UPPSALA UNIVERSITET

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

Fission yield measurements at IGISOL

Andreas Solders

Outline

Motivation

The ion guide technique

Preliminary results & Outlook

UPPSALA UNIVERSITET

Motivation

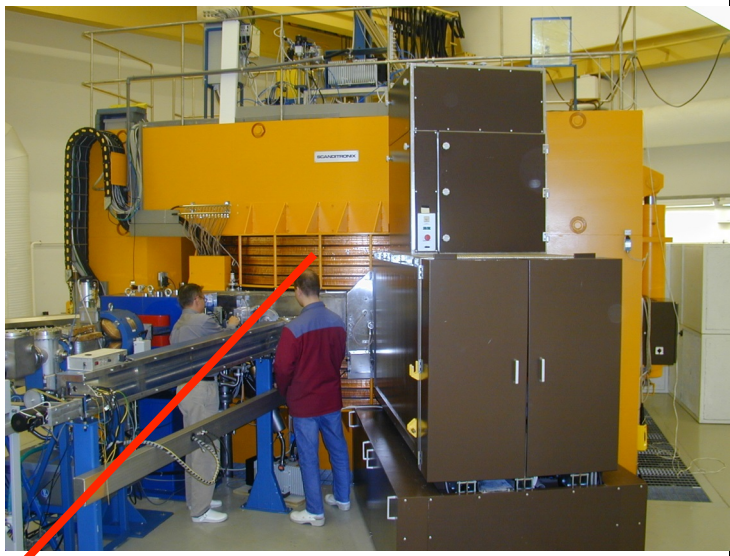
- Reactor applications
  - High quality data on independent fission yields
    - will **decrease the uncertainty** about (spent) fuel composition
    - are relevant for **safety** measures
    - provide information on **core poisoning**
    - improve **burn-up** predictions
- Nuclear theory
  - Nuclear structure models
  - Fission models
- Supernova nucleosynthesis
  - The r-process is believed to be terminated by fission of very neutron rich systems
  - Simulations of this process require accurately known fission yields.

