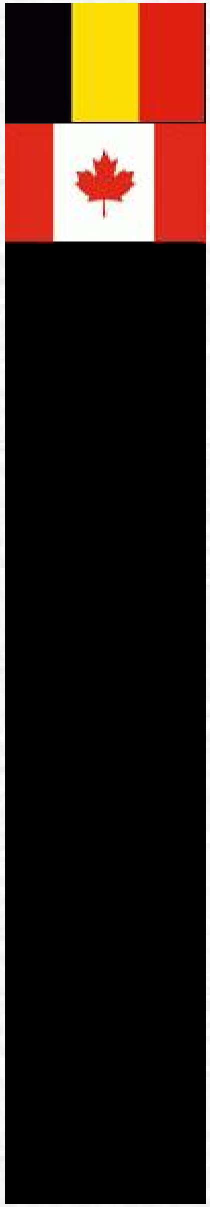
# ***Precision Measurements of Very Short-Lived Nuclei Using an Advanced Trapping System for Highly-Charged Ions***

**Frank Herfurth: GSI Darmstadt**

HELMHOLTZ GEMEINSCHAFT

***for the MATS Collaboration***

# MATS Collaboration



| | |
|---|---|
| Belgium | Universite Bruxelles |
| Canada | TRIUMF |
| France | Paris, CNRS |
| Finland | Jyväskylä |
| Germany | EMAU, FAU, JoGu, GSI, MPIK, JLU, LMU |
| India | Kolkata |
| Russia | PNPI, PSU |
| Spain | Huelva |
| Sweden | Stockholm |
| USA | LLNL, MSU |

**10 countries**
**17 instituts**
**73 members**

Spokesperson:
Klaus Blaum

Co-spokespersons:
Ari Jokinen, Jyväskylä
José Crespo, MPI-K

Project manager:
Frank Herfurth, GSI

# MATS – Ion Trapping:

- effective use of rare species
- extended observation & interaction time
- High-quality q/m selection
- manipulation of charged particles at low energy
  - accumulation & bunching
  - charge breeding
  - polarization

