OKA experiment for studying rare kaon decays

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Abstract

The description of the experiment OKA for studying rare kaon decays is presented. The experiment is performed at IHEP (Protvino, Russia) using RF-separated $K^{\pm}$ beam. Main directions of physical program are briefly discussed.

1 Introduction

Studying kaon decays allows to test Standard Model (SM) and to search for New Physics (NP) beyond SM. One can check the unitarity of quark mixing matrix (CKM) with great precision, look for new kinds of interactions and hence new heavy particles (for example charged Higgs boson or leptoquarks) that can cause Lepton flavor violation (LFV), right currents etc. These new particles can be so heavy that they will not be produced at colliders. Nevertheless they can be observed indirectly through studying rare and ultrarare decays.

There are two main strategies in experimental kaon physics. The first one is aimed at searching for ultrarare decays. These experiments need high statistics and therefore deal with very high intensity unseparated beams. The second way to study kaon decays is precise measurement of decay parameters that can be calculated with high accuracy in SM. The aim of such experiments is to find small deviations ($< 1\%$) from SM predictions. For such purposes clean separated kaon beams are preferable. An example of the first type experiment is NA62 at CERN [1], the second type - OKA experiment at IHEP [2].

2 IHEP separated beam

RF-separated beam at IHEP (Protvino, Russia) is the only operating high energy one in the world. The deflectors for the beam were constructed in Karlsruhe and used at CERN SPS. In 1998 they were moved to Protvino and during next several years were equipped with cryogenic system. The Panofsky-Montague-Schnell scheme of separation is used (fig. 1).

The beam with definite momentum is sent to the system of two deflectors with "-1" optics. The phase shift between deflectors is tuned in such a way that pions have equal relative phase in both deflectors. As a result pions get two deflections that compensate each other and are absorbed in the stopper. The beam momentum can be selected in such a way that kaons would have 180^{o} shift with respect to pions. This way kaons get double deflection and avoid absorber. The deflectors are superconductive and are cooled down to the temperature 1.8K.

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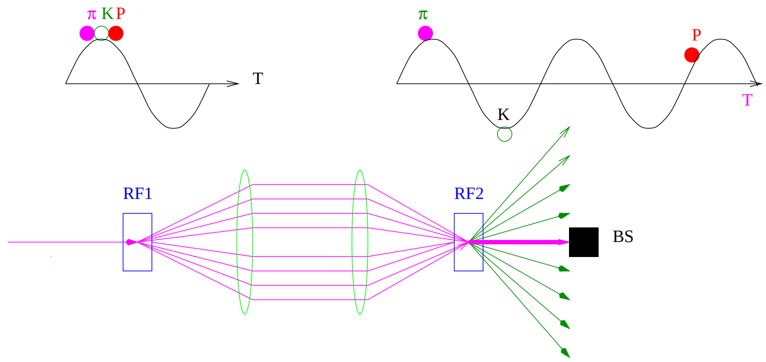

Figure 1: *Panofsky scheme of RF separation*

3 Experimental setup

The OKA collaboration includes 3 institutes - INR RAS (Moscow), IHEP (Protvino) and JINR (Dubna). The beam momentum is p=12.5GeV/c or p=18GeV/c with the intensity $\sim 5 * 10^6$ K/spill.

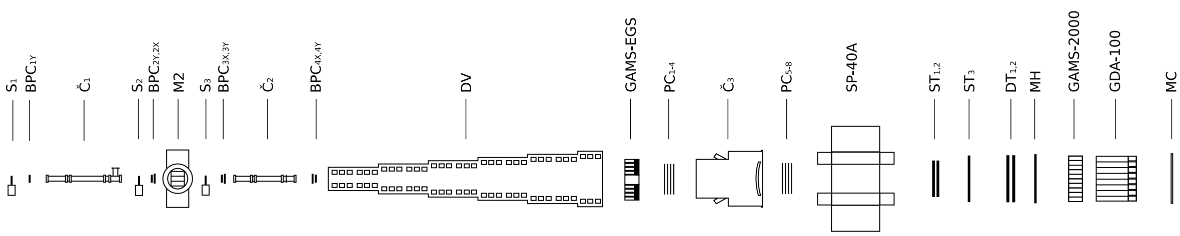

Figure 2: *Elevation view of the OKA detector*

OKA elevation view is shown in fig. 2. The setup includes scintillation counters $S_{1\div3}$, hodoscopes, beam proportional chambers (BPC $_{1Y}$,BPC $_{2\div4X,Y}$), cerenkov counters for identifying primary particles($\mathrm{C}_{1,2}$), decay volume (DV) 11m length with active photon veto system, wide aperture magnetic spectrometer with proportional chambers (PC $_{1\div4}$,PC $_{5\div8}$), drift tubes ($DT_{1\div3}$) and straw tubes ($ST_{1\div2}, ST_3$), bisectional multichannel gamma-spectrometer (GAMS-EGS and GAMS-2000), hadron calorimeter (GDA-100) and muon detectors (MuD).

At the moment the commisioning of the setup is close to completition. First data were taken during November-December run in 2008.

