A Brief History of $\mathrm{Re}(\varepsilon'/\varepsilon)$

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Abstract

During last decade a particular effort has been put to the precise measurement of $\mathrm{Re}(\varepsilon'/\varepsilon)$. Challenging experiments are currently analysing data in order to deduce this fundamental parameter. In this article we will discuss in a comparative way two experimental techniques, these of KTeV at Fermilab and NA48 at CERN, with the aim to give an idea of the difficulty of the measurement and describe the ways these groups have chosen to achieve it.

1 Introduction

Neutral kaons are -at least mathematicaly- existing under many types. In strong interactions, K_0 and $\overline{K_0}$ are produced, differing only by their strangeness value. When interacting weakly, kaons appear as CP[1] symmetry eigenstates K_1 and K_2, linear combinations of K_0 and $\overline{K_0}$. Observations on weak decays lead to the identification of two kaon types since the 1960's, the long-lived $\mathrm{K_L}$ and the short-lived $\mathrm{K_S}$. Until 1964, $\mathrm{K_L}$ ($\mathrm{K_S}$) was thought to be K_1 (K_2) and this was compatible with the observation that $\mathrm{K_L}$ ($\mathrm{K_S}$) was decaying exclusively into 3(2) body final states as required by CP conservation.

A small violation of the CP symmetry has been discovered in 1964 by Christenson, Cronin, Fitch and Turlay [1] who detected a clear signal of $K_L \to \pi^+\pi^-$. This observation has modified the way of thinking of "what a $\mathrm{K_L}$ or a $\mathrm{K_S}$ particle is".

Indeed, the physical particles $\mathrm{K_L}$ and $\mathrm{K_S}$ are linear combinations of the CP eigenstates K_1 and K_2. The mixing of these two eigenstates within the particles is very small. $\mathrm{K_L}$ for instance, is essentially made of K_1 (99.8%) which decays into 3 bodies while also contains 0.2% of K_2 which allows the decay into 2 bodies. This kind of CP no-conservation is called *Indirect*, because it comes from the CP eigenstates mixing. It is represented by the parameter ϵ. In the context of the Standard Model, indirect CP Violation appears naturally because of the existence of more than two quark families [2]. Moreover, another type of CP Violation is theoretically possible: through the so-called "penguin" diagrams, a $\mathrm{K_L}$ can also decay to 2 bodies via its K_2 component. This is in some sense the "true" CP Violation since a given CP eigenstate wouldn't obey to its own symmetry. This *Direct* Violation, represented by the parameter $\epsilon^{'}$, depends on the final decay mode, charged or neutral. To identify direct CP Violation requires therefore the measurement and comparison of CP Violation of $\mathrm{K_L}$ decays into two different channels, $\pi^+\pi^-$ and $\pi^0\pi^0$.

Usually, one measures the relative strength of direct and indirect CPV. This is the so-called $\mathrm{Re}(\varepsilon'/\varepsilon)$ parameter. Precise theoretical computation of all terms entering in the $\mathrm{Re}(\varepsilon'/\varepsilon)$ evaluation becomes difficult because of the hadronic parts. In particular two of them, describing the contributions of QCD and electroweak penguins, are very poorly known resulting to a large uncertainty on the final $\mathrm{Re}(\varepsilon'/\varepsilon)$.

[1] *CP is the product of Charge and Parity symmetries: C transforms a particle to its antiparticle and P inverts all space coordinates (x,y,z)→(-x,-y,-z).*

The different groups working on Re(ε'/ε) market [3], agree that Re(ε'/ε) should be as small as $\approx$0.1% with 50% relative error. There is reasonable hope that in the next year(s) a big step will take place in the theoretical prediction of Re(ε'/ε) , because of expected outputs from Lattice QCD calculations. For further information, the interested reader is kindly requested to have a look at Vittorio Lubicz's talk in this conference, where the Re(ε'/ε) computation problem is extensively discussed.

