Ring Imaging Cherenkov Counter (RICH)

Program Management Plan

March 2014

Table of Contents

1. Introduction

The Italian groups of Bari, Ferrara, Genova, Laboratori Nazionali di Frascati, Roma/ISS of Istituto Nazionale di Fisica Nucleare (INFN – Italy) have proposed the construction of a Ring Imaging Cherenkov (RICH) detector to be installed in the CLAS12 spectrometer of Hall B that will allow clean kaon identification for momenta up to 8 GeV/c. This RICH is foreseen to replace the Low Threshold Cherenkov Counter in one of the sectors of CLAS12. The project is led by INFN (Italy) with collaborators from Chile, UK, Germany, Republic of Korea and the US. This RICH Program Management Plan describes the management of the US scope of the project.

With the CEBAF upgrade, CLAS12 will receive polarized beams of maximum energy of 11 GeV and luminosity up to10^{35} cm^{-2} s^{-1}, providing a world-leading facility for the study of electron-nucleon scattering at these kinematics, with close to full angular coverage. The physics program is extremely broad, but in particular will focus upon three-dimensional imaging of the nucleon through the mapping of generalized and transverse momentum dependent parton distribution functions at unprecedented high x_B. Efficient hadron identification is demanded across the entire kinematical range and, in particular, a π/K separation of ~4σ at 8 GeV/c is the goal. Currently charged hadron identification in CLAS12 is performed by Time-Of-Flight (TOF) detectors, Low and High Threshold Cherenkov Counters (LTCC, HTCC). These will not provide the necessary separation across the range of 3 - 8 GeV/c however, and thus a RICH detector has been proposed for installation into the forward region of CLAS12, replacing one sector of the LTCC.

A RICH detector represents a powerful tool in identifying charged particles produced in nuclear and sub-nuclear interactions. Its performance allows extremely high precision measurement of the speed of particles, through the detection of the Cherenkov light that accompanies their passage in a dense medium with a velocity larger than the velocity of light in the same medium.

