
CERN

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Interdisciplinary aspects and
applications related to the SPES project
Ferrara, Italy
29th of January 2019

The MEDICIS Facility

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

MEDICIS Coordinator – new function

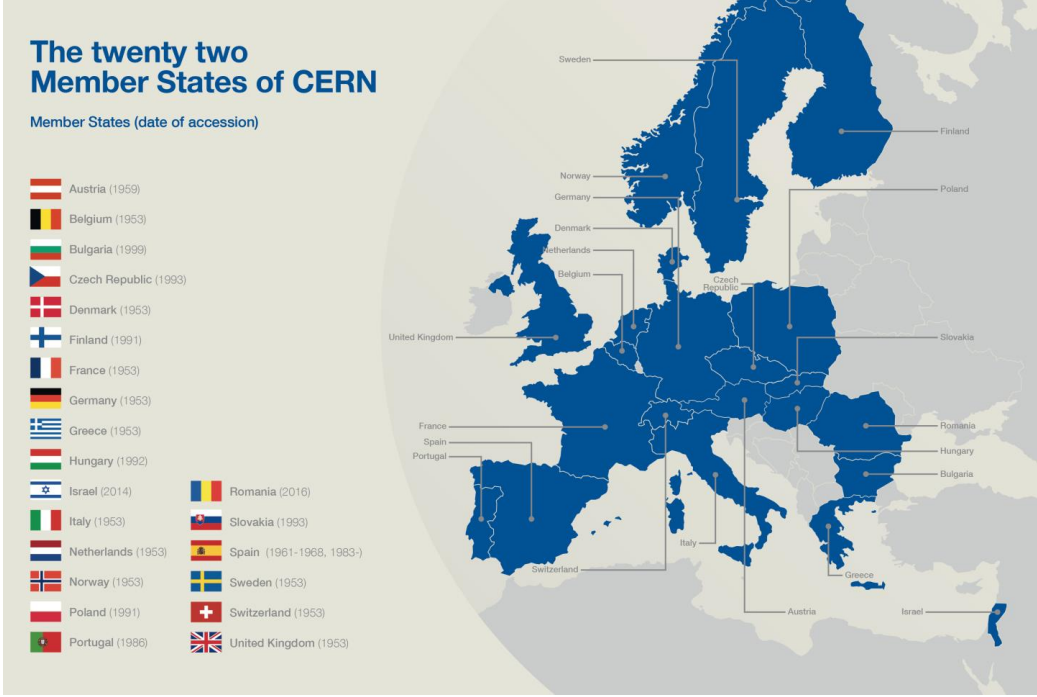
- Schedule target irradiation and isotope separation
  - Machine development or MEDxxx
- Schedule and coordinate interventions and technical stops
- Liaise with:
  - ISOLDE physics coordinator
  - MEDICIS project leader
  - ISOLDE technical coordinator
  - ISOLDE machine supervisors (protons)
  - MEDICIS 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

CERN



In 2016, **16868** working on 2 sites*:

- 2560 staff
- 750 fellows
- 13558 external (scientists, training, etc.)

*CERN Personnel Statistics 2016, https://cds.cern.ch/record/2265782

- Funded by the 22 members states
- Budget of **+1.1 Billion CHF/year**
- With Israel as a member state, it has surpassed the European borders

Operation

Insert target
- 12 min – protons stopped (only at HRS)

