



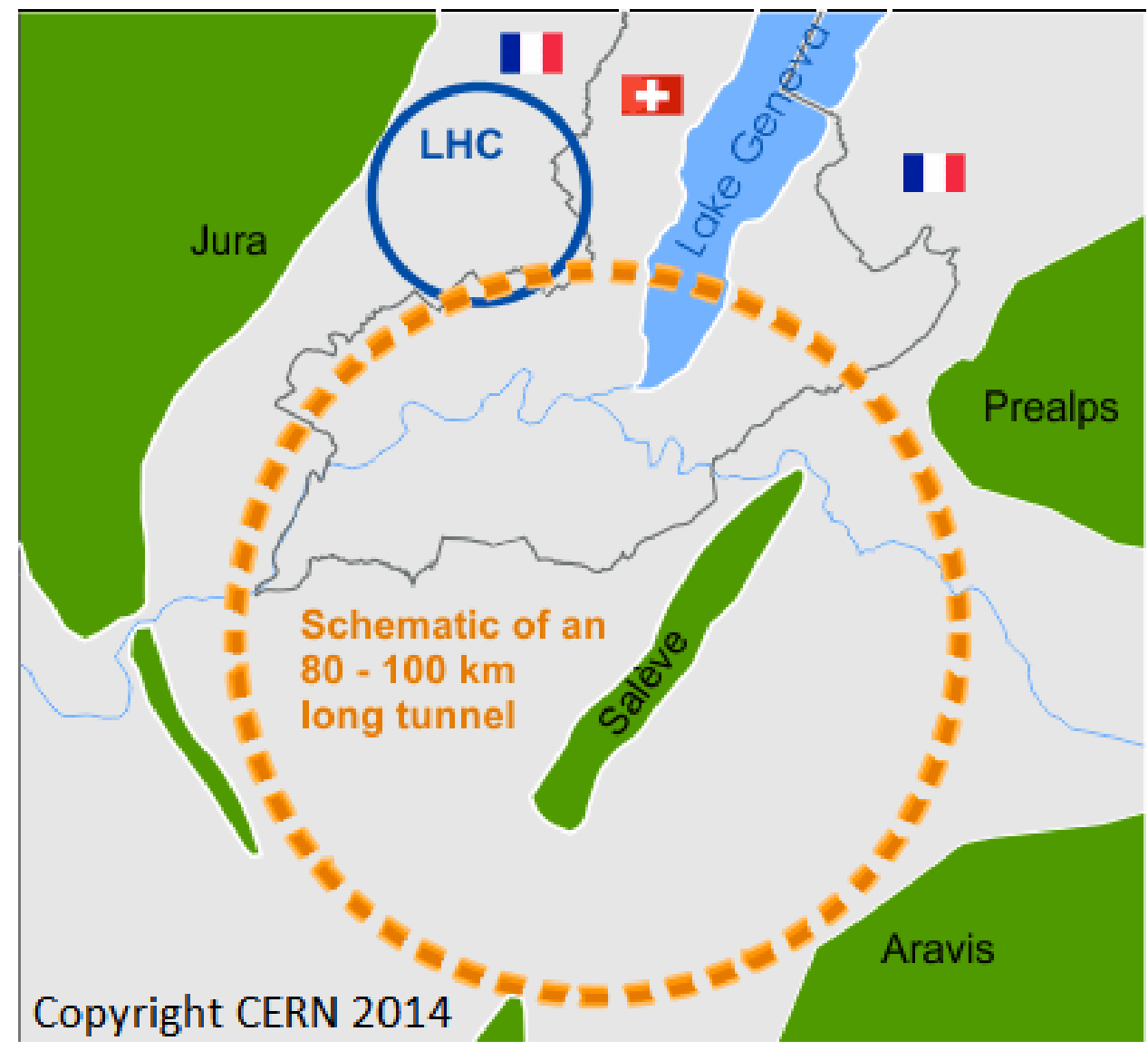
OpenMARS Modelling Approach for Accelerator Availability Studies

