THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY
MANAGED & OPERATED BY:
JEFFERSON SCIENCE ASSOCIATES, LLC

PREPARED BY:
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Hall B Lead Detector Engineer

INFN
RICH Detector for Hall B

MECHANICAL REVIEW
REPORT

RICH DETECTOR MECHANICAL REVIEW REPORT

BACKGROUND OVERVIEW & COMMITTEE CHARGE

At the request of the Physics Division, a review committee was assembled to conduct a review of the RICH detector mechanical design.

Review Team Committee Members

NAME	PHONE	DISCIPLINE
Patrizia Rossi	7740	Physics Deputy and Division Safety Officer
Bob Miller	7867	Hall B Lead Detector Engineer
Bert Manzlak	7556	Physics EH&S Liaison
Paul Collins	5981	12 GeV Safety Manager
Joe Guerra	7260	Hall B Mechanical Designer

REVIEW SCHEDULE

Date: June 20, 2014
Location: CEBAF B207
Time: 8:30AM – 11:00AM

SUPPLIED REFERENCE MATERIALS

Presentations Located at:
https://clasweb.jlab.org/wiki/index.php/2014_June_18_RICH_Mechanical_Review

M. Contalbrigo: The RICH Project

D. Orecchini: RICH Mechanical Shell Design

S. Tomassini: FEA Model Weight Analysis

R. Perrino: Gas System Design Parameters

RICH DETECTOR MECHANICAL REVIEW REPORT

Charge 1: Is the proposed RICH mechanical design well integrated into the CLAS12 detector? I.e. are all the mechanical constraints imposed by the CLAS12 detector taken into account?

Findings:

1. The INFN team provided a 3D model of the RICH detector and the LTCC in June 2014. The model was placed in the Hall model at the final LTCC location. As shown in Figure 1, the minimum distance from the target to the most upstream portion of the RICH detector is 5444 mm. The maximum distance from the target to the most downstream portion of the RICH detector is 6613 mm.

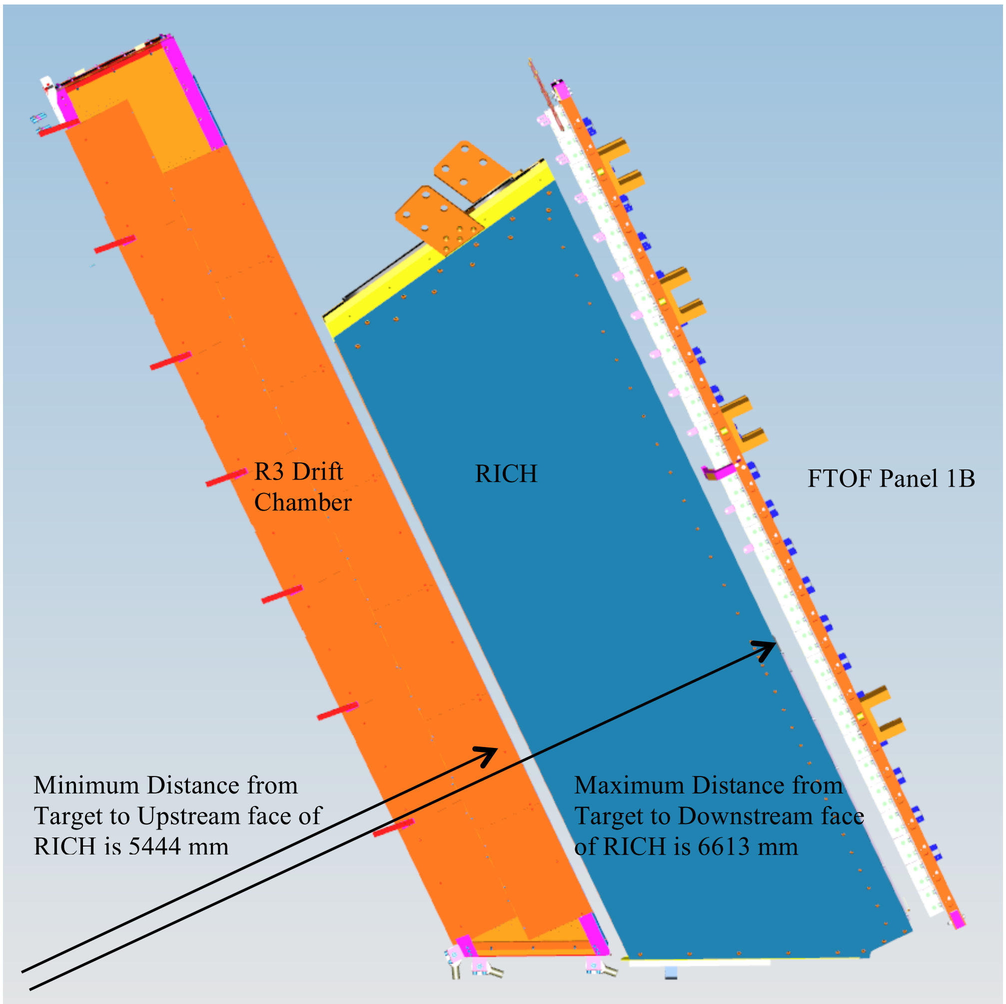

Figure 1: View Showing Clearance Between RICH, R3, and FTOF

2. The clearances were checked to the forward carriage structure and the adjacent detectors and the 3D model shows that the RICH detector fits in the space allotted; see Figure 2. JLab provided a 3D file of the final location of the RICH detector and the mount locations, as well as a file showing the Torus cryostat shadow on the RICH detector on July 11, 2014.

