Minutes of 281st LHC Collimation Working Group Meeting joint with MPP and LBOC

Participants: F. Alessio (FA), J. Boyd (JB), E. Bravin (EB), R. Bruce (RB) (*chairman*), X. Buffat (XB), I. Efthymiopoulos (IE), C. Hernalsteens (CH), M. Hostettler (MH), S. Ilieva (SI), A. Infantino (AI), S. Kostoglou (SK), G. Lerner (GL), B. Lindström (BL) (*scientific secretary*), D. Mirarchi (DM), D. Nisbet (DN), T. Persson (TP), V. Rodin (VR), M. Solfaroli (MS), G. Trad (GT), N. Triantafyllou (NT), M. Trzebinski (MT), J. Uythoven (JU), J. Wenninger (JW), C. Wiesner (CW), D. Wollmann (DW), M. Zerlauth (MZ) **Indico link**.

1 Discussion about TCL6 settings (1/3) (M. Trzebinski)[slides]

Summary of the presentation

MT presented the impact of the new optics. There is a focal point around TCL6, indicating that even minor adjustments to TCL6 significantly affect radiation levels at AFP, observed during a recent tunnel inspection. Current settings have resulted in radiation levels around 300 µSv/h, exceeding the daily limit for personal exposure (50 µSv), despite the machine only being half full. This presents serious safety and operational challenges, not only for personnel but also potentially damaging to nearby electronic systems. The AFP group advocates for the widest possible opening of TCL6 to mitigate these issues.

Discussion

- **GL** asked if the situation has worsened compared to previous years, noting stable BLM measurements. He added that with the RP optics, the TCL6 cleans a bit less and he is surprised that the situation for AFP is worse this year. **AI** confirmed similar dose measurements from the previous year at the PMI directly in front of TCL6.
- **DW** expressed concerns that wider openings of TCL6 could affect downstream electronics, such as the QPS.
- **RB** suggested exploring whether losses near AFP could be occurring independently of TCL6 adjustments.

2 Discussion about TCL6 settings (2/3) (J. Boyd)[slides]

Summary of the presentation

JB discussed the results of the end of fill test this morning. TCL6 settings were sequentially adjusted from the default 1.6 mm to 1.8 mm, and finally to 2 mm. These adjustments resulted in a normalized trigger rate for muons across the full detector, indicated in red. An increase of 4% in the trigger rate was noted when the setting was changed to 1.8 mm, and a total of 9% increase was observed when it was changed to 2.0 mm. From the perspective of FASER, this 9% increase is acceptable during operational periods without the emulsion, a scenario applicable for about 30 inverse femtobarns this year.

Discussion

- **RB** asked if there is a preference for tighter settings when emulsion is used, which **JB** confirmed.
- **SI** mentioned uncertainty about running with half the target and that SND observes a smaller increase of trigger rate compared to FASER.

3 Discussion about TCL6 settings (3/3) (G. Lerner)[slides]

Summary of the presentation

GL presented detailed findings from the BLM data, focusing on the integrated dose from BLMs from cell 14 left 1 to right 1. The radiation levels, which are expected to correlate with the luminosity delivered to ATLAS, appeared consistent in the vicinity of the detector. A discrepancy on the right side was noted due to a displaced BLM. Despite reduced settings in 2024 compared to 2023, the radiation peak at TCL6 remained consistent, indicating that the adjustments had neither improved nor worsened conditions. However, there was a notable increase in losses further downstream, particularly in cells 8 and 9, where the current measurements exceeded previous data, suggesting higher losses that could impact electronic racks and QPS. These systems, which have historically faced issues, now pose an increased risk of dumps due to SEU. This can be attributed to the RP optics configurations.
The presentation also included a review of results from **F. Cerutti**, shown at Chamonix this year, which highlighted that maintaining a TCL6 gap of 1.2 mm would be numerically better than the situation at point 5 in 2023. However, increasing the gap to 1.85 mm would result in worse losses in the downstream sectors of point 1 compared to last year, thus increasing risk of R2E induced dumps. Ideally, a TCL6 setting of around 1.2 to 1.4 mm would be best, but the current setting of 1.6 mm can be considered a compromise.
In addition, the third slide showed backscattered radiation from TCL6 to the XRP, showing a modest reduction in total dose to the XRP by about 20% when TCL6 settings were reduced from 2 mm to 1.2 mm. This was based on last year's optics, suggesting a need for new simulations with the current RP optics to assess their relevance under changed conditions.

