LASER ASSISTED DECAY SPECTROSCOPY AT THE CRIS BEAM LINE AT ISOLDE

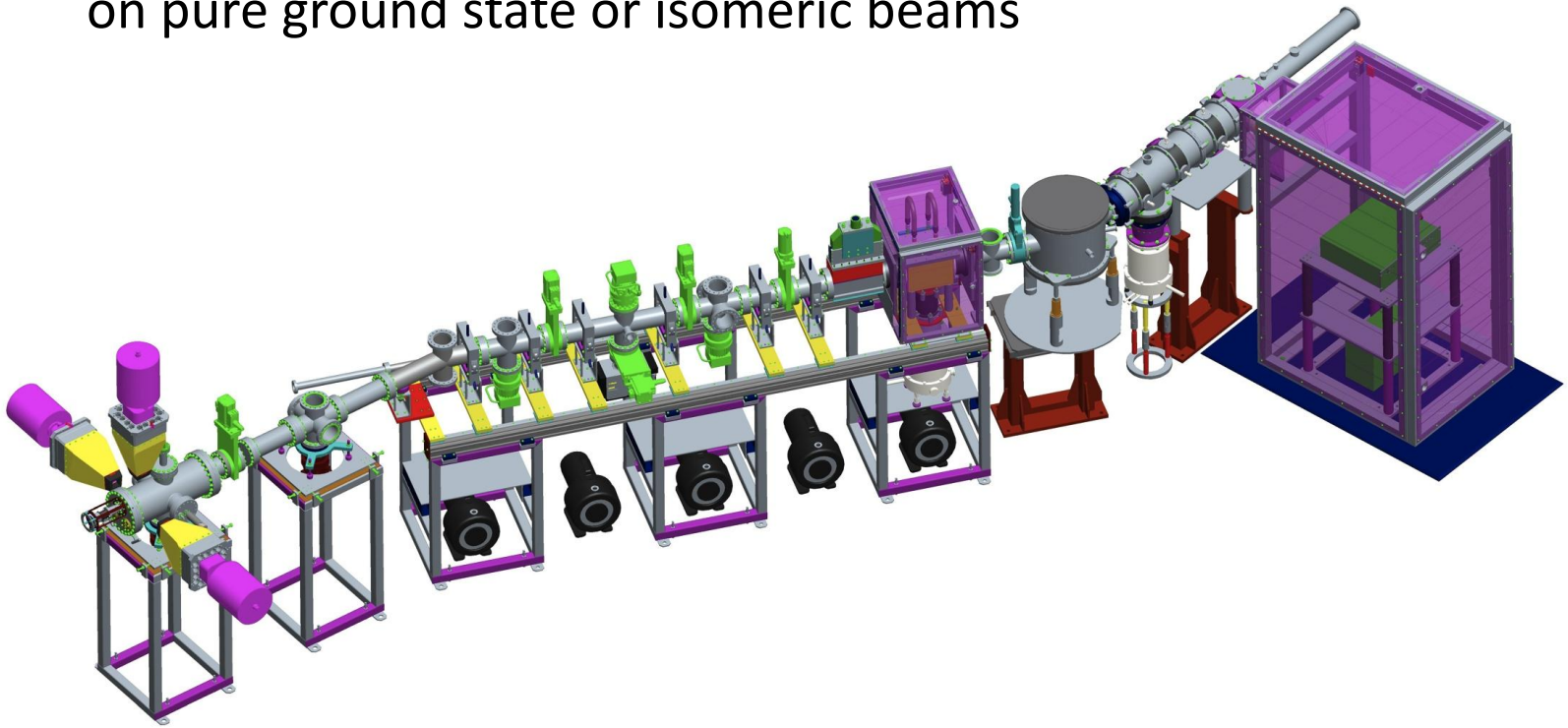
Kara M Lynch
CERN Doctoral Student
The University of Manchester

Outline

- Introduction
- Collinear resonant ionization spectroscopy
  - Selectivity of resonant ionization
- Laser assisted decay spectroscopy
  - Physics case of low-lying isomer in ^{204}Fr
- The CRIS beam line at ISOLDE
- Characterizing the decay spectroscopy station
  - Energy resolution, attenuation and efficiency measurements
- Recent results from the on line run IS471
  - Laser assisted decay spectroscopy of ^{207}Fr
  - Decay spectroscopy of ^{204}Fr
- Outlook and Summary

Introduction

- The CRIS beam line facility at ISOLDE
  - Laser spectroscopy: spin and moments from parent nucleus
  - Decay spectroscopy: level scheme from daughter nucleus
- This allows for spectroscopy measurements to be performed on pure ground state or isomeric beams

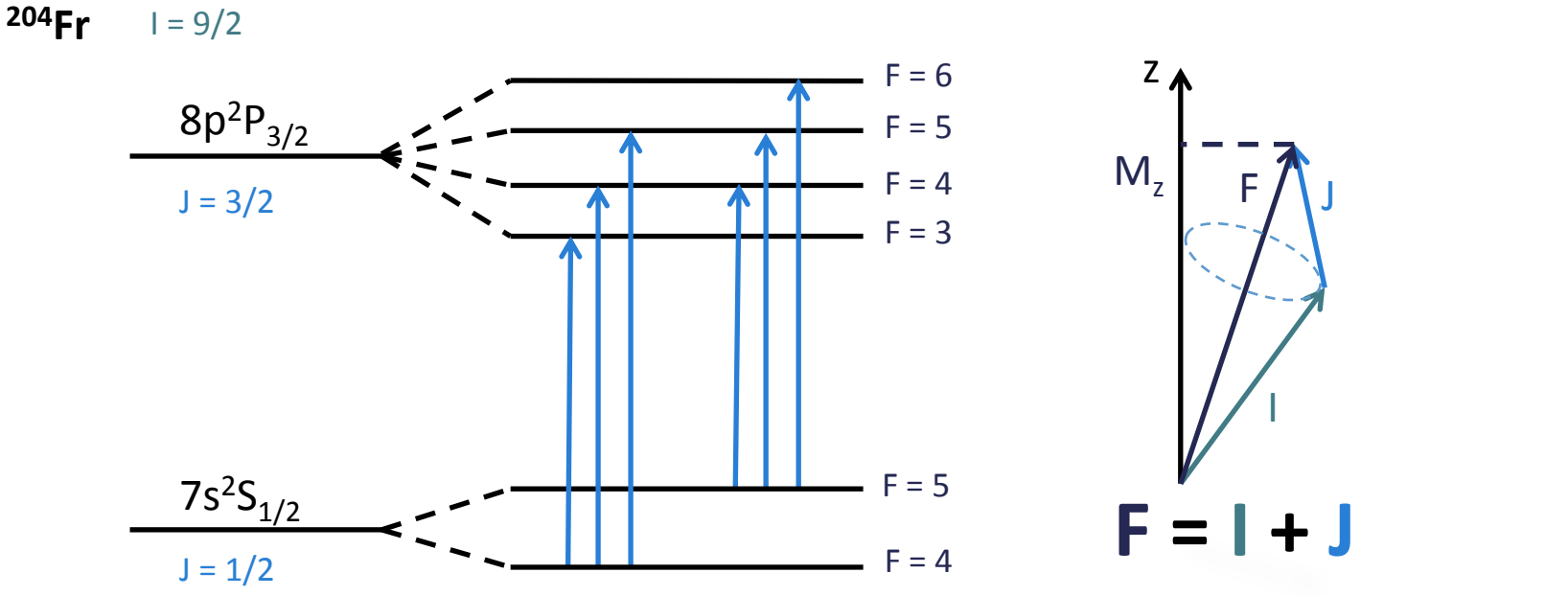


The resolution of collinear spectroscopy and the sensitivity of ion detection

COLLINEAR RESONANT IONIZATION SPECTROSCOPY

Laser spectroscopy

- Scan the frequency, probing an isotope's hyperfine structure



- Nuclear parameters extracted with model-independence:

Nuclear spin I

Electric quadrupole moment Q_s

Magnetic dipole moment μ_I

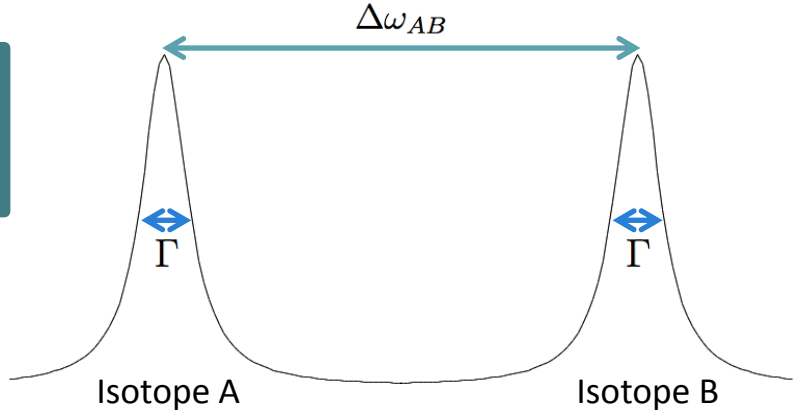
Change in mean square charge radii $\delta\langle r^2\rangle^{AA'}$