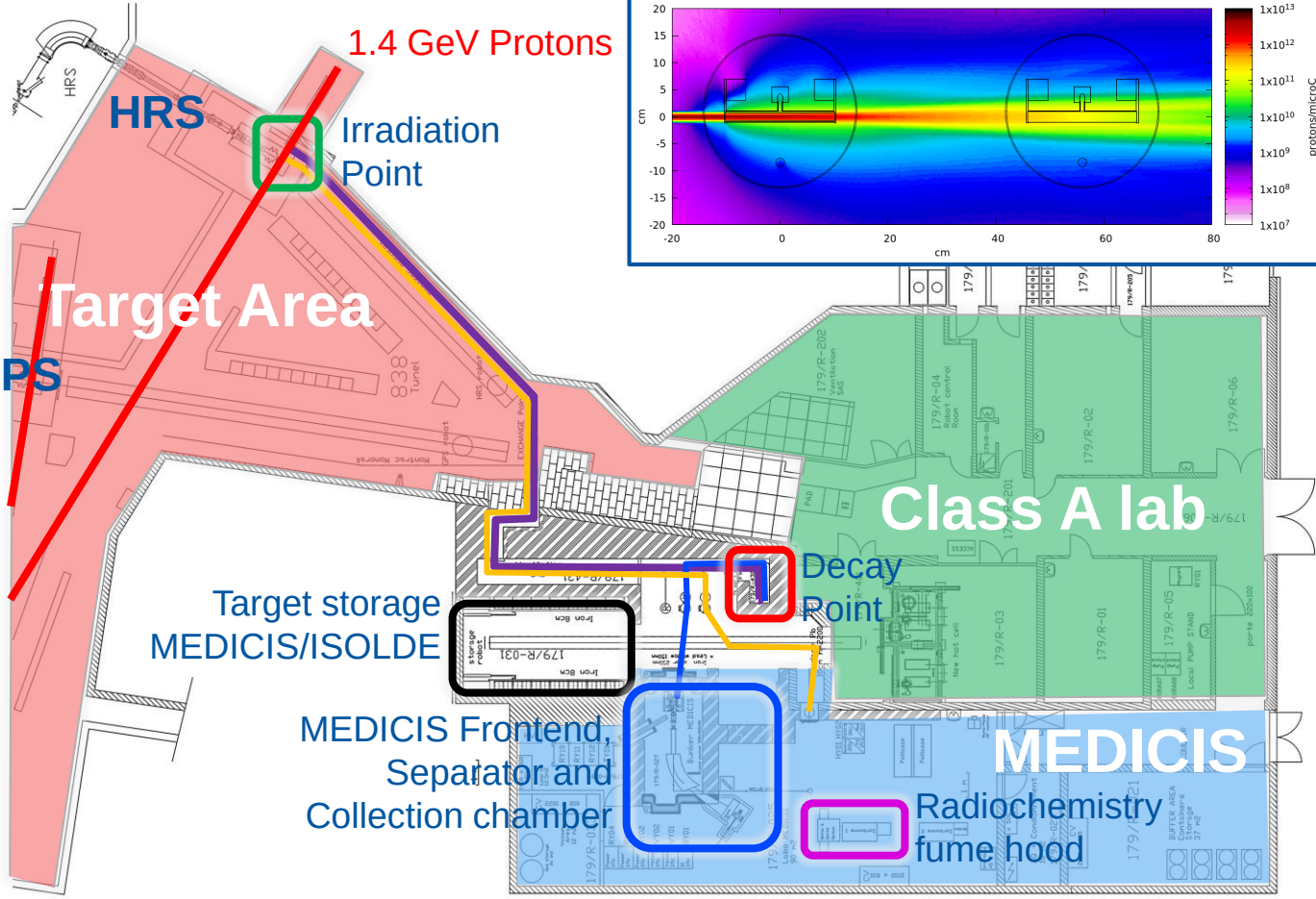
Irradiation
- Transparent to ISOLDE

Retrieve target
- 12 min – protons stopped (only at HRS)

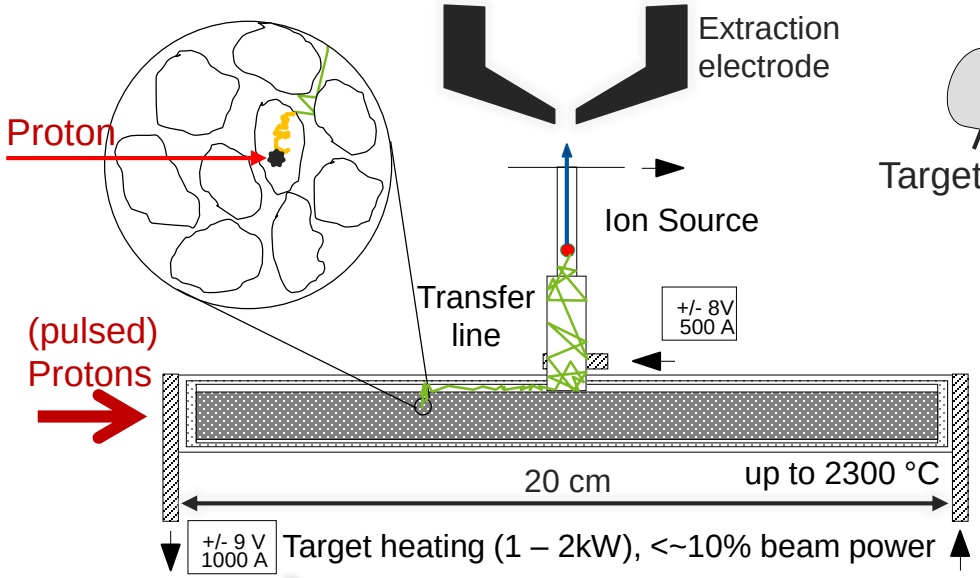
Decay
- Until target reaches <1Sv/h (at 26 cm)

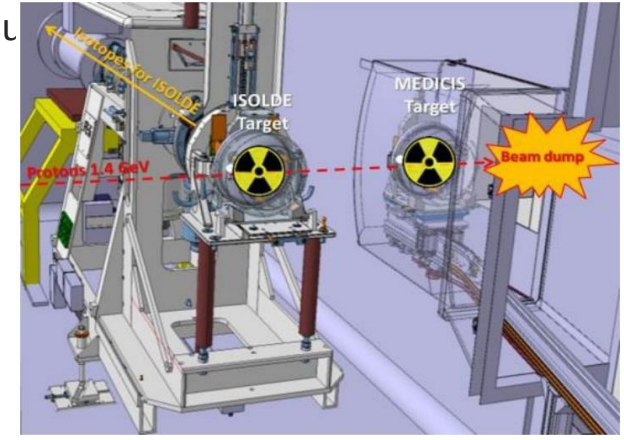
Install in Frontend
- Isotope Extraction

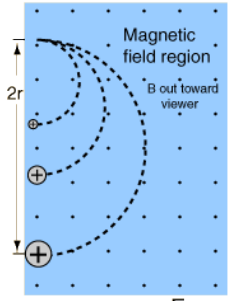
Radiochemistry (future)
- Chemical purification
- Shipping



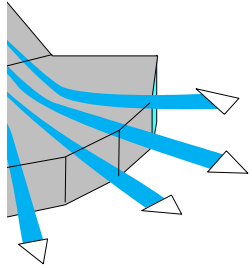
ISOL Isotope Separation ~~OnLine~~







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



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

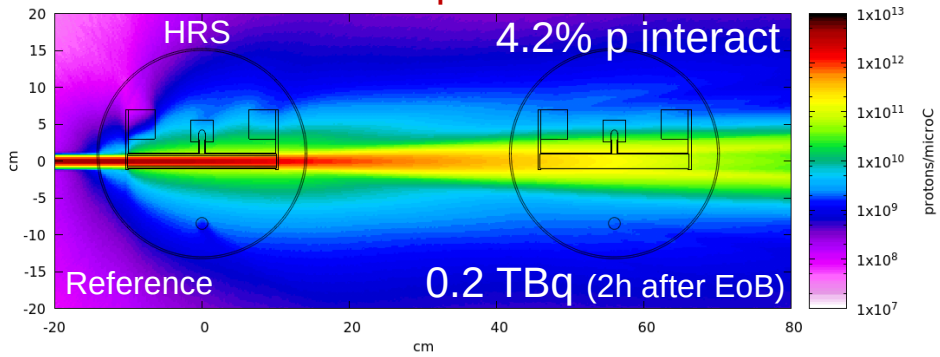
$$Beam\ Int. = \sigma . j . N_t . \varepsilon$$

