EXPERIMENTS' EXPECTATIONS

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Abstract

An overview of the requests from the experiments for 2011 will be given. This will include integrated luminosity considerations, special runs and special beam conditions. The 2011 run schedule is discussed.

INTRODUCTION

The LHC 2010 physics run was presented in details elsewhere [1]. In brief, the LHC produced first pp physics collisions at $\sqrt{s} = 7$ TeV in March 2010, starting with a luminosity of about $8 \cdot 10^{26}\ \mathrm{Hz/cm^2}$ and finally reached $2{\cdot}10^{32}\ \mathrm{Hz/cm^2}$ in October 2010, thus brilliantly surpassing the target. The experiments took advantage of the gradual luminosity increase to step through (i) calibration of the detectors, (ii) "re-discovery" of particle physics (quarkonia, weak bosons, top quarks, ...), thus gauging the level of understanding of their detectors, and finally (iii) to actually produce physics results [2]. The integrated delivered luminosities (2010 totals) were approximately $48\ \mathrm{pb^{-1}}$ (IP1), $0.5\ \mathrm{pb^{-1}}$ (IP2), $47\ \mathrm{pb^{-1}}$ (IP5) and $42\ \mathrm{pb^{-1}}$ (IP8).

The end of 2010 was devoted to a first Pb run (with LHCb switched off). In this case, the luminosity was increased from $3{\cdot}10^{23}\ \mathrm{Hz/cm^2}$ to $3{\cdot}10^{25}\ \mathrm{Hz/cm^2}$. The integrated delivered luminosities were approximately $9.9\ \mu\mathrm{b}^{-1}$ (IP1), $9.3\ \mu\mathrm{b}^{-1}$ (IP2) and $9\ \mu\mathrm{b}^{-1}$ (IP5).

In total, the LHC operated 1074 hours in `STABLE BEAMS` (851 hours with p and 223 hours with Pb) out of about 6600 hours. There were 147 fills with `STABLE BEAMS` (110 with p and 37 with Pb). Yearly summary plots for peak luminosity and integrated luminosity are available at the LHC Programme Coordination web site [3].

An important parameter for 2011 projections is the overall efficiency of the machine for luminosity delivery. Figure 1 shows that, when operation was dedicated to luminosity delivery (like in August and November 2010), about 30% of the scheduled time was actually spent in physics collisions. In 2011, approximately 135 ± 10 days will be dedicated to 3.5 TeV high luminosity physics operation [4]. Thus, for 2011 projections, one could expect at least 970 ± 70 h of `STABLE BEAMS` in the proton run (and 190 h in the Pb run).

Next, we discuss the main expectations from the experiments for proton operation, the special requests for proton operation, and the expectations for the heavy ion (HI) run.

PROTON RUN: 2011 EXPECTATIONS

The goals for 2011 proton running have been set a year ago, namely to deliver an integrated luminosity of at least

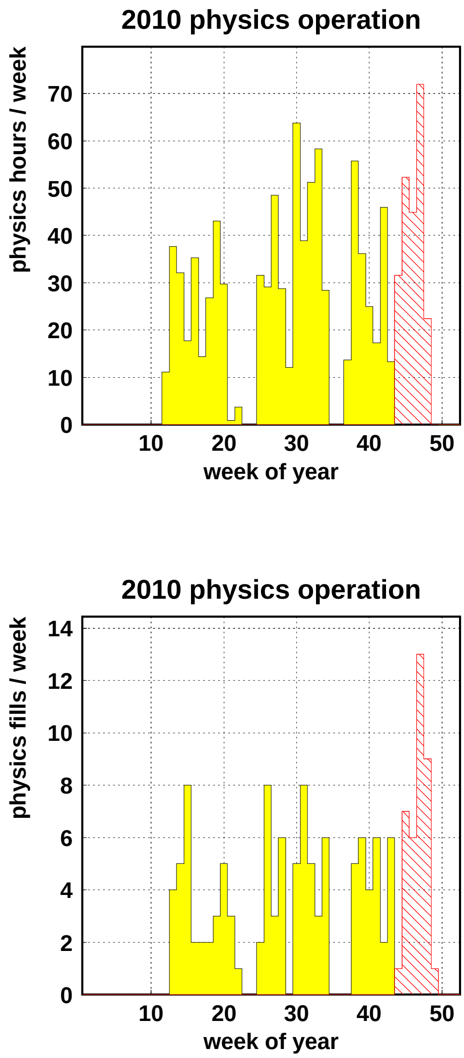

Figure 1: Overview of 2010 proton run. The top (bottom) graph shows the number of fills (hours) of `STABLE BEAMS` per week. Shaded (yellow) histogram: proton run. Hatched (red) histogram: ion run.

