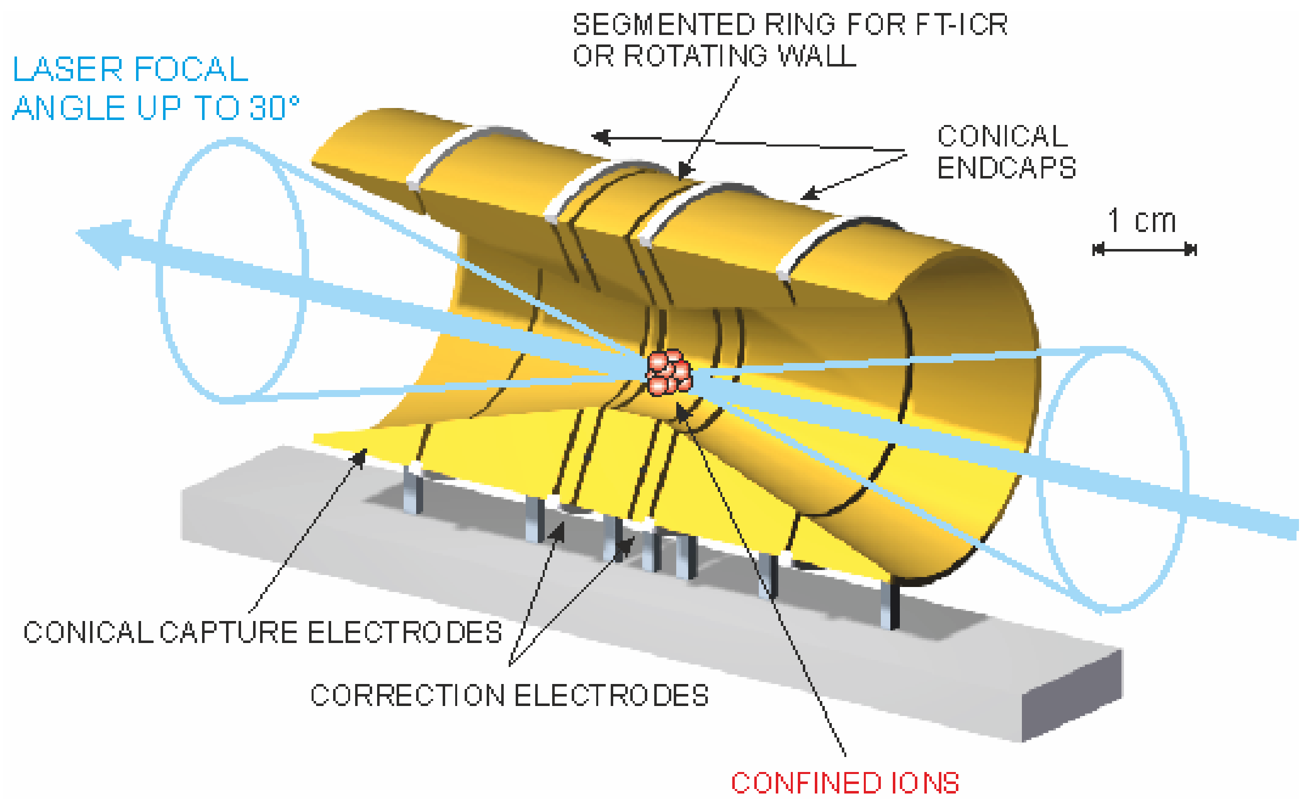
TRAP-ASSISTED STUDIES
@
A HIGH-INTENSITY LASER

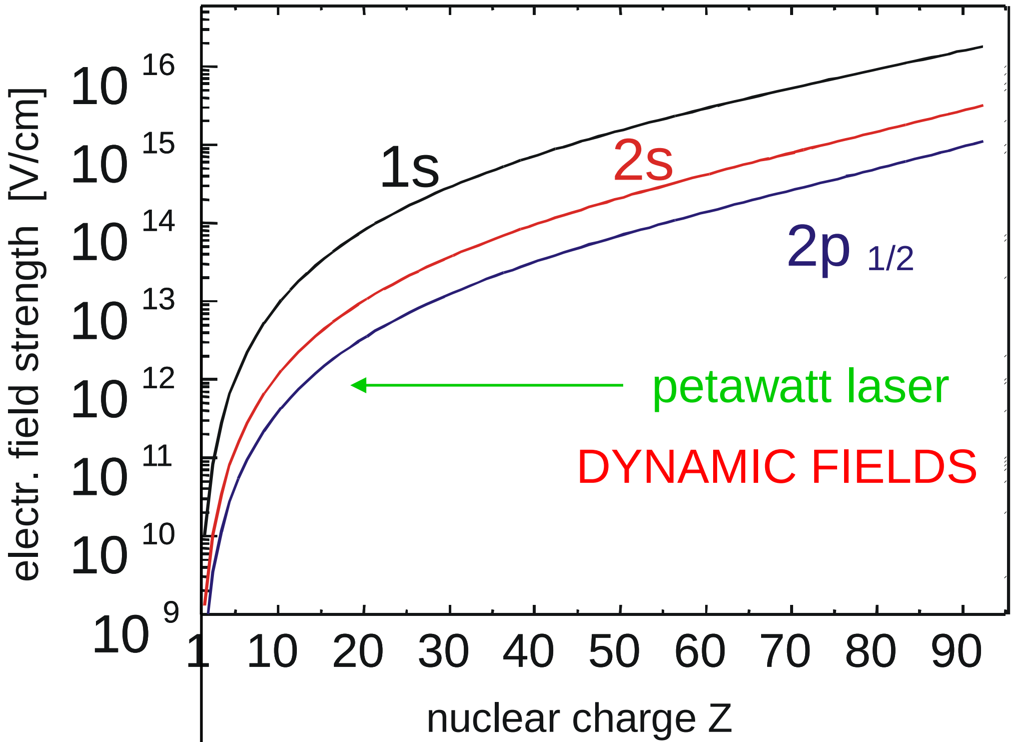


seit 1558

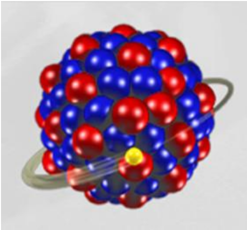
Helmholtz-Institut Jena
Schiller-Universität Jena

GSI

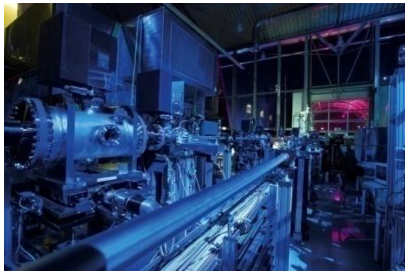
extreme fields



highly charged ions



STATIC FIELDS

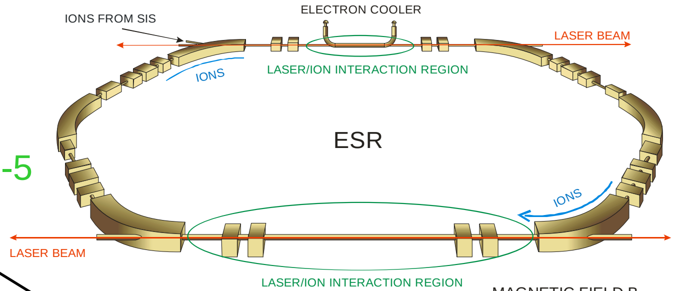


10 4 lightning in air

our extreme field physics in traps

in-ring experiments (e.g. LIBELLE)
(or EBIT)

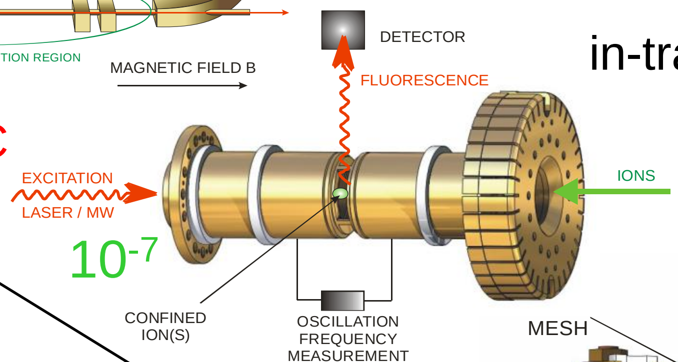
10^{-5}



in-trap spectroscopy (SPECTRAP)