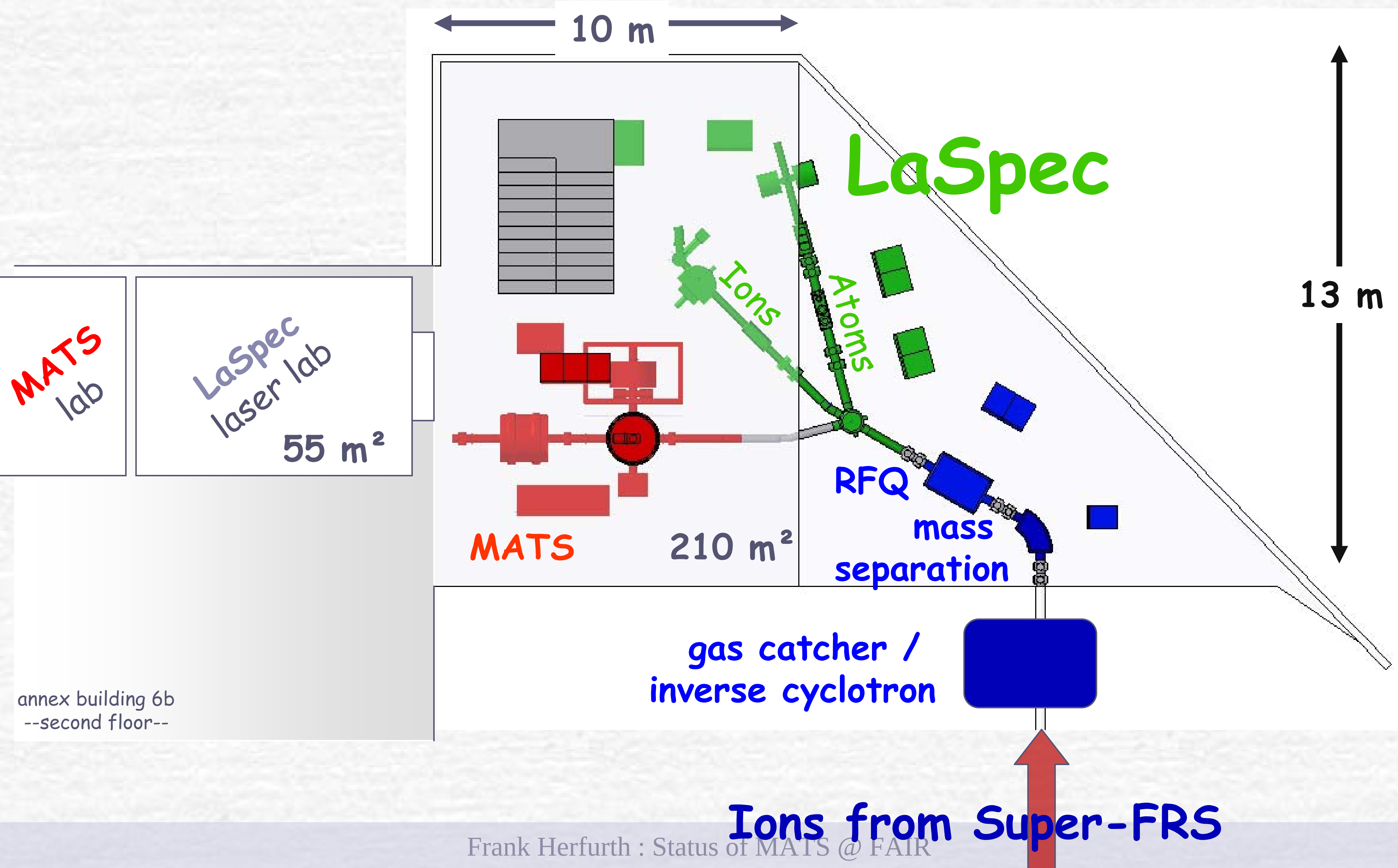
**EFFICIENCY**

**ACCURACY**

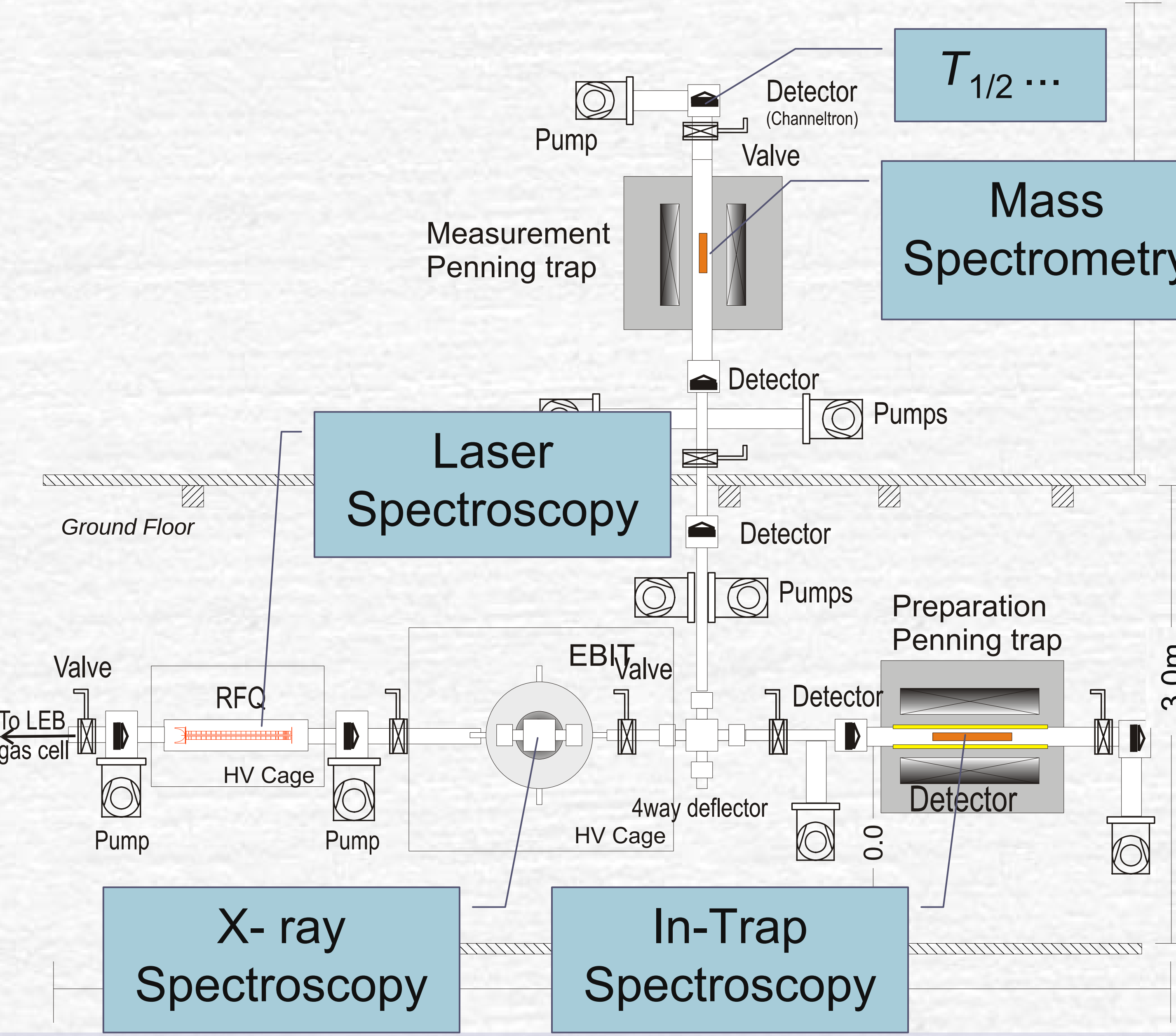
**SENSITIVITY**

**Mass measurements and trap assisted nuclear spectroscopy**

# MATS – Setup:


10 m
13 m
LaSpec
Ions
Atoms
MATS lab
LaSpec laser lab
55 m²
RFQ
mass separation
MATS
210 m²
gas catcher / inverse cyclotron
annex building 6b
--second floor--
Ions from Super-FRS

# MATS – Experiments with Exotic Nuclei




Detectors:

- FT-ICR
- TOF-ICR
