EUROPEAN SPALLATION SOURCE

Development and Realization of the ESS Machine Protection Concept

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Overview

1. The European Spallation Source ERIC (ESS)
2. Damage potential of the proton beam at ESS
3. Machine Protection at ESS: scope and concept
4. Top level requirements and results from first prototypes
5. Governance of Machine Protection at ESS
6. Summary

ESS Plan

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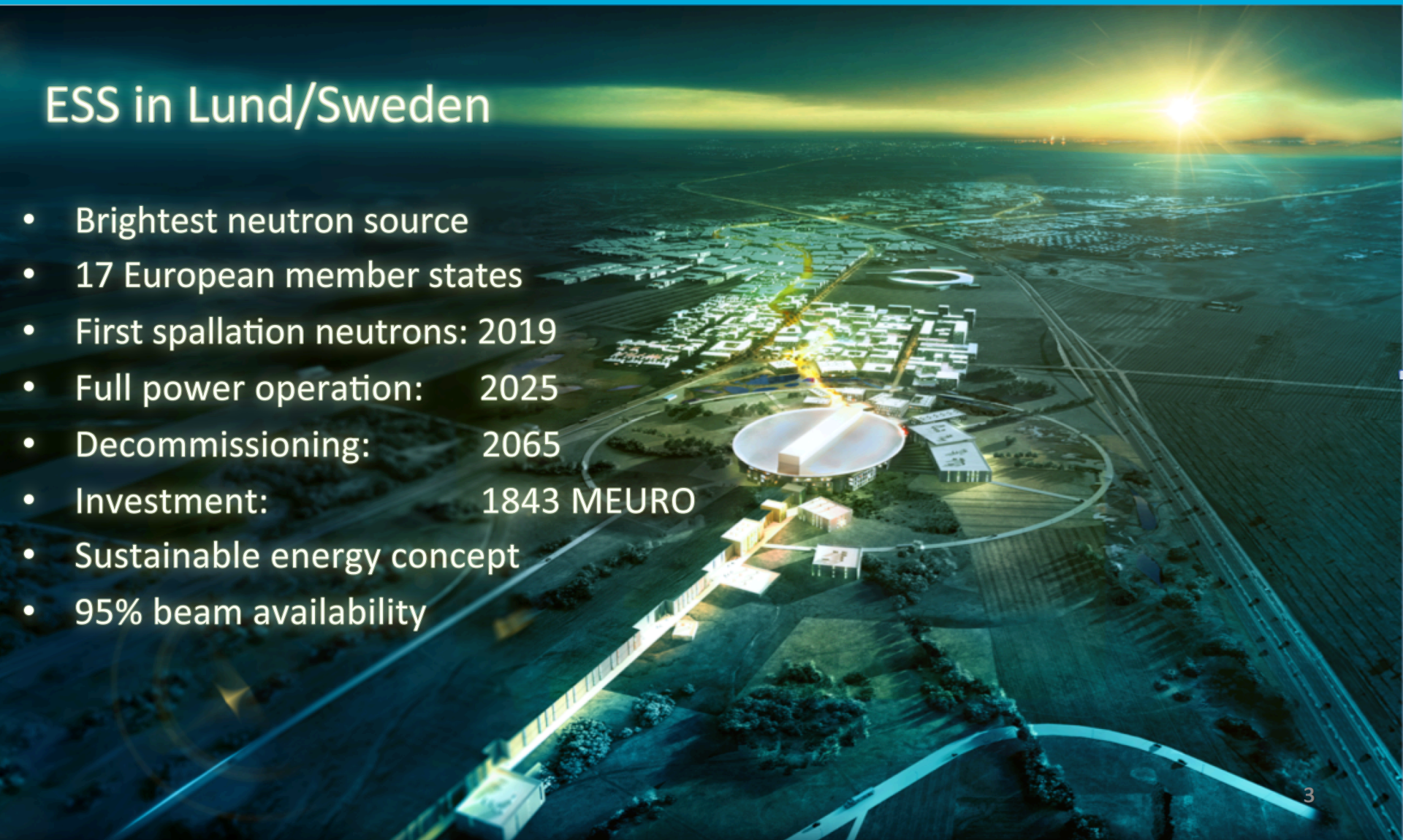

