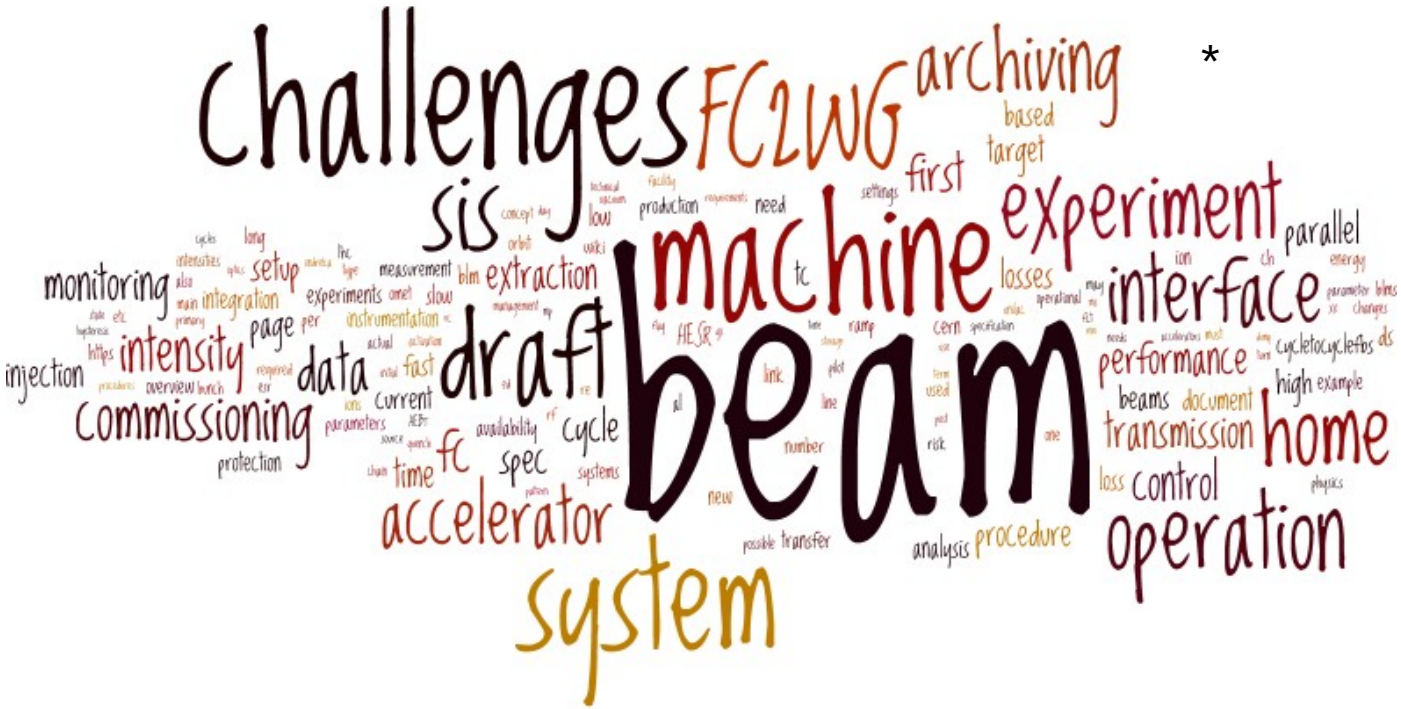
2018 Recommissioning & Dry-Run Strategy and Planning



*

Ralph J. Steinhagen, S. Reimann, D. Severin for the FC²WG

* based on 2015/16 FC2WG presentations & meeting minutes

An attempt on defining a ...

FAIR Figure of Merit

- Integrated Luminosity per experiment

$$\frac{\int \mathscr{L}(t)\,\mathrm{d}t}{\left[\int \mathscr{L}\,\mathrm{d}t\right]_{\mathrm{ref}}} \sim \int_{\mathrm{OP\ year}} \underbrace{\frac{dN_{\mathrm{ions}}/dt}{\epsilon_{\mathrm{x,y,s}}}} \cdot \underbrace{\varepsilon_{\mathrm{FAIR}}} \,\mathrm{d}t$$

Experiment constraints:

- dN_{ions}/dt constant (spill-structure)
- $dN_{ions}/dt|_{max}$ constraints
- ...
- beam brightness: N_{ions} & $\varepsilon_{x,y,s}$
  - x 10-100 higher intensities N_{ions}
  - x 10 beam energies
    → **new:**
  - machine protection
  - activation/loss minimisation (ALARA)

FAIR efficiency (simplified):

$$\varepsilon_{\mathrm{FAIR}} \approx \frac{\langle t_{\mathrm{physics}} \rangle}{\langle t_{\mathrm{physics}} \rangle + \langle t_{\mathrm{operation}} \rangle + \langle t_{\mathrm{down\text{-}time}} \rangle}$$

Primary FC²WG goals:

1. efficient operation
2. better & safe beam control

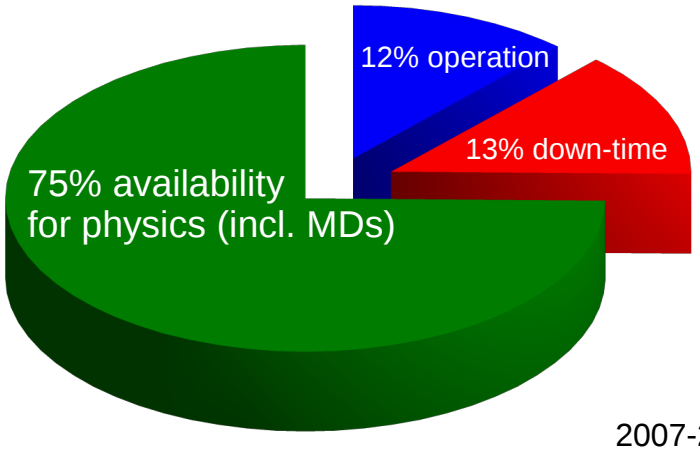
… across the whole accelerator facilitiy

SIS18 Operation Experience & Efficiency

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

Statistik Betrieb | Beginn 01.01.2014 22:00 | Ende 31.12.2014

Status	Ereignis	Gesamt	Minuten	Prozent
SAT	Strahl auf Target (inkl. Nachoptimieren)	12000.35 h	720021	50.18
NO	Nachoptimieren	92.63 h	5558	0.39
STDBY	Standby	6782.43 h	406946	28.36
UNTERBR		5039.55 h	302373	21.07
	EINST	2206.85 h	132411	9.23
	QW	520.52 h	31231	2.18
	AUSF	2312.18 h	138731	9.67
GESAMT		23914.97 h	1434898	100.00



