Laser **I**onisation and **S**pectroscopy of **A**ctinides

Overview of the innovative training network

Bruce Marsh, CERN

ISOLDE Workshop and User Meeting - 5th December 2019

Marie Skłodowska-Curie Actions

"YOU CANNOT HOPE TO BUILD A BETTER WORLD WITHOUT IMPROVING THE INDIVIDUALS."

MARIE SKŁODOWSKA-CURIE

Marie Skłodowska-Curie Actions

The Innovative Training Networks

“Aim to train a new generation of creative, entrepreneurial and innovative early-stage researchers, able to face current and future challenges and to convert knowledge and ideas into products and services for economic and social benefit.”

JRA4 – RESIST RESonance Ionization techniques for SeparaTors

iain.d.moore@jyu.fi, valentin.fedosseev@cern.ch

8 participants

RESIST aimed to refine the highly successful Resonance Ionization Laser Ion Source (RILIS), the In-Gas Laser Ionization and Spectroscopy (IGLIS) and Laser Ion Source Trap (LIST) technologies. The goal was to provide RIBs of the **highest purity** for both ISOL and In-Flight facilities. The JRA **proceeds according to plan**, with **milestones achieved ahead of time**. ***Articles** have been published within the ENSAR2 period by individual participants and further are planned combining several RESIST institutes. **Innovation** links have been provided to NUPIA (Nuclear Physics InnovAtion). **No deviations have occurred from the proposed plan.**

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ENSAR-NEXT – LIONESS (and to LISA)

LIONESS (Lasers, IOns and Nuclei for Environmental Science and Society) was a proposed JRA focused on the development of **state-of-the-art laser-based techniques** and their application in **environmental-based science** in the **actinide and lanthanide elements**. These activities will strengthen the links between basic radioactive ion beam research and societal applications at the Transnational Access Facilities, and beyond. 9 scientific partners, 5 tasks.

Marie Skłodowska-Curie Actions

Laser **I**onisation and **S**pectroscopy of **A**ctinides

- **CERN**-hosted Marie-Curie ITN
- **12** beneficiaries
- **13** partner organisations
- **15** Early Stage Researchers (PhD positions)
- Starting in **November 2019**
- Duration of **48** Months

LISA ITN Kick-off Meeting

Monday 2 Dec 2019, 10:00 → 22:00 Europe/Zurich

513/1-024 (CERN)

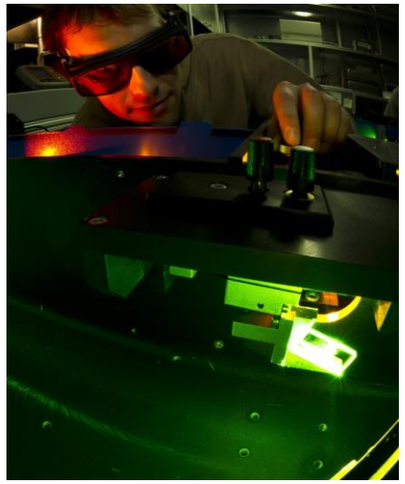
Bruce Marsh (CERN) , Thomas Elias Cocolios (KU Leuven - IKS)

https://indico.cern.ch/event/851894/

Description Launch of the Marie-Curie Innovative Training Network: Laser Ionization and Spectroscopy of Actinides (LISA)

Training Office

Thomas E Cocolios
Training Officer
KU Leuven



Bruce A Marsh
Network Coordinator
CERN

Isabelle M Fontaine
Project Officer
CERN

Franck Rigolet
Industrial Rep
IREPA Laser

TBD
Communication

Changing every year
2. MSquared
3. Hubner Photonics
4. Pantechnik

Prepare the community for the operation and use of the next generation of ISOL facilities that are on the horizon. Contribute to the future-proofing of nuclear and atomic physics expertise.