ESS in September 2015

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ESS LINAC

ESS aims to house the most powerful proton LINAC ever built

Average neutron flux is proportional to average beam power

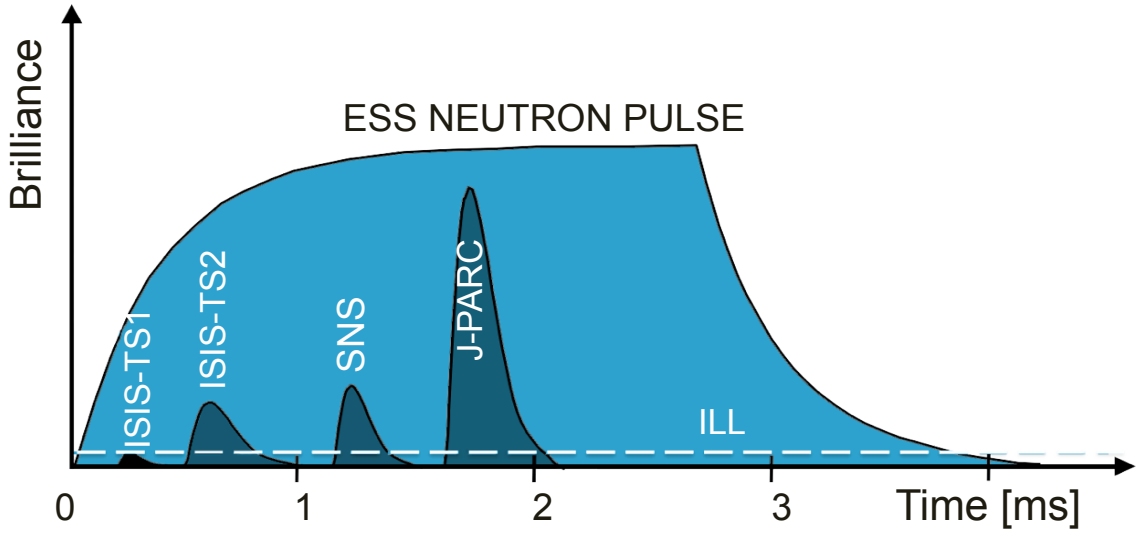
Average beam power will be: **5MW**

Average beam current: **62.5mA**

Proton energy per pulse: **360kJ**

Repetition rate: **14Hz**

Pulse length: **2.86ms**



ESS Target and Experimental Stations

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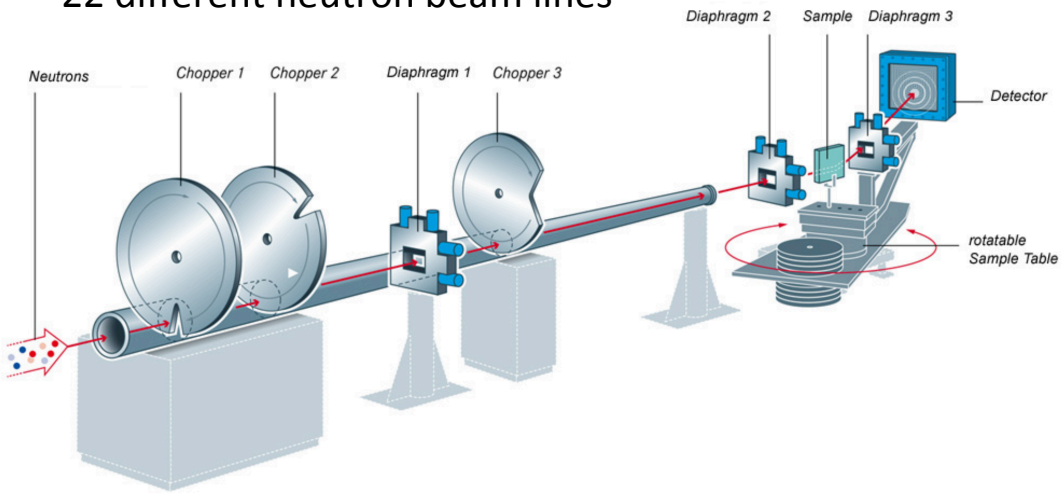
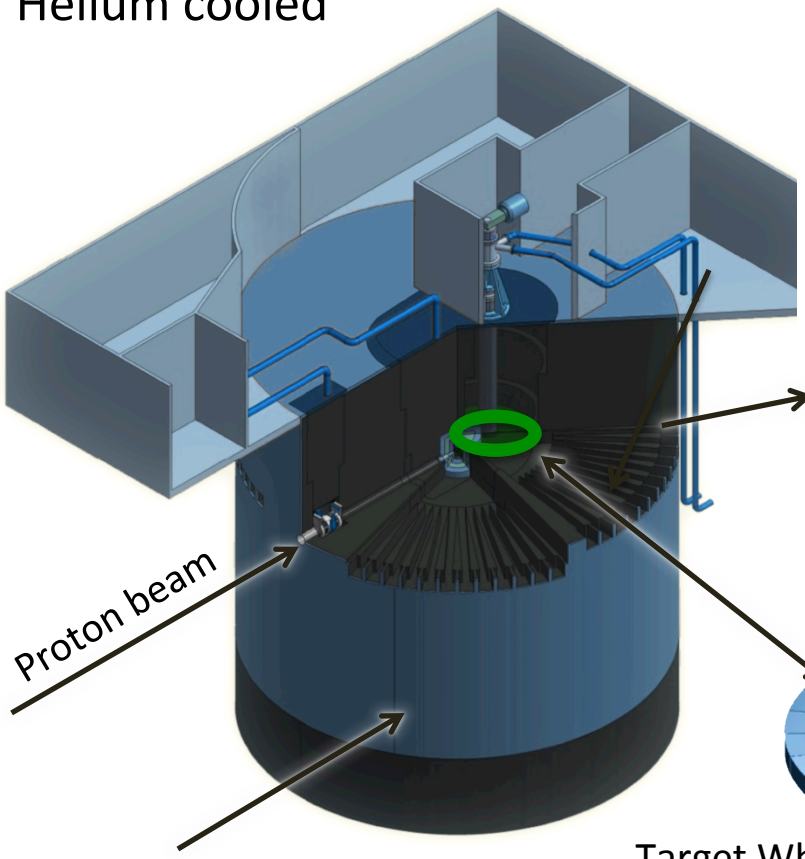
Target with rotating tungsten wheel

