

ESR

Lessons from the beam time 2024 and outlook to 2025

Bernd Lorentz
for the ESR operating team

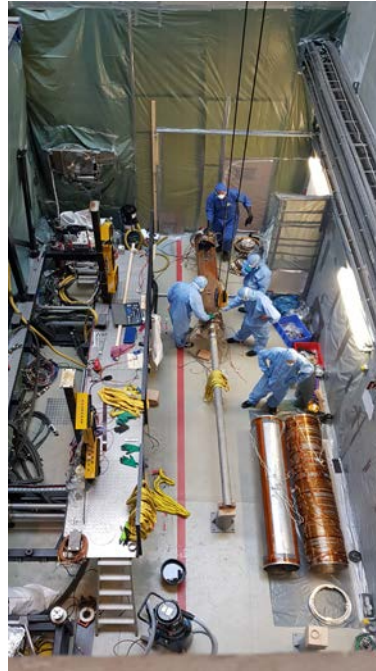
Shutdown work Juli 2022 to February 2024



- Repair of electron cooler drift tube
- Repair of kicker electrodes of stochastic cooling in ESR quadrupole
- Replacement of defective pole face winding in one of the ESR dipoles
- Repair of ionization profile monitor
- Modernization of vacuum system, exchange of (35 year old) ion getter pumps in the arcs, exchange of 2 sector valves.

Shutdown work Juli 2022 to February 2024

repair of electron cooler drift tube in the cooling solenoid



Recommissioning without any problems



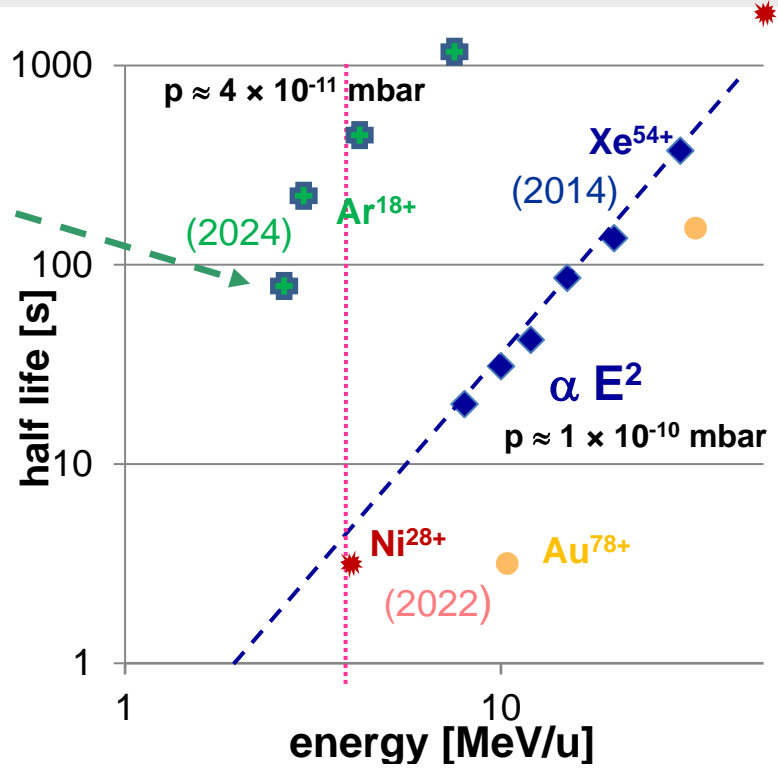
- 02/07/2024 all shutdown work finished
- electron cooler
 - 02/09/24 electron cooler HV commissioned and system fully operational
 - 02/14/24 commissioning with beam
 - 02/21/24 beam delivered to HITRAP (electron cooled, decelerated, extracted)
- stochastic cooling
 - end of february 24: recommissioning, all electrodes operational
 - June 24: successful stacking with stochastic cooling
- pole face winding operational
- ionization profile monitor working
- best vacuum conditions for the last 10 years

despite many complications and necessary adjustments in the shutdown schedule:
ALL SHUTDOWN WORK FINISHED IN TIME FOR COMMISSIONING WITH BEAM!!
recommissioning without problems, thanks to all involved colleagues

improved vacuum => beam lifetime

deceleration of Ar^{18+}
from 45 to 2.5 MeV/u 05/24

Be-like ion beam:
03/21 $^{207}\text{Pb}^{78+}$ 11 MeV/u : $\tau \sim 16$ s \Leftrightarrow
03/24 $^{197}\text{Au}^{75+}$ 12 MeV/u : $\tau \sim 100$ s



ESR operation in 2024



Chronological:

19.-22.02.: $^{12}\text{C}^{6+}$ HITRAP (H000), about 1 day setup ESR (decel. and extraction)

23.-29.02.: $^{18}\text{O}^{8+}$ HITRAP (H000), change by scaling without problem

