Status of the CRIS experiment

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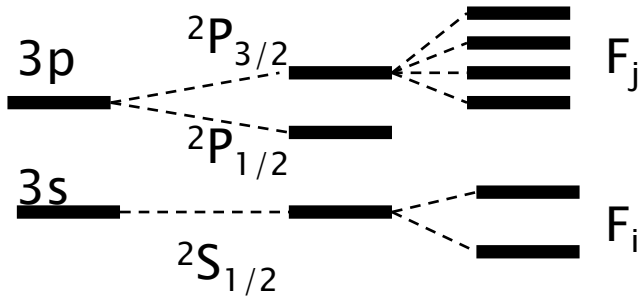
Outline of talk

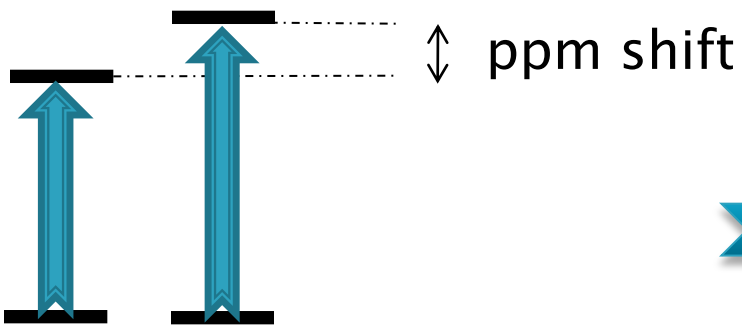
- Introduction to collinear resonant ionization spectroscopy (CRIS)
- Progress since 2008
- Recent Results: laser spectroscopy of Fr
- Outlook

Nuclear moment and radii from laser spectroscopy



Isotope Shift

Spin, magnetic and electric moments , all nuclear observables are extracted without model dependence.

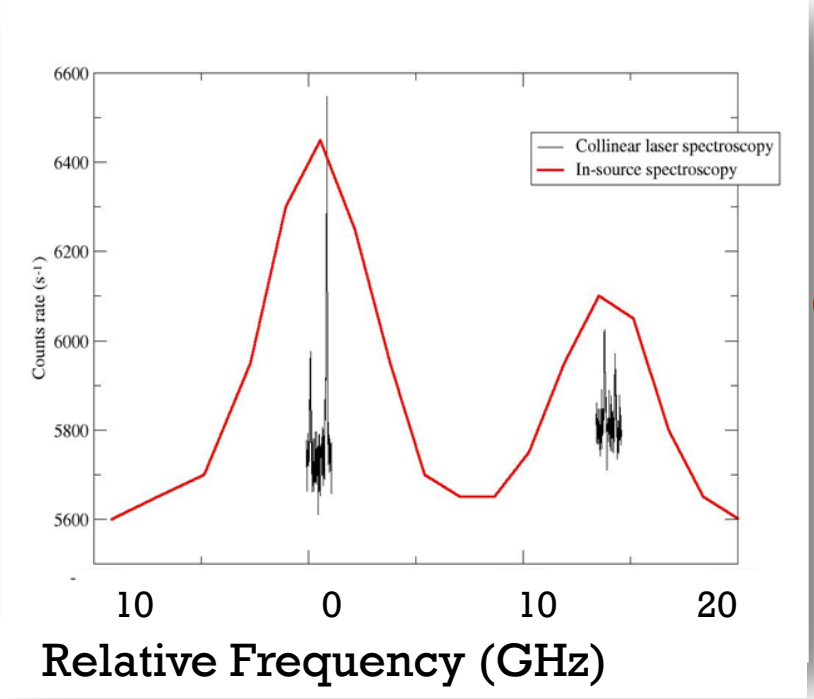


Changes in nuclear charge radii and sensitive to changes in the dynamic nature and deformation as well as volume.

$$\Delta\nu_{IS} = \Delta\nu_{MS} + \Delta\nu_{FS}$$

Sensitivity or resolution?

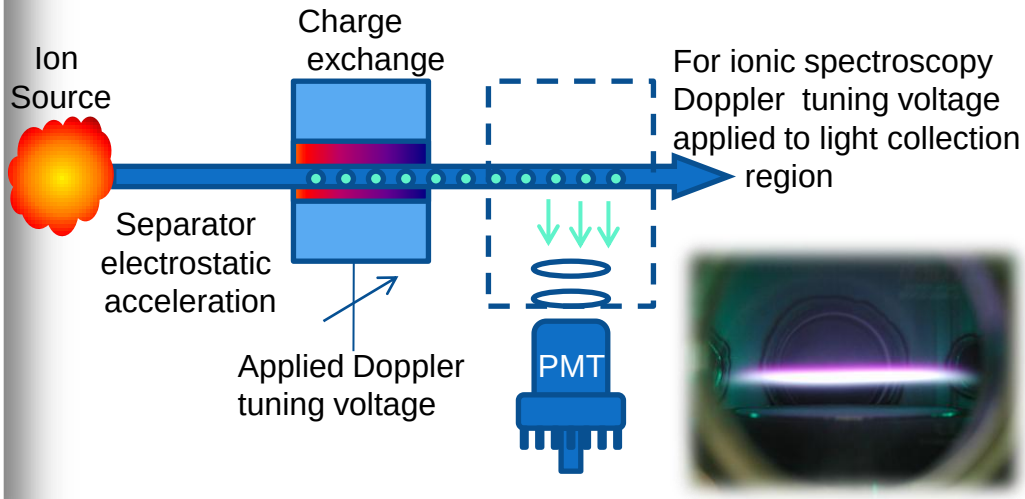
In-source laser spectroscopy



Sensitive to sub 1 atom/s but limited by Doppler broadening to cases with large hfs

Collinear Concept

$$\Delta E = const = \delta(^1/_2 mv^2) \approx mv\delta v$$

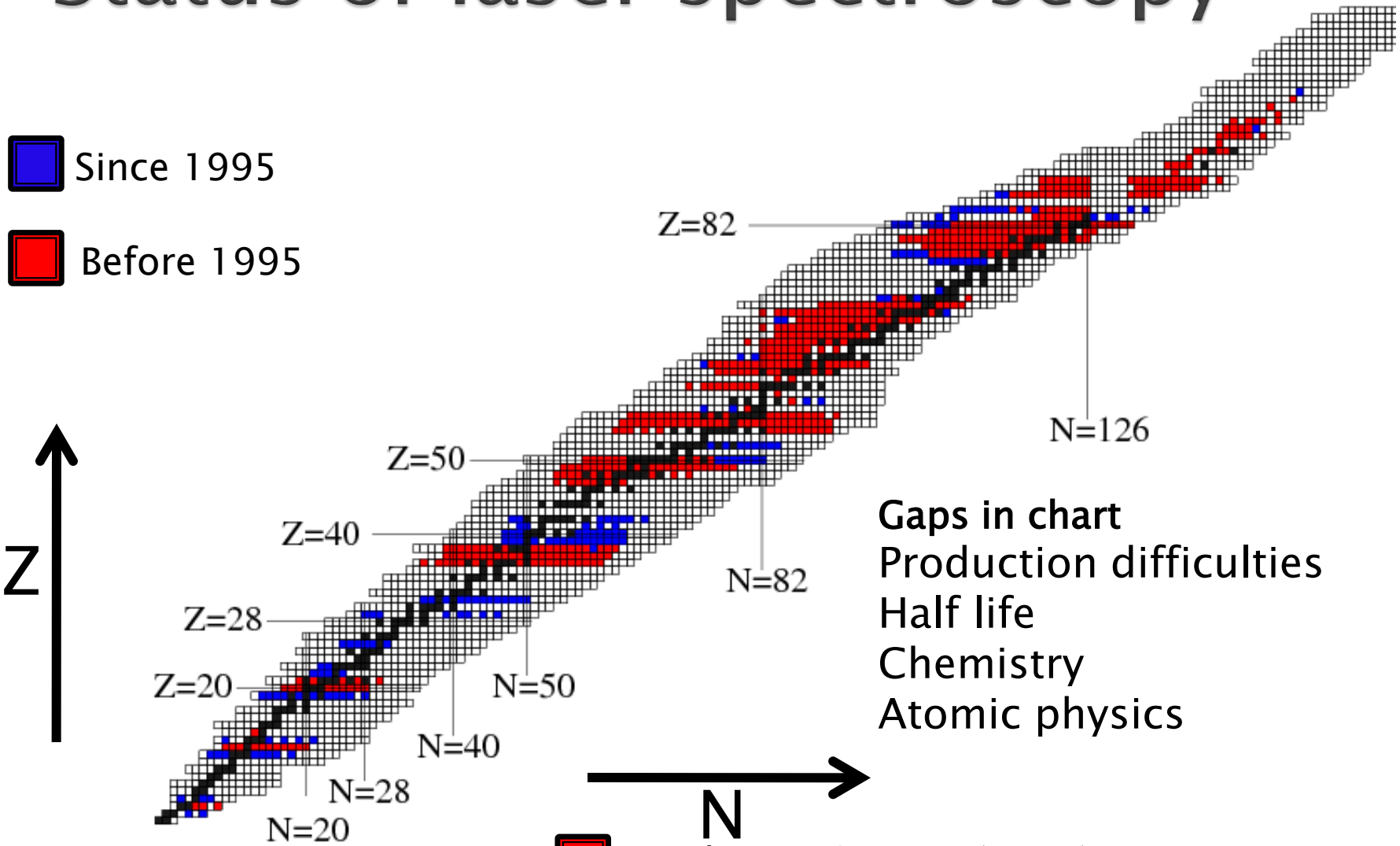


High resolution (sub 10MHz) but low sensitivity (>10^6 /s)