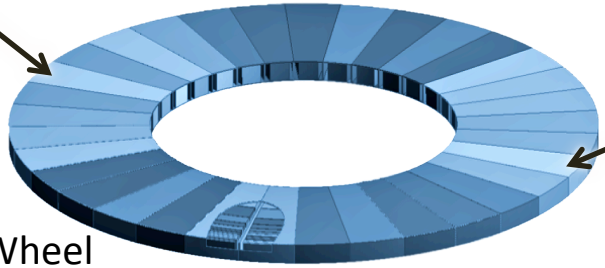
Synchronized to 14Hz

Helium cooled

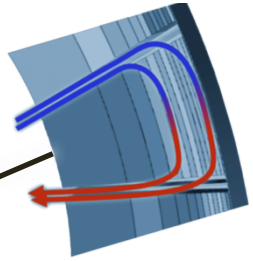
22 different neutron beam lines







Target Wheel



He flow around slices

5MW Proton Beam

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At 5MW, one beam pulse has:

The same energy as a 7.2kg shot travelling at 1100km/h (Mach 0.93).

Shot

This happens 14 times per second.

Damage Potential of the Proton Beam

Assuming **worst case** scenario:

Proton beam impinging perpendicularly on copper or steel (2mm beam size).

Beam Energy in [MeV]	1 - 3.6	3.6 - 90	90 - 216	216 - 2000
Melting Time in [µs]	10 - 20	20 - 200	200 - 400	>400
Beam Stop Time in [µs]	4 - 5	5 - 20	20 - 40	>40

Fastest reaction time required to stop proton beam is **4-5µs** (within the first 50m).

This includes detecting, processing and actual stopping of the proton beam.

It's a challenging task, requiring **fast** systems!