2 Experimental observables

The Re(ε'/ε) parameter is related to four observables:

$$\mathrm{Re}(\varepsilon'/\varepsilon) = (1\text{-}\frac{\Gamma(K_L\to\pi^0\pi^0)}{\Gamma(K_S\to\pi^0\pi^0)}/\frac{\Gamma(K_L\to\pi^+\pi^-)}{\Gamma(K_S\to\pi^+\pi^-)})/6$$

The ratio

$$\mathrm{R}= \frac{\Gamma(\mathrm{K_L}\to\pi^0\pi^0)}{\Gamma(\mathrm{K_S}\to\pi^0\pi^0)}/\frac{\Gamma(\mathrm{K_L}\to\pi^+\pi^-)}{\Gamma(\mathrm{K_S}\to\pi^+\pi^-)}$$

represents the ratio of CP violating ($\mathrm{K_L}$) over CP conserving ($\mathrm{K_S}$) widths into two final modes. In the experimental reality this ratio, called R, is measured by detecting the four decays, namely $\mathrm{K_L}, \mathrm{K_S} \to \pi^+\pi^-$ and $2\pi^0$, within detector apertures. Thus, the true Re(ε'/ε) is deduced correcting for fluxes, acceptances, trigger efficiencies etc, i.e all factors which might bias the measurement and introduce deviations of R_{meas} w.r.t. R_{true}. The difficulty of the Re(ε'/ε) measurement becomes then clear: one has to disentangle the CP violating $\mathrm{K_L}$ modes in a environment full of CP conserving 3-body decays (>99%). As Re(ε'/ε) is expected to be small ($\approx$ 0.1%) one needs high experimental accuracy (of the order of few 10^{-4}) to get a significant result. This goal would be easier achieved if the needed corrections to R_{meas} could have been small and therefore almost negligible for the result.

2.1 The advantages of measuring a double ratio

The necessary corrections for going from R_{meas} to R_{true} can cancel in first order under certain conditions of data taking. Let us give some examples:

- Flux corrections: it is a priori necessary to know the initial number of Kaons in the beam to normalize, for instance, the number of observed $\mathrm{K_L} \to 2\pi^0$ within the acceptance. Nevertheless, this information becomes useless if $\mathrm{K_L} \to 2\pi^0$ and $\mathrm{K_L} \to \pi^+\pi^-$ final states are recorded concurrently. In this case, the absolute flux of initial $\mathrm{K_L}$ beam cancels in the ratio.
- Trigger inefficiencies: triggering is designed, in general, wide enough to not loose any good event. However, it often happens that, finally, one has to correct for some kind of triggering inefficiency, due to failure to record good events for some reason. This correction can cancel in the double ratio if both $\mathrm{K_L}$ and $\mathrm{K_S}$ decays to that final charged or neutral mode, are simultaneously recorded. This remark also concerns instabilities of a specific detector: let's imagine that due to failures of a particular detector we loose events whose reconstruction requires its information. If both beams are concurrently recorded, both $\mathrm{K_S}$ and $\mathrm{K_L}$ modes will be affected in the same way and finally the double ratio will be unbiased in the first order.

The best scenario, as far as correction cancellations are concerned, is when all four modes are concurrently detected. Then a long list of eventual biases would cancel in the double ratio. Only second order effects have to be evaluated for correcting R. If this running mode obviously must be chosen, in practice it is technically difficult. This is why the previous generation of experiments on $\mathrm{Re}(\varepsilon'/\varepsilon)$ followed intermediate solutions for this measurement.

One has to keep in mind that even in the "ideal" case quoted above, some corrections might not cancel. This concerns first-of-all the physical background which is only in $\mathrm{K_L}$ beam and clearly final mode dependent. Secondly, acceptance corrections don't a priori cancel because of the very different lifetimes of $\mathrm{K_L}$ and $\mathrm{K_S}$ particles convoluted by the different topologies of $2\pi^0 \to 4\gamma$ and $\pi^+\pi^-$ events. Physical background and - especially- acceptance corrections would therefore require particular care and can be handled in different ways.

3 Experiments on $\mathrm{Re}(\varepsilon'/\varepsilon)$

Previous generation experiments ended beginning of '90s and published their final results in '93:

E731 Fermilab	$(7.4 \pm 5.9) \cdot 10^{-4}$ [4]
NA31 CERN	$(23.0 \pm 6.5) \cdot 10^{-4}$ [5]

E731 and NA31 were both fixed target experiments, using neutral kaons produced by protons hitting beryllium targets. They chose different methods to build the $\mathrm{K_S}$ beam. Both computed $\mathrm{Re}(\varepsilon'/\varepsilon)$ measuring the double ratio, but not detecting all four modes simultaneously.

