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Isomeric fission yield measurements at IGISOL

Outline

- Motivation
- Experimental Facility
- Preliminary Results
- Future Plans

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Fission Yields

High quality data on independent fission yields

(I) In Fundamental Physics for:

- a better understanding of the fission process (model development)
- studies of neutron rich nuclei far from the line of stability

(II) In Nuclear Energy Applications:

- decrease the uncertainty about spent fuel composition
  (decay heat, radio-toxicity, storage, reprocessing, transmutation)
- relevant for safety measures
  (fission gas production, delayed neutrons, criticality, etc.)
- improve burn-up predictions

Isomeric Yields

Why to bother with the isomers?

- Used to deduce the fission fragment angular momentum.
- Simulations of the astrophysical r-process.
- Simulations of the neutronics and decay heat of nuclear reactors.

e.g: The beta delayed neutron probability from the isomeric state can be an order of magnitude different from that of the ground state (e.g. 0.33% for ^{98}Y, 3.5% for ^{98m}Y).

Motivation

Accurate Fission data FOr Nuclear Safety (AlFONS) project aims at high precision measurements of fission yields

Idea:
To combine fission ion guide with mass identification of ions using a Penning Trap.
Fission Ion Guide is independent to chemistry => ions of every element can be produced.

To identify every nuclide (Z,A) and not only mass selection which can be achieved by the mass separators.

Experimental Facility, University of Jyväskylä

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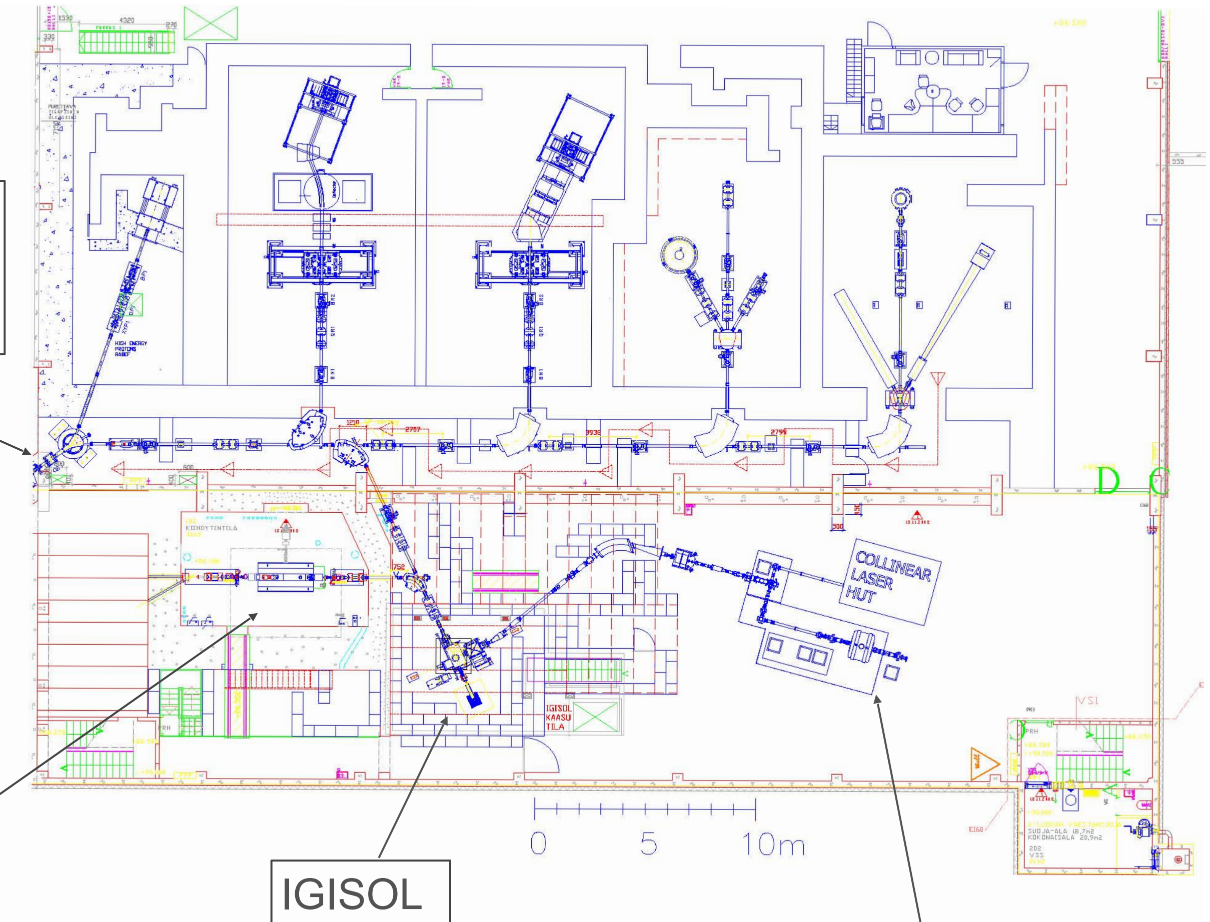
Old Cyclotron
K-130 cyclotron
(can also be used)

