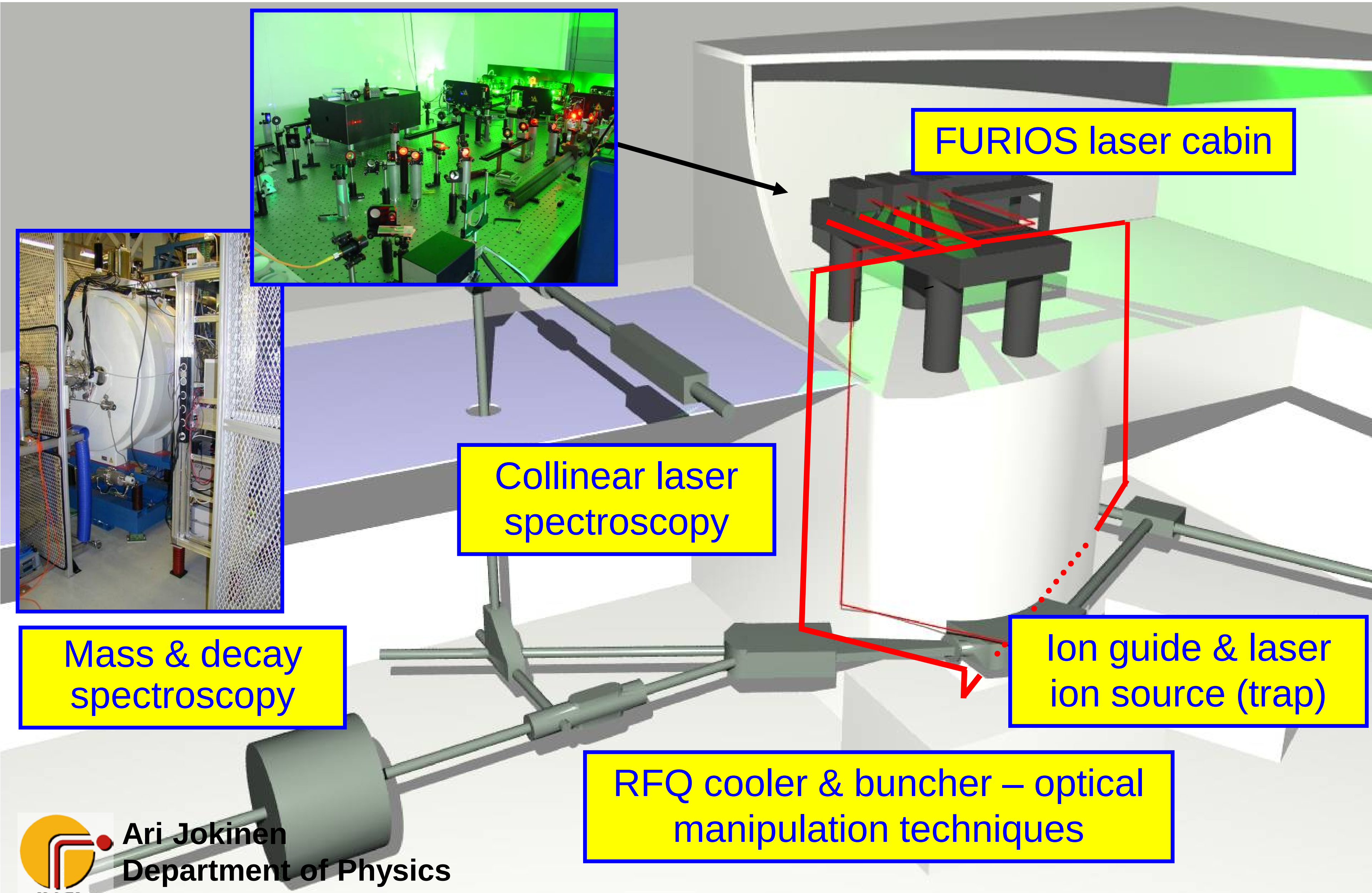
Ion beam production and manipulation at IGISOL



JYFL
Ari Jokinen
Department of Physics
University of Jyväskylä

EURISOL-NET, CERN, 28.6.2011

Ion guide method, the original

- Based on survival of primary ions from nuclear reaction in helium buffer gas
- Fast extraction of ions is required to prevent neutralisation
- Charge state concentration: (0), +1, (+2)
- Produces ions of any element

VOLUME 54, NUMBER 2 PHYSICAL REVIEW LETTERS 14 JANUARY 1985

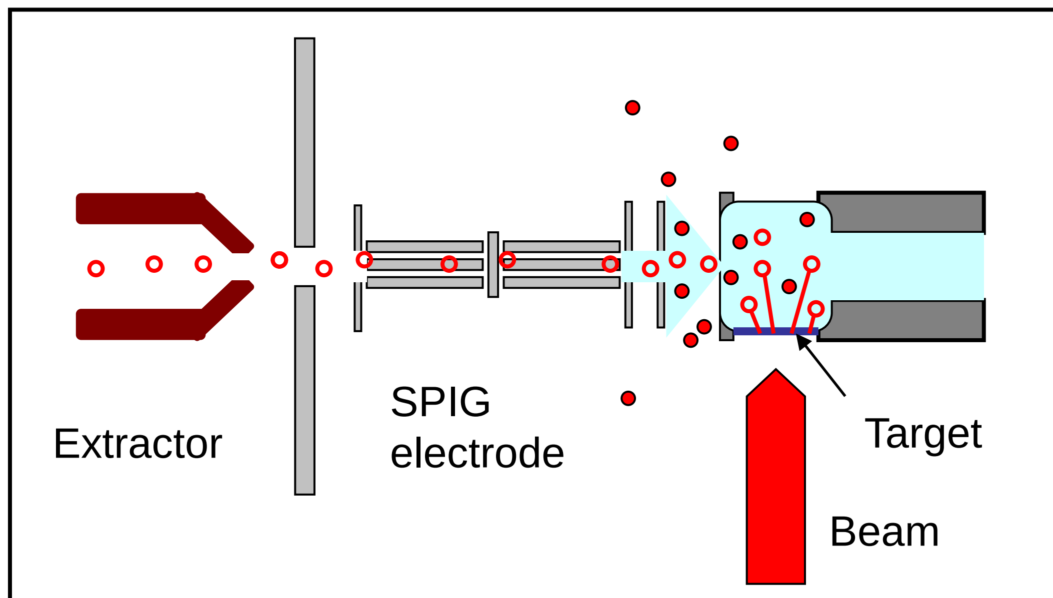
Submillisecond On-Line Mass Separation of Nonvolatile Radioactive Elements: An Application of Charge Exchange and Thermalization Processes of Primary Recoil Ions in Helium

J. Ärje, J. Äystö,[a] H. Hyvönen, P. Taskinen, V. Koponen, and J. Honkanen
Department of Physics, University of Jyväskylä, SF-40100 Jyväskylä, Finland

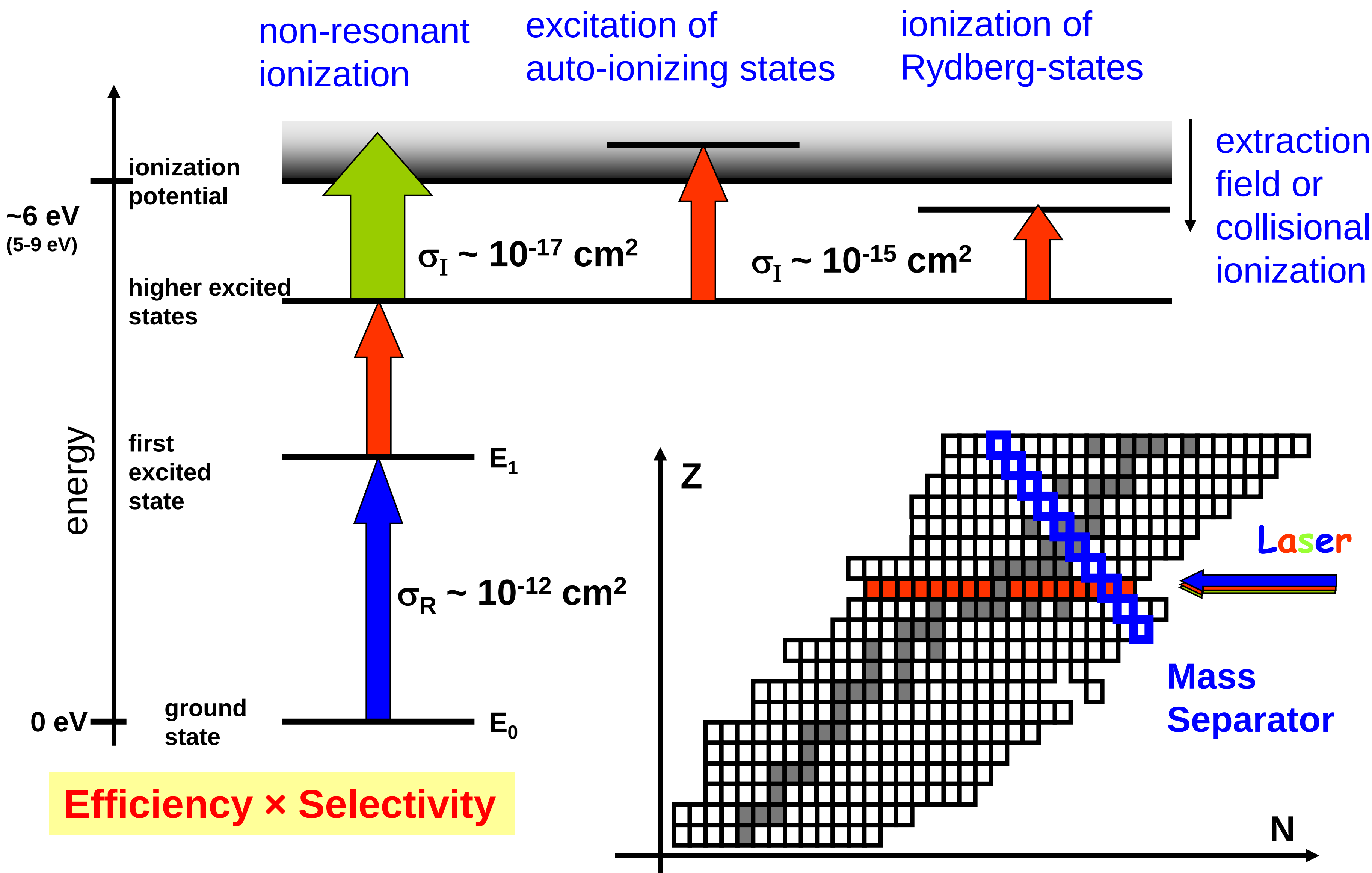
and

A. Hautojärvi and K. Vierinen
Department of Physics, University of Helsinki, SF-00170 Helsinki, Finland
(Received 17 September 1984)

Transportation of thermalized primary recoil ions from nuclear reactions by helium flow has been investigated as a means of injecting short-lived radioactive nuclides into an on-line isotope separator. Several short-lived radioactive isotopes of highly nonvolatile elements such as B, Sc, Nb, and W have been separated. The efficiency for heavy nuclides with half-lives above 1 ms is between 1 and 10%. The shortest-lived activity identified in an on-line separation is the 182-μs isomeric state in ^{207}Bi.



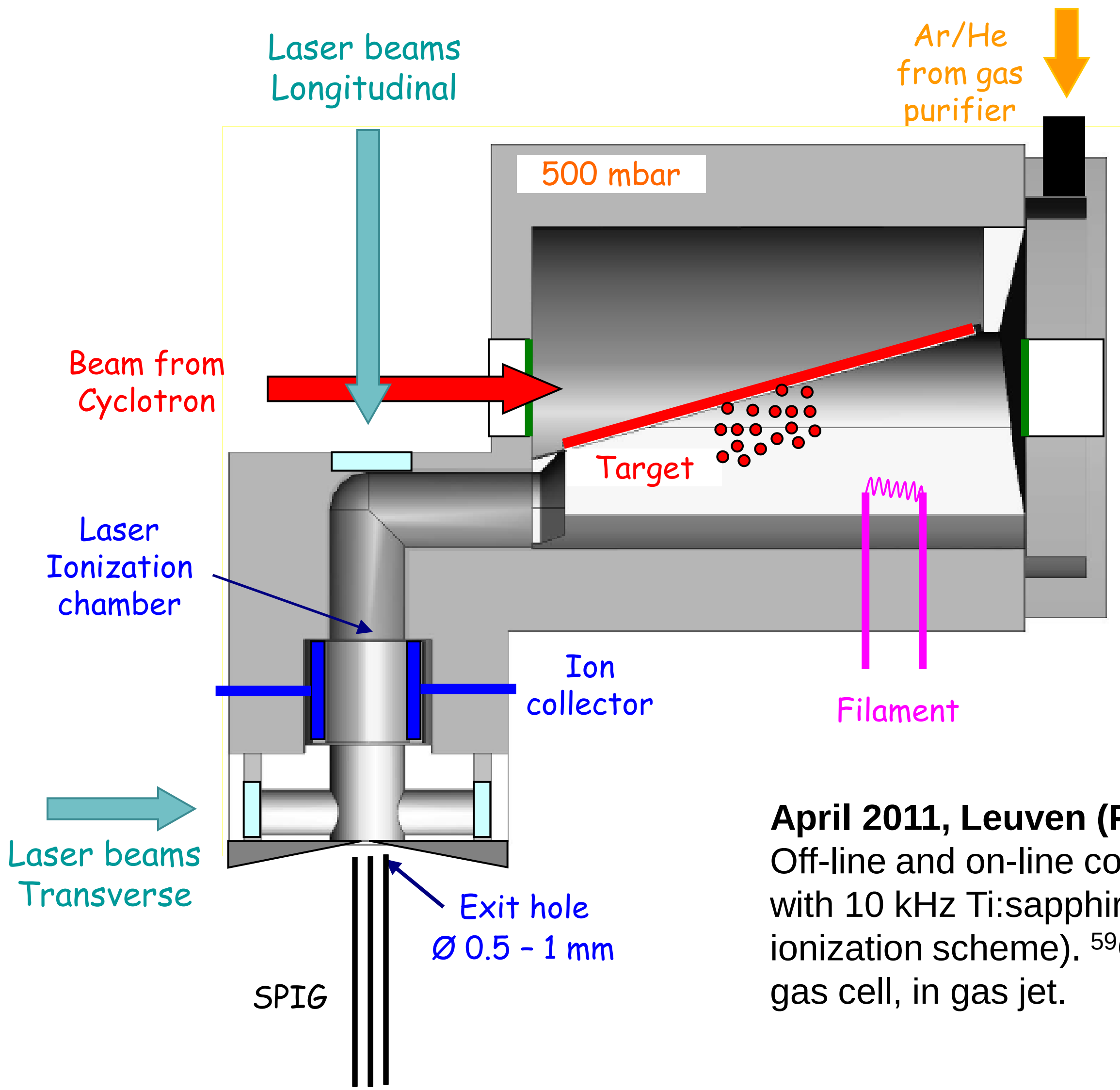
Z selectivity by resonant laser ionization