- E731 was recording one single final mode in simultaneous beams and then changing mode (i.e. they were measuring either $\mathrm{K_L}/\mathrm{K_S} \to \pi^0\pi^0$ or $\mathrm{K_L}/\mathrm{K_S} \to \pi^+\pi^-$). A small part of E731 total sample corresponded to simultaneous four modes detection.
- NA31 was recording both final modes in a single beam and then changing beam (i.e. they were measuring $\mathrm{K_L} \to \pi^0\pi^0/\pi^+\pi^-$ or $\mathrm{K_S} \to \pi^0\pi^0/\pi^+\pi^-$)

Obviously, these two experiments were differently sensitive to several systematics. Their respective results were compatible only at the level of 8%. Moreover, their physical meanings differed: E731 found a result compatible with zero, $(7.4 \pm 5.9) \times 10^{-4}$, while NA31 claimed the existence of a Direct CP violating component with 3.5 standard deviations significance, $(23.0 \pm 6.5) \times 10^{-4}$. To obtain even more precise results a new generation of experiments had already been studied at that time with the aim to achieve final precisions on $\mathrm{Re}(\varepsilon'/\varepsilon)$ of 1 to 2×10^{-4}: KTeV at Fermilab [6], NA48 [7] at CERN and KLOE [8] at Frascati. KLOE is installed in Φ factory and started running last year. The major part of this paper will be devoted to the comparative presentation of KTeV and NA48 since these two experiments have already published results.

3.1 KTeV and NA48: A presentation

KTeV and NA48 are fixed targed experiments. Their designs have been challenging in order to build stable detectors able to run several years, fast electronics to handle the intense beams, precise calorimetry to identify and reject the $3\pi^0$ background, powerful acquisition to cope with high trigger rates. The detector had to be radiation resistant to stand the beam intensities. Long R&Ds have been necessary in several branches and this effort has been also profitable for future experiments which will work in high intensity environment (i.e. Tevatron).

A posteriori one could describe their start-up weeks as painful: the complicated electronics, detectors and triggering systems made physicists suffer and it took a long time to achieve the global system running. Several detector parts have been upgrated later (electronics, readout chips etc).

At the beginning of the new millenium the accumulated statistics of the most suppressed mode $K_L \to 2\pi^0$ was 10M events for KTeV (taken in 96, 97 and 99) and 4M events for NA48 (accumulated in 97, 98 and 99). NA48 will slightly increase its statistics until the end of the foreseen running periods (2000 and 2001).

Both experiments have announced results based on fractions of their statistics. KTeV gave a first result on 10% of its total sample in Februray 99. NA48 announced a result extracted from 97 data in June 99 and a second one in February 2000, coming out from the 98 data period.

In the following we will present the ways to analyse data and extract $\mathrm{Re}(\varepsilon'/\varepsilon)$ in KTeV and NA48.

3.2 The KTeV Beams and Detectors

In figure 1 a schematic view of the Beam Lines and KTeV detector is shown. The KTeV [9] experiment uses protons of 800GeV coming from the Tevatron and impinging a beryllium target. Twin parallel kaon beams are produced, cleaned-up and let flying for 120m after the target in order to keep only the K_L component.

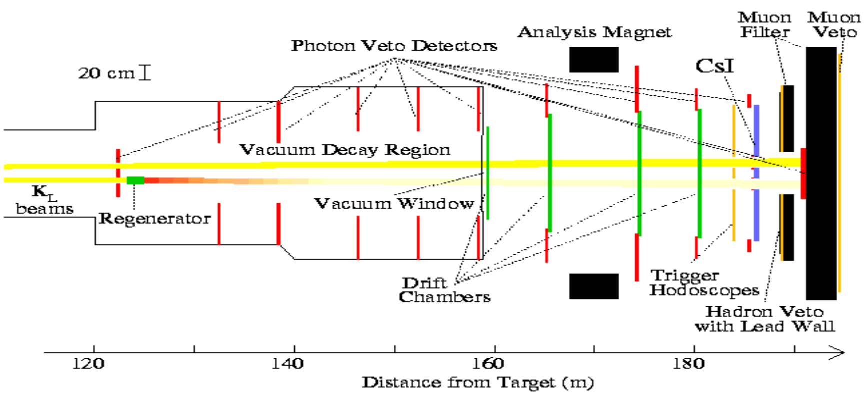

Figure 1: KTeV beam lines and detectors

The decay region is starting after the last collimator. At this level the two beam holes are distant by 10cm. One beam is going through a regenerator made of a series of plastic scintillator blocks and corresponding to two interaction lengths. Because K^0 and $\overline{K}^0$ (contained in K_L particles) have different nuclear cross-sections with matter, their initial mixture is modified. At the end of the regenerator, the previously pure K_L beam is now "regenerated" into $K_L+\rho K_S$ where ρ is proportional to the quantity of traversed matter. The decays of the two parallel beams, K_L (vacuum beam) and K_S (regenerator beam) are then observed by a series of detectors: a magnetic spectrometer made of a central magnet and four chambers reconstruct the