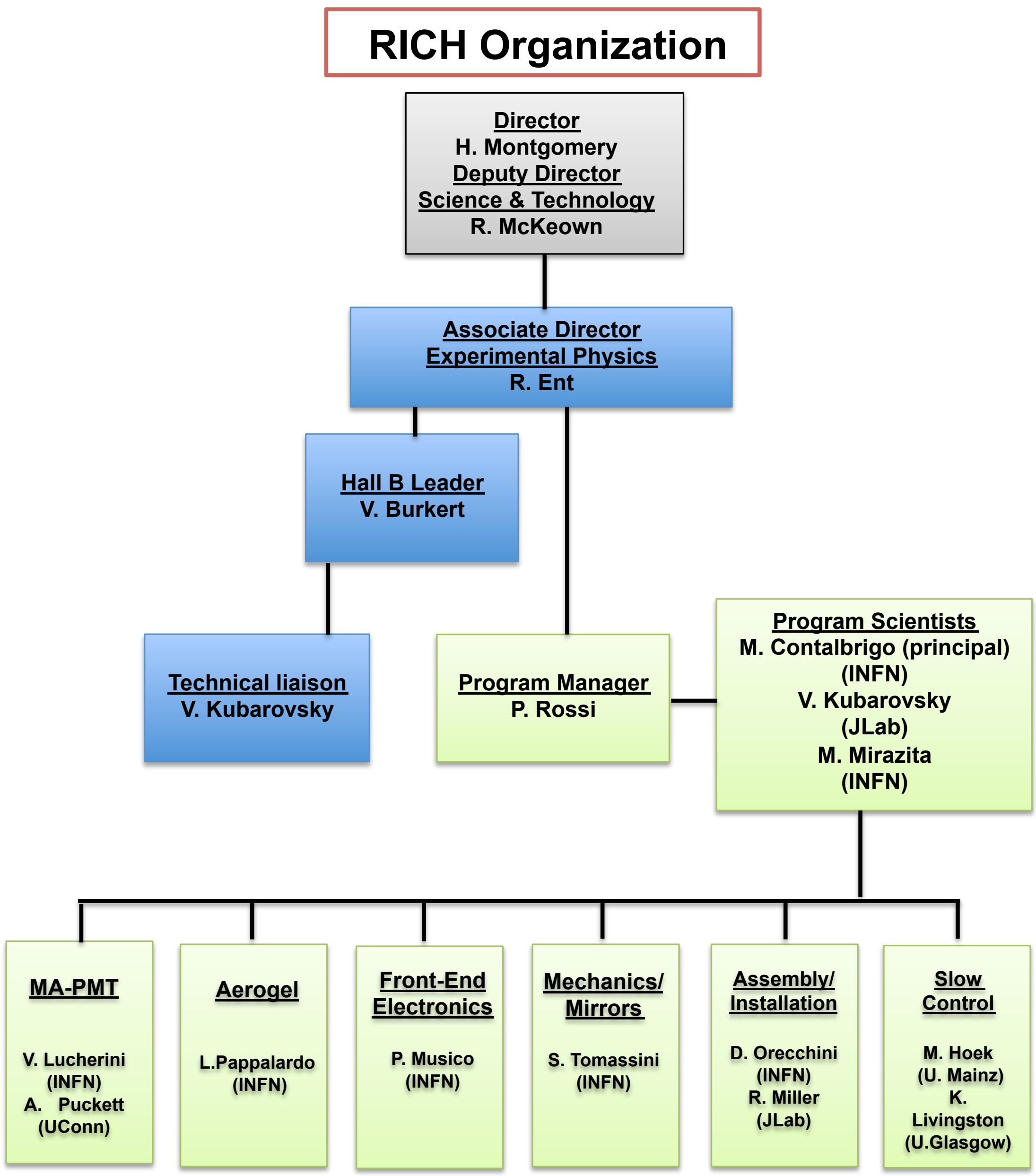
Since the RICH detector must fit into the original CLAS carriage there are several constraints imposed upon its design. Each of the six radial sectors of CLAS12 has a projective geometry, limited gap depth of 1.2 m and ~ 4.5 m^2 entrance windows. There is also the need to minimize the material budget influence on the TOF, the pre-shower calorimeter (PCAL) and the electromagnetic calorimeter (EC) detectors positioned behind the RICH. Simulation studies favour a hybrid imaging RICH design incorporating aerogel radiators, visible light photon detectors and a focusing mirror system. The focusing mirror system will be used to reduce the detection area instrumented by photon detectors to ~1 m^2 per sector minimizing costs and influence on the TOF system.

Multi-anode photomultiplier tubes (MA-PMTs) match the aerogel Cherenkov light spectrum as they detect light in the visible and near-ultraviolet region with high efficiency. They minimize the dead area and simplify the detector layout geometry thanks to the high packing fraction, and provide the required spatial resolution. In addition, being fast and with a high time resolution, they allow efficient discrimination of the background.

Large-scale test beam prototype of the CLAS12 RICH detector has been studied and extensive data analysis and simulation comparisons have been made; also the construction and running of cosmic prototypes for simulation validations and projected performance studies have been performed.

2. Program Organization

The RICH Program will be executed as a joint collaboration between INFN (Italy), Jefferson Lab (JLab, USA), Universidad Tecnica Federico Santa Maria (UFSM – Chile), Argonne National Lab (USA), Glasgow University (UK), J. Gutenberg Universitat Mainz (Germany), University of Connecticut (UConn - USA), Duquesne University (USA), and Kyungpook National University (Republic of Korea).
A clear definition of the roles and responsibilities that individuals and their organizations play will be critical to the success of the RICH Program. Jefferson Lab will take the lead integrating the RICH detector in CLAS12. The INFN, JLab and Universities/Institutions are responsible for producing the deliverables identified later. We show below the RICH Organization Chart. The different colors used in the chart refer to the different levels of the Program: Director and Deputy Director (grey), structure within the Physics Division (blue), RICH Program Organization (within the Physics Division) (green).



Program Management Team:

The Program Management Team (PMT) will monitor overall developments within the program and provide advice as needed. Membership of the PMT will consist of the JLab Associate Director of Experimental Physics, the Program Manager, the Hall B Leader, the Program Scientists, and representatives of participating University and Institution groups. Outside the formal structures of the organization chart above, the PMT will monitor overall progress and meet on a regular basis to discuss issues and progress. The Program Manager will convene these meetings.

