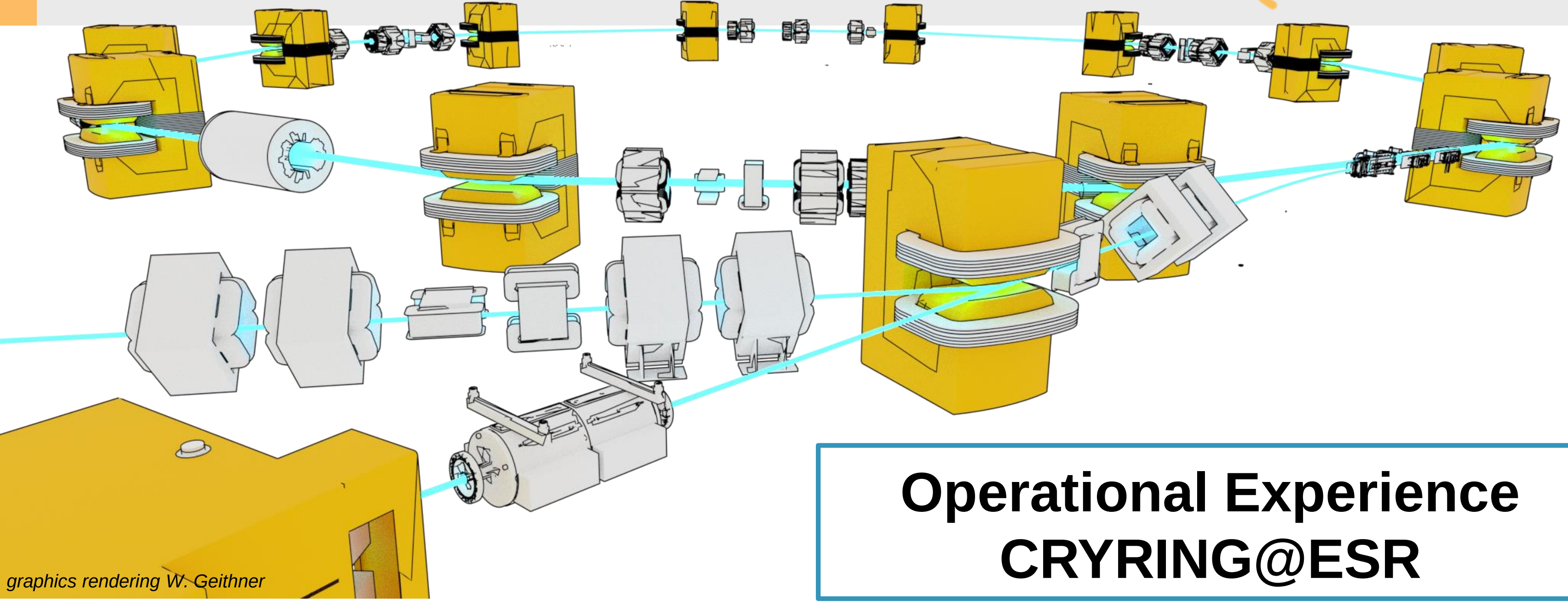


Operational Experience CRYRING@ESR

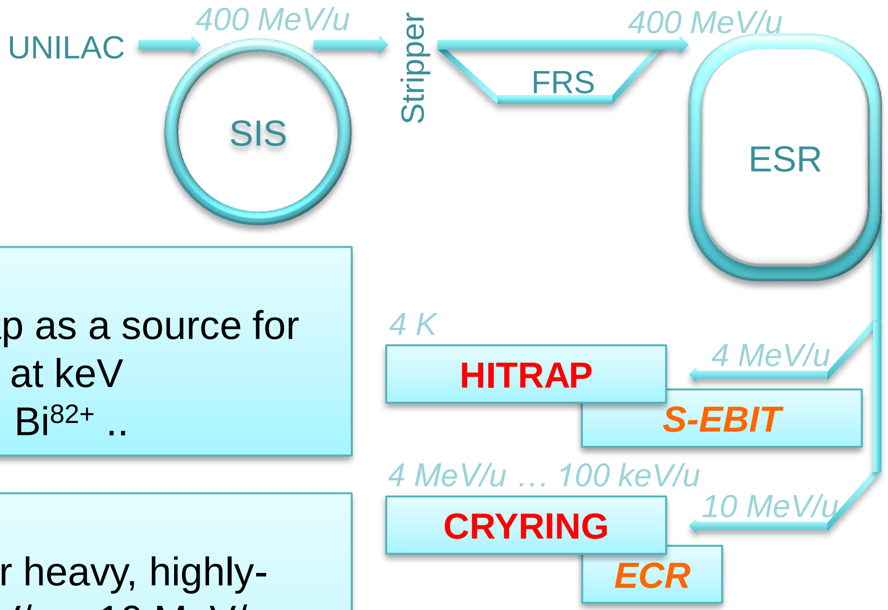
Frank Herfurth

16th February 2023

Operational Experience CRYRING@ESR

- (a short) history (of a low energy storage ring)
- Operation : how does it look like?
  - typical pattern, general approach
  - beams in CRYRING@ESR: local and via HEST from ESR
  - (local) archiving and monitoring
  - beam life time and vacuum
  - electron cooling
- Beam instrumentation (low energy, low charge, low intensity)
- Machine Studies
  - Do we need a compensation solenoid?
  - Chromaticity (correction) and tune diagram
  - Multiturninjection, Fast and synchronized (B2B)
  - fast extraction
- Experiments, Outlook

Slow, Heavy, Highly Charged Ions @ GSI/FAIR



HITRAP

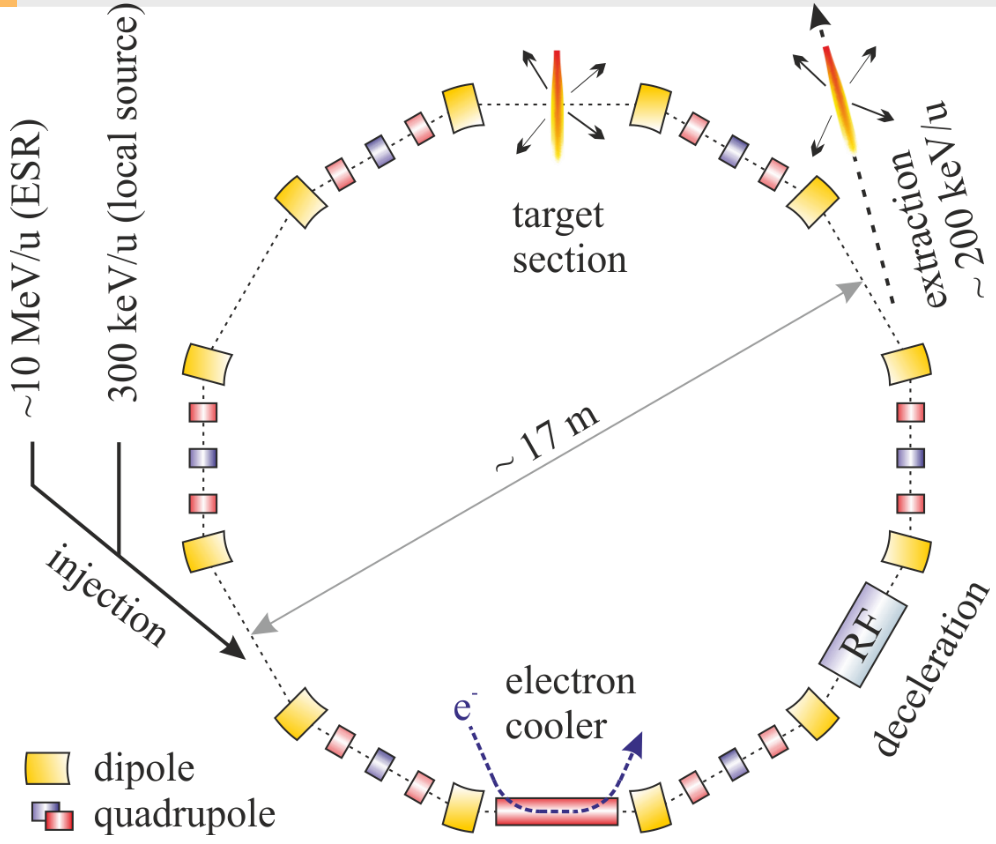
- Linear Decelerator and Trap as a source for heavy, highly-charged ions at keV
- up to 10^6 of ions alike U^{91+}, Bi^{82+} ..

CRYRING@ESR

- Low energy storage ring for heavy, highly-charged ions at 100s of keV/u .. 10 MeV/u
- local injector for lighter, lower charged ions
- Modernized and Reinstalled at ESR (GSI/FAIR)

CRYRING@ESR

- Max. rigidity 1.44 Tm
  - 15 MeV/u U^{92+}
- Min. rigidity ~ 0.054 Tm
  - 150 keV/u protons



- **FAIR Research & Development**
  - Detectors and diagnostic systems
  - FAIR type control system
  - Training of operators on FAIR type system
  - FAIR type safety and radiation monitoring/access system

with real beam (since standalone operation during commissioning possible)

- **Scientific Opportunities**
  - Heavy, highly-charged ions as available at GSI (up to U^{92+}, fragmentation products) at low energy 100 keV/u .. 10 MeV/u – bridge the energy gap between the ESR (> 4 MeV/u) and HITRAP (<10 keV/u)

CRYRING in Stockholm (MSL)

Singly charged positive atomic ions:
H^+, D^+, $^3He^+$, $^4He^+$, $^7Li^+$, $^9Be^+$, $^{11}B^+$, $^{12}C^+$, $^{14}N^+$, $^{16}O^+$, $^{40}Ar^+$, $^{40}Ca^+$, $^{45}Sc^+$, $^{48}Ti^+$, $^{56}Fe^+$, $^{83}Kr^+$, $^{84}Kr^+$, $^{86}Kr^+$, $^{88}Sr^+$, $^{129}Xe^+$, $^{131}Xe^+$, $^{132}Xe^+$, $^{138}Ba^+$, $^{139}La^+$, $^{142}Nd^+$, $^{151}Eu^+$, $^{197}Au^+$, $^{208}Pb^+$

Multiply charged atomic ions:
$^4He^{2+}$, $^{11}B^{2+}$, $^{12}C^{2+}$, $^{12}C^{3+}$, $^{12}C^{4+}$, $^{12}C^{6+}$, $^{14}N^{2+}$, $^{14}N^{3+}$, $^{14}N^{4+}$, $^{14}N^{7+}$, $^{16}O^{2+}$, $^{16}O^{3+}$, $^{16}O^{4+}$, $^{16}O^{5+}$, $^{16}O^{8+}$, $^{19}F^{6+}$, $^{19}F^{9+}$, $^{20}Ne^{2+}$, $^{20}Ne^{5+}$, $^{20}Ne^{6+}$, $^{20}Ne^{7+}$, $^{20}Ne^{10+}$, $^{28}Si^{3+}$, $^{28}Si^{11+}$, $^{28}Si^{14+}$, $^{32}S^{5+}$, $^{36}Ar^{9+}$, $^{36}Ar^{10+}$, $^{36}Ar^{12+}$, $^{36}Ar^{13+}$, $^{40}Ar^{7+}$, $^{40}Ar^{9+}$, $^{40}Ar^{11+}$, $^{40}Ar^{13+}$, $^{40}Ar^{15+}$, $^{48}Ti^{11+}$, $^{58}Ni^{17+}$, $^{58}Ni^{18+}$, $^{84}Kr^{33+}$, $^{126}Xe^{36+}$, $^{129}Xe^{36+}$, $^{129}Xe^{37+}$, $^{136}Xe^{39+}$, $^{136}Xe^{44+}$, $^{207}Pb^{53+}$, $^{208}Pb^{53+}$, $^{208}Pb^{54+}$, $^{208}Pb^{55+}$

Positive molecular ions:
H_2^+, HD^+, H_3^+, D_2^+, H_2D^+, ^3He
NH_2^+, OH^+, CH_5^+, NH_4^+, H_2O^+
$C_2H_2^+$, HCN^+, $C_2H_3^+$, $HCNH^+$,
NO^+, $D^{13}CO^+$, CH_3O^+, CF^+, O_2
$N_2H_7^+$, $D_2{}^{32}S^+$, $CD_3OH_2^+$, CD_3
$D_3{}^{34}S^+$, $C_3H_4^+$, $D_2{}^{37}Cl^+$, $D_5O_2^+$,
HCS^+, $C_2H_5O^+$, DN_2O^+, $C_2H_5OH^+$, CO_2D^+, CD_3CDO^+, $NO^+\cdot H_2O$, O_3^+, $DCOOD_2^+$, $CD_3OCD_2^+$, $C_3D_7^+$, CF_2^+, $NO^+\cdot D_2O$, DC_3N^+, $CD_3OCD_3^+$, $N_3H_{10}^+$, DC_3ND^+, $CD_3ODCD_3^+$, $H_7O_3^+$, COS^+, $N_2O_2^+$, $CH_3OCOH_2^+$, $D_7O_3^+$, $N_3D_{10}^+$, $C_4D_6^+$, $S^{18}O_2^+$, ArN_2^+, $H_9O_4^+$, $CD_3COHNHCH_3^+$, $CD_3CONHDCH_3^+$, $C_6D_6^+$, $PO^{37}Cl^+$, $H_{11}O_5^+$, $C_2S_2H_6^+$, $C_2S_2H_7^+$, $H_{13}O_6^+$, $PO^{35}Cl_2^+$

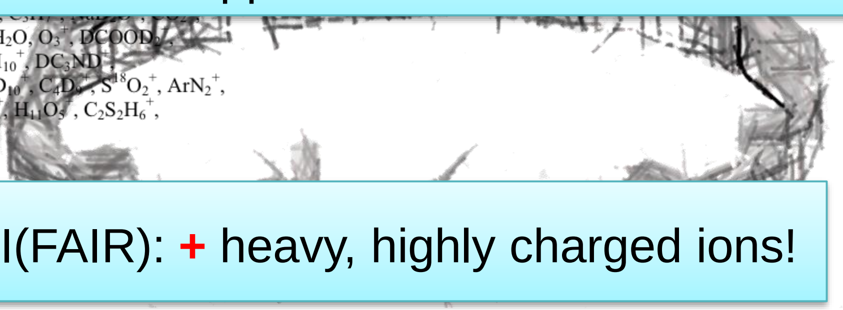
Negative atomic ions:
H^-, Li^-, F^-, Si^-, S^-, Cl^-, Se^-, Te^-

Negative molecular ions:
CN^-, C_4^-, Si_2^- Cl_2^-

~200 different ion species

singly charged (pos. & neg.)
multiply charged
molecular (pos. & neg.)

- Successful operated from 1992 to 2010
- Dismantled and shipped to FAIR/GSI in 2012/13



GSI(FAIR): + heavy, highly charged ions!

.. some documents later ..