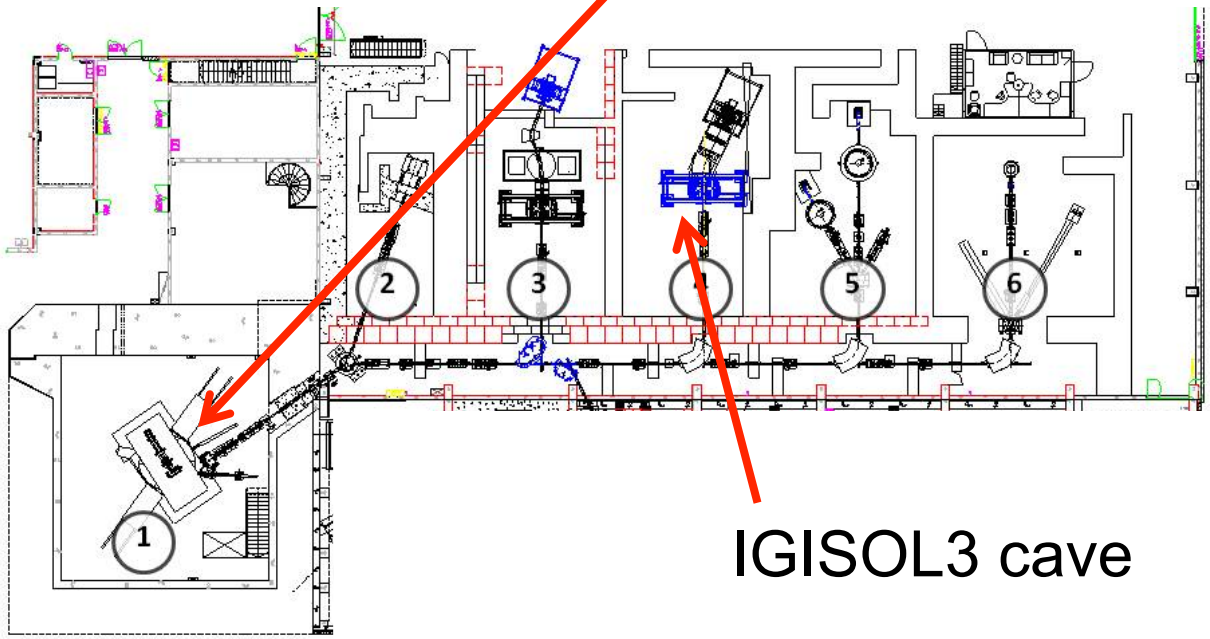
UPPSALA UNIVERSITET

JYFL 2010

Cyclotron K-130

Heavy ion accelerator
Up to 130 MeV





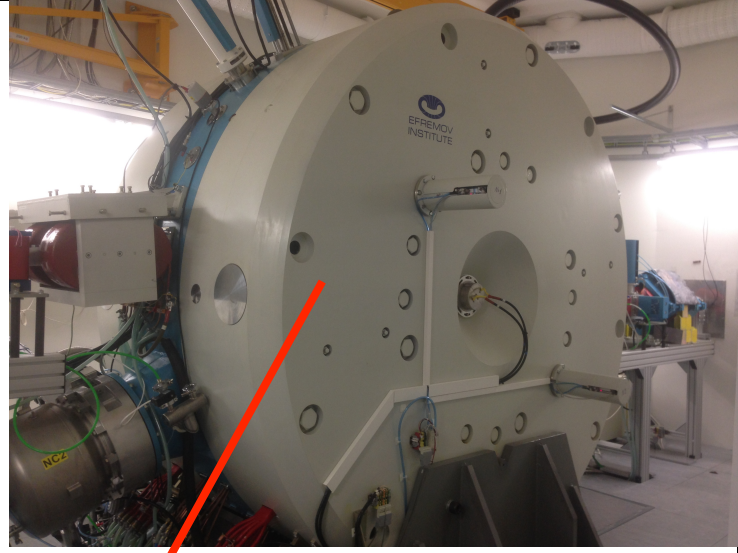
IGISOL3 cave

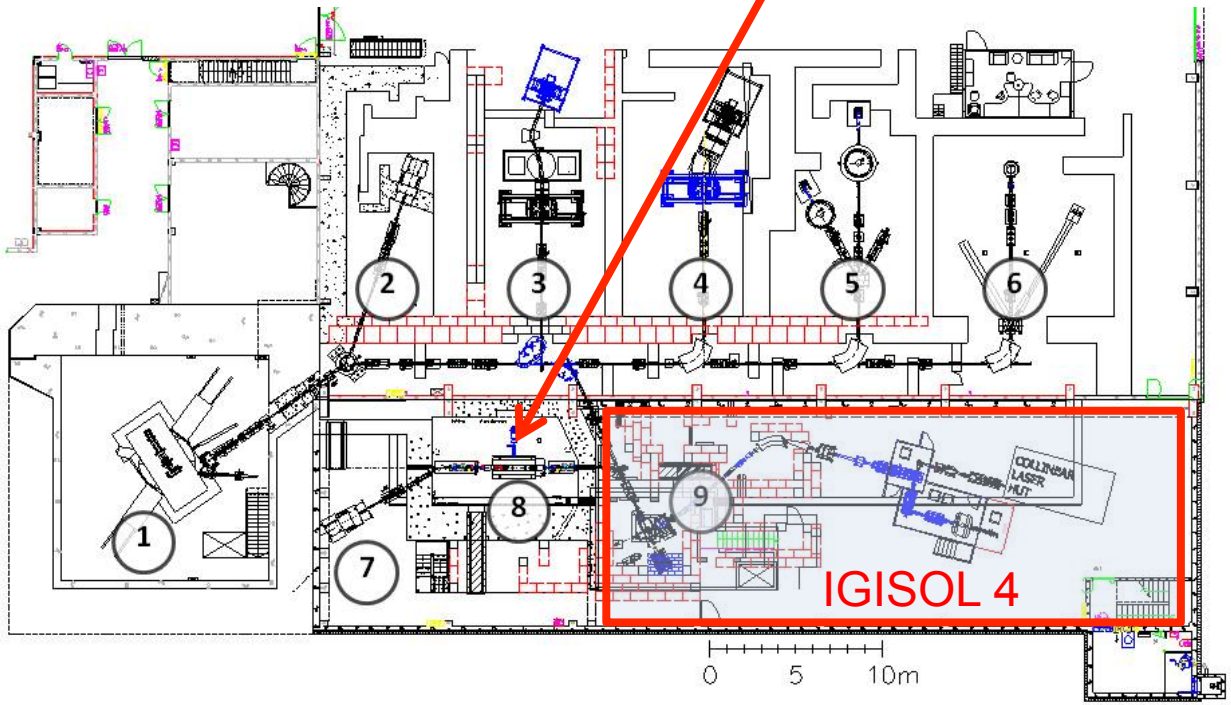
UPPSALA UNIVERSITET

JYFL 2014

Cyclotron MCC30/15

Protons and deutrons
Up to 30 MeV and 200 uA



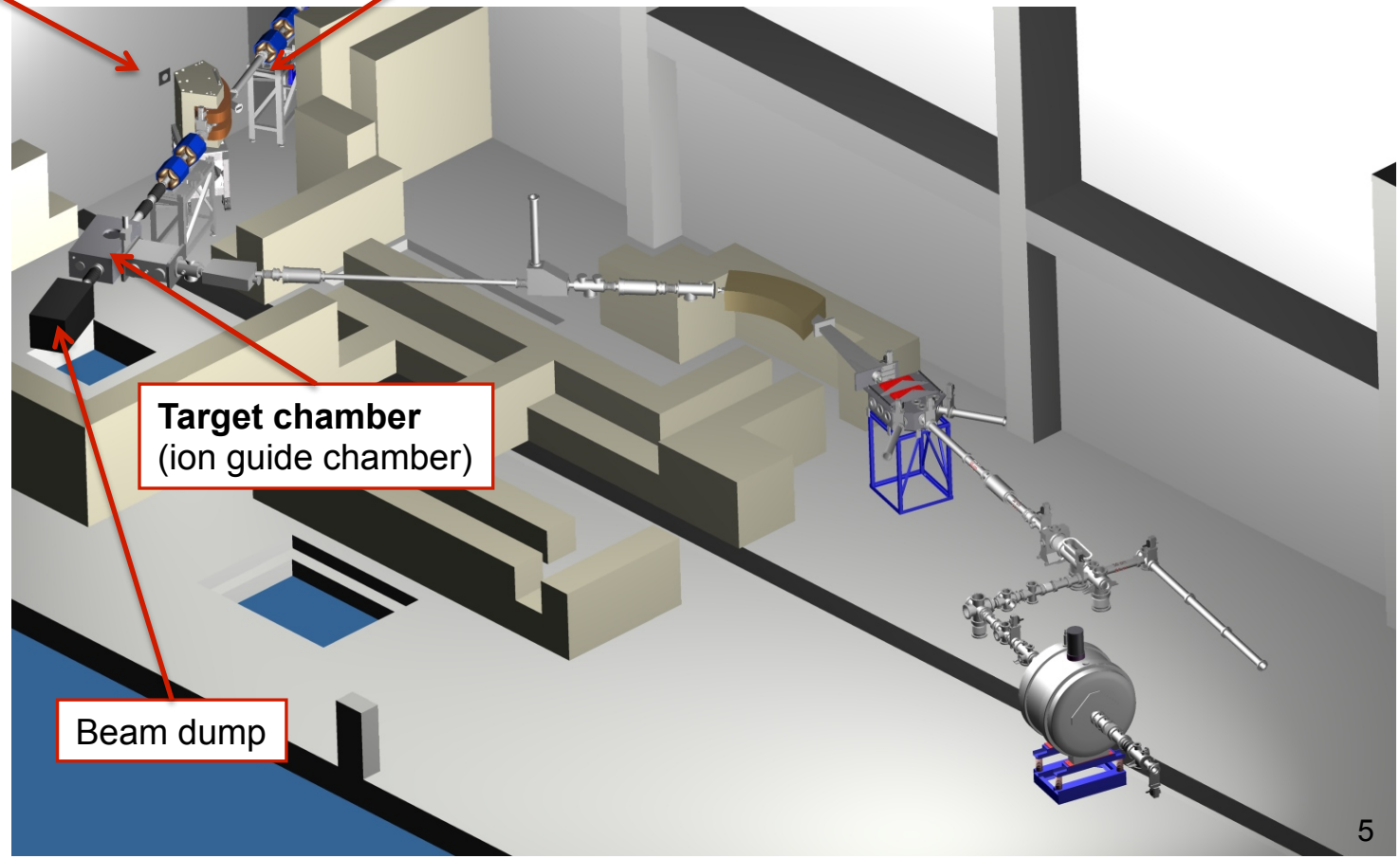


UPPSALA UNIVERSITET

Ion Guide Isotope Separator On Line 4 (IGISOL 4)

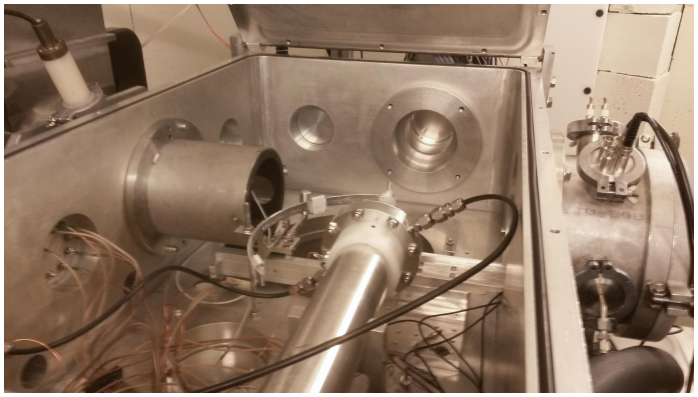
MCC30/15 Cyclotron
p: 18 – 30 MeV @ 100 μA
D: 9 – 15 MeV @ 50 μA

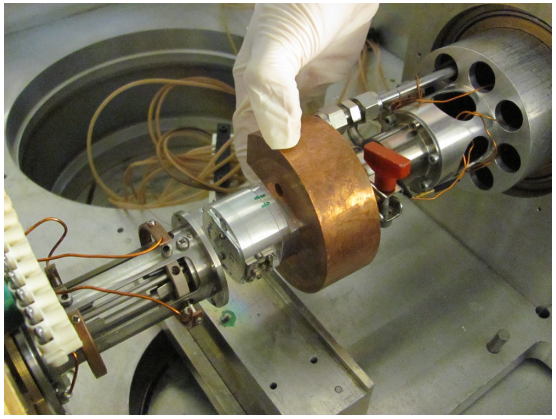
K130 Cyclotron
Heavy ions up to 130 MeV



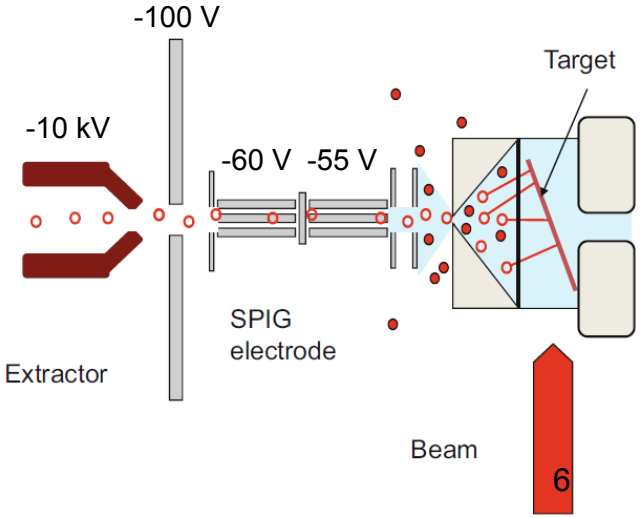
UPPSALA UNIVERSITET

Target chamber and ion guide





- **Helium gas jet**
  - Stops fragments
  - Fragments recombine to singly charged ions
  - Guides fragments to the SPIG
  - Timescale in ms
- **SPIG**
  - Sextupole ion guide
  - Centers products on axis
  - Accelerates by static potentials
- **Extractor**
  - Accelerates products in steps to up 30 kV

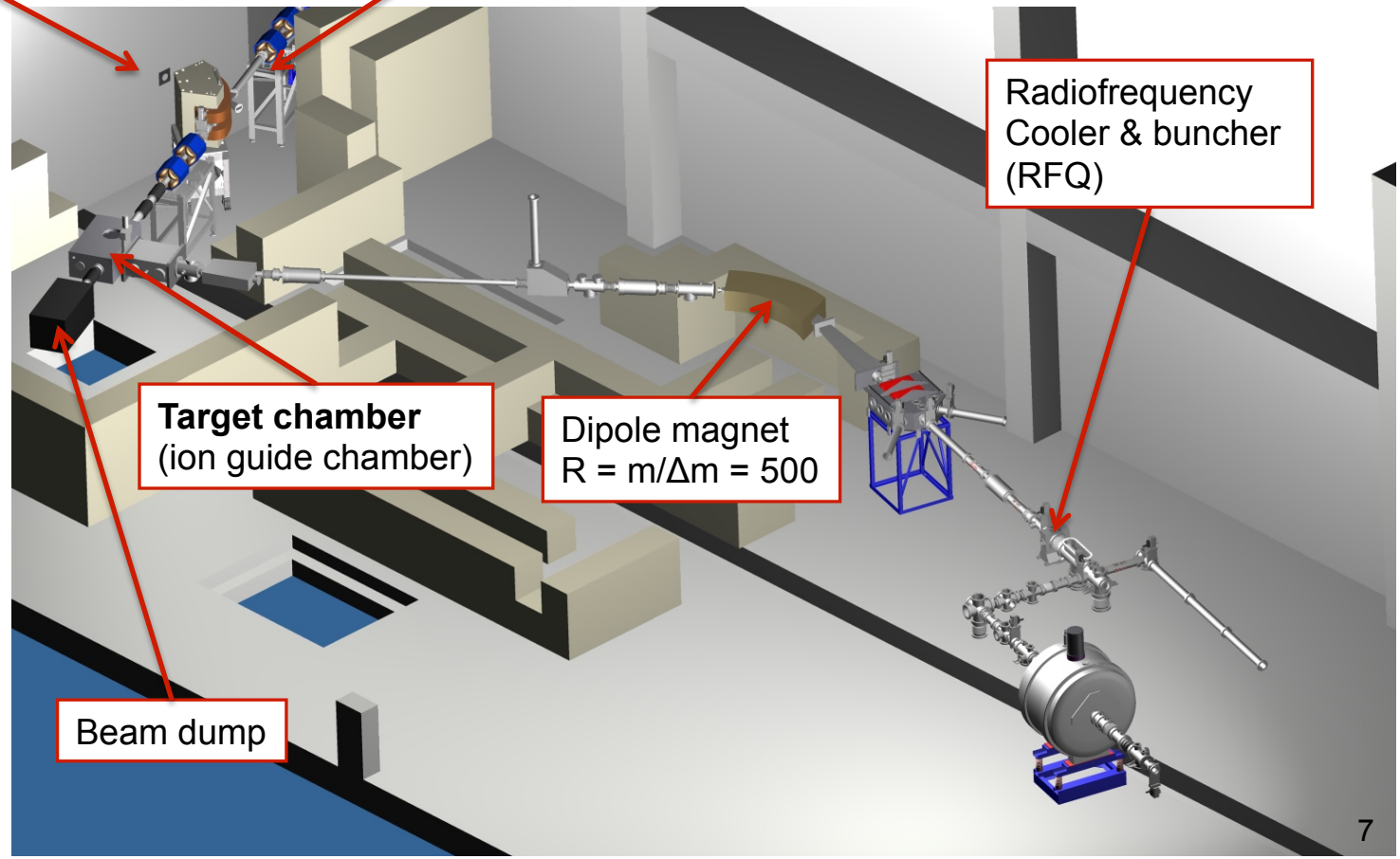


UPPSALA UNIVERSITET

Ion Guide Isotope Separator On Line 4 (IGISOL 4)

