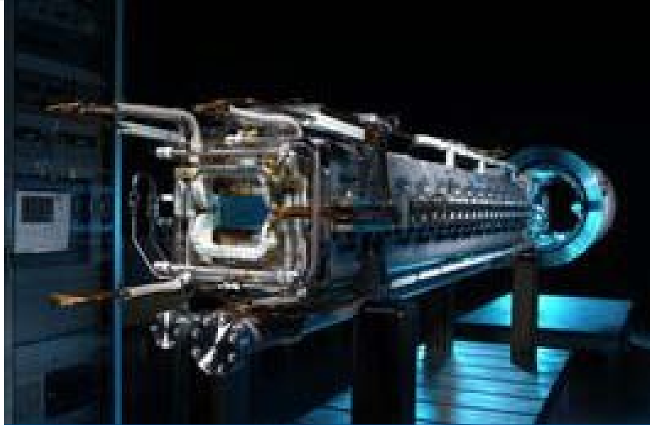




FAIR Commissioning & Control: Status and Outlook until 2025

Ralph J. Steinhagen,

for the FAIR Commissioning & Controls WG (2.14.17 & 2.14.10.10)

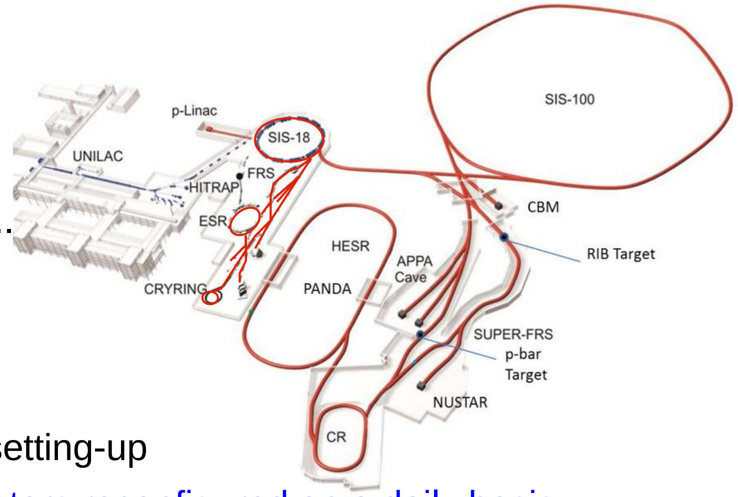
FAIR Experiment and Accelerators Workshop

December 14th, 2018, Darmstadtium, Darmstadt, Germany

Finland France Germany India Poland Romania Russia Slovenia Sweden UK

GSI HELMHOLTZ ASSOCIATION FAIR

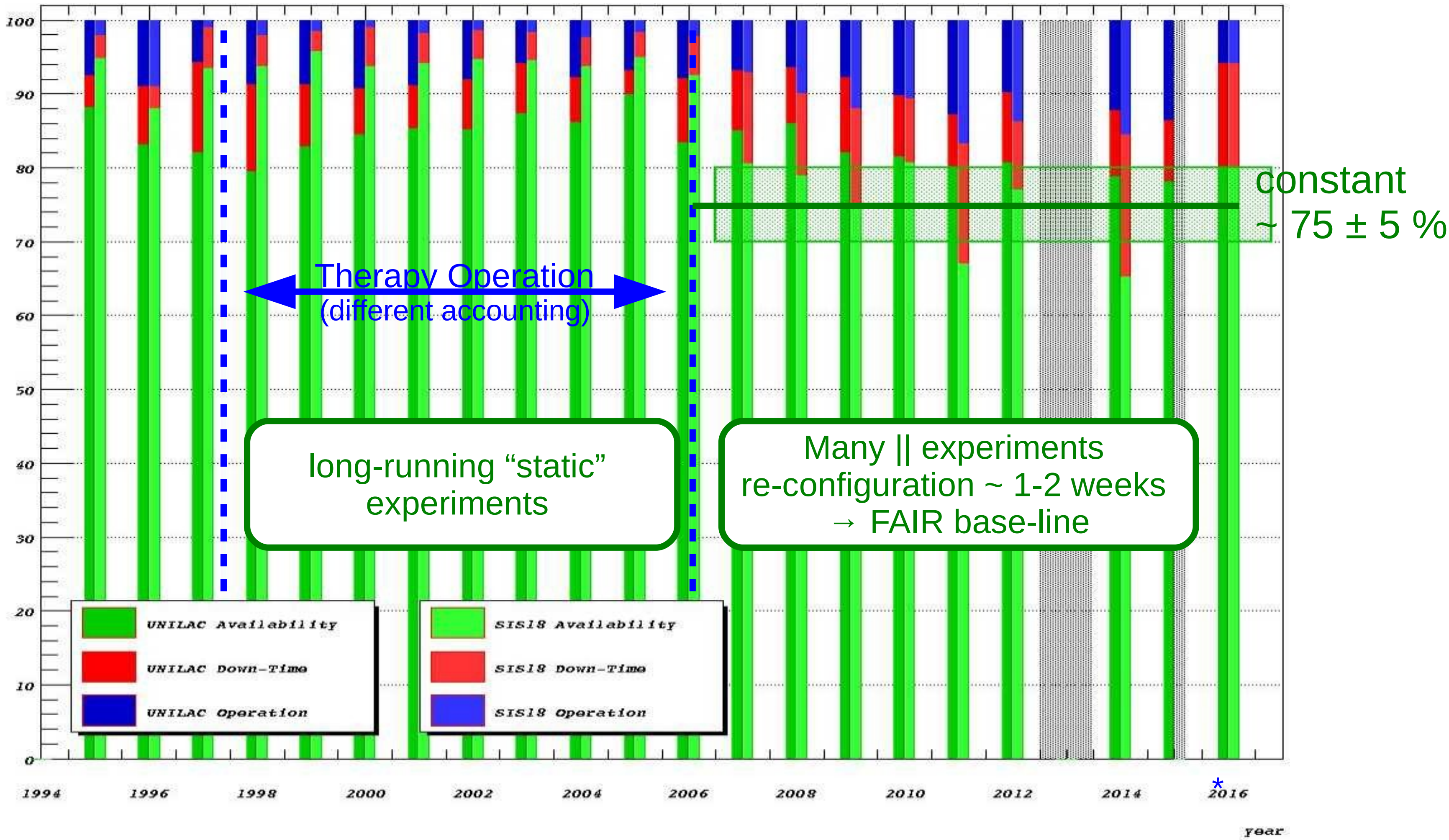
Setting the Scene….



- FAIR ~4 x the size of existing GSI facility
  - non-linear operational complexity increase $O(n^2) \rightarrow O(n^5)$
  - efficiency scalling $\varepsilon_{FAIR} = \varepsilon_{UNILAC} \cdot \varepsilon_{SIS18} \cdot \varepsilon_{SIS100} \cdot \varepsilon_{Super\text{-}FRS} \cdot \varepsilon_{CR} \cdot \varepsilon_{HESR} \cdot \ldots$
- parallel operation of 5-7 distributed experiments
  - lasting typically only 4-5 days, few long-runners
  - large potential for cross-talk between users especially while setting-up
  - world-wide unique requirement: facility and key beam parameters reconfigured on a daily basis
    - target hall/experiment, energy, ion species, intensity, extraction type/length, …
- new challenges w.r.t. GSI:
  - operating beyond present beam parameter envelope, x10-100 higher intensities, x10 higher energies → machine protection & losses/activation become an important issue
  - high-intensity and higher-order feed-down effects require machine and beam parameter control well below the sub-percent level →beyond feed-forward-only (open-loop) modelling and machine reproducibility
  - need to operate FAIR with reduced skeleton crew consisting of only ~5-6 operators (nights & weekends)
    - minimise putting unnecessary stress on crews ↔ ergonomics, human-centric design, (semi-)automation (this talk)

Accelerator Experience & Efficiency

1995-2016: U. Scheeler, S. Reimann, P. Schütt et al.

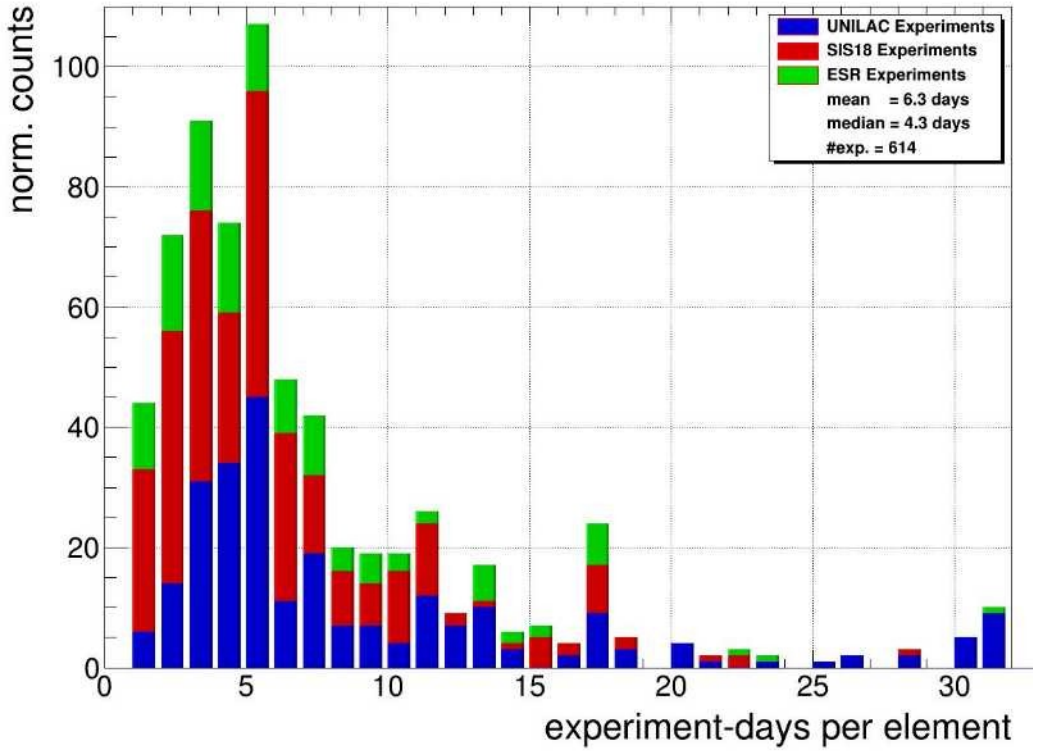


Based on: U. Scheeler, S. Reimann, P. Schütt et al., "Accelerator Operation Report", GSI Annual Scientific Reports 1992 – 2015 + 2016 (D. Severin)
https://www.gsi.de/en/work/research/library_documentation/gsi_scientific_reports.htm
N.B. ion source exchanges are factored out from UNILAC & SIS18 data (~ constant overhead)
Availability: *experiments + detector tests + machine development + beam to down-stream accelerators;*
Down-time: *unscheduled down-time + standby;* Operation: *accelerator setup + re-tuning*

* 2018 operation limitations:
- only ½ UNILAC (w/o A3 & A4)
- only 1 element in SIS18

FAIR Operational Complexity Challenge

Average Experiment Duration



bottom line (1st order):

A) an 'average' GSI/FAIR experiment lasts about 5 days

B) FAIR will accommodate about 5-6 parallel experiments

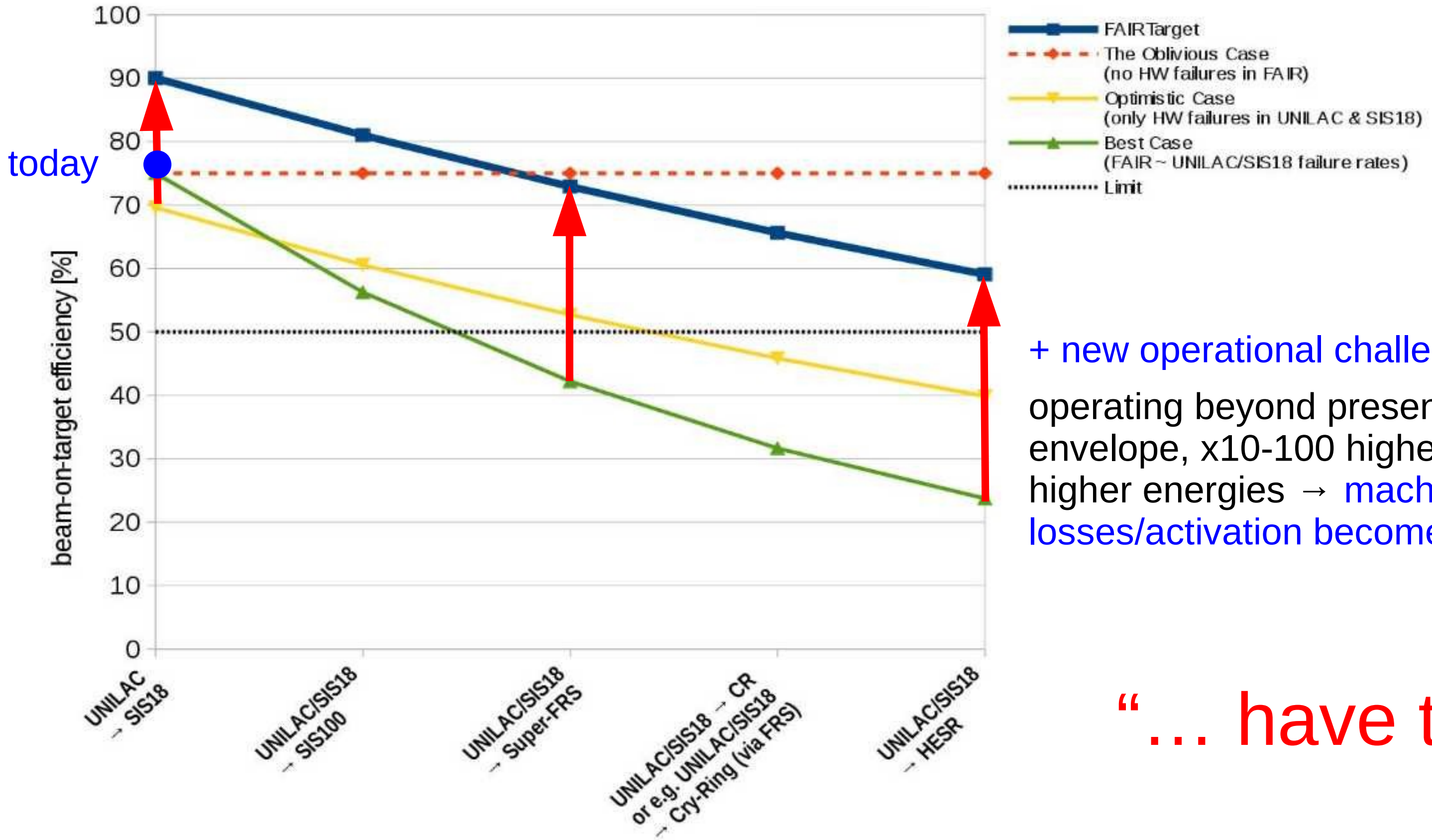
→ expect:

unique to FAIR: setup of new beam-production-chain (BPC) about once per day

FAIR Challenges & Constraints
… SIS18 Operation Experience & Efficiency

- Beam-on-Target figure of merit (FoM) of ~75% → FAIR-BoT (efficiency ε_{FAIR}):

$$\varepsilon_{FAIR} := \prod_{i}^{n_{machines}} \varepsilon_i = \varepsilon_{UNILAC} \cdot \varepsilon_{SIS18} \cdot \varepsilon_{SIS100} \cdot \varepsilon_{SuperFRS} \cdot \varepsilon_{CR} \cdot \varepsilon_{HESR} \cdot \ldots$$



+ new operational challenges:

operating beyond present beam parameter envelope, x10-100 higher intensities, x10 higher energies → machine protection & losses/activation become an issue

"… have to improve!"

