Experiment / LPC input to the MPP workshop 2019

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With input from many colleagues from the accelerators and the experiments

Covered topics

Interlock system:
Inputs from the experiments

Handling of Beam modes / Beam flags

Roman Pots

LHCb: Velo

Interlock handling in the experiments

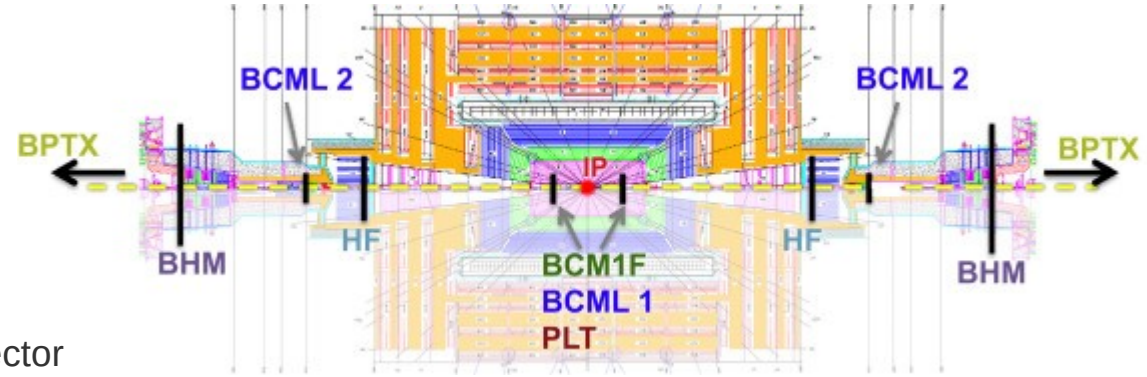
Overview table

- Overview of connections of experiments to
  - **Injection Interlock**
  - **Beam Interlock**
  - Connections always to the interlock of both beams
- Details in the following slides

	ATLAS AFP/ALFA	CMS	ALICE	LHCb	TOTEM/PPS
Injection Inhibit	Handshake	Handshake	Handshake	Handshake BCM ready	Pot position
Beam Interlock	Man. Switch AFP ALFA BCM Magnet (Abrt)	Man. Switch BCM Magnet (Abrt)	Detector Dipole	BCM Velo Magnet (Hw)	Pot Position

CMS Interlock strategy

- **No strategy changes are foreseen for Run 3**
- Magnet: Interlocks (i.e. dumps beam) on fast abort
- The control room interlock switch
  - A feature necessary to be able to test the interlock system
  - Was never used to dump the beam
- Current Beam abort system (BCM diamond detectors)
  - BCM system (Diamond detectors)
    - If beam backgrounds become bad and potentially dangerous for the CMS detector CMS dumps the beam
    - The inner tracker is well protected with this scheme.
    - Based on background measurements at 4 positions in CMS
    - Readout system from LHC BLM system (one relay replaced due to magnetic field)
    - Thresholds have been revised during the life of CMS due to necessary High Voltages changes in the BCM detectors (currently thresholds are a factor ~500 below the damage limit of the inner tracker)
  - 2 dumps recorded
    - UFO with high losses in ATLAS and nearby BLMs
    - Operator mistake



ATLAS Interlock system

- **No strategy changes for Run 3 foreseen**
  - Technically all the Interlock signals of ATLAS can be masked. Policies in the collaboration involving the relevant experts have to be followed.
- Control room switch
  - Was never used so far. Good for tests and emergency cases.
- Interlock on Beam Conditions
  - System based on signals from 2x4 BCMs, 2x6 BLMs
  - BCM thresholds set to equivalent of 250MIPs/cm^2 per 25ns
    - Logic to distinguish background from collision debris
    - Require 3 or 4 background signatures from one side above thresholds at least twice in one orbit or in two consecutive bunch crossings (the latter allows a single bunch to be dumped, in principle)
  - BLM thresholds set compatible to inner tracking detector damage limit
    - Using 40μs running sums. Require 2 from 6 signals above threshold at the same time for both beams
  - BCM interlocks can be masked if total beam intensity does not exceed 1.7e11 particles per beam
    - The same at injection energy since the *deposited charge* is relevant here