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

N_t – Nr of exposed atoms [dim]
j – Proton flux [cm^{-2}]
σ – Cross section [mb]
ε – Efficiency [%]

MEDICIS Irradiation modes

Standard mode of operation



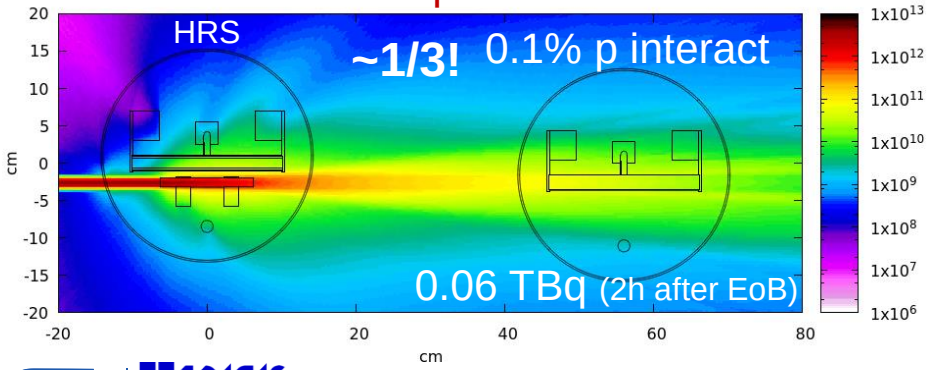
2.3E18 p (3 days)
0.5 Sv/h
30 min after EOB

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

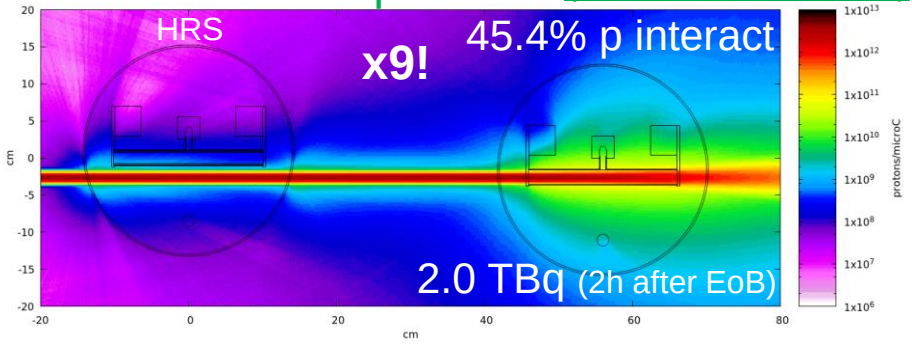
Factor 6x seen in practice (TBC)

Use proton beam during setup times, no interaction to ISOLDE

Standard mode of operation - converter



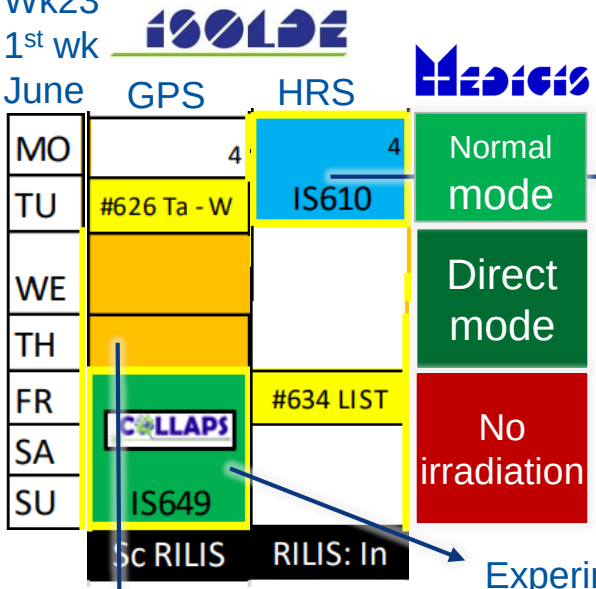
New mode of operation (if no n-conv in HRS)



FLUKA simulation with UCx target in HRS and Ta target in MEDICIS – 4.9E17 protons (15 hours)

