Outlook of production of radioisotopes and radiopharmaceuticals at HIL

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PRZYSZŁOŚĆ FIZYKI JĄDROWEJ NISKICH ENERGII W POLSCE A ROZWÓJ KRAJOWEJ INFRASTRUKTURY BADAWCZEJ,
14-15 January 2019, Warsaw, Poland

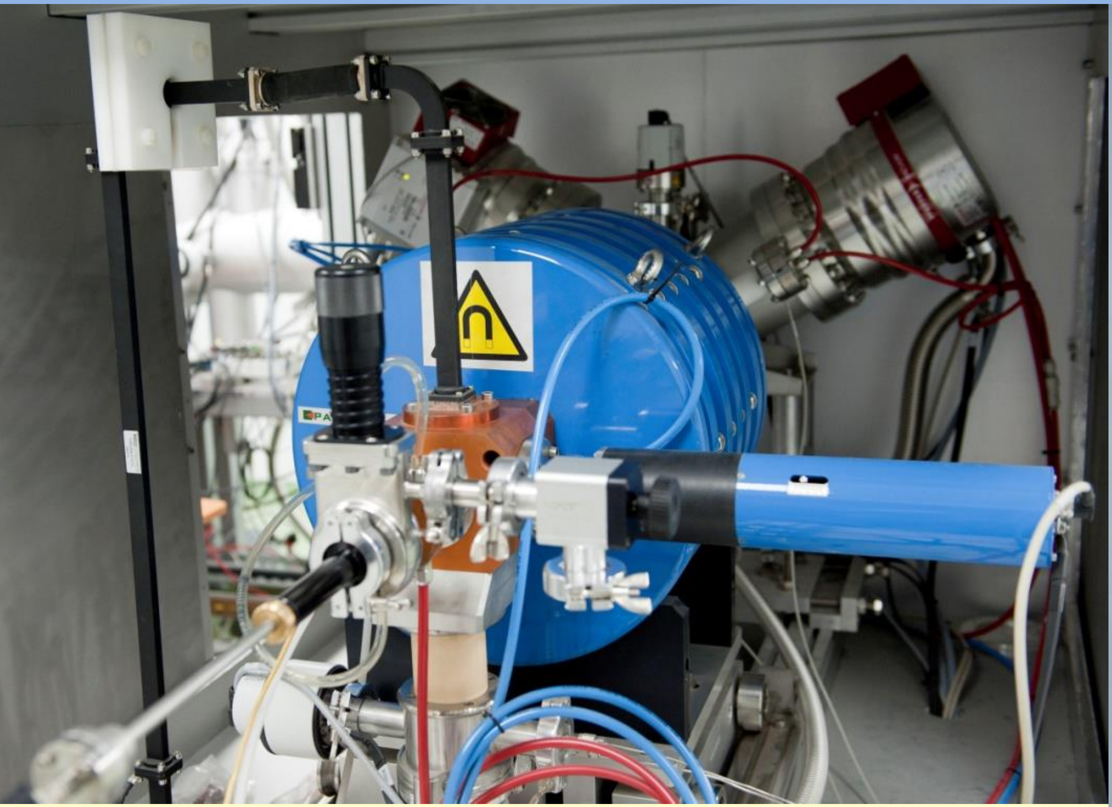
Plan

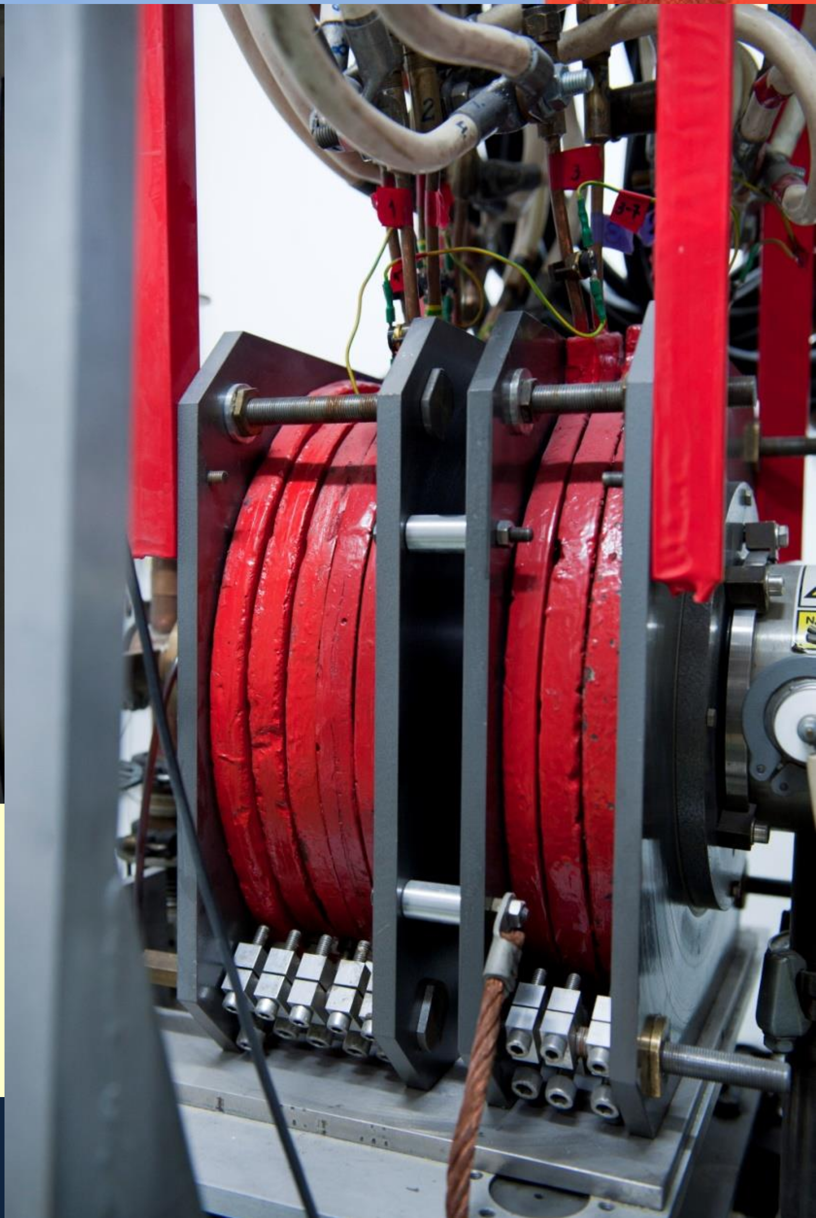
- A standalone target system for internal beam irradiation
- A standalone external target system Patent no P414054