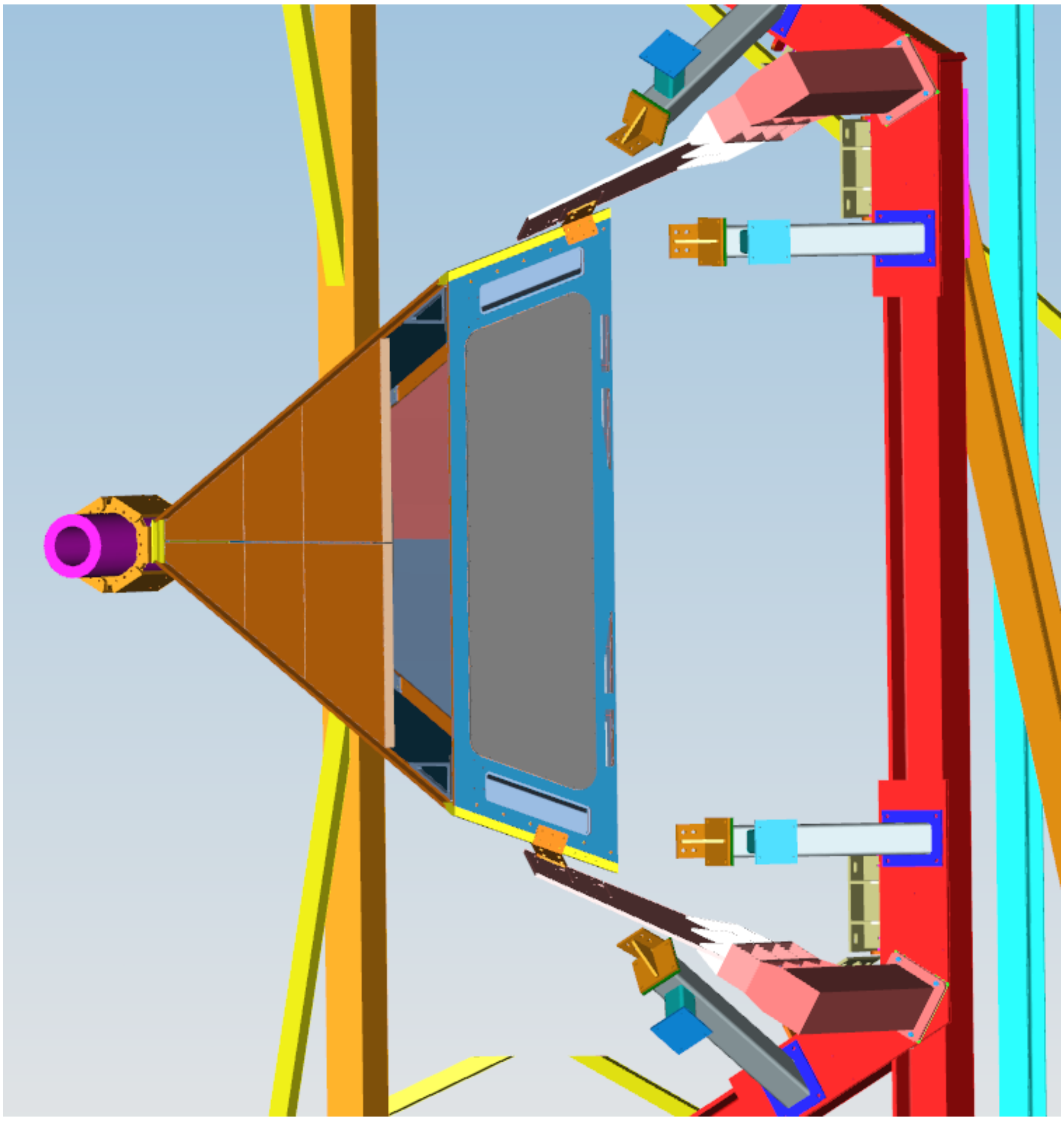

Figure 2: RICH Detector Attached to Forward Carriage Mounting Brackets

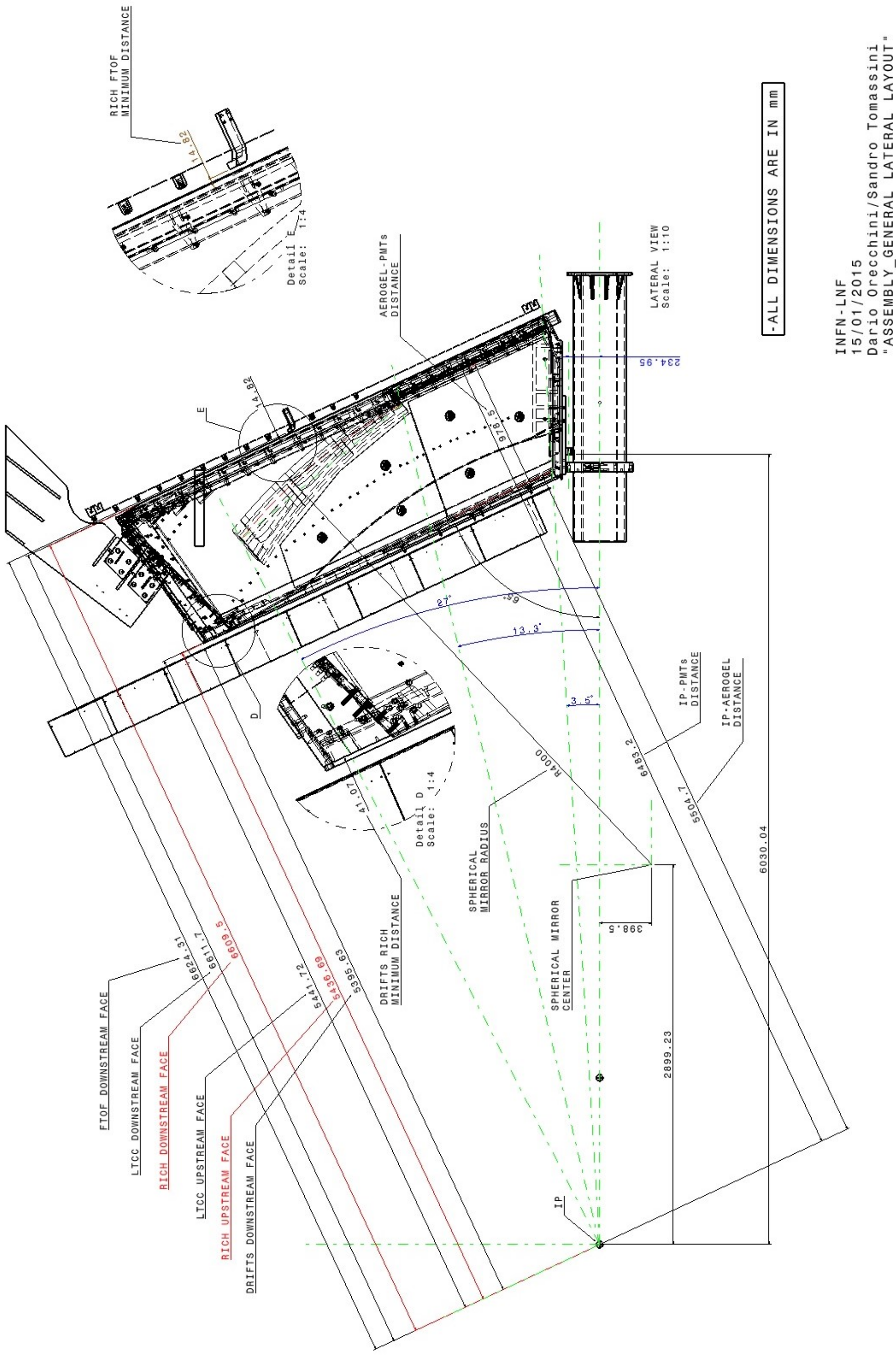

Figure 3: RICH and LTCC detector positions inside CLAS12 from the updated 3D model

