LHCC Report presented to the LHC Resources Review Boards
April 25, 2016

Outline

• Phase I upgrades brief summary

• Phase II upgrades progress and plans

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HL-LHC Goals and Running Conditions

- 3000 fb$^{-1}$ is the target integrated luminosity
- $5 \times 10^{34} \rightarrow 140$ Pile-up is the nominal peak luminosity
- $7 \times 10^{34} \rightarrow 200$ Pile-up is the ultimate peak luminosity (>LS4)
Phase I Detector Upgrades

- All experiments required some level of upgrades to fully exploit the physics potential of Run 2.
- All the upgrades TDRs have been approved and are currently in the implementation phase, with installation spanning from now through LS2.

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Phase I Upgrades

- All TDRs for the Phase I Upgrades have been approved.
  - All experiments are now progressing towards the final engineering design and the implementation phase.

- LHCC will continue monitoring progress. A central repository has been setup to maintain updated information on:
  - Summaries of their Engineering Design Reviews (EDRs)
  - The updated global schedule taking into account the shift in LS2
  - A list of milestones to allow easy monitoring of progress
  - Information on resources
  - Plus Risk Register
ALICE

- Read-out and trigger electronics is progressing well and within the schedule.

- **TPC readout architecture**, the baseline correction has been moved to the common read-out unit (CRU), which has been found to be more robust and flexible than performing it in the SAMPA read-out chip. This implies streaming all raw data to the CRU, requiring limiting the sampling rate to 5 MHz (instead of 10MHz).
  - The collaboration has determined that this limitation is acceptable and that the overall performance is good.
  - The LHCC recommends maintaining or increasing the effort level on the SAMPA development, which remains on the critical path.

- The production of **GEM foils for the TPC read-out** chambers in the CERN workshop has recently suffered from inhomogeneities in the raw material, which are being addressed with the supplier. The LHCC notes that this issue should be monitored closely.
ATLAS

- An in-depth review of the Phase-I upgrade projects was carried out.
- **The trigger and DAQ** (TDAQ) upgrade is progressing well.
- The AM06 read-out chip of the **ATLAS Fast Tracker** (FTK) is now in production. The current schedule foresees to cover the barrel region of the detector with FTK capability during the summer of 2016, with full coverage reached by spring 2017.

- The **Level-1 Calorimeter Trigger Upgrade** has encountered issues with the two types of ASICs employed in the system, leading to concerns for the schedule. Although there is still a reasonable contingency at this time, the LHCC encourages ATLAS to proceed with the developed backup plan if the original design does not guarantee enough technical and schedule safety.

- The upgrade for the **muon New Small Wheel (NSW)** is making good progress for the mechanics, engineering and alignment systems, however, several problems have been encountered in the production of both chamber types, leading to a **very critical schedule for installation in LS2** with no contingency at this point.
  - The LHCC encourages the ATLAS management in getting the project on track in particular through a **mobilization of the muon community**, and by working out time contingency scenarios in case of non-recoverable schedule delays.
• **Trigger system upgrades** have already been completed and will be used in the 2016 running.

• The upgrade of the **HCAL electronics** is complete for the back-end electronics, however significant delays in the production of the front-end electronics put this project on the critical path for installation in the EYETS 2016/17.

• The upgrade of the **CMS Pixel detector**, also foreseen for the EYETS 2016/17, is making steady progress, although delays in module assembly and the production of the read-out chip lead to a critical schedule.

• The LHCC recommends the management to closely follow the development of these projects.

• **A decision is expected by the next LHCC in May** (or in June at the latest) on what can be installed in the upcoming shutdown.
• The Phase-I upgrades are progressing well, with significant advances reported on the Upstream Tracker (UT), Vertex Locator (VELO), Scintillating Fibre Tracker, and Ring Imaging Cherenkov (RICH) detector.

• The submission of the **VELOPIX** chip has been delayed, with a new submission date no later than April. The delay can be absorbed in the schedule.

• The **RICH** schedule has been updated to account for design changes due to radiation tolerance issues with several of the employed electronics components.

