PROTECTION SYSTEMS @ ESS

EUROPEAN SPALLATION SOURCE

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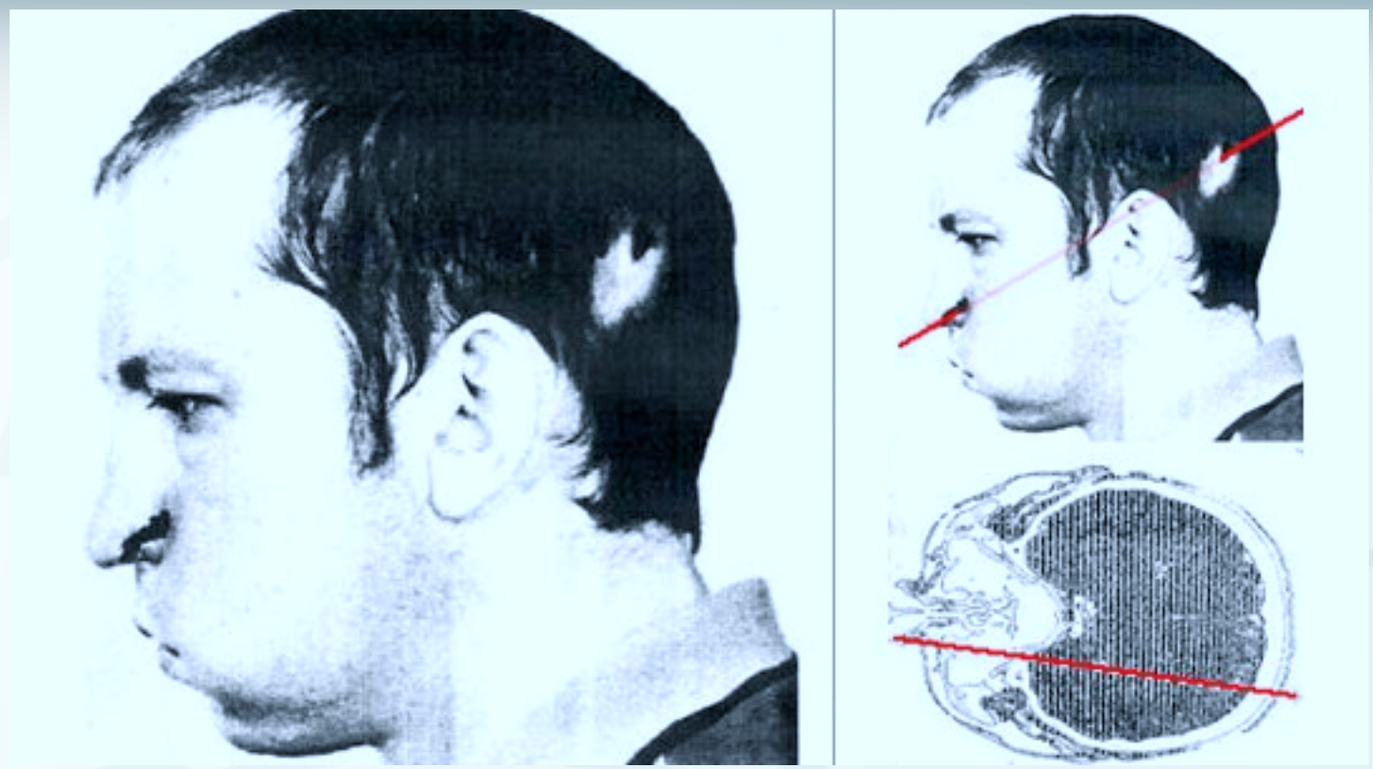
CONTENT

- Damage in accelerators
- Protection Systems at ESS: an overview
- Machine Protection System: Design approach
- Summary

