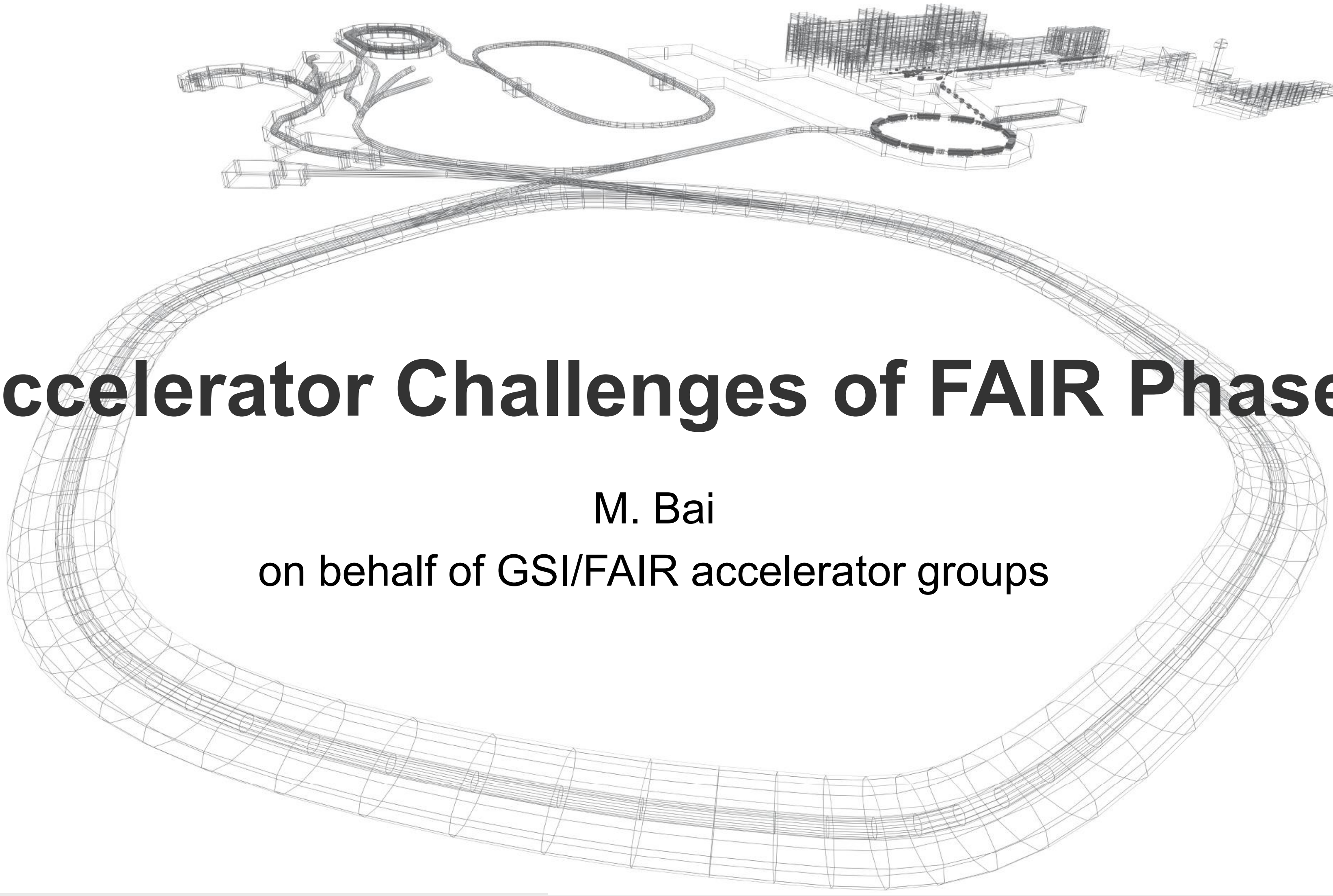


Accelerator Challenges of FAIR Phase 0

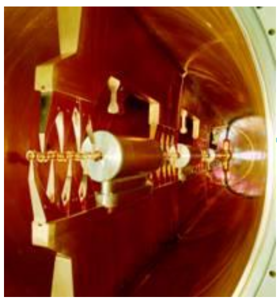
M. Bai
on behalf of GSI/FAIR accelerator groups

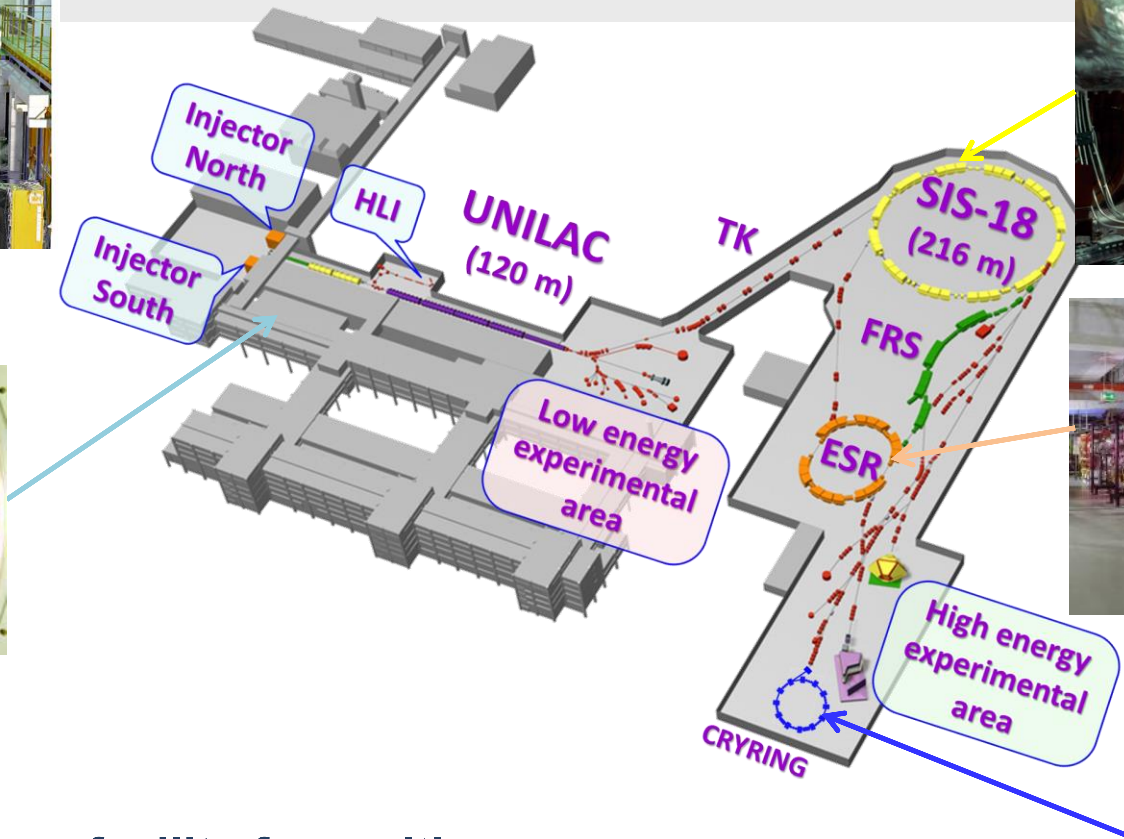
Outline

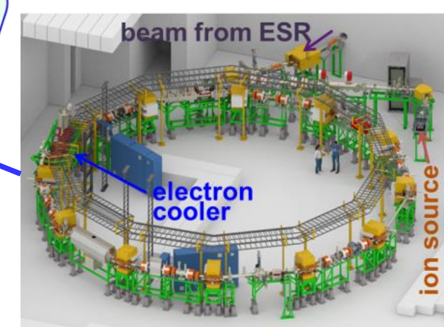
- Brief Introduction of GSI/FAIR accelerator facilities
  - core competences and uniqueness
- Charges and challenges of FAIR Phase 0
  - What is FAIR Phase 0?
  - Status and challenges
    - Beam time 2018 preparation
- Towards FAIR

