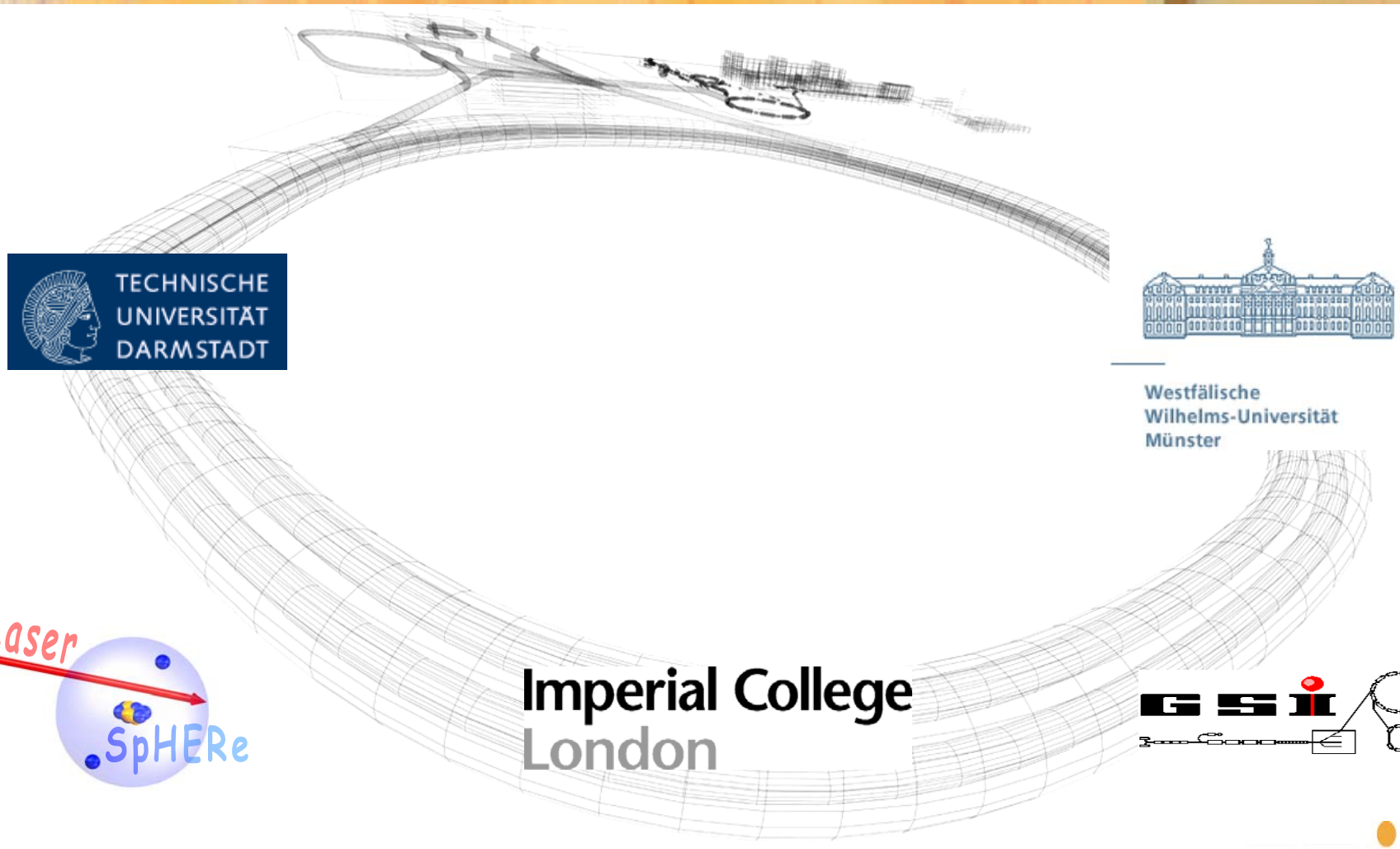
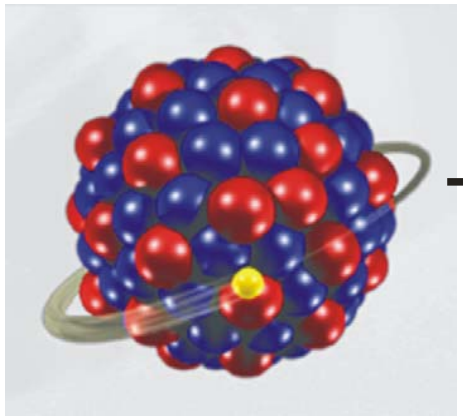
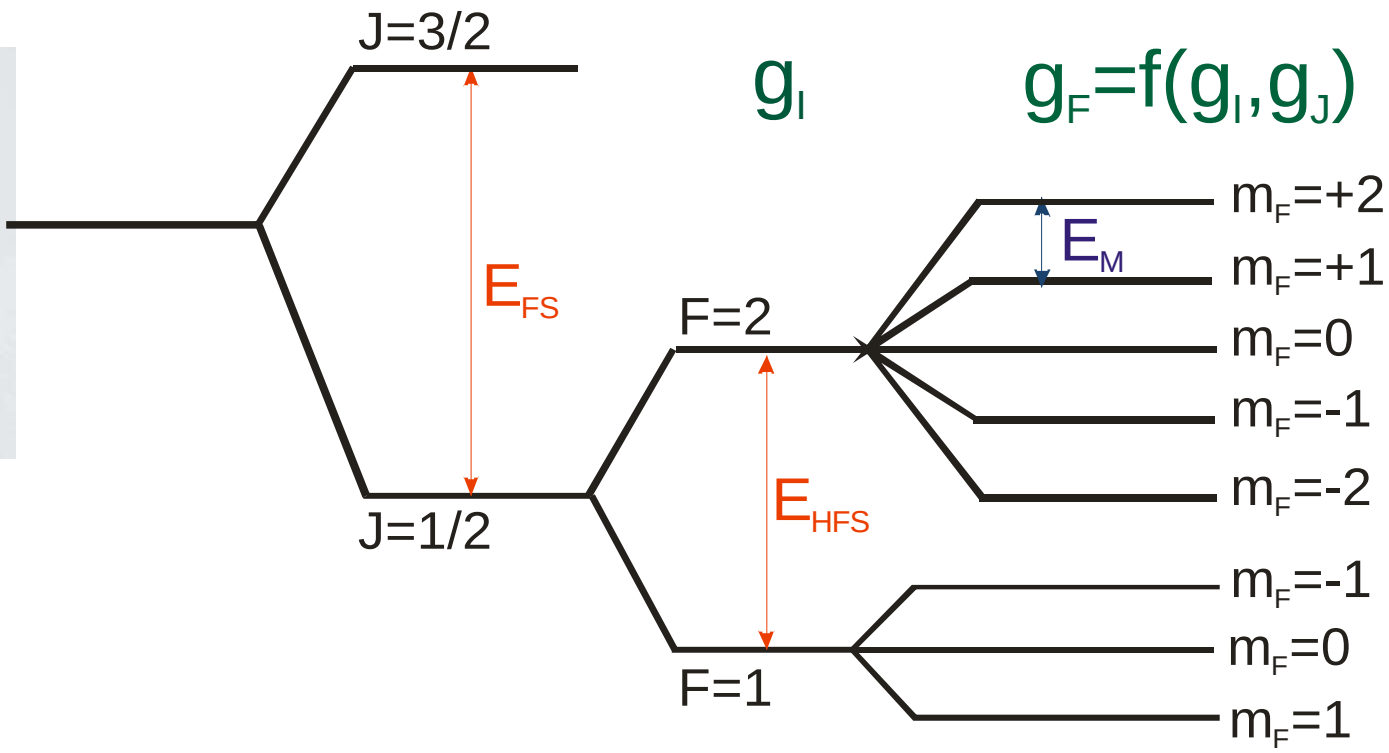
PRECISION SPECTROSCOPY OF FORBIDDEN TRANSITIONS: SPECTRAP @ HITRAP @ ESR



