Operational Radiation Protection at MEDICIS

A CERN Facility for the Production of Non-Conventional Isotopes for Medical Research

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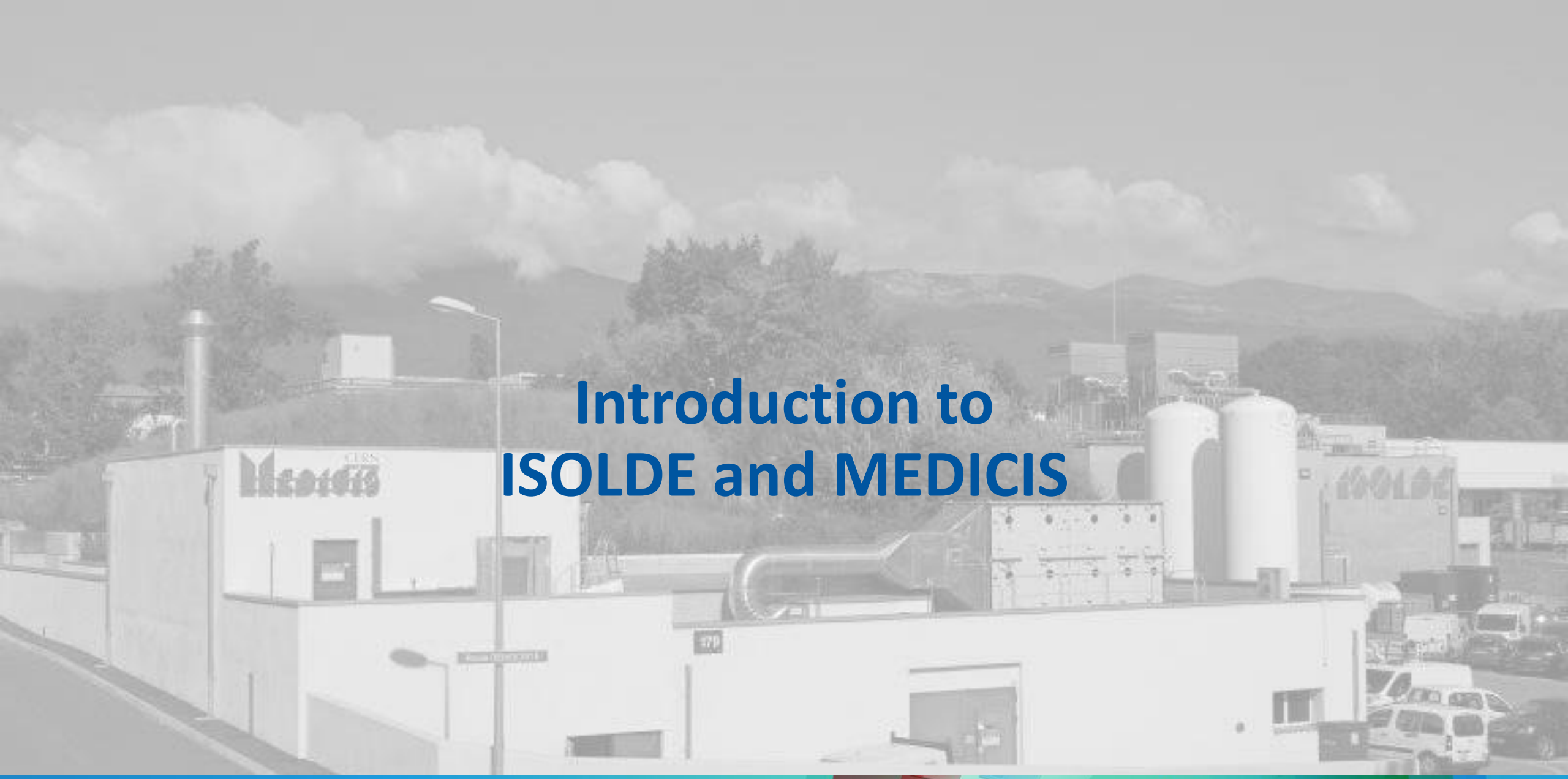
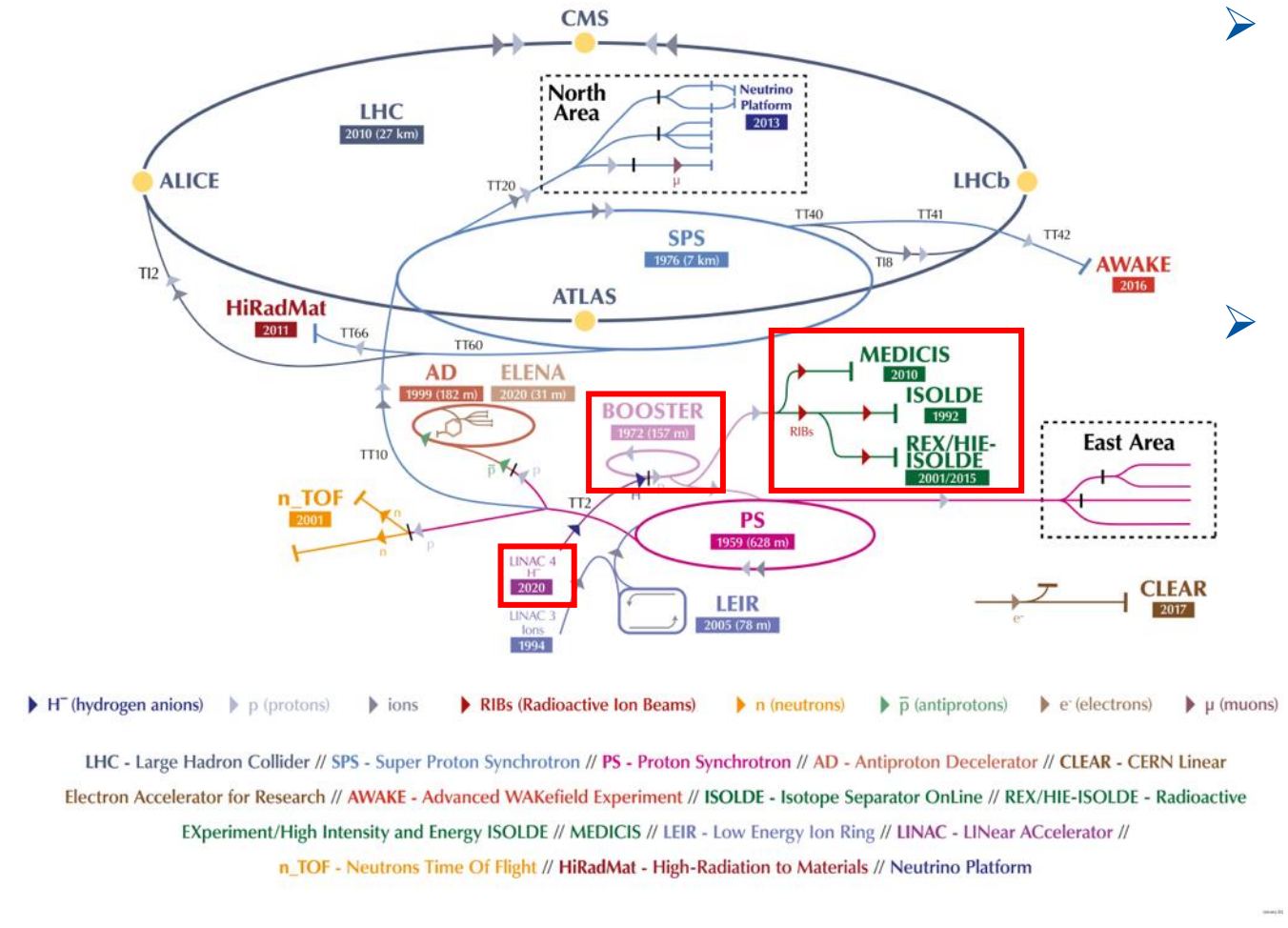
CERN, European Organization for Nuclear Research (Geneva, SWITZERLAND)