GSI/FAIR Accelerator Facilities

Ion sources



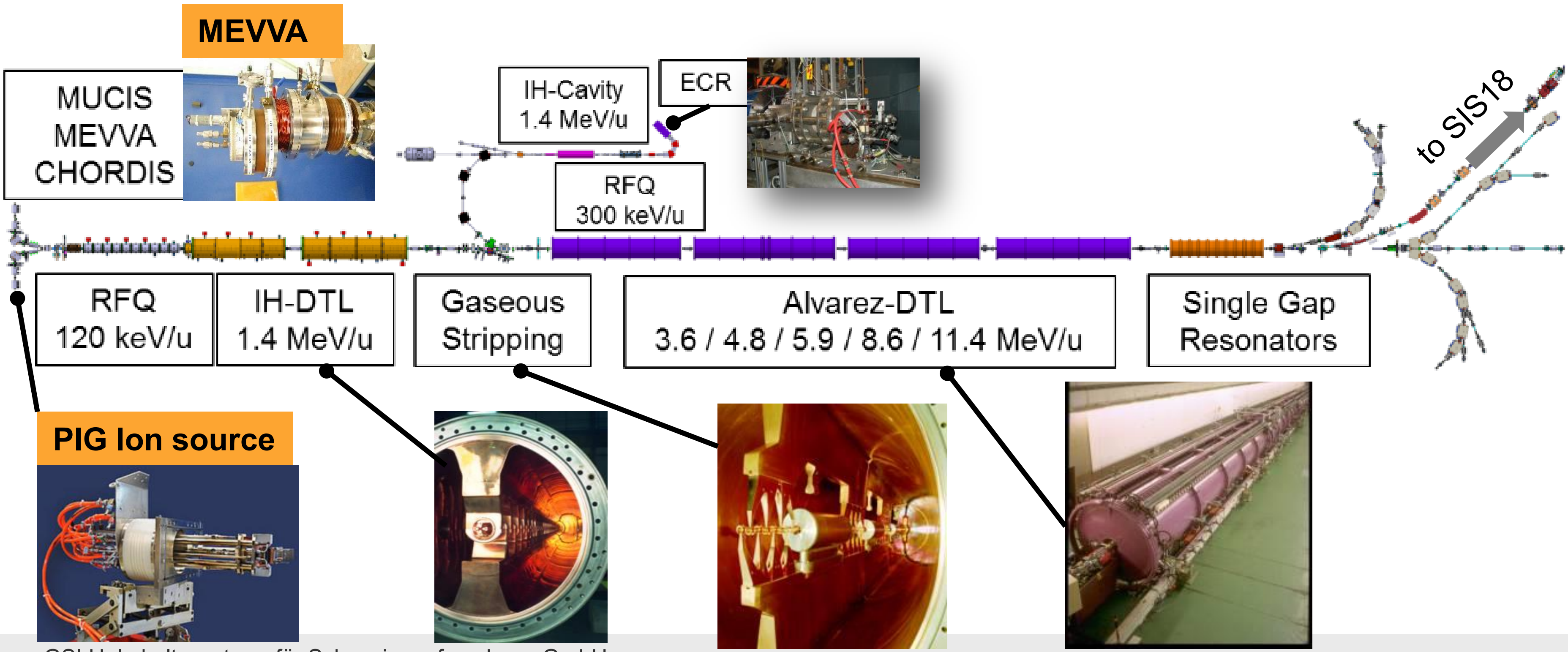




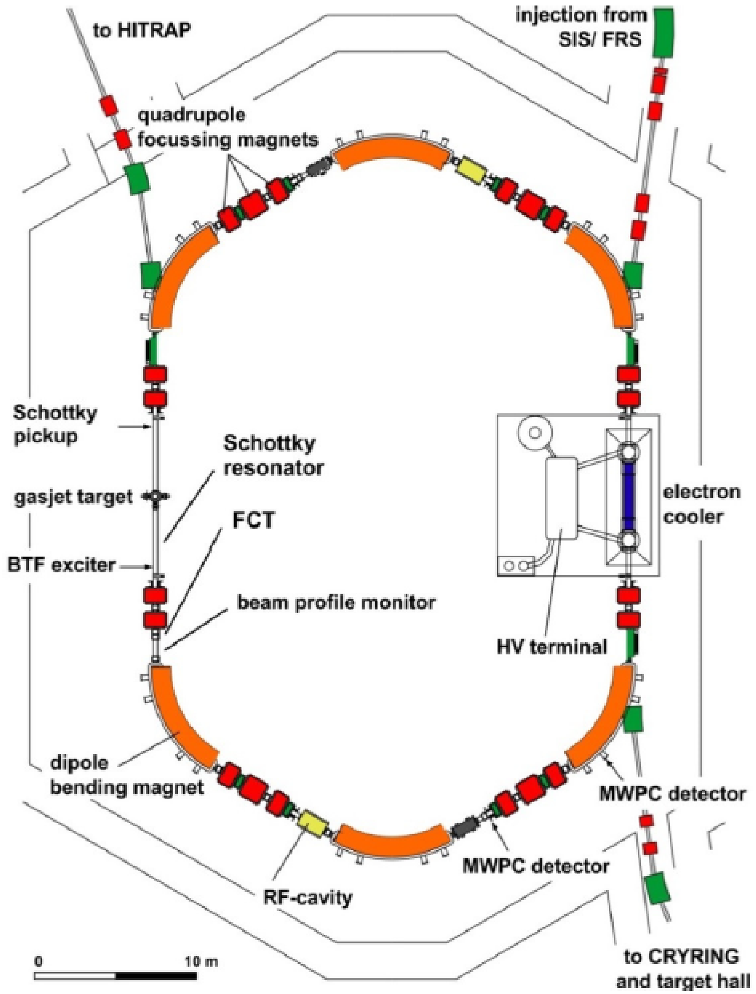
- Unique hadron facility for multi users
  - both dedicated operation as well as parallel operation mode
  - variety of operation modes, relative short transition in between
- Ultra high vacuum technique to reach highest intensity uranium beam!
- Comprehensive beam cooling to enable precision experiments at storage rings

UNILAC Overview

- High current ion sources and ECRIS for high charge state
  - ions: 14N, 16O, 18O, 50Ti, 40Ar, 48Ca, 107Ag, 124Xe, 208Pb, 238U
  - p+ and 12C from molecular beams (isobutane)
- High intensity and bright uranium beams!



Experimental Storage Ring for Heavy Ions



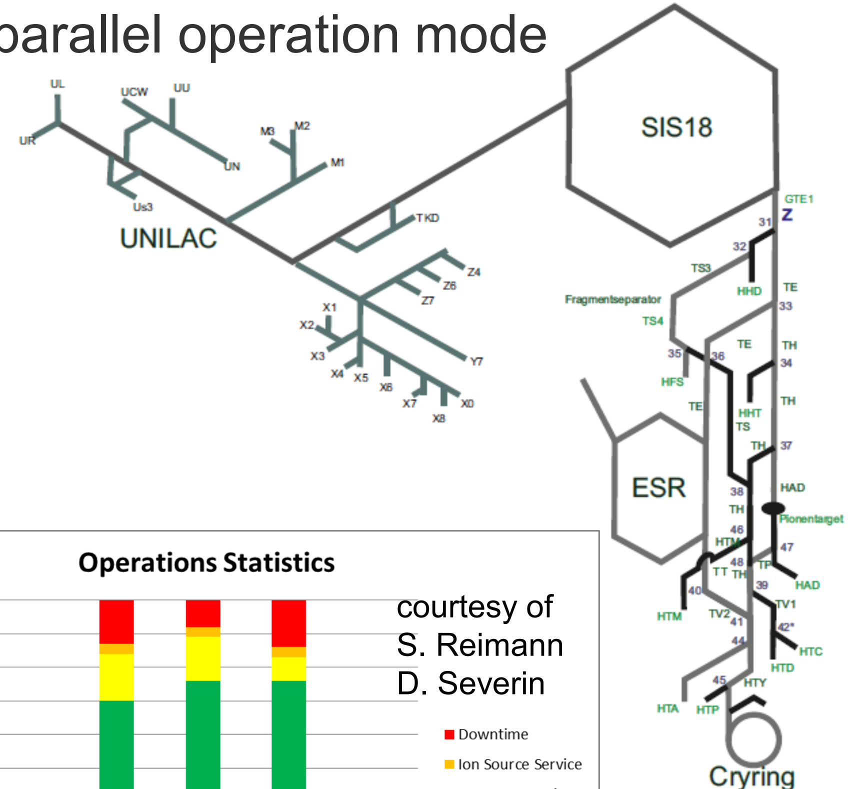
- Fast injection (stable ions / RIBs)
- Stochastic cooling (≥ 400 MeV/u)
- Electron cooling (3 - 430 MeV/u)
- Laser cooling (C^{3+} 120 MeV/u)
- Internal gas jet target
- Deceleration (down to 3 MeV/u)
- Fast extraction (HITRAP/CRYRING)
- Slow (resonant) extraction
- Ultraslow extraction (charge change)
- Beam accumulation
- Multi charge state operation
- Schottky mass spectrometry of RIBs
- Isochronous mode (TOF detector)

