IOP Conf. Series: Journal of Physics: Conf. Series **800** (2017) 012049 doi:10.1088/1742-6596/800/1/012049

The CHarged particle ANTIcounter for the NA62 experiment at CERN

Marco Mirra[1]

Università degli studi di Napoli "Federico II" e Sezione INFN di Napoli, Italy

E-mail: mirra@na.infn.it

Abstract.

The design and performance of a charged particle detector named CHANTI is described. The detector, which operates in vacuum, it is used as a veto counter in the NA62 experiment at CERN.

1. The NA62 experiment

The NA62 experiment at CERN[1] aims at measuring the Branching Ratio (BR) of the ultra-rare kaon decay $K^+ \to \pi^+\nu\bar{\nu}$ with a 10% uncertainty. It is a theoretically very clean Flavour Changing Neutral Current process and represents a valid test for the flavor structure of the Standard Model (SM). The SM prediction is BR($K^+ \to \pi^+\nu\bar{\nu}$)=$(0.84 \pm 0.10) \times 10^{-10}$[2], while the current best measurement, performed by the E787/E949 collaboration, is BR($K^+ \to \pi^+\nu\bar{\nu}$)=$(1.73^{+1.15}_{-1.05}) \times 10^{-10}$[3]. NA62 uses a 75 GeV/c unseparated hadron beam from the SPS with a 6% kaon component. The apparatus is designed to collect kaon decays in flight within a 65 m long evacuated fiducial volume. A critical point of the experiment is the rejection power of the kaon decays that can mimic the signal: kinematical constraints (measuring both K^+ and π^+ momenta), particle identification and veto detectors have to be used.

2. CHANTI detector

The interaction of the beam with the kaon spectrometer (called GTK) represents a possible source of background. Indeed inelastic scattering events can mimic the signal if a produced pion falls into the decay product spectrometer acceptance and is badly reconstructed inside the fiducial volume while no other track is detected. The CHANTI detector is placed just after the GTK to help the rejection of this background by tagging the particle emitted at large angles with respect to the beam (from 49 to 1340 mrad). The detector is composed of 6 stations, of square shape (300×300 mm^2), placed inside the vacuum tube starting at a distance of 27 mm from the last station of the GTK along the beam axis. The hole inside each station is 65 mm in Y and 95 mm in X. Each station is made up of two layers (X and Y) and each layer is composed of 24 scintillator bars arranged parallel to the X(Y) direction and individually shaped at the appropriate length. The bars consists of an extruded polystyrene core doped with blue-emitting fluorescent compounds with a TiO_2 coating. The cross-section of the bar is an isosceles triangle

[1] on behalf of the NA62 CHANTI group: F. Ambrosino, T. Capussela, D. Di Filippo, P. Massarotti, M. Mirra, M. Napolitano, L. Roscilli, G. Saracino, G. Corradi, C. Paglia, D.Tagnani

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

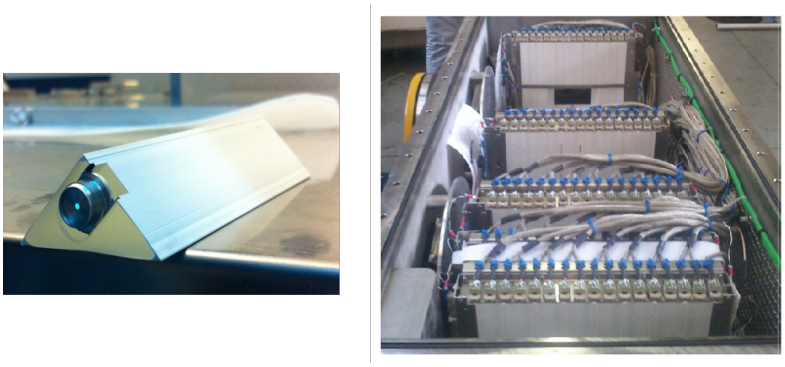


Figure 1. Single scintillator bar (left) and CHANTI stations inside the vacuum chamber (right)

with a base of 33 mm and a height of 17 mm; a hole (1.7 mm diameter) is placed at 8.5 mm from the base to host a WaveLenght Shifting (WLS) fibre Bicron BCF92 (Fig.1 left). The fibre has one side mirrored and is read from the other side by a Hamamatsu SiliconPhotoMultiplier (SiPM). Figure 1 shows the first five CHANTI stations assembled in the vacuum vessel (right). More details about CHANTI can be found in [4].

A VME 9U board (CHANTI-FE) has been developed to power and read the SiPMs. It also gives fast amplification of the signals before passing them to a Time over Threshold (ToT) board [5] which gives a LVDS output of duration equal to the time a signal is above a given threshold. Actually the ToT board is able to give two LVDS outputs for each analog input corresponding to different adjustable level thresholds. This feature allows to correct for time-walk effects with a linear extrapolation when both thresholds are crossed by the signal and to calibrate an average time-walk vs ToT correction, to be used when only the lower thresholds is crossed. The LVDS signal is then processed by a fast TDC. A careful calibration procedure for the CHANTI-FE has been setup in order to precisely control and readout the value of the voltage bias and to readout the current; the calibration constants for DAC and ADC are obtained by measuring the voltage-current curve of a set of high impedance calibrated input resistors. A threshold scan is done for each of the readout SiPMs of the CHANTI system by counting the dark rate at different values of the threshold. Since the SiPM dark rate diminishes by roughly one order of magnitude as the threshold is raised by an amount equivalent to one photoelectron amplitude, a fit of this threshold scan with a proper step function can detemine the amplitude (in mV) of the single photoelectron peak for each channel (Fig.2). This procedure allows to set the thresholds in terms of a quantity directly related to the fundamental process in the scintillator/SiPM (number of photoelectrons) rather than in terms of signal amplitude in mV that depends on the gain of each SiPM and on the electronics channel amplification gain.

