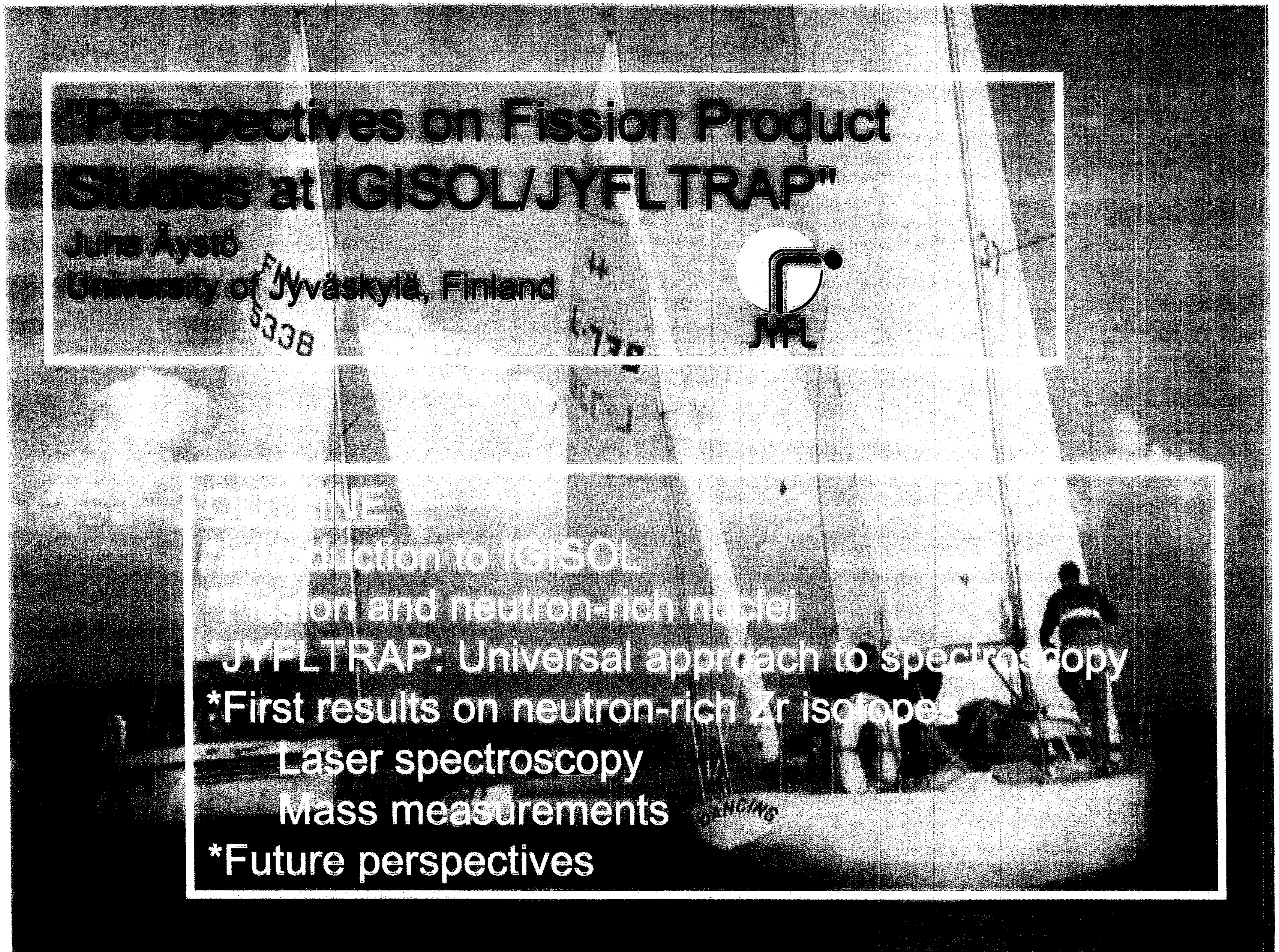
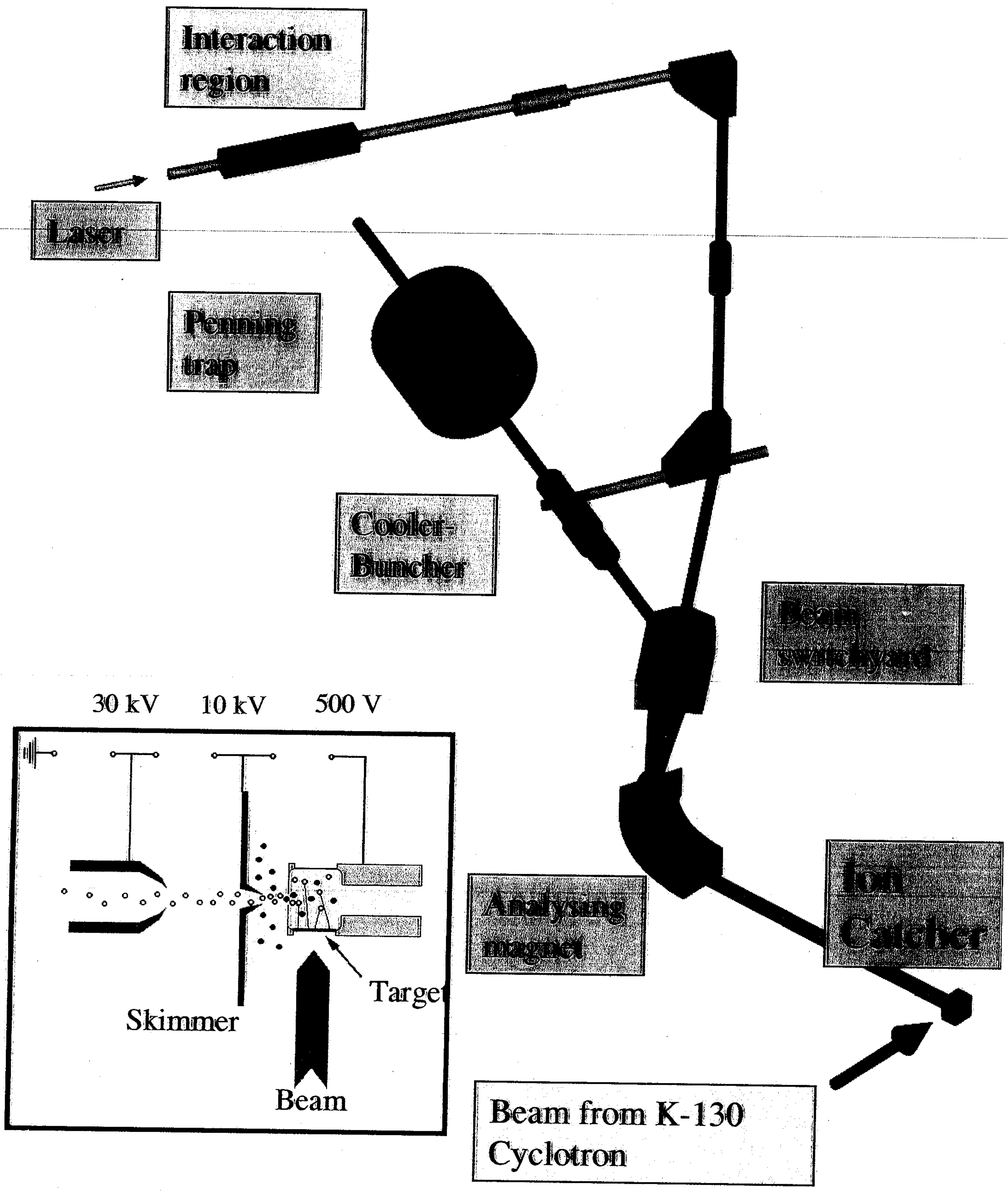
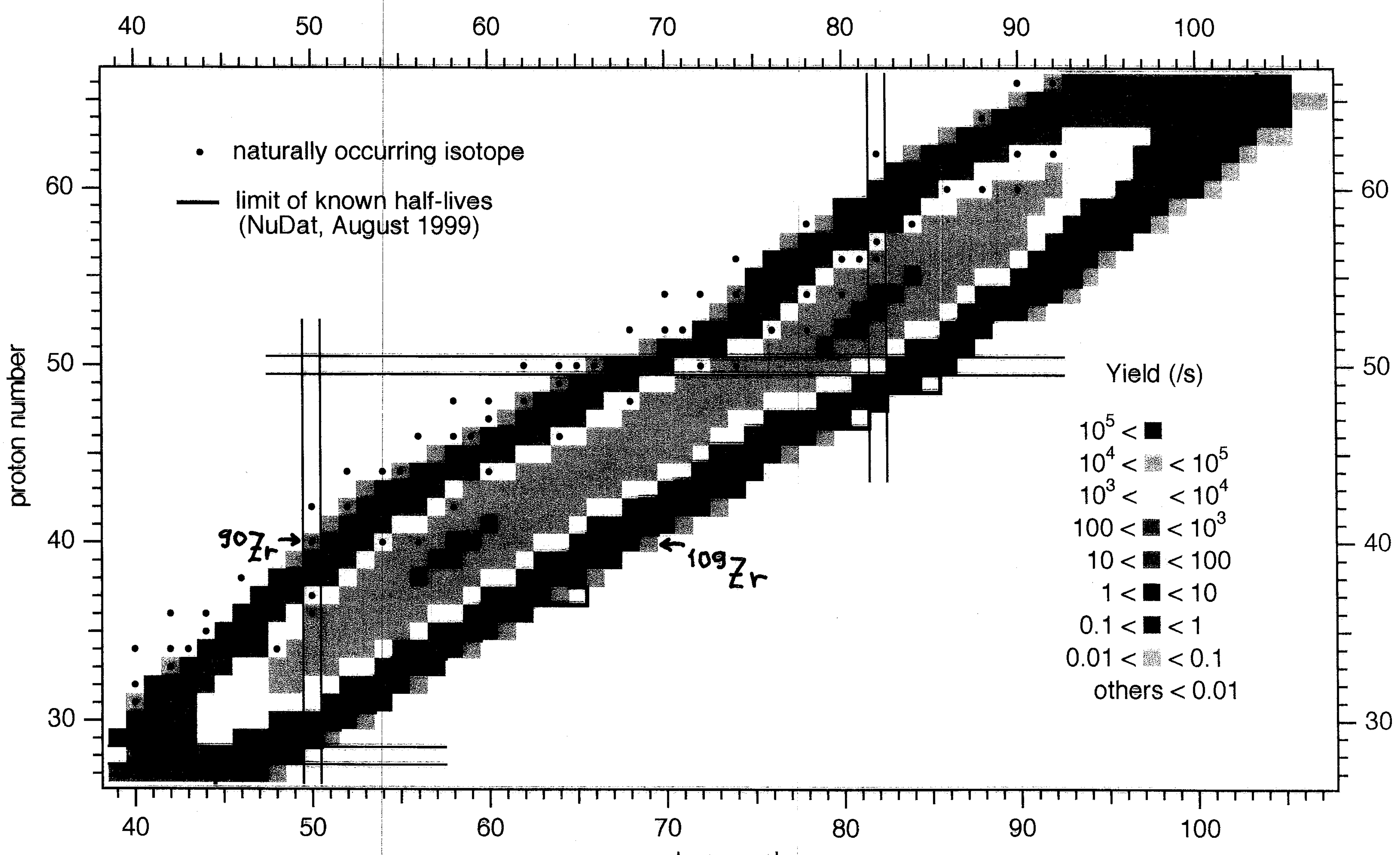

