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# STATUS OF ASYMMETRY MEASUREMENT AT NA48/2 EXPERIMENT

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ABSTRACT

NA48/2 is a high precision experiment of charged kaon decays using a novel design for simultaneous $K^+/K^-$ beams and an upgraded NA48 set-up. The experiment is installed at the SPS site of CERN, where data taking is scheduled to end in August 2004.
The main goal is to search for CP-violation in $K^\pm \to \pi^+\pi^-\pi^\pm$ and $K^\pm \to \pi^0\pi^0\pi^\pm$ decays. The experiment is designed to reach a sensitivity, limited by statistics rather than systematics, of the order of $10^{-4}$ in the measurement of the direct CP-violating asymmetry in the linear slope of the Dalitz plot [1).]
Over $10^6 K_{e4}$ decays have been collected in order to measure $a_0^0$ scattering length and other Kaon rare decays are studied as well.

* On behalf of NA48/2 Collaboration: Cambridge, CERN, Chicago, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, Saclay, Siegen, Torino, Vienna

## 1 Introduction

After the measurement of the direct CP violation component in the decay of the neutral Kaons [2], the NA48 collaboration is actually engaged in the search of direct CP violation in the $K^{\pm} \rightarrow \pi^{+}\pi^{-}\pi^{\pm}$ decays, by measuring the asymmetry

$$A_g = (g^+ - g^-)/(g^+ + g^-), \tag{1}$$

where $g^+$ and $g^-$ are the slope parameters describing, respectively, the linear dependence of the $K^+$ and $K^-$ decay probabilities on the $u$ kinematic variable of the Dalitz plots. The $u$ variable is related to the energy ($E^*_\pi$) of the *odd* pion (the pion having the sign opposite to that of the decaying kaon) in the kaon centre of mass system as follows: $u = (2M_K/m^2) \cdot (M_K/3 - E^*_\pi)$, where $M_K$ and $m$ are the kaon and pion mass, respectively. Exploiting the high detection efficiency and precision in energy measurement for photons of the NA48 Liquid Krypton calorimeter (LKr), also the corresponding asymmetry $A^0_g$ in $K^{\pm} \rightarrow \pi^0\pi^0\pi^{\pm}$ decays will be measured. High statistics ($\sim 10^6$) of $K_{e4}$ can be analyzed allowing the $\pi - \pi$ scattering length parameter $a^0_0$ to be measured with an accuracy of better than $1 \cdot 10^{-2}$. This permits the size of the $q\bar{q}$ condensate of the QCD vacuum postulated in $\chi PT$ to be measured.

## 2 Beam Lines

The beam line transports simultaneously positive and negative particles with average momentum of 60 GeV/c and 3.8% rms. The two beams originate at 0 angle relatively to the impinging primary protons and have $\pm 0.36 mrad$ opening angle on both planes (Fig.1). The fluxes at the end of the final collimator are of $3.8 \cdot 10^7$ positive ppp ($2.2 \cdot 10^6 K^+$) and $2.6 \cdot 10^7$ negative ppp ($1.3 \cdot 10^6 K^-$) in a 16.8 s cycle time and 4.8 s flat-top.

## 3 Detector Apparatus

The main device for $K^{\pm} \rightarrow \pi^{+}\pi^{-}\pi^{\pm}$ decays identification is the magnetic spectrometer [3]: it consists of a dipole magnet ($120 MeV/c$ kick) and 4 drift chamber, two before and two after the magnet. Spatial resolution is $\sim 100 \mu m$ per plane, providing a better than 1% momentum measurement .
The $K^{\pm} \rightarrow \pi^0\pi^0\pi^{\pm}$ decays identification relays on the liquid krypton calorimeter [4] divided in $2 \times 2 cm^2$ cells. Time resolution for showers above 20 GeV is

