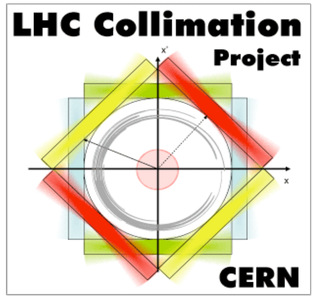

Collimation upgrade: transition from LS2 to Run 3 operation

Stefano Redaelli, BE-ABP, on behalf of WP5 & LHC Collimation team

12th HL-LHC Collaboration Meeting
19-22 September, 2022
Uppsala Universitet, Uppsala, Sweden

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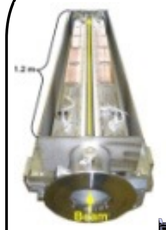
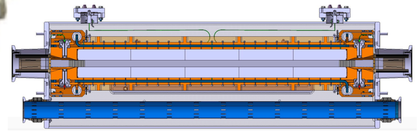
Introduction: WP5 upgrade items

LS3

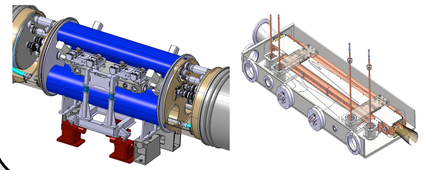


IR collimation: Completely new layouts and collimator designs:
IR1+IR5: incoming and outgoing.
Full remote alignment system (FRAS)

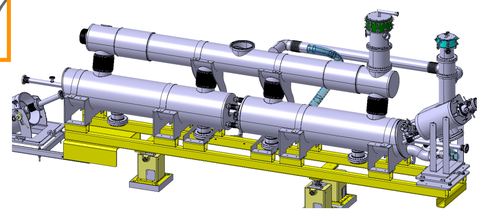


Deferred

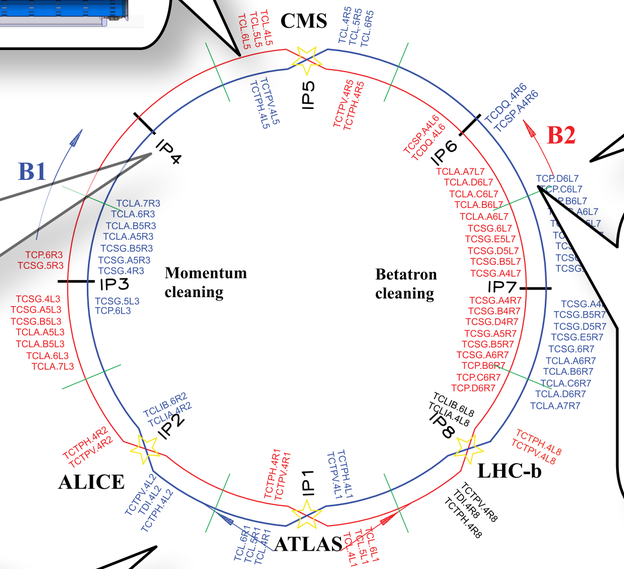
Dispersion suppressor collimations: betatron halo cleaning, DS collimators between 11T dipoles



Descoped from LS3

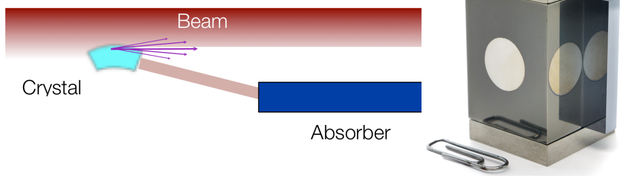


Hollow electron beam: 2 lenses
I_e = 5 A; l = 3 m; En = 10-15KeV; **IP4**



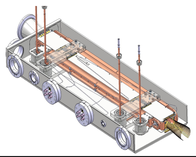
LS2+YETS

Crystal-assisted collimation (Pb ions)
4-8 bent crystals, 50 µrad bending
IP7 (betatron cleaning)



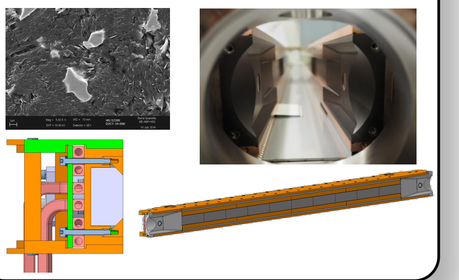
LS2

Dispersion suppressor collimation: Secondary beams from ion physics



LS2+LS3

Impedance reduction: low-impedance, high robustness secondary collimators: coated MoGr
Un-coated MoGr primary collimators.



LS2

Consolidation (not HL): low-impedance primaries (material from WP5), renew controls, maintain / replace rest of system

Collimation upgrade scope: LS2 and LS3

- **Upgrades in the second long shutdown (LS2)**
  - **Dispersion suppressor collimation:**
    - 2 **TCLD** collimators around IR2 for ALICE luminosity upgrade
  - **First phase of the low-impedance upgrade of the system**
    - 8 new secondary collimators make of Mo-coated MoGr (**TCSPM**) IR7
    - MoGr (uncoated) material for 4 new primary collimators (**TCPPM**) in IR7
  - **Upgraded betatron cleaning for heavy-ion beams**
    - 4 crystal primary collimators (**TCPC**) in IR7 (two installations: YETS2021-22 and YETS2022-23)
  - [CONS] New passive absorbers (**TCAPM**) for improved warm-quadrupole lifetime
  - Including spares, 22 new collimators built in LS2
- **Upgrades in the third long shutdown (LS3)**
  - Second phase of the low-impedance upgrade: 10 **TCSPM** in IR7
  - New collimation layouts in IR1/5: 20 movable collimators; 12 fixed masks (**TCT***, **TCL*, TCLM**)

The LS2 upgrade provides an improved collimation performance for Run 3!

Backup slides: more details on new designs

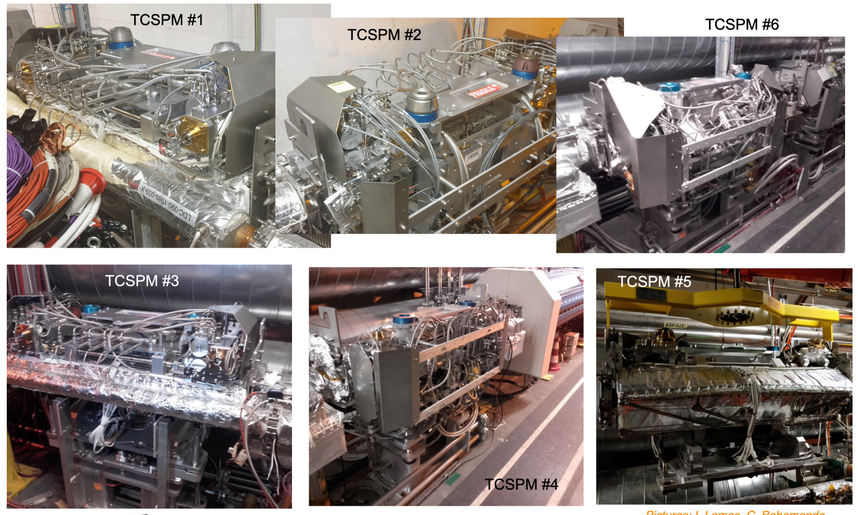
LS2 activities — completed

Important steps for the HL-LHC collimation upgrade carried out in LS2

- Dispersion suppressor collimators, IR2
- Low-impedance secondaries (coated), IR7
- Low-impedance primaries, IR7
  (consolidation items; new material from HL-LHC)
- Passive absorbers for IR7

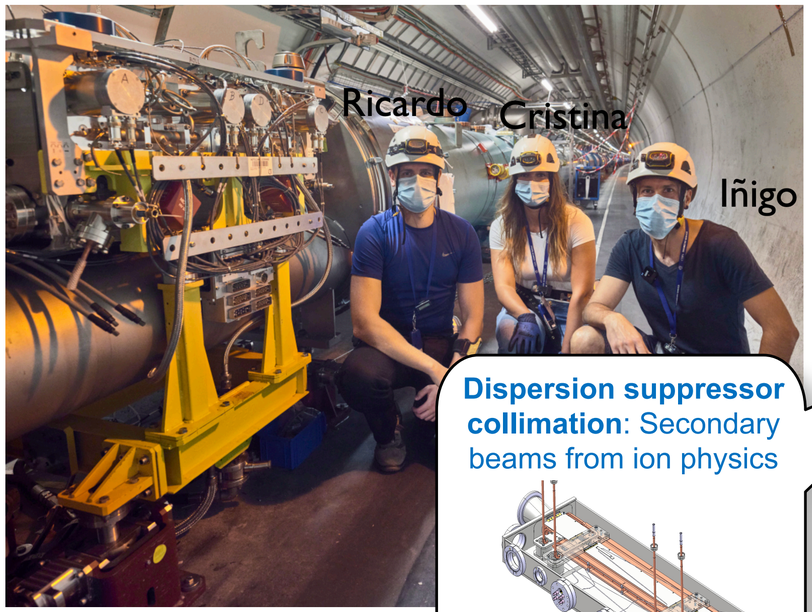
22 collimators built, 18 for installation (4 spares)

