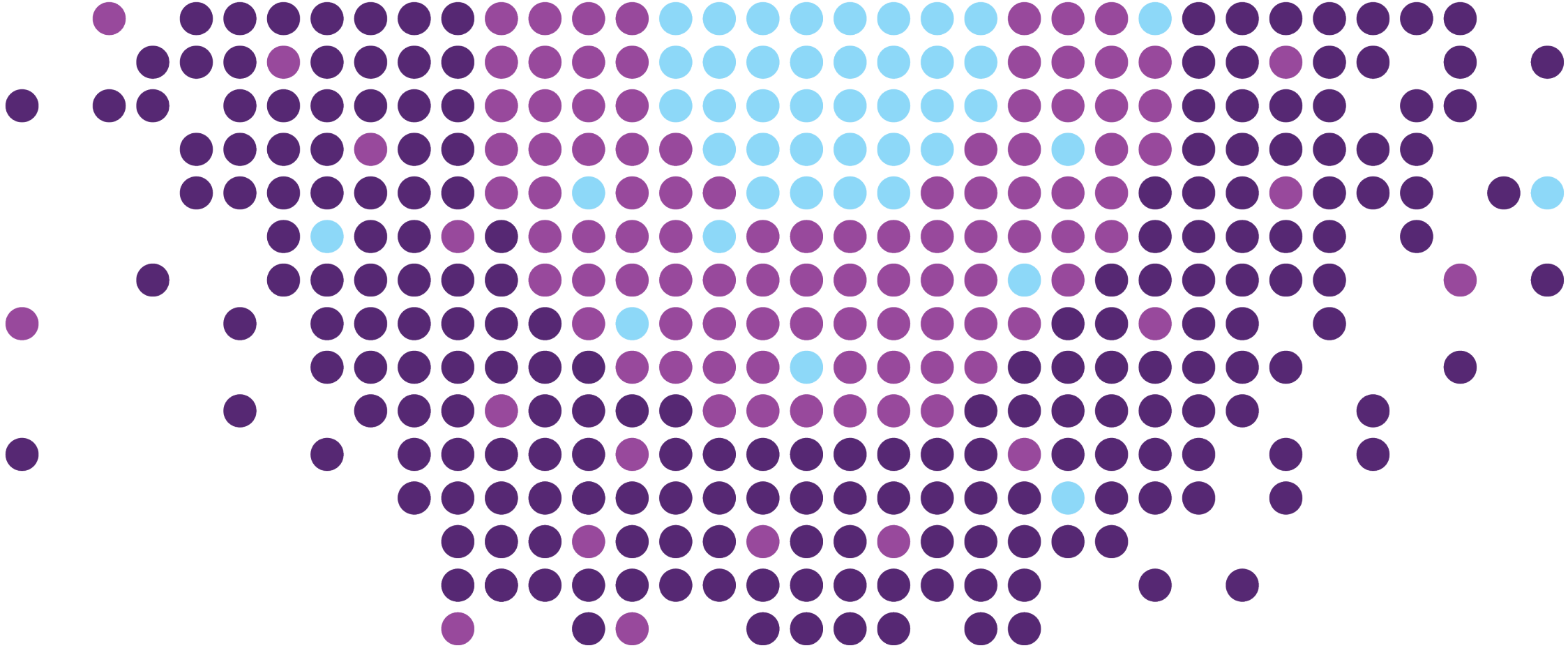


Stephan Heinitz,

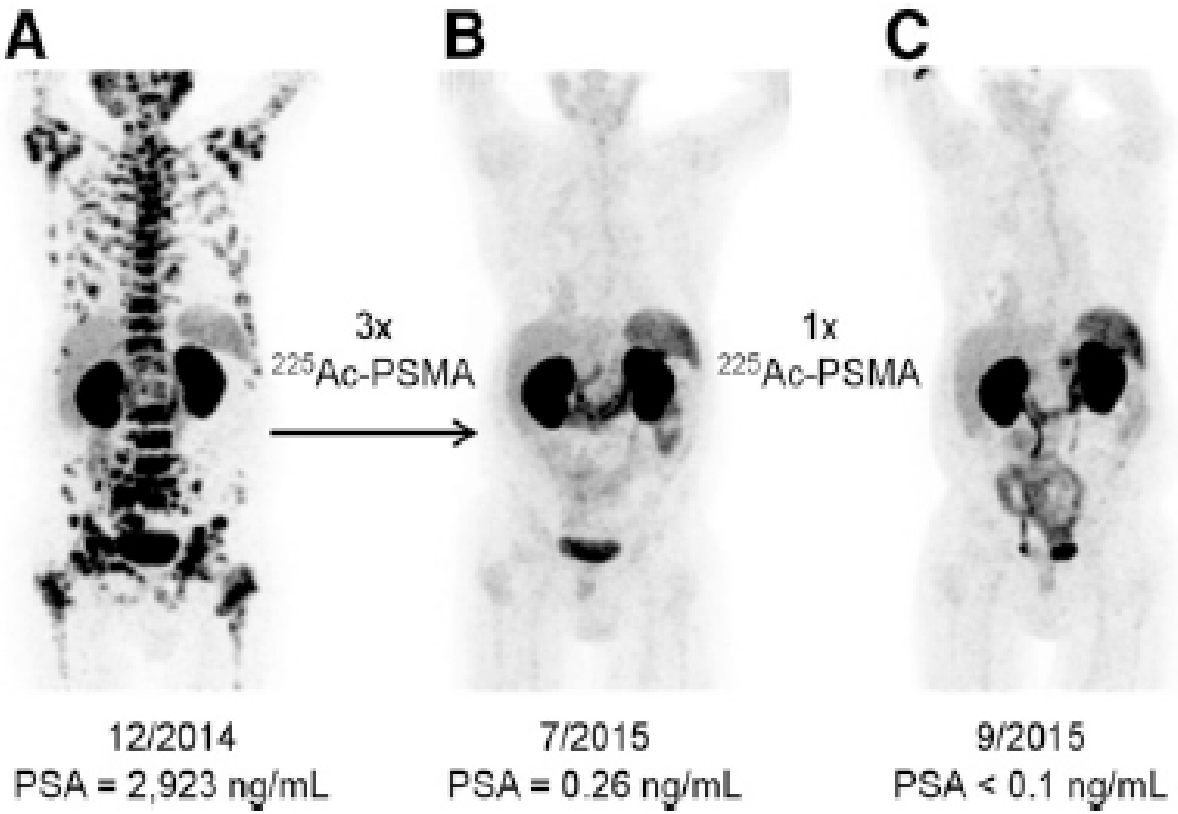
H. Skliarova, J. Heyse, M. Kerveno, A. Plompen, G. Sibbens, A. Tsinganis, J. Wagemans

sck cen
Belgian Nuclear Research Centre

Towards ^{226}Ra target development for photonuclear cross-section measurements

INTDS 29/09/2022

^{225}Ac for Targeted Alpha Therapy (TAT)



source: [1]