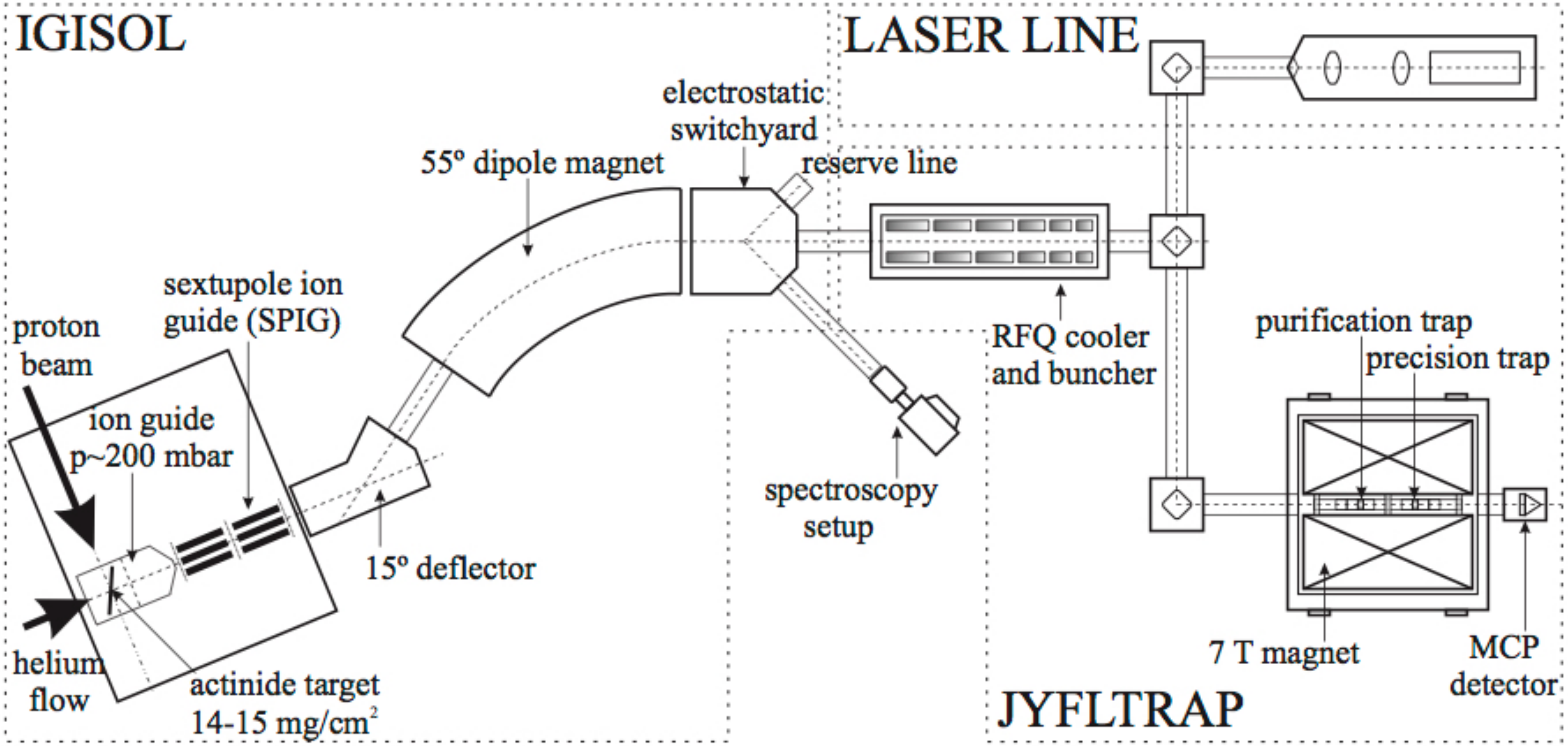


New Cyclotron
(MCC30/15)
p: 18 – 30 MeV @ 100 μA
d: 9 – 15 MeV @ 50 μA

IGISOL

Penning Trap

IGISOL -JYFLTRAP*



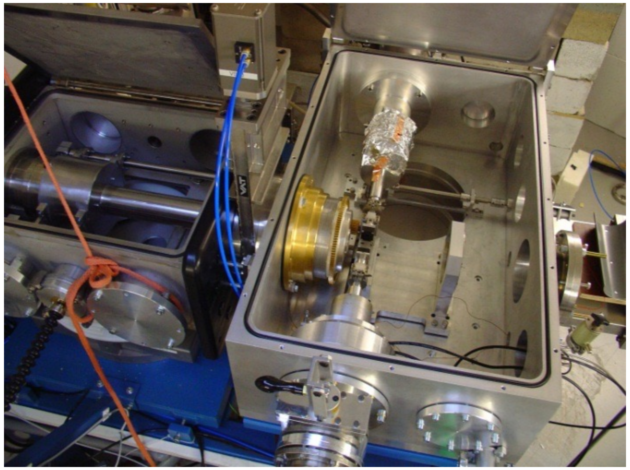
* not in scale

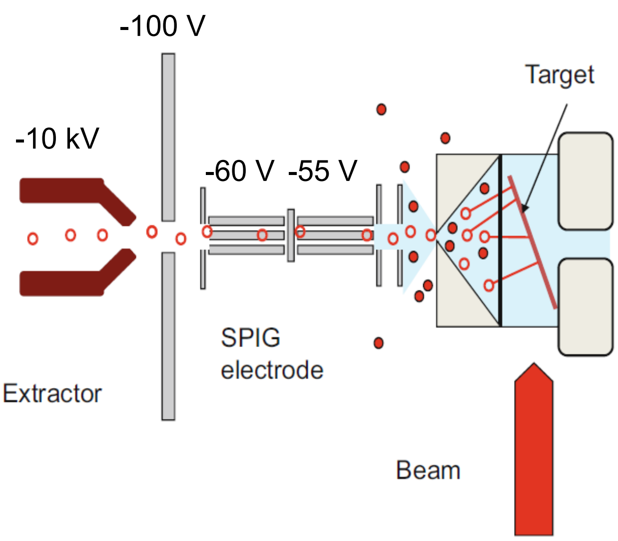
Fission Chamber and Ion Guide

- Helium gas jet