The CHANTI took part in the data taking of NA62 in 2014, 2015 and 2016. The efficiency and spatial resolution have been measured by means of muon halo tracks, which provide a clean sample of straight and penetrating Minimum Ionizing Particles (MIP). Single station efficiency has been measured to be above 99.9% as expected from tests performed on the detector prototype using cosmic rays. A CHANTI hit position is reconstructed in each view as the average of the positions of at least two bars weighted by the energy release in each bar. Indeed the triangular shape of each bar results in a linear relation between the amount of energy released by a straight particle crossing the bar and the distance of its interaction from the bar center. The center-of-charge technique allows to reach a resolution of 1.8 mm (Fig.3 left), better than the intrinsic one resulting from the pitch of the WLS fibres used in the detector. Given the high rate of spurious tracks crossing the detector (muon halo, pion inelastic interactions, etc.), a good time resolution is important to reduce the random vetoes fraction to a few percent, while keeping a

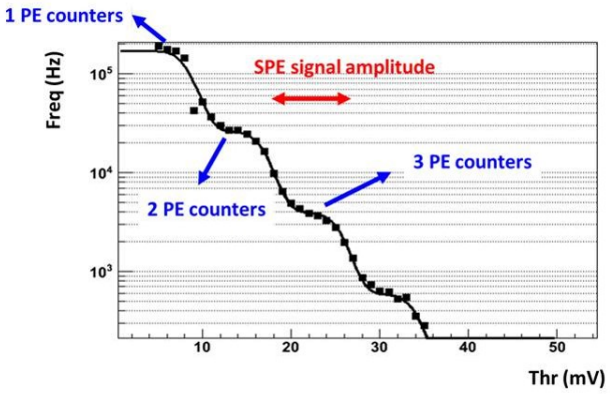


Figure 2. A typical threshold scan curve where the flat part corresponds to the counters of a certain number of photoelectron signal (PE). The distance between two consecutive inflection points of the curve is the single photoelectron (SPE) amplitude. For this particular channel it is found to be about 10 mV.

high efficiency in detecting kaon inelastic interactions. Reaching a few ns single hit resolution is therefore mandatory for CHANTI. Once time-walk correction is taken into account, the typical single hit resolution is found to be 1.2 ns (Fig.3 right).

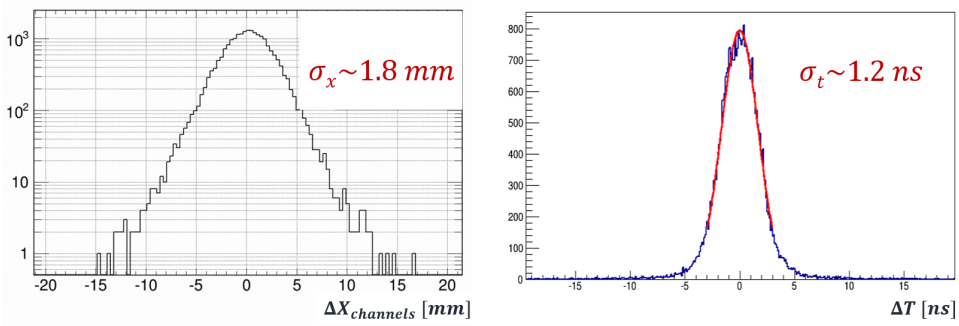


Figure 3. Difference between X position of two hit points on different stations for straight MIP (left) and difference in time between bar hits, after time-walk correction (right).

3. Conclusion

In this work the CHANTI detector was presented. The achieved performance has shown that CHANTI can safely operate in vacuum with a time and spatial resolution of 1.2 ns and 1.8 mm, respectively, in line with the design requirements.

References

[1] A. Ceccucci et al.: *Proposal to Measure the Rare Decay at CERN SPS*, CERN-SPSC-2005-013, SPSC-P-326.
[2] A.J. Buras, D. Buttazzo, J. Girrbach-Noe and R. Knegjens, $K^+ \to \pi^+\nu\bar{\nu}$ *and* $K_L \to \pi^0\nu\bar{\nu}$ *in the Standard Model: status and perspectives*, JHEP 11 (2015) 033 [arXiv:1503.02693].
[3] Anisimovsky et al. [E949 Collaboration], Phys. Rev. Lett. 93, (2004).
[4] F. Ambrosino, et al.: *CHANTI: a fast and efficient charged particle veto detector for the NA62 experiment at CERN.*, JINST 11 P03029, http://dx.doi.org/10.1088/1748-0221/11/03/P03029
[5] A. Antonelli et. al, arXiv:1111.5768