The Laser Ion Source and Trap (LIST) at ISOLDE, CERN

Towards Isobar Free Ion Beams

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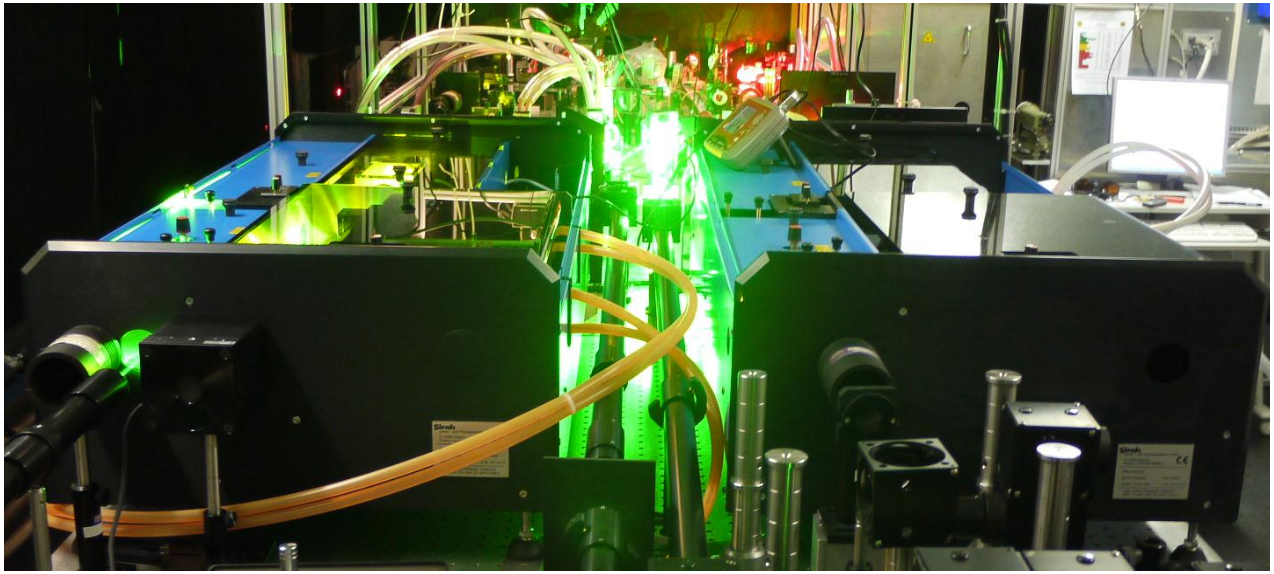
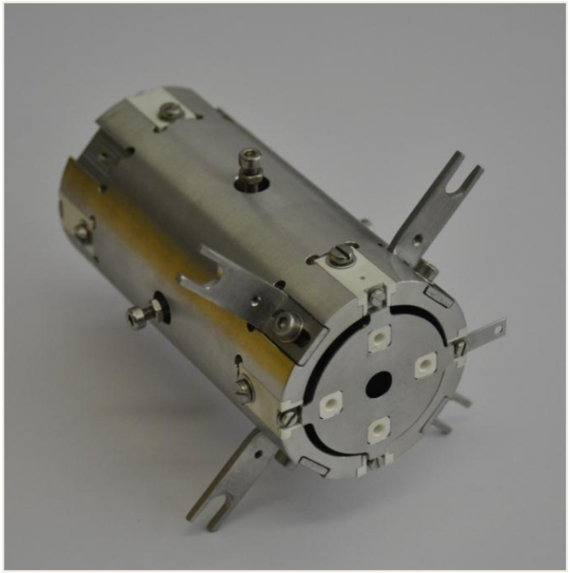
EMIS 2012, Matsue, Japan





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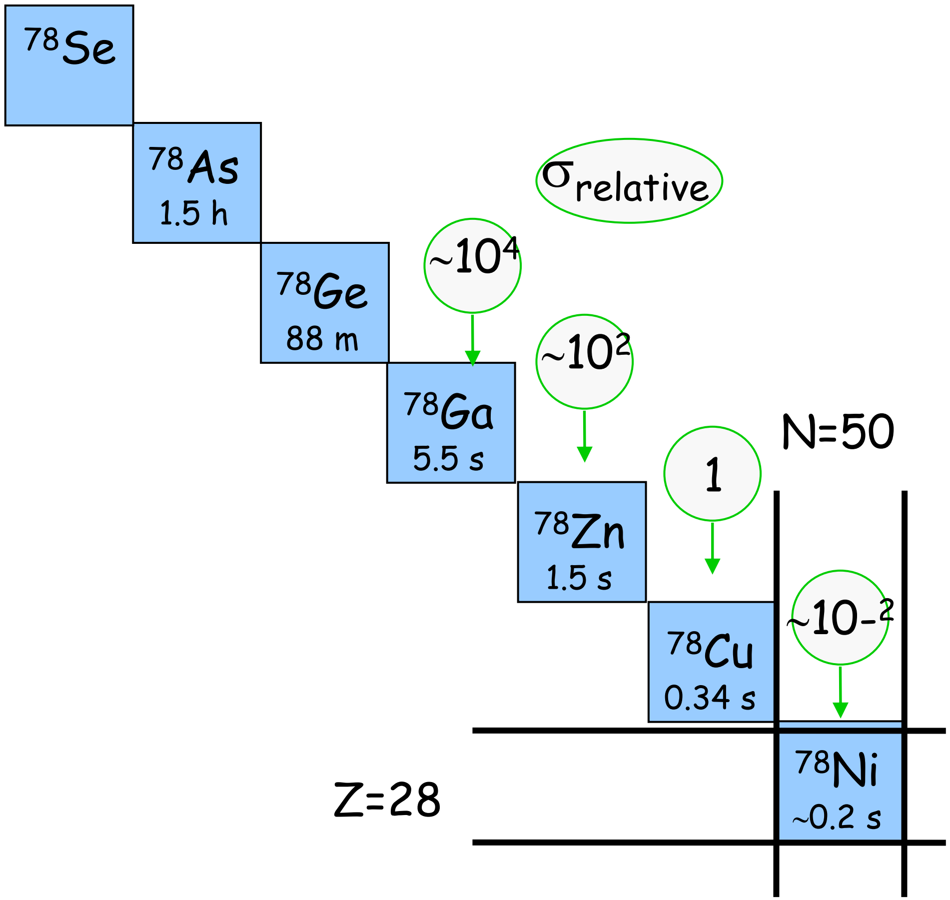
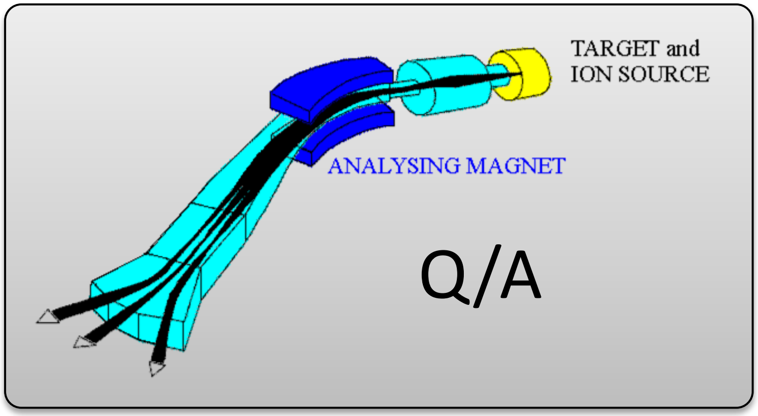
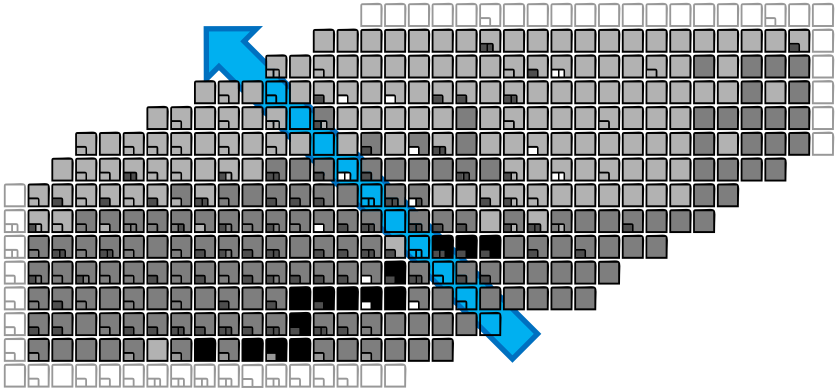
Motivation: Reduction of Isobaric Contamination

Example: isobaric contamination in a ^{78}Ni ion beam:

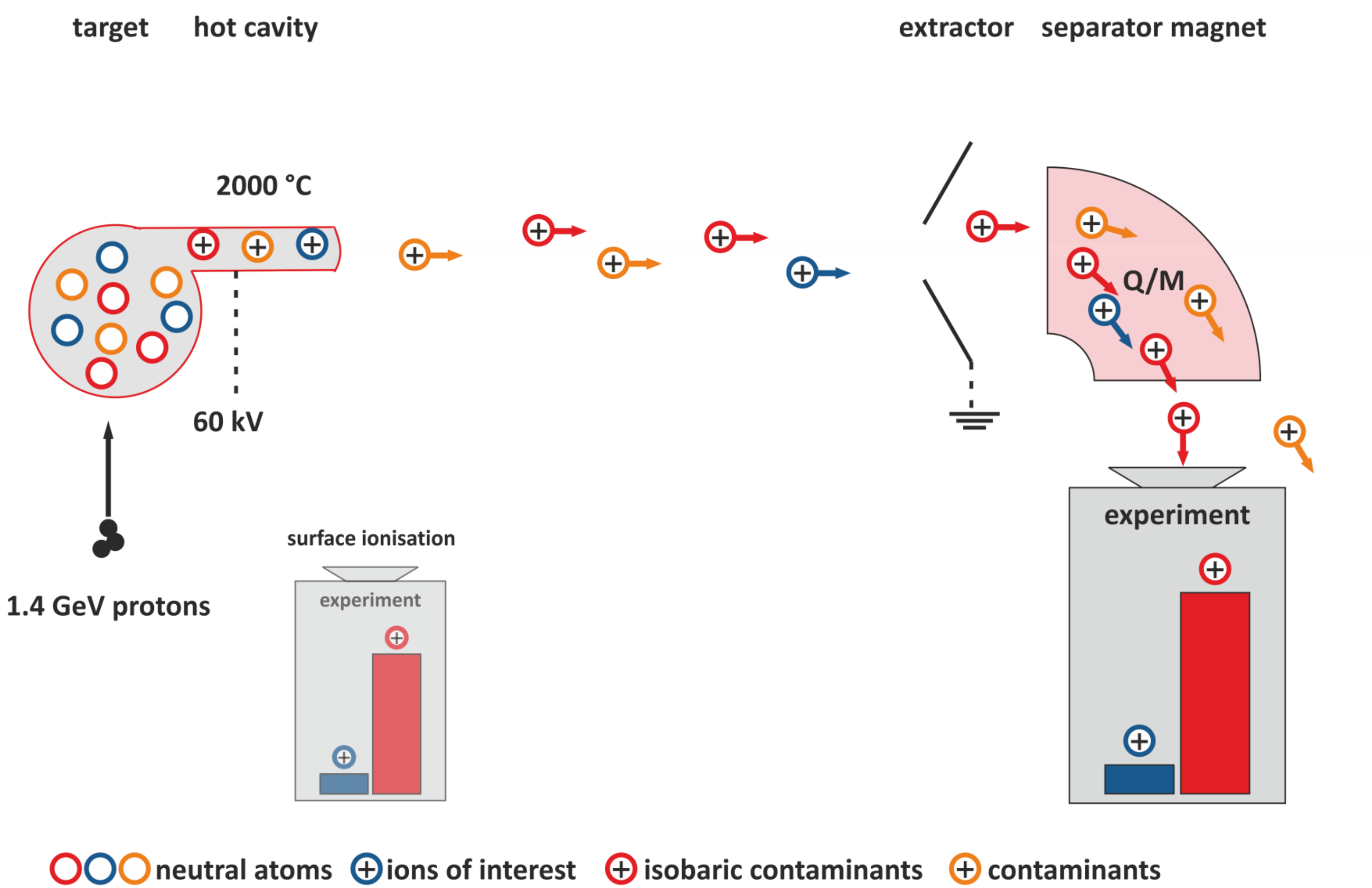
Fission of U with 1 Gev protons







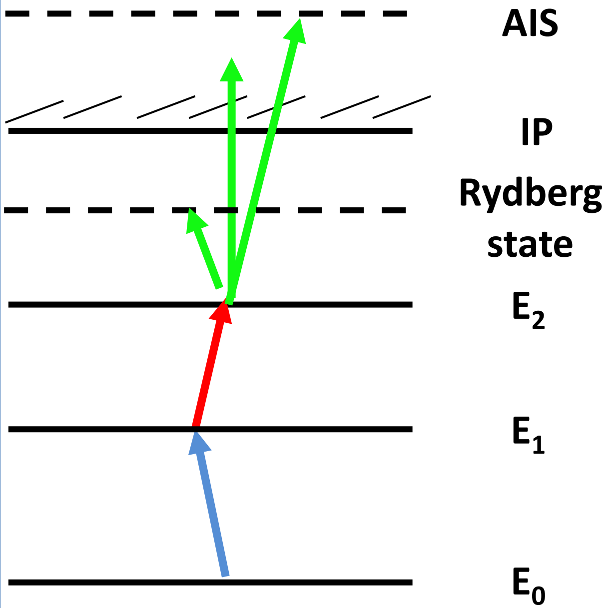
Motivation: Reduction of Isobaric Contamination



- **Nonselective surface ionisation in hot cavity**
- **Strong isobaric contamination might harm or prevent experiments**

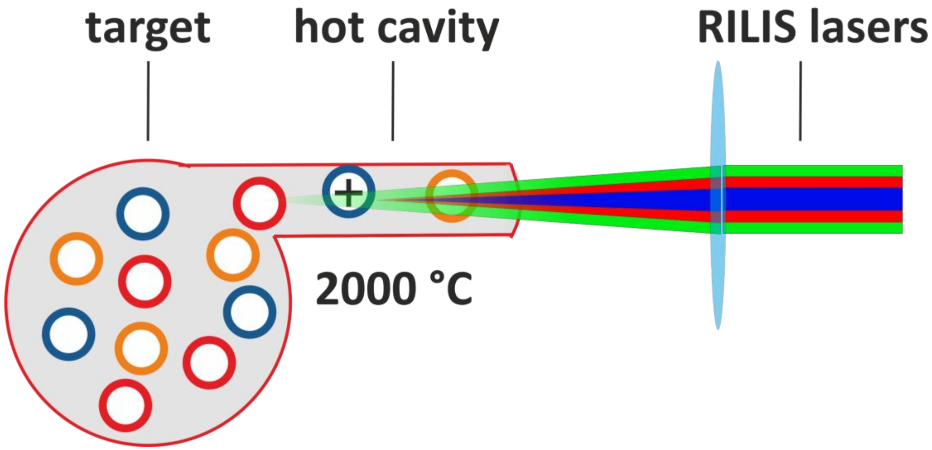
Resonance Ionization Laser Ion Source (RILIS)

Element unique RILIS schemes:



Principle of RILIS:

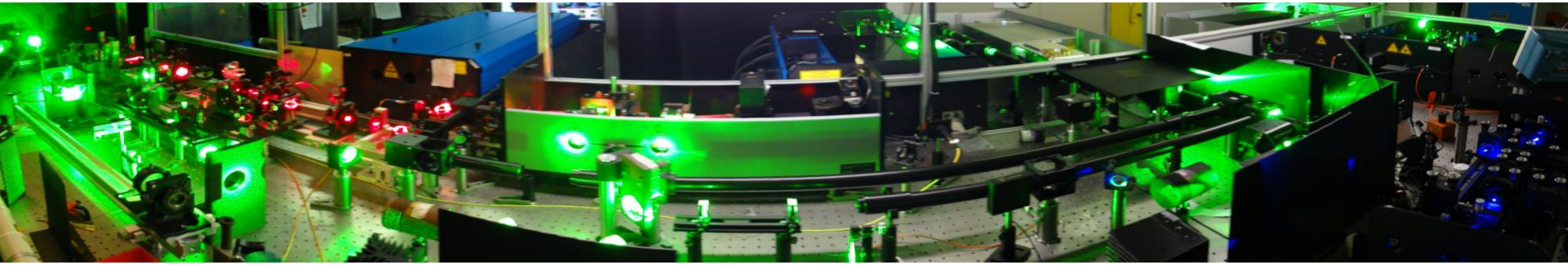
(Talk by B. Marsh)



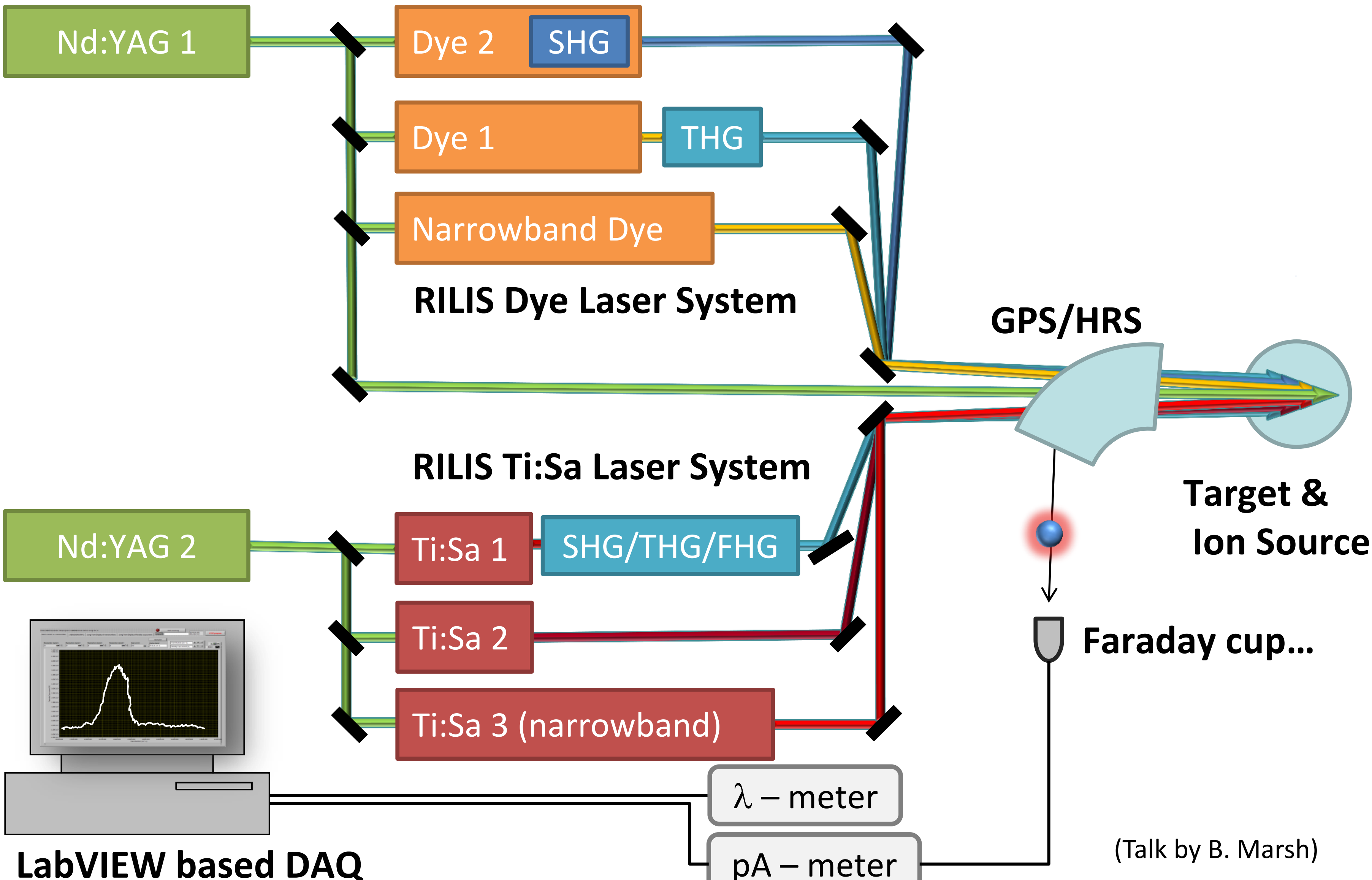
Resonant laser photons on atoms + Stepwise excitation of e^-

→ **Very efficient and element selective ionization!**

A panoramic view of the RILIS laser setup:

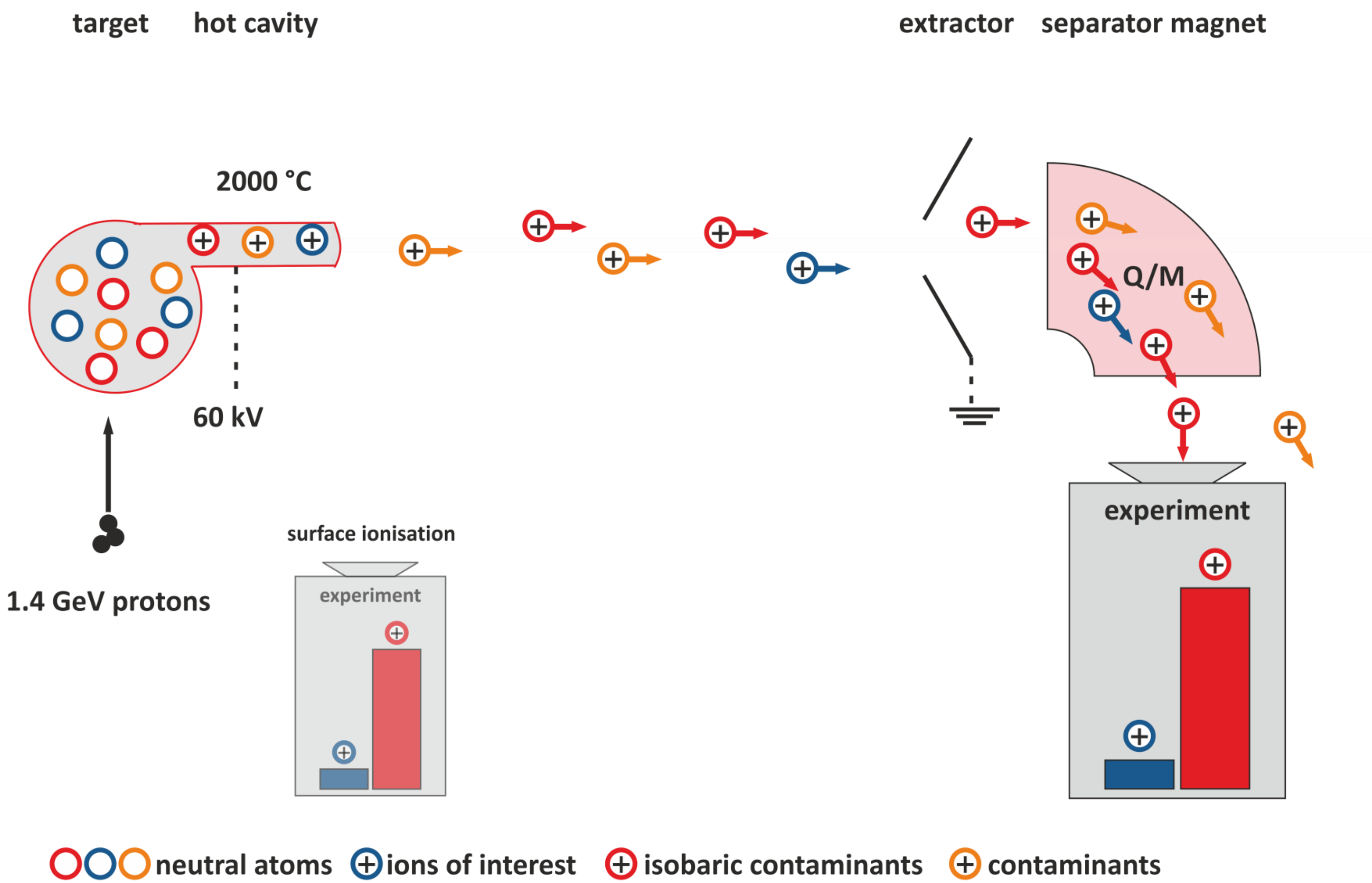


Scheme of RILIS at ISOLDE



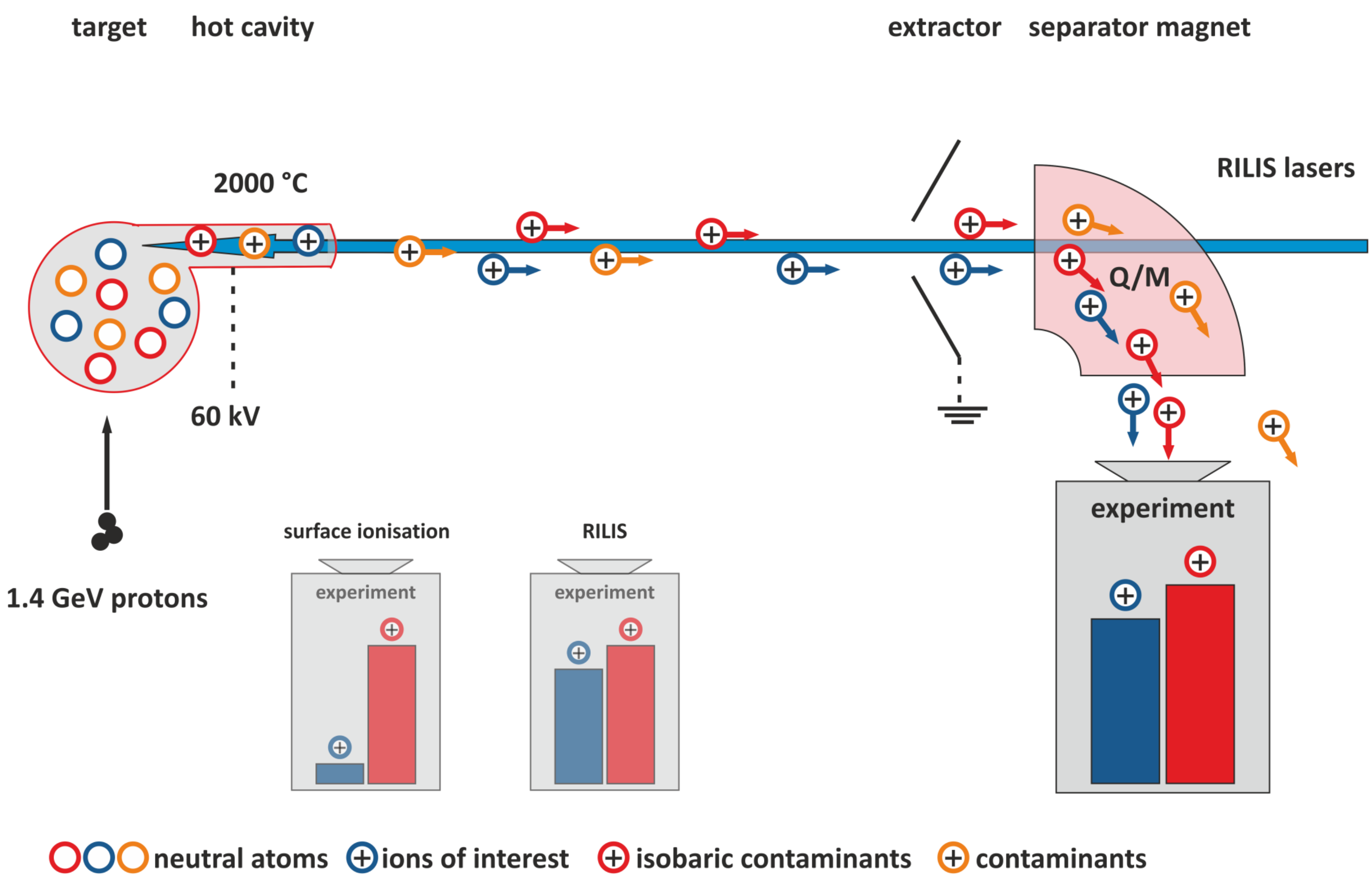
(Talk by B. Marsh)

Isobaric contamination in RILIS beams



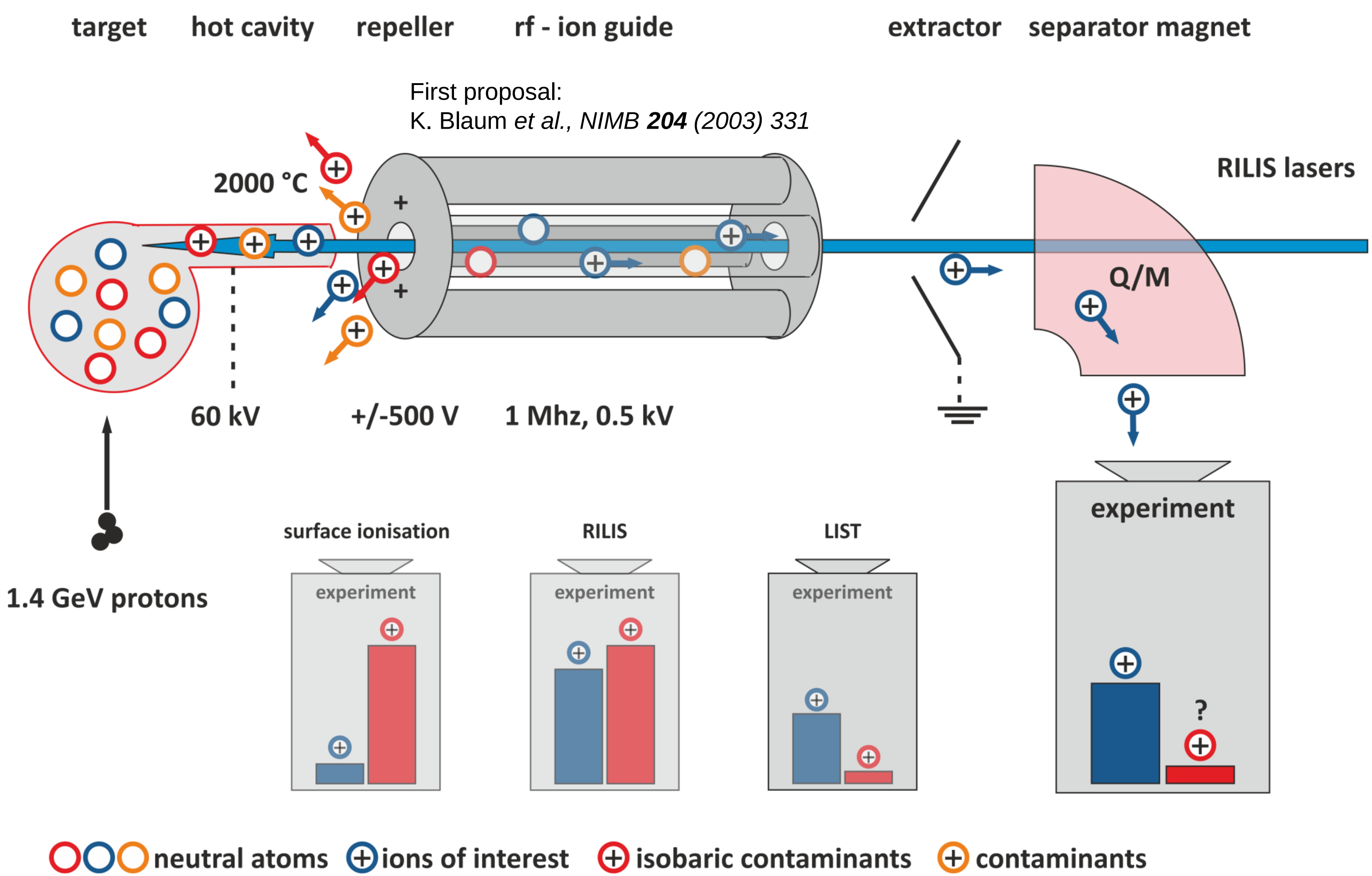
- **Nonselective surface ionisation in hot cavity**
- **Strong isobaric contamination might harm or prevent experiments**

Isobaric contamination in RILIS beams



- **Strong increase of ions of interest**
- **Higher selectivity but isobaric contaminants remain in beam**

Principle of Laser Ion Source and Trap (LIST)

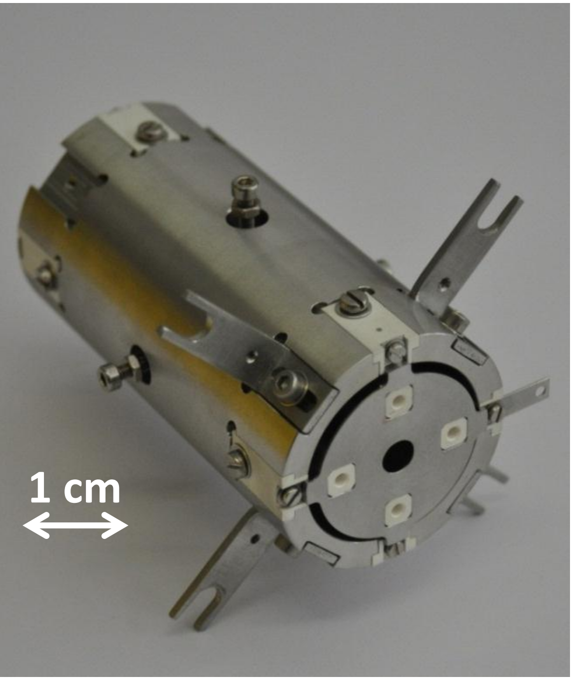


- **Remove surface ions by electrostatic deflection**
- **High selectivity due to laser ionization outside hot cavity**
- **Transverse rf-trapping field guides ions towards extraction region**

LIST Target Assembly

LIST device:

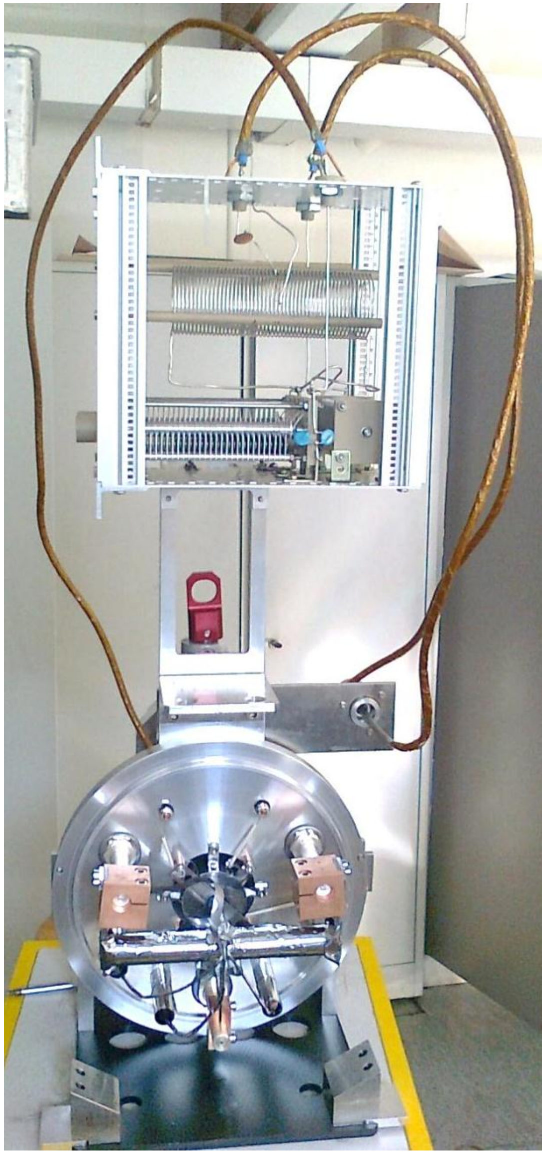
Proposal:
K. Blaum *et al.*, *NIMB* ***204*** *(2003) 331*



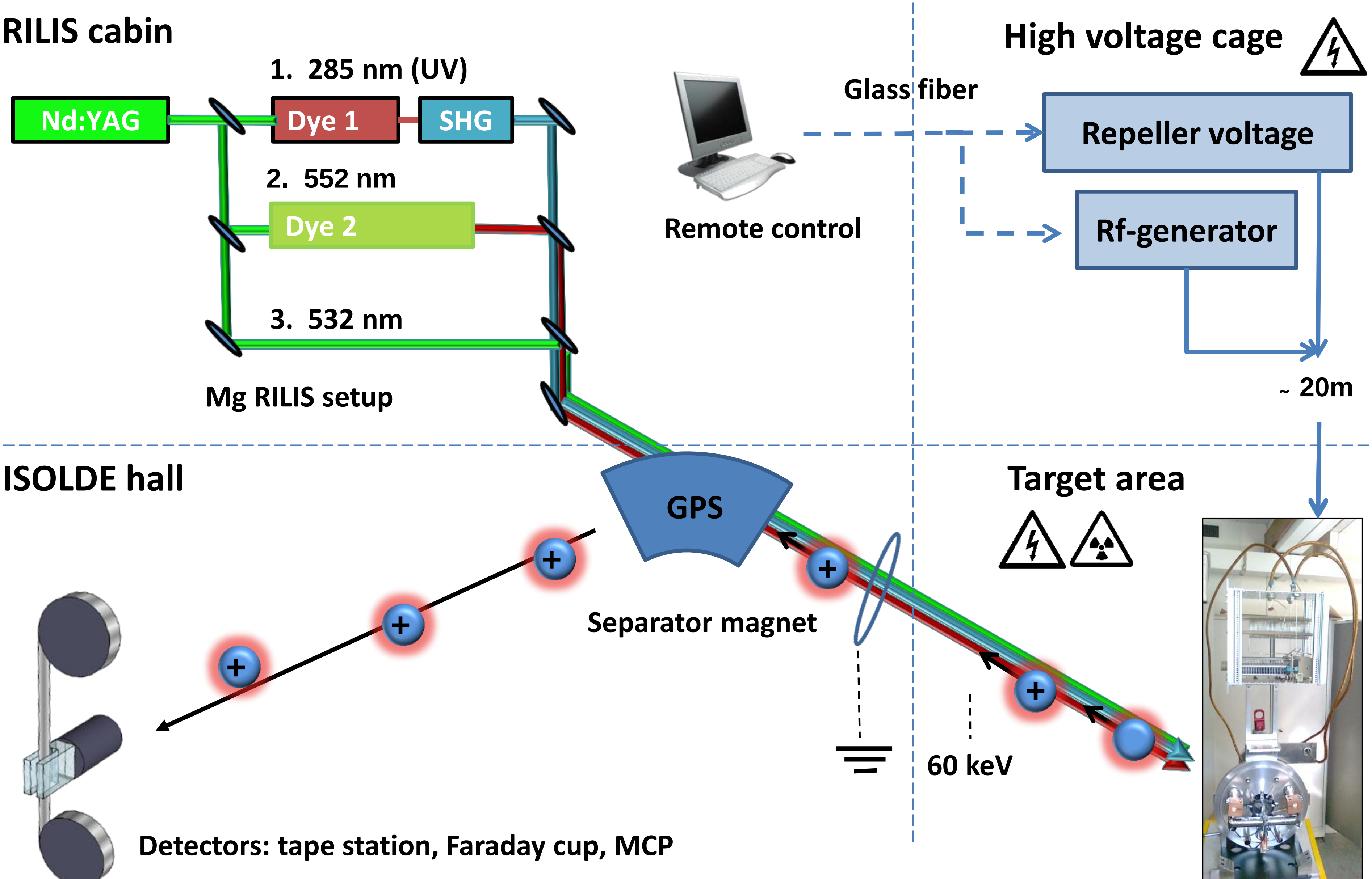
Necassary target modifications:

- **Radiation hard components**
- **Stable support**
- **Automatic rf-connector**
- **Stable line- and target holder**
- **Transducer box**

LIST target unit:

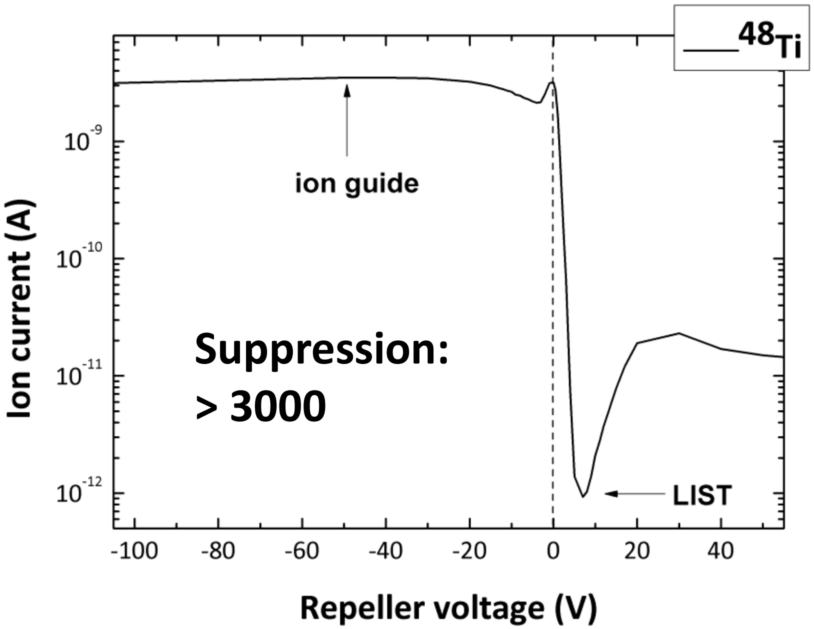


LIST Setup at ISOLDE

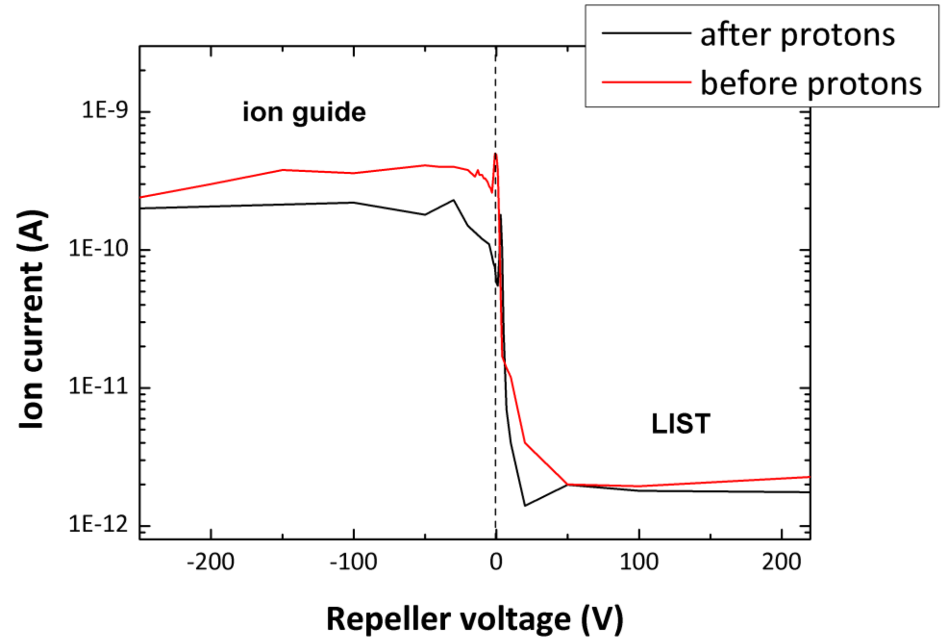


Highlights of LIST run 2011

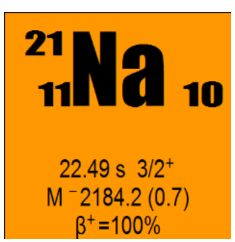
1. Suppression of stable surface ions:



2. Reliability and robustness:

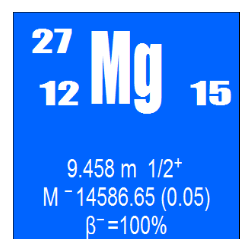


3. Suppression of radioactive ions:



$$\frac{IC_{\text{Ion guide}}}{IC_{\text{LIST}}} > \frac{1600}{1}$$

4. Laser ionization efficiency:



$$\frac{IC_{\text{Ion guide}}}{IC_{\text{LIST}}} \approx 50$$

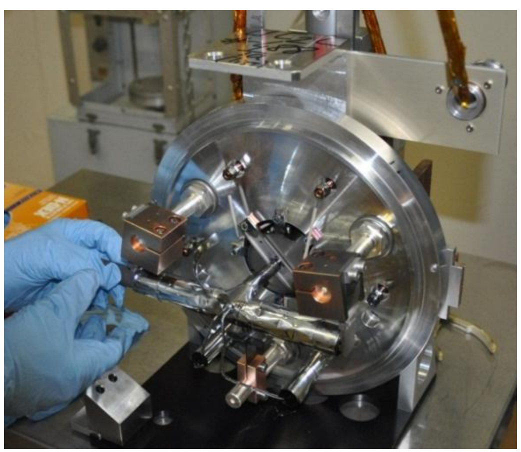
Effective suppression of surface ions but with lower laser ionization efficiency.