⇒ no standard cycle

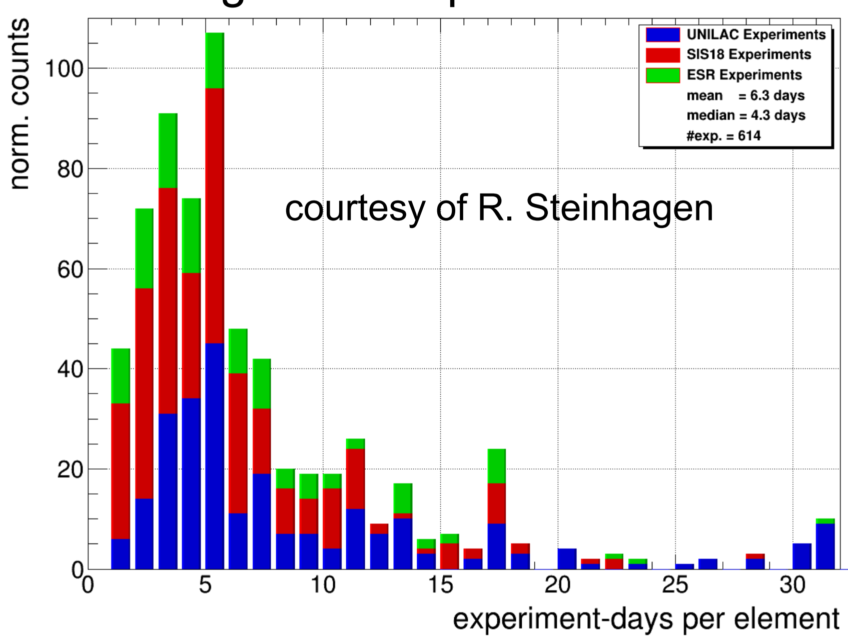
M. Steck, "ESR Re-commissioning and Operations", GSI beam time retreat 2018

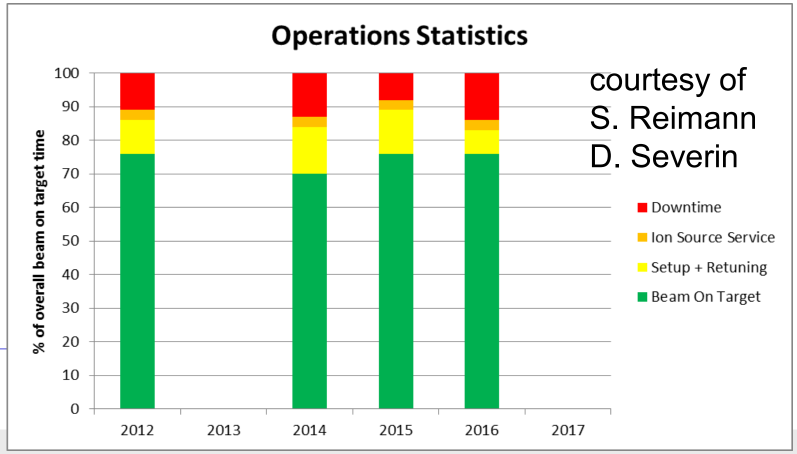
GSI Facilities uniqueness

- Versatileness and flexibilities
  - unique hadron facility for multi users
  - both dedicated operation as well as parallel operation mode
    - variety of operation modes
    - relative short transition in between



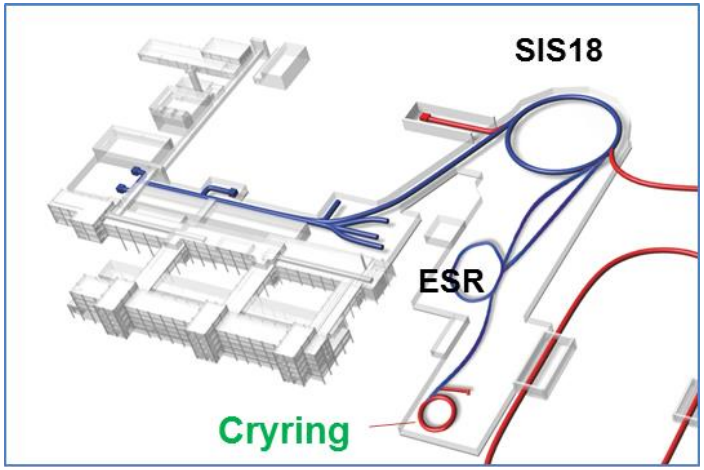
Histogram of experiment durations





FAIR Phase 0

- Goals
  - Limited research program employing and testing new FAIR detectors
  - Exploiting upgraded GSI accelerator facilities
    - upgraded SIS18
    - CRYRING
  - Education of young scientists
  - Maintain and extend skills and expertise
  - Serve and grow national and international user community
  - Essential step for the commissioning of the FAIR experiments => risk reduction



- Program strongly recommended by the "Heuer Report"
- Validated by the JSC in 2016 and presented to both AR and FAIR Council as a GSI activity
- Strategic importance recently confirmed by the Helmholtz Senate Commission for Matter (9 May 2017)
- "the existence of a science program at GSI in Darmstadt is essential for the success of the project."

International PACs for FAIR Phase-0

G-PAC:

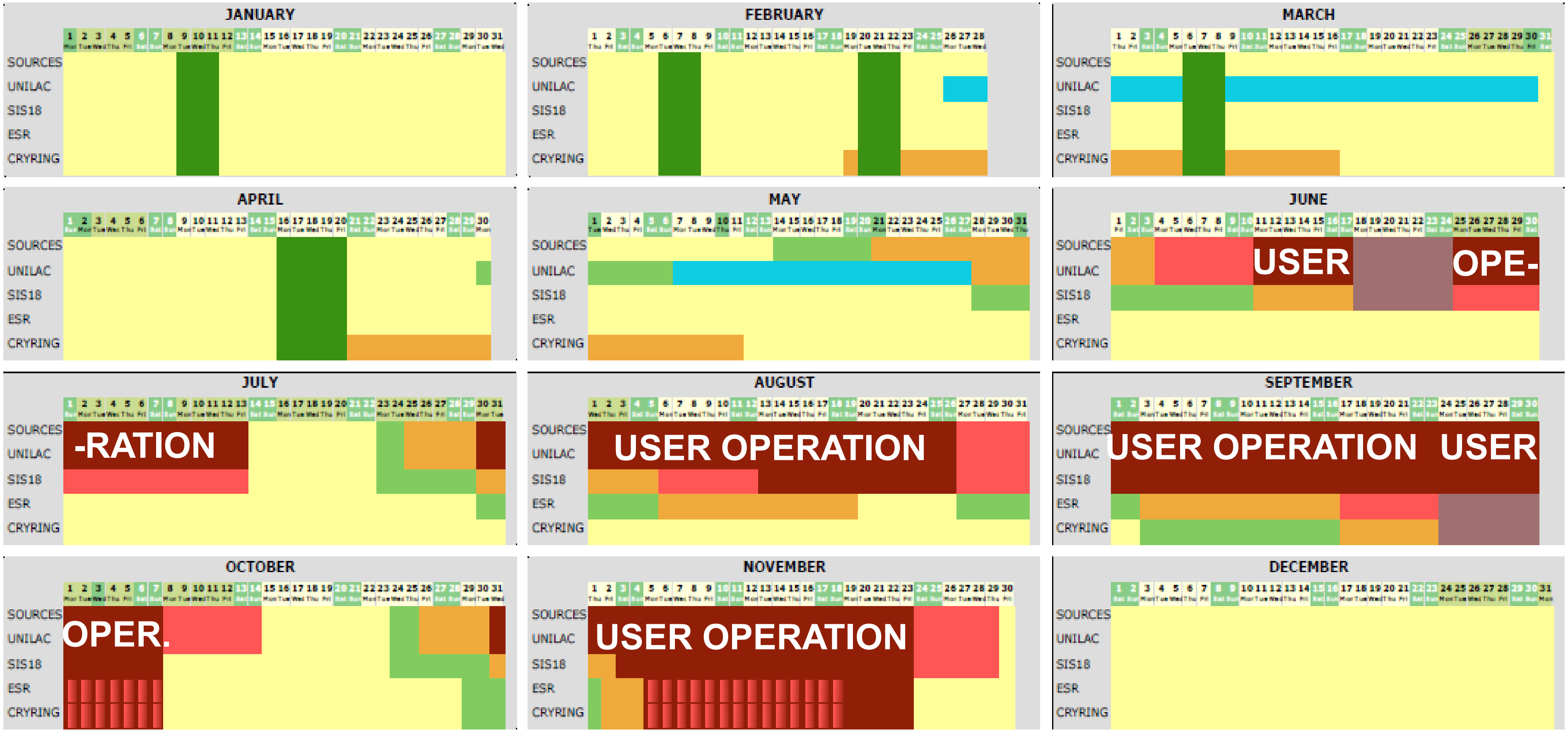
Sydney Galès, CNRS, IPN Orsay, France **- Chair**
Jana Bielcikova, The Czech Academy of Science
Yorick Blumenfeld, Inst. Phys. Nucl., Orsay, France
Paul Greenlees, University of Jyväskylä, Finland
Paul Indelicato, CNRS, Lab. Kastler Brossel, France
André Mischke, Utrecht University, The Netherlands
Witold Nazarewicz, Michigan State Univ., USA
Gerda Neyens, KU Leuven, Belgium
Marek Pajek, Jan Kochanowski Univ., Poland
Thomas Pfeifer, Max-Planck-Institute HD, Germany
Achim Schwenk, TU Darmstadt, Germany
Tomohiro Uesaka, RIKEN, Japan
Eberhard Widmann, Austrian Acad. of Sciences, Austria

