

Progress and future outlook for the CRIS project at ISOLDE

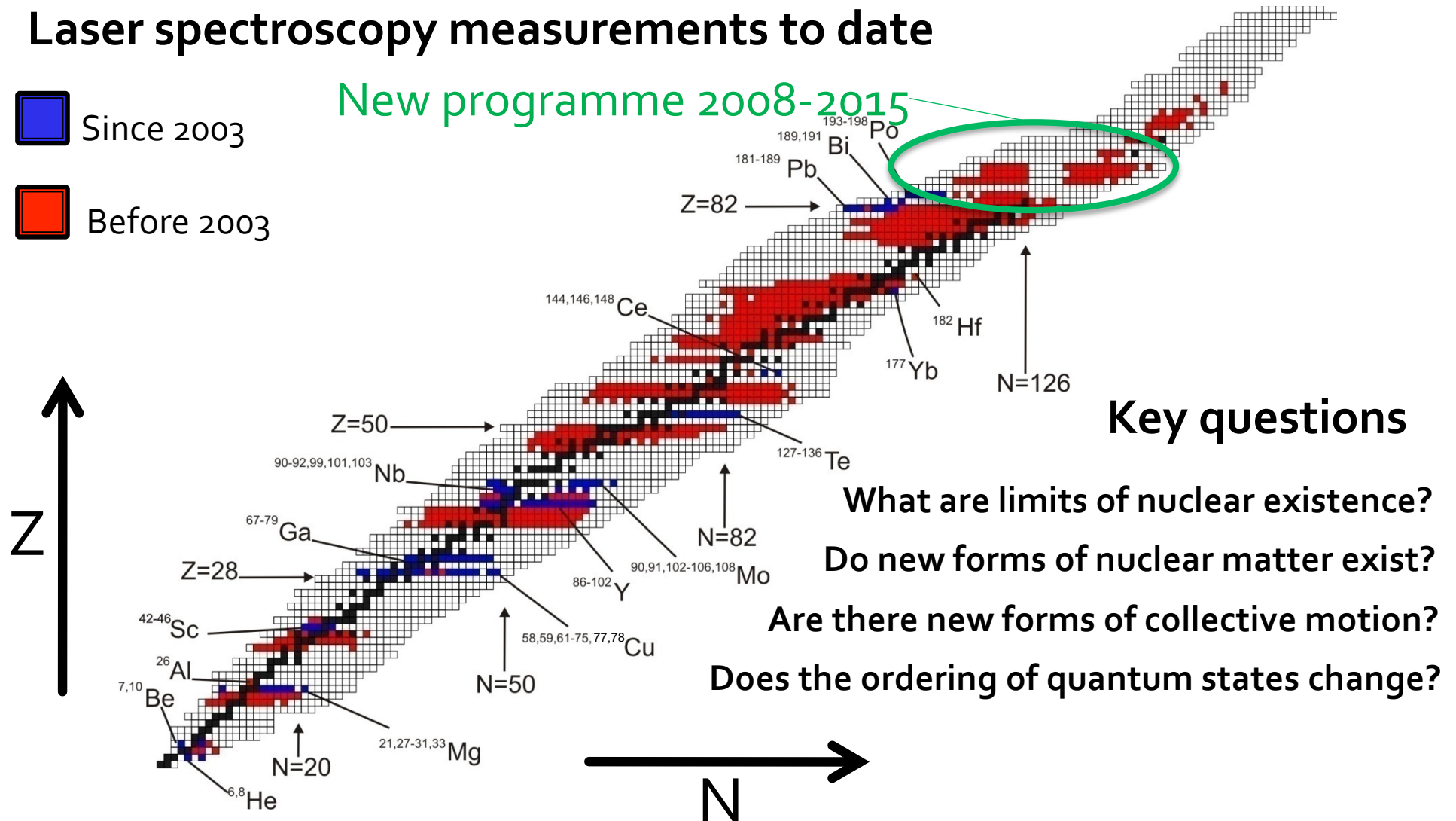
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University of Manchester

HIE-ISOLDE: A unique facility for laser spectroscopy

Laser spectroscopy measurements to date

- Since 2003
- Before 2003

New programme 2008-2015



Key questions

What are limits of nuclear existence?

Do new forms of nuclear matter exist?

Are there new forms of collective motion?

Does the ordering of quantum states change?

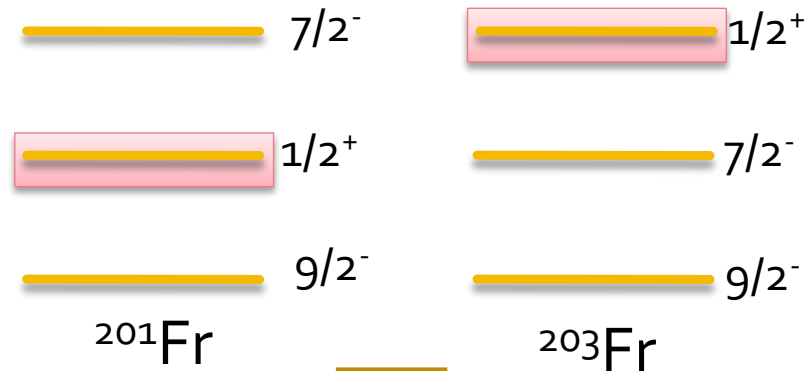
Re-ordering of quantum states in Francium

Systematic reduction in energy of the deformed $\pi(1/2^+)$ in isotopes in this region of the chart

$\pi(1/2^+)$ proton intruder state becomes the ground state in ^{195}At and ^{185}Bi



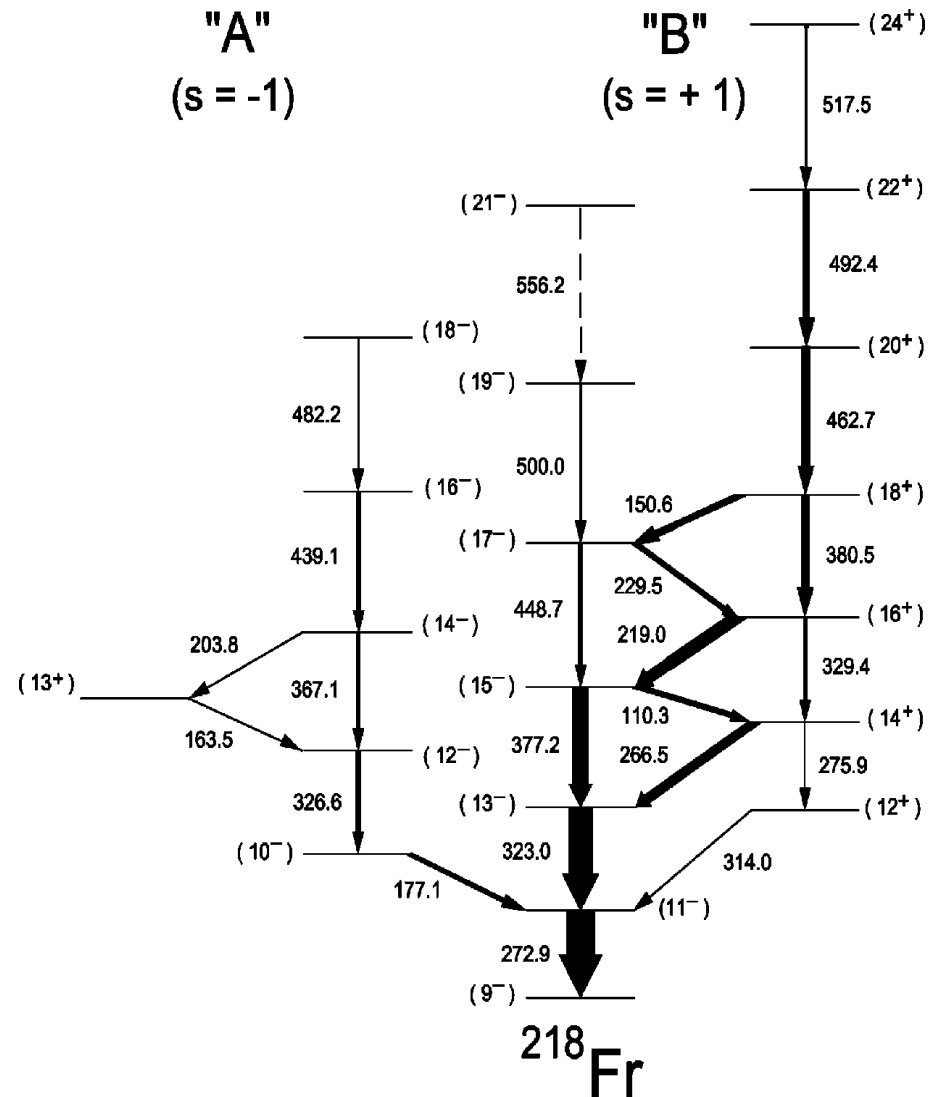
The isomer shifts of $^{201,203}\text{Fr}$ and their magnetic moments will provide important information to better understand the evolution of nuclear structure in this region.



