AP-Workshop at GSI, 09-10.12.2002

Laser Spectroscopy of Radioactive Atoms

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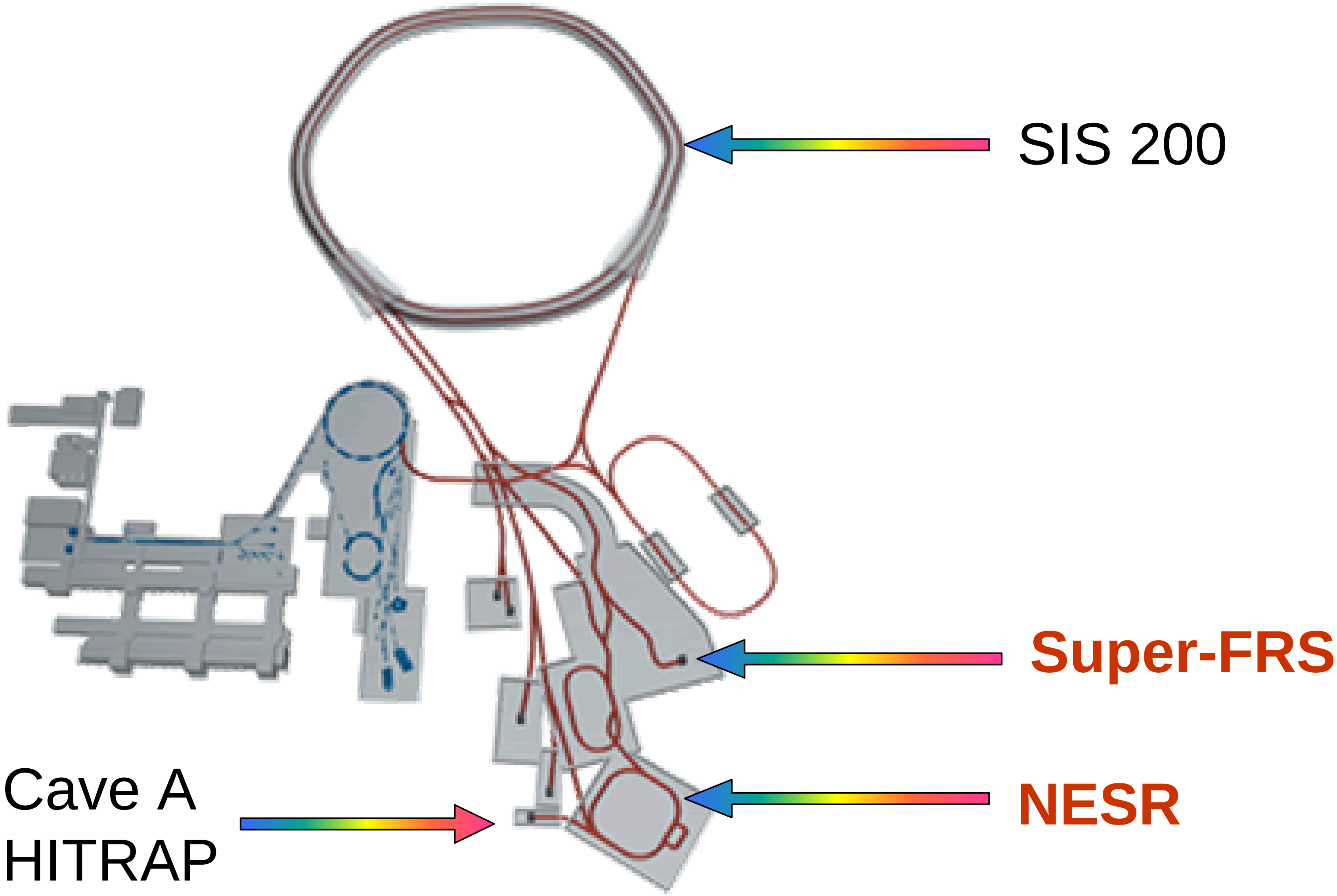
Purposes for Laser Spectroscopy of RIB

