M. Leino

In Beam Studies of SHE at High Beam Intensities

Talk

In-Beam Studies of SHE at High Beam Intensities

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Plan:

- What has been done so far
- What can be done during the next few years
- What could perhaps be done later

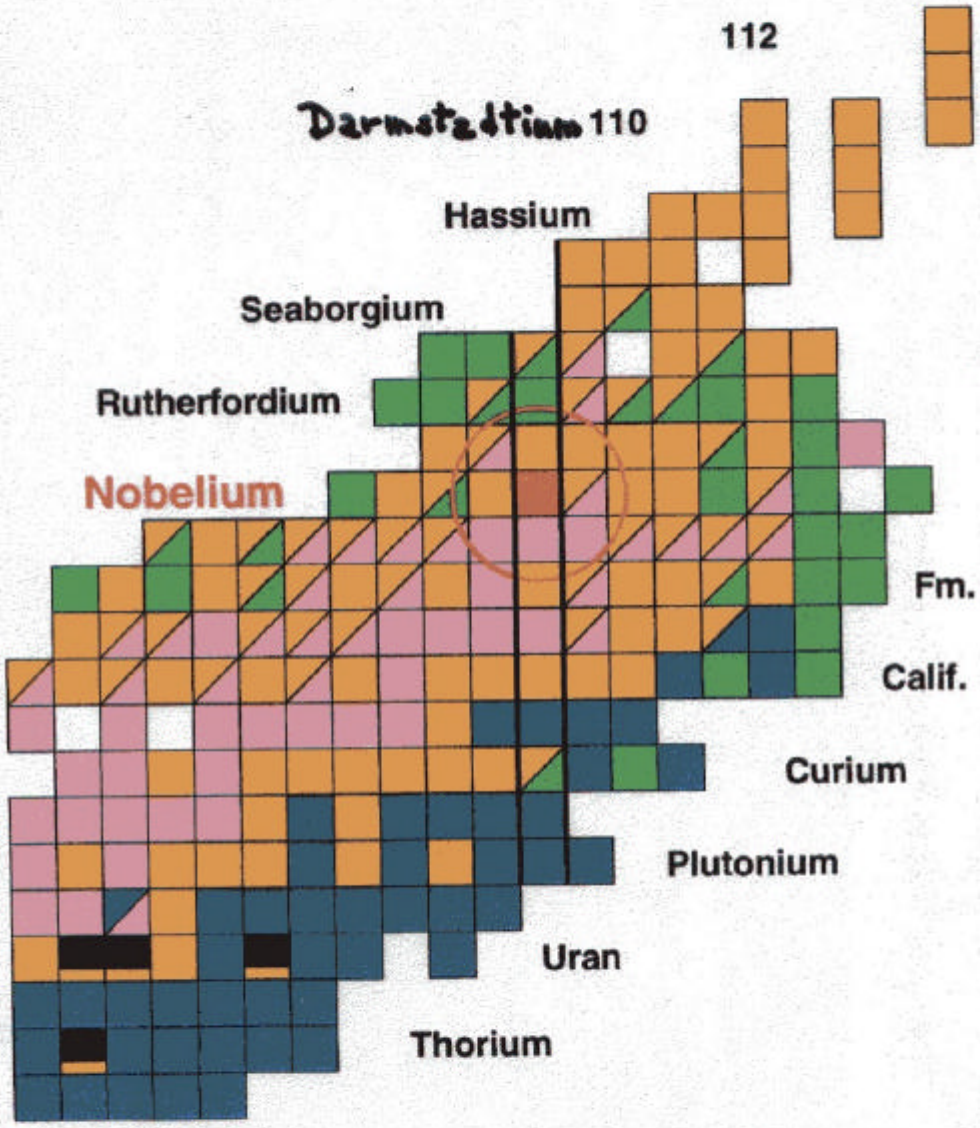
The Future of Superheavy Element Research
February 17-18, 2004
GSI

Collaboration partners include:

JYFL
University of Liverpool
GSI
CERN/ISOLDE
DAPNIA/SPhN CEA-Saclay
CCLRC Daresbury
University of Manchester
University of Surrey
University of York
University of Helsinki
IReS Strasbourg
ANL Argonne
LMU Munich
GANIL
INP Krakow


