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The photon veto system in the NA62 experiment

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Summary. — The NA62 experiment at CERN SPS aims to collect $\mathcal{O}(100) K^+ \to \pi^+\nu\overline{\nu}$ events in two years of data taking with a S/B ratio of about 10:1. The Branching Ratio (BR) for this decay is $\sim 10^{-11}$ and can be predicted with minimal theoretical uncertainties, making it a sensitive probe for New Physics. The guiding principles for the construction of the NA62 detectors are an accurate particle ID, precise timing and excellent veto efficiency. In particular, the veto inefficiency for photons from $K^+ \to \pi^+\pi^0$ decays should be smaller than 10^{-8}. The photon veto system of NA62 consists of three detectors covering different angular regions: Large Angle Veto (LAV), Liquid Krypton calorimeter (LKr) and Small Angle Veto (SAV). The status of the project and present preliminary results from the recent tests will be reviewed.

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PACS 07.05.Fb – Design of experiments.

1. – The NA62 experiment

The ultra-rare $K^+ \to \pi^+\nu\overline{\nu}$ decay is a flavour changing neutral current process induced in the Standard Model (SM) by loop effects; thanks to the good theoretical control of the hadronic matrix element, this decay provides a decisive test for the SM and its extensions. The latest theoretical result is $BR_{K^+\to\pi^+\nu\overline{\nu}}(\mathrm{SM}) = (7.81 \pm 0.80) \times 10^{-11}$ [1] and until now only seven candidates have been observed resulting in the experimental value $BR_{K^+\to\pi^+\nu\overline{\nu}}(\mathrm{exp}) = (17.3^{+11.5}_{-10.5}) \times 10^{-11}$ [2]. The goal of the NA62 experiment at CERN SPS [3] (fig. 1) is to collect $\mathcal{O}(100) K^+ \to \pi^+\nu\overline{\nu}$ events in two years of data taking with a $S/B \sim 10:1$. The experiment will make use of a 75 GeV unseparated positive secondary beam providing a K^+ decay rate of about 10 MHz in the fiducial decay region. The success of the experiment depends crucially in obtaining the required level of background rejection. In particular, photon vetoes are needed to suppress the background coming from $K^+ \to \pi^+\pi^0$ decays (BR = 20.7%) that must be rejected at

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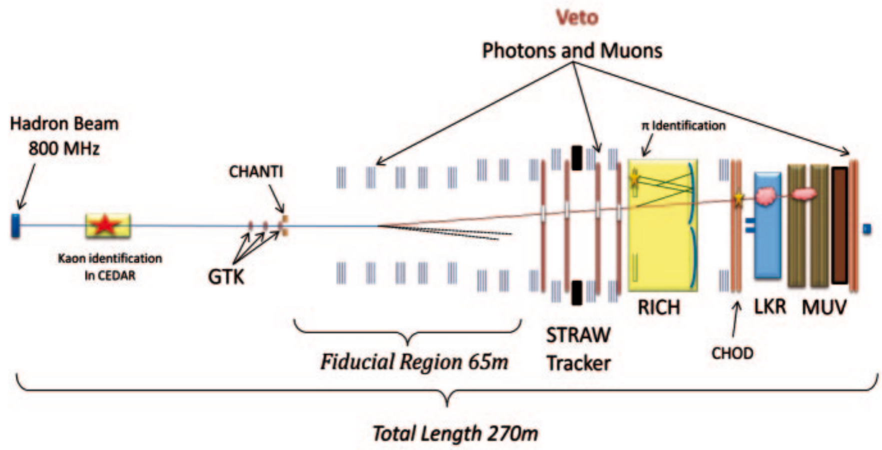

Fig. 1. – Schematic view of the NA62 experiment showing the main subdetectors (not to scale).

the level of 10^{-12}; kinematical cuts on the K^+ and π^+ tracks will give a factor 10^{-4} and ensure 40 GeV of electromagnetic energy in the photon veto so that the π^0 must be detected with an average inefficiency lower than 10^{-8}. The photon veto system is partitioned into three detectors covering different angular regions with respect to the incident beam: Large Angle Veto (LAV), Liquid Krypton calorimeter (LKr) and Small Angle Veto (SAV).