  - Stops fission fragments (< 2 MeV)*
  - Recombines fragments to singly charged
  - Guides fragments to SPIG

- SPIG
  - Sextupole ion guide
  - Centres fragments on axis
  - Accelerates by static potentials

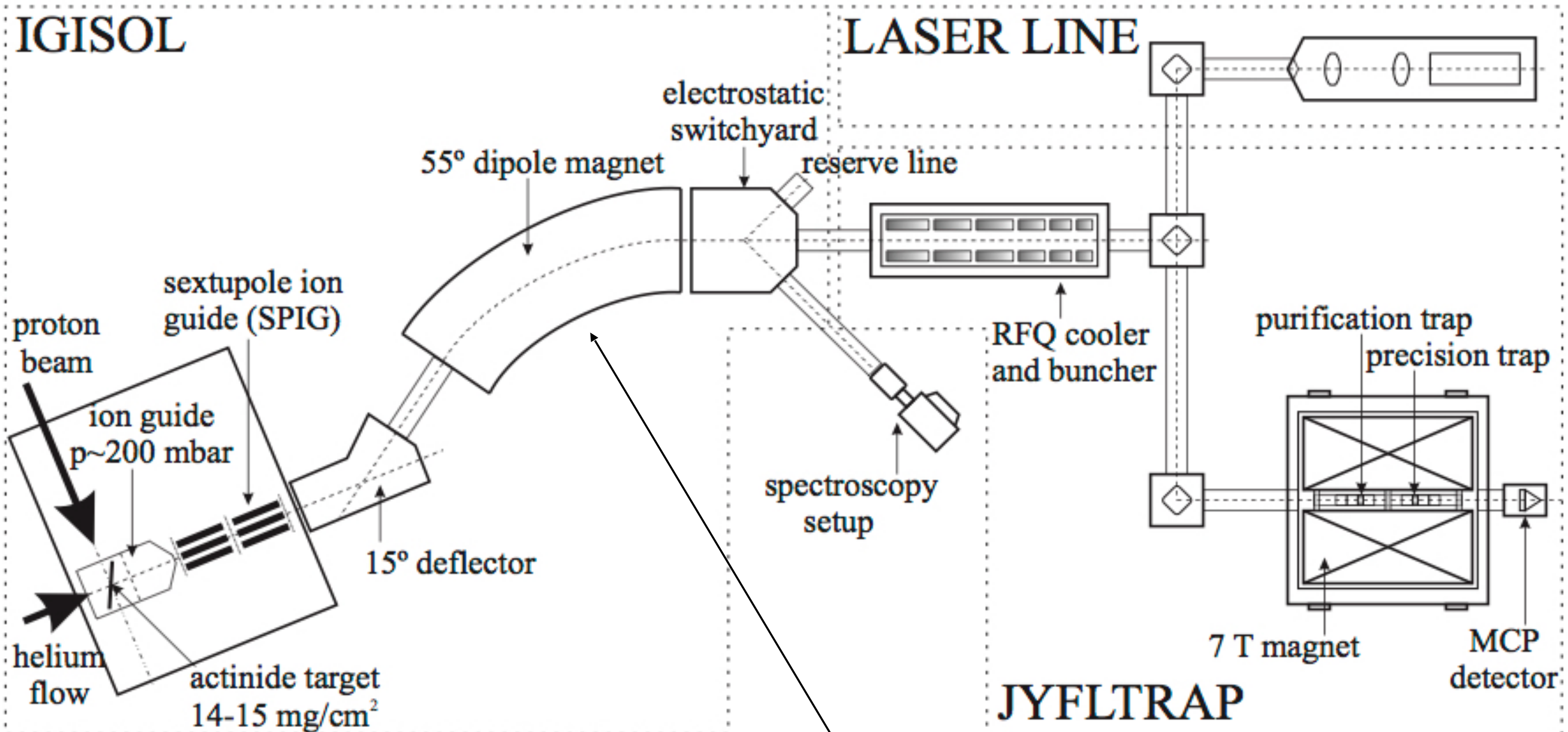
- Extractor
  Accelerates fragments in steps to 30 kV