Scope of Machine Protection at ESS

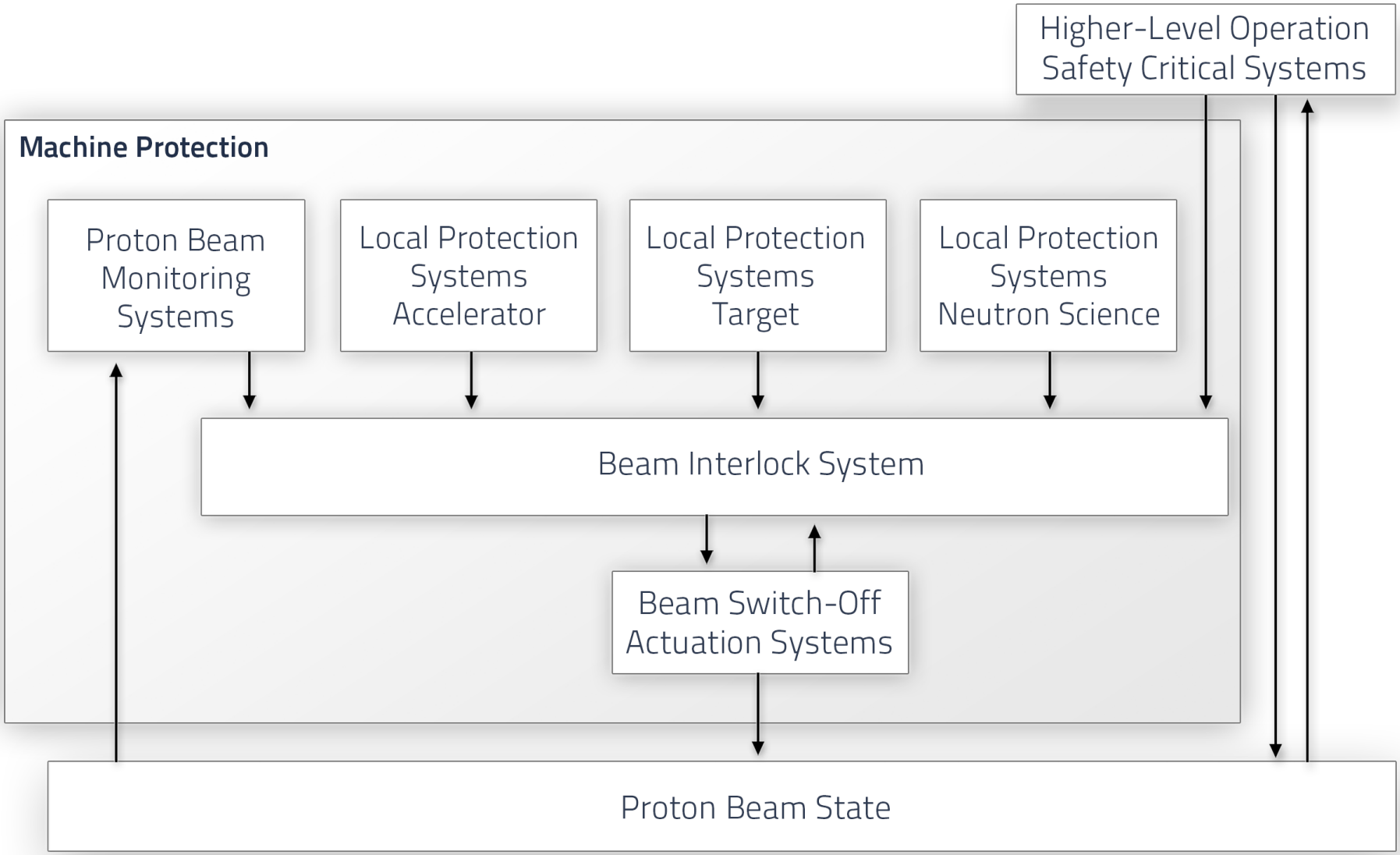
Machine Protection (MP) needs to reliably:

- **protect** the “machine” **from damage**, be it beam-induced or resulting from any other source,
- **protect** the “machine” **from unnecessary beam-induced activation**.