MEDICIS Scheduling

Wk23
1st wk
June

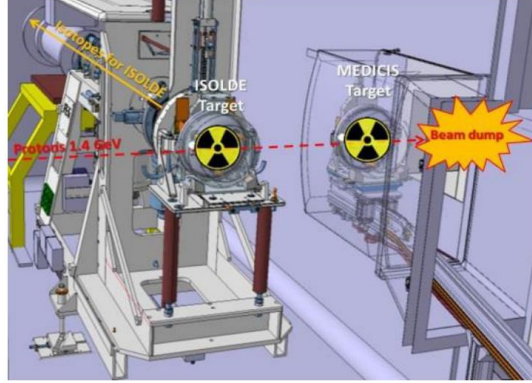


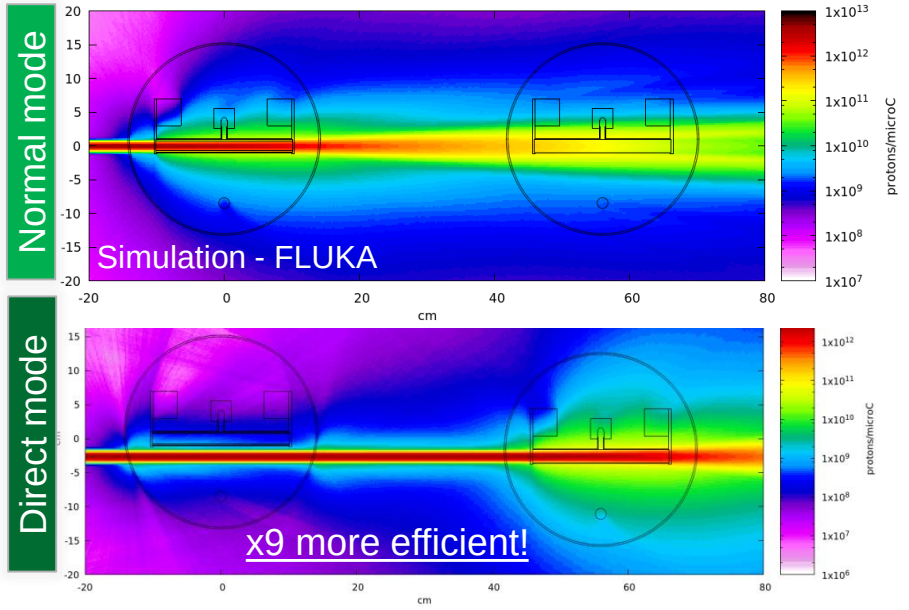
MEDICIS has its target at HRS

Experiment (radioactive)
Protons are already in HRS

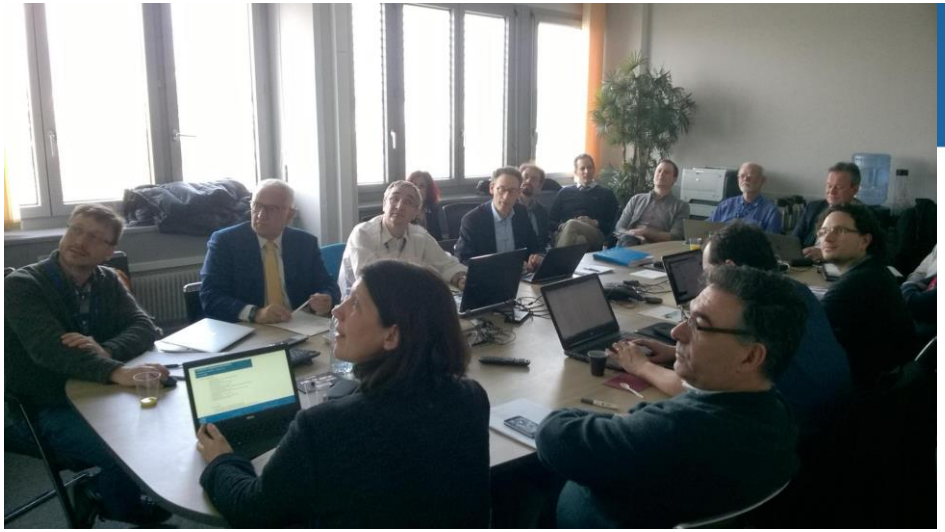
Experiment in GPS
No protons available

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





MEDICIS 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)
- Frédérick 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 Viertl (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)*

2nd Board happened in 3rd of October

3rd Board will happen 20th of March

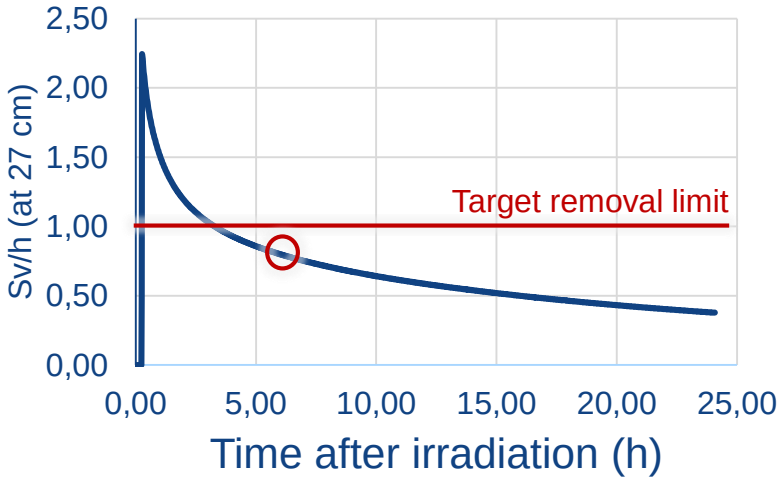
4th Board will happen 18th of September

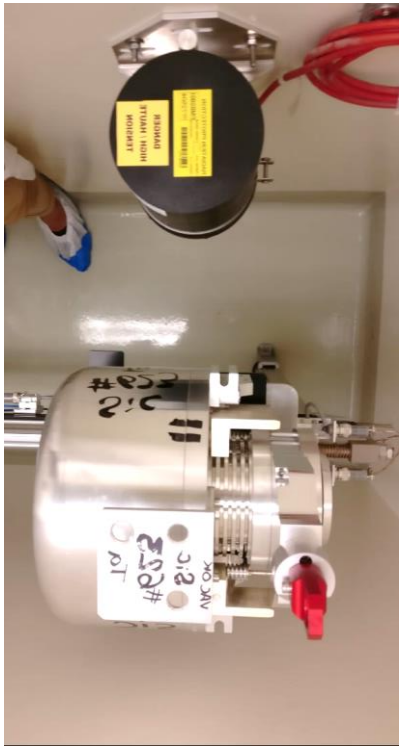
MEDICIS during 2018

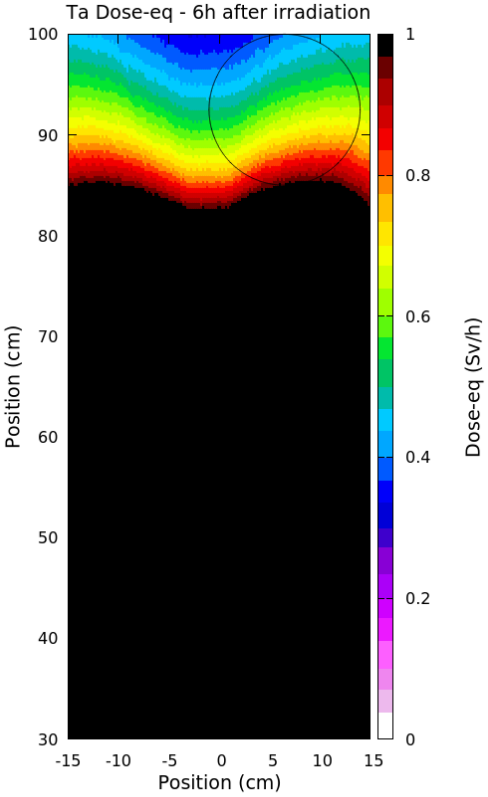
MEDICIS Tb extraction efficiency

MD4 – 155Tb – Mid August 2018

Irradiation for 2 days (1.5E18 protons)

