IL NUOVO CIMENTO **41 C** (2018) 46
DOI 10.1393/ncc/i2018-18046-3

Colloquia: IFAE 2017

Prospects for an experiment to measure $BR(K_L \to \pi^0 \nu\bar{\nu})$ at the CERN SPS

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received 21 April 2018

Summary. — We are investigating the feasibility of performing a measurement of $BR(K_L \to \pi^0 \nu\bar{\nu})$ using a high-energy secondary neutral beam at the CERN SPS in a successor experiment to NA62, to run in LHC Run 4. Some preliminary conclusions from our feasibility studies, a description of the design challenges faced, and the sensitivity obtainable for the measurement are presented here.

1. – Introduction

Precise measurements of the branching ratios for the $K \to \pi\nu\bar{\nu}$ decays can provide unique constraints on CKM unitarity and, potentially, evidence for new physics. It is important to measure both decay modes, $K^+ \to \pi^+\nu\bar{\nu}$ and $K_L^0 \to \pi^0\nu\bar{\nu}$, since different new physics models affect the rates for each channel differently. The NA62 experiment at the CERN SPS is now running with the goal of measuring $BR(K^+ \to \pi^+\nu\bar{\nu})$. In the same site, a new experiment using a high-energy secondary neutral beam could be performed for the measurement of $BR(K_L^0 \to \pi^0\nu\bar{\nu})$ with a technique complementary to the upgrade of the KOTO experiment at J-PARC [1] and a comparable sensitivity.

2. – Plans for a measurement of $BR(K_L \to \pi^0\nu\bar{\nu})$ at SPS

The proposed experiment makes use of a 400 GeV primary proton beam incident on a 400 mm beryllium rod target at an angle of 2.4 mrad, which optimizes the K_L to neutron and photon flux ratios according to existing data on forward kaon production [2] and FLUKA simulations. The beamline design includes a system of three collimators and an absorber to reduce the huge rate of photons. The polar-angle acceptance of the secondary beam is 0.3 mrad; the beam contains about 2.8×10^{-5} K_L's per proton incident on the target (pot). The K_L momentum distribution peaks around 35 GeV/c and has a mean at about 97 GeV/c. There are 6.3×10^{-7} K_L decays in the fiducial volume per pot. Assuming the SM value of $BR(K_L \to \pi^0\nu\bar{\nu})$ and an acceptance fraction of 10%,

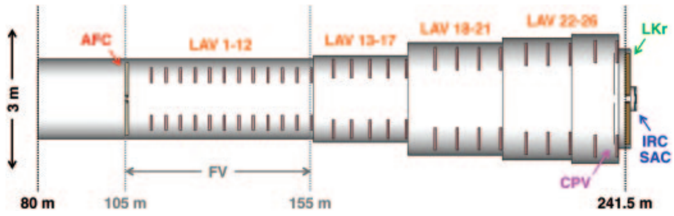

Fig. 1. – Schematic layout of the experiment.

to observe 100 signal events, about 3×10^{13} K_L's must decay in the fiducial volume. Thus, an integrated proton flux of 5×10^{19} pot is required, which we assume is delivered at a rate of 10^{19} pot/yr over the course of five years. This is 6 times larger than the current intensity at NA62; therefore, extensive upgrades to the beamline cavern will be needed. The planned experiment would reuse the NA48 liquid-krypton calorimeter together with new systems of photon veto detectors to extend the coverage in the polar angle. A sketch of the experiment is shown in fig. 1. The K_L momentum is broadly distributed, and a large fraction of background photons are emitted at large polar angle. The photon veto system is required to cover polar angles up to 100 mrad and to be highly efficient down to 100 MeV. These requirements are not satisfied by the existing NA62 Large Angle Vetoes (LAVs), and we plan to construct 26 new LAVs with a different geometry. One possible design for the LAVs would be similar to the Vacuum Veto System detectors planned for the CKM experiment at Fermilab [3]. One of the main challenges of the experiment will be the design of detector to veto the photons at small polar angle (SAC). The SAC must intercept photons from K_L decays that would otherwise pass undetected through the beam pipe, and so is traversed by the neutral beam itself. According to a preliminary FLUKA and GEANT4 simulation of the beamline, the beam contains 3 GHz of neutrons and 700 MHz of photons, to which the detector must be as insensitive as possible. The design studies for this veto detector are ongoing. Furthermore, an Intermediate Ring Calorimeter (IRC) must not intercept the beam but must cover the LKr bore to detect photons from downstream decays. A fast simulation study has been performed in order to estimate the most important background from K_L decays, which turns out to be $K_L \to \pi^0\pi^0$. Events are selected if there are exactly two hits in the LKr and no hits on any of the veto detectors. By imposing the π^0 mass, the invariant mass of the two photons is used to get the z position of the π^0 vertex, which is required to be inside of the fiducial volume. After all of the kinematic cuts, out of 9.6×10^8 generated signal events, 1.9×10^6 are selected, while out of 1.2×10^{12} generated $K_L \to \pi^0\pi^0$, 111 are

Channel	Events expected in 5 years
$K_L \to \pi^0 \nu\nu$	97
$K_L \to \pi^0\pi^0$	111
$K_L \to \pi^0\pi^0\pi^0$	15
$K_L \to \gamma\gamma$	0
$K_L \to$ charged	thought to be reducible

Fig. 2. – Estimated final selected events.

selected. The expected number of selected events in five years of data taking for the signal (SM BR assumption) and the main background modes are listed in the table in fig. 2.

Further study and optimization are still needed, but from these preliminary studies we conclude that a measurement of $BR(K_L \to \pi^0 \nu\bar{\nu})$ at CERN SPS is feasible with no major change in the infrastructure at the NA62 site, apart from the intensity upgrade.

REFERENCES

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