2. – Large Angle Veto (LAV)

The LAV system, designed to cover the angular range from 8.5 to 50 mrad, consists of 12 ring-shaped stations placed all along the beam line. The LAV stations should detect photons above 200 MeV with an inefficiency below 10^{-4}, providing a time resolution of ~ 1 ns and a measurement of the deposited energy of about 10% for 1 GeV photons. During the R&D program, three possible detector technologies were tested by the collaboration: lead/scintillating fibers, inspired by the KLOE calorimeter; rings of lead/scintillating tiles modules; rings of lead-glass crystals from the OPAL experiment calorimeters. After several tests at the Frascati Beam Test Facility, all three options were found to match the inefficiency requirement and the OPAL solution has been chosen (fig. 2).

Each station is made of 4 or 5 rings staggered in azimuth (fig. 2); the whole LAV system contains ~ 2500 crystals with ~ 5000 readout channels (two thresholds for each PMT to allow time slewing correction). During 2010, a dedicated test beam at CERN using electrons has been devoted to measure the time and energy resolution of the LAV station 2. Preliminary results indicate that all requirements are fulfilled: $\sigma(E)/E < 10\%/\sqrt{E}\,(\text{GeV})$ and $\sigma(t) < 300\,ps/\sqrt{E}\,(\text{GeV})$. At the present, five stations have been built.

3. – Liquid Kripton calorimeter (LKr)

The NA62 experiment will reuse the existing liquid krypton calorimeter of NA48 for vetoing photons in the angular range from 1 to 8.5 mrad. The request for this detector

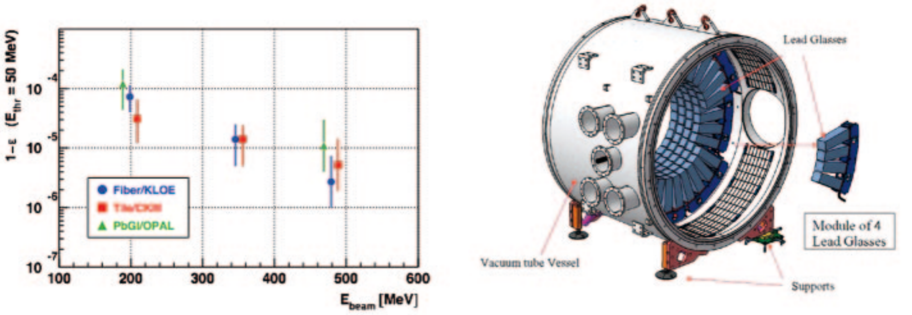

Fig. 2. – Left: Measured efficiencies for the three solutions of LAV as a function of energy. Right: A complete LAV station layout.

is a photon detection inefficiency better than 10^{-5} for energies larger than 35 GeV; measurements based on NA48 data have demonstrated the capability of the LKr to reach the required veto performances. In addition, the calorimeter will provide trigger signals to reduce the Level 0 trigger rate. An update of the old readout system is foreseen, to sustain a rate two orders of magnitude larger than in NA48.

4. – Small Angle Veto (SAV)

The angular region not reached by the LKr due to the presence of the beam pipe, is covered by a rectangular shashlyk calorimeter, the Small Angle Calorimeter (SAC), placed at the end of the experimental setup after the sweeping magnet that deflects the beam. To complement the acceptance of LKr and SAC, an Intermediate Ring Calorimeter (IRC) is located around the beam pipe just in front of the LKr as close as possible to the beam. Both IRC and SAC have to provide a detection inefficiency better than 10^{-4}. A SAC prototype was constructed and tested during a 2006 test run; the result for the inefficiency ($\epsilon = (2.9 \pm 0.3_{\text{stat}}) \times 10^{-5}$ [3]) complies with the requests of the experiment. The technical designs are completed and both IRC and SAC are under construction.

5. – Conclusions

The photon veto system in the NA62 experiment must guarantee an average π^0 detection inefficiency lower than 10^{-8} and an angular hermeticity from 0 to 50 mrad, while each detector must provide an inefficiency smaller than 10^{-4}. Several tests have been made to asses the performance of the detectors; the measurements of the resolutions and inefficiencies were found to match all the imposed requirements. The construction of both LAV and SAV is already started and it's at an advanced stage.

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