IL NUOVO CIMENTO **41 C** (2018) 49
DOI 10.1393/ncc/i2018-18049-0

Colloquia: IFAE 2017

Results and prospects of the NA62 experiment at CERN

Jacopo Pinzino(*)

INFN, Sezione di Pisa - Pisa, Italy

received 21 April 2018

(*) For the NA62 Collaboration: G. Aglieri Rinella, R. Aliberti, F. Ambrosino, R. Ammendola, B. Angelucci, A. Antonelli, G. Anzivino, R. Arcidiacono, I. Azhinenko, S. Balev, M. Barbanera, J. Bendotti, A. Biagioni, L. Bician, C. Biino, A. Bizzeti, T. Blazek, A. Blik, B. Bloch-Devaux, V. Bolotov, V. Bonaiuto, M. Boretto, M. Bragadireanu, D. Britton, G. Britvich, M.B. Brunetti, D. Bryman, F. Bucci, F. Butin, J. Calvo, E. Capitolo, C. Capoccia, T. Capussela, A. Cassese, A. Catinaccio, A. Cecchetti, A. Ceccucci, P. Cenci, V. Cerny, C. Cerri, B. Checcucci, O. Chikilev, S. Chiozzi, R. Ciaranfi, G. Collazuol, A. Conovaloff, P. Cooke, P. Cooper, G. Corradi, E. Cortina Gil, F. Costantini, F. Cotorobai, A. Cotta Ramusino, D. Coward, G. D'Agostini, J. Dainton, P. Dalpiaz, H. Danielsson, J. Degrange, N. De Simone, D. Di Filippo, L. Di Lella, S. Di Lorenzo, N. Dixon, N. Doble, B. Dobrich, V. Duk, V. Elsha, J. Engelfried, T. Enik, N. Estrada, V. Falaleev, R. Fantechi, V. Fascianelli, L. Federici, S. Fedotov, A. Filippi, M. Fiorini, J. Fry, J. Fu, A. Fucci, L. Fulton, S. Gallorini, S. Galeotti, E. Gamberini, L. Gatignon, G. Georgiev, S. Ghinescu, A. Gianoli, M. Giorgi, S. Giudici, L. Glonti, A. Goncalves Martins, F. Gonnella, E. Goudzovski, R. Guida, E. Gushchin, F. Hahn, B. Hallgren, H. Heath, F. Herman, T. Husek, O. Hutanu, D. Hutchcroft, L. Iacobuzio, E. Iacopini, E. Imbergamo, O. Jamet, P. Jarron, E. Jones, T. Jones K. Kampf, J. Kaplon, V. Kekelidze, S. Kholodenko, G. Khoriauli, A. Khotyantsev, A. Khudyakov, Yu. Kiryushin, A. Kleimenova, K. Kleinknecht, A. Kluge, M. Koval, V. Kozhuharov, M. Krivda, Z. Kucerova, Yu. Kudenko, J. Kunze, G. Lamanna, G. Latino, C. Lazzeroni, G. Lehmann-Miotto, R. Lenci, M. Lenti, E. Leonardi, P. Lichard, R. Lietava, V. Likhacheva, L. Litov, R. Lollini, D. Lomidze, A. Lonardo, M. Lupi, N. Lurkin, K. McCormick, D. Madigozhin, G. Maire, C. Mandeiro, I. Mannelli, G. Mannocchi, A. Mapelli, F. Marchetto, R. Marchevski, S. Martellotti, P. Massarotti, K. Massri, P. Matak, E. Maurice, M. Medvedeva, A. Mefodev, E. Menichetti, E. Migliore, E. Minucci, M. Mirra, M. Misheva, N. Molokanova, J. Morant, M. Morel, M. Moulson, S. Movchan, D. Munday, M. Napolitano, I. Neri, F. Newson, J. Noëel, A. Norton, M. Noy, G. Nuessle, T. Numao, V. Obraztsov, A. Ostankov, S. Padolski, R. Page, V. Palladino, G. Paoluzzi, C. Parkinson, E. Pedreschi, M. Pepe, F. Perez Gomez, M. Perrin-Terrin, L. Peruzzo, P. Petrov, F. Petrucci, R. Piandani, M. Piccini, D. Pietreanu, J. Pinzino, I. Polenkevich, L. Pontisso, Yu. Potrebenikov, D. Protopopescu, F. Raffaelli, M. Raggi, P. Riedler, A. Romano, P. Rubin, G. Ruggiero, V. Russo, V. Ryjov, A. Salamon, G. Salina, V. Samsonov, C. Santoni, G. Saracino, F. Sargeni, V. Semenov, A. Sergi, M. Serra, A. Shaikhiev, S. Shkarovskiy, I. Skillicorn, D. Soldi, A. Sotnikov, V. Sugonyaev, M. Sozzi, T. Spadaro, F. Spinella, R. Staley, A. Sturgess, P. Sutcliffe, N. Szilasi, D. Tagnani, S. Trilov, M. Valdata-Nappi, P. Valente, M. Vasile, T. Vassilieva, B. Velghe, M. Veltri, S. Venditti, P. Vicini, R. Volpe, M. Vormstein, H. Wahl, R. Wanke, P. Wertelaers, A. Winhart, R. Winston, B. Wrona, O. Yushchenko, M. Zamkovsky, A. Zinchenko; E-mail: jacopo.pinzino@cern.ch