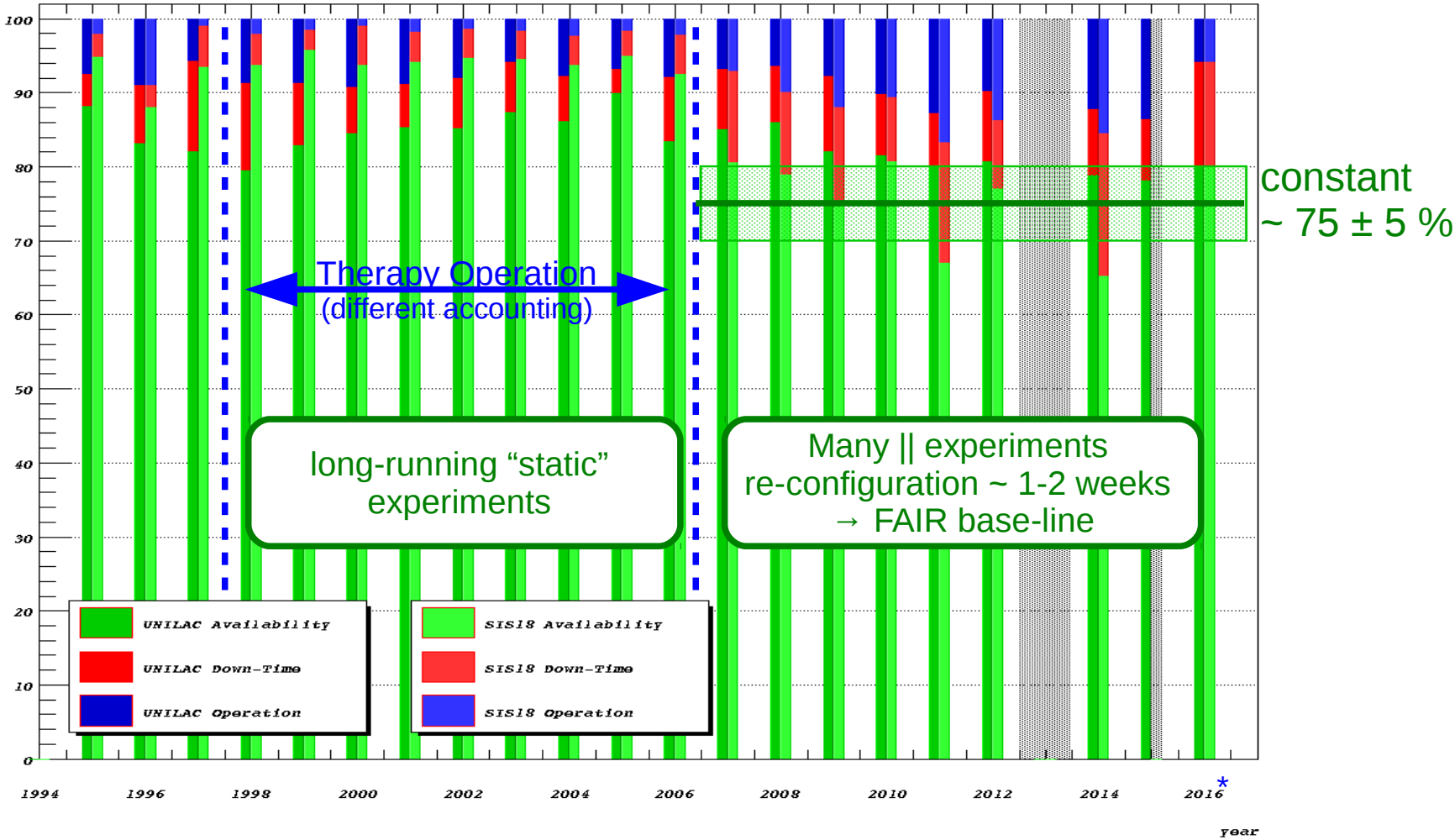
2007-2016

- simple[1,2] estimate, but relates to qualitative control room experience:
  - presently: '~ 1 shift UNILAC' + '1 shift SIS18+TL setup' ↔ 1-2 weeks of experiments
  - potential target after 2-3 years of FAIR operation:
    - simple experiments (e.g. attached to SIS18/SIS100): 1-2 shift setup ↔ 1-2 weeks beam-on-target
    - more complex experiments (e.g. at HESR): ~week setup ↔ months of operation (HESR),
- Need to factor in efficiency evolution: early beam commissioning → reaching final beam parameter
  - N.B. early SIS100-only availability indications (C. Omet et al.): 66 %

[1]possibly strong assumption that new machines can be operated with the same routine, ease and efficiency as the present GSI infrastructure, …
[2] complex beam chains (e.g. HESR) with long beam setup times are typically run longer/more static than shorter (SIS18 experiments)