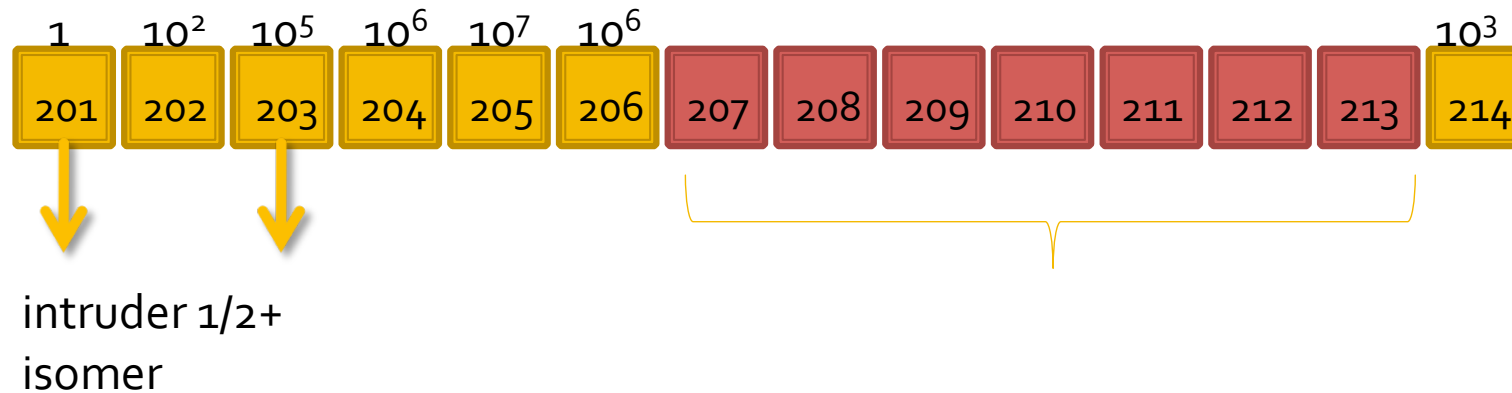
Suggestion that ^{199}Fr has $I=1/2^+$ ground state spin with an associated large oblate deformation.

Border of the region of reflection asymmetry

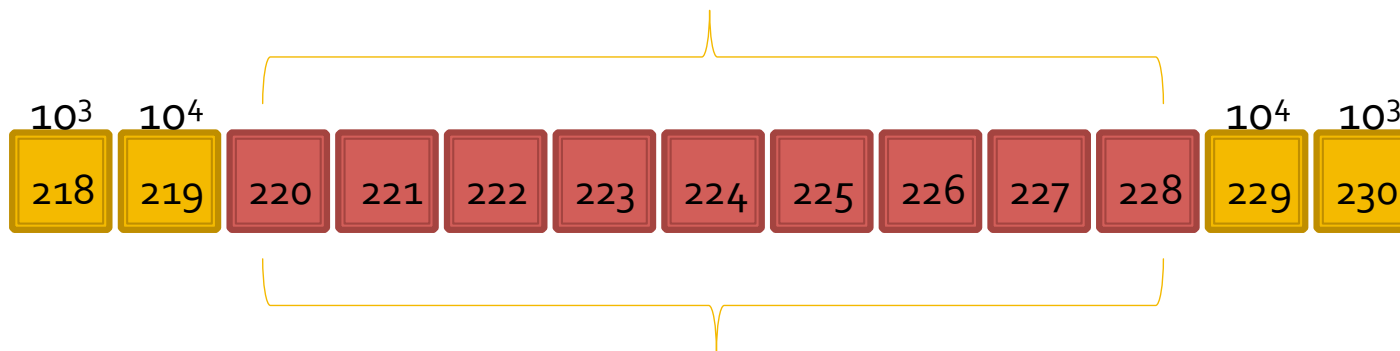
- Region characterised by reversal in odd-even staggering, which is attributed to presence of octupole-quadrupole deformation.
- Also characterised in the interleaving alternating band structure connected by enhance E_1 transitions



Previous and proposed isotopes



Previous measurements



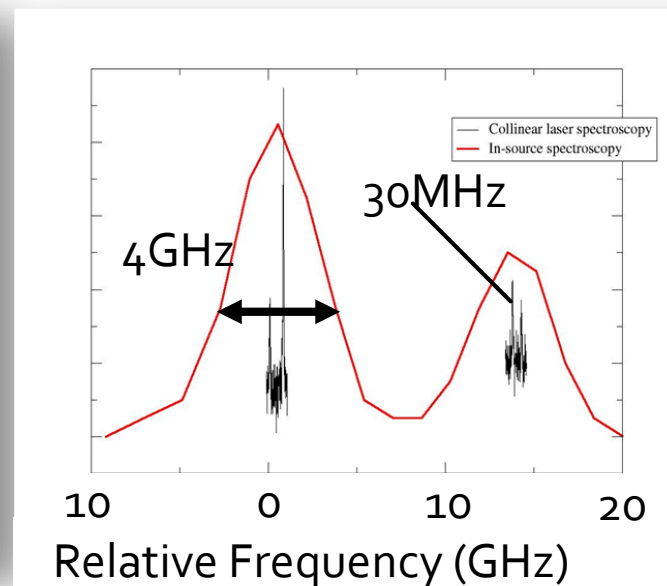
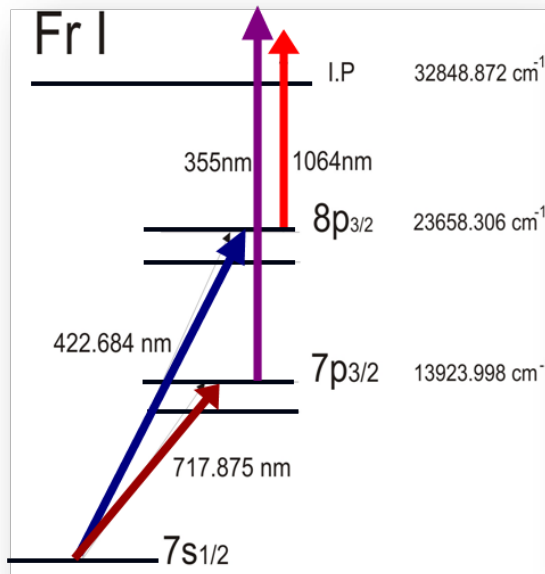
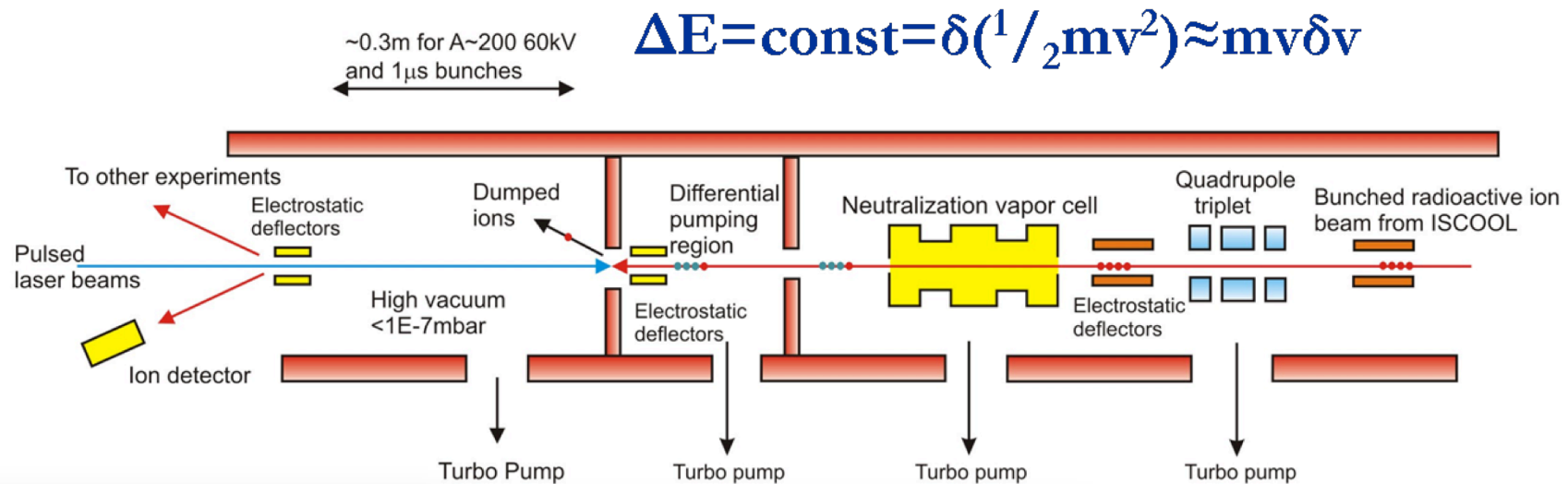
Region of reflection asymmetry

