Эксперименты на лазерном ионном источнике установки ISOLDE

Д.В. Федоров

А.Е. Барзах, П.Л. Молканов, М.Д. Селиверстов, В.Н. Пантелеев

1. Установка ISOLDE (краткое описание)

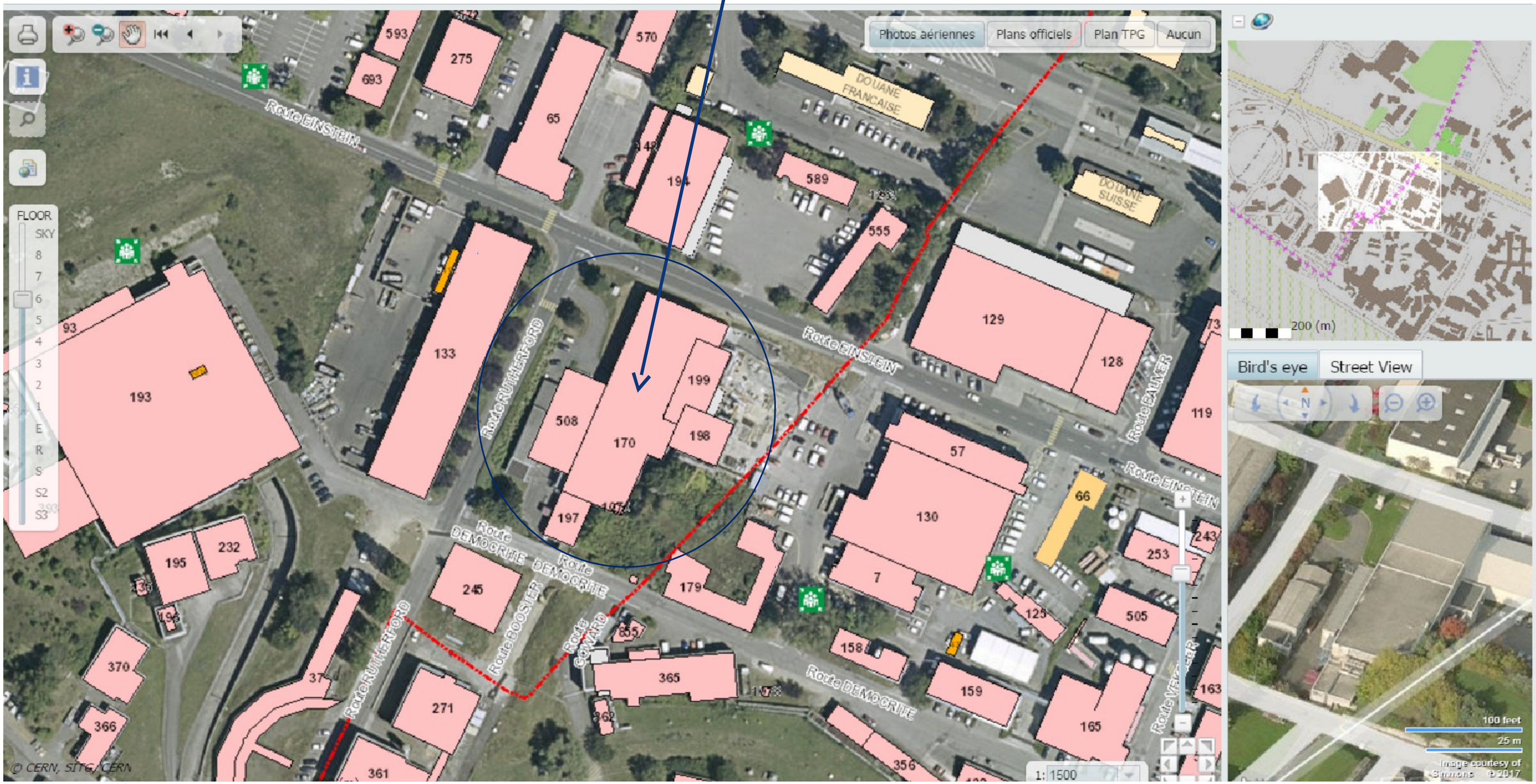
2. Ионные источники ISOLDE

3. RILIS –принцип действия, место и роль

4. Off-line и on-line эксперименты с участием RILIS

5. ПИЯФ в коллаборациях ISOLDE

ISOLDE – **I**sotope **S**eparator **O**n-**L**ine **DE**vice



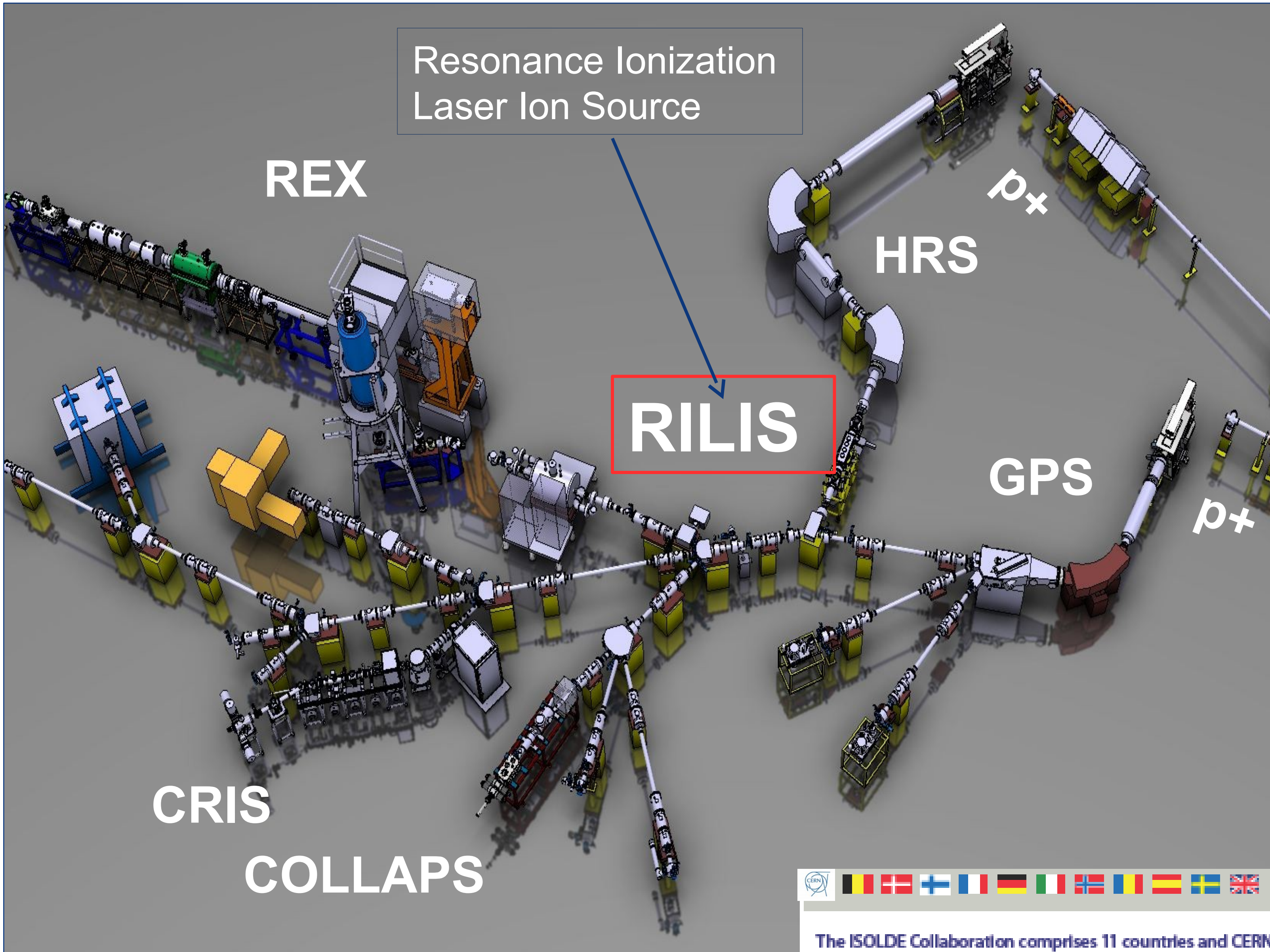
CERN

ISOLDE

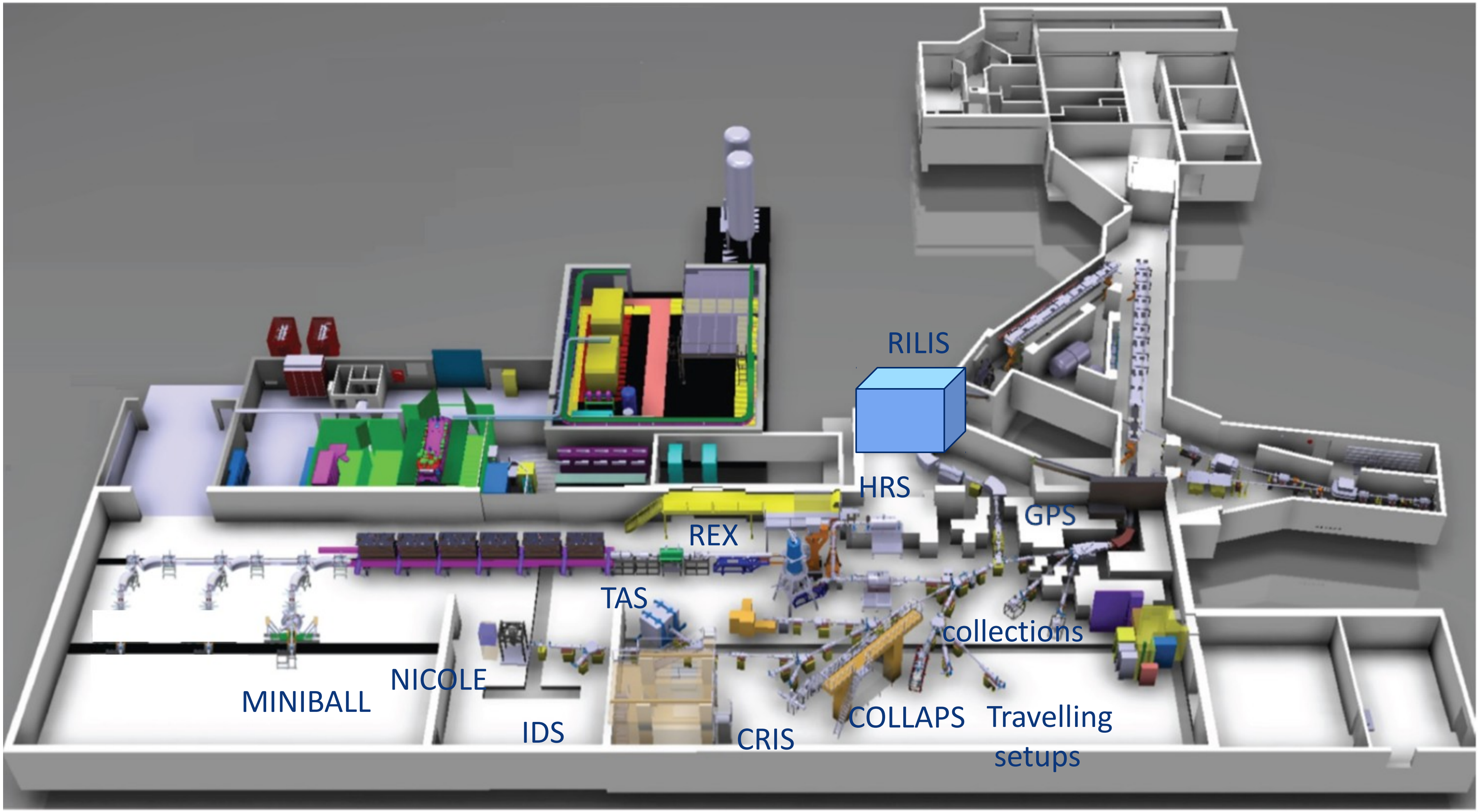
RILIS


ISOLDE
170
CERN
1648
1952
1755
9395 WA 74

ISOLDE – **I**sotope **S**eparator **O**n-**L**ine **DE**vice



ISOLDE – **I**sotope **S**eparator **O**n-**L**ine **DE**vice



ISOLDE – **I**sotope **S**eparator **O**n-**L**ine **DE**vice

ISOLDE Ion Sources

Surface Ionization Ion Source

Plasma Ionization Ion Source

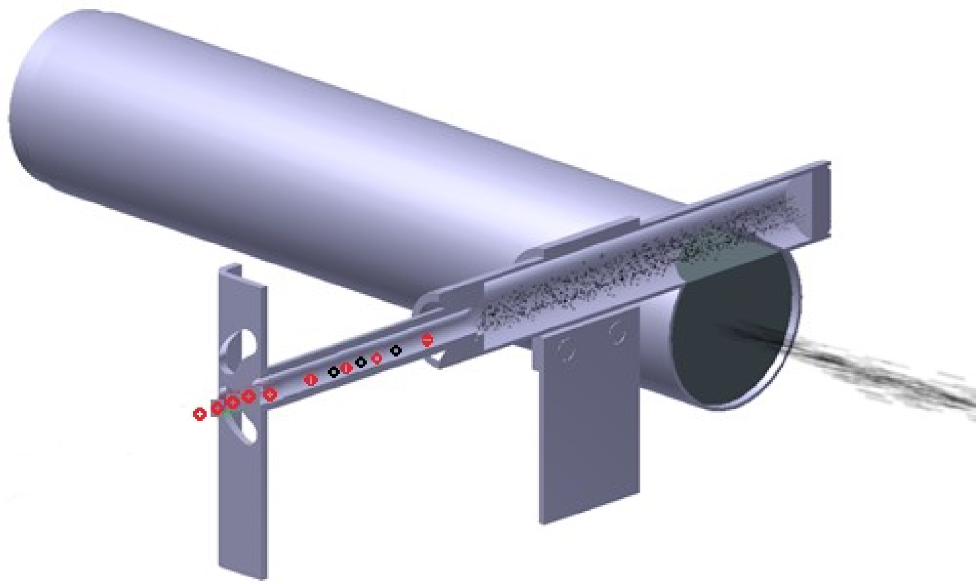
Resonance Ionization Laser Ion Source

ISOLDE Ion Sources

Surface Ionization Ion Source –

for elements low ionization potentials (of about 6 eV)

(Alkali, some Alkali-Earth and Rare-Earth elements)

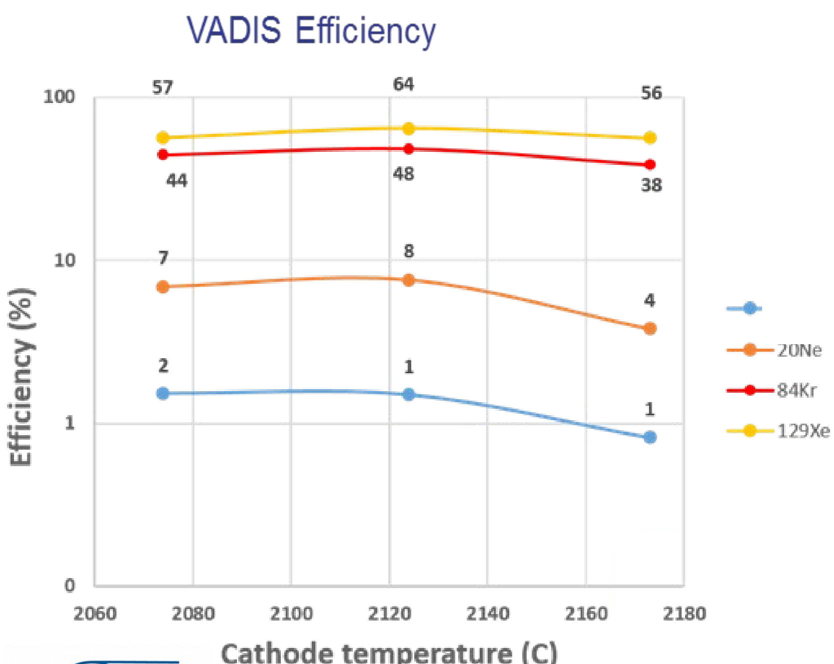


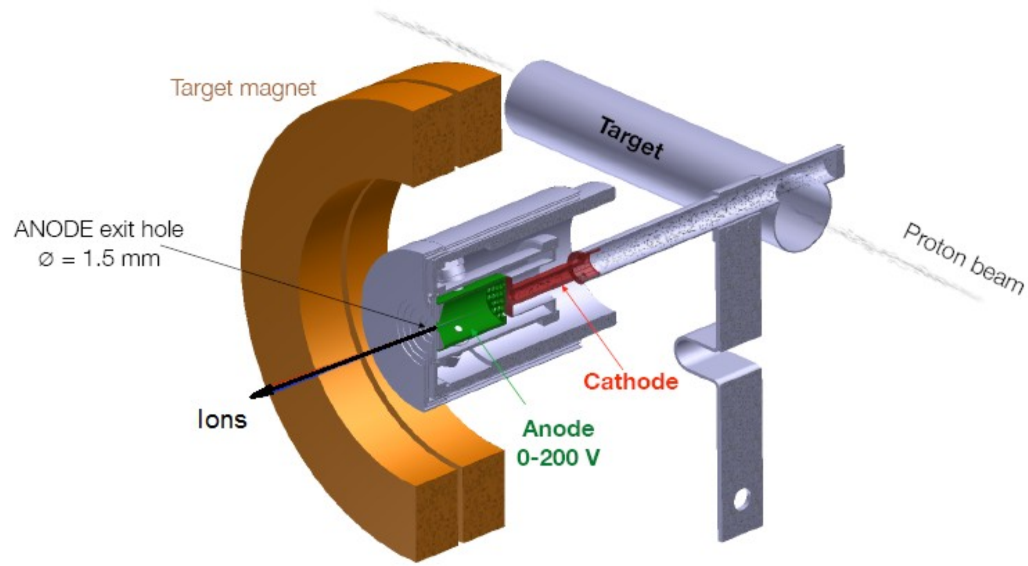
Ionization efficiency:
up to 30% for alkali
1% and less for the others

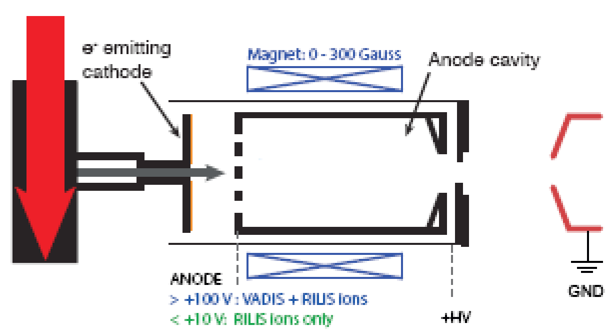
ISOLDE Ion Sources

Plasma Ionization Ion Source

VADIS – Versatile Arc Discharge Ion Source







Laser ionization in a Hot Metal Cavity

First RIBs produced in 1990-1991

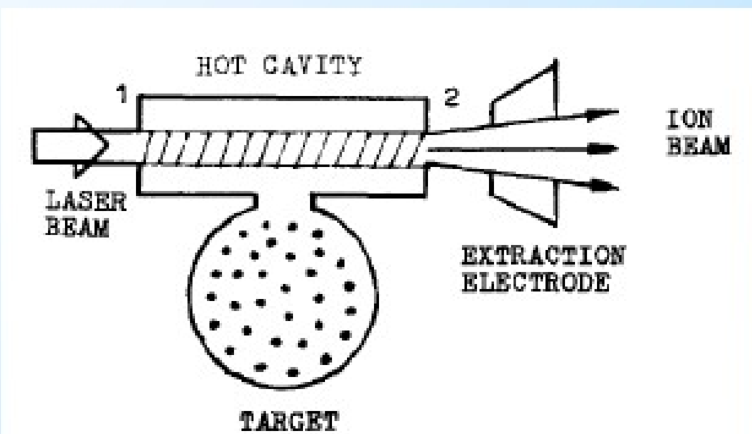
at PNPI (Gatchina, Leningrad district):

Nuclear Instruments and Methods in Physics Research A306 (1991) 400–402

Application of a high efficiency selective laser ion source at the IRIS facility

G.D. Alkhazov, L.Kh. Batist, A.A. Bykov, V.D. Vitman, V.S. Letokhov [1], V.I. Mishin [1], V.N. Panteleyev, S.K. Sekatsky [1] and V.N. Fedoseyev [1]
Leningrad Nuclear Physics Institute, Academy of Sciences of the USSR, Gatchina, Leningrad district 188350, USSR

