Designing ESS Machine Protection Systems highly integrated into operations and commissioning

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  - Machine Protection at ESS
  - Designing MP systems highly integrated into operations and commissioning
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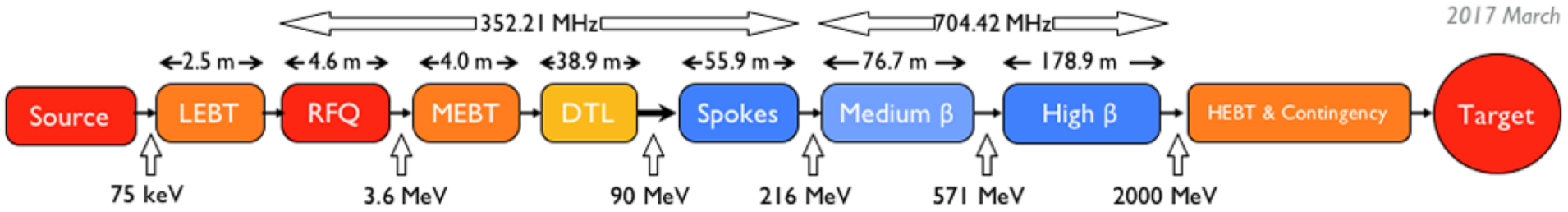
- 2nd Example: Ion Source test mode
- 3rd Example: Beam dump protection
- Conclusions

Introduction

Introduction
European Spallation Source (ESS)