Midwinter Workshop
on Tagging Methods and Experiments
16-17th January 2004, JYFL

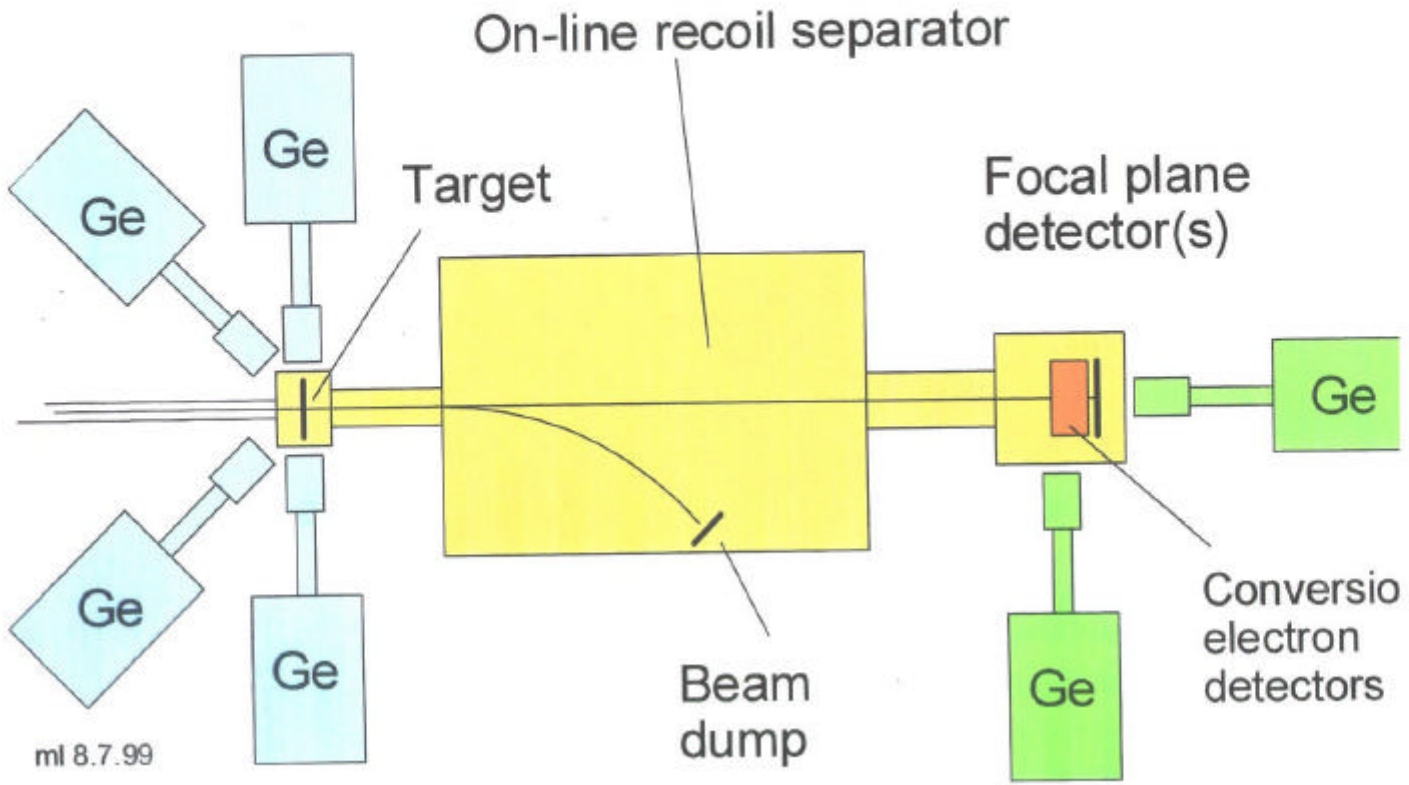
Superheavy Elements



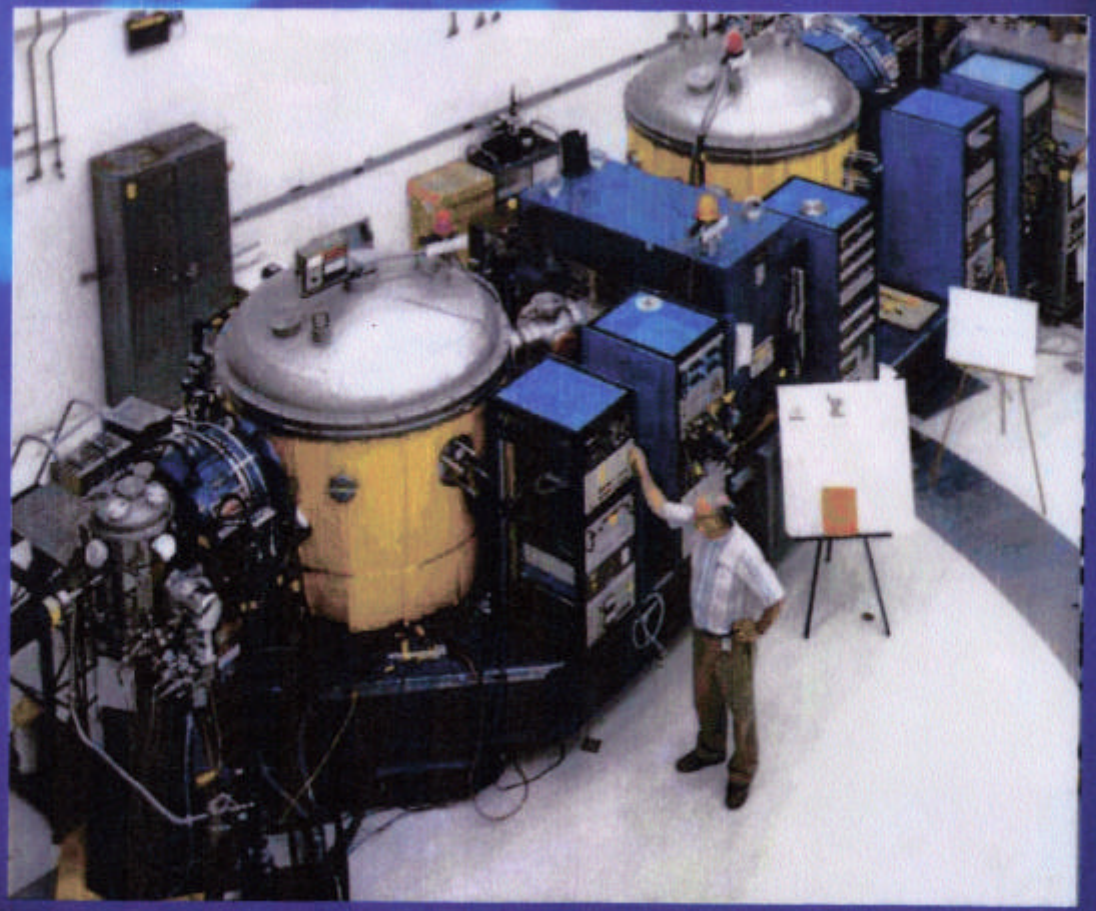
Spectroscopy on the nobelium isotope

^{254}No

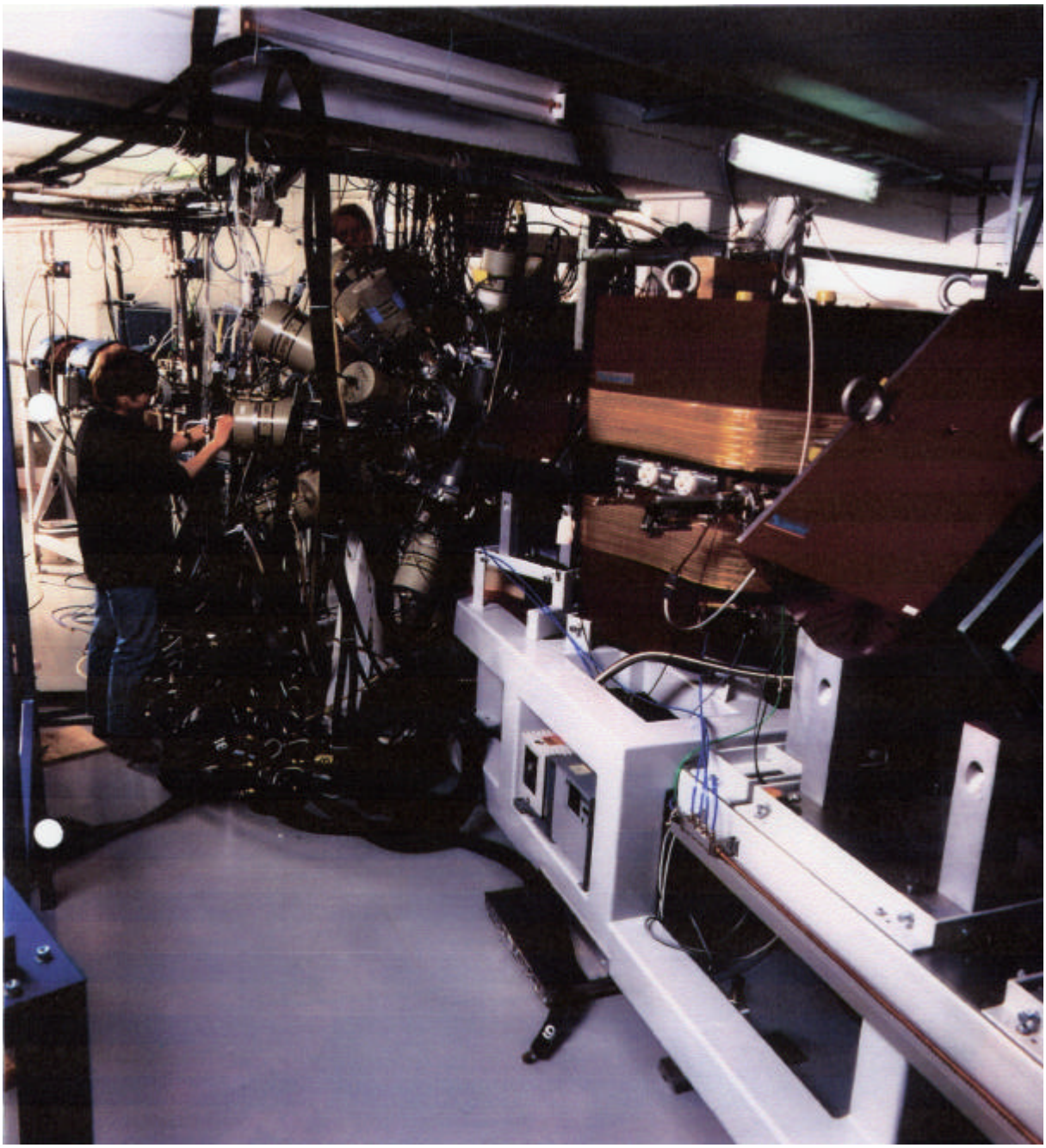
Apparatus for Recoil Decay Tagging (RDT) measurements



The FMA at Argonne Nat. Lab.