Status of laser spectroscopy

Since 1995

Before 1995

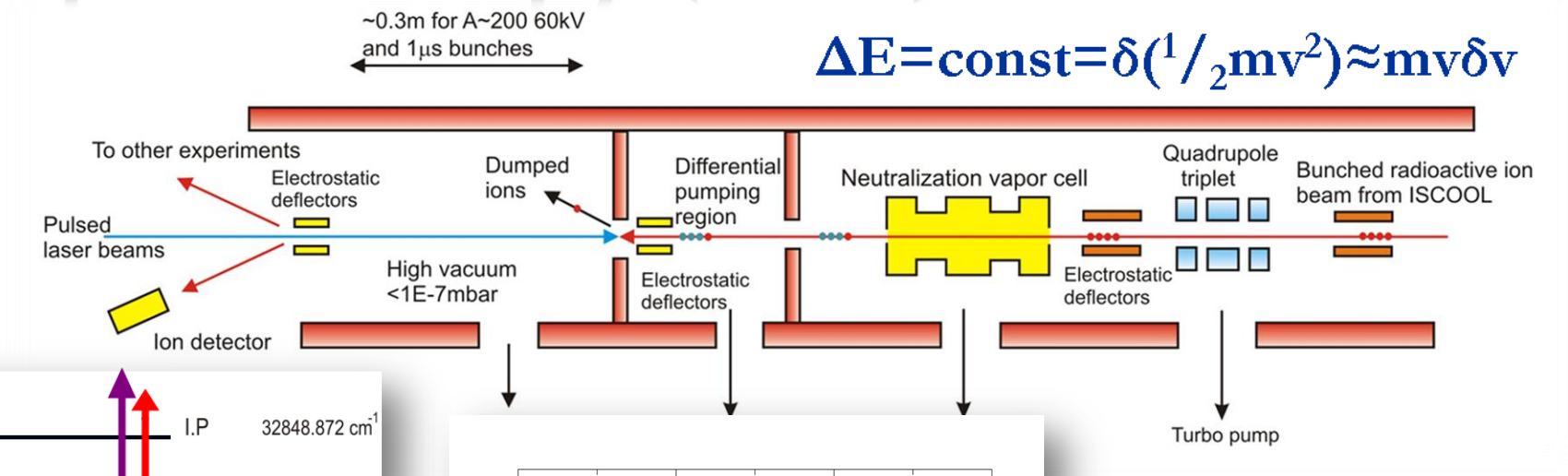


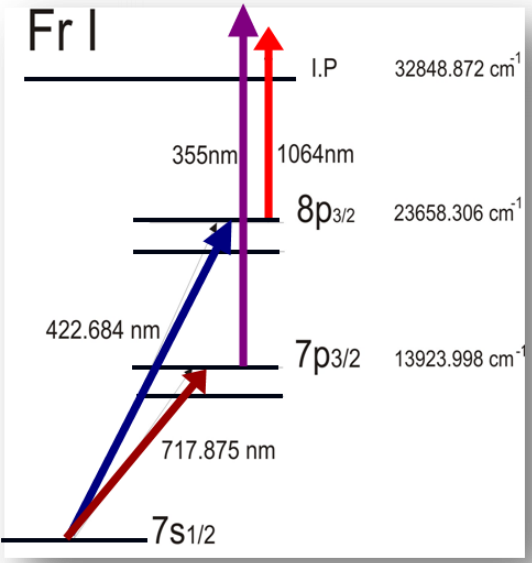
Gaps in chart
Production difficulties
Half life
Chemistry
Atomic physics

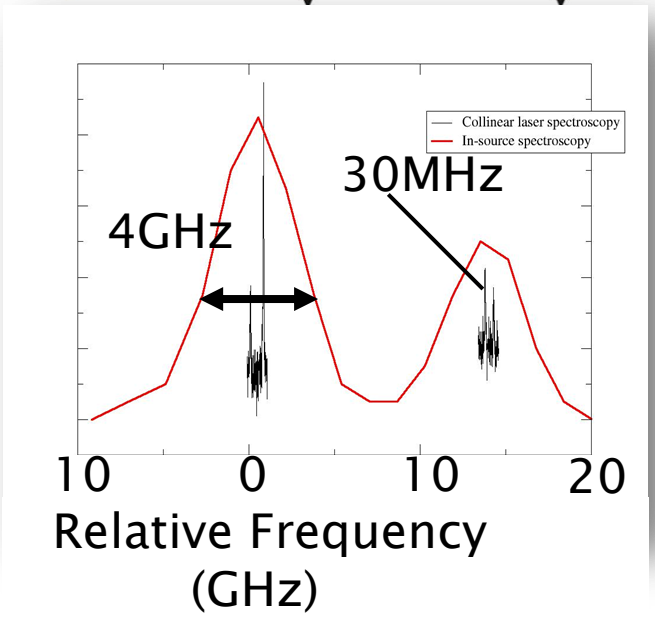
J. Phys. G **21** *707 (1995)*

J. Phys. G **37** 113101 *(2010)*

Collinear Resonant Ionization Spectroscopy (CRIS)



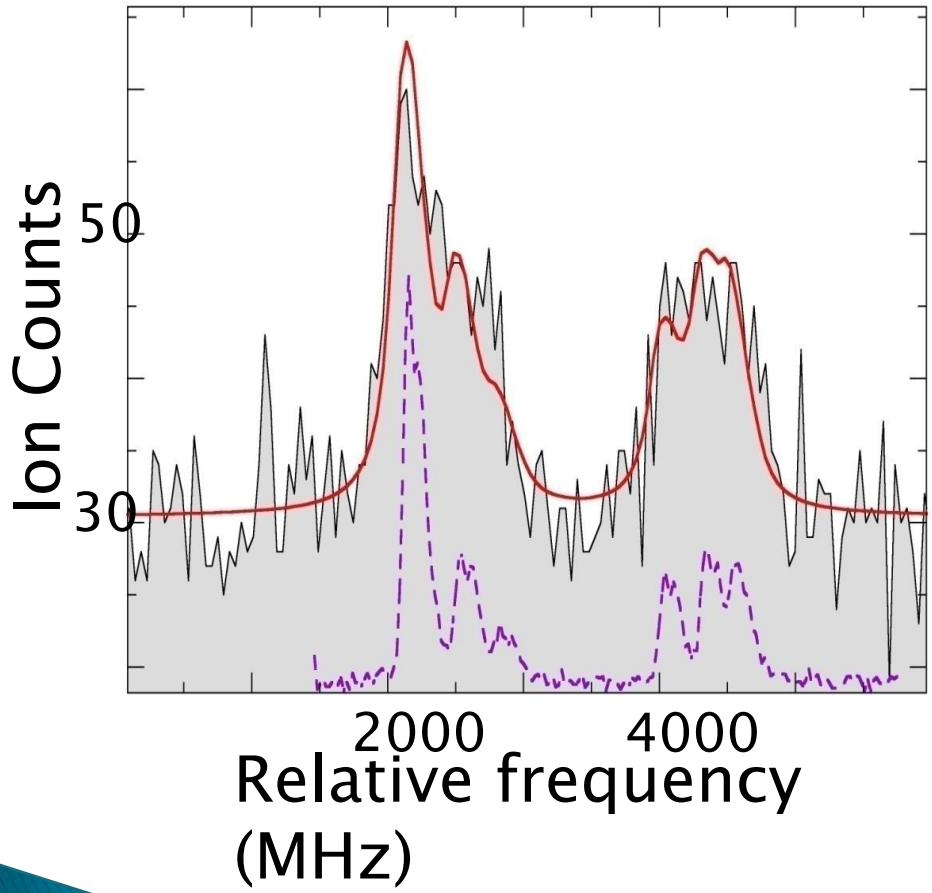




Combining high resolution nature of collinear beams method with high sensitivity of in-source spectroscopy. Allowing extraction of B factors and quadrupole moments.

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

Previous CRIS at JYFL



1:30 From Jyvaskyla off-line tests

Factor of 1000 improvement on photon detection

150MHz linewidth

High background rate 5cts/bunch

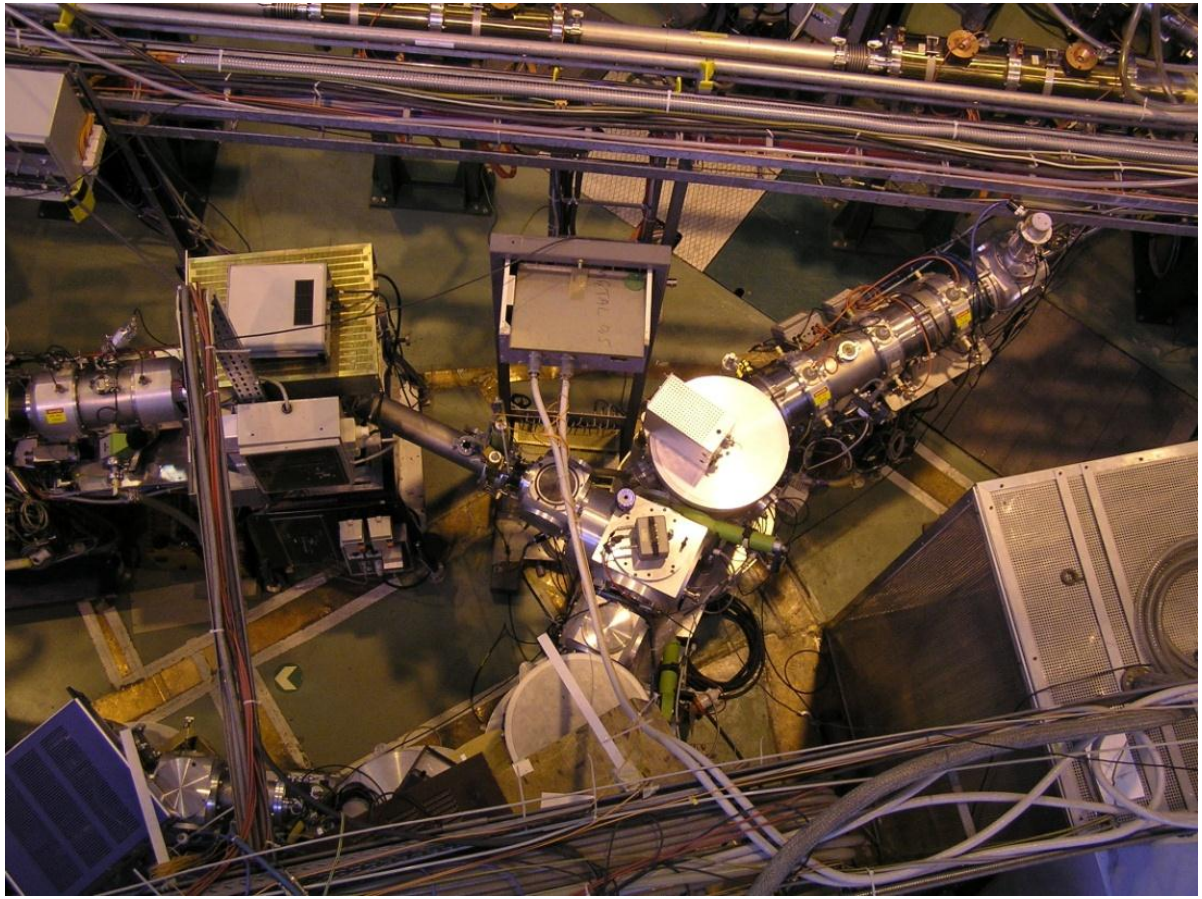
Status in 2008

- Proposal to the INTC accepted

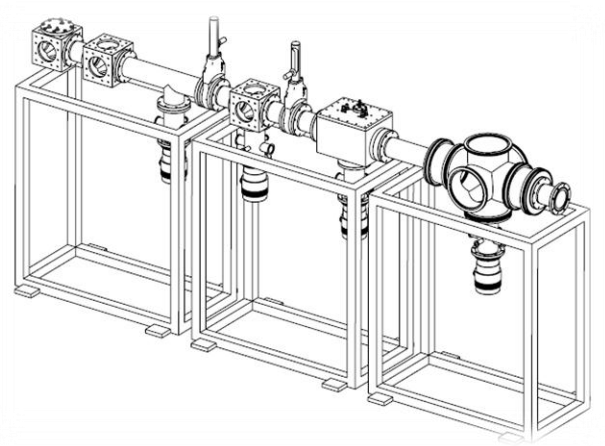
New beam line to be located in the old COMPLIS area.

COMPLIS decommissioning scheduled for the summer of 2008.