FC²-WG guided by: ‘Power-of-10 Law’ and ‘Lean Principles’

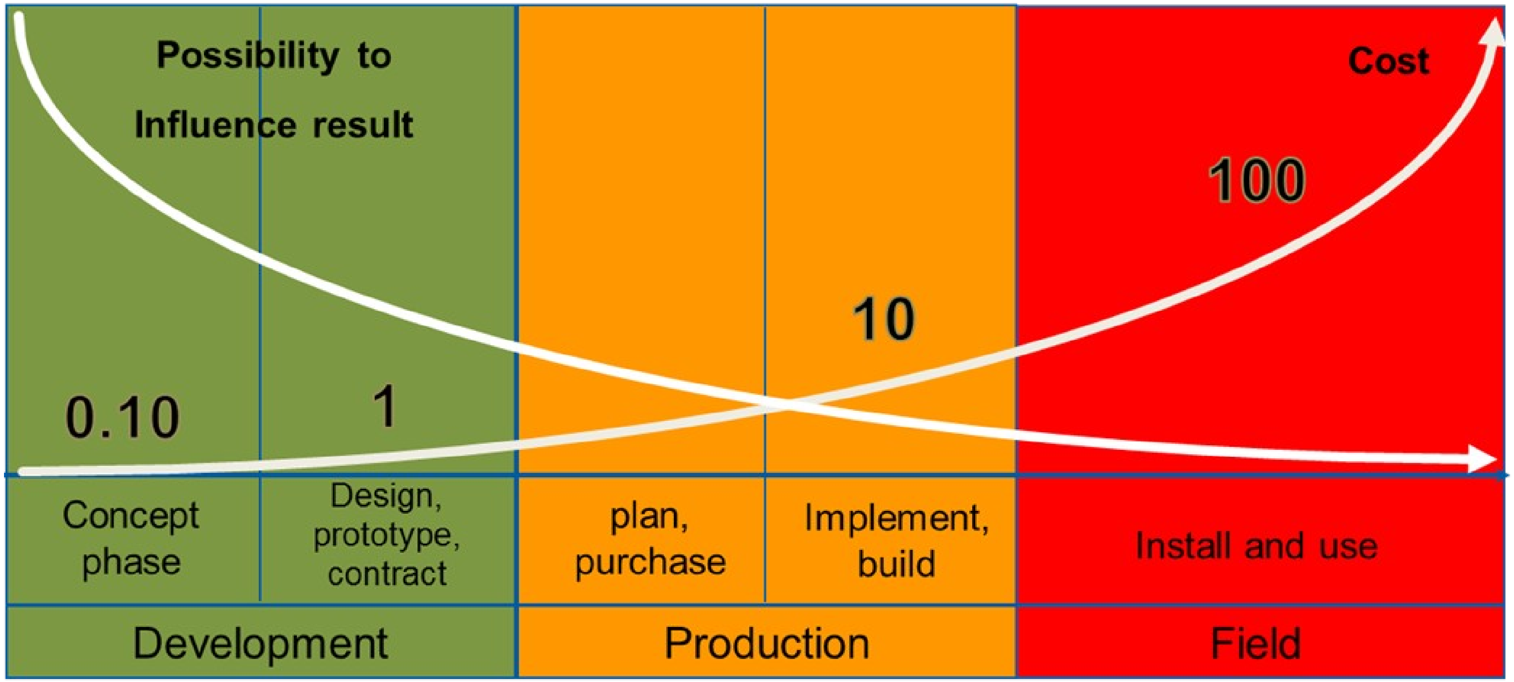


image courtesy Andrea Apollonio, CERN

- The earlier constraints are included in the design, the more effective the resulting measures
- Drives FC²-strategy:
  A) Continuous improvement → right processes to produce right results & for getting it right the first time
     1. commissioning procedures as evolving operation and commissioning standard
     2. system integration: determine of what, how and when is needed

  B) Prevention of inefficiencies, inconsistencies & wastes by design → 'poka-yoke'/'error proofing' principle

Main FAIR Commissioning & Control Activities & Strategy since 2015

A) Hardware/Sub-Component into System Integration into one coherent FAIR Commissioning, Operation and Controls Concept

- devices/functions specified by the MCs & SPL
- priorities on first commonalities, controls prerequisites, and then high-level (machine) specifics
  - SPL, MCs, experiment and management consensus and personnel resource driven & required
- vertical & lateral integration into the control system & operation environment
  → verified during Hardware Commissioning (HWC), 'Dry-Runs' and Beam Commissioning (BC)
  - requires input and active participation by both equipment, experiment and accelerator experts
  - processes driven by 'commissioning procedures', functional requirements, concise interface description between different equipment groups, accelerator experts and SPLs/MCs

B) FAIR (Parallel) Operation Concepts and Requirements → improve facility efficiency through:

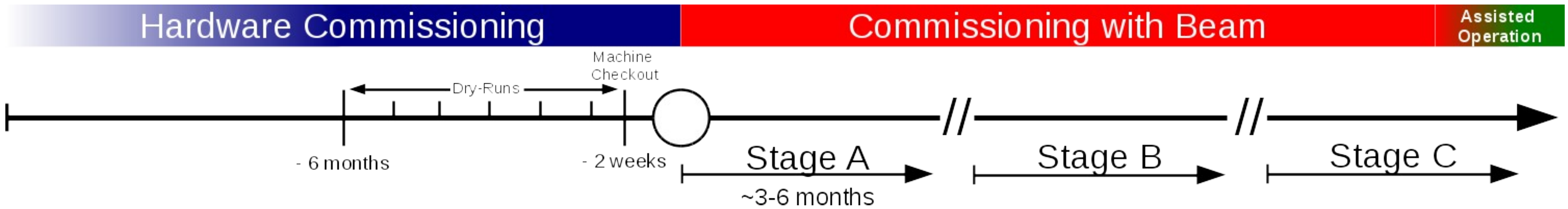
- Improved model based control (aka. Feed-forward) → modular, maintainable and extendable!
  - LSA settings supply, quasi-periodic/static operation, beam-production-chain concept, ...
- (Semi-)Automation → faster turn-around and setup times
  - Sequencer (Testing, HWC & BC), Beam-Transmission Monitoring, Multi-Turn Injection-, Slow-Extraction Optimisations, …
- Beam-Based Feedbacks (cycle-to-cycle) → faster setup-times & more precise parameter control
  - trajectory, orbit, Q/Q', slow-extraction spill, optics, …

C) Physical and SW-Control Room Ergonomics & Human-centred Design → FAIR Control Centre:

- 24h/7 FAIR Operation ist one of the most challenging tasks
- Main-Control-Room should support and not 'get in the way' of operation

FAIR Commissioning Procedure

https://fair-wiki.gsi.de/FC2WG/HardwareCommissioning/



- Distinguish two forms of 'commissioning':

  A)Hardware Commissioning (HWC → SAT A)
  - conformity checks of the physical with contractual design targets,
  - || commissioning of individual systems & tasks ↔ MPLs/equipment group responsibility

  B)Commissioning with Beam (BC → “SAT B” …)
  - Commissioning of beam-dependent equipment
  - Focus on tracking beam progress through the along the beam production chain (
    - threading, injection, capture, acceleration and extraction
  - + 'Dry-Runs': pre-checks at the end of HWC in view of beam operation:
    - Checks conformity of system's controls integration and readiness for Commissioning with Beam
    - check as much control/system functionality without beam as possible
    - Machine ist put into a state assuming that beam could be injected into the ring/segment
      - unavailable devices/systems are at first ignored, noted down, and followed-up at a defined later stage

Driven by ‘Commissioning Procedures’ (↔ ~FATs & SATs) as the first crucial step for the conceptual design and system integration

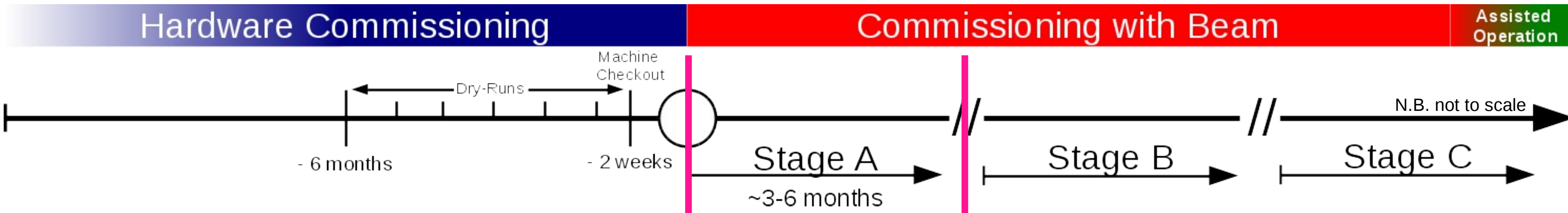
requires input and active participation by both equipment, experiment and accelerator experts

Terminology:

- **Dry-runs**: a rehearsal of the accelerator performance/function, starting typically six month before t
  - needs to (partially) repeated after shut-down or longer technical stop with substantial modificat
  - initial frequency: 1-2 days every month
  - frequency increased depending on the outcome of the initial dry-run tests
- **Machine-Checkout**: intense accelerator performance tests (e.g. machine patrols, magnet/PC hea
  - needs to repeated after every shut-down or longer technical stop
  - repeated also on the long-term during routine operation of existing accelerators (already existin

Commissioning without & with Beam

https://fair-wiki.gsi.de/FC2WG/HardwareCommissioning/
https://fair-wiki.gsi.de/FC2WG/BeamCommissioning



- Split Beam Commissioning into three stages:
  - A) Pilot beams/"easily available" ions (e.g. Ar)
    - basic checks: threading, injection, capture, cool, convert, acceleration/decelerate, stripping & extraction
    - always done with 'safe' ie. low-intensity/brightness beam
      - Ions: simpler optics, beam dynamics → Protons: transition crossing
  - B) Intensity ramp-up & special systems
    - achieving and maintaining of nominal transmission and beam losses
    - commissioning of e.g. e-cooler, slow extraction, transverse fast feedbacks
    - commissioning and validation of machine protection & interlock systems
    - Possibly unsafe operations always preceded by checks with safe beam
  - C) Production operation with nominal intensities
    (N.B. first time counted as 'commissioning' or 'assisted operation' → later: 'regular operation')
    - push physics and beam parameter performance (emittance, momentum spread, ...)
    - identify and improve upon bottlenecks impacting FAIR's 'figure-of-merit
    - make fast setup and switch-over between different beam production chains routine

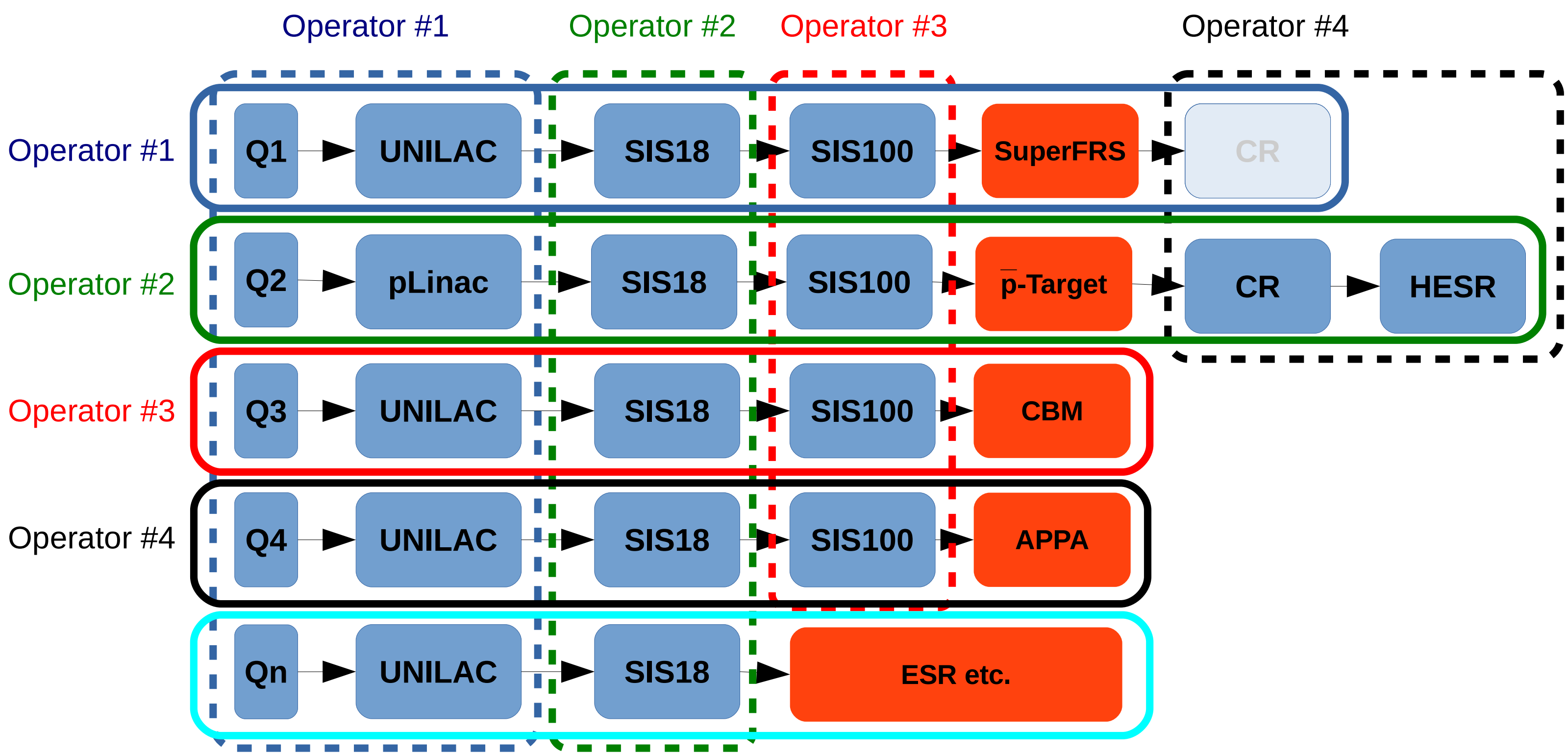
FAIR-'Day 0'

