ESR
Machine Performance During Beam Time 2025

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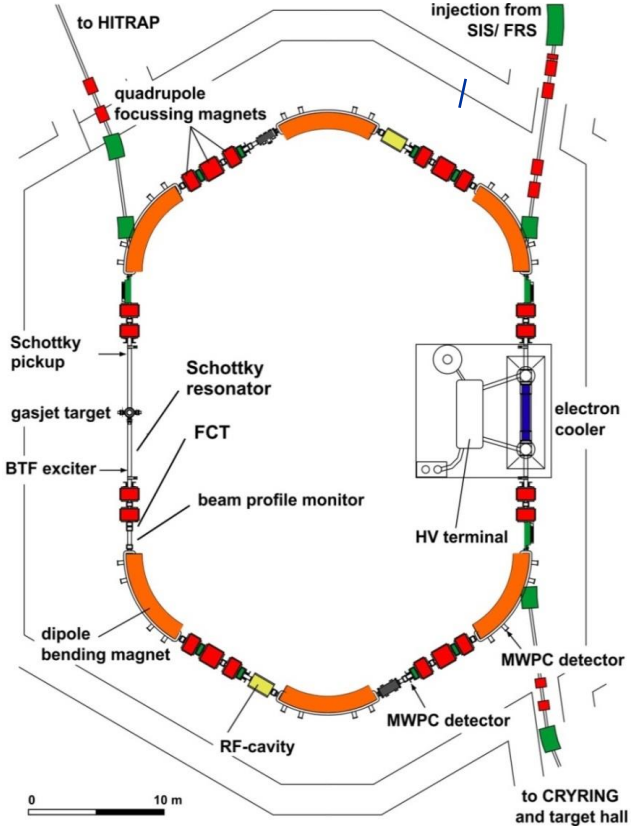
for the ESR operating team

22nd SPARC topical workshop, September 15th and 18th, 2025

ESR operation modes (used in 2025)



- 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 (minumum 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 2025

very smooth operation, almost no failures

a lot of failures and retuning (high temperatures, cooling issues)

Chronological:

07.-24.02.: $^{107}Ag^{45+}$ HITRAP commissioning

25.02-03.03.: $^{78}Kr^{36+}$ ESR internal

09.03.-13.03.: $^{197}Au^{79+}$ HITRAP experiment

18.03.-07.03.: $^{197}Au^{79+}$ CryRing

08.03.-22.03.: $^{197}Au^{79+}$ CryRing

03.04.-07.04.: $^{208}Pb^{82+}$/$^{116}Hf^{82+}$ ESR internal, isochronous mode

28.04.-04.05.: $^{197}Au^{79+}$ machine experiments

12.08.-18.05.: $^{209}Bi^{81+}$ ESR internal

22.05.-01.06.: $^{12}C^{6+}$ machine experiments

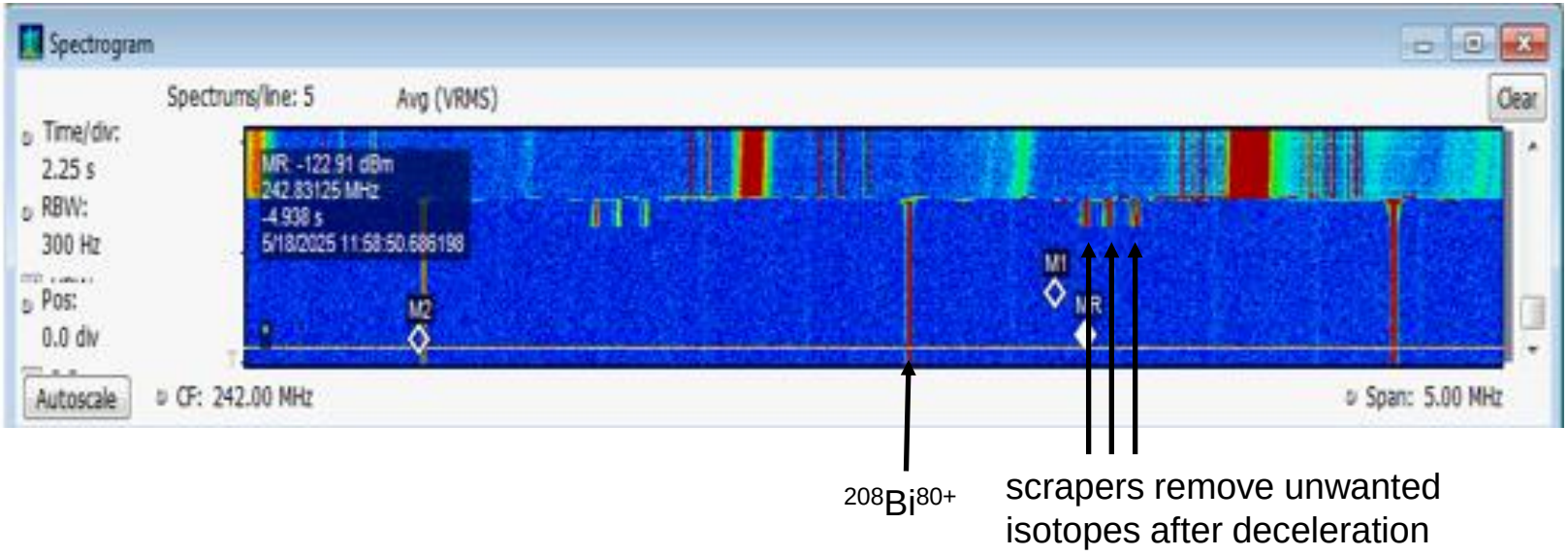
02.06.-11.06.: $^{40}Ar^{18+}$ machine experiments

19.06.-25.06.: $^{238}U^{92+}$/$^{229}Th^{89+}$ ESR internal

30.06.-06.07.: $^{238}U^{91+}$ CryRing

$^{209}Bi^{81+}/^{208}Bi^{80+}$ ESR internal

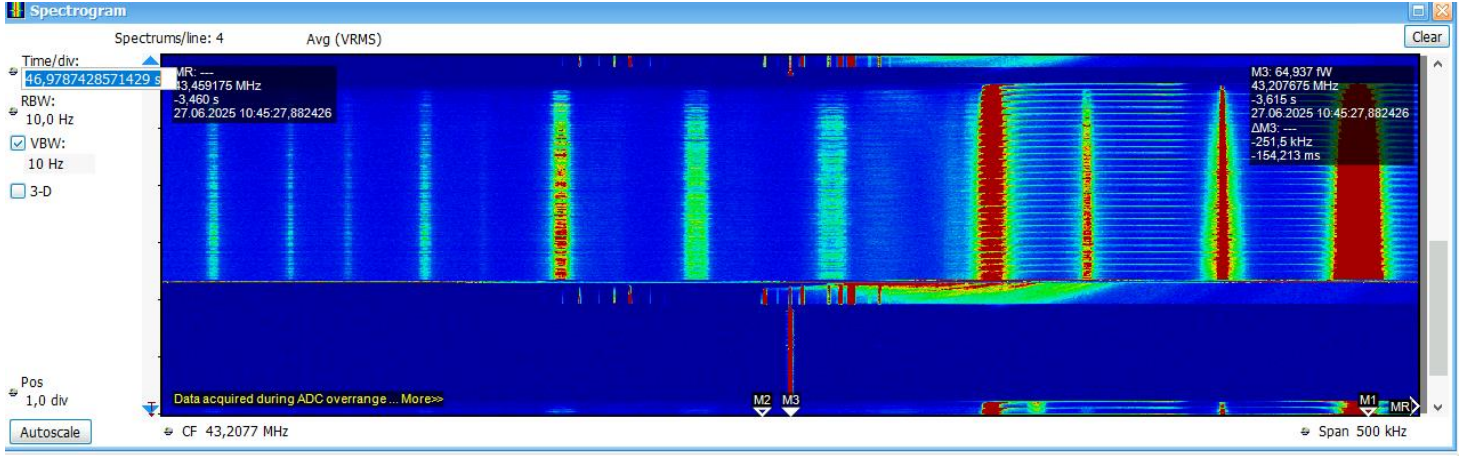
- $^{209}Bi^{68+}$ from SIS18, stripped to $^{209}Bi^{81+}$ in TE Stripper, stacking with stochastic and electron cooling
- Deceleration (400 -> 374 MeV/u)
- Switch to production target, Injection of $^{208}Bi^{81+}$, breading $^{208}Bi^{80+}$ by charge exchange in e-Cooler
- Deceleration of $^{208}Bi^{80+}$ (400 -> 374 MeV/u) and scraping



