Ring Imaging Cherenkov Counter (RICH)

Project Overview

Patrizia Rossi

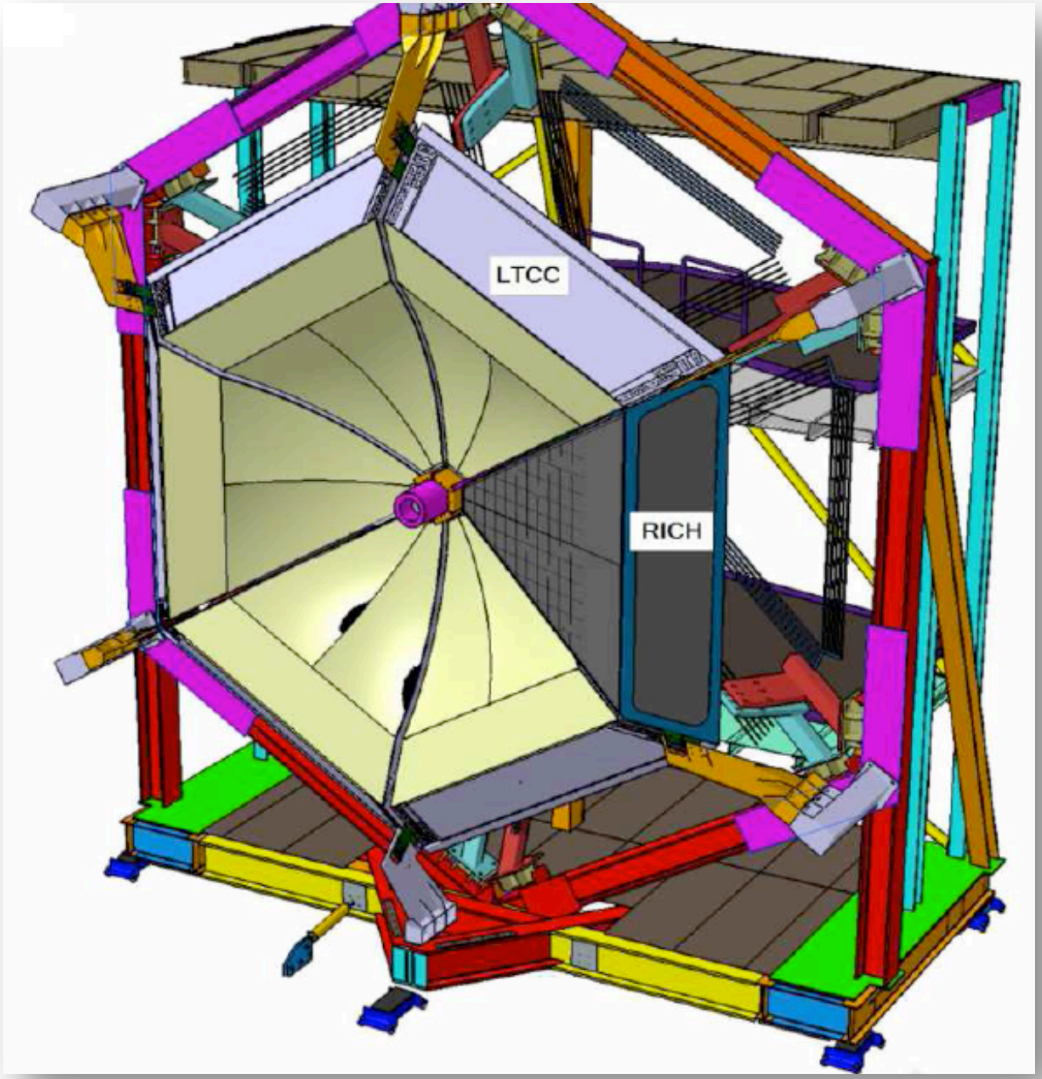
RICH Mid-Term Project Review

October 13, 2015

Organization of the Review

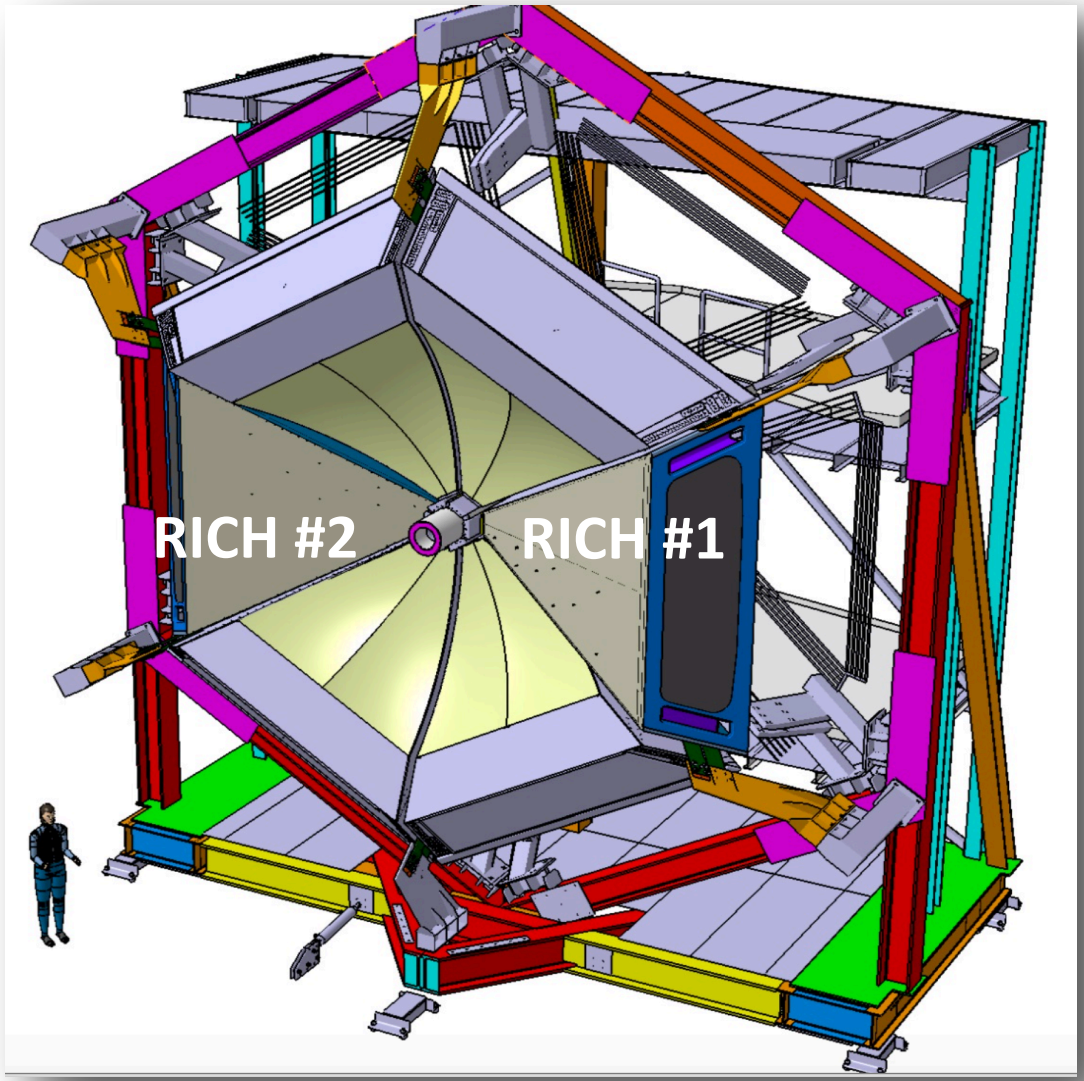
- Overview of the Program (P. Rossi)
  - RICH Detector
  - Collaboration
  - Program Organization & Project Management
  - WBS7: The RICH Program - Status and Milestones
  - Budget
- Presentations on individual WBS7.X (A. Kim, M. Contalbrigo, M. Turisini, D. Orecchini, M. Mirazita, S. Tomassini, S. Pisano)
- Update Management Plan and Re-planning Program (P. Rossi)

