Report of the RICH Technical Review: June 26-27, 2013

A Ring Imagine Cherenkov detector (RICH) has been proposed as an addition to the CLAS-12 baseline equipment to improve kaon identification. The proposal is to replace at least one (and in the future possibly several) of the six Low-Threshold Cherenkov Counter sectors (LTCC) with a RICH module.

The Review panel consisted of Chris Cuevas, Javier Gomez, Clara Matteuzzi, Bob Miller, Andrew Sandorfi (chair) and Carl Zorn. The panel heard 12 presentations from the CLAS RICH Collaboration spread over two sessions on June 26 and 27, 2013. The list of presentations and the charge to the review committee are attached to this report as an appendix.

General comments on the physics motivation:

An important experimental program in Hall-B requires significantly improved kaon separation beyond that of the CLAS-12 baseline design. The physics motivation seems well developed; experiments E12-09-07, -08 and -09 will be lost to the program without a RICH detector and the physics reach of transverse polarized target experiments C12-11-111 and C12-12-009 will be significantly limited. While the PAC approved experiments discussed a two sector RICH configuration, the use of one sector with either unpolarized or longitudinally polarized targets would cost only $\sqrt{2}$ in statistics and is generally regarded as sufficient. (Transverse polarization experiments would benefit greatly in reduced systematics from the operation of two RICH sectors. The schedule for a second RICH sector is not yet clear, but transverse experiments will be at least two years further out in any case.)

Specific findings related to the CHARGE:

I. Are RICH specifications clearly defined and do they reflect the Physics requirements?

The required performance is clear. The most critical range of K/π separation to be provided by the RICH detector is 3.5 - 7 GeV/c in angles out to about 25 degrees. Separation is required at the 4σ level, with pion rejection at ~ 1/500. A RICH detector that successfully met these requirements would enable the approved kaon physics experiments in Hall B.

II. Does the detector design meet the required specifications?

The overall concept meets the required performance goals and the collaboration is well on their way to developing a full design, although several details have yet to be sorted out – eg. mirror fabrication and control, Aerogel tile thickness and mounting, etc, as discussed further in section III below.

To our knowledge, this is the first RICH to combine proximity detection with the detection of reflected light. The concept is clever, with both producing rings on the same PMT array, separated by 6 ns even when generated in the same event. Some compromises in the reflection geometry have been made and several prototype tests have been carried out. Simulations have been performed that show no degradation of timing in the FTOF from multiple scattering in the RICH material, although the effects of interactions and showers in the ~0.2 radiation length of the RICH readout was not discussed.

• We recommend that a full Monte Carlo of CLAS with a RICH sector be developed and tuned, using the information from the prototype test runs. It is regarded as important to include as many details of the materials in the RICH detector package as practical, to assure a realistic simulation. A report should be generated for review by CLAS management to document the simulation and the expected performance of CLAS with a RICH, both the enhanced performance in Kaon separation as well as the extent of any degradation in the response of other CLAS components.

III. Are there outstanding issues requiring additional R&D and/or design changes?

We have grouped the following discussions and recommendations according to the major detector subsystems.

Aerogel:

The collaboration has carried out an extensive analysis of various Aerogel tiles. They have fixed their design on a supplier from Novosibirsk that is regarded by the panel as a reliable source. Nonetheless, the various tiles will have variations that affect RICH performance and these are important to determine.

• We recommend that at least average properties such as index of refraction, transmission and clarity be measured and recorded for each tile prior to installation. We recognize the added potential challenge to the tight time constraints and urge the collaboration to develop procedures required to expedite such a chain of measurements.

• We recommend that, given the large tile size, the variation of the index of refraction across a tile be measured for a sample of tiles, and the typical variation be included in the RICH Monte Carlo.

The tiles tested to date have had one large surface that was smooth and of high optical quality, while the opposite face was apparently rather rough. The Novossibirsk supplier has communicated their belief that the tiles can be made smooth on both large faces. This is particularly important in the multi-layer regions used for reflected light collection.

• We recommend that the collaboration obtain samples of Novossibirsk tiles fabricated with smooth planar surfaces and assess their optical properties.