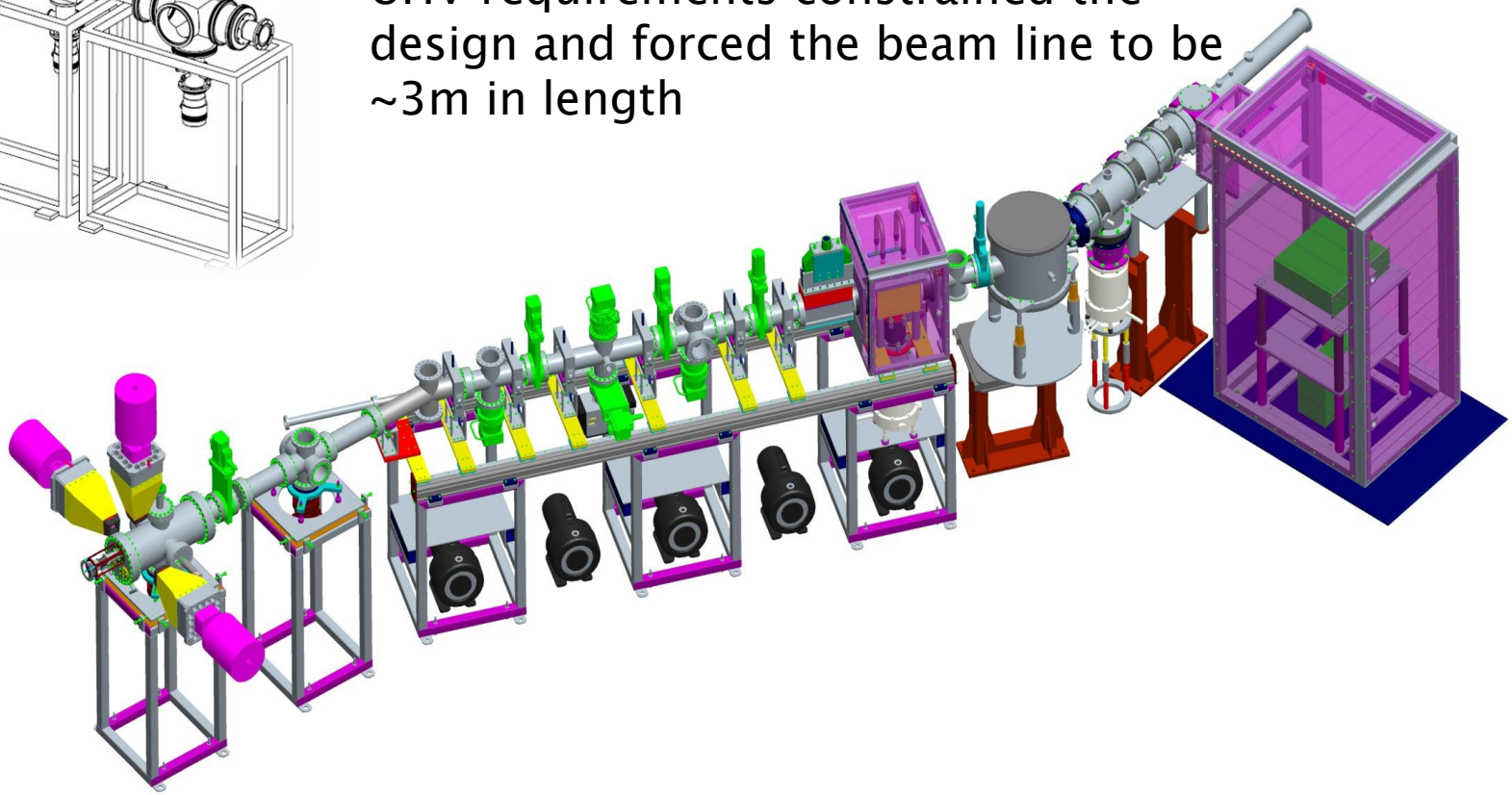
Design work for new beam line started in spring of 2008.



Technical Design

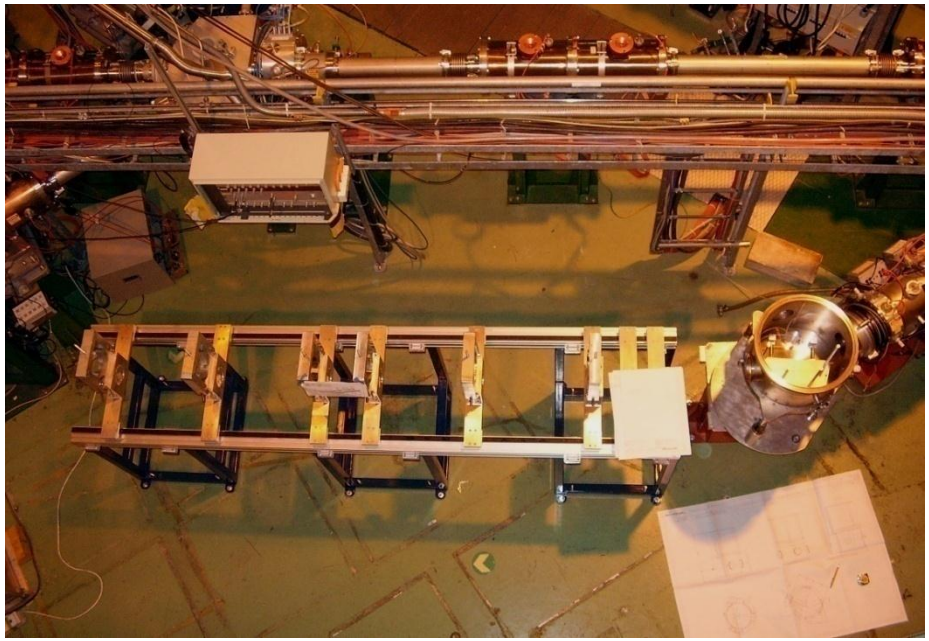


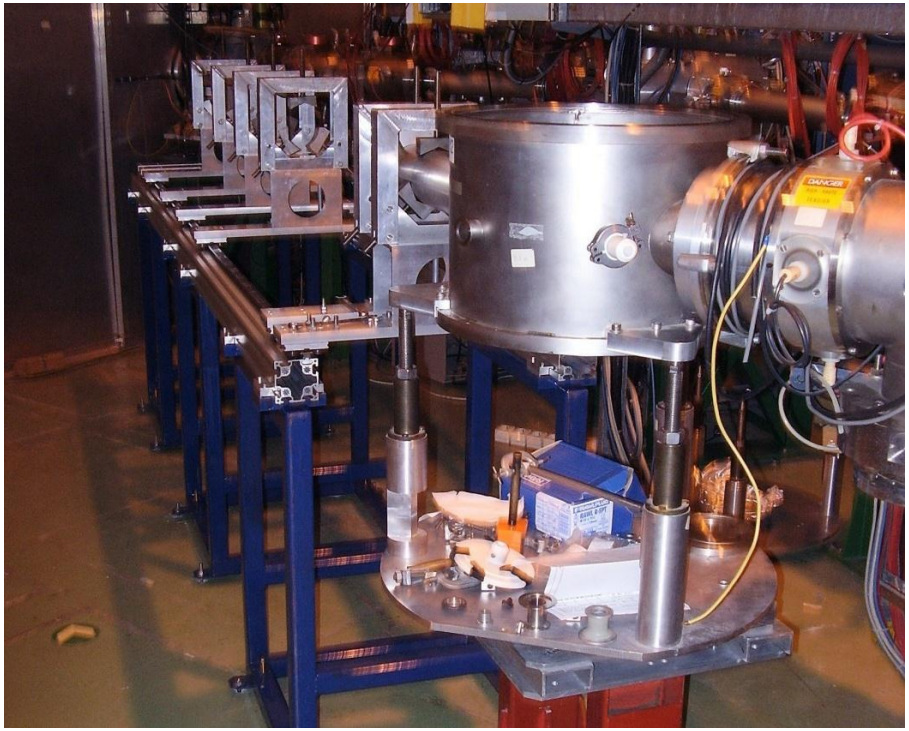
Basic scheme went through several iterations before converging on the final design in 2008.
UHV requirements constrained the design and forced the beam line to be ~3m in length



November 2008

- Initial Installation of railway track for the beam line. The concept allows an individual to remove vacuum sections.

