OUTLOOK FOR 2012

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Abstract

The LHC performance in 2012 is considered. Firstly the approved 2012 schedule is presented. The possible options for the key parameters (energy, bunch spacing, beta*) to be used in 2012 are reviewed. A limited number of scenarios are considered and estimates of their potential performance presented.

INTRODUCTION

2012 will be the final year of operation before the long shut-down planned for 2013/2014 (LS1). The principal goal is to deliver enough integrated luminosity in Atlas and CMS to allow each experiment to independently exclude or discover the Higgs. The total estimated integrated luminosity required is estimated to be between 15 and 20 fb^{-1} [1]. LHCb is hoping for around 1.5 fb^{-1} to, among other things, push down their sensitivity in the $B_s \rightarrow \mu\mu$ channel towards the standard model cross section.

Improvements to the 2011 performance should allow the above targets to be met. The options include a decreased β^*, increased bunch current and improved machine availability.

2012 SCHEDULE

The 2012 schedule, as of February 2012, foresees:

- The end of powering tests around the 7$^{\text{th}}$ March.
- A few days of machine checkout without beam. Some delay at this stage is foreseen as CMS recover fully from the unplanned vacuum intervention that took place in January 2012. First beam is now planned for 14$^{\text{th}}$ March.
- 3 weeks re-commissioning with beam. The exit condition from this phase is "stable beams" with a low number of bunches.
- A 3 day scrubbing run with 25 ns beam. The timing of the scrubbing run is flexible and is contingent on good progress in the re-commissioning phase.
- There will be four 5 day technical stops during the year. Each stop is followed by 2 days to re-establish peak performance.
- There are 22 days of machine development. The length of the first MD block has been reduced to 3 days.
- Atlas foresees ZDC installation (5 days minimum) during last technical stop which precedes the ion run. This removes the need to discuss whether or not the final technical stop should take place or not.
- A 4 day set-up period precedes the 4 week proton-ion run.

For the proton physics run the 36$^{\text{th}}$ International Conference on High Energy Physics (ICHEP2012) in Melbourne 4 - 11 April 2012 provides a virtual constraint. The experiments would like to maximize the integrated luminosity delivered before the middle of June to allow a healthy update of the results presented at the winter conferences. Realistically optimistic estimates are in the 3 to 4 fb^{-1} range to be delivered by the 17$^{\text{th}}$ June.

Table 1: Breakdown of LHC's 2012 schedule.

Activity	Time assigned
Machine check-out	2
Commissioning with beam	21
Machine development	22
Technical stops	20
Scrubbing run	3
Technical stop recovery	6
Initial intensity ramp-up	21
Proton physics running	126
Special physics runs	8
Ion run setup	4
Ion physics run	24

In the estimates presented below, 150 days for proton physics are assumed including ramp and technical stop recovery time.

OPERATION IN 2012

Beam energy

At Chamonix 2011 there was lively debate regarding the decision to run at 4 TeV (with a 50 s main dipole energy extraction time constant). One of the main arguments against 4 TeV was the number of spurious quenches observed in 2010. In 2011 the number of spurious quenches was radically reduced. This was achieved mainly thanks to the improvements introduced to the quench protection system and the installation of snubber capacitors. There have been no beam induced quenches above 450 GeV. It can be noted that 2011 saw: better hardware commissioning procedures (no quenches during this phase); better operational procedures with beam; only 1 single magnet spurious quench with beam (firing of quench heater probably due to an SEU); better knowledge of the RRR (250$\pm$50) of the copper bus bars.

Given this input, and a more detailed analysis elsewhere, there appears to be no reason to not operate at 4 TeV in 2012 [2]. The decision to operate at 4 TeV was confirmed at Chamonix 2012.

Bunch spacing

The bunch spacings on offer from the injectors are shown in table 2. 50 ns proved a good choice in 2011 opening the way to an increased number of bunches and the excellent performance in terms of emittance and bunch intensity. The best that was taken into collisions in 2011 was around 1.45 $\times 10^{11}$ protons per bunch with less than 2 μm at extraction from SPS with around 2.3 μm going into collision.

Table 2: Beam parameters for various bunch spacings at exit of SPS.

Bunch spacing [ns]	From booster	Protons per bunch	emittance [μm]
150	Single batch	1.1×10^{11}	1.6
75	Single batch	1.2×10^{11}	2.0
50	Single batch	1.45×10^{11}	3.5
50	Double batch	1.6×10^{11}	2.0
25	Double batch	1.2×10^{11}	2.7

Looking forward to 2012, 50 ns has proven performance in both the LHC and the injectors. In comparison with 25 ns there are less long range encounters, potentially allowing a lower β^*. There is some limited room for increasing bunch intensity (and perhaps reducing emittance blow-up), however the high luminosity per bunch does bring higher pile-up.

The 25 ns beam has lower bunch current and higher emittances from injectors and would require considerably more total current to match the equivalent 50 ns performance. The higher 25 ns beam current could potentially bring more problems (UFOs, SEEs, RF, vacuum instabilities). There are around twice the number of long range encounters and with larger emittances, there is reduced potential to squeeze. An extended scrubbing period would required to get 25 ns operational. On the positive side the pile-up would be significantly lower.

