ZHAW – Institute of Applied Mathematics and Physics

IAMP_ESS_FBIS

FBIS-SRS

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1 Introduction

1.1 Purpose

The FBIS Requirements Specification provides a detailed specification for functional and non-functional requirements for the Fast Beam Interlock System (FBIS) on system level.

The FBIS will be realized by ZHAW and will be part of the Machine Protection System (MPS) for the European Spallation Source in Lund, Sweden. The document shall serve as a contract between the ESS stakeholders (engineers, technical staff, operators, etc.) to provide a common point of reference for system expectations and limits.

This document shall also serve as a basis for the subsequent FBIS design, implementation and verification activities.

1.2 Scope

The System Requirement Specification (SRS) is a ZHAW document and is based on the MP Requirements and Architecture /MP SRS AS/, Beam Interlock System Requirements Specification /BIS SRS/, Benchmark Use Cases /BIS UCA/ and the FBIS Concept of Operations /FBIS-CONOPS/ documents. This document specifies requirements with the help of "shall" and "should" as following:

- **Shall** is used to indicate a requirement that is contractually binding, meaning it must be implemented, and its implementation verified;
- **Should** is used to indicate a goal which must be addressed by the design team but is not formally verified. Should (goal) statements are used to document design criteria's which are of importance for the FBIS but are (at system level) not verifiable.

The final FBIS shall realize all mandatory requirements.

2 Applicable Documents

Below subchapters list resources which are referenced to from within this document.

2.1 /MP SRS AS/

Reference	ID	Version	Title
/MP SRS AS/	CB:248501	Version 1(1) from 2015-11-29	Machine Protection - Systems Requirements and Architectural Framework

2.2 /BIS SRS/

Reference	ID	Version	Title
/BIS SRS/	CB:248500	Version 1(1) from 2015-06-11	MP Beam Interlock System - System Requirements Specification

2.3 /BIS UCA/

Reference	ID	Version	Title
/BIS UCA/	CB:TBD	TBD	Machine Protection - Benchmark Use Cases

2.4 /FBIS-CONOPS/

Reference	ID	Version	Title
/FBIS-ConOps/	CB:280782	1	FBIS Concept of Operations

2.5 /FBIS-LPSID-IDD/

Reference	ID	Version	Title
/FBIS-LPSID-IDD/	CB:284471	1A	Local Protection System for Interceptive Devices Interface Design Description

2.6 /FBIS-TS-IDD/

Reference	ID	Version	Title
/FBIS-TS-IDD/	CB:283256	1A	ESS Timing System Interface Design Description

2.7 /FBIS-LC-IDD/

Reference	ID	Version	Title
/FBIS-LC-IDD/	CB:284402	1A	LEBT Chopper Interface Design Description

2.8 /FBIS-MC-IDD/

Reference	ID	Version	Title
/FBIS-MC-IDD/	CB:284403	1A	MEBT Chopper Interface Design Description

2.9 /FBIS-IS-IDD/

Reference	ID	Version	Title
/FBIS-IS-IDD/	CB:284401	1A	Ion Source Interface Design Description

3 Acronyms

The following acronyms are used throughout this document:

Acronym	Description
ACCT	AC Current Transformer
FBIS	Fast Beam Interlock System
FC	Farraday Cup
FIM	Fast Interlock Module
FGV	Fast Gate Valve
LPSID	Local Protection System for Interceptive Devices
LPSMAG	Local Protection System (Linac) Magnets
LPSVAC	Local Protection System Vacuum
MP	Machine Protection
MPS	Machine Protection System
RF	Radio Frequency

4 System Overview

The FBIS is part of the Machine Protection (MP) System-of-Systems. In essence, it constitutes the final link between the many MP related systems designed to detect deviations from a safe operational state and the MP related actuation systems designed to dump the proton beam and prevent further proton beam injection and acceleration.

Within this document, "Safe" has to be interpreted in the context of Machine Protection and refers to the "protection of the facility and its devices" only. Neither the FBIS nor Machine Protection in general deal with health and safety of personnel, the public or the environment. In order to achieve and maintain the safe state for the accelerator, the FBIS controls the following MP-related Beam Switch-Off Actuation Systems (in the following referred to as "Actuation Systems"):

- ESS Timing System;
- LEBT Chopper;
- MEBT Chopper;
- Ion Source.

The FBIS bases this control on:

- Beam Permit signals, operational status and health of Local MP-related systems;
- Beam Permit signals, operational status and health of MP-related proton beam monitoring systems;
- "No-beam detected" information from MP-related proton beam monitoring systems;
- The selected operational mode of the accelerator;
- The "Mode" configuration of all relevant MP-related systems;
- Faraday-Cup and Emittance-Measurement-Unit positions.

In the following, the term "Sensor Systems" is used to address Local MP-related Systems and MP-related proton beam monitoring systems. The figure below provides a sketch of the FBIS and its environment.
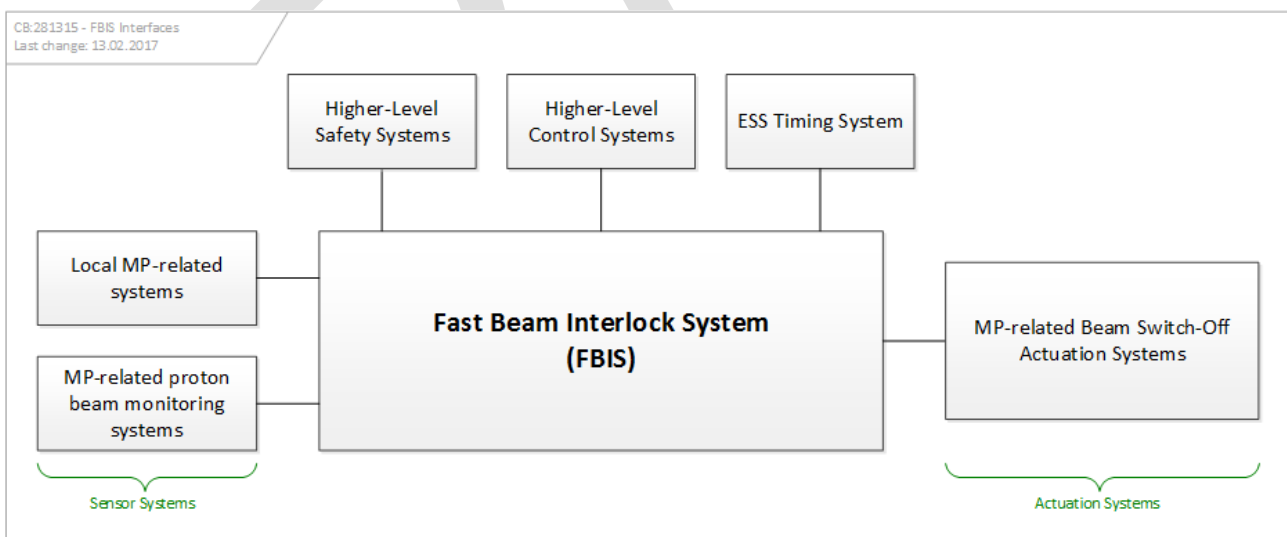
Visualization of the FBIS environment showing sensor subsystems (left of the FBIS), actuation subsystems (right), and management systems (top).

Sketch of the FBIS environment showing sensor subsystems (left of the FBIS), actuation subsystems (right), and management systems (top).

In various places in this document references to beam line section and beam line elements are given. Below figure shows the relative position of these elements as a sketch
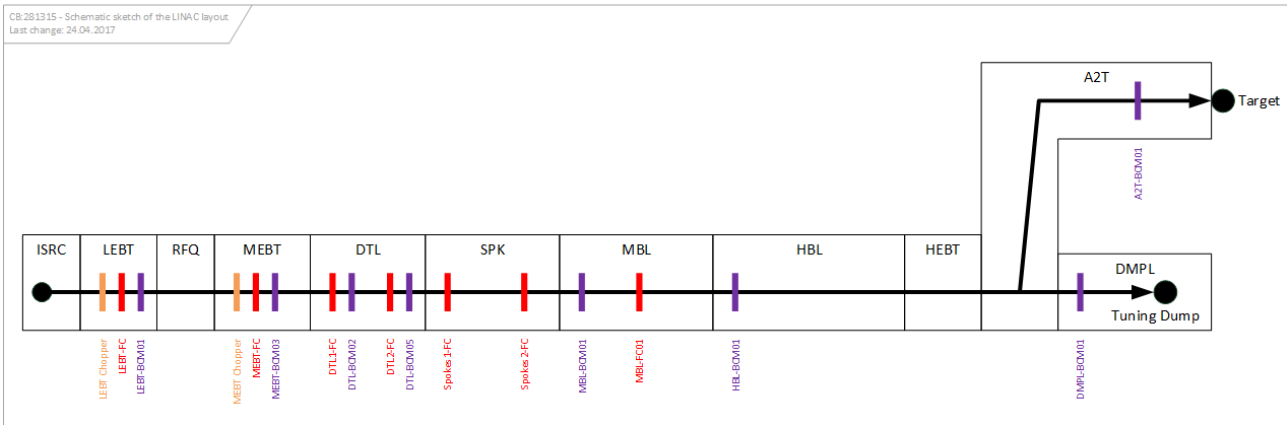
Sketch of the beam line sections and a subset of beam line elements.

5 Document Structure

The FBIS can be viewed as an input-logic-output system (see IEC 61508) performing the following steps:

- Input signal conditioning and mapping
- Decision Logic computation
- Output signal conditioning and mapping

Below figure illustrates these steps from left to right.
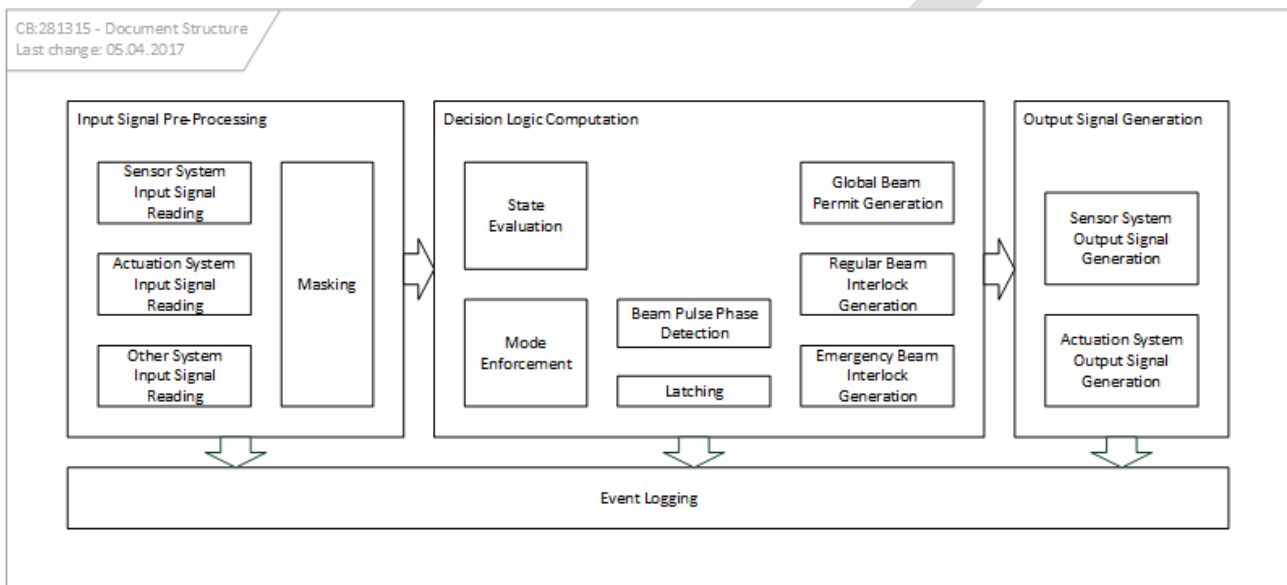
Illustration of the FBIS as an input-logic-output system. The structure of this document resembles the flow from left to right in the figure.

The structure of this document resembles above described and illustrated structure as follows:

Functional requirements about ...	Chapter	Sub-Chapters
... input signal conditioning and mapping	Input Signal Pre-Processing	Sensor System Inputs Actuation System Inputs Masking
... Decision Logic computation	Decision Logic Computation	State Evaluation Mode Enforcement Global Beam Permit Generation Beam Pulse Phase Detection Regular Beam Interlock Generation Emergency Beam Interlock Generation Latching
... output signal conditioning and mapping	Output Signal Generation	Sensor System Output Signals Actuation System Output Signal Generation

Additional functional requirements are given in:

Functional requirements about ...	Chapter
... interfaces in general	Interfaces
... logging	Event Logging

| ... startup and shutdown | Startup and Shutdown |
| ... processing speed | Processing Latency |

Chapter Driving Requirements summarizes the driving requirements from Machine Protection. Chapter Non-Functional System Requirements addresses the non-functional system requirements of the FBIS.

Note that most Sensor, as well as Actuation Systems, bi-directionally interface with the FBIS. This means one and the same system may provide inputs to the FBIS while receiving outputs from the FBIS at the same time.

6 Driving Requirements

The following overall requirements from Machine Protection drive the FBIS System Requirements.

6.1 Minimal Latency

#[ISSUE:63253]

Requirement	The latency time between state changes on FBIS inputs and causing a beam switch-off **should** be minimized
Explanation	The FBIS latency contributes to the reaction time of all Protection Functions involving the FBIS. A clear specification of the reaction time requirements for the individual Fast Protection Functions and a maximal latency requirement for the FBIS would be ideal. However, we believe that it will not be possible for ESS to generate exact requirements specifications, at the level of single micro-seconds, for the reaction time of Fast Protection Functions in this phase of the project. There are simply too many unknowns with respect to the dynamic behavior of many of the accelerator elements at this time. Rather than making a best guess on the maximal tolerable FBIS latency, we adopt the conservative approach to minimize the latency as far as possible.

6.2 Support Staged Commissioning

#[ISSUE:63254]

Requirement	The FBIS **should** support the staged commissioning of the ESS linac.
Explanation	The ESS linac will be build andcommissioned step-by-step, e.g. by adding acceleretor segment after segment. Commissioning a segment with beam will require the Fast Protection Functions that are necessary for that segment to be operational. Hence the parts of the FBIS needed for those functions have to be commissioned beforehand and need to be operational. The FBIS should support the staged commissioning. Once a FBIS part has been tested and verified, changes should only be applied if really necessary.

6.3 Scalable Number of Inputs

#[ISSUE:63270]

Requirement	The FBIS **should** be scalable with respect to number of inputs.
Explanation	ESS is a research facility. We do not expect the list of Protection Functions that is being specified now neither to be complete nor to be static. Changes have to be expected. Adding additional Protection Functions or input signals to the FBIS will only be possible if the physical design is scalable. It should be possible to add inputs to the FBIS without having to compromise too much on the overall FBIS performance and without havint to add a substantial amount of hardware.

6.4 Support ESS Lifetime

#[ISSUE:63271]

Requirement	The FBIS **should** support the intended ESS lifetime.
Explanation	ESS is supposed to have lifetime longer than 20 years. In such a time, electronics components tend to get obsolete, even if carefully selected. While hardware ageing and components obsolescence might force us to replace the FBIS hardware, the basic function of the FBIS is likely to stay the same over the lifetime of ESS. A change of hardware components should be feasible without having to completely redevelop the FBIS functionality.

6.5 Seamless integration into ESS System Landscape

#[ISSUE:63272]

Requirement	The FBIS **should** support seamless integration into the ESS system landscape.
Explanation	The FBIS shall seamlessly integrate into the ESS System Landscape. This addresses in particular EPICS and the ESS Timing System. The FBIS shall also integrate with the ESS Operation.

6.6 Compatible with IEC 61508 SIL2

#[ISSUE:63273]

Requirement	The FBIS **should** be compatible with SIL2 according IEC 61508.
Explanation	Even though the ESS hazard and risk analysis has not yet been completed, and even though Overall Protection Functions requiring stronger risk reduction might be needed, we believe that Protection Integrity Level 2 will be the highest achievable in the context of the ESS project. Aiming at satisfying IEC61508 SIL3 requirements is not realistic in the context of the whole ESS project setup. Thus, the FBIS will have to suffice PIL 2 requirements. Any requirement for a PIL3 Protection Function will need to redefined into a requirement for more than one PIL2 and/or PIL1 Protection Function.

6.7 Maximal Availability

#[ISSUE:63280]

Requirement	The FBIS availability **should** be maximized.
Explanation	The availability requirements for ESS are very high. Machine Protection supports this requirement by taking over the job to prevent and mitigate damage to the machine as well as unwanted activation of the machine. The FBIS is involved in Fast Protection Functions: those are typically the ones that act on hazards that could cause severe damage in a very short amount of time. Producing beam without a fully operational FBIS, which would mean without all of the Fast Protection Functions in a working state, would mean taking a very high risk. This then puts very high availability requirements on the FBIS: the reliability of the FBIS parts has to be high and the Mean-Time-To-Restoration has to be minimized.

7 Functional System Requirements

7.1 Interfaces

7.1.1 LPSID Interface

#[ISSUE:62882]

Requirement	The FBIS **shall** have an interface for the LPSID according to the specification in /FBIS-LPSID-IDD/.
Explanation	The LPSID may request a beam-switch off via FBIS and is hence considered to be a Sensor System in this document.

7.1.2 LPSVAC Interface

#[ISSUE:63711]

Requirement	The FBIS **shall** have an interface for the LPSVAC according to the specification in TBD.
Explanation	The LPSVAC may request a beam-switch off via FBIS and is hence considered to be a Sensor System in this document.

7.1.3 LPSMAG Interface

#[ISSUE:63819]

Requirement	The FBIS **shall** have an interface for the LPSMAG according to the specification in TBD.
Rationale	The ACCT Digital Processing Boards may request a beam-switch off via FBIS and are hence considered to be Sensor Systems in this document.
Explanation	The LPSMAG is considered to be a Sensor System in this document.

7.1.4 ACCT Digital Processing Board Interface

#[ISSUE:63619]

Requirement	The FBIS **shall** have interfaces to the ACCT Digital Processing Boards according to the specification in TBD.

7.1.5 RF Fast Interlock Module Interface

#[ISSUE:63828]

Requirement	The FBIS **shall** have interfaces to the RF Fast Interlock Modules according to the specification in TBD.
Explanation	The RF Fast Interlock Modules may request a beam-switch off via FBIS and are hence considered to be Sensor Systems in this document.

7.1.6 Fast Gate Valve Interface

#[ISSUE:63846]

Requirement	The FBIS **shall** have interfaces to the Fast Gate Valves according to the specification in TBD.
Explanation	The Fast Gate Valves may request a beam-switch off via FBIS and are hence considered to be Sensor Systems in this document.

7.1.7 ESS Timing System Interface

#[ISSUE:63276]

Requirement	The FBIS **shall** have an interface to the ESS Timing System according to the specification in /FBIS-TS-IDD/.
Explanation	The ESS Timing System has a dual role. It provides timing and configuration information and is used to inhibit the proton beam. Hence, it is considered to be an Actuation Systems and a Higher-Level Safety and Control System in this document.

7.1.8 LEBT Chopper Interface

#[ISSUE:62904]

Requirement	The FBIS **shall** have an interface to the LEBT Chopper according to the specification in /FBIS-LC-IDD/.
Explanation	The LEBT Chopper is used to dump the proton beam. Hence it is considered to be an Actuation Systems in this document.

7.1.9 MEBT Chopper Interface

#[ISSUE:62905]

Requirement	The FBIS **shall** have an interface to the MEBT Chopper according to the specification in /FBIS-MC-IDD/.
Explanation	The MEBT Chopper is used to dump the proton beam. Hence it is considered to be an Actuation Systems in this document.

