Collimation scenarios depending on 11T dipole installations during LS2

R. Bruce and S. Redaelli for the WP5 collimation team

Inputs with various people and teams listed in the corresponding sections.

398th LMC meeting, 08/07/2020

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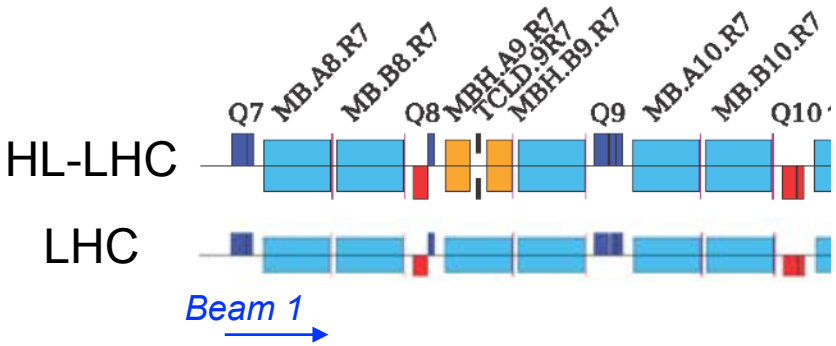
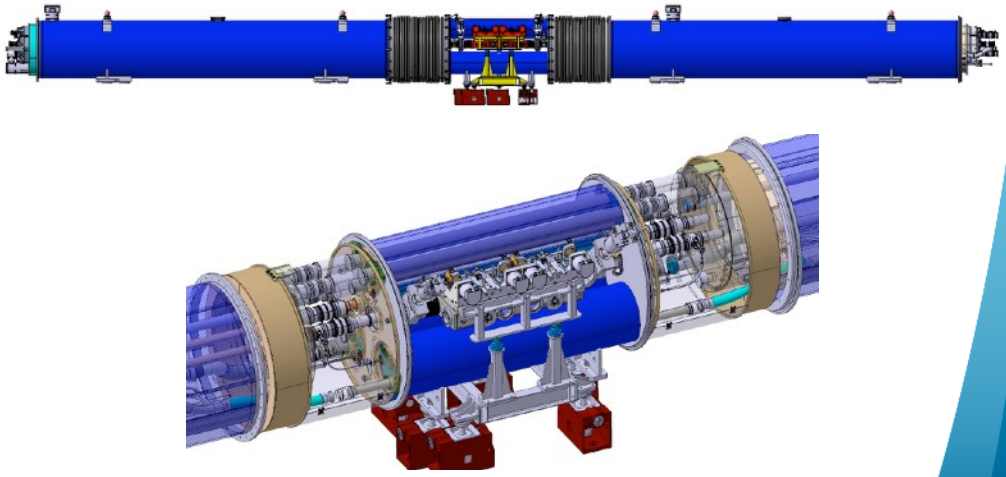
Introduction

- The upgrade of betatron collimation in IR7 based on 1 TCLD collimator per beam to be installed in cell 9 of each dispersion suppressor (DS)
  - 1 unit = 1 TCLD + 2 11T dipoles that replace a 15m long 8.3 T dipole
- Detailed scope within HL-LHC upgrade
  - Proton beams : No imminent limitation for Run 3, potential issue in Run 4
  - Pb ion beams : Limitations in Run 3 following LIU beam intensity upgrade
- Installation in LS2 endorsed to ensure a robust performance in Run 3
  - Refs: 2019 Collimation Review and report to 376th LMC in Apr. 10th, 2019
  - EDMS 1973028, LHC-TC-EC-0013