Isochronous cyclotron K_{max} = 160

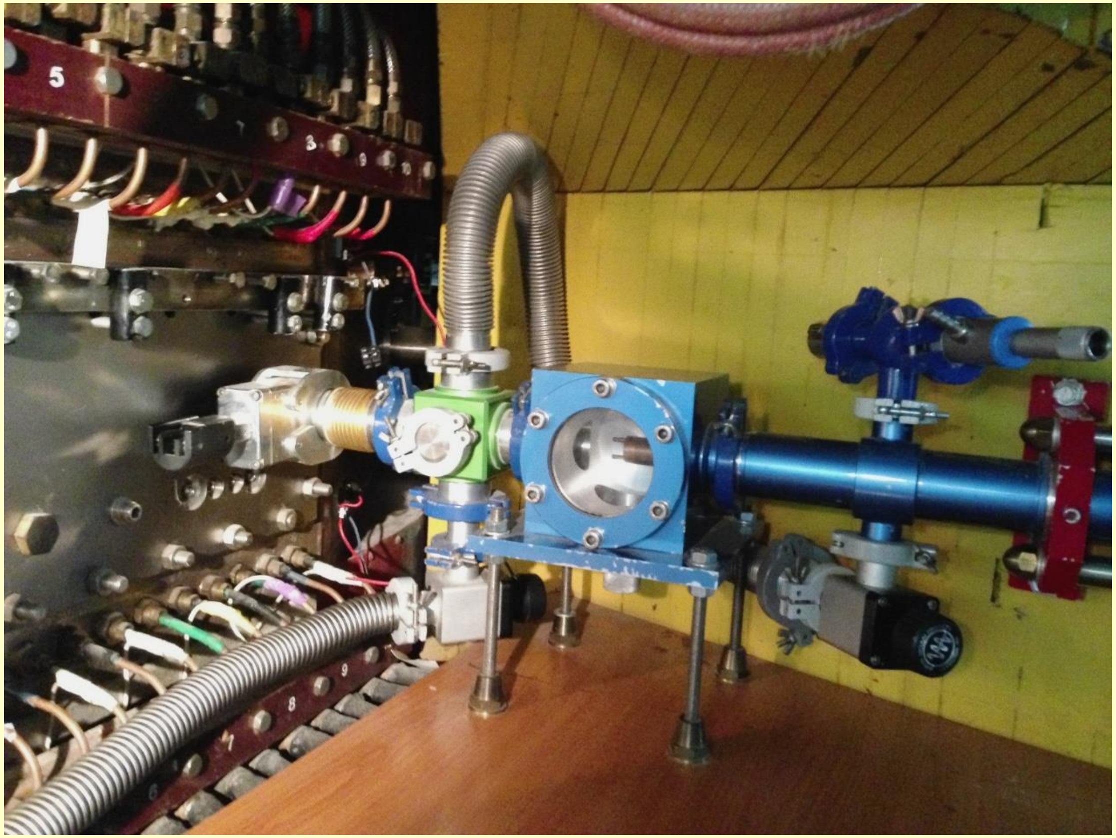
The Heavy Ion Laboratory (HIL), University of Warsaw is equipped with the only one in Poland heavy ion cyclotron U-200P, constructed in collaboration with Dubna and Polish scientific institutions in the seventies and eighties of the 20th century.
This isochronous cyclotron allows to accelerate beams (gaseous and metallic) from Q/A=1/5 to Q/A=1/2 with energies up to 10 MeV/amu.

Two ECRIS - (14.5 GHz) and (9.6 GHz)





Currently the cyclotron is equipped with a simple station which was designed for other purposes then production of medical radioisotopes. The range of available beam energies may be varied from a very initial up to maximal (32 MeV, 1 pμA for α beam) obtainable form the cyclotron.



Unfortunately, this station also has several shortcomings like for example a very weak water cooling system of the target and not automated operations.

