EUROPEAN
PLASMA RESEARCH
ACCELERATOR
WITH
EXCELLENCE IN
APPLICATIONS

Chapter 20: Functional Safety Systems

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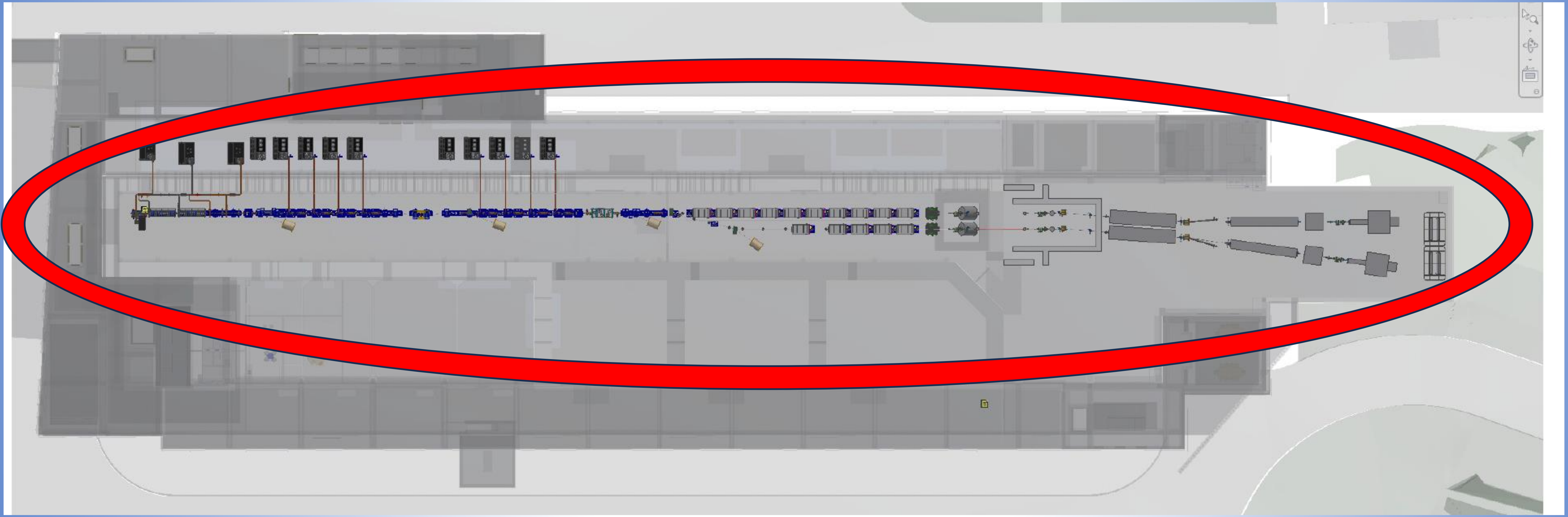
Area

Funded by the European Union



Overview on EuPRAXIA Functional Safety System Chapter

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Functional Safety approach within EuPRAXIA

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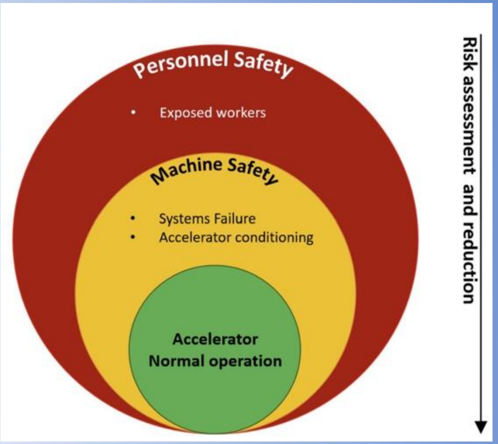
Objective

Ensure the safety of personnel and the protection of accelerator equipment by developing a robust, safe and reliable system in compliance with applicable safety standards and risk assesment.

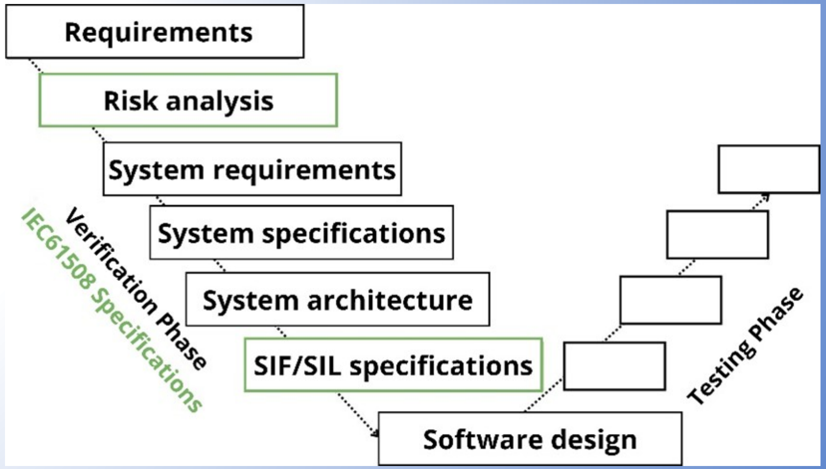


Involved Systems

- MPS (Machine Protection System): safeguard the accelerator and associated equipment
- PSS (Personnel Safety System): protects personnel from radiation and other hazards