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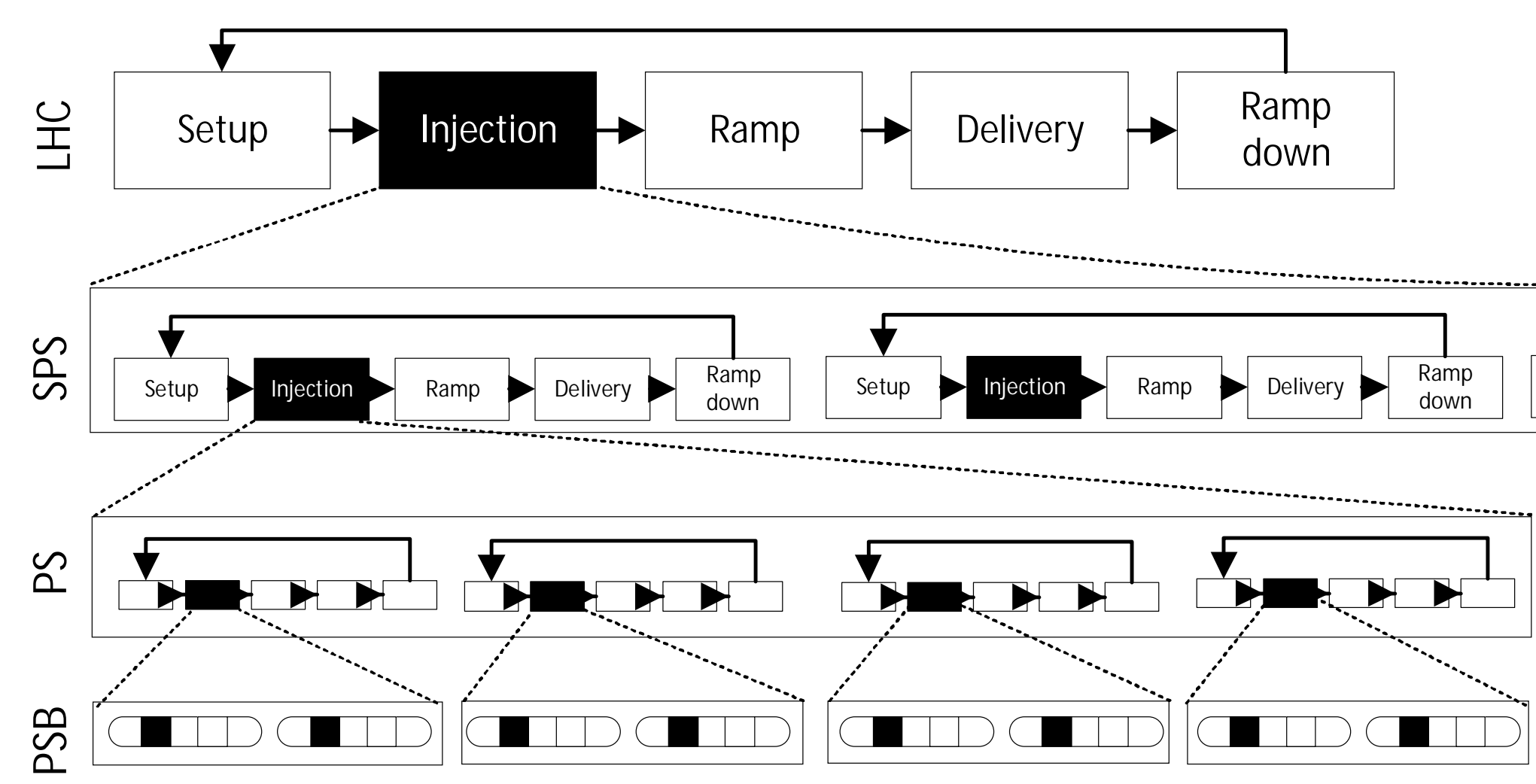
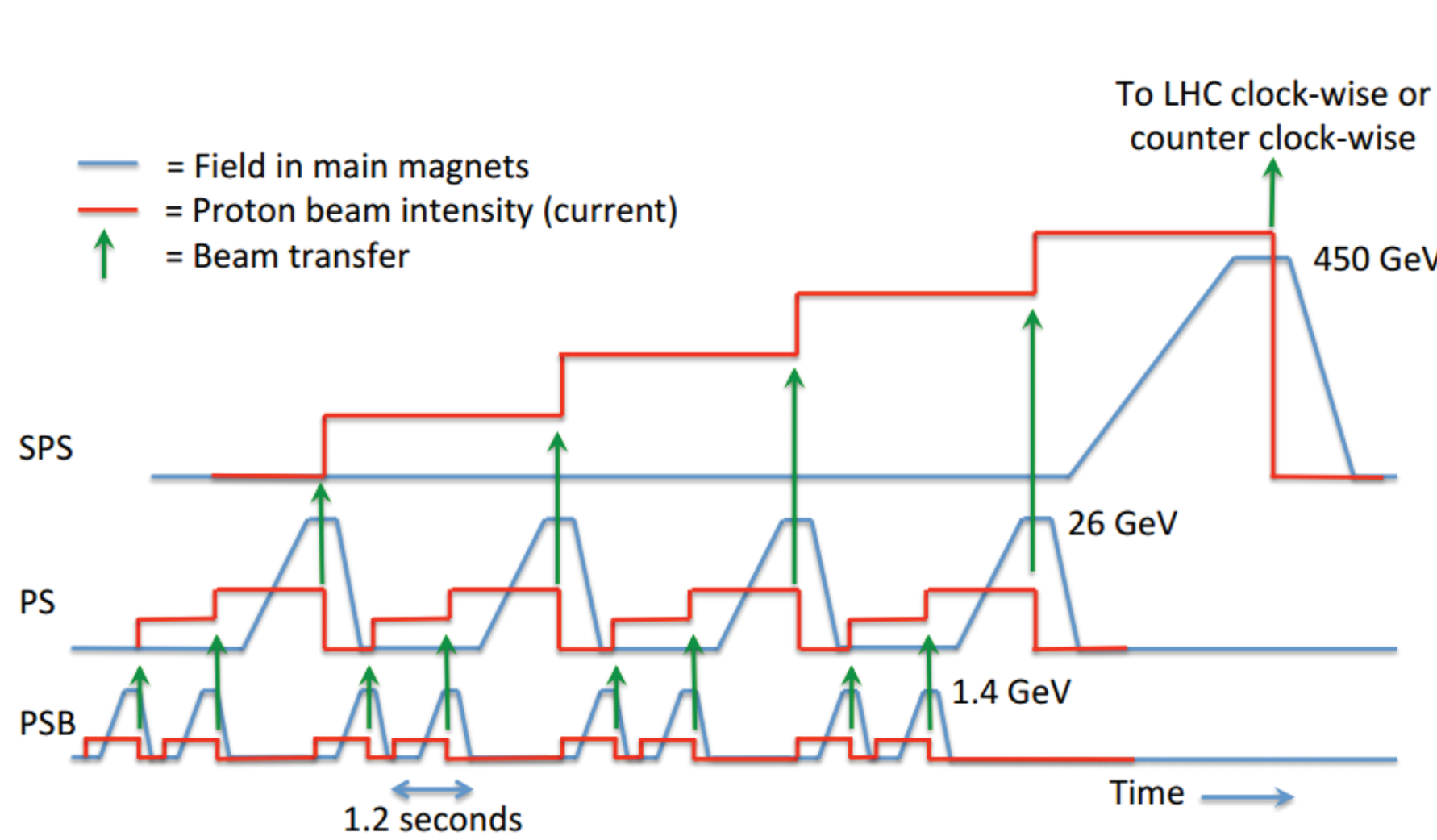