The RICH Program



- The **RICH program** consists of 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 RICH Program



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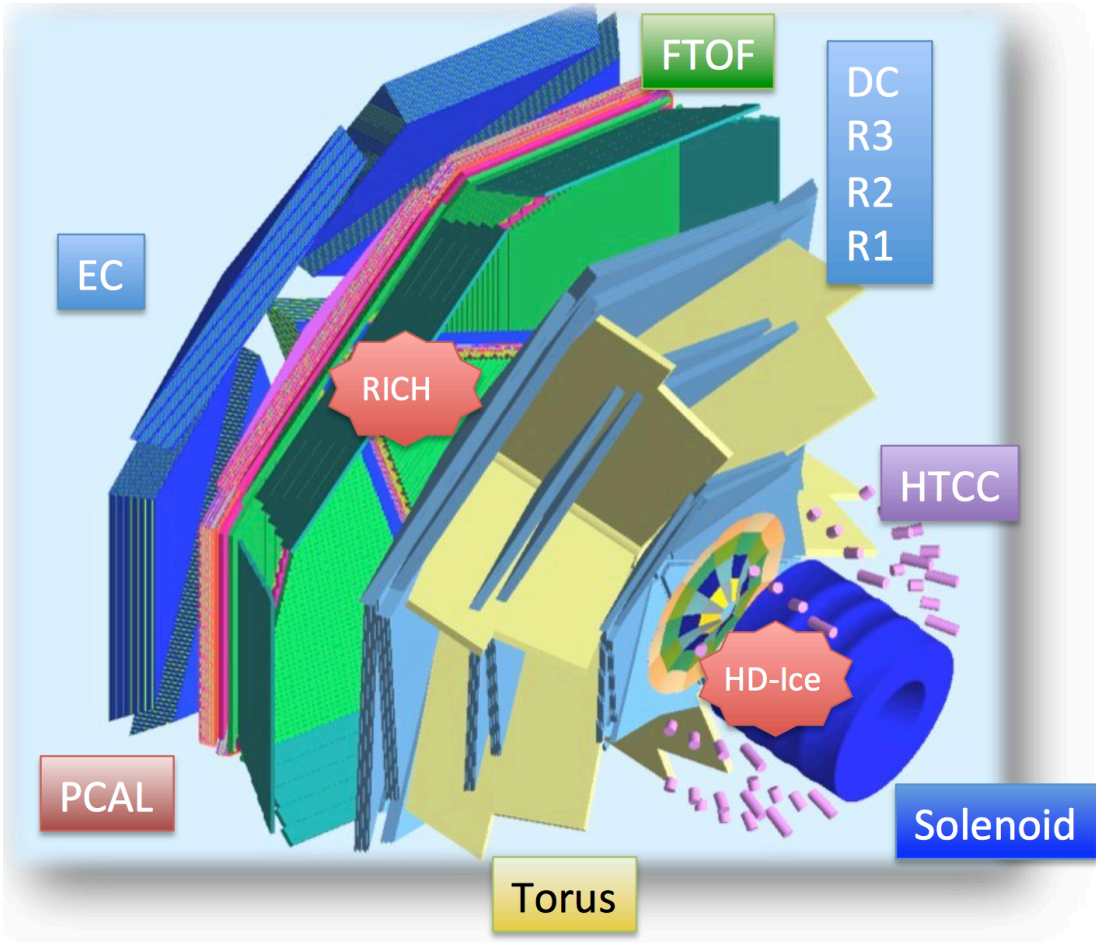
- In September 2013 the INFN/ Italian Ministry of Research made available additional funds for the construction of a **second RICH sector** (which is not part of this program).

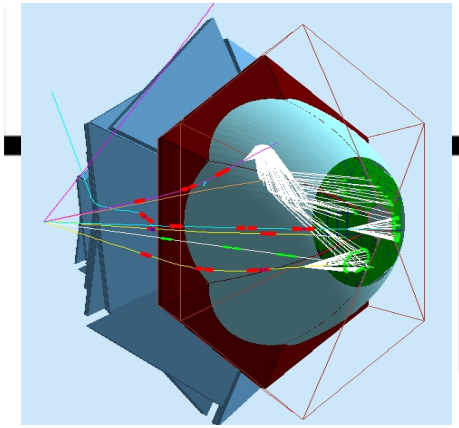
The CLAS12 Spectrometer

- Luminosity up to 10^{35} cm^{-2} s^{-1}
- Highly polarized electron beam
- H and D polarized targets
- Broad kinematic range coverage (current to target fragmentation)



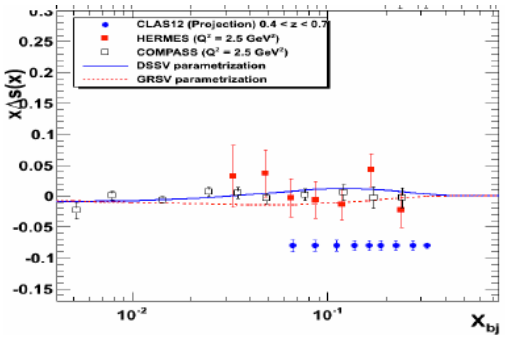
RICH:
Hadron ID for flavor separation

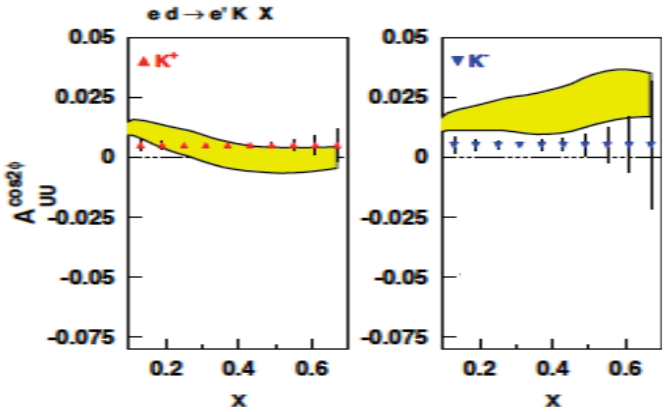
PAC30 report (2006):
Measuring the kaon asymmetries is likely to be as important as pions ....
The present capabilities of the present CLAS12 design are weak in this respect and should be strengthened.

