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ISOLDE Workshop and Users  
meeting 2018

6<sup>th</sup> of December 2018

## The MEDICIS Facility

Overview, 2018 operation report and plans for CERN long shutdown 2

# MEDICIS Coordinator – new function

- Schedule target irradiation and isotope separation
  - Machine development or MEDxxx
- Schedule and coordinate interventions and technical stops
- Liaise with:
  - ISOLDE physics coordinator
  - MEDICIS project leader
  - ISOLDE technical coordinator
  - ISOLDE machine supervisors (protons)
  - MEDICIS operators
  - Radiation protection staff
- PhD in Materials Science and Engineering
- +7 years of radioactive ion beam development (ISOLDE target operation)
- Tasks:
  - 50% MEDICIS Coordination
  - 50% Research
    - Target and ion source development

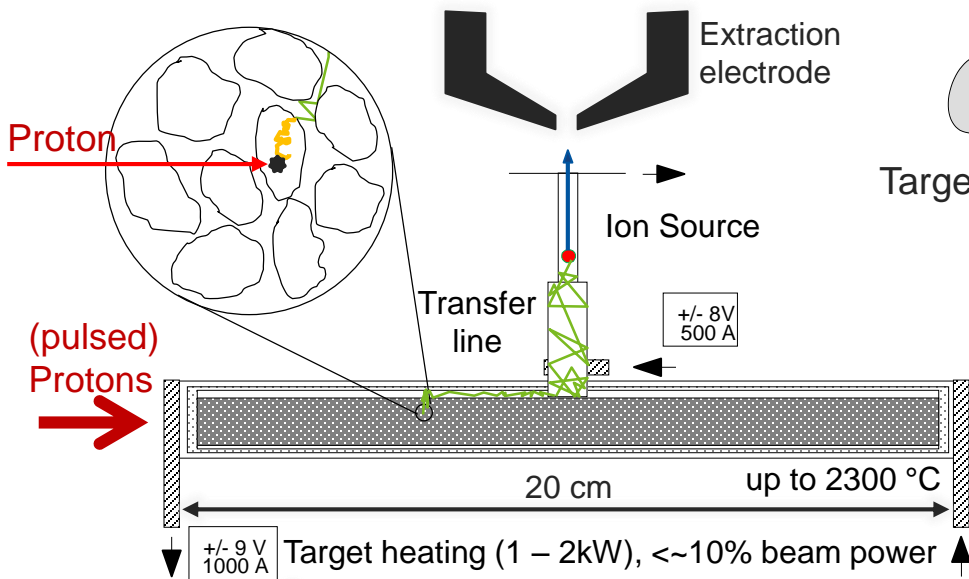
Coordinating MEDICIS  
since August 2018

# MEDICIS overview



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# ISOL Isotope Separation OnLine



1. Production
2. Diffusion
3. Effusion
4. Ionization
5. Mass Separation
6. Transport

$$Beam\ Int. = \sigma \cdot j \cdot N_t \cdot \varepsilon$$

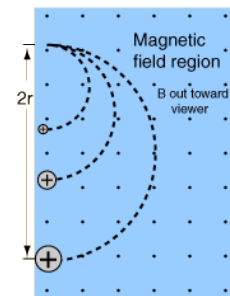
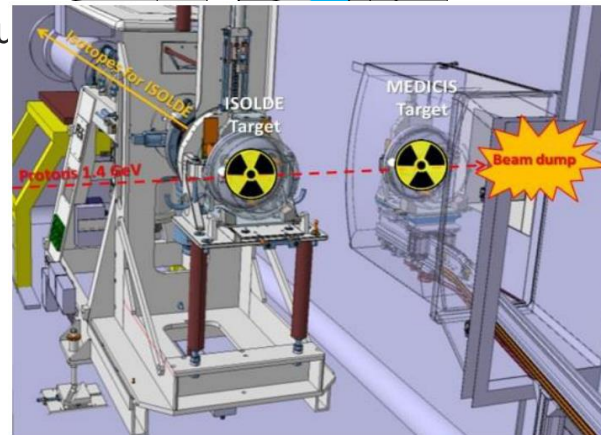
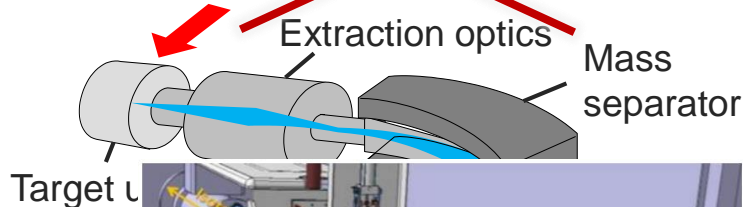
$$\varepsilon = \varepsilon_{diff} \varepsilon_{eff} \varepsilon_{is} \varepsilon_{sep} \varepsilon_{trans}$$

$N_t$  – Nr of exposed atoms [dim]

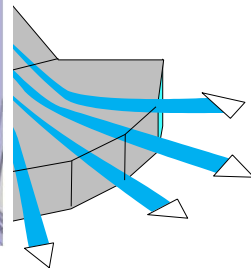
$j$  – Proton flux [ $cm^{-2}$ ]

$\sigma$  – Cross section [mb]

$\varepsilon$  – Efficiency [%]