CRYRING@ESR:
A study group report

Accepted by
- GSI Science Council
- FAIR ECE, AFI, Supervisory Board
- SFAIR, Swedish Science Council

Darmstadt, July 26, 2012

Michael Lestinsky[1], Norbert Angert[1], Ralph Bär[1], Ralph Becker[1], Mario Bevcic[1], Udo Blell[1], Walter Bock[1], Angela Bräuning-Demian[1], Håkan Danared[2], Oleksiy Dolinskyy[1], Wolfgang Enders[1], Mats Engström[3], Achim Fischer[1], Bernhard Franzke[1], Georg Gruber[1], Peter Hülsmann[1], Anders Källberg[3], Oliver Kester[1,4], Carl-Michael Kleffner[1], Yuri A. Litvinov[1], Carsten Mühle[1], Bernhard Müller[1], Ina Pschorn[1], Torsten Radon[1], Heinz Ramakers[1], Hartmut Reich-Sprenger[1], Dag Reistad[3], Galina Riefert[1], Marcus Schwickert[1], Ansgar Simonsson[3], Jan Sjöholm[3], Örjan Skeppstedt[3], Markus Steck[1], Thomas Stöhlker[1,5], Wolfgang Vinzenz[1], and Horst Welker[1]

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[2]European Spallation Source ESS, SE-221 00 Lund, Sweden
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[4]Institut für Angewandte Physik, Goethe-Universität Frankfurt, 60438 Frankfurt a. M., Germany
[5]Helmholtz-Institut Jena, 07743 Jena, Germany

FACILITY FOR ANTIPROTON AND ION RESEARCH

SPARC Collaboration

Technical Design Report:
Experimental Instrumentation of CRYRING@ESR

Z. Andelkovic,[1] C. Brandau,[1,2] M. Dumchev,[3] A. Ehresmann,[4] W. Geithner,[1] A. Georgiadis,[3] V. Hannen,[5] M. Lestinsky,[1*] Y. Litvinov,[1] W. Nörtershäuser,[6] R. Reifarth,[7] Ph. Reiss,[4] O. Rest,[5] R. Sánchez,[1] S. Schippers,[2] T. Stöhlker,[1,8,9] C. Weinheimer,[5] and D. Winzen[5]

on behalf of the SPARC Collaboration

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[2] Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen, D-35392 Gießen
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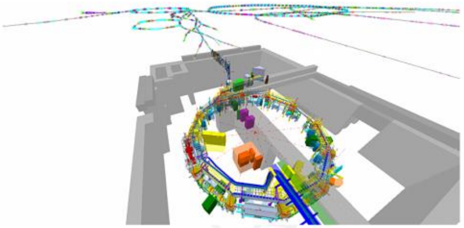
[8] Helmholtz-Institut Jena, D-07743 Jena
[9] Friedrich-Schiller-Universität Jena, D-07743 Jena
[*] Contact person for this TDR

Accepted SPARC TDR

Physics book:
CRYRING@ESR



Editors:
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Atomic Physics Division
GSI Helmholtzzentrum für Schwerionenforschung
D-64291 Darmstadt

April 13, 2016

CRYRING@ESR

$Revision: 1.47 $ $Date: 2016/04/11 14:51:45 $

EPJ-ST 225 (2016) 797

Michael Lestinsky et al.

06/2013

image created by M. Lestinsky

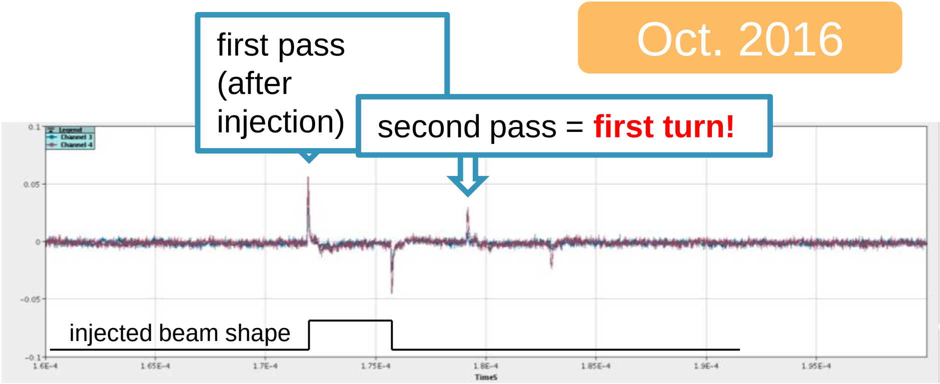

2015, M. Lestinsky (GSI)

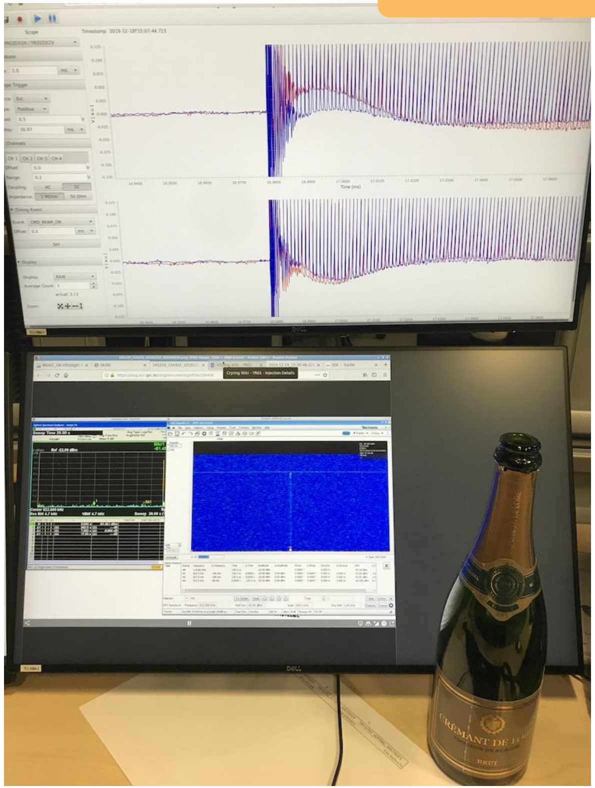

DANFYSIK
01/2016

First Turn and First beam from ESR

19.12.2019

Oct. 2016





Andreas Reiter
ACC Seminar
April, 2022

“Beam Instrumentation at CRYRING@ESR“

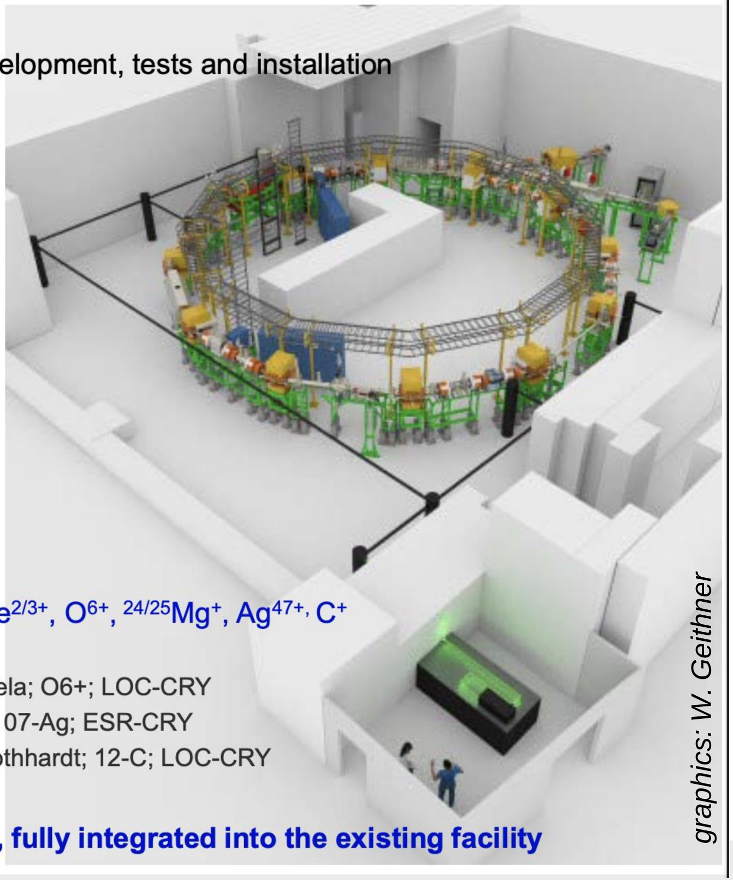
CRYRING@ESR
Rough Timeline

Nov. 2012: KickOff Meeting Controls@GSI
2013 – 2015: Transport & delivery to GSI, system development, tests and installation
Jan. – Aug. 2016: Commissioning of local injector

July 2016: 1st transport ESR to section YR01
Oct. 2016: 1st turn (H_2^+ beam from local injector)
May 2017: 1st electron beam in eCooler
Aug. 2017: 1st stored beam (H_2^+, local injector)
Nov. 2017: 1st cooled beam (H_2^+, local injector)
2018: Commissioning with H_2^+, D^+, Mg^+, Ar^+
Setup of laser laboratory

2019: 1st stored ESR beam (Ar^{18+}, 13 MeV/u)
Comm. with Mg^+, C^+, D^+ ; 1st experiments
2020: Comm. & Experiments with Ne^{7+}, Pb^{78+}, Pb^{82+}
2021: Comm. & Experiments with D^+, Pb^{67+}, U^{91+}, $Ne^{2/3+}$, O^{6+}, $^{24/25}Mg^+$, Ag^{47+}, C^+
- E131 Schippers; 208-Pb; ESR->CRY
- E148 Sanchez; 24-Mg; LOC-CRY
- E138 Weber; 238-U; ESR-CRY
- E140 Lestinsky; Ne3+; LOC-CRY
- E153 Biela; O6+; LOC-CRY
- CMAT; 107-Ag; ESR-CRY
- E129 Rothhardt; 12-C; LOC-CRY

2022: GSI@WORK: Beam Time Schedule



graphics: W. Geithner

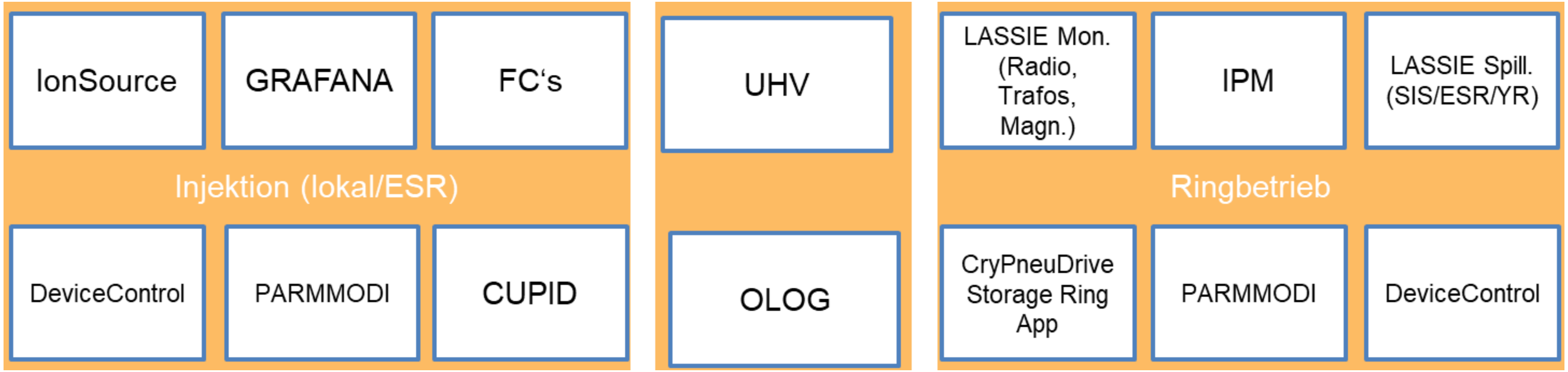
CRYRING@ESR is a scientific instrument, fully integrated into the existing facility

Operational Experience CRYRING@ESR

- (a short) history (of a low energy storage ring)
- **Operation : how does it look like?**
  - **typical pattern, general approach**
  - **beams in CRYRING@ESR: local and via HEST from ESR**
  - **(local) archiving and monitoring**
  - **beam life time and vacuum**
  - **electron cooling**
- **Beam instrumentation (low energy, low charge, low intensity)**
- Machine Studies
  - Do we need a compensation solenoid?
  - Chromaticity (correction) and tune diagram
  - Multiturninjection, Fast and synchronized (B2B)
  - fast extraction
- Experiments, Outlook

Organization of Operation

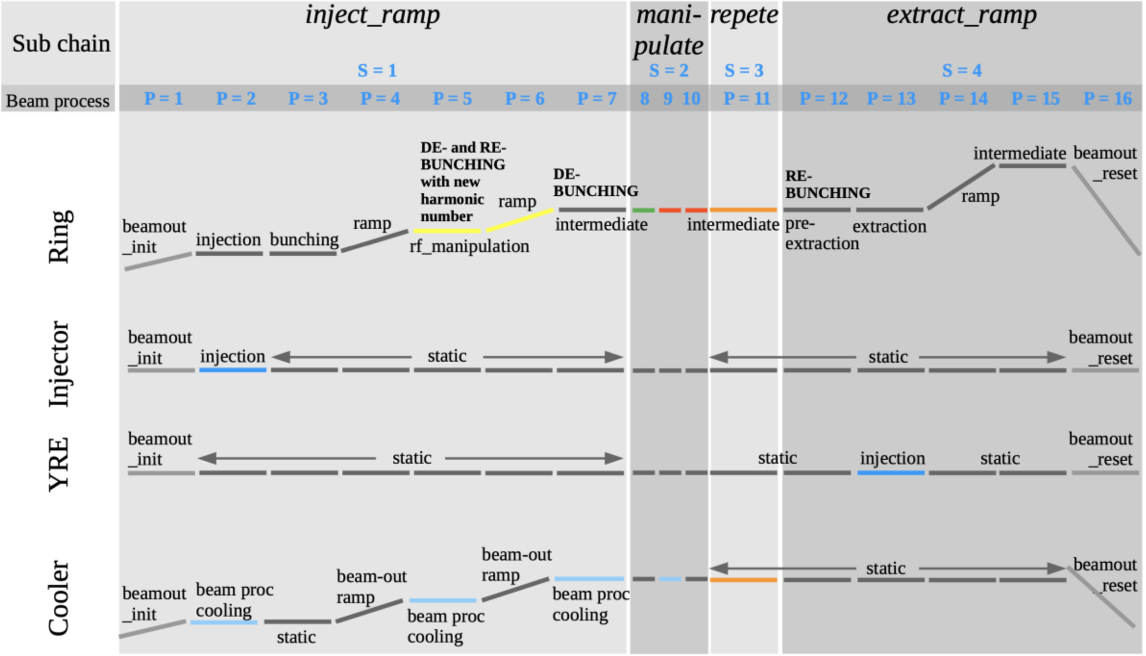
- Order of Apps on Console Screens (after the machine experts clean up their mess)



- CRYRING-Meeting every Tuesday @ 10:30

“Controls”

„CRYRING as a FAIR test facility could be essential for FAIR relevant R&D projects, in particular with respect to accelerator related developments of instrumentation and controls: beam diagnostics, detector development, synchronization, efficient coupling of accel- erators and storage rings, software development etc.“, CRYRING@ESR : A study group report, 2012



Ingrid Kraus et al.

- many iterations of pattern (LSA) modelling
- two generations of ion source applications
- several development steps in bake out and vacuum control
- many customized parts of software
- ..

