The NA62 RICH detector
construction and performance

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Abstract. The RICH detector of the NA62 experiment at CERN SPS is required to suppress $\mu^+$ contamination in $K^+\rightarrow\pi^+\nu\bar{\nu}$ candidate events by a factor at least 100 between 15 and 35 GeV/c momentum, to measure the pion arrival time with $\sim 100$ ps resolution and to produce a trigger for a charged track. It consists of a 17 m long tank filled with Neon gas at atmospheric pressure. Čerenkov light is reflected by a mosaic of 20 spherical mirrors placed at the downstream end of the vessel and is collected by 1952 photomultipliers placed at the upstream end. The construction of the detector will be described and the performance reached during first runs will be discussed.

Keywords: Čerenkov detectors, particle identification

1 The NA62 RICH detector

The NA62 experiment[1] at CERN SPS North Area has been designed to study charged kaon decays and particularly to measure the branching ratio ($\approx 10^{-10}$) of the very rare decay $K^+\rightarrow\pi^+\nu\bar{\nu}$ with a 10% precision. The NA62 experimental apparatus is described in detail in [2].

The largest background to $K^+\rightarrow\pi^+\nu\bar{\nu}$ comes from the $K^+\rightarrow\mu^+\nu\bar{\nu}$ decay, which is 10 orders of magnitude more abundant. This huge background is mainly suppressed using kinematical methods and the very different response of calorimeters to muons and charged pions. Another factor 100 in muon rejection is needed in the momentum range between 15 and 35 GeV/c. A dedicated Čerenkov detector, the RICH, has been designed and built for this purpose. Neon gas at atmospheric pressure is used as radiator, with refraction index $n = 1 + 62.8 \times 10^{-6}$ at a wavelength $\lambda = 300\mu\text{m}$, corresponding to a Čerenkov threshold for charged pions of 12.5 GeV/c. Two full-length prototypes were built and tested with hadron beams to study the performance of the proposed layout[5,6].

The RICH radiator container ("vessel") is a 17 m long vacuum-proof steel tank, composed of 4 cylindrical sections of diameter up to 4 m, closed by two

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thin aluminium windows to minimize the material budget crossed by particles. A sketch of the RICH detector is shown in Fig.1. Fresh neon at atmospheric pressure are injected in the 200 m$^3$ vessel volume after it has been completely evacuated. No purification or recirculation system is used.

A mosaic of spherical mirrors with 17.0 m focal length, 18 of hexagonal shape (350 mm side) and two semi-hexagonal with a circular opening for the beam pipe, is placed at the downstream end of the vessel to reflect and focus Čerenkov light towards the two regions equipped with photomultipliers (PMTs) at the upstream end of the vessel (see Fig.1).

Each mirror is supported using a dowel inserted in a 12 mm diameter cylindrical hole drilled in the rear face of the mirror close to its barycentre. Dowels are connected to the RICH vessel by means of a vertical support panel, made of an aluminum honeycomb structure to minimize the material budget. Two thin aluminium ribbons, each one pulled by a micrometric piezo-electric motor, keep the mirror in equilibrium and allow to modify its orientation. A third vertical ribbon, without motor, avoids on-axis rotation. The mirror orientation is measured by comparing the position of the centre of the Čerenkov ring reconstructed by the RICH PMTs with its expected position based on the track direction reconstructed by the spectrometer and can be finely tuned using piezomotors (see Fig.2).

Two arrays of 976 Hamamatsu R7400-U03 PMTs are located at the upstream end of the vessel, left and right of the beam pipe. The PMTs have an 8 mm diameter active region and are packed in an hexagonal lattice with 18 mm
Fig. 2. (left) Scheme of the mirror orientation system: two ribbons connected to piezo-electric motors pull micrometrically the mirror while a third vertical ribbon avoids on-axis rotation. (centre and right) Position difference between the centre of the Čerenkov ring reconstructed by the RICH PMTs and its expected position based on the track direction reconstructed by the spectrometer, after tuning the mirrors orientation. “+X side” and “–X side” indicate the two locations of the PMTs, on the left and on the right of the beam pipe. Each point represents a single mirror.

pixel size. Each PMT has a bialkali cathode, sensitive between 185 and 650 nm wavelength with about 20% peak quantum efficiency at 420 nm. Its 8-dynode system provides a gain of $1.5 \times 10^6$ at 900 V supply voltage, with a time jitter of 280 ps FWHM. PMTs are located in air outside the vessel and are separated from neon by a quartz window; an aluminized mylar Winston cone\cite{7} is used to reflect incoming light to the active area of each PMT. The front-end electronics consists of 64 custom made boards, each of them equipped with four 8-channels Time-over-Threshold NINO discriminator chips\cite{8}. The readout is provided by 4 TEL62 boards, each of them equipped with sixteen 32-channels HPTDC\cite{9}; a fifth TEL62 board receives a multiplicity output (logic OR of the 8 channels) from each NINO discriminator and is used for triggering. The time resolution of Čerenkov rings has been measured by comparing the average times of two subsets of the PMT signals, resulting in $\sigma_t(\text{ring}) = 70$ ps.

2 Particle identification

In order to assess the RICH performance, the Čerenkov ring radius (which depends on particle velocity) measured by the RICH is related to the track momentum measured by the magnetic spectrometer. Figure 3(left) shows a clear separation between different particles in the momentum range 15–35 GeV/c. Pion-muon separation is achieved by cutting on the particle mass, calculated from the measured values of the particle velocity (from the Čerenkov ring radius) and momentum. The charged pion identification efficiency $\varepsilon_\pi$ and muon mis-identification probability $\varepsilon_\mu$ are plotted in Fig. 3(right) for several values of the mass cut. At $\varepsilon_\pi = 90\%$ the muon mis-identification probability is $\varepsilon_\mu \simeq 1\%$. 
3 Conclusions

The NA62 RICH detector was installed in 2014 and commissioned in autumn 2014 and 2015; it is fully operational since the 2016 run. First performance studies with collected data show that the RICH fulfilled the expectations, achieving a time resolution of 70 ps and a factor $\sim 100$ in muon suppression.

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