First "Splash Events" in 2025

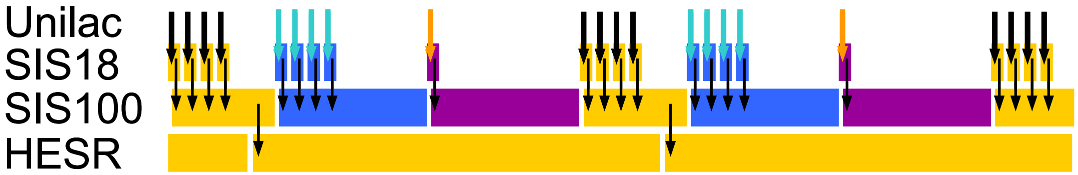
commissioning details & 'what-if-scenarios' planned in 2.14.17.1

First Ingredient: Quasi-Periodic Operation I/II
Operation/Control Paradigm

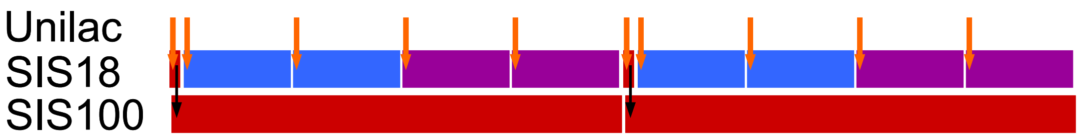
- Some important OP boundary conditions:
  A) Compared to GSI, FAIR facility size and complexity increases roughly by a factor 4
  B) Expect some improvement but 'Operator' & 'System Expert' will likely remain a scarce resource
  (N.B. ~5-6 operators (nights & weekend) ↔ pool of ~35 operators)
- One strategy option: 'One Operator per Accelerator Domain' vs. 'One Operator per Experiment':



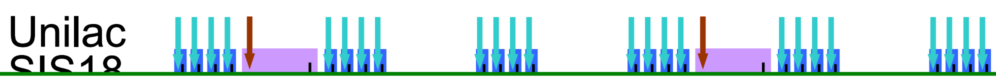
Periodic beam patterns, dominated by one ***main*** experiment – change every two weeks, some run for 2-3 days only:

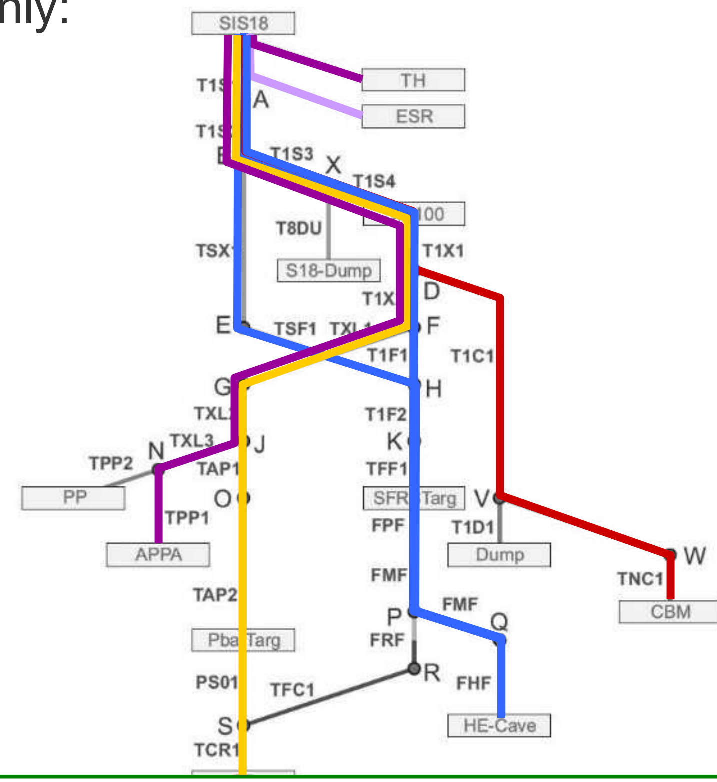


AP + RIB ext. target (U^{28+}) + Biomat



CBM + RIB ext. target (U^{73+}) + AP (LE)





FAIR Operational Challenge:

- presently: 2 shifts for setup of 2 accelerators→ FAIR target: 1-2 shift(s) for setting up 5 accelerators + tighter loss control
- Main strategy/recipe to optimise 'beam-on-target':
  - quasi-periodic cycle operation: limit major pattern changes by construction ↔ beam schedule planning (tools)
  - minimise overhead of context switches → smart tools, procedures & semi-automation, e.g. beam-based FBs, sequencer, …

Second Ingredient: (Semi-)Automation and Beam-Based Feedbacks at FAIR

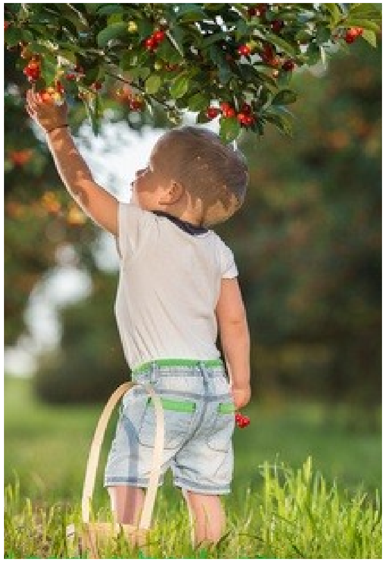
… optimise routine task so that operation crew talents are utilised/focused on more important tasks that cannot be automated

Focus priorities on systems that have a big impact on setup, tracking and optimisation:

- ‘biggest bang-for-the buck’ or ‘low-hanging-fruits’*:
  - ie. systems that are best understood, require least effort/know-how to integrate/implement
- operationally critical or hard to achieve by-hand:
  - e.g. slow-extraction spill control, slow trajectory/focus drifts of beam-on-target
- mitigating drifts that are driven by feed-down effects due to higher-order parameter tuning: e.g. orbit, tune
- ...

Examples:

- beam-transmission-monitoring and other actual-vs-reference monitoring systems → identify, localise and fix failures/near-misses as early as possible
- semi-automated multi-turn/optics/slow-extraction monitoring/correction/… setup tools → improve facility turn-around and setup times
- classic beam-based feedbacks on trajectory, orbit, tune, chromaticity, etc. → monitor and maintain tight parameter tolerances
- Sequencer taks – automation of tasks not yet covered by other routine tools → big time saver for large-scale equipment acceptance/integration tests, recommissioning, or dry-runs
  - N.B. thousands of FAIR devices & machine protection systems that need to be periodically retested/validated



Beam-based Cycle-to-Cycle feedbacks

Generic Beam Control (focus on use-case)

1. Transmission Monitoring System
2. Orbit Control
3. Trajectory Control (threading, inj./extr., targets)
4. Q/Q'(') Diagnostics & Control
5. TL&Ring Optics Measurement + Control (LOCO, AC-dipole techniques etc.,)
6. RF Capture and (later) RF gymnastics
7. Longitudinal Emittance Measurement
8. Transverse emittance measurement
9. Transverse and longitudinal feedbacks

Bread-and-Butter systems for operation (items 1–4)

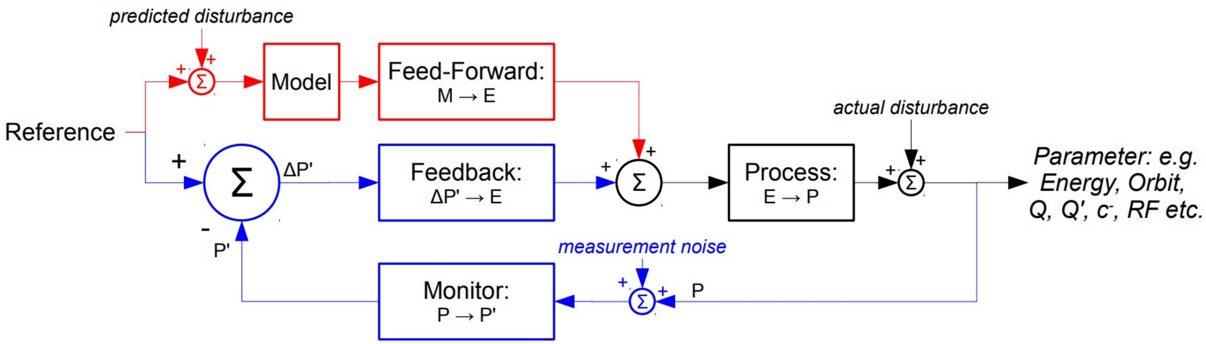
Machine-specific Beam-Based Systems:

- SIS18: multi-turn-Injection (N.B. highly non-trivial, complex subject), Slow-Extraction (K.O. exciter, spill-structure, …)
- SIS100: Slow-Extraction (K.O. exciter, spill-structure, …), RF Bunch Merging and Compression
- ESR, HESR & CR: Stochastic cooling, Schottky diagnostics, …, tbd.

Generic:

- Remote DAQ of Analog Signals (strong impact on HKR migration/operation!)
- Facility-wide fixed-displays, facility & Machine Status (“Page One”)
- context-based monitoring of controls and accelerator Infrastructure,

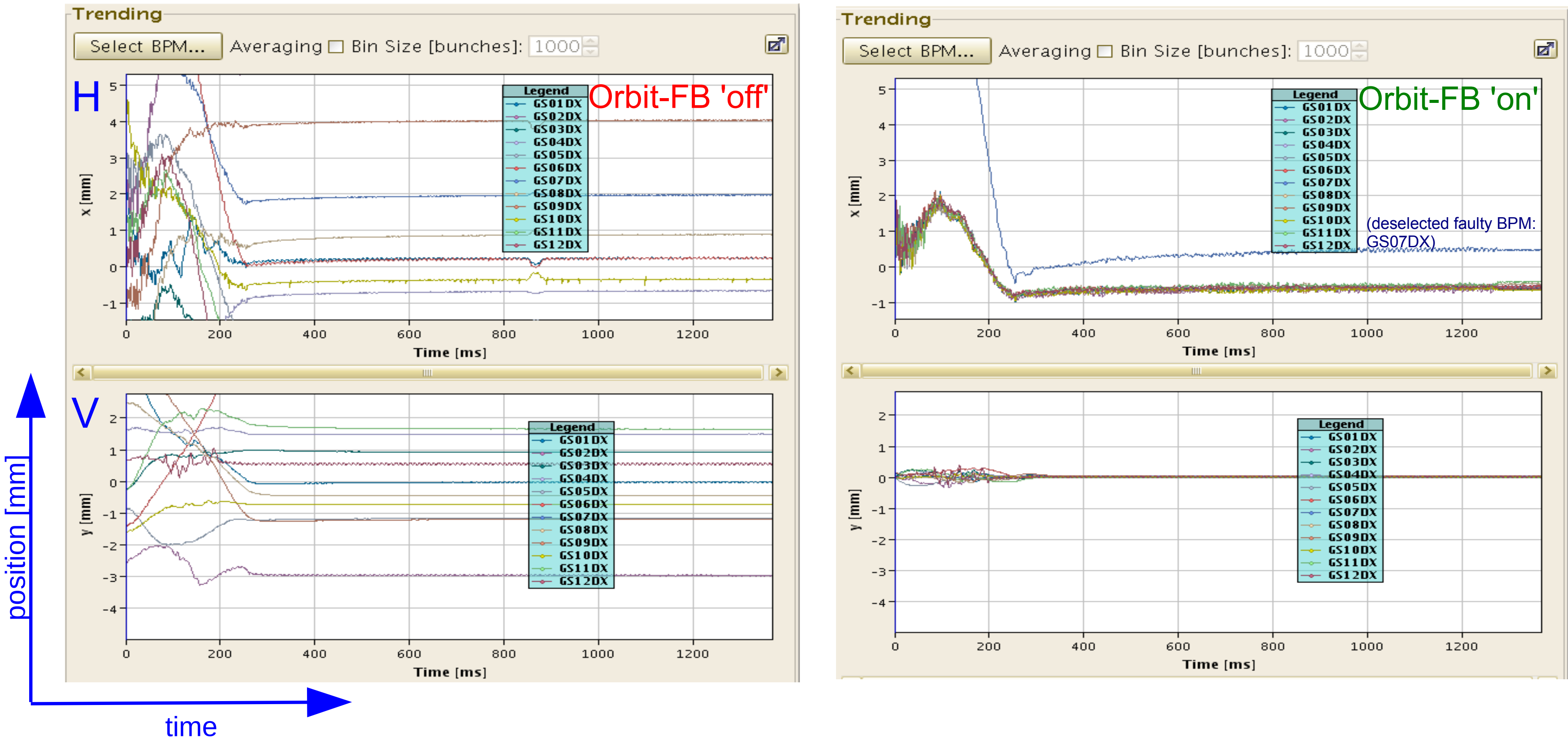
Some notes on implementation



- Real-World challenges of FB & (semi-) automation:
  (hint: usually control theory or beam physic isn't the problem)
  - second-scale FBs/tools are often already quite sufficient for >90% of problems
  - Computers are better than humans for repetitive/quantitative tasks, however: FBs are essentially only as good as
    - beam-diagnostics or machine-parameter measurements they are based-upon
    - integration into the controls & operation environment and exception handling
      - interfaces, interfaces, interfaces….
      - long-term maintenance, upgrades, adaptations, ...
    - developer skills that needs to cover multiple domains: acc. HW, BI, RF, Controls, machine modelling, beam physics, …
    - overall strength depends on the reliability of the weakest link in the chain → however: requires serious controls integration efforts to become robust/operationally ready (typically 80% of tools is exception handling of non-conformities)

