Summary of HL-LHC session @ Chamonix and CMAC recommendations

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24th HL-LHC TCC, 09.02.2017

Outline

- Overview of HL-LHC Session
- Main messages of the talks
- CMAC – findings, comments and recommendation

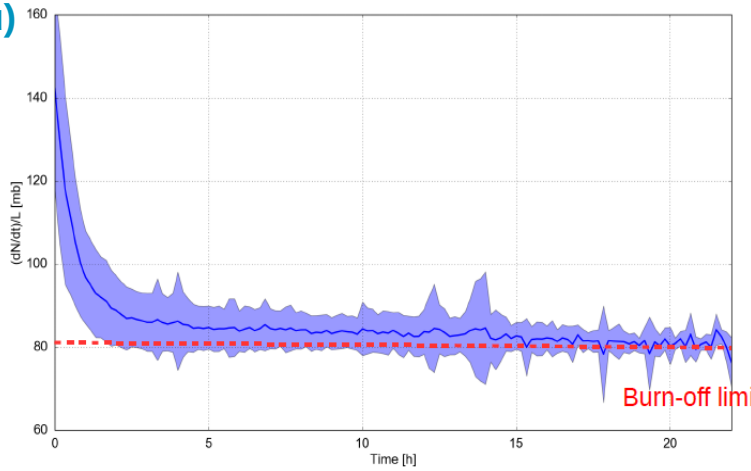
HL-LHC Session (Thursday, 26.01., morning)

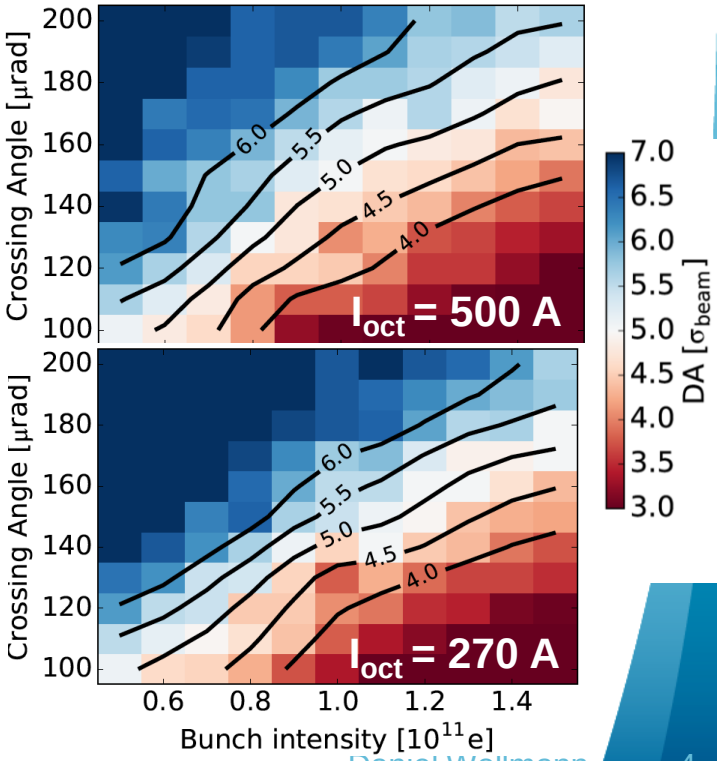
1. HL-LHC: performance sensitivity to parameters change – (Yannis Papaphilippou)
2. Can we simplify the correctors and magnet circuits for HL-LHC? (Riccardo De Maria)
3. Review of the present non-conformities in view of HL-LHC – (Massimo Giovannozzi)
4. Vibration: is it still an issue? (Paolo Fessia)
5. Need for beam halo depletion in the HL-LHC and LIU era (Stefano Redaelli)
6. Collimation: is this a limitation, still? (Roderik Bruce)

HL-LHC: performance sensitivity to parameters change

(Yannis Papaphilippou)

- Luminosity decreases at start of SB **faster than expected** → reduced beam life time due to **dynamic aperture (DA) < 5 σ**.
- Good lifetime for **DA ~ 6 σ**.
- Origins and mitigations:
  - **High octupole currents** → adjust crossing angle
  - **LHCb polarity** → adjust working point
- Using **beam beam wire compensators** could **improve dynamic aperture by 1 – 2 σ** → to be verified in 2017 with beam.

