

DIAGNOSTICS FOR HIGH POWER CW ACCELERATORS*

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Abstract

High power, continuous wave (CW) accelerators are proposed for applications such as Accelerator Driven Systems (ADS) for subcritical reactor strategies and heavy ion accelerators for the production of rare isotopes. Because of the high beam powers and high energy loss with beam interception of material, the beam diagnostic designs are necessarily shifting to non-intercepting, real-time feedback devices that can be fully integrated with the accelerator machine protection system (MPS) and operation control system including online models. Appropriate for these applications, three types of beam diagnostics (lanthanum bromide scintillation coincidence detectors, GaN neutron and gamma detectors, and beam position monitors) are presented.

BACKGROUND

Next generation of high power accelerators are more than ever in need of seamless integrated beam instrumentation, online models, controls system and agile beam characterization of particle losses and feedback systems. Role of beam diagnostics have shifted from a collection of exotic instruments with multiple platforms run individually by engineers and scientists adapted to an accelerator to base lattice from inception optimized specifically for operation. This methodology, not only requires inline beam instruments to be 3D multi-particle integrated modelled with lattice optimized as the accelerator being optimized in lattice but it has to foresee in advance the expected commissioning, operation and upgrade scenarios. To keep up with all expected modes of operations, we have limited choices to preserve design integrity, reliability, safety, and performance. (A) Design and test in collaboration of experts as soon as the project is formalized in an integrated form the fundamental beam instruments such as beam position electrodes and their expected signal delivery. (B) Tools for software development such as complete test stations. In this paper, I report on two such accelerator systems. (1) At Texas A&M University, a complete conceptual Accelerator Driven Subcritical Molten Reactor System is designed. The 100-800 MeV Cyclotron with strong focusing channels of twenty-three helical orbits (Figure 1) is embedded in more than 100 tons of iron preventing any externally accessible beam instrumentation such as loss monitors. It requires active beam orbit feedback system for 10 MW of CW proton beam with the possibility of aborting and landing segmentation loaded beam in numerous aborts located at the missing cavity extraction channel. There is about 0.75 Cm spacing at the inner radii for 100 MeV 400 W faraday cup abort dumps. This highly

challenging cyclotron is compact, flexible and can be reconfigured to run if one of the ten superconducting cavities fails [1]. Second is the most versatile version of a CW Rare Isotope LINACs that have an added complexity of lattice change over to accelerate different radioactive species of same atomic mass to charge ratio as often as once every 4-6 weeks. These LINACS such as the one being considered by Jlab for MEIC or Facility for Rare Isotope Beam designed by R. York in 2009 [2] require full integration of beam diagnostics and operation changeover databases and online applications.

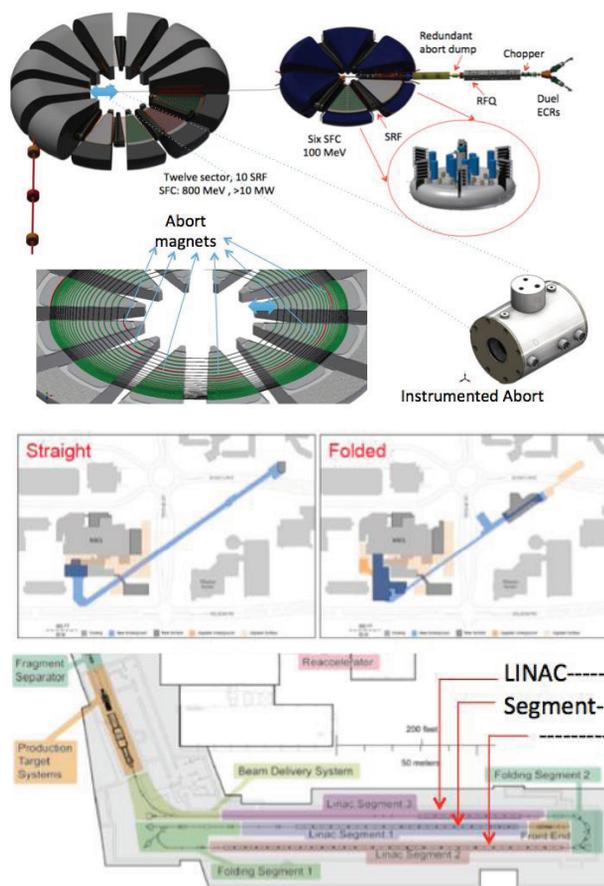


Figure 1: Top shows SFC at Texas, bottom is FRIB design status at MSU in 2010.

Both ADSMS and FRIB require specialized directional beam loss monitors such with energy discrimination, which will be discussed.