A standalone target system for internal beam irradiation

Since several years ago, the Heavy Ion Laboratory has been involved in medical radioisotope production, mainly Astatine-211 element utilizing alpha beam from the U-200P cyclotron ...

… but also isotopes:

$^{40}Ca(\alpha,n)^{43}Sc$,

$^{42}Ca(\alpha,2n)^{44gd}Sc$,

$^{42}Ca(\alpha,2n)$ $^{44}Ti/^{44}Sc$

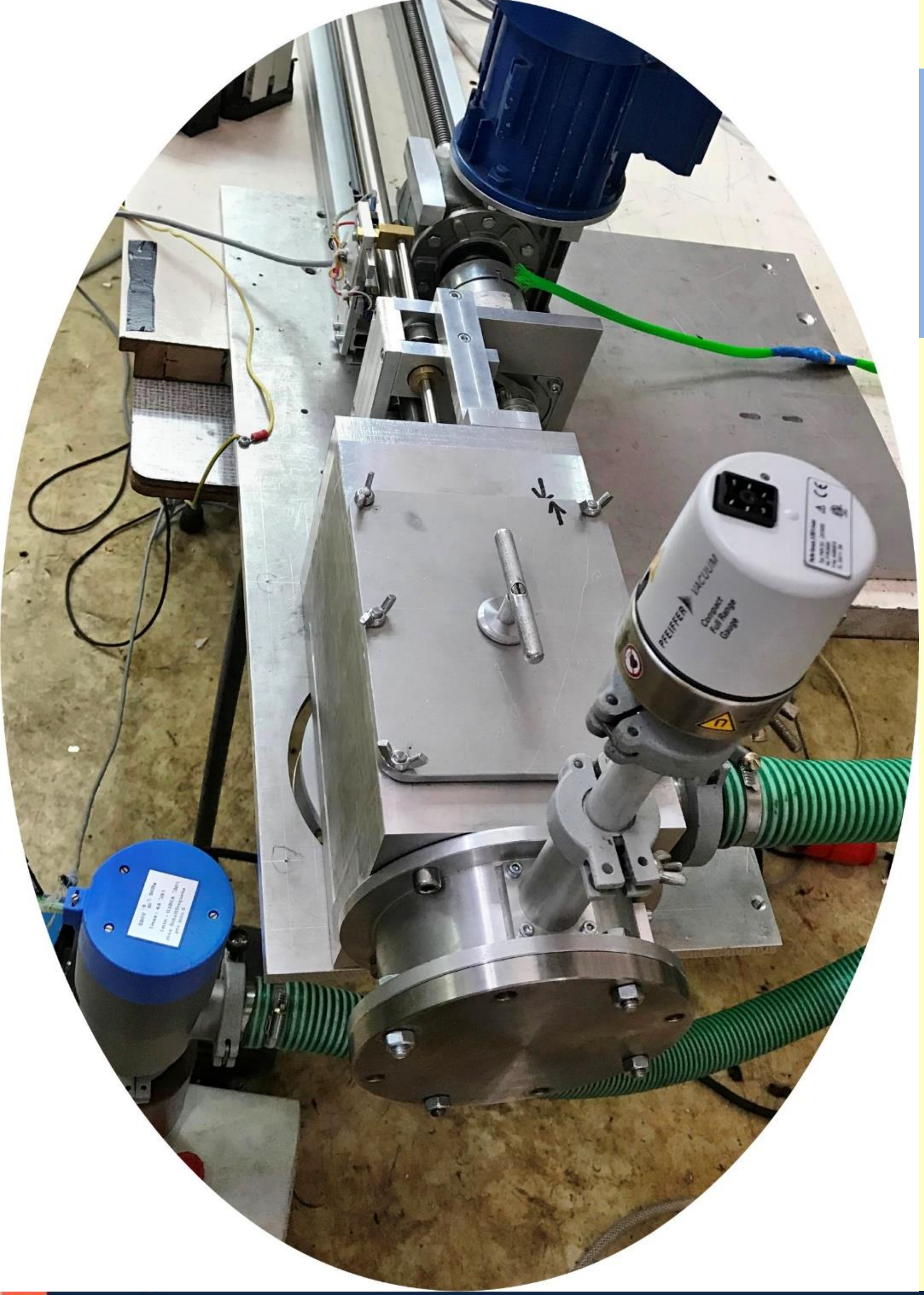
$^{70}Ge(\alpha,2n)^{72}Se/^{72}As$

recently.

Because we have noticed a need for higher beam intensities,
it was decided to design and construct a new, well cooled target station for internal beam irradiation.

The team implementing this project:

J. Choiński, T. Bracha, B. Radomyski, Ł. Świątek, M. Antczak, A. Jakubowski, P. Jasiński, J.Jastrzębski, R. Kopik, K. Łabęda, A. Pietrzak



This station has a new vacuum chamber, a target holder with tilted target, a drive system of the target holder, a drive system of the target station. All operations can be performed remotely using a standalone PLC-based system.

The construction of the target holder with a metallic target should be enough resistant to withstand about 500 W power.

