# MEDICIS – PROMED

## Work Package 1: Mass separation of innovative medical isotopes using CERN-MEDICIS

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JOHANNES GUTENBERG UNIVERSITÄT MAINZ

LARISSA

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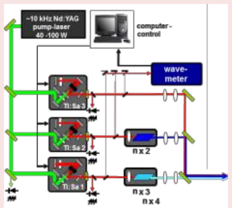
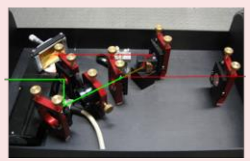
# WG LARISSA Research Activities

***L**aser **R**esonance **I**onization **S**pectroscopy and **S**elective **A**pplications*

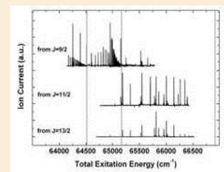
## Laser Development

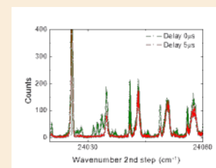


- Reliable powerful pulsed solid-state laser systems
- Tunable lasers for all kinds of spectroscopy
- Combination with mass spectrometry

## Atomic Spectroscopy

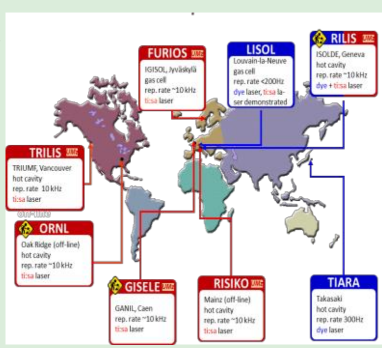



- Atomic energy levels, Ionization potentials, HFS and IS of all-radioactive elements
- Development of excitation schemes for on-line RIS

## On-line Laser Ion Sources

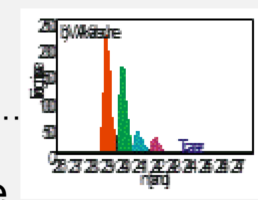
- Lasers for Ion Sources worldwide (CERN,TRIUMF, JYFL,GANIL,RIKEN,RISP, . . . )
- New Developments (LIST, Dual-RILIS, . . . )

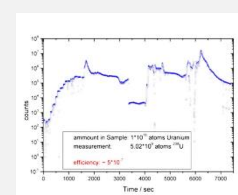



- Isotope Enrichment (ECHo – Neutrino Mass)

## RIS in Radioanalytics and Biomedical

- Analytics of long-lived radionuclides (U, Pu, Np,$^{99}$**Tc**,…
- Isotope selective ultratrace isotopes: $^{41}$**Ca**, $^{90}$Sr, $^{236}$**U**,…
- Application in Biomedical (EU-Osteodiet) & Radioprot.