Introduction to ISOLDE and MEDICIS

*Online collection = beam is impacting the target as the radionuclides are extracted in the form of an ion beam

CERN accelerator complex and ISOLDE

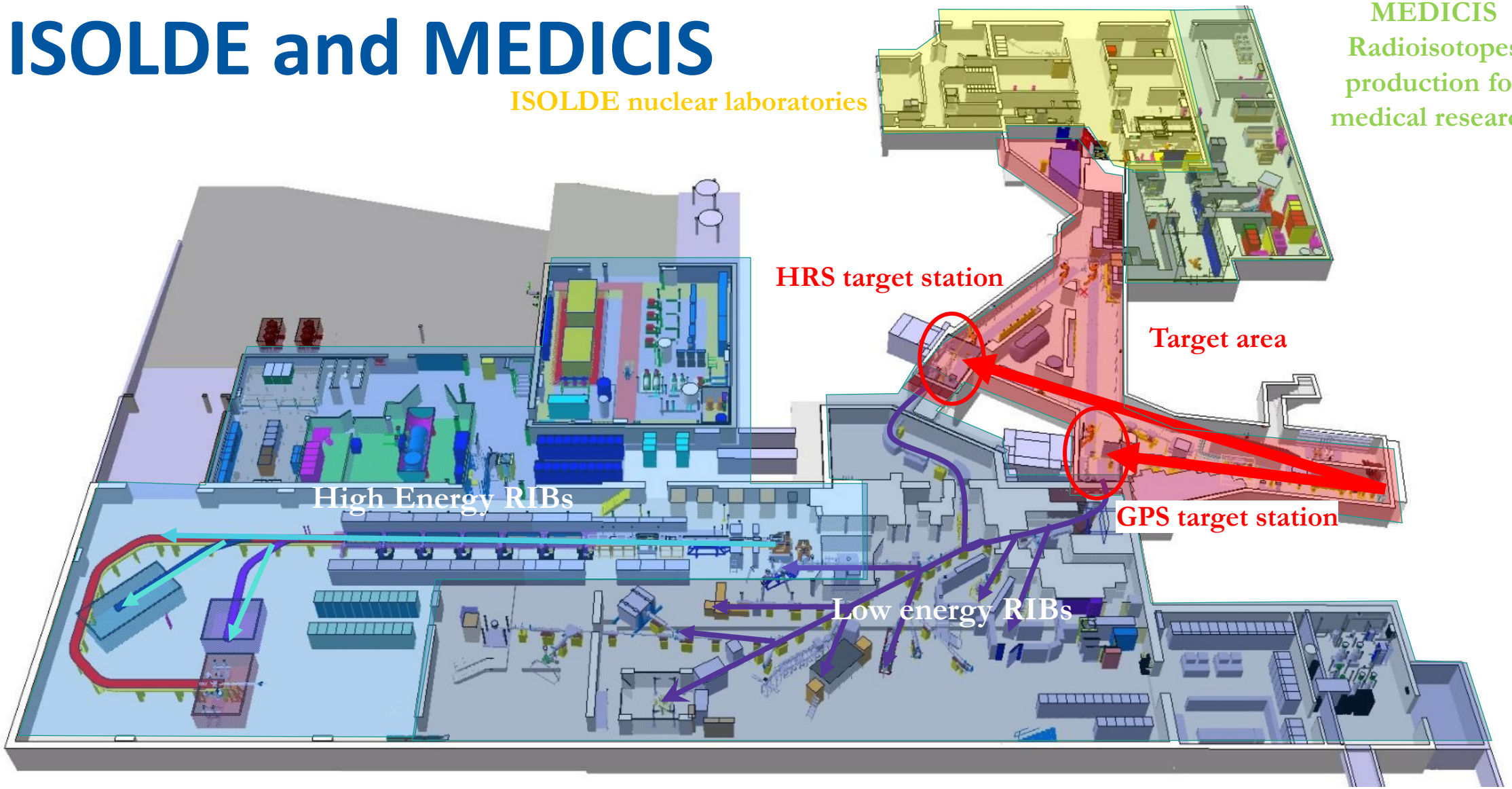


- **ISOLDE** operational at CERN **since 1967** and **since 1992** at its present location
  - Pulsed **protons** at **1.4 GeV** at max. **2 μA (2.8 kW)**
  - **Online* mass separation** of radioisotopes for the production **Radioactive Ion Beams** (RIBs)
  - **~60%** of CERN **protons** goes **to ISOLDE**
- **MEDICIS** part of the **ISOLDE** complex
  - **Offline** mass separation
  - Operational **since end of 2017**