<u>Target station:</u>

Rotating Tungsten wheel

Helium cooled

New moderator design

<u>Proton accelerator:</u>

Max. average beam power: **5 MW**

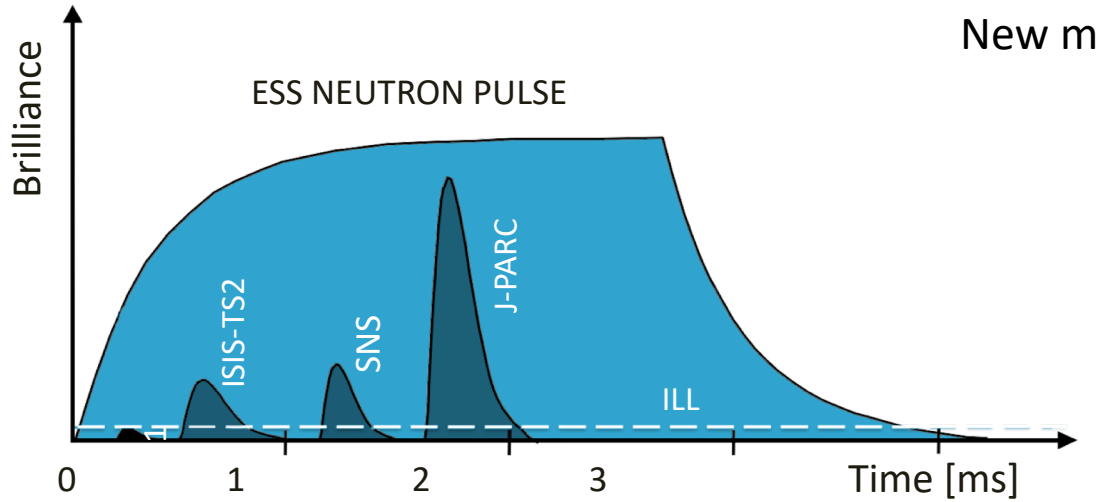
Peak power per pulse: **125 MW**

Average beam current: **62.5 mA**

Max. repetition rate: **14 Hz**

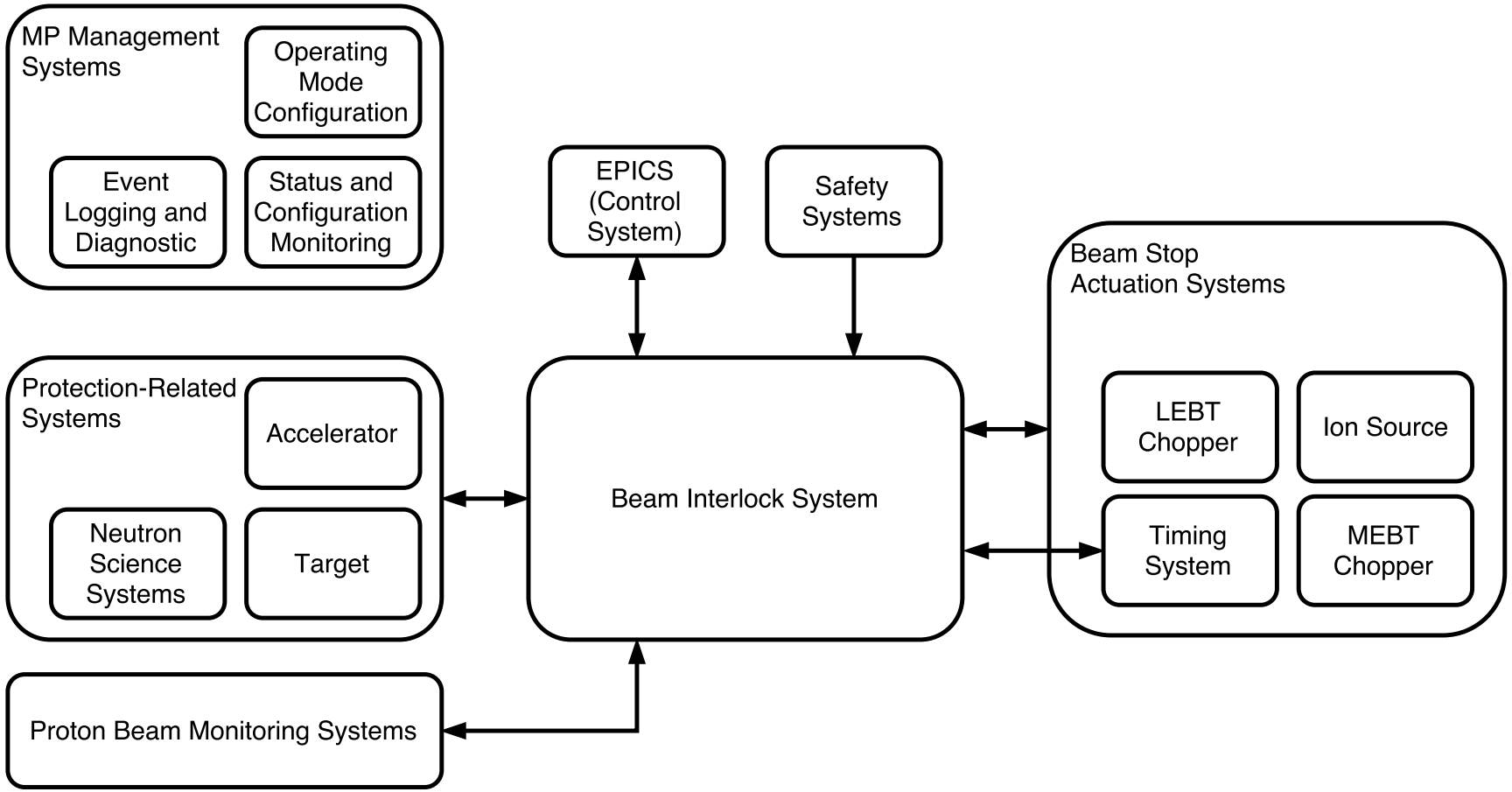
Max. pulse length: **2.86 ms**

Max. proton energy: **2 GeV**



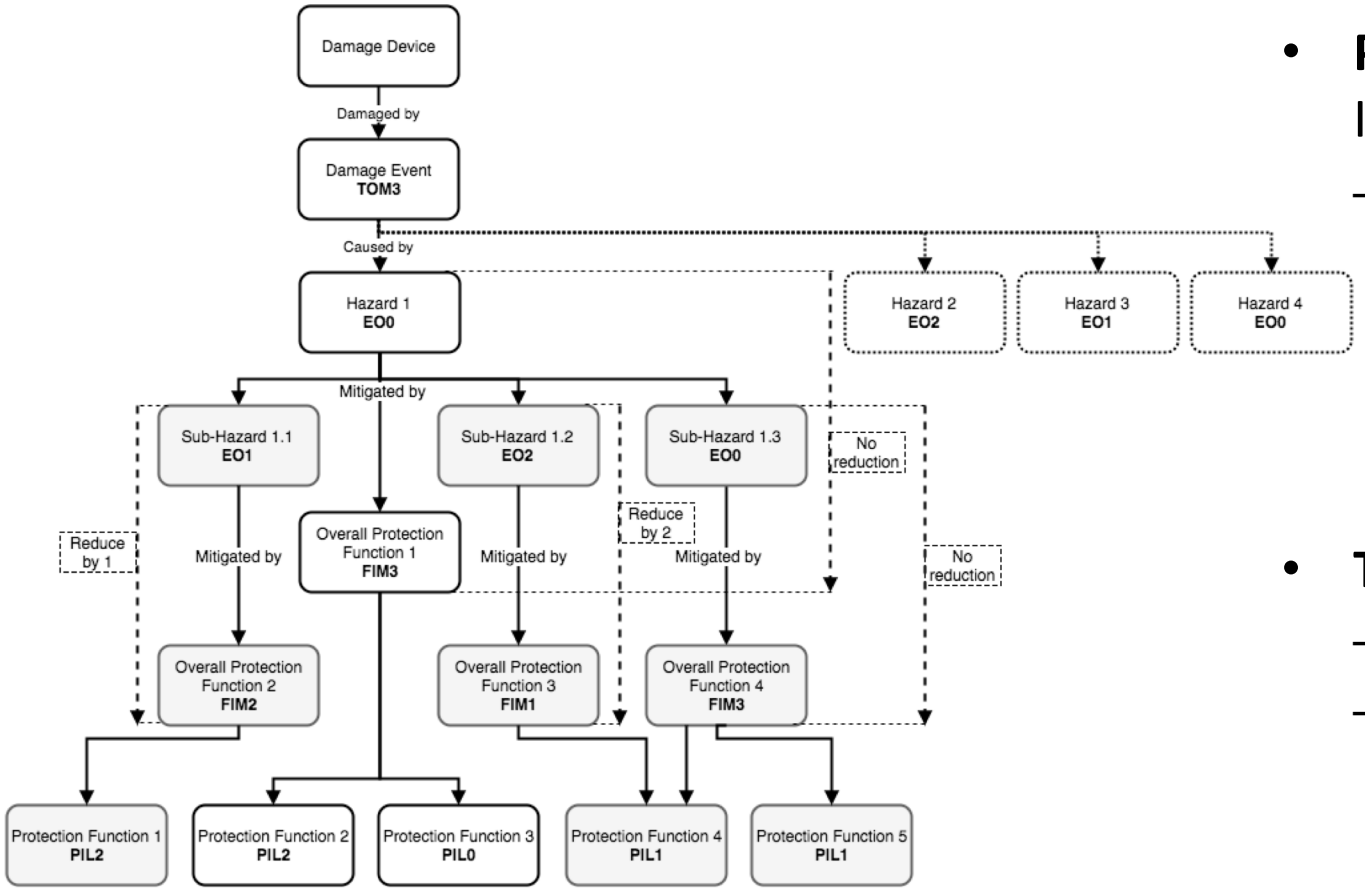
ESS will be a Neutron Factory!

Introduction
Machine Protection at ESS



Introduction
Highly reliable MP Functions

- A specifically developed **analysis method**:



- Following IEC 61508 standard (**functional safety standard** for EEPE)
- **Protection Functions** with **PIL** (Protection Integrity Level) and **response time** requirements
  - Redundancies, test mechanisms, diagnostics, safety equipment, additional layers of protection, etc.

- **Trying to reduce spurious trips**:
  - Not overdesigning machine protection equipment
  - Voting schemas (e.g. 2oo3) for some sensors

Introduction

MP systems integrated into operations and commissioning

- Design process usually focusses on reaching **high reliability** (in the protective sense) as well as **fast response time**
- A **smooth operation has to be facilitated** - sometimes not properly taken care of
- Machine Protection systems have to be **thought together with the rest of the machine**

- MP teams need people with **overall perspective** in addition to technical profiles (PLCs, FPGAs, etc.)
- Good **communication** with operations, accelerator and target teams
- **Review and analyze MP systems** from the overall perspective (use cases, operation modes, etc.)