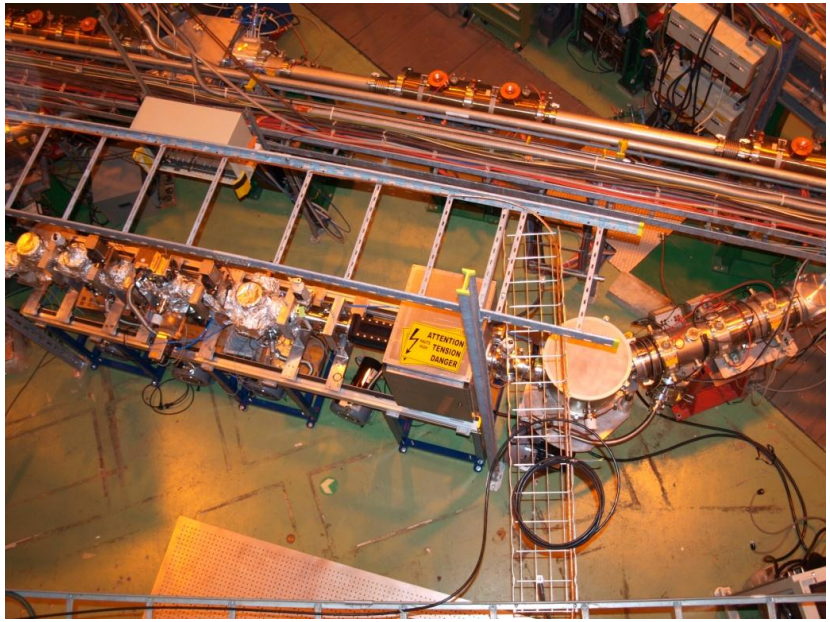




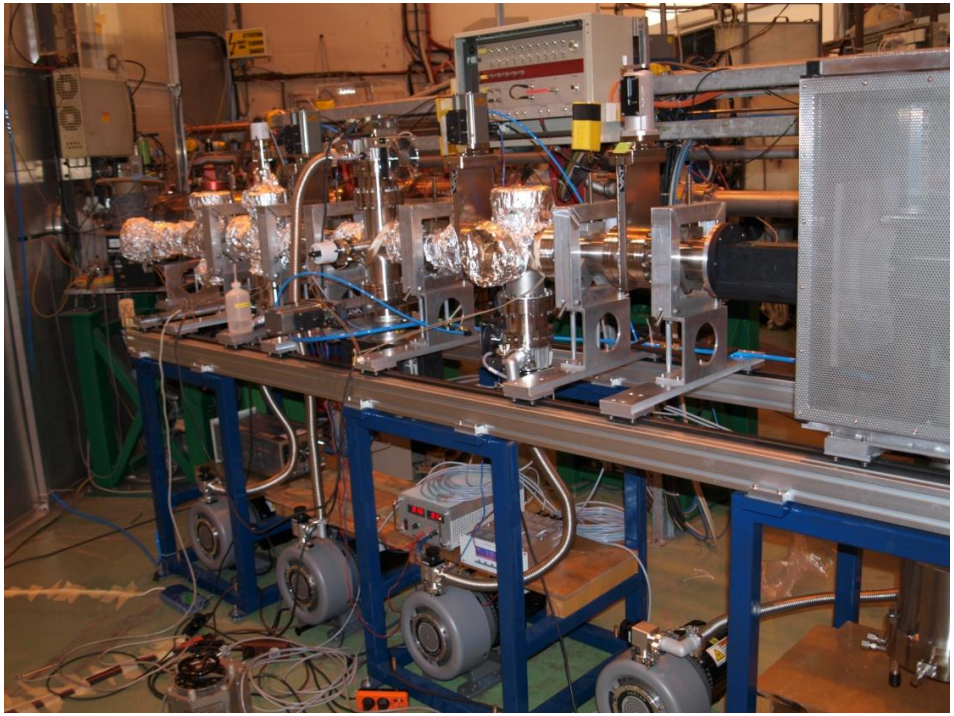
April 2009

- Beam line installation

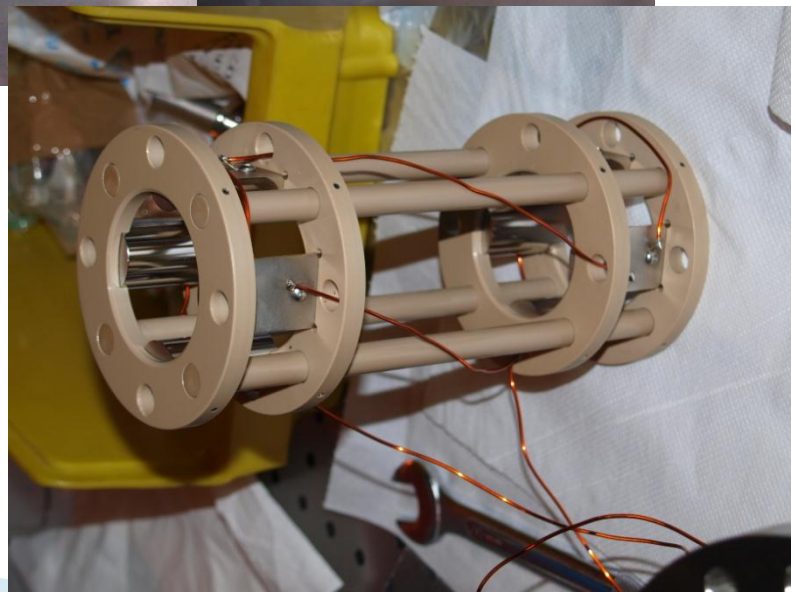
2009: Vacuum testing



Initial bake out of the UHV section and differential pumping tests.
Charge exchange cell and hot oil circulator was tested (with mixed results)

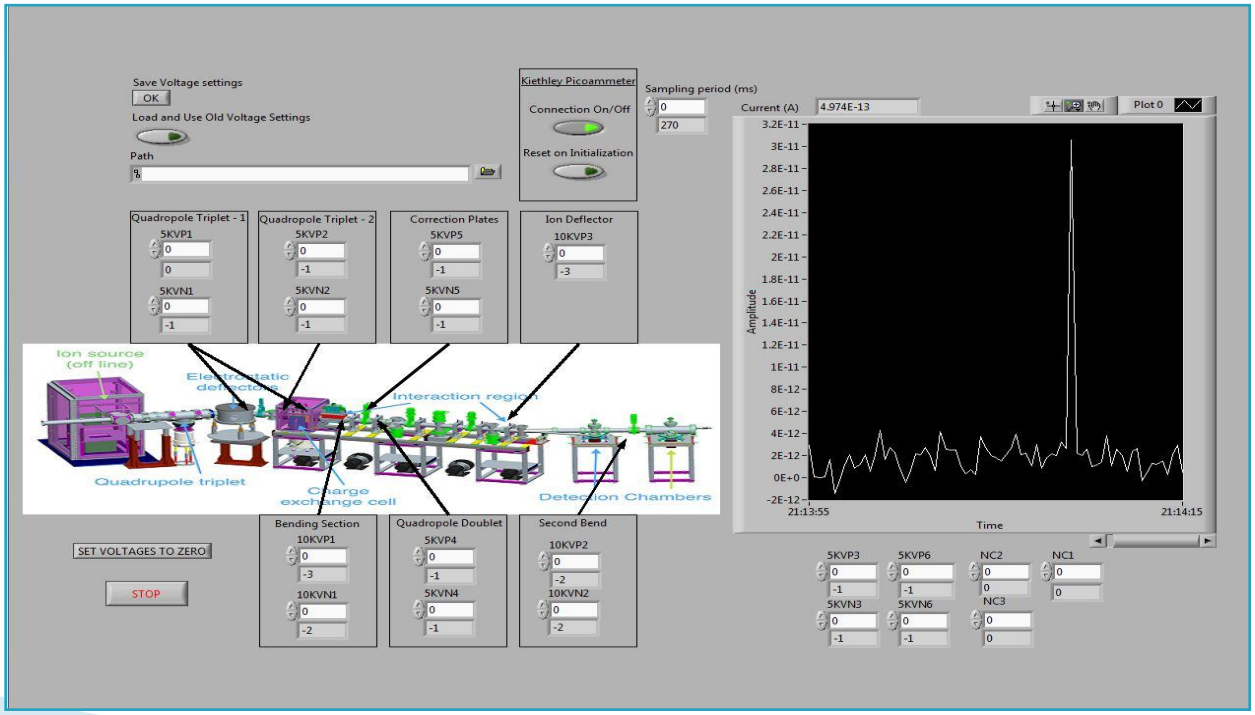


2010: Ion optics installation

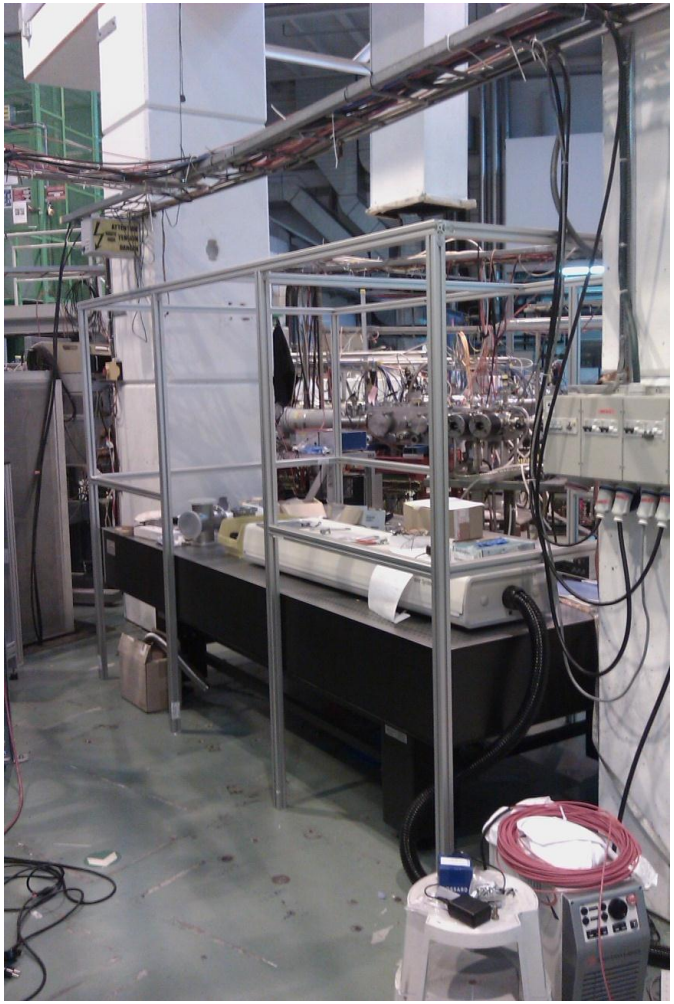


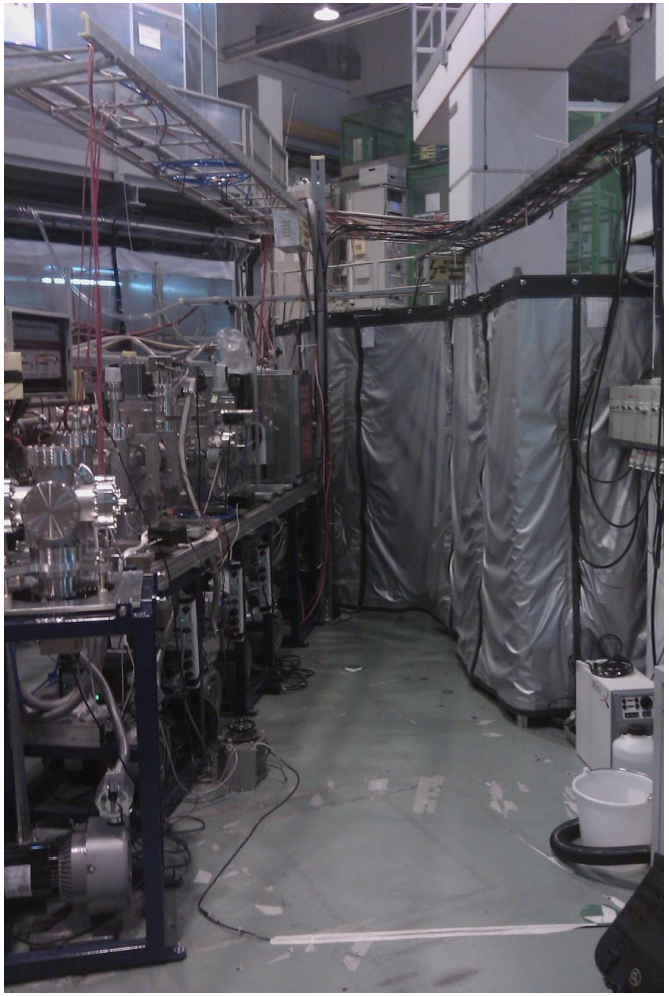
Ion optic tuning

- National Instruments PXI based system
- Can control up to 36 high voltage supplies (currently 20 supplies are used)
- System uses 5kV and 10kV Spellman supplies (MPS series)
- Signal from a Keithley picoammeter is transferred to the PC for tuning.

