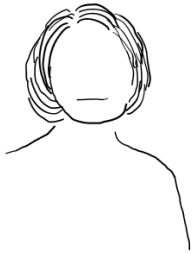
Timing, MPS and control of the beam operation at SARAF

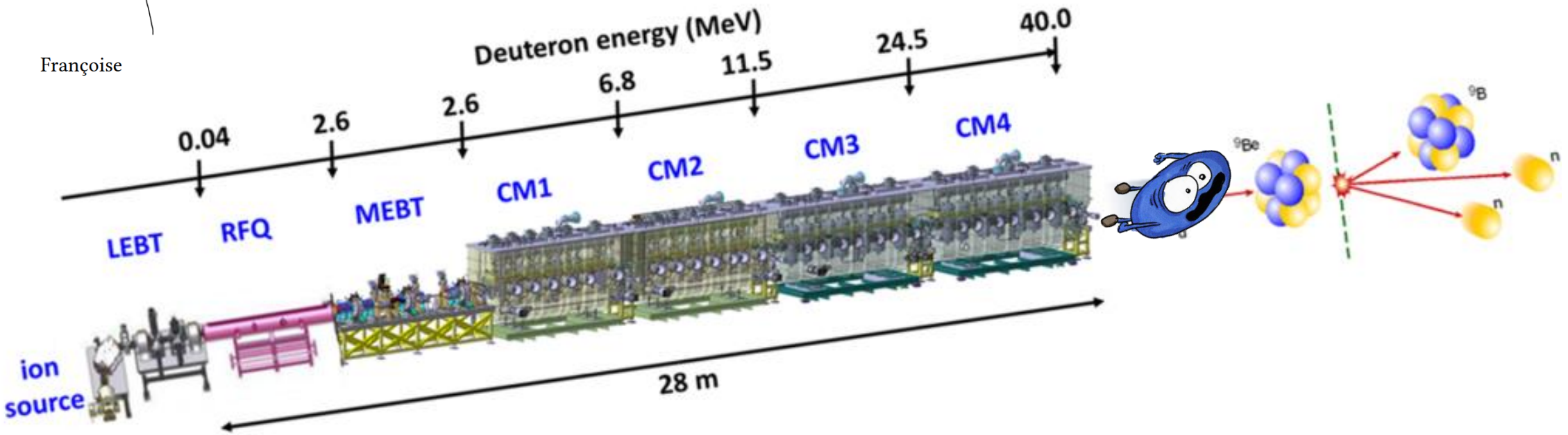
Alexis Gaget IRFU / DIS /LDISC

1. SARAF

SARAF Accelerator



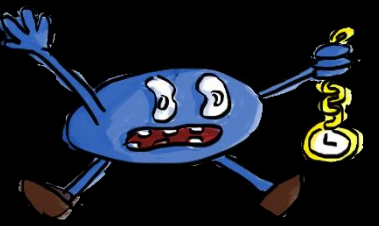
Françoise



Phase 1

Phase 2

2. Timing System

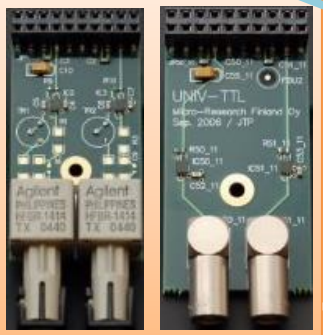


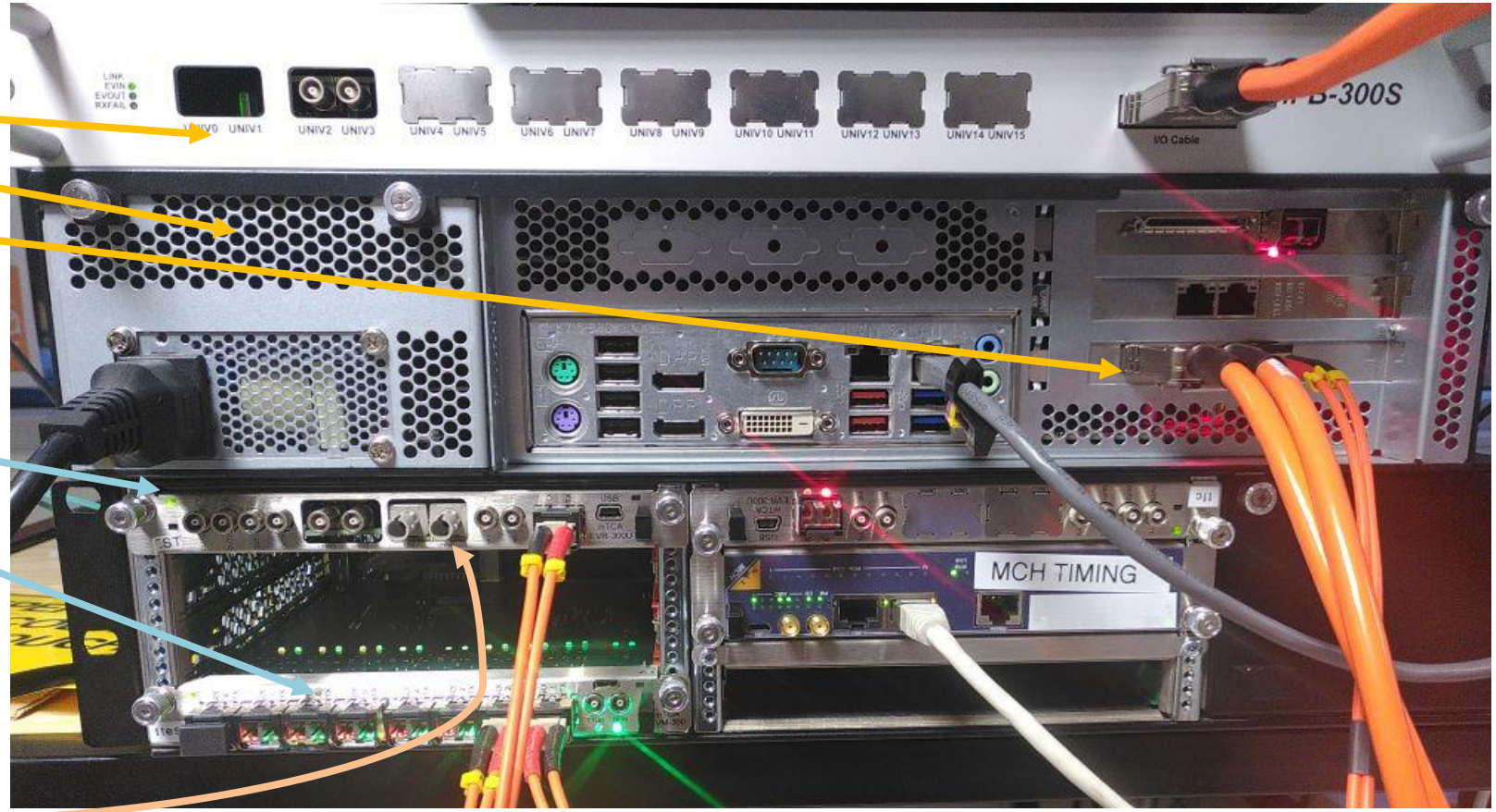
Micro Research Finland (MRF) based

Industrial PC
- IFB300SAM
- IPC Kontron
- PCIe-EVR300DCS

MTCA.4
- NAT R2 crate + MCH PHYS80
- + MCH-COMEXe3
- MTCA-EVR-300U
- MTCA-EVM-300

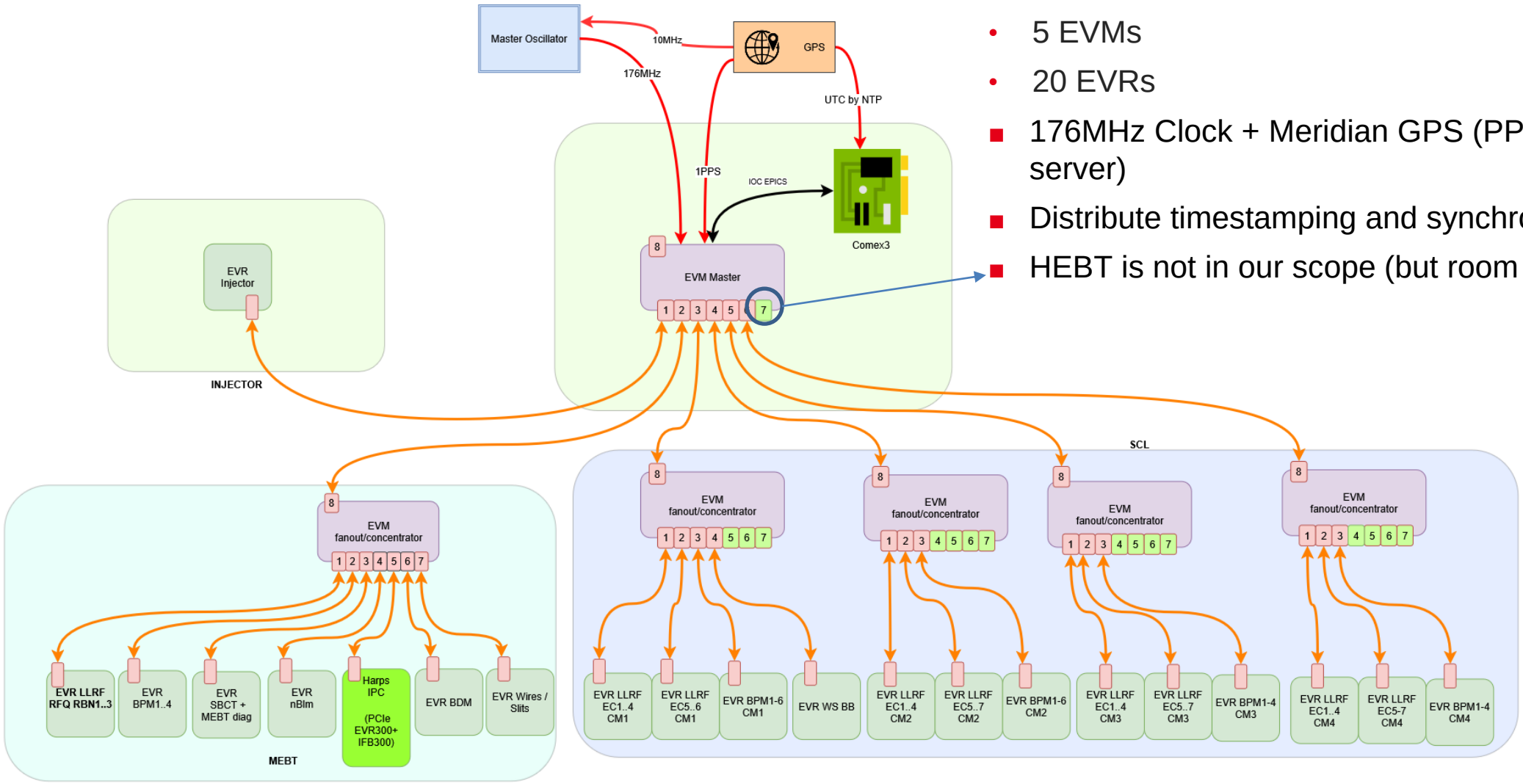
Universal Modules
- TTL 5V output
- TTL input
- Optical fiber