NUPECC Long range plan Recommendations:

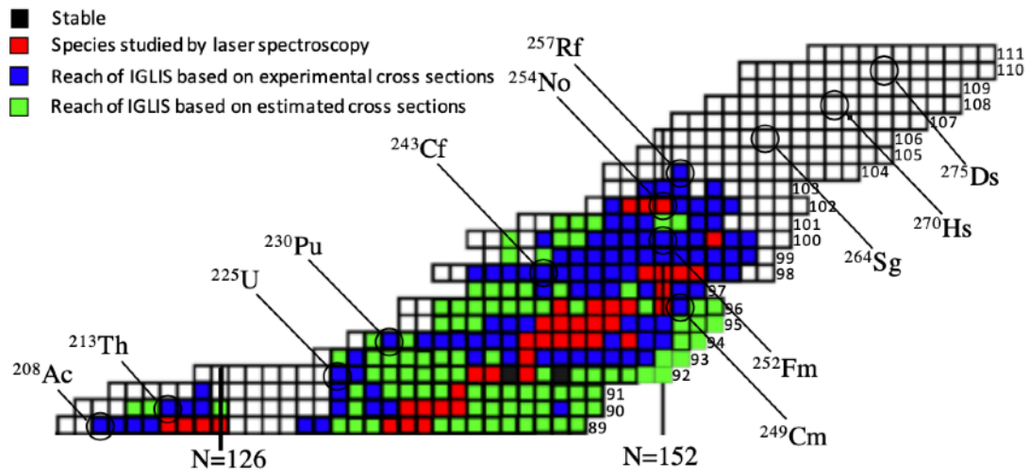
"*Exploitation of European Facilities for the training of the next generation nuclear scientists*
Preference for inter-sectorial aspects and exploitation of nuclear applications"

Research objectives

What?

Increase our understanding of the atomic and nuclear properties of the chemical elements known as the actinides

What are the limits of stability and what is the heaviest element?
How does nuclear structure evolve across the nuclear landscape?



Why?

- Effective production, identification and handling of these elements
- Exploiting the potential for practical applications of the actinides in the fields of medical physics, nuclear applications and environmental monitoring
- Prerequisite for unravelling the structure of the superheavy elements

Who?

World-leading experts in radioactive ion beam research and applications, laser spectroscopy, scientific laser technologies (industrial partners) and nuclear and atomic theorists

How?

4 Scientific Work Packages

- Novel techniques and technologies
- Medical & societal benefits
- Actinide atomic structure
- Exploring the limits of nuclear existence

Research objectives

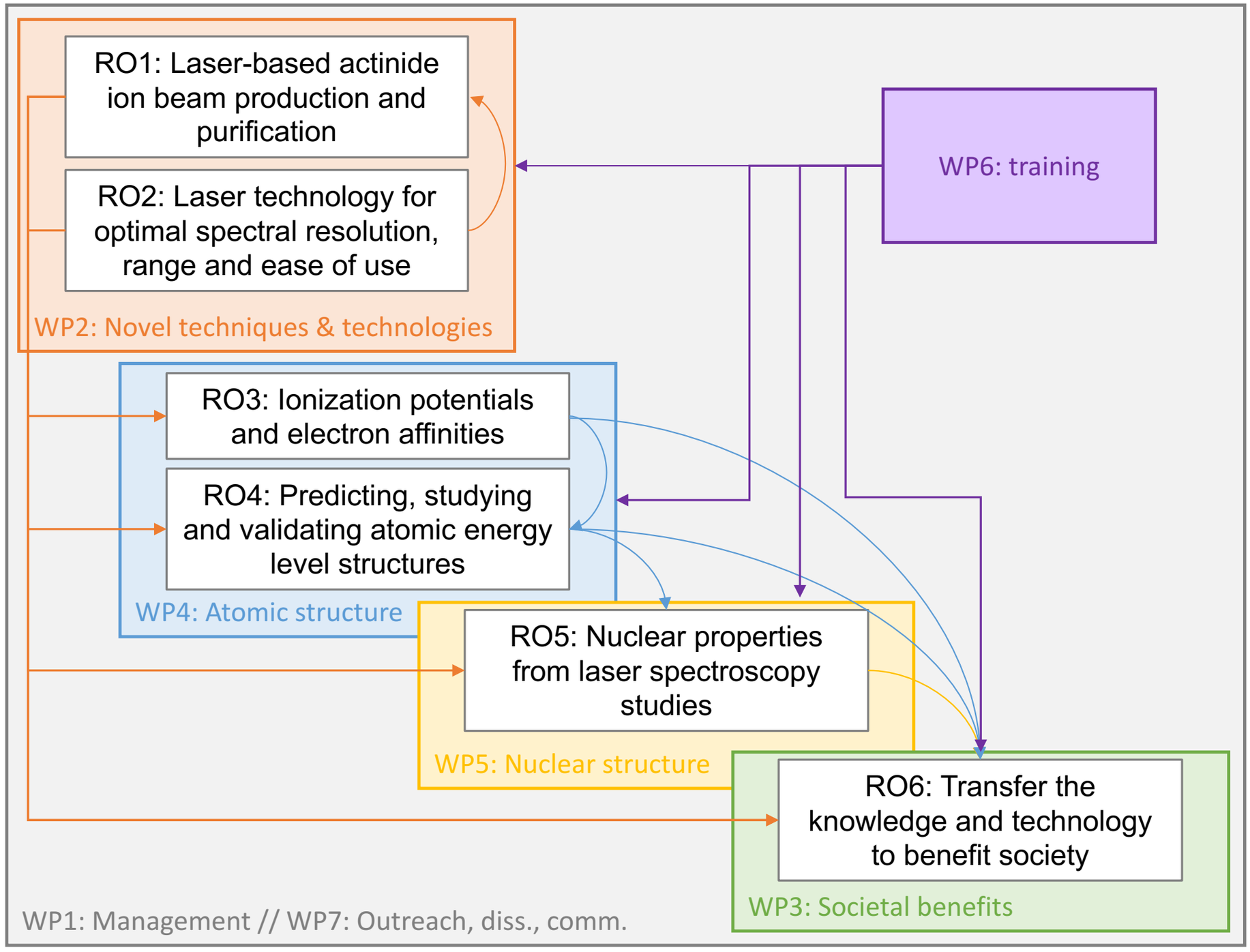
WP Leaders:

CERN

JG|U

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

KU LEUVEN



IISA Beneficiaries + Partners

UNIVERSITY OF GOTHENBURG

university of groningen

PANTECHNIK Boost Your Physics

ANGARA TECHNOLOGY

GANIL spiral2 laboratoire commun CEA/DRF CNRS/IN2P3

ISOLDE

iER

UNIWERSYTET JAGIELLOŃSKI W KRAKOWIE

MANCHESTER 1824 The University of Manchester

JG|U

HÜBNER

Leibniz Universität Hannover

Stable Laser Systems

LARISSA

IRÉPA LASER

TRIUMF

M SQUARED

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

NAGOYA UNIVERSITY

UNSW AUSTRALIA

GSI

KU LEUVEN

TEL AVIV UNIVERSITY

Lawrence Livermore National Laboratory

JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

HOPTEC

The 15 Researchers

ESR #	Recruiting Participant	PhD awarding entity / Doctoral School	Start	Duration
1	KUL	KUL Arenberg Doctoral School	M6	36M
2	CERN	JGU Institute of Physics	M6	36M
3	CERN	JGU Institute of Physics	M6	36M
4	JYU	JYU Doctoral School of the Faculty of Mathematics & Science	M6	36M
5	JGU	JGU Institute of Physics	M6	36M
6	UGOT	UGOT Department of Physics	M6	36M
7	KUL	KUL Arenberg Doctoral School	M6	36M
8	GANIL	Université de Caen PSIME Doctoral School	M6	36M
9	MSL	UNIMAN School of Physics & Astronomy	M6	36M
10	GSI	JGU Department of Chemistry	M6	36M
11	JGU	JGU Department of Chemistry	M6	36M
12	LUH IRS	LUH IRS Faculty of Mathematics & Physics	M6	36M
13	FSU	FSU & Helmholtz-Institute Graduate School	M6	36M
14	RUG	RUG Graduate School of Science & Engineering	M6	36M
15	HUB	JGU Institute of Physics	M6	36M

The ESR Projects

1. Optimized production of 225Ac by the ISOL method for medical applications
2. Development of high-resolution in-source hot-cavity RILIS methods for actinides
3. Target developments for extraction of actinides from thick ISOL targets followed by laser-induced molecular break-up and/or ionization
4. High-resolution laser spectroscopy of actinide elements for nuclear structure
5. Laser spectroscopic investigations on the actinide atomic and nuclear structures
6. Electron affinity measurements by collinear laser photodetachment spectroscopy on negative ions
7. In-gas-jet resonance ionization spectroscopy of actinides
8. In-gas-jet laser spectroscopy optimization for high resolution measurement of actinides
9. Development of low-noise, high-power, tuneable, pulsed, narrow-linewidth Ti:Sa amplifier for ion beam spectroscopy applications
10. Laser spectroscopy of the heaviest actinides, in particular Lr to study atomic and nuclear properties
11. Tailor-made optimized actinide target preparation and characterization for LISA
12. Multi-element ultra-trace detection of radionuclides in environmental samples
13. Developing atomic structure calculations for heavy and superheavy atoms and ions
14. Relativistic coupled cluster (CC) and configuration interaction (CI) investigations of properties of heavy and superheavy elements
15. C-Wave laser development as a turn-key solid-state alternative to CW dye laser.

