

# Operational Radiation Protection at MEDICIS

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

*20<sup>th</sup> European ALARA Network workshop, 2-4 October 2023, AGES Vienna (Austria)*

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

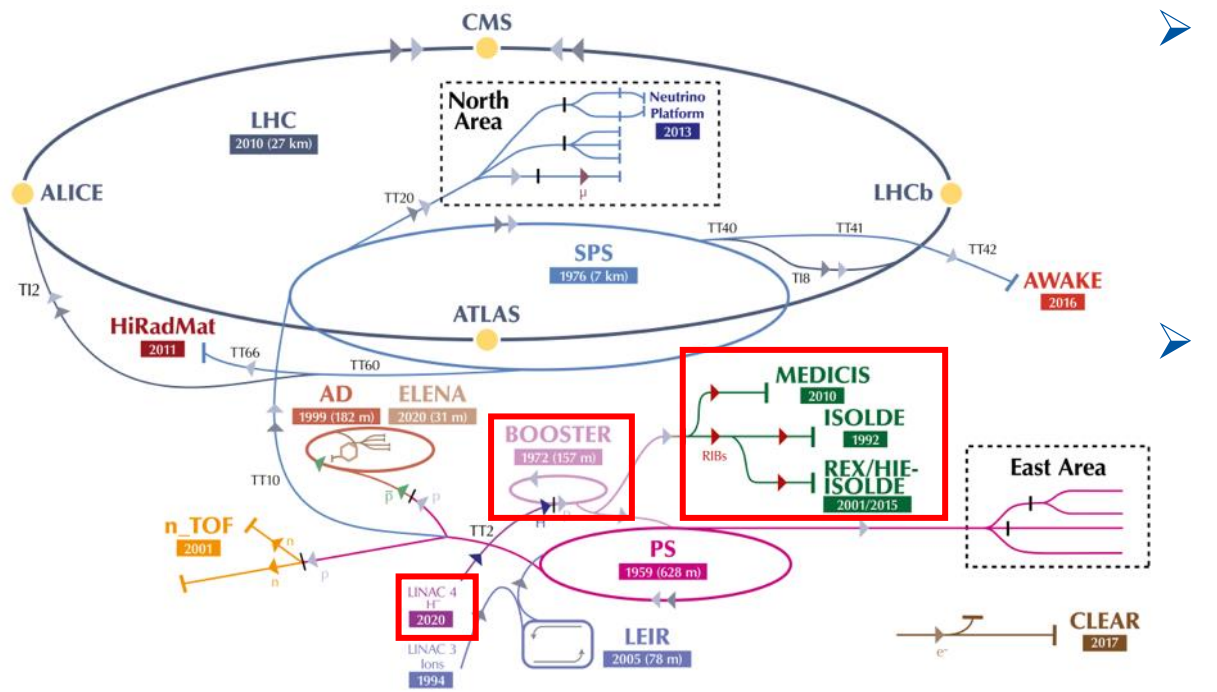




# Introduction to ISOLDE and MEDICIS

\*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**



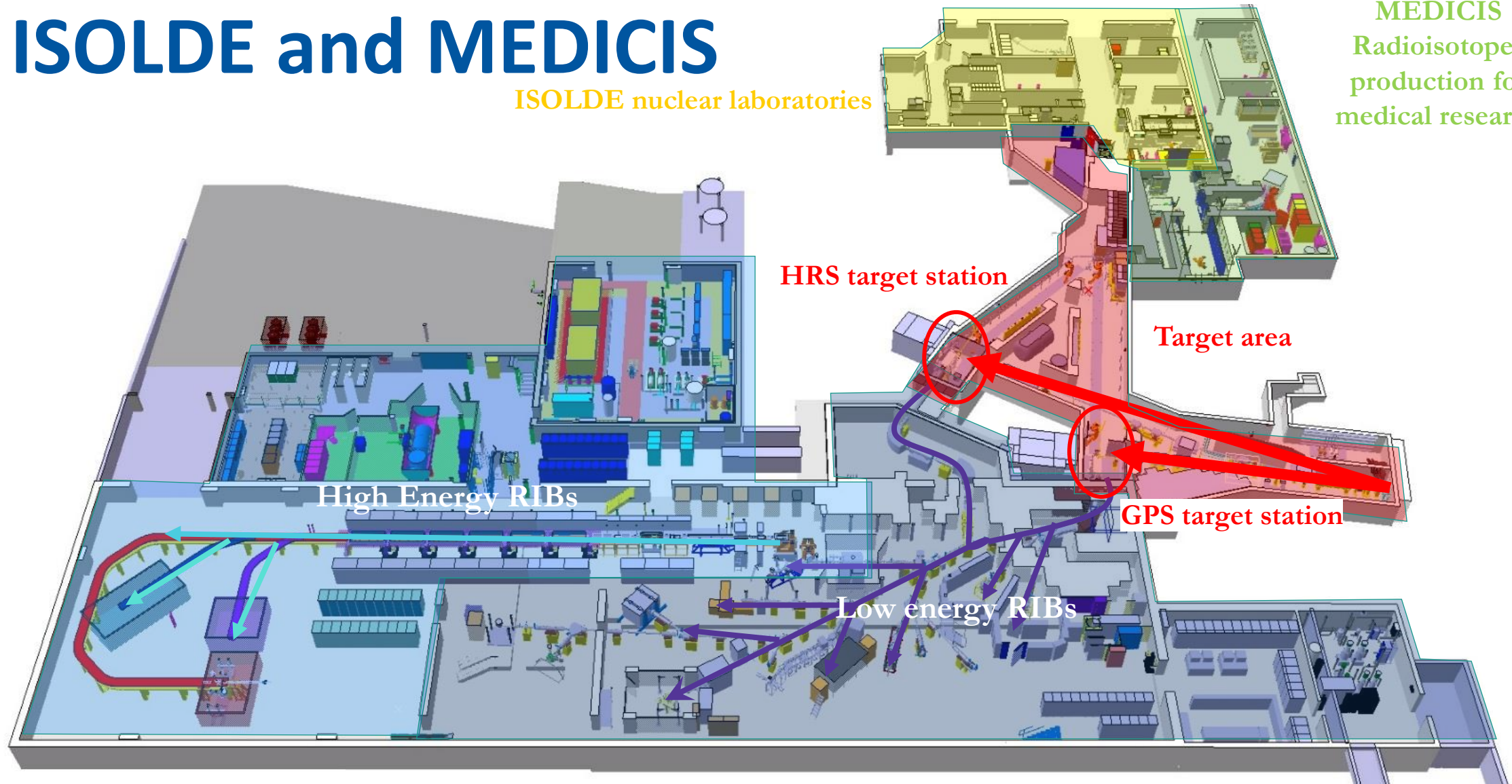
▶ H<sup>-</sup> (hydrogen anions) ▶ p (protons) ▶ ions ▶ RIBs (Radioactive Ion Beams) ▶ n (neutrons) ▶  $\bar{p}$  (antiprotons) ▶ e<sup>-</sup> (electrons) ▶ μ (muons)

LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear Electron Accelerator for Research // AWAKE - Advanced WAKEfield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE-ISOLDE - Radioactive Experiment/High Intensity and Energy ISOLDE // MEDICIS // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n\_TOF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials // Neutrino Platform

# ISOLDE and MEDICIS

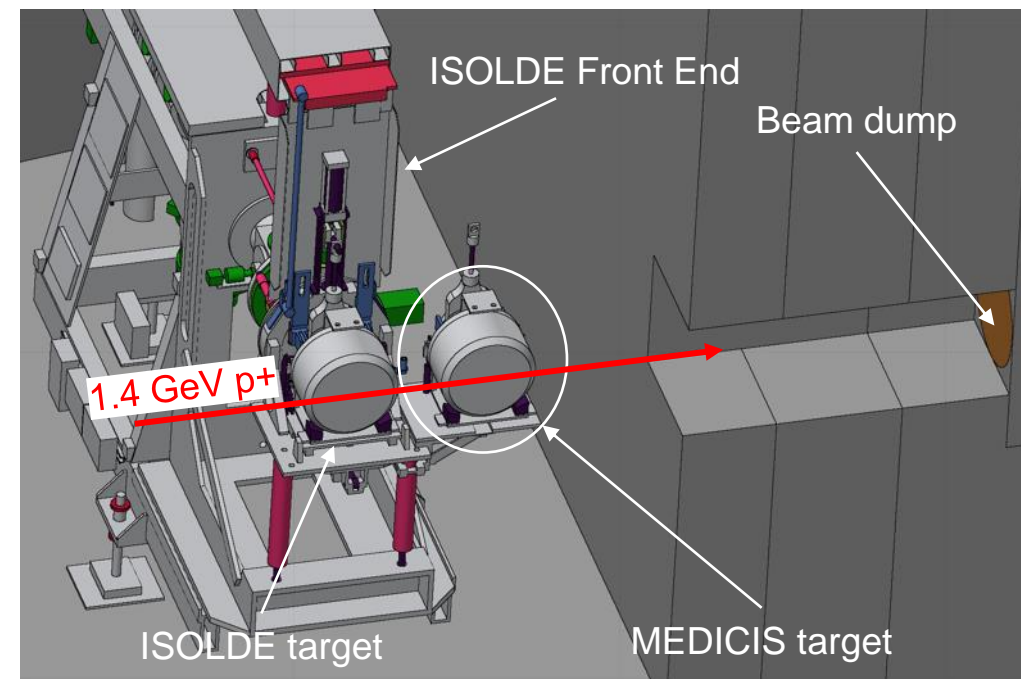
ISOLDE nuclear laboratories

MEDICIS  
Radioisotopes  
production for  
medical research

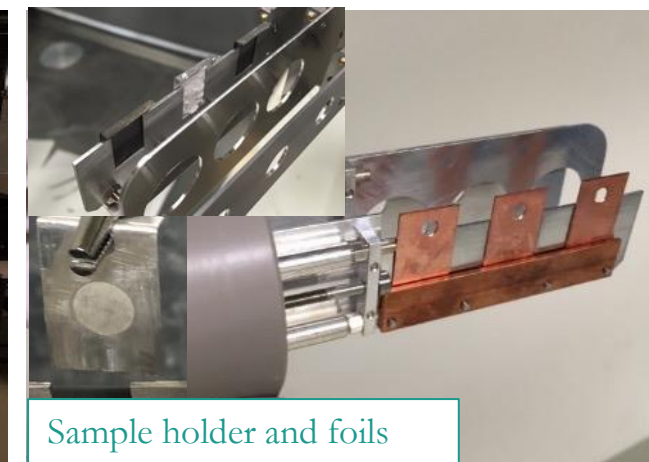
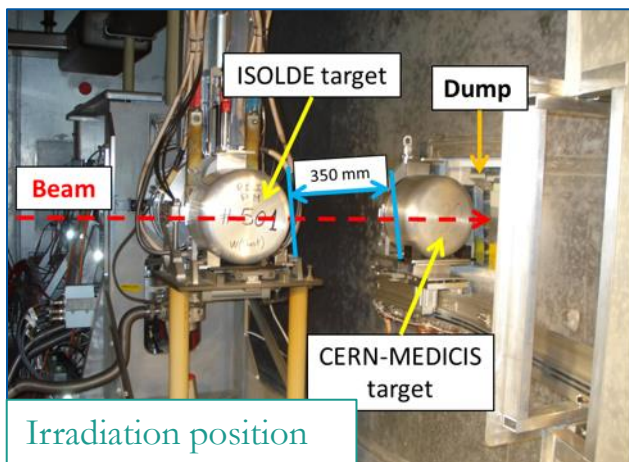
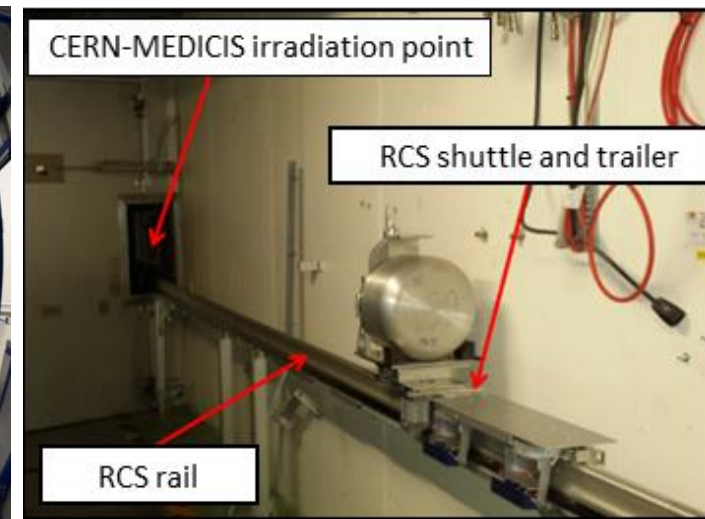
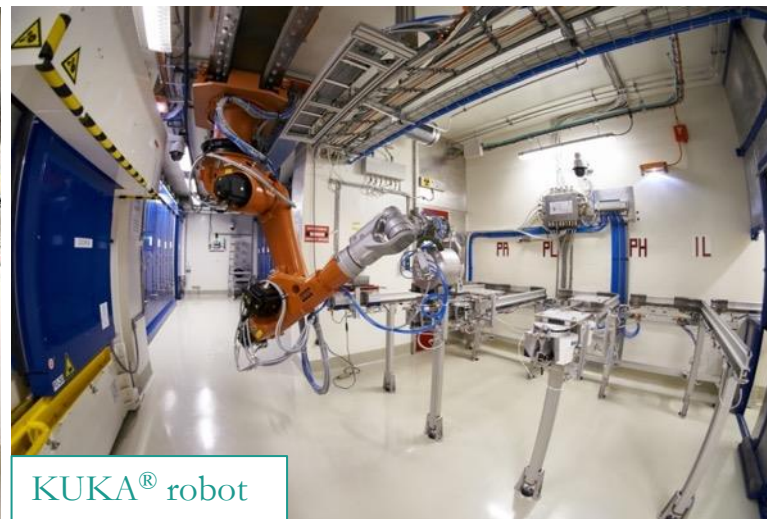