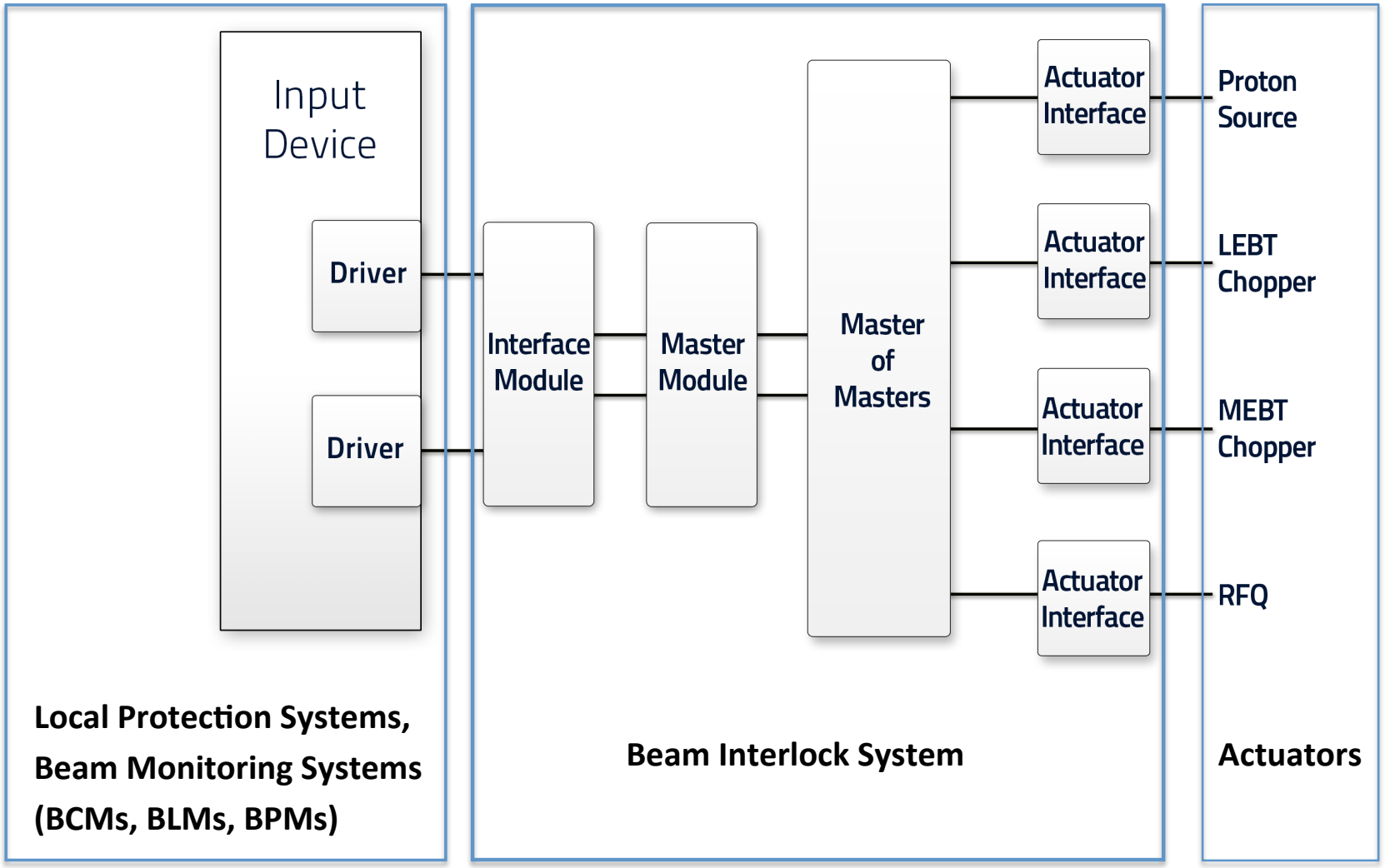
Machine protection will be implemented in a way to:

- **minimize** unnecessary down-time due to **spurious trips**,
- provide optimal **support** for **failure localization**,
- **support** all **operational modes** of the facility,
- **avoid wrong configuration** of equipment,
- **support** operation in **degraded mode.**

