Updated: August 6, 2024

I&I Impact Statement

L2 System Muon

Baseline strategy: The muon Phase 2 upgrade IIC work include I&C on surface and I&C in the ATLAS Pit. If we are able to use MREFC contingency funds (as the budget opportunity) to perform the surface integration and testing at the level laid out in the table on slide 6 of the planning presentation then no modifications will need to be made to the Installation, Integration, and Commissioning plans in the ATLAS pit developed for Muon Phase 2 upgrade in order to achieve the overall target $12M Operations-supported I&I budget.

Purpose of the I&I Impact Statement

If we are unable to employ the baseline strategy above then to achieve a 25% reduction of the proposed IIC budget to the muon system, we would need to drop the activities related to the surface integration for both sMDT/RPC/Elx and MDTTP since they are both tightly coupled.

Quantify reduction ($1,173k)

- sMDT/RPC/Elx (-$988k – 5.5 FTE)
- MDTTP (-$185k – 0.8 FTE-EE)

Impact:

sMDT/RPC/Elx

We have learned lessons from the BIS78 (sMDT+RPC) pilot project in Phase-I upgrade how critical it is to carry out thorough surface integration and test prior to the installation of new detectors in the collision hall. Due to constraints in time, manpower, and delays in the RPC electronics, eight BIS78 modules were simply put together and installed in ATLAS without undergoing necessary surface commissioning. The consequences were severe: The RPC chambers are still not included in the ATLAS TDAQ system for data taking, even three years after installation. Among the 8 sMDT chambers installed, 2 chambers exhibit extremely high noise levels, with noise at least 1,000 times above acceptable limits. The remaining 6 chambers also experience elevated noise levels compared to typical MDT chambers. Despite significant efforts over the past two years to address these problems (since these chambers are near the edge of the barrel and some are still accessible), the issues remain unsolved. These lessons were reported and discussed in the Muon Week meetings. As a result, we are now required to conduct thorough integration and commissioning on the surface before any new detector installations to avoid repeating the mistakes made during the Phase-I upgrade.

The scope of the Phase-II upgrade is significantly larger, involving a total of 104 modules (sMDT+RPC), including 96 BIS1-6 (A and C sides) modules and 8 BIS78 (C-side) modules. The US team built 50 BIS1-6 C-side chambers (including 2 spares)

and the chamber installation frames for RPC integration. If we do not perform surface integration and commissioning for the BIS1-6 modules on the C-side (the US responsibility), it would mean the US will abandon a major commitment to the Muon Phase-II upgrade. No other institutes are prepared to take over the US tasks. Even if a method is found to assemble the sMDT and RPC together without thorough surface tests, the risks would still be high, as observed by the BIS78 pilot project. The US has invested substantial resources in the ATLAS Muon Phase-II upgrade. Without surface integration and commissioning, the innermost barrel layer of the muon spectrometer could become non-functional, jeopardizing the entire ATLAS muon spectrometer barrel system's L0-trigger and momentum measurements. Such a reduction in functionality would be absolutely unacceptable to the ATLAS experiment.

According to the current long shutdown schedule, we will have very limited time to install all 100 BIS1-6 chambers in the collision hall. Only basic checks of the frontend electronics are anticipated within this timeframe. If thorough surface integration is not performed, we may encounter significant issues with these chambers and electronics that could require additional time to resolve.

Once the BIS1-3 chambers are installed, there will be no access to them at all. Access to the BIS4-6 chambers will also be restricted, allowing only minimal opportunities for repairs. As a result, any issues that arise with these chambers and electronics may be difficult or even impossible to address.

MDTTP

Without the surface integration tests, we will be installing a system for which we would not have tested the full DAQ and trigger paths with final chambers and electronics. Since the MDTTP is a completely new system, this increases the probability that there are major issues to debug in USA15, which is much harder to do than with a controlled test stand. Our experience from NSW shows that this approach leads to issues more difficult or impossible to resolve once the system is installed in ATLAS.

In USA15, we will be tied to the ATLAS schedule. If more commissioning work is needed, this increases the probability that some MDT chambers or even layers of chambers will not be working or will not be readout at the start of Run4. This will result in MDT acceptance losses or losing one out the 3 segments and thus affecting the offline muon reconstruction and the Level-0 muon trigger efficiency and rate. Since a three-segments muon has a much better resolution than a two-segments one, it will affect ATLAS physics program. Similarly, if the trigger path is not fully tested, this would result in higher muon trigger rate, which would likely be handled by raising the muon pT trigger threshold or disabling some sectors, either of which will affect ATLAS physics program.

Not performing the surface integration tests will also create a gap in funding of 3 months for all our EEs from whom we need to retain the expertise for the rest of IIC. This increases the probability of loss of key personnel.