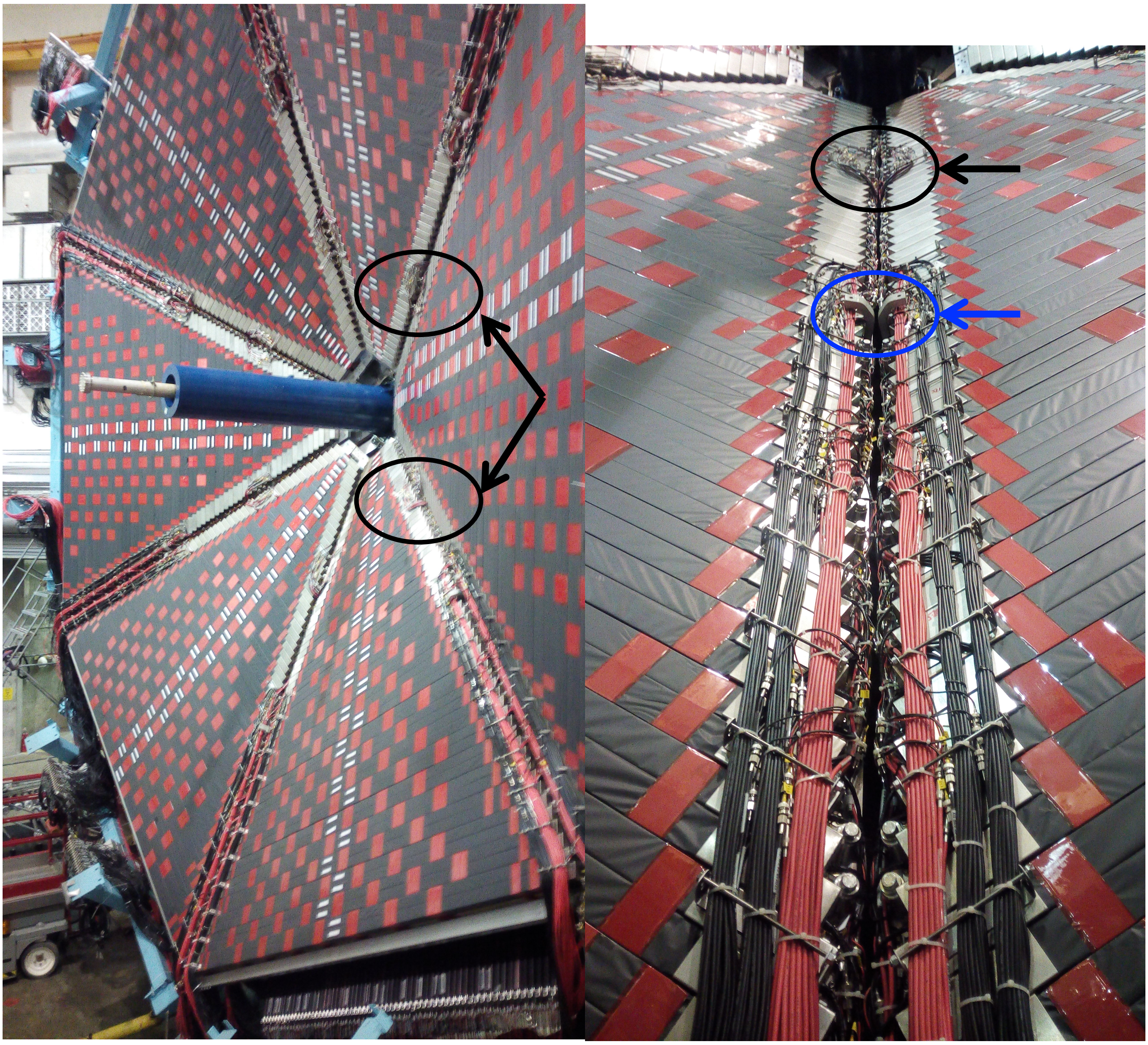

Figure 4: Pictures of the FTOF detector showing the encumbrance of the cables routing and holders: the cable bundles (highlighted in black) seem not accounted for in the 3D model. The L metallic holders (highlighted in blue) is assumed to be the maximum FTOF protrusion.

RICH DETECTOR MECHANICAL REVIEW REPORT

The latest RICH module, slightly upgraded since June 2014 and completed with the closing panels, has been inserted by INFN in the 3D model of the CLAS12 environment provided by JLab.

As shown in Figure 3, the volume and holders of the RICH module correspond to the LTCC ones. The updated distances from the target are:

- DC region-3 downstream face 5396 mm
- RICH upstream face 5436 mm (LTCC upstream face 5442 mm)
- RICH downstream face   6610 mm (LTCC downstream face 6612 mm)
- FTOF upstream face 6624 mm.

A large scale and high-resolution version of Figure 3 will be made available together with this document. The details in Figure 3 show the minimum distance between the RICH detector and the other CLAS12 detectors (DC and FTOF). Note that the details of the FTOF cable routing and holders visible in Figure 4 are fully accounted for in the 3D model except for the cable bundle highlighted in black.

