EXPERIENCE WITH MACHINE PROTECTION SYSTEMS AT PIP2IT

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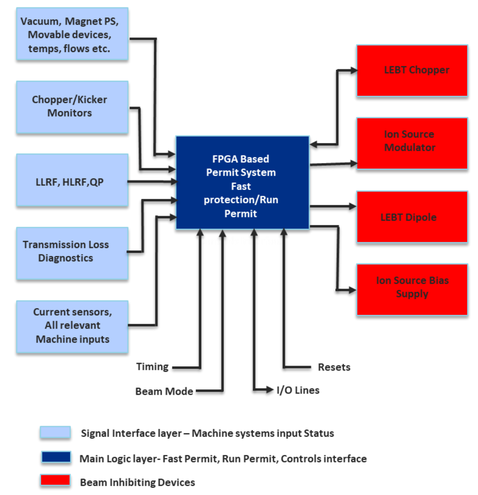
Abstract

The PIP-II Injector Test [1] (PIP2IT) facility accelerator was assembled in multiple stages in 2014 – 2021 to test concepts and components of the future PIP-II Linac that is being constructed at Fermilab. In its final configuration, PIP2IT accelerated a 0.55 ms x 20 Hz x 2 mA H- beam to 16 MeV. To protect elements of the beam line, a Machine Protection System (MPS) was implemented and commissioned. The beam was interrupted faster than 10μs when excessive beam loss was detected. The paper describes the MPS architecture, methods of the loss detection, procedure of the beam interruption, and operational experience at PIP2IT.

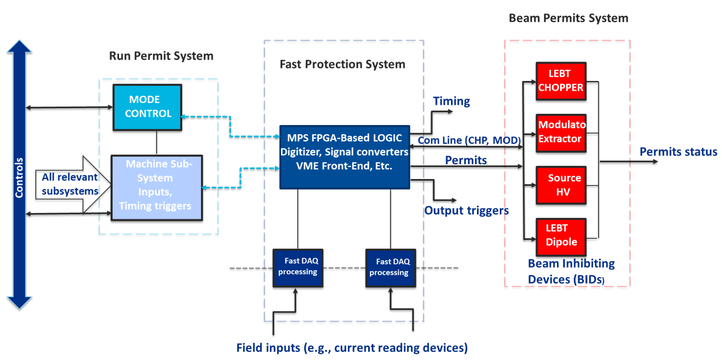
Introduction

PIP2IT Accelerator Layout – A near full-scale Front- End of PIP-II with first two cryomodules

PIP2IT was constructed in two phases. The first phase consisted of the room temperature portion of the machine, or Warm Front-end (WFE), which comprises a H^- ion source, a radio-frequency quadrupole (RFQ) and a transport line for delivering beam to the superconducting section of the accelerator at 2.1 MeV. In the second phase, it was appended by two cryomodules called a Half Wave Resonator (HWR) and a Single Spoke Resonator type1 (pSSR1).