"Perspectives on Fission Product
Studies at IGISOL/JYFLTRAP"
Juha Äystö
University of Jyväskylä, Finland
JYFL
OUTLINE
*Introduction to IGISOL
*Fission and neutron-rich nuclei
*JYFLTRAP: Universal approach to spectroscopy
*First results on neutron-rich Zr isotopes
Laser spectroscopy
Mass measurements
*Future perspectives

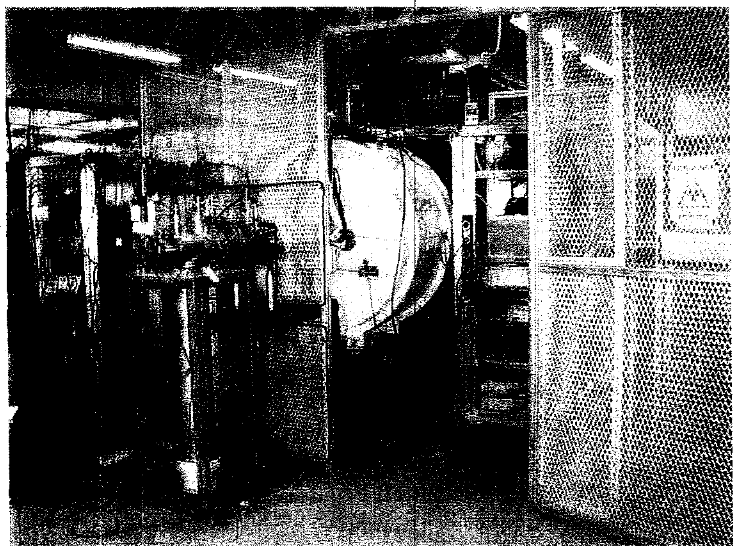
IGISOL lay out



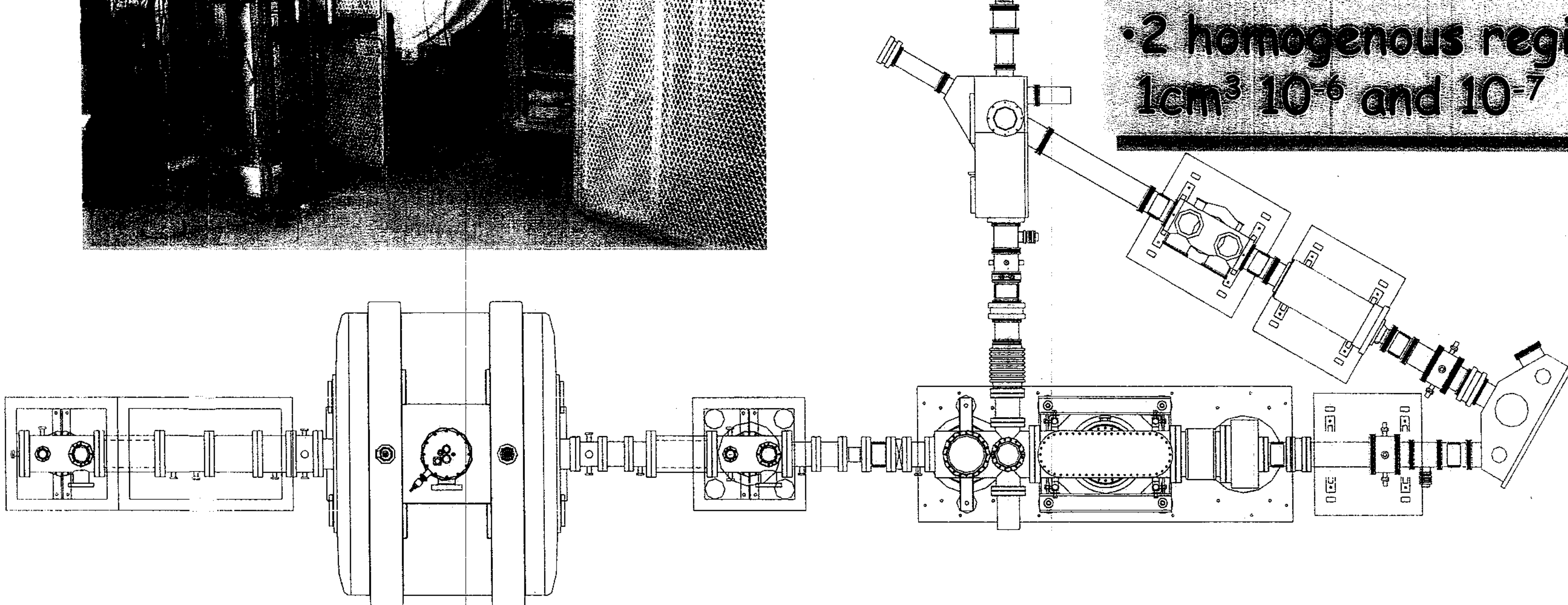
Fission product yields at IGISOL
25 MeV p + ^{238}U



JYFLTRAP LAYOUT



- 7T superconducting magnet
- Magnex Scientific Ltd
- 160mm warm bore
- 2 homogenous regions $1cm^3$ 10^{-6} and 10^{-7}

