The NA62 RICH Detector

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Abstract

The NA62 experiment at CERN, aiming at a precision measurement of the ultra-rare decay $K^+ \rightarrow \pi^+\nu\overline{\nu}$, relies on a gas based RICH detector for π/μ separation and level 0 trigger. The experimental requirements for this detector are a time resolution better than $100ps$ and a muon rejection factor better than 5×10^{-3} in the momentum range $15-35GeV/c$. A first prototype of such a detector has been built and tested in 2007, as a first check of its time resolution and of the light collection technique; it consists in a full length ($18m$) Ne filled vessel equipped with a spherical mirror and 96 PMs on its focal plane, $\approx 17m$ upstream of the mirror. The prototype has been tested at CERN SPS on a $200GeV/c$ pion beam mainly; the time resolution has been found to be about $65ps$, and the light collection, i.e. the number of hit PMs per ring, fairly as expected.

Key words:
Čerenkov detectors, fast timing, photomultipliers

1. Introduction

The purpose of the NA62 experiment [1] at CERN is a precision measurement (10%) of the ultra-rare decay $K^+ \rightarrow \pi^+\nu\overline{\nu}$ (branching fraction $O(10^{-11})$), which provides the possibility to test the SM due to small theoretical uncertainties on the predicted value.

In order to reject events with a BR up to 10 orders of magnitude higher than signal, besides votoes, NA62 will rely on a gas based RICH detector for π/μ separation, with a μ rejection factor better than 5×10^{-3} in the momentum range $15-35GeV/c$, for L0 trigger and for measuring event time with a resolution below $100ps$.

The NA62 RICH [2] is a $\approx 18m$ long tube ($\phi \approx 3m$) filled with Ne at atmospheric pressure and room temperature, equipped with a mirror[1] ($17m$ in focal length), at the downstream end, and about 2000 PMs, at the upstream end.

As first step in the development of a RICH detector capable of fulfilling the experimental requirements, a full length prototype equipped with 96 PMs (Hamamatsu R-7400) and a spherical mirror with $17m$ focal length has been built. A test beam has been performed [4], aimed at measuring the time resolution, the light collection technique, based on Winston's cones[3], andthe Cerenkov angle and the track angular resolutions. Also the final selection of PM type has been done.

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[1]Several segmentation configurations to cover the largest area ($\approx 7m^2$) with the minimal number of sustainable and reliable pieces are under study.

2. Test beam experimental setup

The detector response has been tested using a beam of $200GeV/c$ momentum (spread $\approx 1.8\ 10^{-3}$), with a divergence of $30\mu rad$; at the prototype position its composition was 96.2% of π^-, 3.0% of K^- and 0.8% of $\overline{p}$.

2.1. Detector

Ne at atmospheric pressure and room temperature has $(n-1) \approx 60\ 10^{-6}$, so the maximum Čerenkov angle (θ_l) is about $11mrad$. 96 PMs have been installed to optimize the light collection around θ_l.

Front-end and read-out is based on NINO ASIC [5] and HPTDC ASIC [6]. A standard VME TDC module (CAEN V1190A) has been used. The time over threshold technique, is implemented in the NINO ASIC for measuring both time and amplitude for allowing off-line slewing correction (to timing).

3. Data analysis

The aim of the test was 1) to verify the Čerenkov angle resolution, even though with a bias due to the limited number of PMs; 2) to measure the number of photoelectron multiplicity per event (multiplicity of hit PMs) which plays a key role in the estimation of the behavior of the final detector in different momentum regions; 3) the time resolution in measuring the particle crossing time.

