



Interdisciplinary activities - medical applications

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Medical applications of nuclear & radiation physics

- Nuclear medicine
 - ▶ use of radioisotopes for imaging & treatment
- Radiation medicine
 - ▶ x-ray imaging
 - ▶ radiation therapy
 - ▶ proton beam therapy
- Nuclear biophysics
 - ▶ use of radioisotopes to probe in-vivo chemistry kinematics

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- Nuclear medicine
 - ▶ use of radioisotopes for imaging & treatment
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 - ▶ proton beam therapy
- Nuclear biophysics
 - ▶ probing the interaction of charged particles with life elements
 - ▶ use of radioisotopes to probe in-vivo chemistry kinematics

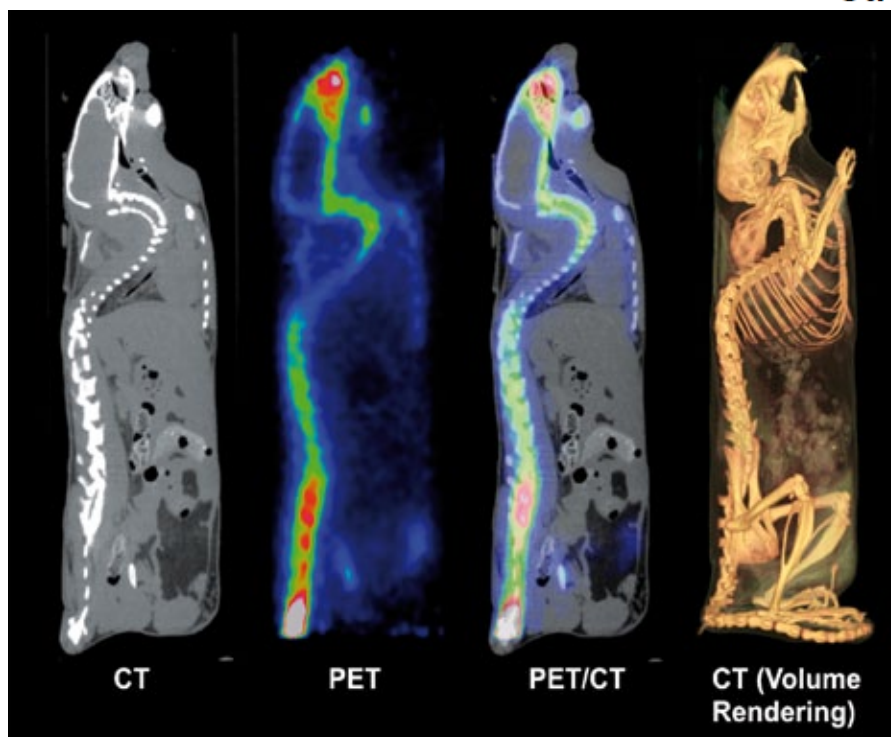
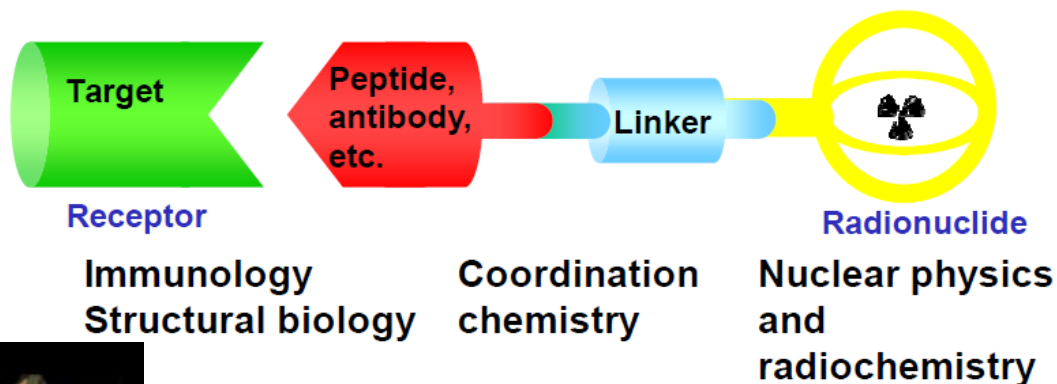


Nuclear medicine

- ◆ isotope production
- ◆ radiopharmacy

Radioisotopes for nuclear medicine

Radioisotopes are attached to biomolecules used to target specific receptors in the body to image active areas, identify cells, or treat cancer.



Medical radioisotopes have to answer many criteria:

- ➔ available (production)
- ➔ can be handled (half-life)
- ➔ high benefit / low toxicity (decay modes, branching ratios, half-life)
- ➔ stable within the biomolecule

Medical radioisotope production



Nuclear reactors are used to produce many neutron-rich radioisotopes, such as the SPECT isotope ^{99m}Tc , including the BR2 reactor at SCK·CEN in Mol, Province of Antwerp.

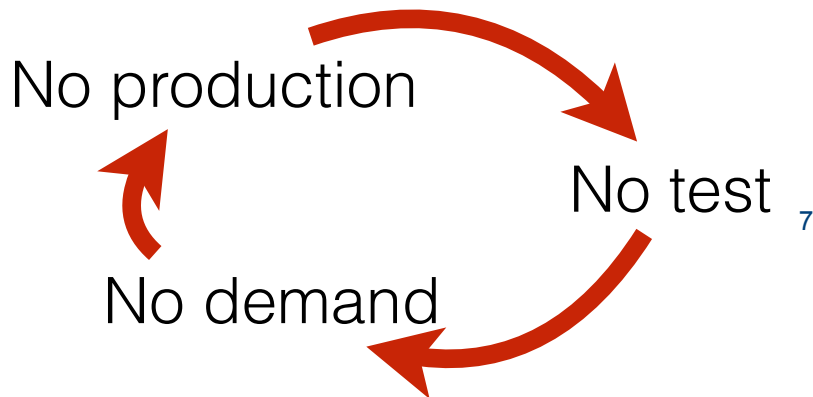
These reactors are not economically sustainable and survive thanks to large subsidies. A supply crisis of ^{99m}Tc is expected by the year 2016.

Small cyclotrons, with energies ranging from 15 to 100 MeV are used to create specific isotopes for locally-based, dedicated applications, such as ^{18}F for PET or ^{82}Sr for heart imaging. IBA, a Belgian company based in Louvain-La-Neuve, Province of Walloon Brabant, is a spin-off from the Cyclotron Research Centre and is a world leader in medical cyclotrons.