1st G-PAC Meeting for FAIR Phase-0 Program
19-21 September 2017

P. Giubellino, "From GSI/Fair Phase 0 to FAIR operation", GSI beam time retreat 2018

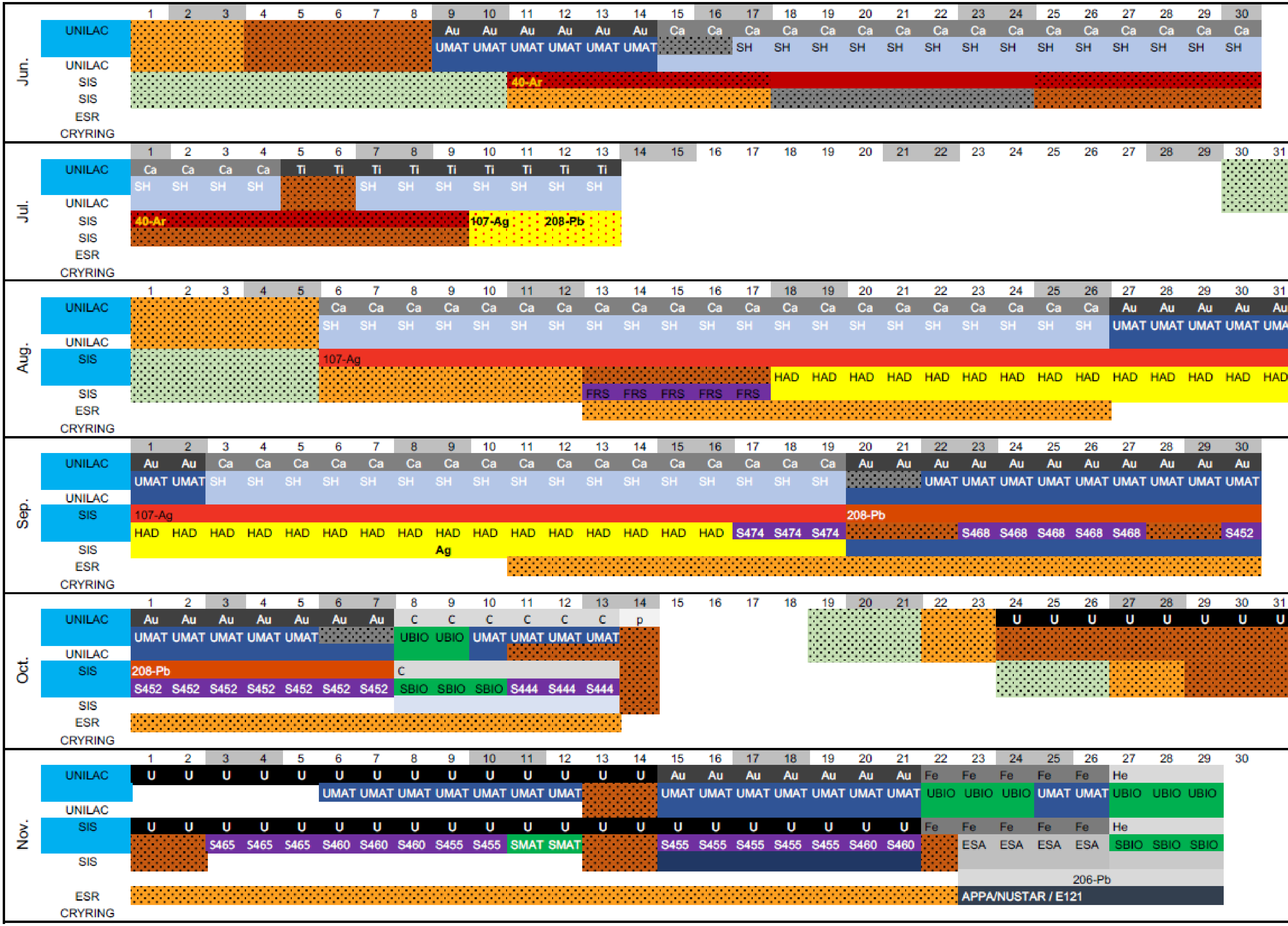
Accelerator Operations 2018

Starting in summer 2018, about three months per year of user beam time for experiments and tests of FAIR detectors



P. Giubellino, “From GSI/Fair Phase 0 to FAIR operation“, GSI beam time retreat 2018

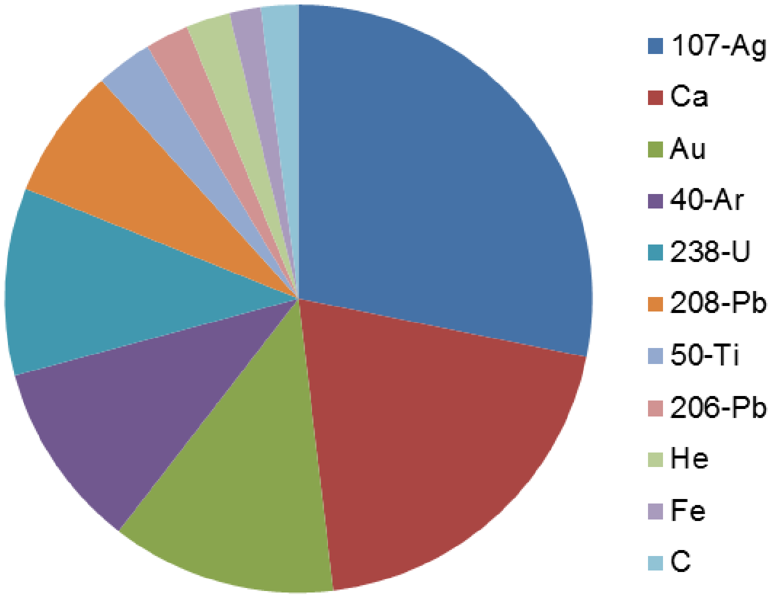
2018 Beam Schedule



Beam time 2018 Goal

- Ensure the smooth operation with nominal performance, i.e. beam species and intensities in 2016

			UNILAC		SIS18	
Projectile	Charge	Isotope	Average particle current	MAX Rep rate*	Nominal Intensity (per Cycle)	MAX Rep Rate (fast extraction)
U	73	238			2,00E+09	1Hz
Pb	67	208			1,00E+09	0,5Hz
Au	65	197			1,50E+09	1Hz
	26		0,1 pµA	50Hz		
Xe	48	124			2,00E+09	1Hz
Ag	43	107			1,00E+09	1Hz
Ti	22	50			2,00E+08	1Hz
	12		0,8 pµA	50Hz		
Ca	20	48			5,00E+08	1Hz
	10		0,8 pµA	50Hz		
Ar	18	40			3,00E+10	1Hz
O	8	18			5,00E+10	1Hz
	3	16/18	1 pµA	50Hz		
N	7	14			7,00E+10	0,35Hz
C	6	12			4,00E+09	1Hz
	2		2,4 pµA	50Hz		
H	1				8,00E+10	0,1Hz



Beam time 2018 Goal

- Ensure the smooth operation with nominal performance, i.e. beam species and intensities in 2016, for all scheduled experiments
- Successfully commission the FAIR control system of all GSI circular accelerators plus CRYRING including HEST and FRS
  - **Retrofitting the dated hardware/system with modern control systems and standards (Front-End-Software-Architect, LHC-Software-Architect)**
  - Full fledged computer based operation mode, instead of scope based