Beams in CRYRING@ESR

- ions from ESR
  - transfer efficiency (2022) ~ 50%!
    - I.e. 1e6 ions at 10 MeV/u in ESR = 5e5 ions in YR
  - example: up to 2e6 U^{91+} ions in YR
- ions from local injector
  - intensity limited by ion source and physics at low energy
  - independence allows for more flexibility
- new ions species from local source
  - being developed are Li and S. Tests for W planned.

local injector	GSI complex (from ESR)
H_2^+, D^+	Ar^{18+}
C^+, $^7Li^+$, O^{6+}, $Ne^{2,7+}$, Mg^+	Pb^{78+}, Au^{78+}, U^{91+}
S^{3+}, ^6Li, $W^{?+}$	

Decelerate, Extract, Transfer

ESR → **CRYRING@ESR**

> 60%

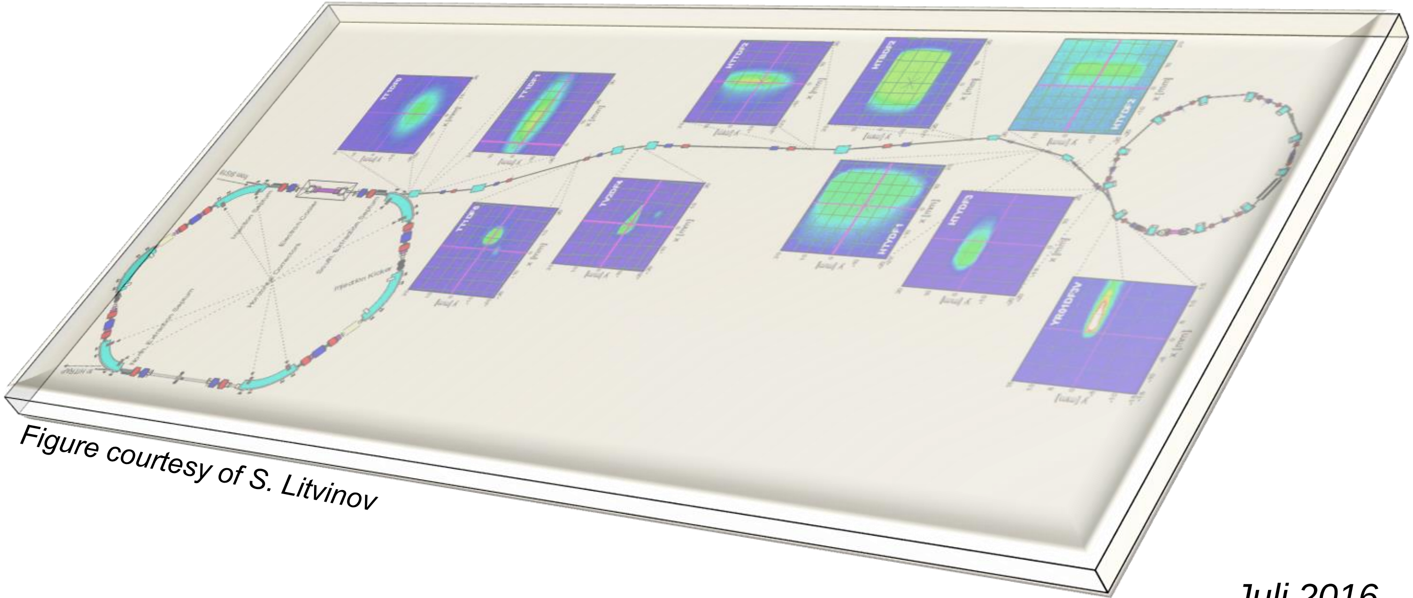
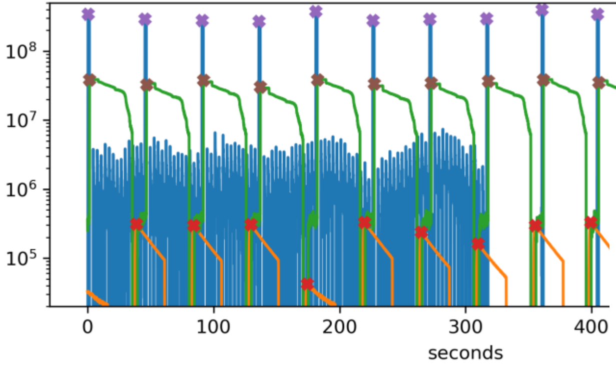
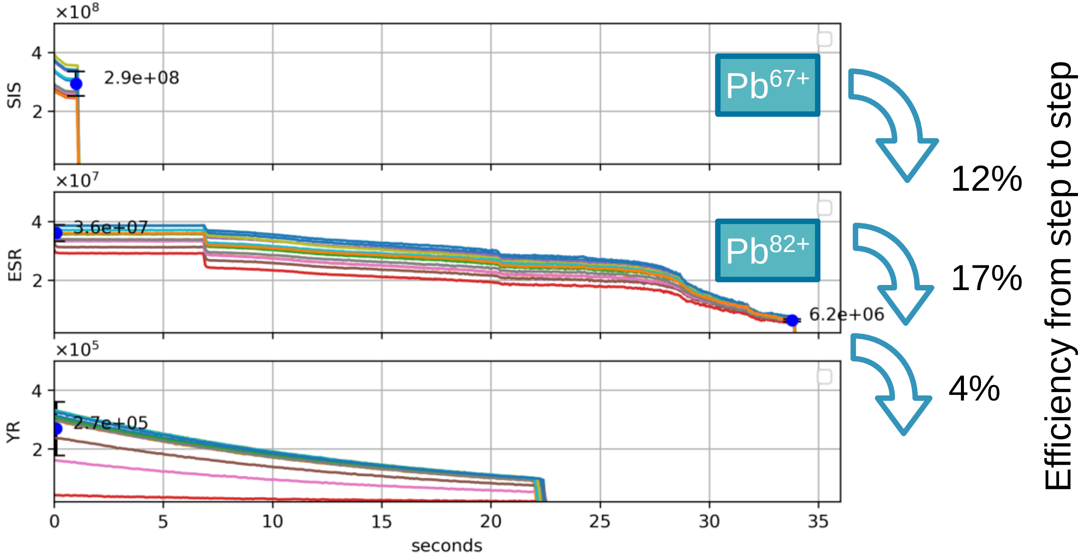


Figure courtesy of S. Litvinov

Juli 2016

Intensities ESR - CRYRING@ESR



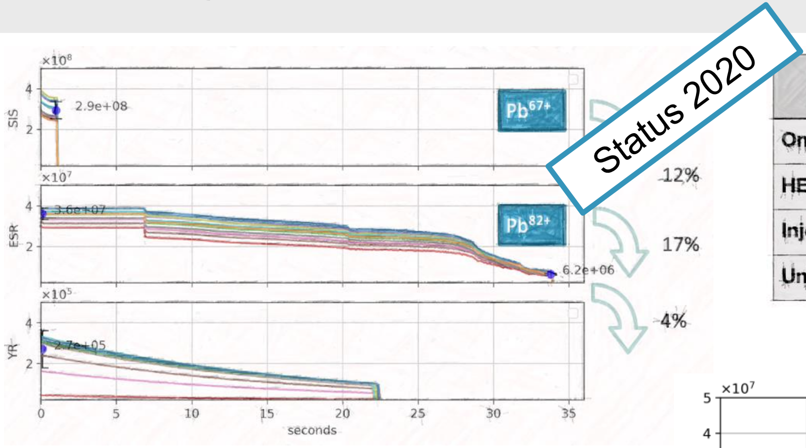


Proposed Measures:

- Add diagnostics to identify losses
- Invest time to tune HEST
- Rebunch in the ESR
- Synchronize RF and Kicker in ESR

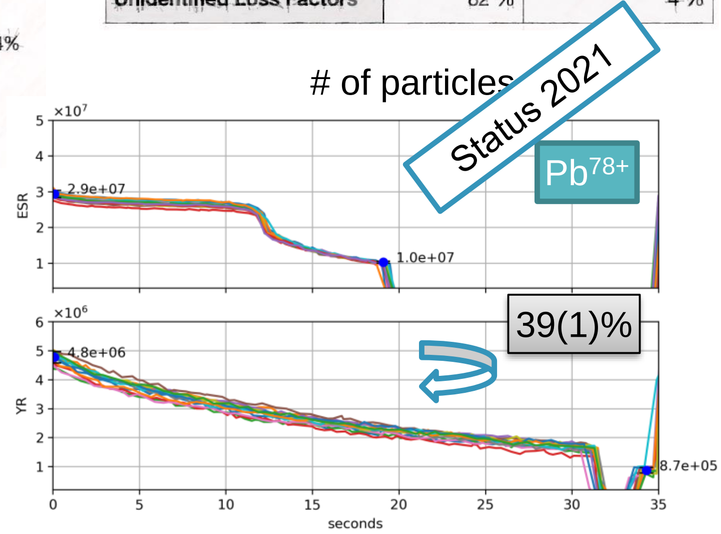
https://sps2013.gsi.de/websites/cryring/CryringWiki/....Intensities.pdf

Transfer Efficiency ESR - CRYRING@ESR



	Loss per step in %	Resulting beam intensity in %
One out of two bunches	50 %	50 %
HEST GHTYDC1-DC2	45 %	27.5 %
Injection/bunching	20 %	22 %
Unidentified Loss Factors	82 %	4 %

# of particles

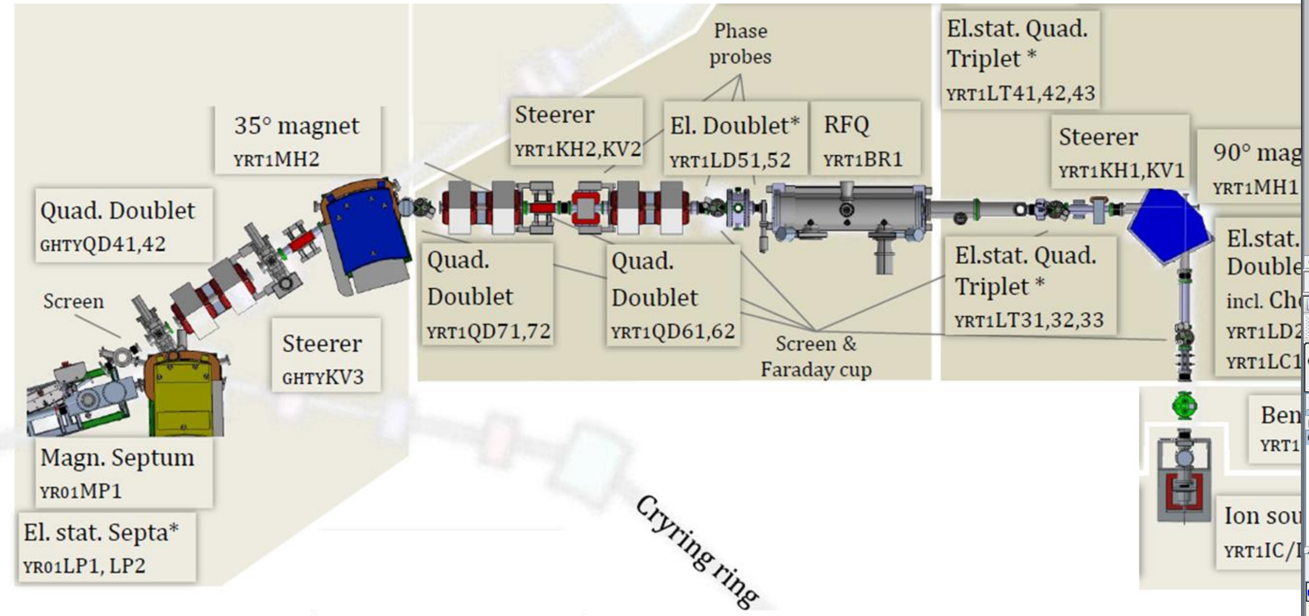


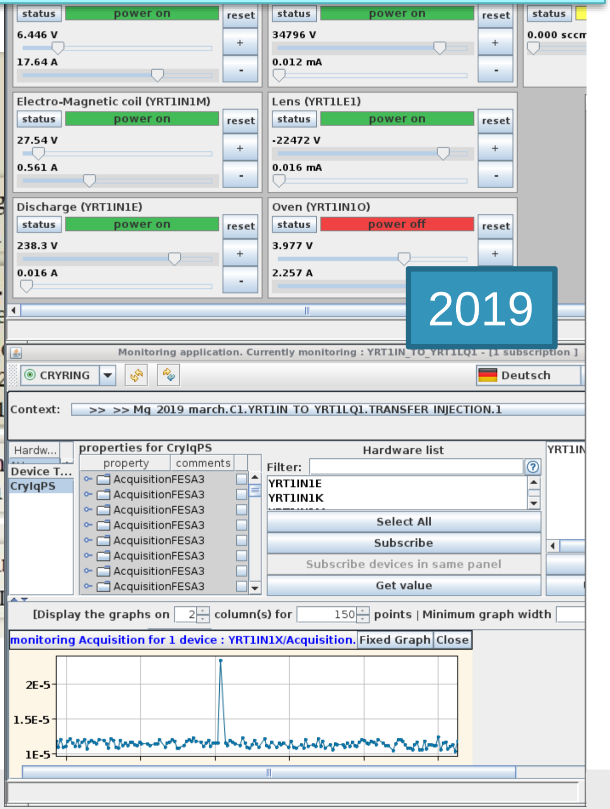
- Add diagnostics to identify losses ✓
- Invest time to tune HEST ✓ *(helped very much by ByPassTrim feature)*
- Rebunch in the ESR ✓
- Synchronize RF and Kicker in ESR ✓

Varying external fields hamper transfer efficiency

Local Injector

- Two ion source types, MINIS, ECR, both with oven
- Typical intensities of beam for injection – 1 .. 100 μA
- Uninterrupted operation time depends on ion species and supply
- Ions produced so far H_2^+, **D^+**, C^+, Li^+, O^{6+}, Ne^{2+}, Ne^{7+}, Mg^+, Ar^+





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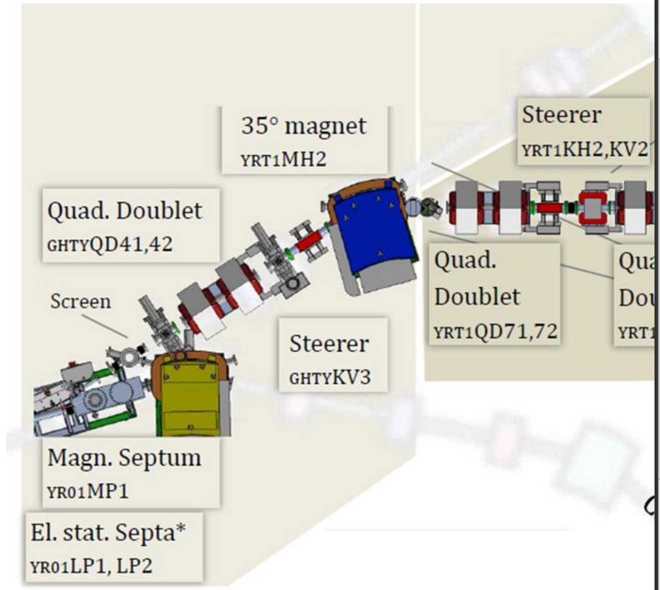
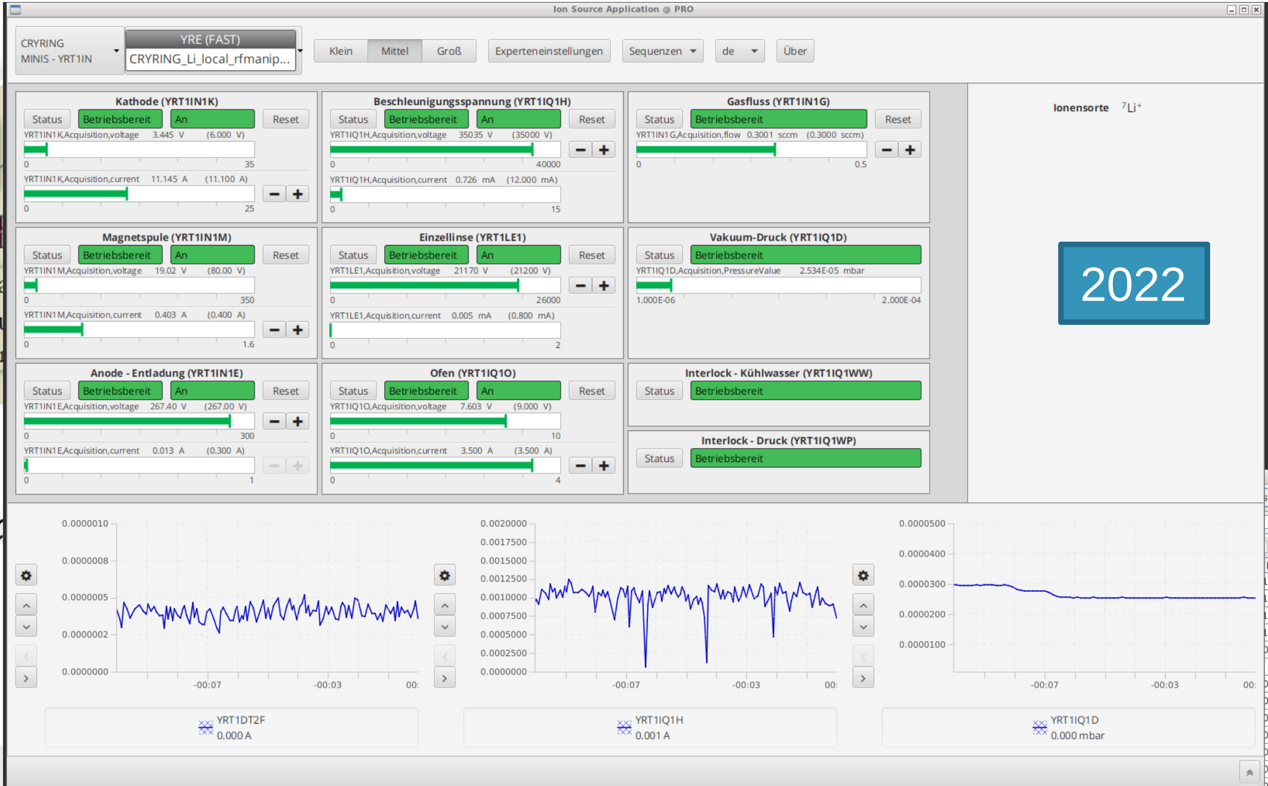