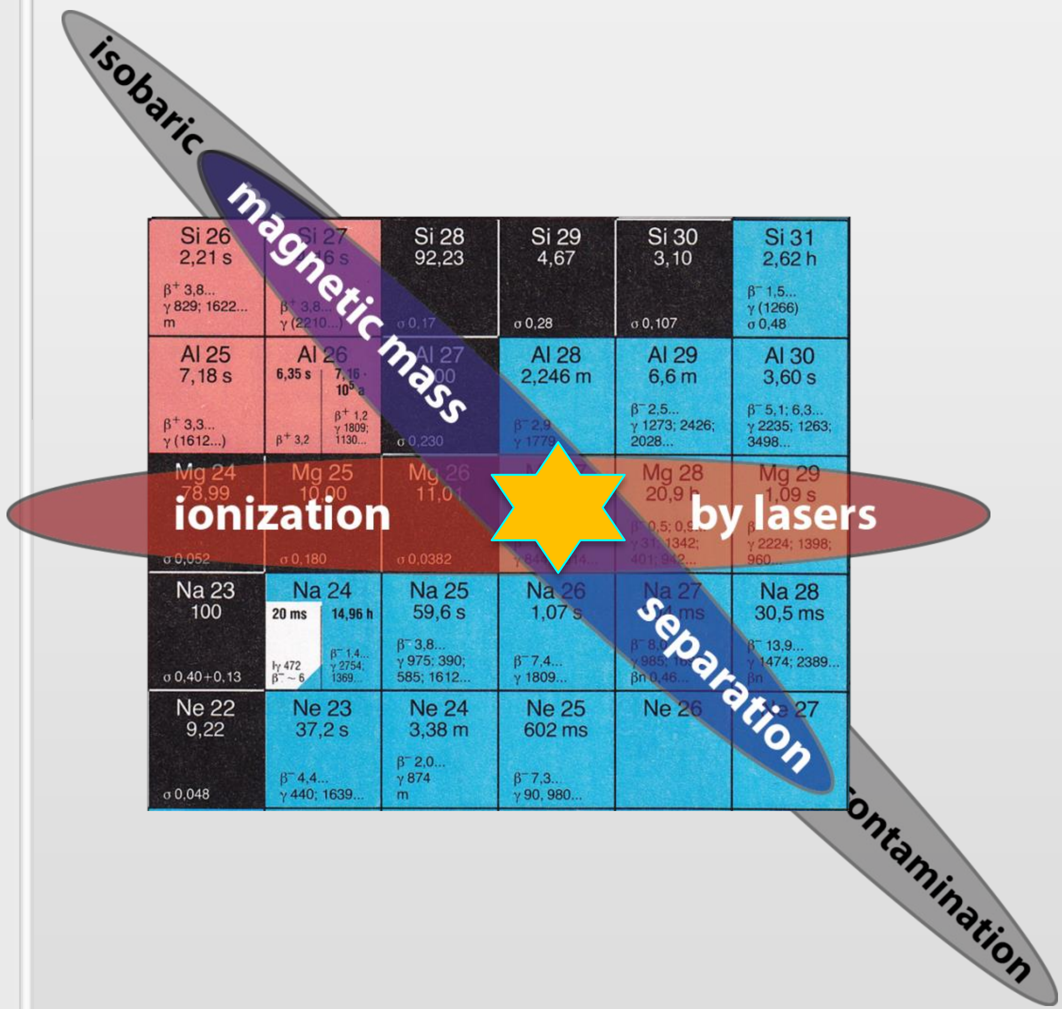


# Laser Resonance Ionization in Radioion Production

Production of **radioisotopes** using radioactive ion beam facilities (**RIBs**)
e.g. ISOLDE/CERN (ISOLDE-MEDICIS)

- Requirements:
  - **Powerful driver** for nuclear reactions
    → efficient radioisotope generation
  - **Efficient ionization & mass selection** of the radioisotope of interest
    → disturbed by **isobaric** contaminations
    - especially for **rare earth** isotopes

- Relevance of **RILIS laser ionization:**
  - **Most efficient** ionization process
  - **Unrivaled selectivity** for beam purity
    → **element selection** and preeminent suppression of isobaric contaminations