charged modes allowing the measurement of vertex decay and particle momentum. Chambers have only horizontal and vertical wires and the correct association of X and Y track information requires additional external information which is given actually by the calorimeter.
Neutral modes are detected by a CsI calorimeter [11] made of 3100 blocks of pure (non doped) crystals of $27X_0$ (50cm long) and of two granularities: $2.5\times2.5\text{cm}^2$ in the central region (where photon density is higher) and $5\times5\text{cm}^2$ in the outer region. The advantage of a such calorimeter is the excellent stochastic term in the resolution (resulting to a 0.8% for a 10GeV photon as shown in figure 2 left). A meticulous crystal wrapping is required to equalize the light collection longitudinally within 5%. Moreover permanent calibration with a Cs-137 source followed the stability of the response of each crystal. After all corrections the obtained response is linear within few permil.
The experiment is surrounded by circular Vetoes detecting photons escaping acceptance.
At the end of the line, Muon Vetoes are used to identify $K_L \to \pi\mu\nu$ decays.

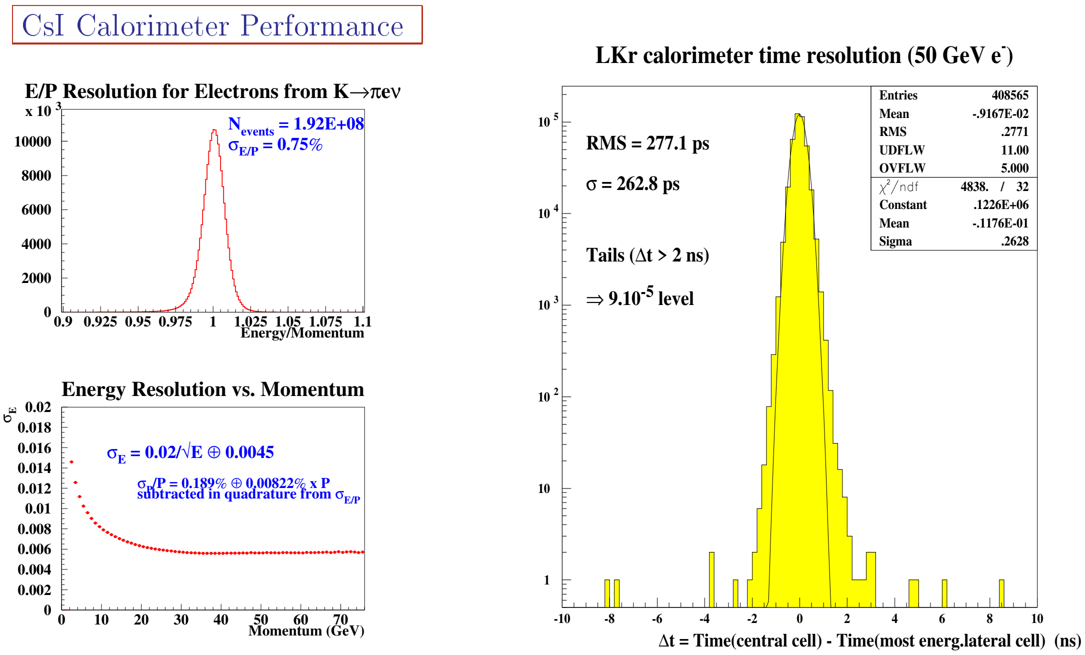

Figure 2: Performances of the KTeV CsI calorimeter (left). Instrinsic time resolution of the LKr calorimeter of NA48 (right)

A caracteristic point of KTeV is that the two beams hit the detectors in different places, left and right. This offers the possibility to easily disentangle a K_L decay from a K_S one reconstructing its centre of gravity in the detectors and comparing it with the known regenerator position (in front of the left or of the right beam hole). The regenerator moves from one hole to the other every minute, in such a way that K_L and K_S decays are equally sensitive to eventual left-right asymmetries of the detectors.