STATIC

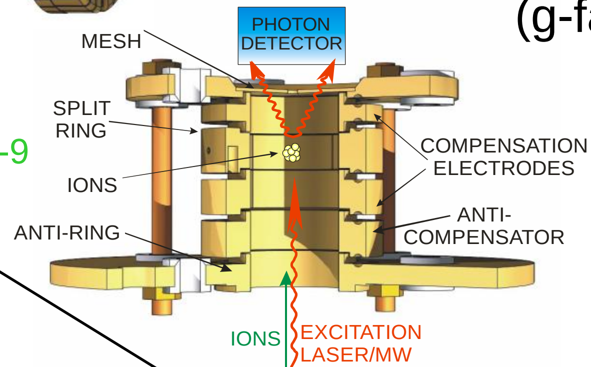
10^{-7}



DYNAMIC

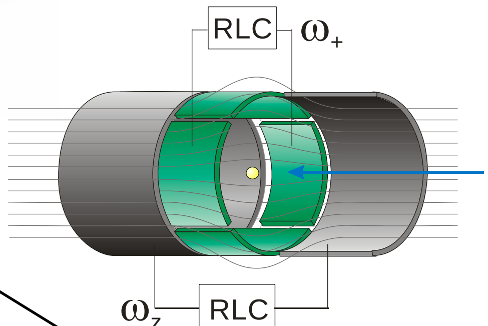
double-resonance spectroscopy
(g-factor)

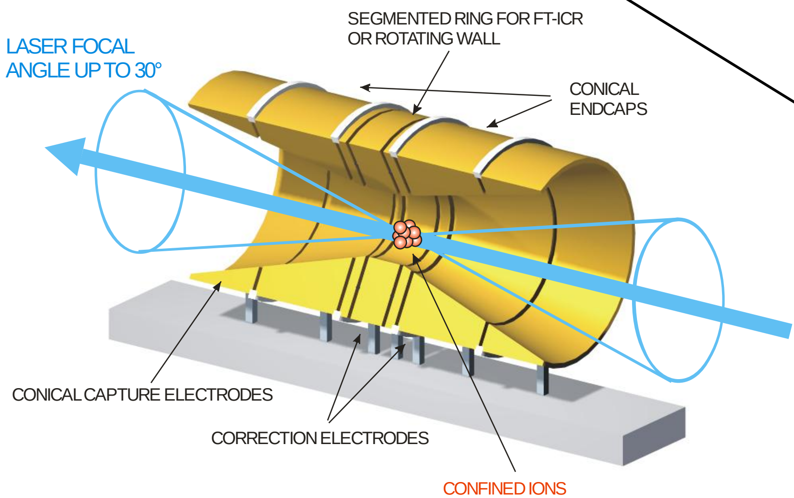
10^{-9}



blind spectroscopy

10^{-11}





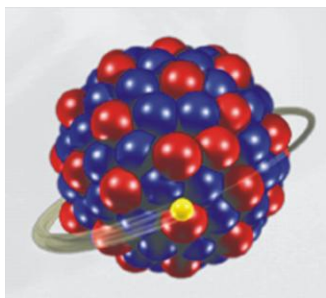
PHELIX
POLARIS
FLASH
JETI

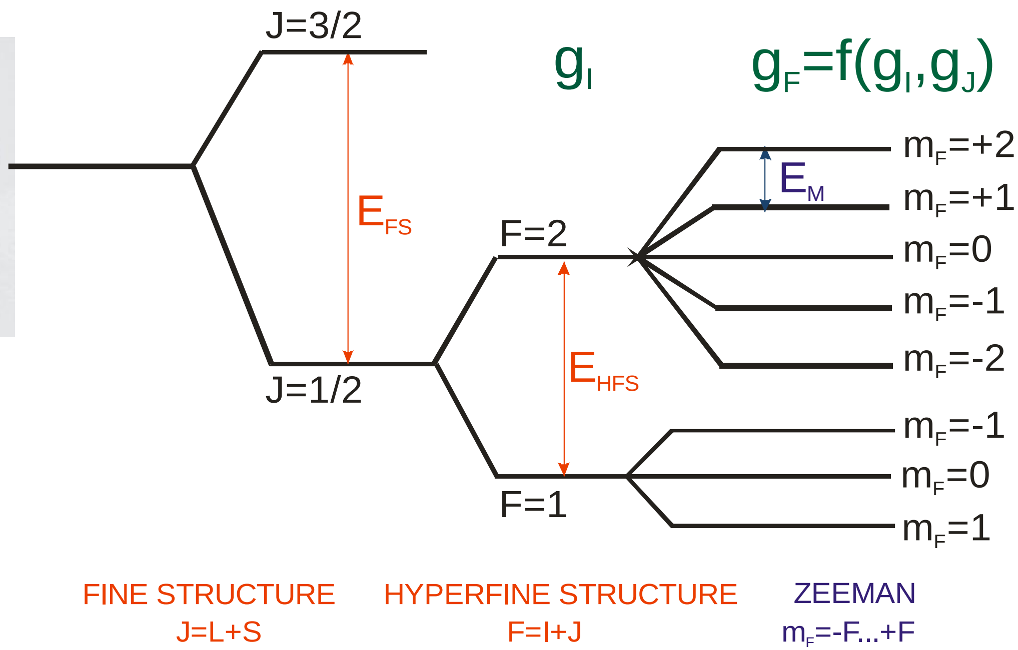
GSI

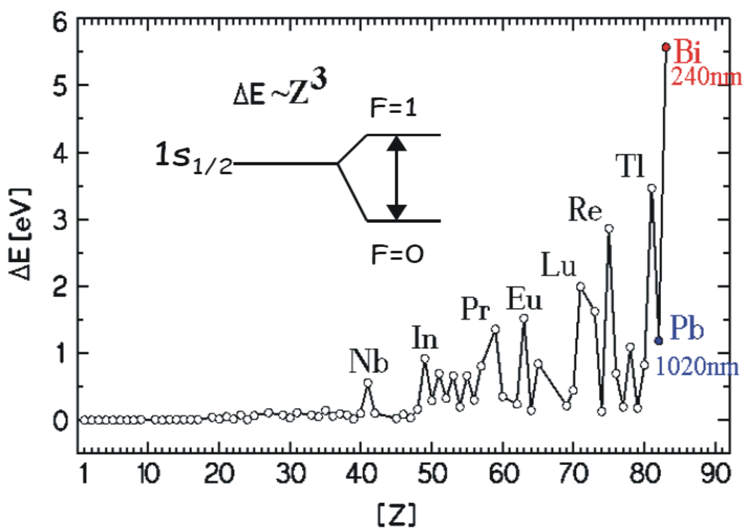
precision spectroscopy of forbidden transitions in HCI (optical laser / MW)

Transition energy (frequency)	Z^2
Fine-structure (multiplet) splitting	$\alpha^2 Z^4$
Hyperfine splitting	$(m_e/m_p)\alpha^2 Z^3$
Lamb shift	$\alpha^5 Z^4$