- Si(Li) electron

Precision trap:

mass measure-ments

Cooler trap:

beam preparation & spectroscopy

Magn. deflector:

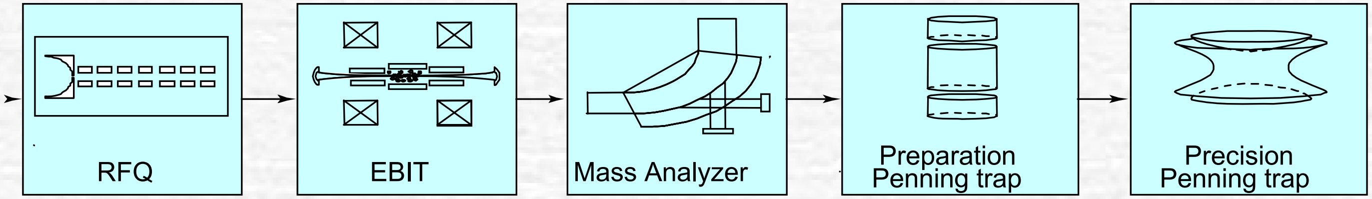
q/m separation

EBIT:

charge breeding

$$f_c = \frac{1}{2\pi} \cdot \frac{q}{m} \cdot B$$

# Technical Specifications




**Design parameters:**

| | |
|---|---|
| Overall efficiency | 1-5% |
| Maximum resolving power | $10^8$ |
| Accessable half-life | 10 ms |
| Relative mass uncertainty | $10^{-9}$ |