Received 6 December 1990 and in revised form 25 March 1991



Yb, Nd, Ho - off-line
Ho - on-line

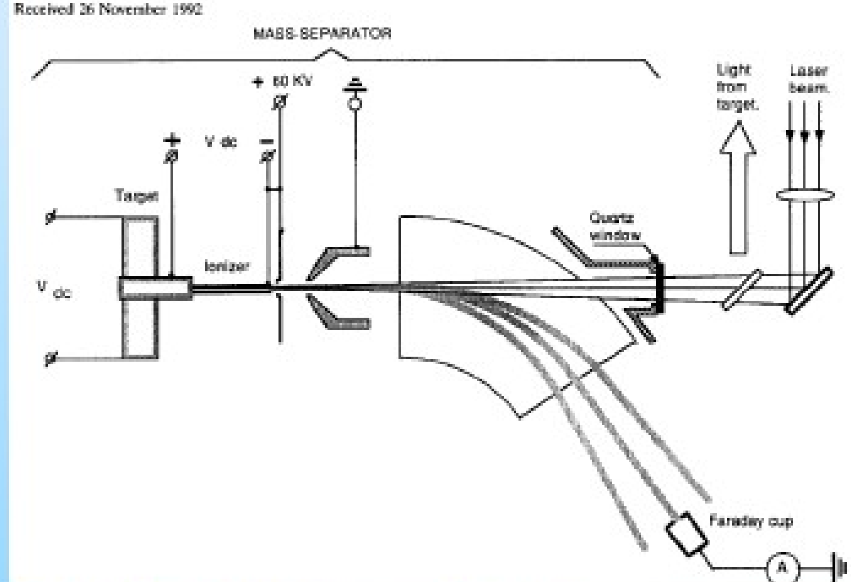
at CERN:

Nuclear Instruments and Methods in Physics Research B73 (1993) 550–560

Chemically selective laser ion-source for the CERN–ISOLDE on-line mass separator facility

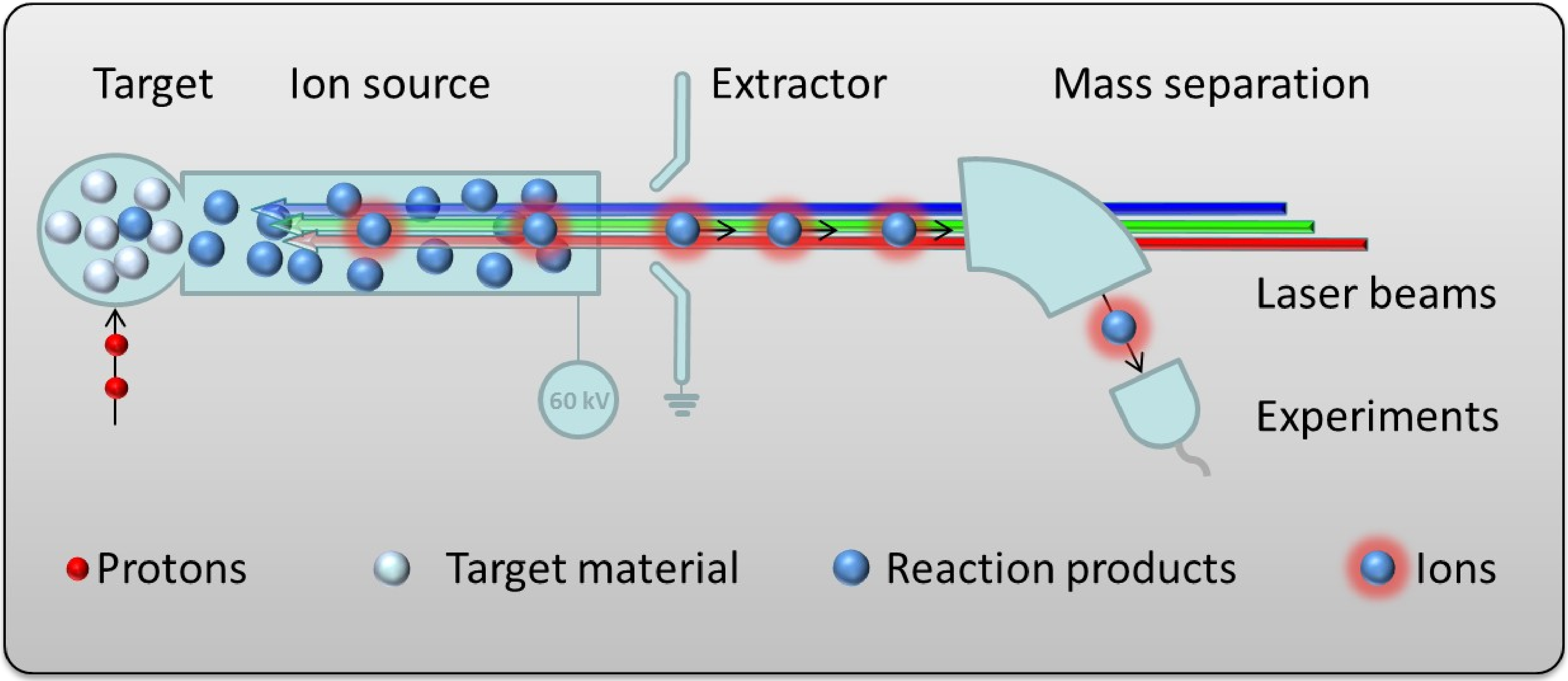
V.I. Mishin [1], V.N. Fedoseyev [1], H.-J. Kluge [2], V.S. Letokhov [1], H.L. Ravn [3], F. Scheerer [2], Y. Shirakabe [4], S. Sundell [3], O. Tengblad [3] and the ISOLDE Collaboration
PPE Division, CERN, Geneva, Switzerland

Received 26 November 1992

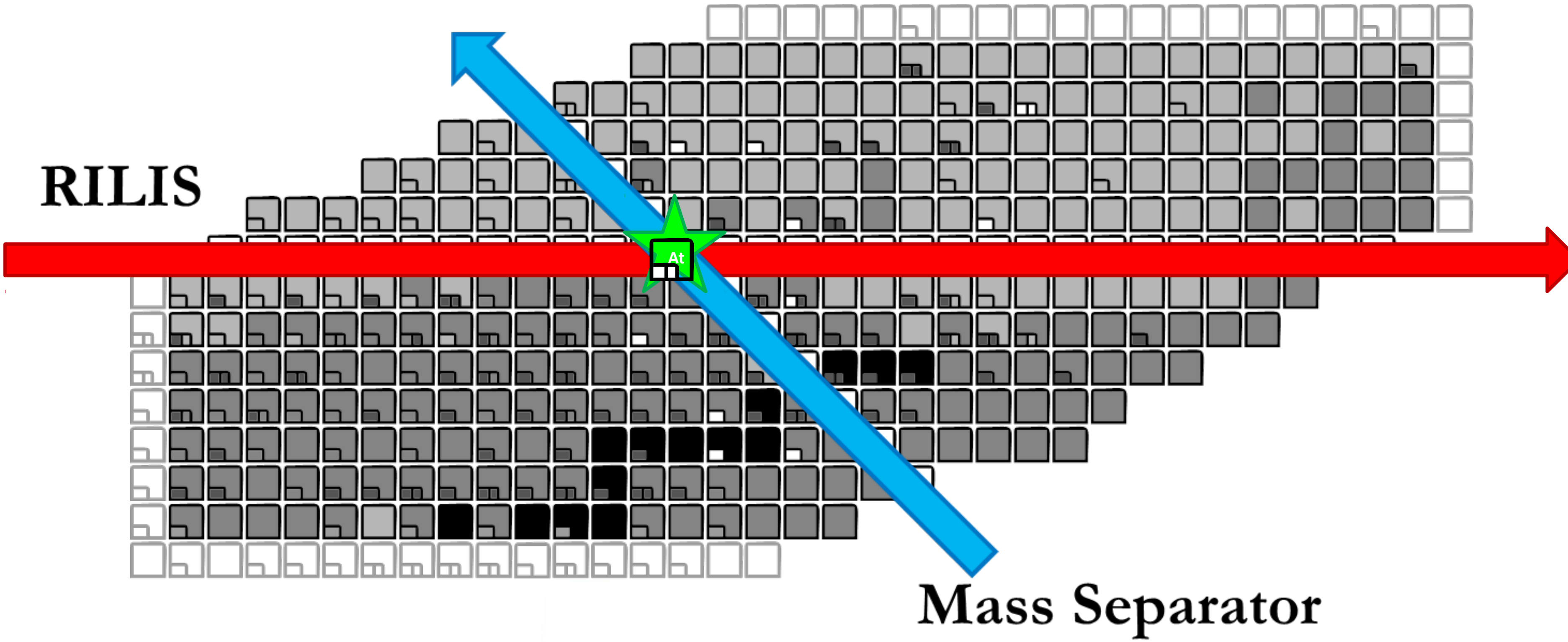


Yb, Tm, Sn, Li - off-line
Yb – on-line

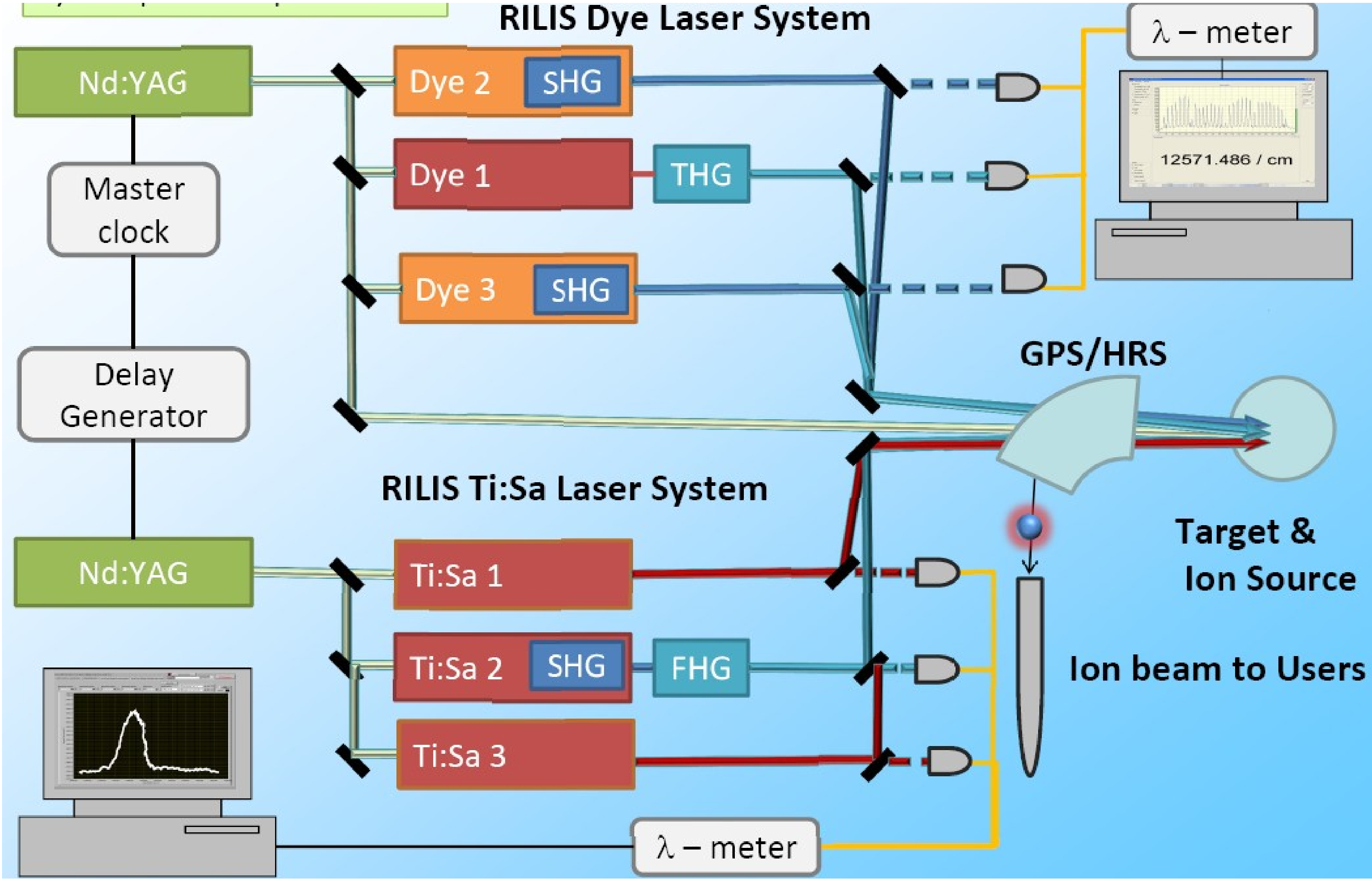
RILIS – **R**esonance **I**onization **L**aser **I**on **S**ource

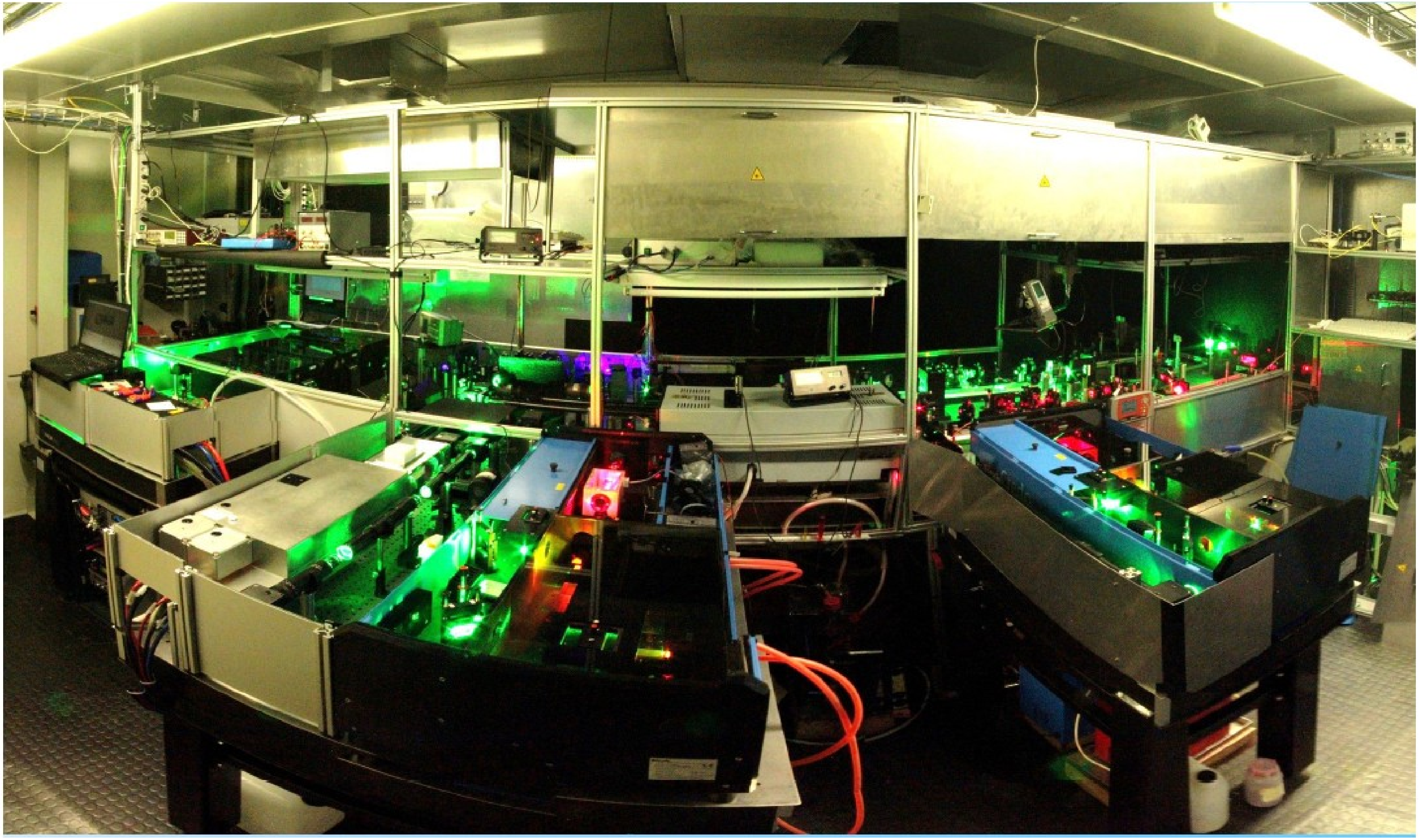


RILIS + mass separating magnets = Isotopic selectivity



Laser set-up of RILIS





RILIS

CERN

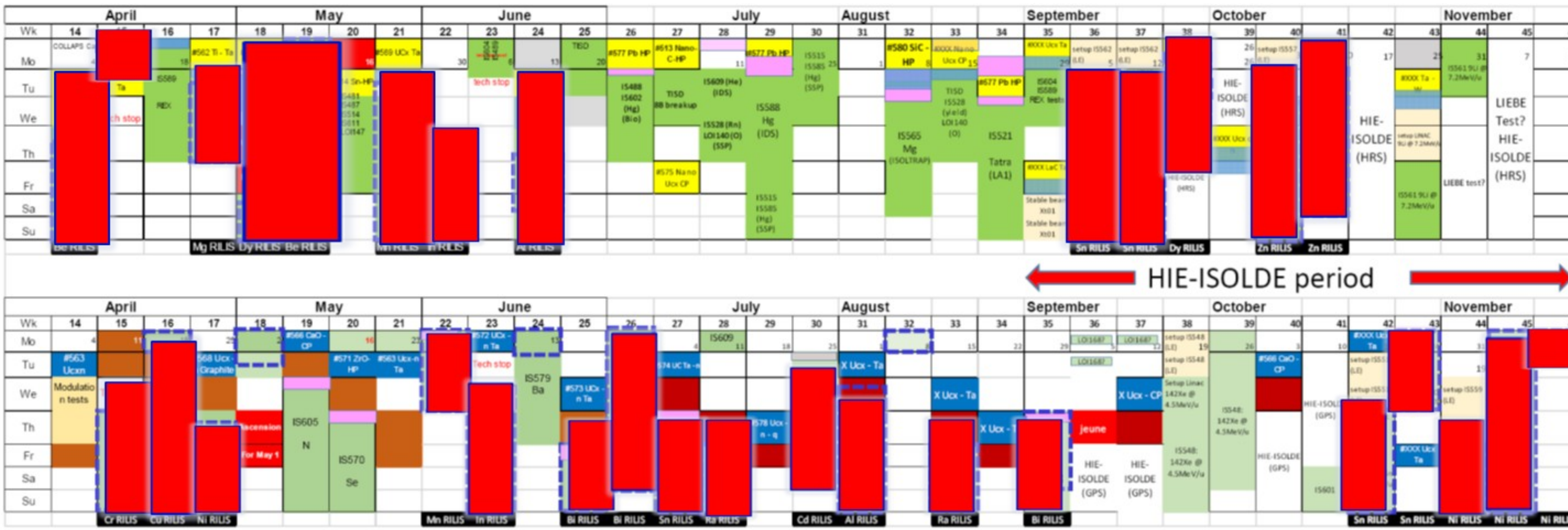
ISOLDE


February

ISOLDE SCHEDULE 2016

(Weeks 14-46)

GPS

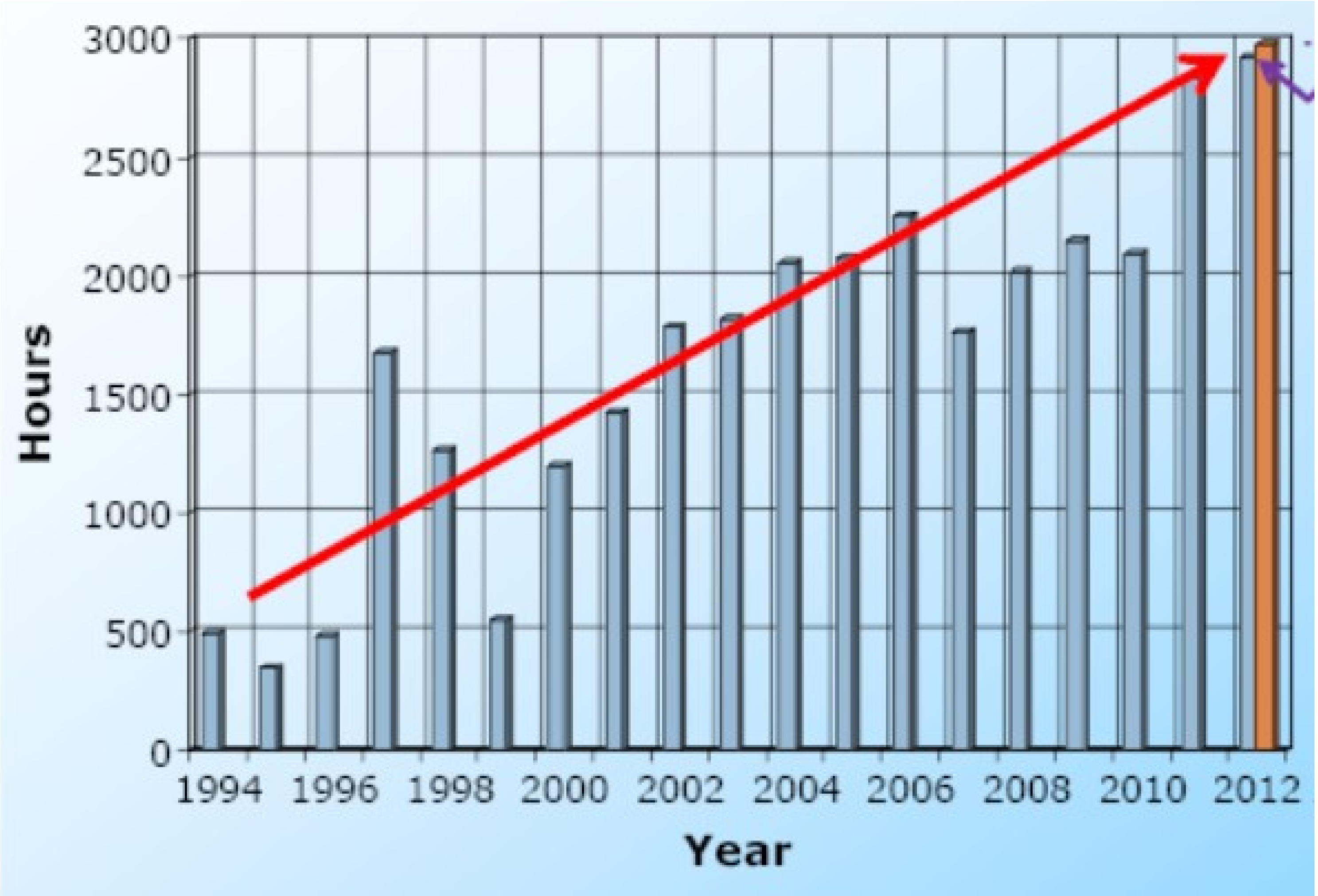


HRS

- Target change GPS
- Target change HRS
- CERN holiday
- Setting up HRS
- Setting up GPS
- Physics HRS
- Physics GPS
- RILIS run
- Proton Scan Yields