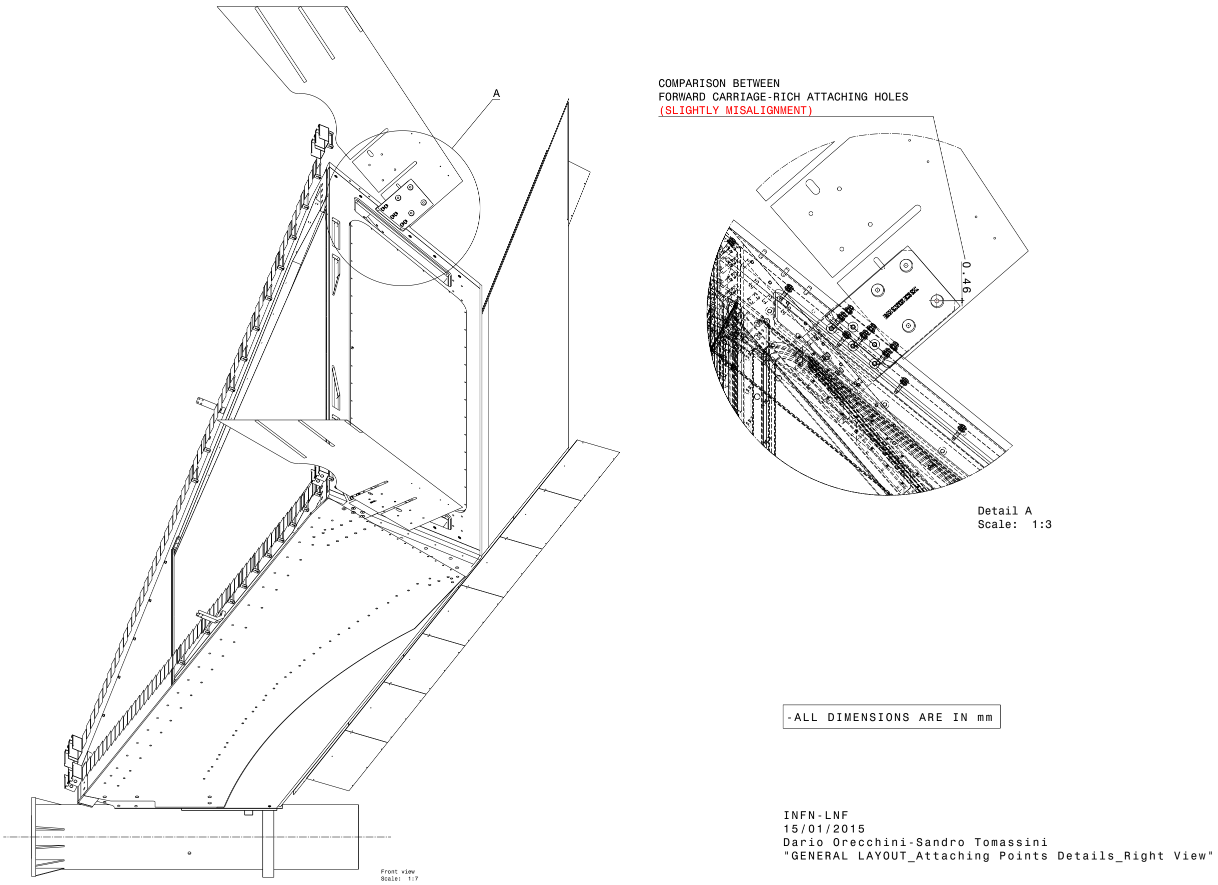

Figure 5: Matching of the right RICH holder and the forward carriage stirrup

There RICH holders match the forward carriage stirrups as shown in Figure 5 and 6. The RICH central holder and the beam-pipe collar holes match, as shown in Figure 7. The RICH central holder perfectly overlaps the position of the LTCC one but there is a longitudinal displacement of about 3 cm with respect the beam-pipe collar, as shown in Figure 8.

