Engineering Department

The RILIS and LIST: Status and prospects

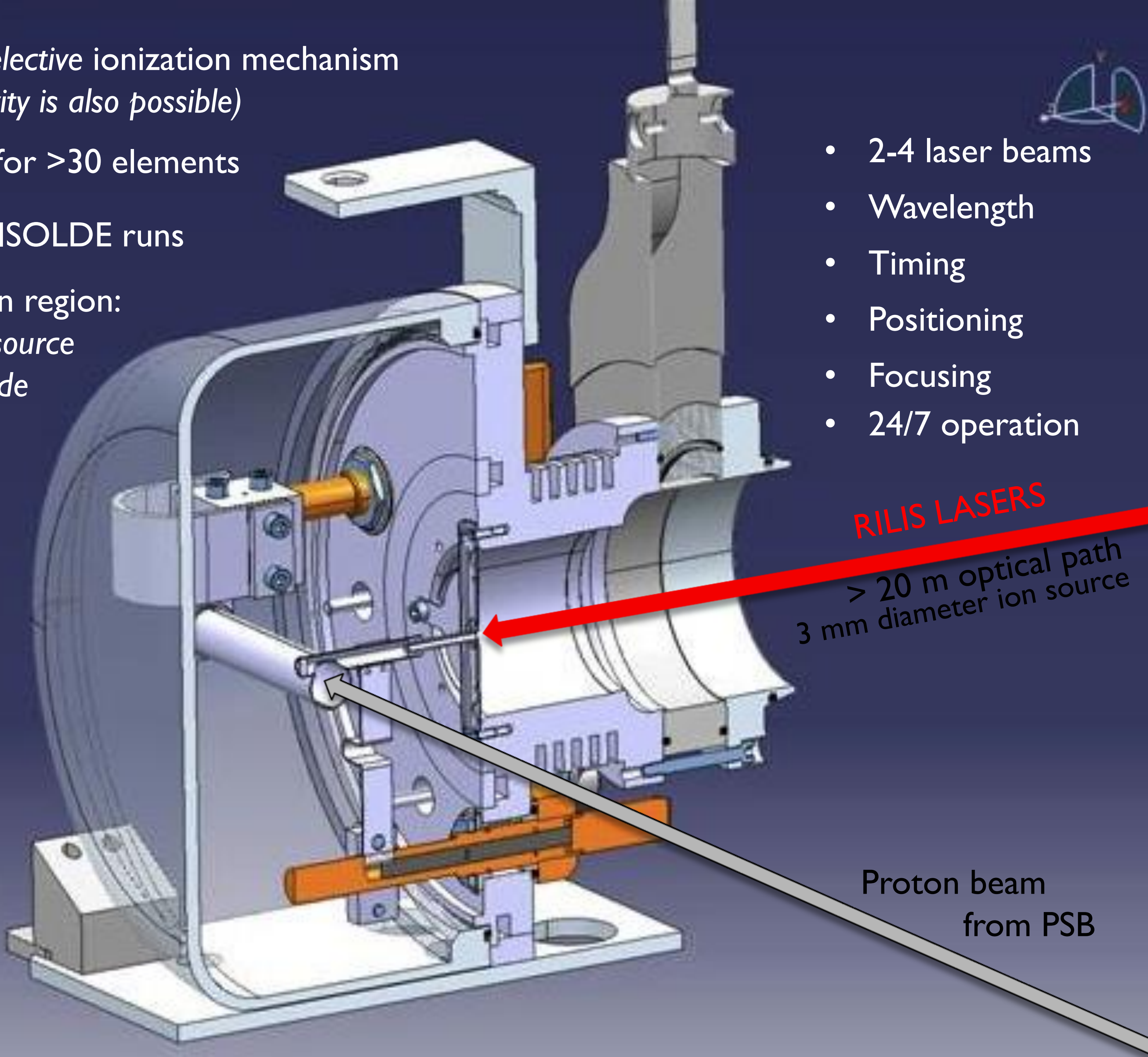
Bruce Marsh - EN-STI-LP

ISOLDE Workshop

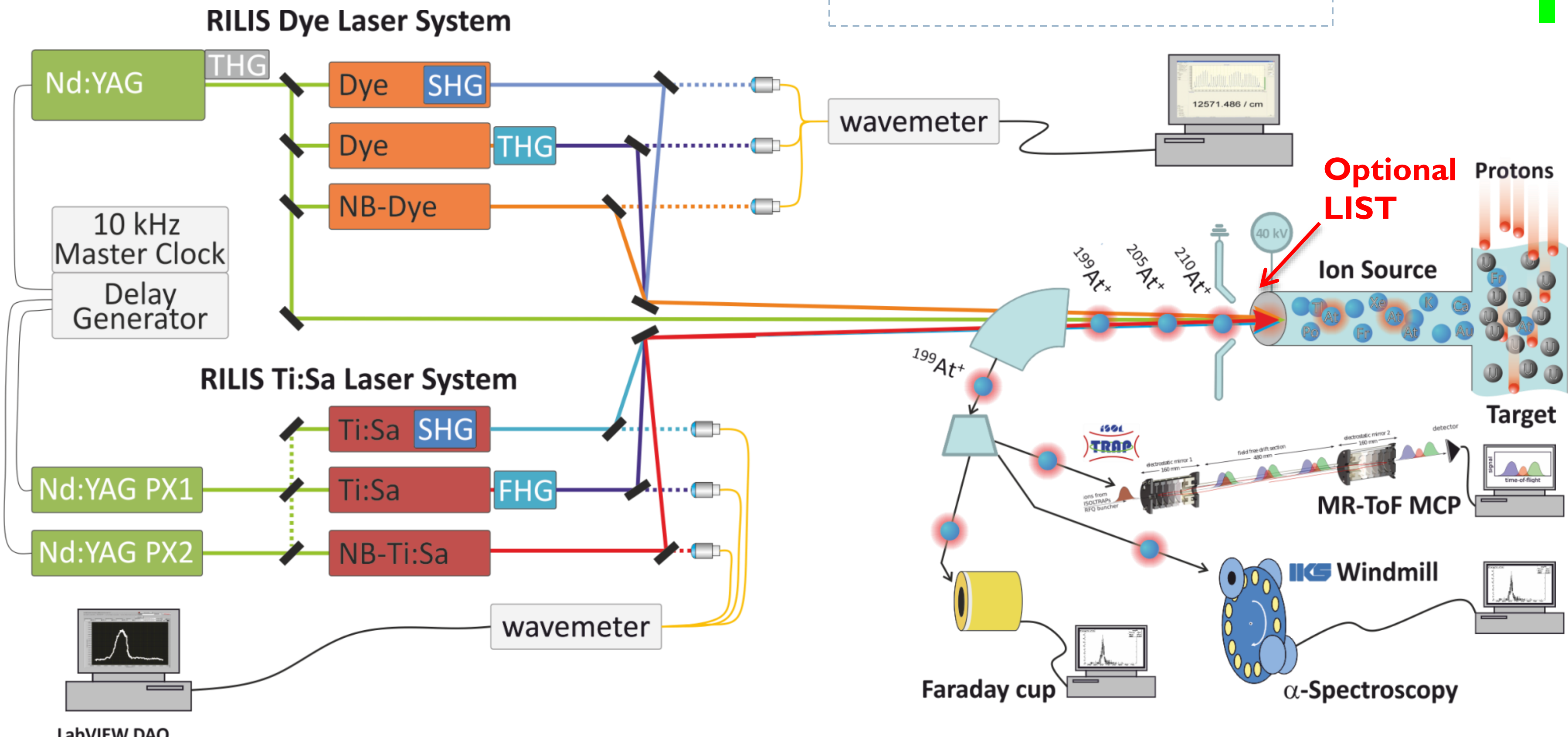
26th November 2013

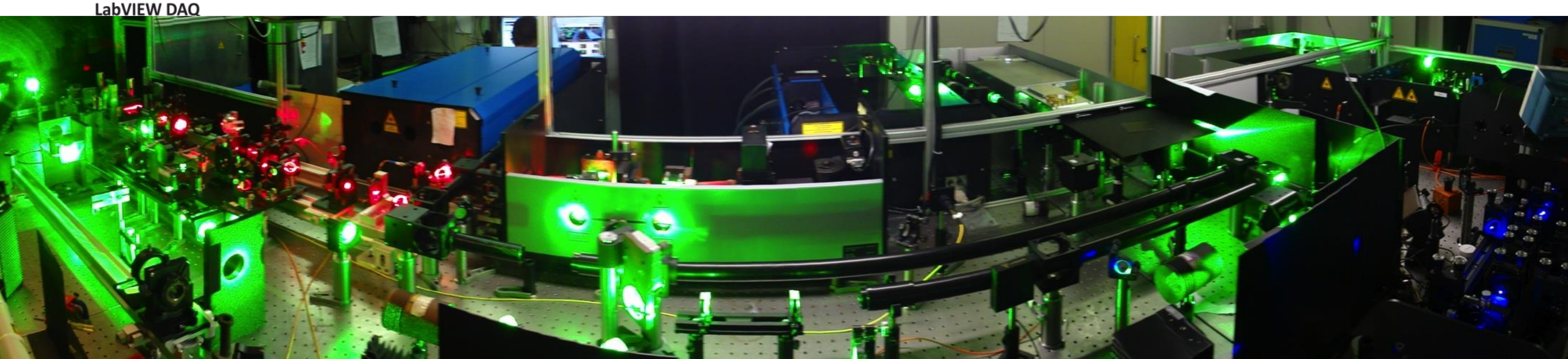
- 100% *element selective* ionization mechanism
  (isomer selectivity is also possible)
- Can be applied for >30 elements
- Used for >50% ISOLDE runs
- Laser interaction region:
  - *Hot surface ion source*
  - *LIST RFQ ion guide*

- 2-4 laser beams
- Wavelength
- Timing
- Positioning
- Focusing
- 24/7 operation



RILIS in 2012





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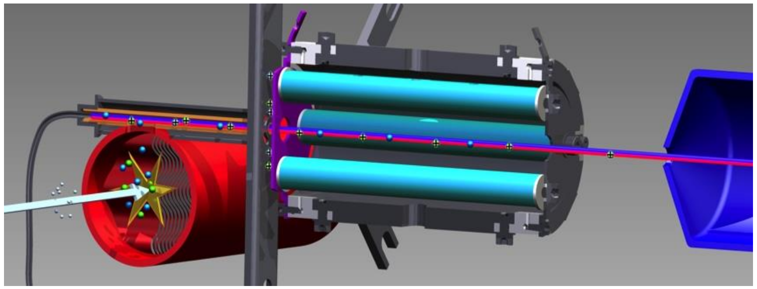
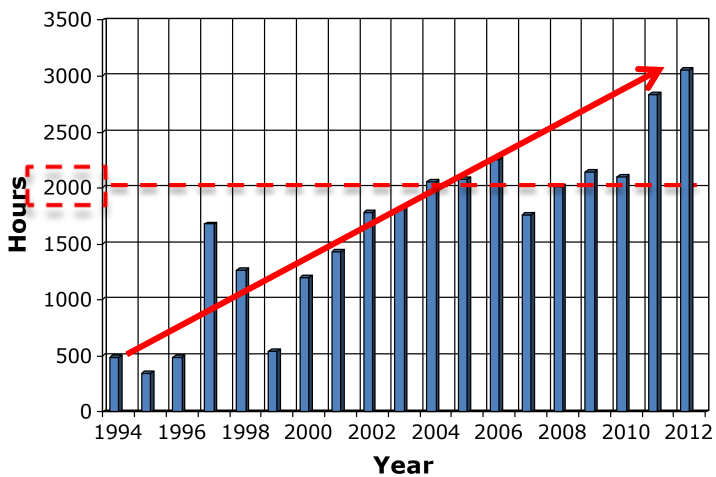
Highlights

RILIS



- First LIST physics run

CURRENT quality factors:
Selectivity improvement = 10^4-10^5
Efficiency loss = 20x



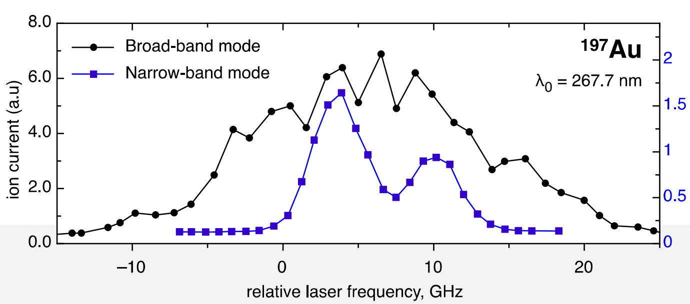
- Record # of operating hours

3060 h

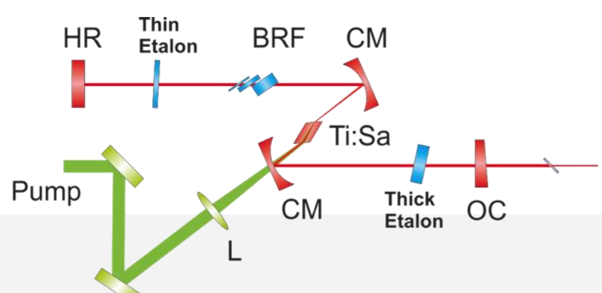
344 RILIS operator shifts

24 runs

13 elements



- Dual etalon, narrow-band Ti:Sa



Au **Po**

Fr (CRIS)

ISOLDE

GENERAL RILIS DEVELOPMENTS

- Extension of RILIS cabin
  - Enlarged entrance/storage and work area to maximize the useable laser laboratory space
- RILIS machine protection system
  - Installation of a machine protection and monitoring system to reduce reliance on shift-based operation
- Space stabilization of laser beams
  - Upgrade of existing commercial system to enable active stabilization of 3 beams and UV beams
- GPS laser beam launch
  - Replacement of prisms by high-reflectivity dielectric mirrors will reduce the losses of laser power in the beam transport to GPS mass separator
- HRS laser window
  - Extension tube for window mounting outside the 90^{o} magnet will enable monitoring of window quality during operation and simplify its replacement
- Laminar flow box containment of all laser tables

Laser developments

- Improved motorization of Narrow-band TiSa
- Ongoing TiSa R&D
- A dedicated, high power Nd:YVO laser for non resonant ionization
  - High beam quality industrial laser could significantly improve efficiency for many schemes.