# MEDICIS: the concept

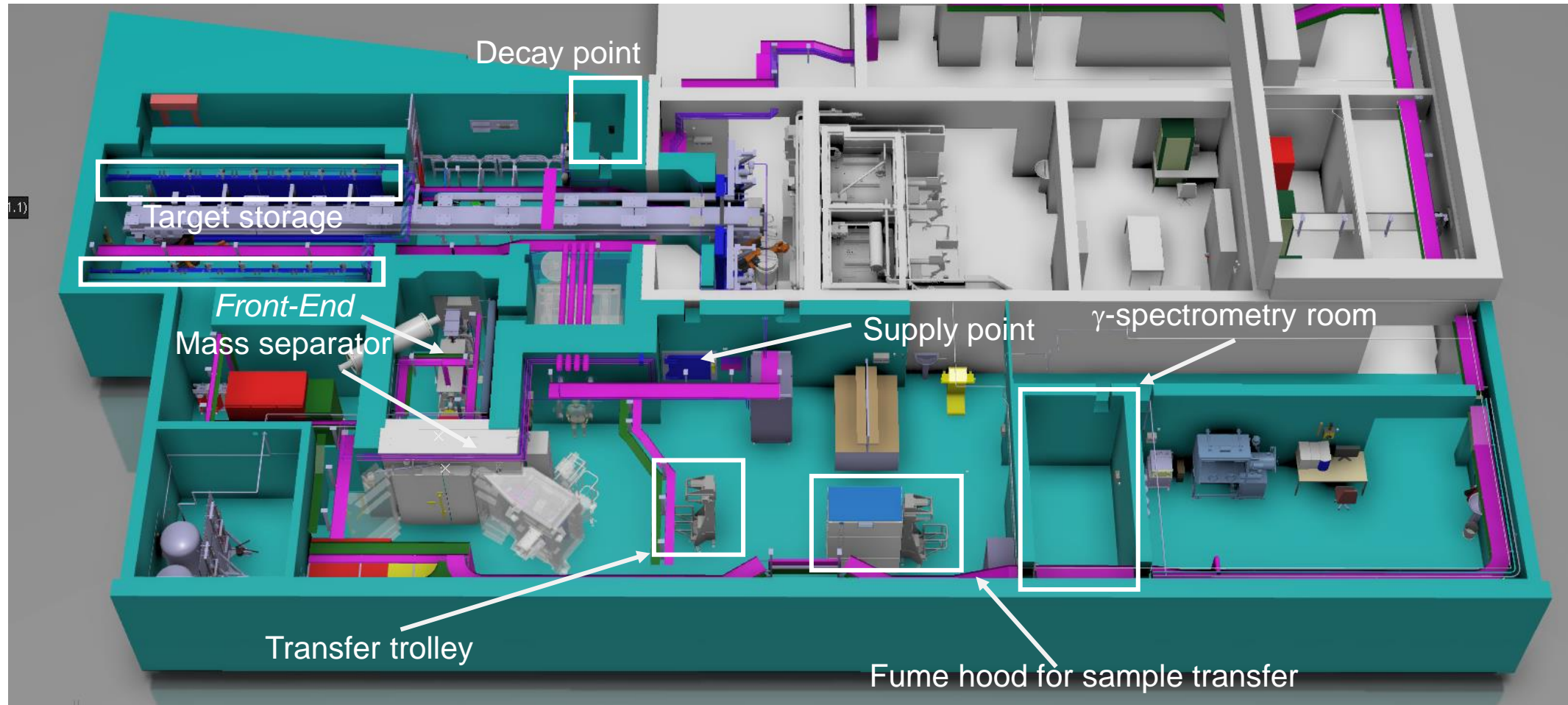
- MEDICIS is a **Collaboration** between **CERN** and **14 research institutes/hospitals/universities**
  - Scientific program based on needs/requirements defined by the Collaboration
- **MEDICIS operation principle**
  - MEDICIS target inserted between ISOLDE target and beam dump
  - MEDICIS target “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  $t_{1/2} \sim$  hours