Director and Deputy Director: (Hugh Montgomery and Robert McKeown, respectively – JLab)

- Primary interface with DOE Office of Nuclear Physics.
- Provide overall guidance.

Associate Director, Experimental Physics: (Rolf Ent – JLab)

- Gives final approval for initiation of any project in any given year.
- Reports status and progress (milestones achieved and problems encountered) to the Director and Deputy Director
- Convenes external review panels in consultation with the Program Manager and Program Scientists as needed.
- Receives and evaluates documented findings of convened external reviews.

Hall B Leader: (Volker Burkert – JLab)

- Coordinates with the Program Manager the allocation of resources in Hall B to ensure that this project is completed in a timely fashion and at the same time to not interfere with other developments and the beam schedule in the Hall.
- Appoints, in close collaboration with the Program Scientists, internal review panels as needed and helps to implement the guidance provided by such reviews.
- Reports to the Associate Director of the Physics Division the developments and year to year resource needs of the RICH program as integrated in Hall B.
- Negotiates with higher management regarding the development of an overall Hall B schedule that includes this project.

Program Manager: (Patrizia Rossi – JLab)

Is the central coordinator of all RICH program activities. Her responsibilities include:

- Oversight of the project:
  - Convenes regular meetings
  - Monitors progress and reports to the JLab AD, Experimental Physics
  - Documents progress
- Sees that money spent on each sub-project is appropriate for that project. (**i.e.** approves all JLab expenditures).

Program Scientists: (Marco Contalbrigo (principal) – INFN, Valery Kubarovsky – JLab, Marco Mirazita – INFN).

- As the intellectual leaders of the program, they are responsible for defining the detailed technical specifications of the RICH detector.
- Work with the Program Manager to ensure all projects meet the necessary technical standards.
- Monitor progress on each subsystem.
- Initiate, in close collaboration with the Program Manager, informal meetings and

discussions to facilitate communication among the members of the program.

- Initiate, in close collaboration with the Hall Leader, internal project and subsystem reviews.
- Provide the Program Manager with timely, expert advice on technological issues.

Technical Liaison: (Valery Kubarovsky – JLab)

- Will facilitate the communication between the foreign Institutions/Universities and Hall B.
- Reports to the Hall B Leader, both routine and extraordinary developments.
- Supervises MA-PMTs tests.

Subsystem managers: Have technical and schedule responsibility for each of the technical subgroups. The subgroups include:

- Multi Anode Photomultiplier tubes
- Aerogel radiator
- Electronics
- Mechanics/Mirrors
- Slow control
- Assembly/Installation

Each subsystem manager is responsible for:

- Overseeing the day-to-day work on his or her subsystem.
- Reporting developments to the Program Manager and Program Scientists.

3. Program Assumptions, Constraints and Dependencies

Assumptions

Program assumes that funding will be made available from the JLab Capital Equipment annual base budget. The RICH Project will start in FY13 and continue until FY16.

Dependencies

The RICH project requires the completion of CLAS12 as part of the JLab 12 GeV upgrade project.

The RICH project described here represents the US scope of an INFN-led international project. It relies on contribution of funds from international groups such as INFN/Italy, Chile, Germany, UK and Republic of Korea. INFN/Italy program costs have been approved, Chile program costs have been requested.

The RICH project relies on manpower already committed by non-US collaborators. The US scope provides manpower to guarantee successful integration in CLAS12, purchasing and testing of various electronics components, and installation by the Hall B technical crew.

The development of the DAQ electronics is being done by the Jefferson Lab Fast Electronics group as part of generic pipelined electronics development. The schedule will be tracked simultaneously with the RICH project.

4. Program Risk Management

The project risk will be managed by the Program Manager according to the plan described below. Levels of risk are identified for each element by the Program Manager in concert with the relevant subsystem managers.

Cost contingency is evaluated based on Risk Factors and Weighting Factors as described in Section 5.

5. Program Methodology for Estimating Cost Contingency:

For each subsystem of the RICH Project, a list of expenditures was developed. These lists include cost estimates based on various inputs that included catalog prices, vendor quotes, estimates based on previous experience, and technical estimates.