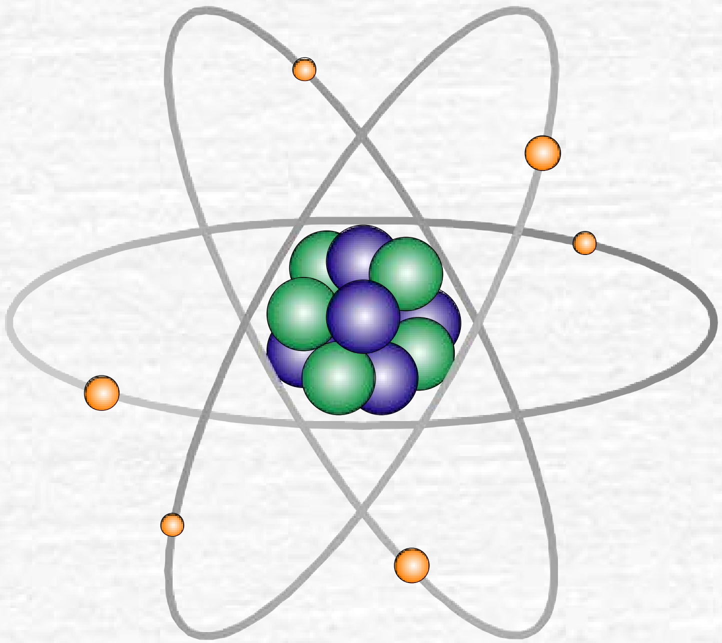
**Organisation and responsibilities**

| | |
|---|---|
| Mainz, Greifswald, GSI, MSU, Stockholm: | Penning trap system |
| Orsay, Jyväskylä, Gießen, Huelva: | RFQ cooler and buncher |
| Heidelberg, Livermore, Stockholm: | EBIT |
| Greifswald, Mainz, PNPI: | Detection system and electronics |
| PNPI, Munich, Jyväskylä, Huelva: | Trap assisted spectroscopy |

# Applications of Mass Spectrometry

**High-accuracy mass measurements allow one to determine the atomic and nuclear binding energies reflecting all forces in the atom/nucleus.**

K. B., Phys. Rep. 425, 1-78 (2006)



= $N \cdot$ + $Z \cdot$ + $Z \cdot$

– binding energy

$$M_{\text{Atom}} = N \bullet m_{\text{neutron}} + Z \bullet m_{\text{proton}} + Z \bullet m_{\text{electron}} - (B_{\text{atom}} + B_{\text{nucleus}})/c^2$$