Collinear resonant ionization laser spectroscopy (CRIS)

- RIS performed on a fast atomic bunched beam.
- Pulsed Amplified CW laser has a resolution which is Fourier limited.
- Background events are due to non-resonant collisional ionization, which is directly related to the vacuum
- Very high total experimental efficiency
 - Neutralization (element dependent)
 - Ionization efficiency 50-100% (no HFS)
 - Detection efficiency almost 100%
 - Transport through ISCOOL 70%
 - Transport to experiment 80-90%

1:30 From Jyvaskyla
off-line tests
(K. Flanagan, PhD)

Collinear Resonant Ionization Spectroscopy (CRIS)



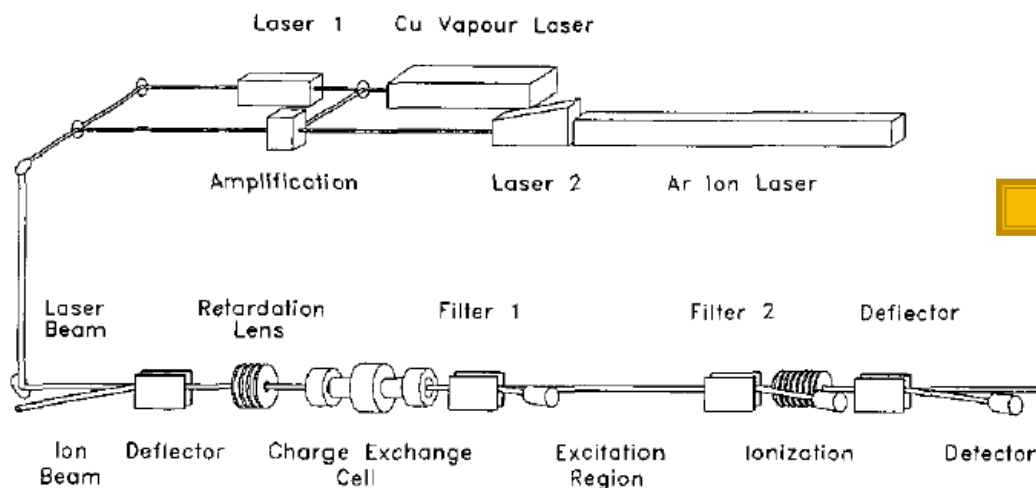
Combining high resolution nature of collinear beams method with high sensitivity of in-source spectroscopy. Allowing extraction of B factors and quadrupole moments.

Yu. A. Kudriavtsev and V. S. Letokhov, *Appl. Phys.* **B29** 219 (1982)

Previous CRIS of Yb at ISOLDE

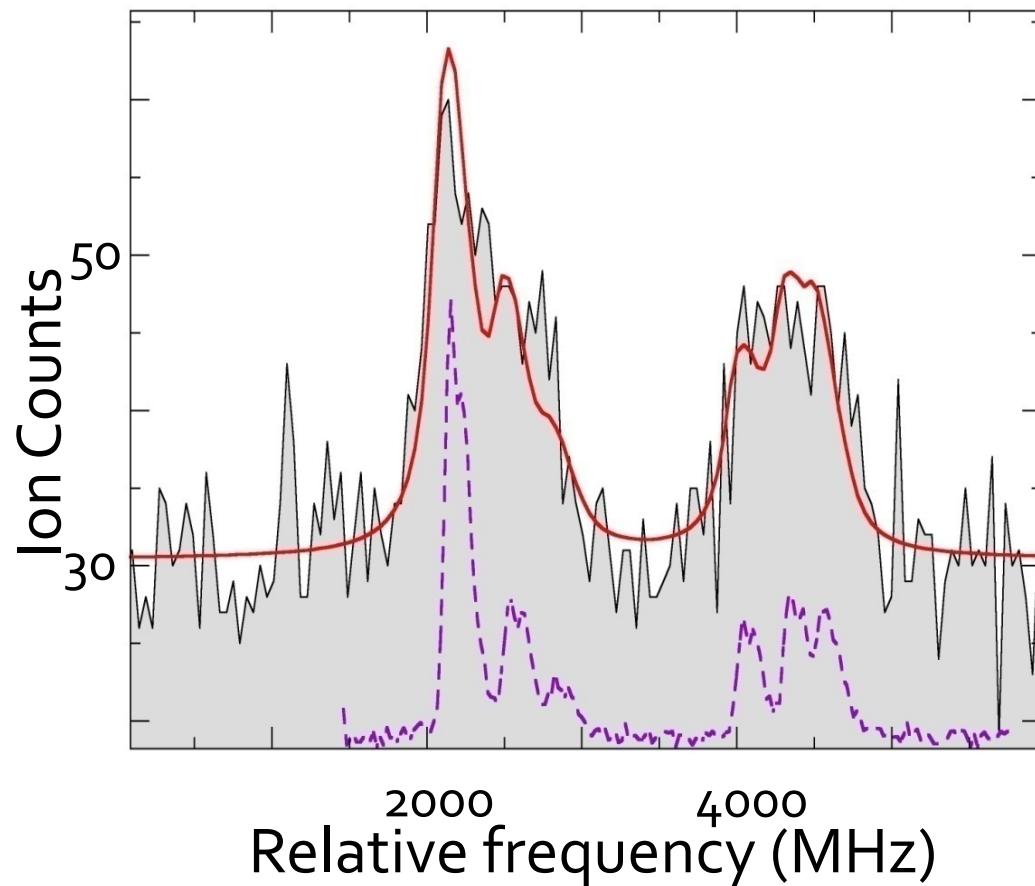
Ch. Schulz *et al.*, J. Phys. B, **24** (1991) 4831

- Charge exchange efficiency into meta stable states
- Below saturation on second step
- CW beam and duty cycle losses due to lasers