The Aerogel from Novossibirsk is hydrophilic. This is not a fundamental problem, but will require some additional design considerations. For example,

- the typical rate of change in the index of refraction with humidity should be measured, as well as procedures required to restore the nominal value.
- the assembly procedure should be considered. The large tiles (20 cm X 20 cm X 2 cm) will be very fragile and will take time to install, so assembly will require a dry environment. (eg. LHCb Aerogel was assembled in a 20% humidity room, which itself has safety considerations.)
- we presume the Aerogel of the RICH will be bathed in some dry gas – N_2 was discussed; nevertheless, the housing in CLAS-12 should be designed in such a way that recovery from accidental water absorption can be performed in situ.
- Charged particles can generate scintillations in Nitrogen, as in most gases, and can create a background in the MAPMTs. The resulting light should be uniformly distributed and may not disturb the pattern recognition, but that would need to be verified by simulation. Alternatively, such scintillations can be quenched with an appropriate choice of gas mixture, as in Morii et al, NIM A526 (2004)399. (For example, the RICH-2 in LHCb uses CO_2 to quench scintillation in CF_4.) However, if a quenching additive is used, its absorption by Aerogel should be investigated to ensure that it does not adversely affect the transmission and index of refraction.

• We recommend that the collaboration investigate the potential background from scintillations in the gas within the RICH chamber and the affect on the Aerogel of any mitigating measures.

Since the detector will be completely assembled in a clean room, it must be transported across the Lab, down the truck ramp and lifted and rotated with the installation tooling. This requires a robust package able to withstand a force of about twice gravity in any direction. It is not clear if the planned supports for the various components (eg. the Aerogel tiles) are consistent with such requirements.

• We recommend that a Finite-Element-Analysis (FEA) be undertaken for the entire detector, considering all loads generated in transport, installation, and maintenance.

Mirrors:

While possible suppliers of 0.5 m^2 mirrors have been identified, the design has not yet converged to a supplier of choice. Further R&D is needed to develop the assembly and mounting of a 5 m^2 composite with controlled curvature and alignment. We see this as the component with the most uncertain time scale and the potential for significant unanticipated costs.

• We recommend that the collaboration focus R&D efforts to develop a reliable time line that leads to a mirror system which can be adequately characterized prior to installation.

MAPMT:

The collaboration has thoroughly studied currently available options for Multi-Anode Photo-Multiplier Tubes (MAPMTs). The preferred choice is the Hamamatsu H8500, operated at 1075V. This is quite close to the manufacturer's maximum rating of 1100V.

• We recommend that aging studies be initiated to check the long-term effects on the dark current of the H8500 when operated at 1075 V.

The collaboration presented very thorough results from a PMT scanning system. While some characterization of each PMT is needed, such extensive testing on each of the 400 PMTs is probably time-prohibitive, given the tight schedule.

• We recommend that a procedure be developed to provide some characterization of the pixel by pixel response of each MAPMT, possibly through a gain measurement in response to uniform illumination.

In the H8500 tests, the separation of the single-photo-electron signal from the pedestal ranged from adequate (but not great) to poor. A new H12700 MaPMT would potentially provide a significant improvement, although the delivery schedule is still very much uncertain. Since the readout is compatible with either, there is a natural desire to wait for the H12700 MAPMTs; but this must be carefully weighed against the very restricted time-table.

• We recommend that the collaboration analyze and adopt a firm decision date, at which point they revert to H8500 MAPMTs, at least for this first RICH sector, if Hamamatsu cannot demonstrate mass production of H12700 units.

Readout:

The collaboration has identified two possible ASICs, which have already been developed for other applications, MAROC and DREAM. There seem to be no fundamental obstacles, although it was not clear how or where the readout components would be developed. Several iterations of completely routed prototype boards will need to be built to be certain that the devices selected meet the readout bandwidth and trigger rate requirements.

• We recommend that the collaboration develop a full plan for the readout and DAQ with a cost analysis to identify responsibilities for design, construction and implementation.

Regarding radiation hardness, a total neutron dose of 10^9 cm^{-2} yr^{-1} was estimated for the maximum CLAS luminosity of 10^{35} cm^{-2} s^{-1}. The energy spectrum should be considered, since there will be at least a component of fast neutrons from an extended hydrogen target. Since single photon detection thresholds are important, some effort to identify and minimize sources of neutrons would be prudent to avoid any increase in noise.

The development of pattern recognition algorithms seems on track. The expected performance could be better clarified by studying efficiencies and miss-identifications as a function of momentum, as well as efficiency versus miss-identification at a fixed momentum. These can help to determine the required alignment accuracy needed to optimize performance.