3.3 The NA48 beam Lines and Detectors

Figure 3 gives a schematic view of the NA48 beam lines [10]. The initial 450GeV proton beam coming from the SPS hits a beryllium target. Output products are

cleaned-up and the neutral kaon component is let flying along 120m in order to finaly obtain a pure K_L beam. The survived proton beam after the K_L target is deviated and attenuated by passing through a bending channelling crystal. The chosen fraction of protons (10^{-5} corresponding to $3{\times}10^7$ protons) is then sent close to the final collimation where it impinges a second target. After a 6m long collimation the K_S component is largely dominating. At the entrance of the fiducial region, K_L and K_S beams are distant in the vertical plane by 7.2cm. The K_S beam is sligthly converging in order to illuminate the same area in the detectors as the K_L beam. In order to identify the mother beam of a given detected event one uses the timing coincidence between event time (reconstructed by detectors) and closest K_S proton time. This time is measured by a tagging station [13] which is installed after the bending crystal and detects all protons which are going to produce the K_S beam. Two close protons are separated down to 4ns.
A magnet placed between the second and the third (among four) wire chambers bends charged tracks and allows the momentum reconstruction. Each chamber contains 8 planes of wires oriented following four directions in order to resolve ambiguities in track reconstruction.
NA48 chosen a quasi-homogeneous calorimeter, made of $\approx$10m^3 of liquid Krypton [12] where the ionization signal is readout by Cu-Be-Co electrodes. A cell is made by three such electrodes, cathode-anode-cathode, with dimensions of 2cm$\times$2cm$\times$127cm.

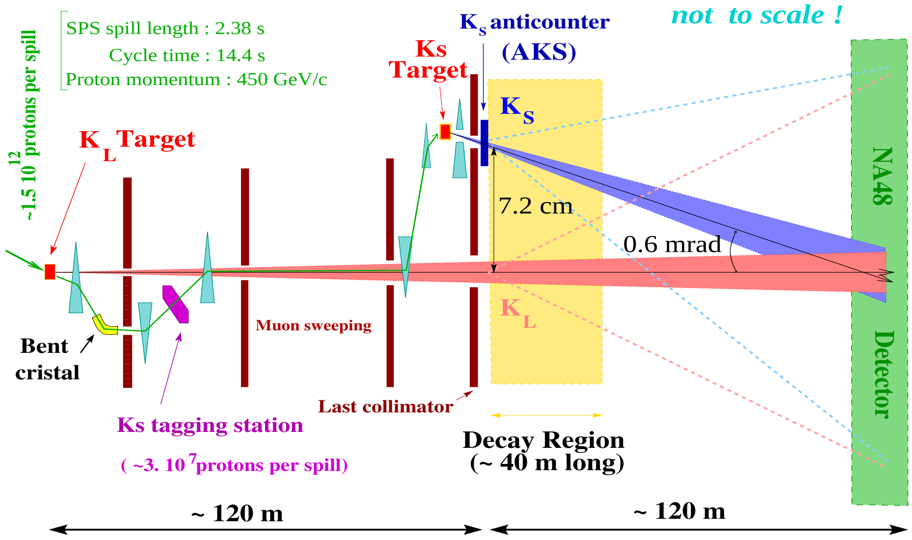

Figure 3: NA48 beam line schematic view

The gap stability is guaranteed by 5 planes which guide the electrodes longitudinally and also apply a small zig-zag. The stochastic term after recontruction is $3.2\%/\sqrt{E}$ which translates to 1.5% resolution at 10GeV, taking also into account of noise and constant terms. The constant term is 0.5% (over the $\approx$13000 cells). In addition to good energy performances, a challenging time measurement was mandatory for this calorimeter, in order to efficiently disentangle K_L and K_S neutral final modes. The neutral event time is reconstructed in the LKr calorimeter with a resolution of $\approx$250ps and the tails are less than 10^{-4} (figure 2 right).
A series of Muon Vetoes identify and reject muons from $K_L \to \pi\mu\nu$.

4 Analysis

The analysis methods used by the two experiments are, in general, similar. In the following we will describe the common parts and underline the important differences.

4.1 Identification of $\pi^+\pi^-$ modes

Both experiments use a spectrometer to reconstruct charged final modes. The strength of the magnet is higher in KTeV wrt NA48 and this is translated in a better reconstructed Kaon mass resolution. In addition, KTeV chambers with only X and Y wire planes are lighter wrt NA48 ones (X, Y, U and V) and this offers a lower multiple scattering term in the momentum resolution although this implies a combined calorimeter-spectrometer information to solve track reconstruction ambiguities.

	KTeV	NA48
P_T Kick	412MeV/c	250MeV/c
$\pi^+\pi^-$ mass Resolution	1.6MeV	2.5MeV
$\sigma(P)/\mathrm{P}$ (%)	$0.2\oplus 0.008\times\mathrm{P}$	$0.5\oplus 0.009\times\mathrm{P}$

$\mathrm{K_L} \to \pi\mu\nu$ decays are rejected by identifying muons in the dedicated vetoes. Comparing the track momentum and the energy in the calorimeter matching the extrapolated track, electrons from $\mathrm{K_L} \to \pi e\nu$ are identified and rejected. A cut on the transverse momentum is applied to reject further 3-body backgrounds and scattered events

After all, one evaluates the contribution of all kinds of remaining background under the signal.