29.02.-07.03.: machine time (recomissioning sto. cooling system) and setup $^{197}\text{Au}^{75+}$

08.-22.03.: $^{197}\text{Au}^{75+}$ CryRing (C025/MAT)

15.-28.04.: $^{36}\text{Ar}^{18+}$ HITRAP (H000), about 1 day setup ESR (decel. and extraction)

29.04.-03.05.: machine experiments (6 experiments, 8 shifts)

14.-21.05.: $^{100}\text{Mo}^{42+}/^{98}\text{Mo}^{42+}/^{98}\text{Zr}^{40+}/^{96}\text{Sr}^{39+}$ isochronous mode ESR (E018)

23.05-03.06.: U^{89+} by charge exchange from U^{90+} for HTA (E095), 1 day setup time

04.-07.06.: machine experiments (2 experiments, 4 shifts)

08.-18.06.: $^{238}\text{U}^{92+}/^{229}\text{Th}^{89+}$ ESR internal (E052)

19.-28.06.: $^{238}\text{U}^{92+}$ + ESR internal with deuterium gas jet target (E028)

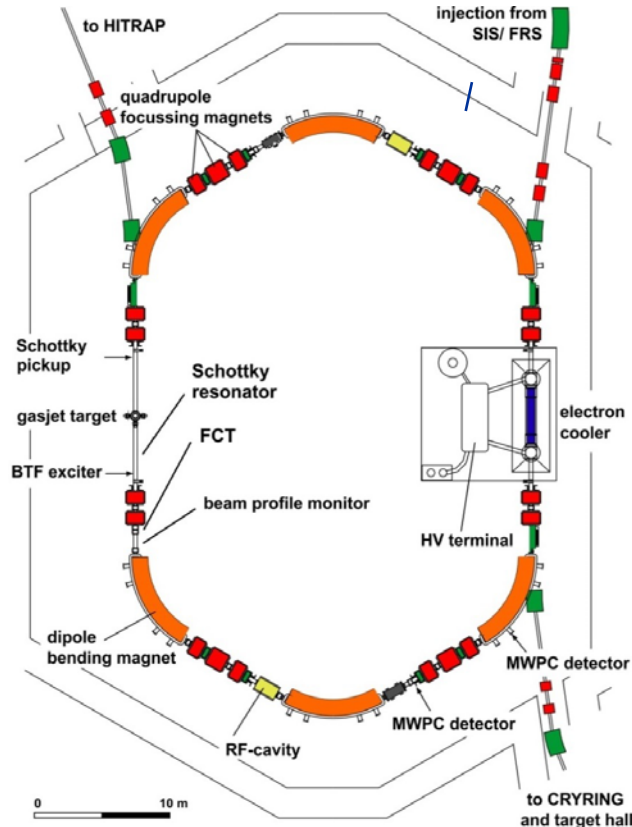
- ESR: internal with isochronous optics, $^{100}\text{Mo}^{42+}/^{98}\text{Mo}^{42+}/^{98}\text{Zr}^{40+}/^{96}\text{Sr}^{39+}$
 - no problems, requires significant setup time!
- ESR internal $^{238}\text{U}^{92+}/^{229}\text{Th}^{89+}$, stacking with stochastic cooling
 - this kind of experiments requires LONG setup times!!!
 (setup time went into the experiment time)
 unfortunately cancelled just after start of datataking, because of failure of infrastructure

some lengthy discussion about beam size/quality of extracted beam
two days of checking ESR settings, all found to be good, no improvement

finally good conditions found by combined effort of CryRing/ESR teams
(extr. ESR, transfer line, inj. CryRing optimized)

remark: for extraction kick in ESR, the injection kicker is used
=> large orbit distortions all around the ESR required
no electron cooling for extraction setting possible, an increase of emittance
of the beam can not be excluded
(topic in list of ESR upgrade options: ‚Extraction Kicker for CryRing‘)

ESR operation modes



- injection of cooled beams from SIS18
- storage of highly charged ions and secondary beams via TE or FRS
- stochastic cooling (400 MeV/u)
- electron cooling (3 - 420 MeV/u)
- internal gas jet target
- deceleration (minimum 3 MeV/u)
- fast extraction to HITRAP or CRYRING
- charge exchange extraction
- accumulation
- isochronous optics mode
- schottky mass spectrometry of RIBs
- slow resonance extraction

ESR operation in 2024 was very successful!!

