Beam Loss Monitor System for the Low-Energy Heavy-Ion FRIB Accelerator

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Abstract

Radiation transport simulations reveal shortcomings in the use of ion chambers for the detection of beam losses in low-energy, heavy-ion accelerators like FRIB. Radiation cross-talk effects due to the specific FRIB paper-clip geometry complicate locating specific points of beam loss. We describe an economical and robust solution that complements ionization chambers. A specifically designed device, the halo monitor ring (HMR), is implemented upstream of each cryomodule to detect beam loss directly. Together with fast response neutron scintillators, the new integrated BLM system satisfies both machine protection and sensitivity requirements.

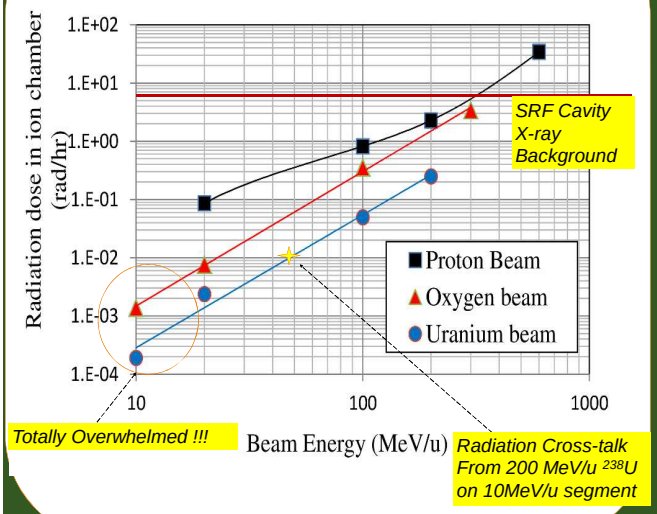
FRIB loss detection guideline

Beam Loss Distribution [W/m]	HMR Intercepted Current at LS1 [nA]	HMR Intercepted Current at LS3 [nA]	Stop Beam?	BLM Response Time
≤1	≤ 100	≤ 10	No	
1 < loss < 10	$10^2 < I1 < 10^3$	$10 < I3 < 10^2$	Yes	1 sec
≥10	≥ 10^3	≥ 10^2	Yes	15 μs

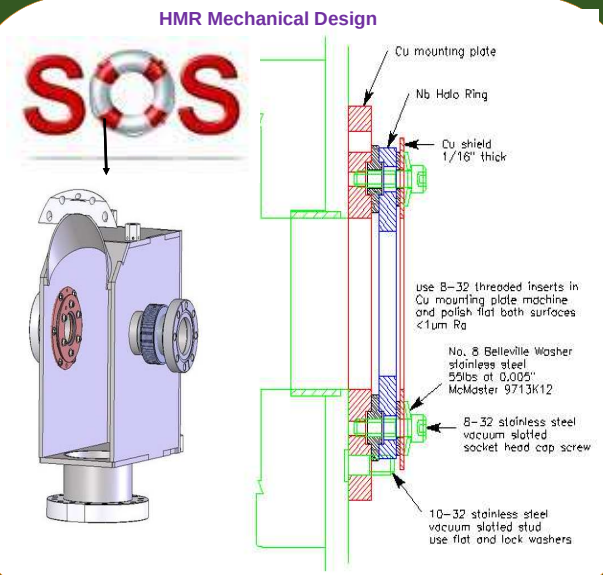
Signal requirement for HMR

- The electronics shall detect 100 pA (≤0.01 W/m) in a time scale of 60 seconds, with maximum error of 50pA.
- The electronics shall detect 10 nA (≤1 W/m) in a second, with maximum error of 1nA.
- The electronics shall respond to 100 nA (≤10 W/m) within 15μs.

Radiation Dose by 1 W/m Beam Loss at Different Energies



HMR Mechanical Design



FRIB BLM System Planning

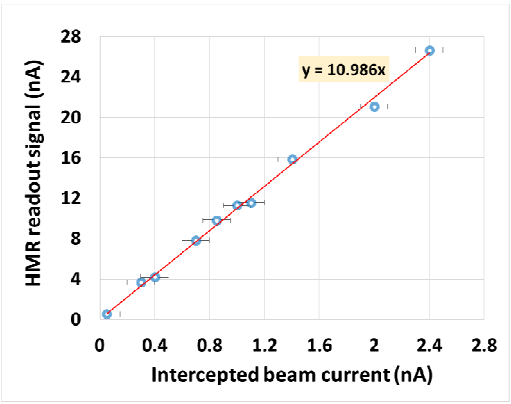
Type	Quantity	Location
Halo Monitor Ring	49	Upstream of each cryomodule
Neutron Scintillator	24	Uniformly distributed in the accelerator closure
Movable Ion Chamber	20	Areas of expected high beam power deposition & high energy part of FRIB

HMR Measurement with $^{18}O^{3+}$

$I_{HMR} = \alpha \cdot I_{ion}$ Due to secondary electrons

No need of electron suppression voltage!

Measurement of α with $^{18}O^{3+}$ beam



FRIB Facility for Rare Isotope Beams
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Michigan State University designs and establishes FRIB as a DOE Office of Science National User Facility in support of the mission of the Office of Nuclear Physics.