Commissioning document of the CLAS12 RICH

M. Contalbrigo, V. Kubarovsky, M. Mirazita

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Abstract

This is an integration to the CLAS12 Commissioning Document describing the Commissioning procedure for the RICH detector.

Contents

1 Quality Assurance and System Checkout

1.1 Quality Assurance Phase

The quality assurance phase includes tests of the various components of the RICH detector: the RICH box, the Aerogel, the Mirrors, the MultiAnode PMTs and the Front End electronics.

An assembly test of the RICH module box will be performed before its delivery to JLab. For this operation, it has been designed a special assembly structure, that will be used also during the assembly and installation at JLab. A detailed survey of the the dimensions of the box, the position of the RICH mounting points and of the attaching points of the inner elements will be performed by using optical methodes (for example laser tracker). Markers will be placed on the RICH module in order to be sure that the assembly and installation at JLab will match the design tolerances.

Each aerogel tile is accompanied by a passport reporting all the optical and geometrical characteristics as measured by the producer before the shipment. These characteristics are: side lengths, thickness, density, scattering length, absorption coefficient A_0. Acceptance tests will be performed on each tile by measuring the transparency and the scattering lenght. Same tests will be repeated over the time in order to continuously monitor the quality of the aerogel. For a subsample of 10% of the delivery, the full set of measurements will be performed before acceptance.

The quality of the mirrors will be checked via optical and mechanical measurements of the shape of the surface. For the spherical mirror, a measurement of the size of the spot produced by the mirror when illuminated by a point-like source (D_0 measurement) will also be performed.

The Multi-Anode PMTs (MAPMTs) have been tested using a setup made of a laser source emitting a photon beam in the blue light wavelength region at a few photon intensity level. A dedicated DAQ system based on FADCs will be used to record the spectrum measured by each pixel of the MAPMTs. The analysis of these spectra include extraction of the gain and efficiency. These data will be stored in the CLAS12 database.

The Front-End electronic is based on the MAROC3 chip for the readout of the MAPMT channels and on an FPGA for the communication, via optical link, to the CLAS12 DAQ. The total number of readout channels is about 25000. This electronics is organized in tiles feeding groups of 2 and 3 MAPMTs. A tile has one HV and one LV connection and is composed by an adapter board, an ASIC or MAROC board and a FPGA board. There is one MAROC chip per MAPMT and one FPGA chip per tile. The correct functionality of each board will be verified by performing electric checks on well defined test points.

1.2 System Checkout

The assembly of the RICH box will run in parallel with the assembly of the main inner elements, such as the electronic panel, the mirrors and the aerogel.

The assembly of the readout electronics will be performed by pairing the adapter board with the MAPMTs on the inner side of the panel and the ASIC and FPGA boards on the outer side. After completion of the assembly on the supporting panel, the correct functionality of the system will be verified by switching on the HV of the

MAPMTs and the LV of the FE cards. Acquisition tests with cosmic rays will be performed. A test of the cooling system, including the slow controls for temperature, humidity and air flow readout, will be also done.

The sub-mirrors composing the various RICH mirror panels (the frontal and lateral planar ones and the spherical one) will be assembled on their supports and aligned by using optical methodes. Then, the panels will be installed in the RICH box and the relative alignment and the position with respect to the reference markers will be checked. Possible misalignments will be compensated by adjusting the mounting screws of the various panels.

As last assembly step before sealing the RICH module, the aerogel tiles will be installed on the frontal panel. A special closing box will be used during this operation in order to prevent any possible damage due to the humidity absorption and to be able to flux dry nitrogen on the aerogel.

The assembly of the RICH box will be performed following the procedure established in the assembly test before the shipment. Once completed, the inner elements will be installed inside the RICH. Since, when the RICH has been sealed, the position of any inner element cannot be directly verified, it will be important in this phase to check the reliability of the mirror mounting points. This will be done by repeating the mirror installation procedure more than once. Finally, the precise verification of the markers attached externally to the box will be done.

