Prospects for studying ion-neutral interaction potentials of SHE

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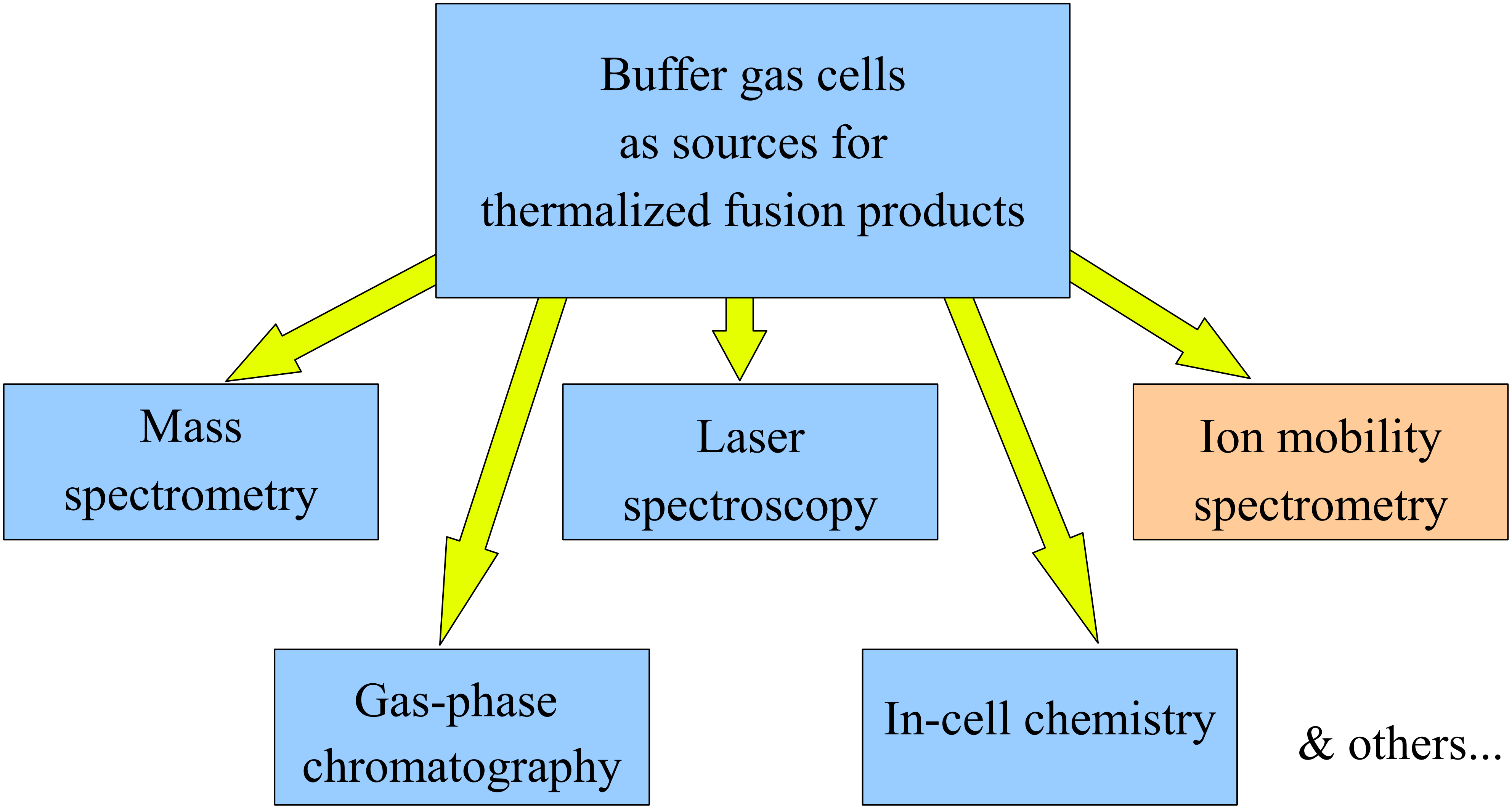
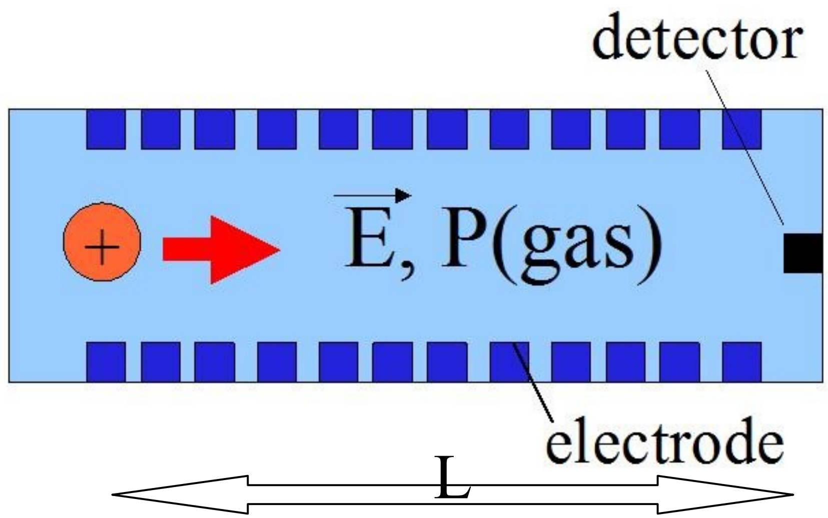
Introduction: Scientific methods