GSI

spectroscopy of HCI: M1-transitions





FINE STRUCTURE J=L+S

HYPERFINE STRUCTURE F=I+J

ZEEMAN m_F=-F...+F

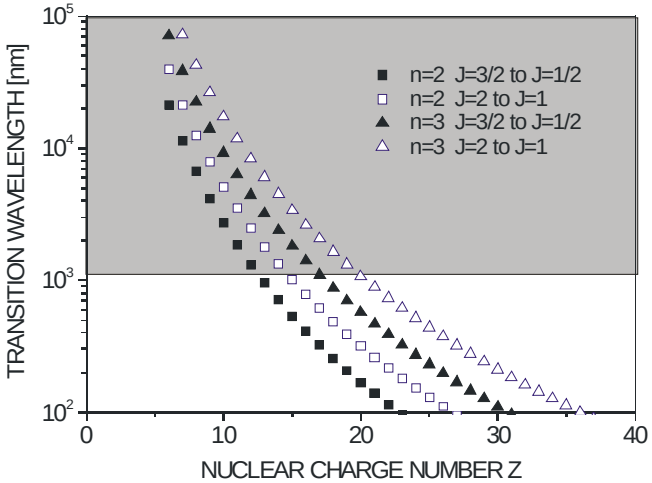
transition energies (for QED test ~ Z^2) 10^{-7} – 10^{-9}

