EXPERIMENTS EXPECTATIONS

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Abstract

This paper presents the expectations and the constraints of the experiments relatively to the commissioning procedure and the running conditions for the 2015 data taking period. The views about the various beam parameters for the p-p period, like beam energy, maximum pileup, bunch spacing and luminosity limitation in IP2 and IP8, are discussed. The goals and the constraints of the 2015 physics program are also presented, including the heavy ions period as well as the special running conditions.

STANDARD P-P RUNNING CONDITIONS

Before discussing individual parameters it needs to be re-stated that, from the physics point of view, the principle guiding the discussion on beam conditions is to maximize *total integrated* luminosity *usable for physics.*

This means, first of all, that when discussing the 2015 data-taking period one should consider the implications on the integrated luminosity reach of the whole Run 2 period. Moreover, considering machine performance, one should weigh the effect of reaching ultimate peak luminosity against the potential price to be paid in terms of commissioning time or machine availability, as well as any resulting condition, e.g. excessive pileup, that could degrade the data taking or analysis efficiency of the experiments.

Pileup and bunch separation

As always stated the most critical parameter for the high luminosity experiments is the number of interactions per crossing. A higher level of pileup has negative implications on several aspects of the experiments, including the readout capability, due to increase in detector occupancy, the trigger efficiency, affected by the higher rate of fakes, the reconstruction and analysis efficiencies, as well as the systematic uncertainties. All those aspects concur in decreasing the experimental accuracy that can be reached for a given delivered integrated luminosity. The requirements on online and offline computing resources increase as well with higher pileup. Clearly the negative effect of pileup is incremental, as well as analysis and physics dependent, hence one should not take any limit described in this paper as a sharp threshold, below which there is no effect and above which the experiments would stop working, but rather consider pileup as the key parameter to optimize the physics yield of LHC in conjunction with all other relevant machine parameters. ATLAS and CMS have studied carefully several effects and agree that a maximum level of pileup of about 50 would be manageable in Run 2, and would not require luminosity levelling. It must be made clear though that handling such a level of pileup is challenging and it is hence only considered acceptable as an initial fill value, assuming the natural luminosity decay. In a scenario in which the fill luminosity would instead need to be levelled to a constant value, it would be preferable to target a much lower pileup value, ideally between 30 and 40.

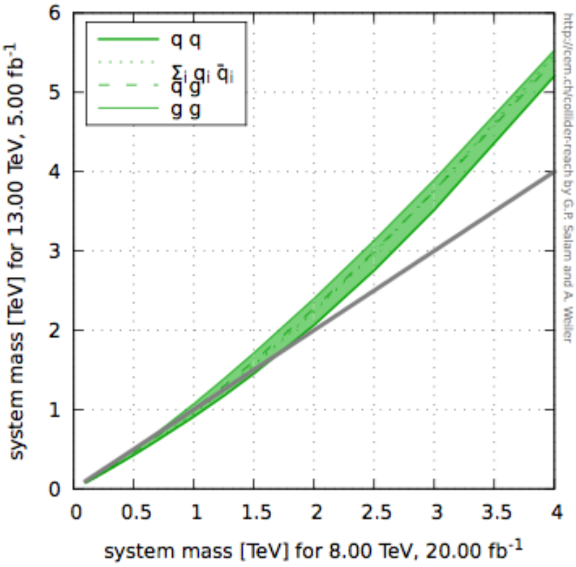

Figure 1: Discovery potential comparison: parton-parton system mass for which one gets the same number of events for 5 fb^{-1} delivered at a center of mass energy of 13 TeV with respect to 20 fb^{-1} delivered at a center of mass energy of 8 TeV. See [1] for more information.

As it is obvious that, for the same total peak luminosity, a beam with a larger number of colliding bunches has a lower pileup level, it is considered of paramount importance to aim at running with a bunch spacing of 25 ns, to maximize the ultimate physics reach of the LHC machine. It is understood and accepted by all experiments that running with 25 ns bunch spacing will need a longer commissioning period and could result in lower integrated luminosity delivered in 2015 with respect to an alternative setup with 50 ns, but it is still considered as the supported scenario in view of the longer term scientific goals. It must be otherwise stressed that the increase in beam energy will significantly improve the potential for discovery of new physics even with moderate luminosity (see figure 1), hence the 2015 data taking period should not be considered simply as a commissioning campaign. It is also understood that a phase of machine re-commissioning with 50 ns spacing will be needed, but it is expected to be limited to what is required for establishing the machine conditions without spending time in optimizing performance.