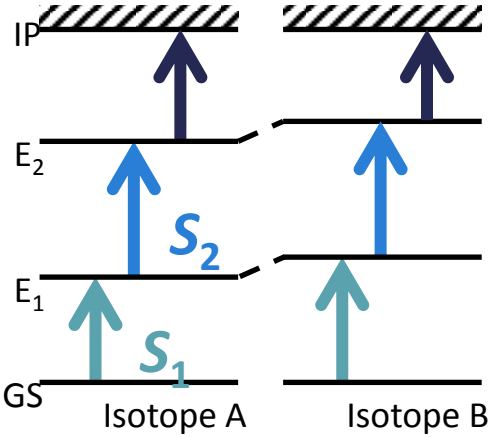
Selectivity of resonant ionization

- When the laser frequency is on resonance with a HF transition, the isotope is resonantly ionized
- Resonant ionization selects the isotope of interest

Selectivity of an isotope is:

$$S = \left(\frac{\Delta\omega_{AB}}{\Gamma}\right)^2$$





$S = S_1 \times S_2$ $\quad S = \prod S_n$

The higher the number of excitation steps, the greater the selectivity

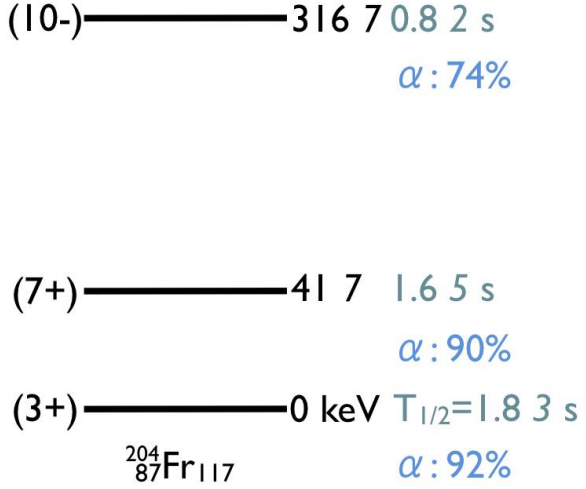
- Analogous to the mass resolution in mass spectrometry

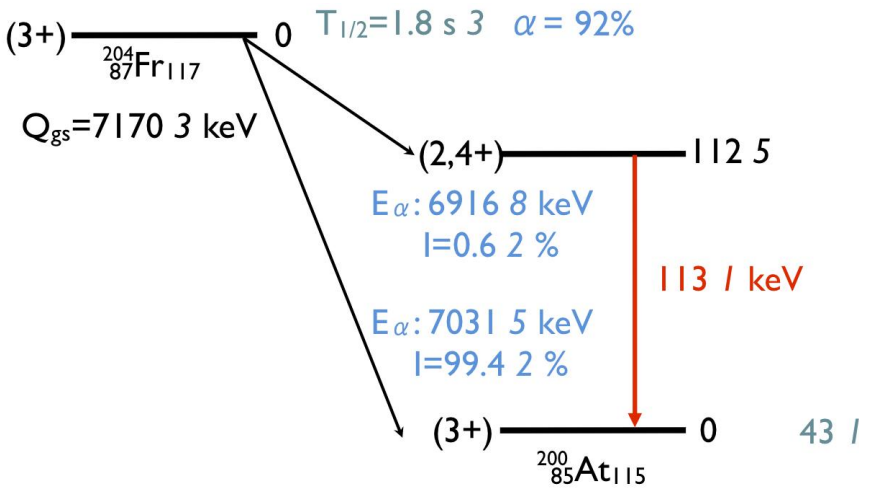
Due to the high selectivity of collinear spectroscopy, sensitive secondary experiments can be performed

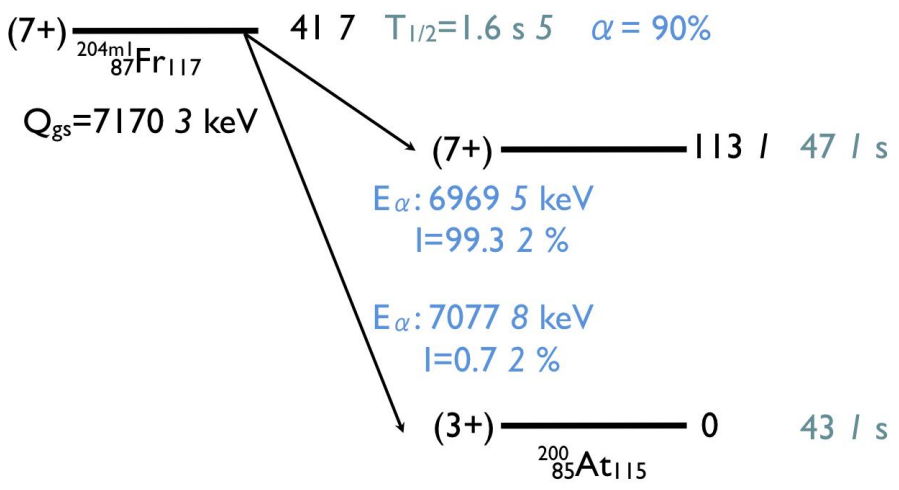
LASER ASSISTED DECAY SPECTROSCOPY

Physics case of ^{204}Fr

- ^{204g}Fr and ^{204m1}Fr are within 41 keV of each other
- Different spins leads to different HFS
- Decay spectroscopy can be performed on pure isomeric beams with a suppression of the ground state by a factor of 10^4

