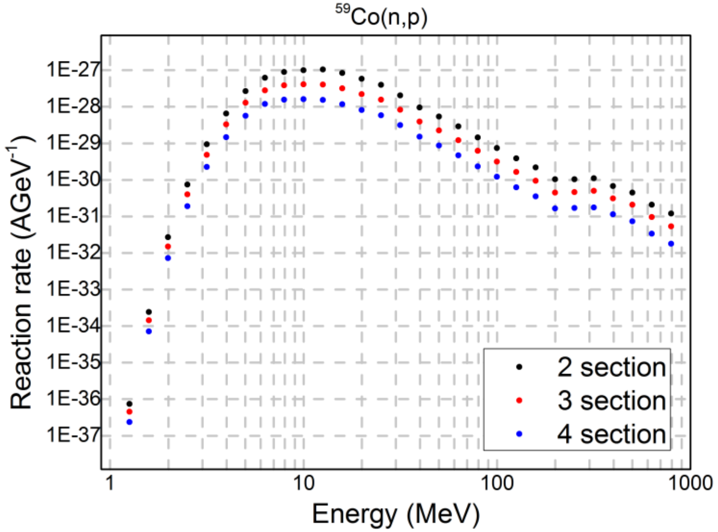


Energy spectra calculated by MCNPX 2.7 by Martin Suchopar.



- TENDL 2012, TALYS 1.6



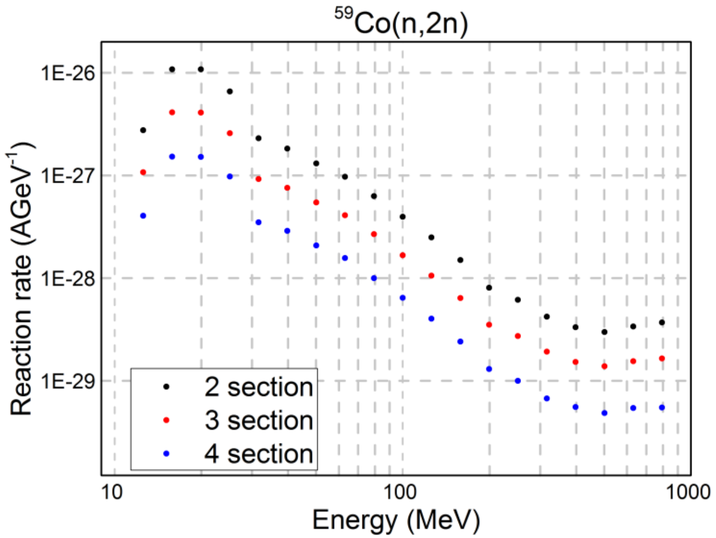


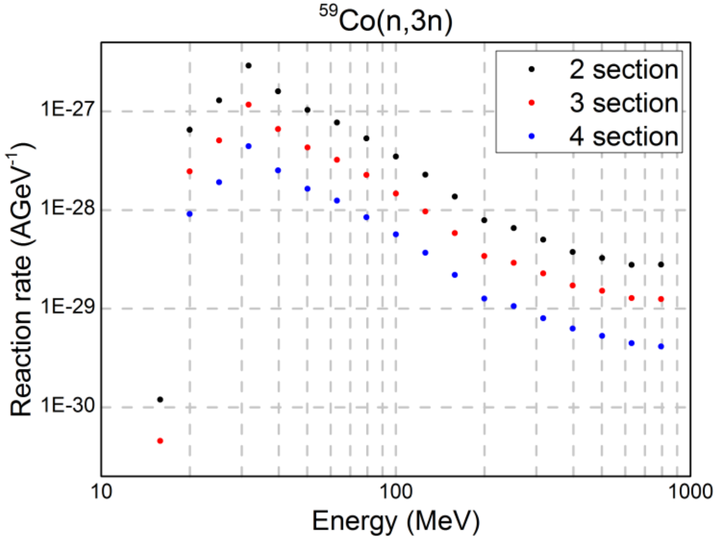
Cross section

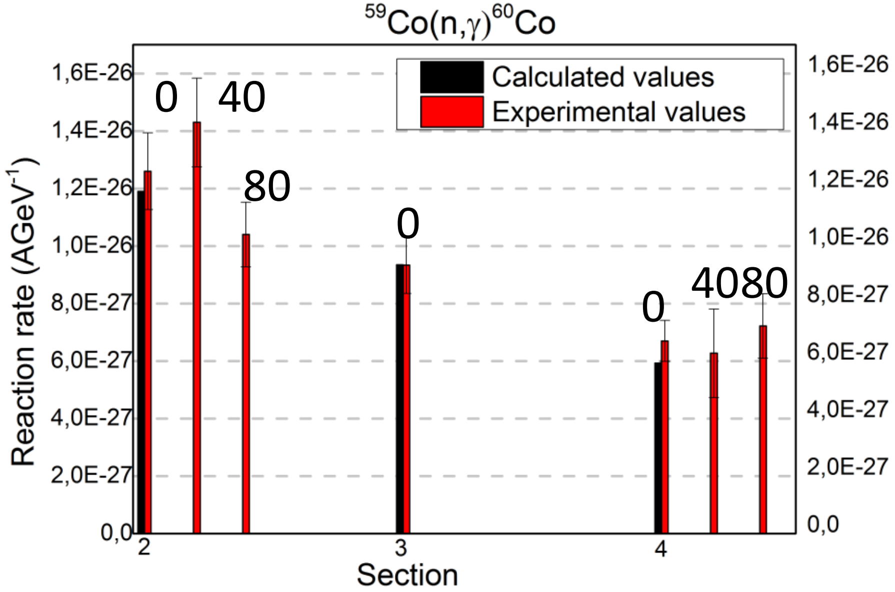
$$R_{Cal} = \sum_{i}^{n} \sigma_i(En) \cdot \phi_i(En)$$