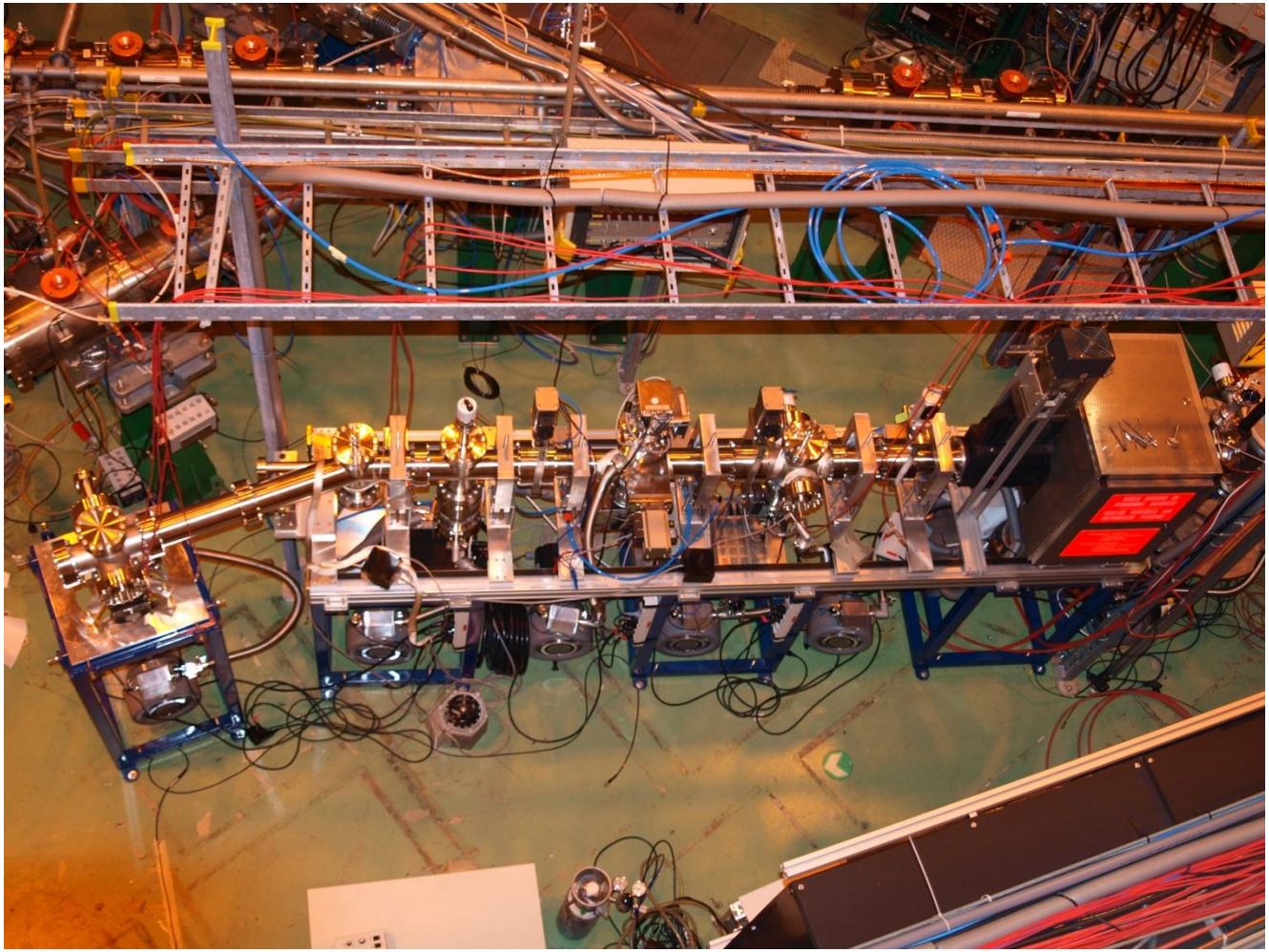


2010: Installation of lasers

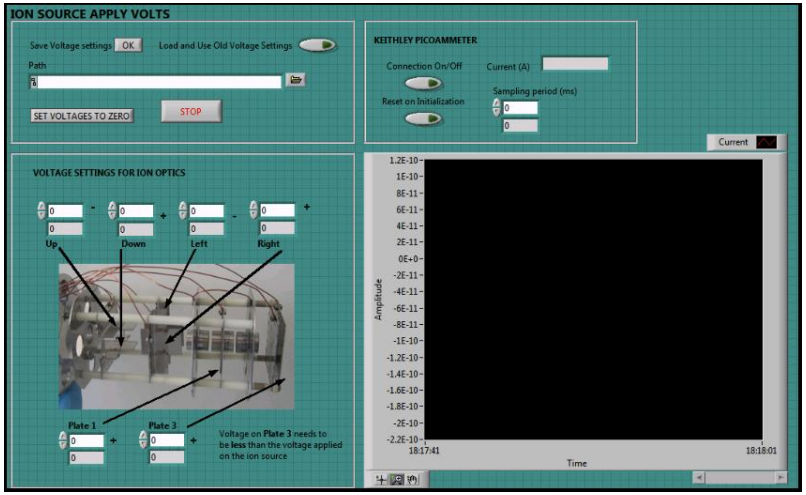




October 2010

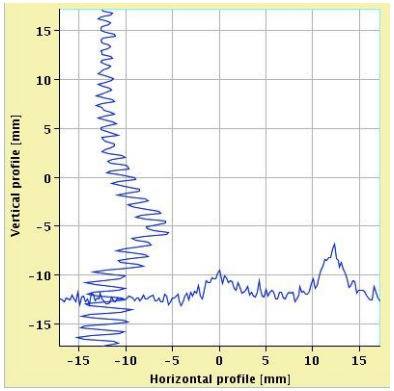


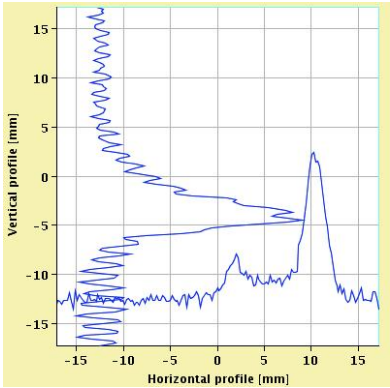
2011:Off-line ion source

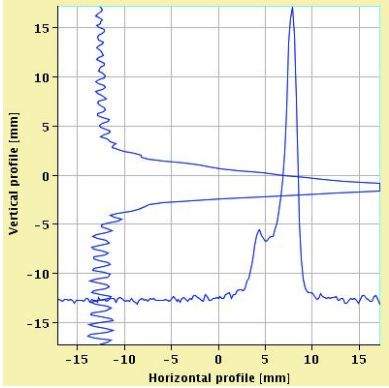


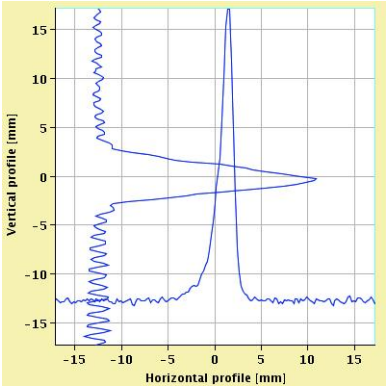
- Diagnostics on the ion source were carried out with a wire scanner and a Faraday cup.
- A LabView programme was created to apply volts to the steering and focusing optics in the chamber, and to read the current on the Faraday cup.

Ion source tests

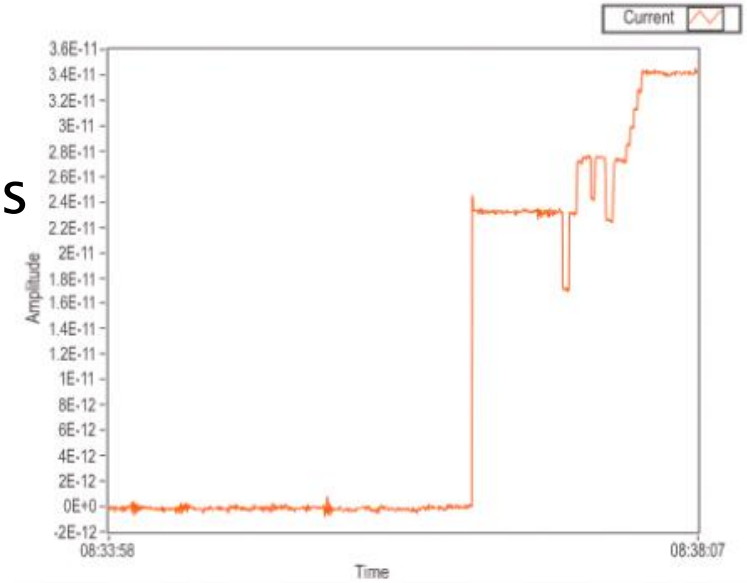








- Optimizing the ion beam profile using the optics of the Einzel lense.
- The current on the ion source was set at 40 A and the bias voltage was 2 kV.
- Stable operation of 100-300pA over many days of use.
- Currently tested with Rb, Cs and In.

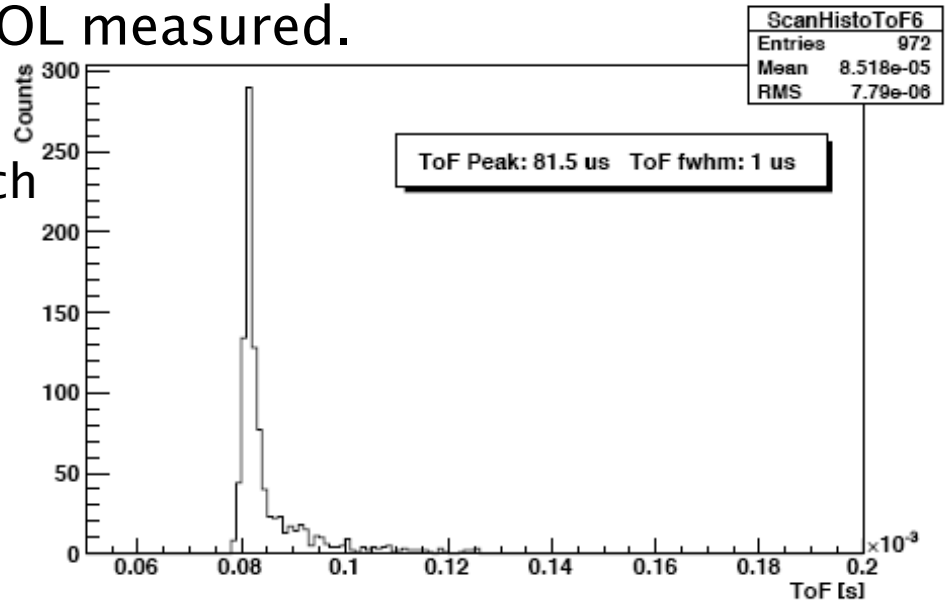


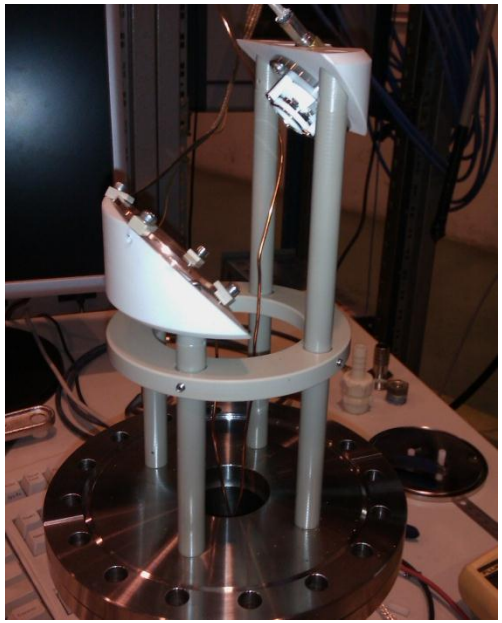
MCP detector installed and tested

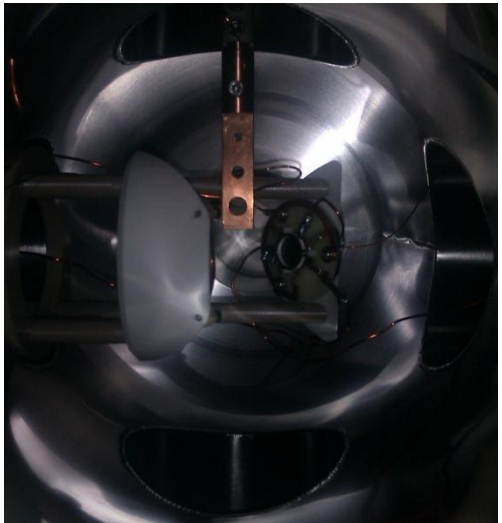
- MCP arranged to look at secondary electrons from a biased copper dynode.
- For beam tuning the dynode acts as a Faraday cup.
- TOF spectra of a bunched Rb beam from ISCOOL measured.