2 Commissioning Without Beam

2.1 RICH Calibration

The calibration and equalization of the RICH readout system is done in three steps. The first step is the measurement of the MAPMT gains in the single photoelectron regime performed during the quality assurance phase. These results will be used to select groups of two or three MAPMTs with similar average gains to be mounted on the same readout tile.

The second step is the setting of the preamplifier gain (one value per channel) and of the digital threshold (one value per MAPMT) of the MAROC3 chip. The calibration of the MAROC3 chip will be done with dedicated runs in self-trigger mode or with a charge injector. These runs will be periodically repeated for stability verification.

In the last step, the MAPMT and FE calibration data will be merged in order to equalize the response of all the readout channels, so that, ideally, one threshold value, common for all the channels, at a level of a fraction of one p.e. signal, could be set.

Cosmic ray measurements will also be performed. In a first phase, they will be performed using the electronic panel only to verify the correct functionality of the system. In a second phase, after completion of the RICH assembly and before installation in CLAS12, they will be used to verify the RICH performances. During these measurements, the RICH will be rotated in horizontal position using the assembly structure, with the front panel and the aerogel on the bottom. Cosmic rays will produce Cherenkov photons on the aerogel, then will be reflected by the planar mirrors to the photodetector plane. Cherenkov photons produced on the MAPMT window can also be used to study the capability of the reconstruction software in distinguishing rings with different radius.

3 Commissioning With Beam

3.1 Commissioning Phase

After good beam is established, the RICH is turned on and data with electron trigger will be accumulated to check the correct operation of the RICH detector. For these studies, good reconstructed tracks from the CLAS12 tracking system must be available.

The first phase of the commissioning will check the ring reconstruction software. Data with magnetic field off will be used to verify the alignment of the photodector plane by comparing the particle trajectory projection with the cluster hit position on the MAPMTs. Events without reconstructed tracks in the RICH sector will be used to study the background level.

Then, the torus magnetic field will be turned on and electron tracks will be used to study the alignment of the mirror system. Data with torus configuration different from the nominal one, in particular with lower or reversed field, and various beam energies will be accumulated to establish the RICH acceptance limits in the largest kinematic range possible. Data at various beam current will be used to study the reconstruction algorithm at different background levels.

3.2 Performances Studies

The collected data will be used to verify the RICH KPP, which is the capability to distinguish between pions, kaons and protons at small angles, when the Cherenkov photons are detected directly by the photodetectors, without reflections on the mirrors. The Particle IDentification (PID) software compares the measured hit pattern to the one produced by a given particle hypothesis through a likelihood function. The calculation of the likelihood for every particle hypothesis will be tuned by using narrow resonances produced in exclusive events, as for example K_S for pions, ϕ for kaons and Λ for protons. Then, the PID capabilities will be analyzed by studying the π/K and K/p rejection factors versus the likelihood cuts. The cuts will be optimized in order to maximize the particle detection efficiency and minimize the contamination due to wrong identification.

4 Appendix: RICH Commissioning Information

4.1 Contact Persons

RICH contac persons			
Name	Affiliation	email	Area of responsibility
V. Kubarovsky	JLab	vpk@jlab.org	Hardware/Software
M. Contalbrigo	INFN-Fe	mcontalb@fe.infn.it	Hardware/Software
M. Mirazita	INFN-LNF	mirazita@lnf.infn.it	Hardware/Software

4.2 Quality Assurance and System Checkout

4.2.1 Quality Assurance

RICH Mechanic structure survey: EEL124	
Description	Check of the relative position of the panels forming the RICH structure. The target points installed on the RICH mechanics will be used for the survey. The measured positions must match the ones measured during the assembly test performed at the company.
Special equipments	Laser tracker. Faro-arm.
Softwares	NA
Manpower and time needed	
Information to be saved in database	

