PROCEEDINGS OF SCIENCE

Results from ISTRA+ experiment

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The form-factor measurements in $K \to \mu\nu\gamma$ decay were performed for the first time in the region of INT- term with the total statistics of 22k decays. The value of $F_V - F_A = 0.16 \pm 0.04(\mathrm{stat}) \pm 0.05(\mathrm{syst})$ was obtained.
The ratio $\mathrm{Br}(K_{e3})/\mathrm{Br}(K_{\pi 2}) = 0.2449 \pm 0.0004 \pm 0.0014(\mathrm{syst})$ was measured with the statistics of 2.2M events. The value $V_{us} = 0.2275 \pm 0.0009 \pm 0.0022(\mathrm{theor})$ was extracted from these measurements.

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1. $K \to \mu\nu\gamma$ form-factors

The photon emission in $K \to \mu\nu\gamma$ decay is considered to originate from two processes: bremsstrahlung (IB) and structure-dependent emission (SD±) connected with electroweak structure of decay vertex. The last term is very sensitive to EW parameters, provides good test of ChPT and its interference with IB term (INT±) depends on vector and axial form-factors constants (kinematics variables are missed):

$$\frac{d\Gamma}{dxdy} = A_{IB} f_{IB} + A_{SD}\left[(F_V+F_A)^2 f_{SD+} + (F_V-F_A)^2 f_{SD-}\right] - A_{INT}\left[(F_V+F_A)^2 f_{INT+} + (F_V-F_A)^2 f_{INT-}\right]$$

The previous measurements by E787 (BNL)[1] and E246 (KEK)[2] were focused on SD± region (Fig.1, central plot).

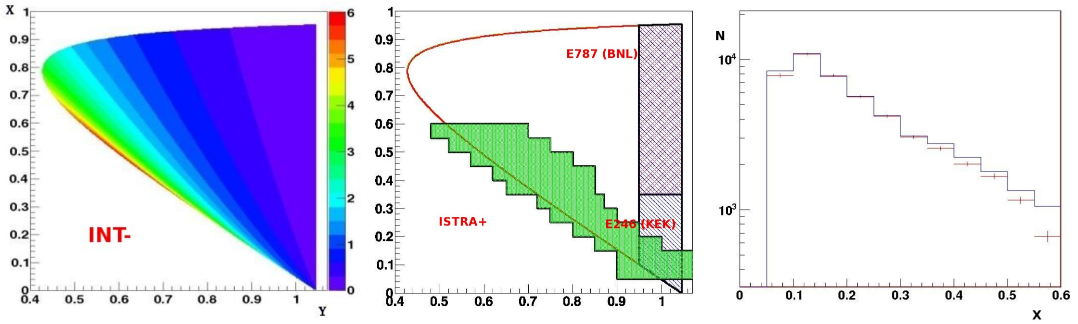

Fig.1 Dalitz plots with INT- term (left) and regions covered by different experiments (center). Resulting number of signal events extracted in different X-strips (right) with clean IB term (histogram).

The main background sources are $K_{\mu3}$ and $K_{\pi2}$ decays which were generated with dedicated MC with very large statistics in addition to the signal MC.

Three variables ($M(\mu\nu\gamma)$, Y and $\cos\Theta_{\mu\gamma}$) were fitted in separate X-strips to extract number of signal events. In total 22k events were extracted. The results are presented in Fig.1 (right plot). One can clearly observe negative sign of INT- term (lack of events).

Normalizing on IB terms and making use of complete analytical expressions, we got:

$$F_V - F_A = 0.16 \pm 0.05(\text{stat}) \pm 0.05(\text{syst}).$$

This result can be compared with the prediction of ChPT O(p^4): $F_V - F_A = 0.052$[3].

2. $K \to e\nu\pi^0$ decay and V_{us} term of CKM matrix

This decay provides the best source of information concerning V_{us} of CKM matrix. Strong interest arose to high statistics/low systematics measurements after E865 (BNL)[4] reported 2.5σ branching increase with respect to PDG value.