Off-line R&D

- RILIS R&D at ISOLDE offline separator and Mainz RISIKO
  - Tests of high resistance cavity materials (graphite)
  - Improved beam gating method
  - ToFLIS project
  - LIST improvements/characterization
  - RILIS @ VADIS
- Develop RILIS power-meter target
  - Summer student (Alexandra Zadvornaya) worked on this project and tested the unit offline.
- New RILIS/LARIS dye handling/preparation laboratory
  - Under construction in 252-R-002 (next to LARIS lab).
  - Proper equipment, storage and safety measures – as requested by HSE

SPECTROSCOPY and IONIZATION SCHEMES

- Installation of a reference cell at RILIS
- Improved motorization of Narrow-band TiSa
- Ionization of refractory metals
  - Study of laser ionization in VADIS cavity
- New and improved RILIS schemes for the Dual RILIS system
  - According to requests from ISOLDE users: **Ba**, Te, Cr, Er, …

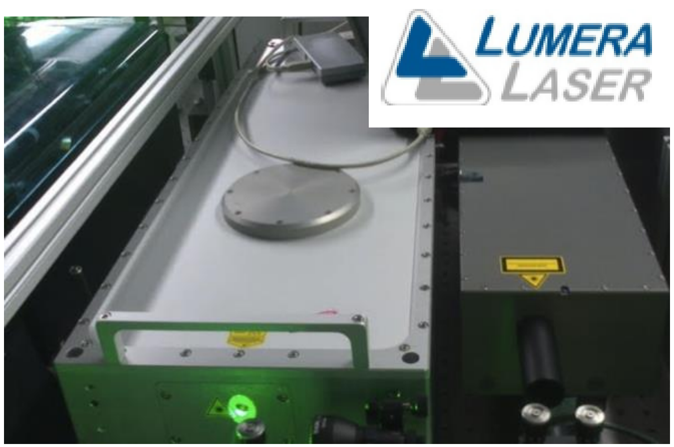
Part 1

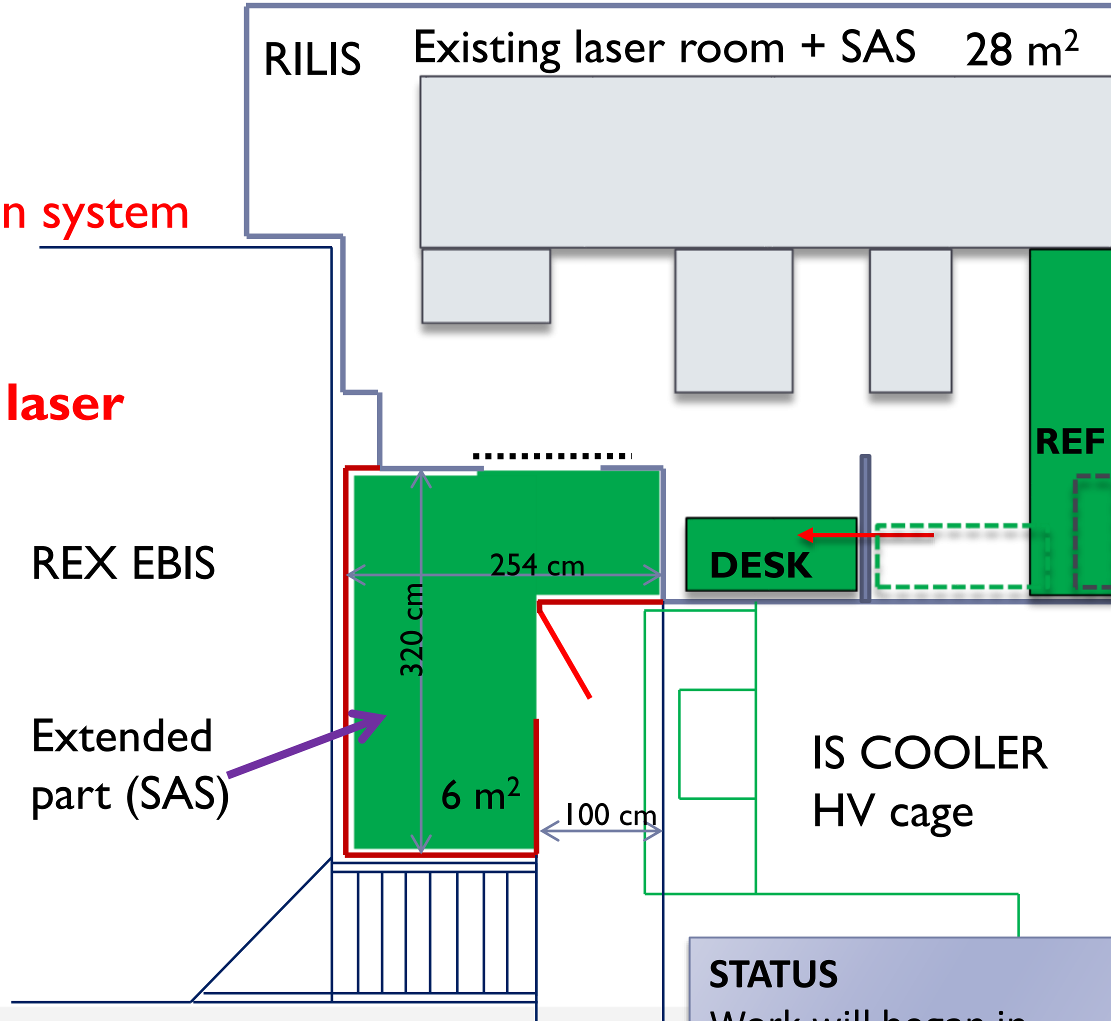
- RILIS technical improvements
- Preparations for on-call operation
- Planned future facilities

RILIS room extension

Required for:

- Safety
- Reference cell installation
- Dye handling
- Upgrade of beam observation system
- Improved ventilation system
- Comfort/ergonomics
- **Installation of extra YAG laser**

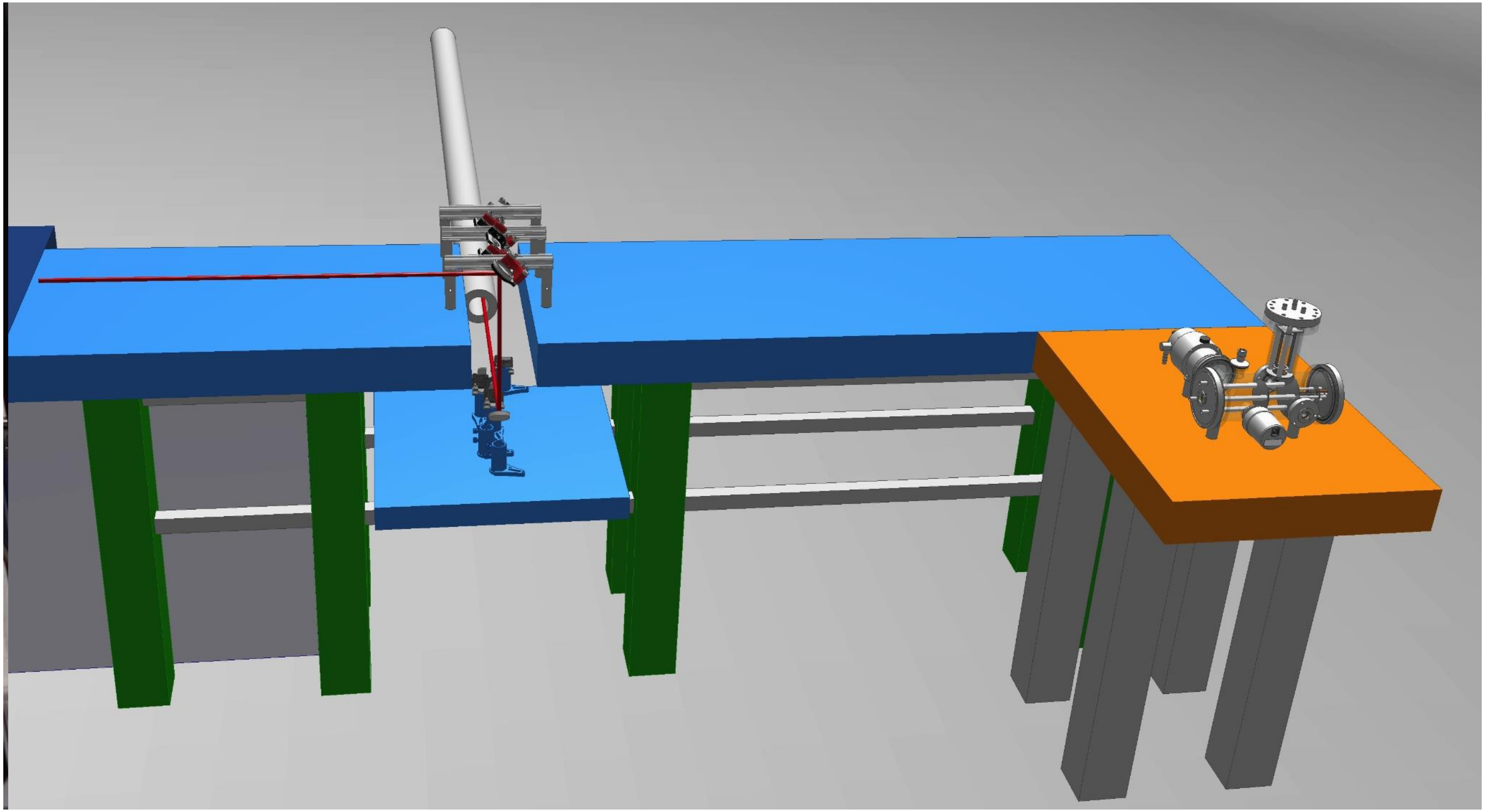




- **40W at 10 kHz**
- **17ns Pulse**
- **Much better transmission efficiency to ion source**
- **Higher efficiency and reduced setup time for many elements**

STATUS
Work will began in November
TBC December 2013

New GPS laser beam launch system



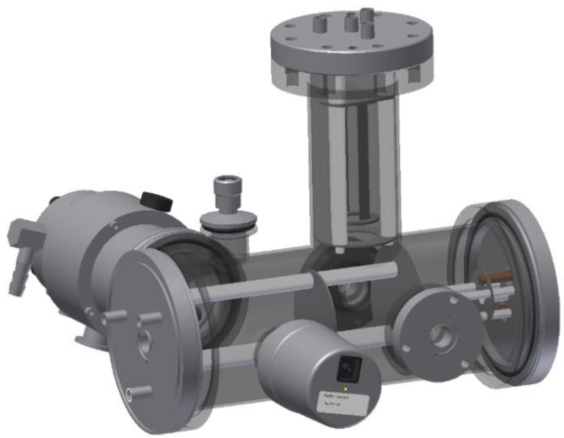
Benefits:
4 beams to GPS
Fewer power losses
Improved ergonomics

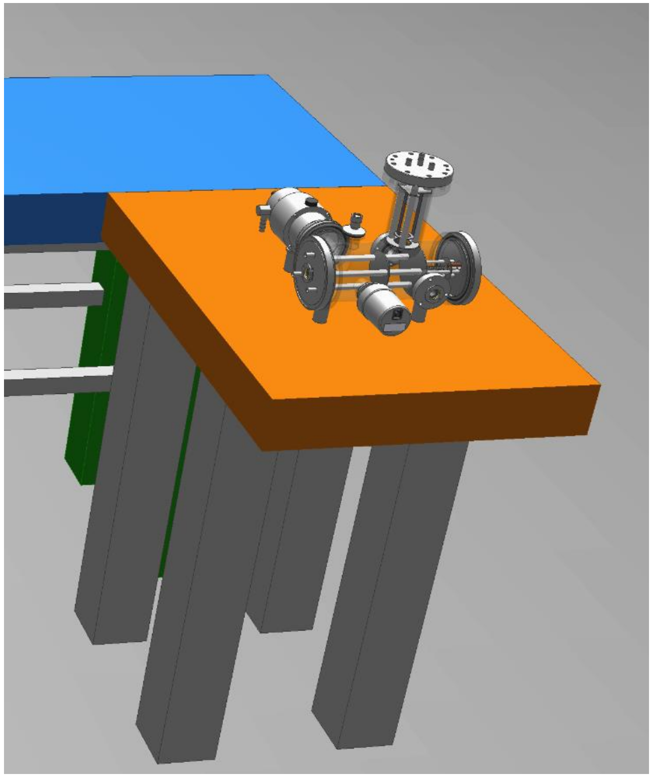
STATUS:
Designed by
Sebastian Rothe (Fellow)
Parts ordered

RELATED projects/tasks:
New reference beam area
New beam stabilization system
Reference cell installation

Reference cell for RILIS

Thermal atomic beam unit
Built by T.Kron (Univ Mainz).
Fibre coupling of lasers under investigation by Tom Day Goodacre (CERN)





Benefits:
Non invasive RILIS optimization (not positions)
Reference measurements for spectroscopy
Scheme development

STATUS:
Assembled and ready for use at ISOLDE offline separator

RELATED projects/tasks:
To be installed at RILIS after construction of new reference area

On-call operation

2012

13 elements

3060 h

24 runs

344 RILIS operator shifts

Until now:
RILIS operation is organized in 8-hours shifts:

4 persons on shift rota + 1 person on-call

Regular breaks in laser operation are needed for rest:
Not more than 3 weeks of work without free days.