Cycle-to-Cycle Orbit-FB Proof-of-Concept

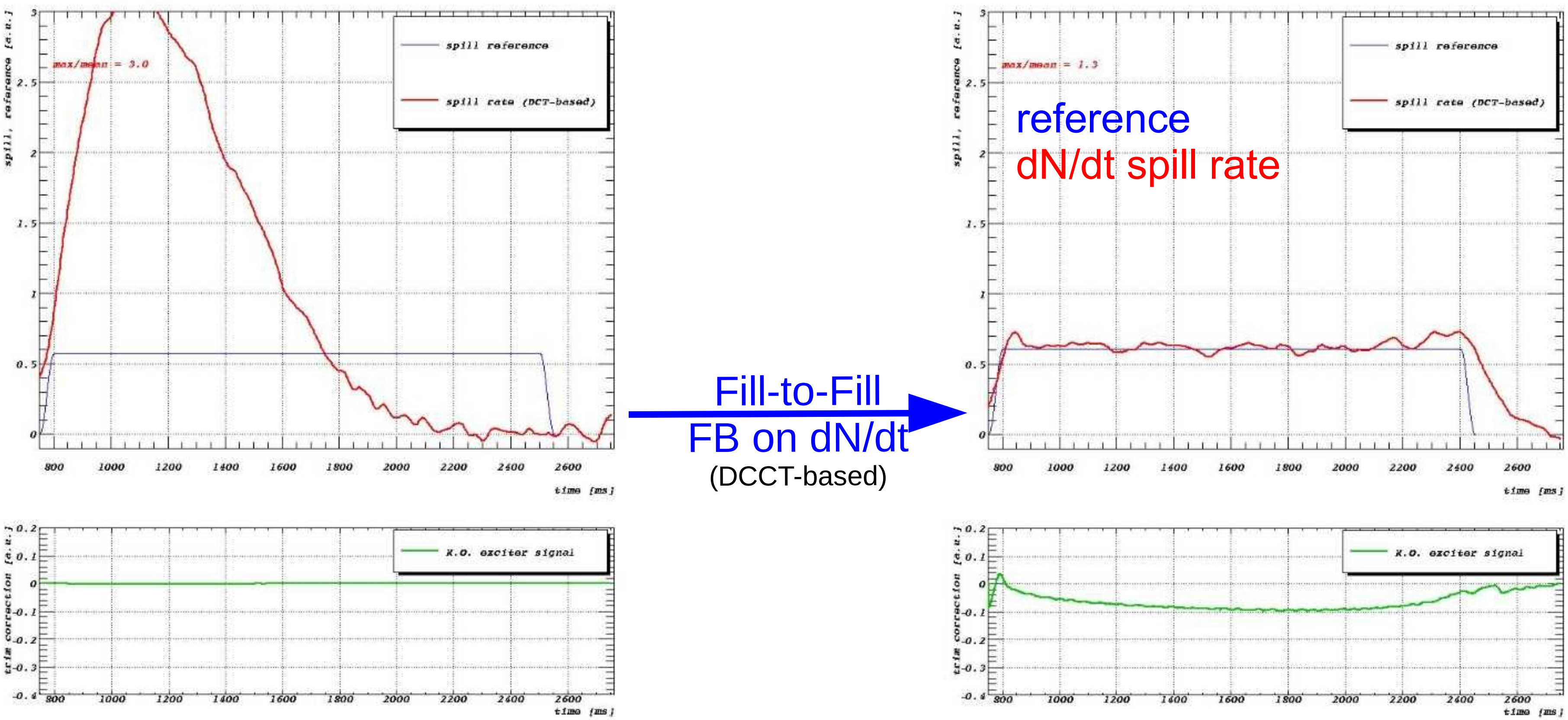
B. Schlei, H. Liebermann, R. Steinhagen



- some workarounds needed, but overall success and results look promising
  - need to follow-up: reliability, performance issues related to CO & BI + detailed integration before being put into regular operation
  - N.B. remaining horizontal oscillation due to uncorrected Δp/p mismatch → radial-loop/Energy-FB

Cycle-to-Cycle Macro-Spill-FB Proof-of-Concept

R. Steinhagen, H. Liebermann

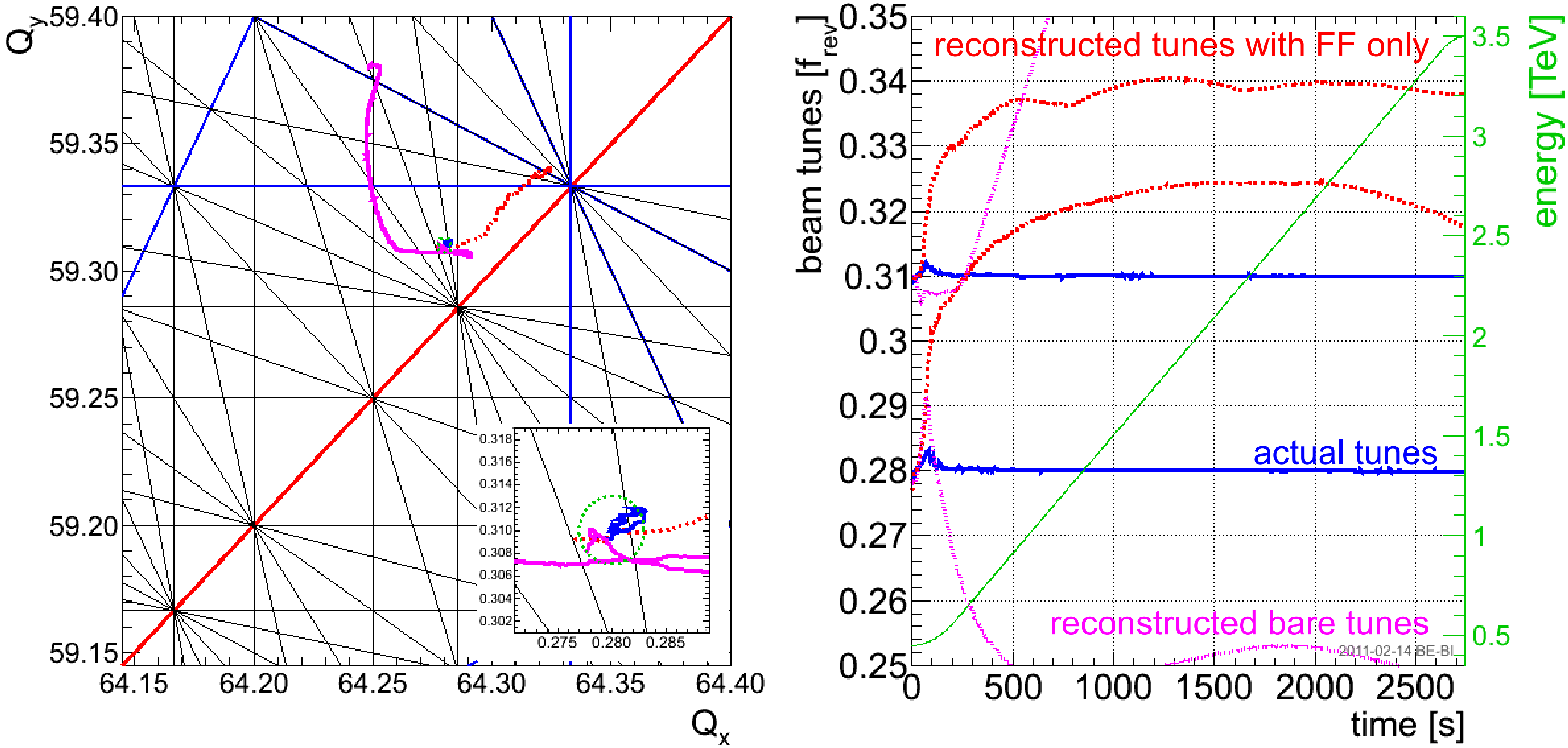


- some workarounds needed, but overall success and results look promising
  - need to follow-up: K.O. exciter power-limitation handling (easily for >10 Tm operation)
    - Alternative: FB using fast extraction quadrupole or main-quads
  - Desirable: direct FB signal from experimental detectors

animated GIF - link

Higher-Order Beam Parameter Stability
Example: LHC Tune Feedback Operation

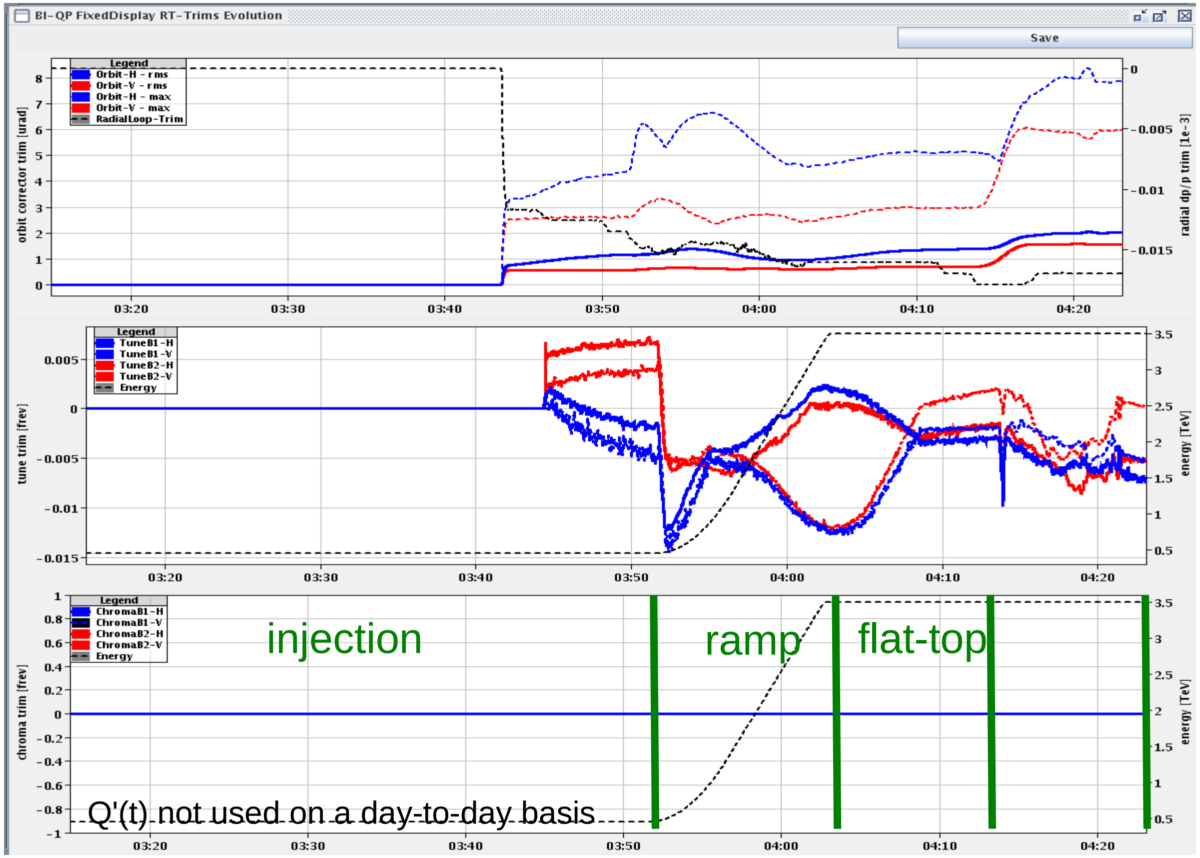
- … Q/Q'-FBs help mitigating these feed-down effects while allowing OP crews to work on other more pressing issues → stability of actual observable became secondary
  - N.B. BBQ instrumentation is key-ingredient to success



Higher-Order Beam Parameter Stability

Example: Feedback Integration and Operation at LHC

- trims become de-facto standard to assess the FB and machine performance and to improve machine modelling (done off-line) → also base-line for FAIR



Orbit-FB & Radial-Loop Trims (µrad)

Tune-FB trims

Q'(t)-FB trims

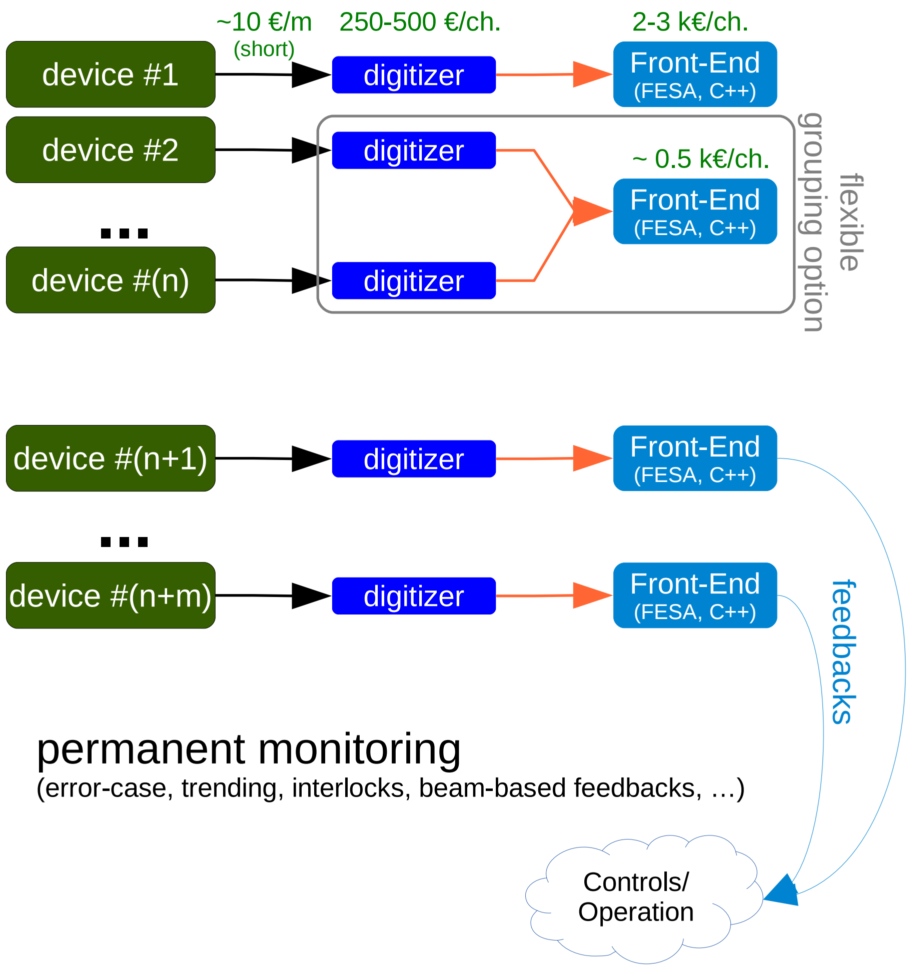
Energy (TeV)

β*-squeeze

Digitization of Analog Signals at FAIR

https://edms.cern.ch/document/1823376/

- targeted concept
  (underlying assumption: scopes/digitizers are cheap, RF switches are expensive)