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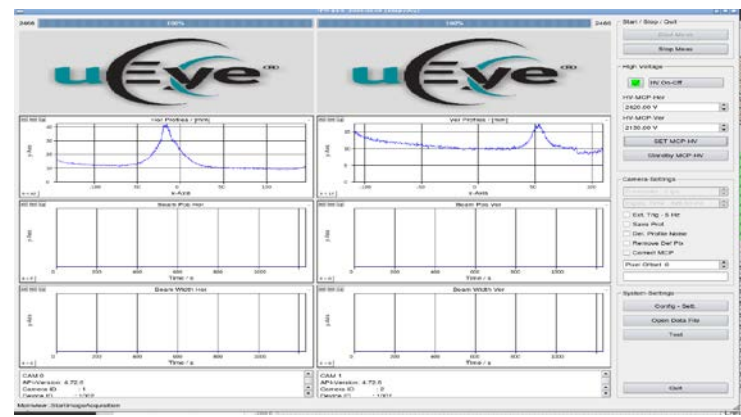
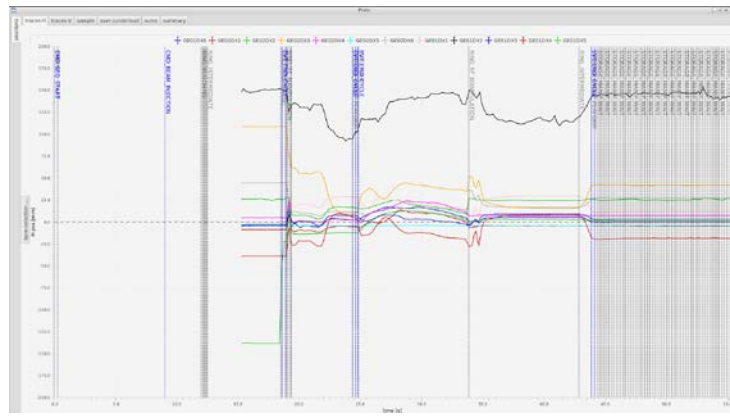
- LSA and storage ring expert app offers a very flexible operation of the storage ring
=> all experiment requirements can be satisfied (and more)
- operation need a deep understanding of the ongoing experiment and setup,
(we still encountered unexpected, surprising behaviour of our actions, caused by the specific settings of subchains)
this is probably just a question of getting used to it, but requires constant checking the result of trims/setup changes. (which is sometimes hard to do during setup of the machine...)
- previously reported latencies are significantly reduced, but there are still some trims/setup changes with significant waiting time before activation
- the transition of ESR hardware to FAIR standards is not yet completed, the performance is therefore restricted
- monitoring the system and error diagnosis is not possible adequately due to the lack of actual values (istwert erfassung!) and archiving and should be given **high priority!!!**

digitization of beam diagnostics

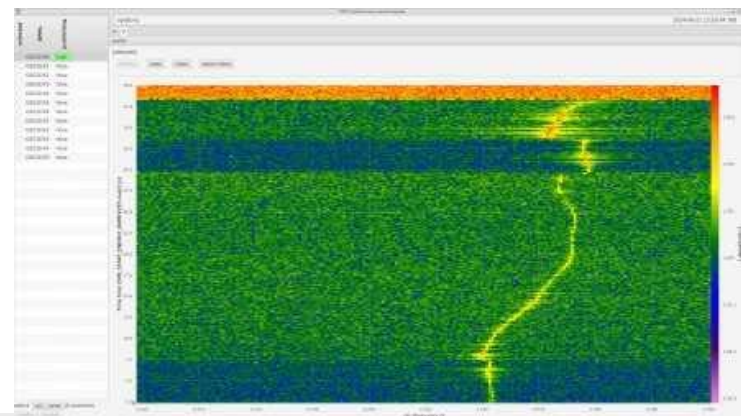
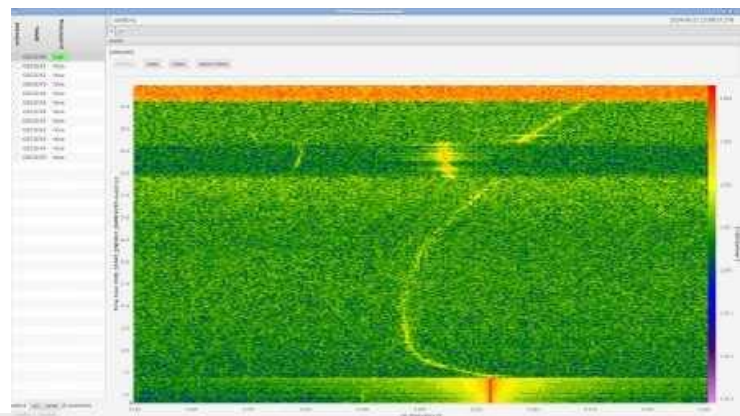
many apps under development and already available,
but still some expert support needed for setup



