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PET Cyclotron Audit



Cyclotron



Radiopharmacy



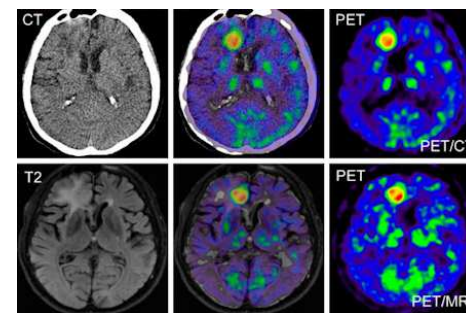
Transport



Nuclear Medicine



PET-CT Scanner



Diagnostics



 Location of radiopharmaceutical cyclotrons

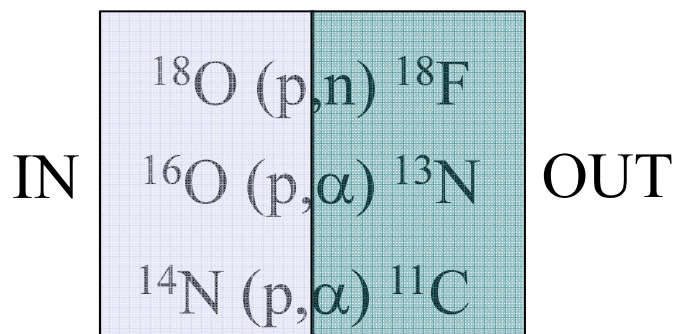


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Cyclotron for Radiopharmacy



- Particle Accelerator
- Protons or Deuterons
- Nuclear reactions in target
- Produce radioactive nuclei





Produced nuclides

Example: Cyclotron at University Hospital Zurich

Nuclide	T _{1/2} [min]	Activity per irradiation [GBq]	Dose Rate @ 1m [mSv/h]
F-18	110	250	40
C-11	20	60	9.6
N-13	10	15	2.4
O-15	2	10	1.6

Needs shielding in hotcells with 10 cm of lead!
Attenuation of a factor 10^6 necessary!



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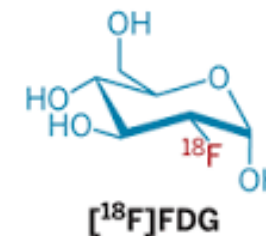
Production of radiopharmaceuticals



