Close-out Report for Muon (g-2) Operational Readiness Review

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for the Review Committee

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Introduction

- The committee thanks the Muon (g-2) collaboration for their nice presentations and their prompt replies to our questions.
- The committee thanks Pushpa Bhat, Steve Geer, and Lisa Vega for all their help in preparing for and running the review.

Introduction

- Muon (g-2) is to be congratulated for their successful startup and their first wiggle plot, which was produced rapidly upon receiving first beam.

- Bottom line: While a significant amount of work remains, the Muon (g-2) collaboration has a deep understanding of what's required to achieve their physics goals.

Question 1

- Is there a completed Experiment Operations Plan (EOP) document? The document should include (a) an outline of the Science goals (b) a description of operations tasks and how they will be covered, (c) ES&H activities and how they will be managed, (d) organization charts showing the management structure for the experiment and how it interfaces with the laboratory, (e) Fermilab resources and roles as they pertain to each Division (f) the model for data processing and analysis including the computing budget and effort required, (g) a list of the identified resources available, and (h) a description of the roles and responsibilities of each institution together with a list of support required by each institution from funding agencies.

Not quite - There is a solid draft that includes items a-h, but a few things are missing as discussed in the recommendations.

Question 1

- Findings
  - A draft Experimental Operations Plan for the Muon (g-2) Experiment has been written describing the main operational tasks of the experiment.
  - The EOP also describes the roles & responsibilities of the Fermilab Divisions, including ESHQ.
  - The EOP provides an estimated budget required to operate the experiment from FY2018-2020.

Question 1

- Comments
  - While the EOP describes the roles, resources and commitments of each institution, but there is no formal documentation such as SOWs or MOUs that confirm that the institutions are willing and able to fulfill these roles. Such documentation would likely be useful to ensure there are no misunderstandings that would result in major operational risks.
  - The ESH&Q activities described neither address radiation safety requirements, nor Operational Readiness Clearance processes, which are important parts of the overall ESHQ oversight.
  - It appears that the budget assumes that university research grants will provide support for their associated commitments to g-2 operations, including travel to Fermilab.
  - An analysis coordinator has not been appointed, which may be hampering progress associated with analysis preparations.
  - The responsibilities of the shift personnel are not described in detail nor the lines of authority for those on shift. This could lead to confusing situations in the control room that may cause undue operational risk.
  - The information provided does not allow a quantitative comparison of whether sufficient personnel effort is available to commission, take data, and publish first results. There are two impediments to making this evaluations. First, the FTEs available were tallied based on the ill-defined metric of "fraction of research time", so that each person is normalized to a different total number of effort hours. Second, an estimate of the FTE required for commissioning, data taking, and publication was not provided.

Question 1

- Recommendations
  - Determine the number of FTEs needed to commission and operate the experiment and to produce first physics results. Tally the available FTE in a consistent manner to facilitate an assessment of whether sufficient effort is available. Modify the EOP to include this information.
  - Include reference to radiation safety and ORC processes in EOP.
  - Finalize the EOP and obtain the required sign-offs.
  - Formalize an agreement with each institution providing operations support to help ensure expectations of all parties are clearly defined.
  - Develop lines of authority and responsibilities for shift personnel and document them.
  - Appoint an analysis coordinator as soon as possible and no later than the end of the calendar year.
  - Work with the laboratory and collaboration to identify additional effort needed to meet your commissioning and physics goals.

Question 2

- Has it been demonstrated that the experiment is ready for physics-quality data taking? If not, what actions are required to make it ready?

Not yet - The experiment acknowledges that they are not yet ready for physics quality data. They need to (re)commission several detector systems in their final configurations and the proton and muon beam lines both need to be tuned-up. Considerable work remains prior to achieving “physics quality” data, but the necessary work is largely known.

Is there a clear plan for monitoring (the beam and) the data quality and has the associated infrastructure been tested? If not, what actions are required to adequately monitor the data quality?

Yes, the associated infrastructure for monitoring beam and data quality has been demonstrated, but unclear whether performance metrics have been formalized.

Question 2

- Findings
  - A five week “Engineering Run” occurred in 2017 and utilized a reduced rate muon beam without proton removal.
  - All detector systems were examined during the 2017 commissioning run. Performance issues were identified with several systems and must be addressed before physics-quality data taking can begin.
  - Mitigations to address the performance issues identified in the Engineering Run have been developed and are being implemented during the 2017 Shutdown.
  - Once the mitigations are in place, additional beamline and detector commissioning is required before physics-quality data taking can begin.
  - A Commissioning Run is currently scheduled for Nov-2017 : Feb-2018.
  - Five systems have zero spares and the WFD5 5 channel digitizer system has 8 spares for 312 units (2.6%). For some systems components may be repaired instead of replaced.

