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$K^+ \to \pi^+ \nu\bar{\nu}$ measurement at the NA62 experiment

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Summary. — The high precision of the theoretical prediction and the strong suppression make the ultra-rare kaon decay $K^+ \to \pi^+ \nu\bar{\nu}$ an excellent probe for new physics. The NA62 experiment at CERN SPS aims to measure $BR(K^+ \to \pi^+ \nu\bar{\nu})$ with a 10% precision. NA62 collected data in 2016, 2017 and 2018. The 2016 data has been analyzed and the result published: one candidate signal event was found, showing that the decay-in-flight techinque works. The 2017 sample is currently under analysis and 2.5 ± 0.4 Standard Model signal events are expected, while the background is still under study.

1. – The $K^+ \to \pi^+ \nu\bar{\nu}$ decay

The $K^+ \to \pi^+ \nu\bar{\nu}$ decay is highly sensitive to new physics since it has a strong GIM and CKM suppression and an extremely precise theoretical prediction in the Standard Model (SM) [1]: $BR(K^+ \to \pi^+ \nu\bar{\nu}) = (0.84 \pm 0.10) \times 10^{-10}$. The current experimental value is given by the BNL E949 experiment measurement [2]: $BR^{BNL}(K^+ \to \pi^+ \nu\bar{\nu}) = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$, but its uncertainty is too high for a meaningful comparison with the theoretical prediction. The NA62 experiment aims at measuring the branching ratio with a 10% precision to allow a comparison with the SM value.

2. – Analysis strategy

A complete description of the NA62 experimental apparatus can be found in [3]. A high-energy (400 GeV) proton beam from the SPS impinges on a beryllium target, producing a high-momentum (75 GeV/c) kaon beam. The kaon decays in the fiducial volume and the charged particles and photons produced in the decay are detected. The analysis relies on kinematical separation, charged particle identification and photon rejection to reach the desired sensitivity and background rejection. The main background is given by the most common kaon decays: $K^+ \to \mu^+ \nu_\mu$, $K^+ \to \pi^+ \pi^0$ and

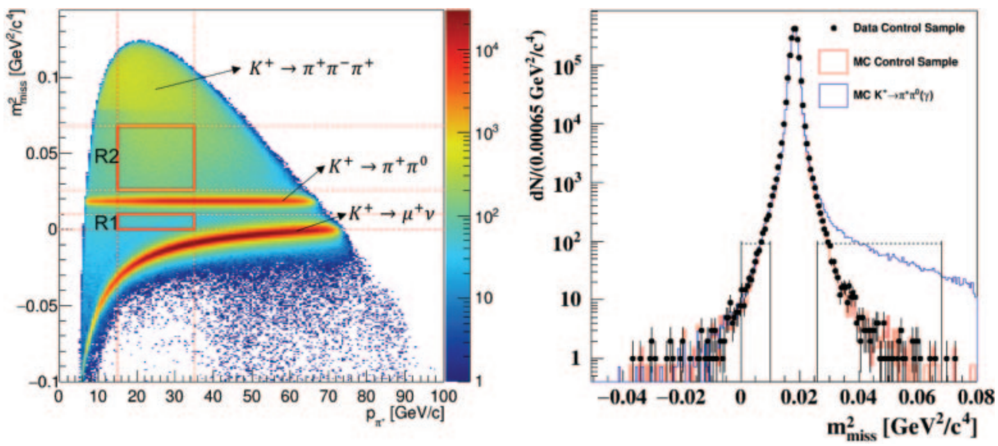

Fig. 1. – Left: m^2_{miss} as a function of the track momentum. The background channels regions are clearly visible, while the red lines define the signal regions. Right: m^2_{miss} of the $K^+ \to \pi^+\pi^0$ background for data (dots) and MC samples (colored line). The non-Gaussian tails enter the two signal regions.

$K^+ \to \pi^+\pi^-\pi^+$. The main kinematics variabile used in the analysis is the squared missing mass: $m^2_{miss} = (P_K - P_\pi)^2$, where P_K and P_π are the 4-momenta of the kaon and the charged decay particle in the pion mass hypothesis. The m^2_{miss} as a function of the track momentum is used to define two signal regions, kept blinded until the completion of the analysis, as well as control regions used to validate the background estimation (fig. 1).