Accelerator Experience & Efficiency

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



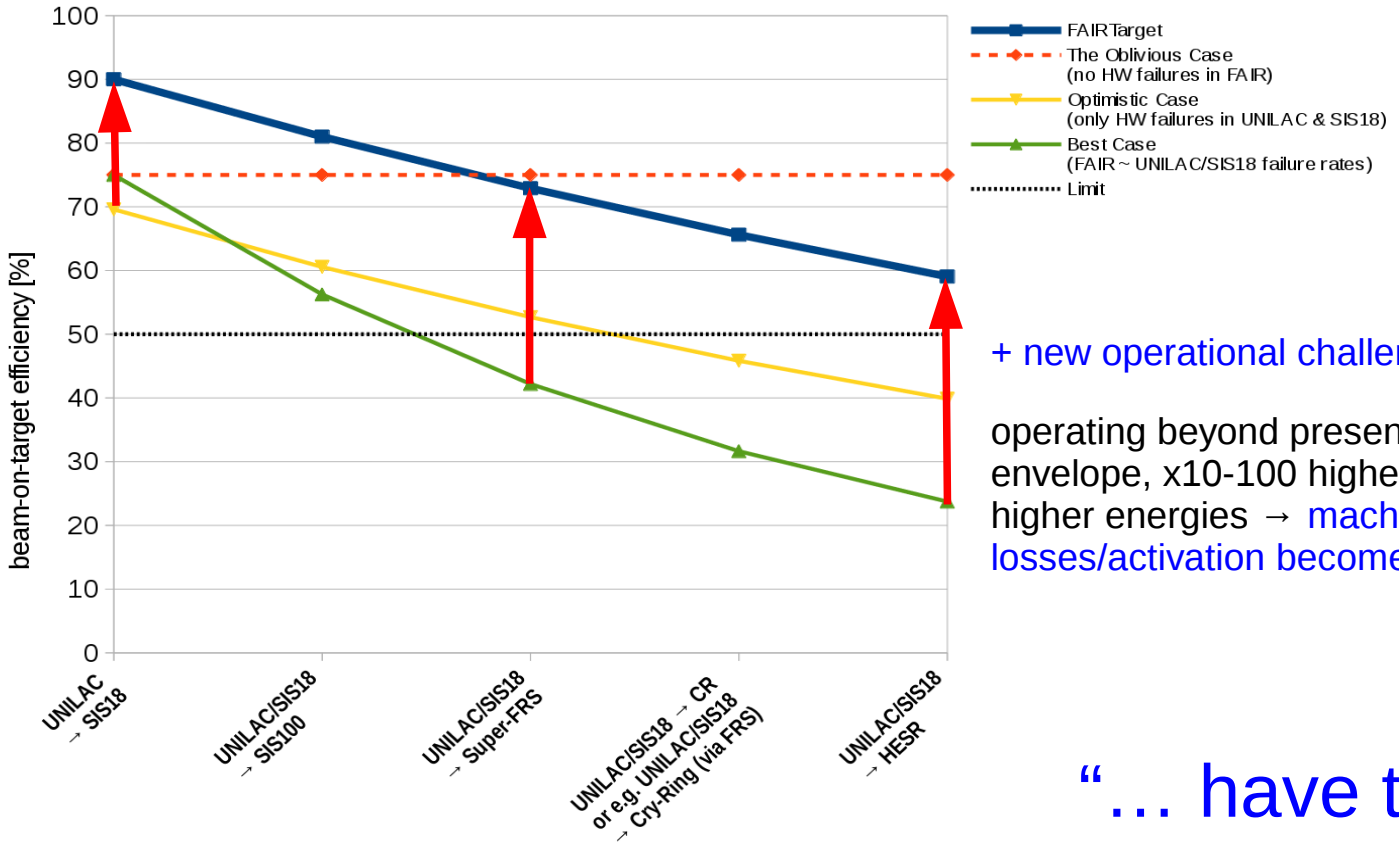
Based on: U. Scheeler, S. Reimann, P. Schütt et al., "Accelerator Operation Report", GSI Annual Scientific Reports 1992 – 2015 + 2016 (D. Severin)
https://www.gsi.de/en/work/research/library_documentation/gsi_scientific_reports.htm
N.B. ion source exchanges are factored out from UNILAC & SIS18 data (~ 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 Challenges & Constraints
… SIS18 Operation Experience & Efficiency

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

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

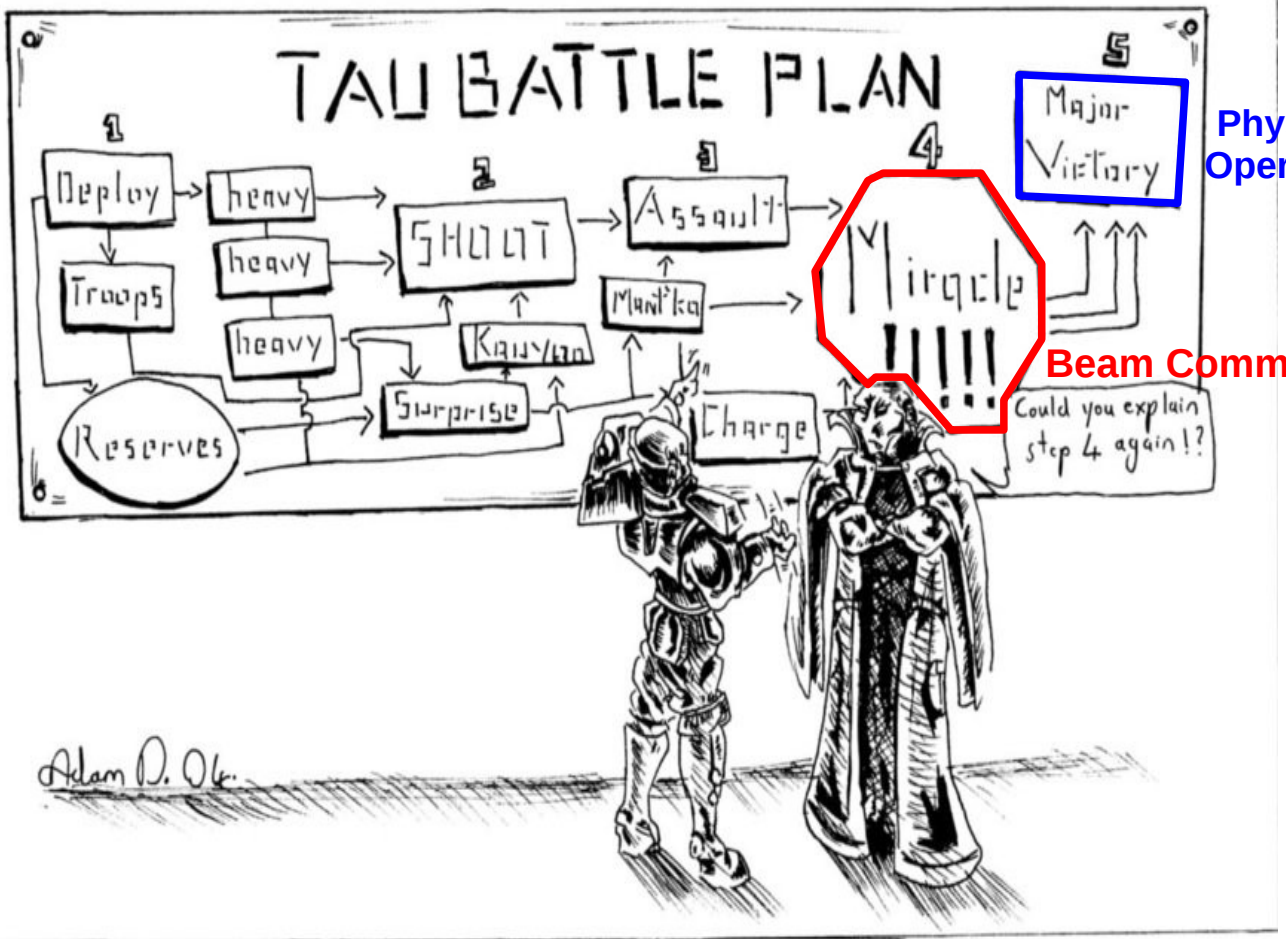


+ new operational challenges:

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

"… have to improve!"