1st Example: Movement of Insertable Devices

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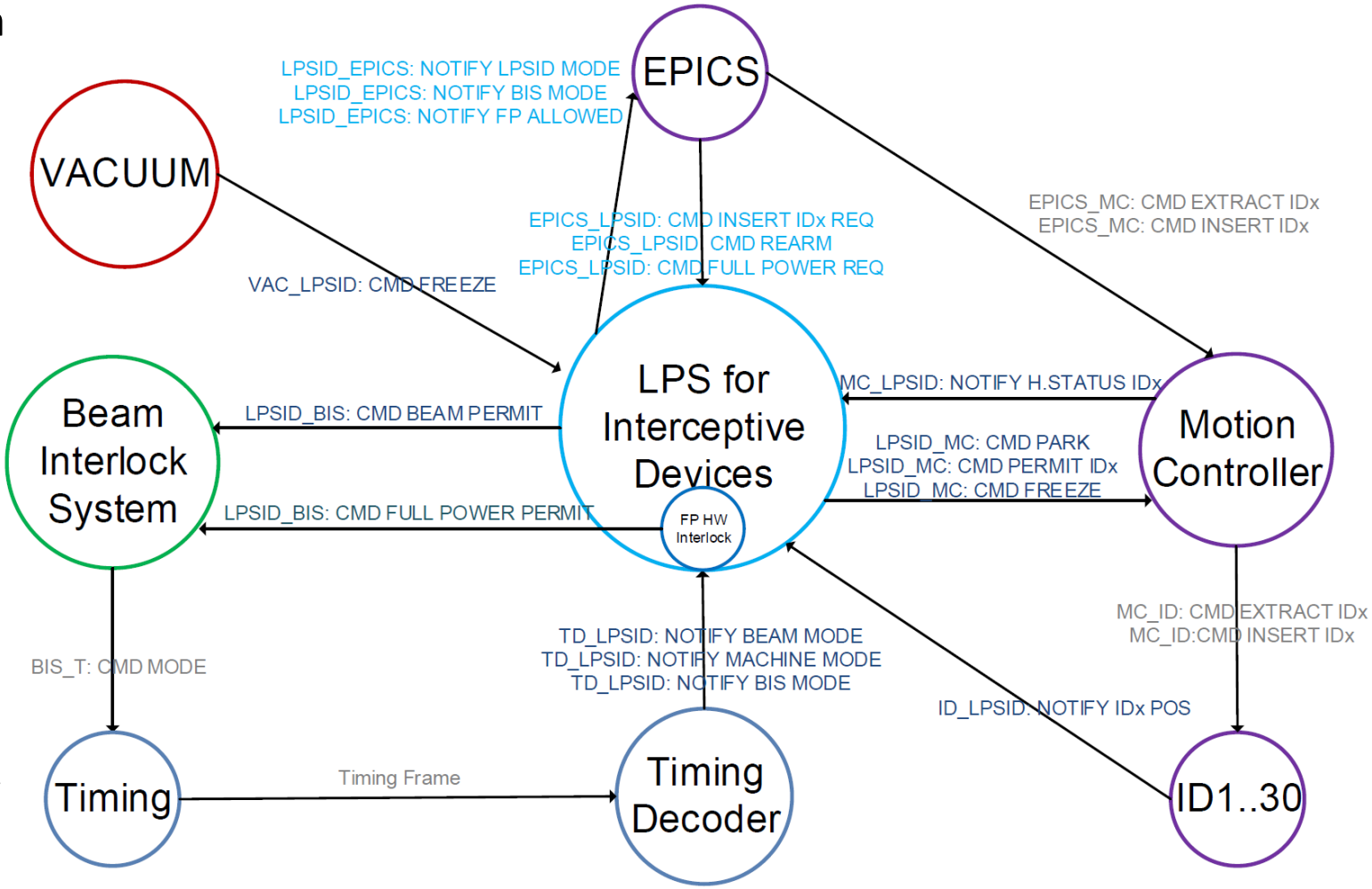
Context

