ISOLDE GUI Meeting

03 June 2019

RILIS LS2 activities and upgrades

Bruce Marsh, *CERN EN-STI-LP*

EN Engineering Department

RILIS in 2018

- **14** elements:
  - **In, Sc, Mg, Cu, Dy, Bi, Sn, Be, Mn, Mg, Sb, Hg, Tl, Ac, Al**.
- **21** separate on-line runs (not including target-ion-source development time).
- **3** elements for new neutron-converter tests over 2 days:
  - **Ga, In, Zn**.
- **60 %** of ISOLDE shifts in 2018, **>2000 h** operation.

GPS schedule 2018

	April				May				June					July					August				September				October				November	
WK	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
MO	9	16	#534/567 Sn VDS 23	30	7	MD: FTS 14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	IS629 3	#641 UC Ta 10	17	24	1	8	#633Th 15	22	#638 UC W 29	5	p⁺ off 0600 12
TU		TISD		May-01	EC-Ol	MD:FTS			IS610	ISBM	Tech Stop	Medical isotopes	#659 UC VD7		#665 53Mn						IS629: 11Be @ 7MeV/u (IS655) XT03	IS634 EC-Ol		Tech stop	#619 Pb VD5				#534 Sn VD5			Prep for winter
WE		TISD		#599 Ti foils	IS634					²²Mg to LA1	#655 Ta - W	IS528 IS638												(IS655) (IS604)	IS585							
TH	#513/ #650		IS611 IS640 IS647 IS652 IS653		Ascension													#650/513 MWCNT	XT03 IS616: 4.5MeV/u	#635 UC Ta		Jeune	IS576 IS578 IS630 IS648 IS653		IS602			Gandalph Negative run: IS615				Physics
FR					#653 UC - Ta n				#634 LIST						#632 ThC VD7										IS638					XT03	(IS655)	(separate file)
SA		IS633					IS622			IS614	IS528			IS644 (LOI205)	IS644: 4.8MeV/u (IS506)		IS552: 4.1MeV/u								IS640					IS561 9Li @ 7.5MeV/u	LOI198		
SU																															IS637	
		8B: IDS	111Cd		RILIS: Mg		RILIS: Cu		RILIS: In	RILIS: Mg	RILIS: Dy (night-time)	RILIS: Dy		96Kr / 212Rn			22x Rn		8B		RILIS: Be	RILIS: Be	RILIS: Mn		199Hg		RILIS: Hg	RILIS: At MD on HIE	111Cd		RILIS: Ac	(GLM/GHM/LA 1)

HRS schedule 2018

	April				May				June					July					August				September				October				November	
WK	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
MO	9	16	23	#651 ZrO HP 30	#652 ZrO HP 7	#618 UC - Ta/W 14	21	28	4	11	18	25	#658 UC Ta (+CF4) 2	9	16	23	30	6	13	20	27	3	10	17	24	#662 UC n 1	IS638 8	15	22	#642 UC n(ew)-conv	TISD 5	p⁺ off 0600 12
TU				May-01					#626 Ta - W	TBC	Tech Stop													Tech stop				(tbc) UC		TISD	TISD	Prep for winter
WE				TISD								Machine development			637 UC W (+CF4								IS654							#672 CaO VD7	
TH		#627 Ta - W			Ascension		#654 UC - W				Machine development					IS552 IS553: 4.1MeV/u	#631 LaC Ta	IS562: 4.4MeV/u	#639 LaC Ta			Jeune					tuning IDS	IS645		Physics
FR													IS650 IS637 IS608									134Sn @ 7.33MeV/u	#623 SiC	IS651 28Mg @ 9.5MeV/u	IS621 28Mg@9.5 MeV/u			VITO	IS641		WISArD	(separate file)
SA																																
SU	IS639		IS532	IS623	IS642	IS645		IS620	IS649										IS613		#643 UC + 34S					IS635		(end Sat night)		LOI172	
	In RILIS (#640 LaC - n)		Sc RILIS In RILIS	RILIS test Ge 34S	70Br	26Na		K beams	Sc RILIS				RILIS: Bi			22xRa/142Ba		Sn RILIS	Sn RILIS		134Sn+34S		RILIS: Mg		RILIS: Sb		MD on HIE		RILIS: Tl	RILIS: for TISD	

Highlights - Selectivity

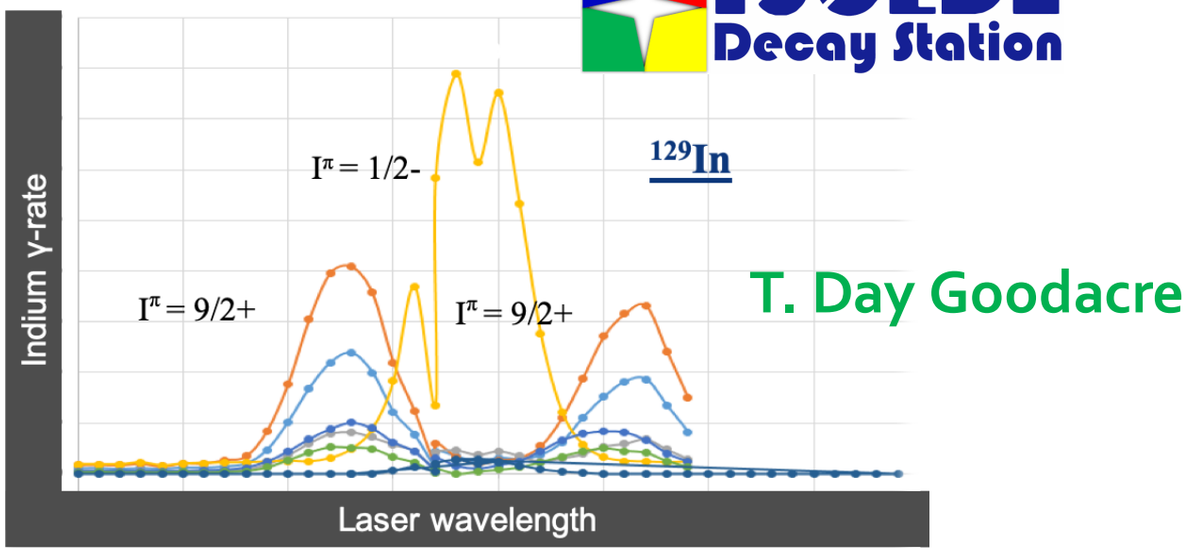
- **Isomer-selective** ionization of neutron-rich **In** isotopes for IDS.
  - First hyperfine-structure scan with ISOLDE Decay Station!
  - Used for future in-source experiments.

Open Access

β decay of ^{133}In: γ emission from neutron-unbound states in ^{133}Sn

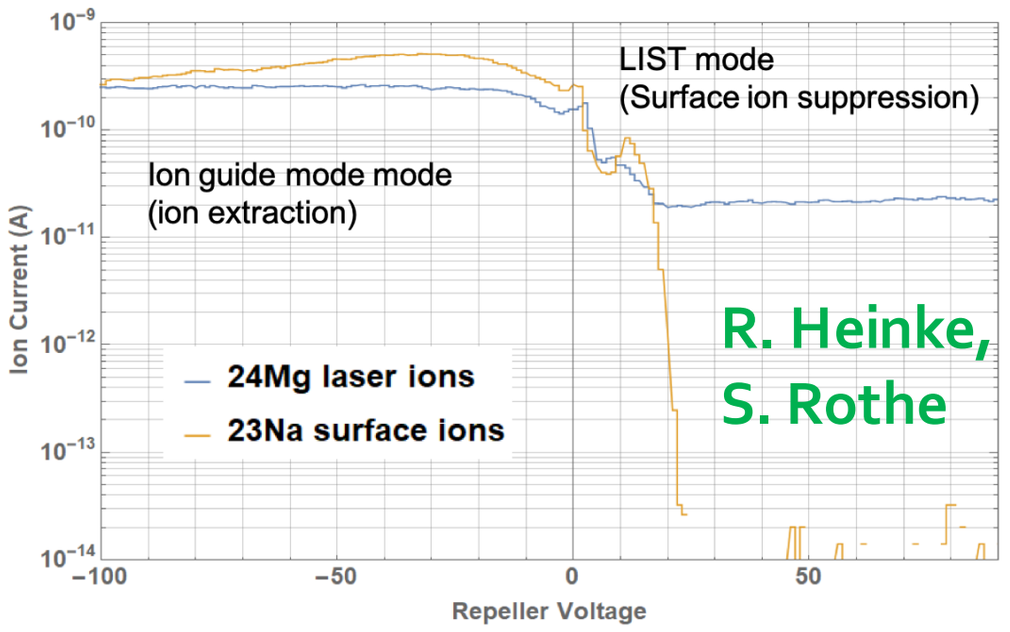
M. Piersa *et al.* (IDS Collaboration)
Phys. Rev. C **99**, 024304 – Published 5 February 2019

ISOLDE Decay Station



T. Day Goodacre

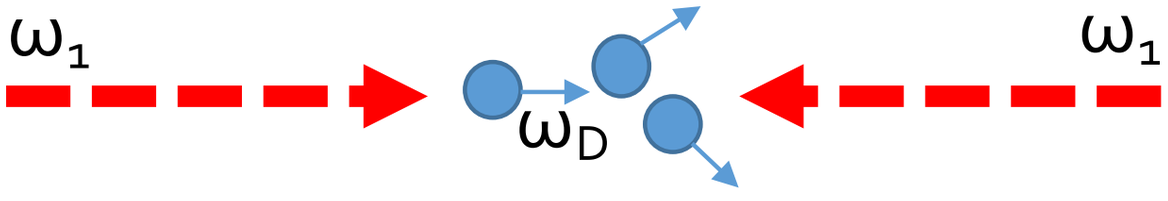
- Suppression of surface-ionized ^{22}**Na** for ^{22}**Mg** experiment using LIST.
  - ^{21}**Na** suppression: **10^6** – No ^{22}**Na** seen by users!
  - ^{22}**Mg** loss factor: **27**.