# The JOGU RISIKO off-line mass separator

## for laser ion source development and isotope enrichment

**Magnetic sector-field Mass Spect.**

60 kV two stage acceleration

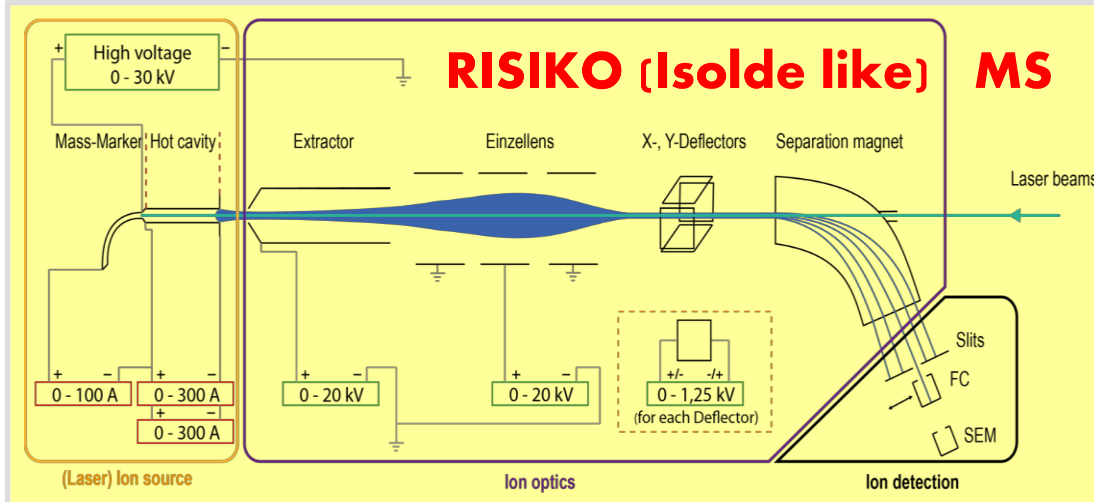
60° double focussing separator magnet

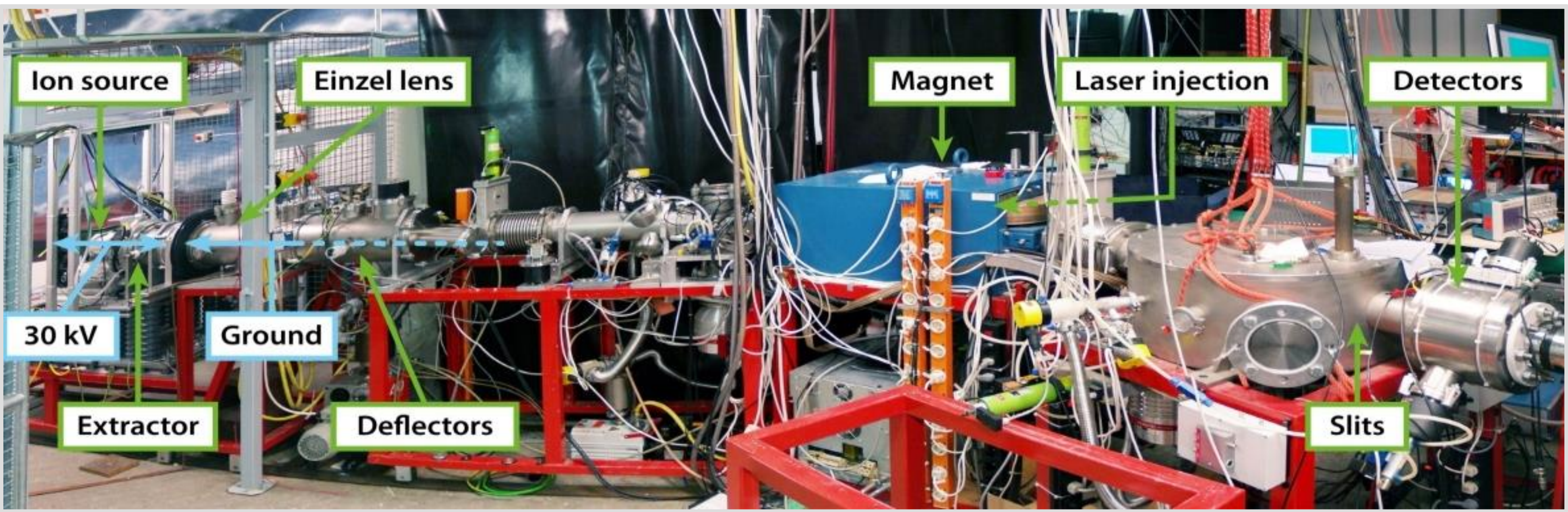
Mass resolution: $\frac{m}{\Delta m} \sim 1000$

Isotopic abundance sensitivity $S_{m\pm1} \approx 10^4$

(radioisotope applications

only below exception limit)



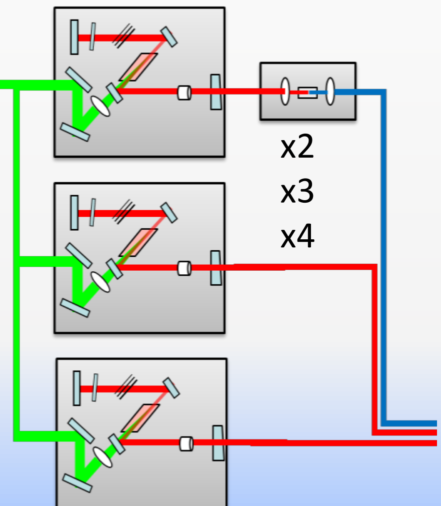



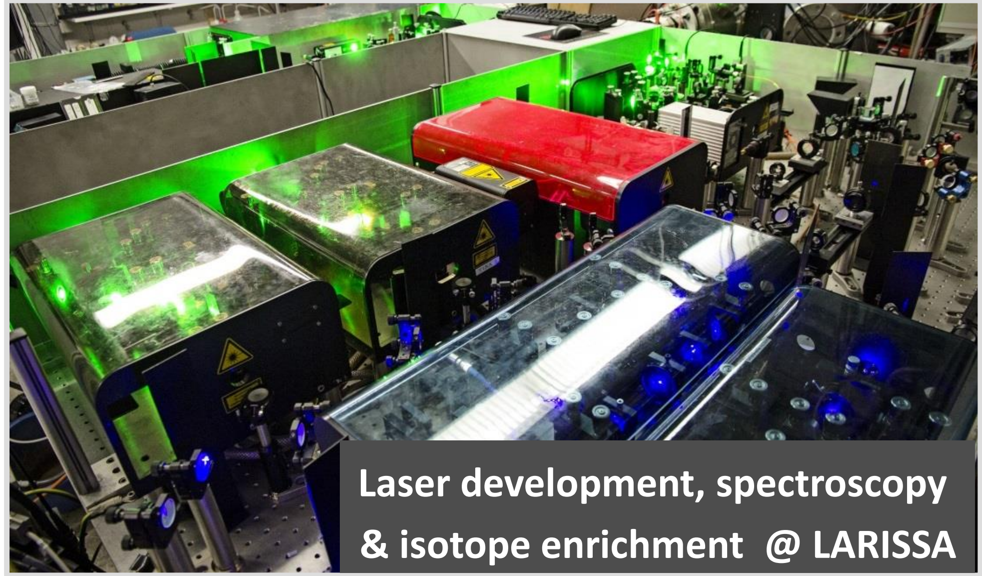
# RIS LASER Development Lab at JOGU Mainz

