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Cyclotron life cycle - Introduction

Radek Trtílek

11th April 2024

UJV Group

PEOPLE I INNOVATION I TECHNOLOGY

GENERAL INTRODUCING OF THE UJV GROUP

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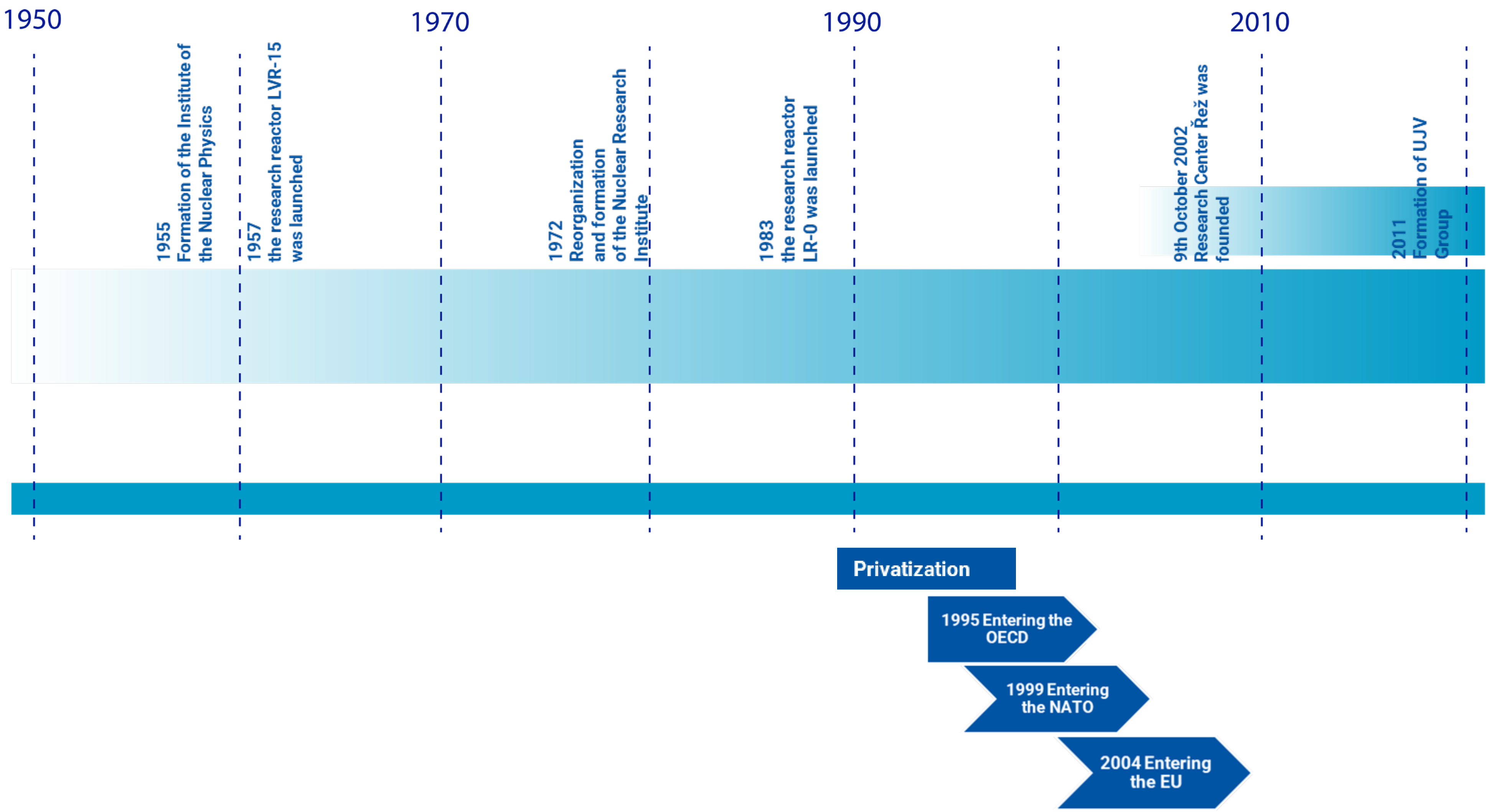
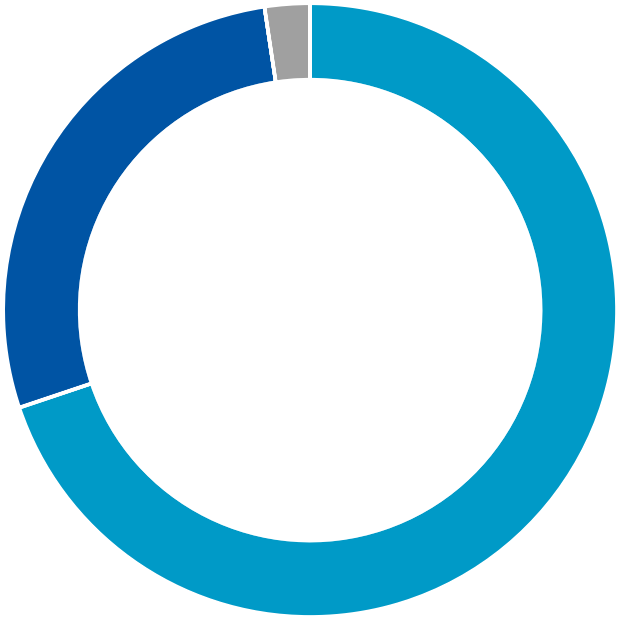
HISTORY OF NUCLEAR RESEARCH IN ŘEŽ



SHAREHOLDERS

ČEZ, a. s.	69,85 %
Slovenské elektrárne, a. s.	27,77 %
Municipality of Husinec	2,38 %



UJV Group

The portfolio of services of **ÚJV Řež** is synergistically complementary to its 100% owned subsidiaries, together form the **UJV Group**

UJV Group consists of:

ÚJV Řež	www.ujv.cz
Research Centre Řež	www.cvrez.cz
Research and Testing Institute Plzeň	www.vzuplzen.cz
ŠKODA PRAHA	www.skodapraha.cz
RadioMedic	www.radiomedic.cz

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UJV Group – people, experience, infrastructure

- **Applied research, design and engineering activities in:**
  - **Energy: Nuclear & Hydrogen**
  - **Heavy industry**
  - **Healthcare, Nuclear medicine**
- **State-of-the-art workplace in the Czech Republic and in the European context**
- **Experienced specialists**
- **Unique technical infrastructure**

OUR WORKFORCE COUNTS APPROX.
1300+
EMPLOYEES

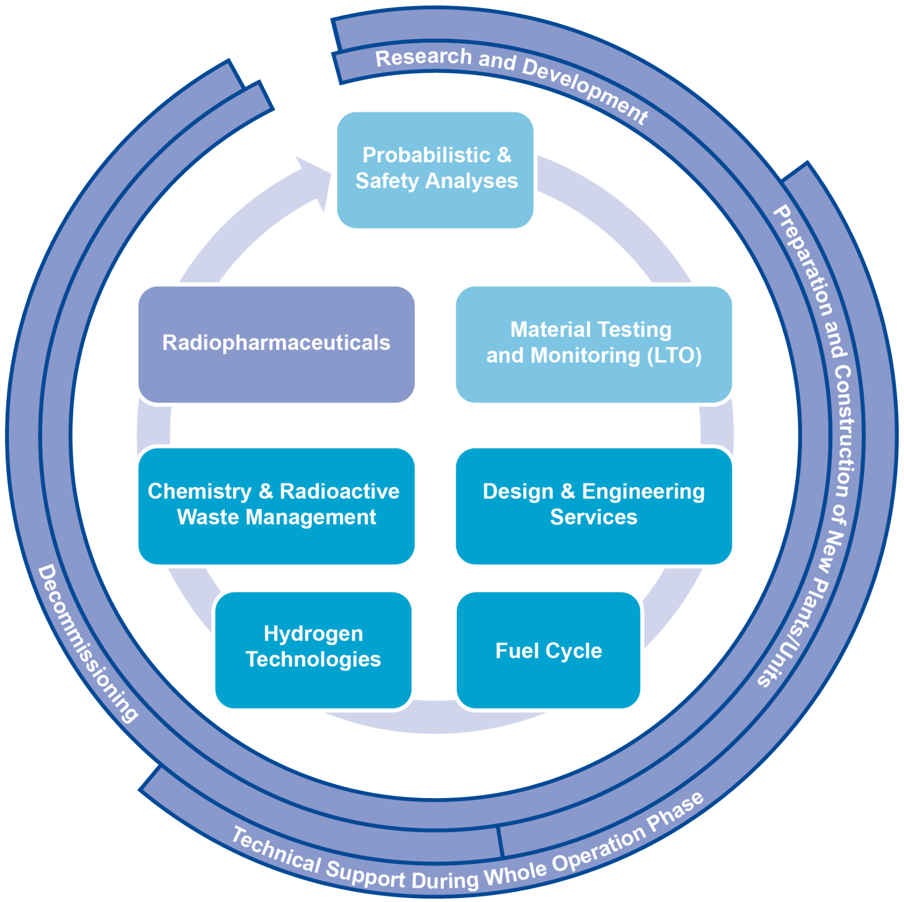
HISTORY
65+
YEARS

ANNUAL REVENUE
€ >120 million

TOTAL ASSETS
€ >200 million

PRODUCTS & SERVICES

- **Design and engineering**
- **Nuclear safety and reliability analysis**
- **Fuel cycle support services**
- **Technical support for operation of nuclear and conventional power plants**
- **Radwaste and decommissioning**
- **Radiopharmaceuticals**
- **Hydrogen Technologies**
- **Applied R&D (across all fields)**



Cyclotron life cycle I - Operation

Ondřej Komžák

11th April 2024

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PEOPLE I INNOVATION I TECHNOLOGY

SOURCE OF RADIONUCLIDES - CYCLOTRON

Positron emitters are produced nowadays mainly on the so-called cyclotron.
A cyclotron is a particle accelerator producing protons and deuterons, that are aimed at target containing a non-radioactive substance for irradiation

Fluorine-18: target: liquid, 18O-enriched water

$$^{18}O + p \rightarrow {}^{18}F + n$$

Carbon-11: target: gas, nitrogen oxide mixture

$$^{14}N + p \rightarrow {}^{11}C + \alpha$$

PET RADIOPHARMACEUTICALS IN CZECH REPUBLIC

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R&D PET centre Řež

PET centre Praha

PET centre Brno

Production:

PET centres operated by ÚJV ŘEŽ
- Praha
- Brno
- Řež

PET radiopharmaceuticals users

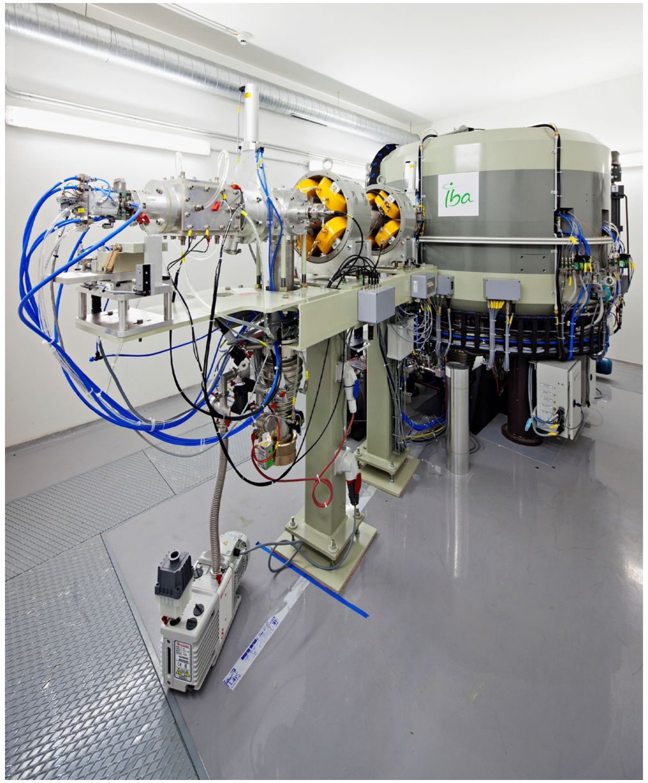
Mikro PET/CT:
- Institute of Physiology Czech Academy of Sciences – Praha
- Institute of Molecular and Translational Medicine – Olomouc

