

LHC RELATED PROJECTS AND STUDIES – PART(I)

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Abstract

This session was the first of the two sessions dealing with future projects and the associated studies. Starting with descriptions of the plans and needs of the LHCb and ALICE experiments which are less extensively documented than those of ATLAS and CMS, it addressed the plans for the High Luminosity LHC and for the upgrade of the injectors, both for protons and other ions.

WILL ALICE BE RUNNING DURING THE HL-LHC ERA?

(J. Wessels, Westfaelische Wilhelms-Universitaet Muenster)

The ALICE collaboration is actively preparing plans for upgrading the detector and make it capable to operate at about 5 times the nominal luminosity (Lead-Lead collisions at $6 \cdot 10^{27} \text{ cm}^{-2}\text{s}^{-1}$ in view of collecting 10 nb^{-1} during the HL-LHC era, after LS3). Until 2020, the main goal is to accumulate $\sim 1 \text{ nb}^{-1}$ with Lead-Lead collisions, including potentially a run with Proton-Lead. A run with Argon-Argon is foreseen immediately before LS3, using the beam characteristics achievable by the injectors without specific modifications. After LS3, the option of other ions than Lead is open (e.g. Uranium). To meet the luminosity expected with Lead-Lead collisions, the baseline proposal is to increase the number of bunches in LHC by a factor between 2 and 3.

Discussion

H. Burkhardt: Would ALICE continue also with p-p collisions during HL-LHC? The problem could be that the background will increase together with the signal.

J. Wessels: It is difficult to estimate the background in these conditions, but p-p collisions are necessary in any case for every observable mentioned with Pb-Pb collisions. Estimations were done up to LS2 for p-p collision, and the background seems to be under control. Statistics will be sufficient with collisions from the “natural” satellites.

M. Mangano: For the jet quenching one needs high luminosity. Moreover, high-b tagging efficiency, as J/Ψ tagging could be better done by ATLAS and CMS?

J. Wessels: Jet quenching is still the priority and ATLAS and CMS could also help. Still, in particular for the J/Ψ , measurements at low transverse momentum are needed, with also minimum bias events. It will not be sufficient to have only triggered events, in particular for the J/Ψ polarization.

WILL LHCb BE RUNNING DURING THE HL-LHC ERA?

(B. Schmidt, PH/DT)

There is a strong case for continuing to run the LHCb experiment after LS2 and even LS3. The physics case for upgrading the detector and integrating up to 50 nb^{-1} has been endorsed by the LHCC in June 2011. The upgrade is planned during LS2 (2018), with data taking during the following 10 years of run. For that purpose, the levelled luminosity is expected to be brought up to $2 \cdot 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ (10 times nominal). Bunch spacing of 25 ns is fundamental for running at this luminosity with an acceptable pile-up ($\mu=4$). Rotation of the beam-screen in the triplet is requested to facilitate using an external vertical crossing angle, preferably during LS1.

Discussion

S. Fartouk: The required integrated luminosity, and the peak luminosity with levelling are not consistent. Applying the same arithmetic than for the high luminosity experiments $10^{33} \text{ cm}^{-2}\text{s}^{-1}$ is sufficient for LHCb to integrate 50 fb^{-1} during the HL-LHC decade.

B. Schmidt: In the LOI, $10^{33} \text{ cm}^{-2}\text{s}^{-1}$ was asked but after further analysis $2 \cdot 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ is now preferred as peak luminosity after the upgrade.

S. Fartouk: This could be a problem for the ATLAS and CMS luminosity burn out.

J. P. Tock: It is not possible to turn the triplet beam screens to optimise the aperture during LS1 because it would require removing the triplets and transporting them to the surface.

B. Schmidt: It is desirable if feasible. If not, it should then be planned during LS2.

L. Rossi: A new TAS will probably not be necessary, adjusting the BLM thresholds more precisely. Even though D1 and D2 are superconducting magnets, the quench levels are probably large enough to cope with $2 \cdot 10^{33} \text{ cm}^{-2}\text{s}^{-1}$.