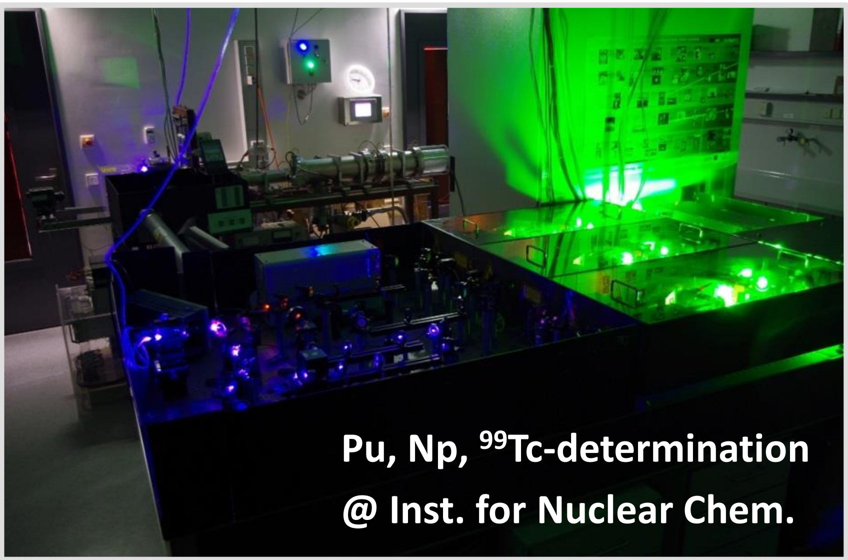
## & applications in analytics, atomic spectroscopy & RIS scheme development

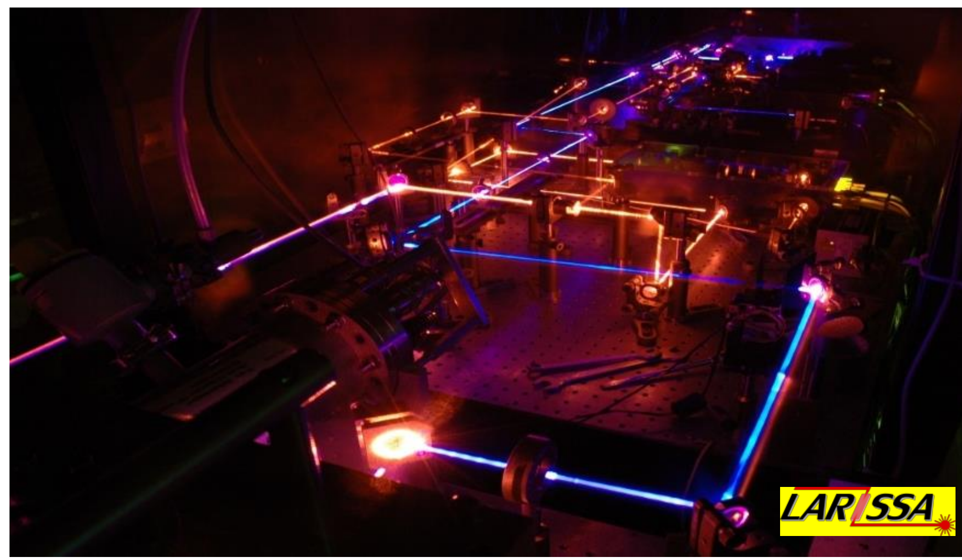
frequency doubled
Nd:YAG 532 nm

High rep.-rate
Ti:sa laser systems
incl. higher harm.,
SHG, THG & FHG
& full ISST control