ISOLDE and MEDICIS

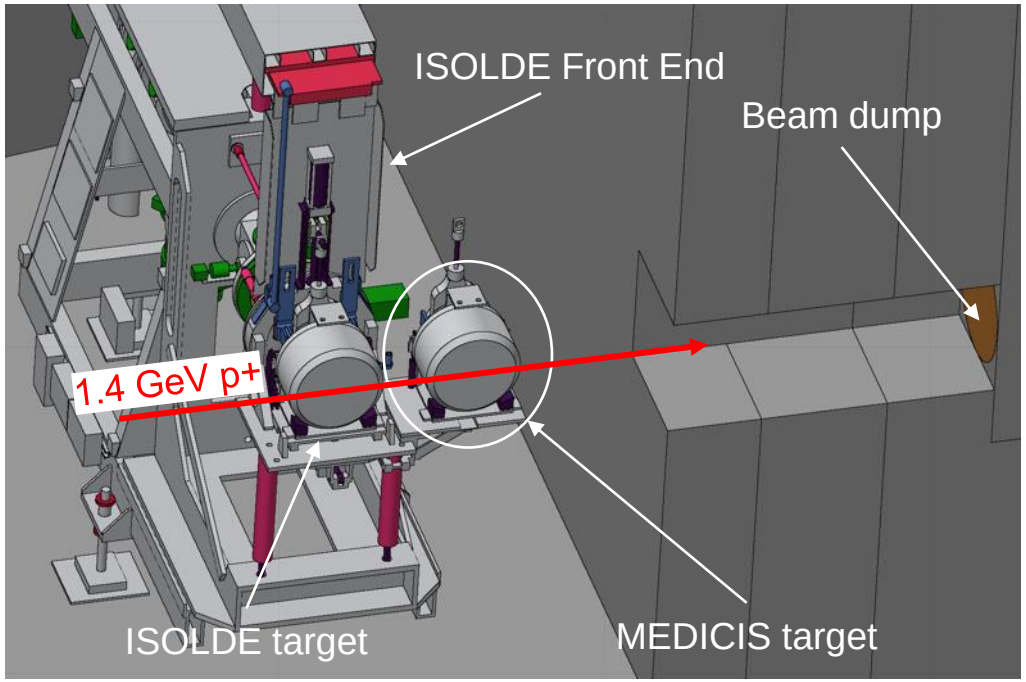
ISOLDE nuclear laboratories

MEDICIS
Radioisotopes production for medical research



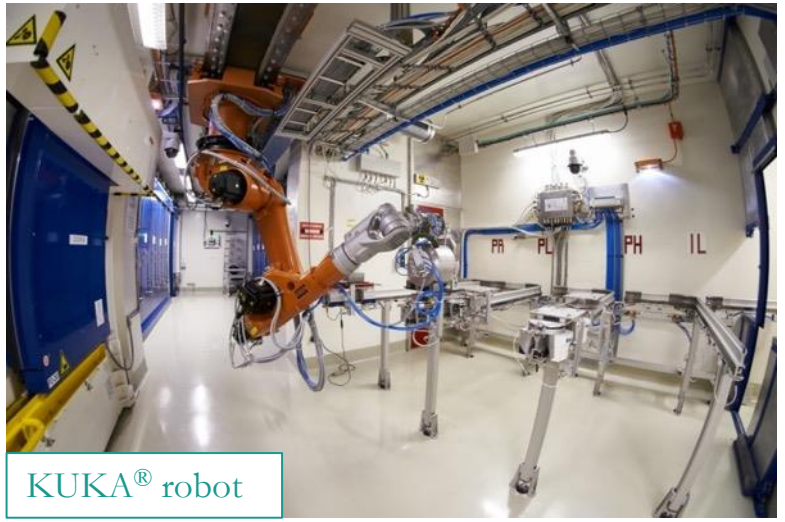
MEDICIS: the concept

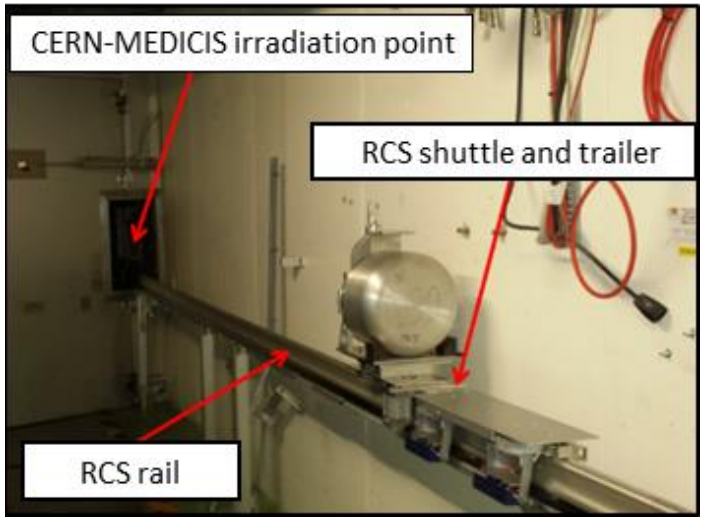
- MEDICIS is a **Collaboration** between **CERN** and **14 research institutes/hospitals/universities**
  - Scientific program based on needs/requirements defined by the Collaboration
- MEDICIS **operation principle**
  - MEDICIS target inserted between ISOLDE target and beam dump
  - MEDICIS target "uses" protons not interacting with the upstream ISOLDE target
  - Target retrieved remotely to the MEDICIS lab and coupled with the MEDICIS Front End
  - Collection of radioisotopes performed offline → radionuclides with $t_{1/2}$ ~hours