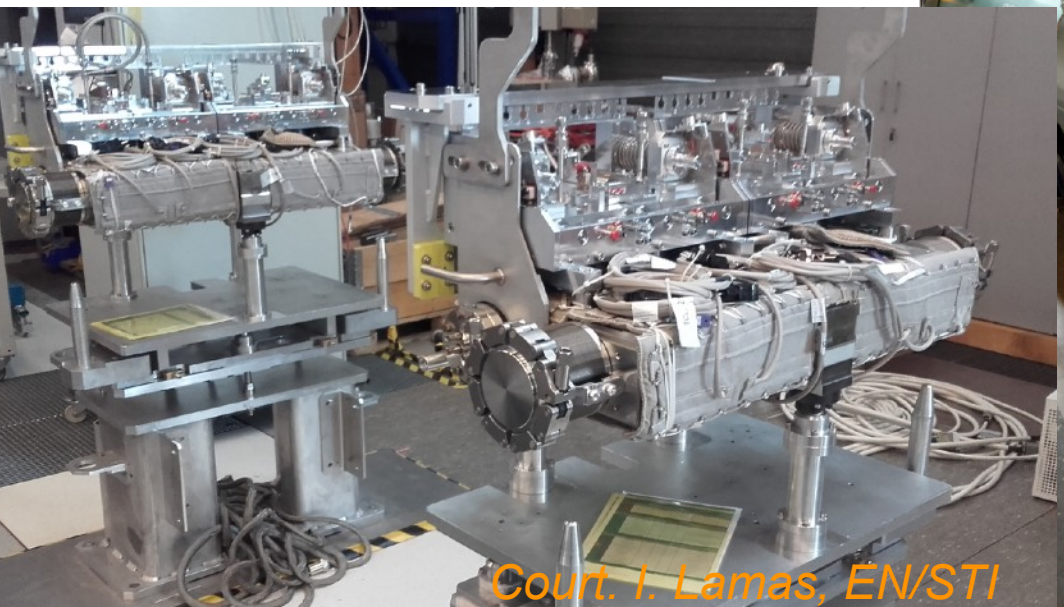


Baseline and alternative scenarios

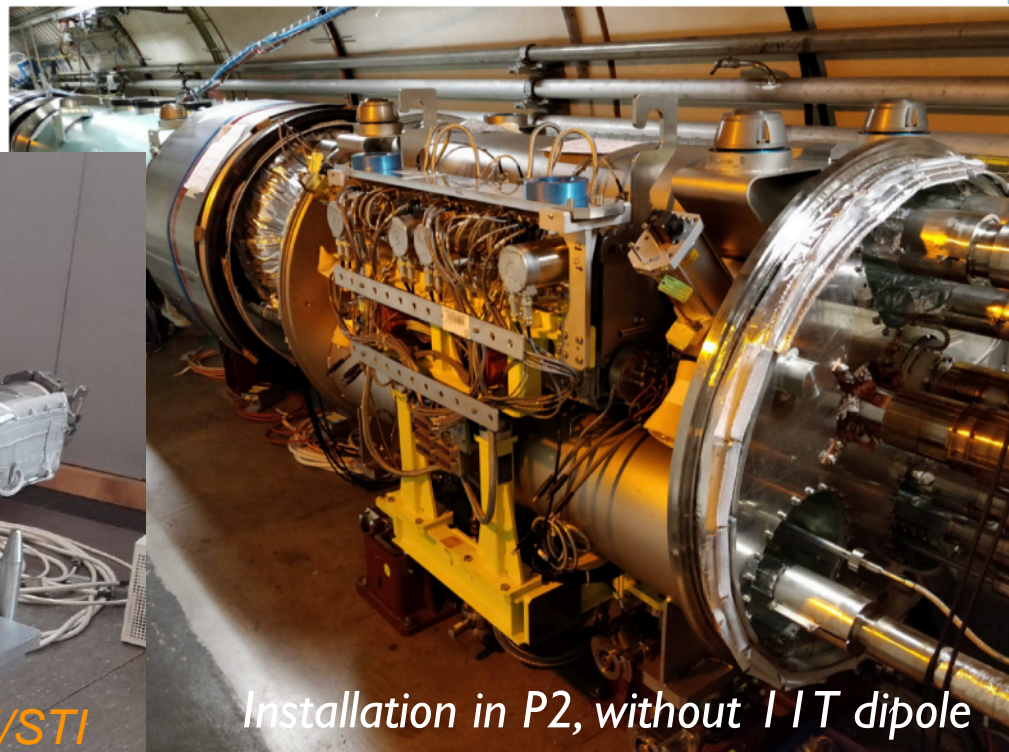
- Baseline with 2 TCLDs, one per beam, gives a solid performance upgrade
  - Estimated margin to quench of about a factor ~2-3, including further improvements (new collimator materials, local orbit bump, magnet tilt — see talk by R. Bruce)
  - Gain in NbTi magnet larger; performance relies on higher limits of Nb_3Sn
- Two alternative scenarios are envisaged with the present schedule
  - Only one 11T dipole / TCLD unit available
    - Definition of which beam to be equipped
    - Alternative cleaning improvements for the other beam
  - No 11T dipole / TCLD unit available
    - Alternative cleaning improvements for both beam
  - Focus: ion performance in Run 3
- Improvements of betatron cleaning without TCLD: **crystal collimation**
  - Integrated into the WP5 upgrade baseline in Dec. 2019 through in-kind contribution by Russia (PNPI/IHEP)
  - Following successful beam tests in 2018 with Pb ion beam
  - Scenarios for deploying crystal collimation in IR7 discussed below