Efficiency × Selectivity

C. Geppert, EMIS conference, (2007)

Resonant laser ionization in a gas cell



Dual Chamber design

The aim: *(by separating stopping and laser ionization chambers)*

- Increasing laser ionization efficiency at high cyclotron beam currents
- Increasing selectivity (collection of non-neutral ions)

April 2011, Leuven (PREMAS-related):
Off-line and on-line comparison of 200 Hz dye laser system with 10 kHz Ti:sapphire system at LISOL (using same ionization scheme). ^{59}Cu ($T_{½}$=82 s), ^{63}Cu (stable) studied in gas cell, in gas jet.

Principle of gas jet LIST

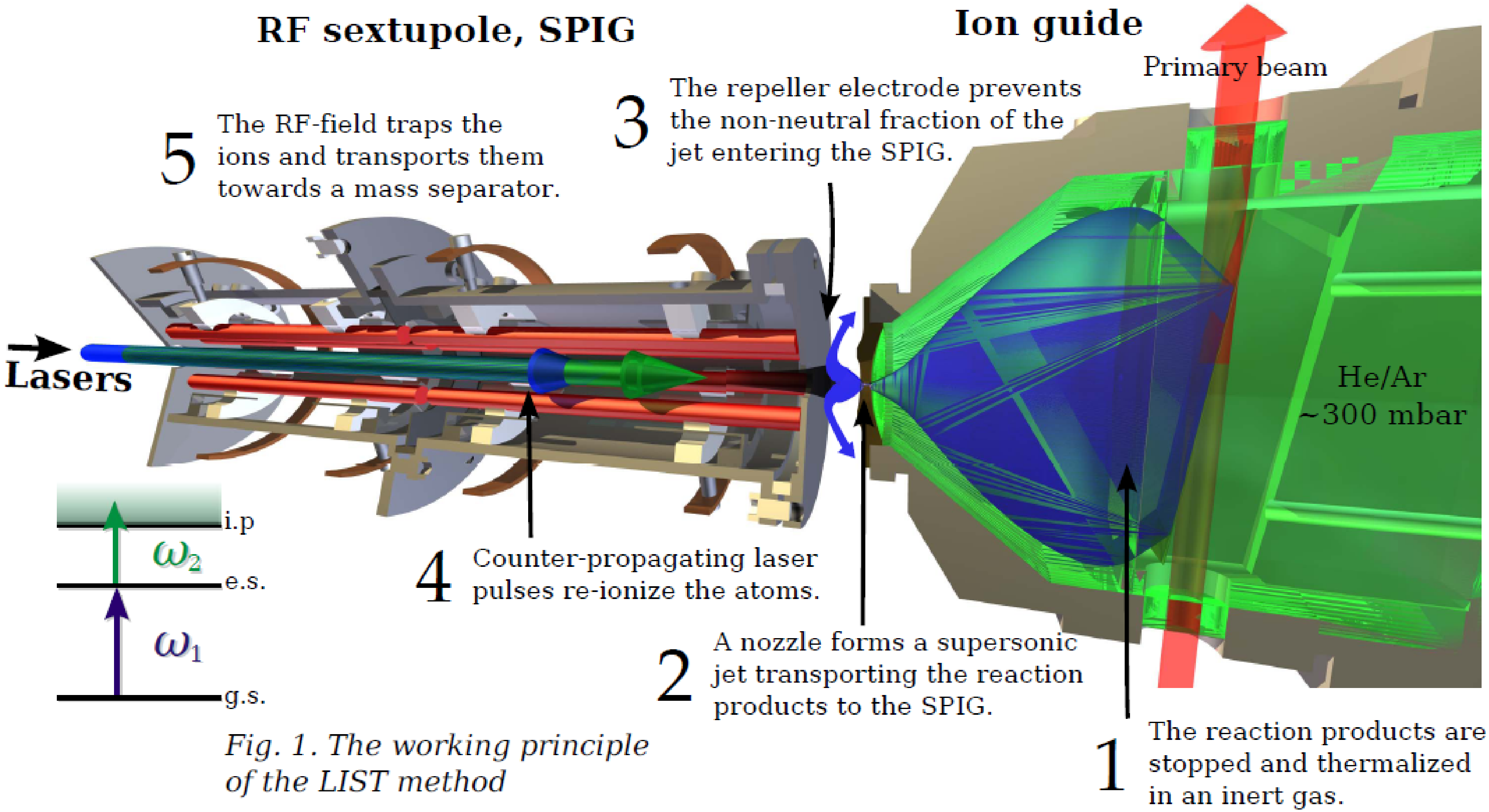
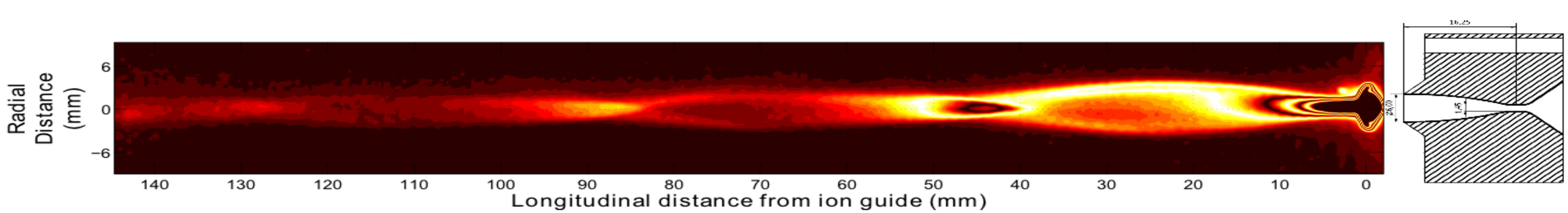
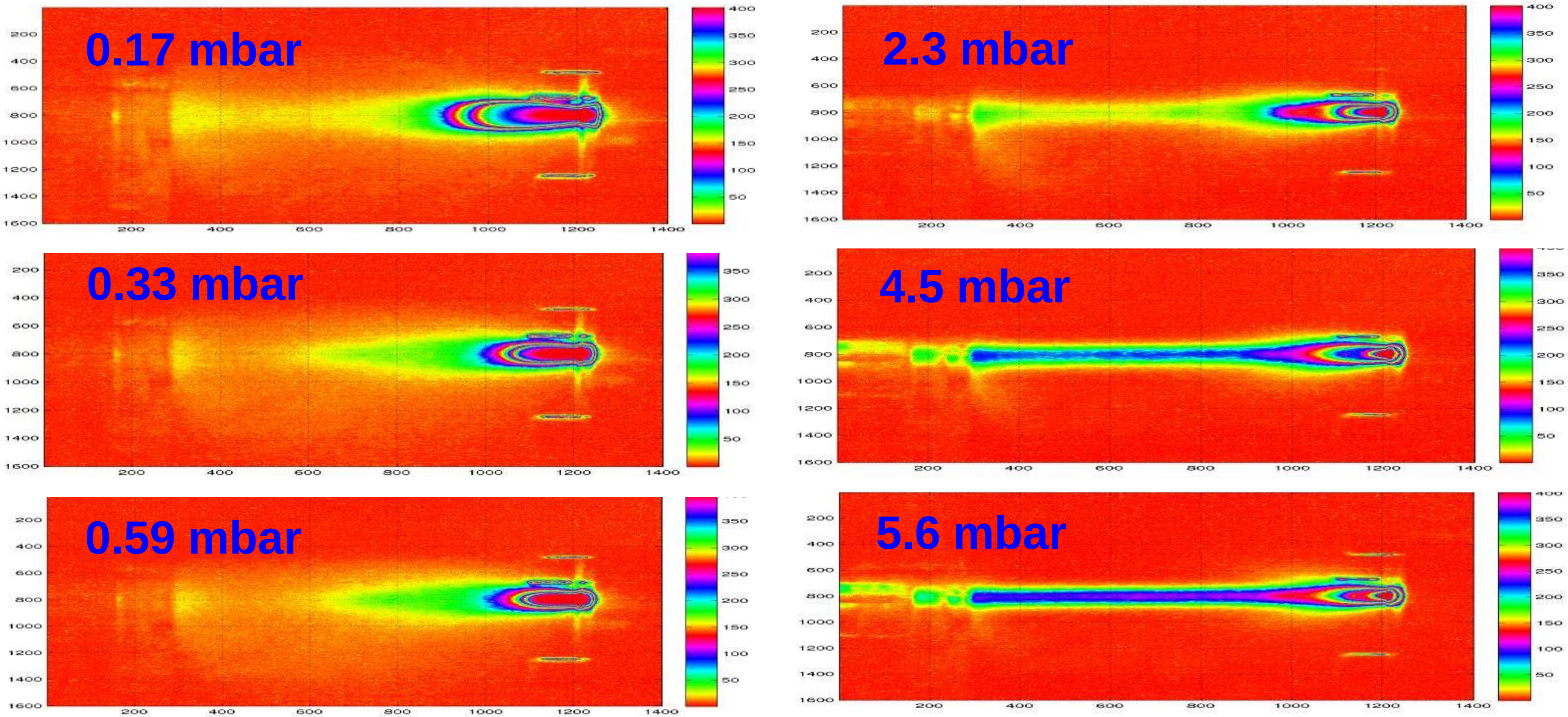
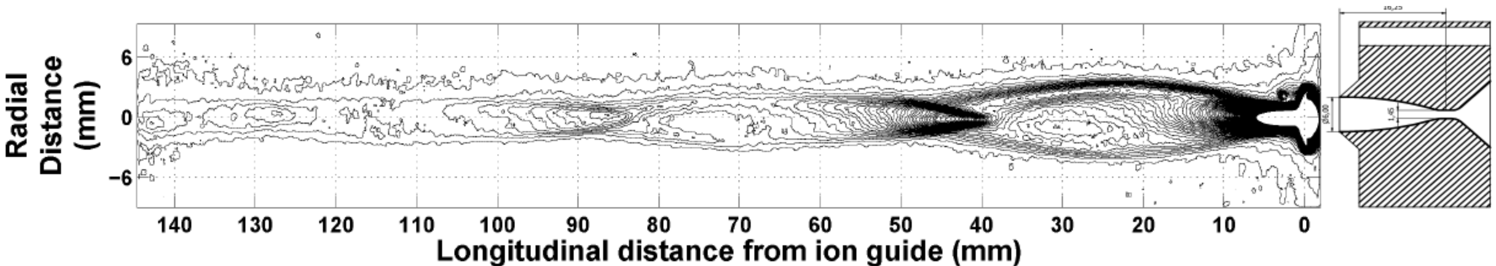


Fig. 1. The working principle of the LIST method



Gas jet studies for improved LIST (JYFL)