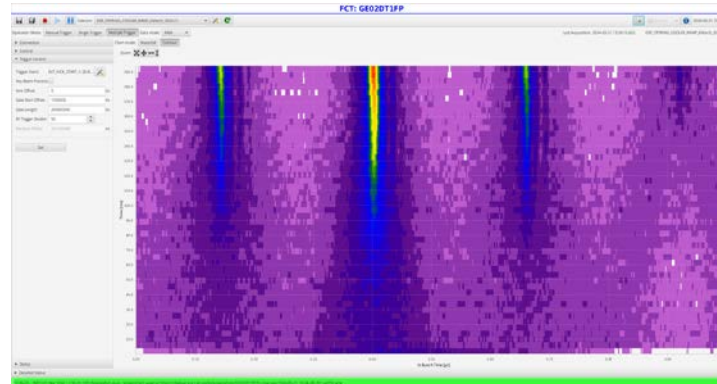
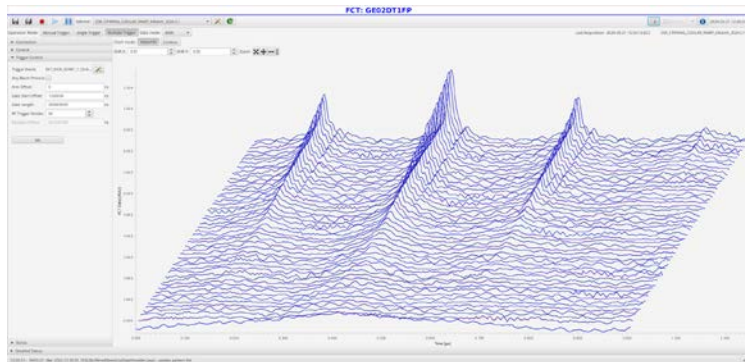
orbit
and
ipm



tune



FCT



- make more use of available beam diagnostics for machine setup
(expert support needed and usually available)
will take some time to setup proper measurements,
but potentially leads to improved performance
- improve understanding of ESR optics
- study of deceleration losses (PhD work in progress)
- „Online“ optics model
(no plan how to realize, yet: e.g. within the ESR team, some student,
some support from Controls, external support....)

NEED FOR MORE SETUP/MACHINE TIME!!

As reported, practically all required operation modes of ESR
were successfully executed in 2024

ESR IS READY FOR 2025 BEAMTIME*

*we need a new stripper target in the TE line

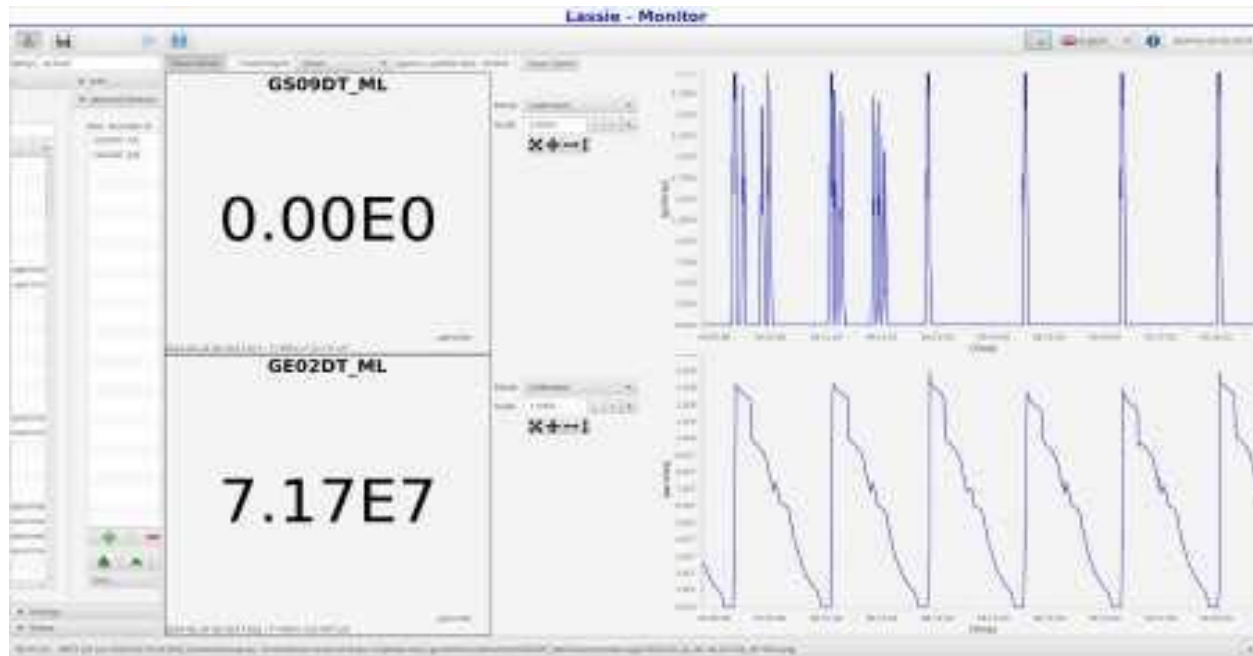
Reminder to the experimenters: the shutdown has started
if you need to install, replace equipment please report this asap,
so it can be put in the shutdown planning