MCC30/15 Cyclotron
p: 18 – 30 MeV @ 100 μA
D: 9 – 15 MeV @ 50 μA

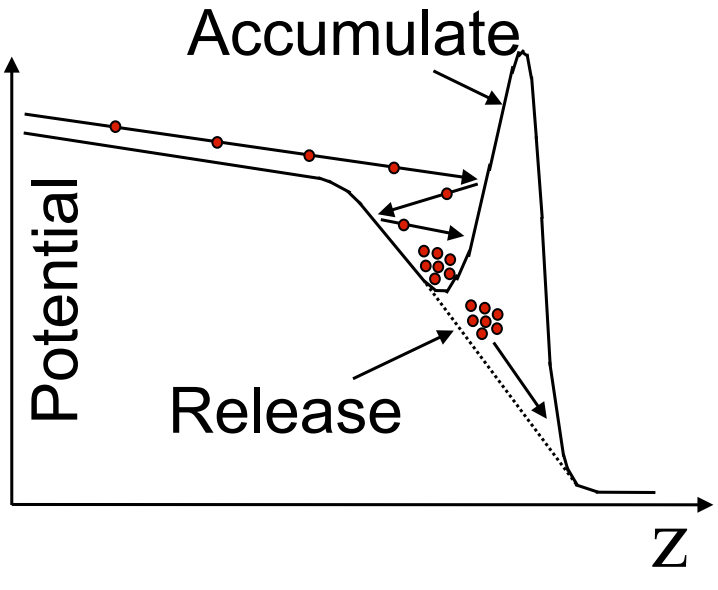
K130 Cyclotron
Heavy ions up to 130 MeV

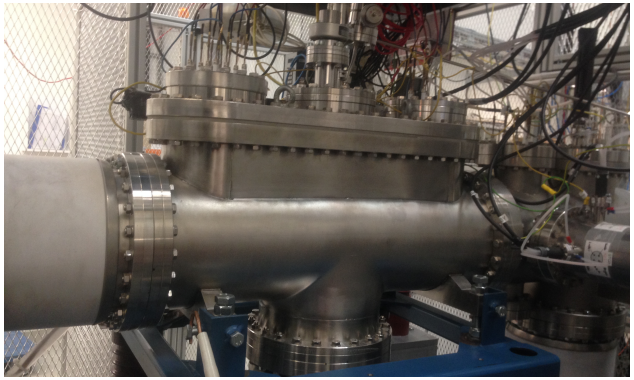


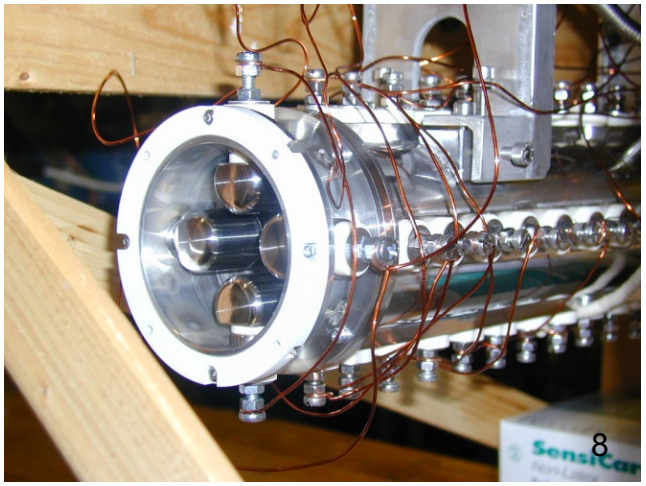
UPPSALA UNIVERSITET

RFQ cooler and buncher

- Radial confinement by high frequency quadrupole field
- Axial confinement by static electric potentials
- Gas filled
  - Energy loss in ion-atom collisions
- Cooler and buncher
  - Accumulate for ~100ms
  - Bunch length < 15 ms
  - Thousands of ions per bunch
  - Energy spread < 1 eV