- Investigation of Nuclear Ground State Properties
  - ➢ Hyperfine Structure, Isotope Shift and Isomer Shifts provide model-independent data of nuclear properties

- Manipulation of radioactive samples and beams
  - ➢ Production of Isobarically Pure Beams (LIS)
  - ➢ Laser Cooling
  - ➢ Polarization via Optical Pumping

- Testing Fundamental Symmetries
  - ➢ Weak Interaction Studies
  - ➢ Search for Parity Non Conservation in radioactive Fr
  - ➢ Anapole Moment

Laser Spectroscopy at the Future Facility



Nuclear Ground State Properties

Isotope Shift (IS)

↓

Mean Square Charge Radii

$$\delta\langle r^2\rangle^{AA'}$$

Hyperfine Structure (HFS)

↓

Nuclear Spin I

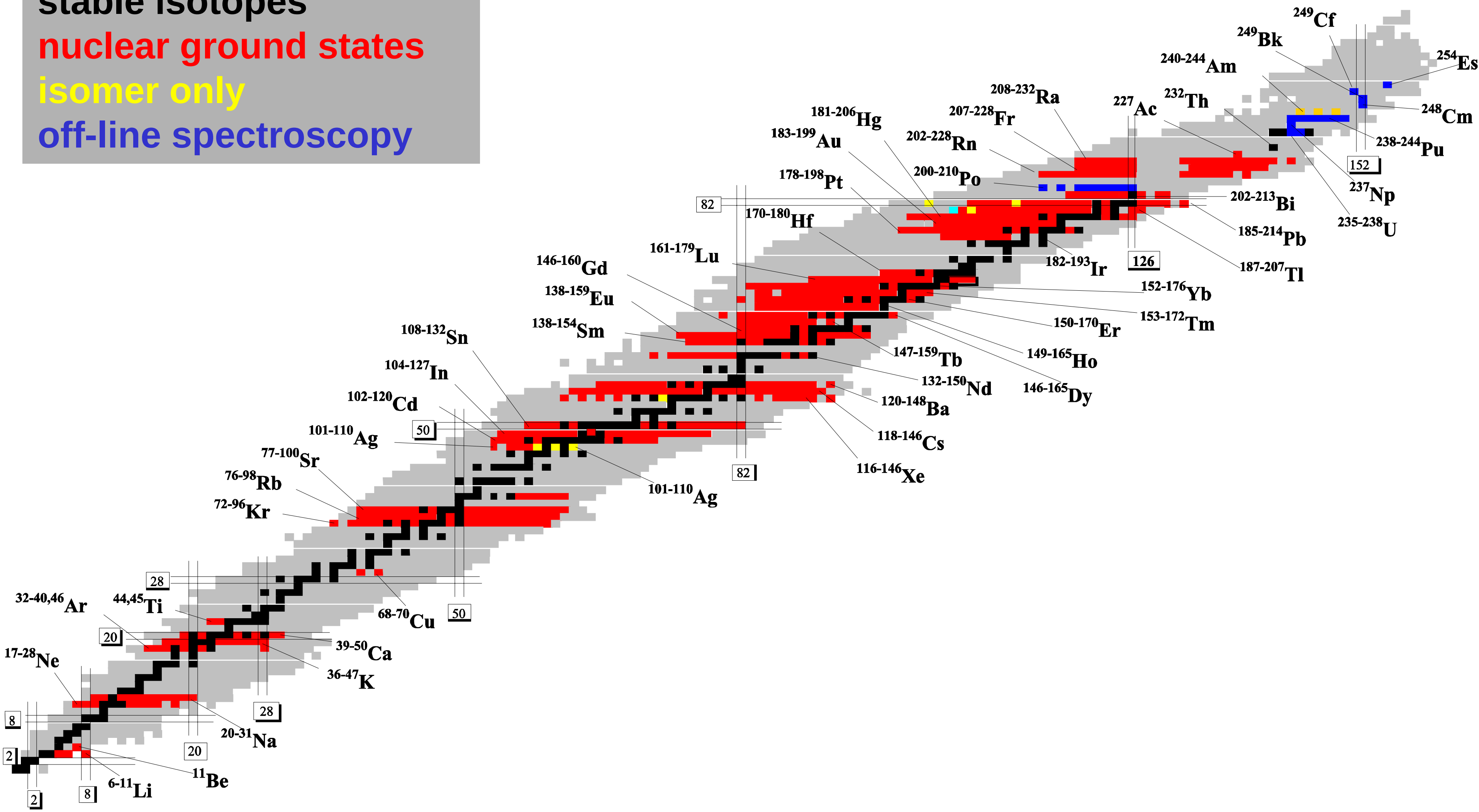
Magnetic Dipole Moment μ_I

Electric Quadrupole Moment Q_s

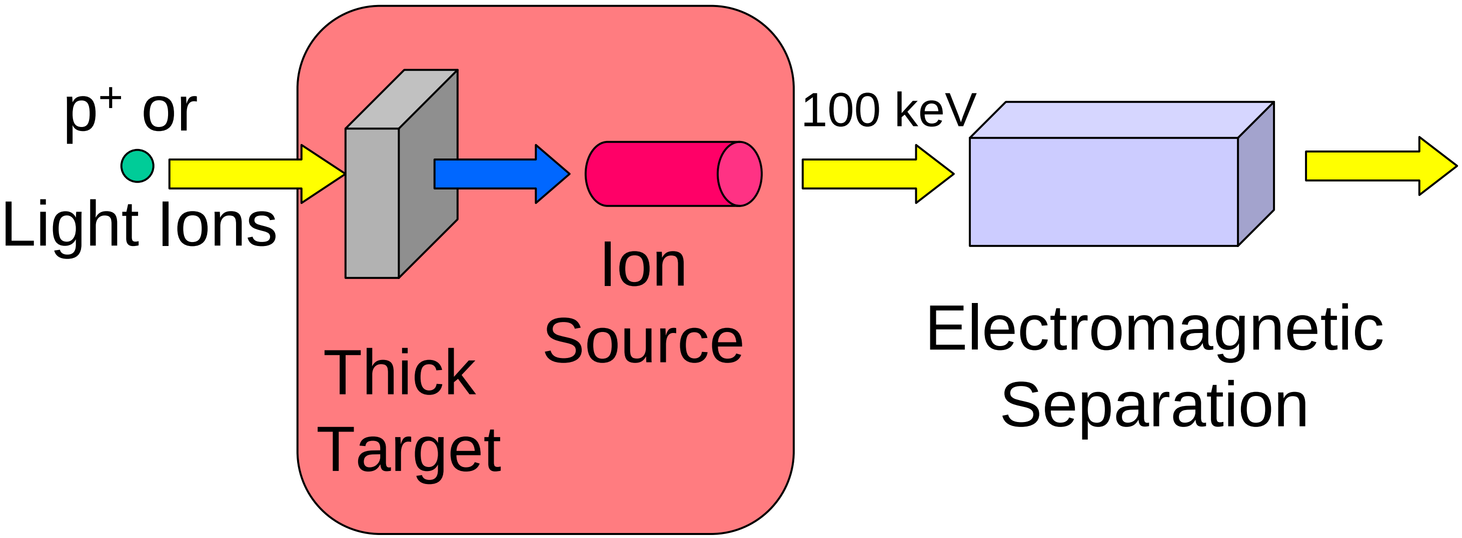
Hyperfine Anomaly

Laser Spectroscopy On-Line

stable isotopes
nuclear ground states
isomer only
off-line spectroscopy



ISOL = Isotope Separation On-Line

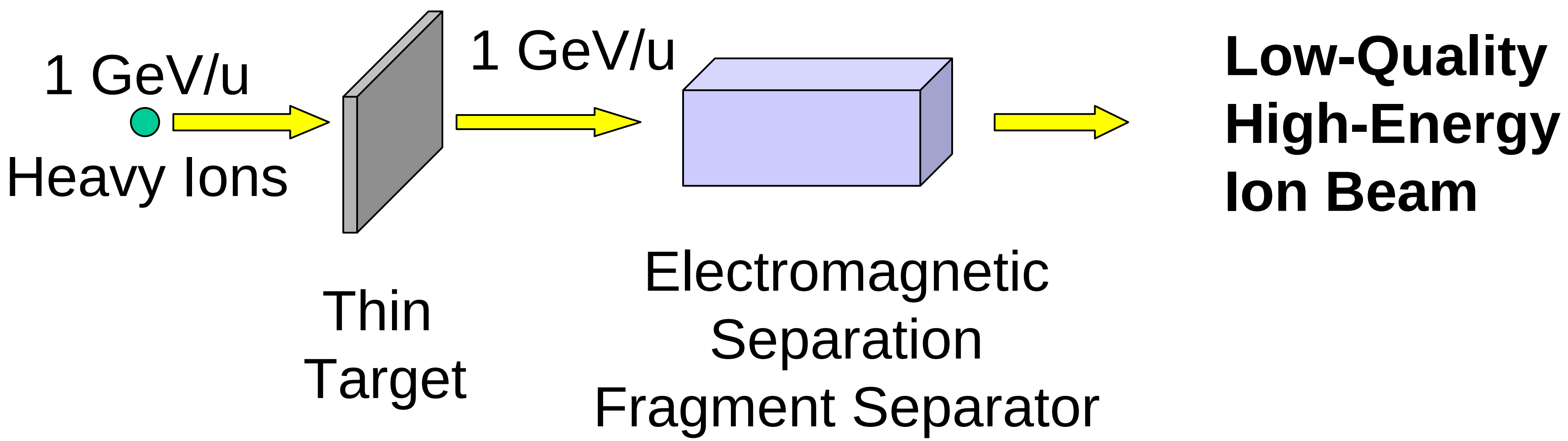