Laser Development

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Laser spectroscopy

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New techniques and production methods

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Atomic and nuclear theory

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Practical applications

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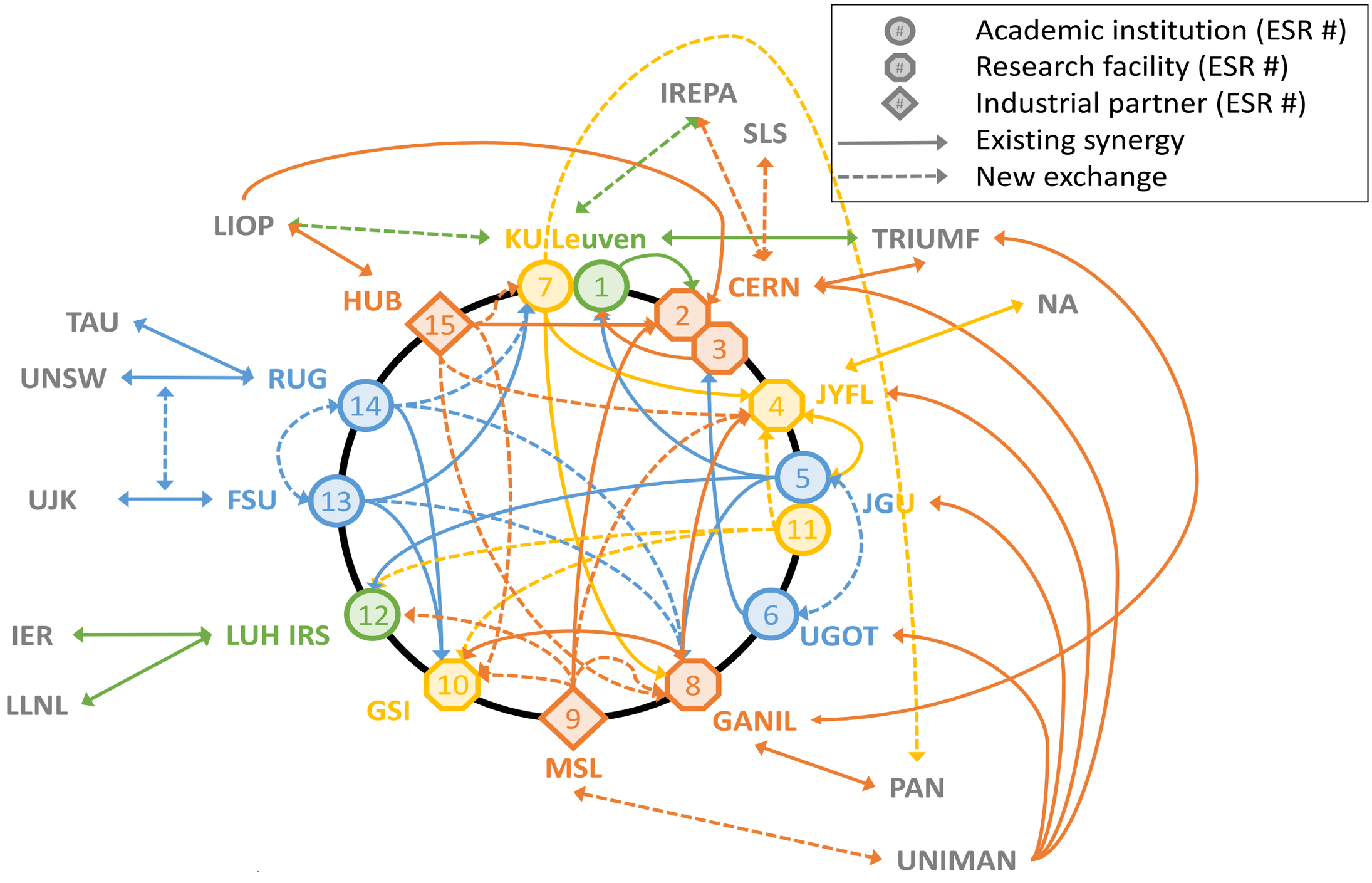
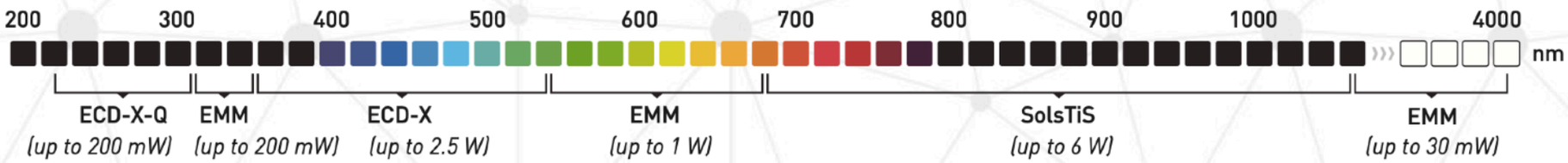
The beneficiaries and partners