TCLD collimator status

- The TCLD collimator production in industry is completed. No issue to meet LS2 schedule from the collimation point of view.
  - Installation planned around two IRs: IR2 (ALICE luminosity upgrade) + IR7
  - 5 collimators delivered to CERN (4 for tunnel + 1 spare unit): IR2 + IR7
  - Prototype built at CERN workshop also conform for installation
- Started TCLD installation in IR2 (no 11T dipoles, TCLD in cell 11 at the connection cryostat).
  - First unit installed in February (left side), second unit planned for July 27th
- Two TCLDs for IR7 are being prepared for tunnel installation
  - Priority given to IR7 installation of primary and secondary coll.



Court. I. Lamas, EN/STI



Installation in P2, without 11T dipole

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Based on inputs from various teams: BE/ABP, BE/OP, TE/MSC, TE/CRG + Marzia's team

B1 vs B2 : Collected arguments — i

If there will be only one 11T/TCLD unit available, which beam should be equipped ?

1. Collimation cleaning performance — improve the worse beam
   - No significant performance differences for protons in 2017-2018. B2 was worst in previous years (in particular in 2015) with larger IR7 settings. Conclusion: no strong argument.
   - B2 is worse than B1 for Pb ion beams. Up to 50% difference, not systematically seen in all loss maps.
   - (Reference: Evian2019 paper on Run 2 by Nuria Fuster)
2. Crystal collimation as alternative for ion beams — equip with TCLD the beam with poorer crystal performance.
   - Better having TCLD on B2 because crystal collimation cleaning in B1 better.
   - (Reference: Various ColUSM presentations by Marco D'Andrea)
3. Cooling capacity of the sector margin.
   - Serge and Rob expressed a preference to have the TCLD in Beam 2 (S67).

B1 vs B2 : Collected arguments — ii

4. Check if there are any limitations in the DS for implementing local bumps that are under study to mitigate the losses in the first 11T dipole upstream of the TCLD.
   - No issues for any side according to OP (Joerg).
5. Confirm that there are no constraints from settings/impedance.
   - This is expected to be ok: both sides equivalent.
6. Installation schedule discussed early on with planning team
   - See Marzia's input: Beam 2 preferred and still feasible in present schedule
7. Is there specific preference from the OP?
   - Jörg pointed out that in 2018 there were more "10 Hz" events in B1. Suggestion to have the 11 T dipoles on B2 that was less exposed to fast losses < 1 Hz because of concerns of quench limits on the ~ms timescale
8. Any preference by ALICE for the p/Pb operation?
   - We had no strong indications by ALICE so we consider both sides equivalent

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Following the different arguments, there is a clear preference to install first in Sector 6-7 (TCLD on beam 2) in the scenario where one single unit is available for LS2.

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- Introduction
- Beam 1 / Beam 2
- **Crystal collimation plans**
- Conclusions

Based on recent discussions with: G. Arduini, R. Bruce, B. Di Girolamo, S. Gilardoni, A. Masi, A. Perillo

LHC crystal collimation layouts

Four crystals installed in the LHC: two per beam, one per plane. Provided and validated by the UA9 collaboration. 2 producers: PNPI (3 crystals) and INFN-Fe (1).