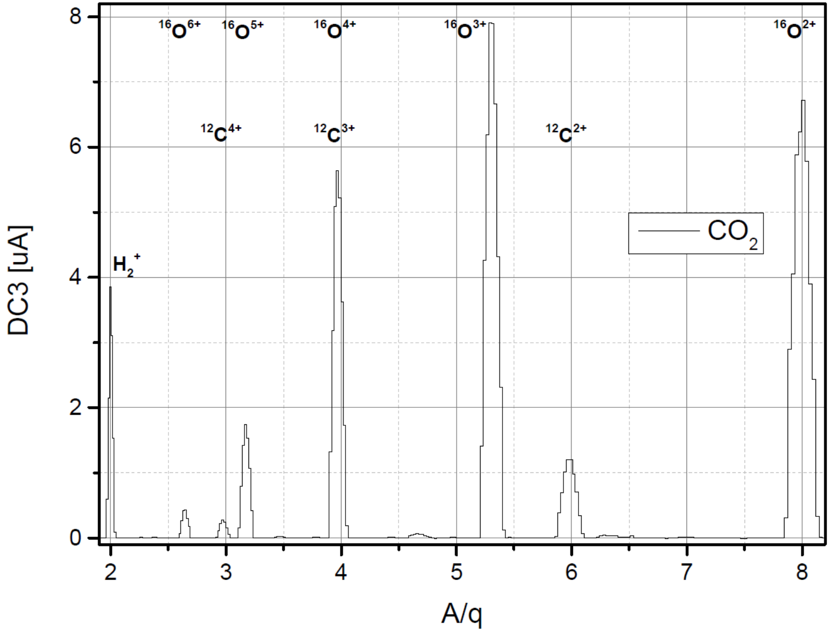
Ion Source Challenges

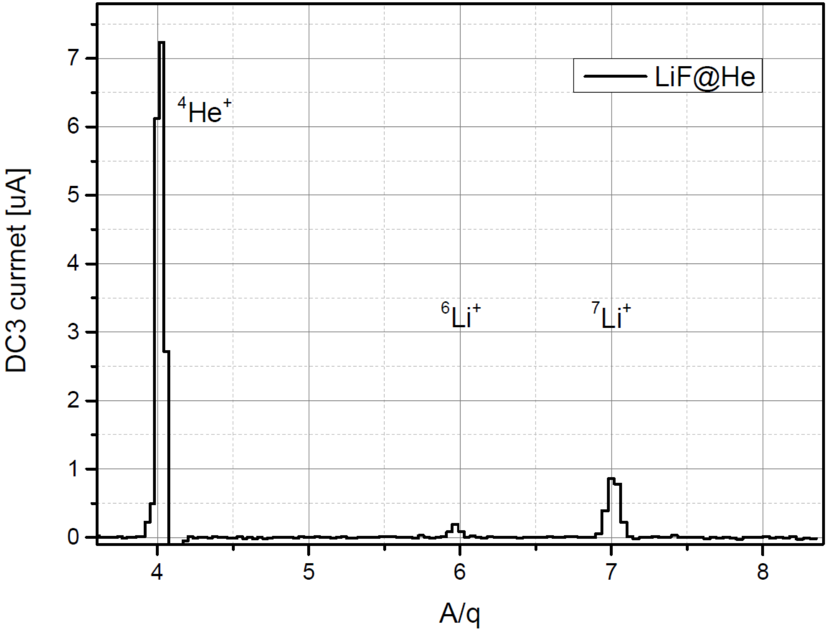
BEAM TIME RETREAT 2022

- Original purpose: commissioning using easy ions (H2+, D+)
  - Developed MINIS for operational stability, also included oven for Mg^+
- ECR Source (modified source from Uni Giessen, S. Schippers et al.)
  - more stable, less interventions, more intense beams
  - on loan from Uni. Gießen
  - old device (plasma chamber, magnet, MW generator)
  - eventually broken (plasma chamber, magnet, MW generator) and being rebuilt in the moment
- operational challenges
  - complex local injector including source, linac – same FTEs for all components
  - many short term changes due to failures and experiment requirements
- Aim: A reliable source for local beam investigations, commissioning and exp.

Ion Source – some Elements

- Li^+ – MINIS
- O^{6+} - ECR

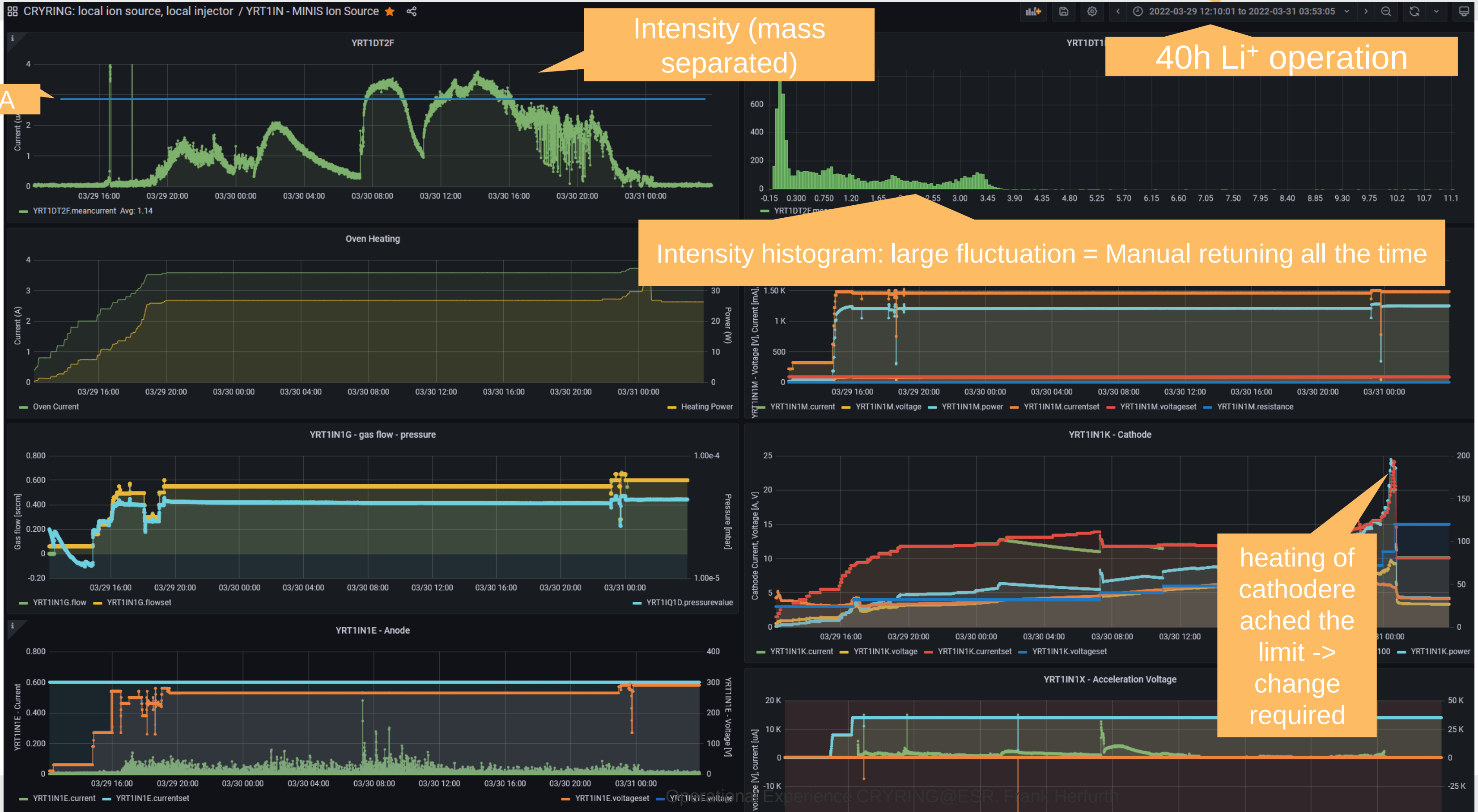




Gleb Vorobjev et al.

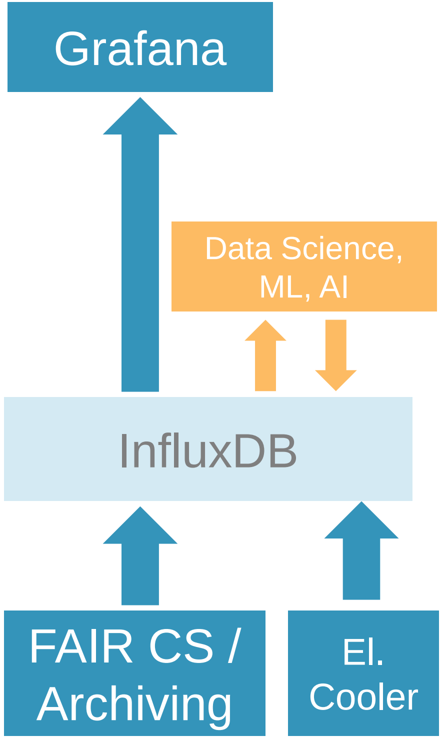
Spectra created with **`DeviceAutomator`**

Ion Source Monitoring – Operation for Li^+



Wolfgang Geithner et al.

Decelerators/YR Data-Logging and Visualization



- Since 2019, now with server hosted by central IT
- short-term and mid-term (hours-weeks) monitoring of data relevant for CRYRING & UNILAC Ion Source operation:
  - **Cryo system of electron cooler: LHe level, temperatures**
  - vacuum system, ion source, intensities (local, ESR, SIS relatable)
  - Precision measurements of electron cooler high voltage
- Disk space is sufficient for ½ year of CRYRING@ESR operation
- System maintenance & support by 1 Person from Decelerators team

Wolfgang Geithner et al.

- Organisational setup does not scale for whole GSI/FAIR
- InfluxDB open source version has limitations inacceptable for standard/GSI wide operation
- Non-standard / Non-CS compliant system

Pressure Monitoring

in this example: 24h period on May 2nd, 2022

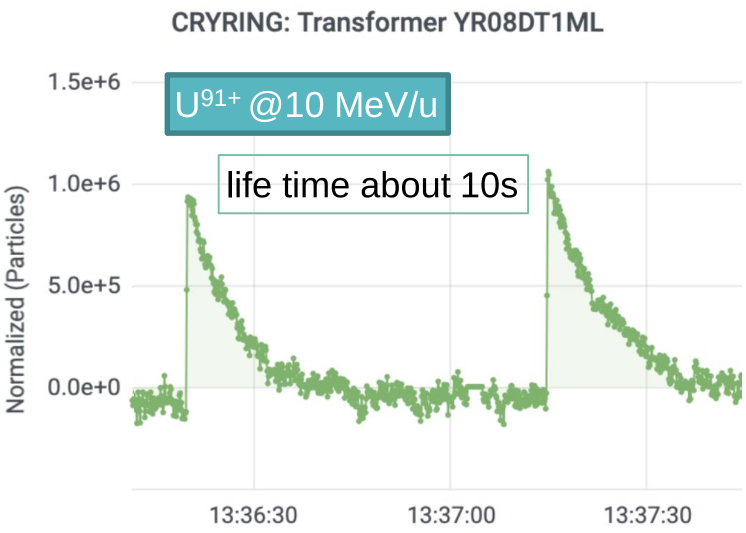
Average Pressure
using GRAFANA allows for simple combination of values (no programming, only configuration)

Vacuum Conditions

Main effort in 2020 went into sections 05 – 08:

- addition of new ion getter pumps
- NEG coating of some easily accessible parts

Next big improvement in the e-cooler section this shutdown (2022 – 2023)

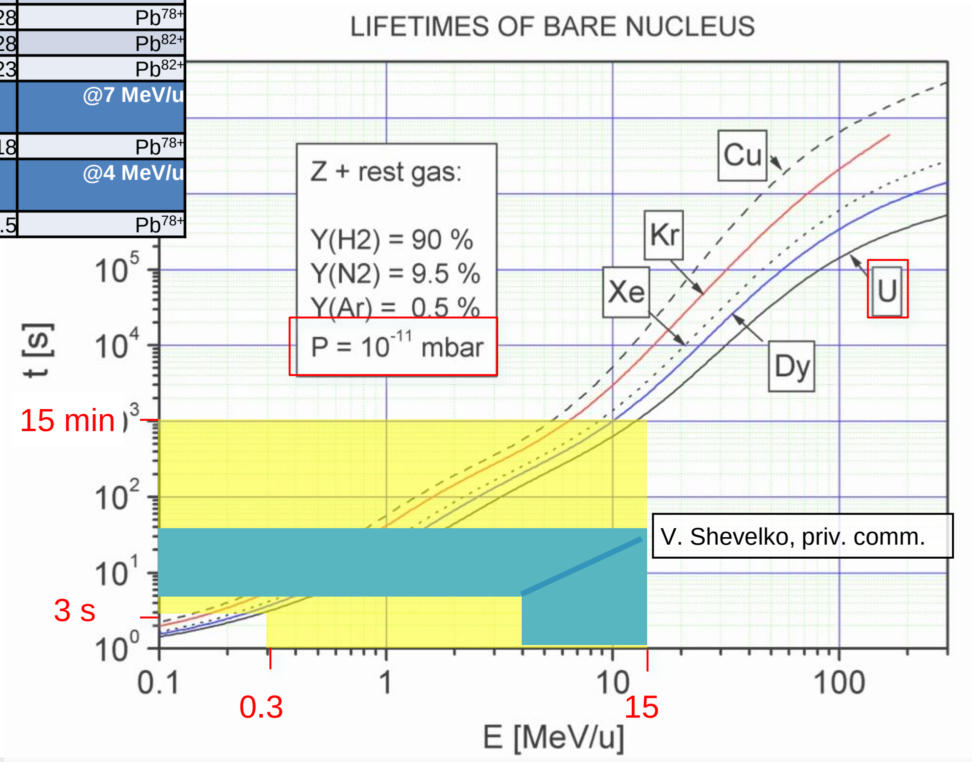


pretty good for first experiments
needs constant improvements for later experiments

Ultra High Vacuum & Beam Life Time

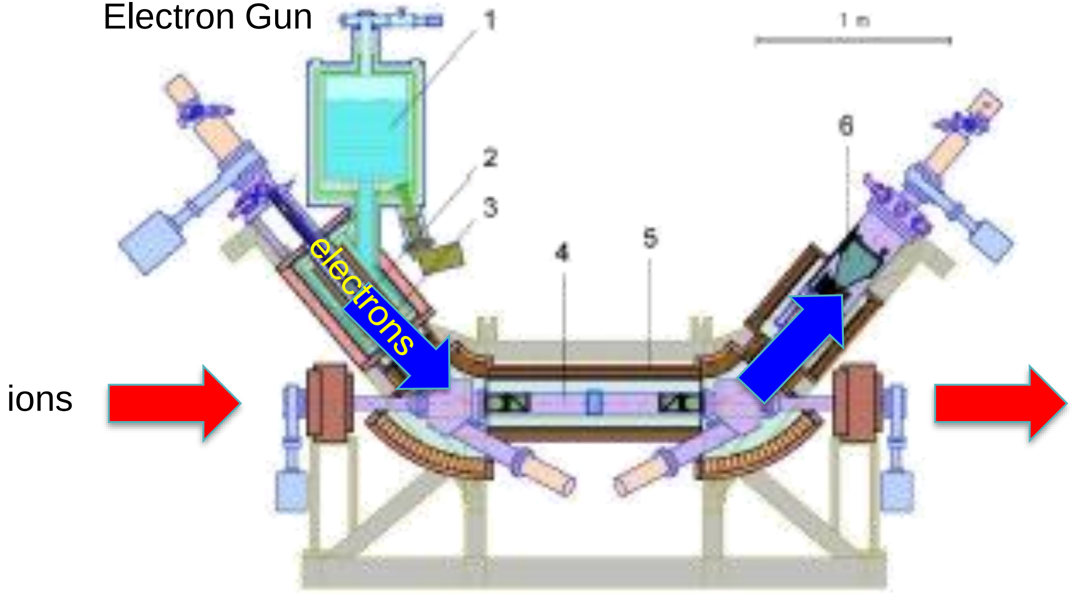
M. Lestinsky et al.