Luminous region and optics

In addition to being affected by the total level of pileup, the experiments are also sensitive to the density of collisions over the luminous region, in particular for the efficiency of the reconstruction of the event's primary vertex in the tracker detectors. Hence, for high total pileup values, the length of the luminous region becomes an important parameter. The experiments would prefer to keep the luminous region at the beginning of the fill to values not significantly shorter than those of Run 1. Decreases of the order of about 10% would be acceptable, while shorter lengths may require further study. There is instead no major concern with adjusting the bunch length or the crossing angle to reduce the luminous region during the fill, in view of moderating the decay of luminosity. It is to be noted that also an excessive lengthening of the luminous region may reduce track reconstruction efficiency in ATLAS and CMS as well as the LHCb VELO acceptance for long-lived B mesons. As a general remark, it would be important for the experiments to know the expected beam parameters as early as possible for MC production.

There are no particular concerns from ATLAS and CMS with respect to the choices of optics at the IP. Injecting at lower β* would not be a problem as the Van der Meer scan campaign will anyway require ad-hoc optics. Even the possible adoption of flatter optics is not seen as a problem, at least up to a β_x/β_y ratio of 2-3.

Filling schemes

The only constraint with respect to filling schemes for physics data taking is that they should include few bunches not colliding in IP 1 and IP5, for both beam 1 and beam 2. These bunches have proven to be essential to background studies, as otherwise the experiments would have no direct way to evaluate the level of beam-gas interactions. It is proposed to shift, for one of the two beams only, the initial injection of 12 bunches, required for machine protection checks. Despite the fact that the non-colliding bunches should be as similar as possible to the colliding ones, it would be acceptable to inject lower charge for those ones, to mitigate potential instabilities due to lack of Landau damping.

Levelling and crossing in LHCb

The analysis of LHCb's Run 1 data has not shown a significant improvement of systematic uncertainties due to the tilted crossing angle scheme. This requirement is thus relaxed for Run 2. It is anyhow suggested to aim at minimising differences between the crossing angles for the two experiment's magnet polarities. A regular polarity swap will still be requested about every 100 pb^{-1} delivered to LHCb.

In 2015 LHCb will need the luminosity in IP8 to be levelled to 4-6 10^{32} $cm^{-2}s^{-1}$. While there is no particular preference for the specific mechanism of levelling, it is suggested by all experiments that a partial implementation of levelling based on modulation of β* in IP 8 may be useful in view of collecting general experience on the β* levelling approach, that could prove useful in case such a mechanism should need to be deployed at a later stage in IP1 and IP5.

ALICE conditions during the p-p period

The ALICE experiment needs to collect data in minimum-bias conditions during the whole p-p data taking period. This means that the luminosity in IP 2 should be levelled in a range between 5 10^{29} $cm^{-2}s^{-1}$ and 2 10^{30} $cm^{-2}s^{-1}$. Assuming a bunch separation of 25 ns, which implies that most bunches collide head-on in IP 2, the required reduction of luminosity must be achieved mostly by beam separation. Looking at beam profiles measured in Run 1 during Van der Meer scan campaigns one can derive that a separation of the order of 5 σ will be needed. Dedicated studies must be carried on early on to assess the feasibility of such conditions. In particular the stability of luminosity conditions at such extreme separations should be addressed as well as the operational procedure to bring ALICE into collisions with a large enough separation, to avoid the risk of frequently triggering a beam dump when removing the separation bump. It is to be reminded in fact that ALICE BCMs have a dump threshold presently estimated to be set at a luminosity of about 6 10^{31} cm^{-2} s^{-1} [2].

ALICE requires to have few bunches colliding in IP 2 during the 50 ns period. An ad-hoc filling scheme with few head-on collisions would be preferable given the relative instability of conditions achieved with the main-satellite collisions approach followed in Run 1.

HEAVY IONS CONDITIONS

Four weeks of running have been allocated for Heavy Ions data taking in 2015. It has been decided to run with Pb-Pb collisions at the equivalent nucleon energy of 5.02 TeV. The luminosity reach is expected to exceed the maximum value acceptable by ALICE of 10^{27} cm^{-2} s^{-1} (see [3]), hence a levelling mechanism will have to be setup at least in IP 2. It is suggested to implement levelling as well in IP 1 and IP 5, despite not directly needed by ATLAS and CMS, to limit the performance penalty in ALICE, due to the larger ions burn-off in the other collision points. It is also to be reminded that ATLAS and CMS require a reference sample of p-p collisions at the equivalent proton energy. The actual extent of this data taking period, as well as its detailed schedule are still being discussed in the LPC meetings, but it is required that the necessary commissioning is carried out before the start of the Heavy Ions period.