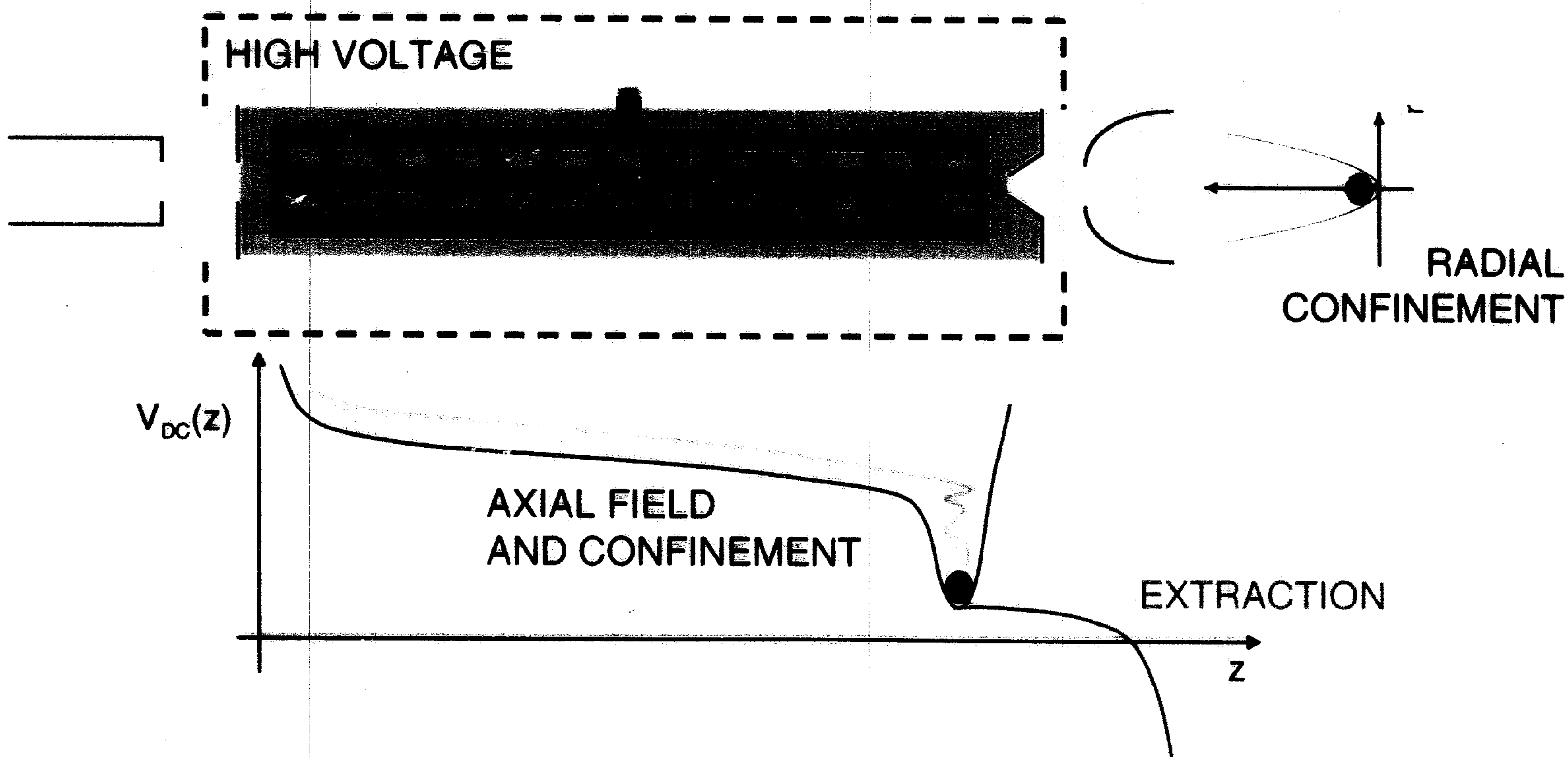


Ions in

Double Penning trap
Trap 1 $\Delta M/M < 10^{-5}$
Trap 2 $\Delta M/M < 10^{-6}$

RFQ cooler-buncher trap
0.5 eV / 10 μs

RFQ ion cooler and buncher



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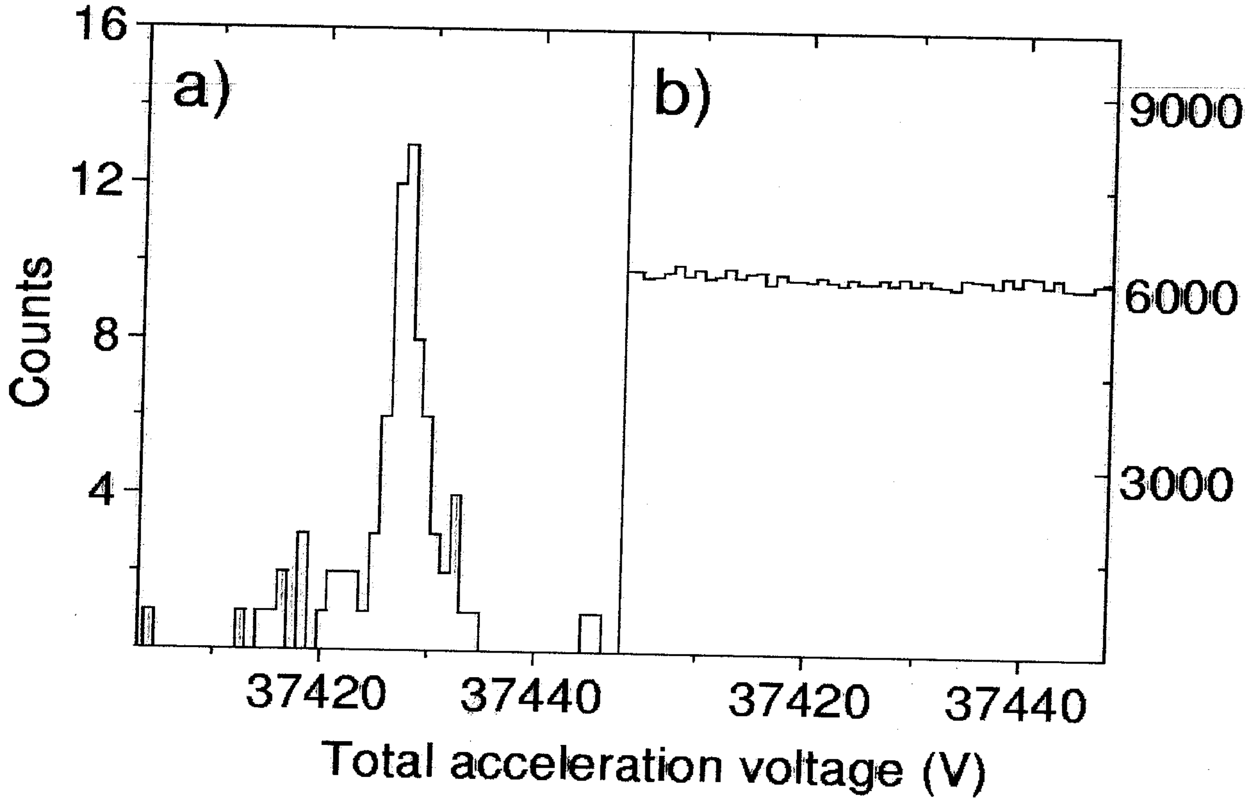
Resonance fluorescence spectrum for ^{174}Hf
$d\,s^2\,{}^2D_{3/2}$ - $d\,s\,p_2\,D_{5/2}$ transition

A. Nieminen et al. Phys. Rev. Lett. 88(2002)094801

Ion rate 1300 s-1