2014

On-call operation for all compatible* runs

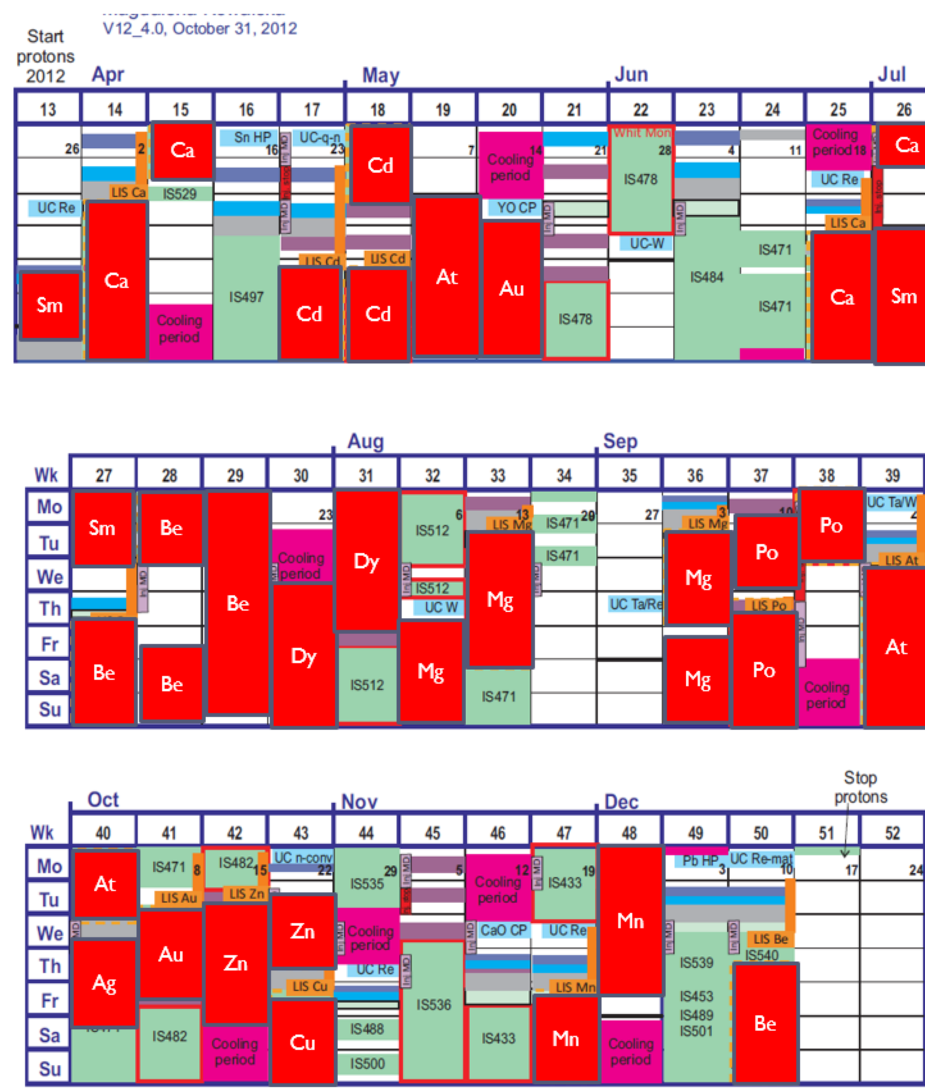
4-5 people share on-call duties

More time available for R&D (LARIS/Offline) and laser setup

> 3 weeks continuous operation should be possible

** Not possible in some difficult cases*

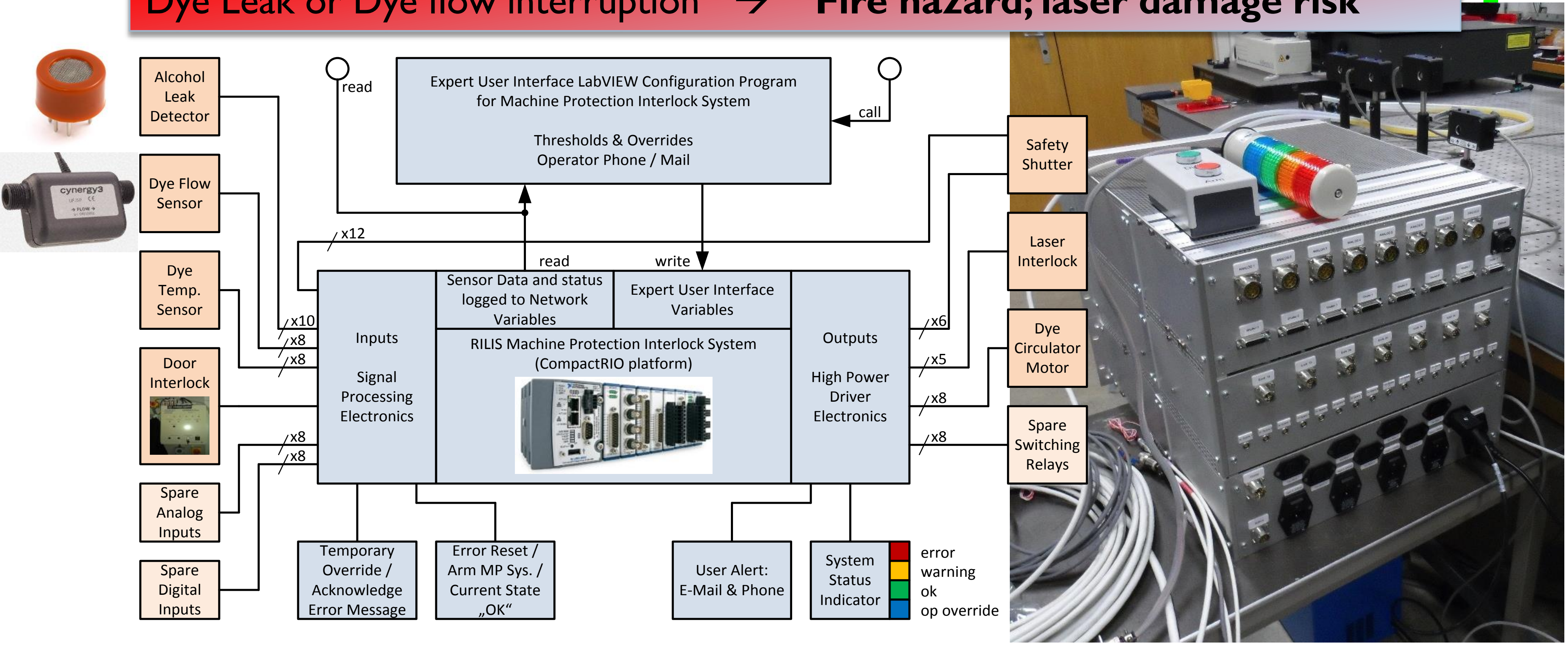
ISOLDE RILIS SCHEDULE 2012



RILIS machine protection: built and being tested

RILIS

Dye Leak or Dye flow interruption → Fire hazard; laser damage risk



- ROBUST and INDEPENDENT system
- Hardware to control multiple laser interlocks and shutters
- Laser dye leak detection / Dye flow detection
- Sends data to RILIS DAQ / Monitoring system
- Offline testing round 2 – this week
- Installation in January 2014

Preparation for **‘on-call’** RILIS operation

In collaboration with EN-STI-ICE (Sergio Batuca and Mark Butcher)

Engineering Department

On-call operation

RILIS

4 requirements for On-Call operation:

1) Machine protection / safety

To avoid risk of equipment damage or danger to personnel. This must be a ROBUST system (PC independent).

2) Performance monitoring

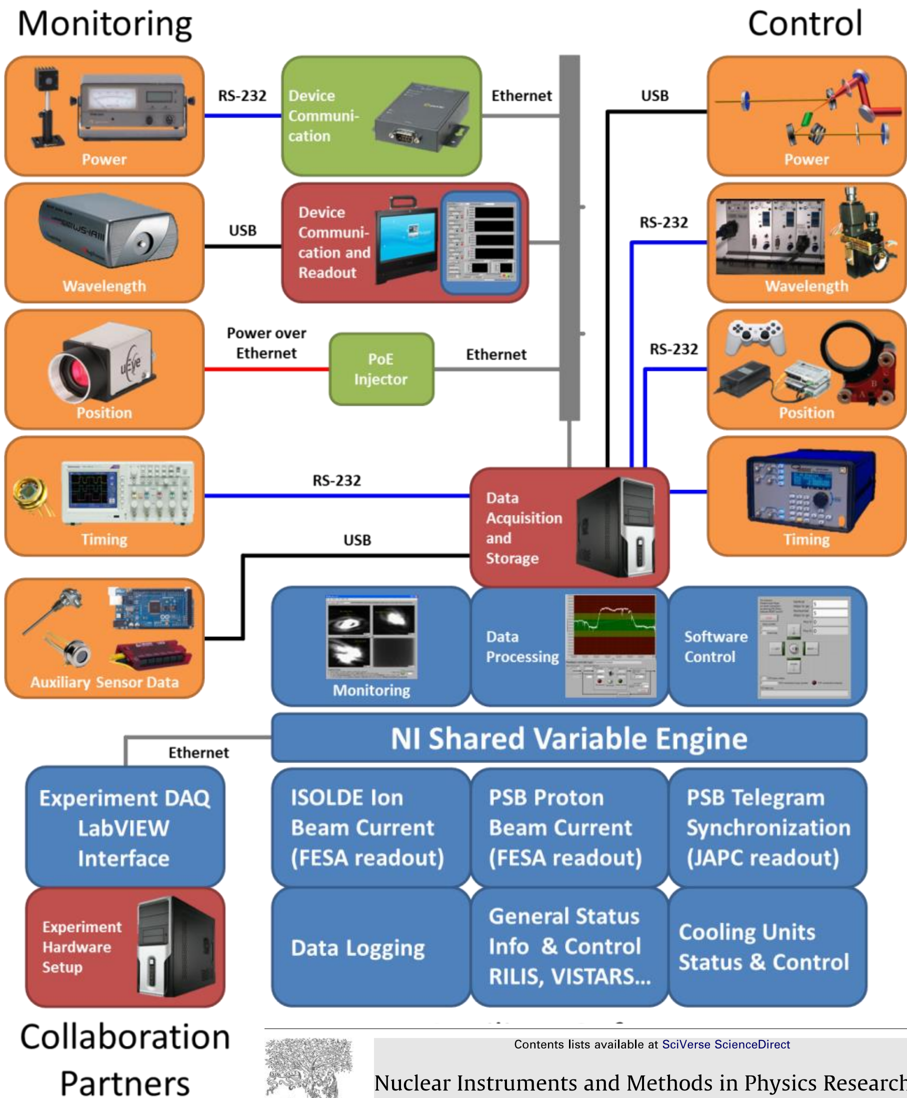
Remote monitoring of key parameters with an alert system to request operator intervention.

3) Automation

To maintain RILIS performance therefore reducing the frequency of operator interventions.

4) Improved environmental conditions

- Better temperature stability.
- Rapid fresh air replacement.
- Improved air cleanliness and dust protection



Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research B

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

ELSEVIER

Data acquisition, remote control and equipment monitoring for ISOLDE RILIS

R.E. Rossel [a,b,c,*], V.N. Fedosseev [a], B.A. Marsh [a], D. Richter [c], S. Rothe [a,b], K.D.A. Wendt [b]

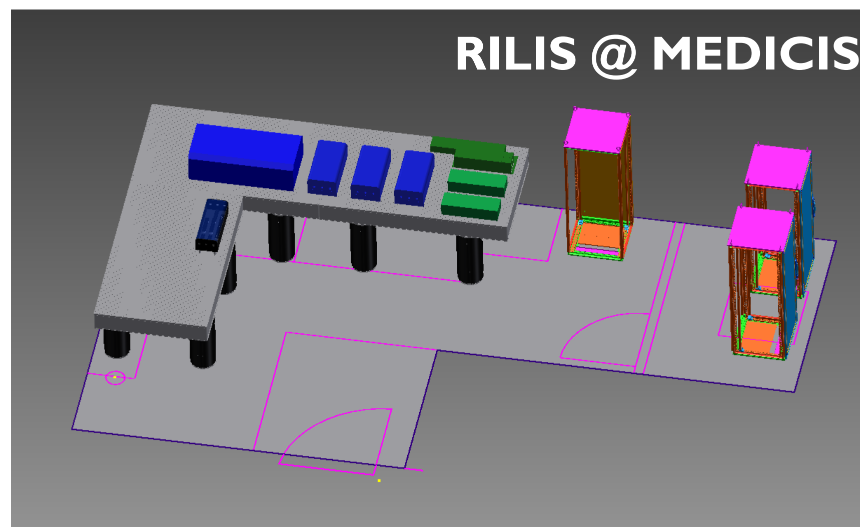
[a] CERN, Geneva, Switzerland

Continued work of RILIS technical student ***Ralf Rossel*** *and CERN Fellow* ***Sebastian Rothe***