Thank you for your attention

Additional transparencies

Highlight from 2024 operation

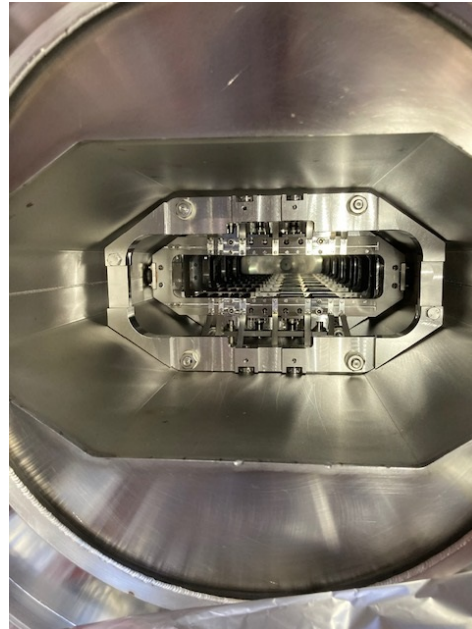
intensity $^{238}\text{U}^{92+}$ delivered to experiment E028 at 17 MeV/c regularly
over one week+ $> 5e7$



nominal intensities ^{238}U
91+/92+ 40 MeV $4E+07$
91+/92+ 10 MeV $5E+06$

Shutdown work Juli 2022 to February 2024

repair of kicker-electrode of the
stochastich cooling in ESR
quadrupole



HITRAP Commissioning: deceleration to 4 MeV/c and fast extraction to HITRAP

$^{12}\text{C}^{6+}$

$^{18}\text{O}^{8+}$

$^{36}\text{Ar}^{18+}$

CryRing experiments: deceleration and fast extraction

$^{197}\text{Au}^{75+}$

CryRing internal und material research

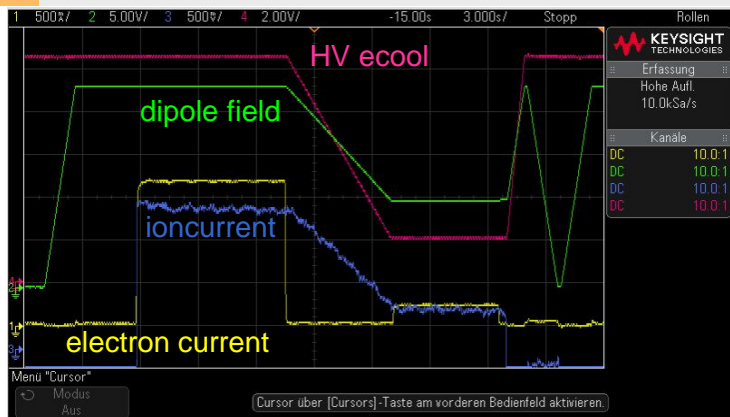
ESR: internal with isochronous optics, $^{100}\text{Mo}^{42+}/^{98}\text{Mo}^{42+}/^{98}\text{Zr}^{40+}/^{96}\text{Sr}^{39+}$

HTA: $^{238}\text{U}^{89+}$ charge exchange extraction of $^{238}\text{U}^{90+}$

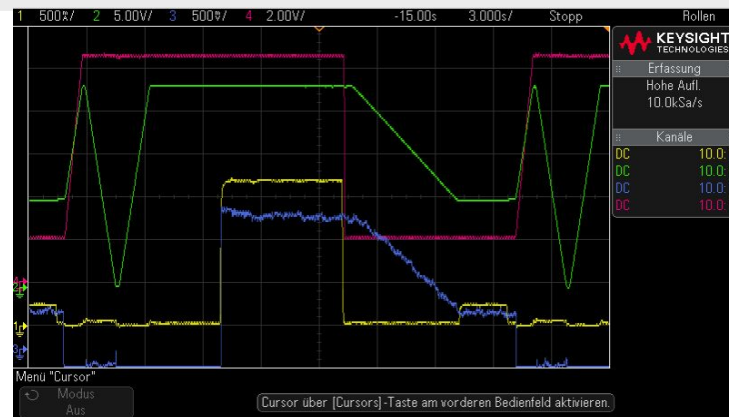
ESR internal $^{238}\text{U}^{92+}/^{229}\text{Th}^{89+}$, stacking with stochastic cooling