Under construction PET/CT workplace :
- Karlovarská krajská nemocnice

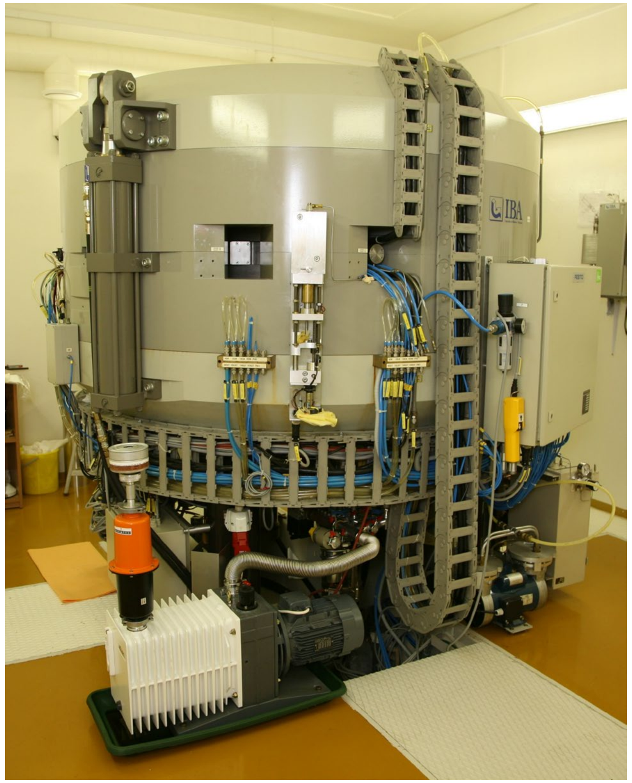
PET/CT (PET/MR) workplaces – hospitals:
- Nemocnice Na Homolce Praha
- Všeobecná fakultní nemocnice v Praze
- Ústřední vojenská nemocnice Praha
- Protonové centrum Praha
- Fakultní nemocnice Plzeň
- Krajská zdravotní nemocnice Chomutov
- Masarykova nemocnice v Ústí nad Labem
- Nemocnice České Budějovice
- Krajská nemocnice Liberec
- Nemocnice Jihlava
- Pardubická nemocnice
- Fakultní nemocnice Hradec Králové
- Masarykův onkologický ústav v Brně
- Fakultní nemocnice Brno
- Fakultní nemocnice Olomouc
- Krajská nemocnice Tomáše Bati Zlín
- Nemocnice AGEL Nový Jičín
- Fakultní nemocnice Ostrava

3 IBA CYCLOTRONS

PET Řež - Cyclone 18/9, installed 2012



PET Praha – Cyclone 18/9, installed 1999



PET Brno - Cyclone 18/9, installed 2007

PET CENTRE PRAGUE

- Address:

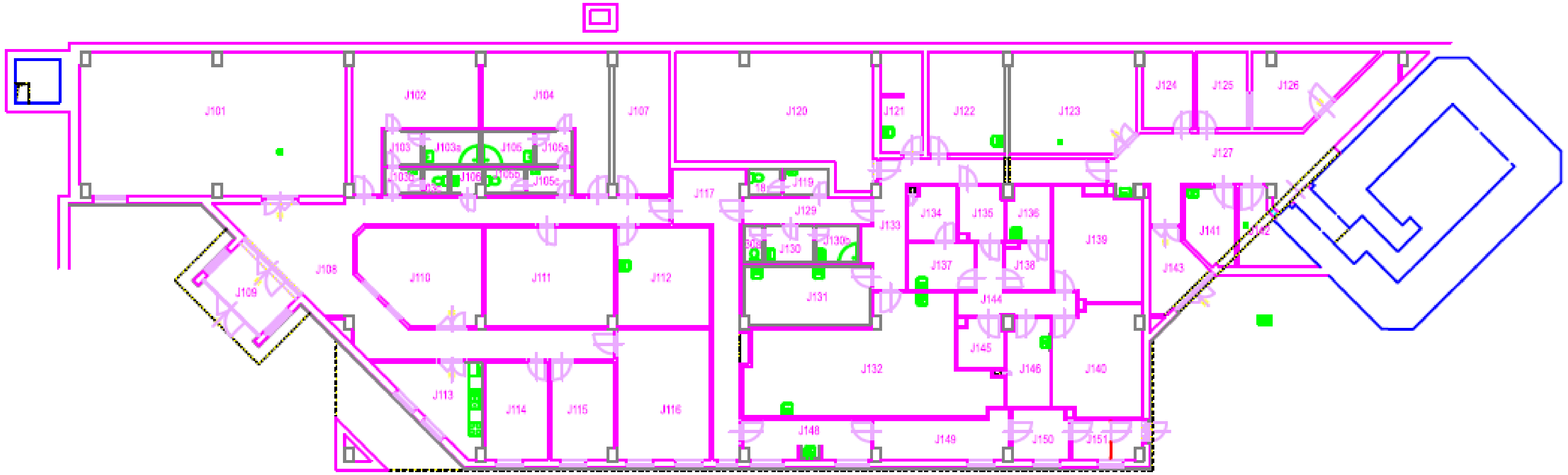
  Nemocnice Na Homolce area

  Roentgenova 2, 150 30 Praha 5 – Motol

  Česká republika

  GPS: 50.0746047N, 14.3570258E

- The site is classified as category III workplace by the Act no. 263/2016 Coll., Atomic Act.



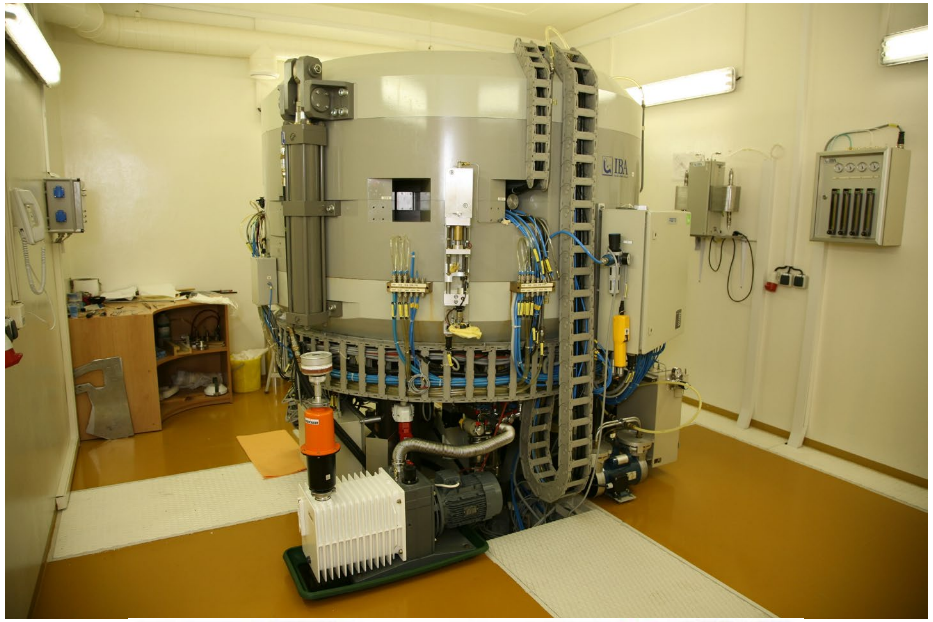
NINETIES – BUILDING STAGE

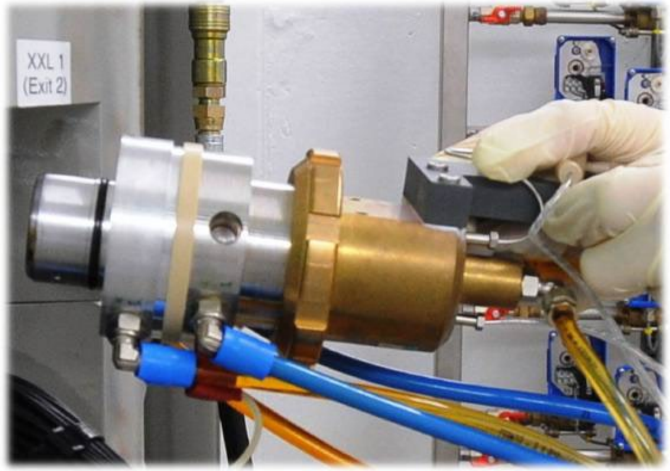
17.12.1998 Future vault
The bearing piles are 14-16 meters deep

30.1.1999 – reinforcing the walls

ORIGINAL CYCLOTRON OF ÚJV ŘEŽ AT PET PRAGUE

IBA Cyclone 18/9	
Launched	November 1999
decomissioned	March 2022
Used for	18F, very scarcely 11C
Mass	25000 kg
External dimensions	2050 X 2200 mm
Input	55 kW/ 6 kW (stand-by)
Accelerated ions	H-
Extracted ions	H+ (proton)
Highest ion source work current	80 μA
Kinetic energy of accelerated particles	18 MeV
Plane of acceleration	horizontal
targets	Liquid 2 x XXL, 1 x LV, 1 x MV, gas $^{11}CO_2$
	Enriched water, N2 + 1%O2, N2 + 2%CO2 (for deuterons)
Stripper system	Independently controlled carousels with 2 strippers per port





UPGRADE OR REPLACEMENT?

2017 – study of PET Centre Prague: Evaluation of state of site, defining the next steps

Upgrade

- − Warranty scope
- − Replaced parts will be outdated faster
- − High price if compared to new cyclotron purchase
- − Shorter lifetime compared to new cyclotron

- + Minimum intervention to building structure
- + Known and verified technology

Replacement

- − Serious intervention to the building structure
- − Restriction of both ÚJV and Nemocnice Na Homolce sites
- − Longer launching period, training necessary
- + Shielding of targets, easy maintenance access, lower doses
- + Consumables available
- + Maintenance technologies available

BENEFITS, REASON FOR REPLACEMENT

- The PET Centre Prague started working in 1999 (the cyclotron started to be used even a year earlier).
- More frequent failures and shutdowns for repairs expected
- Increased probability of fatal, unrepairable failure and forced replacement of the cyclotron (a complication with replacing the burnt-out transformer coil in 2016 was a warning)
- The manufacturer offered exchange of whole parts of cyclotron
  - Disadvantageous price compared to whole cyclotron
  - Would not solve the problem of outdated and discontinued replacement parts

- Benefits:
  - New, more powerful and more reliable cyclotron
  - Better radiation protection of employees
  - Full warranty and support from manufacturer
  - Possibility of remote access (helpdesk, counseling)
  - Easily available consumables and spare parts

FEASIBILITY STUDY

- Preliminary basic **shielding calculations**
- Construction idea proposal of shielding
- Description of new production concept including the definition of construction modifications of the cyclotron vault (dispositions, mediums nets, air conditioning etc.) and related building modifications (ancillary systems, cyclotron cooling, sample transport etc..)
- Preliminary **statics assessment** (encumberment by new cyclotron and related modifications in object)
- **Electric supply** – idea proposal
- Low-voltage current – basic proposal of modifications
- **Radioactive waste disposal** and assessment of effect to current waste management of the Na Homolce Hospital
- **Fire protection and health safety**
- **Radiation protection and control**

CRUCIAL RISKS

- Budget overrun
- Failure to keep the schedule
- Bad collaboration of the subjects
- **Failure of building reconstruction**
- Delay in the planned term of reconstruction of the building by the owner and scheduling collision with the delivery and installation of the cyclotron
- **Shortage or absence of spare part (covid-19)**
- IBA failing to produce and deliver the cyclotron in time
- Failure to obtain necessary permits and documents from state authorities

EVALUATION OF CYCLOTRON DECOMISSIONING

- Proposed process of decomissioning
  1) Disassembly and downstripping of the cyclotron in the vault of PET Prague
  2) Extraction of cyclotron through the vault roof, transport to truck and ADR transport for decomissioning to Řež
  3) Part-by-part true decomissioning in the UJV Řež premises
- Proposed measurement process
  1) Drilling probes
  2) Cutting the cyclotron apart, transport to Dukovany NPP, measurement and return to ÚJV