Industrial participation for state of the art laser development

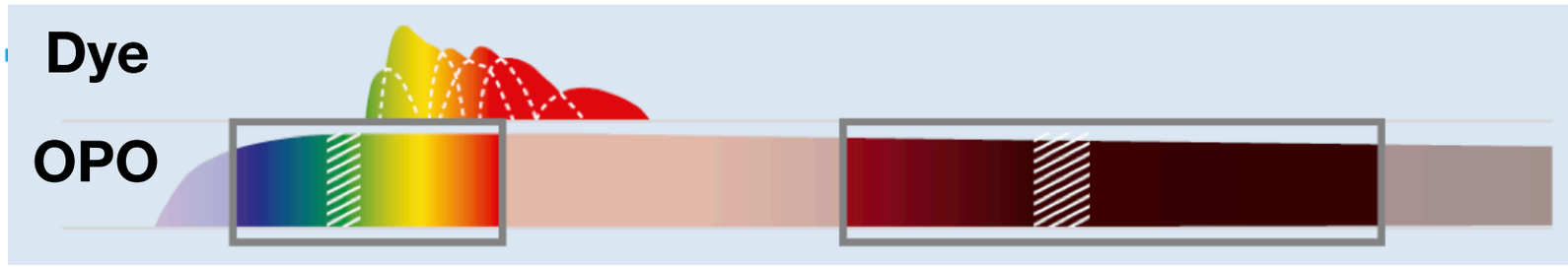
ADVANCED RESEARCH PLATFORMS

SOLSTIS
MODULAR DESIGN
210 nm - 4 µm



C-WAVE | THE TUNABLE CW LASER LIGHT SOURCE

Tunable frequency-converted cw optical parametric oscillatior (OPO)



LISA-ITN | ESR (#15) PROJECT

Development of a solid-state tunable CW laser based on HUB's existing C-WAVE concept with **customized linewidth options** and **enhanced output power levels**, optimized for actinide research.

M7-M12
- Comparison and investigation of different linewidth customization concepts for tunable CW lasers

M13-M18
- Production & validation of customized linewidth OPO prototype

M19-M24
- Investigation of cavity designs for enhanced power levels

M25
- Test C-WAVE system with pulsed dye amplifier by Liop-Tec
  (Dr. Jürgen Lindener-Roenneke, Liop-Tec GmbH)

M26-31
- Production & validation of a high power OPO prototype with customized linewidth option

M32-38
- Implementation and validation of the outcomes at the CERN-ISOLDE facility
  (Bruce A. Marsh, CERN)