4.2 Identification of $\pi^0\pi^0$ modes

Neutral decays are reconstructed using photon energies and positions in the calorimeter. In order to find the vertex position an additional constraint is however necessary. In the KTeV case, one assumes the π^0 mass and one makes all photon pairs combinations. Among resulting vertices the two closest are kept and they are combined to give the most probable value of the decay vertex. Then this vertex is used to compute the Kaon mass.
In the NA48 case, one assumes that the invariant mass of the decay was the one of a neutral kaon. This constrains the vertex decay point. Then the best among all possible combinations of $\gamma\gamma$ pairs is kept to reconstruct the $2\pi^0$s.
Both experiments compute a χ^2 representing the event compatibility with a $2\pi^0$ final state. All cases of $3\pi^0$ background events, with lost or fused photons, are located in the tails of the χ^2 distribution and they are rejected.

After all, one evaluates the contribution of all kinds of remaining background under the signal.

4.3 Distinguishing a $\mathrm{K_L}$ from a $\mathrm{K_S}$ in KTeV

To identify the mother beam of a detected decay, KTeV takes profit of the parallel, distant by 10cm, beam technique. Looking at the centre of gravity, in both charged and neutral final mode cases, the beam origin is, in general, unambiguous.

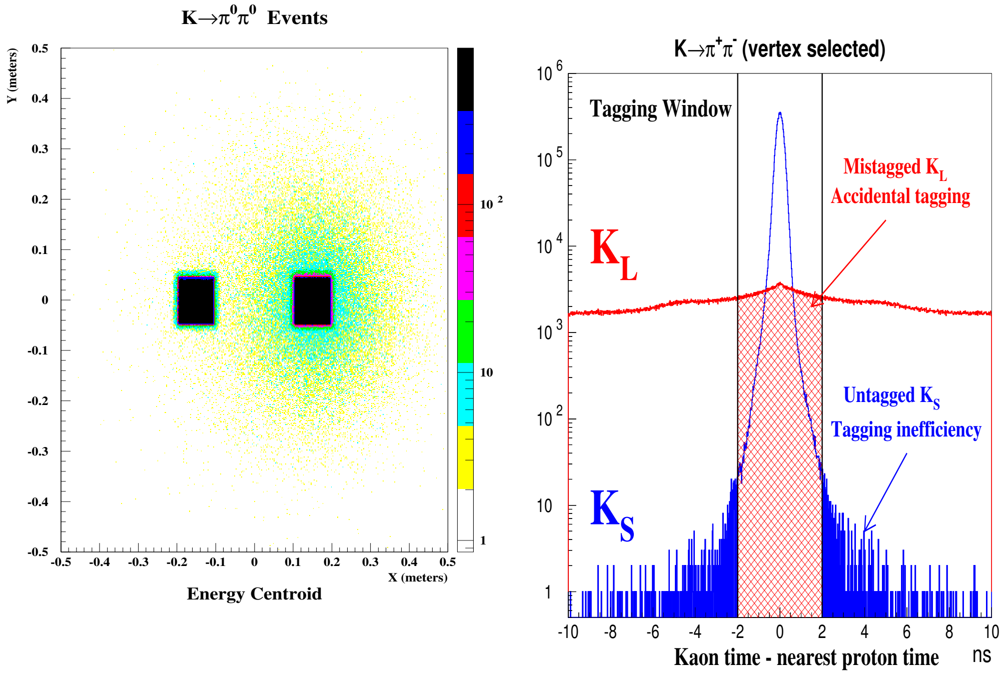

Figure 4: Beam separation: energy centroids in KTeV (left) and tagging in NA48 (right)

In figure 4 left, the energy centroids in the calorimeter are shown for neutral events. The distance between the two beam images is 10cm. The halo comes from the scattered events in the regenerator, before decaying. In this case, the event trajectory can be deviated by much in such a way that, after decaying, the event is reconstructed in the opposite beam position. This effect is precisely studied in charged mode looking at the P_T^2 distribution and then introduced into a detailed simulation in order to evaluate its contribution to the neutral mode.