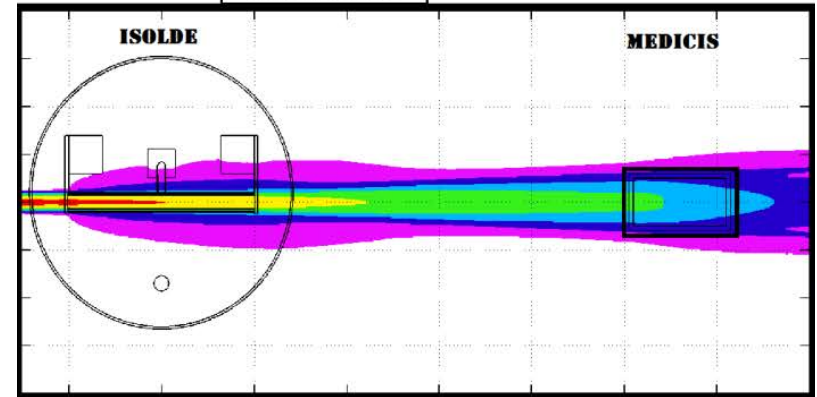
The New Radioisotopes Conundrum

- With the closure of many reactors in 2016, the medical community foresees a crisis in supplying ^{99m}Tc for medical imaging. Everybody panics and alternatives have to be found.
- Targeted radiotherapy is very limited, although very potent, and its latest new addition (RaCl_2) took >10 years to get validated.
- Any new isotope, whether for imaging or therapy, requires lengthy clinical tests and validation during which there is no market value for its production.