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METHODOLOGY

Challenges

To circumvent the 90% reliability barrier, a total revamp of planning per historical knowledge is required. We know that cutting the number of diagnostics, limiting testing, removing commissioning time, limiting integration testing and missing Q/A have always resulted in added cost, delays and more importantly the dissatisfaction of facility users. We also know multiple platforms of the adhoc control systems, diagnostics and application programs, and vaporware software is not tool that allow us to sustain a reliable operational machine. Then: why insist on repeating? My solution might seem relatively rigid for to rangers and nonconformists but the standard for industry has been practitioner that mostly have to optimize time, cost and reliability by teamwork.

In order to design, implement, test, commission and hand-over to operation a set of beam instruments, the following questions required machine specific answers:

- 1) What failure modes will cause beam losses?
- 2) What amount of beam loss will cause permanent machine damage?
- 3) What are the Machine Protection System [MPS] specifics necessary to prevent permanent machine damage from beam loss?

Based on machine lattice design and beam dynamics progress and any updated error failure analysis, I was able to reshape the BLM, MPS and BPM design framework without any need to emphasize numerical time to abort the beam [3], see Figure 2. Required timing, synchronization, clocks and triggers became part of the solution of the above rather than an independent system. The redundancies required to maintain well over five 9's for ultra-reliabilities take away individual finite-state checks of the subsystem and incorporate them as tags and flags of the parent controls logic. As such, one should clearly make the decision to either adapt integrated fourth generation controls logic of MPS, beam instruments, timing and machine application feedback systems or stay with traditional departmental I/O connectivity among the above. BLMs and BPM especially feedback systems for high power ADSMS. It is impractical to have infinite number of loss monitors to measure and react within answers to the above questions as there are combinations of simultaneous device failures have to be considered as options of fast shutdown.

General Layout and Detection

At start of projects a considerable time is spent on streamlining and aligning the relevant component of a subproject, see Figure 3. Roles are defined and assignment is made per complete machine specifications from special run cases, commissioning, operations and upgrade. It was extremely important to follow Risk Analysis, Mitigation Matrix [RAMM] at every step to be able to interject on performance expectation and compare with intermediary test results, see Figure 4.

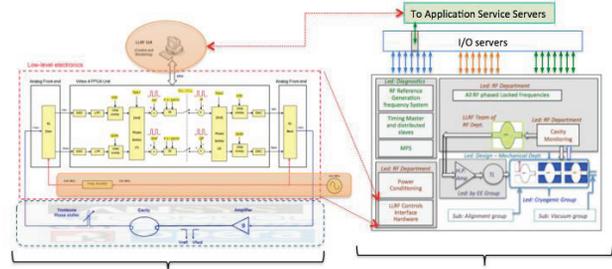


Figure 2: Distributed and managed autonomous systems shown to right vs. present stand alone model.

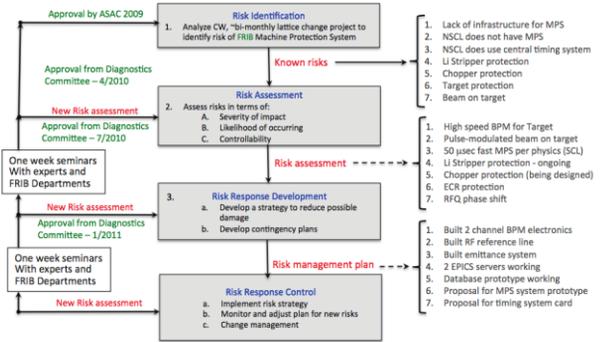


Figure 3: Risk Management Process as Instrumentation systems are formed to physics specification for cw beam with rapid change over as new risks and challenges of design integrates to the infrastructure without a single component being manufactured.

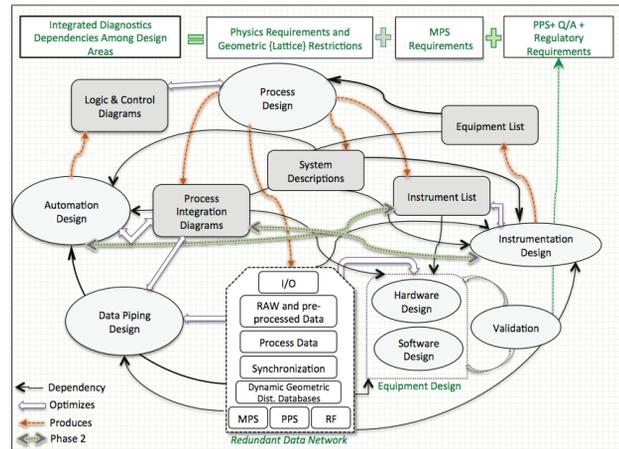


Figure 4: Integrated Diagnostics logic evolution process.