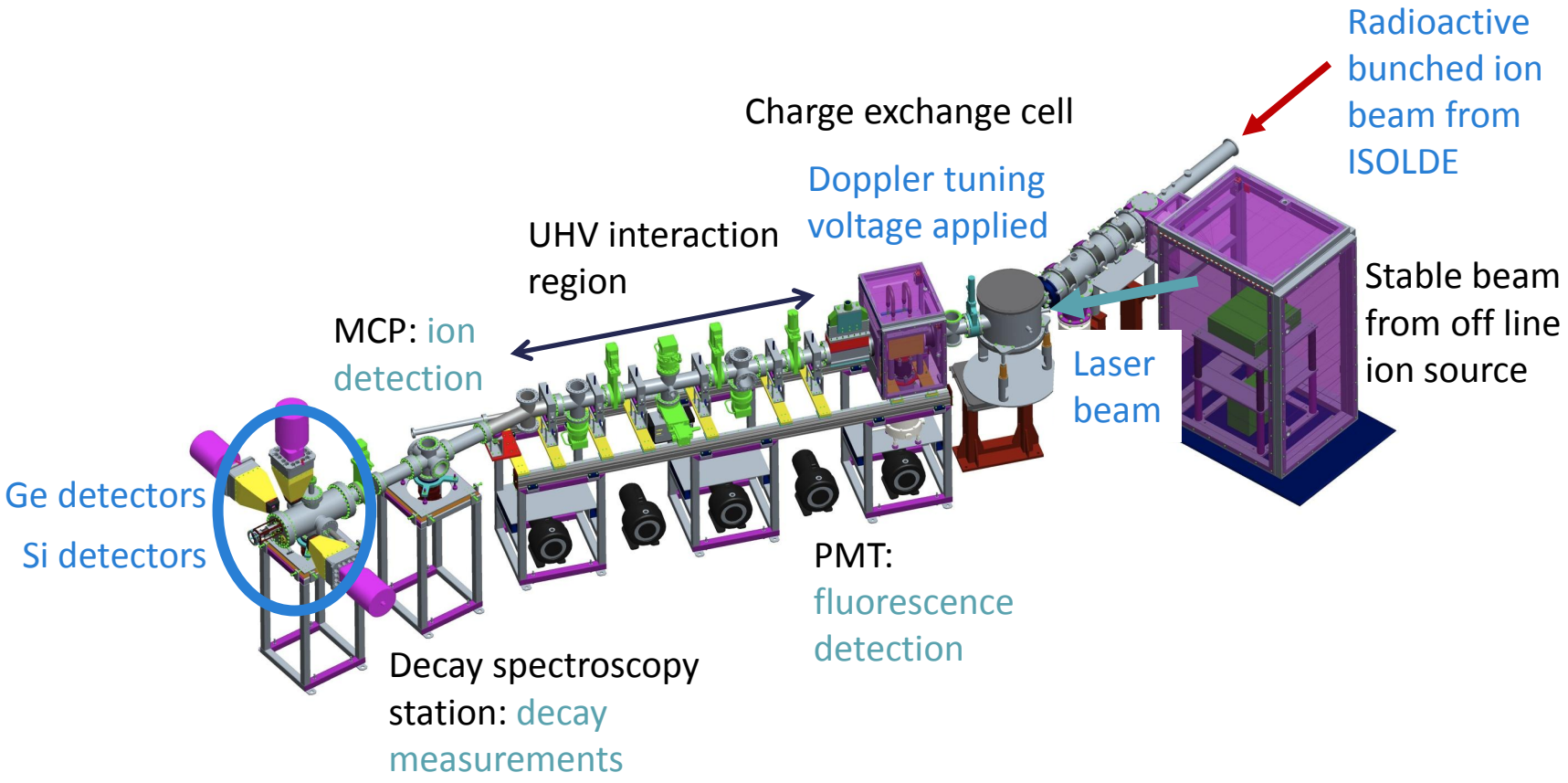






THE CRIS BEAM LINE

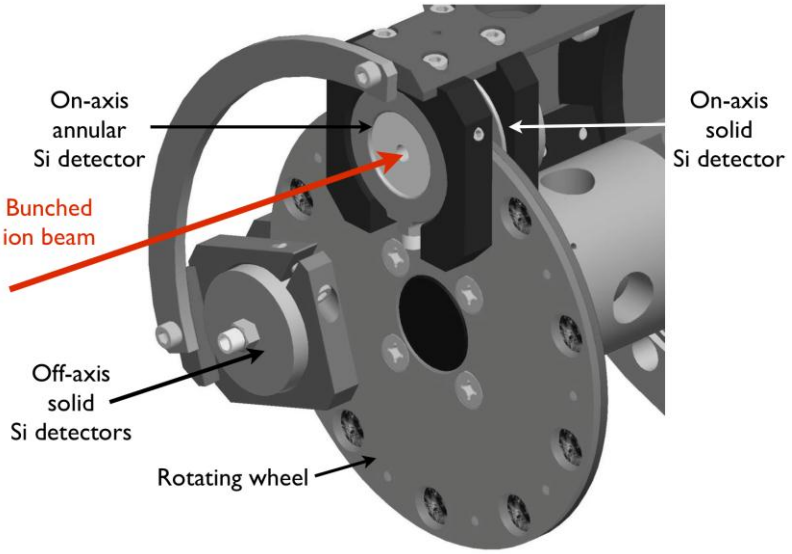
Layout of the CRIS beam line

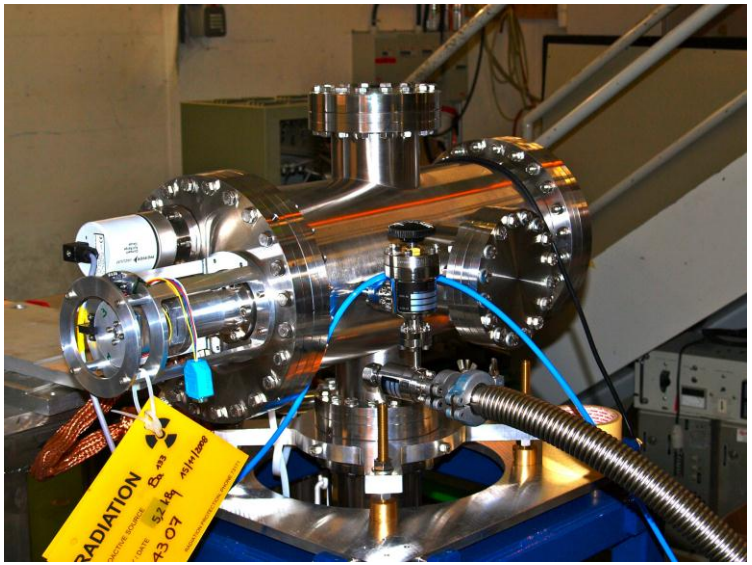


- Collinear geometry gives a reduction in the thermal Doppler broadening by a factor of 10^3, improving resolution

$$\Delta E = \delta(\tfrac{1}{2} m v^2)$$
$$= m v \delta v$$
$$\approx \text{constant}$$

The decay spectroscopy station



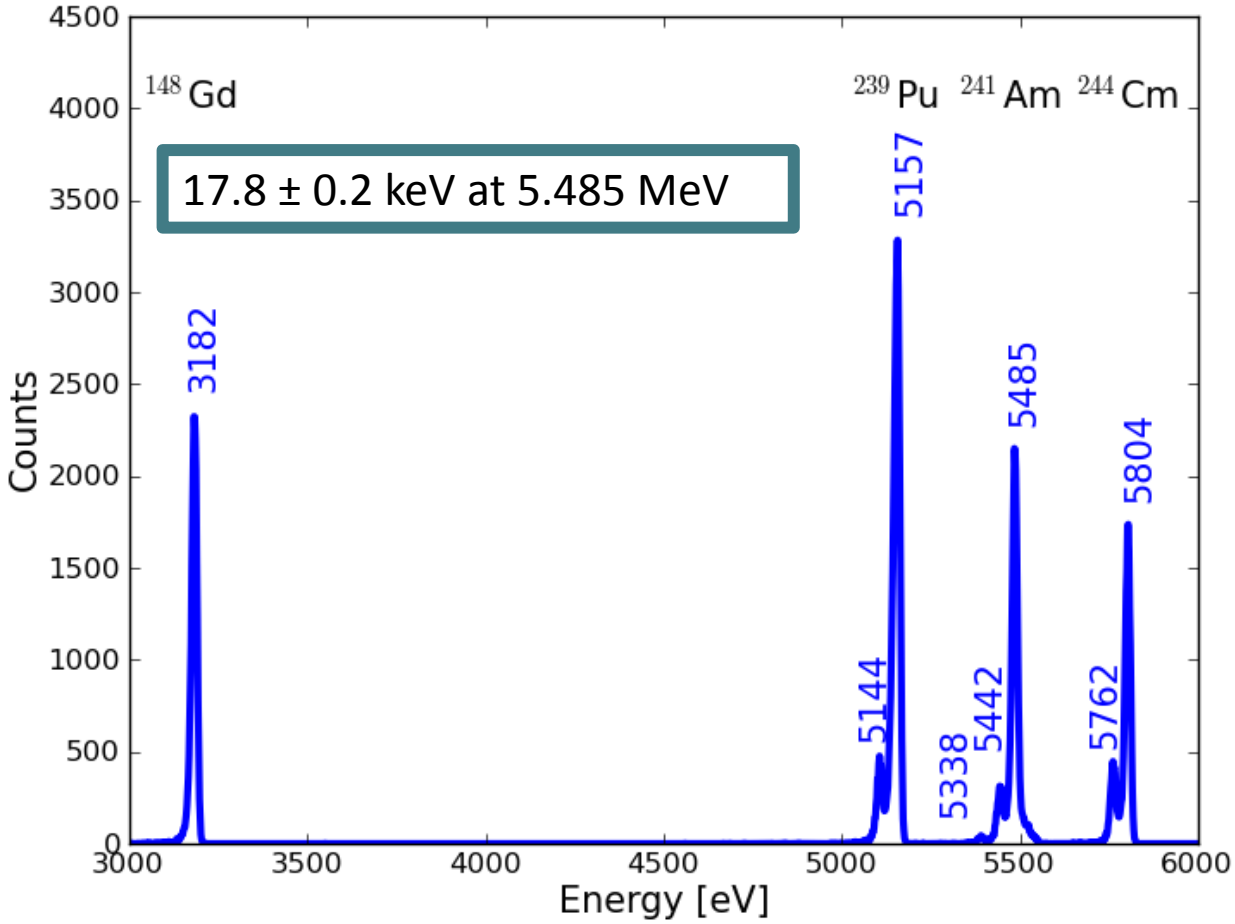


- Rotating wheel implantation system
- 10 carbon foils
- Two Si detectors for alpha-decay detection either side of carbon foil
- Ge detectors for gamma-ray detection
- Steel wheel rotates and a new ion bunch is implanted into the fresh carbon foil