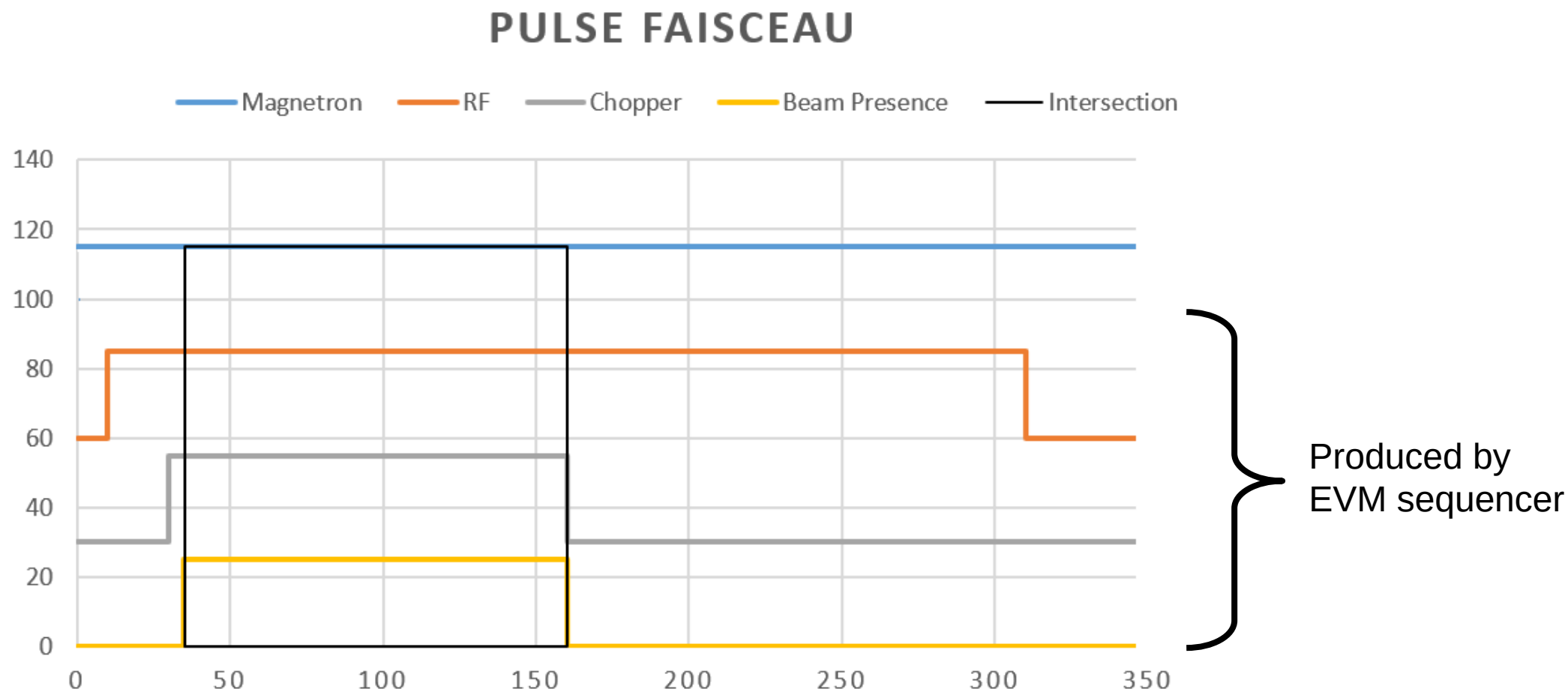
« You don’t know MRF ? Come to the Timing Workshop on Thursday »

Timing Topology

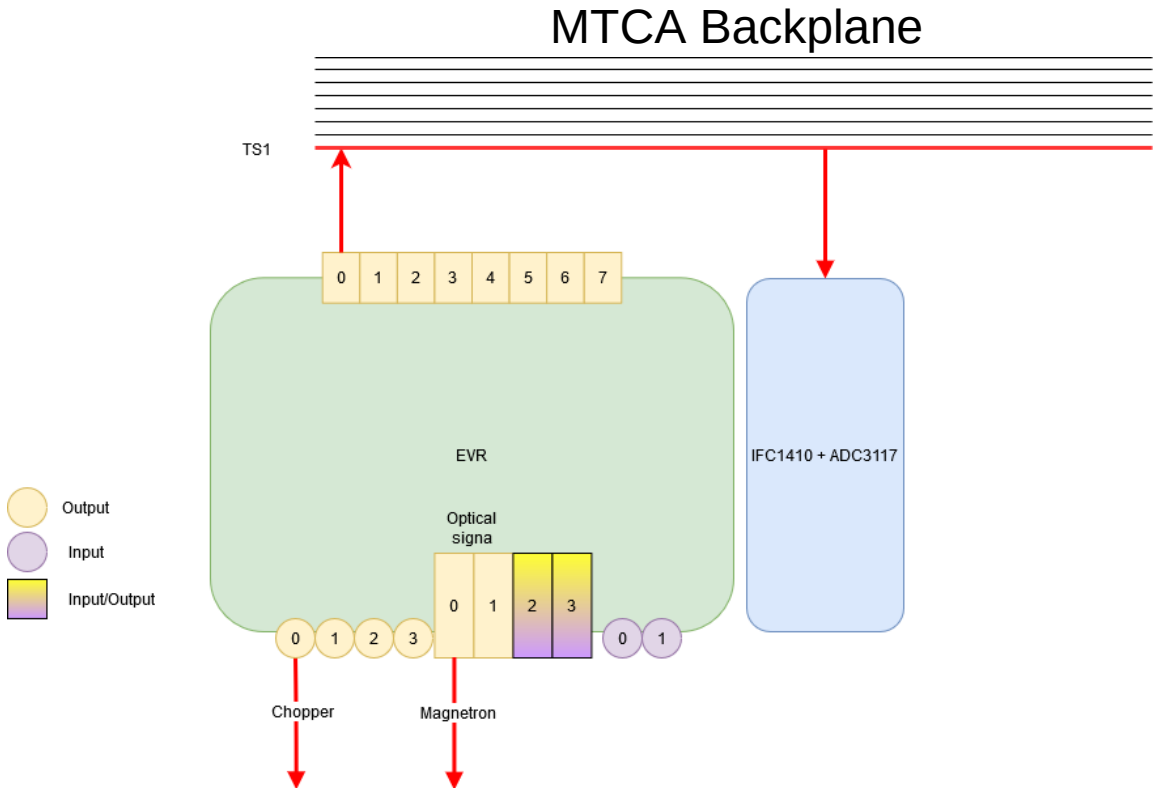


- Timing System, Micro Research Finland (MRF) based:
- 5 EVMs
- 20 EVRs
- 176MHz Clock + Meridian GPS (PPS, 10MHz, NTP server)
- Distribute timestamping and synchronization
- HEBT is not in our scope (but room planned for it)

