IL NUOVO CIMENTO **41 C** (2018) 52
DOI 10.1393/ncc/i2018-18052-5

Colloquia: IFAE 2017

Status of the KLOE-2 experiment at DAΦNE

Andrea Selce(*) on behalf of the KLOE-2 Collaboration
Dipartimento di Matematica e Fisica Università Roma Tre and INFN Roma Tre - Roma, Italy

received 21 April 2018

Summary. — The KLOE-2 experiment, at the INFN Frascati National Laboratories, represents the continuation of the KLOE experiment. Compared to the previous detector, consisting of a drift chamber and an electromagnetic calorimeter both immersed in a 0.5 T magnetic field, the apparatus has been upgraded with several new detectors; the goal is to study $\gamma\gamma$ interactions and to improve calorimeter hermeticity and spatial resolution on the vertex position. A single-photon trigger logic was also implemented. The program is to perform high-precision CPT symmetry and quantum coherence tests using neutral kaons, $\gamma\gamma$-physics studies and searches of particles of hidden dark-matter sectors, togheter with hadron physics below 1 GeV. KLOE-2 started data taking in November 2014 and is presently collecting data, with the target to collect more than 5 fb^{-1} integrated luminosity before end of March 2018.

1. – Introduction

The KLOE-2 experiment [1] at the INFN Frascati National Laboratories (LNF) represents the continuation of the KLOE experiment, ended in 2005 after collecting 2.5 fb^{-1} integrated luminosity. Both experiments were placed at the DAΦNE ϕ-factory, an e^+e^- collider with center-of-mass energy of 1019.4 MeV, the mass of the ϕ-meson. KLOE-2 started the data taking campaign in November 2014, with the target to collect more than 5 fb^{-1} before the end of March 2018. After 3.5 years of data taking (until end of June 2017), the KLOE-2 experiment collected a total of 3.9 fb^{-1} of the 4.9 fb^{-1} delivered by DAΦNE.

2. – The KLOE-2 detector

Along with the pre-existing KLOE detector, consisting of a drift chamber and a calorimeter, new detectors have been installed: a novel cylindrical GEM Inner Tracker (IT) to improve tracking and vertexing, four tagging stations (two LETs and two HETs)

(*) E-mail: `andrea.selce@roma3.infn.it`

for $\gamma\gamma$-physics studies and new calorimeters (QCALTs and CCALTs) to enlarge the angular acceptance of the apparatus.

Drift chamber and electromagnetic calorimeter. The KLOE detector consisted of a large Drift Chamber (DC) and an Electromagnetic Calorimeter (EMC), both immersed in a 0.5 T axial magnetic field provided by a superconductive coil. The drift chamber [2] is a multi-wire proportional chamber, with full stereo-geometry, that accomplishes track reconstruction with high momentum resolution ($\sigma_p/p = 0.4\%$), providing $\simeq 150\,\mu$m spatial resolution in the bending plane. Cluster reconstruction is performed by the Pb-scintillating fibers calorimeter [3] with $\sigma_E/E = 5.7\%/\sqrt{E\,(\mathrm{GeV})}$ and $\sigma_t = 54\,\mathrm{ps}/\sqrt{E\,(\mathrm{GeV})} \oplus 140\,\mathrm{ps}$, with 98% of solid angle coverage. The DC and EMC performance turn out to be very stable in time, despite the very different operational conditions of the present KLOE-2 data taking, with about five times more background than in the past.

The taggers. Low-Energy Taggers (LETs) and High-Energy Taggers (HETs) have been installed to detect electrons and positrons scattered in $e^+e^- \to e^+e^-\gamma^*\gamma^* \to e^+e^-X$ reactions. Two identical LET stations [4], each consisting of an array of 5×4 LYSO crystals read out by a Silicon Photomultiplier (SiPM), have been placed symmetrically at 1 m at both sides of the IP, in order to tag electrons and positrons with energy $160 < E < 400\,\mathrm{MeV}$. Similarly, to tag $e^\pm$ with energy greater than 420 MeV two HET stations [4] have been placed at 11 m away from the IP, in symmetrical positions. The sensitive area of each HET detector is made up of a set of 28 plastic scintillators. Light emitted from each $3 \times 5 \times 6\,\mathrm{mm}^3$ plastic scintillator is read out througth plastic light guide by photomultipliers.

New calorimeters. Two new Quadrupole CALorimeters with Tiles (QCALTs [5]) have been installed at both sides of the Interaction Point (IP), around the DAΦNE *low-*β quadrupoles. Each 1 m long sampling calorimeter consists of 5 layers of 5 mm thick scintillator plates, alternated with 3.5 mm thick tungsten plates, for a total $\sim 5\,X_0$, optically connected to the SiPM. In order to enlarge the angular acceptance down to 10°, with the aim of improving multi-photon detection in rare decays such as $K_S \to \gamma\gamma$, $\eta \to \pi^0\gamma\gamma$ and $K_S \to 3\pi^0$, two identical Crystal CALorimeters with Timing (CCALTs) [5] have been mounted very close to the IP, near the first focusing quadrupoles of DAΦNE. Each CCALT module is made of 4 aluminum shells, with projective geometry, containing 4 LYSO crystals readout by SiPM.