Reserve for HIE:
- IS569
- IS607

KJ 28.07.16



3000
2500
2000
1500
1000
500
0
Hours
1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year

RILIS in 2016

- **130** days of RILIS operation (mostly 24-hr on-call operation)

3120 h

- **22** separate RILIS runs
- **14** different elements: Be, Cr, Cu, Mg, Ni, Dy, Mn, In, Bi, Sn, Ra, Cd, Al, Zn

In 2016 RILIS ionized atoms were used for:

>75% of ISOLDE physics

Experiments with RILIS at ISOLDE

OFF-LINE:

- **Ion-source development**
- **Investigations of ionization schemes for “new” elements**

ON-LINE:

- **Search for ionization schemes for some elements**
- **RILIS just as an ion source for ISOLDE experiments**
- **RILIS as a significant part of ISOLDE experiments**
- **Laser in-source spectroscopy – ISOLDE experiments initiated by RILIS team.**

Ion-source development

Nuclear Instruments and Methods in Physics Research B 376 (2016) 39–45

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

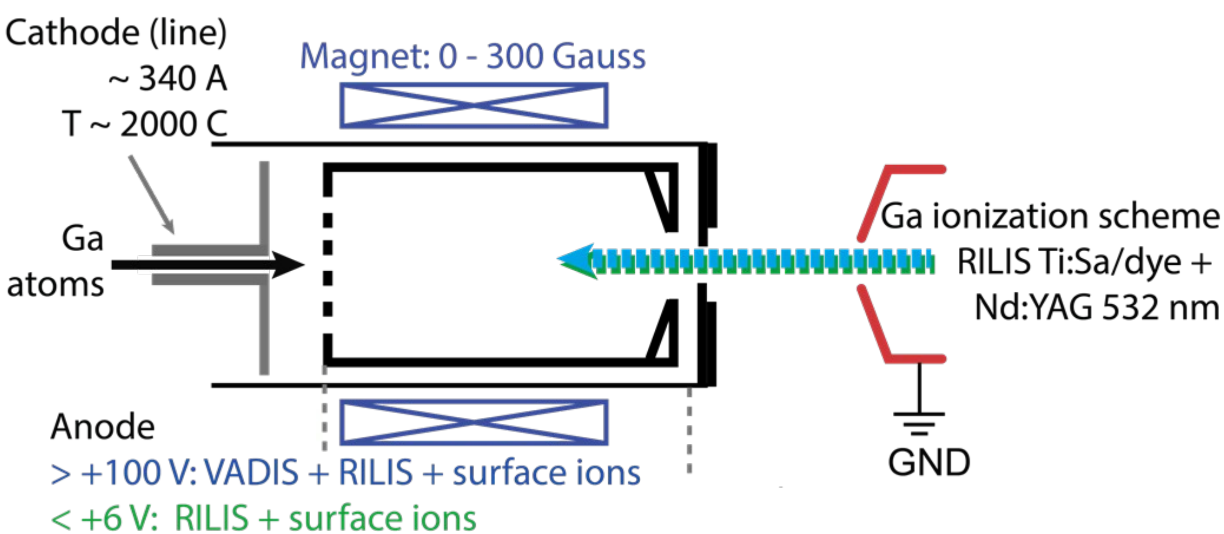
journal homepage: www.elsevier.com/locate/nimb

ELSEVIER

BEAM INTERACTIONS WITH MATERIALS AND ATOMS

Blurring the boundaries between ion sources: The application of the RILIS inside a FEBIAD type ion source at ISOLDE

T. Day Goodacre [a,b,*], J. Billowes [b], R. Catherall [a], T.E. Cocolios [b], B. Crepieux [a], D.V. Fedorov [c], V.N. Fedosseev [a], L.P. Gaffney [e,1], T. Giles [a], A. Gottberg [a], K.M. Lynch [a], B.A. Marsh [a], T.M. Mendonça [a], J.P. Ramos [a,d], R.E. Rossel [a,f,g], S. Rothe [a], S. Sels [e], C. Sotty [e], T. Stora [a], C. Van Beveren [e], M. Veinhard [a]

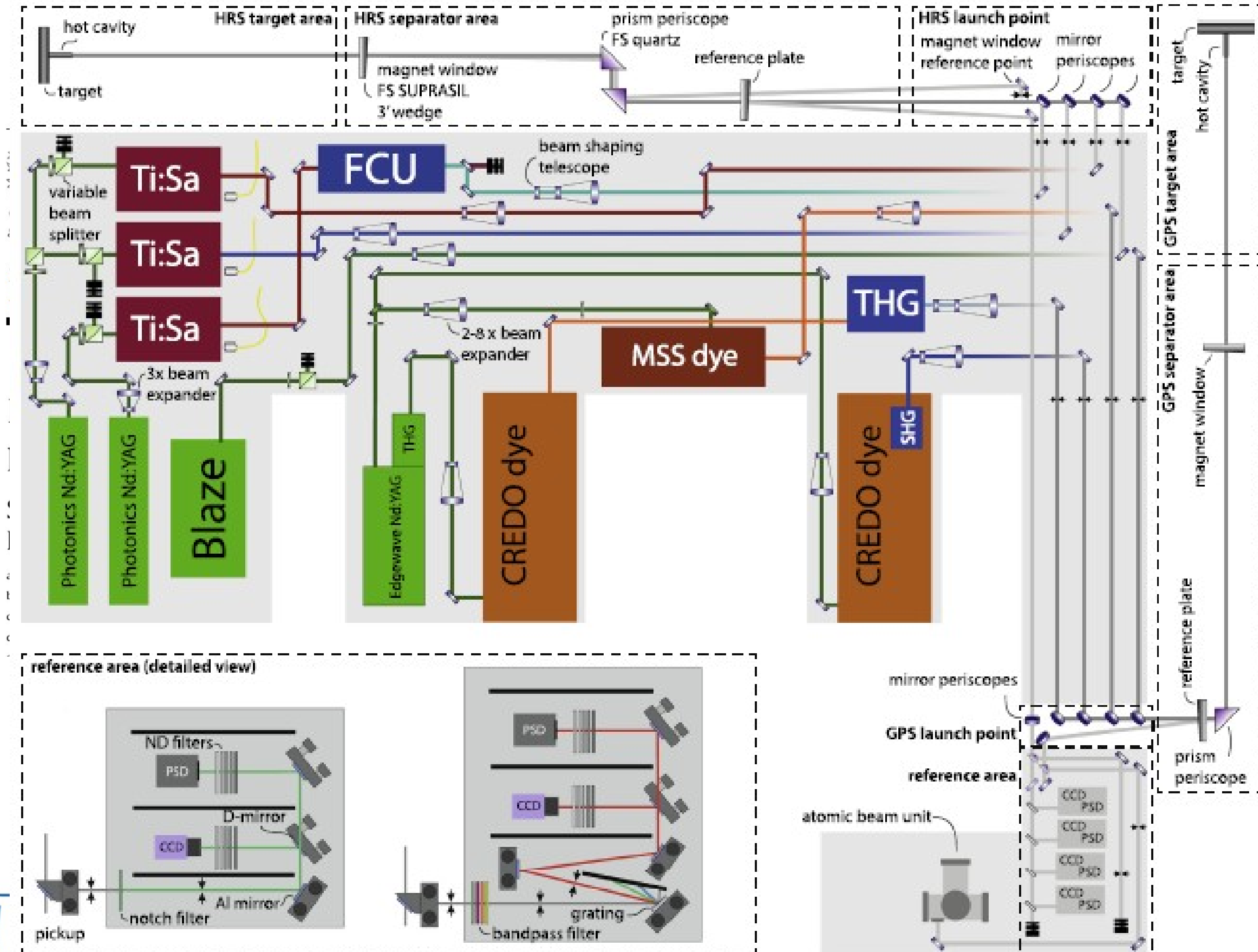


RILIS

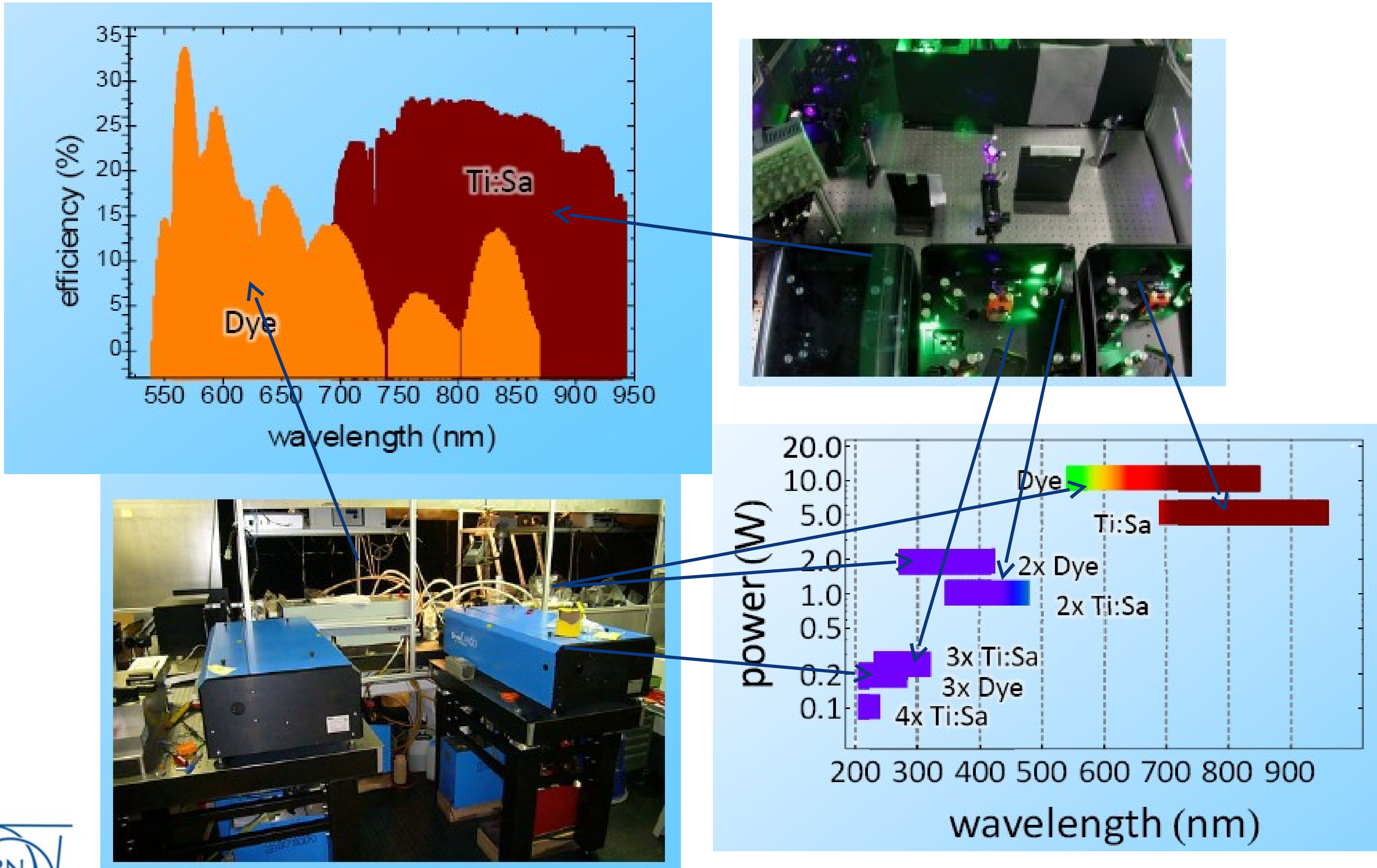
CERN

ISOLDE

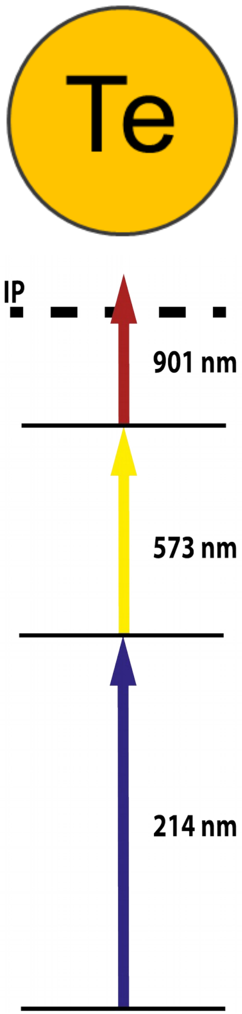
Ion-source development



Ion-source development



Ionization scheme development (off-line)



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Resubmission of Proposal P-277 to the ISOLDE and Neutron Time-of-Flight Committee

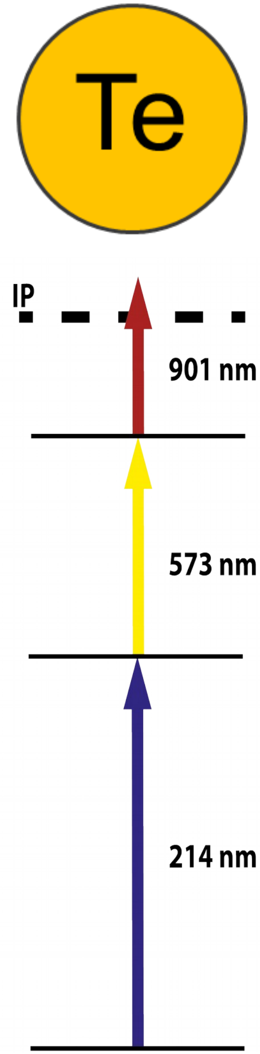
Coulomb excitation of ^{116}Te and ^{118}Te: a study of collectivity above the $Z = 50$ shell gap

January 5, 2011

T. Ahn[1], H. Al-Azri[2], T. Bloch[3], P. A. Butler[4], N. Bree[5], T. Bäck[6], S. Bönig[3], J. Cederkäll[7], B. Cederwall[6], I. G. Darby[5], J. Diriken[5], D. O'Donnell[4], C. Fahlander[7], L. P. Gaffney[4], T. Grahn[8], B. Hadinia[9], M. Huyse[5], D. G. Jenkins[2], A. Johnson[6], P. Joshi[2], D. T. Joss[4], R. Julin[8], T. Kröll[3], J. Leske[3], B. S. Nara Singh[2], A. Nicholls[2], R. D. Page[4], J. Pakarinen[10], E. S. Paul[4], N. Pietralla[3], P. Rahkila[8], E. Rapisarda[5], M. Sandzelius[8], M. Scheck[3], J. Simpson[11], J. F. Smith[9], R. Wadsworth[2], P. Van Duppen[5], D. Voulot[10], F. Wenander[10], V. Werner[1]

Ionization scheme development (off-line)

RILIS



Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

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

ELSEVIER

Laser resonance ionization scheme development for tellurium and germanium at the dual Ti:Sa–Dye ISOLDE RILIS ☆

CrossMark

T. Day Goodacre [a,b,*], D. Fedorov [c], V.N. Fedosseev [a], L. Forster [a], B.A. Marsh [a], R.E. Rossel [a,d,e], S. Rothe [a], M. Veinhard [a]

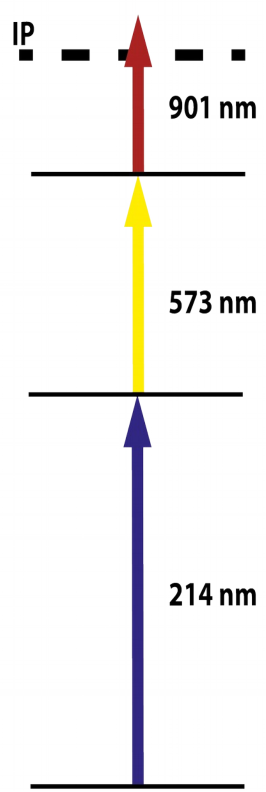
[a] CERN, CH-1211 Geneva 23, Switzerland
[b] School of Physics and Astronomy, The University of Manchester, Manchester M13 9PL, United Kingdom
[c] Petersburg Nuclear Physics Institute, 188350 Gatchina, Russia
[d] Institut für Physik, Johannes Gutenberg Universität, D-55099 Mainz, Germany
[e] Faculty of Design, Computer Science and Media, Hochschule RheinMain, Wiesbaden, Germany

CERN

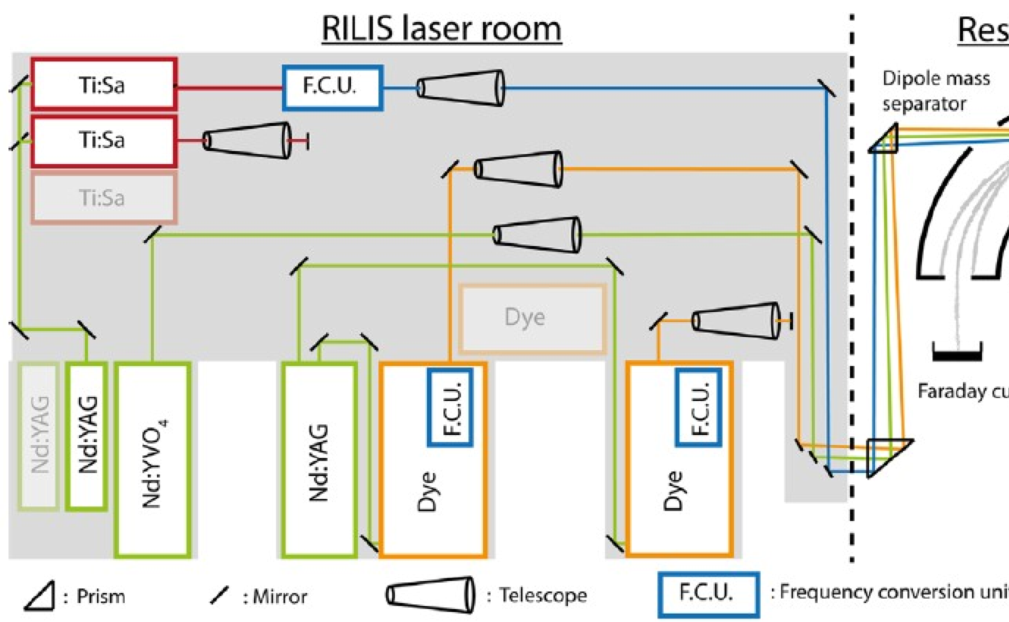
ISOLDE

Ionization scheme development (off-line)