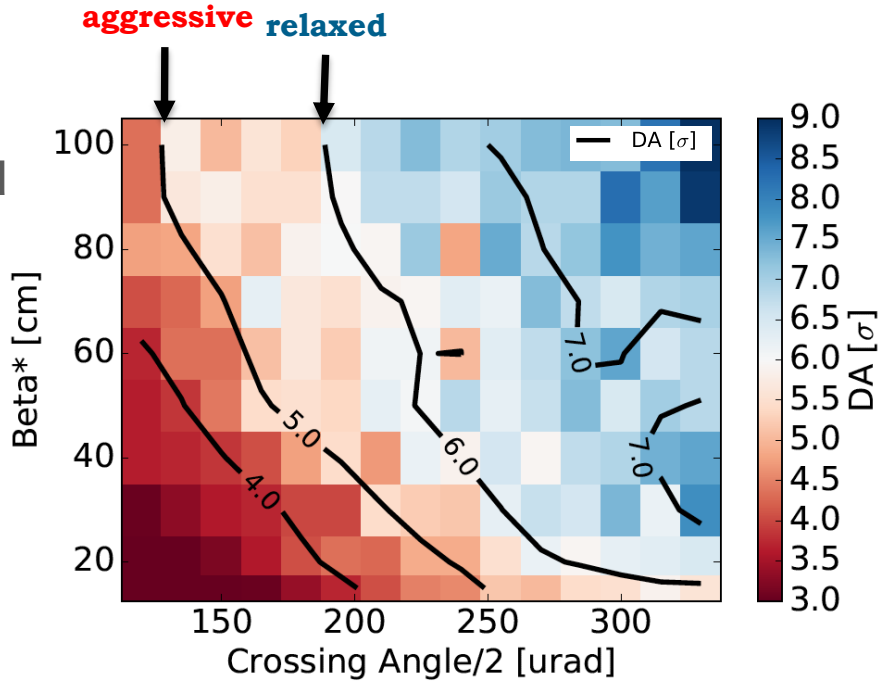




HL-LHC: performance sensitivity to parameters change – Leveling

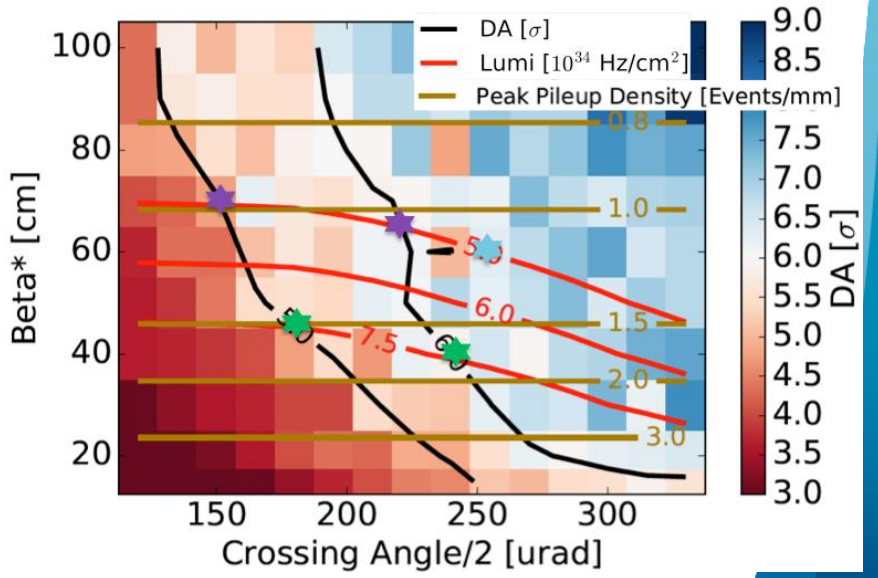
(Yannis Papaphilippou)

- **Reduction of crossing angle** at constant DA during **beta* leveling** →increased leveling time; 1-2 % increase in **integrated luminosity**; 10 -15 % reduction of **pile up density**
- **Separation** leveling provides **comparable gains**, but high bunch intensities require **higher crossing angles**.