RICH Mirrors: EEL-121	
Description	Check of the accuracy of the spherical mirror surface with spot size and Shack-Hartmann measurements. 1. Alignment of the Shack-Hartmann sensor axis. 2. Alignment of the mirror axis with respect to the Shack-Hartmann axis. 3. Alignment of the light source and photocamera for the spot size measurement. 4. Measure the spot size as a function of the distance from the mirror. 5. Wave-front measurement with the Shack-Hartmann sensor at the minimum spot size distance.
Special equipments	Two optical tables. Shack-Hartmann sensor. Point-like source with LED and optical fiber. CCD photocamera. Remotely controlled motors for the alignment of the system.
Softwares	Linux software for the remote control of the motors and CCD. Root analysis software for the spot size measurements. Shack-Hartmann reconstruction software.
Manpower and time needed	About 2 days per mirror, based on previous experience
Information to be saved in database	

RICH Mirror alignment: EEL124	
Description	Verify the relative alignment of the RICH mirrors. Four mirror systems must be aligned: 1. the frontal planar panel. 2. the lateral planar panel. 3. the bottom planar panel. 4. the spherical panel. The relative alignment of the mirrors composing each panel will be checked first. Then the panel will be installed in the RICH and its alignment with respect to the others will be checked with optical methods. The position of the panel can be optimized by acting on the adjusting screws of the three attaching points on the RICH structure.
Special equipments	Laser tracker. Faro-arm.
Softwares	NA
Manpower and time needed	
Information to be saved in database	

RICH Aerogel: Catholic University (Washington)	
Description	Check of the optical quality of the aerogel tiles
Special equipments	Spectrophotometer
Manpower and time needed	About 1 day per 10 tiles, based on previous experience The work is performed at the Catholic University (Washington).
Information to be saved in database	Average transparency and refractive index of the tiles

RICH Aerogel: Ferrara	
Description	Check of the optical quality of the aerogel on a subsample of tiles
Special equipments	Laser. CCD photocamera. Remotely controlled motors to scan the surface of the tile.
Manpower and time needed	About 1 day per tile, based on previous experience The work is performed in Ferrara.
Information to be saved in database	

RICH Multi-Anode PMT	
Description	Characterization of the MAPMT
Special equipments	Laser source. Flash-ADC. Remote-controlled motors to scan the MAPMT entrance window.
Manpower and time needed	
Information to be saved in database	Gain and single photon resolution of each channel

RICH Electronics: EEL-121	
Description	
Special equipments	
Manpower and time needed	
Information to be saved in database	

4.2.2 System Checkout

Checkout of High Voltage system	
Description	Connect the detector to HV supply, verify cable map, switch on, check of current monitor.
Manpower and time needed	
Software	CLAS12 slow control
Computing resources	NA
Dependencies from other systems	Cooling system must be checked out prior to HV system.
Information to be saved in database	HV distribution map

Checkout of Low Voltage system	
Description	Connect the detector to LV supply, verify cable map, switch on, check of current and voltage monitor.
Manpower and time needed	
Software	CLAS12 slow control
Computing resources	NA
Dependencies from other systems	Cooling system must be checked out prior to HV system.
Information to be saved in database	LV distribution map

Checkout of the Front-End electronics	
Description	ASIC and FPGA configuration, calibration, channel mapping, noise level, etc
Manpower and time needed	
Software	CLAS12 DAQ and slow control, calibration software
Computing resources	
Dependencies from other systems	Cooling system, HV and LV must be checked out prior to HV system.
Information to be saved in database	Channel map, calibration data

Checkout of the Gas systems	
Description	1. Nitrogen lines: gas flow, humidity, leak tests. 2. Cooling air lines: gas flow, temperature, humidity, leak tests.
Manpower and time needed	
Software	CLAS12 slow control
Computing resources	NA
Dependencies from other systems	Cooling system, HV and LV must be checked out prior to HV system.
Information to be saved in database	Flow, pressure, humidity and temperature data