Question 2

- Comments
  - Low beam rate commissioning was extremely useful, but understanding of high beam rate reliability of pulsed power systems is essential for efficient experiment operation.
  - There does not appear to be sufficient expertise available to address the issues associated with the pulsed power systems in a timely manner. This poses a significant risk to the commissioning time scale and, by extension, the physics goals.
  - The storage ring vacuum appears to limit the ability to run the electrostatic kickers and quadrupoles and has a major impact on the stored muon beam quality. While improvements have been made and plans formed to increase pumping capacity, outgassing from the trackers appear to be the most significant remaining limitations on vacuum quality. Testing the mitigation stategies to resolve the outgassing from the tracker should be implemented at the earliest practical time.
  - An aggressive commissioning plan was outlined that provides first physics quality data in Feb 2018. It may not be possible to complete all tasks/studies on this timescale.
  - It would be nice to have more details in commissioning plan including prioritization of critical tasks to allow for timely publication of first data.
  - For high risks systems, it would be good to ensure adequate spares have been identified or an acceptable repair plan has been developed and documented.
  - Analysis to determine omega_p appears to have expertise concentrated in very few people.

Question 2

- Recommendations
  - Include in your commissioning plan a list of priorities and minimal performance thresholds for critical systems to conform with first publication goals.

Question 3

- Is there a well-understood run plan for FY18, consistent with accelerator schedule and performance? Yes - there is a well understood run plan for FY18.

Have adequate resources from the laboratory and the collaboration been identified for an efficient and safe running of the experiment and for maintenance of the detector? No – there appear to be shortfalls in areas critical to their success.

Is it clear who is responsible for what?

Not quite – while non-FNAL collaborators seem to understand responsibilities, there are no formal documents to establish responsibility for labor or M&S costs.

Question 3

- Findings
  - The accelerator run plan ramps to full intensity by February 2018.
  - Full intensity corresponds to 1e12 POT in 16 pulses, separated in 2 batches of 8 (with 10 msec time between pulses).
  - There are multiple pulsed power supply systems that have to pulse in burst mode at 100 Hz and average 11.43 Hz.
    - In the Accelerator : Li Lens, PMAG, DR Inj Septa, DR Abort Septa
    - In the Ring: Injection Kickers, Quadrupoles
  - The spares budget presented in the EOP was $100k in FY18 and $10k in FY19 and FY20.
  - The speakers identified multiple systems that require modifications to mitigate issues identified during the 2017 Engineering Run. Many of these modifications are scheduled to finish just-in-time for FY2018 Commissioning Run.
  - The necessary vacuum has not been attained. The cause is believed to be outgassing from the tracking detectors.
  - There is sparking in both the quadruples and kicker magnets. This is exacerbated by the vacuum situation, but may be a problem on its own that could limit the physics sensitivity of the experiment.

Question 3

- Comments
  - FNAL PPD is identified as being responsible in the EOP for the kicker and quadrupole systems. The Rings Ops manager identified these as areas where the support team is light. As PPD is not flush with experienced pulsed power supply engineers, the experiment will depend on experts from BNL and Cornell (where the systems originated). Given the importance of these systems to the success of the experiment, this seems to pose a significant risk to the success of the experiment.
  - There is a lot in the run plan to complete by February and not completely clear that all the resources exist. Commissioning and optimizing all the upgrades and modifications will take significant effort.
  - The Rings spares components seemed thin, especially given the minimal spares budget pool.
  - The commissioning schedule appears optimistic given the number of items that must work better than the previous run.
  - It would be useful to clearly define the minimum requirements for each of the subsystems before the experiment can make it's first data run.
  - Resources appear to be thin, especially on pulsed power supply support and, perhaps, the M&S for critical spares.

Question 3

- Recommendations
  - Generate a resource loaded schedule for commissioning, and use it in operations planning. This should include work for all the subsystems (vacuum, particle detectors, magnetic sensors, beam diagnostic, magnets, DAQ…)
  - Work with the laboratory and the funding agencies to create an ongoing plan for spares production of critical components.
  - Work with laboratory and collaboration to identify resources needed to address shortfalls in areas critical to success.

Question 4

- Are there robust plans for data processing and data analysis? Have adequate resources from the laboratory and the collaboration been identified for data analysis to meet these goals?

Not yet - Their plans for data processing and data analysis are under development. Based on the current assumptions, there appear to be adequate resources.