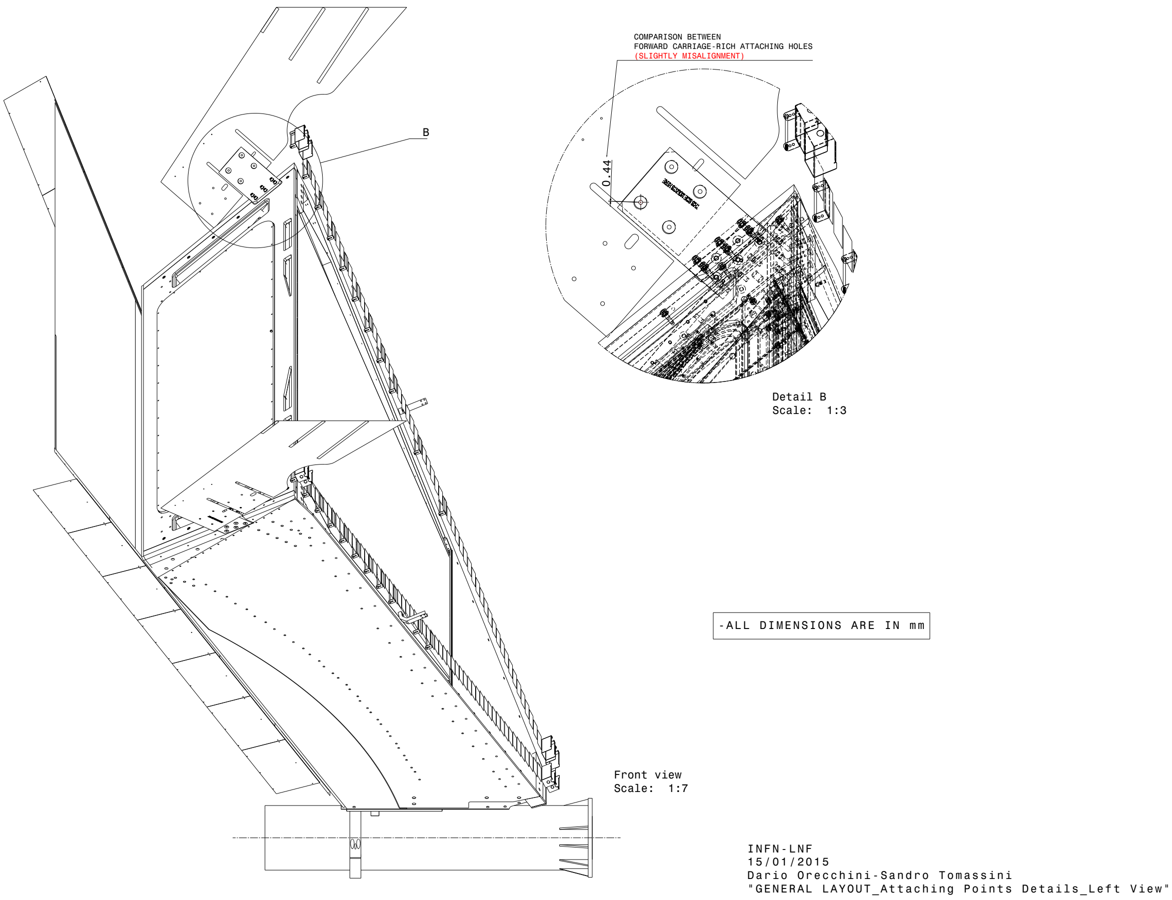

Figure 6: Matching of the left RICH holder and the forward carriage stirrup

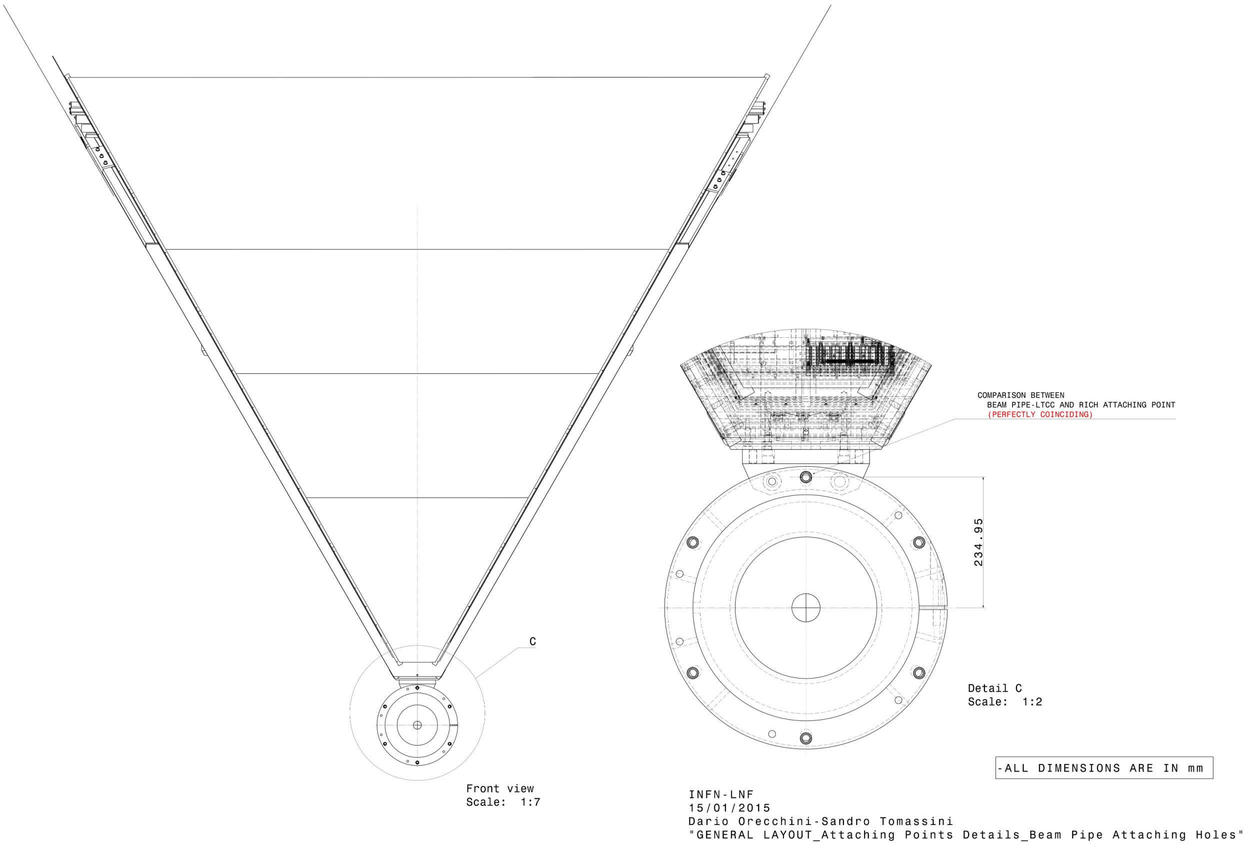

Figure 7: Matching of the central RICH holder and the beam-pipe collar holes

INFN will provide a 3D file of the updated RICH module and mount locations by February 9, 2015.

Questions:

A. May you verify the current positions of RICH and other detectors reported in Figure 3? Are the distances correct and acceptable?
B. We assumed the maximum FTOF protrusion is the L metallic elements highlighted (in blue) in Figure 4. Is it correct?
C. Is there any conflict between the cable bundles highlighted (in black) in Figure 4 and the possible 1-inch RICH extension downstream the electronic box for the insertion of the suggested insulation panel to reduce the heat load on the FTOF?

D. Is the beam-pipe collar (highlighted in Figure 8) movable in z or should the RICH (LTCC) central stirrup be modified to match the fixed z position of the beam-pipe collar?
E. Is there any recommended material for the RICH holders (our suggestion is AISI-316L)?
F. Is any of the RICH parts required to be made of non-magnetic material?

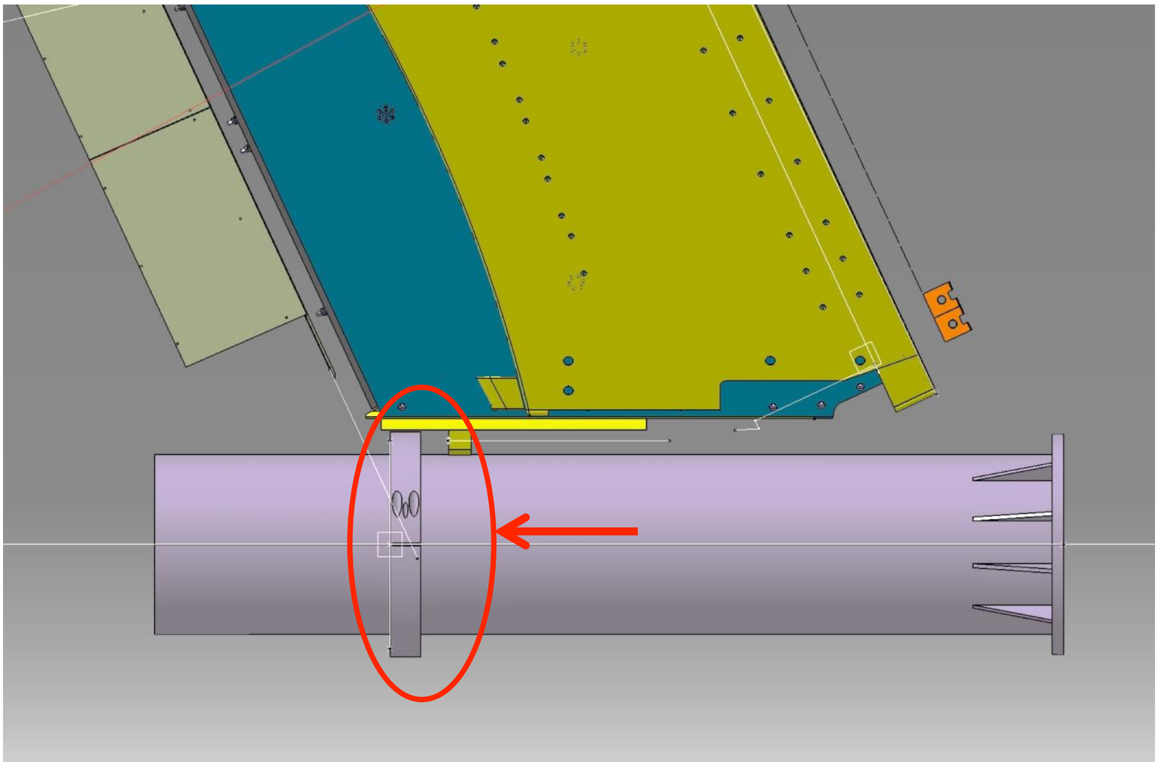

Figure 8: Shift along the beam line (z) of the beam-pipe collar versus the central RICH holder

Comments:

1. The RICH detector will fit through the truck ramp horizontal if one of the mounting stirrups are removed. The LTCCs were removed using this method and since then, the door width has been increased by 4 inches. See Figure 9.

The stirrups can be removed when needed because bolted to the main structure.

Figure 9: LTCC Removal from the Hall

2. JLab will conduct an engineering review of the final lifting fixture design and follow the JLab lift plan guidance.

The RICH group will take care to follow JLab regulations and provide all the information for the review.

3. The composite entrance and exit panels add substantial stiffness to the mechanical shell. If these panels are included in the FEA analysis, the deflection of the side walls will be reduced.

Although the two panels add stiffness to the mechanical shell, not considering them should give a more conservative result. The exit panel can be included in the static analysis but the RICH group has worked in the hypothesis the entrance panel will be fixed to the RICH case after the installation of the RICH module into the forward carriage. In this way the mechanical stress and strain of the panel will be minimized: this is crucial because of the fragile nature of the elements (mirror and aerogel radiator) supported by the panel itself. The fixing holes will be large enough to compensate the deformation of the mechanical case and mate the two structures.