Damage Potential of Beams

Bugorski got stuck in the beam pipe and SAW the proton beam coming

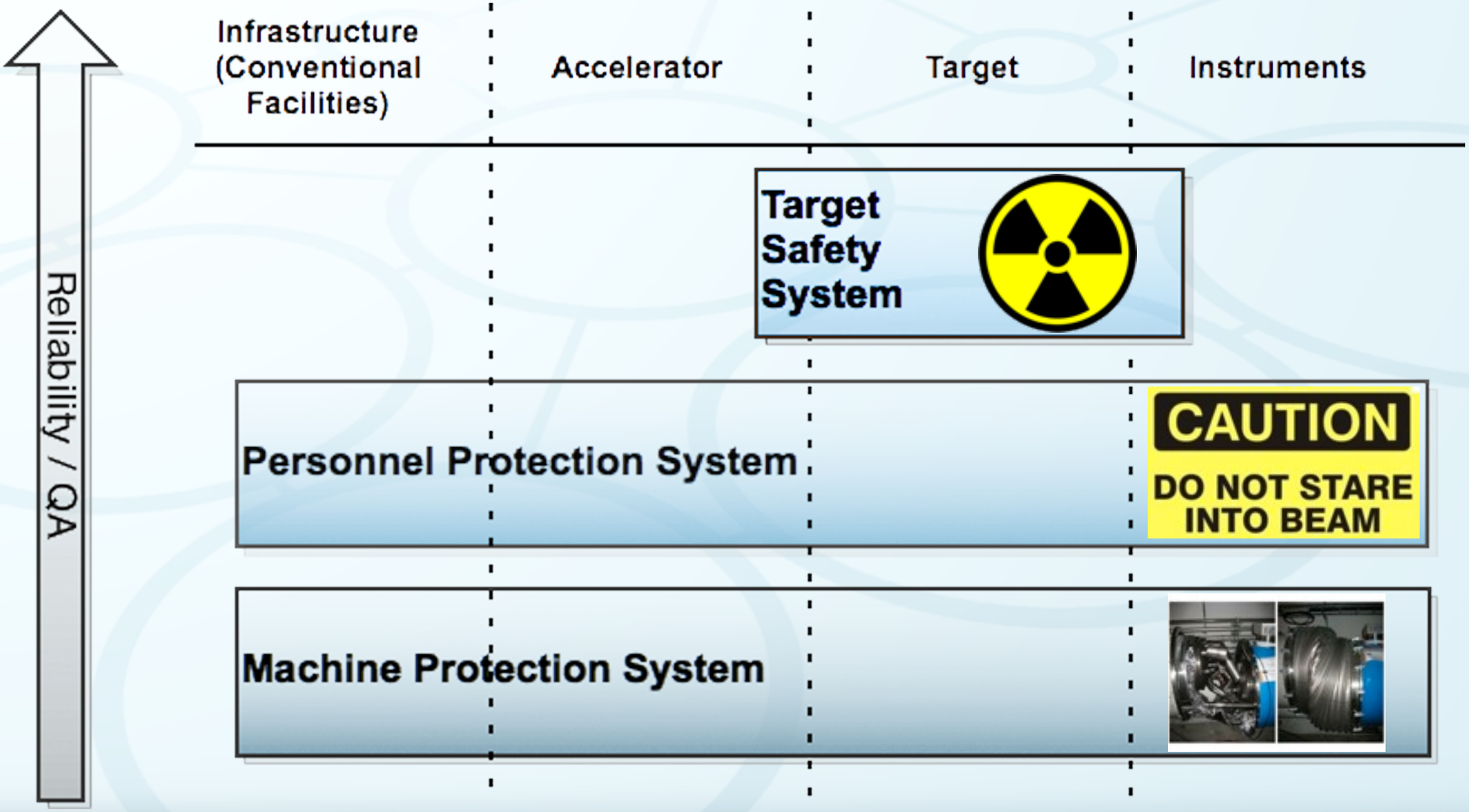


Magnet testing

LHC accident 2008

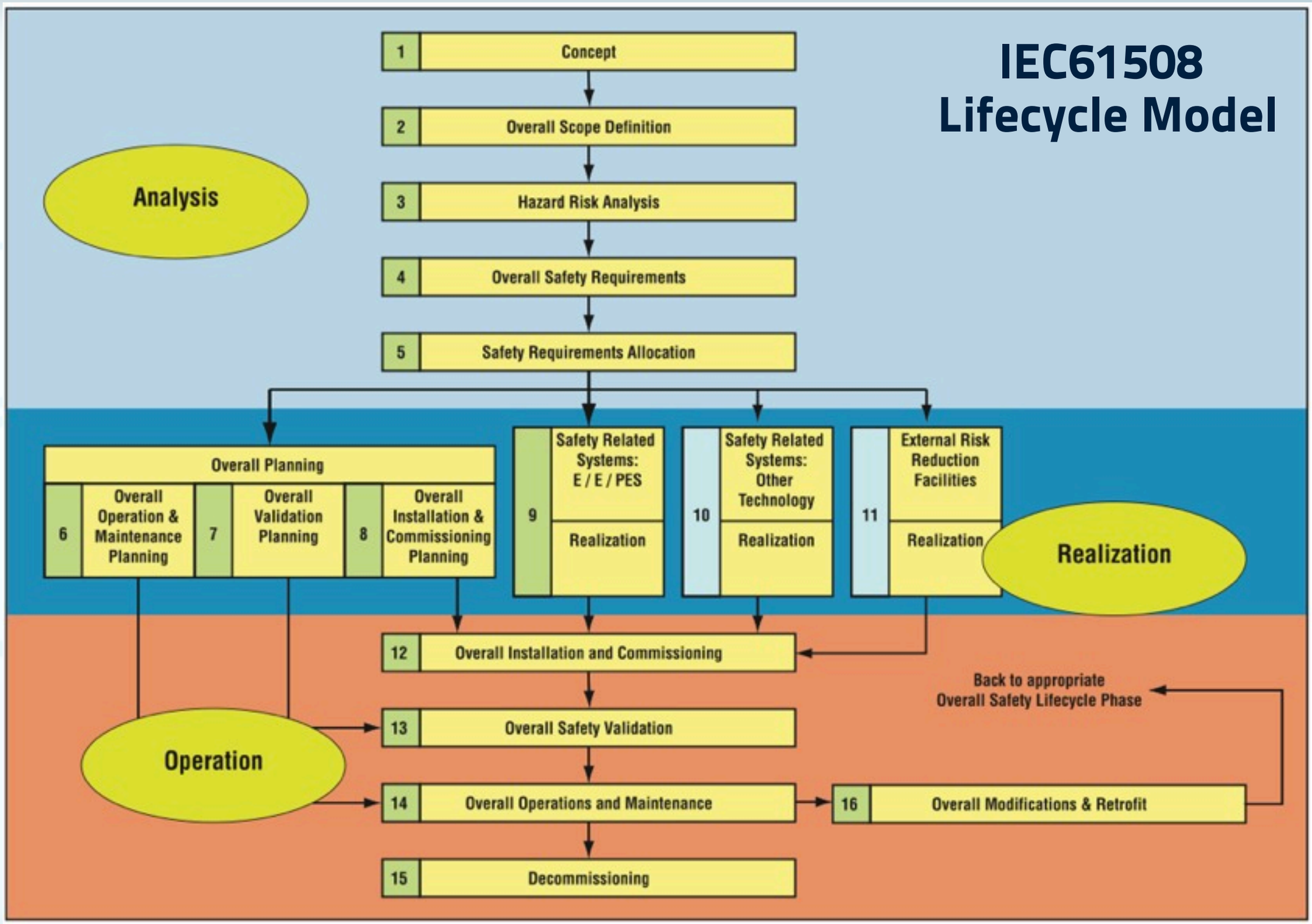
Protection **Systems @ ESS**

Several layers of safety & protection & control systems



Design of **Mission Critical Systems**

IEC61508 Lifecycle Model



Machine **Protection System (MPS)**

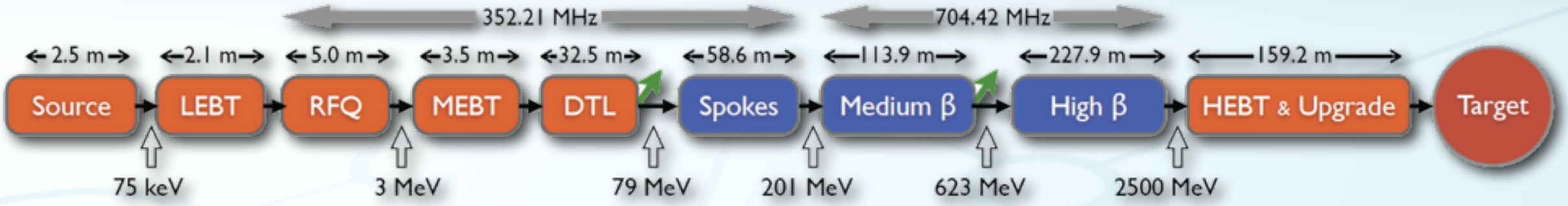
Concept:
Protect machine against damage due to beam losses/malfunctioning equipment

Design Function:
Turn off proton beam upon detection of non-nominal conditions

Overall Scope:
MPS = supporting system, rather than an intervening one
MPS must optimize the integrated machine performance

Achtung!
Avoid false triggers leading to unnecessary downtime
BUT NEVER BE BLIND!

Hazard and **Risk Analysis for MPS**



Risk analysis based on HAZID (Hazard Identification) **methodology and SIL** (Safety Integrity Level) **allocation**

Done for Target Station and A2T (Accelerator to Target) **line**

Currently ongoing for accelerator (~30 systems involved, vacuum, cryo, RF, ...)

Risk analysis will be merged with reliability analysis !