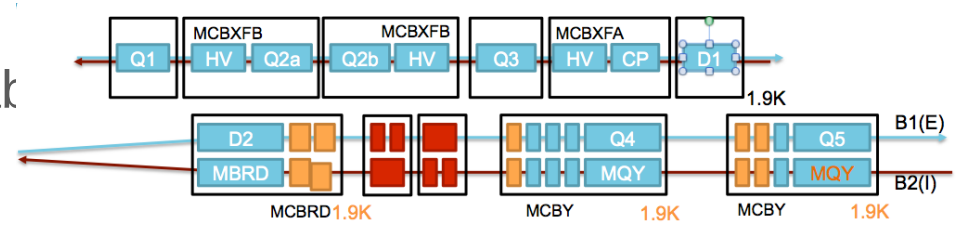
Discussion

- **Mitigation measures** (working point, LRBB compensator, …) and optimization of the crossing angle may allow to **re-establish** the margins of the **old baseline**.
- Studies taking into account **field errors** are required.
- Some mitigations should be used with high intensity beam after successful validation during MDs to **gain operation experience**.



Can we simplify the correctors and magnet circuits for HL-LHC?
(Riccardo de Maria)

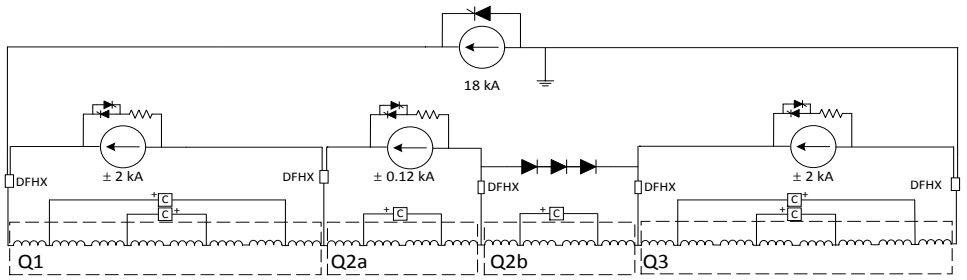
- HL-LHC requires **extra corrector strength** for orbit adjustments at crab cavities and un-anticipated needs → additional correctors in MS.
- Simplifications for **Q4 / Q5 corrector** circuits:
  - **3 instead of 4** correctors → no change of crossing plane; no additional CC.
  - Powering of two correctors in **one circuit** → possible impact on availability
- Compensate reduction of DA at beta*=15 cm
  - **additional sextupole** correctors in Q10 (IP1 / 5);
  - **Disconnect focusing sextupoles** in Q14 (under study to identify additional impacts);



Type	Number	Strength
MCBXFB	2	2.5 Tm
MCBXFA	1	4.5 Tm
MCBRD	2	5 Tm
MCBY.4	4 (1.9K)	2.8 Tm
MCBY.5	3 (1.9K)	2.8 Tm

Can we simplify the correctors and magnet circuits for HL-LHC?
(Riccardo de Maria)

- ATS optics requires 170 T/m for **Q5 left of IP6 (MQY)** (today's limit at 4.5 K 160 T/m) → **go to 1.9 K** (baseline) OR **push magnet @ 4.5 K**.
- 120 A trim in Q2a/b of triplet could be avoided if **response functions** were **included in magnetic model**.