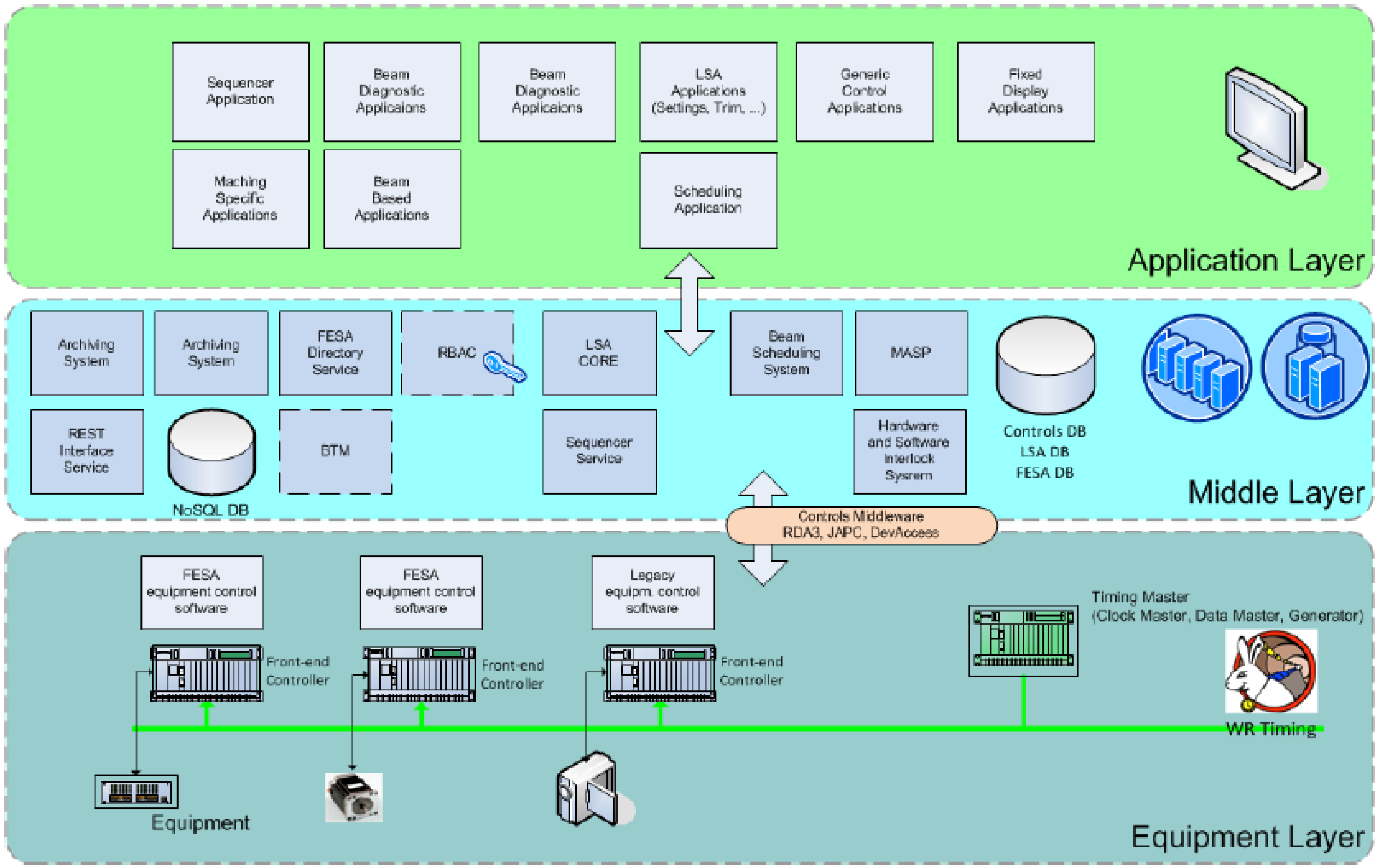
FAIR Control System Stack

R. Bär, “Accelerator Controls Status“, GSI beam time retreat 2018

Presentation Tier

Middle Tier powerful servers

Resource Tier FESA



- Standard 3 tier model; distributed OO system
- Modular design with well defined interfaces

Beam time 2018 Goal

- Ensure the smooth operation with nominal performance, i.e. beam species and intensities in 2016, for all scheduled experiments
- Successfully commission the FAIR control system of all GSI circular accelerators plus CRYRING including HEST and FRS
  - Retrofitting the dated hardware/system with modern control systems and standards (Front-End-Software-Architect, LHC-Software-Architect)
  - Full fledged computer based operation mode, instead of scope based

fits?

Beam time 2018 Goal

- Ensure the smooth operation with nominal performance, i.e. beam species and intensities in 2016, for all scheduled experiments
- Successfully commission the FAIR control system of all GSI circular accelerators plus CRYRING including HEST and FRS
- Commissioning the SIS18 upgrade measures for FAIR
  - **Fast ramping rate (2.7 Hz) for FAIR booster mode**
    - New main dipole power convertor for reaching 10T/s ramping rate
    - New h=2 MA RF cavities for acceleration
    - New IPM for turn-2-turn beam profile measurements
- Commissioning HEST upgrade for high intensity operation
  - vacuum upgrade and new optics to relax the beam losses

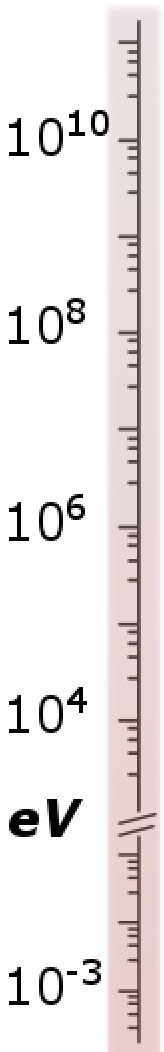
Beam time 2018 Goal

- Ensure the smooth operation with nominal performance, i.e. beam species and intensities in 2016, for all scheduled experiments
- Successfully commission the FAIR control system of all GSI circular accelerators plus CRYRING including HEST and FRS
- Commissioning the SIS18 upgrade measures for FAIR
- Recommission the ESR with the new FAIR control, along with other refurbished systems/components, barrier bucket, beam instrumentation, stochastic cooling, etc
- Demonstrate reliable routine stand-alone operation of CRYRING, and delivery first physics experiments in stand-alone mode
  - *Completion of CRYRING commissioning requires decelerated beams from ESR*

Unique Challenges

- Retrofitting the GSI facility operation with current control systems and standards
  - Don’t be surprised by un-expected!
- Storage ring commissioning
  - the available controls functionalities for the ESR in 2018 will be limited
    - limited scope of the ESR re-commissioning, especially in re-establishing deceleration and slow extraction
    - eliminate the possibility of commissioning CRYRING and HI-TRAP with the ESR beam

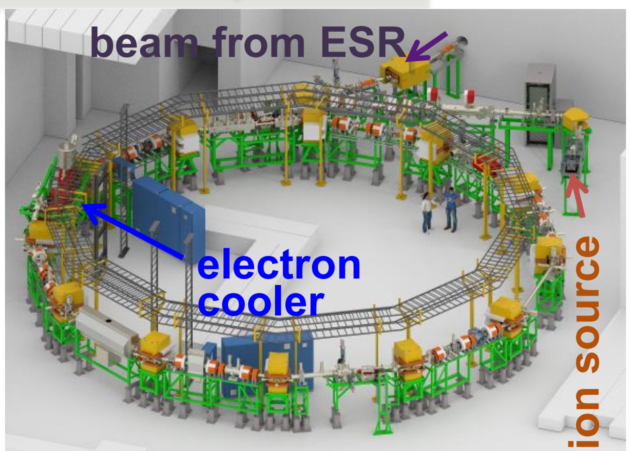
Storage, deceleration and trapping of ion beams



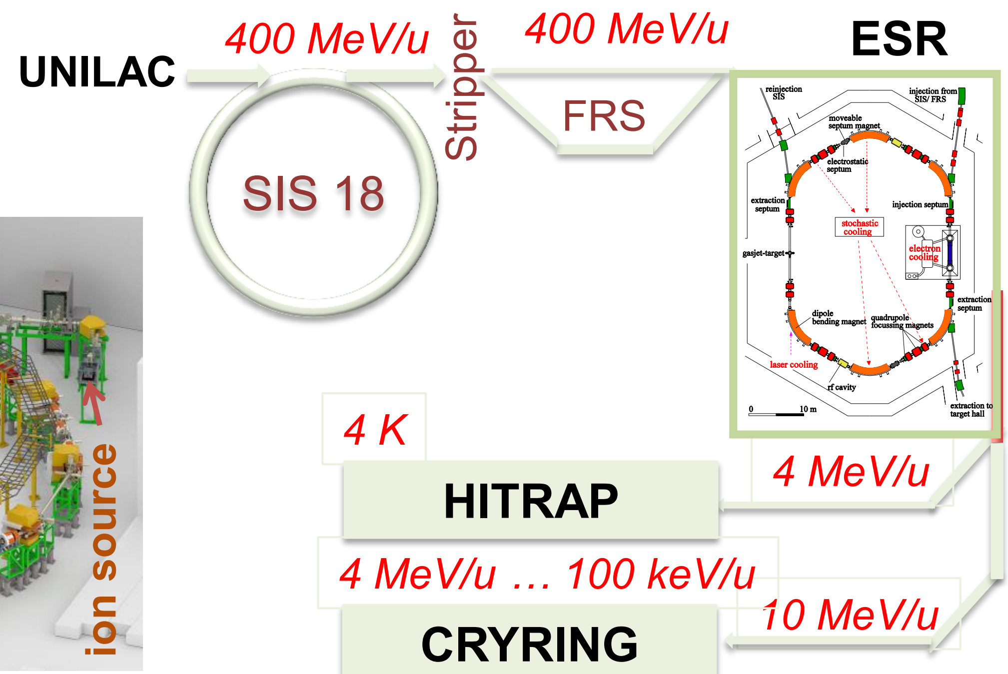
Experimental Storage Ring
- stable ions and RIBs
- multi-charge state
- beam accumulation
- fast/slow extraction