# MEDICIS: the facility 1/2



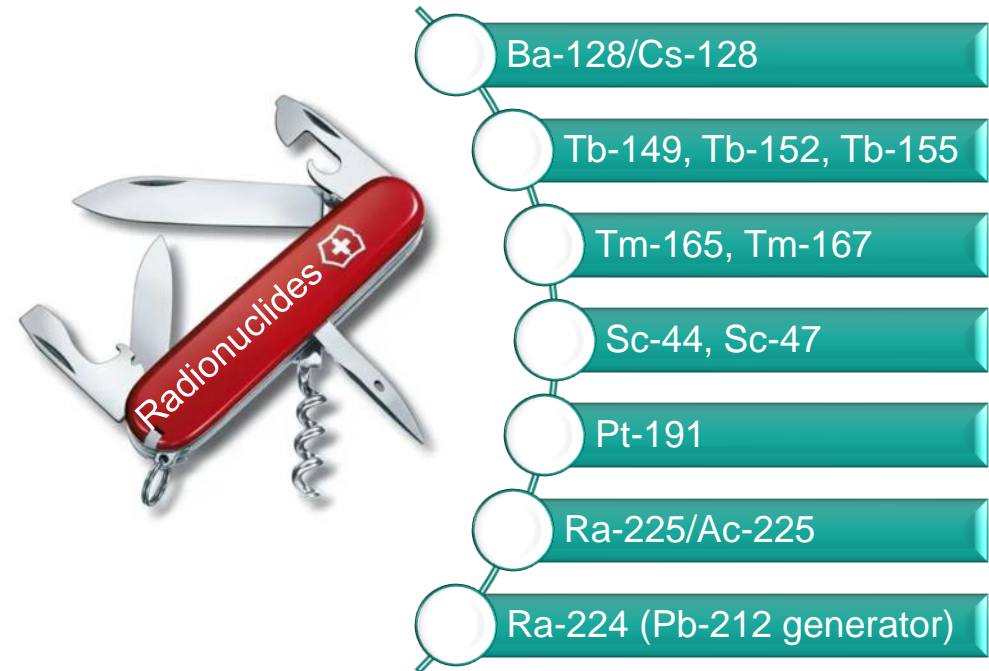
# MEDICIS: the facility 2/2



# MEDICIS: standard operation



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





# MEDICIS: non-standard operation

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



Sample irradiation in cyclotrons or research reactors

PAUL SCHERRER INSTITUT



Use of external radioactive samples

Er-169

Yb-175

Pt-195m

Tb-155

