# The measurement of the absolute branching ratio of the $K^+ \to \pi^+\pi^0(\gamma)$ decay at KLOE.

KLOE Collaboration:

F. Ambrosino, A. Antonelli, M. Antonelli, F. Archilli, C. Bacci, P. Beltrame, G. Bencivenni, S. Bertolucci, C. Bini, C. Bloise, S. Bocchetta, V. Bocci, F. Bossi, P. Branchini, R. Caloi, P. Campana, G. Capon, T. Capussela, F. Ceradini, S. Chi, G. Chiefari, P. Ciambrone, E. De Lucia, A. De Santis, P. De Simone, G. De Zorzi, A. Denig, A. Di Domenico, C. Di Donato, S. Di Falco, B. Di Micco, A. Doria, M. Dreucci, G. Felici, A. Ferrari, M. L. Ferrer, G. Finocchiaro, S. Fiore, C. Forti, P. Franzini, C. Gatti, P. Gauzzi, S. Giovannella, E. Gorini, E. Graziani, M. Incagli, W. Kluge, V. Kulikov, F. Lacava, G. Lanfranchi, J. Lee-Franzini, D. Leone, M. Martini, P. Massarotti, W. Mei, S. Meola, S. Miscetti, M. Moulson, S. Müller, F. Murtas, M. Napolitano, F. Nguyen, M. Palutan, E. Pasqualucci, A. Passeri, V. Patera, F. Perfetto, M. Primavera, P. Santangelo, G. Saracino, B. Sciascia, A. Sciubba, F. Scuri, I. Sfiligoi, T. Spadaro, M. Testa, L. Tortora, P. Valente, B. Valeriani, G. Venanzoni, R. Versaci, G. Xu.

**Abstract**

The preliminary result on the absolute branching ratio of the decay $K^+ \to \pi^+\pi^0(\gamma)$, obtained by the KLOE experiment operating at the DAΦNE Frascati $\phi$-factory, is presented.

# 1 DAΦNE and KLOE

The DAΦNE $e^+e^-$ collider operates at a total energy $W = 1020$ MeV, the mass of the $\phi(1020)$-meson. Since 2001, the KLOE experiment has collected an integrated luminosity of about 2.5 $\mathrm{fb}^{-1}$. Results presented below are based on an integrated luminosity of about 250 $\mathrm{pb}^{-1}$. The KLOE detector consists of a large cylindrical drift chamber, DC, surrounded by a lead/scintillating-fiber electromagnetic calorimeter, EMC. The drift chamber [1] is 4 m in diameter and 3.3 m long, has full stereo geometry and operates with a 90% helium - 10% isobutane gas mixture. The momentum resolution is $\sigma(p_T)/p_T \sim 0.4\%$. Two track vertices are reconstructed with $\sim 3$ mm resolution. The calorimeter [2], composed of a barrel and two endcaps, covers 98% of the solid angle. Energy and time resolution are $\sigma(E)/E = 5.7\%/\sqrt{E(\mathrm{Ge}V)}$ and $\sigma(t) = 57\mathrm{p}s/\sqrt{E(\mathrm{Ge}V)} \oplus 100\mathrm{p}s$. A superconducting coil surrounds the detector and provides a solenoidal field of 0.52 T. The KLOE trigger [3], uses calorimeter and drift chamber information. For the present analysis, only events triggered by the calorimeter have been used.

# 2 The tag mechanism

The $\phi$-meson decays most of the times into $K\bar{K}$ pairs; these are quasi anticollinear in the laboratory due to the small crossing angle of the $\mathrm{e}^+\mathrm{e}^-$ beams. Therefore the detection of a $K(\bar{K})$ guaranties the presence of a $\bar{K}(K)$ of given momentum and direction. Therefore identified $K^\mp$ decays tag a $K^\pm$ beam and provide the normalization sample for signal count. This procedure is a unique feature of a $\phi$-factory and gives the possibility of measuring absolute branching ratios. Charged kaons are tagged using their two-body decays, $K^\pm \to \mu^\pm\nu_\mu$ and $K^\pm \to \pi^\pm\pi^0$, accounting for $\sim$85% of the total decay channels. We have about $1.5 \times 10^6 K^+K^-$ events/$\mathrm{pb}^{-1}$. The two body decays are identified as peaks in the momentum spectrum of the charged decay particle evaluated in the kaon rest frame and assuming the pion mass.

