Activity Report 2016 - JLAB12

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1 Introduction

The Frascati JLAB12 group participates in the physics program carried on by the CLAS collaboration in the Hall B of the Jefferson Laboratory (JLab). The physics program of the group is focused on the precision study of the three-dimensional structure of the nucleon and its internal dynamics. This is achieved through the determination of three-dimensional parton distribution functions: the Transverse Momentum Dependent parton distribution (TMD), the Generalized Parton Distribution (GPD) and the Fracture functions.

The 2016 activity of the group has been mainly devoted to the construction of a Ring Imagning CHerenkov (RICH) detector to improve the particle identificaton (PID) capabilities of the CLAS12 detector which is installad in the Hall B of the JLab.

2 The CLAS12 RICH detector

The construction of a RICH detector to improve the PID capabilities of the CLAS12 spectrometer of the Hall B at JLab is in progress under the lead of INFN physicists. The goal of the detector is to achieve a pion/kaon separation at the level of 1:500 in the momentum range between 3 and 8 GeV/c.

The detector is composed by an aerogel radiator, an array of multianode photomultiplier tubes (MAPMTs) for the Cherenkov light detection and a mirror system to direct the large angle photons onto the photodetectors. All these elements are contained in a large trapezoidal box, of approximate height of 3.5 m and large base of about 4 m.

In June 2016, the RICH project passed through an Experimental Readiness Review, where the JLab management reviewed the status of the detector in preparation toward the installation of the detector in CLAS12 foreseen by September 2017 [1].

2.1 The RICH mechanic structure

The RICH mechanics box is made by structural elements (two lateral panel, the lower base and the two upper angular blocks) in aluminum and a number of other elements (frontal and back panels, top panel, reinforcement ribs) in carbon fiber. Its construction has been awarded in 2014 by the *Tecnolgie Avanzate srl* (Veroli, Italy), started in 2015 and has been completed in 2016. During summer 2016, an assembly test has been successfully performed (see Fig. 1). The test was completed with a detailed laser tracker survey, in order to verify the compliance with the engineering drawings. Negligible discrepancies, at a level of few mm or less, have been found, basically in agreement with the Finite Elements Analysis (FEA) of the expected deformations. The structure was then dismounted, packed, and shipped to JLab.

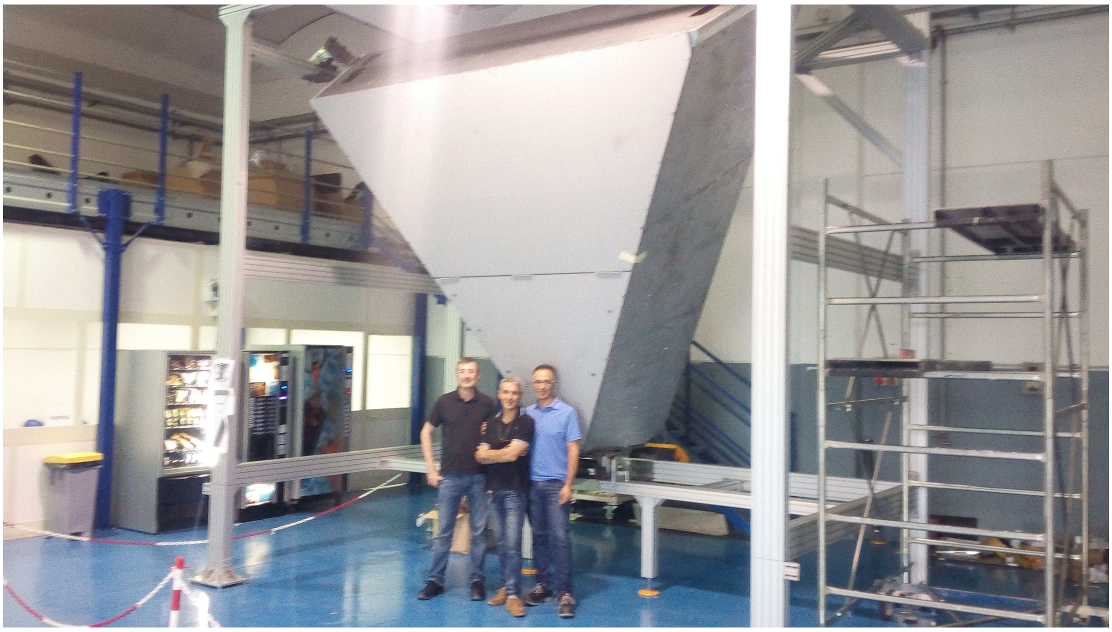


Figure 1: *The RICH mechanical structure after the assembly test.*

2.2 The RICH mirror system

The RICH incudes spherical and planar mirrors in order to contain the Cherenkov photons inside the detector and to direct them toward the photodetectors. This mirror system is composed by spherical and planar mirrors. The spherical mirror, with a radius of 4 m, is segmented in 10 submirrors assembled on a support anchored to the RICH mechanical structure. The planar mirrors are installed on the panels forming the mechanical structure: four on the sides, one on the bottom and two on the front of the RICH.