High-quality low-energy ion beam, High intensity for long-lived isotopes

Limits: $T_{1/2}$ ~ 10 ms
no reactive elements
no refractory elements

Good conditions for Fast Beam Collinear Laser Spectroscopy

In-Flight Fragmentation



All Elements

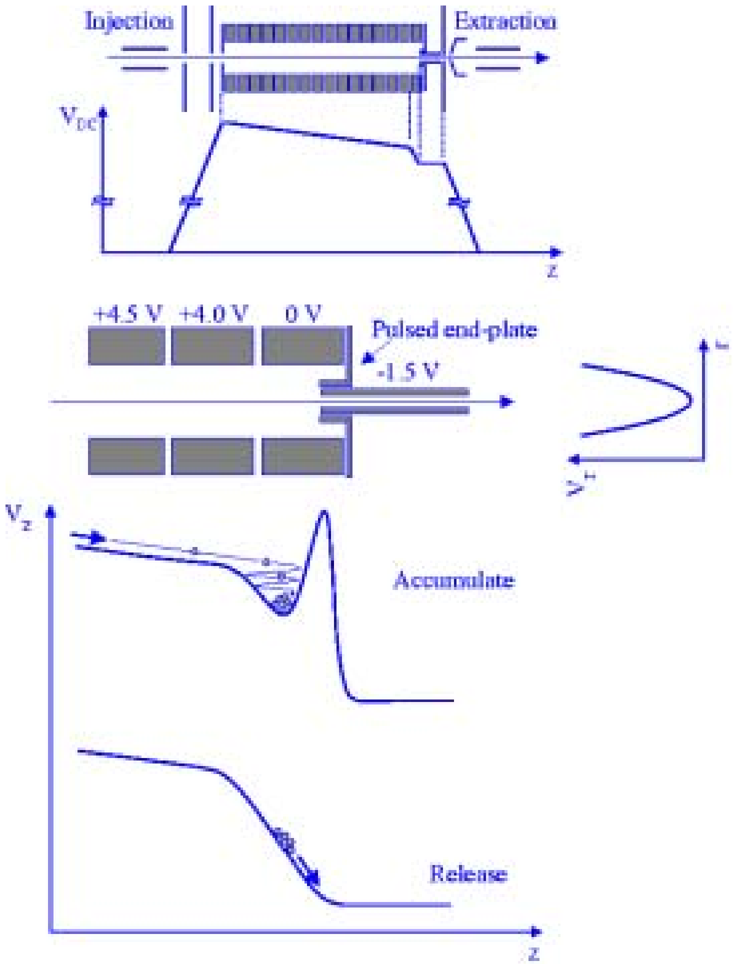
chemically non-selective