$^{238}U^{92+}/^{229}Th^{89+}$ ESR internal

refined procedure for purification of 229Th89+:

- 40xstacking with stoch. cooling and synchr. RF SIS18-ESR, electron cooling after accumulation
- deceleration and debunching for scraping unwanted fragments,
- rebunching of the 229Th89+ for laser excitation measurements



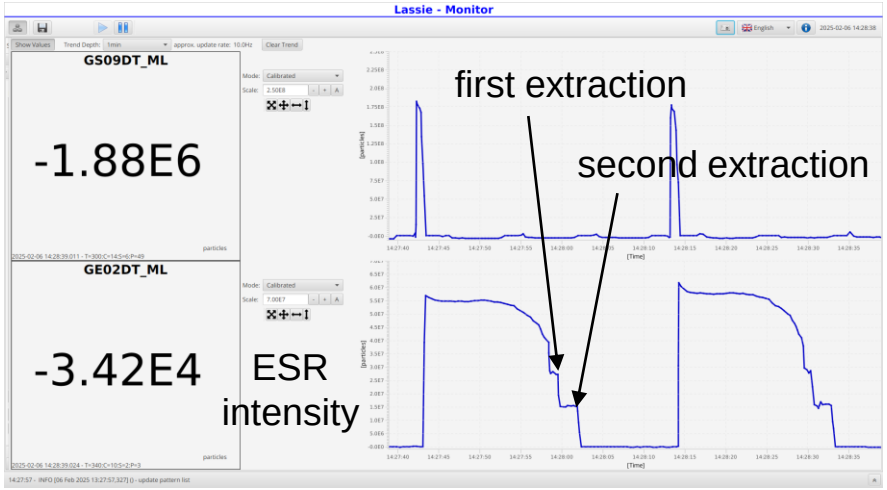
many failures during the whole time of this experiments
over the whole accelerator chain (hot weather...)

Machine Experiments in 2025

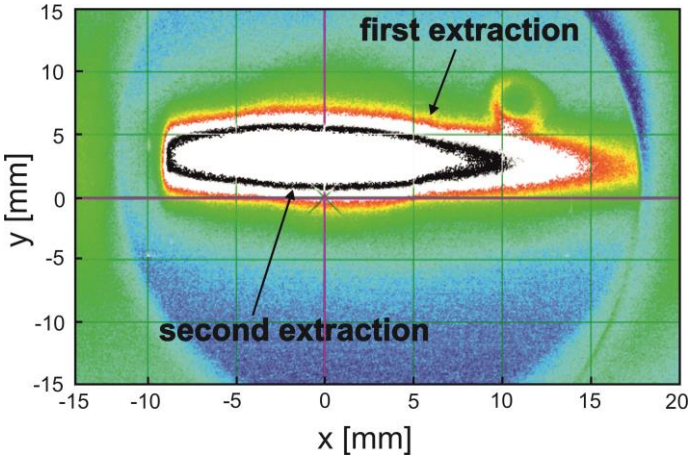
For the first time ESR machine experiments were executed
in parallel to user operation at other places, leading to signigicant improvement in available time.
(very usefull, I hope this can be continued in the future...)