Checkout of the DAQ and trigger	
Description	Test of different DAQ and trigger configurations
Manpower and time needed	
Software	CLAS12 slow control and DAQ
Computing resources	Computer farm
Dependencies from other systems	Need DC information
Information to be saved in database	

Checkout of the Safety System	
Description	Checkout and test of the interlocks between HV, LV, cooling, gas systems
Manpower and time needed	
Software	CLAS12 slow control and safety system
Computing resources	None
Dependencies from other systems	All interlocked systems
Information to be saved in database	None

4.3 Commissioning Without Beam

4.3.1 Special Calibration Procedures

Pedestal runs	
Description	Determine the baseline of the Front-End electronics
DAQ configuration and trigger	Clock trigger
Manpower and time needed	
Software for analysis of results	
Computing resources	
Dependencies from other systems	HV on/off to compare noise levels
Information to be saved in database	Pedestals

Dark runs	
Description	Calibration of the Front-End electronics using thermal noise.
DAQ configuration and trigger	Internal trigger
Manpower and time needed	
Software for analysis of results	
Computing resources	
Dependencies from other systems	
Information to be saved in database	Single p.e. level and resolution

Charge injector runs	
Description	Calibration of the Front-End electronics using the internal charge injector
DAQ configuration and trigger	Internal trigger
Manpower and time needed	
Software for analysis of results	
Computing resources	
Dependencies from other systems	
Information to be saved in database	Single p.e. level and resolution

4.3.2 Calibration with Cosmic Rays

Cosmic runs with the electronic panel (EEL121 and EEL124)	
Description	Check of the full electronic system. Data will be acquired with the electronic panel put in horizontal position, with the MAPMT entrance window up. A simple tracking system could be setup for determining the cosmic trajectories.
DAQ configuration and trigger	RICH DAQ software
Manpower and time needed	
Software for analysis of results	RICH analsys software
Computing resources	Computer farm
Dependencies from other systems	Cooling system and interlocks must be on.
Information to be saved in database	

Cosmic runs with the whole RICH (EEL-124)	
Description	Check of the RICH with cosmics. Data will be acquired with the RICH put in horizontal position on its transportation trolley, with the aerogel panel down. Cherenkov photons will be produced in the aerogel, then reflected back by the frontal mirror toward the photodetectors. A simple tracking system could be setup for determining the cosmic trajectories.
DAQ configuration and trigger	RICH DAQ software
Manpower and time needed	
Software for analysis of results	RICH analsys software
Computing resources	Computer farm
Dependencies from other systems	Cooling system and interlocks must be on.
Information to be saved in database	

4.4 Commissioning With Beam

RICH detector reconstruction calibration	
Description	After initial system checkout, a series of runs with different conditions will be performed. 1. Runs at different beam current to study the noise level. 2. Runs with torus off to check the detector geometry. 3. Runs with different torus magnetic field, including reverse field, to study the performance of the detector.
DAQ configuration and trigger	CLAS12 electron trigger
Manpower and time needed	
Software for analysis of results	CLAS12 tracking and RICH reconstruction software
Computing resources	Computer farm
Dependencies from other systems	All the CLAS12 detector on
Information to be saved in database	Several tuning parameters for the RICH reconstruction (background level, tracking resolution, single photon resolution, etc.).

RICH detector PID in the direct light case	
Description	Study the Kaon/Pion and Kaon/Proton rejection powers in the case of direct detection of the Cherenkov photons. Production data taken with liquid hydrogen target. Narrow resonances will be used to verify the RICH PID, for example: 1. K_S for pions. 2. ϕ for kaons. 3. Λ for protons.
DAQ configuration and trigger	CLAS12 electron trigger
Manpower and time needed	
Software for analysis of results	CLAS12 and RICH reconstruction and PID software
Computing resources	Computer farm
Dependencies from other systems	All the CLAS12 detector calibrated
Information to be saved in database	Kaon detection efficiency vs pion and proton contamination.