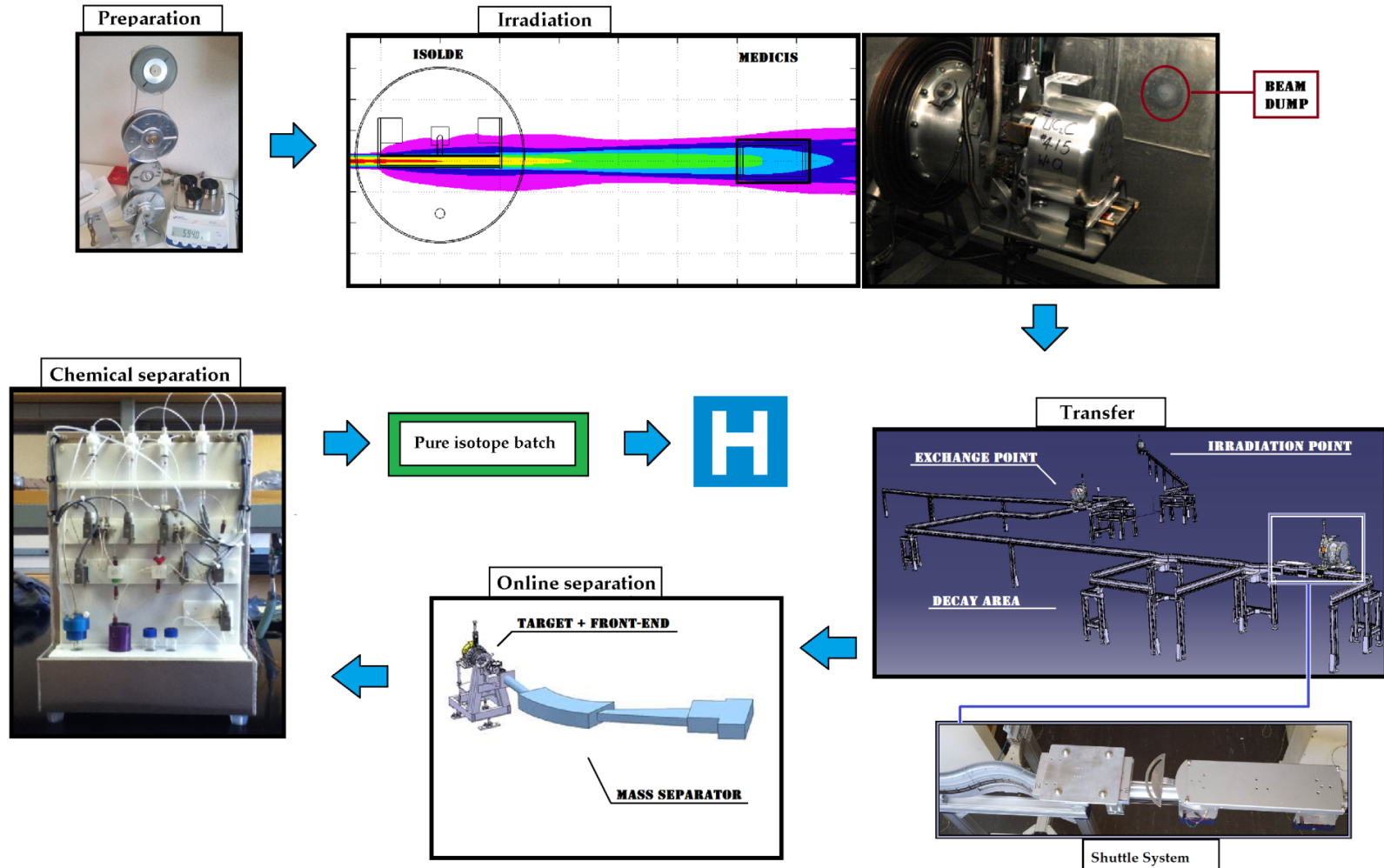


Free beam for “free” radioisotopes at CERN

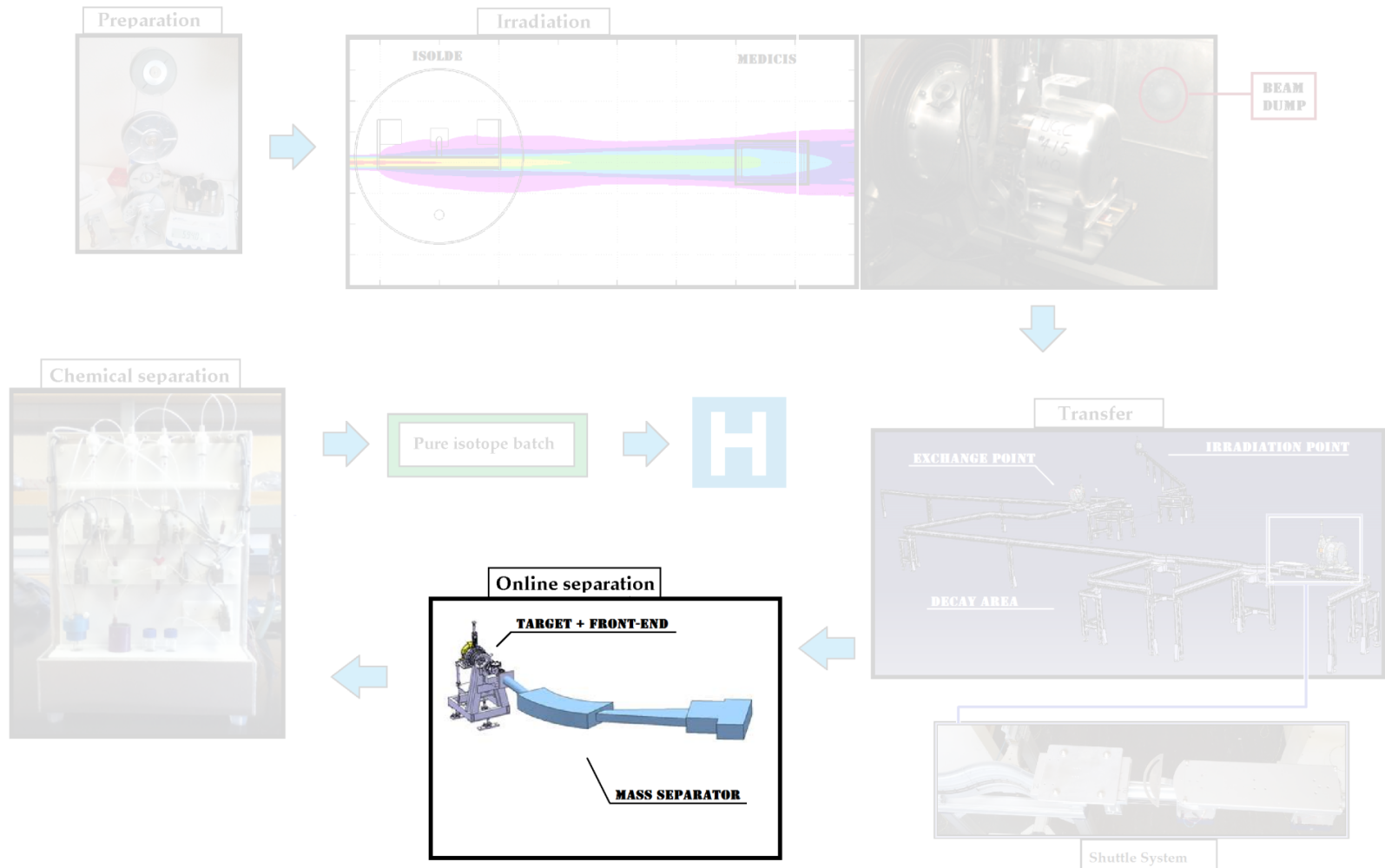
- 80% of the proton beam goes through the ISOLDE target unaffected
- That beam is then sent onto another target
- The target can be removed from the target area towards a Class A laboratory **(video)**
- An off-line separator is used to extract radioisotopes of interest