- ESS has **many devices that can move** inside the beam pipe (instrumentation, beam stops, Gamma blockers, Vacuum valves…)
- Many can not deal with **high intensity** beam modes
- Some are **water cooled** -> can be not ready for beam
- Moving them in the wrong moment can imply very **long downtimes**

1st Example: Movement of Insertable Devices

MPS-ID old design

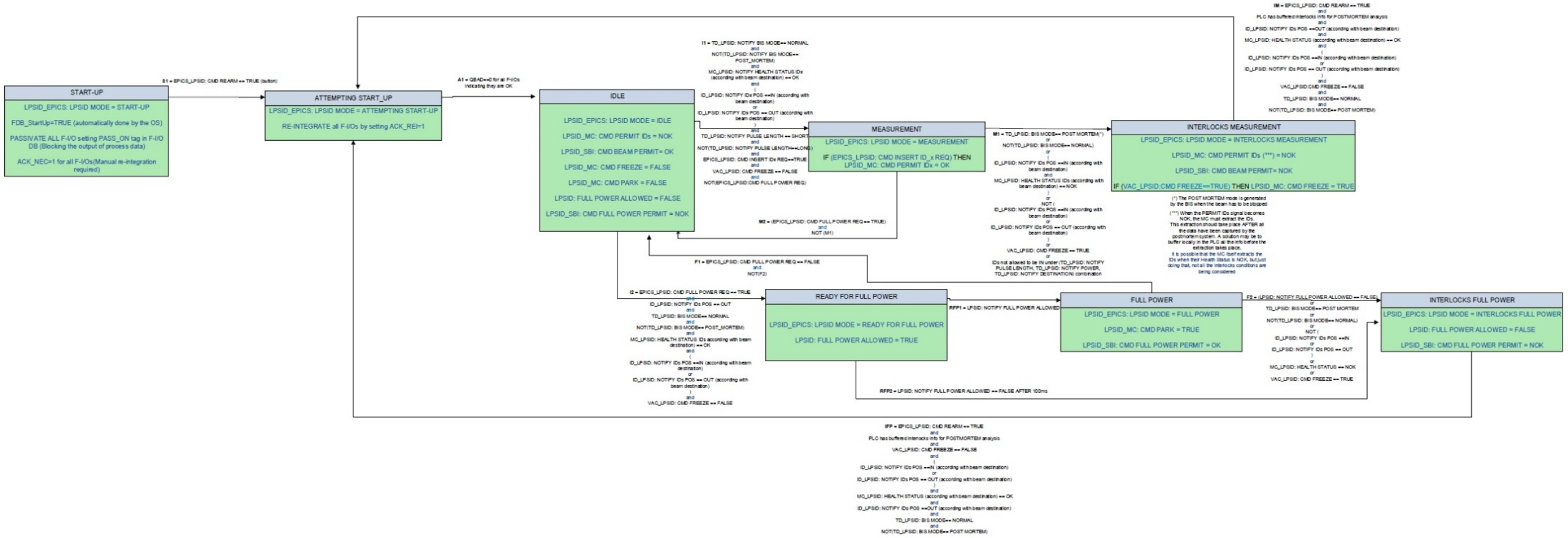
- The system **was made very reliable** (from the protection point of view)
- Any **movement had to be ”approved”** by the MP System:
  - Movement requested to MP (in or out)
  - MP checked status of everything (beam mode, current position of ID, status of water cooling, etc.)
  - If everything ok -> movement permit
- However, many situations (e.g. any anomaly) would lead to **not permitting movement** (fail safe)
- Some situations required to **go physically to the tunnel** and move the device



1st Example: Movement of Insertable Devices

MPS-ID old design

- Quite complex state machine with many checks:



1st Example: Movement of Insertable Devices
Current design

New design:

- Any ID **downstream of beam destination can move** (not defining if inserted or extracted)
- All IDs **can move if beam mode is "no beam"**
- Allows for **addition of new machine sections** while maintaining the integrity of existing commissioned sections

- **Freedom for operators** except when the situation is dangerous (no movement allowed if beam would be stopped)
- **Simpler design** with less undesired stops
- **Easier commissioning, testing and machine restart**

1st Example: Movement of Insertable Devices
Summary

- **Requirements** given to the designers were too **generic**
- **Design choices were not well communicated** to the rest of the team
- **Reviewing** the design and going through **use cases** helped to identify what was really necessary
- **New requirements** (more clear and specific) helped in the new design
- Similar approach for RF, Vacuum, Magnets, etc.