HL-LHC OPERATION WITH PROTONS AND IONS

(O. Bruning, BE/ABP)

Among the multiple constraints to be faced in the LHC for reaching the HL-LHC goals, recent experience has shown that the head-on beam-beam interaction is much less harmful than previously estimated. However, the limitations resulting from beam energy, collective effects and electron clouds remain. The present set of parameters for the HL-LHC is designed to maximize the integrated luminosity per year while respecting these constraints. Luminosity levelling using crab cavities at the level of

$5 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ in IP1 and IP5, is the aim for limiting pile-up in the detectors. The baseline option assumes a β^* of 15 cm with 25 ns bunch spacing, $2 \cdot 10^{11}$ p/b, 2.5 mm.mrad. Alternatively, if electron-clouds remain an issue after scrubbing, 50 ns bunch spacing would be an alternative option, with $3.3 \cdot 10^{11}$ p/b and 3 mm.mrad.

Based on present experience, a transverse emittance blow-up of 10 to 20 % should be accounted for between injection and collision.

Reaching an integrated luminosity of 200-300 $\text{fb}^{-1}/\text{year}$ is extremely challenging and requires an average turnaround time smaller than 5 h and an average fill duration of more than 7 h.

Meeting the needs of the ALICE experiment with ions after LS3 is within reach in the LHC, provided that the injectors can fill the collider with between two and three times as many bunches as in 2011.

Discussion

Q: The Luminosity reduction factor comes only in the crossing plane. Could one change the optics then in the other plane to increase the luminosity?

O. Bruning: The option of getting flat beams through optics is open.

R. Brinkmann: Is there any option without crab cavities?

O. Bruning: The baseline is to use crab cavities. Flat beams through optics is an alternative option which remains under study.

S. Fartouk: Crab cavities are needed to reach such high luminosity.

R. Schmidt: Reliability deserves a lot of work for reaching the availability needed for long fills and short turnaround times in HL-LHC.

S. Redaelli: If the crab cavities do not work, how will the HL-LHC goals change?

O. Bruning: Flat beams should allow reaching one half of the luminosity. In addition, shorter bunches or even smaller transverse emittances could be contemplated.

L. Rossi: Shorter bunches will increase heat deposition on the beam screen. Tests are necessary to estimate how much the cooling capacity of the beam screen could be increased.

O. Bruning: The analysis of the hardware systems that would limit the beam current is the subject of a special work package. Concerning the cooling system, the cryoplants themselves represent a hard limit. The abort dumps are other potential limitations.

S. Fartouk: Cooling in the arcs could be just enough for operation with shorter bunches. How optimistic is the goal of 200-300 fb^{-1}/y ?

O. Bruning: 200 fb^{-1}/y seems reachable. It is not clear if the e-clouds will constitute a serious limit. The detrimental effects of e-clouds are not limited to the heating of the beam screen. They can also trigger beam instabilities and degrade beam quality.

E. Chapochnikova: IBS at injection could be an issue which may be mitigated with a controlled bunch-by-bunch blow-up. Concerning the total beam current, the

LHC RF power would have to be upgraded for dealing with more than $1.7 \cdot 10^{11}$ p/b with 25 ns spacing.

J. Jowett: how did you estimate the number of days of run per year?

O. Bruning: based on experience until now, it is reasonable to expect runs of 150 d/y. A commissioning period will continue to be necessary every year, because of the very high beam power in HL-LHC.

CAN THE PROTON INJECTORS MEET THE HL-LHC REQUIREMENTS AFTER LS2?