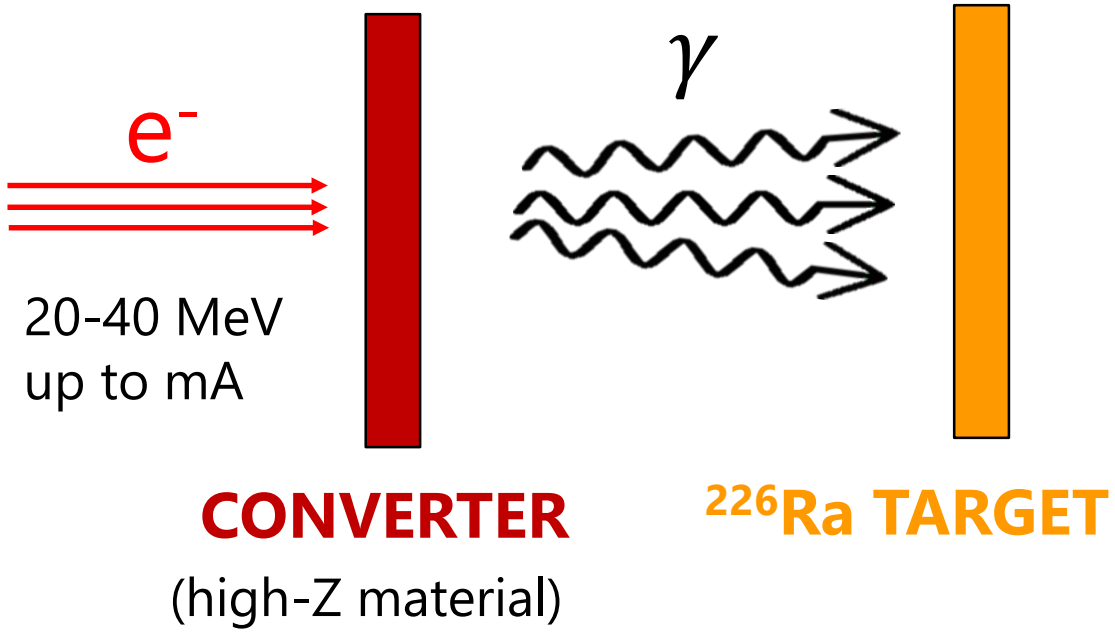
Ac 225
9.920 d

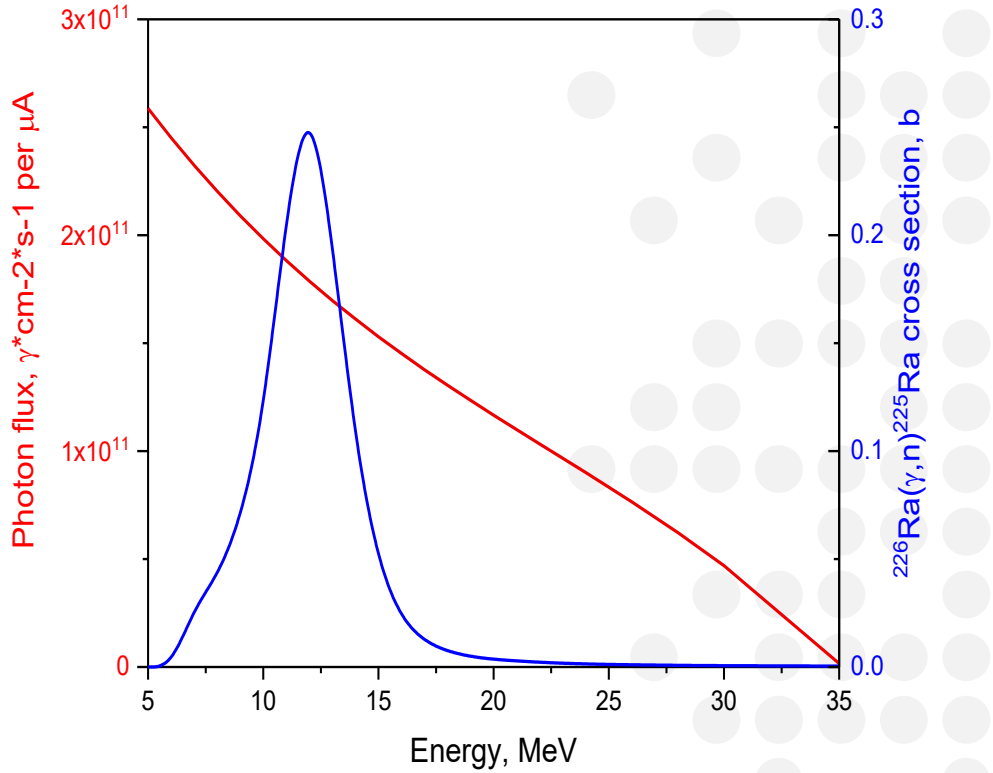
α 5.830, 5.793
5.732..., C14
γ 100, (150, 188
63...), e^-

[1] Kratochwil C. et al., JNM **57** 12 1941 (2016)

Photonuclear production of ^{225}Ac

$$^{226}Ra(\gamma,n)^{225}Ra \xrightarrow{14.9\ d} {}^{225}Ac$$





Only two measurements of the integral $^{225}Ra/^{225}Ac$ production yields have been reported in literature:

1. Melville, G., et al. Applied Radiation and Isotopes. **2007**; 65(9):1014-1022
2. Maslov, O.D., et al. Radiochemistry. **2006**; 48(2):195-197.