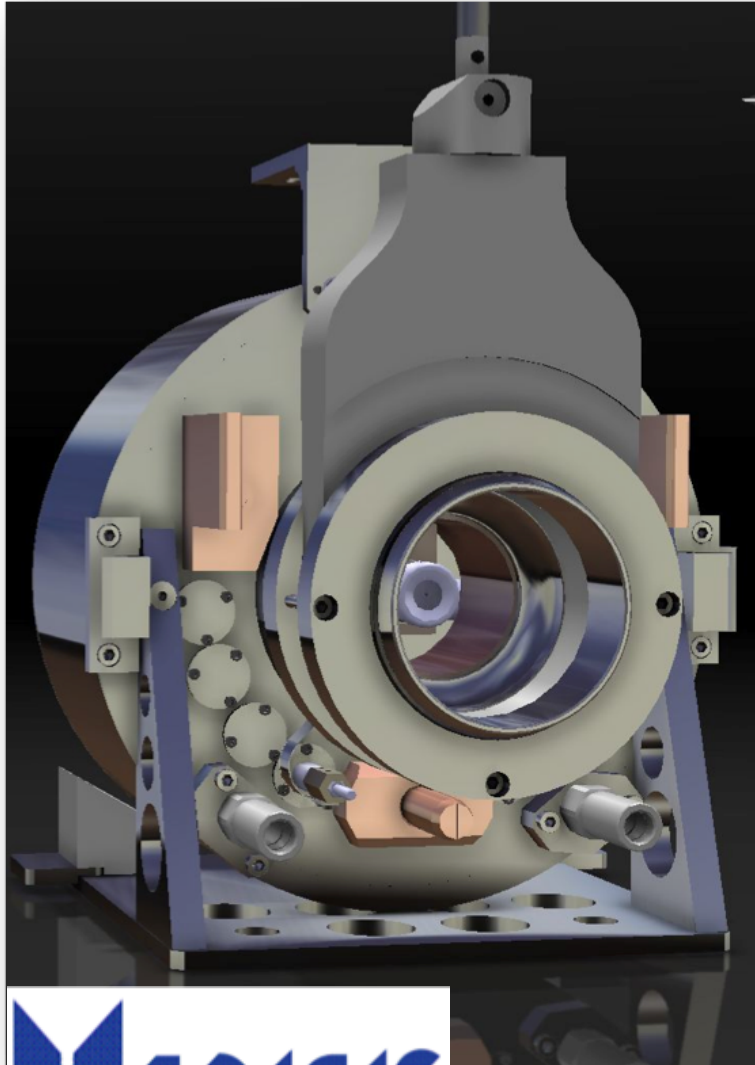
CERN-MEDICIS from A to Z



CERN-MEDICIS from A to Z

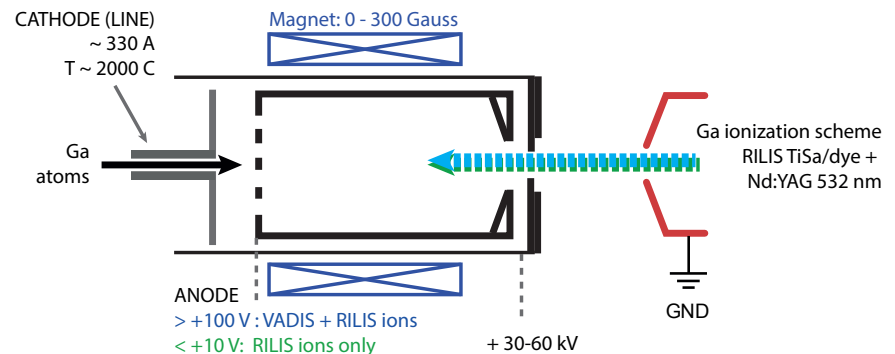


CERN-MEDICIS: the ion source

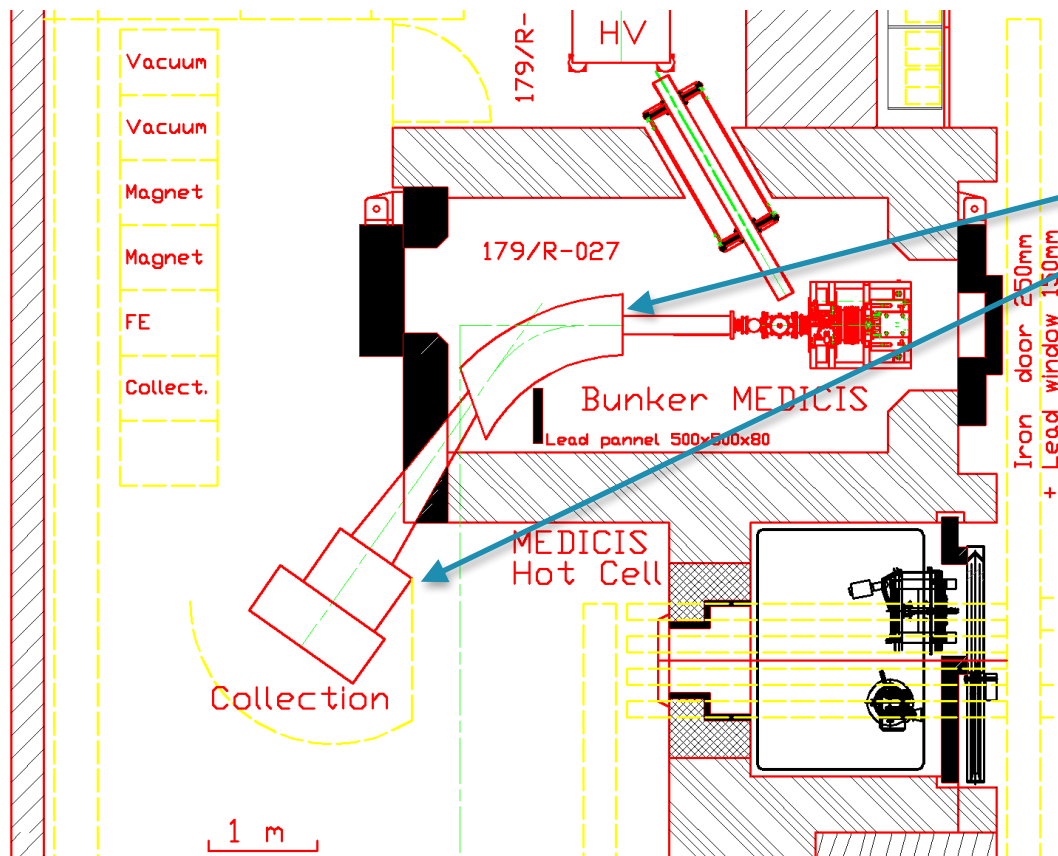


CERN-MEDICIS will use an ISOLDE-type target-ion-source module. For versatility, the choice of ion source is the VADIS, a plasma ion source that has demonstrated high efficiencies.

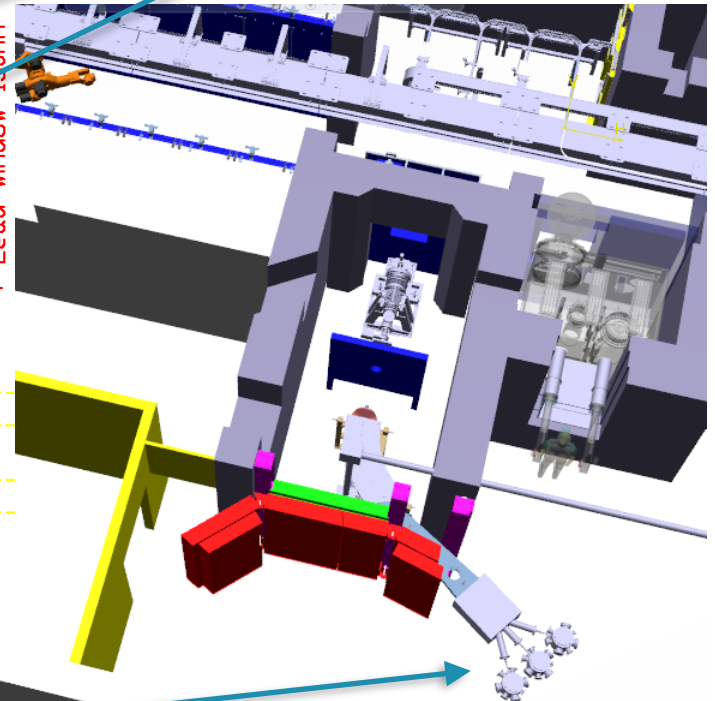
Recent developments by the ISOLDE Target Group, RILIS, and Windmill Collaboration have combined VADIS with laser ionisation. Further simulation and characterisation of this ion source are ongoing by a KU Leuven PhD student at CERN.



CERN-MEDICIS: the separator



Dipole magnet & switchyard from the LISOL separator, used for 40 years in Louvain-La-Neuve!