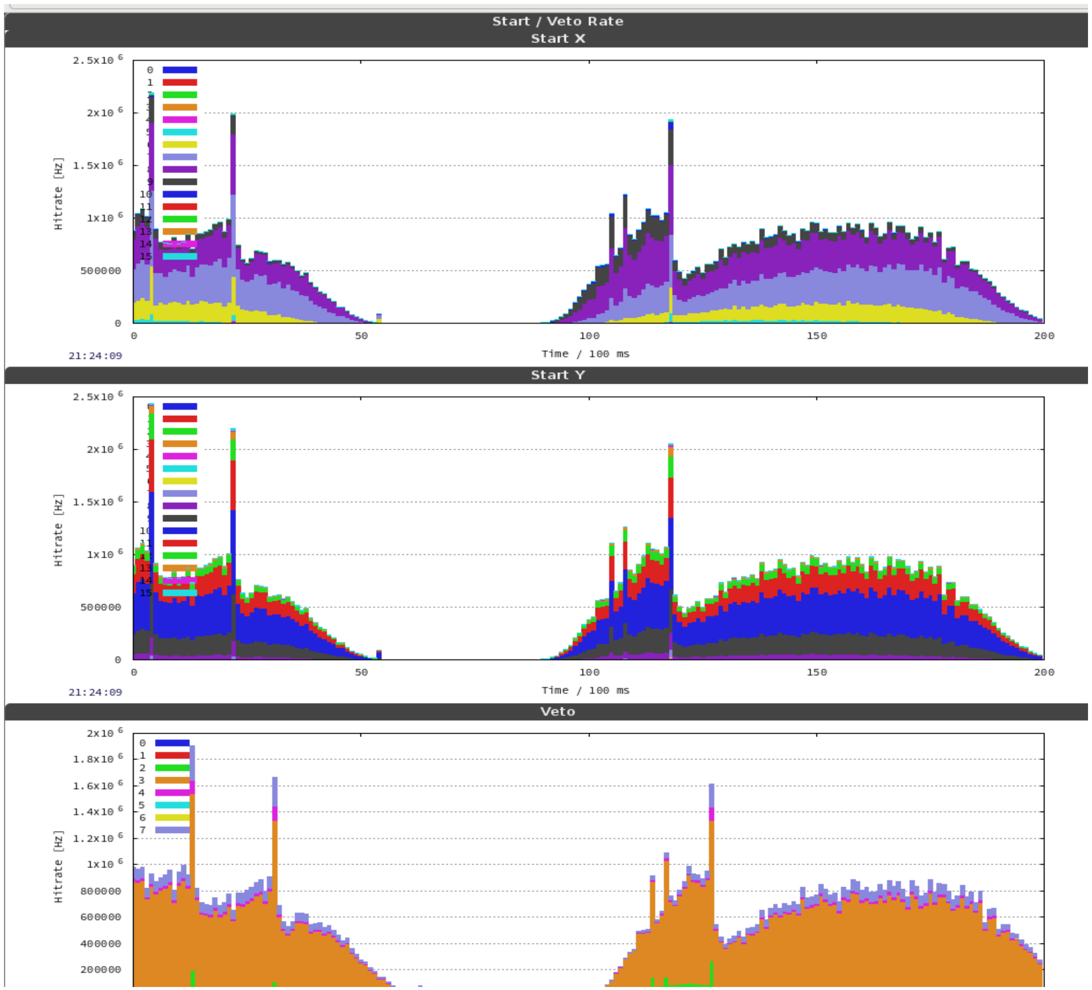


permanent monitoring
(error-case, trending, interlocks, beam-based feedbacks, …)

start deployment ≥2018 (SIS18), crucial for:
- migration to new FAIR Control Centre (FCC),
- optimisation of commissioning & operation
- automated tracking/isolation of faults (↔ post-mortem)
- less-biased performance indicator

link: more details

In a control room not so far far away...



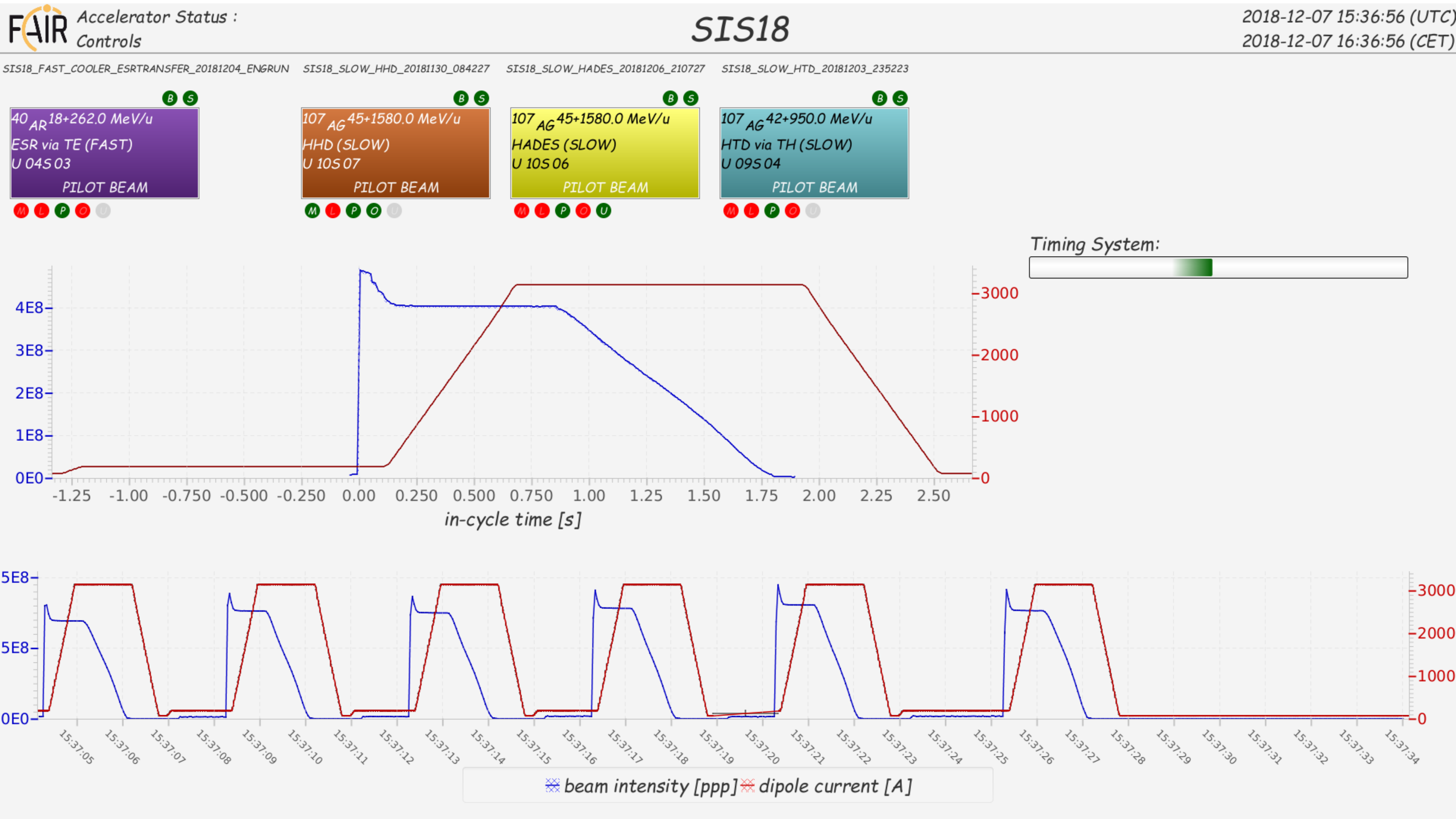
... likely caused by spurious equipment input

Digitizer are key to monitor all critical devices that may act upon the beam!

- continuous actual-vs-reference monitoring → efficiently localise & isolate faults or rare events
- complimented by Archiving System → tracking of (especially) rare events.

Digitization of Analog Signals at FAIR

Example: SIS18 Machine Status



FAIR Archiving System

https://edms.cern.ch/document/1176039/

- *… collect and store all pertinent accelerator data centrally to facilitate the analysis and tracking of the accelerator performance as well as its proper function.*

- Combined Archiving and Post-Mortem storage concepts
- Aim at storing maximum reasonable amount of data
  - facilitates data mining (performance trends, rare failures, …)
  - key to understanding and improving accelerator performance
  - also: use feedback action to improve machine model (data mining)!

Quality Management	Document Type:	Document Number: F-DS-C-11e	Date: 2016-07-18
FAIR	Detailed Specification	Template Number: Q-FO-QM-0005	Page 1 of 24

Document Title:	**Detailed Specification of the FAIR Accelerator Control System Component "Archiving System"**
Description:	This document is the Detailed Specification of the accelerator control system component 'Archiving System'. Its task is to collect and store all pertinent accelerator data centrally to facilitate the analysis and tracking of the accelerator performance as well as its proper function.
Division/Organization:	CSCO
Field of application:	FAIR Project, existing GSI accelerator facility
Version	V 4.5

Prepared by:	Checked by:	Approved by:
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Archiving

Post-Mortem

N.B. importance: quantitative accelerator performance and bug, transient recording & fault-tracking indicators

Sequencer Framework

Semi-automated Tests for HW and Beam Commissioning

HWC and Beam Commissioning require efficient tools for testing

- perform initial and acceptance tests, early detection of non-conformities and faults
- perform QA and regular re-validation tests
- considering size and complexity of FAIR, and limited resources: efficient and reliable execution and documentation of tests

→ Development of a **Sequencer framework**, as a core part of the FAIR control system to aid semi-automated testing

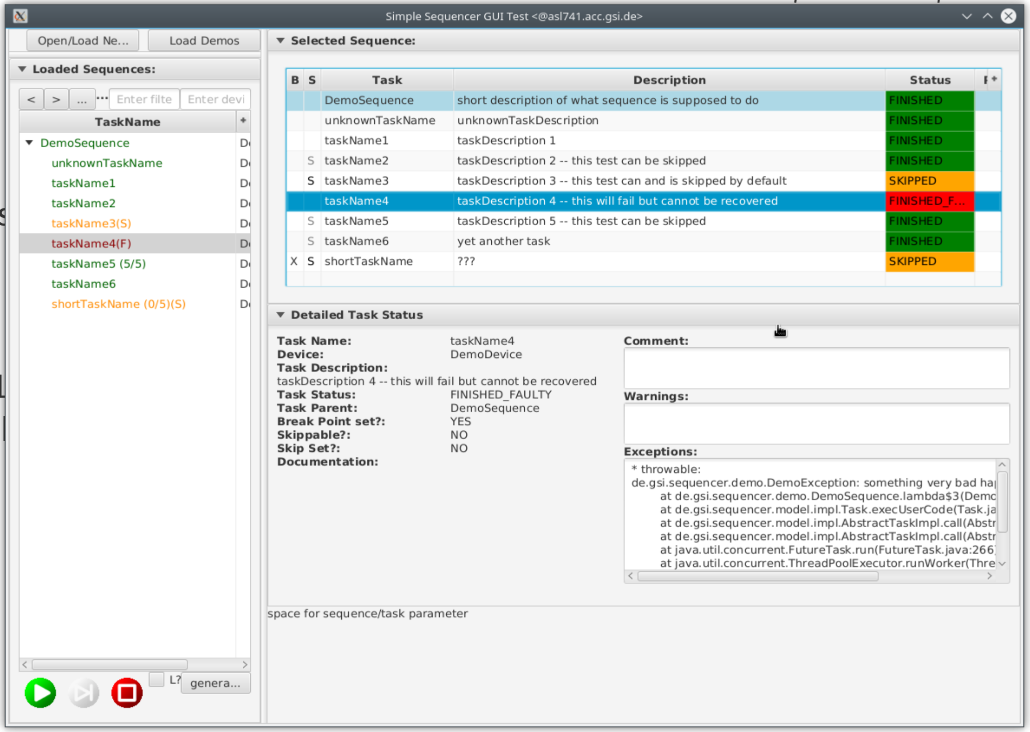
Sequencer architecture conceptually divided into:

- middle-tier *sequencer service* (run sequences, generate automated reports)
- the *sequences* with a subset of *tasks* (testing steps
- graphical user interface (GUI) program

Operational experience so far:

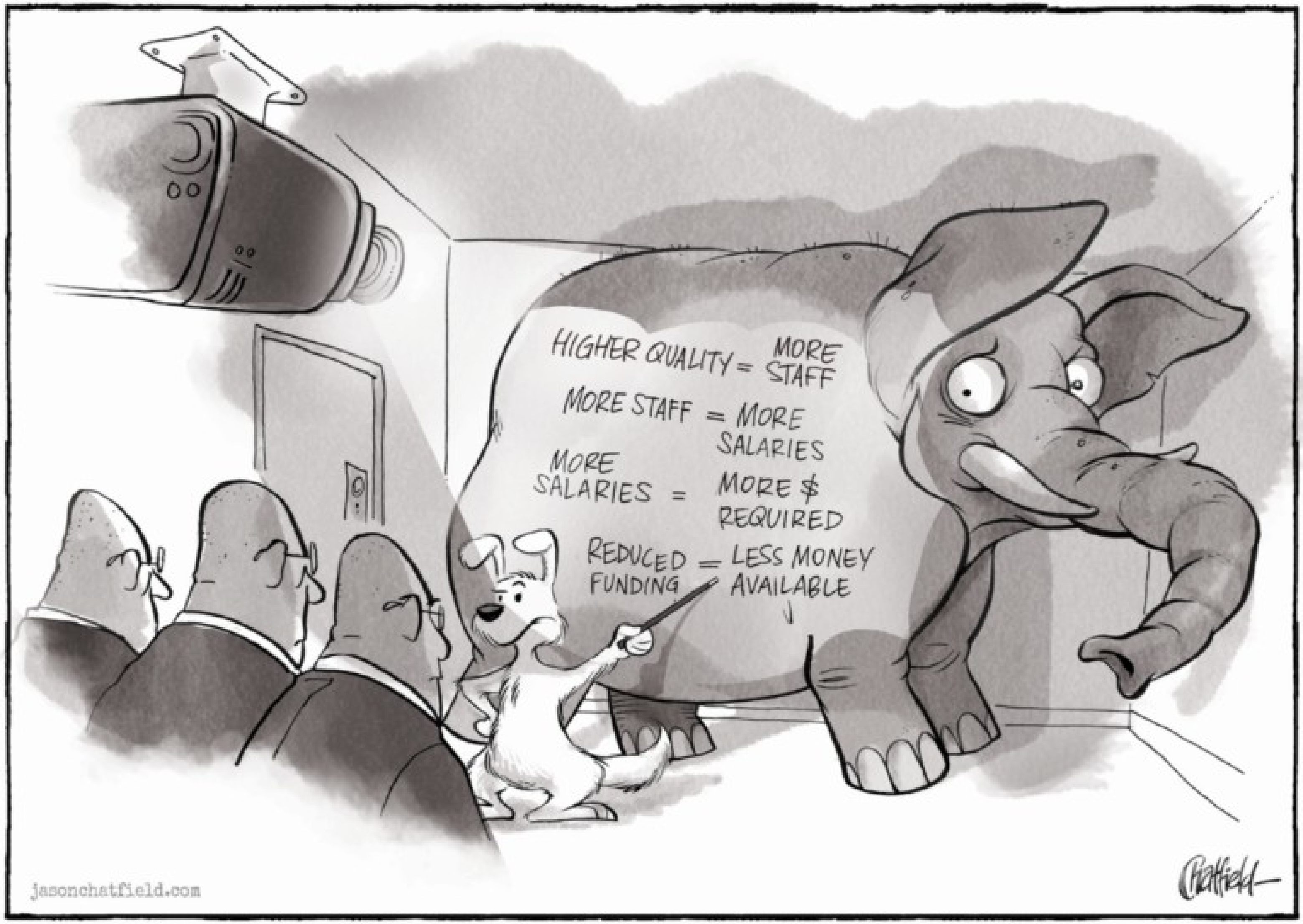
- was tested and used already since Dry-runs in 201
- establish process of writing Sequencer tasks parall to development (in progress)

Sequencer GUI impression



The Elephant in the Room … Status

… or: “when will this all be operationally available.”