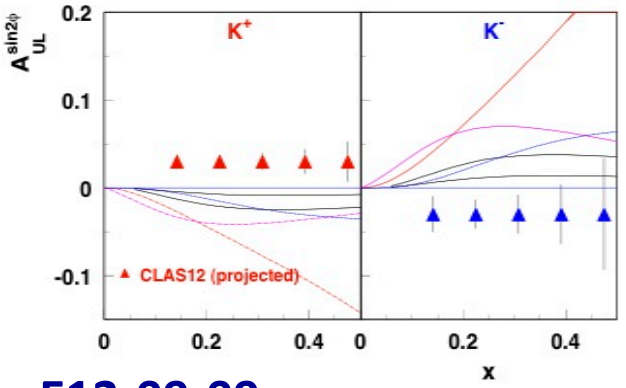


Kaon Program @ CLAS12

RICH detector for flavor separation of quark spin-orbit correlations in nucleon structure and quark fragmentation







E12-09-07:
Studies of partonic distributions using semi-inclusive production of Kaons

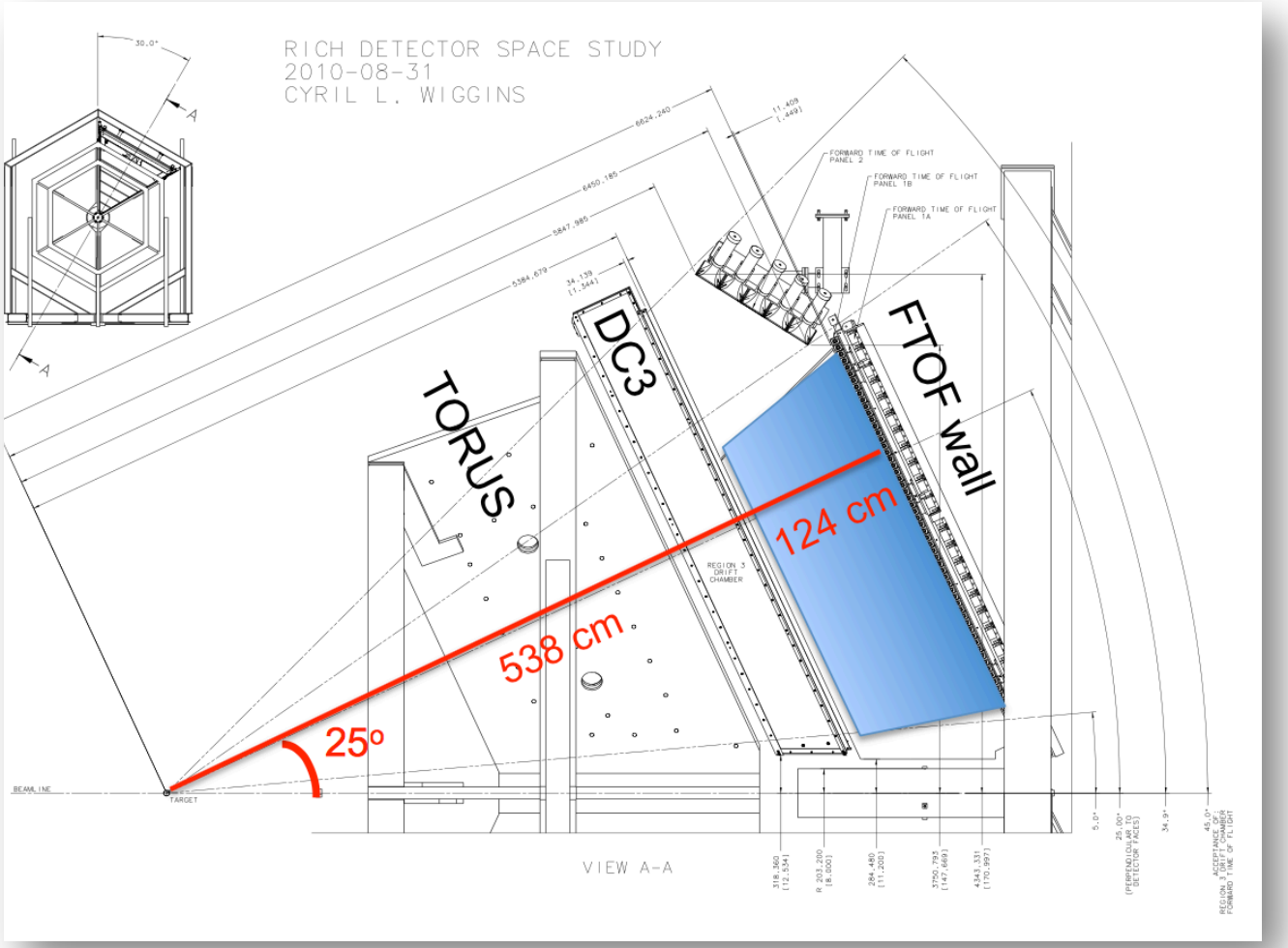
E12-09-08:
Studies of Boer-Mulders Asymmetry in Kaon Electroproduction with H and D Targets

E12-09-09:
Studies of Spin-Orbit Correlations in Kaon Electroproduction in DIS with polarized H and D targets