*A. Al-Adili et al: "Ion counting efficiencies at the IGISOL facility" arXiv:1409.0714v1

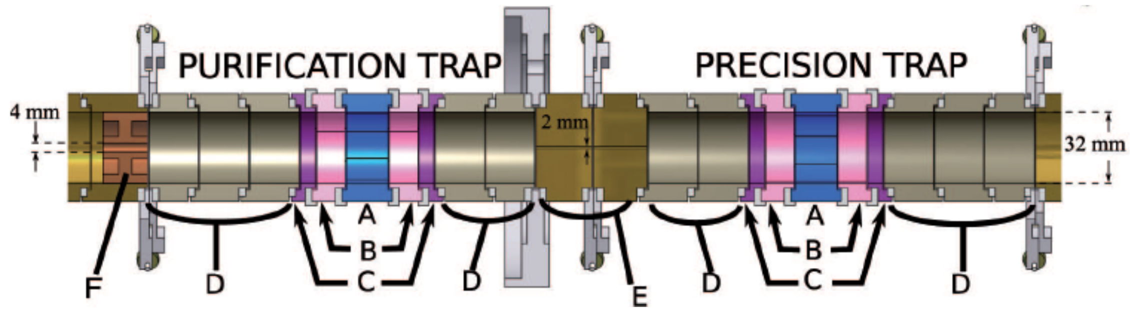
IGISOL -JYFLTRAP

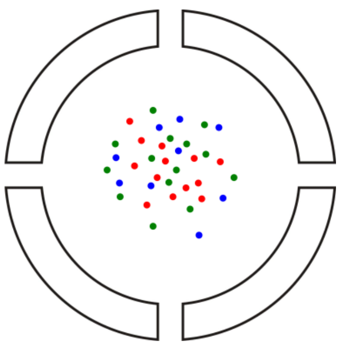


Resolving power
M/ΔM=500

Mass Separation in JYFLTRAP

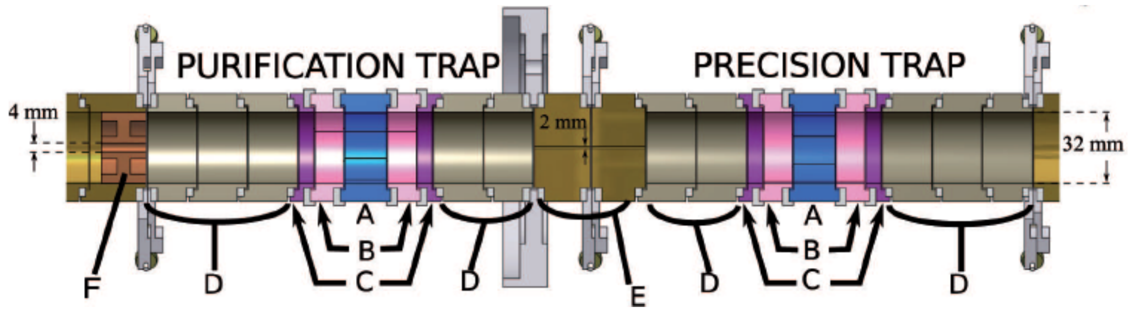
Double cylindrical trap

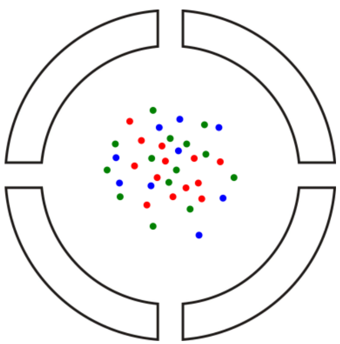


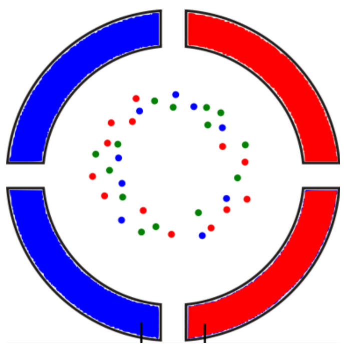


Mass Separation in JYFLTRAP

Double cylindrical trap