CHARACTERIZING THE DSS

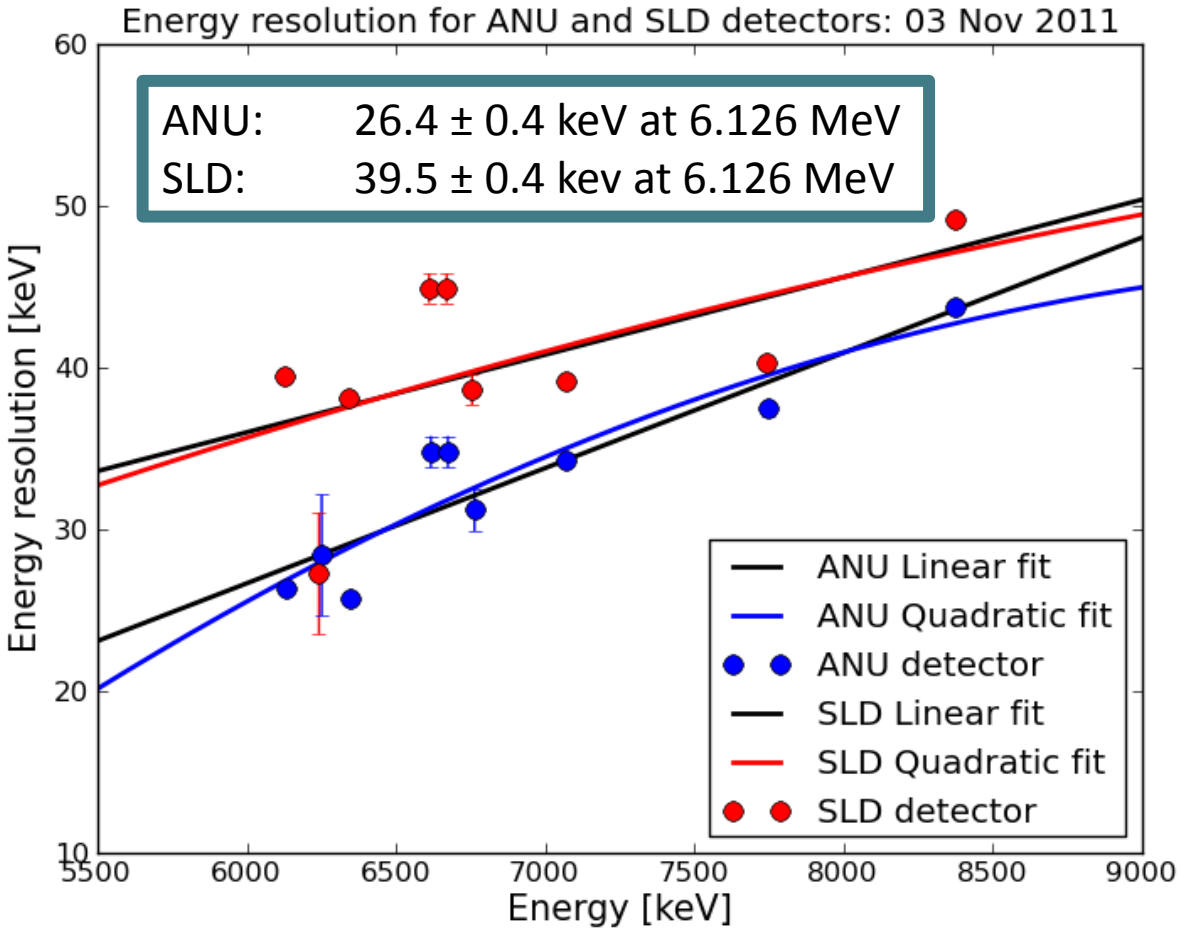
Energy resolution measurements

- The energy resolution of the SLD silicon detector was calculated off line



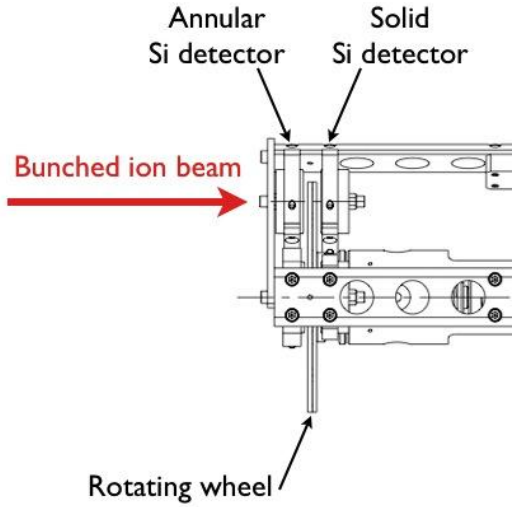
Energy resolution measurements

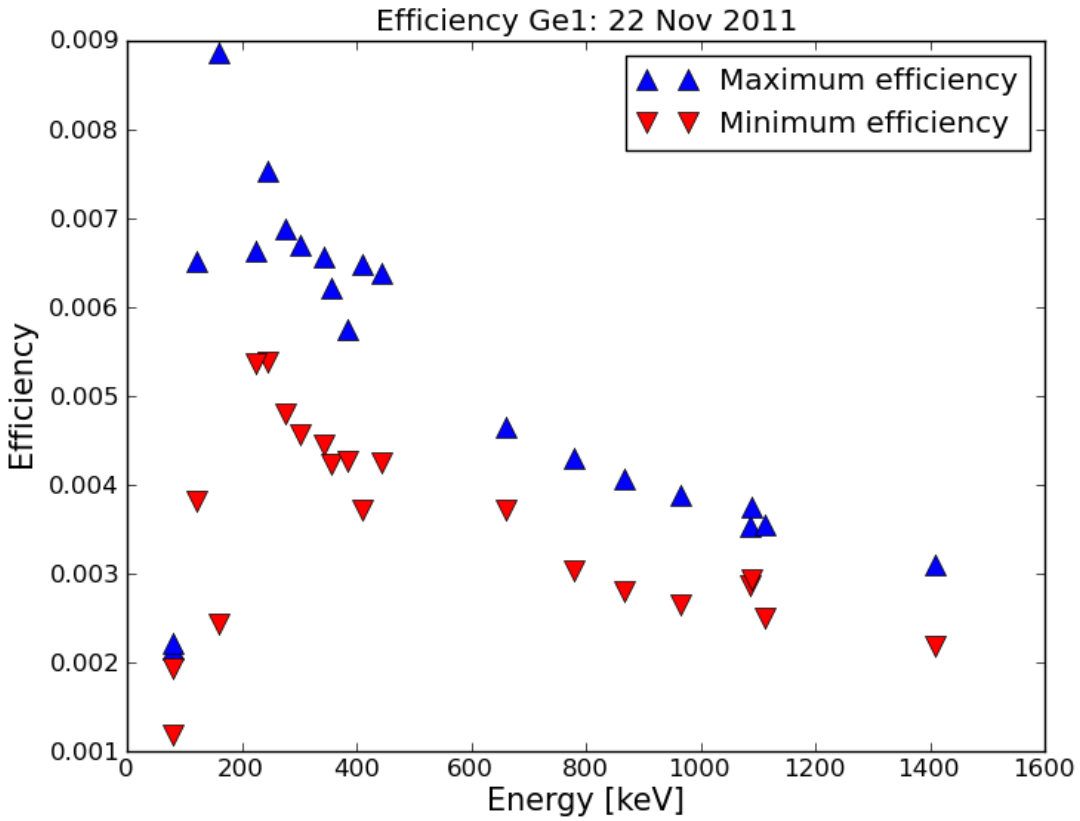
- The energy resolution of the silicon detectors was also calculated on line



Efficiency of the Ge detector

- The efficiency of the Ge detector was corrected for the presence of the two SLD and ANU silicon detectors in the chamber



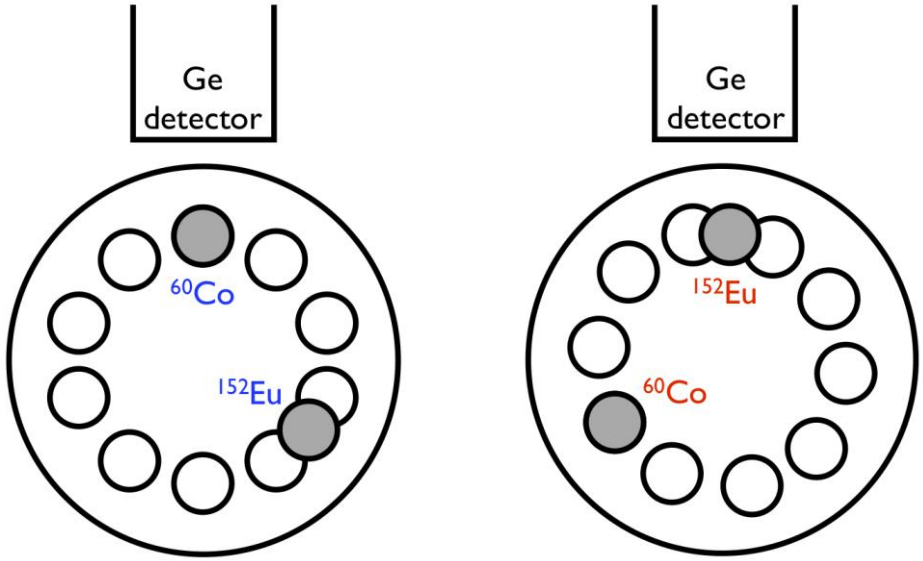


- The SLD detector had no effect
- The ANU detector attenuated the gammas rays by:

