

CYCLOTRON PRODUCTION OF RADIOPHARMACEUTICALS USED IN PET IMAGING



Giorgi Gavashelishvili

Liv Hospital / Radiation Medicine Center Activities

Radiation Therapy

Appropriate License:

- Utilization of Ionization Radiation Source for Medical Purposes (Treatment) - Agency for Nuclear and Radiation Safety
- Utilization of Ionization Radiation Generators for Medical Purposes (Treatment & Diagnostic) - Agency for Nuclear and Radiation Safety

Nuclear Medicine

Appropriate License:

- Utilization of Radiopharmaceutical Products for Treatment Purposes - Agency for Nuclear and Radiation Safety
- Utilization of Radiopharmaceutical Products for Diagnostic Purposes - Agency for Nuclear and Radiation Safety

Liv Hospital / Radiation Medicine Center Medical Personnel

Radiotherapy Department

- Five Medical Doctors
- Two Senior and three Junior Medical Physicists
- Six RTTs
- Two Nurses

Nuclear Medicine Department

- Three Medical Doctors
- One Medical Physicist
- One Radio-Pharmacist
- One Technician
- Five Nurses

One Person is responsible for the Nuclear and Radiation Safety/Security

In total: 30 employees

Liv Hospital / Radiation Medicine Center Equipment

Radiotherapy Department:

- Linear Accelerator: **ELEKTA Versa HD** (2016)
- Linear Accelerator: **ELEKTA Synergy Platform** (2016)
- **UJP Terabalt 100** - Radiotherapy Treatment Unit (2016)
- **UJP Terasix** - Conventional Simulator (2016)
- **TOSHIBA Aquilion LB** - CT (2010) Refurbished in 2016



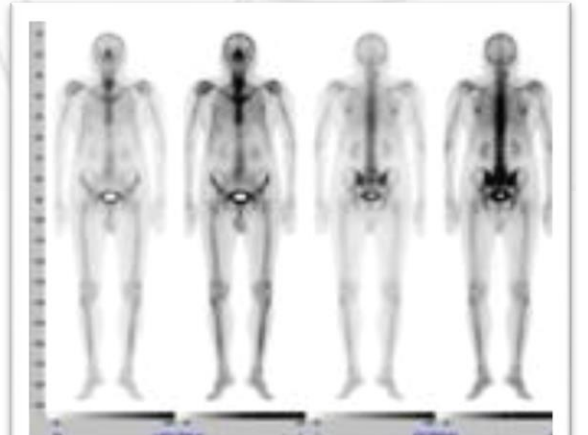
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Liv Hospital / Radiation Medicine Center Equipment

Nuclear Medicine Department:

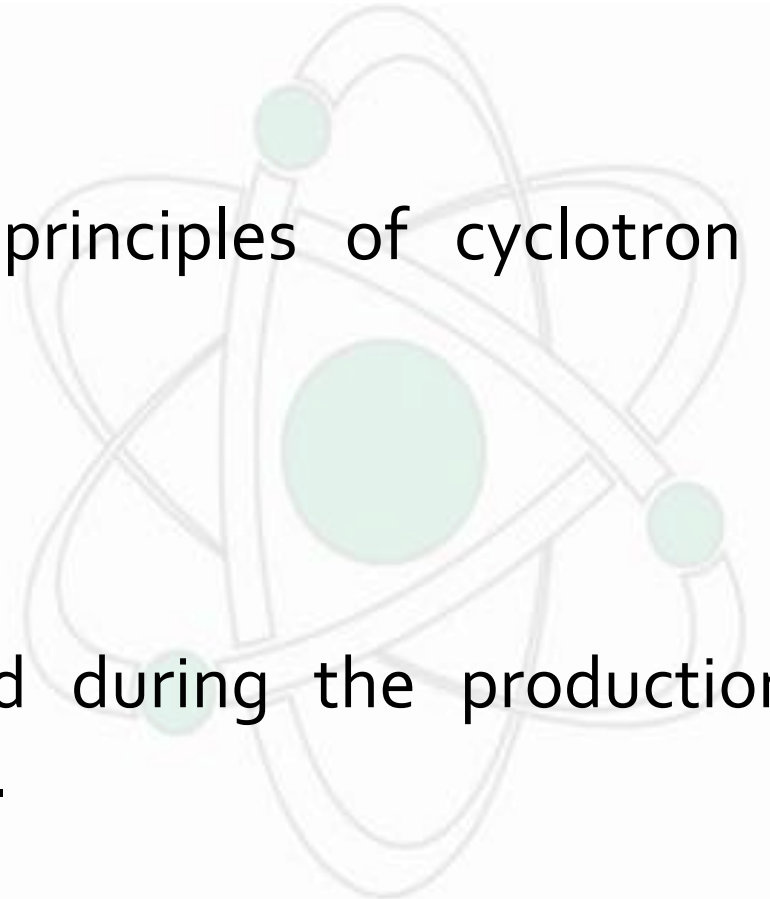
ECAM – SCINTRON

- SPECT gamma camera with a field of view of 53,5cmx40cm per head
- Suited for all studies of the nuclear medicine diagnostic
- Remanufactured with new crystal
- Handling of the Patient-Handling-System for all operations identic
- Bodycontouring enables minimum distance between detectors and patient for optimum quality
- Adjustable caudalt tilts



Objectives

- To understand the main operational principles of cyclotron and production of radiopharmaceuticals.
- Radiation level and hazards associated during the production of radiopharmaceuticals in cyclotron facility.