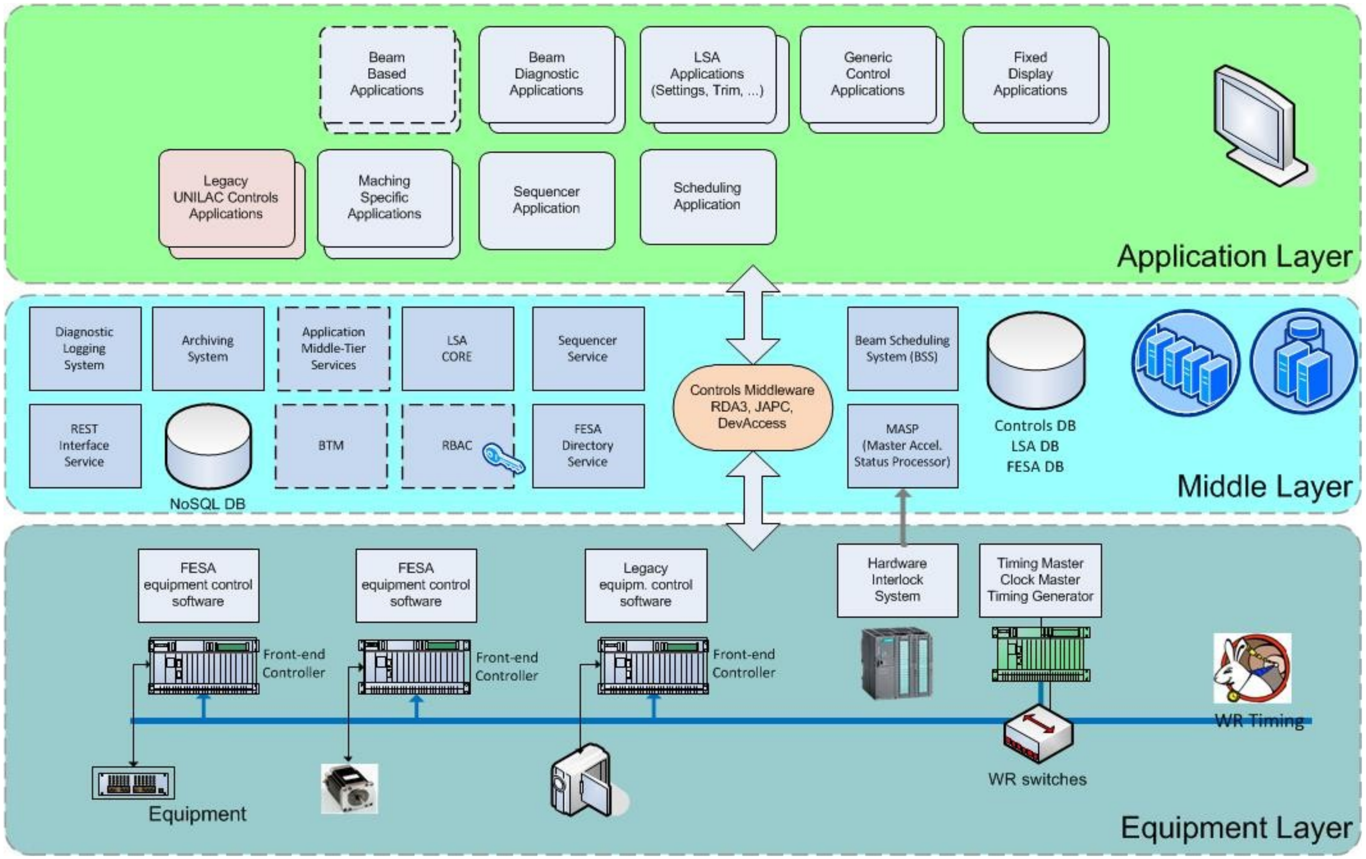
Control System Architecture Stack

Not exhaustive...

Presentation Tier

Middle Tier powerful servers

Resource Tier FESA



???

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

Topics vs. Resources & Staging

R. Bär & R. Steinhagen

topic started
topic active
topic not started

...
BC-Stage B,
BC-Stage C,
Machine Availability Anlysis, adv. beam parameters optimisation, FAIR performance model, optimisation,

functionali
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2025
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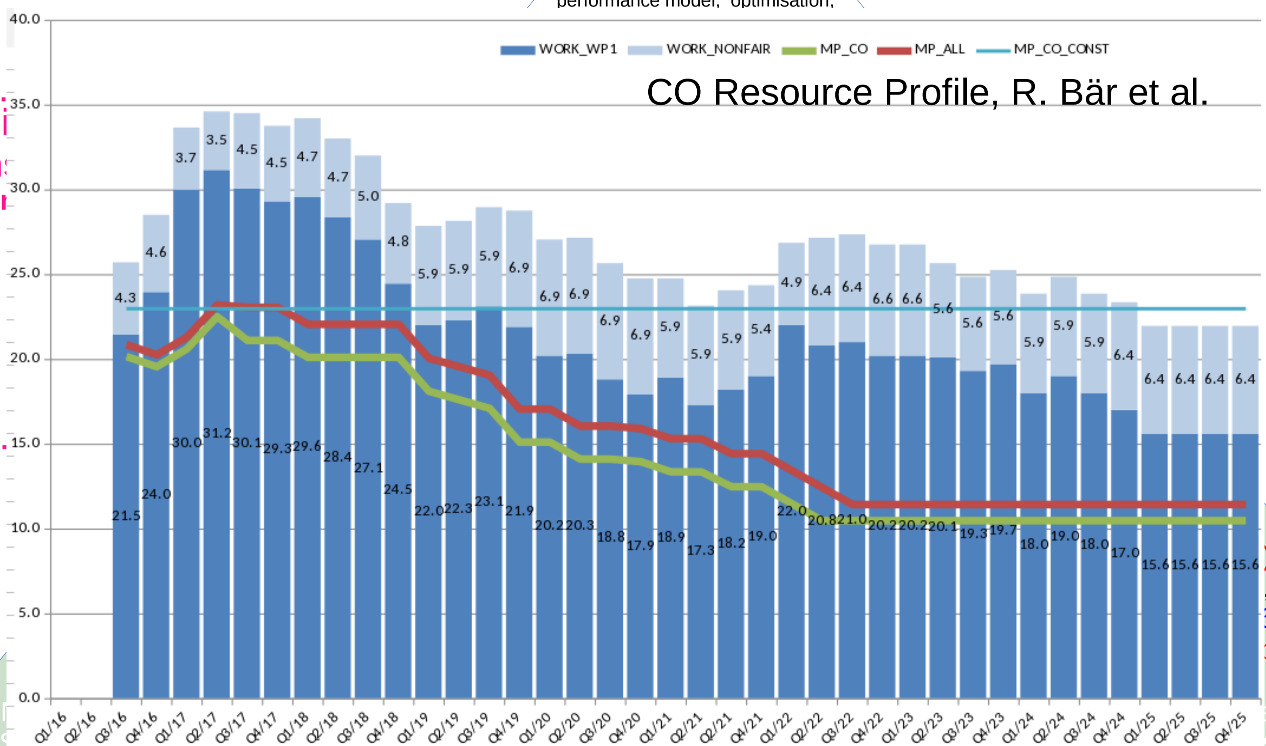


FC²: 105 person-years (missing)

ACO:
203 person-years

), , , 6): plication, Schottky, al Settings
(MCS), ... , Web Facility Overview ("Page-1"), Web Developments, Fixed Displays, MASP GUI, Beam Requestor GUI, Archiving GUI, Fast Beam Abort, Post Mortem Analysis, Monitoring GUI, IonSource GUI, BTM GUI

Control System Effort & Cost Comparison

GSI/FAIR ↔ CERN (COCOMO II -based)

	GSI/FAIR		CERN
Total:	**3.2 MSLOCs**	**Min:**	**12.0 MSLOCs**

legacy systems → f90

language:	SLOCS
java:	1236810 (38.38%)
cpp:	990110 (30.73%)
ansic:	492459 (15.28%)
f90:	160651 (4.99%)
python:	159864 (4.96%)
sh:	74152 (2.30%)
fortran:	49298 (1.53%)
asm:	30226 (0.94%)
php:	17493 (0.54%)
pascal:	7662 (0.24%)
ada:	1177 (0.04%)
yacc:	1113 (0.03%)
perl:	917 (0.03%)
tcl:	285 (0.01%)
awk:	105 (0.00%)

language:	SLOCS
java:	8618862 (71.80%)
cpp:	2592078 (21.59%)
ansic:	558217 (4.65%)
python:	129853 (1.08%)
sh:	53927 (0.45%)
ada:	14382 (0.12%)
perl:	13609 (0.11%)
php:	12506 (0.10%)
cs:	3556 (0.03%)
ml:	2052 (0.02%)
tcl:	1780 (0.01%)
jsp:	1302 (0.01%)
csh:	968 (0.01%)
yacc:	959 (0.01%)
awk:	328 (0.00%)
exp:	281 (0.00%)
fortran:	72 (0.00%)
sed:	11 (0.00%)
ruby:	7 (0.00%)

N.B. here:

SLOCS total physical Source Lines of Code

FTE person-year (Full-Time-Equivalent) according to COCOMO (II)

costs intern:
1 FTE = average salary = 50 kEUR/year (overhead = 2.40)

costs extern:
1 FTE = average salary = 160 kEUR/year (overhead > 2.40)

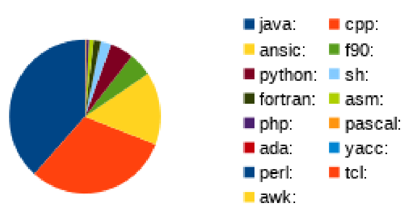
generated using David A. Wheeler's 'SLOCCount'.

	GSI/FAIR	CERN
Development Effort Estimate	**871 FTEs**	**3320 FTEs**
Total Estimated Cost to Develop	**104 MEUR**	**395 MEUR**

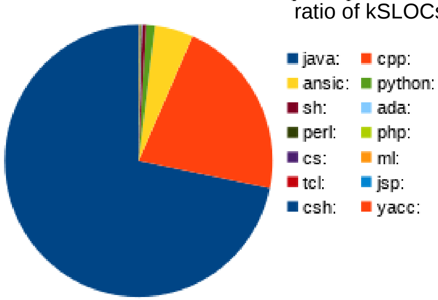
N.B. FTEs are very rough estimates with large error bars for a project of this size… !!

→ in-lack of better tools at least qualitative scaling, relations and order of magnitude seems reasonable

GSI code base (SVN)
ratio of kSLOCs



CERN code base (SVN)
ratio of kSLOCs



FAIR Control Centre (FCC)

https://edms.cern.ch/document/1821654/

Requirements & Conceptual Design – primary goals:

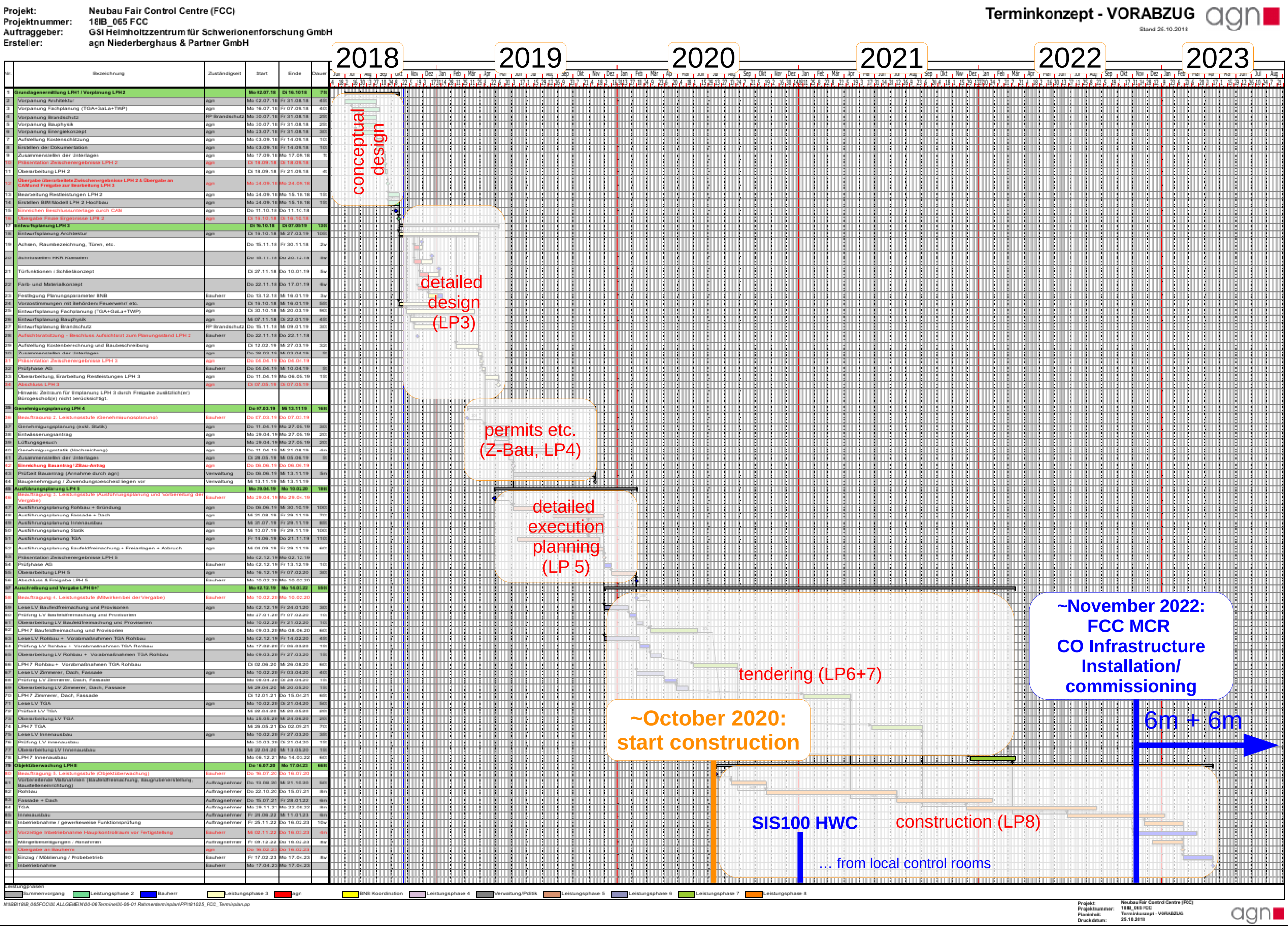
- provide sufficient room for the operation of the existing and enlarged GSI/FAIR facility
  - includes control of technical infrastructure, cryogenics, and storage-ring experiments or those tightly interwined with acclerator operation
- **Ergonomics: Main Control Room should not "get in the way of it's primary function"**
  - establish functional relationships between MCR & ancillary rooms
  - validate/check w.r.t. FAIR Commissioning & Control concept
  - validate/check whether input for building planner is feasible and consistent with DIN/ISO norms
- Keep within set budget

thumbs-up to our directorate that respected & honoured user ergonomics requirements