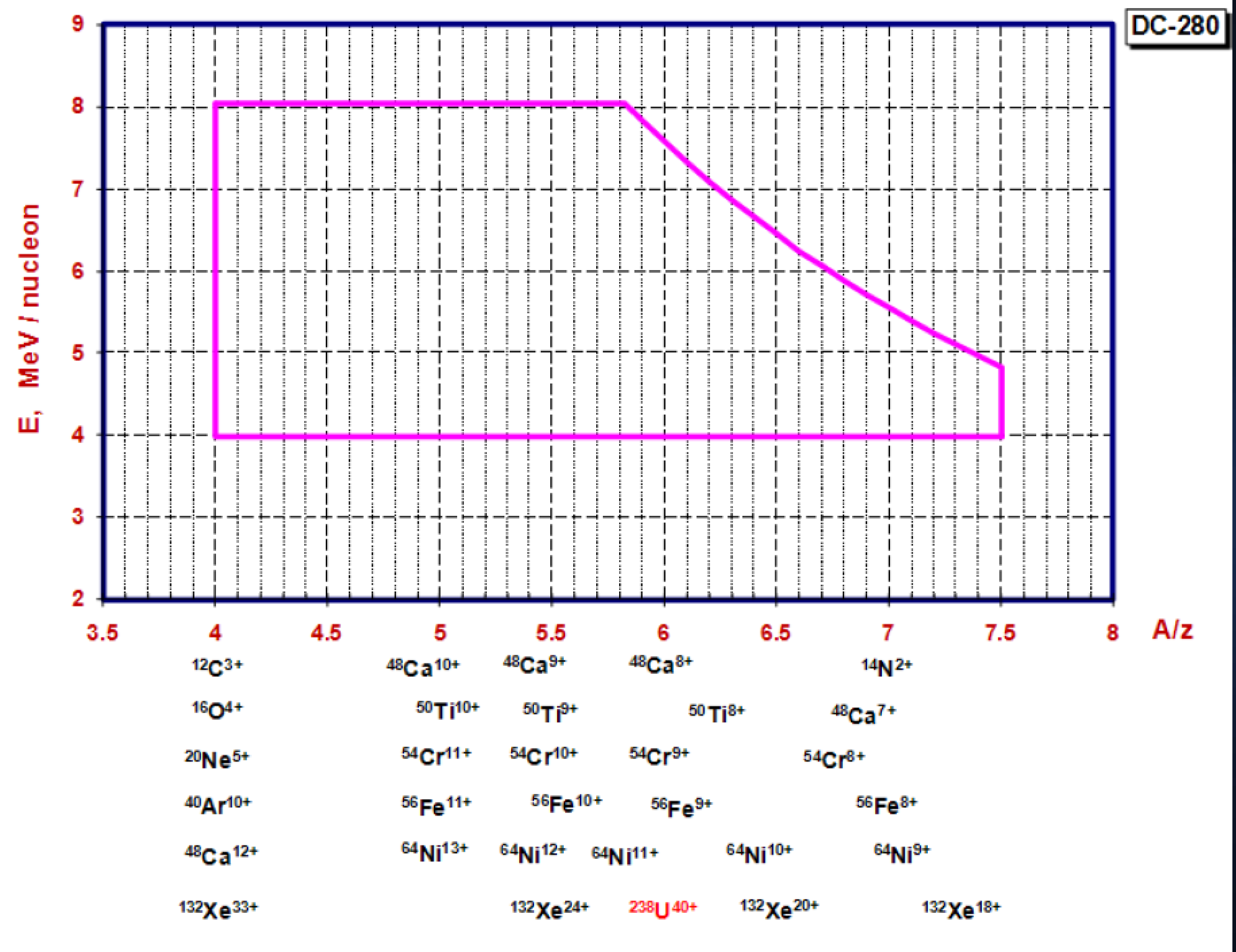
During a target irradiation a beam current, temperature and water flow will be on-line monitored.

A list of isotopes possible to be produced with an alpha beam in future

radioisotope	$T_{1/2}$	main energy line [keV]	reaction	energy of α [MeV]	possible application
^{43}K	22.6 h	(β^{-}) 373, 617	$^{40}Ar(^{4}He,p)^{43}K$	3.7 $\nearrow$	heart muscle, brain tumor
^{52}Fe	8.2 h	$(\beta^{+}$ i EC$)$ 169, 511	$^{50}Cr(^{4}He,2n)^{52g}Fe$, $^{52}Cr(^{3}He,3n)^{52g}Fe$	18 $\nearrow$ 10 $\nearrow$	hematology, bone marrow
^{67}Ga	78 h	(EC) 93, 185, 300	$^{64}Zn(^{4}He,p)^{67}Ga$, $^{64}Zn(4He,n)^{67}Ge \rightarrow {}^{67}Ga$ (18.7 m)	4.2 $\leftrightarrow$ 19	liver, spleen, bones, bone marrow, intestines, SPECT
^{97}Ru	2.9 d	(EC) 216, 324	$^{nat.}Mo(^{4}He,xn)^{97}Ru$, $^{nat.}Mo(^{3}He,xn)^{97}Ru$	44 12 $\leftrightarrow$ 36	malignant tumors, pathological changes, bones, myocardial infarction
^{111}In	2.8 d	(EC) 171, 245	$^{109}Ag(^{4}He,2n)^{111}In$	20 $\leftrightarrow$ 30	scintigraphy of leukocytes, neuroendocrine tumors, monoclonal antibodies, SPECT
^{123}I	13.3 h	(β^{+}) 159	$^{121}Sb(^{4}He,2n)^{123}I$	25 $\leftrightarrow$ 31	ocular melanoma, thyroid, liver, lungs, heart, prostate and so on, SPECT
^{129}Cs	32.4 h	(EC) 372, 411	$^{127}I(^{4}He,2n)^{129}Cs$	15.8 $\nearrow$	hart, lungs, stomach
^{167}Tm	9.3 d	(EC) 208	$^{165}Ho(^{4}He,2n)^{167}Tm$	16.5 $\nearrow$	bone system
^{199}Tl	7.4 h	(EC) 158, 208, 247, 465	$^{197}Au(^{4}He,2n)^{199}Tl$	28	perfusion myocardial scintigraphy