R. Heinke, S. Rothe

Highlights - Doppler-free 2-photon spectroscopy

$$(\omega_1+\omega_D)+(\omega_1-\omega_D)=2\omega_1$$



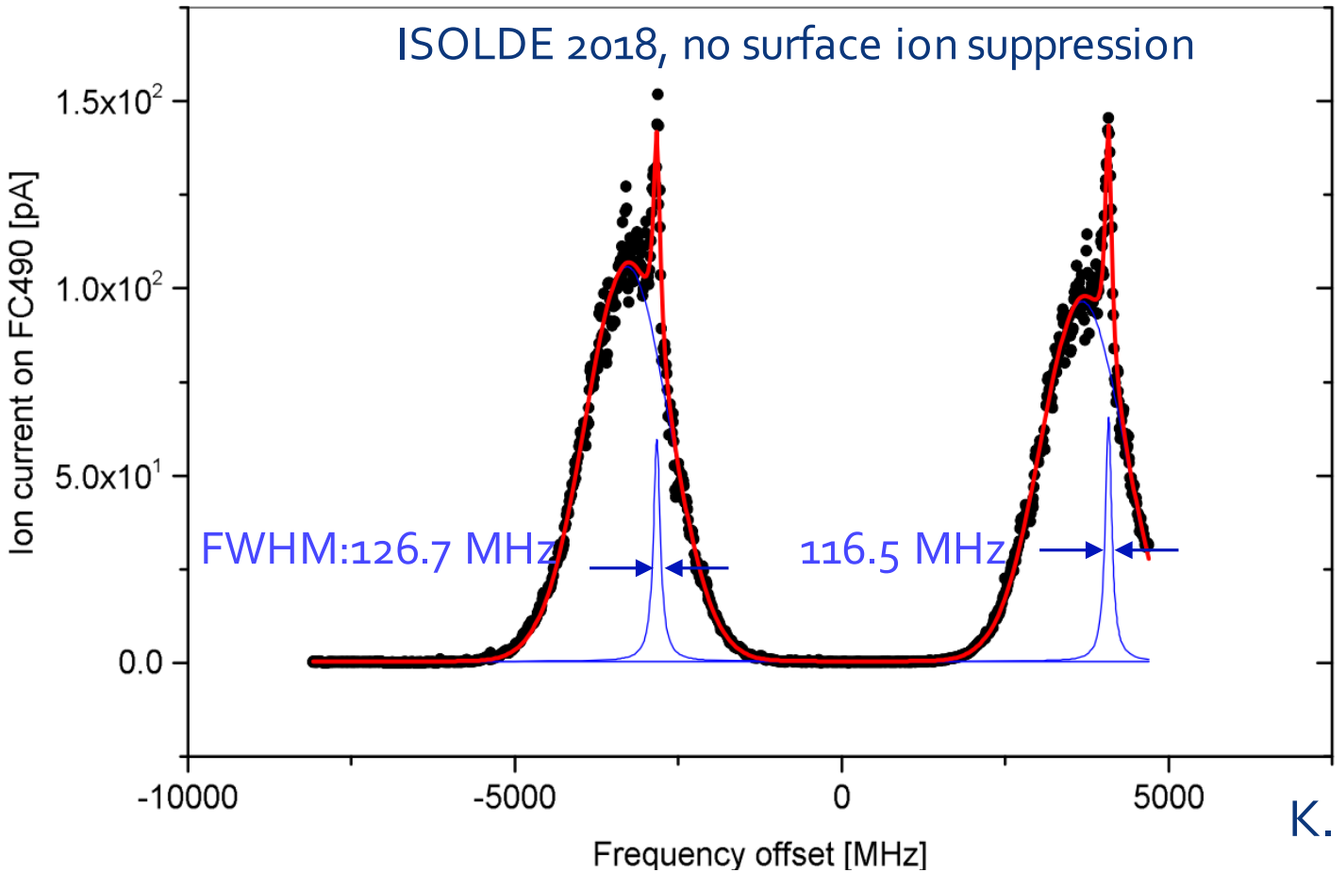
First demonstration of Doppler-free 2-photon in-source laser spectroscopy at the ISOLDE-RILIS

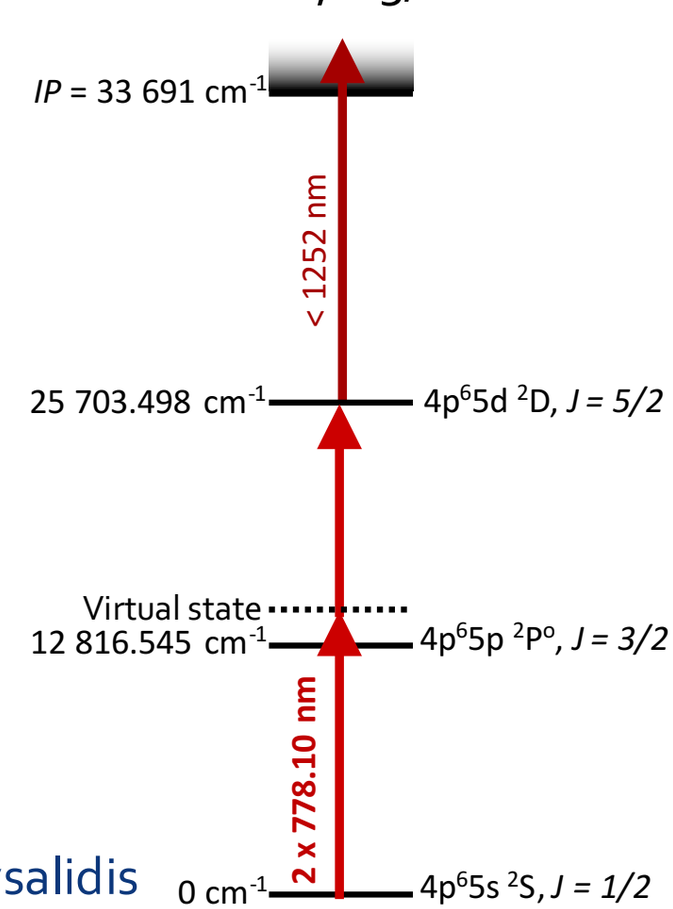
K. Chrysalidis [a, b], S.G. Wilkins [a], R. Heinke [b], A. Koszorus [c], R. De Groote [d], V.N. Fedosseev [a], B. Marsh [a], S. Rothe [a], R. Garcia Ruiz [a], D. Studer [b], A. Vernon [e], K. Wendt [b]

Show more

https://doi.org/10.1016/j.nimb.2019.04.020

- Measurement of 5s-5d transition in 87Rb.
- Published in EMIS proceedings by K. Chrysalidis.
- Optimization of mirror geometry during LS2.





K. Chrysalidis

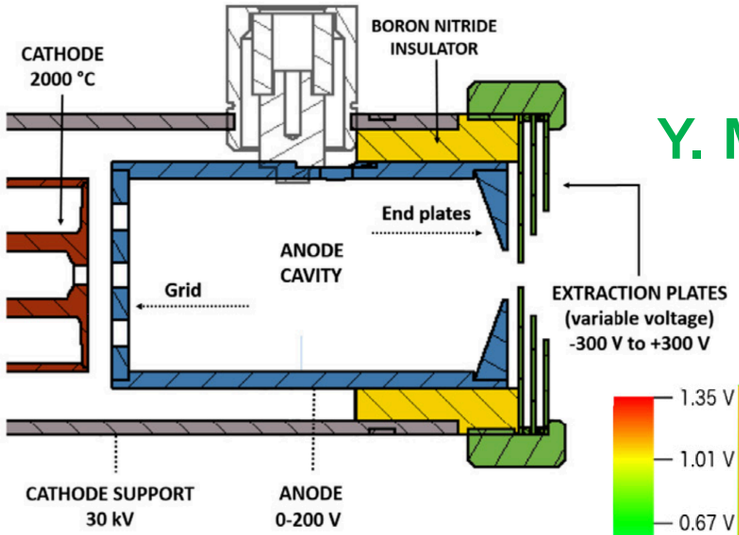
Highlights - VADLIS advancement

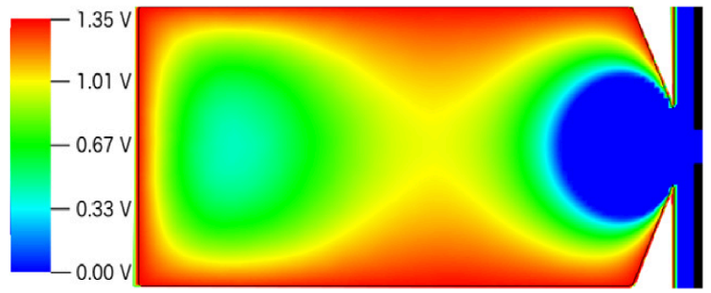
- VSim simulations to optimize extraction of laser ions during RILIS-mode operation.
- New design with variable extraction voltage.
- Improvement in laser-ion extraction demonstrated off-line with **Ga**.
- On-line demonstration with **Mg, Mo, Hg**.
  - **> factor 2** improvement.