4 Physical program

The baseline of OKA experimental program is improving the results of well-known ISTRA+ experiment[3] on larger statistics. To compare ISTRA+ and OKA sensitivity, a simple estimation could be done for the number of kaons per spill:
$N_{ISTRA+} = 3 \times 10^6 spill^{-1} \times 3\% kaons = 9 \times 10^4$
$N_{OKA} = 5 \times 10^6 spill^{-1} \times 60\% kaons = 300 \times 10^4$
$OKA/ISTRA+ \sim 30$

The program is being tuned by the latest results of NA48/2, NA62, KLOE. Below the main directions of OKA physical program are briefly discussed.

4.1 χPT tests, deviations from SM

For several years, the possibility of LFV in Kl2 decays has been one of the most popular topics in kaon physics. The best current result is obtained by KLOE [4]. NA62 plans to significantly improve the statistics and reach $\sim 0.3\%$ accuracy in measuring R=BR(Ke2)/BR(Kμ2). [5]. The expected statistics for $K^- \rightarrow e^-\nu_e$ at OKA is $\sim 10^5$events and comparable with that of NA62.

Semileptonic Kl3 decays provide the best means for $|V_{us}|$ measurement and also allow to measure formfactors with great precision. ISTRA+ put best limits on f_T and f_S formfactors [6] on 0.5M event statisitcs. The expected statistics at OKA is ~20M events.

The decays $K^- \rightarrow l^-\nu_l\gamma$ ($l = e, \mu$) are sensitive to hadronic weak currents in low-energy region. The decay amplitude includes two terms: internal bremsstrahlung (IB) and structure dependent term (SD). IB contains radiative corrections from $K^- \rightarrow l^-\nu_l$. SD allows to probe electroweak structure of kaon via measuring F_V and F_A formfactors. There are just a few experimental results [7], [8]. OKA will get $\sim 10^6$ events of $K^- \rightarrow \mu^-\nu_\mu\gamma$ and $\sim 10^4$ events of $K^- \rightarrow e^-\nu_e\gamma$.

4.2 T-odd correlations in radiative $Kl3$ decays

Radiative Kl3 decays (K$\mu3\gamma, Ke3\gamma$) are interesing to test ChPT and search for New Physics using T-odd kinematical variable $\xi = \frac{1}{M_K^3}\overrightarrow{p}_\gamma \cdot [\overrightarrow{p}_\pi \times \overrightarrow{p}_l]$.

In SM the expected value for asymmetry $A_\xi = \frac{N(\xi>0)-N(\xi<0)}{N(\xi>0)+N(\xi<0)}$ is less than that in SM extensions (K$\mu3\gamma$: $A_\xi \sim 1.14 \times 10^{-4}$ for SM, $A_\xi \sim 2.6 \times 10^{-4}$ for SM extensions[9]; $Ke3\gamma$: $A_\xi \sim 0.6 \times 10^{-4}$ for SM, $A_\xi \sim 0.8 \times 10^{-4}$ for SM extensions[10]). The best estimation for A_ξ is obtained by ISTRA+ [11],[12]. The expected statistics at OKA is $\sim 10^5$ events.

4.3 Beyond the baseline

In models with spontaneous supersymmetry breaking the superpartners of a Goldstone fermion, goldstinos (pseudoscalar P and scalar S), should exist. In some versions of gravity-mediated and gauge-mediated theories one or both of these sgoldstinos are light enough to be observed in kaon decays. In left-right symmetric extensions of SM sgoldstinos can be observed in decay $K^- \rightarrow \pi^-\pi^0 P$. The best upper limit on BR of this decay is obtained by ISTRA+ [13].

The separated beam makes it possible to perform fixed target program at OKA setup. This includes search for exotic states with hidden strangeness in $K^-p \rightarrow K^+K^-\pi^0\Lambda$, search for pentaquark states $uuss\bar{s}$, spectroscopy and decays of light mesons.

5 Conclusions

The commisioning of new experimental setup OKA for studying rare kaon decays is close to completion. The setup operates with RF separated kaon beam. A wide physical program is planned which is competitive with other experiments. The improvement in statistics is a factor of ~ 60 with respect to the previous experiment ISTRA+.

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References

[1] G.Anelli et al. CERN-SPSC-2005-013, CERN-SPSC-P-326, Jun 2005. 93pp.

[2] V.F.Obraztsov, L.G.Landsberg. Nucl.Phys.Proc.Suppl.99B:257-264,2001; hep-ex/0011033.

[3] V.N.Bolotov et al., IHEP preprint 8-98,1998.

[4] F.Ambrosino et al. PoS KAON:050,2008; arXiv:0707.4623.

[5] R.Fantechi. J.Phys.Conf.Ser.110:072009,2008.

[6] O.P.Yushchenko et al. Phys.Lett.B589:111-117,2004; hep-ex/0404030.

[7] S.C.Adler et al. Phys.Rev.Lett.85:2256-2259,2000; hep-ex/0003019.

[8] Y.Akiba et al. Phys.Rev.D32:2911,1985.

[9] V.Braguta, A.Likhoded, A.Chalov. Phys.Rev.D68:094008,2003; hep-ph/0305067.

[10] V.Braguta et al. Phys.Atom.Nucl.67:1003-1009,2004.

[11] V.N.Bolotov et al. Phys.Atom.Nucl.70:734-740,2007; hep-ex/0510064.

[12] O.G.Tchikilev et al. Phys.Atom.Nucl.70:29-34,2007; hep-ex/0506023.

[13] O.G.Tchikilev et al. Phys.Lett.B602:149-156,2004; hep-ex/0308061.