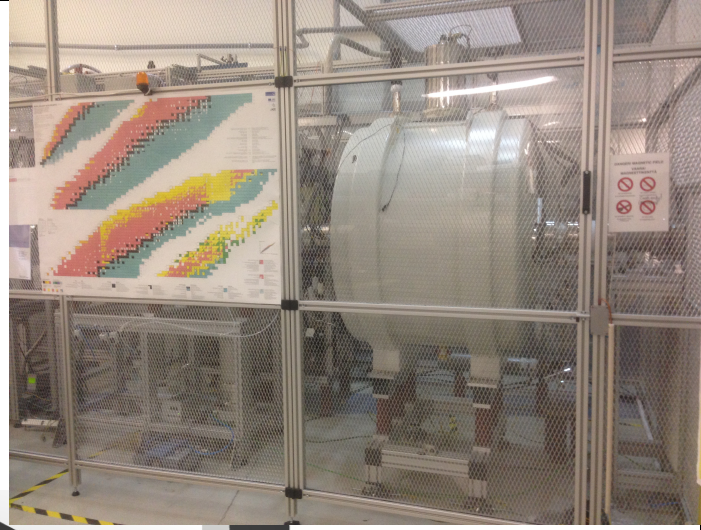


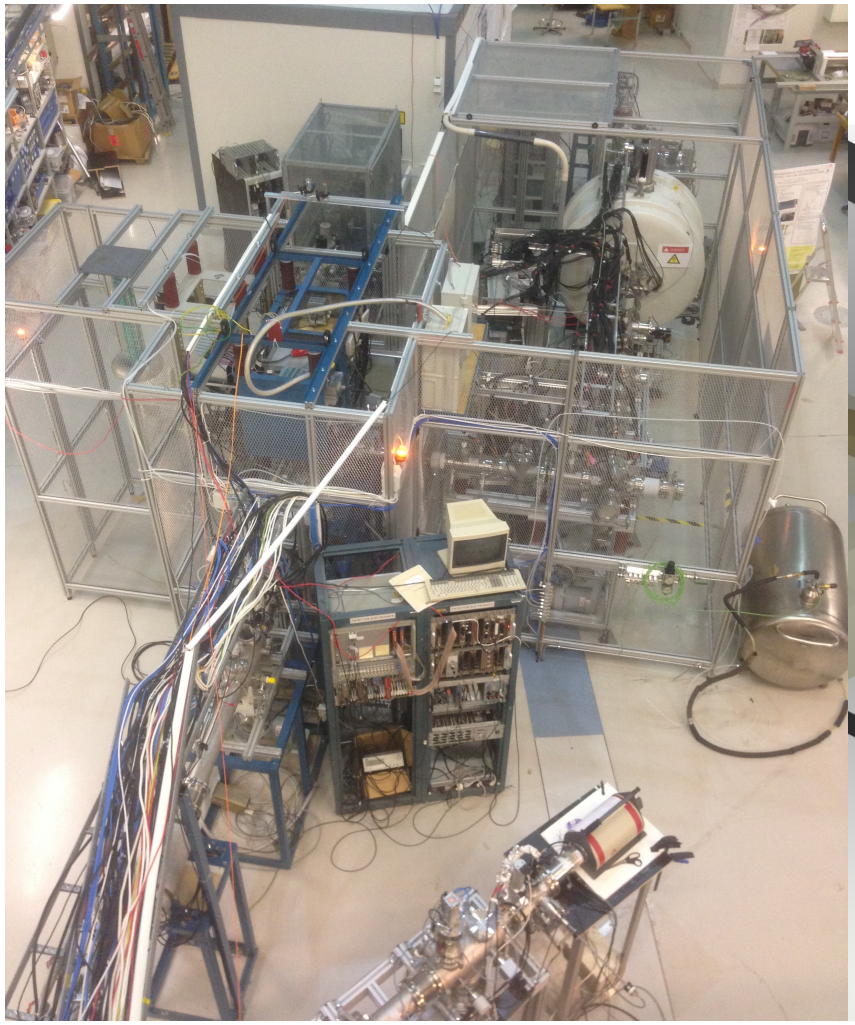


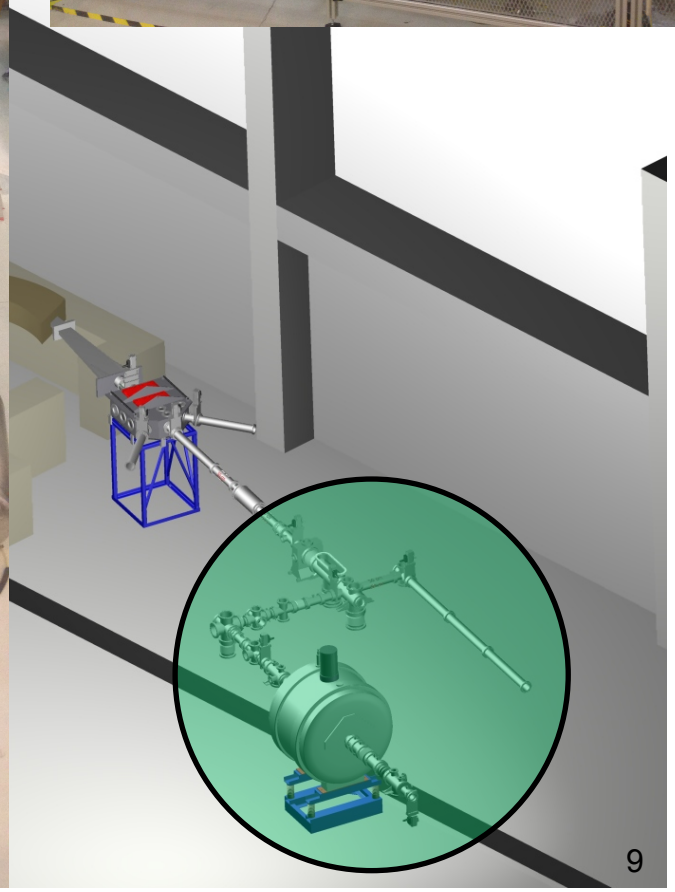
UPPSALA UNIVERSITET

JYFLTRAP

7 T superconducting magnet



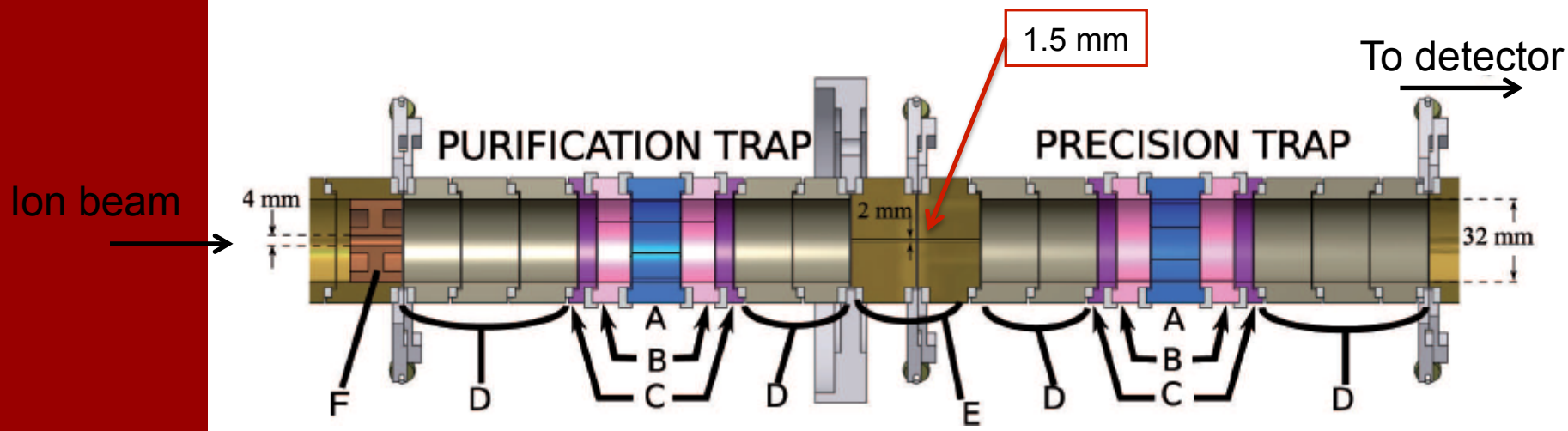


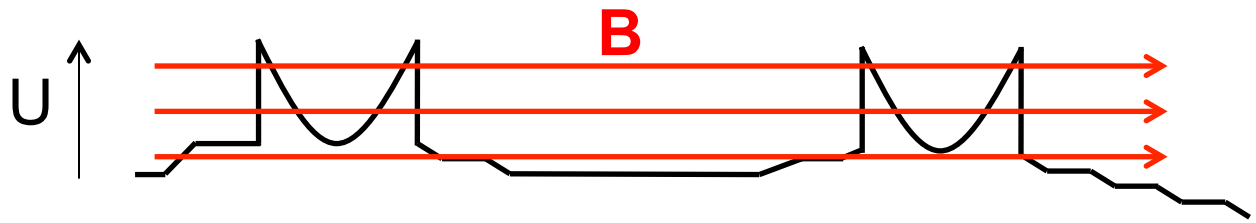


UPPSALA UNIVERSITET

JYFLTRAP

Double cylindrical trap

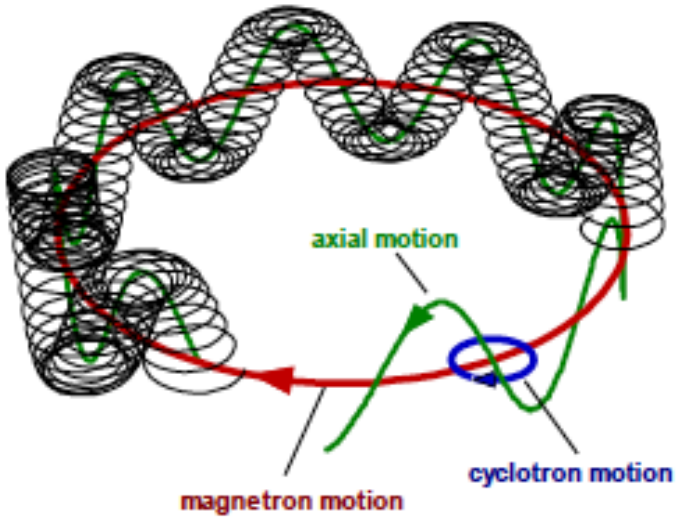




UPPSALA UNIVERSITET

Motions in the trap

- Axial motion:
  - oscillation in electrostatic potential
  - $\nu_z = 2\pi\sqrt{\frac{2qV}{md^2}} \approx 100\ kHz$
- Magnetron motion:
  - E x B drift
  - Mass independent
  - $\nu_- = \frac{1}{2}\left(\nu_c - \sqrt{\nu_c^2 - \nu_z^2}\right) \approx 1\ kHz$
- Reduced cyclotron motion:
  - Oscillation in B-field
  - Perturbed by electric field
  - Mass dependent
  - $\nu_+ = \frac{1}{2}\left(\nu_c + \sqrt{\nu_c^2 - \nu_z^2}\right) \approx 1\ MHz$

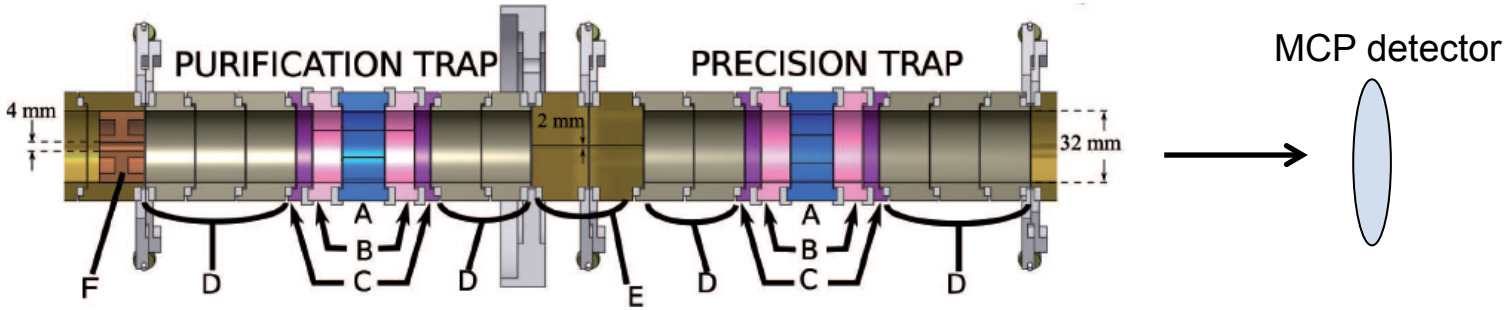


$$\nu_c \approx \nu_s = \nu_+ + \nu_-$$

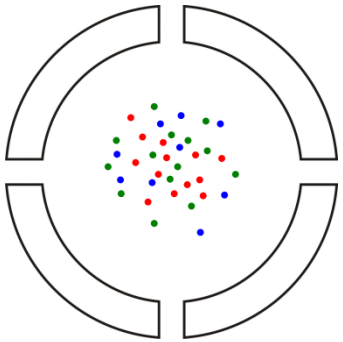
UPPSALA UNIVERSITET

JYFLTRAP

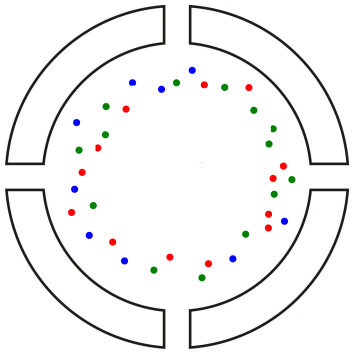
Dipole magnetron excitation

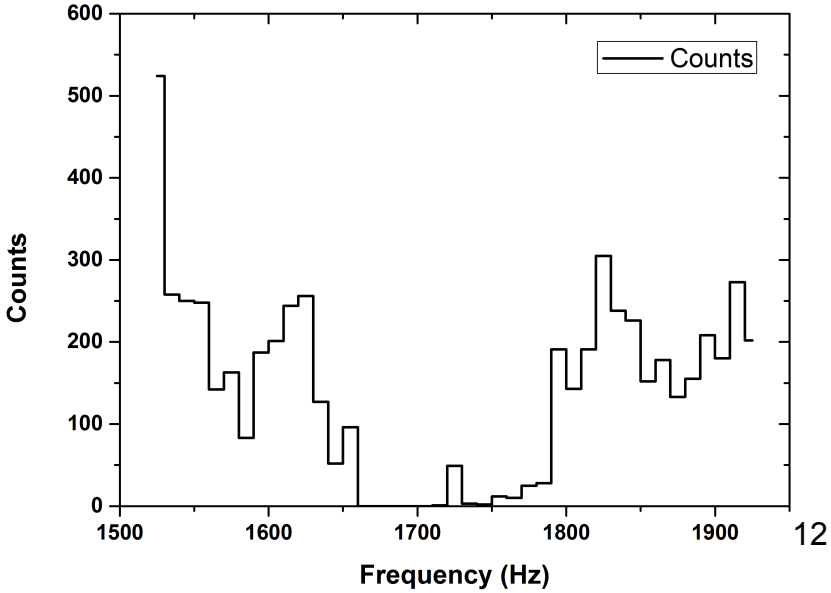


Before:



After:

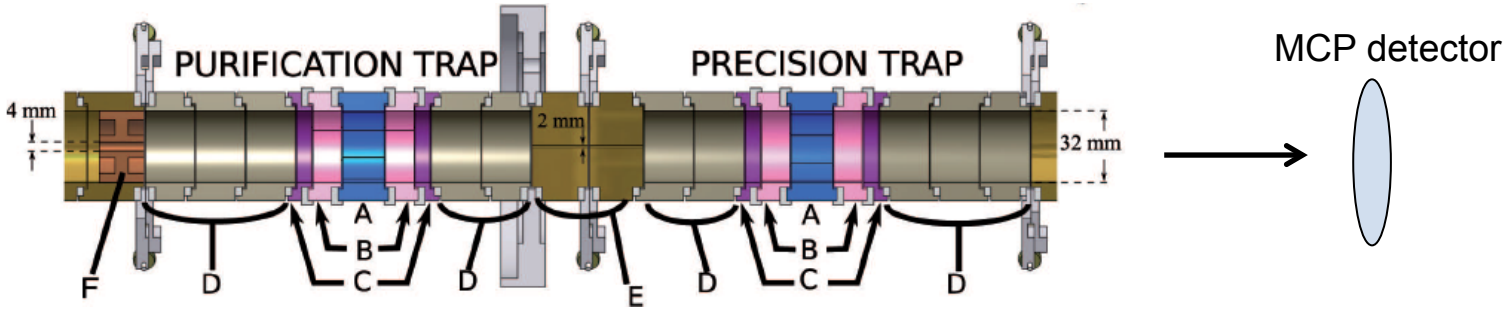




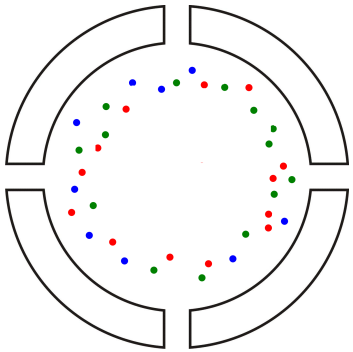
UPPSALA UNIVERSITET

JYFLTRAP

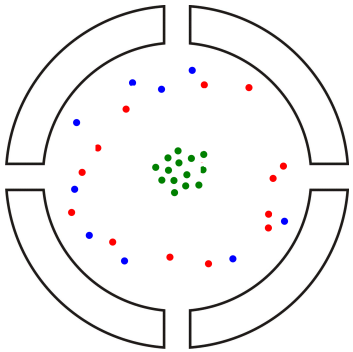
Mass sensitive re-centering with quadrupole excitation

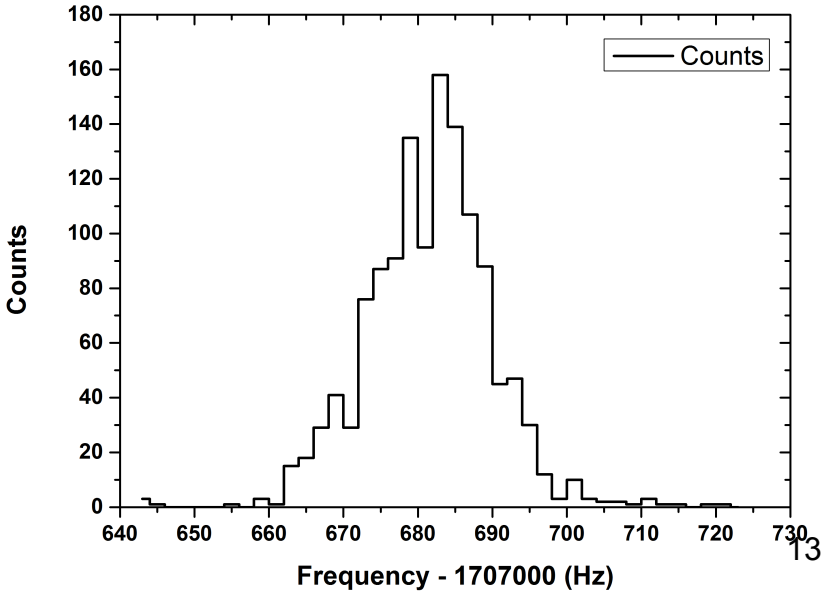


Before:



After:

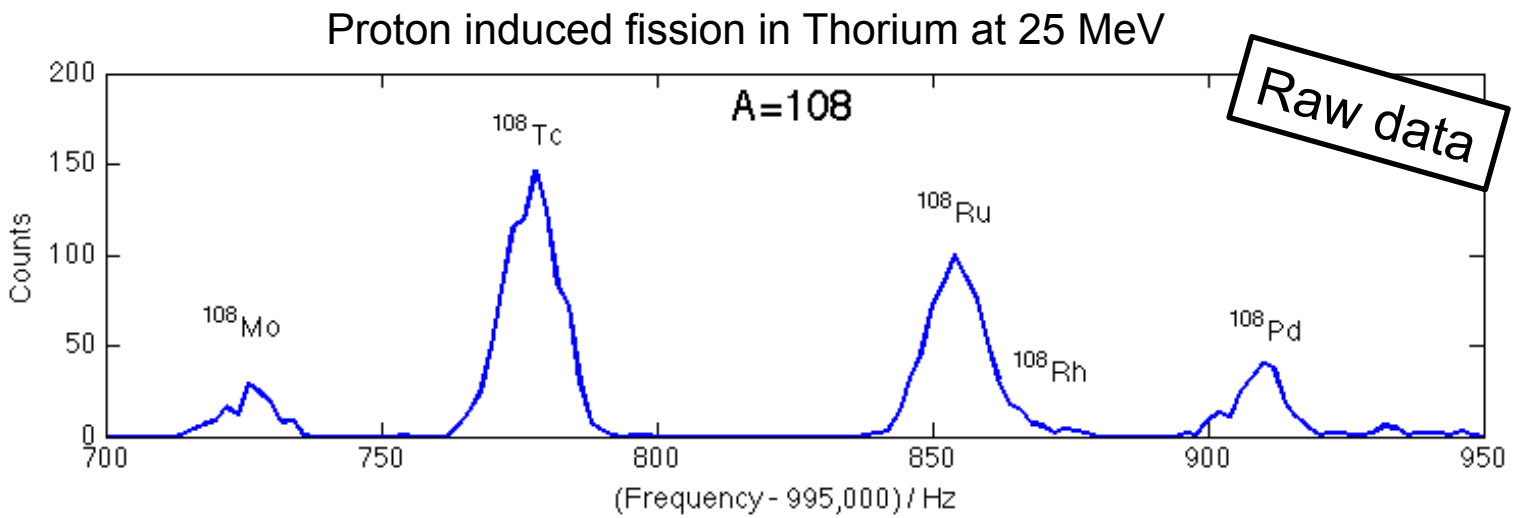




UPPSALA UNIVERSITET

JYFLTRAP

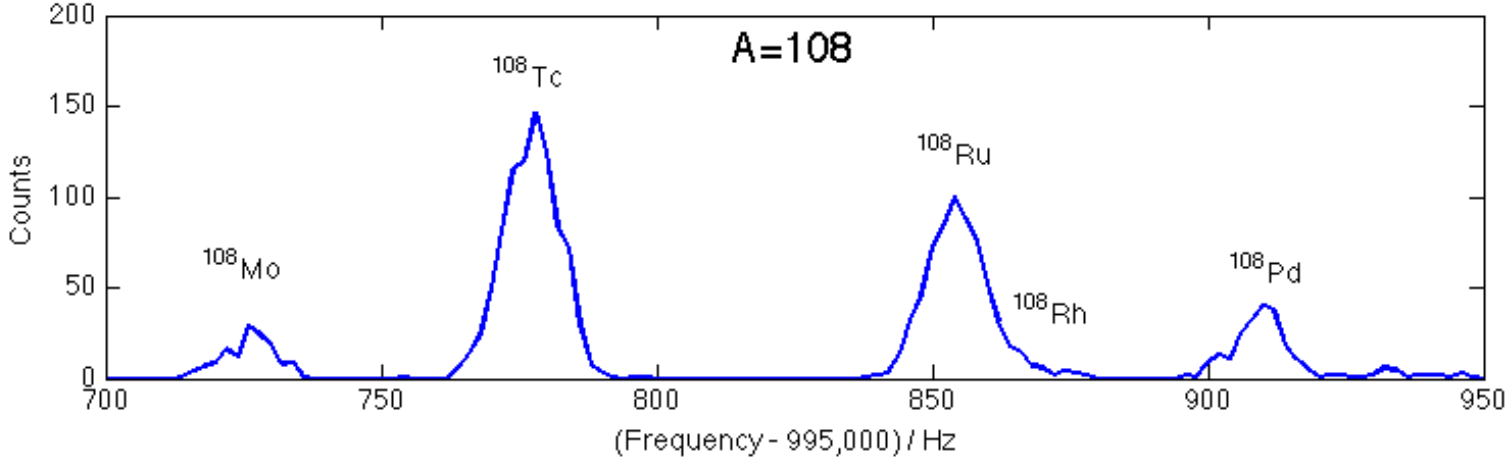
Mass scan

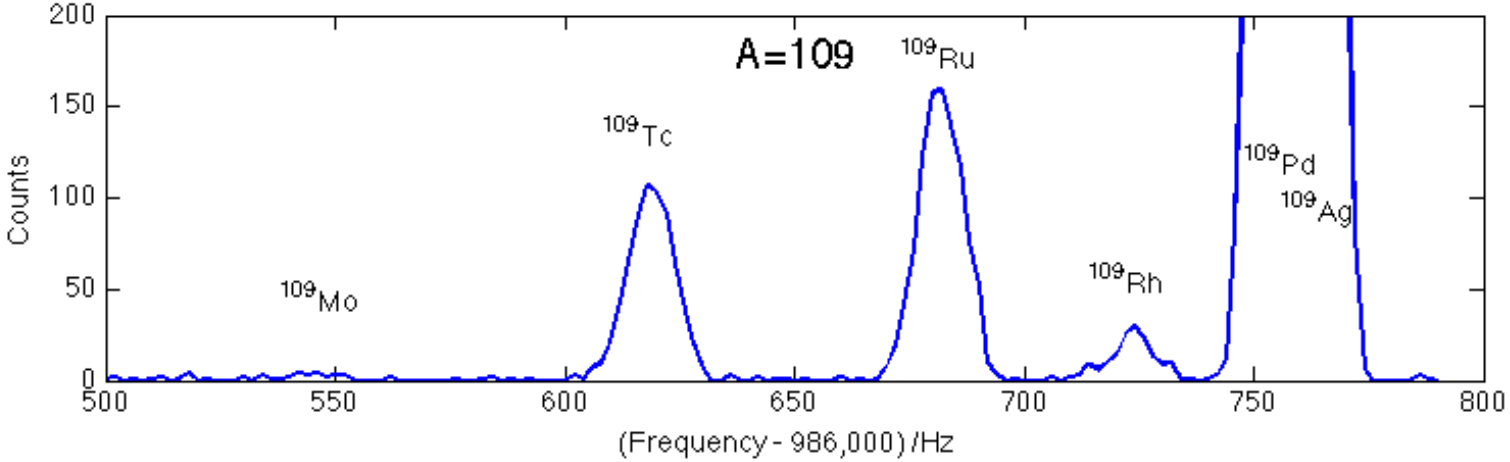


UPPSALA UNIVERSITET

JYFLTRAP

Mass scan

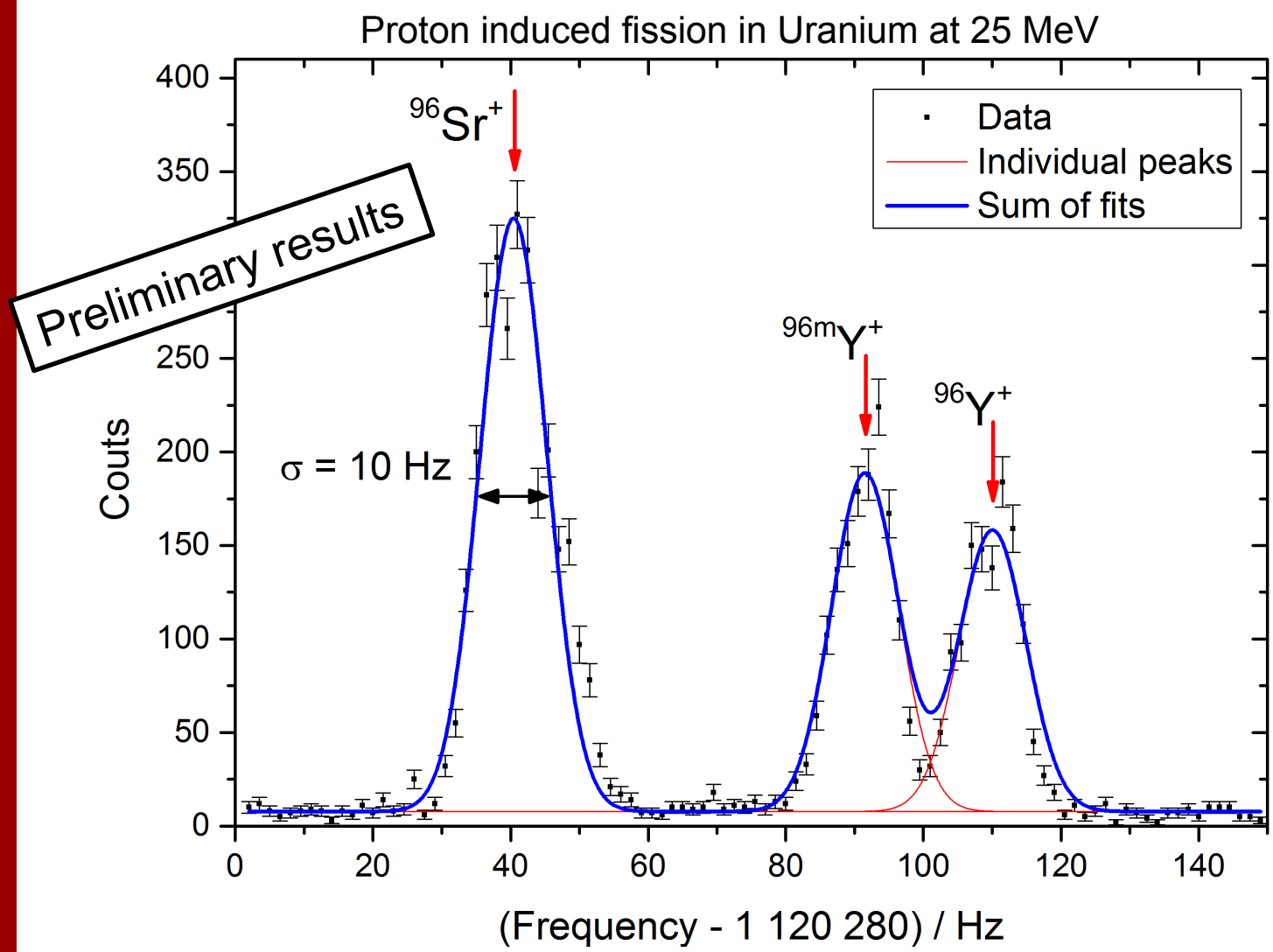




UPPSALA UNIVERSITET

JYFLTRAP

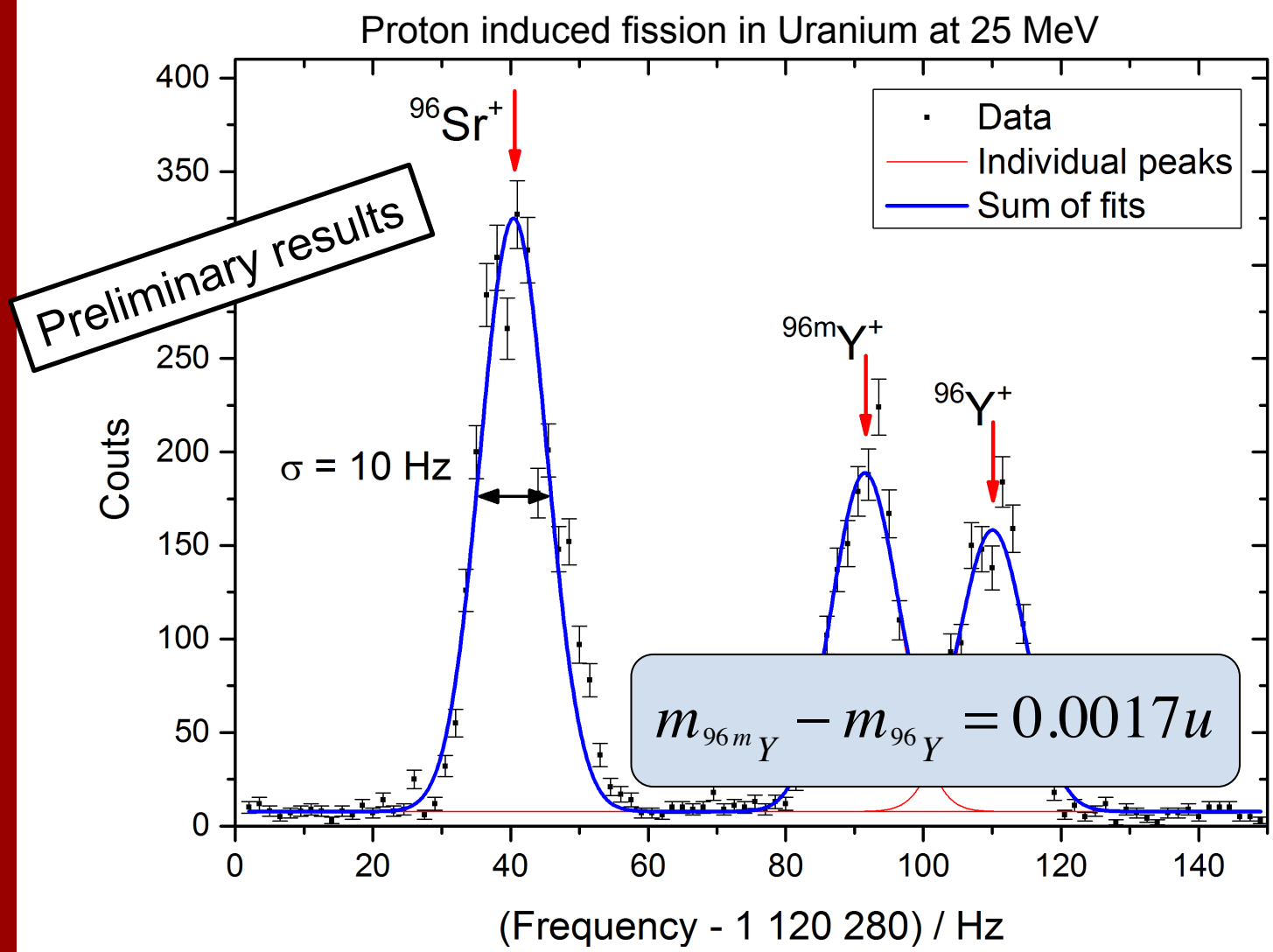
Isomeric yield ratios



UPPSALA UNIVERSITET

JYFLTRAP

Separation of isomers



UPPSALA UNIVERSITET

Preliminary results

Isomeric yield ratios of proton induced fission

		^{81}Ge	^{96}Y	^{97}Y	^{97}Nb	^{128}Sn	^{130}Sn
p+Th (25 MeV)	2010	0.07(1)	1.45(6)	2.58(28)			
	2014	0.07(2)	1.51(9)	2.81(18)		0.82(8)	0.63(18)
p+^{nat}U (25 MeV)	2013 (jun)	0.06(5)	1.09(11)				0.39(27)
	2013 (aug)	0.09(5)	1.25(22)	1.85(23)	0.20(60)		
	2014	0.58(27)				0.90(12)	0.66(38)

Courtesy of Dmity Gorlev

UPPSALA UNIVERSITET

Current projects and future plans

- New measurement with TFBCs
  - Characterization of neutron field
  - TFBCs as online neutron monitors?
- Development of a ion guide for neutron induced fission
- Independent yield measurements of neutron induced fission in ^{238}U, ^{232}Th, ^{235}U, …