The resolution on the event time has been found to be $65ps$. Figure 1 shows the different behavior of two subtypes of PMs (R7400-U03 and R7400-U06) used during

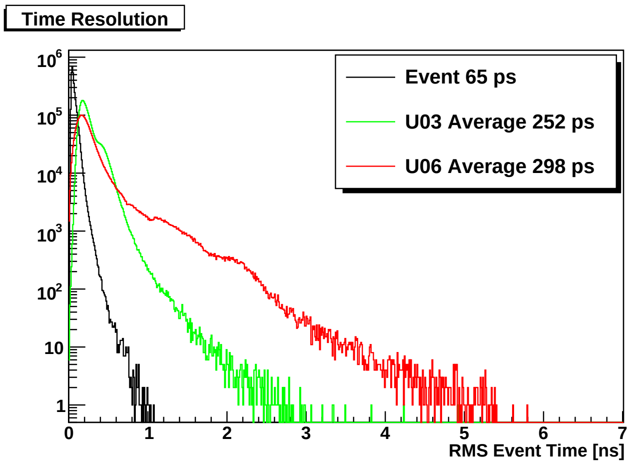

Figure 1: Global time resolution and comparison between R7400-U03 and R7400-U06.

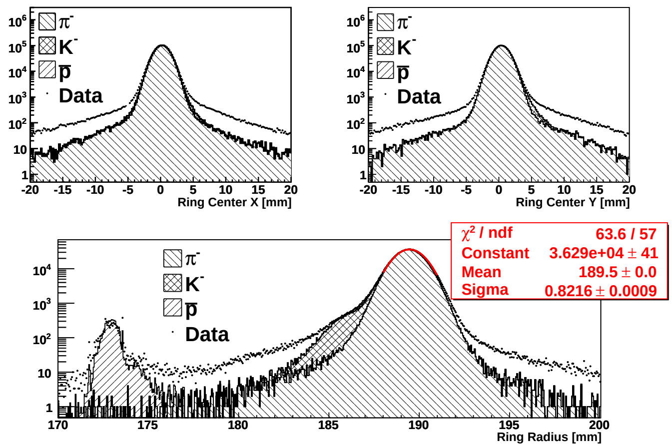

Figure 2: Comparison between data and MC related to Čerenkov angle resolution and track angular resolution; differences in tails are probably due to beam halo or large angle scattering upstream the detector.

the test (72 U03 and 24 U06); U06 exhibit a worse time resolution, so it has been decided to use only U03 in the future.

The average number of PMs hit in a single event was 17, while the Čerenkov angle resolution (fig. 2) was about $50\mu rad$, biased by the insufficient number of PMs[2].

Besides these main features of the prototype, which proved to fit the design goals, the triggering capability of the detector has been verified offline using data taken without external trigger. This technique also gives the possibility to study the time structure of hits in an arbitrary large time window around the Čerenkov event time, allowing for additional timing characterization of the PMs and the detector itself.

[2]In the final detector is expected to be $65\mu rad$ for θ_l

4. MonteCarlo simulation

A Geant4 [8] based MonteCarlo simulation of the prototype has been developed and validated, with the purpose of "scaling" it to the final detector design and evaluate its performaces. Generation, full optical propagation and detection of Čerenkov photons has been taken into account. In addition scintillation of Ne, reflectivity of the vessel and of the PMs flange and the upstream scintillators have been introduced, for higher order effects[11].

4.1. Photon detection efficiency

In order to better disentangle the various optical inefficiency sources, i.e. mirror and Winston's cones reflectvity and light transmission, and to have a better prediction of the performance of the final detector, quantum efficiencies (QE) of PMs are being studied. Since individual QE measurements for each PM are not provided by the manufacturer, to avoid the huge effort of performing it for about 2000 PMs, exploiting the fact that PMs of the same type tend to have quite the same QE dependence on wavelength, it should be feasible to use a typical response curve for all of them, and find the correct normalization for each one, measuring the QE for a small subset and using the provided blue sensitivity index measurement. The absolute QE of 8 PMs has been measured at 6 different wavelength, with an estimated accuracy of about 1%. Figure 3 shows the results in comparison with a typical response curve provided by Hamamatsu. In spite of the appreciable difference in shape between present measurements and the typical curve, the fluctuation of the spectral response among the 8 PMs tested is within 1%, confirming that a typical curve really exhists and could be used as a reference. The discrepancy between measurements and Hamamatsu data could be due to a wrong calibration of the normalization powermeter used and it is under investigation. The correlation between measured QEs and corresponding blue index parameters (fig. 4) is very good