- The planning partially came from Decommissioning of a IBA Cyclone 18 PET facility document and this study:

IOP Publishing | Society for Radiological Protection
Journal of Radiological Protection
J. Radiol. Prot. 41 (2021) 1344–1365 (22pp)
https://doi.org/10.1088/1361-6498/ac28f0

Practical Matter Article

Decommissioning procedure and induced activation levels, calculations and measurements in an 18 MeV medical cyclotron

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CrossMark

Abstract

The present article describes the decommissioning of a self-shielded 18 MeV medical cyclotron IBA Cyclone 18/9 after 14 years of operation. A Monte Carlo simulation of the possible nuclear reactions was performed in order to plan the decommissioning activities. During the cyclotron dismantling, the activities of the cyclotron components, concrete wall and floor samples were measured. Residual activities were analysed by means of an HPGe detector and liquid scintillation counting, and compared with simulation data. Dosimetry of the staff involved in the decommissioning procedure was monitored by individual TL dosimeters and/or digital dosimeter. The cyclotron component analysis confirmed the presence of gamma and pure beta emitters, ^{22}Na, ^{54}Mn, ^{60}Co, ^{65}Zn, ^{207}Bi, ^{55}Fe, ^{63}Ni at different values of specific activity, depending on the positioning of the sample point and on the alloy of the sampled part. In these components the presence of gamma and pure beta emitters was measured

[#] Contributed equally to this work and considered co-first authors.
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DEPOSITION OF OLD CYCLOTRON

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- A year of work on sampling the different parts and material types of the accelerator
- Using spectrometry, it will be determined when it is safe to release the parts to normal waste
- Working with the only available study from Italy, with 25 to 30 years estimated time

	Italy	PET Centre Prague
Type	IBA Cyclone 18/9	IBA Cyclone 18/9
Runtime	14 years (2001-2015)	23 years (1999-2022)
Accelerated ions, source	Only H-	H-, D- rarely before 2011
Main production use	18 MeV production of 11C and 18F	18 MeV production of 11C and 18F
Targets	Enriched water and gaseous mix of 14N+1%O2	Enriched water and gaseous mix of 14N+1%O2 N2 + 2%CO2 (for D- ions)
Usage	400 μAh/week, 20800 μAh/year, 291200 μAh in 14 years	800 μAh/week, 41600 μAh/year, 956800 μAh in 23 years
Deposition site	Off the site of new cyclotron	Off the site of new cyclotron
Number of probes	53 (depth 10 cm, diameter 2,5 cm)	N/A
Main detected radionuclides	63Ni, 54Mn, 60Co, 55Fe, 65Zn	Expected after shutdown: 63Ni, 54Mn, 60Co, 55Fe, 65Zn

Study Decommissioning procedure and induced activation levels, calculations and measurements in an 18 MeV medical cyclotron (R. Calandrino et al., Journal of Radiological Protection 6. 12. 2021), where the medical physics scientists from San Raffaele hospital and Campoverde radiometric lab took 53 samples from parts of cyclotron (IBA Cyclone® 18/9) after 5 years from decomissioning, and modeled (method Monte Carlo, programme FLUKA 2020.0.5.) activity levels towards release limit for ^{60}Co (0,1 kBq/kg), that should také 25 years in this study (30 for copper coils)

PREPARATORY STAGE

- Agreement on future contract with NHH
- Reconstruction
- **Negotiations about cyclotron installation with NHH**
- Basic documentation
- **Requirements for new cyclotron**
- **Choosing general supplier**
- **Choosing the cyclotrone**
- Building Authority permission and related decision-making authorities
- Plan of gradual **decrease of activities of the site**
- Plan of **relaunching the site** to routine activity
- All necessary statements and **permissions** from the State Institute for Drug Control
- All necessary statements and permissions from the State Office for Nuclear Safety
- Strategy of **handling of the old cyclotron**

NEGOTIATIONS WITH THE NA HOMOLCE HOSPITAL ABOUT INSTALLATION

- Negotiations and signing an agreement on future contract between UJV and the Na Homolce hospital as the building owner
  - Ensures commencing the reconstruction of the PET Centre Prague building
  - Would guarantee the renting for minimum of 2 x 8 years with logical extension for more
  - Explicitly stated part related to cyclotron replacement, or the same subject adequately governed in other way.

- A valid agreement is an impassable condition for continuation of the project.

- The desired result was an approval of NHH for the cyclotron exchange and both sided participating in close cooperation in this project. NHH representative should be included in the project team.

zdroj GeoPortal Praha

ASSESSMENT OF SLOPE STATICS, TRANSPORT ROUTE AND CRANE PLACEMENT

- It is necessary to plan thoroughly the placement of the crane, thanks to the reqiured distance of extraction (maximum weight, axis of the crane, etc.)
- necessary to be able to get a "big enough" crane to the site.

Zdroj: Geoportal Praha

STATE AUTHORITIES

SÚKL State Institute for Drug Control

State Institute for Drug Control

- According to GMP inspector from SIDC, no permission of SIDC is required for the cyclotron replacement
- Requirements for relaunching the production
  - SIDC expects us to show qualifiying tests (acceptance test), as the proof that the equipment adheres to our requirements and specifications of manufacturer
  - Target - after installation it has to be verified that there are no impurities and contaminants generated, e.g. by testing for presence of long-living radionuclide impurities in the final product

SÚJB State Office for Nuclear Safety

State Office for Nuclear Safety

- Most important parts (prepared by ENERGOPROJEKT PRAHA, ÚJV Řež)
  - Description and reasoning of planned changes
  - Expected schedule and timeframe
  - Proofs that the effects of reconstruction would not affect radiation protection and safety
  - Proposal of update of approved and presented documentation
  - Ensuring safe nuclear waste handling

- Separately processed and presented documents
  - Technical procedure for disconnection, disassembly and extraction of old cyclotron
  - Study of radiation situation of PET Centre Prague

MANAGEMENT OF PROJECT

- **Investor and end-user of cyclotron**: ÚJV Řež, a. s.
  - Feasibility study
  - Technical requirements study
  - Risk definition and their minimization to acceptable level for realization

- **General contractor**: ŠKODA PRAHA a.s.
  - Engineering, Procurement and Construction for the whole project
  - Cooperation with Client (ÚJV Řež, a. s.) as an expert company in nuclear business and end user of cyclotrone
  - Subcontractor selection and management (IBA, VF, Hanyš, EGP, Labox),
  - Collaboration with building owner (NNH) and reporting to Client (ÚJV Řež, a. s.)
  - General schedule and logistics

- Subcontractor suppliers of technologies / works

SUPPLIERS – TEAM MEMBERS

ÚJV Řež, a. s.
Divize ENERGOPROJEKT PRAHA

CVŘ Research Centre Řež

iba

ŠKODA PRAHA

VF NUCLEAR

LABOX spol. s r.o.
1993-2022

HANYŠ

NEMOCNICE NA HOMOLCE

NEW CYCLOTRON REQUIREMENTS

- Designed for accelerating particles by high-frequency electric field producing charged particles:
  - Protons 13/14/15/16/18 MeV, **150 μA on-target**
- Designed for **PET radionuclide production**
- Must allow **horizontal access** to operators
- Must contain two proton sources
- Must allow irradiation of two targets at once (**dual beam**)
- Must have **shielding sufficient** to reduce radiation burden on-site
- A part of the delivery would be a **study of radiation burden** in vicinity of the vault at maximum power of the supplied targets.
- Must allow for production of these nuclides : **18F, 11C,** 68Ga, 15O, 13N, 64Cu.
- Must allow for additional installarion of targets for 68Ga, 13N, 15O, 64Cu.

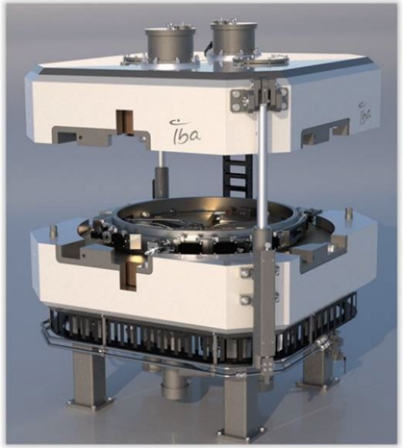
SPECIFICATIONS OF REQUIRED TARGETS

- Required available slots for inserting targets :6-8.
- Required target types:
  - **Liquid target** (2 pcs, simultaneous irradiation possible);
    - Target material: Enriched water - $H_2{}^{18}O$, volume specified by supplier
    - End of irradiation activity: **290 GBq**; at 120 min (18F)
  - **Liquid target**
    - Target material: Enriched water - $H_2{}^{18}O$, volume specified by supplier
    - End of irradiation activity: **590 GBq**; at 120 min (18F)
  - **Gas target** (for producing ^{11}C-CO_2)
    - Target material N_2 + 0,5-1% O_2
    - End of irradiation activity:**130 GBq**; at 30 min (11C)

TECHNICAL SPECIFICATIONS THE RIGHT CYCLOTRON

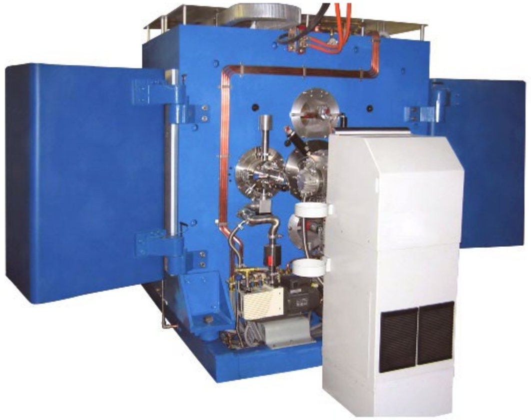
- The crucial requirement was possibility to install the machine into the current vault at PET Centre Prague
  without construction interventions to building..

- **Vault dimensions**:
  - Height 3 000 mm
  - Width 4 000 mm
  - Length 5 000 mm
  - Maximum mass: 24 tons



iba

- **Placement on bearing piles**:
  - 4 piles in square arrangement
  - Area of one bearing pile is 450 mm x 450 mm
  - The pitch of the piles is 600 mm
  - Outer dimensions are 1 500 x 1 500 mm
  - Dimenstion of the installation hole is **2 800 mm x 2 800 mm**



ADVANCED CYCLOTRON SYSTEMS, INC.

ÚJV NUCLEAR RESEARCH INSTITUTE

OTHER REQUIREMENTS

- **Power supply room**
  - Must adhere to current construction solution
  - Room dimensionsi (footpriint): 5 800 x 3 500 x 2 250 x 5 000 mm
  - Height of room: 3 200 mm
  - The distance between vault (cyclotron) and power supply room is 11 000 mm. The room has elevated floor connected to vault by under-floor channels. 8 x DN110 mm grommets available.
  - Distance between power supply room and control room is 2 500 mm, connection lines again under elevated floor.
  - A important part of the room is the air conditioning for siphoning off produced abundant heat
- **Control room**
  - Neighboring to the power supply room, separated by transparent glass wall.
  - Installation in the power supply room must allow the operators to monitor current state and read current data from their room. The control room has to be equipped by PC with control SW for cyclortron, monitor and printer.
- **Connection to synthesis lab**
  - Provided by capillary lines, max. 25 m length. Between the cyclotron vault and synthesis lab, a shielded channel (300 mm high) is connecting the rooms, caplillary lines are drawn through it.
- **Current structural state of preparation**
  - Width of the floor channels, number and size of the protective tubes, semi-hot cells requirements, access blocking, air conditioning controls.
  - Checking whether the current cooling circuit has enough capacity for the new cyclotron.

CHOOSING THE RIGHT CYCLOTRON

- **Advanced Cyclotron Systems**
  - Unsatisfactory regarding dimensions and weight. Other parameters were hence not evaluated.

