Technical, Cost, and Schedule Review of the CLAS12 RICH

On September 5-6, 2013 a technical, cost, and schedule review was held of the CLAS12 RICH detector. The review panel, convened by Rolf Ent, included David Abbott, Javier Gomez, Thomas Hemmick (chair), Allison Lung, Clara Matteuzzi, Curtis Meyer, and Robert Miller. Jehanne Gillo and Sergio Zimmermann sat in as observers. Formal presentations were given by Harut Avakian (Physics Overview), Marco Contalbrigo (RICH Project Overview), Luciano Pappalardo (Aerogel Tests), Matthias Hoek (H8500 Tests), Marco Mirazita (RICH Prototype and Tests), Evaristo Cisbani (Front-End Electronics), Chris Cuevas (DAQ and Trigger), Sandro Tomassini (Mechanical Design), Marco Contalbrigo (Integration in CLAS12), Patrizia Rossi (Project Management), and Rolf Ent (Readiness Review Process).

All presentations were of excellent quality and reflected an impressive body of work. It is clear that the collaboration is talented, enthusiastic, and hard working. We also recognize substantial and critical support of multiple institutions, particularly the leading effort from INFN, that has been necessary to bring the project to its current advanced state.

CHARGE-1 Evaluate the feasibility and merit of the proposed technical approach including: [1]the completeness of the technical design and scope, [2]the maturity of the technical design, and [3]the likelihood that the detector will deliver the stated science goals.

Findings – Technical Design

1. The PID capabilities of the baseline CLAS12 detector are insufficient to support a robust strange quark physics program due to insufficient Kaon identification at high momentum. This program involving strange quarks is a major portion of the CLAS-12 physics program, and many parts of it will be unique.
2. Currently at least 10 proposals representing 25-30% of approved beam time for CLAS12 can benefit from the introduction of the RICH detector. This detector is a critical component for three of these.
3. Kaon ID in the forward (5^{o}-30^{o}) direction is required in the momentum range 3-8 GeV/c bounded at the low end by existing TOF capability and at the high end by the kinematic limit and must achieve 1:500 rejection of pion background.
4. Among all currently known technology, only the Ring-imaging Cherenkov effect can achieve the necessary PID performance. Additionally, aerogel is the only known material whose index of refraction is correct for Kaon ID in the desired momentum range. n=1.05 material with 4-5 mrad θ_c resolution results in 4σ K-π separation and thereby 1:500 rejection.

5. Because SiPM technology requires further validation with regard to large area use and radiation tolerance and LAPPD technology is not mature, high granularity PMT's provide the only viable photon detection technology for the aerogel radiator.
6. To fit within the space of one LTCC sector and save significant cost on instrumenting the focal plane, the RICH design features BOTH classic proximity focus of a 2cm n=1.05 radiator for $\theta<13^{o}$ and a mirror focus system for 6 cm n=1.05 radiator at $\theta>13^{o}$ sharing the same focal plane detectors. The 6 cm thickness is chosen for the outer radiator to compensate for photon losses due to passing the light through the aforementioned the 2 cm radiator twice before detection.
7. A thorough characterization of transparency, transreflectance, absorption length, scattering length, thickness uniformity, index uniformity, and humidity damage/recovery has been performed on aerogel from several manufacturers. Aerogel supplied by Novosibirsk has been tested and has met or exceeded the RICH specifications.
8. At 1 meter expansion gap, pixel sizes below 1 cm are required to achieve the angular resolution. The H8500 series of MAPMT detectors (with or without UV glass) have ideally-sized pixilation (5.8 mm). A future product, H12700, has the potential to achieve better single photon detection allowing operation at lower gain and perhaps improved longevity.
9. Extensive tests of H8500 detectors with pulsed light sources and in test beam demonstrated 85% or higher efficiency for separating single p.e. signals from noise, low cross talk, sufficient magnetic field tolerance, sufficiently low dark currents, and adequate gain uniformity (assuming 1:2 – 1:4 amplification adjustment) to detector single photons from >90% of all channels in a large array.
10. MAROC3 electronics has insufficient trigger latency of analog outputs (100 nsec w/ 8μsec req'd), but beam and bench tests on binary (hit/no-hit) outputs show no loss in performance at single photon discrimination. If coupled with an external digital latency buffer (FEM) and time digitization of fast analog sums, the chip meets every performance spec.
11. DREAM electronics used in the CLAS12 tracking could, after significant signal attenuation, yield analog hit information at the cost of nanosec-level timing information.
12. After carrying out beam tests, it is demonstrated that the detector reaches/exceeds the Cherenkov angle resolution specs in the proximity mode. Simulation results lead the collaboration to conclude that the performance criteria are also met in the mirrored configuration in the absence of misalignment troubles. Overall performance is improved with the non-UV glass version due to limited dispersion.