Discussion

- **RB** noted that last year TCL6 was opened for the AFP and observed a greater reduction in dose than simulations predicted. **MT** confirmed that opening the settings improved the situation significantly.
- **GL** asked for clarification on when the TCL6 was opened last year. **RB** replied that they were opened on the request of AFP due to high doses and that he would need to check when it was implemented. **JB** recalled an instance where TCL6 was not fully closed during one fill (9072), potentially linked to the XRP. **SR** remarked that no fills were intentionally conducted with fully open collimators, suggesting settings were aligned with previous operational stages. **MT** highlighted that the settings discussed were implemented in April the previous year, and the TCL6 setting of 1.9 mm was used throughout the year.
- **RB** asked about quantifying the risk of R2E if settings were expanded to 2 mm. **GL** provided speculative estimates based on simulations at other settings and optics, indicating potentially a factor of two increase in risk. **VR** introduced additional data points, prompting **GL** to illustrate how minor adjustments in gap size could significantly increase R2E

risks, particularly stressing the guidelines from Chamonix to keep losses at IR1 manageable compared to IR5.

- **RB** inquired about QPS dumps in IR5 last year, to which **GL** replied noting a few incidents, underscoring the potential increase with relaxed collimator settings.
- **RB** and **JW** discussed possible configurations, considering running with a 1.6 mm gap when emulsion was in use, and potentially expanding to 2 mm when it was out, weighing the risk of dumps. **DW** mentioned upcoming changes to electronics boards to reduce sensitivity, planned for deployment in TS1. **MH** suggested maintaining the current configuration until TS1, and then reevaluate. **RB** concluded that we keep 1.6 mm until some time after TS1, until FASER takes out the emulsion, even though no R2E issues were recorded to date.
- **JB** queried about employing different settings on either side of the TCL6, dependent on whether FASER or SND had emulsion in use. **RB** affirmed there were no fundamental objections to this approach, though R2E constraints would limit the extent of opening.
- **JW** emphasized the need for an observable to justify adjustments. **GL** discussed the utility of BLM data in monitoring cumulative dose impacts in downstream cells, stressing that the radiation levels now already supersede those of the previous year. **MT** noted that they need an access to measure the dose.

  RB proposed experimenting with a 2 mm opening on one side to assess the impact. **GL** recommended immediate monitoring of BLM data upon any setting adjustment to quickly gather relevant data for an R2E assessment, since it would take several weeks if we want to look at the number of actual QPS failures. **MH** suggested comparing the BLM measurements with in-situ activation measurements to see how reliable the BLMs are for assessing this. **JB** and **Gerardo** confirmed that both FASER and SND would remove emulsion soon, allowing more flexibility in TCL6 settings shortly.

4 2024 loss map analysis (N. Triantafyllou)[slides]

Summary of the presentation

NT presented a summary of the validation loss maps that were done during commissioning this year. Due to the new optics, all steps had to be done, resulting in approximately 130 loss maps. The DS inefficiency for B1H, B2H and B1V was better at all top energy stages this year compared to last year, while B2V was the same. The hierarchy factor improved significantly in B2H but remained similar for the other cases. The TCSP losses in IP6 improved significantly at most stages for both beams and planes. The TCT losses are similar to last year. She concluded that the loss maps indicate a good cleaning and that there is no indication of any issue that would hinder operations, nor any hint of what could explain the hierarchy issues seen in normal operations at 30 cm.

Discussion

- **TP** asked about the loss maps with higher chroma and octupole. **DM** and **NT** replied that neither online nor offline analysis showed any issues that could explain the hierarchy degradation.

- **JW** remarked that **DM** rechecked all TCS alignment in B2 and that they were all consistent.

5 Collimation hierarchy breakage: beam-beam bunch-by-bunch orbit and optics effects (M. Hostettler)[slides]

Summary of the presentation

MH presented a study on bunch-by-bunch orbits due to different number of long range beam-beam encounters for the different bunches. Since the orbit feedback would correct the average orbit, the peak bunch-by-bunch variation w.r.t. average orbit is the critical number, which at a maximum is 70 µm in TCSG.A6R7.B2, not enough to explain the hierarchy breakage. RP optics have no significant impact, however the sign of the xing angle in IP1 plays a role, with negative sign, as last year, being better. There was no indication of a sudden degradation at 33 or 30 cm beta*. The beam-beam effect also induces a bunch-by-bunch beta beating, around 5 to 10 %. This, alone, is too small to explain the hierarchy breakage, in particular since the beta beating would increase the effective gap of the TCS in IR7.