Multiple extractions for HITRAP

Bunching on 2nd harmonic, duplicate extraction subchain,
kick 1st bunch, readjust hf phase in second extr. subchain to kick the second bunch



first screen ESR to HITRAP



courtesy: S.Litvinov

option for more efficient HITRAP setup

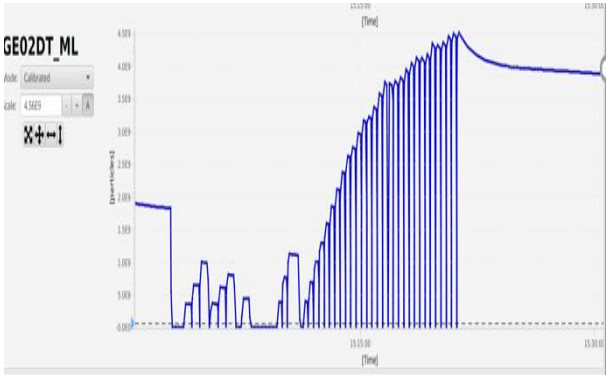
could not directly be used by HITRAP, needs special pattern, controls setup

Stacking with fixed Barrier Bucket (or H=1)

of importance especially for future FAIR storage rings

but also can be more effective than the usually applied stacking with stochastic cooling on injection orbit and electron cooling on displaced orbit

intensity increase from 5e8 upto 4e9 for 12C6+



Procedure: Synchronization between SIS HF and ESR HF allows injection into the unstable region of the bucket, the beam is then cooled into the stable bucket area

injected bunch accumulated bunch

SIS kicker

ESR kicker

ESR bunch (2 bpm‘s)

SIS bunch 4th harmonicc

Stochastic Cooling

Possible extension of energy range in the future

measured shunt impedance at stochastic pickups between 200-400 MeV/u

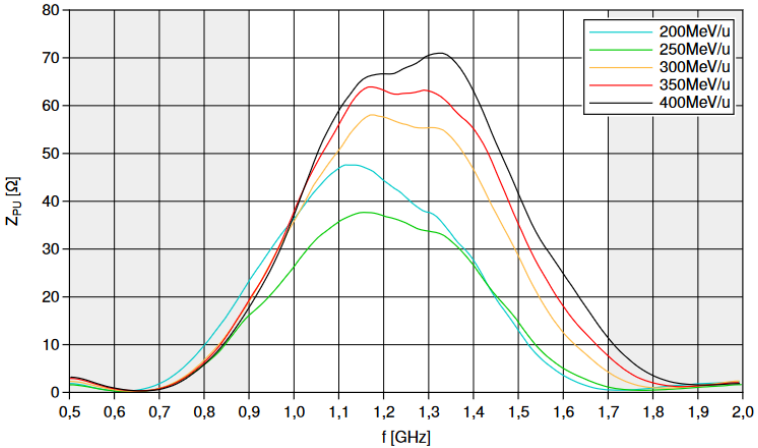


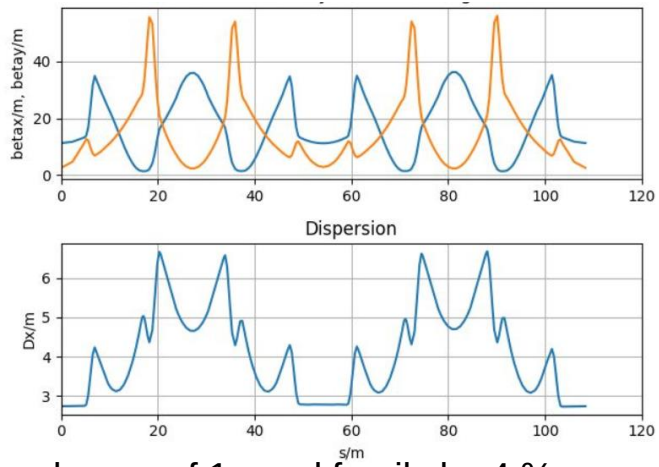
Abbildung 4.4: geglättete Shuntimpedanzen

courtesy: C.Peschke

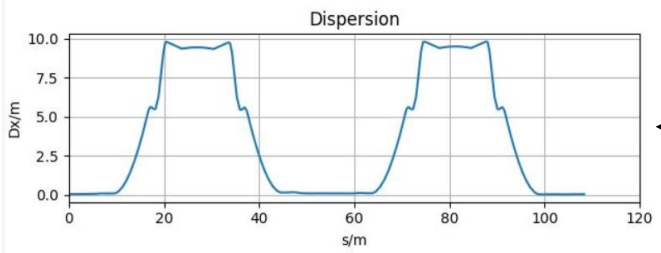
Study of real stochastic cooling at different energies (which also involves the stochastic kicker efficiency) will follow in the future