ESR internal $^{238}\text{U}^{90+}$ with deuterium gasjet target

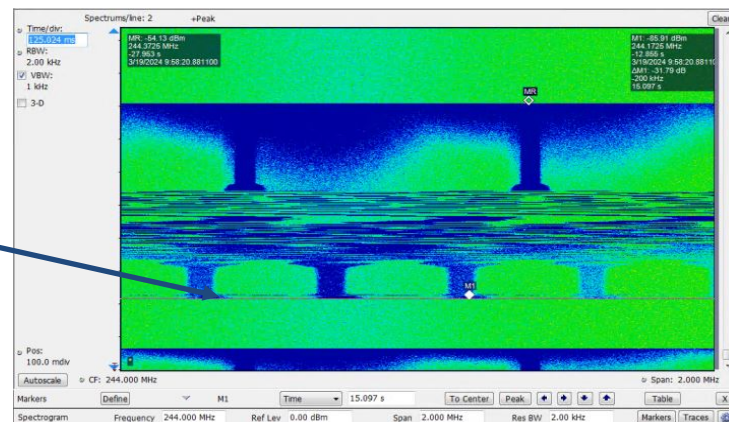
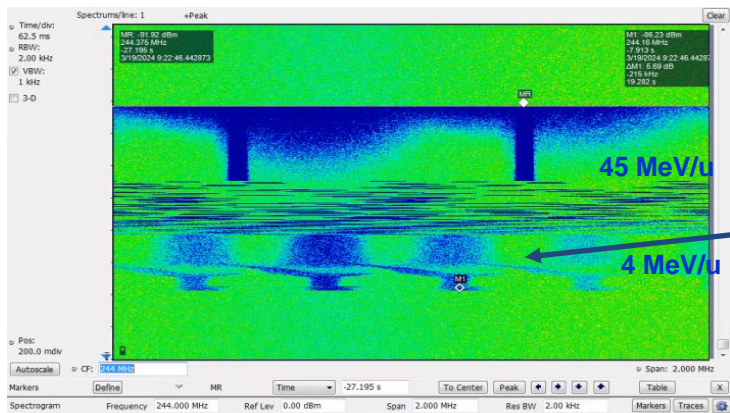
flexibilization of ESR operation



Independent ramps for HV ecool and ring magnets



reduction of cycle time by avoiding waiting time for HV



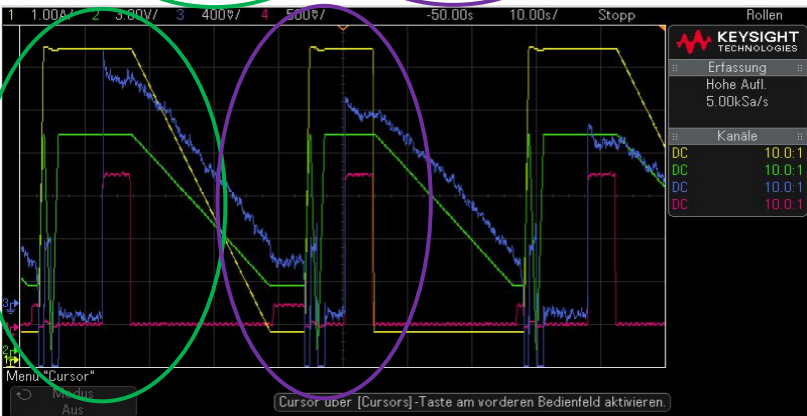
flexibilization of ESR operation

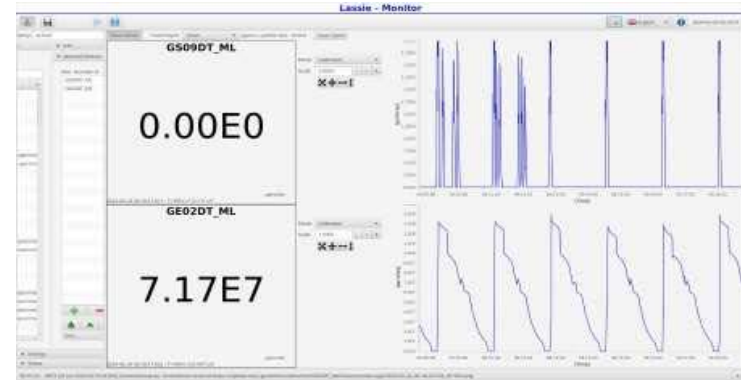
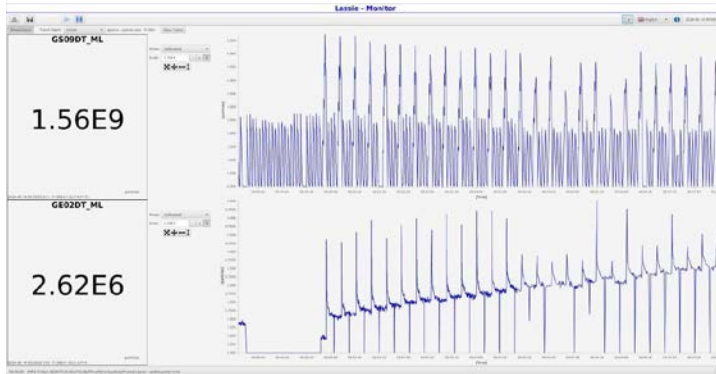