- **Stargen EU s.r.o. (in lieu of GE Healthcare)**
  - Not able to fulfill technical nor qualification requirements of the tender

- **IBA RadioPharma Solutions**
  - Chosen producer

THE CHOICE MADE - CYCLONE KIUBE 150

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- Parameters:

Dimensions: 1900 x 1900 x 1800 mm (w x h x d)
Weight: 18 000 kg

Accelerated ions	H-
Extracted ions	H+ (proton)
Proton beam current	150 µA
Energy	18 MeV proton Dual energy option: 13-18 MeV selectable on two exits
Acceleration plane	Horizontal
Extraction ports and target vacuum valves	8 independent fully piped and wired;4 vacuum valves installed in standard (4 others in option)
Stripper system	8 independent with 2 foils per port (redundancy); 4 stripper system installed in standard (4 others in option)
Targets – planned to be instaled	
Liqiud targets – ^{18}F	2 x Nirta Conical 8, 296 GBq/2h (8 Ci/2h)
	1 x Nirta Conical 16, 597 GBq/2h (16 Ci/2h)
Gas targets – $^{11}CO_2$	1 x Nirta 11C-CO2, 130 GBq/30 min (4 Ci/30 min)
Other possible targets	
Liquid	$^{13}NH_3$ and ^{68}Ga
Gas	$^{11}CH_4$, $^{15}O_2$ and $^{18}F_2$

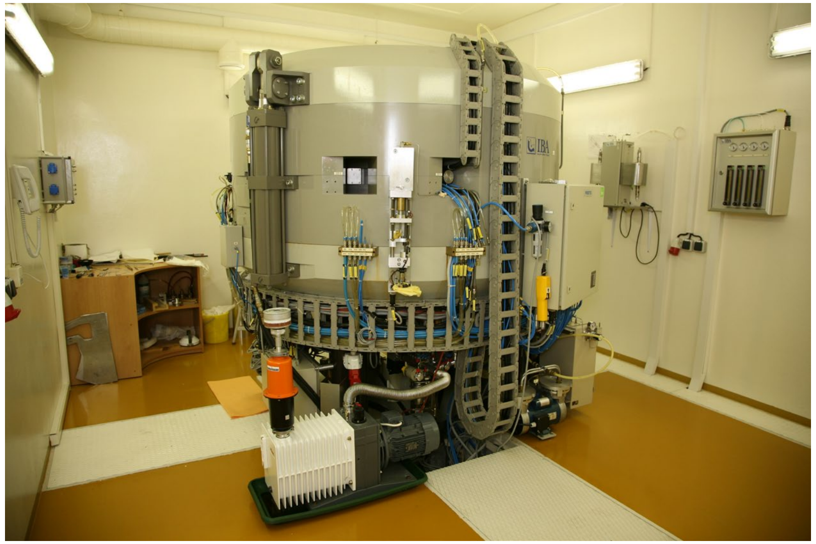
- Conditions of installation:

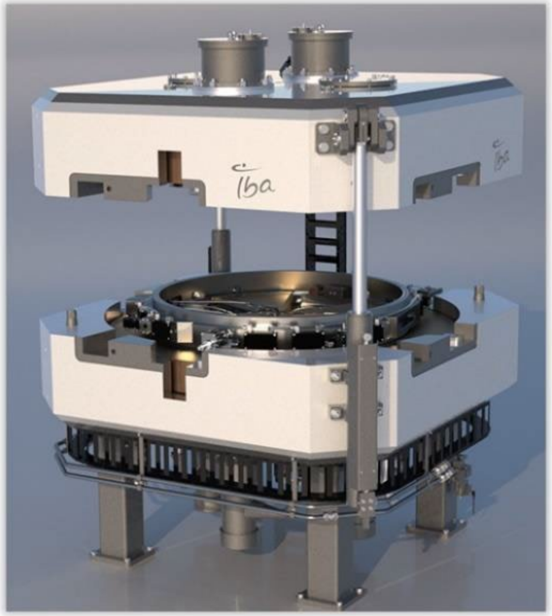
Output 70 kVA, input 55 kW running and 6 kW on standby, water cooling 55 kW, compressed air 7 bar, technical gases for cyclotron and targets

COMPARISON OF OLD AND NEW CYCLOTRON

The KIUBE has following advantages compared to Cyclone 18/9

- Better access to inner chamber – **safer and easier maintenance**
- **Source adjustment without opening**
- **Faster evacuation**
- Easier target maintenance
- Longer maintenance intervals – less exposition, lower doses for technicians
- **Increase in production** (more efficient ion source with 16 Ci liquid target, expected output activity about 592GBq/2 hrs irradiation time)
- More flexibility with dual beam mode (two targets at once)
- Online data support
- Less energy demanding



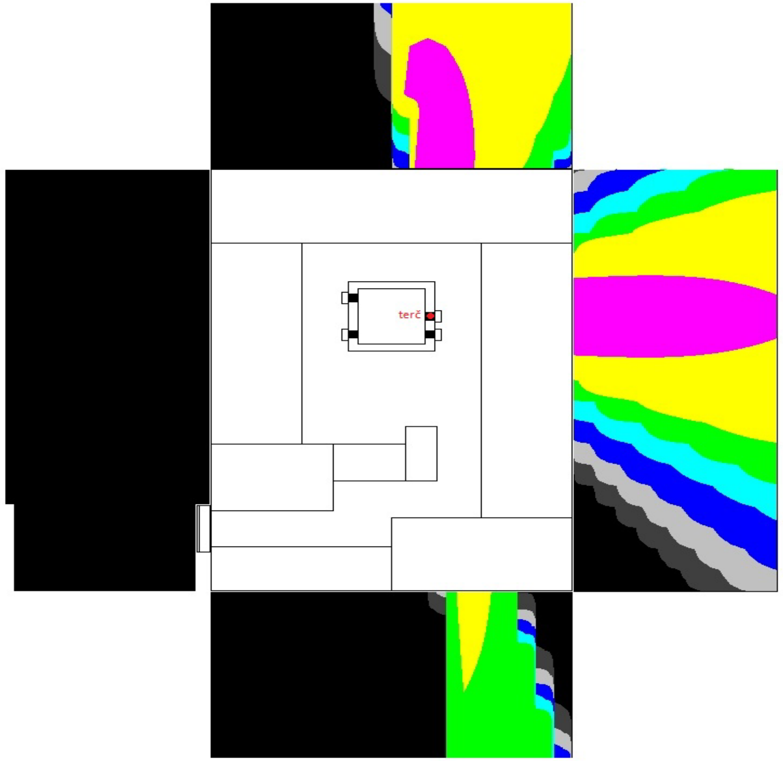


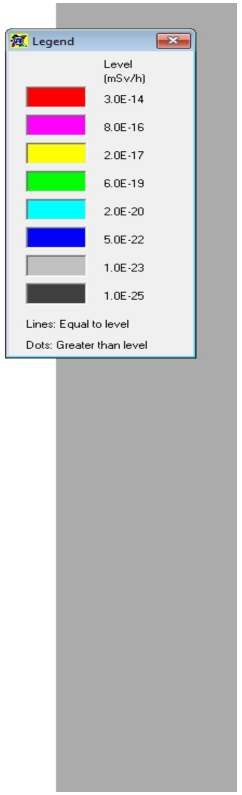
RADIATION PROTECTION

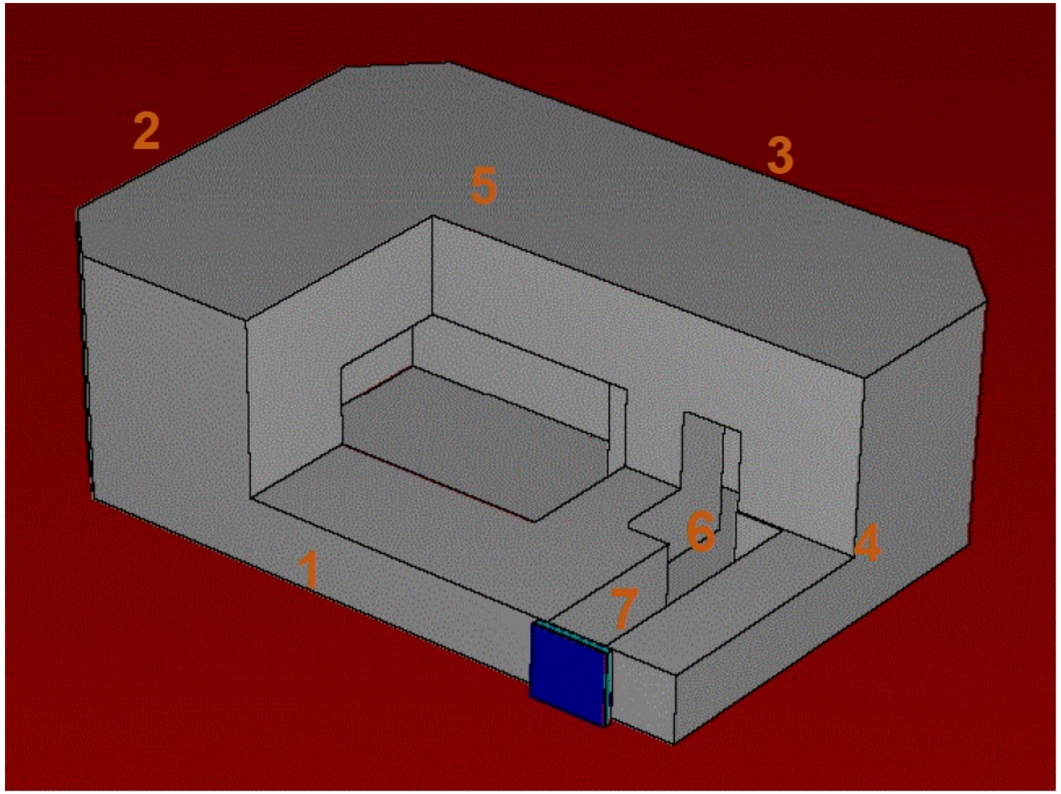
- **Class A radiation workers required** for manipulation with the cyclotron.
- The SONS (SUJB) was consulted about the reconstruction and fulfilling all legal requirements:
  - Old cyclotron would be transported to ÚJV
  - The site where the cyclotron (important source of ionizing radiation) was installed would continue its activities, only with more advanced technology – change of category III site requiring permission by § 9, par. (2), lett.. c) **Atomic Law**
- **Orientative measurements of cyclotron**:
  - Closed cyclotron: Surface dose rate **4 µSv/hr**.
  - Open cyclotron Surface dose rate **500 µSv/hr**.
- **Operator doses**:
  - Maintenance activities – max. 300 µSv / year.
  - Monthly dose of Class A radiation worker cannot exceed 6 000 µSv/month and legal limit 20 000 µSv/yr.
- It is appropriate to approach the cyclotron one day after shutdown (Air in vault air T1/2 = 1,83 hr, 10x half-llie = 18 hrs).
- First slight decrease in activity happens after 10 days, mainly in targets. Further would occur far later, when the cyclotron is deposited in ÚJV.
- Cyclotron would be transported under ADR-7 by truck to ÚJV Řež

RADIATION SITUATION STUDY

- Related to proving that the effects of reconstruction would not negatively affect the radiation protection and safety.
- A clear result showing the necessity to eliminate primarily neutron radiation







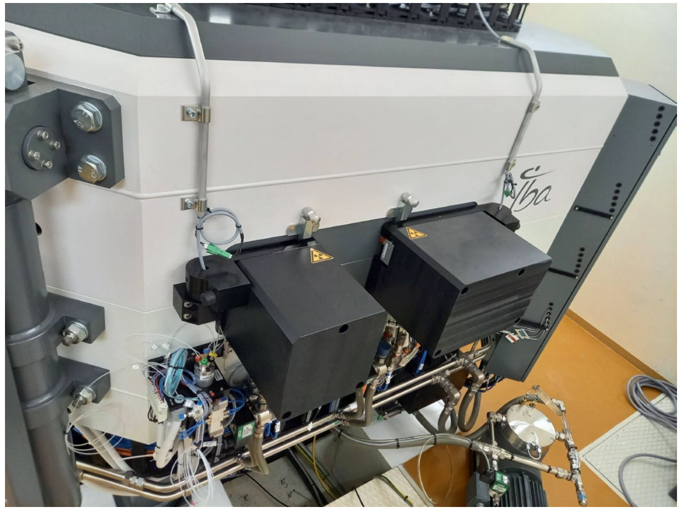
RADIATION SITUATION STUDY – NEUTRON RADIATION

