

FCC Availability Studies



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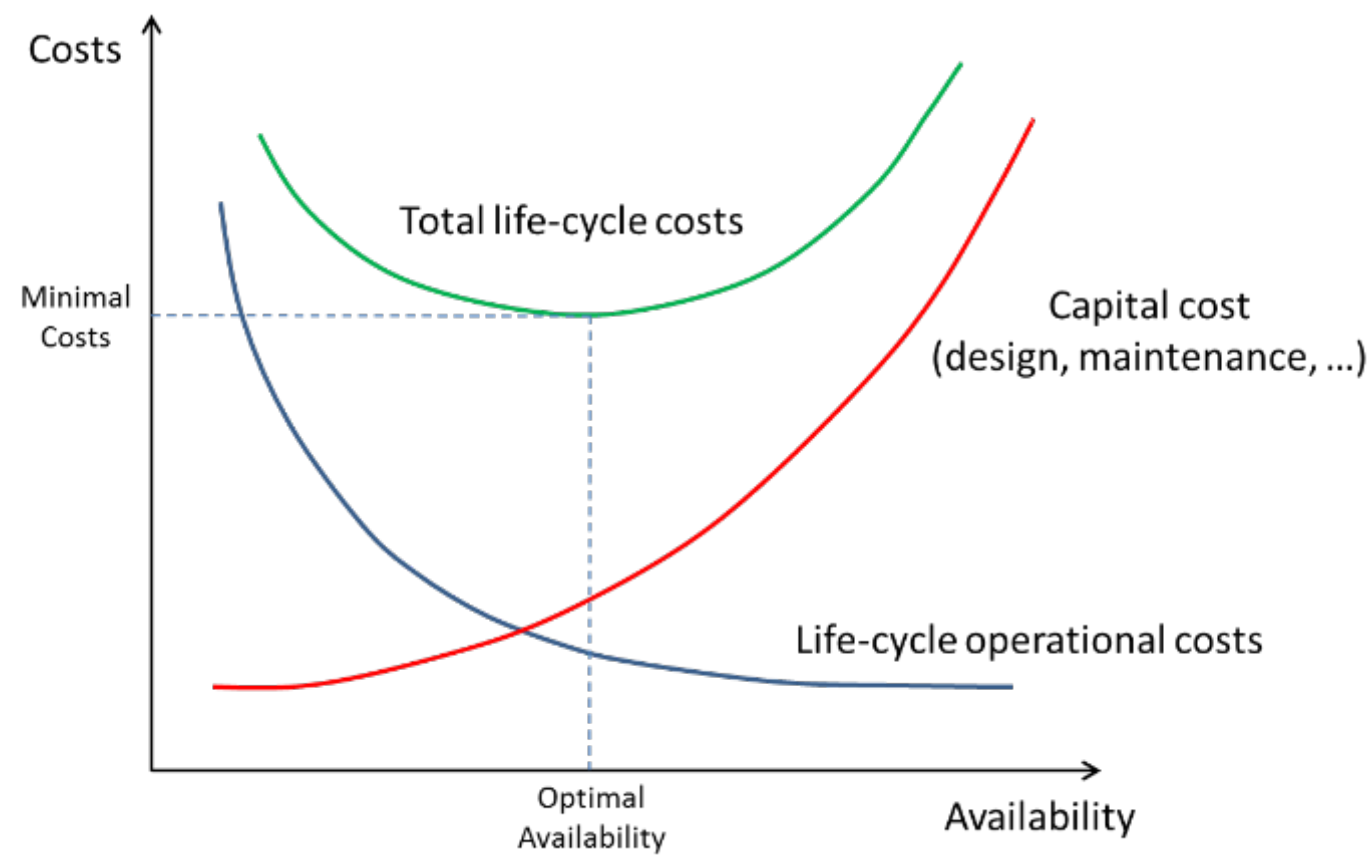
Motivation

Availability is a measure of the useful time of beam delivered to physics experiments.