The beam position monitor pickups, Figure 5, beam loss monitors suitable to these accelerators are shown in Figures 6 and 7 of this paper in conjunction with priorities to achieve expected excellence from devices. Mentality of removing diagnostics, limiting software testing or providing resources to alleviate yearly shortcoming has shown in the past regrettable commissioning scenarios even on micro scale systems. At the same time, I have made sure to avoid duplicating unnecessary technology or tools for the sake of in house production. Figure 5 shows a rapid development of tools and electronics, I foresaw necessary for a complex MPS software development but

at a fraction of cost adapting hardware and software commercial tools. This meant real equipment for online orbit development that one can use. I have added a suite of diagnostics similar to the Spallation Neutron Source at Oak Ridge and CW Rare Isotope Beam such as FRIB's latest of R. York design at MSU suitable monthly lattice changeover, folded linac above 200 kW for 10 MW operations. In this paper, I show the systems but only

discuss two relevant to both ADSMS of diagnostics similar to the Spallation Neutron Source at Oak Ridge and CW Rare Isotope Beam such as FRIB's latest of R. York design at MSU suitable monthly lattice changeover, folded linac above 200 kW for 10 MW operations. In this paper, I show the systems but only discussed two relevant to both ADSMS and RIB.

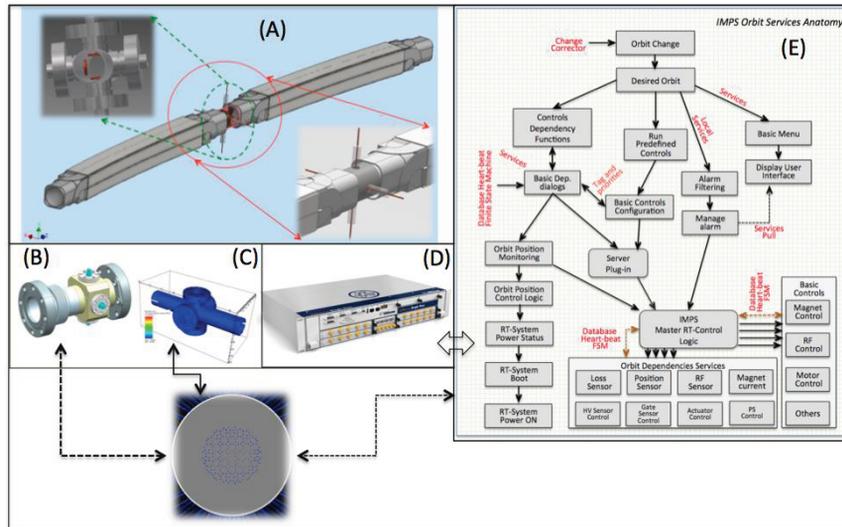


Figure 5: Inline diagnostics are integral part of multi-particle lattice optimization for both high intensity, low energy section and beam orbit feedback system. In this picture (A) Four buttons BPM of ADSMS, (B) Similarly, I developed collaboration with Fermilab to design FRIB SCL BPM electrodes, design verified by Tech-X software (C), (D) 2-Channel BPM electronics for FRIB manufactured and delivered in 2011 by Instrumentation Technologies.

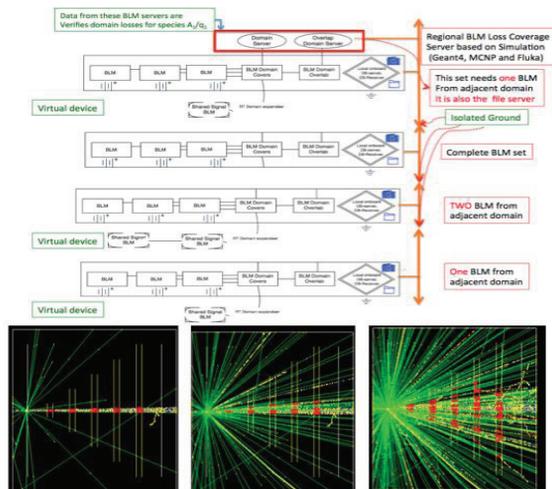


Figure 6: Beam loss distribution based on energy trigger overlaps and veto setup.

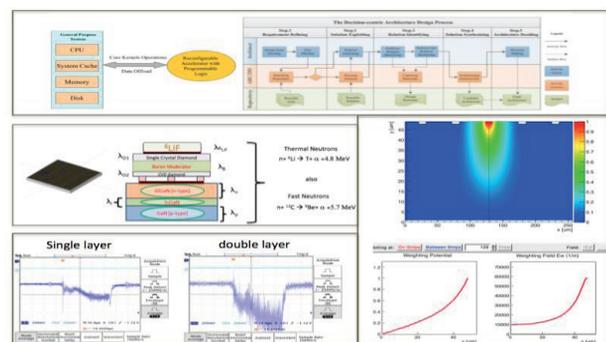


Figure 7: GaN rad hard radiation detectors Bottom left is response of single layer and two-layer is shown, photon boost is shown to the right. Schematics of DAQ are shown above.

CONCLUSION

Integrated Instrumentation, control, and physics modelling optimizes path to high intensity frontiers.

ACKNOWLEDGMENT

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