Comments – Technical Design

1. The RICH team presented an impressive amount and quality of work exhibiting significant and positive progress even in the short interval following last June's review. This work has taken the technical design to a quite advanced stage.
2. The current design is demonstrated by beam tests and simulations to be adequate for achieving the stated performance.
3. The Russian aerogel is not only good enough, it also appears to be the only identified source that could accept a production order that meets design specifications now.

4. The production capacity declared by the aerogel producer (2 m^2/year) places this item directly on the critical path for timely completion of the detector. Delays in aerogel production could delay the installation of the RICH module in 2016.
5. In the current design, the RICH is a single heavy module that would be installed in one piece. Extreme care is required to not damage fragile components such as the aerogel tiles. A design study should be undertaken to determine whether the aerogel panel could be installed after the main body of the detector is rigged into place. If feasible, an added benefit would be the possibility of easy service to both the aerogel layer, detector focal planes and mirrors during a long shutdown period.
6. A more detailed rigging plan for the detector (including transport to the hall and specific motions during the lift) should be formulated at this time as well as a detailed assembly procedure plan since these considerations can critically affect the mechanical design.
7. A mirrored surfaces below the 6 cm aerogel is not useful because of absorption and scattering through this much aerogel.
8. The possibility of better devices (PMT, aerogel, mirror, readout chips…) becoming available soon always creates the desire to test these new devices before making any purchases. Such tests use up schedule contingency, redirect manpower, and risk cost increases. These tests should only be undertaken if the prospective gain in **physics** performance is significant.
9. Timing information at any level will improve out-of-time background rejection. Timing information at the 1 nsec level (MAROC-only) will allow ring searching to be performed in 3D (x,y,t) instead of merely 2D and might improve PID effectiveness.
10. Extensive MAROC tests show such exceptional performance of the binary outputs, such that pulse height information (DREAM-only) helps only if there is a mysterious noise pattern (which could be debugged prior to beam arrival).
11. The committee feels that the 1 nanosec timing information provided by the MAROC chip is much more likely to serve a useful role in the long term RICH performance than the pulse height information available from the DREAM chip.
12. Because the form factor of the RICH electronics must be matched to the PMT arrangement and geometrically-limited intra-detector space, adopting the DREAM chip would not relieve the labor of designing a unique FEM card, but might reuse the FPGA firmware from the trackers.
13. The collaboration should define what level of improvement in any technology (e.g. MAPMT single p.e. performance, aerogel absorption length, etc.) is required to justify various cost increases (what improvement is worth 10% in cost, what improvement is worth 20% in cost), schedule delays (6 mos, 12 mos), and manpower investment (FTE). Do not pursue minute improvements that involve significant risk.
14. Consider whether other materials for the mechanical support of the electronics in the active area of the detector are worth pursuing.
15. Due to the extreme angular resolution requirements of the RICH, mounting schemes that favor lack of stress/deformation on the mirror should be pursued with higher priority than those that locate the mirror most securely. Data can be used to compensate a mirror whose alignment changes, but nothing can compensate for a deformed mirror.

Recommendations – Technical Design

1. The collaboration should determine a date at which further R&D (e.g. better backside surface) would risk the timely production of adequate quantities of aerogel and stop all further R&D at or prior to that date.
2. Studies of mechanical deformations and resulting stresses on the entire detector should include operation, installation, transportation, maintenance (local fixture(s)), and earthquake loads.
3. A more quantitative evaluation of the front-end electronic FPGA board design and component choices such as the FPGA and the fiber transceiver should be made to establish that radiation effects in close proximity to the beam line will not compromise the performance of the readout electronics.

Charge-2 Evaluate the feasibility and completeness of the proposed budget and schedule, including the workforce requirements and availability.

Findings – Proposed Budget & Schedule

1. The RICH project will be carried out by an international collaboration consisting of INFN, JLab, UTFSM and others. Construction is envisioned to be conducted over a three year period between FY13 and FY16, to be completed no later than the end of FY16.
2. A high-level subsystem schedule was shown including manufacturing, engineering, procurement, assembly, and installation. Level 1 and Level 2 schedule milestones have been identified that occur roughly once per quarter. Schedule float for each milestone ranging from 1.5 months to 12 months was also presented.
3. The proposed budget for JLab includes both labor and procurements, while the budgets for the other collaboration institutions only include procurements.
4. The proposed budget for JLab is $1,801K, for INFN is similar, and for UTFSM is $300K.
5. UTFSM has submitted two proposals totaling $300K to support the RICH mirror procurement. Decisions on these two proposals are expected in approximately 2 months and 6 months.
6. The RICH Collaboration has identified several options for supporting the UTFSM portion of the mirror procurement if the two pending funding proposals are not fully funded.
7. The cost contingency has been evaluated using a risk-based assessment and ranges from 10% to 30% depending on subsystem. The overall contingency on the proposed JLab budget is 20%.
8. The proposed budget for JLab does not include overhead, escalation, or management effort.
9. Manpower tables by name as a function of fiscal year were presented for INFN, JLab, and UTFSM as well as the specific ties to the Level 1 milestones.

