

Storage Ring Mode for FAIR

Andreas Schaller, Jutta Fitzek, Hanno Christian Hüther, Raphael Müller,
Benjamin Peter, Anneke Walter *GSI, Darmstadt, Germany*



Abstract

For the future Facility for Antiproton and Ion Research (FAIR), which is currently under construction, a new Control System is being developed and already used at major parts of the GSI facility. The central component for Settings Management within the FAIR Control System is based on CERN's framework "LHC Software Architecture" (LSA) and enhanced by FAIR specific features. One of the most complex features is the control mechanism of storage ring operations, the so-called Storage Ring Mode. This operation mode allows to manipulate device settings while the beam is circulating in the ring. There are four different types of possible changes in the Storage Ring Mode: skipping, repetition, breakpoint and manipulation. The Storage Ring Mode was developed in late 2019 and first used with beam in 2020 at the existing heavy ion Storage Ring ESR at GSI. This contribution illustrates in detail how the Storage Ring Mode is implemented within LSA and other subsystems. It also shows how it is operated using the Expert Storage Ring Mode application.

Motivation

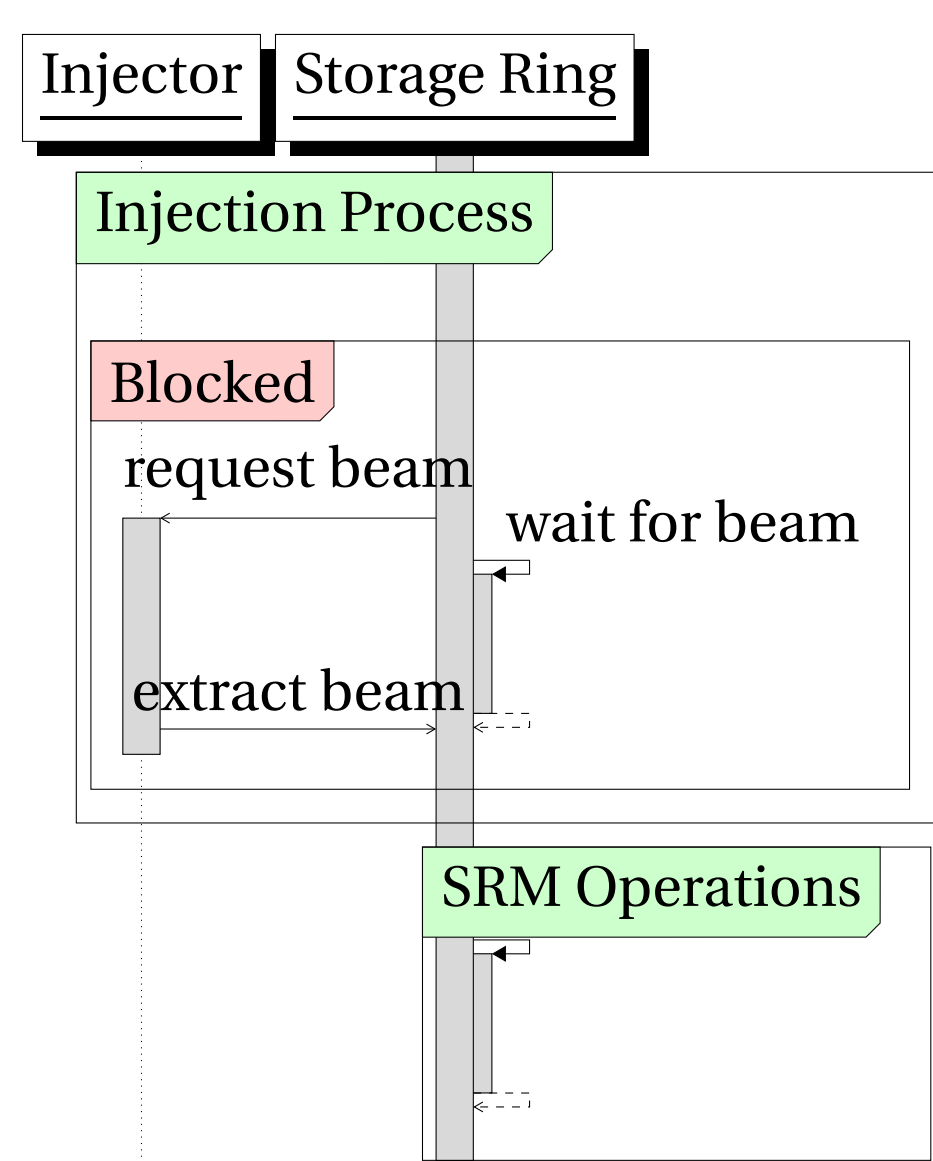
Storage rings have been regularly and routinely operated at GSI since 1990. The new Control System for FAIR has supported operation of synchrotron rings using fully pre-planned schedules since 2015. In 2019, the FAIR Control System was enhanced to support Storage Ring Mode operation, using flexible, interactive schedules and allowing in-cycle modifications of stored beams.