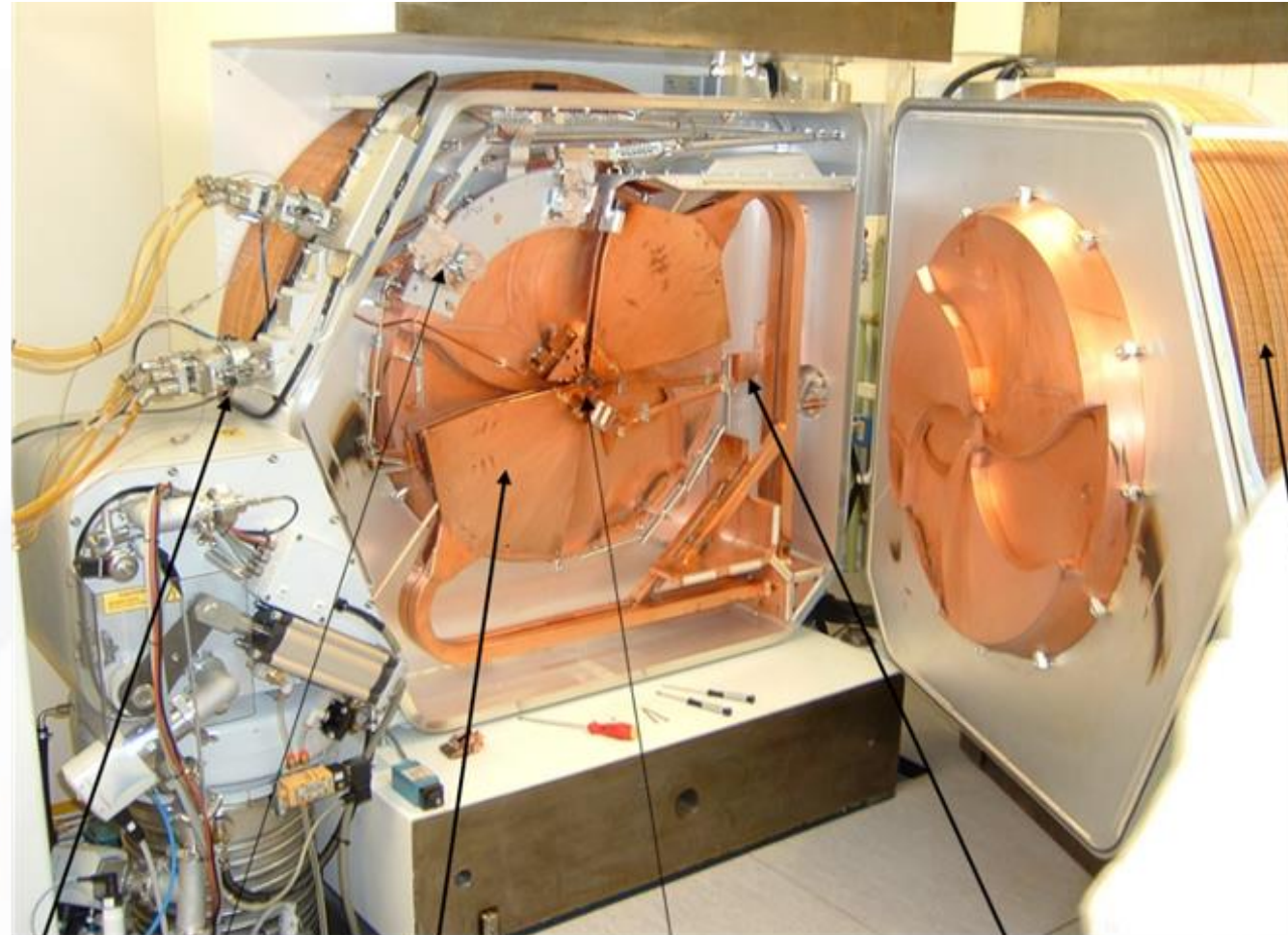


Nuclear reactions

- Energetic charged particle passes through any material, there is some probability that it will interact with a nucleus along its path.
- The incoming particle must have sufficient energy to overcome electrostatic repulsion between the positively charged particles and the positively charged nucleus (Coulomb barrier) and whether the reaction is exothermic or endothermic (Q value).

Radionuclide	$T_{1/2}$ minutes	Decay mode	Reaction	Energy (MeV)
^{11}C	20.3	β^+	$^{14}\text{N} (p, \alpha)$	11-17
^{13}N	9.97	β^+	$^{16}\text{O} (p, \alpha)$ $^{13}\text{C} (p, n)$	19 11
^{15}O	2.03	β^+	$^{15}\text{N} (p, n)$ $^{14}\text{N} (d, 2n)$ $^{16}\text{O} (p, pn)$	11 6 >26
^{18}F	110	β^+	$^{18}\text{O} (p, n)$ $^{\text{nat}}\text{Ne} (d, \alpha)$	11-17 8-14