7.1.10　　Ion Source Interface

#[ISSUE:62906]

Requirement	The FBIS **shall** feature an interface to the Ion Source according to the specification in /FBIS-IS-IDD/.
Explanation	The Ion Source is used to "interlock" proton beam production and extraction. Hence it is considered to be an Actuation Systems in this document.

7.1.11　　Control System Interface

#[ISSUE:63429]

Requirement	The FBIS **shall** have an interface to the Control System according to the specification in TBD.
Explanation	The Control System is part of the Higher-Level Safety and Control Systems.

7.2 Input Signal Pre-Processing

7.2.1 Sensor System Inputs

The FBIS receives inputs from the following Sensor Systems:

- Local Protection Systems:
    - LPS Interceptive Devices (LPSID)
    - LPS Vacuum (LPSVAC)
    - LPS Linac Magnets
    - LPS Bending Magnets
    - LPS Raster Scanning Magnet System
    - LPS Target
    - LPS Neutron Science Section
- Beam Instrumentation:
    - ACCT Digital Processing Boards
    - BLM Digital Processing Boards
    - BPM Digital Processing Boards
- Radio Frequency
- Fast Gate Valves

Requirements related to these inputs are given in the following sub-chapters.

7.2.1.1 LPSID Inputs

The following requirements address inputs received from the LPSID. An overview about the inputs is given in below figure.

CB:281315 - LPSID FBIS Interface (Inputs)
Last change: 03.08.2017
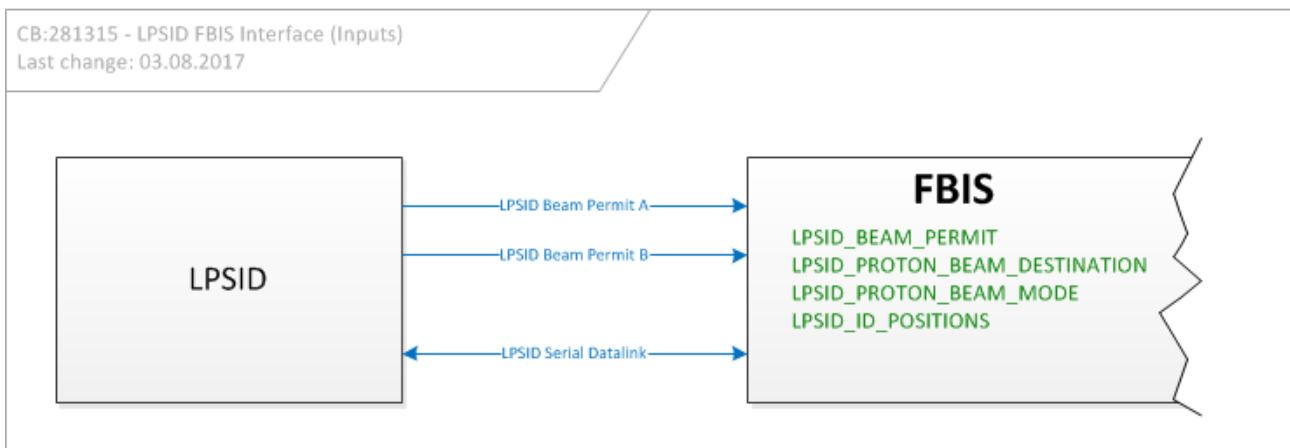
Inputs from the LPSID.

7.2.1.1.1   LPSID Beam Permit Input

#[ISSUE:64447]

Requirement	The FBIS **shall** read from the LPSID Interface: • The signal "LPSID Beam Permit A" • The signal "LPSID Beam Permit B" • The data field "LPSID Beam Permit"

7.2.1.1.2   LPSID Beam Permit

#[ISSUE:65039]

Requirement	The FBIS **shall** have a LPSID_BEAM_PERMIT with two possible states: "OK" and "NOK".

7.2.1.1.3   LPSID Beam Permit State

#[ISSUE:64021]

Requirement	The FBIS **shall** set the LPSID_BEAM_PERMIT to "OK" **when**: • The signal "LPSID Beam Permit A" is "High", **and** • The signal "LPSID Beam Permit B" is "Low", **and** • The data field "LPSID Beam Permit" is "OK" else it is set to "NOK".
Incoming References	[65039] LPSID Beam Permit [64447] LPSID Beam Permit Input

7.2.1.1.4   LPSID Beam Permit Errors

#[ISSUE:64022]

Requirement	The FBIS **shall** consider the LPSID_BEAM_PERMIT as erroneous and set it to "NOK" **if**: • The signal "LPSID Beam Permit A" differs from the state of the signal "LPSID Beam Permit B" for longer than TBD, **or** • The signal "LPSID Beam Permit A" differs from the state of the data field "LPSID Beam Permit" for longer than TBD, **or** • The signal "LPSID Beam Permit B" differs from the state of the data field "LPSID Beam Permit" for longer than TBD, **or** • An invalid state of the data field "LPSID Beam Permit" is received, **or** • An error of the "LPSID Lifesign" is detected, **or** • The "LPSID CRC" checksum indicates that the message is wrong, **or** • A telegram timeout is detected.
Incoming References	[65039] LPSID Beam Permit [64447] LPSID Beam Permit Input

7.2.1.1.5   LPSID Proton Beam Destination Input

#[ISSUE:63214]

Requirement	The FBIS **shall** read from the LPSID Interface: • The data field "LPSID Proton Beam Destination"
Explanation	The variable is used for Mode Enforcement

7.2.1.1.6   LPSID Proton Beam Destination
#[ISSUE:65139]

Requirement	The FBIS **shall** have a LPSID_PROTON_BEAM_DESTINATION with the possible states defined in Proton Beam Destination States

7.2.1.1.7   LPSID Proton Beam Destination State
#[ISSUE:65142]

Requirement	The FBIS **shall** set the status LPSID_PROTON_BEAM_DESTINATION to data field "LPSID Proton Beam Destination".
Incoming References	[65166] ESS Timing System Requested Proton Beam Destination [65139] LPSID Proton Beam Destination [63214] LPSID Proton Beam Destination Input

7.2.1.1.8   LPSID Proton Beam Destination Errors
#[ISSUE:64024]

Requirement	The LPSID_PROTON_BEAM_DESTINATION **shall** be considered as erroneous and set to "None" **if**: • An invalid mode is received, **or** • An error of the "LPSID Lifesign" is detected, **or** • The "LPSID CRC" checksum indicates that the message is wrong, **or** • A telegram timeout is detected.
Incoming References	[65166] ESS Timing System Requested Proton Beam Destination [65139] LPSID Proton Beam Destination [63214] LPSID Proton Beam Destination Input

7.2.1.1.9   LPSID Proton Beam Mode Input
#[ISSUE:63274]

Requirement	The FBIS **shall** read from the LPSID Interface: • The data field "LPSID Proton Beam Mode".
Explanation	The variable is used for Mode Enforcement

7.2.1.1.10 LPSID Proton Beam Mode
#[ISSUE:65143]

Requirement	The FBIS shall have a LPSID_PROTON_BEAM_MODE with the possible states defined in Proton Beam Mode States

7.2.1.1.11 LPSID Proton Beam Mode State
#[ISSUE:65144]

Requirement	The FBIS **shall** set the status LPSID_PROTON_BEAM_MODE to data field "LPSID Proton Beam Mode".
Incoming References	[65167] ESS Timing System Requested Proton Beam Mode [65143] LPSID Proton Beam Mode [63274] LPSID Proton Beam Mode Input

7.2.1.1.12 LPSID Proton Beam Mode Errors
#[ISSUE:64026]

Requirement	The LPSID_PROTON_BEAM_MODE **shall** be considered as erroneous and set to "None" **if**: • An invalid mode is received, **or**

	• An error of the "LPSID Lifesign" is detected, **or** • The "LPSID CRC" checksum indicated that the message is wrong, **or** • A telegram timeout is detected.
Incoming References	[65167] ESS Timing System Requested Proton Beam Mode [65143] LPSID Proton Beam Mode [63274] LPSID Proton Beam Mode Input

7.2.1.1.13 LPSID ID Positions Input

#[ISSUE:63596]

Requirement	The FBIS **shall** read the LPSID_ID_POSITIONS read from the LPSID Interface.
Explanation	The signal is used for State Evaluation and Mode Enforcement.

7.2.1.1.14 LPSID ID Positions

#[ISSUE:65146]

Requirement	The FBIS shall have a LPSID_ID_POSITIONS with the possible states defined in ID Positions States

7.2.1.1.15 LPSID ID Positions State

#[ISSUE:65147]

Requirement	The FBIS **shall** set the status LPSID_ID_POSITIONS to data field "LPSID ID Positions.
Incoming References	[65146] LPSID ID Positions [63596] LPSID ID Positions Input

7.2.1.1.16 LPSID ID Positions Errors

#[ISSUE:65148]

Requirement	The LPSID_ID_POSITIONS **shall** be considered as erroneous and set to "Error" **if**: • Invalid positions are received, **or** • An error of the "LPSID Lifesign" is detected, **or** • The "LPSID CRC" checksum indicated that the message is wrong, **or** • A telegram timeout is detected.
Incoming References	[65146] LPSID ID Positions [63596] LPSID ID Positions Input

7.2.1.2   LPSVAC Inputs

The following requirements address input signals received from the LPSVAC. An overview about the inputs is given in below figure.
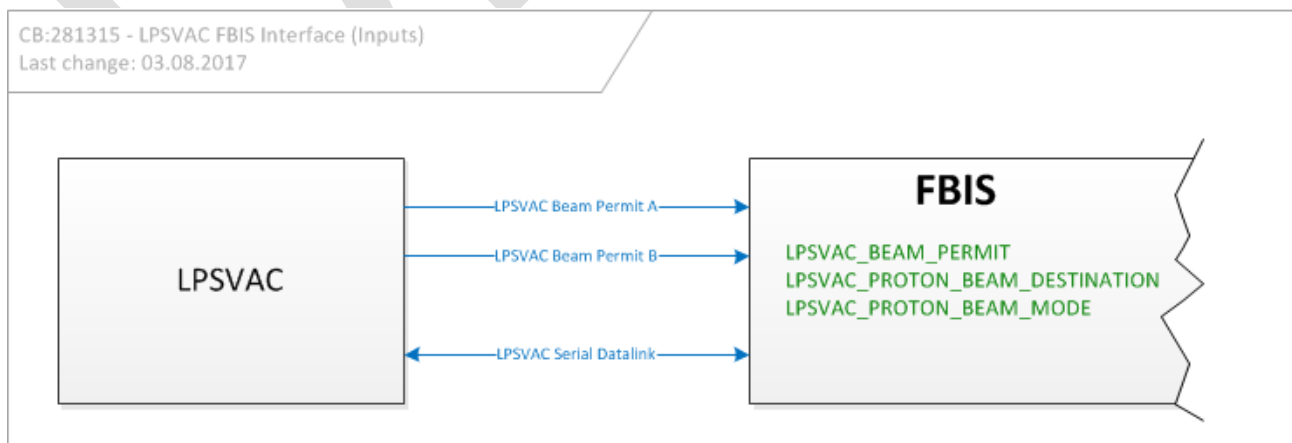
Input signals from the LPSVAC.

7.2.1.2.1 LPSVAC Beam Permit Input

#[ISSUE:63712]

Requirement	The FBIS **shall** read from the LPSVAC Interface: • The signal "LPSVAC Beam Permit A" • The signal "LPSVAC Beam Permit B" • The data field "LPSVAC Beam Permit"
Explanation	The signal is used for State Evaluation

7.2.1.2.2 LPSVAC Beam Permit

#[ISSUE:65051]

Requirement	The FBIS **shall** have a LPSVAC_BEAM_PERMIT with two possible states: "OK" and "NOK".

7.2.1.2.3 LPSVAC Beam Permit State

#[ISSUE:64084]

Requirement	The FBIS **shall** set the LPSVAC_BEAM_PERMIT to "OK" **when**: • The signal "LPSVAC Beam Permit A" is "High" **and** • The signal "LPSVAC Beam Permit B" is "Low" **and** • The data field "LPSVAC Beam Permit" is "OK" else it is set to "NOK".
Incoming References	[65051] LPSVAC Beam Permit [63712] LPSVAC Beam Permit Input

7.2.1.2.4 LPSVAC Beam Permit Errors

#[ISSUE:64086]

Requirement	The LPSVAC_BEAM_PERMIT **shall** be considered as erroneous and set to "NOK" **if**: • The discrete signal "LPSVAC Beam Permit A" differs from the state of the physical signal "LPSVAC Beam Permit B" for longer than TBD, **or** • The discrete signal "LPSVAC Beam Permit A" differs from the state of the data field "LPSVAC Beam Permit" for longer than TBD, **or** • The discrete signal "LPSVAC Beam Permit B" differs from the state of the data field "LPSVAC Beam Permit" for longer than TBD, **or** • An invalid state of the data field "LPSVAC Beam Permit" is received, **or** • An error of the "LPSVAC Lifesign" is detected, **or** • The "LPSVAC CRC" checksum indicates that the message is wrong, **or** • a telegram timeout is detected.
Incoming References	[65051] LPSVAC Beam Permit [63712] LPSVAC Beam Permit Input

7.2.1.2.5 LPSVAC Proton Beam Destination Input

#[ISSUE:63713]

Requirement	The FBIS **shall** read from the LPSVAC Interface: • The signal "LPSVAC Proton Beam Destination"
Explanation	The signal is used for Mode Enforcement

7.2.1.2.6 LPSVAC Proton Beam Destination

#[ISSUE:65150]

Requirement	The FBIS shall have a LPSVAC_PROTON_BEAM_DESTINATION with the possible states defined in Proton Beam Destination States.

7.2.1.2.7 LPSVAC Proton Beam Destination State

#[ISSUE:65151]

Requirement	The FBIS **shall** set the status LPSVAC_PROTON_BEAM_DESTINATION to data field "LPSVAC Proton Beam Destination".
Incoming References	[65150] LPSVAC Proton Beam Destination [63713] LPSVAC Proton Beam Destination Input

7.2.1.2.8   LPSVAC Proton Beam Destination Errors
#[ISSUE:64088]

Requirement	The FBIS **shall** consider the LPSVAC_PROTON_BEAM_DESTINATION as erroneous and set it to "None" **if**: • An invalid mode is received, **or** • An error of the "LPSVAC Lifesign" is detected, **or** • The "LPSVAC CRC" checksum indicates that the message is wrong, **or** • A telegram timeout is detected.
Incoming References	[65150] LPSVAC Proton Beam Destination [63713] LPSVAC Proton Beam Destination Input

7.2.1.2.9   LPSVAC Proton Beam Mode Input
#[ISSUE:63714]

Requirement	The FBIS **shall** read from the LPSVAC Interface: • The signal "LPSVAC Proton Beam Mode"
Explanation	The signal is used for Mode Enforcement

7.2.1.2.10 LPSVAC Proton Beam Mode
#[ISSUE:65149]

Requirement	The FBIS shall have a LPSVAC_PROTON_BEAM_MODE with the possible states defined in Proton Beam Mode States

7.2.1.2.11 LPSVAC Proton Beam Mode State
#[ISSUE:65152]

Requirement	The FBIS **shall** set the status LPSID_PROTON_BEAM_MODE to data field "LPSID Proton Beam Mode".
Incoming References	[65149] LPSVAC Proton Beam Mode [63714] LPSVAC Proton Beam Mode Input

7.2.1.2.12 LPSVAC Proton Beam Mode Errors
#[ISSUE:64090]

Requirement	The FBIS **shall** consider the LPSVAC_PROTON_BEAM_MODE as erroneous and set it to "None" **if**: • An invalid mode is received, **or** • An error of the "LPSVAC Lifesign" is detected, **or** • The "LPSVAC CRC" checksum indicated that the message is wrong, **or** • A telegram timeout is detected.
Incoming References	[65149] LPSVAC Proton Beam Mode [63714] LPSVAC Proton Beam Mode Input

7.2.1.3   LPSMAG Inputs

The following requirements address input signals received from the LPSMAG. An overview about the inputs is given in below figure.
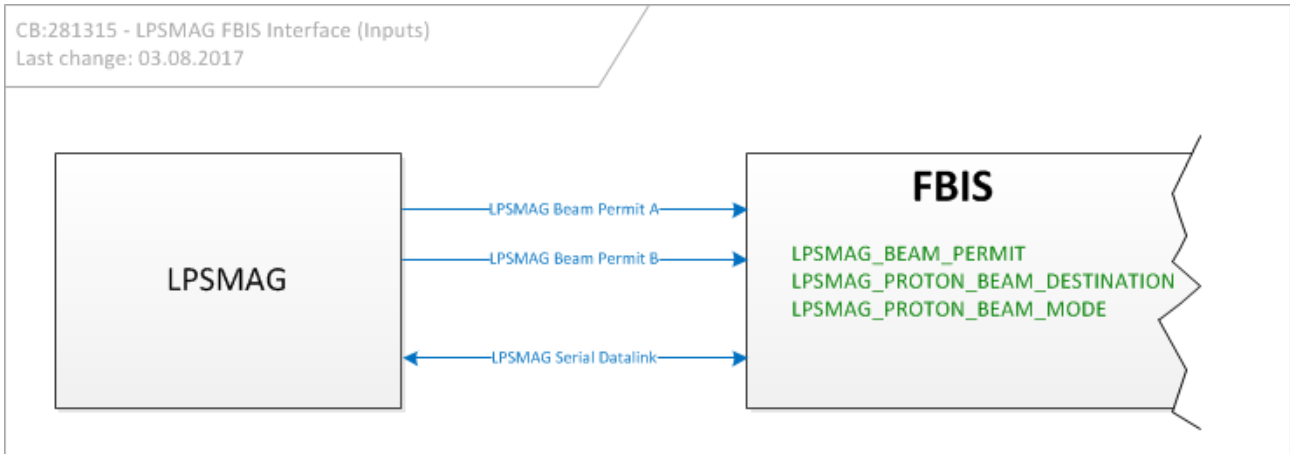
Input signals from the LPSMAG.

7.2.1.3.1 LPSMAG Beam Permit Input

#[ISSUE:63821]

Requirement	The FBIS **shall** read from the LPSMAG Interface: - The signal "LPSMAG Beam Permit A" - The signal "LPSMAG Beam Permit B" - The data field "LPSMAG Beam Permit"
Explanation	The signal is used for State Evaluation

7.2.1.3.2 LPSMAG Beam Permit

#[ISSUE:65052]

Requirement	The FBIS **shall** have a LPSMAG_BEAM_PERMIT with two possible states: "OK" and "NOK".