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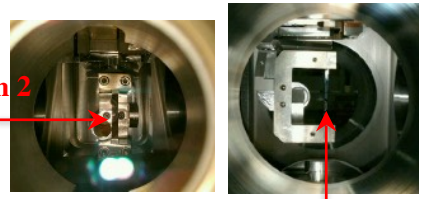
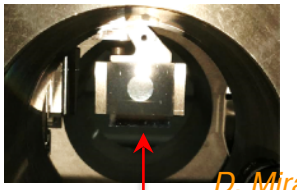


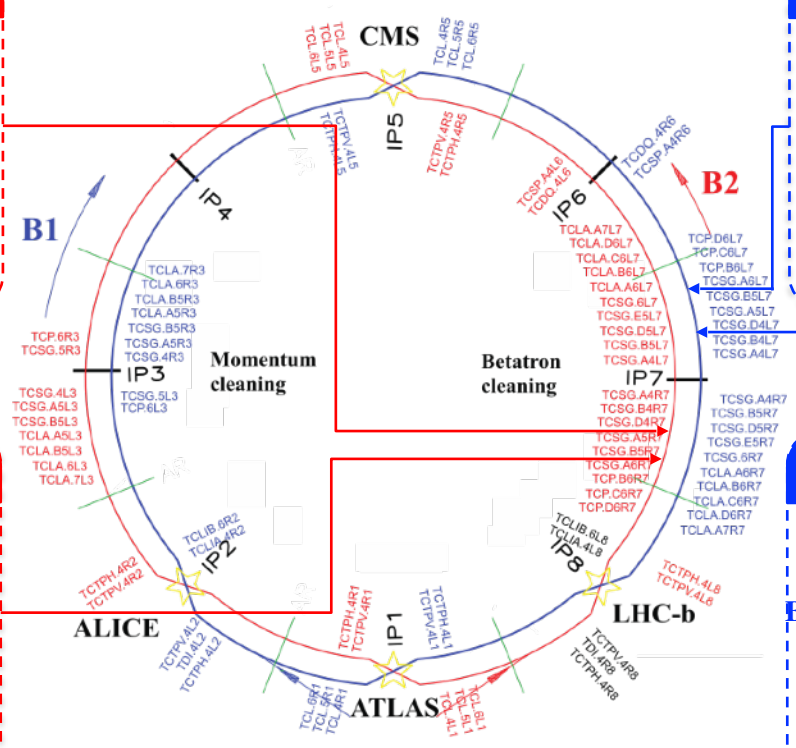
PNPI

Pics. courtesy of Y. Gavrikov

TCPCV.A6R7.B2



PNPI



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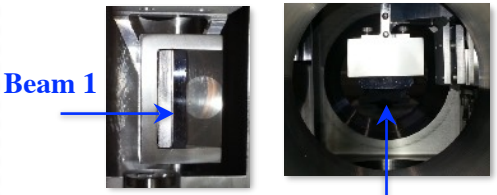

PNPI

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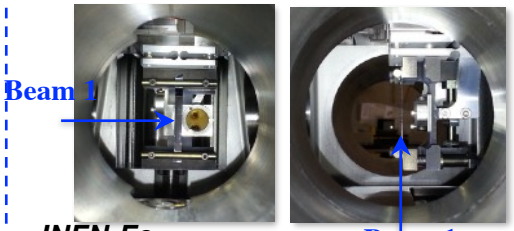

INFN-Fe

"TCPC" assembly (crystal primary collimator): Tank with "replacement" chamber, interferometer and linear stage, crystal holder).

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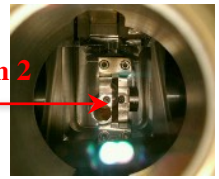

PNPI

Pics. courtesy of Y. Gav

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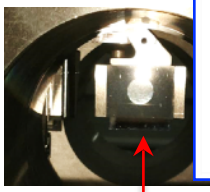