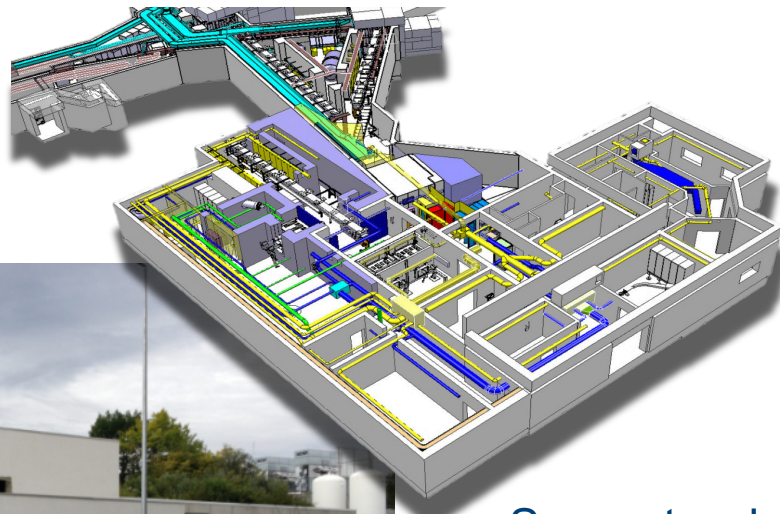


New collection chamber prototypes.

MEDICIS timeline



Ground breaking
3 Sept 2013



Separator delivery
Ongoing



Building delivered
15 Oct 2014

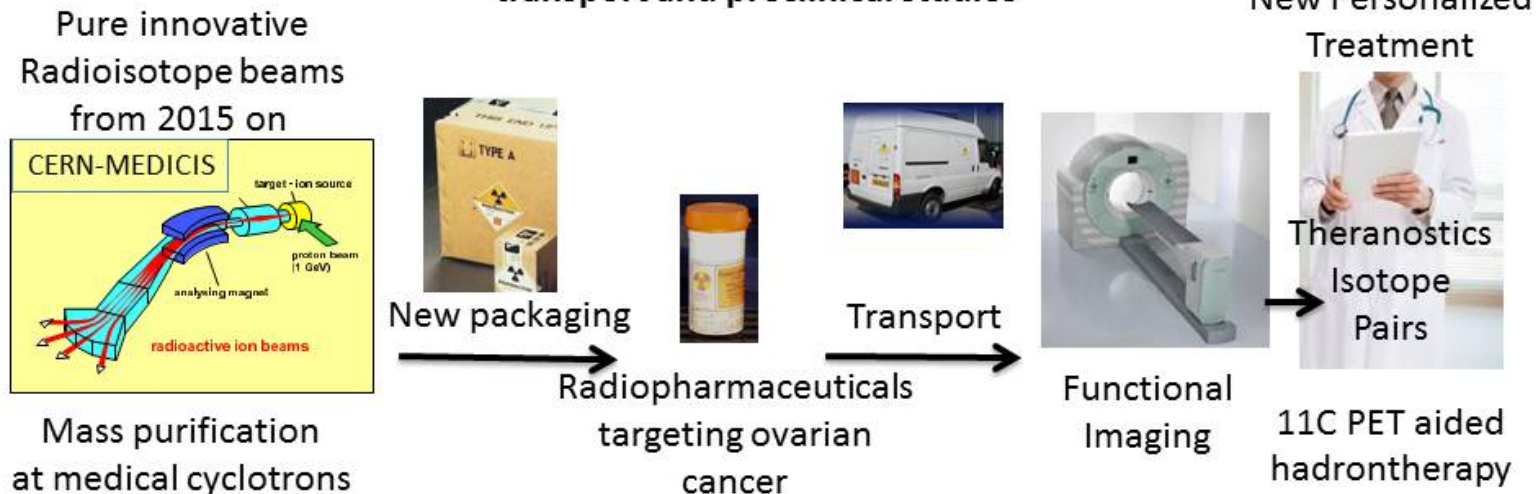


MEDICIS-Promed

A Horizon2020 Marie Skłodowska-Curie Actions:
Innovative Training Network



**MEDICIS-PROMED: Innovative treatments based on radioactive ion beam production,
transport and preclinical studies**



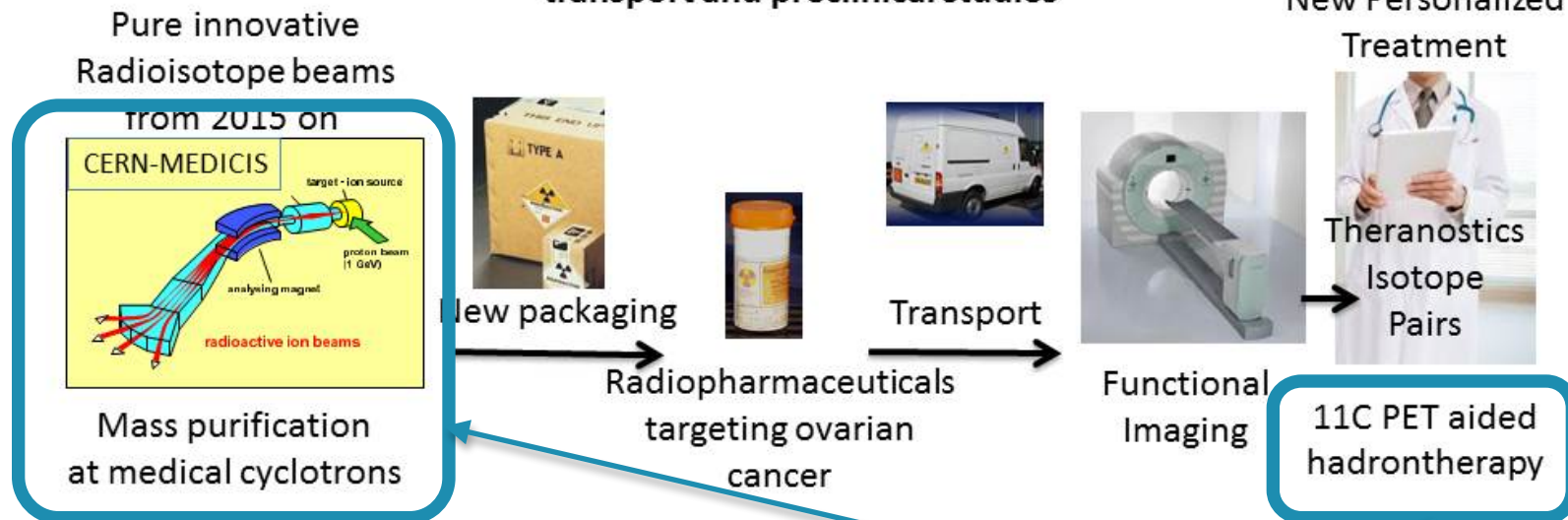
— CERN — The University of Manchester — University of Mainz —
— AAA — C2TN — CNAO — Lerner Pax — KU Leuven —
— CHUV — HUG - EPFL — MedAustron —
— Oxford University Consulting — ARRONAX — ILL —