The labor required to build each item was folded in only for the JLab cost estimate, not for the other Institutions contributing to the RICH construction and installation in CLAS12.

This section describes how the cost contingency for a given RICH subsystem was calculated. Risk is a function of the following factors: the sophistication of the technology, the maturity of the design effort, the accuracy of the cost sources, and the impact of delays in the schedule. Risk analysis was performed for each subsystem. Results of this analysis are related to a contingency, which is listed for each costed element.

Definitions

Base Cost Estimate – The estimated cost of doing things correctly the first time. Contingency is not included in the base cost.

Cost Contingency – The amount of money, above and beyond the base cost, that is required to ensure the Project's success. This money is used only for omissions and unexpected difficulties that may arise. Contingency funds are held by the Associate Director of the JLab Physics Division.

Risk Factors

Schedule Risk

No schedule risk has been assigned to this project since a delay in the completion of the RICH will not put the schedule of the CLAS12 spectrometer completion at risk. The installation of the RICH detector is foreseen at the beginning of FY17, approximately one year before the first experiment where the RICH would be needed might be scheduled. Therefore, the RICH Program has approximately one year of fixed float at the back end of the schedule in this Management Plan.

Cost Risk

Cost risk is based on the data available at the time of the cost estimate. For elements for which there is a recent price quote from a vendor or a recent catalog price, we assign a 10% contingency. This applies to the mechanics (which includes the installation tools and the construction of the RICH external frame and the electronic panel). If there is not a sufficiently robust production process we assign another 15%. This is the case for the Front-End electronics. If the items are not "off-the-shelf" of a single vendor we will discuss the contingency under the technical risk. This is applicable for the aerogel and the mirrors.
A special case is the MA-PMTs which is a catalog item for which we have a recent price quote. However the contingency is set somewhat higher (20%) than other catalog items in order to reflect possible changes in the technical specifications and/or exchange rate.

Finally, a 30% contingency has been assigned to the shipment as the estimated cost is based on previous experience and not on a quote.

Technical Risk

Based on the technical content or technology required to complete the element, the technical risk indicates how common the technology is that is required to accomplish the task or fabricate the component. If the technology is so common that the element can be bought "off-the-shelf", i.e. there are several vendors that stock and sell the item, it has very low technical risk, therefore we did not assign additional contingency. On the opposite end of the scale are elements that extend the current "state-of-the-art" in this technology. For these, we assigned a 30% contingency. This is relevant for the aerogel and the mirrors.

Design Risk

It is directly related to the maturity of the design effort. When the element design is nearly complete, quantity counts and parts lists finished, the risk associated with design is nearly zero; therefore a risk factor of 0 is applied. This applies to the RICH external frame and the electronic panel. When no accurate studies have been made, we assign 30%. This is applicable to the gas system and slow control.

6. Program Change Control

Once the baseline for the RICH Project has been established and approved, a formal baseline change control process will be followed.

- The RICH PMT will act as Change Control Board (CCB) to evaluate proposed (see Table below) changes to the project baseline. Membership of the CCB will consist of the Program Manager, the Hall Leader, the Program Scientists, and the Associate Director when needed.

Change Control approval levels will be handled in accordance with the table below:

Table 6.1 Project Change Control Approval Authority

	Level 0 **Associate Director Experimental Physics**	**Level 1** **Program Manager** **&** **Hall B Leader**	**Level 2** **Program Scientists**
Scope / Technical	Any change in scope and/or performance that affects the science	Any change that affects the Deliverables or Key Performance Parameters	NA

Schedule	Any cumulative change at WBS Level 1 that delays completion by > 6 months	Any change to a Level 1 Milestone, or any change to a Level 2 Milestone > 3 months	Any change to a Level 2 Milestone >2 months and ≤ 3 months
Cost	Any cumulative change at WBS Level 1 that increases the TPC by > 100K$	Any cumulative change at WBS Level 1 > 50K$ and ≤ 100 K$	Any cumulative change at WBS Level 2 >25K$ and ≤ 50K$

7. Program Environment, Safety, Health, & Quality

All phases of the RICH Program will be carried out in accordance with the Jefferson Lab Environment, Health and Safety (EH&S) policies and procedures as documented in the Jefferson Lab "EH&S Manual" including obeying all local, state and federal regulations. The laboratory has as one of its guiding principles the protection of the health and safety of its employees, contractors and the public. The environmental, safety, and health risks/issues are considered small and manageable within current standard processes.