Structure of the cyclotron



Target

Beam extractor

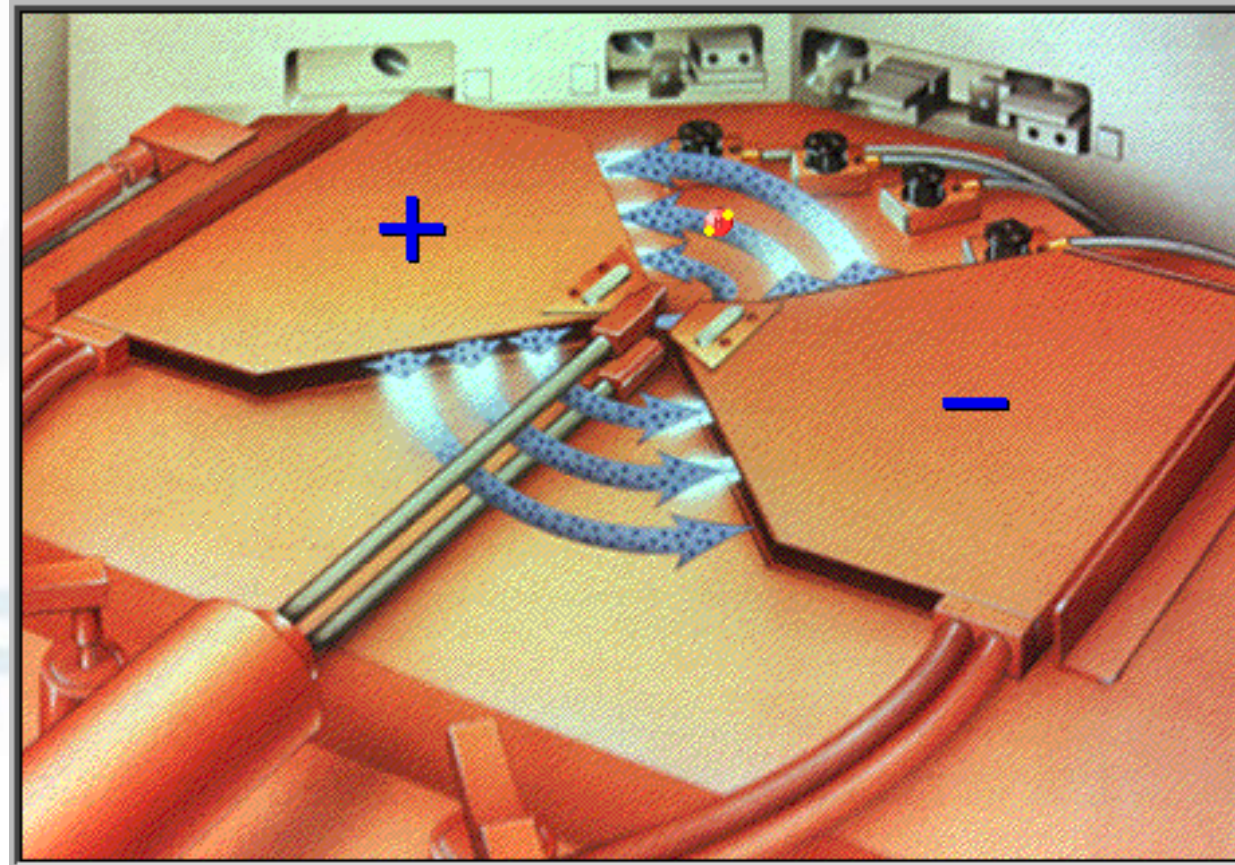
DEEs

Ion source

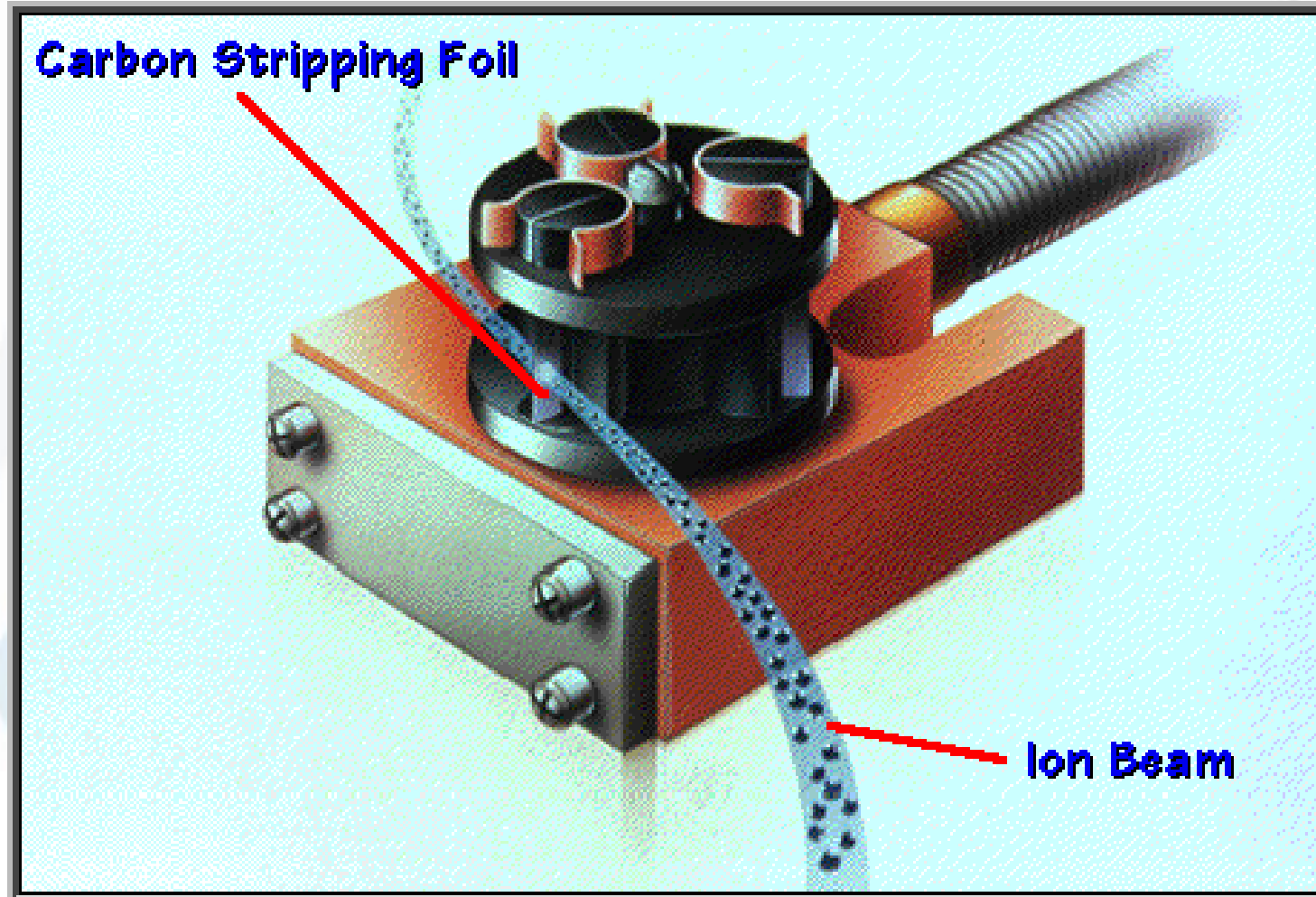
Vacuum pump

Magnetic coil

Main steps in the cyclotron to perform the production of radionuclide



Main steps in the cyclotron to perform the production of radionuclide

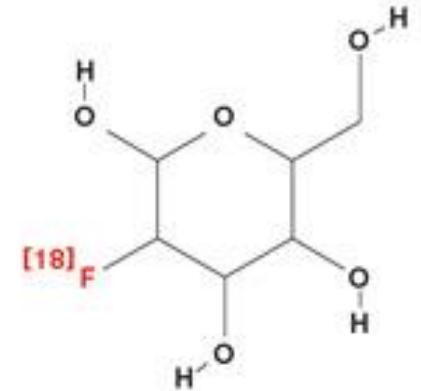


Main steps in the cyclotron to perform the production of radionuclide

1. Negative ions are created in the center of the cyclotron
2. Ions are extracted from the ion source using RF
3. Ions are accelerated using RF
4. Ions are kept in orbit by a strong homogenous, vertically applied, magnetic field
5. Ions polarity is changed from negative to positive using a carbon stripping foil
6. Positive ions bend in the opposite direction in the magnetic field
7. Positive ions bombard the media in the target