A. Al-Adili, M. Lantz, A. Mattera,
S. Pomp, A.V. Prokofiev, V. Rakopoulos,
A. Solders

UPPSALA UNIVERSITET

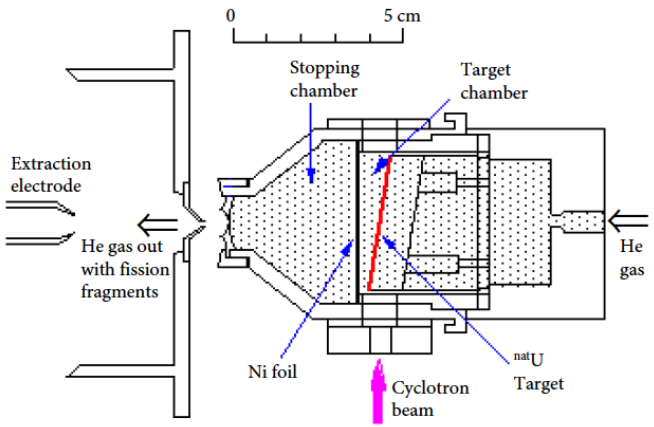
D. Gorelov, H. Penttilä,
S. Rinta-Antila & the
IGISOL team

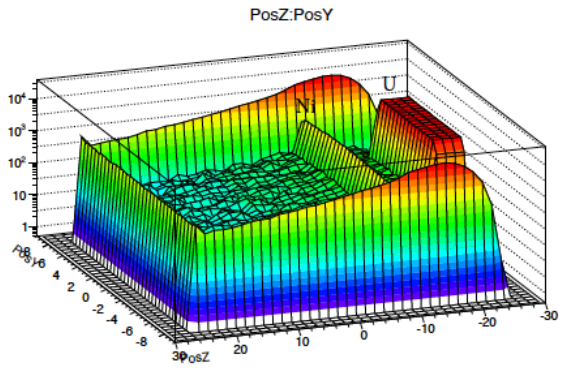
JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

