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UCG Report on the Phase II Upgrade of the ATLAS Muon Spectrometer[1]

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Process

At its September 2017 meeting the LHCC gave conditional approval to the ATLAS Muon System Upgrade TDR on its scientific and technical merit. However, the LHCC required significant revisions of the TDR to cover the R&D programs and the decision paths to production. At the UCG kickoff meeting the day after, we requested revisions in the UCG Cost Appendix, concerning manpower, schedule and risks. The UCG then reviewed the revised Cost Appendix and sent ATLAS a large number of questions, which were discussed in an interim Vidyo meeting, followed by a few additional questions. On Nov 28 at CERN the LHCC approved the revised TDR, after which we received 4 hours of presentations from the Muon group, followed by an afternoon of breakout sessions, and "homework" questions. The confidential preliminary "money matrix" was reviewed by the chairs of the UCG and LHCC.

Project Overview

The Muon System Upgrade consists of three semi-independent projects: Drift Tubes (MDT); Resistive Plate chambers (RPC), and Thin Gap Chambers (TGC), with supporting electronics, mechanical systems and services. In addition to identifying and tracking muons the system plays a vital role in the trigger. The situation was much improved from what it was in September, and we thank the ATLAS Muon group for addressing our concerns and questions, and for their careful preparation for the review. The presentations were uniformly of high quality and helped us greatly in our evaluation. The cost, schedule, resources and risks appear reasonable. The collaboration is working hard to understand, fix, and prevent the leaks that have been plaguing them for years. It's a very big and tedious job, with the goal of reducing greenhouse gas emissions by an order of magnitude. Success is essential to deal with future environmental restrictions. We are pleased to report that the Upgrade is ready for approval.

Cost Situation

The total cost of the upgrade is CHF 28M, an 8 per cent increase since the time of the scoping document (SD). However, 40% of the cost of the power supplies was moved to the M&O budget, reducing the cost of the project itself to 92 per cent of the SD. (This does not include an option to add a high eta tagger). We are supportive of moving power supply costs to M&O. Most of the core cost items have quality flag 1 or 2, based on firm quotes or similar recent purchases. The power system (CHF 7M), however, has not yet been designed in detail and hence remains at level 4, based on the cost of the present system. These systems are always a challenge, but the estimate here appears conservative. A new DCS system is also still in the design phase, but the cost should not exceed CHF 0.56M. Finally we were pleased to note that the spending profile has moved forward since the revision and now looks reasonable.

Schedule

The schedule shows that all items will be available at CERN a year before needed under the current LS3 schedule. In most cases this is actual float in addition to the time needed for commissioning. The LS3 schedule is very tight, so it is important to understand the critical path and thereby how much

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global flexibility exists. The UCG will conduct a review of the entire LS3 campaign and schedule at its February meeting. We suggest that all PDR/FDRs/PRRs be explicitly tracked and managed as milestones, including preliminary milestones in the out years. The impact of any further NSW delays needs to be closely monitored.

Resources

All level 2 WBS items have sufficient EOI's to cover the core costs, and the supply of manpower (FTE's) is sufficient to fill all needs. Most of the commitments are at the "confirmed by group leader" level, which is reasonable before MOU's are signed. All items except the TGCs are plausibly covered in the Money Matrix. Though the TGCs are only at 86 per cent, Israel is expected to provide the rest. Overlaps and conflicts with the delayed NSW have been studied and are manageable. We are concerned by the apparent paucity of engineering, but the project assures us it's a matter of semantics, because many people engaged in the engineering are physicists with engineering skills and experience.

Drift Tubes (sMDT's) and Electronics

The IB layer MDTs must be replaced by thinner sMDTs to free up space for the new thin gap RPCs. They will be operated under same conditions as MDTs and are expected to be equally reliable. On-chamber readout electronics of all MDT chambers must be replaced to be compatible with the new ATLAS trigger and readout scheme. The R&D is completed and final chamber design is under way. QA/QC procedures are well understood from experience with MDTs. Costs are based on quotes and actuals from established and qualified vendors and previous experience. Manpower appears to be sufficient based on previous experience, and there appears to be over one year of float in the schedule. Installation is probably the most challenging portion of the project.