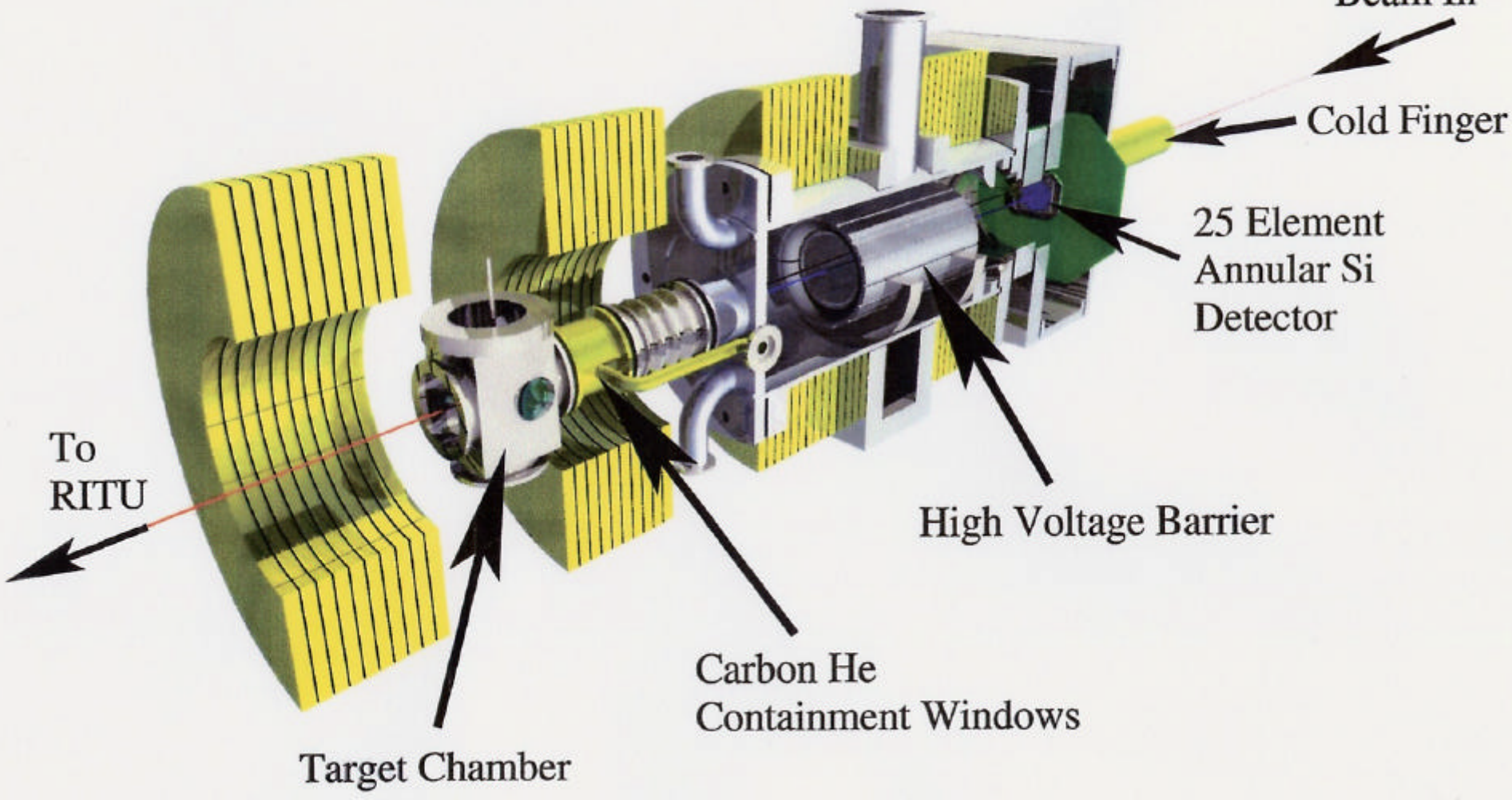


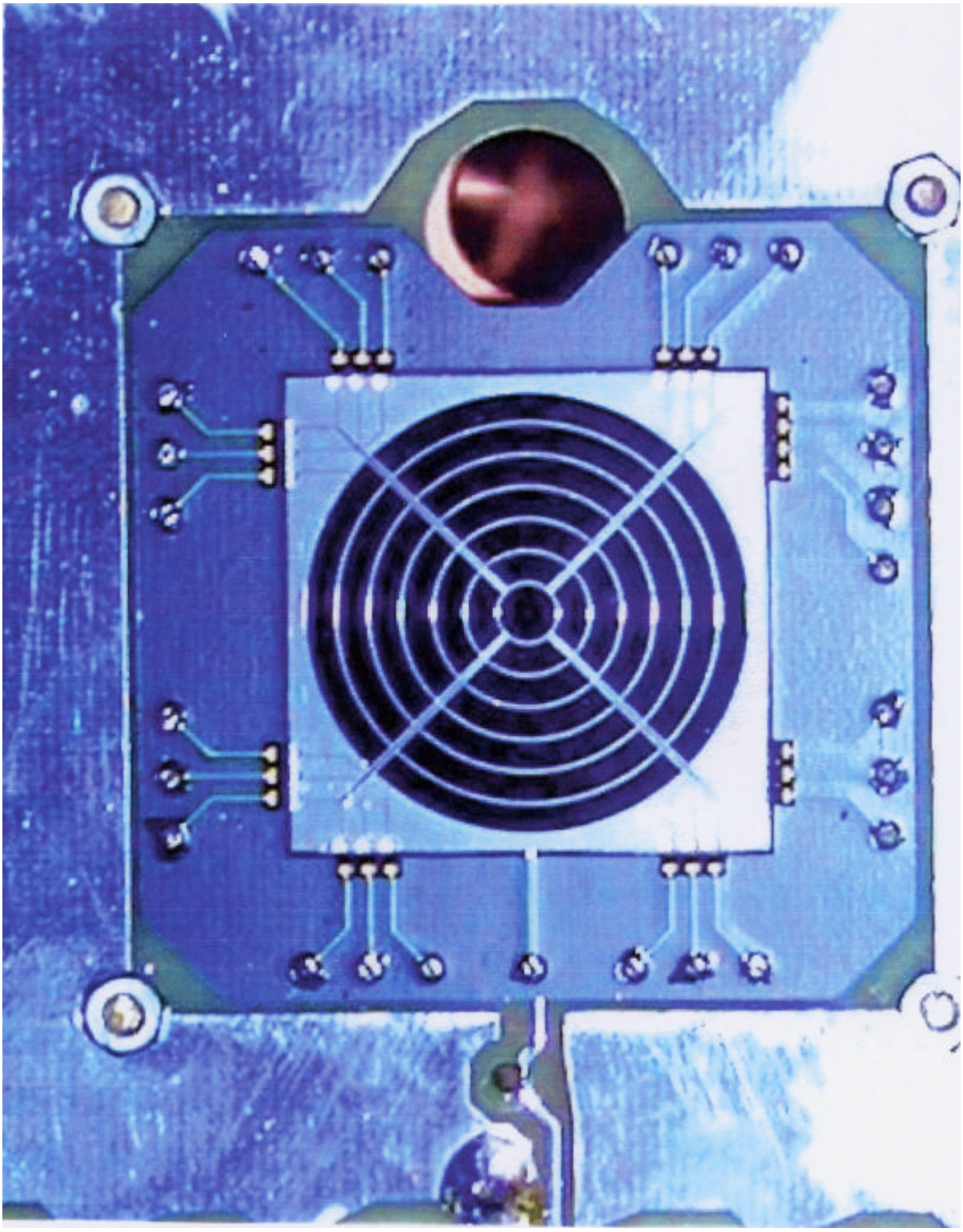
Energy acceptance: ± 15%, M/Q range (at f. p.): ± 4%, opening angle: ± 2.3°



The SACRED Electron Spectrometer

LIVERPOOL - JYVÄSKYLÄ





In-beam studies around ^{254}No at JYFL

Gas-filled recoil separator RITU and

- JUROSphere, SARI, JUROGAM Ge-arrays
- SACRED conversion electron spectrometer

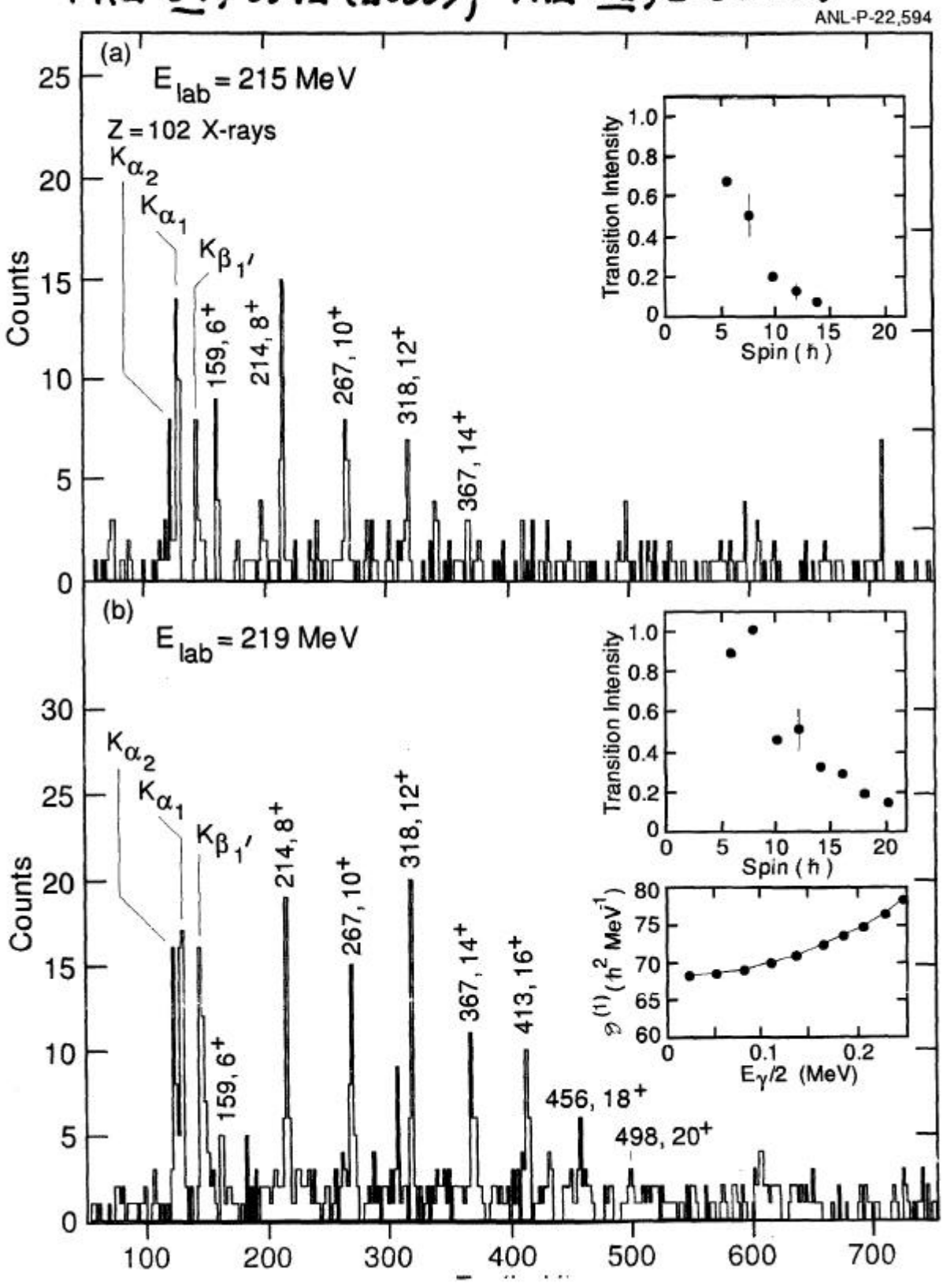
• ^{208}Pb(^{48}Ca,2n)^{254}No	Aug 1998 γ
• ^{206}Pb(^{48}Ca,2n)^{252}No	June 1999 γ
• ^{209}Bi(^{48}Ca,2n)^{255}Lr	Sep 1999 γ
• ^{208}Pb(^{48}Ca,2n)^{254}No	Mar 2001 e^-
• ^{207}Pb(^{48}Ca,2n)^{253}No	Mar 2001 e^-
• ^{204}Hg(^{48}Ca,2n)^{250}Fm	Oct 2001 γ
• ^{204}Hg(^{48}Ca,2n)^{250}Fm	Mar 2002 γ
• ^{205}Tl(^{48}Ca,2n)^{251}Md	Nov 2002 e^-
• ^{208}Pb(^{48}Ca,2n)^{254}No	Apr 2003 γ
• ^{205}Tl(^{48}Ca,2n)^{251}Md	Jun 2003 γ