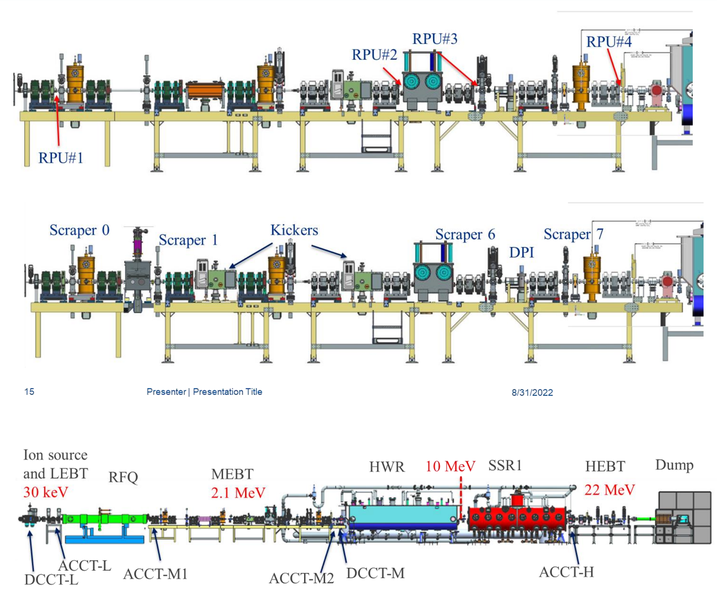


Protection System Scheme

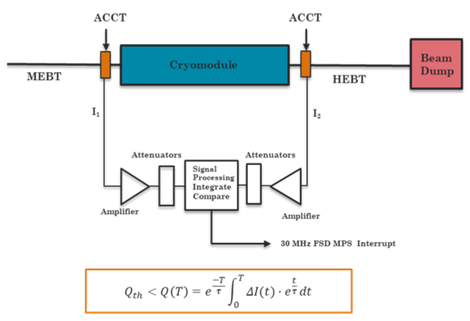


The MPS ultimately received Ok/Not-Ok signals from subsystems and managed permits to Beam Inhibiting Devices (BIDs).

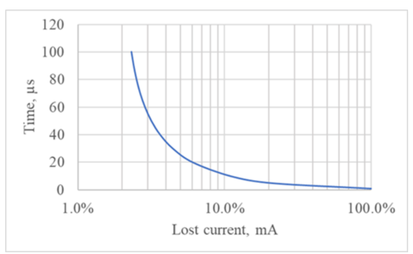
- Beam inhibited by 4 devices administratively controlled upstream of the RFQ.
- Global protection performed by comparison of signals from pairs of current-sensitive devices.
- Local protection controlled the beam loss to multiple electrically isolated electrodes in the MEBT.
- Run protection signals from the subsystems (vacuum, RF etc.).
- Defined beam modes and machine configuration



Beam Loss

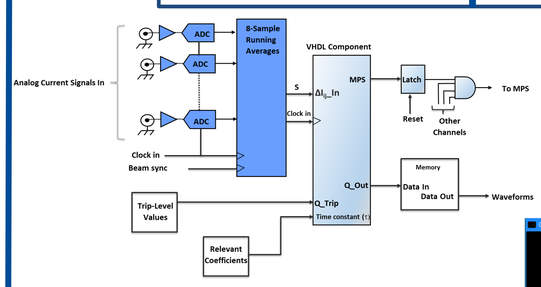


$$Q_{th} < Q(T) = e^{\frac{-T}{\tau}} \int_0^T \Delta I(t) \cdot e^{\frac{t}{\tau}} dt$$

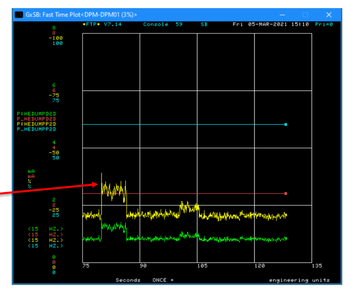


System	Power, W	Q_{th}, mA-μs	τ, μs	Based on
Scrapers	75	100	5000	Scraper current
HWR/pSSR1	20	20	2000	ACCT diffs
PEs	40	100	5000	PE current
DPI	25	2	2000	DPI current

VHDL Component



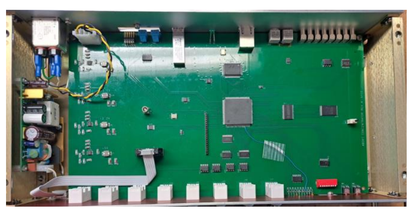
Differential current crossing a threshold



Component used for beam current measurements:

- 30 MHz MPS permit signal out removed LEBT Chopper 5 MHz permit
- Response time < 200 ns

System Hardware



FPGA based signal concentrator hardware designed and tested for a distributed MPS system

- Drops local permit within 100ns on detection of a low input
- Communicates to other units within 140 ns to 270 ns
- 8 optically isolated input
- Fiber connection

Summary

MPS operational experience at PIP2IT successfully verified the global method for loss detection, the hardware design for developing a distributed system for PIP-II capable of a 10 μs response time and methods, instrumentation and tools for protecting the Warm Front End.

References

[1] "The Proton Improvement Plan-II (PIP-II) Final Design Report", 2021 (unpublished).

[2] E. Pozdeyev *et al.*, "Beam Commissioning and Integrated Test of the PIP-II Injector Test Facility", presented at LINAC'22, Liverpool, UK, September 2022, paper MO1PA01.

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