Electron Current	Lifetime Measured / s	Lifetime „beamcalc" / s	@10 MeV/u
12 mA	24(1)	33	Pb^{78+}
22 mA	8(1)	28	Pb^{78+}
12 mA	19(1)	28	Pb^{82+}
22 mA	12(1)	23	Pb^{82+}
			@7 MeV/u
12 mA	12(1)	18	Pb^{78+}
			@4 MeV/u
12 mA	5(1)	7.5	Pb^{78+}

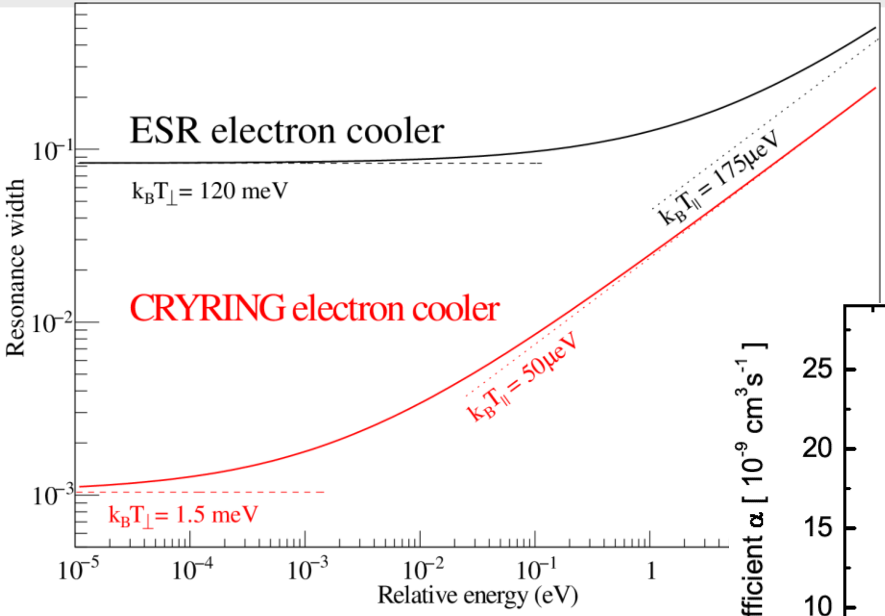


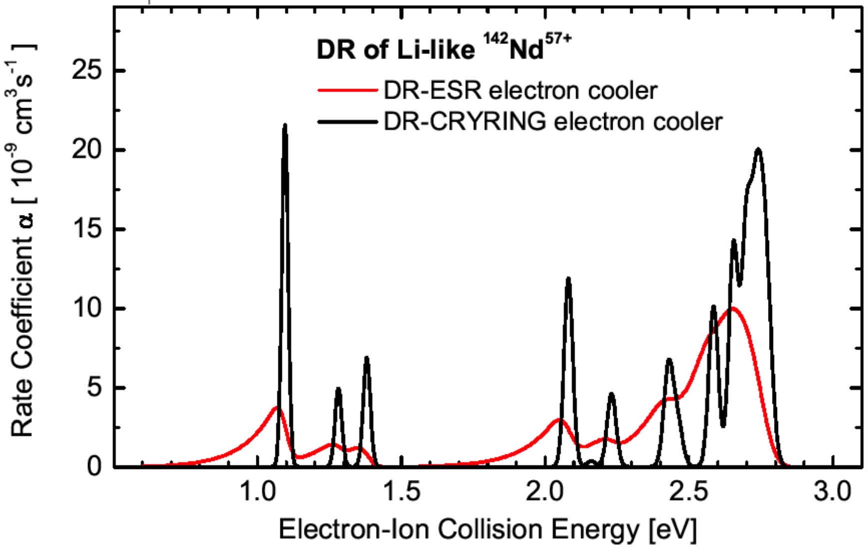
Electron Cooler

Superconducting magnet for Electron Gun



Electron Cooling ESR - CRYRING





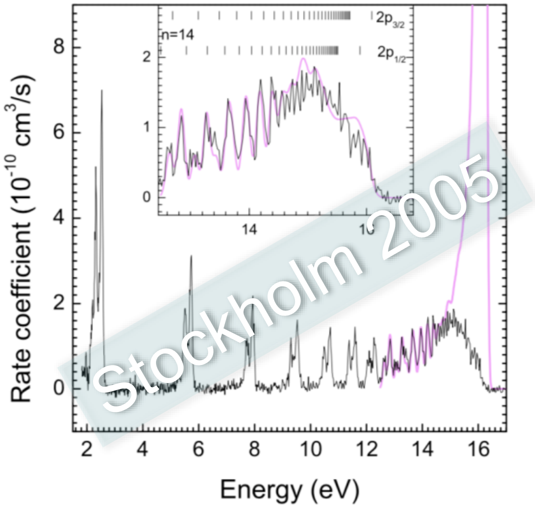
C. Brandau priv. comm.

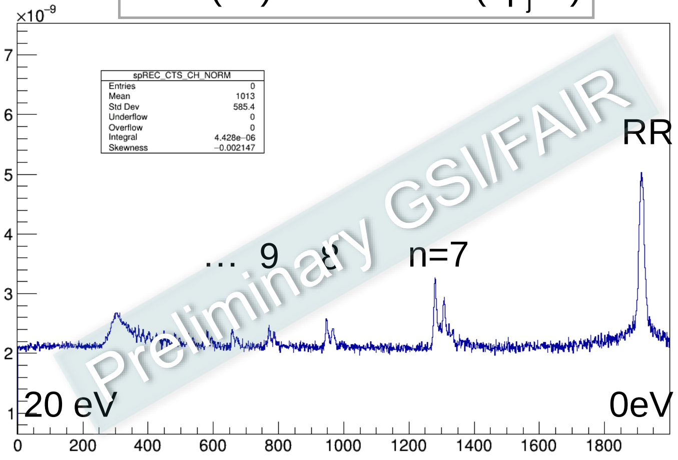
E-Cooler is now (2020) operational

- LHe filling procedure works now reliable
- EGun perveance close to design value
- EGun alignment done - Expansion up to 100 available

Dielectronic Recombination of Li-like Ne:

Ne^{7+} (2s) + e^- -> Ne^{6+} ($2p_j$ nl)





S. Böhm et al., Astronom. & Astrophys. 437 (2005) 1151

E. Menz, M. Lestinsky et al.

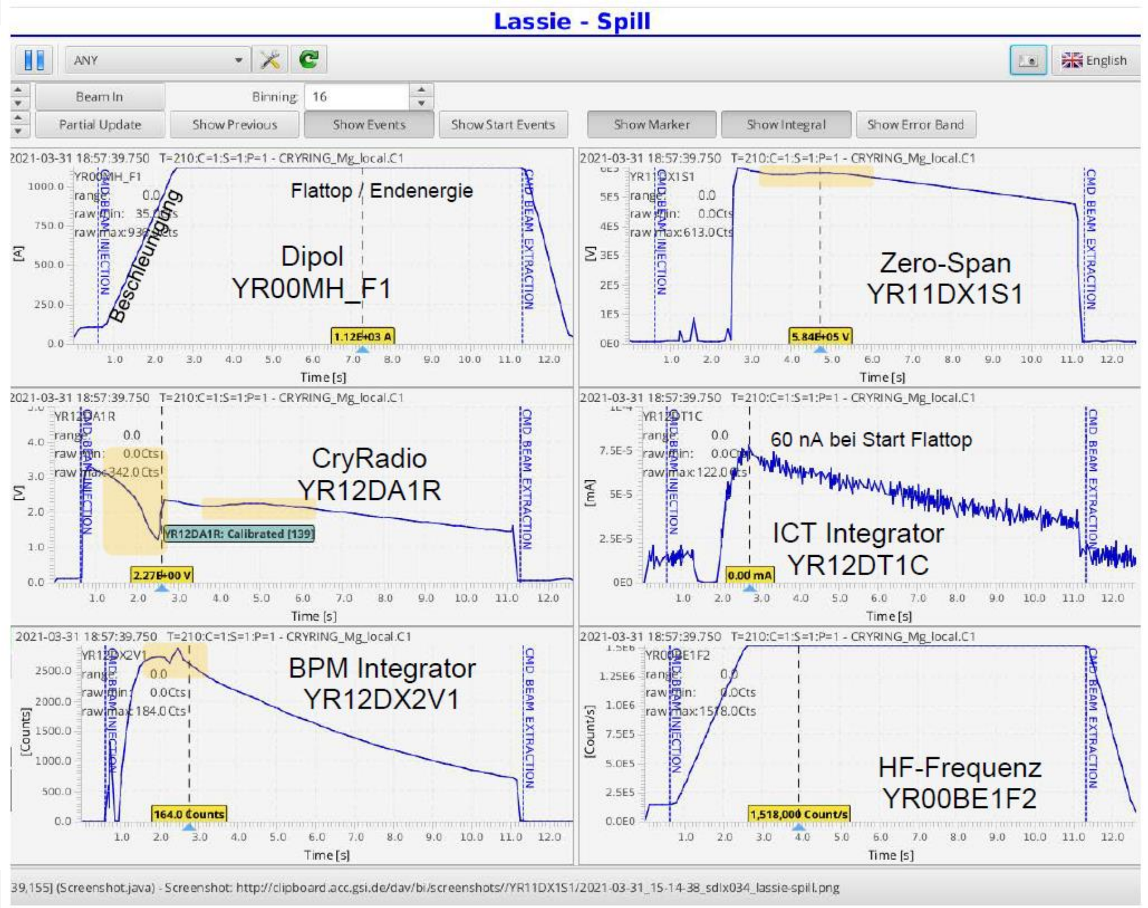
Beam Instrumentation

- intensity measurement
  - first turn, injection: Faraday cups
  - stored beam:
    - Integrating current transformer and parametric current transformer, *CCC* (absolute)
    - BPM sum rate, IPM count rate, intensity of Schottky noise (relative)
- position measurement
  - first turn: fluorescent screens
  - Beam position monitor (BPM) and Ionization profile monitor (IPM)
- “momentum” measurement
  - Schottky pickup, *Laser spectroscopy*

Andreas Reiter
ACC Seminar
April, 2022

“Beam Instrumentation at CRYRING@ESR“

Beam Instrumentation

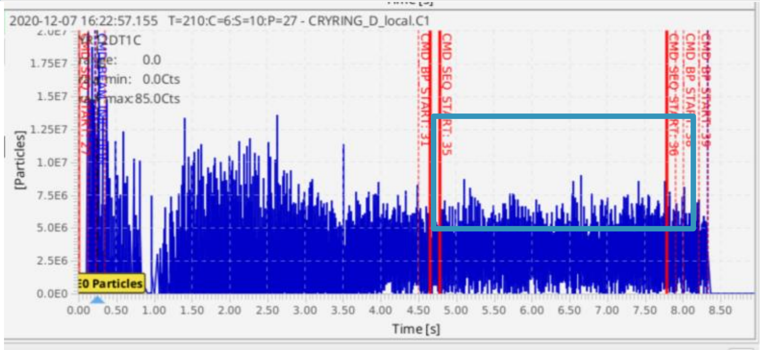


screenshot and labelling by Andreas Reiter,
„Strom- und Intensitätsmessung mit Scaler System", Sep. 2021

Detection limits

dedicated run in Dec 2020

investigated the lower limit for necessary intensity
Guinee pig D^+ @5 MeV/u ($1 \cdot 10^7$ particles = charges / μA)

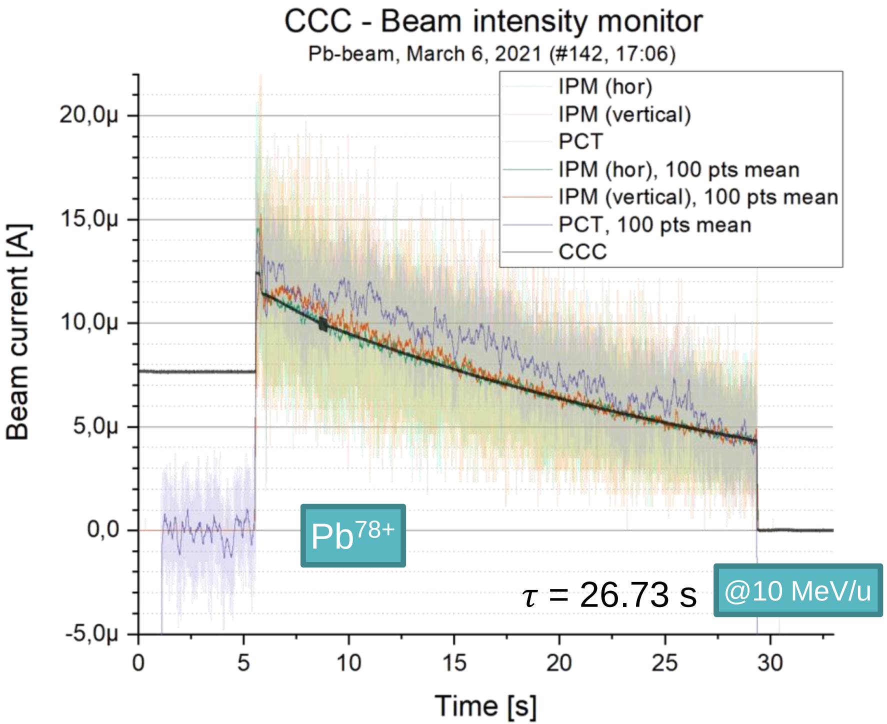


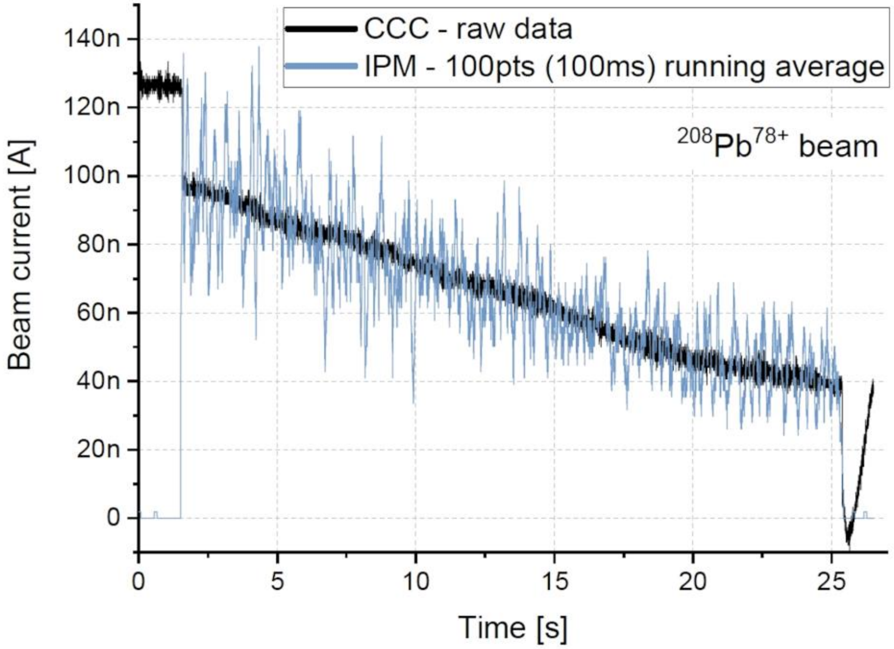
- for intensity measurement
  - with CCC: 5 nA ($5 \cdot 10^4 q$)
  - bunched beam (ICT, CRYRADIO): 20 nA ($2 \cdot 10^5 q$)
  - DC Trafo: 5 μA ($1 \cdot 10^7 q$)
- for ring setup
  - injection and cooling
    - IPM: 300 nA ($3 \cdot 10^6 q$)
    - Bunches on BPM, Schottky, Neutral Particle Counter: 150 nA ($1.5 \cdot 10^6 q$)

Conclusion: Need at least $1.5 \cdot 10^6$ charges **stored** to setup a cooled, accelerated beam

Info: typical transfer efficiency of mass separated beam from local source to ring: 20%

Detection limits – intensity : CCC



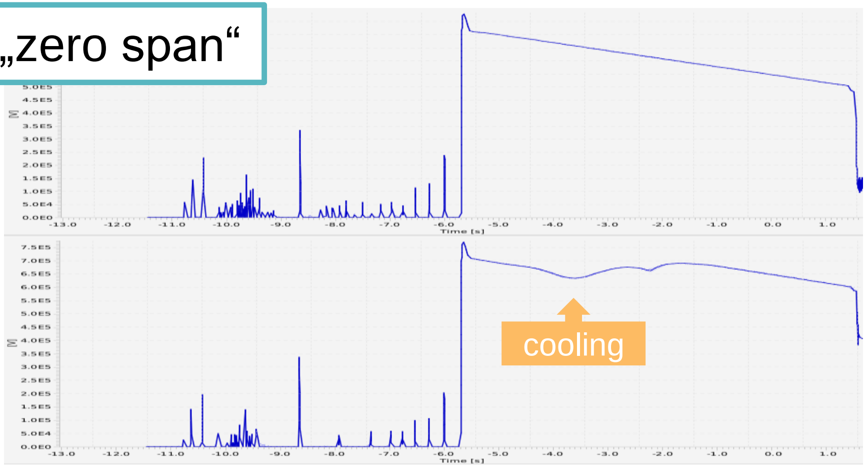


Cryogenic Current Comparator
installed, tested, removed ... to be continued

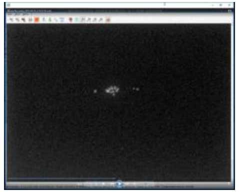
PhD David Haider, Thomas Sieber et al.

