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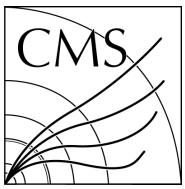

R&D in preparation for upgrades of the CMS detector for High Luminosity LHC

1 Gantt chart

The Gantt chart has been updated with input from several different sources:

- the overall LHC schedule is indicated using information presented by CERN Director for Accelerators S. Myers at the EPS Conference in July 2011[1].
- Two variants of the possible CMS trigger upgrade schedule are included. One is an outline, based on the CMS Upgrade Technical Proposal[2], which foresees operation of a new trigger after LS2. It has been adjusted (by hand) to the new accelerator schedule dates. The second is a variant based on the internal planning in WP3, assuming that an upgraded calorimeter trigger must start operation – at least in parallel with the existing trigger – immediately after LS1 in early 2015. For this Gantt, the details have been suppressed to retain only the main items.
- A simplified schedule is included for the Phase I pixel Tracker upgrade, based on the outline schedule given in the CMS Upgrade Technical Proposal.
- A moderately detailed, but provisional, schedule is included for the Phase II Tracker upgrade. This has been prepared by CMS as a working model but is still unofficial. It includes quite a number of details and cross-connections and was intended to give greater credibility to time estimates.
- The UK project schedule has been updated to include the main milestones of the work packages, but removing the individual details, many of which continue to evolve with the schedules referred to previously.
- Finally there is a simplified section indicating the next steps for Phase I upgrade planning for the UK which is intended to culminate in the preparation of a proposal to the PPRP for longer term funding of a UK upgrade project and long term R&D for the Phase II tracker.

The main difficulty of maintaining a useful Gantt chart for the R&D project has been to try to match it to the CMS requirements, which have evolved for two reasons: the evolution of the CMS machine schedule and the continuous development of new ideas for the final systems. The most prominent example affecting the UK is the proposal – not yet in definite form – to replace the current calorimeter trigger.

Because the Phase I upgrade was originally foreseen to take place much earlier, but was then delayed, ideas have changed significantly about what was possible in implementing a new trigger. In addition the urgency has changed since some elements of the present trigger have limited spares or parts gradually becoming obsolescent, while at the same time the possible requirements from the LHC machine have become more demanding. Not only could the LHC be operating at twice the design luminosity of 2×10^{34} $cm^{-2}s^{-1}$ at 14 TeV energy after LS2 but collisions might be taking place with 50 ns bunch spacing, instead of 25ns. Thus the trigger might have to cope with a factor 4 more pileup in each bunch crossing, which is obviously substantially higher than the original design. In addition, ideas about the physics channels which the trigger selects have been continuously evolving, but there are no studies yet at such high luminosity providing good guidance about the impact on performance.

Presently, it seems that LS2 will be from the end of 2017 to early 2019. If this shutdown is the target for a trigger upgrade, it comes much later than expected, increasing pressure on maintenance of the present hardware. Conversely, if the trigger is upgraded in LS1 it would seem that new hardware has to be ready perhaps no later than the end of 2013 to be installed in time. Alternatively a plan has to be developed which would allow the new trigger to be fully installed in end of year Technical Stops, which is also not easy given other activities under way in parallel and the relatively short duration.

There are similar considerations for the upgraded Tracker which, according to the latest schedule, should be installed in LS3 after the end of 2021. Although this seems remote, even a cursory attempt

[1] http://indico.in2p3.fr/contributionDisplay.py?contribId=969&confId=5116
[2] http://cdsweb.cern.ch/record/1355706?ln=en

to develop a detailed project plan for the Tracker replacement demonstrates that it is a major challenge. Significant uncertainties include:

- the physics requirements; while the tracker is a general purpose detector the guidance from theorists has been to request better performance in future, in terms of lower material to enhance the track reconstruction efficiency, but in a vastly more congested environment than the present.
- the need for track-triggering; given the pressure on the trigger to constrain the L1 rate to 100 kHz with a latency of about 6.4 μs, only by using tracking information does it seem possible to maintain this.
- the material budget and power consumption of triggering detectors, and their performance – since they are completely novel.
- the technological challenges of assembling both "conventional" and triggering modules, where it seems likely that new assembly techniques and advanced ASIC technologies will be needed.
- the difficulties of delivering power, the types of optical components which will be available and how to deploy them, the issues of cooling the extra power which is almost certain to be required in future.

Consequently the most attention in this R&D project has been to adapt the planning to both the success in developing new hardware, software and firmware and to the external circumstances while working intensively where possible with potential collaborators and attempting to find a common perspective. Fortunately, the technical developments have gone relatively smoothly so far with a high success rate. At the same time, the features which are now being requested for both tracker and trigger are quite different than originally foreseen so some milestones, such as development of a new tracker module, are much harder to define while the actual technologies to be used are uncertain.

In all cases, UK groups have been engaging closely in detailed discussions with our CMS colleagues on the details. However, as yet there is not complete consensus on the objectives and timescales and the Gantt charts should be interpreted accordingly. In other words, there is a major difference between scheduling R&D and defining definite milestones for such a project as this one, compared to a construction project.