Introduction: Ion Mobility Spectrometry (IMS)



Ion drift motion in gas & electric fields:

Mobility: $K = L / (E * t_{drift})$

IMS in chemistry:

- State selected ion chemistry ...

C. Iceman, et al., J. Am. Soc. Mass Spectrom. 18 (2007) 1196
P. Kemper, et al., J. Am. Chem. Soc. 112 (1990) 3231

- Study of molecule-molecule interaction potentials / polarizabilities
- Study of molecular bond lengths
- Study of reaction rate constants (via ATD- / Ion-Rate analysis)

IMS in physics:

- Access to ion-atom interaction potential of short-lived isotopes ($t_{1/2}$<1s)
- Assignment/verification of valence electron configurations also of SHE

Introduction: Mobility & interaction potentials

Ion drift motion in gas & homogeneous electric field:

For molecule ions (in N_2, air) => *K* almost sensitive to size / shape
For monoatomic ions (in He, Ar) => *K* sensitive to:

- mass, if ion mass << mass of gas atom
- size, if ion mass >> mass of gas atom
- both, for nearly equal masses

According to Viehland-Mason theory:

Mobility <=> Collision Cross Section <=> Ion-Neutral Interaction Potential V(r)

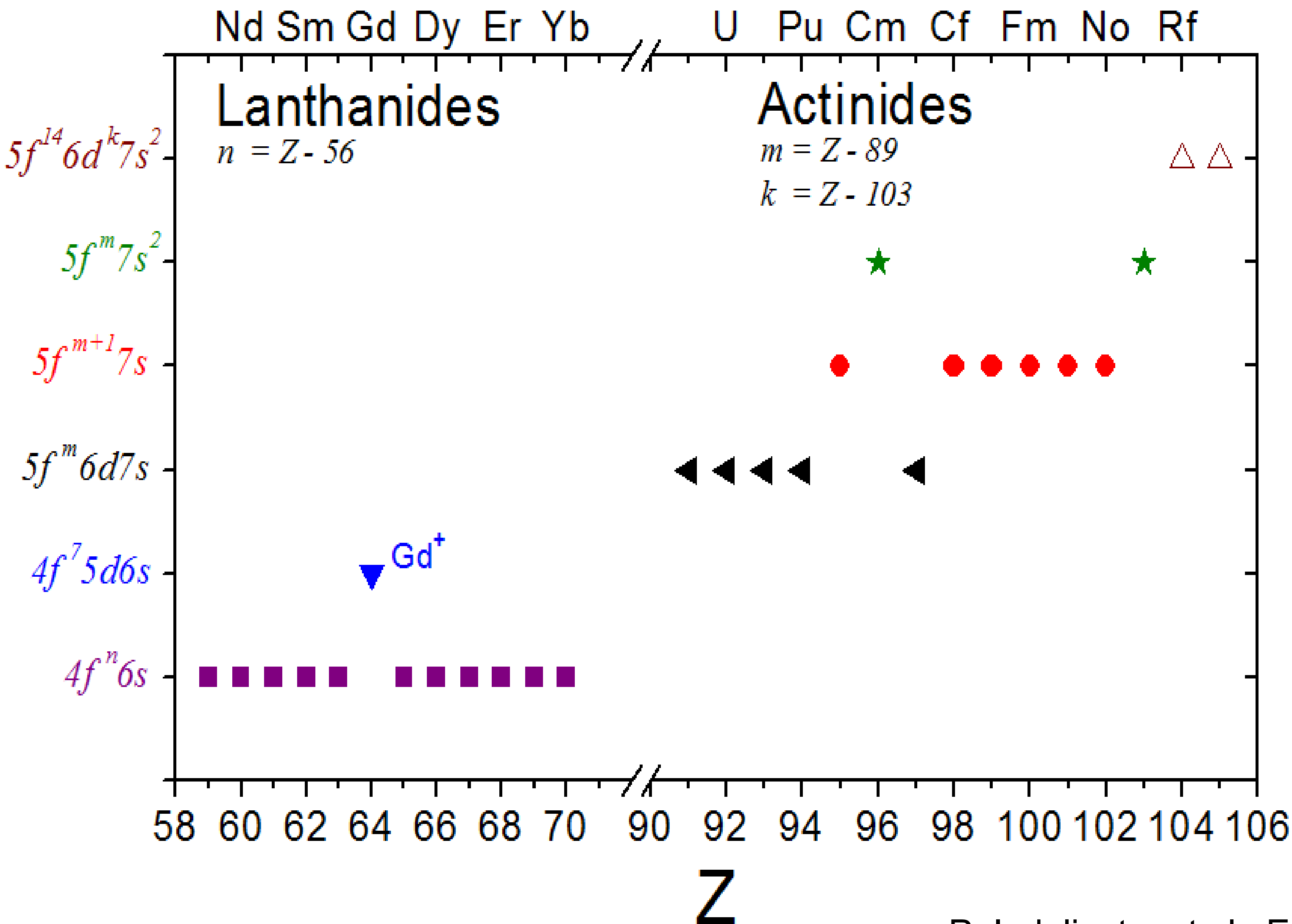
$$V(r) = (C_n/r^n) - (C_6/r^6) - (C_4/r^4)$$