nuclear magnetic moment in absence of shielding 10^{-5} – 10^{-6}

electron magnetic moment: fundamental constants 10^{-9} – 10^{-10}

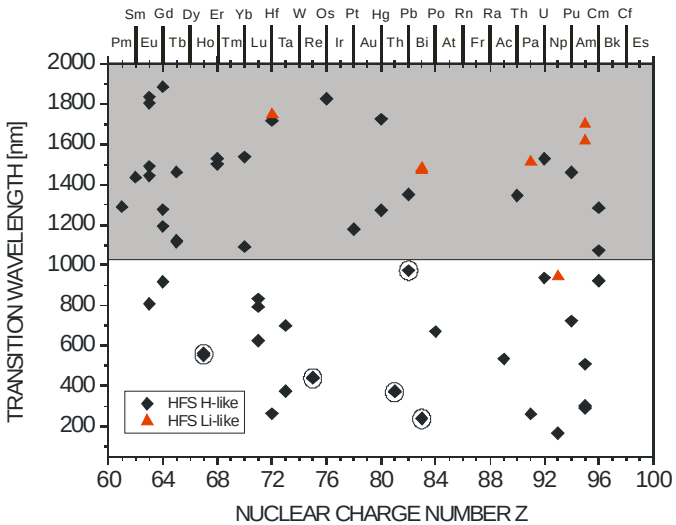
ions of interest

FS: medium-heavy H-, Li- and B-like ions



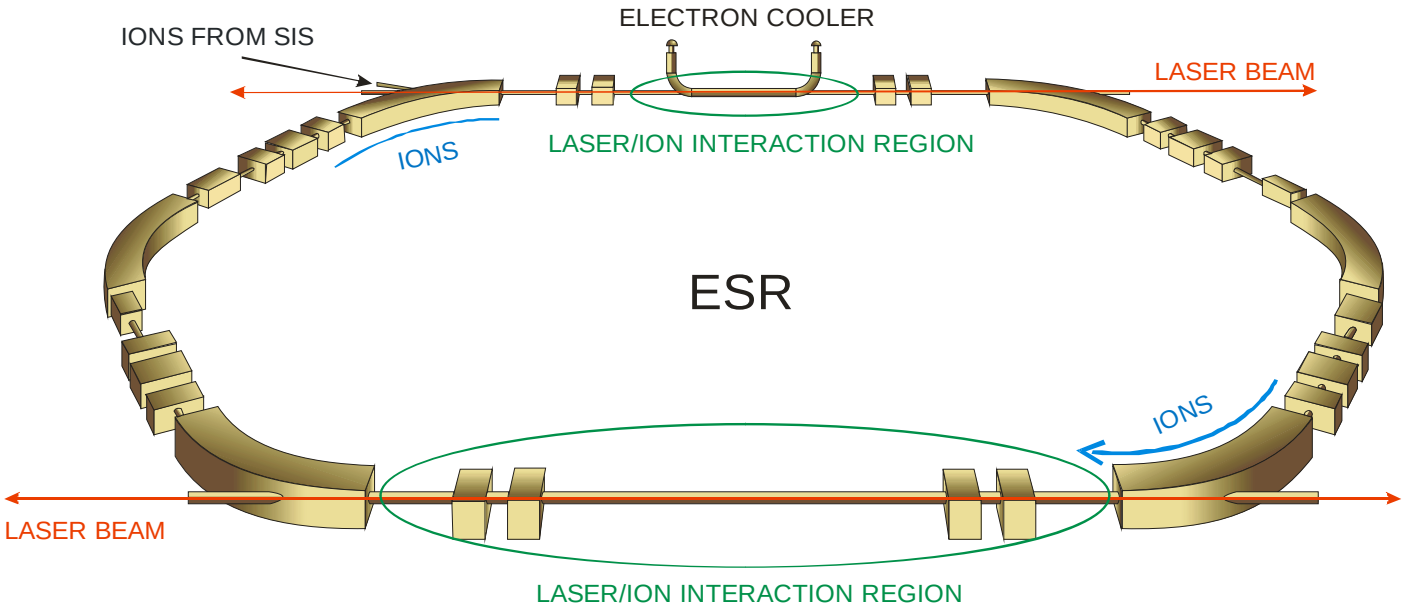
Group	Ion	Conf.	Transition	λ [nm]	A [1/s]
IIIA	(16)S^{11+}	$2s^22p$	$^2P_{1/2}$-$^2P_{3/2}$	761.10	21
	(18)Ar^{13+}	$2s^22p$		441.24	104
	(26)Fe^{13+}	$3s^23p^4$		530.29	60
	(27)Co^{14+}	$3s^23p$		435.06	109
IVA	(20)Ca^{14+}	$2s^22p^2$	$^3P_0$-$^3P_1$	569.44	95
	(21)Sc^{15+}	$2s^22p^2$		435.44	208
	(22)Ti^{16+}	$2s^22p^2$		337.08	440
	(23)V^{17+}	$2s^22p^2$		263.36	921
	(33)As^{19+}	$3s^23p^4$		243.80	1100