Experimental data for (γ,*) reactions on ^{226}Ra

Data Selection

Retrieve ◉Selected ○Unselected ○All Reset

Output: ☑X4+ ☑EXFOR ☑Bibliography ☐TAB ☐C4 ☐PlotC4

Plot: ☐Quick-plot (cross-sections) ☐ungroup /product: ☐Advanced plot [how-to] using ☐C5 and ☐convert ratios to σ

Narrow incident energy (optional), eV: Min: ☐ Max: ☐

☐Apply Data re-normalization (for advanced users, results in: C4, TAB and Plots)

	n	Display	Year	Author-1	Energy range,eV	Points	Reference	Subentry#P NSR-Key	Info+
	1)	88-RA-226(G,F),,DA,FF,BRA/REL C4: MF=4 MT=?							
		Quantity: [DA] Angular distribution of particle specified							
g	1	+ i X4 X4+ X4± T4	1968	E.A.Zhagrov+	9.10e6	7	+ J,YF,7,264,1968	M0185003 [6] 1968ZH03 An[7]=15:85	
g	2	+ i X4 X4+ X4± T4			1.07e7	7		M0185004 [6] 1968ZH03 An[7]=15:85	
g	3	+ i X4 X4+ X4± T4			1.45e7	7		M0185005 [6] 1968ZH03 An[7]=15:85	
g	4	+ i X4 X4+ X4± T4			1.80e7	7		M0185006 [6] 1968ZH03 An[7]=15:85	
g	5	+ i X4 X4+ X4± T4			2.20e7	7		M0185007 [6] 1968ZH03 An[7]=15:85	
g	6	+ i X4 X4+ X4± T4			2.60e7	7		M0185008 [6] 1968ZH03 An[7]=15:85	
	2)	88-RA-226(G,F),,SIG,,BRS C4: MF=3 MT=?							
		Quantity: [CS] Cross section							
g	7	+ i X4 X4+ X4± T4 Cov	1971	E.A.Zhagrov+	9.00e6	2.00e7 23	+ J,YF,13,934,1971	M0195002 [6] 1971ZH02	
	3)	(88-RA-226(G,F),,SIG,,BRA/REL)/(92-U-238(G,F),,SIG,,BRA/REL) C4: MF=203 MT=?							
		Quantity: [CS] Cross section							
g	8	+ i X4 X4+ X4± T4 Cov	1968	E.A.Zhagrov+	8.25e6	2.50e7 6	+ J,YF,7,264,1968	M0185002 [6] 1968ZH03	

No ^{226}Ra(γ,n)^{225}Ra cross section data published to date!

INTDS International Nuclear Targets Development Society

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Biblio index

Below (open access mode) you find the list of contributions to the latest meeting, the 29th World Conference held in October 229, 2020.

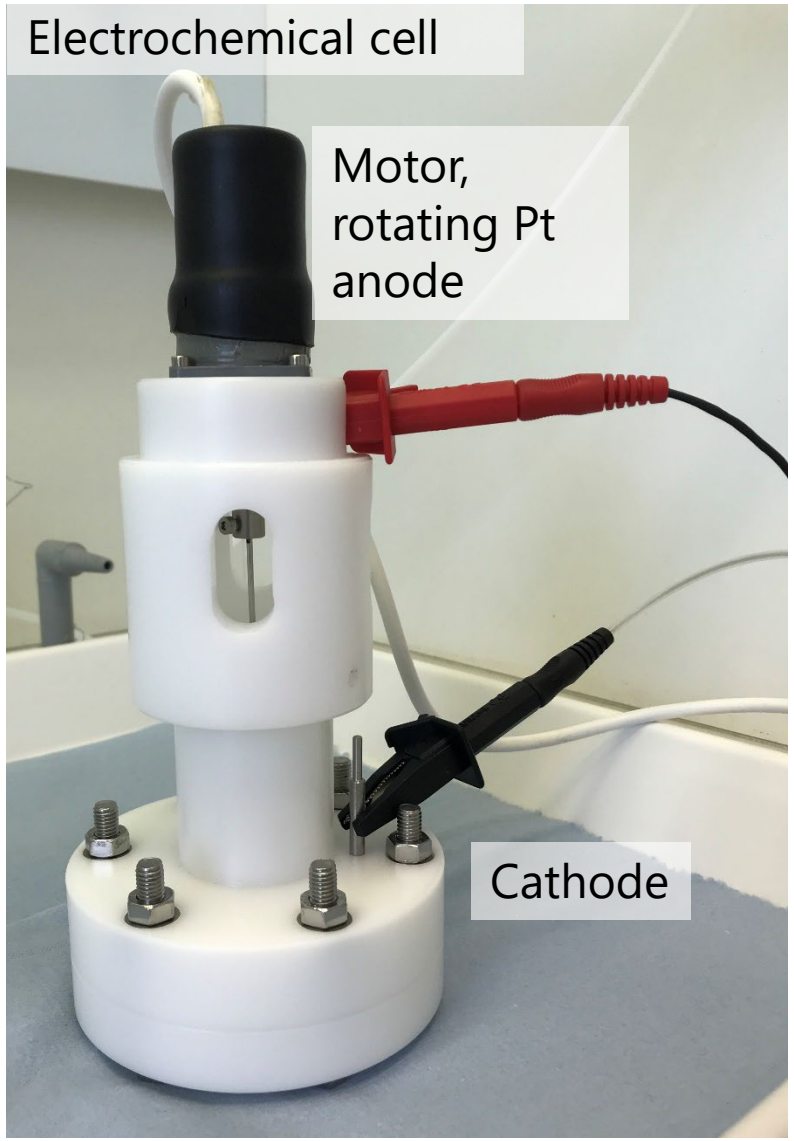
The **entire INTDS bibliography index** currently listing 1165 articles (searchable with keywords, authors name, journals or p