LIST On-Line Run 2012: First Physics

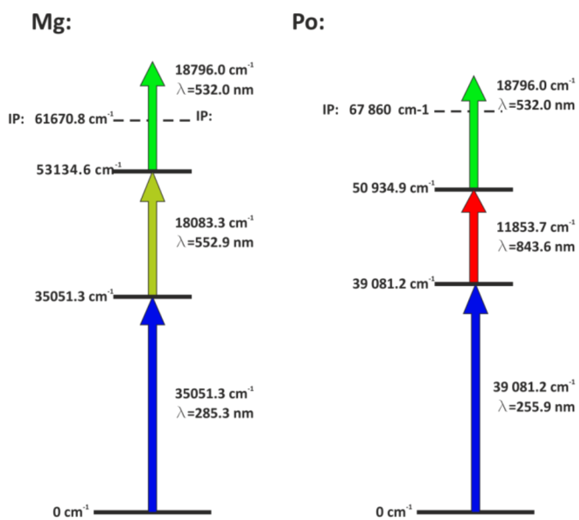
Goals of second LIST on-line run:

- Test of improved LIST design for higher efficiency
- Proof of principle with strongly outgassing Ucx-target
- First real on-line applications of LIST at ISOLDE
- Provide highly purified beams of Mg and Po

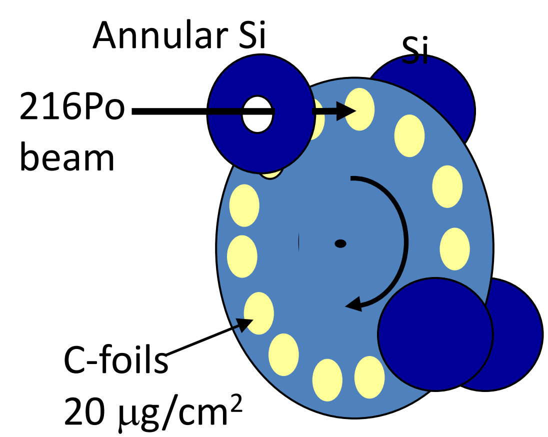
UCx-target:



RILIS schemes for Mg and Po:

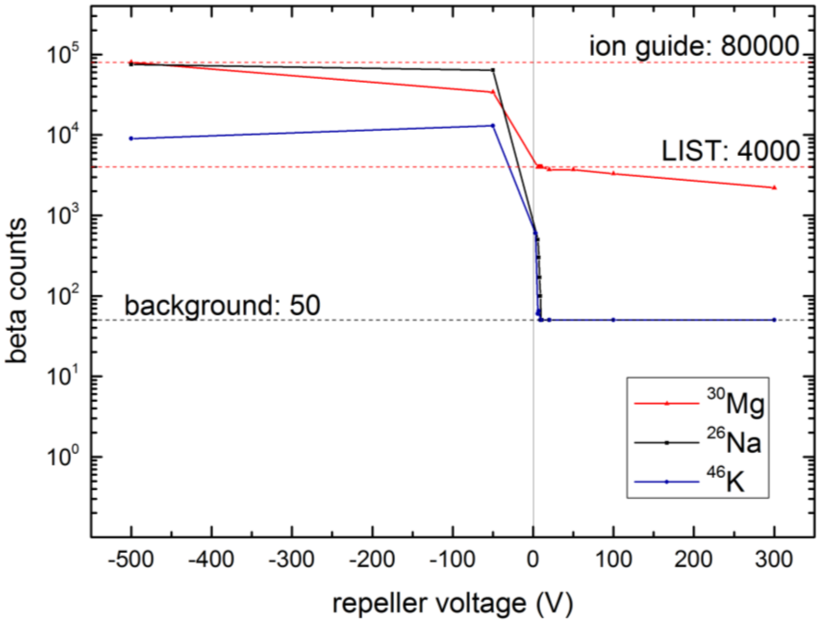


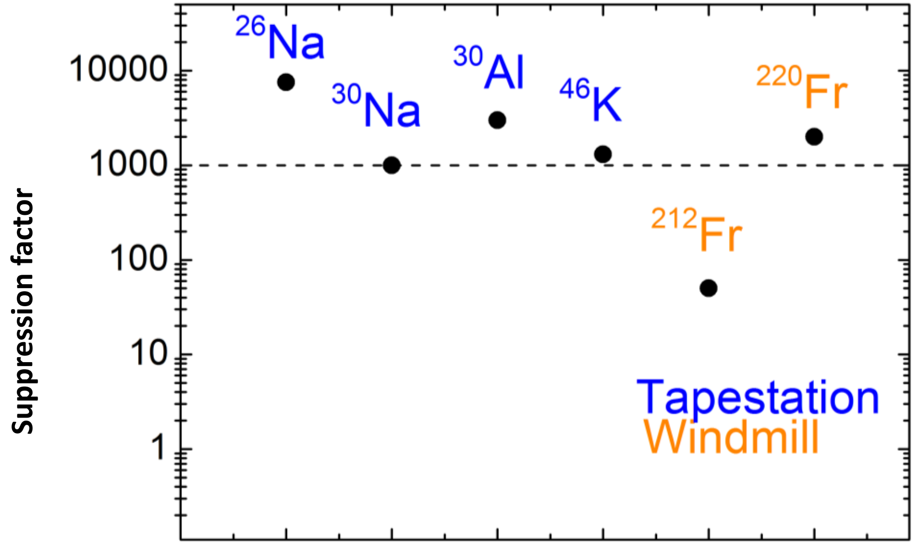
α detector (Windmill, Leuven):



LIST Performance 2012: Efficiency and Suppression

Scans of repeller voltage for different masses with β-detector:





- **<u>Ion Guide vs. LIST:</u>**

^{30}Mg: $\frac{IC_{\text{Ion guide}}}{IC_{\text{LIST}}} \approx 20$

^{208}Po: $\frac{IC_{\text{Ion guide}}}{IC_{\text{LIST}}} \approx 20$

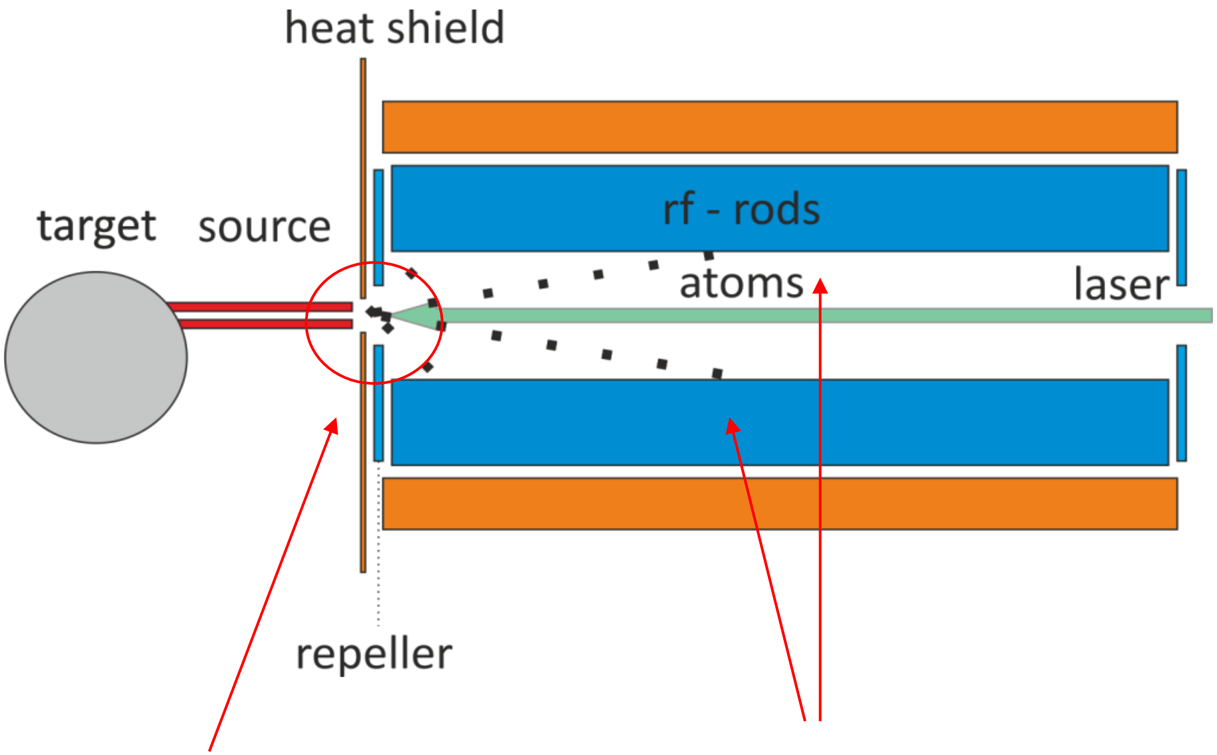
(2011: ≈ 50)

- **<u>Overall suppression:</u>**

3 orders of magnitude

➢ **But limits for certain isotopes**

Limits of LIST …



Limits of ionization efficiency:

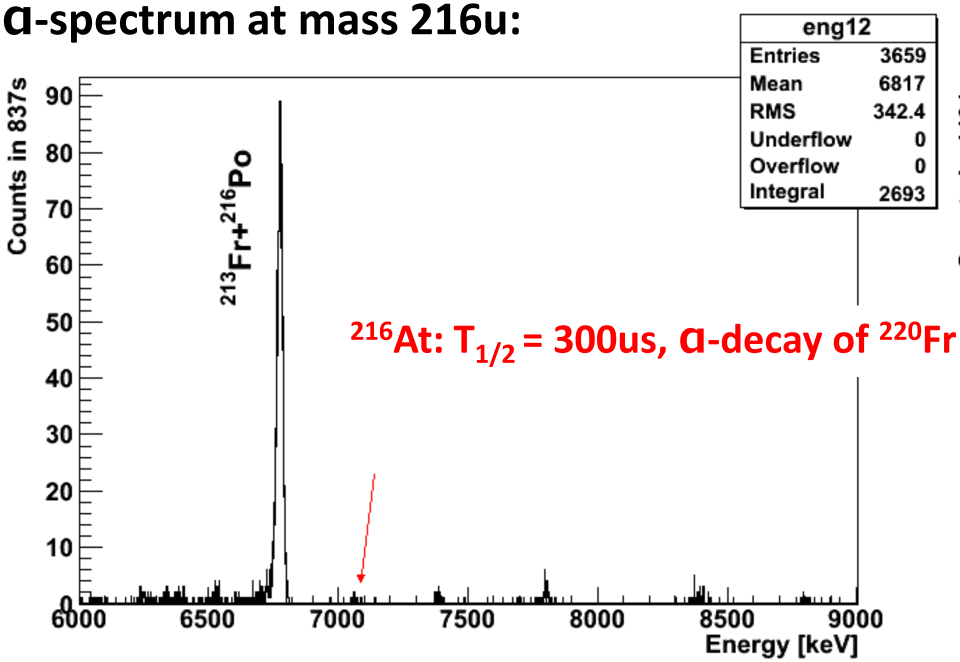
- **Laser-atom overlap in LIST mode**

Limits of suppression:

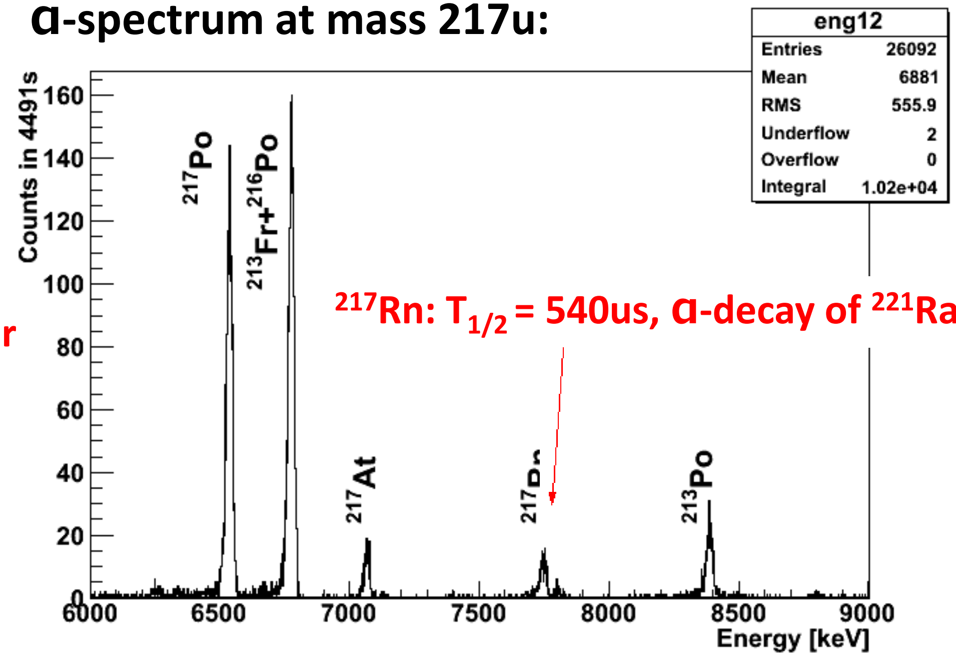
- **Neutral atoms pass repeller**
  - ➢ **Condensation on cold surfaces**
  - ➢ **In-trap decay**
  - ➢ **Other ionization mechanics**