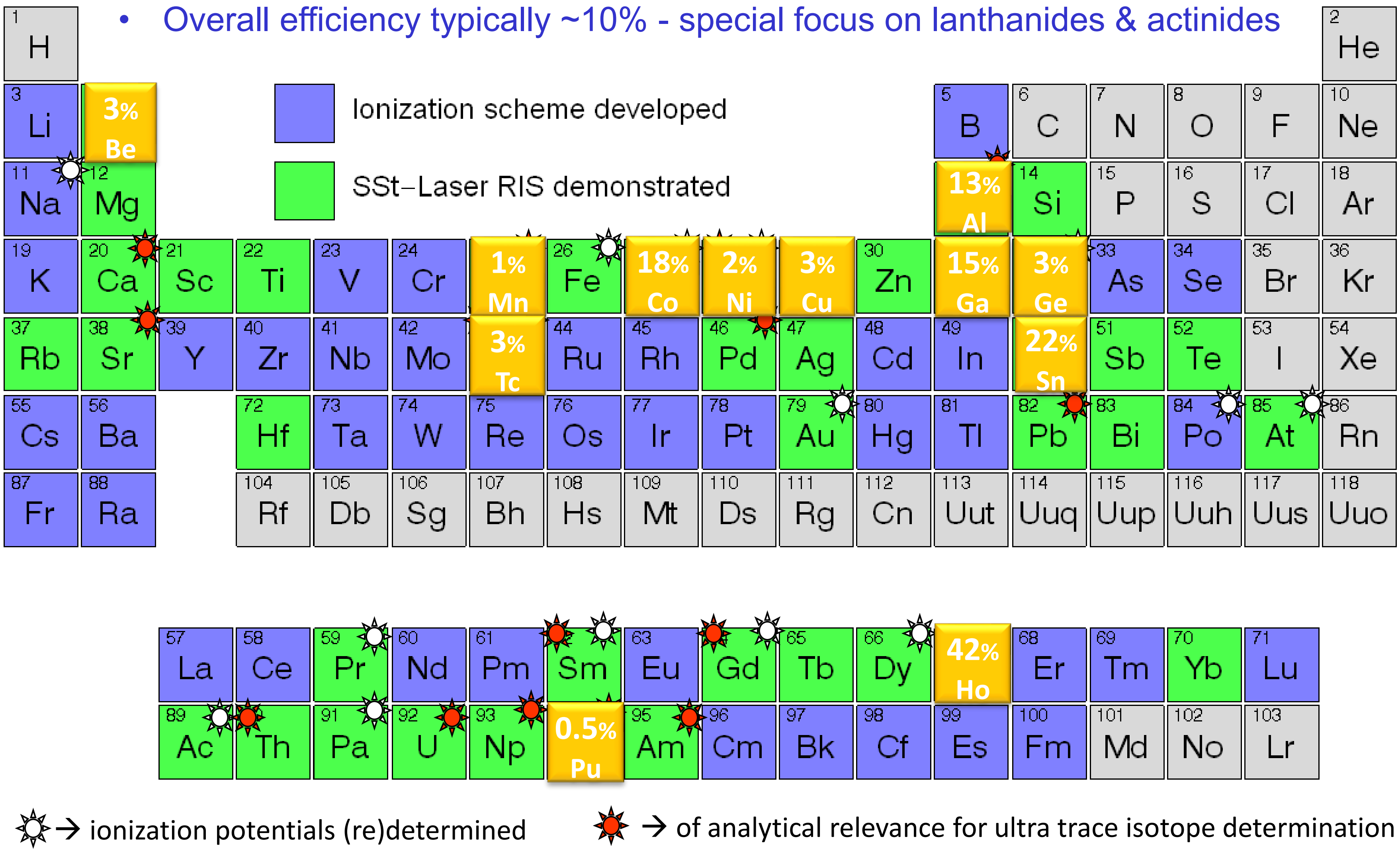



# Today: 45 Elements of Solid State Ti:Sa Laser RILIS

- 45 elements demonstrated for on-line RILIS, ~ 40 others possible
- Overall efficiency typically ~10% - special focus on lanthanides & actinides



# MEDICIS – PROMED Work Package 1 Description

| | | | |
|---|---|---|---|
| **Work package number [9]** | **WP1** | **Lead beneficiary [10]** | **3 – JOHANNES GUTENBERG UNIVERSITAET MAINZ** |
| **Work package title** | **Mass separation of innovative medical isotopes using CERN-MEDICIS** | | |
| **Start month** | 4 (01.Aug.15) | End month | 48 (01.April.19) |

JOGU, Germany, has been attributed as work package leader for WP 1

## *Objectives*

1. **Design and test of new mass separator components to produce new medical isotopes**
2. **Design and homologation of new packaging for intercountry isotopes transport in Europe**

## *Description and Role of Partners*

**Metallic foil targets with protective graphene layers**

– Uman (Graph. Inst.) – CERN – 10m - laboratories to handle uranium foils and grow graphene layers.

**Uranium carbide nanofiber targets**

– IST (C2TN) – AAA – 3m - production of targets for 8-30MeV cyclotron
– ARRONAX – 3m - production of target for 70MeV cyclotron.

**Remotely operated laser ion sources for medical cyclotrons**

– JOGU – HUG – 6m - setting-up atomic vapour-lasersystem.

**Production and safety aspects of theranostics 149/152Tb**

– CERN-MEDICIS – ILL – 5m - production of 161Tb.

**Design and homologation of new containers for theranostic isotope pair transportation**

– Lemer Pax – CERN – 3m - Monte Carlo simulations
– ILL – 3m - 177Lu transportation.