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Radiochemistry in Belgium



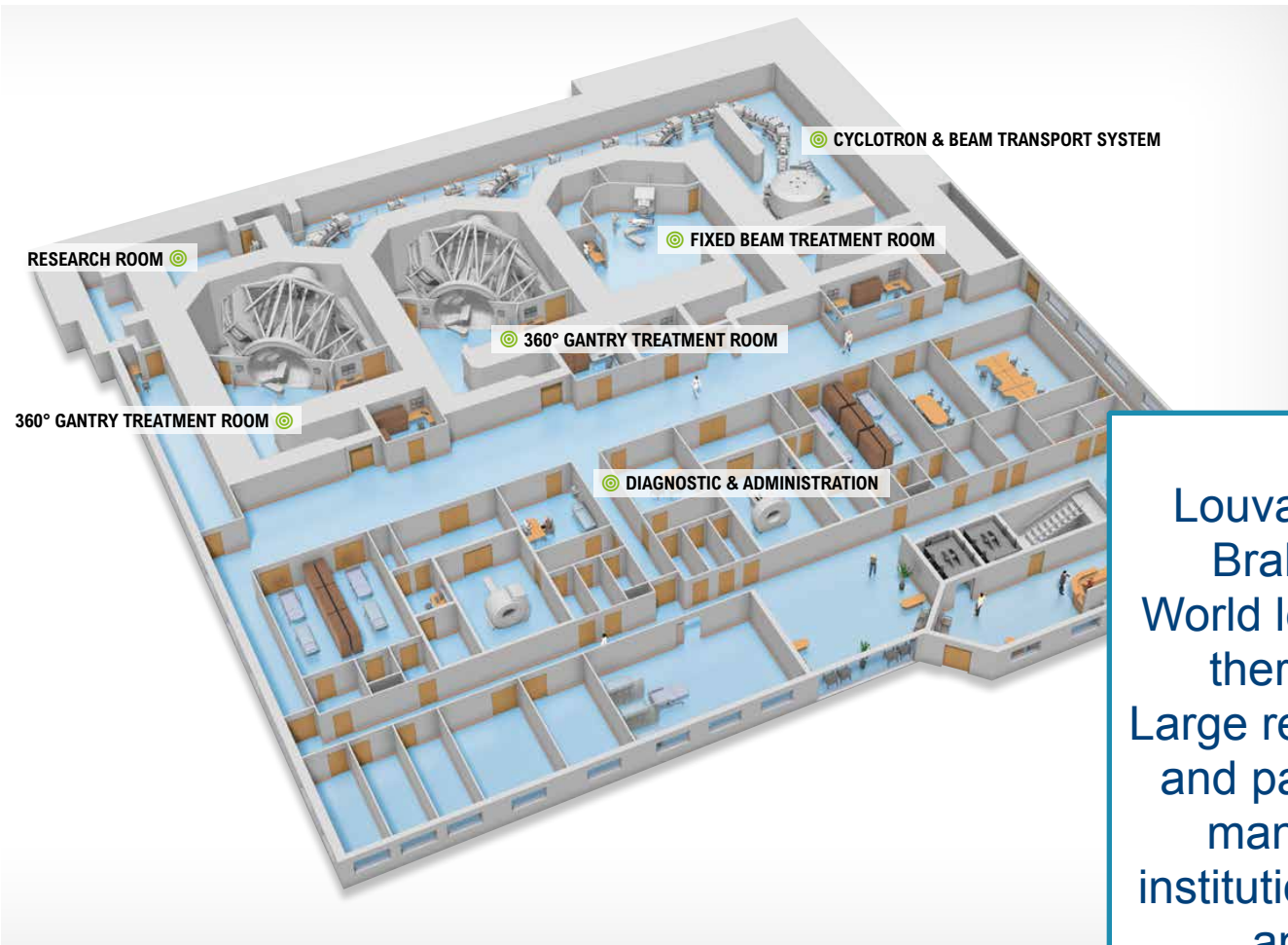
Institut des Radioéléments - IRE
One of the 5 world producers of ^{99}Mo generators
Based in Fleurus, Province of Hainaut



Radiation medicine

- ◆ proton therapy centres
 - ➔ UZ Leuven
 - ➔ Charleroi

IBA cyclotrons



IBA
Louvain-La-Neuve,
Brabant Wallon
World leader in proton
therapy centres
Large research division
and partnership with
many academic
institutions, in Belgium
and abroad

2 new proton therapy centres in Belgium

KU Leuven & Université Catholique de Louvain are joining up for the construction of a €40M proton therapy centre in UZ Gasthuisberg in Leuven.

The Wallonia Region will also invest €47M in the construction of a proton therapy centre in a Centre of Excellence in Charleroi, Province of Hainaut.





Nuclear biophysics

- ◆ reactions on C, N, O
- ◆ in-vivo β -NMR

Double use of the proton therapy centres

- Possible multiple extraction / delivery of the proton beams from the cyclotron
- Have 1 room dedicated to therapy
- **Have 1 room dedicated to research**
 - this room may be retrofitted for therapy if the demand increases in the future
 - used for different research topics, including biophysics
 - studying the nuclear reaction cross-sections on life elements: C, N, O

In-vivo β -NMR



1A	2A	3A	4A	5A	6A	7A	8A
1 H	2 He						
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg ²⁺	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe
27 Co	28 Ni	29 Cu ⁺	30 Zn ²⁺	31 Ga	32 Ge	33 As	34 Se
35 Br	36 Kr						
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru
45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te
53 I	54 Xe	55 Cs	56 Ba	57 La	58 Ce	59 Pr	60 Nd
61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er
69 Tm	70 Yb	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os
77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po
85 At	86 Rn	87 Fr	88 Ra	89 Ac	90 Th	91 Pa	92 U
93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm
101 Md	102 No	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs
109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv
117 Ts	118 Og						

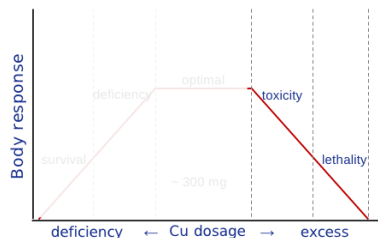
Property	NMR	β -NMR
# molecules	10^{18}	10^5
Nuclear polarization	External field ($\ll 1\%$)	Optical pumping, tilted foils, etc up to 100%
Isotopes	Mostly stable	Radioactive
Detection	Magnetic response	β asymmetry

Human body:

- 99% 4 major elements:
O (43 kg), C (16 kg), H (7 kg),
N (1.8 kg)
- 1% 21 other elements:
Ca, Mg, Fe, Zn, Cu ...