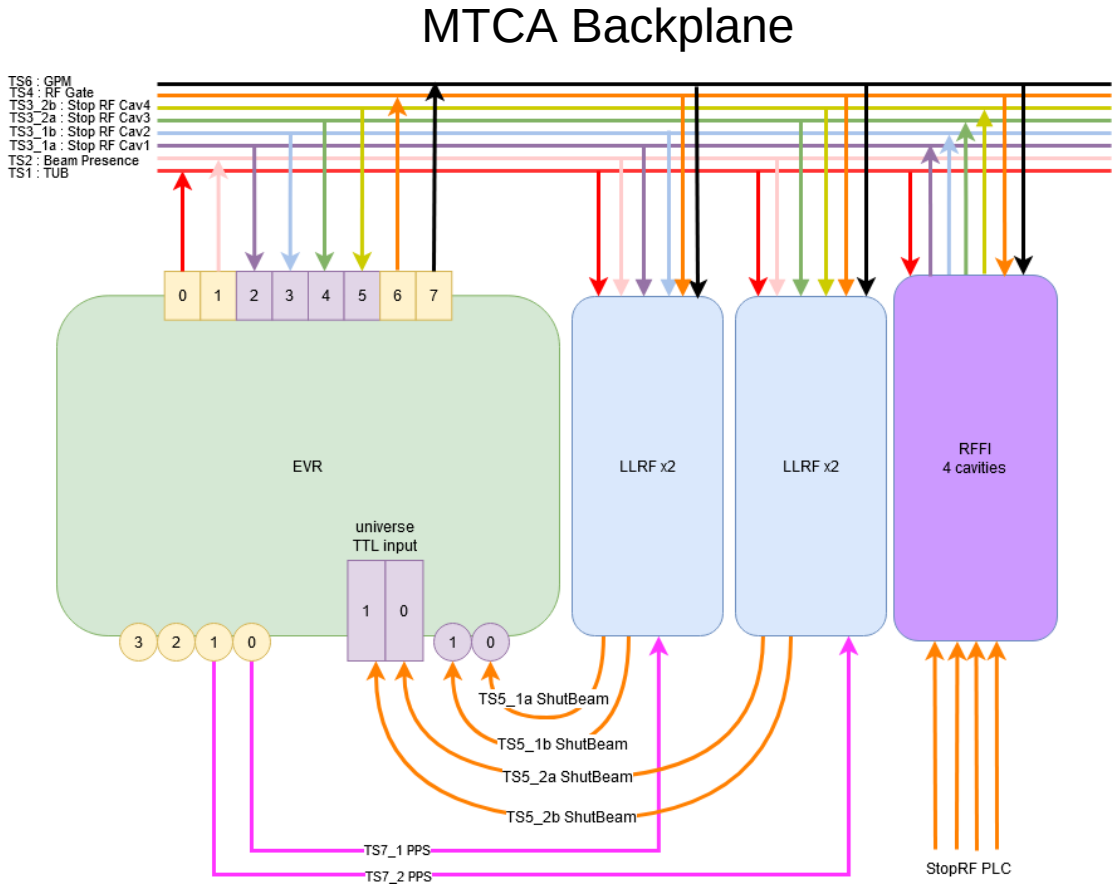
Pulse Generation



Some MTCA EVR examples



EVR Injector

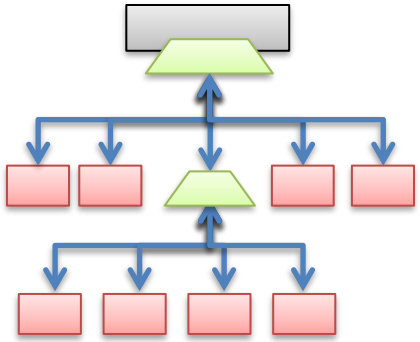


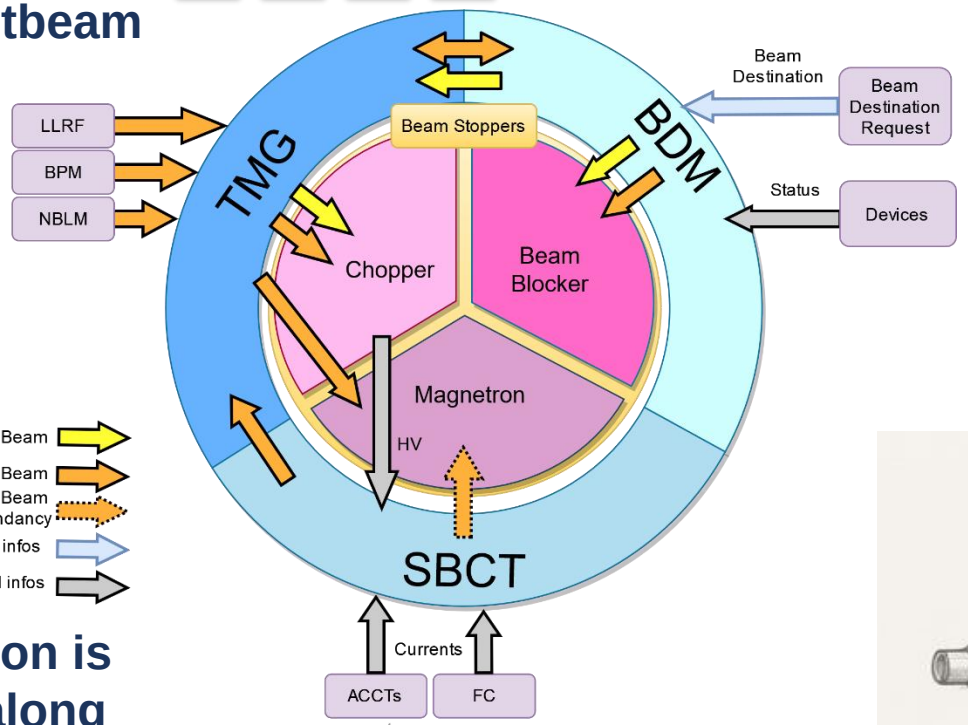
EVR LLRF

2. Machine Protection System

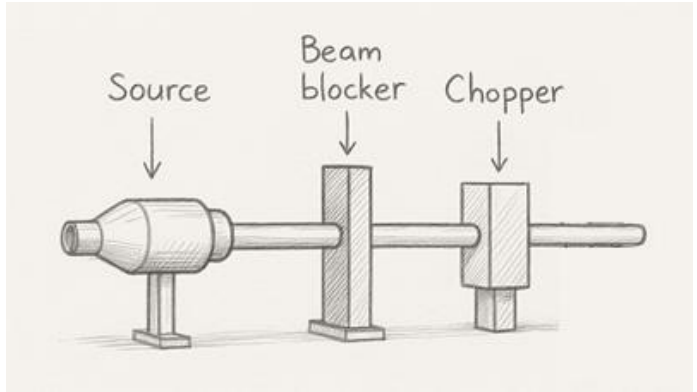
Machine Protection System

Timing (TMG) is the heart of the MPS creating or shutting the beam pulse through chopper and magnetron and being the messenger of the shutbeam event





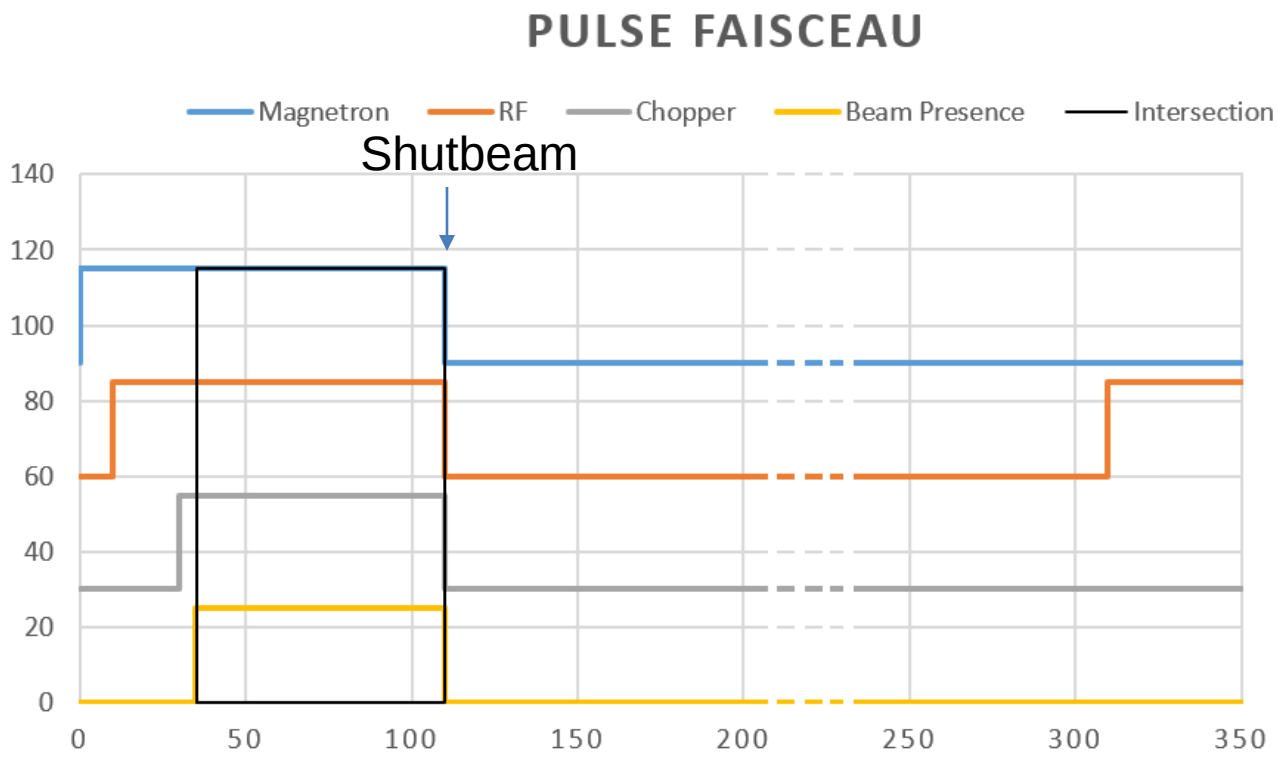
Beam destination master (BDM) controls that conditions to get the beam to a destination are checked. Linked to all PLC all along the accelerator through Profinet



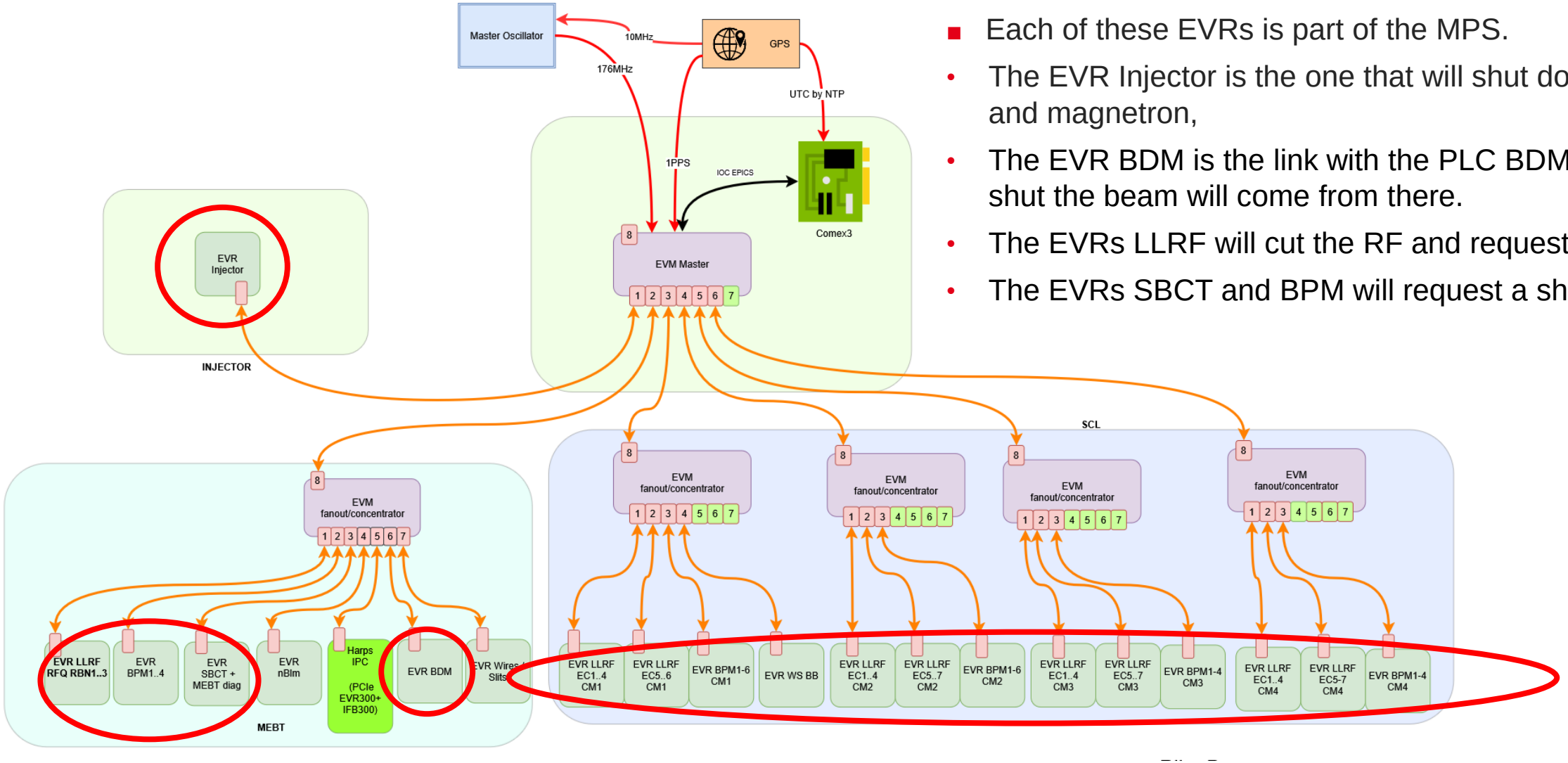
Section Beam Current Transmission is checking current of the beam all along the accelerator and compare them.