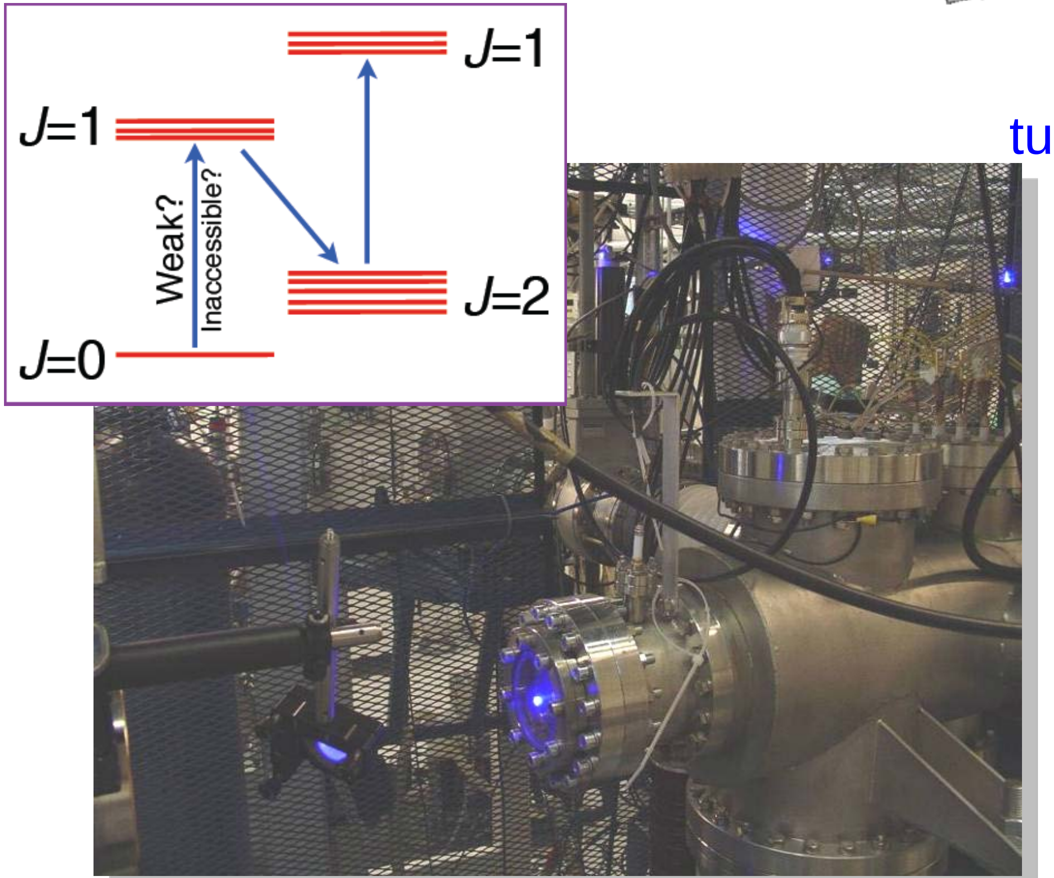


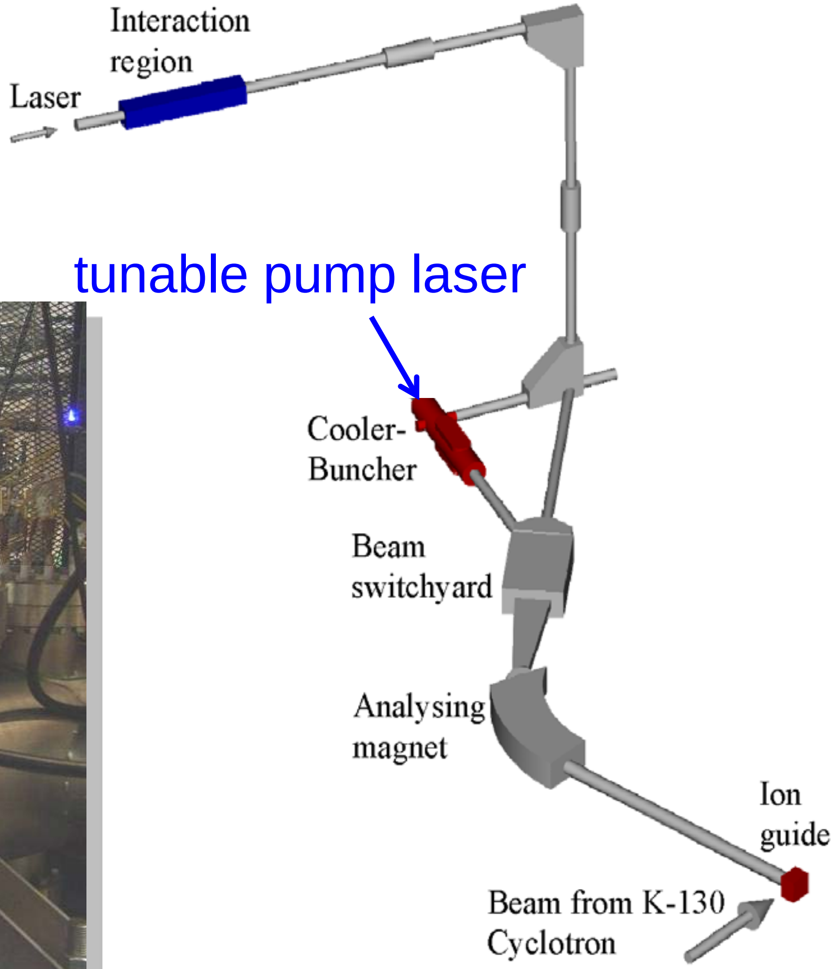
P_{He} = 56 mbar

*M. Reponen, I.D. Moore et al., NIM A **635** (2011) 24*

Manipulation of the atomic/ionic spin for laser spectroscopy

- Access to more accessible/efficient transitions
- New elements to study





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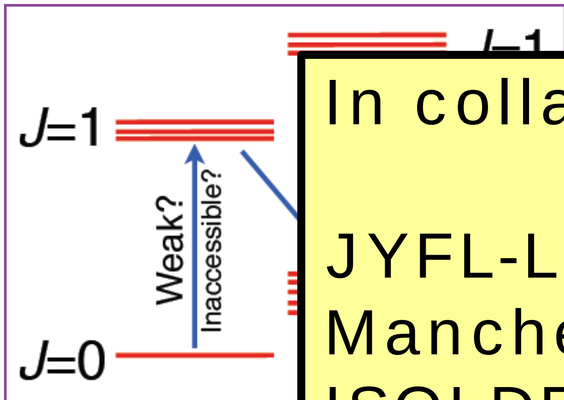
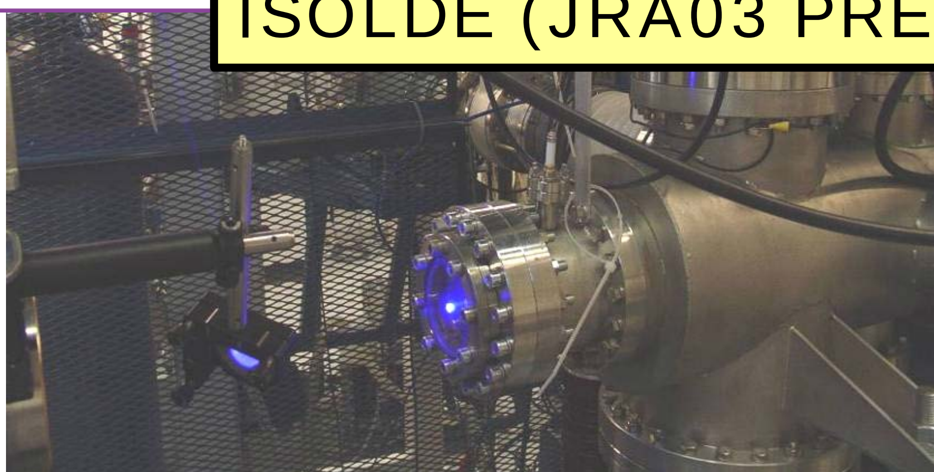
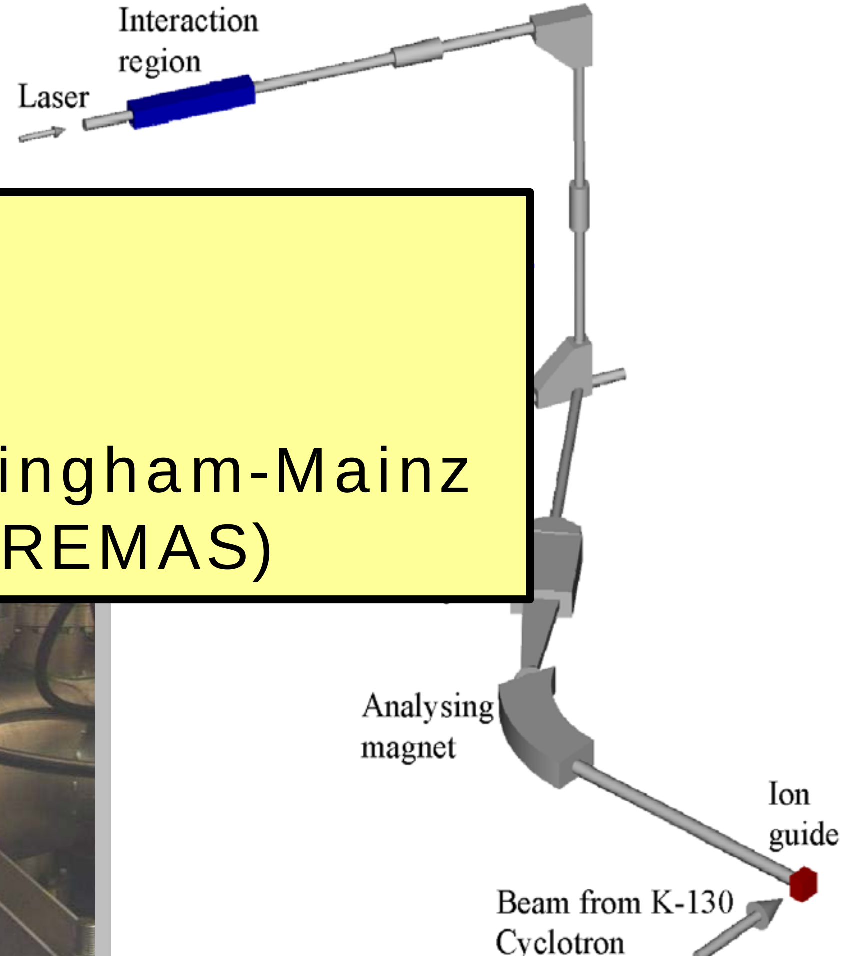


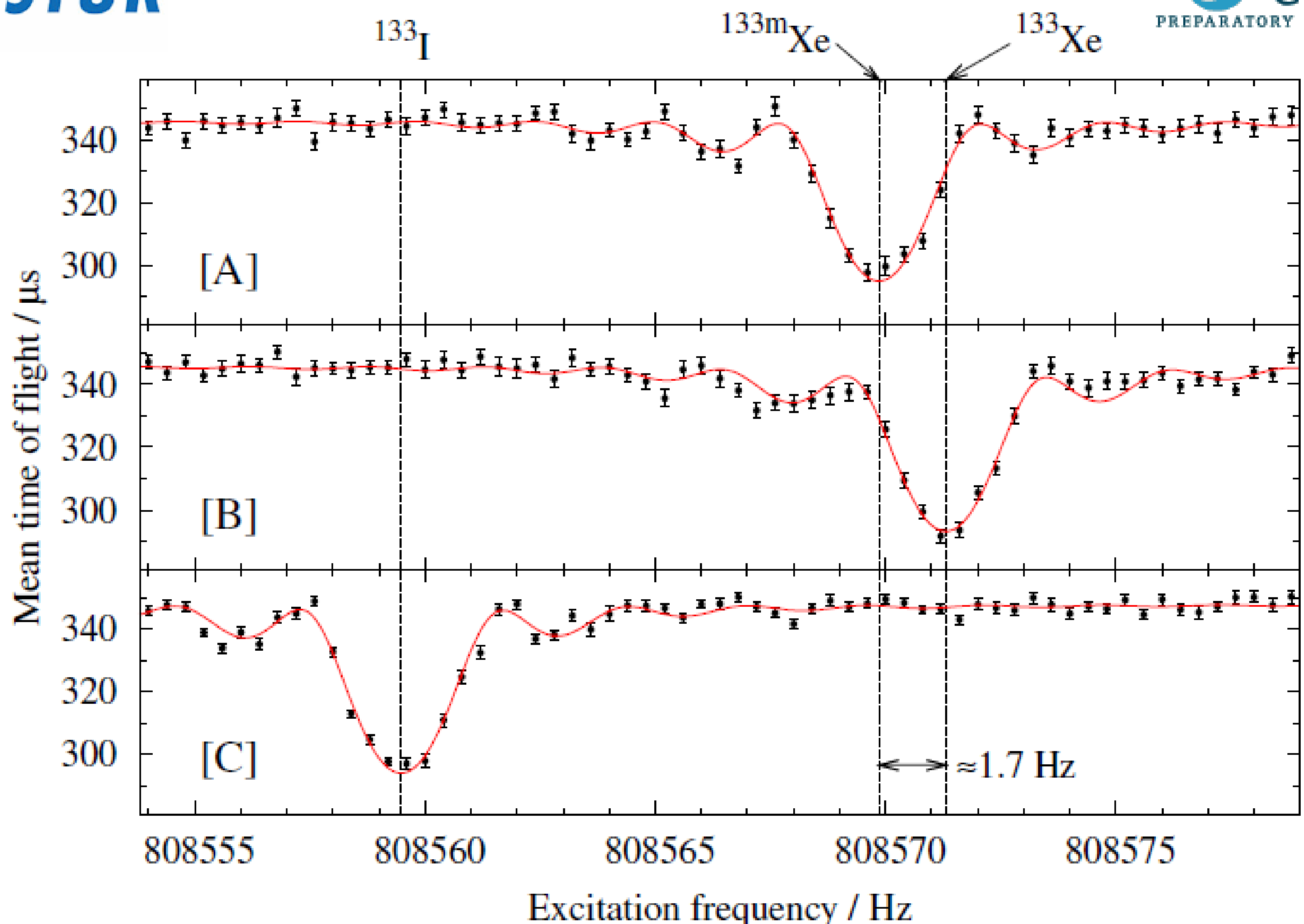
In collaboration:

JYFL-Leuven
Manchester-Birmingham-Mainz
ISOLDE (JRA03 PREMAS)