RPC's

This is an extremely labour-intensive project. The core cost is only CHF 5M, but it's the tip of the iceberg! A strong management team is in place, but we note that only 2 Institutions are represented. We suggest adding a young manager, possibly from one of the institutions not included. This will reinforce the structure and will give visibility to new people and institutions. The main R&D activity is to determine if phenolic glass is superior to bakelite for the gas gaps, with a decision to be reached in 2019. The other major project is a new FE amplifier-shaper ASIC, where engineering and manpower are lean. The schedule is well done and reasonable.

We suggest that the group consider trying to advance the FE-ASIC schedule in order to keep some contingency. In case of trouble or delay the FE-ASIC team could be reinforced. We also suggest they test the "final" chamber configuration as soon as feasible: FE, HV, LV, cables, grounding...

A major goal for the upgrade is to reduce the present gas leak rate of 700 litres/hr by an order of magnitude, to allow long-term operation under financial and environmental constraints. A root cause analysis is crucial. While the drastic leaks after recent shutdowns can likely be prevented, the gradual secular rise in leak rate is a serious issue, as it could be due to an aging mechanism. We suggest that the group test the repair process in the laboratory to quantify the time and the number of FTE needed to complete the job. It goes without saying that is crucial to avoid the same problem in the new chambers.

RPC FE Electronics 5.3

The amplifier-shaper ASIC schedule drives everything and looks quite tight. The critical engineer is also involved in developing an ASIC for PET silicon strips (prototype full analog chain + ADC should be available next year) that might help accelerate the development of the ASIC, but this has to be demonstrated. The overview and detailed schedules need to be aligned. There is only one foundry involved in the ASIC development, which poses a significant schedule risk, albeit with small probability.

The schedule for the RPC Trigger and Readout Electronics contains 6 months of contingency between production end and installation start. This could be improved to 12 months by ordering FPGAs earlier. A few people are over-committed but the situation should improve after the Phase I upgrades are complete, including NSW. Among the risks, if problems or delays arise with the 'standard' vendor in Italy, it may be necessary to go to a Korean vendor. For this to work it is important to get an official quotation, estimate the transportation costs and extra FTE's required, and arrange for supervisors for production and Q/A in Korea.

Thin Gap Chambers (TGC's)

The Weizmann institute is one of the lead institutes for NSW sTGC chamber construction, and is the lead institute for the phase-II TGC construction. The main production activities for the TGC are planned for 2022, by which time the NSW construction will be completed. There is a risk of overlap between the NSW and phase-2 activities, but also an opportunity because a team of new technicians (10 needed at peak assembly) and experts will be trained during the NSW assembly. In the worst case chamber installation (replacement) will start after LS3, and completed in one YETS. There is a slight concern that the spending profile looks a bit late. Only 86% of funding is in hand so far, but an expected contribution from Weizmann will retire this risk.

The FE electronics is the same on the old and new detector, but the Q4/Q5 items (EIL4 triplet adaptor boards and components) pose a risk. Most of the cost estimates come from recent production of ASICs for g-2 at KEK, and are probably reasonable. Fiber costs are QF4 pending the design of the routing patch panel (awaiting the TDAQ TDR). The schedule allows for an extra ASIC prototype if required, but it is not explicitly included.

Integration

Good system engineering will be important for designing the various detectors to fit together where space is tight, and in ensuring efficiency in installation. The new sMDT-thin RPC combinations are a good example.

Power Systems (PBS 5.8):

The design of the ATLAS muon LV is still in progress. A quality factor of QF4 is assigned to the cost estimate because the final system may differ from the one used in the cost estimate: possible different vendor(s); a different configuration; longer cables; higher voltages, etc. Possible commonality with ATLAS LAr, CMS Muon, and perhaps other experiments presents an opportunity to reduce costs. The group should consider engaging in a value-engineering exercise, perhaps engaging external engineering labor.

Conclusions

The status of the Muon Upgrade project is much improved relative to the situation in September, due in a large extent to careful preparation. The cost, schedule, resources and risks appear reasonable. Appropriate milestones should be defined, extending through to the completion of the upgrade project. ATLAS should make sure that the engineering solutions are of first-rate quality.

The campaign to cure the RPC leaks is a big job, and presents a risk because the extent of success will not be known for a couple of years.

<u>We recommend Step 2 approval by the RB and RRB to allow resources to become available and MOU's to be signed.</u> Vigorous oversight of project, including external reviews, is essential going forward.