Presentation and discussion at CERN MARP meeting

10 February 2021

Machine Availability and Reliability Panel (MARP) : initiatives in the field of reliability engineering in the three departments of the A&T Sector.

MARP areas:

1)Design of dependable electronic systems
2)Availability tracking and availability-driven performance optimization
3)Machine learning applied to the reliability analysis of complex systems
4)Reliability analysis of new accelerator systems
5)Coordination of training courses and European projects
6)Development of availability/reliability analysis tools and method

Note:
there are many parallel initiatives at CERN in the field of ML/AI applied to accelerator design and operation.
Ongoing effort to federate/coordinate the different initiatives

Why are we interested in ML/AI

Several collaborators, in particular from SEEIIST, do not have experience in accelerators but have competences and people ready to collaborate in software, and strong interest in AI-related topics. Interest in finding subjects to collaborate with CERN on topics related to medical accelerators.

Technically, two elements are of paramount importance in medical accelerators, much more than for scientific accelerators:

1. **Accelerator Reliability**
2. **Beam stability**

Reliability can be improved by: a) appropriate design (redundancy, architecture); b) preventive maintenance; c) fast automatised procedures (beam recovery after failure, switch to degraded performance,…)

All this is based on knowing the architecture, the history, and the data from other similar facilities to take decisions → Machine Learning

Beam stability depends on hardware stability and beam physics. Can be improved by: a) selection of appropriate hardware; b) fast feedback systems; c) slow feed-forward systems based on previous history and data analysis → Artificial Intelligence

Please note that this is my personal view of the problem, I am an hardware person and I am lost with all what is software!

Possible subjects for collaboration with MARP

Specific subjects of collaboration with MARP – profiting of the existing platform for predictive maintenance studies

- extend the work that is already going on with reliability analysis for therapy linacs (using the data from Linac4) to ion therapy synchrotrons – or more in general to “small synchrotrons”. For this, we can profit from the large amount of operational data accumulated by the CNAO facility in Pavia and draw some lessons for the design and operation of the SEEIIST “advanced” synchrotron. The CERN PSB and PS can be other useful sources of data.
- comparison of our normal conducting and superconducting synchrotron designs in terms of reliability and beam stability: there are reasons to believe that superconducting might be better (less components, simpler and more stable power supplies), but can we prove this “feeling”?

Our interests can be summarised in 3 topics:

1. Design optimisation for reliability of ion therapy synchrotrons
2. Predictive maintenance and operation plans for ion therapy synchrotrons
3. Procedures for dose delivery stabilisation.

The discussion is open!

Summary

The collaboration with MARP is only a part of our general interest in ML/AI, which at the moment covers:

1. Design optimisation for reliability of ion therapy synchrotrons
2. Predictive maintenance and operation plans for ion therapy synchrotrons
3. Procedures for dose delivery stabilisation.

At the meeting, it was decided that a CERN correspondent for ML/AI will be nominated, to interact with the different CERN and external actors and define an action plan (in a couple of weeks…)

ML/AI as 5th NIMMS Workpackage

The **Next Ion Medical Machine Study (NIMMS)** is a collaborative study coordinated by CERN, aimed at leveraging on CERN technologies developed for HEP for a new generation of accelerators for cancer therapy with ion beams

	Workpackage	Objectives
1	Superconducting magnets (D. Tommasini, TE/MSC)	Comparison of magnet technologies (CCT, costheta) and cables (NbTi, HTS). Design of prototype magnets (gantry and synchrotron).
2	High-frequency hadron linacs (A. Lombardi, BE/ABP)	End-to-end beam dynamics design, study of 180-degree bend, design of medium-beta accelerating structures (5-20 MeV/u), RF optimisation.
3	Gantries (M. Cirilli, IPT/KT)	Advanced design and comparison of 2 gantry options (optics and mechanical structure): Rotational (SIGRUM) and Toroidal (GaToroid).
4	Synchrotron design (E. Benedetto, SEEIIST)	Design of superconducting and normal conducting synchrotrons with advanced features: multi-turn injection for 10^{10} particles per pulse, fast and slow extraction, multiple ion operation, new upgraded linac injector.

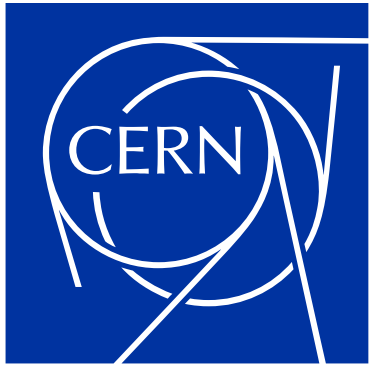
There is space here for a 5th Work Package… could it be related to application of ML/AI to design and operation of the next generation of ion accelerators?

NIMMS as a «technology toolbox» more than a single fully-fledged design

NIMMS collaboration

Partners: **SEEIIST**, TERA Foundation, GSI, INFN, CIEMAT, Cockcroft Institute, Manchester University, CNAO, Imperial College, MedAustron, U. Melbourne, Riga Technical University.

Participation in EU Projects: HITRIplus (2021-25), IFAST (2021-25)



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