$1\ \mathrm{fb^{-1}}$ to each of IP1, IP5 and IP8. Given the excellent results obtained in 2010, a substantially larger integrated luminosity can probably be achieved for IP1 and IP5. However, for IP8 the task is more challenging, as will be discussed below.

Highlights of the ATLAS and CMS physics potential, in particular concerning the Higgs discovery reach or exclusion limits, have been updated by the experiments and presented elsewhere [5]. Assuming 3.5 TeV beam energy, with about 2.5 fb^{-1} ATLAS and CMS can each independently exclude at 95% CL the Standard Model (SM) Higgs with any mass. With about 6 fb^{-1} ATLAS and CMS can each independently obtain a 3σ observation from the LEP bound (≈ 115 GeV) to about 500 GeV.

The LHCb potential was also reminded [5]. Illustratively, with 1 fb^{-1} LHCb can exclude at 95% CL the FCNC[1] rare decay $B_s \rightarrow \mu^+\mu^-$ branching ratio down to about $6 \cdot 10^{-9}$, leaving little room for hypothetical enhancements of this decay by New Physics, such as supersymmetry. A signal above the SM value ($5 \cdot 10^{-9}$) and below the current Tevatron limit ($\sim 37 \cdot 10^{-9}$) could also be discovered by LHCb and open a door on New Physics territory.

Naturally, the main wish of ATLAS, CMS and LHCb is to obtain the largest possible integrated luminosity. For ATLAS and CMS, this can be planned without any limitation on pile-up other than the design values (which are probably beyond reach for 2011), while for LHCb the pile-up should be limited, as discussed below. In general, for the same reach in integrated luminosity, acquiring physics data with less pile-up is more favorable. This statement is valid for all experiments. Therefore, once good conditions with trains have been established (with the maximum number of long-range encounters for the chosen bunch spacing), a rapid increase of the number of bunches to the maximum possible is desirable (to about 900 for 75 ns spacing or about 1400 for 50 ns spacing).

As a reminder, the luminosity and average number of interactions per crossing are given by

$$\begin{aligned} L &= n\ f_{\text{rev}}\ \frac{N^2\ S\ \gamma}{4\pi\ \varepsilon_N\ \beta^*} \\ \mu &= \sigma_{\text{inel}}\ \frac{N^2\ S\ \gamma}{4\pi\ \varepsilon_N\ \beta^*} \end{aligned} \tag{1}$$

where N is the bunch population, n the number of bunch pairs colliding at the given IP per LHC turn, ε_N the normalised transverse emittance, $\gamma = 3.5\ \text{TeV}/0.938\ \text{GeV} \approx 3730$ is the Lorentz factor, β^* the optics function at the given IP, $f_{\text{rev}} = 11245$ Hz is the LHC revolution frequency, σ_{inel} is the inelastic cross section and S is a reduction factor which includes effects due to the local geometric parameters: the crossing half-angle α, the ratio of the longitudinal and transverse beam sizes (in the local crossing plane), and a possible transverse separation d_w along the transverse axis $w = x$ or y.

In October 2010, the LHC was routinely operated with 368 bunches of nominal bunch population ($1.15 \cdot 10^{11}$) and low emittance ($\sim 2.5\ \mu$m). In 2011, a factor 2.3 from the lower β^* (1.5 m) in IP1 and IP5 can be expected, and a factor of 2.6 or more from the increased number of colliding pairs (900 or more, as opposed to 348). Therefore, from the 2010 experience, and if e-cloud scrubbing facilitates 75 ns operation with 900 bunches or more [6], a peak luminosity of $L = 10^{33}\ \text{Hz/cm}^2$ in IP1 and IP5 seems within reach. The average number of inelastic interactions per crossing would be $\mu \approx 7.3$, a value still perfectly acceptable for ATLAS and CMS which were designed for $\mu = 25$ to 30. With such luminosity, one can expect delivering 26 $\text{pb}^{-1}/10$ h (this includes a factor of 0.7 for luminosity decay) and 2.5 fb^{-1} in 970 h. A rapid L increase to the "reasonably expectable" value is important, since every week lost for intensity ramp-up will imply a loss of integrated luminosity at the end of the year (when peak luminosity will be maximal, perhaps even in excess of $10^{33}\ \text{Hz/cm}^2$). This could be a loss of as much as 0.2 fb^{-1} per week.