Plan of Action



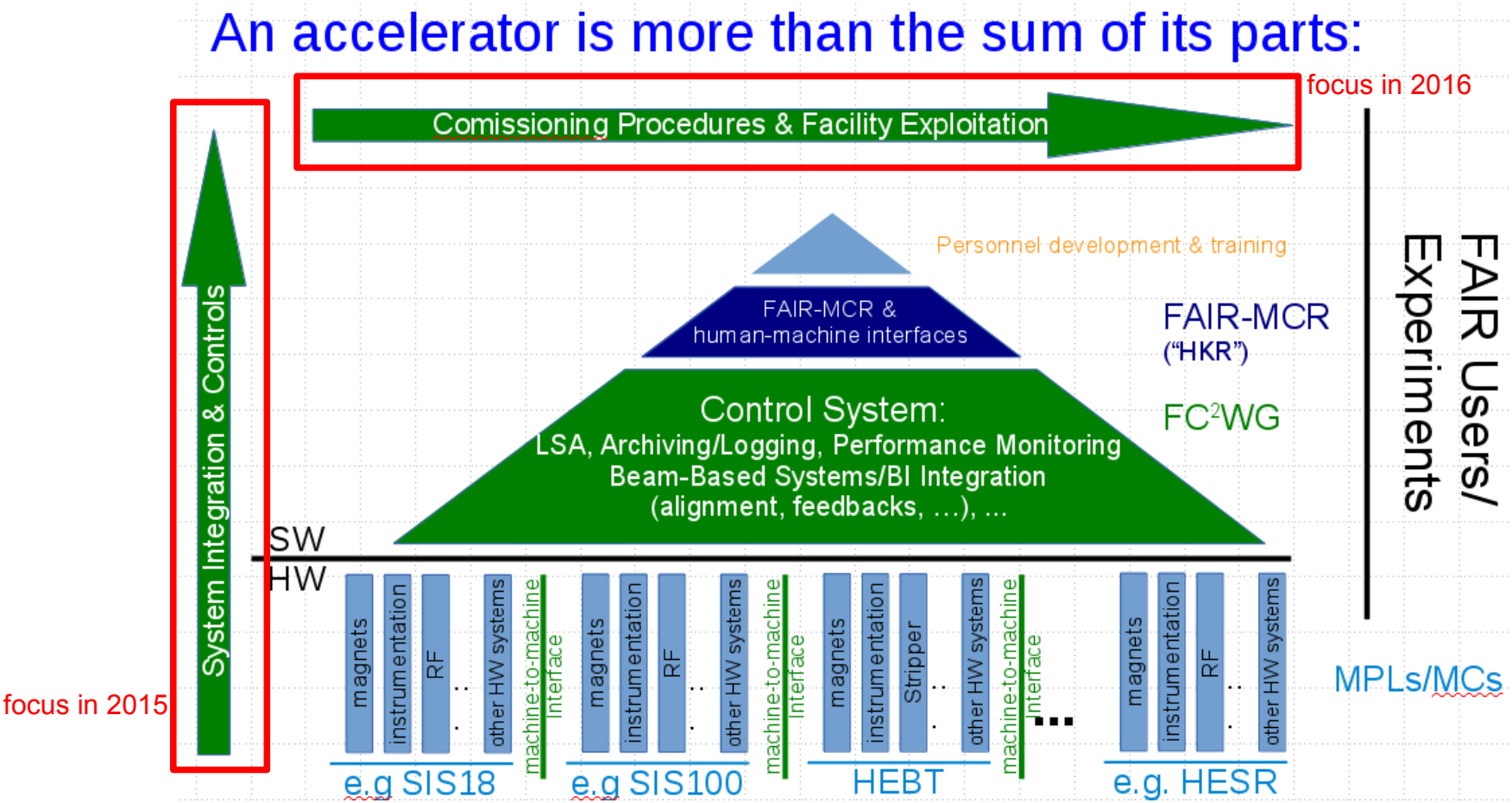
Physics Operation

Beam Commissioning

Need to be more explicit w.r.t. 'item 4' for commissioning and operation of FAIR.

FAIR Commissioning & Control WG

http://fair-wiki.gsi.de/FC2WG/



- FAIR Commissioning & Control Working Group
  - platform to discuss, coordinate and work-out FAIR commissioning and operation
  - open to all who can participate and contribute to this subject!