7.2.1.3.3 LPSMAG Beam Permit State

#[ISSUE:64085]

Requirement	The FBIS **shall** set the LPSMAG_BEAM_PERMIT to "OK" **when**: - The signal "LPSMAG Beam Permit A" is "High" **and** - The signal "LPSMAG Beam Permit B" is "Low" **and** - The data field "LPSMAG Beam Permit" is "OK" **else** it is set to "NOK".
Incoming References	[65052] LPSMAG Beam Permit [63821] LPSMAG Beam Permit Input

7.2.1.3.4 LPSMAG Beam Permit Errors

#[ISSUE:64087]

Requirement	The FBIS **shall** consider the LPSMAG_BEAM_PERMIT as erroneous and set it to "NOK" **if**: - The discrete signal "LPSMAG Beam Permit A" differs from the state of the discrete signal "LPSMAG Beam Permit B" for longer than TBD, **or** - The discrete signal "LPSMAG Beam Permit A" differs from the state of the data field "LPSMAG Beam Permit" for longer than TBD, **or** - The discrete signal "LPSMAG Beam Permit B" differs from the state of the data field "LPSMAG Beam Permit" for longer than TBD, **or** - An error of the "LPSMAG Lifesign" is detected, **or** - The "LPSMAG CRC" checksum indicates that the message is wrong.
Incoming References	[65052] LPSMAG Beam Permit [63821] LPSMAG Beam Permit Input

7.2.1.3.5 LPSMAG Proton Beam Destination Input

#[ISSUE:63822]

Requirement	The FBIS **shall** read from the LPSMAG Interface: • The signal "LPSMAG Proton Beam Destination"
Explanation	The signal is used for Mode Enforcement

7.2.1.3.6 LPSMAG Proton Beam Destination
#[ISSUE:65153]

Requirement	The FBIS **shall** have a LPSMAG_PROTON_BEAM_DESTINATION with the possible states defined in Proton Beam Destination States

7.2.1.3.7 LPSMAG Proton Beam Destination State
#[ISSUE:65154]

Requirement	The FBIS **shall** set the status LPSMAG_PROTON_BEAM_DESTINATION to data field "LPSMAG Proton Beam Destination".
Incoming References	[65153] LPSMAG Proton Beam Destination

7.2.1.3.8 LPSMAG Proton Beam Destination Errors
#[ISSUE:64089]

Requirement	The FBIS **shall** consider the LPSMAG_PROTON_BEAM_DESTINATION as erroneous and set it to "None" **if**: • An invalid mode is received, **or** • An error of the "LPSMAG Lifesign" is detected, **or** • The "LPSMAG CRC" checksum indicates that the message is wrong.
Incoming References	[65153] LPSMAG Proton Beam Destination

7.2.1.3.9 LPSMAG Proton Beam Mode Input
#[ISSUE:63823]

Requirement	The FBIS **shall** read from the LPSMAG Interface: • The signal "LPSMAG Proton Beam Mode"
Explanation	The signal is used for Mode Enforcement

7.2.1.3.10 LPSMAG Proton Beam Mode
#[ISSUE:65155]

Requirement	The FBIS shall have a LPSMAG_PROTON_BEAM_MODE with the possible states defined in Proton Beam Mode States

7.2.1.3.11 LPSMAG Proton Beam Mode State
#[ISSUE:65156]

Requirement	The FBIS **shall** set the status LPSMAG_PROTON_BEAM_MODE to data field "LPSMAG Proton Beam Mode".
Incoming References	[65155] LPSMAG Proton Beam Mode [63823] LPSMAG Proton Beam Mode Input

7.2.1.3.12 LPSMAG Proton Beam Mode Errors
#[ISSUE:64091]

Requirement	The FBIS **shall** consider the LPSMAG_PROTON_BEAM_MODE as erroneous and set it to "None" **if**: • An invalid mode is received, **or** • An error of the "LPSMAG Lifesign" is detected, **or** • The "LPSMAG CRC" checksum indicated that the message is wrong.
Incoming References	[65155] LPSMAG Proton Beam Mode [63823] LPSMAG Proton Beam Mode Input

7.2.1.4 ACCT Inputs

The following requirements address input signals received from the ACCT Digital Processing Boards. An overview about the inputs is given in below figure.

CB:281315 - ACCT Digital Processing Board Interface (Inputs)
Last change: 03.08.2017
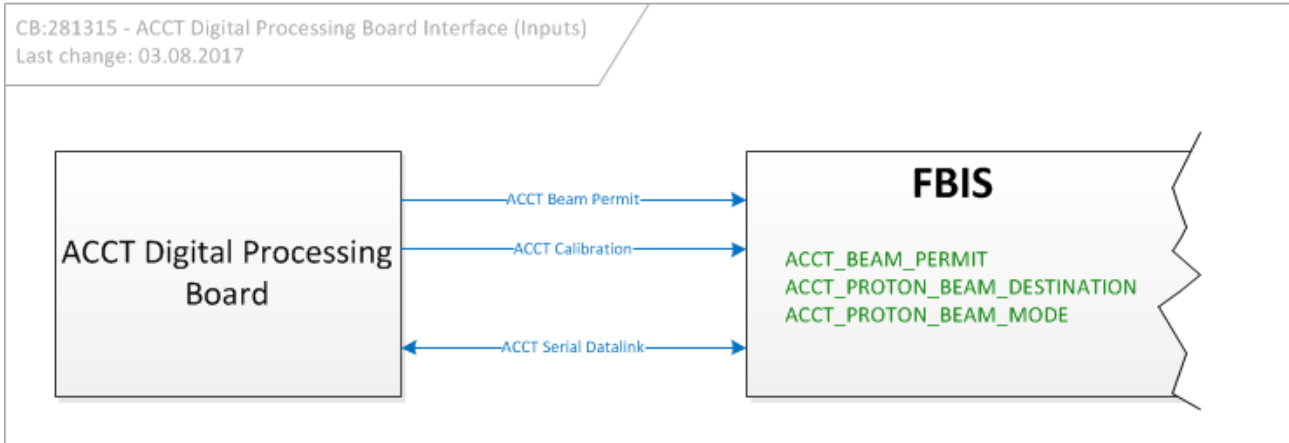
Input signals from the ACCT Digital Processing Boards. As there are multiple processing boards (not explicitly shown in the figure) the respective FBIS variables are indexed.

7.2.1.4.1 ACCT_x Beam Permit Input

#[ISSUE:63621]

Requirement	The FBIS **shall** read from the ACCT Digital Processing Board Interface: • The discrete signals "ACCT *x* Alarm" • The data fields "ACCT *x* Calibration" (*x* stands for 1 through 7.)
Explanation	The signal is used for State Evaluation
Incoming References	[64453] DTL-010:SCU

7.2.1.4.2 ACCT_x Beam Permit

#[ISSUE:65162]

Requirement	The FBIS **shall** have a ACCT_*x*_BEAM_PERMIT with two possible states: "OK" and "NOK". (*x* stands for 1 through 7.)

7.2.1.4.3 ACCT_x Beam Permit State

#[ISSUE:64092]

Requirement	The FBIS **shall** set the ACCT_*x*_BEAM_PERMIT to "OK" **when**: • The signal "ACCT *x* Alarm" is "High" **and** • The data field "ACCT *x* Alarm" is "No Alarm" **and** • The signal "ACCT *x* Calibration" is "High" **and** • The data field "ACCT *x* Calibration" is "Not Calibrating" **else** it is set to "NOK".
Incoming References	[65162] ACCT_x Beam Permit [64453] DTL-010:SCU [63621] ACCT_x Beam Permit Input

7.2.1.4.4 ACCT_x Beam Permit Errors

#[ISSUE:64093]

Requirement	The FBIS **shall** consider the ACCT_*x*_BEAM_PERMIT as erroneous and set it to "NOK" **if**: • The discrete signal "ACCT *x* Alarm" differs from the state of the data field "ACCT *x* Alarm" for longer than TBD, **or** • An invalid state of the data field "ACCT *x* Alarm" is received, **or**

	• The discrete signal "ACCT *x* Calibration" differs from the state of the data field "ACCT *x* Calibration" for longer than TBD, **or** • An invalid state of the data field "ACCT *x* Calibration" is received, **or** • An error of the "ACCT *x* Lifesign" is detected, **or** • The "ACCT *x* CRC" checksum indicates that the message is wrong, **or** • A telegram timeout is detected.
Incoming References	[65162] ACCT_x Beam Permit [64453] DTL-010:SCU [63621] ACCT_x Beam Permit Input

7.2.1.4.5   ACCT_x_ Proton Beam Destination Input
#[ISSUE:63654]

Requirement	The FBIS **shall** read from the ACCT Digital Processing Board Interface: • The signal "ACCT *x* Proton Beam Destination" (*x* stands for 1 through 7.)
Explanation	The signal is used for Mode Enforcement
Incoming References	[64453] DTL-010:SCU

7.2.1.4.6   ACCT_x Proton Beam Destination
#[ISSUE:65163]

Requirement	The FBIS **shall** have a ACCT_*x*_PROTON_BEAM_DESTINATION with the possible states defined in Proton Beam Destination States. (*x* stands for 1 through 7.)

7.2.1.4.7   ACCT_x Proton Beam Destination State
#[ISSUE:65159]

Requirement	The FBIS **shall** set the status ACCT_*x*_PROTON_BEAM_DESTINATION to data field "ACCT *x* Proton Beam Destination".
Incoming References	[65163] ACCT_x Proton Beam Destination [63654] ACCT_x_ Proton Beam Destination Input

7.2.1.4.8   ACCT_x_ Proton Beam Destination Errors
#[ISSUE:64096]

Requirement	The FBIS **shall** consider the ACCT_*x*_PROTON_BEAM_DESTINATION as erroneous and set it to "None" **if**: • An invalid mode is received, **or** • An error of the "ACCT *x* Lifesign" is detected, **or** • The "ACCT *x* CRC" checksum indicates that the message is wrong.
Incoming References	[65163] ACCT_x Proton Beam Destination [64453] DTL-010:SCU [63654] ACCT_x_ Proton Beam Destination Input

7.2.1.4.9   ACCT_x_ Proton Beam Mode Input
#[ISSUE:63652]

Requirement	The FBIS **shall** read from the ACCT Digital Processing Board Interface: • The signal "ACCT *x* Proton Beam Mode" (*x* stands for 1 through 7.)
Explanation	The signal is used for Mode Enforcement
Incoming References	[64453] DTL-010:SCU

7.2.1.4.10 ACCT_x Proton Beam Mode
#[ISSUE:65160]

Requirement	The FBIS shall have a ACCT_*x*_PROTON_BEAM_MODE with the possible states defined in Proton Beam Mode States. (*x* stands for 1 through 7.)

7.2.1.4.11 ACCT_x Proton Beam Mode State
#[ISSUE:65157]

| Requirement	The FBIS **shall** set the status ACCT_*x*_PROTON_BEAM_MODE to data field "ACCT *x* Proton Beam Mode".
Incoming References	[65160] ACCT_x Proton Beam Mode [63652] ACCT_x_ Proton Beam Mode Input

7.2.1.4.12 ACCT_x_ Proton Beam Mode Errors
#[ISSUE:64097]

Requirement	The FBIS **shall** consider the ACCT_x_PROTON_BEAM_MODE as erroneous and set it to "None" **if**: • An invalid mode is received, **or** • An error of the "ACCT Lifesign" is detected, **or** • The "ACCT CRC" checksum indicates that the message is wrong.
Incoming References	[65160] ACCT_x Proton Beam Mode [64453] DTL-010:SCU [63652] ACCT_x_ Proton Beam Mode Input

7.2.1.5   RF Inputs

The following requirements address input signals received from the RF Fast Interlock Modules. An overview about the inputs is given in below figure.
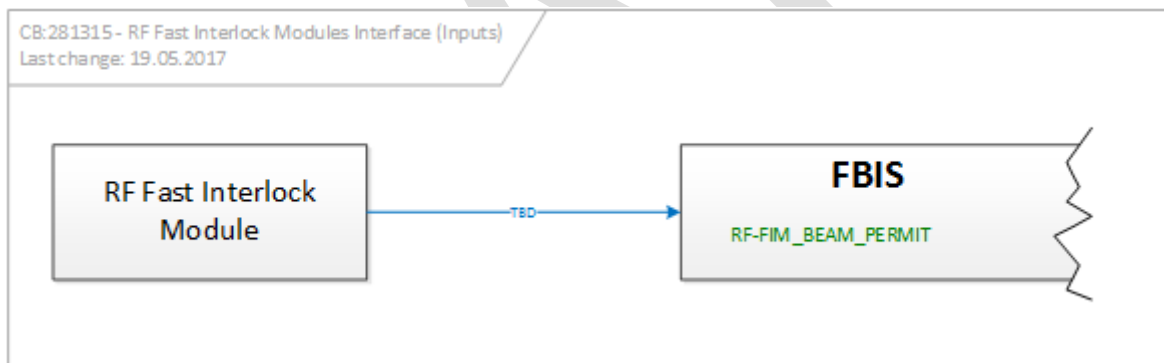
Input signals from the RF Fast Interlock Modules. As there are multiple interlock modules (not explicitly shown in the figure) the respective FBIS variable is indexed.

7.2.1.5.1   RF-FIM_x Beam Permit Input
#[ISSUE:63830]

Requirement	The FBIS **shall** read from the RF Fast Interlock Module Interface: • The signal "TBD *x*" (*x* stands for 1 through 155.)
Explanation	The signal is used for State Evaluation
Incoming References	[64453] DTL-010:SCU

7.2.1.5.2   RF-FIM_x Beam Permit
#[ISSUE:65053]

Requirement	The FBIS **shall** have a RF-FIM_*x*_BEAM_PERMIT with two possible states: "OK" and "NOK". (*x* stands for 1 through 155.)

7.2.1.5.3   RF-FIM_x Beam Permit State
#[ISSUE:64126]

Requirement	The FBIS **shall** set the RF-FIM_*x*_BEAM_PERMIT to "OK" **when**: • TBD **else** it is set to "NOK".
Incoming References	[65053] RF-FIM_x Beam Permit [64453] DTL-010:SCU [63830] RF-FIM_x Beam Permit Input

7.2.1.5.4 RF-FIM_x Beam Permit Errors
#[ISSUE:64127]

Requirement	The FBIS **shall** consider the RF-FIM_*x*_BEAM_PERMIT as erroneous and set it to "NOK" **if**: • TBD
Incoming References	[65053] RF-FIM_x Beam Permit [64453] DTL-010:SCU [63830] RF-FIM_x Beam Permit Input

7.2.1.6 Fast Gate Valve Inputs

The following requirements address input signals received from the Fast Gate Valves. An overview about the inputs is given in below figure.
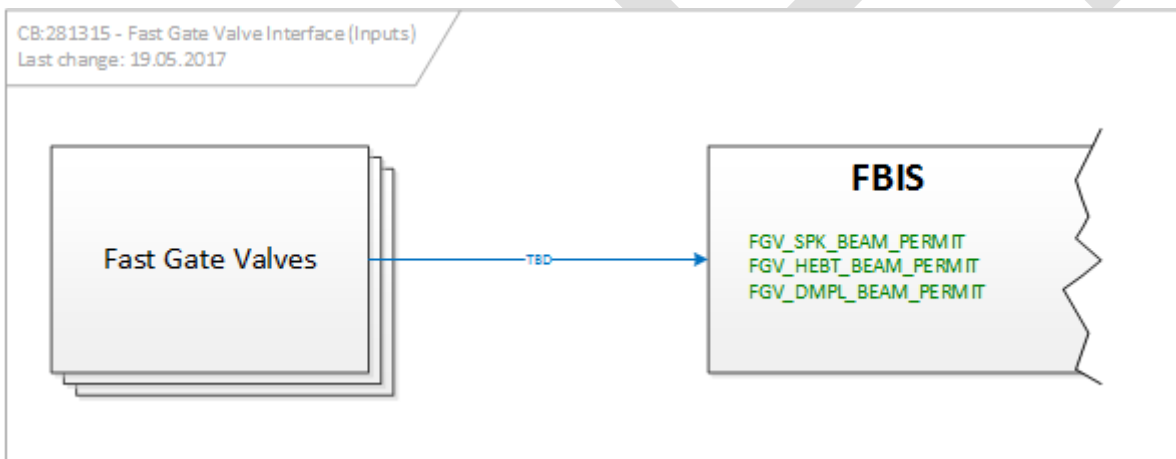
Input signals from the Fast Gate Valves.

7.2.1.6.1 FGV Spokes Beam Permit Input
#[ISSUE:65048]

Requirement	The FBIS **shall** read from the Fast Gate Valve Interface: • The signal "TBD"

7.2.1.6.2 FGV Spokes Beam Permit
#[ISSUE:63848]

Requirement	The FBIS **shall** have an FGV_SPOKES_BEAM_PERMIT with TBD possible states: "TBD" and "TBD"
Explanation	The signal is used for State Evaluation

7.2.1.6.3 FGV Spokes Beam Permit State
#[ISSUE:64128]

Requirement	The FBIS **shall** set the FGV_SPOKES_BEAM_PERMIT to "TBD" **when**: • TBD
Incoming References	[65048] FGV Spokes Beam Permit Input [63848] FGV Spokes Beam Permit

7.2.1.6.4   FGV Spokes Beam Permit Errors

#[ISSUE:64131]

Requirement	TBD
Incoming References	[65048] FGV Spokes Beam Permit Input [63848] FGV Spokes Beam Permit

7.2.1.6.5   FGV HEBT Beam Permit Input

#[ISSUE:65049]

Requirement	The FBIS **shall** read from the Fast Gate Valve Interface: • The signal "TBD"

7.2.1.6.6   FGV HEBT Beam Permit

#[ISSUE:63849]

Requirement	The FBIS **shall** have a FGV_HEBT_BEAM_PERMIT with TBD possible states: "TBD" and "TBD".
Explanation	The signal is used for State Evaluation

7.2.1.6.7   FGV HEBT Beam Permit State

#[ISSUE:64129]

Requirement	The FBIS **shall** set the TBD to "TBD" **when**: • The signal "TBD" is "TBD"
Incoming References	[65049] FGV HEBT Beam Permit Input [63849] FGV HEBT Beam Permit

7.2.1.6.8   FGV HEBT Beam Permit Errors

#[ISSUE:64132]

Requirement	TBD
Incoming References	[65049] FGV HEBT Beam Permit Input [63849] FGV HEBT Beam Permit

7.2.1.6.9   FGV Dump Line Beam Permit Input

#[ISSUE:65050]

Requirement	The FBIS **shall** read from the Fast Gate Valve Interface: • The signal "TBD"

7.2.1.6.10 FGV Dump Line Beam Permit

#[ISSUE:63850]

Requirement	TBD
Explanation	The signal is used for State Evaluation

7.2.1.6.11 FGV Dump Line Beam Permit State

#[ISSUE:64130]

Requirement	TBD
Incoming References	[65050] FGV Dump Line Beam Permit Input

7.2.1.6.12 FGV Dump Line Beam Permit Errors

#[ISSUE:64133]

Requirement	TBD
Incoming References	[65050] FGV Dump Line Beam Permit Input

7.2.2 Actuation System Inputs

The FBIS receives inputs from the following Actuation Systems:

- ESS Timing System
- LEBT Chopper
- MEBT Chopper
- Ion Source

Requirements related to these inputs are given in the following sub-chapters.

7.2.2.1 ESS Timing System Inputs

The following requirements address input signals received from the ESS Timing System. An overview about the inputs is given in below figure.
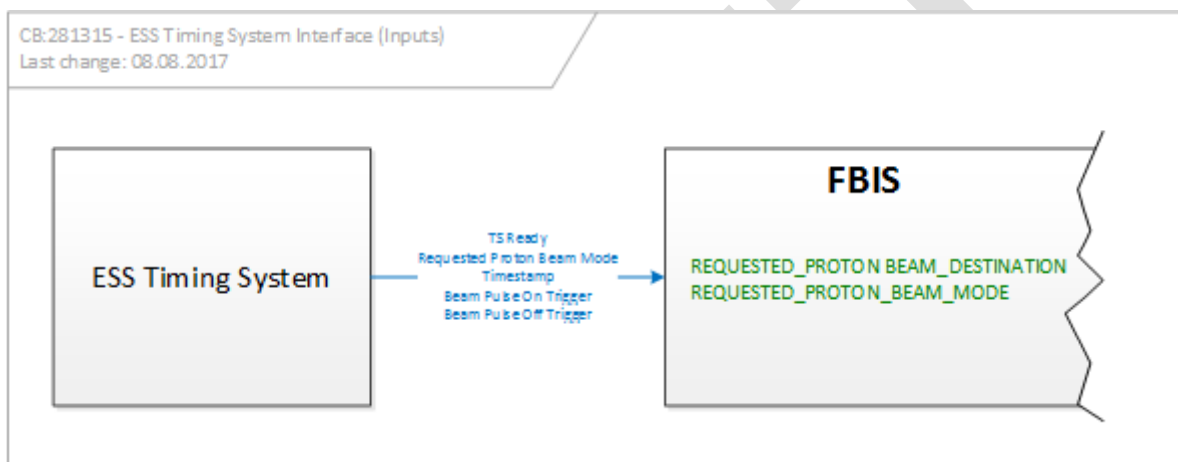
Input signals from the ESS Timing System.