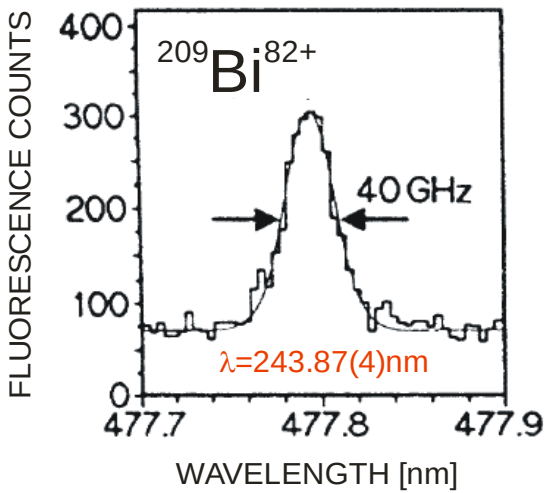
HFS: heavy H- and Li-like ions

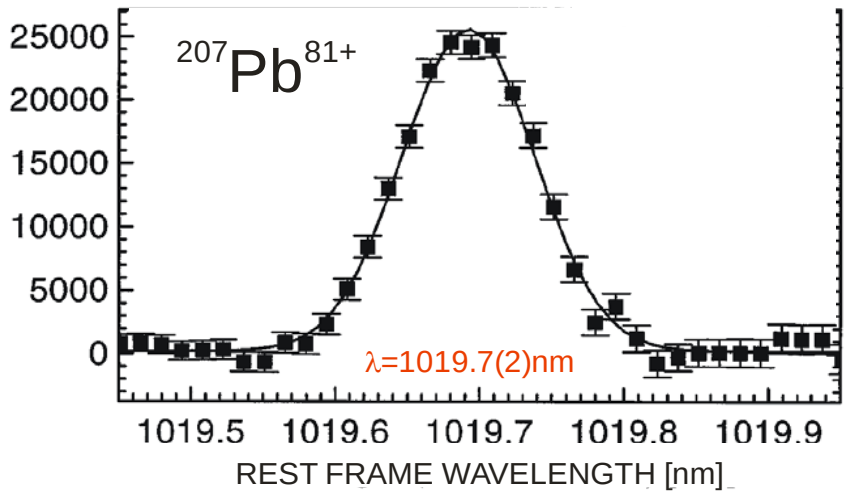


Type	Ion	Transition	λ [nm]	A [1/s]
H-like	$^{165}Ho^{66+}$	F=3 – F=4	572.6	-
	$^{185}Re^{74+}$	F=2 – F=3	456.5	-
	$^{187}Re^{74+}$	F=2 – F=3	452.2	-
	$^{203}Tl^{80+}$	F=0 – F=1	386.3	-
	$^{205}Tl^{80+}$	F=0 – F=1	382.6	-
	$^{207}Pb^{81+}$	F=0 – F=1	1019.7	20
	$^{209}Bi^{82+}$	F=4 – F=5	243.9	2849
	$^{235}U^{91+}$	F=3 – F=4	1538	9
Li-like	$^{209}Bi^{80+}$	F=4 – F=5	1514	12

previous measurements: ESR







forbidden transitions so far measured

TABLE II: Measured values for the ground state hyperfine splittings in highly charged ions.

species	λ [nm]	transition	type and reference
$^{165}Ho^{66+}$	572.6(1.5)	F=4 → F=3	EBIT [27]
$^{185}Re^{74+}$	456.05(3)	F=3 → F=2	EBIT [28]
$^{187}Re^{74+}$	451.69(5)	F=3 → F=2	EBIT [28]
$^{203}Tl^{80+}$	385.822(30)	F=1 → F=0	EBIT [29]
$^{205}Tl^{80+}$	382.184(34)	F=1 → F=0	EBIT [29]
$^{207}Pb^{81+}$	1019.7(2)	F=1 → F=0	ESR [30]
$^{207}Pb^{81+}$	1019.5(2)	F=1 → F=0	ESR [31]
$^{209}Bi^{82+}$	243.87(4)	F=5 → F=4	ESR [32]
$^{209}Bi^{82+}$	243.87(2)	F=5 → F=4	ESR [31]
$^{209}Bi^{80+}$	0.820(26) eV	F=5 → F=4	EBIT [33]
$^{209}Bi^{80+}$	0.791(5) eV	F=5 → F=4	EBIT [34]

E_{HFS}

typical relative uncertainty

10^{-4}

...numerous E_{FS} from EBIT measurements — 10^{-4}

(but only one laser spectroscopy measurement – Ar^{13+}) — 10^{-7}

... numerous g_I from NMR — 10^{-4}

TABLE I: Comparison of theoretical and experimental g_J-factor values.