E12-12-07: Exclusive Phi Meson Electroproduction with CLAS12

In general, the whole CLAS12 physics program will benefit from a better PID

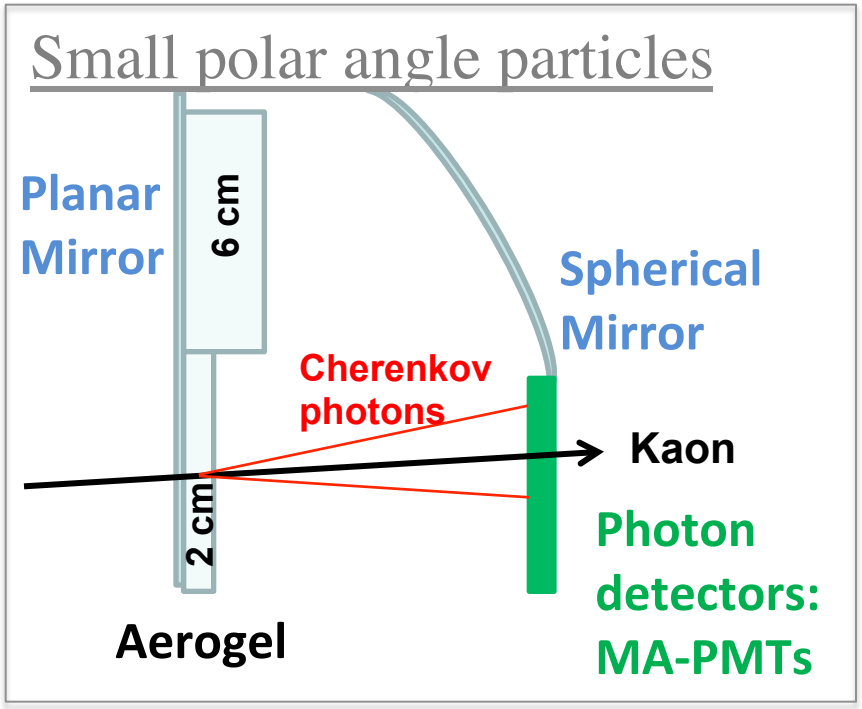
CLAS12 Geometry Constraints

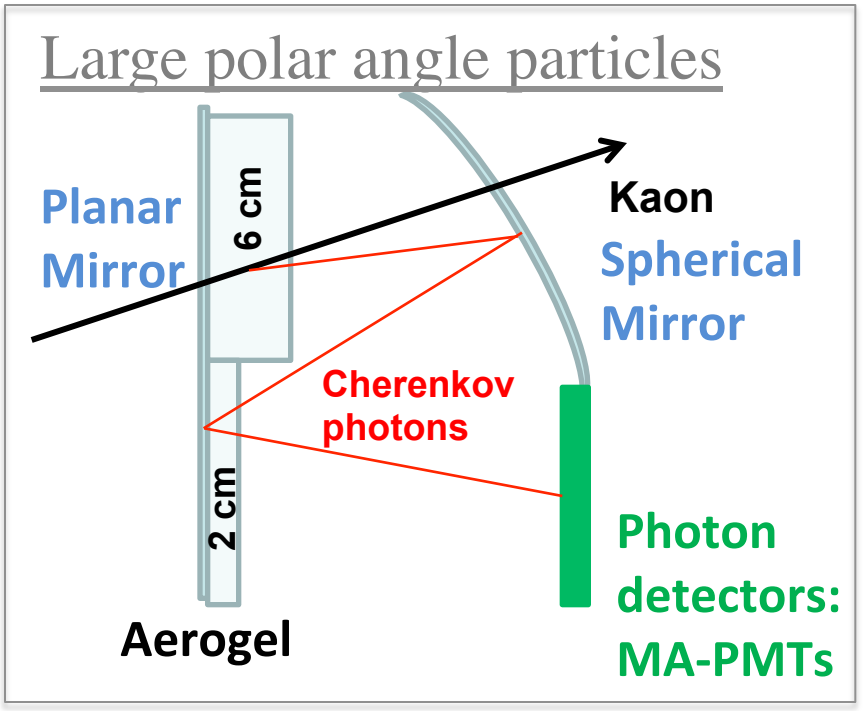


- ~ 5 m from IP
- ~ 1 m gap
- Several m^2 surface

The RICH Design

Hybrid solution: proximity gap plus focusing mirrors





- **Direct rings for high momentum particle** ➔ best performance
- **Reflected rings for low momentum particle** ➔ less demanding
  - Minimize photon detector area ➔ cost
  - Multiple passages within aerogel ➔ photon losses but focusing mirrors allow for thicker aerogel (more photons)
  - Minimum interference with TOF

The RICH Program

The RICH program is executed as a joint collaboration between

- Argonne National Lab (USA)
- Duquesne University (USA)
- Kyungpook National University (Republic of Korea)
- INFN, sezione di Bari (Italy)
- INFN, sezione di Ferrara (Italy)
- INFN, sezione di Genova (Italy)
- INFN, sezione di Roma 1 & ISS (Italy)
- INFN, Laboratori Nazionali di Frascati(Italy)

INFN leader of the collaboration

- J. Gutenberg Universitat Mainz (Germany)
- Thomas Jefferson National Accelerator Facility (USA)
- Universidad Tecnica Federico Santa Maria (UFSM – Chile)
- University of Connecticut (USA)
- University of Glasgow (UK)

The RICH Program (cont'd)

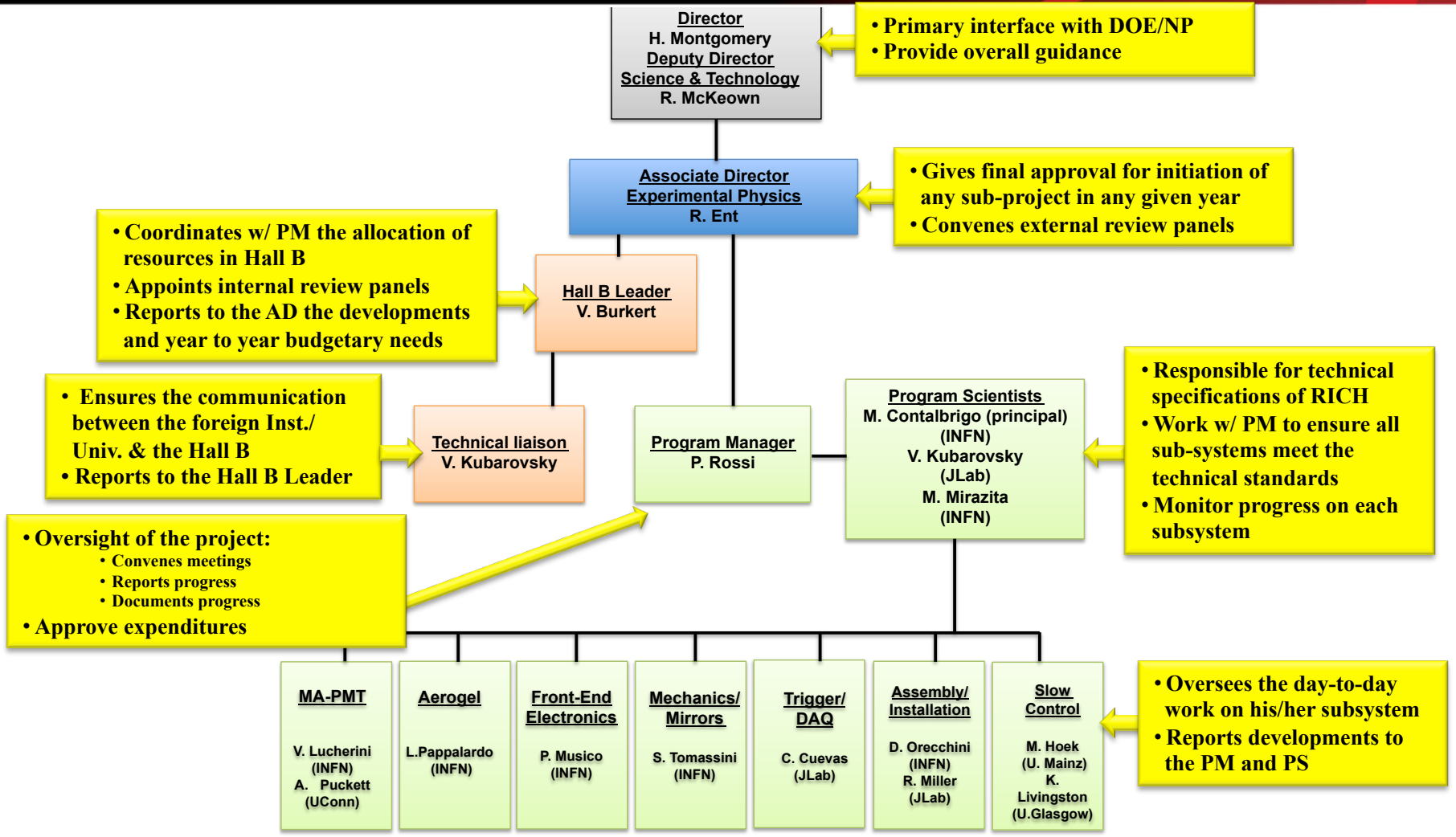
- The RICH program represents the **US scope of the construction of one RICH sector**. Program assumes that funding are made available from the **JLab Capital Equipment** annual base budget.
- Progress on the program is reported to DOE in quarterly reports.
- The US scope, described by the RICH Management Plan, provides:

US Scope of the project	% of JLab TOTAL cost
Purchasing and testing Multi-anode photomultiplier tubes (MA-PMTs)	73
Purchasing and testing part of the aerogel	18.2
Manpower for installation in CLAS12	1.2
Gas system & slow control	3.5
Management of the project	4.1

The RICH Program (cont'd)

- The development of the DAQ electronics is of generic purpose. It is done by the Jefferson Lab Fast Electronics group as part of pipelined electronics development.
- The schedule of this "off project" part is tracked simultaneously with the RICH program.
- The project relies heavily on manpower already committed by non-US collaborators.
- A clear definition of the roles and responsibilities that individuals and their organizations play are identified in the RICH Organization Chart.

Program Organization & Project Management



- RICH weekly meetings, via Bluejeans are held every Friday.
- Documentation of the meetings is stored in the wiki page: https://clasweb.jlab.org/wiki/index.php/Clas12_RICH/Meetings.

WBS7: RICH Program

- The program started on September 30, 2013 after a technical, cost, and schedule review took place at JLab on September 5 and 6.

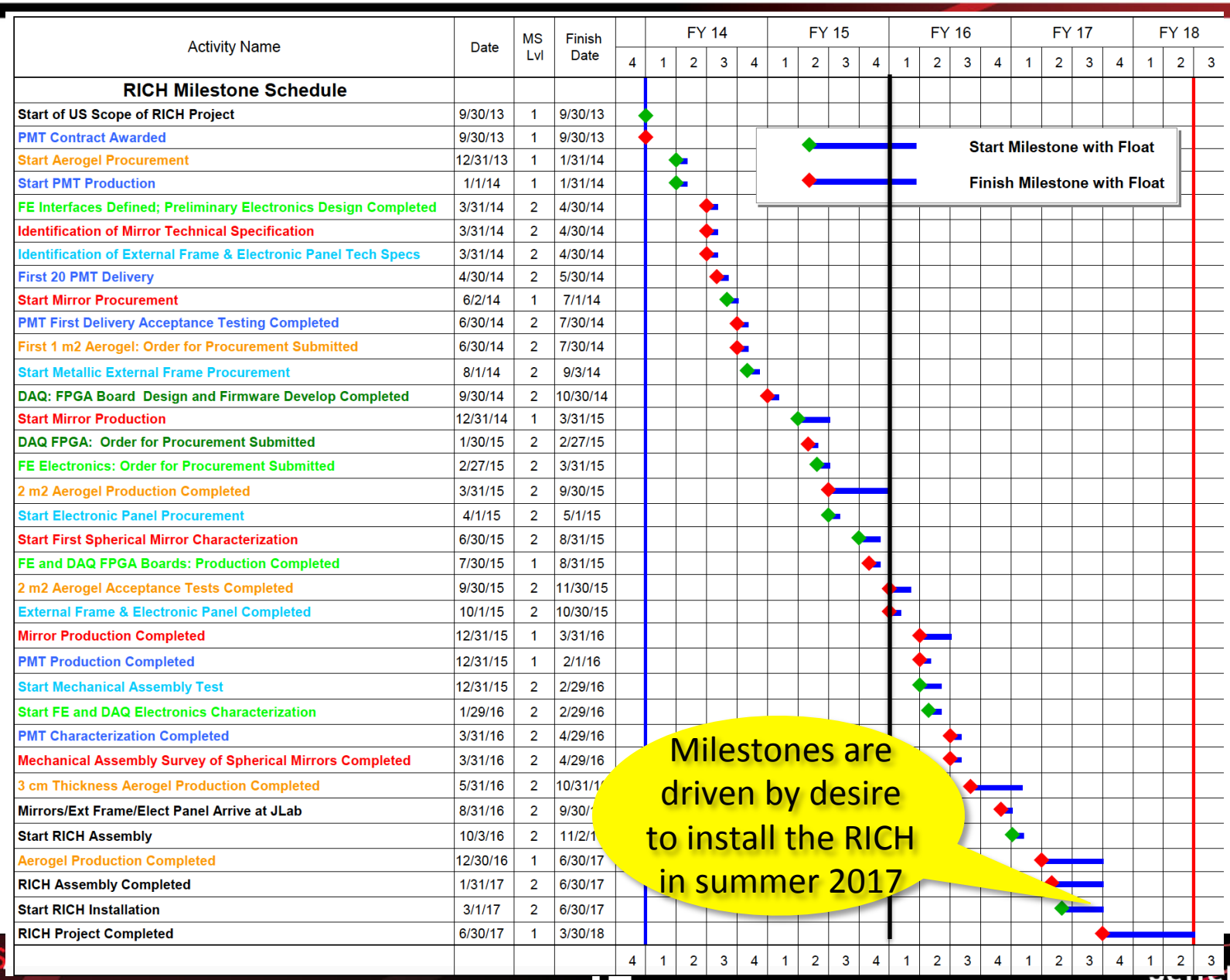
- Work Breakdown Structure:.

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

- In response to the September 2013 review a set of milestones including the “off project” endeavors has been compiled.

RICH Milestones

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	10/31/1
Mirrors/Ext Frame/Elect Panel Arrive at JLab	8/31/16	2	9/30/
Start RICH Assembly	10/3/16	2	11/2/1
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



WBS 7.2: MA-PMTs

Milestone	Date	Lev	Float-months	Milestone Achieved
PMT Contract Awarded	9/30/13	1	0	✔
Start PMT Production	1/1/14	1	1	✔
First 20 PMT Delivery	4/30/14	2	1	✔
PMT First Delivery Acceptance Testing Completed	6/30/14	2	1	✔
PMT Production Completed	12/31/15	1	1	
PMT Characterization Completed	3/31/16	2	1	

TOTAL MA-PMTs : 380 (+28 already available from INFN)

- Sep. 2013: Hamamatsu contract awarded for the FULL production of the MA-PMTs H8500 model.
- April 2014: production changed into the H12700 model for the remaining PMTs. This change implied a cost increases of 4% (a modest fraction of the assumed 20% contingency).