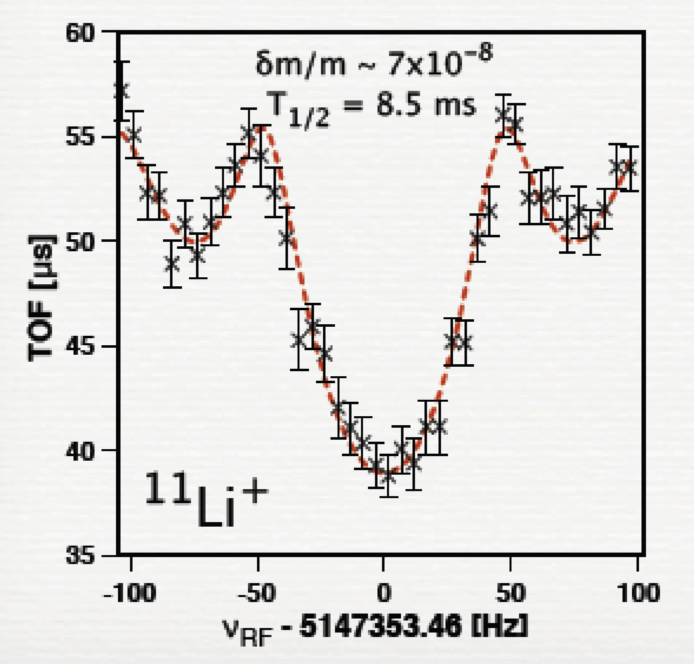
# Applications of Mass Spectrometry

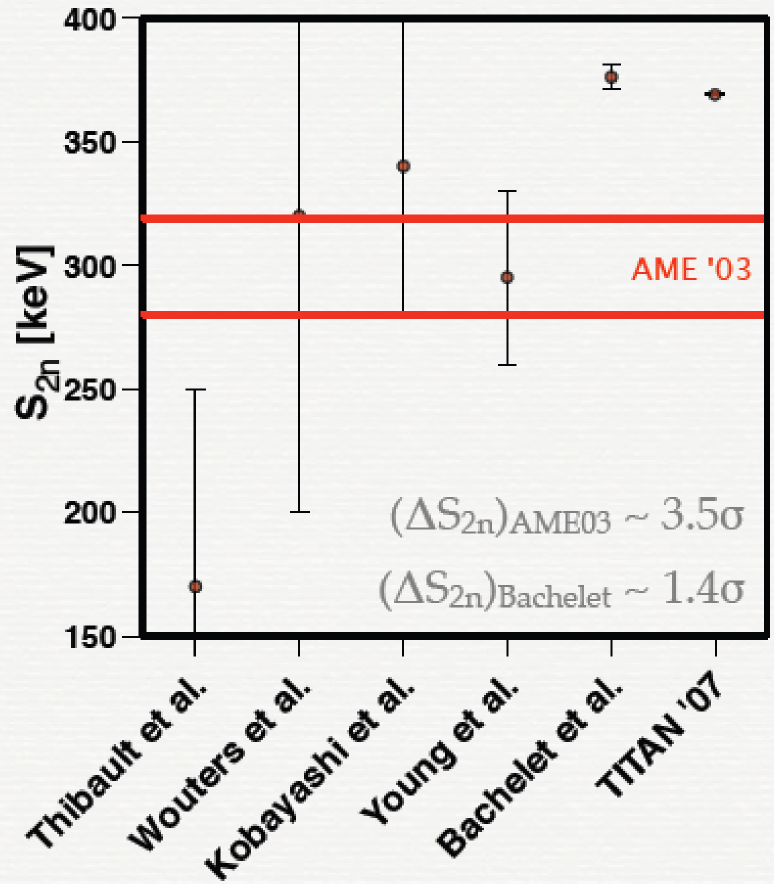
MATS

**High-accuracy mass measurements allow one to determine the atomic and nuclear binding energies reflecting all forces in the atom/nucleus.**

| K. B., Phys. Rep. 425, 1-78 (2006) | δm/m |
|---|---|
| General physics & chemistry | $\leq 10^{-5}$ |
| Nuclear structure physics<br>- separation of isobars | $\leq 10^{-6}$ |
| Astrophysics<br>- separation of isomers | $\leq 10^{-6}$ |
| Weak interaction studies | $\leq 10^{-8}$ |
| Metrology - fundamental constants | $\leq 10^{-9}$ |
| CPT tests | $\leq 10^{-10}$ |
| QED in highly-charged ions<br>- separation of atomic states | $\leq 10^{-11}$ |