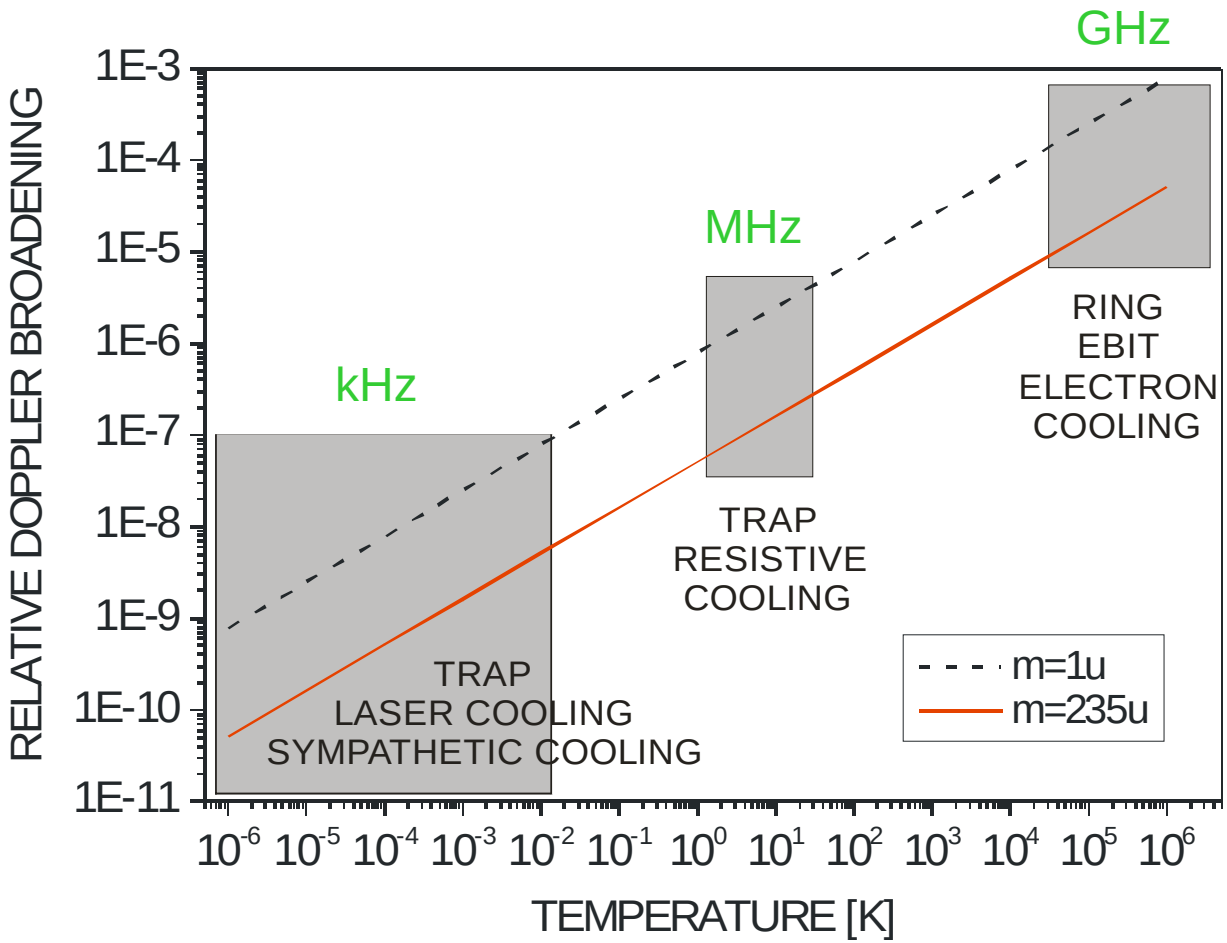
value	$^{12}C^{5+}$	$^{16}O^{7+}$
theory total [12]	2.001 041 590 18(3)	2.000 047 020 32(11)
experiment [3, 4]	2.001 041 596 3(10)(44)	2.000 047 026 0(15)(44)

g_J

10^{-9}

going to cool ions

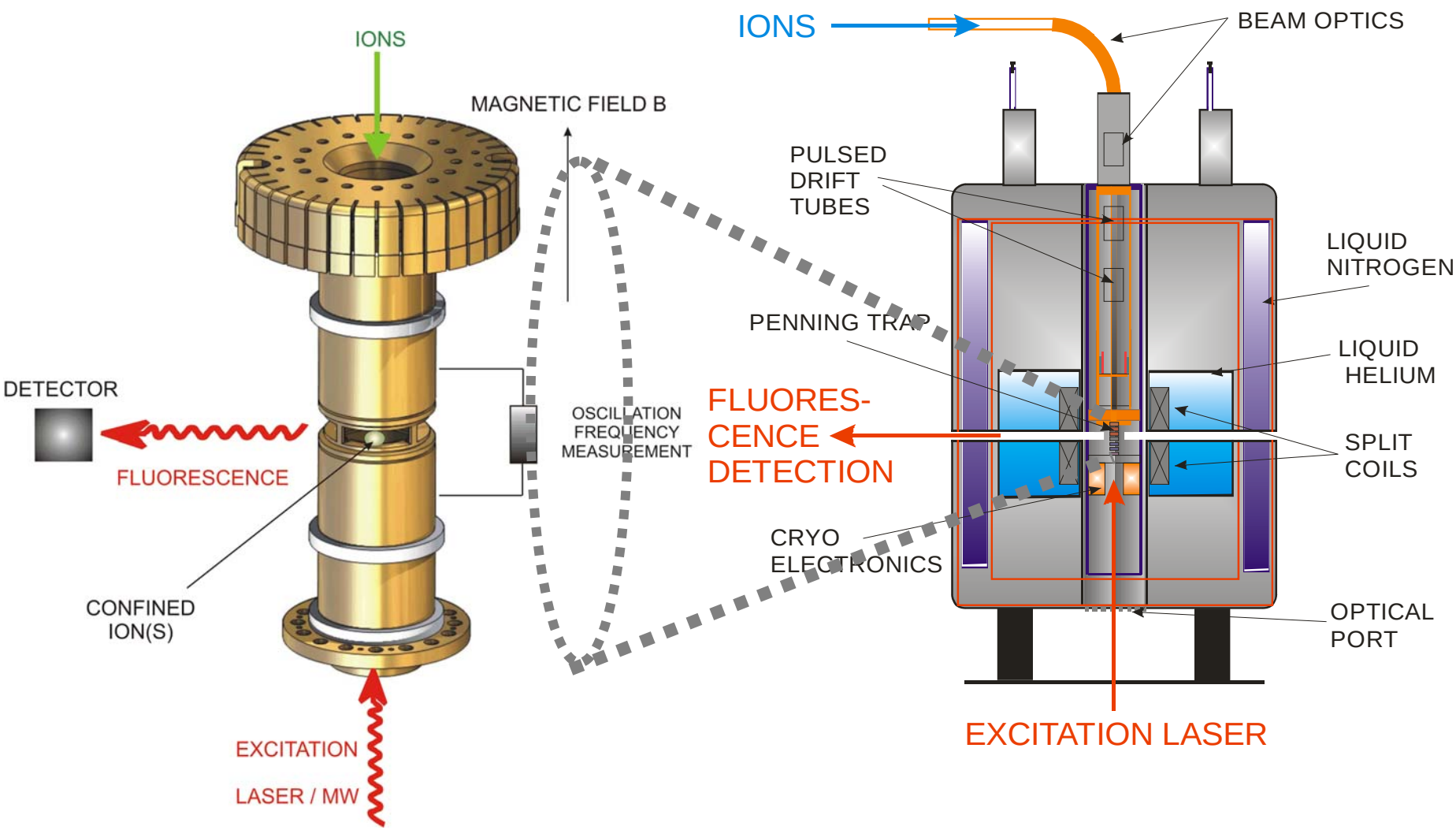
relative Doppler broadening of FS and HFS transitions



