Review on $\gamma\gamma$ physics at KLOE-2

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Abstract. The $\gamma\gamma$ physics at KLOE-2 experiment is made possible after the recent KLOE upgrade with new small angle tagging detectors along the DAFNE beam line. These taggers allow to detect the final leptons coming from process $e^+e^- \rightarrow e^+e^-\gamma^*\gamma^*$ giving the possibility to measure the transition form factor of the pseudoscalar mesons. These measurements provide constraints to the models used to calculate the hadronic light-by-light contribution to the muon anomaly. The KLOE-2 prospects for $\gamma\gamma$ physics of the new data-taking, started in November 2014 with the upgraded detector, are reviewed.

1 Introduction

The KLOE-2 data taking started in November 2014, with the goal to collect at least 5 fb^{-1} of integrated luminosity in 2 - 3 years. Until June 2015 DAΦNE provided 1 fb^{-1} of luminosity, that has been collected by KLOE-2 with an efficiency of about 80%. During this period the DAΦNE peak luminosity was about $2{\times}10^{32}$ cm^{-2} s^{-1}, and the integrated luminosity collected in a day was about 10 pb^{-1}.

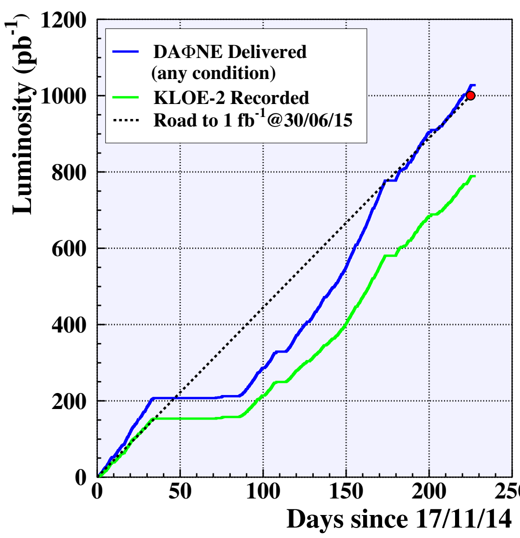

Figure 1. Integrated luminosity collected by KLOE-2 since the start of the new data-taking.

One of the main items of the KLOE-2 physics program [1] is the measurement of the Transition Form Factors (TFFs) of the pseudoscalar mesons both in the space-like and in time-like region of momentum transfer. The TFFs describe the coupling of mesons to photons and provide information about the nature of the mesons and their structure.

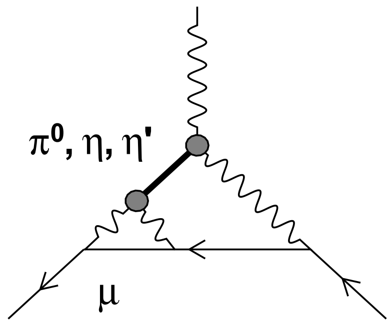

Figure 2. Dominant contribution to the hadronic LbL scattering for the (g-2)$_\mu$ theoretical calculation.

Recently the interest in the TFFs has been renewed since they are an essential ingredient in the calculation of the hadronic Light-by-Light (LbL) scattering contribution to the anomalous magnetic moment of the muon [2]. The leading contribution to the LbL scattering is the single pseudoscalar exchange where the TFFs enter at the vertices connecting the pseudoscalar to photons.

The calculation of this contribution is model dependent since the exchanged meson is off-shell, and the TFFs for off-shell meson are not measurable quantities.

Nevertheless any experimental information, both for space-like and time-like squared momentum transfer q^2, can help in constraining the models used in the calculations.

Another physics item that will be addressed by KLOE-2 is the $\gamma\gamma$ physics, *i.e.* processes like $e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-X$, where X is a final state with even

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charge conjugation. The expected number of events as a function of the $\gamma\gamma$ energy $W_{\gamma\gamma}$ can be parameterized by the following expression:

$$\frac{dN}{dW_{\gamma\gamma}} = L_{int}\frac{dF}{dW_{\gamma\gamma}}\sigma_{\gamma\gamma\to X} \quad (1)$$

where L_{int} is the integrated luminosity, $\sigma_{\gamma\gamma\to X}$ the $\gamma\gamma$ cross-section, and $\frac{dF}{dW_{\gamma\gamma}}$ is the luminosity function. Since DAΦNE is operated at $\sqrt{s} \simeq M_\phi$, the accessible final state are either single pseudoscalar, $X = \eta$, π^0, or the double pion production, $X = \pi\pi$.
The cross-section for single pseudoscalar is:

$$\sigma_{\gamma\gamma\to X}(q_1^2, q_2^2) = \frac{8\pi^2}{M_X}\Gamma(X \to \gamma\gamma)\left|F(q_1^2, q_2^2)\right|^2 \quad (2)$$

with $(q_1^2 + q_2^2) = M_X^2$.