The Lead beneficiary JOGU will monitor the progress of the Work Package while the different contributing institutes will define the scientific methodologies and the exact nature and timeframe of the intersectorial & eventual inter work package secondment for the various projects.

# MEDICIS – PROMED WP 1: Partners involved

JG|U

**Contract in this aspect not fully coherent ???** **(at least for our understanding!)**

– **Participation per Partner…** identified as

1 – CERN, EU
3 – JOGU, Germany
4 – AAA, France (Info on being not actually involved in WP 1)
8 – LEMER PAX, France

– **further contributing Beneficiaries**

2 – Graphene Inst. (UMan), UK (no reply on email to Kostya Novozelov, wrong contact
5 – C2TN (IST) , Portugal

– **and Partner Organisations**

o – HUG, Switzerland
o – ILL, France (EU)

# WP1 List of Milestones

| Milestone number [18] | Milestone title | WP number [9] | Lead Beneficiary | Due Date (in months) [17] | Means of verification |
|---|---|---|---|---|---|
| **MS 1** | Graphene growing and characterization on Tantalum foil as protective layer | WP1 | 2 – UMAN (Graphene Inst.), GB | 20 (01.12.16) | |
| **MS 2** | Synthesis of nanofibers of Lanthanum carbide | WP1 | 5 – IST, Italy | 15 (01.07.16) | |
| MS 3 | Laser Ionization with high efficiency of $^{177}$Lu beams | WP1 | 3 – JOGU, Germany | 24 (01.04.17) | |
| **MS 4** | Development of a container type B(u), for alpha isotopes transport | WP1 | 8 - LEMERPAX, France | 16 (01.08.16) | |
| **MS 5** | Operation and Radioprotection of mass separated isotopes at MEDICIS | WP1 | 1 – CERN, Switzerland | 30 (01.10.17) | |

# WP 1 List of Deliverables

| Deliverable Number | Deliverable Title | Lead beneficiary | Type | Dissemination level | Due Date (in months) |
|---|---|---|---|---|---|
| **D1.1** | $^{99}$Mo/Tc production with metal uranium/ graphene targets at CERN-MEDICIS | 2 - UNIVERSITY OF MANCHESTER | Report | Public | 40 |
| **D1.2** | Uranium carbide nanofibers target development | 5 - IST | Report | Public | 30 |
| **D1.3** | Remote laser ion source operation system for installation at medical cyclotrons | 3 - JOGU MAINZ | Report | Public | 36 |
| **D1.4** | Design of new containers for theranostic isotope pairs transportation | 8 - LEMER PAX | Report | Public | 24 (01.04.18) |
| **D1.5** | Production of theranostics 149/152Tb at CERN-MEDICIS and shipping | 1 - CERN | Report | Public | 40 |

# The five ESRs in Work Package 1

## 2

| ESR 2 | CERN | PhD : Y | Start : Month 4 | Duration 36 months | D1.5 (WP1) |
|---|---|---|---|---|---|

Production of $^{149/152}$Terbium theranostics isotopes at CERN-MEDICIS and shipping

Objective : to define the proper operational conditions and safety boundaries for the production and shipping of radioisotopes from radioactive ion beams

Expected Results: The CERN-MEDICIS facility is the first facility to start operation for the production of medical istope batches by mass separation. The necessary engineering validation and documentation steps will be elaborated for its safety file. This includes the procedure and design of isotope batch collection chambers, coupling of radiochemical purification modules to the isotope mass separator. The efficiencies for the collection of $^{149/152}$Terbium will be determined, and different engineering systems, such as targets and ion sources will be selected and optimized to achieve the best figures.

Planned secondment: -ILL – M16-20 – Production of the complementary $^{161}$Terbium & mass separation of $^{163}$Erbium

CERN

## 4

| ESR4 | Graphene Institute | PhD :Y | Start : Month 4 | Duration 36 months | D1.1 (WP1) |
|---|---|---|---|---|---|

Metallic foil targets with protective graphene layers to produce innovative isotopes

Objective: To study the possibility and mechanisms of graphene growth on uranium, thorium and other metals to form a protective layer. To characterised the grown graphene layer and its ageing in difficult environments

Expected Results: It has been demonstrated recently, that graphene can serve as a completely impermeable membrane on a surface of a metal. Furthermore, as graphene can be grown conformal on a piece of metal of any shape, it can be used as a corrosion protection. We would like to use graphene as a corrosion protection on uranium, thorium and other metals. Different metals allow for different mechanisms of graphene growth. We will investigate a possibility of graphene growth on uranium, thorium and other metals, the mechanisms of such growth and will optimise the process. Growth on Tantalum will first be investigated. The student will get familiar with the basic methods of graphene characterisation (AFM, SEM, Raman, etc). and develop new methods to characterise graphene on uranium.