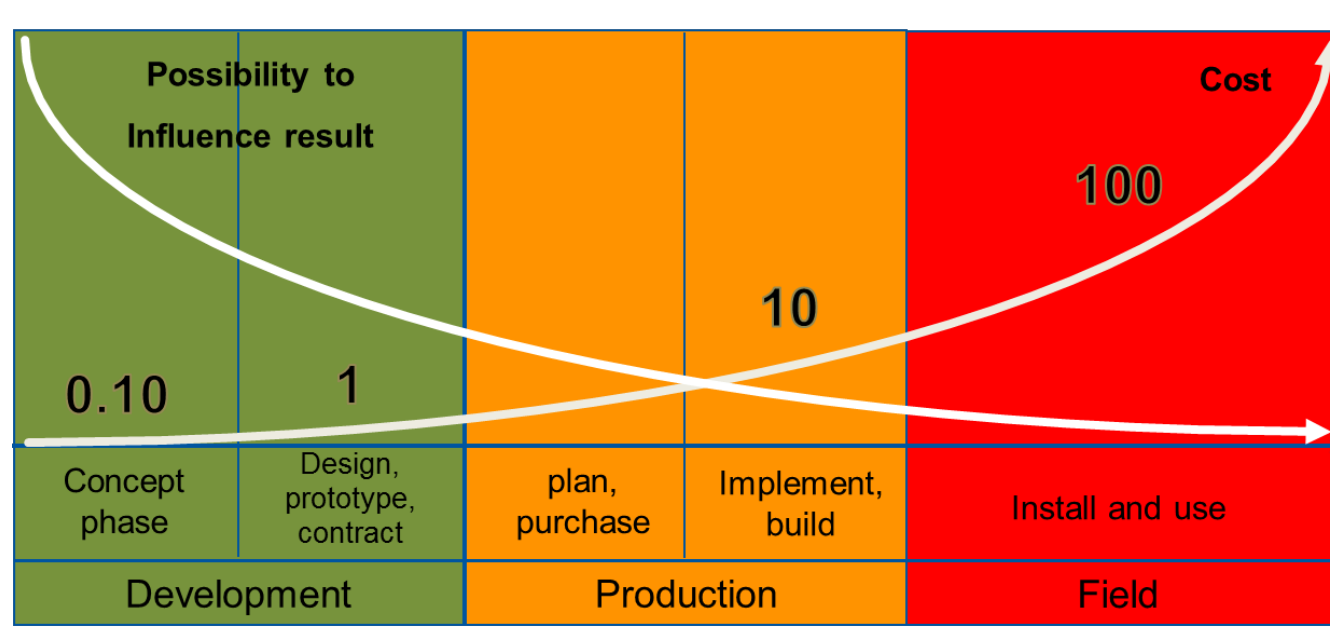
$$\mathcal{L}_{\text{int}} = \int_0^T \mathcal{L}(t') dt'$$

Beam Performance
Availability!

Integrated luminosity [fb⁻¹] is the key performance indicator for particle colliders.



For a set target integrated luminosity, operation costs decrease with increasing availability. However, the cost to achieve higher availability requires higher capital expenses.