Coated secondary collimators: 8 installed IR7

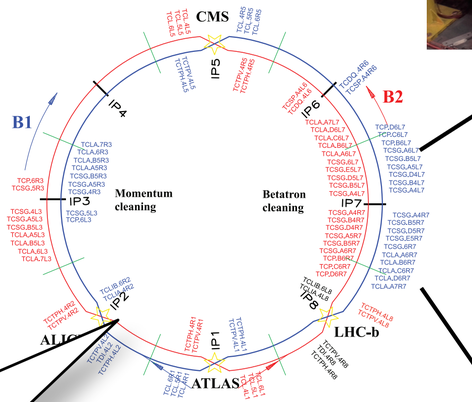


Pictures: I. Lamas, C. Bahamonde

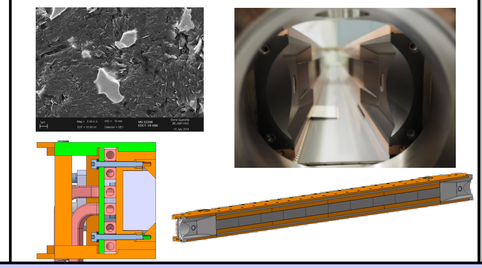
Very successful collaboration across several groups in the ATS sector! Particular thanks: SY/STI.



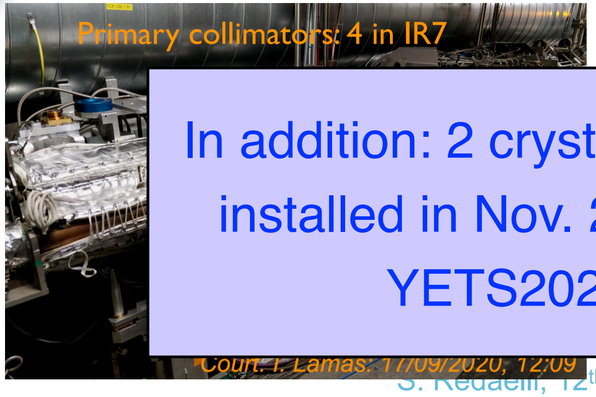
Dispersion suppressor collimation: Secondary beams from ion physics



Impedance reduction: low-impedance, high robustness secondary collimators: coated MoGr
Un-coated MoGr primary collimators.



Primary collimators: 4 in IR7



In addition: 2 crystal primary collimators (TCPCs) installed in Nov. 2021; 2 will be installed in the YETS2022-23 (+2 spares built)

Coll. I. Lamas: 17/09/2020, 12:09

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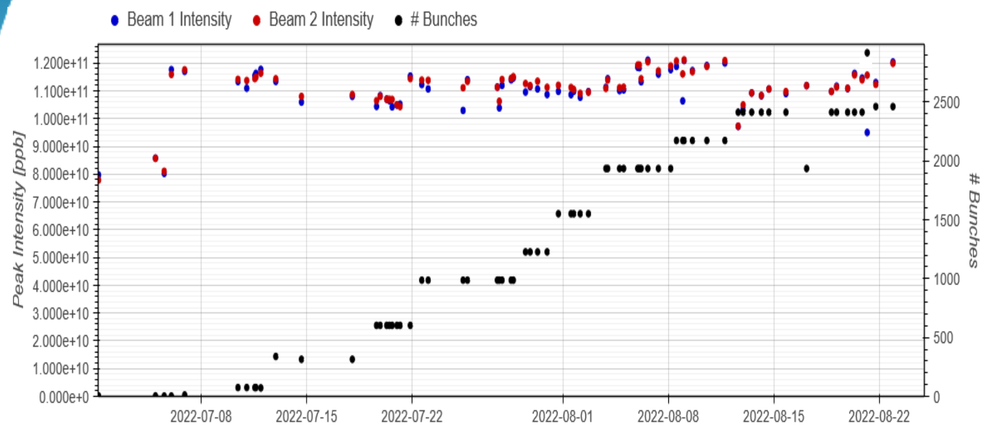
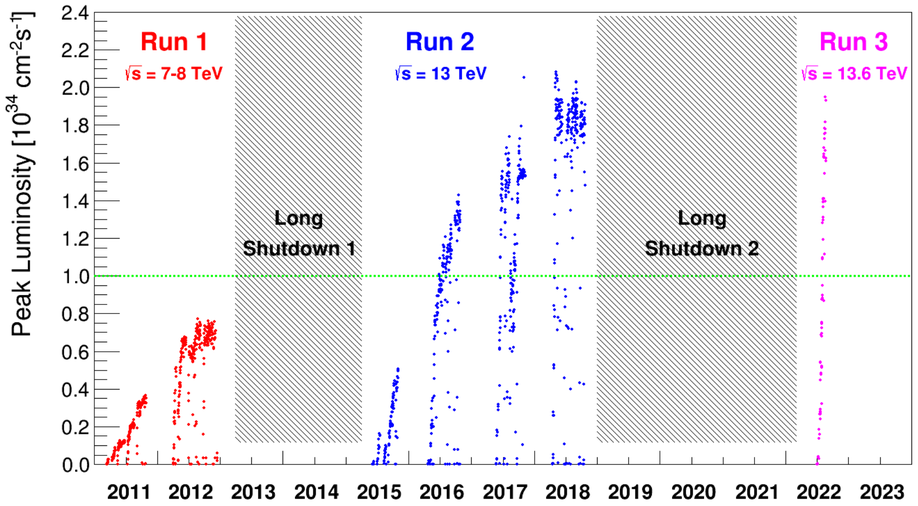
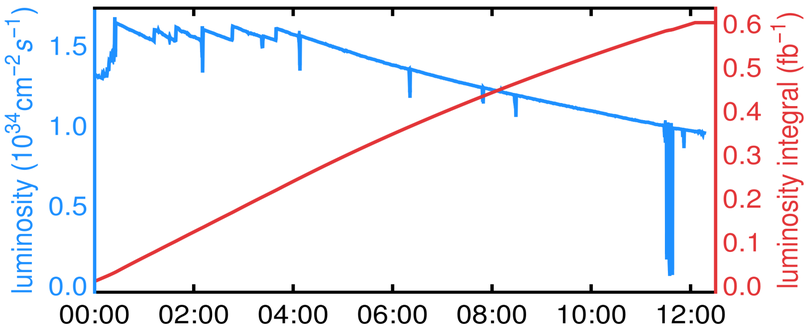
LHC status in a nutshell