Enhancing the extraction of laser-ionized beams from an arc discharge ion source volume

Y. Martinez Palenzuela [a, c], B.A. Marsh [a], J. Ballof [a, b], R. Catherall [a], K. Chrysalidis [a, d], T.E. Cocolios [c], B. Crepieux [a], T. Day Goodacre [a, e, f], V.N. Fedosseev [a], M.H. Huyse [c], P.B. Larmonier [a, g], J.P. Ramos [a], S. Rothe [a], J.D.A. Smith [h], T. Stora [a], P. Van Duppen [c], S. Wilkins [a]

Y. Martinez Palenzuela





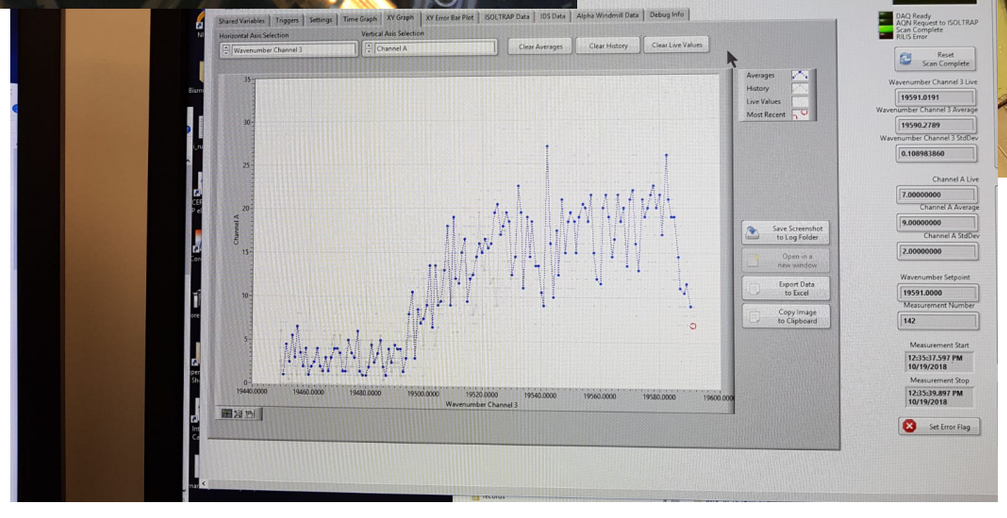
Isotope	Background $V_e = 0$ V	Lasers On $V_e = 0$ V	Lasers On(*) $V_{e\,opt}$	Enhancement factor	Laser scheme (nm)) $\{\lambda_1 \lambda_2 \lambda_3\}$
^{24}Mg	8 pA	8.5 nA	23.5 nA	2.8	{285|553|532} [17]
^{98}Mo	0 pA	13.4 pA	103 pA	7.7	{380|416|635} [21]
^{196}Hg	18 pA	58 pA	133 pA	2.3	{256|313|532} [22]

Highlights - GANDALPH collaboration

- Electron photo-detachment experimental campaigns with GANDALPH in 2016 and 2018.

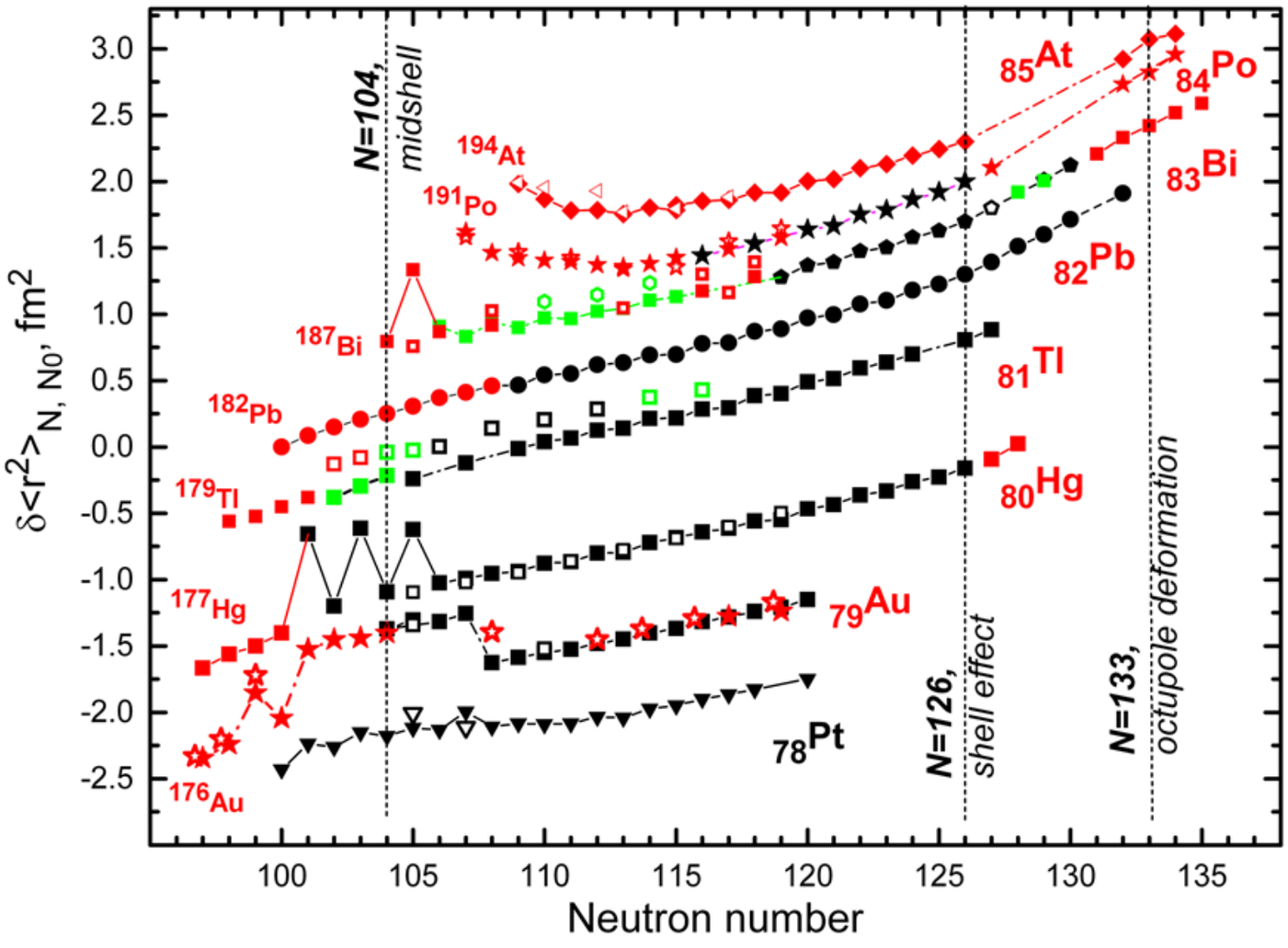
- Laser light from RILIS sent through GANDALPH at GLM beam line.

- Photo-detachment of **I** and **At** achieved!



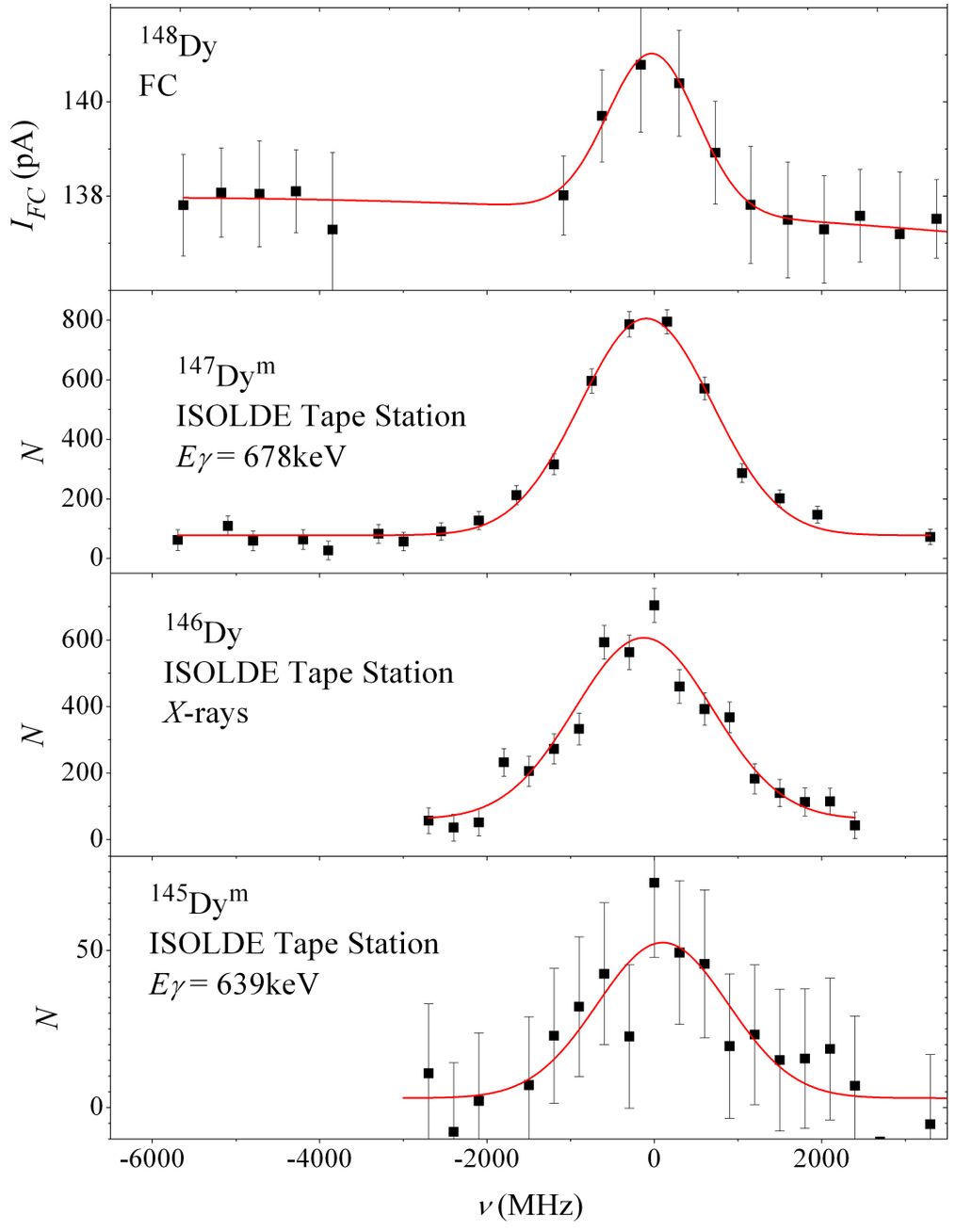
In-source Spectroscopy

- Continuation of the in-source spectroscopy program in the lead region.
- In-source spectroscopy continues to provide measurements at the sensitivity frontier.
  - **2016:** Bismuth.
  - **2017:** Bismuth.
  - **2018:** Bismuth, Dysprosium (**Z=66**).
- New example of shape staggering in **Bi.**
  - Occurs at same neutron number as in **Hg**.
  - **^{187}Bi: 0.02 ions/s**.



