

Beam Loss in the First Segment of the FRIB Linac

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Loss Monitoring

Why monitor beam loss?

- Assist with tuning
- Minimize activation
- Extend machine lifetime
- Avoid beam damage

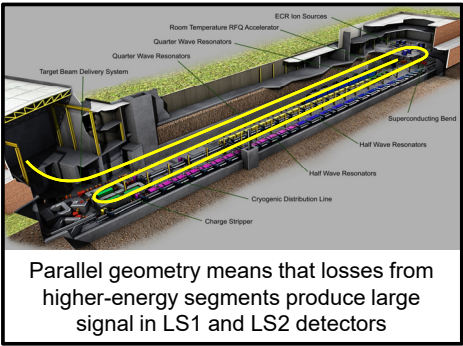
Challenges for FRIB

- High beam intensity
- Folded geometry
- Superconducting components

Loss Limits

- High beam intensity means significant damage is possible quickly
- Slow loss limits set primarily by heat load (magnet quenching) and machine degradation, rather than activation of beamline parts

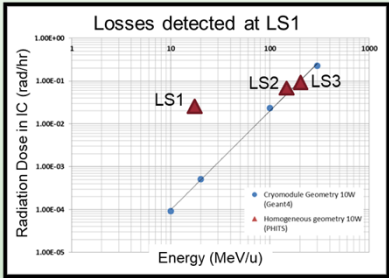
Beam loss (W/m)	Stop beam?	Response time
$P < 1$	No	≥ 1 sec
$1 \leq P < 10$	Yes	1 sec (slow)
$P \geq 10$	Yes	$< 15 \mu\text{s}$ (fast)



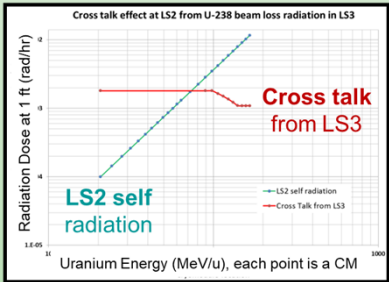
Parallel geometry means that losses from higher-energy segments produce large signal in LS1 and LS2 detectors

Radiation Cross Talk Simulations

Z. Liu, IPAC 2012, MOPPR077



Only 1.5% of dose detected at LS1 is from LS1 losses



Cross talk from LS3 dominates low-energy half of LS2

Devices

Beam Measurements

- Halo monitor rings (HMR)
- Beam current monitors (BCM)

Radiation Measurements

- Ionization chambers (IC)
- Neutron detectors (ND)

Temperature Measurements

- Resistive temperature devices (RTD)

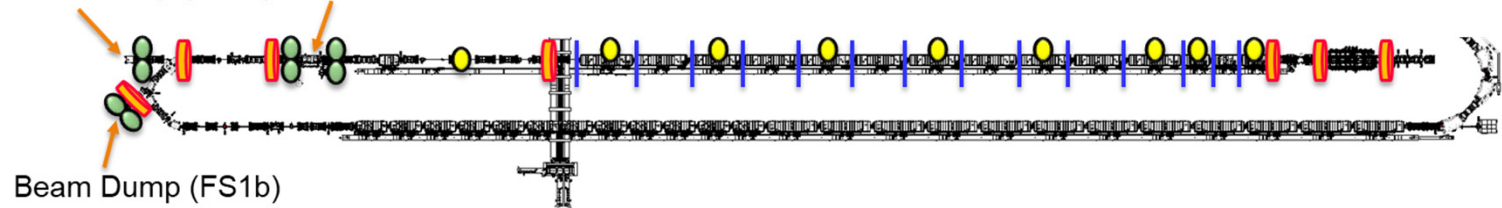
Commissioned

	LS1	FS1	LS2 low energy	LS2 high energy	FS2	LS3	BDS
Fast Loss < 35 ms	DBCM HMR	DBCM BLM	DBCM BLM	DBCM BLM	DBCM BLM	DBCM BLM	DBCM BLM
Slow loss 100 ms	HMR/Temp HMR/Temp	BLM	BLM Temp	BLM DBCM	BLM DBCM	BLM DBCM	BLM DBCM

Distribution

- BCM distributed throughout accelerator
- HMR/Temp important for slow losses in LS1
 - HMR in boxes between cryomodules, RTDs within cryomodules
- BLM important for slow losses in rest of linac
 - ND primarily mounted to outside of cryomodules
 - IC mounted to magnet stands below beamline in folding segments (pairs)

Beam Dump (FS1a) Carbon stripper



- Beam Current Monitor (BCM)
- Halo Monitor Ring (HMR)
- Neutron Detectors, Ion Chambers