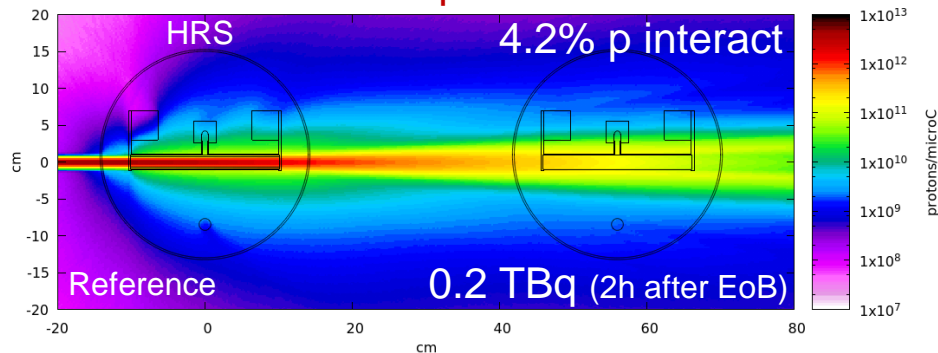


$$r = \frac{mv}{qB} = \frac{mE_s}{qBB_s}$$



# MEDICIS Irradiation modes

## Standard mode of operation



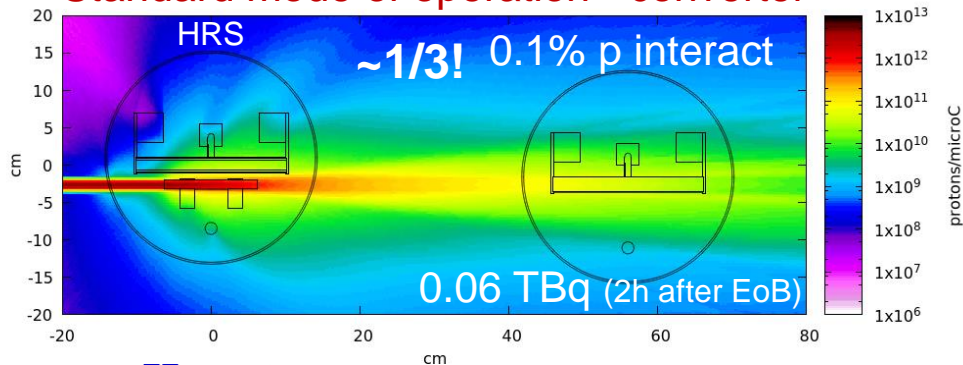
2.3E18 p (3 days)  
0.5 Sv/h  
30 min after EOB

1.5E18 p (2 days)  
1.9 Sv/h  
30 min after EOB

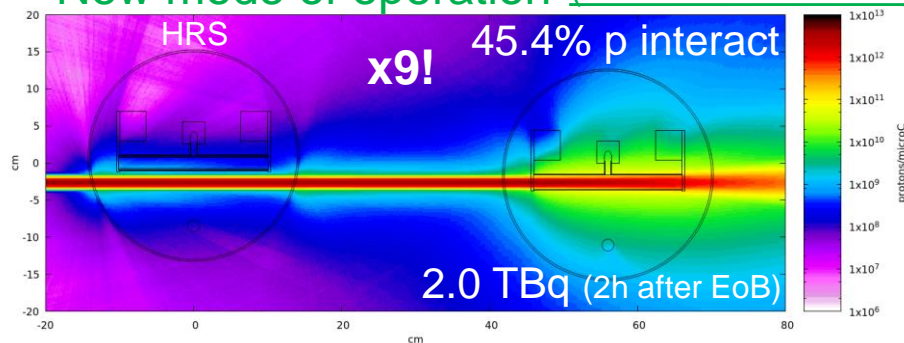
Factor 6x seen in practice (TBC)

Use proton beam during setup times, no interaction to ISOLDE

## Standard mode of operation - converter



## New mode of operation (if no n-conv in HRS)



# MEDICIS Scheduling

Wk23

1st wk

ISOLDE

June

GPS

HRS

MEDICIS

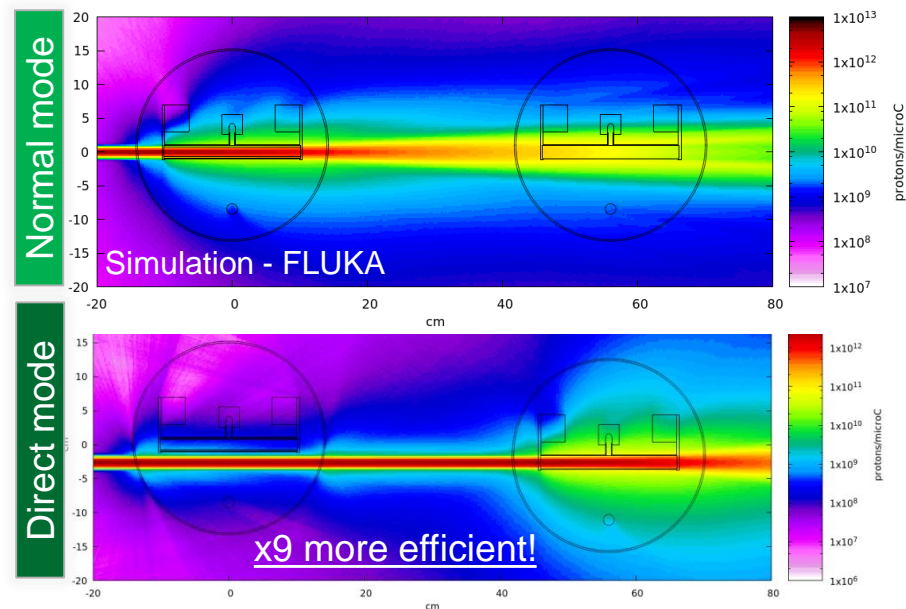
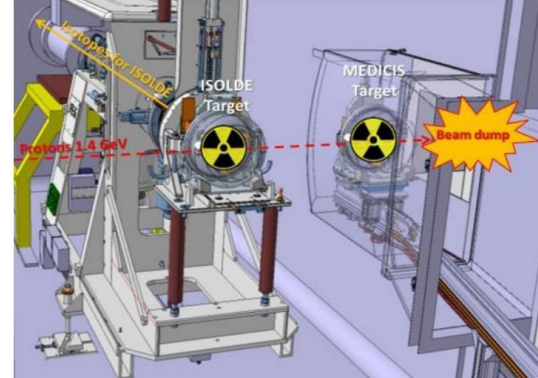
MO		4	4	Normal mode
TU	#626 Ta - W	IS610		Direct mode
WE				
TH				
FR		#634 LIST		No irradiation
SA	COLLAPS			
SU	IS649			
	Sc RILIS	RILIS: In		

Experiment (radioactive)  
Protons are already in HRS

Experiment in GPS  
No protons available

Machine setup time  
No protons necessary at GPS or HRS  
Switch protons on for MEDICIS

MEDICIS has its target at HRS





# Operation

## Insert target

- 12 min – protons stopped (only at HRS)

## Irradiation

- Transparent to ISOLDE

## Retrieve target

- 12 min – protons stopped (only at HRS)