Functional MP Architecture Concept

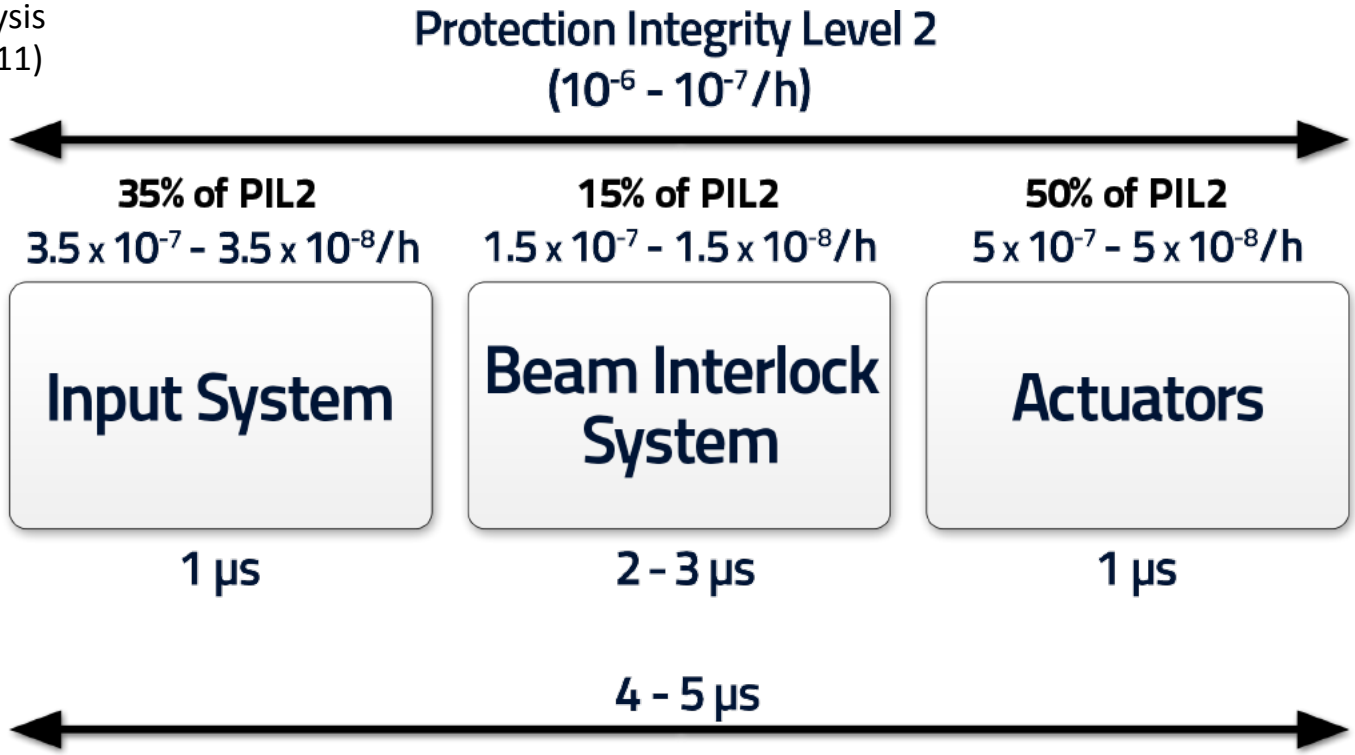


BIS Concept (adapted from CERN)



Top Level Requirements

Based on risk analysis
(IEC61508, IEC61511)

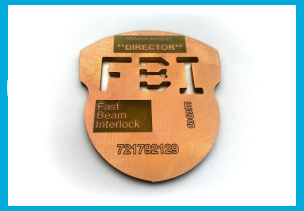


Requirements which are not trivial.

Two independent and diverse redundant beam interlock systems:

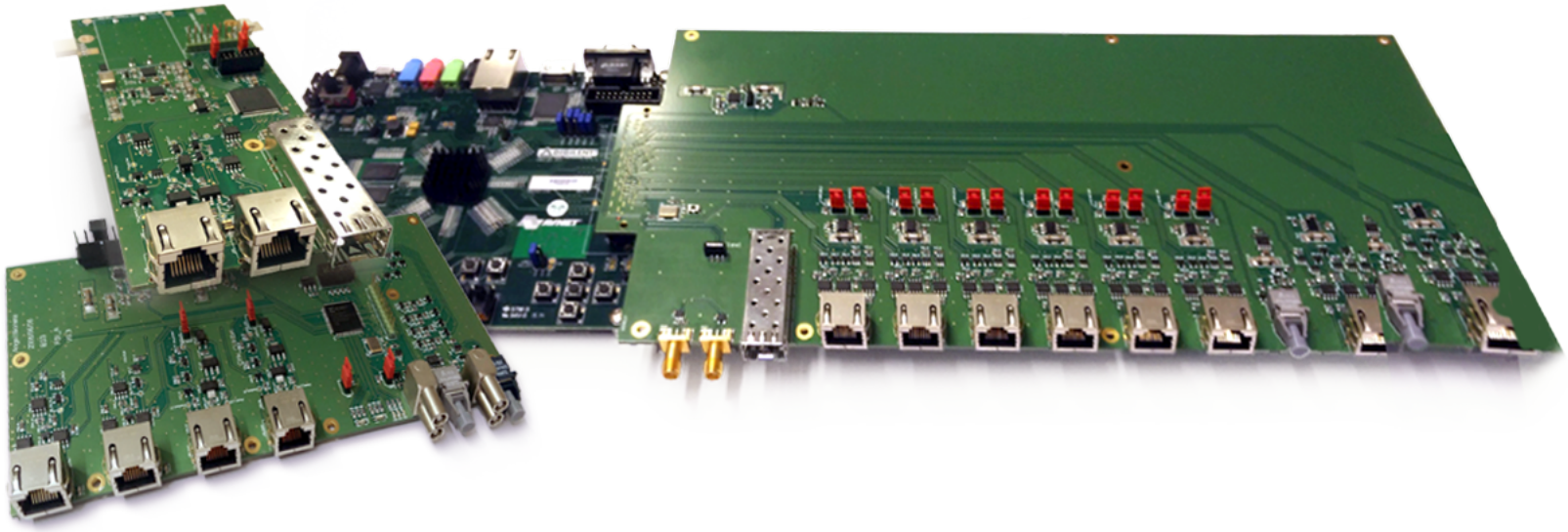
- Fast Beam Interlock FBI System/ FPGA based
- Slow Beam Interlock SBI System/ PLC based

