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The $K^+ \to \pi^+ \nu\bar{\nu}$ decay: First results from the NA62 experiment

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Summary. — NA62 is a fixed target experiment installed in the CERN North Area that studies the physics of the K^+ meson. Its main purpose is to carry out a precision test of the Standard Model, measuring the branching ratio of the ultra-rare $K^+ \to \pi^+ \nu\bar{\nu}$ decay with a 10% precision, then probing New Physics evidence. NA62 collected data in 2016 and 2017, and the 2018 run is going on. The full 2016 data sample has been analysed. It shows that the new *in flight* technique for the study of the $K^+ \to \pi^+ \nu\bar{\nu}$ decay works, and 1 signal candidate event has been observed.

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

The $K^+ \to \pi^+ \nu\bar{\nu}$ decay is one of the best environments to test the Standard Model in the Flavour Physics sector, because it is very sensitive to Physics beyond the Standard Model and its very small branching ratio is precisely predicted by the theory [1]: $BR^{SM}(K^+ \to \pi^+ \nu\bar{\nu}) = (0.84 \pm 0.10) \cdot 10^{-10}$. The branching ratio measurement has already been performed by the BNL E949 Collaboration obtaining [2] $BR^{BNL}(K^+ \to \pi^+ \nu\bar{\nu}) = (1.73^{+1.15}_{-1.05}) \cdot 10^{-10}$, using kaon decays at rest. The NA62 aim is to perform the measurement with a $\simeq 10\%$ precision, comparable with the Standard Model prediction.

2. – The $K^+ \to \pi^+ \nu\bar{\nu}$ analysis

A full description of the NA62 beam and detector is provided in [3]. The following analysis is related to the 2016 data sample. All the details of the analysis, together with its results, are reported in [4].

In order to reach the expected signal sensitivity and background rejection, the analysis is based on kinematics, charged-particle identification and photon rejection.

The most relevant physics quantity to study the kinematics is the squared missing mass: $m^2_{miss} = (P_K - P_\pi)^2$, where $P_{K,\pi}$ are the 4-momenta of the beam particle (kaon) and of the decay particle under the pion hypothesis. The m^2_{miss} as a function of the

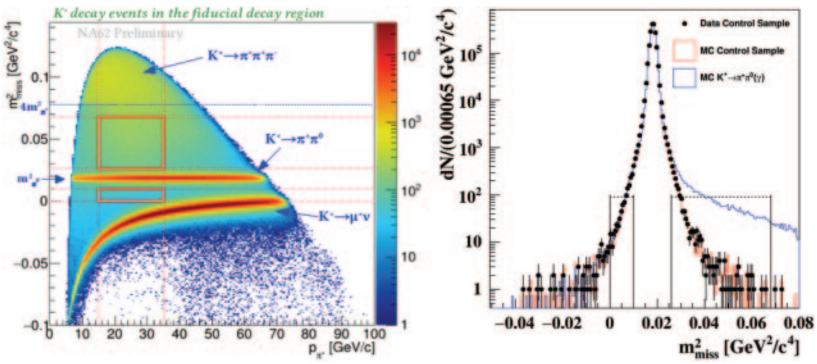

Fig. 1. – Left: m^2_{miss} as a function of the track momentum. The kinematic regions of the background channels $K^+ \to \pi^+\pi^0, K^+ \to \mu^+\nu, K^+ \to \pi^+\pi^+\pi^-$ are clearly visible. The red boxes define the two signal regions. Right: m^2_{miss} of $K^+ \to \pi^+\pi^0(\gamma)$ events in data (dots) and MC samples (red and blue lines). One can see how the tails of the distribution enter into the two signal regions.