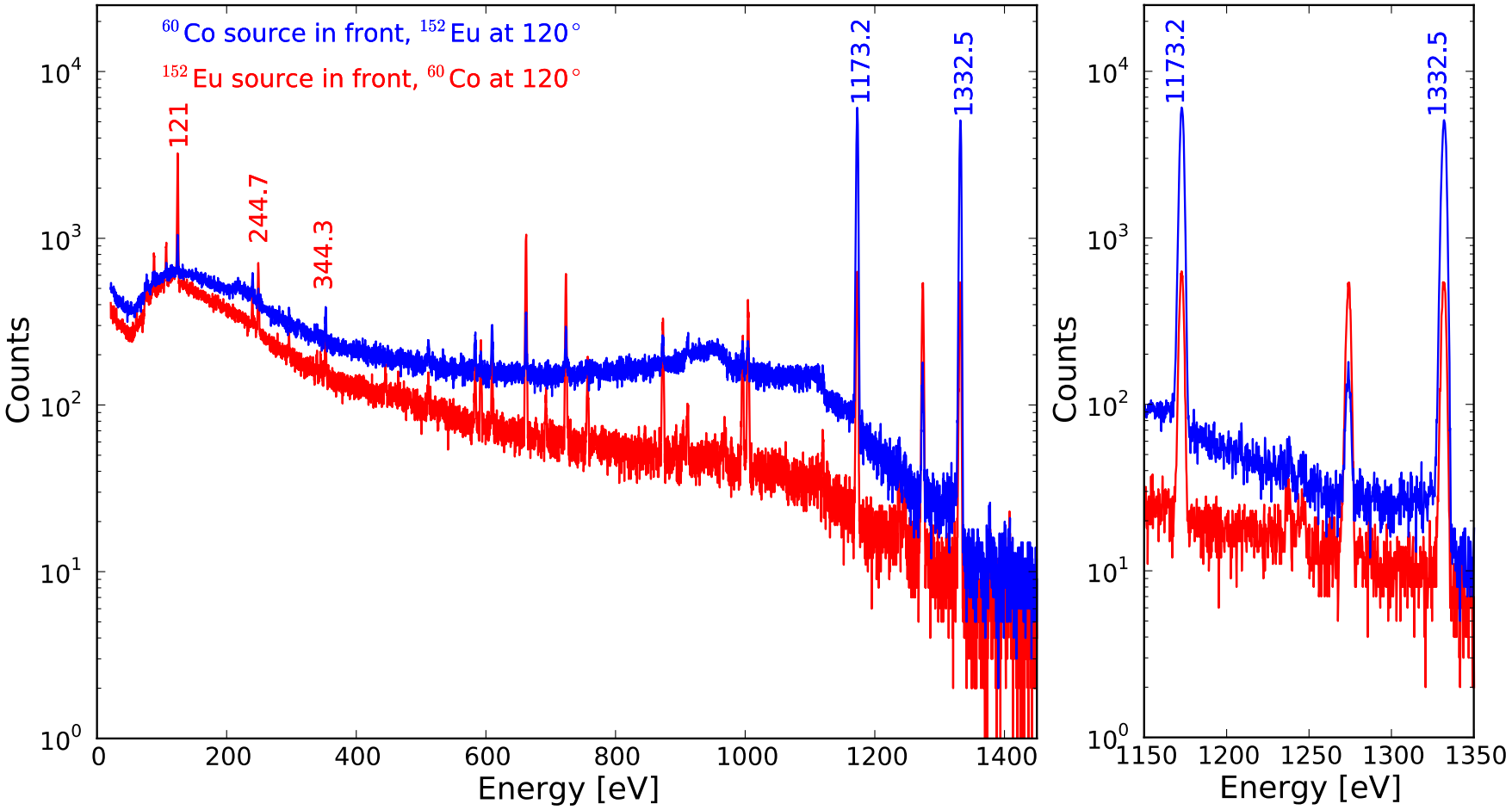
5 ± 1 %

Attenuation measurements

- The attenuation of the gamma rays by the steel windmill was measured:
  - Blue spectrum shows ^{60}Co in front of Ge detector, ^{152}Eu at 120°
  - Red spectrum shows ^{152}Eu in front of Ge detector, ^{60}Co at 120°



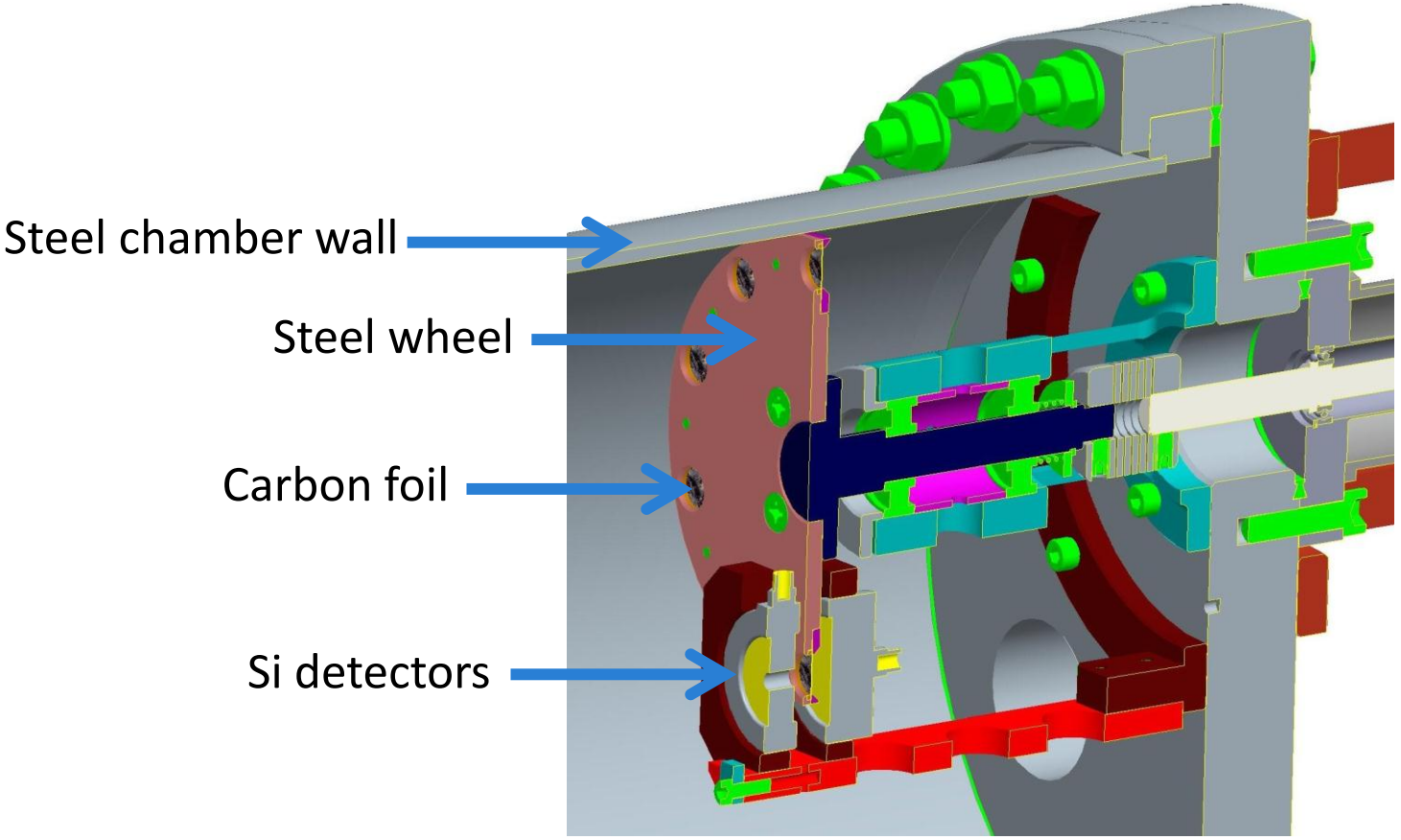
Attenuation measurements



Large attenuation of the gamma rays by the steel wheel

Attenuation measurements

- The attenuation of the gamma rays by the wall of the steel chamber was measured with ^{241}Am and ^{154}Eu sources:



Attenuation measurements

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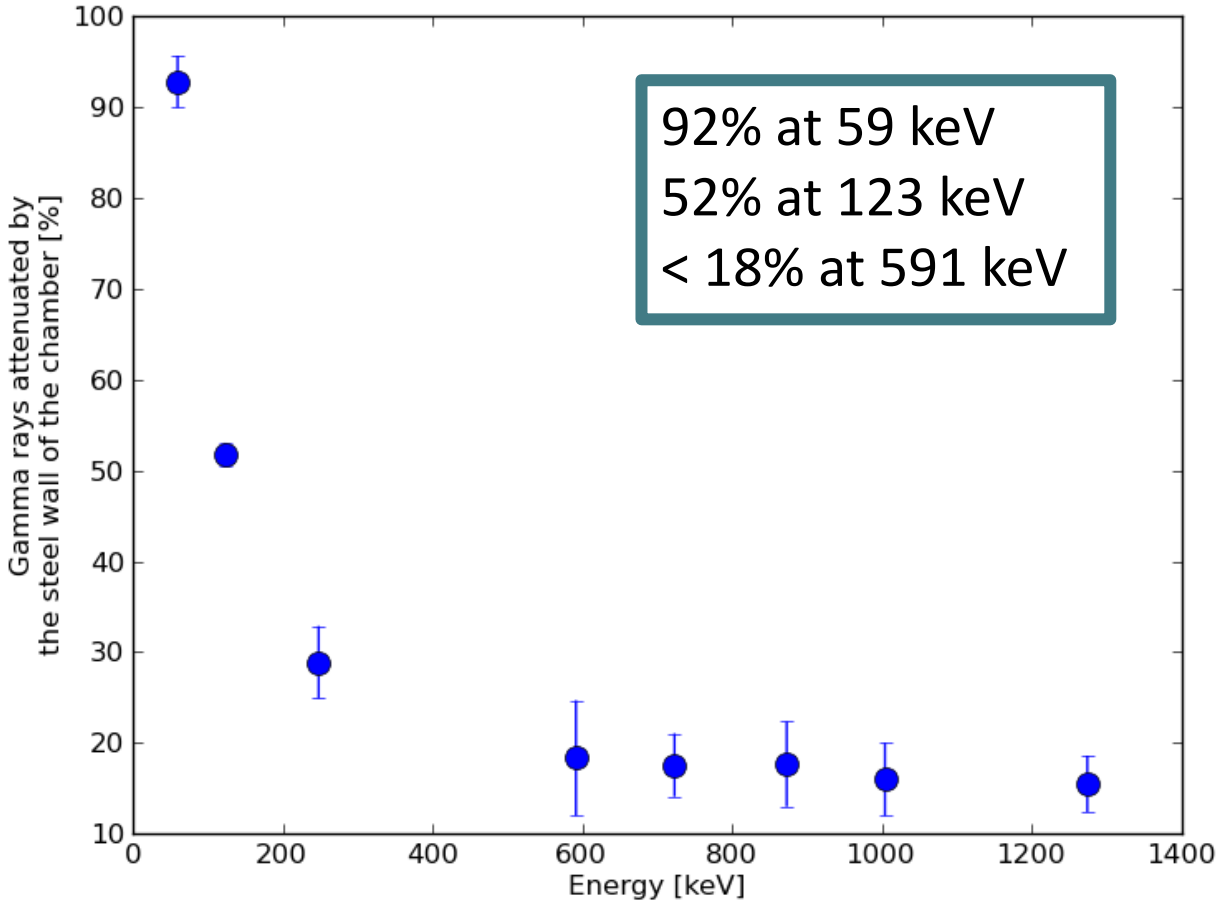
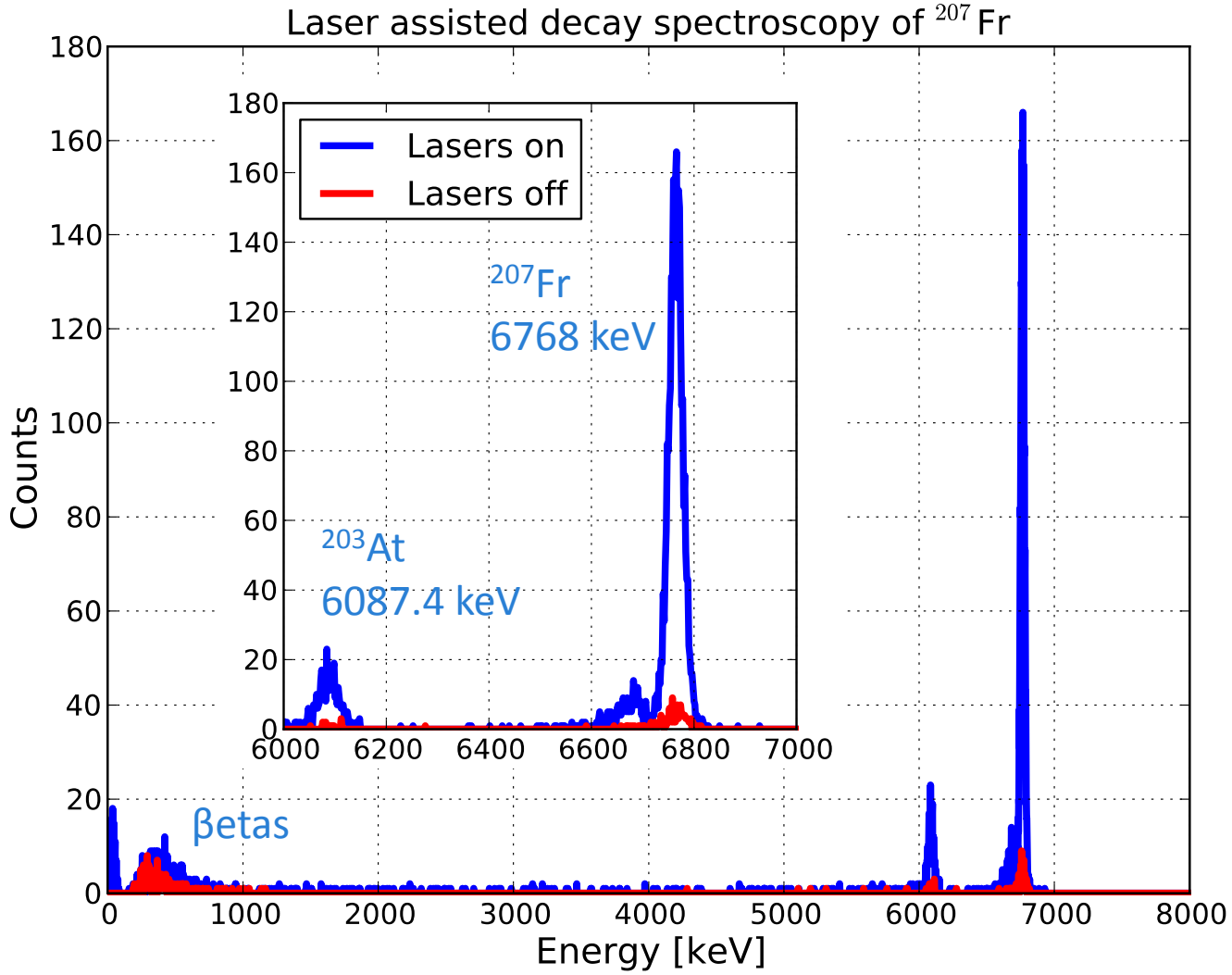
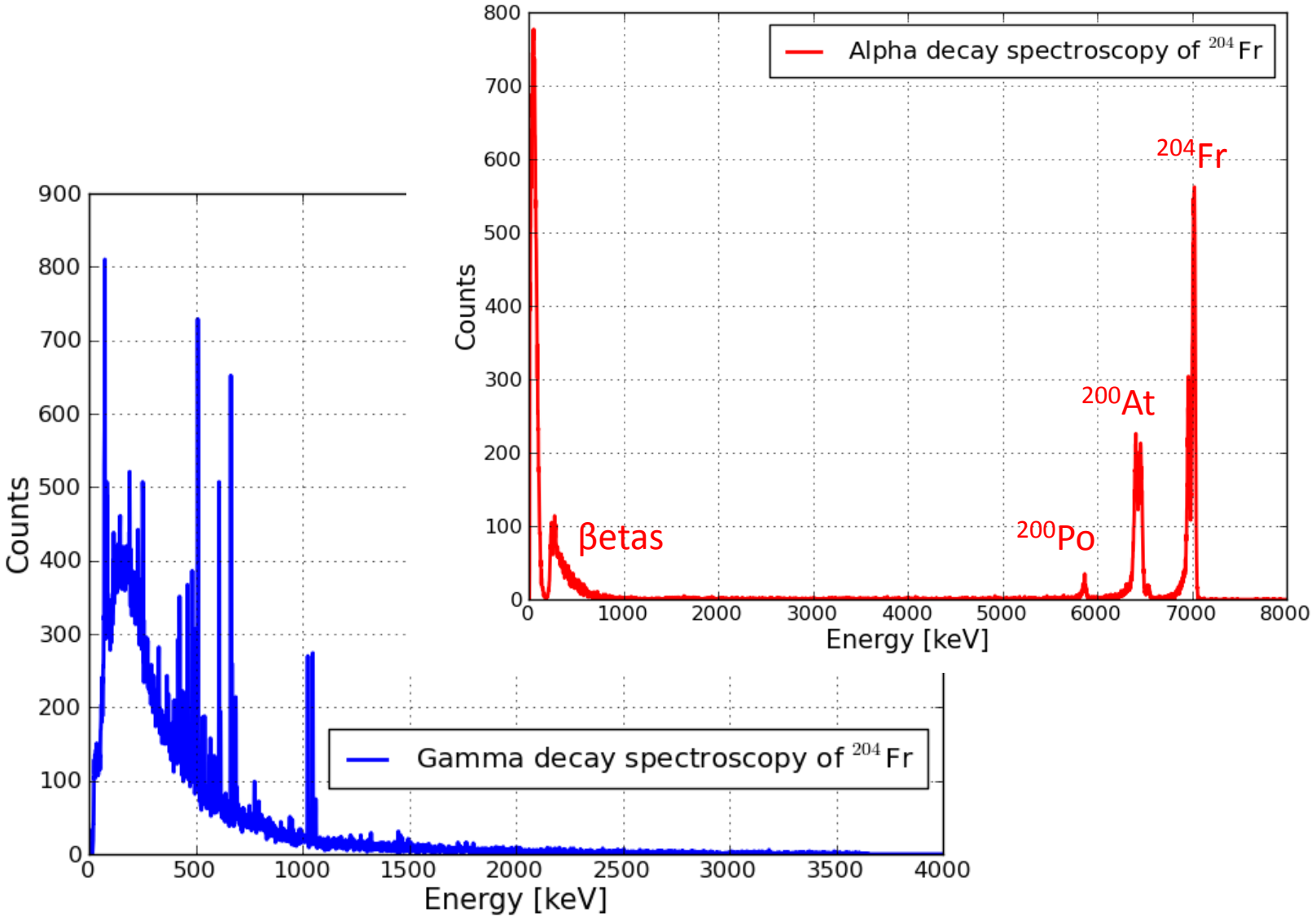