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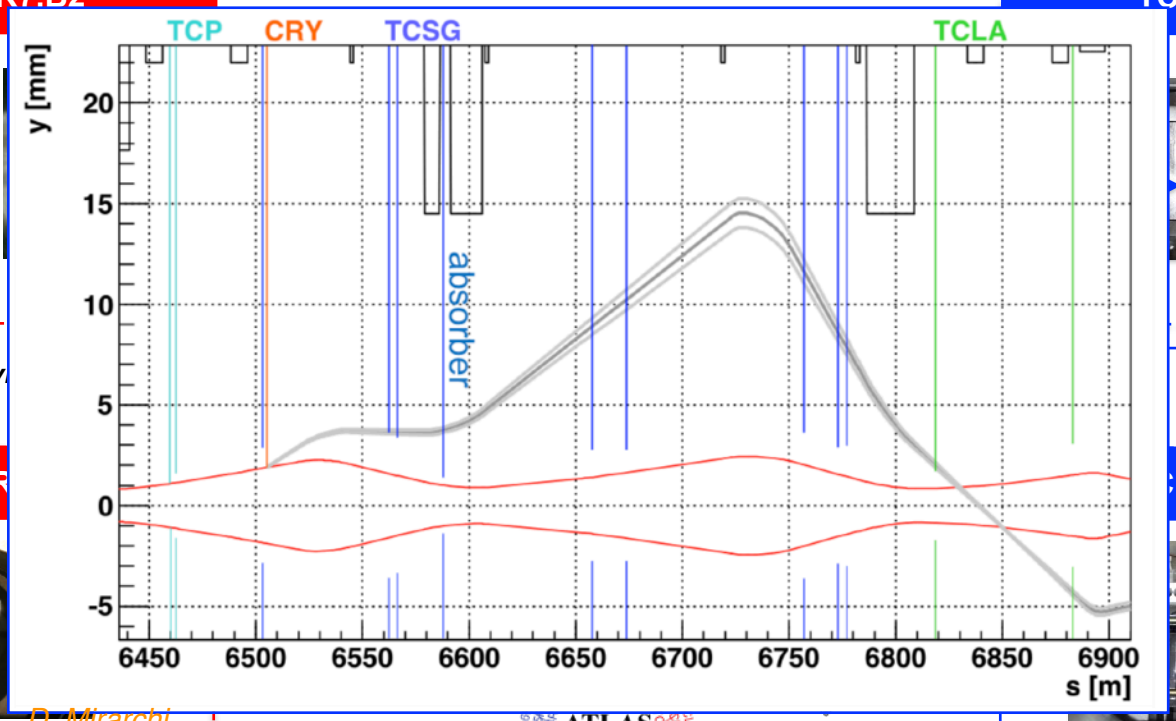
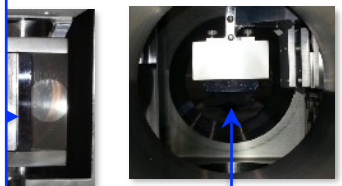


D. Mirarchi

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

TCPCV.A6L7.B1



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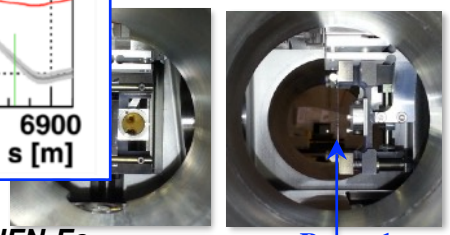
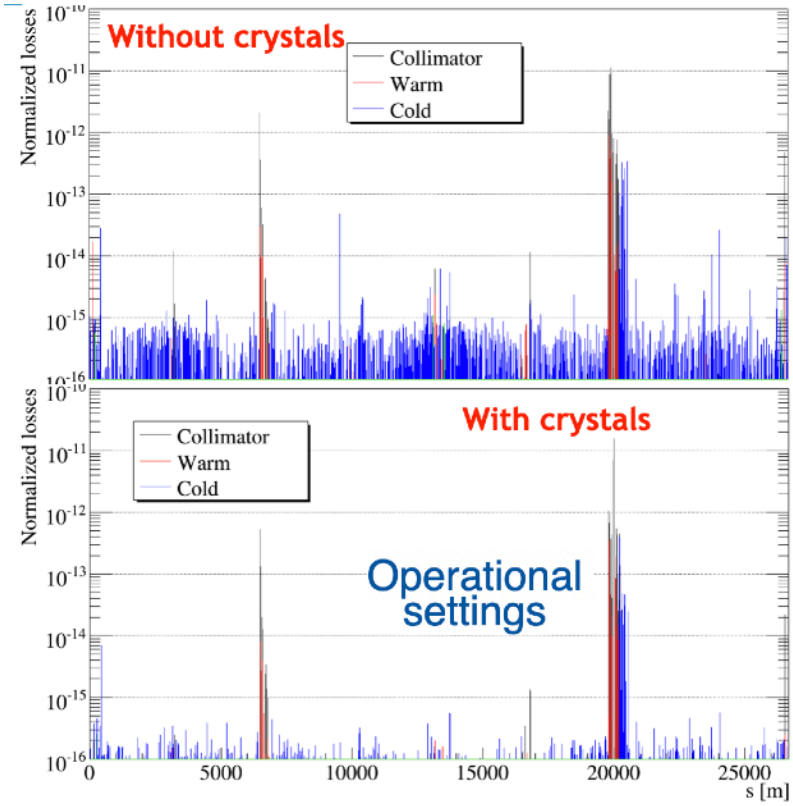


