FAIR Accelerator & Beam Modes

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Quality Management	Document Type:	Document Number: F-TC-C-07	Date: 02.10.2015
FAIR @ GSI	**Technical Concept**	Template Number:	Page 1 of 15

Document Title:	**Accelerator and Beam Modes**
Description:	Technical Concept for definition and integration of Accelerator Modes and Beam Modes in the accelerator control system
Division/Organization:	CSCO, PBSP
Field of application:	Project FAIR@GSI, existing GSI accelerator facility
Version	V 0.2

Abstract

This technical concept proposes two fundamental modes: the *'accelerator mode'* covering rule sets and operational sequence outside of beam operation and that are defined per accelerator or beam-line section (e.g. shutdown, setup, physics run, etc.); and the *'beam mode'* covering rule sets during beam operation and that are defined per accelerator or beam-line section and Beam-Production-Chain (e.g. no beam, pilot beam, stable beam, etc.).

The purpose of these modes is to communicate the intended accelerator operation, and to condition the various control sub-system responses (e.g. archiving, interlock and fast-beam-abort systems, management of critical settings, etc.). The accelerator control system will distribute this information to the accelerator devices, experiments and wider FAIR community.

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Accelerator and Beam Modes

- Purpose:
  - A) Communication of intended accelerator operation to experiments, FAIR and wider community
    - what to expect and when
  - B) Conditioning of control sub-system responses
    - e.g. logging, interlocks, management of critical settings (RBAC), machine sequencer, access system, …

→ associated rules of what is allowed, when, where etc. some examples:

- limit parameter changes during data taking – aka. 'Stable Beams'
- no beam data being logged during 'shut-down' period
- no high-intensity beam injected into an 'empty' machine
- block certain operation during un-safe mode of operation, e.g.
  - moving in beam screens during production runs
  - settings change that could affect efficiency/safety of machine operation (e.g. slow-extraction)
  - uncontrolled remote tests on an operational devices during beam operation

Glossary: 'Mode' & 'Actual States'

Mode:

- deliberate user-driven state used to precondition the control system behaviour and responses independent of the actual accelerator or beam state → 'reference' or 'desired target' of operation (long-term)
  - formal agreement between accelerator operations and experimental users w.r.t. what to expect
- Tracked by operator (initially) and semi-automated sequencer to follow normal operational sequence
  - Example 1: 'Shut-Down' →'Cool-Down' → 'Machine Check-Out'
  - Example 2: … → 'no beam' → 'pilot beam' → 'intensity ramp-up' → 'adjust' → 'stable beams/production for physics' → ...
  - need to limit number of mutually exclusive and concise modes ↔ overhead of settings generation and their checks
- no real-time requirements

Actual State:

- measured current state of the accelerator/beam (short-term)
  - perviates accelerator & beam mode definition & equally used as a ad-hoc/post condition
  - Examples: Beam-Presence-Flag (BPF), Setup-Beam-Flag (SBF), Injection & Extraction Permit (MP interlock states)
- real-time requirements

- Examples:
  - 'No Beam' beam mode declares intend (as an agreement) that there will be no beam in the machine
  - 'Beam Presence Flag' is measured actual state whether there is (/was) beam in the machine or not
    - N.B. obviously a 'NO BEAM' beam mode & 'BPF=true' should lead to an interlock

- Shouldn't mix 'modes' with 'actual states' to prevent circular dependencies, priority/causality inversions

Accelerator & Beam Modes

- Main modes:
  1) Accelerator (Machine) Modes
     - covering rule sets outside of beam operation
     - defined per accelerator/transfer-line segment
  2) Beam Modes
     - covering rule sets during beam operation
     - defined per accelerator/transfer-line segment and beam-production-chain

- Main Actual States:
  - Beam Presence Flag (BPF)
    - indicates that settings have been validated with Setup- (Pilot-) or Physics-Beam
    - prevents high-intensity injections into an 'empty' machine with new untested magnetic settings or modified machine conditions
  - Setup Beam Flag (SBF)
    - Indicates beam used to setup beam production chain (typ. low-intensity)
    - SBF provides flexibility of masking interlocks during setup periods
      - rationale: interlocks targeted for high-intensity operation may impact setup and availability with low-intensities
    - defined per accelerator or transfer-line segment (where necessary)