Detection limits - setting up cooling

„zero span“



„indirect“ tuning of cooling at low intensity/energy/charge, since IPM and costing beam Schottky not possible



neutral particle imaging (works only for 1+ ions)

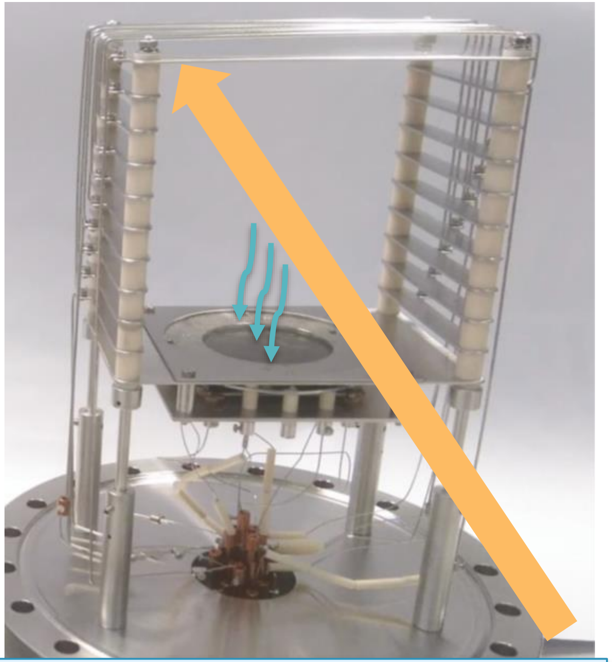
M. Lestinsky, E. Menz, et al.

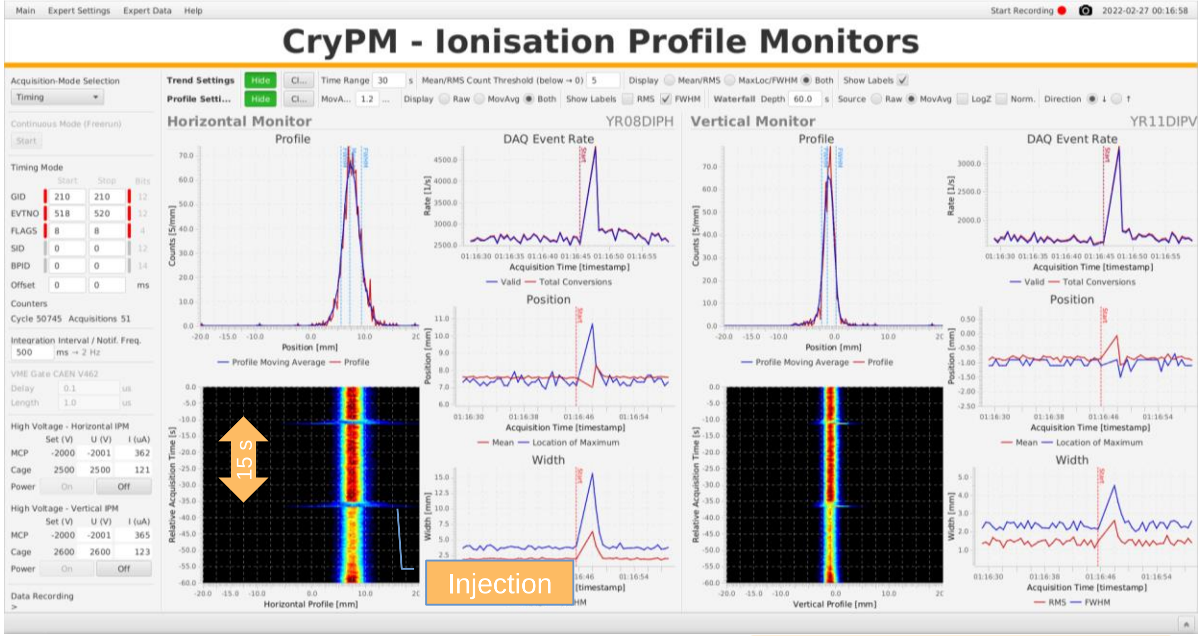
	LCI @ 100 keV/u	HCI @ 10 MeV/u
current	0.3 μA	3 μA
velocity β	2% c	14% c
ecool	100 V	5500 V
lifetime	10 sec	10 sec

BPM.	✗ ✓	✓
Schottky	✗ ✓	✓
AC Transf.	✓	✓
DC Transf.	✗	✓
IPM	✗	✓

overview by Zoran Andelkovic

IPM – Ionization Profile Monitor



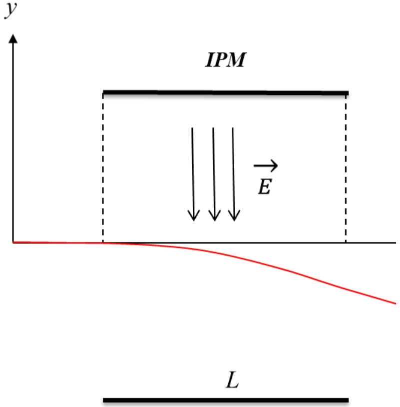


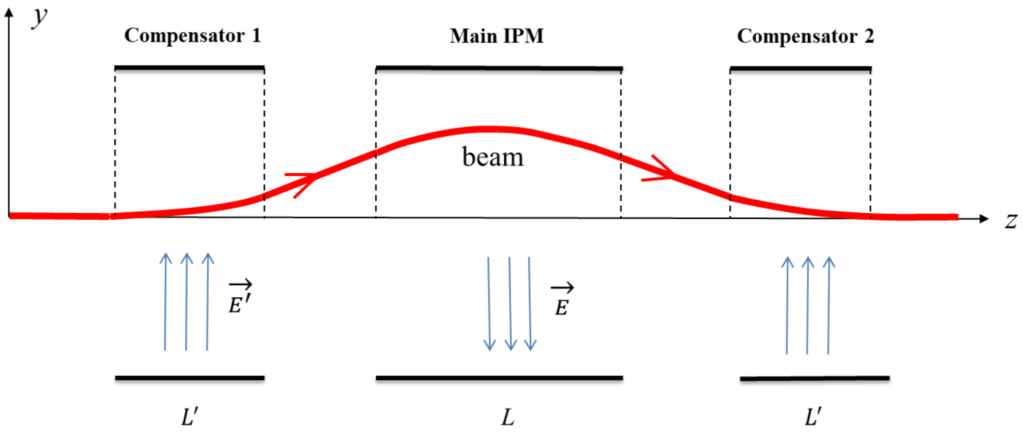
- 100 x 80 mm^2 field cage
- MCP stack with resistive anode
- VME peak sensing ADC
- lots of magic from our BEA colleagues

D$^+$ accelerated from **300 keV/u** to 1.5 MeV/u and cooled

Low Energy IPM

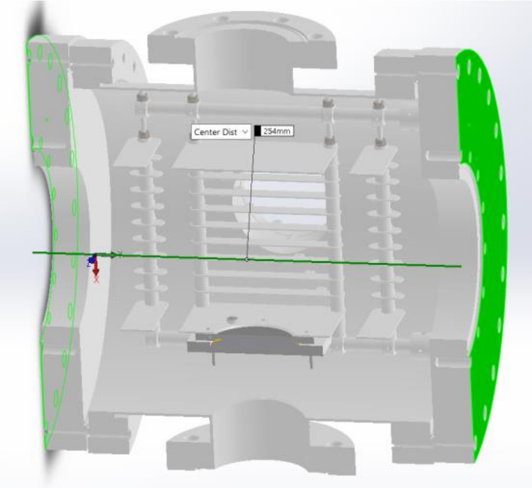
present IPM → low Energy IPM

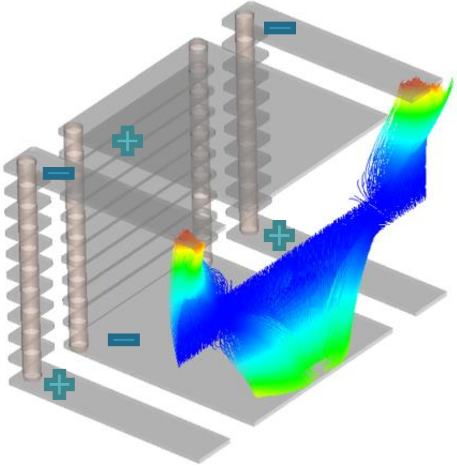


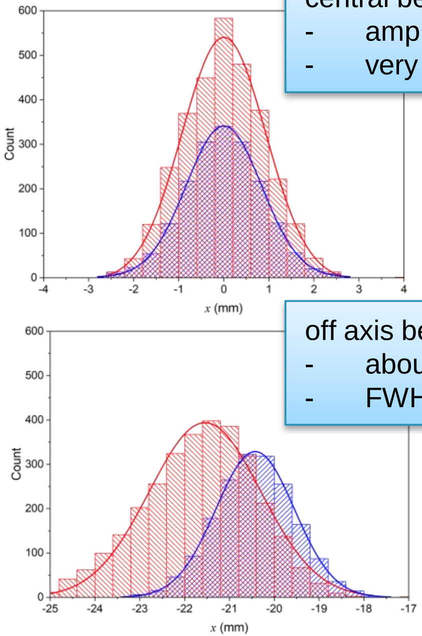


Low Energy IPM

- Design ready, Vacuum chamber and parts ordered, to be tested in May/June
  - drop in replacement for old one!
  - field distortion causes managable image distortion







central beam:
- amplification due to focussing
- very small increase of FWHM

off axis beam:
- about 10% error in position
- FWHM increased up to 150%

main electr. field only
correction field added

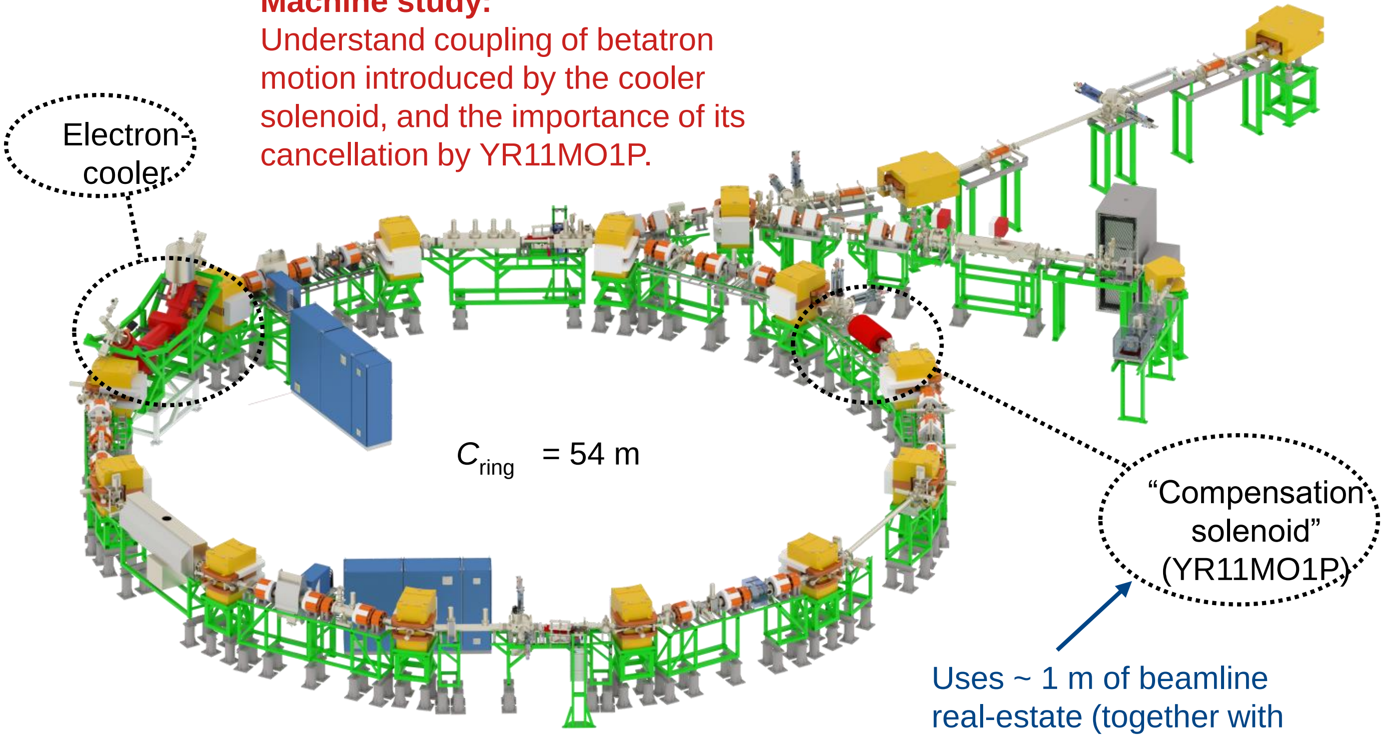
Bowen Zhou, Zoran Andelkovic, Rudi Hettinger, Nikita Kotovsky, Andreas Reiter et al.

Operational Experience CRYRING@ESR

- (a short) history (of a low energy storage ring)
- Operation : how does it look like?
  - typical pattern, general approach
  - beams in CRYRING@ESR: local and via HEST from ESR
  - (local) archiving and monitoring
  - beam life time and vacuum
  - electron cooling
- Beam instrumentation (low energy, low charge, low intensity)
- **Machine Studies**
  - **Do we need a compensation solenoid?**
  - **Chromaticity (correction) and tune diagram**
  - **Multiturninjection, Fast and synchronized (B2B)**
  - **fast extraction**
- Experiments, Outlook

Motivation

Machine study:
Understand coupling of betatron motion introduced by the cooler solenoid, and the importance of its cancellation by YR11MO1P.