- (C_n/r^n): Pauli repulsion
- (C_6/r^6): London dispersion & high order contributions
- (C_4/r^4): dipole attraction

C_i: Constants
r : Molecular distance
n : Fitting parameter

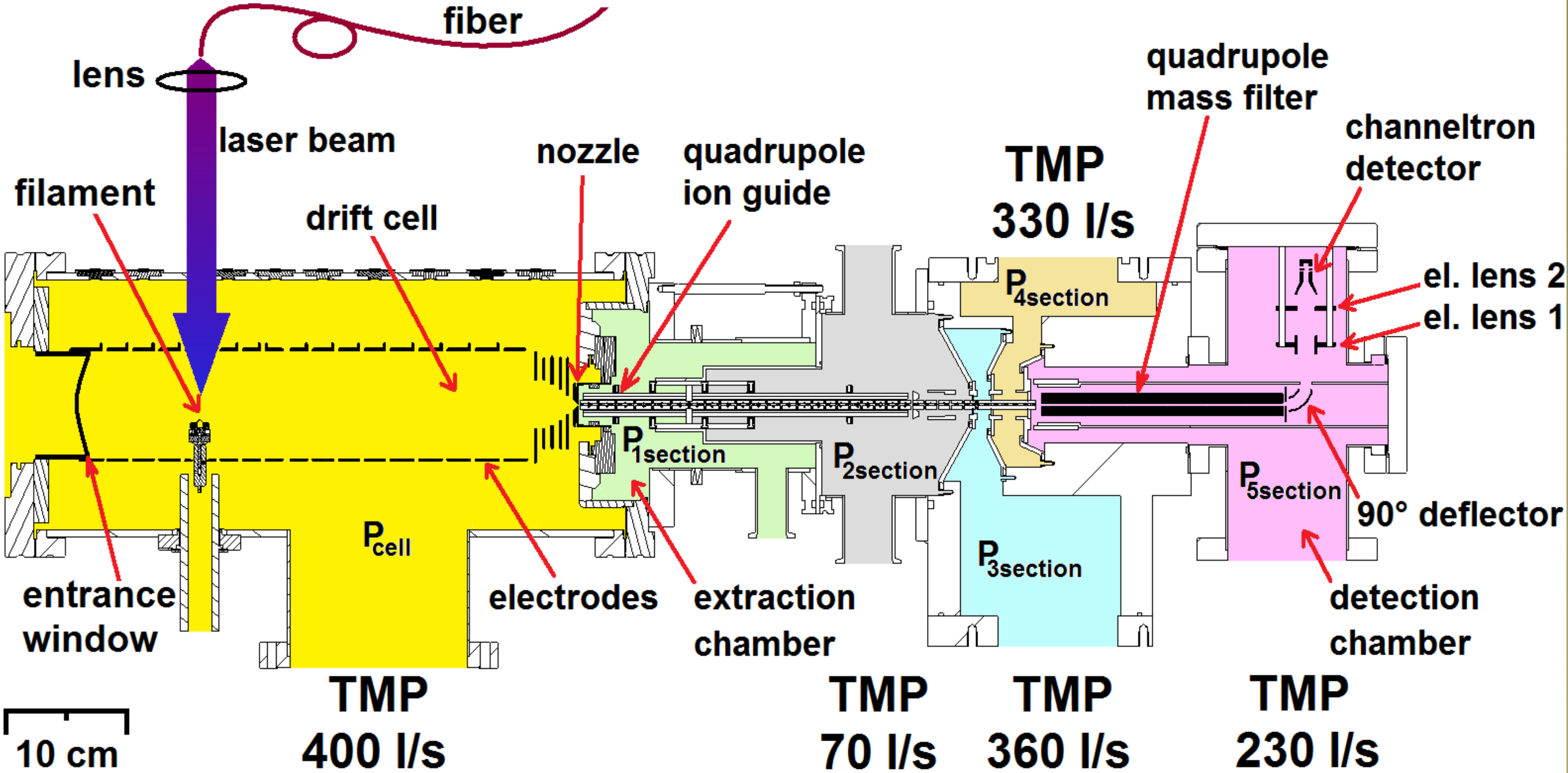
Potential for studying the impact of electron configuration on V(r) of the heaviest elements by IMS methods