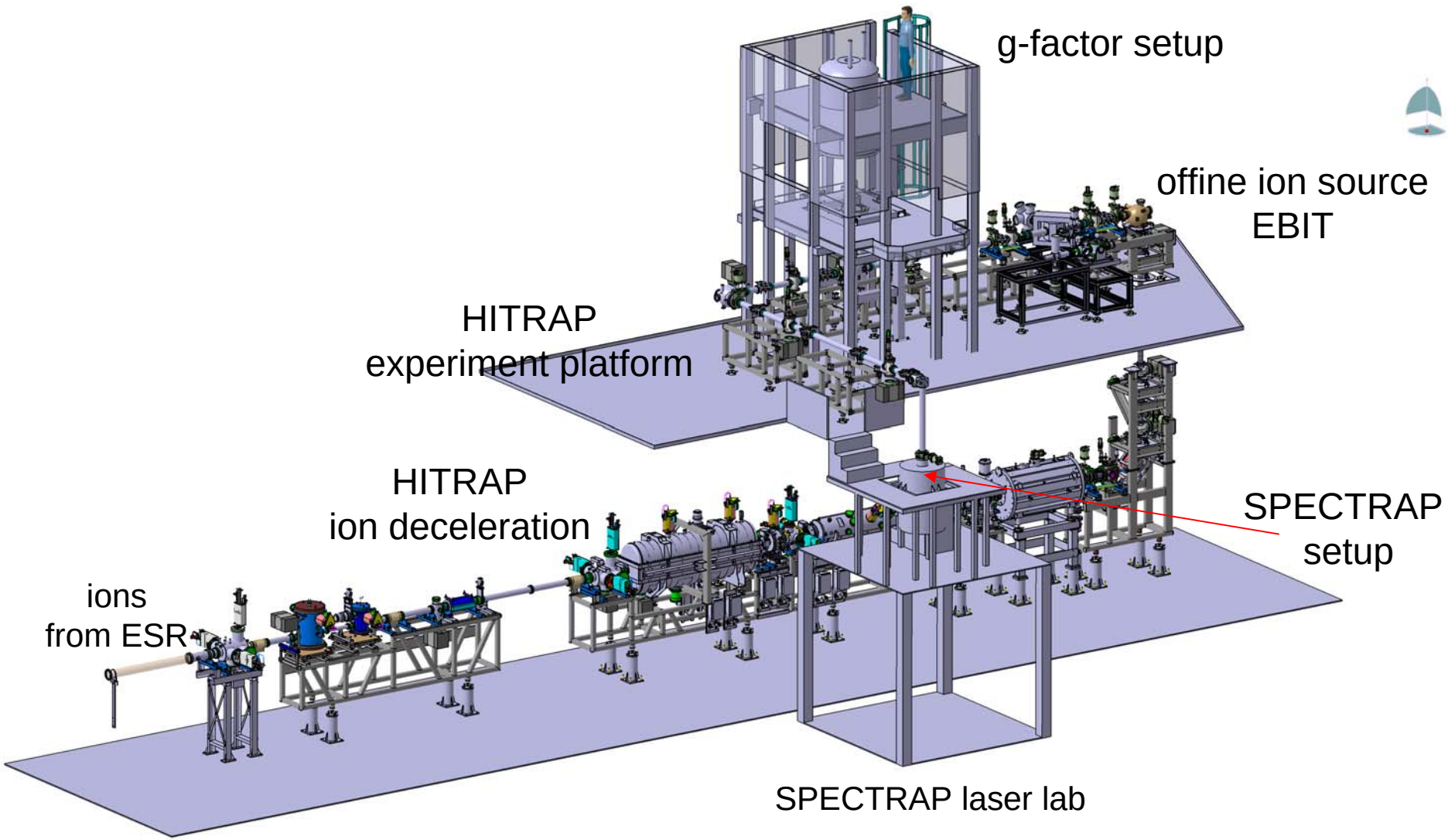
EBIT:
Ar^{13+} @ 10^{6} K
accuracy 10^{-7}

SPECTRAP:
ions @ 10^{1} K
accuracy ...