7.2.2.1.1 ESS Timing System Beam Inhibit Status
#[ISSUE:63226]

Requirement	The FBIS **shall** read from the ESS Timing System Interface: • The signal "TS Ready"
Explanation	The signal is used for State Evaluation

7.2.2.1.2 ESS Timing System Requested Proton Beam Destination Input
#[ISSUE:63551]

Requirement	The FBIS **shall** read from the ESS Timing System Interface: • The signal "Requested Proton Beam Destination"
Explanation	The signal is used for Mode Enforcement.

7.2.2.1.3 ESS Timing System Requested Proton Beam Destination
#[ISSUE:65166]

Requirement	The FBIS **shall** have a REQEUSTED_PROTON_BEAM_DESTINATION with the possible states defined in Proton Beam Destination States.

7.2.2.1.4 ESS Timing System Requested Proton Beam Destination State
#[ISSUE:65168]

Requirement	The FBIS **shall** set the status REQUESTED_PROTON_BEAM_DESTINATION to data field "Requested Proton Beam Destination".

7.2.2.1.5   ESS Timing System Requested Proton Beam Destination Errors
#[ISSUE:65170]

Requirement	The FBIS **shall** consider the REQUESTED_PROTON_BEAM_DESTINATION as erroneous and set it to "None" **if**: • TBD.

7.2.2.1.6   ESS Timing System Requested Proton Beam Mode Input
#[ISSUE:63550]

Requirement	The FBIS **shall** read from the ESS Timing System Interface: • The signal "Requested Proton Beam Mode"
Explanation	The signal is used for Mode Enforcement

7.2.2.1.7   ESS Timing System Requested Proton Beam Mode
#[ISSUE:65167]

Requirement	The FBIS shall have a REQUESTED_PROTON_BEAM_MODE with the possible states defined in Proton Beam Mode States

7.2.2.1.8   ESS Timing System Requested Proton Beam Mode Errors
#[ISSUE:65171]

Requirement	The FBIS **shall** consider the REQUESTED_PROTON_BEAM_MODE as erroneous and set it to "None" **if**: • TBD.

7.2.2.1.9   ESS Timing System Requested Proton Beam Mode State
#[ISSUE:65169]

Requirement	The FBIS **shall** set the status REQUESTED_PROTON_BEAM_MODE to data field "Requested Proton Beam Mode".

7.2.2.1.10 ESS Timing System Timestamp
#[ISSUE:63552]

Requirement	The FBIS **shall** read from the ESS Timing System Interface: • The "Timestamp"
Explanation	The signal is used for Event Logging.

7.2.2.1.11 ESS Timing System Beam Pulse On Trigger
#[ISSUE:63553]

Requirement	The FBIS **shall** monitor the "Beam Pulse On Trigger" read from the ESS Timing System Interface.
Explanation	The signal is used for Beam Pulse Phase Detection.

7.2.2.1.12 ESS Timing System Beam Pulse Off Trigger
#[ISSUE:63554]

Requirement	The FBIS **shall** monitor the "Beam Pulse Off Trigger" read from the ESS Timing System Interface.
Explanation	The signal is used for Beam Pulse Phase Detection.

7.2.2.2   LEBT Chopper Input Signals
The following requirements address input signals received from the LEBT Chopper. An overview about the inputs is given in below figure.

Input signals from the LEBT Chopper.
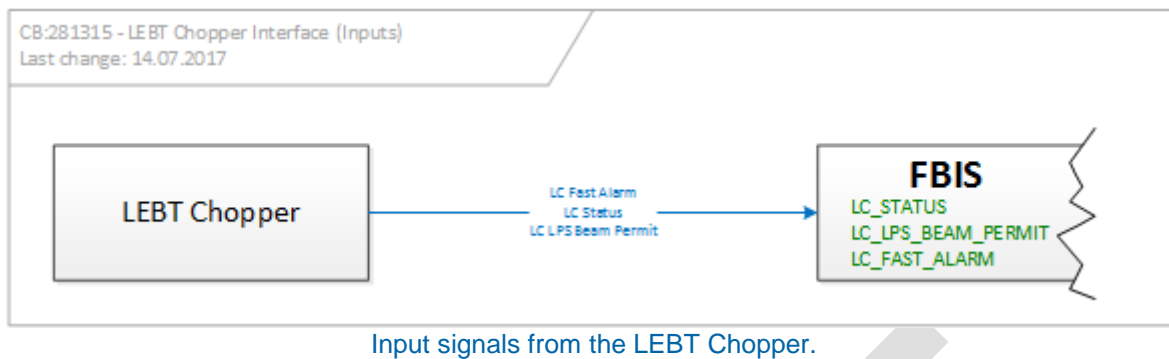
7.2.2.2.1 LEBT Chopper Status Input
#[ISSUE:63534]

Requirement	The FBIS **shall** read from the LEBT Chopper Interface: • The signal "LC Status"
Explanation	The signal is used for State Evaluation

7.2.2.2.2 LEBT Chopper Status
#[ISSUE:65119]

Requirement	The FBIS **shall** have a LC_STATUS with TBD possible states: TBD.

7.2.2.2.3 LEBT Chopper Status State
#[ISSUE:64872]

Requirement	The FBIS **shall** set the LC_STATUS to "TBD" **when**: • The signal "LC Status" is TBD, i.e. the LEBT Chopper deflects the proton beam else it is set to "TBD".
Incoming References	[65119] LEBT Chopper Status [63534] LEBT Chopper Status Input

7.2.2.2.4 LEBT Chopper Status Errors
#[ISSUE:64873]

Requirement	The FBIS **shall** consider the LC_STATUS as erroneous and set it to "not deflecting" **if**: • A cable is broken, **or** • A cable is unconnected.
Incoming References	[65119] LEBT Chopper Status [63534] LEBT Chopper Status Input

7.2.2.2.5 LEBT Chopper LPS Beam Permit Input
#[ISSUE:64874]

Requirement	The FBIS **shall** read from the LEBT Chopper Interface: • The signal "LC LPS Beam Permit"

7.2.2.2.6 LEBT Chopper LPS Beam Permit
#[ISSUE:65120]

Requirement	The FBIS **shall** have a LC_LPS_BEAM_PERMIT with two possible states: "OK" and "NOK".

7.2.2.2.7 LEBT Chopper LPS Beam Permit State
#[ISSUE:64875]

Requirement	The FBIS **shall** set the LC_LPS_BEAM_PERMIT to "TBD" **when**: • The "TBD" is "TBD"

	else it is set to "TBD".
Incoming References	[65120] LEBT Chopper LPS Beam Permit [64874] LEBT Chopper LPS Beam Permit Input

7.2.2.2.8   LEBT Chopper LPS Beam Permit Errors

#[ISSUE:64877]

Requirement	The FBIS **shall** consider the LC_LPS_BEAM_PERMIT as erroneous and set it to "TBD" **if**: • TBD
Incoming References	[65120] LEBT Chopper LPS Beam Permit [64874] LEBT Chopper LPS Beam Permit Input

7.2.2.2.9   LEBT Chopper Fast Alarm Input

#[ISSUE:65121]

Requirement	The FBIS **shall** read from the LEBT Chopper Interface: • The signal "LC Fast Alarm"

7.2.2.2.10 LEBT Chopper Fast Alarm

#[ISSUE:65123]

Requirement	The FBIS **shall** have a LC_FAST_ALARM with two possible states: "OK" and "NOK".

7.2.2.2.11 LEBT Chopper Fast Alarm State

#[ISSUE:64878]

Requirement	The FBIS **shall** set the LC_FAST_ALARM to "TBD" **when**: • TBD else it is set to "TBD".
Incoming References	[65123] LEBT Chopper Fast Alarm [65121] LEBT Chopper Fast Alarm Input

7.2.2.2.12 LEBT Chopper Fast Alarm Errors

#[ISSUE:64879]

Requirement	The FBIS **shall** consider the LC_FAST_ALARM as erroneous and set it to "TBD" **if**: • TBD
Incoming References	[65123] LEBT Chopper Fast Alarm [65121] LEBT Chopper Fast Alarm Input

7.2.2.3   MEBT Chopper Input Signals

The following requirements address input signals received from the MEBT Chopper. An overview about the inputs is given in below figure.
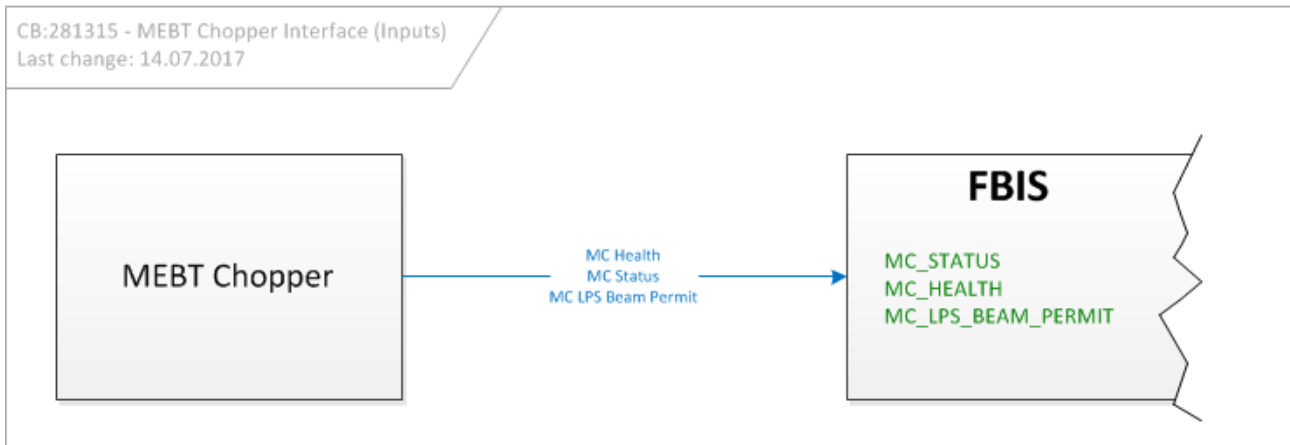
Input signals from the MEBT Chopper.

7.2.2.3.1 MEBT Chopper Status Input

#[ISSUE:63569]

Requirement	The FBIS **shall** read from the MEBT Chopper Interface: • The signal "MC Status"
Explanation	The signal is used for State Evaluation

7.2.2.3.2 MEBT Chopper Status

#[ISSUE:65124]

Requirement	The FBIS **shall** have a MC_STATUS with TBD possible states: TBD.

7.2.2.3.3 MEBT Chopper Status State

#[ISSUE:64866]

Requirement	The FBIS **shall** set the MC_STATUS to "TBD" **when**: • The MEBT Chopper deflects the proton beam else it is set to "TBD".
Incoming References	[65124] MEBT Chopper Status [63569] MEBT Chopper Status Input

7.2.2.3.4 MEBT Chopper Status Errors

#[ISSUE:64869]

Requirement	The FBIS **shall** consider the MC_STATUS as erroneous and set it to "not deflecting" **if**: • A cable is broken, **or** • A cable is unconnected
Incoming References	[65124] MEBT Chopper Status [63569] MEBT Chopper Status Input

7.2.2.3.5 MEBT Chopper LPS Beam Permit Input

#[ISSUE:63567]

Requirement	The FBIS **shall** read from the MEBT Chopper Interface: • The signal "MC LPS Beam Permit"
Explanation	The signal is used for State Evaluation

7.2.2.3.6 MEBT Chopper LPS Beam Permit

#[ISSUE:65054]

Requirement	The FBIS **shall** have a MC_LPS_BEAM_PERMIT with two possible states: "OK" and "NOK".

7.2.2.3.7 MEBT Chopper LPS Beam Permit State

#[ISSUE:64806]

Requirement	The FBIS **shall** set the MC_LPS_BEAM_PERMIT to "OK" **when**: • The "MC LPS Beam Permit" is "TBD" else it is set to "NOK".
Incoming References	[65054] MEBT Chopper LPS Beam Permit

7.2.2.3.8 MEBT Chopper LPS Beam Permit Errors

#[ISSUE:64876]

Requirement	The FBIS **shall** consider the MC_LPS_BEAM_PERMIT as erroneous and set it to "TBD" **if**: • TBD

7.2.2.3.9 MEBT Chopper Health Input

#[ISSUE:63568]

Requirement	The FBIS **shall** read from the MEBT Chopper Interface: • The signal "MC Health"
Explanation	The signal is used for State Evaluation

7.2.2.3.10 MEBT Chopper Health

#[ISSUE:65125]

Requirement	The FBIS **shall** have a MC_HEALTH with TBD possible states: TBD.

7.2.2.3.11 MEBT Chopper Health State

#[ISSUE:64808]

Requirement	The FBIS **shall** set the MC_HEALTH to "healthy" **when**: • The "MC Health" is "TBD" else it is set to "unhealthy".
Incoming References	[65125] MEBT Chopper Health

7.2.2.3.12 MEBT Chopper Health Errors

#[ISSUE:64809]

Requirement	The FBIS **shall** consider the MC_HEALTH as erroneous and set it to "TBD" **if**: • TBD
Incoming References	[65125] MEBT Chopper Health

7.2.2.4 Ion Source Input Signals

The following requirements address input signals received from the Ion Source. An overview about the inputs is given in below figure.
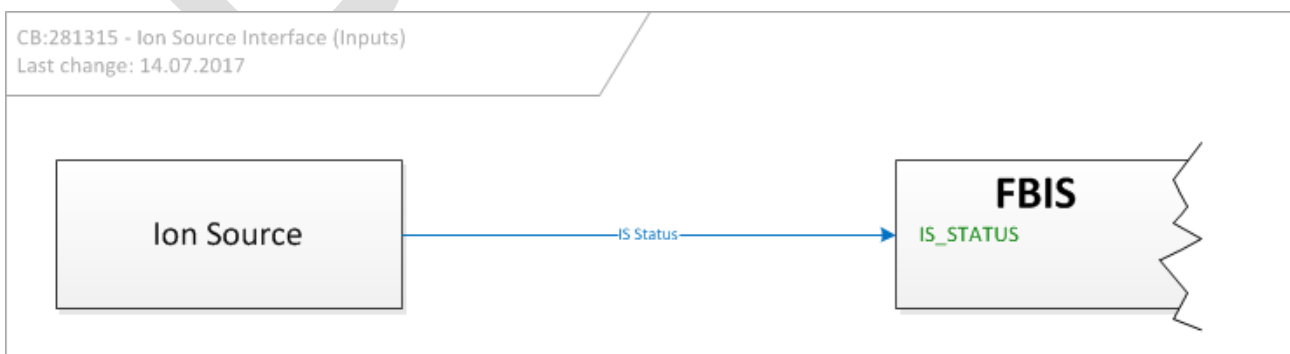
Input signals from the Ion Source.

7.2.2.4.1 Ion Source Status Input

#[ISSUE:63599]

Requirement	The FBIS **shall** read from the Ion Source Interface: • The signal "IS Status"
Explanation	The signal is used for State Evaluation

7.2.2.4.2 Ion Source Status

#[ISSUE:65126]

Requirement	The FBIS **shall** have a IS_STATUS with TBD possible states: TBD.
Incoming References	[63599] Ion Source Status Input

7.2.2.4.3 Ion Source Status State

#[ISSUE:65127]

Requirement	The FBIS **shall** set the IS_STATUS to "TBD" **when**; • The signal "TBD" is "TBD" else it is set to "TBD".
Incoming References	[65126] Ion Source Status [63599] Ion Source Status Input

7.2.3 Latching of Erroneous Input Signals

#[ISSUE:63589]

Requirement	The FBIS **shall** latch the status of an erroneous input signal.
Explanation	If an input signal is erroneous the FBIS latches the NOK in order to make the operator aware of the signal error.

7.2.4 Input Signal Control System Readout

#[ISSUE:62890]

Requirement	The FBIS **shall** provide the actual input signal states during runtime for readout through the Control System Interface.
Explanation	The states of input signals is made available for readout at all times for diagnostic purposes.

7.2.5 Logging of Erroneous Input Signals

#[ISSUE:63590]

Requirement	The FBIS **shall** write error states of an errouneous input signal to the Event Logging.

7.2.6 Logging of Input Signal State Changes

#[ISSUE:64027]

Requirement	The FBIS **shall** write state changes of input signals to the Event Logging.

7.2.7 Variables Control System Readout

#[ISSUE:64028]

Requirement	The FBIS **shall** provide the actual states of decision logic variables during runtime for readout through the Control System Interface.
Explanation	The states of output signals is made available for readout at all times for diagnostic purposes.

7.2.8 Logging of Variables State Changes

#[ISSUE:64029]

Requirement	The FBIS **shall** write state changes of decision logic variables to the Event Logging.

7.2.9 Masking

The FBIS allows Masking selected FBIS input signals under clearly specified circumstances. The following requirements specify generic requirements about masking followed by requirements under which circumstances masking is allowed.

How the masking feature influences the FBIS Decision Logic computation is specified in the chapters describing the evaluation of conditions (for example chapter Beam Permit States Evaluation).

The following illustration shows how masking works in general.
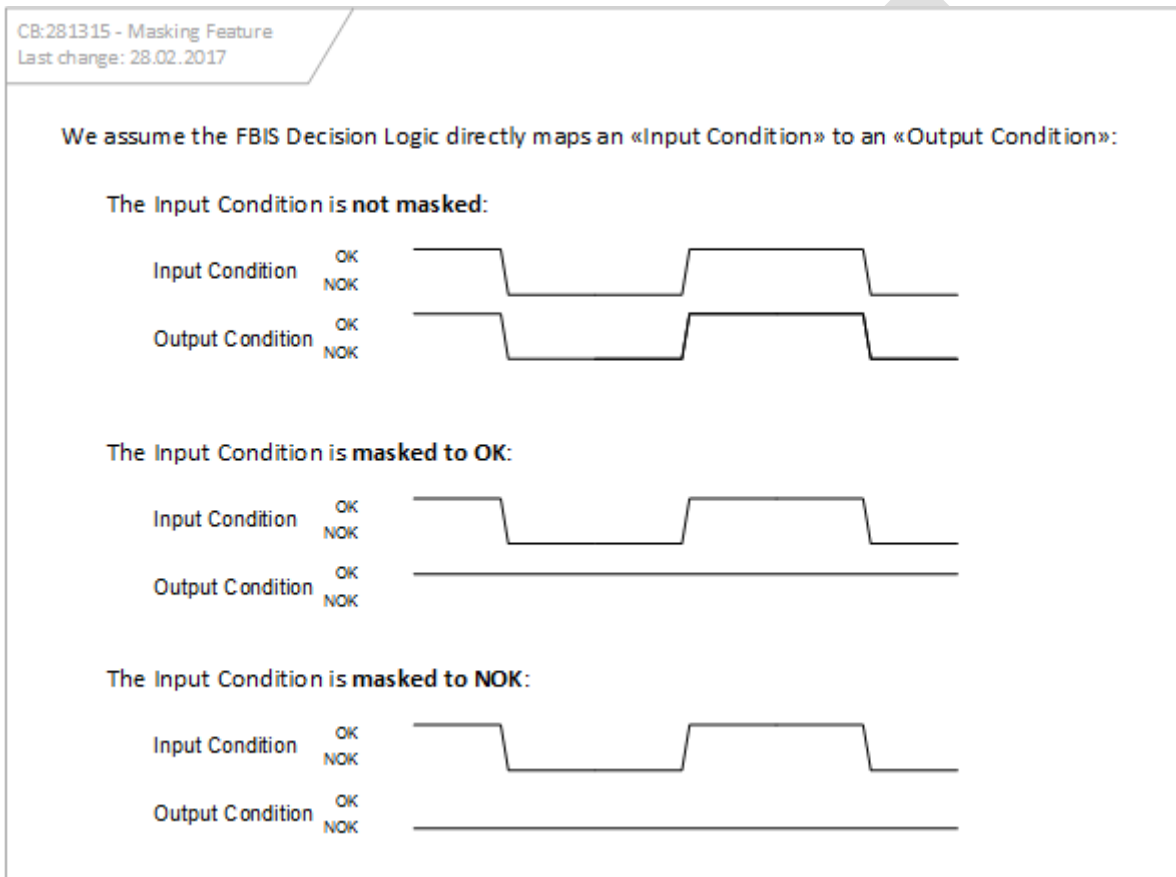
Illustration how the masking feature influences the computation of the FBIS Decision Logic.