2nd Example: Ion Source test mode

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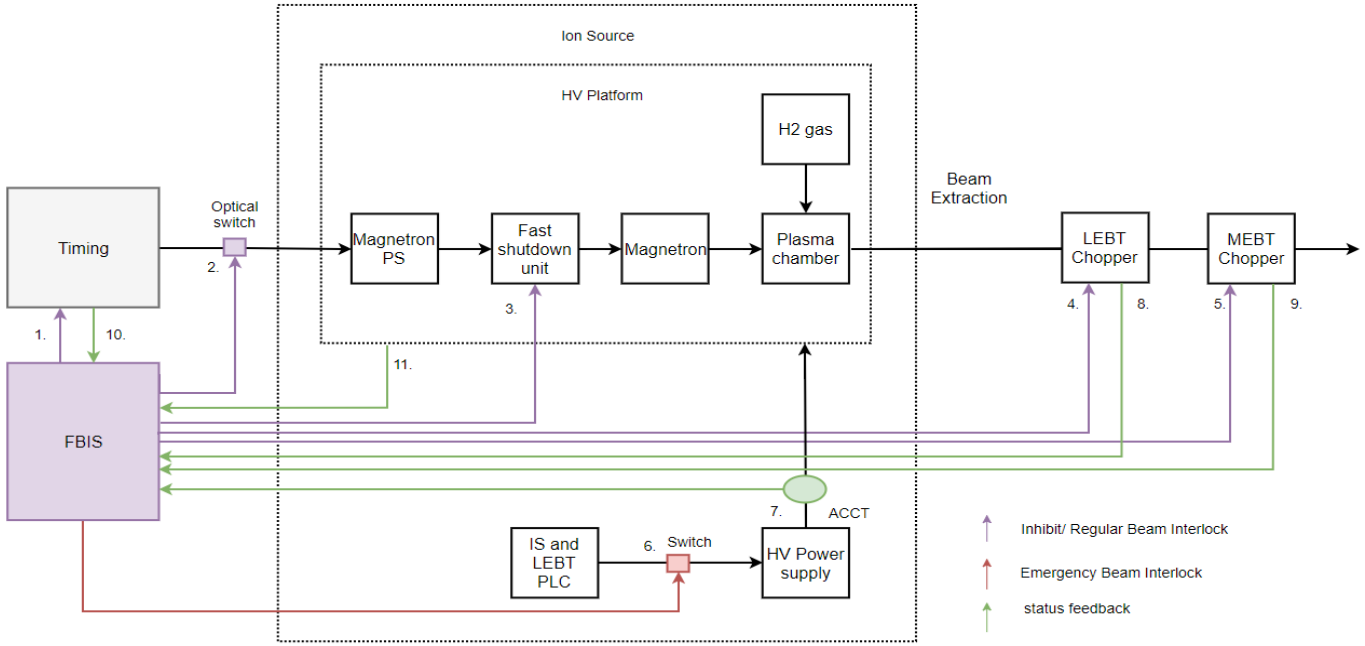
The Ion Source at ESS

- The Ion Source + LEBT was an **in-kind** from INFN
- They build a **local protection system** and made tests both in Catania and at ESS
- When working together with the next stages of the accelerator (+ RFQ + MEBT + DTL), it will be **connected to the ESS Machine Protection Systems -> main actuator** for MP