## Decay

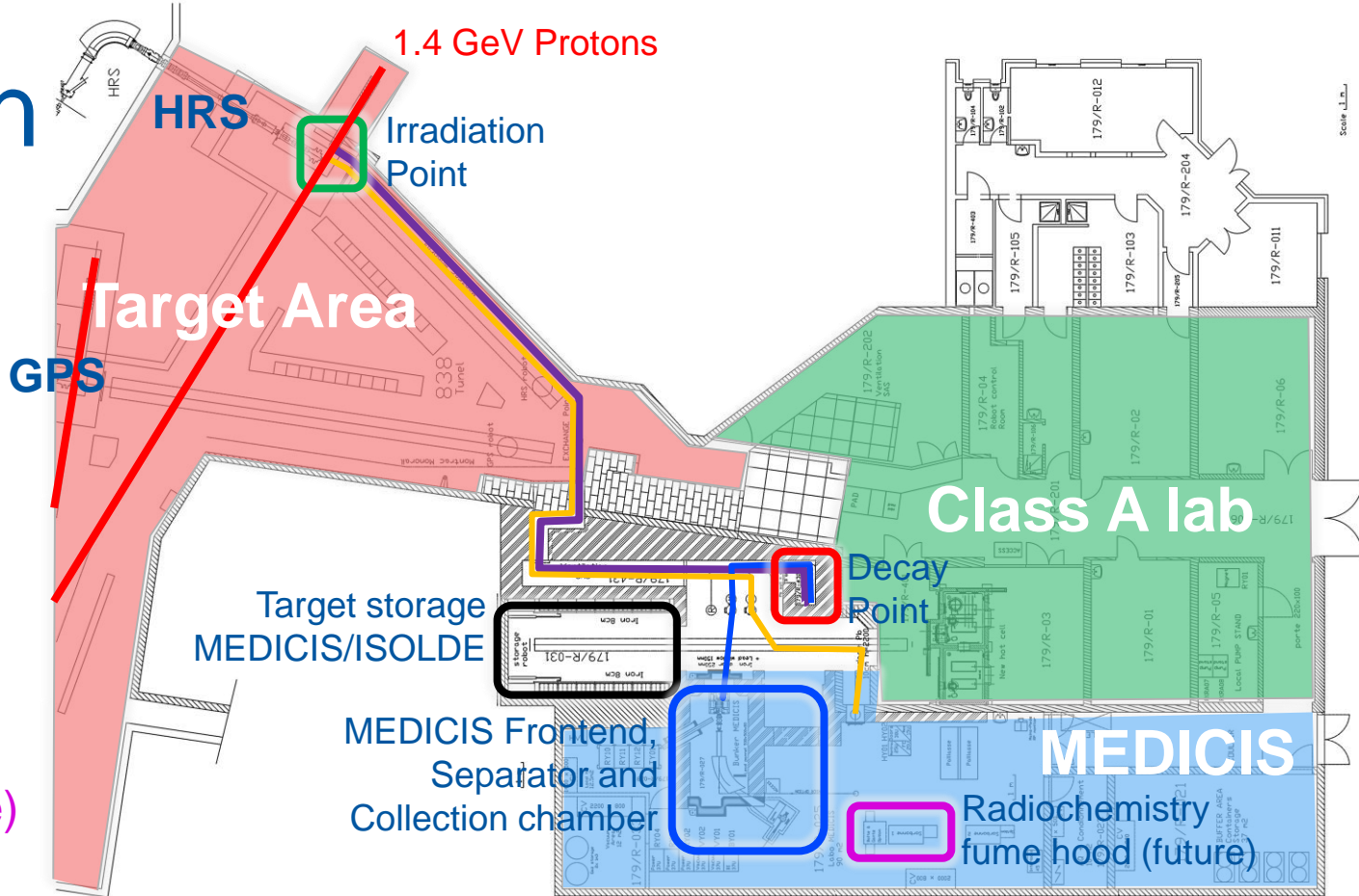
- Until target reaches  $<1\text{ Sv/h}$  (at 26 cm)

## Install in Frontend

- Isotope Extraction

## Radiochemistry (future)

- Chemical purification
- Shipping





# MEDICIS Collaboration



## 1st MEDICIS Collaboration Board Meeting

📅 Wednesday 21 Feb 2018, 09:00 → 17:00 Europe/Zurich

📍 4-3-001 (CERN)

Description [Liste de participants:](#)

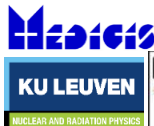
- Thierry Stora (CERN)
- Frédéric Bordry (CERN's Director for Accelerators and Technology)
- Simone Gilardoni (CERN)
- Thomas Elia Cocolios (KULeuven)
- Prof. Oyen Wim (ICR – Institute of Cancer Research, UK)
- Nick van Dermeulen (PSI)
- Antonio Paulo (Instituto Superior Técnico, Portugal)
- Dr. Michel Forni (Hôpital de La Tour, Geneva)
- Prof. Ismael Martel Bravo (FABRIS - Fundación Andaluza Beturia para la Investigación en Salud, Spain).
- Prof. Ferid Haddad (Arronax, France)
- Prof. Klaus Wendt (University of Mainz, Germany)
- Prof. Martin Walter (Head of Nuclear Medicine and Molecular Imaging, Geneva Hospital)
- Gerda Neyens (CERN)
- David Vierthl (Lausanne University Hospital Center)
- Dante Gregorio (CERN)
- Tor Bjørnstad (IFE – Institute for Energy Technology, Norway)
- Frank Bruchertseifer (European Commission)

Via remote-connection:

- Prof. Susanta Lahiri (SINP - The Saha Institute of Nuclear Physics, India)
- Dr Martyn Sené (Deputy CEO for the National Physical Laboratory - NPL)
- Prof. John Prior Head of Nuclear Medicine and Molecular Imaging, Lausanne University Hospital Center)

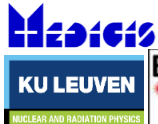
2<sup>nd</sup> Board happened in 3<sup>rd</sup> of October