4. The maximum steady state temperature for the time of flight system has been studied by Dan Carman. The results are:

   There are four issues related to temperature effects on the FTOF:

   1). Temperature-dependence of scintillation material

   According to the manufacturer's data sheets for BC-404 and BC-408, the light output is independent of temperature from -60C to 20C. However, as the temperature increases about 20C, there is a slight decrease in light output such that at 60C, the light output has dropped by about 5% compared to that at 20C.

   Conclusion: The material is reasonable temperature stable in terms of light output within a reasonable range about "room temperature", however temperatures in the vicinity of 60C will have a slight impact on timing resolution.

   2). Temperature-dependence of construction materials

   The construction materials of the FTOF detector system (Tedlar, epoxy, Al foil, fiberglass tape, Mylar tape) are known to be quite stable at room temperatures (~24C). Certainly temperatures within 10C might be still considered within the bounds of the definition of "room temperature" and as such, we would not expect any issues in such temperatures.

   3). Temperature-dependence of PMT/divider assemblies

   There is a known temperature coefficient of the PMT/divider assemblies that gives rise to an increase of dark current with temperature. This increased dark current could, in principle, lead to noise on the leading edge of the PMT signals that would negatively impact the timing resolution. Also, the PMT/divider assembly lifetime depends on the integrated current. Thus as the dark current increases at the elevated temperatures, it would lead to a shorter operating life of these units. However, the increase of temperatures from ~24C (normal Hall B temperature) within about 10C would not be expected to have any significant impacts on performance.

   4). Temperature-dependent of scintillator mechanical stability

   There is a known affect that leads to softening of plastic scintillator with increasing temperature. With materials like BC-404 and BC-408 they are known to have definite "softening points" at temperatures of 70C.

However, softening effects, which cause the material to flow like a viscous liquid over time, have been seen in scintillators stored in temperatures at about 40C. The flow time constant becomes longer with decreasing temperatures. This mechanical stability effect is perhaps the biggest concern associated with temperatures elevated above room temperatures.

<u>It is recommended for the mechanical stability of the materials to keep them in temperatures no higher than 30C at steady state.</u>

Recommendations:

1. The RICH detector group should show by analysis that the steady state temperature of the FTOF panel 1B will not exceed 30C. It is acceptable to extend the RICH detector 1 inch downstream at the electronics box location to install insulation to reduce the heat load on the FTOF. The insulation must not interfere with the FTOF panel 1B cables. Contact Joe Guerra for dimensions of the cable locations if insulation is used.

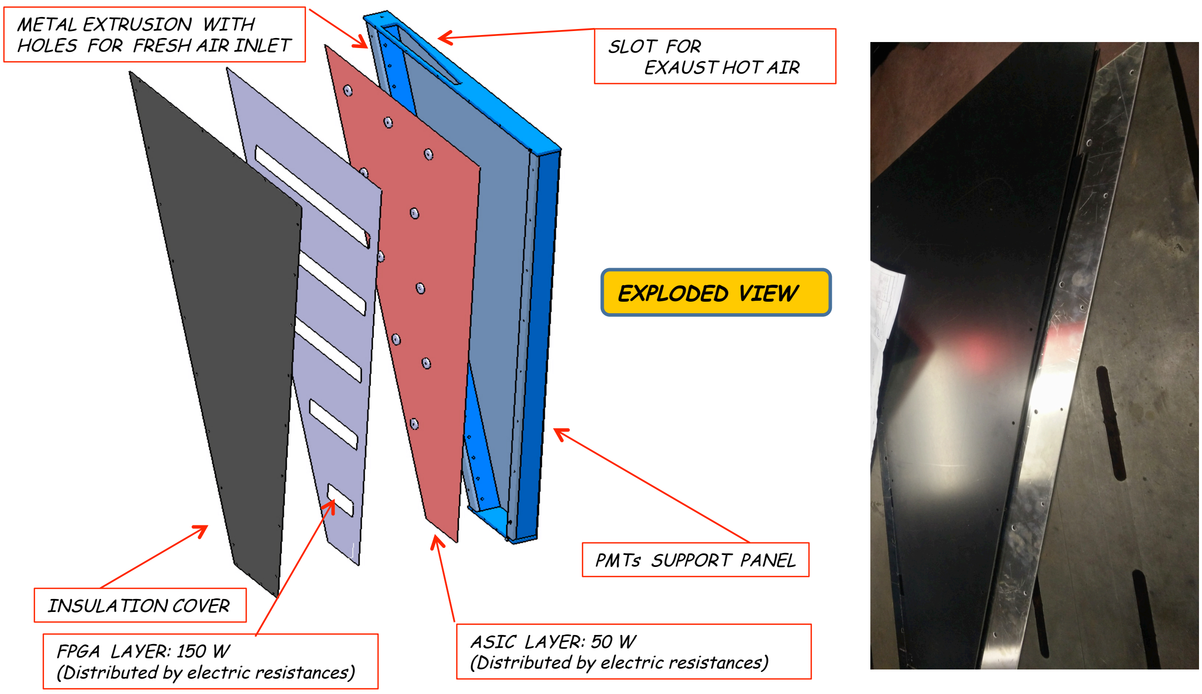

Figure 10: Exploded view of the real scale cooling prototype (halved module) and the relative panels under construction at Frascati Laboratory.

A solution is under study to place insulation inside the electronic box and/or outside the box itself without interfering with the FTOF cables and mechanical structures.

A first survey of the FTOF and forward carriage clearance in Hall-B has been done in November by Frascati engineers together with Valery Kubarovsky.

A FEM analysis to evaluate the thermo fluid dynamics of the electronic box is underway.

A real-scale test setup is under construction in Frascati Laboratory to measure the real field temperature inside and outside the box, validate the FEM analysis and evaluate the efficiency of the cooling system, see Figure 10 and 12.

A real-scale prototype reproducing a section of the electronic panel has been assembled at Frascati Laboratory to test the mechanical couplings, the gas sealing and the routing of cables and services, see Figure 11 and 12.