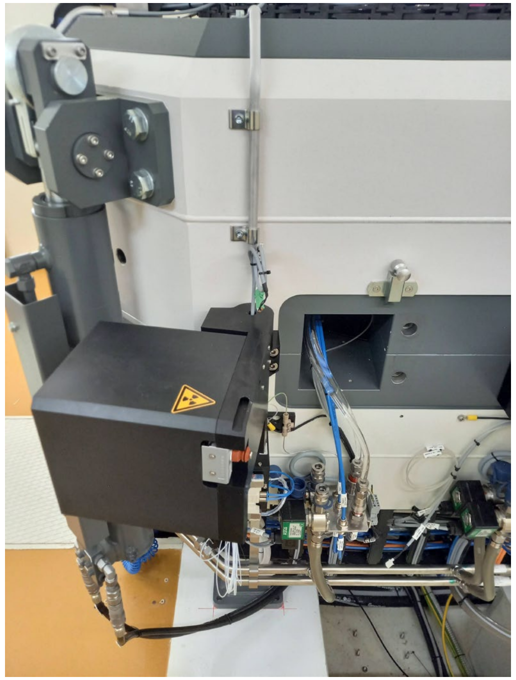
Point of interest - location	DRE [mSv/rok]
1 – behind the wall, hall-ward (m.č. 127)	2,65
2 – outer NE edge of object	0,78
3 – outer SE edge of object	0,45
4 – behind the wall, SW direction	0,24
5 – roof	0,26
6 – corridor	129 000
7 – corridor behind the door	**15 100**

Point of interest (distance from door)	DRE [mSv/yr] No plating, incl. Shielding door	DRE [mSv/yr] Plating 2x 5cm, incl. Shielding door	DRE [mSv/yr] Plating 2x 5cm + 1x 10cm, incl. Shielding door
8 (0 m)	**28-36**	**15-19**	13-16
9 (0,5 m)	**18-23**	10-13	7-9
10 (1 m)	11-14	6-8	3-4
11 (2 m)	5-7	3-4	1,7-2
12 (3 m)	3-4	2-2,5	1-1,2

RADIATION SITUATION STUDY

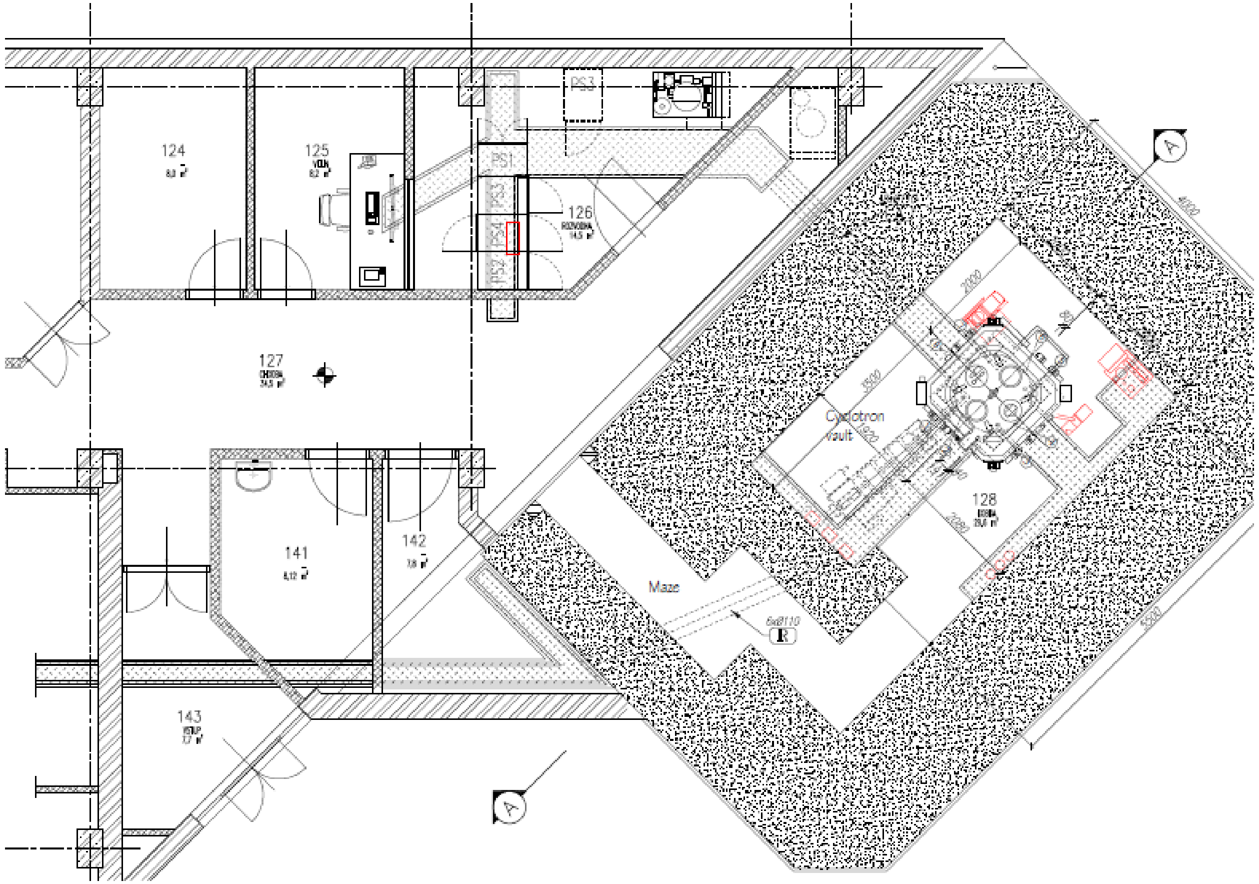
- The study concluded that following modifications have to be made:
  - Installation of shielding doors by targets
  - Replacement of vault door – doubling the shielding thickness compared to old one
  - Installation of polyethylene plates along the labyrinth access corridor
  - All to eliminate the neutron radiation





ORIENTATION OF CYCLOTRON

- Objective: Maximize the production – place suitable targets in suitable positions
- Targets has to be placed so that they do not point at space with high probability of presence of employees
- The new cyclotron has differens span and positions of "legs", the placement to original place had to be verified.
- The position was shifted by 80 mm and rotated by 180°



FUTURE PERSPECTIVES

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- Experience gained from the realization of cyclotron replacement and installation project – **ready to repeat such project** at other production PET sites.
- **Knowledge and experience** gained regarding deposition, sampling and determining strategy of **disposal of used cyclotrone**.
- **Support from cyclotron manufacturer** (maintenance, spare parts, remote access, new components development)
- **Increase of production capacity** (higher output, larger targets, dual beam mode)
- Possible purchase of new targets for more nuclides
- **All advantages provide higher stability of performance of our PET Centres**

Cyclotron life cycle II - Replacement

Martin Spilka

11th April 2024

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UJV Group

PEOPLE I INNOVATION I TECHNOLOGY

SKODA PRAHA - PRODUCTS & SERVICES

- 2020 ŠKODA PRAHA becomes part of the ÚJV Group
- 2014 certification according to BS OHSAS 18001
- 2006 - 2017 Extensive renewal and expansion program for ČEZ (~ 4 bil. EUR)
- 2005 ČEZ becomes the owner of ŠKODA PRAHA
- 2001 certification according to EN ISO 14001
- 1998 certification according to EN ISO 9001
- 1990 transformation into the joint stock company ŠKODA PRAHA
- 1953 state enterprise Energostroj founded

SKODA PRAHA - PRODUCTS & SERVICES

- **NUCLEAR POWER PLANTS - conventional island of nuclear power plants, Balance of Plant**
  - Consultancy and Owner's Engineering (OE) services for nuclear power plants
  - As EPC contractor of nuclear power plant projects in Czech and Slovak Republic, we have performed supplies of conventional island and balance of plant
  - Our activities include upgrade of power plant systems, increase of power output and implementation of most recent safety standards
- **RENEWABLES AND WASTE TO ENERGY - Biomass, Solar Parks, Biogas, Waste to Energy**
  - We offer in cooperation with recognized global manufacturers EPC and engineering services of biomass fired and biogas stations as well as municipal waste incineration plants and solar parks
- **FOSSIL FUEL PLANTS – Coal fired, Gas fired, Oil fired**
  - ŠKODA PRAHA acts as EPC Contractor as well as a provider of engineering, owner's engineering and consultancy services
  - ŠKODA PRAHA provides tailor made engineering solutions using the state of art technologies

EPC – ENGINEERING PHASE

- **Client requirements** and expectations were summarized in an Appendix to the EPC Contract
- **EPC Contractor** prepared design documentation using following inputs:
  - existing hard copy drawings of NNH,
  - information about available utilities provided by NNH utilitiy management
  - some information needed to be veried /checked on spot by measurements and surveys (ceilings, channels ets.)
  - there were also some design data available from old cyctlotrone and its auxiliaries.
- **Design meetings with IBA to go through BBOD** item by item and discuss whether particular requirements are fullfilled
- **Fullfilment of BBOD requirements** with acceptable diversions approved by IBA was critial for IBA to allow shipment to site
- **FAT** tests were performed prior to the shipment to site
- **SAT** tests on site to verify design parameters

EPC - EXECUTION STAGES

- Obtaining the state authorities‘ permissions
- Creating a cyclotron vault model
- Evaluation of the vault, including doors
- Evaluation of the vault statics
- Vault modifications – shielding panels
- Design activities
- Evaluation of statics of the slope (building is located on steep slope)
- Evaluation of the transport route through the hospital area – huge crane
- Evaluation of the means and way of transport of the new cyclotron - truck
- Evaluation of the radiation monitoring / of new cyclotron
- Opening the vault roof, extracting of old cyclotron and temporary coverage of vault
- Cyclotrone FAT testing
- Transport of old cyclotron and handling of the old cyclotron
- Transport of new cyclotron
- Installation of new cyclotron
- Closing the roof of the vault
- SAT testing and handover

OLD CYCLOTRON LOGISTICS - REMOVAL

- **Vault roof** and ceiling concrete panels were **removed** one by one and deployed to the nearby car park area for temporary storage

- As long as there were no original **transport fixators** available (after assembly were returned to manufacturer and were no longer available). We had **to manufacture new ones** as per the IBA drawings to allow both parts of cyclotrone to be fixed and ready for lifting

- The **old cylotrone** was then **lifted** and put to the shielded transport container

OLD CYCLOTRON LOGISTICS - REMOVAL

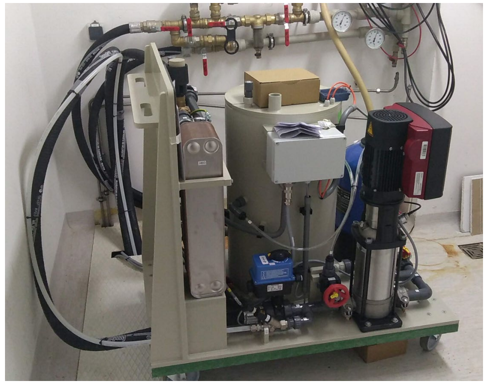
- **Vault roof opening** had to be covered by one of the concrete panels (last one), sealed by plastic foil and weather proofed by metal roof deck, because there were about 3 weeks expected for new cyclotrone to arrive.
- After old cyclotrone removal r**emaining** disassembly works **removed** old cyclotrone **auxiliary systems** and site was ready for IBA inspection to allow shipment of new cyclotrone