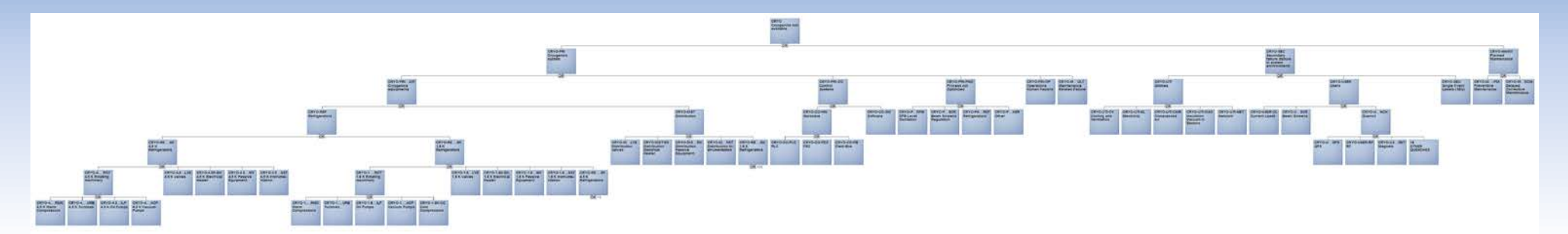
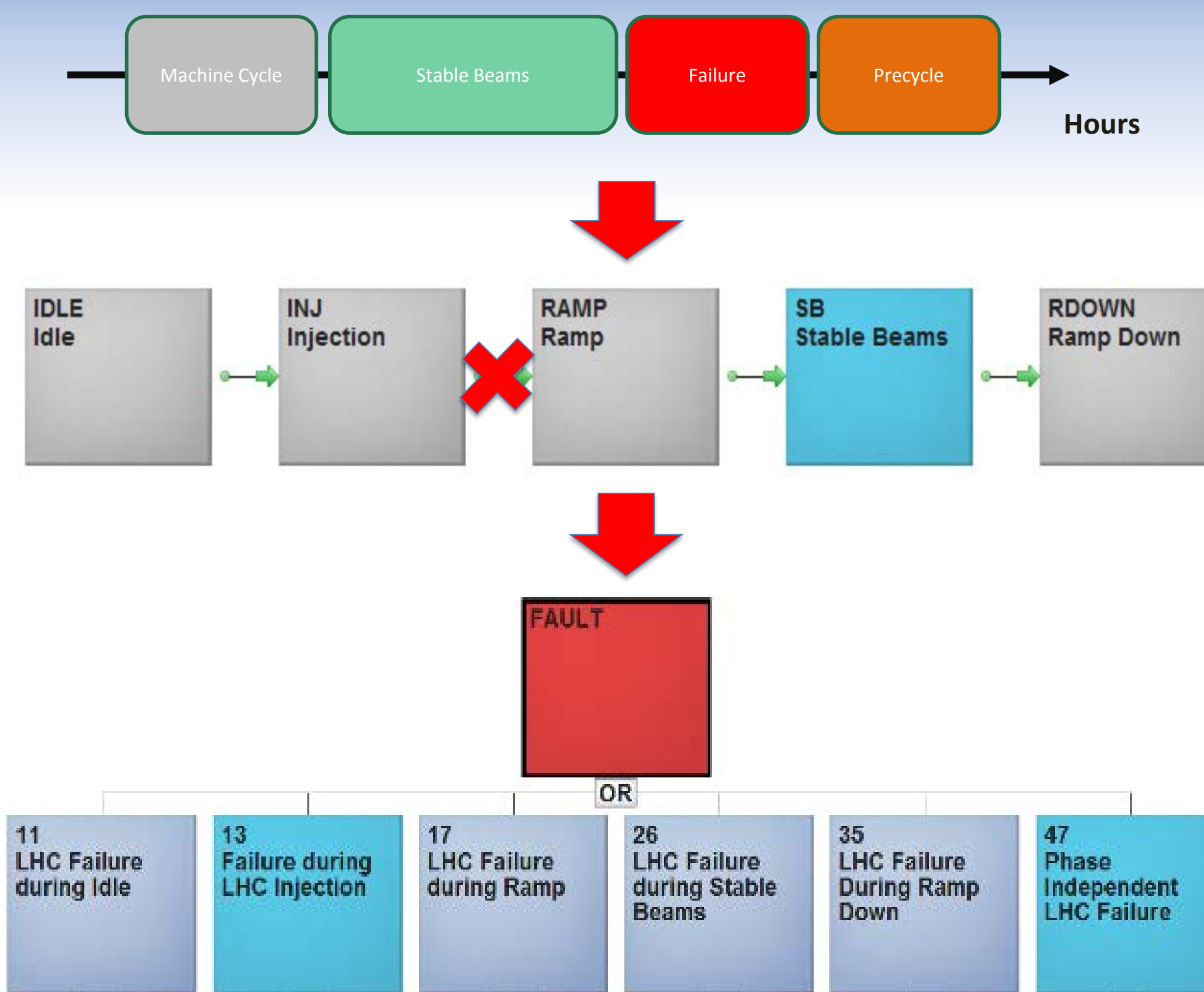