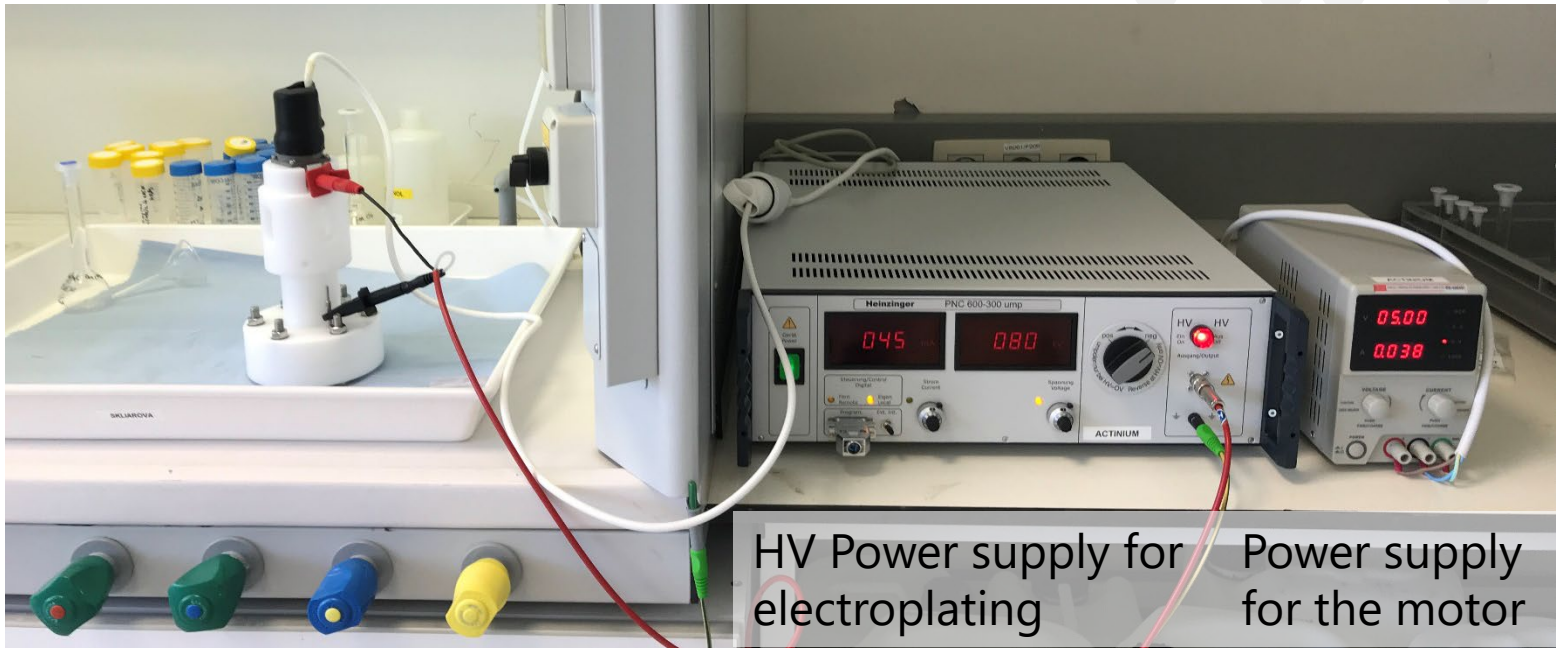
in.

List of contributions to 29th World Conference

1144. Masahiro Yoshimoto, Yoshio Yamazaki, Takamitsu Nakanoya, Pranab Kumar Saha and Michikazu Kinsho;
Progress status in fabrication of HBC stripper foil for 3-GeV RCS at J-PARC in Tokai site
EPJ Web Conf. 229, 2020; DOI: https://doi.org/10.1051/epjconf/202022901001

Experimental set-up





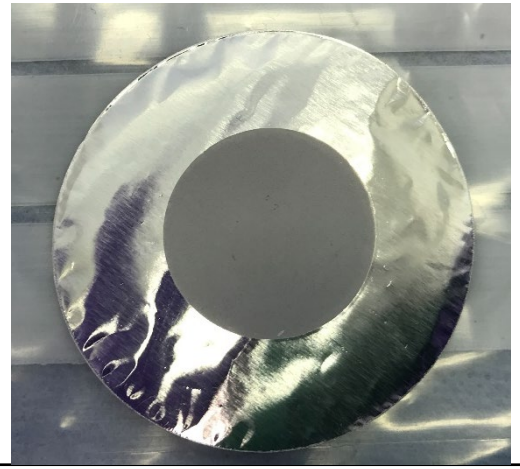
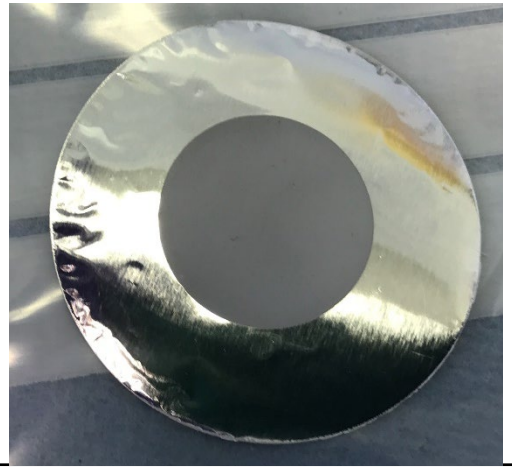
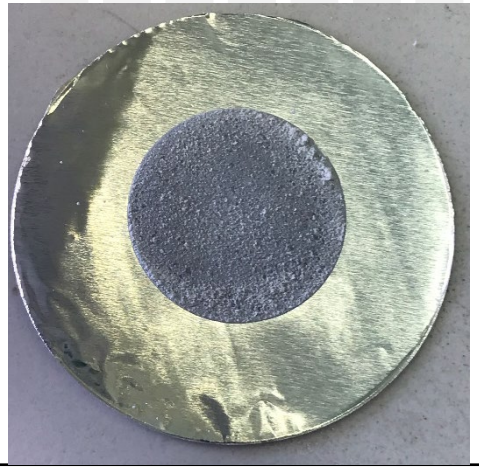
40-120V

5V ~0.03A
34 rpm

Distance cathode-anode 1 cm

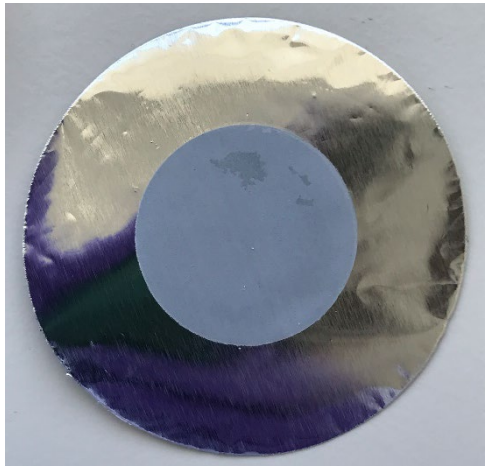
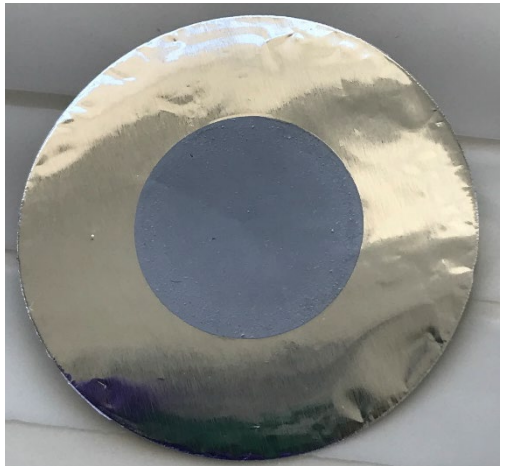
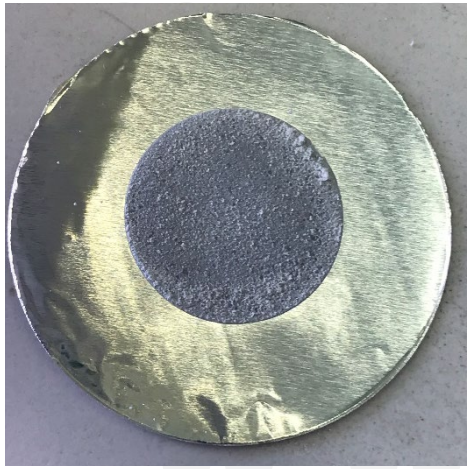
$Ba(NO_3)_2$ dissolved in 2.5mL HNO_3 0.05M + 20 mL Isopropanol