3<sup>rd</sup> Board will happen February/March



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# MEDICIS during 2018

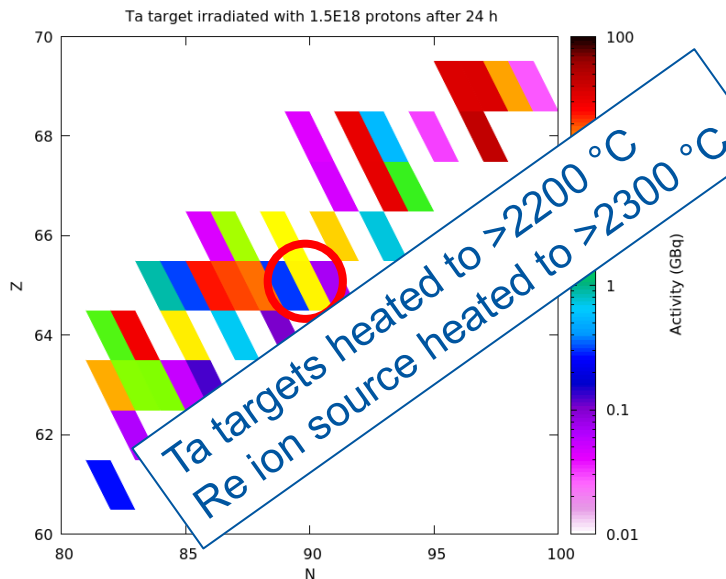
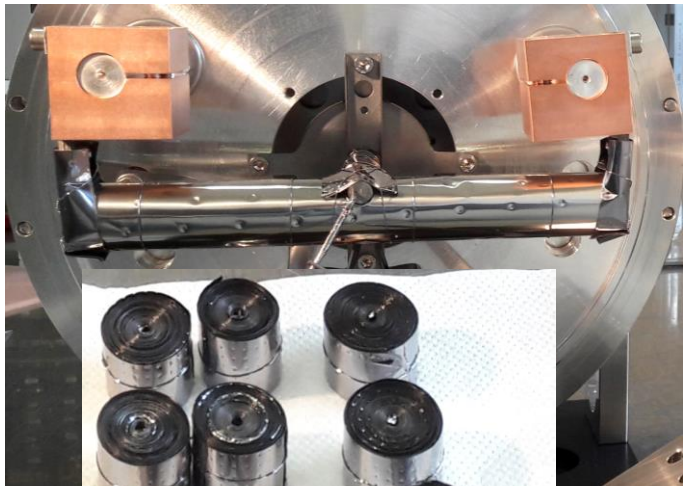


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# MEDICIS Tb extraction efficiency

Irradiation for 2 days  
( $1.5E18$  protons)



6.9 GBq –  $^{155}\text{Tb}$   
24 h after EoB

Extracted:  
49.7 MBq  
(5 days after EoB)

Extraction  
efficiency:  
**1.2%\***

ISOLDE – 1.5%  $^{149}\text{Tb}$  (600 MeV – 80s-90s)

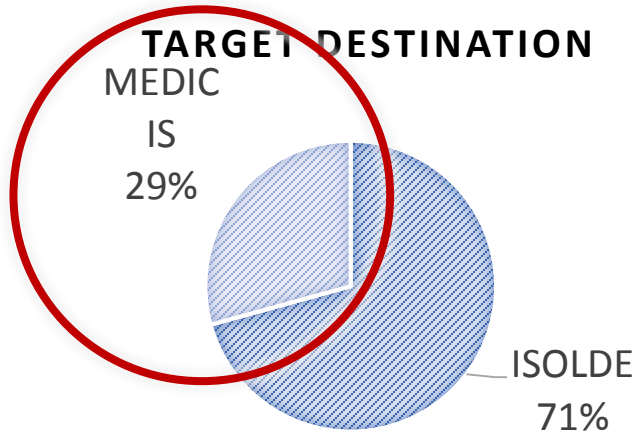
Already reached 5%  
End of September

\*value fluctuates from target to target

\* $^{155}\text{Tb}$  after EoB – 4.0 GBq 6

# Target production

Targets reused up to 5 times!



## MEDICIS budget and manpower contribution

Total targets assembled end of 2018 : **49**

- Delivered to ISOLDE: **29**
- Delivered to MEDICIS: **10** + 2 in December
- Used for development: **8** (16%)

#	Isotope	Target	Ion source
5 (4)	$^{149,152,155}\text{Tb}$ , $^{165}\text{Tm}$	Tantalum (3 with O <sub>2</sub> leak)	Surface – Rhenium/Tungsten
1		Large container Ta	Surface - Tungsten
2 (1)	$^{225}\text{Ra(Rn)}$ , $^{67}\text{Cu}$	Uranium carbide	VADIS – Hot transfer line
2 (1)	$^{47}\text{Sc}$	Titanium	VADIS – Hot transfer line
4	$^{169}\text{Er}$ , $^{155,152}\text{Tb}$	External source - ILL (Grenoble), Arronax (Nantes), NMC (Riga)	Surface – Rhenium/Tungsten
1	Any ( $^{11}\text{C}$ )	Proton irradiation stand (any material) – no source	

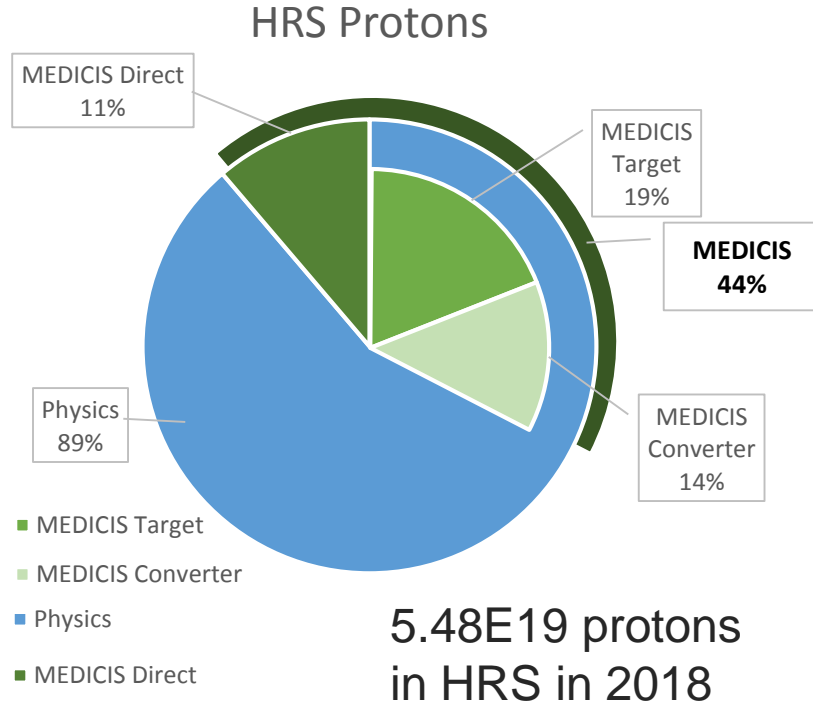
**15 targets (12 in 2018) since MEDICIS startup (Oct 2017)**