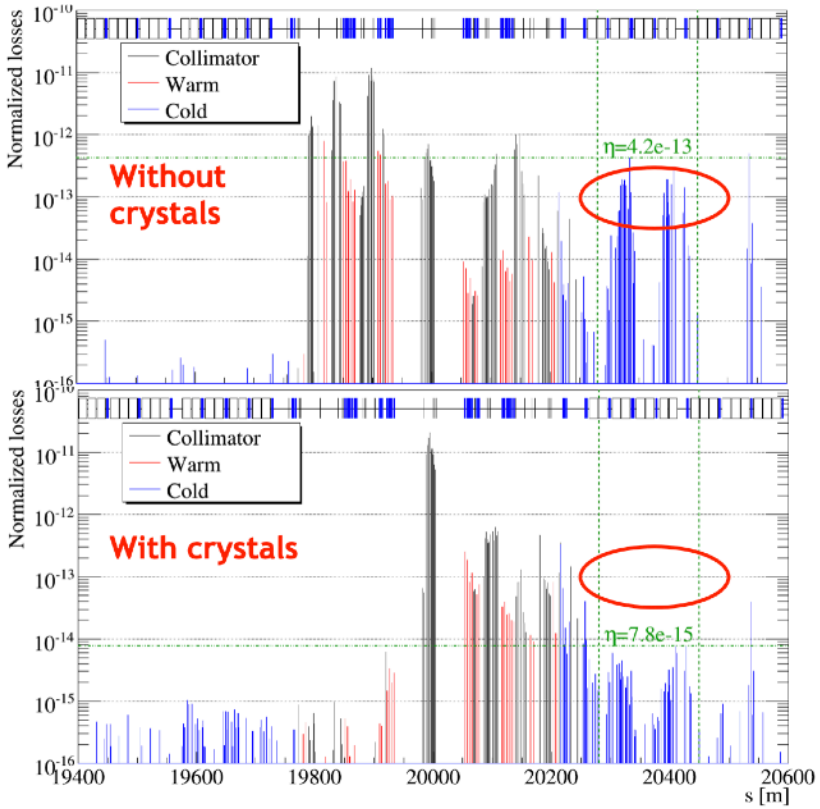
INFN-Fe

"TCPC" ass
cham

Present devices were designed for MD usage in the test stand and need to be upgraded for regular operational usage.