Uses ~ 1 m of beamline real-estate (together with Schottky electrodes)

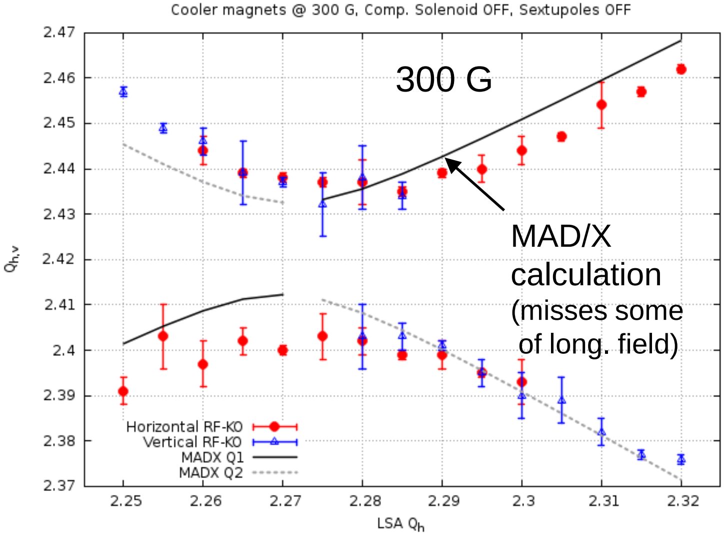
Claude Krantz – CRYRING@ESR Users Meeting

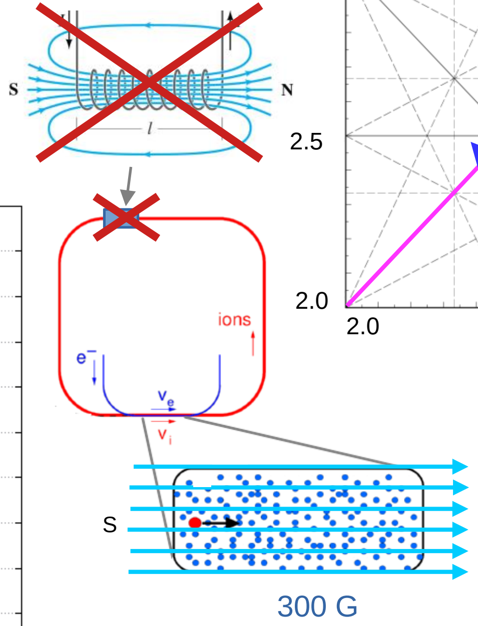
Betatron coupling

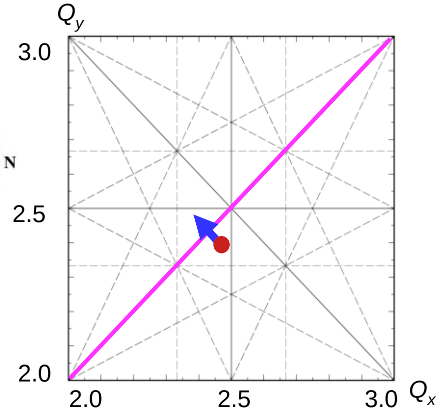
Cooler solenoid @ **300 G**
(*but no electron cooling*)

+

compensation solenoid disabled.







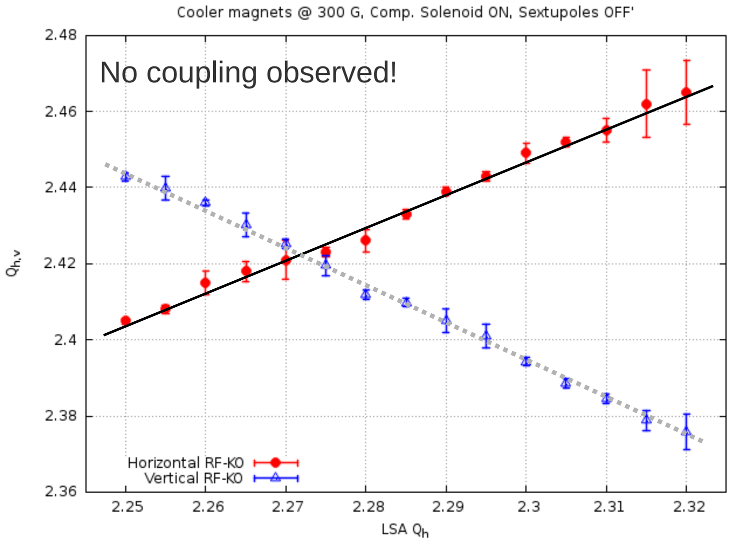
Claude Krantz – CRYRING@ ESR Users Meeting

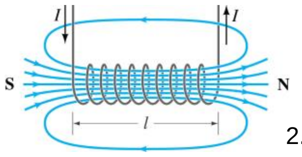
Betatron coupling

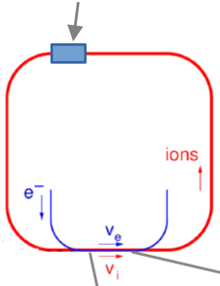
Cooler solenoid @ 300 G
(*but no electron cooling*)

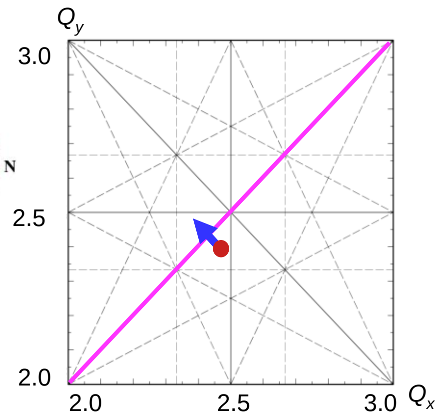
+

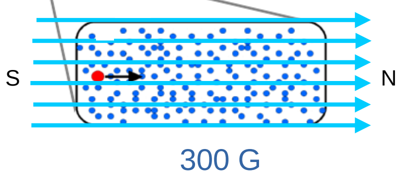
compensation solenoid enabled.







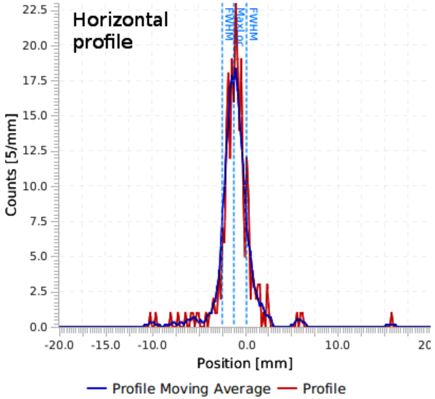


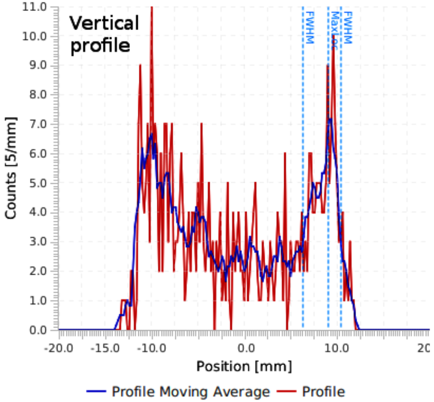


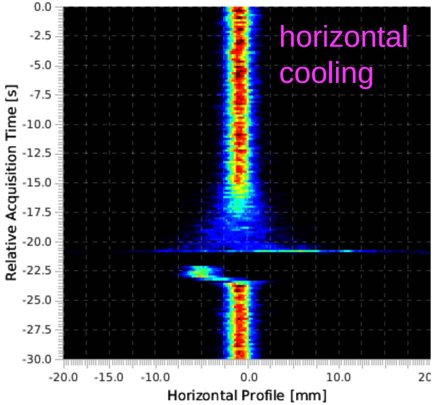
→ Compensation seems near-perfect!

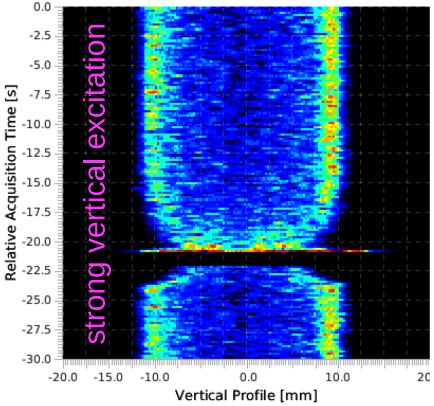
Claude Krantz – CRYRING@ESR Users Meeting

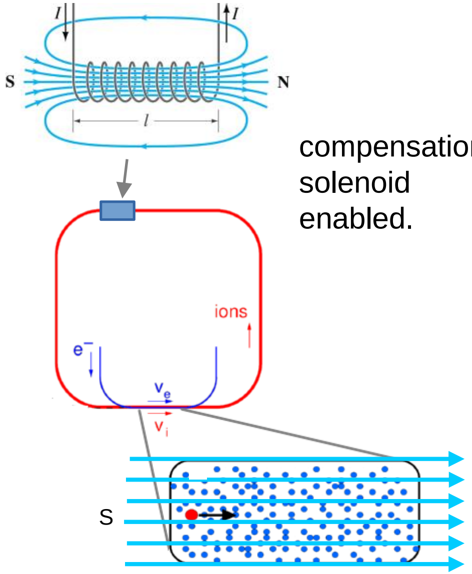
Electron cooling





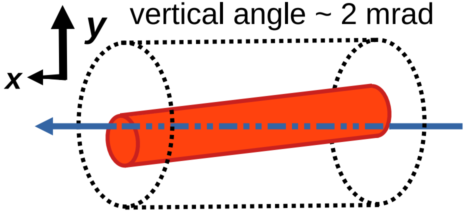






compensation solenoid enabled.

vertical angle ~ 2 mrad



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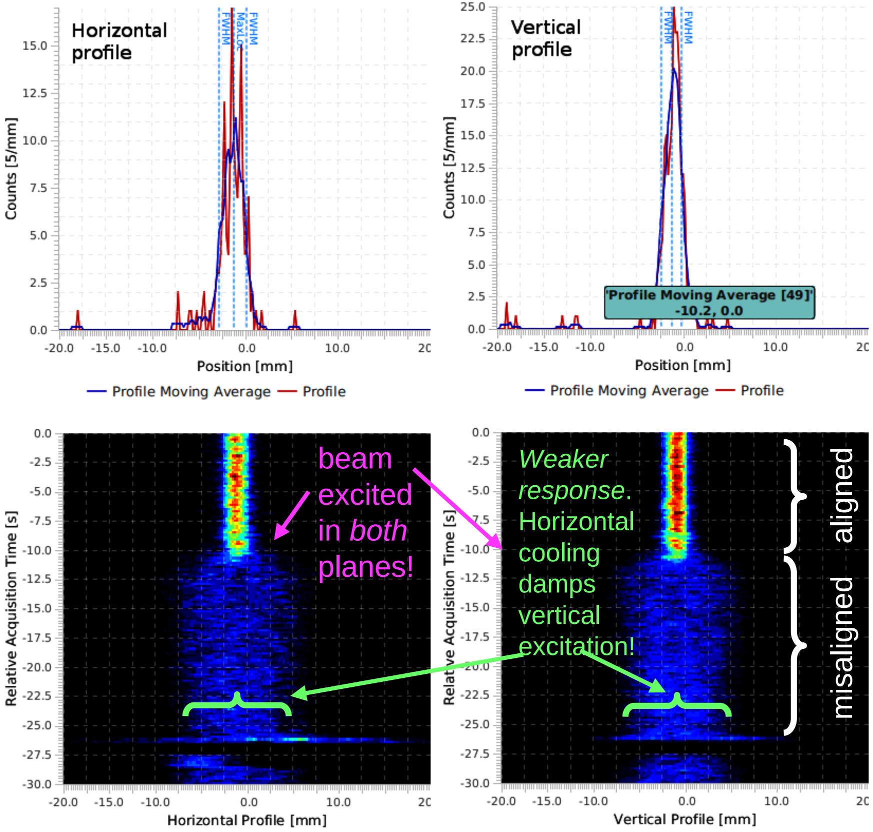
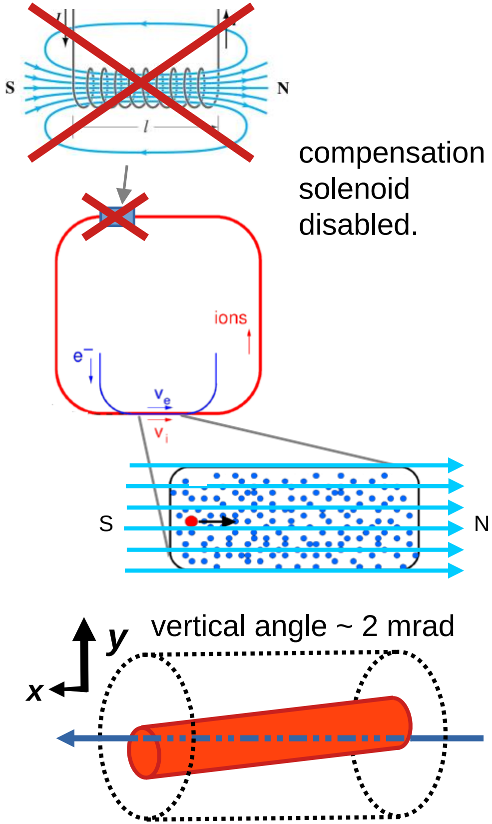
Electron cooling





compensation solenoid disabled.

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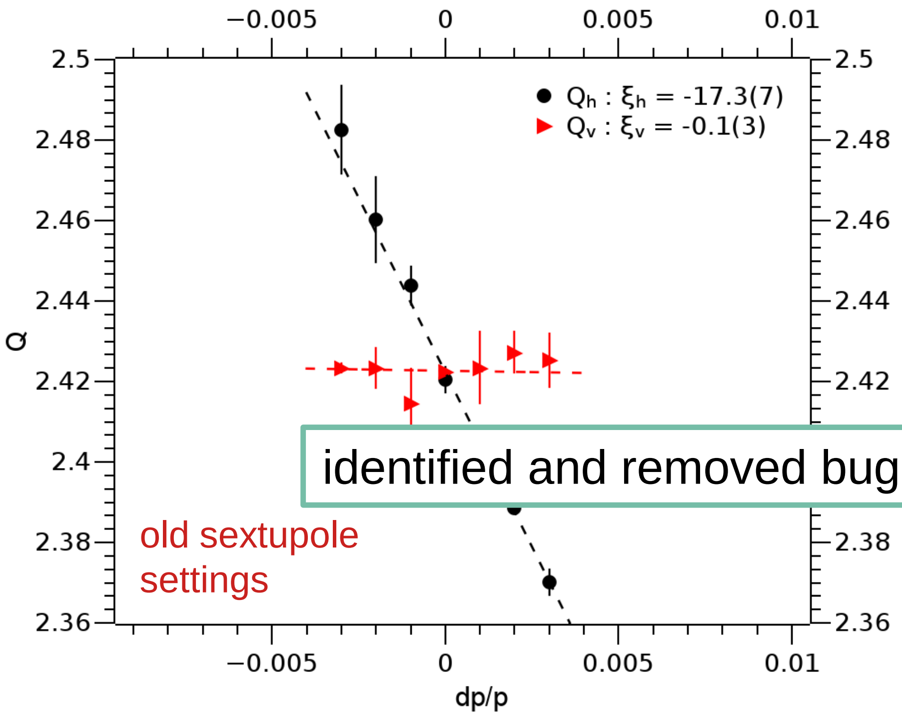
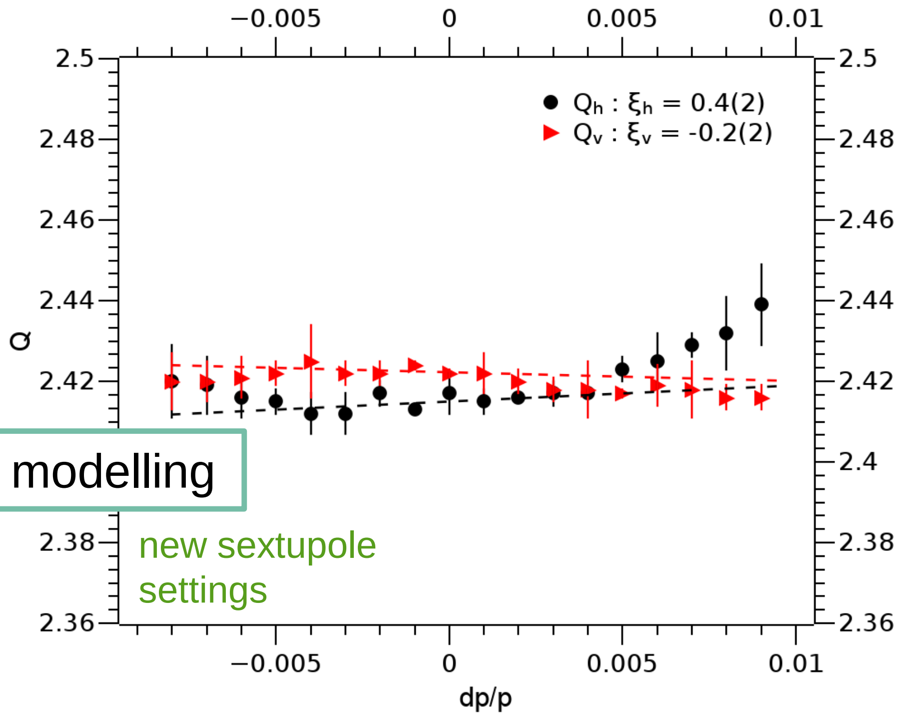
Sextupole settings to correct Chromaticity