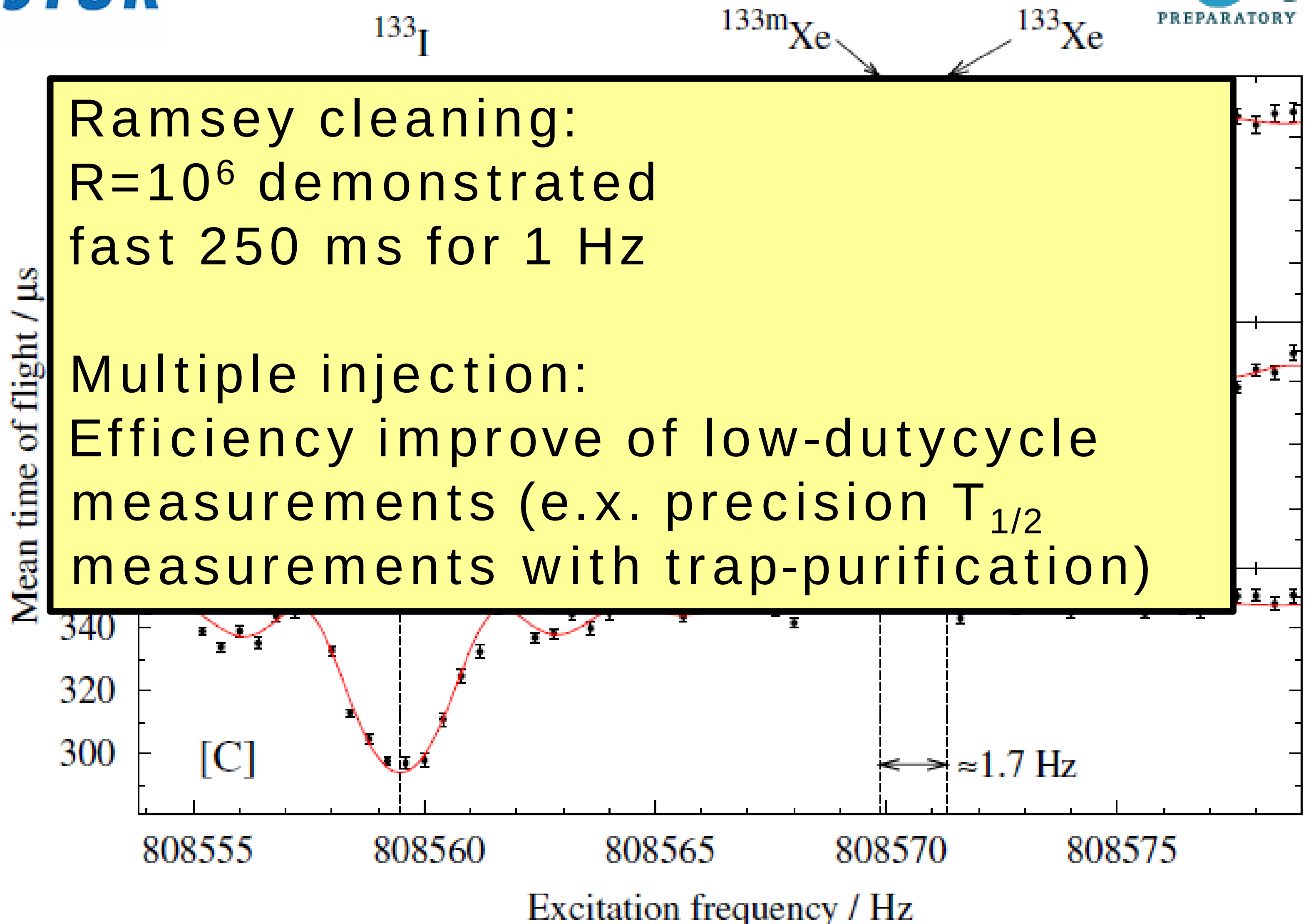




Unambigious identification of states by their MASS



Unambigious identification of states by their MASS

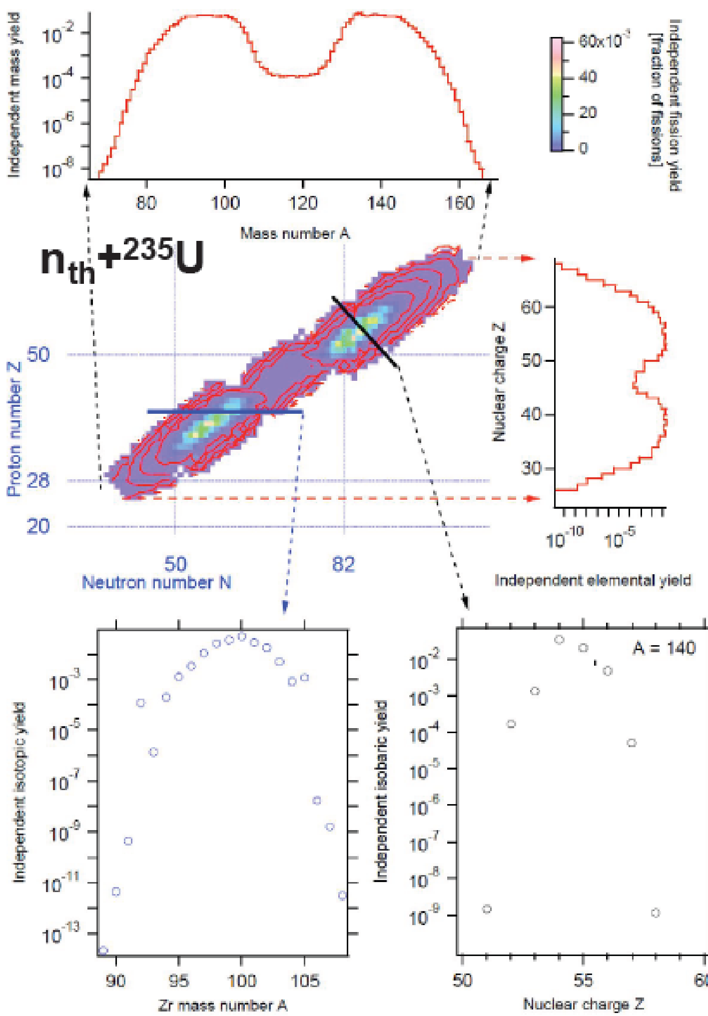


Ramsey cleaning:
R=10^6 demonstrated
fast 250 ms for 1 Hz

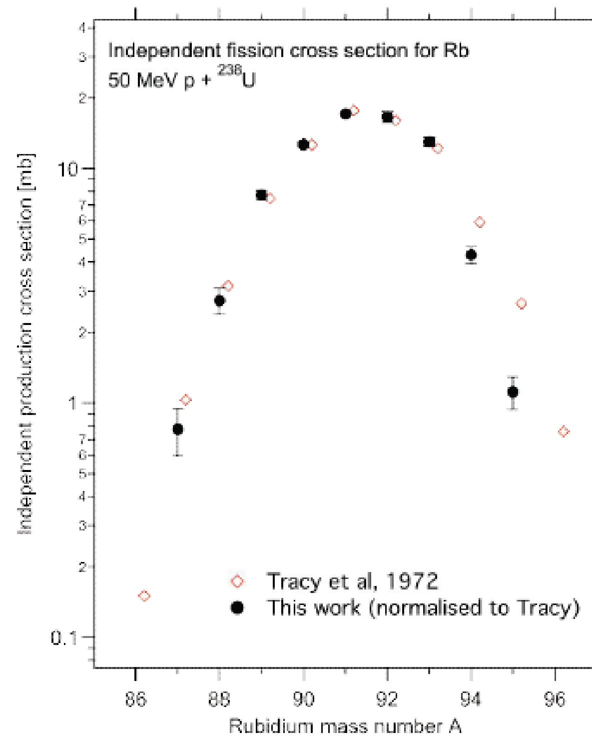
Multiple injection:
Efficiency improve of low-dutycycle measurements (e.x. precision $T_{1/2}$ measurements with trap-purification)

Independent fission yields

- Independent or direct fission yields are directly related to fission cross section
- Mass yields, isotopic yields, elemental yields, and isobaric charge disrtibutions are cuts and projections of this



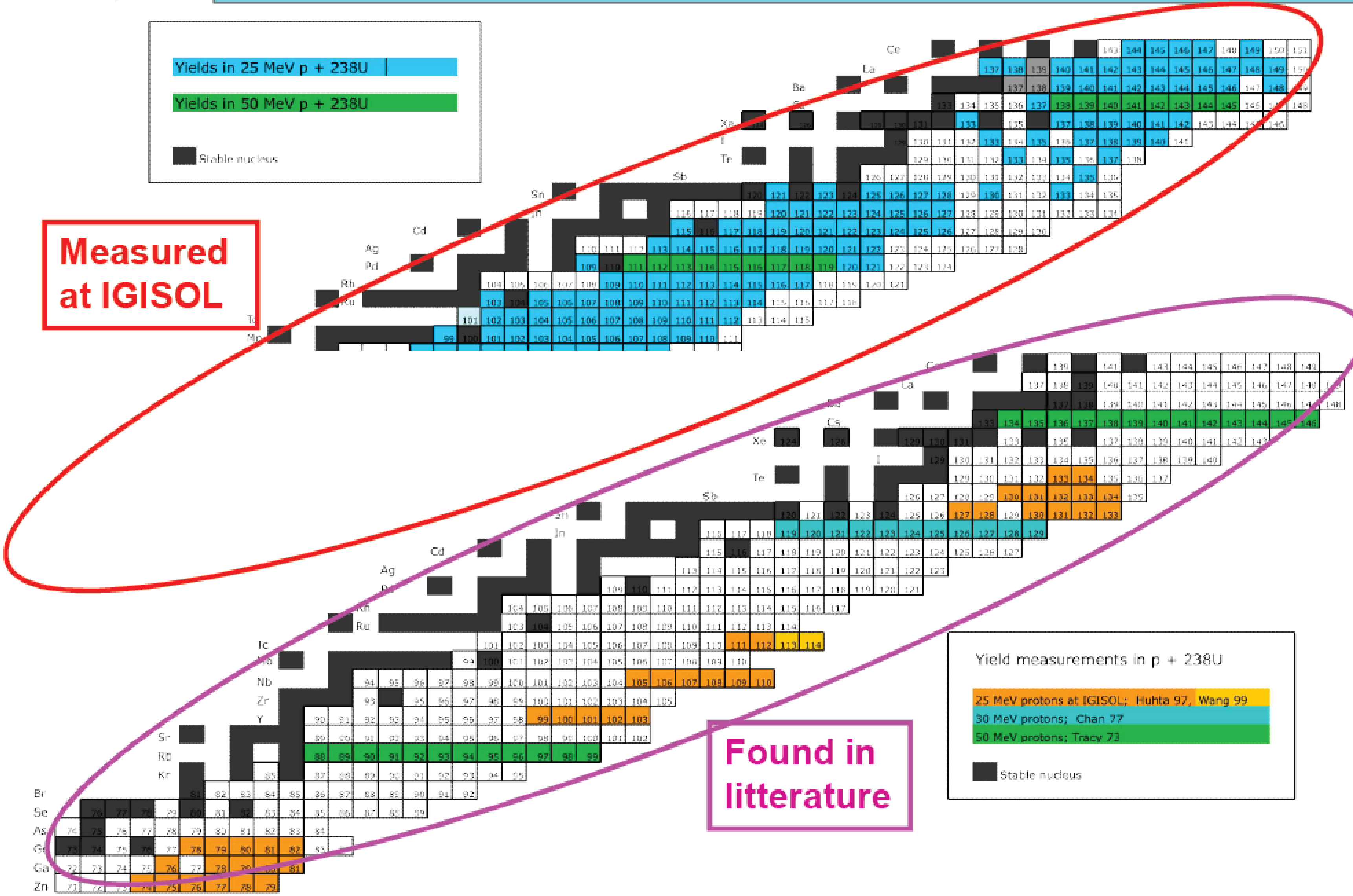
P.Karvonen, Thesis, Univ. Jyväskylä, 2010