IV. Has the impact on CLAS-12 performance been fully evaluated?

With 10^{35} luminosity, the expected multiplicity is only between 3-6. That being the case, the multiplicity in one RICH sector is about 1. The readout is being designed around the 8 μs CLAS trigger latency. The RICH is not expected to have any adverse effects upon CLAS and we expect this to be documented in the Report that is recommended in section II above.

V. Has the integration of a RICH into CLAS-12 been adequately addressed?

The collaboration is designing a RICH sector assuming the space limitations defined by an LTCC sector. Estimates for a RICH sector assembly have almost the same weight distribution as an LTCC sector, so that LTCC installation fixtures can be utilized. The fields of the torus magnet do not appear to pose any significant problems. Access to the RICH is estimated to take 5 days, using standard Hall B methods for opening CLAS for service.

The space required for cooling the readout electronics is being studied and needs to be carefully modeled. An estimated 400 W is generated by the readout electronics and forced-air cooling is planned which will raise the emerging air stream to 40^{o} C. It is important that this exhaust not heat up the scintillators of the FTOF, which contain many glue joints.

- We recommend that Jlab/Hall-B provide a defined volume for the RICH detector, including available cooling and cabling spaces, as well as defining the required attachments to the forward carriage. We recommend that Jlab/Hall-B provide a suitable limiting temperature in the region of the FTOF and that the collaboration demonstrate by calculation that this limit can be held. Suitable steps should be taken to protect against a failure of the airflow.

VI. Is the RICH construction and installation schedule consistent with the CLAS-12 schedule?

The target date for one fully installation-ready sector is April 1, 2016. The construction window is challenging. The overview of the construction schedule is plausible, but lacks the detail required to study interdependences and the consequences of component delays. Difficult choices may be required to meet the target date of April 1, 2016.

- We recommend that the collaboration develop a detailed work-breakdown that includes the resources required for each step in order to track closely the schedule.

<u>Summary</u>:

A talented and dedicated collaboration is aggressively pursuing the development of a detector that would significantly enhance the capabilities of the CLAS-12 baseline design. Retrofitting a detector into predetermined constraints is always a challenge. Much progress has already been made. Although several challenges remain, the panel offers their strong encouragement to continue. The potential gain is high. To quote Blair Ratcliff from NIM A502 (2003) 211,

One Ring to rule them all, One Ring to find them,
One Ring to bring them all, correlate and bind them
In the RICH where PID truths lie.

RICH TECHNICAL REVIEW Preliminary Agenda

Wednesday 26th June

8:15-8:20	Start of the Public Session
8:20-8:35	Physics Goals (H. Avakian)
8:40-9:00	The CLAS12 Spectrometer (V. Kubarovsky)
9:10-9:30	RICH Project Overview (M. Contalbrigo)
10:15-10.35	Aerogel Test Results (L. Pappalardo)
10:45-11:05	H8500 Test Results (M. Hoek)
11:15-11:45	The RICH Prototype (M. Mirazita)

Thursday 27th June

8:15-8:20	Start of the Public Session
8:20-8:40	Front-End Electronics (E. Cisbani)
8:50-9:05	DAQ & Trigger (B. Raydo)
9:10-9:30	Mechanical Design & Mirrors (S. Tomassini)
9:40-9:55	Assembly and Installation in CLAS12 (Jlab Engineer)
10:30-10:50	RICH Construction & Installation Schedule (M. Contalbrigo)
11:00-11:20	Commissioning & Operation Plans (M. Contalbrigo)
11:30-12:00	Final Discussion

Review of the One-Sector RICH Counter for CLAS12 – 6/26-27/2013

Charge to the review committee:

Review panel for the CLAS12 RICH will evaluate the design, the so far completed R&D and prototyping, construction, installation, commissioning and operation plans. Specific aspects of the project that must be addressed are:

- Are the detector specifications clearly defined and do they reflect the physics requirements?
- Does the detector design meet the required specifications? Please specify in detail.
- Are there remaining issues in the project that require additional R&D and/or design changes?
- Has the impact of the RICH on the CLAS12 performance been evaluated? Specifically, does the RICH have any limiting effect on the performance of CLAS12, e.g. the maximum luminosity at which CLAS12 can be operated?
- Has the integration of the RICH into CLAS12 been addressed, in particular:
  - Possible interference with the other CLAS12 detector systems and the Torus magnet
  - The location of utility lines and signal readout cabling
  - The access for repair and maintenance
- Is the schedule for the construction and installation of the RICH in line with the CLAS12 installation plan
- Other comments that address potential weaknesses of the chosen design.