ATLAS interlock system

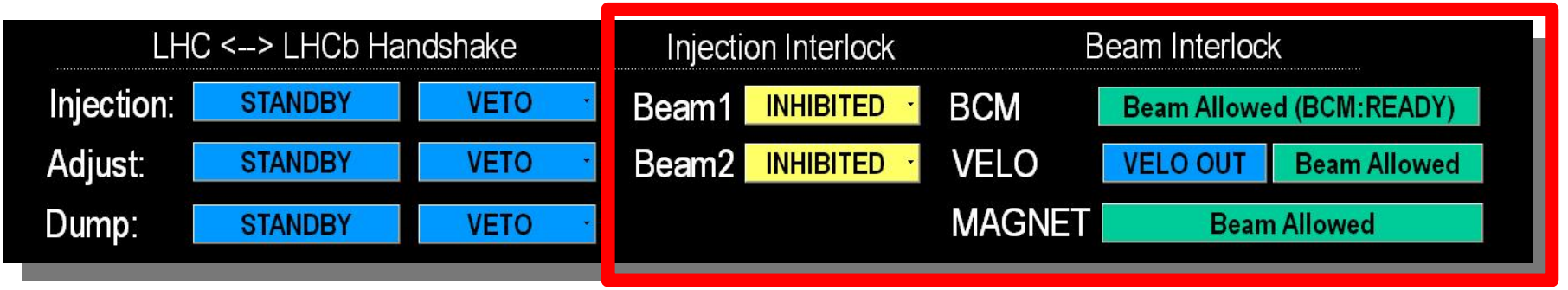
- Injection interlock
  - Multiple conditions on the state of the ATLAS subdetectors must are required to give beam-permit
    - e.g. high voltage values, pot positions
  - Injection key of shift-leader (hand-shake)
  - BCM and BLM can dis-allow further injection if already beam in the machine:
    - BCM: same logic as Beam interlock
    - BLMs: require 2/6 signals above threshold on at least one side
- Magnet interlock
  - Since 2014: Dump beam on fast Solenoid ramp-down
    - No dump on slow-abort or Toroid ramp-down
  - Handled by EP-DT-DI

ALICE interlock

- Dipole magnet state is connected to Interlock system
  - However no direct interlock when the magnet is ramping; The state of the magnet system must change to trigger the dump
  - Hence when the magnet is ramped accidentally with beam in the machine we dump on losses.
  - The Magnet interlock system is the same as the one of LHCb
- BCM interlock of ALICE
  - 7 (A-side) and 8 (C-side) BCM diamond detectors
  - Interlock logic based on 3 running sums (40μs, 80μs and 1.28ms)
  - A signal over threshold in three adjacent BCMs will dump the beam
    - Thresholds are different for pp running and PbPb running
    - Thresholds are higher when ALICE is in “safe” mode (outside Stable Beams)
      - (Factor 5-8 depending on the threshold)
    - Thresholds have been kept constant over Run 2 except for some high-lumi tests where ALICE ran with higher luminosity than usual
- Activities in LS2
  - Additional BCMs will be installed
    - Some tuning of the thresholds will be needed at Startup

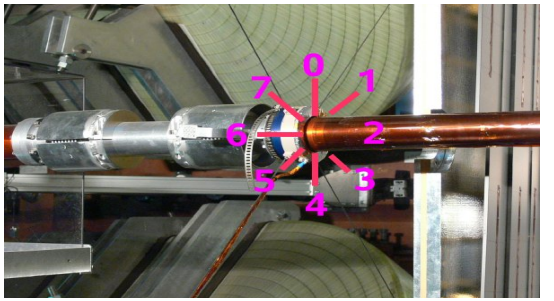
LHCb : Run 1 & 2

Three inputs to the Beam Interlock System:



- LHCb Magnet
  - Hardware state signal connected to Beam Interlock
    - No interlock on ramping magnet when the magnet state is “ok”
    - Same interlock system as ALICE
- VELO
  - Hardware signal “VELO in and SSB flag FALSE” or VELO in and Movable Devices Allowed in FALSE”
- BCM (Beams Condition Monitor)
  - Inhibit injection if BCM control system is not ready (via sw, but no dump). See next slide

LHCb: BCM in Run 1 & 2



- Based on 2 running sums (RS):
  - 2x40μs (short) and 32x40μs (long)
- System has no dependence on control/software
  - Immediately operational on power-up
  - Reset after dump normally by software but may be done with hardware
- Beam permit (Injection Permit) is false for O(2-3 min) after PM
- **Dump logic:**
  - Dump criteria based on three adjacent diamonds (short RS)
    Dump threshold for 2x40μs RS is set to 36k MIPs/sec per sensor
  - Dump threshold is multiplied by 10^3 at injection to avoid unnecessary dumps (“sun glasses”)
    - Done since the beginning of 2011 after investigation that our thresholds were too tight
- Dump thresholds ‘hardcoded’ in VHDL code
  - Need recompilation of firmware if needs to change them
- BCM ready is to be acknowledged by shifter before accepting

LHCb : Interlocks in Run 3

- No change to LHCb Magnet System
- VELO
  - Interlock on hardware signal «VELO in and SSB flag FALSE»
    - Movable Devices Allowed In flag will be ignored
      - Simplifies the logic
      - SSB False and Movable Devices allowed = True never happened (would be UNSTABLE BEAMS which is in discussion to be removed anyway)
- BCM (Beams Condition Monitor)
  - Hardware and interlock logic remains the same (as of now)
  - New thresholds to be computed based on higher brightness from beams, based on new calibration and based on new higher instantaneous luminosity
  - Include the possibility to mask dump whenever injection studies are being performed (to speed up inject and dump)

Accelerator and Beam Modes

Accelerator & Beam Modes

- Why is this a topic for the experiments:
  - Accelerator and Beam modes represent the states of the LHC state machine
  - Experiments trigger automatic actions on state changes
    - In particular: HV and LV systems are ramped up and down
    - Part of the safety actions to protect the detectors from potentially dangerous situations
  - Unforeseen changes (i.e. changes not foreseen in the state model) or unexpected changes trigger unexpected transitions in the detector state (or even worse, situations which need experts help to resolve)
  - State changes can be triggered by human beings (CCC shift crew can decide or overwrite state changes) → unexpected state changes may happen
    - This leads to situations (~ 1 time per year) where detectors where powered down at the wrong moment →beam time lost for the relevant detector
    - In CMS the topic was particularly sensitive during the time of the DC-DC converter problem in the PIXEL: power-cycles lead to loss of channels
    - However CMS discussed with OP and concluded that the current system can stay in place as it is.
      - It is safe for the detectors
      - It is good enough so that a complete re-design seems not justified (no significant beam time loss for anybody so far)

Input from Experiments

- Ongoing discussion in OP and with Experiments
  - Remove states which have never been used or are mis-leading:
  - “UNSTABLE BEAMS”, “INJECT & DUMP”, “CIRCULATE & DUMP”
  - Needs careful evaluation of options how to remove and technical consequences
  - Existing software should not breakATLAS, ALICE, CMS and LHCb
- Judgement of the experiments:
  - No objections to remove “UNSTABLE BEAMS”, “CIRCULATE & DUMP” and “INJECT & DUMP”
    - LHCb *would like* UNSTABLE BEAMS to be removed

Roman Pots

ALFA/AFP [ATLAS]