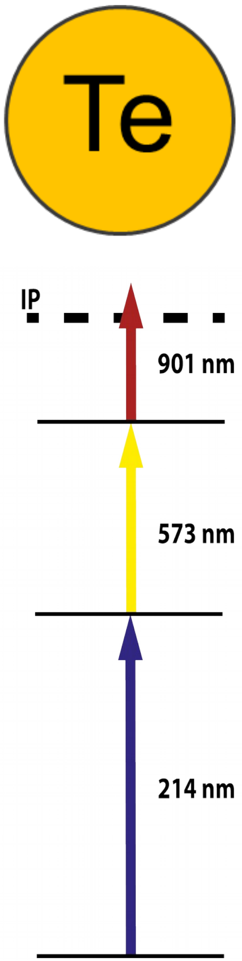
Te



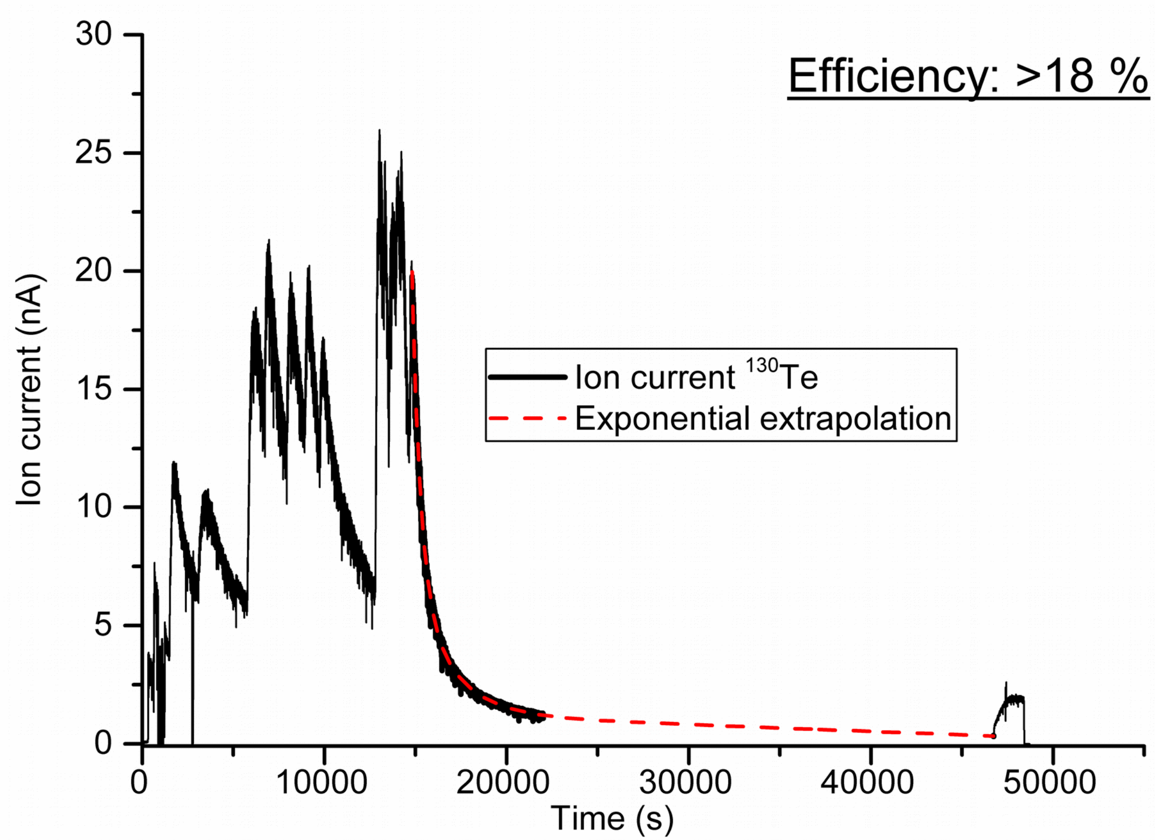
Transition (cm^{-1})	Upper state config., term, J	Wavenumber (cm^{-1})	Air wavelength (nm)	Relative ion current
0–46 652.738	$5p^3(^4S^o)6s$, $^3S^0$, 1	46 652.74	214.281	–
46 652.738–63 669.944	$5p^3(^4S^o)7p$, b ^5P, 1	17 017.21	587.478[a]	0.35[b]
46 652.738–63 921.485	$5p^3(^4S^o)7p$, ^3P, 2	17 268.75	578.922	1[b]
46 652.738–63 982.463	$5p^3(^4S^o)7p$, ^3P, 0	17 329.73	576.883[a]	0.24[b]
46 652.738–64 088.997	$5p^3(^4S^o)7p$, ^3P, 1	17 436.26	573.360	0.74[b]
64 088.997–75 181.41 (20)	New	11 092.41 (20)	901.270[a]	2.5



Ionization scheme development (off-line)



Ionization efficiency measurement



Ionization scheme development (on-line)

At

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ISOLDE and Neutron Time-of-Flight Committee

Addendum to the IS534 Proposal
(based on the text submitted in May 2013)

Beta-delayed fission, laser spectroscopy and shape-coexistence studies with astatine beams

15th January 2014

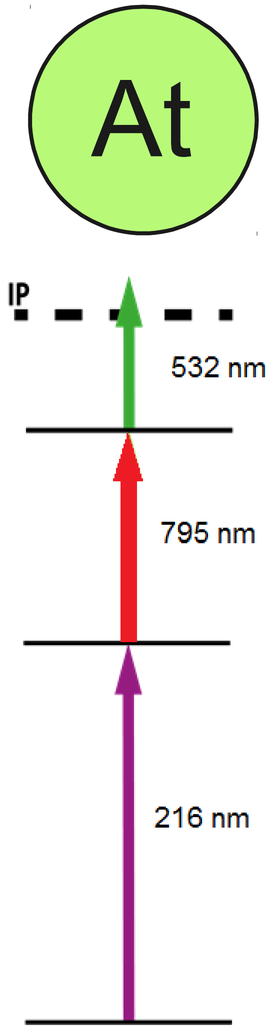
A. N. Andreyev[1,2], A. E. Barzakh[4], B. Andel[5], S. Antalic[5], D. Atanasov[3], B. Bastin[17], K. Blaum[3], Ch. Borgmann[6], T. E. Cocolios[7], T. Day Goodacre[6,7],H. De Witte[8], J. Elseviers[8], D. Fedorov[4], V. Fedosseev[6],L. Ghys[8], F. Herfurth[9], M. Huyse[8], Z. Kalaninova[5], M. Kowalska[6], U. Köster[10], S. Kreim[6], D. Lunney[11], K. Lynch[6,7], V. Manea[11], B.A. Marsh[6], P. Molkanov[4], D. Neidherr[9], K. Nishio[2], R.D. Page[12], D. Radulov[8], S. Raeder[8], E. Rapisarda[6], M. Rosenbusch[13], R.E. Rossel[6, 15], S. Rothe[6], L. Schweikhard[13], M. Seliverstov[4], I. Strashnov[7], I. Tsekanovich[18], V. Truesdale[1], P. Van den Bergh[8], C. Van Beveren[8], P. Van Duppen[8], K. Wendt[14], F. Wienholtz[13], R. N. Wolf[13], K. Zuber[16]

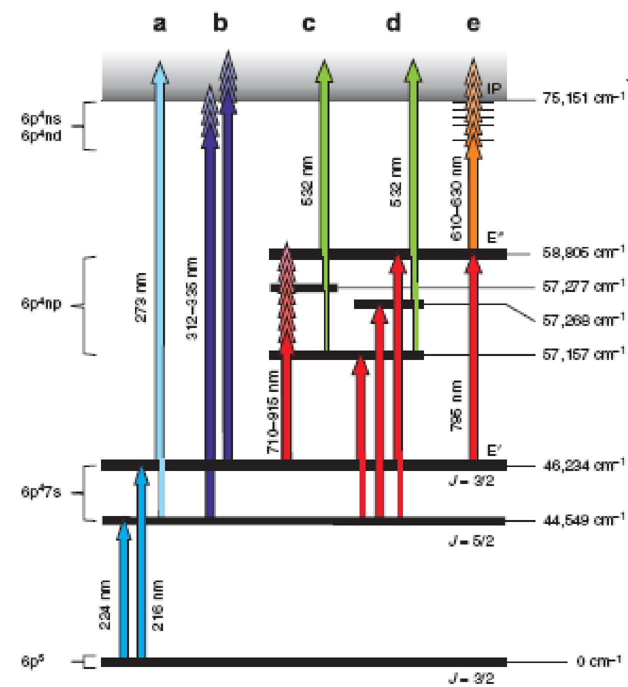
[1]University of York, York, UK
[2]Advanced Science Research Center, JAERI, Tokai-mura, Ibaraki, Japan
[3]Max Planck Institute for Nuclear Physics, Heidelberg, Germany
[4]Petersburg Nuclear Physics Institute, Gatchina, Russia
[5]Comenius University, Bratislava, Slovakia
[6]CERN, Geneva, Switzerland
[7]University of Manchester, UK
[8]KU Leuven, Instituut voor Kern- en Stralingsfysica,Leuven, Belgium
[9]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany
[10]ILL, Grenoble, France
[11]CSNSM-IN2P3-CNRS, Université Paris-Sud, Orsay, France
[12]Oliver Lodge Laboratory, University of Liverpool, Liverpool, UK
[13]Ernst-Moritz-Arndt University, Greifswald, Germany
[14]Johannes Gutenberg-University, Mainz, Germany
[15]Hochschulle RheinMain, Wiesbaden, Germany
[16]Technical University Dresden, Germany
[17]GANIL, France
[18]CENGB, Bordeaux, France

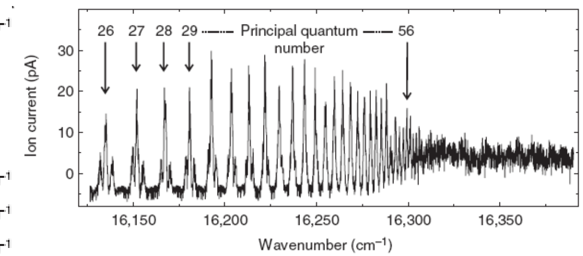
CERN-INTC-2014-028 / INTC-P-319-ADD-2
15/01/2014

Spokespersons: Andrei Andreyev (University of York) [Andrei.Andreyev@york.ac.uk]
Anatoly Barzakh (Gatchina) [barzakh@mail.ru]
Piet Van Duppen (IKS) [Piet.VanDuppen@fys.kuleuven.be]
Valentin Fedosseev (CERN) [Valentin.Fedosseev@cern.ch]

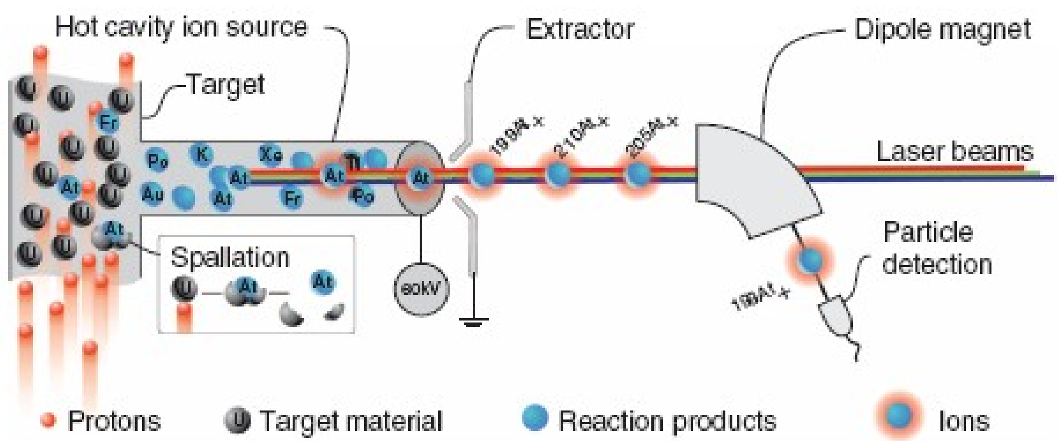
Ionization scheme development (on-line)







IP=9.31751(8) eV



Ionization scheme development (on-line)

At

nature COMMUNICATIONS

ARTICLE

Received 21 Aug 2012 | Accepted 27 Mar 2013 | Published 14 May 2013

DOI: 10.1038/ncomms2819

OPEN

Measurement of the first ionization potential of astatine by laser ionization spectroscopy

S. Rothe[1,2], A.N. Andreyev[3,4,5,6], S. Antalic[7], A. Borschevsky[8,9], L. Capponi[4,5], T.E. Cocolios[1], H. De Witte[10], E. Eliav[11], D.V. Fedorov[12], V.N. Fedosseev[1], D.A. Fink[1,13], S. Fritzsche[14,15,†], L. Ghys[10,16], M. Huyse[10], N. Imai[1,17], U. Kaldor[11], Yuri Kudryavtsev[10], U. Köster[18], J.F.W. Lane[4,5], J. Lassen[19], V. Liberati[4,5], K.M. Lynch[1,20], B.A. Marsh[1], K. Nishio[6], D. Pauwels[16], V. Pershina[14], L. Popescu[16], T.J. Procter[20], D. Radulov[10], S. Raeder[2,19], M.M. Rajabali[10], E. Rapisarda[10], R.E. Rossel[2], K. Sandhu[4,5], M.D. Seliverstov[1,4,5,12,10], A.M. Sjödin[1], P. Van den Bergh[10], P. Van Duppen[10], M. Venhart[21], Y. Wakabayashi[6] & K.D.A. Wendt[2]

Ionization scheme development (on-line)

RILIS

Ra

Request for RILIS enhanced Ra Ion beams at ISOLDE

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Collinear resonance ionization spectroscopy of radium ions

May 30, 2014

K.M. Lynch[1], J. Billowes[2], M.L. Bissell[1], I. Budinčević[1], T.E. Cocolios[2], T. Day Goodacre[2,3], R.P. de Groote[1], V.N. Fedosseev[3], K.T. Flanagan[2], S. Franchoo[4], R.F. Garcia Ruiz[1], H. Heylen[1], T. Kron[5], B.A. Marsh[3], G. Neyens[1], R.E. Rossel[3,5,6], S. Rothe[3], I. Strashnov[2], H.H. Stroke[7], K.D.A. Wendt[5].

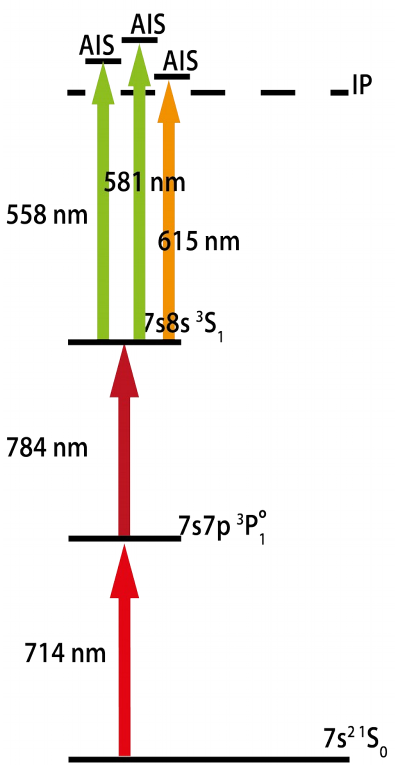
CERN

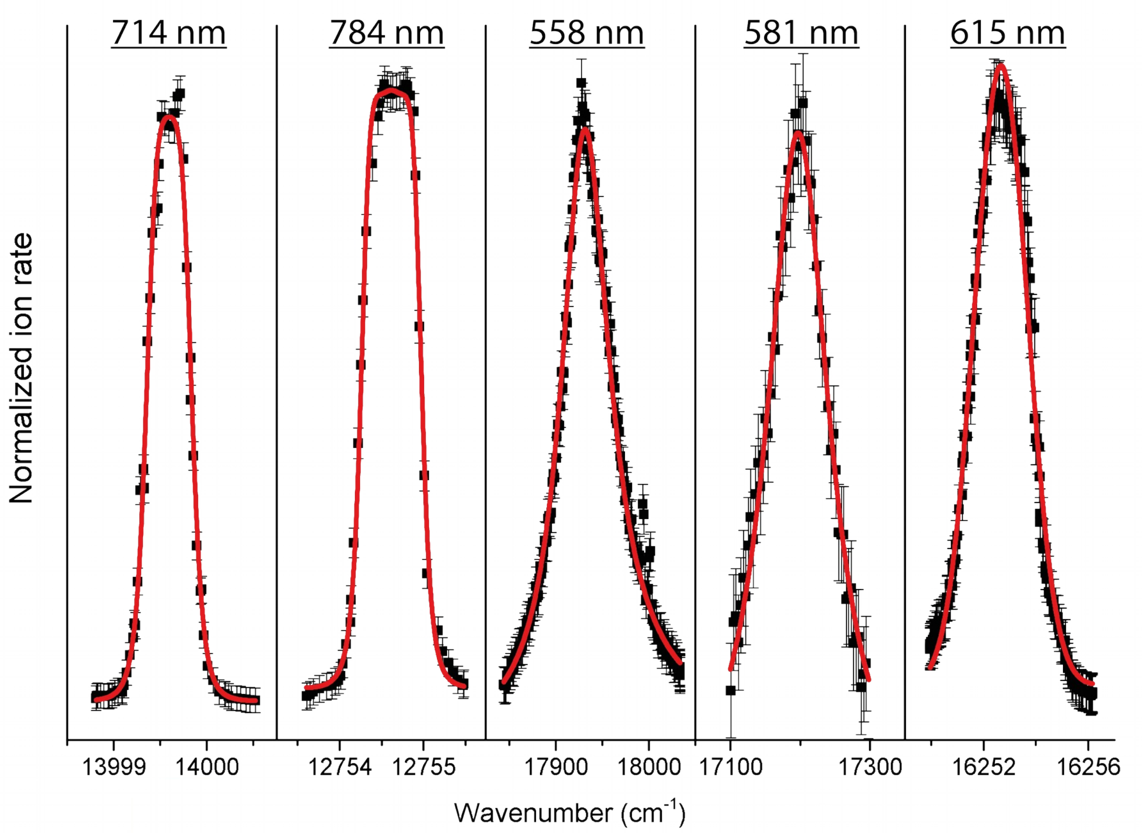
ISOLDE

Ionization scheme development (on-line)

RILIS

Ra





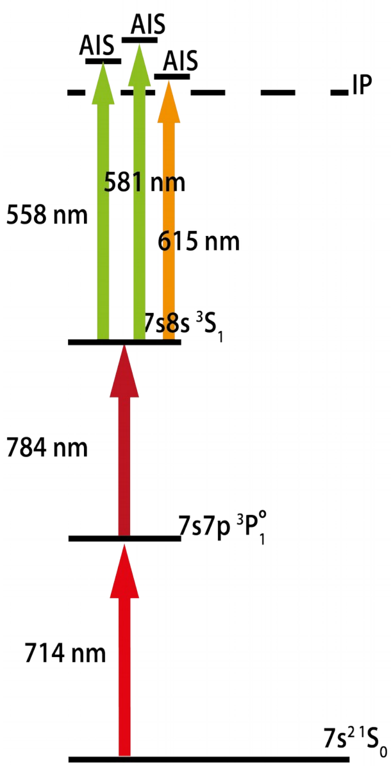
CERN

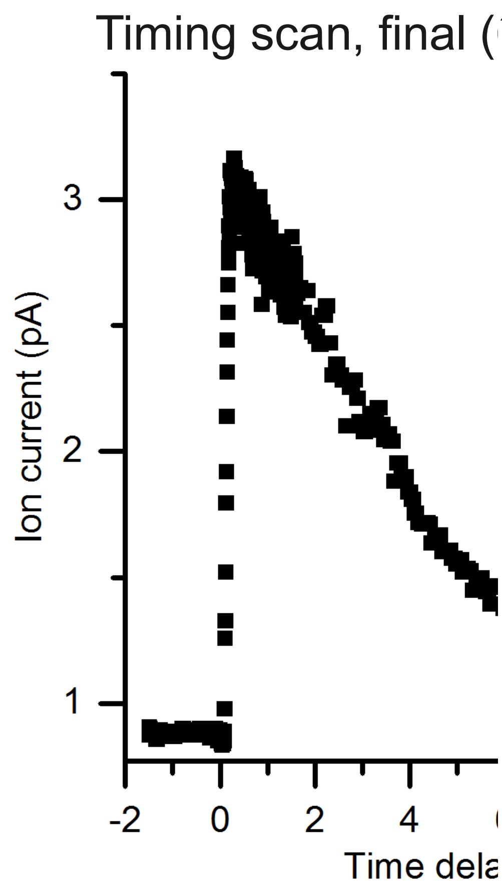
ISOLDE

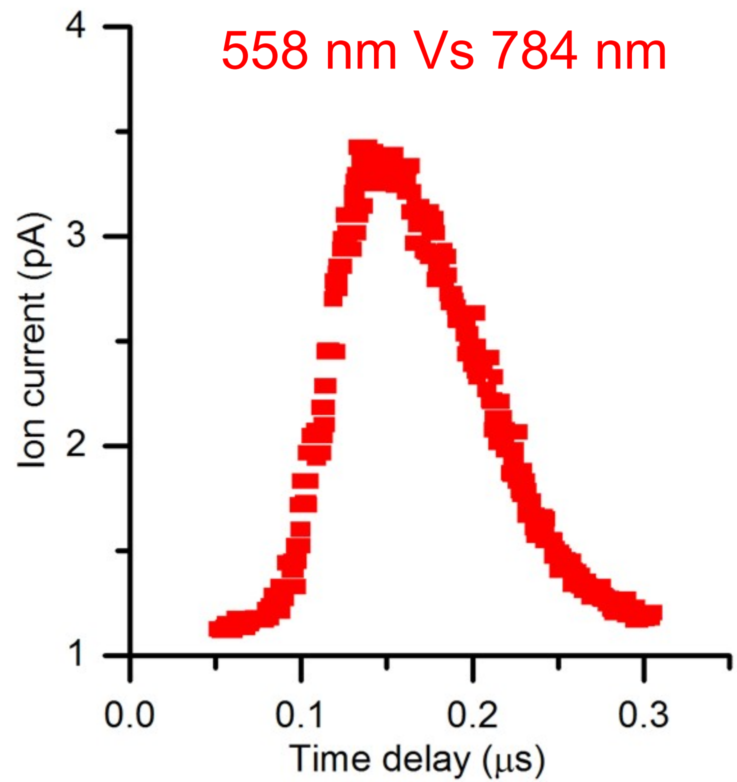
Ionization scheme development (on-line)