3. – Preliminary results and future plans

The analysis on 2016 data [4] saw one signal candidate which allowed to set an upper limit on the $K^+ \to \pi^+\nu\bar{\nu}$ branching ratio:

$$BR(K^+ \to \pi^+\nu\bar{\nu}) < 14 \times 10^{-10} \quad \text{at } 95\% \text{ CL} \tag{1}$$

Table I. – *Expected number of background events in the signal regions.*

Process	Expected events in signal regions
$K^+ \to \pi^+\pi^0(\gamma)$	$0.35 \pm 0.02_{stat} \pm 0.03_{syst}$
$K^+ \to \mu^+\nu_\mu(\gamma)$	$0.16 \pm 0.01_{stat} \pm 0.05_{syst}$
$K^+ \to \pi^+\pi^-e^+\nu_e$	$0.22 \pm 0.08_{stat}$
$K^+ \to \pi^+\pi^-\pi^+$	$0.015 \pm 0.008_{stat} \pm 0.015_{syst}$
$K^+ \to \pi^+\gamma\gamma$	$0.005 \pm 0.005_{syst}$
$K^+ \to l^+\pi^0\nu_l$	$0.012 \pm 0.012_{syst}$
Upstream background	Analysis ongoing

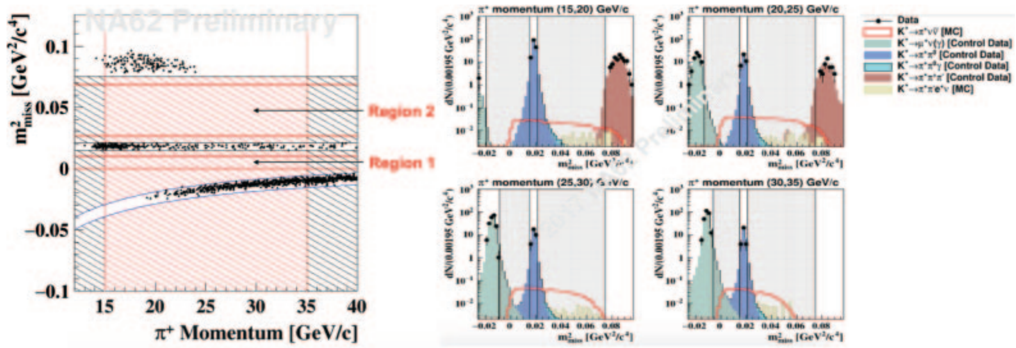

Fig. 2. – Left: m^2_{miss} as a function of the track momentum for the 2017 data sample. The signal and control regions are blinded. Right: m^2_{miss} distribution in four $5\,\text{GeV}/c$ wide momentum bins in the 15–35 GeV/c range. The signal regions are blinded. The expected signal from MC is shown as a red line, while the main background contributions obtained from data are shown in different colors, according to the legend.

This result proves that the NA62 technique to study the decay works. The analysis on 2017 data is ongoing, with a strategy similar to the one adopted for the previous year, with little improvements in the charged particle identification and photon rejection. The measured Single Event Sensitivity is $SES = (0.34 \pm 0.04) \times 10^{-10}$, 10 times better than the one achieved in 2016. This corresponds to

$$N^{SM}_{\pi\nu\nu} = 2.5 \pm 0.4 \tag{2}$$

expected SM signal events. The background estimation is ongoing, with specific focus on the so-called "upstream background", which is due to decays that happen before the fiducial volume and kaon-pion track mismatching. The expected background events in the signal regions are shown in table I. The analysis will also take advantage of the momentum dependence of m^2_{miss}, performing the signal search in four different momentum bins in the 15–35 GeV/c range, each $5\,\text{GeV}/c$ wide (fig. 2). The aim for the full 2016, 2017 and 2018 dataset is to perform a branching ratio measurement with a higher precision than the current one. Ultimately, NA62 will continue its data taking after LS2 to reach the aimed precision.

REFERENCES

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