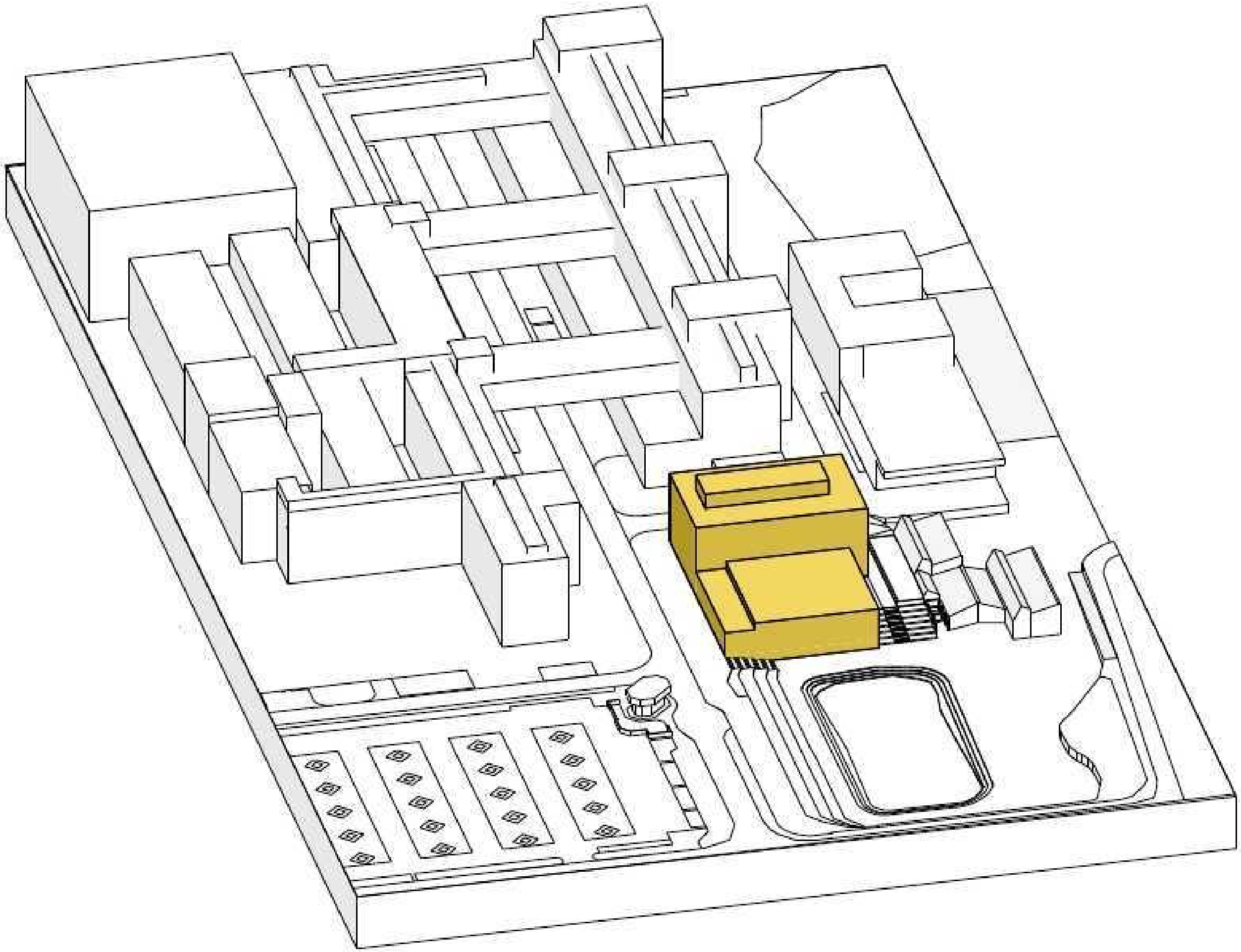
FCC estimated "ready" for HWC starting 2022 (+ backup option)

Open issues:

- OP-readiness (notably UNILAC) to move to new FCC building

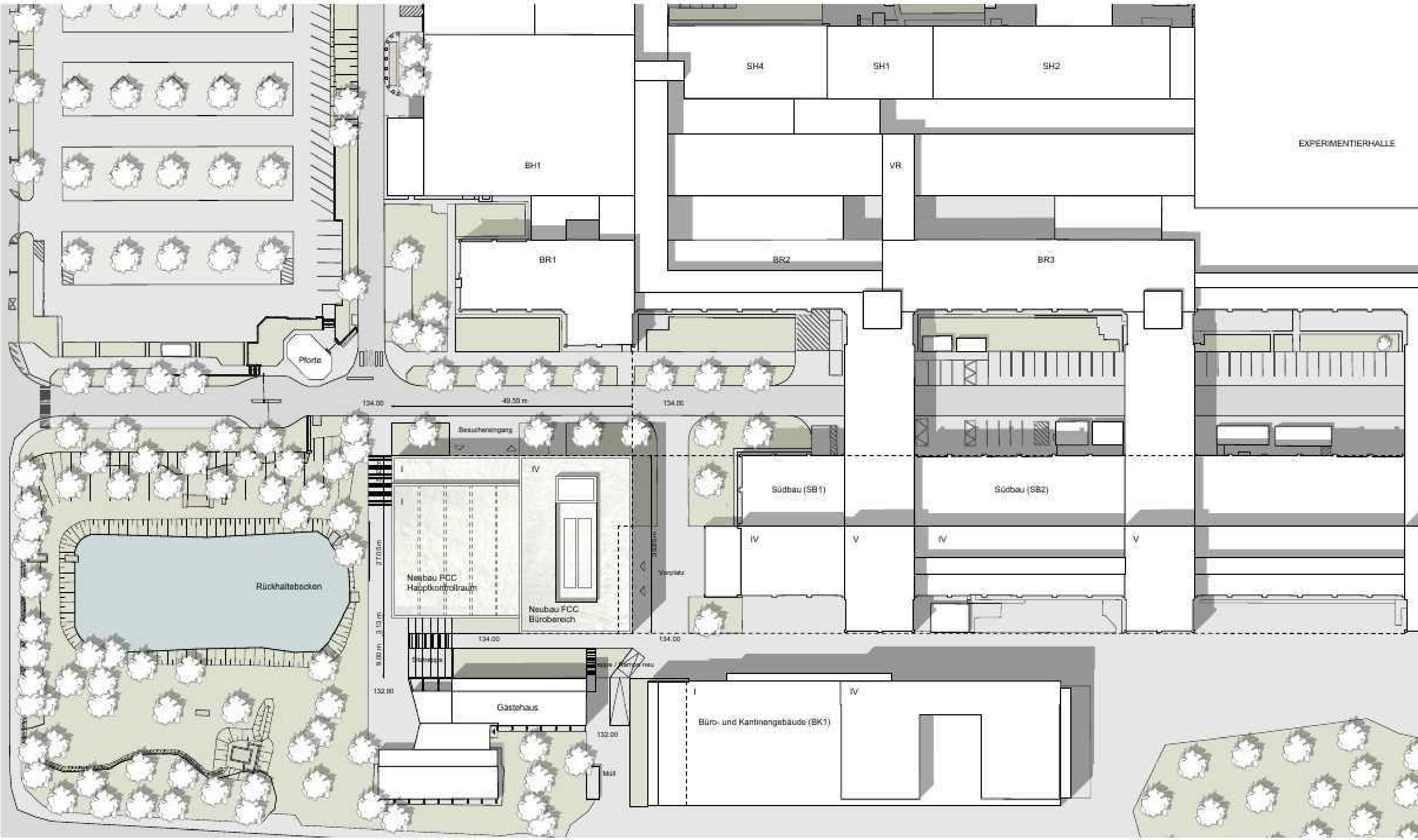

Projekt: Neubau Fair Control Centre (FCC)
Projektnummer: 18IB_065 FCC
Auftraggeber: GSI Helmholtzzentrum für Schwerionenforschung GmbH
Ersteller: agn Niederberghaus & Partner GmbH
Terminkonzept - VORABZUG
Stand 25.10.2018
2018
2019
2020
2021
2022
2023
conceptual design
detailed design (LP3)
permits etc. (Z-Bau, LP4)
detailed execution planning (LP 5)
tendering (LP6+7)
~October 2020: start construction
~November 2022: FCC MCR CO Infrastructure Installation/ commissioning
6m + 6m
SIS100 HWC
construction (LP8)
… from local control rooms

FAIR Control Centre (FCC)
LPh2/3 concept



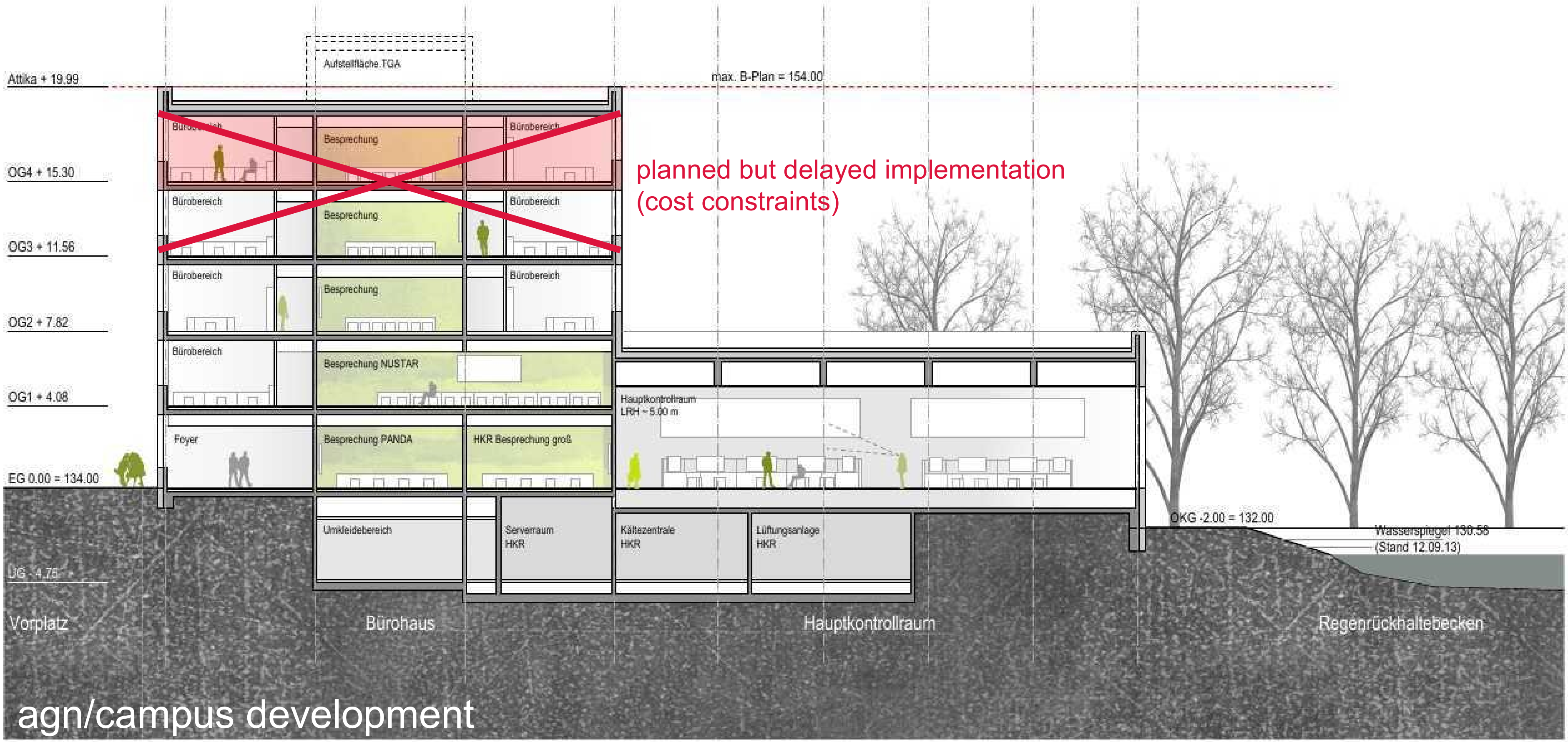
FAIR Control Centre (FCC)

LPh2/3 concept



FAIR Control Centre (FCC)

Co-use by Accelerator and Experiments



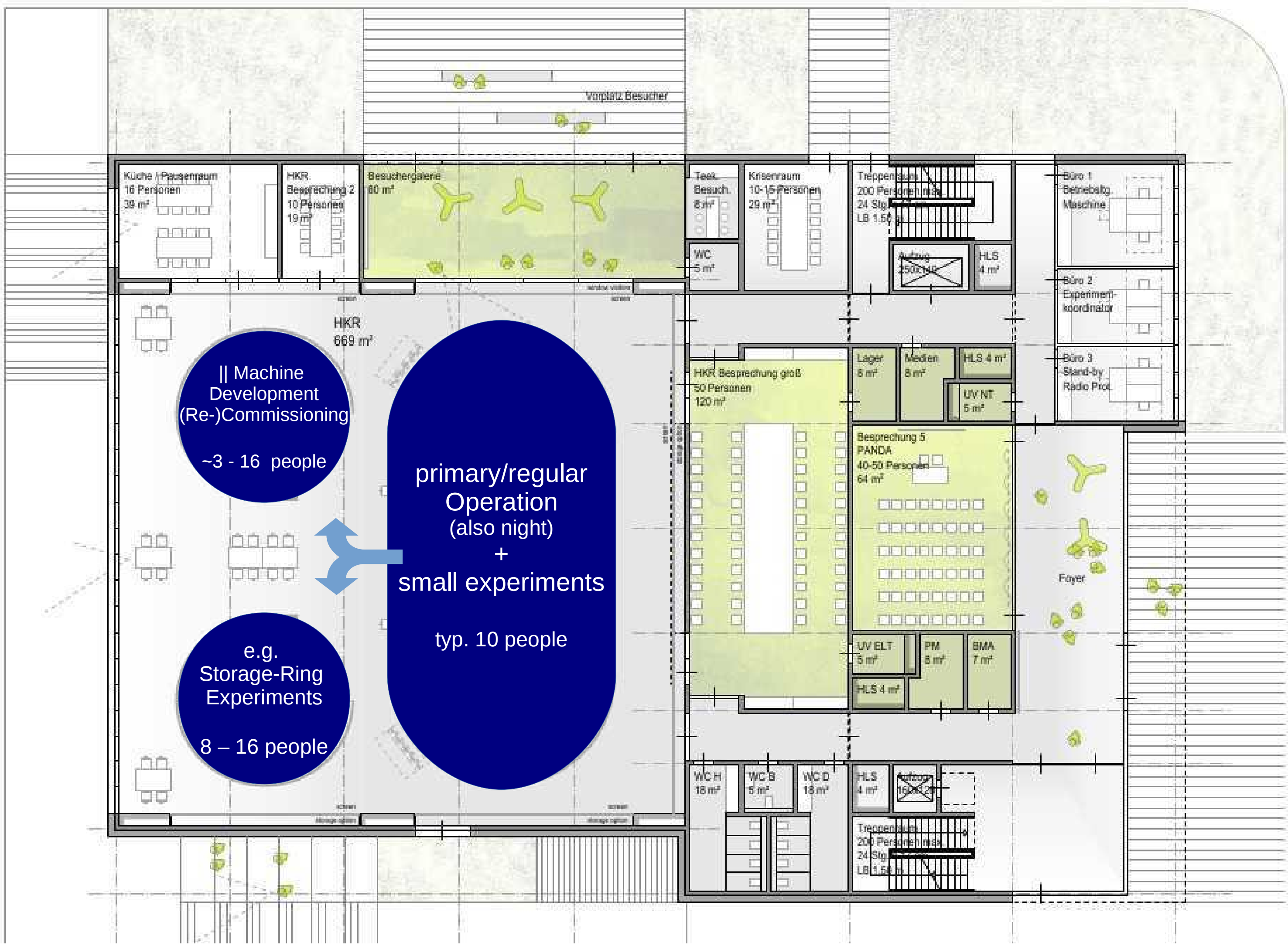
planned but delayed implementation
(cost constraints)