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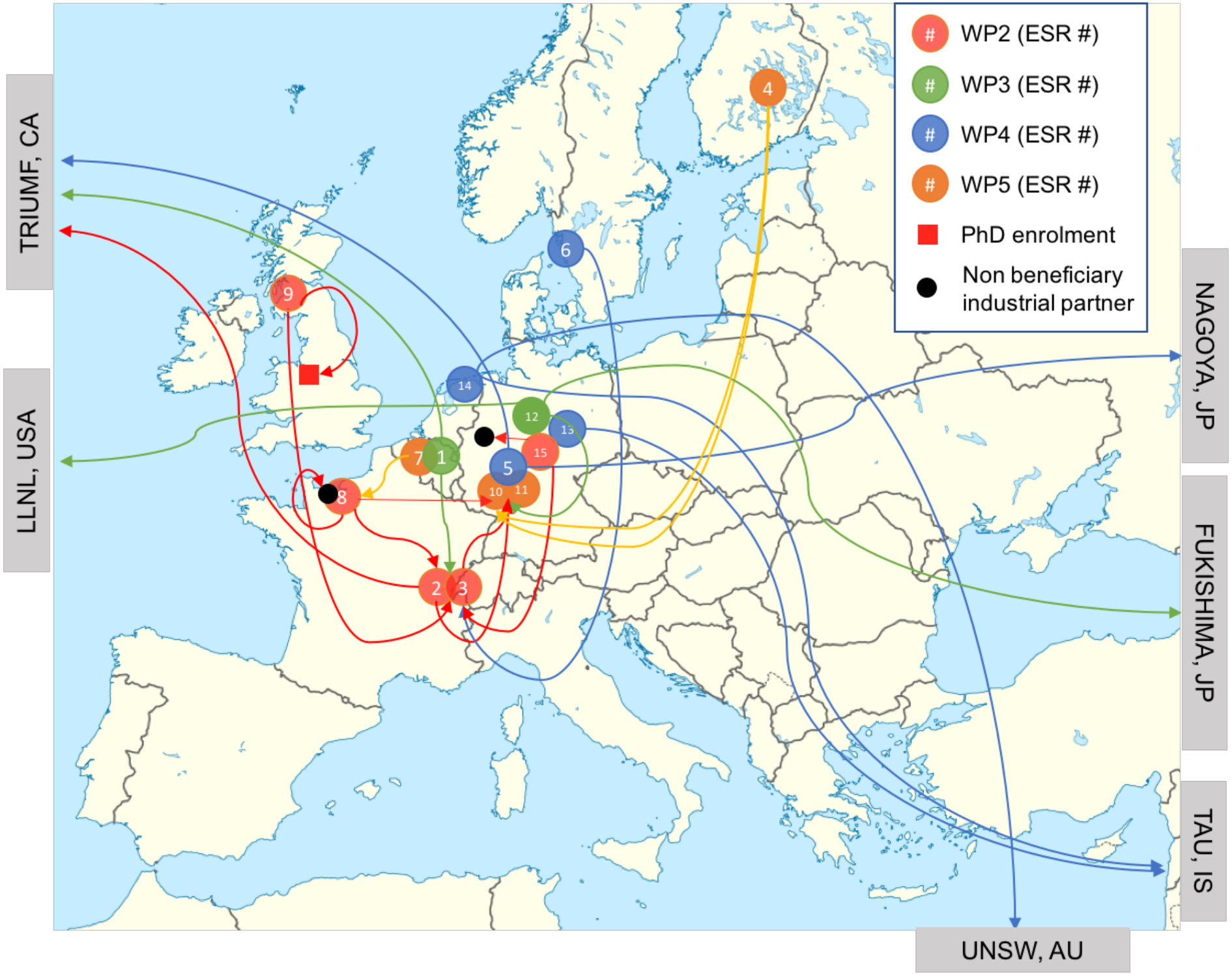
Secondments



Research interplay example

Address the lack of fundamental nuclear structure data in the actinide region

Theory

university of groningen

TEL AVIV UNIVERSITY

UNIWERSYTET JAGIELLOŃSKI W KRAKOWIE

Lawrence Livermore National Laboratory

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

Experiment

GANIL laboratoire commun CEA/DRF — spiral2 — CNRS/IN2P3

JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

GSI

ISOLDE

TRIUMF

Laser technologies

LARISSA

HÜBNER

Introduce and adapt the Hubner 'C-Wave' laser to improve the spectral coverage

M SQUARED

Develop the pulse-amplified Ti:Sapphire laser into a **commercial-grade product**

MANCHESTER 1824 The University of Manchester

LOPTEC

NAGOYA UNIVERSITY

New techniques

JG|U

KU LEUVEN

ISOLDE

Applications

KU LEUVEN

iER

Leibniz Universität Hannover

Research interplay example

Address the lack of fundamental nuclear structure data in the actinide region
Probe Octopole deformation in Th and U

direct impact on the validation and further development of atomic and nuclear models

High resolution laser spectroscopy of actinides

Introduce and adapt the Hubner 'C-Wave' laser to improve the spectral coverage

Develop the pulse-amplified Ti:Sapphire laser into a **commercial-grade product**

Actinide target preparation

Gas jet spectroscopy development

High resolution In-source RIS

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Recruitment starts next week!

https://lisa-itn.web.cern.ch

(coming soon)