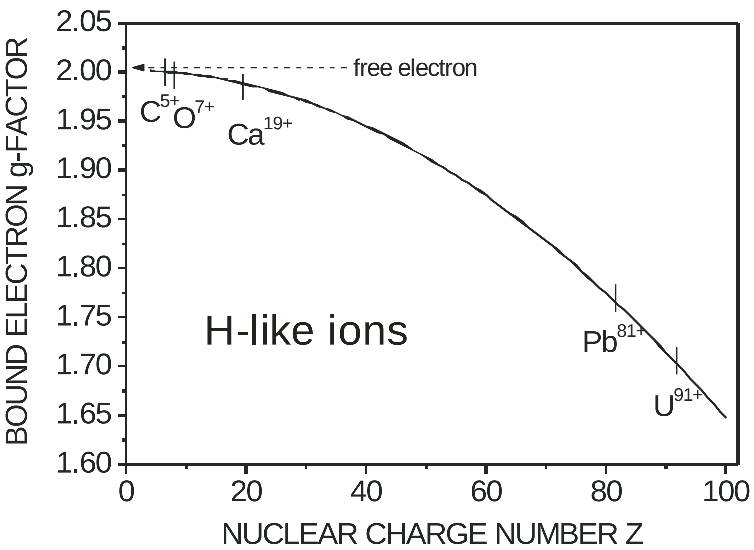
HCI

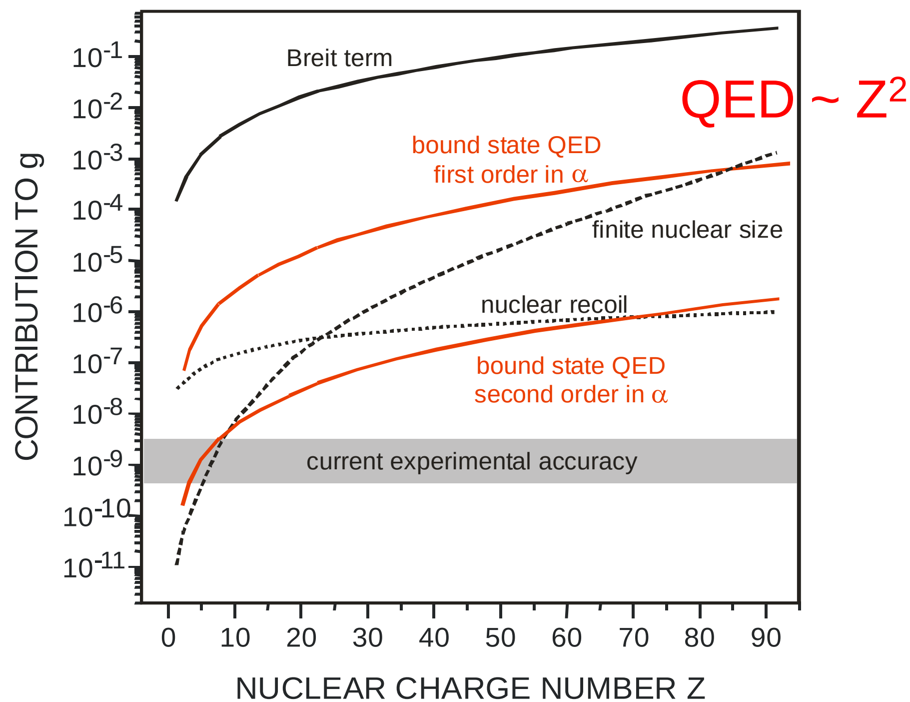


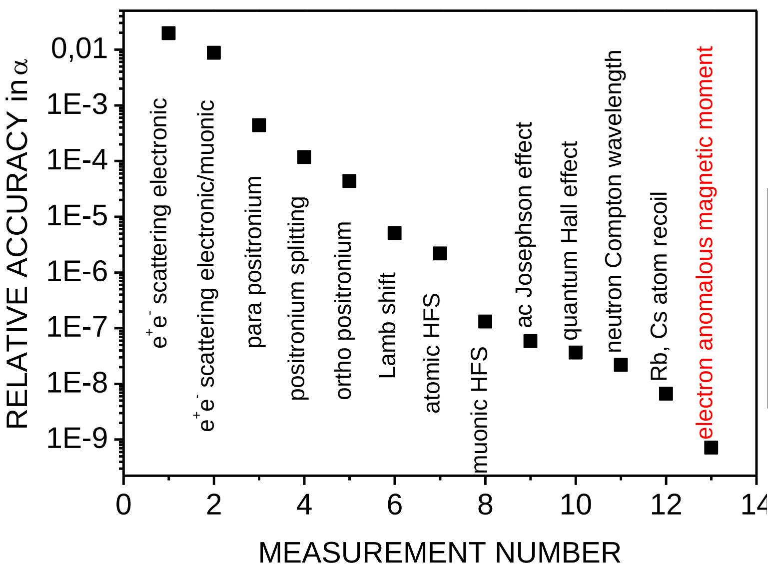


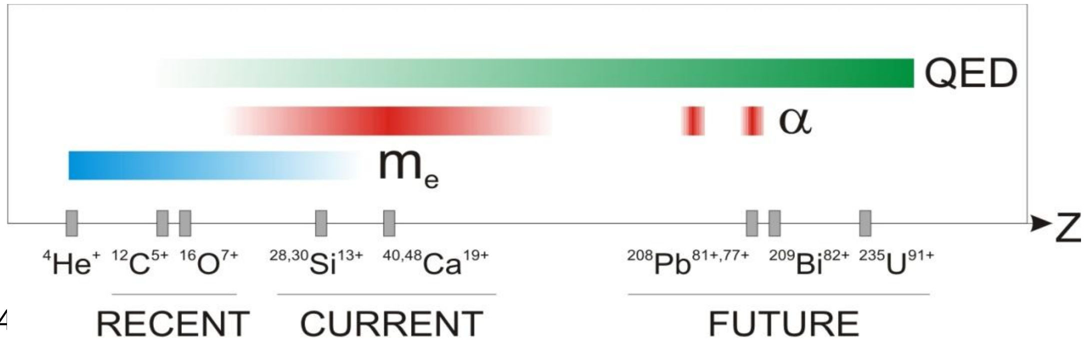


background: QED and fundamental constants



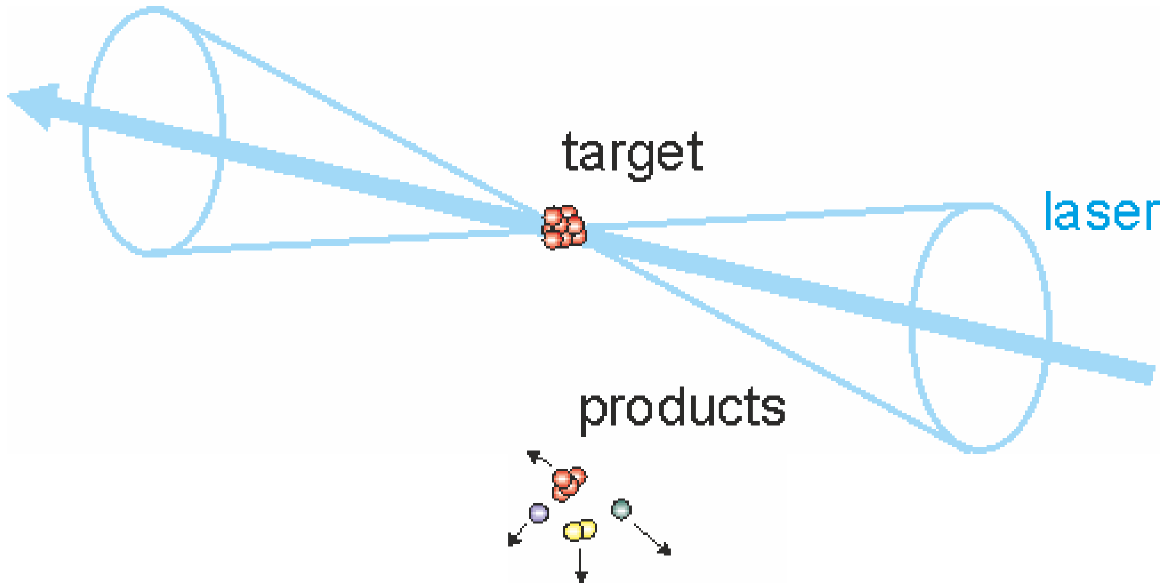






laser-induced reaction / analysis

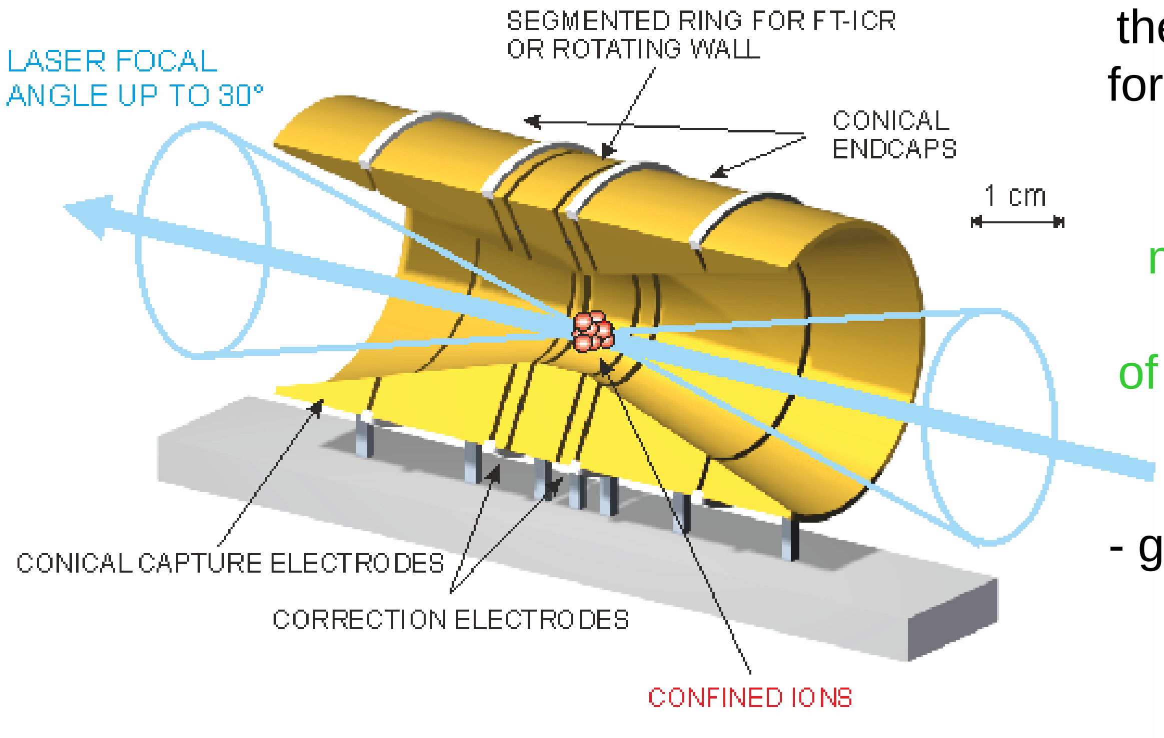
applications may be different but tools can be the same



typical problems: what exactly was the target?
what exactly are the products?

for charged particles both can be controlled by use of a Penning trap