**12 targets still operational**

**MEDICIS has a quota of 10 targets per year  
Have more now, but will reuse in 2019!**

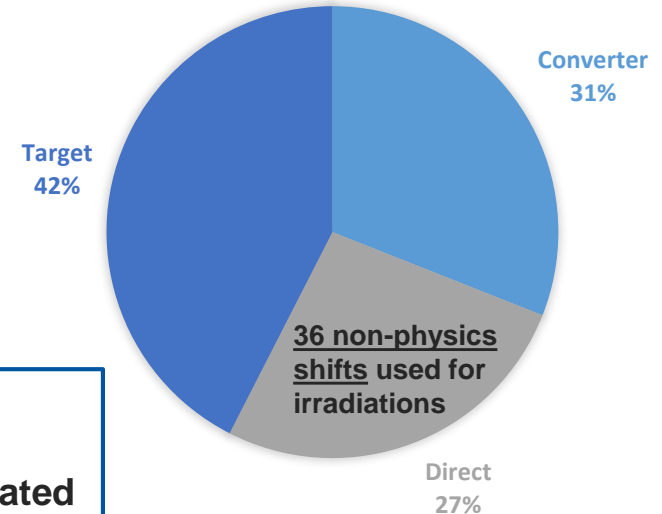
# MEDICIS Statistics

26 irradiations  
19 isotope extractions (or attempts)

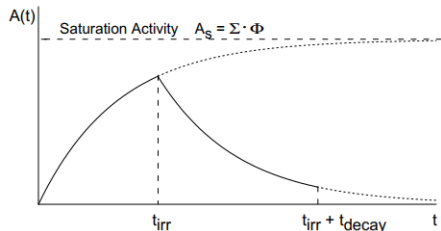
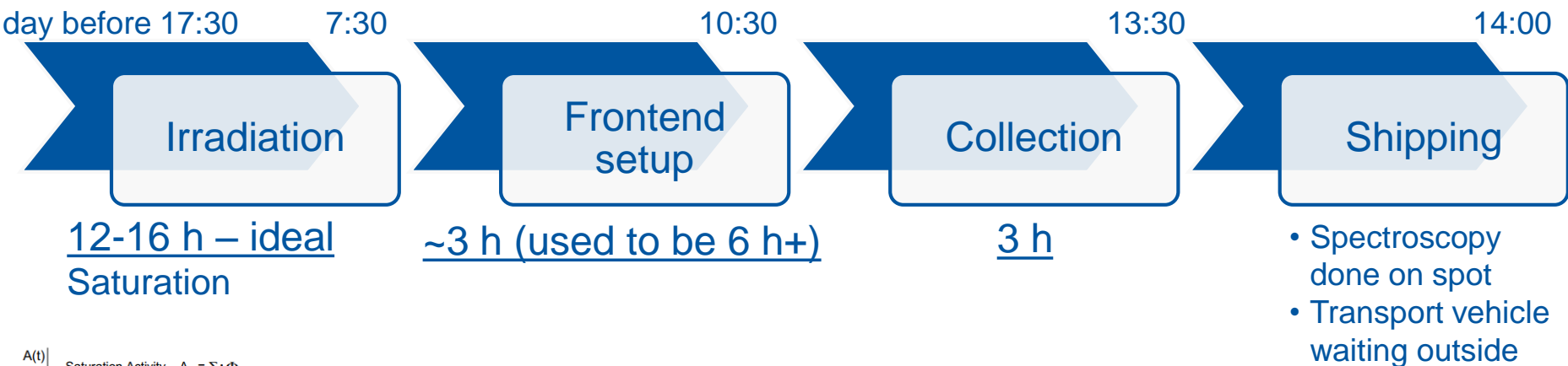


From ISOLDE  
physics run,  
MEDICIS Irradiated  
~5 hours/day  
~1.5 days/week

1092 HOURS OF IRRADIATION  
138 shifts - 45.5 days



# 149Tb – race against time



1. Vacuum pumping (30 min)
2. Water cooling (HV operation) – used to be 4 h, now is 15 min
3. Target heating (~1.5 h)
4. Beam setup (with target below optimum release T) – 1h

Challenging! Need good coordination and good team!



# Results from MEDICIS

Activities from few MBq to 100 MBq

- Still improving!

## Main Achievements:

- Extraction of  $^{155}\text{Tb}$ 
  - Delivery of  $^{155}\text{Tb}$  to NPL (England) and then to C2TN (Portugal)
- Extraction of  $^{149}\text{Tb}$  (impure)
- Extraction of  $^{149}\text{Tb} + ^{16}\text{O}$  (almost pure)
  - Delivery to CHUV (Lausanne)
- Separation and extraction of  $^{169}\text{Er}$  – ILL external source
  - Fulfilled MEDICIS experiment
- Extraction of  $^{165}\text{Tm}$  – opportunistic isotope
  - Delivered to CHUV (Lausanne)
- $^{11}\text{C}$  diffusion studies (with help from SSP)
  - Fulfilled MEDICIS Experiment

## Ongoing Tb experiments:

- Tb activities are increasing and being more consistent

## Problems:

- Mass separator hall probe
  - Low resolution at high masses
- Large container target broken
- Collection chamber sample arm
- No  $^{47}\text{ScF}$  due to gas problem
- No  $^{67}\text{Cu}$  and  $^{225}\text{Ra}$  due to technical problems on the UCx targets
- Frontend electrode stuck

# Irradiations for ISOLDE at MEDICIS

MEDICIS collaboration board approved use of MEDICIS for non-medical applications, as long as they are approved by INTC.