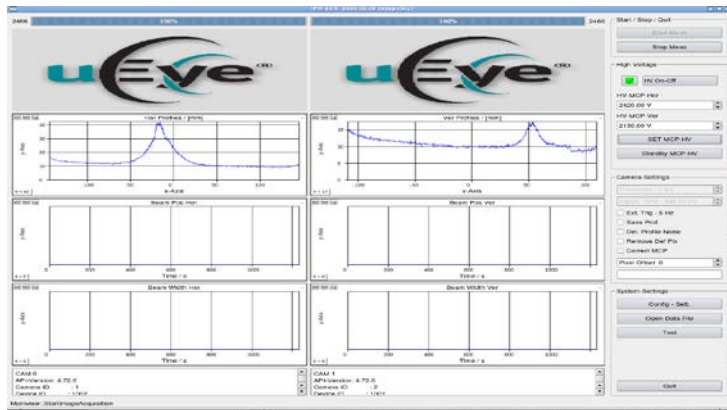
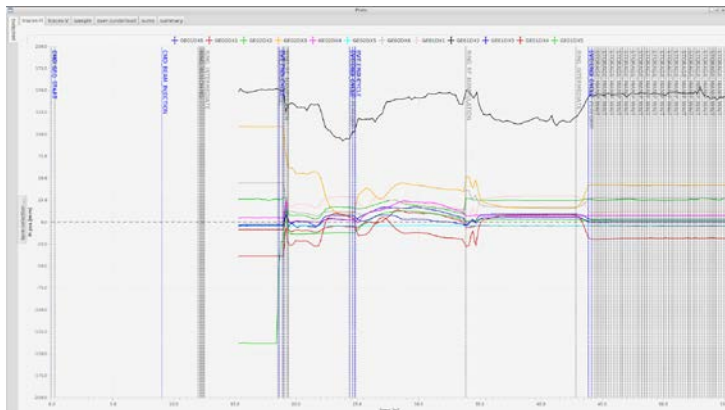
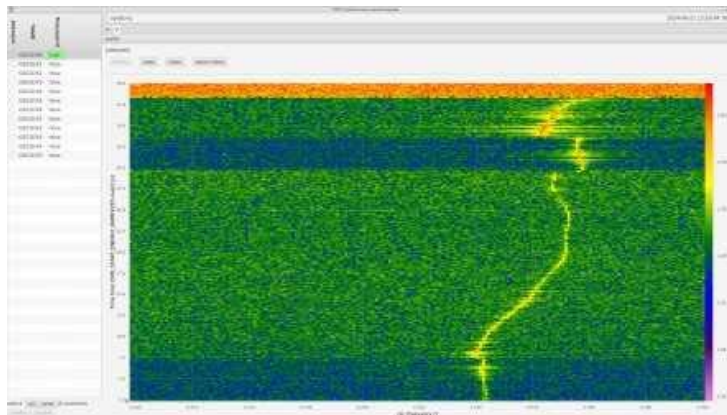
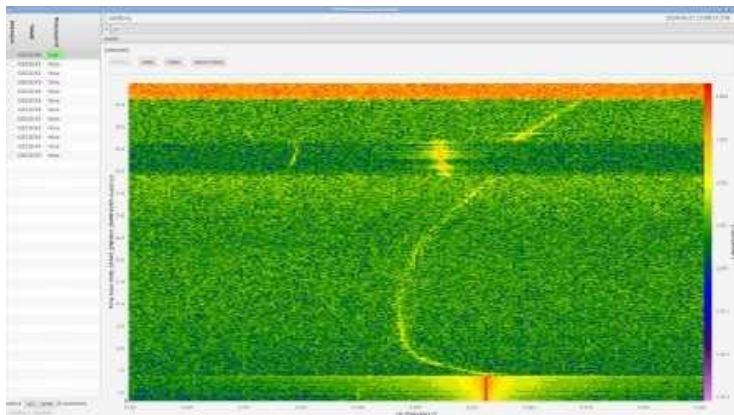
two pairs of coupled pattern:
possibility for storage of different ions
(same rigidity, but different velocity)