Collaboration between:

JYFL * University of Liverpool (R.-D. Herzberg et al.) * GSI (F. P. Heßberger et al.) * DAPNIA/SPhN CEA-Saclay (Y. Le Coz et al.) * University of Helsinki (K. Eskola) * ANL (T. L. Khoo) * LMU University Munich (P. Reiter) * GANIL (G. de France) * INP Krakow (J. Styczen)

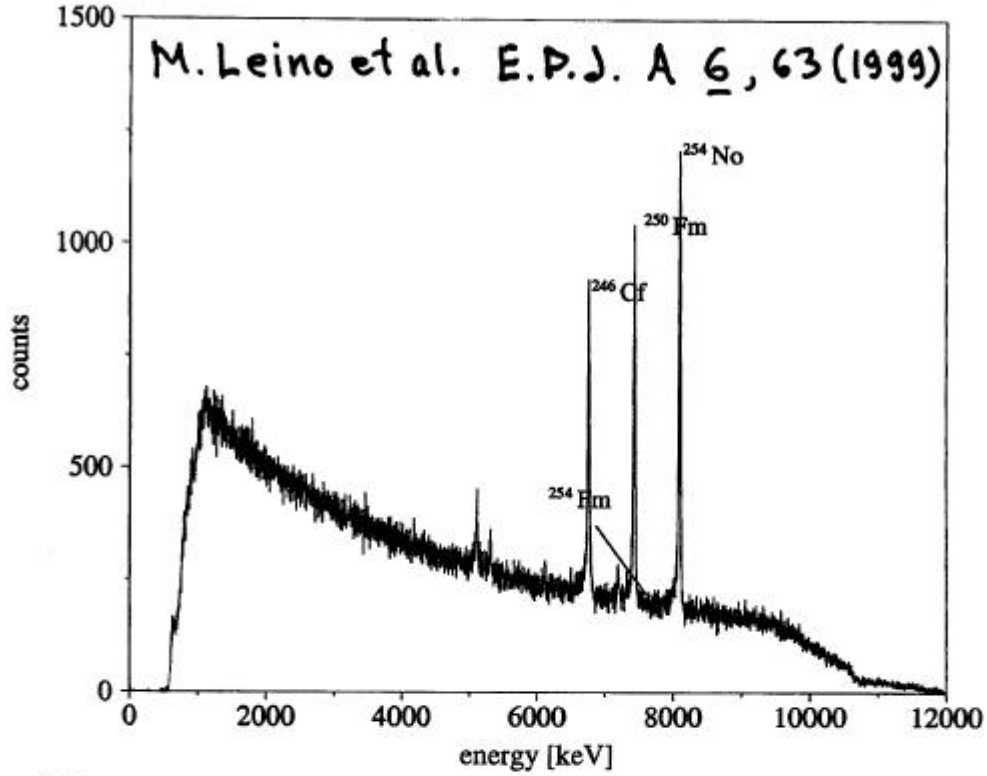
$^{208}Pb(^{48}Ca,2n)^{254}No$ P. Reiter et al.

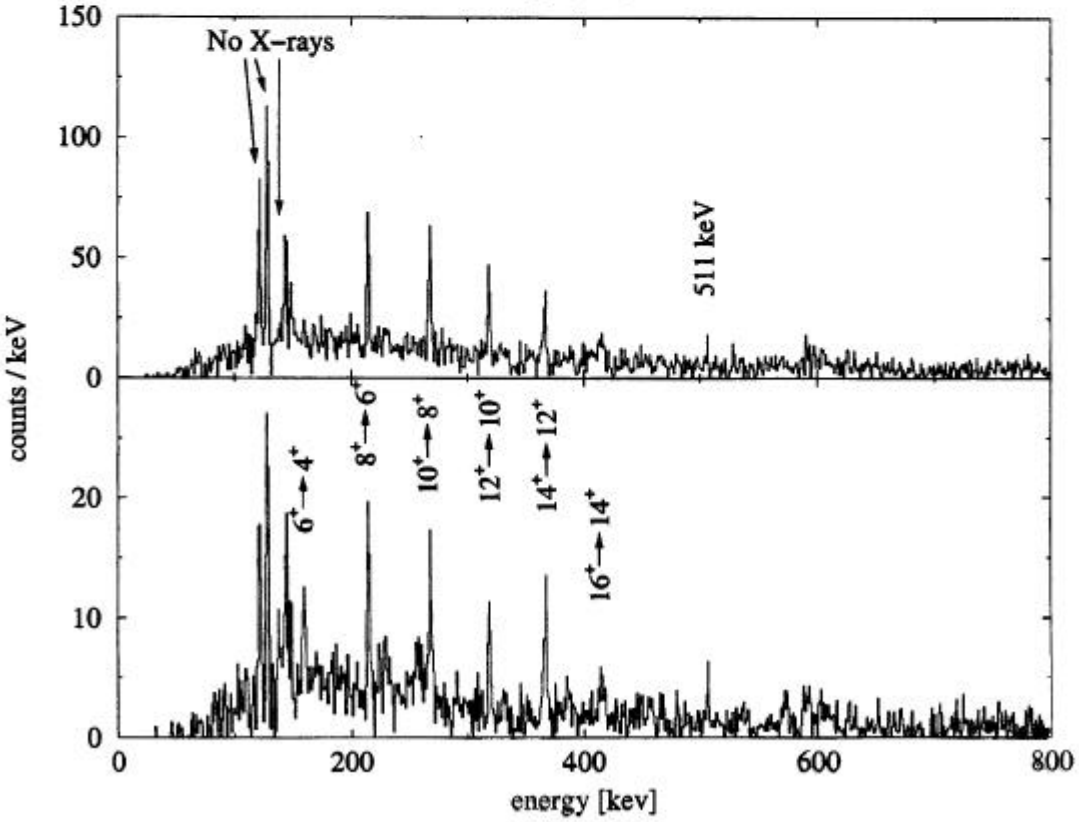
PRL 84, 3542 (2000); PRL 82, 509 (1999)