RECENT RESULTS FROM IS471

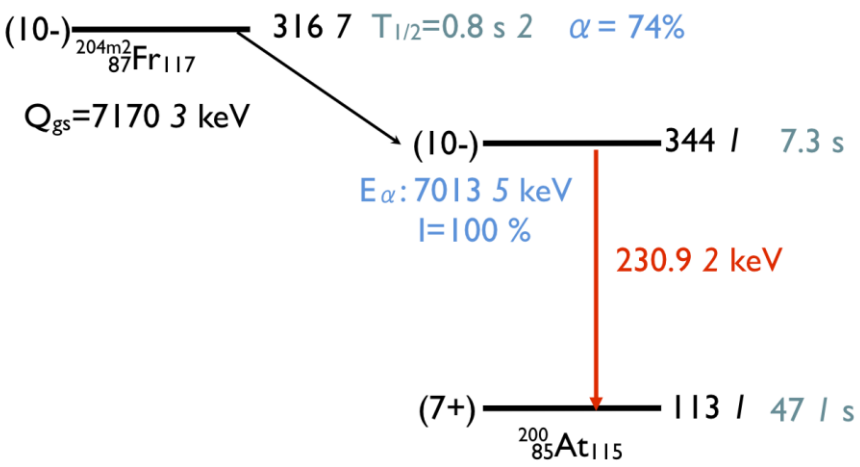
Laser assisted decay spectroscopy of ^{207}Fr



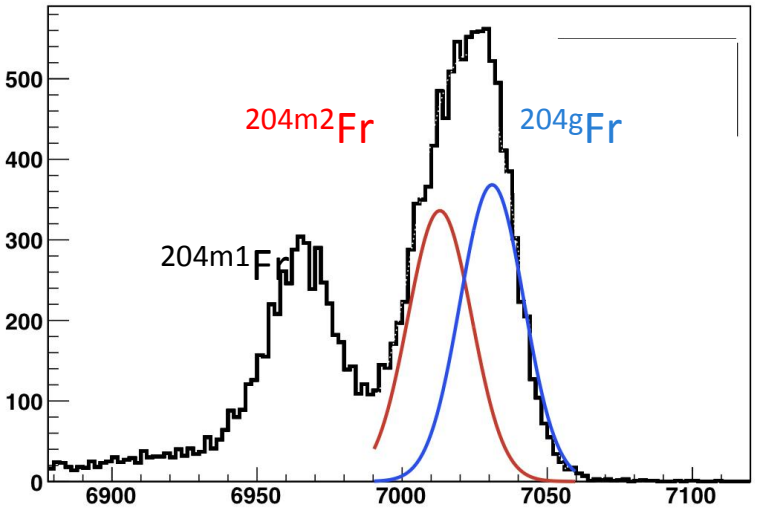
Decay spectroscopy of ^{204}Fr



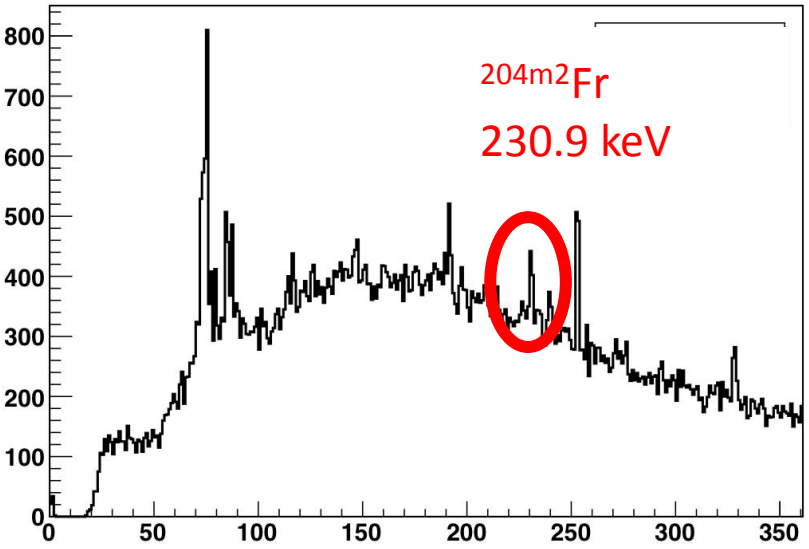
Decay spectroscopy of ^{204}Fr



The alphas emitted from ^{204}Fr



The gammas detected



- Using the characteristic HFS of each isotope, a pure GS or isomeric beam can be studied
- Tuning the lasers on resonance, the blue spectrum would be obtained for ^{204g}Fr and the red spectrum for ^{204m2}Fr

Outlook

- Finalize the data analysis from on line run IS471 in November 2011
- Preparation for laser assisted decay spectroscopy of:
  - the remaining francium isotopes $^{201-206, 218, 219}$Fr
    - the detailed study of the two isomers of ^{202}Fr for β-delayed fission
  - neutron-rich copper isotopes $^{76-78}$Cu
    - search for isomers
    - and understanding their decay

Summary

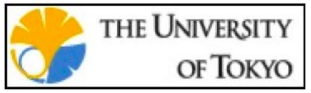
- Use the selectivity of collinear resonant ionization spectroscopy to perform decay spectroscopy on pure isomeric beams e.g. ^{204}Fr
  - Laser spectroscopy provides spin, moments and change in mean square charge radii
  - Decay spectroscopy provides level scheme of the daughter nucleus
- Laser assisted decay spectroscopy has been performed on ^{207}Fr in November 2011
- Future experimental campaigns involve the remaining francium isotopes and copper isotopes