Storage Ring Mode Coupling Options

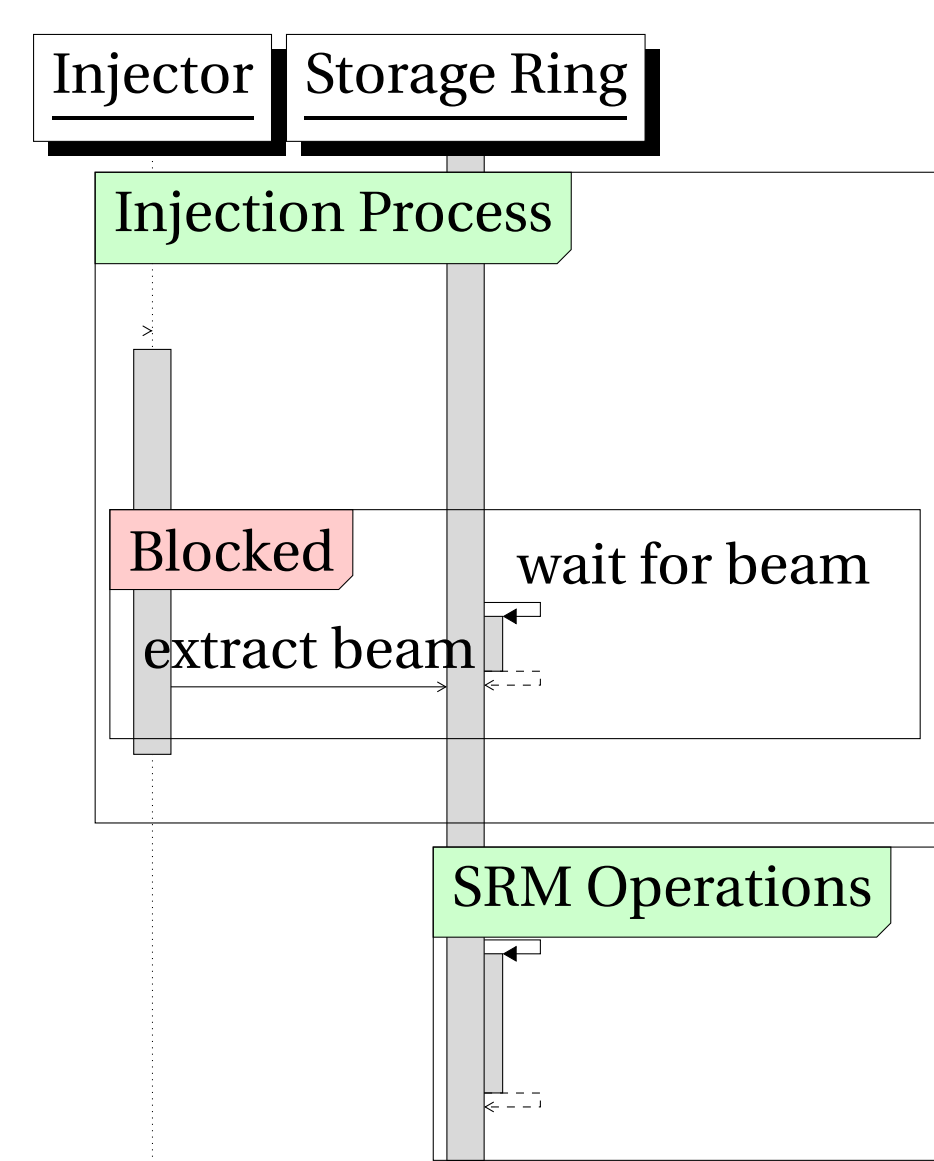
For injecting beam from a source machine into a storage ring, two different coupling options were developed:

- Strong Coupling
 - Ensures beam delivery
 - Storage ring is blocked during beam creation
- Weak Coupling (Fire and Forget)
 - Storage ring can be used for other beams (different injectors) while beam is created
 - Needs manual synchronization

Strong Coupling



Weak Coupling Fire and Forget



Storage Ring Mode Key Features

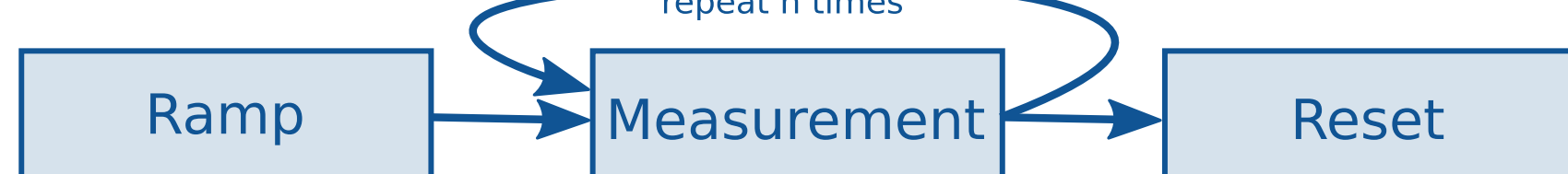
1. Breakpoint: break and continue on user action



2. Skipping: used for optional parts, e.g. measurements



3. Repetition: repeat for a predefined number of executions



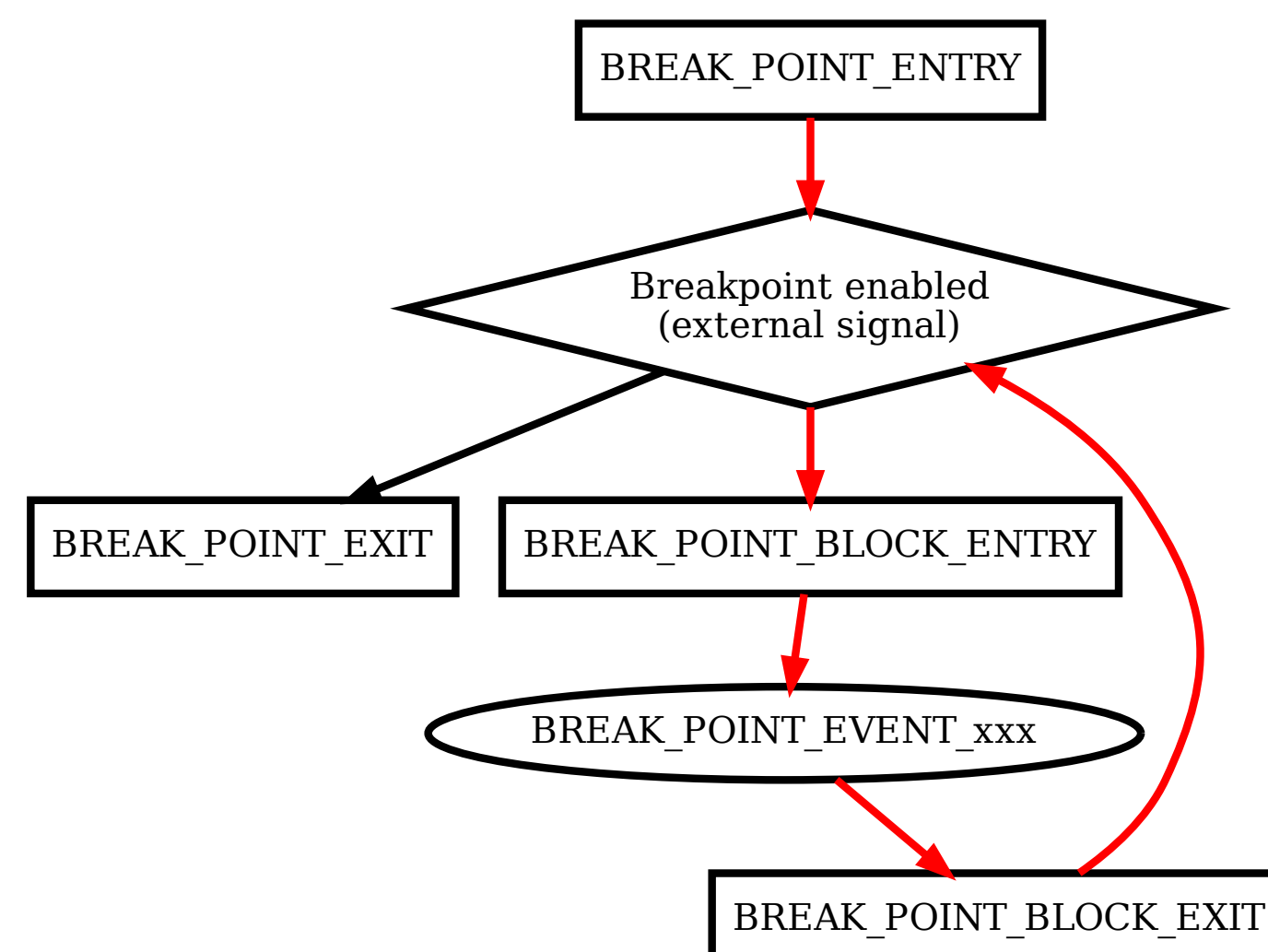
4. Manipulation: pause execution and modify settings