In-source Spectroscopy - Dysprosium

- Continuation of IS608 for Bi (Z=83).
- First in-source measurements of Dy (Z=66).
- First on-line use of narrowband intracavity-doubled grating Ti:Sa.
- Motivation: to measure changes in mean-square charge radii below N=82.
- Combination of Faraday cup/tape station scans.



Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

In-source laser spectroscopy of dysprosium isotopes at the ISOLDE-RILIS

K. Chrysalidis[a,b,*], A.E. Barzakh[c], R. Ahmed[d], A.N. Andreyev[e], J. Ballof[a,f], J.G. Cubiss[e], D.V. Fedorov[c], V.N. Fedosseev[a], L.M. Fraile[a,g], R.D. Harding[e], U. Köster[h], B.A. Marsh[a], C. Raison[e], J.P. Ramos[a], R.E. Rossel[a], S. Rothe[a], K. Wendt[b], S.G. Wilkins[a]

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[h] Institut Laue-Langevin, F-38042 Grenoble, France

A. Barzakh

Recent publications

Letter | Published: 01 October 2018

Characterization of the shape-staggering effect in mercury nuclei

B. A. Marsh ✉, T. Day Goodacre, [...] K. Zuber

Nature Physics **14**, 1163–1167 (2018) | Download Citation

Open Access

Charge radii and electromagnetic moments of $^{195-211}$At

J. G. Cubiss *et al.*
Phys. Rev. C **97**, 054327 – Published 29 May 2018

Editors' Suggestion | Open Access

Change in structure between the $I=1/2$ states in ^{181}Tl and ^{177,179}Au

J.G. Cubiss [a, b] ✉, A.E. Barzakh [c], A.N. Andreyev [a, d, b], M. Al Monthery [a], N. Althubiti [e], B. Andel [f], S. Antalic [f], D. Atanasov [g], K. Blaum [g], T.E. Cocolios [h, e, b], T. Day Goodacre [b, e], R.P. de Groote [h], A. de Roubin [g], G.J. Farooq-Smith [e, h], D.V. Fedorov [c], V.N. Fedosseev [b], R. Ferrer [h], D.A. Fink [b, i] ... K. Zuber [t]

In-source laser spectroscopy of dysprosium isotopes at the ISOLDE-RILIS

K. Chrysalidis [a, b] ✉, A.E. Barzakh [c], R. Ahmed [d], A.N. Andreyev [e], J. Ballof [a, f], J.G. Cubiss [e], D.V. Fedorov [c], V.N. Fedosseev [a], L.M. Fraile [a, g], R.D. Harding [e], U. Köster [h], B.A. Marsh [a], C. Raison [e], J.P. Ramos [a], R.E. Rossel [a], S. Rothe [a], K. Wendt [b], S.G. Wilkins [a]

Shape staggering of midshell mercury isotopes from in-source laser spectroscopy compared with density-functional-theory and Monte Carlo shell-model calculations

S. Sels *et al.*
Phys. Rev. C **99**, 044306 – Published 12 April 2019

Open Access

Changes in mean-squared charge radii and magnetic moments of $^{179-184}$Tl measured by in-source laser spectroscopy

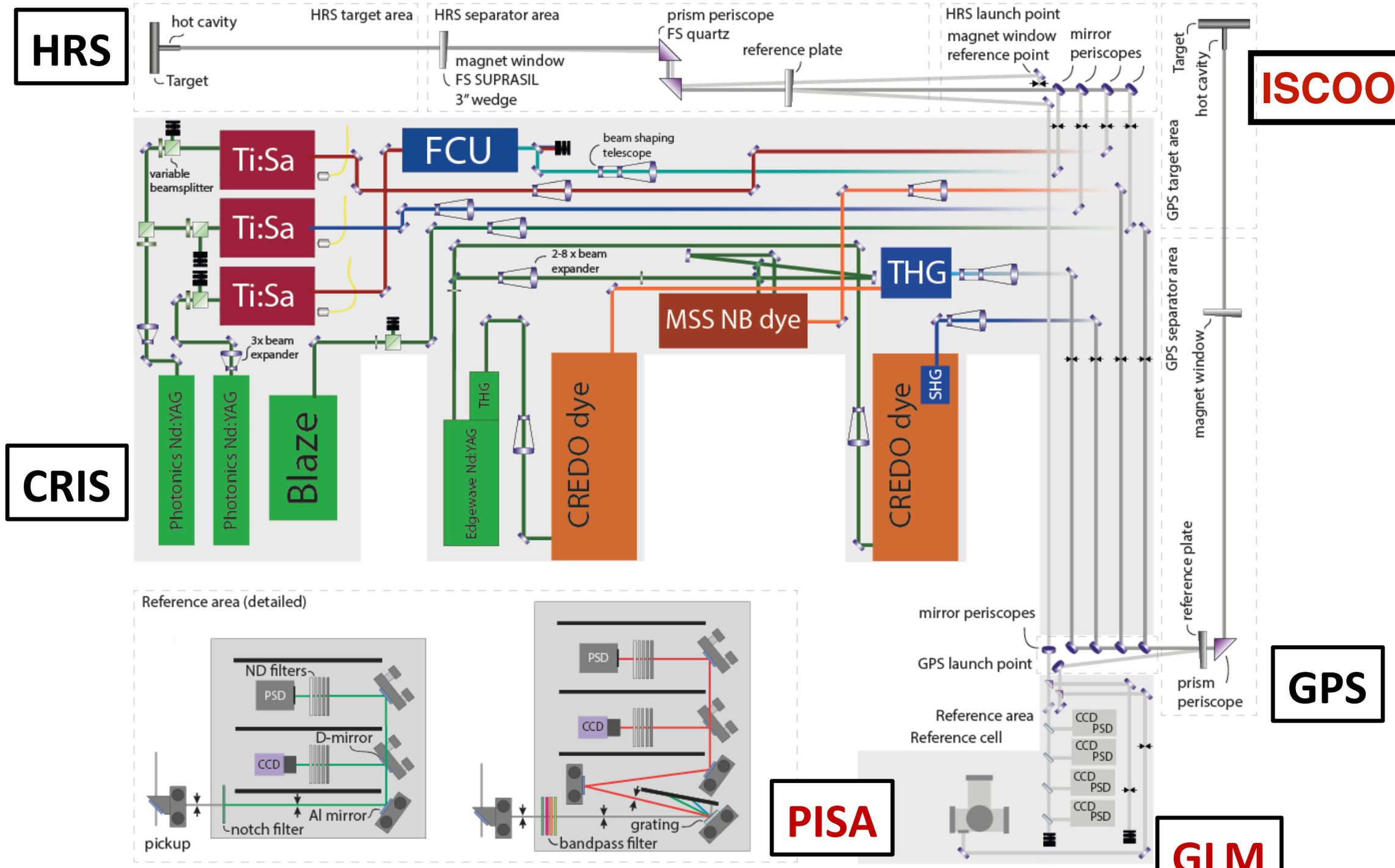
A. E. Barzakh *et al.*
Phys. Rev. C **95**, 014324 – Published 23 January 2017

- Many more papers in the pipeline!

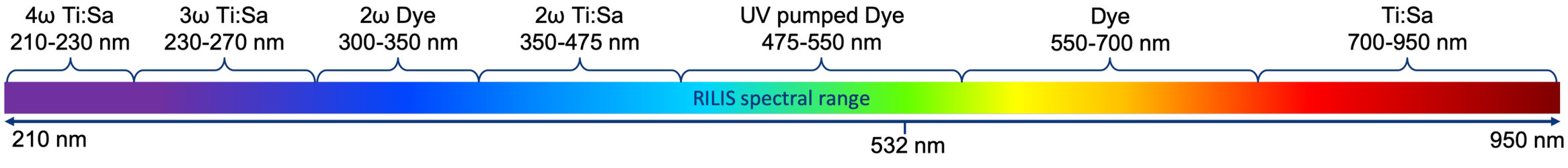
Open Access

Inverse odd-even staggering in nuclear charge radii and possible octupole collectivity in ^{217,218,219}At revealed by in-source laser spectroscopy

A. E. Barzakh *et al.*
Phys. Rev. C **99**, 054317 – Published 14 May 2019



S. Rothe et al. Nuclear Instruments and Methods in Physics Research B 376 (2016) 91–96



Goals for Post-LS2 RILIS

Reliability and availability

- Laser hardware consolidation
- Dual HRS and GPS use

Performance

- Spectral resolution
- Spectral range
- Selectivity

Scope for new developments and ongoing collaboration

- Offline R&D facilities
- RILIS @ MEDICIS

Aims for after LS2

ISBM activities

RILIS activities

MEDICIS

Fully operational RILIS @ OFFLINE 2

Fully operational RILIS @ MEDICIS

New dye lasers @ RILIS

Spare Blaze equivalent laser @ RILIS

Dual beam observation system (GPS and HRS) @ RILIS

Fourier limited linewidth Dye and Ti:Sapphire systems @ RILIS

RAMAN laser at RILIS?

CERN-supported RILIS control/DAQ

LIST operational at HRS and GPS

Modified VADLIS as standard

High-resistance (Sigradur) RILIS cavity

Offline demonstration of ToFLIS

LIST with PI option ?

Feasibility study of laser-induced molecular breakup

New Dye Lasers

LiopStar-HQ - high repetition rate

Investigate the addition of 2 LIOPTEC dye lasers at RILIS

Compact and more ergonomic alternative to Sirah Credo laser

Quieter operation and easier to manipulate dye circulators

Move one Sirah laser to Offline 2 ?