Beam Optics studies

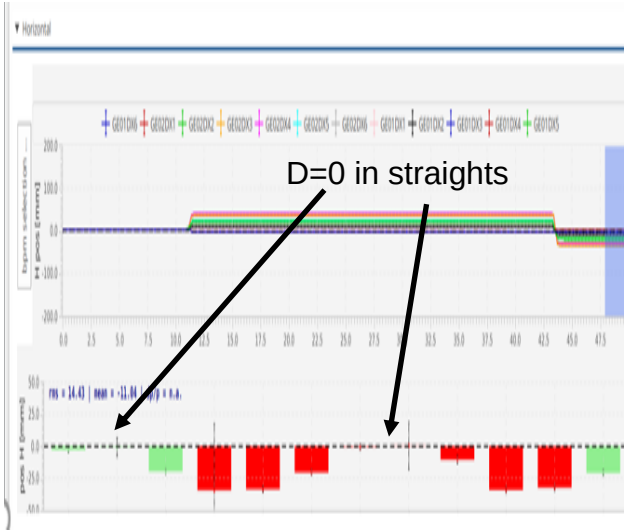
old „standard optics“



change of 1 quad family by 4 %,
tune adjustment with two different families
(beta function aprox. the same)



difference orbit when changing
the momentum of the stored beam
by change of bunching frequency
=> dispersion around the ESR