Introduction: Valence electron configurations of singly charged ions



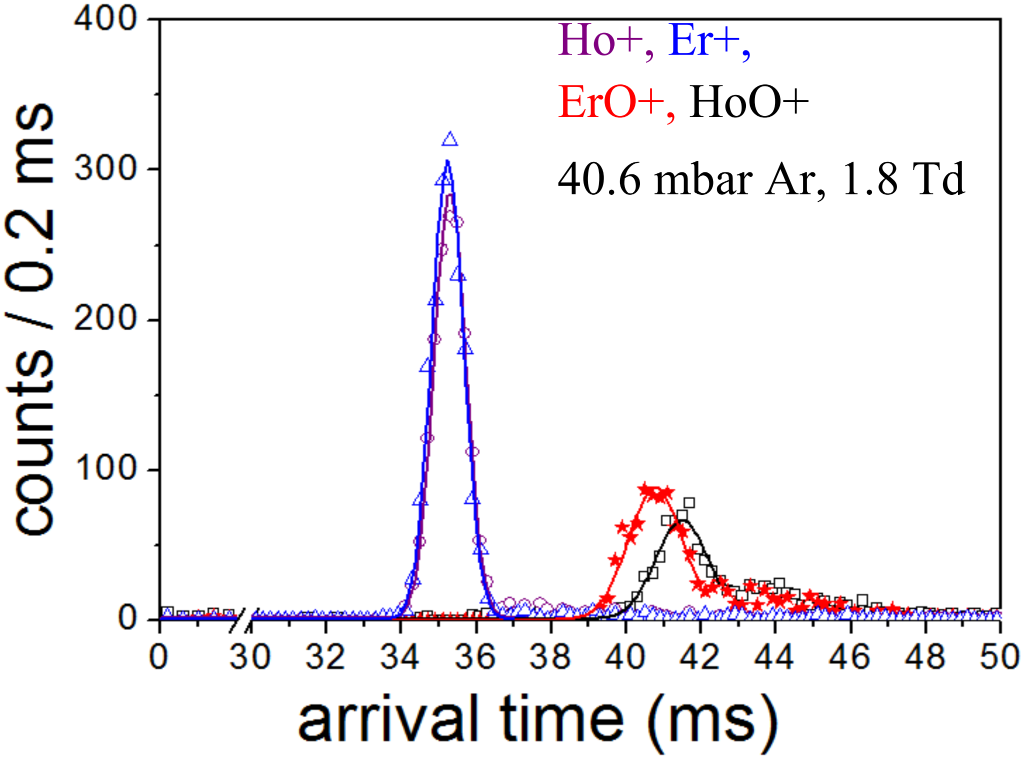
P. Indelicato, et al., EPJ D (2007)

The setup: The ion mobility spectrometer

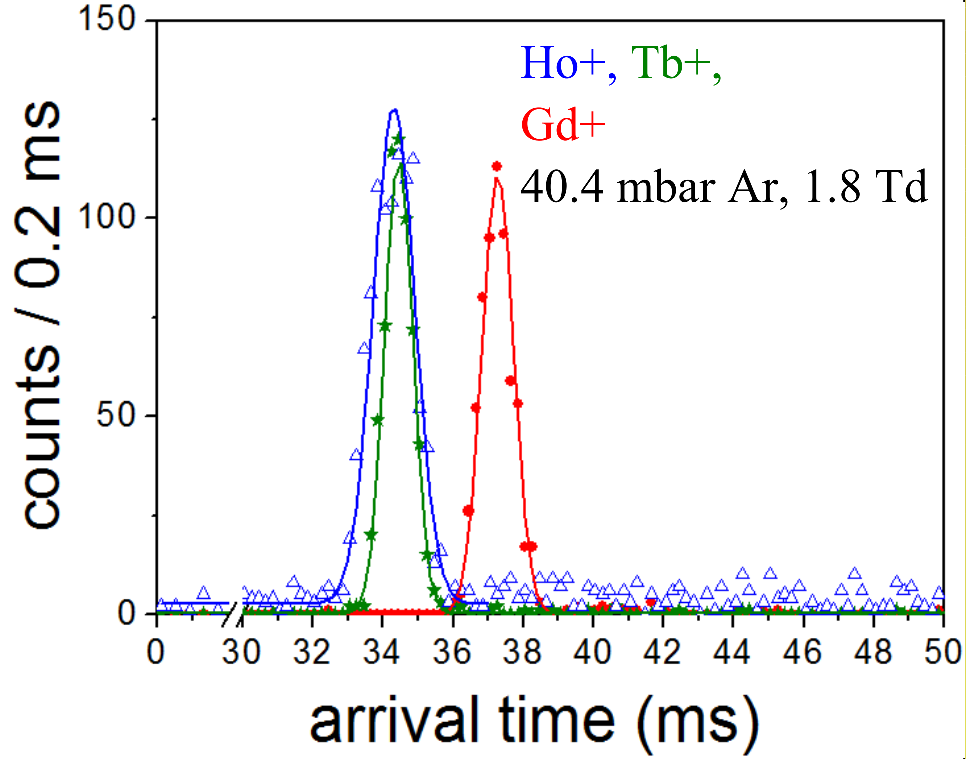


Results: resolving power

* Achieved resolving power: 45
* Lanthanide oxides could be discriminated in time due to lanthanide contraction.