Planned secondment: CERN – M25-35 The growth of graphene on radioactive metals such as uranium and thorium, for the production of yet inaccessible isotopes by mass separation, such as $^{99}$Molybdenum, will be undertaken at CERN.

UMan

? Marina Nazarova

## 5

| ESR5 | JOGU | PhD : Y | Start : Month 4 | Duration 36 months | D1.3 (WP1) |
|---|---|---|---|---|---|

Remotely operated Laser Ion Source for radiolanthanide purification at medical cyclotrons

Objectives: efficient mono-isobaric ion beam production via elemental selective laser ionization

Expected Results: Each chemical element needs a defined 2 or 3 –steps laser ionization scheme. Terbium, Lutetium and Erbium isotopes will first be considered, using solid-state diode lasers that are better suited for remote operation. The ion source cavity (length, material, temperature) at the mass separator will afterward be developed to increase the ionization efficiencies. Finally a fully automated control software and monitoring will be implemented fo foresee its transfer at a medical cyclotron.

Planned secondment: HUG M34-39: setting up and test of atomic vapour cell-laser system at HUG cyclotron

JOGU

## 7

| ESR7 | C2TN | PhD : Y | Start : Month 4 | Duration 36 months | D1.2 (WP1) |
|---|---|---|---|---|---|

Uranium Carbide nanofibers targets for increased stability and extraction yield of alpha-emitting radioisotopes

Objectives: Improve the release properties, hence the yield efficiency, of the classical uranium carbide targets, by changing the method of production and the final microstructure.

Expected Results: Nanofibers are expected to improve both the stability of the target materials and isotope release properties of key radioisotopes, such as heavy alpha emitters such as 211At, 212Bi, and eventually some volatile radiolanthanides. The nanofibers will be produced by electrospinning, changing the precursors, the spinning conditions. The final material will be characterized with XRD, SEM, BET, etc.

Planned secondment: ARRONAX M19-21 : design of a 47Sc production target for cyclotron; AAA : M36-38 : test production of 47Sc at industrial cyclotron units

C2TN

## 10

| ESR10 | PAX | PhD : Y | Start : Month 4 | Duration 36 months | D1.4 (WP1) |
|---|---|---|---|---|---|

New shielded packaging container for nuclear medicine isotopes

Objective: To obtain a new technology type B certified shipping container.

Expected Results: The typical isotopes ($^{149,152,155,161}$Tb, $^{177}$Lu, $^{47,48,49}$Sc, etc) and activities for shipment will first be defined. The European shipping regulations will then be studied in details. First dimensioning of the required shielding, mechanical resistance with be done by Monte-Carlo simulations and by Finite Element Model Mechanical codes. A first prototype will be constructed and checked for effective shielding capacity, leak tightness, shock resistance, etc. A second packaging will be constructed, learning from the prototype, and documentation will be filed to obtain its homologation. Specific innovations, such as direct transfer of the collected isotopes from the separator into the packaging are foreseen.

Planned secondment: ILL-M12-14 Dr. U. Koester, validation of principle ; CERN, Dr J Vollaire (Radioprotection) M28-30 Monte-Carlo simulations .

LPAX

# ESR 2: Production and Safety aspects of theranostics $^{149/152}Tb$ at CERN-MEDICIS and shipping

**Name:** Nhât-Tân VUONG
**Nationality:** Switzerland
**Start date:** 04. Jan. 2016

## Main Objectives:

- **Radiochemical purification of isotopes after mass separation**

  **Objective**: To define the proper operational conditions and safety boundaries for the production and shipping of radioisotopes from radioactive ion beams.

  - Specification & purchase of radiochemical purification modules and product analysis.
  - Implementation of chemical purification process at CERN MEDICIS-PROMED facility including safety aspects.
  - Optimization: Improvement of product yield and product quality.
  - Conditioning of final product before shipping.

- **Development of Irradiated Uranium Carbide Oxidation Process**

  **Objective**: To develop an oxidation process for the long term storage of irradiated uranium carbide target material.

  - Development and optimization of oxidation process under safe conditions.
  - Definition of safety boundaries, product quality, and procedures.
  - Specification and purchasing of equipment for product oxidation and product analysis.
  - Implementation of oxidation module in CERN MEDICIS-PROMED Hot-Cell.

# ESR5

# Remotely operated Laser Ion Source for radiolanthanide purification at medical cyclotrons

| | | | |
|---|---|---|---|
| **Name:** | Vadim Gadelshin | **Supervisor:** | Prof. Dr. Klaus Wendt |
| **Nationality:** | Russian Federation | **Affiliation:** | JGU Mainz |
| **Start date:** | 11.01.2016 | **Progress:** | 2,78% |

**Overall mission:** Design and test of new mass separator components to produce new medical isotopes

## New mass separator designs and components:

- Preparation of **Lu**, **Tb** and **Er** isotope production, initially requested for the MEDICIS project;
- identification of a suitable laser ionization scheme for each element;
- specific development & refinement of the laser ion source unit at the RISIKO mass separator.