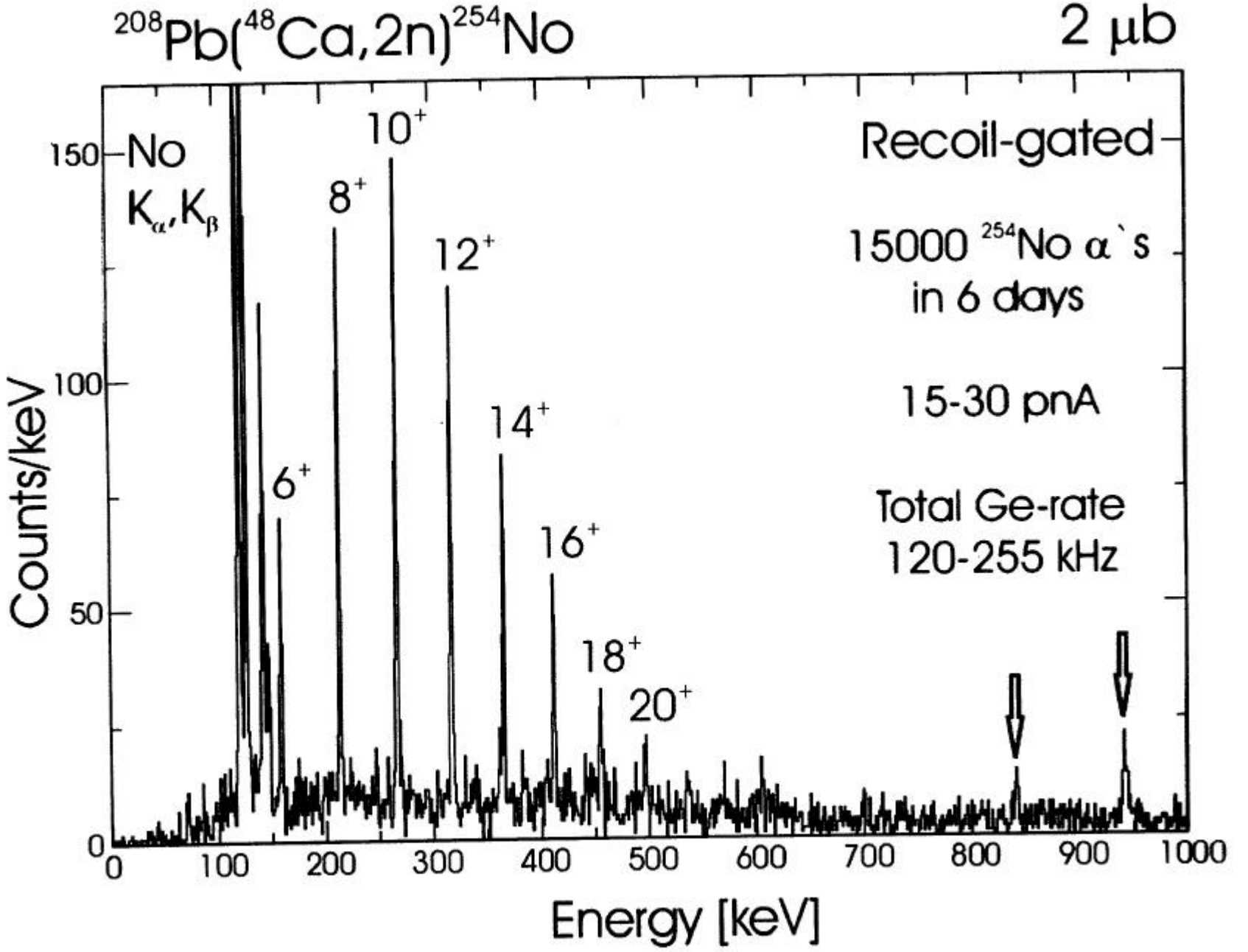


First Study of 254No at JYFL

SARI Array, two week irradiation, 5 pnA, 13500 254No alphas





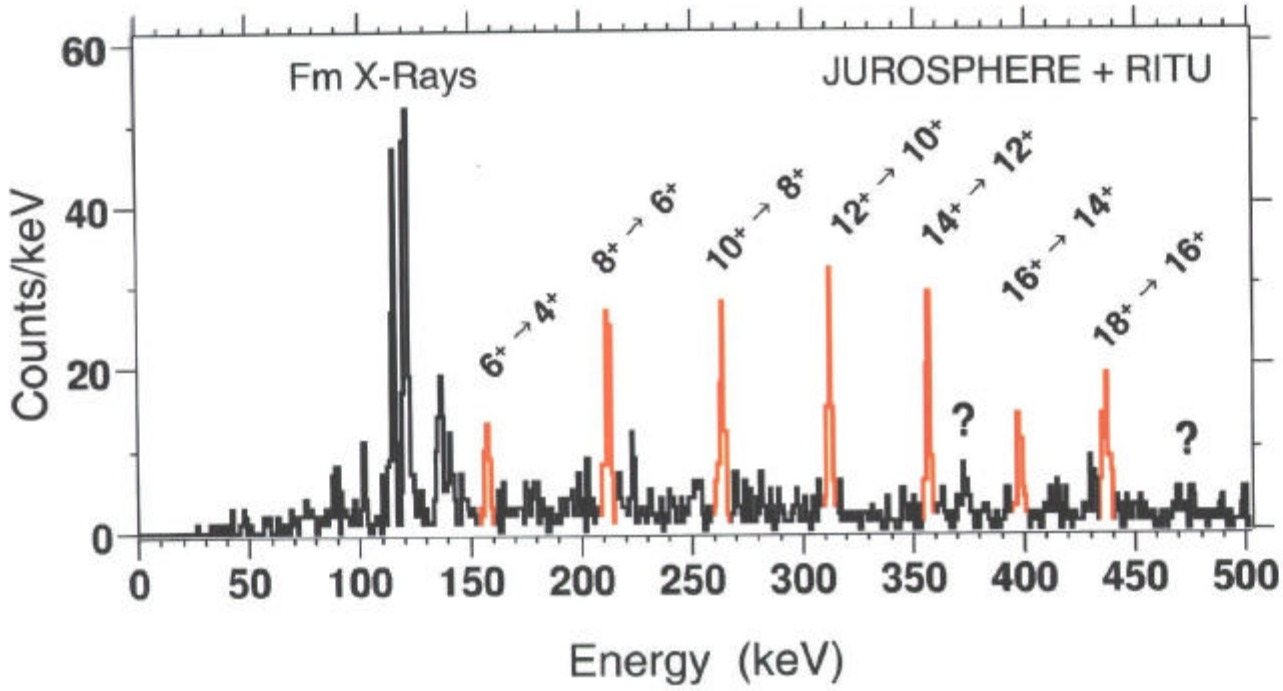


Preliminary Data

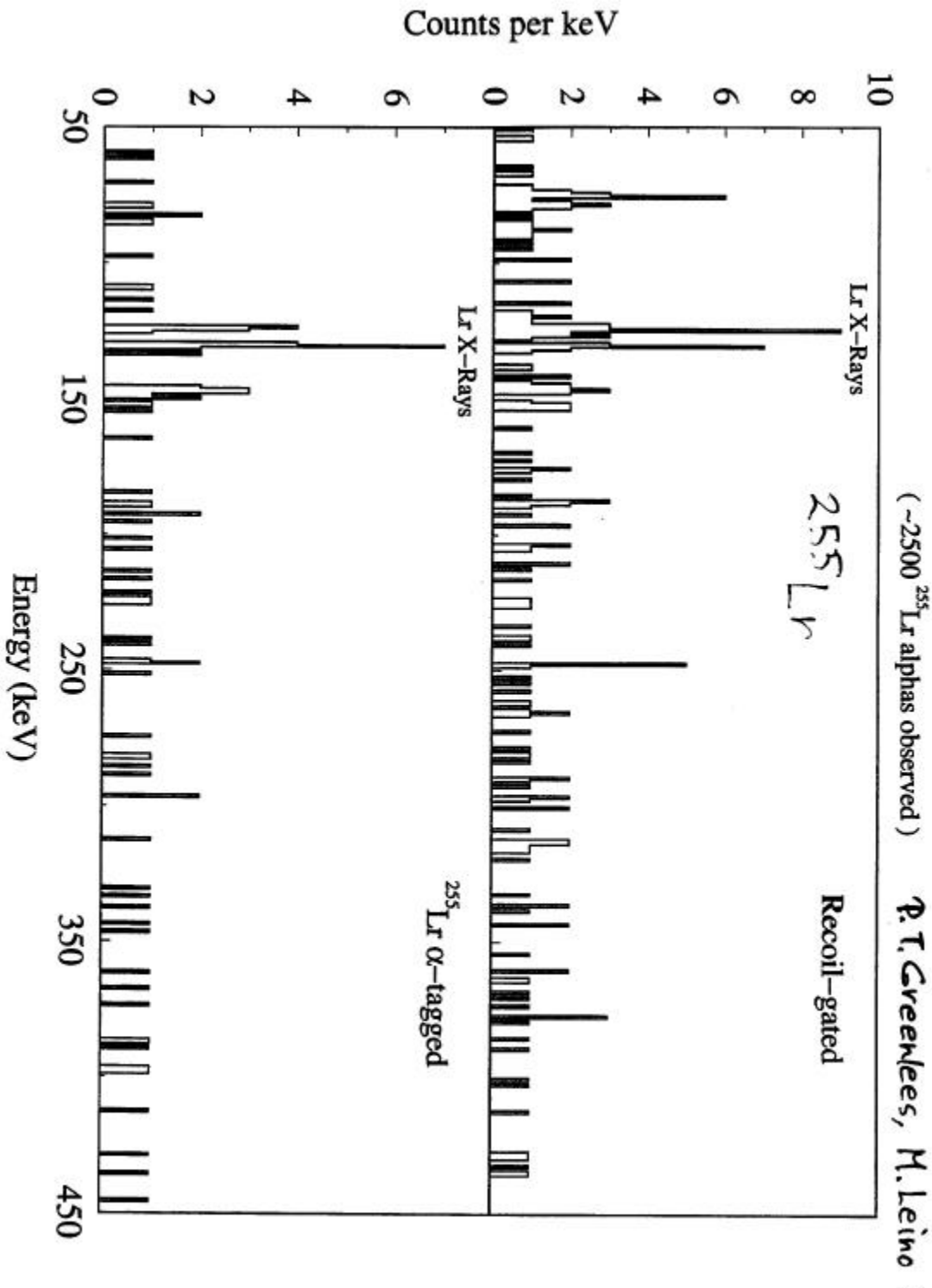
S. Eeckhaudt et al. JUROGAM+RITU 2003

K.-U Hereberg, R. Leino, J. [illegible]