Timing Graphs for Storage Ring Mode Features

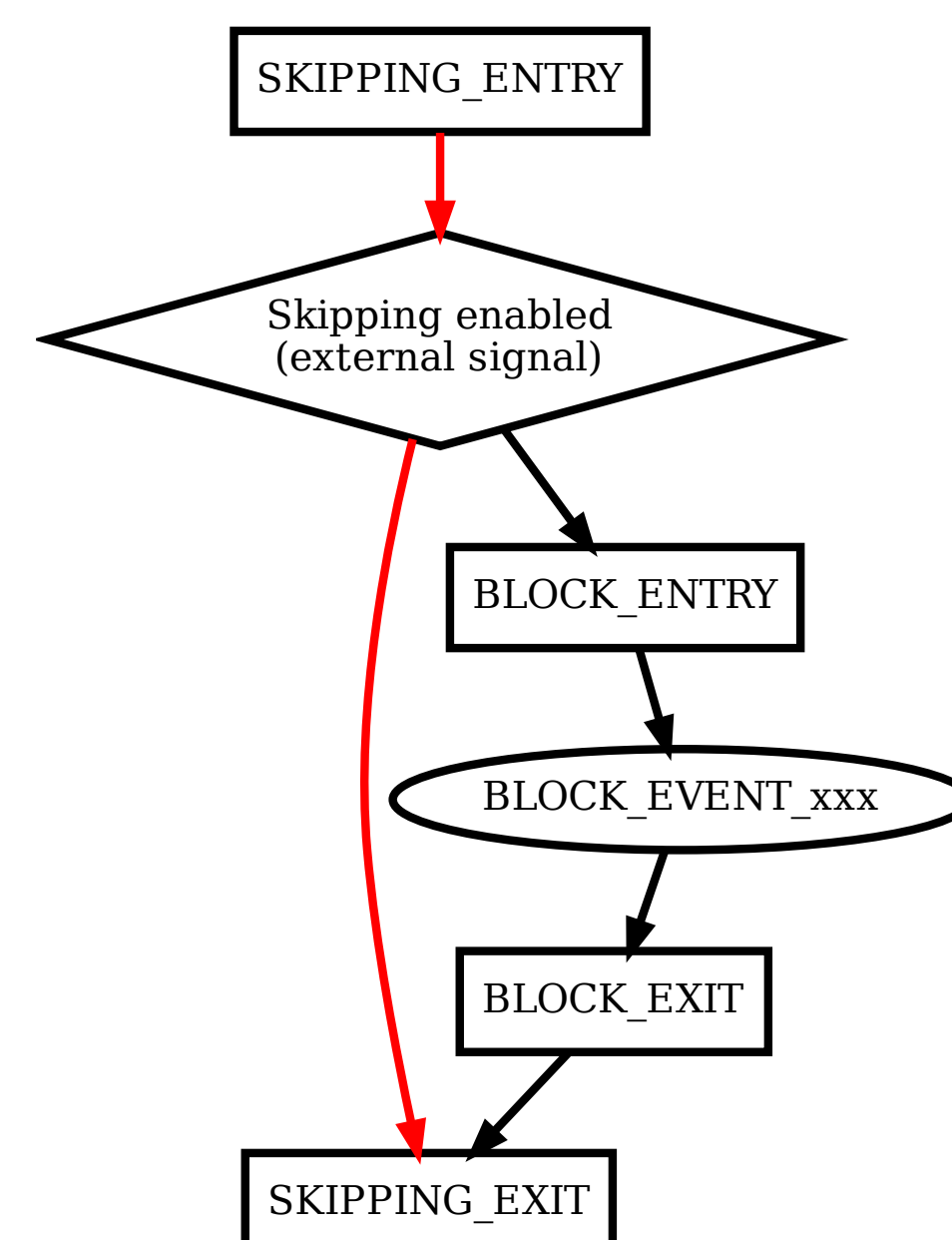
1. Breakpoint

Breakpoints are implemented using a loop in the timing system's scheduling graph