• The LHCC notes that these delays should be monitored carefully, however the current schedule is still compatible with the planned installation in LS2.

• The upgrade of the LHCb online system is progressing well, with two milestones recently reached ahead of schedule.
Phase II Detectors Upgrades

Why

- Maintain detector performance in the presence of high radiation doses, increased pile-up, and challenging trigger rates.
- Possibly introduce moderate performance improvements that will allow to take fully advantage of the HL-LHC physics program, e.g. extended coverage
- Detectors must work well at nominal luminosity (140PU) and only moderately degrade at ultimate luminosity (200PU)

When

- For the most part upgraded detectors will be installed during LS3, currently scheduled for 2.5 years starting in 2024
- Some limited and mature elements may be installed in LS2, with some advantage in terms of schedule, early tests, and reduced material activation: CMS FWD GEM, beam pipes, ...

What

- Many detector elements, readout electronics, data acquisition system and online computing will require significant upgrades —> part of this review
- Also distributed offline computing will require significant redesign and improvements —> part of a separate review process
Phase II Upgrades Approval Process

- **Document** detailing the process prepared in consultation with DRC and the experiments (CERN-LHCC-2015-007) (attached to the agenda)

  - **Step1**: Approval of preliminary design for the complete set of Phase-II upgrades -
    - Concluded in September 2015 —> presented to RRB
    - Including scoping options
  
  - **Step2**: Approval of baseline design, cost and schedule
    - TDRs submission foreseen between end 2016 and end 2017
    - Regular monitoring of LHCC and UCG
  
  - **Step3**: Approval for construction
    - After Engineering Design Review or equivalent
Step 1 Summary - Performance

• For both experiments the Reference Scenario provide performant detectors capable of addressing the physics at the HL-LHC.

• The limitations of the Low Scenario are very apparent, offering significantly worse detector capabilities.
  • Generally speaking, reduced detector performance affects Standard Model (SM) physics less severely than signatures of physics Beyond the SM (BSM).

• In the Intermediate Scenario, the nominal physics performance is only moderately deteriorated.
  • The detector redundancy is significantly reduced, resulting in a less robust apparatus, more sensitive to detector inefficiencies and failures, and less capable of dealing with the harsher running conditions as anticipated by the ultimate luminosity available.
Step 1 Summary - Cost

- **Costing** has been presented in great detail, assigning to each estimate a quality flag defining the level of uncertainty. A large fraction of the cost estimates are already based on actual quotes.
  - Nonetheless these proposals are **not at the TDR level**, and large uncertainties remain, which may be as large in scale as the cost differences between the various scoping scenarios.
  - The committee noted, though, that many of the items are estimated with a healthy level of conservative realism, which indicates that it should be possible to maintain the current figures when moving to the TDRs.

- The **funding outlook** represented in the money-matrix is guardedly optimistic, with substantive, relatively encouraging interactions in progress with the Funding Agencies, in much greater detail than at the same stage of the original construction.
  - Large uncertainties remain, and it will take time to secure commitments. Fortunately there appears to be an almost complete alignment of interests with needs.
Step 1 Completion

October 2015 RRB meeting deliberations:

• The RRBs consider the Step 1 of the approval process for the Phase-II Upgrades for the ATLAS and CMS experiments successfully completed.

• A scale of funding between the full funding and the intermediate scenario seems to meet the performance requirements.

The CERN Management, supported by the recommendations of the LHCC and the UCG, deems as realistic the availability of prospective funds contained in the preliminary “Money Matrices” submitted by the experiments.

The experiments are therefore encouraged to proceed to the next step of the Phase-II upgrades, as described in the document CERN-LHCC-2015-007.