…and Some Surprises: Beams of Short-Lived Isotopes

α-spectrum at mass 216u:



α-spectrum at mass 217u:



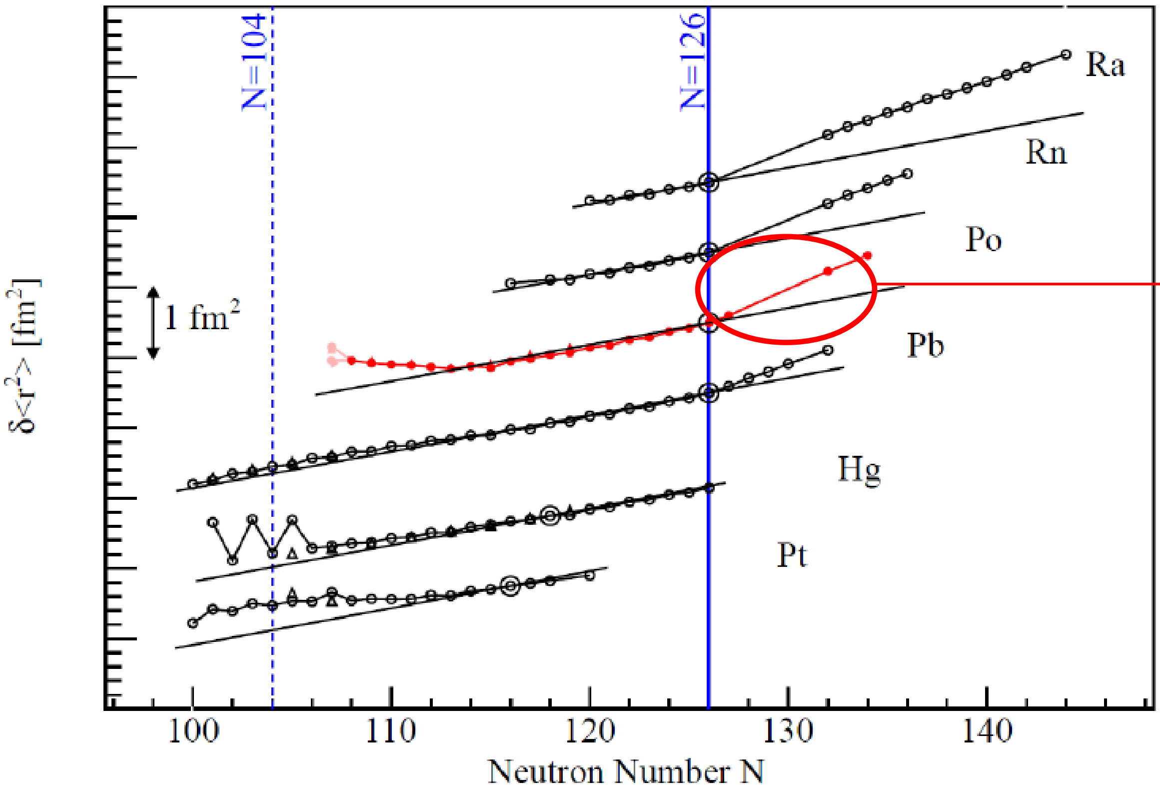
- Condensation of mother nuclei on rods
- In-trap decay on rf-rods
- Trapping in rf-potential and extraction towards ISOLDE beam line

➢ **Observation of 0.2 counts/sec of ^{216}At($T_{1/2}$ = 300us) and ^{217}Rn ($T_{1/2}$ = 54us)**

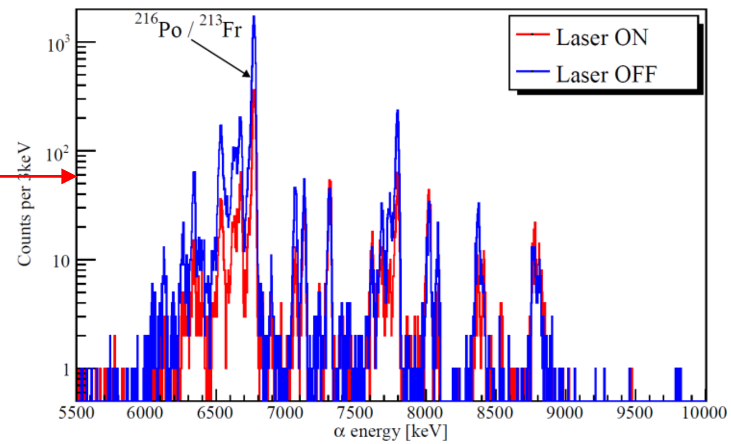
Motivation: Laser Spectroscopy on Polonium

Two measurement campaigns in 2007 and 2009 at ISOLDE/CERN

Mean square radii of Po-isotopes among other elements:



Po invisible due to Fr contamination:

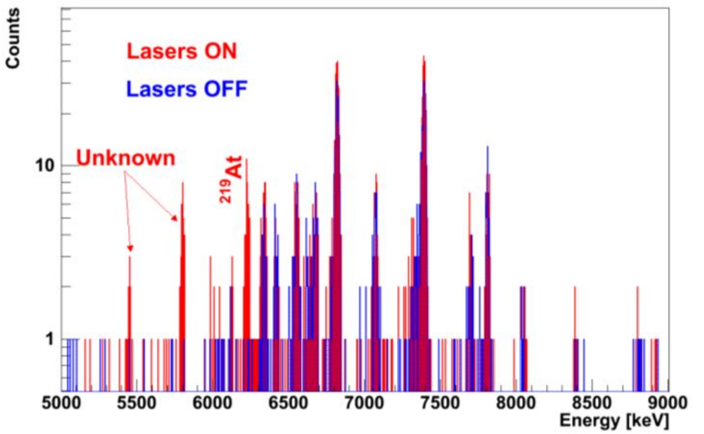


- **Several Po-isotopes remained unstudied due to strong Fr-contamination**
- **Using LIST to suppress Fr contamination in 2012**

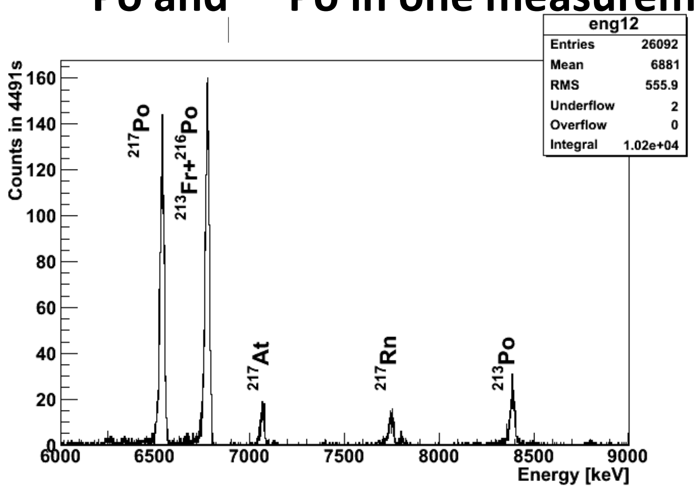
T. E. Cocolios, 2008, PhD thesis

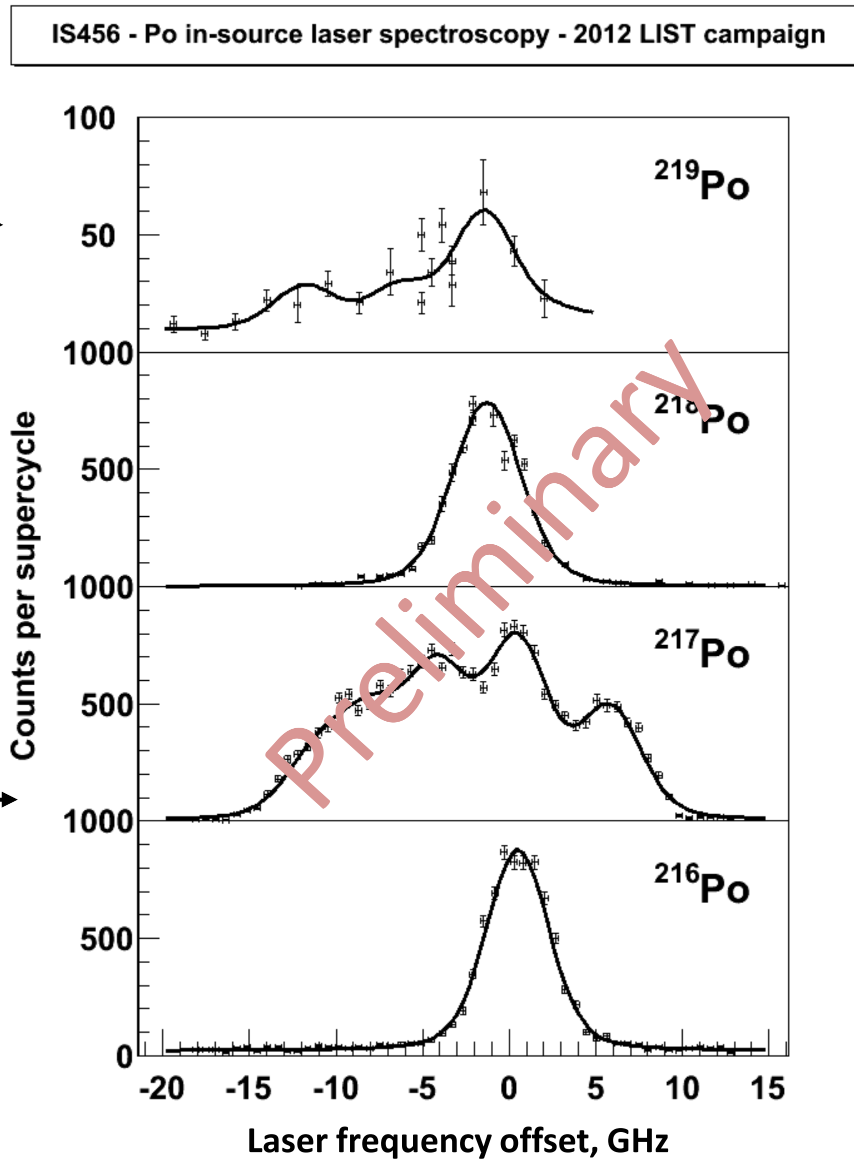
Polonium Spectroscopy: HFS and IS

- **New Po-decay data on mass 219**



- **^{216}Po and ^{217}Po in one measurement**





➢ **Direct measurement of IS of ^{216}Po and ^{217}Po**

Summary

- LIST suppresses isobaric contaminants and improves selectivity of RILIS

- Proof of principle by 2011 on-line run:
  - Suppression of > 1000
  - Ionization efficiency reduction by ≈50x (Mg)

- First real physics application in 2012:
  - Suppression of > 1000, but limited by in-trap decay for certain isotopes
  - Ionization efficiency reduction by ≈20x (Mg,Po)
  - Production of ion beams of short-lived ions by in-trap decay
  - Laser spectroscopy of $^{216-217}$Po possible due to suppression of Fr by LIST

LIST is now an established ion source option for ISOLDE users

Acknowledgements

...and special thanks to the collaborators:

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... and the whole IS456 collaboration