that can be entered or exited by a user signal.



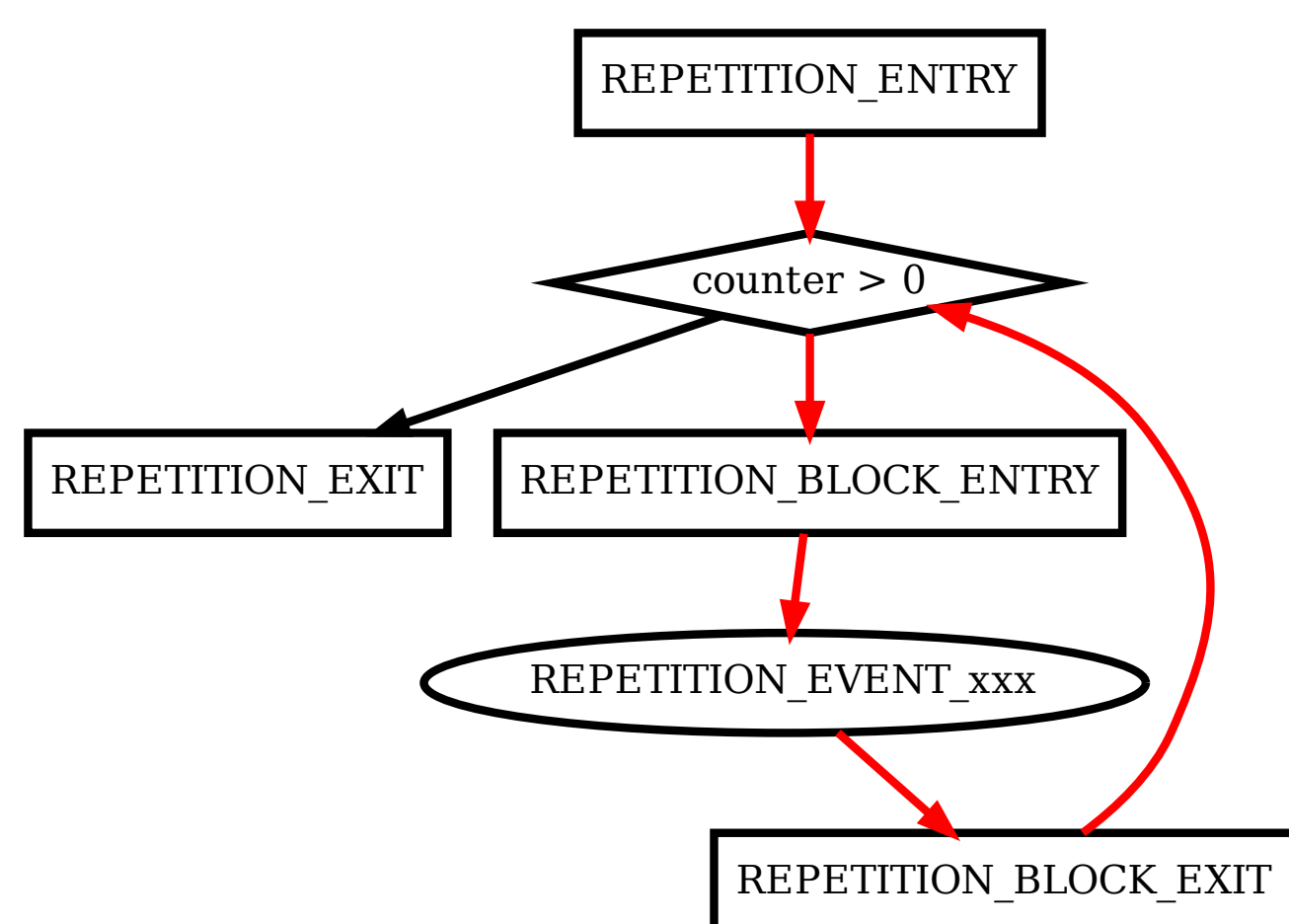
2. Skipping

A branch of events in the timing graph can be skipped upon user request.