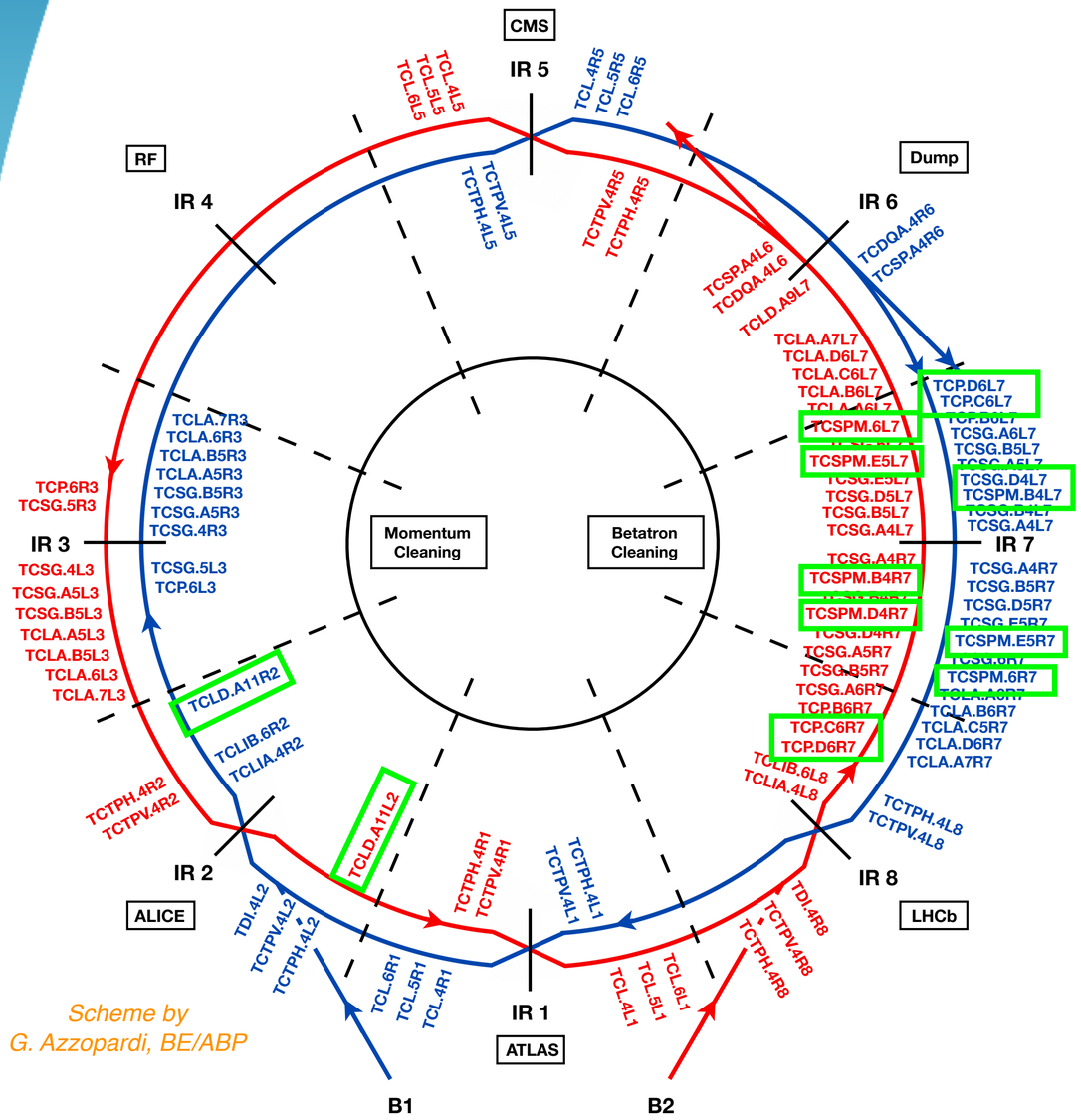
Various operational aspects in 2022 are already particularly relevant for beam collimation:

- **330 MJ of beam stored energy at 6.8TeV**
  - No quench from circulating-beam losses
- **Peak bunch current ~ 1.25 x 10^{11} p**
- **Peak luminosity close to 2 x 10^{34}cm^{-2}s^{-1}**
- **Luminosity levelling schemes**

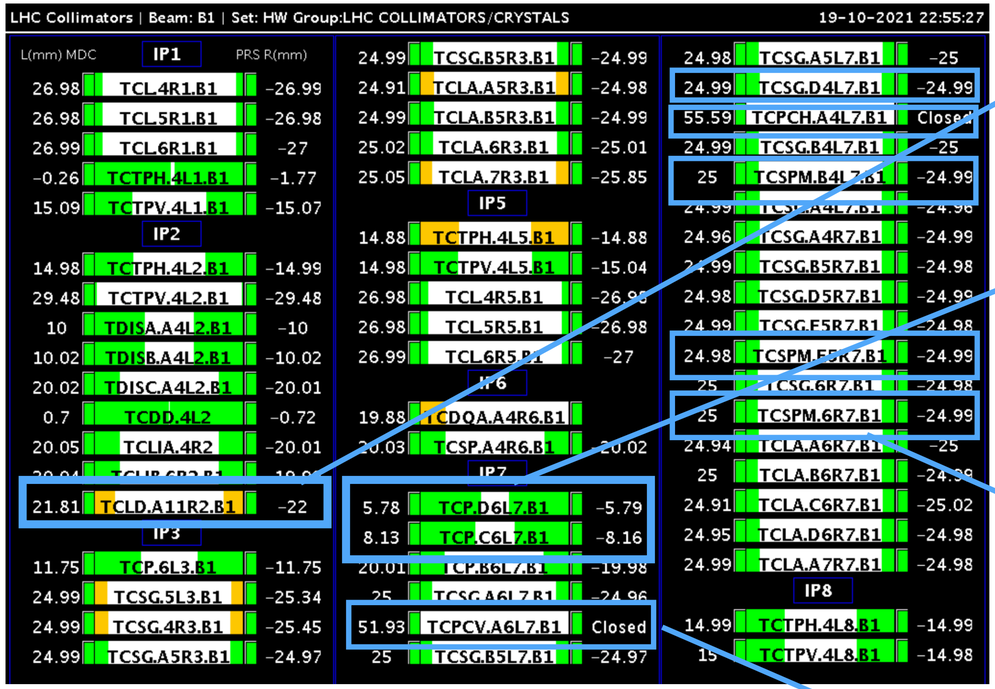
WP5 LS2 upgrades:
- Improve performance in view of the progressive deployment of LIU beams (in particular for ion beams)
- Reduce workload from LS3
- Validate some key upgrade choices

New devices available and the Run 3 performance can profit from them!

The upgraded collimation system for Run 3



Scheme by G. Azzopardi, BE/ABP



TCLD: dispersion suppressor IP2

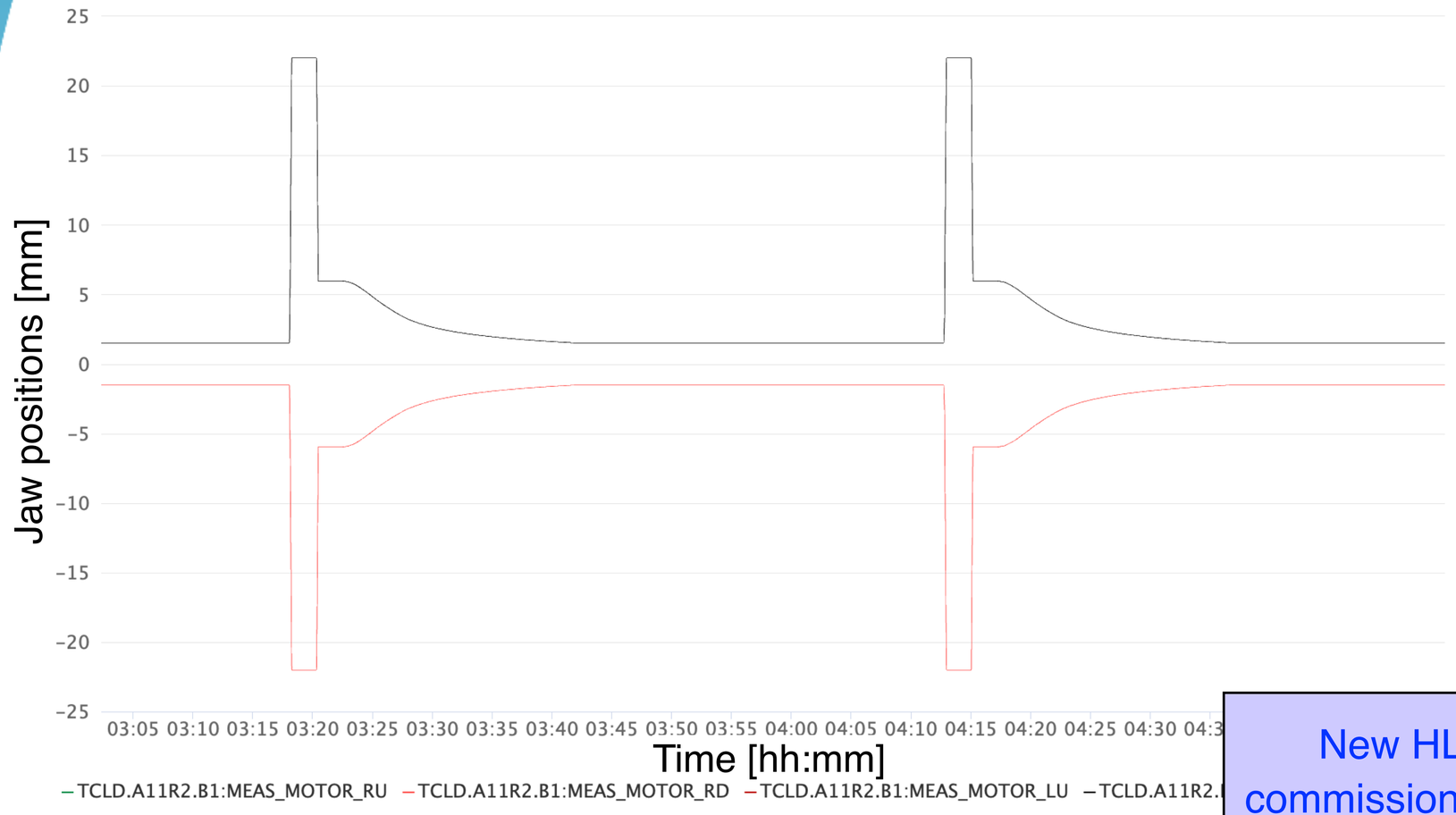
TCPPMs: New primaries

TCSPMs: New secondaries

TCPCs: New & old crystals

2021-22 hardware commissioning → OK!