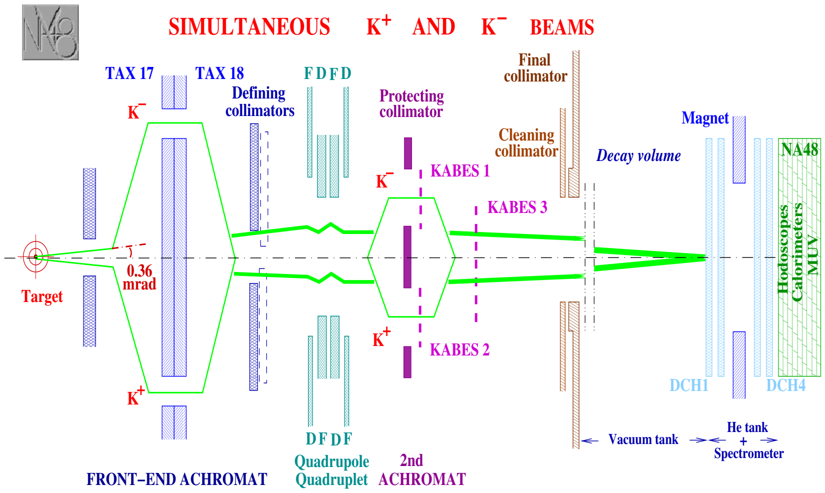


Figure 1: *Vertical section of the simultaneous $K^+$ and $K^-$ beam line (not to scale).*

better than 300 ps, position resolution better than 1.3 mm and energy resolution better than 1%.

A new detector called KABES, built specifically for NA48/2 is installed $\sim 40m$ after the proton target. It is a TPC Micromega detector, providing particle by particle beam momentum measurement with a resolution better than 1%.

## 4 Data Taking

In order to minimize systematic uncertainties related to the apparatus asymmetry and beam structure, the magnetic fields in the spectrometer and beam line magnets were alternated regularly. The spectrometer magnet current was alternated on a daily basis, and all the beam line magnets were cycled and inverted once per week during the machine development pauses. The latter frequency was chosen to minimize losses of data, since the procedure is rather long and requires subsequent retuning of the beams, which in any case needed to be done after the MD.

Actual results are based on 2 self-complete data set, called *supersamples* and 1 partial supersample accumulated on the last month of 2003 data taking for a total of 720 million $K^+_{3\pi}$ and 400 million $K^-_{3\pi}$. In addition $\sim$ 50 millions of $K^\pm \to \pi^\pm\pi^0\pi^0$ were reconstructed for the same *supersamples*.

## 5 Asymmetry Measurement

Given the parametrization of the $K^\pm \to 3\pi$ Daliz plot: $|M(u,v)|^2 \sim 1 + gu + hu^2 + kv^2$, if acceptance for $K^+$ with magnetic field up is equal to acceptance for $K^-$ with magnetic field down, and in case of perfect time stability, $A_g$ can be extracted by a linear fit:

$$R_S(u) = \frac{N(u, K^+, B_{up})}{N(u, K^-, B_{down})} \propto (1 + g_+u)/(1 + g_-u) \sim (1 + 2gA_gu) \qquad (2)$$

we have also the symmetrical ratio $R_J(u) = N(u, K^+, B_{down})/N(u, K^-, B_{up})$ where the subscripts $S$ and $J$ are chosen to indicate the direction of deflection of pions of the same charge as the kaon by the spectrometer magnet toward the *Saleve* and *Jura* sides. In order to study systematic effect, it is useful to define $R_+(u) = N(u, K^+, B_{up})/N(u, K^+, B_{down})$ and $R_-(u) = N(u, K^-, B_{up})/N(u, K^-, B_{down})$ as the sum $R_+(u) + R_-(u)$ is different from 0 only for apparatus induced asymmetries.

It can easily be proved that:

- any Right-Left acceptance asymmetry which is stable between successive runs with $U$ and $D$ polarities of the magnetic field does not affect either $A_S$ or $A_J$;
- a Right-Left symmetric change in acceptance during or between successive runs could affect both $A_S$ and $A_J$ but would be canceled when averaging $A_S$ and $A_J$.

Thus a deviation from zero in the average of these slopes:

$$A = 0.5 \cdot (A_S + A_J)$$

would signal the CP-violating asymmetry, as long as the set-up is either *stable in time* or *symmetric*.

At this preliminary stage of the analysis the Collaboration considers premature to show any number which could be ascribed to a real physics effect. Therefore, the above-mentioned slopes are shown with *offsets* applied to the scale. Preliminary results show that asymmetry value is stable with Kaon momentum (Fig.2) and that it is stable with time (Fig.3).