System Architecture:

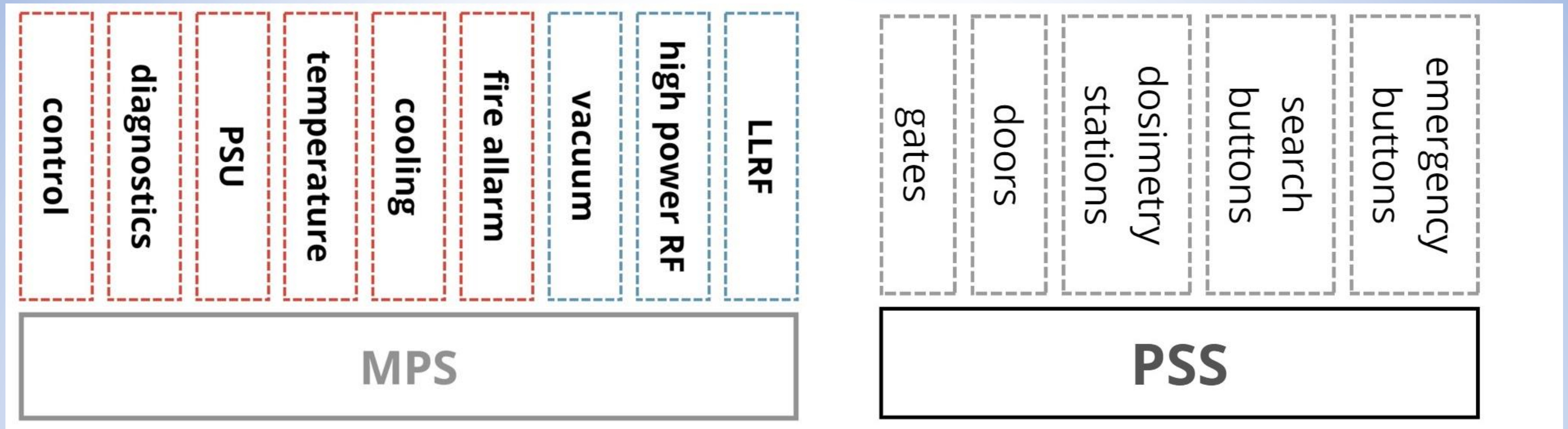
- Designed following the V-model development lifecycle
- Validation and rigorous verification at each stage of the system's design and implementation, ensuring systematic traceability
- This approach supports the development of high-integrity safety systems, from initial requirements to final testing and deployment.



Standards Compliance: IEC-61508, ANSI N43.1, NCRP REPORT N.88

Requirements and Specifications

MPS
Detect interlocks
Prevent anomalies
Optimize operations and performance



PSS
Preventing access to bunker and restricted areas
Enable/disable RF and triggers

Requirements (examples):
<u>SR01:</u> RF, Vacuum, Temperature Monitoring
<u>SR05:</u> Operate reliably during electrical anomalies or outages
…

Specifications (examples):
<u>SS01:</u> A multi-head system is required for signal monitoring (Ref.SR01)
<u>SS02:</u> The cRIO PSU must be backed by a UPS to guarantee 10 minutes (600 s) of operation during outages. (Ref. SR05)
…

Requirements (examples):
<u>SR02:</u> Access Lock During Active Beam
<u>SR05:</u> Event and Access Tracking
…

Specifications (examples):
<u>SS03:</u> Electromechanical locks shall be installed on all controlled-area doors. (Ref. SR02)
<u>SS09:</u> All critical safety events shall be logged with timestamps and user IDs. (Ref. SR05)
…

Architecture and Functional Safety (MPS)

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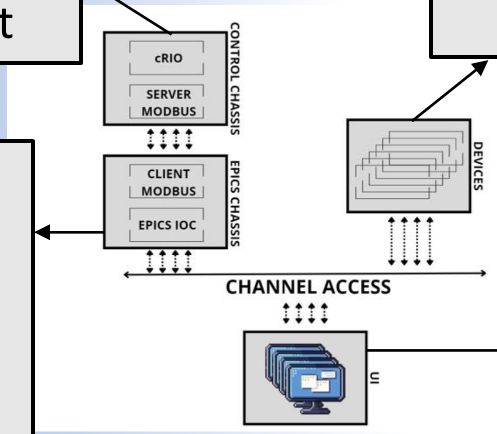
Architecture