Ra

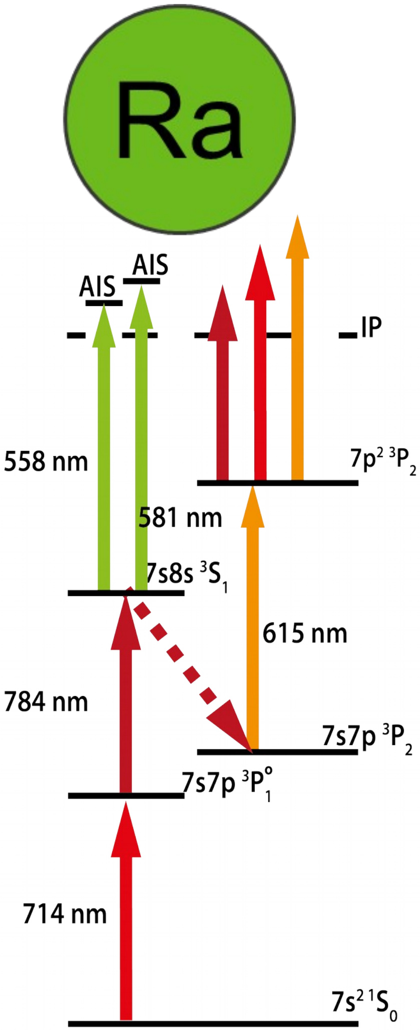
Strange effects observed at 615 nm transition

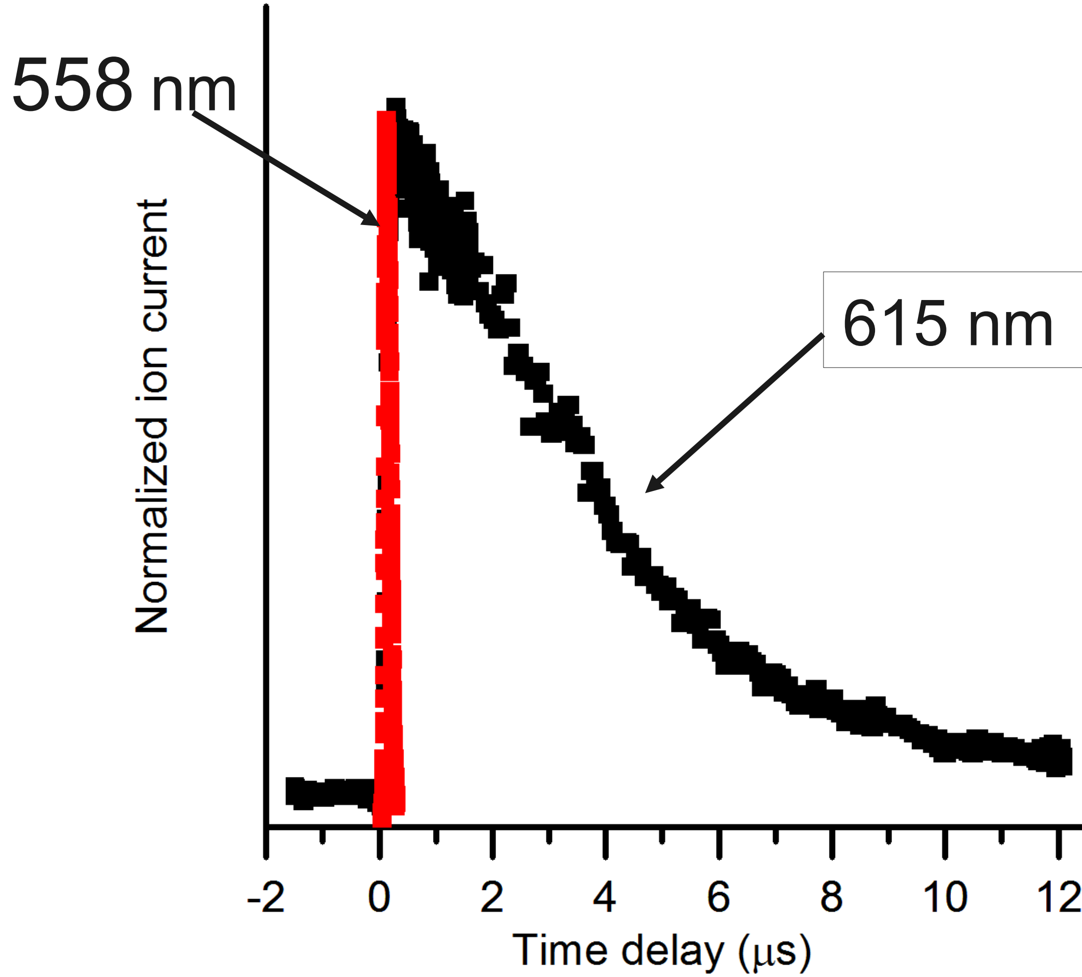




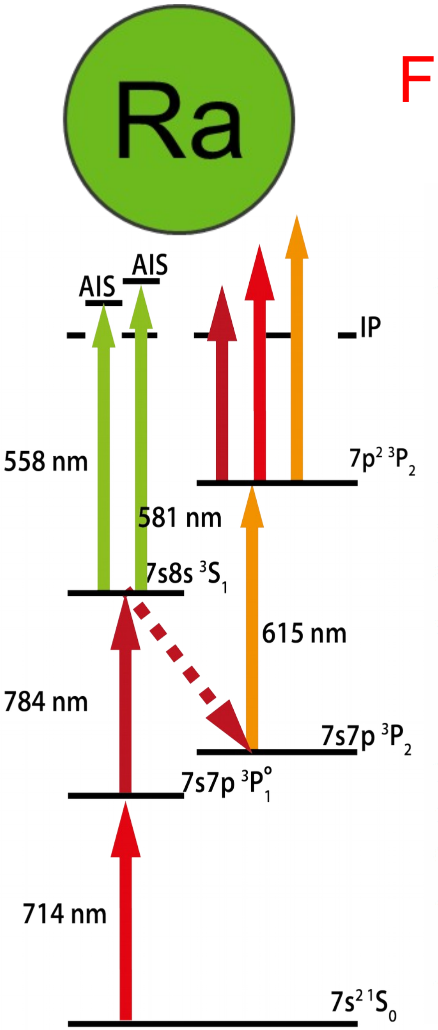


Ionization scheme development (on-line)



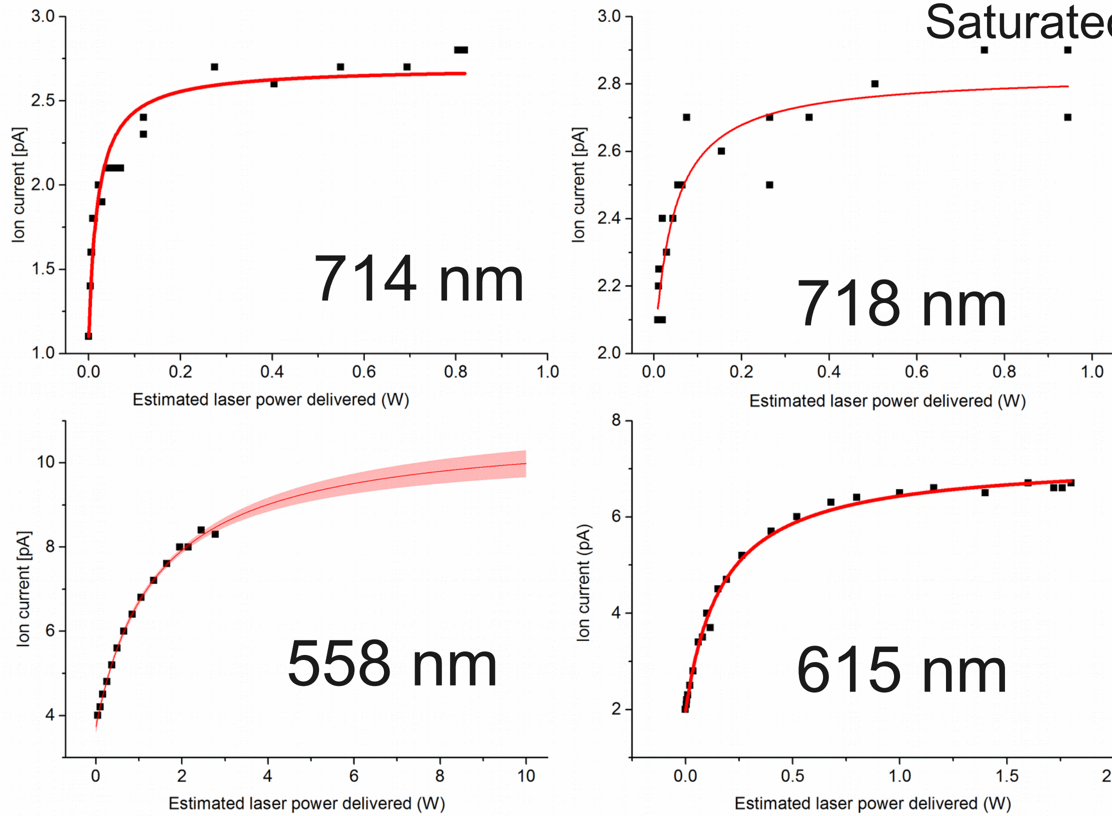


Ionization scheme development (on-line)



First RILIS ionization scheme with optical pumping!

Saturated transitions



Applied twice on-line in 2016

ISOLDE physics with RILIS

- **RILIS as an ion source for ion beam production**
- **RILIS as a significant part of experiments**
- **Laser in-source spectroscopy – experiments initiated by RILIS team**

RILIS for ion beam production

- **Until now – the main mode of RILIS operation**

- **In 2016: COLLAPS, CRIS, IDS, REX-Miniball, ISOLTRAP, Solid-state Physics, Medicine…**

RILIS is a significant part of experiment

Smaller, but quickly growing part of ISOLDE experiments

RILIS team is regarded as an experiment participant

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Q-values of Mirror Transitions for fundamental interaction studies

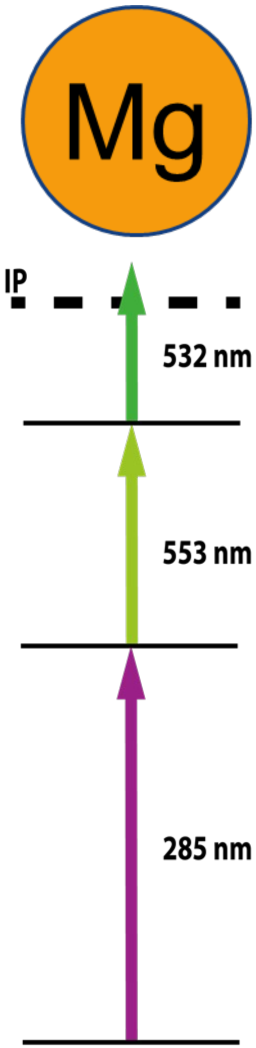
May 28th 2013

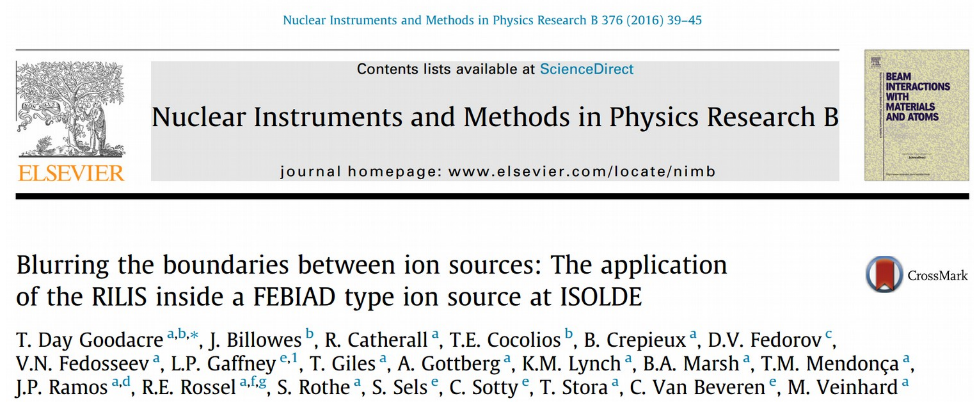
M. Breitenfeldt[1], D. Atanasov[2], K. Blaum[2], T. Eronen[2], P. Finlay[1], F. Herfurth[3], M. Kowalska[4], S. Kreim[4], Yu. Litvinov[3], D. Lunney[5], V. Manea[5], D. Neidherr[3], T. Porobic[1], M. Rosenbusch[6], L. Schweikhard[6], N. Severijns[1], F. Wienholtz[6], R.N. Wolf[6], K. Zuber[7]

Experiment needs ion beams of Mg, Ne and Na

Initial plan: plasma ion source to be used

Too high contamination for Mg in plasma source





Nuclear Instruments and Methods in Physics Research B 376 (2016) 39–45

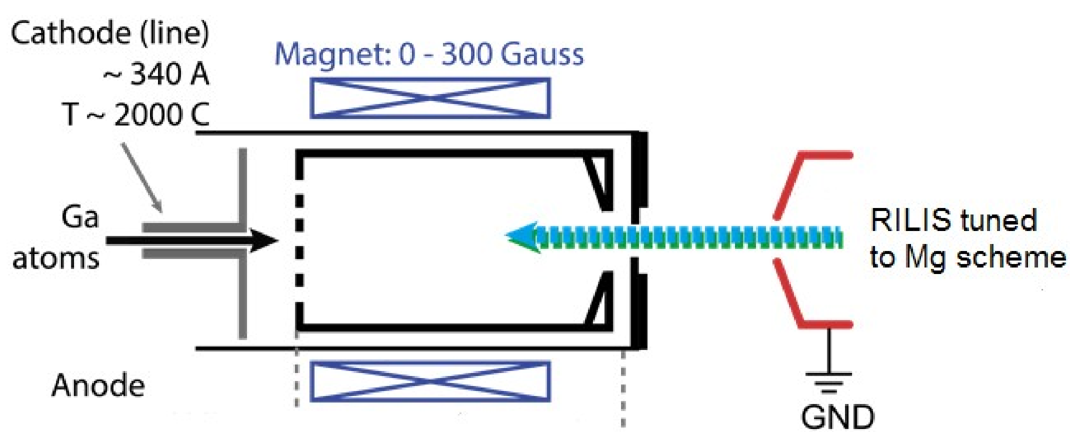
Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

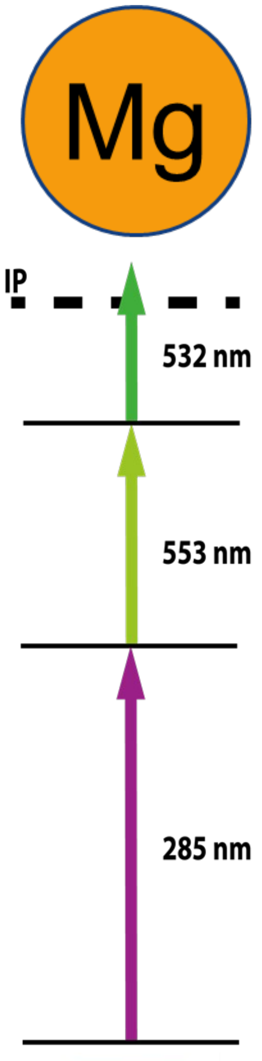
journal homepage: www.elsevier.com/locate/nimb

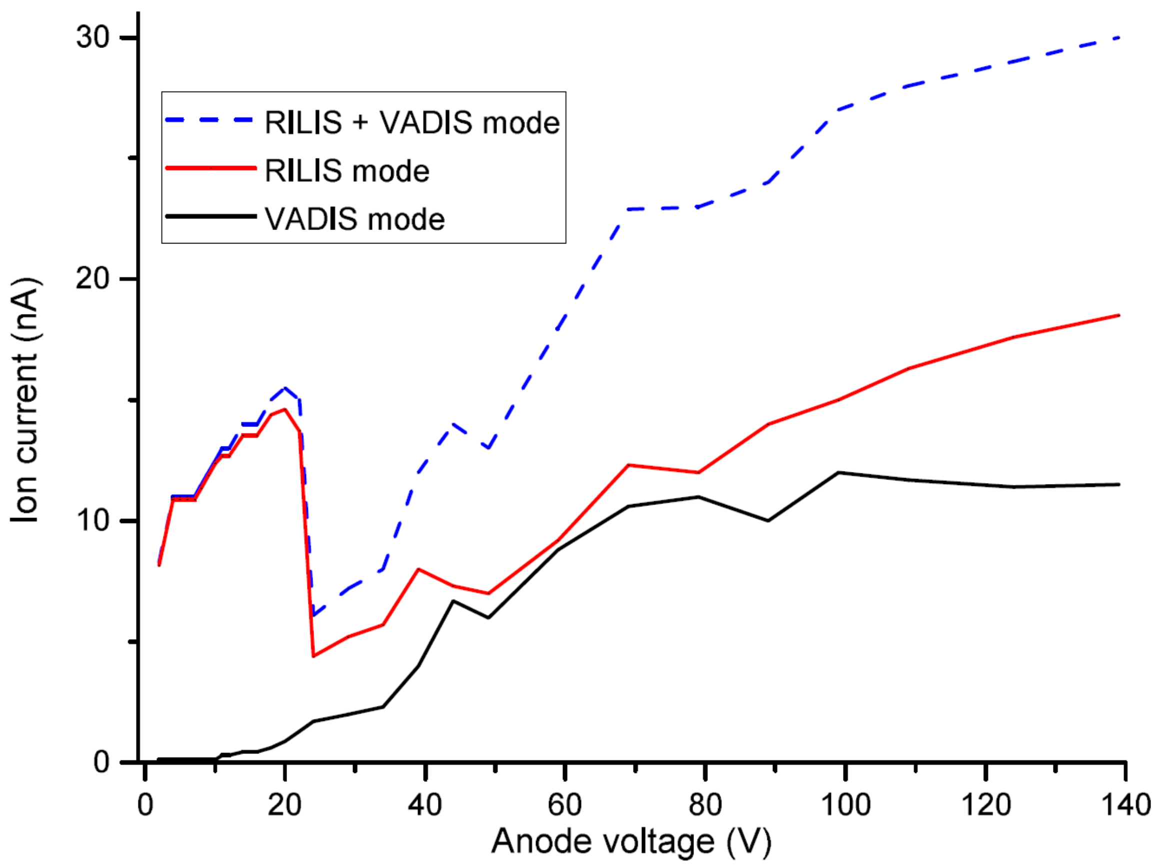
Blurring the boundaries between ion sources: The application of the RILIS inside a FEBIAD type ion source at ISOLDE

T. Day Goodacre [a,b,*], J. Billowes [b], R. Catherall [a], T.E. Cocolios [b], B. Crepieux [a], D.V. Fedorov [c], V.N. Fedosseev [a], L.P. Gaffney [e,1], T. Giles [a], A. Gottberg [a], K.M. Lynch [a], B.A. Marsh [a], T.M. Mendonça [a], J.P. Ramos [a,d], R.E. Rossel [a,f,g], S. Rothe [a], S. Sels [e], C. Sotty [e], T. Stora [a], C. Van Beveren [e], M. Veinhard [a]



Too high contamination for Mg in plasma source





^{7}Be target production for n-TOF

PAUL SCHERRER INSTITUT

ISTITUTO NAZIONALE DI FISICA NUCLEARE

^{7}Be(n,α) and ^{7}Be(n,p) cross-sections measurement for the Cosmological Lithium problem at the n_TOF facility at CERN

M. Barbagallo, N. Colonna, A. Musumarra, J. Andrejewski, L. Cosentino, E. Maugeri, J. Perkowski, B. Langhans, M. Mastromarco, A. Gawlik, D. Schumann, A. Mengoni, P. Finocchiaro F. Kappeler, L. Damone, A. Pappalardo, O. Aberle, S. Heinitz, R. Dressler, E. Chiaveri and the **n_TOF collaboration**.