use of a Penning trap



non-linear photoionisation
giant resonances
strong-field effects

„transparent“ experiment

the Penning trap as a universal tool for the study of reactions induced by a high-intensity laser

main motivation: non-destructive real-time analysis of multiphoton ionization processes with high resolution

- good ion localization and extended storage times (minutes)

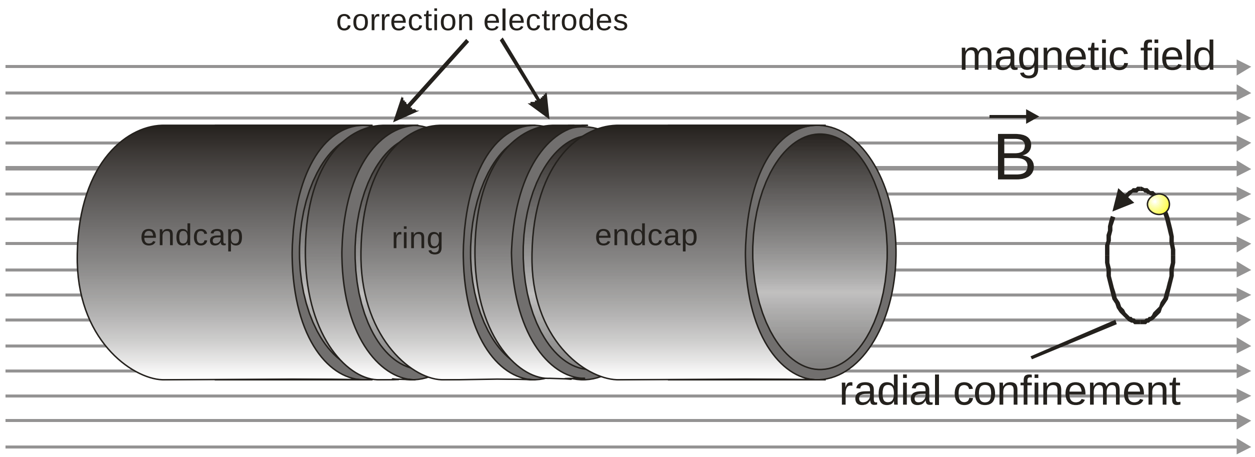
- well-controlled and clean environment for various reactions