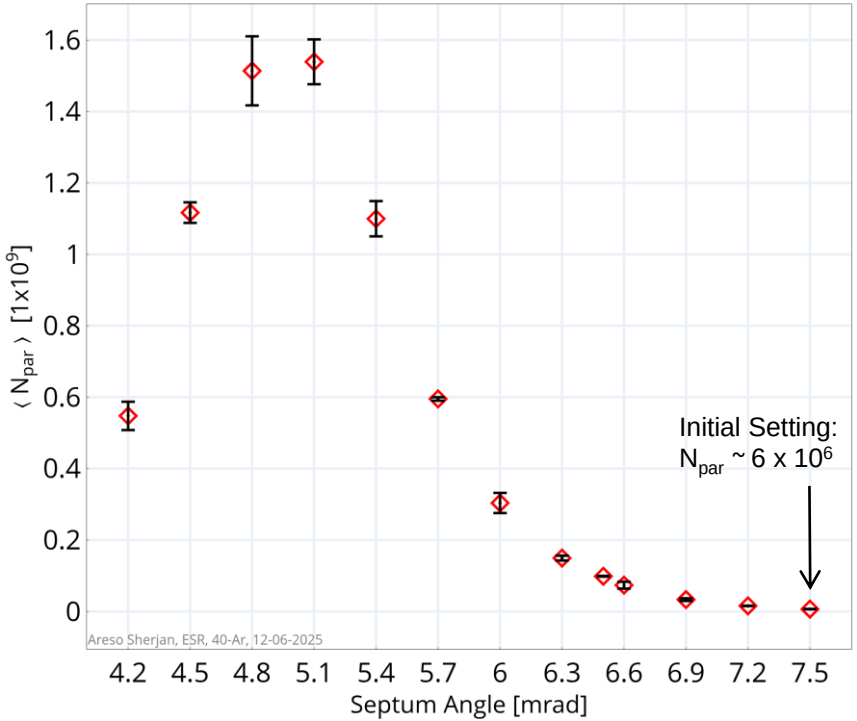


This will be our
„new standard optics“
and will used in the
future

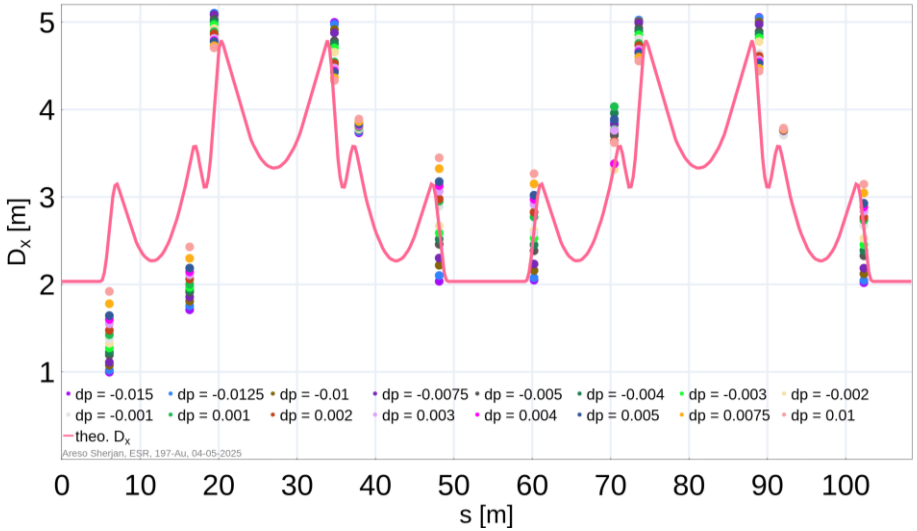
(button in LSA to
easily adjust D in
straight sections
will be prepared)

Investigation of Deceleration

Possible improvement of efficiency in the future



Optics Model for Deceleration Studies



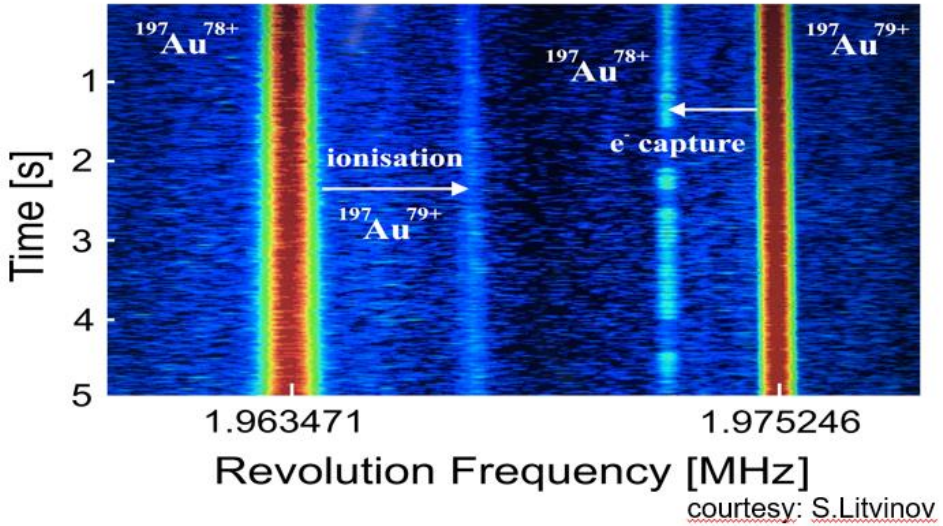
Measurement Campaign at ESR May, June 2025
Areso Sherjan/ Giuliano Franchetti

Many thanks to O. Chorniy and T. Giacomini for the support.

courtesy: A.Sherjan

Co-colliding beams

storage of two different ions of the same rigidity, on identical orbit, opening up the way to new experiments (demonstrated for Au78+, 79+ and U91+, 92+, could also be applied to different ions with apropriately selected chargestates)