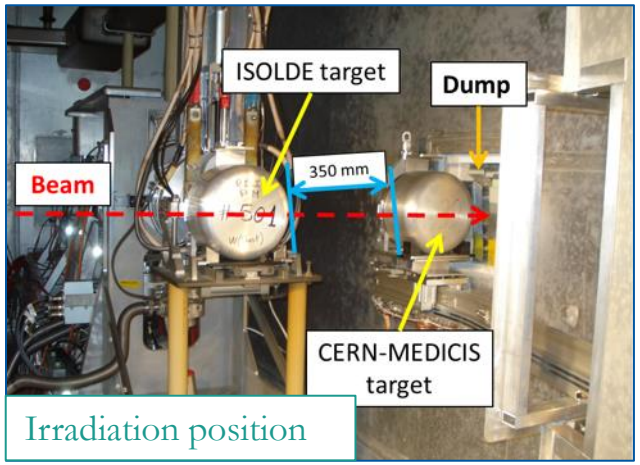


MEDICIS: the facility 1/2

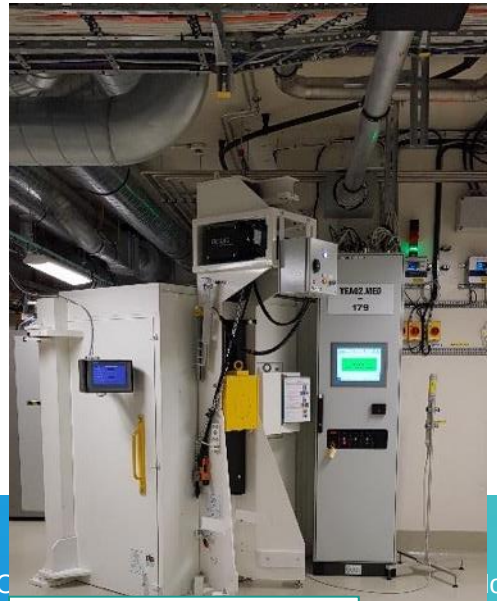

MEDICIS lab


KUKA® robot

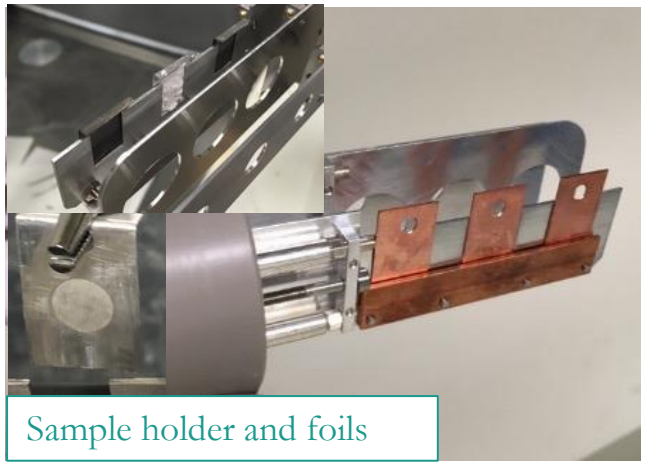




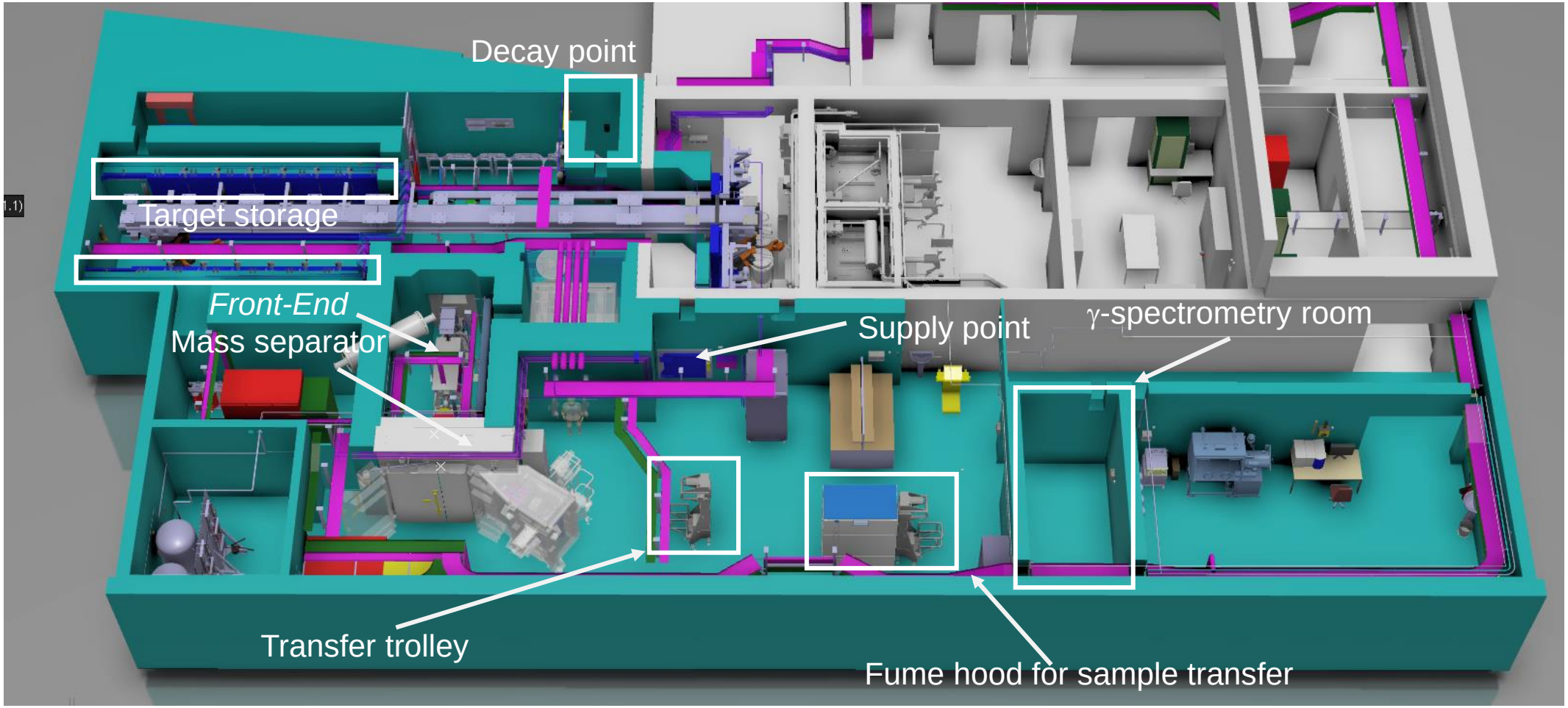
Irradiation position


Collection point


Fume hood


Sample holder and foils

MEDICIS: the facility 2/2



MEDICIS: standard operation

Activities in the target: ~GBq
Collected activities: up to hundreds of MBq

- Ba-128/Cs-128
- Tb-149, Tb-152, Tb-155
- Tm-165, Tm-167
- Sc-44, Sc-47
- Pt-191
- Ra-225/Ac-225
- Ra-224 (Pb-212 generator)

MEDICIS: non-standard operation

MEDICIS operational also when protons are not available (e.g. stop of accelerator complex)!

ARRONAX

Sample irradiation in cyclotrons or research reactors

NEUTRONS FOR SOCIETY

PAUL SCHERRER INSTITUT PSI

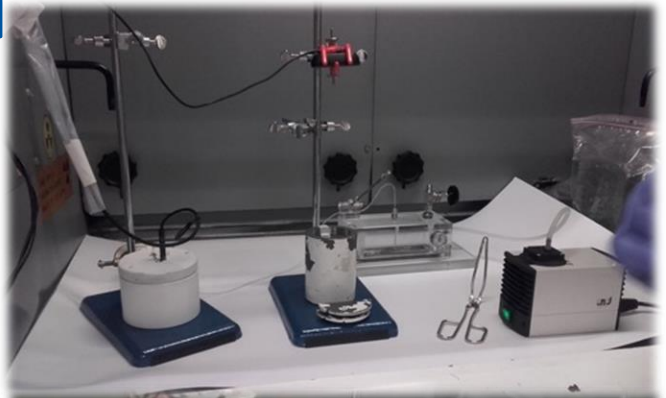
Use of external radioactive samples

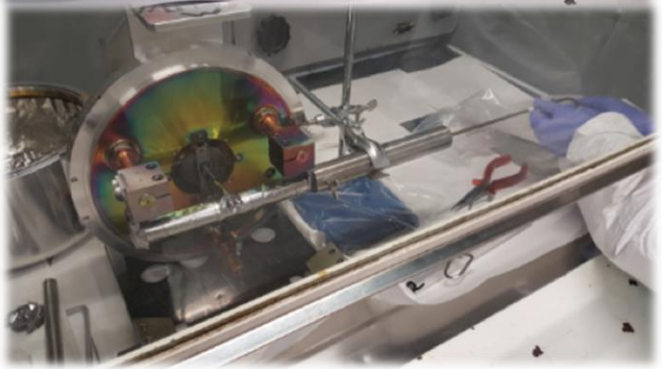
- Er-169
- Yb-175
- Pt-195m
- Tb-155
- Sm-153
- Tm-167
- Ac-225