FCC Study Motivation

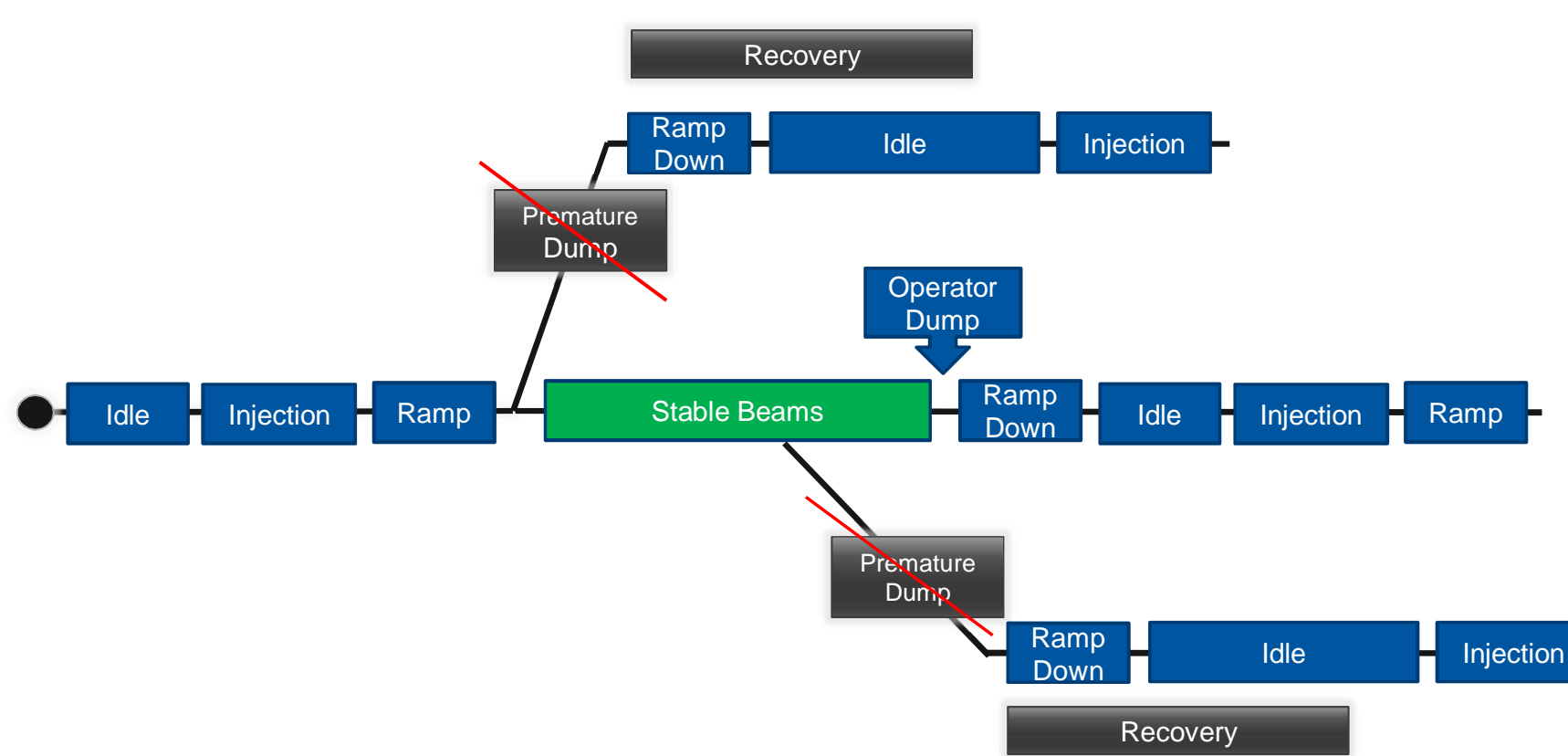


FCC will be four times larger than the current LHC. Increasing complexity creates a challenge for operational availability, which needs to be taken into account in the system design. FCC study started research for predicting the performance of the future machine with operations modeling. The initial research [1] motivated developing OpenMARS approach for combined fault and operations modeling. The work was done in collaboration with Tampere University and Ramator Oy. Status: early prototype & NASA tech. readiness level 4-5.