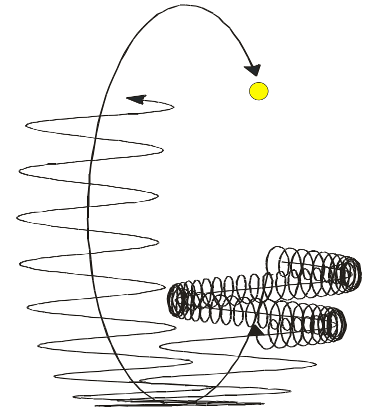
- numerous manipulation techniques

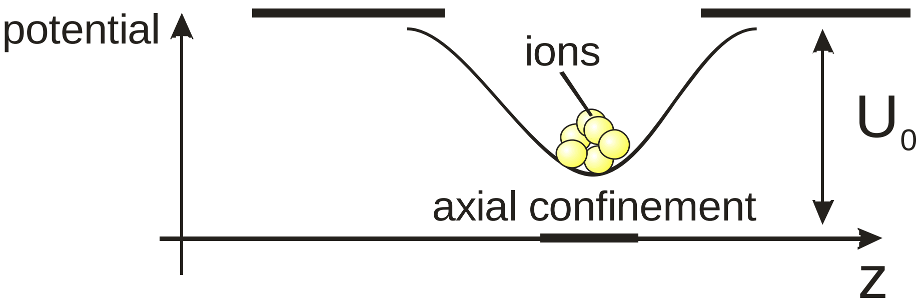
- non-destructive detection

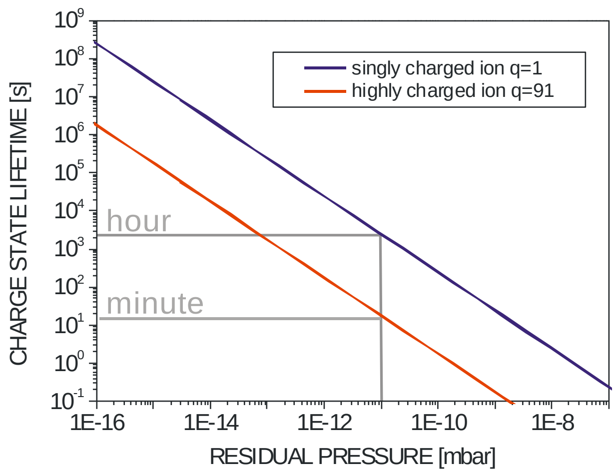
GSI

Penning trap principles









typical parameters: B = 6 T

U_0=100 V

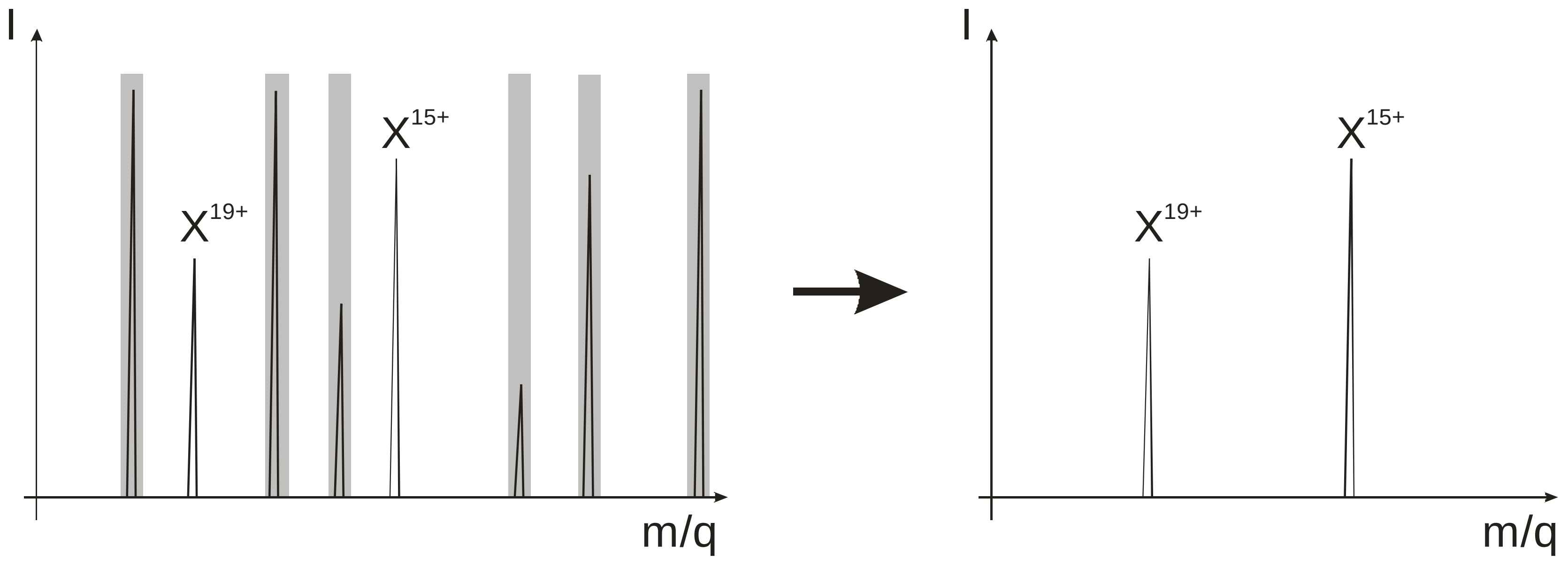
d=20 mm

ω_- , ω_z, ω_+ = 10 kHz, 100 KHz, 10 MHz

techniques (1) : ion selection

selection of any mass to charge ratio combination
by resonant ejection of all unwanted ions

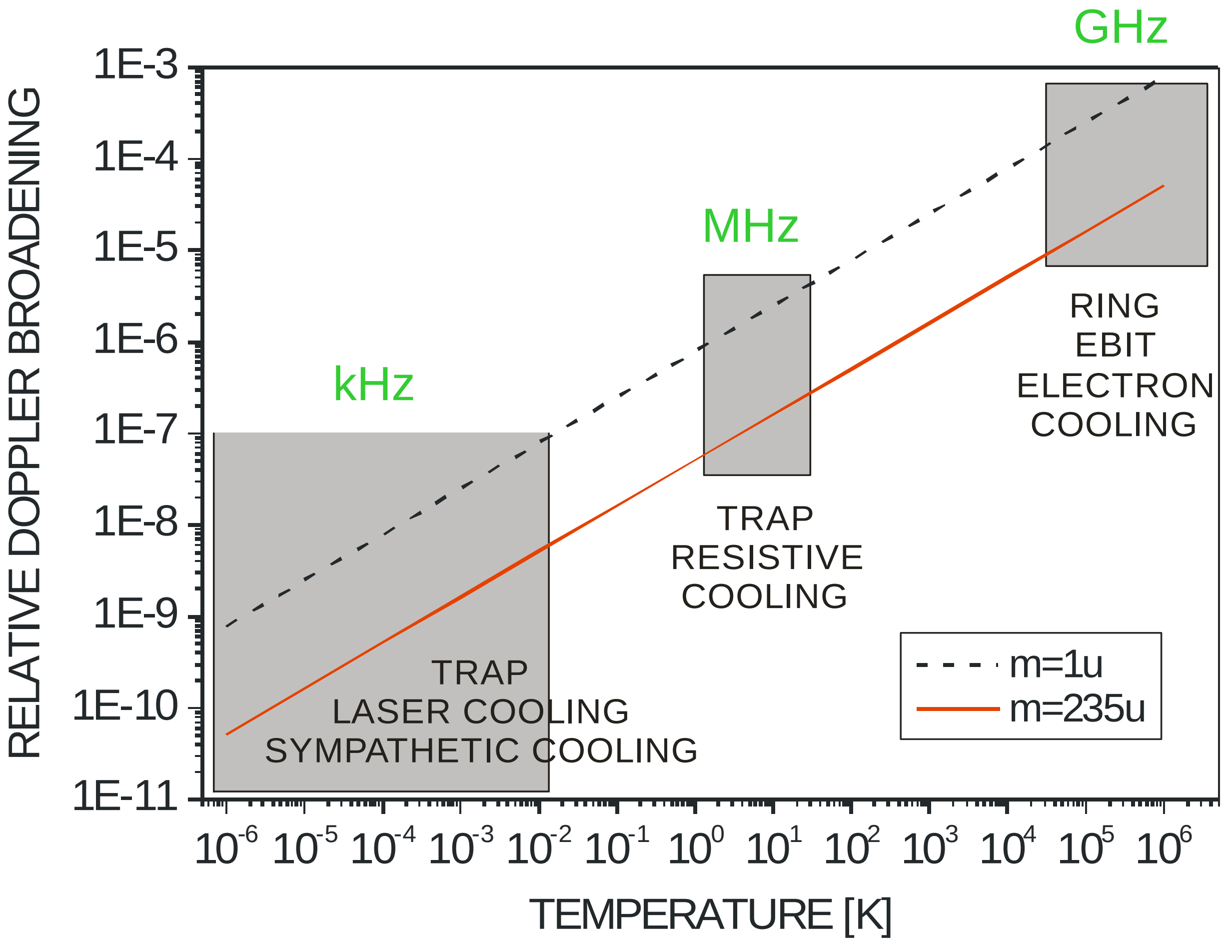
SWIFT (stored waveform inverse Fourier transform)