Machine Protection System

- During a shutbeam
  - All the pulses are immediatly interrupted
  - Sequence continue, but Beam Presence and Chopper pulses are masked



Timing + MPS



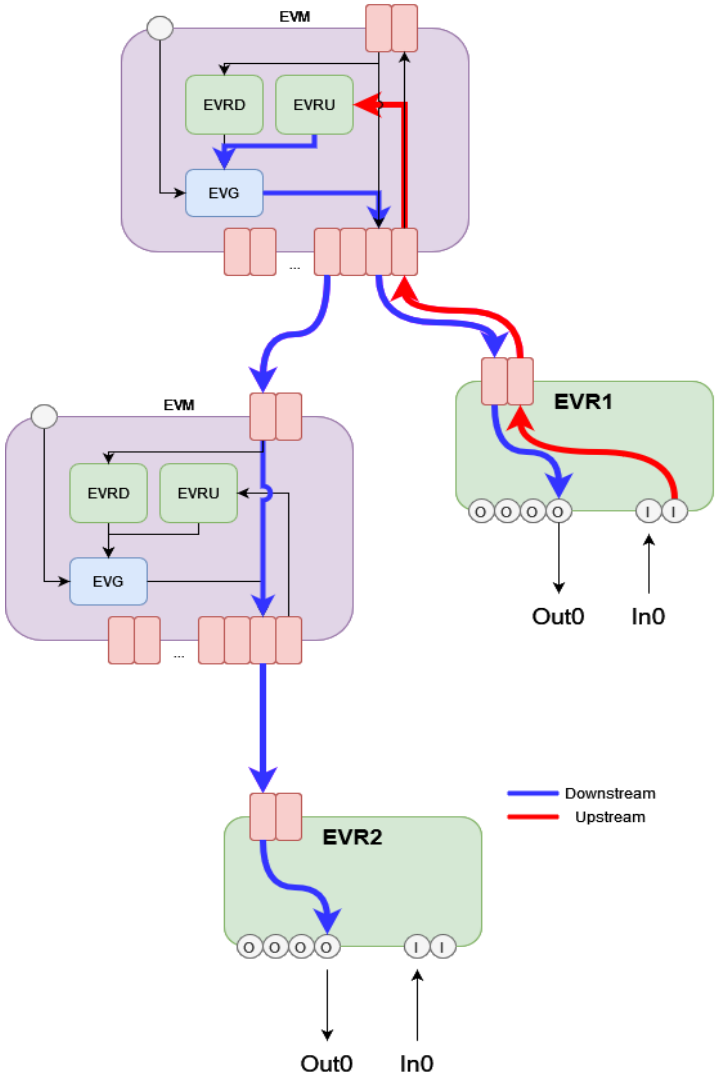
- Each of these EVRs is part of the MPS.
- The EVR Injector is the one that will shut down, chopper and magnetron,
- The EVR BDM is the link with the PLC BDM; requests to shut the beam will come from there.
- The EVRs LLRF will cut the RF and request a shutbeam.
- The EVRs SBCT and BPM will request a shutbeam.

Timing + MPS

- Use of the upstream event principle
  - An input of the EVR is triggered, and an event is sent upstream and redistributed by the EVM Master to all EVRs.
- Cons: Cannot use delay compensation because MPS events cannot be delayed.

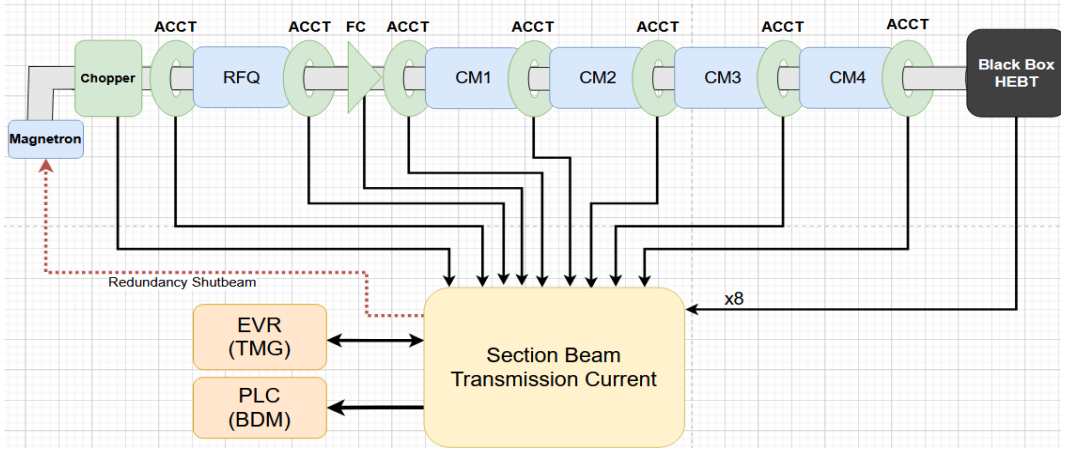
=> Recently solved by Jukka: creation of a priority event that is not delayed. Presentation and demonstration during the Timing Workshop.

Gabriel (CEA) has almost finished integrating this new function into the mrfioc2 EPICS driver.



Section Beam Current Transmission (SBCT)

- The Section Beam Current Transmission checks the beam current along the accelerator and compares the measurements (ACCTs, Faraday cups, chopper…).

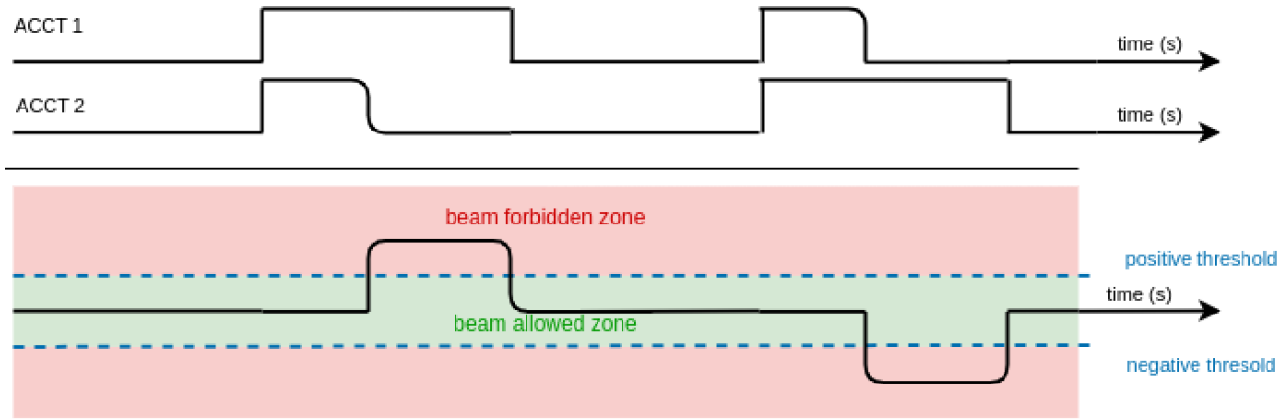


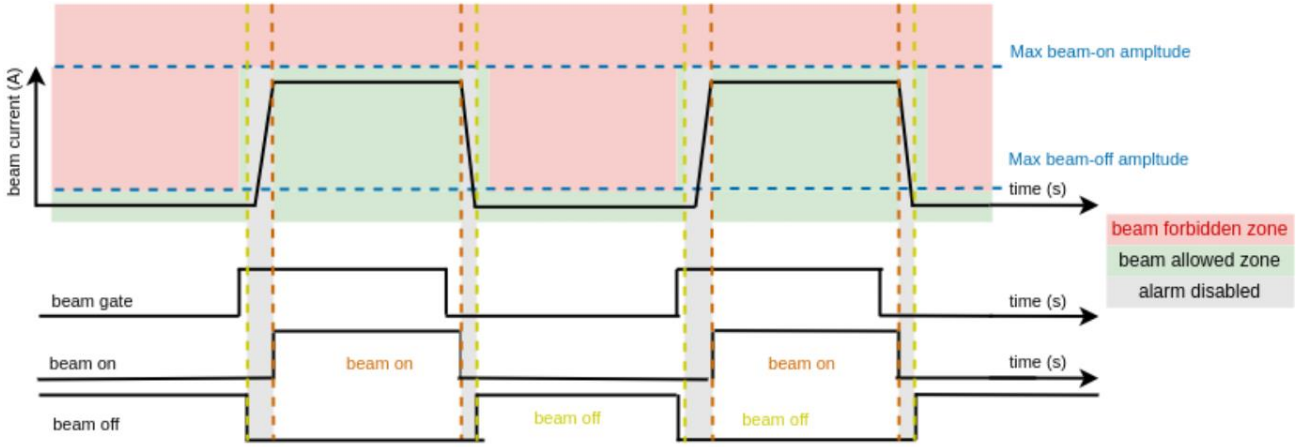
Victor N.

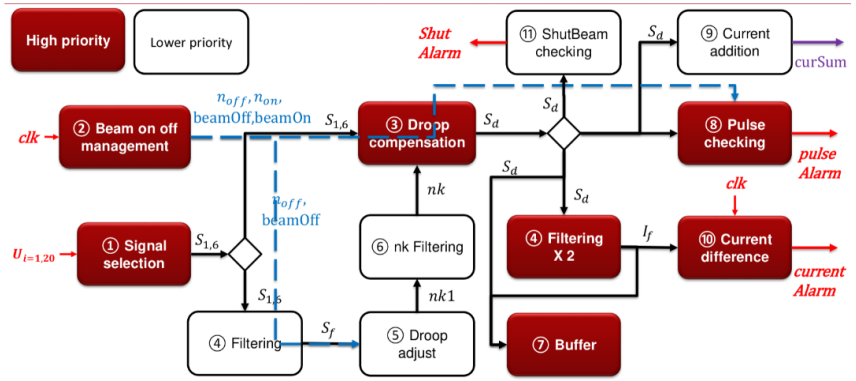
- MTCA IOxOS based :
  - ADC3117 : 20 channels, 5 MSamples/sec, ±10 V
  - DIO3118 datasheet : 16 I/O
  - MTCA.4 AMC : IFC1410 (FPGA Xilinx Kintex Ultrascale + CPU PPC)

Section Beam Current Transmission (SBCT)

- Different functions implemented
- Current differences
- Beam Amplitude checking
- Beam On/Off management
- Etc …