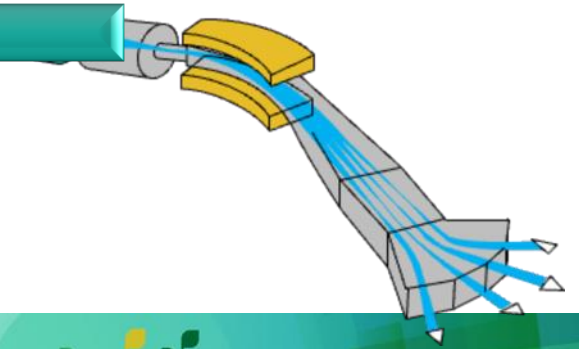
separation on MEDICIS Front End

Collection retrieval

γ-spectrometry and shipping







Operational radiation protection at MEDICIS

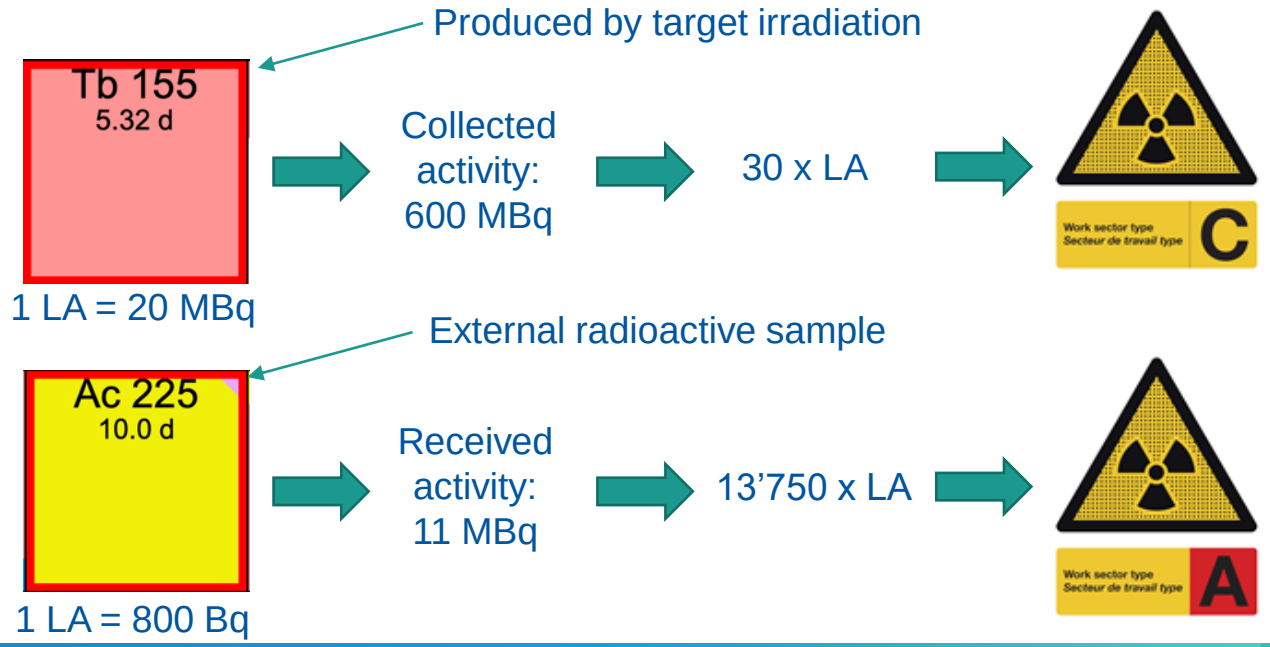
*ORaP = Swiss Radiological Protection Ordinance
**Inhalation of activity at licensing limit, LA, on a single occasion yields a E_{50} = 5 mSv

MEDICIS laboratory: work sector according to ORaP*

*"Activities involving **radioactive material above** the **licensing limit**, with the exception of sealed radioactive sources, must be carried out within controlled areas in rooms which are designed as **work sector** as specified in Article 81." [Art. 78]*

Work sector	
Type C	1-100 x LA
Type B	1-10'000 x LA
Type A	1 to > 10'000 x LA

Being MEDICIS a work sector of type A guarantees the highest level of safety and a reasonable degree of flexibility (research facility)



Requirement	A	B	C
Floor, working surface	Continuous and waterproof layer, sealed		
Changing room	X		
Decontamination shower	X		
Sink at proximity for decontamination	X	X	X
Forced ventilation	X	X	
Minimum 5 air renewal per hour	X	X	
Underpressure w.r.t nearby rooms	X	X	
Underpressure in case of power failure	X		

ALARA approach at CERN

A formalized ALARA approach is vital for a successful Radiation Protection of over 10’000 Radiation Workers and is supported and enforced by the CERN management.
Optimization at CERN is consistently implemented from design, operation to dismantling of facilities at various levels depending on the radiological risks

Group 1 criteria define **ALARA level**

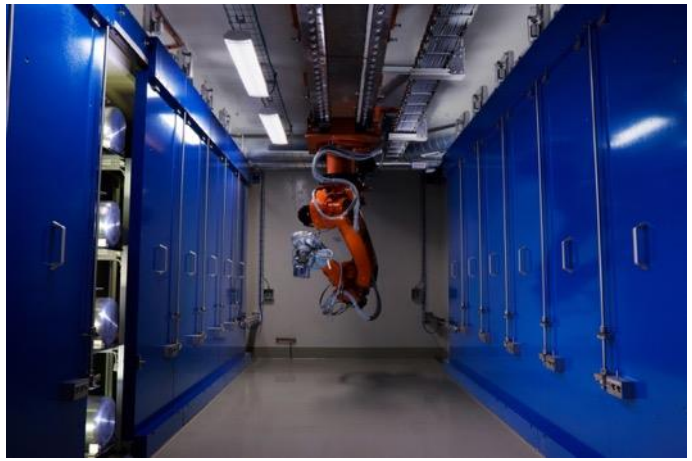
Individual dose equi.	**Level I**	100 µSv	**Level II**	1 mSv	**Level III**
Collective dose equi.		500 µSv		5 mSv	

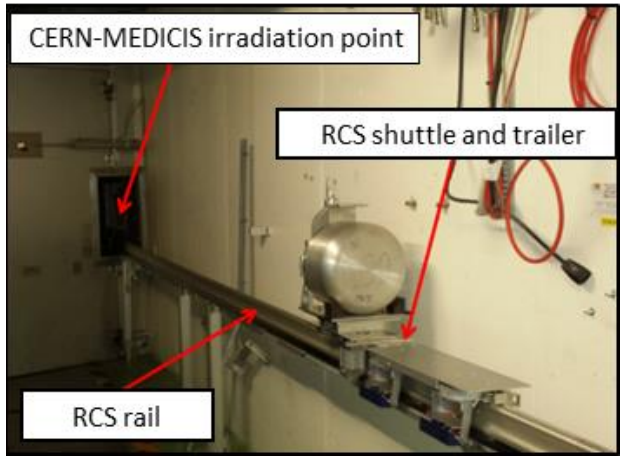
Group 2 criteria are the **bases of a radiological risk assessment** (including accidents and incident scenarios) prior to the final ALARA level classification of the intervention.

Ambient dose equivalent rate	**Level I**	50 µSv/hr	**Level II**	2 mSv/hr	**Level III**
Airborne activity in CA		5 CA		200 CA	
Surface contamination in CS		10 CS		100 CS	