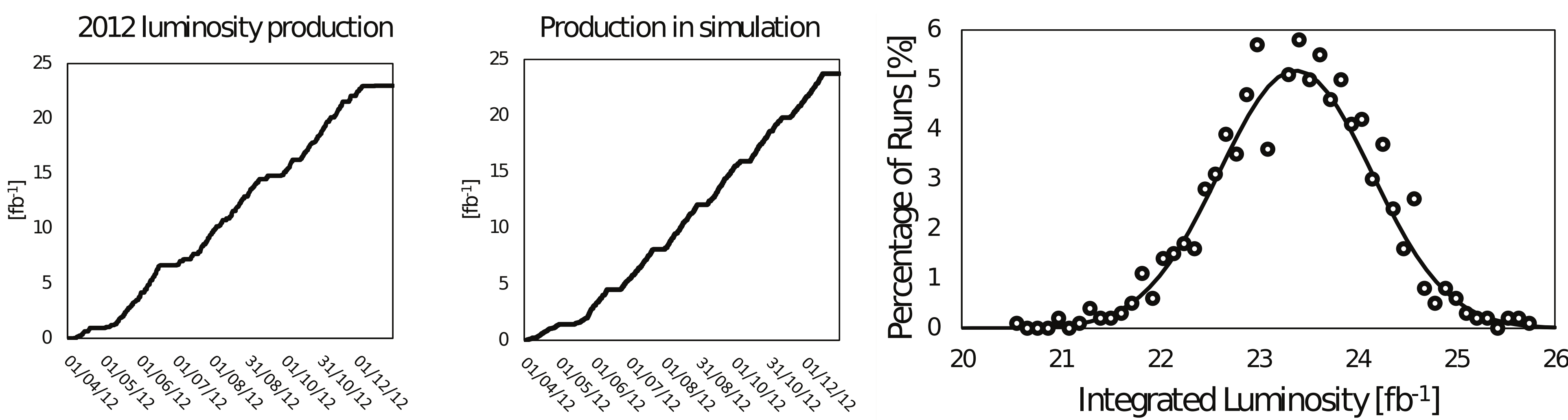
Operations Modeling



Above figures show how a single collider cycle is modeled. The injection phase consists of multiple injector cycles that are needed to fill the collider. The model creates operation state sequences similar to those seen on the left where a failure can affect the operations at any state.



Model Validation

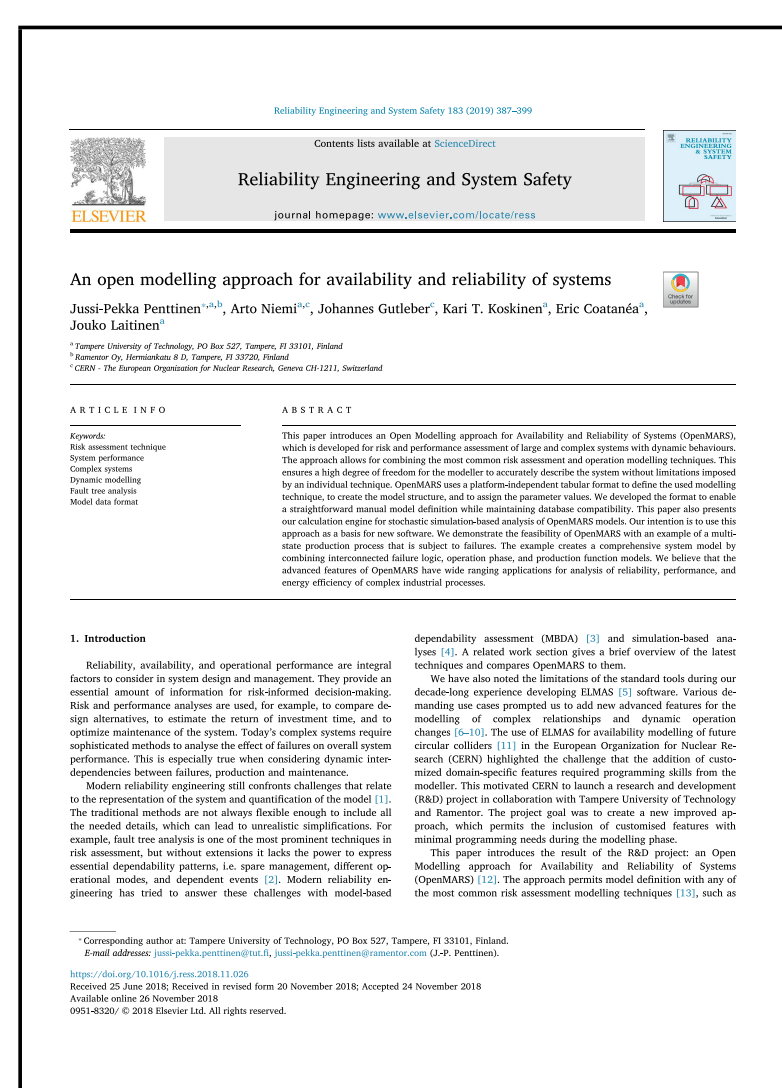


Paper [1] presented the model validation against LHC 2012 operations. Graphs show the actual 2012 luminosity production compared to a single simulation round result. The distribution of thousand simulation round results shows that the average result is close to the actual production of 23.27 fb⁻¹.