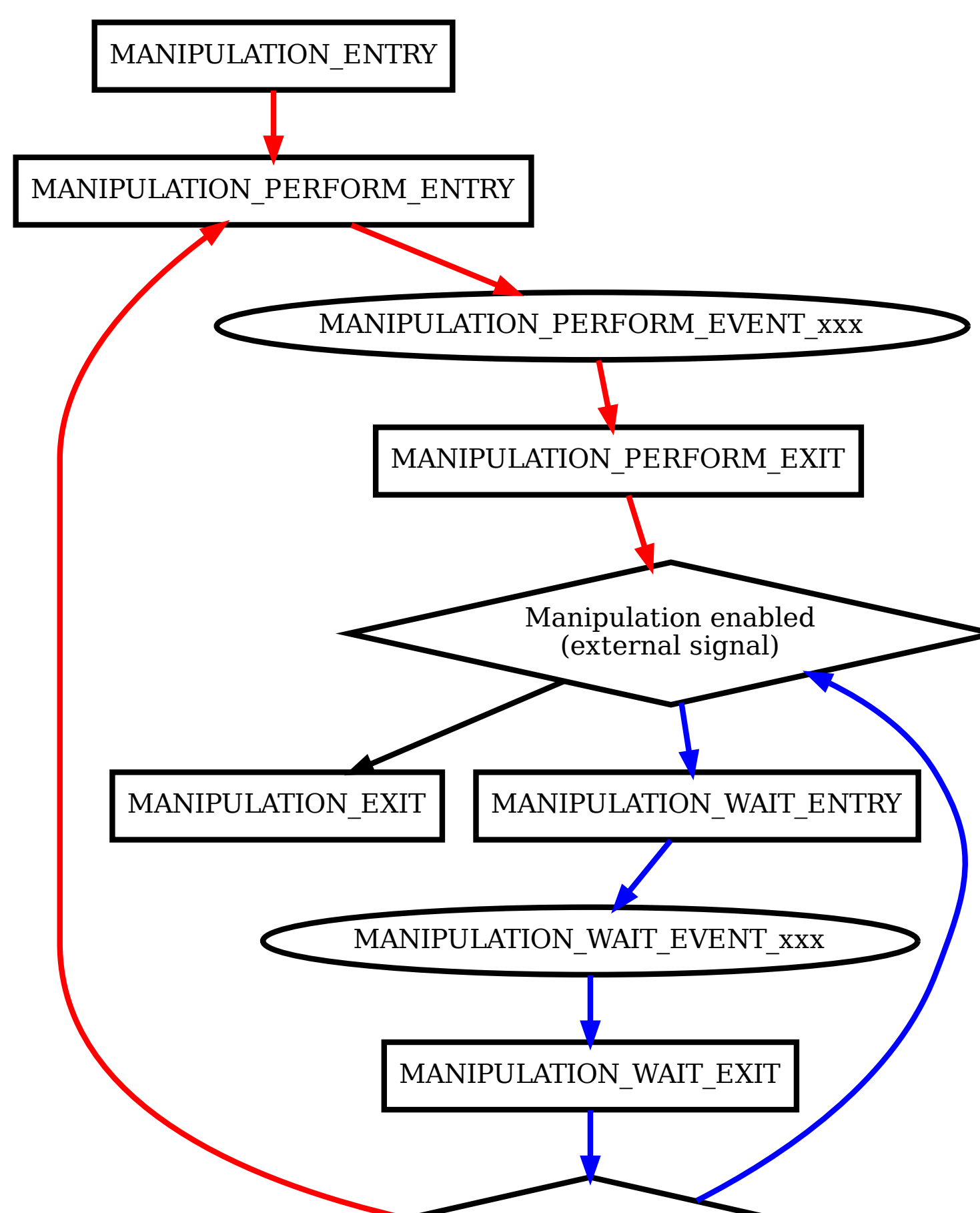
3. Repetition

A branch of events can be repeated a predefined number of times. At runtime, the user can abort remaining repetitions.

