Machine Protection System for SARAF Linac

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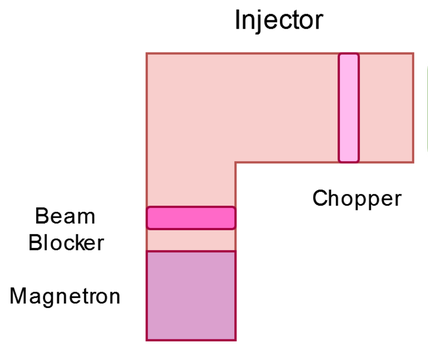
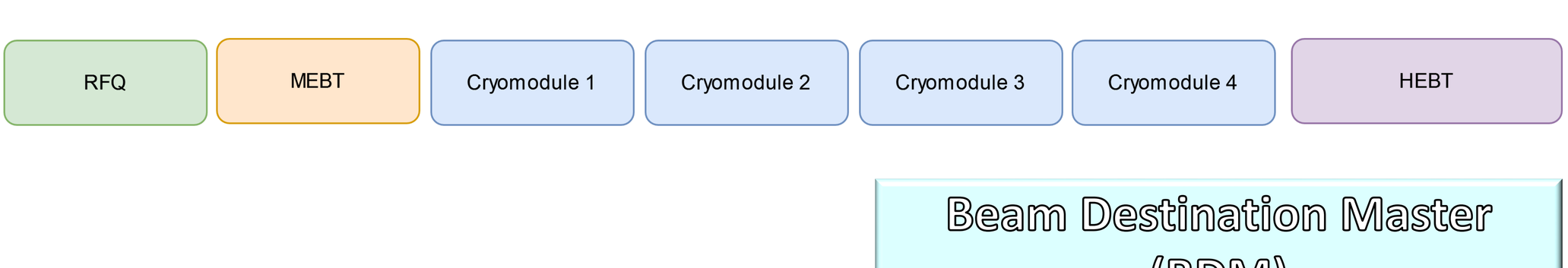
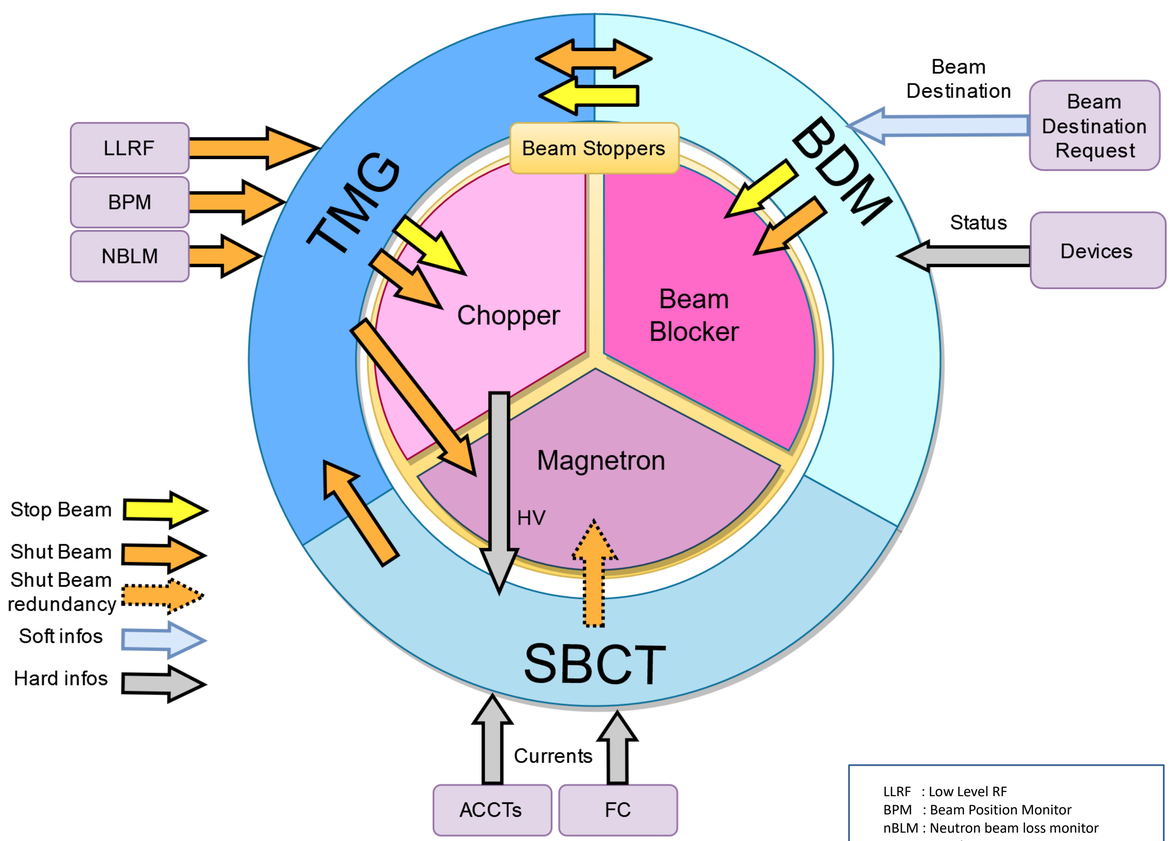
CEA Saclay Irfu is in charge of the major part of the control system of the SARAF LINAC accelerator based at Soreq in Israel. This scope also includes the Machine Protection System (MPS). This system prevents any damage in the accelerator by shutting down the beam in case of detection of risky incidents like interceptive diagnostics in the beam or vacuum or cooling defects. So far, the system has been used successfully up to the MEBT. It will be tested soon for the super conducting Linac consisting of 4 cryomodules and 27 cavities.
This Machine Protection System relies on three sets: the MRF timing system that is the messenger of the “shut beam” messages coming from any devices, IOxOS MTCA boards with custom FPGA developments that monitor the Section Beam Current Transmission along the accelerator and a Beam Destination Master that manages the beam destination required. This Destination Master is based on a master PLC. It permanently monitors Siemens PLCs that are in charge of the “slow” detection for fields such as vacuum, cryogenic and cooling system.