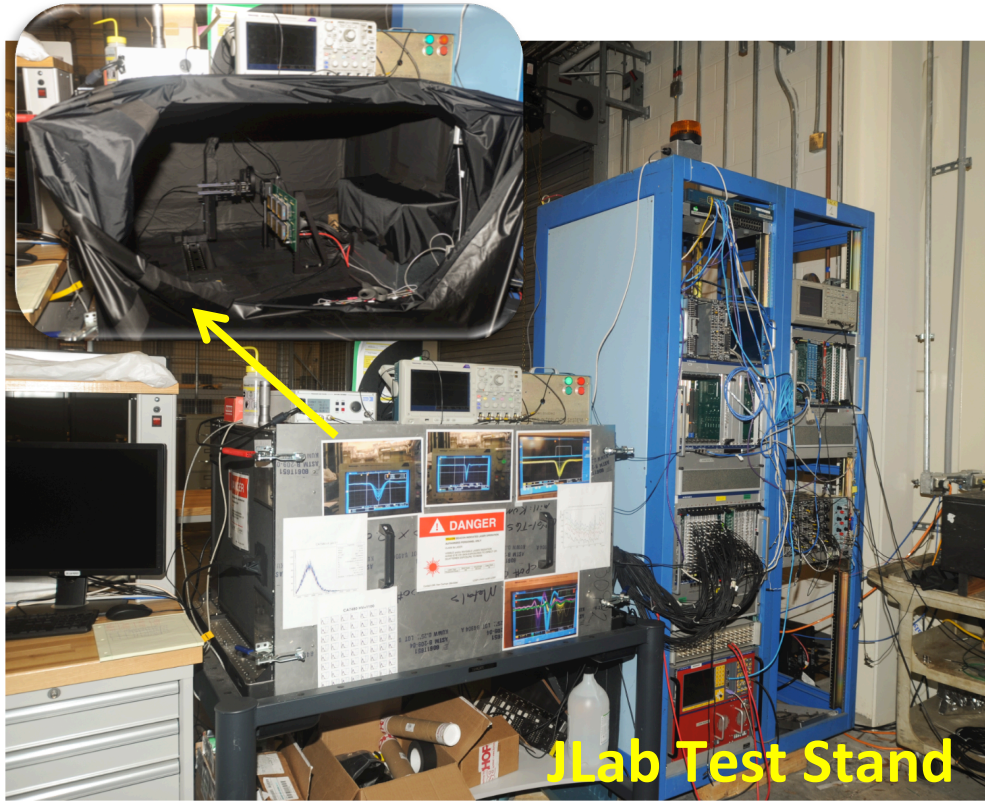
WBS 7.2: Status

- By now we have: 80 H8500 + 260 H12700 = **340 PMTs**

Talk by A. Kim

➔ **89.5% of the production is done!**

- 310 have been tested at JLab and all mach the specifications.



The WBS 7.2 responsibility changed from INFN to JLab

- Since May 2015, 30 PMTs/month have been delivered instead of the planned 20
- At this rate **the 380 PMTs production will be completed around November/December 2015** ➔ **the next milestone "PMT Production Completed (12/31/15)" will be reached on schedule**
- **The last milestone "PMT characterization completed (3/31/16)" will be reached ahead of schedule.**

WBS 7.3: Aerogel

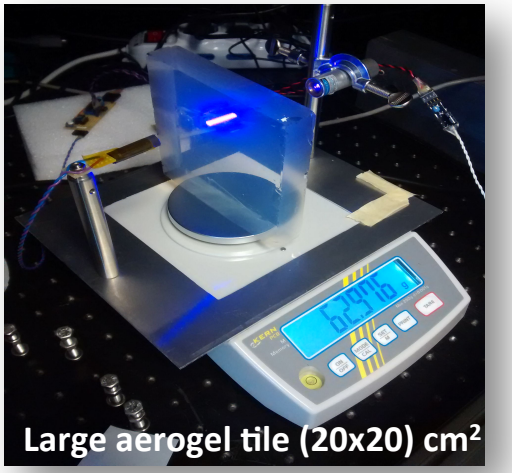
Milestone	Date	Lev	Float-months	Milestone Achieved
Start Aerogel Procurement	12/31/13	1	1	✔
First 1 m^2 Aerogel: Order for Procurement Submitted	6/30/14	2	1	✔
2 m^2 Aerogel Production Completed	3/31/15	2	6	41%
2 m^2 Aerogel Acceptance Test Completed	9/30/15	2	2	20%
3 cm Thickness Aerogel Production Completed	5/31/16	2	5	
Aerogel Production Completed	12/30/16	1	6	

- 6 cm aerogel thickness layer:
  - 2 layers of 3 cm, "2 m^2 "each
  - each "2 m^2 " is 44 tiles

  2 cm aerogel thickness layer:
  - 1 layer of 2 cm
  - 32 tiles

Talk by M. Contalbrigo

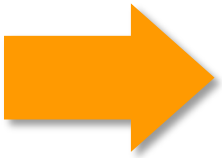
TOTAL = 120 aerogel tiles


Large aerogel tile (20x20) cm^2

- What we have :
  - 18 tiles of 3 cm thickness ➔ **need 102 more tiles to complete the production**

WBS 7.3: Aerogel

- **Production Rate & Efficiency**
  - Order processed by INFN in June 2014 but finalized in September (issues with the contract terms) and production started only in November 2014.
  - Temporarily vacancy of the raw chemical material at the beginning of 2015 caused additional 1-2 months delay in the aerogel production.
  - ~3 months (June-September 2015) spent by the Russian vendor to finalize the acceptance test procedure.
  - So far Russian vendor has produced **7 batches in less than 4 months** ➔ 105 tiles: 50 without cracks, 18 passed our specifications.