Mitigation:

sMDT/RPC/Elx
Michigan and MPI each constructed 50 sMDT chambers, while the RPC chambers are being built by Italian and Chinese groups. The RPC chambers will be mounted on the sMDT mechanical frame to form a single module, which will then be installed in the collision hall. Joint testing will be conducted for each module, with each institution responsible for the detectors they have built. We do not anticipate other institutions taking over the integration activities for the 50 sMDT chambers built by Michigan. The US ATLAS management team needs to discuss with the ATLAS management team if we drop these integration activities.

Risk: see update risk register (if surface integration cannot be done in neither MREFC and IIC)

- Added risk
    - RN-06-11-06-007: Increased complexity of the IIC work due to lack of surface sMDT+RPC integration tests
        - High (based on BIS78 experience)
        - 6-12 mos and $360k-$720k cost increase

MDTTP:
Unfortunately, it is very unlikely that our international partners could pick up the work, since the expertise resides predominantly in the US, with most of the US personnel based at CERN (which is not the case of our international partners).
The US is responsible for core costs of 100% SM, 54% CM and 75% of FW, 100% of SW. The current IIC budget provides 70% of the labor needed at the ATLAS level, about in-par with US level of effort during MREFC.

If more debugging is needed while in USA15 due to the lack of prior testing, we would need to increase the US manpower during IIC, since the expertise resides predominantly in the US and we are tied to the LS3 schedule and having various chambers, section commissioned in time.

Risk: see update risk register (if surface integration cannot be done in neither MREFC and IIC)

- Added risk (should have been there before. Assumed was global risk. Should be set to low in baseline - ie surface integration done under MREFC)
    - RN-06-11-06-013: Loss of key personnel
        - Low -> Moderate
        - 3 mos -> 9 mos / 120k -> 360k
- Increase risks

- RN-06-11-06-010: Integration more complex than anticipated
  - Moderate/low -> high
  - 1mo -> 6 mos / 65k ->390k
- RN-06-11-06-011: Commissioning more complex than anticipated
  - Moderate/low -> high
  - 1mos -> 12 mos / 40k -> 480k

Purpose of surface integration for sMDT/RPC/EIx:

The RPC chambers will be mounted on the sMDT mechanical frame to form a single unit. It is crucial to conduct joint integration of sMDT and RPC chambers once they are assembled together. We will handle the integration of the 50 sMDT chambers built by Michigan, while MPI will oversee the integration of the remaining 50 sMDT chambers. The Italian and Chinese groups will be responsible for the RPC chambers. Without this crucial testing, we risk installing untested sMDT+RPC units in the collision hall. Joint tests are essential to identify potential issues such as grounding problems, noise interference, and temperature effects. For instance, the new (s)MDT chambers will have new electronics that generate more heat, which, when shielded by the RPC chambers, could lead to increased noise. Previous experience with BIS78 chambers during Phase-I has demonstrated that these chambers can become non-operational or exhibit degraded performance if not properly integrated and tested. After installation, half of the chambers will be inaccessible, and others will have limited access. Therefore, it is essential to perform integration tests on the surface while we still have access to both the detectors and electronics.

Purpose of surface integration for MDTTP:

Minimal testing with external systems (MDT FE, SL and FELIX) were planned in the original RLS. These tests consisted in establishing basic communication with the external interfaces but without validation of the actual DAQ and trigger paths firmware. Now with changes in various system schedules and better understanding of hardware availability of external dependencies (e.g. SL, FELIX, TTC and Central Trigger components), we have the opportunity to setup full vertical slice test on surface at CERN that would enable us to get the L0MDT firmware to an installation ready state and perform suite of tests with cosmic data to fully validate the hardware and firmware with all the external interfaces before starting installation and integration in USA15.
For example, the cosmic test stand would enable us to interface with final MDT FE electronics mounted on chambers, configuring the FE boards via DAQ software communicating via L0MDT and perform scale tests with multiple mezzanines and CSMs, sending the cosmic data all the way to the DAQ system via FELIX. Similarly, we will be able to perform rate tests using noise data from the on-chamber electronics. In addition, the firmware trigger path could also be exercised using cosmic data to reconstruct straight tracks across three station layers.
This surface tests would reduce the effort required to bring up the L0MDT system once in USA15, which is a much more challenging environment to work in. Additionally, some of the external components will be installed late into LS3, thus requiring a fast turnaround for integration and commissioning of all L0MDT blades servicing the 64 sectors.

- This test stand will be an extension of the surface integration test stand for the sMDT/RPC/EIx
- L0MDT system is a totally new system for ATLAS, not only responsible for providing MDT trigger, but also to readout ALL MDT/sMDT chambers and responsible for configuration and monitoring of the new MDT FE electronics.
    - Such a system needs a lot of intensive tests and debugging to make it work as a whole.
    - From past experience, installing a new system in ATLAS without having performed thorough full chain integration tests on surface results in a system being much harder to debug, need for increasing manpower during IIC and potentially a not working system when data taking start, which would be very detrimental to ATLAS.