Beam Stoppers

Beam stoppers are designed to rapidly deactivate the beam when they receive a 'shutbeam' request:
- The chopper can shut down in approximately 100 ns.
- The magnetron, can shut down in approximately 10 µs.
- The Beam Blocker can shut down in approximately 100 ms.

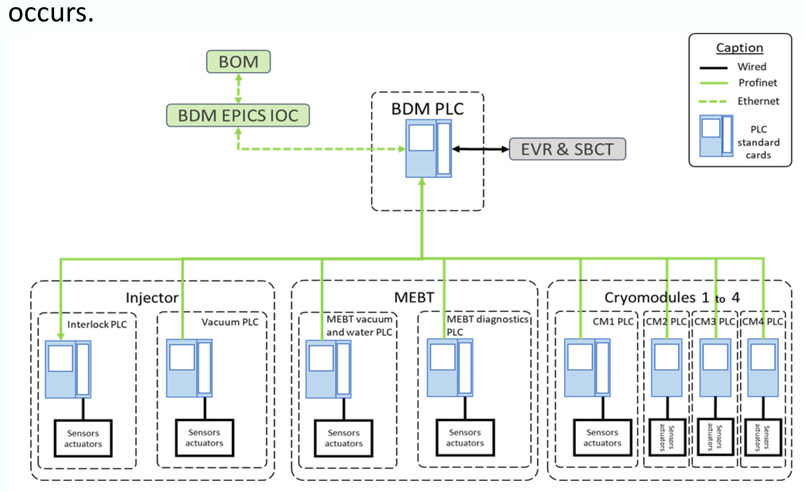


LLRF : Low Level RF
BPM : Beam Position Monitor
nBLM : Neutron beam loss monitor
FC : Faraday Cup
LEBT : Low Energy Beam Transport
MEBT : Medium Energy Beam Transport
HEBT : High Energy Beam Transport

Beam Destination Master (BDM)

Hardware platform:
- PLC Siemens 1500

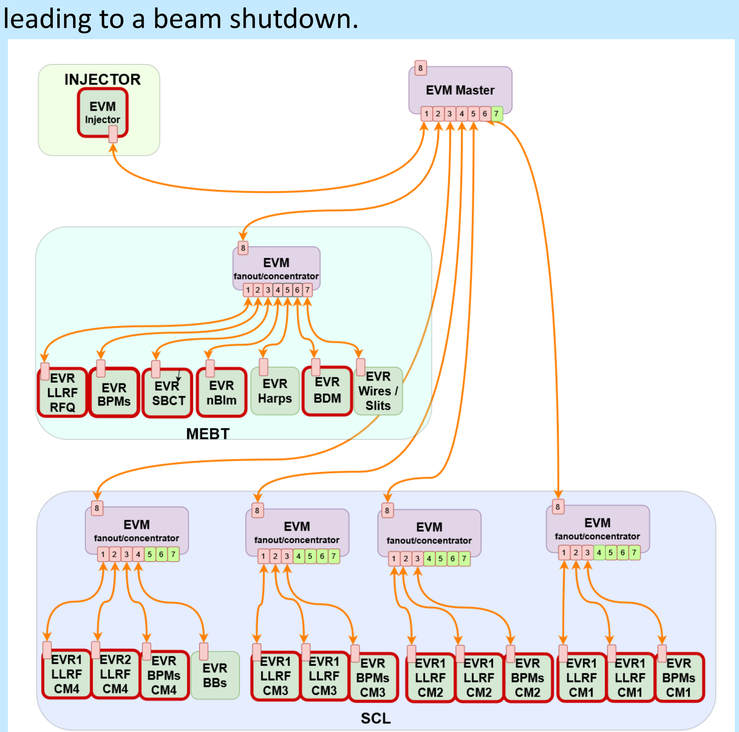
The BDM functions are:
- Checking that conditions required to reach the requested destination are respected.
- Shutting the beam down if conditions are no longer respected.
- Stopping the beam if the user requests a new destination.
- Inserting the beam blocker when a shutbeam or a stop-beam occurs.