Alternating dipole field at magnetron frequency, f_m

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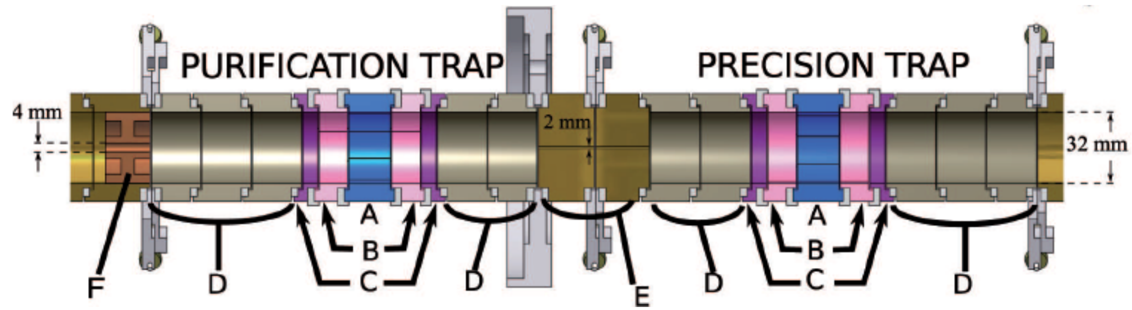
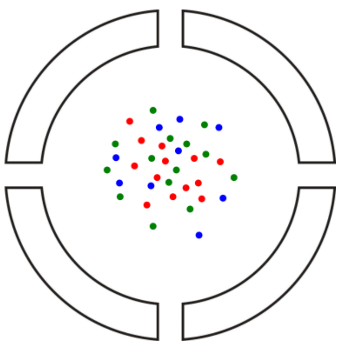
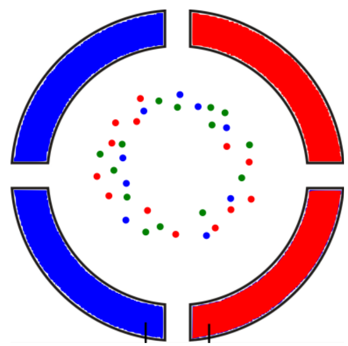
Mass Separation in JYFLTRAP

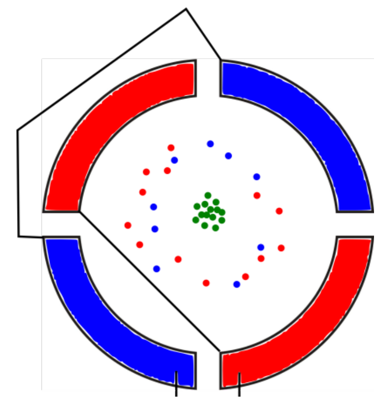
Double cylindrical trap







Alternating dipole field at magnetron frequency, f_m



Alternating quadrupole field. Convertion if $f=f_c$.