Sm-153

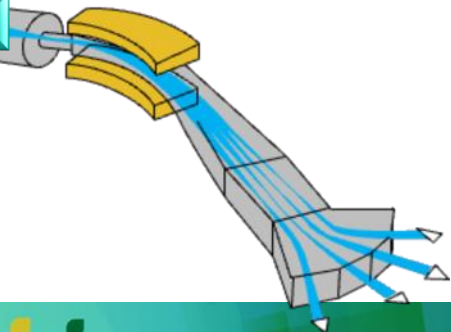
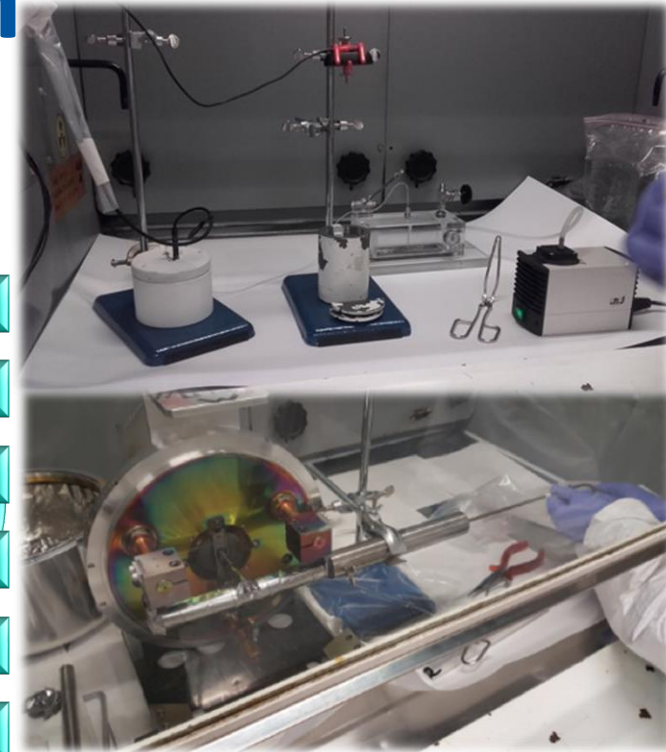
Tm-167

Ac-225

γ-spectrometry and shipping

Collection retrieval

separation on MEDICIS Front End





# Operational radiation protection at MEDICIS

\*ORaP = Swiss Radiological Protection Ordinance

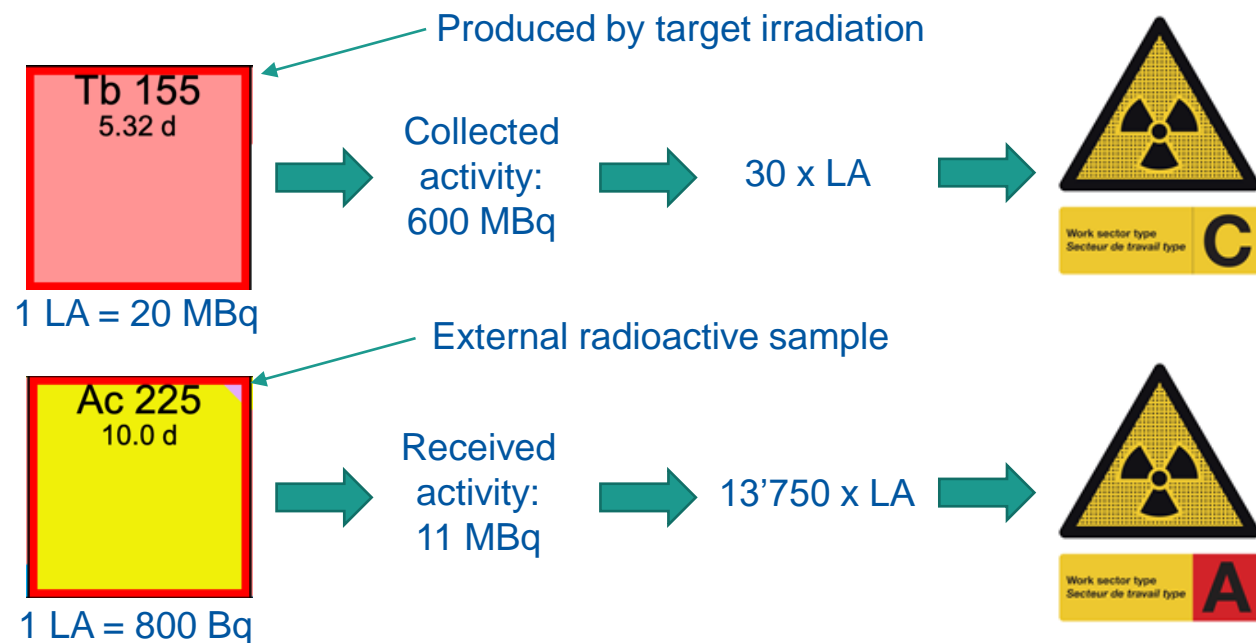
\*\*Inhalation of activity at licensing limit, LA, on a single occasion yields a  $E_{50} = 5 \text{ mSv}$