It is important to address availability and requirements from conceptual design across the entire accelerator lifecycle

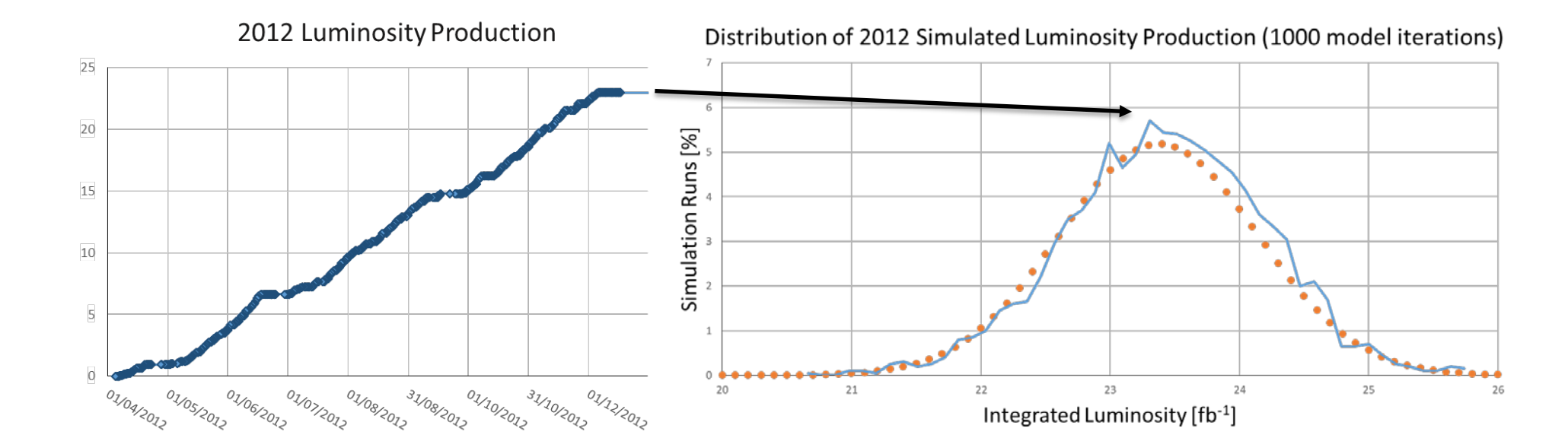
Scope of the Study

The study evaluates the suitability of industrial reliability methods for the domain of particle accelerators taking the LHC as a case study. The goal is to identify and analyse possible design and operational scenarios for the FCC-hh and assess the potential of methods for the LHC High Luminosity upgrade. The study aims to identify key impact factors on availability and luminosity production. However, the study does not intend to give specific guidelines for individual system design and optimization.