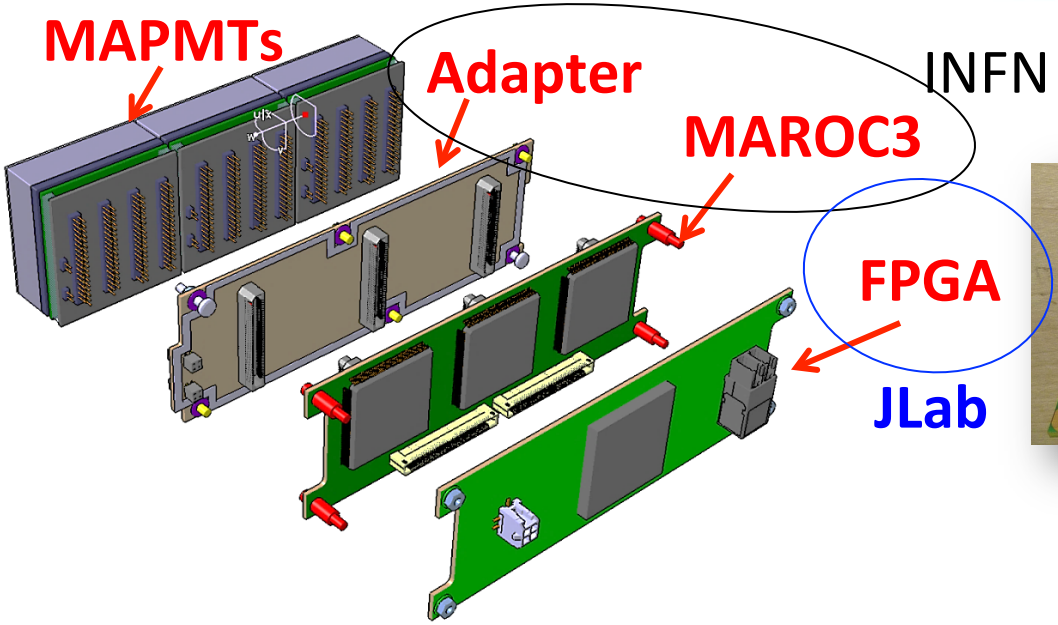


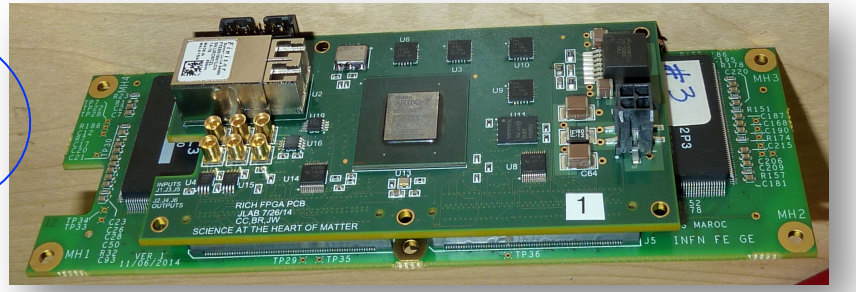
  - **production rate: 2 batches/month**
  - **production efficiency: 2.5 good tiles/batch ➔ 17%**

WBS 7.3: Status

- **Mitigation actions**
  - **The production rate is fixed → We have been working to increase the production efficiency to go to initial goal of 25% .**
    We have found that we can reach this goal by releasing the too stringent requirements on planarity .
  - Assuming a production efficiency of 25% starting in January 2016 the aerogel production will be completed by March 2017. **This leaves four months float before the installation of the detector.**
  - In the conservative scenario to keep the production rate at 17% level, we will complete the production in June 2017 just in time for the installation (in this case we will still meet the last milestone within the float).
  - There will be a visit to the Russian vendor in Novosibirsk on December 14-18, 2015 (Contalbrigo, Mirazita, Rossi) to oversee the production.
- First 9 aerogel tiles are "on travel" to JLab.
- Next order of 2 m^2 will be submitted by JLab in FY16 as per schedule.

WBS 7.4: Front End Electronics





Talk by M. Turisini

Milestone	Date	Lev	Float - months	Milestone Achieved
FE Interfaces Defined; Preliminary Electronics Design Completed	3/31/14	2	1	✔
DAQ: FPGA Board Design and Firmware Develop Completed	9/30/14	2	1	✔
DAQ FPGA: Order for Procurement Submitted	1/30/15	2	1	✔
FE Electronics: Order for Procurement Submitted	2/27/15	2	1	✔
FE & DAQ FPGA Boards: Production Completed	7/30/15	1	1	10%
Start FE & DAQ Electronics Characterization	1/29/16	2	1	

WBS 7.4: Status

- Both the MAROC and the FPGA have been tested against the radiation hardness following the recommendations of the project review. No problem found.
- Order for procurement has been submitted for both the FE and DAQ FPGA electronics boards (for the FPGA: 72K$ of the FY15 JLab OPS funds).
- 10 FPGA boards (out of 151) are in our hands and are being tested.
- There was a significant delay in the delivery of the MAROC ASICS which will now be available by November 2015 ➔ The full production of the FPGA DAQ & FE electronics is foreseen to be completed by March 2016 and the full chain electronics characterization is planned to start a couple of months later. However, **this change in schedule is not critical for project as this leaves more than one year of float before the assembly of the detector.**

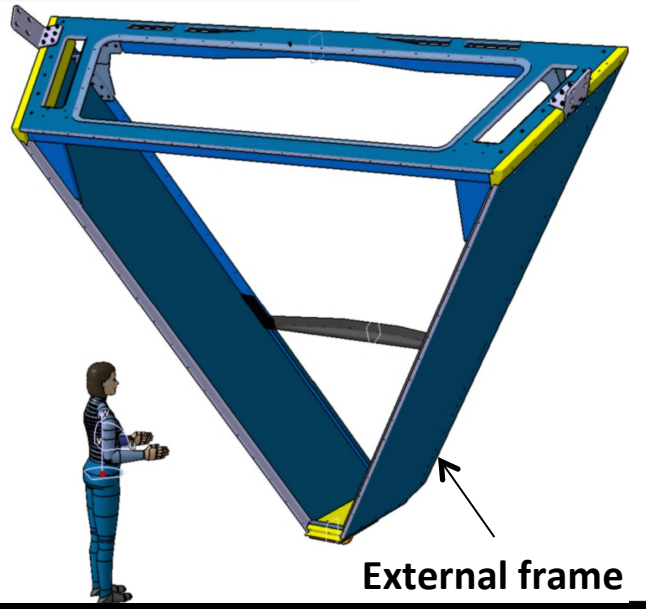
The DIRC collaboration in Hall D and SoLID in Hall A, and the JLab Detector Group are planning to use the RICH FE and DAQ electronics developed by the JLab and INFN groups.

WBS 7.5: Mechanics

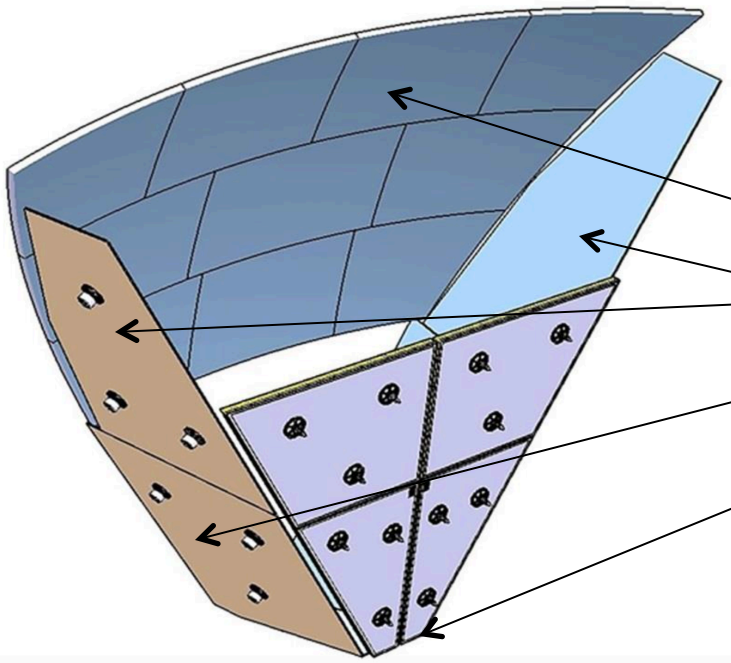
Milestone	Date	Lev	Float-months	
Identification of Ext. Frame & Electronic Panel Design Tech Specs	3/31/14	2	1	✔
Start Metallic External Frame Procurement	8/1/14	2	1	✔
Start Electronic Panel Procurement	4/1/15	2	1	✔
External Frame & Electronic Panel Completed	10/1/15	2	1	
Start Mechanical Assembly Test	12/31/15	2	2	