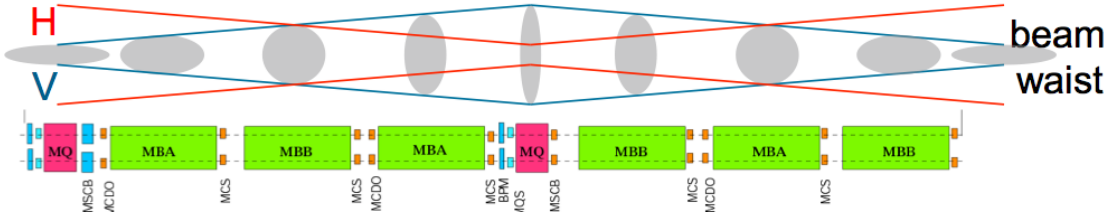
Discussion

- MS corrector flexibility will be re-gained with new Q4 (MQYY) and it's correctors (not in baseline).
- Magnets having the same function can be **powered in one circuit**. Consequences on **availability and aperture** have to be considered.
- No problem to measure the Q2a/b transfer functions precisely.

Review of the present non-conformities in view of HL-LHC
(Massimo Giovannozzi)

- Overview of **existing non-conformities** in magnet system and their impact on LHC and HL-LHC operation → full **consolidation before HL-LHC era**.
- **Time evolution** of non-conformities not know → **regular testing** of selected non-conforming magnets during future HW commissioning campaigns.

  - Classes of magnets affected
    - Main magnets (dipoles and quadrupoles)
    - Orbit correctors (also for crossing scheme generation)
    - Cell correctors



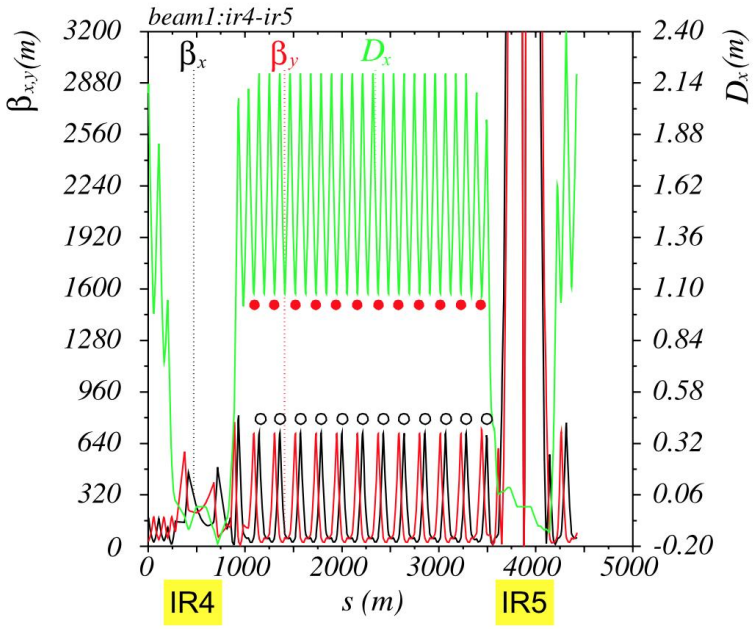
- Each dipole has:
  - Sextupoles spool piece
- Some have also:
  - Octupoles and decapoles

- Each quadrupole has:
  - Beam Position Monitor
  - Dipole corrector
  - Sextupoles
- Some have
  - Trim quadrupole, skew quadrupole, skew sextupole, octupoles

M. Giovannozzi - CERN 5

Review of the present non-conformities in view of HL-LHC
(Massimo Giovannozzi)

- HL-LHC will be **more sensitive** to missing circuits than current LHC → **two types of arcs** with different beta functions due to telescopic squeeze.