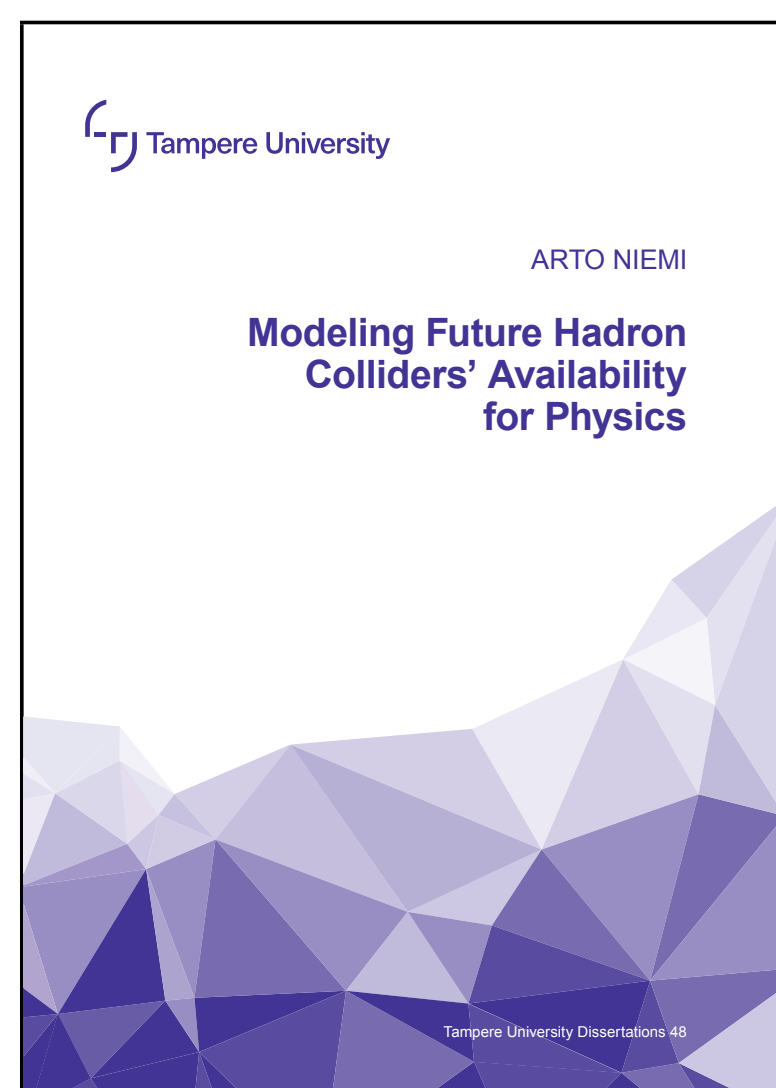
OpenMARS Literature



CERN-ACC-2018-0006 [2]