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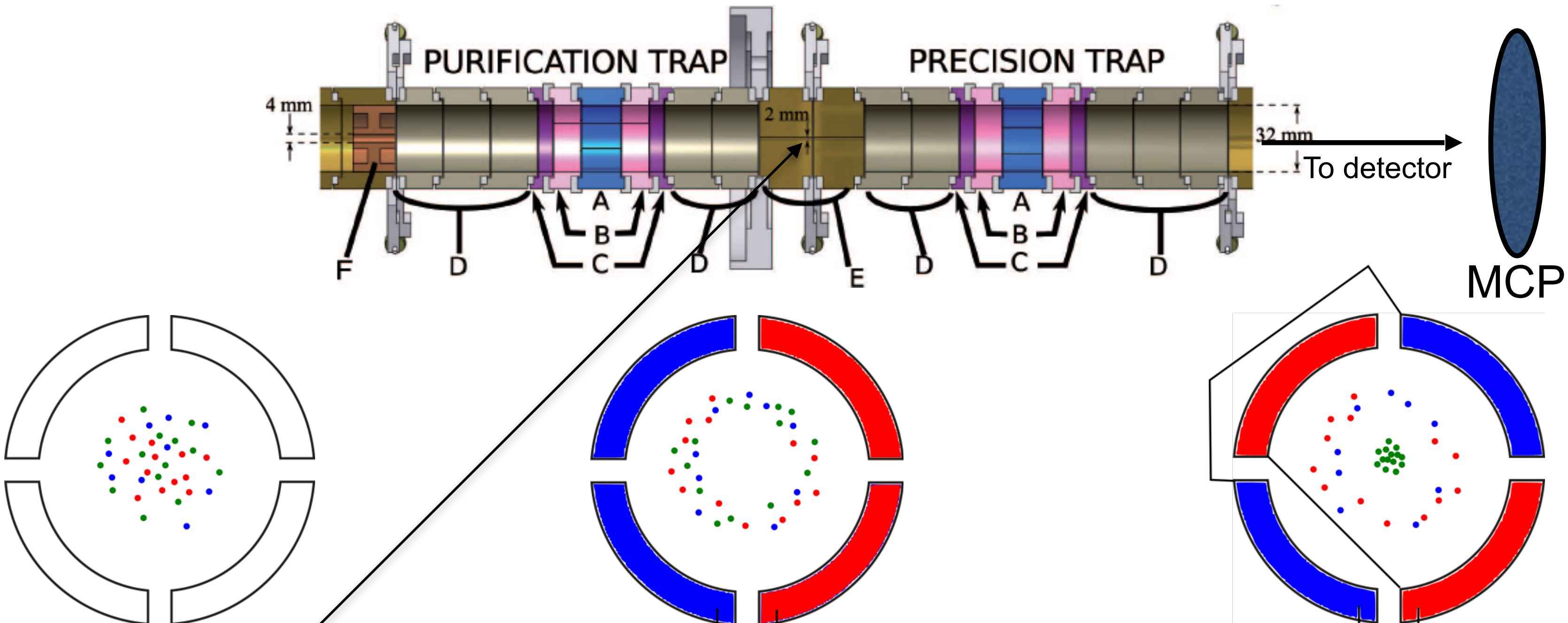
Mass Separation in JYFLTRAP