NH_4OH fixing was avoided to facilitate the recovery

Experiment #	29	30	31
Voltage	**80 V**	**100 V**	**120 V**
Time	20 min	20 min	20 min
Average current	33.7 mA	47.4 mA	63.2 mA
m_d, mg	2.27	2.43	2.83
m_{Ba}, mg	**0.07**	**0.09**	**0.07**
Ba deposited from sol.	**60%**	**83%**	**64%**
Temperature increase	23-28.7=5.7ºC	23.2-30.0=6.8ºC	23.2-36.6=13.4ºC
Dep density, mg/cm²	0.72	0.77	0.9
Photo			

$Ba(NO_3)_2$ ~1mg per solution: 2.5mL HNO_3 0.05M + 20 mL Isopropanol

By XRD analysis sample 31 contains: $BaO_2 \cdot 8H_2O$; $BaO_2 \cdot H_2O_2$; $Ba(OH)_2$

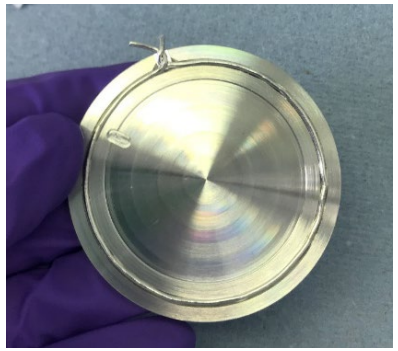
Experiment #	33	32	31
$Ba(NO_3)_2$ mass, mg	**0.01**	**0.1**	**1**
Average current	**41.9 mA**	**40.3 mA**	**63.2 mA**
m_d, mg	1.43	1.73	2.83
m_{Ba}, mg	**0.0008**	**0.007**	**0.07**
Ba deposited from sol.	**64%**	**70%**	**64%**
Temperature increase	-	23.2-29.5=6.3ºC	23.2-36.6=13.4ºC
Dep. density, mg/cm²	**0.45**	**0.55**	**0.9**
Photo			

120 V 20 min,18 µm Al foil

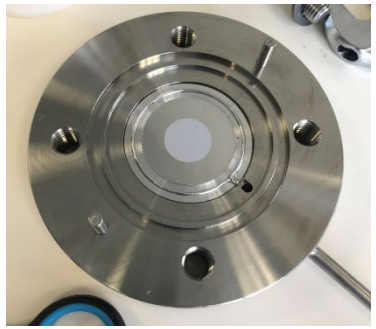
solution: 2.5 mL HNO_3 0.05M + 20 mL Isopropanol with different amount of $Ba(NO_3)_2$. Solution has to be intensively mixed before deposition