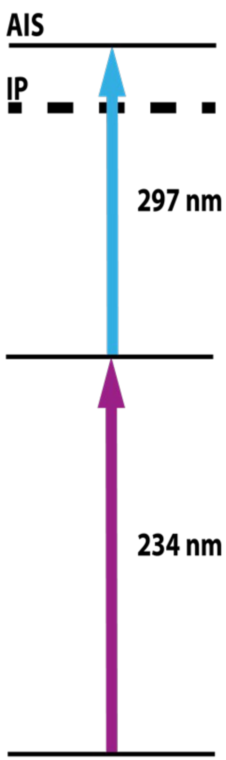
J. Schell, J. M. Correia, K. Johnston, M. Borges-Garcia, U. Koester, B. Marsh, T. Goodacre, R. Catherall, A. Bernardes, T. Stora, J. Ballof, B. Crepieux.

Isolde Workshop and Users Meeting, CERN, December 2016

Requirements: isotope selective ionization, reduce cavity ion load

^{7}Be target production for n-TOF

^{7}Be to be extracted from irradiated target material delivered from PSI

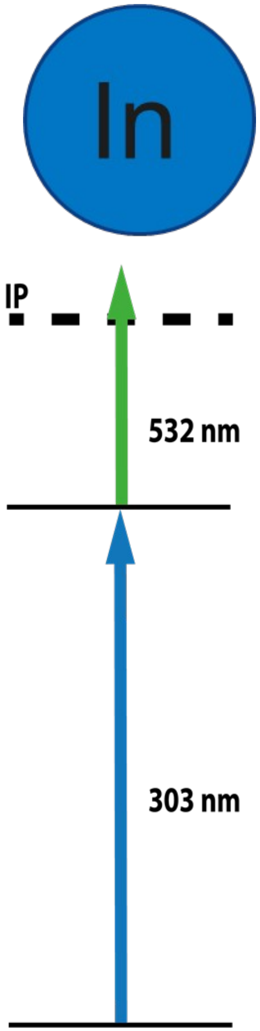


Solutions:

1. RILIS selective ionization of Be atoms – to reduce cavity ion load

2. Reduction of first step linewidth 16 GHz to 9 GHz leads to isotope selectivity increased from factor 3 to 10

Isomer selective ionization of In



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

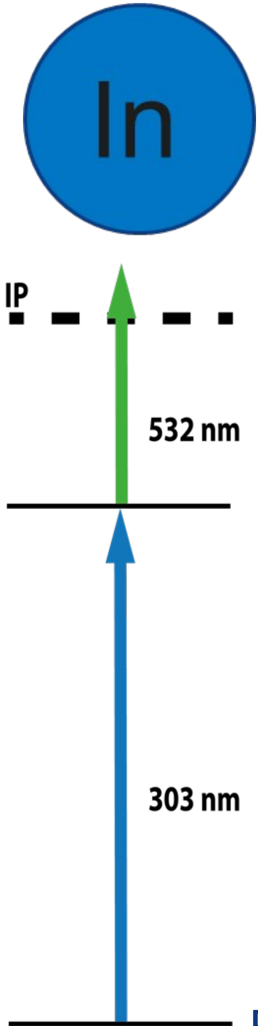
Proposal to the ISOLDE and Neutron Time-of-Flight Committee

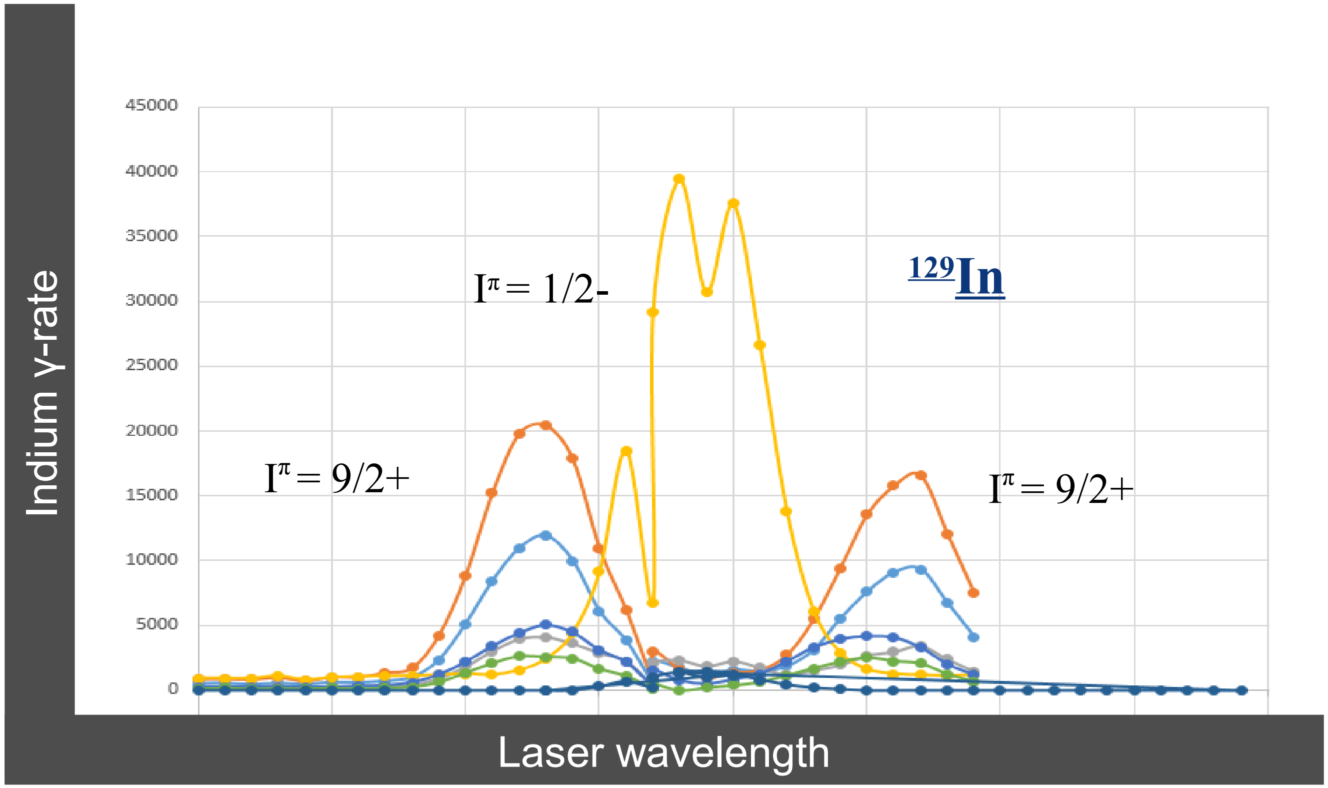
Gamma and fast-timing spectroscopy of the doubly magic ^{132}Sn and its one- and two-neutron particle/hole neighbours

October 12, 2015

L.M. Fraile[1], A. Korgul[2], A. Gargano[3], A. Aprahamian[4], A. Algora[5], G. Benzoni[6], M.J.G. Borge[7], M. Carmona[1], C. Costache[8], A. Covello[9], H. Duckwitz[10], P. Van Duppen[11], V. Fedosseev[7], G. Fernández-Martínez[12], D. Ghiţă[8], T. Grahn[13,14], P.T. Greenlees[13,14], R. Grzywacz[15,16], C. Henrich[12], P. Hoff[17], M. Huyse[11], T. Ilieva[12], Z. Janas[2], A. Jokinen[13], J. Jolie[10], M. Karny[2], M. Kicińska-Habior[2], Th. Kröll[12], W. Kurcewicz[2], U. Köster[18], S. Lalkovski[19], R. Lică[7], M. Madurga[7], N. Mărginean[8], R. Mărginean[8], B. Marsh[7], C. Mazzocchi[2], C. Mihai[8], R.E. Mihai[8], A.I. Morales[6], K. Moschner[10], S. Nae[8], A. Negret[8], V. Paziy[1], M. Piersa[2], P. Rahkila[13,14], J. Pakarinen[13,14], J.-M. Régis[10], E. Ruchowska[20], K.P. Rykaczewski[16], G. Simpson[21], Ch. Sotty[8], M. Stanoiu[8], M. Stryjczyk[2], O. Tengblad[22], A. Turturica[8], J.M. Udías[1], V. Vedia[1], W.B. Walters[23], N. Warr[10], H. De Witte[11].

Isomer selective ionization of In





RILIS is the only option when low production rate or/and close half-lives

Optical pumping in COLLAPS

Mn

Physics Letters B 760 (2016) 387–392

Contents lists available at ScienceDirect

Physics Letters B

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ELSEVIER

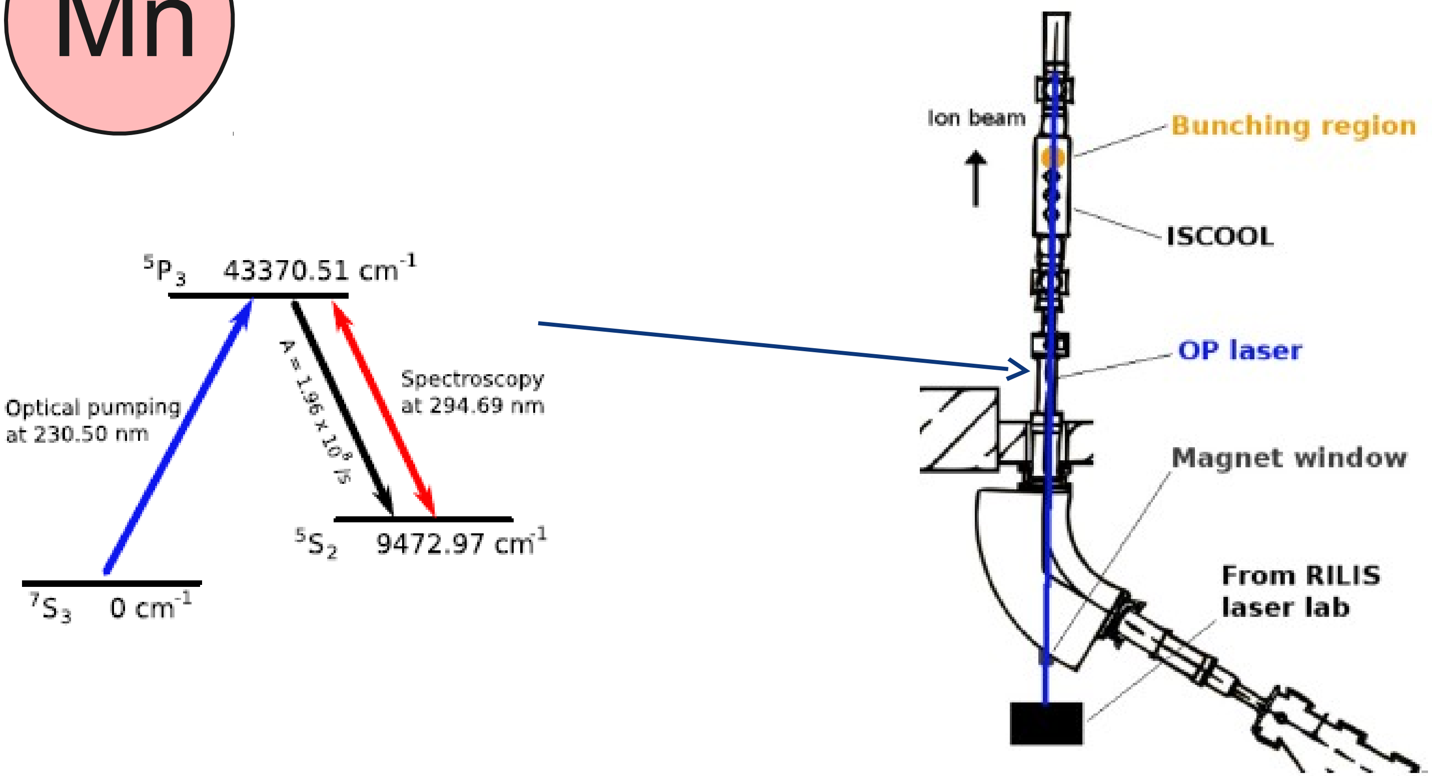
Quadrupole moments of odd-A $^{53-63}$Mn: Onset of collectivity towards $N = 40$

C. Babcock [a,b,*], H. Heylen [c,*], M.L. Bissell [d], K. Blaum [e], P. Campbell [d], B. Cheal [a], D. Fedorov [k], R.F. Garcia Ruiz [c], W. Geithner [g], W. Gins [c], T. Day Goodacre [d,b], L.K. Grob [i,d], M. Kowalska [b], S.M. Lenzi [h], B. Maass [i], S. Malbrunot-Ettenauer [b], B. Marsh [b], R. Neugart [e,j], G. Neyens [c], W. Nörtershäuser [i], T. Otsuka [f], R. Rossel [b], S. Rothe [b], R. Sánchez [g], Y. Tsunoda [l], C. Wraith [a], L. Xie [d], X.F. Yang [c]

[a] Oliver Lodge Laboratory, Oxford Street, University of Liverpool, L69 7ZE, UK
[b] ISOLDE, CERN, CH-1211 Geneva 23, Switzerland
[c] KU Leuven, Instituut voor Kern- en Stralingsfysica, 3001 Leuven, Belgium
[d] School of Physics and Astronomy, University of Manchester, M13 9PL, UK
[e] Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany
[f] Dept. of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[g] GSI Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt, Germany
[h] Dipartimento di Fisica e Astronomia dell'Università and INFN, Sezione di Padova, I-35131 Padova, Italy

Mn

Optical pumping in COLLAPS

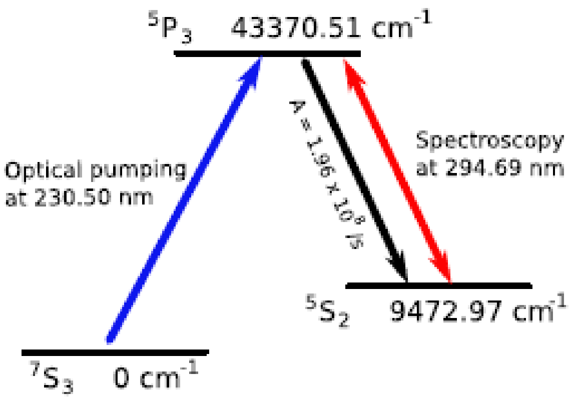


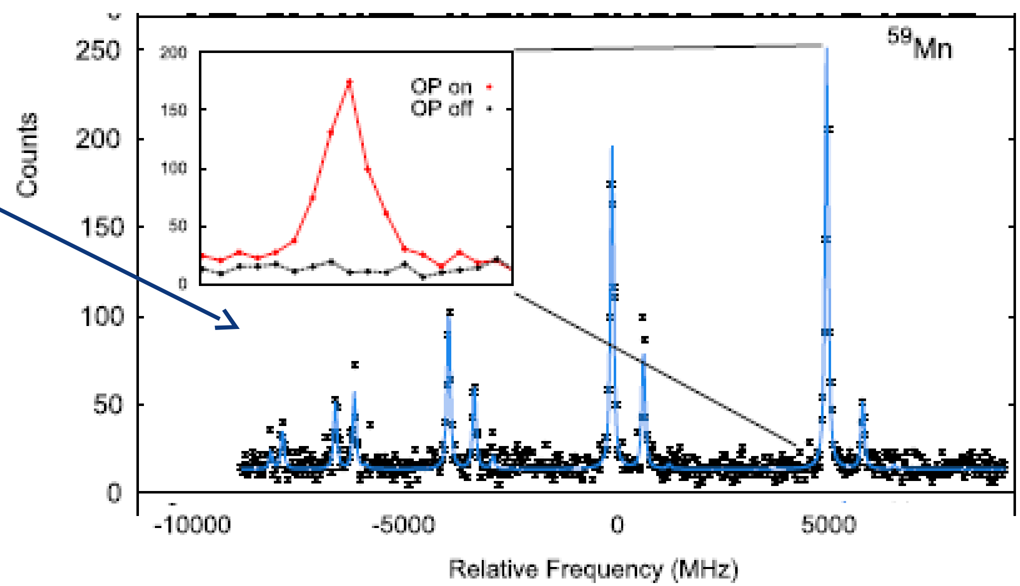
Schematic for the entry of optical pumping (OP) lasers from the RILIS laser lab into the cooler/buncher (ISCOOL), where they interact with trapped ions in the bunching region

Mn

Optical pumping in COLLAPS

Example of hfs spectrum for ^{59}Mn with the optical pumping (OP) laser on and off





Without the use of optical pumping, no resonant counts were seen !

Laser in-source spectroscopy – experiments initiated by RILIS team

In-source laser spectroscopy

Study of nuclear ground state/isomer properties (spins, charge radii, electromagnetic moments)

Beta-delayed fission study

Laser spectroscopy with RILIS, detection FC, Windmill and ISOLTRAP

RILIS

In-source laser spectroscopy

At Au Po Hg Bi

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Shape-coexistence and shape-evolution studies for bismuth isotopes by in-source laser spectroscopy and beta-delayed fission in ^{188}Bi.

13.10.2015

A. N. Andreyev[1,2], A. E. Barzakh[3], N. Althubiti[7], B. Andel[5], S. Antalic[5], D. Atanasov[4], J. Billowes[7], K. Blaum[4], T. E. Cocolios[8], T. Day Goodacre[6,7], J. Cubiss[1], D. Doherty[1], D. Fedorov[3], V. Fedosseev[6], R. Harding[1], F. Herfurth[9], M. Huyse[8], S. Kreim[4], , D. Lunney[10], V. Manea[4], B.A. Marsh[6], P. Molkanov[3], M. Mougeot[10], D. Neidherr[9], K. Nishio[2], M. Rosenbusch[11], R.E. Rossel[6,13], S. Rothe[6,7], L. Schweikhard[11], C. Seiffert[6], M. Seliverstov[3], S.Sels[8], I. Tsekanovich[15], P. Van den Bergh[8], P. Van Duppen[8], A. Welker[6,14], K. Wendt[12], F. Wienholtz[11], H. De Witte[8], R. N. Wolf[4], K. Zuber[14]

CERN

ISOLDE

In-source laser spectroscopy

Hg

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

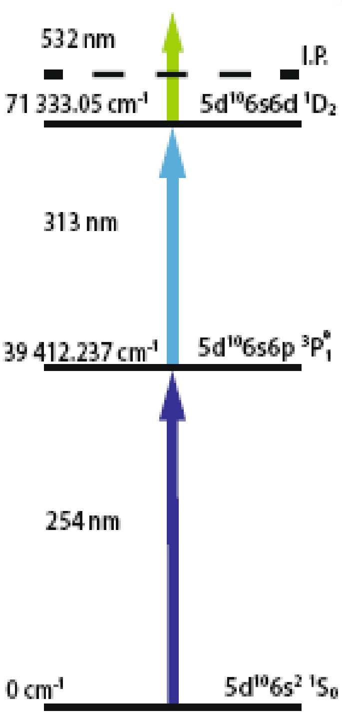
In-source laser spectroscopy of mercury isotopes