The LHCC and the UCG as well as the Management will regularly update the RRB on progress of the process.
Step 2 - Elements (I)

The process for this step will follow the methodology and requirement corresponding to a base-line phase review process. In particular:

1. **For each upgrade element** identified in the global detector upgrade programme, the experiment **will submit a TDR** to the LHCC and UCG, with the purpose of validating each element’s design and establish a firm cost and schedule for approval. TDRs are expected to cover the entirety of a complex system and not be limited to small specific items. A TDR should include:
   - Physics motivation and performance, with a discussion of the optimization of cost vs capability and of the performance benchmarks connected with the specific detector element and the global detector.
   - Detailed description and design of all the components of the detector system.
   - Detailed budget with risk register, estimate of uncertainties, and mitigation plan.
   - Technical and scientific manpower required, and its availability at the participating institutions.
   - Scenarios for less than full funding, documenting the science trade-offs.
   - A detailed project management plan including the global organization of the work and responsibilities including WBS and work-packages, organization structures, distribution of responsibilities and decision making processes, schedule and key milestones including project phases, review strategy and deliverables, and risk management, including proposed level of contingency on cost and schedule.
Step 2 Elements (II)

2. The experiment will provide also a separate, confidential appendix containing:
   - A money matrix indicating how the costs will be shared among the funding agencies. This will also include a list of institutes and countries contributing to each detector component for the planned upgrades.
   - A funding profile showing that funds will be available as needed to meet the costs and schedule.

3. The LHCC and the UCG will be responsible for the review of each sub-system TDR separately, assessing the scientific soundness as well as the technical, financial, and schedule viability of the project, convening technical subcommittees as needed.
   Approval is contingent on the anticipated availability of adequate funding. A set of relevant benchmarks defining project success will be defined and agreed in the process.

4. Upon a positive review, the LHCC/UCG will recommend to the CERN RB the acceptance of the technical design, cost estimate, and schedule as firm baselines for the project.
   The CERN management will keep the RRB informed of progress throughout the TDRs review process and, upon approval; the appropriate MoU addenda will be drawn up and opened for signatures.
UCG review of Phase II upgrades

- LHCC and UCG are monitoring closely the TDR preparation
- Dedicated review held on Feb 29
- UCG common recommendations for both ATLAS and CMS:
  - As stated in the Step 1 approval from the RRB, the experiments are to design to “a scale of funding between the full funding and the intermediate scenario.” It is especially important to keep this in mind for the tracker TDR’s, as they are high-cost, and are likely to be the first to be submitted.
  - Where major risks exist, fallback positions should be developed if possible.
  - Authoritative technical evaluations of the TDR’s are essential, and to accomplish this the LHCC and UCG will need to be augmented with additional expertise. As the best expertise likely resides in ATLAS and CMS it would be very helpful if the experiments and committees could work together to find a way for experts from one of the experiments to contribute their comments and advice to the other experiment.
UCG Recommendations for ATLAS

1. A fixed set of milestones should be produced for the preparation of each TDR, and then tracked throughout the project.

2. Priority should be given to the work on the forward calorimeter options to reach a decision (and cost estimate) as soon as possible.

3. ATLAS should produce a plan for accomplishing the phase-I and phase-II muon upgrades within schedule.

4. Cost estimates for each subsystem should be updated regularly, so that the overall cost of the project remains understood as TDRs are submitted.
UCG Recommendations for CMS

1. CMS should explain the criteria that constitute the trigger point for transitioning from R&D/design development to producing the TDR.

2. For each TDR, a fixed set of milestones should be produced and then tracked throughout the project.

3. Cost estimates for each subsystem should be updated regularly, so that the overall cost of the project remains understood as TDRs are submitted.

4. CMS should provide more information on the TDAQ TDR at the next meeting.
Phase II TDRs are coming.

- A detailed plan for TDR submission is in place
  - LHCC + UCG will conduct the necessary reviews in the next couple of years
- Many big procurement processes will go through CERN
  - Years 2017 -> onward
  - Need to define the process well to avoid delays

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Conclusion

• The Phase II upgrade programme overall scope is now well defined with reasonable funding expected.

• The ATLAS and CMS Phase II upgrade projects are now proceeding to detailed detector design, compiling Technical Design Reports that will establish a baseline cost and schedule for construction.

• Guiding principle should always be the detector physics performance —> optimize the use of resources

NO PHYSICS ?  NO RESOURCES !