An important difference with 2010 operation is that the high luminosity LHC experiments have already recorded more than 45 pb^{-1} of data at $\sqrt{s} = 7$ TeV. Therefore, any operation at a luminosity of less than $\sim 2 \cdot 10^{32}\ \text{Hz/cm}^2$ will contribute negligibly to the total integrated luminosity. For illustration, operation with 100 bunches (i.e. $1.1 \cdot 10^{32}\ \text{Hz/cm}^2$) would deliver 2 pb^{-1}/day (this includes a factor 0.7 for luminosity decay and 0.3 for the time fraction in `STABLE BEAMS`). Under the same assumptions but with 900 bunches, luminosity delivery would go at a pace of 18 pb^{-1}/day. These numbers are to be compared with $\sim 45\ \text{pb}^{-1}$ (on tape) and $\geq 1000\ \text{pb}^{-1}$ (2011 base target).

Thus, there is no request for physics operation with 50 to $\lesssim 300$ bunches. Ideally, the 2011 intensity ramp-up should be reduced to the minimum required for safe machine operation (i.e. recommissioning and machine protection validation).

The case of IP8 - LHCb

LHCb has been designed for a luminosity of around $2 \cdot 10^{32}\ \text{Hz/cm}^2$ and an average number of inelastic interactions per crossing μ of 0.4 to 0.5. In 2010, the LHCb Collaboration (successfully) deployed important efforts to cope with an increased pile-up, in order to maximize the recorded luminosity. A peak luminosity close to the LHCb design luminosity was achieved with 344 colliding pairs, instead of the nominal 2622 colliding pairs. This means that LHCb was able to take good data with $\mu \approx 2.5$ to 3, i.e. a factor 6 beyond the original design value. For 2011, not much further "stretching" of the LHCb detector capability can reasonably be expected.

For 2011, LHCb wishes to have the following luminosity and maximum average number of interactions per crossing

$$L_{\text{lhcb}} \approx 3 \cdot 10^{32}\ \text{Hz/cm}^2 \tag{2}$$

$$\mu_{\text{lhcb}} \lesssim 2.5\ . \tag{3}$$

The luminosity limit is probably a softer limit than the pile-up limit and could slightly increase with experience. From these requirements, and assuming an inelastic cross section of $\sigma_{\text{inel}} = 72$ mb, one can derive

$$n_{\text{thr}} = \frac{L_{\text{lhcb}}\ \sigma_{\text{inel}}}{\mu_{\text{lhcb}}\ f_{\text{rev}}} \approx 770 \tag{4}$$

[1] Flavor changing neutral current.

where $n_{\rm thr}$ is the "threshold" value of the number n_8 of bunch pairs colliding in IP8 below which it is not possible to deliver a constant luminosity $L = L_{\rm lhcb}$ without exceeding the pile-up limit (3).

Assuming 970 hours of `STABLE BEAMS`, a start-of-fill luminosity of $L_{\rm lhcb}$, and *no* luminosity leveling, one obtains an integrated luminosity of at most $0.73\ {\rm fb}^{-1}$ (an overall factor of 0.7 was applied to take into account the luminosity decay). With luminosity leveling, an integrated luminosity of just about $1\ {\rm fb}^{-1}$ is possible.

Two methods of luminosity leveling were considered. The first one would use a range of (decreasing) values of β^* during an LHC fill, with beams colliding head-on. The second one would use a sufficiently small β^* and adjust the vertical beam separation during the fill (reducing the separation as the value of N^2/ε_N decays). The first method seems a more favorable solution for long term, but requires substantial developments and involves a number of machine protection issues. The second method is operationally much simpler and was already successfully applied in 2010 to IP2 (ALICE, horizontal separation) from July to October. It was also tested in two occasions at IP8 (with 150 ns and 50 ns) and implicitly tested at each luminosity optimisation or Van der Meer scan at all IPs. No significant instability or beam loss associated with beam separation could be evidenced in 2010, despite the nominal bunch intensity and the lower than nominal transverse emittances. The interpretation of this "robustness" of the LHC beams was discussed elsewhere [7], where it was also recommended to study further beam-beam effects (and the beam-beam limit) in the presence of long-range encounters.