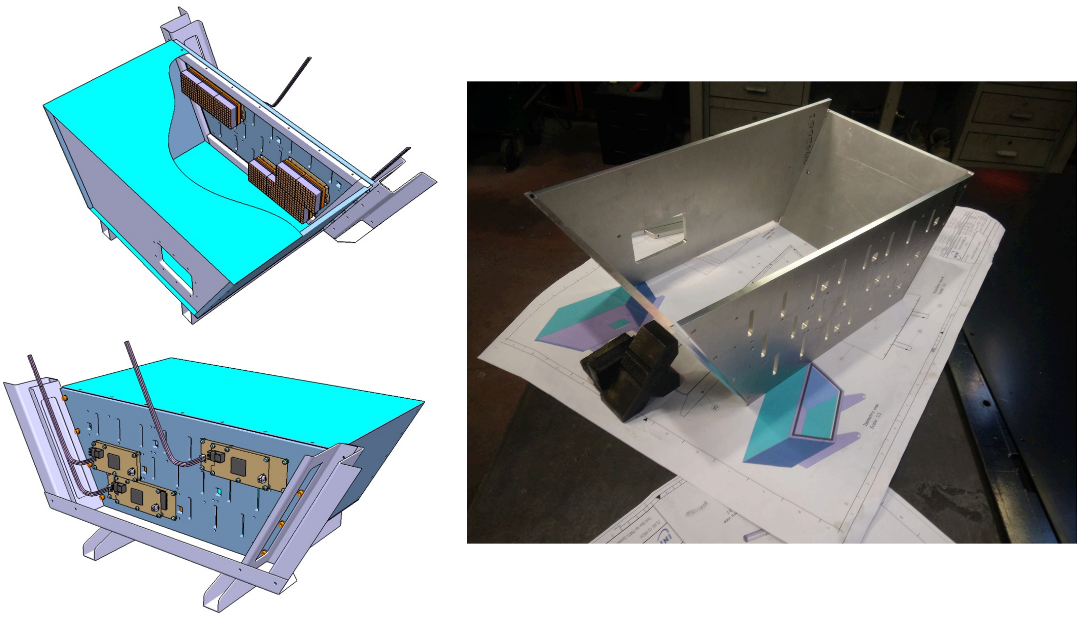

Figure 11: Design and assembling of a real-scale section of the electronic panel.

Figure 12: Assembling of the electronic panel and cooling prototypes.

Charge 2: Are the external envelope frame and closing panel materials in accordance with the Jlab safety rules and regulations?

Findings:

1. The RICH detector is consists of an aluminum frame, aluminum honeycomb panels for the sides, and composite carbon fiber with foam core entrance and exit panels. These materials are used in other applications in Hall B and they are in accordance with the Jlab safety rules and regulations.

Comments:

1. None

Recommendations:

1. Cabling, PMTs and electronics were mentioned, so ensure the procurements of these items are acceptable per JLab electrical and fire protection guidance.

The RICH group will take care of JLab electrical and fire protection guidance. The PMTs are standard devices working at 1 kV voltage. The RICH group is collaborating with Chris Cuevas to define cables and electronics.

Charge 3: Are the gas systems proposed to keep the aerogel dried and the electronics thermal power dissipation system following the JLab safety rules and regulations?

Findings:

1. The flow diagram for the N_2 dry gas system has been reviewed by the Hall B gas system expert, George Jacobs.

2. The electronics thermal power dissipation system is in the conceptual stage right now and there is not enough information to determine if it meets the JLab safety rules and regulations.

Comments:

1. The design pressure for the N_2 system is much higher than a typical purge system used on Hall B detectors. The RICH group is encouraged to study the JLab systems and discuss the pressure with George Jacobs.

2. The heat load from the electronics should be measured to determine the design load of the cooling system including a factor of safety.

Recommendations:

1. The internal pressure of the RICH detector from the N_2 dry gas system shall be included in the FEA analysis of the detector. The statement: "pressure: wanted levels of ~30-40 mbar are not expected to affect mechanics significantly" must be confirmed via analysis.

   The internal pressure of the RICH, due to the purging gas, has been reduced as much as possible, to the level of about 1 mbar, in order to maintain the effectiveness of the purging system and reduce the load on the structures itself.

   FEM analysis of the RICH module and panels has been performed with two different level of pressure (1 mbar and 0.5 mbar).

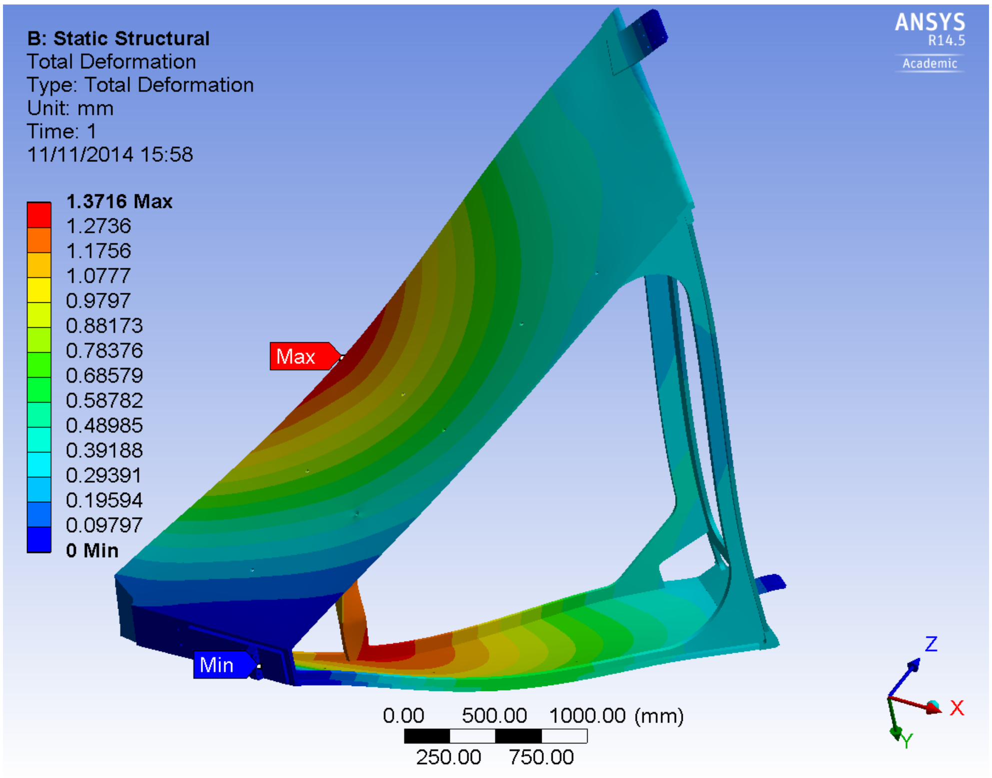

Figure 13: Mechanical deformation of the RICH structure with loads and an internal pressure of 1 mbar

The stress and strain level on the structure results acceptable. With an overpressure of 1 mbar acting on the external surfaces, the maximum deformation of the RICH structure is 1.4 mm, with an increase of about 10% with respect to the case of 0 mbar internal pressure (and only weight accounted for), see Figure 13. At the same overpressure the entrance panels gets a maximum displacement of few tens of mm, see Figure 14.