$$\xi = \frac{dQ}{d(\delta p/p)}$$

- improved correction = larger accessible range = more robust acceleration

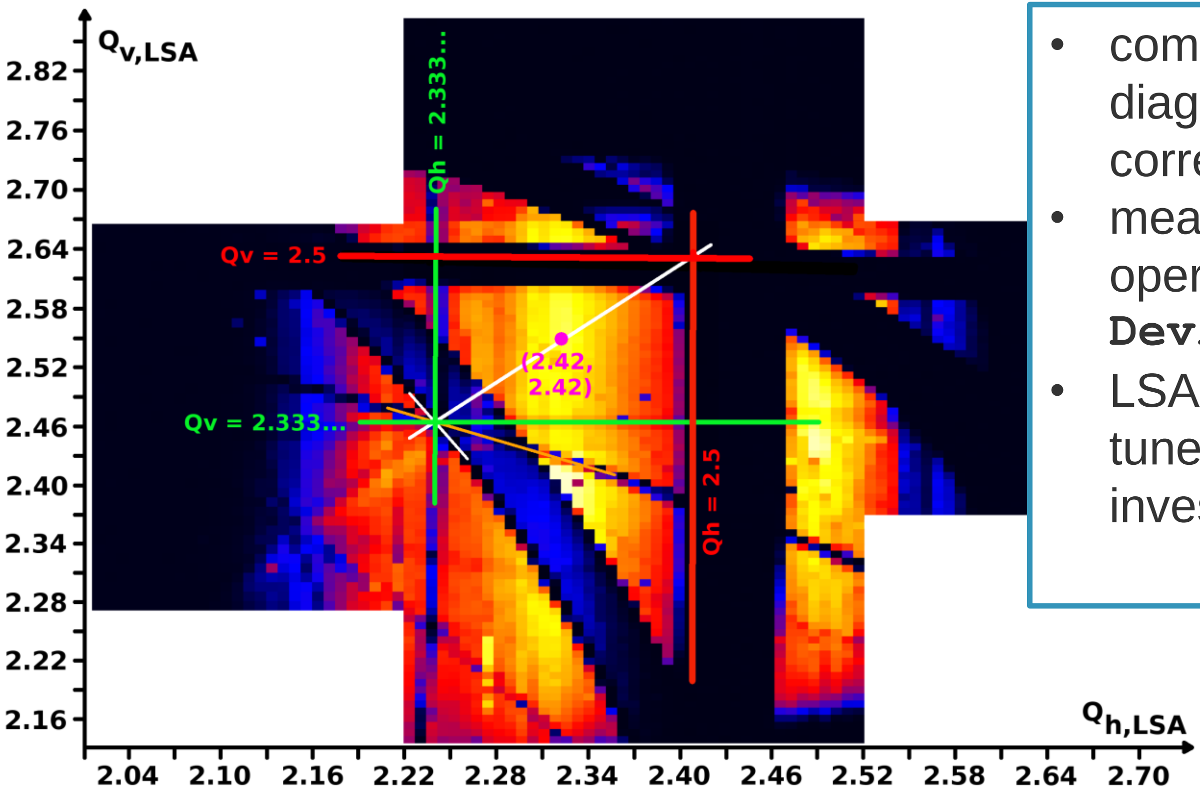


identified and removed bug in modelling



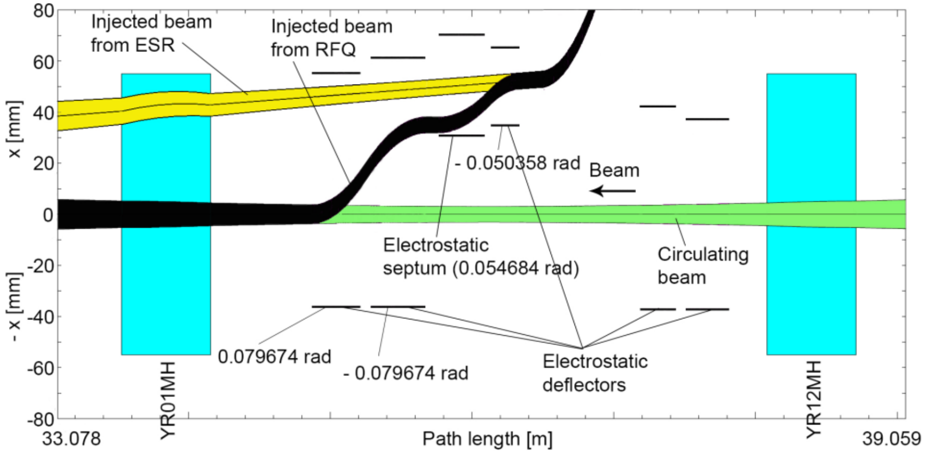
C. Krantz, R. Hess, I. Kraus et al.

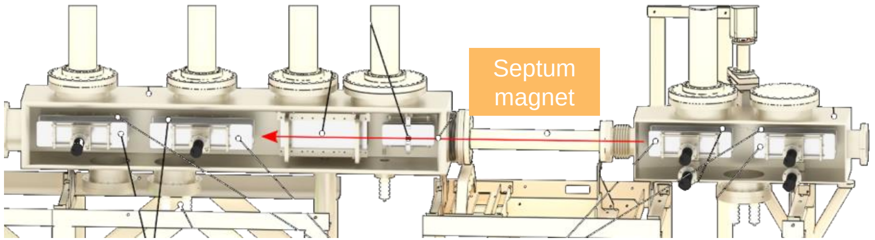
Tune Diagram

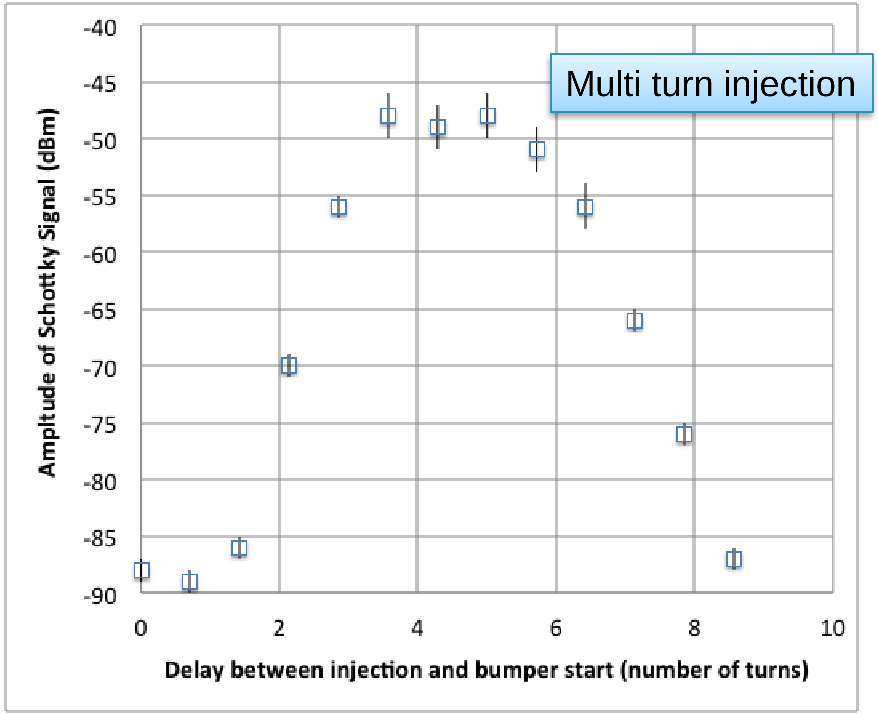


- complete stability diagram (tune diagram) incl. proper chrom. correction
- measured during nights (no operator intervention) using **`DeviceAutomator`**
- LSA/Model vs. Reality offset of tunes observed before, investigation ongoing

Injection – Multiturn from local injector, Fast from ESR





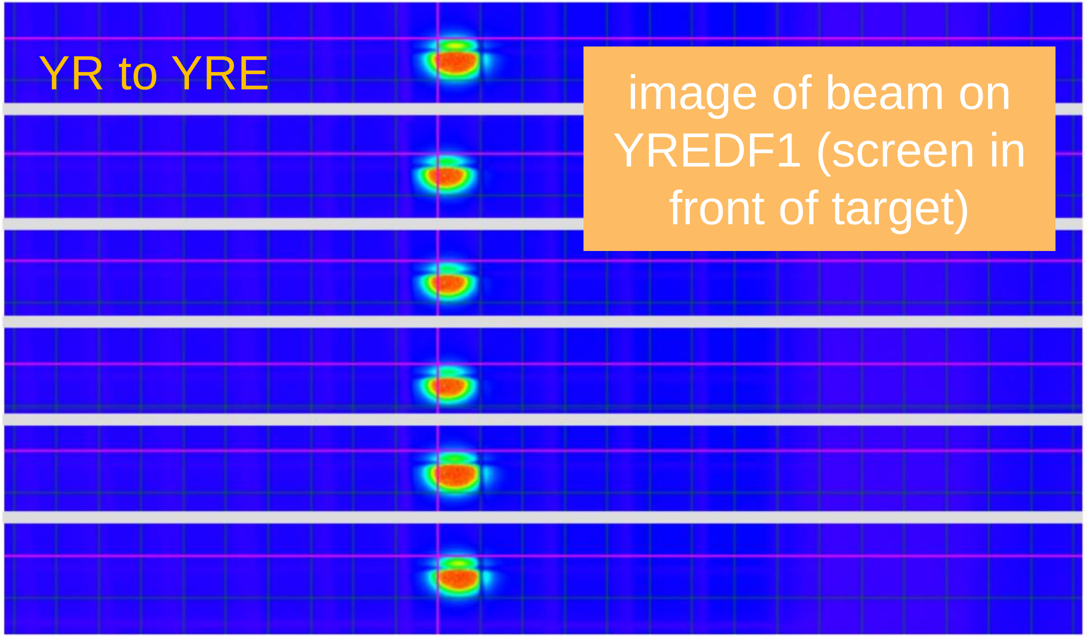


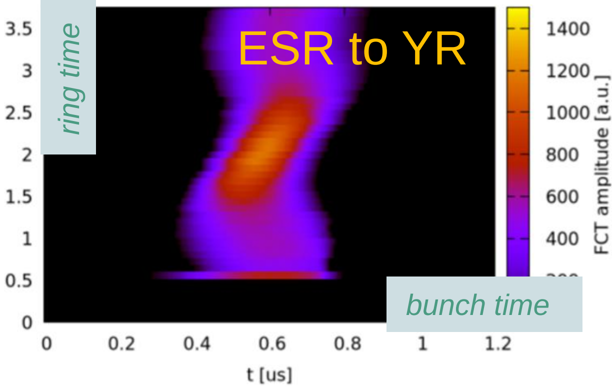
Design by MSL, calc.+figure Oleksii Gorda

Svetlana Feodotva, Nikita Kotovsky, et al.

Bunch-to-Bucket and RF synchronisation

below: images of six consecutive extractions – the beam is always well centered





- tested in parallel and for the running CMAT exp.
- extraction in sync with ring RF = reproducible position in kicker field = stable position on target

D. Beck et al. – Bunch to Bucket System

A common effort!

External Partners
HIJ Jena
Stockholm University
Krakow University
KVI Groningen

CRYRING@ESR

SPARC
APPA
collaboration

Atomic Physics
- Decelerator Experiments
- SPARC Det.

Accelerator Operations
- Decelerators

BMBF (Ministry)
„Verbundforschung“

GSI/FAIR Expert Groups
Construction
Facility Engineering
Mechanical Design/Integration
Ion Sources
System Design
UNILAC RF
Accelerator Physics
Ring RF
Magnets
Vacuum
Power Suppl.
Beam Diagns.
Controls
Assembly
Beam Cooling

Z. Andelkovic, N. Bauer, A. Bräuning-Demian, R. Bär, H. Danared, C. Dimopoulou, O. Dolinskyy, W. Enders, M. Engström, S. Fedotova, B. Franzke, M. Frey, W. Geithner, O. Gorda, L. Heyl, P. Hülsmann, A. Källberg, Th. Köhler, N. Kotovskiy, M. Lestinsky, S. Litvinov, Y. Litvinov, J. Mohr, I. Pschorn, A. Reiter, G. Riefert, J. Roßbach, A. Simonsson, T. Sieber, J. Sjöholm, M. Steck, Th. Stöhlker, G. Vorobjev, N. Winckler, ... and many more.
THANK YOU!!

Part of “FAIR Phase-0” experimental program

- GPAC’22 Proposals for local and ESR beams

	GPAC call 2022: CRYRING@ESR proposal overview				
Proposal ID	Announced title	Spokesperson	Intitute	Country	Beam
G-22-00070	Dielectronic and trielectronic recombinati	Biela-Nowaczyk, Weronika	U Krakow	PL	S12+
G-22-00072	Commissioning and First Storage Ring Exp	Brandau, Carsten	GSI	DE	Xe54+
G-22-00026	Investigating the destruction of deuteriun	Bruno, Carlo	U Edinburgh	UK	p+
G-22-00086	Ultra-high resolution study of the 15O(α,	Bruno, Carlo	U Edinburgh	UK	16O, 15O
G-22-00087	Astrophysical nuclear reactions between l	Bruno, Carlo	U Edinburgh	UK	6Li
G-22-00029	X-ray spectroscopy of slow Xe54+ + Xe co	Hillenbrand, Pierre-Michel	U Giessen	DE	Xe54+
G-22-00047	Absolute rate coefficients from dielectron	Lestinsky, Michael	GSI	DE	S3+, Ne3+
G-22-00152	Systematic measurement of electron capt	Petridis, Nikolaos	GSI	DE	Xe54+, U9x+
G-22-00159	Fast Ion – Slow Ion Collisions for Atomic F	Prigent, C.; Lamour, Emily	INSP Paris	FR	Ar18+
G-22-00058	Ion beam and level population dynamics i	Sanchez, Rodolfo	GSI	DE	Mg+
G-22-00025	High-resolution electron-ion collision spe	Schippers, Stefan	U Giessen	DE	U88+ (Xe50+)
G-22-00037	Atomic processes in the wake of neutron-	Schippers, Stefan	U Giessen	DE	W14-17+
G-22-00134	High-Resolution Spectroscopy of X-Ray Tr	Weber, Günter	HIJ	DE	U90+

+ MAT-PAC Experiments

Coordinator CRYRING@ESR Experiments: M. Lestinsky

Summary

- **CRYRING@ESR routinely provides user beam time**
- All systems work well, however, aging components require(d) some action
- Control system developed since 2015 into a mature system
- vacuum conditions still improving
- challenging experiments ahead (complexity of installation, intensity)

CRYRING@ESR oportunities

	Project	Benefits	Downsides
1	Linac RF	• Expand m/q to 4..5 – more ion species from local source accessible	
2	E-Cooler magnet replacement	• Much more reliable operation • adopted design to gained knowledge	• expensive, needs long lead time
3a	new Ion Source	• Higher charge states in stand alone mode	• possible only with external funding (ELEMENTS)
3b	Ring-RF	• Less losses (50%) due to speedier acceleration or deceleration	• needed for few cases only (C$^+$, HCI deceleration)

Thank you for your attention