FAIR Control Centre (FCC)

Architectural View/Context

FCC Main Control Room Floor

... work in progress



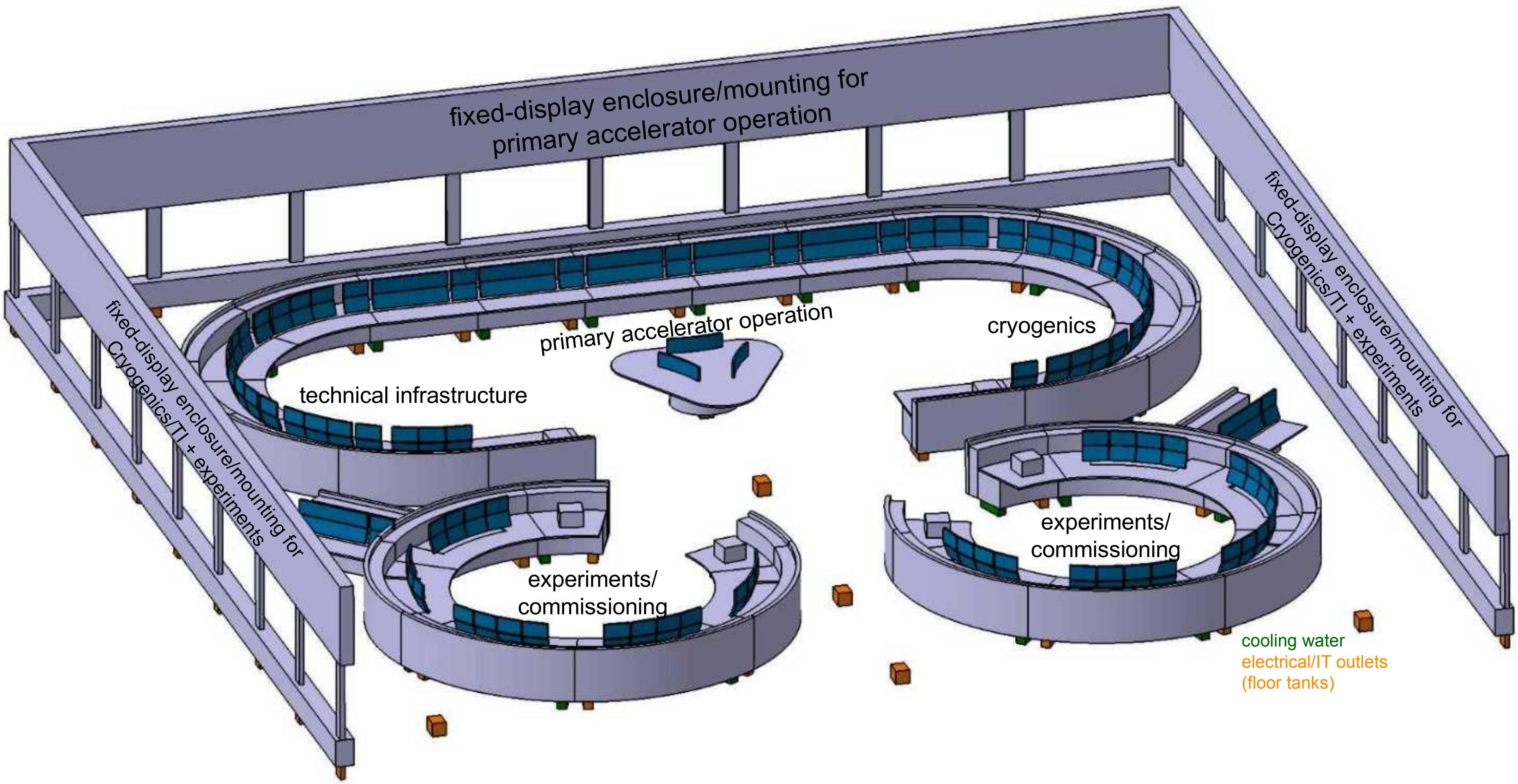
FCC Primary-User Concept

Main Control Room – Interior View (100° view angle)

FCC Primary-User Concept
Main Control Room – Visitor View #1

FAIR Control Centre (FCC)

Mechanical Console and Fixed-Display Pre-Design



David See et al.

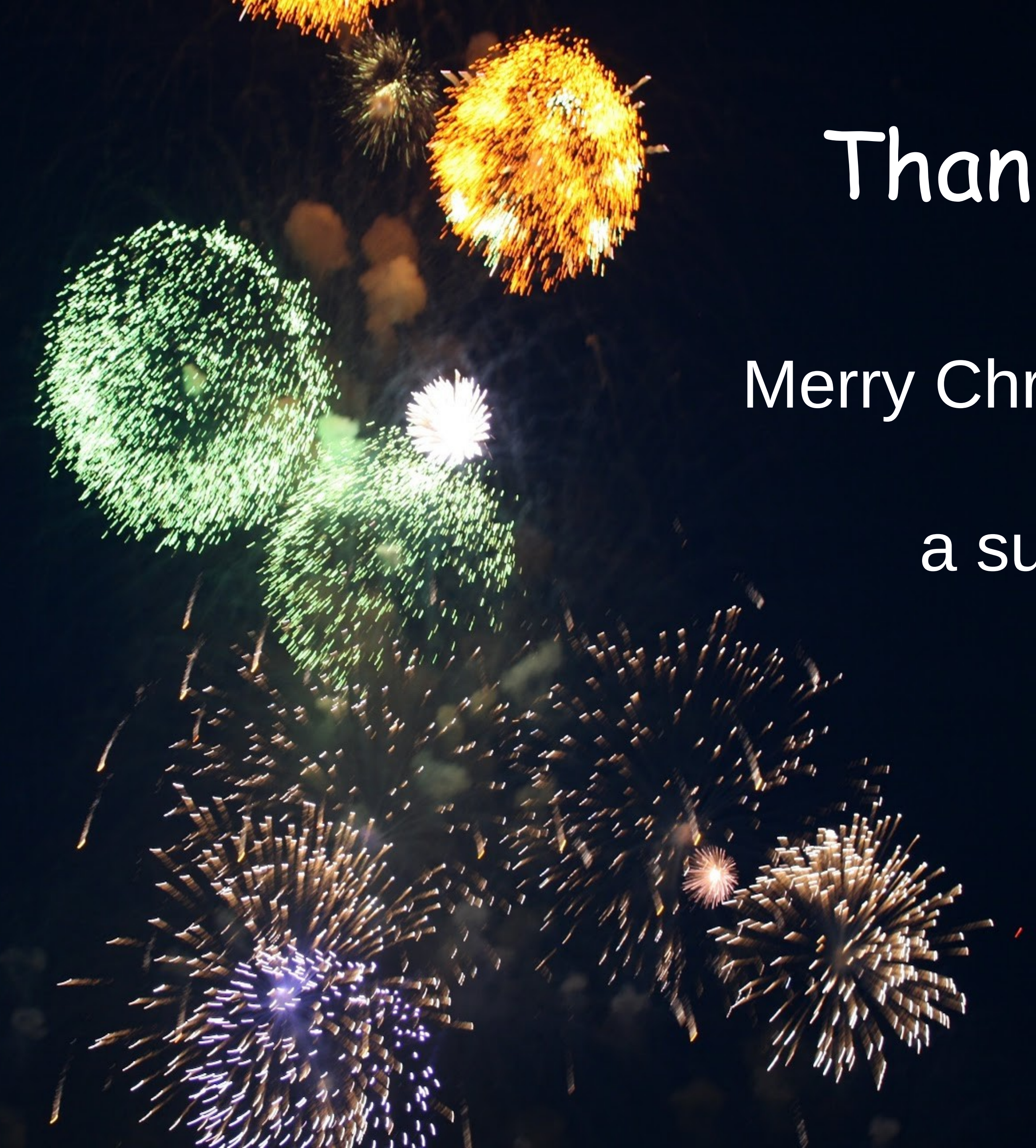
Summary

- FAIR basics from a commissioning & operation point of view:
  - Facility size quadruples → non-linear operational complexity increase $O(n^2)$ → $O(n^5)$
  - 5-7 parallel experiments + typically lasting only 4-5 days → world-wide unique requirement: reconfigure facility on a daily basis
  - new challenges w.r.t. GSI:
    - x10-100 higher intensities, x10 higher energies → machine protection & losses/activation become an important issue
    - machine and beam parameter control on the sub-percent level →beyond static feed-forward (open-loop) machine modelling and machine reproducibility
    - have to be able to operate FAIR with reduced OP skeleton crew of ~5-6 operators → minimise unnecessary stress on OP crews

- FC^2-strategy driven by:
  - Continuous improvement process
    - commissioning procedures as evolving operation and commissioning standard
    - system integration: determine of what, how and when is needed
  - Prevention of inefficiencies, inconsistencies & wastes by design → 'poka-yoke'/'error proofing' principle (example: digitizer/fault isolation)

- Main Optimisation Strategies:
  - Improved model based control: quasi-periodic operation, beam-production-chain concept, … → LSA operationally deployed since 2018
  - Beam-Based feedbacks and (semi-)automated setup tools are key ingredient for efficient operation and commissioning → optimise and automise routine task so that OP talents are utilised/focused on more important tasks that cannot be automated
    - actual-vs-reference monitoring system, semi-automated setup tools, classic beam-based feedbacks, and Sequencer to automate tasks not yet covered by other tools
    - requires serious controls integration efforts and resources (~ 3 → 12 MSLOCs)
      - Basic control system functionality to be implemented by 2025 (still challenging task) → be patient
      - Efficiency improving (semi-)automation is planned and scheduled but lacks implementation resources → be even more patient
        - constructive skilled contributions/resources are welcome ...

- FAIR Control Centre and Main Control Room on track → expect installation/commissioning by Q1/2023



Thank You!

Merry Christmas!

&

a successful 2019!

References

- HIC4FAIR'15 (Hamburg):
  - *"Options for Parallel Operation"* → link
- HIC4FAIR'16 (Rheingau):
  - *"FAIR Commissioning & Control WG - Status & Strategy Update"* → link
  - *"Machine Experiment Interface - 2nd Iteration"* → link
- Special FC2WG & FCC Projectgroup Info-Meeting'17
  - *"FCC – FAIR Control Centre -- Concepts, Requirements & Next Steps"* → link
  - K. Berkl: *"Neubau - FAIR Control Centre – FCC"* → link
- MAC'18 - Machine Advisory Committee: *"FAIR Commissioning & Control WG Status"* → *link*
- … more documentation (Google: 'FC2WG'): FC2-WG Homepage, Presentations & Minutes

FAIR Commissioning Procedures

- Develop a (initial/re-)commissioning and operation strategy:
  - memorandum of understanding between stake-holders (SPLs, MCs, AP, BI, CO, RF, ...)
    - define when, where and how the individual accelerator systems should fit in
  - identify and define missing procedures, equipment and tools, e.g.:
    - define, check the need or priority of applications vs. 'use cases'
    - define, check integration and interface between specific equipment and CO/ OP environment
  - focus first on commonalities across then specifics within individual accelerators
    - MPLs/MCs define pace & resources of how fast to achieve the above
  - dissemination/knowledge transfer from groups that constructed and performed the initial HW commissioning to the long-term operation
    - training of operational crews (physics, operation, tools, ...)
  - scheduling tool for technical stops to follow-up possible issues found

*Procedure aims not only at the initial first but also subsequent re-commissioning e.g. after (long) shut-downs, mode of operation changes and/or regular operation

Accelerator Controls Commonalties/Differences GSI/FAIR ↔ CERN

	GSI/FAIR	CERN
vertical/horizontal controls integration:	• ACO (alone) bears full responsibility for controls core infrastructure, vertical and horizontal integration • notable exception: BI & partially: Ring-RF	• Equip. groups responsible for vertical HW & SW integration • CO responsible for controls core infrastructure and some lateral systems (timing, LSA, Oasis, Alarms, ...) • OP et al. heavily involved in horizontal integration & control room apps development
settings supply (LSA-based)	• Beam-Production-Chain, Pattern and flexible Beam-Process- & Timing concepts → different lab-specific implementations	• Super-Cycle, Hypercycle & semi-static Timing concepts → different lab-specific implementations
control room visualisations/tools:	• only few (legacy-type) Java/Swing dependencies • JavaFX as primary workhorse for applications • strong Java/C++ community • very small Python community (↔serious maintenance issues) • evaluating: C++/Qt & WebAssembly	• massively invested into Java & Swing (500+ apps) • custom web-based technologies/tools • JavaFX projects now frozen → discontinued • strong Java & Python community • evaluating: Python/Qt & WebAssembly
controls code base	3.2 Million SLOCs • ~10% to be replaced legacy	• 12 Million SLOCs
application devs outside controls:	• only a few CO-type devs outside ACO: 3 BI, 2 SYS, 3 OP (beginner) ACO: 2 (+1) JavaFX + 2 Java-Swing-only devs • 1 web-based app developer (OP)	• est. total: > 100 FTEs (BE-BI, BE-CO, BE-ICS, BE-OP, BE-RF, BE-ABP, ...) • producing the bulk of useful (often rapid-prototyped) tools • second-job of many operators and EICs • nearly all groups have their own SW section with their application developer
experiment client composition:	• vast majority running less than a week • require (presently) typically 1-2 days to setup	• long-running experiments (weeks … months, ie. @ LHC) • less overhead w.r.t. machine setup vs. beam-on-target
accelerator operation:	• GSI: pool of about 20 operator (2-3 Ops/shift) • FAIR: 5-6 acc. Ops/shift + 1-2 Cryo-/TI-Ops/shift • very-low degree of automation: predominantly manual tuning based on analog hardware	pool of about 90+ operators/EICs (+ Cryo/TI Ops) • high degree of automation, beam-based tools, modular system design, …