The CRIS Collaboration

J. Billowes, B. Cheal, K.T. Flanagan, T.J. Procter, A. Smith.

M. Bissell, S. De Schepper, K. Dewolf, G. Neyens,
M.M. Rajabali, W. Vanderheijden, P. Vingerhoets

T.E. Cocolios,
K.M. Lynch, B. Marsh



R. Hayano, T. Kobayashi

G. Simpson

S. Rothe, K. Wendt

M. Hori,
H. Aghai Khozani

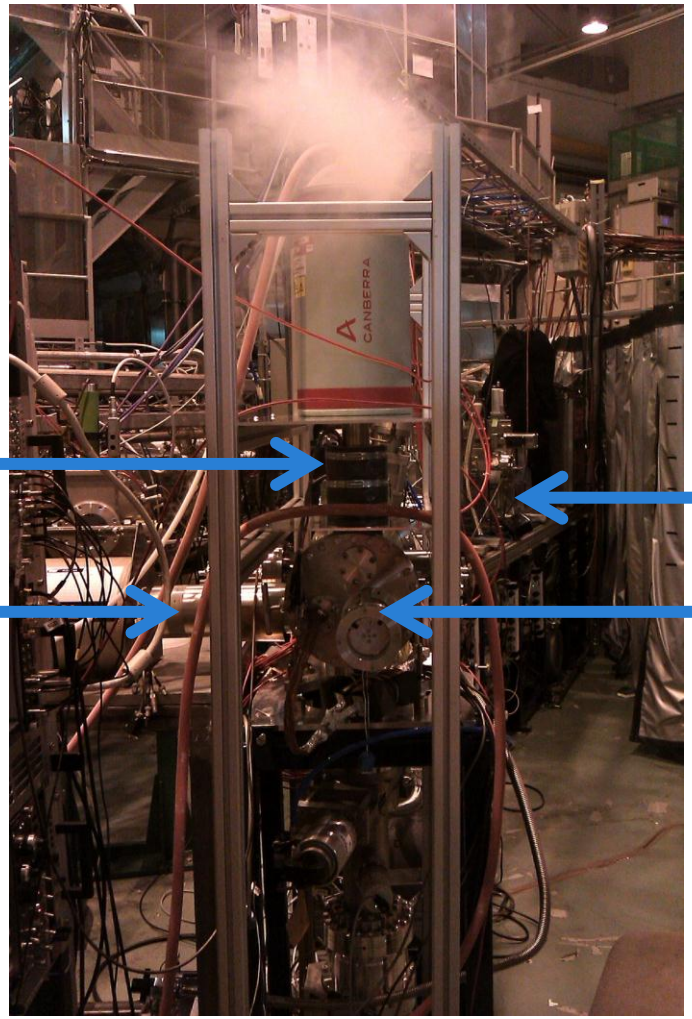
F. Le Blanc

H.H. Stroke

THANKS FOR YOUR ATTENTION

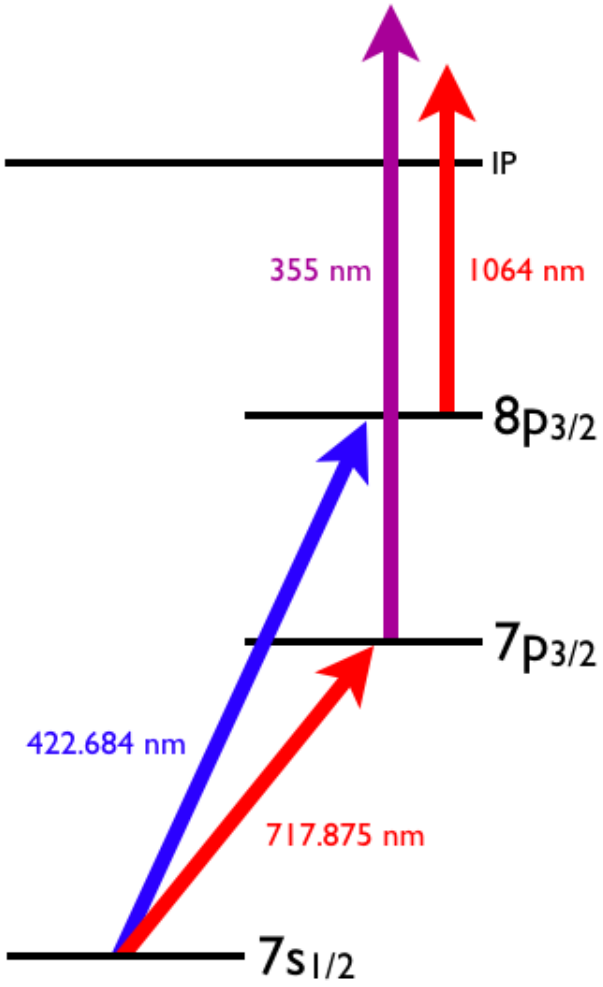
BACK UP SLIDES

The decay spectroscopy station



Ionization of francium

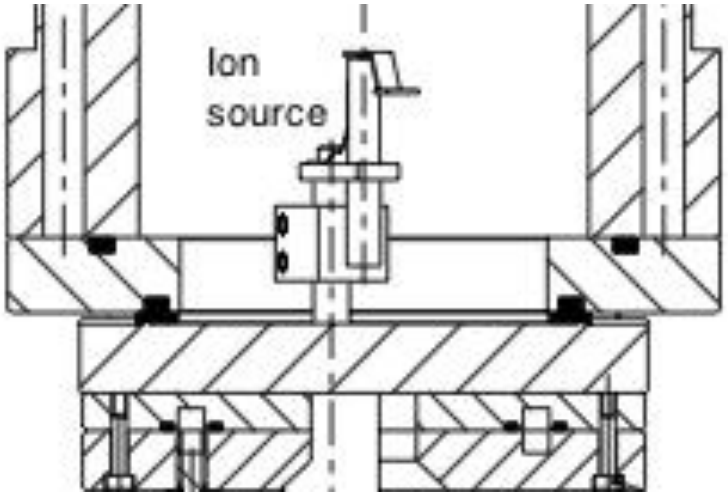
- Beam collinearly overlapped with the two laser beams
  - 422nm
  - 1064nm
- Atoms resonantly ionized when on resonance with the laser
- Pulsed amplified TiSa laser used

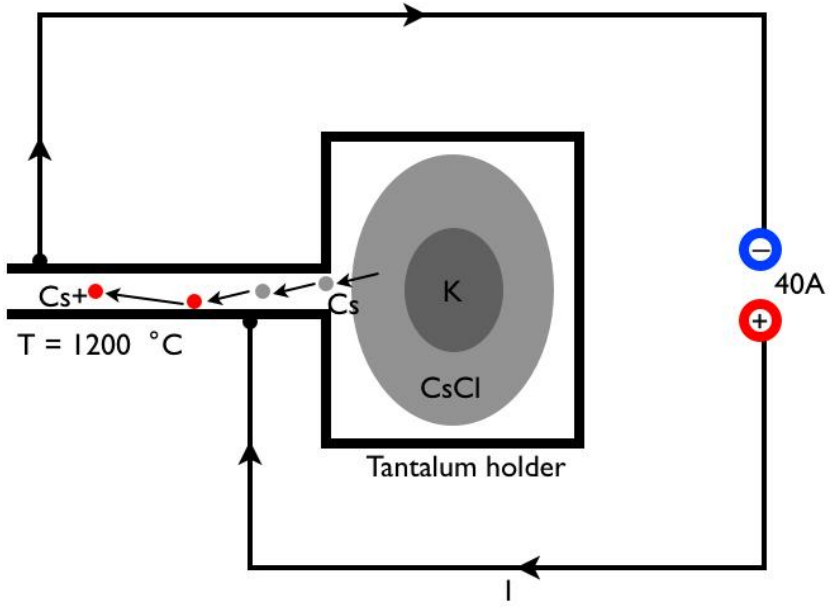


Ionization scheme of francium

The CRIS ion source

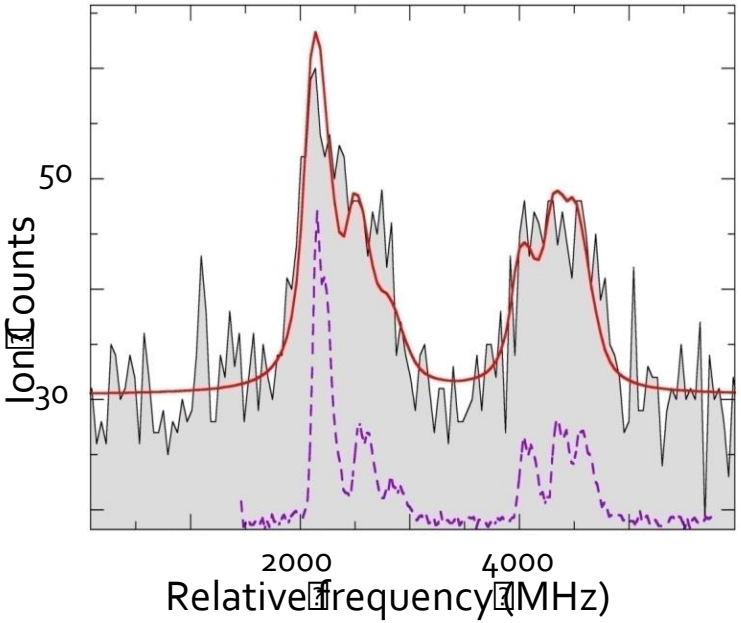
- Off line ion source produces Cs^+ ions
- Einzel lens focuses the ion beam
- 90° bend deflects the ion down the beam line





Ion detection vs. fluorescence detection

- Higher energy resolution with fluorescence detection
  - high powered pulsed laser causes power broadening
- Ion detection is a factor of 10^3 more efficient than fluorescence detection
  - sacrifice resolution for the ability to detect rare isotopes



Ion detection
Fitted spectrum
Fluorescence detection

200 ions per bunch
6 scans
1:30 efficiency