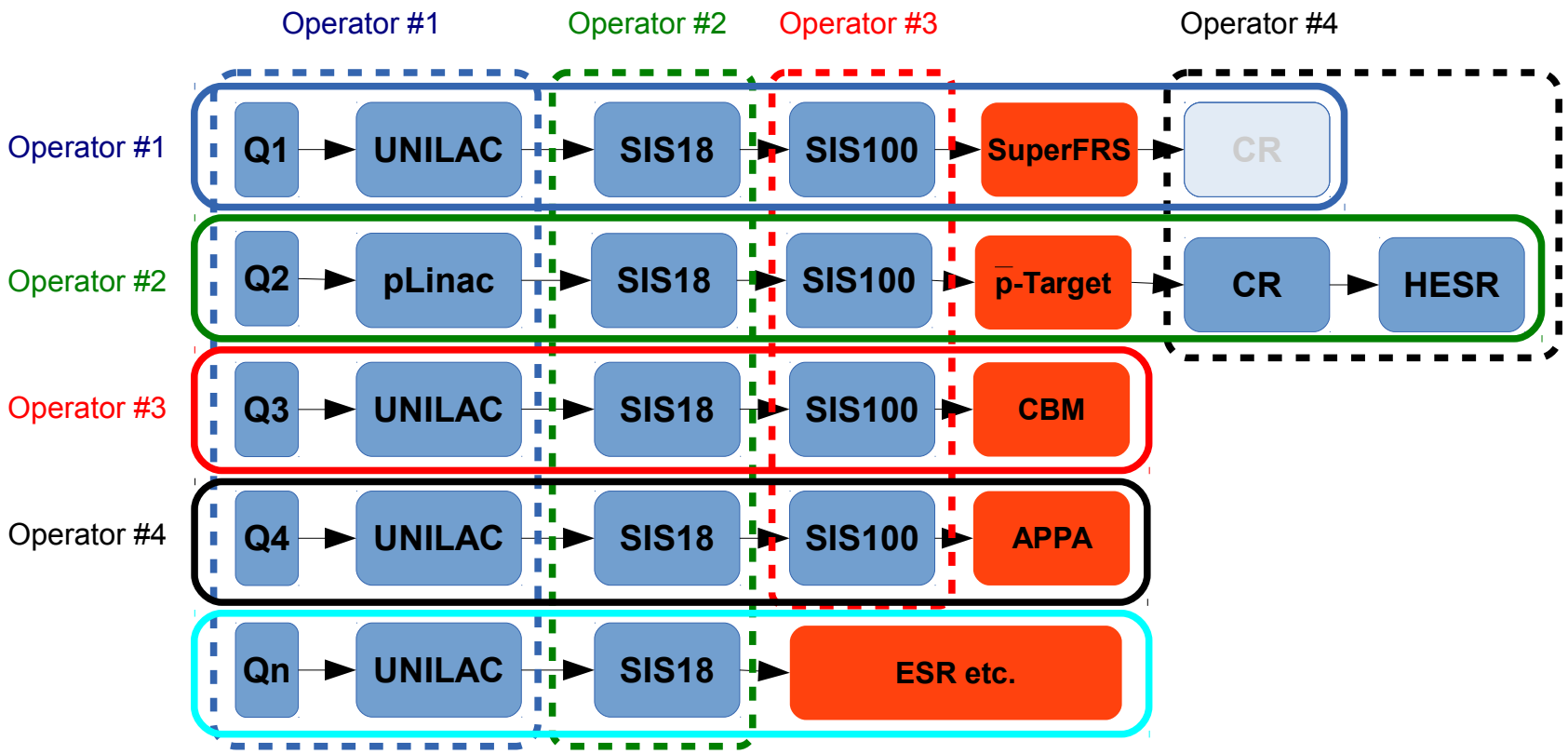
FC²WG Control Topics
– more than “Control System” & Data Supply

- Facility & Interface Analysis
  - Procedures: HWC, HWC-'Machine Check Out', BeamCommissioning, BC-Stage A (pilot beams), BC-Stage B (intensity ramp-up), BC-Stage C (nominal/production operation) Beam parameters, FAIR performance model, optimisation, Accelerator & Beam Modes
- Beam Instrumentation & Diagnostics – System Integration
  - Intensity (DCCTs) & beam loss (BLMs) → Beam Transmission Monitoring System (BTM), trajectory & orbit (BPMs), Q/Q', optics (LOCO & phase-advance), longitudinal & transverse emittance (FCTs. WCM, screens, IPM, etc.), Δp/p, long. bunch shape (FCTs, Tomography), abort gap monitoring, ...
- Accelerator Hardware – System Integration
  - Power converter, magnets, magnet model, RF, injection/extraction kicker, tune kicker/AC-dipole, beam dump, collimation/absorbers, cryogenics, vacuum, radiation monitoring, k-modulation, machine-experiment interfaces
- Control System
  - Archiving system, analog signal acquisition, test-beds, timing, bunch-to-bucket transfer, cyber security, role-based-access, middleware, RT & Feedbacks, daemons
- Components
  - post-mortem, management of critical settings (safe-beam settings), machine protection, interlocks, beam quality checks, daemons, 'Page One', aperture model, ...
- Applications
  - Sequencer (semi-automated procedures), fixed-displays, ...
  - Beam-Based Applications, Cycle-to-Cycle Feedbacks & GUIs → second talk

FAIR Operation/Control Paradigm

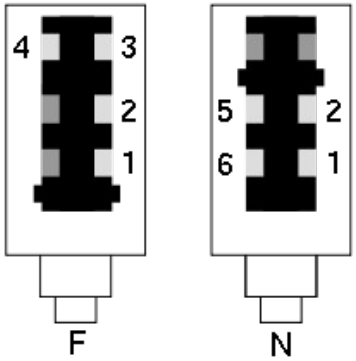
- Some important OP boundary conditions:
  - A) Compared to GSI, FAIR facility size and complexity increases roughly by a factor 4
  - B) Expect some improvement but 'Operator' & 'System Expert' will likely remain a scarce resource

- One strategy item: 'One Operator per Accelerator Domain' vs. 'One Operator per Experiment':

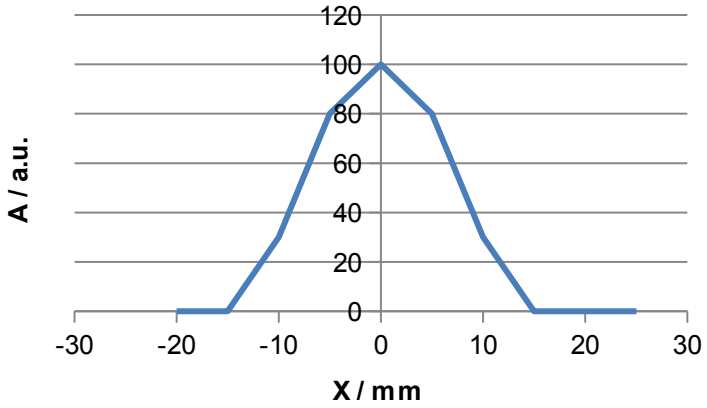


Poka-Yoke (ポカヨケ) – 'Mistake-Proofing'

- Origin:
  - to avoid (yokeru) inadvertent errors (poka)
  - industrial processes designed to prevent human errors
    - Concept by Shigeo Shingo: 'Toyota Production System' (TPS, aka. 'lean' systems)
  - minimise common mistakes, procedural errors, etc. affecting machine performance and protection