$\sigma_i(TENDL\ 2012, TALYS\ 1.6)$ $\phi_i($ **MCNPX 2.7**$)$

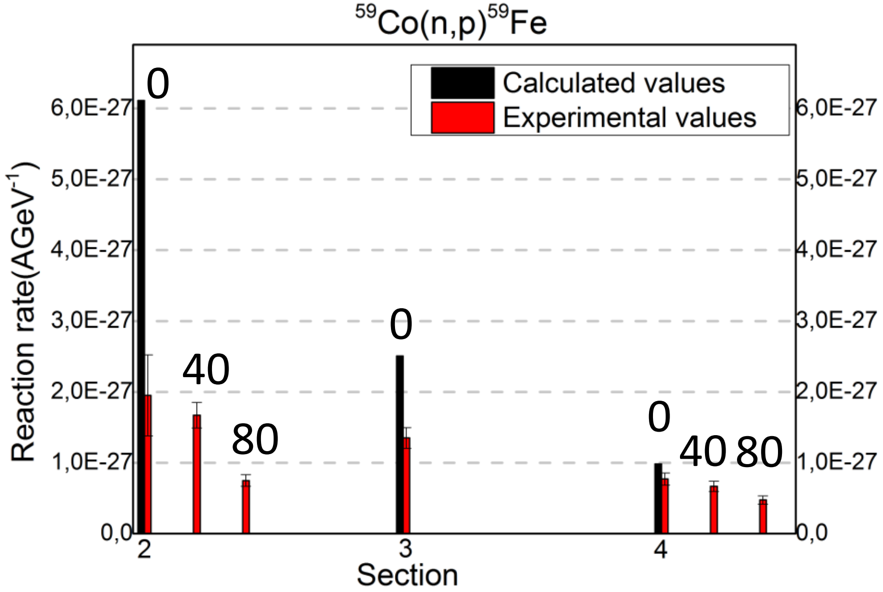
Neutron flux



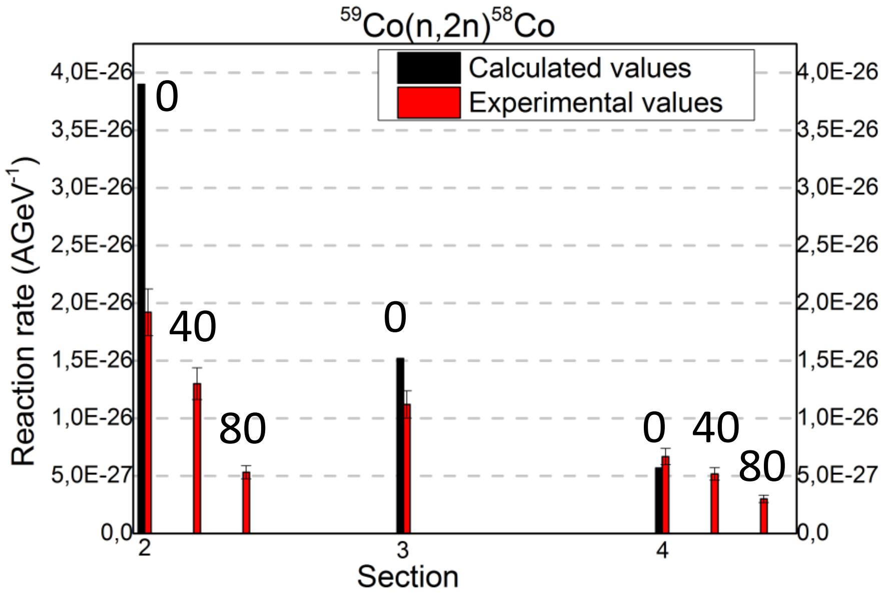




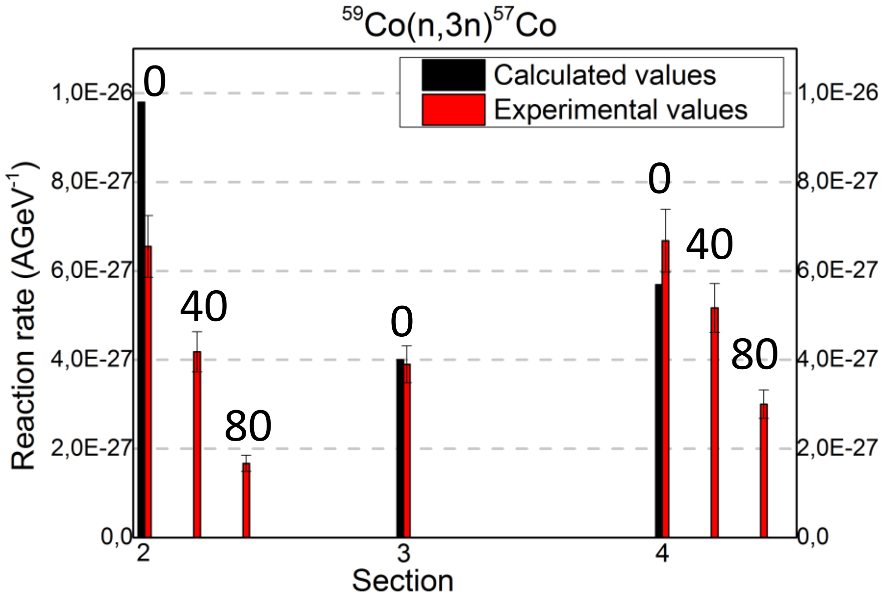
59Co(n,γ)60Co
Calculated values
Experimental values
Reaction rate (AGeV-1)
Section
1,6E-26
1,4E-26
1,2E-26
1,0E-26
8,0E-27
6,0E-27
4,0E-27
2,0E-27
0,0
2
3
4
0
40
80
0
0
4080



59Co(n,p)59Fe
Calculated values
Experimental values
Reaction rate(AGeV-1)
Section
6,0E-27
5,0E-27
4,0E-27
3,0E-27
2,0E-27
1,0E-27
0,0
2
3
4
0
40
80
0
0
40
80



59Co(n,2n)58Co
Calculated values
Experimental values
Reaction rate (AGeV-1)
Section
4,0E-26
3,5E-26
3,0E-26
2,5E-26
2,0E-26
1,5E-26
1,0E-26
5,0E-27
0,0
2
3
4
0
40
80
0
0
40
80



59Co(n,3n)57Co
Calculated values
Experimental values
Reaction rate (AGeV-1)
Section
1,0E-26
8,0E-27
6,0E-27
4,0E-27
2,0E-27
0,0
2
3
4
0
40
80
0
0
40
80

59Co(n,γ)				59Co(n,p)			
Sections	R_{Exp}	R_{Cal}	$\frac{R_{Exp}}{R_{Cal}}$	**Sections**	R_{Exp}	R_{Cal}	$\frac{R_{Exp}}{R_{Cal}}$
2	(1.26±0.13) E-26	(1.19±0.01)E-26	**(1.06±0.12)**	2	(1.95±0.57) E-27	(6.11±0.061)E-27	**(0.32±0.30)**
3	(9.34±0.99)E-27	(9.34±0.09)E-27	**(1.00±0.12)**	3	(1.35±0.15)E-27	(2.51±0.03)E-27	**(0.54±0.12)**