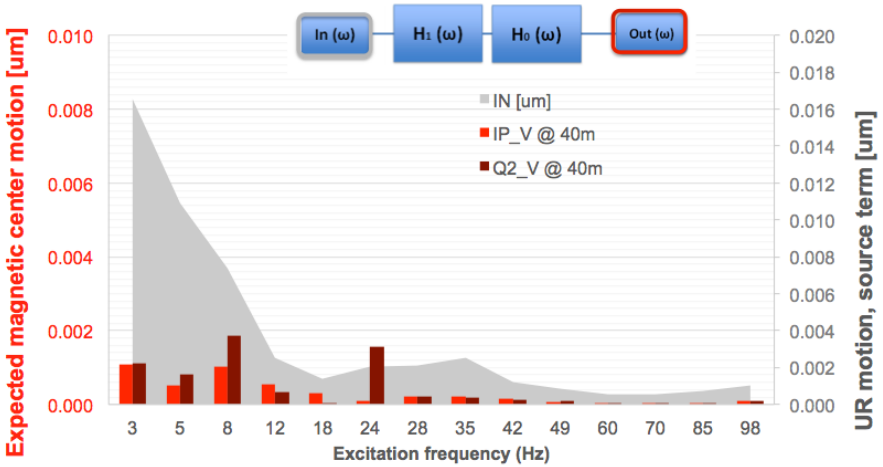


Discussion

- Non-conformities are **well documented** by MP3.
- **Re-testing** of some critical non-conformities already **foreseen** in coming HW campaign.
- Future **nested triplet orbit correctors** will be **more robust** → larger operational margins.

Vibration: is it still an issue?
(Paolo Fessia)

- Studies and experimental investigations estimate **transvers movement of magnetic center** in LHC triplets magnets to up to **0.002 um** at different frequencies.



- **Hydraulic hammers** (used for excavation) operating at 8 Hz causing much **stronger movements** in higher harmonics → use **less effective tools** OR **modify operating frequency**.

Vibration: is it still an issue?
(Paolo Fessia)

- **Seismic stations** installed around all C.E. areas and operational since 12.2016 → sufficient time to **record reference data** before start.
- Specific frequencies measured previously seem to be mainly linked to the cold mass and not the support → **active beam feedback possible**, but requires installation of additional corrector magnets

- Surface station (North area):

➢ *Station in operation since December 2016 with local data storage due to issue with the LAN installation. Data roaming to SED and CERN database planned for March*

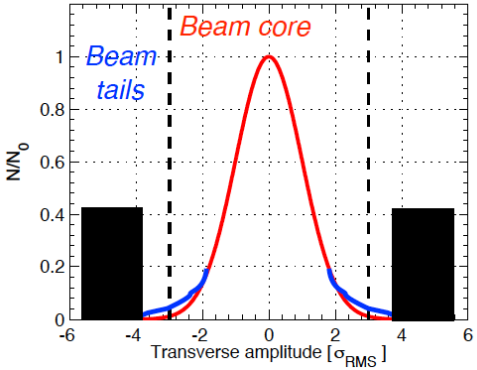
Discussion

- C.E. schedule provides more than **six months margin** and only part of shaft excavation taking place during beam operation.
- **Feed forward from vibrations** into beam seems **not possible** (transmission too slow).
- **Background noise** due to geothermic project will be added to the current models.
- Effect on **flat beams** to be **evaluated in future**.
- Newly installed **ground motions sensors** provide the required **sub-micron resolution**.

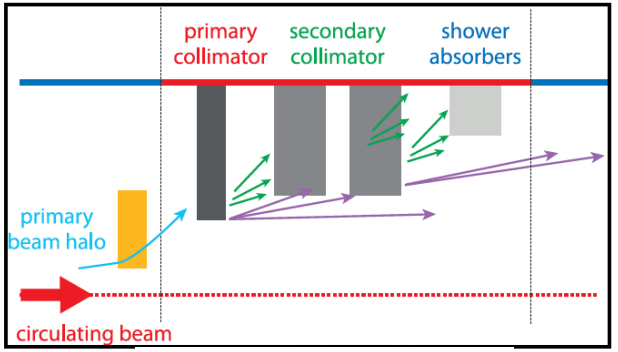
Need for beam halo depletion in the HL-LHC and LIU era

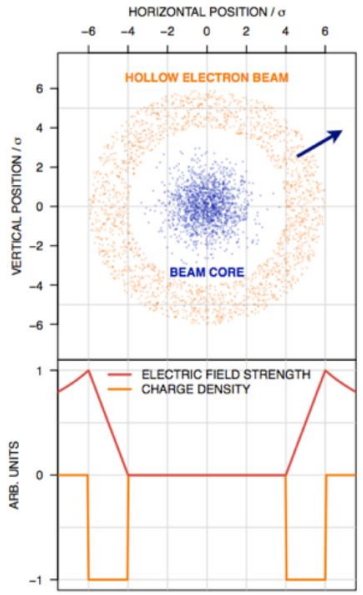
(Stefano Redaelli)