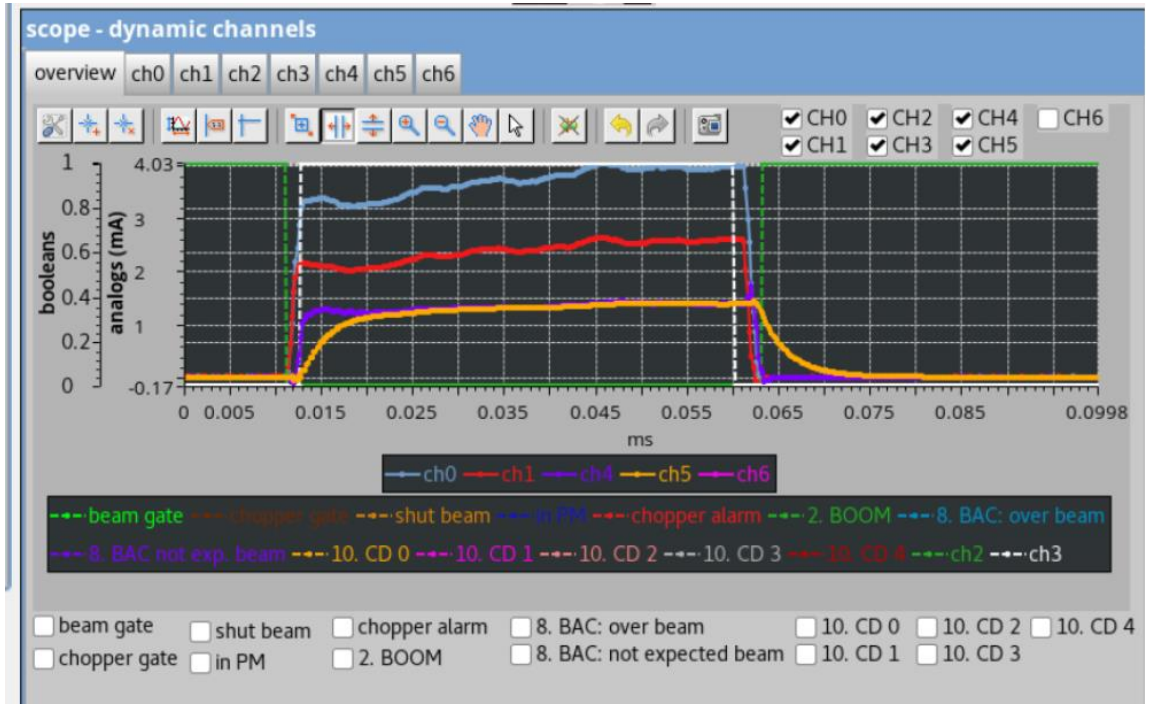




Section Beam Current Transmission (SBCT)

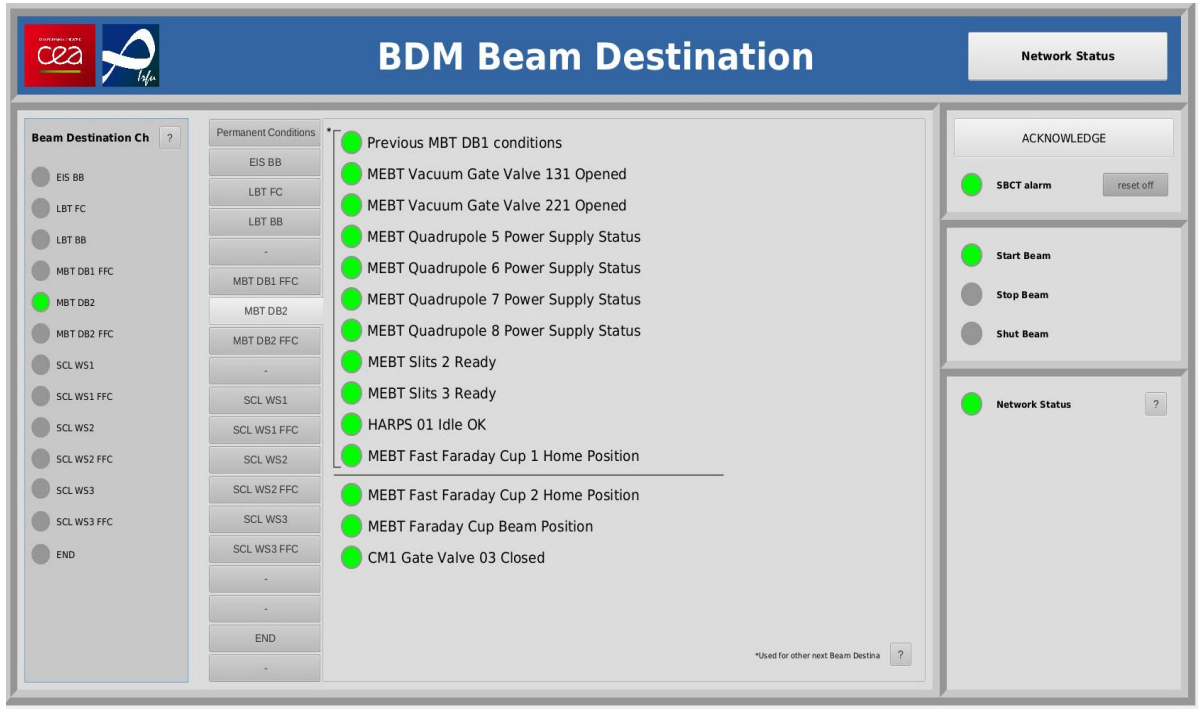
Victor N.

- EPICS
- epicsComGen or “Epics comme j’aime” : generates communication between FPGA registers and EPICS PVs
- 1300 PVs EPICS



Beam Destination Master (BDM)

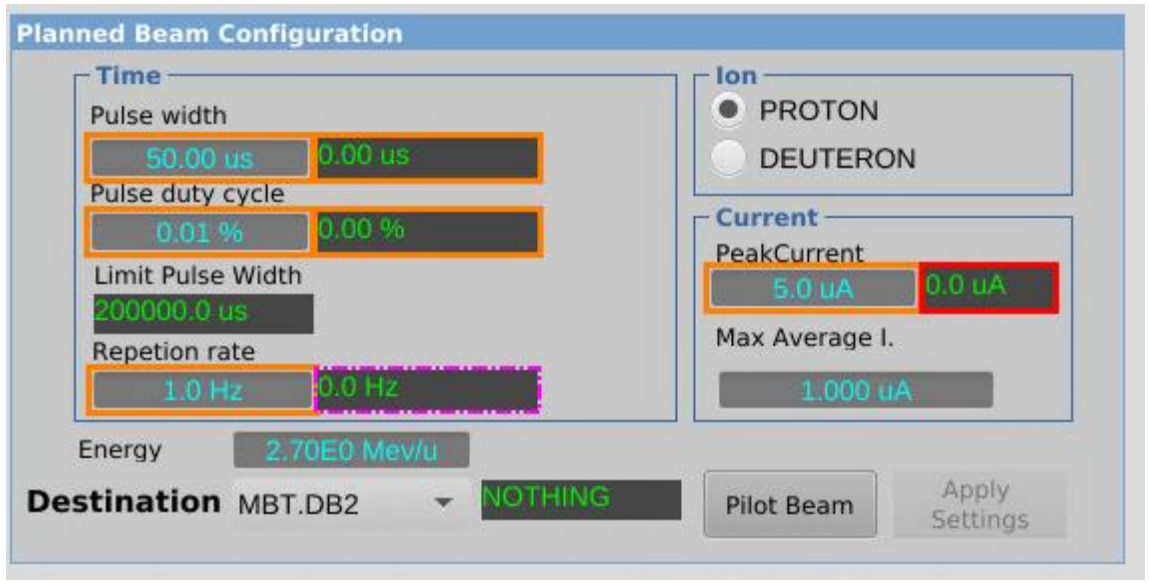
- **Beam destination master (BDM) controls that conditions to get the beam to a destination are checked. Linked to all PLC all along the accelerator through**
- Siemens PLC based
- S7PLC (read) / Modbus (write) (no opc-ua yet at the time)
- PLCParsertool generate communication between PLC registers and EPICS PVs



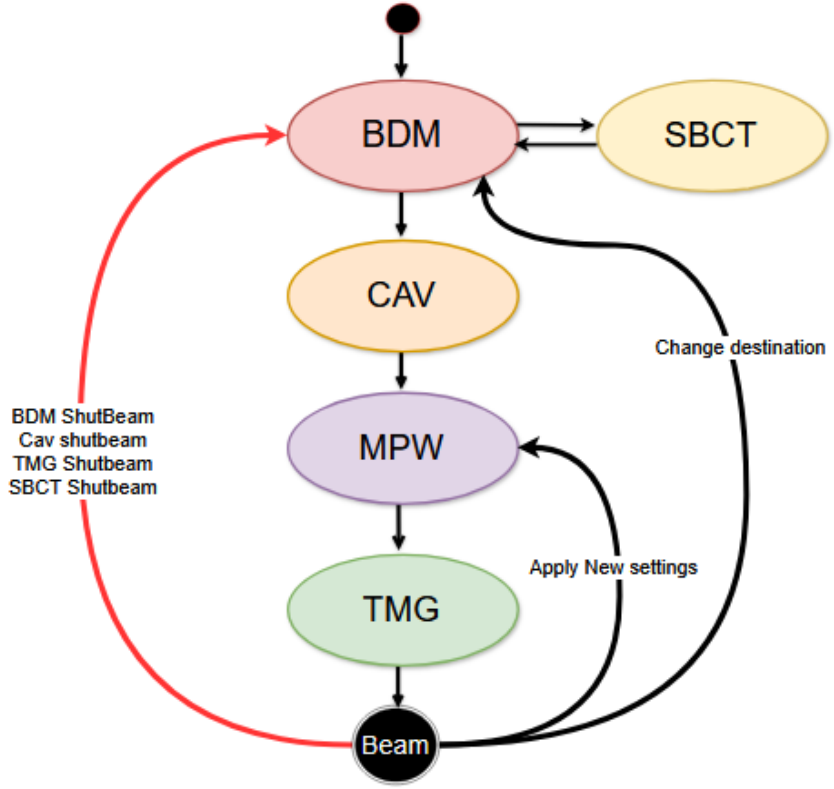
2. Beam control

Beam control

When the operator asks for a **pilot beam** (default configuration: 1 Hz, 50 µs), the following SNL sequence is launched.