EN STI

RILIS

LARISSA

CERN

RUPRECHT-KARLS-UNIVERSITÄT HEIDELBERG

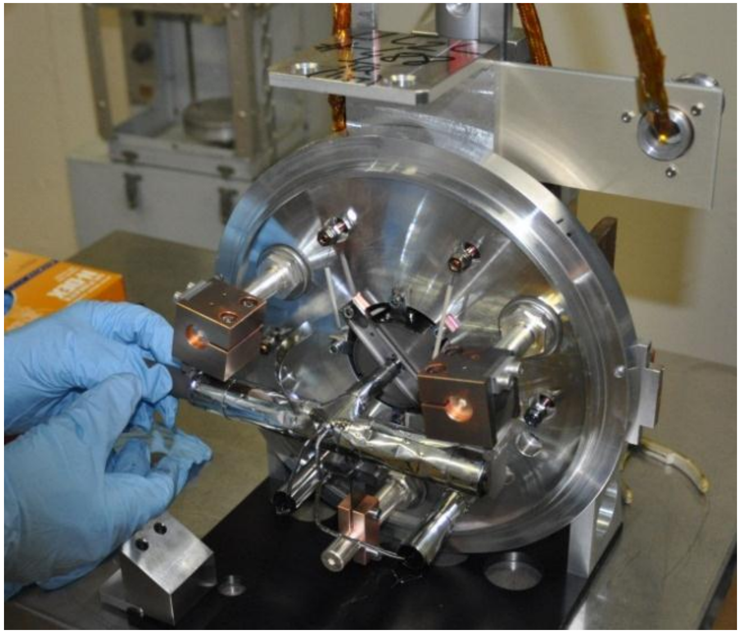
MAX-PLANCK-GESELLSCHAFT

JG|U JOHANNES GUTENBERG UNIVERSITÄT MAINZ

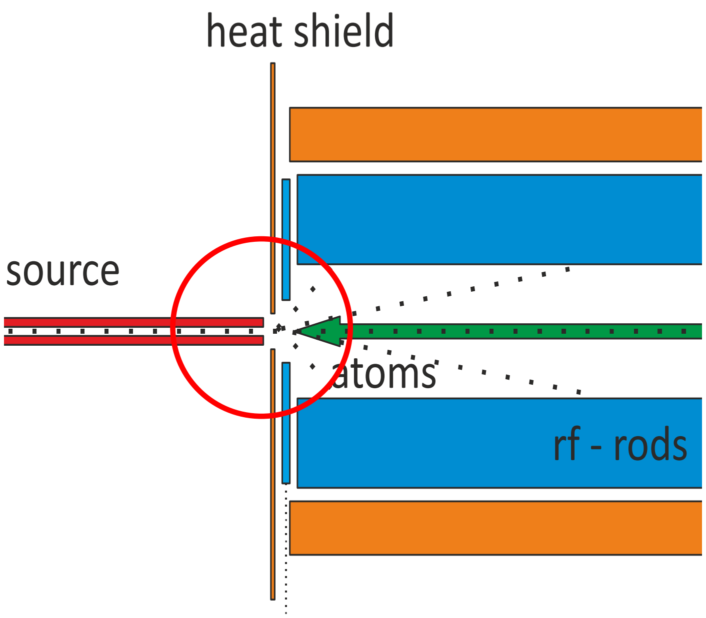
LIST On-Line Target 2012

Challenges:

- First real physics application of LIST target
  - ➢ Robustness and reliability is essential
- Strongly outgassing UCx-target
  - ➢ Strong ion load in hot cavity
  - ➢ more contaminants expected
  - ➢ Concerns regarding coating of insulators



Filling the LIST target with UCx pellets

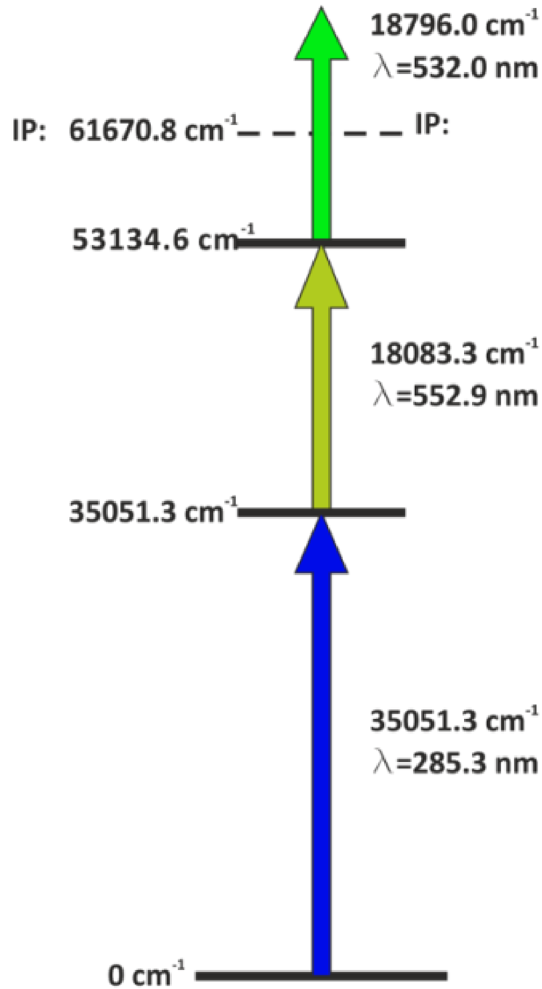


Modifications of LIST to improve efficiency:

- Improved design of insulators
- reduced distance repeller to source: 4 to 1.5mm
- repeller opening widened : 6 to 13mm

LIST Run 2011: First On-Line Test

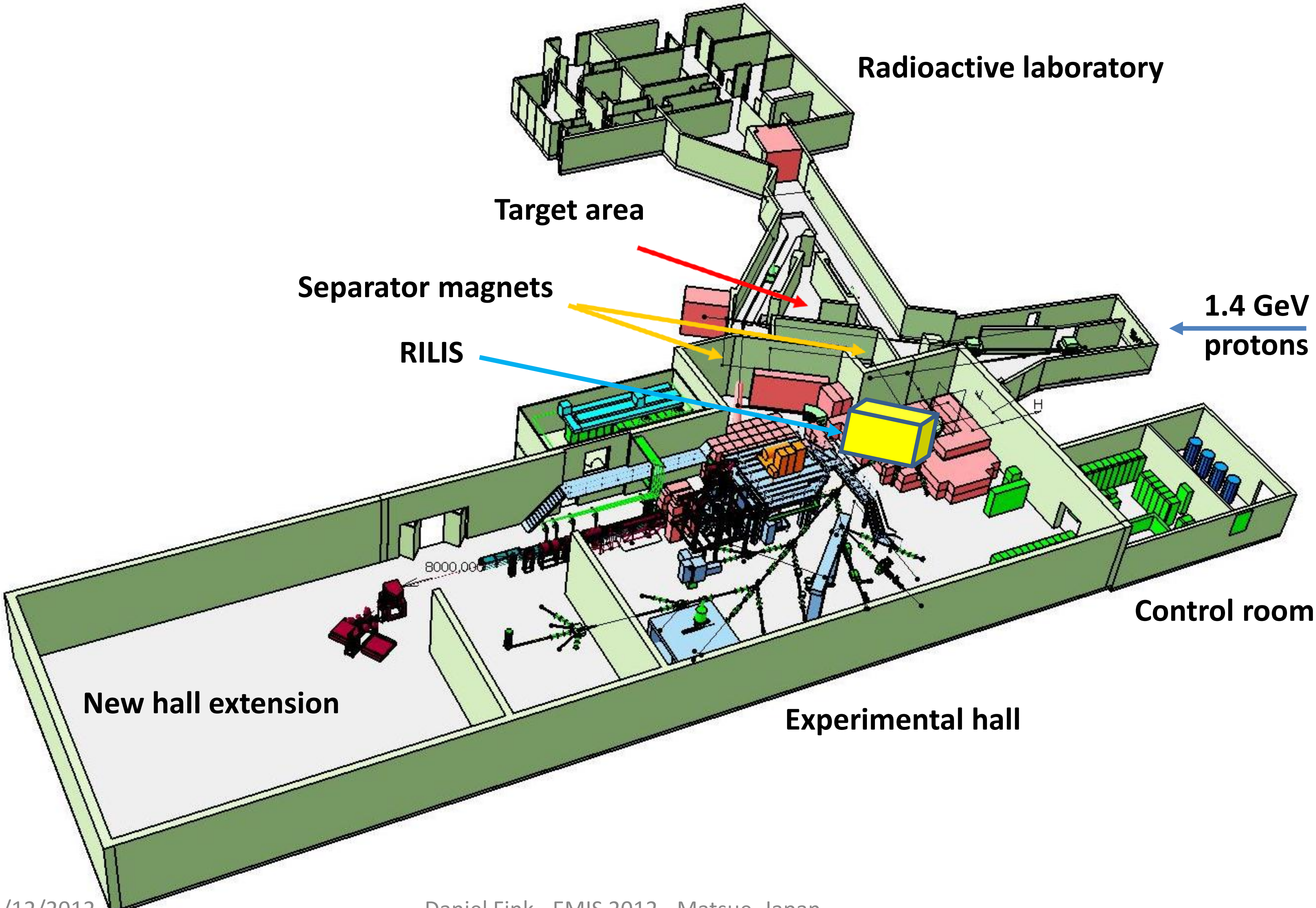
Mg scheme:



Goals of LIST-run 2011:

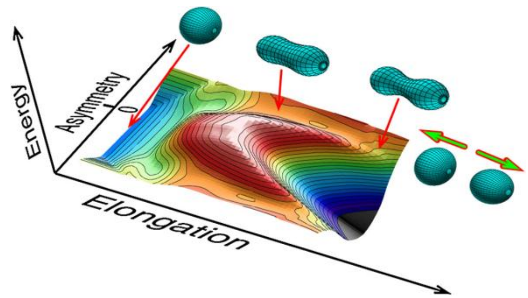
1. **Proof of principle using Mg beams**
2. **Characterizing LIST with radioactive isotopes**
3. **Test of reliability and robustness**
4. **Compare on-line- to off-line performance**