ALARA at MEDICIS: technical implementation

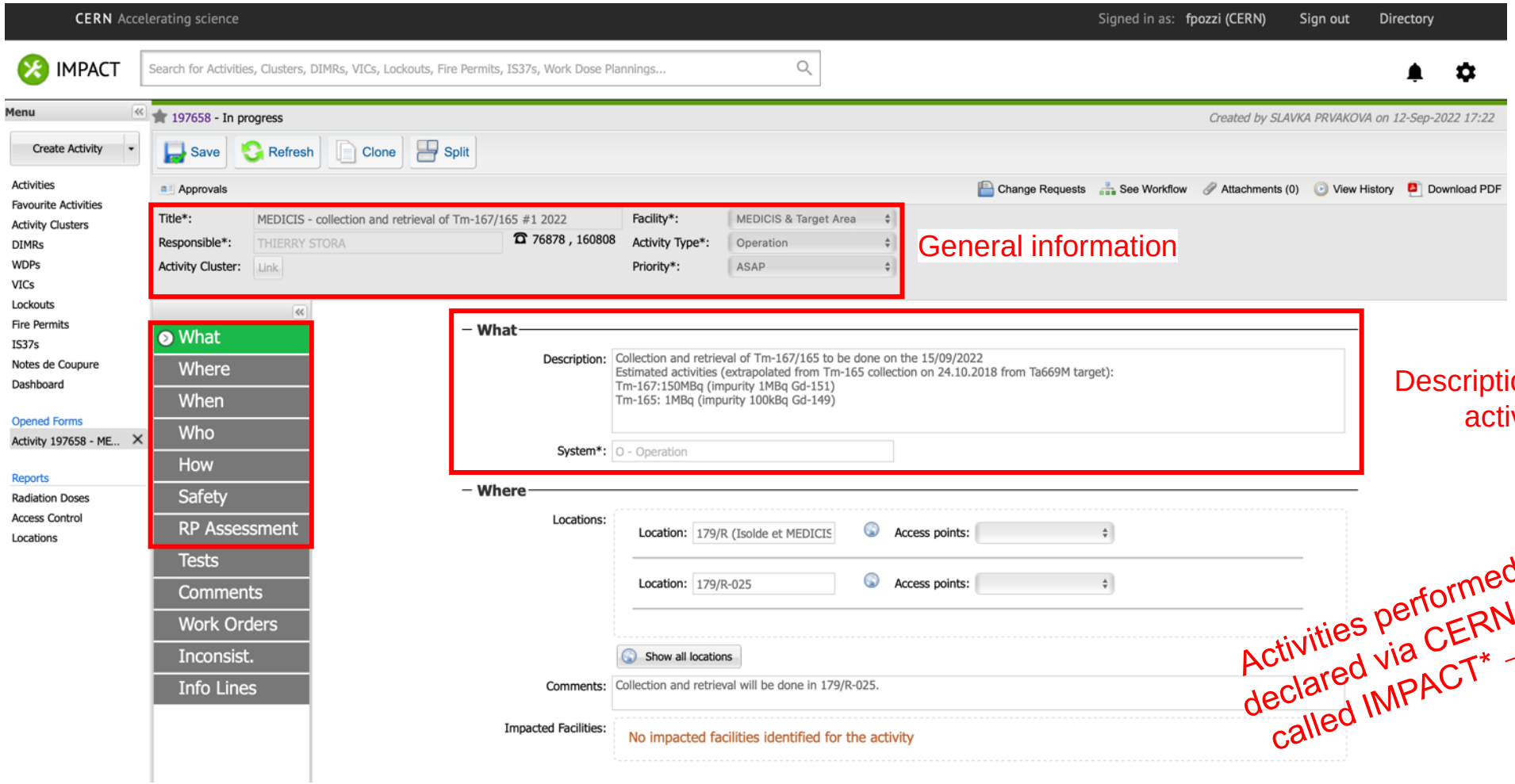
- Targets remotely handled (robot + rail conveyor system RCS)
- Shielded decay point for target cool-down
- Ongoing radionuclide implantation remotely controlled
- Target remotely stored by robot in dedicated shielded shelves
- Collection retrieval optimized





*IMPACT = Intervention Management Planning and Coordination Tool

ALARA at MEDICIS: procedural implementation



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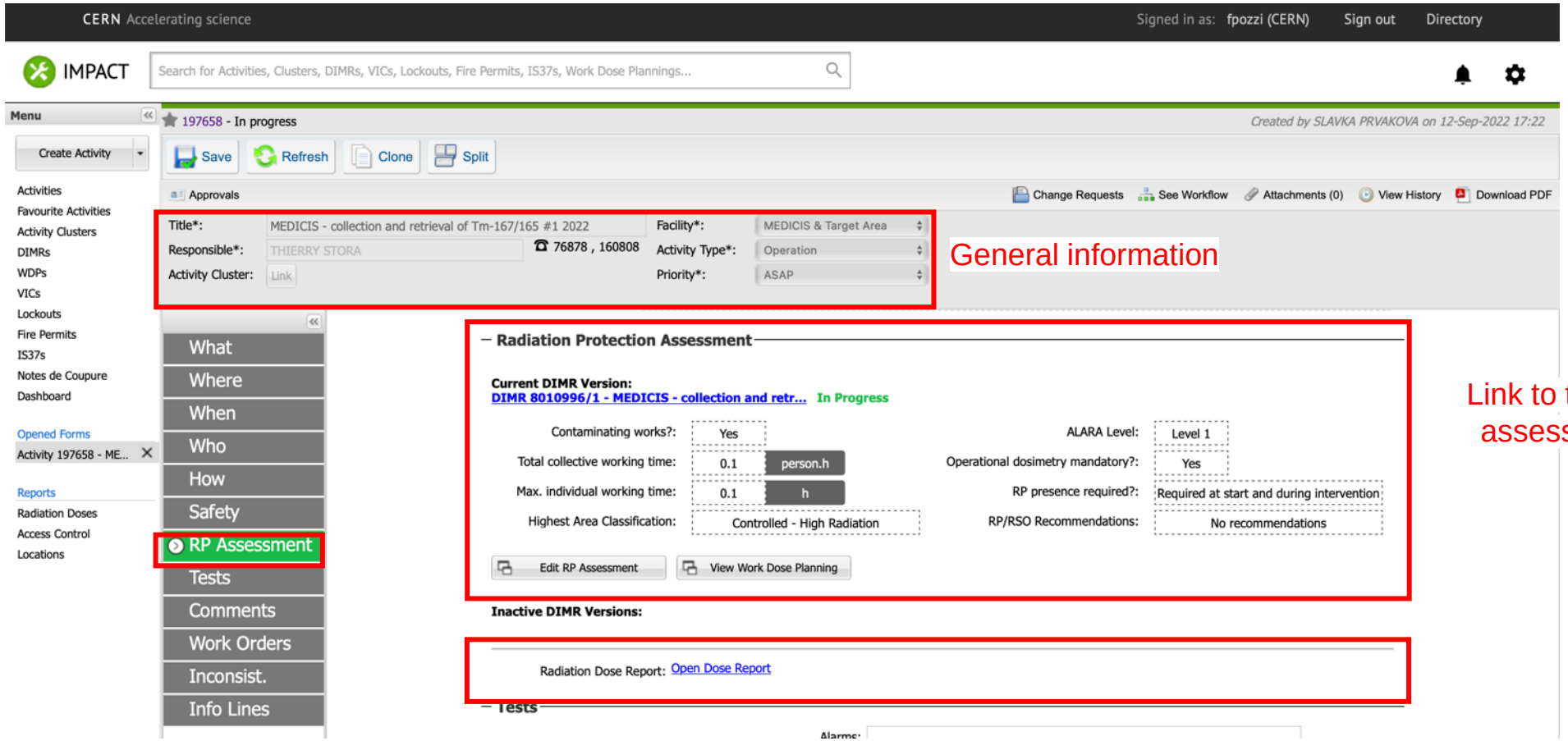
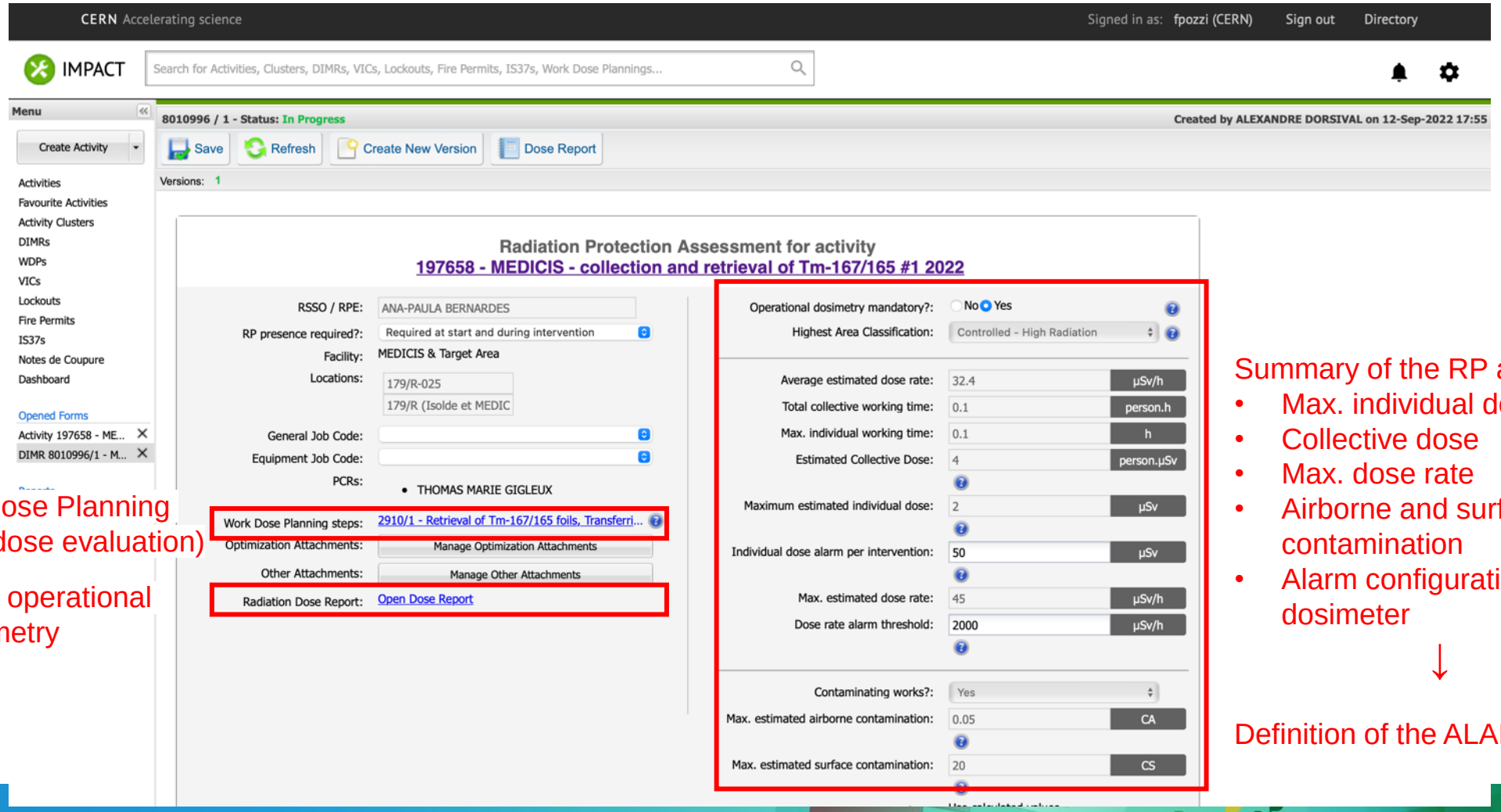