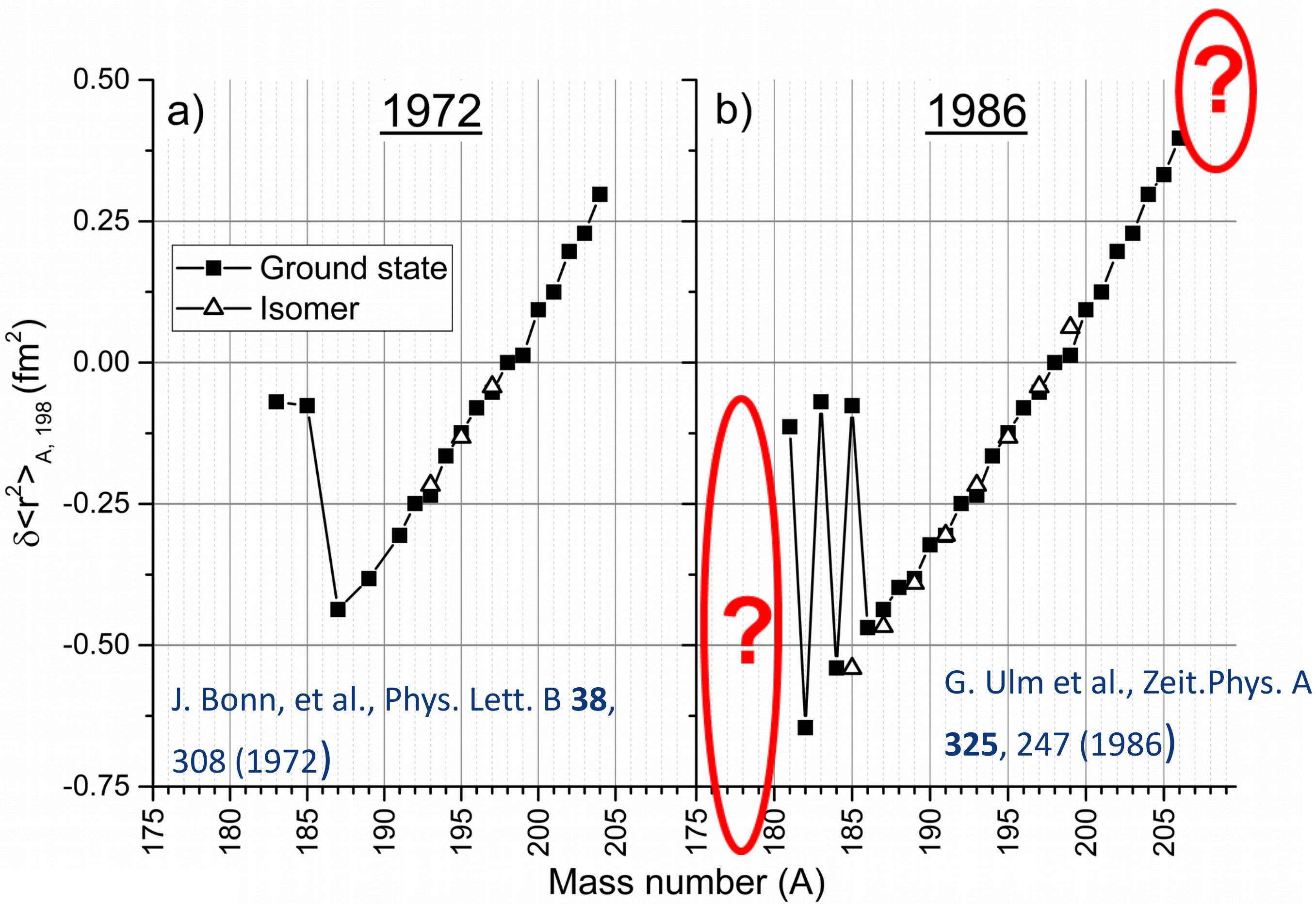
October 10, 2014

L. P. Gaffney[1], T. Day Goodacre[2,3], A. N. Andreyev[4], M. Seliverstov[5,2], N. Althubiti[3], B. Andel[11], S. Antalic[11], D. Atanasov[10], A. E. Barzakh[5], K. Blaum[10], J. Billowes[3], T. E. Cocolios[3], J. Cubiss[4], G. Farooq-Smith[3], D. V. Fedorov[5], V. N. Fedosseev[2], R. Ferrer[1], K. T. Flanagan[3], L. Ghys[1,12], C. Granados[1], A. Gottberg[2], F. Herfurth[8], M. Huyse[1], D. G. Jenkins[4], D. Kisler[10], S. Kreim[10,2], T. Kron[7], Yu. Kudryavtsev[1], D. Lunney[13], K. M. Lynch[1,2], B. A. Marsh[2], V. Manea[10], T. M. Mendonca[2], P. L. Molkanov[5], D. Neidherr[8], R. Raabe[1], J. P. Ramos[2], S. Raeder[1], E. Rapisarda[2], M. Rosenbusch[9], R. E. Rossel[2,7], S. Rothe[2], L. Schweikhard[9], S. Sels[1], T. Stora[2], I. Tsekhanovich[6], C. Van Beveren[1], P. Van Duppen[1], M. Veinhard[2], R. Wadsworth[4], A. Welker[14], F. Wienholtz[9], K. Wendt[7], G. L. Wilson[4], S. Witkins[3], R. Wolf[10], K. Zuber[14]

In-source laser spectroscopy

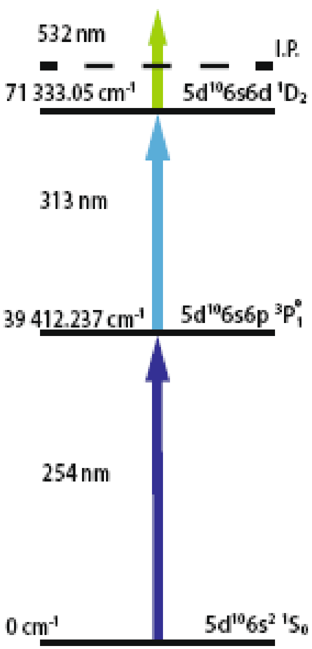
Hg





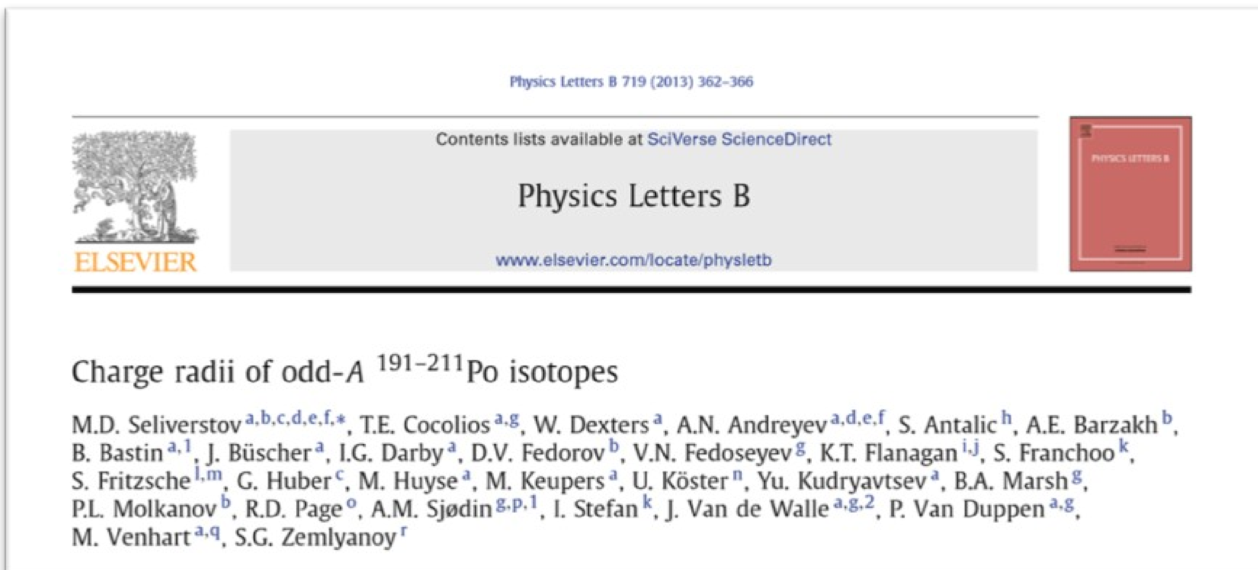
In-source laser spectroscopy

Hg



Next steps require a higher sensitivity method

In-source spectroscopy
sensitivity record ~0.01 ions/s (^{191}Po)



Physics Letters B 719 (2013) 362–366

Contents lists available at SciVerse ScienceDirect

Physics Letters B

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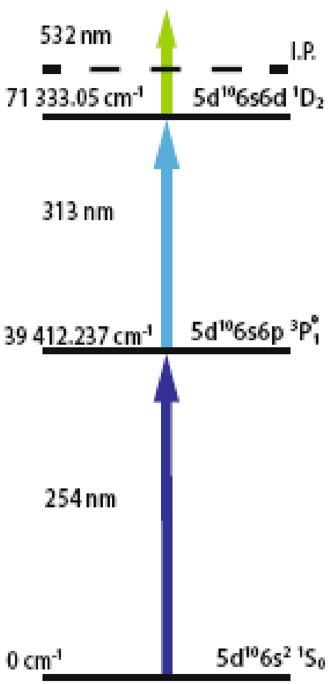
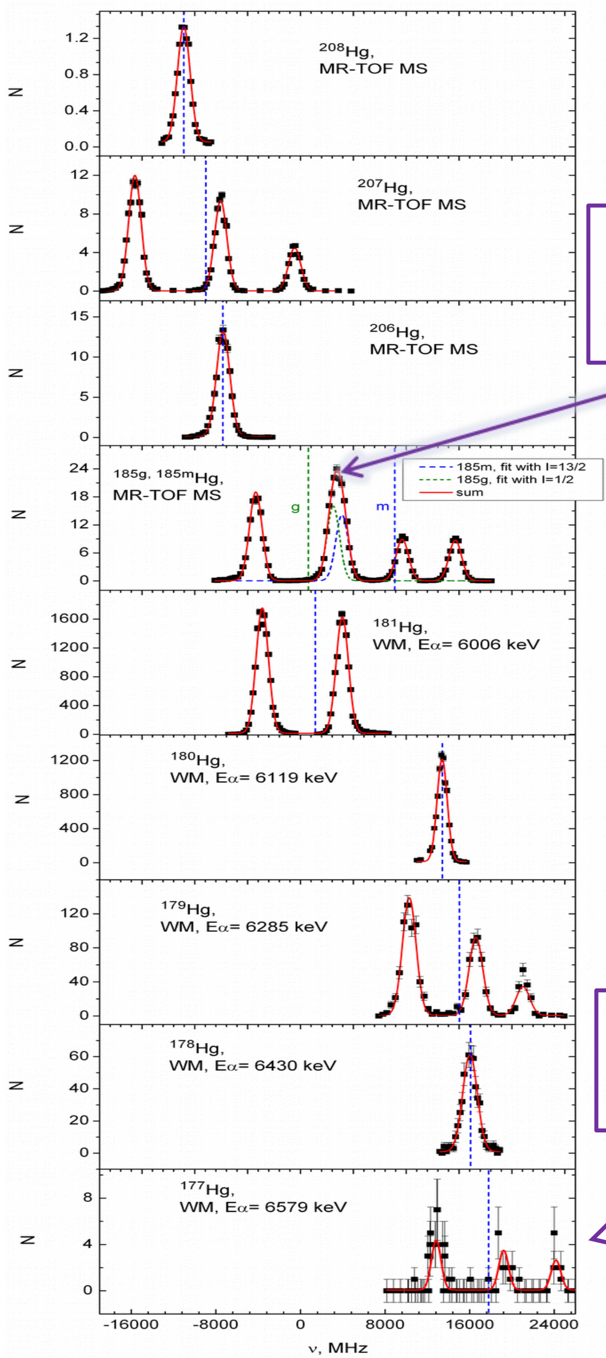
ELSEVIER

Charge radii of odd-A $^{191-211}$Po isotopes

M.D. Seliverstov [a,b,c,d,e,f,*], T.E. Cocolios [a,g], W. Dexters [a], A.N. Andreyev [a,d,e,f], S. Antalic [h], A.E. Barzakh [b], B. Bastin [a,1], J. Büscher [a], I.G. Darby [a], D.V. Fedorov [b], V.N. Fedoseyev [g], K.T. Flanagan [i,j], S. Franchoo [k], S. Fritzsche [l,m], G. Huber [c], M. Huyse [a], M. Keupers [a], U. Köster [n], Yu. Kudryavtsev [a], B.A. Marsh [g], P.L. Molkanov [b], R.D. Page [o], A.M. Sjødin [g,p,1], I. Stefan [k], J. Van de Walle [a,g,2], P. Van Duppen [a,g], M. Venhart [a,q], S.G. Zemlyanoy [r]

2015





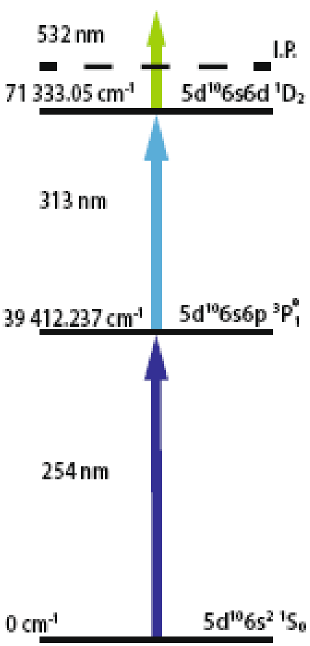
Resolution of the method is of about 2-3 GHz

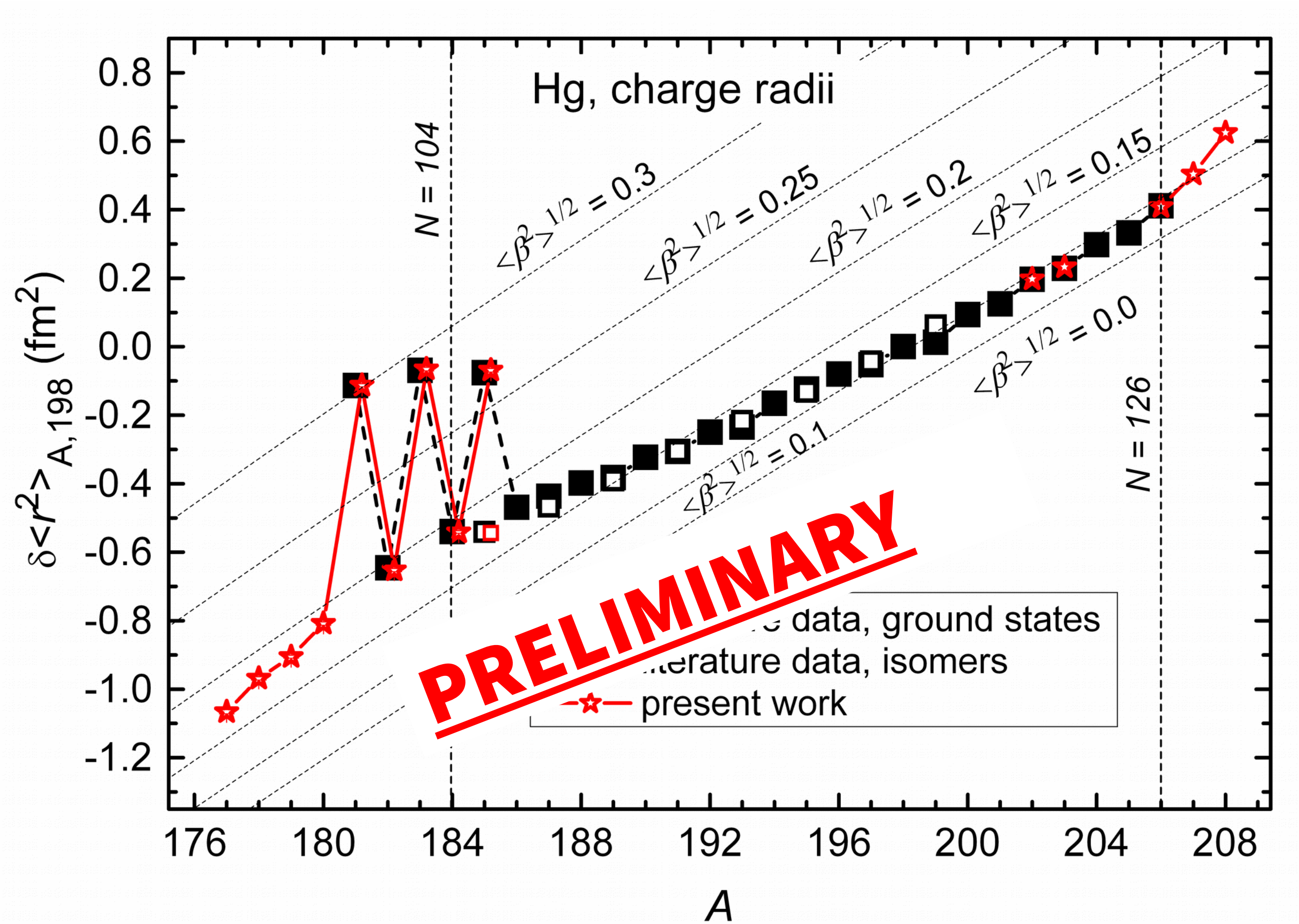
Successful Isotope shift and Hyperfine structure measurements

Sensitivity ~0.1 ions/s (^{177}Hg)

In-source laser spectroscopy

Hg

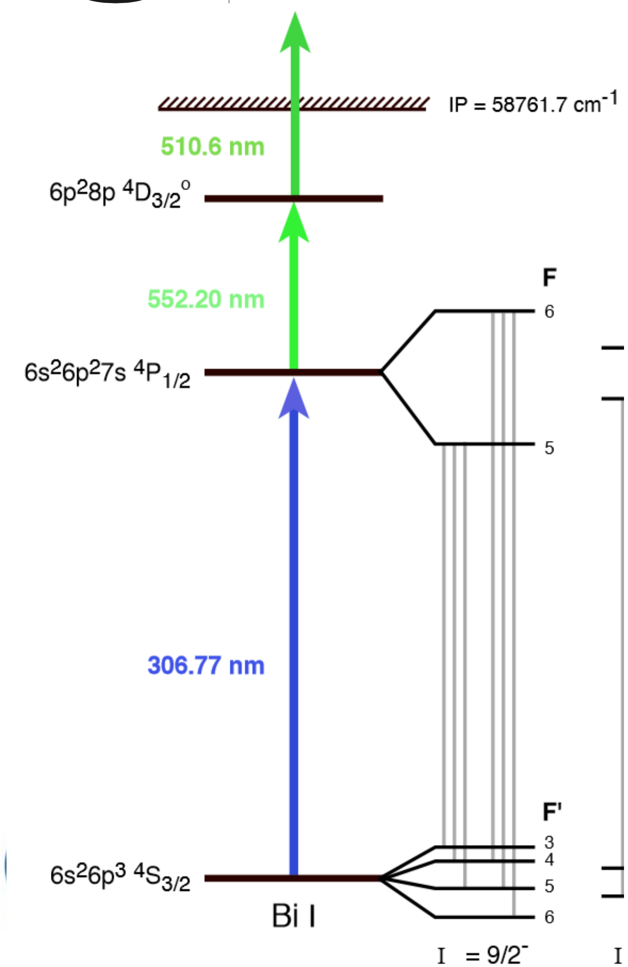




In-source laser spectroscopy

Bi

2016



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Shape-coexistence and shape-evolution studies for bismuth isotopes by in-source laser spectroscopy and beta-delayed fission in ^{188}Bi.

13.10.2015

A. N. Andreyev[1,2], A. E. Barzakh[3], N. Althubiti[7], B. Andel[5], S. Antalic[5], D. Atanasov[4], J. Billowes[7], K. Blaum[4], T. E. Cocolios[8], T. Day Goodacre[6,7], J. Cubiss[1], D. Doherty[1], D. Fedorov[3], V. Fedosseev[6], R. Harding[1], F. Herfurth[9], M. Huyse[8], S. Kreim[4], , D. Lunney[10], V. Manea[4], B.A. Marsh[6], P. Molkanov[3], M. Mougeot[10], D. Neidherr[9], K. Nishio[2], M. Rosenbusch[11], R.E. Rossel[6,13], S. Rothe[6,7], L. Schweikhard[11], C. Seiffert[6], M. Seliverstov[3], S.Sels[8], I. Tsekanovich[15], P. Van den Bergh[8], P. Van Duppen[8], A. Welker[6,14], K. Wendt[12], F. Wienholtz[11], H. De Witte[8], R. N. Wolf[4], K. Zuber[14]

RILIS

In-source laser spectroscopy

Bi

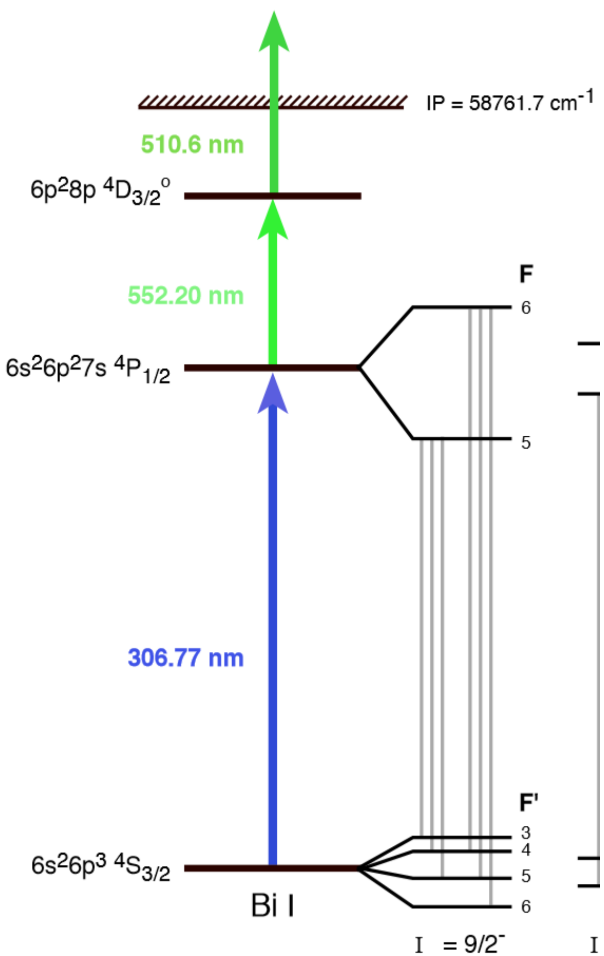
2016

-Second step linewidth>60 GHz

-Active timing stabilization of the scanning laser

-Active power stabilization of the scanning laser

-Wavelength monitoring



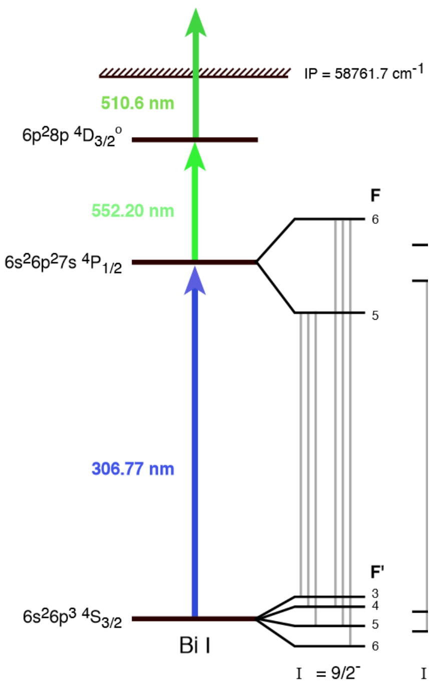
Extension of the charge radii measurements from ^{187}Bi-^{218}Bi