THE NEW DC-280 CYCLOTRON. STATUS AND PERSPECTIVES

G.G. Gulbekian, S.N. Dmitriev, Yu.Ts. Oganessian, B.N. Gikal, I.V. Kalagin, V.A.Semin, S.L. Bogomolov, I.A.Ivanenko, N.Yu.Kazarinov, G.N. Ivanov, N.F.Osipov



A standalone external target system at Radiopharmaceuticals Production and Research Center at HIL UW

It is protected by RP patent No. P414054

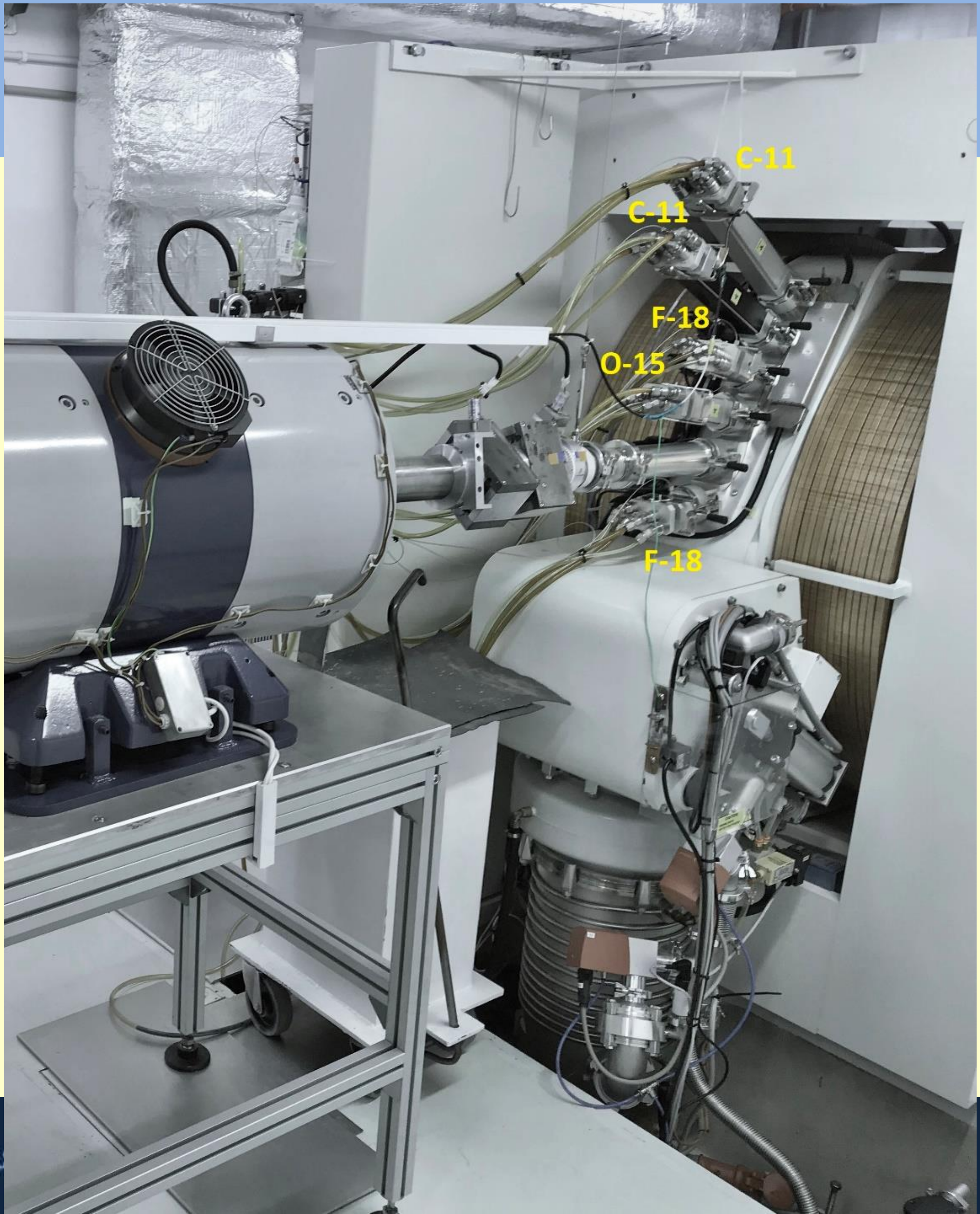
Radiopharmaceuticals Production and Research Centre

with high current PETtrace commercial cyclotron dual beam,

p – 16.5 MeV 80 μA
and
d – 8.4 MeV 60 μA

INAUGURATION **2012**

The set of target systems at RPRC: C-11, O-15, F-18



Alternative Methods for the ^{99m}Tc Production

Agreement No PBS1/A9/2/2012 funded by the National Centre for Research and Development