Total efficiency
1:100 000

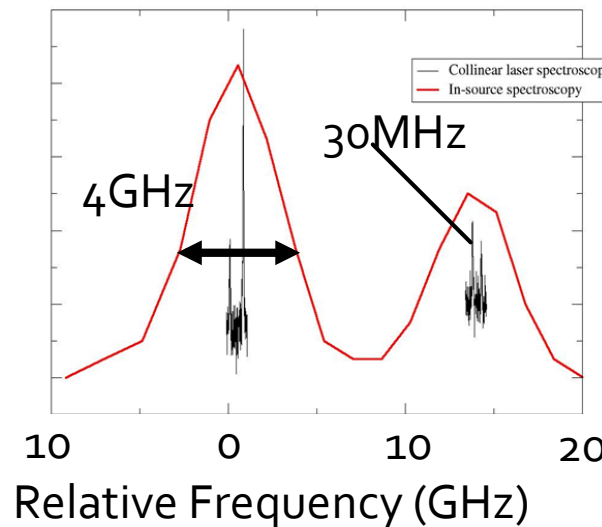
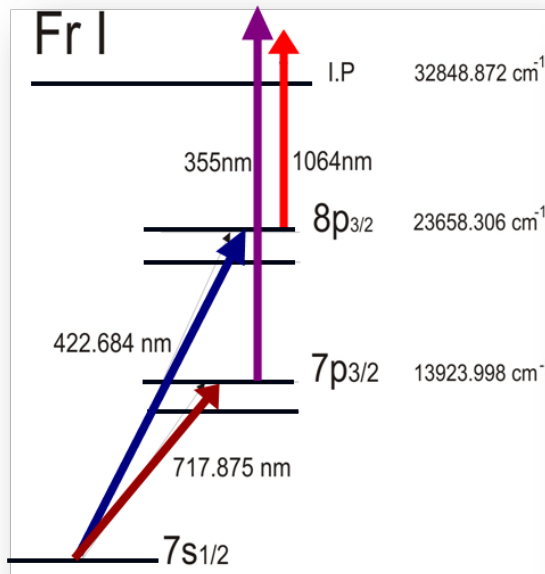
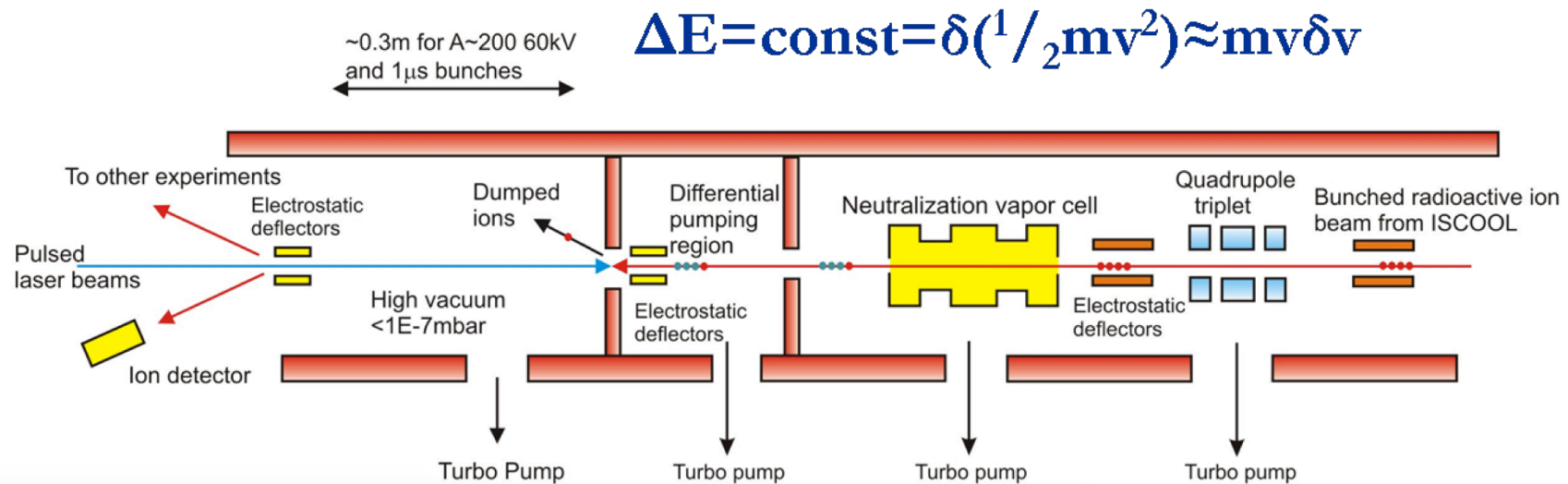
Off-line CRIS test at the IGISOL



- 200 ions per bunch
- 6 scans
- 1:30 efficiency
- Factor of 1000 increase in detection efficiency.

Background due to non-resonant collisional ionization in poor vacuum (10^{-5} mbar)
~5 non resonant ions per bunch

Collinear Resonant Ionization Spectroscopy (CRIS)



Combining high resolution nature of collinear beams method with high sensitivity of in-source spectroscopy. Allowing extraction of B factors and quadrupole moments.

Yu. A. Kudriavtsev and V. S. Letokhov, *Appl. Phys.* **B29** 219 (1982)