Based on the above arguments, it is proposed to use the beam separation method in 2011 to level the luminosity in IP2 and IP8. The β^* for IP8 is to be chosen small enough that leveling to constant luminosity $L = L_{\rm lhcb}$ is possible throughout a full fill once sufficient bunches are colliding at IP8 ($n_8 \geq n_{\rm thr}$). Early beam-beam tests in 2011 should clarify the validity range of the beam separation method for luminosity leveling, a topic also important for future operation of LHC (HL-LHC).

We will use the approximation

$$S = \left(1 + (\frac{\sigma_z}{\sigma_x}\ \tan\alpha)^2\right)^{-1/2} \cdot e^{-\frac{d_y^2}{4\sigma_y^2}} \qquad (5)$$

where σ_z and $\sigma_{x,y}$ are the longitudinal and transverse beam sizes, which are each assumed here to be identical for the two beams ($\sigma_{z,1} = \sigma_{z,2}$, $\sigma_{x,1} = \sigma_{x,2}$ and $\sigma_{y,1} = \sigma_{y,2}$), and a crossing in the x-z plane was assumed (like in IP8). For a crossing in the y-z plane (like in IP2), the x and y indices should be exchanged.

Figure 2 shows the required separation d_y in IP8 (in units of the local beam size σ_y) as a function of N^2/ε_N for two example values of β_8^*. As long as the number n_8 of colliding pairs in IP8 is less than $n_{\rm thr} \approx 770$, the pile-up requirement (3) limits the luminosity at LHCb. Luminosity leveling by y-separation can be used to keep $\mu \leq 2.5$.

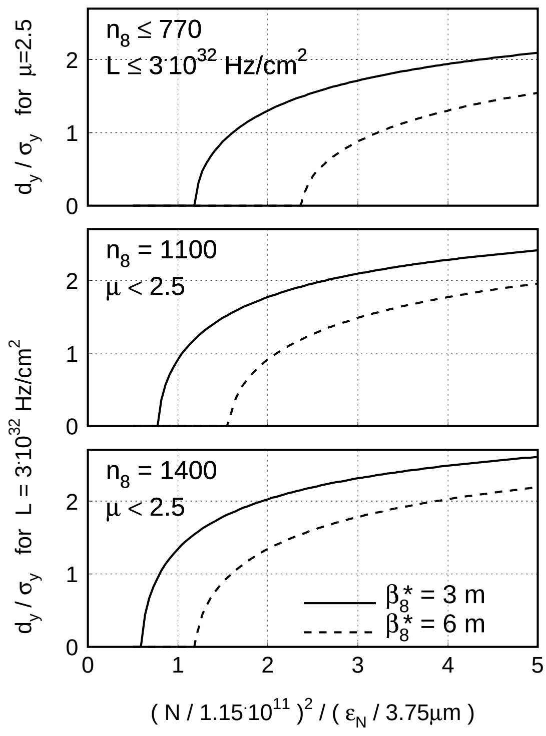

Figure 2: The top graph shows, as a function of N^2/ε_N, the required beam separation at IP8 for the initial phase of 2011 ($n_8 \leq 770$) with constant pile-up and a luminosity still below what LHCb can operate with. The middle (bottom) graph shows the required beam separation at IP8 when $n_8 = 1100$ (1400) with constant luminosity and reduced pile-up.

When n_8 exceeds $n_{\rm thr}$, the luminosity can be kept as close as possible to the LHCb requirement (2). Note that the luminosity is sub-optimal (i.e. $L < L_{\rm lhcb}$) whenever N^2/ε_N is smaller than the value for which $d_y = 0$. The 2011 start-up value for N^2/ε_N is expected to be 2 times larger than nominal ($N \approx 1.2 \cdot 10^{11}$ and $\varepsilon \approx 2.5\ \mu$m [4]) and will be further pushed up during the year. Assuming that the parameter N^2/ε_N decays by a factor 2 during a fill, one should ideally choose a β_8^* value such that the required separation never falls to zero. From figure 2, the choice $\beta_8^* \approx 3$ m seems appropriate.

The strategic choice to use luminosity leveling by beam separation at IP8 relies on the assumption that this technique will function for the values of bunch population, tranverse emittance and fill patterns that can reasonably be foreseen for 2011. If the limits of this leveling technique were to be found in the course of 2011, a fall-back solution would have to be considered (like β^* leveling).

Hereabove, it was argued that $1\ {\rm fb}^{-1}$ could be delivered to IP8 if luminosity leveling is efficiently used. This estimation assumes 970 hours of physics collisions at $3 \cdot 10^{32}\ {\rm Hz/cm}^2$. This luminosity can only be reached once the LHC machine collides at least 770 bunches at IP8. Before this point, the luminosity will be limited by the pile-up constraint. Therefore, utilization of luminosity leveling and a rapid increase of the number of bunches are crucial for meeting the target of $1\ \mathrm{fb}^{-1}$ delivered to IP8.