# 3 Measurement of the absolute branching ratio of the $K^+ \to \pi^+\pi^0(\gamma)$ decay.

The measurement of the branching ratio (BR) is performed using 250 $\mathrm{pb}^{-1}$ collected at $\phi$ peak. The normalization sample is given by $K^- \to \mu^-\overline{\nu}(\gamma)$ tagged events, providing a pure $K^+$ beam for signal search. In order to minimize the impact of the trigger efficiency on the reconstruction of the signal decay channel, we require the tagging kaon alone to satisfy the EMC trigger request, hereafter *self-triggering tag*. Nevertheless a residual dependency of the tagging criteria on the decay mode of the signal kaon is still present and it is accounted for in the final branching ratio measurement.The decision of using $K^-$ to tag and $K^+$ for signal search has been taken to neglect corrections to the BR from nuclear interactions (NI) of the kaon ($\sigma_{NI}(K^+) \sim \sigma_{NI}(K^-)/10^2$). The choice of $K^-_{\mu 2}$ decays for tagging purpouses allows us to separate as much as possible the tag hemisphere from the signal hemisphere, minimizing possible interference in track reconstruction and cluster association.

The signal selection of $K^+ \to \pi^+\pi^0(\gamma)$ decays uses DC information only. The $K^+$ is identified by a positive track moving outwards in the DC with momentum $70 < p_K < 130$ MeV/c and having point of closest approach (PCA) to the interaction point with $\sqrt{x^2_{PCA} + y^2_{PCA}} < 10$ cm and $|z_{PCA}| < 20$ cm. Decay vertices (V) in the drift chamber fiducial volume are selected, $40 < \sqrt{x^2_V + y^2_V} < 150$ cm, with the momentum difference between the kaon and the secondary $-320 < \Delta p = |\overrightarrow{p}_K| - |\overrightarrow{p}_{sec}| < -50$ MeV/c and the charged decay particle momentum in the kaon rest frame in pion mass hypothesis $50 < p^* < 370$ MeV/c.

After this selection, the $K^+ \to \pi^+\pi^0(\gamma)$ signal count is extracted from the fit of the $p^*$ distribution in the window starting from $p^*_{cut}$=180 MeV/c (see figure 1). This spectrum exhibits two peaks, the first at about 236 MeV/c from $K^+ \to \mu^+\nu$ decays, $K_{\mu 2}$ *peak*, and the second at about 205 MeV/c from $K^+ \to \pi^+\pi^0$ decays, $K_{\pi 2}$ *peak*; lower $p^*$ values are due to three body decays. The momenta of the charged secondaries produced in the kaon decay have been evaluated in the kaon rest frame using the pion mass hypothesis. Therefore the $K_{\pi 2}$ *peak*, evaluated using the correct mass hypothesis, appears to be symmetric while the $K_{\mu 2}$ *peak* is asymmetric do to the incorrect mass hypothesis used (pion instead of muon).

The fit to the $p^*$ distribution is done using the following three contributions:

1. $K_{\mu 2}$ *peak*: this contribution accounts for $K^+ \to \mu^+\nu(\gamma)$ decays and it is taken directly from a DATA control sample selected using calorimetric information only;

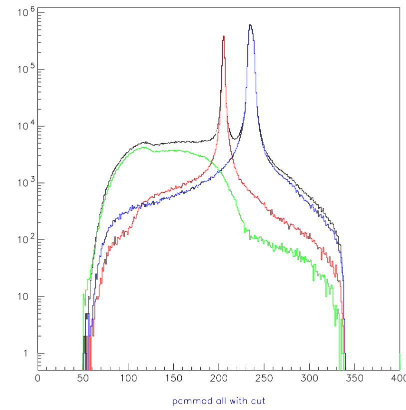


Figure 1: Spectra of the charged secondary momentum in the kaon mass rest frame assuming the pion mass obtained from MonteCarlo simulation. Two peaks are visible, the $K_{\pi 2}$ *peak* at 205 MeV and the $K_{\mu 2}$ *peak* at 236 MeV. Blue corresponds to $K^+ \to \mu^+\nu$, red to $K^+ \to \pi^+\pi^0$ and green to $three-body$ decays.