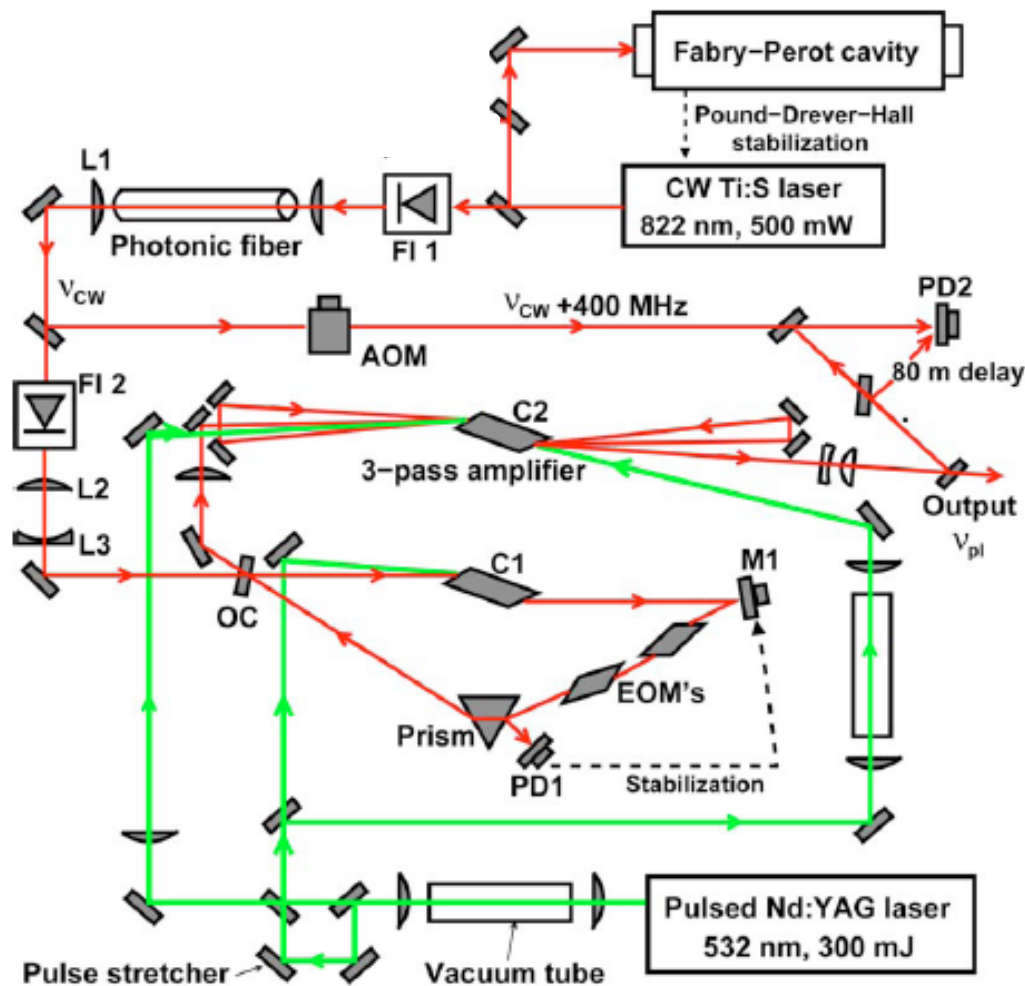
Laser System

M. Hori and A. Dax OPTICS LETTERS **34**, 1273 (2009)

Tested tuning range 726–941 nm

Line width ~6MHz

$E=50\text{--}100\text{ mJ}$

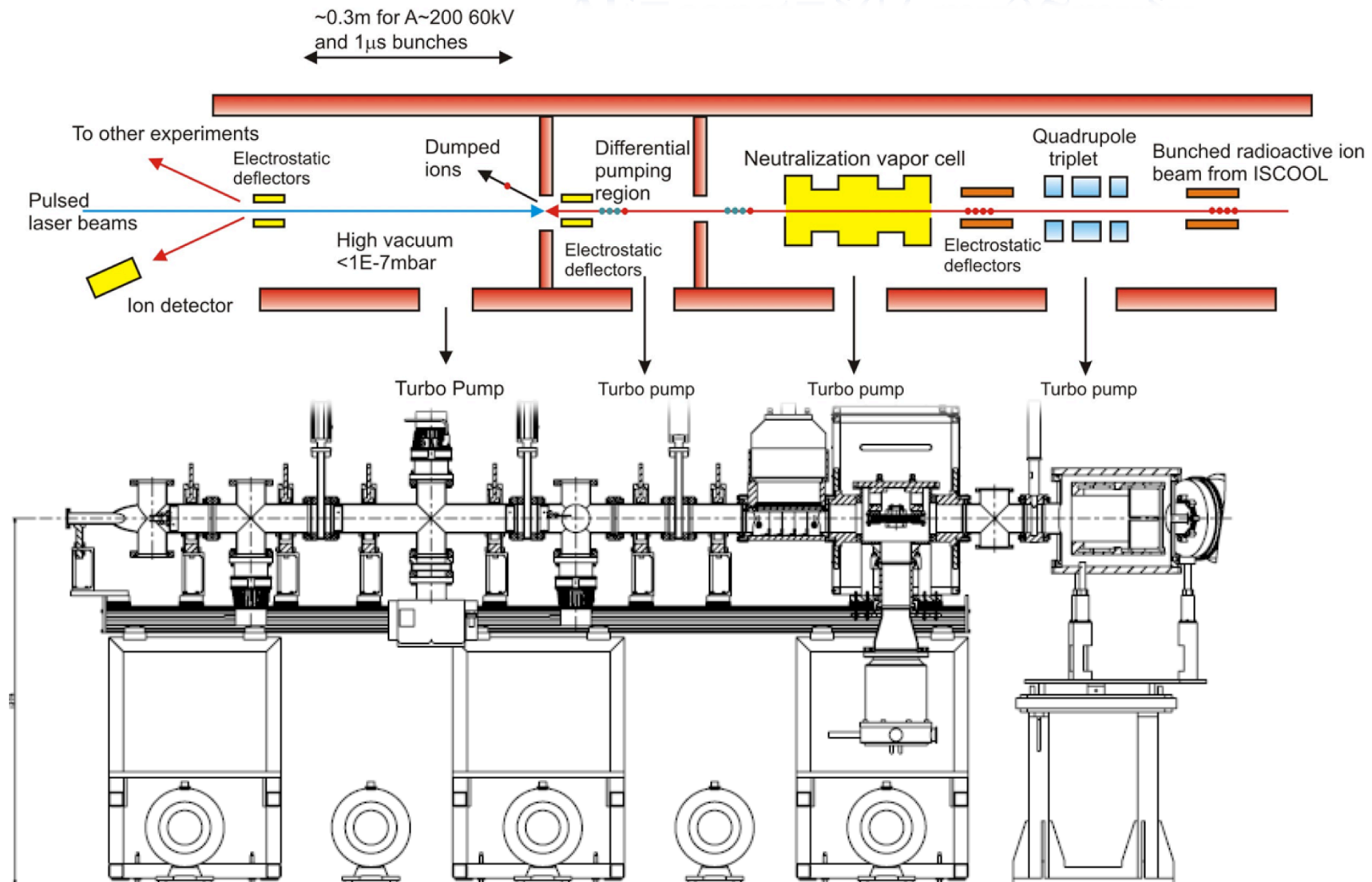


Replacing CW TiSa with a diode laser system (845nm, 300mW)

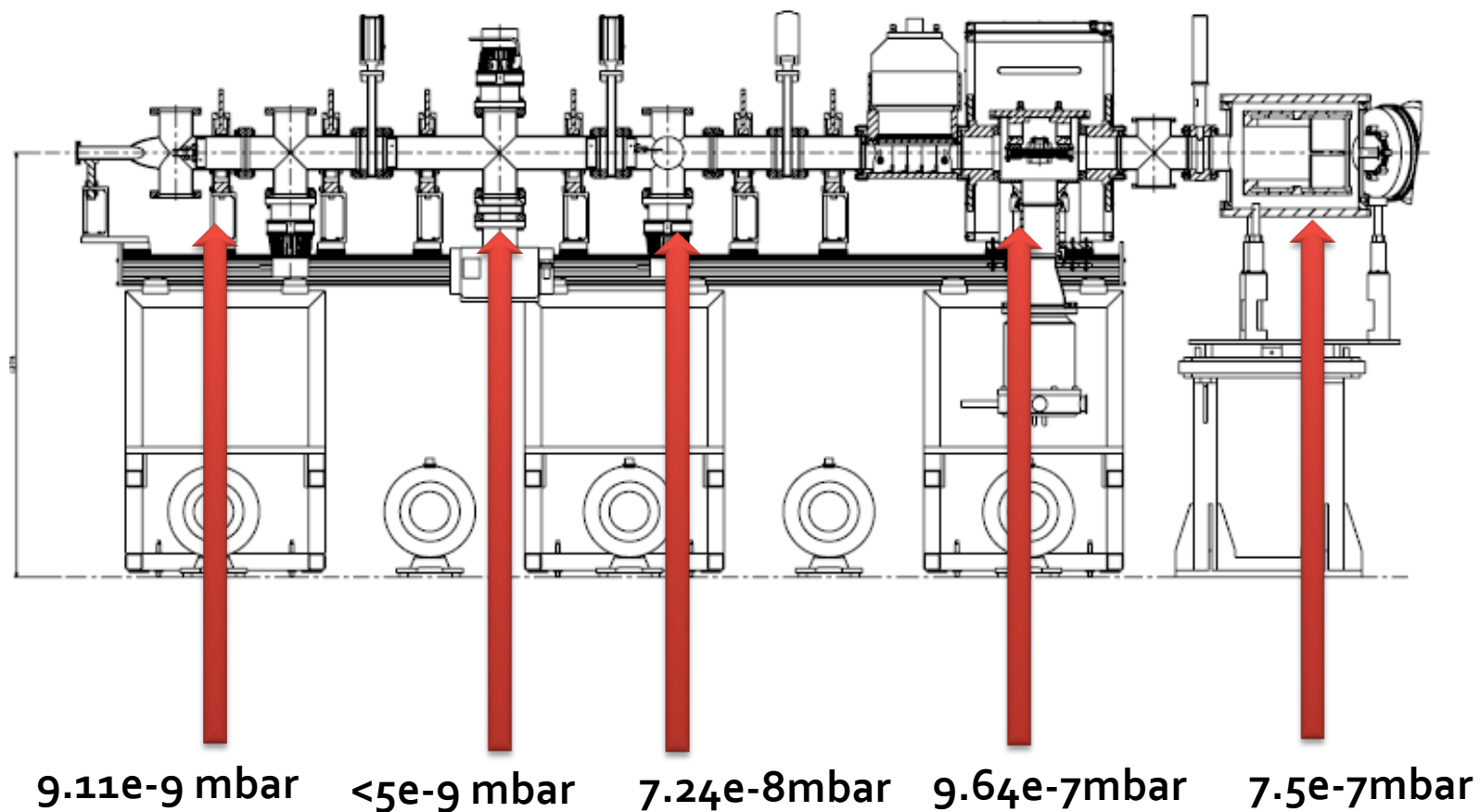
Turn key table top system with minimal interventions during operation.