# 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 $\mu$ Sv	Level II	1 mSv	Level III
Collective dose equi.		500 $\mu$ Sv		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 $\mu$ Sv/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

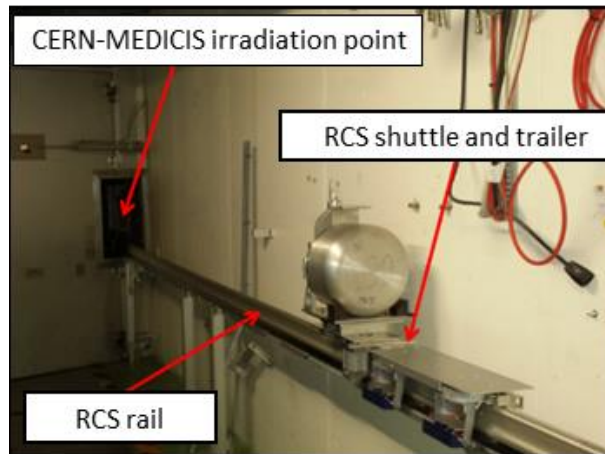
Targets remotely handled (robot + rail conveyor system RCS)

Shielded decay point for target cool-down

Ongoing radionuclide implantation remotely controlled

Target remotely stored by robot in dedicated shielded shelves

Collection retrieval optimized



# ALARA at MEDICIS: procedural implementation

The screenshot displays the IMPACT web application interface. At the top, it shows 'CERN Accelerating science' and 'Signed in as: fpozzi (CERN)'. The main header includes the IMPACT logo and a search bar. The left sidebar contains a menu with categories like 'Activities', 'Favourite Activities', 'Activity Clusters', 'DIMRs', 'WDPs', 'VICs', 'Lockouts', 'Fire Permits', 'IS37s', 'Notes de Coupure', 'Dashboard', 'Opened Forms', 'Reports', 'Radiation Doses', 'Access Control', and 'Locations'. The main content area shows details for activity 197658, including fields for Title, Responsible, Activity Cluster, Facility, Activity Type, and Priority. A red box highlights the 'General information' section. Below this, a 'What' section contains a description of the activity, and a 'Where' section lists locations. A red box highlights the 'What' section. A red box highlights the 'RP Assessment' option in the left sidebar. A red box highlights the 'Description of the activity' section. A red box highlights the 'Activities performed at MEDICIS declared via CERN electronic tool called IMPACT\* -> RP approval' section.

**General information**

**Description of the activity**

**Activities performed at MEDICIS declared via CERN electronic tool called IMPACT\* -> RP approval**

# ALARA at MEDICIS: procedural implementation

The screenshot displays the IMPACT web interface. At the top, it shows 'CERN Accelerating science' and user information 'Signed in as: fpozzi (CERN)'. A search bar is present with the text 'Search for Activities, Clusters, DIMRs, VICs, Lockouts, Fire Permits, IS37s, Work Dose Plannings...'. The main content area is titled '197658 - In progress' and includes a 'General information' section with fields for Title, Responsible, Activity Cluster, Facility, Activity Type, and Priority. Below this is a 'Radiation Protection Assessment' section with various input fields and dropdown menus. A sidebar on the left contains a menu with options like 'RP Assessment' highlighted. A red box highlights the 'RP Assessment' section, and another red box highlights the 'General information' section. A red arrow points from the 'RP Assessment' section to the text 'Link to the RP assessment'.

**General information**

Title*:	MEDICIS - collection and retrieval of Tm-167/165 #1 2022	Facility*:	MEDICIS & Target Area
Responsible*:	THIERRY STORA 76878 , 160808	Activity Type*:	Operation
Activity Cluster:	<a href="#">Link</a>	Priority*:	ASAP

**Radiation Protection Assessment**

Current DIMR Version:  
[DIMR 8010996/1 - MEDICIS - collection and retr...](#) In Progress

Contaminating works?:	Yes	ALARA Level:	Level 1
Total collective working time:	0.1 person.h	Operational dosimetry mandatory?:	Yes
Max. individual working time:	0.1 h	RP presence required?:	Required at start and during intervention
Highest Area Classification:	Controlled - High Radiation	RP/RSO Recommendations:	No recommendations

[Edit RP Assessment](#) [View Work Dose Planning](#)

Inactive DIMR Versions:

Radiation Dose Report: [Open Dose Report](#)

Link to the RP assessment

# ALARA at MEDICIS: procedural implementation

CERN Accelerating science

Signed in as: fpozzi (CERN) Sign out Directory

IMPACT Search for Activities, Clusters, DIMRs, VICs, Lockouts, Fire Permits, IS37s, Work Dose Plannings...