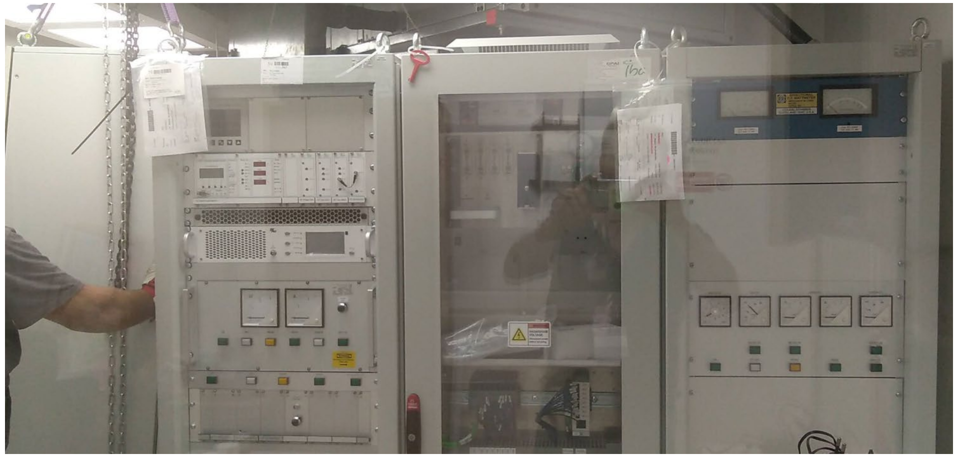
OLD CYCLOTRON AUXILIARY SYSTEMS

- All the **auxiliary systems** not suitable for new cyclotrone were **removed** and those contaminated transported together with old cyclotrone in shielded container.
- **Vault door** were **removed** as well.
- **Switchboards were removed** and floor chanels cleared and chanel plates adjusted

NEW CYCLOTRON AUXILIARY SYSTEMS

- Cyclotrone **cooling unit installed** in nearby vault room
- **New compressor and compressed air system** was **installed** (independent from hospital compressed air network as before)
- **New control switchboard installed** above existing floor chanels



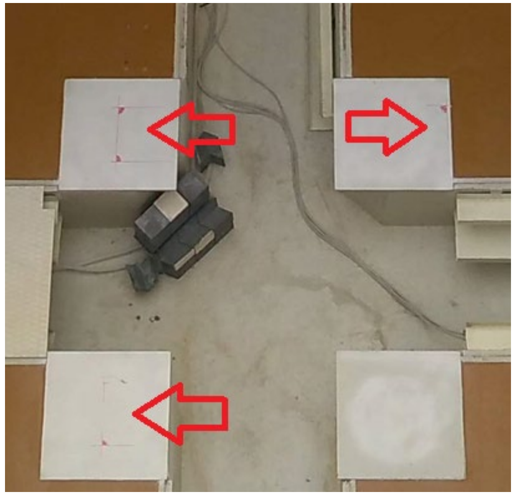


NEW CYCLOTRON AUXILIARY SYSTEMS II

- **Vault door** were **installed** together **with additional shielding** to the corridor as specified in shielding study
- **Ultrasonic flow meter** was installed on the cooling supply pipe which is cooling desk plate heat exchanger of cyclotrone cooling system – cooling water is provided by NNH chiller

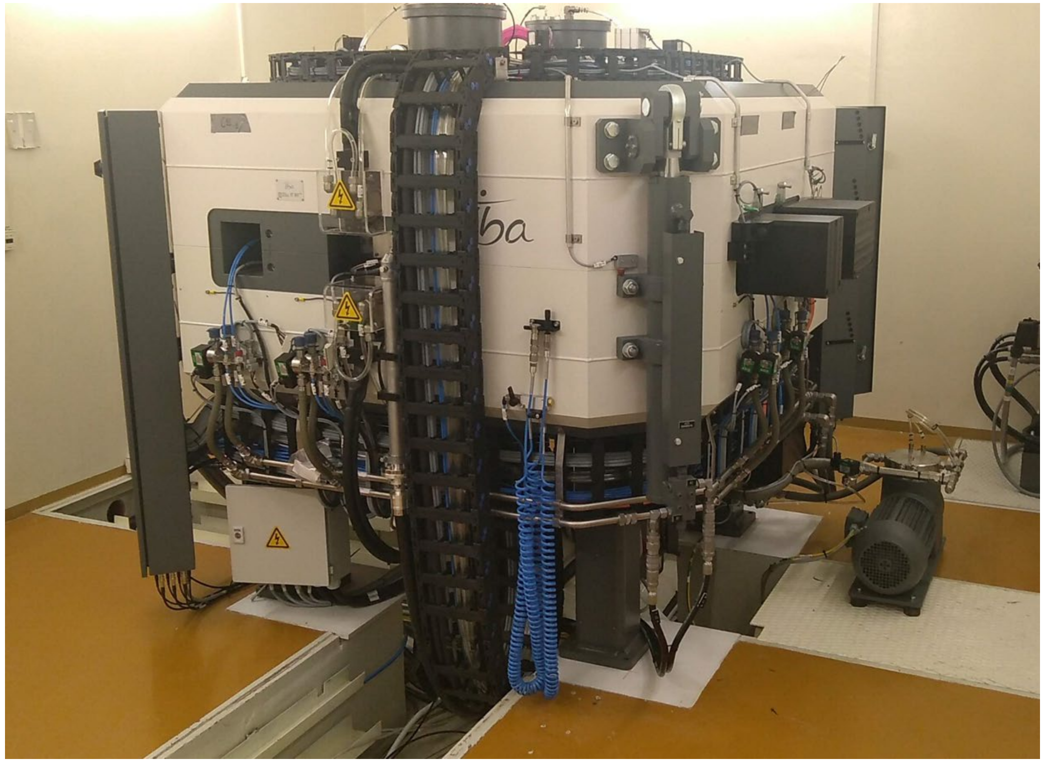
NEW CYCLOTRONE LOGISTICS - INSTALLATION

- After new cyclotrone arrival **vault roof** and ceiling concrete panel were **lifted again** and put to the nearby car park area.
- Exact **location** of new cylotrone supports **were marked** on steel supporting plates in the vault. Crane operator had to sensitively maneuver to place cyclotrone on exact place.
- Finally **all** concrete panels, roof insulation and roof deck **was placed back** into its original position.



NEW CYCLOTRON LOGISTICS – SAT

- After new cyclotrone was installed together with all auxiliary systems **SAT test** were **performed**
- SAT tests checked and verified
  - Target configuration
  - Building interlocks – beam on and emergency break
  - Proton beam characteristics - measurement of target current as the current on beam dump
  - Radioisotope production of 18F
  - Radioisotope production of 11C
- Finally UJV representatives and **operators were trained** on spot and via electronic tuition and tests



RESULTS OF THE RECONSTRUCTION

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To succesfully finish reconstruction, the following had to be presented to SUJB:

- Proof of shielding efficiency
- Successful SAT tests of cyclotron

Probe location	Dose rate equivalent [μSv/h]		
	Before reconstruction	After reconstruction	Difference
Background	0,1	0,1	0
Control room	2,6	0,4	-2,2
Hall in front of vault door (neutrons)	3	1	-2,0
Hall in front of vault door (gamma)	12,8	1	-11,8
Hall 1 m from vault wall	0,4	0,3	- 0,1
Vault roof	0,3	0,4	+0,1

CHALLENGES DURING RECONSTRUCTION

- Ensuring that **the signal** from semi-hot cells **will trigger** cells being open/closed - Installation of manually operated buttons activated by operators after checking the SHC
- Unavailability and delays of some cyclotron components (covid19, **supply chain worldwide disruption)** at the supp lier side(IBA) - some components delayed without affecting the schedule
- The **reconstruction of PET Centre Prague building** was planned to June 2022 with expected duration of 2-3 months – new cyclotrone installation had **to be coordinated** with these activities

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Cyclotron life cycle III – Preparation for disposal

Radek Pošvař

11th April 2024

UJV Group

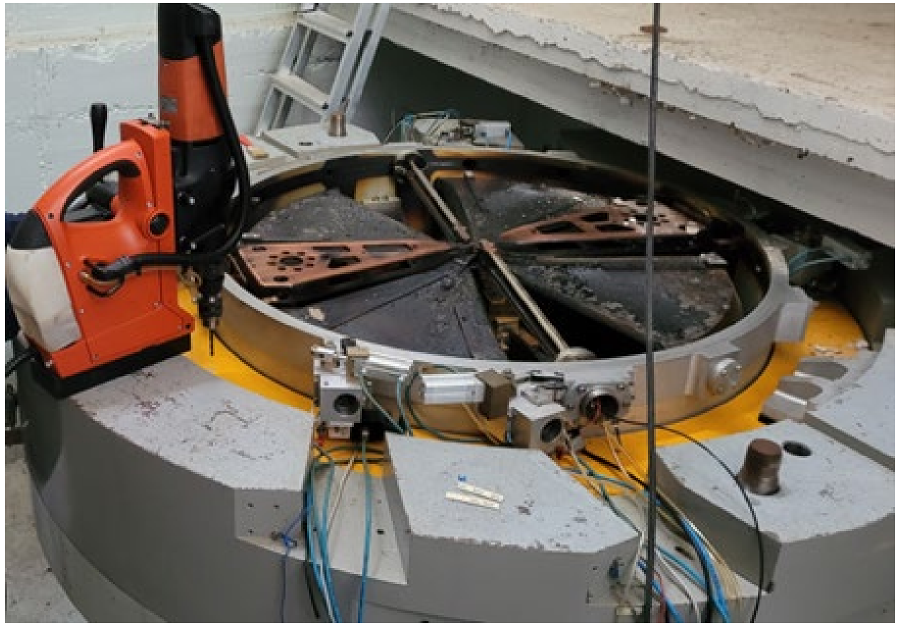
PEOPLE I INNOVATION I TECHNOLOGY

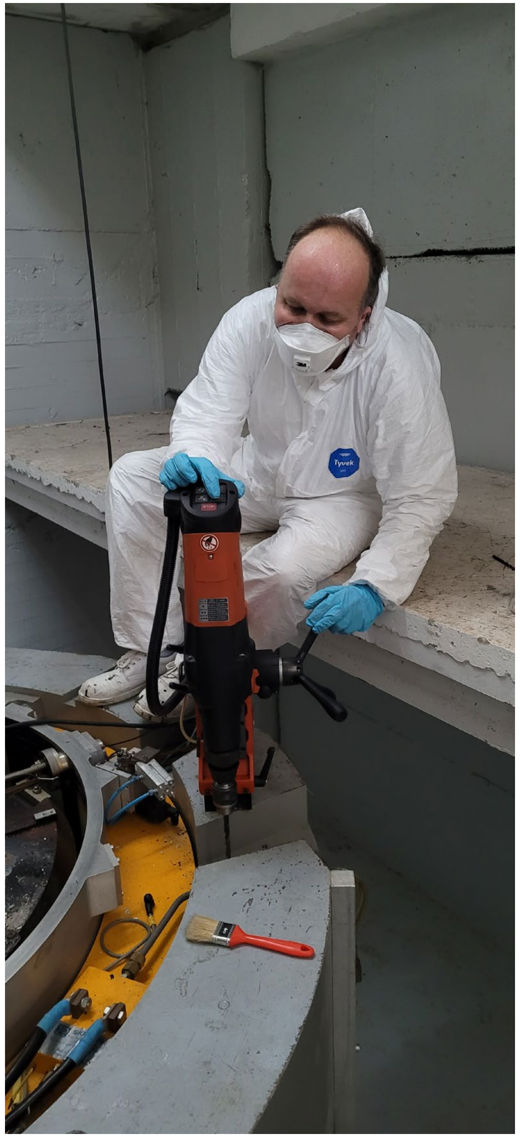
STORING OF THE CYCLOTRON AT ÚJV

- Two halves of cyclotron each weighting 12 t are stored in building No. 211/8 **High Level Waste Storage** (HLW Storage)
- Manipulation were done by series of bridge cranes
- Planned to be stored here until the entire cyclotron reaches the environmental release limit