# Pushing the Half-Live Limit



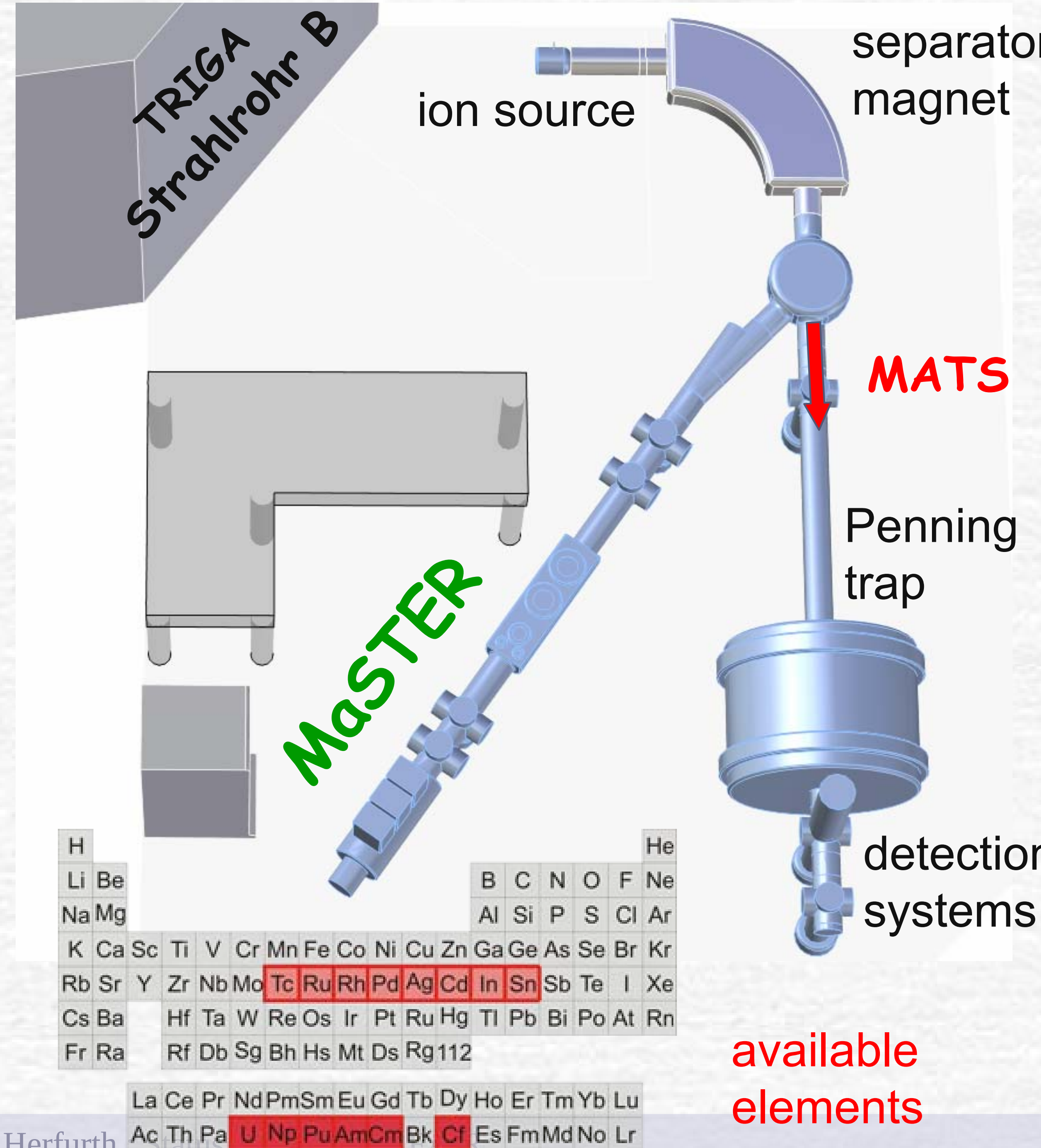




- Measurements of $^{11}$Li ($T_{1/2}$=8.5 ms) with the Penning trap facility TITAN (TRIUMF)