Then the radiative width $\Gamma(X \to \gamma\gamma)$ of the pseudoscalar meson, and the TFF $F(q_1^2, q_2^2)$ for space-like q^2 can be measured. Concerning the double pion final state, it is interesting to study the production of the lowest mass scalar meson $f_0(500)$, but it is also important for the new dispersive approach proposed for the hadronic LbL scattering [3].

2 Detector upgrade

As a first step of the detector upgrade, a tagger system for scattered electrons and positrons in $\gamma\gamma$ processes has been installed already in 2010. It consists of two different devices: the Low Energy Tagger (LET) and the High Energy Tagger (HET), referring to the energy of the detected electrons or positrons.

2.1 The Low Energy Tagger

The LET [4] has been designed to detect $e^\pm$ with energy between 150 and 350 MeV escaping from the beam-pipe, and it is placed at about 1 m from the IP. Since in this region there is no correlation between the energy and the scattering angle of the particles, a calorimetric device has been chosen. Then the LET consists of two calorimeters, each made of 4×5 LYSO crystals of $1.5 \times 1.5 \times 20$ cm^3 dimensions. The crystals are readout by SiPM. The two calorimeters are placed symmetrically with respect to the IP, as shown in Fig. 3.

2.2 The High Energy Tagger

The HET [5] is designed to detect scattered $e^\pm$ of $E >$ 400 MeV. These particles escape the beam-pipe after the first bending dipole of DAΦNE, that can thus be used as spectrometer. The trajectories of the scattered electrons are strongly correlated with their energy. Then the HET is made of two scintillator hodoscopes readout by PMT, symmetrically placed 11 m far from the IP (Fig. 4).

The HET is acquired asynchronously with respect to the main KLOE detector, and for each KLOE trigger the HET information concerning three DAΦNE beam revolutions is stored. The synchronisation is performed by using a machine signal. In Fig. 5 the time difference between the two HET stations is shown: the accelerator time structure of about 2.7 ns period is clearly visible. The superimposed histogram is the same distribution resulting from a run with separated beams in the IP, and shows that the level of background is less than 10%.

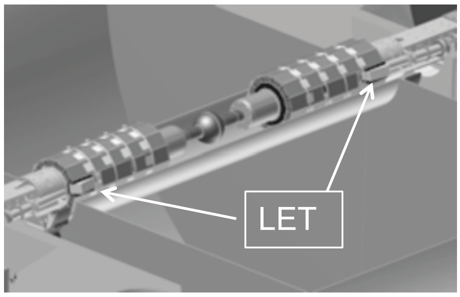

Figure 3. Sketch of the LET calorimeter positioning.

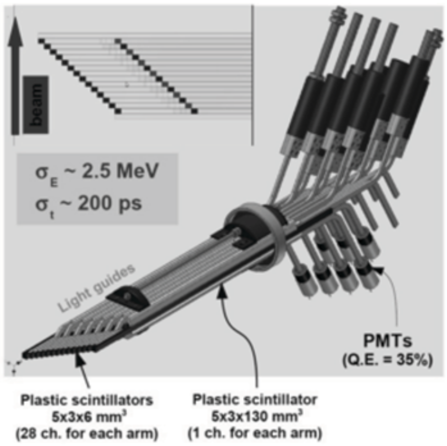

Figure 4. Sketch of the HET hodoscope.

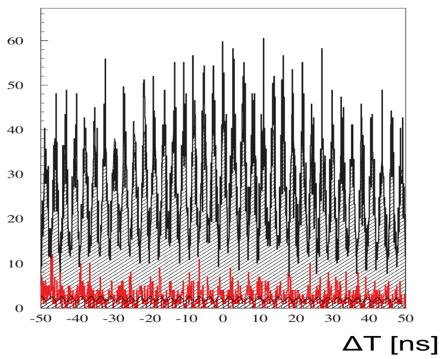

Figure 5. Time difference between the two HET stations. Black: colliding beams; red: no collisions.

3 Conclusion

A simulation of the KLOE-2 experiment with 5 fb^{-1} of data taking was performed. Numerical results indicate a feasibility of $\sim$ 1% statistical error in the measurement of $\Gamma_{\pi^0\to\gamma\gamma}$ [6]. Such a precision is better than the current experimental world average and the theoretical accuracy. The π^0 electromagnetic transition form factor $F(Q^2)$ ($Q^2 = -q^2$) in the region $0.01 < Q^2 < 0.1\,\mathrm{GeV}^2$ can be measured with a statistical error of < 6% in each bin. This low Q^2 measurement can test the consistency of the models which have been fitted so far to the data from CELLO, CLEO and BaBar at higher Q^2 and will serve as an important test of the strong interaction dynamics at low energies. The proposed measurements with the KLOE-2 experiment can also have an impact on the value and precision of the contribution of a neutral pion exchange to the hadronic light-by-light scattering in the muon $g-2$.

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