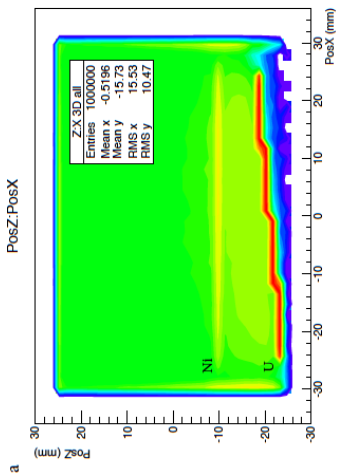
UPPSALA
UNIVERSITET

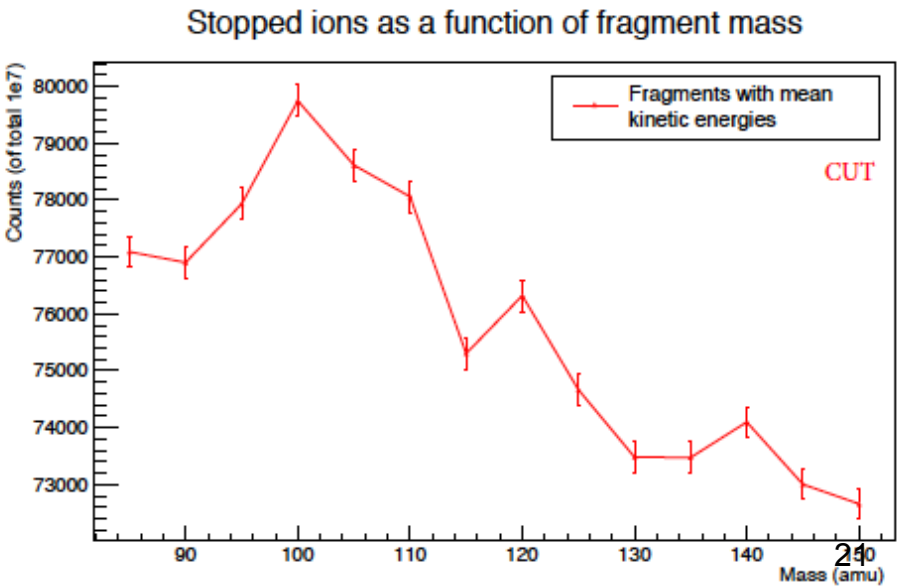
EXTRA

UPPSALA UNIVERSITET

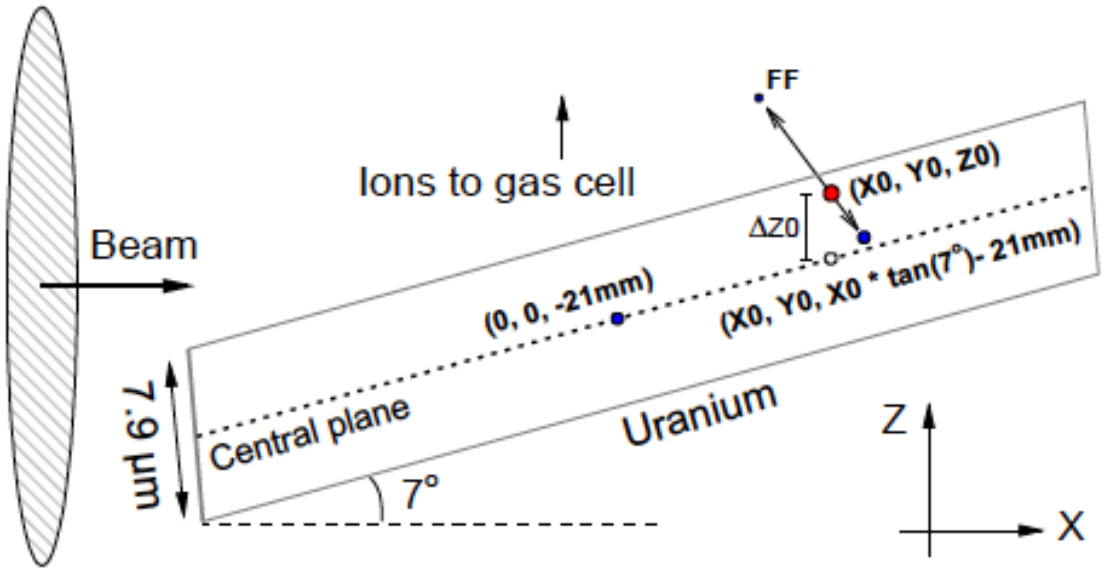


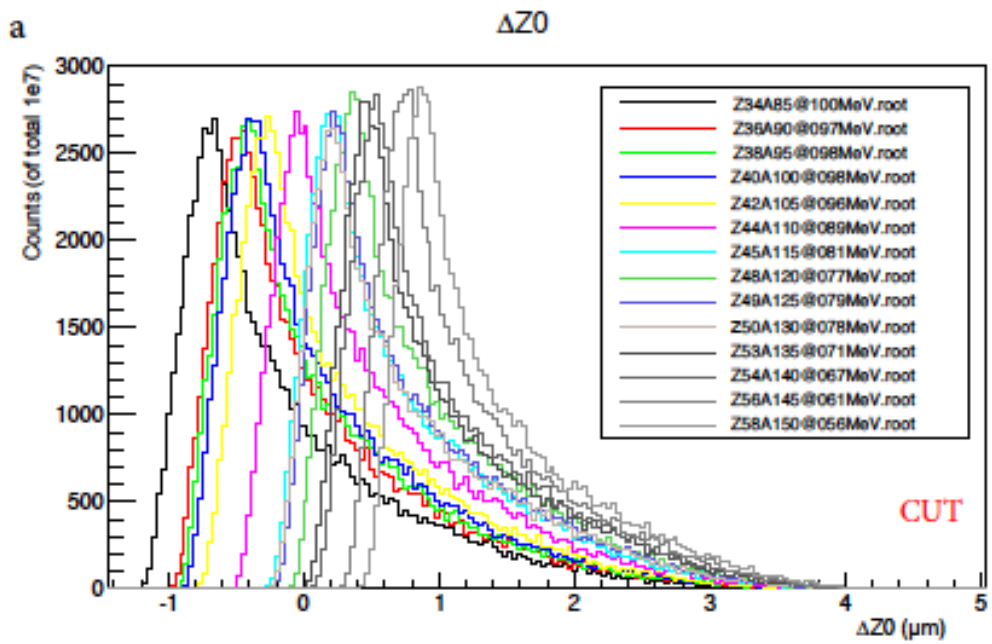






UPPSALA UNIVERSITET

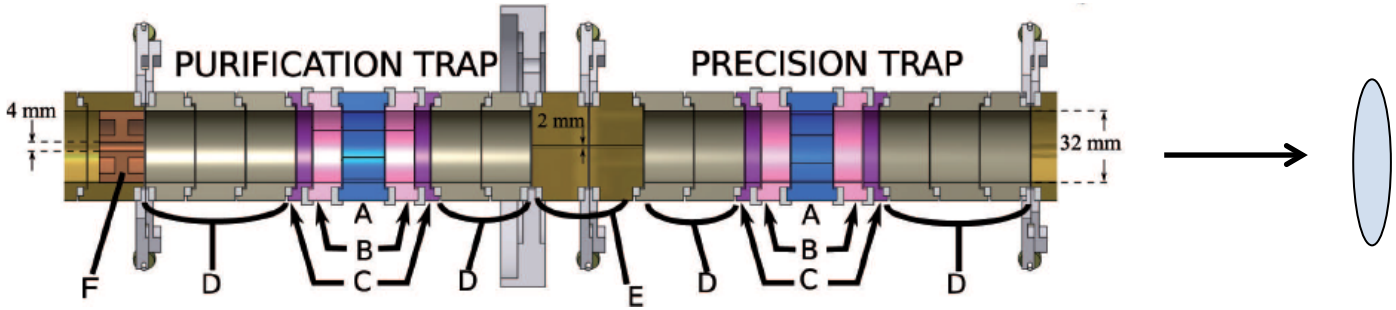


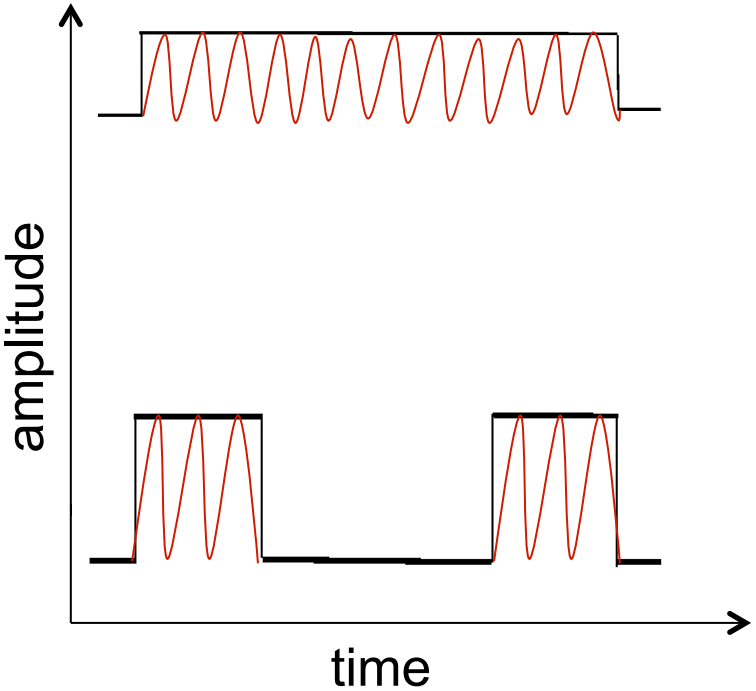


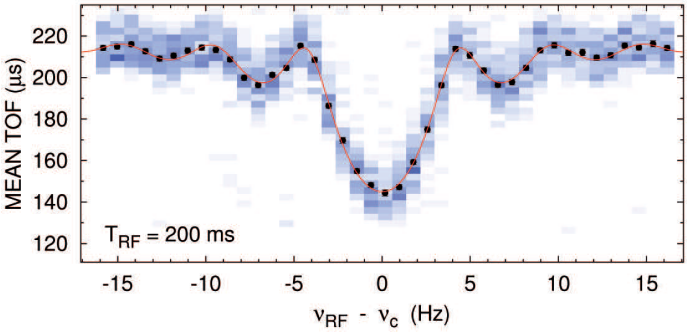
UPPSALA UNIVERSITET

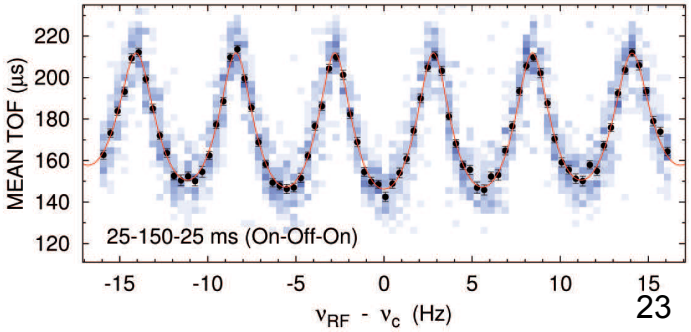
JYFLTAP

Ramsey excitation





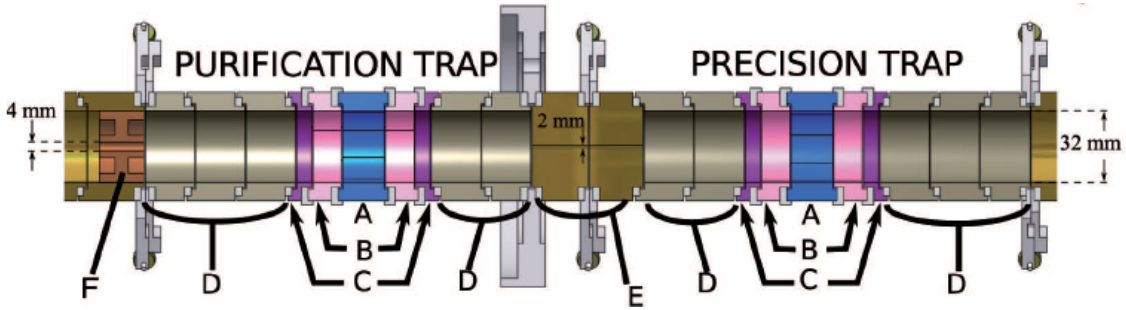


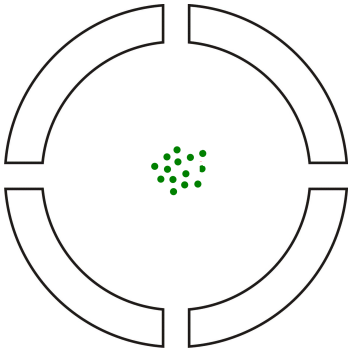


UPPSALA UNIVERSITET

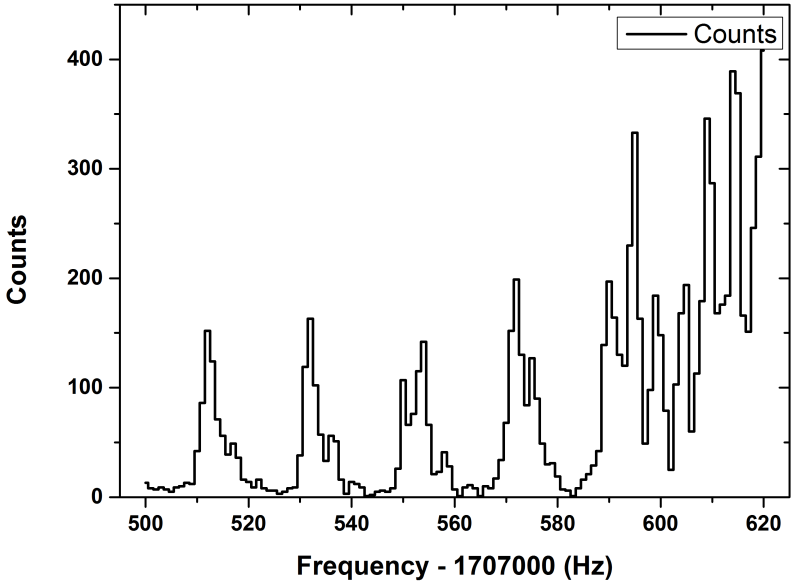
JYFLTAP

Ramsey cleaning





MOVIE

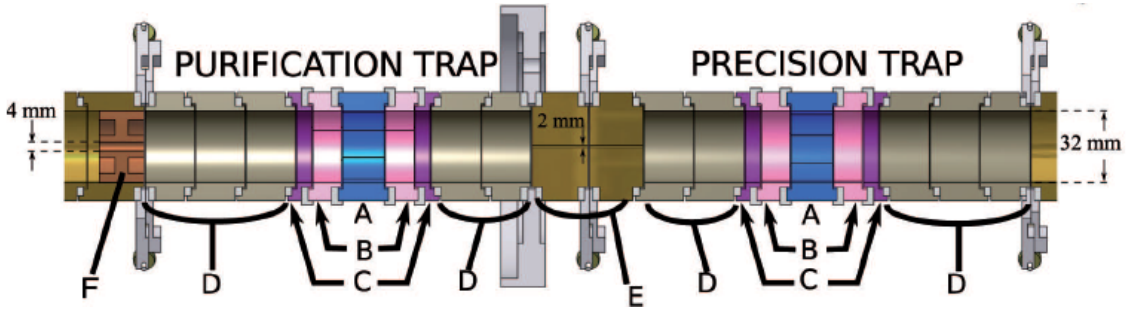


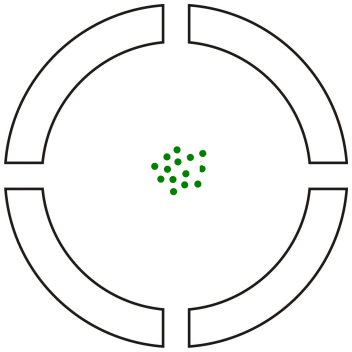
Ramsey dipole excitation at reduced cyclotron frequency!

UPPSALA UNIVERSITET

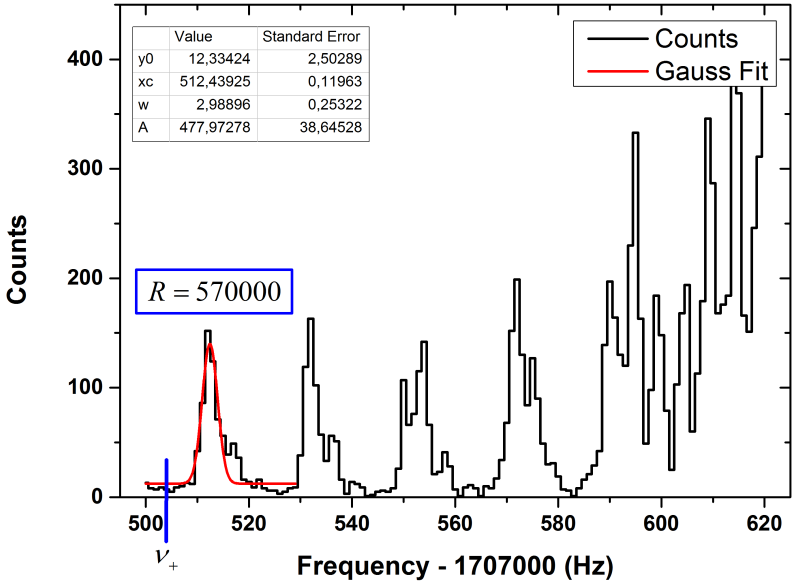
JYFLTAP

Ramsey cleaning





MOVIE



Back to purification trap, re-center and extract.

UPPSALA UNIVERSITET

JYFLTAP

Ramsey cleaning