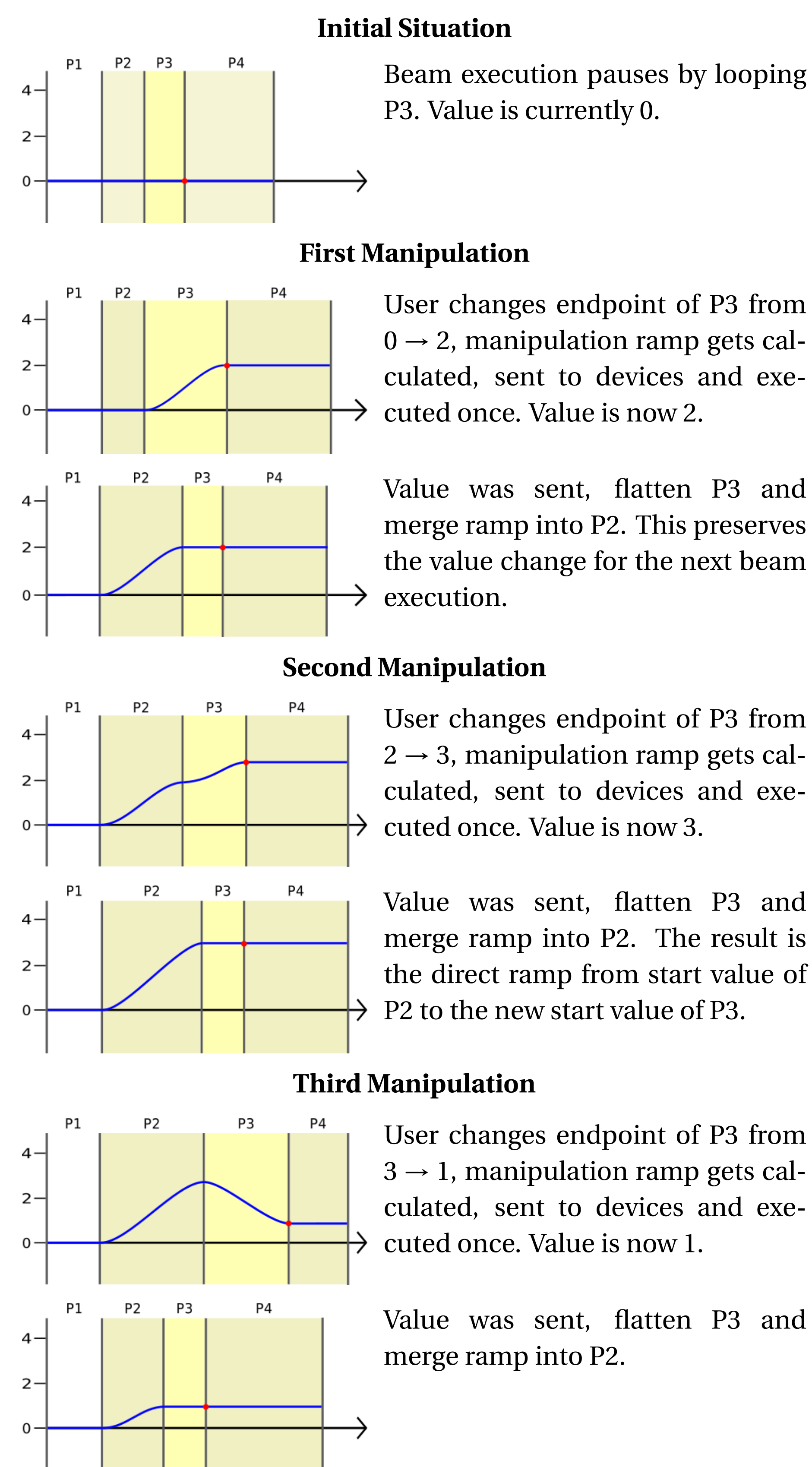


4. Manipulation

Manipulations start by executing the perform step after which the decision is taken to wait for a manipulation or continue the storage ring operation. During the manipulation, the system ensures that the manipulation's timing events are executed once with the new settings, which are then incorporated into the previous settings for the next beam execution.