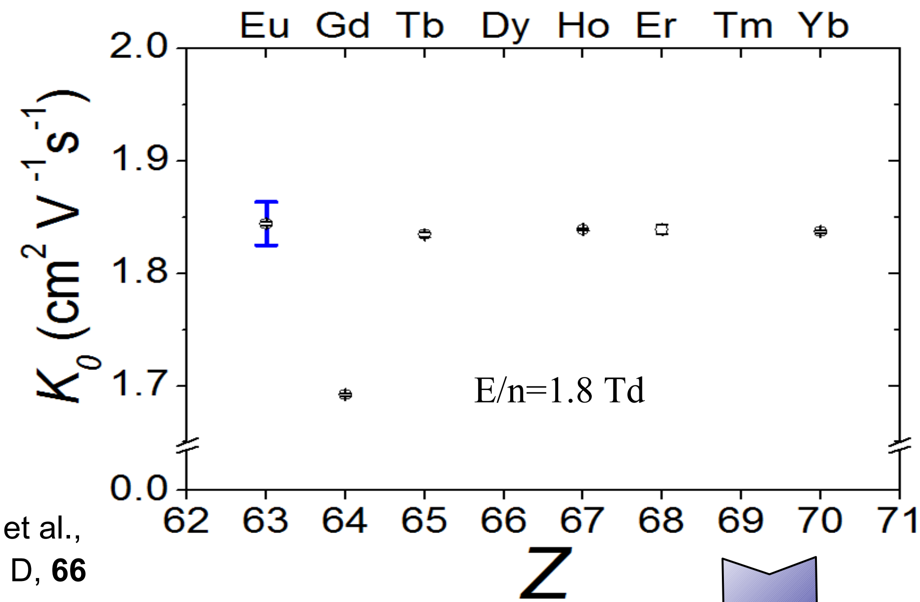


* Gadolinium ions seem to have a larger cross section compared with the other investigated ions



Results: Interaction potential

Ion mobility of Lanthanides:

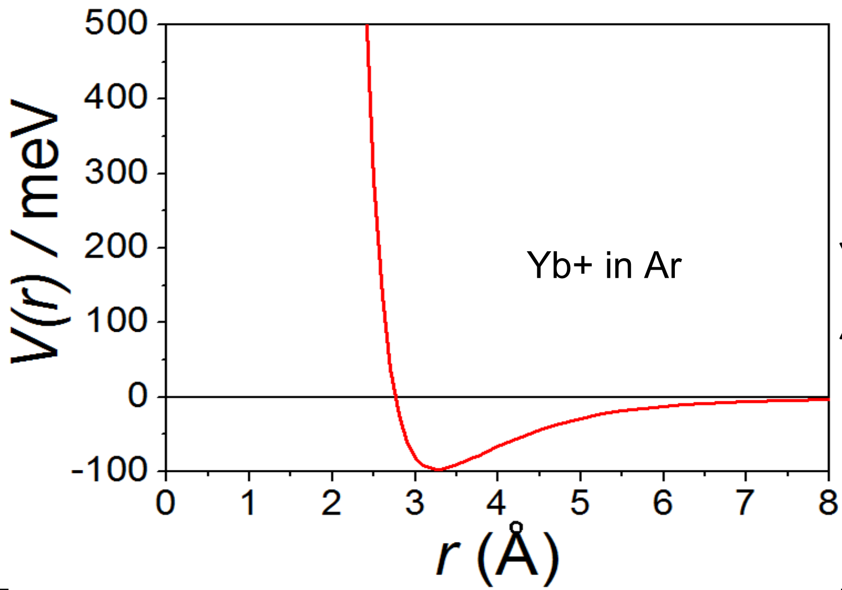


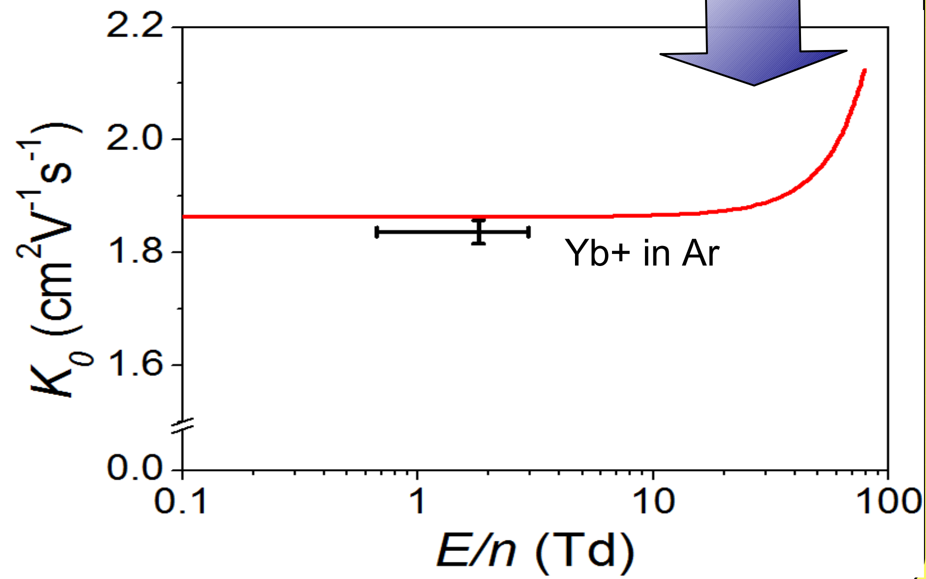
* All lanthanide ions exhibited nearly the same drift time except for Gd+

=> Sensitivity to valence electron configuration

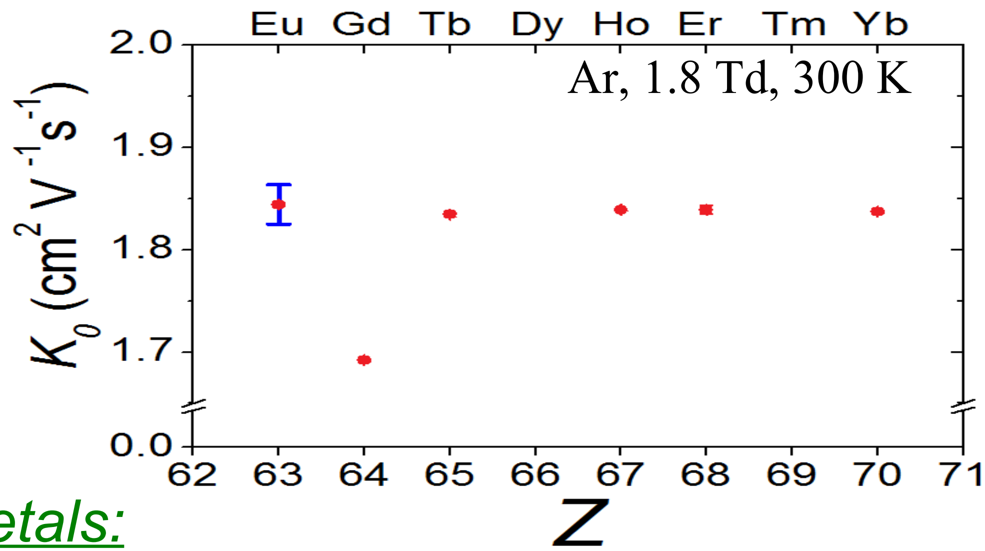
Relativistic calculation of V(r) for Yb-Ar system:

M. Laatiaoui et al., Eur. Phys. J. D, **66** (2012) 232





Outlook: Sensitivity to valence electron configuration



M. Laatiaoui et al.,
Eur. Phys. J. D, **66** (2012) 232

Rare earth metals:

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu

$4f5d^2$ $4f^46s$ $4f^66s$ $4f^75d6s$ $4f^{10}6s$ $4f^{12}6s$ $4f^{14}6s$

$4f^36s$ $4f^56s$ $4f^76s$ $4f^96s$ $4f^{11}6s$ $4f^{13}6s$ $4f^{14}6d^2$

P. Indelicato et al.,
Eur. Phys. J. D **45**, 155 (2007)

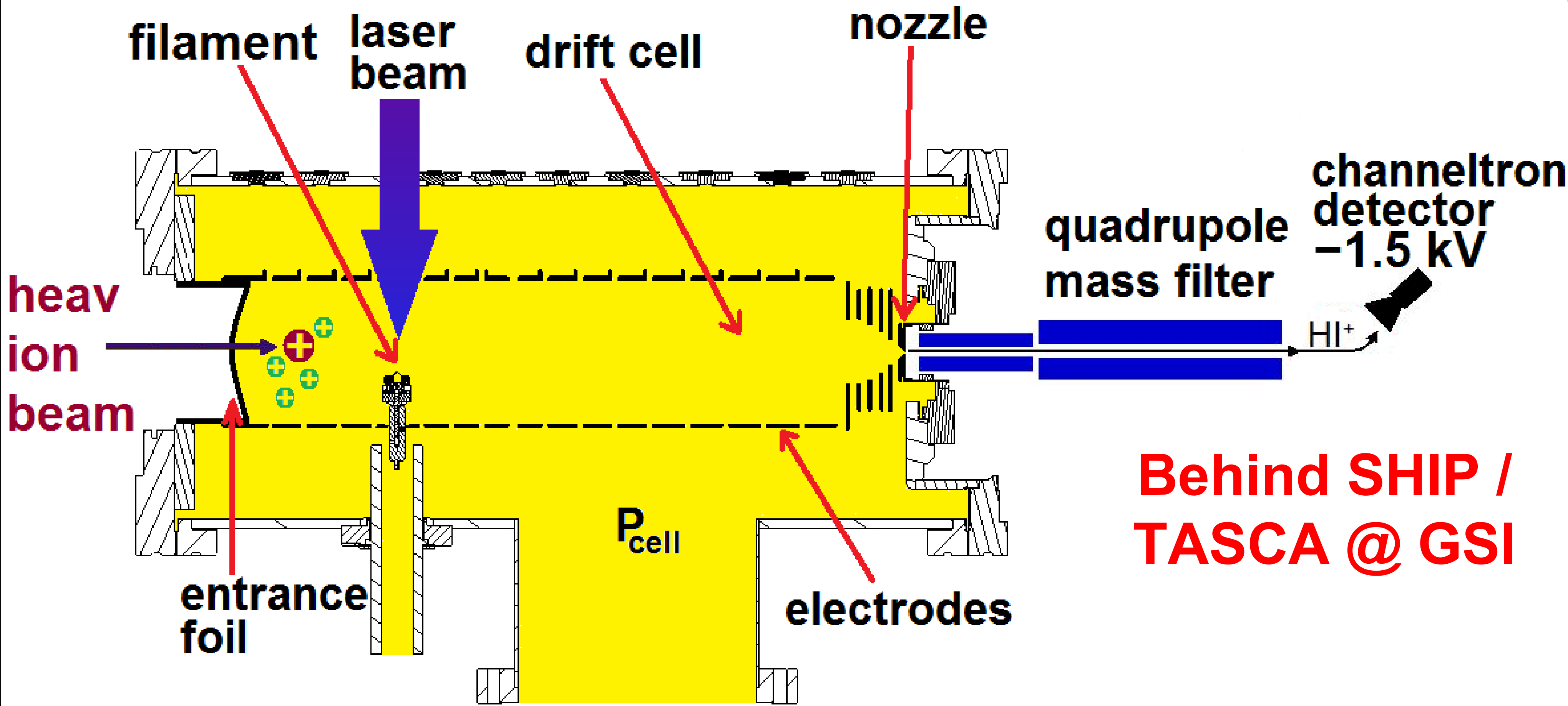
5f-shell elements:

90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Du	Sg	Bh	Hs

$5f^26d$ $5f^36d7s$ $5f^56d7s$ $5f^77s^2$ $5f^{10}7s$ $5f^{12}7s$ $5f^{14}7s$ $5f^{14}6d7s^2$ $5f^{14}6d^47s$ $5f^{14}6d^57s^2$

$5f^26d7s$ $5f^46d7s$ $5f^77s$ $5f^86d7s$ $5f^{11}7s$ $5f^{13}7s$ $5f^{14}7s^2$ $5f^{14}6d^27s^2$ $5f^{14}6d^47s^2$