Novel laser system for radioactive ion beam facilities

Collinear Resonant Ionization Spectroscopy (CRIS)



Collinear Resonant Ionization Spectroscopy (CRIS)



Results from this lunchtime

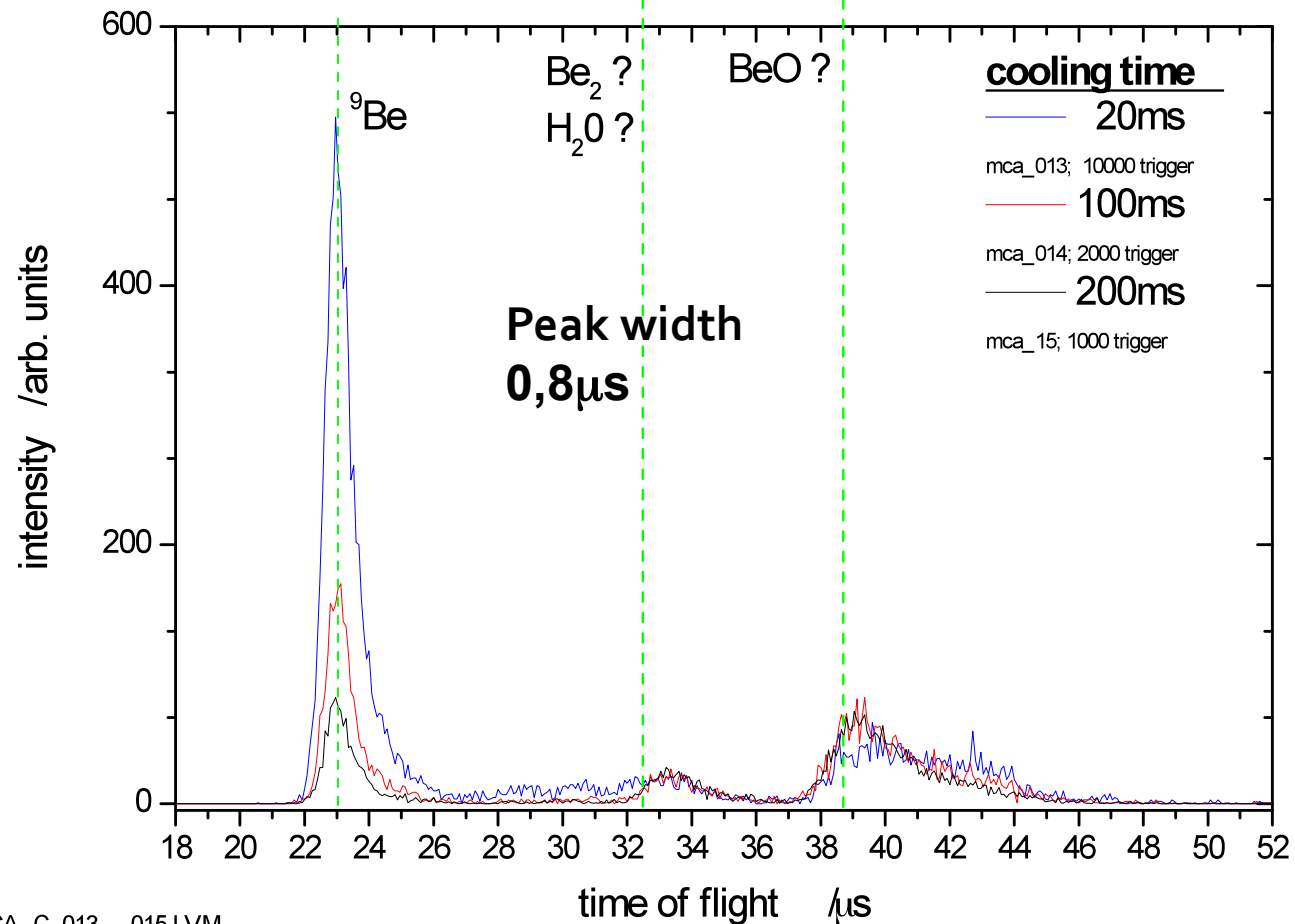
Pulse width from Be tests

TOF Spectra ISCOOL ${}^9\text{Be}$
mass 9

mass 18

mass 26

detector: SEM1
signal: ions
RFQ: set1



**<20cm spatial bunch
length at A~200**

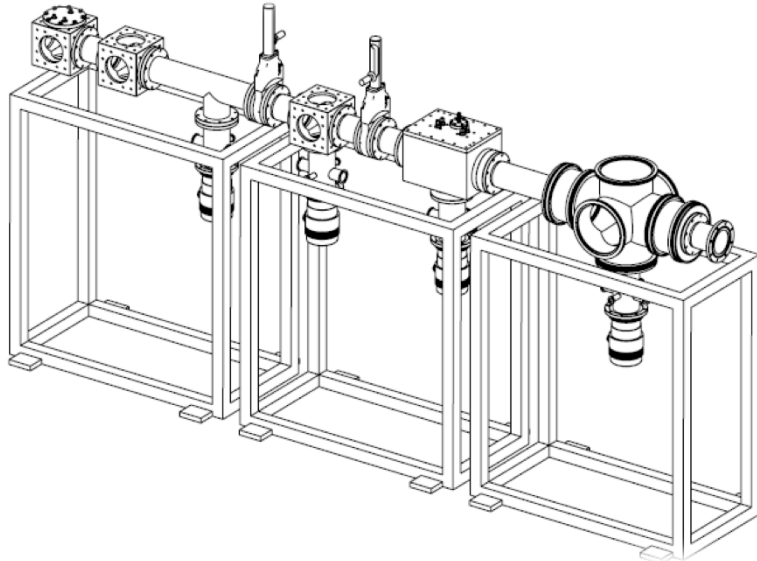
Status in Spring 2008



COMPLIS experiment
beam line.