NEW planned RILIS installations

New OFFLINE separator

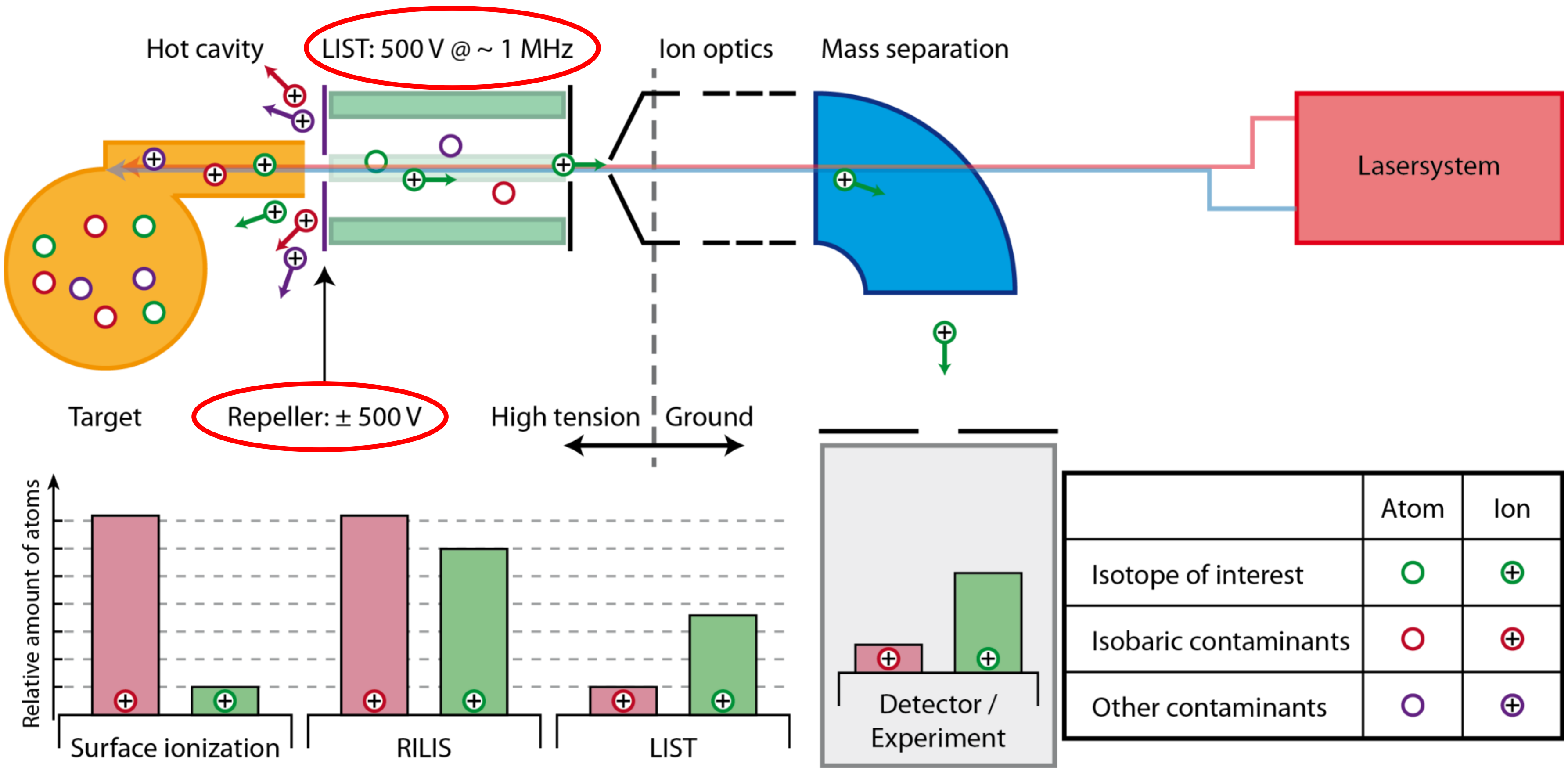
- Testing of new ionization schemes
- Development of new approaches to laser ion sources
- Study of laser – ion interaction in the RF-cooler
- Efficiency measurements



Part 2

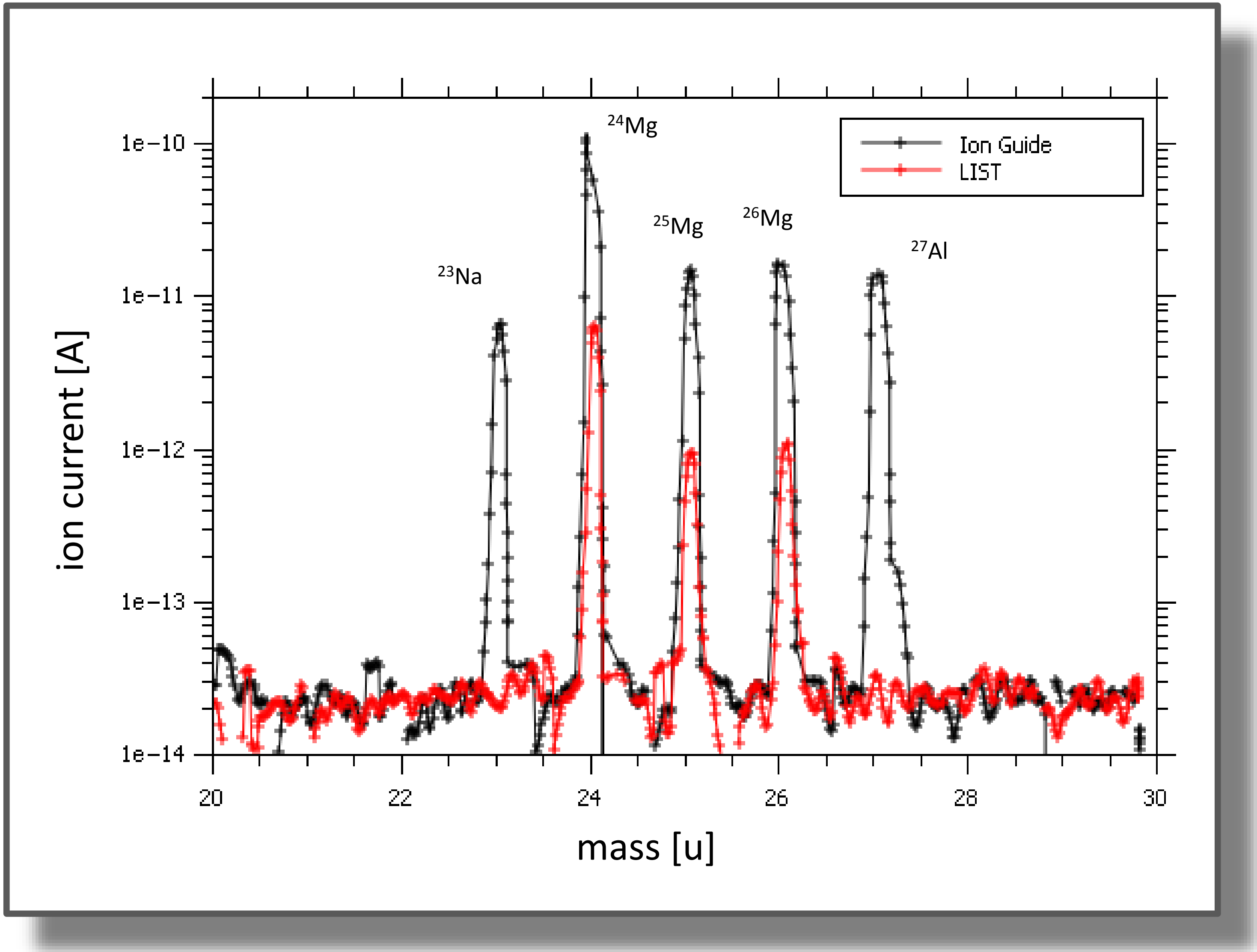
- LIST improvements
- Hot-cavity RILIS optimization
- Ionization scheme development

Laser Ion Source Trap (LIST) (aka **IG-LIS** in TRIUMF)



	Atom	Ion
Isotope of interest	○	⊕
Isobaric contaminants	○	⊕
Other contaminants	○	⊕

- **Suppression of surface ions by electrostatic repeller**
- **Highly selective laser ionization inside the LIST**
- **Ion guiding towards extraction by transverse rf-trapping field**
- **Shielding of laser interaction region from high field gradient of extraction electrode**



ion current [A]
mass [u]
1e−10
1e−11
1e−12
1e−13
1e−14
20
22
24
26
28
30
Ion Guide
LIST
^{23}Na
^{24}Mg
^{25}Mg
^{26}Mg
^{27}Al

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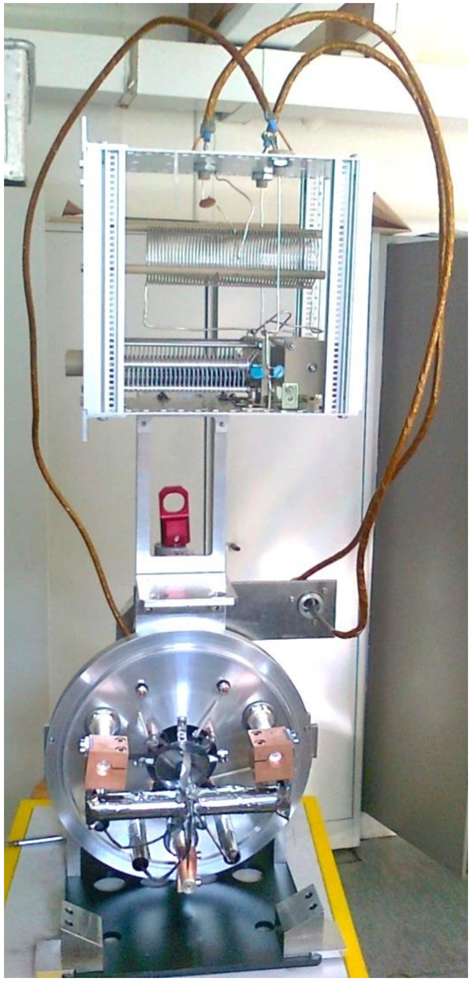
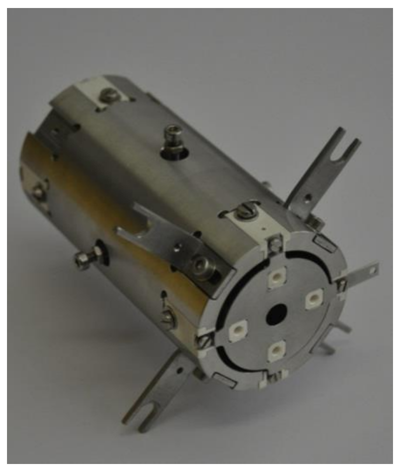
LIST operation in 2012

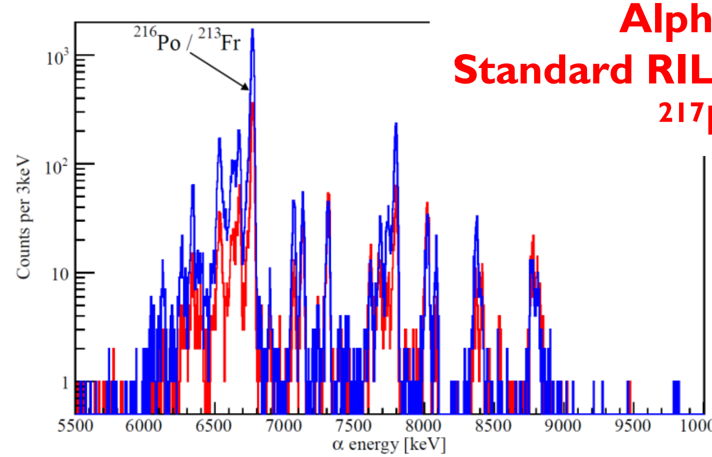
RILIS

LIST + UCx run for Fr suppression for laser spectroscopy of Po

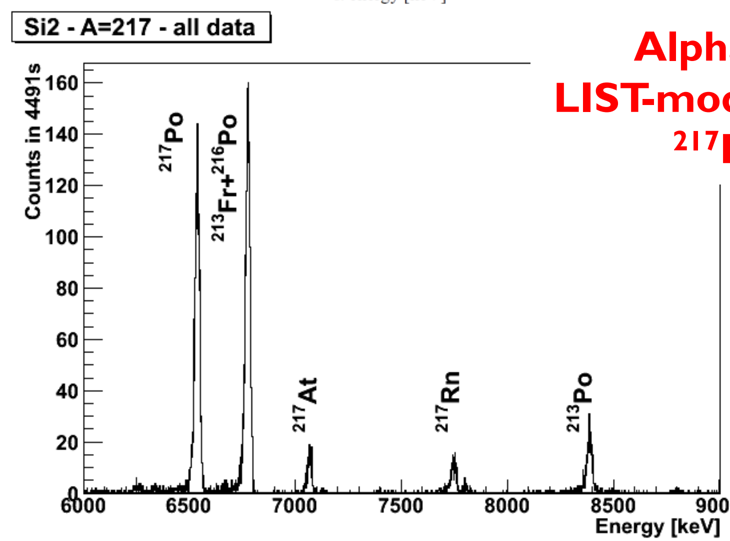


- Suppression of >1000 for most surface ions
- Ionization efficiency reduction by ≈20x (Mg,Po)





Alphas
Standard RILIS
^{217}Po



Alphas
LIST-mode
^{217}Po

Daniel Fink (CERN, Univ. Heidelberg) and **Sven Richter** (Univ. Mainz): **PhD work**

LIST operation in 2012

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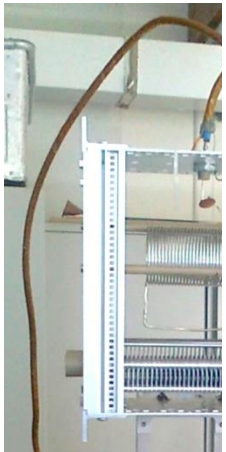
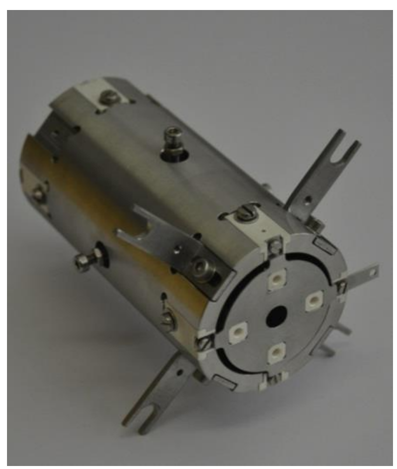
Nuclear Instruments and Methods in Physics Research B

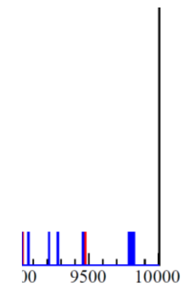
journal homepage: www.elsevier.com/locate/nimb

First application of the Laser Ion Source and Trap (LIST) for on-line experiments at ISOLDE