cRIOs operating under MODBUS for device management

All systems under MPS control, including 24 V contacts

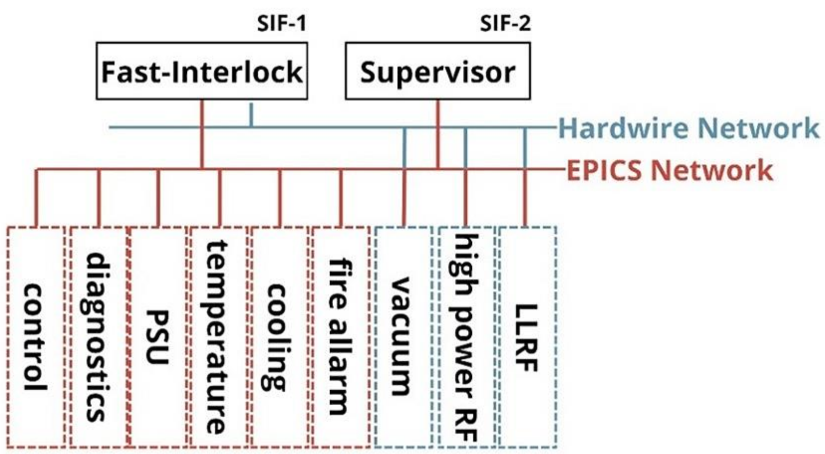


EPICS IOC on Ethernet using a client/server architecture for communication and PV data storage

Multi-head monitors in the control room running LabVIEW for monitoring and data analysis

Functional Safety

Based on the risk matrix [1], the required SIL for the SIFs is **SIL-1**, corresponding to a Probability of Failure per Hour (PFH) in continuous mode between 10^{-6} and 10^{-5}.



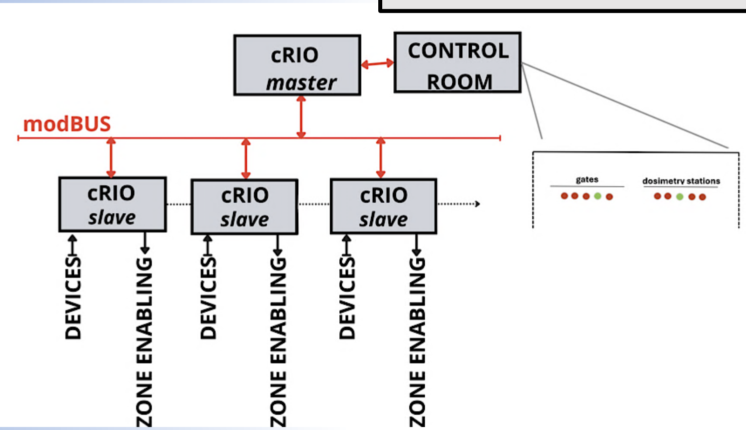
[1] Advanced beam protection systems for high brightness electron-beam and linac-based Compton sources, S. Pioli, 2019, NFN-19-07-LNF

Architecture and Functional Safety (PSS)

Architecture

A LabVIEW-based supervisor monitors the status of enabled/disabled devices.

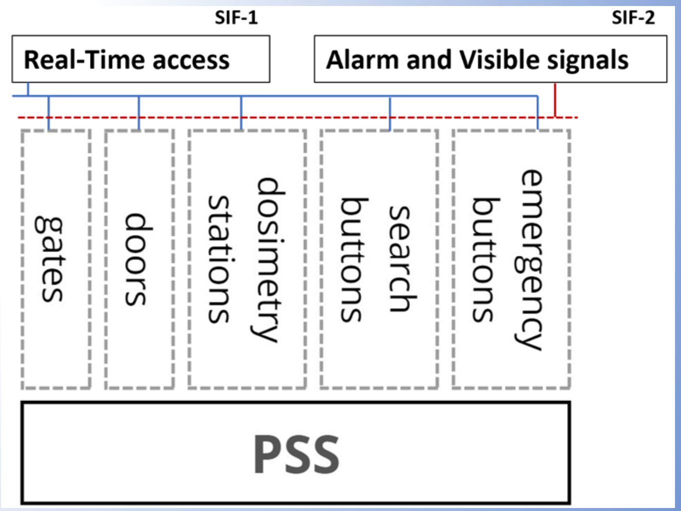
Distribuited architecture in master - slave configuration



All devices and all cRIO output modules, configurated normally open with interlocks assumed active-low. Redundant 24 VDC contacts are used to enhance reliability.

Functional Safety

Based on the risk matrix [1], the required SIL for the SIF-1 is **SIL-2** - PFH in continuous mode between 10^{-7} and 10^{-6};
for the SIF-2 is **SIL-1** - PFH in continuous mode between 10^{-6} and 10^{-5}.



[1] Advanced beam protection systems for highbrightness electron-beam and linac-based Compton sources, S. Pioli, 2019, NFN-19-07-LNF

Achievements:
Technological Readiness Level (Sub-Components)

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Sub - systems	TRL	Comments
PSS	9	The PSS architecture has already been defined based on a proven configuration, currently in use at the TEX, SSRIP and soon at EuAPS facilities, where it has been validated with the same operational logic and hardware setup.
MPS	9	The MPS architecture has been defined and validated based on a configuration already implemented at the TEX, SSRIP and soon EuAPS facilities and further tested in other accelerator environments, confirming its reliability and scalability.