Simultaneous HRS and GPS RILIS

- Upgraded laser beam observation system and stabilisation system

- Re-arrange optical layout with compact telescope systems and additional optics/optomechanics

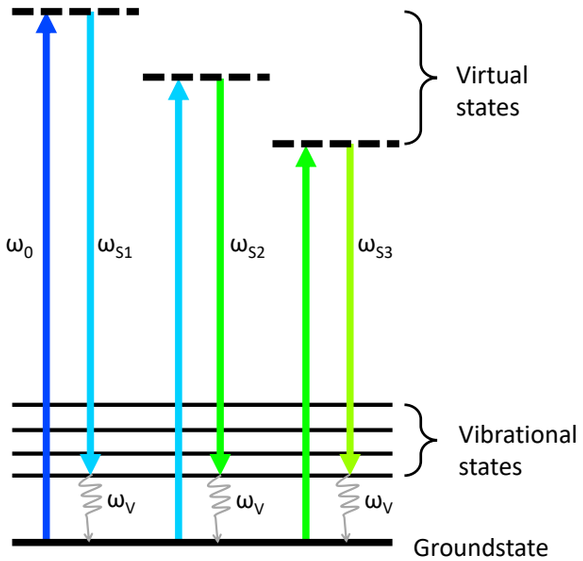
Reduced setup time, faster switching between elements and mass separators

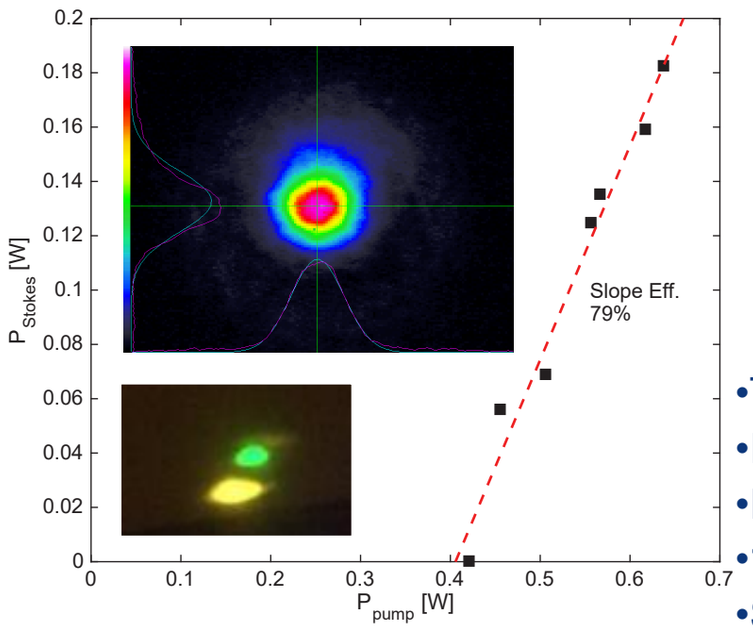
Consolidate RILIS controls and monitoring systems

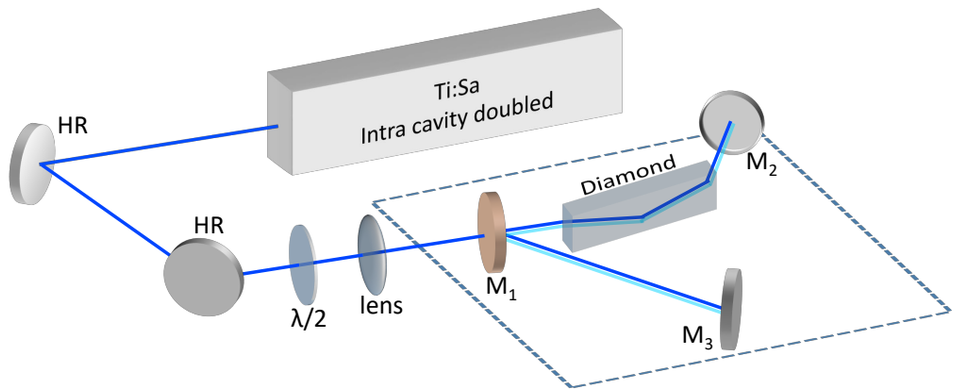
- 50% of EN/SMM PJAS working on this task jointly with development of control system for the off-line mass separator.

Improve long-term maintenance and expandability of RILIS DAQ and controls, and make use of CERN specialist support

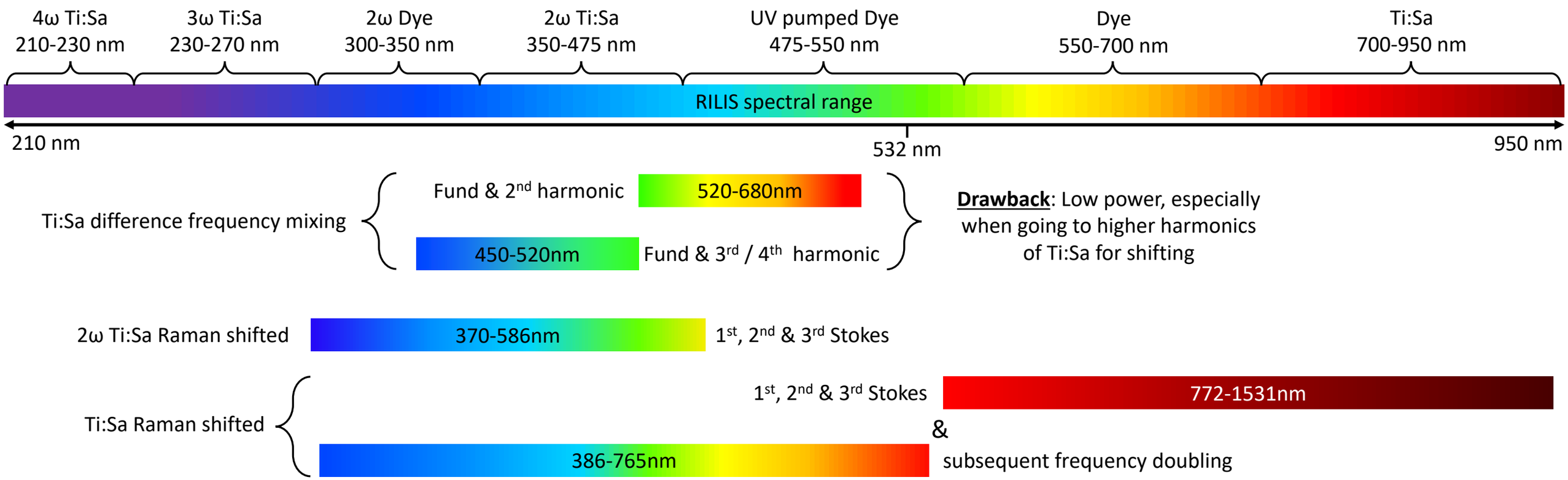
Raman Laser development







- Tunable, broadband output achieved from a compact cavity.
- Results submitted to Optics Letters by **K. Chrysalidis.**
- Funding from Knowledge Transfer obtained for ongoing R&D
- **1** PhD student, **1** technical student.
- Starting **June 2019**.



Pulsed Dye Amplifier

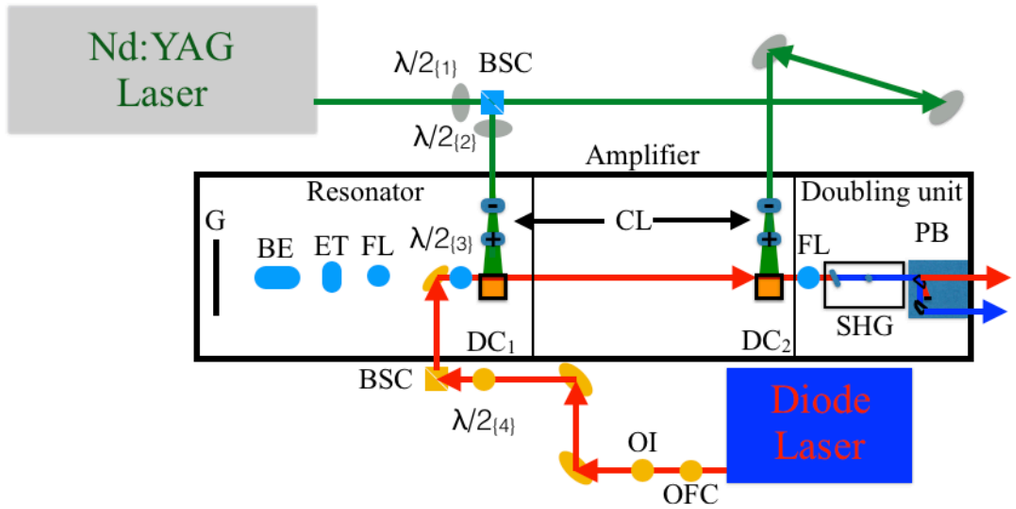
- Linewidths of ‘standard’ RILIS lasers **> 800 MHz**.
- Future spectroscopy applications require high-resolution laser systems (**<100 MHz**).
- Doppler-free 2-photon spectroscopy.
- Perpendicular illumination in LIST.

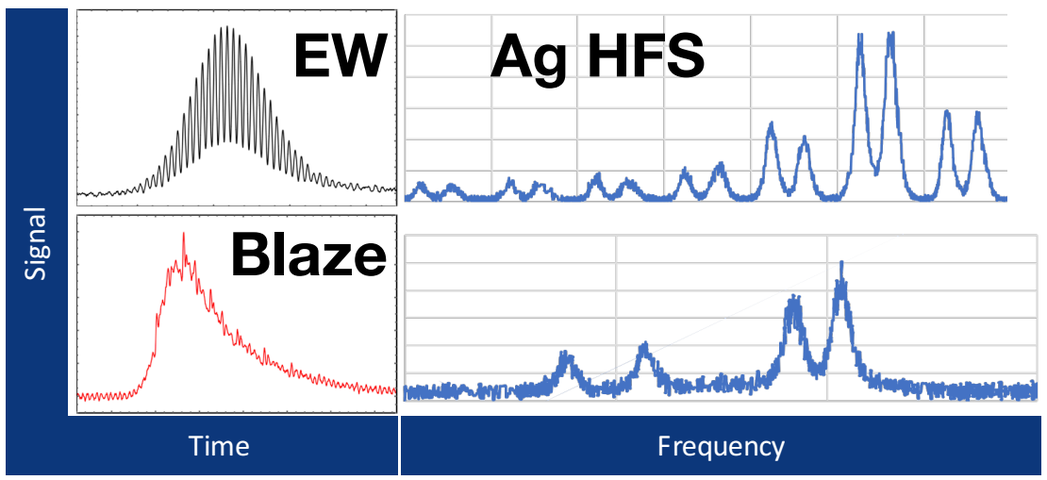
Solution:
Develop the Fourier-Limited linewidth lasers

~~Injection-seeded Ti:Sapphire ring laser~~

Pulsed Dye Amplifier

- Temporal profile of pump laser critical for single-frequency output.
- Spectroscopy on stable silver shows frequency sidebands when using Edgewave as pump.
- System requires development (including identification of suitable pump laser).