The case of IP2 - ALICE

It is reminded that pp physics is an integral part of the ALICE physics programme. Similar to last year, the ALICE Collaboration would like to operate at a luminosity L_{alice} ranging from $5 \cdot 10^{29}\ \mathrm{Hz/cm^2}$ to $5 \cdot 10^{30}\ \mathrm{Hz/cm^2}$ and with $\mu \leq 0.05$. This will be achieved by not squeezing IP2 ($\beta_2^* = 10$ m) and separating the beams in the horizontal direction. With 75 ns operation most bunches collide in IP2. With 50 ns (and 150 ns) operation, a few bunches are specially arranged to give collisions in IP2. For $L_{\mathrm{alice}} = 5 \cdot 10^{30}\ \mathrm{Hz/cm^2}$, the required separation d_x will generally be driven by the pile-up constraint and will range from 3.2 to $3.8\ \sigma_x$. Such luminosity can be achieved with 75 ns spacing and several hundreds of bunch pairs colliding in IP2 ($n_2 \geq 640$) while keeping $\mu \leq 0.05$. For $L_{\mathrm{alice}} = 5 \cdot 10^{29}\ \mathrm{Hz/cm^2}$ and many bunch pairs colliding at IP2 (e.g. 900), the required d_x may be as high as $\sim 4.8\ \sigma_x$.

Spectrometer magnets

The ATLAS and CMS magnets will be operated with the same (fixed) value and sign as in 2010. For LHCb, the external angle will be kept constant and the internal angle is fully compensated by corrector magnets. Only one set of TCT positions needs to be prepared and validated. In the case of ALICE, since the external angle sign will change when the internal angle is reversed, the TCTs must be set up and validated for each polarity independently. In addition, in IR2 the combined effect of the solenoid and dipole cannot be fully compensated by the dipole correctors. This effect needs to be taken into account and, ideally, its impact on ease of polarity reversal should be minimized.

The ALICE and LHCb Collaboration would like to collect the same amount of data with each spectrometer polarity for each set of physics conditions. Therefore, minimizing the number of changes in physics conditions will reduce the number of requested reversals. During 3.5 TeV high luminosity LHC operation, the frequency of polarity reversal is expected to be of the order of once per month.

It was pointed out that, if the emittance is adequately chosen, a mode of operation can be found which allows one to constantly keep the LHCb spectrometer magnet at nominal value [8]. LHCb would much prefer such a solution, since it minimizes the fatigue imposed on the magnet and increases its life time.

Non-colliding bunches

Experiments are generally interested in having at least one bunch per beam that does not collide at their IP. This allows them to monitor background conditions and, possibly, disentangle different sources of background. The collisionless time around the arrival of the non-colliding bunch needs to be long enough (exact time yet to be specified, but typically from 0.1 to 1 μs). Such a feature can be incorporated by shifting one or two SPS batches, or by adding an isolated bunch.

PROTON OPERATION: SPECIAL REQUESTS

A “special request” means here a request for operation outside the 2011 parameter envelope that will be used for luminosity production at a center-of-mass energy $\sqrt{s} =$ 7 TeV. Here, all special requests from the experiments are outlined.

Intermediate energy run

A pp center-of-mass energy $\sqrt{s} = 2.76$ TeV corresponds to the nucleon-nucleon equivalent of Pb-Pb collisions at $\sqrt{s} = 7\ Z$ TeV, and is of particular interest for the HI community. The ALICE Collaboration has requested a proton run at $E = 1.38$ TeV to be scheduled as soon as possible, in order to allow them a combined analysis of the 2010 Pb data and $\sqrt{s} = 2.76$ TeV pp data. This request was strongly supported by the LHCC and approved by the Research Board. ALICE requires 35 h of `STABLE BEAMS` at an inelastic interaction rate at IP2 $R = \mu\ n_2\ f_{\mathrm{rev}}$ of 3 to 10 kHz. This will allow them to collect the requested 50 million events. The average number of interactions per crossing should not exceed 0.05. From this, one can derive that the number of colliding bunch pairs at IP2 should be larger than 5.

The setup time for this run was estimated to be about three 8 h shifts [9]. The main steps are: a test ramp and dump with a probe bunch, and 2 or 3 fills for loss maps (collimator settings validation and asynchronous dump test).