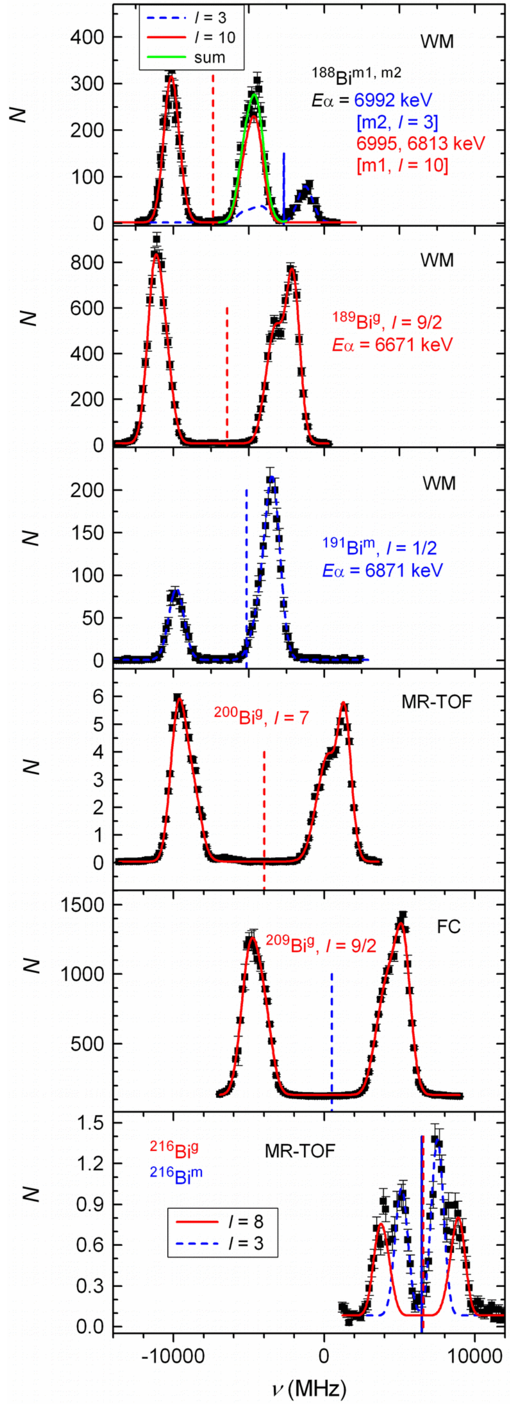
Isomer selectivity for BDF

ISOLDE

RILIS

Bi





2016

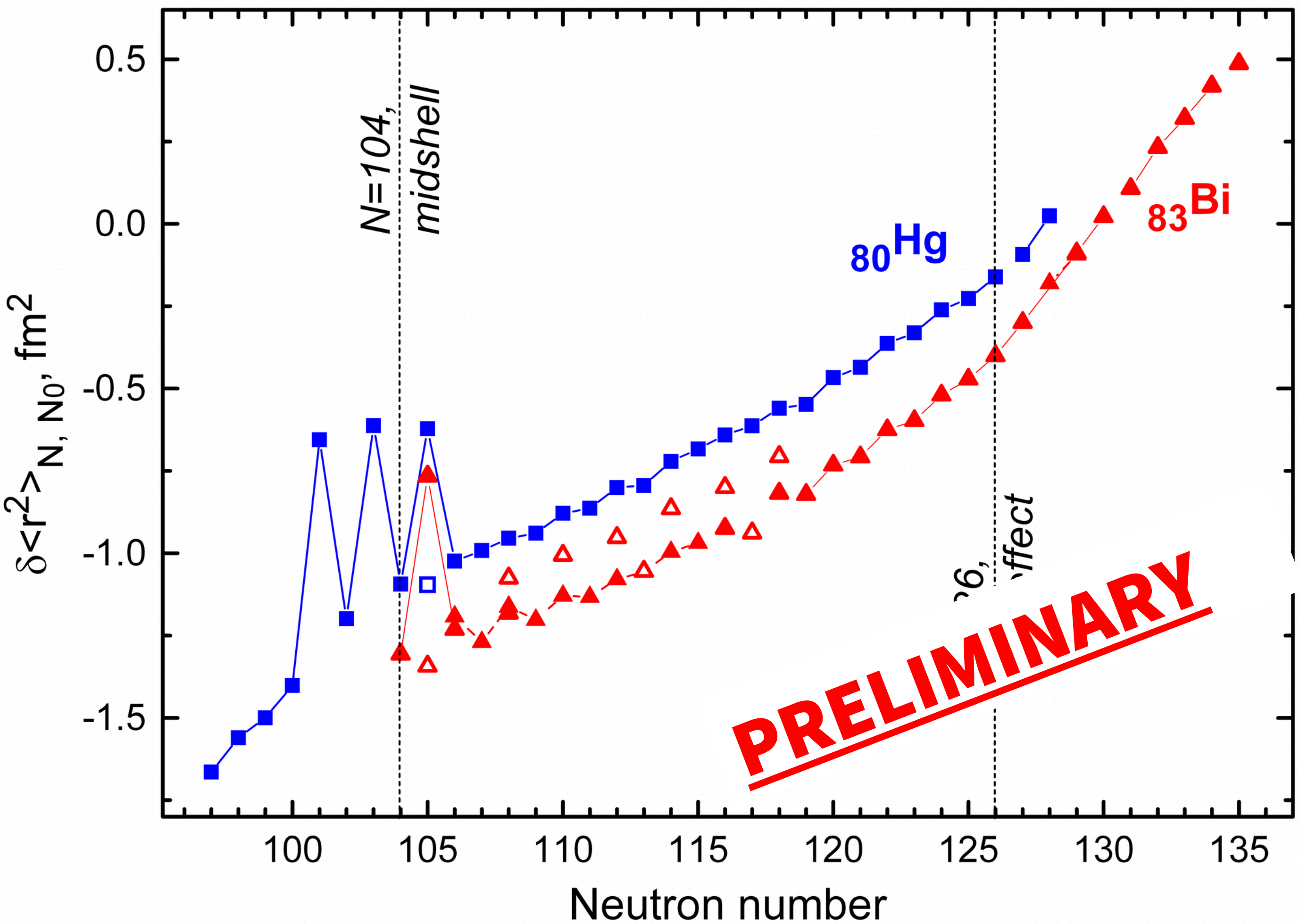
PRELIMINARY

CERN

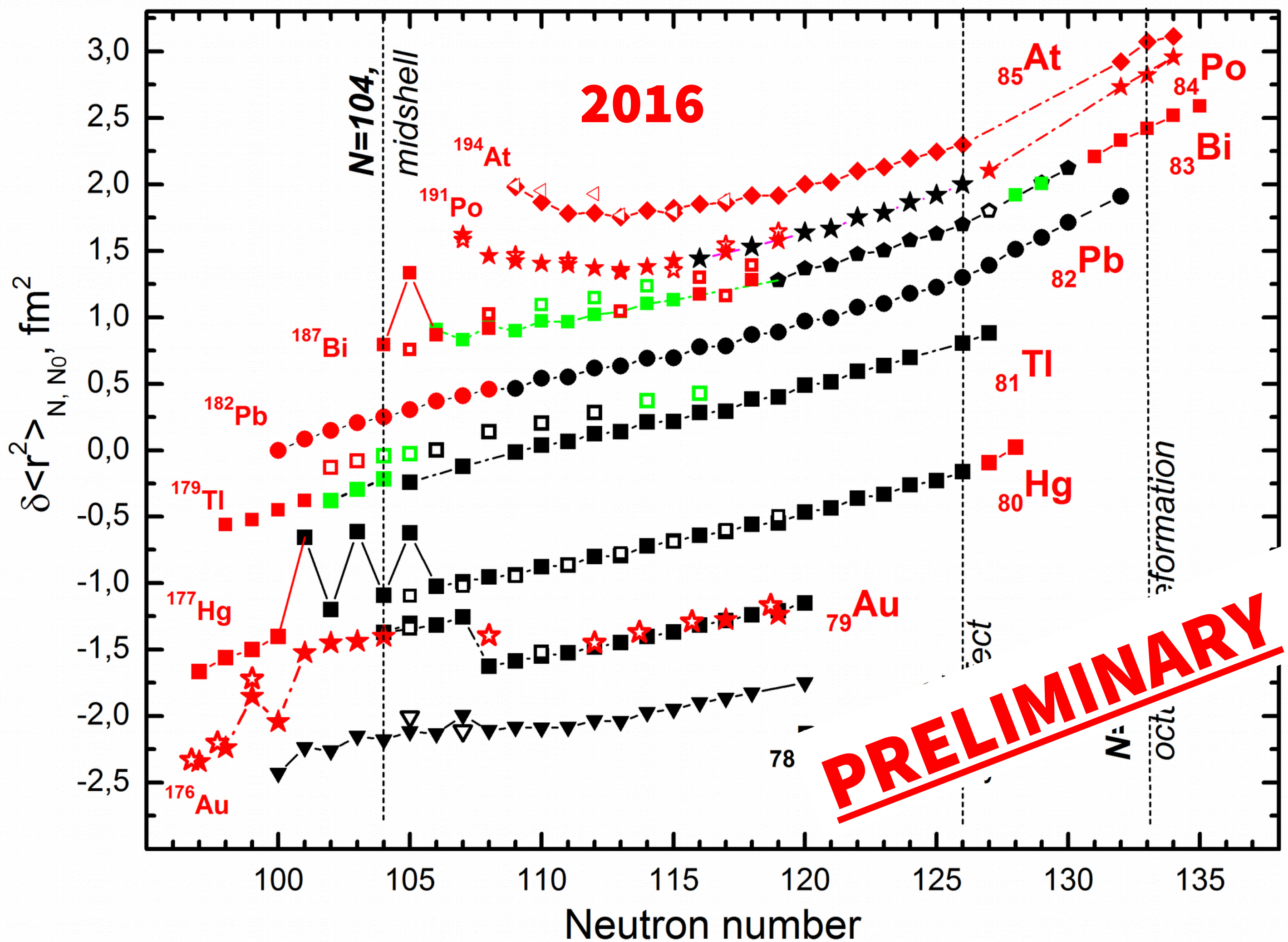
ISOLDE

In-source laser spectroscopy

Bi



In-source laser spectroscopy



RILIS

PHYSICAL REVIEW C **88**, 024315 (2013)

Changes in the mean-square charge radii and magnetic moments of neutron-deficient Tl isotopes

A. E. Barzakh,* L. Kh. Batist, D. V. Fedorov, V. S. Ivanov, K. A. Mezilev, P. L. Molkanov, F. V. Moroz, S. Yu. Orlov, V. N. Panteleev, and Yu. M. Volkov

Petersburg Nuclear Physics Institute (PNPI), NRC Kurchatov Institute, Gatchina 188300, Russia

(Received 14 June 2013; revised manuscript received 21 July 2013; published 19 August 2013)

In-source laser spectroscopy experiments for neutron-deficient thallium isotopes at the 276.9-nm atomic transition have been carried out at the Investigation of Radioactive Isotopes on Synchrocyclotron facility of Petersburg Nuclear Physics Institute. New data on isotope shifts and the hyperfine structure for $^{183-207}$Tl isotopes and isomers are presented. The changes in the mean-square charge radii and magnetic-moment values are deduced. It is shown that nuclear properties of Tl isotopes and isomers smoothly change at the neutron midshell and beyond without development of strong deformation in contrast to the adjacent Hg nuclei. A rather great isomer shift between $I = 1/2$ and $I = 9/2$ states for odd Tl isotopes is preserved for both sides of the previously investigated mass range. For the first time, a similar isomer shift is found for the odd-odd isotope ^{186}Tl. The close resemblance of the charge radii isotopic behavior for the Tl and Pb ground states is demonstrated.

DOI: 10.1103/PhysRevC.88.024315 PACS number(s): 21.10.Ft, 21.10.Ky, 27.80.+w, 31.30.Gs

I. INTRODUCTION

As stressed in a recent review [1], understanding the occurrence of shape coexistence in atomic nuclei is one of the greatest challenges faced by theories of nuclear structure. In this respect, the neutron-deficient isotopes near $Z = 82$ exhibit the most extensive manifestation of shape coexistence. In these nuclei, examples of prolate, oblate, and spherical structures have been found at low excitation energy (see Ref. [1] and references therein). Although the shape coexistence is a common feature of the all isotopic chains in this region (in the vicinity of the neutron midshell $N = 104$), the behavior of the ground- and isomeric state shapes differs markedly for different Z's. In the Hg isotopic chain ($Z = 80$), strong odd-even staggering is observed (the ground states of the odd-A isotopes with $N < 105$ are strongly deformed, whereas, the even-A isotopes remain nearly spherical or weakly deformed, see Ref. [2]). Both odd- and even-neutron Au isotopes ($Z = 79$) change their shapes from weakly oblate (or triaxial) to strongly prolate deformed after $N = 107$ due to the influence of the $\pi h_{9/2}$

isotopes $^{186-205,207,208}$Tl [7–18] have been performed. Isotope shifts (ISs) and hyperfine structures (hfs) were measured in the 535-nm transition. Thus, the previous laser spectroscopic investigations ended at $N = 105$ before the neutron midshell where the most pronounced shape staggering or shape transition effects are expected. It is of importance to continue these studies beyond the midshell.

Previously, it was also found that some Tl isomers with $I = 9/2$ (^{187,191,193}Tl^m) have markedly greater deformation than the corresponding ground states (see Ref. [15] and references therein). In particular, this reveals itself in a rather great isomer shift in the optical lines. The isomers with $I = 9/2$ are well known for the majority of the odd neutron-deficient Tl nuclei ($A = 181$–201; see Ref. [19]). All of them are treated as intruder states with the odd proton in the $\pi h_{9/2}$ shell at the moderate oblate deformation. This interpretation is supported by the observation of the strongly coupled bands built on these states (see Ref. [1] and references therein). Intruder-based states with the $(\pi h_{9/2}, \nu i_{13/2})$ configuration were also found

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

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Hyperfine structure and isotope shifts have been measured for the ground and isomeric states in the neutron-deficient isotopes $^{179-184}$Tl using the 276.9-nm transition. The experiment has been performed at the CERN-Isotope Separator On-Line facility using the in-source resonance-ionization laser spectroscopy technique. Spins for the ground states in ^{179,181,183}Tl have been determined as $I = 1/2$. Magnetic moments and changes in the nuclear mean-square charge radii have been deduced. By applying the additivity relation for magnetic moments of the odd-odd Tl nuclei the leading configuration assignments were confirmed. A deviation of magnetic moments for isomeric states in ^{182,184}Tl from the trend of the heavier Tl nuclei is observed. The charge radii of the ground states of the isotopes $^{179-184}$Tl follow the trend for isotonic (spherical) lead nuclei. The noticeable difference in charge radii for ground and isomeric states of ^{183,184}Tl has been observed, suggesting a larger deformation for the intruder-based $9/2^-$ and 10^- states compared to the ground states. An unexpected growth of the isomer shift for ^{183}Tl has been found.

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I. INTRODUCTION

The region of the neutron-deficient isotopes near the proton shell closure at $Z = 82$ has drawn considerable interest as it exhibits a clear manifestation of shape coexistence in nuclei

the even-A isotopes remain weakly deformed, probably of the oblate type, at least down to ^{182}Hg. The weakly oblate character of the ground states of the even $^{182-188}$Hg has been determined through Coulomb excitation measurements [5]. At the same

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Some support from Russia:

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(в долларах США)

Эксперимент	Координатор	Распределение 2016 года	Истрачено по проектам	Истрачено, процент
1	2	3	4	5
CAST	В.А. Матвеев	[illegible]	[illegible]	[illegible]
ISOLDE	Д.В. Фёдоров	6 300	6 246	99,1
RD50	А.Г. Залужный	[illegible]	[illegible]	[illegible]

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Support from PNPI:

Travel expenses, insurance: of about 300 000 RUR

RILIS Team

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Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

GENEVE, SUISSE
GENEVA, SWITZERLAND

December 10, 2015

Agreement N° 01/2015

between

ISOLDE COLLABORATION,
CERN, Geneva, Switzerland

and

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Article 5. Addresses for Correspondance

5.1. PNPI shall send documents of a technical nature to:

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Signed in Geneva December 10, 2015,

for the ISOLDE Collaboration

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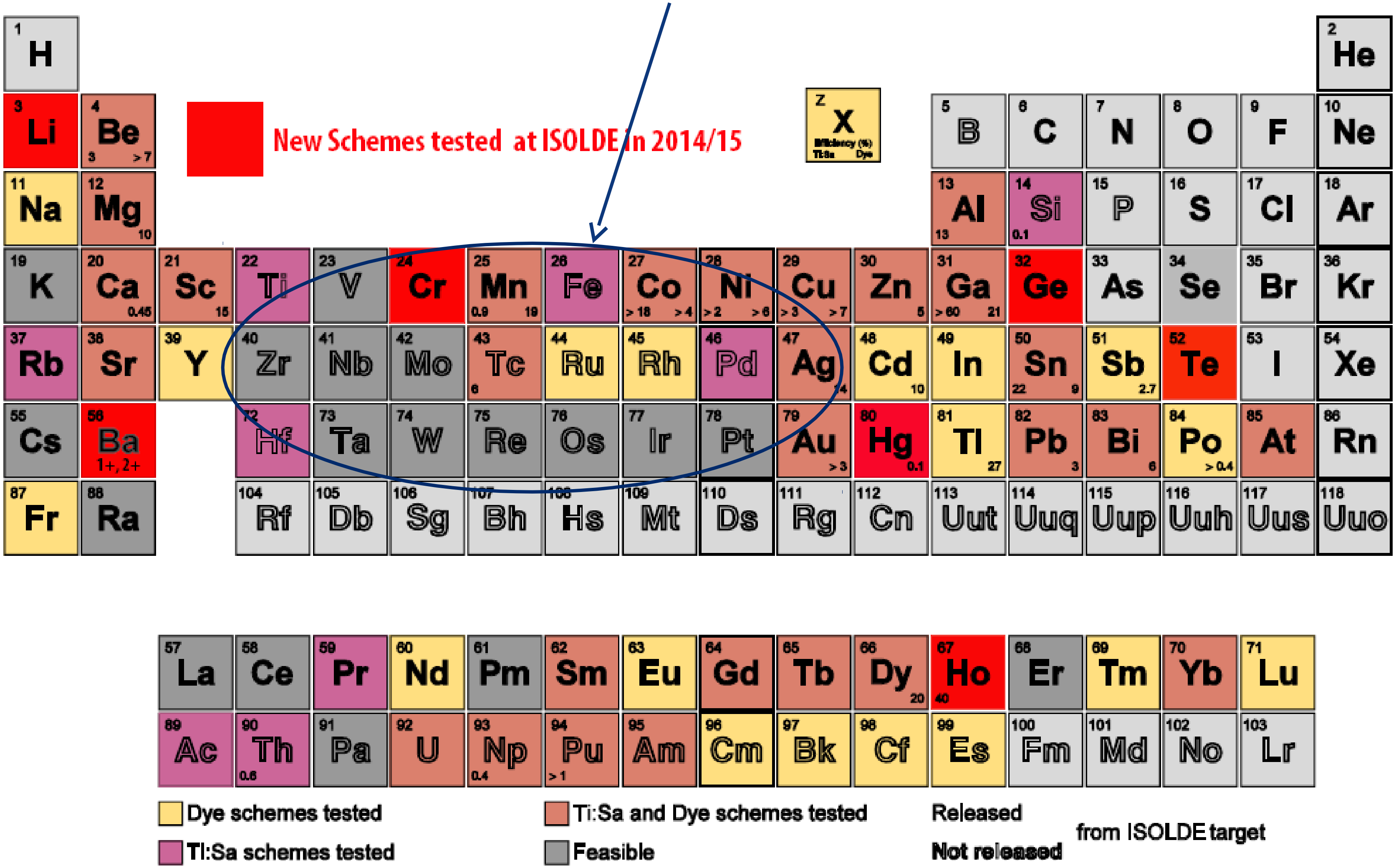
Refractory elements



Achieved in 2016 at ISOLDE: **Eu**, **Te** efficiency, alternative **Bi** scheme, **Ra**, **Fe**