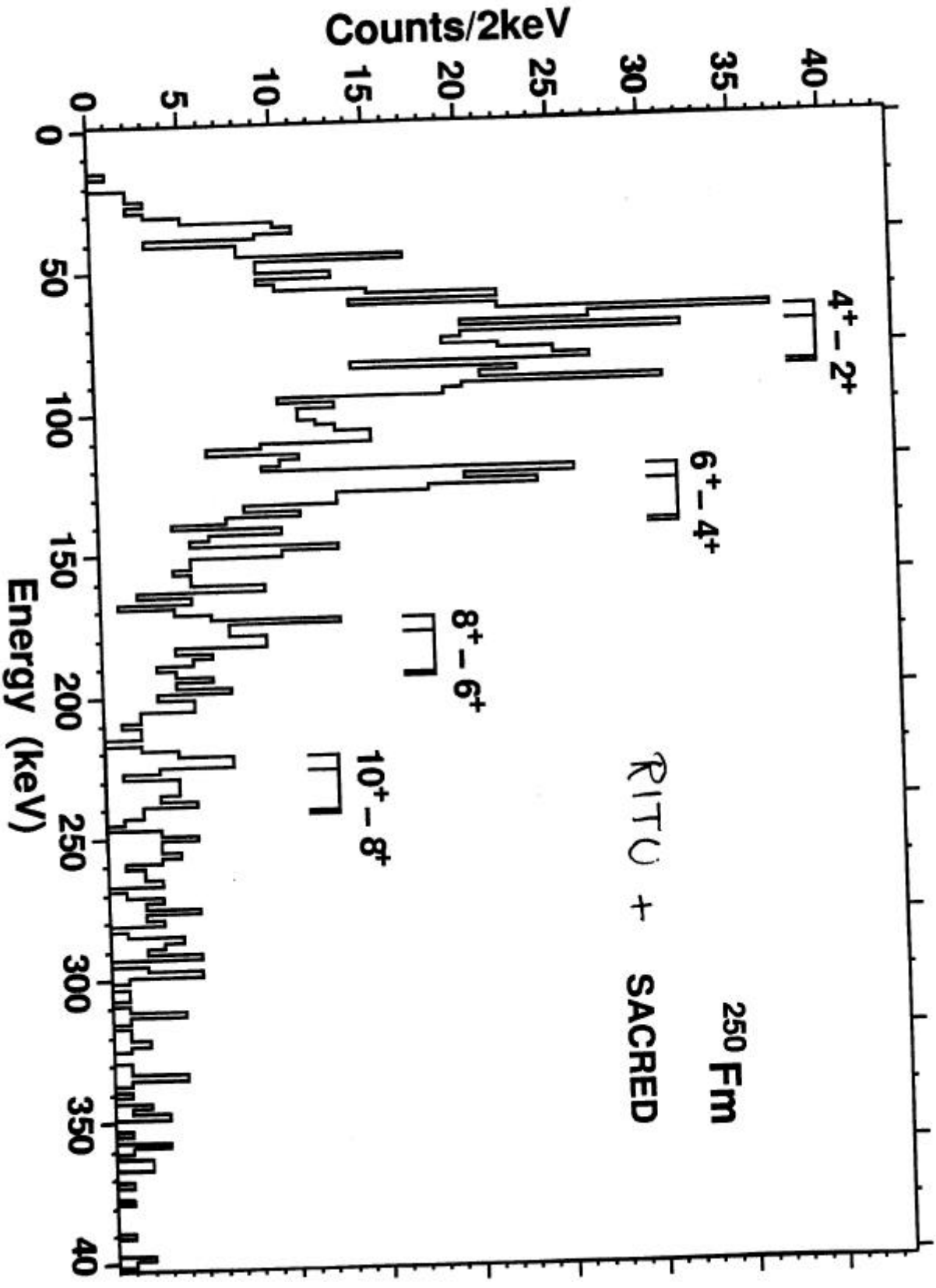
^{250}Fm gamma spectra



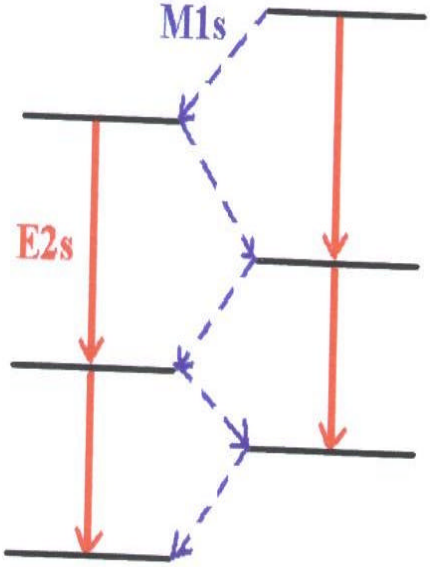
Preliminary Data

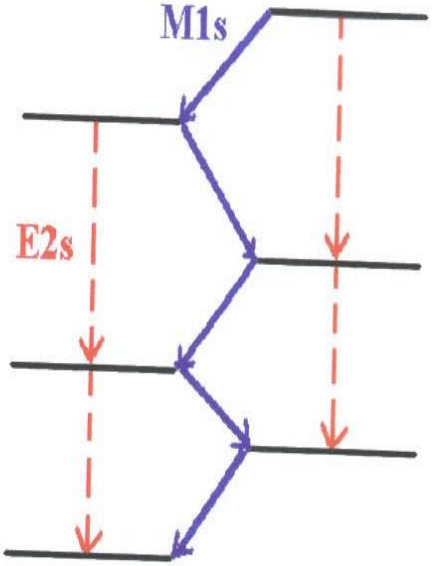


R.-D.Herzberg et al.