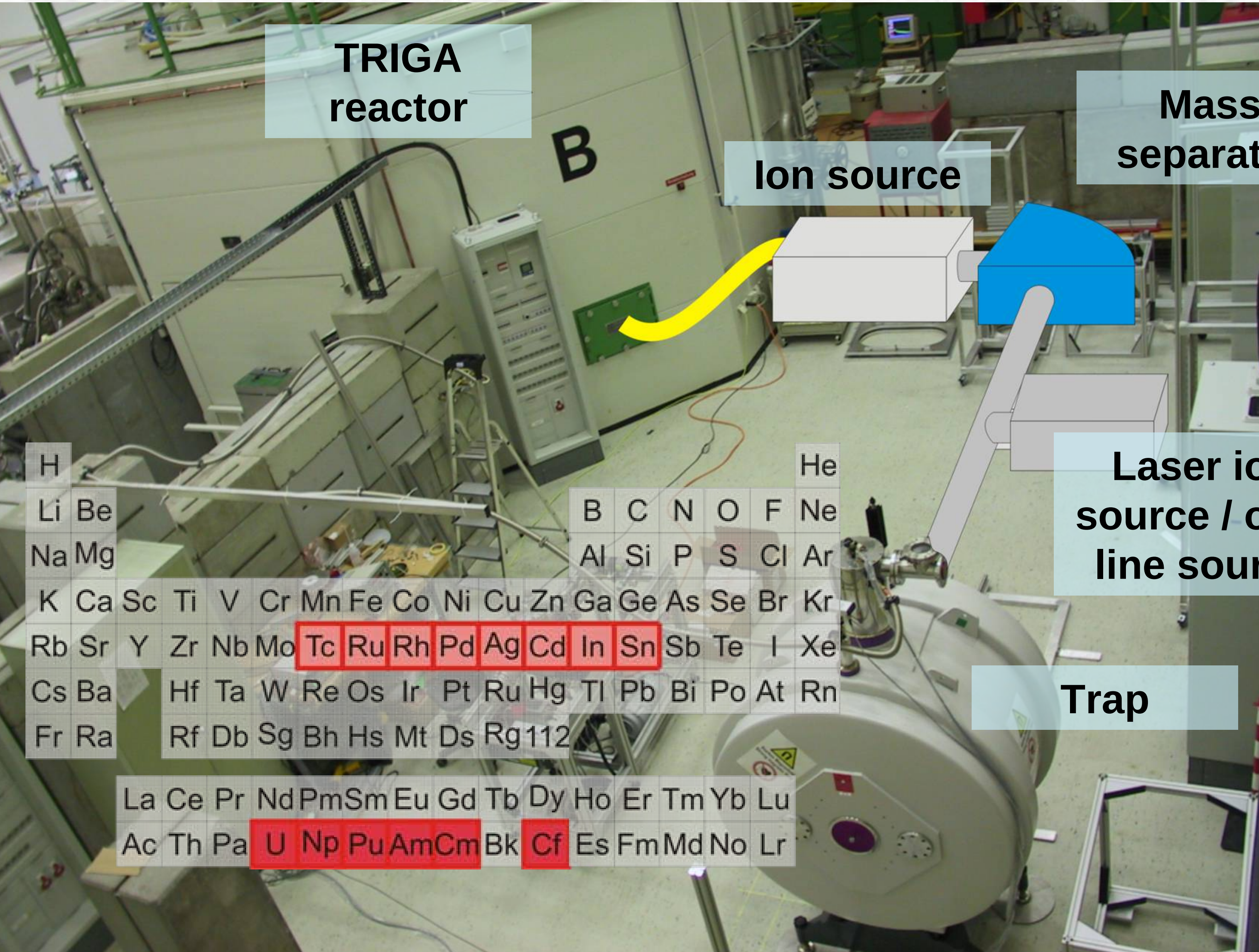
*courtesy of J. Dilling and R. Ringle*

# TRIGA-SPEC

In collaboration with:
K. Eberhardt
G. Hampel
W. Nörtershäuser
N. Trautmann

# TRIGA – Trap

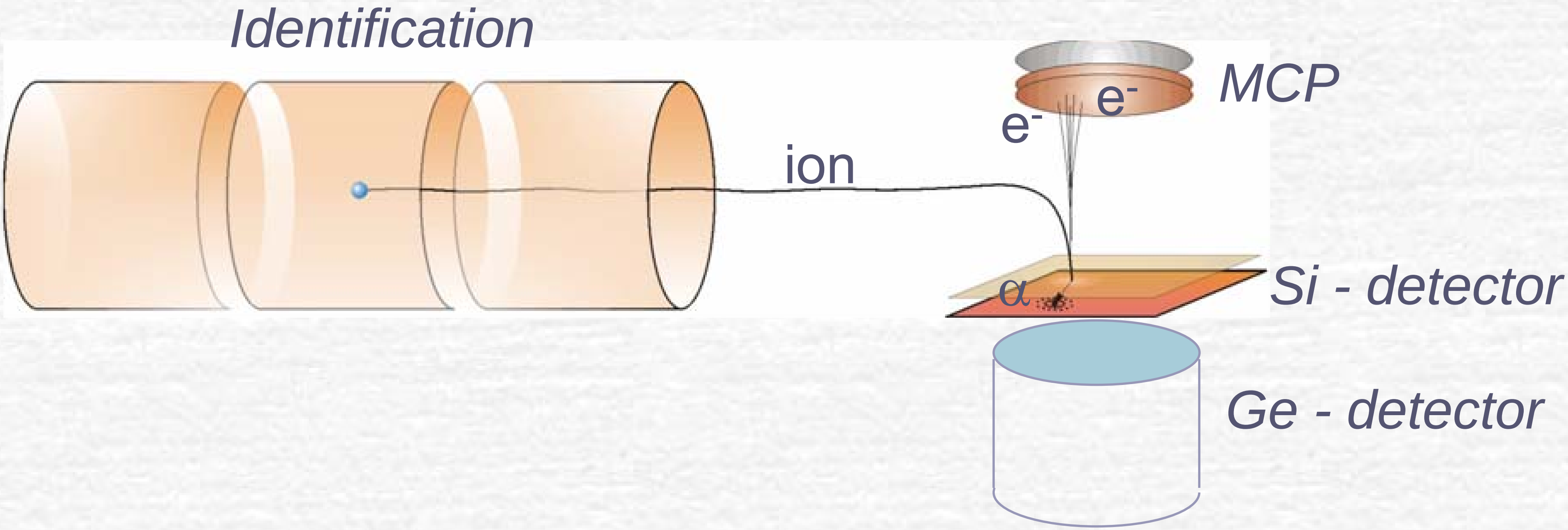

TRIGA reactor
B
Ion source
Mass separator
Laser ion source / off – line source
Trap
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba Hf Ta W Re Os Ir Pt Ru Hg Tl Pb Bi Po At Rn
Fr Ra Rf Db Sg Bh Hs Mt Ds Rg 112
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr

# New Application: α–Spectroscopy

**Decay behind the trap:**
• pure ion ensemble (even if low lying isomers were present)

**In-trap decay**
• source without backing, i.e. no straggling, no energy loss

**Example 1:**
α, γ – decay spectroscopy with unambiguously identified ions

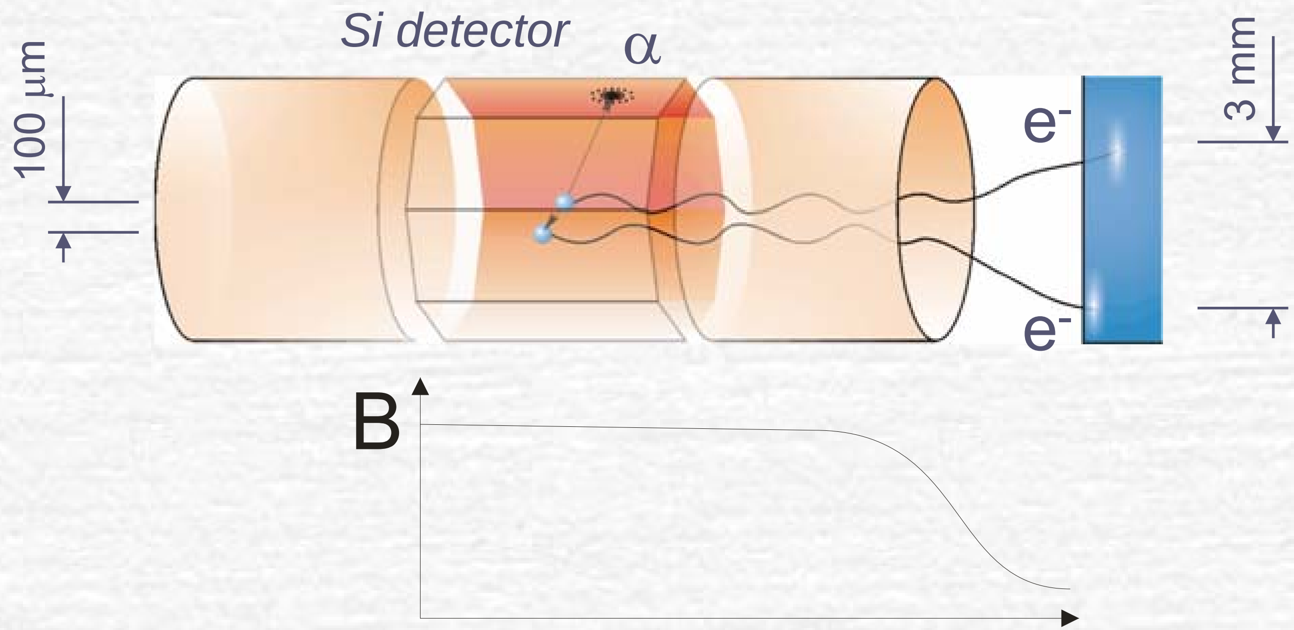


# New Application: $\alpha$–Spectroscopy

**Decay behind the trap:**
• pure ion ensemble (even if low lying isomers were present)

**In-trap decay**
• source without backing, i.e. no straggling, no energy loss

**Example 2:**
Life-time measurements of $0^+$- or $2^+$-states populated by $\alpha$-decay
$\tau(2^+) \rightarrow Q_0$, $\tau(0^+) \rightarrow \rho^2(E_0)$




*in collaboration with LMU Munich. Thirolf et al.*

# Latest News

- Setup of a Penning trap prototype system at the nuclear research reactor TRIGA Mainz
- New MR-TOF-MS developments (Gießen)
- Finland: start to finance FAIR-projects
- TDR – submission date 2008/2009
- Readiness to move the equipment to the building in 2012/2013
- Readiness for beam in 2013/2014
- IMoU ready and signed