~10^3 ions/bunch

FWHM~1μs



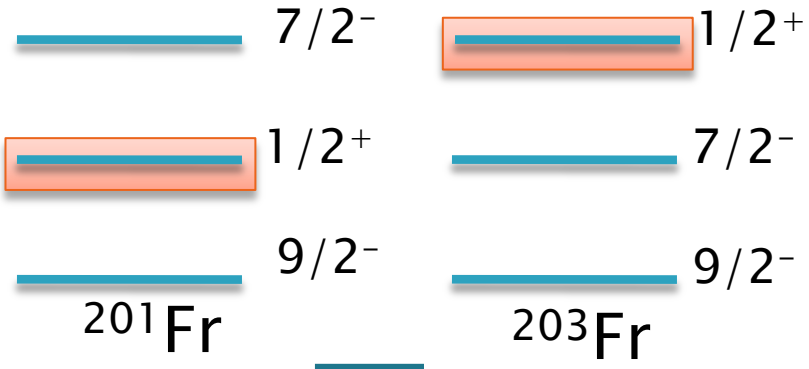




Re-ordering of quantum states in Francium

Systematic reduction in energy of the deformed *π(1/2+)* in isotopes in thi region of the chart

π(1/2+) proton intruder state becomes the ground state in 195At and 185Bi

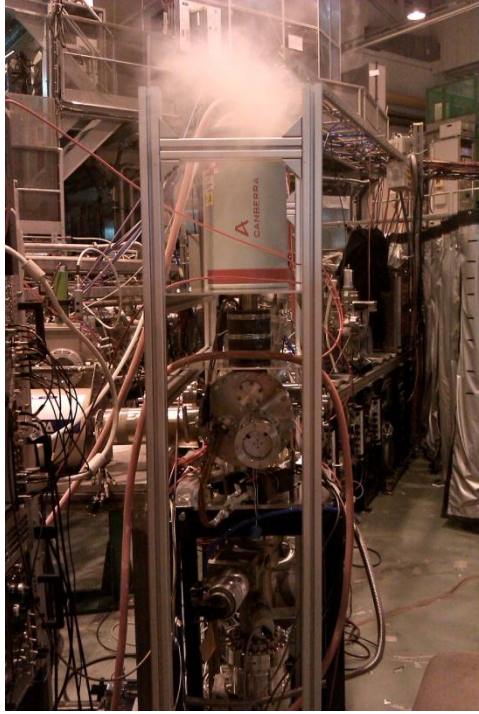


The isomer shifts of ^{201,203}Fr and their magnetic moments will provide important information to better understand the evolution of nuclear structure in this region.

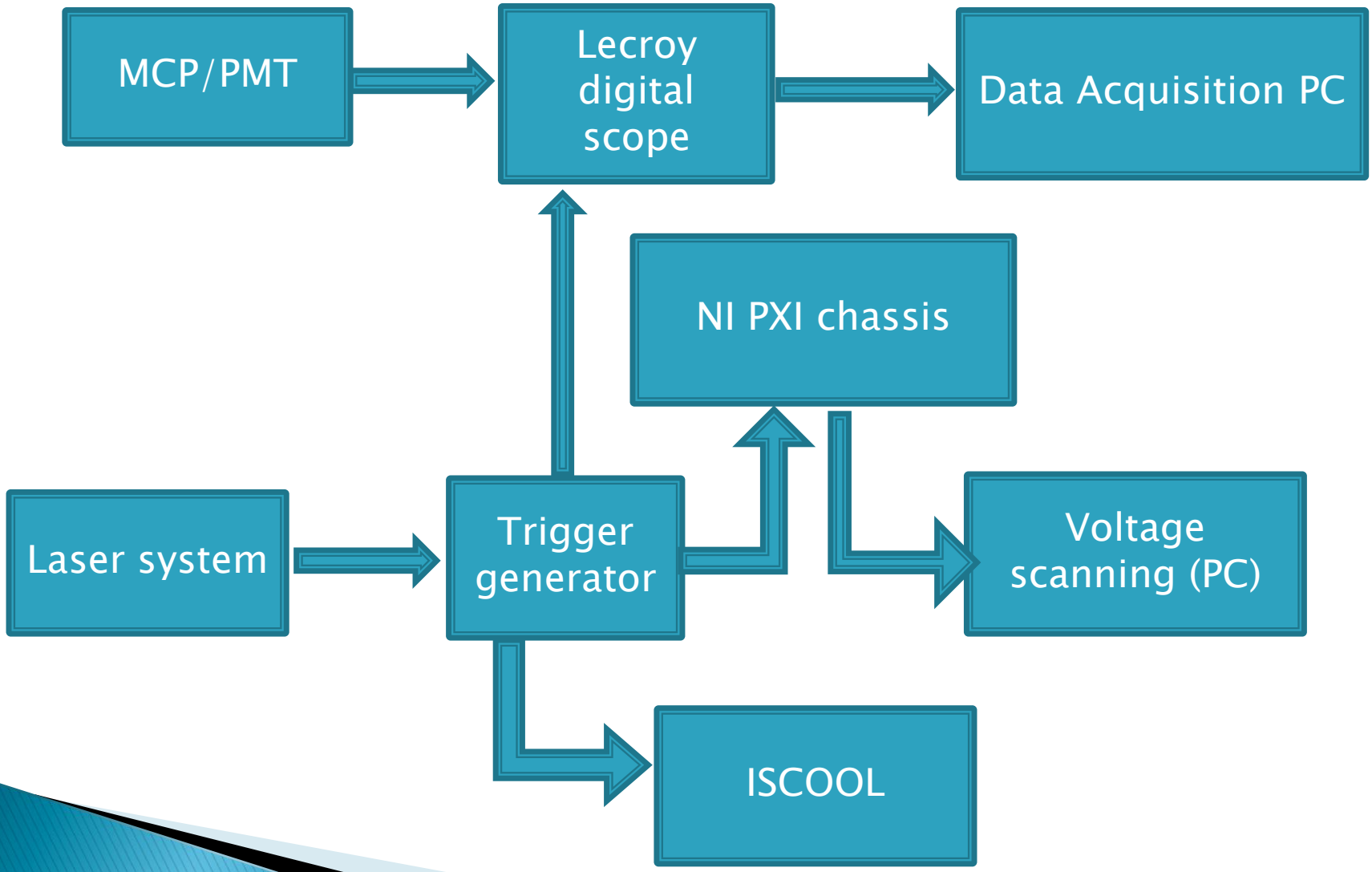
Suggestion that ^{199}Fr has I=1/2^{+} ground state spin with an associated large oblate deformation.

On-line run 2011

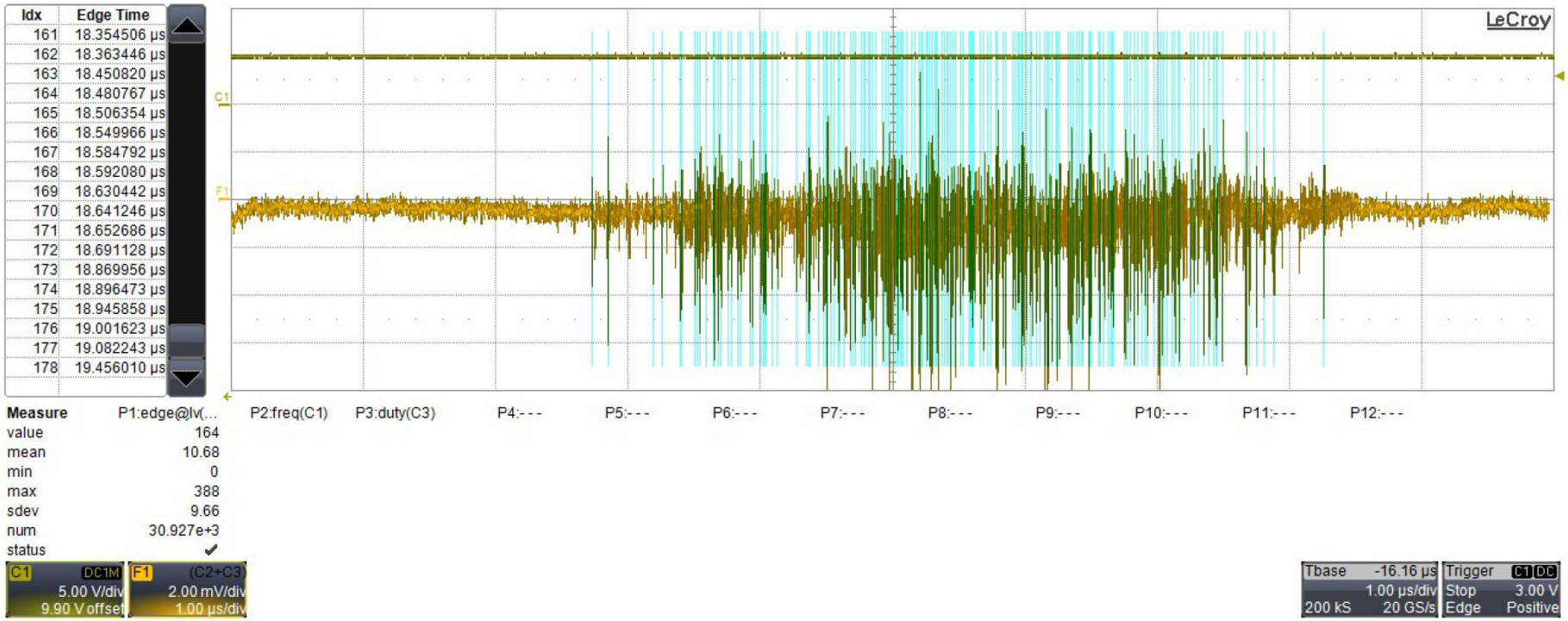
- Commissioning run of the CRIS experiment
- Goals of the experiment
  - Demonstrate CRIS at ISOLDE
  - Demonstrate laser assisted decay spectroscopy with CRIS (Kara Lynch)
  - Fully commission the beam line (charge exchange cell, high voltage tuning, ion detection setup and digital data acquisition.
  - Test new laser system for CRIS.