Table I. – *Expected numbers of signal and background events in the two signal regions.*

Process	Expected events in the two signal regions
Signal: $K^+ \to \pi^+\nu\bar{\nu}$ (SM)	$0.267 \pm 0.001_{stat} \pm 0.020_{syst} \pm 0.032_{ext}$
$K^+ \to \pi^+\pi^0(\gamma)$	$0.064 \pm 0.007_{stat} \pm 0.006_{syst}$
$K^+ \to \mu^+\nu(\gamma)$	$0.020 \pm 0.003_{stat} \pm 0.003_{syst}$
$K^+ \to \pi^+\pi^+\pi^-$	$0.002 \pm 0.001_{stat} \pm 0.002_{syst}$
$K^+ \to \pi^+\pi^-e^+\nu$	$0.018^{+0.024}_{-0.017}\|_{stat} \pm 0.009_{syst}$
upstream background	$0.050^{+0.090}_{-0.030}\|_{stat}$
Total background	$0.15 \pm 0.09_{stat} \pm 0.01_{syst}$

track momentum is used to identify the different kinematic regions, both for the signal and the background channels (fig. 1, left). The two signal regions are blinded during the analysis.

The signal acceptance is estimated through Monte Carlo simulation, while the expected background in the two signal regions is evaluated extrapolating the tails of the background channels distributions (fig. 1, right). Control regions are defined between the background and the signal regions in order to validate the background estimations.

The measured Single Event Sensitivity is $SES = (3.15 \pm 0.01_{stat} \pm 0.24_{syst}) \cdot 10^{-10}$, where the main contribution to the systematic error is given by the measurement of the random veto efficiency.

The expected numbers of events in the two signal regions, for both the signal and the background, are summarised in table I. The *upstream background* contribution is due to events with a decay before the fiducial region and an accidental kaon-pion matching.

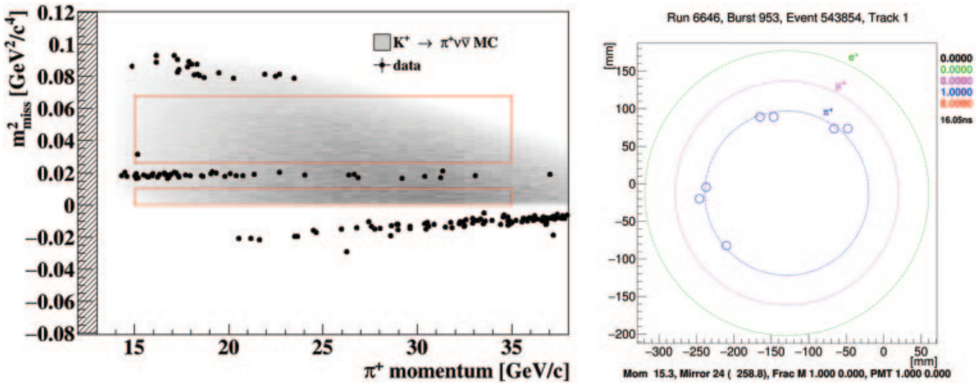

Fig. 2. – Left: m^2_{miss} as a function of the track momentum for events that pass the $K^+ \to \pi^+\nu\bar{\nu}$ selection. The gray area corresponds to the distribution of the $K^+ \to \pi^+\nu\bar{\nu}$ MC events. The red boxes define the two signal regions. The event observed in the signal region 2 is shown. Right: position of the hits in the Ring Imaging Cherenkov (RICH) detector forming the ring associated to the pion track in the observed signal event. The circles illustrate the positron, muon and pion hypotheses, showing a perfect agreement with the pion one.

3. – Results and prospectives

Unblinding the signal region one $K^+ \to \pi^+\nu\bar{\nu}$ candidate event is observed (fig. 2). An upper limit on the $K^+ \to \pi^+\nu\bar{\nu}$ branching ratio is then obtained:

$$BR(K^+ \to \pi^+\nu\bar{\nu}) < 14 \cdot 10^{-10} \,@\, 95\% \, CL \tag{1}$$

in agreement with both the Standard Model prediction and the previous measurements.

The 2016 data analysis proves that the NA62 technique to study the $K^+ \to \pi^+\nu\bar{\nu}$ decay works. For the 2017 and 2018 data a reduction of the background and an increase of the signal selection efficiency are expected, because of both off-line analysis improvements and forseen hardware interventions. From the complete data sample, the sensitivity of about 20 Standard Model $K^+ \to \pi^+\nu\bar{\nu}$ events is supposed to be reached.

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