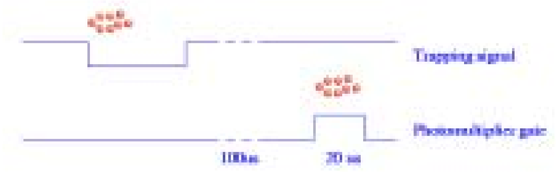
Limits: $T_{1/2}$ ~ 1 μs

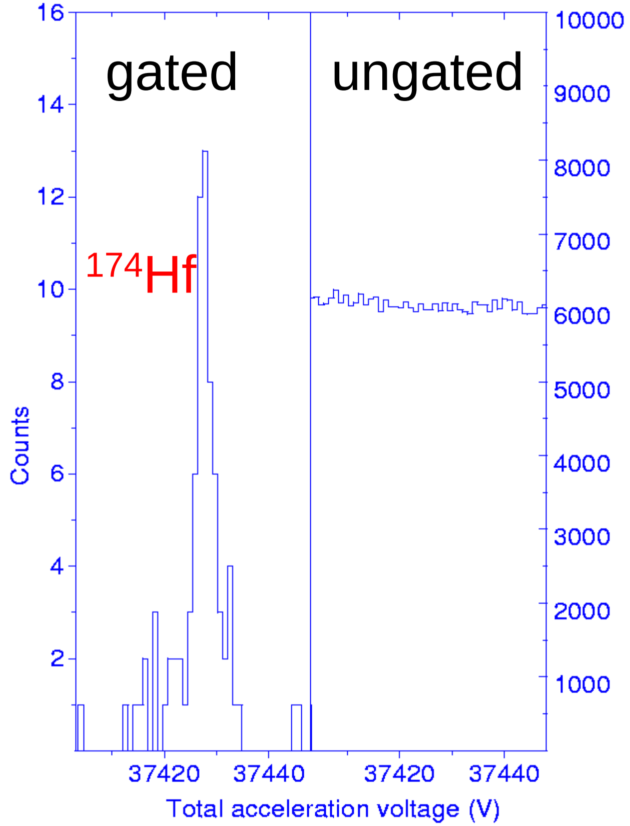
Low Intensities

Complementary to ISOL Technique

Improving Collinear Spectroscopy: Cooling and Bunching

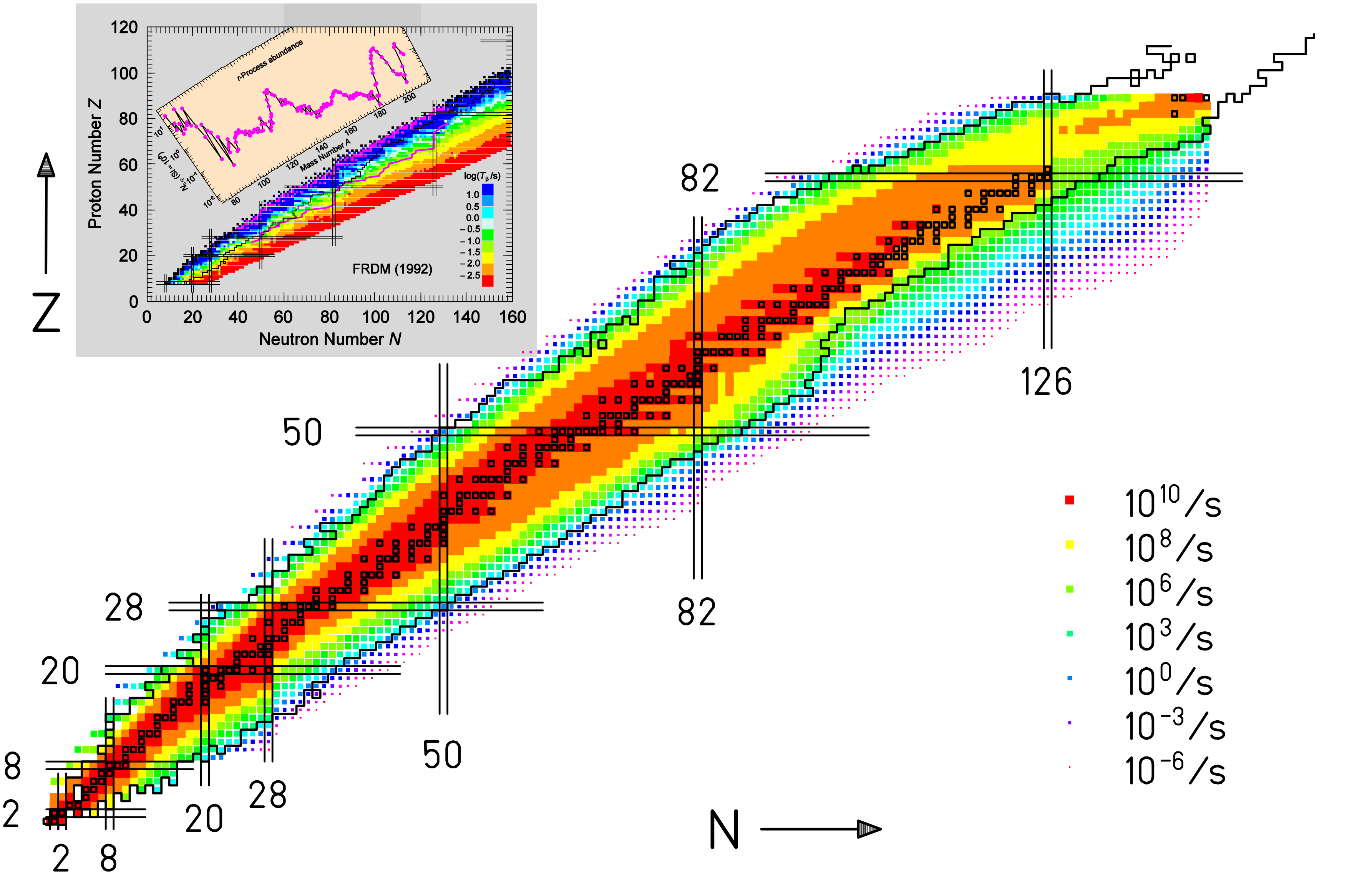






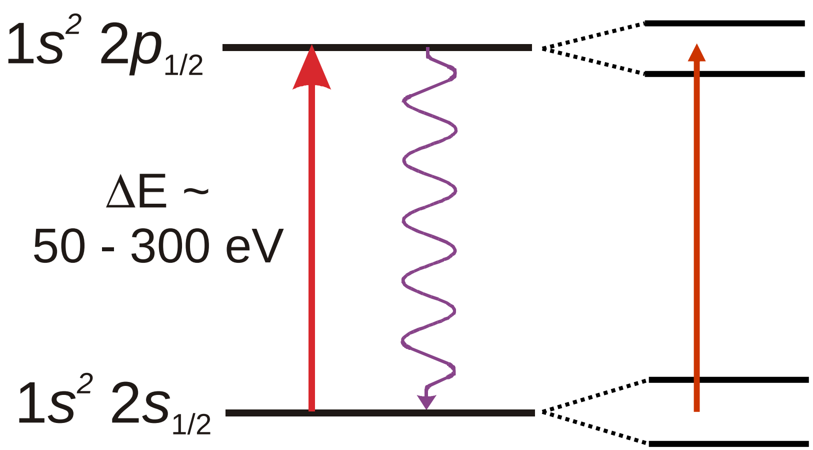
A. Nieminen *et al.*, PRL **88**, 094801 (2002)