4.4 Distinguishing a $\mathrm{K_L}$ from a $\mathrm{K_S}$ in NA48

In NA48, the separation between the two beams is done by mean of tagging. In figure 4 right, the time difference between the event time and the nearest proton time is shown for charged events. If the event did come for the $\mathrm{K_S}$ beam, a proton should be at its origin and a time coincidence should be found within the $\pm$2ns defined window. This is shown for true $\mathrm{K_S}$ events: the tagging inefficiency is very small ($(1.97\pm0.05)\times10^{-4}$ in 1998 sample). Requiring coincidences implies that some part of $\mathrm{K_L}$ would be identified as $\mathrm{K_S}$ as well because of the high proton rate in the tagger. Eleven per cent of $\mathrm{K_L}$ have been mistagged as $\mathrm{K_S}$ in 1998. Final data samples are corrected for both inefficiency and mistagging fractions. In charged mode, where $\mathrm{K_S} - \mathrm{K_L}$ separation can also be achieved by vertex recontruction (in the vertical plane) the evaluation is straightforward. In the neutral mode, several methods exist to measure tagging inefficiency, mistagging probability and constrain eventual differences with the charged mode.

4.5 Background fractions in KTeV and NA48

By studying identified 3 body ($\mathrm{K_L} \to \pi e \nu$, $\mathrm{K_L} \to \pi \mu \nu$ and $\mathrm{K_L} \to 3\pi^0$) decays, one can deduce the amount of expected background remaining events, after all applied cuts, in the defined signal regions.

Under K→ $\pi^+\pi^-$ signal

Background source	KTeV Vacuum	KTEV Regener.	NA48 K_L
$K_L \to \pi e\nu + K_L \to \pi\mu\nu$	0.69×10^{-3}	0.03×10^{-3}	1.9×10^{-3}
Scatt. in Collimator	0.14×10^{-3}	0.14×10^{-3}	-
Scatt. in Regenerator	-	0.73×10^{-3}	-
TOTAL	0.83×10^{-3}	0.89×10^{-3}	1.9×10^{-3}

Under K→ $\pi^0\pi^0$ signal

Background source	KTeV Vacuum	KTeV Regener.	NA48 K_L
$K_L \to 3\pi^0$	2.7×10^{-3}	0.1×10^{-3}	0.66×10^{-3}
Scatt. in Collimator	1.5×10^{-3}	1.4×10^{-3}	1.0×10^{-3}
Scatt. in Regenerator	3.0×10^{-3}	10.7×10^{-3}	-
Regenerator junk	-	0.1×10^{-3}	-
TOTAL	7.3×10^{-3}	12.2×10^{-3}	1.7×10^{-3}

In charged mode, KTeV takes profit of the better Kaon mass and P_T^2 resolutions, coming from the stronger field. In this way the remaining $K_L \to \pi e\nu$ and $K_L \to \pi\mu\nu$ level under the signal is smaller than in NA48. In neutral mode, $3\pi^0$s with fused or lost photons give similar fractions of background in both experiments ($\approx$0.3%). However in NA48, the chosen K_L weighting analysis method decreases this fraction to 0.07%. Furthermore, in KTeV case, the regenerator contributes to an additional kind of background which becomes especially important in neutral final state (1.2%).

4.6 Fitting R in KTeV and NA48

After background subtraction in KTeV, four samples are left corresponding to Vacuum beam (K_L decays) and Regenerator beam (essentially K_S) decays to $\pi^0\pi^0$ and $\pi^+\pi^-$ final modes. Because of the very different decay shape distributions of K_L and K_S events, acceptance correction in KTeV is as large as 5.5% on R, correction which must therefore be known with great precision. The four decay distributions are corrected for acceptances coming from a very detailed Monte Carlo simulation, where all known effects like trigger and detector efficiency, regeneration, $K_S - K_L$ interference and precise detector apertures are simulated. Re$(\varepsilon'/\varepsilon)$ comes out (among other parameters) from a fit of the data in 10GeV bins to minimize energy spectra differences.

In NA48, after background subtraction, one has to deal with four samples, namely tagged $\pi^0\pi^0$ and $\pi^+\pi^-$ (essentially K_S, having a $\pm$2ns coincidence with a proton in tagger) and untagged (K_L) $\pi^0\pi^0$ and $\pi^+\pi^-$. All samples are corrected for the misstagged fraction of K_L events and for trigger inefficiencies. The acceptance correction is calculated after weighting decay distributions of K_L events with the corresponding K_S lifetime. In this way, K_S and K_L spectra become at first order similar and this decreases the acceptance correction on R to 0.3%. The drawback of the weighting method is a 35% increase of the statistical error on R. The raw R ratio is corrected in 5GeV energy bins and the final result is given by an unbiased estimator.

The differences of analysis techniques followed by the two experiments are translated to the correction factor they have to apply to raw R. In KTeV, a total correction of $\approx$5% is applied, largely dominated by the acceptance. In NA48 R_{meas} correction is limited to 0.37% (thanks to weighting).