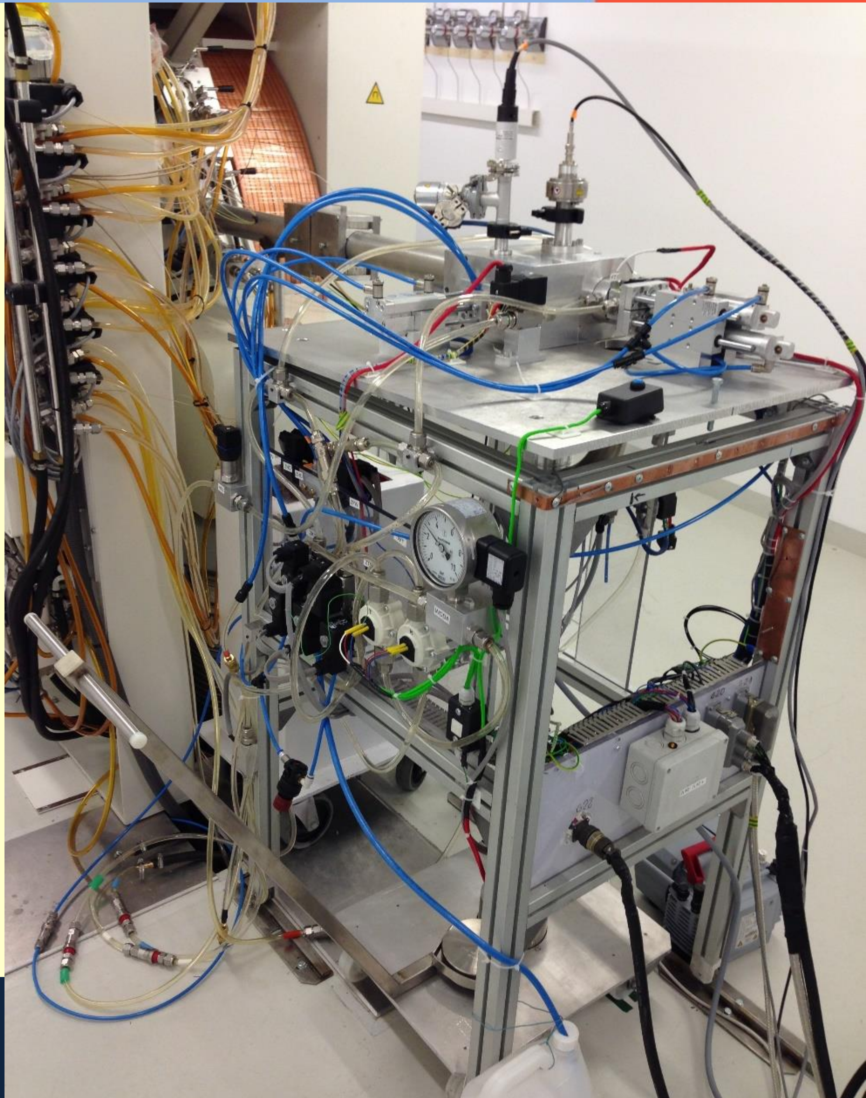
The consortium of:
the Polatom – National Centre for Nuclear Research
the Institute of Nuclear Chemistry and Technology
the University of Warsaw
01.11.2012 – 31.10.2015

^{100}Mo(p,2n)^{99m}Tc

As the outcome of the ALTECH project.

The HIL team implementing this task in the project:

J. Choiński, T. Bracha, B. Radomyski, Ł. Świątek,
M. Antczak, A. Jakubowski, P. Jasiński, J. Jastrzębski,
R. Kopik, M. Kopka, K. Łabęda, A. Pietrzak



Since 2015 till 2018 we executed the grant ***”The development of methods for production of new radiopharmaceuticals based on Sc radionuclides used in positron tomography (PET)” [PET-SKAND]*** agreement no PBS3/A9/28/2015 awarded to a consortium, and financed by the National Centre for Research and Development.

Production of:

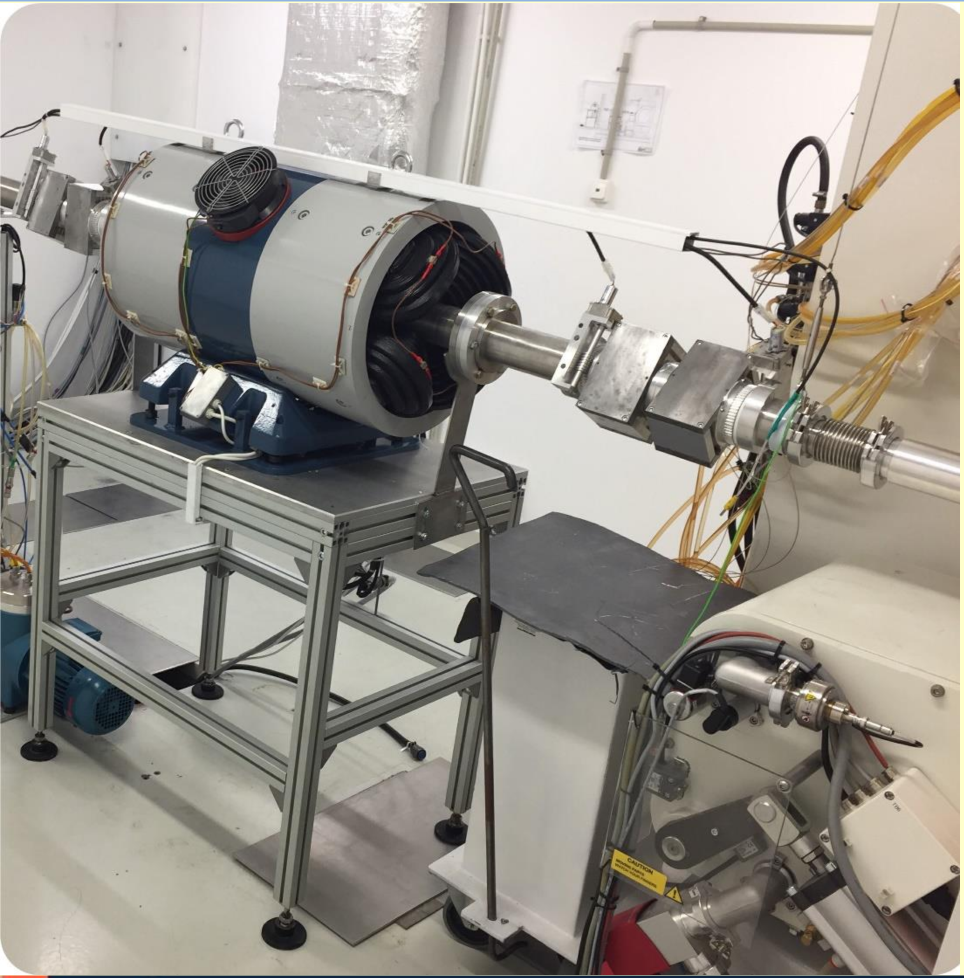
$^{43}Ca(p,n)^{43}Sc$

$^{42}Ca(d,n)^{43}Sc$

$^{44}Ca(p,n)^{44}Sc$

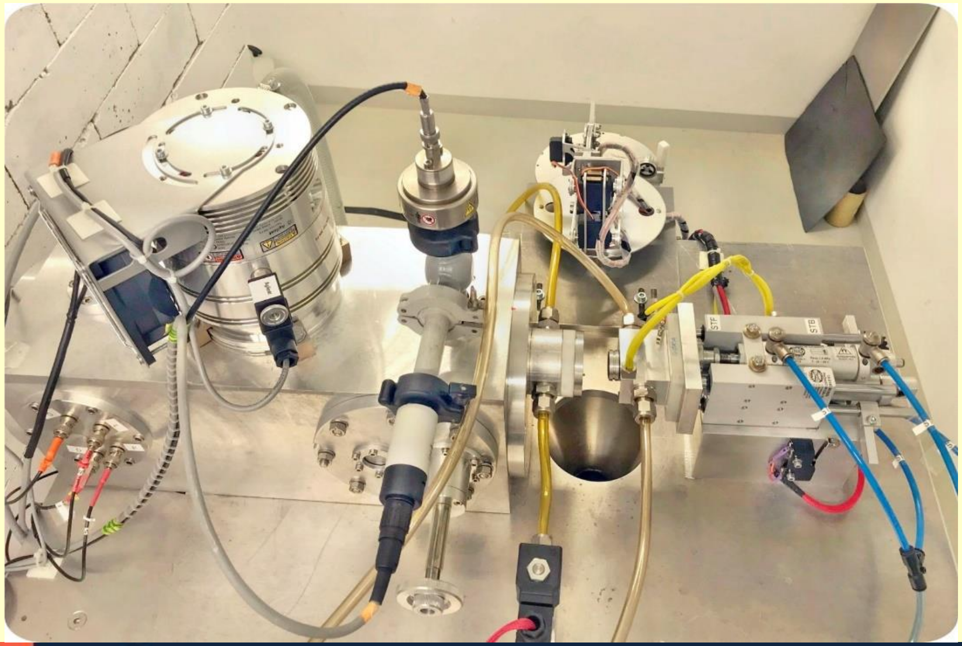
consortium of:
the Institute of Nuclear Chemistry and Technology
the Polatom – National Centre for Nuclear Research
the University of Warsaw

A standalone external target system has been upgraded.