7.2.9.1 Generic Masking Requirements

The following requirements specify the generic requirements on masking of FBIS Input Signals.

7.2.9.1.1 Masking Feature (OK/NOK Signals)

#[ISSUE:63016]

Requirement	The FBIS **shall** allow to mask individual FBIS input signals of type OK/NOK to "Mask to OK", "Mask to NOK", or "No Masking" during runtime via the Control System Interface **when** the Masking Conditions are met.
	<table><tr><td>**Masking**</td><td>**Effect**</td></tr><tr><td>Mask to OK</td><td>The signal is treated as "OK"</td></tr><tr><td>Mask to NOK</td><td>The signal is treated as "NOK"</td></tr><tr><td>No Masking</td><td>The state of the signal reflects the actual input state</td></tr></table>
Incoming References	[63831] RF-FIMx Beam Permit Mask to OK [63826] LPSMAG Proton Beam Mode Masking [63825] LPSMAG Proton Beam Destination Masking [63824] LPSMAG Beam Permit Mask to OK

[63721] LPSVAC Proton Beam Mode Masking
[63720] LPSVAC Proton Beam Destination Masking
[63719] ACCTx Proton Beam Mode Masking
[63660] ACCTx No Beam Mask to OK
[63659] ACCTx Proton Beam Destination Masking
[63658] LPSVAC Beam Permit Mask to OK
[63656] ACCTx Beam Permit Mask to OK
[63537] MEBT Chopper Controller Health Mask to OK
[63536] LEBT Chopper LPS Beam Permit Mask to OK
[63192] Mask to NOK
[62929] LPSID Beam Permit Mask to OK
[62927] Logging of Masking Changes
[62926] Control System Masking Readout

7.2.9.1.2 Masking Feature (Beam Destination)

#[ISSUE:63715]

Requirement	The FBIS **shall** allow to mask individual FBIS input signals reflecting beam destination to "Masked" or "No Masking" during runtime via the Control System Interface **when** the Masking Conditions are met.

Masking	Effect
Masked	The signal is not evaluated for Mode Enforcement
No Masking	The signal is evaluated for Mode Enforcement

Incoming References	[63831] RF-FIMx Beam Permit Mask to OK [63826] LPSMAG Proton Beam Mode Masking [63825] LPSMAG Proton Beam Destination Masking [63824] LPSMAG Beam Permit Mask to OK [63721] LPSVAC Proton Beam Mode Masking [63720] LPSVAC Proton Beam Destination Masking [63719] ACCTx Proton Beam Mode Masking [63660] ACCTx No Beam Mask to OK [63659] ACCTx Proton Beam Destination Masking [63658] LPSVAC Beam Permit Mask to OK [63656] ACCTx Beam Permit Mask to OK [63537] MEBT Chopper Controller Health Mask to OK [63536] LEBT Chopper LPS Beam Permit Mask to OK [63192] Mask to NOK [62929] LPSID Beam Permit Mask to OK [62927] Logging of Masking Changes [62926] Control System Masking Readout

7.2.9.1.3 Masking Feature (Proton Beam Modes)

#[ISSUE:63718]

Requirement	The FBIS **shall** allow to mask individual FBIS input signals reflecting the proton beam mode to "Masked" or "No Masking" during runtime via the Control System Interface **when** the Masking Conditions are met.

Masking	Effect
Masked	The signal is not evaluated for Mode Enforcement
No Masking	The signal is evaluated for Mode Enforcement

Incoming References	[63831] RF-FIMx Beam Permit Mask to OK [63826] LPSMAG Proton Beam Mode Masking [63825] LPSMAG Proton Beam Destination Masking [63824] LPSMAG Beam Permit Mask to OK [63721] LPSVAC Proton Beam Mode Masking [63720] LPSVAC Proton Beam Destination Masking [63719] ACCTx Proton Beam Mode Masking

	[63660] ACCTx No Beam Mask to OK
	[63659] ACCTx Proton Beam Destination Masking
	[63658] LPSVAC Beam Permit Mask to OK
	[63656] ACCTx Beam Permit Mask to OK
	[63537] MEBT Chopper Controller Health Mask to OK
	[63536] LEBT Chopper LPS Beam Permit Mask to OK
	[63192] Mask to NOK
	[62929] LPSID Beam Permit Mask to OK
	[62927] Logging of Masking Changes
	[62926] Control System Masking Readout

7.2.9.1.4   Default Masking

#[ISSUE:62925]

Requirement	The FBIS **shall** by default use "No Masking" for all FBIS input signals.
Rationale	"No Masking" is the fail-safe configuration for FBIS input signals.
Incoming References	[62927] Logging of Masking Changes [62926] Control System Masking Readout

7.2.9.1.5   Control System Masking Readout

#[ISSUE:62926]

Requirement	The FBIS **shall** provide the actual configuration of the FBIS input signal masking during runtime through the Control System Interface.
Explanation	This allows for example to display information about the masking to the operator.

7.2.9.1.6   Logging of Masking Changes

#[ISSUE:62927]

Requirement	The FBIS **shall** write changes to masking to the Event Logging.

7.2.9.1.7   Clear Mask

#[ISSUE:63194]

Requirement	The FBIS **shall** clear masks to "No Masking" as soon as the Masking Conditions are not fulfilled anymore.
Incoming References	[63831] RF-FIMx Beam Permit Mask to OK [63826] LPSMAG Proton Beam Mode Masking [63825] LPSMAG Proton Beam Destination Masking [63824] LPSMAG Beam Permit Mask to OK [63721] LPSVAC Proton Beam Mode Masking [63720] LPSVAC Proton Beam Destination Masking [63719] ACCTx Proton Beam Mode Masking [63660] ACCTx No Beam Mask to OK [63659] ACCTx Proton Beam Destination Masking [63658] LPSVAC Beam Permit Mask to OK [63656] ACCTx Beam Permit Mask to OK [63537] MEBT Chopper Controller Health Mask to OK [63536] LEBT Chopper LPS Beam Permit Mask to OK [63192] Mask to NOK [62929] LPSID Beam Permit Mask to OK

7.2.9.1.8   Masking of Redundant Signals

#[ISSUE:63189]

Requirement	The FBIS **shall** allow to mask the redundant signals individually, **when** an input signal is communicated in a redundant manner and the Masking Conditions are fulfilled.

Explanation	If a beam permit is for example communicated by means of a discrete signal and a data link, the FBIS allows to mask the discrete signal and data link individually.
Incoming References	[63831] RF-FIMx Beam Permit Mask to OK [63826] LPSMAG Proton Beam Mode Masking [63825] LPSMAG Proton Beam Destination Masking [63824] LPSMAG Beam Permit Mask to OK [63721] LPSVAC Proton Beam Mode Masking [63720] LPSVAC Proton Beam Destination Masking [63719] ACCTx Proton Beam Mode Masking [63660] ACCTx No Beam Mask to OK [63659] ACCTx Proton Beam Destination Masking [63658] LPSVAC Beam Permit Mask to OK [63656] ACCTx Beam Permit Mask to OK [63537] MEBT Chopper Controller Health Mask to OK [63536] LEBT Chopper LPS Beam Permit Mask to OK [63192] Mask to NOK [62929] LPSID Beam Permit Mask to OK

7.2.9.2 Masking Conditions

The following sub-chapter specify the masking conditions for input signals.

7.2.9.2.1 Masking of Sensor System Input Signals

The following requirements specify the masking conditions for sensor system input signals.

7.2.9.2.1.1 Mask to NOK
#[ISSUE:63192]

Requirement	The FBIS **shall** allow masking all sensor system input signals of type OK/NOK individually to "Mask to NOK" at all times without restrictions.
Rationale	Masking input signals to NOK does not impose a danger to the machine.
Explanation	Masking to NOK may be useful during the commissioning phase.

7.2.9.2.1.2 LPSID Beam Permit Mask to OK
#[ISSUE:62929]

Requirement	The FBIS **shall** allow to mask the LPSID_BEAM_PERMIT to "Mask to OK" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.3 LPSVAC Beam Permit Mask to OK
#[ISSUE:63658]

Requirement	The FBIS **shall** allow to mask the LPSVAC_BEAM_PERMIT to "Mask to OK" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.4 LPSVAC Proton Beam Destination Masking
#[ISSUE:63720]

Requirement	The FBIS **shall** allow to mask the LPSVAC_PROTON_BEAM_DESTINATION to "Masked" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.5 LPSVAC Proton Beam Mode Masking
#[ISSUE:63721]

Requirement	The FBIS **shall** allow to mask the LPSVAC_PROTON_BEAM_MODE to "Masked" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.6 LPSMAG Beam Permit Mask to OK

#[ISSUE:63824]

Requirement	The FBIS **shall** allow to mask the LPSMAG_BEAM_PERMIT to "Mask to OK" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.7   LPSMAG Proton Beam Destination Masking
#[ISSUE:63825]

Requirement	The FBIS **shall** allow to mask the LPSMAG_PROTON_BEAM_DESTINATION to "Masked" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.8   LPSMAG Proton Beam Mode Masking
#[ISSUE:63826]

Requirement	The FBIS **shall** allow to mask the LPSMAG_PROTON_BEAM_MODE to "Masked" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.9   ACCTx Beam Permit Mask to OK
#[ISSUE:63656]

Requirement	The FBIS **shall** allow to mask the ACCTx_BEAM_PERMIT to "Mask to OK" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.10   ACCTx Proton Beam Destination Masking
#[ISSUE:63659]

Requirement	The FBIS **shall** allow to mask the ACCTx_PROTON_BEAM_DESTINATION to "Masked" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.11   ACCTx Proton Beam Mode Masking
#[ISSUE:63719]

Requirement	The FBIS **shall** allow to mask the ACCTx_PROTON_BEAM_MODE to "Masked" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.12   ACCTx No Beam Mask to OK
#[ISSUE:63660]

Requirement	The FBIS **shall** allow to mask the ACCTx_NO_BEAM to "Mask to OK" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.1.13   RF-FIMx Beam Permit Mask to OK
#[ISSUE:63831]

Requirement	The FBIS **shall** allow to mask the RF-FIMx_BEAM_PERMIT to "Mask to OK" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.2   Masking of Actuation System Input Signal Reading
The following requirements specify the masking conditions for actuation system input signals.

7.2.9.2.2.1   MEBT Chopper Controller Health Mask to OK
#[ISSUE:63537]

Requirement	The FBIS **shall** allow to mask the MC_HEALTH to "Mask to OK" **when**: • The ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.2.9.2.2.2   LEBT Chopper LPS Beam Permit Mask to OK
#[ISSUE:63536]

Requirement	The FBIS **shall** allow to mask the LC_LPS_BEAM_PERMIT to "Mask to OK" **when**:

	• Th ENFORCED_PROTON_BEAM_MODE is "Probe Beam".

7.3 Decision Logic Computation

The actual behavior of the FBIS is implemented by the FBIS Decision Logic. The FBIS Decision Logic drives the Global Beam Permit, Regular Beam Interlock and Emergency Beam Interlock and requests beam switch-offs based on the following:

- Beam Permit states;
- No Beam states;
- Health states
- Mode information from Sensor Systems;
- Mode information from the Control System;
- Mode information from the ESS Timing System;
- Triggers from the ESS Timing System;
- User Data from Sensor Systems;
- Operational readiness and health information from Sensor Systems;
- Operational readiness and health information from Actuation Systems;
- Status feedback from Actuation Systems.

The FBIS Decision Logic depends on the

- configuration which can be altered during run-time (like masking)
- configuration which can be altered only when the FBIS is in maintenance.

Specifying the overall logic in the form of a single table is due to the complexity of the FBIS Decision logic not adequate. An Example of such a table reflecting the logic of a simple AND gate featuring two inputs and one output is illustrated in the figure below.
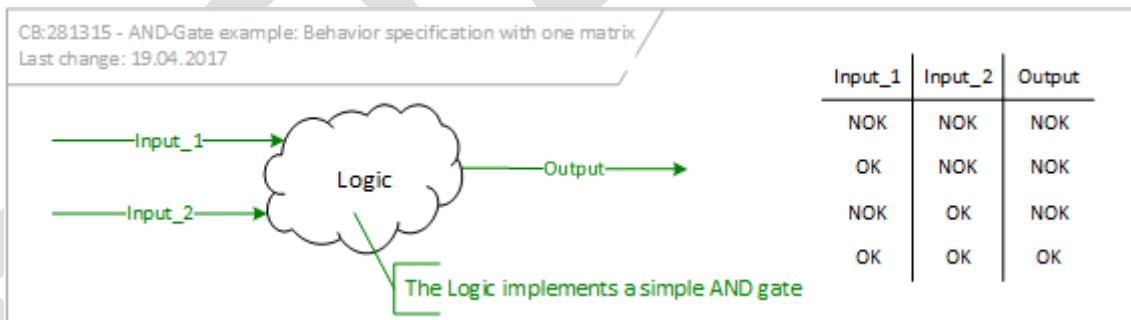
Example how the logic of an AND-gate can be expressed with a single table

Instead, the FBIS Decision Logic is specified with the help of multiple tables. Each table specifies an $Output_k$ which is part of the Output. The $Output_k$ is then computed by a logical AND of all $Output_k$.

CB:281315 - AND-Gate example: Behavior specification with multiple matrices
Last change: 19.04.2017
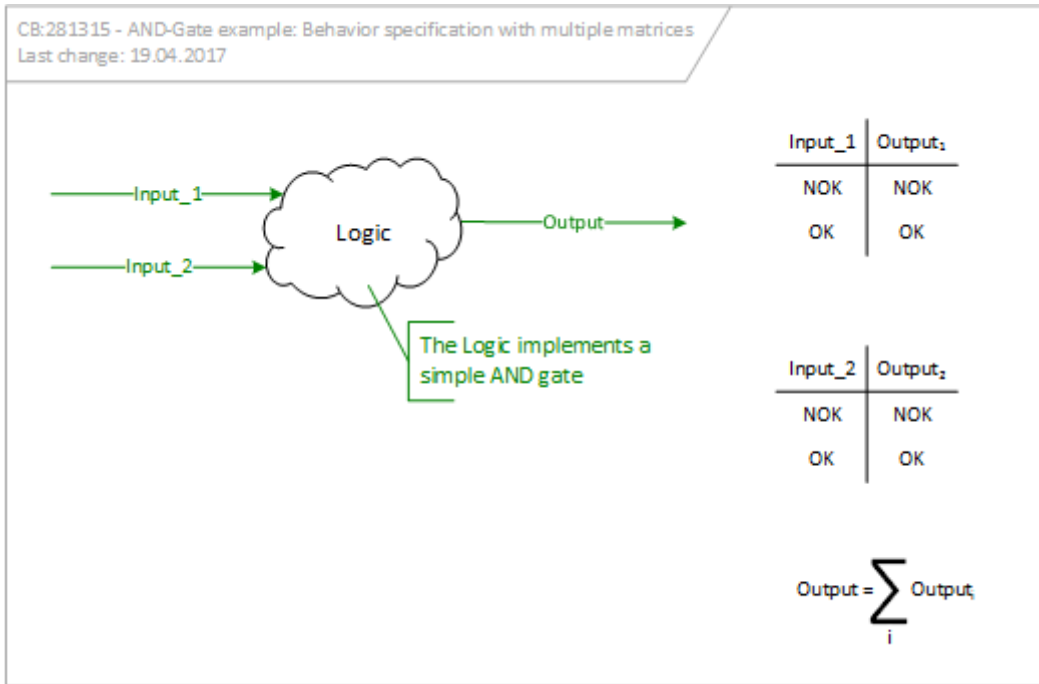
Example how the logic of an AND-gate can be expressed with multiple tables

This document makes use of that structure for example when specifying the state of the Global Beam Permit, Regular Beam Interlock and Emergency Beam Interlock.

7.3.1 State Evaluation

7.3.1.1 Beam Permit States Evaluation

The FBIS constantly evaluates all beam permit states and sets the Global Beam Permit according to the below requirements.

7.3.1.1.1 LPSID Beam Permit Evaluation

#[ISSUE:62932]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:

LPSID_BEAM_PERMIT	GLOBAL_BEAM_PERMIT$_k$
OK	OK
NOK	NOK

7.3.1.1.2 LPSVAC Beam Permit Evaluation

#[ISSUE:63722]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:

LPSVAC_BEAM_PERMIT	GLOBAL_BEAM_PERMIT$_k$
OK	OK
NOK	NOK

7.3.1.1.3 LPSMAG Beam Permit Evaluation

#[ISSUE:63827]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:

LPSMAG_BEAM_PERMIT	GLOBAL_BEAM_PERMIT$_k$
OK	OK

		NOK	NOK	

7.3.1.1.4   ACCT_1 Beam Permit Evaluation

#[ISSUE:63197]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:
	<table><tr><th>ACCT_1_BEAM_PERMIT</th><th>GLOBAL_BEAM_PERMIT$_k$</th></tr><tr><td>OK</td><td>OK</td></tr><tr><td>NOK</td><td>NOK</td></tr></table>
Rationale	The signal shall not have an influence on the Global Beam Permit when the beam destination is upstream of the ACCTs the signal is associated with.
Incoming References	[64452] DTL-010:DLN

7.3.1.1.5   ACCT_2 Beam Permit Evaluation

#[ISSUE:63622]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:
	<table><tr><th rowspan="2">ACCT_2_BEAM_PERMIT</th><th colspan="2">GLOBAL_BEAM_PERMIT$_k$ with respect to ENFORCED_PROTON_BEAM_DESTINATION</th></tr><tr><th>DTL1</th><th>Other</th></tr><tr><td>OK</td><td>OK</td><td>OK</td></tr><tr><td>NOK</td><td>OK</td><td>NOK</td></tr></table>
Rationale	The signal shall not have an influence on the Global Beam Permit when the beam destination is upstream of the ACCTs the signal is associated with.

7.3.1.1.6   ACCT_3 Beam Permit Evaluation

#[ISSUE:63623]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:
	<table><tr><th rowspan="2">ACCT_3_BEAM_PERMIT</th><th colspan="2">GLOBAL_BEAM_PERMIT$_k$ with respect to ENFORCED_PROTON_BEAM_DESTINATION</th></tr><tr><th>LEBT, MEBT, DTL1, DTL2, Spokes1, Spokes2</th><th>Other</th></tr><tr><td>OK</td><td>OK</td><td>OK</td></tr><tr><td>NOK</td><td>OK</td><td>NOK</td></tr></table>
Rationale	The signal shall not have an influence on the Global Beam Permit when the beam destination is upstream of the ACCTs the signal is associated with.