4	(6.70±0.71)E-27	(5.93±0.0)E-27	**(1.13±0.12)**	4	(7.70±0.86)E-28	(9.85±0.10)E-28	**(0.78±0.12)**

59Co(n,2n)				59Co(n,3n)			
Sections	R_{Exp}	R_{Cal}	$\frac{R_{Exp}}{R_{Cal}}$	**Sections**	R_{Exp}	R_{Cal}	$\frac{R_{Exp}}{R_{Cal}}$
2	(1.92±0.20) E-26	(3.90±0.04)E-26	**(0.49±0.12)**	2	(6.55±0.69) E-27	(9.79±0.10)E-27	**(0.67±0.12)**
3	(1.12±0.12)E-26	(1.52±0.02)E-26	**(0.74±0.12)**	3	(3.90±0.42)E-27	(4.00±0.04)E-27	**(0.98±0.12)**
4	(5.69±0.06)E-27	(7.82±0.08)E-01	**(1.17±0.12)**	4	(2.32±0.25)E-27	(1.52±0.02)E-27	**(1.53±0.12)**

Comparison of experimentally measured (R_{Exp}) and calculated (R_{Cal}) reaction rates. For the calculations of the TALYS 1.6 and MCNPX 2.7.

Conclusions

- Interaction of secondary neutrons with ^{59}Co nuclei has been experimentally investigated and analyzed.
- Secondary neutron field has been generated as a result of irradiation of the massive uranium target ***QUINTA*** with the JINR Nuclotron deuteron beam with energy 4 AGeV. Experimental samples were situated in different positions of the neutron field.
- Results of R_{exp} were compared with R_{cal} calculated of MCNPX2.7. Reaction (n,γ) had a good agreement within one standard deviation, other results of reactions were not in agreement.

Thank you for your attention