## Testing and implementation of new components:

- Characterization & application of the JOGU **Ti:Sa**pphire laser systems for lanthanides;
- optimization of the laser ionization efficiencies under conditions of the MEDICIS separator, e.g. at new ISOLDE off-line separator;
- demonstration of highly selective laser ionization and ion beam purity in Luthetium isotopes.

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# ESR 7

- Recruited (contract started 1st of January, 2016);
- Name: Sanjib Chowdhury;
- National from India.

## Progress of the work

- La precursors were prepared;
- Problems on the La precursors solubility;
- Was started the preparation of Y precursors.

# ESR 10 presentation

Project in collaboration with Lemer Pax and GIP Arronax.

Starting date: 20 October 2015
Name of the ESR Student: Maddalena MAIETTA
Nationality: Italian

**Main objectives**:

1) Design of a Type B certified shipping container dedicated to transport of radioactive isotopes produced at the CERN-MEDICIS facility to other Institutes or Clinics;

2) To be defined is the participation to the MEDICIS collection chamber design;

3) Work on mass separation process for new isotopes production to use in nuclear medicine.

# Work done in the first three months

- Identification of the typical isotopes used in nuclear medicine research.

Constraints on half-life, branching ratio and emitted gamma energies,
helped to reduce the number of suitable isotopes.
This list integrates the one furnished by the MEDICIS Collaboration.

- For each isotope, it has been determined:
  - The decay type and the main usage;
  - The transportable activity limits (in both Type A and B container) required by International Regulations (AIEA).
  - With the limit of 1 GBq, the container type to use (only α emitters need Type B container).

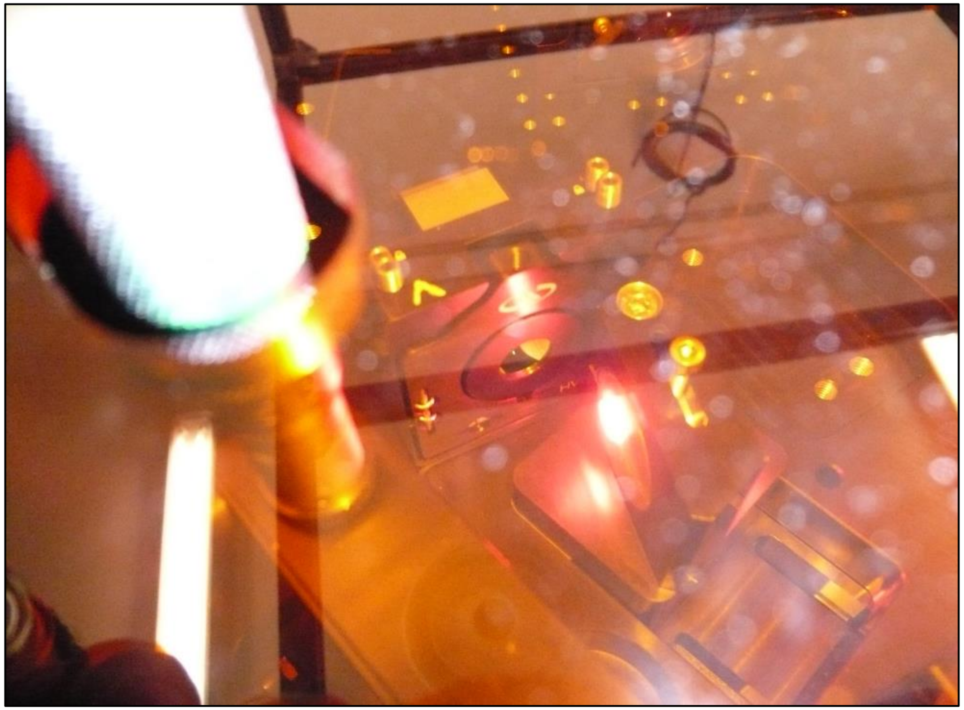
- Study of the interface in between collection chamber and shipping container:
  - The configuration proposed by T.E. Cocolios and A.Brown is our starting point;
  - A list of issues and questions (on safety rules, future irradiation targets, dimensions constraints) has been drawn up. It will be soon diffused to the different research groups.

- MCNPX simulations of beta decay isotopes sources enclosed in simple geometries.

# Summary and Outlook for the Project at 02/16

JG|U

- WP 1 activities for MEDICIS – have already or are just starting
- ESRs will conduct research activities according to programme and hopefully time schedule
- Secondment and training will be provided according to schedule



**Thank you for your attention...**