The method of measurement is based on the observation that $K \to e\nu\pi^0$ decay is the dominant source of electrons in kaon decays. All other channels contribute much less than 1% of electrons. This observation allows to avoid reconstruction of π^0 and use E/P ratio in the calorimeter and P_{cm} for charged track in fit of MC-generated distributions which include the signal as well as main backgrounds. The verification of the method is shown in Fig.2

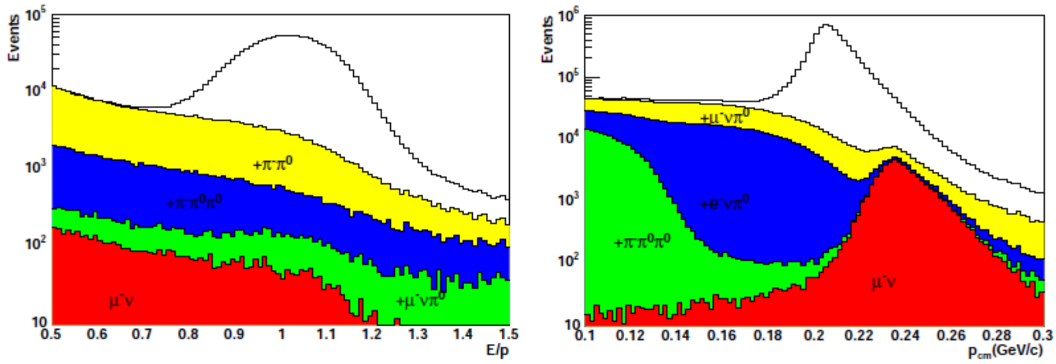

Fig.2 E/P (left) and P_{cm} (right) for different kaon decay channels. The signal is white histogram.

The signal peak was approximated by a sum of two Gaussian and background as simple exponential (for E/P) and as 4-th order polynomial (for P_{cm}). The total amount of 2.2M $K \to e\nu\pi^0$ events were extracted with

$$\mathrm{Br}(K_{e3})/\mathrm{Br}(K_{\pi 2}) = 0.2449 \pm 0.0004(\mathrm{stat}) \pm 0.0014(\mathrm{syst}), \quad \mathrm{Br}(K_{e3}) = 5.124 \pm 0.009(\mathrm{stat}) \pm 0.030(\mathrm{syst})\%$$

K_{e3} decay rate can be expressed as:

$$\Gamma(K_{e3}) = \frac{\mathrm{Br}(K_{e3})}{\tau(K)} = \frac{G_\mu^2}{384\pi^3} M_K^5 |V_{us}|^2 |f_+(0)|^2 I_K^e S_{EW} (1 + \delta_{SU_2} + \delta_+^e)^2$$

where corrections are absorbed in $S_{EW}(1 + \delta_{SU_2} + \delta_+^e)^2$ and decay phase space integral

$$I_K^e = \int_0^{(M_K - M_\pi)^2} dt \frac{1}{M_K^8} \lambda^{3/2} (f_+(t)/f_+(0))^2, \quad \text{where } \lambda = (M_K^2 - t - M_\pi^2)^2 - 4tM_\pi^2$$

contains t-dependent form-factor and is evaluated using out results from [5] where the quadratic non-linearity in the form-factor was measured: $I_K^e = 0.15912 \pm 0.00084 \pm 0.00114(\mathrm{syst})$.

Putting everything together and making use of the theoretical value for $f_+(0) = 0.961 \pm 0.008$, we get:

$$|V_{us}||f_+(0)| = 0.2186 \pm 0.0009 \pm 0.0012(\mathrm{theor}), \quad |V_{us}| = 0.2275 \pm 0.0009 \pm 0.0022(\mathrm{theor})$$

References

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