First Prototype of the FBI System



Interface Module

Master Module

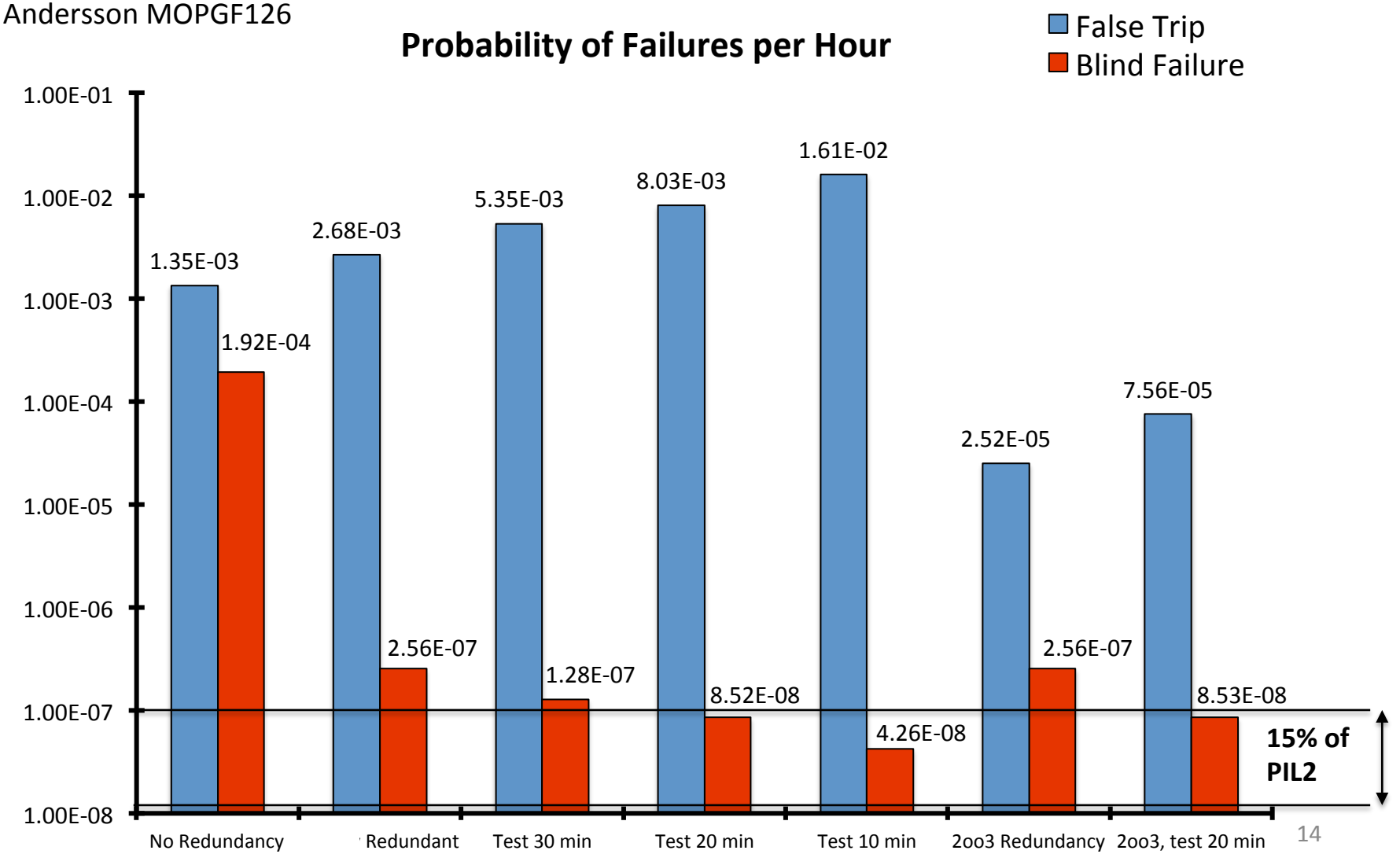


Actuator Interface Module

See MOPGF138 from A. Monera Martinez for more details

Initial Results from FMEDA of the FBIS Prototype

See R. Andersson MOPGF126



Challenges

The **challenge** is not only to build a Beam Interlock System,
but to **make sure the systems** connected to it provide **sufficient protection integrity.**

Traceability of requirements and
standardized documentation of all systems relevant for Machine Protection is very important.