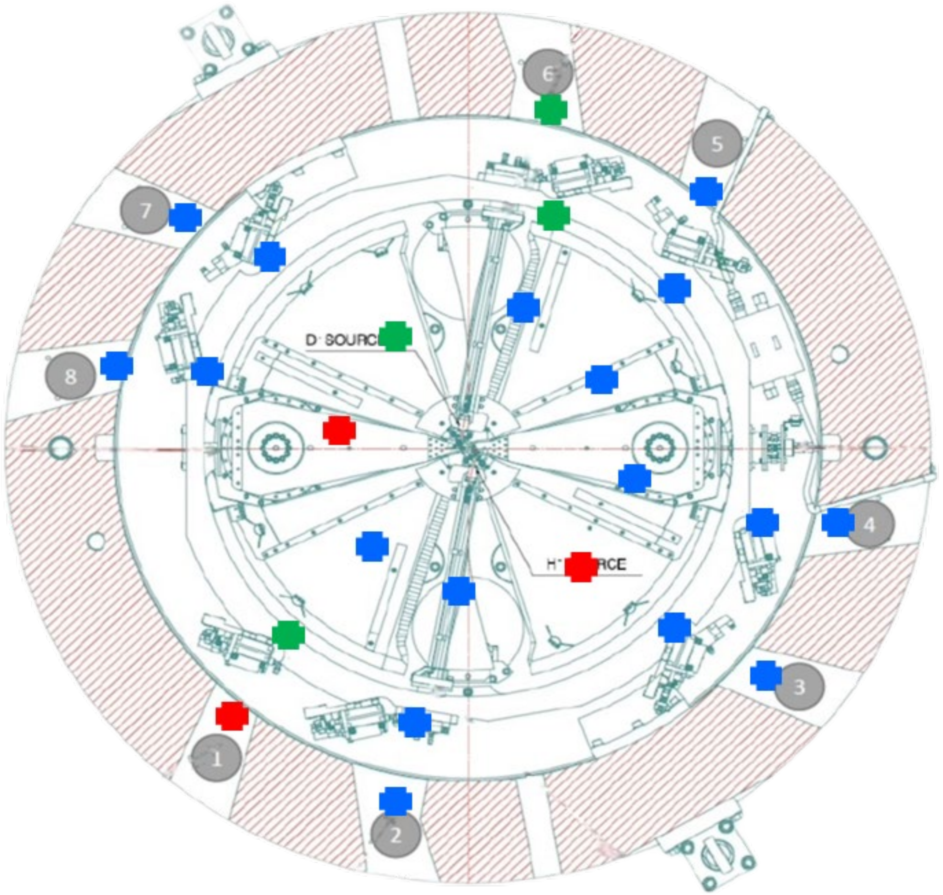
SAMPLING

- 16 samples were taken by drilling
- The depth of each drill hole was 3 cm and the drill diameter was 1 cm
- The drill used for sampling was equipped with an electromagnet for safe attachment to the body of the cyclotron during drilling





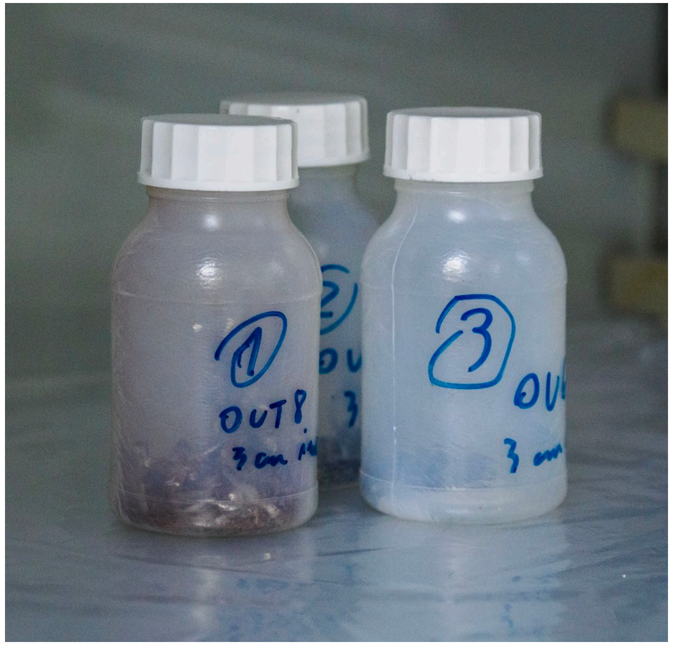
RADIOLOGICAL CHARACTERIZATION



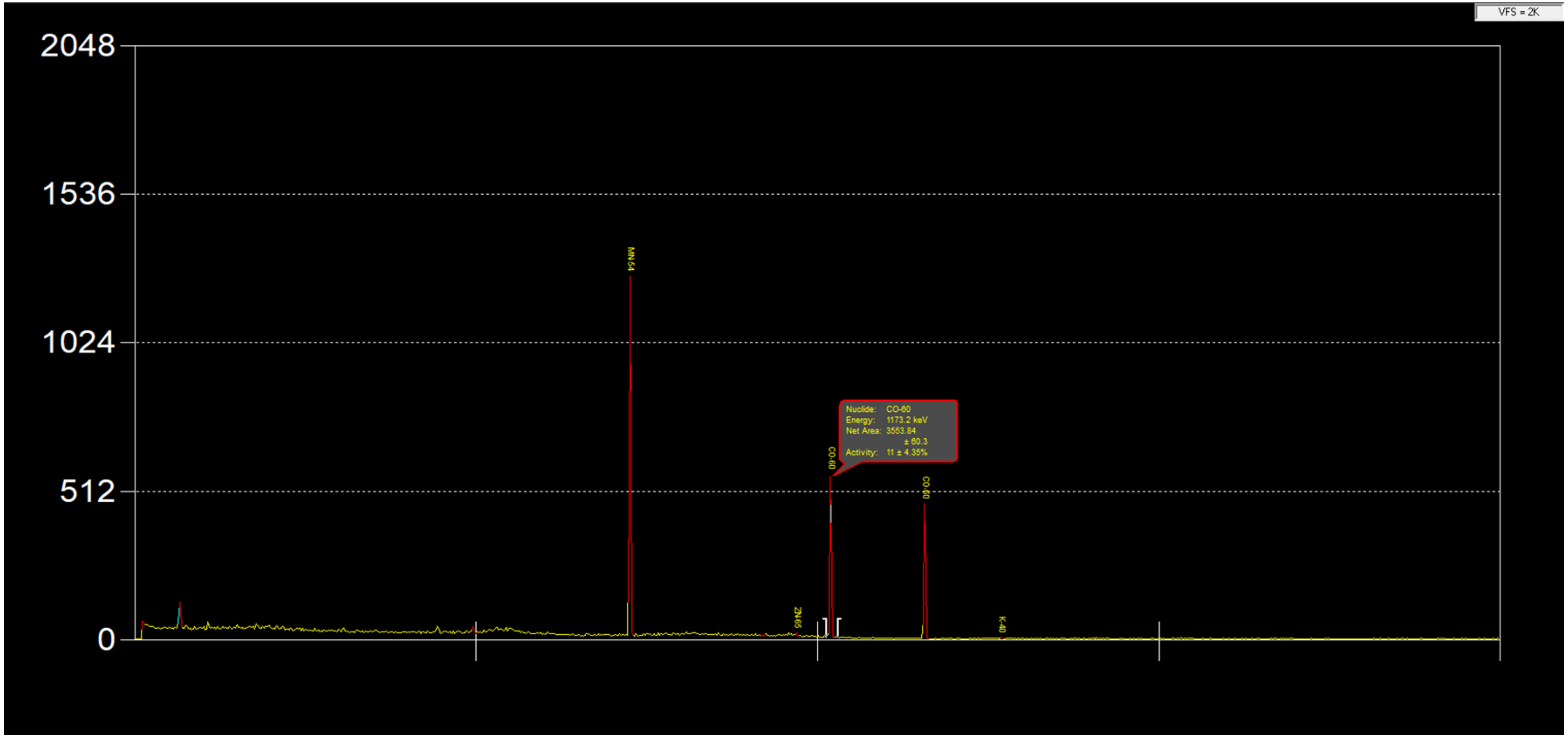
- DER 10 - 90 µSv/h
- DER 100 - 200 µSv/h
- DER 210 - 800 µSv/h

RADIOLOGICAL CHARACTERIZATION

- All 16 samples were characterized by HPGe gamma spectroscopy
- Main activity caused by Mn-54 and Co-60
- The results are compatible with the article *Decommissioning procedure and induced activation levels, calculations and measurements in an 18 MeV medical cyclotron*, but Prague cyclotron was used approximately twice as much, so the activities are higher