t_{meas}=25 min

a) gated
bunch length 28 µs
accumulation time 500 ms
b) ungated

[redacted]



PRINCIPLE

1. Axial oscillation

$$\omega_z = \sqrt{\frac{qV_0}{md^2}}$$

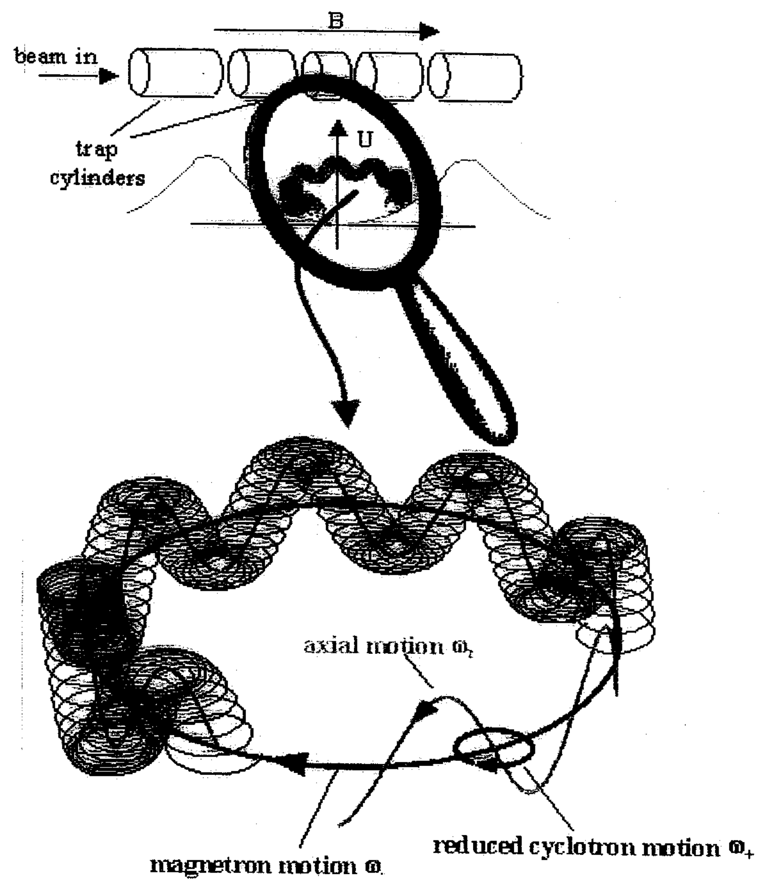
2. Magnetron motion (slow):

$$\omega_- = \frac{\omega_c}{2} - \sqrt{\frac{\omega_c^2}{4} - \frac{\omega_z^2}{2}}$$

3. Cyclotron motion (fast):

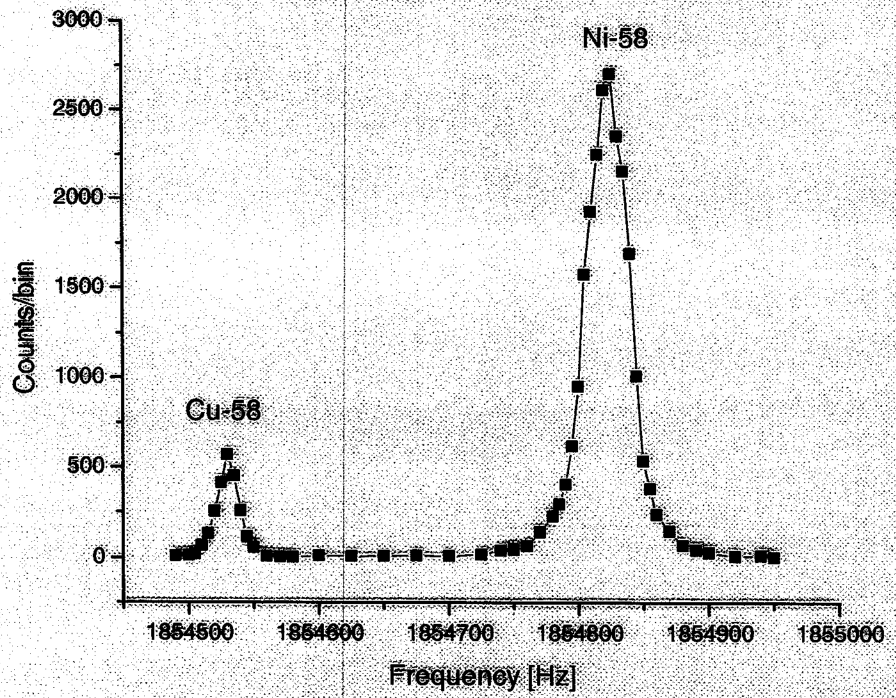
$$\omega_+ = \frac{\omega_c}{2} + \sqrt{\frac{\omega_c^2}{4} - \frac{\omega_z^2}{2}}$$