"Stress tests": order of hundred full-cycle functions executed by all collimators



Machine protection tests: verification of all interlocks

	Status
Position/Gap Interlocks	
Local Mode Interlock	
Test Power Cut and PRS Reboot Interlock	
Test temperature interlock	
Test RBAC interlock	
Test MCS-Collimator role info	
Goniometers Replacement Chamber Interlock	

Collimation system testing and commissioning, following the MPS procedure EDMS-889345.

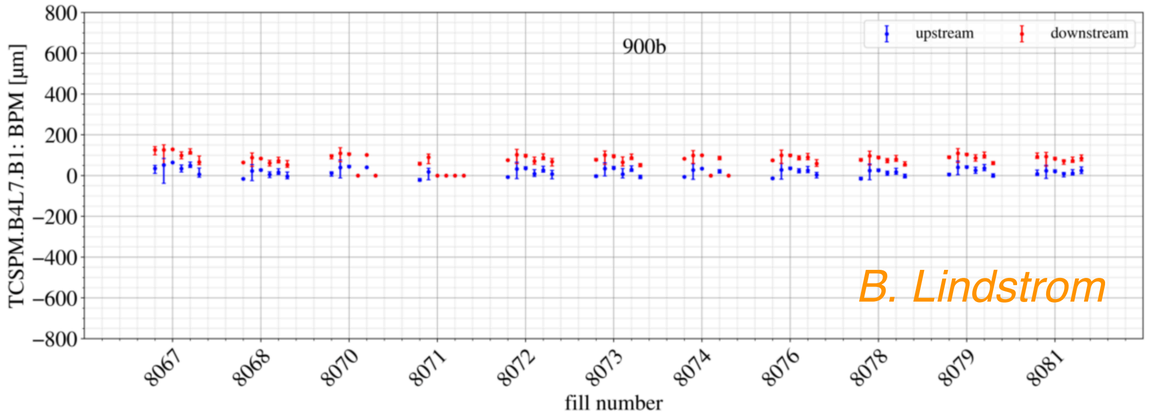
New HL-LHC hardware was part of the commissioning without and with beam from the beginning (2021 pilot run & 2022 operation)

Details: Collimation Working Group, #265 (talk by D. Mirarchi, BE/OP)

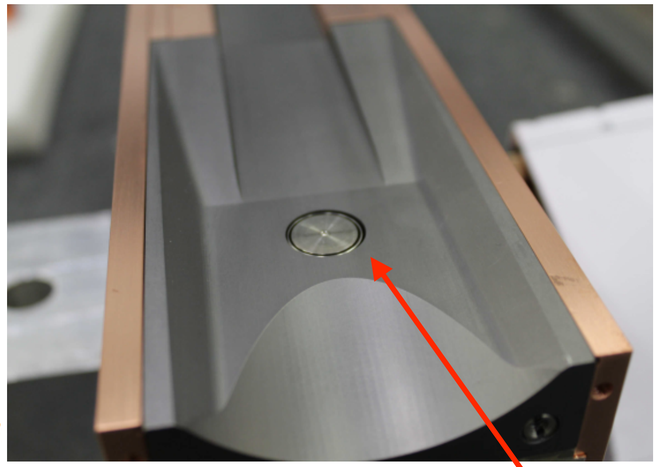
New BPM collimators in operation

- BPMs are the collimation “eyes” that allow faster alignment, continuous orbit measurements and beam interlocks
  - Now 12 IR7 collimators with BPM (before only around experiments and in dump region)
- Enable verification of collimator tilt → identified a few collimators that were re-aligned
- Adds operational flexibility: critical asset for levelling at HL-LHC

Thanks to the SY/BI team.