LHC Availability Model



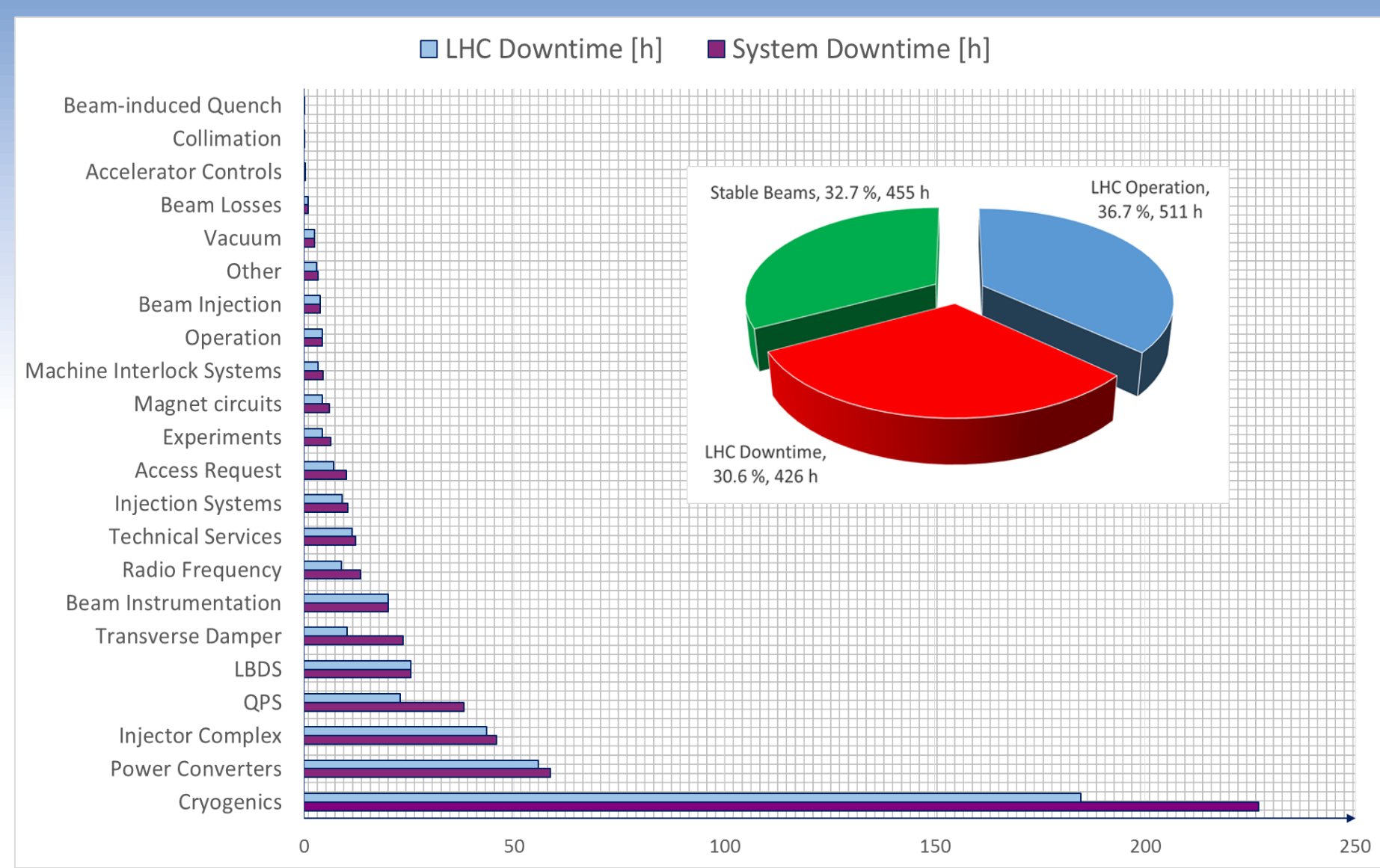
A detailed fault tree was developed for the LHC Cryogenics system to better understand and be able to scale fault distributions. The control room operators will now capture data and classify faults according to this fault tree.