EARLY COMMISSIONING PERIOD

At this moment the only specific request from the experiments for the initial machine commissioning period is to deliver about 20 beam splashes per beam in both IP1 and IP 5 as well as few TED shots, during the sector tests of sector 78, for LHCb alignment studies. It is also expected that stable beams conditions will be established as soon as possible to allow detectors and triggers commissioning. Some data taking in stable beams conditions will be regularly requested during the phases of intensity ramp up. Dedicated runs with low or very low pileup are not requested at the moment as we expect to collect data in such conditions parasitically during the special run for LHCf.

SPECIAL RUNS

Given the shortness of the 2015 data taking period and the extent of the commissioning campaign, it has been decided to limit the program of special runs to a minimum. The only exceptions foreseen at this moment are special runs for LHCf and a high β* period for diffractive physics in ALFA and TOTEM, as well as two Van der Meer scan campaigns.

LHCf run and VdM scans

It is envisaged to combine the first VdM scan and the LHCf data taking periods and to schedule them in the very early days of the 2015 physics period (within about a week of data taking). An early VdM scan is indeed needed for an initial calibration of the luminosity measurements, given the change in beam energy. The LHCf run needs instead to be scheduled before about 500 pb^{-1} of luminosity are delivered to IP 1, to prevent significant degradation of the LHCf detector that suffers from radiation damage even when left in garage position.

LHCf needs to take data with large β* as well as with very low pileup ($\mu<0.01$) and large bunch separation (>2μs). Due to the increased beam energy and the subsequent natural reduction of the beam size, it is established that the VdM scan will need to be performed with un-squeezed optics in order to keep the luminous width significantly larger than the experiments' vertex resolution, to study the non-linear x-y beam correlations that are a dominant source of uncertainty for the luminosity calibration. It is thus suggested to establish ad-hoc optics to accommodate both programs. The requested values of β* are 19 m for IP 1 and IP 5, while LHCb would benefit from a larger value, between 30 and 40 m.

The requests in terms of luminosity per bunch are significantly different for the two programs, hence it is suggested to always inject bunches of about $7\ 10^{10}$ protons, ideal for the VdM scans, and reduce the pileup in IP 1 by separation when providing data to LHCf.

It is essential to remind that LHCf will need a half crossing angle of 145 μrad. Despite not being ideal, it is accepted that the initial VdM campaign will be performed with the same crossing angle, to allow the commissioning of a single machine setup for both programs.

It is foreseen to start this special run campaign with the VdM scans in the four interaction points and then proceed with the LHCf data taking. LHCf will ideally start collecting data during the scan in IP 5. It is still unclear if a filling scheme can be established to allow LHCf to also take data parasitically during the scans in IP 2 and IP 8 and yet have a total current compatible with operating the DCCT detectors in their preferred range.

A second VdM scan period will need to be scheduled in the second part of the 2015 run, for reaching ultimate precision. This run will need a setup without crossing angle.

Both VdM scans will need a rather large emittance (about 3 μm) as well as special care in the injector chain to deliver beams with nearly-gaussian transverse profile.

High beta runs

Both ALFA and TOTEM have requested data taking with β* of 90 m for diffractive physics studies. TOTEM in particular has requested a joint data-taking period with CMS with the target of collecting about 10 pb^{-1} of central diffractive event data. Given the need for low pileup conditions, it is foreseen to inject bunches with a charge of about $7\ 10^{10}$ protons. To maximize total luminosity and yet respect the minimal bunch separation requirements of TOTEM, it is suggested to setup a filling scheme with about 1000 bunches and 75 ns of bunch spacing. This requires the development of a machine setup with a crossing angle. It is important to state that even in those ideal conditions one would only reach a luminosity of about $10^{31}\ cm^{-2}s^{-1}$, making the TOTEM statistics goal quite difficult to reach, given 2015 tight schedule. Any degradation of these ideal conditions would immediately put the scientific program in danger.

Since the insertion of the Roman Pots with standard optics is envisaged, it is suggested that end of fill studies be scheduled to test the mechanism during the machine commissioning and intensity ramp-up programs.

ACKNOWLEDGMENTS

We wish to thank in particular the Run Coordinators of ALICE, ATLAS, CMS, LHCb, LHCf and TOTEM for their essential input as well as our colleagues working on the LHC and injectors operations for countless explanations and discussions about machine parameters and constraints.

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