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Exotic particle searches at NA62

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Summary. — High-intensity setup and detector performance make NA62 particularly suited for searching for new physics in the hidden sector. Sensitivity projections for these researches are reported in this work.

1. – NA62 framework

NA62 [1] is a fixed target experiment at CERN using protons from the Super-Proton-Synchrotron (SPS) facility hitting a beryllium target to produce an intense secondary beam of positive particles (∼6% of kaons) of 75 GeV/c momentum. NA62 has the main purpose to measure with 10% precision the branching fraction of the rare decay $K^+ \to \pi^+\nu\bar{\nu}$. This requires to do the association between the decaying K^+ and the π^+ by matching the upstream and downstream tracks by means of good timing detectors (∼100 ps). Moreover a $O(10^4)$ background suppression from kinematics, a $O(10^7)$ muon suppression and a hermetic photon rejection to prevent $K^+ \to \pi^+\pi^0$ decays to mimic the signal (∼10^8 rejection factor) are needed. The layout of the experiment is shown in fig. 1. The description of the experimental apparatus can be found in [1].

2. – NA62 in dump mode

NA62 has been designed and built requiring high beam rate, full particle identification, hermetic coverage and very light, high rate tracking. The NA62 collaboration is currently discussing the possibility to use a fraction of the beam time during Run 3 (2021-2023) to operate NA62 in beam-dump mode [2, 3], to search for hidden sector candidates in a MeV-GeV mass range such as Heavy Neutral Leptons (HNL), Dark Photons, Dark Scalars and Axion-Like Particles (ALPs). It is possible that we have not observed any of these potential DM candidates due to their extremely feeble interactions with the SM sector and fixed target (or beam-dump) experiments are particularly useful to search for new weakly coupled, long-lived particles in the MeV to GeV range. The high intensity at the SPS and the large production of charm mesons with the 400 GeV proton beam allow accessing a wide variety of light long-lived exotic particles. The beryllium target used by NA62 is followed by two 1.6 m long, water-cooled, beam-defining copper collimators (TAX) which can act as a dump (∼$10.7\lambda_I$). ALPs can be produced directly in the beam dump in the fusion of two photons coming from the proton-nucleus interaction (Primakoff production [4]). Although the transverse momenta of the produced ALPs are small, the detector is placed far away from the target (>100 m) and therefore covers only a small angle from the production point. Taking the detector acceptance into account and assuming that all background can be suppressed, NA62 would have a sizeable discovery potential for ALPs in the mass range of ∼30–200 MeV (fig. 2, left). Dark Photons A' can be produced in decays of mesons created in the beam dump, assuming A' is coupled to quarks, or in hard Bremsstrahlung from the beam protons. NA62 can look for visible decays of A' to e^+e^- and $\mu^+\mu^-$ pairs. Figure 2 (middle) shows the expected sensitivities assuming 2 $\times 10^{18}$ protons on target (equivalent of 2 years of running) and zero background, taking into account the trigger efficiency and detector

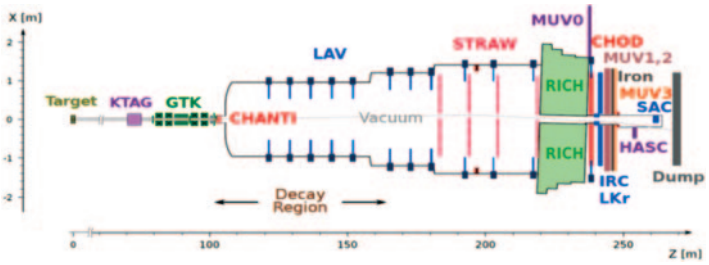

Fig. 1. – NA62 experimental layout.

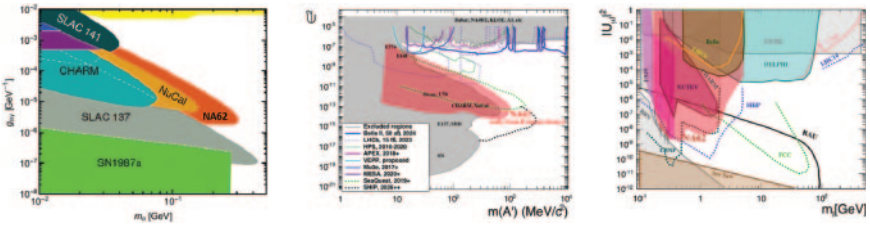

Fig. 2. – Left: projected sensitivity of NA62 in the (mass of ALP, ALP-coupling) parameter space for a number of 1×10^{18} protons on target with no background assumption; middle: NA62 sensitivity (90% CL) to A' in the ($m_{A'}$, A' coupling to γ) parameter space considering 2 years of data-taking (2×10^{18} protons on the beryllium target); right: NA62 sensitivity (90% CL) to HNL in the (mass of HNL, HNL coupling to γ) parameter space considering 2 years of data-taking [3]. Comparisons with other experiments are also shown.

acceptance. NA62 could be sensitive to even larger phase space since only production in the beryllium target is considered in this estimate, and not in the TAX. Concerning the HNL, they can be produced in decays of mesons created in the dump and NA62 can search for them in the 60 m long decay volume of the detector. Unlike the heavy neutrino search done in $K^+ \to l^+\nu$ decays, the searches for visible decays of the HNL are model dependent. Possible final states to look for are $e^\pm\pi^\mp$, $\mu^\pm\pi^\mp$ and $e^+e^-\nu$. The expected sensitivity is shown in fig. 2 (right).

During the 2016 run NA62 collected several hours of data at different intensities with a closed TAX. In addition, since the 2016 run, the trigger configuration includes chains for exotic searches which are run in parallel with the main trigger. The collected data is used for feasibility studies and tests of the zero-background hypothesis. The preliminary analysis indicates that zero background is achievable [3].

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