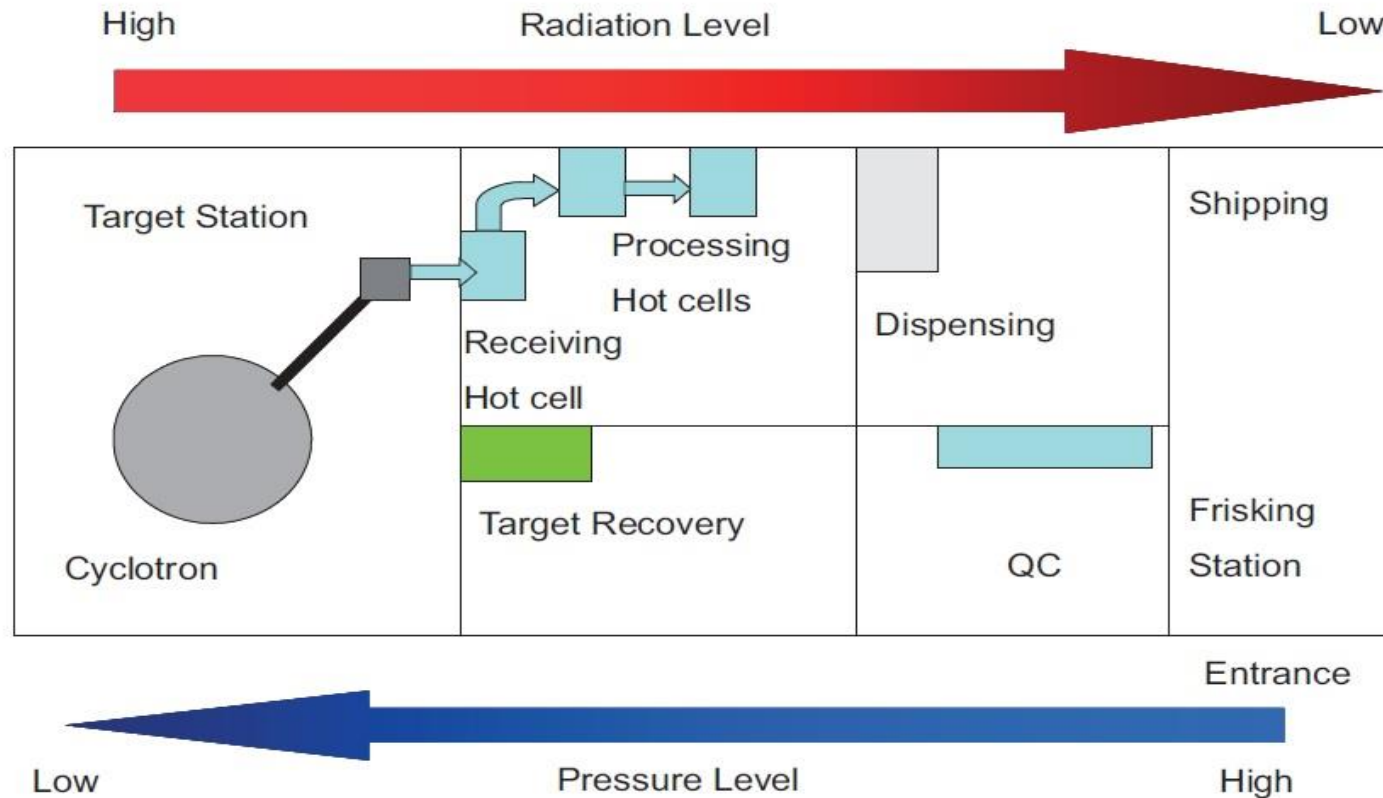
FLUORINE-18

- Has a unique half-life of 109.77 min. This time is long enough to perform a complicated chemistry (labelling), and to allow the transportation over some distance. Simultaneously is short enough to keep low the radiation dose to the patient.
- Emits a positron of relatively low energy, which travels a short distance before disintegrating and emitting 511keV gamma rays (this permits a good image quality with excellent accuracy).



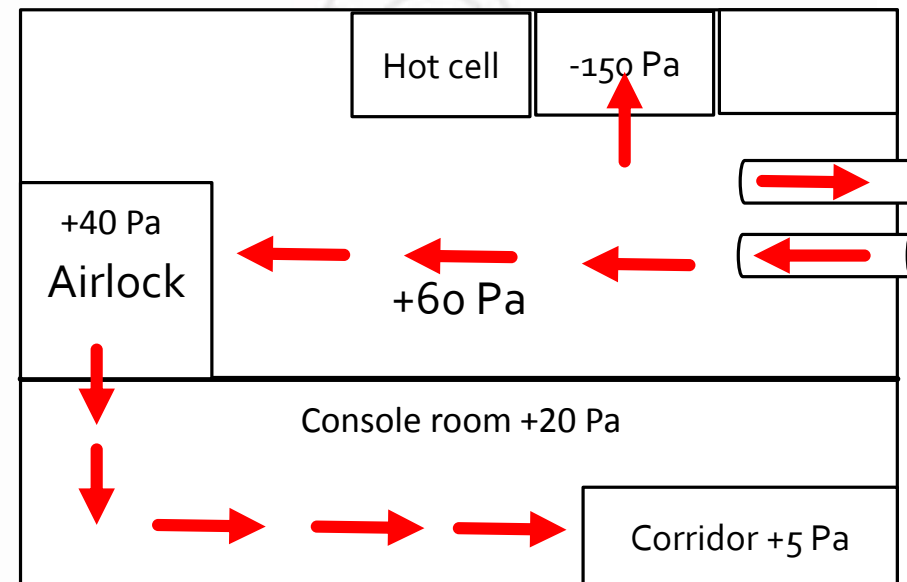
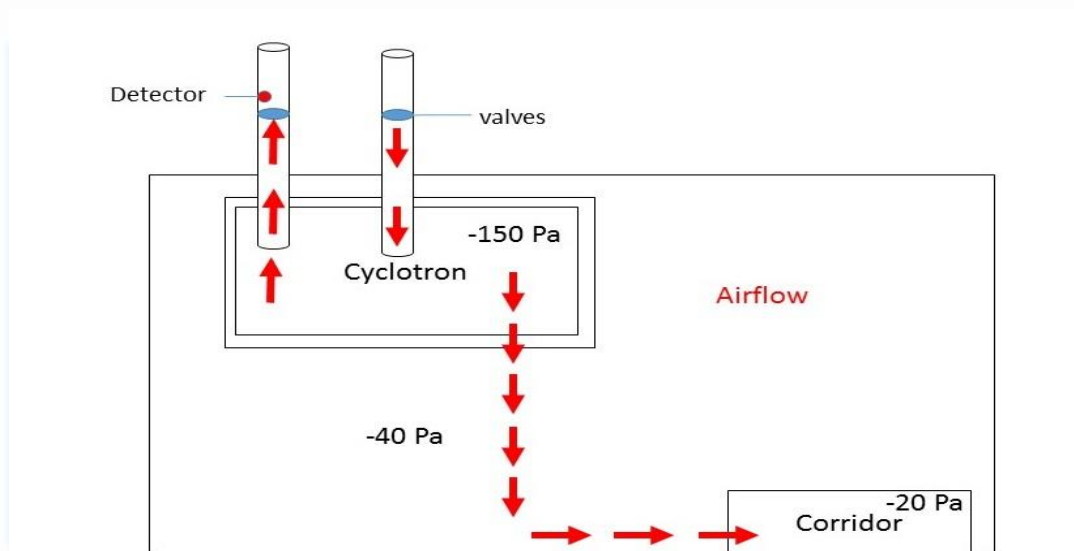
Chemical purity of ^{18}O enriched water needs to be higher than 99.99%; Target volume, ranging from 0.5 to 2.5 mL; Proton beam of 3–20 MeV; Beam currents of 20–100 μA ; Irradiation time is from 30 min to 3 h.