Question 4

Findings

- The Muon g-2 experiment presented a plan for the processing of the initial physics data period based upon their experience from the Summer 2017 Commissioning run experience. The estimated resources requested for this initial dataset is approximately 18 M CPU hours for data reconstruction and 9 M CPU hours for simulation. The corresponding storage request for the raw MIDAS data, reconstructed data, and simulation samples is approximately 2 PB of Enstore tape. These estimates align with the requests that were made at the February 2017 SCPMT presentation.
- The experiment presented the current development of the offline reconstruction to include the calorimetric reconstruction of omega_a, tracking reconstruction for muon beam profiling, and plans for the development of the omega_p calculation. The plan covers most aspects of the analysis path necessary for completion of the initial experimental results. The experiment highlighted several aspects of the offline reconstruction where assistance from SCD expertise might help identify opportunities for significant performance improvements.

Question 4

Findings

- A detailed organization chart for the g-2 Production Group was presented that included utilizing both local and remote effort to manage and operate the offline production workflows and software development. The current status of the production workflows was presented highlighting the extensive utilization of SCD/FIFE services within those workflows. The need for additional SCD/FIFE expertise was highlighted by the experiment in order to streamline workflow, provide access to additional computing resources outside of Fermilab, and to incorporate additional services such as POMS.

Question 4

- Comments
  - The Muon g-2 experiment has made significant progress incorporating the recommendations of the 2017 Computing Review. The successful processing of the Summer 2017 Commissioning dataset provides a baseline for understanding the accuracy of the computing model for the experiment. The presentation of the expected resource needs for the coming initial physics dataset did not appear to differ significantly from the estimates of February 2017. It's important for the experiment to present the assumptions used in those estimates and compare them with the results of the commissioning dataset performance.
  - The recognition of specific areas where SCD expertise could make significant impact on the reconstruction software is an important step to decreasing computing resources needs. Having a focused effort will be important to address large memory footprints in offline software and to take advantage of the significant progress made in multithreading algorithms. To our knowledge, the experiment has not formally requested SCD's assistence.
  - The creation of a focused and operational Production Group as soon as possible is an important part of achieving the physics publication goals of the experiment. The formation of the Production Group has occurred, but the recent formation combined with turnover in personnel, makes it important that they continue to focus the development of full end-to-end production and analysis code. The experiment acknowledged the need for SCD/FIFE assistance in improving workflows, but they did not estimate the needed effort level that would be requested from SCD (nb. these estimates have since been provided).

Question 4

- Recommendations
  - Update and refine the estimates for resource needs made in February 2017 based on the measured performance using a (near) final and complete version of reconstruction and calibration software. Corrections for a large memory footprint should be called out, if necessary. Include the resources necessary for the omega_p determination.
  - Generate a more thorough assessment of the simulation samples needed to achieve your physics goals, including first publication.
  - Formally engage SCD in a discussion to identify the relevant expertise effort needed to improve performance of the reconstruction software and the associated data handling and work flow.
  - Further investigate how to best leverage existing software and computing tools from outside the experiment such as OSG and AWS for both simulation and production workflows.

Question 5

- Are there clear goals set for reporting and publishing the results from the experiment in a timely fashion?

Yes - there are clear goals set for the publication of Muon (g-2) results with uncertainties of 400, 200, and 140 ppb in 2019, 2020, and 2021, respectively.

Question 5

- Findings
  - A series of NIM articles for the major subsystems are planned as well as two PRD style papers on field shimming and analysis and muon beam dynamics.
  - Publications of g-2 measurements with uncertainties of 400, 200, 140 ppb are planned in CY19, 20, and 21, respectively.
  - The experiment has speakers committee to coordinate reporting the results at meetings and conferences.

Question 5

- Comments
  - The major components of the analysis chain are well understood. However, the full analysis chain has not been exercised and the coordination between analysis sub-groups is in the initial stages of development.
  - The analysis organization includes operational, software, algorithm, and physics tasks. It is not clear if this organization is optimized toward reaching physics goals of the experiment.
  - The collaboration should consider publishing an overview NIM paper describing the experiment that precedes NIM articles on specific subsystems. This paper could be used as the main detector reference for g-2 publications.
  - The proposed publication schedule appears aggressive and will require quick commissioning of the experiment, reaching multiple operational specifications, well understood algorithms, and extensive analysis and computing efforts.

Question 5

- Recommendations
  - Develop a schedule with well defined milestones (e.g. run conditions, systematic targets) and decision points for the first publication.

Question 6

- Does the committee recommend further actions to ensure full exploitation of the Muon (g-2) program?

Nothing beyond what was included in previous recommendations.

Question 6

- Recommendations
  - none

Closing

- These will be posted to Indico after any required fixes.
- Committee will develop a draft of the written report by 23 October.
  - Will be shared with Spokespersons for fact checking.
- Aim to issue Final report by 31 October.
- The recommendations will be followed by Program Planning via the EMG meetings.
- Thank you!