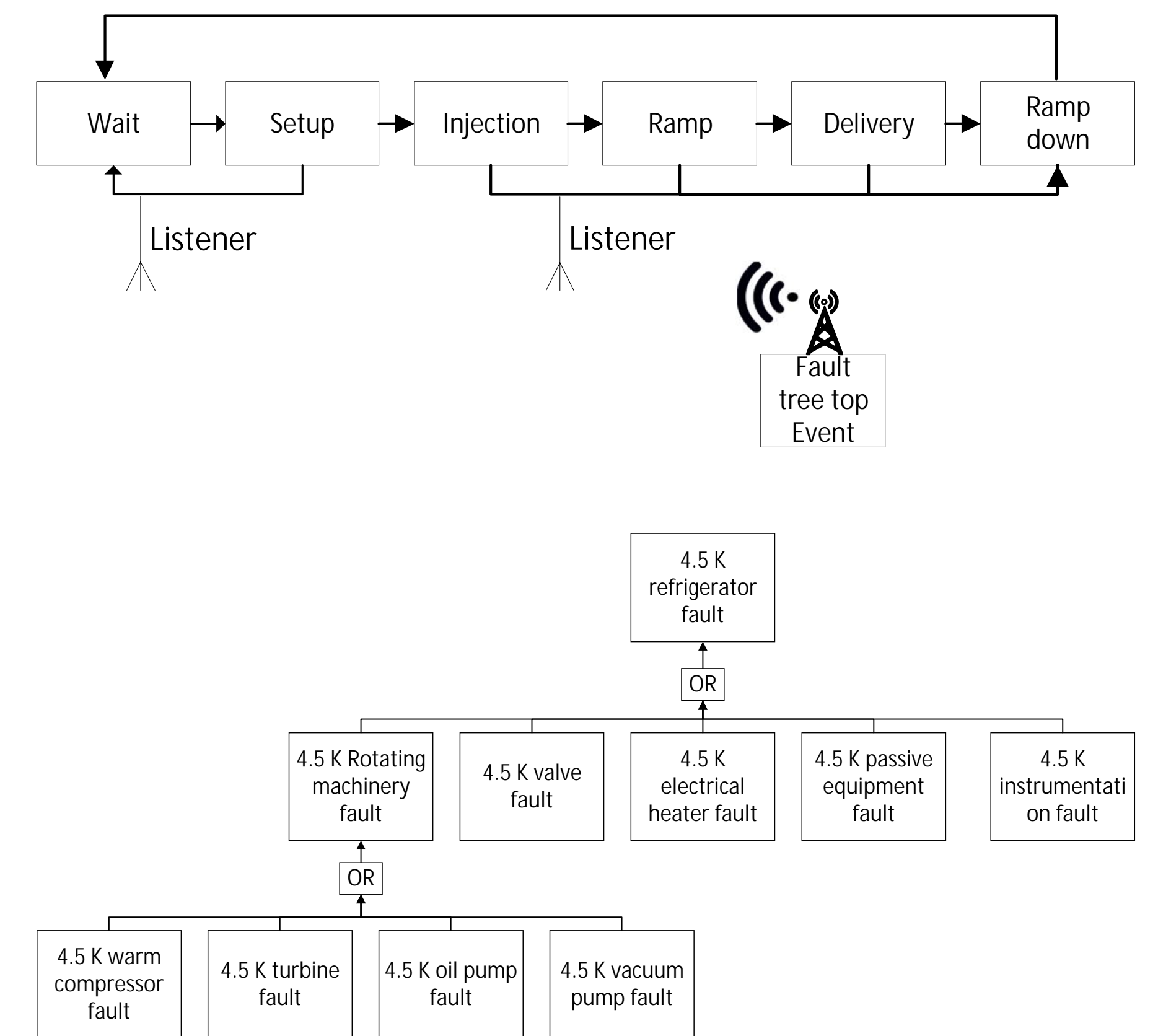
CERN-ACC-2018-0049 [3]



CERN-THESIS-2018-389 [4]