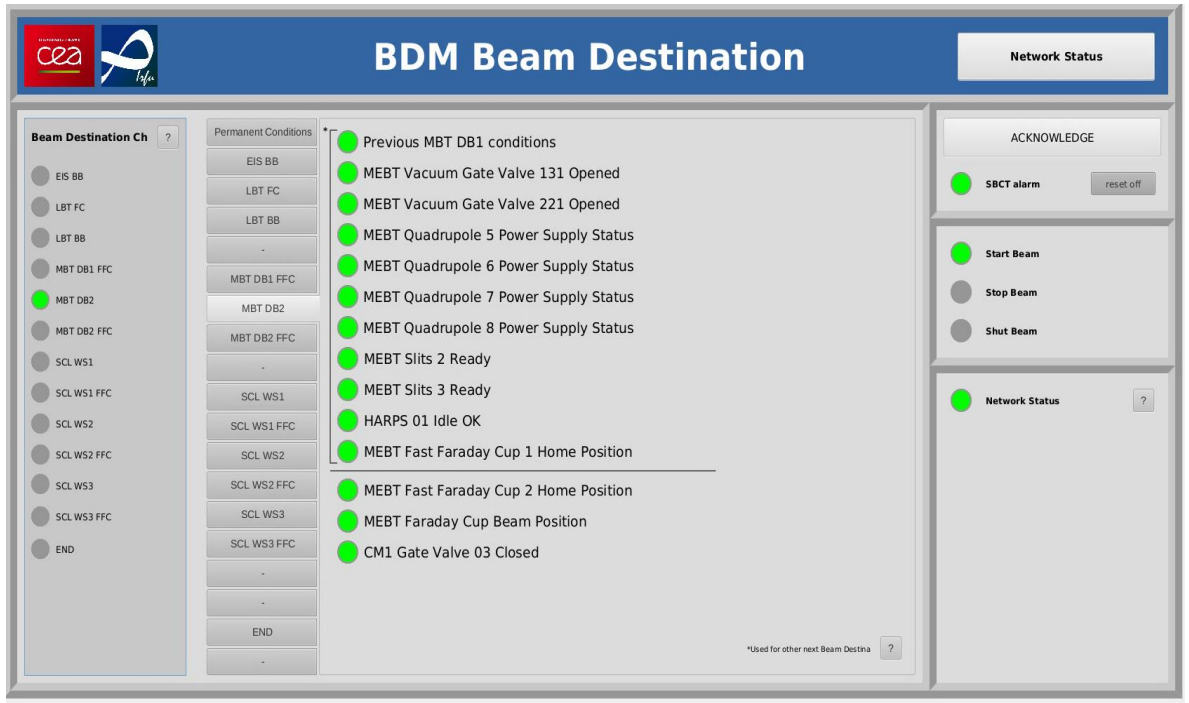
Example of configuration for destination MEBT Diagnostic box 2



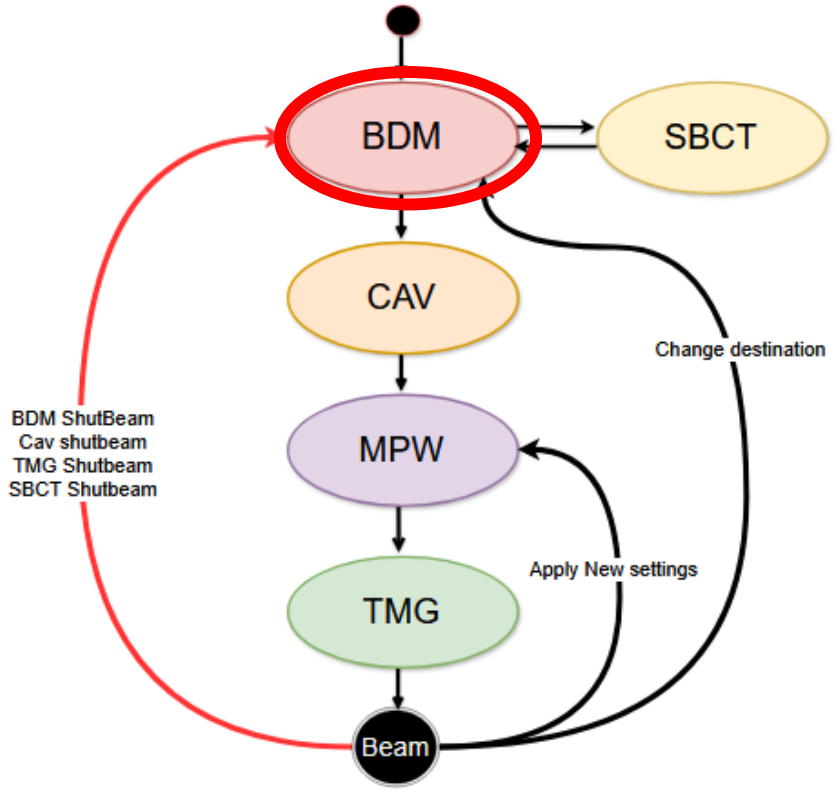
Beam control

When the operator asks for a **pilot beam** (default configuration: 1 Hz, 50 µs), the following SNL sequence is launched.

- **Beam Destination master (BDM)**
  - Check Beam condition for a beam destination



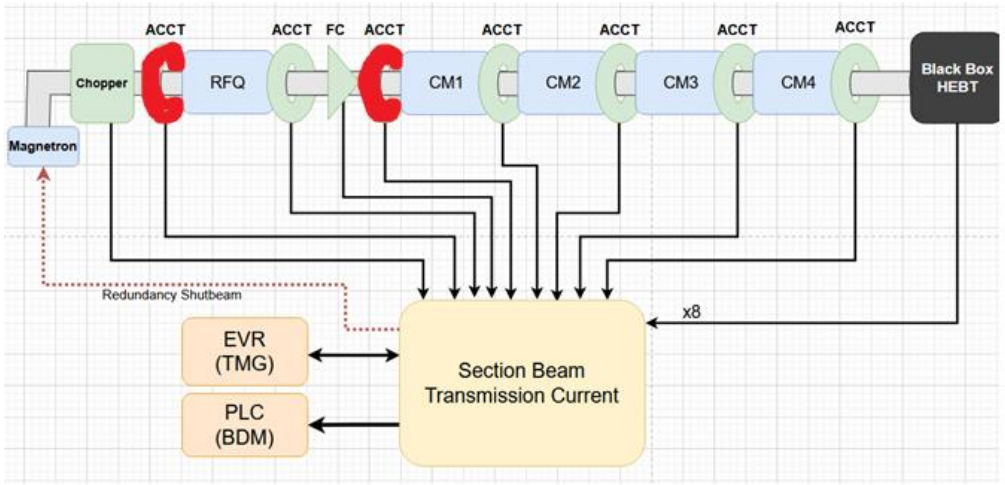
Example of configuration for destination MEBT Diagnostic box 2



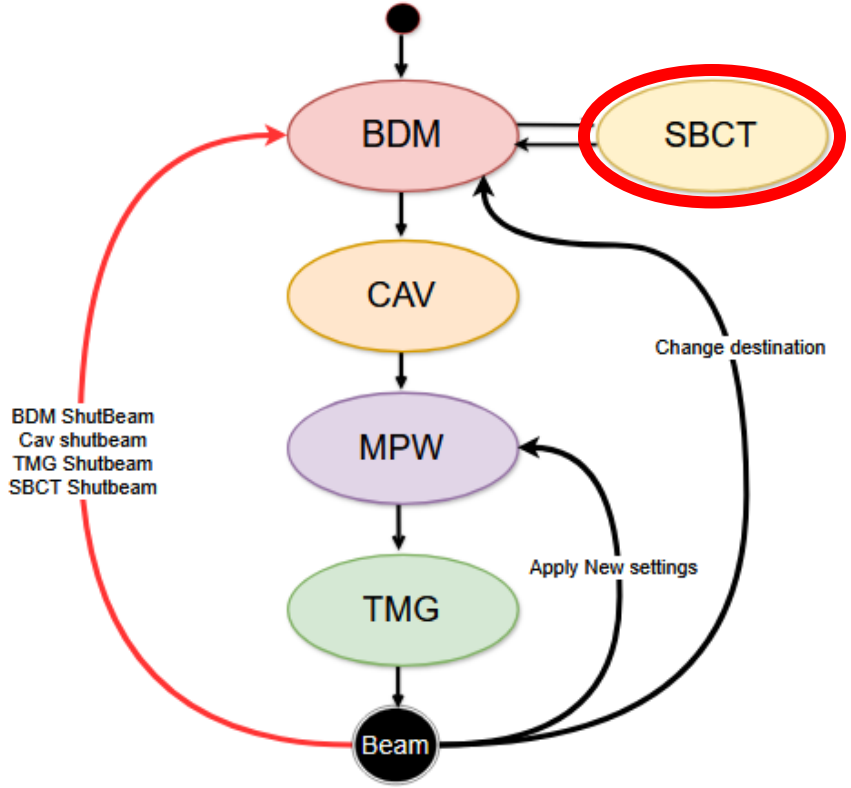
Beam control

When the operator asks for a **pilot beam** (default configuration: 1 Hz, 50 µs), the following SNL sequence is launched.

- **Beam Destination master (BDM)**
  - Check Beam condition for a beam destination
- **Section Beam Current Transportation (SBCT)**
  - Configure security to reach a beam destination.



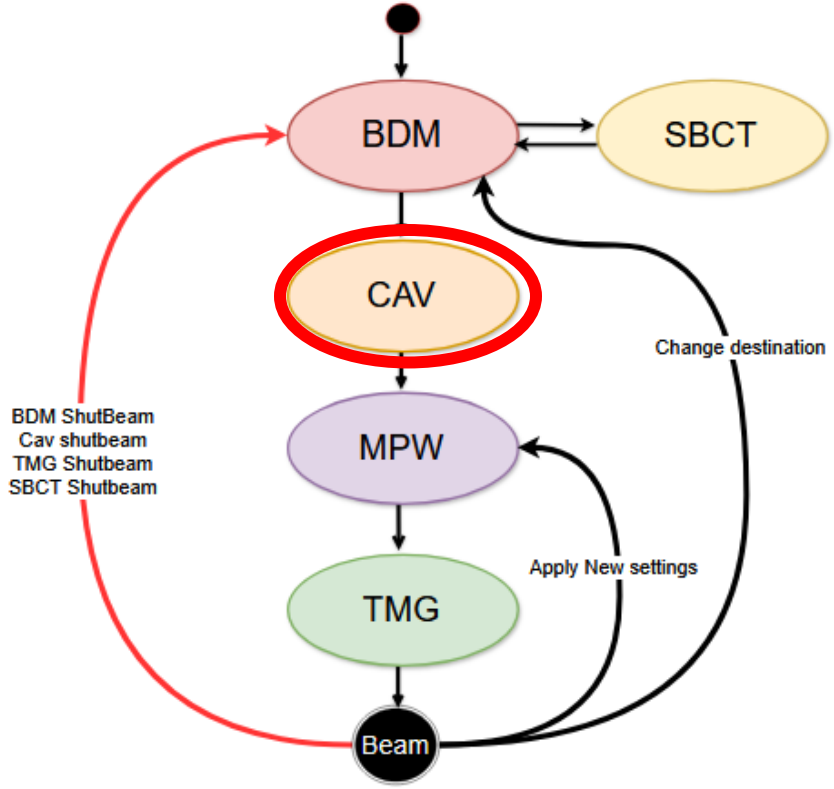
Example of configuration for destination MEBT Diagnostic box 2



Beam control

When the operator asks for a **pilot beam** (default configuration: 1 Hz, 50 µs), the following SNL sequence is launched.