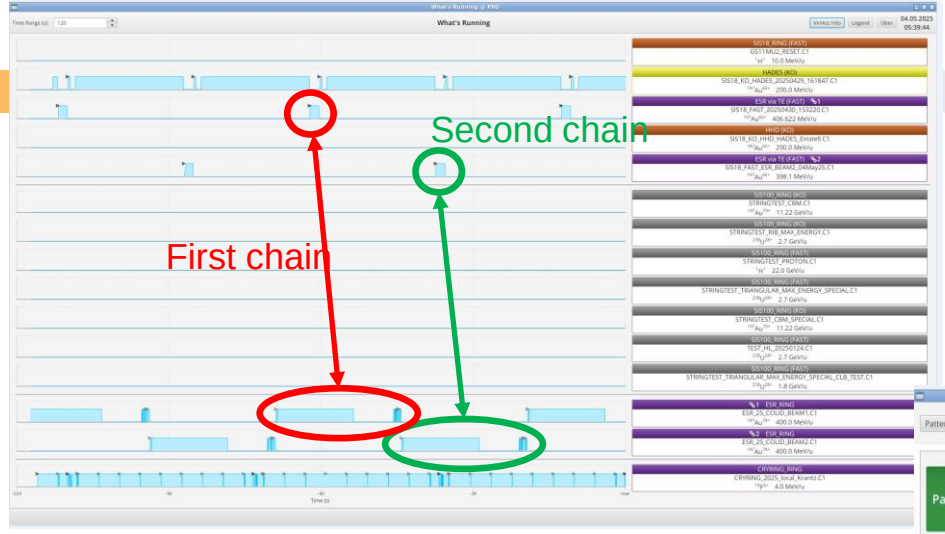


courtesy: S.Litvinov

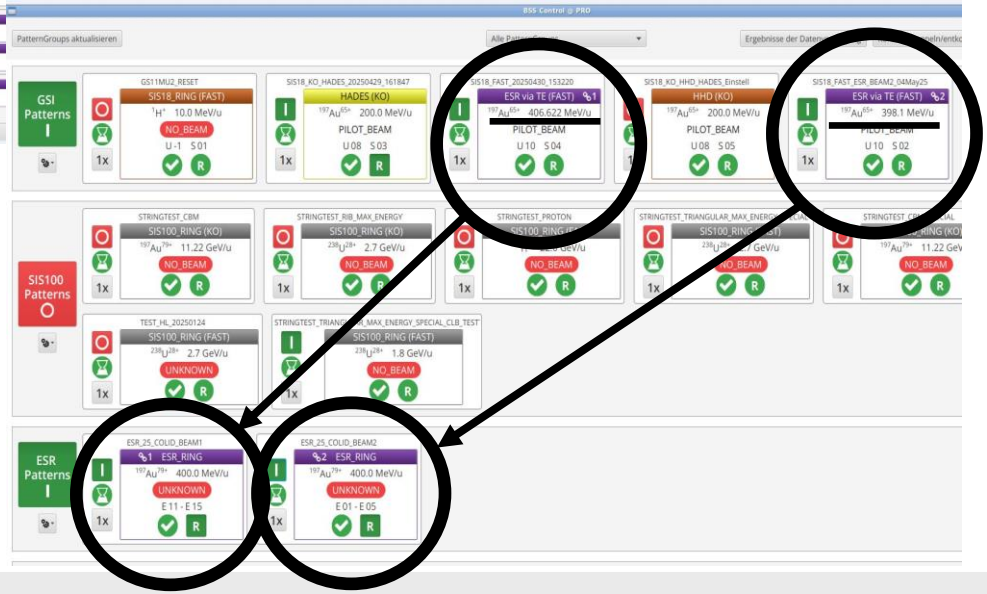
next steps:

- bunch the two beams
- cool the two beams
- crossing of the two beams at dedicated location