Double cylindrical trap

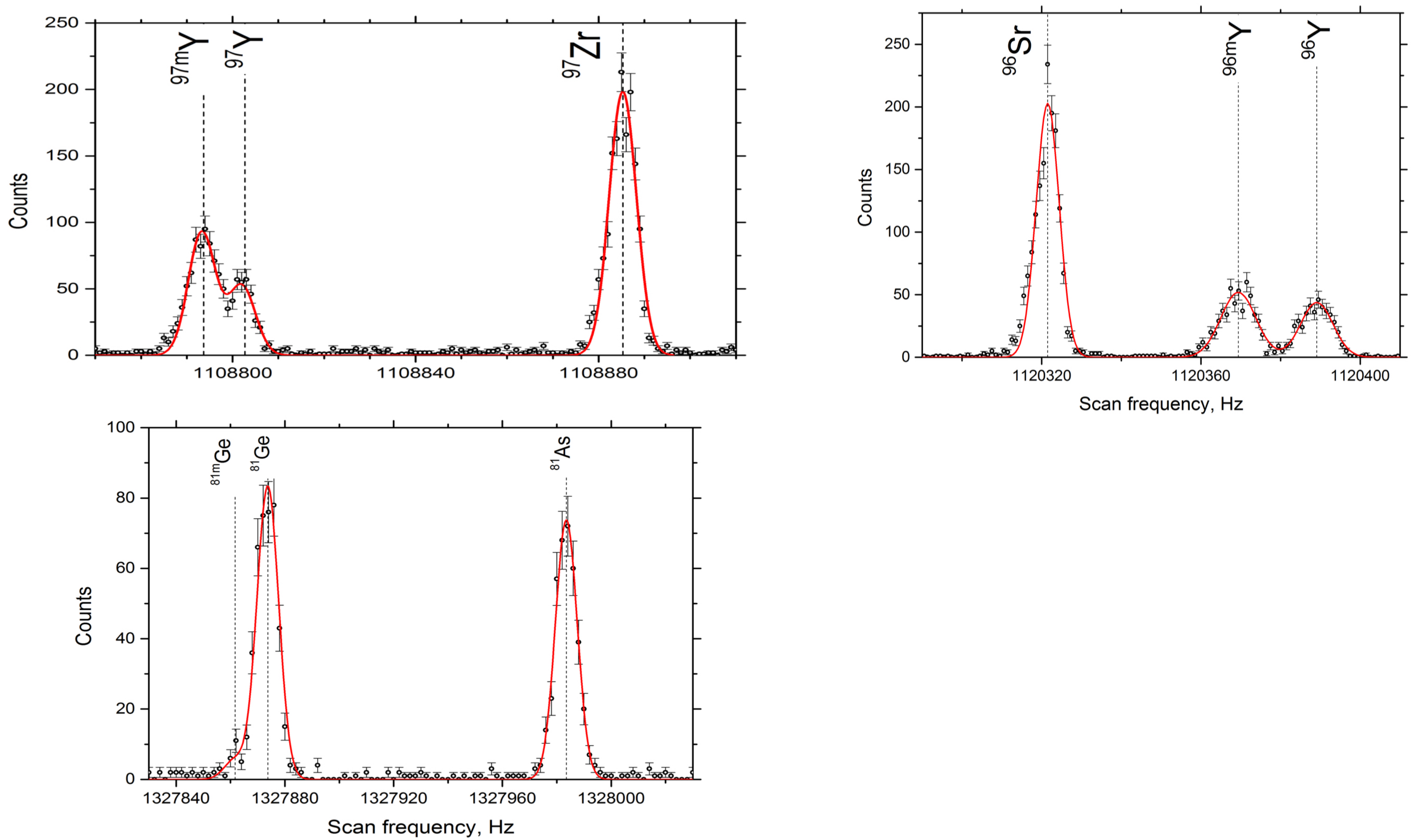


Alternating dipole field at magnetron frequency, f_m

Alternating quadrupole field. Convertion if $f=f_c$.

Extraction through 2 mm aperture either to precision trap for further manipulation or to MCP detector.

Mass Spectra



Proton-induced fission on ^{238}U

Which nuclides can be separated with the purification trap:

Nuclide	**^{81}Ge**	**^{96}Y**	**^{97}Y**	**^{97}Nb**	**^{128}Sn**	**^{130}Sn**
$T_{1/2}$	7.6 s	5.34 s	3.75 s	72.1 m	59.07 m	3.72 m
J_p	9/2+	0-	1/2-	9/2+	0+	0+
Isomer	**^{81m}Ge**	**^{96m}Y**	**^{97m}Y**	**^{97m}Nb**	**^{128m}Sn**	**^{130m}Sn**
J_p	1/2+	8+	9/2+	1/2-	7-	7-
$T_{1/2}$	7.6 s	9.6 s	1.17 s	58.7 s	6.5 s	1.7 m
E_{level} (keV)	679	1140	667	743	2091	1946

Preliminary Results*

Isomeric pair experiment	^{81}Ge	^{96}Y	^{97}Y	^{97}Nb	^{128}Sn	^{130}Sn
2013-06-04	0.06±0.05	1.09±0.11	Unclear		Unclear	0.39±0.27
2013-08-29	0.09±0.05	1.25±0.22	1.85±0.23	0.20±0.60	Unclear	
2014-05-27	0.58±0.27				0.90±0.12	0.66±0.38