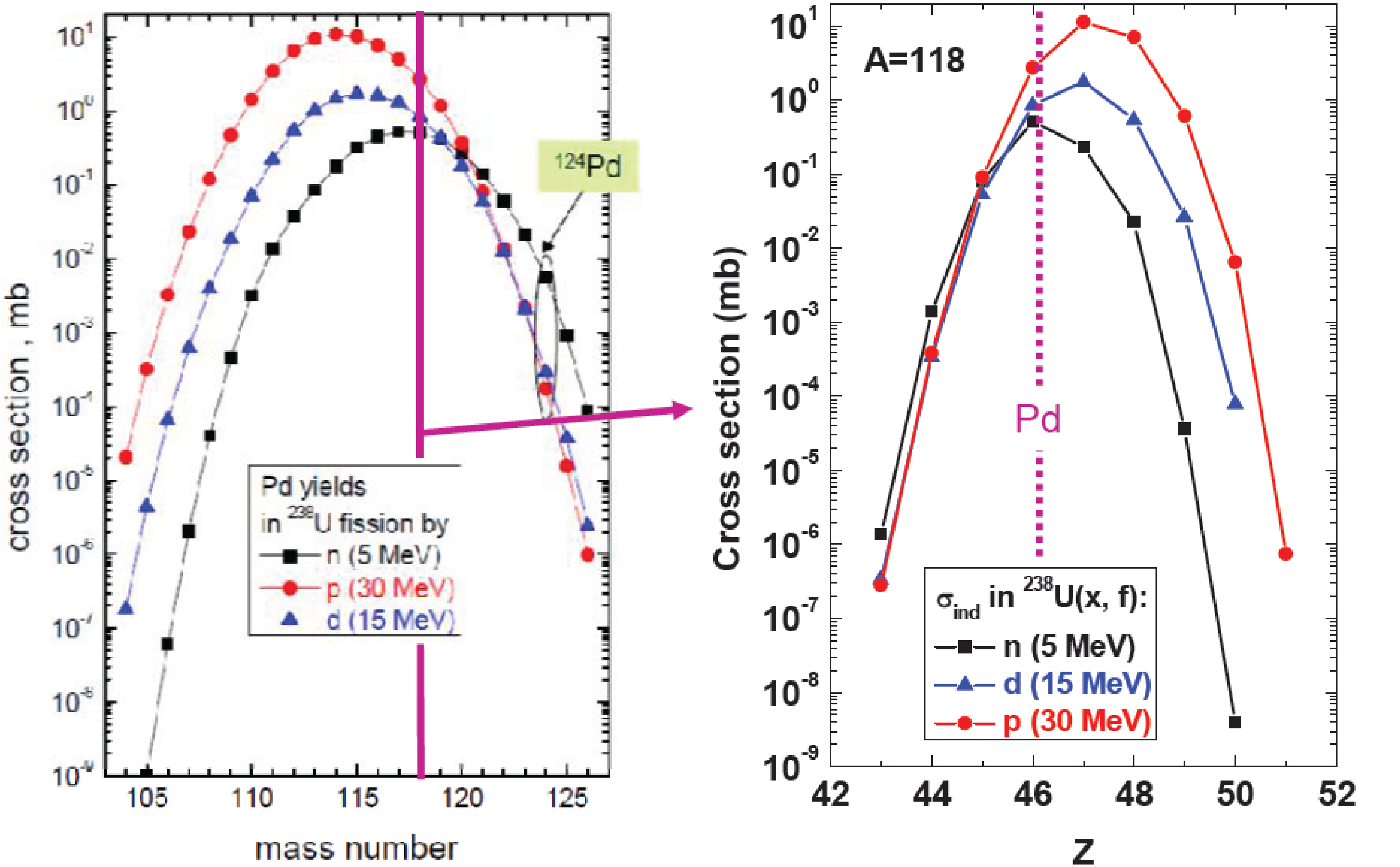
H.Penttilä et al, Eur. Phys. J. A 44, 140, 2010

UNIVERSITY OF JYVÄSKYLÄ

Proton induced fission yields at IGISOL



proton vs. neutron induced fission



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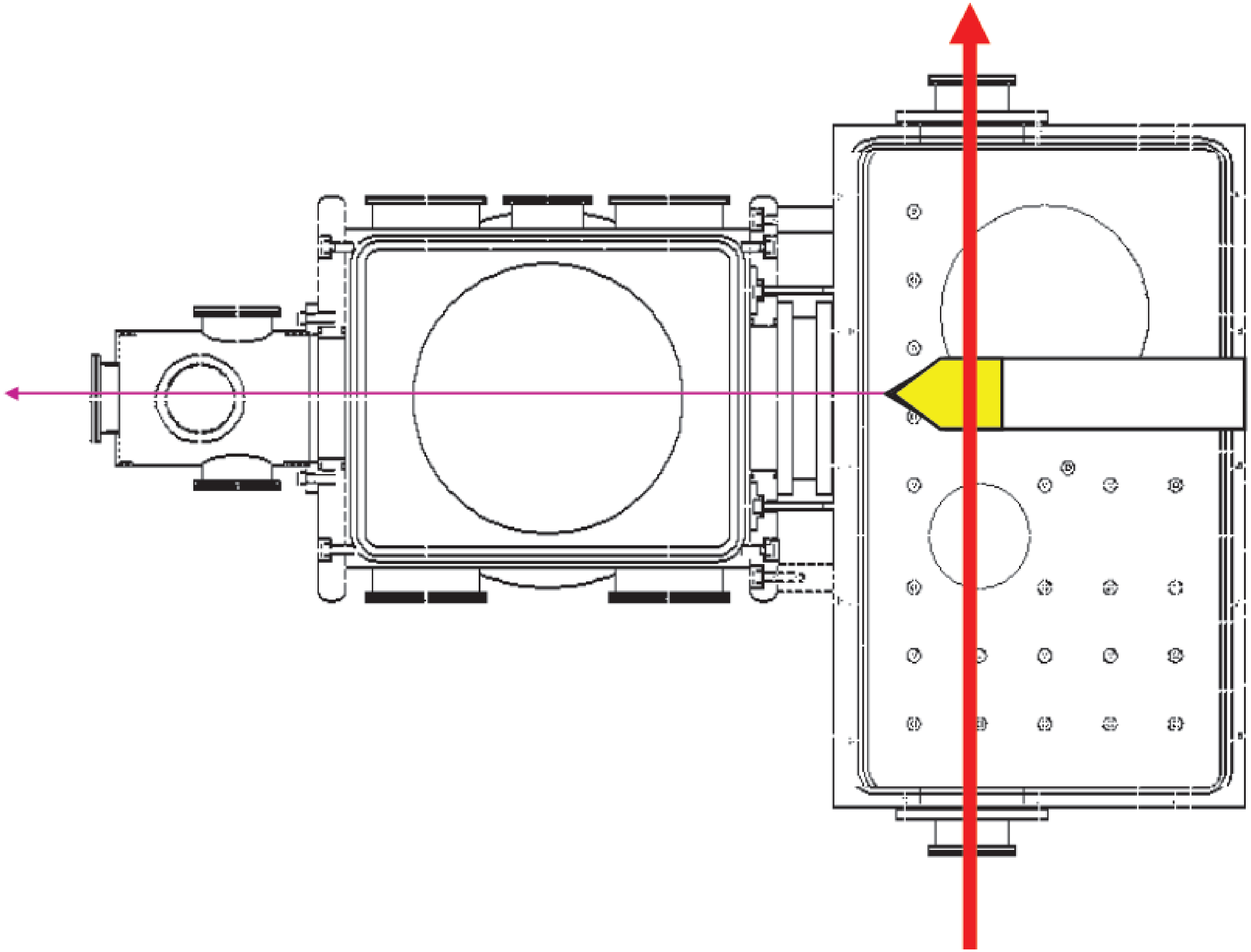
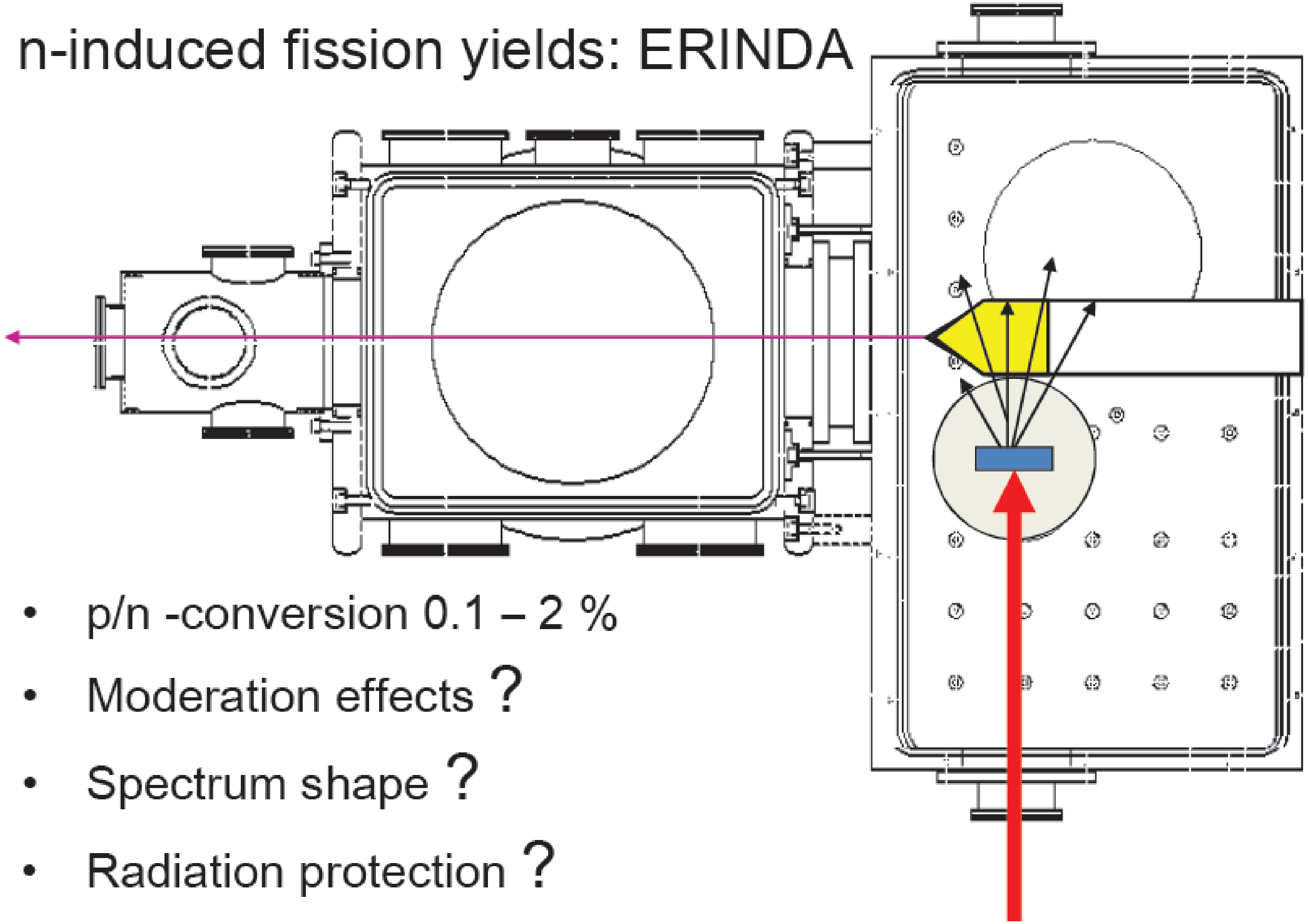
Proton induced fission



Neutron induced reactions with a converter target

- fundamental research of most neutron rich nuclei
- n-induced fission yields: ERINDA



- p/n -conversion 0.1 – 2 %
- Moderation effects ?
- Spectrum shape ?
- Radiation protection ?

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Neutron induced reactions with a converter target