Discussion

- **RB** highlighted that even with the addition of beta beating and orbit offsets, the required 300 microns displacement is not achieved. **MH** added that the possibility of a minor misalignment on top of this has very low probability.
- **SK** questioned the issues observed only on beam 2 and not on beam 1, suggesting that if it were related to phase advance, simulations would have indicated such. **MH** replied that the simulations indeed do not show any difference between the beams.
- **XB** and **TP** discussed the reliability of the simulations and the beam-beam model. **XB** noted that while the model is generally good, it may lack certain elements like magnetic errors or misalignments, which typically do not have large effects. He highlighted the uncertainties related to e-cloud effects in the triplet as significant.
- **EB** pointed out that beam-beam effects are one of the few plausible explanations for the observed phenomena.
- **TP** suggested doing an MD with weak-strong BB, one with pilots that can be excited for measurements and one with nominal beam. This could help validate the simulation. **JW** added that we would then miss any effect of a two-beam e-cloud in the triplet. **MH** proposed a reverse test setup: filling beam 1 fully while introducing 8 bunches in beam 2 to isolate the ecloud from BB effects.
- **IE** emphasized the need for a solution that increases beta beat more significantly at the secondary collimators than at the primary, to break the hierarchy.
- **XB** stressed the importance of examining beta beat at individual collimators and discussed the implications of beam coupling which would produce large amplitudes in x and y. However even with a reduced tune separation no such observation was made, in the simulations, and coupling from skew long range in LHCb can likely be excluded.

6 Collimation hierarchy breakage: BBB loss and lifetime observation (S. Kostoglou)[slides]

Summary of the presentation

SK presented her studies regarding the collimation hierarchy breakage. The first part of the presentation focused on the analysis of the bunch-by-bunch losses and effective cross-section, using the dBLM signals close to the primaries. Based on the average dBLM signal, a distinct signature, which is a flat signal for B2, was reported when the collimator hierarchy breaks, while there is no such observation in the FBCT.
Furthermore, analysis of the bunch-by-bunch dBLM revealed a reversal of the effective cross-section at 36-33cm where bunches most affected by LRBB loose less than others, while at 30cm, the effective cross-section appears low and flat for all bunches in B2. Looking at the signal of the dBLM close to the secondaries, an increase in B2 losses was shown when the hierarchy breaks. For two fills 9514 and 9518, a potential correlation with a tune trim applied (1e-3) was reported, i.e. the breakage occurs after about 30 minutes in 30 cm, after tune trims before switching on the wires.
In the second part of the presentation, some observations on LHCb were reported, not relevant to the hierarchy breakage, but potentially related to the losses in adjust. For bunches colliding in IP8, worse effective cross section and worse lifetime are observed (for B1 in all fills) in stable beams but also already in adjust.
Last, it was suggested to study the impact of the SPS scraping (which is less aggressive this year wrt 2023) to see if there is an impact from the tails, in view of both the hierarchy issue and the losses in adjust.

Discussion

- **JW** emphasized, that the flat signal means that the losses are no more at the primary, as indicated in the machine BLMs.
- **GT** inquired about the behavior of the signature flat signal over time, to which **SK** responded that it becomes noisy but does not exhibit an upward trend. Further discussion focused on one of the example signals that were shown, where a sharp increase of the flat signal after a period of time was observed. That was attributed to emittance scans conducted at that moment.
- **JW** noted the sharpness of the reversal of effective cross section at 36 cm, indicating no transition point. **GT** added that these observations should be independent of the crossing angle, which does not change at that stage.
- **SK** suggested that the bad lifetime in adjust could be related to the tune. **JW** replied that there is no difference in adjust wrt last year, adding however that in some of the recent fills where the separation was higher, the lifetime was better.
- **MH** commented that the DA simulations for B1 are different from B2.
- **GT** commented that traditionally in the past B1 followed beam-beam pattern and B2 e-cloud; however this is not the case this year.
- **SK** asked about the possibility of an asynchronous collapse in IP1/5 and IP8, in order to not see the impact of beam-beam and understand if it is indeed related to IP8. **JW** replied that it could be possible.

- Concerning the SPS scraping, **SK** commented that the tails when the beam leaves the SPS seem to be the same as when it enters LHC.
- It was commented that the aggressive longitudinal blow-up in the ramp is not 100 % controllable, resulting in different bunch lengths. **GT** replied that the uncertainty of the longitudinal blow-up is the same as last year. He added that a new trend in bunch length evolution when colliding and not colliding can be observed, which was not the case last year, and suggested it might be worth further investigation.
- It was concluded that, during the hierarchy breakage, it seems that all particles are escaping the primaries. **JW** highlighted that it is important to understand where the particles go. It was suggested to open or close the primaries more, in a configuration where the hierarchy is broken, and/or to open all the secondaries. It was reported that we can open the secondaries up to +- 300 um. Last, it was noted that previous attempts including opening of the two suspicious secondaries did not show any significant difference, although this was in a fill where the hierarchy was not fully broken and with small setting changes.