Data Acquisition



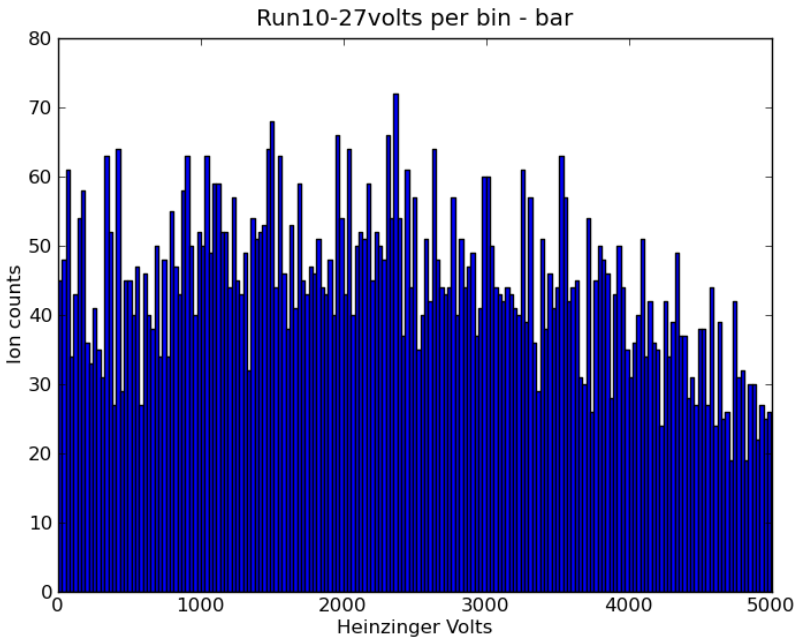
Digital Data Aquisition



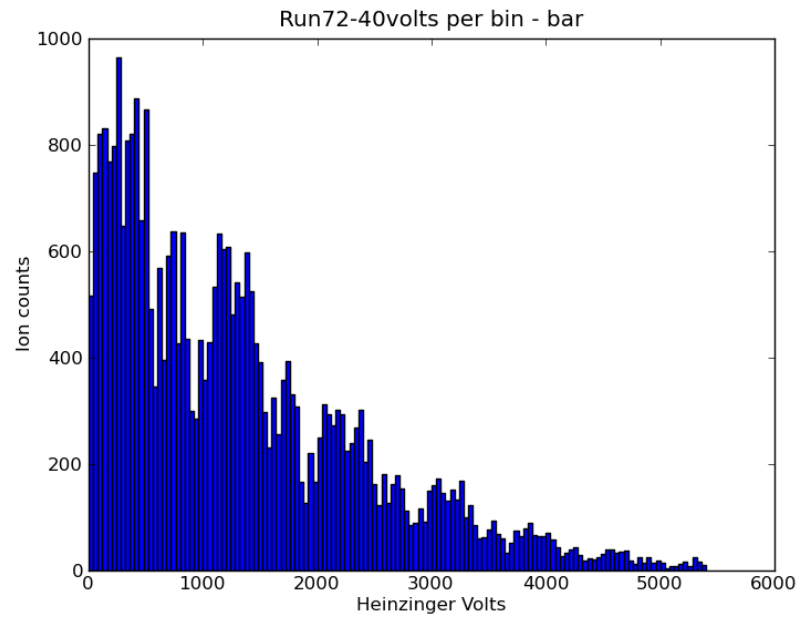
- Example of an ion bunch recorded by the digital data acquisition.
- Full time stamping of every event for off-line analysis.

Beam tuning effect

Negative voltage



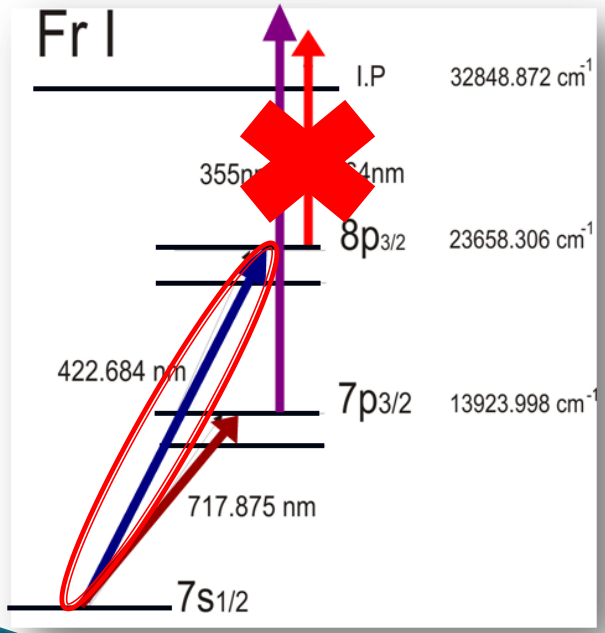
Positive voltage



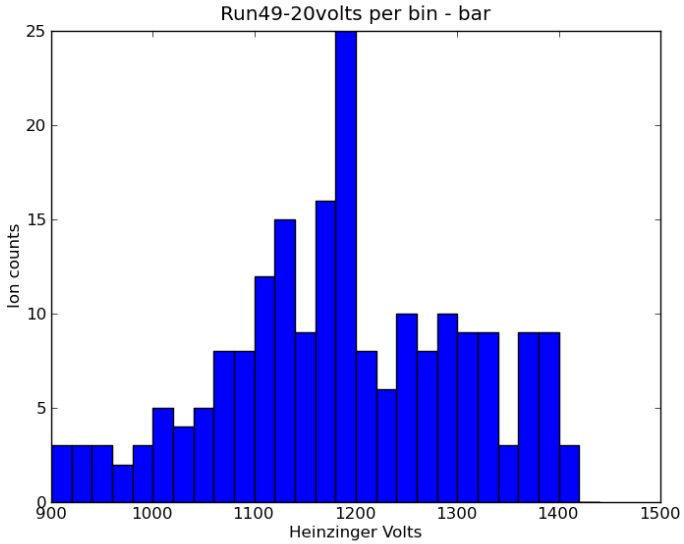
Associated with a misalignment of the beam through the charge exchange cell. As a high voltage is applied to the cell the beam is further deflected.

Results

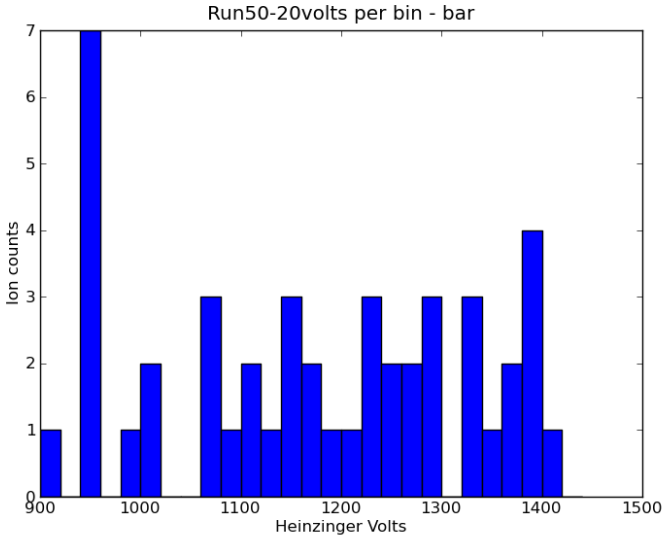
- Resonant ionization of Fr
- Two step scheme.
- 1064nm laser off



Laser on



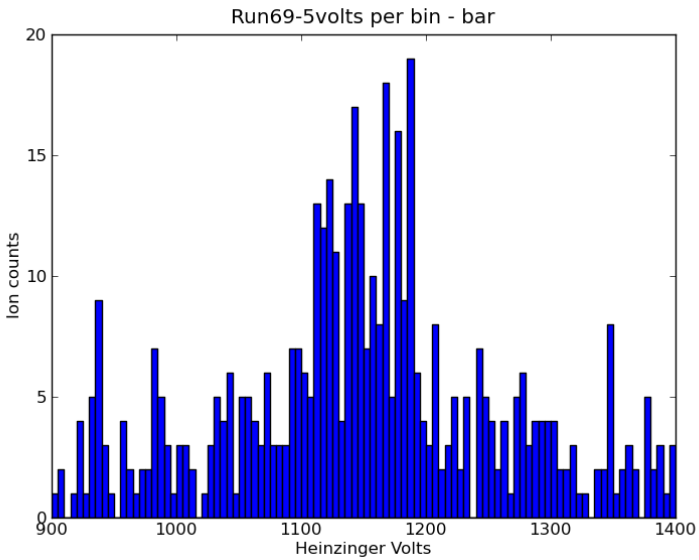
Laser off



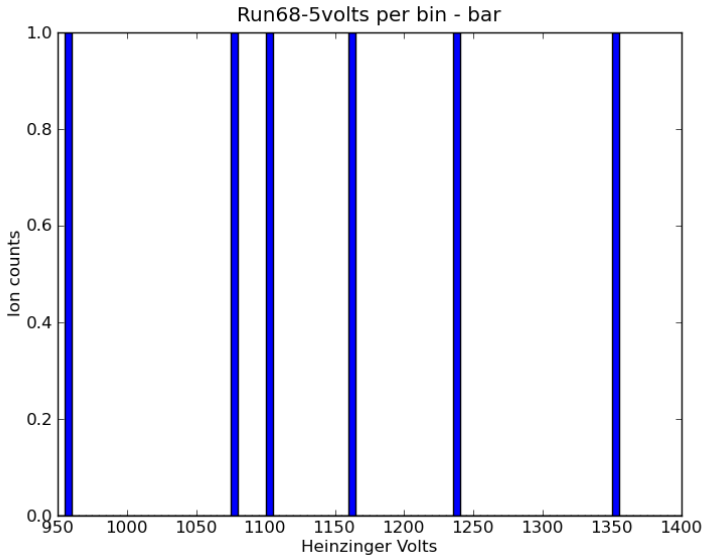
Results

- Further optimization of the 422nm (scans carried out over a range 20-200μJ/pulse.
- Majority of the background is due to 422+422 non-resonant ionization.
- With both lasers blocked the observed background is associated with collisional ionization.
- Pressure ~1-2x10^{-8}mbar