Targets for irradiation of ^{226}Ra

Al container



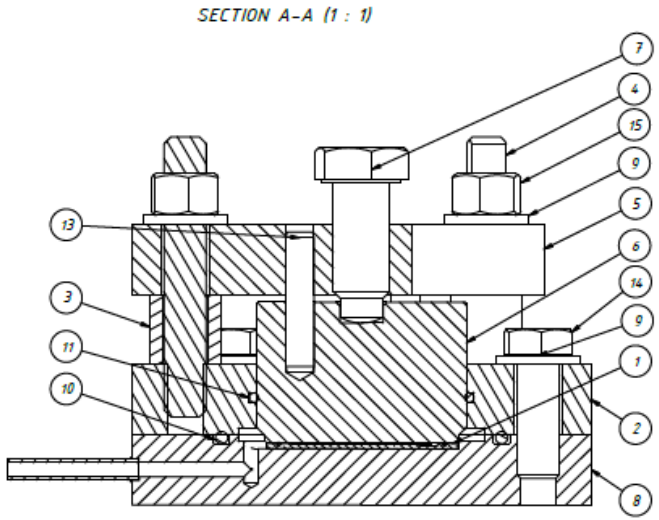
Indium seal



Electroplated target

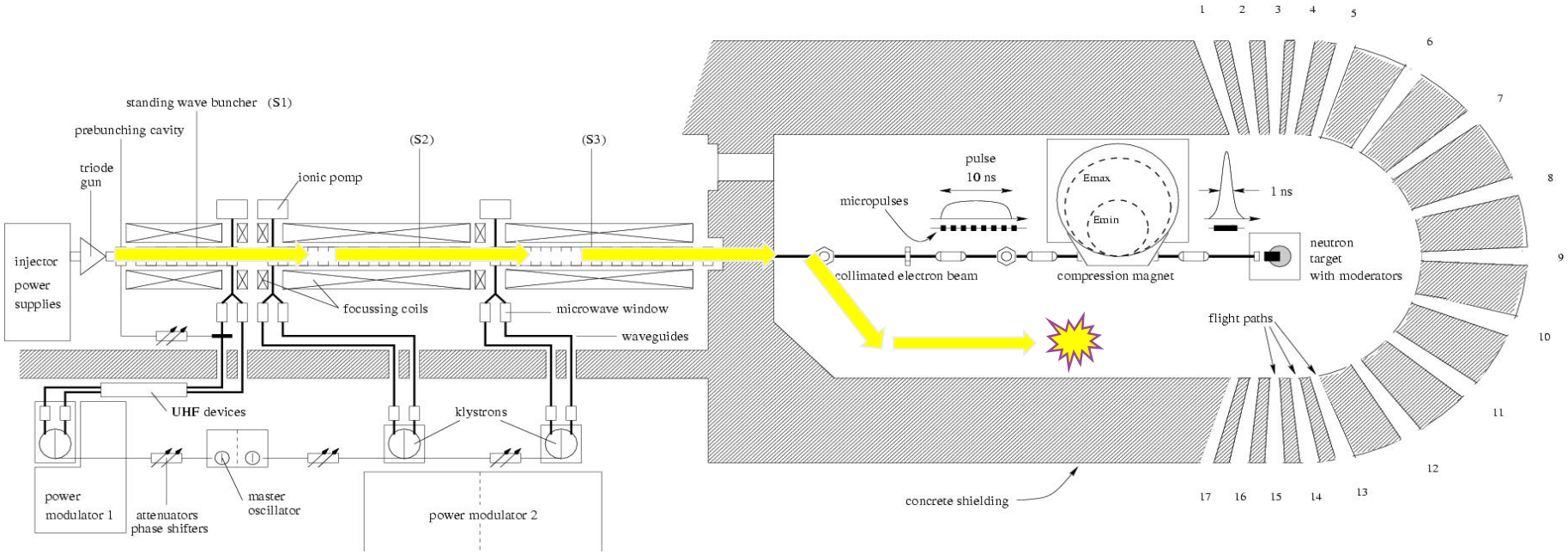
Al foil lid

Hermetically sealed target



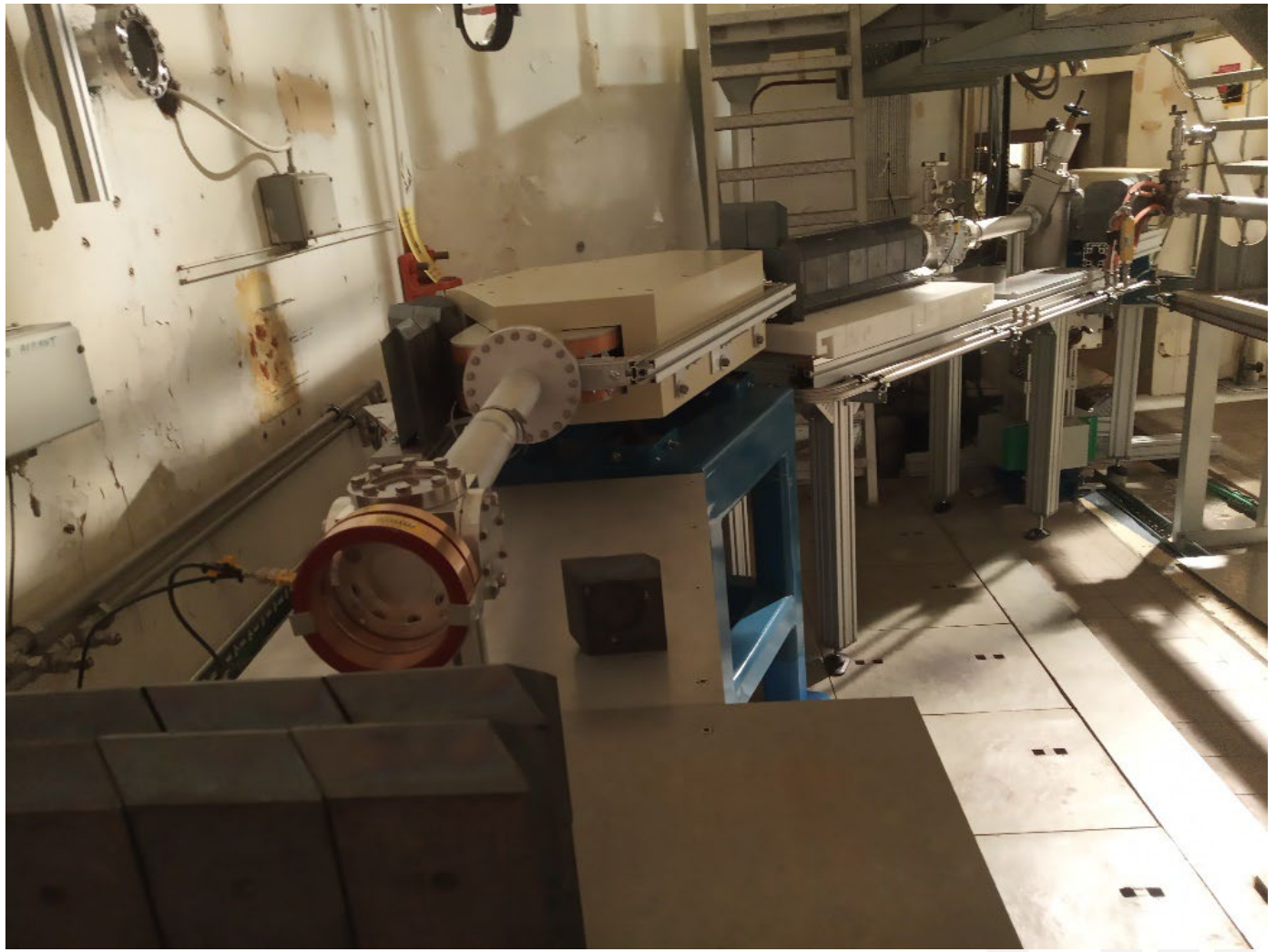

JRC
EUROPEAN COMMISSION
GELINA

GELINA – New Beam Line for Radioisotope Production Studies



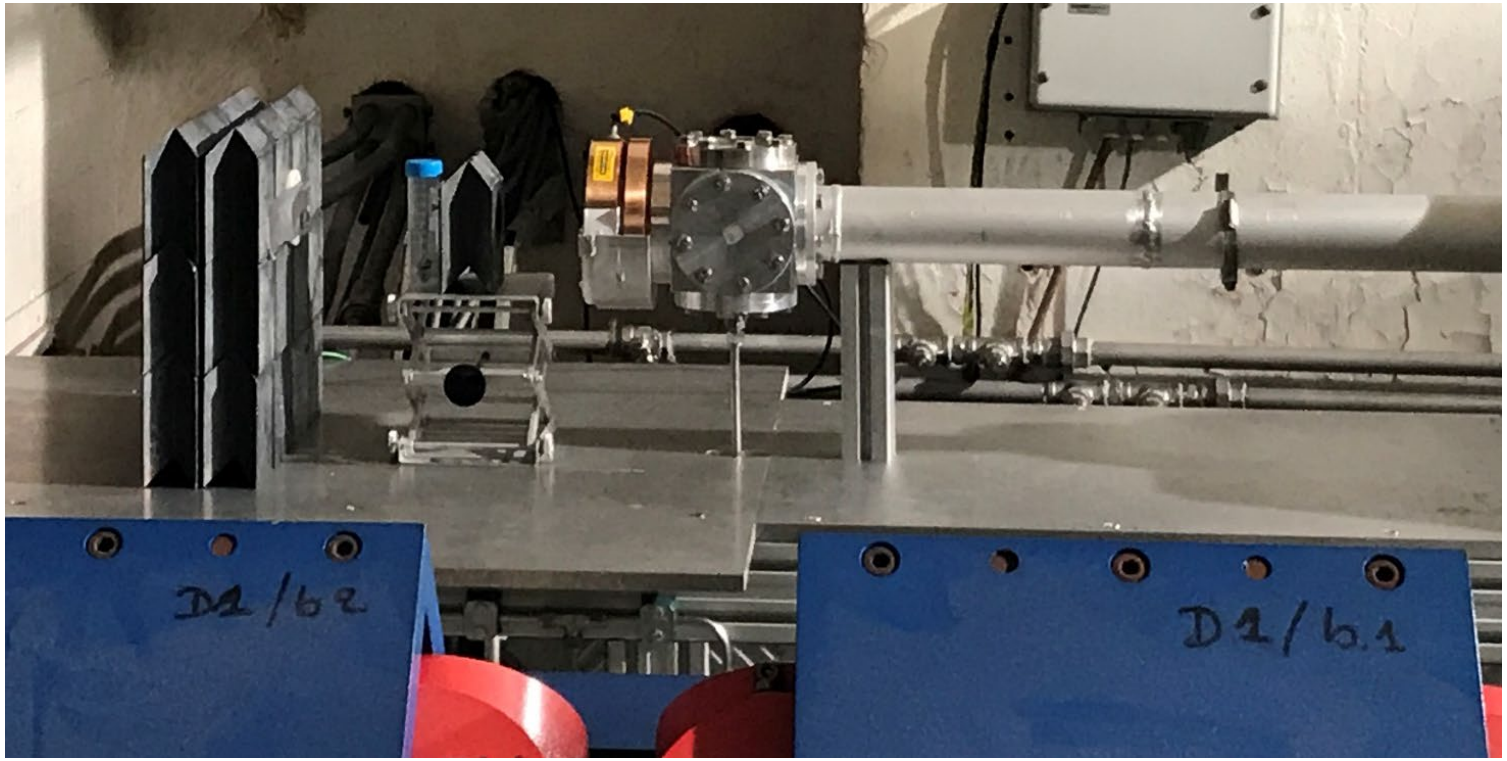
New Operating Parameters

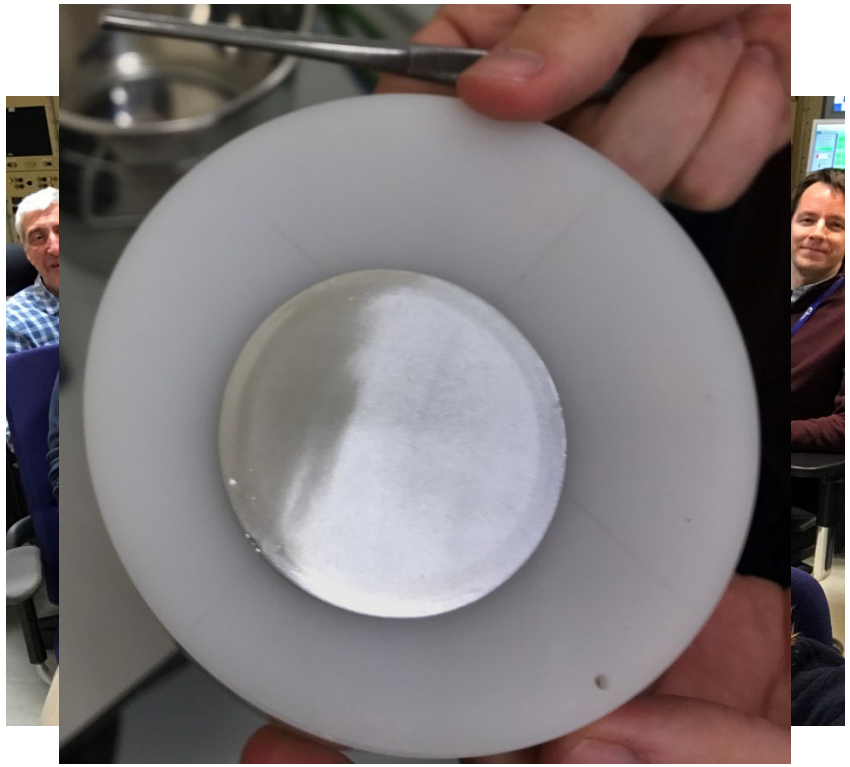
Average Current	: **up to 10 μA**	Frequency	: up to 200 Hz
Mono-energetic Beam	: **[20,150] MeV**	Pulse Width	: up to 3.3 μs
Mean Power	: **up to 1 kW**		



We had first photons for our project!

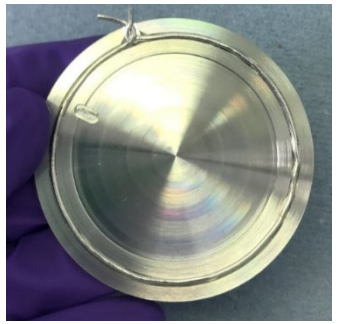
On 28.04.2022 at 15:44 – first beam on target - 0.4 µA 60 MeV for 4.5 min from GELINA e-accelerator.





Dummy target irradiation

60MeV 0.425 uA e-beam 4.5min irradiation



Color	Name	Material	Dimension	Mass
	Container lid	Al Thermo Fisher (Alfaaesar) 99.99%	Ø54mm × 0.1mm	0.6167 g
	Target	Al Goodfellow 99.99%	Ø40mm × 0.25mm	0.8451 g
	Indium wire	In Goodfellow 99.999%	Ø1mm × 15cm	0.9729 g
	Container	Al bulk 99%	Ø54mm × 1.525mm	7.9732 g
	Total		Ø54mm × 1.925mm	10.4075 g