RICH Program work will be conducted under the laboratory's existing Integrated Safety Management (ISM) Program. ISM is an integral part of Jefferson Lab's management structure spelled out in detail in the "EH&S Manual", the "Quality Assurance Manual", and various management manuals and training documents. Particular attention and planning will be given to those items which have the greatest potential to impact the project cost, schedule, and performance. Extensive testing and evaluation will be carried out for all of the critical components whether purchased or fabricated and assembled in house. RICH Project work will be performed under the standards and codes set forth in the TJNAF DOE JSA contract, Federal Occupational Safety and Health Act (OSHA), 29 Code of Federal Regulations (CFR) 1926, 10 CFR851, and Virginia OSHA as supplemented by Jefferson Lab work rules.

Prior to the use of any hardware built under the RICH Program in an experiment, the Physics Division at JLab will require completion of a "Readiness Review". The "Readiness Review" focuses on the technical readiness of all the experiment's components and their safe operation.

Training

Principal players are Ph.D. physicists, their students, engineers, and qualified technicians. No additional training beyond what is already required to work safely and effectively at their respective institutions is required. Naturally, all work done at JLab will be done in accordance with the procedures and training requirements spelled out in the JLab EH&S manual. Work done at the Universities/Institutions will be done in compliance with the rules and procedures spelled out at each Institution.

8. Program Communications

Program communications must be proactive and timely, responding to accomplishments and emerging issues or activities. Communications will focus on disseminating information regarding program objectives, strategies, problems/issues, and status. Due to the collaborative nature of the RICH Program team, use of phone calls and e-mails will be the central mode of communication among participants. The Program Manager will convene regular monthly meetings by phone, Skype, and/or ReadyTalk connections available for those off-site.

RICH Project and Reviews

Progress on each component will be monitored by the Program Scientists and reported to the Program Manager.

The JLab RICH Program Manager will provide a monthly status update to the Associate Director of Experimental Physics via a short written report and a monthly meeting.

JLab will convene external review panels to evaluate progress on an as needed basis. In the event of any serious problems in the interim, e.g., a detector performance issue, additional appropriate reviews would be convened by JLab.

RICH Program Team meetings will be held regularly to keep collaborators informed of progress and problems.

9. The RICH Program

a. Scope

WBS 7	**RICH Project**	**WBS 7.1**	Project Management
		WBS 7.2	MA-PMT
		WBS 7.3	Aerogel
		WBS 7.4	Front End Electronics
		WBS 7.5	Mechanics
		WBS 7.6	Mirrors
		WBS 7.7	Gas System
		WBS 7.8	Slow Control
		WBS 7.9	Shipment

b. High Level Deliverables

1. Completion of one sector of RICH detector to provide CLAS12 with the capability to identify kaons with momentum between 3 and 8 GeV/c with a rejection power with respect to pions and protons of about 1:500
2. Installation of the RICH in CLAS12
3. Procurement and testing of 400 PMTs
4. Procurement and testing of 5.3 m^2 of aerogel
5. Production and installation of the mirror system for the RICH
6. Validation of the characteristics of the Front End and DAQ Electronics

c. Roles and Responsibilities

Person	Responsibility
Marco Contalbrigo (INFN) Valery Kubarovsky (JLab) Marco Mirazita (INFN)	**Project Scientists Technical Oversight**
Patrizia Rossi (JLab)	**Project Management**
Vincenzo Lucherini (INFN)/ Andrew Puckett (UConn)	**MA-PMTs Tech. Oversight**
Luciano Pappalardo (INFN)	**Aerogel radiator Tech. Oversight**

Paolo Musico (INFN)	**Front-End Electronics Tech. Oversight**
Sandro Tomassini (INFN)	**Mechanics/Mirrors Tech. Oversight**
Matthias Hoek (U. Mainz) / K. Livingston (U. Glasgow)	**Slow Control Tech. Oversight**
Dario Orecchini (INFN) / Robert Miller (JLab)	**Assembly/Installation Tech. Oversight**

d. Schedule

The RICH Program schedule covers approximately 3 years.