CRYRING
- electron cooling
- stand-alone operation

HITRAP

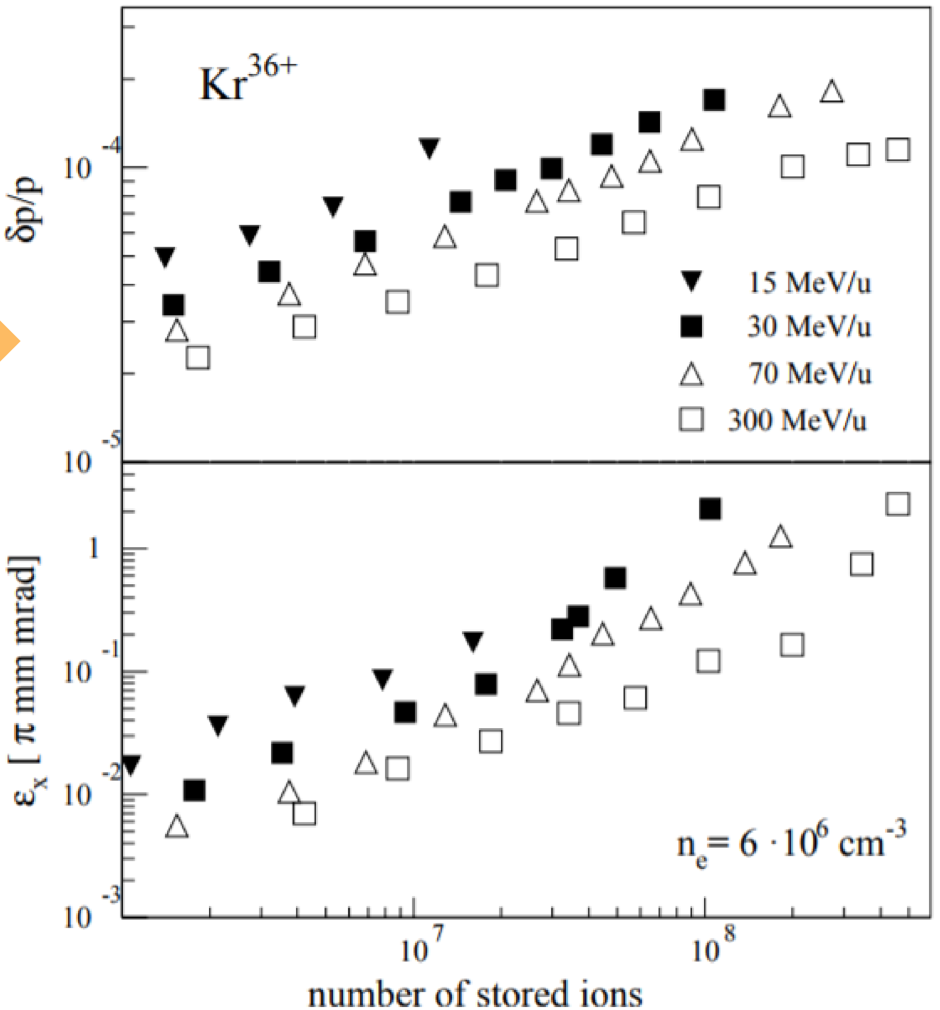


ESR R&D Highlights
- Comprehensive beam cooling
- Isochronous mode
- high precision Schottky spectrometry for single particle detection



The Deceleration in the ESR

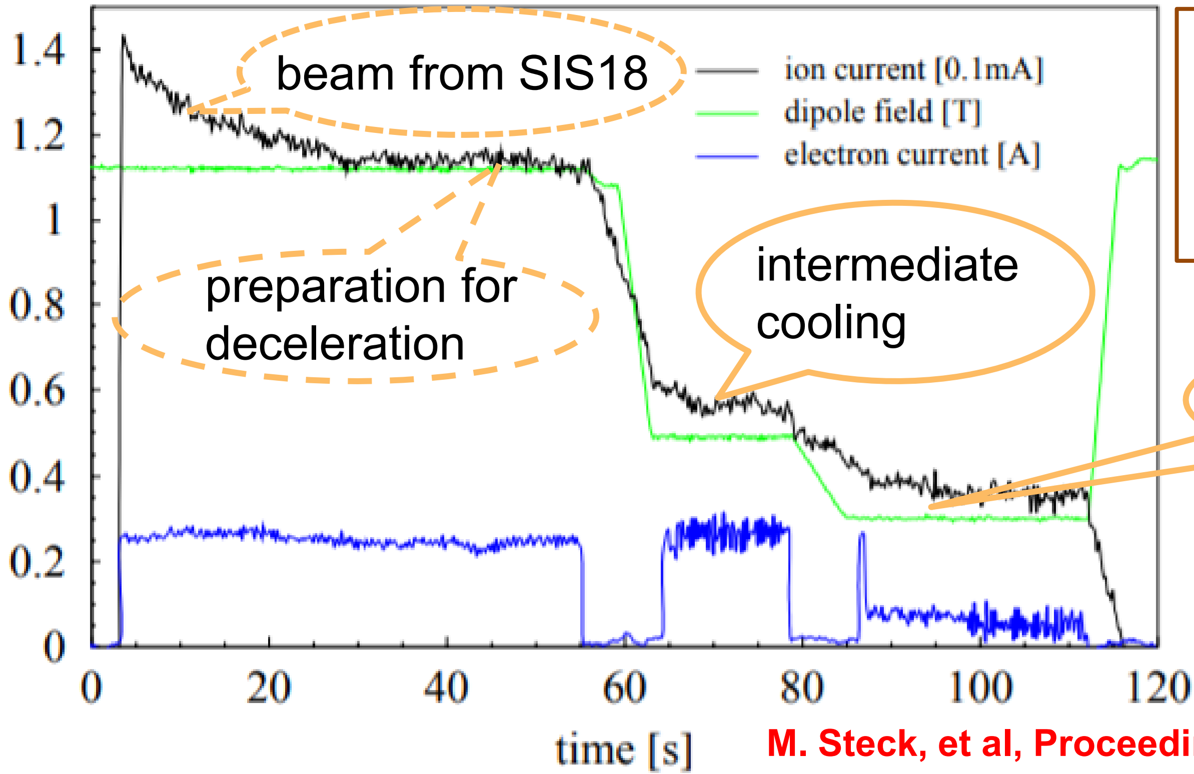
- The symmetry between acceleration and deceleration is often broken in terms difficulty
  - acceleration: adiabatic damping
  - **deceleration means to cope with larger emittance**



M. Steck, et al, Proceedings of EPAC 2000, Vienna, Austria

The Art of Deceleration

- Deceleration requires many careful machine tuning and beam manipulation
- Be able to have controls to allow stand-alone tuning of the machine settings is highly critical



Cycle for deceleration of U92+ from 300 MeV/u to 15 MeV/u with intermediate cooling at 30 MeV/u.

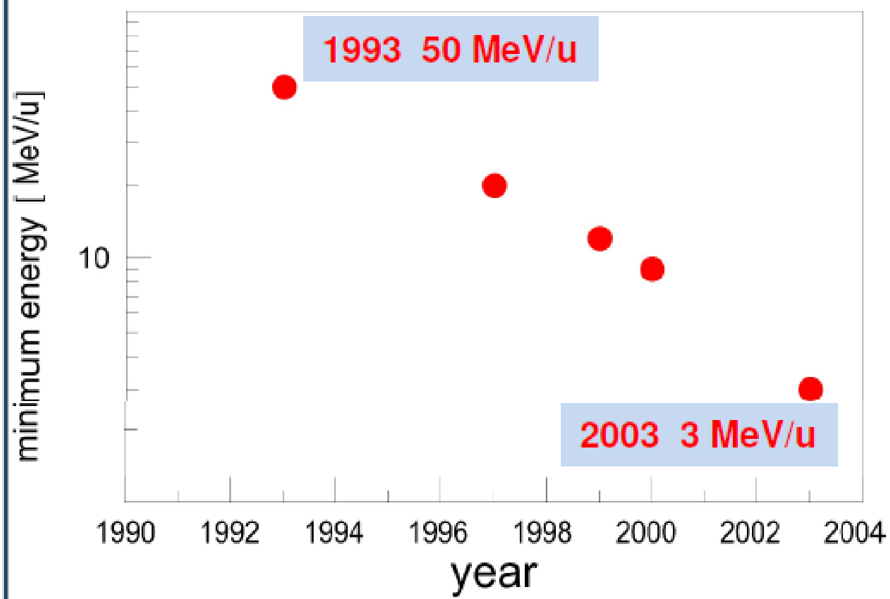
M. Steck, et al, Proceedings of EPAC 2000, Vienna, Austria

The Art of Deceleration

- Deceleration requires many careful machine tuning and beam manipulation
- Be able to have controls to allow stand-alone tuning of the machine settings is highly critical
- It took a long way to reach 3 MeV/u at ESR!