$^7\text{Be}$  (53.22d) at 5 MeV/u for IS554

$^{223}\text{RaF}$  (11.4d),  $^{225}\text{RaF}$  (14.8d),  
 $^{226}\text{RaF}$  (1600 a) for IS657

#635-UCx -  $7.96\text{E}17$  p (direct)

+4 indirect irradiations

2.2 days – EoB 23/10/2018



6 extra days of beamtime  
(16/11->21/11) for ISOLDE

IS554

#637-UCx -  $6.74\text{E}17$  p (direct)

3.4 days – EoB 19/10/2018



12 extra days of beamtime  
(21/11->03/11) for ISOLDE

IS657

Total of 18 days (~54 shifts) of  
extra beam time for ISOLDE  
physics thanks to MEDICIS!

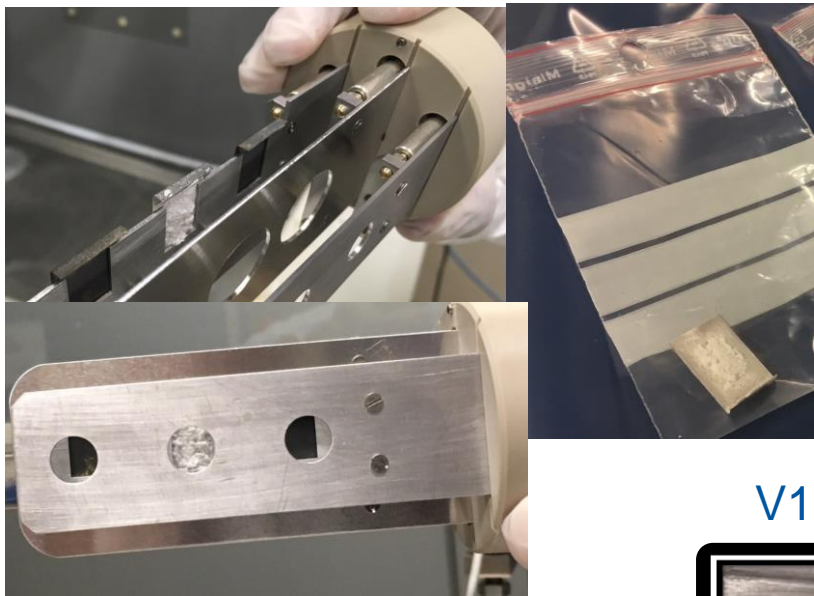
Good Synergy!

# $^{149}\text{Tb}$ implantation in salt

Normal:  
Zn coated Au foil

## Advantages:

- Potassium Nitrate ( $\text{KNO}_3$ ) – easy dissolution
- Collection on the TbO mass ( $149+16 = 165$ )
- No contaminants – simplify radiochemistry
- Low activity (1.8 MBq)
- **Development on-going to promote TbO formation**



Almost pure sample

- Normal 1 Tb to 20 contaminant
- Now: 1.8 Tb to 1 contaminant (Gd)

V1



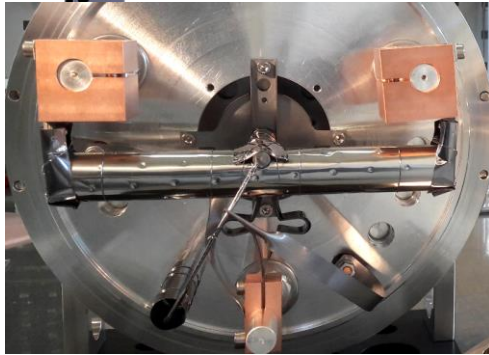
V2



V3



# Large Ta container



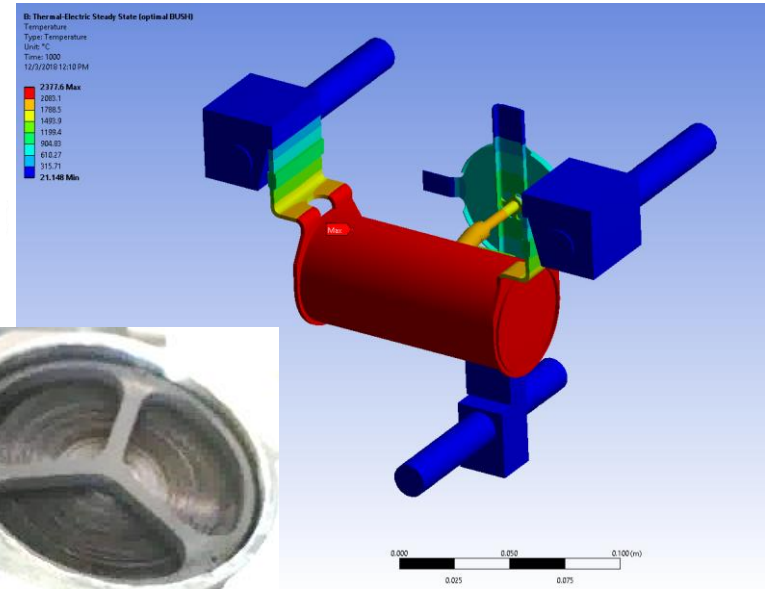
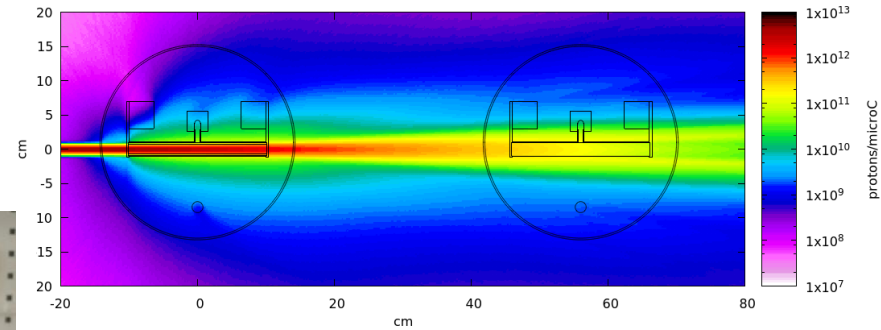
ISOLDE