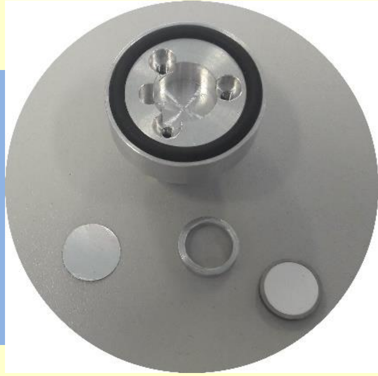


The beam line:

- length 340 cm,
- one electro-magnetic quadruple dublet and
- four correction magnets made of permanent magnets;

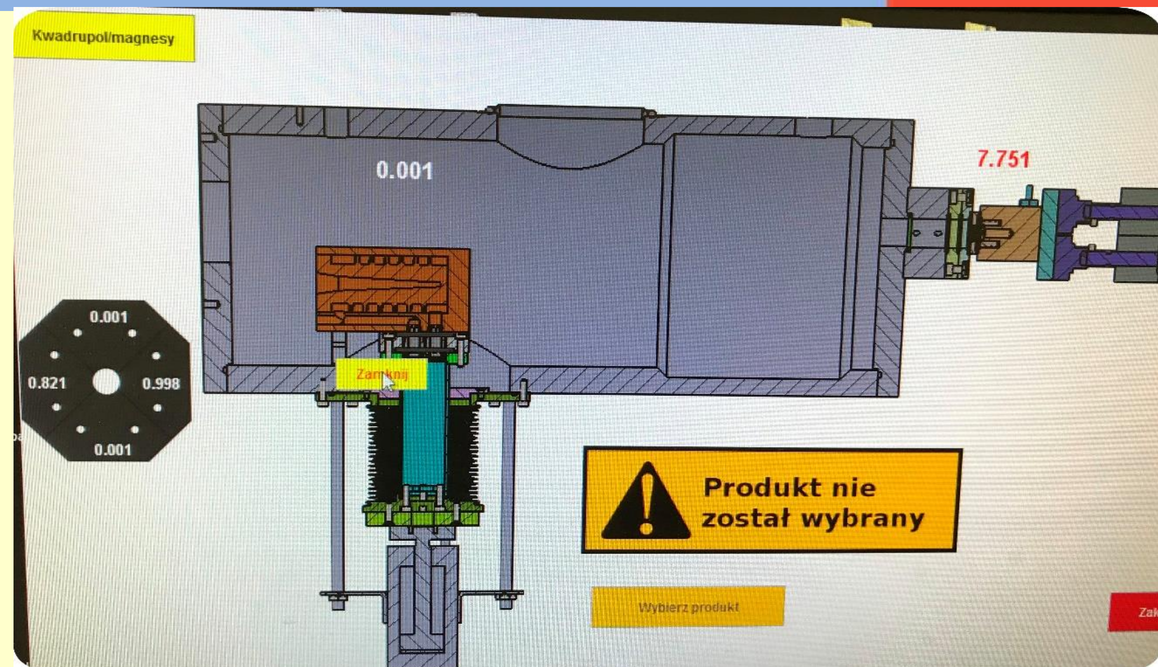


- a vacuum chamber equipped with a diagnostic system consisting of a tantalum collimator and a Faraday cup and with its complete, autonomous vacuum system; the tantalum collimator consists of four independent electrodes;
- a target chamber;
- a helium cooling system of the vacuum window;
- a water cooling system of the Faraday cup;
- a water cooling system of the target chamber;
- a compressed air system;
- a robot that loads targets to the target chamber;
- an autonomous control system;



$CaCO_3$ target
courtesy of Anna Stolarz

Target after irradiation



GUI

The objective of this system is the production of different isotopes from metallic or powder targets.

p 16.5 MeV, **d** 8.4 MeV, **α** 32 MeV

isotope	$T_{1/2}$	reasonable production [% nat. abundance]	possible application
^{45}Ti	3.08 h	**^{45}Sc(p,n)** [100%]	PET
^{60}Cu	23.7 m	**^{60}Ni(p,n)** [26%],	PET/3ɣ
^{64}Cu	12.7 h	**^{64}Ni(p,n)** [0.9%]	PET; β-/Auger therapy
^{66}Ga	9.49 h	**^{66}Zn(p,n)** [28%] or **^{63}Cu(α,n)** [69%]	PET/3ɣ
^{68}Ga	67.7 m	**^{68}Zn(p,n)** [18%] or **^{65}Cu(α,n)**	PET
^{86}Y	14.74 h	**^{86}Sr(p,n)** [10%]	PET/3ɣ
^{89}Zr	78.4 h	**^{89}Y(p,n)** [100%] **PROMISING**	PET/3ɣ, studied @HIL (2016)
^{90}Nb	14.6 h	**^{90}Zr(p,n)** [51%]	PET/3ɣ
^{110m}In	69.1 m	**^{110}Cd(p,n)** [12%] or **^{107}Ag(α,2n)** [52%]	PET/3ɣ
^{123}I	13.2 h	**^{123}Te(p,n)** [0.9%] or **^{122}Te(d,n)** [2.6%]	SPECT
^{124}I	4.18 d	**^{124}Te(p,n)** [5%] or **^{121}Sb(α,n)** [57%] **PROMISING**	PET/3ɣ
^{165}Er	10.3 h	**^{165}Ho(p,n)** [100%] **PROMISING**	Auger therapy
^{186}Re	90.6 h	**^{186}W(p,n)** [28%] or **^{184}W(α,np)** [31%]	SPECT; β- therapy
^{55}Co	17.54 h	**^{54}Fe(d,n)** [6%]	PET/3ɣ
^{61}Cu	3.32 h	**^{60}Ni(d,n)** [26%] **PROMISING**,	PET
^{103}Pd	17 d	**^{103}Rh(d,2n)** [100%] **PROMISING**	brachytherapy

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Thank you very much for your attention!

www.slcj.uw.edu.pl