Timing System (TMG)

Hardware platform:
- MRF Timing System Cards
- MTCA Event Master (EVM) 300
- MTCA Event Receiver (EVR) 300U

The primary function of the SARAF timing system is to ensure the synchronization of the entire accelerator. However, it also serves a dual purpose by using the bidirectional MRF optical fiber network to transmit fast machine protection messages across the network. All devices able to detect hazards requiring a ‘shutbeam’ are connected to the TMG through EVRs. The EVR Injector is responsible for shaping the beam and in the event of an issue, a ‘shutbeam’ event is distributed to the EVR Injector leading to a beam shutdown.



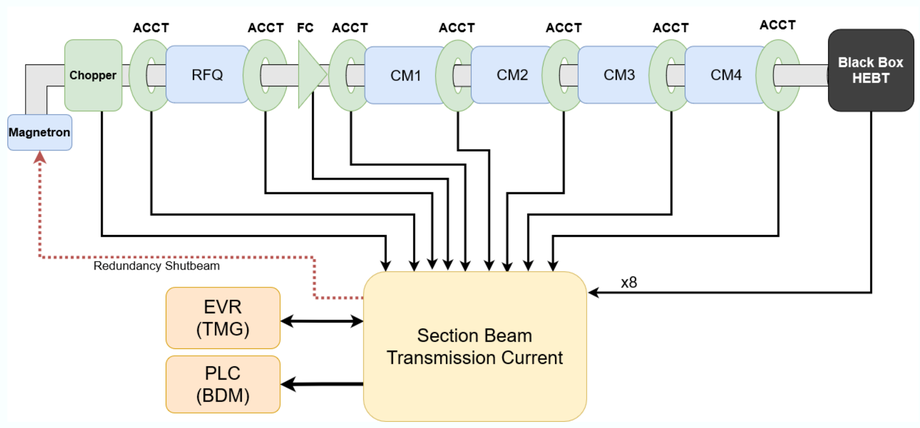
Architecture of the timing system. EVRs used for the MPS highlighted in red

More details in “MRF Timing System Design At SARAF” – THPV022 – ICALEPCS2021.

Section Beam Current Transmission (SBCT)

Hardware platform:
- MTCA IOxOS IFC1410 + ADC3117 + DIO3118
- FPGA Xilinx Ultrascale, IOxOS Tosca II platform

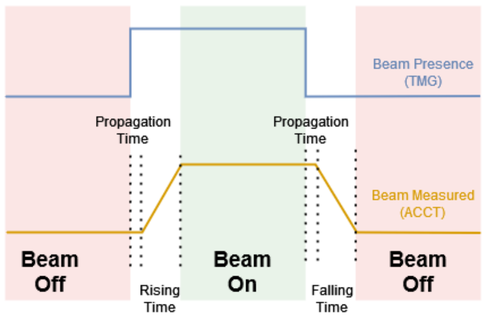
The SBCT checks the current transmission along the accelerator thanks to AC Current Transformers (ACCTs) and 1 Faraday Cup (FC). Its FPGA-based design enables fast problem detection.



The SBCT acquires beam current in the accelerator from different ACCTs, and Faraday Cup, and also the chopper voltage

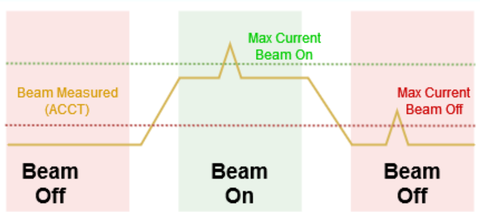
Beam On/Off management

The SBCT is responsible for verifying that the beam is both OFF and ON precisely when it is expected to be. The SBCT includes the propagation time of the beam and the falling and rising edges of the pulse.



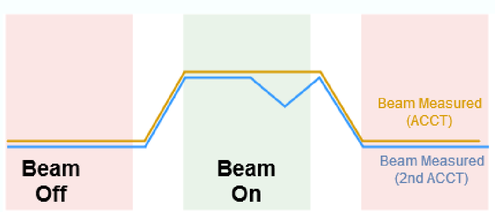
Beam Amplitude Checking

The SBCT authorizes a certain level for the signal depending on whether the beam is ON or OFF. If the signal goes higher than one of the limits, the SBCT requests a ‘shutbeam’.



Current differences

According to different configurations dependent on the beam destination, the SBCT compares current between its sensors (ACCTs, FC).



Shut beam redundancy

The SBCT never directly shuts the beam, instead it requests it from the TMG. However, if after a specified duration (12µs by default) it detects that the beam is still active, it directly shuts down the magnetron.

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