*DIMR (from the French) = *Dossier d'Intervention en Milieu Radiologique*

ALARA at MEDICIS: procedural implementation



Work and Dose Planning (step-by-step dose evaluation)

Follow-up of operational dosimetry

Summary of the RP assessment:

- Max. individual dose
- Collective dose
- Max. dose rate
- Airborne and surface contamination
- Alarm configuration for active dosimeter

↓

Definition of the ALARA level

Radiation protection monitoring

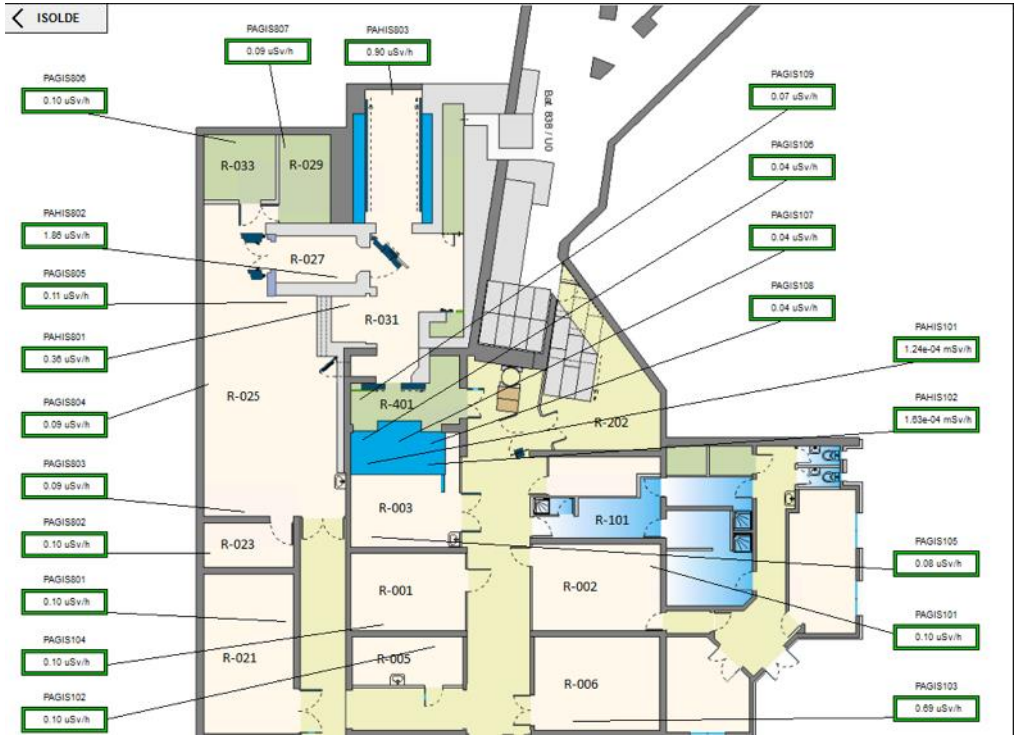
Dosimetry
- Whole body
  - Personal passive dosimeter
  - Active operational dosimeter
- Extremities
  - Ring dosimeter (passive)
  - Active probe (for high activity samples)

External exposure
- Area mixed field monitor (High-pressure ionisation chamber)
- Low range gamma probe (proportional counting tube)
- High range gamma probe (GM counting tube)

Surface and airborne contamination
- Alpha/beta particulate monitor
- Hand and Foot monitor

Environment
- Iodine sample
- Aerosol sampler
- Online gas monitor
- Alpha/beta online monitor

All monitors integrated into the Radiation and Environment Monitoring Unified Supervision (REMUS)