Pb ion cleaning performance

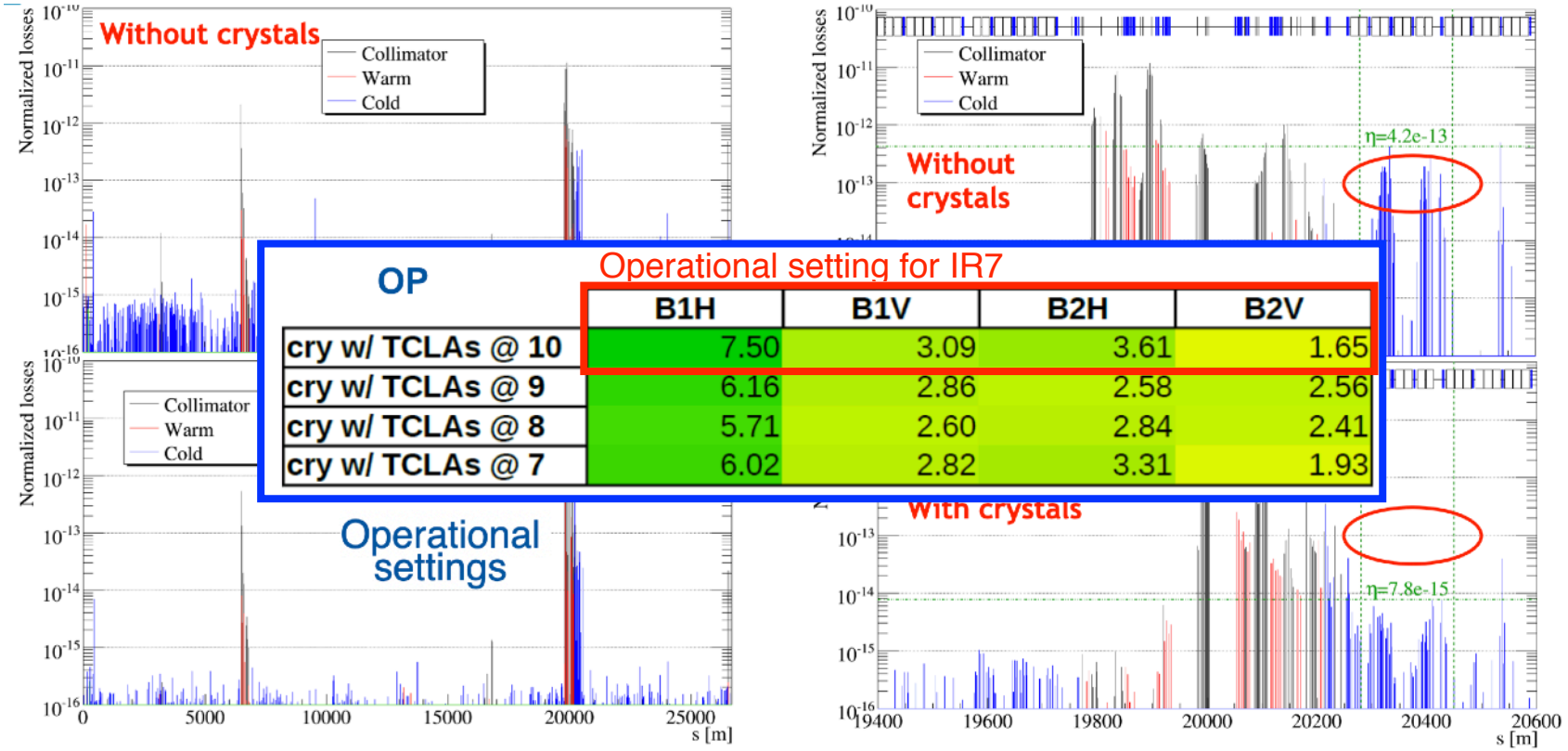




- Overall reduction of losses around the ring with crystal added to system.
- Tested with high ions intensities (~600 bunches)!
- Cleaning improvement up to a **factor 7** (more with optimised settings).
- Not the same improvement with all crystals — to be understood.

(measurements available for a broad variety of settings)

Pb ion cleaning performance



OP — Operational setting for IR7

	B1H	B1V	B2H	B2V
cry w/ TCLAs @ 10	7.50	3.09	3.61	1.65
cry w/ TCLAs @ 9	6.16	2.86	2.58	2.56
cry w/ TCLAs @ 8	5.71	2.60	2.84	2.41
cry w/ TCLAs @ 7	6.02	2.82	3.31	1.93

- Overall reduction of losses around the ring with crystal added to system.
- Tested wit
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Empirical gains based on BLM readings — simulations of full dynamics and energy deposition with crystal not finalized yet.

(measurements available for a broad variety of settings)

Plans for crystal system upgrade

- Controls upgrade was planned for Run 3 (EN/SMM)
  - Following discussions: A. Masi, S. Redaelli, D. Wollmann: add interlock limits as a function of time for ramp and squeeze, applicable to both present/future systems
  - Can report to the LMC the details after final approval at CWG / MPP panels
- Bent crystals procured through two contracts with INFN and PNPI
- Present “TCPC” (crystal primary collimator) uses two design versions, not conceived for long-term, high-reliability operations
  - In previous schedule, we had no choice but to use them in 2021 after the controls upgrade, if needed, and intervene in the YETS2021 to replace them
  - Now, we are exploring the PNPI/IHEP the possibility to complete the installation in LS2. Backup: installation in the following YETS2022.
- Start of in-kind activities in PNPI/IHEP was delayed: signatures in Apr. 2020 and cash flow expected in Sep. 2020
  - Working with them on a schedule for having enough TCPC in 2021 for two scenarios:
    - 2 new TCPCs for B1 if one TCLD/11T unit can be installed on B2 (challenging)
    - 4 new TCPCs for both beam if no TCLD/11T unit is available (very challenging)
  - Schedule critical: conditions in IR7 after pilot beam tests in fall 2021? We will come back with a concrete proposal when we have the production schedule in Russia.