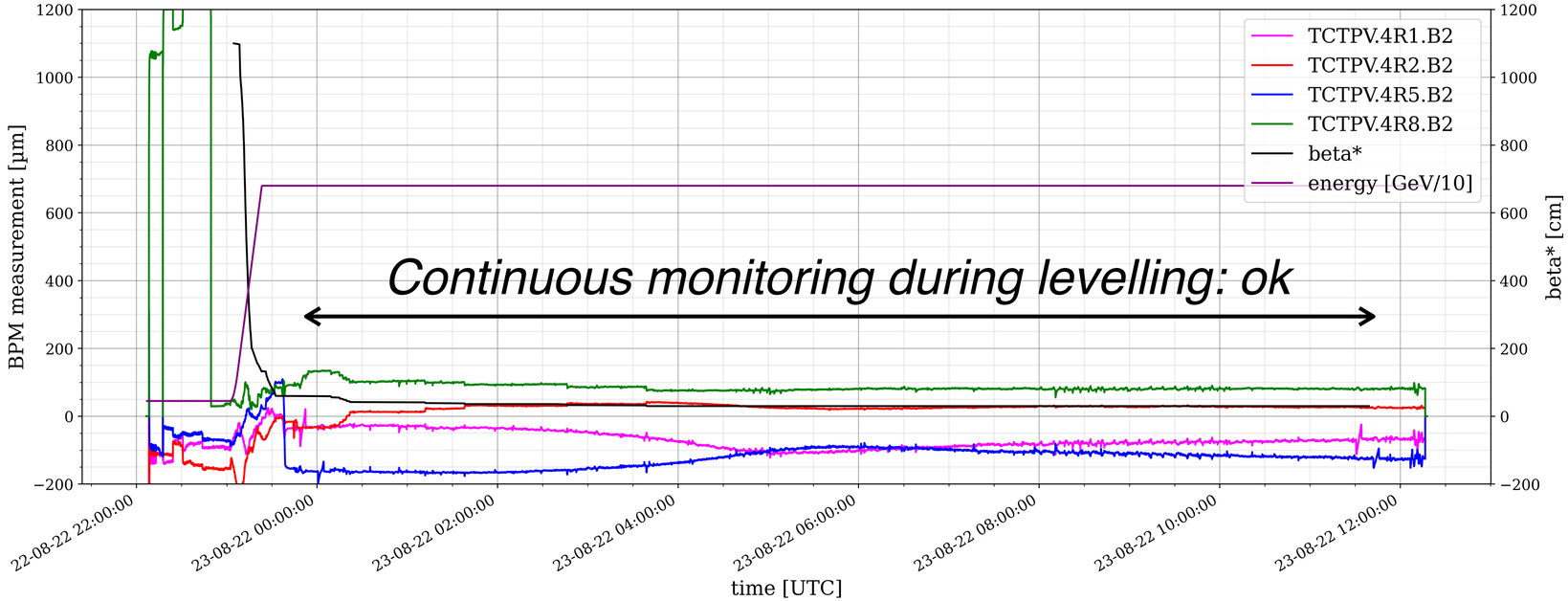


B. Lindstrom



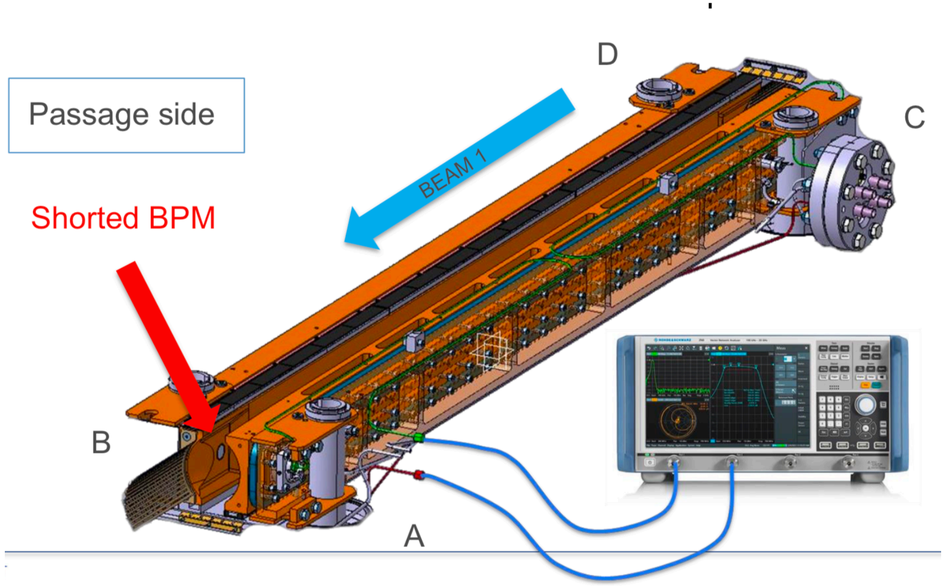
F. Carra

BPM Pick-up Button

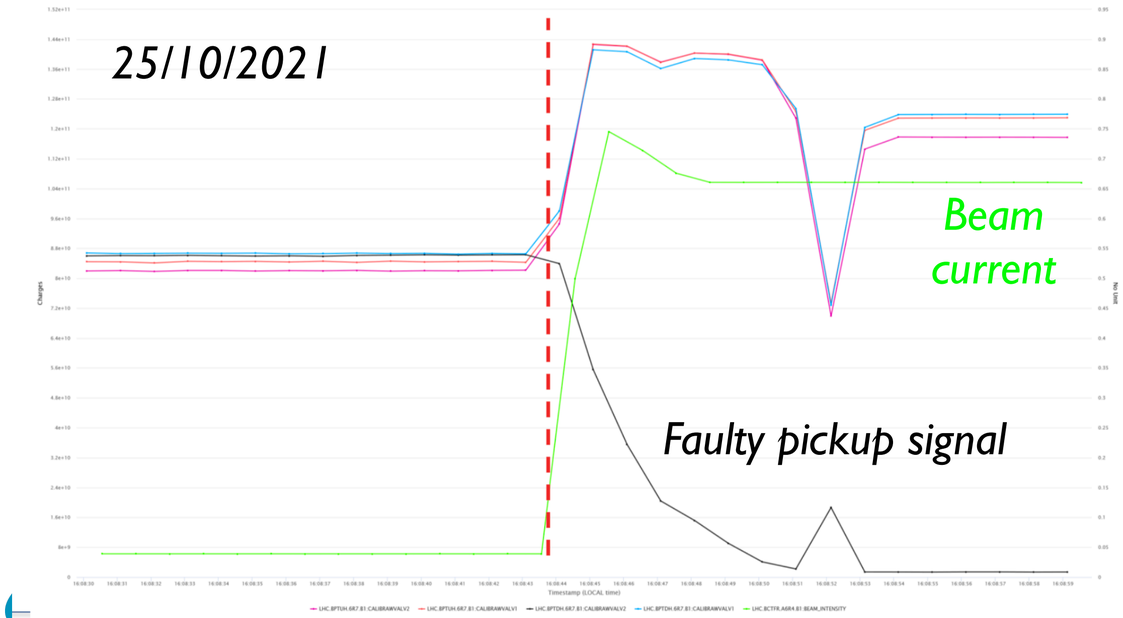


Issue of short in a collimator BPM — fixed!

- ✓ The HCTCSPM001-CZ000004 was installed in the slot TCSPM.6R7.B1 during LS2.
- ✓ The BPM acquisition chain was successfully tested and validated after the installation.
- ✓ The BPM acquisition chain + DOROS were verified with beam on 23/10/2021.
- After checking the logged data we found that the LHC.BPTDH.6R7.B1 was not sending the expected signal to DOROS.
- On the 12th of May during the access period, a short circuit of ~1.5 Ohms was detected on the LHC.BPTDH.6R7.B1 channel.



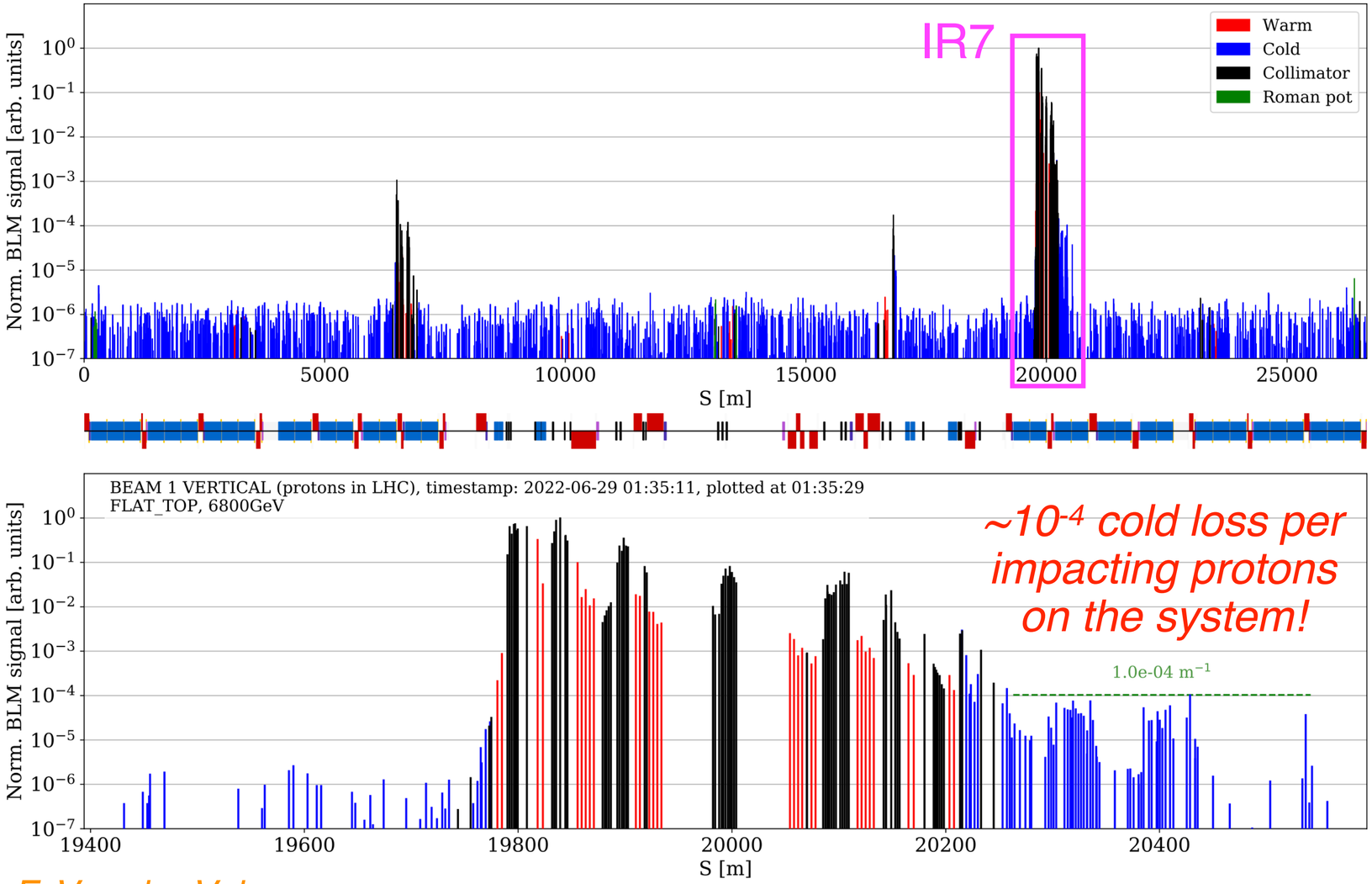
By checking the logged data it was possible to trace back the error to 25/10/2021.



On May 17th, the SY-BI team intervened in IR7. After a detail diagnostic to **localise the short**, it was "burned away" by applying a small current <200mA

- Orbit measurements at this collimator fully back in operation and operational since then