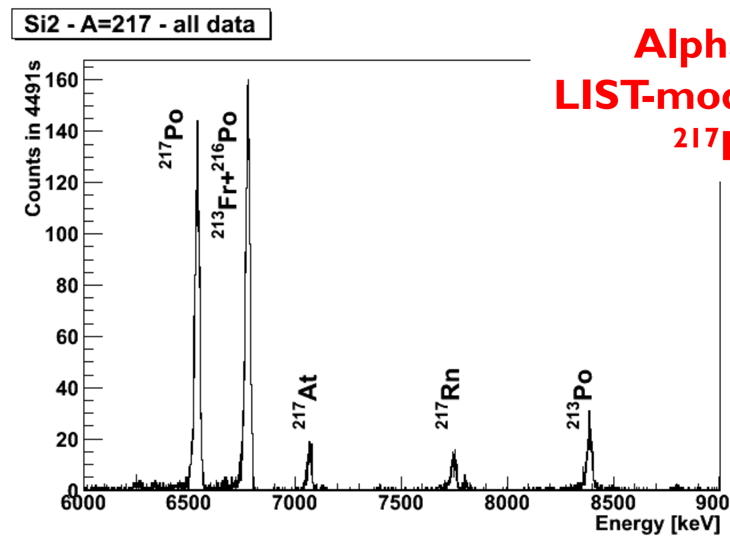
D.A. Fink [a,b,c,*,1], S.D. Richter [d], B. Bastin [e], K. Blaum [b], R. Catherall [a], T.E. Cocolios [a,f], D.V. Fedorov [g], V.N. Fedosseev [a], K.T. Flanagan [f], L. Ghys [h,i], A. Gottberg [a,j], N. Imai [k], T. Kron [d], N. Lecesne [e], K.M. Lynch [a,f], B.A. Marsh [a], T.M. Mendonca [a,l], D. Pauwels [h], E. Rapisarda [a], J.P. Ramos [a,m], R.E. Rossel [a,d], S. Rothe [a,d], M.D. Seliverstov [g,n], M. Sjödin [e], T. Stora [a], C. Van Beveren [h], K.D.A. Wendt [d]







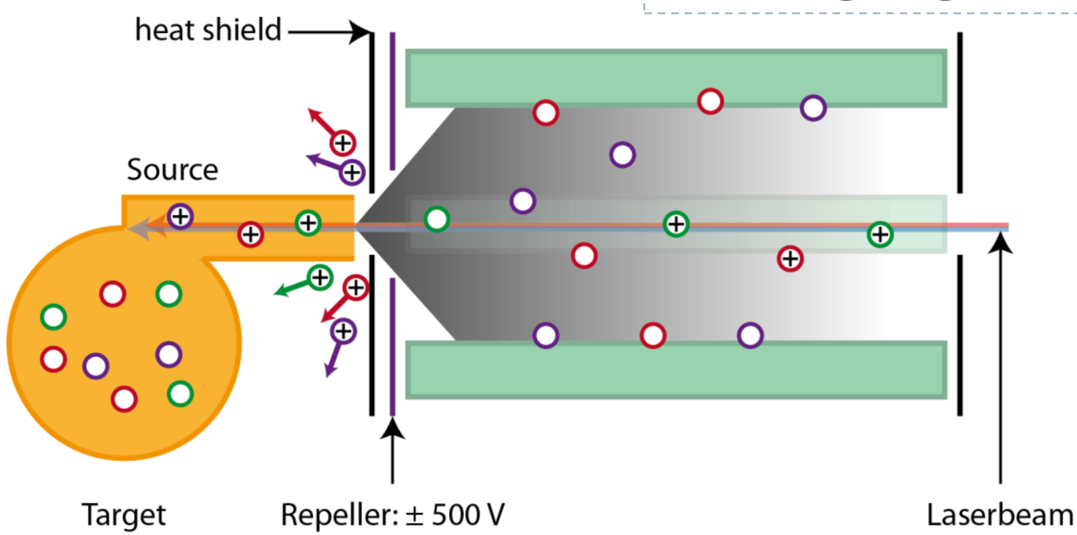
Alphas
ard RILIS
^{217}Po



Alphas
LIST-mode
^{217}Po

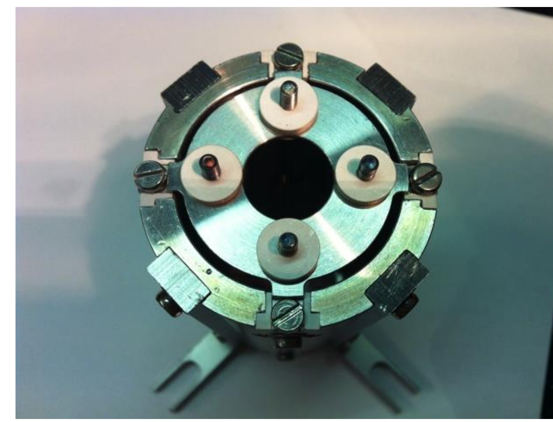
Daniel Fink (CERN, Univ. Heidelberg) and **Sven Richter** (Univ. Mainz): **PhD work**

Ongoing LIST development / issues

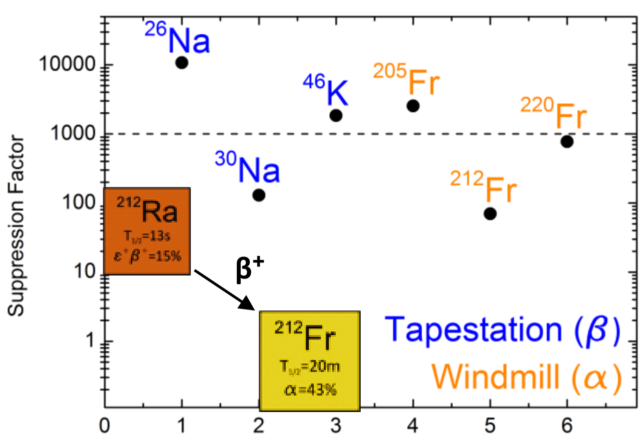


CURRENT quality factors:
Selectivity improvement = 10^4-10^5
Efficiency loss = 20x

New LIST with thinner RFQ rods:



- Loss factor due to laser/atom overlap (>20)
- Secondary ionization mechanisms
- Problem with ion-guide mode at high ion currents
- Time structure studies



LIST mode ion guide efficiency decline at high proton intensity.
Daniel Fink, PhD work

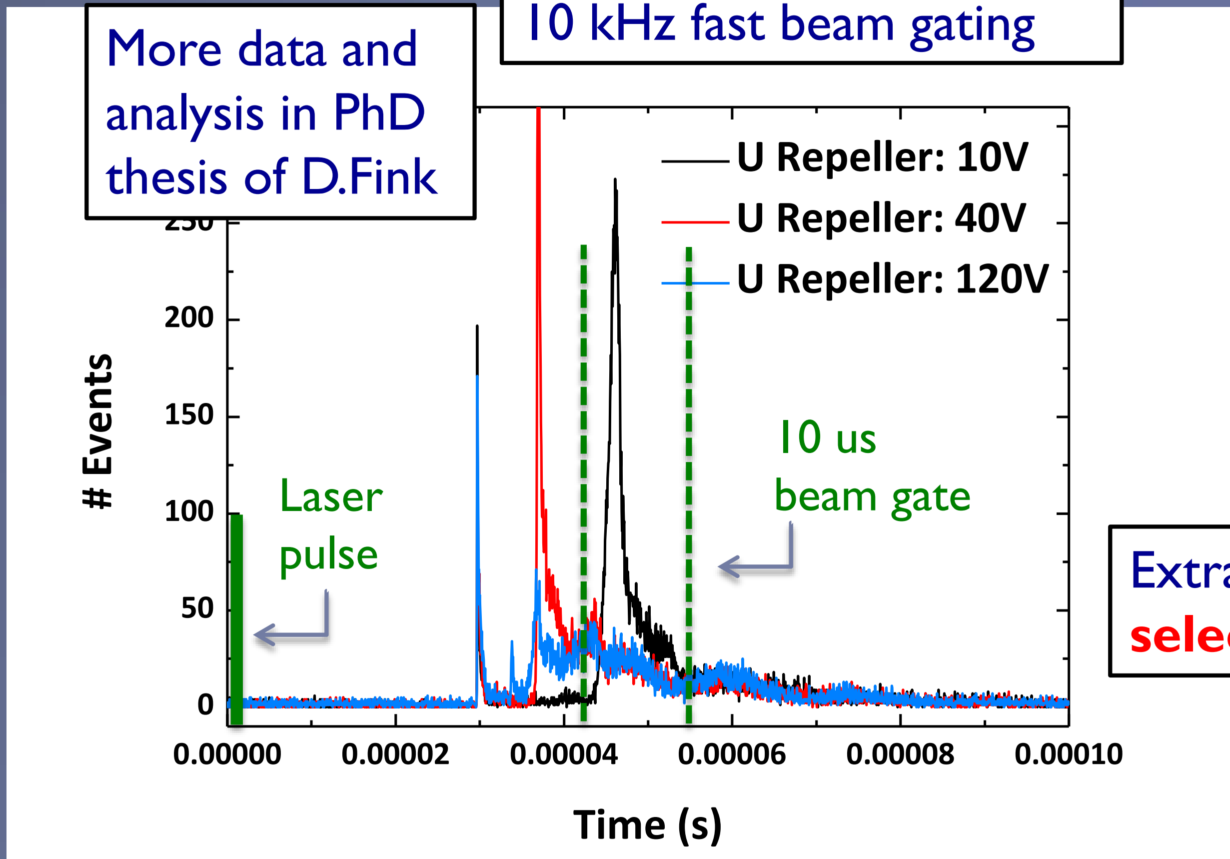
Reduced suppression of 212Fr due to:
-> β + decay of 212Ra in LIST

Currently under further investigation by Sven Richter @ Mainz heat shield

Laser ion bunch time structure

10 kHz fast beam gating

More data and analysis in PhD thesis of D.Fink



Extra factor of **~10 selectivity**

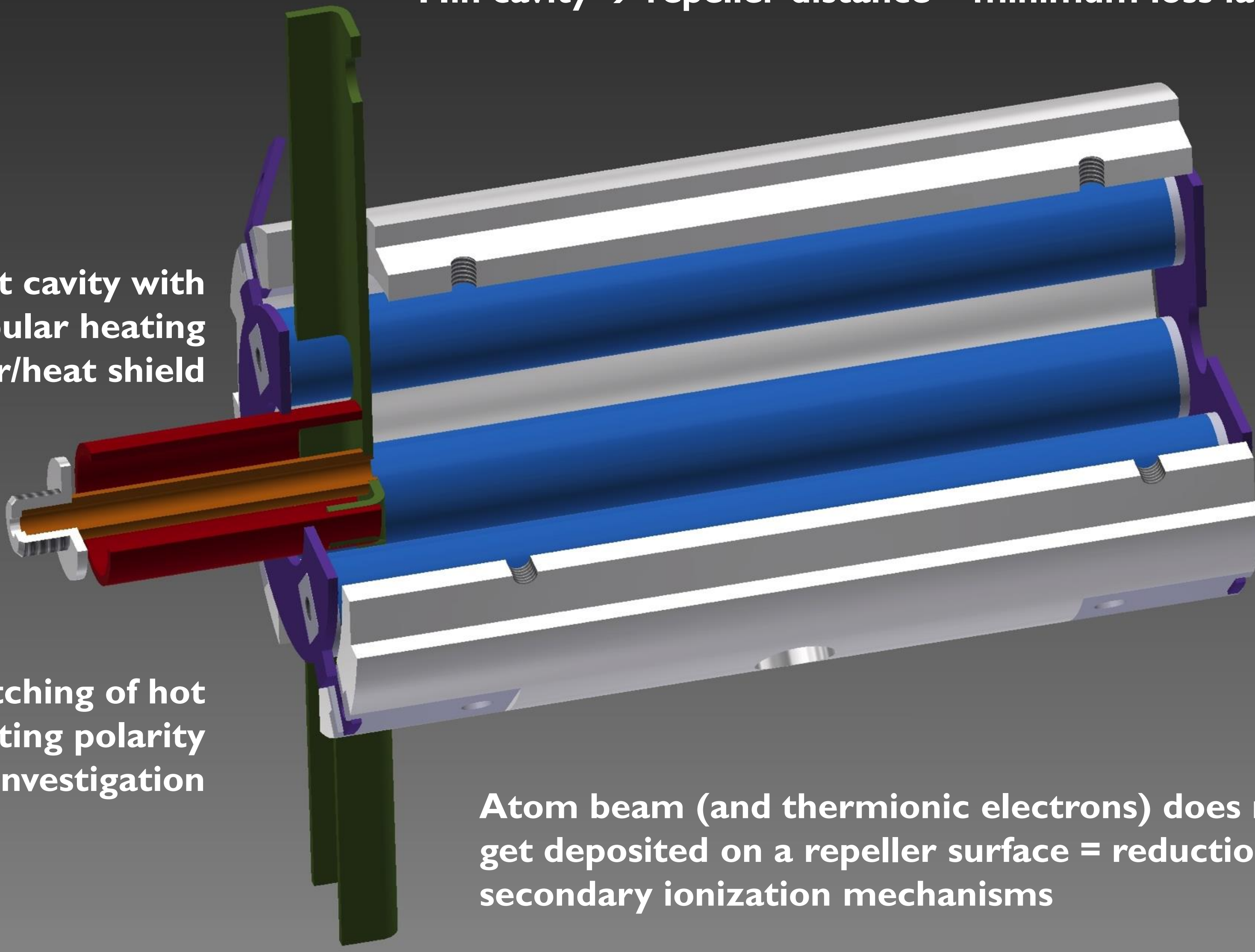
- Lo
- Se
- Pr
- Ti

Suppression Factor

0 1 2 3 4 5 6

Cavity exit sits inside RFQ Ion guide structure:
Min cavity → repeller distance = minimum loss factor