Accelerator vs. Beam Mode Matrix

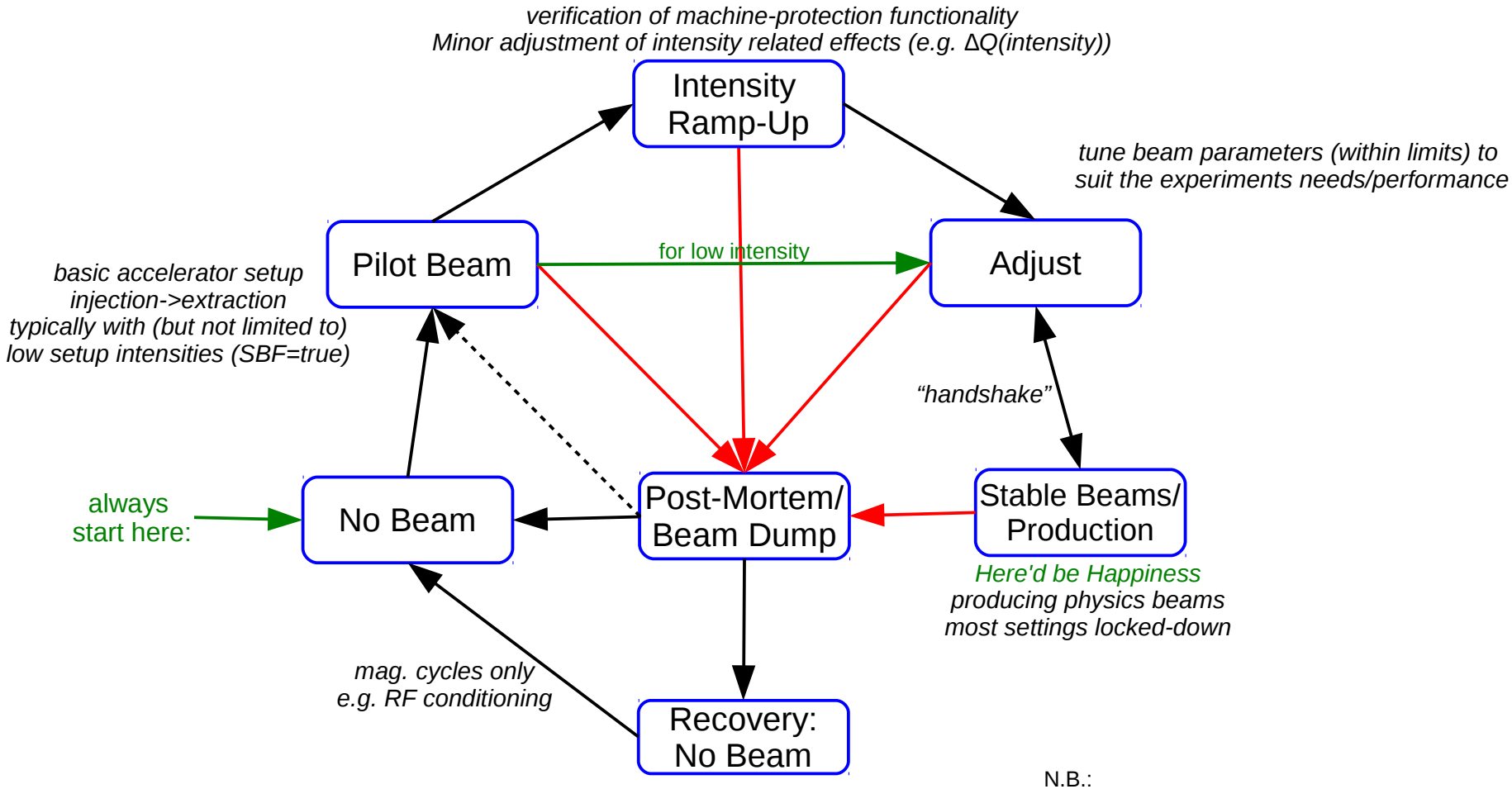
Beam Mode	Accelerator Mode: Shut-down	Cool-down	Bake-Out	Warm-Up	Beam Operation: Machine-Checkout	Access	Machine Test	Beam Setup	Physics	Machine Development
No Beam	X	X	X	X	X	X	X	X	X	X
Pilot Beam								X	X	X
Intensity Ramp-Up								X	X	X
Adjust								X	X	X
Stable Beams									X	
Post-Mortem								X	X	X
Recovery								X	X	X