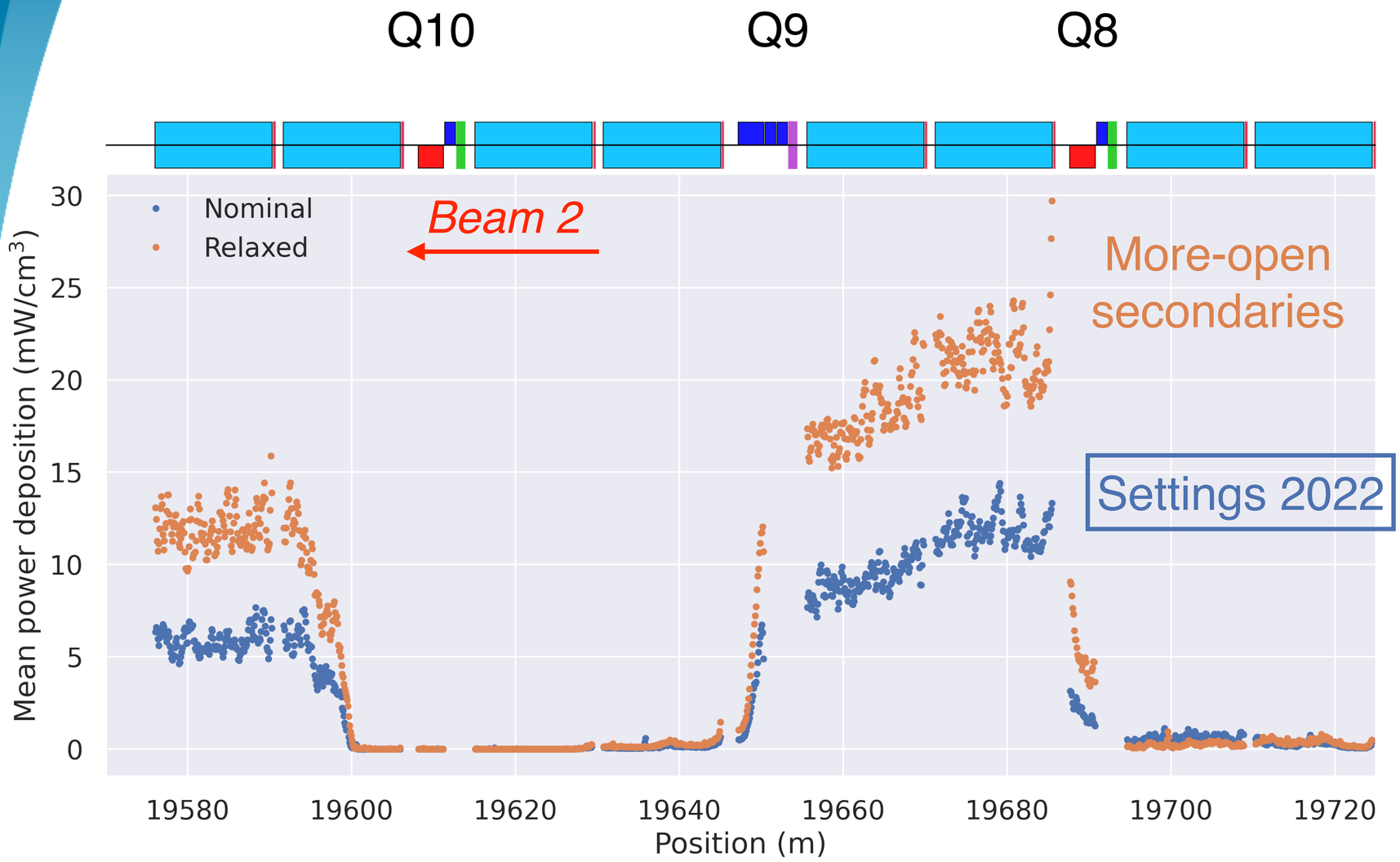
Collimation cleaning performance



- The system setup in 2022 worked smoothly and profited from the new BPM collimators
- Similar settings as in 2018 used: cleaning performance at the level of 10^{-4} achieved
  - *No quench so far from circulating-beam losses!*
- New material of primary collimators provides an improved cleaning performance

F. Van der Veken

Expected energy deposition in cold magnets

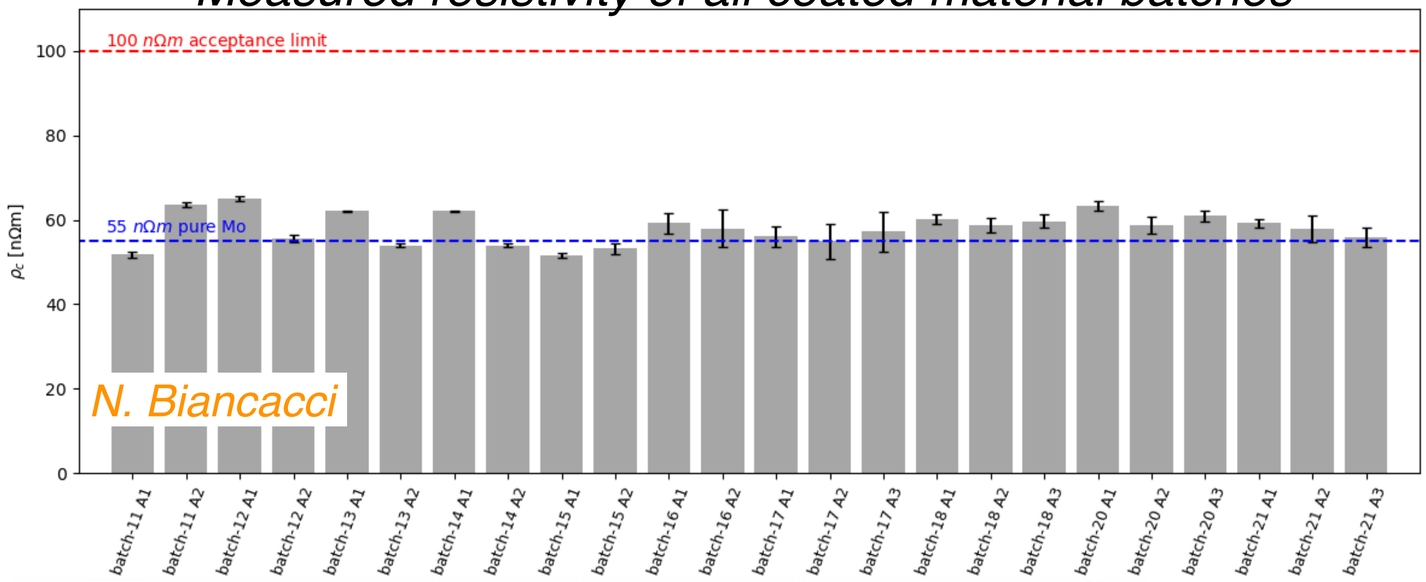


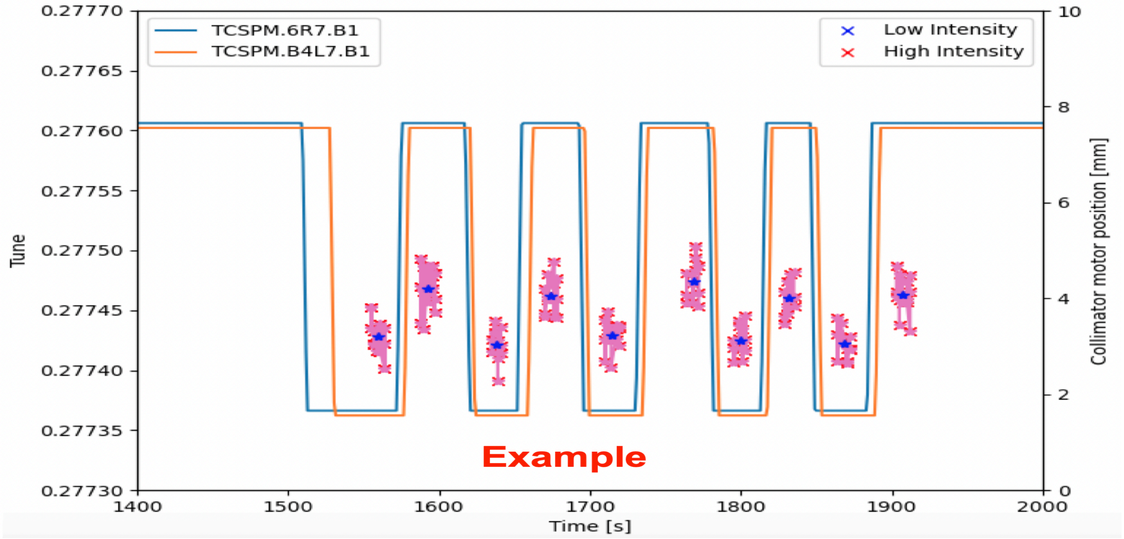
- Peak losses for 0.2h lifetime (scaled to HL-LHC parameters) produce ~15mW/cm^3 in the DS dipoles
- New TCPs improve cleaning by 15-20%
- *"More-open settings" conceived to perform quench tests in 2022, providing +50% in peak losses.*