Hot cavity with
tubular heating
connecter/heat shield

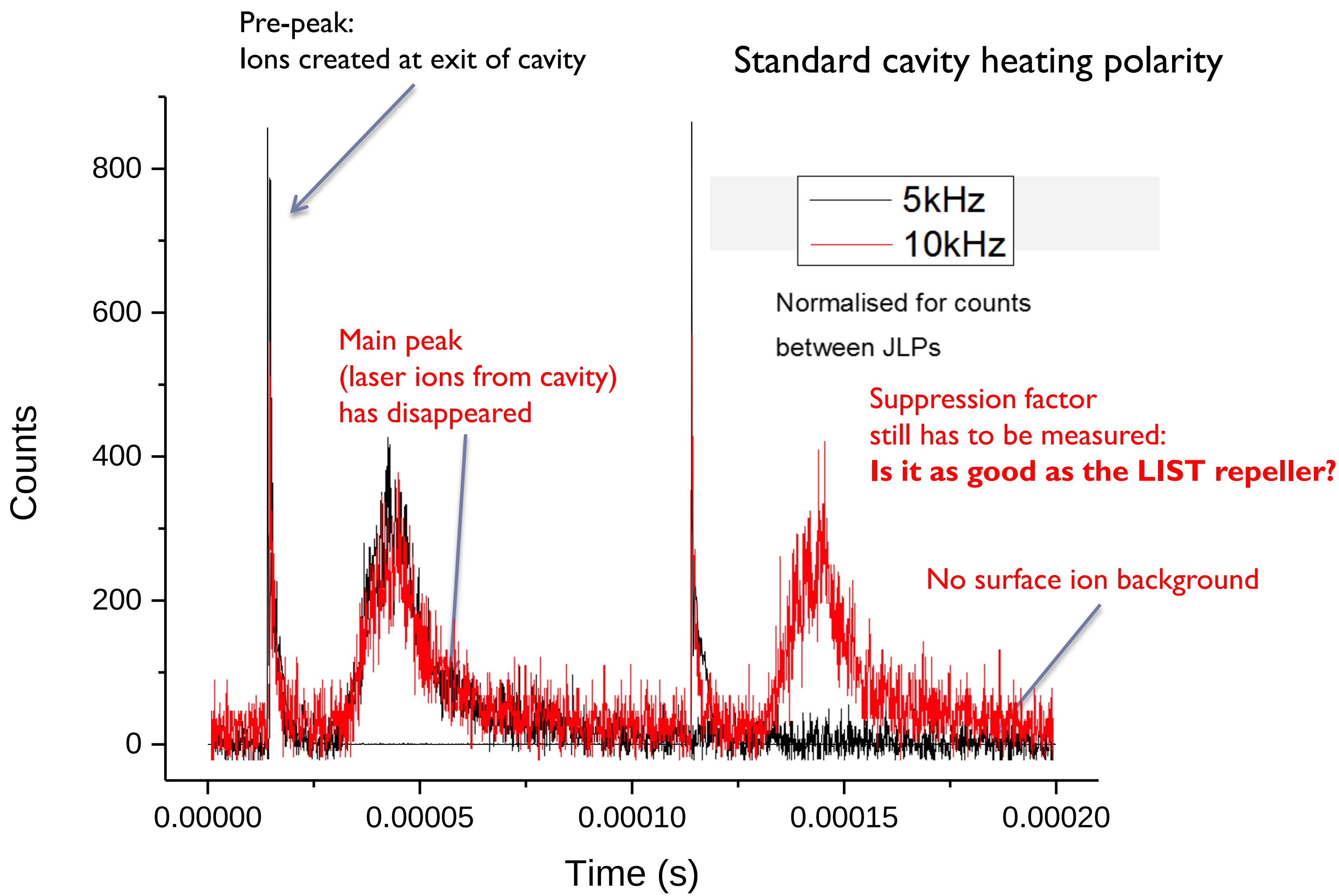


Quick switching of hot
cavity heating polarity
is under investigation

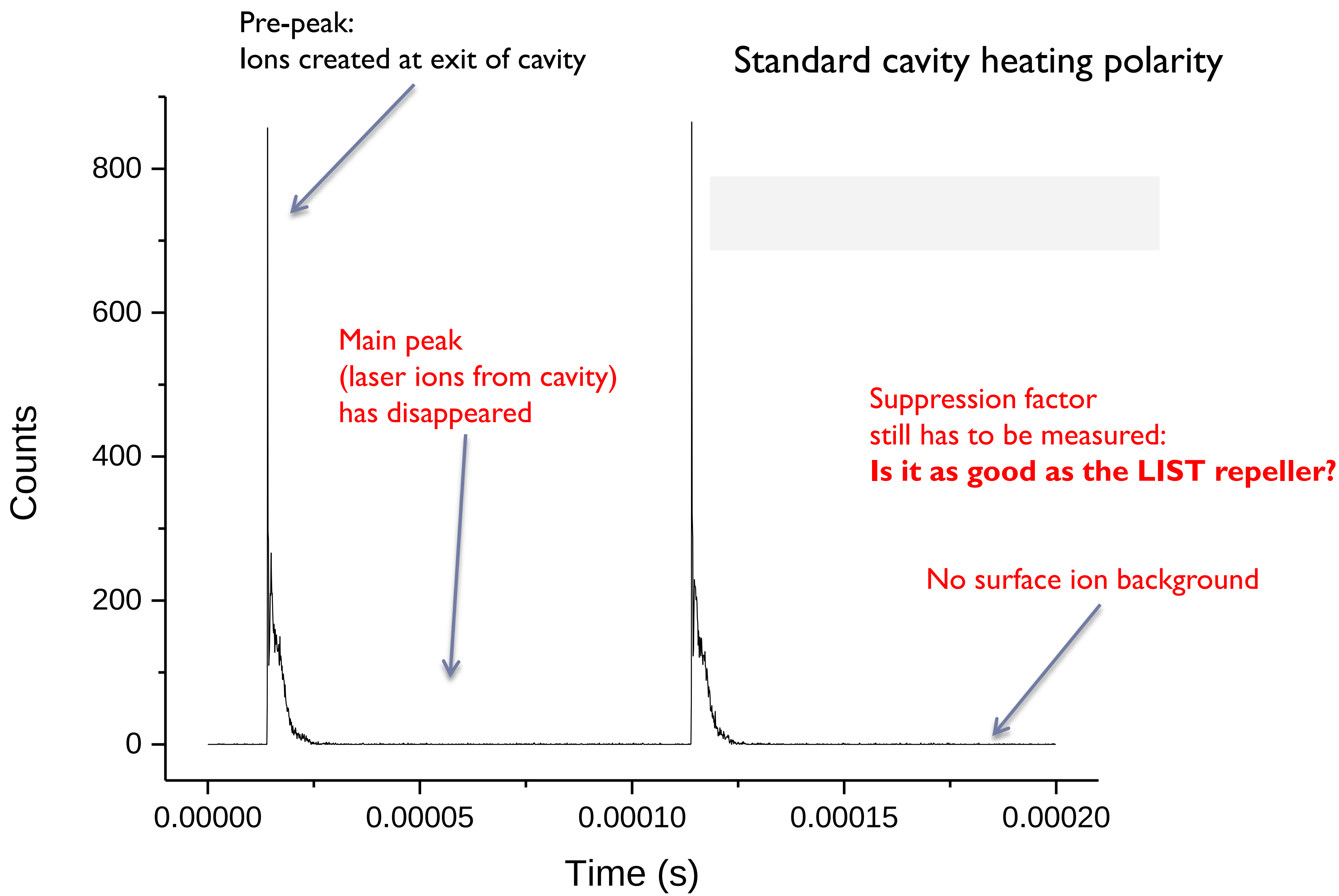
Atom beam (and thermionic electrons) does not
get deposited on a repeller surface = reduction of
secondary ionization mechanisms

Drawing by Sven Richter (Mainz)

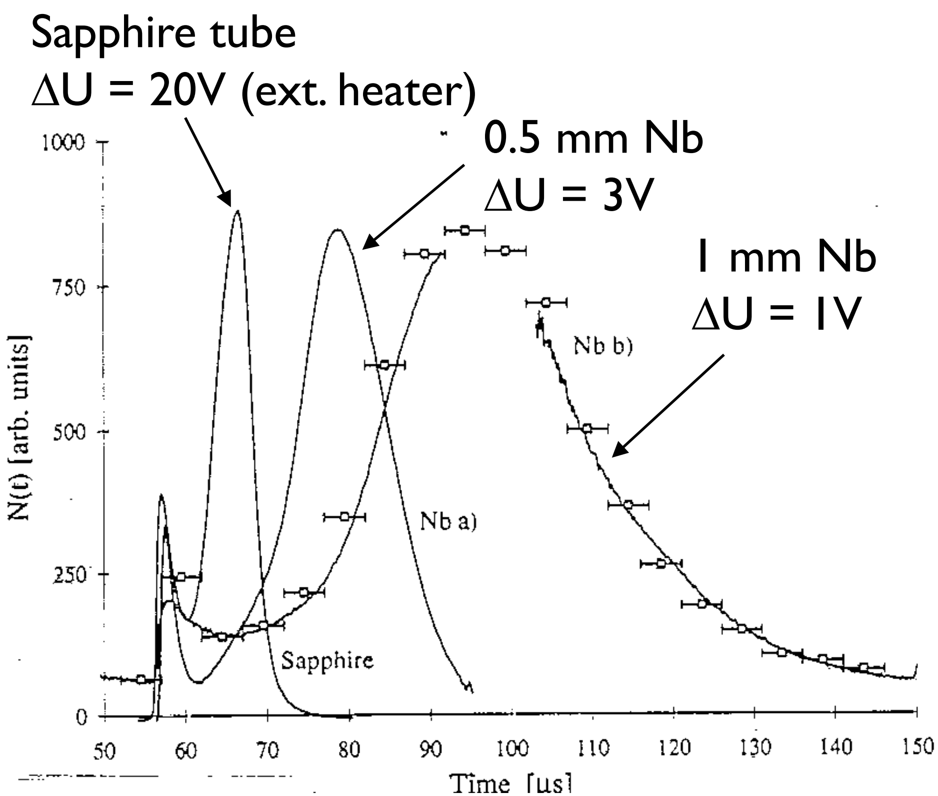
Inverted line as an ion repeller



Inverted line as an ion repeller



High resistance cavity concept

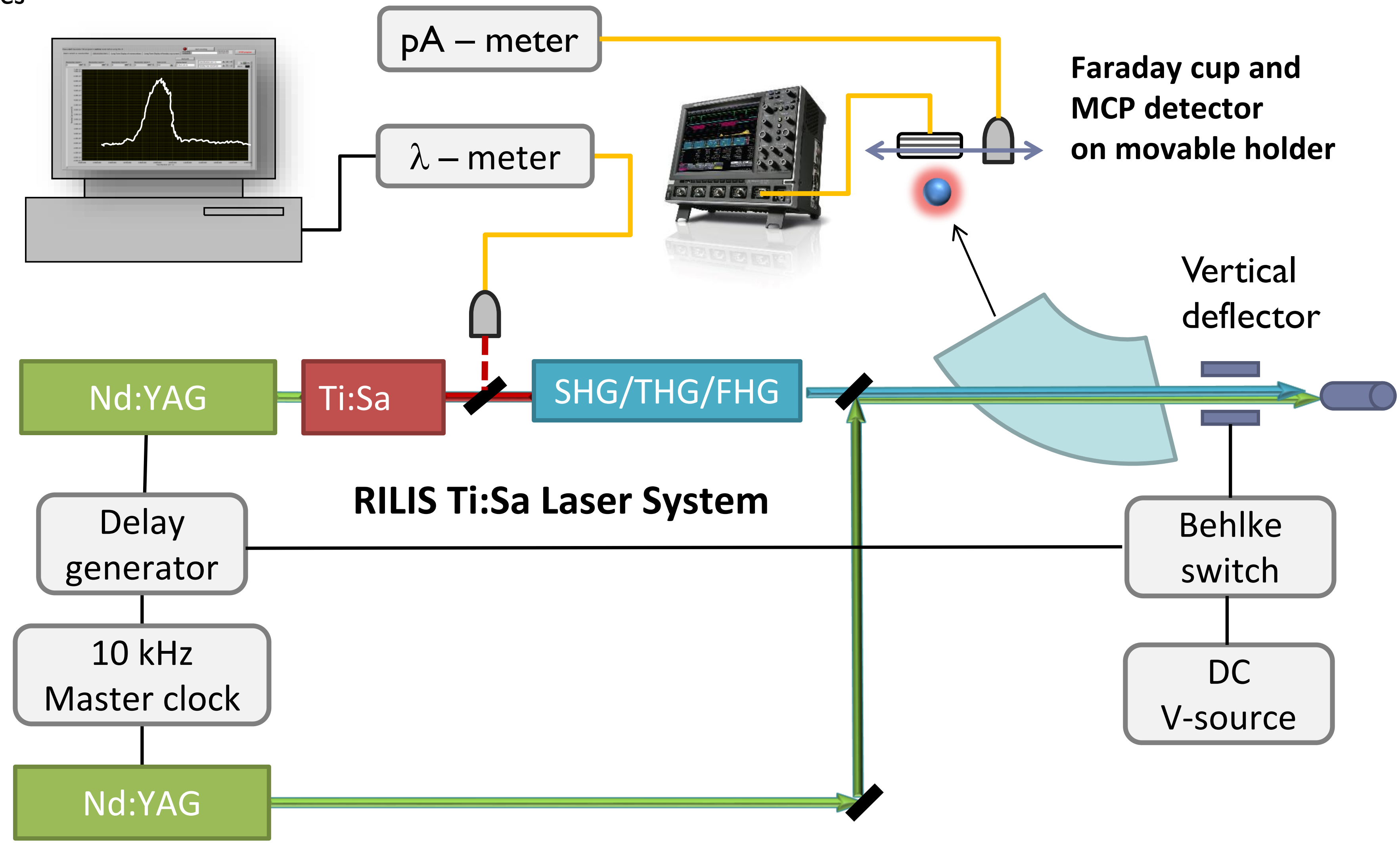


The development of a thin Nb cavity, used in combination with micro-gating, enabled the discovery of ^{129}Ag

Production of radioactive Ag beams with a chemically selective laser ion source
Y. Jading et al., NIMB 126 (1997) 76-80

RILIS cavity tests at off-line mass separator

A simplified laser system is setup at the off-line ISOLDE mass separator – producing Ga ion beams for testing RILIS cavities