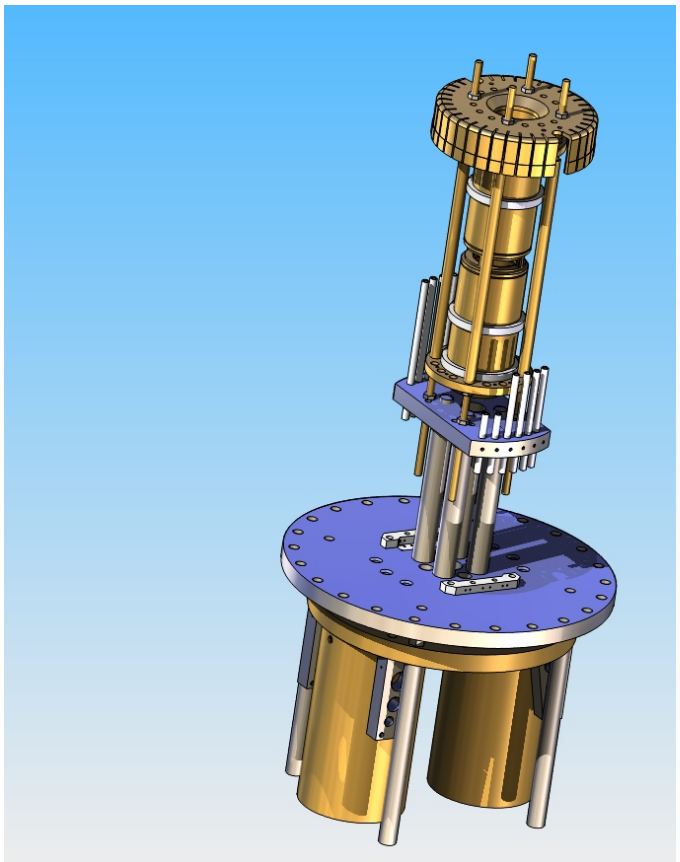
trap arrangement

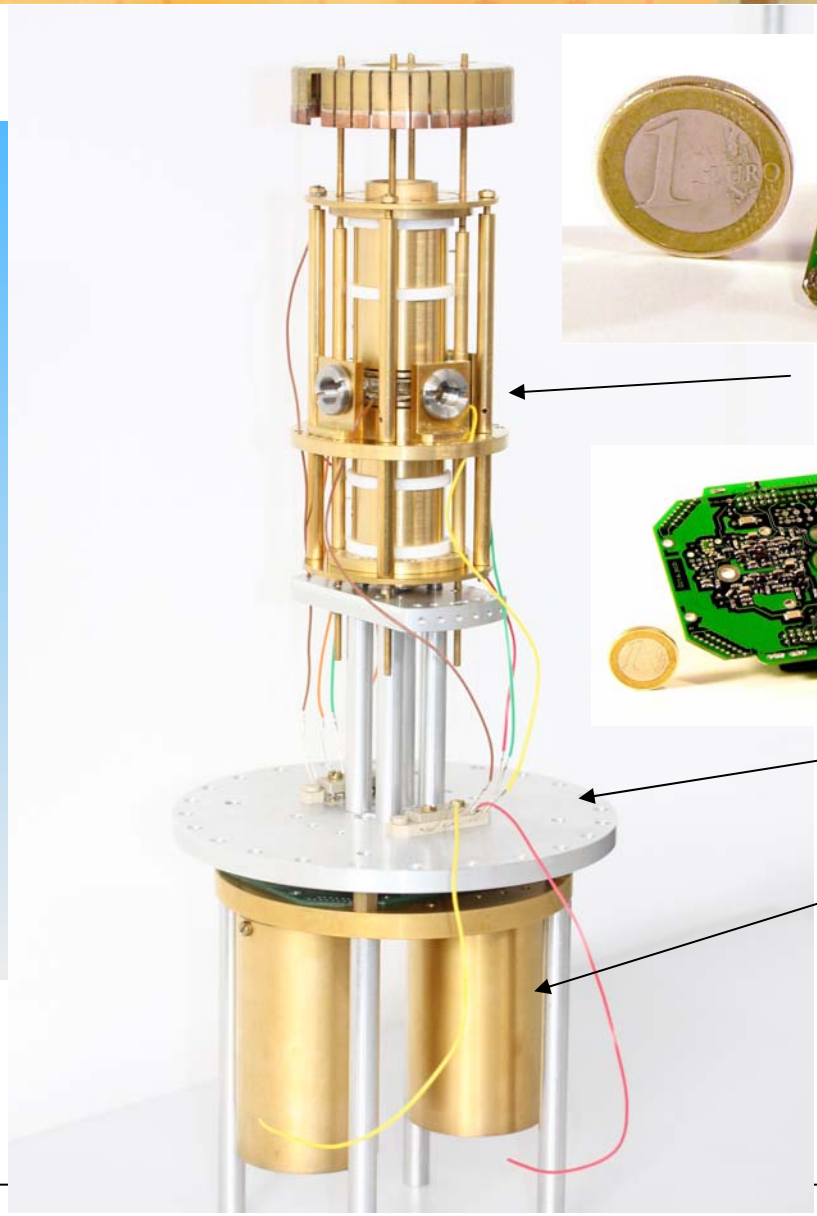


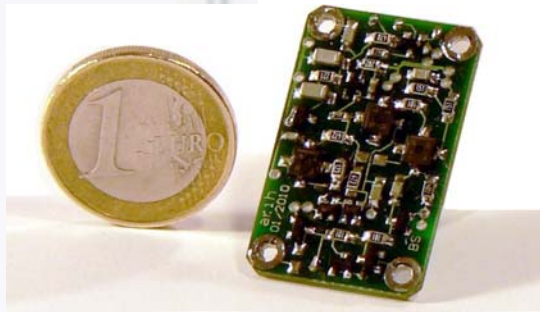
SPECTRAP @ HITRAP



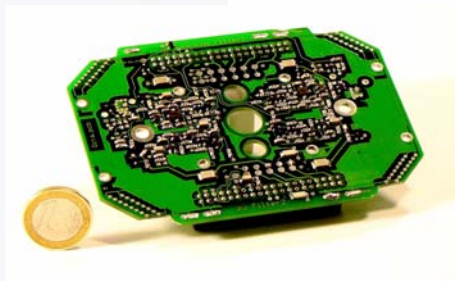
SPECTRAP Penning trap







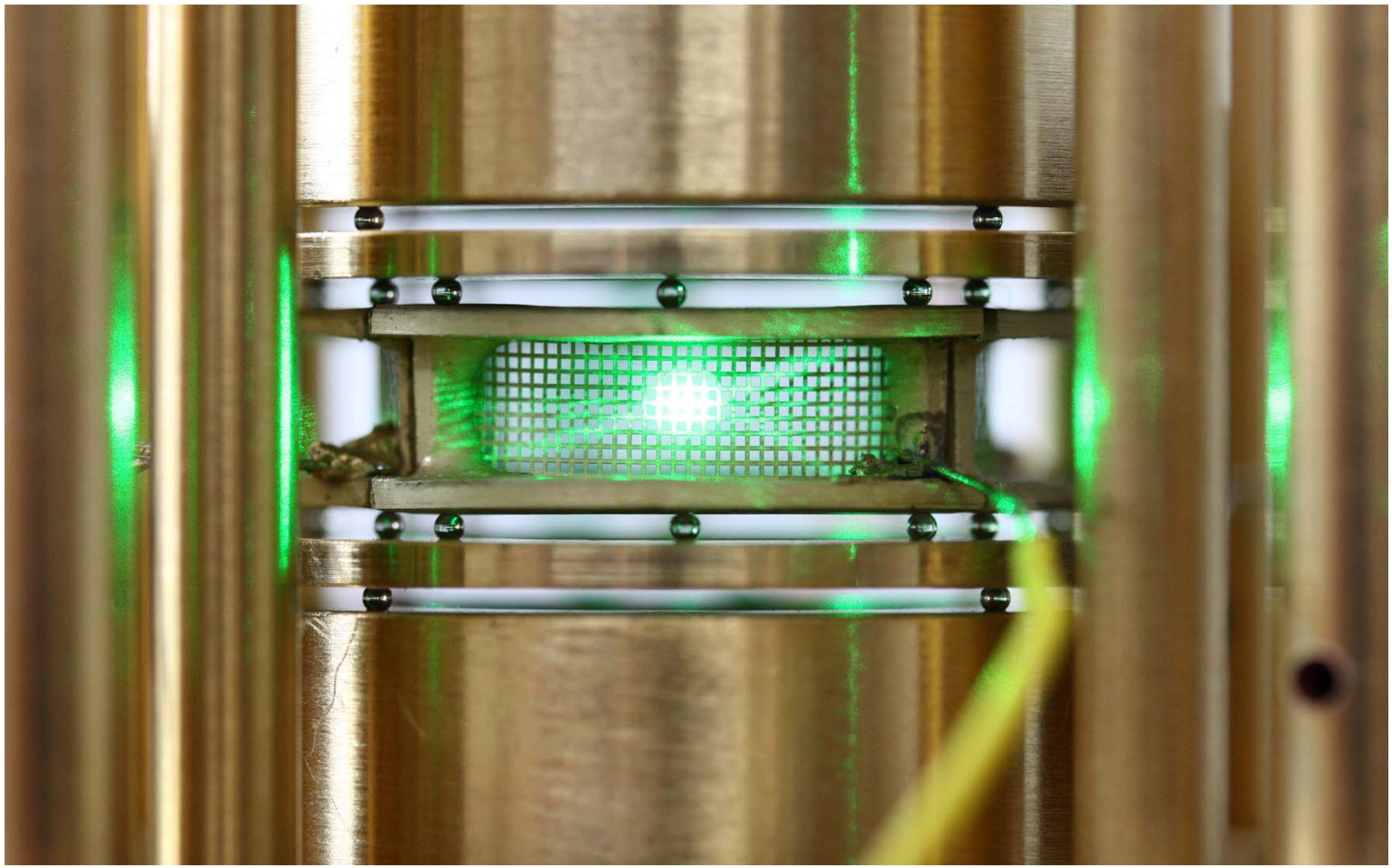
trap centre



mount

resonators

transparent ring



SPECTRAP

status

we have:

- magnet setup with assembled (test) beamline
- experimental control electronics (LabVIEW-based)
- trap with installed cryo-electronics almost ready
- laser systems for Mg^{+} and Bi^{82+} almost ready

we need:

- ions (offline source / EBIT / HITRAP)
- detectors (under way, Uni Münster)

next steps:

- install and wire the trap (july)
- cool down the magnet and
- get ions

further contributions

- Z. Andjelkovic (poster, setup)
- D. Segal (poster, trap-related)
- R. Jöhren (talk, detectors)
- D. von Lindenfels (poster, double resonance)
- S. Albrecht (poster, lasers)