P. Hermes, V. Rodin

First look at collimator impedance

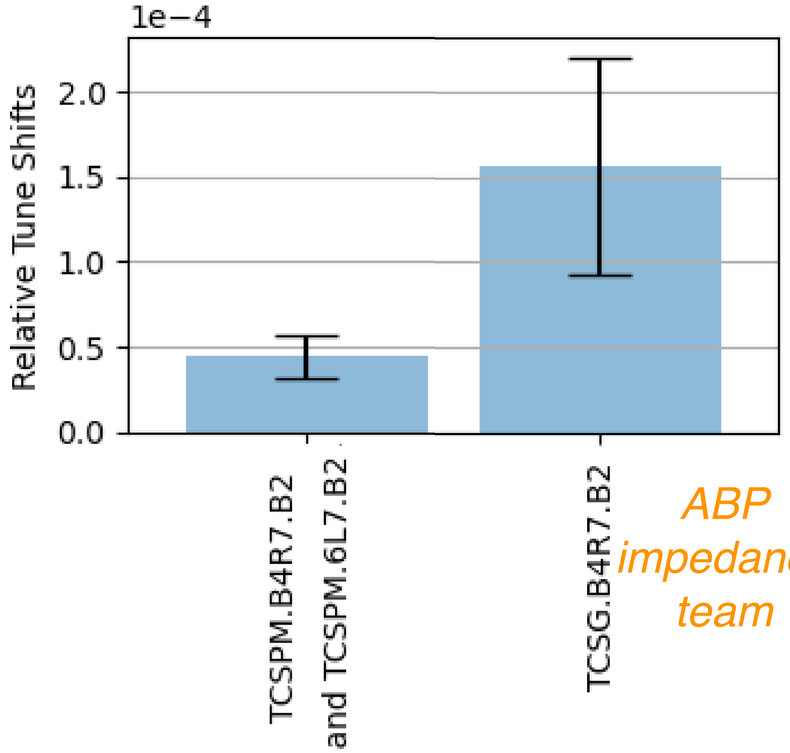
Measured resistivity of all coated material batches





A. Kurtulus

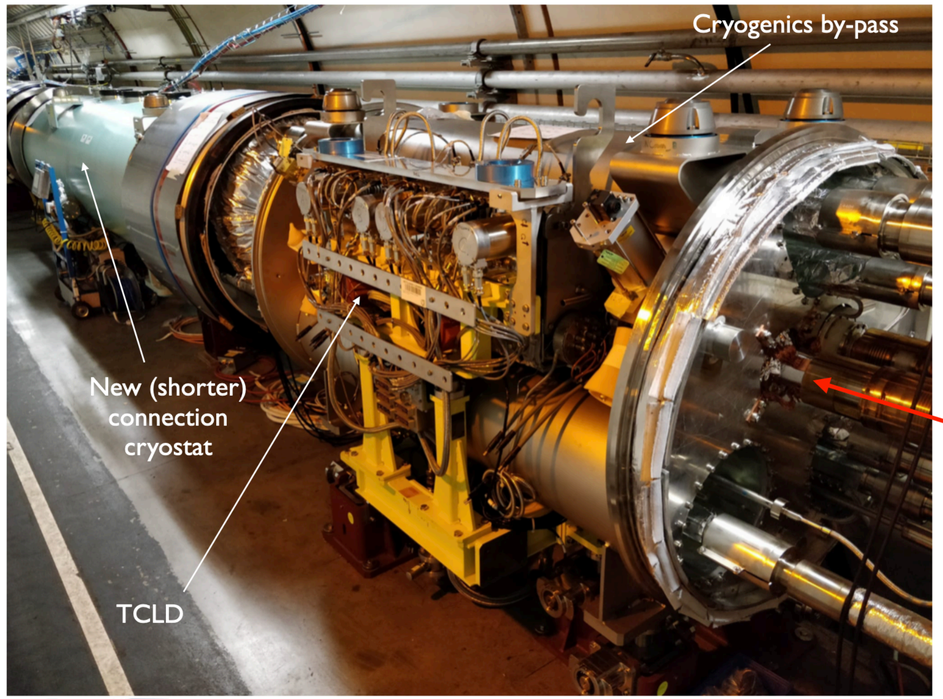
MoGr+Mo **CFC**



ABP impedance team

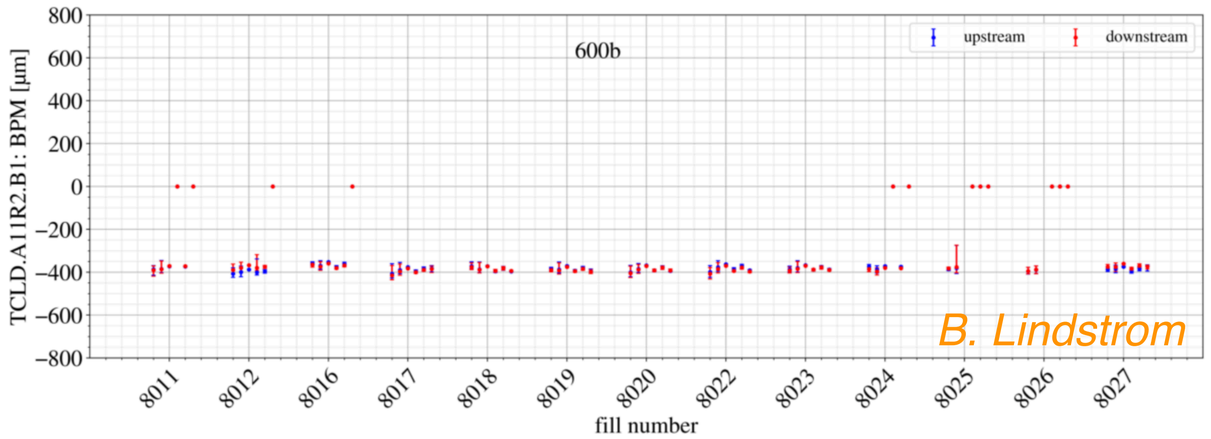
- Comparison ongoing with models to assess with beam the surface resistivity and the overall impact on stability models
- Measurements need to continue with higher bunch current.

TCLDs: waiting for Pb ion collisions

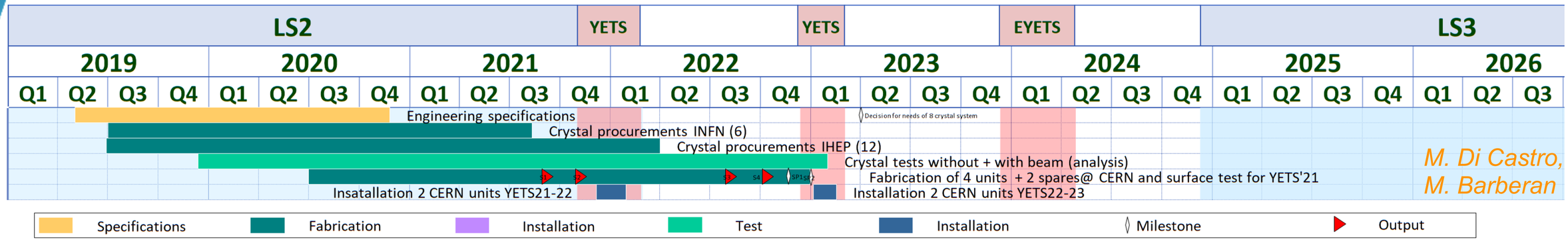


For the ALICE upgrade: TCLD at the connection cryostat will catch secondary beams from ion collisions. 1 TCLD per side.

- Part of the HW and beam commissioning
- Kept open during proton operation
  - Checked at every fill to confirm the operational state and controls and interlocks
- BPM checked — TCLDs are very well aligned



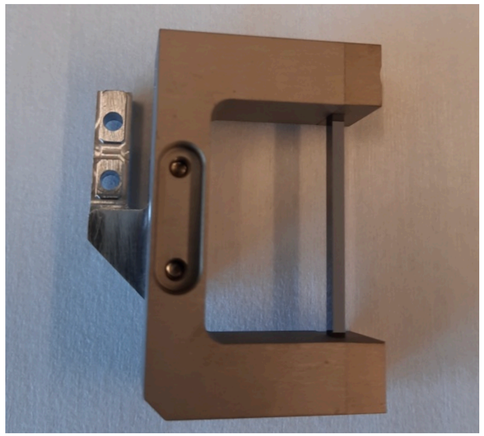
Crystal collimation update — a crash effort



M. Di Castro, M. Barberan

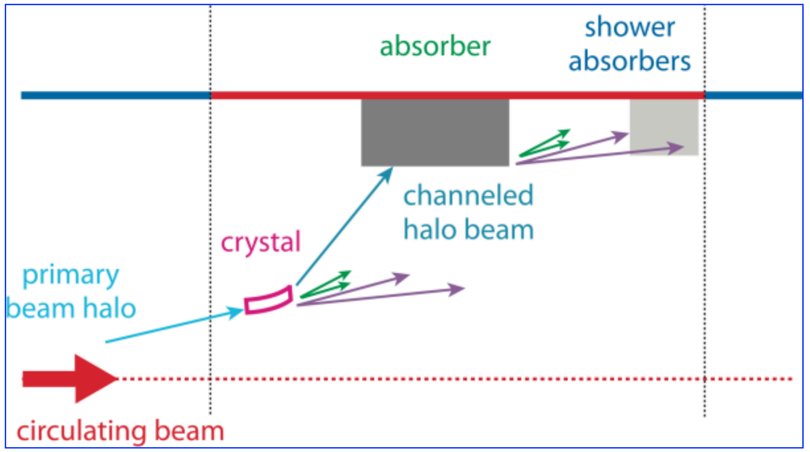
- Schedule established after Russian in-kind delays: full internalisation at CERN (6 units)
  - Two installation campaigns in YETS2022 & YETS2023
- TCPC assembly production at CERN fully on track for the remaining 4 devices
- Bent-crystal productions had some delays, but we received in 2021 enough crystals for the installation goals (INFN-Fe delivered by now all crystals; PNPI delivery on hold in 2022).