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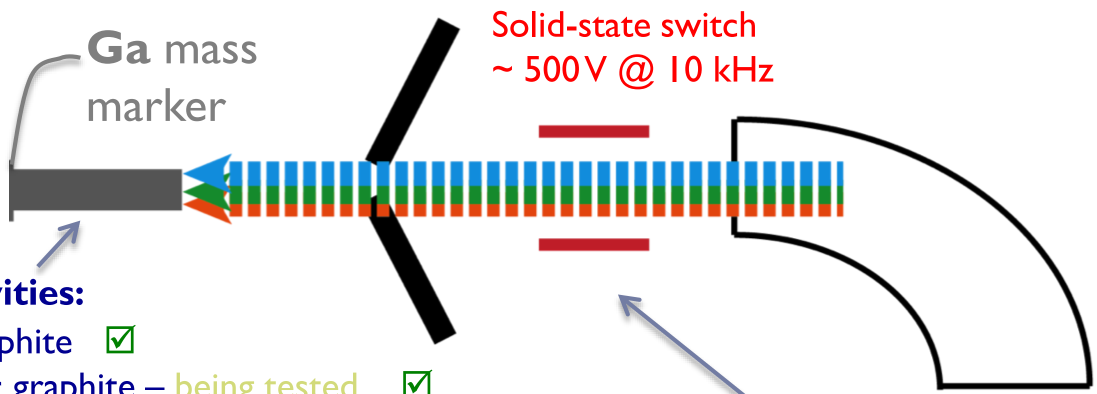
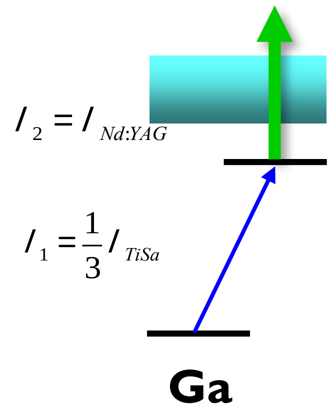
RILIS

Narrow laser-ion bunch width + micro beam gate tests

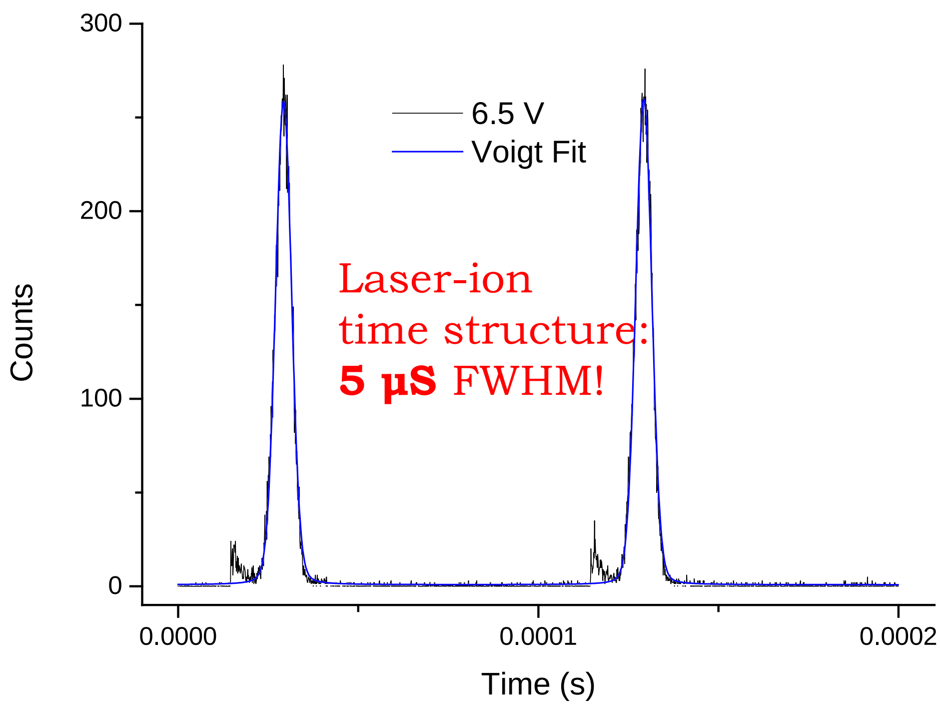




High Ω cavities:

1. Thin graphite ☑
2. Pyrolytic graphite – being tested ☑
3. Sigradur 'glassy' graphite ☐ – under construction
4. Pulsed heating for higher voltage ☐ –under investigation

5 us beam gating test



The fast beam gate is capable of a 1µs beam gate!
This would give a **100 x** surface ion suppression!
Challenge : make a 1µs wide laser ion bunch.
Required pulsed cavity heating and possibly ToFLIS technique

Scheme development for RILIS

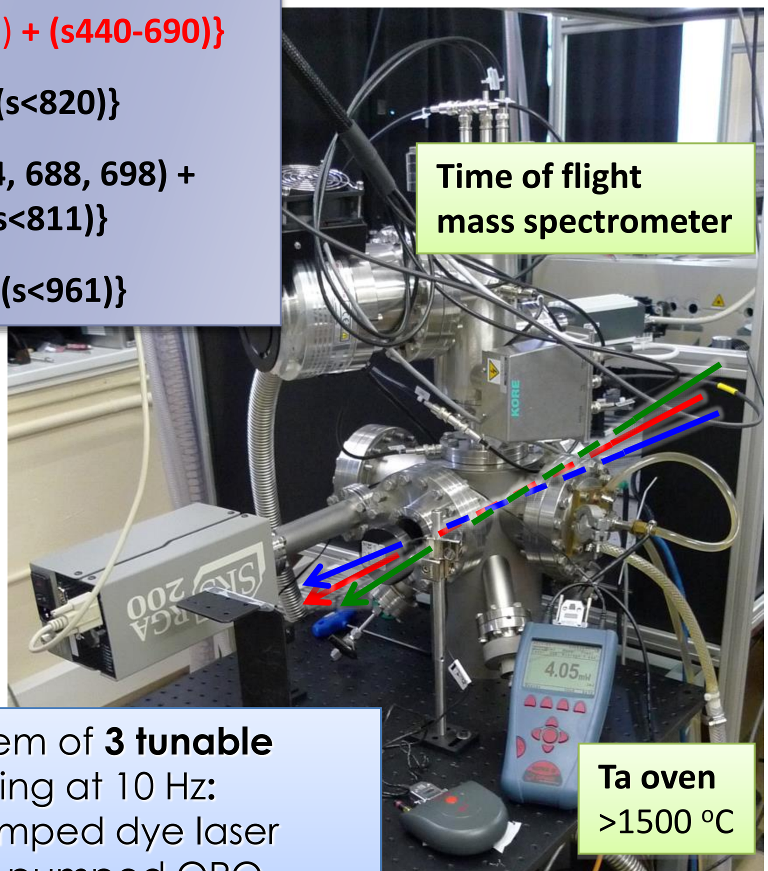
LARIS

Ba {(350 (700/2) **+ (s440-690)}**

Li {670 + 610 + (s<820)}

Cr {360 + (531.4, 688, 698) + (s<1260,s<811,s<811)}

Er {391 + 753 + (s<961)}



Versatile system of **3 tunable lasers** operating at 10 Hz:

- Nd:YAG pumped dye laser
- Nd:YAG UV pumped OPO
- Nd:YAG 532nm pumped OPO
- 3 frequency doublers

RILIS

For offline tests of LARIS schemes at end of LS1

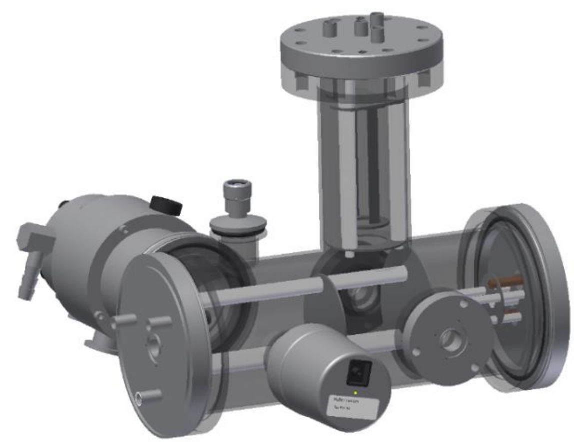
Once the **reference cell** is installed:

(Cr) {360 + 390 + (within 1000cm^-1 of IP)}

Check efficiency of pre-existing Co & Ge AIS schemes from Leuven/Mainz:

Ge {253 + 910 + 781} 3.3% efficiency at Oakridge

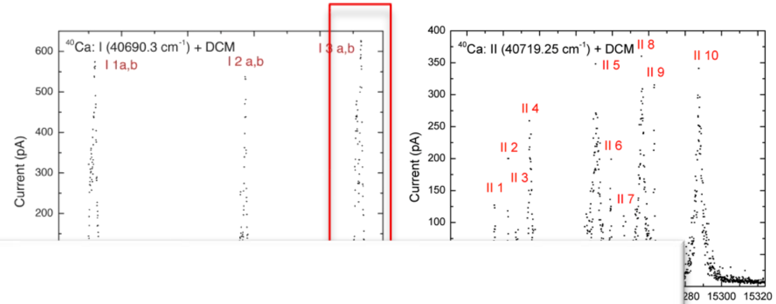
Hg search for AI at RILIS

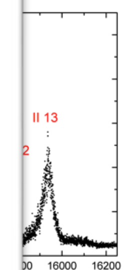


Calcium scheme development performed **during on-line operation**

RILIS

a) Scans for Auto-ionization states using spare Sirah Dye laser
b) AI Transitions from two intermediate levels were observed
c) Enhancement of ionization efficiency of a **factor of >10** w.r.t 50 W green beam for non resonant ionization!
d) Only possible due to the use of a TiSa for 1st step



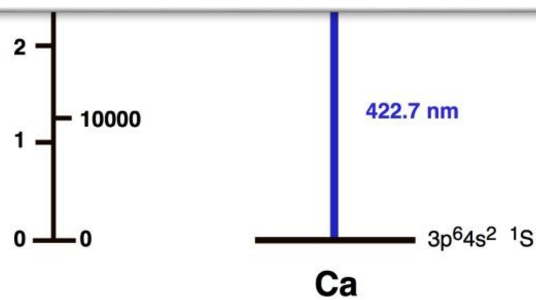


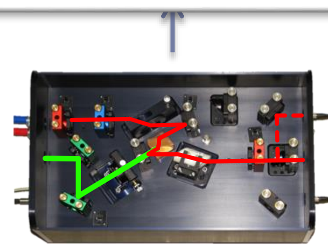
LETTER

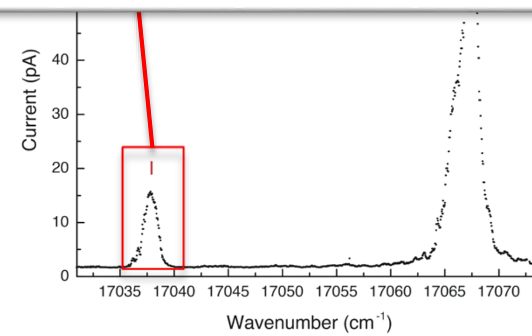
doi:10.1038/nature12226

Masses of exotic calcium isotopes pin down nuclear forces

F. Wienholtz[1], D. Beck[2], K. Blaum[3], Ch. Borgmann[3], M. Breitenfeldt[4], R. B. Cakirli[3,5], S. George[1], F. Herfurth[2], J. D. Holt[6,7], M. Kowalska[8], S. Kreim[3,8], D. Lunney[9], V. Manea[9], J. Menéndez[6,7], D. Neidherr[2], M. Rosenbusch[1], L. Schweikhard[1], A. Schwenk[7,6], J. Simonis[6,7], J. Stanja[10], R. N. Wolf[1] & K. Zuber[10]





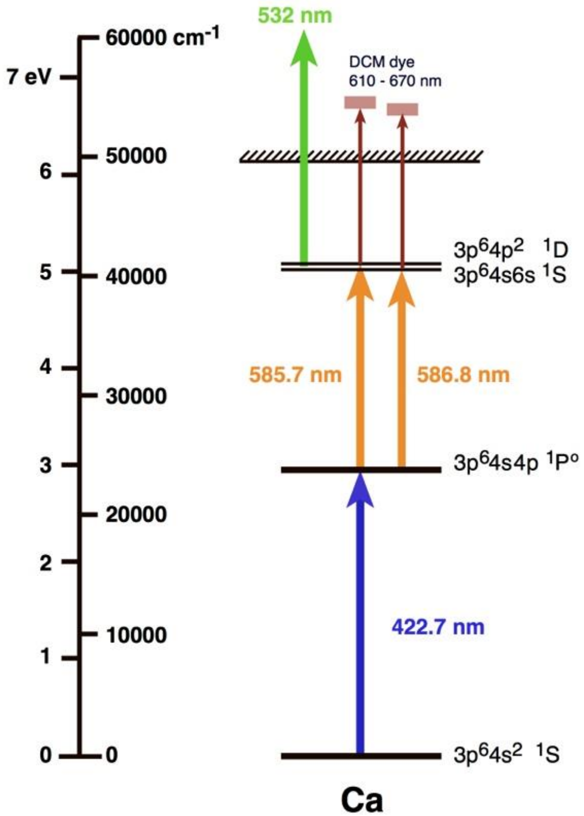


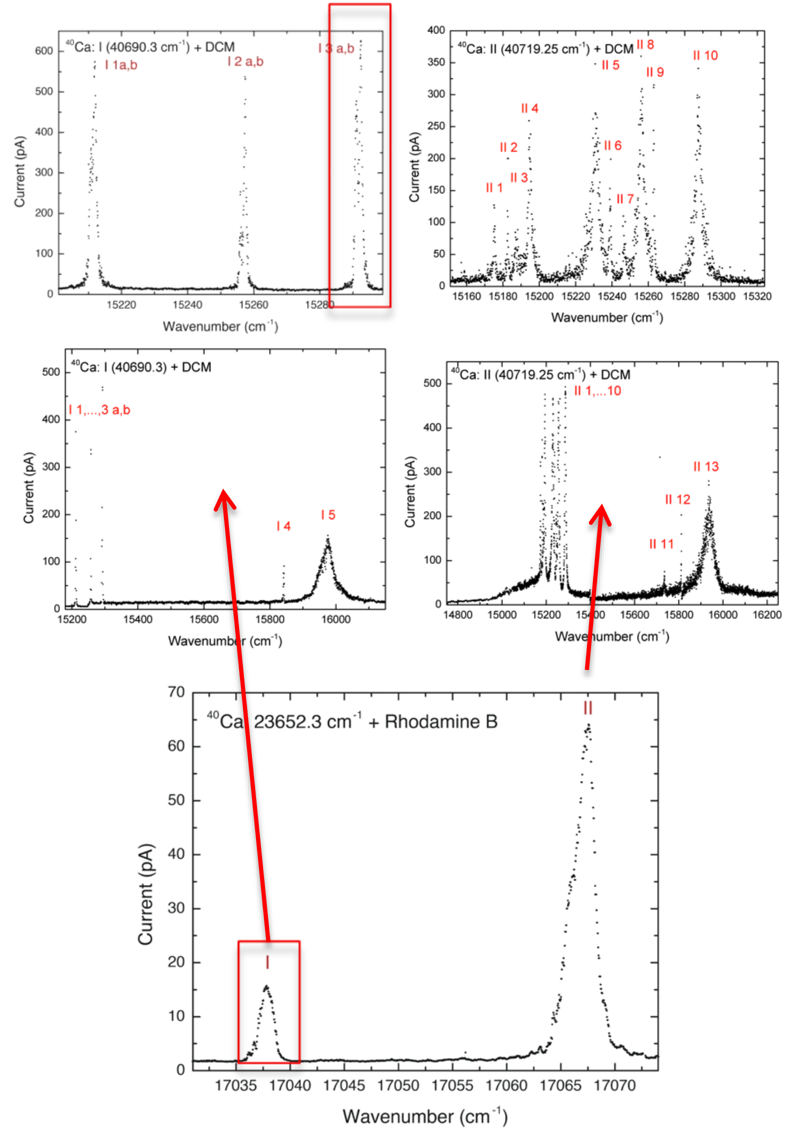
- Daniel Fink: PhD work

Calcium scheme development performed during on-line operation

RILIS

a) Scans for Auto-ionization states using spare Sirah Dye laser
b) AI Transitions from two intermediate levels were observed
c) Enhancement of ionization efficiency of a **factor of >10** w.r.t 50 W green beam for non resonant ionization!
d) Only possible due to the use of a TiSa for 1st step