Mg^{2+} , Cu^+ and Zn^{2+}

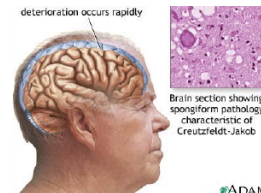
- (+) Some of the most abundant ions in human body
- (+) Closed shell ions \rightarrow silent in most spectroscopic techniques



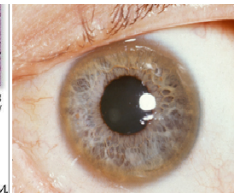
Alzheimer



Parkinson

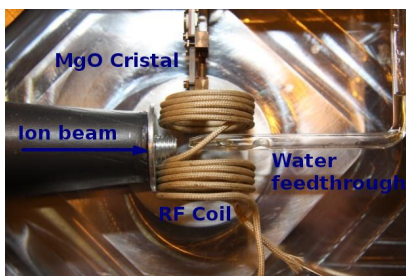
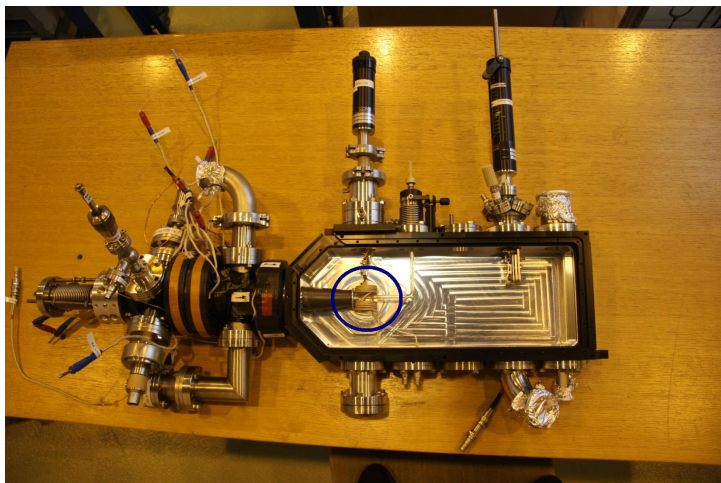