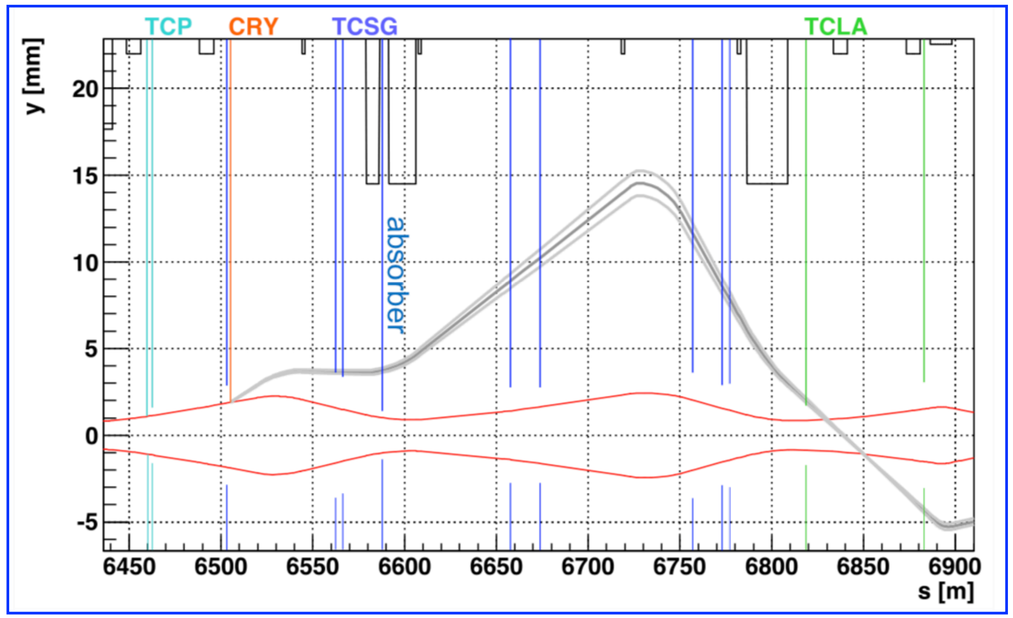
Courtesy Y. Gavrikov

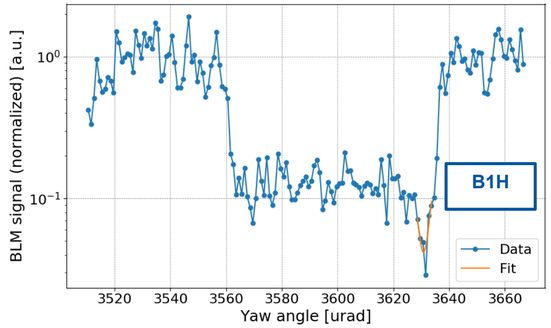


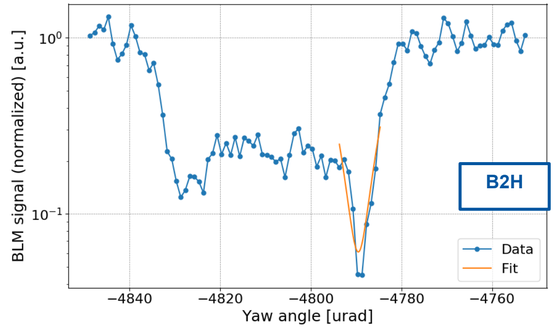
M. Di Castro

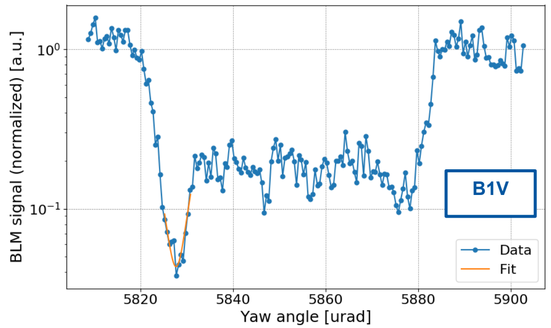
Angular scans at 6.8 TeV (protons)

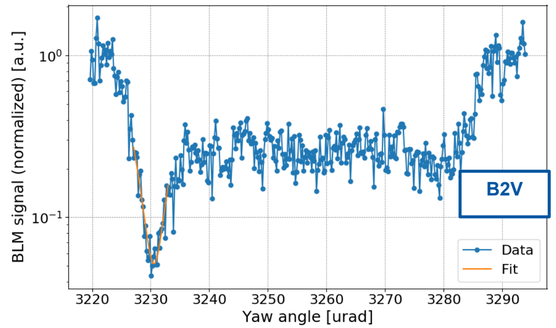












M. D'Andrea

- All 4 crystal devices operational: good performance observed with protons
- Plan to use them already in the 2022 Pb ion run

TCP = primary collimator
TCSG = secondary collimator
TCLA = shower absorber

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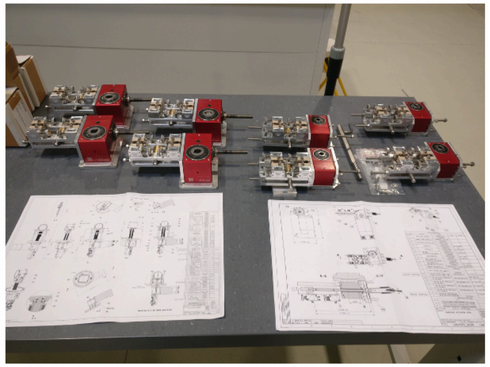
LHC installation milestone

- Installation of 2 TCPCs planned in the YETS2022-23
  - Replace the two horizontal crystals from Run 2
- ECR in circulation, after presentation to the TCC (25/09/2022)
- Identified the best crystals in the pool of 6 available from INFN and PNPI (14/09/2022)
  - Following a complete validation of crystals, including X-rays (BE/CEM) and SPS beam (UA9 collaboration) tests — many thanks to the teams involved

TCPC tanks components under production and linear stages assembled (courtesy of SY-STI)



Next steps in Run 3

The issues with Russian in-kind and recent baseline changes affected strongly WP5:

- **11T dipoles** → LS2 installation deferred
- **Crystal collimation** of ion beams → fully internalised
- **HELs** → No more compatible with LS3, so de-scoped
- **LS3 collimator production** → fully internalised

The progressive availability in the LHC of the LIU beams gives the opportunity to re-assess the needs of deferred items and in general to understand future limitations for HL-LHC.

Various important priorities identified for WP5, both for MDs and for standard operation:

- Study the need for dispersion suppressor upgrades in IR7 for proton beams
  → **Quench tests** with beam
- Study **beam lifetime** as well as effects from beam-tail losses
- Characterise beam tail population and diffusion for different beam paramet… configuration and collimator settings
- Assess the **collimation impedance** with the upgraded Run 3…
- Advanced scenarios: New IR7 optics for reduced impedan… …leaning

Dedicated LHC MD discussions in the parallel sessions.

Conclusions

- The new collimators installed in the LHC are fully operational for Run 3

  The LS2 & YETS2022 WP5 upgrades were completed successfully.

- The HL-LHC collimators were successfully commissioned and are now relied upon operationally at the LHC

  Although the LHC is still far from the performance target for Run 3, important feedback already gained on operational aspects relevant for the HL-LHC. More to come!

- The new crystal collimators were tested extensively with proton beams and are planned to be used for the Pb ion run at the end of the year.

  New and old hardware behaves as expected

  Two more units are being prepared for installation in the YETS2023 to complete the upgrade

- Outstanding beam tests are planned to consolidate upgrade plans

  Still hopefully in 2022: quench tests to assess needs for 11T dipoles

  Lifetime assessment, halo measurements and new optics in IR7 to be scheduled