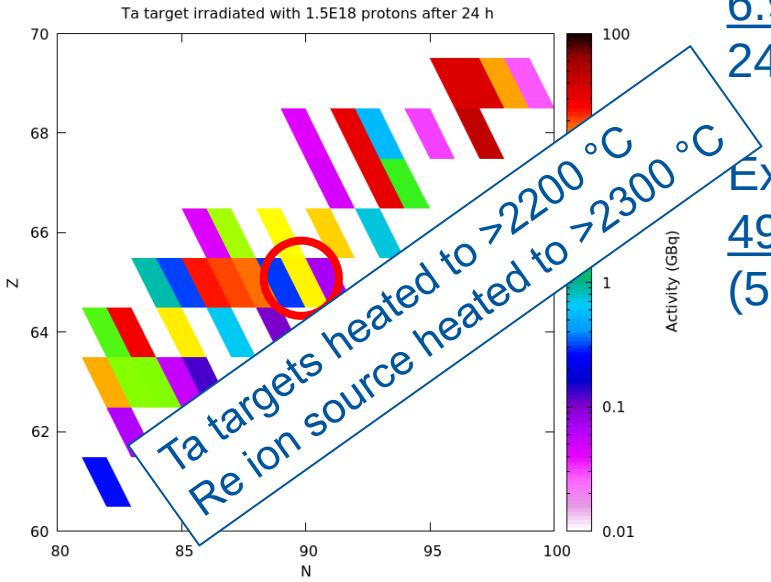






MEDICIS Tb extraction efficiency

Irradiation for 2 days
(1.5E18 protons)



6.9 GBq – 155Tb
24 h after EoB

Extracted:
49.7 MBq
(5 days after EoB)

Extraction efficiency:
1.2%*

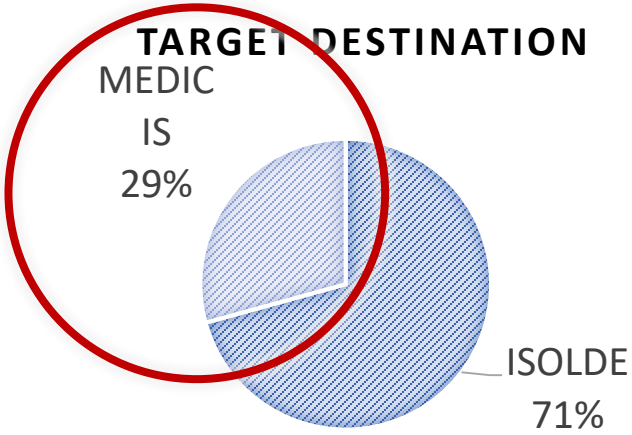
ISOLDE – 1.5% 149Tb (600 MeV – 80s-90s)

Already reached **5%**
End of September

*value fluctuates from target to target
*155Tb after EoB – 4.0 GBq

Target production

Targets reused up to 5 times!



#	Isotope	Target	Ion source
5 (4)	^{149,152,155}Tb, ^{165}Tm	Tantalum (3 with O_2 leak)	Surface – Rhenium/Tungsten
1		Large container Ta	Surface - Tungsten
2 (1)	^{225}Ra(Rn), ^{67}Cu	Uranium carbide	VADIS – Hot transfer line
2 (1)	^{47}Sc	Titanium	VADIS – Hot transfer line
4	^{169}Er, ^{155,152}Tb	External source - ILL (Grenoble), Arronax (Nantes), NMC (Riga)	Surface – Rhenium/Tungsten
1	Any (^{11}C)	Proton irradiation stand (any material) – no source	

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

MEDICIS budget and manpower contribution

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

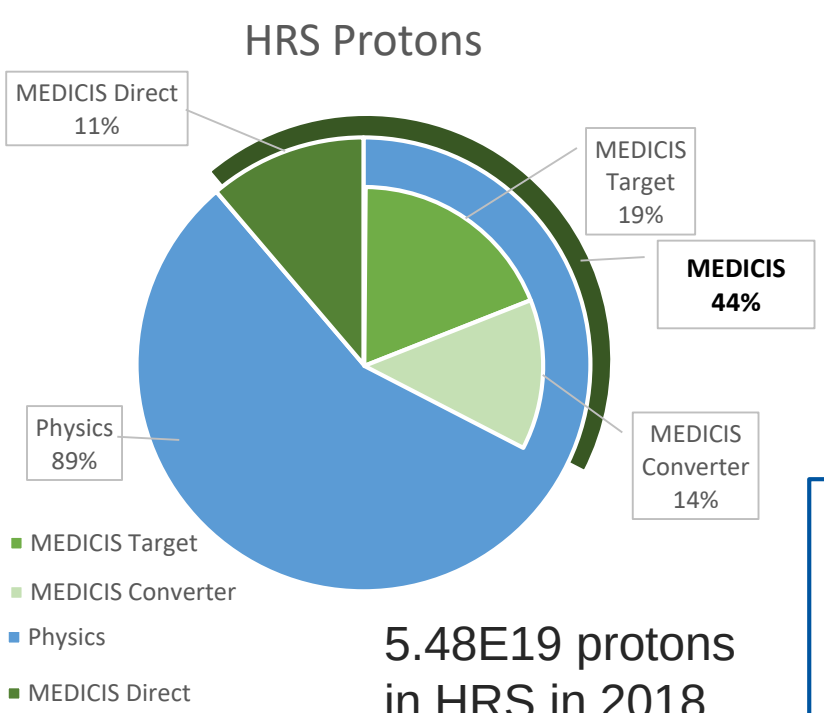
- Delivered to ISOLDE: **29**
- Delivered to MEDICIS: **10** + 2 in December
- Used for development: **8** (16%)