Summary. — $K^+ \to \pi^+ \nu\overline{\nu}$ is one of the theoretically cleanest meson decay where to look for indirect effects of new physics complementary to LHC searches. The NA62 experiment at CERN SPS is designed to measure the branching ratio of this decay with 10% precision. NA62 started to take date with a good beam intensity in 2016. The analysis of the 5% of 2016 data acquired, in view of the final measurement, will be presented.

1. – The NA62 experiment

The NA62 experiment is located in the CERN North Area SPS extraction site and it aims at measuring the Branching Ratio of the ultra-rare FCNC kaon decay $K^+ \to \pi^+ \nu\overline{\nu}$ collecting about 100 events in two years of data taking [1]. This decay is a very useful process to study flavour physics and to obtain a stringent test of the Standard Model (SM); the Branching Ratio (BR) of these decays can be computed with high precision [2], $BR(K^+ \to \pi^+ \nu\overline{\nu})(SM) = 8.4 \pm 1.0 \times 10^{-11}$ where the uncertainty is dominated by the current precision of the CKM mixing matrix input parameters.

The strong suppression of the SM contributions and the remarkable theoretical precision of the SM rate make this decay a powerful probe for possible new physics. The combination of the branching ratio of these two decays ($K^+ \to \pi^+ \nu\overline{\nu}$ and $K^0 \to \pi^0 \nu\overline{\nu}$) allows to determine the β angle of the unitarity triangle from K decays only and, in this way, to have a powerful test on the standard model.

The most accurate measurement of this decay, $BR(K^+ \to \pi^+ \nu\overline{\nu}) = 17.3^{+11.5}_{-10.5} \times 10^{-11}$, was obtained by the E787 experiment and its upgrade E949 at BNL (from 1995 to 2002) which collected seven events [3]. NA62 aims at improving the measurement of this branching ratio reaching a precision of at least 10%.

2. – NA62 experimental setup

The NA62 experiment [4] uses protons at $400\,\mathrm{GeV}/c$ coming from the Super-Proton-Synchrotron (SPS) hitting a beryllium target to generate a secondary beam of positive particles. The secondary beam is composed of π^+(70%), p (23%) and K^+(6%) with an average momentum of $75\,\mathrm{GeV}/c$.

The $K^+ \to \pi^+ \nu\overline{\nu}$ signature is one track in the final state matched in time with one K^+ track upstream the decay region and nothing else, because the two neutrinos are undetectable. The K^+ in the beam are identified by the KTAG, a nitrogen differential Cherenkov detector. The momentum and directions of all beam particles are measured with the Gigatracker made of three stations of silicon hybrid pixels. The charged decay products are tracked by a magnetic straw chambers spectrometer and are identified using a ring imaging Cherenkov detector (RICH), a hadronic calorimeter (HCAL) and a muon veto detector made of fast scintillators. The most important source of background is the $K^+ \to \pi^+ \pi^0$ decay, where the two photons from the π^0 are missed. A photon veto system is designed to reject these events. It is composed of a Large-Angle Veto (LAV) detector made of 12 stations of lead-glass rings, a liquid krypton (LKr) electromagnetic calorimeter and two shashlik calorimeters.

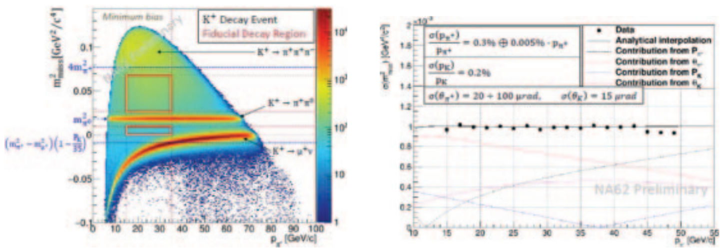

Fig. 1. – m^2_{miss} distribution under π^+ mass hypothesis as a function of the momentum of the track measured in the straw spectrometer after a selection for single track from kaon decays (left). Resolution of the m^2_{miss} miss *vs.* momentum, with the kaon momentum measured by GTK (right).

Let P_K and P_π be the 4-momenta of K^+ and of the charged particle produced from the kaon decay under the π^+ hypothesis, respectively. The squared missing mass, $m^2_{miss} \stackrel{def}{=} (P_K - P_{\pi^+})^2$, has a three-body decay shape; it can be used to separate the signal from the main kaon decays, defining two signal regions around the $K^+ \to \pi^+\pi^0$ peak. Information from the particle identification system are useful to suppress decays with muons and positrons in the final state and the hermetic photon veto system is used to reject events with photons. In the final analysis two other requirements are applied: the decay vertex has to be found in the first 65 m of the decay volume and the reconstructed downstream particle must have a momentum between 15 GeV/c and 35 GeV/c.