- fundamental research of most neutron rich nuclei
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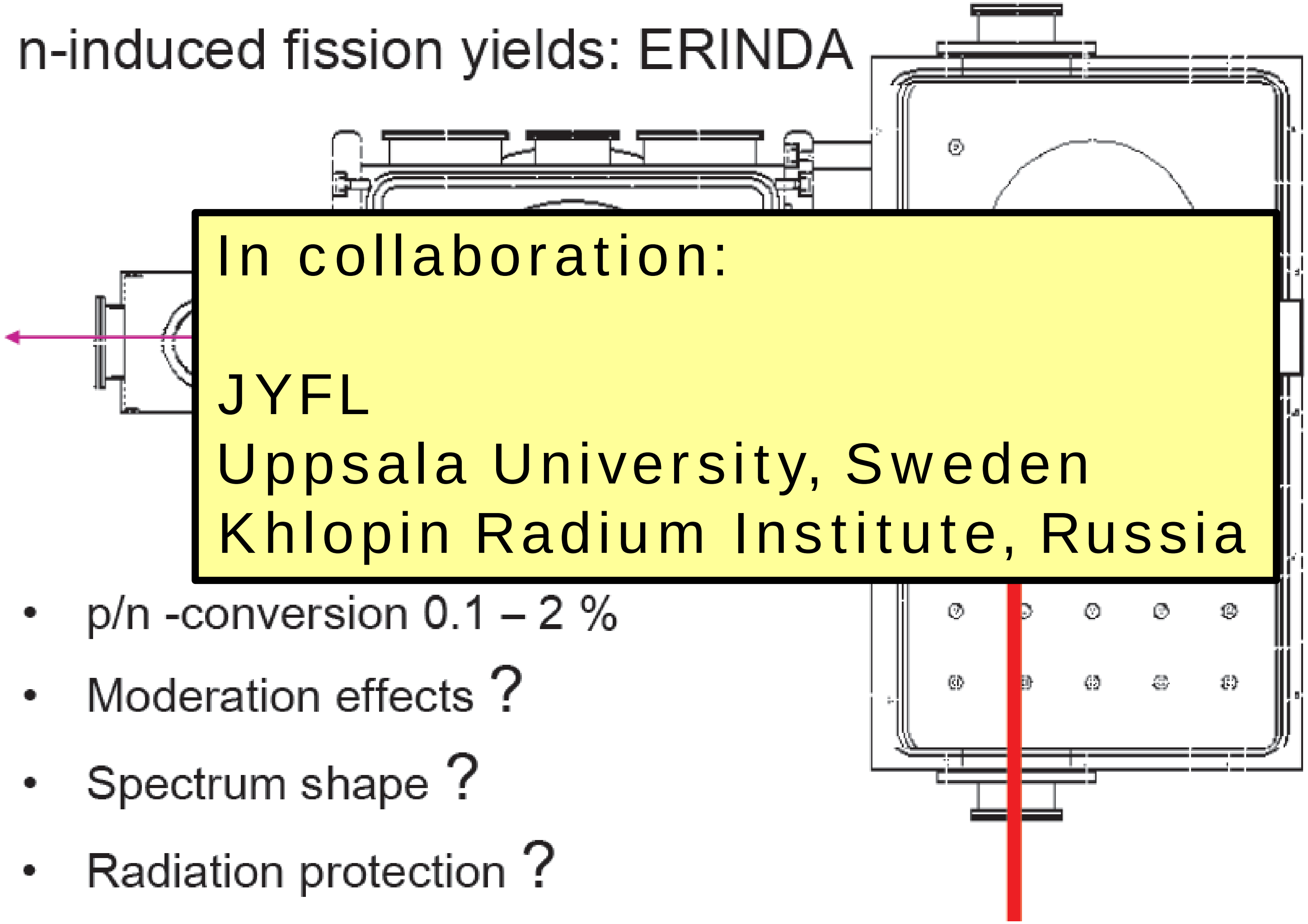
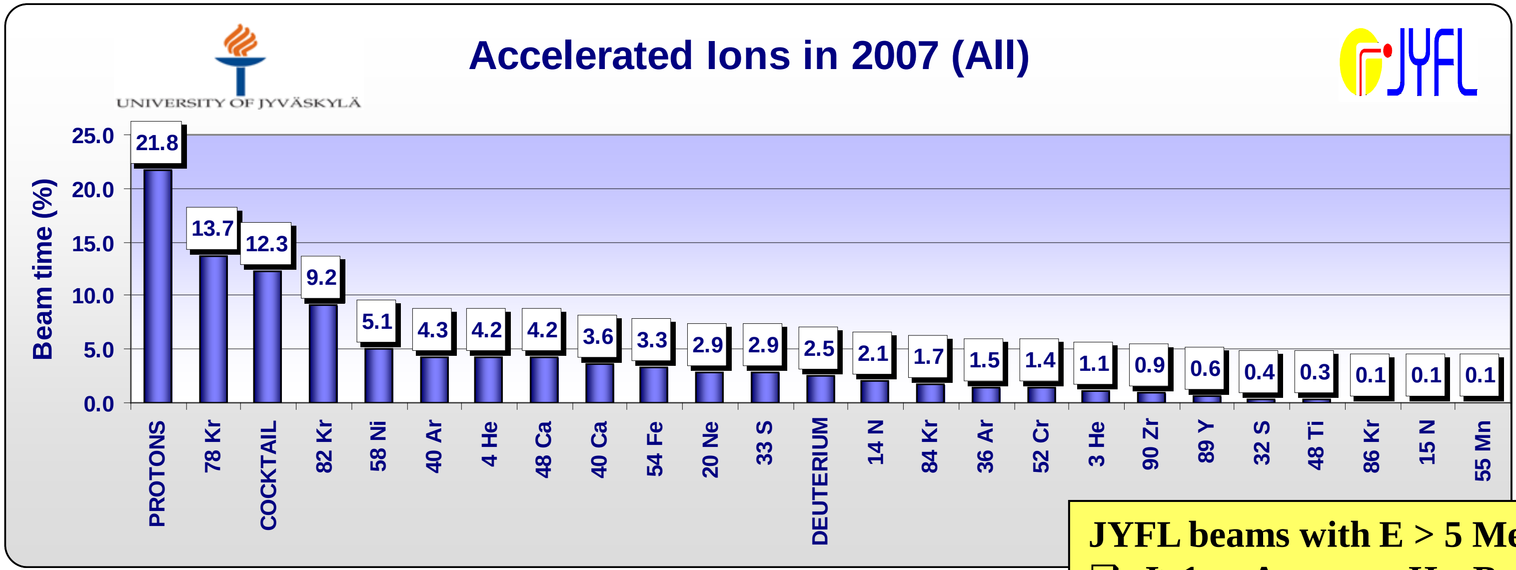


In collaboration:

JYFL
Uppsala University, Sweden
Khlopin Radium Institute, Russia

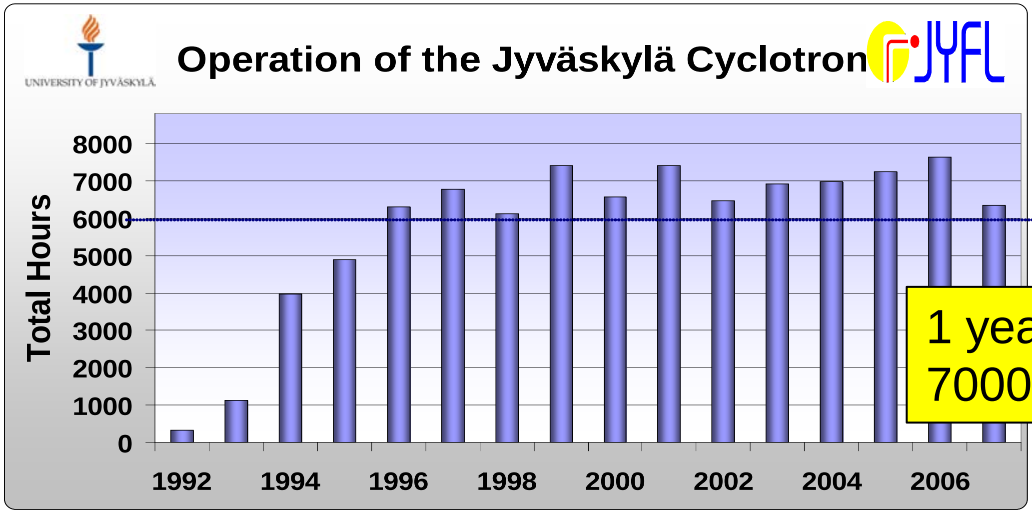
- p/n -conversion 0.1 – 2 %
- Moderation effects ?
- Spectrum shape ?
- Radiation protection ?

Operation statistics of K130 (+ 3 sources)



JYFL beams with E > 5 MeV/u

- ❑ I>1 pμA — p, He, B, C, N, O, Ar
- ❑ I>100 pnA — F, Ne, Mg, Al, Si, S, Cl, Ca, Fe, Cr, Ni, Cu, Zn, Kr
- ❑ I>10 pnA — Ti, Mn, Ge, Sr, Zr, Ru, Xe



1 year = 8760 hours

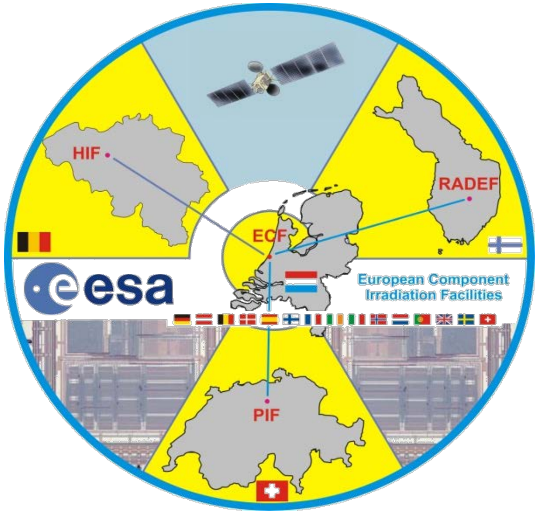
7000 hours = 875 eight-hour shifts

Radiation effects facility, RADEF

UNIVERSITY OF JYVÄSKYLÄ

Official test laboratory of ESA since 2005

ESTEC/Contract No. 18197/04/NL/CP
”Utilisation of the High Energy Heavy Ion
Test Facility for Component Radiation Studies”



- ESA beam times allocated upon request
- Non-ESA beam times on commercial basis or via PAC

22 users from 10 countries, e.g.

- **CNES, Service Environnement Spatial et Composants Nouveaux, Toulouse, France**
- **CEA, Comité Européen des Assurances, Bruyere-le-Chatel, France**
- **EADS Space Transportation Co., Bremen, Germany**
- **Alter Technology Group, Spain**
- **IDA, Institut für Datentechnik und Kommunikationsnetze, Braunschweig, Germany**
- **INTA, Instituto Nacional de Tecnica Aeroespacial, Madrid, Spain**
- **JAXA, Japan Aerospace Exploration Agency, Japan**
- **ONERA, Office National d'Etudes et de Recherches Aérospatiales, Toulouse, France**
- **Saab Ericsson Space Co., Gothenburg, Sweden**
- **Sandia National Laboratories, Albuquerque, USA**
- **Swedish Space Corporation, Stockholm, Sweden**
- **Thales Alenia Space Co., Toulouse, France**
-
-
-

Radiation effects facility, RADEF

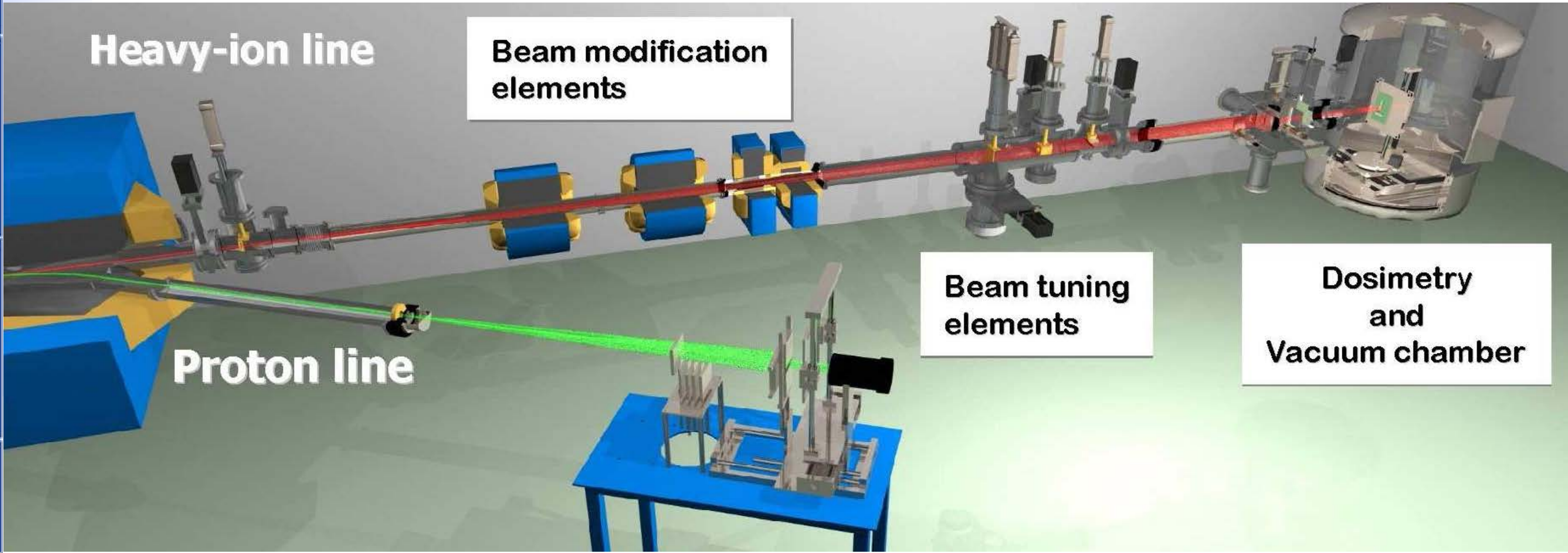
UNIVERSITY OF JYVÄSKYLÄ

Heavy-ion line

- Cocktail species N, Ne, Si, Ar, Fe, Kr, Xe
- Energy 9.3 MeV/u, i.e. 1.2 GeV for Xe
- LET from 6 to 69 MeV/(mg/cm^2) and range 90 to 200 μm in silicon
- Irradiations both in vacuum and air

Proton line

- Energies from few MeV to 60 MeV, adjusted by the degraders
- Irradiations in air



Specifications of beams

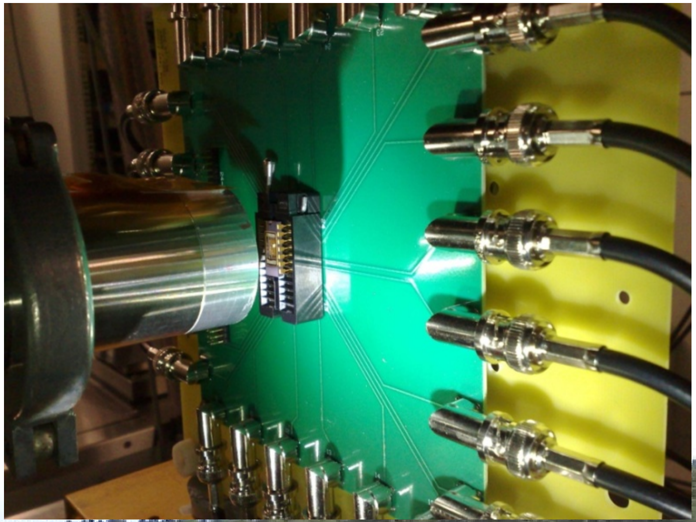
UNIVERSITY OF JYVÄSKYLÄ

Heavy ions

- High penetration cocktail @ **9.3 MeV/amu**
- Low energy coctail @ **3.6 MeV/amu**
- Other beam energies at request
- Ion change time: **few min** (within the cocktail)
- Flux: **0 – 10^6** ions/sec·cm^2 (depending on the ion)
- Spot size: 2x2 cm^2 (up to 7x7cm^2 demonstrated in vacuum)
- **i.e. wide beam only**
- Homogeneity: ±10%
- In **vacuum** and in **air**

Protons

- Energy: 0 – **60 MeV**
- Flux: 100 – 10^{12} p/sec·cm^2
- Spot size: ~10 cm^2
- Homogeneity: ±10%
- DUT mounting: standard plate (same in the heavy ion line)