- **International review** performed (October 2016) to assess the need of active Halo depletion.
- **Active halo** control would allow **controlling diffusion speed** and static **halo population**, and **distributing losses** over time → **transparent integration** into current collimation system.
- Measurements in LHC show stable **overpopulated tails** → HL-LHC stored energy in tails **33 MJ** outside 3.5 sigma.
- **Fast failures** (e.g. by crab cavities) expected for HL-LHC → high **losses into aperture** / collimation system.
- Further study of **crab cavity failure modes** required.
- **SPS crab cavity test essential**.
- Hollow e-lens would **mitigate the effect of fast failures** in HL-LHC → **implementation recommended** by review panel.



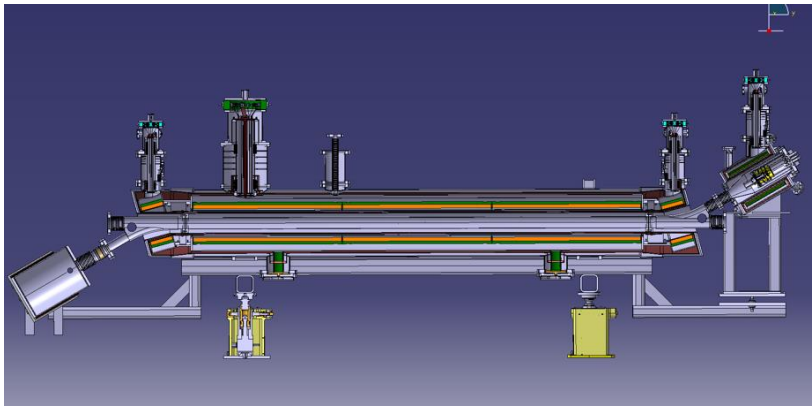
Collimation with active halo control





Need for beam halo depletion in the HL-LHC and LIU era
(Stefano Redaelli)

- Effect of **increased bunch intensities** on fast **loss spikes** and **instabilities** to be studied further.
- Complete technical solution under development → **review of technical design** foreseen for autumn 2017.
- **Cost impact** to be evaluated by next Cost & Schedule review.