Conclusions

Conclusions

- Since 2017, **MEDICIS** is **operational at CERN** to produce **non-conventional isotopes for medical research**
- The **radiological challenges** related with handling (non-conventional) **unsealed radioactive samples/targets** are addressed as follows by operational radiation protection
  - **ALARA approach** implemented since the design of the facility (**technical implementation**)
  - Laboratory complying with highest Swiss standards in matter of **radiation protection and safety**
  - Formalised **ALARA procedure** constantly implemented
  - Availability of an extensive **radiation protection monitoring systems** (external and internal exposure)
  - **Dedicated supervision** by **two radiation protection staff** assigned to MEDICIS/ISOLDE installations

Back-up slides

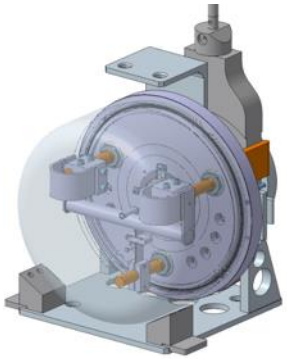
References

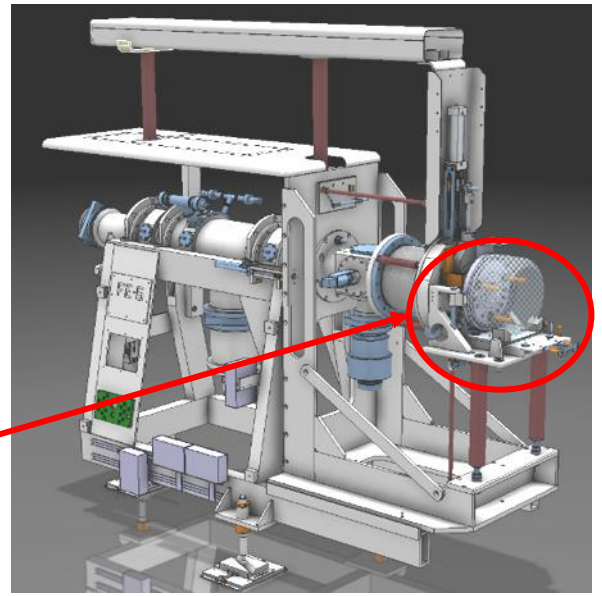
- MEDICIS website: https://medicis.cern
- C. Duchemin *et al.,* **CERN-MEDICIS: A review since commissioning in 2017**, *Front. Med., 15 July 2021,* https://doi.org/10.3389/fmed.2021.693682
- F. Pozzi et al., Operational Radiation Protection Challenges at MEDICIS, a CERN Facility for the Production of Non-Conventional Isotopes for Medical Research, Proceedings ICRS 14/RPSD 2022, Seattle, September 25-29, 2022, pp 207-210.

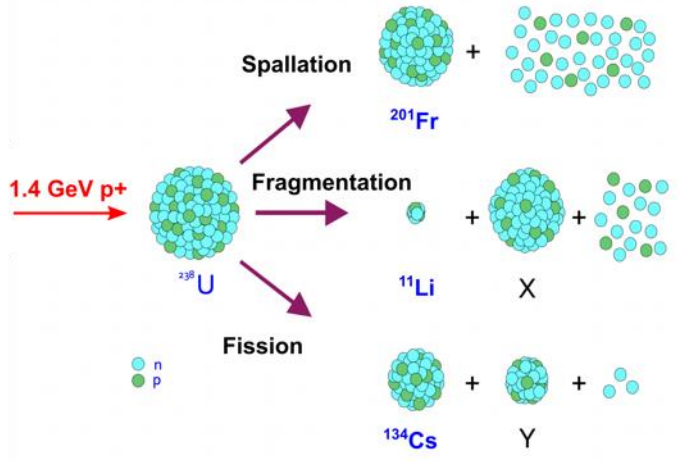
*Online collection = beam is impacting the target as the radionuclides are extracted in the form of an ion beam

RIBs production at ISOLDE

- **~30 targets per year**
  - ~60% of targets made of depleted Uranium Carbide (UCx)
  - Target lifetime of ~10 days (typically 5e18 protons on target)
- **Online* production of Radioactive Ion Beams (RIBs)**
  - Proton/target interaction (spallation/fragementation/fission)
  - Target heated up to 2300 °C (diffusion of radionuclides)
  - Ionisation and extraction of radionuclides by electrostatic field (up to 60 kV)
  - Mass separation
  - RIB transported to the experiment
- **Applications**: nuclear and atomic physics, solid-state physics, material and life sciences







CERN's radiological area classification

Expressed in Bq/m^3 and specific for each radionuclide
Inhalation of an activity equivalent to 1xCA over one year (2000 h) → E_{50} = 20 mSv

<20% of the working time

Expressed in Bq/cm^2 and specific for each radionuclide

MEDICIS lab. → Limited Stay
mainly due to external exposure
during collection retrieval and
potential risk of contamination

Area	Annual dose limit (year)	Ambient dose equivalent rate: permanent occupancy	Ambient dose equivalent rate: low occupancy	Sign	Specific airborne radioactivity*	Specific surface contamination**
...signated	1 mSv	0.5 µSv/h	2.5 µSv/h	RADIATION	0.05 CA	1 CS
Radiation Area: Supervised	6 mSv	3 µSv/h	15 µSv/h	Dosimeter obligatory	0.1 CA	1 CS
Radiation Area: Simple Controlled	20 mSv	10 µSv/h	50 µSv/h	SIMPLE CONTROLLED / CONTRÔLÉE SIMPLE	0.1 CA	1 CS
Radiation Area: Limited Stay	20 mSv	-	2 mSv/h	LIMITED STAY / SÉJOUR LIMITÉ	100 CA	4000 CS
Radiation Area: High Radiation	20 mSv	-	100 mSv/h	HIGH RADIATION / HAUTE RADIATION	1000 CA	40000 CS
Radiation Area: Prohibited	20 mSv	-	> 100 mSv/h	NO ENTRY / DÉFENSE D'ENTRER	> 1000 CA	> 40000 CS

Controlled Area

Internal dosimetry

- Working with **unsealed radioactive sources** entails **risk of incorporation**
  - It **must be addressed by** appropriate **screening measurements** and **procedures**, in particular in the context of contamination incidents
  - **Challenges** arise from measurement difficulties for **low-energy beta emitters** (Ac-227, Ni-63) or in risk assessment for nuclides that are not yet covered by national legislations (Ac-225, Ac-227, Sc-44)
- **Internal monitoring program at MEDICIS being set-up**
  - In-vivo **screening measurements** → has an incorporation taken place or not?
  - **Incorporation measurements** → quantification of incorporated activity and E_{50}
- **Collaboration** between **CERN** and **Institute of Radiation Physics (IRA) in Lausanne (Switzerland)**
  - Establish **competence centre for internal dosimetry** (in vitro measurements, whole body spectrometer, electronic interface…)
  - Establishment of **routine screening measurements** with conventional RP instruments
  - Development of **dose assessment procedures** in the event of an intake incident
  - Establish routine **whole body counting measurements at CERN**
  - Elaborate new **procedures** for **biological sample analysis**
- Reference: S. Medici, **Development of a triage monitoring programme for the intake of radionuclides at CERN**, PhD thesis, CERN-THESIS-2020-149