2.2.1 The planar mirrors

The seven planar mirrors of the RICH are produced by the *MediaLario Technologies* (Bosisio Parini, Lecco, Italy). They have a sandwich structure made by two skins of thin glass with an aluminum core. The four lateral mirrors have skins of 1.6 mm thickness, while the two frontal ones, being in the CLAS12 acceptance, have a 0.7 mm thickness. The first two lateral mirrors have been produced and delivered. The accuracy of the surface of these mirrors has been measured at LNF by using a Coordinate Measuring Machine [2]. The machine provides the (x,y,z) coordinates of the mirror surface with an accuracy on z of about 1 μm. An example of the results is shown in Fig. 2. The left plot shows the profile of the surface, from which an accuracy of 2.7 μm RMS has been obtained. The mesh of measured points allows the calculation of the local slope of the surface, which is the more relevant parameter that can be extracted from these data, being directly related to the angular resolution in the photon detection. The reconstructed slope profile of this mirror is shown in the right plot of the Fig. 2. The RMS of the slope is 0.06 mrad, well below our maximum limit of 0.25 mrad. Few spots have been found where the local slope is close or slightly higher than this limit, but the fraction of the total area of these spots is of the order of few percent, thus totally acceptable.

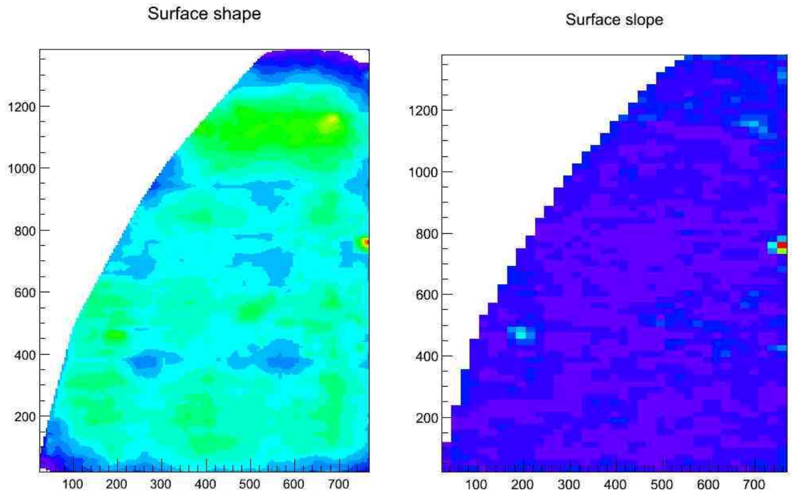


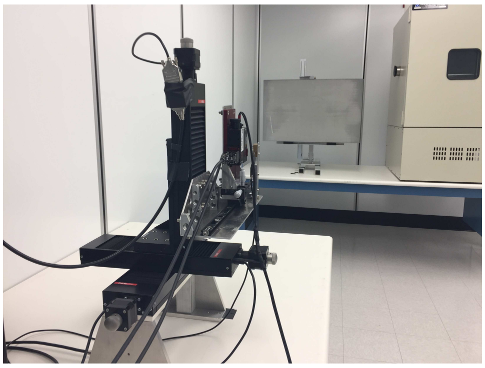
Figure 2: *CMM measurement of one of the lateral planar mirrors. Left plot: profile of the surface. Right plot: reconstructed slope of the surface.*

2.2.2 The spherical mirrors

The spherical mirrors have been produced by the *Composite Mirror Applications inc.* (CMA, Tucson, USA), which already produced mirrors for other physics experiments such as LHCb. They are made by a sandwich of two skins and a honeycomb core in carbon fiber. Compared to the LHCb mirrors, an improvement of about 20% in the areal density has been achieved (the equivalent radiation length is about 1% X_0). All the spherical mirrors have been produced, delivered to JLab and tested by performing a reflected spot size measurement with a point-like light source. For a perfect mirror, when the source and the screen are at its center of curvature, the reflected spot would be a point. Thus, one can define the so-called D_0 of the mirror as the diameter of the circle containing 95% of the reflected light. The smaller the D_0, the better the mirror. The CLAS12 RICH optical specifications required a $D_0 < 2.5$ mm.