Translation into **Requirements**

Example from HAZID (A2T line):

- **Top event:** First bending magnet fails at full power
- **Consequences:** Beam pipe will be damaged when hit by beam, vacuum fails, proton beam can reach high bay and expose workers to radiation
- **Safety Barriers:** Radiation monitors that can detect and initiate a beam shutdown within 1 pulse, MPS, fast valve
- **Todo:** Investigate time needed for the bending magnet to fail, time needed to melt steel/copper from a full power pencil beam exposure to the accelerator's and target's equipment

Top Level **Requirements**

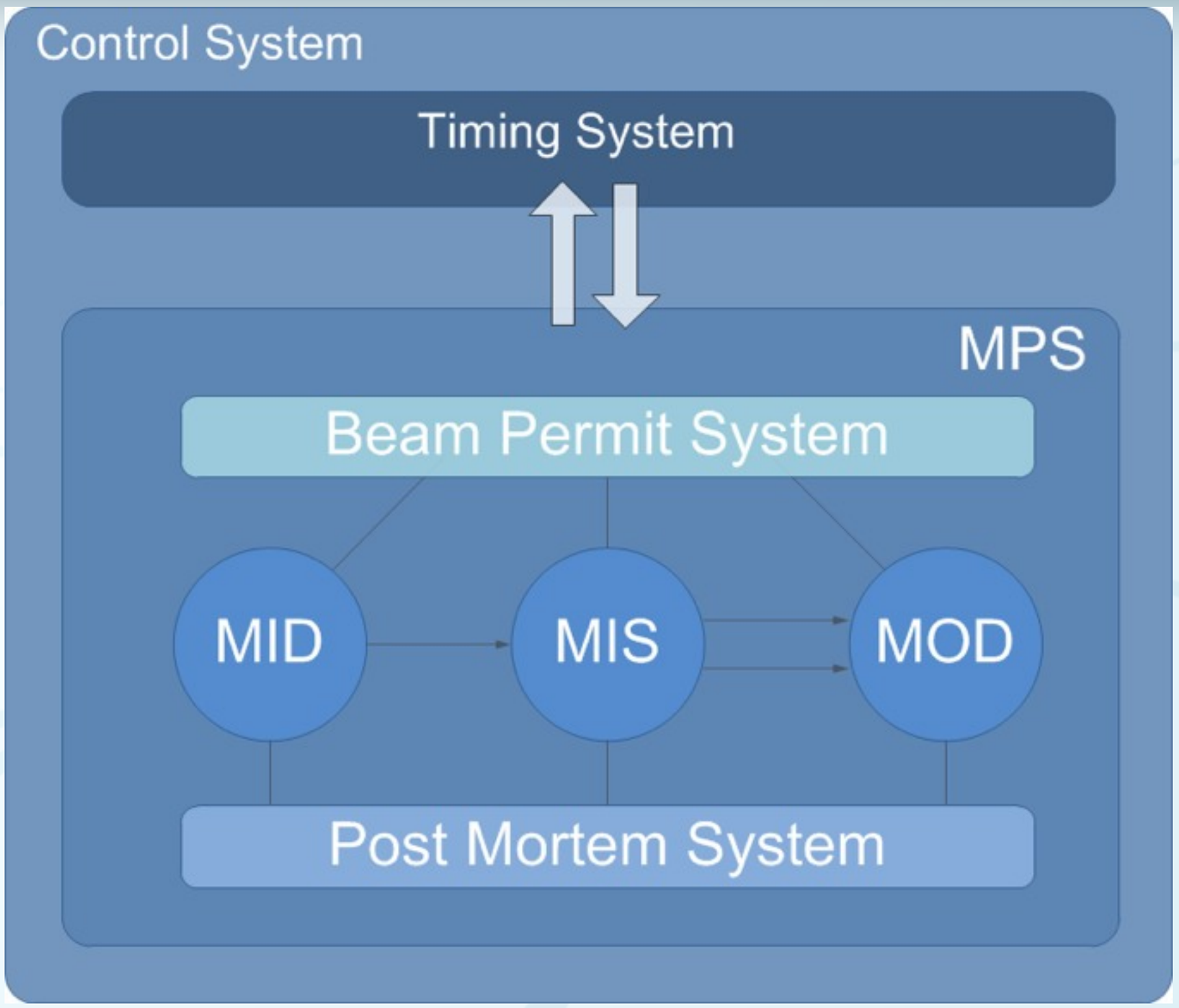
Results (so far):

- **Time needed to melt steel, copper in warm LINAC is $5x10^{-6}$ s and $40x10^{-6}$ s in the cold LINAC**
- **Use Beam Current Monitors (BCMs) as radiation monitors for detection of ultra-fast beam losses (response time $2x10^{-6}$ s)**

Related MPS Requirements (so far):

- **The proton beam must be shutdown within less than $5x10^{-6}$ s**
- **BCMs and BLMs must be connected to MPS via hardwired links**
- **Mitigation devices which will get a trigger signal from MPS must be connected via hardwired links and must be very fast**

MPS Architecture



The **Difficult Part**

- **Balancing protection and availability**

- **Understanding the users needs!!!**

- **Define machine states and modes needed to operate the machine, sequence of modes + systems responsible**

Summary

It is very important to define a procedure for validation of requirements

Regular internal/external reviews/audits help defining bottlenecks (from early on)

Risk analysis and reliability assessment should be performed before and after final product design + during operation

Interfaces to other systems must be communicated & defined together