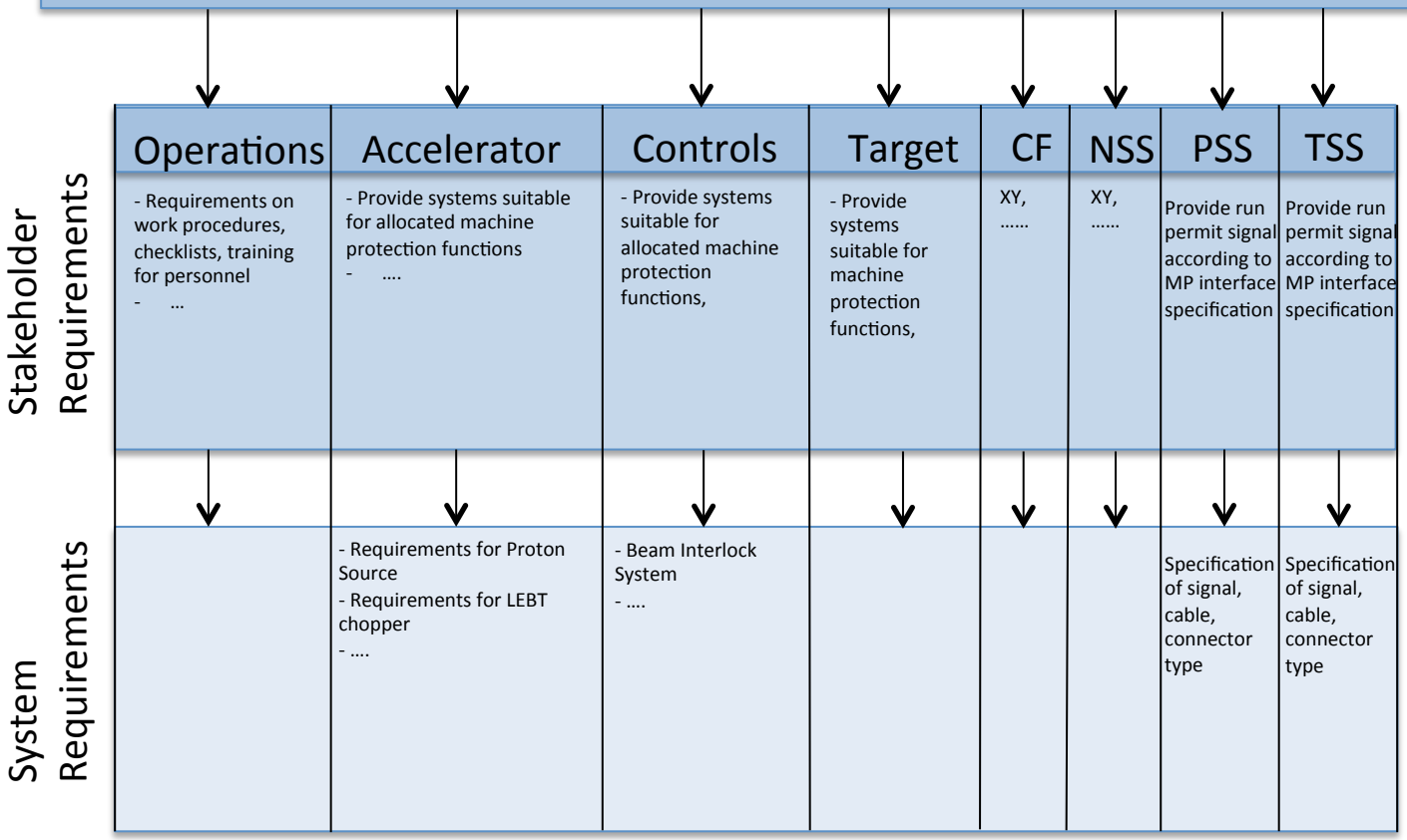
Governance of Machine Protection

Machine Protection Committee: Take on responsibility and take decisions

MPC domain/ responsibilities:

(Corresponding to analysis part of IEC61508)

Approval of **concept**, overall **scope,**
Coordination of **hazard risk analysis,**
Approval of overall **machine protection requirements,**
Coordination of machine protection **requirements allocation.**



Summary

Presented scope and concept for ESS Machine Protection.

Different concept ideas for the BIS are currently under investigation.

First prototyping started.

A decision making body is helpful when implementing Machine Protection at a complex facility like ESS.

Special thanks to the CERN team (R. Schmidt et al.) and
the ZHAW team (C. Hilbes et al.).