7.3.1.1.7   ACCT_4 Beam Permit Evaluation

#[ISSUE:63624]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:
	<table><tr><th rowspan="2">ACCT_4_BEAM_PERMIT</th><th colspan="2">GLOBAL_BEAM_PERMIT$_k$ with respect to ENFORCED_PROTON_BEAM_DESTINATION</th></tr><tr><th>LEBT, MEBT, DTL1, DTL2, Spokes1, Spokes2, MBL</th><th>Other</th></tr><tr><td>OK</td><td>OK</td><td>OK</td></tr><tr><td>NOK</td><td>OK</td><td>NOK</td></tr></table>
Rationale	The signal shall not have an influence on the Global Beam Permit when the beam destination is upstream of the ACCTs the signal is associated with.

7.3.1.1.8   ACCT_5 Beam Permit Evaluation

#[ISSUE:63625]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:		
	ACCT_5_BEAM_PERMIT	**GLOBAL_BEAM_PERMIT$_k$ with respect to ENFORCED_PROTON_BEAM_DESTINATION**	
		LEBT, MEBT, DTL1, DTL2, Spokes1, Spokes2, MBL	**Other**
	OK	OK	OK
	NOK	OK	NOK
Rationale	The signal shall not have an influence on the Global Beam Permit when the beam destination is upstream of the ACCTs the signal is associated with.		

7.3.1.1.9   ACCT_6 Beam Permit Evaluation

#[ISSUE:63626]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:		
	ACCT_6_BEAM_PERMIT	**GLOBAL_BEAM_PERMIT$_k$ with respect to ENFORCED_PROTON_BEAM_DESTINATION**	
		LEBT, MEBT, DTL1, DTL2, Spokes1, Spokes2, MBL	**Other**
	OK	OK	OK
	NOK	OK	NOK
Rationale	The signal shall not have an influence on the Global Beam Permit when the beam destination is upstream of the ACCTs the signal is associated with.		

7.3.1.1.10   ACCT_7 Beam Permit Evaluation

#[ISSUE:63627]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:		
	ACCT_7_BEAM_PERMIT	**GLOBAL_BEAM_PERMIT$_k$ with respect to ENFORCED_PROTON_BEAM_DESTINATION**	
		LEBT, MEBT, DTL1, DTL2, Spokes1, Spokes2, MBL, Tuning Dump	**Other**
	OK	OK	OK
	NOK	OK	NOK
Rationale	The signal shall not have an influence on the Global Beam Permit when the beam destination is upstream of the ACCTs the signal is associated with.		

7.3.1.1.11   MEBT Chopper LPS Beam Permit Evaluation

#[ISSUE:63611]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:		
	MC_LPS_BEAM_PERMIT	**GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION**	
		"LEBT"	**Other**
	OK	OK	OK
	NOK	OK	NOK
Rationale	The signal shall only have an influence on the Global Beam Permit when the beam destination is downstream of the LEBT FC.		

7.3.1.1.12   MEBT Chopper Health Evaluation

#[ISSUE:63818]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:

| MC_HEALTH | GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION | |
	"LEBT"	Other
OK	OK	OK
NOK	OK	NOK

Rationale	The signal shall only have an influence on the Global Beam Permit when the beam destination is downstream of the LEBT FC.

7.3.1.1.13 RF-FIM_1..4 Beam Permit Evaluation

#[ISSUE:63837]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:		
	RF-FIM_x_BEAM_PERMIT (x=1..4)	GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION	
		"LEBT"	Other
	OK	OK	OK
	NOK	OK	NOK
Explanation	The signals shall not have an influence on the Global Beam Permit when the beam destination is upstream of the cavities the signals are associated with.		
Incoming References	[64452] DTL-010:DLN		

7.3.1.1.14 RF-FIM_5..9 Beam Permit Evaluation

#[ISSUE:63838]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:		
	RF-FIM_x_BEAM_PERMIT (x=5..9)	GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION	
		"LEBT", "MEBT"	Other
	OK	OK	OK
	NOK	OK	NOK
Explanation	The signals shall not have an influence on the Global Beam Permit when the beam destination is upstream of the cavities the signals are associated with.		

7.3.1.1.15 RF-FIM10..35 Beam Permit Evaluation

#[ISSUE:63843]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:		
	RF-FIMx_BEAM_PERMIT (x=10..35)	GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION	
		"LEBT", "MEBT", "DTL"	Other
	OK	OK	OK
	NOK	OK	NOK
Explanation	The signals shall not have an influence on the Global Beam Permit when the beam destination is upstream of the cavities the signals are associated with.		

7.3.1.1.16 RF-FIM36..71 Beam Permit Evaluation

#[ISSUE:63845]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:

RF-FIMx_BEAM_PERMIT (x=36..71)	GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION	
	"LEBT", "MEBT", "DTL", "Spokes1, "Spokes2"	Other
OK	OK	OK
NOK	OK	NOK
Explanation	The signals shall not have an influence on the Global Beam Permit when the beam destination is upstream of the cavities the signals are associated with.	

7.3.1.1.17 RF-FIM72..155 Beam Permit Evaluation

#[ISSUE:63844]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:	
	RF-FIMx_BEAM_PERMIT (x=36..72)	GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION	
		"LEBT", "MEBT", "DTL", "Spokes1, "Spokes2"	Other
	OK	OK	OK
	NOK	OK	NOK
Explanation	The signals shall not have an influence on the Global Beam Permit when the beam destination is upstream of the cavities the signals are associated with.	

7.3.1.1.18 Fast Gate Valve SPK Beam Permit Evaluation

#[ISSUE:63851]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:	
	FGV_SPK_BEAM_PERMIT	GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION	
		"MBL", "Target", "Tuning Dump"	Other
	OK	OK	OK
	NOK	NOK	OK
Explanation	The signal shall not have an influence on the Global Beam Permit when the beam destination is upstream of the spokes beam line section.	

7.3.1.1.19 Fast Gate Valve HEBT Beam Permit Evaluation

#[ISSUE:63852]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:	
	FGV_HEBT_BEAM_PERMIT	GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION	
		"Target", "Tuning Dump"	Other
	OK	OK	OK
	NOK	NOK	OK
Explanation	The signal shall not have an influence on the Global Beam Permit when the beam destination is neither the Target nor the Tuning Dump.	

7.3.1.1.20 Fast Gate Valve DMPL Beam Permit Evaluation

#[ISSUE:63853]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ according to the following table:	
	FGV_DMPL_BEAM_PERMIT	GLOBAL_BEAM_PERMIT$_k$ with respect to the ENFORCED_PROTON_BEAM_DESTINATION	

	"Tuning Dump"		Other
OK	OK		OK
NOK	NOK		OK
Explanation	The signal shall not have an influence on the Global Beam Permit when the beam destination is different than the Tuning Dump.		

7.3.1.2   No Beam States Evaluation

In order to decide whether beam is off after requesting a beam switch-off, the FBIS supervises the No Beam States. Additionally, these states are used to request a beam switch-off if beam is detected downstream a FC beam destination.

7.3.1.2.1   Beam Inhibit No Beam Supervision

#[ISSUE:62937]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT1_NO_BEAM does not reflect "OK" within TBD, **and** • The GLOBAL_BEAM_PERMIT is "NOK".
Explanation	In case beam is detected with the LEBT-BCM01 while the FBIS causes a Beam Inhibit, the FBIS shall escalate to a Regular Beam Interlock.

7.3.1.2.2   Regular Beam Interlock No Beam Supervision

#[ISSUE:62993]

Requirement	The FBIS **shall** set the EMERGENCY_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT1_NO_BEAM does not reflect "OK" within TBD, **and** • The REGULAR_BEAM_INTERLOCK is "NOK".
Explanation	In case beam is detected with the LEBT-BCM01 while the FBIS causes a Regular Beam Interlock, the FBIS shall escalate to an Emergency Beam Interlock.

7.3.1.2.3   LEBT Beam Destination No Beam Supervision

#[ISSUE:62938]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT1_NO_BEAM does not reflect "OK" within TBD, **and** • The ENFORCED_PROTON_BEAM_DESTINATION is "LEBT".
Explanation	The FBIS shall cause a Regular Beam Interlock when beam is detected by the LEBT-BCM01 which is downstream of the LEBT-FC beam destination.

7.3.1.2.4   MEBT Beam Destination No Beam Supervision

#[ISSUE:63673]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT1_NO_BEAM does not reflect "OK" within TBD, **and** • The ENFORCED_PROTON_BEAM_DESTINATION is "MEBT".
Explanation	The FBIS shall cause a Regular Beam Interlock when beam is detected by the MEBT-BCM03 which is downstream of the MEBT-FC beam destination.

7.3.1.2.5   DTL1 Beam Destination No Beam Supervision

#[ISSUE:63672]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT1_NO_BEAM does not reflect "OK" within TBD, **and** • The ENFORCED_PROTON_BEAM_DESTINATION is "DTL1".
Explanation	The FBIS shall cause a Regular Beam Interlock when beam is detected by the DTL-BCM02 which is downstream of the DTL1-FC beam destination.

7.3.1.2.6   DTL2 Beam Destination No Beam Supervision

#[ISSUE:63674]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT2_NO_BEAM does not reflect "OK" within TBD, **and** • The ENFORCED_PROTON_BEAM_DESTINATION is "DTL2".
Explanation	The FBIS shall cause a Regular Beam Interlock when beam is detected by the DTL-BCM05 which is downstream of the DTL2-FC beam destination.

7.3.1.2.7   Spokes1 Beam Destination No Beam Supervision

#[ISSUE:63675]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT3_NO_BEAM does not reflect "OK", **and** • The ENFORCED_PROTON_BEAM_DESTINATION is "Spokes1".
Explanation	The FBIS shall cause a Regular Beam Interlock when beam is detected by the MBL-BCM01 which is downstream of the Spokes1-FC beam destination.

7.3.1.2.8   Spokes2 Beam Destination No Beam Supervision

#[ISSUE:63676]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT3_NO_BEAM does not reflect "OK", **and** • The ENFORCED_PROTON_BEAM_DESTINATION is "Spokes2".
Explanation	The FBIS shall cause a Regular Beam Interlock when beam is detected by the MBL-BCM01 which is downstream of the Spokes2-FC beam destination.

7.3.1.2.9   MBL Beam Destination No Beam Supervision

#[ISSUE:63677]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT4_NO_BEAM does not reflect "OK", **and** • The ENFORCED_PROTON_BEAM_DESTINATION is "MBL".
Explanation	The FBIS shall cause a Regular Beam Interlock when beam is detected by the HBL-BCM01 which is downstream of the MBL-FC beam destination.

7.3.1.2.10 Tuning Dump Beam Destination No Beam to Target Supervision

#[ISSUE:63678]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT6_NO_BEAM does not reflect "OK", **and** • The ENFORCED_PROTON_BEAM_DESTINATION is "Tuning Dump".
Explanation	The FBIS shall cause a Regular Beam Interlock when beam is detected by the A2T-BCM02 which is located in the linac section towards the Target.

7.3.1.2.11 Target Beam Destination No Beam to Tuning Dump Supervision

#[ISSUE:63679]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • The ACCT6_NO_BEAM does not reflect "OK", **and** • The ENFORCED_PROTON_BEAM_DESTINATION is "Tuning Dump".
Explanation	The FBIS shall cause a Regular Beam Interlock when beam is detected by the DMPL-BCM01 which is located in the linac section towards Tuning Dump.

7.3.1.3 Switch-Off Status Evaluation

In order to decide whether beam is off after requesting a beam switch-off the FBIS supervises the state of the Actuation Systems.

7.3.1.3.1 ESS Timing System Status Supervision
#[ISSUE:62895]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**:
	• The TS_STATUS does not reflect "OK" within TBD, **and**
	• The GLOBAL_BEAM_PERMIT is "NOK".

7.3.1.3.2 LEBT Chopper Status Supervision
#[ISSUE:63541]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**:
	• The LC_STATUS does not reflect "OK" within TBD, **and**
	• The GLOBAL_BEAM_PERMIT is "NOK".

7.3.1.3.3 MEBT Chopper Status Supervision
#[ISSUE:63548]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**:
	• The MC_STATUS does not reflect "OK" within TBD, **and**
	• The GLOBAL_BEAM_PERMIT is "NOK", **and**
	• The ENFORCED_PROTON_BEAM_DESTINATION is not "LEBT"
Explanation	No escalation shall take place if the beam destination is LEBT.

7.3.1.3.4 Ion Source Status Supervision
#[ISSUE:63600]

Requirement	The FBIS **shall** set the EMERGENCY_BEAM_INTERLOCK$_k$ to "NOK" **when**:
	• The IS_STATUS does not reflect "OK" within TBD, **and**
	• The REGULAR_BEAM_INTERLOCK is "NOK".

7.3.1.4 TBD

TBD: Ditto for all other "types" of input signals.

7.3.1.4.1 Regular Beam Interlock when Global Beam Permit reflects NOK
#[ISSUE:62991]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**:
	• The GLOBAL_BEAM_PERMIT is "NOK", **and**
	• **(** The BEAM_PULSE_PHASE is "Intra Pulse", **or**
	• The BEAM_PULSE_PHASE is "Unknown" **).**
Rationale	That the Global Beam Permit equals or switches to NOK while a beam pulse is generated (intra-pulse phase) is an unexpected situation during regular operation. Hence this the FBIS shall cause a Regular Beam Interlock directly.

7.3.2 Mode Enforcement

7.3.2.1 Enforced Proton Beam Destination
#[ISSUE:63612]

Requirement	The FBIS **shall** have an ENFORCED_PROTON_BEAM_DESTINATION mode with the possible states defined in Proton Beam Destination States.

7.3.2.2 Enforced Proton Beam Destination Computation
#[ISSUE:62942]

| Requirement | The FBIS **shall** compute the ENFORCED_PROTON_BEAM_DESTINATION according to the following table: The first column specifies the signal, the other columns specify whether it has to be involved in the computation (cell reads"Yes") or not (cell reads "No"). |

Signal	REQUESTED_PROTON_BEAM_DESTINATION									
	LEBT	MEBT	DTL1	DTL2	Spokes1	Spokes2	MBL	Tuning Dump	Target	None
LPSID_PROTON_BEAM_DESTINATION	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
LPSVAC_PROTON_BEAM_DESTINATION	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
LPSMAG_PROTON_BEAM_DESTINATION	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
ACCT1_PROTON_BEAM_DESTINATION	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
ACCT2_PROTON_BEAM_DESTINATION	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
ACCT3_PROTON_BEAM_DESTINATION	No	No	No	No	No	No	Yes	Yes	Yes	No
ACCT4_PROTON_BEAM_DESTINATION	No	No	No	No	No	No	No	Yes	Yes	No
ACCT5_PROTON_BEAM_DESTINATION	No	No	No	No	No	No	No	Yes	Yes	No
ACCT6_PROTON_BEAM_DESTINATION	No	No	No	No	No	No	No	Yes	Yes	No
ACCT7_PROTON_BEAM_DESTINATION	No	No	No	No	No	No	No	No	Yes	No

	The ENFORCED_PROTON_BEAM_DESTINATION **shall** be "None" unless all signals involved in the computation including the REQUESTED_PROTON_BEAM_DESTINATION reflect the same mode.
Explanation	The computation of the Enforced Proton Beam Destination depends on the Requested Proton Beam Destination. Depending on the requested destination, signals are included in the computation or excluded. If the requested proton beam destination is "None" the Enforced Proton Beam Destination is "None" as well.
Incoming References	[63613] Default Proton Beam Destination State [63612] Enforced Proton Beam Destination [62943] Proton Beam Destination Mismatch

7.3.2.3 Default Proton Beam Destination State

#[ISSUE:63613]

Requirement	The ENFORCED_PROTON_BEAM_DESTINATION **shall** be set to the default state "None", **until**: • It has been computed for the first time.

7.3.2.4 Proton Beam Destination Mismatch

#[ISSUE:62943]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ to "NOK" **when**: • The ENFORCED_PROTON_BEAM_DESTINATION is "None".
Rationale	The FBIS shall request a beam switch-off as long as no consistent proton beam destination is enforced.
Incoming References	[62944] Logging of Enforced Proton Beam Destination Changes

7.3.2.5 Logging of Enforced Proton Beam Destination Changes

#[ISSUE:62944]

Requirement	The FBIS **shall** write state changes of the ENFORCED_PROTON_BEAM_DESTINATION to the Event Logging together with a timestamp.

7.3.2.6   Enforced Proton Beam Destination Control System Readout

#[ISSUE:63618]

Requirement	The FBIS **shall** provide the state of the ENFORCED_PROTON_BEAM_DESTINATION during runtime through the Control System Interface.

7.3.2.7   Enforced Proton Beam Mode

#[ISSUE:62951]

Requirement	The FBIS **shall** have an ENFORCED_PROTON_BEAM_MODE with the possible states defined in Proton Beam Mode States.
Incoming References	[62945] Enforced Proton Beam Mode Control System Readout

7.3.2.8   Enforced Proton Beam Mode Computation

#[ISSUE:63615]

Requirement	The FBIS **shall** compute the ENFORCED_PROTON_BEAM_MODE according to the following table: The first column specifies the signal, the other columns specify whether it has to be involved in the computation or not.										

The FBIS **shall** compute the ENFORCED_PROTON_BEAM_MODE according to the following table:
The first column specifies the signal, the other columns specify whether it has to be involved in the computation or not.

Signal	ENFORCED_PROTON_BEAM_DESTINATION									
	LEBT	MEBT	DTL1	DTL2	Spokes1	Spokes2	MBL	Tuning Dump	Target	None
REQUESTED_PROTON_BEAM_MODE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LPSID_PROTON_BEAM_MODE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LPSVAC_PROTON_BEAM_MODE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LPSMAG_PROTON_BEAM_MODE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ACCT1_PROTON_BEAM_MODE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ACCT2_PROTON_BEAM_MODE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ACCT3_PROTON_BEAM_MODE	No	No	No	No	No	No	Yes	Yes	Yes	Yes
ACCT4_PROTON_BEAM_MODE	No	No	No	No	No	No	No	Yes	Yes	Yes
ACCT5_PROTON_BEAM_MODE	No	No	No	No	No	No	No	Yes	Yes	Yes
ACCT6_PROTON_BEAM_MODE	No	No	No	No	No	No	No	Yes	Yes	Yes
ACCT7_PROTON_BEAM_MODE	No	No	No	No	No	No	No	No	Yes	Yes

The ENFORCED_PROTON_BEAM_MODE **shall** be "None" unless all signals involved in the computation reflect the same mode.

Explanation	The computation of the Enforced Proton Beam Mode depends on the Enforced Beam Destination. Depending on the destination, proton beam mode signals are included in the computation or excluded. If no destination is enforced, by default all proton beam mode signals are considered for the computation.
Incoming References	[63616] Default Proton Beam Mode [62951] Enforced Proton Beam Mode [62945] Enforced Proton Beam Mode Control System Readout [62918] Proton Beam Mode Mismatch

7.3.2.9   Default Proton Beam Mode

#[ISSUE:63616]

Requirement	The ENFORCED_PROTON_BEAM_MODE **shall** be set to the default state "None", **until**:
	• It has been computed for the first time.
Incoming References	[63617] Logging of Enforced Proton Beam Mode Changes [62945] Enforced Proton Beam Mode Control System Readout

7.3.2.10 Proton Beam Mode Mismatch

#[ISSUE:62918]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ to "NOK" **when**:
	• The ENFORCED_PROTON_BEAM_MODE is "None".
Rationale	The FBIS shall request a beam switch-off as long as no consistent proton beam mode is enforced.

7.3.2.11 Logging of Enforced Proton Beam Mode Changes

#[ISSUE:63617]

Requirement	The FBIS **shall** write state changes of the ENFORCED_PROTON_BEAM_MODE to the Event Logging together with a timestamp.