⇒ collisions of co-moving beams
(Ref.: Franzke, NIMB 24/25 (1987))

possibility for parallel operation of ESR
for multiple users

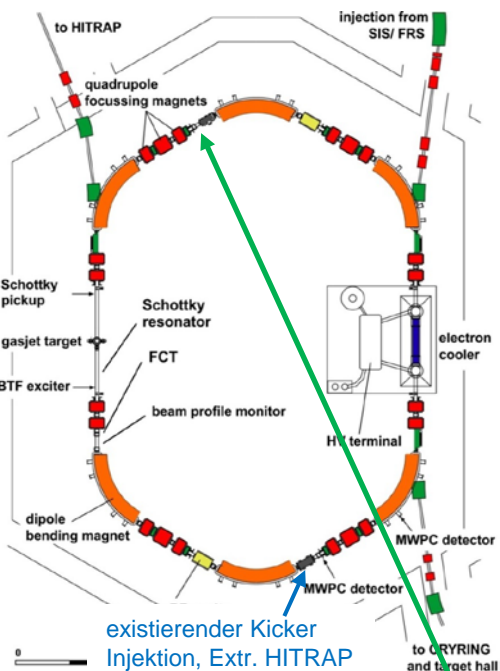




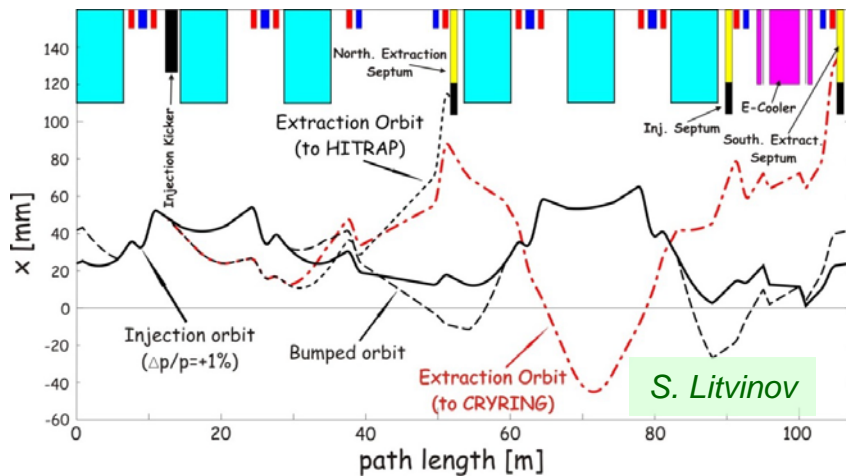
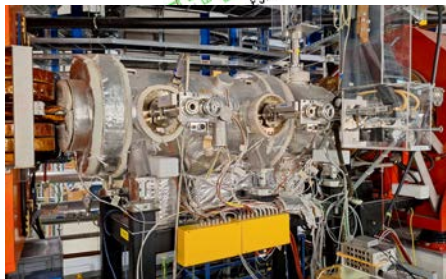


1 Extraktions-Kicker für CRYRING

aus der Anfangsphase des ESR-CRYRING Projektes (2014):
 fast beam extraction from ESR to CRYRING is employing a sophisticated scheme with a distorted closed orbit for the circulating beam before extraction to CRYRING
 consequence: no cooling during extraction, risk of unacceptable heating and emittance growth, particularly for highly charged ions

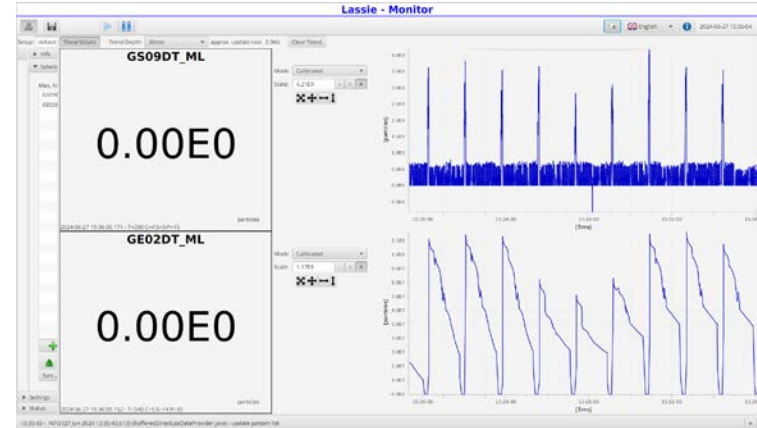


aktuelle Kammer für langsame Extraktion mit zwei Septa im Nordbogen



Lösung: dedizierter Extraktionskicker im Norden des ESR, dadurch zusätzlich frei werdender Platz

Stripper thema



- 1 Vakuumverbesserung: vollständiger Ersatz der Ionengetterpumpen
Ersatz der Ti-Sublimatoren durch NEG-Module
weitere Ersatzbeschaffungen sind zu erwarten
- 2 neue Hochspannungsgeräte für Elektronenkühler
- 3 Beschaffung neuer Stromversorgungen
- 4 Beschaffung von Messgeräten für Remotebetrieb (FCC)
- 5 Umrüstung aller Geräte auf SCUs erforderlich,
erlaubt flexibleren Betrieb und komplexere Betriebsabläufe (Patterns)
- 6 Archivierung relevanter Daten sollte mit Priorität verfügbar gemacht werden,
insbesondere auch für die Nutzer