Al 1.8mm thick Ø54 mm

Al 0.25mm thick Ø4 cm

In 0.785 mm thick wire with rectangular profile R= 2,3..2,4 cm

Distance converter target 1 cm

Pb 1.8x4 cm thick (full stopping e-beam) Ø14 cm

Gaussian beam d=2cm

Post-irradiation analysis and MCNP modelling

60MeV 0.425 uA e-beam 4.5min irradiation
Gaussian beam profile Ø2cm

Al impurities %: Mn 0.25, Ti 0.035, Cr 0.05, Si, Mg possible

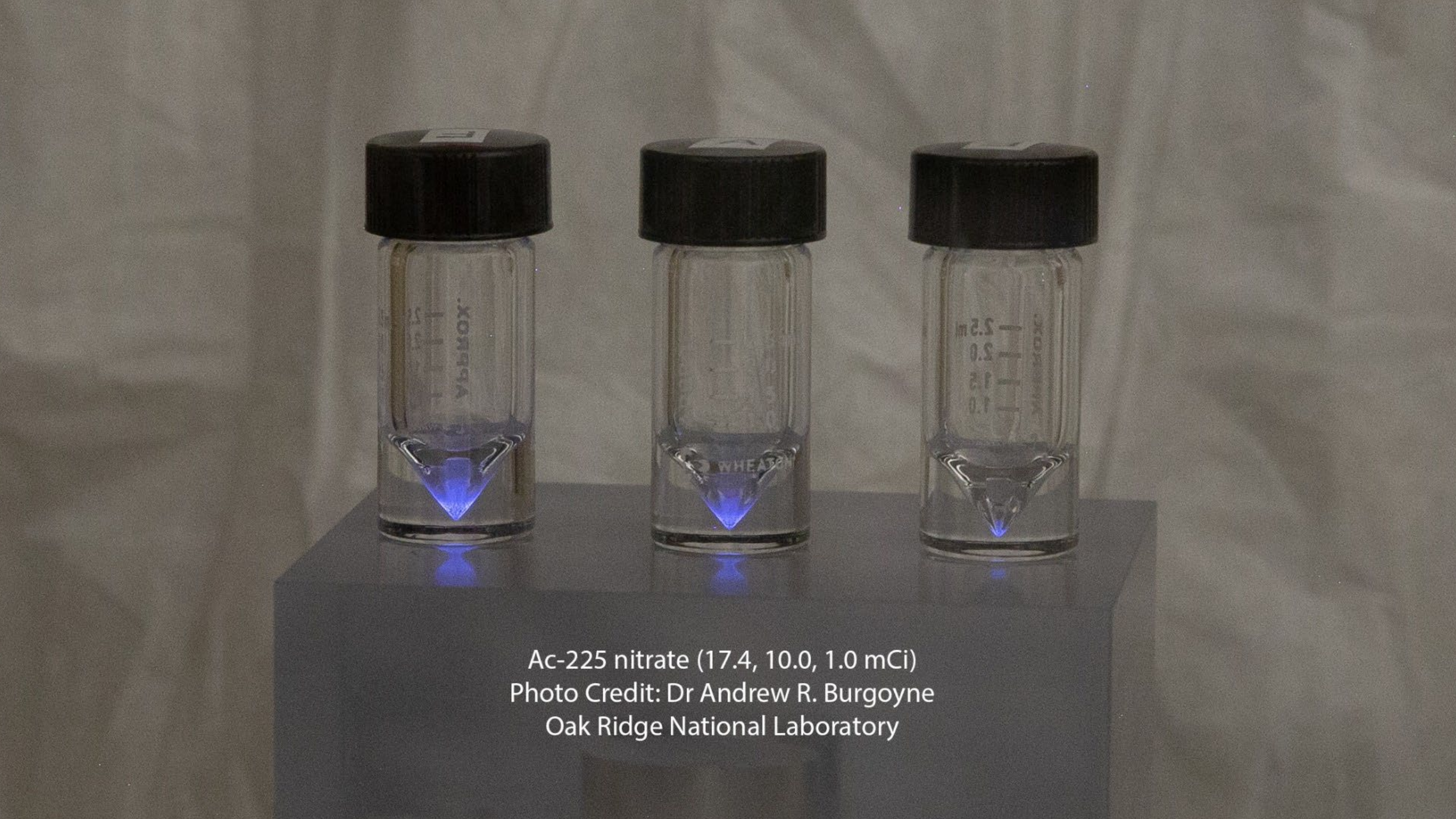
	Isotope	In-111	In-112	In-112m	In-113m	In-114m	In-115m	In-116m	Na-22	Na-24	Mg-27	Cr-49	Cr-51	Sc-47	Mn-52m	Mn-54	Mn-56
	Bq $T_{1/2}$	*2.805 d*	*14.97 m*	*20.56 m*	*1.658 h*	*49.51 d*	*4.486 h*	*54.29 m*	*2.6019y*	*15h*	*9.458 m*	*42.3 m*	*27.7 d*	*3.349 d*	*21.1 m*	*312.2 d*	*2.579 h*
45 min after EOB, spec.1	Genie spec1	27.22	21080.79	5884.22	2767.22	218.78	2840.33	14956.06		2824.14	5765.78	190.46		14.73	118.51		113.28
	SIM spec1	11.86	7251.01	4167.33	2281.76	102.24	7716.41	2170.19	2.97	1389.30	3845.16	155.48	16.89	13.78	101.79	8.47	13.07
	Ratio exp/SIM	2.30	2.91	1.41	1.21	2.14	0.37	6.89		2.03	1.50	1.22		1.07	1.16		8.66
	Genie EOB	27.41	134662.84	22702.94	3657.82	218.87	3148.92	24939.54		2912.85	108535.72	367.14		14.81	441.72		135.53
	Sim EOB	10.80	7867.87	15932.55	3016.27	102.28	8554.75	3606.39	2.97	1431.76	72381.65	301.59	16.89	13.85	377.06	8.47	15.64
	Ratio exp/SIM	2.54	17.12	1.42	1.21	2.14	0.37	6.92		2.03	1.50	1.22		1.07	1.17		8.66
4 d after EOBspec.2	Genie spec2	9.43				137.00			2.30	31.90							
	SIM_spec2	3.71				95.77			2.96	7.33		-	15.01	5.19		8.38	-
	Ratio exp/SIM	2.54				1.43			0.78	4.35							
15 d after EOB spec. 3	Genie spec 3	0.62				127.20			0.50				9.18	0.50		5.42	
	SIM_spec3	0.25				82.24			2.93			-	11.40	0.53		8.18	-
	Ratio exp/SIM	2.53				1.55			0.17				0.80	0.94		0.66	
50 d after EOB spec.4	Genie spec 4					79.25			2.47				4.81			5.87	
	Sim spec 4					50.50			2.86				4.73			7.57	
	Ratio exp/SIM					1.57			0.86				1.02			0.78	

Neutron reactions simulation statistics is still to be improved

Activity produced in container components will be less then that of $^{225/226}Ra$

Future plans, or the long way to a (γ,n) cross-section …

- Preparation of suitable ^{226}Ra targets
- Characterization of these in terms of homogeneity and stability
- Irradiation of ^{nat}Ba, ultimately ^{226}Ra targets at JRC Geel
- Destructive analysis of ^{226}Ra targets for ^{225}Ra yield measurements
- Deconvolution of the photon flux distribution using MCNP and Au, Co and Mo monitor foils
- Irradiations at increasing e-beam energies
- …



Ac-225 nitrate (17.4, 10.0, 1.0 mCi)
Photo Credit: Dr Andrew R. Burgoyne
Oak Ridge National Laboratory

SCK CEN
Belgian Nuclear Research Centre
Studiecentrum voor Kernenergie
Centre d'Etude de l'Energie Nucléaire

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