The other experiments will also take data during this special physics run. The physics programme of ATLAS and CMS concentrates on hard probes (“rare” events). For this reason, ATLAS and CMS would like to run at the maximum possible luminosity achievable without extra setup time. For CMS the physics programme would be well covered with about $300\ \mathrm{nb}^{-1}$ (at this level, the statistical uncertainties would match those of the 2010 Pb data sample). Similarly, ATLAS would like to record at least $100\ \mathrm{nb}^{-1}$ and take a small data sample with low pile-up ($\mu < 0.01$), which could be arranged either by keeping a probe bunch or by separating the beams in IP1 for part of the running time. The LHCb Collaboration wishes to record at least $25\ \mathrm{nb}^{-1}$, if possible with both polarities (provided this does not cost extra setup time). The detailed aperture (crossing angle) and collimator settings in these runs may influence the choice of the VELO gap that LHCb will adopt fro operation. This needs to be followed up.

The ALICE requirements can be fulfilled with unsqueezed optics and a number of bunches still compatible with zero crossing angle. If beams are colliding head-on at IP2, the parameter N^2/ε_N should be $\leq 7.8 \cdot 10^{20}\ \mu\mathrm{m}^{-1}$, e.g. $N \leq 4 \cdot 10^{10}$ for $\varepsilon_N = 2\ \mu$m. However, to maximize luminosity at IP1 and IP5 it would be preferable to use nominal bunch population, the smallest possible emittance ($\varepsilon_N = 1.5\ \mu$m ?) and the largest possible number of bunches (156 bunches ?). In this case, a transverse separation of 2 to 3 $\sigma_{\rm beam}$ should be applied at IP2.

The choice of the crossing schemes needs to be finalized and should be mainly driven by ease of operation and minimisation of setup time.

All experiments will request a Van der Meer scan during one of the $E = 1.38$ TeV physics fills. This may limit the acceptable value of N/ε_N (but only for that particular fill). In particular, ALICE needs to be able to operate its trigger detectors during the van der Meer scan, i.e. the maximum pile-up in IP2 should not exceed $\mu \simeq 0.3$ during the scan. This is important for ALICE to obtain a reliable cross section normalisation. Length scale calibrations will also be required.

The operational envelope for this intermediate energy run and associated luminosity calibration measurements needs to be defined.

TOTEM / ALFA special requests

The physics programme of TOTEM and ATLAS/ALFA foresees operation during bulk high luminosity physics and in special conditions.

TOTEM and ATLAS/ALFA request their Roman Pots (RPs) to be aligned with beam as soon as possible in squeezed β^* conditions, such as to be able to take data during 2011 luminosity production with the RPs moved into "squeezed physics" position (likely between 10 to 15$\sigma_{\rm beam}$ from the beam orbit). This will allow them to collect data at large values of the four-momentum transfer squared $|t|$. The alignment exercise was performed for TOTEM in 2010 for 3.5 m squeeze (with a single nominal bunch) and took about 4 hours (for 12 RPs). This year TOTEM will utilize 24 RPs and ATLAS/ALFA 8 RPs. Such an alignment will be needed after each collimator re-alignment. TOTEM also asks to be able to take data for a few hours, for example (but not necessarily) at the end of the alignment exercise, with the RPs set at about 5 $\sigma_{\rm beam}$ from the beam orbit in order to reach lower $|t|$ values (down to around 0.2 GeV^2). This would require modest total beam intensity ($\lesssim 5 \cdot 10^{11}\ p$) in the machine.

TOTEM would like to collect diffractive physics data ($\mathcal{L} \geq 10\ \mathrm{nb}^{-1}$) with low pile-up ($\mu = 0.01...0.05$) to fully profit from the now complete detector system (RPs, T2 and T1). The T1 detectors were successfully installed during the 2010-2011 winter stop. Taking $\mathcal{L} \approx L \cdot 0.7 \cdot T = n_5\,(\mu/\sigma_{\rm inel})\,f_{\rm rev}\,0.7 \cdot T$ one obtains that TOTEM needs a running time T of the order of 500 h with a single bunch. Therefore, this could be delivered without any beam time cost by adding four probe bunches during the first physics fills (e.g $4 \times 1.15 \cdot 10^{10}$ at nominal emittance of 3.75 μm), if a running time of about 125 h is achieved in these conditions. This would not limit luminosity production for the other experiments, as long as the machine is not fully occupied with bunch trains. It is therefore important that the TOTEM RPs be ready for taking data before the intensity ramp-up.