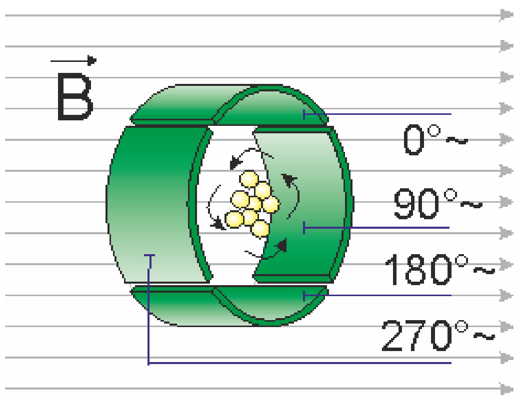
timescale: ms

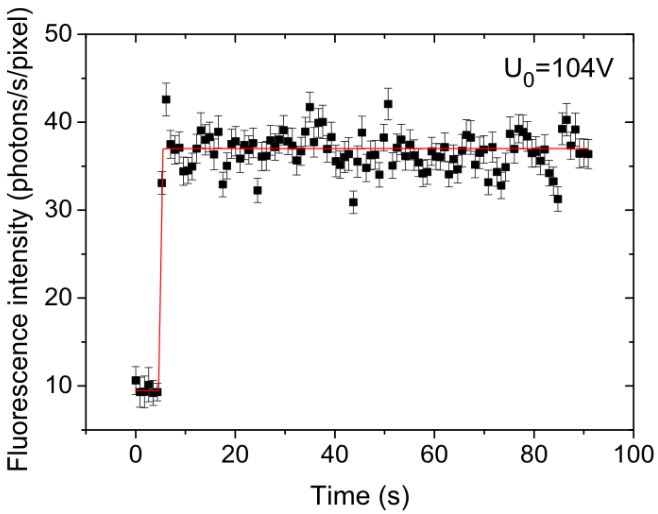
techniques (2) : ion cooling

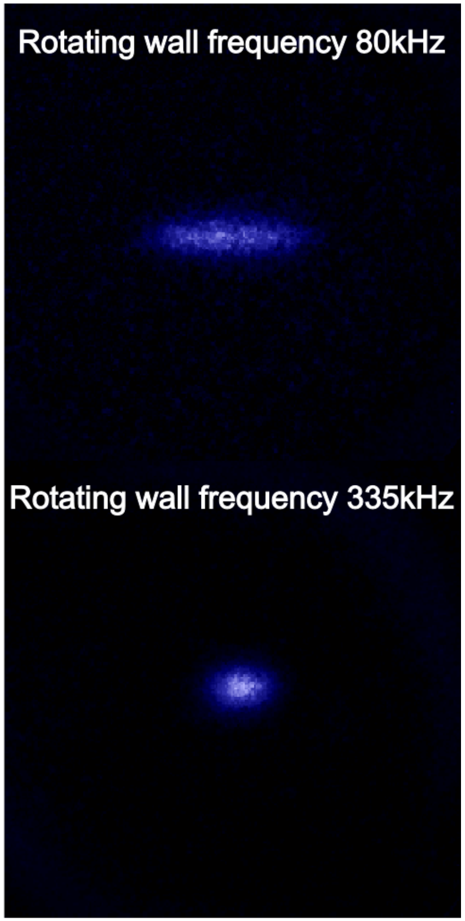
relative Doppler broadening of optical transitions

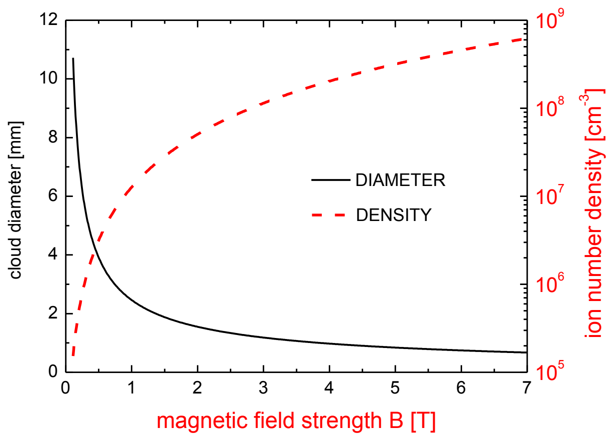


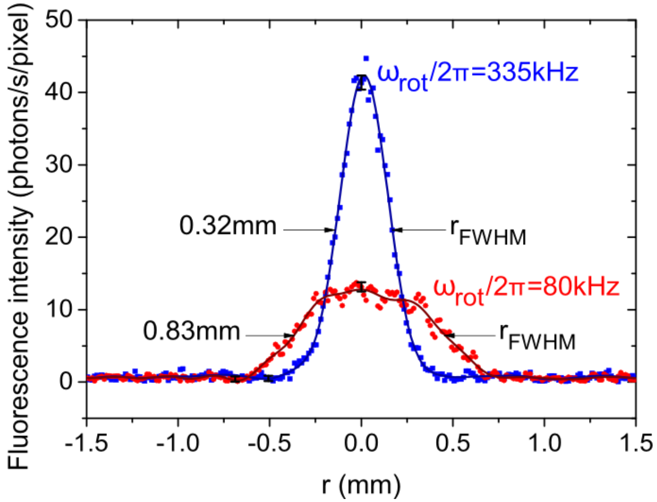
techniques (3) : compression by rotating wall



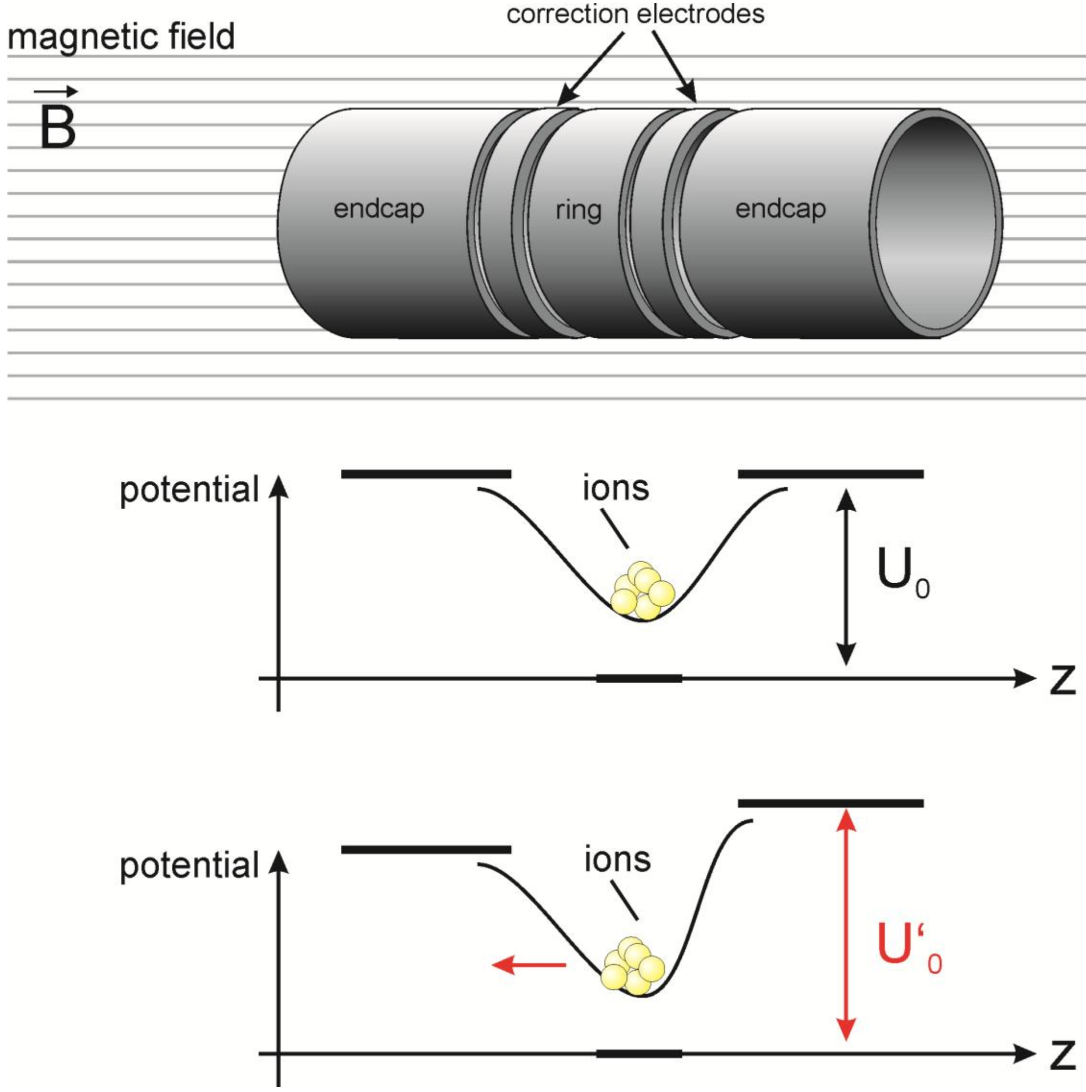








techniques (4) : ion positioning



ion position control
relative to laser focus
by potential asymmetry
ms, μm

shot-to-shot scan of
the effective laser
field strength

combination: experimental cycle (example)