PPS [CMS] / TOTEM

ATLAS RP Interlocks

- Interlock of Roman Pots (ALFA and AFP)
  - AFP and ALFA have independent connections to the interlock system since they are used in different occasions independently from each other.
  - Override keys in CCC exist
  - Signals into the BIS can be masked
  - In general only one beam is dumped
  - Logic for both systems (ALFA & AFP)
    - Dump if Pots are outside of the allowed position range (LVDT values)
    - Pots are not in “Home” position AND “movable devices allowed” flag NOT active leads to beam dump
    - Pots 150µm closer to beam than settings → spring retraction of pots
    - Pots more than 200µm closer to beam than settings → spring retraction AND Beam-dump

ATLAS RP -“incidents”

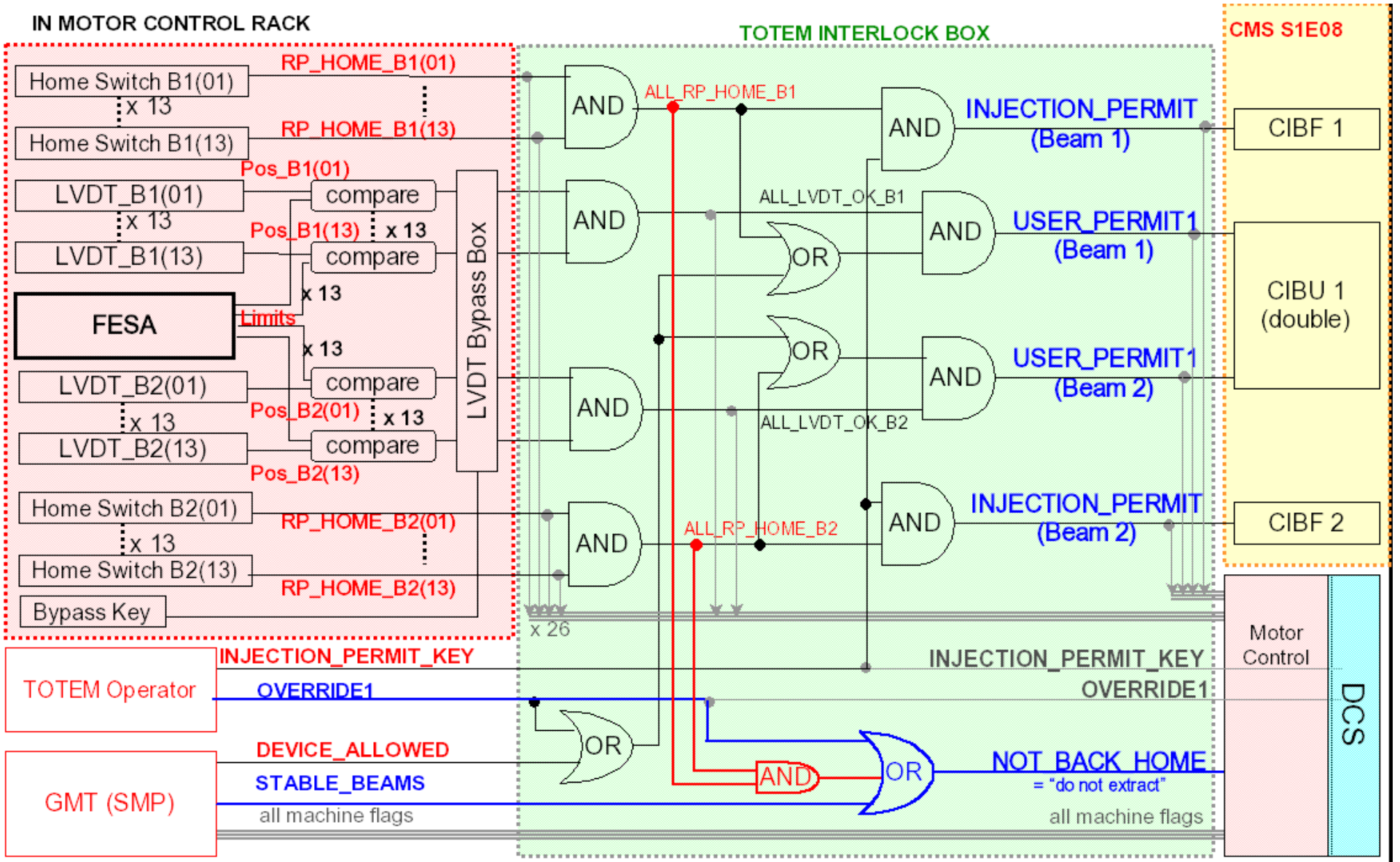
- 2018 AFP pot “C-near” was retracted several times and caused one Beam dump
  - Traced down to cross talk of cable to vacuum pump for the AFP secondary vacuum to LVDT cable
  - Solution: use different cable for vacuum pump
- Similar problems have been observed in ALFA in 2017/2018
  - One beam dump in 90m run due to noisy LVDT readings in ALFA
  - No different cable for vacuum pump available:
    - Decide to leave pump continuously ON during ALFA special runs
      - The switching process causes the LVDT reading spikes
- ATLAS observed one “drifting” LVDT which was replaced
- 2018: AFP pot did not reach Home after spring-retraction
  - Needed expert intervention to solve
  - Established procedure to give ATLAS injection permit not to block LHC
    - No operation of AFP until problem resolved
  - Temporary fix after TS1: changed Home position of switch by 0.65mm
  - Extra springs might be installed in LS2
  - Exact cause of the incident is being investigated (during LS2)