C. A. Granados Buitrago

~picosecond laser for molecular breakup

0-200 kHz (600 fs), 100W @ 515 nm

FX series INNOSLAB laser

OR

InnoLas Photonics

FEMTO*

FEMTO-1030-25-Yb-2500
FEMTO-515-15-Yb-2500

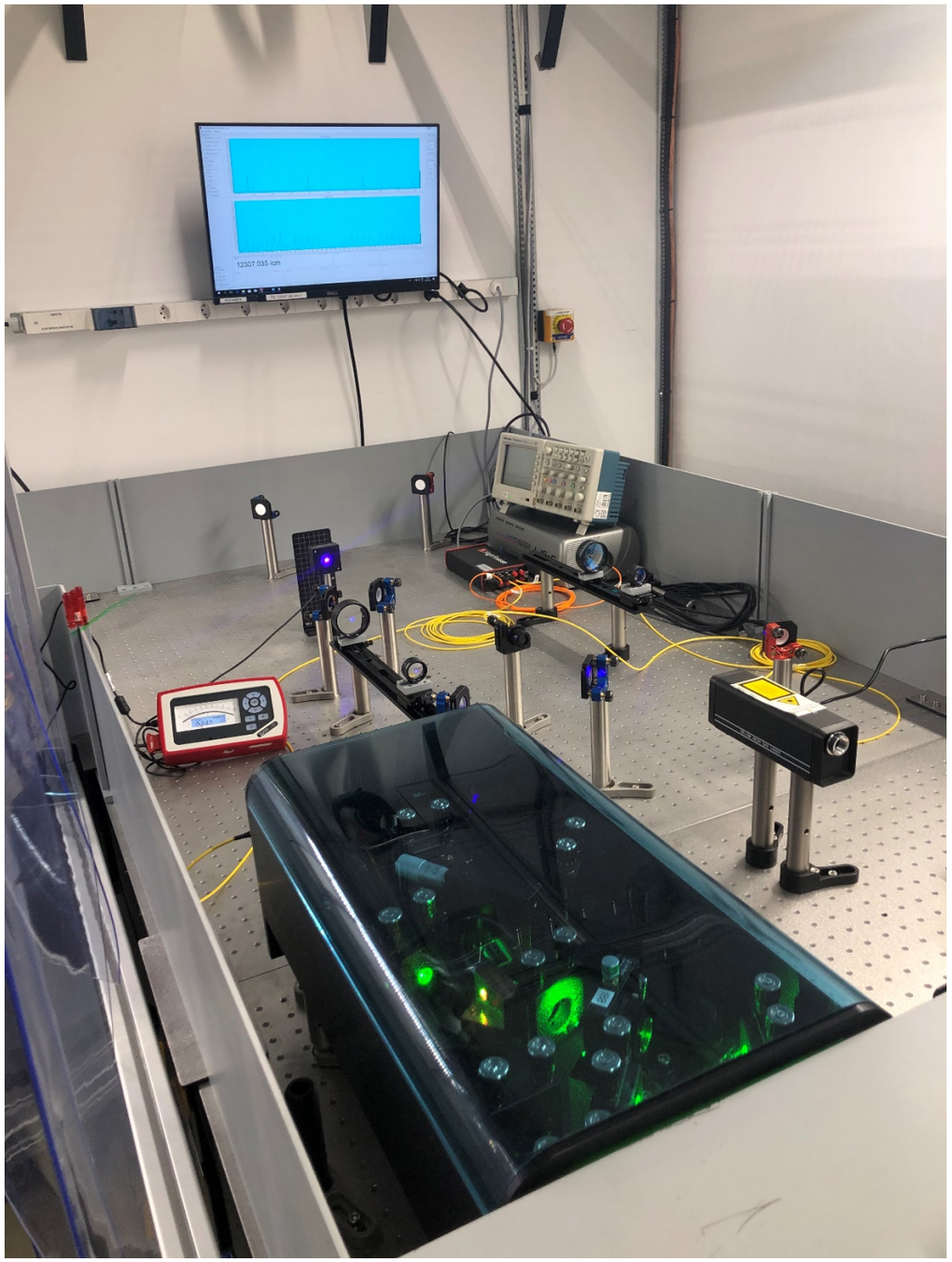
75 x peak power increase w.r.t our 100 W IS-series laser

> 20 laser-molecule interactions per molecule (in hot cavity)

8 MW @ 515 nm @ 1MHz

MELISSA (MEDICIS Laser Ion Source)

- Laser-ion-source lab at MEDICIS is now **operational.**
- Current installation:
  - **1x** Z-cavity Ti:Sa.
  - **1x** InnoLas Nanio 532-18-Y.
- Achieved **laser-ionized terbium** in **April** using single-laser scheme.
- To be installed soon:
- **2x** Grating Ti:Sa.
- **1x** pump laser.
- First radioisotope collections in coming months.



MELISSA: Laser ion source setup at CERN-MEDICIS facility. Blueprint

V.M. Gadelshin[a,f,*], V. Barozier[b], T.E. Cocolios[c], V.N. Fedosseev[b], R. Formento-Cavaier[d,e], F. Haddad[d], B. Marsh[b], S. Marzari[b], S. Rothe[b], T. Stora[b], D. Studer[a], F. Weber[a], K. Wendt[a]

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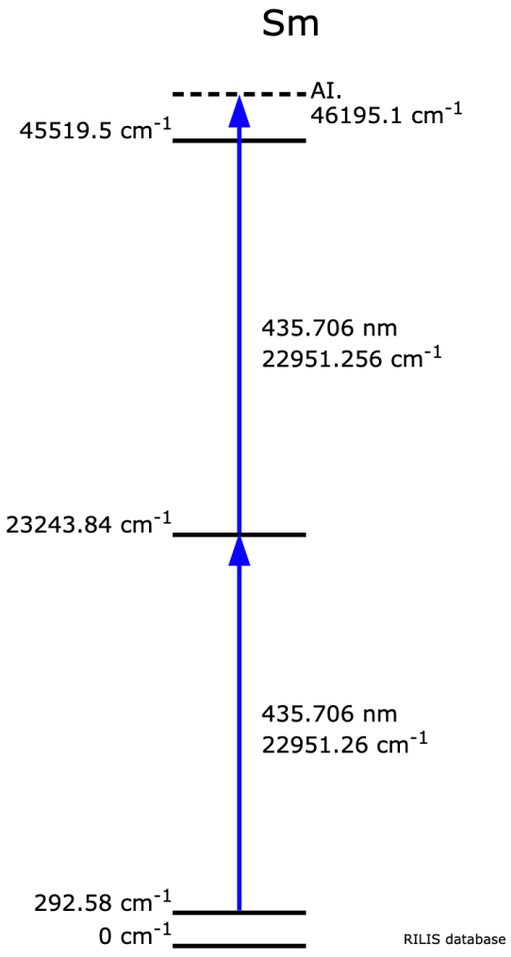
V. Gadelshin, K. Dockx

RILIS @ OFFLINE 2

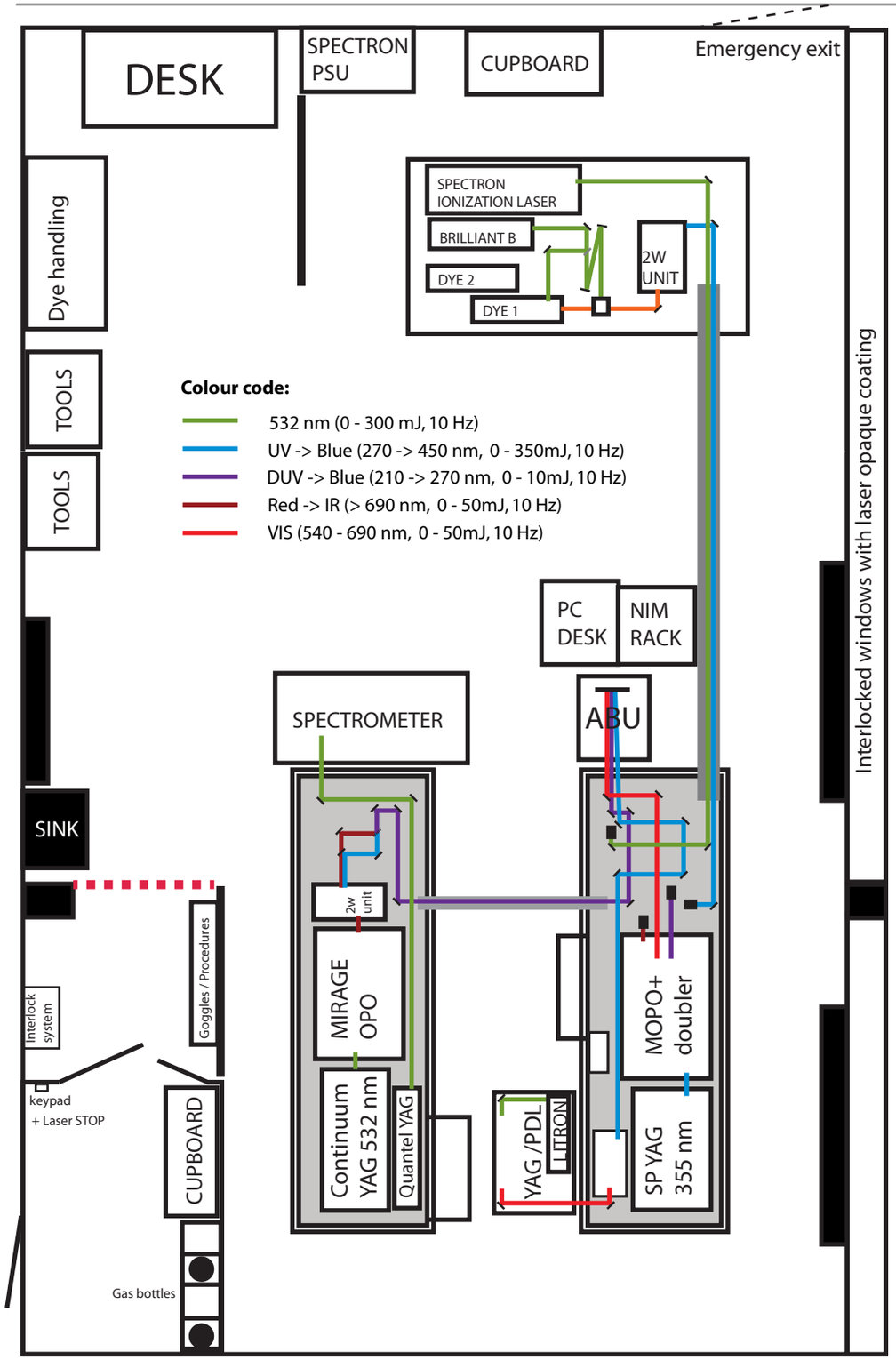
- New offline separator dedicated for research and development.
  - Home for RILIS developments during CERN's Long Shutdown 2 and beyond.