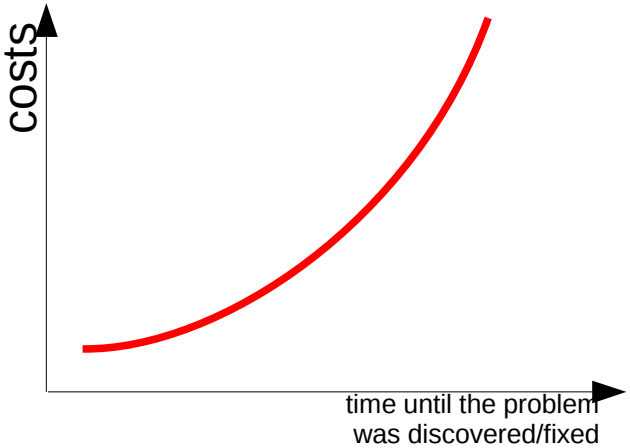
- Real-World Examples:
  - Polarity protection of electrical plugs (e.g. phone, Ethernet cable)
    - SIS18 profile grid connectors
  - Procedures: e.g. ATM machine: need to retrieve card before money is released (↔ prevents missing card)



Poka-Yoke (ポカヨケ) – 'Mistake-Proofing'
Reaction-Time and Cost → “fix” errors early

Fix problems early, when and where they occur

- Minimises procrastination of errors: “Safety starts with safe habits”!
  - big losses with big intensities → bad (activation)
  - large losses with small intensities → probably OK? … No!
    - requires paradigm change!
  - Interdependence between beam parameter & systems



- Early indication of developing/not-yet-critical faults:
  - Post-Mortem analysis ('as good as new' SIL assurance)
  - Preventative maintenance
  - fix “domino effect” problems at the source not its symptoms
    - e.g. fix problems with low-intensity beam rather than with high-intensity beam (avoids revalidation of loss patterns, MPS setup, …)
    - e.g. fix basic accelerator parameters before moving on to higher-order effect (e.g. extraction/injection energy/trajectory → orbit → tune → chromaticity → optic → … → driving term s

COMMISSIONING

≠

FAIR one-of-a-kind prototype,
pushing the ion intensity & other limits

↓

Should maintain realistic goals
& strategy how-to reach them

FAIR Commissioning Procedure I/II

- Develop a (initial/re-)commissioning and operation strategy:
  - MoU between various stake-holders (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

FAIR Commissioning Procedure II/II

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 (BPC)
    - 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

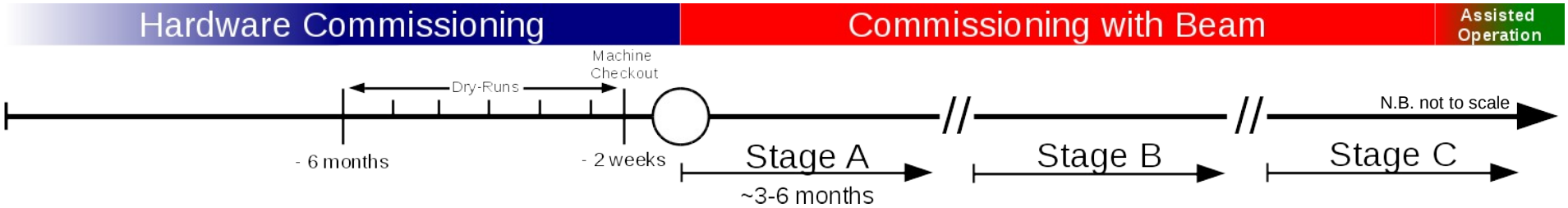
Terminology:

- **Dry-runs**: a rehearsal of the accelerator performance/function, starting typically six month before the targeted real BC
  - needs to (partially) repeated after shut-down or longer technical stop with substantial modifications
  - 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 heat runs, etc.), typically two weeks before BC
  - needs to repeated after every shut-down or longer technical stop
  - repeated also on the long-term during routine operation of existing accelerators (already existing procedures/usus for existing machines)

Dry-Runs for Accelerator
= equivalent of Pre-flight Checks in Aviation

Commissioning with Beam

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



- Split Beam Commissioning into three stages:

A) Pilot beams/"easily available" ions (e.g. U28+, 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
- <u>make fast setup and switch-over between different beam production chains routine</u>

Example: FAIR Commissioning Procedures

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

BeamCommissioning - BeamCommissioning - FC2WG - FAIR Wiki - Google Chrome

https://fair-wiki.gsi.de/foswiki/bin/view/FC2WG/BeamCommissioning/WebHome

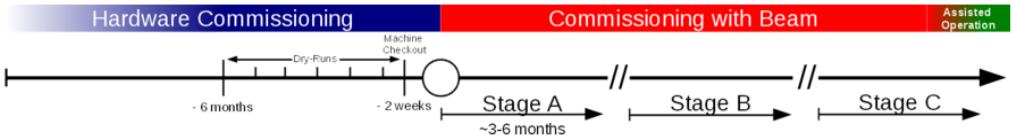
Log in | Register

Commissioning & Control Working Group (FC²WG)

Home | Minutes | Next Agenda | Dry-Runs | Commissioning Procedures | Control Topics | Admin

BC Overview
Stage A - Pilot Beams
Phase A.1 - Injection and First Turn
Phase A.2 - Circulating Pilot
Phase A.3 - Injection initial Commissioning
Phase A.4 - Ramp
Phase A.5 - Injection & Extraction Optics
Phase A.6 - Extraction
Phase A.7 - Final Focus/Target Steering
Phase A.8 - Preliminary Physics runs
Phase A.9 - Special aspects
Stage B - Intensity Ramp-up
Phase B.1
...
Stage C - Production Operation with nominal Intensities
Phase C.1
...

You are here: FC2WG » BeamCommissioning



The Commissioning with Beam (BC) for FAIR is grouped into the following three stages:

Stage A - Pilot Beams

Main focus for 2018
(re-commissioning, new CO)

- **main aim**:
  - drive the beam expeditiously through the BeamProductionChain (BPC): from the sources, through the synchrotrons, beam transfers, up to the experimental targets/storage rings
  - check basic 'accelerator mechanics': threading, injection, capture, cool, convert, acceleration/decelerate, stripping & extraction
  - identify beam-related limitations: polarities, RF, beam instrumentation, machine alignment, effective physical machine aperture, ...
- always done with 'safe' resp. low-intensity/brightness beam
  - initially with 'easily available' ions (e.g. U28+, Ar -> simpler optics, beam dynamics, etc.), then protons (tests transition crossing, etc.)