e. Project Cost

The cost of the RICH detector is reported in the three tables below. In Table 9.1, the base cost for each subsystem is listed together with the percentage applied contingency, the cost contingency in K$ and the total cost (base cost+ cost contingency). Percentage FTEs of the JLab Project Manager and the Technical Liaison is reported in the Project Management row. In the table, the share of the cost of each subsystem among JLab, INFN and Chile is also reported. For Jlab both the Direct and Burdened costs are listed. The cost contingency for JLab is 310,5K$ (~25%). Table 9.2 shows the flow of the expenditure through FY13-FY14-FY15-FY16 for the **base cost** of the project. Table 9.3 shows the items that contribute to the cost of each subsystem.

Table 9.1

WBS		Base Cost (K$)	Con (%)	Cost Con. (K$)	TOTAL Cost (K$)	JLab Direct Cost	JLab Burdened Cost	INFN	CHILE
7.1	Project Management	34,1			34,1	34,1	68,3		
7.2	MA-PMTs	950	20	190	1140	1140	1217,4		
7.3	Aerogel	550,8	30	165,2	716	253	304,5	463	
7.4	Front End Electronics	180,1	25	45	225,1			225,1	
7.5	Mechanics	55,5	10	5,6	61,1	13,75	20,75	47,3	
7.6	Mirrors	436,5	30	131	567,5			267,5	300
7.7	Gas System	20	30	6	26	26	39		
7.8	Slow Control	10	30	3	13	13	20		
7.9	Shipment	20	30	6	26			26	
	TOTAL	**2257**	25	**551,8**	**2808,8**	**1479,85***	**1669,95****	**1028,9****	**300*****

* The JLab Direct Cost includes procurement & labor
** The JLab Burdened Cost includes G&A applied to the base cost
** The INFN TOTAL includes ONLY procurement;
Labor: An average for each fiscal year of 10FTE physicists + 4.5FTE technicians & engineers
*** The CHILE TOTAL includes ONLY procurement.

Table 9.2

	Fiscal Year Quarter	FY13 IV (K$)	FY14 I (K$)	FY14 II (K$)	FY14 III (K$)	FY14 IV (K$)	FY15 I (K$)	FY15 II (K$)	FY15 III (K$)	FY15 IV (K$)	FY16 I (K$)	FY16 II (K$)
WBS 7.1	Project Management		11				11				11	
WBS 7.2	MA-PMTs	200		375				375				
WBS 7.3	Aerogel		103,1		167,2		50	85,9			144,6	
WBS 7.4	Front End Electronics		16				150,9					13,2
WBS 7.5.1	Mechanics-Labor										10,5	
WBS 7.5.2	Mechanics-Procurement					27,3			15,7		2	
WBS 7.6	Mirrors		15,4		61,5	115,4		128,8	115,4			
WBS 7.7	Gas System										20	
WBS 7.8	Slow Control										10	
WBS 7.9	Shipment											20

	FY13	FY14	FY15	FY16
TOTAL JLAB	200	386	436	198,1
TOTAL INFN		390,5	381,3	33,2
TOTAL CHILE		115,4	115,4	

Table 9.3

Project Management	- 4% FTE: Project Manager; 4% FTE: Technical Liaison. - The total cost of the Project Management includes Fringe, G&A and 3% escalation over 3 years.
MA-PMTs	- The cost is for 380 MA-PMTs. The total number of PMTs for the RICH detector is 400 but INFN already owns 28.
Aerogel	- Manufacturing engineering. - 5.3 m^2 of aerogel produced by Budker INP (Russia).
F-E Electronics	- Manufacturing engineering. - Integrated Circuits (MAROC, NINO, Ext ADC, delay line, voltage regulator, DAC). - Passives (resistors, capacitors, inductors, multilayer PCB, misc. hardware). - Connectors (SAMTEC TMM, SAMTEC, LV power).
Mechanics	- RICH external frame (aluminum alloy). - Electronic panel (durostone plus aluminum alloy). - Installation tools. - 0.14 JLab FTE Manpower for installation in CLAS12.
Mirrors	- Spherical Mirrors: Carbon Fiber Reinforced Polymer (CFRP) Substrate, Mold, CFRP support and positioning Frame, Coating. - Flat Mirrors: CFRP support Frame, Glass.
Gas System	- Filters, lines, flux and pressure regulators, Nitrogen gas, chiller.
Slow Control	- Gas Sensors, lines.
Shipment	-

f. Institutional Contributions

In Table 9.4, the contribution of each collaborating Institution to the RICH Program is reported.