- Completed:
  - Laser interlock design and installation.
  - Laser tables installed.
  - Optical table layout designed.
  - Air-conditioning and water-cooling circuit installation.

- To be completed:
  - Install spare laser hardware.
    - PX1, IC-doubled Z-cavity for Sm ionization.



The LARIS Lab



Recently the Lab has been used for laser development and GANDALPH construction

But - The lab is not equipped for this

Decision to re-purpose the lab for multiple activities :

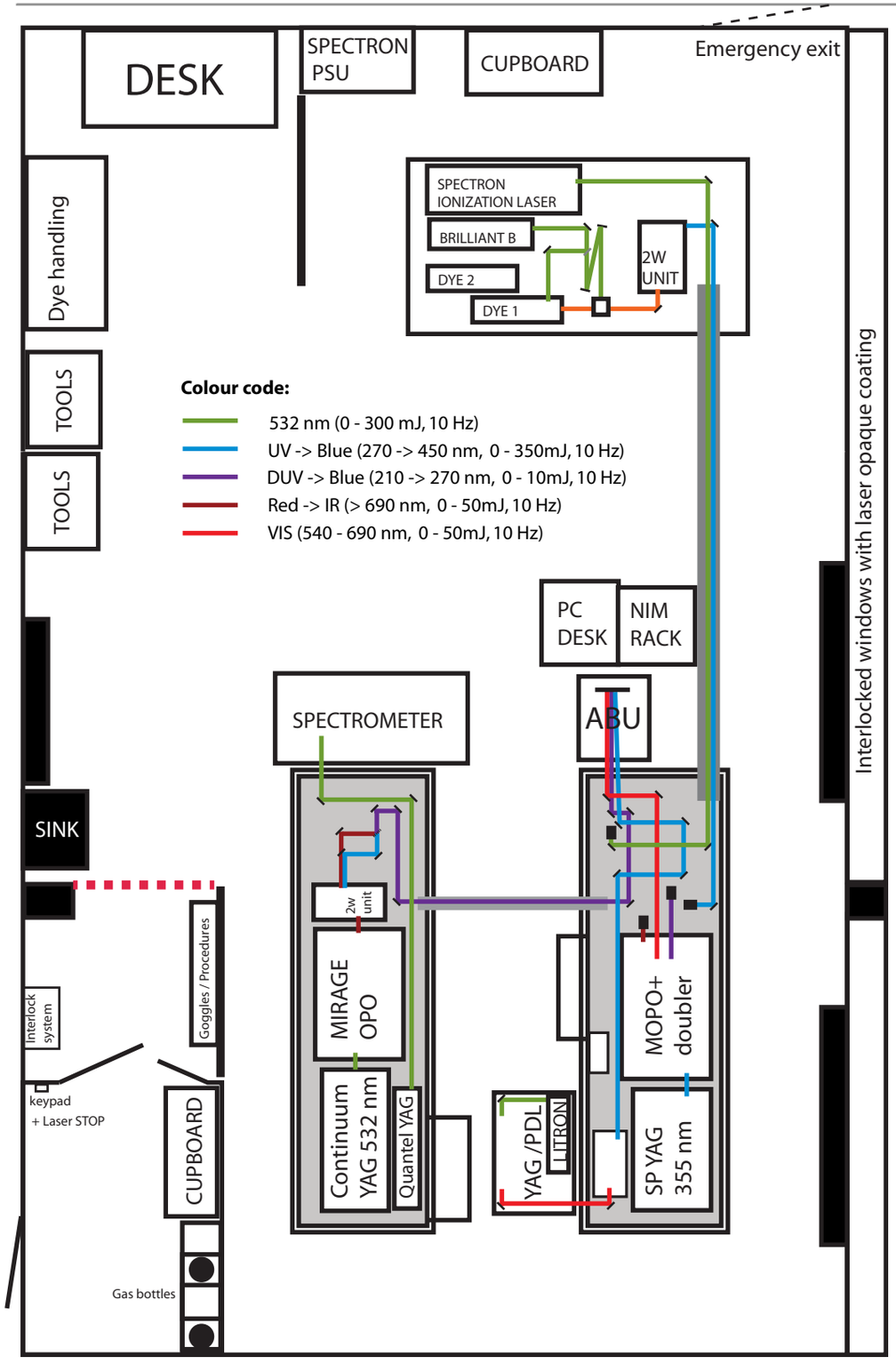
GANDALPH upgrades

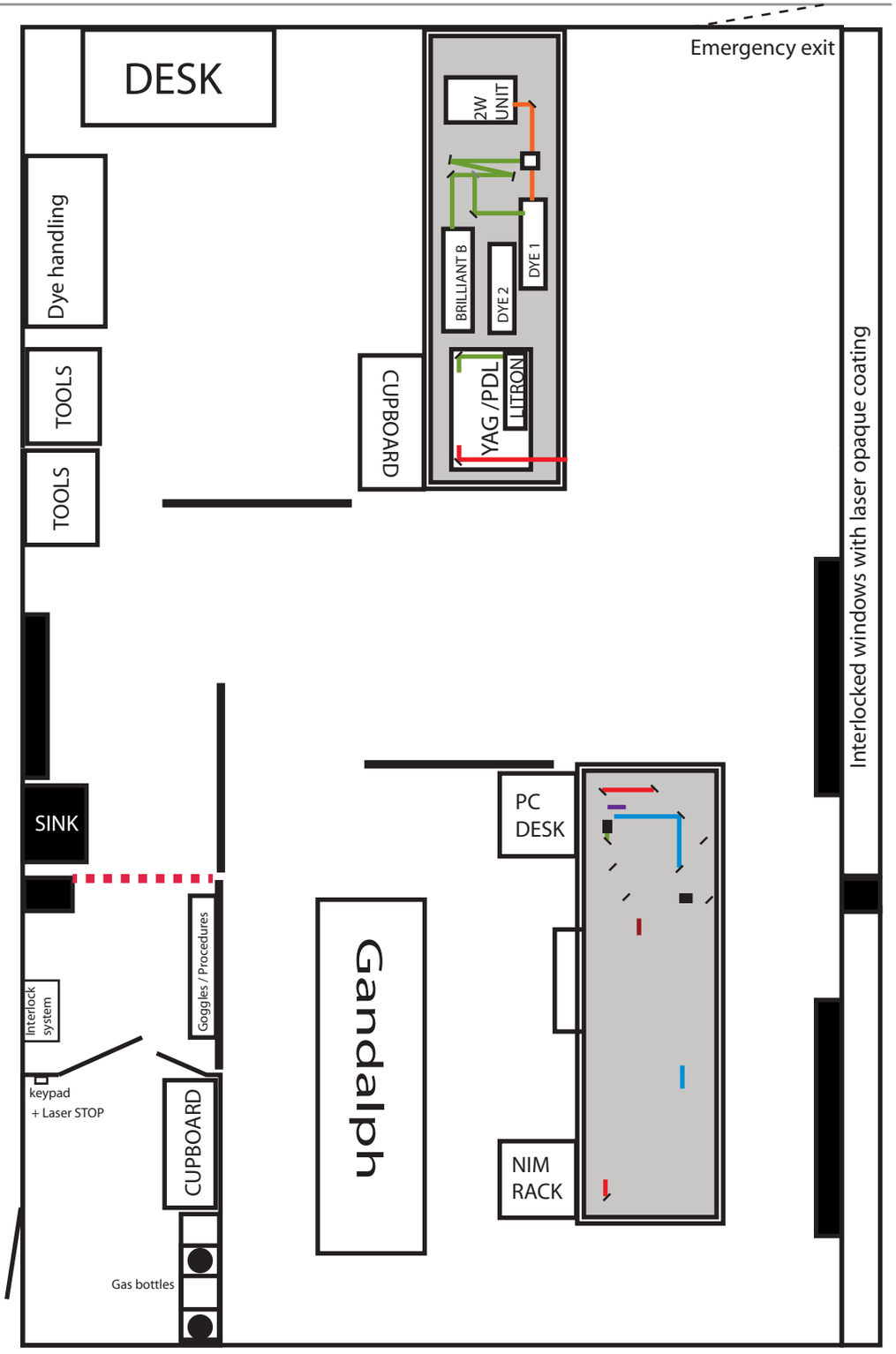
Ion source test bench with pump stand

Laser development and maintenance

Training

The LARIS Lab





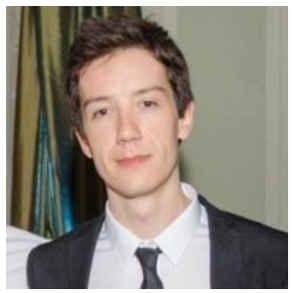
RILIS team in 2020

Valentin Fedosseev

Section Leader
EN-STI-LP

Bruce Marsh

Staff Member
EN-STI-LP



Shane Wilkins

CERN Fellow
So far granted a 6 month extension till April 2020

Katerina Chrysalidis

Doctoral student

CERN Fellow
from Jan 2020

+ New MELISSA Post-Doc - Reinhard Heinke
+ Singular Light KT funded PhD student (Mid 2019 onwards).
+ LISA PhD student in 2020

Maintenance | WM calibrations | Re-cabling | Chiller maintenance | Chiller maintenance | Re-organising

Upgrades | Diode laser (14kEUR)? | New Computers

Chillers | Cleaning | re-cabling work | reference area | Tidy up | Chillers | New dye laser | Cleaning | Chillers | Raman laser | Cleaning | Chillers | Blaze replacement | Cleaning | Chillers

5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4

2019 | 2020 | 2020

5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4

Tb | Molecule | Not yet scheduled .....