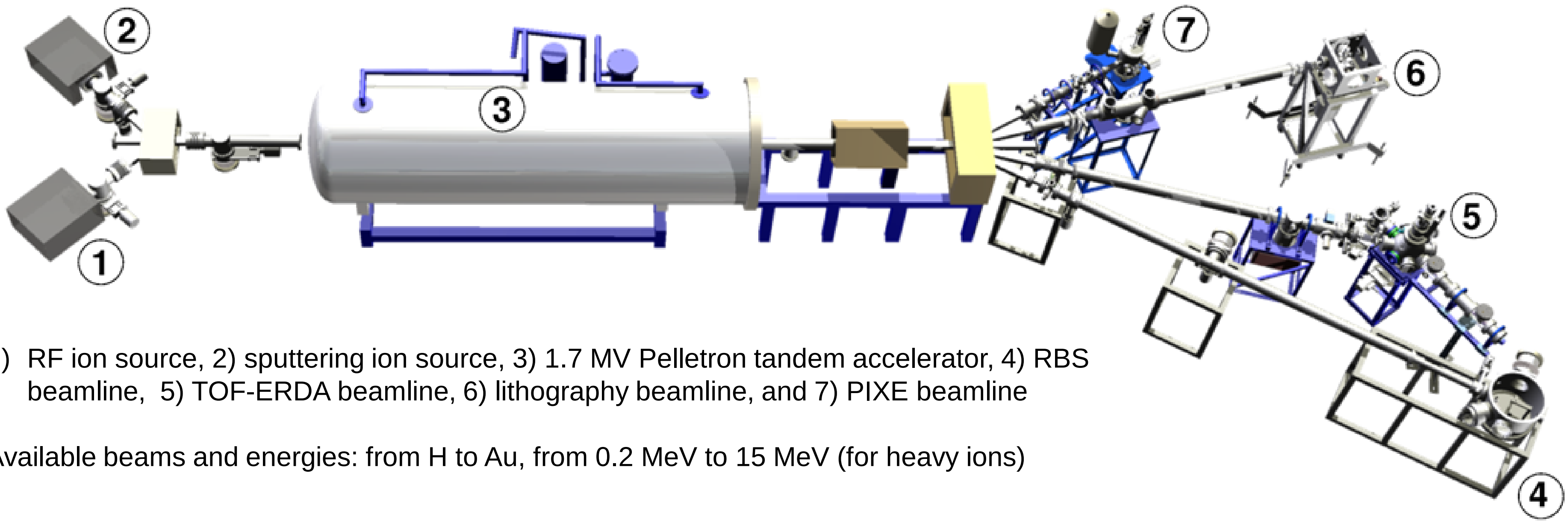


Accelerator based materials physics

1.7 MV Pelletron tandem-accelerator
donated by VTT in Sep. 2006
First beam Feb. 2007

Materials physics at Pelletron Laboratory

- Main research fields: Development and application of ion beam techniques for characterization and modification of surfaces, thin films and biomedical samples
- Key equipment:
  - 1.7 MV Pelletron accelerator, in Jyväskylä since 2006
  - Profilometer, scanning electron microscope, vacuum oven, 2 keV ion gun etc.



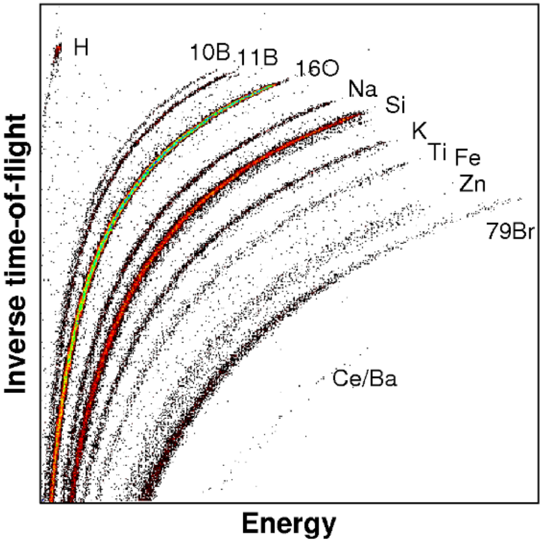
1) RF ion source, 2) sputtering ion source, 3) 1.7 MV Pelletron tandem accelerator, 4) RBS beamline, 5) TOF-ERDA beamline, 6) lithography beamline, and 7) PIXE beamline

Available beams and energies: from H to Au, from 0.2 MeV to 15 MeV (for heavy ions)

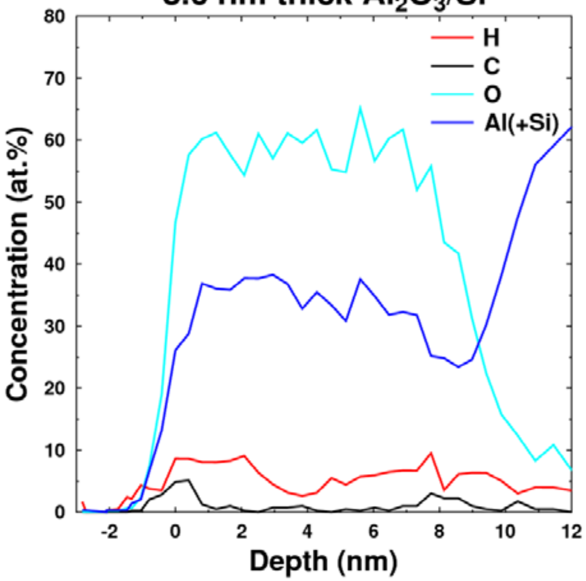
Possibilities at Pelletron Laboratory

- Ion beam analysis
  - Heavy ion time-of-flight elastic recoil detection analysis (TOF-ERDA)
    - Quantitative depth profiling of all elements, including hydrogen, down to level of 0.1 at.% or below
    - Different isotopes can be separated <50 u
    - With low energy incident ions depth resolution ~1nm at the surface, with higher energies profiling upto hundreds of nanometers
  - Rutherford Backscattering Spectrometry (RBS)
    - Sensitive and standard technique for depth profiling of heavy elements on a light substrate
  - Particle Induced X-ray Emission (PIXE)
    - Sensitive technique for measuring sample composition for elements heavier than Al without depth information
    - Proton microprobe with beam spot <10 µm will be installed in 2011
- Ion beams for irradiation/detector testing
  - Direct quasi-monoenergetic direct or scattered beams are available for irradiation and detector testing in the energy range of 0.2-15 MeV (highest energies for heavy ions)

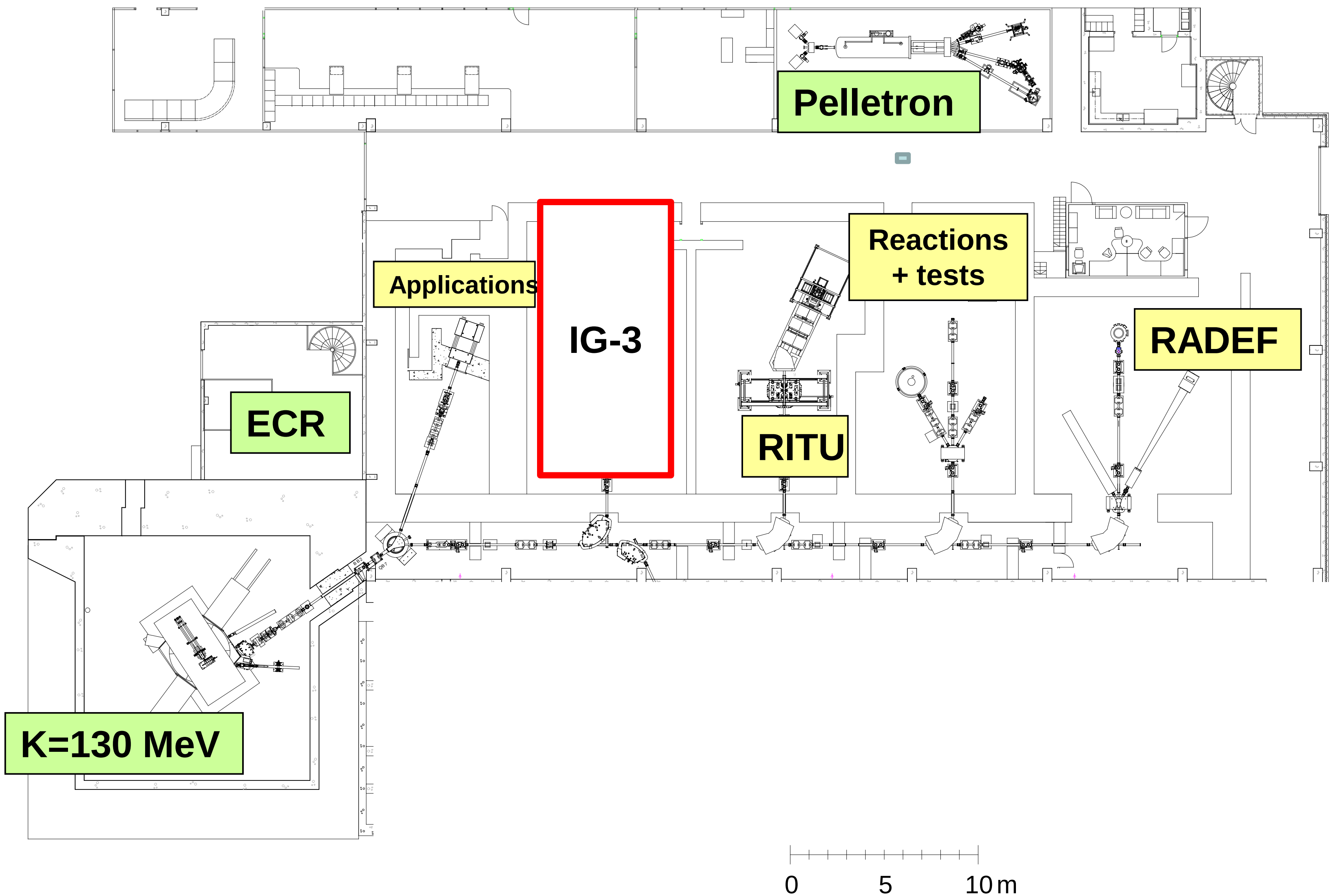
Beam 10. 2 MeV ^{79}Br, boroslicate sample



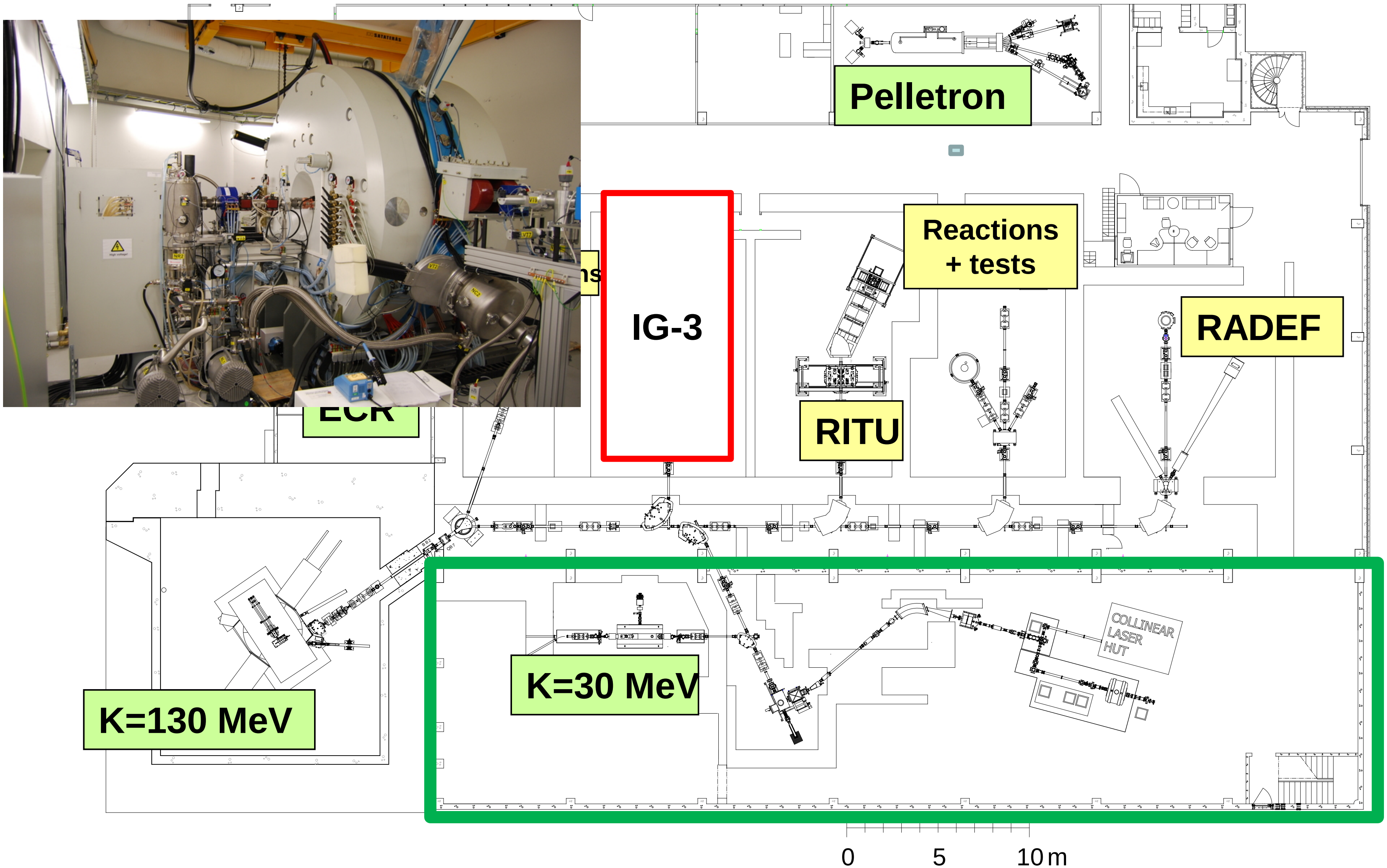
8.6 nm thick Al_2O_3/Si



JYFL Accelerator Laboratory upgrade



JYFL Accelerator Laboratory upgrade



2009-10

MCC30/15 specifications:

Magnet structure:

Four sectors, pole diameter 150 cm

<T> = 1.25 T, coil power 12 kW

Weight over 50 tons

RF-system:

Frequency 40.68 MHz and dee voltage 40 kV generating 25 kW output power

Power consumption:

<120 kW / < 8 kW (Power on / Standby)

Ion source:

External CUSP-type source delivering up to 0.7/1.5 mA

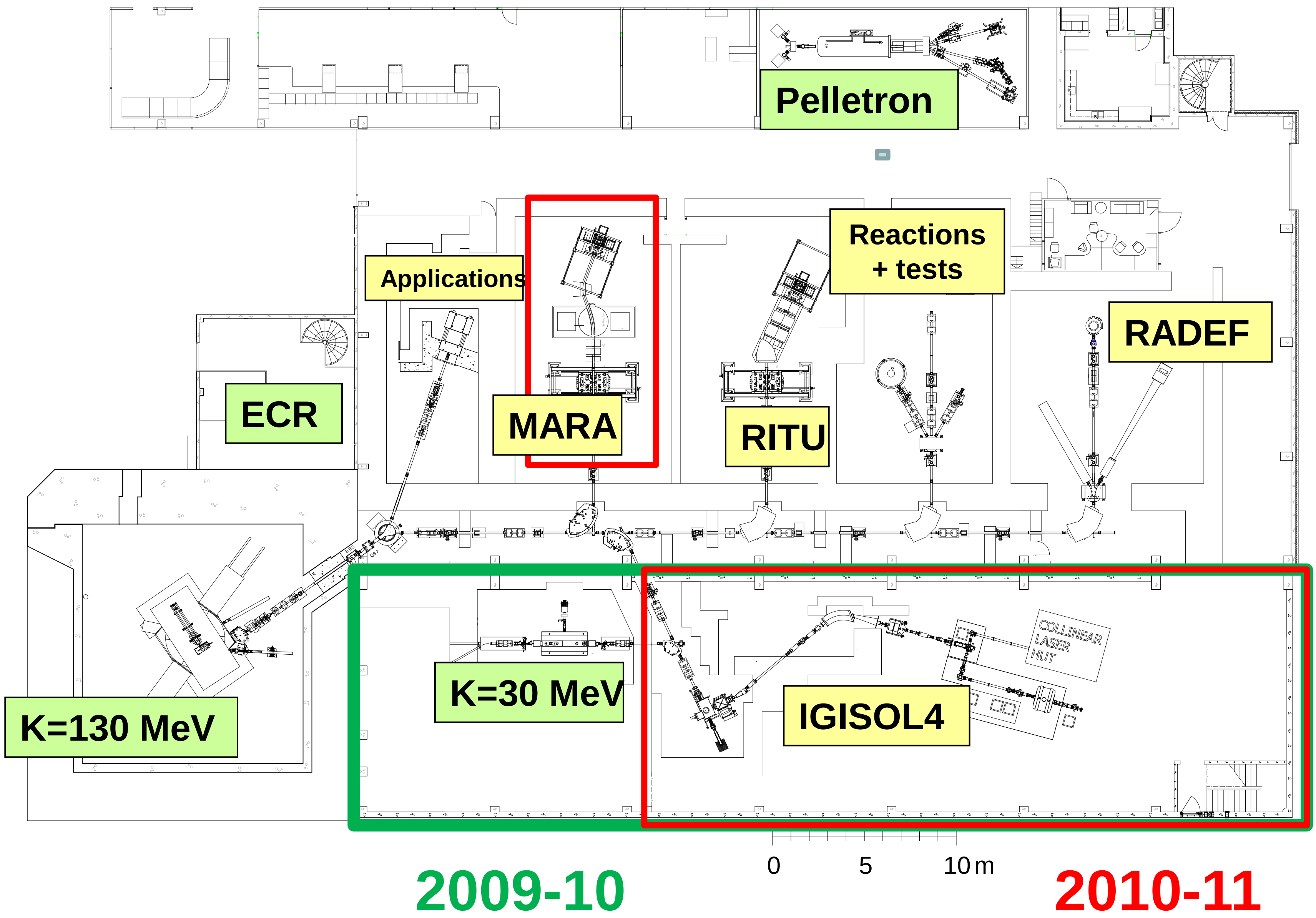
Ion beams: Protons (H^-) 18-30 MeV, 100 μA [3kW]
Deuterons (d^-) 9-15 MeV, 50 μA

Beams specifications reached (with pulsed beam) !

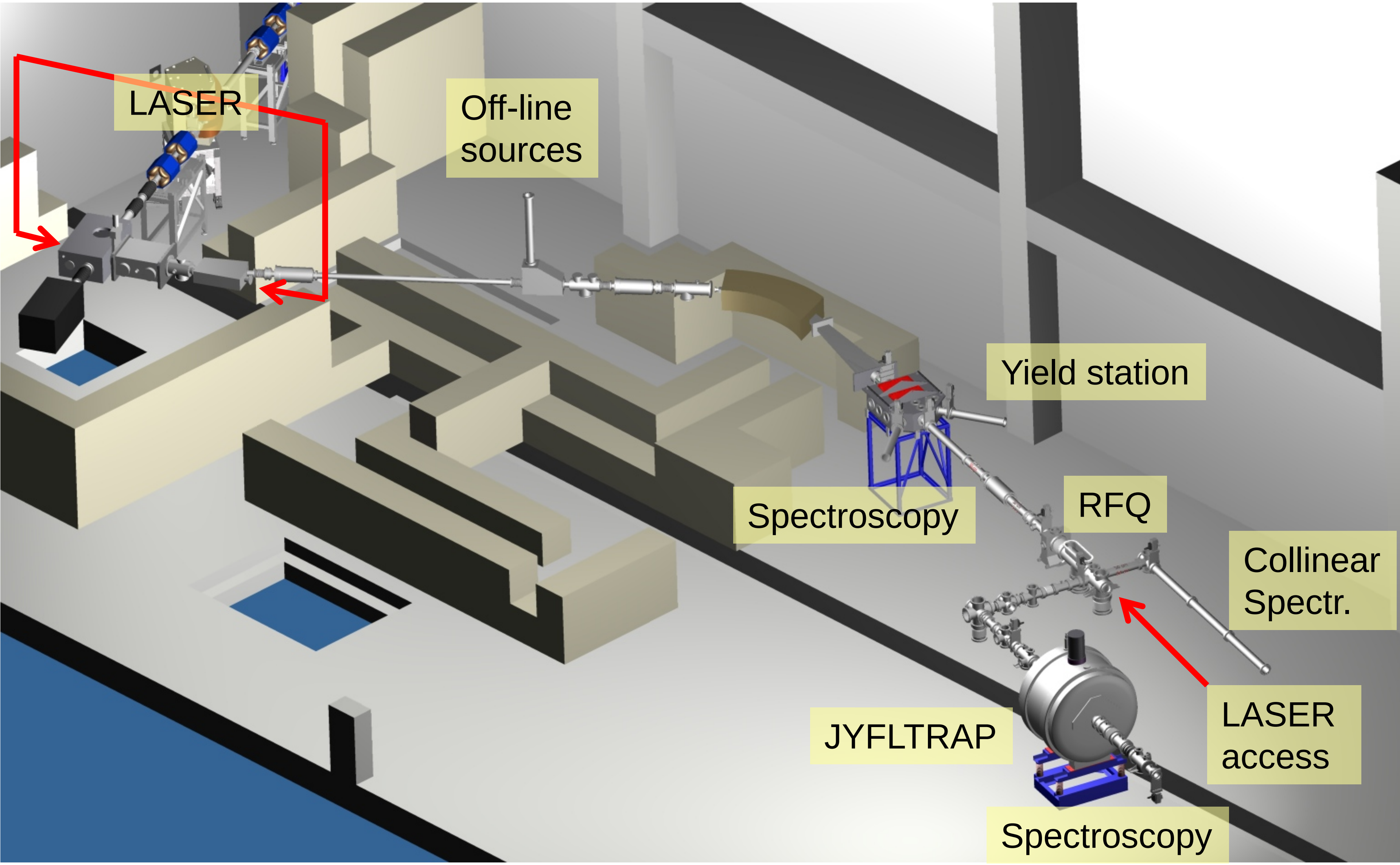
New ion source to be developed

➔ higher intensity (~300 μA [10 kW]) and longer lifetime of the cathode

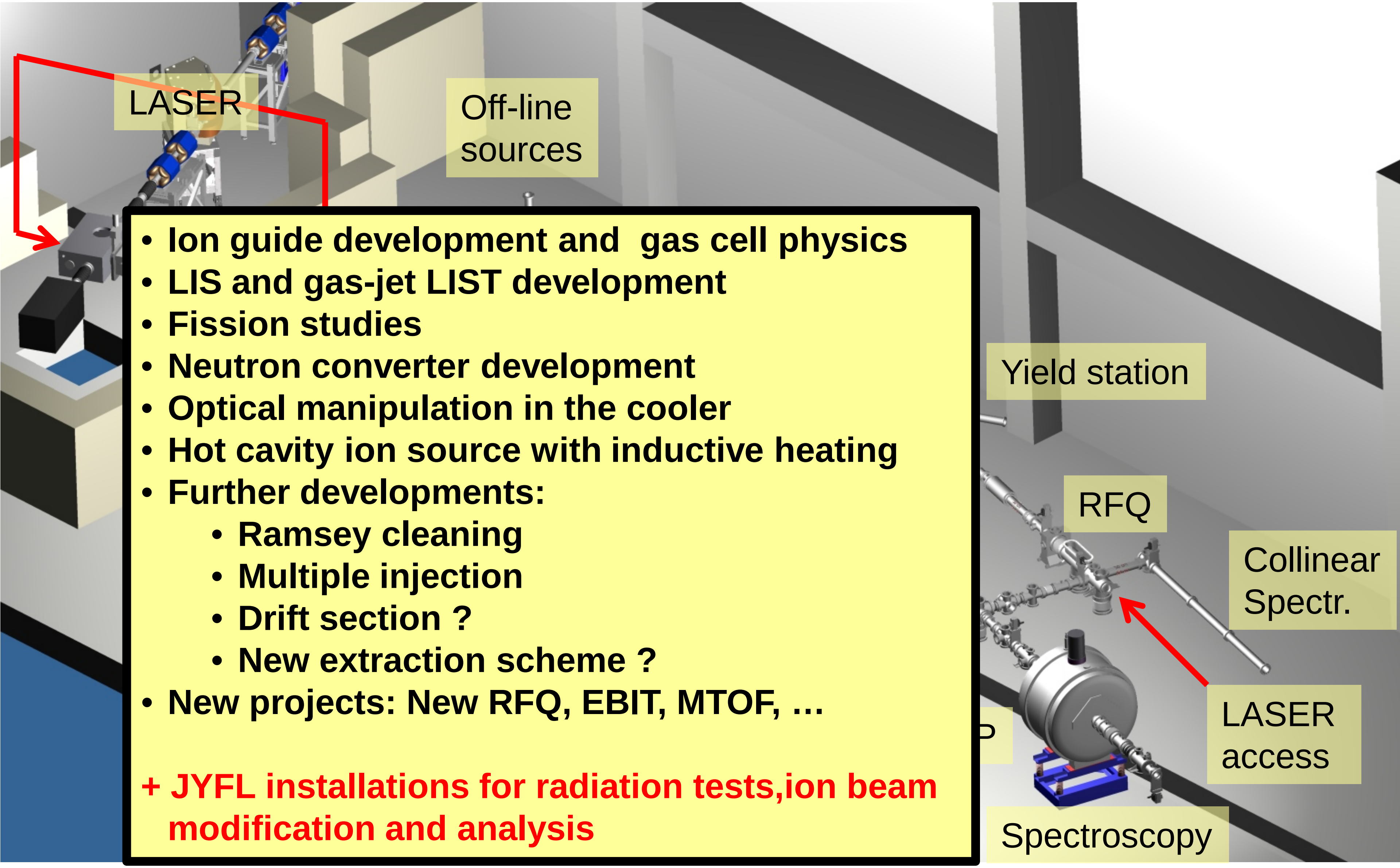
JYFL Accelerator Laboratory upgrade



IGISOL4


LASER
Off-line
sources
Yield station
Spectroscopy
RFQ
Collinear
Spectr.
JYFLTRAP
LASER
access
Spectroscopy

IGISOL4 + EURISOL-NET



- **Ion guide development and gas cell physics**
- **LIS and gas-jet LIST development**
- **Fission studies**
- **Neutron converter development**
- **Optical manipulation in the cooler**
- **Hot cavity ion source with inductive heating**
- **Further developments:**
  - **Ramsey cleaning**
  - **Multiple injection**
  - **Drift section ?**
  - **New extraction scheme ?**
- **New projects: New RFQ, EBIT, MTOF, …**

+ JYFL installations for radiation tests,ion beam modification and analysis

Ari Jokinen
E-mail: ari.s.jokinen@jyu.fi

http://www.jyu.fi/science/laitokset/fysiikka/en/research/accelerator