$$\omega_+ + \omega_- = \omega_c = \frac{q}{m} B$$



$$\omega_+ + \omega_- = \omega_c = \frac{q}{m} \cdot B$$

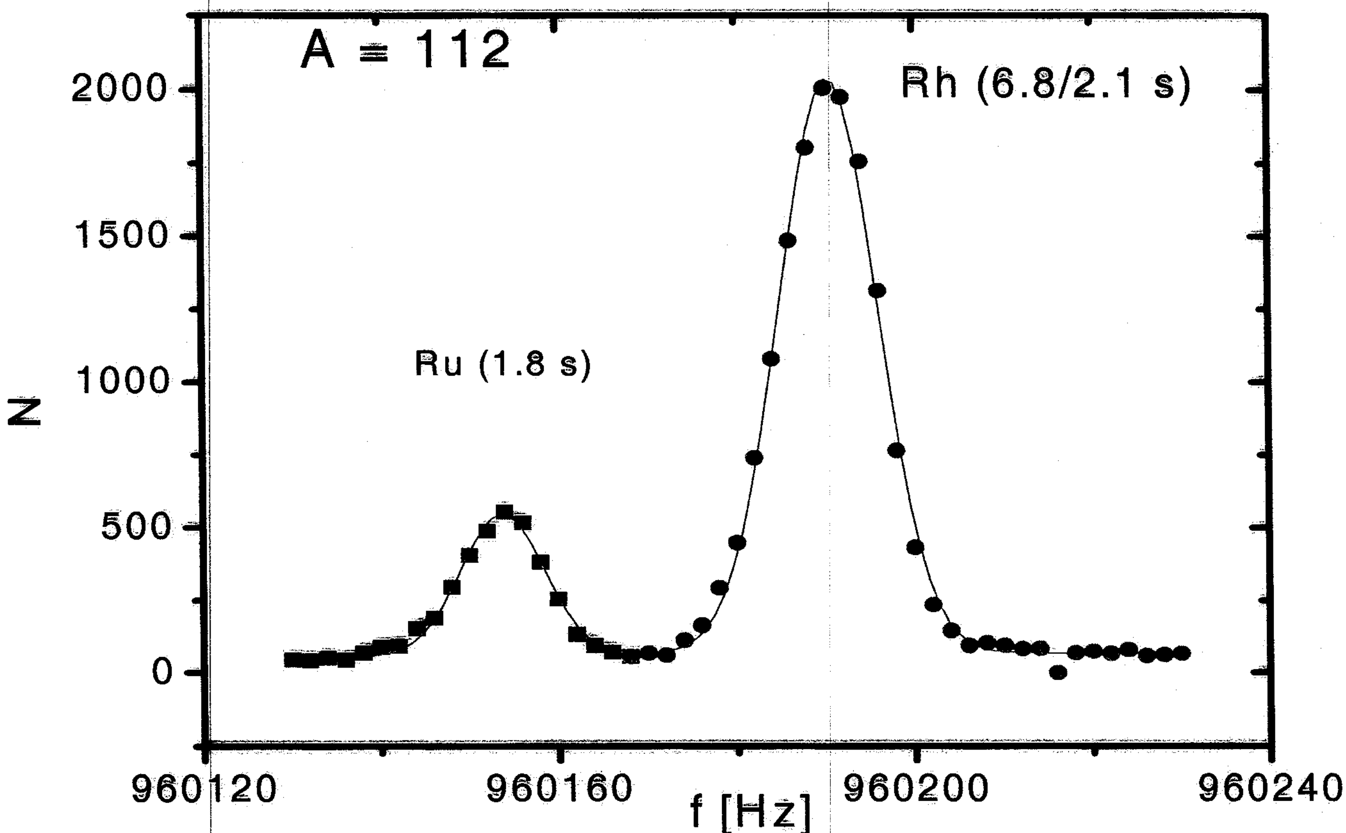
First radioactive ^{58}Cu ions



- Total cycle time 450ms
- p = 0.045 mbar
- Cooling time 330 ms
- ω_- 15ms / 115mV
- ω_C 90ms / 200mV

- FWHM = 41 Hz
- R = 45000

Separation of ^{112}Ru and ^{112}Rh



$\Delta M/M_{FWHM} = 1.4\ 10^{-5} \Rightarrow 1.47$ MeV

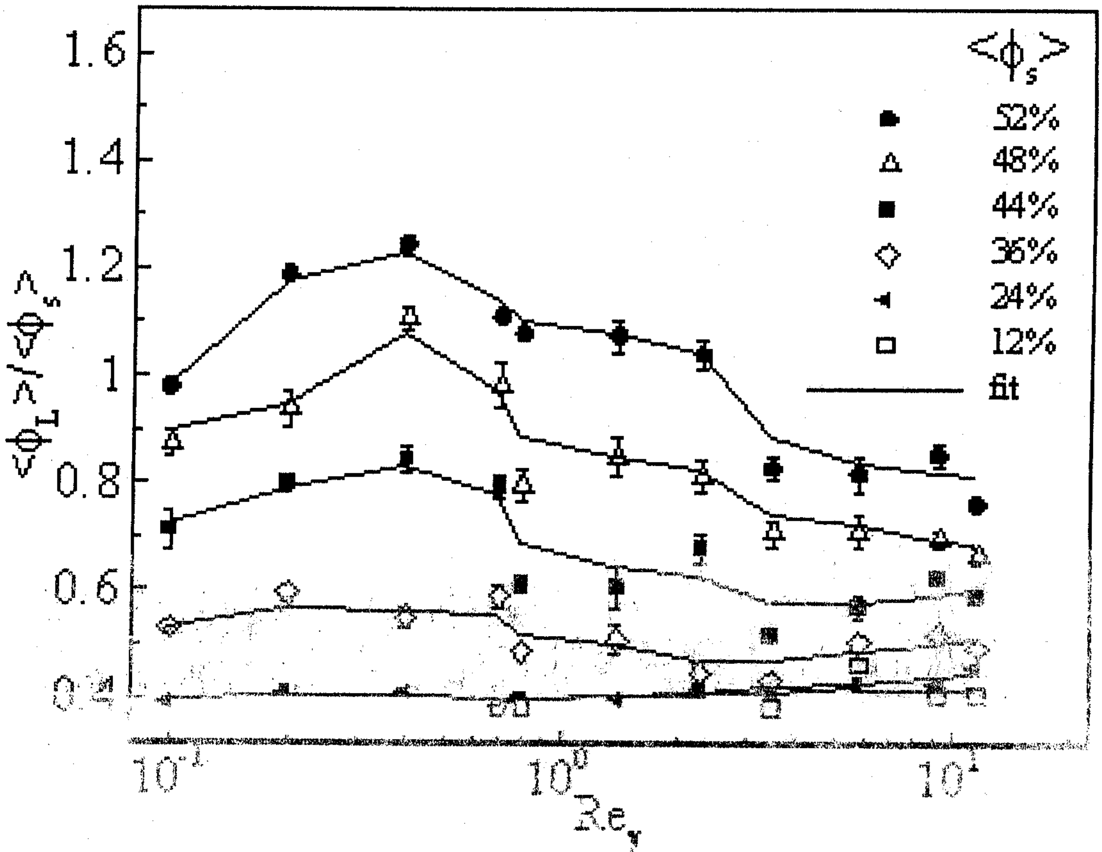
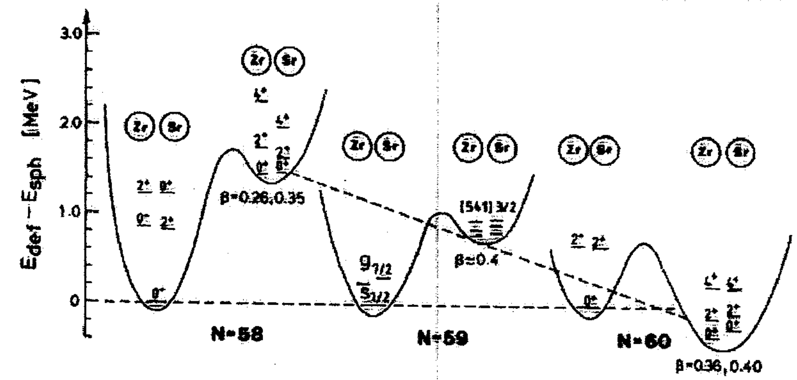