A comparison of the achievable performances is given below. However, the advantages of 50 ns for the 2012 run are clear.

Squeeze

The collimation group has proposed the use of tight collimator settings in 2012. By bringing the primary and secondaries in further, the system is able to protect a smaller aperture (expressed in beam sigma) in the experiments' interaction region thereby allowing the reduction of β^* well below the minimum of 1 m used in 2011.

Three options have been proposed [3]:

- A β^* of 70 cm based on tight collimator settings and a linear combinations of margins based on last year's experience. (The margins are those related to beta beating, set-up, positioning and orbit movements.)
- A β^* of 60 cm based on tight collimator settings and adding the margins in quadrature.
- A back-up solution of 90 cm based on intermediate collimator settings similar to those used operationally in 2011. The settings represent a well-understood set-up with proven performance.

The tight settings are not yet proven having been tried a couple of times in 2011. An end-of-fill attempt passed off without problems, however instability problems were observed at the end of squeeze (with high intensity). Issues to be resolved include improved orbit control in ramp and squeeze in particular at matched points in the squeeze. Instability/impedance control is anticipated with high Landau damping octupoles settings and tighter chromaticity margins during routine operation.

Tight settings offer over 20% increase in performance but increased sensitivity to beam perturbations with a potential impact on efficiency. The effects of strong octupoles remain to be seen as does Operations' ability to control the chromaticity to the stated margins.

POTENTIAL PERFORMANCE

The potential performance for four scenarios are shown in table 3. For clarity 3.5 TeV figures are suppressed. The scenarios are:

1. 50 ns beam with β^* = 90 cm and intermediate collimator settings;
2. 50 ns beam with β^* = 70 cm and tight collimator settings, linear combination of margins;
3. 50 ns beam with β^* = 60 cm and tight collimator settings, margins combined in quadrature;
4. 25 ns beam with β^* = 80 cm and intermediate collimator settings.

From the table 3, it is clear that tight settings and a squeeze to either 70 or 60 cm are of importance if the stated goals are to be met in good time in 2012. For this reason it is foreseen to start with tight settings and qualify them with reasonably high intensities bunches ($48\times1.4\times10^{11}$) as soon as possible (with octupoles at an appropriate level). Squeeze settings to 0.6 m and 0.7 m should be prepared. Commissioning to 0.6 m initially should be performed with the usual measurement and correction of orbit, optics, chromaticity at 90, 70 and 60 cm.

Table 3: Potential performance in 2012. Collimators refers to the choice of intermediate or tight settings. Margins to the option of combining these linearly or in quadrature.

Option	1	2	3	4
Collimators Margins	int linear	tight linear	tight quad.	
ϵ_N [μm]	2.5	2.5	2.5	3.3
β_* [cm]	90	70	60	80
Crossing angle [μrad]	240	268	290	380
Reduction factor	0.9	0.86	0.83	0.75
Colliding pairs	1331	1331	1331	2700
Protons/bunch $\times 10^{11}$	1.55	1.55	1.55	1.15
Peak luminosity $cm^{-2}s^{-1}$	4.9	6.0	6.7	3.9
Pile-up	24	29	33	9
Days of physics	150	150	150	140
Int. luminosity	12.7	15.5	17.5	9.4

Integrated Luminosity

Besides table 3, estimates for the potential integrated luminosity for 2012 have been presented elsewhere [4]. Assuming 4 TeV, a β^* of 70 cm and 148 days of physics, the estimates were: around 16 fb^{-1} for 50 ns; and 10 fb^{-1} for 25 ns. These agree with other recent estimates based on around 150 scheduled days for physics. (Note ramp-up time and recovery from technical stop is included in the quoted scheduled days.)

OTHER ISSUES

- The β^* in IR8 will remain at 3 m in 2012.
- An inclined crossing scheme in IR8 is proposed and under investigation. This will serve to reduced the net crossing angle in LHCb, which is particularly large for one polarity setting.
- The β^* in IR2 will be reduced to 3 m in 2012. Combined with satellite-main collisions, this should give Alice their desired luminosity. Plans for artificially induced ”enhanced” satellites are shelved.

CONCLUSIONS

The principal goal is clearly the delivery of around 15 fb^{-1} to each of Atlas and CMS to allow the independent exclusion or discovery of the Higgs. This should be possible in 2012 given:

- an increase in energy to 4 TeV giving an increase in peak luminosity of 12% from emittance reduction (plus some slight increase margin to squeeze further).
- Injector performance equal or better than that of 2011. The hope here is to push towards an offered maximum of around 1.6 $\times 10^{11}$ protons per bunch with the predicted increase in transverse emittance.
- The use of tight collimator settings allowing a reduction in β^* to 70 or 60 cm.
- Continued LHC machine availability in the same order or better than that experienced in 20011. The R2E mitigation measures foreseen for key systems will be critical in this regard.

REFERENCES

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[4] S. Myers, LHC Machine Status Report, 108th LHCC Meeting, December 8, 2011.