The setup for these measurements has been designed and constructed at LNF (see left plot in Fig. 3) and then shipped to JLab. The extracted D_0 values are reported in the right plot of Fig. 3. Once the light source size (about 0.9 mm) is deconvoluted, we obtain a D_0 between 1.0 and 1.5 mm for all the mirrors, well below our limit of 2.5 mm. From these results we estimate a contribution to the angular resolution below 0.1 mrad.

The mirrors will be assembled on a support which is anchored to the RICH. This support is made by a skeleton of C-shaped carbon fiber straight sections reinforced at the crossing points. The mirrors and the support will be assembled together on top of a mockup in foam, by using mounting elements in peek (produced by the LNF workshop) glued on the back of the mirrors and screwed on the support. The is now being constructed by the CMA and its delivery is foreseen by the and of spring 2017.



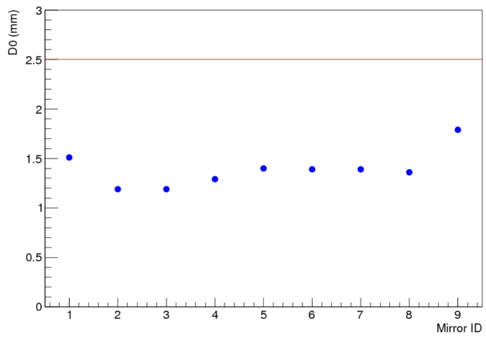


Figure 3: *The setup for the spherical mirror tests at JLab (left plot) and the D_0 values extracted from the data (right plot).*

2.3 The aerogel radiator

The CLAS12 RICH utilizes about 120 large size tiles of 20×20 cm^2 area and refractive index $n = 1.05$ produced by the Budker and Boreskov Insititutes for Nuclear Physics at Novosibirsk (Russia). They are assembled on the RICH in two sections. The first section, with 2 cm thickness tiles, is installed on the frontal planar mirrors. The second section, made by two layers of 3 cm thickness tiles, is installed on the carbon fiber entrance panel.

The purchase of the first layer of the 3 cm section has been completed during the 2016 and all the tiles have been delivered to JLab. Acceptance and characterization tests have been performed after delivery. In particular, precise measurement of the transmittance have been perfromed at the *Catholic University of America* (Washington, USA) using a Lambda 650 S Perkin-Elmer spectrophotometer. The transmittance T as a function of the wavelength λ can be parametrized using the Hunt formula:

$$T = A_0 e^{-Ct/\lambda^4} \quad (1)$$

where t is the thickness of the tile, A_0 is the transparency and the clarity parameter C is related to the scattering length L_{sc} through:

$$\Lambda_{sc} = \lambda^4 / C \quad (2)$$

In the left plot of Fig. 4, we show the transmittance measured for one of the tile in 5 different points. These curves have been fitted using eq. (1) to extract the scattering length and of the transparency coefficient. The values of A_0 and L_{sc}, averaged over the 5 measurements, are shown in Fig. 4 for all the 3 cm tiles. These results, in agreement within the uncertainties with the values produced by the vendor, confirmed that all the tiles fulfill the technical specification (showed by the vertical red lines in Fig. 4 for A_0 and L_{sc}).

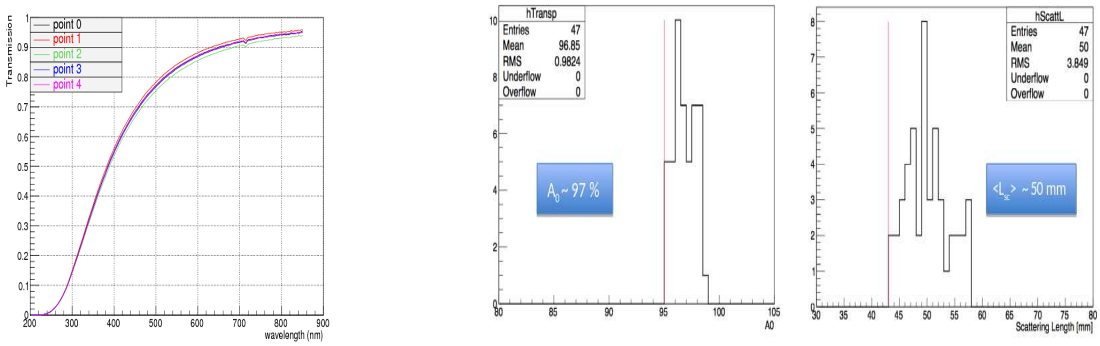


Figure 4: *Left plot: transmittance as a function of the wavelength measured in 5 points of one tile. Center (right) plot: average transparency (scattering length) distributions for the 3 cm tiles.*