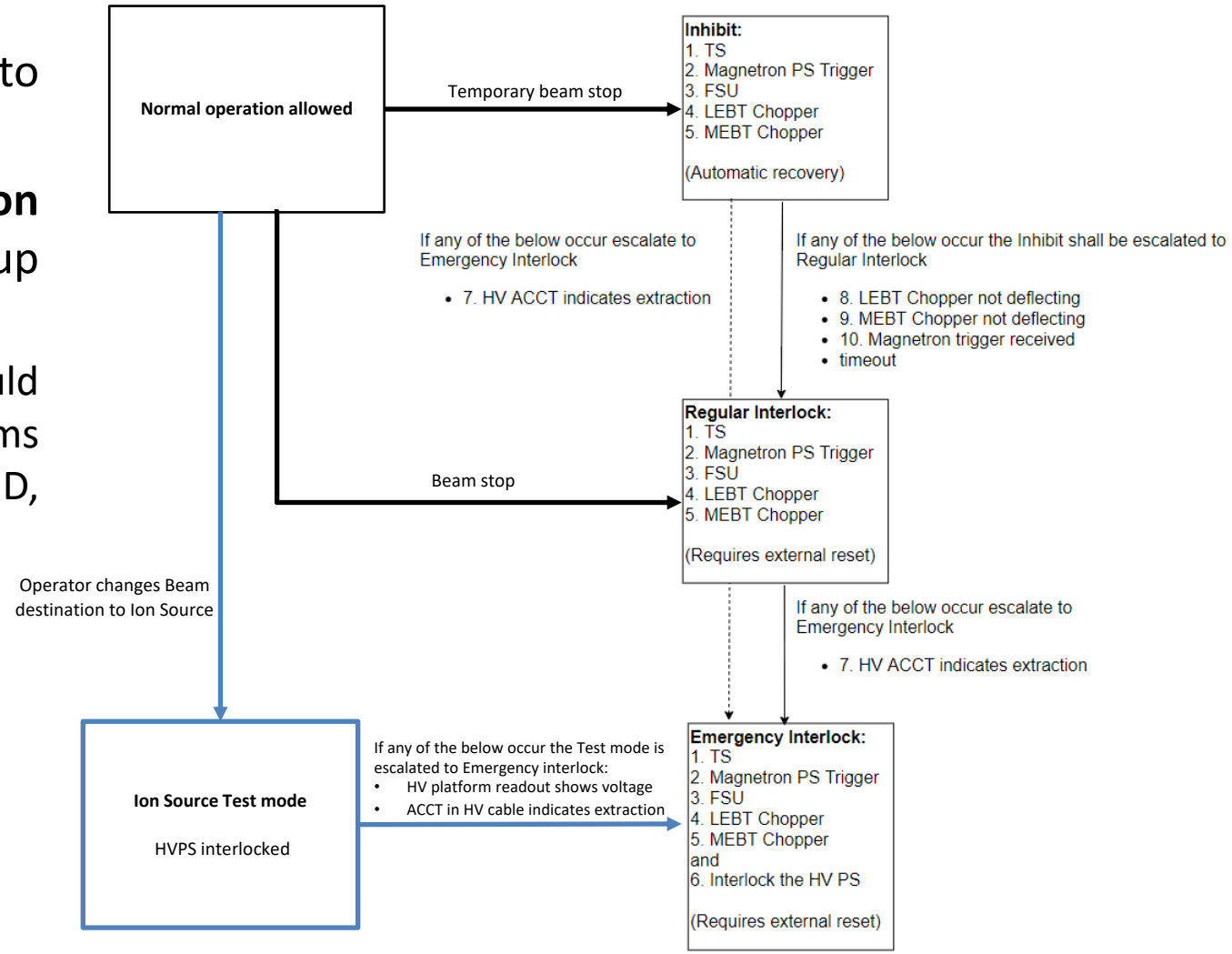


2nd Example: Ion Source test mode

No dedicated operation mode for IS tests

- Design efforts focused mainly on being able to **stop beam** reliably and quickly
- However, **no option of operating with only the Ion Source** was foreseen -> for tests use Faraday Cup to stop the beam:
  - **More systems** needed to operate -> tests would require **agreement with different groups** and systems (vacuum, FC motion control, cooling, MPSID, electrodes PS, LEBT components, etc.)
  - Insertion and extraction of **FC would take time**
  - **Ion source would get cold** -> less stable