7.3.2.12 Enforced Proton Beam Mode Control System Readout

#[ISSUE:62945]

Requirement	The FBIS **shall** provide the state of the ENFORCED_PROTON_BEAM_MODE during runtime through the Control System Interface.

7.3.3 Global Beam Permit Generation

The FBIS has a Global Beam Permit state. The Global Beam Permit state defines whether further protons may be injected and accelerated respectively whether protons already in the accelerator have to be dumped or not.

7.3.3.1   Global Beam Permit Possible States

#[ISSUE:65102]

Requirement	The FBIS **shall** have a GLOBAL_BEAM_PERMIT with two possible states: "OK" and "NOK".

7.3.3.2   Global Beam Permit

#[ISSUE:62818]

Requirement	The FBIS **shall** compute a GLOBAL_BEAM_PERMIT as logical AND of all GLOBAL_BEAM_PERMIT$_k$
Explanation	An overview about all logic rules defining the state of the Global Beam Permit is given in Logic Rules Defining the Global Beam Permit.
Incoming References	[65102] Global Beam Permit Possible States [62858] Logging

7.3.3.3   Default Global Beam Permit State

#[ISSUE:62828]

Requirement	The GLOBAL_BEAM_PERMIT **shall** be set to the default state "NOK", **until**:
	• All GLOBAL_BEAM_PERMIT$_k$ have been evaluated, **and** • The GLOBAL_BEAM_PERMIT has been computed for the first time.
Rationale	NOK is the fail-safe state for the Global Beam Permit.
Incoming References	[63631] Power-On Behaviour

7.3.3.4   Setting Global Beam Permit to NOK via Control System

#[ISSUE:62831]

Requirement	The FBIS **shall** allow setting the state of the GLOBAL_BEAM_PERMIT to "NOK" via the Control System Interface.
Explanation	This feature may be used to inhibit beam on purpose.

7.3.3.5 Setting Global Beam Permit to OK via Control System
#[ISSUE:63434]

Requirement	The FBIS **shall** not allow setting the state of the GLOBAL_BEAM_PERMIT to "OK" via the Control System Interface.
Rationale	The Control System shall have only the possibility to veto on the Global Beam Permit which leads to the safe state.

7.3.3.6 Control System Readout
#[ISSUE:62857]

Requirement	The FBIS **shall** provide the GLOBAL_BEAM_PERMIT status for readout through the Control System Interface during runtime.

7.3.3.7 Logging
#[ISSUE:62858]

Requirement	The FBIS **shall** write state changes of the GLOBAL_BEAM_PERMIT to the Event Logging.

7.3.4 Beam Pulse Phase Detection

The FBIS has a Beam Pulse Phase state. The Beam Pulse Phase state is based on the beam pulse on and off triggers received via the ESS Timing System.

7.3.4.1 Beam Pulse Phase
#[ISSUE:62966]

Requirement	The FBIS **shall** have a BEAM_PULSE_PHASE with three possible states: "Intra Pulse", "Inter Pulse", and "Unknown".

7.3.4.2 ESS Timing System Beam Pulse On Triggers
#[ISSUE:63275]

Requirement	The FBIS **shall** set the ESS BEAM_PULSE_PHASE to "Intra Pulse" **when**: • A "Beam Pulse On Trigger" is received via the ESS Timing System Interface.
Incoming References	[63553] ESS Timing System Beam Pulse On Trigger [62969] Logging [62968] Control System Readout [62966] Beam Pulse Phase

7.3.4.3 ESS Timing System Beam Pulse Off Triggers
#[ISSUE:63277]

Requirement	The FBIS **shall** set the ESS BEAM_PULSE_PHASE to "Inter Pulse" **when**: • A "Beam Pulse Off Trigger" is received via the ESS Timing System Interface.
Incoming References	[63554] ESS Timing System Beam Pulse Off Trigger [62969] Logging [62968] Control System Readout [62966] Beam Pulse Phase

7.3.4.4 Default Beam Pulse Phase State
#[ISSUE:62967]

Requirement	The BEAM_PULSE_PHASE **shall** be set to the default state "Unknown", **until**: • The first reception of a "Beam Pulse On Trigger", **or** • The first reception of a "Beam Pulse Off Trigger".

Rationale	The FBIS Decision Logic enters a safe state and remains in that state when the Beam Pulse Phase condition is "unknown".

7.3.4.5 Multiple Beam Pulse On Triggers

#[ISSUE:63278]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **when**: • A "Beam Pulse On Trigger" is received, **and** • The BEAM_PULSE_PHASE is "Intra Pulse".
Explanation	The FBIS causes a Regular Beam Interlock if multiple beam pulse on triggers are received whithout beam pulse off triggers in between.
Incoming References	[62969] Logging [62968] Control System Readout [62966] Beam Pulse Phase

7.3.4.6 Control System Readout

#[ISSUE:62968]

Requirement	The FBIS **shall** provide the BEAM_PULSE_PHASE status for readout through the Control System Interface during runtime.

7.3.4.7 Logging

#[ISSUE:62969]

Requirement	The FBIS **shall** write state changes of the BEAM_PULSE_PHASE to the Event Logging.

7.3.5 Regular Beam Interlock Generation

The FBIS has a Regular Beam Interlock state.

7.3.5.1 Regular Beam Interlock Possible States

#[ISSUE:65100]

Requirement	The FBIS **shall** have an REGULAR_BEAM_INTERLOCK with two possible states:"OK" and "NOK".

7.3.5.2 Regular Beam Interlock

#[ISSUE:62997]

Requirement	The FBIS **shall** compute REGULAR_BEAM_INTERLOCK as logical AND of all REGULAR_BEAM_INTERLOCK$_k$.
Explanation	An overview about all logic rules defining the state of the Regular Beam Interlock is given in Logic Rules Defining the Regular Beam Interlock.
Incoming References	[65100] Regular Beam Interlock Possible States [63000] Logging

7.3.5.3 Default Regular Beam Interlock State

#[ISSUE:62998]

Requirement	The REGULAR_BEAM_INTERLOCK **shall** be set to the default state "NOK", **until**: • All REGULAR_BEAM_INTERLOCK$_k$ have been evaluated, **and** • The REGULAR_BEAM_INTERLOCK has been computed for the first time.
Incoming References	[63631] Power-On Behaviour

7.3.5.4 Global Beam Permit NOK due to Regular Beam Interlock

#[ISSUE:63555]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ to "NOK" **if**: • The REGULAR_BEAM_INTERLOCK is "NOK".
Rationale	A Regular Beam Interlock shall include a beam inhibit and result in a Global Beam Permit NOK.

7.3.5.5   Control System Readout

#[ISSUE:62999]

Requirement	The FBIS **shall** provide the REGULAR_BEAM_INTERLOCK status for readout through the Control System Interface during runtime.

7.3.5.6   Logging

#[ISSUE:63000]

Requirement	The FBIS **shall** write state changes of the REGULAR_BEAM_INTERLOCK to the Event Logging.

7.3.6 Emergency Beam Interlock Generation

The FBIS has an Emergency Beam Interlock.

7.3.6.1   Emergency Beam Interlock Possible States

#[ISSUE:65101]

Requirement	The FBIS **shall** have an EMERGENCY_BEAM_INTERLOCK with two possible states: "OK" and "NOK".

7.3.6.2   Emergency Beam Interlock

#[ISSUE:63003]

Requirement	The FBIS **shall** compute an EMERGENCY_BEAM_INTERLOCK with the states "OK and "NOK" as logical AND of all EMERGENCY_BEAM_INTERLOCK$_k$.
Explanation	An overview about all logic rules defining the state of the Emergency Beam Interlock is given in Logic Rules Defining the Emergency Beam Interlock.
Incoming References	[65101] Emergency Beam Interlock Possible States [63006] Logging

7.3.6.3   Default Emergency Beam Interlock State

#[ISSUE:63004]

Requirement	The EMERGENCY_BEAM_INTERLOCK **shall** be set to the default state "NOK", **until**: • All EMERGENCY_BEAM_INTERLOCK$_k$ have been evaluated, **and** • The EMERGENCY_BEAM_INTERLOCK has been computed for the first time,
Incoming References	[63631] Power-On Behaviour

7.3.6.4   Global Beam Permit NOK due to Emergency Beam Interlock

#[ISSUE:63557]

Requirement	The FBIS **shall** set the GLOBAL_BEAM_PERMIT$_k$ to "NOK" **if**: • The EMERGENCY_BEAM_INTERLOCK is "NOK".
Rationale	An Emergency Beam Interlock shall include a beam inhibit and result in a Global Beam Permit NOK.

7.3.6.5   Regular Beam Permit NOK due to Emergency Beam Interlock

#[ISSUE:63556]

Requirement	The FBIS **shall** set the REGULAR_BEAM_INTERLOCK$_k$ to "NOK" **if**: • The EMERGENCY_BEAM_INTERLOCK is "NOK".
Rationale	An Emergency Beam Interlock shall include a Regular Beam Interlock.

7.3.6.6 Control System Readout

#[ISSUE:63005]

Requirement	The FBIS **shall** provide EMERGENCY_BEAM_INTERLOCK status for readout through the Control System Interface during runtime.

7.3.6.7 Logging

#[ISSUE:63006]

Requirement	The FBIS **shall** write state changes of the EMERGENCY_BEAM_INTERLOCK to the Event Logging.

7.3.7 Latching

Certain FBIS Decision Logic States are configured to always latch "NOK" states (configured to "Latch NOK"). Only after an external reset, the state may switch back to "OK". All other FBIS Decision Logic State, for which latching is not explicitly specified as mandatory, may be configured to "No Latching" or "Latch NOK" during runtime.

How the latching feature influences the FBIS Decision Logic computation is specified in Generic Latching Requirements. Mandatory Latching specifies the mandatory latching.

The following illustration shows how the latching feature works in general.
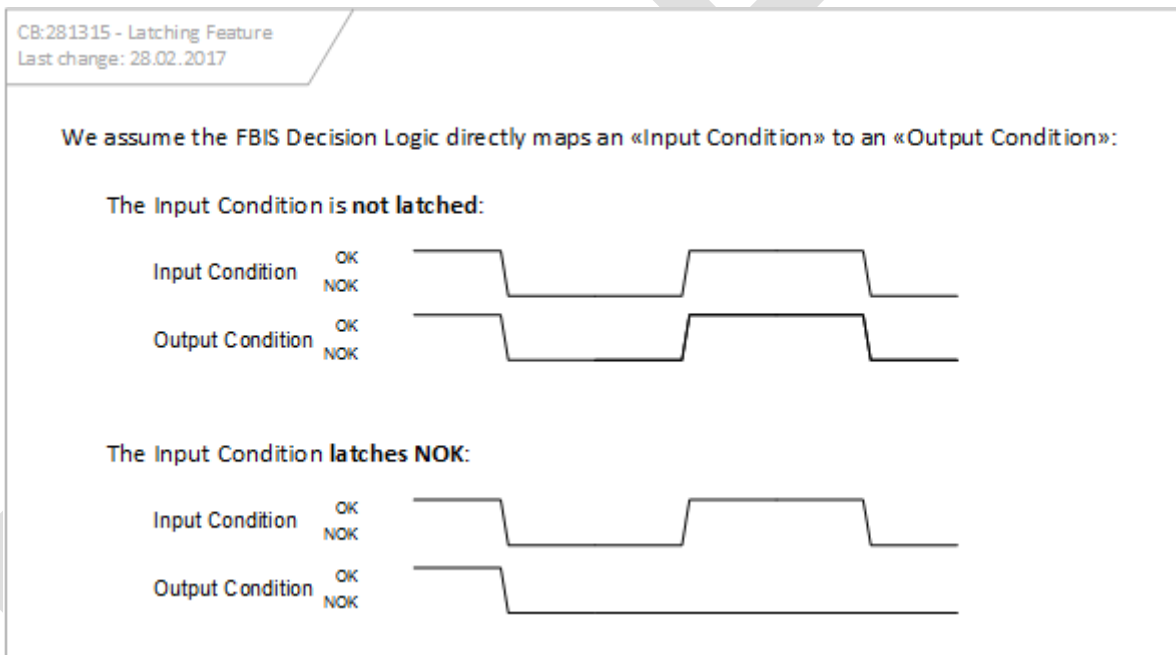
Illustration how the latching feature influences the computation of the FBIS Decision Logic.

7.3.7.1 Generic Latching Requirements

The following requirements specify the generic requirements on latching of FBIS Decision Logic Conditions.

7.3.7.1.1 Latching Feature

#[ISSUE:63017]

Requirement	The FBIS **shall** allow to latch individual FBIS Decision Logic States. The influence of latching to the FBIS Decision Logic computation **shall** be as following:
	<table><tr><th>Latching Configuration</th><th>Influence on Computation of FBIS Decision Logic</th></tr><tr><td>None</td><td>No influence on computation</td></tr><tr><td>Latch NOK</td><td>As soon as the status reflects NOK that status **shall** remain until externally reset via Control System</td></tr></table>

7.3.7.1.2 Latching Feature Configuration

#[ISSUE:63009]

Requirement	The FBIS **shall** allow changing the latching configuration of FBIS Decision Logic States individually: • To "No Latching", **or** • To "Latch NOK" via the Control System Interface (given that latching for the respective state is not explicitly stated as mandatory in this document).

7.3.7.1.3 Default Latching Configuration

#[ISSUE:63010]

Requirement	The FBIS **shall** by default set latching of FBIS Decision Logic states: • To "No Latching" (unless latching for the respective condition is explicitly stated as mandatory in this document).

7.3.7.1.4 Control System Latching Configuration Readout

#[ISSUE:63011]

Requirement	The FBIS **shall** allow the Control System to read the latching configuration of FBIS Decision Logic States at all times.

7.3.7.1.5 Logging of Latching Configuration Changes

#[ISSUE:63012]

Requirement	The FBIS **shall** write changes to the latching configuration to the Event Logging together with a timestamp.

7.3.7.2 Mandatory Latching

The following requirements specify for which FBIS Decision Logic States latching NOK is mandatory and may not be configured to "No Latching".

7.3.7.2.1 Regular Beam Interlock Latching

#[ISSUE:63014]

Requirement	The REGULAR_BEAM_INTERLOCK **shall** be configured: • To "Latch NOK" at all times.

7.3.7.2.2 Emergency Beam Interlock Latching

#[ISSUE:63018]

Requirement	The EMERGENCY_BEAM_INTERLOCK **shall** be configured: • To "Latch NOK" at all times.

7.3.7.3 External Reset Feature

#[ISSUE:63115]

Requirement	The FBIS **shall** reset all latched FBIS Decision logic states **when**: • An external reset command via Control System is received.

7.3.7.4 External Reset Logging

#[ISSUE:63116]

Requirement	The FBIS **shall** write the reception of an external reset command to the Event Logging together with a timestamp.

7.4 Output Signal Generation

7.4.1 Sensor System Output Signals

The FBIS generates output signals to the following Sensor Systems:

• Local Protection Systems:

- o LPS Interceptive Devices
- o LPS Vacuum
- o LPS Linac Magnets
- o LPS Bending Magnets
- o LPS Raster Scanning Magnet System
- o LPS Target
- o LPS Neutron Science Section
- Beam Instrumentation:
  - o BCM Processing Boards
  - o BLM Processing Boards
  - o BPM Processing Boards
- Radio Frequency
- Fast Gate Valves

Requirements for these interfaces and the output signals generated are given in the following sub-chapters.

7.4.2 Actuation System Output Signal Generation

The FBIS generates output signals to the following Actuation Systems:

- ESS Timing System
- LEBT Chopper
- MEBT Chopper
- Ion Source

Requirements for these interfaces and the output signals generated are given in the following sub-chapters.

7.4.2.1 ESS Timing System Output Signals

The following requirements address output signals generated for the ESS Timing System. An overview about the outputs is given in below figure.
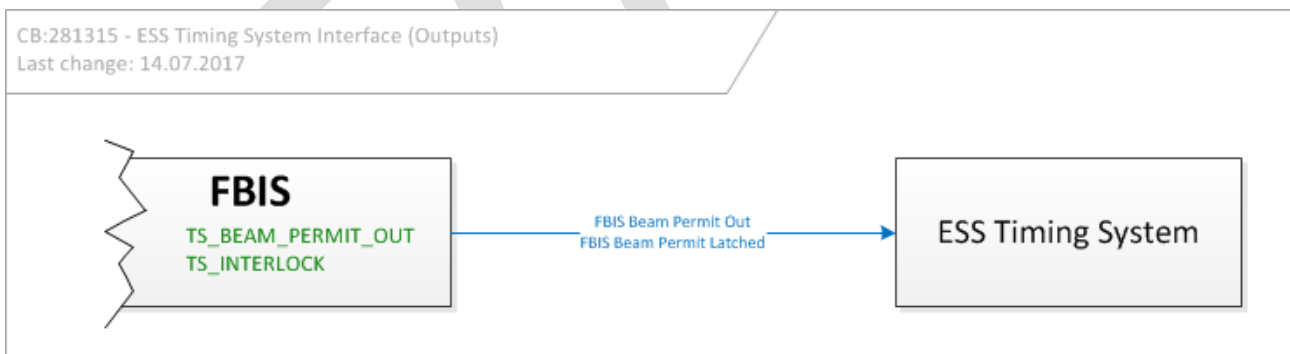
Output signals to the ESS Timing System.

7.4.2.1.1 ESS Timing System Beam Permit Out

#[ISSUE:65106]

Requirement	The FBIS **shall** have a TS_BEAM_PERMIT_OUT with two possible states: "OK" and "NOK".

7.4.2.1.2 ESS Timing System Beam Permit Out State

#[ISSUE:62959]

Requirement	The FBIS **shall** set the TS_BEAM_PERMIT_OUT to "OK" **when**: • The GLOBAL_BEAM_PERMIT is "OK", **and** • The REGULAR_BEAM_INTERLOCK is "OK", **and** • The EMERGENCY_BEAM_INTERLOCK is "OK" else it is set to "NOK".

Incoming References	[65106] ESS Timing System Beam Permit Out

7.4.2.1.3 FBIS Beam Permit Out

#[ISSUE:65130]

Requirement	The FBIS **shall** set the "FBIS Beam Permit Out" according to ESS Timing System Interface to "TBD" **when**: • TS_BEAM_PERMIT_OUT is "OK" **else** it is set to "TBD".

7.4.2.1.4 FBIS Beam Permit Out Latched

#[ISSUE:63602]

Requirement	The FBIS **shall** set the "FBIS Beam Permit Latched" according to ESS Timing System Interface to "TBD" **when**: • The GLOBAL_BEAM_PERMIT is latched to "NOK", **or** • The REGULAR_BEAM_INTERLOCK is latched to "NOK", **or** • The EMERGENCY_BEAM_INTERLOCK is latched to "NOK", **else** it is set to "TBD".

7.4.2.2 LEBT Chopper Output Signals

The following requirements address output signals generated for the LEBT Chopper. An overview about the outputs is given in below figure.
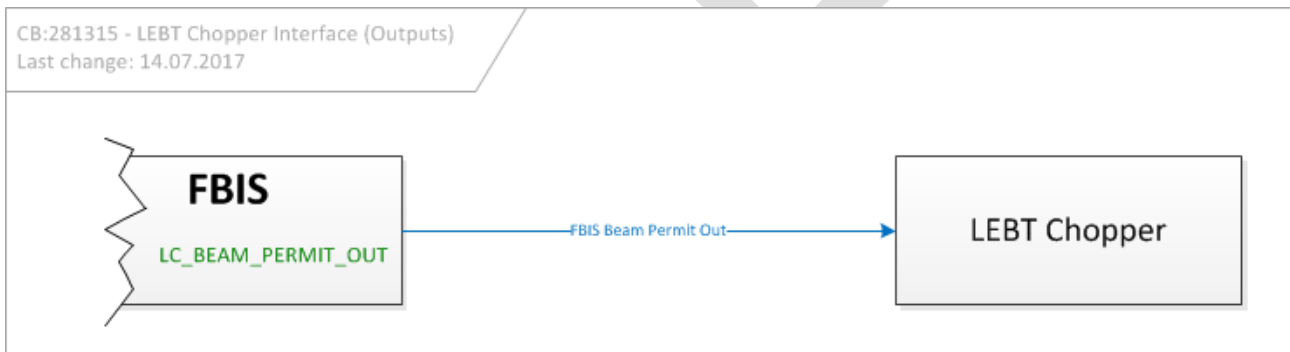
Output signals to the LEBT Chopper.