2.4 The RICH software

During 2016, the development of the software necessary to manage and operate the RICH detector has been started. The geometric description of the main components (aerogel, mirrors and photodetectors) of the RICH has been implemented in the general CLAS12 software framework, which includes a GEANT4 based simulation (GEMC) and a java reconstruction package. The two systems share a common database where the geometry information are stored. In addition, the optical properties of the sensitive volumes have been implemented in the simulation software. In Fig. 5, we show the current RICH implementation as can be seen from the GEMC graphic viewer, together with the simulation of one 8 GeV pion interacting in the aerogel radiator and producing the Cherenkov cone. The simulated data are now being used to develop the RICH reconstruction and particle identification code.

3 List of Conference Talks by LNF Authors in Year 2016

1. P. Rossi - *Physics Opportunity with an Electron-Ion Collider*, invited talk at the **XIIth International Conference onBeauty, Charm, and Hyperons in Hadronic Interactions (BEACH 2016)** - 12 - 18 June 2016, Fairfax (USA)

2. S. Pisano - *TMD measurements at Jefferson Lab*, invited talk at the **QCD-N'16, 4th Workshop on the QCD Structure of the Nucleon** - 11-15 July, 2016, Getxo (Spain)

3. M. Mirazita - *The new large-area hybrid-optics RICH detector for the CLAS12*, invited talk at the **9th International Workshop on Ring Imaging Cherenkov Detectors** 5-9 September 2016 Bled (Slovenia)

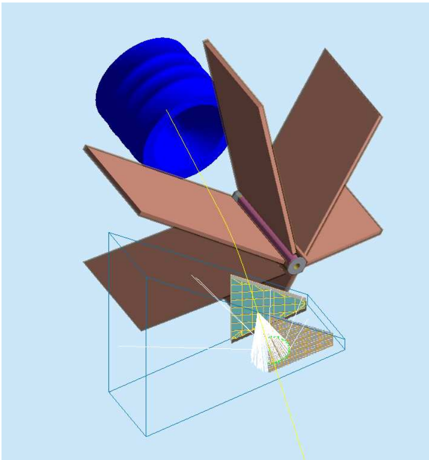


Figure 5: *Drawing of the RICH and of the torus and solenoid coils in the CLAS12 simulation.*

4. P. Rossi - *Nuove opportunita' per la Fisica Adronica negli USA*, invited talk at **Terzo Incontro Nazionale di Fisica Nucleare - INFN2016** - 14 - 16 November 2016, Frascati (Italy)

5. P. Rossi - *Studies of TMDs at JLab*, invited talk at the **3D Parton Distribution Workshop** - 29 November - 2 December 2016, Frascati (Italy)

4 List of Publications by LNF Authors in Year 2016

1. S. Anefalos Pereira, V. Lucherini, M. Mirazita, R. A. Montgomery, A. Orlandi, D. Orecchini, J. Phillips, S. Pisano, P. Rossi, S. Tomassini, A. Viticchie' *et al.*, *Test of the CLAS12 RICH large-scale prototype in the direct proximity focusing configuration*, Eur.Phys.J. A52 (2016) no.2, 23.

2. S. Pisano, M. Radici, Di-hadron fragmentation and mapping of the nucleon structure, Eur.Phys.J. A52 (2016) no.6, 155.

3. M. Mirazita *et al.*, *The large-area hybrid-optics RICH detector for the CLAS12 spectrometer*, Proceeding of the 9th International Workshop on Ring Imaging Cherenkov Detectors, NIM A (in press).

4. S. Pisano, *Precise Measurements of DVCS at JLab and Quark Orbital Angular Momentum*, Proceeding of the Light Cone 2015 conference, Few Body Syst. 57 (2016) no.8, 633-638.

References

1. https://clasweb.jlab.org/wiki/index.php/Ancillary_Equipment_Review#Agenda

2. Mitutoyo CRYSTA-Apex S 9206