Radiation level gradient



Cyclotron vault – 5Sv/h near the target when beam is on, in the hot cells – 20mSv/h and 12-15mSv/h for dispensing cells.

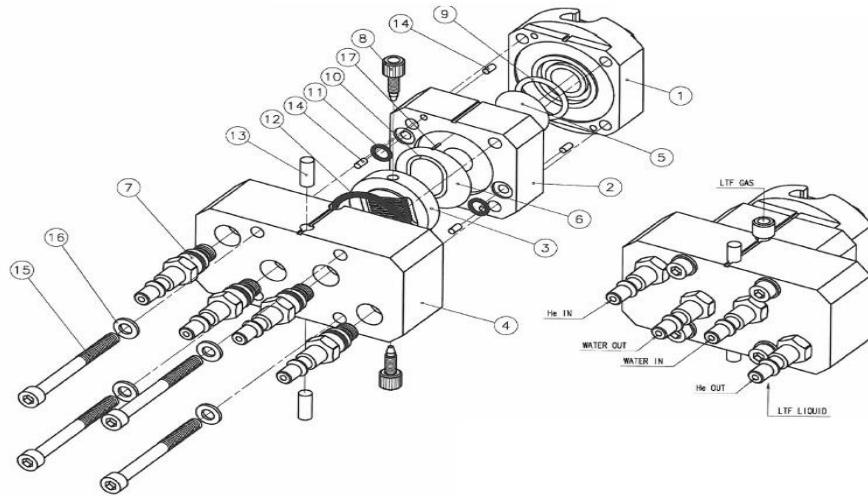
Airflow



It is essential that radioactive material (dust, airborne radioactivity, etc.) is not thrown from the areas with high levels of contamination to the areas of low contamination.

Maintenance

- Generally cyclotron needs maintenance twice per year and it lasts approximately 1 week per maintenance. Special procedures for maintenance are required provided by the manufacturer company.
- During the maintenance radiation level is very high. Cyclotron needs to be opened to change ion source, target, and other parts. It is necessary to measure and maintain the distances between parts inside.