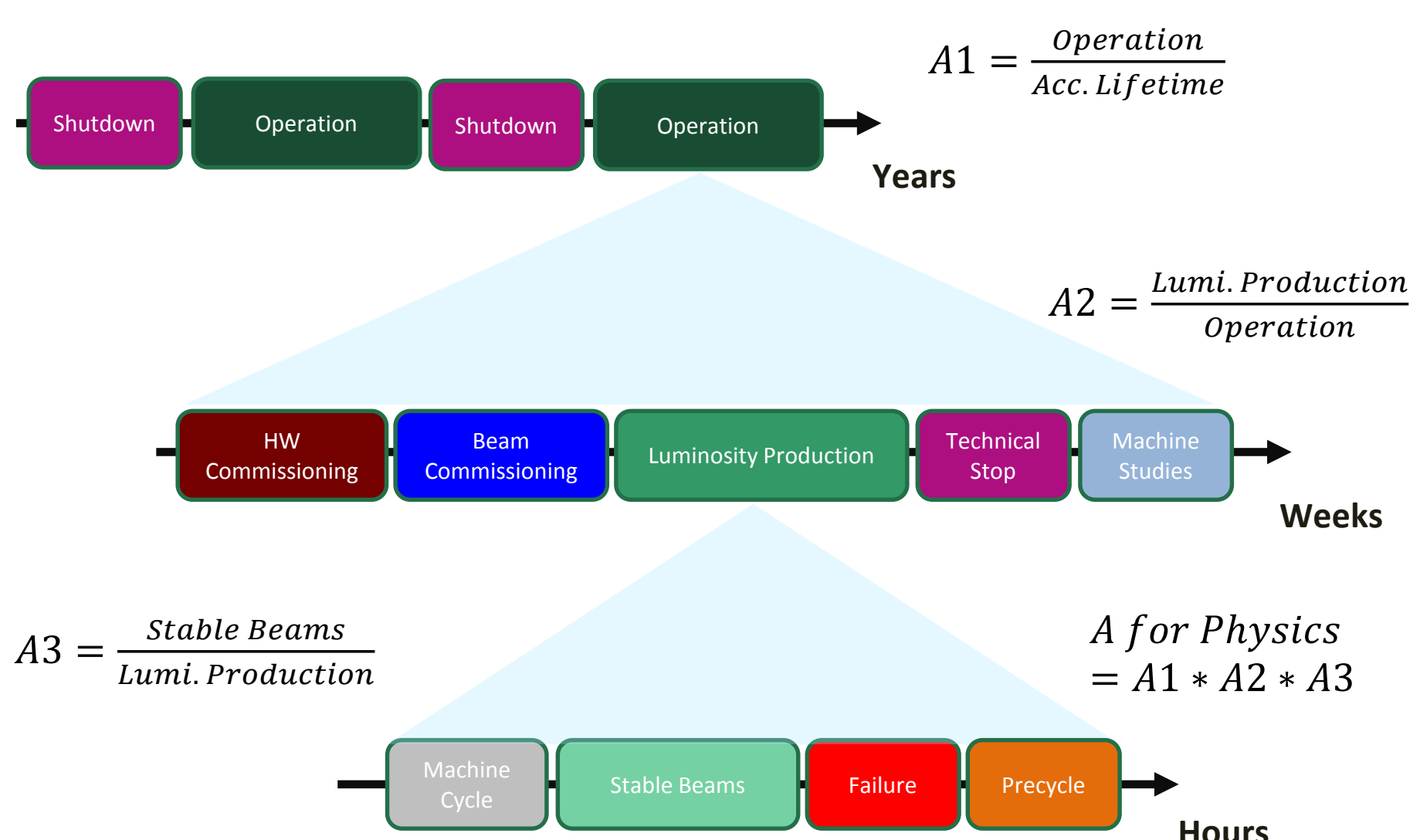
A Monte-Carlo based reliability software tool is used as a platform for modelling. Markov-chain models are used for the state transitions. A phase dependent fault tree generates failures based on failure distributions.

The model accuracy was validated against the 2012 luminosity production. The actual production was 23.27 fb⁻¹. Taking 2012 failure rates and beam parameters as inputs, the model reproduces the production amount within 1 % accuracy. Calculating 1 000 simulation rounds takes about 10 minutes on a laptop.