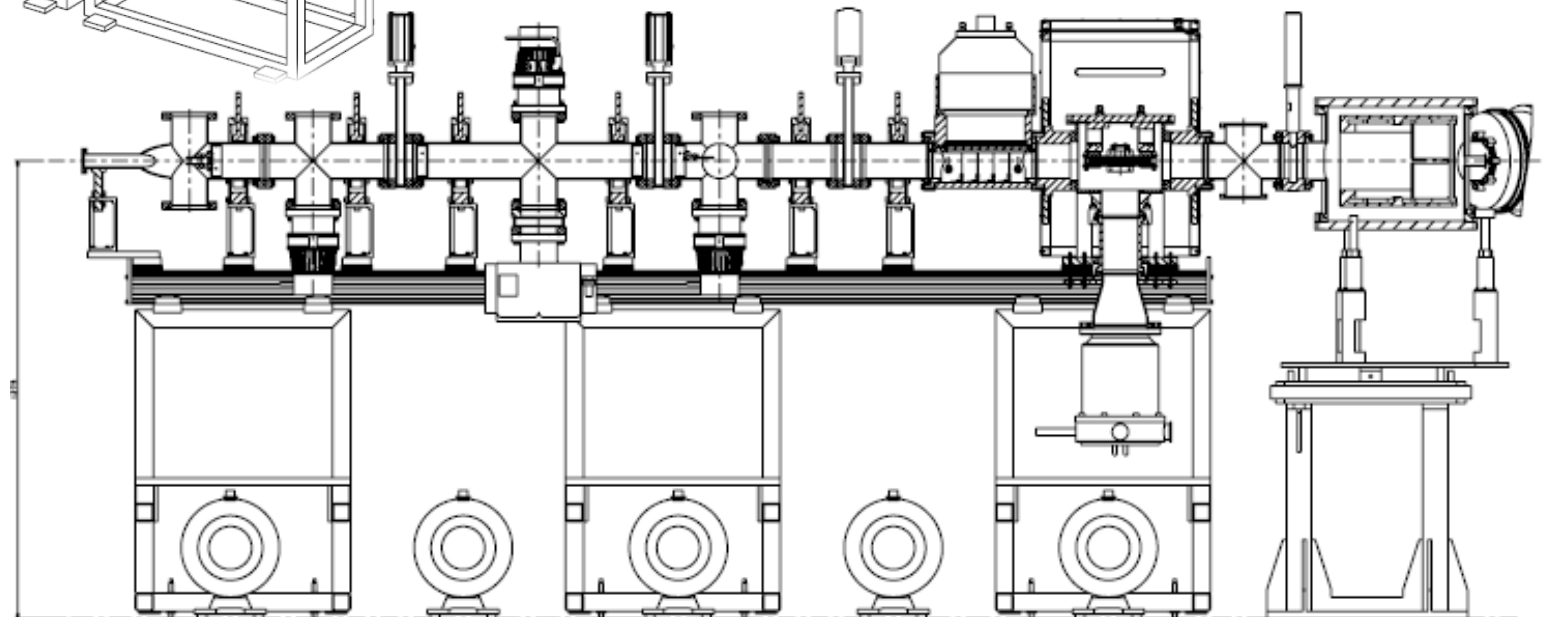
Quadrupole Triplet and
34 degree bend
retained for CRIS

Evolution of design during 2008

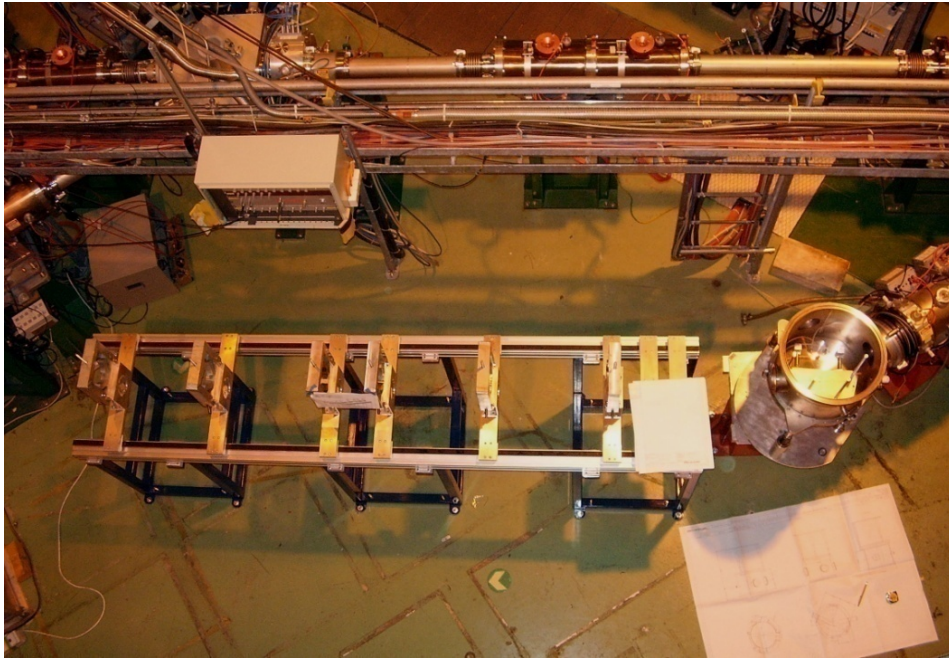


Basic scheme went through several iterations before converging on the final design.

UHV requirements constrained the design and forced the beam line to be ~3m in length



November 2008



Allows one person to open the vacuum system and move chambers.