The inner tracker. The Inner Tracker (IT) [6] is a novel ultra-light detector inserted in the free space between the beam pipe and the DC inner wall, to improve the resolution on decay vertices close to the IP. A low material budget (below 2% X_0) allows to minimize dead spaces, multiple scattering of low-momentum tracks, photon conversions and kaon regeneration. The IT is composed by four concentric Cylindrical GEM (CGEM) [7] detectors, each consisting of a triple-GEM detector with $650\,\mu$m longitudinal X strips pitch, filled with a Ar:iC_4H_{10} 90:10 gas mixture.

A first set of alignment and calibration parameters, obtained from cosmic-ray muons without magnetic fields, shows a spatial resolution of about $400\,\mu$m. Compared to the DC only case, the combination of IT and DC information in the $\phi \to \pi^+\pi^-\pi^0$ decay shows an increse of about $\sim$35% on resolution on the Point of Closest Approach (PCA) of the tracks to the beam line, and improvement on the vertex resolution, too. Recently, a second set of parameters allowed spatial resolutions to go below 400 μm for three of the four layers.

The single-photon trigger. The Single-Photon Trigger (SPT) logic was permanently added to the standard trigger since November 2016. The SPT triggers at least one energy cluster in the barrel, with a nominal threshold of 350 MeV. The goal is to trigger events with photon and dark boson associated production. With this threshold, dark boson mass up to 600 MeV could be explored. The SPT adds only 300 Hz over the standard KLOE-2 trigger.

3. – Physics at KLOE-2

The KLOE-2 experiment is a unique environment for several kinds of studies [8]. The ϕ-meson decays ∼34% of the times in a $K_S - K_L$ entangled state. Detecting one of the two mesons it is possible to select a pure sample of the other meson. This tagging technique allows very precise measurements, including K_S Branching Ratios (BR) in semileptonic decays and in rare CP-violating decays ($K_S \rightarrow 3\pi$). The entangled state also allows studies of discrete symmetries, like CP and CPT violations, with different methods. The upgrade of the detector with the taggers allows studies on $\gamma\gamma$-physics. Searches of dark bosons are also possible in different channels, with the dark bosons decaying in Standard Model particles inside the detector; now, with the new single-photons trigger, it is possible to also tag dark bosons decaying in light dark particle, or outside the detector. Hadron physics below 1 GeV measurement are possible.

Several articles were published in the last years in all of these research fields.

The most recent one is the measurement of the running of the α_{QED} in the $e^+e^- \rightarrow \mu^+\mu^-$ process, with the KLOE data [9]. This is the first ever measurement of the α_{QED} running below 1 GeV: the hypotesis of a leptonic only contribution to α_{QED} is excluded at ∼6 standard deviations.

Meanwhile analysies on new data started, for example, on the direct search of the rare CP-violating decay $K_S \rightarrow \pi^0\pi^0\pi^0$. The present KLOE limit for this decay is $\mathrm{BR}(K_S \rightarrow \pi^0\pi^0\pi^0) < 2.6 \times 10^{-8}$ at 90% CL, with 1.7 fb^{-1} [10]. For the KLOE-2 data, some selection criteria for the signal region definition have been hardened to cope with increased background. Untill now, 224 pb^{-1} of the KLOE-2 new data have been analyzed without evidence of signal, giving an upper limit of $\mathrm{BR}(K_S \rightarrow \pi^0\pi^0\pi^0) < 1.8 \times 10^{-7}$ at 90% CL.

4. – Conclusions

KLOE-2 is presently taking data at the DAΦNE e^+e^- collider, with the goal to collect more than 5 fb^{-1} before end of March 2018. Sub-detectors has been optimized and their performances are within expectations. Physics analyses with the old and new data samples are in progress.

REFERENCES

[1] Bossi F. and KLOE Collaboration, *Nuovo Cimento*, **30** (2008) 10.
[2] Adinolfi M. *et al.*, *Nucl. Instrum. Methods A*, **488** (2002) 51.
[3] Adinolfi M. *et al.*, *Nucl. Instrum. Methods A*, **482** (2002) 364.

[4] Babusci D. *et al.*, *Acta Phys. Pol. B*, **46** (2015) 81.
[5] Happacher F. and Martini M., *Acta Phys. Pol. B*, **46** (2015) 87.
[6] Archilli F. *et al.*, arXiv:1002.2572v1 and LNF-10/3(P), INFN-LNF, Frascati (2010).
[7] Bencivenni G. and Domenici D., *Nucl. Instrum. Methods A*, **581** (2007) 581.
[8] Amelino-Camelia G. *et al.*, *Eur. Phys. J. C*, **68** (2010) 619.
[9] Anastasi A. *et al.*, *Phys. Lett. B*, **767** (2017) 485.
[10] Babusci D. *et al.*, *Phys. Lett. B*, **723** (2013) 54.