LHC Availability in 2015



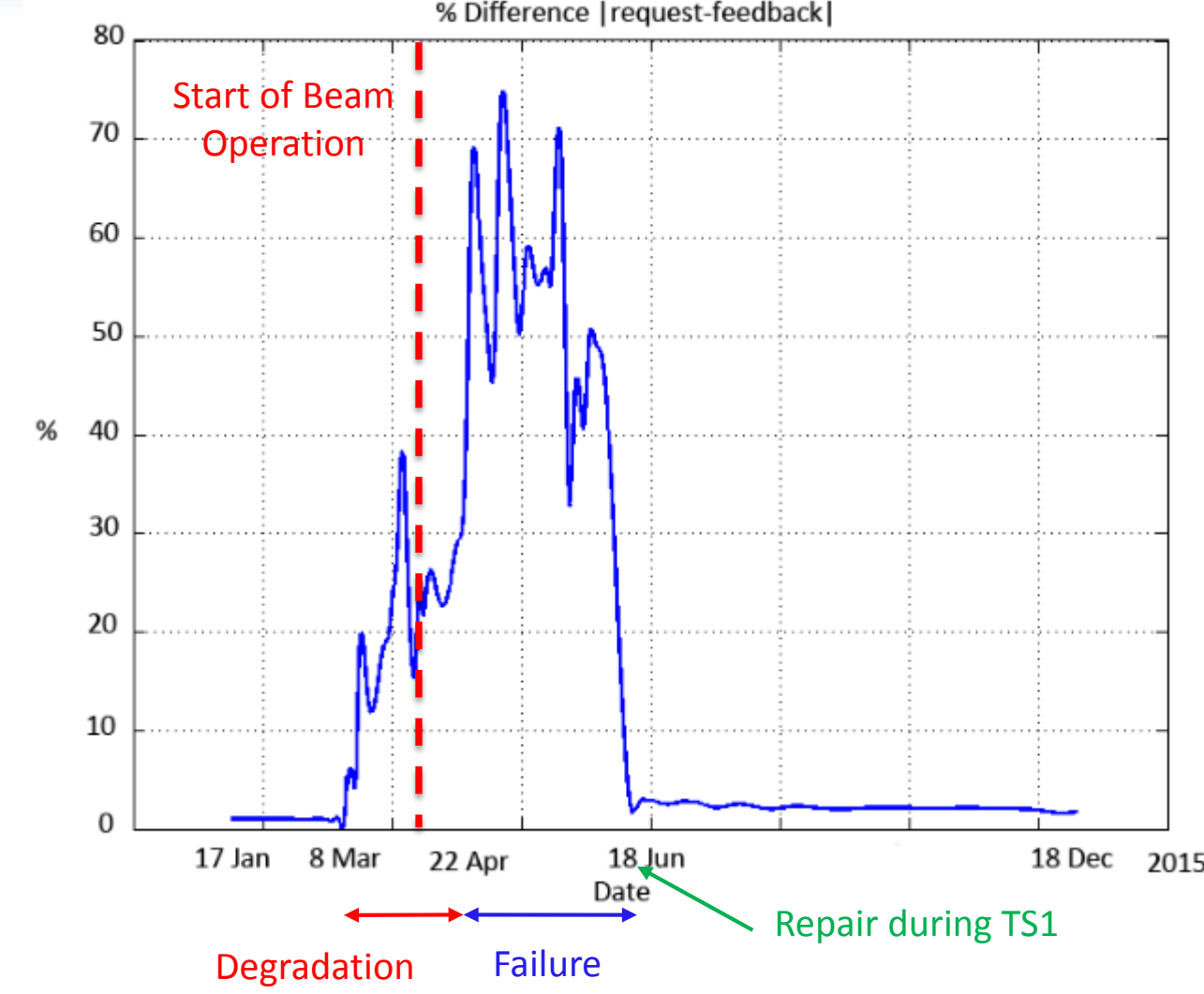
- Cryogenics system was the main contributor for the downtime
- The Stable Beams percentage was 33 %