“Railway track” installation

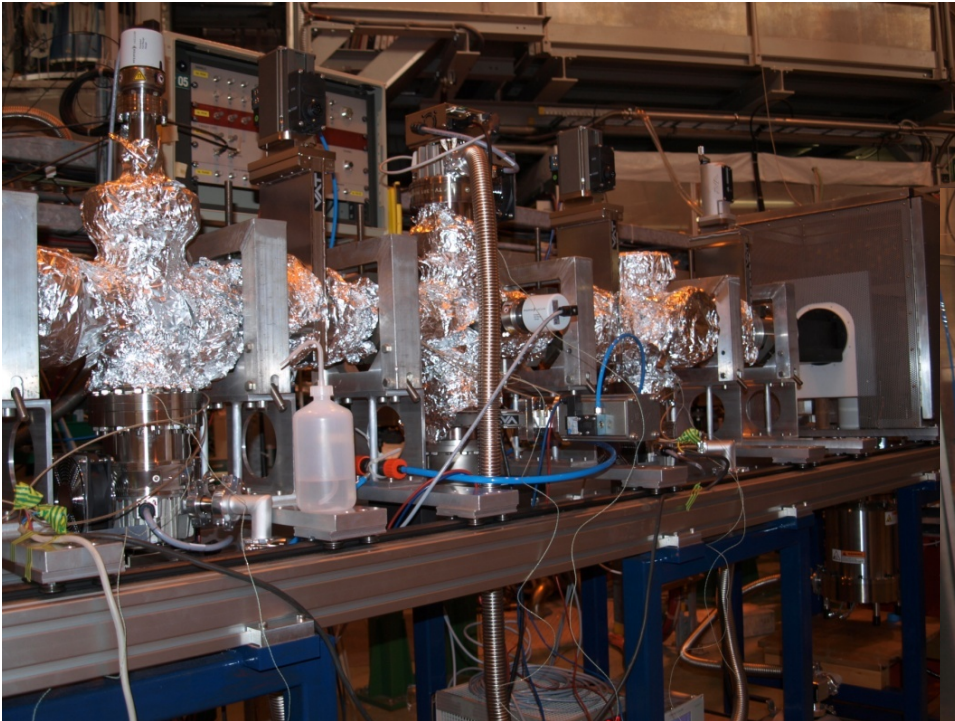


April 2009



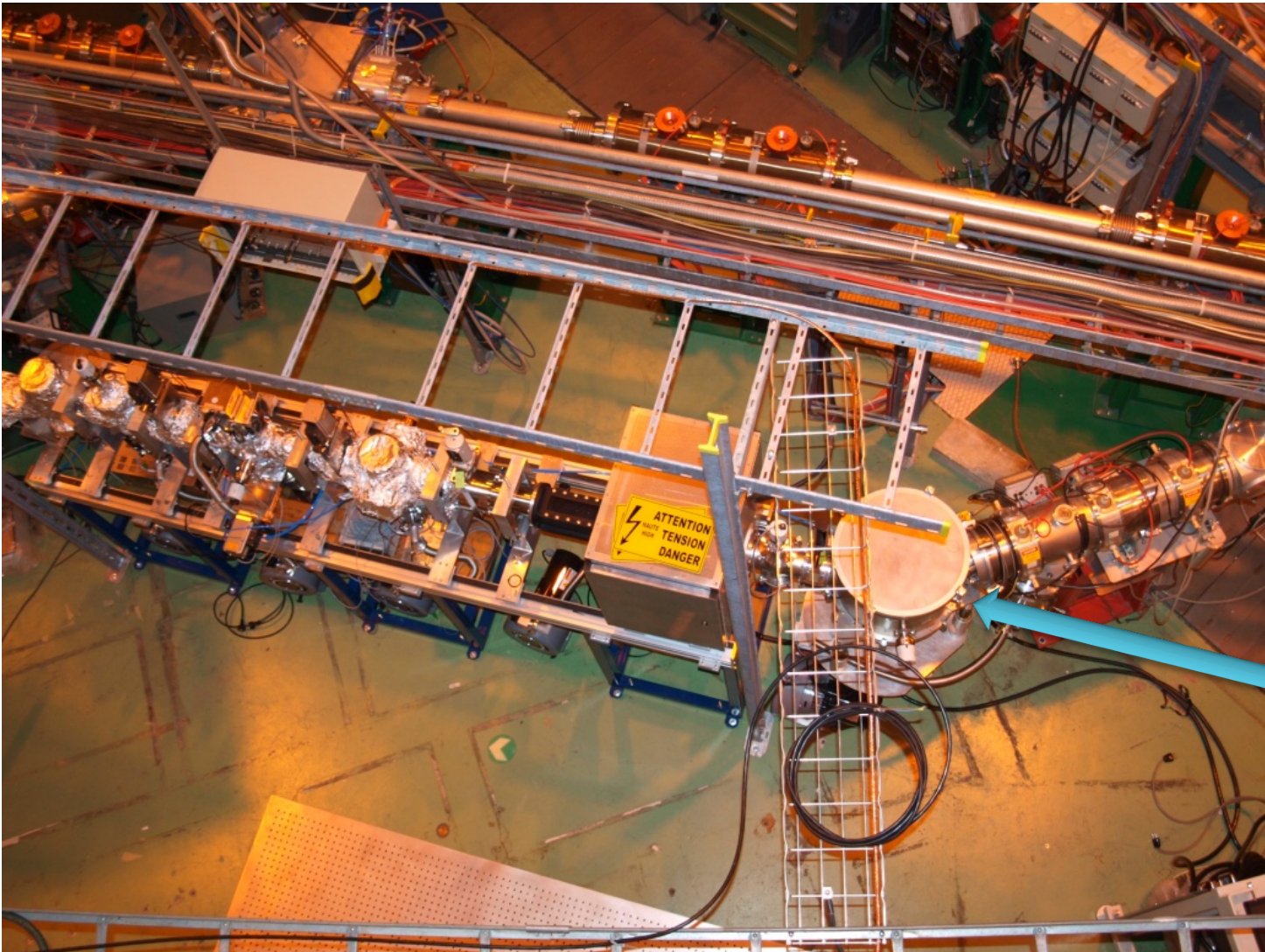
Delivery of vacuum chambers, Faraday cage, charge exchange cell and installation of pumps.

July 2009



Vacuum testing, initial bake-out of UHV section reached $<5 \times 10^{-9}$ mbar (limit of the gauge) in the interaction region.

November 2009



ISOLDE beam from
HRS

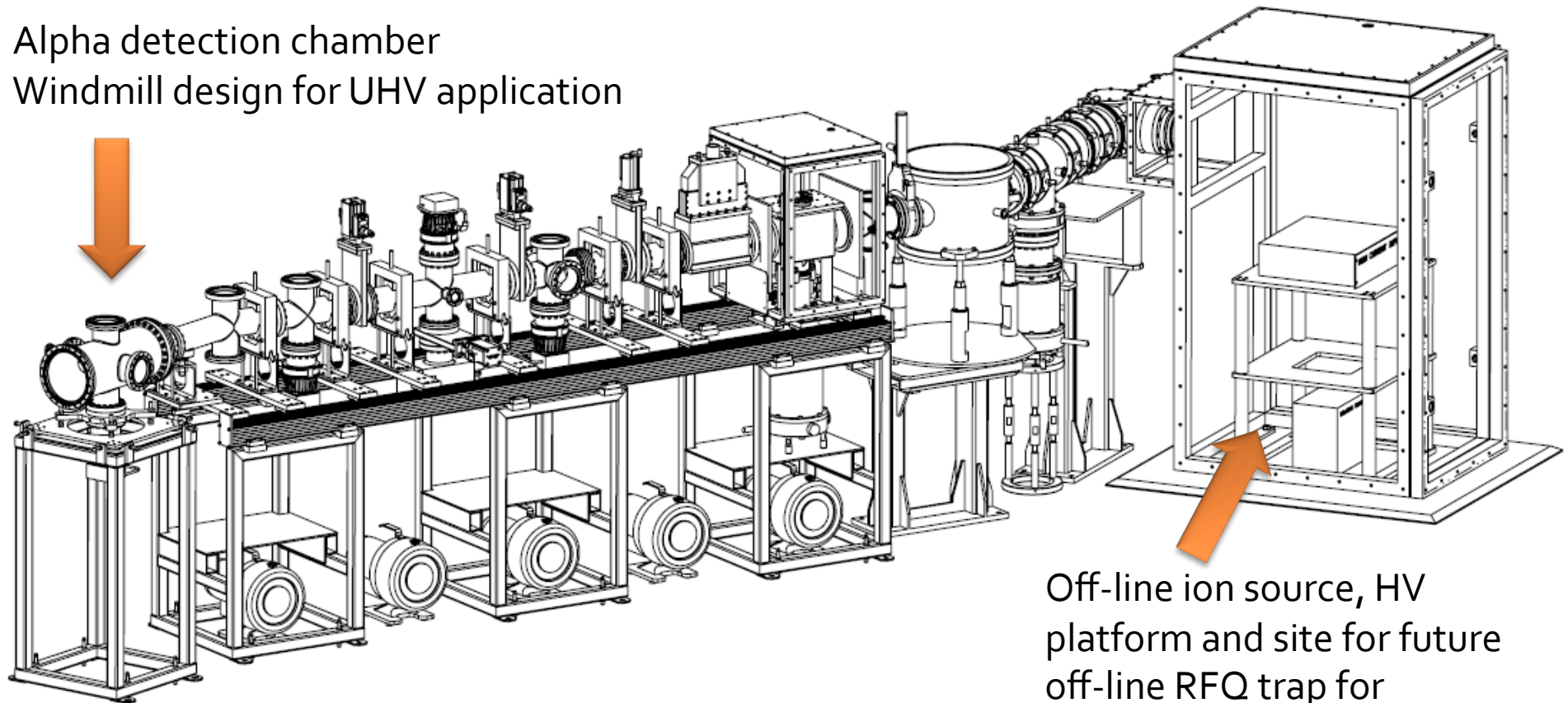


Laser launch direction
into the beam line



Future: 2009-2010

Alpha detection chamber
Windmill design for UHV application



Off-line ion source, HV platform and site for future off-line RFQ trap for technique development

Work in 2009

- Ion optic calculations in Leuven (Wannes Vanderheijden).
- Differential Pumping tests.
- Installation of high voltage supplies and controls (National Instruments PXI system).
- Installation of off-line ion source, MCP detection setup at end of beam line.
- Safety commission report and preparation of procedure document for experiment.

2010

- Stable beam tuning
- Installation and testing of dye laser system
- Delivery of novel compact diode laser system (July)
- Installation and testing of on-line ion detection system
- Off-line testing with stable beams
- First on-line run October-November 2010

Thank you for your attention

Collaboration

J. Billowes, M. Bissell, F. Le Blanc, B. Cheal, K.T. Flanagan,
D.H. Forest, R. Hayano, M. Hori, T. Kobayashi, G. Neyens, T. Procter,
H.H Stroke, G. Tungate, W. Vanderheijden, P. Vingerhoets, K. Wendt.



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Limiting factors: Efficiency and isobaric contamination

- From the ISCOOL tests in November a limit of 10^7 per bunch were trapped and measured on an MCP.
- Conservative efficiency of 1:30 (number from Jyvaskyla work) and a pressure of 10^{-9} mbar and a high isobaric contamination of 10^7 (expect much lower).

Background suppression:

Pressure 10^{-9} mbar = 1:200 000

Detection of secondary electrons by MCP



Limited to > 100pps

Alpha decay detection allows removal of all isobaric contamination (50-100cts/s)



Limited >5pps

With 50% efficiency and signal limited noise regime = 0.3pps

This underlines the importance of improving beam purity for future HIE-ISOLDE and ISCOOL work