- The Italian "TECNAVAN" Company will provide: the external frame , the electronic panel, the front panel.
- The company will perform the mechanical assembly tests in situ and will ship the three pieces to JLab where they will arrive by March 31, 2016.
- **Due to the new mechanical construction plan the last two milestones are now grouped in a single one with a completion date of 12/31/2015 + 2 months float (thus milestone will be reached).**

Talk by D. Orecchini



WBS 7.6: Mirrors



Talk by M. Mirazita

Ten spherical mirrors
Four lateral planar mirror
Four frontal planar mirrors
One bottom mirror
➔**Nine planar mirrors**

Milestone	Date	Lev	Float months	
Identification of Mirror Technical Design Specification	3/31/14	2	1	✔
Start Mirror Procurement	6/2/14	1	1	✔
Start Mirror Production	12/31/14	1	3	✔
Start First Spherical Mirror Characterization	6/30/15	2	2	0%
Mirror Production Completed	12/31/15	1	3	
Mechanical Assembly Survey of Spherical Mirrors Completed	3/31/16	2	1	

WBS 7.6: Status

Planar Mirrors:

- The production has started at the end of March 2015 in line with the milestone.
- The 1st planar mirror has been produced and the characterization is in progress
- The production will be completed together with the spherical mirrors

Spherical Mirrors:

- The order to the CMA company has been awarded with five months delay with respect to the schedule (August 2015) due to the change in the technology for the mirror.

➔ *Mitigation actions :*

- *Changed radius of curvature from 4m to 2.7 m → CMA could use a mold already in house thus reducing time and cost. Simulation studies showed that the RICH performances with the new mirror radius are not significantly changed with respect to the old one.*
- *There was a visit to CMA in April 2015 (M. Contalbrigo, P. Rossi) and more are planned in 2016 to witness the status of the production.*

- The first two spherical mirrors will arrive at JLab by March 2016 and the production will continue at a rate of two mirrors/2 months ➔ **production complete by the end of November 2016.**
- The Mechanical Assembly Survey of the mirrors will be **completed by March 2017.**

The change in schedule leaves four months float before the installation of the RICH

WBS 7.7/7.8: Gas System/Slow Control

WBS 7.7 Gas System (Nitrogen, Air)

Talk by S. Tomassini

- The preliminary gas system design https://clasweb.jlab.org/wiki/images/0/0c/20140321.pptx.pdf has been reviewed during the RICH Mechanical Review (June 2014).
- Following the recommendation of the mechanical review committee, a real size prototype of half of the electronic panel to study the cooling system airflow has been designed and built and tests have been performed (S. Tomassini's talk)
- From these test we have a preliminary estimate of the airflow we need to keep the TOF safe.
- The simulations of the heat produced by the RICH electronics are ongoing and confirm the test results.
- Plan is to simulate the full size module for optimizations.

WBS 7.8 Slow Control

- The software for the HV slow control is ready and it has been tested with the JLab PMT stand.
- The power supply model has been chosen in order to be compatible with the CLAS12 slow control.

RICH Construction/Installation

Milestone	Date	Lev	Float-months	New date	Float-months
Start of US Scope of RICH Project	9/30/13	1	0	9/30/13	0
Mirrors/Ext Frame/Elect Panel Arrive at JLab	8/31/16	2	1	8/31/16	4
Start RICH Assembly	10/3/16	2	1	10/3/16	1
RICH Assembly Completed	1/31/17	2	5	8/1/17*	1
Start RICH Installation	3/1/17	2	4	8/1/17*	1
RICH Project Completed	6/30/17	1	9	9/30/17	6

Talk by S. Tomassini

- A detailed plan for the RICH assembly at JLab and for the installation in Hall B has been developed (*https://clasweb.jlab.org/wiki/images/0/08/RICHInstallation.pdf*).

- The installation plan takes into account:

a) the updated schedule for the construction of the RICH detector elements
b) The new philosophy to **assemble the RICH detector outside the hall** (* this links the "RICH Assembly Completed" and "Start RICH Installation" milestones **)**
c) the availability of the assembly space at JLab

RICH Calibration

- The construction of the RICH detector is being heavily guided by the use of software:

Talk by S. Pisano

  - to validate the test measurements
  - to guide the choice of materials of the different components
  - to establish the selection criteria for the aerogel, PMTs, mirrors..
  - to understand the detector performance
  - …

- A significant effort is now devoted to the implementation in Java of a calibration constant database where we intend to store all constants for geometry and calibration.

- Because of the complicated geometry of the CLAS12 RICH a considerable effort is being also devoted to develop the reconstruction algorithm for the evaluation of the the Particle Identification performances of the detector. The program will be tested and optimized during the “commissioning with beam” phase.

Project Cost

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*****

- JLab burdened cost of the project ~1.7M$ with ~25% cost contingency.
- Initial plan: cost for each subsystem shared among JLab, INFN and Chile .
- Chile didn't contribute to the mirrors ➔ **INFN is providing the funds**

JLab Project Cost: ETC

WBS	ITEM	DIRECT (K$) (BASE+ CONTINGENCY)	BURDENED (K$)	MONEY SPENT (K$) (by 9/30/ 2015)	ETC BURDENED (K$)
WBS 7.1	Project Management	34,1	68,3	42,1	26,2
WBS 7.2	MA-PMT	1140	1217,4	1061	0 *
WBS 7.3	Aerogel	253	304,5	0	304,5
WBS 7.5	Mechanics	13,75	20,75	0	20.75
WBS 7.7	Gas System	26	39	0	39
WBS 7.8	Slow Control	13	20	0	20
					410,45

* PMTs are essentially completed

Conclusions and Outlook

The RICH program represents the US scope of the construction of one RICH sector for CLAS12.

This program leveraged funds for the construction of a second RICH sector (which is not part of this program) funded by the INFN/Italian Ministry of Research.

Major accomplishments have been achieved since the start of the Program in FY13:

- the **MA-PMTs** production and characterization will be completed in time or ahead of schedule. By now 89.5% of the production has been done.
- The production of the **Front End and DAQ electronics** will be completed by March 2016, i.e. 16 months before the planned RICH installation in CLAS12. This leaves plenty of time for testing/debugging.
  The DIRC collaboration in Hall D and SoLID in Hall A, and the JLab Detector Group are planning to use the same FE and DAQ electronics.
- The **mechanics** of the detector will be provide by the same company which will test the complete structure before shipping it at JLab where it will arrive by March 2016.

Conclusions and Outlook (cont'd)

- We encountered some technological problems in the construction of the **spherical mirrors** which we overcame but this introduced a delay in the schedule. This initial delay is being recovered and will not impact the RICH assembly schedule.

- **The aerogel is the most critical part and drives the schedule of the Program**. We had a slow production start but it should improve with time. We are now working to optimize specifications versus production efficiency. A completion of the aerogel production is foreseen by March 2017.

- **The Program ETC is 410K$ which is ~25% of the total cost.**

- Despite variations in the schedule production of some RICH detector components, **still our schedule fulfills the original goal to have the RICH installed in CLAS12 in summer 2017.**

We would like to request some changes in the PMP (see my later talk)