(B. Goddard, TE/ABT)

The beam specifications for HL-LHC are very demanding, especially when a degradation of the brightness of 20 % is taken into account in the LHC itself, as mentioned in the previous talk. Taking into account reasonably optimistic emittance blow-up and beam loss in the injectors and estimating the benefit expected from the planned upgrades for fighting the known limitations in these machines, the beam characteristics at injection in the LHC do not meet the HL-LHC requirements. With 25 ns bunch spacing (resp. 50 ns) the SPS could deliver $2.3 \cdot 10^{11}$ p/b within $3.6 \mu\text{rad}$ (resp. $2.7 \cdot 10^{11}$ p/b in $2.7 \mu\text{rad}$). This has to be compared with HL-LHC specifications of $2.2 \cdot 10^{11}$ p/b in $2.3 \mu\text{rad}$ (resp. $3.7 \cdot 10^{11}$ p/b in $2.7 \mu\text{rad}$). A number of optimistic assumptions are necessary for reaching the HL-LHC figures, concerning the success of measures against space charge, instabilities, e-clouds and to minimize beam loss.

The timeline of the LIU project foresees the implementation of most modifications and upgrades during LS2. A commissioning period of adequate duration (some months) will be necessary to re-obtain similar beam performance than before LS2 and to be able to resume physics in LHC.

Discussion

Y. Papaphilippou: There are reasons to expect that with the Q20 optics, the SPS could operate with a Laslett space charge tune-shift of -0.19. Past measurement at 14 GeV/c, have shown that it could reach -0.2. That would bring the 50 ns bunches at the edge of the SPS possibilities.

V. Chohan: The duration of the re-commissioning but also the duration of LS2 should be clearly analysed.

R. Garoby: The durations mentioned in the presentation do not include the connection of LINAC4 which is assumed to take place before LS2. If this is not the case, the stop of the injectors could be longer.

R. Steerenberg: To reduce the effect of space charge in the PS, the length of the injection flat bottom might be reduced, typically from 1.2 s to 0.9 or even 0.6 s.

S. Gilardoni: This possibility is known but not yet fully studied. The 0.6 s repetition rate will not be possible due to a limitation of the injection elements of the PSB with the Linac4.

G. Arduini: Longitudinal stability in the PS is a crucial limit. How much is it known? Is there a feedback foreseen?

H. Damerau: The impedance of the cavities themselves is sufficient to explain longitudinal instabilities. A powerful wide-band feedback system is planned for installation during LS1.

S. Gilardoni: The space-charge tune shift of -0.26 mentioned in the PS is not an absolute limit, but the observed space-charge for the existing operational LHC beams. Still, studies are on-going to determine the maximum tolerable tune shift, i.e., the real limit.

R. Garoby: With 25 ns bunch spacing, the feasible emittance results from space charge in the PS. It could be brought to the level expected by HL-LHC using batch compression schemes like those described by H. Damerau in Session 7.

NECESSARY LIU STUDIES IN THE INJECTORS DURING 2012

(G. Rumolo, BE/ABP)

MDs during 2011 and 2012 will be instrumental in defining the performance goals and specifying the equipment to be installed or upgraded during the LIU project. Although significant progress was made in 2011, a lot of subjects deserve more beam time and simulations in 2012. These include collective effects in longitudinal and transverse phase planes due to space charge, e-clouds, and impedances in all machines, and the diagnostic of emittance blow-up and beam loss up to injection in the LHC.

Discussion

E. Métral: Could a larger space-charge tune-shift be acceptable in the PS by optimizing further the optics?

S. Gilardoni: This possibility is indeed under study.

L. Rossi: 25 ns is the baseline for the upgrade. It is especially important to assess the space-charge limit of the PS, which seems for the moment to be the bottleneck.

R. Garoby: This subject is given an important priority for the MDs in 2012.

SPS: SCRUBBING OR COATING?

(J.M. Jimenez, TE/VSC)

The operation of the SPS with high intensity bunched beams is limited by electron cloud build-up in both the arcs and long straight sections. Amorphous Carbon (aC) coating has now progressed enough to be considered as a viable cure and to be confirmed as baseline solution for the SPS. Scrubbing still deserves more experiments and simulations but has not been discarded as an alternative. It will in any case remain a mitigation measure, limited by the specific characteristics of stainless steel to a secondary electron yield of ~ 1.3 . Wide band feedback is a challenging solution which is worth to continue pursuing because of its wide potential interest.