Stage B - Intensity Ramp-up & Special Systems

- **main aim**:
  - achieving and maintaining nominal machine performance for a limited number of reference beam
  - check that the accelerator design and systems can achieve (near) nominal beam parameters, e.g. beam intensities, nominal transmission and beam losses for e.g. U28+ & proton beams, etc.
- commissioning of e.g. e-cooler (if not needed earlier), slow extraction, transverse fast feedbacks
- commissioning and validation of machine protection & interlock systems
- possibly unsafe operations always preceded by checks with safe beam

Stage C - Production Operation with nominal Intensities

- **main aim**:
  - make fast setup and switch-over between different BeamProductionChains routine
  - push physics and beam parameter performance (intensity, brightness/emittance, momentum spread, ...)
  - identify and improve upon bottlenecks impacting FAIR's 'figure-of-merit'
  - improve the machine model using beam based techniques

Log in or Register

Toolbox
Create New Topic
Index
Search
Changes
Notifications
RSS Feed
Statistics
Preferences

Webs
FC2WG
BeamCommissioning
HardwareCommissioning
Main
Sandbox
System

Example: FAIR Commissioning Procedures

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

BCStageA1 - BeamCommissioning - FC2WG - FAIR Wiki - Google Chrome

https://fair-wiki.gsi.de/foswiki/bin/view/FC2WG/BeamCommissioning/BCStageA1

Commissioning & Control Working Group (FC²WG)

Home | Minutes | Next Agenda | Dry-Runs | Commissioning Procedures | Control Topics | Admin

BC Overview
Stage A - Pilot Beams
Phase A.1 - Injection and First Turn
Phase A.2 - Circulating Pilot
Phase A.3 - Injection initial Commissioning
Phase A.4 - Ramp
Phase A.5 - Injection & Extraction Optics
Phase A.6 - Extraction
Phase A.7 - Final Focus/Target Steering
Phase A.8 - Preliminary Physics runs
Phase A.9 - Special aspects
Stage B - Intensity Ramp-up
Stage C - Production Operation with nominal Intensities

You are here: FC2WG » BeamCommissioning » BeamCommissioningStageA » BCStageA1

FAIR Commissioning Phase A.1) - Injection and First Turn

initial test in 2018

Last modified by WolfgangGeithner on 07 Mar 2016 - 09:29 - r11

- Description
- Entry Conditions
- Machine Setup
- Procedure
  - Details of activities
- Problems
- Exit conditions
- Open Questions & Action Items
- References
- Acronyms

Description

- Commissioning of the last section of the preceding transfer line (matching section + few metres before) and the injection region
- First commissioning of key beam instrumentation
- Commissioning of the trajectory acquisition and correction
- Threading the ring (first turn)
- Closing the orbit to be ready for phase A.2 Circulating Pilot Beam

Entry Conditions

Show...

Machine Setup

Show...

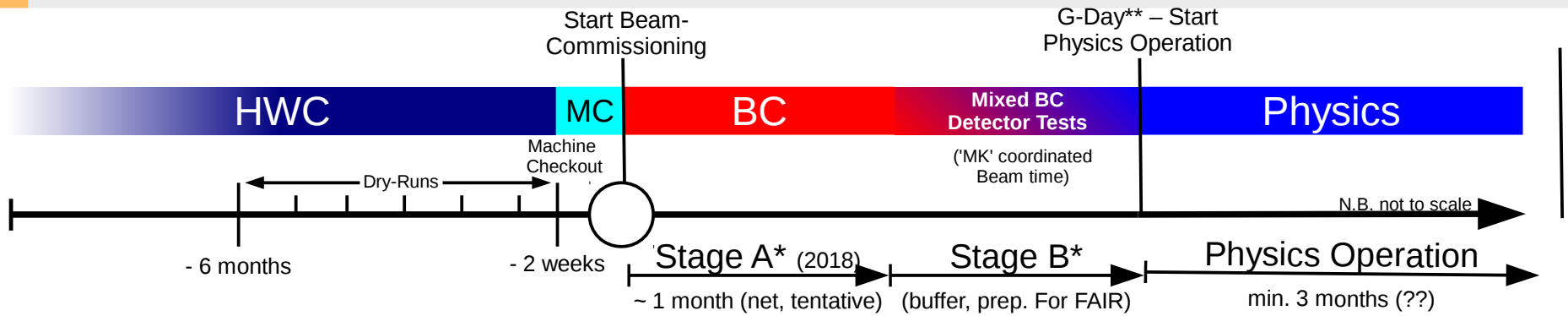
Procedure

Step	Activity	Who	Priority	Special Procedures YR GS GE 1S CR HR
A.1.1	Commission Injection Region (1 Pilot Bunch)			
.01	Commission final metres of preceding TL		1	X
.02	Setup injection elements with beam		1	
.03	Beam commissioning injection screens & grids		1	
.04	Detailed steering onto moved-in injection collimator (if available -> otherwise vacuum chamber)		1	
.05	Power injection kicker/bumper		1	
.06	Check stability of transfer lines and trajectory without injection kicker/bumper		2	
.07	Check stability of injected trajectory with injection kicker/bumper ON, measure kicker/bumper waveform		2	
.08	Beam commissioning Software-Interlock-System (parasitic)		2	
.09	Perform aperture scan at magnetic/electro-static injection septa		2	
A.1.2	Threading Beam around the Ring			
.01	Open injection absorber/collimator (if applicable, or not dumped onto vacuum chamber)		1	
.02	Coarse beam commissioning of BPMs (asynch. acquisition/narrow band, if available)		1	
.03	Commission trajectory acquisition and correction		1	
.04	Threading around ring		1	
.05	First measurement of energy mismatch (correction if needed)		1	
.06	First BPM and corrector polarity checks and repairs		1	
.07	Beam commissioning of DCCTs & ICT		1	

Log in | Register
Toolbox: Create New Topic, Index, Search, Changes, Notifications, RSS Feed, Statistics, Preferences
Webs: FC2WG, BeamCommissioning, HardwareCommissioning, Main, Sandbox, System