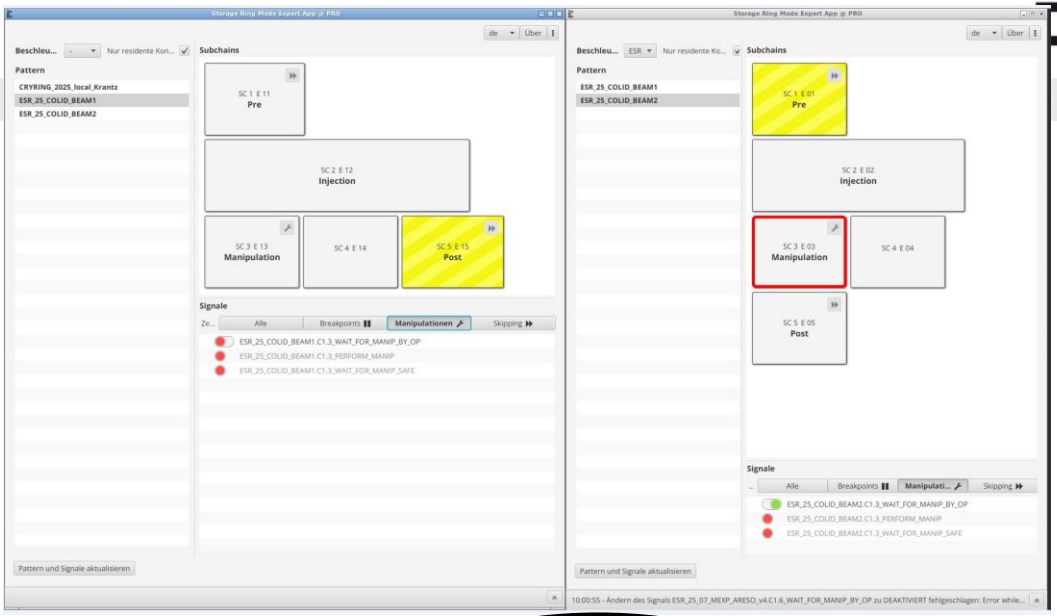
Two SIS18-ESR chains

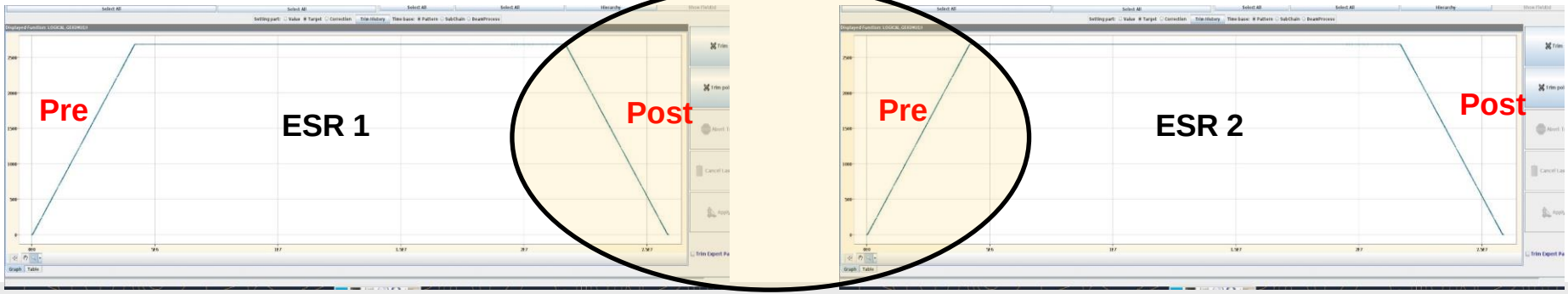


- We run 2 chains one after each other.



Running 2 ESR together





Summary

ESR operation in 2025 was successfull

only during the Thorium experiment a lot of problems were encountered

- LSA and storage ring expert app offers a very flexible operation of the storage ring
  - ⇒ all experiment requirements can be satisfied
  - ⇒ it opens up the way to new developments (e.g. multiple extractions, storing different ions simultaneously)
- 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!!!
- Machine experiments in parallel to running physics experiments at SIS18 worked well, and should be continued

Outlook to 2026

Shutdown work 2025/2026

- **Repair of Extraction Septum in direction HITRAP (exchange of coil) (Nov. 2025)**
- **Preparation work in the target region for upcoming experiments (postponned after Dry Run 2025)**
- **Work on the mechanics of pressurized air drives (exchange of aged parts)**
  (Strategy for longer term solution under discussion)
- **Exchange of MCP‘s of IPM (venting Southern Arc of ESR, after Dry Run)**
- **regular maintanance work**
- **conversion of the recently acquired PTB Main e-cooler HV device for use with faster ramp speed**

- **Dry Run in February 2026**

ESR will be ready for operation from FCC in Sept. 2026

Thank you for your attention