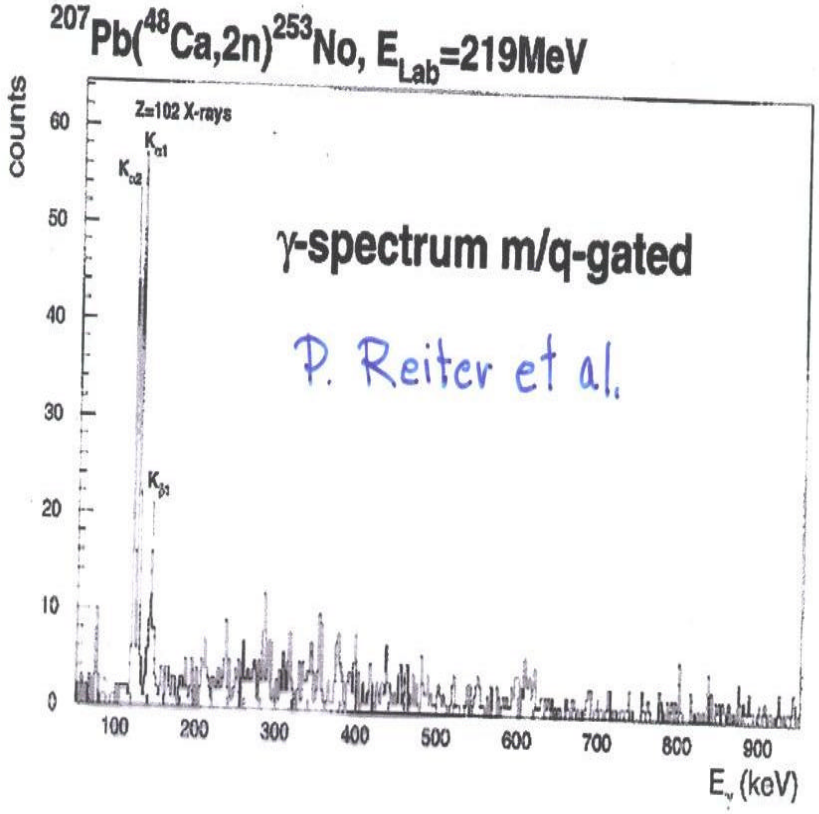
Odd mass SHE nuclei - experiment





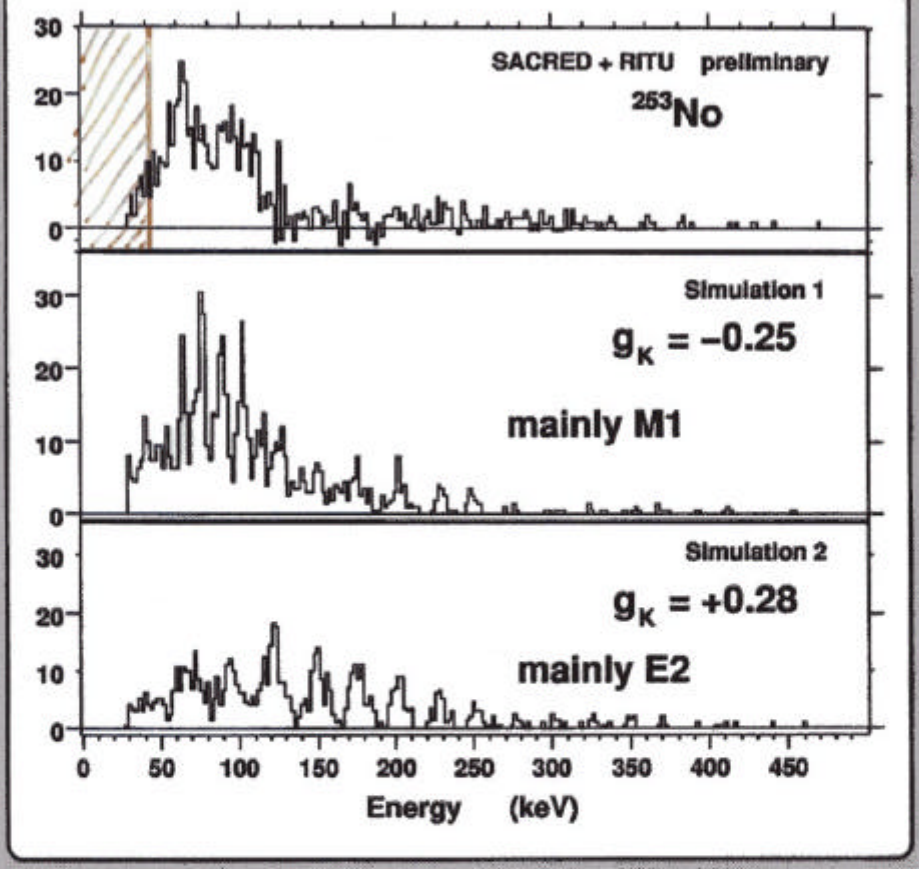
$K = 7/2^+$ $g_K = 0.27$

$K = 9/2^-$ $g_K = -0.25$



P. Butler

Simulation

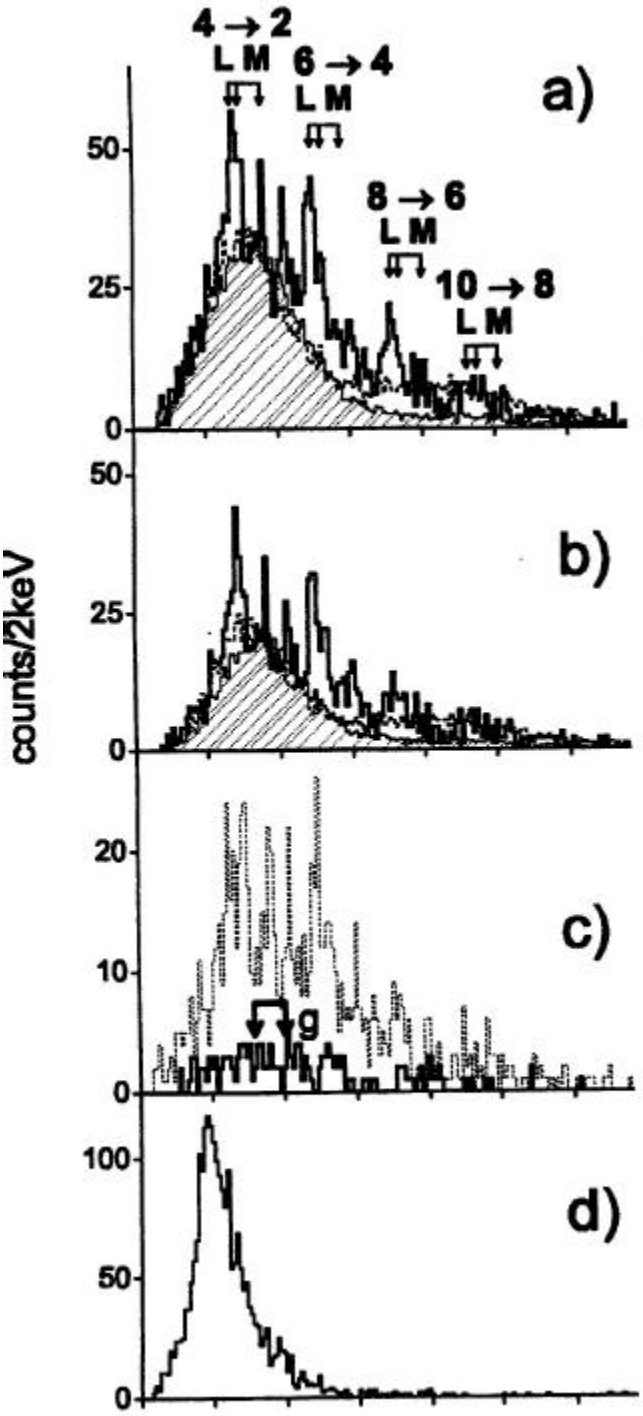


e.g.: $9/2^-$ [734]: $g_k = -0.25\,\mu_N$

$7/2^+$ [624]: $g_k = +0.28\,\mu_N$

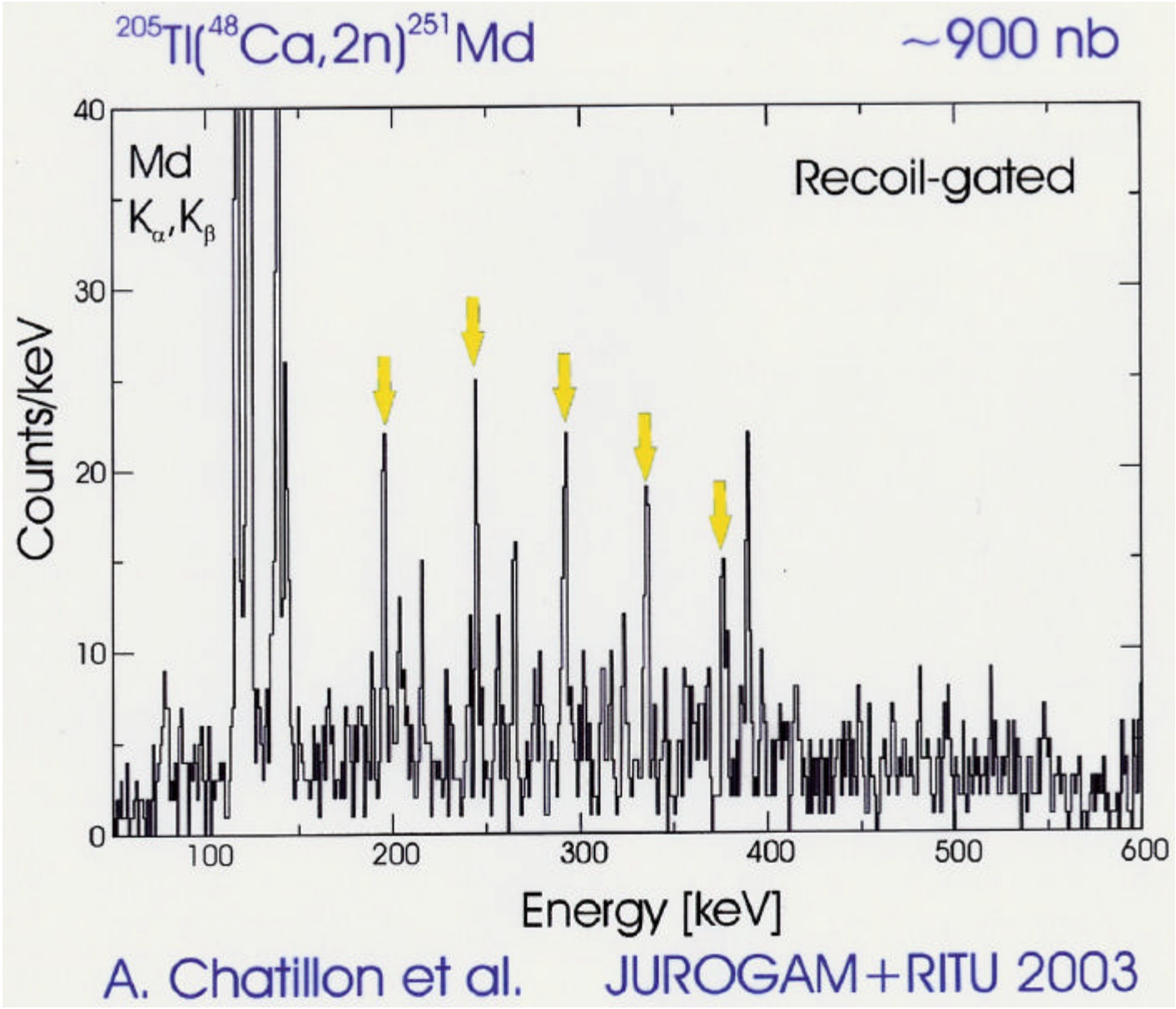
$g_R = 0.41\ \mu_N$

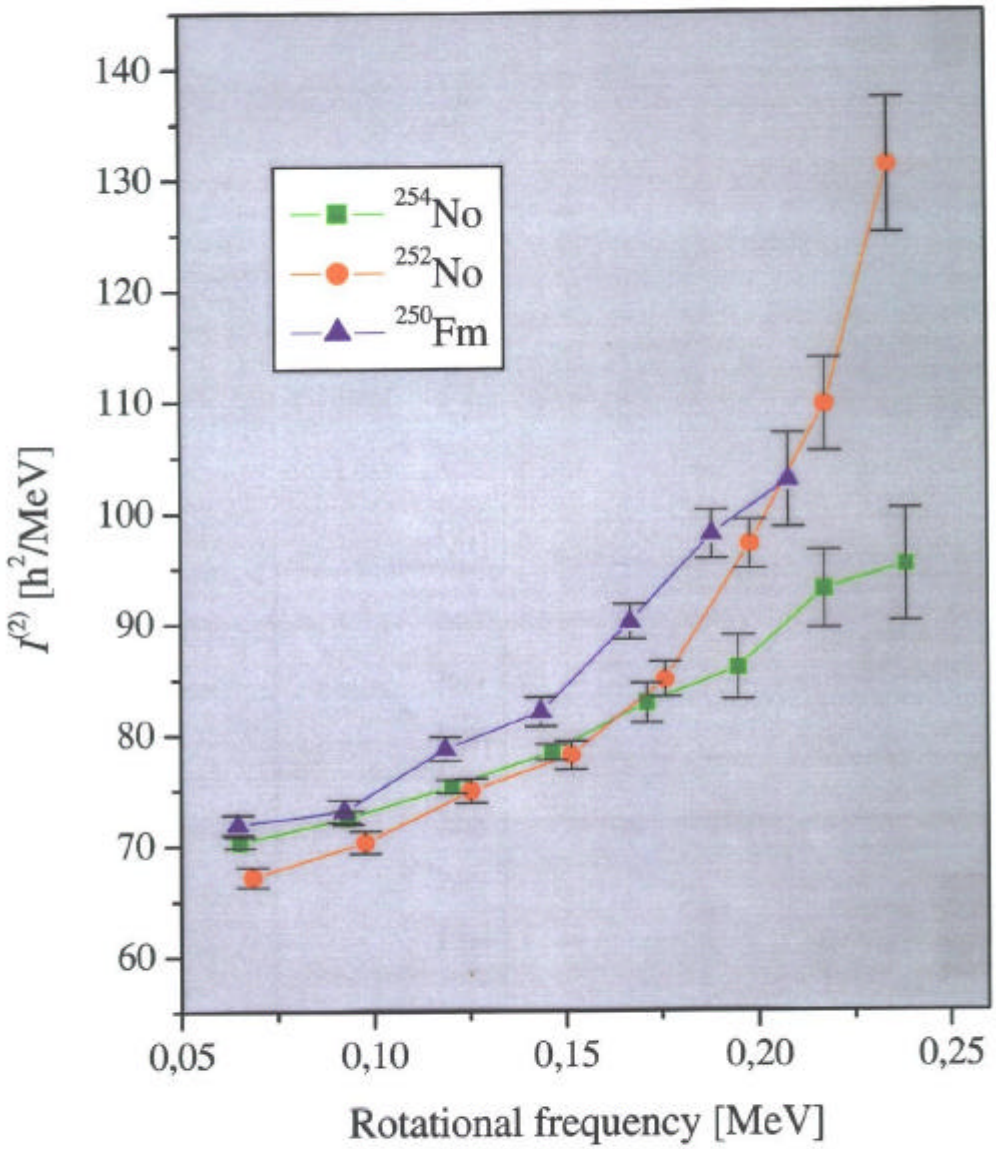
^{254}No



P. A. Butler et al.
Phys. Rev. Lett 89, 202501 (2002)

RITU + SACRED


^{205}Tl(^{48}Ca,2n)^{251}Md
~900 nb
Md
K_α, K_β
Recoil-gated
Counts/keV
Energy [keV]
0
10
20
30
40
100
200
300
400
500
600
A. Chatillon et al.
JUROGAM+RITU 2003


140
130
120
110
100
90
80
70
60
$\mathcal{I}^{(2)}$ [$\hbar^2$/MeV]
^{254}No
^{252}No
^{250}Fm
0,05
0,10
0,15
0,20
0,25
Rotational frequency [MeV]

Present limits (at JYFL)

Gamma-rays in-beam

Pile-up sets a limit of 10 kHz / channel
⇒ beam intensity typically limited to 30 pnA

Contributing factors:
- Background from filling gas reduced by differential pumping