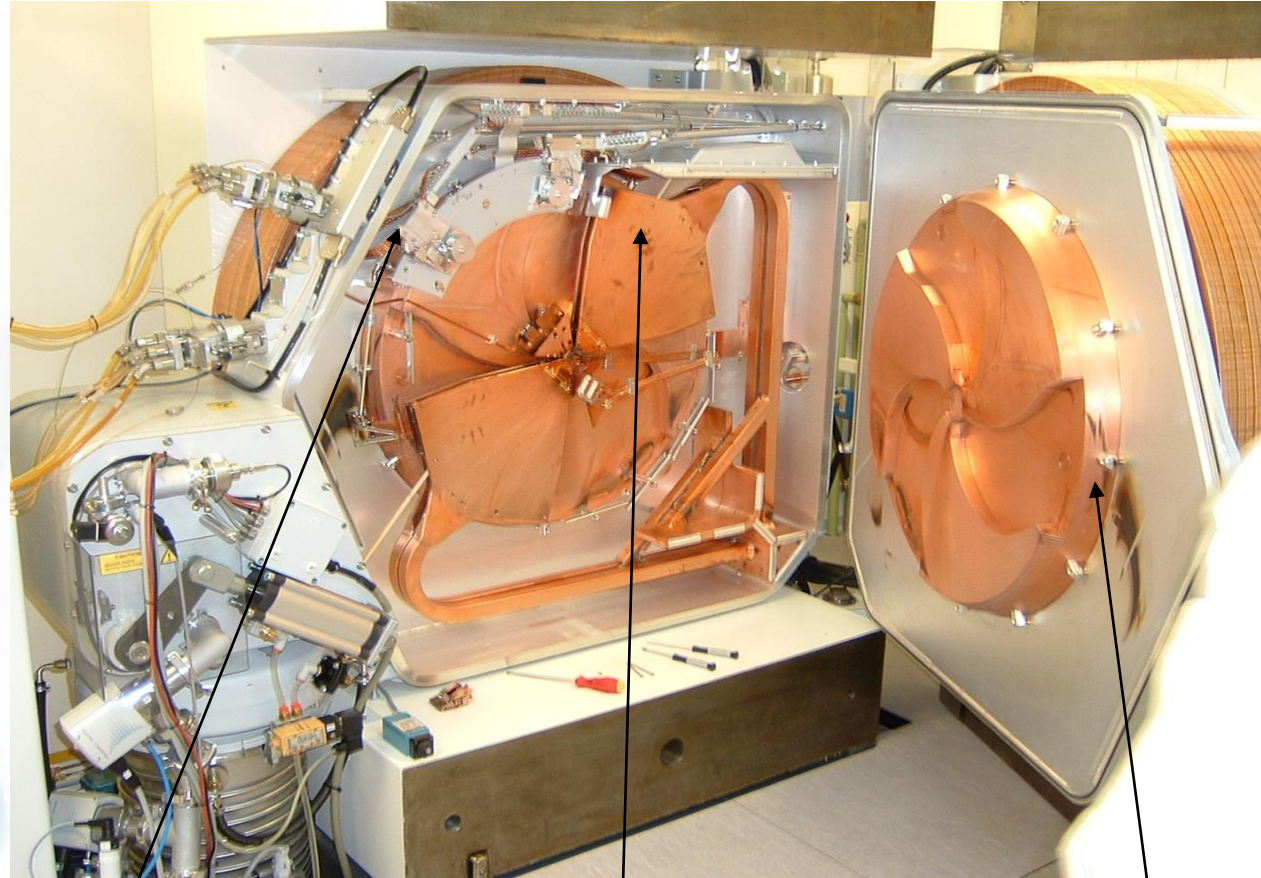
Target structure. Figure: 1. Front flange target; 2. HE cooling flange; 3. Silver body; 4. Rear flange; 5. Havar foil 0.025; 6. Havar foil 0.050; 7. Male connector; 8. Male fitting; 9. Helicoflex; 10. Helicoflex oval; 11-12. O-ring; 13-14-17. PIN; 15. Screw; 16. Washer.

RADIONUCLIDE IMPURITIES PRODUCED IN HAVAR FOILS

Product	$T_{1/2}^a$	Reaction	Threshold (MeV)
^{55}Co	17.5 h	$^{58}\text{Ni}(p,\alpha)$	1.36
^{56}Co	77 d	$^{56}\text{Fe}(p,n)$	5.44
^{57}Co	272 d	$^{57}\text{Fe}(p,n)$	1.65
		$^{60}\text{Ni}(p,\alpha)$	0.27
		$^{58}\text{Ni}(p,2p)$	8.31
^{58}Co	71 d	$^{58}\text{Fe}(p,n)$	3.14
^{57}Ni	35.6 h	$^{58}\text{Ni}(p,pn)$	12.43
^{51}Cr	27.7 d	$^{52}\text{Cr}(p,pn)$	12.27
^{52}Mn	5.6 d	$^{52}\text{Cr}(p,n)$	5.60
^{95}Tc	20 h	$^{95}\text{Mo}(p,n)$	2.50
^{96}Tc	4.3 d	$^{96}\text{Mo}(p,n)$	3.80
^{181}Re	19.9 h	$^{182}\text{W}(p,2n)$	10.65
$^{93\text{m}}\text{Mo}$	6.85 h	$^{93}\text{Nb}(p,n)$	3.60

^a $T_{1/2}$ = half-life.

Maintenance



150-216uSv/h

60uSv/h

18uSv/h



THANK YOU!

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