*courtesy of D. Gorelov

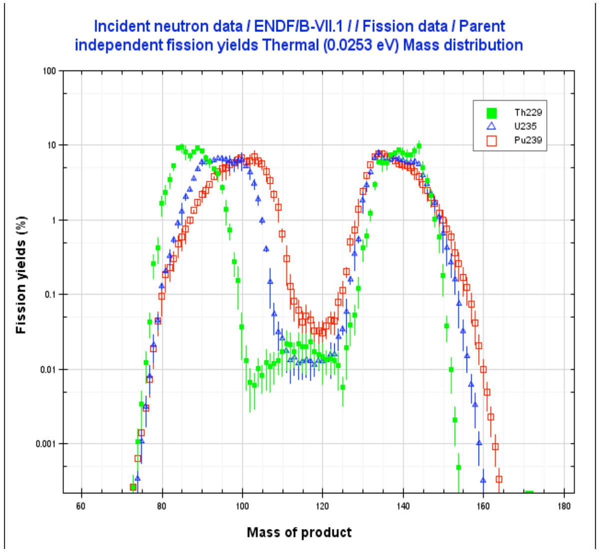
Future Plans

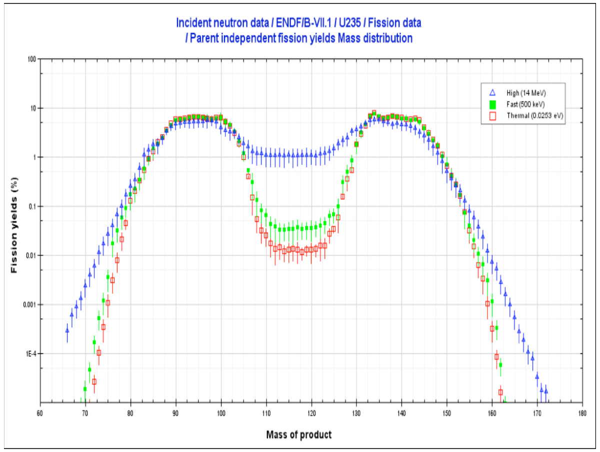
Neutron induced independent fission yields of:

- Various actinides (^{238}U, ^{235}U, ^{232}Th, …)
- Energy dependence
- Isomeric yield ratios

with high neutron energies (>14 MeV)

Characterisation of the neutron flux on site (winter-spring 2015)





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Thank you for your attention!

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SKB
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Swedish Nuclear Fuel and Waste Management Co. (SKB)

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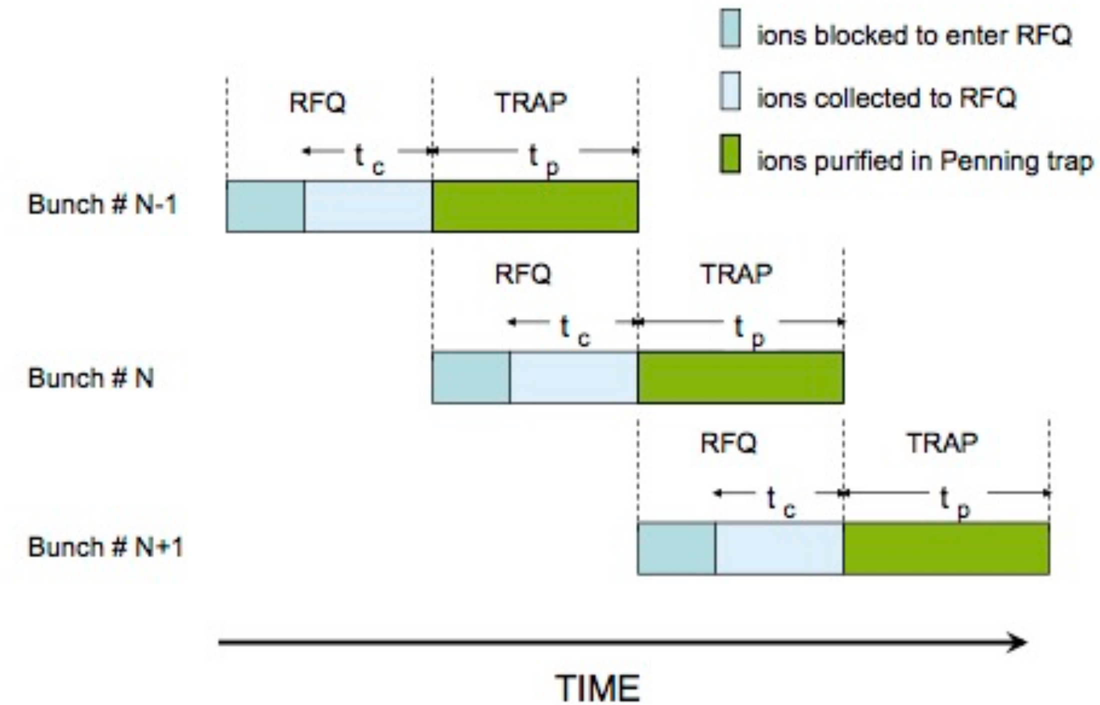
Timing of the experiment



The selected purification cycle length t_p dictates the timing of the experiment. While an ion bunch is purified in the Penning trap, the next bunch is prepared in the RFQ.