Comments – Proposed Budget and Schedule

1. To limit cost and schedule risk, it will be important to carefully define the manufacturing tolerances for the mirror, aerogel and MAPMT procurements soon.

2. Including sufficient procurement planning and contract award time into the RICH project schedule will be necessary in order to understand the overall project duration and schedule float.
3. Project tracking would be facilitated by the development of a high level resource-loaded schedule that includes Level 1 and Level 2 milestones for all major subsystems as well any links to the start of assembly at JLab.
4. The cost and schedule risk presented by the pending UTFSM proposals for $300K is acceptable given the multiple avenues identified by the collaboration for alternate support.
5. The commitment and availability of manpower within the three primary institutions is evident.
6. Overall the level of manpower assigned to Level 1 milestones seems reasonable, although detailed task-specific workforce planning was not presented.
7. In order to reduce schedule risk, it will be important to align dates associated with Options in the MAPMT contract with time required to fully study the H12700 model.
8. Generally, the level of cost contingency is appropriate for this stage of the RICH project. However, the inclusion of overhead, escalation, and/or management effort into the proposed JLab base budget of 1.801 M$ will lower the effective cost contingency.

Recommendations – Proposed Budget and Schedule

1. The collaboration should develop a more detailed work-breakdown structure and a high level resource-loaded schedule to facilitate tracking of progress.
2. The JLab budget estimates should be adjusted to reflect inclusion of overhead and escalation and appropriate management effort.
3. For the purposes of project planning, change the completion date of the project from September 2016 to September 2017 to establish 12 months of schedule contingency.

Charge-3 Evaluate the effectiveness of the proposed management structure, both in terms of the integration of the RICH within CLAS12 and the approach to ES&H

Findings – Approach to ES&H

1. The Experiment Readiness Review (ERR) used by the Physics Division to bring new experiments on-line was presented. Within this process, a preliminary hazard analysis of the detector indicated that there were no hazards that merited a preliminary design of the detector and, in the ERR process, a 1st safety review. The detector will undergo a review ("2nd stage review") at a later stage, when it is nearing completion and before it is put into the detector.

Comments – Approach to ES&H

1. Since CLAS12 is a completely new detector system and the first experiments using the RICH will be also using many new other detectors systems undergoing commissioning, it may be more manageable, from the point of view of responsibilities, to assess and

commission each detector system by itself under an Operating Safety Procedure (OSP or Temporary Operating Safety Procedure, TOSP). An experiment, specially the early commissioning ones, will then rely on having all these OSPs/TOSPs to receive beam and commission the various subsystems.
2. The ERR process will be an effective management tool for the ES&H aspects of CLAS12 and the RICH detector.

Findings – Integration

1. A RICH schedule, as presented, will have the detector ready for installation into CLAS12 nearly a year before first-beam. The mechanical design of the RICH has become much more defined since the Technical Review of June 2013, including how the aerogel tiles will be held in place and the mirror alignment guaranteed. Simulations of how the new RICH detector will affect the performance of existing detectors were presented.

Comments – Integration

1. During the presentation it became clear that the mechanical design for the RICH counter made several assumptions about the orientation of the detector during fabrication, transport and installation that did not seem to have been confirmed with Hall B engineering staff.

Findings – Management Structure

1. A Program Management Plan has been developed and was provided to the Review Committee.

Comments – Management Structure

1. The key personnel identified in the Program Management Plan are very experienced, and have shown commitment and dedication to the RICH Project.
2. The Program Management Plan is well developed overall, however several important aspects such as Key Performance Parameters and Schedule Milestone Tables are not included.
3. It will be important to crisply define the roles and responsibilities of the JLab Technical Liaison and JLab Program Scientist with regards to the oversight of the MAPMT procurement and acceptance testing.
4. The management team is developing a creative approach to the major procurement of MAPMTs in order to launch the JLab scope and reduce overall schedule risk.

Recommendations – Management Structure

1. The collaboration should develop the high level Key Performance Parameters (KPPs) for the RICH Project, and include it in the Program Management Plan (PMP). Upon completion, the

language in the Change Control Approval Authority Table in the PMP should be re-evaluated for the distinction between Level 0 and Level 1 Scope/Technical control.

2. Include Tables of Level 1 and Level 2 schedule milestones in the PMP.
3. Modify the language in the PMP Change Control Approval Authority Table for Level 0 Cost control to read “Any cumulative change at WBS Level 1 that increases the TPC by > $100K$.
4. Develop a simple monthly report to track progress.