2 cm diameter  
20 cm length  
60 cm<sup>3</sup> volume



MEDICIS

5 cm diameter  
10 cm length  
200 cm<sup>3</sup> volume



V. Samothrakis, M. Ballan, S. Marzari, et al.

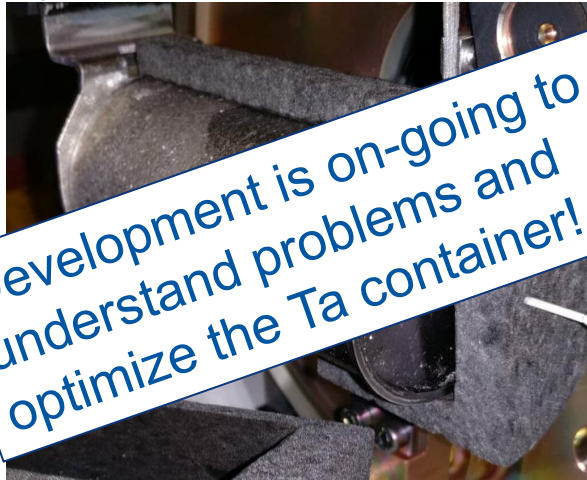
1000A (normally ~750A)  
Reach 2400 °C

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# Large Ta container

Container tested offline and reach temperatures predicted by the simulations.



Development is on-going to understand problems and optimize the Ta container!

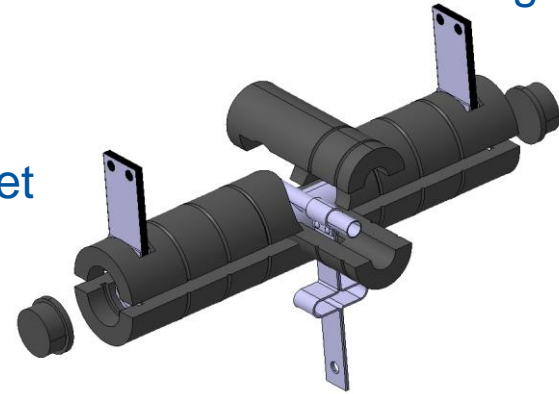
Ta heavily recrystallized

Work of V. Samothrakis also to improve the target temperature uniformity!

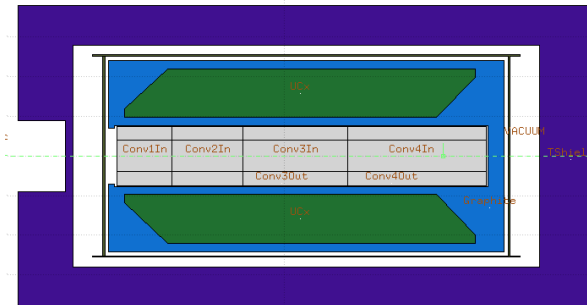
Target irradiated at MEDICIS!

- Container failed at the end of the collection
- Not much  $^{155}\text{Tb}$  was seen
- Presence of graphite can trap Tb

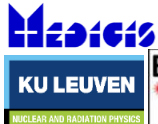
Spin-off to ISOLDE target and ion source shielding



Twin container used for the p2n converter annular prototype (J.P. Ramos, et al.)  
See talk of S. Rothe



# Plans for CERN Long Shutdown 2



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# CERN Long Shutdown 2 (LS2)

MEDICIS is probably one of the few facilities at CERN that runs during LS2

- $^{169}\text{Er}$  from ILL in Grenoble
- $^{152,155}\text{Tb}$  from Arronax in Nantes
- $^{47}\text{Sc}$  from NMC in Riga

Operation of 1 to 2 weeks per month

Plan of 2 technical stops – for maintenance and upgrades

- MELISSA, radiochemistry, others...



# MEDICIS Technical Stops

## Follow CERN facilities Schedule

Plan technical stops, commissioning and operation phases

### Technical stop 1

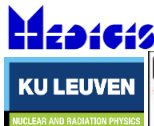
07/01/2018 -> 01/03/2018

- Laser installation and commissioning
- Gas system upgrade (molecular beams)
- Separator magnet upgrade
- Radiochemistry fume hood installation
- Targets to ISR
- Frontend maintenance

### Technical stop 2

(TBD)

- Thermocouple controls install
- Gas system controls install
- Collection chamber vacuum upgrade
- Laser 2<sup>nd</sup> set of optics installation
- Tasks not done from technical stop 1



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## MEDICIS schedule (LS2) 2018/19

[illegible]

**Schedules**

Select schedule  
Schedule type: LHC  
Schedule: LHC 2018 1.5 Approved

Choose view  
View: year  
Today

**January**

Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	2	3	4	5	6	7
2	8	9	10	11	12	13	14
3	15	16	17	18	19	20	21
4	22	23	24	25	26	27	28
5	29	30	31				

**February**

Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	29	30	31	1	2	3	4
2	5	6	7	8	9	10	11
3	12	13	14	15	16	17	18
4	19	20	21	22	23	24	25
5	26	27	28				

**March**

Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	26	27	28	29	30	31	
2	5	6	7	8	9	10	11
3	12	13	14	15	16	17	18
4	19	20	21	22	23	24	25
5	26	27	28	29	30	31	

**May**

Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	30	31	1	2	3	4	5
2	6	7	8	9	10	11	12
3	13	14	15	16	17	18	19
4	20	21	22	23	24	25	26
5	27	28	29	30	31		

**June**

Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	23	24	25	26	27	28	29
2	30	1	2	3	4	5	6
3	7	8	9	10	11	12	13
4	14	15	16	17	18	19	20
5	21	22	23	24	25	26	27

**July**

Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	23	24	25	26	27	28	29
2	30	31	1	2	3	4	5
3	6	7	8	9	10	11	12
4	13	14	15	16	17	18	19
5	20	21	22	23	24	25	26

**September**

Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	24	25	26	27	28	29	30
2	1	2	3	4	5	6	7
3	8	9	10	11	12	13	14
4	15	16	17	18	19	20	21
5	22	23	24	25	26	27	28

**October**

Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	29	30	31	1	2	3	4
2	5	6	7	8	9	10	11
3	12	13	14	15	16	17	18
4	19	20	21	22	23	24	25
5	26	27	28	29	30	31	

**November**

Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	26	27	28	29	30	31	
2	3	4	5	6	7	8	9
3	10	11	12	13	14	15	16
4	17	18	19	20	21	22	23
5	24	25	26	27	28	29	30

February																								March			Month
7							8							9										Wk no.			
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2	3	Day								
ilation																			Frontend								
enance																											
hood																			Lab								
ection																			Lasers								
																			Offline								