The hard core of the work in KTeV and NA48 is the study of the result stability as a function of several variables. To evaluate the total systematic uncertainty, the sensitivity of the result to known effects is computed by MonteCarlo and/or using data samples. The KTeV technique requires a titanesque simulation work in order to achieve the precise knowledge of the acceptance correction. Both experiments are sensitive to the energy scale in the neutral mode which defines, through the way of reconstructing the events, the vertex scale as well. An energy shift would translate to an apparent position displacement. The energy scale stability is therefore followed through the position reconstruction of a well known sharp object: the regenerator edge in KTeV and the anticounter in front of the K_S beam hole in NA48. Finally, a series of cuts and running conditions have been systematically verified in order to check the stability of the final result.

5 Results and perspectives

In the table below the announced results of KTeV and NA48 are shown. Both experiments are working on their respective large remaining data samples towards a further understanding and stronger constraints of possible systematics. Combining the four more precise results from E731, NA31, KTeV and NA48 one obtains a new world average of Re$(\varepsilon'/\varepsilon)$ =$(19.4\pm2.5)\times10^{-4}$. This value clearly confirms the existence of a non zero Direct CP Violating component. The absolute amount of this contribution remains however still controversial.

Announced results

KTeV February 1999	$(28.0\pm3.0(\text{stat})\pm2.8(\text{syst}))\times10^{-4}$ [14]
NA48 June 1999	$(18.5\pm4.5(\text{stat})\pm5.8(\text{syst}))\times10^{-4}$ [15]
NA48 February 2000	$(12.2\pm2.9(\text{stat})\pm4.0(\text{syst}))\times10^{-4}$ [16]

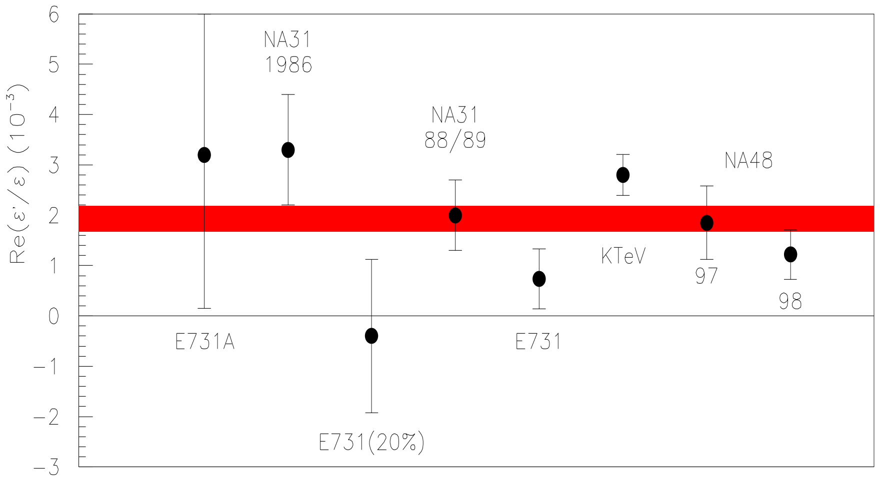

Figure 5: The most recent precise results

This will hopefully be clarified soon, after the end of the analysis in KTeV and NA48. In this purpose, the KLOE experiment running at the Φ factory of the Frascati Laboratory will also contribute, offering in few years a Re$(\varepsilon'/\varepsilon)$ measurement from different methods.

Concluding, one must underline once again the enormous effort of the Direct CP-violation hunters, to perform delicate and so precise measurements. The outcoming result means that $K^0 \to \pi^+\pi^-/K^0 \to$all is larger by $(8.6\pm1.1)\times10^{-6}$ than $\overline{K^0} \to \pi^+\pi^-/\ K^0 \to$all.

Currently, CP non-conservation starts to be studied in the B meson system (BELLE, BABAR presentations in this conference). Considering all constraints together, there is reasonable hope that a deeper understanding of the CP Violation mechanism will be achieved within forthcoming years.

6 Aknoweledgements

I am grateful to Ed Blucher and Bob Tschirhart from KTeV for the material they gave me in the preparation of this talk. I enjoyed reading Peter S. Shawhan's PhD thesis [17] where I found all necessary information concerning KTeV analysis.
Finally, I would like to warmly thank the organizers of PIC2000 for the nice conference they offered to all of us.

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[7] NA48 is a Cagliari, Cambridge, CERN, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Orsay, Perugia, Pisa, Saclay, Siegen, Torino, Vienna and Warsaw collaboration.

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