0 s

- ion capture from external source or in-trap production

- possible ion cooling to 4 K or below

- ion selection („clean target“) e.g. by „SWIFT“

- ion centering / positioning and compression by „rotating wall“

5 s

PREPARATION

@ 10 Hz

- laser interaction, e.g. multiphoton ionisation

- non-destructive detection (charge state evolution)

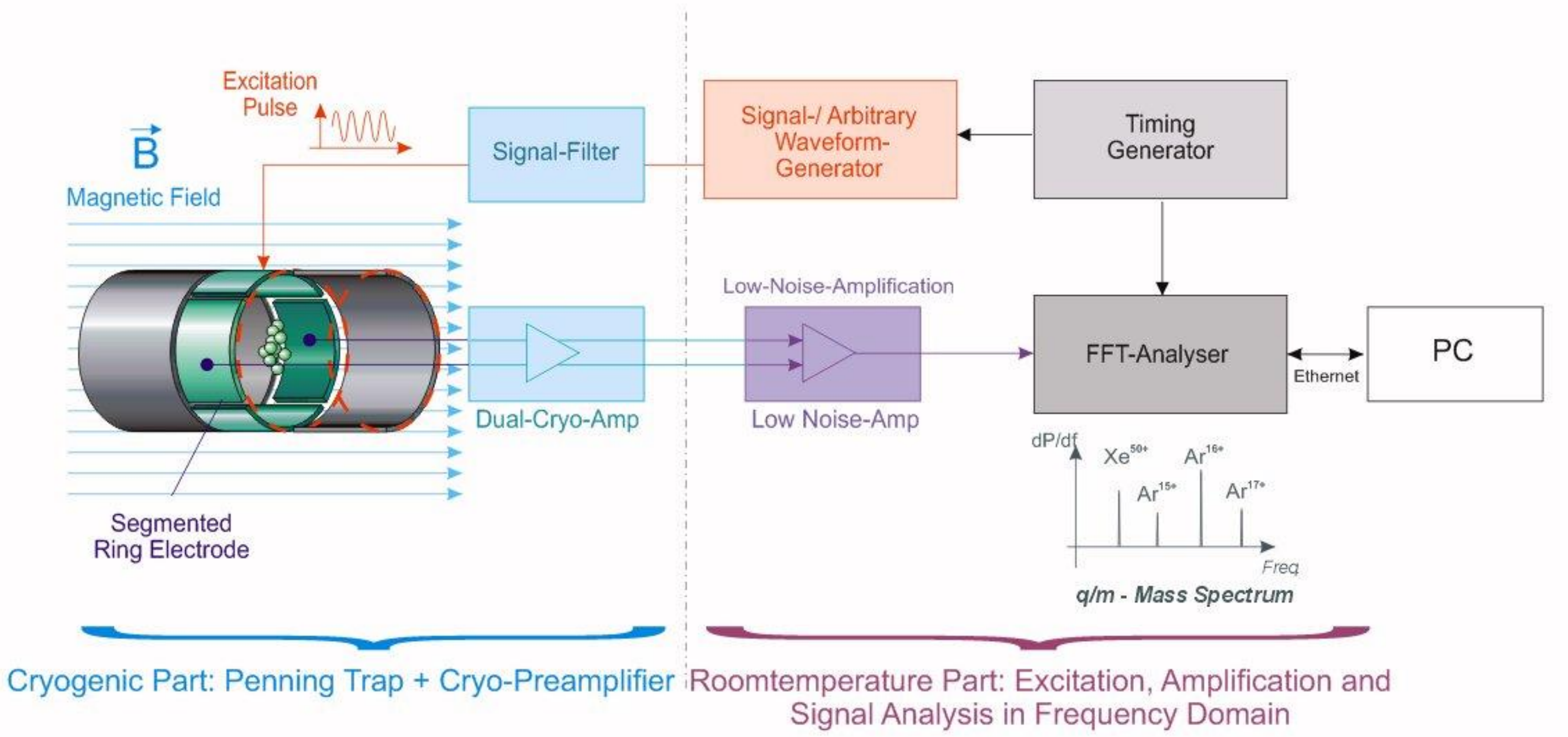
INVESTIGATION

- product ions still in trap for further measurements...

FTICR mass spectrometry

limit: of order 1000 charges (broad band), single ion (resonant)

10 Hz seconds

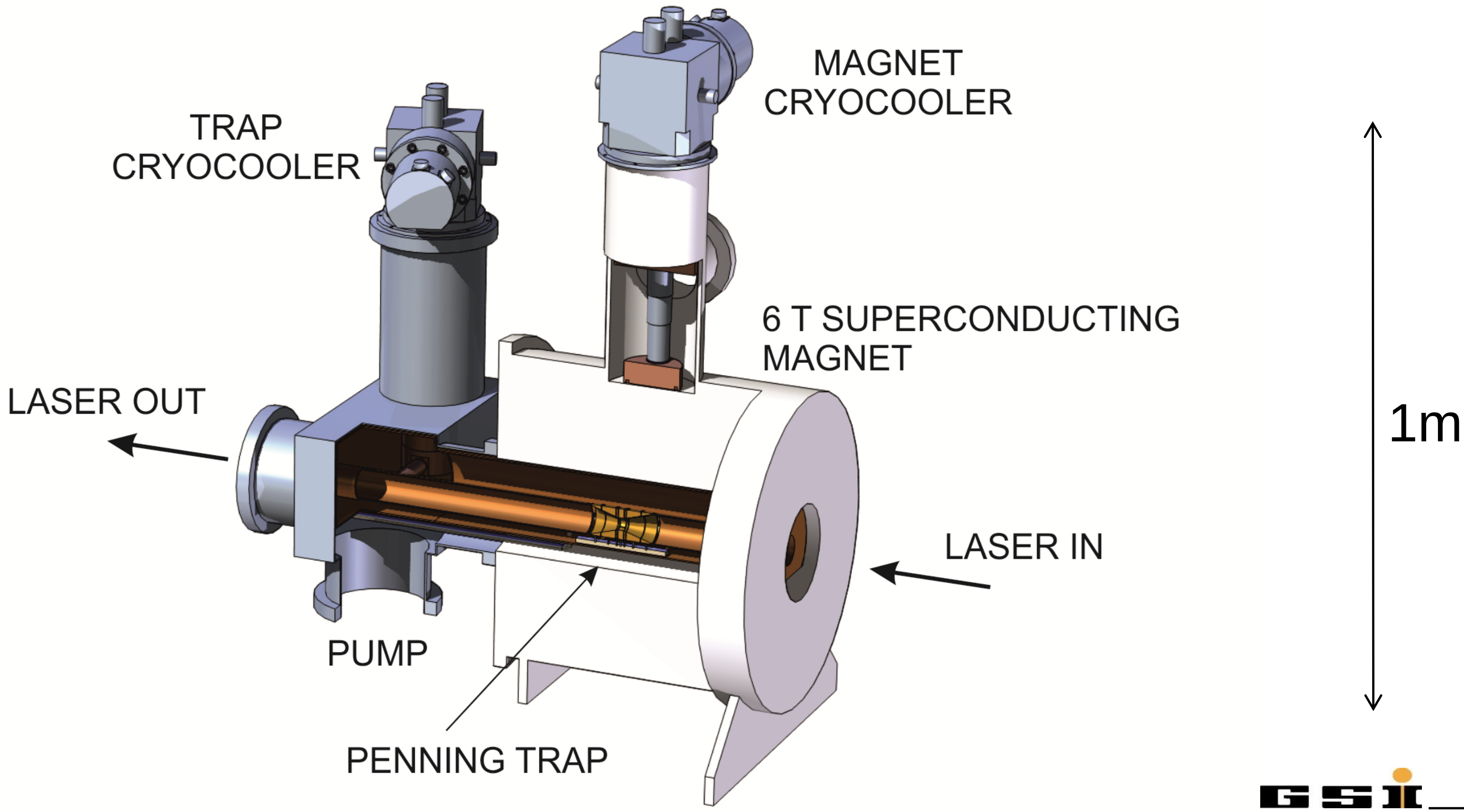


non-destructive detection

setup schematic

Penning trap in a dry superconducting magnet:
high operation stability, high resolution, yet easy transport and flexible use