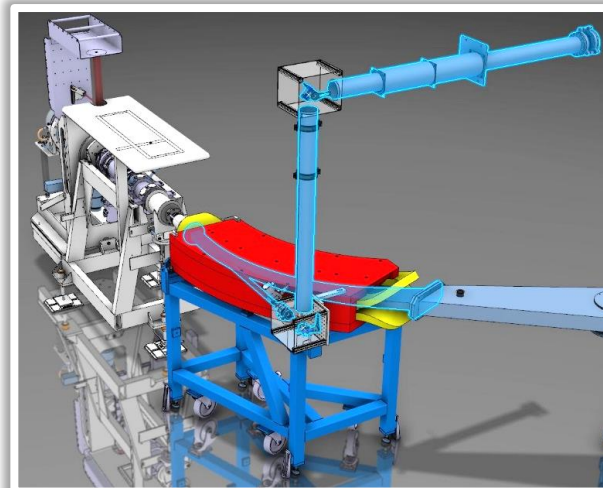
April																								Month
15							16							17										Wk no.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Day					
69Er from ILL collection																			Frontend					
																			Lab					
ser Ionized Er																			Lasers					
																			Offline					

# MELISSA - Lasers at MEDICIS

During Technical stop 1

TODO list:

- Room (floor, painting and SAS) ✓
- Ventilation ✓
- Laser tables ✓
- Infrastructure (power, network) ✓
- Laser safety system **Ongoing**
- Laser optics installation **End of Jan**
- Commissioning of laser beam to frontend **Early February**
- Stable beam tests (Er, Tb, Sm – one laser) **Last week of February**
- Radioactive laser ionized Tb **Early March**



Work of V. Gadelshin

**Max efficiency for Tb: 5%**

(J.P. Ramos and T. Stora)

**Max efficiency for Er: 0.3%**

(R. Formento)

1<sup>st</sup> laser is here

2<sup>nd</sup> coming in February



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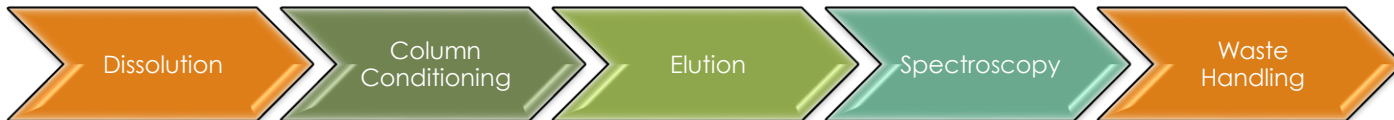
V. Fedosseev, V. Gadelshin, B. Marsh  
 T.E. Cocolios, K. Dockx, K. Wendt,

# Radiochemistry at MEDICIS

Zn deposited in Au foil

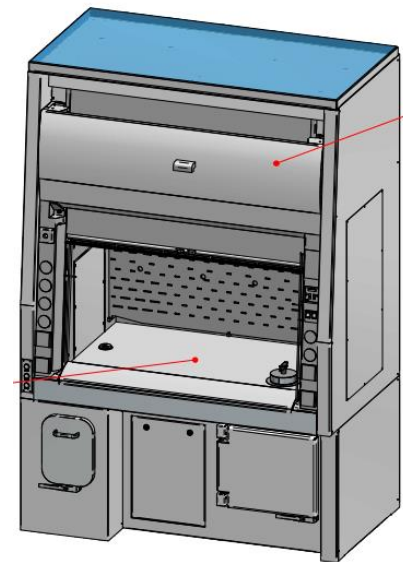


KNO<sub>3</sub> deposited in Al foil



- In development
- No licensing at MEDICIS yet (2018)
- Radiochemistry was being done with partners
- Planed radiochemistry commissioning during technical stops.

Radiochemistry fume hood will be installed in January in MEDICIS lab



# Thank you! Merci! Obrigado!

Comments or questions?

A **big thanks** to the MEDICIS local team (**the dream team**):

Thierry Stora (project leader), Cristina Ferrari (secretary), Richard Catherall (Section leader)

*Radiochemistry*: Moazam Khan, Nhat-Tan Vuong

*Robot Operation*: Giordano Lili, Giacomo Lunghi, Jean Luis Grenard

*Safety*: Ana Paula Bernades, Julien Riegert, Beatriz Conde Fernandez

*Operation*: Laura Lambert, Eric Chevallay, Pascal Fernier

*Spectro and shipping*: Nicolas Riggaz, Philippe Bertreix

*RP*: Fabio, Pozzi, Alexandre Dorsival, Matthieu Deschamps, Elodie Aubert

*Engineering*: Stefano Marzari, Vasileos Samothrakis, Vincent Barozier

*LabVIEW and controls*: Kevin Develle, Cedric Charrondiere, Christophe Mitifiot

*ISOLDE*: Karl Johnston and ISOLDE operation team

*ISOLDE technicians*: Julien Thiboud, Bernard Crepieux, Ermanno Barbero, Andres Vietez Suarez

*Lasers (MELISSA)*: Valentine Fedosseev, Vadim Gadelshin, Bruce Marsh, Thomas Cocolios, Kristof Dockx, Klaus Wendt

and Julien Para-Lopez, Simon Stegemann, Marco Buzio, Roberto Formento Cavaier, Simone Gilardoni, Jose Somoza,

MEDICIS Promed team, the MEDICIS Collaboration and many others!

All the external partners that have been actively discussing with us!

## Final Conference

The Final Conference on **MEDICIS-Promed and related science topics** will be held at

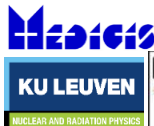
"The Ettore Majorana Foundation and Centre for Scientific Culture"

**Erice (Italy) 30<sup>th</sup> April - 4<sup>th</sup> May 2019**



## Scientific Topics

- Accelerator techniques for medical isotope production
- Devices and engineering for isotopes handling
- Methods for production of novel radioisotope in theranostics
- Radioisotope beams in hadron therapy
- Pre-clinical research and development of new radiopharmaceuticals



J. P. Ramos | 6<sup>th</sup> of December 2018  
ISOLDE Workshop and Users meeting 2018

Abstract submission  
deadline: 28th February 2019