Discussion

E. Jensen: The trend of a slow increase of the SEY in the SPS can be observed over the years. Is there a model and is saturation expected?

M. Jimenez: There is presently no model. Saturation seems however to be present, hopefully below 1.3. A check of the surfaces will be done after LS1 and before LS2.

L. Rossi: Is there enough time between LS1 and LS2 to fully validate the solution(s) against e-clouds?

M. Jimenez: Yes. For coating, the studies are already well mature. Scrubbing will require more effort and beam-time to reach the same maturity.

L. Rossi: Is one year sufficient to coat all SPS vacuum chambers?

M. Jimenez: Yes, but only if no any other major activity is foreseen in the LHC. The coating will be done in-situ, without the need of opening the magnets.

L. Rossi: If all chambers cannot be coated during LS2, priority should be given to the MBB chambers.

E. Jensen: What is the expected lifetime of the SEY? Could you repeat the process of coating again?

M. Jimenez: Coating is expected to be done only once.

M. Taborelli: No aging was observed on the coated chambers. A slow deterioration was seen only on some samples which were not in direct view of beams. No aging was observed on cut parts of the e-cloud monitors. Concerning the intervention in-situ, the magnets will be removed from their positions and transported to an underground cavern where the chamber will be coated. No coating will be done on too radioactive MBs.

G. Arduini: Alternatively, inserts could be used for magnets that cannot be removed.

Y. Papaphilippou: With the Q20 optics, experiment shows that the threshold for e-cloud instability is raised.

M. Jimenez: Compared to the LHC, heat deposition in the SPS arcs is not an issue because the SPS magnets are normal conducting.

L. Evans: In the LHC, the worse vacuum with 25 ns bunch spacing is likely to damage electronics because of radiation.

M. Jimenez: Pressure transients are expected during the scrubbing run when desorption is pretty large. The limit would then be given by beam stability rather than the electron-induced heat.

PLANS FOR IONS IN THE INJECTOR COMPLEX

(D. Manglunki, BE/OP)

The overall performance of the ion injector complex is exceeding expectations for the "intermediate" scheme where 200 ns spaced bunches (nominal: 100 ns) are provided by the SPS. Batches of 24 bunches with an average intensity of $1.4 \cdot 10^8$ ions/b in $0.85 \mu\text{m}$ have been regularly injected in the LHC (expected: $0.9 \cdot 10^8$ ions/b in $1.2 \mu\text{m}$). Doubling or possibly tripling the number of bunches circulating in LHC would meet the requirements

of ALICE during the HL-LHC era. This implies generating bunches with 50 ns spacing in the PS and decreasing the SPS injection kicker rise-time. The goal will be attained if the PS injectors (LEIR + Linac3) can be upgraded to deliver twice as much intensity per pulse within the same transverse emittances. This is likely to require significant developments which should begin as soon as possible.

The delivery of Argon and Xenon ions will be possible after LS1, using the equipment prepared for fixed target experiments. Other species will need specific R&D, concerning source and pre-accelerator, plus the analysis of specific safety measures (e.g for Uranium).

Discussion

J. Jowett: Beam characteristics of the injectors, in their present state, are only a factor of 2-3 away from long-term ALICE requirements. More work and MDs are needed to assess the difficulty of bridging this performance gap.

R. Garoby: This workshop is the opportunity to collect a formal request in terms of beam parameters, luminosity and ion species.

J. Jowett: Until 2019, the detectors will be the limit, constraining the peak luminosity.

O. Bruning: Is the installation of the 100 MHz system in the SPS compatible with HL-LHC?

E. Chapirova: Such an additional system will increase impedance and make it more difficult to approach the beam characteristics of HL-LHC. In any case, it will be expensive because amplifiers and electronics have to be rebuilt.