Menu 8010996 / 1 - Status: In Progress Created by ALEXANDRE DORSIVAL on 12-Sep-2022 17:55

Activities  
Favourite Activities  
Activity Clusters  
DIMRs  
WDPs  
VICs  
Lockouts  
Fire Permits  
IS37s  
Notes de Coupure  
Dashboard

Opened Forms  
Activity 197658 - ME... X  
DIMR 8010996/1 - M... X

Operational dosimetry mandatory?:  No  Yes  
Highest Area Classification: Controlled - High Radiation

Average estimated dose rate:	32.4	µSv/h
Total collective working time:	0.1	person.h
Max. individual working time:	0.1	h
Estimated Collective Dose:	4	person.µSv
Maximum estimated individual dose:	2	µSv
Individual dose alarm per intervention:	50	µSv
Max. estimated dose rate:	45	µSv/h
Dose rate alarm threshold:	2000	µSv/h
Contaminating works?:	Yes	
Max. estimated airborne contamination:	0.05	CA
Max. estimated surface contamination:	20	CS

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)

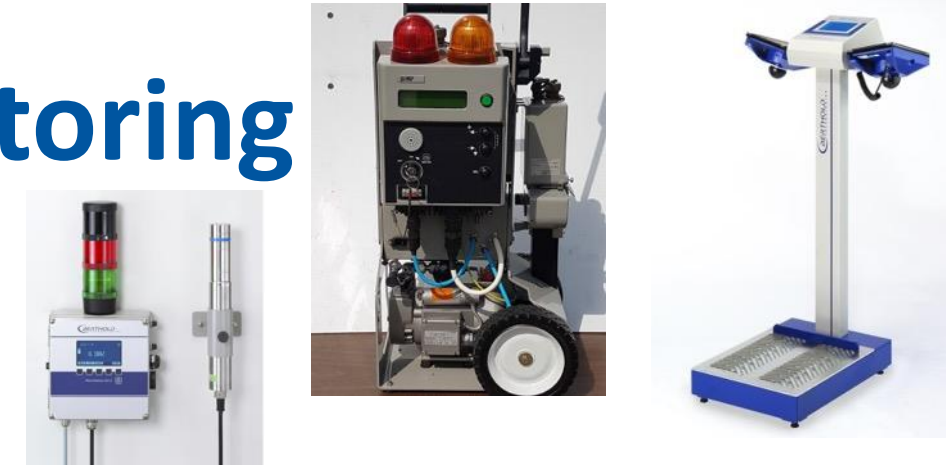


## Surface and airborne contamination

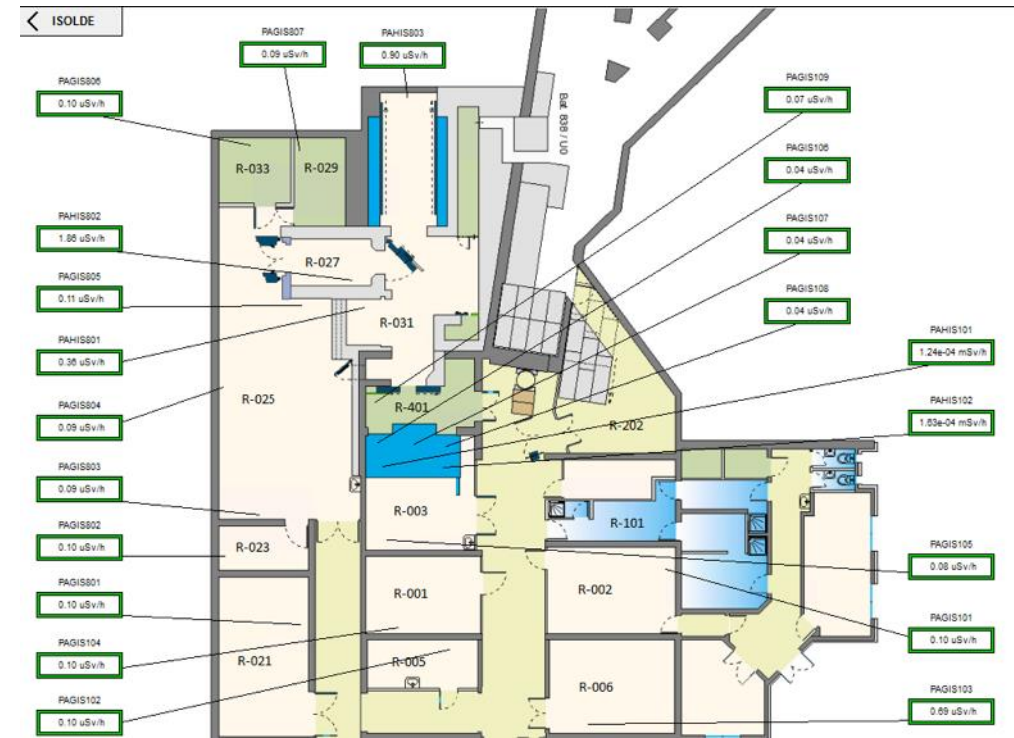
- Alpha/beta particulate monitor
- Hand and Foot monitor

## Environment

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



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



# Operational Radiation Protection Challenges at MEDICIS, a CERN Facility for the Production of Non-Conventional Isotopes for Medical Research

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## INTRODUCTION

MEDICIS (MEDical Isotopes Collected from ISOLDE) is a CERN research facility [1], which is operating since end of 2017. MEDICIS aims at providing a wide range of radioisotopes, some of which can only be produced at CERN thanks to the unique ISOLDE facility, for medical research. These radioisotopes are destined primarily to hospitals and research centers in Switzerland and across Europe. The production, collection and conditioning of these unsealed radioactive sources entails a risk of external