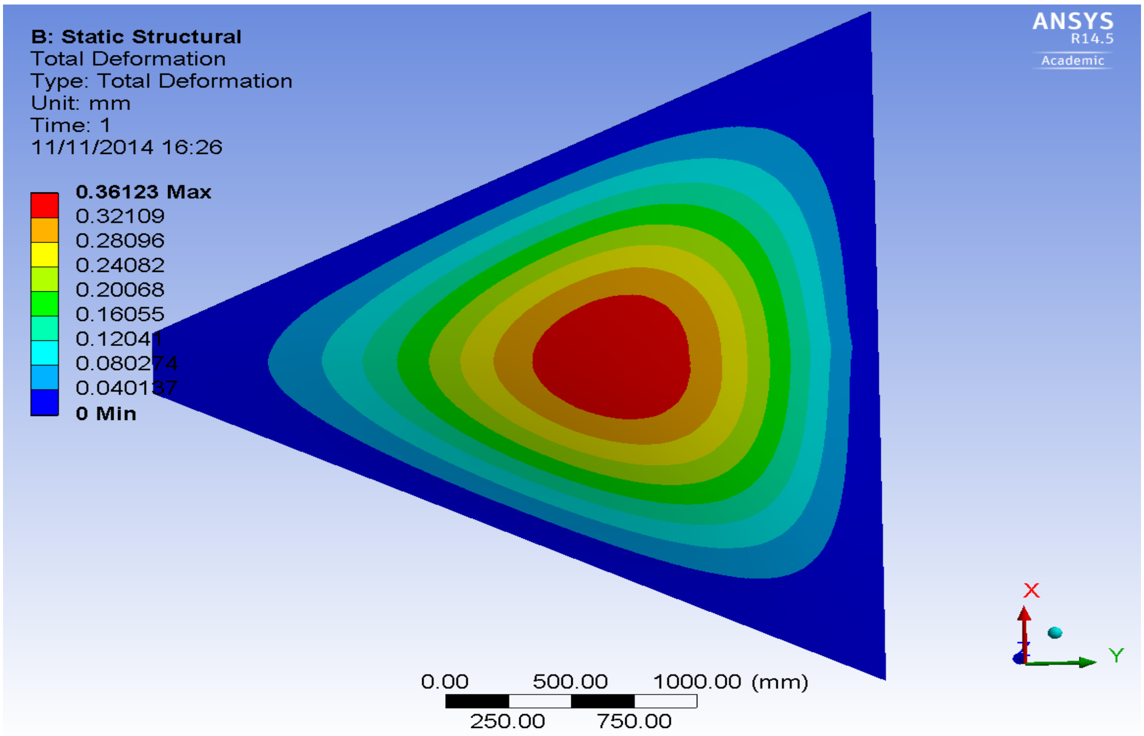

Figure 14: Mechanical deformation of the entrance panel with loads and an internal pressure of 1 mbar

2. A properly sized relief valve will be required after the pressure regulator, preferably a properly sized 15 psig relief to eliminate pressure system requirements downstream. The pressure regulator used must be for pure gas and have the proper outlet pressure range of 0-15psig (0-1 bar).

3. The controller for the N_2 system shall be an Allen Bradley CompactLogix to match the other Hall B gas system controllers for ease of programming and maintenance.

4. The dry nitrogen volume, all be it relatively small, shall have an approved oxygen deficiency hazard safety review per JLab ODH guidance.

5. The final design of the dry nitrogen piping and ventilation systems shall be reviewed by a JLab engineering subject matter expert(s).

The RICH group has started a collaboration with George Jacobs to ensure the RICH gas system conforms to the Hall-B regulation and safety and fulfills the above recommendations.

In November, Frascati engineers had a first meeting with George Jacobs to review the conceptual design of the RICH N_2 purge gas system, discuss its compatibility with the Hall-B nitrogen supply line and identify basic elements, i.e. pressure regulator, relief valve, rotameter, bubbler and black nylon lines, see Figure 15.

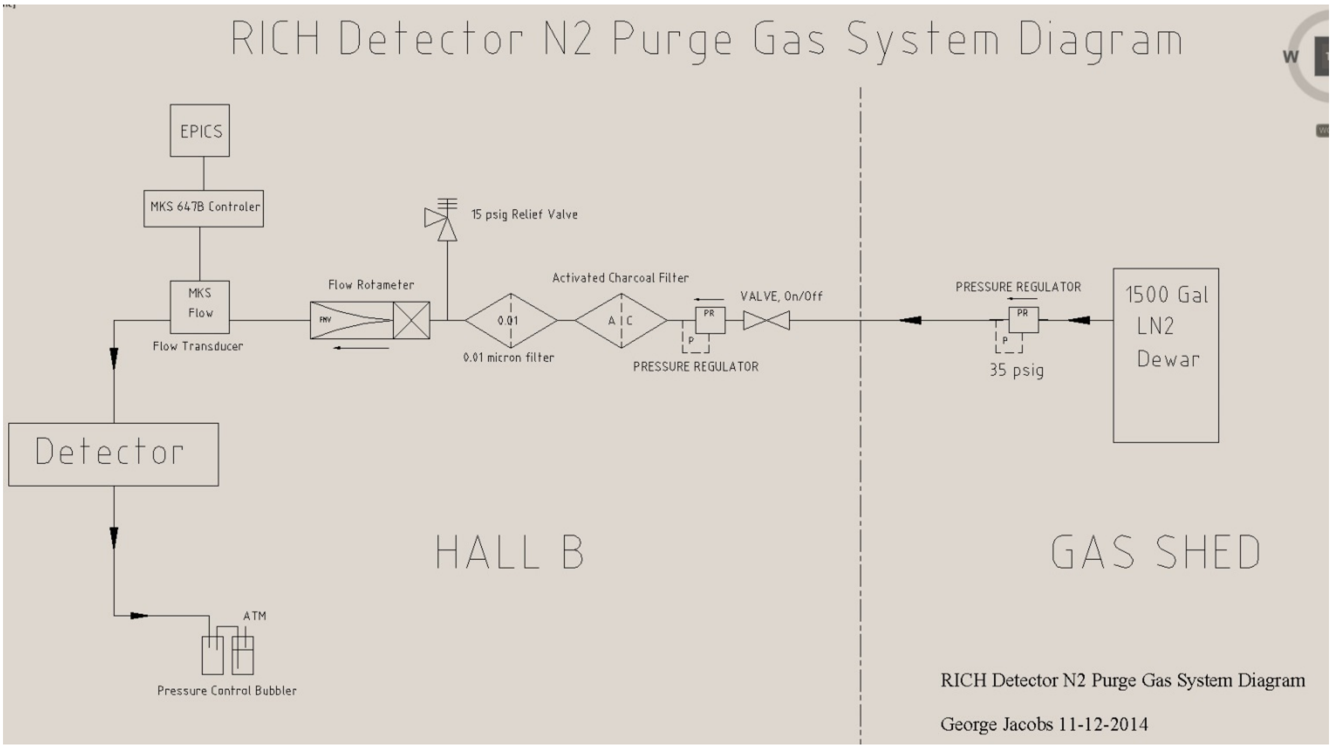

Figure 15: Conceptual design of the RICH gas system reviewed by George Jacobs.