2. $K_{\pi 2}$ *peak*: this contribution accounts for $K^+ \to \pi^+\pi^0(\gamma)$ decays and it is taken directly from a DATA control sample selected using calorimetric information only;

3. $three-body$ decays: this contribution accounts for $three-body$ decays and it is taken from MC simulation.

Figure 2 shows the result of the fit of the $p^*$ distribution performed on the selected DATA sample. Using a total number of tagging events $N_{tag} = 12,113,686$ and $p^*_{cut} = 180$ MeV/c, we obtain $N_{K^+\to\pi^+\pi^0(\gamma)}|_{FIT} = 818,347 \pm 1,912$. Different colours indicate the different contributions: green for $K^+ \to \pi^+\pi^0(\gamma)$ decays, red for $K^+ \to \mu^+\nu(\gamma)$ decays and light blue for $three-body$ decays.

The efficiency has been evaluated directly on DATA from a control sample selected using calorimetric information only, to avoid correlation with the DC driven sample selection. Given the tag by $K^- \to \mu^-\overline{\nu}(\gamma)$ decays, the control sample selection for the evaluation of this efficiency is given by $K^+ \to X^+\pi^0$

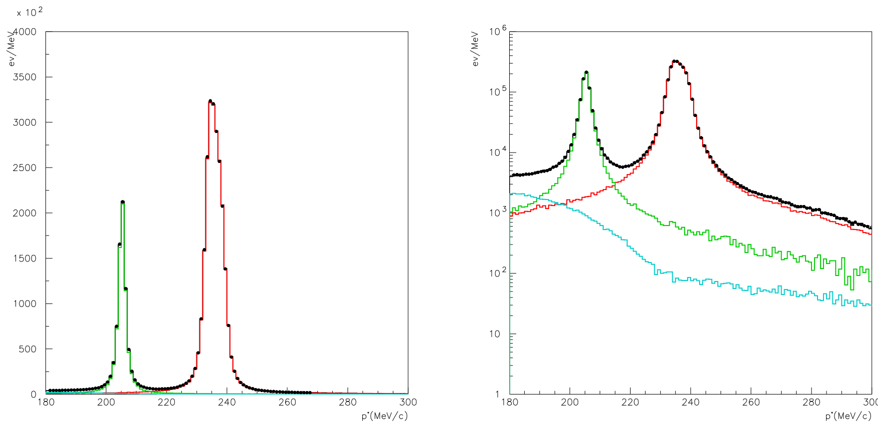


Figure 2: Fit of the $p^*$ distribution: black dots are DATA to be fit and solid black line is the fit output. The three contributions used to fit the DATA are: $K_{\mu 2}$ peak (red), $K_{\pi 2}$ peak (green) and $three-body$ decays (light blue).

decays identified via the reconstruction of $\pi^0 \to \gamma\gamma$ decay vertices. Corrections to the efficiency accounting for possible distortions induced by the control sample selection have been evaluated using MC simulation.

A preliminary evaluation of systematic uncertainties has been done and the preliminary measurement of the absolute branching ratio of the $K^+ \to \pi^+\pi^0(\gamma)$ decay, at the few permil level of precision, will be presented at the conference.

# References

[1] M. Adinolfi *et al.*, [KLOE Collaboration], *The tracking detector of the KLOE experiment*,
*Nucl. Instrum. Meth* **A 488** 2002 51

[2] M. Adinolfi *et al.*, [KLOE Collaboration], *The KLOE electomagnetic calorimeter*,
*Nucl. Instrum. Meth* **A 482** 2002 364

[3] M. Adinolfi *et al.*, [KLOE Collaboration], *The trigger system of the KLOE experiment*,
*Nucl. Instrum. Meth* **A 492** 2002 134

[4] S. Eidelman *et al.*, Particle Data Group, *Phys. Lett.* **B 592** 2004 1