Hotcells in GMP Lab



Chemical Synthesis



Tracer molecule

Products

¹⁸F-FDG, ¹⁸F-DOPA, ¹⁸F-Cholin, ¹⁸F-FMISO, ¹⁸F-FET, ¹⁸F-Fluorid

H₂¹⁵O, ¹⁵O₂

¹³NH₃

¹¹C-Racloprid



Radiation protection hazard

Staff

- Direct radiation of cyclotron
- Activated air
- PET Nuclides

Environment/population

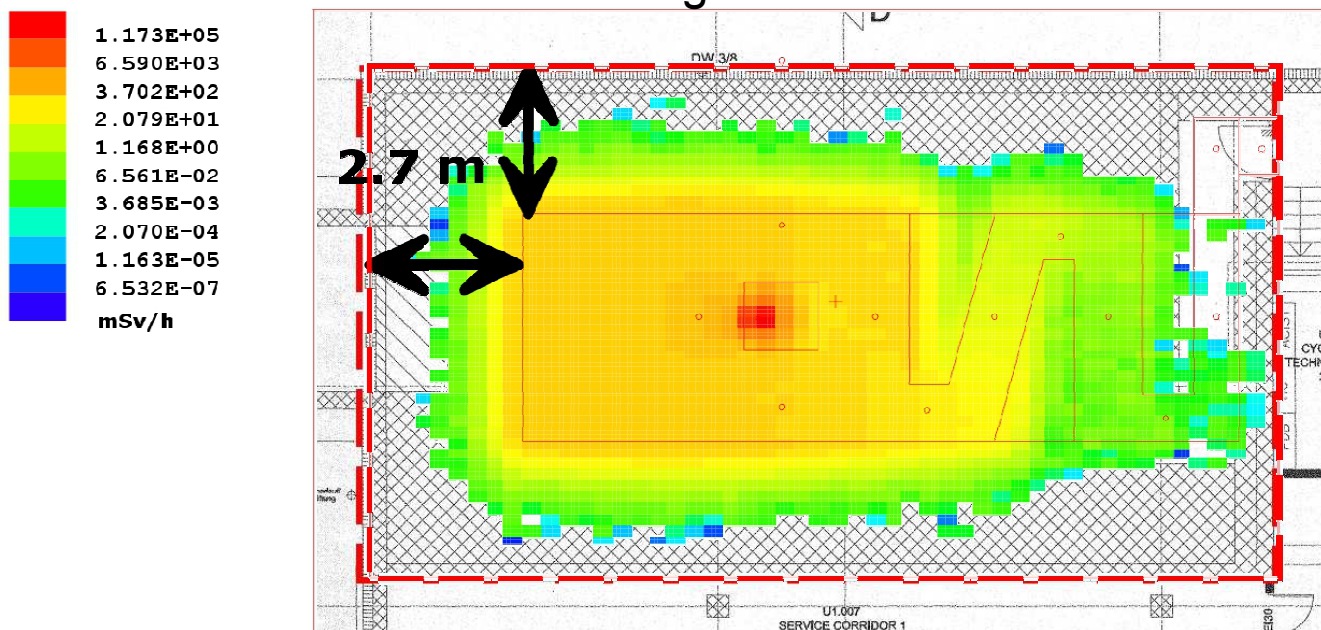
- Airborne emissions
- Direct radiation of cyclotron

Radioprotection measures needed



Radioprotection of bunker

During irradiation



Débit de dose ambient - photons (mSv/h)



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Position 2:

Doserate:

30 cm: 7 mSv/h

50 cm: 4.5 mSv/h

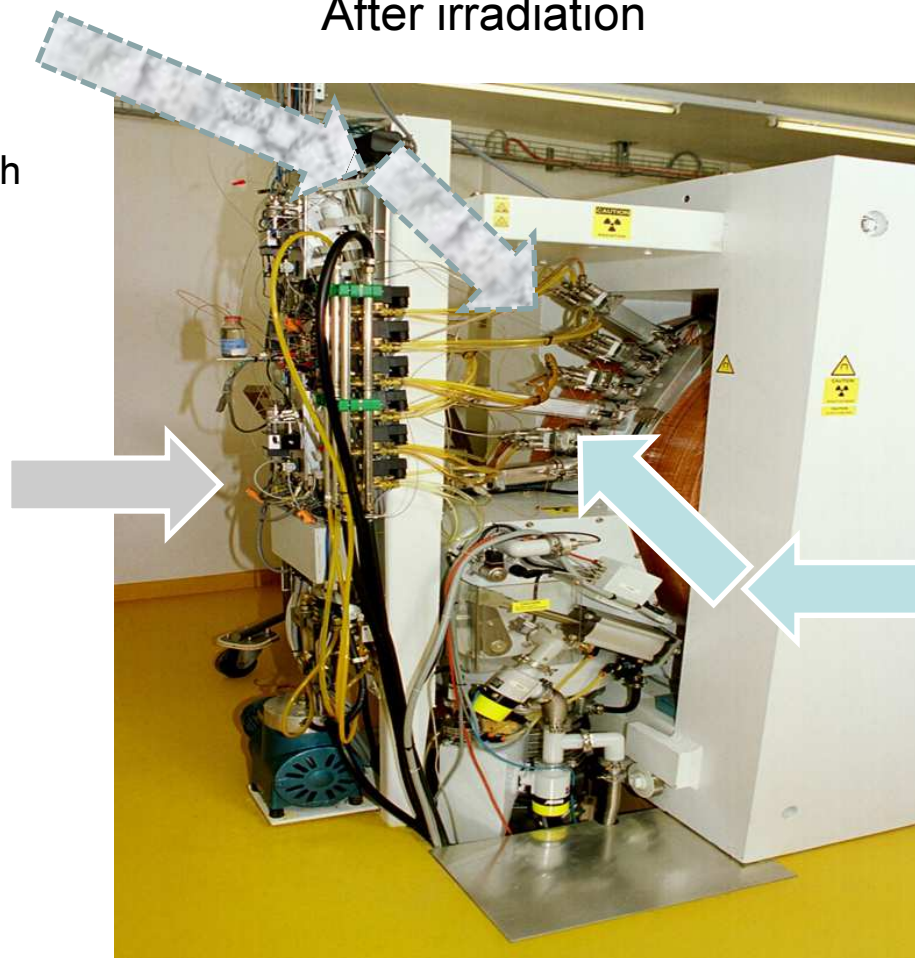
100 cm: 1.65 mSv/h

Position 3:

Doserate

60-90 μ Sv/h

After irradiation



Position 1:

Doserate

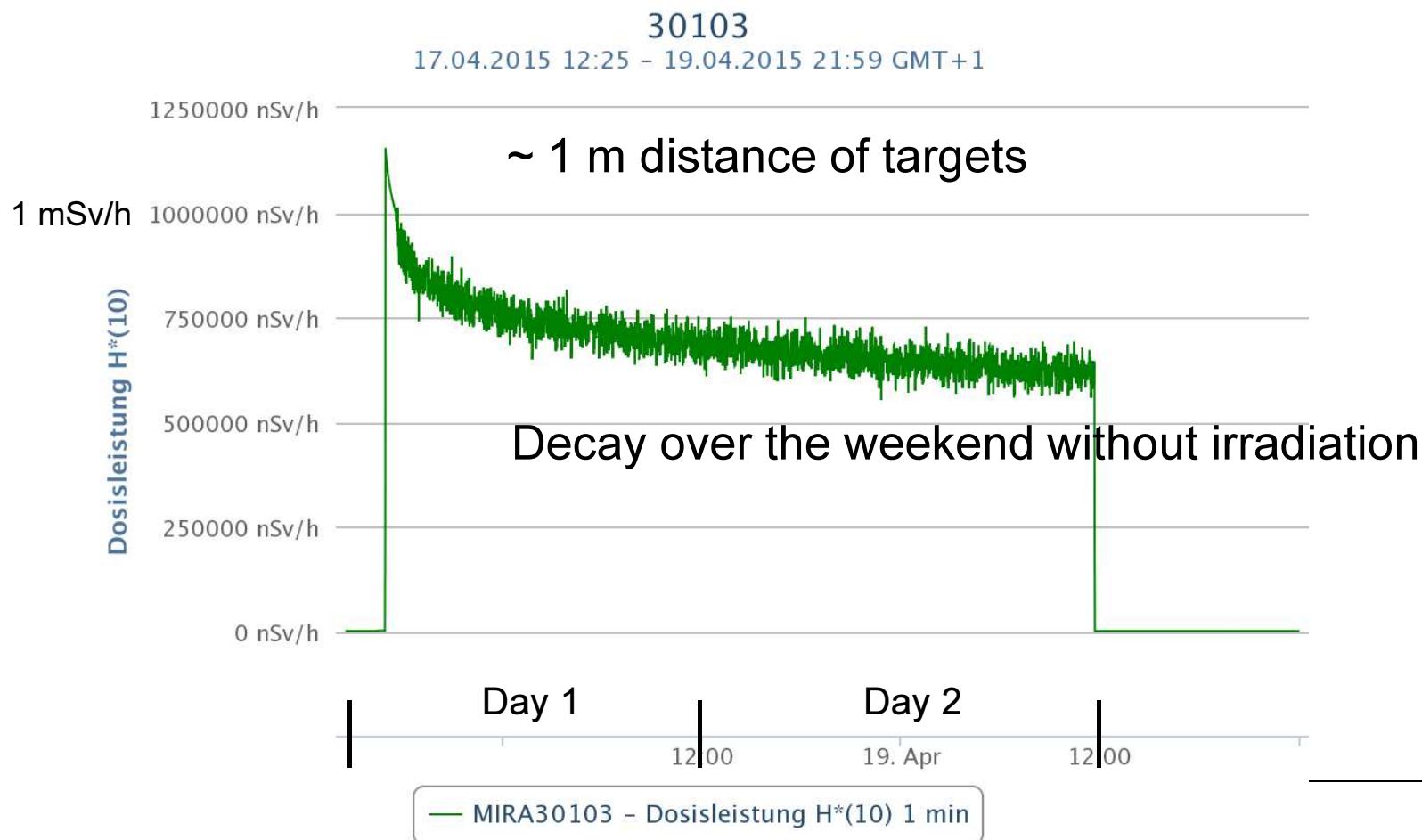
30 cm: 7 mSv/h

50 cm: 4 mSv/h

100 cm: 0.8 mSv/h



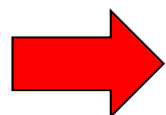
Doserate in bunker after irradiation



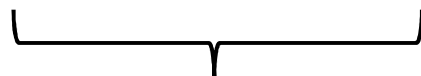


Incidents that happened

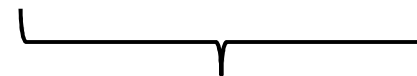
- Broken target: emission of gaseous N-13
- Gas leakage by targets: emission of gaseous N-13, C-11 or O-15.
- Open hotcells when activity present
- Transfer of gaseous products into open hotcells



Direct radiation, inhalation, environmental emissions



Staff



Population



Checkpoints in Audit

- Safety
- Monitoring
- Quality assurance
- Incidents
- Measurements
- Radioactive waste
- Installation
- Education Staff
- Dose
- Ventilation
- Bunker
- Documentation and directives



Main Hazards

- Bunker - Cyclotron
- Activated air in bunker
- Transfer of activity into hotcells
- Escape of radioactive gases from hotcells
- Handling of product (Quality assurance, Transport)
- Radioactive waste storage
- Wrong manipulation of equipment



Radioprotection ordinance

- Art. 94 Prevention

The licence holder must adopt appropriate measures to prevent abnormal occurrences.

Necessity of diverse technical safety measures and good practice



Safety measures

Scenario to prevent	Technical and organizational safety
Direct irradiation of staff	• Dose rate monitoring with alarm • Personal electronic dose meters with alarm • Entry restriction as a function of dose rate • Safety interlock with transfer of nuclides
Air contamination	• Depression in lab and hot cell • Air Compressing System ACS • Decay line



Scenario to prevent	Technical and organizational safety
Emissions in the environment	• Air Compressing System/Decay line • Monitoring of emissions • Measurement in exhaust of rooms • Double clack valve
Irradiation in bunker	• Interlock for door • Access control • Dose rate mapping before maintenance
Emission in case of fire	• Separate fire zones for labs • Fire damper



Existing technical safety features

Institute	Dose rate monitoring with recording and alarms	Interlock for delivery	Interlock for delivery between two hotcells	Depression in labs	Air Compressing system (ACS) / WGHS	Decay line	Monitoring ambient air	Quantitative monitoring of air release	Double clack valve	Circuit switch bunker	Interlock bunker door	Access control bunker	Fire protection
1	X	X	X	X	X		X	X	X	X	X	X	X
2				X		X				X	X	X	X
3	X	X	X	X	X		X	X	X	X	X	X	X
4	X	X		X	X	X	X	X	X	X	X	X	X
5	X	X		X		X	X	X	X	X	X	X	X



Summary

Institute	Installation	Education	Personal Dose	Waste	Ventilation	Bunker	Shielding	Decommissi.	Monitoring	Safety	Maintenance	Incidents	Directive
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1. Green : Alright, no additional measures needed
2. Orange : Small measures or changes necessary
3. Red : More significant measures necessary



Summary of the SFOPH audits

- Quality of the radioprotection is good
- However some measures/improvements are needed for
 - Financial provisions for decommissioning of bunker
 - Transfer of radioactive waste to appropriate site (PSI)
 - Installation of device for the monitoring of air
 - Installation of dose rate monitoring with alarm mode
 - Periodical maintenance of equipment
 - Optimise radioprotection issues during QA of radiopharmaceutical
 - Education of staff and radiation protection expert deputies



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Thank you for your attention

Any question ?