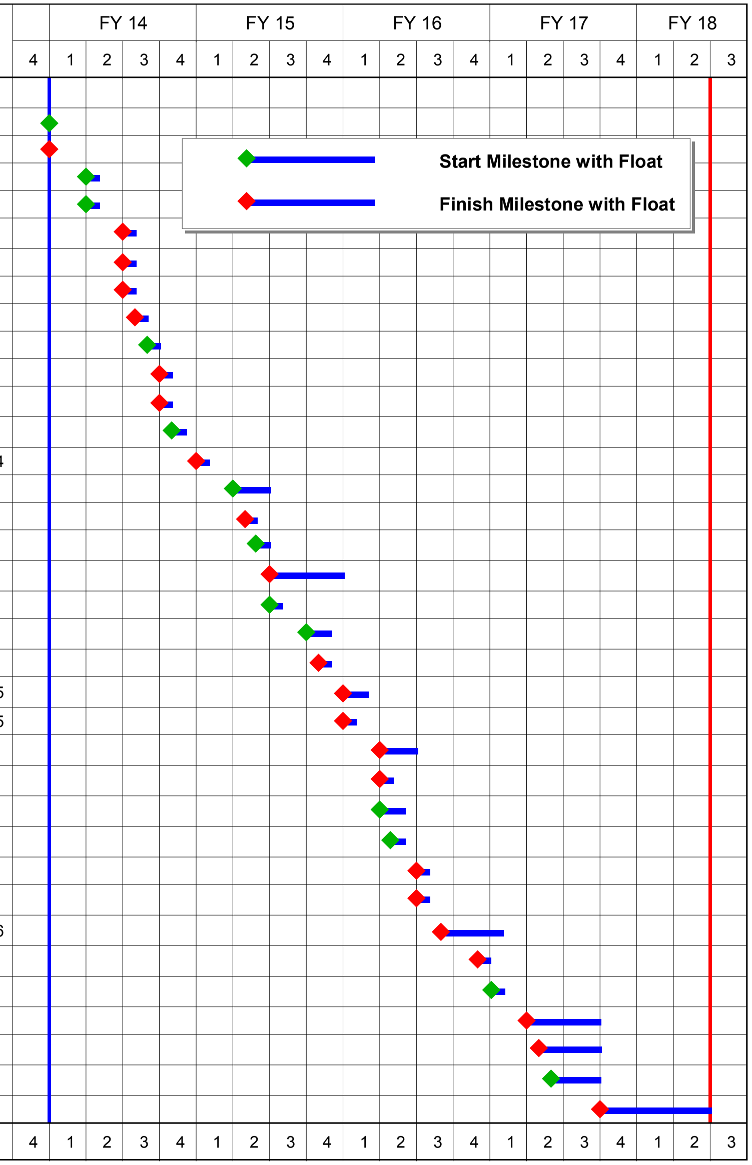
Table 9.4

INSTITUTION	CONTRIBUTIONS
Argonne National Lab, USA	• Feasibility studies • Simulations • Pattern Recognition and Event Reconstruction
University of Connecticut, USA	• PMTs test characterization
Duquesne University, Pittsburgh, USA	• Simulation software maintenance
University of Glasgow, Glasgow, UK	• PMTs detailed characterization • Cosmic test of a small RICH prototype • Slow control development and maintenance
Kyungpook National University, Republic of Korea	• PMT test characterization
INFN Sezione di Bari, Bari, Italy	• Gas system construction
INFN Sezione di Ferrara, Ferrara, Italy	• Design and construction of the large scale RICH prototype • Acceptance tests and characterization of the aerogel • Simulations • Pattern Recognition and event reconstruction • Design, prototyping, construction of the Front End Electronics
INFN Sezione di Genova, Genova, Italy	• Design, prototyping and construction of the Front End Electronics
INFN Laboratori Nazionali di Frascati, Frascati, Italy	• Design and construction of the large scale RICH prototype • PMTs detailed characterization • Mirrors design and quality acceptance tests • Mechanical design
INFN Sezione di Roma1 & ISS, Roma, Italy	• Design, prototyping, construction of the Front End Electronics
Institut fur Kernphysik, Mainz, Germany	• Slow control development and maintenance
Thomas Jefferson National Accelerator Facility, Newport News, VA, USA	• Acceptance test and characterization of the MA-PMTs • Installation of the RICH detector in CLAS12
Universidad Tecnica Federico Santa Marıa, Valparaiso, Chile	• Development of the Front End electronics for the RICH large scale prototype • Mirrors design and quality acceptance tests

g. Project Milestones

Table 9.5 Level 1 and Level 2 milestones for the RICH Program.

Activity Name	Date	MS Lvl	Finish Date
RICH Milestone Schedule			
Start of US Scope of RICH Project	9/30/13	1	9/30/13
PMT Contract Awarded	9/30/13	1	9/30/13
Start Aerogel Procurement	12/31/13	1	1/31/14
Start PMT Production	1/1/14	1	1/31/14
FE Interfaces Defined; Preliminary Electronics Design Completed	3/31/14	2	4/30/14