Of2 Lam flow

DEV Lam flow

Raman laser development

Offline Lab setup (Dev lab, LARIS, OFL 1&2)

Ionization scheme development : What are the priorities?

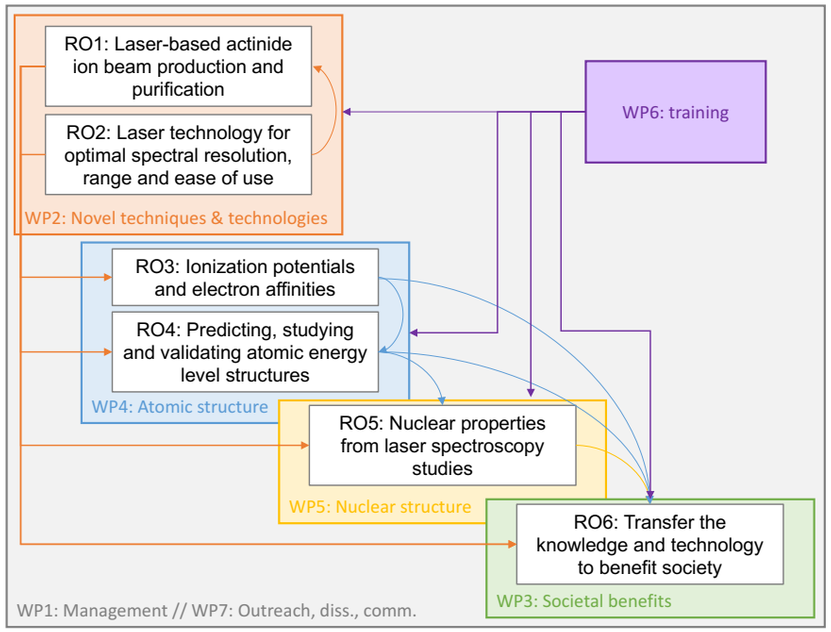
MEDICIS operation and development | 2nd Tisa | 2nd pump laser | Reference area | MRC system

RILIS Laser development

Offline Separator R&D | VADLIS tests | ToF-LIS | Sigradur cavity | Molecular breakup | 2-ph Rb

Laser Ionization and Spectroscopy of Actinides

"LISA aims to train the next generation of atomic, nuclear and laser scientists by conducting research to increase our understanding of the atomic and nuclear properties of the chemical elements known as the actinides"



From November 2019 - November 2020

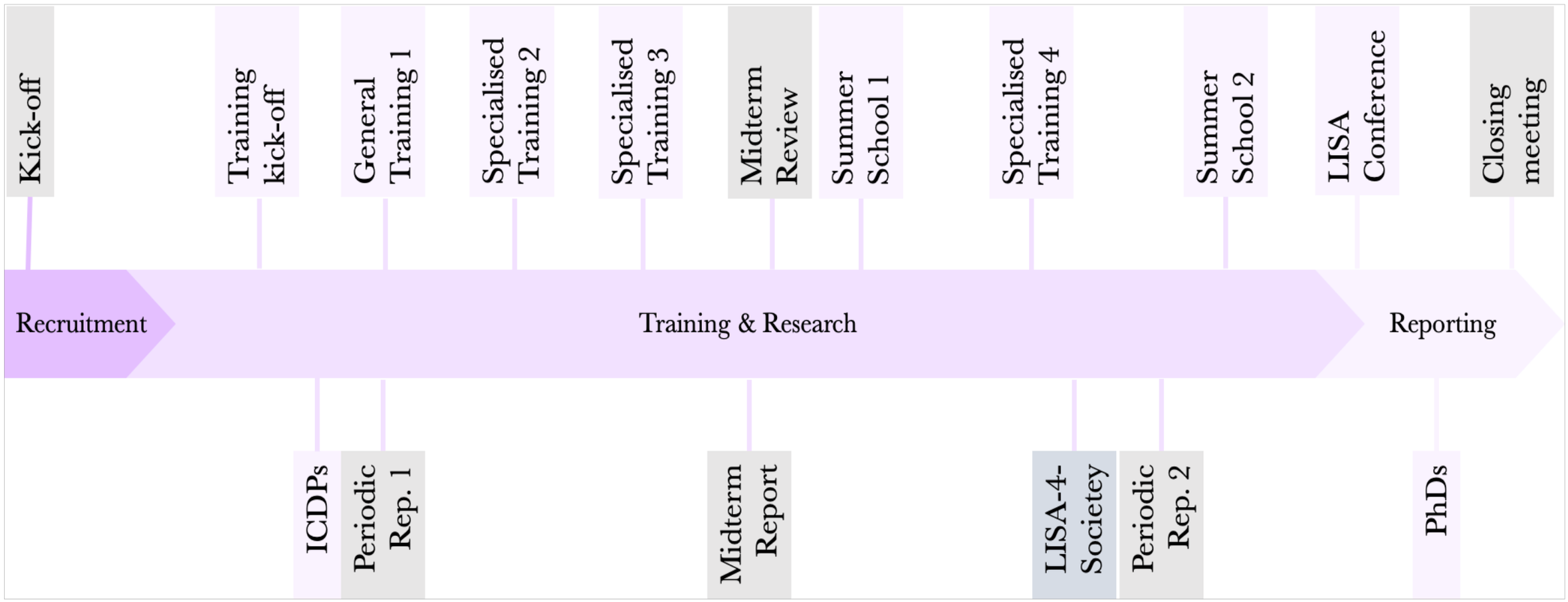
15 fully-funded 36 month PhD positions, across 12 different locations

MARIE CURIE ACTIONS

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
TOTAL				**540M**

November 2019

November 2023



ESR2	**CERN**	**Y**	**Start: M6**	**Duration: 36**	**D2.2**

Project title: Development of high-resolution in-source hot-cavity RILIS methods for actinides. (**WP2**: Novel techniques and technologies for actinide research)

Objectives: Combining the unparalleled sensitivity of in-source resonance ionization spectroscopy with the resolution required to resolve sub 1 GHz hyperfine structures and isotope shifts in atomic transitions of actinides. For this goal, the work towards the implementation of the PI-LIST device (perpendicular-illuminated Laser Ion Source Trap) shall be performed at ISOLDE. This will include the design and setup of infrastructure required for the on-line PI-LIST operation followed by characterization of its performance and high-resolution laser spectroscopy studies using the PI-LIST. Optimal ionization schemes for actinium (together with ESR1) and protactinium shall be established in the frame of this project.

The eventual application of PI-LIST for actinide elements at ISOLDE will rely on the successful extraction of actinium and protactinium isotopes from an ISOLDE target (ESR3). The two fellows will closely collaborate to ensure the complementarity of these development projects.

Development of optimal ionization schemes of actinides for ISOLDE will be performed via laser spectroscopy of actinide elements in close collaboration with JGU (ESR5). Such links are already established and will be further enhanced in the course of the proposed ITN.

Expected results: Implementation of the PI-LIST at ISOLDE on-line isotope separation facility [D2.2]; demonstration of sub-Doppler resolution and enhanced isomer selectivity using the PI-LIST; selection of the optimal laser ionization schemes for actinium and protactinium; new experimental results on IS and HFS of atomic transitions in actinides (WP4&5).

Planned secondment(s): JGU (Klaus Wendt) – M9-10 – training and study of PI-LIST at RISIKO mass separator; TRIUMF (Jens Lassen) – M15-16 – training and study of LIST operation at the ISAC facility; JGU (Klaus Wendt) - M21-22 – laser ionization studies of actinides.

Enrolment in Doctoral degree: JGU Institute of Physics under the supervision of Prof Klaus Wendt

ESR3	**CERN**	**Y**	**Start: M6**	**Duration: 36**	**D2.4**

Project title: Target developments for extraction of actinides from thick ISOL targets followed by laser-induced molecular break-up and/or ionization. (**WP2**: Novel techniques and technologies for actinide research)

Objectives: Study and optimize the reaction conditions required to create volatile molecular species of refractory elements in general and actinides in particular. Develop a dissociation scheme for the provision of atomic species suitable for efficient laser ionization or in-source laser spectroscopy.

Expected results: Extraction of radiogenic actinide elements from an ISOL target and delivered in atomic form to the users. Determine the production yield and purity of the beams and report the new beam availability to the community.

Planned secondment(s): JGU (Christoph E. Düllmann) – M8-10 – working on the sample preparation to be used for the actinide molecular release studies; TRIUMF (Thomas Day Goodacre, Peter Kunz) – M15-17 – Extraction of actinides from thick targets at the ISAC facility. Participation in activities around radioactive ion beam development involving actinide beams and molecular beam extraction. Gaining experience in radioactive detection techniques used to assess the quantity and quality of the produced isotopes.

Enrolment in Doctoral degree: JGU in the Department of Chemistry under the supervision of Prof Christoph E. Düllmann