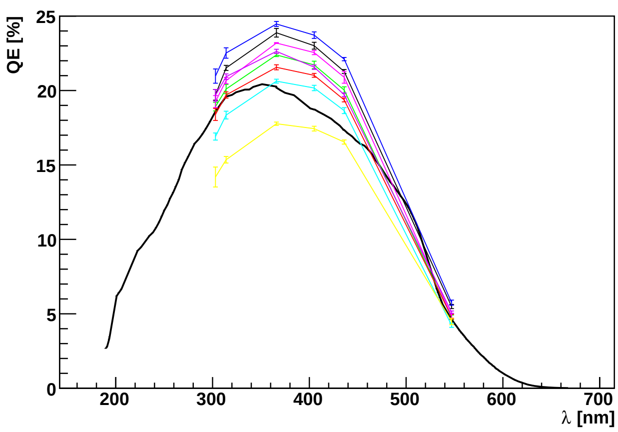

Figure 3: Quantum efficiency of 8 PMs (R7400-U03) (points) and typical curve by Hamamatsu (solid black line).

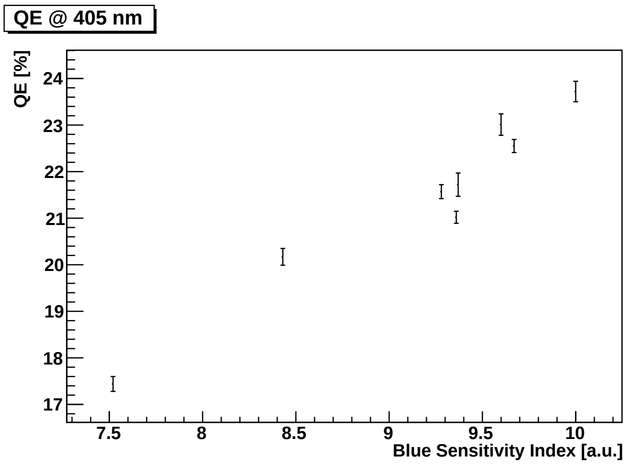

Figure 4: Correlation between QE, measured at $405nm$, and Blue Senstivity Index provided by Hamamatsu.

and endorse our method; indeed the technique should provide the information requested to improve the accuracy of the simulation.

5. Next prototype

A new prototype is going to be built and tested before summer 2009 with the purpose of measuring the rejection factor for muons; the PMs flange has been redesigned to host about 400 PMs, which will instrument the region of the focal plane related to rings from muons and pions in the range $15-35GeV/c$ and $\beta = 1$ (fig. 5). As the number of PMs is increased, the heat produced by voltage dividers becomes an issue, so in the new PMs flange a cooling system has been embedded; the new mechanical structure, which has also been designed to improve light tightness, will be evaluated as actual prototype for the final detector.

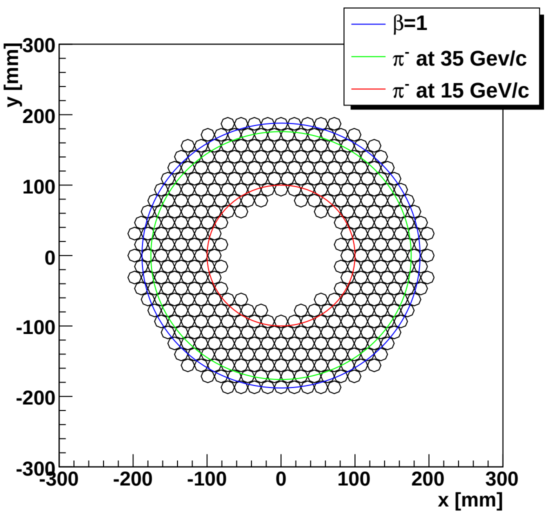

Figure 5: Position of photodetectors that will be installed and expected positions for Čerenkov rings.

The data are planned to be collected using using the final trigger and acquisition electronics built for the NA62 and based on the TELL1 board[7], with the trigger algorithm implemented.

6. Conclusion

The 2007 test beam has been successful, both for expected results and for further information about higher order effects; data has been used to validate a MonteCarlo simulation which helped in the interpretation of data and will provide guidelines for future investigation. A new prototype design is being finalized, in preparation for a new test beam that will take place before summer 2009, to measure the actual muon rejection factor in experimental conditions more similar to the NA62 data taking.

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