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

Slide from S. Rothe

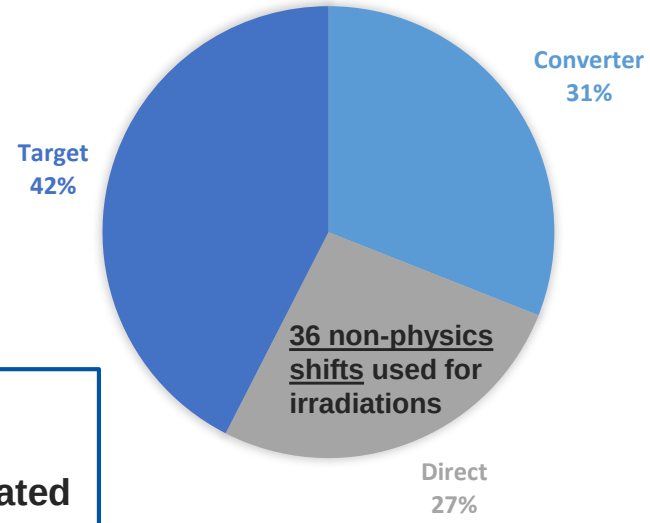
MEDICIS Statistics

26 irradiations
19 isotope extractions (or attempts)



5.48E19 protons in HRS in 2018

1092 HOURS OF IRRADIATION
138 shifts - 45.5 days



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

149Tb – race against time

day before 17:30 | 7:30 | 10:30 | 13:30 | 14:00

Irradiation

12-16 h – ideal
Saturation

Frontend setup

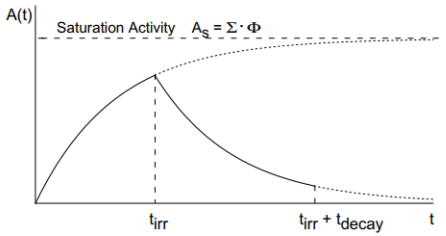
~3 h (used to be 6 h+)

Collection

3 h

Shipping

- Spectroscopy done on spot
- Transport vehicle waiting outside



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

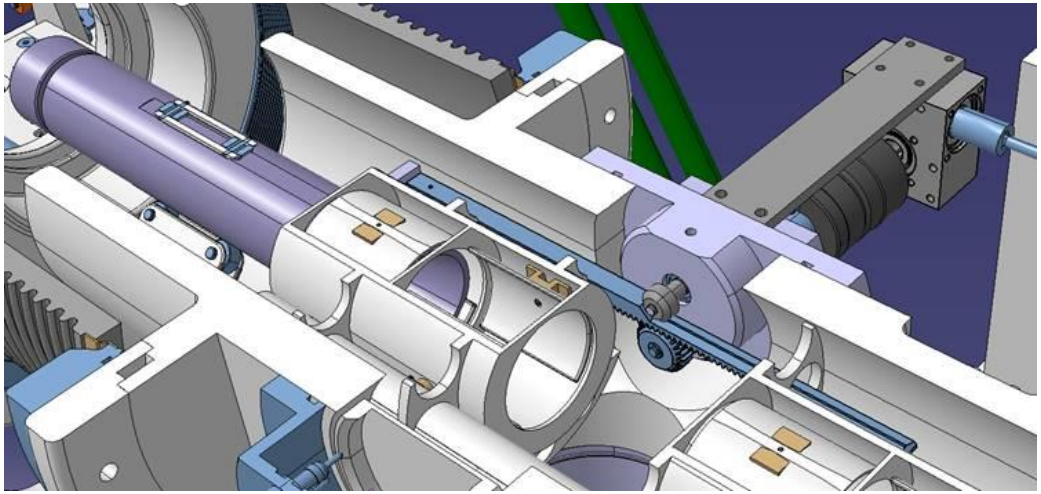
Activities from few MBq to 100 MBq
- Still improving!

Main Achievements:
- Extraction of ^{155}Tb
  - Delivery of ^{155}Tb to NPL (England) and then to C2TN (Portugal)
- Extraction of ^{149}Tb (impure)
- Extraction of ^{149}Tb + 16O (almost pure)
  - Delivery to CHUV (Lausanne)
- Separation and extraction of ^{169}Er – ILL external source
  - Fulfilled MEDICIS experiment
- Extraction of ^{165}Tm – opportunistic isotope – 120 MBq (>99% pure)
  - Delivered to CHUV (Lausanne)
- ^{11}C diffusion studies (with help from SSP)
  - Fulfilled MEDICIS Experiment

Ongoing Tb experiments:
- Tb activities are increasing and being more consistent

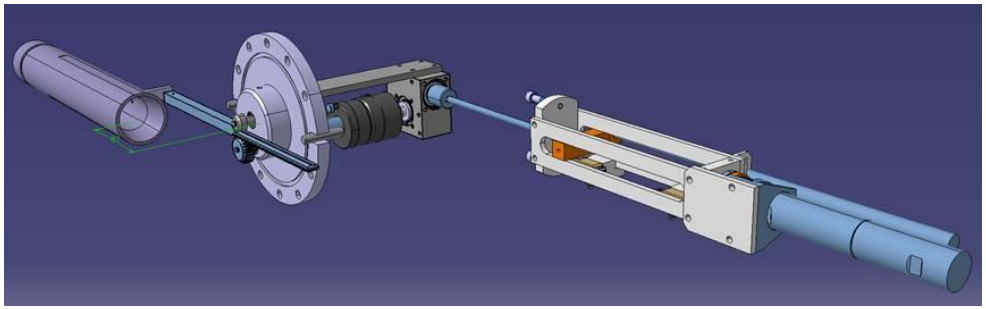
Problems:
- Mass separator hall probe
  - Low resolution at high masses
- Large container target broken
- Collection chamber sample arm
- No ^{47}ScF due to gas problem
- No ^{67}Cu and ^{225}Ra due to technical problems on the UCx targets
- Frontend electrode stuck

(extraction electrode stuck)