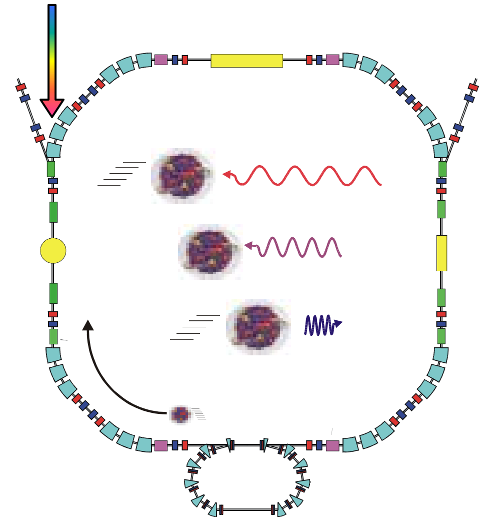
Super-FRS Predicted Production Rates

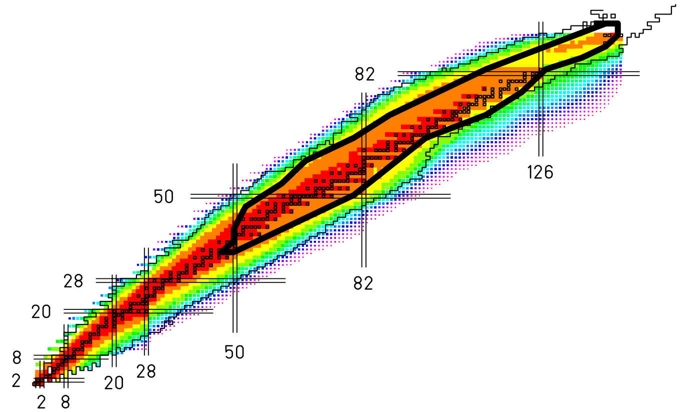


NESR:
Spectroscopy of Highly Charged Ions

(A) X-Ray-Spectroscopy: $2s_{1/2} \rightarrow 2p_{1/2}$ in lithium-like heavy ions







transition energy

⇓

QED in strong fields

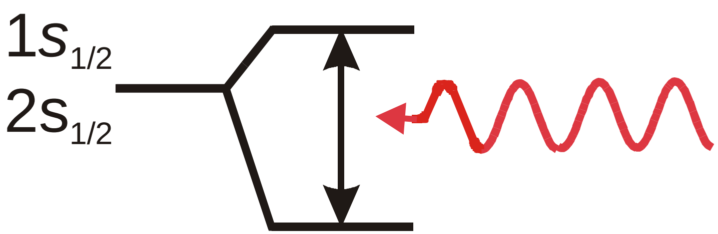
IS, HFS

⇓

Nuclear Properties

NESR:
Spectroscopy of Highly Charged Ions

(B) Optical Spectroscopy: Ground-State Hyperfine Structure



<u>Testing:</u>
QED in strong fields
Hyperfine Structure
Magnetization Distribution

<u>Alternative:</u>

At HITRAP it will be possible to perform HFS measurements with Highly Charged Ions at rest!

Conclusion

The Future Facility at GSI provides many interesting scenarios for laser spectroscopy:

- **SIS-200**: Laser Cooling and spectroscopy of Li-like heavy ions
- **NESR**: X-ray and optical spectroscopy on H-like and Li-like ions
- **Super-FRS**: Gas-Cell, cooling and bunching of ions **+** collinear spectroscopy, ion- or atom traps
- **HITRAP**: HFS-Spectroscopy on trapped highly charged ions

→ **Better knowledge of nuclear structure**