N.B. defined per accelerator/transfer line segment

N.B. defined per accelerator/transfer line segment & beam production chain

concatenation of <accelerator mode>:<beam mode>
e.g. 'Shut-down:No Beam', 'Physics:Pilot Beam'

Proposal:
FAIR Beam Modes – State Diagram



normal operational path
error/fault case
low-intensity

N.B.:
1) omitted arrows to 'No Beam'/'Pilot Beam' for better visibility (always possible)
2) modes follow existing normal setup routine, initial transition acknowledged by operator, subsequent driven automatically by sequencer

FAIR Accelerator Modes

Follows annual life-cycle of accelerator facility

- **Operation without Beam:**
  - SHUTDOWN
    - could imply possibility of open/controlled access or no powering
  - COOLDOWN (SIS100, SFRS)
    - typ. 2-3 weeks, limited/no access
    - need to distinguish between a 'warm' and cold' shutdown?
  - BAKE-OUT (SIS18, HEBT, …) – similar to cool-down
  - WARM-UP (SIS100, SFRS)
  - RECOVERY (SIS100, SFRS)
    - after quench, partial vacuum loss, typ. few hours - day
    - includes e.g. periodic magnet CYCLING to stabilise hysteresis
  - MACHINE-CHECKOUT
    - operations tests without beam in view of beam operation
    - (e.g. power converter calibration, magnet patrol, etc.)
    - done once after a long shutdown, typ. few weeks before beam operation
  - ACCESS (during beam operation periods)
    - controlled access for specific tasks only (signature by MCs & OP)
- **Operation with Beam:**
  - BEAM SETUP or MACHINE SETUP
    - focus on initial/re-commissioning, machine setup after long shut-down + OP training
  - PHYSICS
  - MACHINE DEVELOPMENT
    - focus on accelerator/beam physics aspects
- MACHINE TEST (during beam operation periods)
  - controls, RF, new front-end, ... tests w/o beam + OP training
  - Ad-hoc during beam operation but not 'Physics' nor 'MD'

operation without beam
(part of shut-down coordination)

describe main aim
of machine operation
+
info & Accounting
type modes

FAIR Beam Modes

- Follows life-cycle of beam setup and production – also not new, de-facto how
  - NO BEAM
    - prevent/stop beam being injected by design (↔ mode)
  - PILOT BEAM – alternate: Beam Setup?
    - Establishing main machine parameters: injection steering, RF capture, ramp, orbit, Q/Q', optics checks, extraction
      - typically done with low setup-intensities
  - INTENSITY RAMP-UP – should we differentiate stages? e.g.: INT. RAMP-UP #1, INT. RAMP-UP #2, ... ?
    - beam parameter tuning and checks related to increasing intensities (e.g. slow extraction, space-charge, etc.)
    - check of interlocks & machine protection functionalities (limited user group only ↔ special RBAC role for e.g. interlock settings)
  - ADJUST
    - Perform actions/change minor beam parameters (“minor” needs to be defined)
    - tune beam parameters (within limits) to suit the experiments needs/performance
  - STABLE BEAMS – alternate: PRODUCTION (for physics)
    - main intend is to deliver stable beam to experiments
    - tbd: very limited machine tuning
  - BEAM-DUMP or POST-MORTEM
    - response to quench, MP action, or other action that needs to be analysed before one can continue with normal operation
  - RECOVERY
    - recovering from severe post-mortem, essentially includes 'CYCLING'
- For storage rings (essentially only ESR & HESR)
  - Do we need INJECTION/ACCUMULATION & RAMP modes?

Beam Modes are not new!
already practise in normal operation
→ plan to make CS also aware of them
→ allows to define rules, statistics, ...