With the dedicated $\beta^* = 90$ m optics [10] a first measurement of the total cross section and of luminosity with the Optical Theorem would be possible (at $\sqrt{s} = 7$ TeV). TOTEM and ATLAS/ALFA request such optics to be developed and used in 2011.

The time for machine developments has been estimated to be about 5 shifts (with a large uncertainty) [10, 11]. For TOTEM, 4 fills of about 8 h with the 90 m optics would be enough to cover the physics programme at 3.5 TeV. The desired conditions are summarized in table 1 (the table was composed for $E = 4$ TeV; hence, the numbers are indicative) [12]. The distance $d_{\rm RP}$ of the RPs relative to the beam are given in units of transverse beam size $\sigma_{\rm beam}$ at the RPs (one expects transverse sizes of the order of 0.5 mm). The quantity $|t_{50}|$ denotes the low edge of the four-momentum transfer squared $|t|$ for which the acceptance falls to 50%. The lower the reach in $|t|$, the more precise the extrapolation of the elastic cross section at $|t| = 0$. The statistical error $\delta\sigma_{\rm el}(|t| = 0)$ of the extrapolated elastic cross section is given in the table. It should be small enough that the total error be dominated by systematic uncertainties. These will be affected, in particular, by uncertainties on the local optics. For example, for TOTEM, the proton transport matrix elements and hence the betatron functions β_x and β_y at the RP positions have to be known within an uncertainty of the order of 1%. The same level of precision is required for the dispersion D_x and D_y, which is needed to reconstruct the proton momentum loss in diffractive events. The detailed requirements on local optics measurements for TOTEM and ATLAS/ALFA will need special attention.

We note that ATLAS/ALFA would like to have two 90 m physics runs in the second half of 2011, possibly one in September and one shortly before the heavy ion run.

Table 1: Indicative TOTEM requirements for the four runs with 90 m optics. Details explained in the text.

run	1	2	3	4
ε_N	3	3	1	1
$d_{\rm RP}/\sigma_{\rm beam}$	8	6	8	6
$N/10^{10}$	7	7	6	6
$L/(\mathrm{Hz/mb})$	6.9	6.9	15	15
μ	0.05	0.05	0.1	0.1
$\lvert t_{50}\rvert/\mathrm{GeV}^2$	0.019	0.011	0.0070	0.0043
$\mathcal{L}/(\mathrm{nb}^{-1}/8\ \mathrm{h})$	0.2	0.2	0.4	0.4
$\delta\sigma_{\rm el}(\lvert t\rvert = 0)$	$\sim 1.5\%$	$\sim 1\%$	$< 1\%$	$< 1\%$

The 90 m optics run should accomodate $\beta^* = 90$ m at IP1 and IP5. In addition, ALICE and LHCb will also take data during these runs, profiting from the small pile-up to collect reference data. Therefore, it is likely that more than one bunch will be used. LHCb will also perform beam-gas luminosity calibration measurements. The optics at IP2 and IP8 can be either "injection optics" (10 m) or defocused optics ($\beta^* > 10$ m).

Luminosity calibration

A series of luminosity calibration measurements was carried out in 2010 at $\sqrt{s} = 7$ TeV. A total accuracy of around 5% was achieved [13]. Assuming the beam energy will not be changed in 2011, there is no urgent request to improve on this accuracy. However, an accuracy of 2% with the Van der Meer scan method and the beam-gas imaging method seems possible. The physics motivation for such an accurate measurement was discussed elsewhere [13]. For example, such a precise absolute measurement of the top quark production cross section could approach the top mass sensitivity of the method based on kinematic distributions. A precision of 2% in weak boson production cross sections would allow one to constrain parton distribution functions.

To reach such a level of precision, a number of systematic studies would be required and dedicated luminosity calibration fills would be needed [10]. The importance of such studies and dedicated fills will have to be balanced against the associated loss of integrated luminosity.

ION RUN: 2011 EXPECTATIONS

In 2010 Pb operation, a peak luminosity of $3 \cdot 10^{25}$ $\mathrm{Hz/cm^2}$ was achieved. The β^* value was 3.5 m, the number bunches was 137 and their population was up to $1.2 \cdot 10^8$ Pb ions. Transverse emittances around 1.5 μm were obtained. The bunch spacing was 500 ns, long enough to facilitate usage of a zero crossing angle scheme.