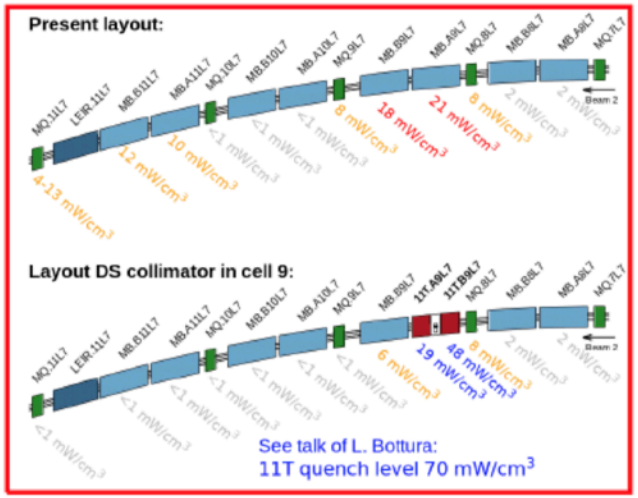
Conclusions

- We studied alternatives to improve the collimation betatron cleaning in Run 3 as a backup to the availability of 11 T dipoles
  - Focus on lead ion beams, following the intensity upgrade
- Proposed a choice for installation for the scenario when one unit only can be installed: TCLD on B2, in cell 9 of sector 67.
  - Many thanks to planning team
- Alternatively, cleaning can be improved by crystal collimation
  - Integrated in the upgrade baseline in Dec. 2019 through PNPI/IHEP in-kind
  - We need to install as soon as possible 2 or 4 new devices to equip one or 2 beams, depending on different scenarios for 11 T dipole availability.
  - There is the possibility to use temporarily the present “MD” system (quite good performance for B1), with no guarantee for reliable operation
- Following the positive feedback from PNPI/IHEP, and the integration in the baseline, we are now working on a schedule for LS2
  - Need to understand when they can start the activities with the present funding
  - Schedule for production in 2021 under discussion
  - Need to review scenarios for installations at the end of 2021 with the CERN planning team and the groups involved

Reserve slides

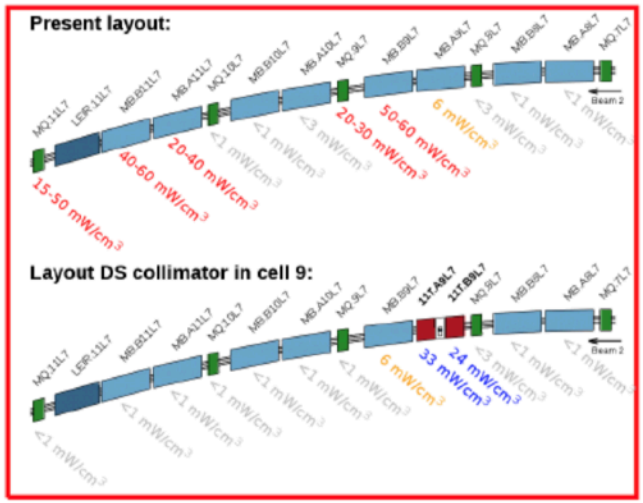
Cleaning performance

Protons, Run 4



- *cures loss cluster in cell 9, but locally increased power density in upstream 11T magnet*
- *very good cleaning in cell 11 (and globally)*

Lead ions, Run 3



- *cures loss cluster in cell 9, but locally increased power density in 11T magnets*
- *very good cleaning in cell 11 (and globally)*

Key (recent) refs:
— 2019 Collimation review
— M. Lamont's report to the LMC Apr. 20th, 2019

Various caveats: total beam intensities; design minimum beam lifetime (0.2h, pessimistic)

- Subject of various reviews and discussions.
- Main outcome, assuming a quench limit of present dipoles of ~20 mW/cm^3:
  Protons: potentially at the limit (Run 4): 21 mW/cm^3
  Ions: x2-3 above quench limits (Run3): 50-60 mW/cm^3
- Upgraded DS: better factors ~ 3 for both cases, thanks to higher quench limits of 11T dipole (see further more details in Roderik's talk).
- Installation in LS2 would ensure a robustness performance already in Run 3