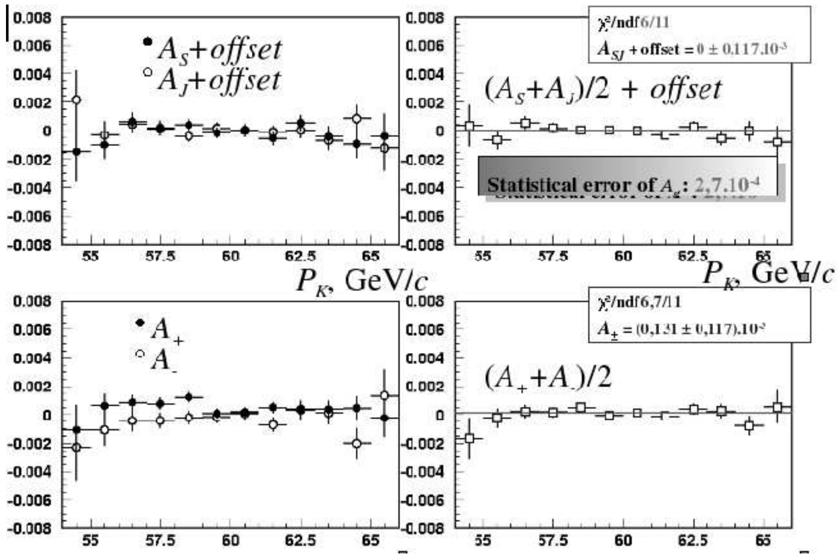


Figure 2: *The slopes $A_S$, $A_J$, $A_+$, $A_-$ and their averages $A$ integrated over all momenta and measured independently in each couple of day-samples with opposite orientation of magnetic field relative to the overall average value (an offset is introduced on the vertical scales).*

## 6 Summary

The experiment NA48/2 has been well prepared and the beam line, detector and triggers put into operation and tuned. The data accumulated in the 2003 run corresponds to only a part ($\sim 50\%$) of the planned statistics for the measurement of the direct CP-violating asymmetry in charged kaon decays.

A preliminary express analysis of a part of the 2003 run shows that the estimated statistical precision and systematic uncertainties of the measured asymmetry $A_g$ are in agreement with those indicated in the proposal. The experiment will benefit fully from the complement of running time in 2004.

## References

1. J.R. Batley *et al*, CERN/SPSC 2000-003, (2000);
   NA48/2 status report (2001);

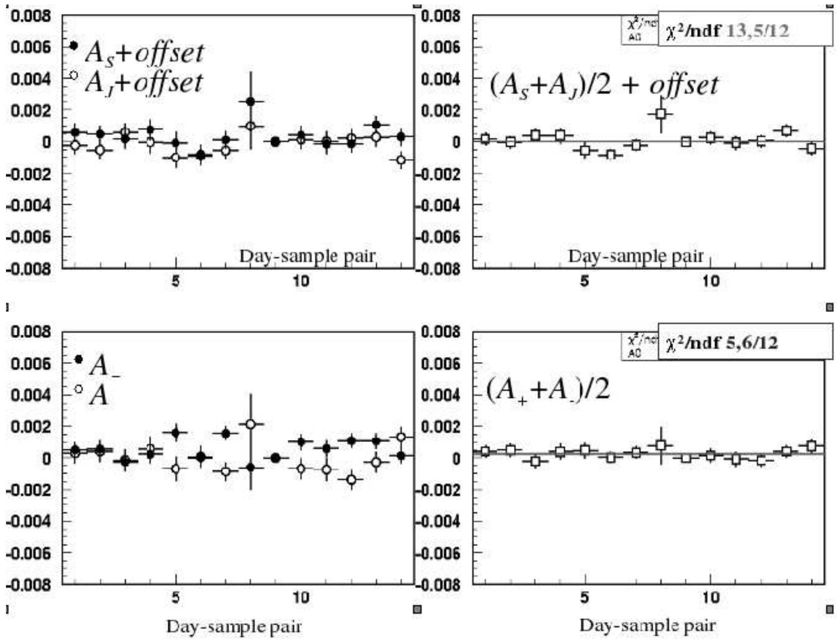


Figure 3: *The slopes $A_S$, $A_J$, $A_+$, $A_-$ and their averages $A$ integrated over all momenta and measured independently in each couple of day-samples with opposite orientation of magnetic field relative to the overall average value (an offset is introduced on the vertical scales).*

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