For 2011 several improvements are being considered. A factor 2.3 or more in peak luminosity could come from the squeeze (3.5 m versus $\beta^* \leq 1.5$ m ?). The 2011 proton experience will help deciding on the β^* targets for the ion run. A factor 4.5 could be gained from the number of bunches, using the "nominal" scheme with 100 ns spacing and 592 bunches [14]. However, it is currently unclear whether higher-than-nominal bunch populations with small emittances can also be obtained for the nominal scheme. So far, populations of $1 \cdot 10^8$ Pb have been achieved in the injector with about twice nominal emittance [15]. Intermediate schemes (200 ns spacing ?) are being investigated and an optimum between the 2010 scheme and the nominal scheme might be found [16]. Realistically, a peak luminosity 4 to 5 times larger than in 2010 could be expected. Following this, a delivered integrated luminosity of 30 $\mu\mathrm{b}^{-1}$ per IP in 2011 seems a target within reach. It would quadruple the total integrated luminosity.

The main request from the experiments is a maximisation of the delivered integrated luminosity. In addition, the ALICE Collaboration would like to operate with no shadowing of the ZDC by the TCTVB collimators and they would like to collect approximately the same amount of data with the two magnetic field polarities. An additional preference is a zero net crossing angle (unless there is a substantial gain in luminosity with a bunch separation and/or β^* value that is/are incompatible with a zero net crossing angle). In any case, a small net crossing angle is generally preferable for all experiments.

Finally, it has been noted that, if the prospects for a substantial increase of the total delivered Pb-Pb luminosity in 2012 were modest, a first p-Pb run in 2012 may become scientifically more pertinent than a third Pb-Pb run. In such a case, ALICE would support p-Pb exploratory studies during the 2011 ion run.

SCHEDULING

A draft LHC operation schedule was proposed in this workshop [4]. Beam operation starts on February 21 with 20 to 30 days of recommissioning and continues with proton operation until November 6, followed by heavy ion operation until December 12. Six 4-day technical stops are planned, each followed by one day of machine operation recovery. All but the first stop are preceded by a 4-day block of machine developments (MDs). Approximately 10 days have been reserved for e-cloud scrubbing. This leaves approximately 145 ± 10 days of physics operation. Assuming that about 10 days can be devoted to special requests, then 135 ± 10 days would be dedicated to high luminosity physics operation (with $n \geq 900$ bunches).

The intermediate energy run is scheduled to start with setting up on April 2, and will be followed by the LHC scrubbing run. However, depending on progress with machine recommissioning, this run might be moved to just before the first technical stop.

Machine developments for the 90 m optics could start in the first MD block. However, 90 m physics operation will not take place in the first half of 2011.

Dedicated physics fills for luminosity calibration measurements at 3.5 TeV will also not be scheduled in the first half of 2011.

The top priority for the first half of 2011 will be to rapidly establish efficient luminosity delivery with a luminosity in excess of 10^{33} $\mathrm{Hz/cm^2}$ in IP1/IP5 and stabilized around $3 \cdot 10^{32}$ $\mathrm{Hz/cm^2}$ in IP8.

CONCLUSION

A number of special requests and desiderata from the LHC experiments have been presented. The main (and most time-consuming) of these requests are reminded here:

- Intermediate energy run ($E = 1.38$ TeV): 3 shifts to set up and 35 h in `STABLE BEAMS`,

- 90 m optics: about 5 shifts to set up and 4×8 h fills for physics,

- Accurate luminosity calibration: several systematic studies and 2 dedicated fills for the actual luminosity calibration measurements.

The implementation of these special activities will have to be balanced with the loss of integrated luminosity for the mainstream physics programme.

The target of 1 fb^{-1} for IP8 will be challenging, but seems possible if continuous luminosity leveling by beam separation is successfully applied throughout 2011 and if a rapid increase of the number of bunches (770 and beyond) is achieved. This would allow LHCb to explore uncharted particle physics territory. The target of 1 fb^{-1} for IP1 and IP5 seems well within reach and more could be hoped for. With 6 fb^{-1} ATLAS and CMS would be able to (each independently) close the question of the SM Higgs!

The experiments, impressed by 2010 LHC performance results, are looking forward to a prosperous data collection in 2011. 2010 will remain as the memorable year when the LHC machine started to deliver. 2011 could become “une année charnière” for physics.

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[2] A compilation of LHC physics publications can be found on the LPCC web site, https://cern.ch/lpcc and links therein.

[3] https://cern.ch/lpc and links therein.

[4] See M. Meddahi in these proceedings.

[5] See W. Murray in these proceedings.

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