Fig. 10a Variation of layering index $\langle\phi_L\rangle/\langle\phi_s\rangle$ as a function of particle Reynolds number for various area fractions.

First mass measurements with the purification trap

- Capturing efficiency of the trap 60%
- Transmission between 30-35 %
- Total Efficiency 20%
- Mass accuracy better than 10^{-6}

Structure of neutron-rich Zr isotopes



"Ground state changes from spherical to deformed via coexistence"

See, G. Lhersonneau et al., Phys. Rev. C49(1994)1379 & refs.

Further studies:

Beta decay experiments at IGISOL on ^{97}Zr, ^{99}Zr, ^{103}Zr

Prompt ff – γ ray coincidence experiments on

^{99}Zr: W. Urban et al., Eur. Phys. J. A16(2003)11

^{98,99}Zr: Nucl. Phys. A689(2001)605

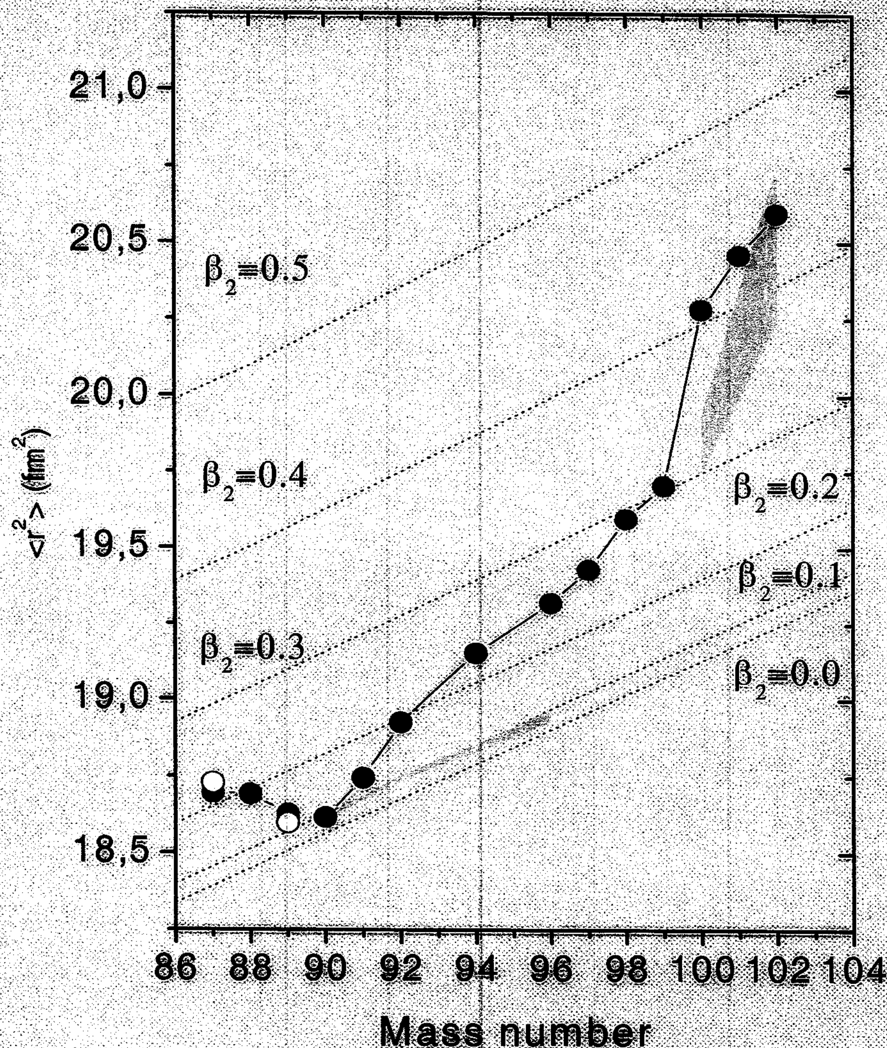
^{100}Zr. C.Y. Wu et al., Phys. Lett. B541(2002)59

Collinear laser spectroscopy at IGISOL

$^{96\text{-}102}$Zr: P. Campbell et al., Phys. Rev. Lett. 89(2002)082501

However:

No reliable direct mass measurements existed so far!



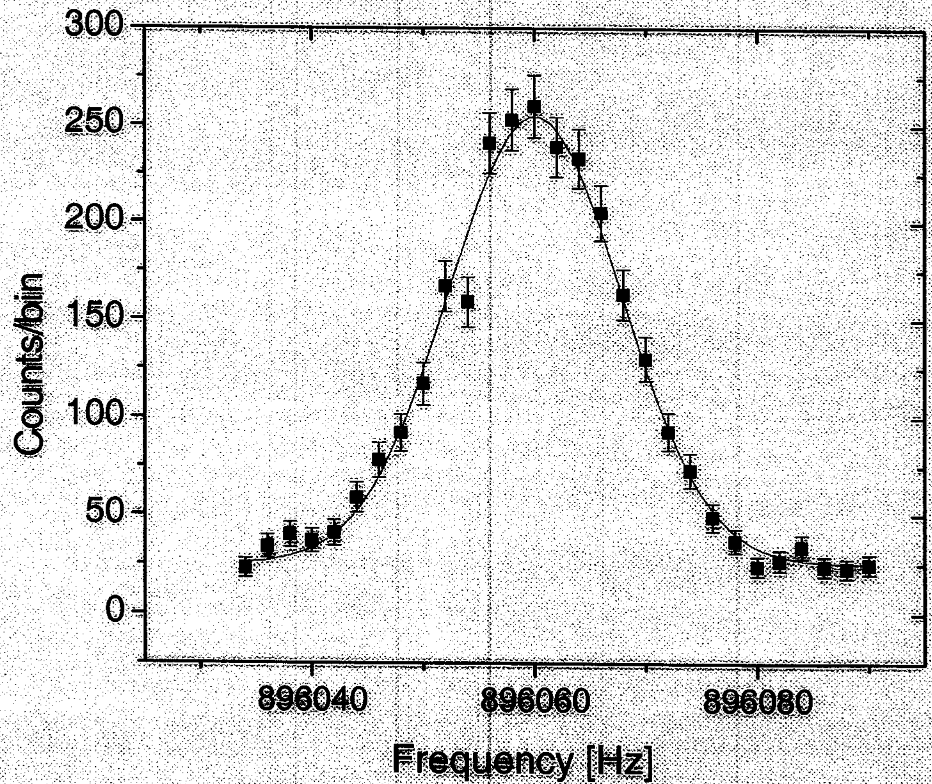
Deformation of Zr isotopes deduced from:

- Charge radii (points)
- B(E2) (shade)

P. Campbell, et al.
Phys. Rev. Lett. 89(2002)082501

ZrO^+ mass measurements

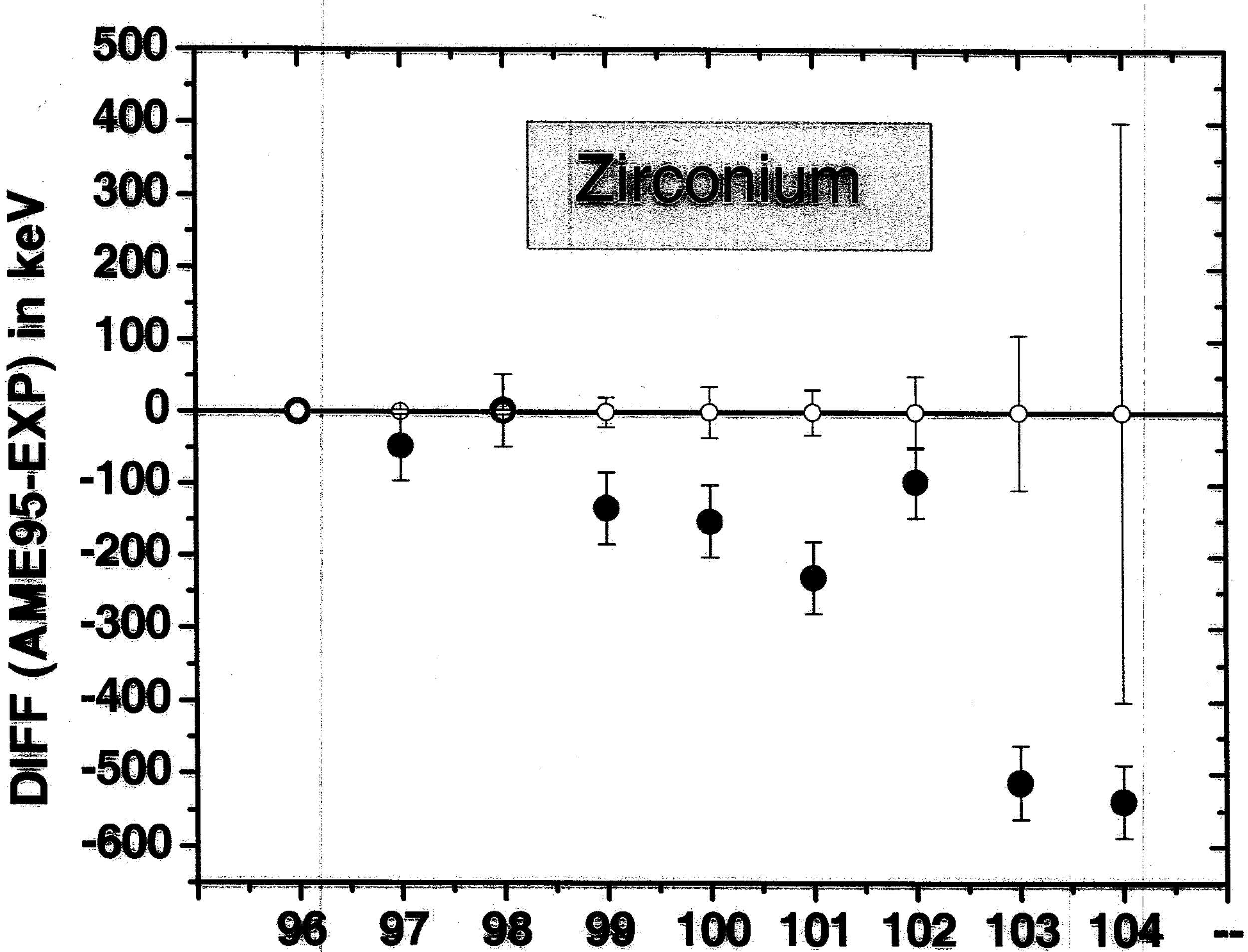
$^{104}Zr\ T_{1/2} = 1.2$ s



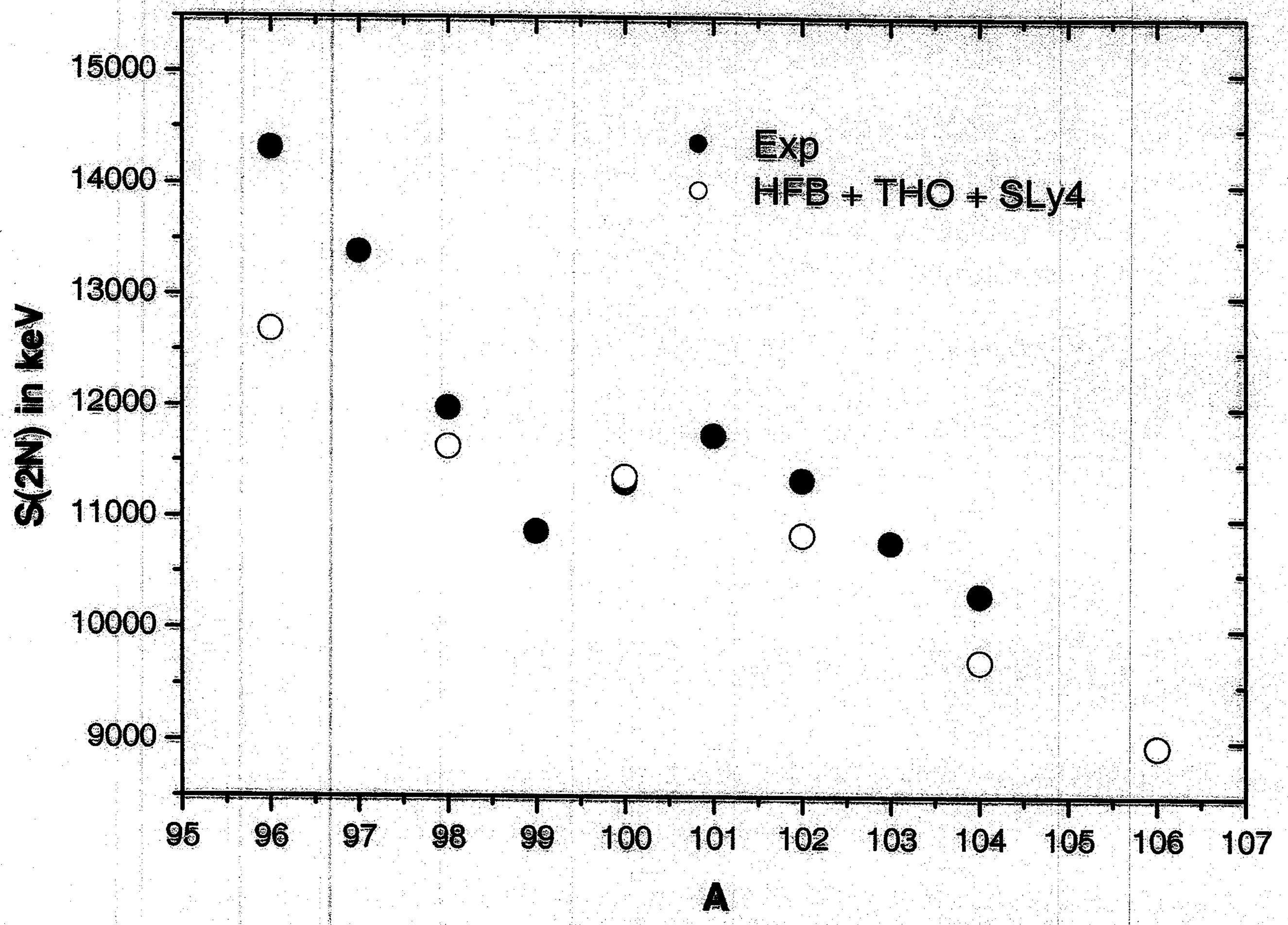
- Total cycle time 450ms
- p = 0.03 mbar
- Cooling time 330 ms
- ω_- 15ms / 160mV
- ω_C 90ms / 190mV