7.4.2.2.1 LEBT Chopper Beam Permit Out

#[ISSUE:64966]

Requirement	The FBIS **shall** have a LC_BEAM_PERMIT_OUT with two possible states: "OK" and "NOK".

7.4.2.2.2 LEBT Chopper Beam Permit Out State

#[ISSUE:64880]

Requirement	The FBIS **shall** set the LC_BEAM_PERMIT_OUT to "OK" **when**: • The GLOBAL_BEAM_PERMIT is "OK" else it is set to "NOK".
Incoming References	[64966] LEBT Chopper Beam Permit Out

7.4.2.2.3 FBIS Beam Permit Out

#[ISSUE:64882]

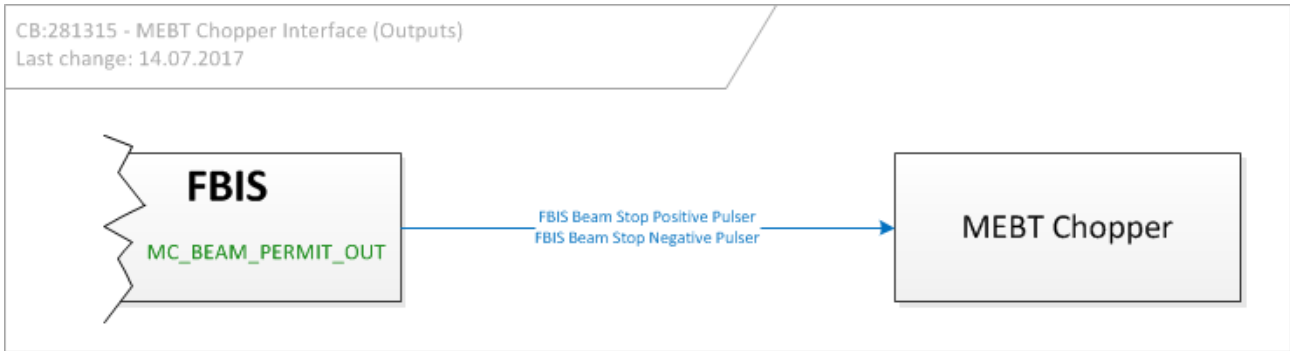| Requirement	The FBIS **shall** set the "FBIS Beam Permit Out" according to LEBT Chopper Interface to "OK" **when**: • LC_BEAM_PERMIT_OUT is "OK" else it is set to "NOK".

7.4.2.3 MEBT Chopper Output Signals

The following requirements address output signals generated for the MEBT Chopper. An overview about the outputs is given in below figure.

CB:281315 - MEBT Chopper Interface (Outputs)
Last change: 14.07.2017

Output signals to the MEBT Chopper.

7.4.2.3.1 MEBT Chopper Beam Permit Out

#[ISSUE:64967]

Requirement	The FBIS **shall** have a MC_BEAM_PERMIT_OUT with two possible states: "OK" and "NOK".

7.4.2.3.2 MEBT Chopper Beam Permit Out State

#[ISSUE:64799]

Requirement	The FBIS **shall** set the MC_BEAM_PERMIT_OUT to "OK" **when**: • The GLOBAL_BEAM_PERMIT is "OK", **and** • The REGULAR_BEAM_INTERLOCK is "OK", **and** • The EMERGENCY_BEAM_INTERLOCK is "OK" **else** it is set to "NOK".
Incoming References	[64967] MEBT Chopper Beam Permit Out

7.4.2.3.3 FBIS Beam Stop Positive Pulser

#[ISSUE:63538]

Requirement	The FBIS **shall** set the "FBIS Beam Stop Negative Pulser" of the MEBT Chopper Interface to "OK" **when**: • MC_BEAM_PERMIT_OUT is "OK" **else** it is set to "NOK".

7.4.2.3.4 FBIS Beam Stop Negative Pulser

#[ISSUE:64800]

Requirement	The FBIS **shall** set the "FBIS Beam Stop Positive Pulser" of the MEBT Chopper Interface to "OK" **when**: • MC_BEAM_PERMIT_OUT is "OK" **else** it is set to "NOK".

7.4.2.4 Ion Source Output Signals

The following requirements address outputs generated for the Ion Source. An overview about the outputs is given in below figure.

CB:281315 - Ion Source Interface (Outputs)
Last change: 14.07.2017
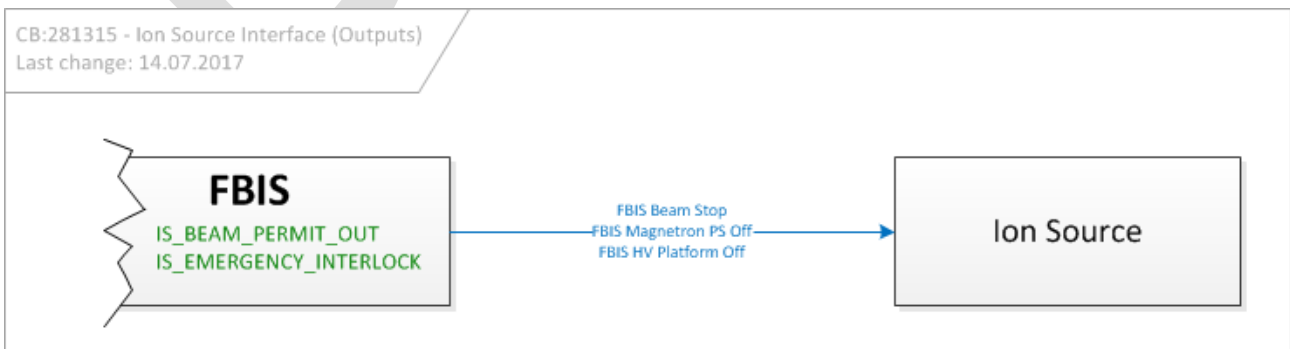
Output signals to the Ion Source.

7.4.2.4.1 Ion Source Beam Permit Out

#[ISSUE:65134]

Requirement	The FBIS **shall** have a IS_BEAM_PERMIT_OUT with two possible state: "OK" and "NOK".

7.4.2.4.2 Ion Source Beam Permit Out State

#[ISSUE:63603]

Requirement	The FBIS **shall** set the IS_BEAM_PERMIT_OUT to "OK" **when**: • The GLOBAL_BEAM_PERMIT is "OK", **and** • The REGULAR_BEAM_PERMIT is "OK", **and** • The EMERGENCY_BEAM_PERMIT is "OK" **else** it is set to "NOK".
Incoming References	[65134] Ion Source Beam Permit Out

7.4.2.4.3 FBIS Beam Stop

#[ISSUE:65135]

Requirement	The FBIS **shall** set the "FBIS Beam Stop" according to Ion Source Interface to "TBD" **when**: • IS_BEAM_PERMIT_OUT is "OK" **else** it is set to "TBD".

7.4.2.4.4 Ion Source Emergency Beam Interlock

#[ISSUE:65137]

Requirement	The FBIS **shall** have a IS_EMERGENCY_BEAM_INTERLOCK with two possible states: "OK" and "NOK".

7.4.2.4.5 Ion Source Emergency Beam Interlock State

#[ISSUE:65138]

Requirement	The FBIS **shall** set the IS_EMERGENCY_BEAM_INTERLOCK to "OK" **when**: • The EMERGENCY_BEAM_PERMIT is "OK" **else** it is set to "NOK".
Incoming References	[65137] Ion Source Emergency Beam Interlock

7.4.2.4.6 FBIS Magnetron PS Off

#[ISSUE:63604]

Requirement	The FBIS **shall** set the "FBIS Magnetron PS Off" according to Ion Source Interface to "TBD" **when**: • IS_EMERGENCY_BEAM_INTERLOCK is "OK" **else** it shall be set to "TBD".

7.4.2.4.7 FBIS HV Platform Off

#[ISSUE:65136]

Requirement	The FBIS **shall** set the "FBIS HV Platform Off" according to Ion Source Interface to "TBD" **when**: • IS_EMERGENCY_BEAM_INTERLOCK is "OK" **else** it shall be set to "TBD".

7.4.3 Output Signal Control System Readout

#[ISSUE:62963]

Requirement	The FBIS **shall** provide the actual output signal states during runtime for readout through the Control System Interface.

7.4.4 Logging of Output Signal State Changes

#[ISSUE:65132]

Requirement	The FBIS **shall** write state changes of output signals to the Event Logging.

7.4.5 Logging of Variables State Changes

#[ISSUE:65133]

Requirement	The FBIS **shall** write state changes of decision logic variables to the Event Logging.

7.5 Event Logging

The FBIS has an event log for diagnostic, debugging and port-mortem analysis.

7.5.1 Timestamp

#[ISSUE:63279]

Requirement	The FBIS **shall** add the "Timestamp" from the ESS Timing System, received via the ESS Timing System Interface to all logging events.
Explanation	The FBIS uses the timestamp for logging purposes.
Incoming References	[63605] Log Events Persistance [63552] ESS Timing System Timestamp [62863] Log Events Control System Readout

7.5.2 Timestamp Resolution

#[ISSUE:63193]

Requirement	The resolution of the event logging timestamp information **shall** be better than 1 micro-second.
Incoming References	[63605] Log Events Persistance [62863] Log Events Control System Readout

7.5.3 Log Events Control System Readout

#[ISSUE:62863]

Requirement	The FBIS **shall** provide the event loggings for readout through the Control System Interface during runtime.

7.5.4 Log Events Persistance

#[ISSUE:63605]

Requirement	The FBIS **shall** store the log events of at least the last 5 minutes persistently.
Explanation	Storing the log events of the last 10 minutes or more allows the operator to perform diagnostics on the FBIS.

7.6 Startup and Shutdown

7.6.1 Power-On Behaviour

#[ISSUE:63631]

Requirement	Upon Power-On the FBIS **shall** enter a safe state by causing a Regular Beam Interlock.
Explanation	See also the following requirements: - Default Global Beam Permit State - Default Regular Beam Interlock State - Default Emergency Beam Interlock State

7.6.2 Power-On Self Test

#[ISSUE:63632]

Requirement	Upon Power-On the FBIS **shall** perform a self test.

7.6.3 Shutdown Sequence

#[ISSUE:63633]

Requirement	The FBIS **shall** have a defined shutdown sequence which allows to safely shutdown the FBIS.

7.7 Processing Latency

7.7.1 Beam Permit Processing Latency

#[ISSUE:63471]

Requirement	The latency introduced by the FBIS between a beam permit transition to NOK **and** causing a beam inhibit **shall not** exceed 5 us.

7.8 Diagnostic Interface

The following requirements about debugging and diagnostic features apply.

7.8.1 Diagnostic Interface

#[ISSUE:63045]

Requirement	All programmable FBIS components **shall** have a diagnostic interface.
Rationale	During development it is required to have a look inside the running firmware for diagnostics, debugging and testing.
Explanation	The diagnostic interface shall provide insights into memory segments, variables, etc.

7.8.2 On-Site Information

#[ISSUE:63046]

Requirement	All physical assemblies and physical parts of the FBIS **should** provide On-Site Information as feasible and meaningful.
Explanation	Note: This may include for example LEDs on front-pannels or printed circuit boards.

7.9 Firmware Updates

The following requirements address FBIS Firmware. The term "firmware" includes firmware of FPGA's but also other programmable components such as CPUs.

7.9.1 Firmware Update

#[ISSUE:64267]

Requirement	All FBIS programmable components **shall** have a means to update decision logic firmware.

7.9.2 Firmware Acceptance

#[ISSUE:64271]

Requirement	All FBIS programmable components **shall** accept only valid firmware and reject invalid firmware updates.
Rationale	In order to prevent unauthorized updates it is required to check whether the firmware is valid.
Explanation	Valid firmware is defined as: • File or data stream is in correct format • Data is not corrupt • Sender of firmware update is authorized

7.9.3 Firmware Configuration Identification

#[ISSUE:64270]

Requirement	All FBIS programmable components **shall** have means to identify configuration of the actual loaded decision logic firmware.
Rationale	It is expected to have several firmware variants and configurations. Therefor commissioning engineers, maintainers and operators need to identify the actual loaded firmware configuration.
Explanation	The firmware configuration may consist of: • Name • Version (Release.Subrelease.Fix) • Date and Time • Checksum

8 Non-Functional System Requirements

8.1 Mechanical

The following requirements about mechanical aspects apply.

8.1.1 Rack Mountable

#[ISSUE:62994]

Requirement	All physical assemblies of the FBIS **shall** be mountable into a 19" rack.

8.1.2 Height Units

#[ISSUE:63040]

Requirement	None of the physical assembly of the FBIS **shall** occupy more than 12 height units.

8.1.3 Weight

#[ISSUE:63053]

Requirement	None of the physical assembly of the FBIS **shall** exceed the weight of 20 kg.
Explanation	20 kg is assumed to be an upper limit for handling physical devices without specific lifting devices.

8.1.4 Identification

#[ISSUE:63041]

Requirement	Physical parts specific to the FBIS **shall** be clearly identifiable as parts of FBIS.
Explanation	Note: This may include for example patch-pannels for cables, printed circuit boards, debugging adapters, etc.

8.2 Temperature

8.2.1 Operating Temperature Range

#[ISSUE:63048]

Requirement	The FBIS **should** be able to be operated within a temperature range from 20°C to 30°C.
Explanation	Note: The normal ambient temperature is assumed to be 25°C

8.2.2 Storage Temperature Range

#[ISSUE:63049]

Requirement	The FBIS **should** be able to be stored within a temperature range from TBD.
Explanation	Note: The normal storage temperature is assumed to be 20°C.

8.3 MTBF and Lifetime

8.3.1 Lifetime

#[ISSUE:63051]

Requirement	The FBIS **should** have a life span of TBD hours assuming a normal operating temperature of 25°C.

8.3.2 MTBF

#[ISSUE:65103]

Requirement	The FBIS **should** have a MTBF of more than TBD assuming a normal operating temperature of 25°C.

8.4 Electrical

8.4.1 Power Supply

#[ISSUE:63055]

Requirement	The FBIS **shall** have a power supply using 230V net power at 50 Hz.

8.4.2 EMI

#[ISSUE:63056]

Requirement	The FBIS **should** be compliant to EN 61000-4-3:2008

8.4.3 ESD

#[ISSUE:63057]

Requirement	The FBIS **shall** be compliant to EN 61000-4-2:2009 with respect to Surge, Burst, TBD.

8.5 Maintenance

8.5.1 Physical Unit Replacement

#[ISSUE:63629]

Requirement	The FBIS **should** support exchanging physical units within 1 hour.
Explanation	In order to maximize availability, the FBIS should support an easy exchange of physical units in less then 1 hour whenever possible. Note: This requirement does not address cabling.

8.5.2 Maintenance during Runtime

#[ISSUE:63630]

Requirement	The FBIS **shall** not support maintenance during runtime.
Explanation	During FBIS maintenance, the FBIS itself might not be fully operational. Other means have to be taken to protect the machine.

9 Appendix

9.1 Logic Rules Defining the Global Beam Permit

The following list contains all logic rules which define the GLOBAL_BEAM_PERMIT:

- LPSID Beam Permit Evaluation
- LPSVAC Beam Permit Evaluation
- LPSMAG Beam Permit Evaluation
- ACCT_1 Beam Permit Evaluation
- ACCT_2 Beam Permit Evaluation
- ACCT_3 Beam Permit Evaluation
- ACCT_4 Beam Permit Evaluation
- ACCT_5 Beam Permit Evaluation
- ACCT_6 Beam Permit Evaluation
- ACCT_7 Beam Permit Evaluation
- MEBT Chopper LPS Beam Permit Evaluation
- MEBT Chopper Health Evaluation
- RF-FIM_1..4 Beam Permit Evaluation
- RF-FIM_5..9 Beam Permit Evaluation
- RF-FIM10..35 Beam Permit Evaluation
- RF-FIM36..71 Beam Permit Evaluation
- RF-FIM72..155 Beam Permit Evaluation
- Fast Gate Valve SPK Beam Permit Evaluation
- Fast Gate Valve HEBT Beam Permit Evaluation
- Fast Gate Valve DMPL Beam Permit Evaluation
- Beam Inhibit No Beam Supervision
- Proton Beam Destination Mismatch
- Proton Beam Mode Mismatch
- Global Beam Permit NOK due to Regular Beam Interlock
- Global Beam Permit NOK due to Emergency Beam Interlock

9.2 Logic Rules Defining the Regular Beam Interlock

The following list contains all logic rules which define the REGULAR_BEAM_INTERLOCK:

- ESS Timing System Status Supervision
- LEBT Chopper Status Supervision
- MEBT Chopper Status Supervision
- Multiple Beam Pulse On Triggers
- Regular Beam Permit NOK due to Emergency Beam Interlock

9.3 Logic Rules Defining the Emergency Beam Interlock

The following list contains all logic rules which define the EMERGENCY_BEAM_INTERLOCK:

- Ion Source Status Supervision

9.4 Proton Beam Destination States

The following list contains all Proton Beam Destination states:

- "LEBT";
- "MEBT";

- "DTL1";
- "DTL2";
- "SPK1";
- "SPK2";
- "MBL";
- "Tuning Dump";
- "Target";
- "None".

9.5 Proton Beam Mode States

The following list contains all Proton Beam Mode states:

- "Probe Beam";
- "Fast Tuning";
- "Slow Tuning";
- "Long Pulse Verification";
- "Shielding Verification";
- "Production";
- "None".

9.6 ID Positions States

The following list contains all ID Positions states:

- LEBT-010-EMU001 {Moving; Extracted; Inserted; Error}
- LEBT-010-FC001 {Moving; Extracted; Inserted; Error}
- MEBT-010-FC001 {Moving; Extracted; Inserted; Error}
- MEBT-010-WS001 {Moving; Extracted; Inserted; Error}
- MEBT-010-WS002 {Moving; Extracted; Inserted; Error}
- MEBT-010-WS003 {Moving; Extracted; Inserted; Error}
- MEBT-010-EMU001 {Moving; Extracted; Inserted; Error}
- DTL-020-FC001 {Moving; Extracted; Inserted; Error}
- DTL-040-FC001 {Moving; Extracted; Inserted; Error}
- SPK-020-WS001 {Moving; Extracted; Inserted; Error}
- SPK-040-WS001 {Moving; Extracted; Inserted; Error}
- SPK-050-WS001 {Moving; Extracted; Inserted; Error}
- MBL-020-WS001 {Moving; Extracted; Inserted; Error}
- MBL-040-WS001 {Moving; Extracted; Inserted; Error}
- MBL-050-WS001 {Moving; Extracted; Inserted; Error}
- HBL-020-WS001 {Moving; Extracted; Inserted; Error}
- HEBT-080-WS001 {Moving; Extracted; Inserted; Error}
- HEBT-110-WS001 {Moving; Extracted; Inserted; Error}
- HEBT-140-WS001 {Moving; Extracted; Inserted; Error}
- A2T-120-WS001 {Moving; Extracted; Inserted; Error}