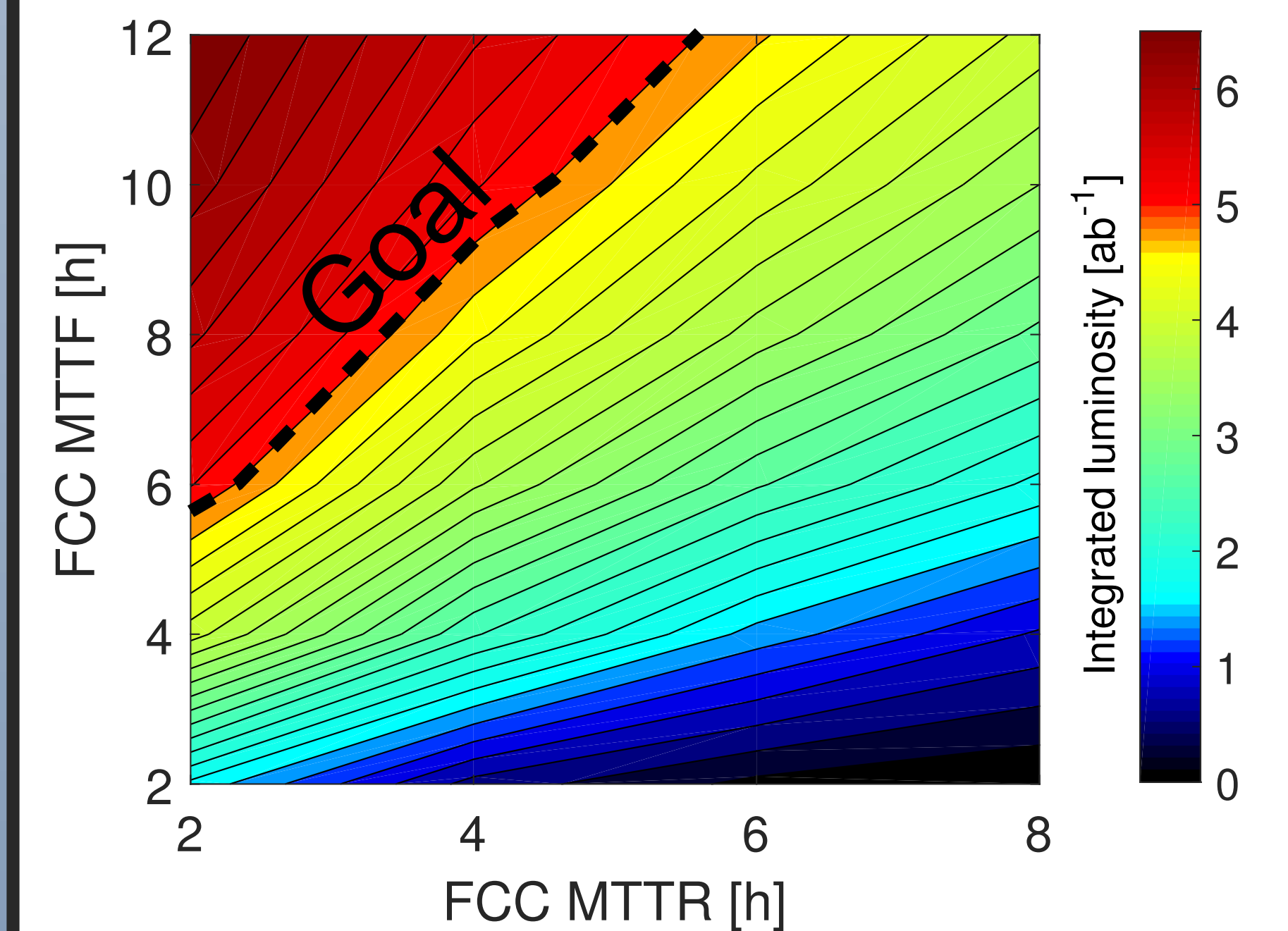
OpenMARS approach is well documented. Documents [2, 3] focus on the tabular model definition format that is used for defining and storing OpenMARS models. Thesis [4] gives an overview of the FCC availability studies and presents how the collider operations model can be implemented in the OpenMARS format.

Failure Modeling



Failures are modeled with fault trees that are connected to operations cycle modeling. OpenMARS supports so-called radio-listener concept where individual models can send messages. The top figure shows how a fault tree informs the cycle model to trigger a beam dump. The lower figure shows an example of a fault tree for an LHC cryogenic plant.

Sensitivity Analyses



Sensitivity analysis shows how failure and repair rates affect luminosity production in the FCC-hh. These analyses are useful to measure uncertainty when a parameter value is known only as a range.

References

- [1] A. Niemi, A. Apollonio *et al.* Phys. Rev. Accel. Beams, vol. 19, p. 121003, 2016.
- [2] J.-P. Penttinen, A. Niemi & J. Gutleber, Tech. Rep. CERN-ACC-2018-0006, CERN, 2018.
- [3] J.-P. Penttinen, A. Niemi *et al.* Reliab. Eng. Syst. Saf. vol 183, pp. 387-399, 2019.
- [4] A. Niemi, "Modeling Future Hadron Colliders' Availability for Physics", Ph.D. thesis, Tampere University, 2019.