3. – Preliminary result of the 2016 run

The main goal of the 2016 run is to assess the experiment sensitivity at the level of 10^{-10}; this work shows the result obtained with the analysis of 2.3×10^{10} K^+ decays that is about the 5% of the 2016 data recorded at 40% of the nominal intensity. A single track selection was chosen as a preliminary step towards the $K^+ \to \pi^+\nu\overline{\nu}$ measurement. We selected tracks reconstructed in the STRAW spectrometer matching with energy depositions in calorimeters. The downstream track has to match a Gigatracker track in

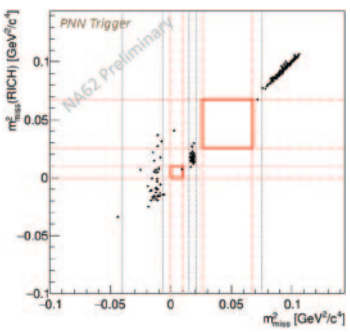

Fig. 2. – m^2_{miss} distribution using the information obtained from the RICH detector as a function of m^2_{miss} using STRAW information. The event in the first box is outside of the signal region if we use even the m^2_{miss} distribution computed with the nominal beam momentum (without the GTK).

time and space, forming a vertex in the decay region with it, in order to select events originating from kaon decays. The Gigatracker track has to be in-time with a kaon-like signal in KTAG. The m^2_{miss} distribution for the 2016 data, recorded at 40% of the nominal intensity and computed using the GTK and the STRAW spectrometer, together with its resolution are shown in fig. 1. Two different versions of the m^2_{miss}, computed using the information obtained from the RICH detector as an alternative to the STRAW spectrometer or using the nominal momentum of the beam, are useful to improve the kinematical suppression (see fig. 2).

The resolution of the m^2_{miss} is measured using the width of the $K^+ \to \pi^+\pi^0$ peak and it is found to be $1 \times 10^{-3}\,\mathrm{GeV}^2/c^4$, close to design value. The resolution as a function of momentum is shown in fig. 1. The tracking system of NA62 is also designed to provide a rejection factor of about 10^4 for $K^+ \to \pi^+\pi^0$ and $K^+ \to \mu^+\nu$ using m^2_{miss} to separate signal from backgrounds, respectively. The measured fraction of $K^+ \to \pi^+\pi^0$ and $K^+ \to \mu^+\nu$ events in the signal region are, respectively, about 6×10^{-4} and 3×10^{-4}.

The NA62 particle identification is designed to separate π^+ from μ^+ and e^+ in order to guarantee a suppression factor of 10^7 for $K^+ \to \mu^+\nu$ in addition to the kinematic rejection. The $K^+ \to \pi^+\pi^0$ sample used for kinematic studies and a pure muon sample of $K^+ \to \mu^+\nu$ were used to study the $\pi^+ - \mu^+$ separation in RICH and calorimeters. A muon contamination of 1% was achieved with the RICH and a π^+ ID efficiency of 80% measured in a momentum region between 15 and $35\,\mathrm{GeV}/c$. The RICH provides also an even better separation between π^+ and e^+. The calorimeters provide, on the same π^+ and μ^+ samples, a muon suppression factor of about 10^5 for a π^+ efficiency of 80%. Several analysis techniques are under study to get the optimal separation.

The photon veto system is designed to suppress decays with photons and π^0 in the final state. The measured π^0 efficiency on the 2016 data is $(1.2 \pm 0.2) \times 10^{-7}$. The corresponding signal efficiency is above 90%, being the losses mainly due to π^+ interactions in the RICH material producing extra clusters in LKr.

After the particle identification no events of 2.3×10^{10} K^+ decays (about the 5% of the 2016 data) are inside the signal region.

To conclude, the preliminary analysis of 2016 data, obtained at 40% of nominal beam intensity, is promising and NA62 is approaching the 2016 goal to test the sensitivity for measuring $K^+ \to \pi^+\nu\bar{\nu}$ down to 10^{-10}.

REFERENCES

[1] Anelli G. *et al.*, *Proposal to measure the rare decay $K^+ \to \pi^+\nu\bar{\nu}$ at the CERN SPS*, CERN Report (2005).
[2] Buras Andrzej J. *et al.*, *JHEP*, **11** (2015) 33, arXiv:1503.02693 [hep-ex].
[3] Artamonov A. V. *et al.*, *Phys. Rev. Lett.*, **101** (2008) 191802, arXiv:0808.2459 [hep-ex].
[4] Cortina Gil E. *et al.*, *JINST*, **12** (2017) P05025, arXiv:1703.08501 [physics.ins-det].