Identification of Mirror Technical Specification	3/31/14	2	4/30/14
Identification of External Frame & Electronic Panel Tech Specs	3/31/14	2	4/30/14
First 20 PMT Delivery	4/30/14	2	5/30/14
Start Mirror Procurement	6/2/14	1	7/1/14
PMT First Delivery Acceptance Testing Completed	6/30/14	2	7/30/14
First 1 m2 Aerogel: Order for Procurement Submitted	6/30/14	2	7/30/14
Start Metallic External Frame Procurement	8/1/14	2	9/3/14
DAQ: FPGA Board Design and Firmware Develop Completed	9/30/14	2	10/30/14
Start Mirror Production	12/31/14	1	3/31/15
DAQ FPGA: Order for Procurement Submitted	1/30/15	2	2/27/15
FE Electronics: Order for Procurement Submitted	2/27/15	2	3/31/15
2 m2 Aerogel Production Completed	3/31/15	2	9/30/15
Start Electronic Panel Procurement	4/1/15	2	5/1/15
Start First Spherical Mirror Characterization	6/30/15	2	8/31/15
FE and DAQ FPGA Boards: Production Completed	7/30/15	1	8/31/15
2 m2 Aerogel Acceptance Tests Completed	9/30/15	2	11/30/15
External Frame & Electronic Panel Completed	10/1/15	2	10/30/15
Mirror Production Completed	12/31/15	1	3/31/16
PMT Production Completed	12/31/15	1	2/1/16
Start Mechanical Assembly Test	12/31/15	2	2/29/16
Start FE and DAQ Electronics Characterization	1/29/16	2	2/29/16
PMT Characterization Completed	3/31/16	2	4/29/16
Mechanical Assembly Survey of Spherical Mirrors Completed	3/31/16	2	4/29/16
3 cm Thickness Aerogel Production Completed	5/31/16	2	10/31/16
Mirrors/Ext Frame/Elect Panel Arrive at JLab	8/31/16	2	9/30/16
Start RICH Assembly	10/3/16	2	11/2/16
Aerogel Production Completed	12/30/16	1	6/30/17
RICH Assembly Completed	1/31/17	2	6/30/17
Start RICH Installation	3/1/17	2	6/30/17
RICH Project Completed	6/30/17	1	3/30/18



3. Signatures

Submitted by:

Dr. Rolf Ent ______________________________

Associate Director, Physics

Dr. Patrizia Rossi ______________________________

RICH Project Manager

Approved by:

Dr. Hugh Montgomery ______________________________

Director, Jefferson Lab

Concurrence:

Dr. Jehanne Gillo ______________________________

Division Director, NP

Date of Final Signature: ________________