RELEVANT RESULTS FROM THE NA48 EXPERIMENT

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ABSTRACT

We report relevant results from NA48 experiment at CERN SPS. NA48 was proposed in 1990 [1] to study direct CP violation in $K^0 \to \pi\pi$ to a level of accuracy sufficient to resolve the inconclusive status left by the previous measurements performed by NA31 [2] and E731 [3]. In 2002 NA48 published the final result [4]. Small modification to the experimental setup have allowed NA48 to go forward with an extensive investigation of $K^0$ rare decays and hyperon decays. Some results are already available and reported here together with the final CP violation measurement.

1 The measurement of $Re(\epsilon'/\epsilon)$

It is well known that the decay of $K^0/\bar{K}^0$ into two pions violates CP. Such a violation can have two contributions: one, indirect, associated to $K^0/\bar{K}^0$ mixing and another, direct, coming from the decay amplitude. The amount of direct CP violation in this decay is parametrized by the parameter $Re(\epsilon'/\epsilon)$, which can be computed in the framework of the standard electro-weak-model, albeit with large theoretical uncertainties. Typical theoretical predictions of $Re(\epsilon'/\epsilon)$ varies from few $10^{-4}$ to about $2 \times 10^{-3}$, even though with large exceptions.

$Re(\epsilon'/\epsilon)$ is connected to the double ratio of decay rates according to the following formula:

$$R = \frac{\Gamma(K_L \to \pi^0\pi^0)}{\Gamma(K_S \to \pi^0\pi^0)} \cdot \frac{\Gamma(K_L \to \pi^+\pi^-)}{\Gamma(K_S \to \pi^+\pi^-)} \approx 1 - 6 \cdot Re(\epsilon'/\epsilon)$$ (1)
In order to exploit the cancellation in the double ratio of systematic uncertainties, the experimental apparatus consists of two concurrent and almost co-linear beams, one providing the experiment with $K_L$ decays and the other one with $K_S$ decays and the $K^0$ to $\pi\pi$ decays are reconstructed in the same decay region. A tagging station is devoted to identify the $K^0$ decay as a $K_S$ or a $K_L$ decay. In 2002 NA48 has published [4] the final result of the measurement:

$$Re(\epsilon'/\epsilon) = (15.3 \pm 2.6) \times 10^{-4}$$  \hspace{1cm} (2)

It is the most precise measurement ever done as shown in Fig.1. The world average value is also reported together with the uncertainty (yellow band).

2 Selected items about rare decays

The radiative kaon decays are ideally suited to test the validity of the Chiral Perturbation Theory ($\chi PhT$). The processes may be described in a perturbative expansion of momenta: $O(p^2), O(p^4)$. Examples of this type are $K_S \rightarrow \gamma\gamma$ and $K_L \rightarrow \pi^0\gamma\gamma$. In both cases there is no contribution from the $O(p^2)$ term, while the $O(p^4)$ contribution is predicted to better than 5% by $\chi PhT$. NA48 has measured [5],[6]:

$$BR(K_S \rightarrow \gamma\gamma) = (2.78 \pm 0.06_{stat} \pm 0.02_{MCstat} \pm 0.04_{syst}) \times 10^{-6}$$  \hspace{1cm} (3)
\[ BR(K_L \rightarrow \pi^0\gamma\gamma) = (1.36 \pm 0.03_{\text{stat}} \pm 0.03_{\text{syst}} \pm 0.03_{\text{norm}}) \times 10^{-6} \]  

(4)

The value of \( BR(K_S \rightarrow \gamma\gamma) \) deviates from \( \mathcal{O}(p^4) \) prediction and indicates a large \( \mathcal{O}(p^6) \) contribution. The \( \mathcal{O}(p^4) \) contribution to \( K_L \rightarrow \pi^0\gamma\gamma \) turns out to be also an underestimation of the decay rate. Anyway at \( \mathcal{O}(p^6) \) the rate may be reproduced by adding a contribution from the VDM mechanism, via the coupling constant \( a_v \) that NA48 has measured to be:

\[ a_v = -0.46 \pm 0.03_{\text{stat}} \pm 0.04_{\text{syst}} \]  

(5)

3 Hyperon decays in NA48

The target used for the production of \( K^0 \)s is also a huge source of hyperons. By using the small fraction of hyperons that passed the standard triggers in the previous years, the NA48 collaboration has already published results on hyperon physics [7]:

\[ m(\Xi^0) = [1314.82 \pm 0.06(stat.) \pm 0.20(syst.)] \text{MeV}/c^2 \]  

(6)

\[ BR(\Xi^0 \rightarrow \Lambda\gamma) = [1.90 \pm 0.34(stat.) \pm 0.19(syst.)] \times 10^{-3} \]  

(7)

\[ BR(\Xi^0 \rightarrow \Sigma^0\gamma) = [3.14 \pm 0.76(stat.) \pm 0.32(syst.)] \times 10^{-3} \]  

(8)

In the 2002 special triggers have been dedicated to hyperon decays and NA48 claims main achievements to:

1. study form factors and flavor symmetry violations in the \( \Xi^0 \) decays;

2. give an alternative measurement of \( V_{us} \) (CKM parameter) using \( \Xi^0 \) (and \( \Lambda \)) beta decay instead of kaon beta decays.

References

1. CERN Geneva - CERN-SPSC-90-22