Setting Manipulation (exemplary)

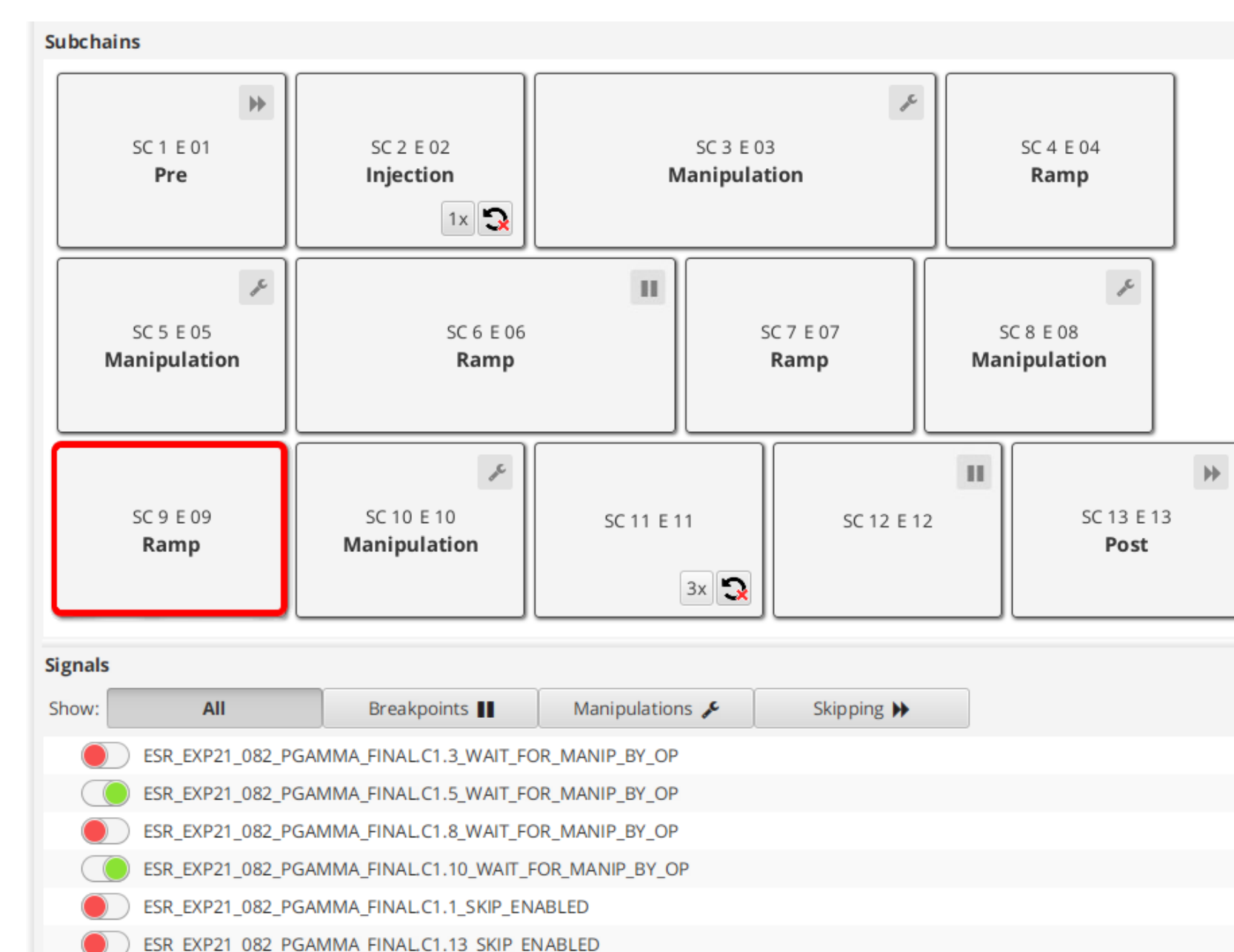


Involved Subsystems

- Timing Master
 - White Rabbit-based timing system, executes events
- Beam Scheduling System (BSS)
 - Enriches timing schedule by signal information
 - Reacts on (de-)activation of signals
 - Supplies Timing Master
- LHC Software Architecture (LSA)
 - Generates timing schedule, supplies devices and BSS
- Storage Ring Mode Application (StoRiMo App)
 - Monitor and control Storage Ring Mode features

Storage Ring Mode in Production

The StoRiMo Application provides an overview of the different parts of a storage ring execution. The red border indicates the current point of execution. Small indicator icons visualize the Storage Ring Mode features available at this part. The signals below can be switched by the user to enable or disable those features.



Outlook

Converting Storage Ring Mode context to Synchrotron Mode context (and back) to allow for deterministic schedules once the beam is setup, e.g. for synchronizing with another machine.