Prion

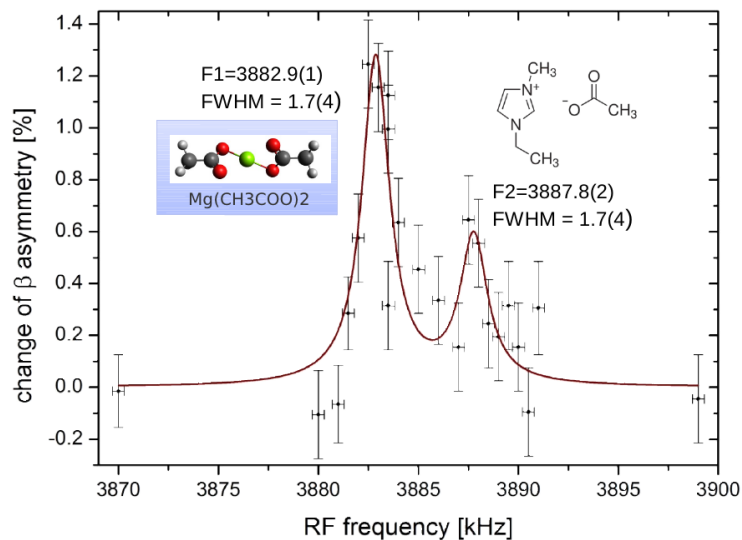


Wilson

In-vivo β -NMR at ISOLDE



β -NMR spectrum of ^{31}Mg in an Ionic Liquid

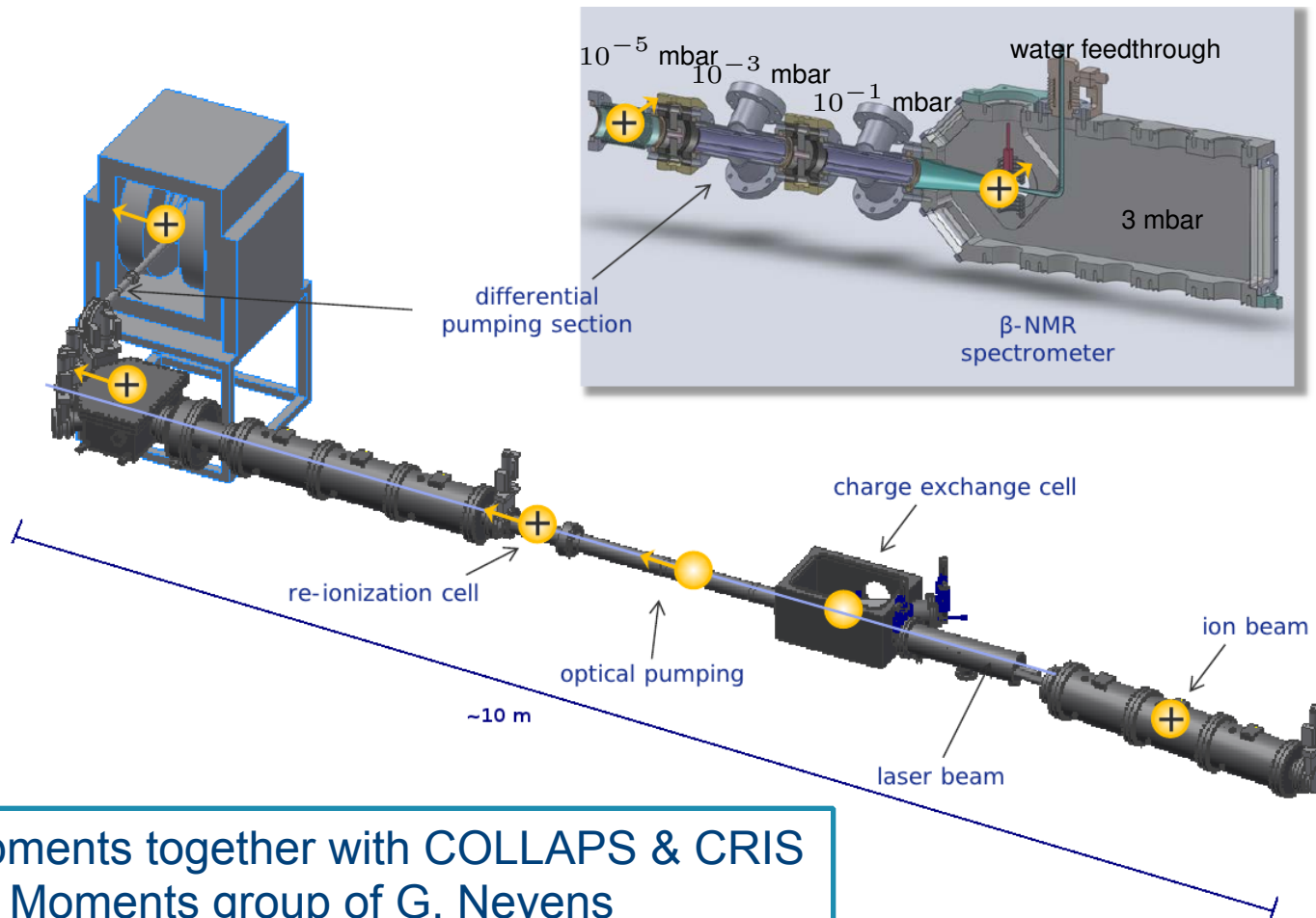


For the first time (August, 2012):

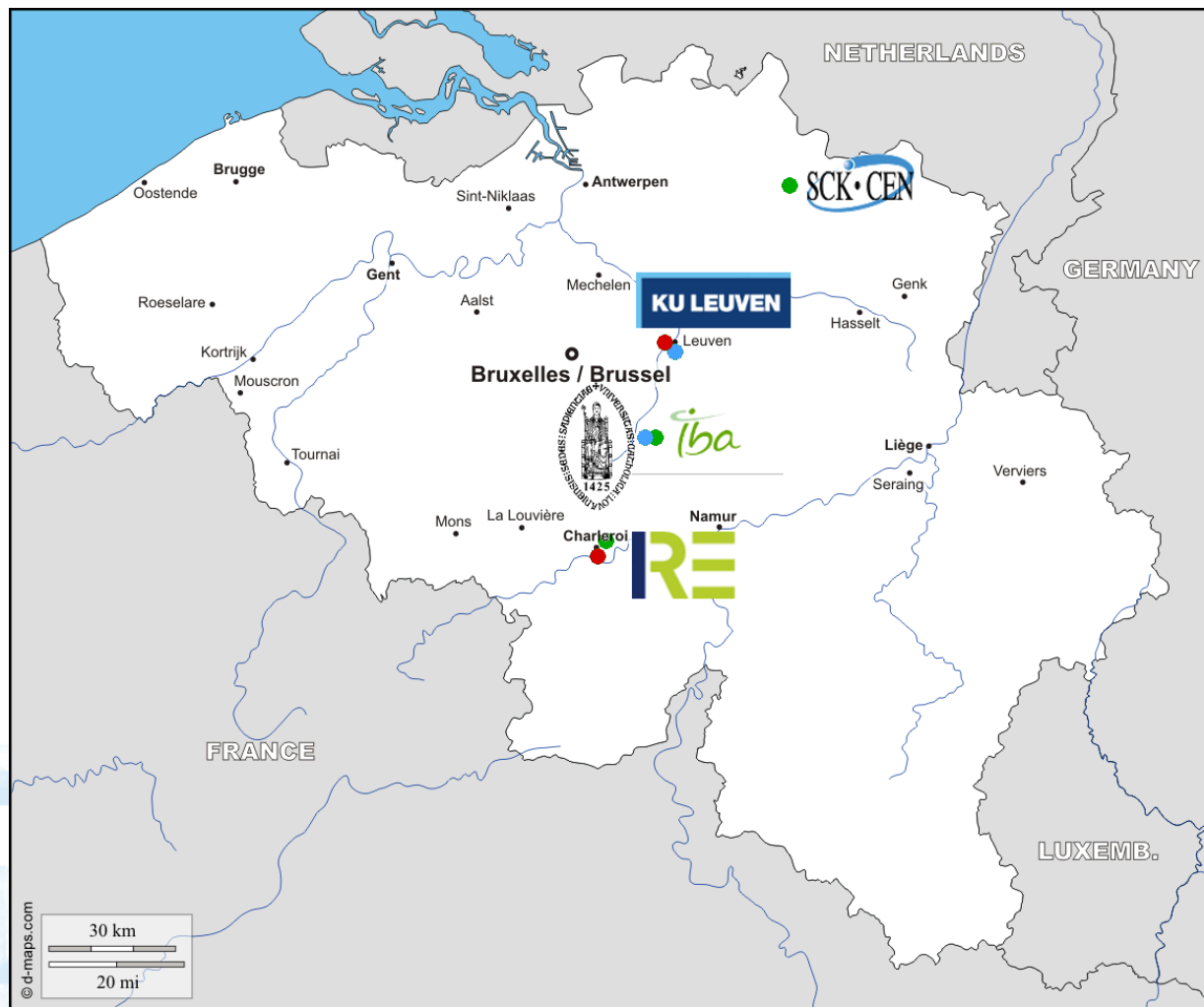
- β -NMR measured in a liquid medium
- Signal recorded from metal ions (Mg II) in a body-like liquid environment

A. Gottberg, M. Stachura, M. Kowalska et al.
ChemPhysChem 15 (2014) 3929.

In-vivo β -NMR: the setup



Developments together with COLLAPS & CRIS
Nuclear Moments group of G. Neyens



For more information on radioisotopes in Belgium, visit Rad4Med.be

Thank you for your attention!