History of ESR Deceleration

M. Steck, "ESR Re-commissioning and Operations", GSI beam time retreat 2018



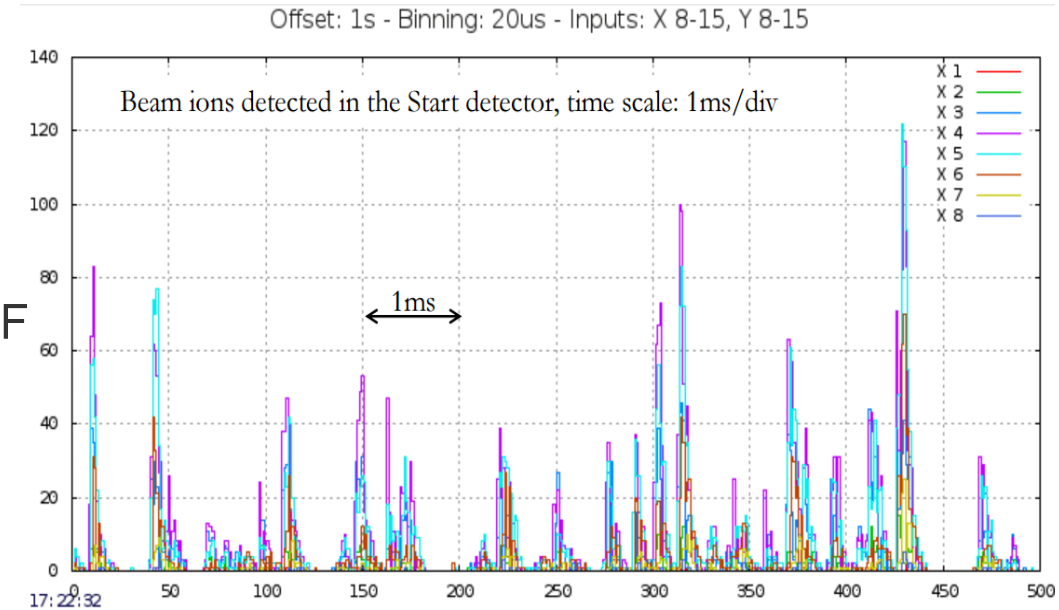
from presentation at HITRAP steering committee 3 December 2003

Unique Challenges

- Retrofitting the GSI facility operation with current control systems and standards (Front-End-Software-Architect, LHC-Software-Architect)
  - Don’t be surprised by un-expected!
- Storage ring commissioning
  - the available controls functionalities for the ESR in 2018 will be limited
    - limited scope of the ESR re-commissioning, especially in re-establishing deceleration and slow extraction
    - eliminate the possibility of commissioning CRYRING and HI-TRAP with the ESR beam
  - re-establishing the ESR radioactive ion operation requires the availability of FRS
- Rising risks on machine availability/reliability due to aging components, **especially with UNILAC**

Unique Challenges

- Parallel operation
  - balance between # of experiments served vs. efficiency
  - heavily depend on the scope of new control systems, as well as the technical soundness of the pre-injectors
- Quality of the SIS-18 slow extracted beam
  - stability of beam position on target
  - micro spill structure
    - Not yet comprehensive measurements to ping down the smoking gun(s)
    - Encourage experience with VHF cavity from the BNL AGS [K. Brown et al]



WEPAK007, R. Singh et al

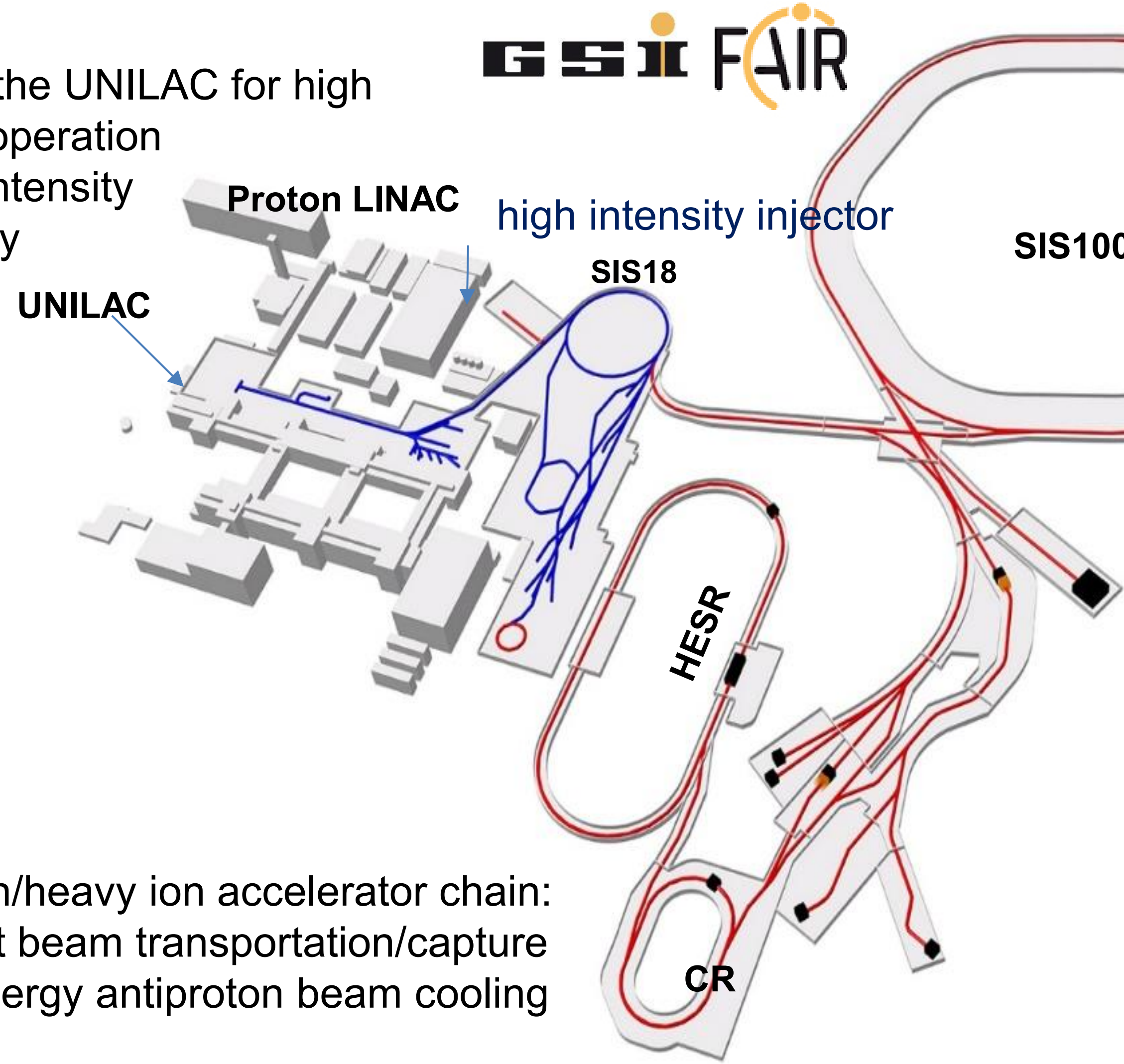
Beam time 2018 preparation status

- **Most of the shutdown activities have been progressing well**
  - Renovated air ventilation system in the UNILAC RF gallery is now in the state that RF test for UNILAC operation can get started
  - The old SIS18 switching magnet TSIMUI will be re-installed
  - The ESR electron cooler will be resembled as soon as the Asbestos are removed
- **GaF project completed, shutdown activities in the SIS-18 area started**
  - Two surveys were carried out to monitor the ground motion. Up to 10mm vertical shifts have been seen in the SIS18 as well as the TKs
  - Surveys of storage rings' area and HEST are scheduled
  - Realignment if needed
- **New Transformer North ready for the AEG test on Feb. 23, 2018**