Outlook: IMS @ actinides

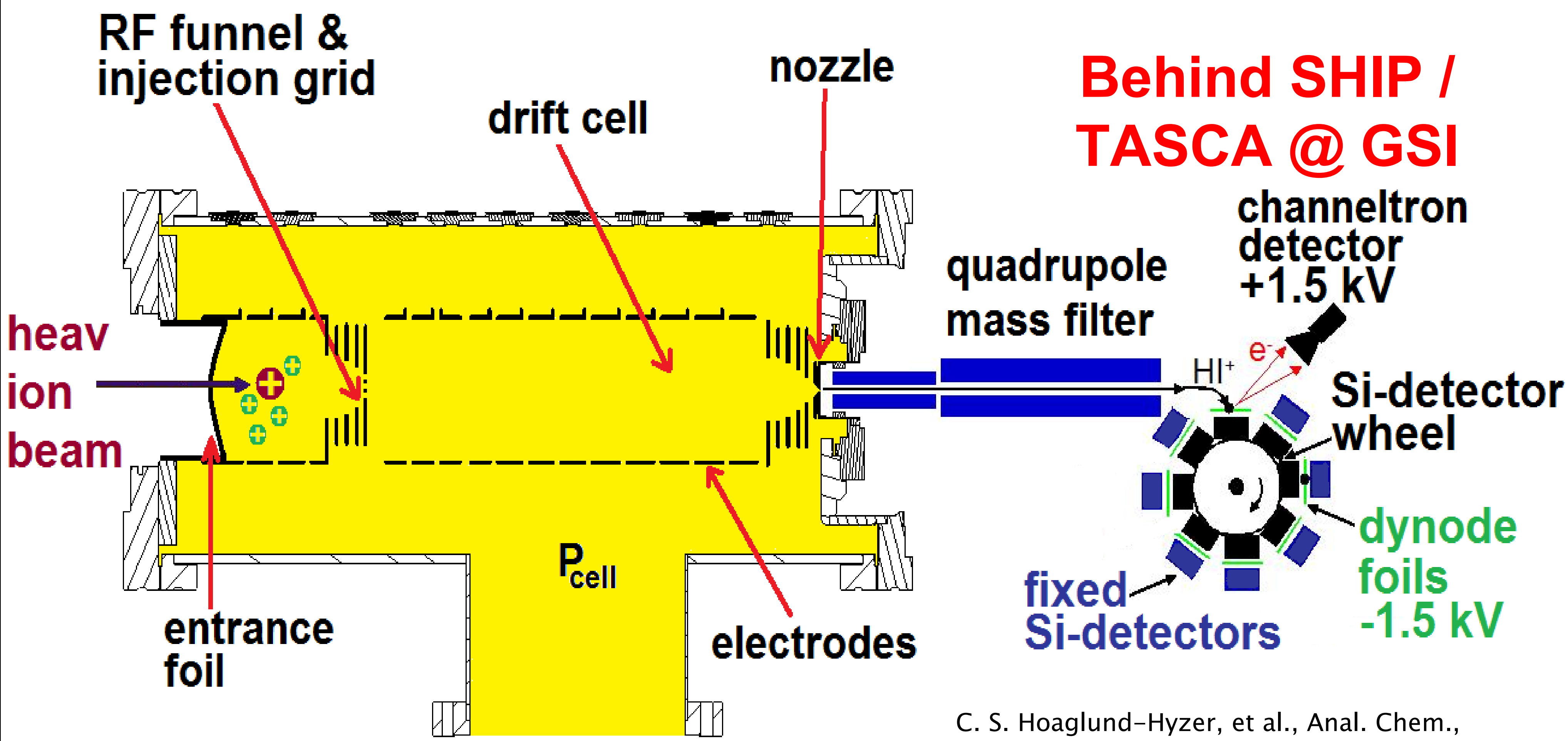


Behind SHIP / TASCA @ GSI

* **Suitable for abundant elements / elements of known atomic excitation schemes (up to fermium)**

M. Sewtz et al., Spectrochimica Acta Part B 58 (2003) 1077–1082

Outlook: IMS @ short-lived SHE



C. S. Hoaglund-Hyzer, et al., Anal. Chem., 2001, 73 (2), pp 177-184

B. H. Clowers, et al., Anal. Chem., 2008, 80 (3), pp 612-623

* Ion trap & injection grids inside the gas cell to determine t_0 and z_0

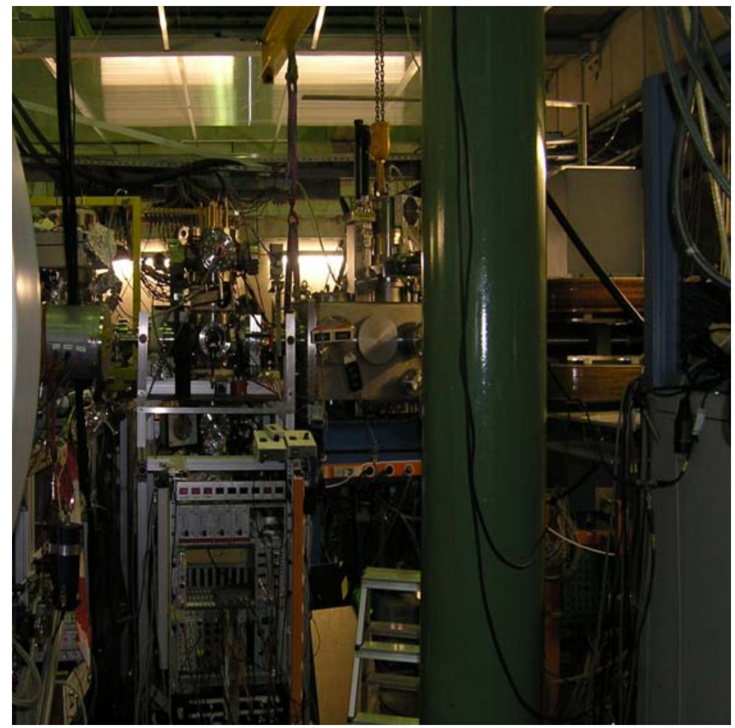
Outlook: Laser spectroscopy and IMS studies at trans-uranium elements

* Hyperfine interaction studies at actinides
* Level search at trans-fermium elements
* Possibility for IMS studies at trans-uranium elements

@ SHIP/ TASCA

Laser lab @SHIPTRAP

Laser spectroscopy cell behind SHIP



Thanks