- **Beam Destination master (BDM)**
  - Check Beam condition for a beam destination
- **Section Beam Current Transportation (SBCT)**
  - Configure security to reach a beam destination.
- **Cavity Application (CAV)**
  - Check that every cavity up to the beam destination is up and ready.
  - A cavity is READY for operation if :
    - the LLRF is ON,
    - the LLRF is in regulation mode,
    - the measured accelerating voltage has reached the target accelerating voltage and is stable enough,
    - the external alarm is enabled.

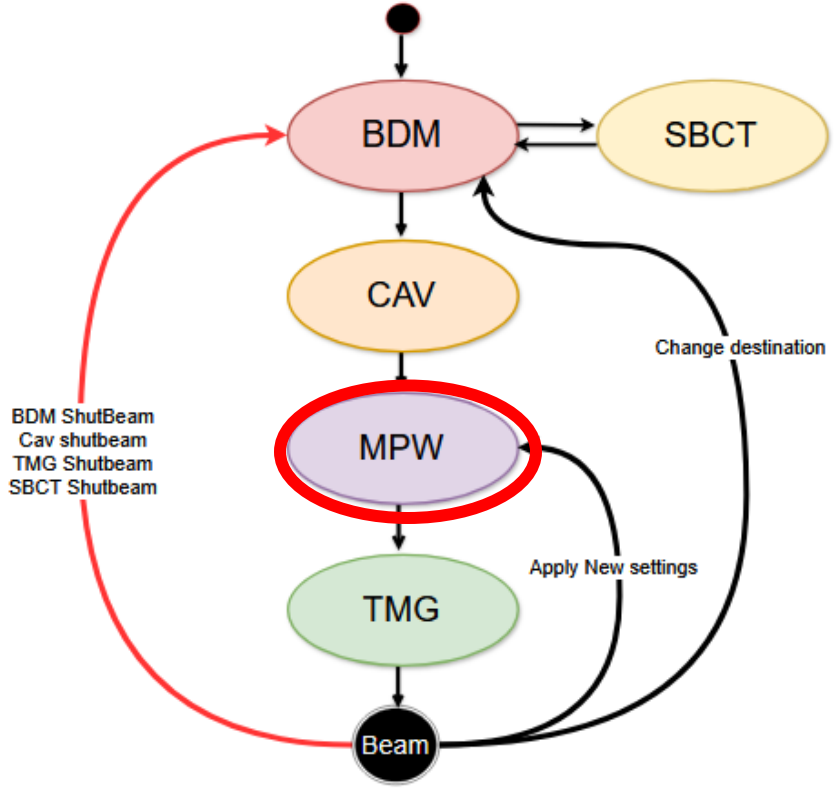


Example of configuration for destination MEBT Diagnostic box 2 : RFQ + 3 Rebunchers

Beam control

When the operator asks for a **pilot beam** (default configuration: 1 Hz, 50 µs), the following SNL sequence is launched.

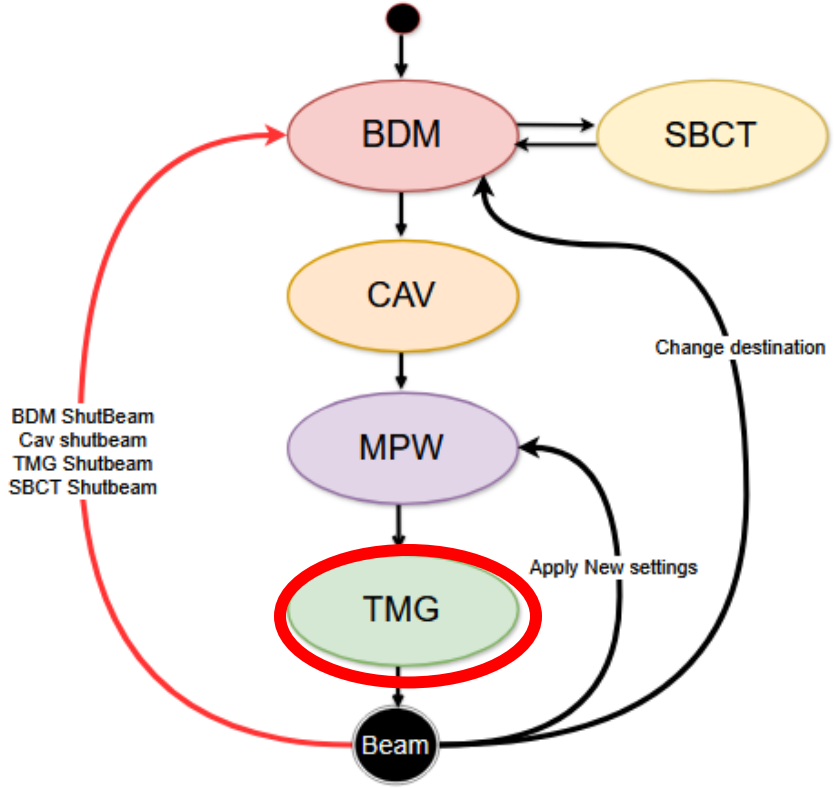
- **Beam Destination master (BDM)**
  - Check Beam conditions for a give beam destination
- **Section Beam Current Transportation (SBCT)**
  - Set correct configuration to reach a beam destination.
- **Cavity Application (CAV)**
  - Checks that every cavity up to the beam destination is up and ready.
- **Max Pulse Width (MPW)**
  - According to the destination and inserted elements, authorize a maximum current to avoid damaging any equipment.
  - For destination MEBT Diagnostic box 2 FFC , the beam hits a Fast Faraday Cup, which is a fragile equipment, so only a very low beam current is authorized.



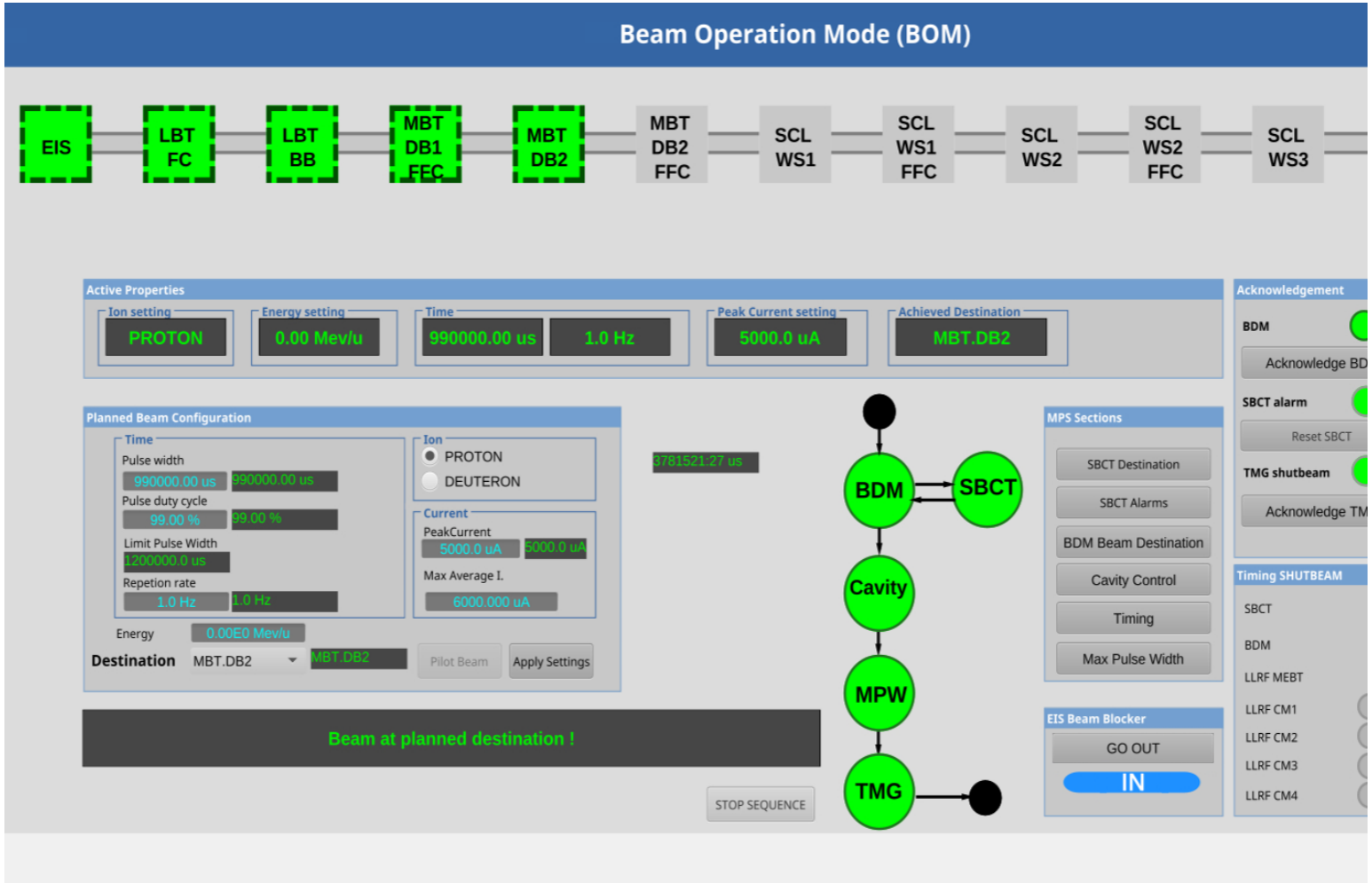
Beam control

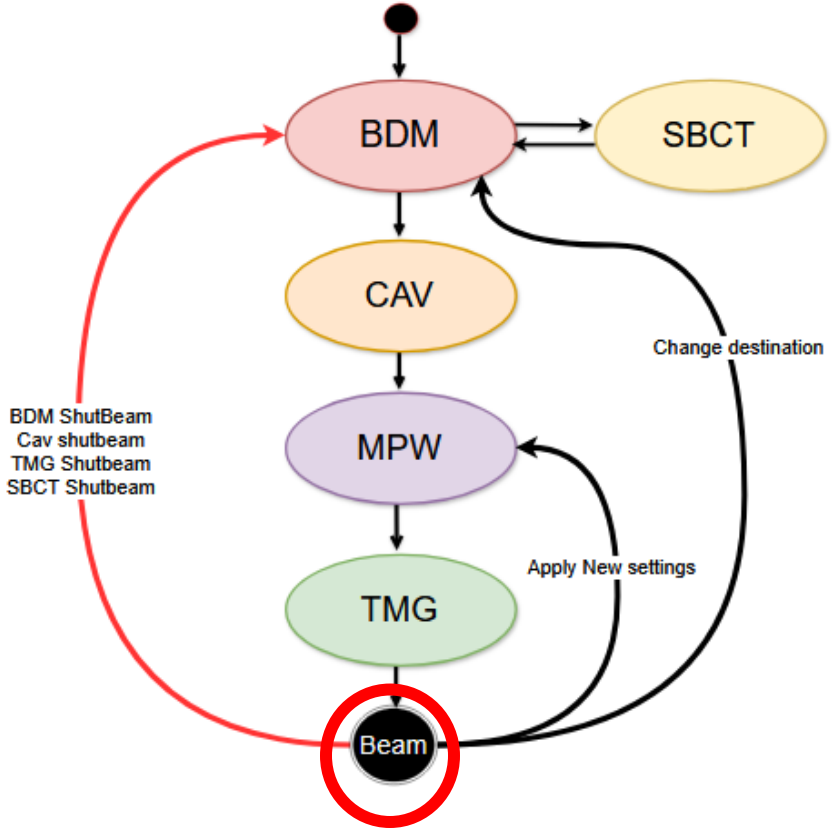
When the operator asks for a **pilot beam** (default configuration: 1 Hz, 50 µs), the following SNL sequence is launched.