Laser on

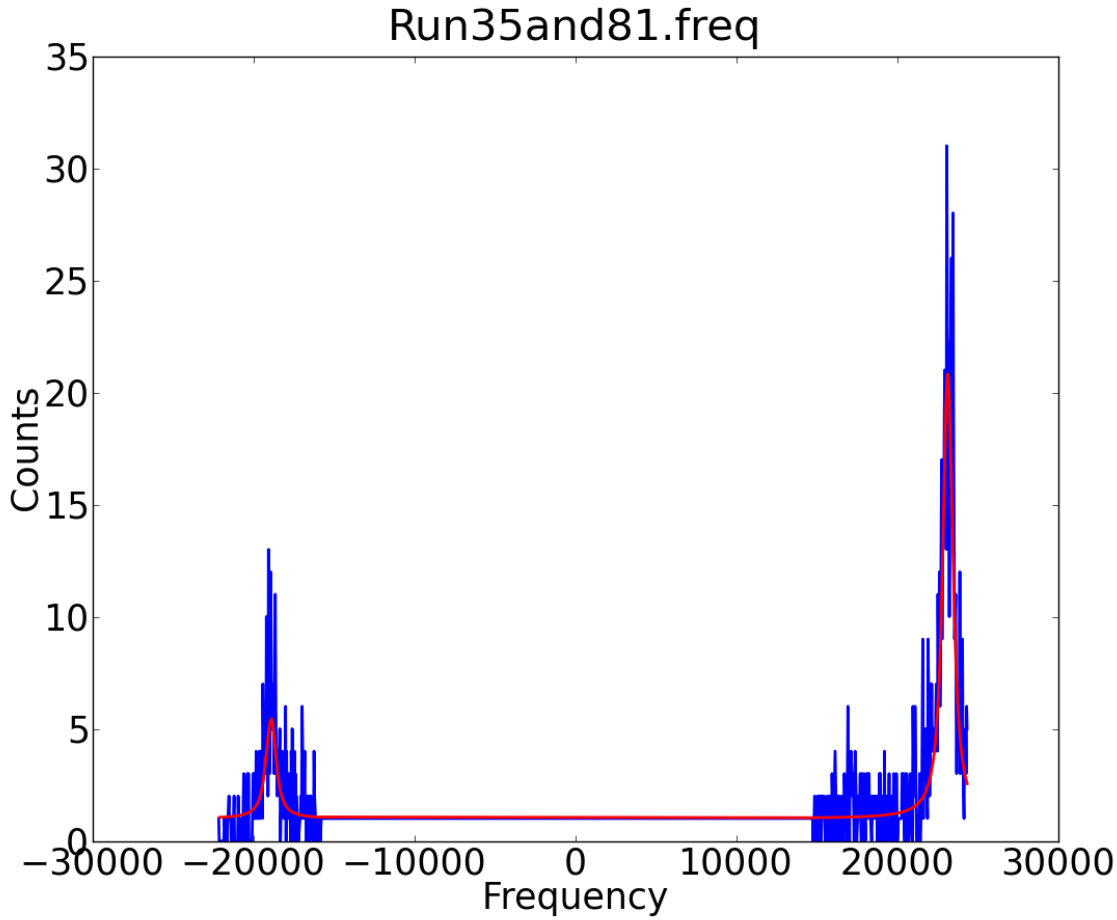


Laser off



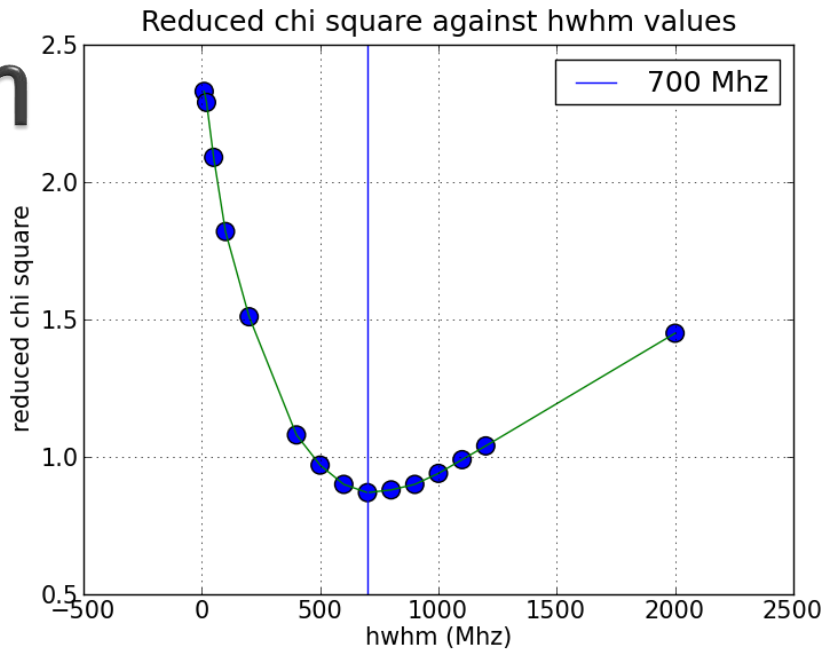
Results: HFS of ^{207}Fr

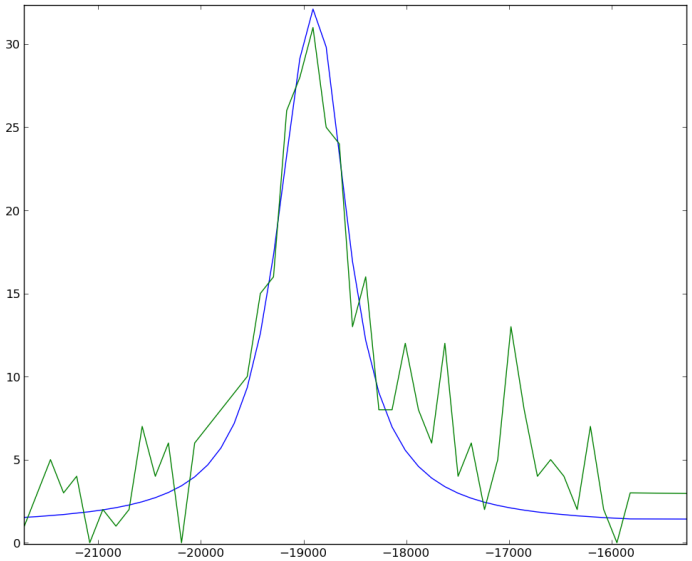
- Literature: $A(S_{1/2})=8484(1)$MHz $I=9/2$
- Preliminary result from this work: $A(S_{1/2})=8390(100)[200]$MHz
- Low background rate~0.05/s



Results: resolution

- Multiplet of three transitions within the peak.
- Linewidth ~1GHz.
- Preliminary results.
- Analysis is on-going.
- New laser system was used in this experiment. Characteristics of this device are under study.



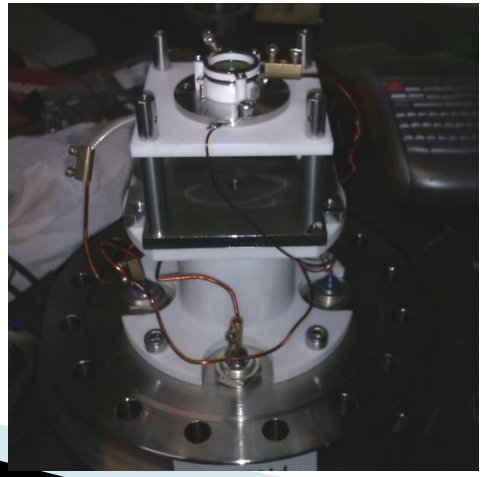


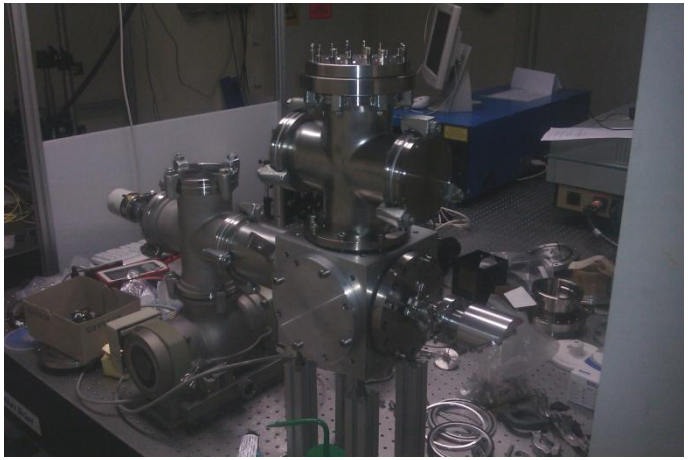
Summary

- Beam line fully commissioned
- ~50% neutralization efficiency of Fr demonstrated. Beam mistuning minimized.
- First hyperfine spectra of Fr measured.
- Digital data acquisition demonstrated
- Decay spectroscopy station demonstrated (Kara Lynch, the next talk)
- Suppression of Fr (with lasers off) is ~ factor of 10000
- Currently low experimental efficiency, can account for some this effect.

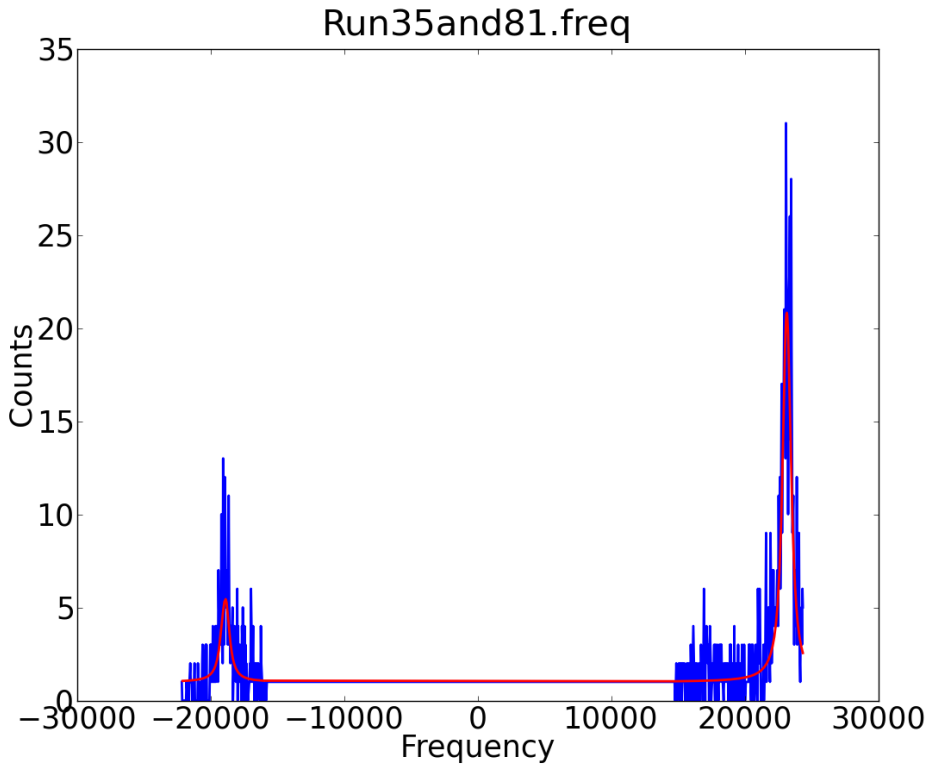
Outlook for 2012

- On-going off-line tests using the CRIS beam line and ion source.
- New atomic beam unit has been constructed to study future RIS schemes and better test the laser system.
- Further on-line experiments planned for Fr and now also neutron rich Cu.





Many thanks to the ISOLDE team and all of the people involved in the CRIS project.



Thank you for your attention

Collaboration

J. Billowes, M.L Bissell, B. Cheal, T.E. Cocolios, A. Dax, K.T. Flanagan, M. Hori, H. A. Khozani, T. Kobayashi, F. Le Blanc, O. Levinkron, D. Lunney, K.M. Lynch, G. Neyens, T.J. Procter, M.M. Rajabali, S. Rothe, A.J. Smith, A. Soter, H.H Stroke, W. Vanderheijden, K. Wendt.

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