Restart, test and maintenance more difficult



2nd Example: Ion Source test mode
Summary

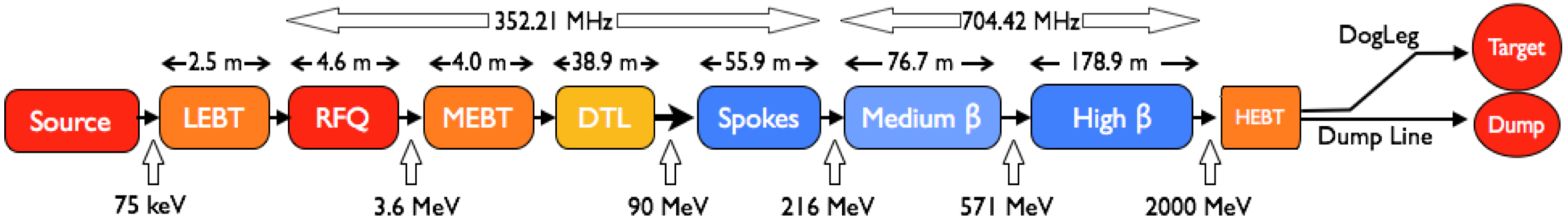
- Lack of **operation requirements** (and a solid operations team)
- **Isolation of design teams** made both teams take incorrect considerations
- However, MP team **knowledge of Ion Source and overall ESS accelerator operation** helped in identifying the problem

- **New operation mode** beneficial for operations, commissioning and for availability

3rd Example: Beam dump protection

3rd Example: Beam dump protection
Context

- **Accelerator division** responsible of **accelerating structures** and **transport lines**
- **Target division** responsible of **Target** and **Beam dump**
- **Integrated Controls Division** – Machine Protection **in charge of protection** of all of these systems



3rd Example: Beam dump protection

The issue

- Target and beam dump have the same “owner”
- Beam dump protection is quite simple

→ Protection of both systems was included in one system: Target protection system (MPSTrg)

- Made sense in order to **reduce interfaces** with groups (documentation, agreements, installation…)
- **However, commissioning the accelerator** with beam dump would require MPSTrg to be up and running -> **no tests, commissioning or start-up could be done in parallel with the target**.
- **Organizational structures and responsibilities** didn’t match a design optimized for operations.

3rd Example: Beam dump protection

Result and conclusions

- The **protection of the Dump** is carried out by the **protection of Insertable Devices (MPSID)**
- Now, **MPSID** already takes care of all intermediate beam destinations (except target)

- New design with **no interdependency** between accelerator and target
- Easy tests, commissioning, restart, ramp-up, etc. -> **higher availability**

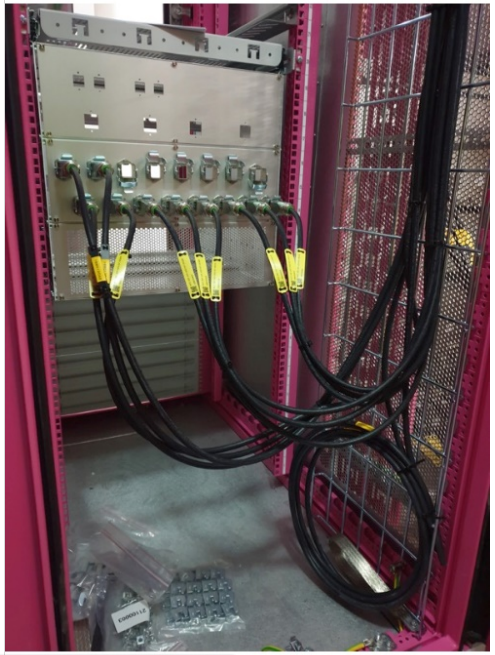
Conclusions

Conclusions

- **Machine protection** is very important for ESS (high damage potential)
- It has to be **fast and reliable**
- But it also has to be **thought in conjunction** with the whole machine
- **Less problems** for operations and commissioning **if analyzed and reviewed** during the design phase
- **More trust** on Machine Protection systems (operators not trying to find “alternative paths”)
- And all of this leads to **higher availability**

And… some pictures!

Connecting
to Vacuum



MPS-ID Crate
in FEB

MPS Racks in FEB

Fast Beam Interlock System

Thanks!