Recommissioning & Operation in 2018 I/II

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

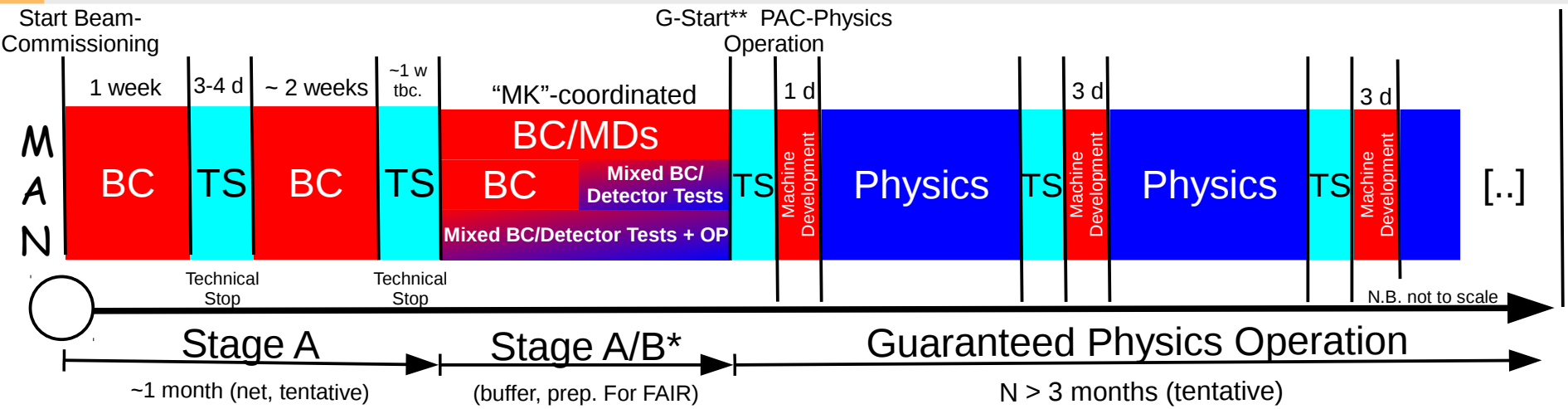


- Hardware Commissioning → coordinated by Sub-Project-Leaders & Machine Coordinators
  - link-existing facilities (GAF), upgrades, machine re-alignment, “SATs”, HW systems (equip. groups),
- Dry-Runs – for all machines post (possibly also UNILAC), each two days, fixed dates (↔ experts availability), starting:
  - Dry-Run #1 – 17.10.2017: CO-core: LSA, Timing System, Archiving System, SCUs, CO core application, …
  - Dry-Run #2 – 14.11.2017: as before + tbd.
  - Dry-Run #3 – 12.12.2017: as before + tbd.
  - Dry-Run #4 – 09.01.2018: as before + BI + related applications
  - Dry-Run #5 – 06.02.2018: as before + Experiments (proposal) + Machine-Experiment Interfaces
  - Dry-Run #6 – 20.02.2018: as before + AEG + “last-minute” checks
  - Dry-Run #7 – 06.03.2018: buffer
- Machine-Checkout – intensive “last minute checks” (N.B closed tunnel/machine):
  - UNILAC: -1 month → BC- 'day 0'
    - patrols, heat runs: RF & power supply conditioning, ...
  - SIS, ESR, CRY: -3 weeks → BC- 'day 0'
    - patrols, heat runs: RF & power supply/AEG conditioning, safety systems: personnel safety, access system, legal ZKS & RP checks (§66 Abs. 2 StrlSchV), “very last-minute” checks/bug fixes: vacuum, power, BI, CO, ...

* in 2018: light-version w.r.t. commissioning of new machines
** “guaranteed” start physics operation (Plan A), no hick-ups, sacrificial buffer being activities related to 'Stage B'

Recommissioning & Operation in 2018 II/II

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



- Stage-A: Initial Beam Commissioning (BC): 2 dedicated 3 week@24h/7 BC blocks, main aim:
  - drive beam expeditiously through the Beam Production Chain: sources → synchrotrons & beam transfers → exp. targets & storage rings
  - check basic 'accelerator mechanics': threading, injection, capture, cool, convert, acceleration/decelerate, stripping & extraction
  - identify beam-related limitations: polarities, RF, beam instrumentation, machine alignment, effective physical machine aperture, ...
- Immediately followed by dedicated, scheduled Technical Stop (TS)
  - needed for follow-up of HW (tunnel) and SW issues (CO, …)
- Stage-A/B*: Mixed-BC, Machine-Development, Detector Tests (aka. "splash events" for experiments) & Operator Training
  - N.B. "old machine" but completely new CO, substantial modifications
- Physics operation: as promised/targeted nett 3 months (to be confirmed), grouped into 2-3 blocks interleaved with
  - TS: routine maintenance → increases overall availability, follow-up of OP/CO/equipment issues + major ion species/source changes
  - MDs: follow-up of beam physics issues, CO improvements (e.g. beam-based FBs), improve facility to reach nominal FAIR parameters
    - N.B. also better for guaranteeing smooth restart/picking-up of physics operation after technical stops (experts availability)

Upcoming FC²WG Topics

- 2018 Controls Retrofitting
  - 'what changes' vs. 'what will remain the same'
- Digitisation of analog signals – mandatory pre-requisite for major MCR upgrade and move to new FCC (!!)
  - Clarification of which signals remain to be digitised after the CO Retrofitting for 2018
  - Choice of technology for remaining signals (CO, BI, HV, RF, …) → should aim at limited number of platforms
    - Probably open items: fast (10-100 MHz) level time- and frequency domain signals
- RBAC & Management-of-Critical Settings (MCS) kick-off
  - Initially concepts and required roles (ie. Operator, MP-Expert, BI-Expert, RF-Expert, …)
- Beam Transformer Integration & Beam Transmission System (in-kind) → review by FC²WG before SPLs' sign-off
  - Specification dead-line: soonish < Q3-2017
- BPM integration into CO/OP concepts → part of in-kind requirements → review by FC²WG before SPLs' sign-off
- Detailed Dry-Run Planning – starting from November (contacted already CO, RF, EPS, HV, BI)

- BLM/BTM Specification + Integration, dead-line: end-2016
- Kicker/Septa Integration → Q2-2018
- Java Application & FESA Training (~ 2016/2017)
- New LSA-based Control Systems → OP Training?!?

FAIR, can we do it?

Yes, we can!

Appendix