ATLAS Run 3

- AFP is concerned about increased heating of the pots with LIU beams
  - Additional cooling capacities will be provided
  - Tests are foreseen in 2019

Interlock logic TOTEM

Regularly discssed in MPP; **no changes foreseen**



TOTEM / PPS Roman Pots

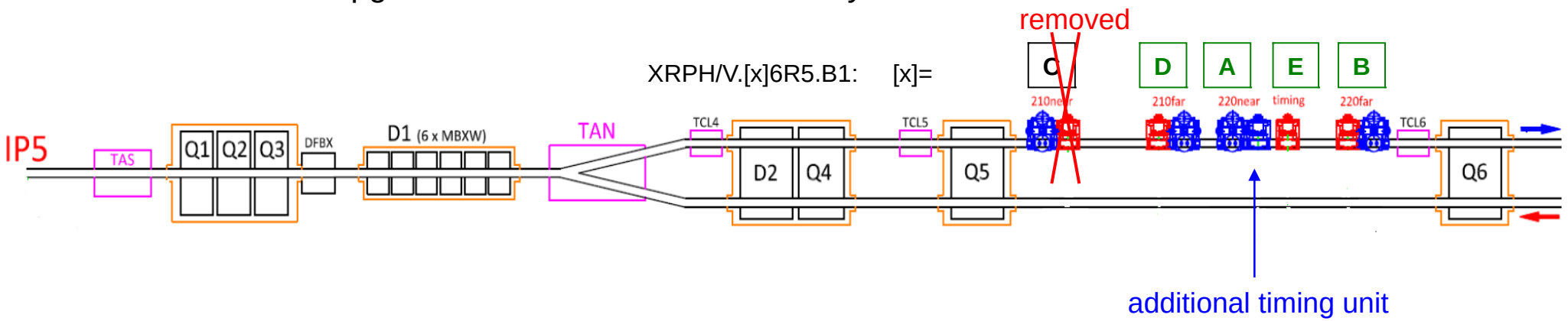
- LVDT issues
  - In general problem with the Amplifier for the LVDT signals
  - No redundancy (one LVDT per pot)
  - TOTEM: One spurious dump on high LVDT reading in 2017
  - Implemented mitigation (as done in ALFA and AFP):
    - Require 3 consecutive readings beyond threshold (10ms interval) before dumping
  - No change for Run 3 foreseen