The ISOLDE Laboratory



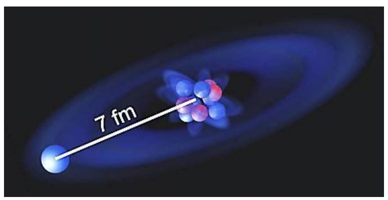
Physics at ISOLDE: an Alchemist's Dream

Nuclear reactions

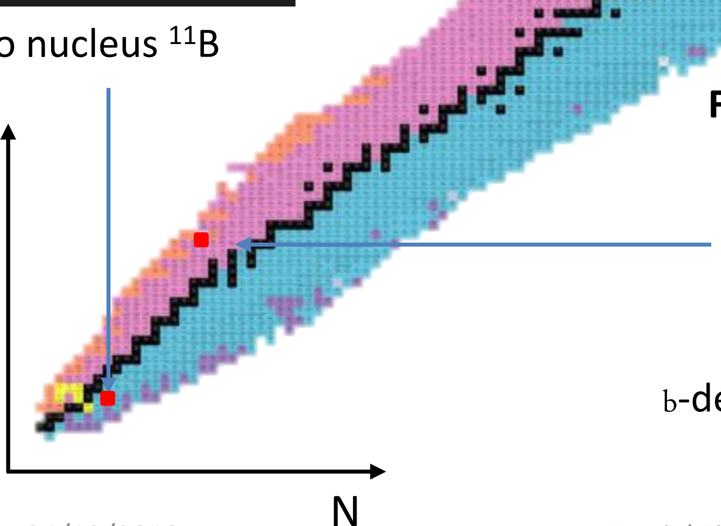


Asymmetric fission in ^{180}Hg

Size and shape of exotic nuclei

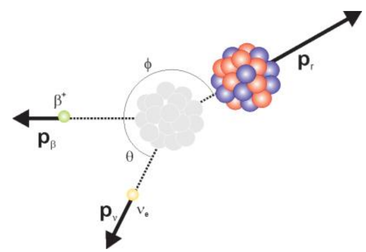


Halo nucleus ^{11}B



Nucleosynthesis in the universe

Fundamental symmetries



b-decay of ^{35}Ar

+ Laser spectroscopy

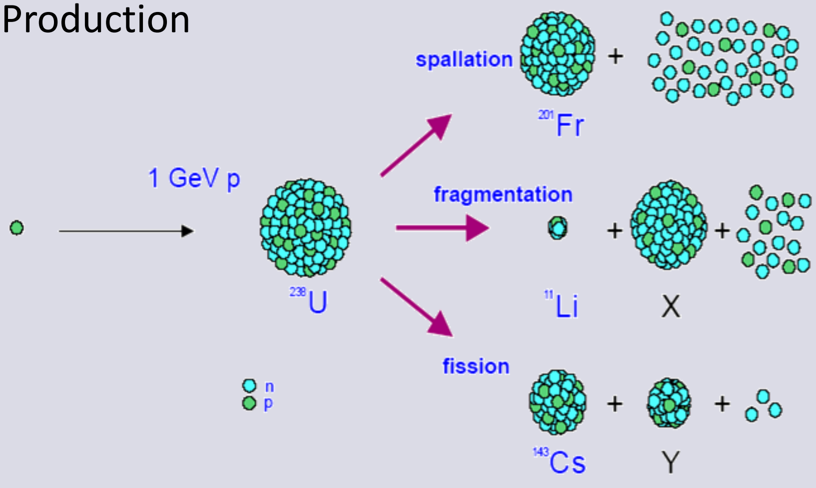
+ Biophysics

+ Solid state physics

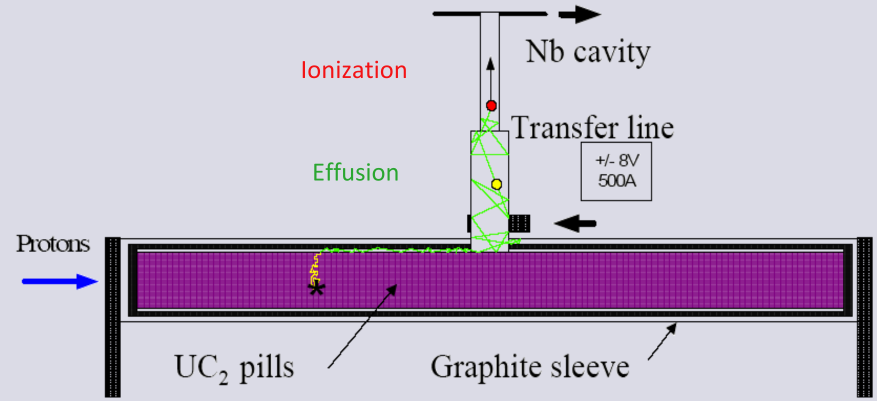
… and much more

The Isotope Separator On-Line (ISOL) Process

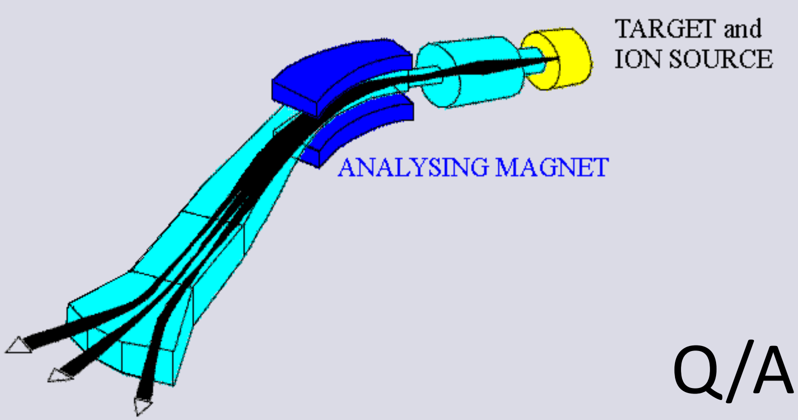
Production



Extraction/Ionization

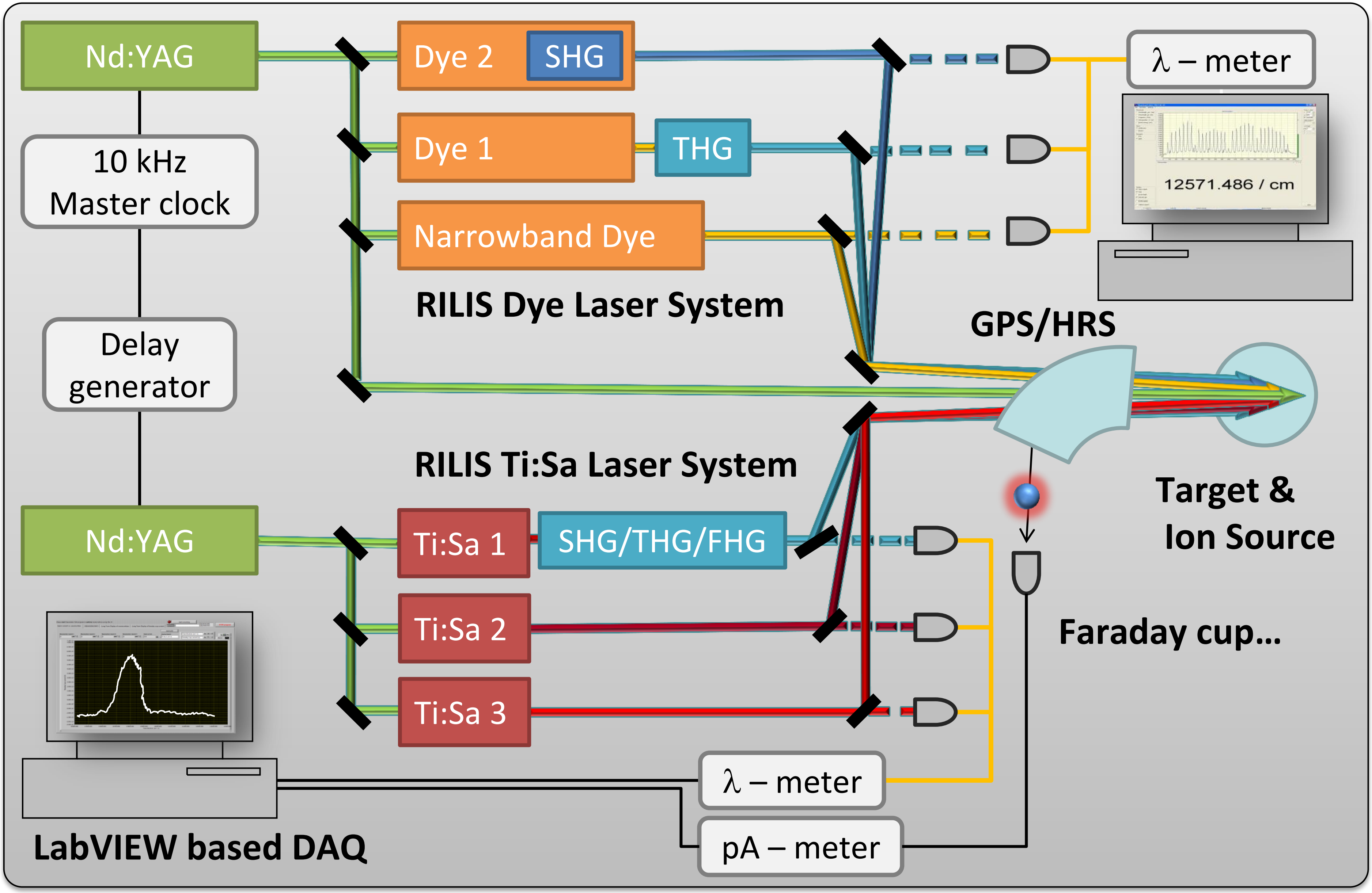


Isotope Separation

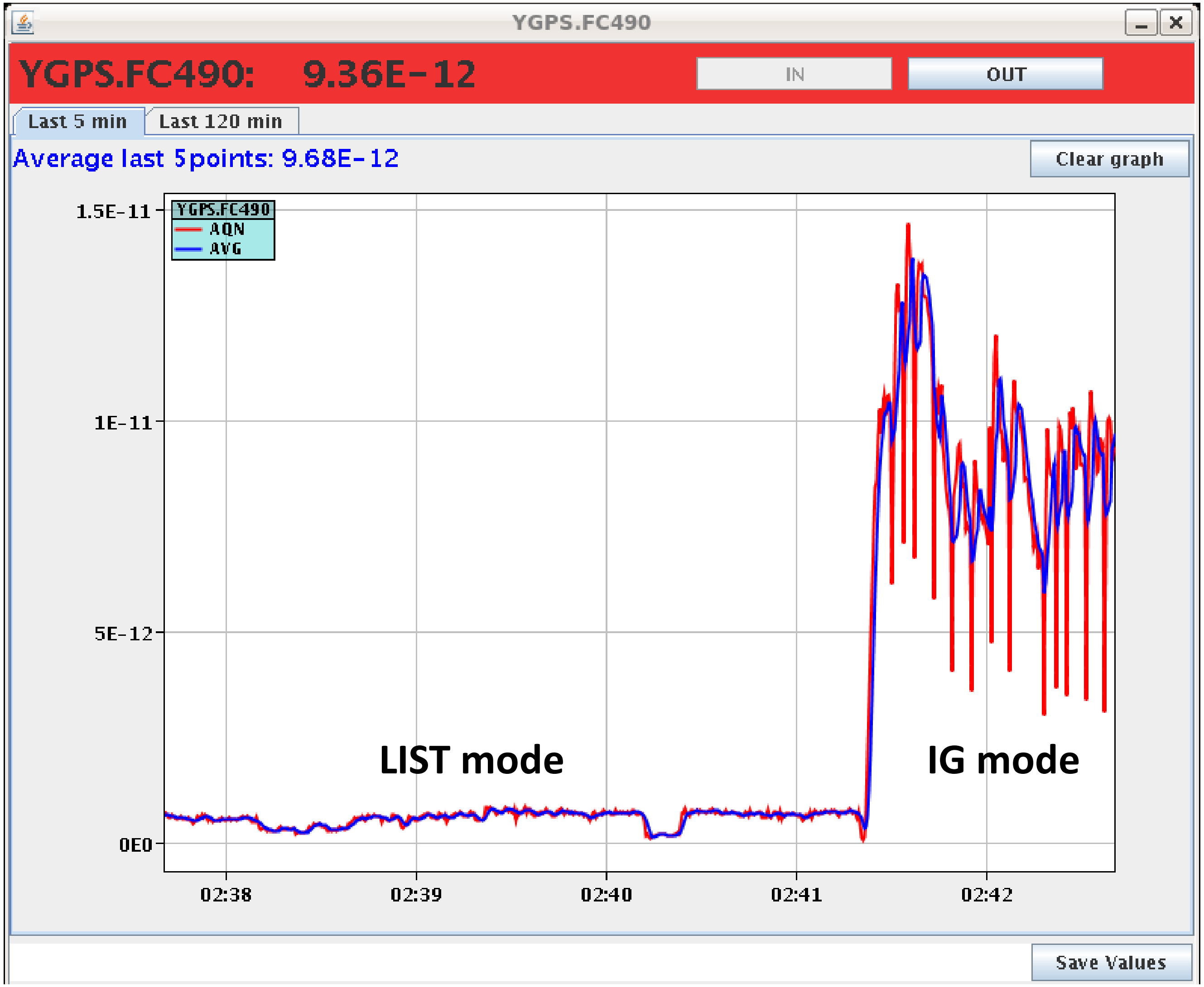


Post acceleration or to Experiment

Scheme of RILIS at ISOLDE



Other Features: Easier Beam Tuning



→ **Optimization in LIST mode much easier due to invisible proton impacts**