- FWHM = 18 Hz
- R = 45000

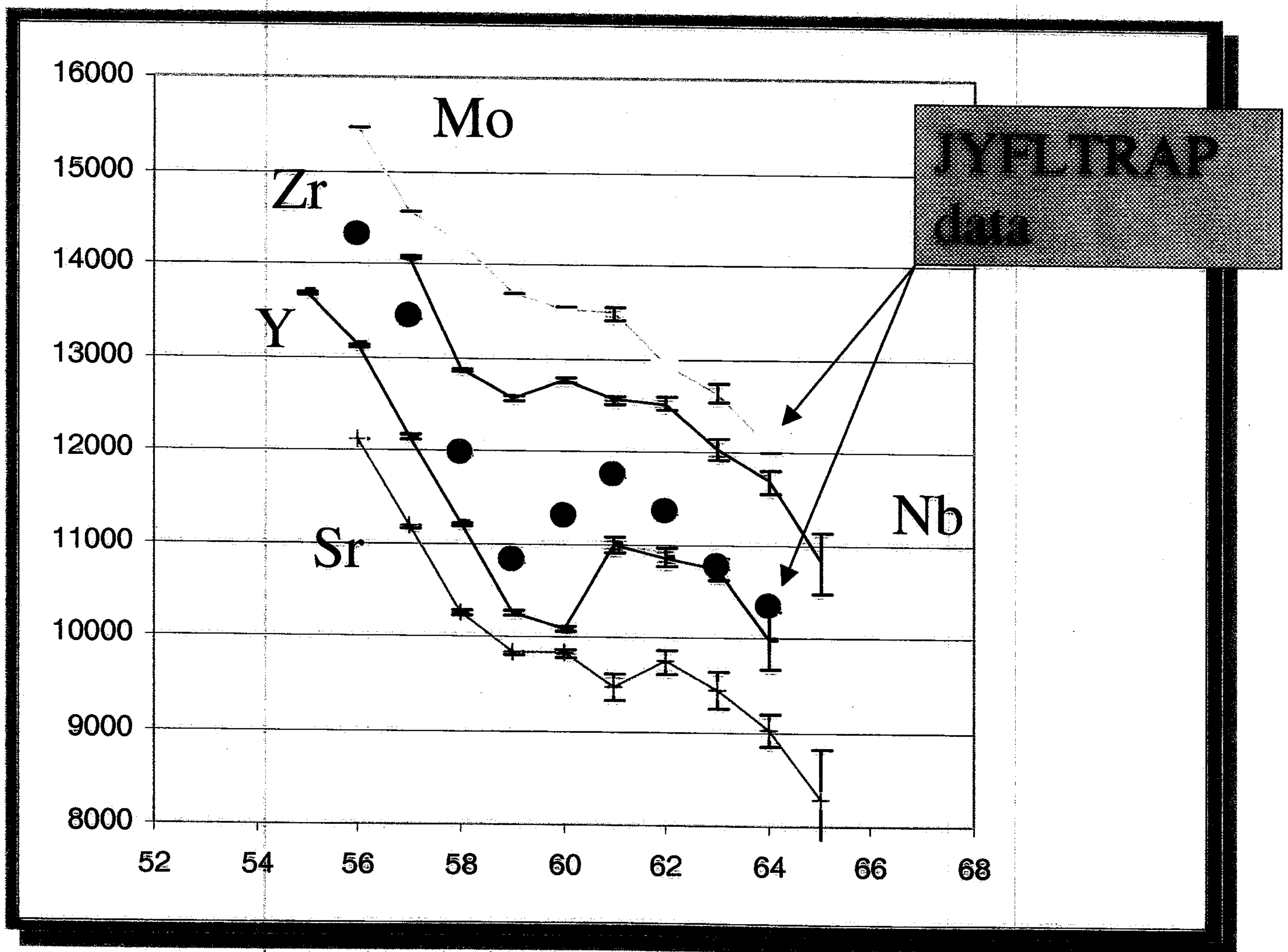
preliminary Zr results



Yale, June 2003


Exp
HFB + THO + SLy4
S(2N) in keV
15000
14000
13000
12000
11000
10000
9000
95
96
97
98
99
100
101
102
103
104
105
106
107
A

S_{2n} values across N=60   AME-02+JYFLTRAP



What level of accuracies are needed?

- Fundamental interactions and symmetries (< 1 keV)
  - Q-values of nuclear β decay
    - CVC theory and unitarity of CKM matrix
    - Search for scalar and tensor currents
- Charge symmetry in nuclei (1 keV)
  - Isospin multiplets and Coulomb energy differences
- Nuclear structure (10-100 keV)
  - Global correlations (100 keV)
  - Local correlations (10 keV)
    - Local deformation, coexistence, mixing and pairing
  - Drip-line phenomena and halos (10 keV)
- Nuclear astrophysics (>10 keV)

Summary and future perspectives

JYFLTRAP @ IGISOL

Ion cooler and Purification trap fully operational

Half-lives less than 100 ms can be accessed

All chemical elements possible, if using the IGISOL technique

Succesful program on n-rich Zr and other refractory fission products

Precision trap operational later in 2003

Future spectroscopy efforts

Decay studies of isobarically purified beams

In-trap spectroscopy – precision CE measurements

Collinear laser spectroscopy

Precision mass measurements (0.1 – 10 keV)

IGISOL upgrade (end of 2003)

100 µA, 20-80 MeV protons

laser ion source

JYFL

EXO TRAPS

U. Hager, J. Hakala, J. Huikari, T. Eronen, V. Kolhinen, A. Jokinen, S. Kopecky, A. Nieminen, S. Rinta-Antila, J.Ä.

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J. Billowes
P. Campbell

THE UNIVERSITY OF BIRMINGHAM

G. Tungate

LMU
Ludwig
Maximilians
Universität
München

J. Szerypo