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**HANDBOOK ON  
NEUTRAL KAON INTERFEROMETRY AT A  $\Phi$ -FACTORY**



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## PREFACE

At the beginning of 2006 the KLOE experiment concluded its data-taking phase at the DAΦNE  $e^+e^-$  collider, the  $\phi$ -factory of the Frascati National Laboratories of INFN (LNF), collecting about  $2.5 \text{ fb}^{-1}$  of total integrated luminosity. At the same time there was an intense activity to outline the future LNF research programs<sup>1</sup>, and more generally the INFN roadmap for the following years. A couple of working groups, set-up in the framework of the INFN roadmap studies, investigated in detail the prospects for  $e^+e^-$  physics at LNF in the hypothesis of a new DAΦNE machine upgraded in luminosity and energy<sup>2</sup>. In the meanwhile a proposal for the continuation of the KLOE physics program was submitted by the KLOE-2 collaboration<sup>3</sup> to the LNF directorate, where the hypothesis of a  $\phi$ -factory able to deliver an integrated luminosity of about  $50 \text{ fb}^{-1}$  in few years of data taking was considered.

A unique feature of a  $\phi$ -factory is the production of neutral kaon pairs in a pure quantum state with the consequent possibility to study quantum interference effects, and to have pure monochromatic tagged  $K_S$  and  $K_L$  beams. Besides the possibility to measure to high accuracy most, if not all, of the properties of the kaon system, the correlation between the two kaons could open up new horizons in the study of discrete symmetries and of the basic principles of quantum mechanics. For instance possible CPT violations could manifest in conjunction with tiny modifications of the initial correlation, decoherence effects, or Lorentz symmetry violations, which, in turn, might be justified in a quantum theory of gravity. At KLOE the sensitivity to some observable effects reached the level of the interesting Planck's scale region, i.e.  $O(m_K^2/M_{\text{planck}}) \sim 2 \times 10^{-20} \text{ GeV}$ , which is a very remarkable

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<sup>1</sup> <http://www.lnf.infn.it/lnfadmin/direzione/roadmap/roadmap.html>

<sup>2</sup> F. Ambrosino et al., Eur. Phys. J C 50 (2006) 729, see also

<http://www.roma1.infn.it/people/bini/roadmap.html>,

<http://www.infn.it/csn1/Roadmap/Gruppok/index.html>

<sup>3</sup> <http://www.lnf.infn.it/lnfadmin/direzione/roadmap/LoIKLOE.pdf>

level of accuracy (presently unreachable in other similar systems, e.g. the B meson system), and significant improvements are expected with an integrated luminosity of  $50 \text{ fb}^{-1}$ .

Moreover recent theoretical studies demonstrated that entangled neutral kaons at a  $\phi$ -factory are suitable to test the foundations of quantum mechanics, such as Bohr's complementarity principle, the quantum erasure and marking concepts, and the coherence of states over macroscopic distances, while for the more "classical" test with Bell's inequalities, new ideas have been put forward.

During the working group activity, it immediately appeared evident the necessity of a comprehensive and updated review on neutral kaon interferometry, and of an extended assessment of its physics potentials. In fact, the few excellent papers in the DAΦNE Physics Handbook<sup>4</sup>, after more than ten years since its publication, needed at least an update to take into account the vast subsequent literature on this subject.

Therefore as a first step toward this aim, a mini-workshop entitled "Neutral kaon interferometry at a  $\phi$ -factory: from quantum mechanics to quantum gravity" was held on March 24th 2006 in Frascati<sup>5</sup>. Review talks were given by G. Amelino-Camelia, J. Bernabeu, R. Bertlmann, A. Bramon, R. Floreanini, A. Go, B. Hiesmayr, G. Isidori, R. Lehnert, N. Mavromatos, and myself. I thank all the speakers for having accepted the invitation, for their interesting presentations, and for their contribution to the success of the workshop.

As a second more ambitious project, the idea was put forward to write a comprehensive report gathering all relevant and updated information on the subject, which was scattered in the literature. The report would have been in the form of a handbook (as a sort of addendum to the DAΦNE Physics Handbook), with extensive and comprehensible contributions, useful to experimental physicists and to people willing to have a comprehensive overview on neutral kaon interferometry at a  $\phi$ -factory. In this spirit, written contributions were given by all speakers of the above mentioned workshop, joined by M. Arzano, F. Benatti, J. Ellis, G. Garbarino, A.

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<sup>4</sup> The second DAΦNE Physics Handbook, edited by L. Maiani, G. Panzeri, N. Paver, INFN-LNF, Frascati, 1995

<sup>5</sup> The slides are available at <http://www.roma1.infn.it/people/didomenico/roadmap/kaoninterferometry.html>.

Marcianò, D. Nanopoulos, J. Papavassiliou, and S. Sarkar. I warmly acknowledge them, without whom contribution the present Handbook would have not become a reality.

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I express my gratitude to the Spokesperson of the KLOE experiment P. Franzini for useful discussions on the subject and for being for me a constant point of reference, to R. Baldini for stimulating discussions and suggestions, to J. Lee-Franzini, G. Capon, M. Curatolo and all people attending with interest, and contributing to the lively atmosphere and the success of the workshop.

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I wish to thank L. Sabatini for her invaluable help in the logistic preparation of the workshop, and all the SIS staff for their constant support. Finally, a special thank to L. Invidia for her crucial help and patience in the completion of this volume.

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