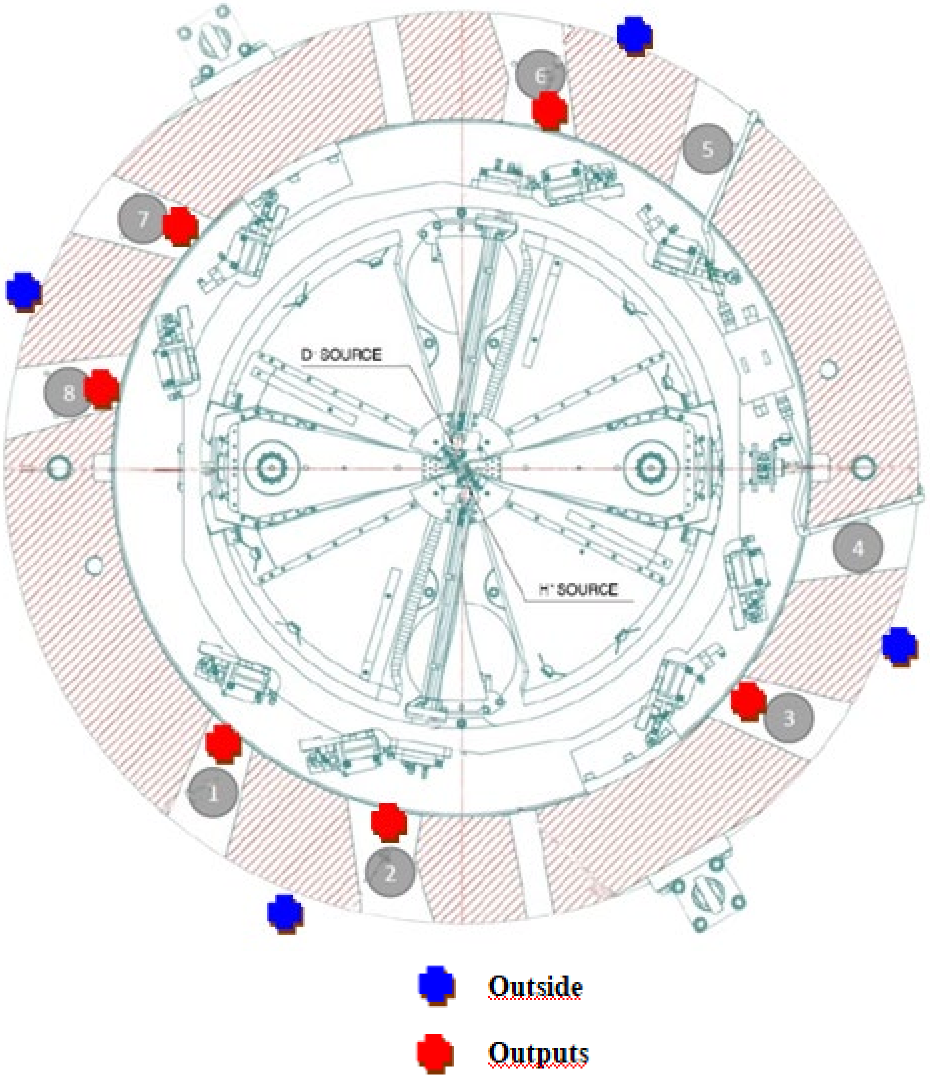


RADIOLOGICAL CHARACTERIZATION



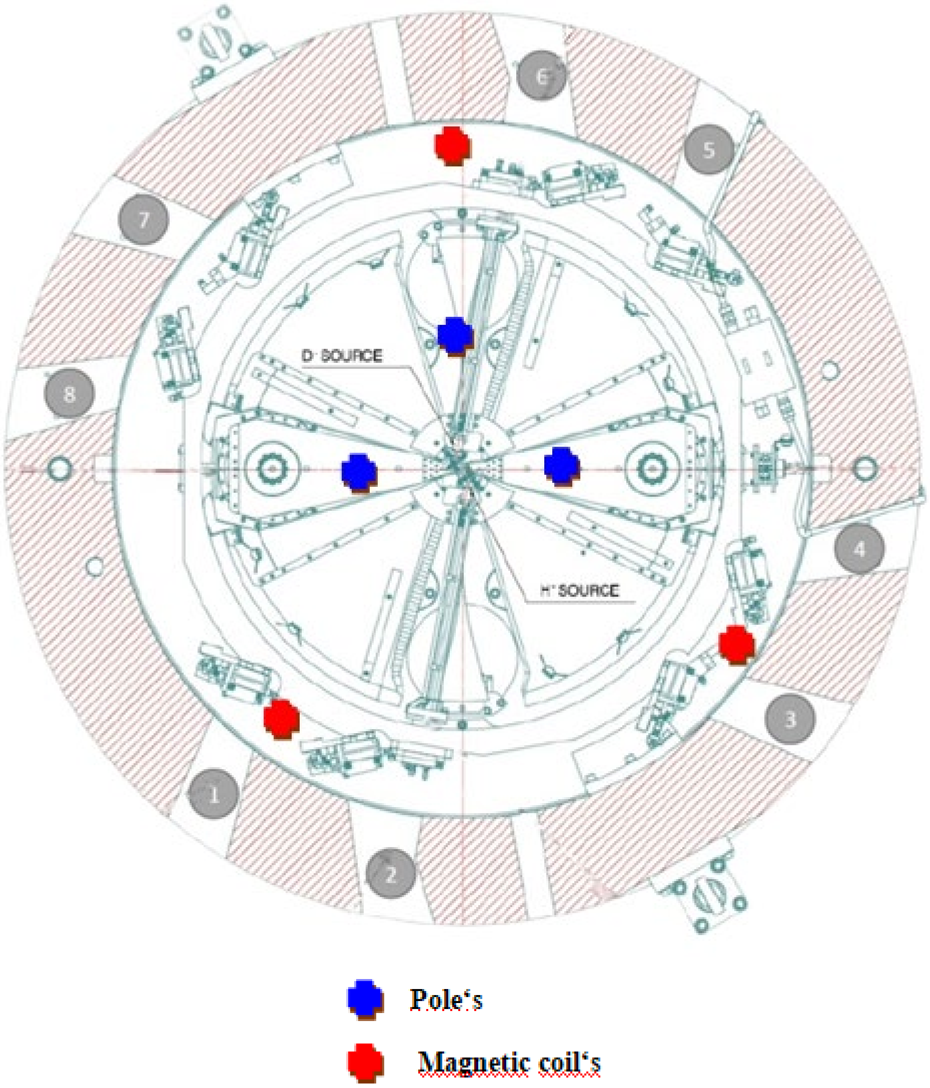
ANALYSIS RESULTS (1/2)

Sample	Mn-54 Bq/kg	Co-60 Bq/kg
Output 1	1,6E+04	1,2E+04
Output 2	4,5E+04	2,6E+04
Output 3	2,3E+03	2,9E+03
Output 6	9,4E+04	4,5E+03
Output 7	5,9E+03	5,5E+03
Output 8	1,5E+04	1,1E+04
Outside 1	1,3E+04	3,6E+03
Outside 2	1,1E+03	5,3E+02
Outside 3	9,8E+03	5,0E+03
Outside 4	6,5E+02	2,8E+02



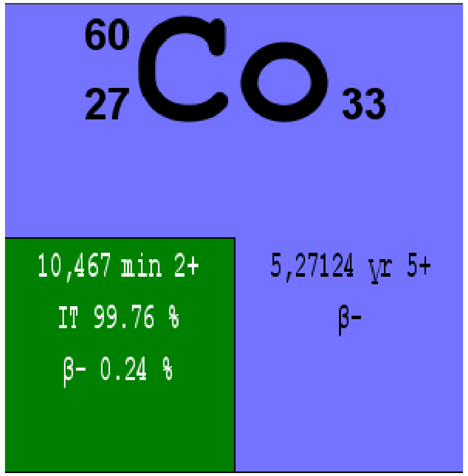
ANALYSIS RESULTS (2/2)

Sample	Mn-54 Bq/kg	Co-60 Bq/kg
Cu coil 1	-	1,4E+03
Cu coil 2	1,7E+02	1,5E+04
Cu coil 3	-	1,8E+03
Pole 1	3,6E+03	5,5E+03
Pole 2	4,9E+03	5,2E+03
Pole 3	8,4E+03	8,0E+03

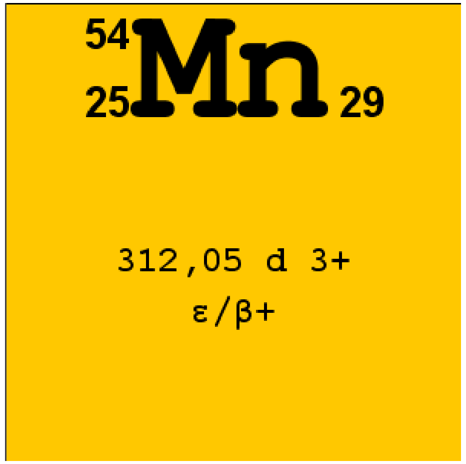


HOW LONG WE WILL HAVE TO STORE THE CYCLOTRON

- **Co-60 half-life 5,27 years**
  - Highest activity 26 000 Bq/kg - Output 2
  - Clearence level 100 Bq/kg
  - Time until reaching clearence level **42,3 years**



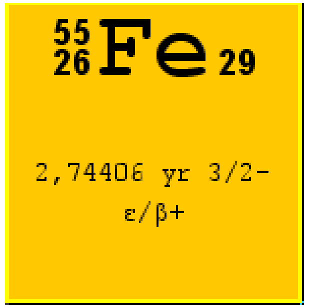
- **Mn-54 half-life 312,20 days**
  - Highest activity 94 000 Bq/kg - Output 6
  - Clearence level 100 Bq/kg
  - Time until reaching clearence level **8,4 years**



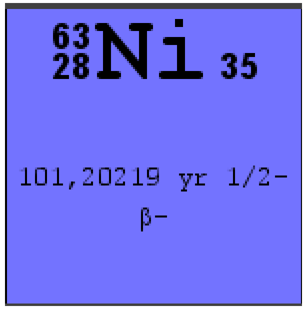
BETA NUCLIDES

- The gamma spectrometry cannot measure all nuclides
- Pure beta radionuclides meassurement (esp. Fe-55 and Ni-63)

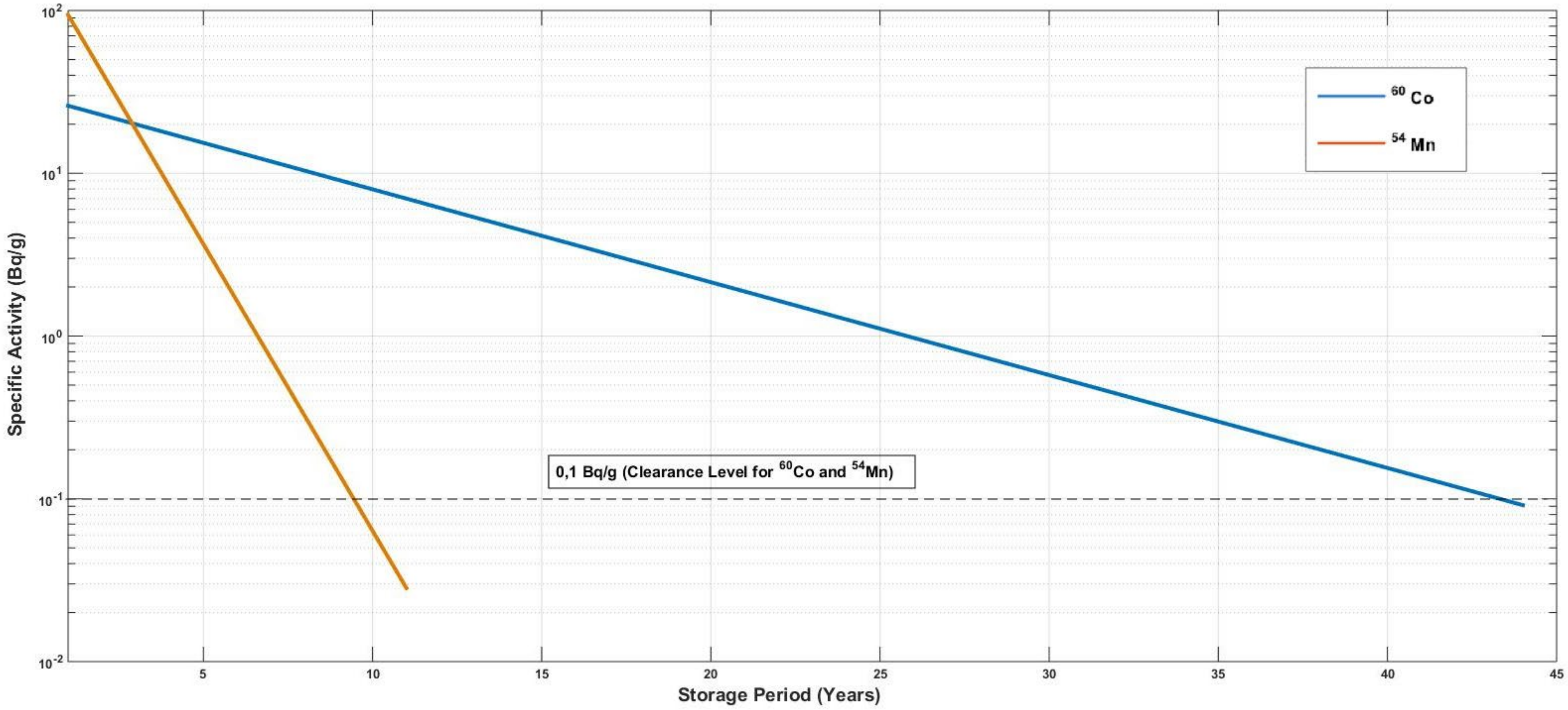
- Fe-55 half-life 2,7 years
  - Clearence level 1 000 kBq/kg
  - Activity "Output 6" 87,3 kBq/kg
  - Time until reaching clearence level **OK**



- Ni-63 half-life 101,2 years
  - Clearence level 100 kBq/kg
  - Activity "Output 6" 0,75 Bq/kg
  - Time until reaching clearence level **OK**



HOW LONG WE WILL HAVE TO STORE THE CYCLOTRON



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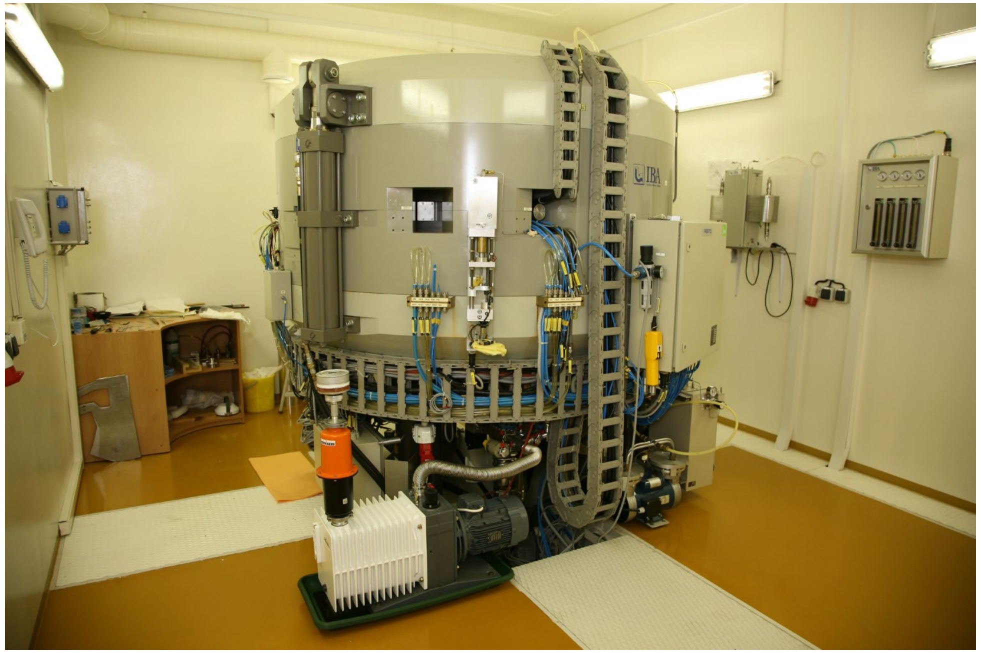
STRIPPING DOWN THE CYCLOTRON



Thank you for your attention

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