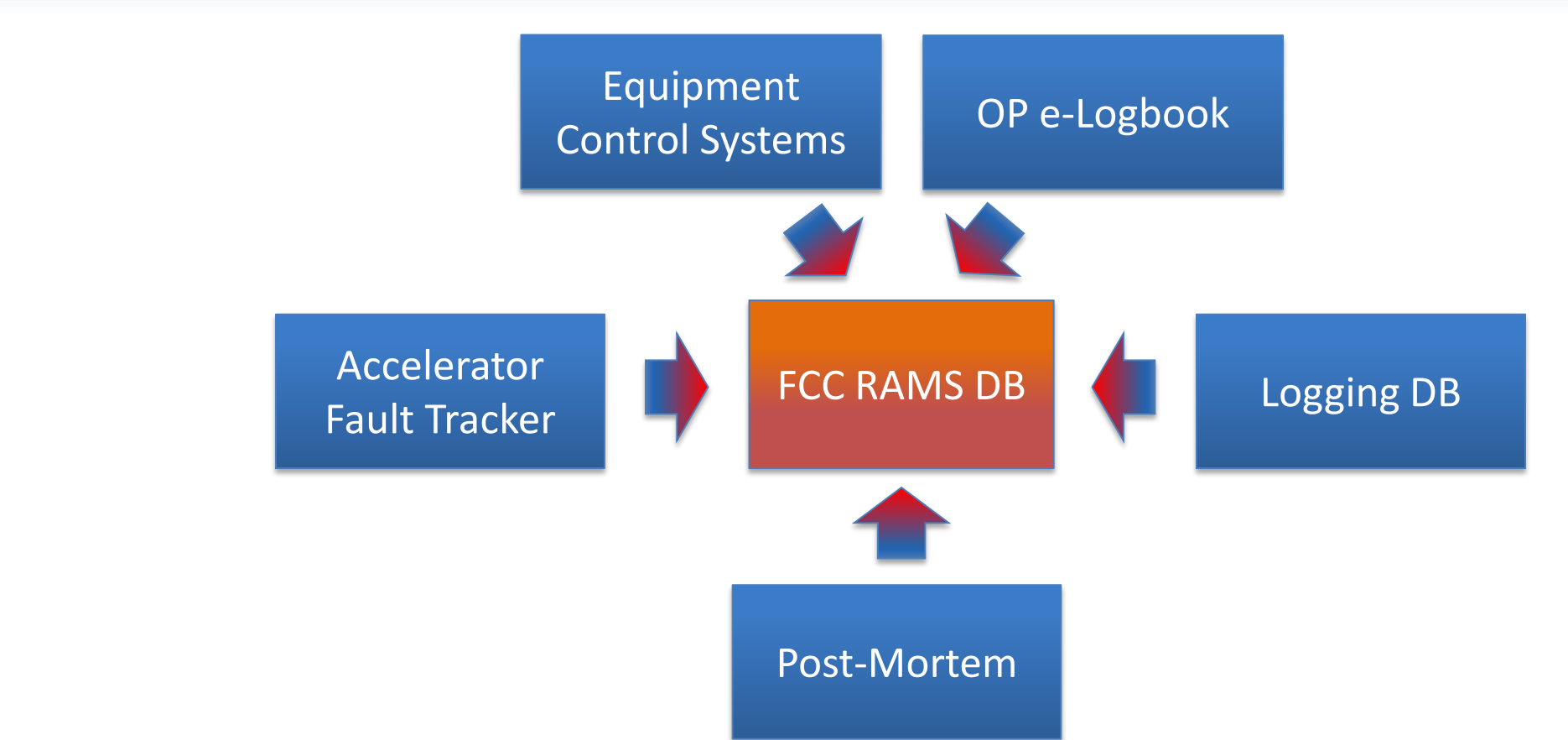
Collider availability for physics depends on:

- Scheduled operation time
- Length of commissioning periods and technical stops during operations
- Machine cycle and downtime during production periods

Exploring the Potential of Condition-Based Maintenance



The data from a slide valve shows the start of the fault in March 2015. However, the failure was recorded after the beam operations started in April. The fault could have been corrected before that.



A dedicated database collaboration was started with CERN IT department. Data availability, quality and consistent monitoring of the signal trends are necessary to derive useful reliability figures.

Collaboration Contributions

CERN
Coordination, modelling simulation, analytics, data management, use-case definition, technical infrastructure

Ramentor Oy
Modelling and simulation
Software, training

Tampere U. of Tech.
Method and tool consultancy

Uni. Stuttgart
Method and tool consultancy, training

Tech. Uni. Delft
Analytics, cryogenics system modelling

Uni. Wien
Data analytics platform development

Join us in the FCC RAMS study!
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Conclusions & Outlook

Availability is one of the key performance indicators for the integrated luminosity production of a collider. Estimates of the achievable availability of the FCC-hh will be one of the main factors for the feasibility assessment. Future studies should focus on:

- Definition of an FCC cycle duration
 - Analysis of different injector options
 - Identify strategy for scaling number of components (e.g. number of power converters, redundancy in cryogenic system,...)
 - Data quality management
- Extending the study to the FCC-ee would require expertise and data on lepton machines.