PPS: LS2 Activities and Recommissioning

LS2 activities:

- CMS beamline levelling including Roman Pots
- New detector packages for all existing tracking and timing Roman Pots
- Empty Roman Pot unit XRPH.A6 to be equipped with diamond detectors in addition to XRPH.E6 .
  (→ two Time-Of-Flight measurements per side of IP5)
  → Full metrological survey of all Roman Pots needed

- Maintenance and upgrade of Roman Pot movement system



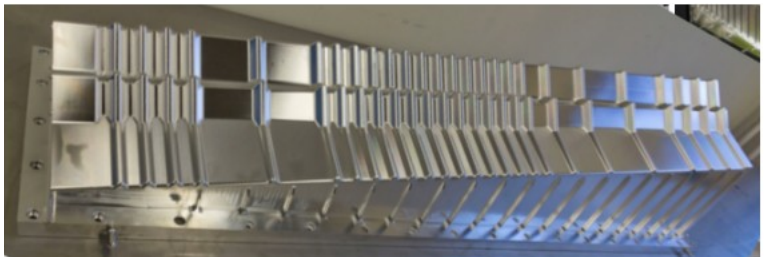
Commissioning:

- Movement and interlock tests in cooperation with MPP and OP
- Beam-based alignment in cooperation with collimation WG, validation by MPP
- Calibration data for new optics configuration (same fill as beam-based alignment).

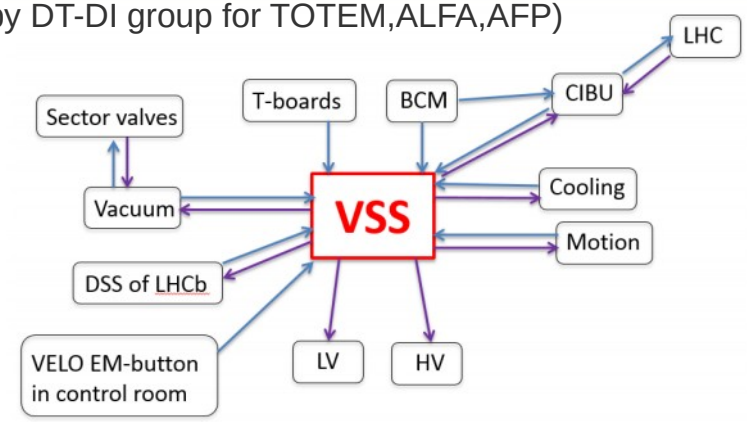
LHCb VELO review in MPP

Specific items: new LHCb VELO

- LCHb : Review of the new Velo system
  - Dedicated MPP meeting on 25/1/2019
  - Safety aspects of Run 2 and for the new VELO system discussed



- New VELO
  - New RF foil separates detector package from primary vaccuum
    - 3.5mm clearance from beam (and 0.9mm from detector)
  - New cooling system based on evaporating CO_2 running in micro-channels embedded in the 500µm substrate
  - Only minor changes to movement system which operated successfully in Run 1 & 2
    - Change to new PLC based on NI PXI-FPGA module (originally developed by DT-DI group for TOTEM,ALFA,AFP)
- VELO safety system
  - Inputs from Cooling, movement system and Vacuum systems
  - The new centralized system will be based on NI Compact RIO-FPGA system (originally developed for TOTEM)



LHCb VELO VSS LAYOUT

- Conclusions of Review
  - The manual retraction of the VELO should be possible without damage to cables and be tested every year
    - Follow up from incident at the end of 2018 where VELO got stuck due to powering problems of the motion system
  - The functional specifications for the new CO_2 cooling system need to be documented and reviewed. Failure scenarios have to be described with the expected consequences.
  - The new movement safety system will be reviewed