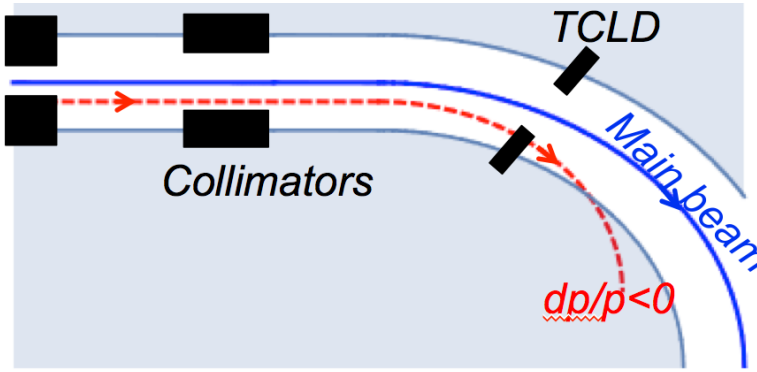


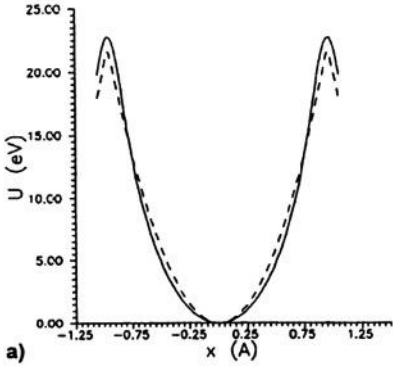
Discussion

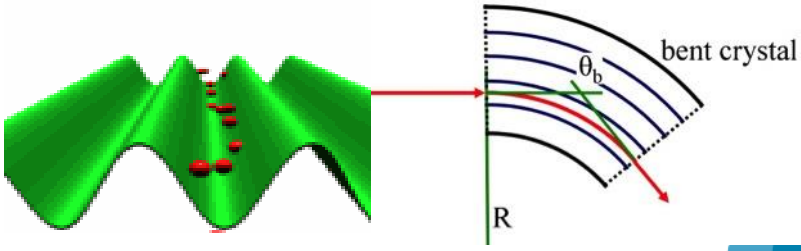
- Halo control via e-lens is not increasing the baseline performance but might be **necessary to avoid unexpected shortfalls**.
- Introduction of **instabilities due to halo removal** needs to be carefully considered.
- Mechanism of halo creation and effect of increased bunch populations needs to be studied further.
- **Experiments with LIU beams** after LS2 will provide important information.
- Possible installation of e-lens: LS3 or LS4.
- Evaluate **alternative methods**.

Collimation: is this a limitation, still?
(Roderik Bruce)

- HL-LHC proton losses into IP7 dispersion suppressor might **limit performance** → installation of TCLD collimators during LS2 providing **factor 3-4 margin** (baseline).
- For **ion operation** cleaning much worse → Quench experiments showed allowed intensity **factor 4 below requirements**.
  - Increase minimal allowed **beam lifetime** (12 mins) by factor 4.
  - Install **additional TCLDs** in IP7 DS (not in baseline).
  - Use **crystal collimators** to improve cleaning **by factor ~3** → further studies required.
- Increased power load from ion debris mitigated by TCLD collimators in IP2.







Collimation: is this a limitation, still?
(Roderik Bruce)

- **Stabilizing HL-LHC beams** with current CFC collimators will require 350-500 A octupole current → replacement of secondary collimators by **low impedance materials** required.
- **Reduction of phase advance** between dump kicker (MKD) and tertiary collimators will allow for tighter collimator settings → nearly **recover beta*=15 cm**.
- Further reduce setup time of collimation system by implementing **BPM buttons in all new collimators**.

Discussion

- **Prototype collimator** with three different material combinations (MoGr, MoGr + TiN, MoGr + Mo) is being installed in LHC to **measure impedance effects**. Radiation tests are under way.
- More **robust and lighter material for tertiary** collimators (as foreseen in baseline) must be balanced against **background creation** for experiments.
- **More studies with crystal** collimators are required.
- A massive absorber to intercept channeled particles is under study.

CMAC-Findings

- All scope changes resulting from the re-baseline of Sept 2016 have been included in the physics model of the HL-LHC.
- The performance of the present collimation scheme, while meeting baseline requirements, is challenged. Adding two hollow beam lenses are considered and would remove significant risk.
- Electron cloud induced heat loads present one of the biggest challenges to the HL-LHC performance. Varying heat load by sector, various scrubbing techniques and a variety of other mitigation measures are under investigation.
- Long range Beam-Beam compensation with wires is crucial.
- Flat beam performance is essential to understand to mitigate risk of crab cavity performance.

CMAC - Comments

- The scope changes from the re-baseline in September of 2016, while increasing risks and narrowing margins in several areas, do not affect the ability to achieve the ultimate Luminosity goal of HL-LHC as far as we can assess.
- Uncertainties in predicting the halo require large design margins for the collimators. Hollow electron lenses, a proven technology, can further mitigate this risk. The HL-LHC team should further evaluate (calculate and measure) the necessity and management might want to consider inclusion into the baseline, even at increased cost.
- If electron cloud has a strong negative impact on emittance growth at injection only techniques which will allow e-cloud reduction will resolve the problem.

CMAC -Recommendations

- Execute all necessary experiments, with and without beam, during CY17 which can impact major activities for LS2.
- Define a strategy to either intrinsically reduce the heat load stemming from the e-cloud. In case that is not possible, evaluate the maximum possible heat load that could be cooled in the shield and develop a strategy to do that.

Thank you for your attention!