## Conclusions

At ISOLDE, only 10% of the proton beam interacts in the target, whilst the remaining protons are absorbed inside beam dumps situated after the targets. The MEDICIS principle is to insert an additional thick target between the ISOLDE target on the HRS Front-End and its beam dump. Consequently, the MEDICIS target can be irradiated in parallel to the ISOLDE one and be retrieved remotely from the target area to MEDICIS laboratory after a predefined irradiation time and given number of protons. After the irradiation, the target can be temporarily stored for decay before being transferred to the MEDICIS Front-End. Once the target is connected to the MEDICIS Front-End, the

# 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

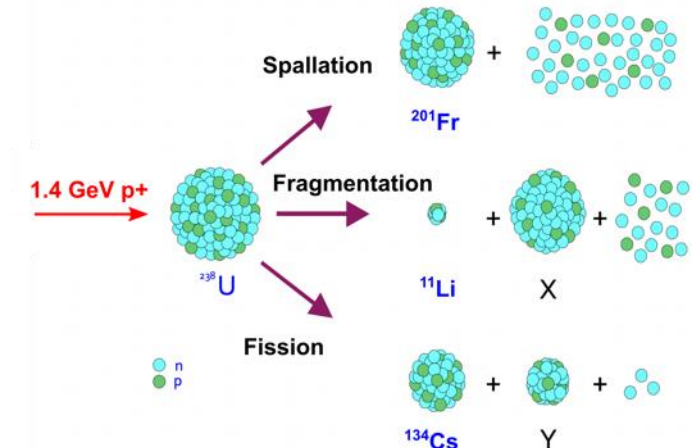
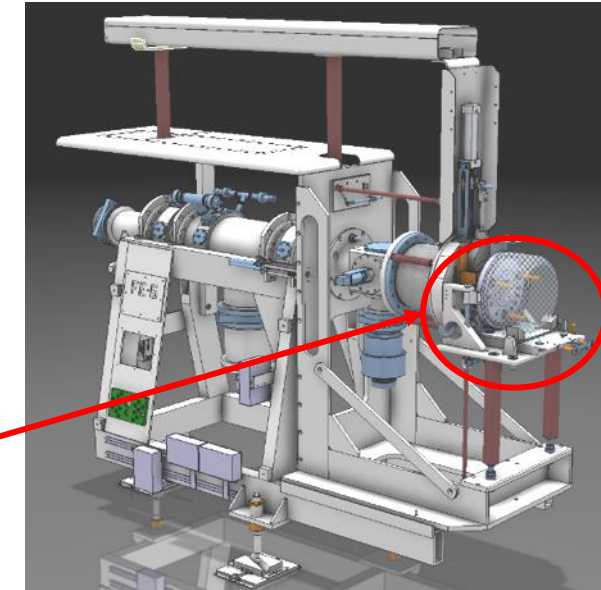
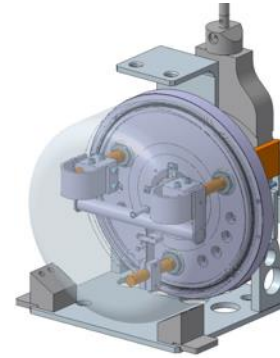
# References

- 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  $5 \times 10^{18}$  protons on target)
- **Online\* production of Radioactive Ion Beams (RIBs)**
  - Proton/target interaction (spallation/fragmentation/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



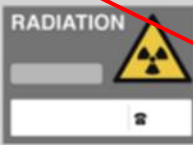







# CERN's radiological area classification

Expressed in Bq/m<sup>3</sup> and specific for each radionuclide  
 Inhalation of an activity equivalent to 1xCA over one year (2000 h) → E<sub>50</sub> = 20 mSv

<20% of the working time

Expressed in Bq/cm<sup>2</sup> 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		Sign	RADIATION 		Specific airborne radioactivity*	Specific surface contamination**
		permanent occupancy	low occupancy					
Designated	1 mSv	0.5 µSv/h	2.5 µSv/h				0.05 CA	1 CS
Supervised	6 mSv	3 µSv/h	15 µSv/h	Dosimeter obligatory Dosimètre obligatoire 			0.1 CA	1 CS
Simple Controlled	20 mSv	10 µSv/h	50 µSv/h	SIMPLE CONTROLLED / CONTRÔLÉE SIMPLE Dosimeter obligatory Dosimètre obligatoire 			0.1 CA	1 CS
Limited Stay	20 mSv	-	2 mSv/h	LIMITED STAY / SÉJOUR LIMITÉ Dosimeters obligatory Dosimètres obligatoires  			100 CA	4000 CS
High Radiation	20 mSv	-	100 mSv/h	HIGH RADIATION / HAUTE RADIATION Dosimeters obligatory Dosimètres obligatoires  			1000 CA	40000 CS
Prohibited	20 mSv	-	> 100 mSv/h	NO ENTRY DÉFENSE D'ENTRER 			> 1000 CA	> 40000 CS

# 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](#)