  MOZGBF2, P. Spiller, Status of the FAIR Project
- **Dry run**
  - a total of 8 scheduled. 7 were carried out. Last one scheduled in the mid of May
- **Vacuum bake-out gets started**
  - 1st bake in the SIS18 went very well, no leaks!
  - CRYRING is also on the list for its March beam time

Look forward

Upgrade the UNILAC for high intensity operation
- Beam intensity
- reliability



Fast ramping super-conducting synchrotron:
- Fast ramping superconducting magnet
- Low beam loss
- Machine protection
- Operation reliability

Antiproton/heavy ion accelerator chain:
- Efficient beam transportation/capture
- High energy antiproton beam cooling

High current ion source operation of U4+ beam at high repetition rate for SIS18 FAIR operation

- higher than 3 Hz repetition rate is required for FAIR operations
- the option of using composite materials with enhanced physical properties in the cathodes is currently under investigation

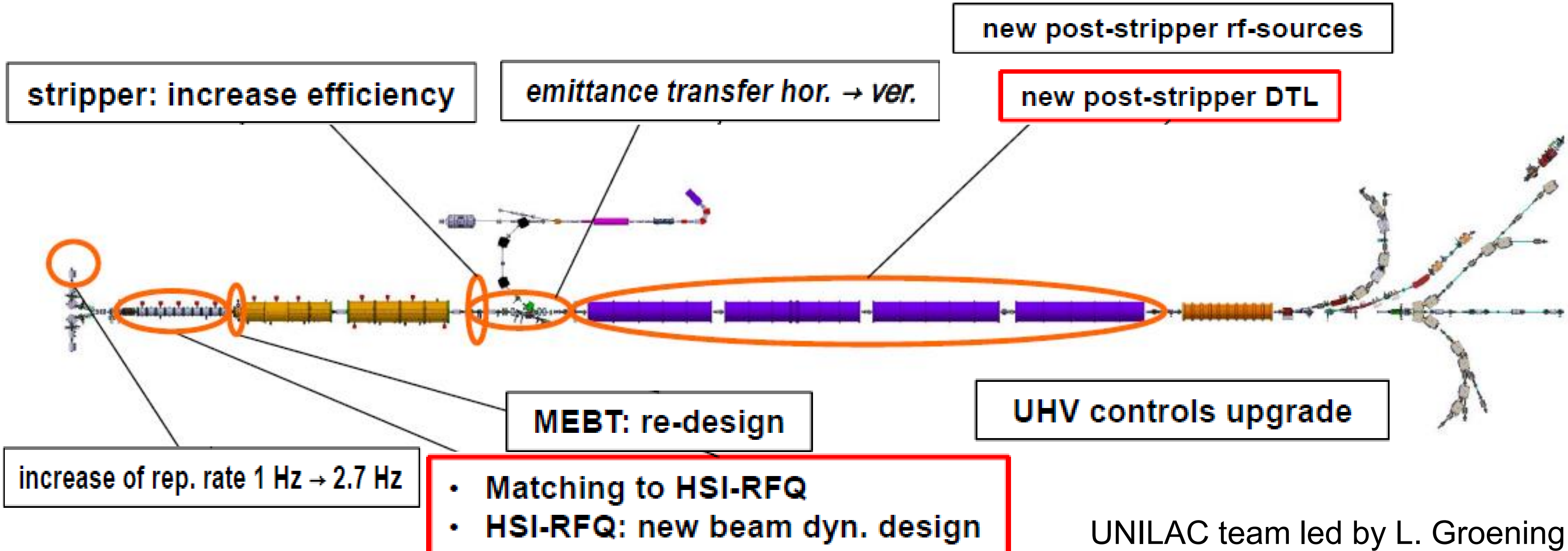
ECRIS for cw and dedicated pulsed operation

- to overcome the limitation of 14.5 GHz CAPRICE ECRIS:
  - limitation of intensities, as well as ions with masses only beyond Xe (e. g.: Nd, Sm, Au, Pb, Bi, U)
- stage wise approach
  - replace existing 14.5 GHz with conventional 18 GHz ECRIS
  - Full performance upgrade with SC-ECRIS

UNILAC upgrade

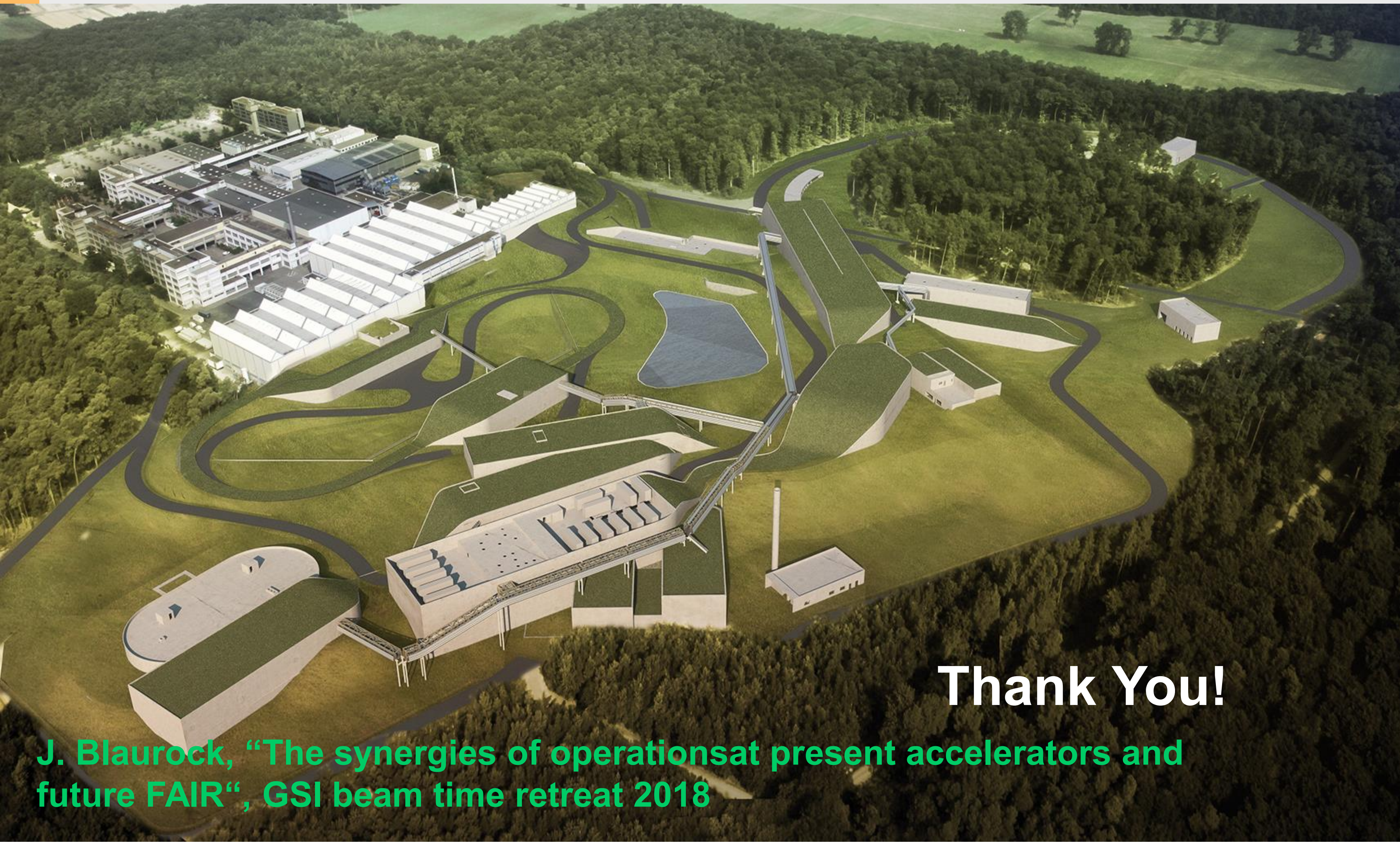
Design goal

ion A/q	≤ 8.5, i.e. $^{238}U^{28+}$	
beam current (pulse) * A/q	1.76 (0.5% duty cycle)	mA
input beam energy	2.2	keV/u
output beam energy	3.0 - 11.7	MeV/u
normalized total output emittance, horizontal / vertical	0.8 / 2.5	mm mrad
beam pulse duration	≤ 1000	µs
beam repetition rate	≤ 10	Hz
operating frequency	36.136 / 108.408	MHz
length	≈ 115	m



UNILAC team led by L. Groening

FAIR 2025


Thank You!
J. Blaurock, “The synergies of operationsat present accelerators and future FAIR“, GSI beam time retreat 2018