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Engineering Department

Calcium scheme development performed **during on-line operation**

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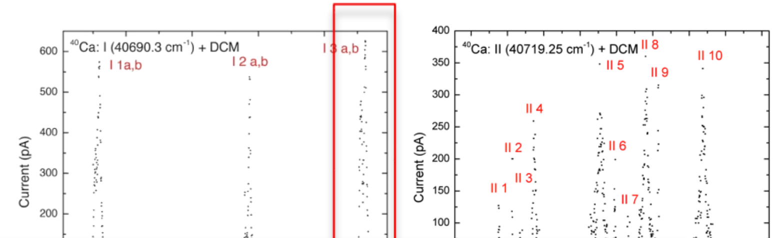

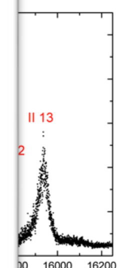

LETTER

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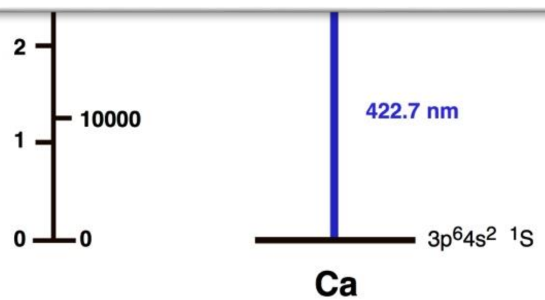
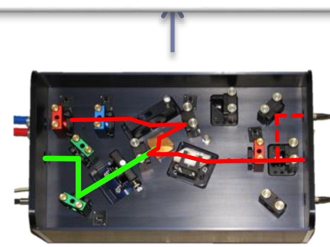
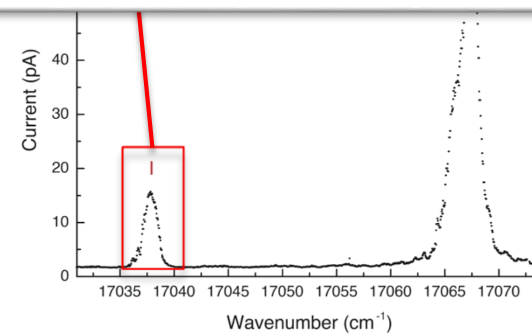


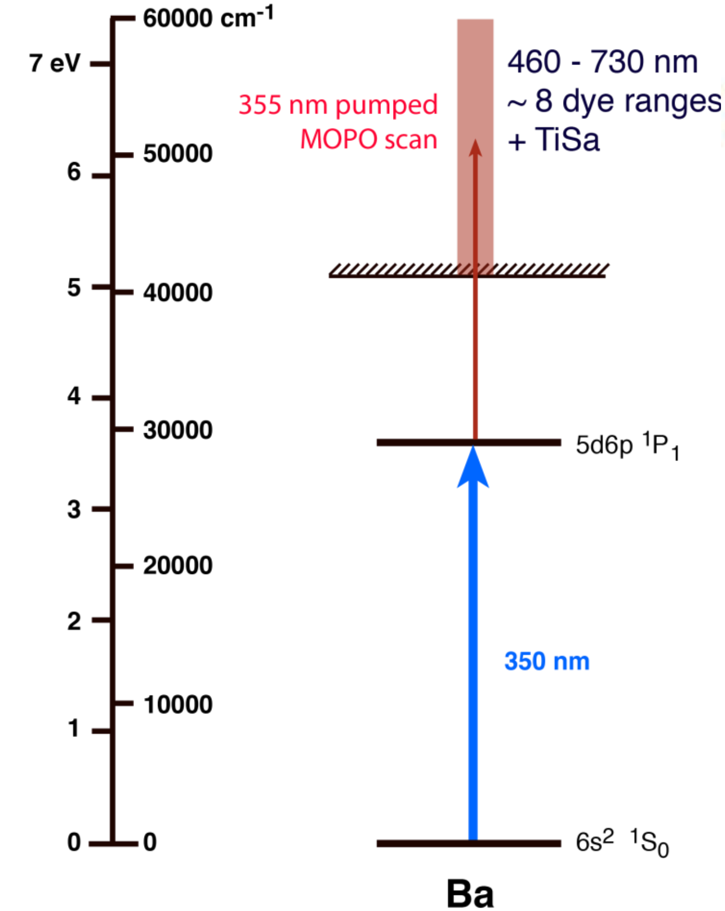


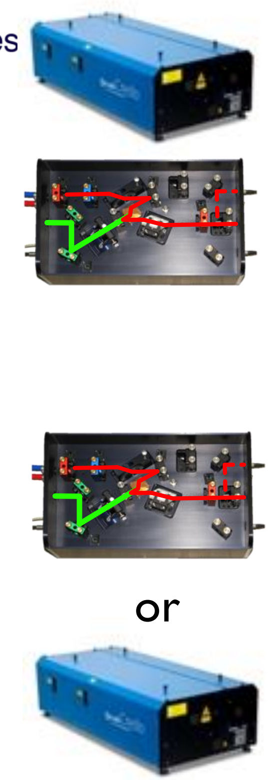


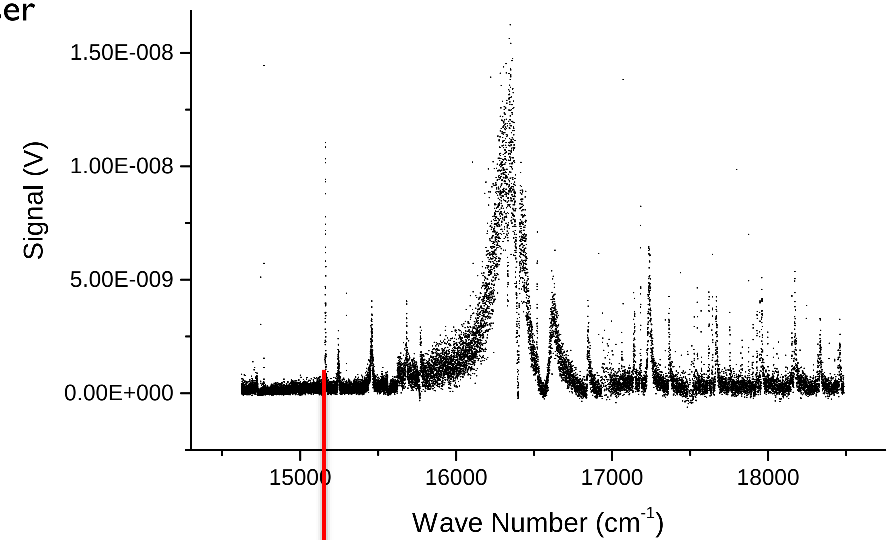
- Daniel Fink: PhD work

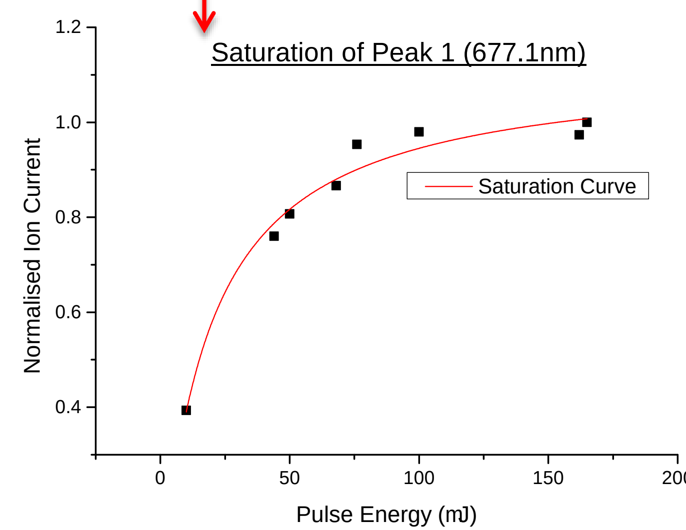
Barium scheme @ LARIS

a) Scans for Auto-ionization states using spare Sirah Dye laser
b) Select suitable AIS for maximum efficiency and RILIS convenience (several dye ranges + TiSa wavelength)
c) Compare schemes and make efficiency measurement @ RILIS during startup period (April-May).







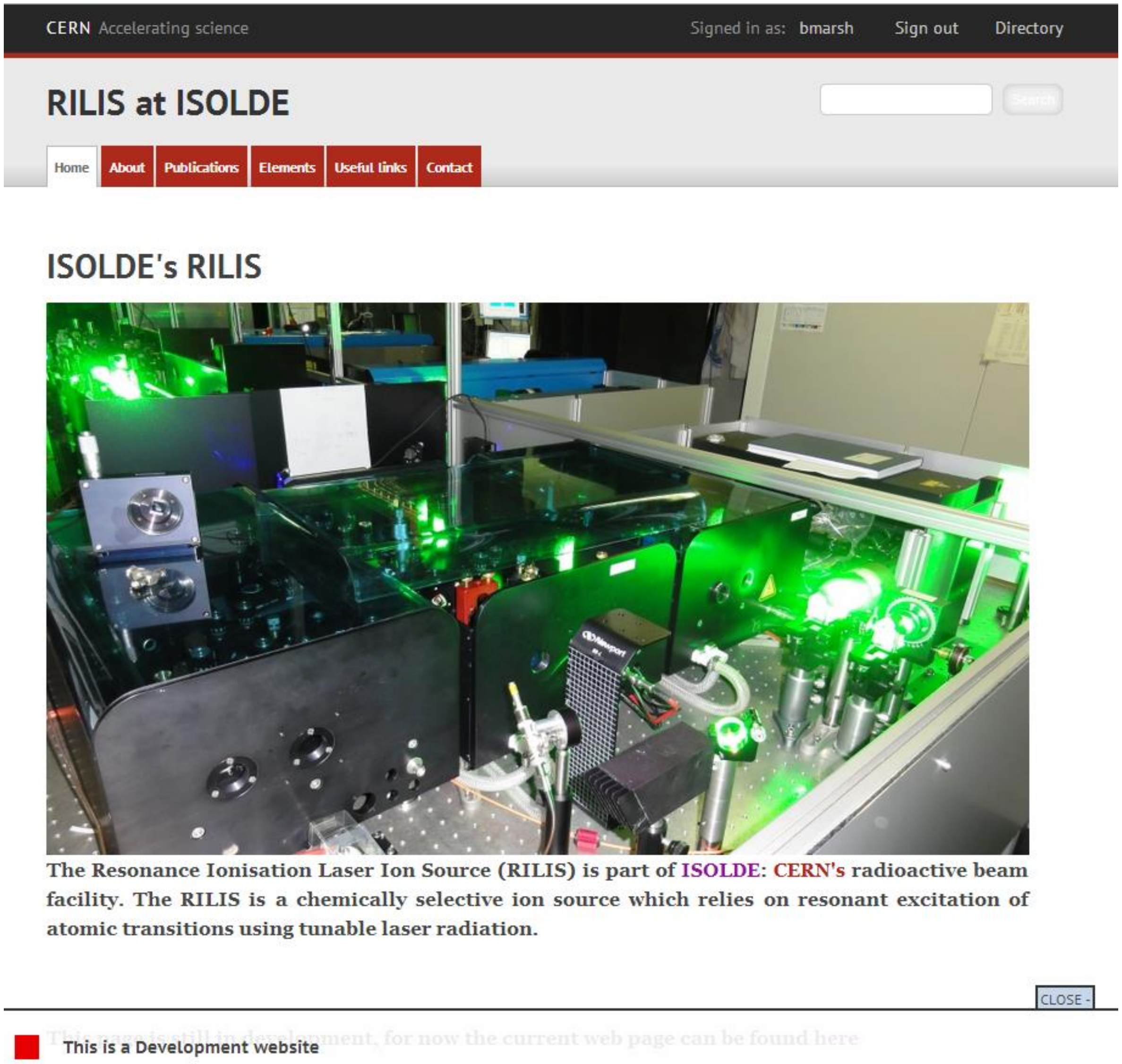


Tom Day Goodacre : PhD work

Engineering Department

New RILIS website

RILIS



Benefits:
Better layout
Updated contact and publication info
Link to RILIS elements database
Correct RILIS scheme info

STATUS
Almost ready!
About to go online
Link from ISOLDE webpage will be updated

Made by Tom Goodacre
(and CERN DRUPAL team)

Acknowledgements

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