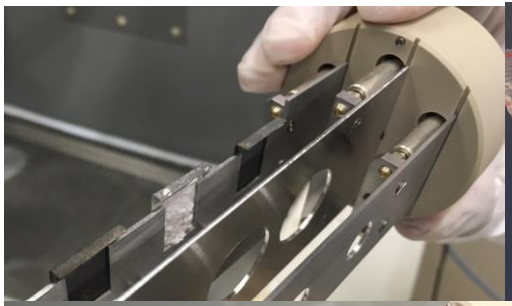
Integrated SPES design with some modifications

1. Mechanism being assembled
2. Stress tests – many cycles
3. Installation at MEDICIS (Mar 2019)
4. Installation at ISOLDE (2019)



149Tb implantation in salt

Normal:
Zn coated Au foil



Advantages:

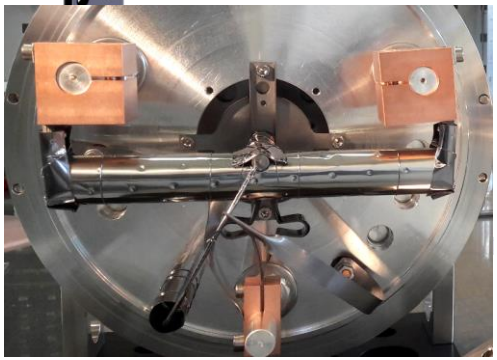
- Potassium Nitrate (KNO_3) – easy dissolution
- Collection on the TbO mass (149+16 = 165)
- No contaminants – simplify radiochemistry
- Low activity (1.8 MBq)
  - **Development on-going to promote TbO formation**

V1 V2 V3

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

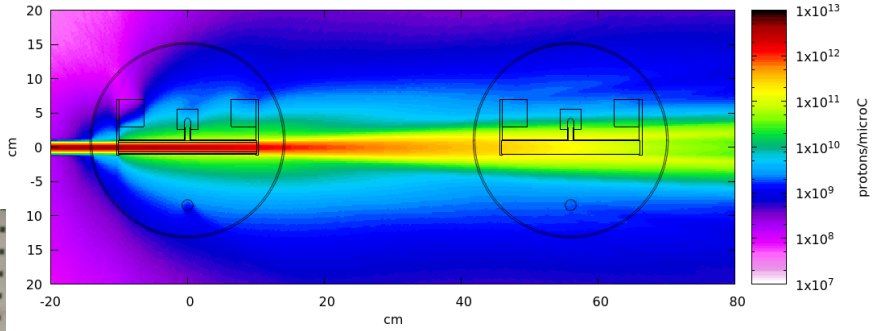
First shipping of 149Tb from MEDICIS (to CHUV)
Salt foil development – M. Khan

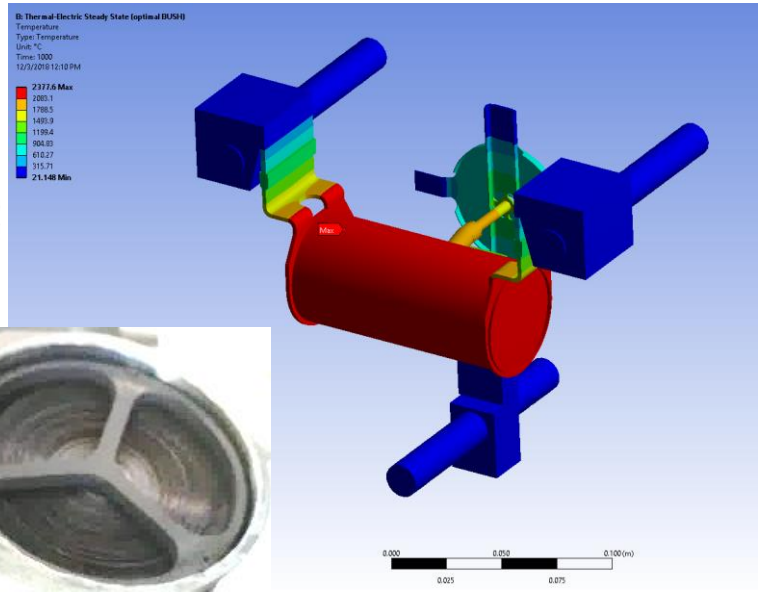
Large Ta container



ISOLDE

MEDICIS





2 cm diameter
20 cm length
60 cm^3 volume

5 cm diameter
10 cm length
200 cm^3 volume

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

1000A (normally ~750A)

Reach 2400 ºC

Plans for CERN Long Shutdown 2

CERN Long Shutdown 2 (LS2)

LS2 = no protons for ~2 years at CERN (upgrade and maintenance)

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

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

Operation of 1 to 2 weeks per month

Plan of 2 technical stops – for maintenance and upgrades

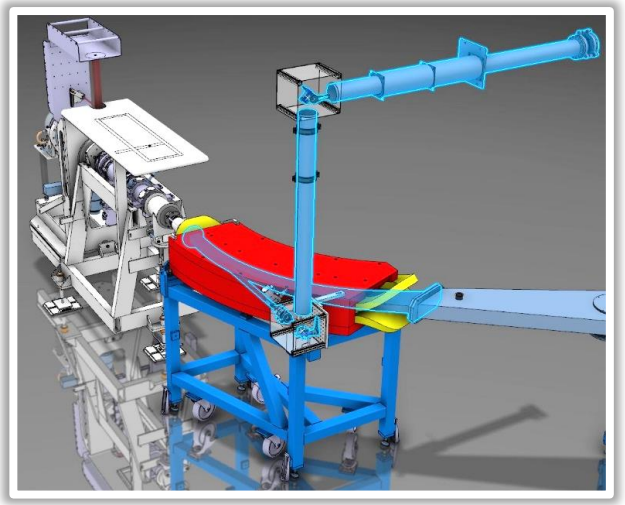
- MELISSA, radiochemistry, others…

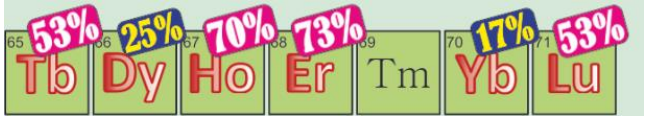
MELISSA - Lasers at MEDICIS

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% x10
(J.P. Ramos and T. Stora)