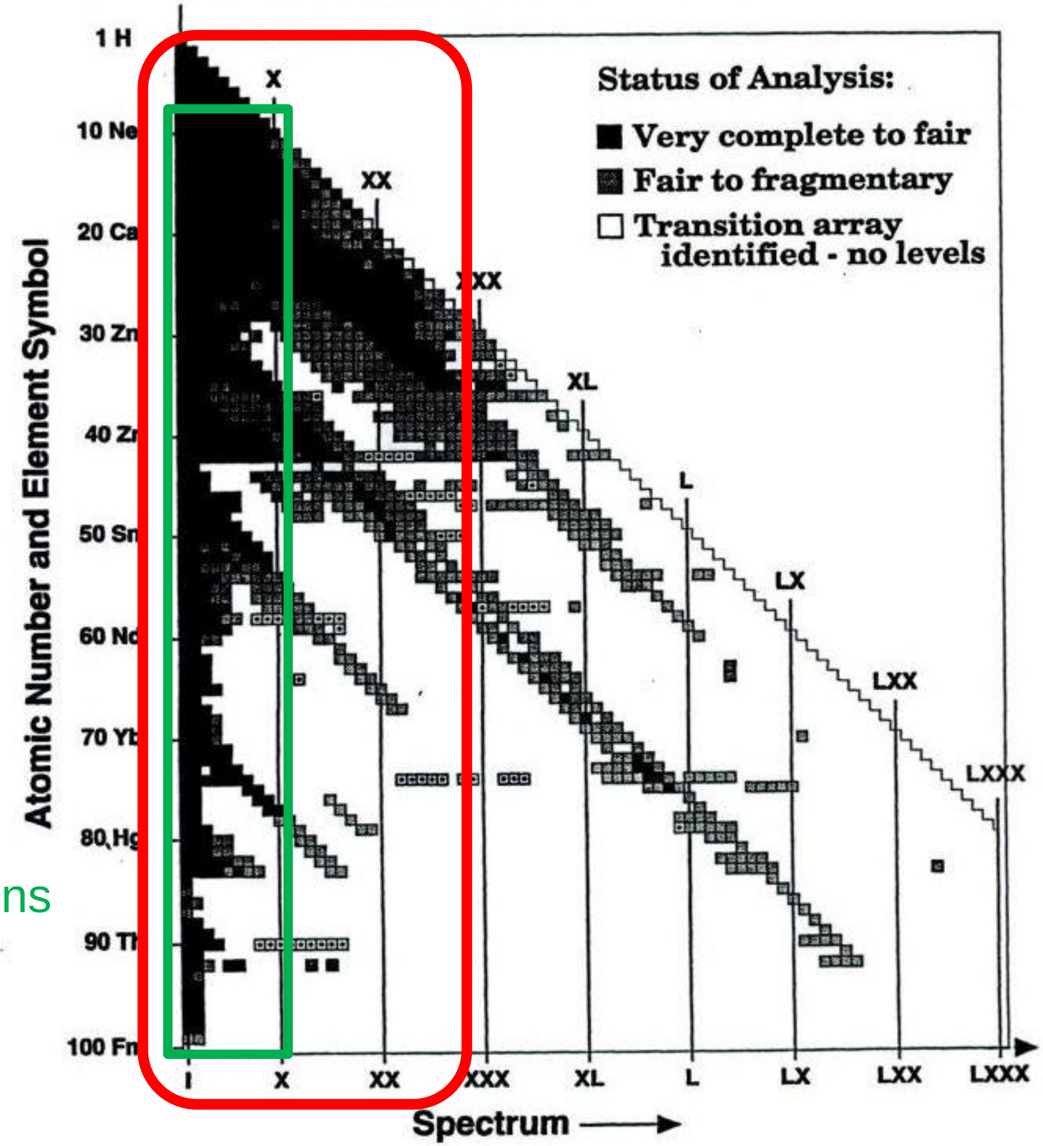
@ PHELIX, FLASH (II), JETI, POLARIS,...



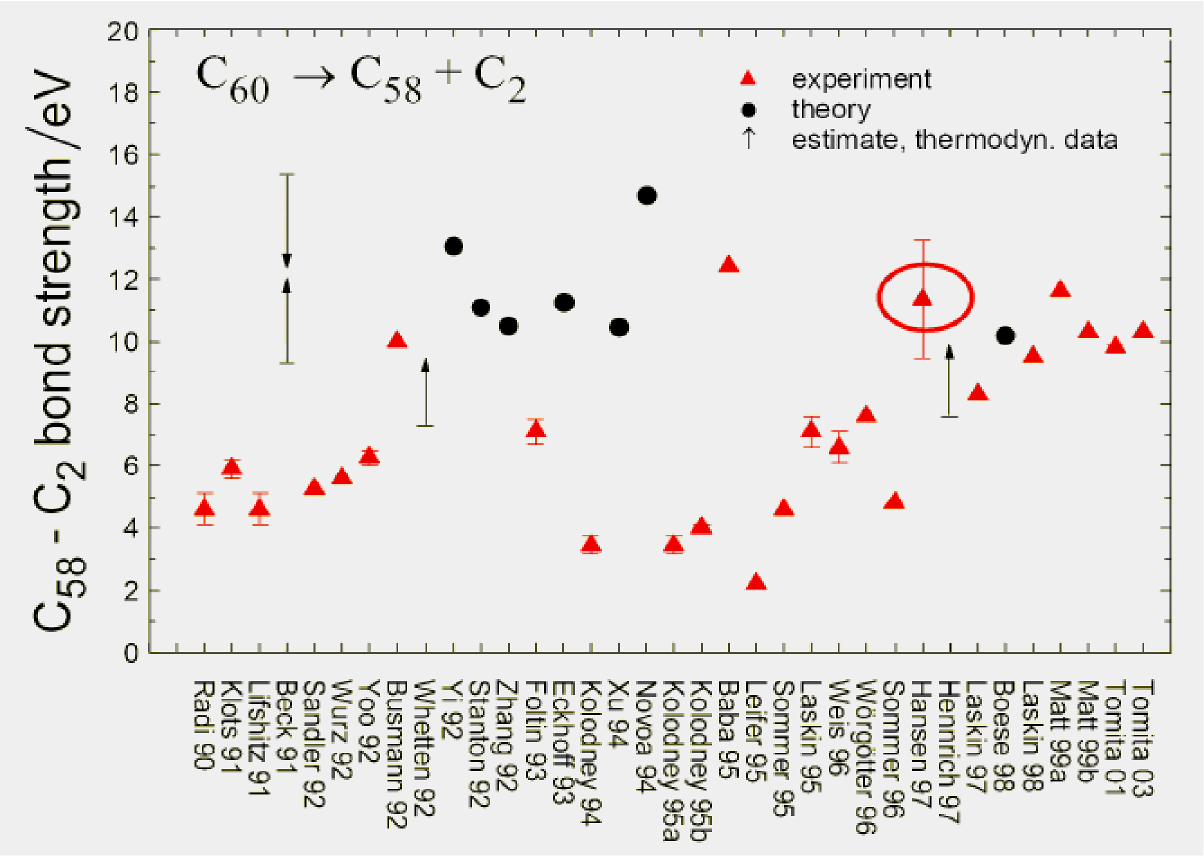
highly charged ions

single shot production

E1 transitions



possible FLASH II application: fullerene stability



results vary
between 2 and 15 eV!

C_{60}^+ -> C_{58}^+ -> C_{56}^+ @ 80 eV, scan few eV

C_{58}^+ -> C_{56}^+ @ 70 eV, scan few eV

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