- Maximum beam higher in cold fusion reactions than e.g. in the Po region

Conversion electrons in-beam

SACRED with 25 pixels
Limit 10 kHz / channel
⇒ beam intensity typically limited to 5 pnA

Decisive factors:
- Barrier voltage
- Need good vacuum
- e^- count rate much more unevenly distributed than γ-rays in Ge detectors

Future improvements

Gamma-rays in-beam

Clover detectors don't give much improvement

Main hope: Digital electronics

30 kHz limit / channel

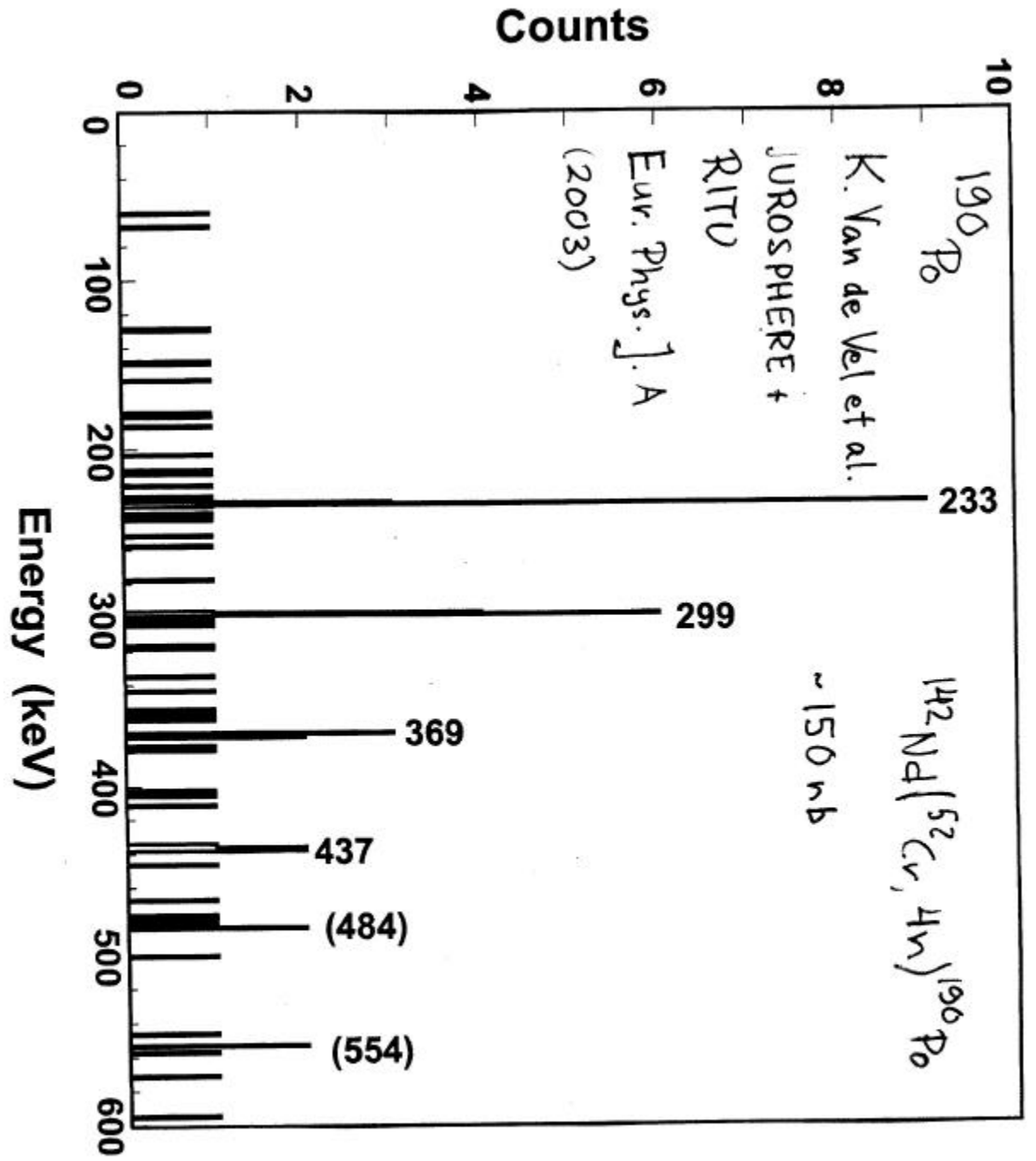
^{254}No: 100 pnA limit
⇒ need a rotating target

Conversion electrons (and γ's) in-beam

SAGE project (e^--γ coincidences; ≈ 10% efficiency for e^-, ≈ 4 % efficiency for γ) U.K.

Factor of 10 in pixel number for electrons
250 channels
⇒ (too?) expensive to go digital

Much improved background conditions because of the coincidence


Counts
Energy (keV)
0
2
4
6
8
10
0
100
200
300
400
500
600
233
299
369
437
(484)
(554)
190 Po
K. Van de Vel et al.
JUROSPHERE +
RITU
Eur. Phys. J. A
(2003)
142Nd(52Cr, 4n)190Po
~ 150 nb