Max efficiency for Er: 0.3% x200
(R. Formento)

1st laser is here
2nd coming in February

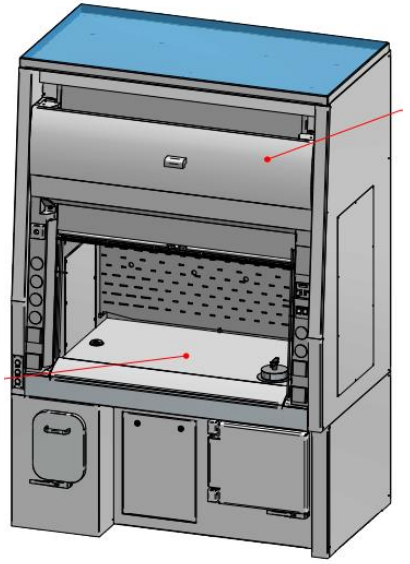
Radiochemistry at MEDICIS

Zn deposited in Au foil

KNO_3 deposited in Al foil

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

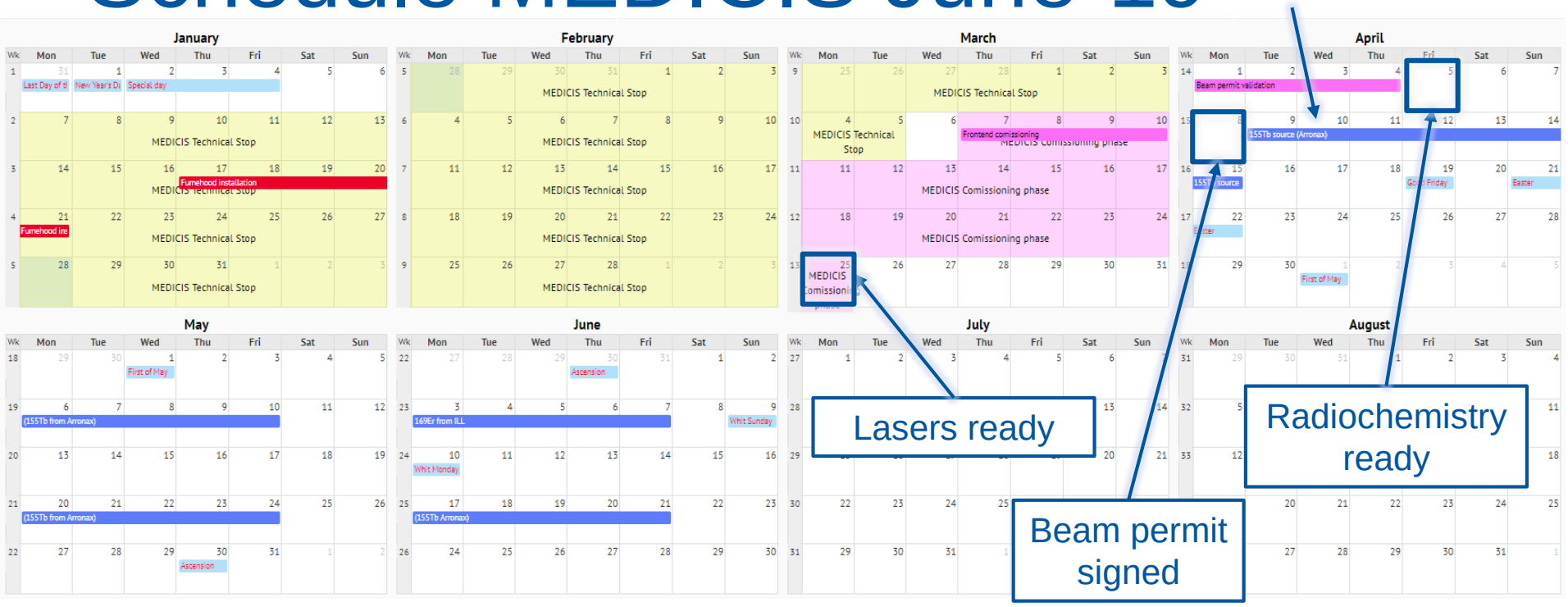
Radiochemistry fume hood installed this month in MEDICIS lab



M. Khan, N.-T. Vuong, et al.

Schedule MEDICIS June-19

1st collection of 2019



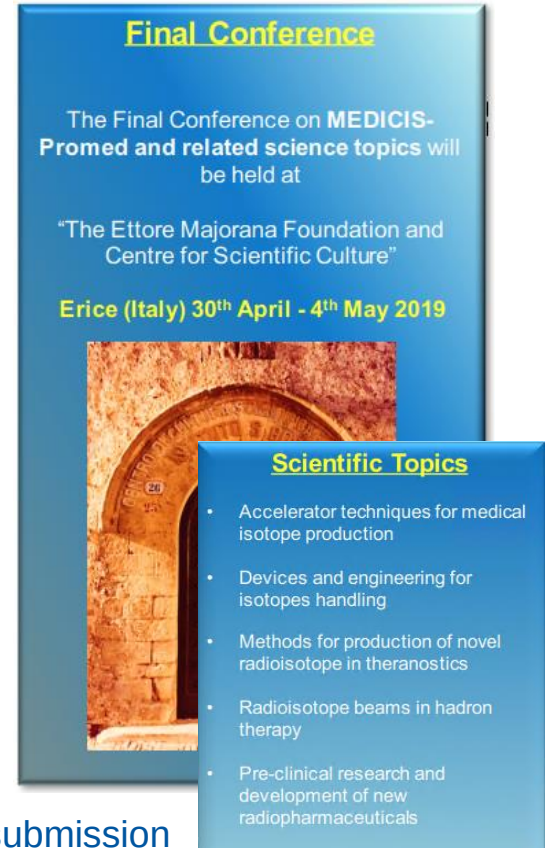
Thank you! Merci! Obrigado!

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!



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