- **Beam Destination master (BDM)**
  - Check Beam condition for a beam destination
- **Section Beam Current Transportation (SBCT)**
  - Configure security to reach a beam destination.
- **Cavity Application (CAV)**
  - Check that every cavity up to the beam destination is up and ready.
- **Max Pulse Width (MPW)**
  - According to destination and element inserted will authorize a maximum current in order to do not damage any equipment.
- **Timing (TMG)**
  - Checks that the optical fiber network up to this destination is working properly.



Beam control





Conclusion

- For now it gives great satisfaction for the commissioning of the MEBT of SARAF.
- SBCT is still in active development and testing.
- We hope to test everything soon with the first cryomodule.

- Perspective
  - MRF will be used for Titan accelerator in Saclay (MPS not included this time)
  - MRF + MPS architecture has been proposed for pre-project for ICONE accelerator.

("Introduction to the software and hardware platforms for the Pre-Project of the ICONE Accelerator – Spring EPICS Meeting 2025)

Merci

- MRF TIMING SYSTEM DESIGN AT SARAF
  - October 2021
  - DOI: 10.18429/JACoW-ICALEPCS2021-THPV022

- MACHINE PROTECTION SYSTEM AT SARAF
  - October 2023
  - DOI:
  - 10.18429/JACoW-ICALEPCS2023-THPDP102

- EPICS CONTROL SYSTEM FOR BEAM OPERATION AT SARAF LINAC ACCELERATOR
  - September 2025
  - DOI:
  - 10.18429/JACoW-ICALEPCS2025-THPD098

CEA SACLAY

alexis.gaget@cea.fr

Check Optical fiber connection

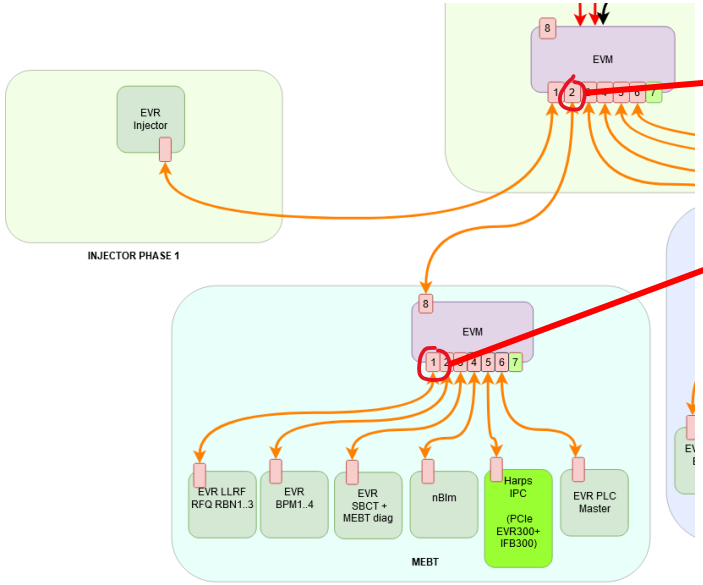
Check TX (upstream) connexion.

Native in the driver through PV $(PREFIX):Link-Sts

Check RX (downstream) connexion

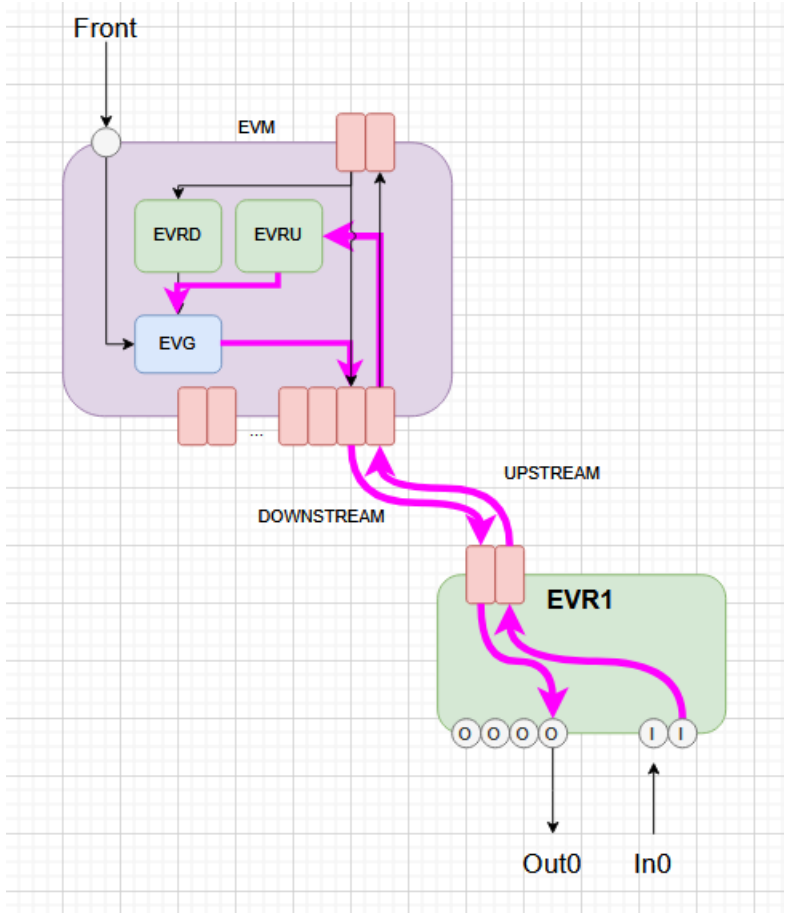
Not native in EVR, we need to use EVM informations and knowing in which positions are connected the EVR. Indicated in the cmd of the EVR

When more than 1 floor we need to know the « full path ». EVM Master + EVM Fanout




```
epicsEnvSet(FREQ, "88")
epicsEnvSet("CHANNEL_EVM_MASTER","2")
epicsEnvSet("CHANNEL_EVM","1"
#Load common Prefix
< iocPrefixEnv.cmd
```

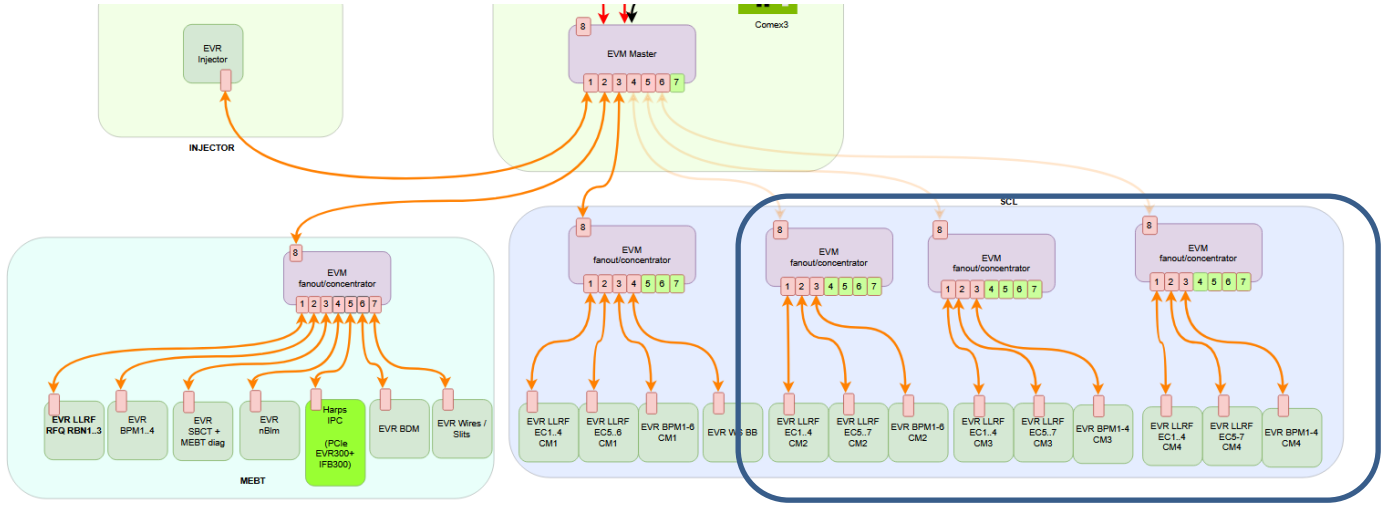
LLRF EVR configuration



RF conditioning

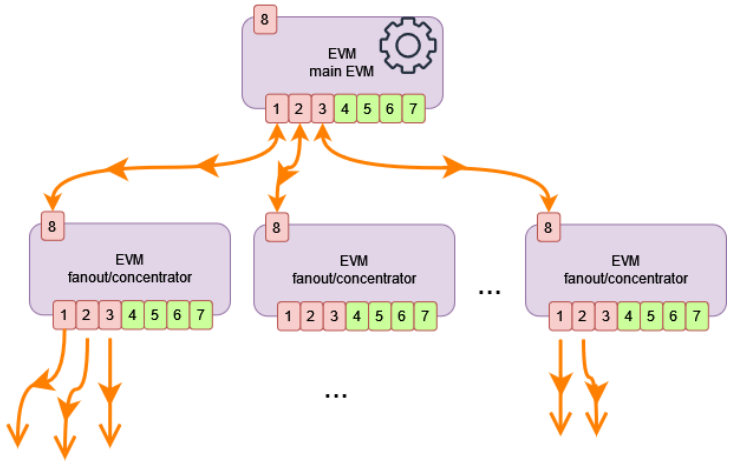
- Pilot Beam Mode
  - Standard mode where all EVMs and EVRs are connected as one tree.
  - Beam

- RF Conditioning Mode
  - We can dissociate any EVM from the rest to make it autonomous.
  - Allows independant RF conditioning operation.



RF conditioning for cryomodule 2-3-4

Pilot Beam Mode



RF Conditioning Mode