NA48/Internal
NA48/
August 27, 1998

Preliminary efforts to isolate K_L , K_S $\rightarrow$ π^+ π^- γ events.

T.C. Petersen[a], M. Velasco[b]

[a]Niels Bohr Institute, Copenhagen, Denmark
[b]CERN, Geneva, Switzerland

Abstract

We have done efforts to isolate the rare decay K_L , K_S $\rightarrow$ π^+ π^- γ, with the goal of reproducing an article of the E731 collaboration [1] concerning the decay in question. After a short introduction, the used cuts will be described and the result of them presented. These initial steps lays the ground for futher studies of the decay channel, which is also a background in the ϵ' measurement.

1 Introduction

The decay K_L , $K_S \rightarrow \pi^+ \pi^- \gamma$ is a CP–concerving rare dacay with measured branching ratios of 4.61 $\pm$ 0.14) $* 10^{-5}$ and $(1.78 \pm 0.05) * 10^{-3}$ for K_{long} and K_{short} respectively. Inner bremsstrahlung (IB) dominates the K_{short}–decay, but in the K_{long}–decay the underlying mechanisme for IB is CP–violating and therefore highly suppressed, and therefore the direct emission (DE) process constitues two thirds of the phase space with photon energies above 20 MeV in the CM frame. A difference in the ratios of the bremsstrahlung branching ratio to $\pi^+ \pi^-$ between K_L and K_S–decays, could be a sign of direct CP–violation in this decay mode. For further references, see [1] and [2].

2 Cuts

In order to isolate the decay, a great number of cuts has to be applied to the data. Below are listed the cuts made on the data, some with a histogram showing the efficiency of the cut. They have been put in catagories, and are listed in the order they are introduced in the analysis program. Finally, more cuts are suggested and discussed.

2.1 Trigger cut

Since we are looking at a charged decay, demanding the charged trigger to fire seems natural. The charged triggers are then divided into two catagories:

- *Main* $\pi^+ \pi^-$.............................. (the first bit)
- *Minimum bias*..................... (the three consecutives bits)

The first one has a cut on the invariant mass of the pions, and may for that reason not trigger on $\pi^+ \pi^- \gamma$ events with E_γ above a certain value, whereas the second does not have this cut. However, the first trigger contains the most data, and for this reason, both triggers have been included[1)]. This cut discards about 42 % of the events.

2.2 Initial demands

The initial demands need little explaination and are the following:

- *Two charged tracks.*
- *One positive and one negative track.*
- *1–3 clusters in the LKr.*
- *One vertex only.*

Events with only one cluster in the LKr are included in order not to discard cases where none of the pions deposited energy. These cuts discards about 22 % of the events (see figure 1a).

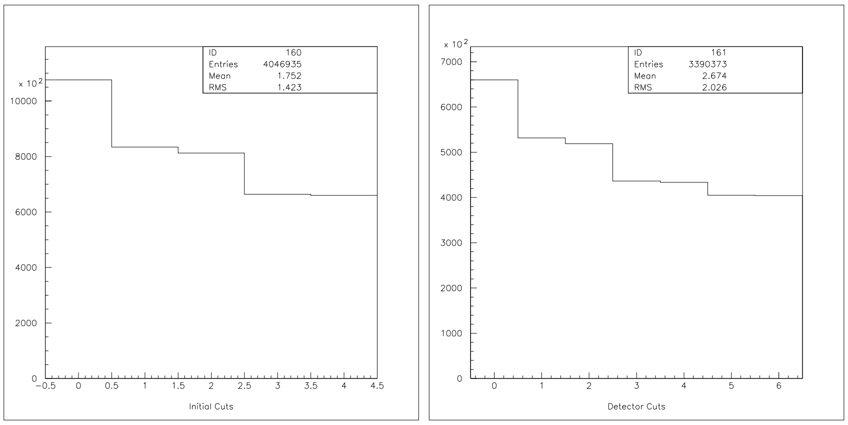

Figure 1: The efficiency of the different cuts: a) Initial cuts. b) Detector cuts.

1) In 5 % of the cases, both triggers went of, and these events were in the further analysis considered *minimum bias* triggers.

2.3 Detector cuts

The detector cuts that seems mandatory are:

- *Minimum track momentum*, that is, greater than 15 GeV.
- *Small closest distance of approach*, which means smaller than 1.4 cm.
- *No clusters close to the beam pipe and the outer edge*, i.e. have a beam distance between 17.0 cm and 110.0 cm.
- *No hits in the dead column*, comming down to not hitting the LKr between 46.3 cm and 52.3 cm.
- *No tracks close to the beampipe when entering the magnet*, that is further away than 5.0 cm.
- *Reasonable z–vertex position*, which means between 0.0 m and 50.0 m.

The cut on z–vertex position is in order to be able to destinguish between K_L and K_S, since the two beams after 50.0 m starts to superposition. These cuts altogether discards about 38 % of the events (see figure 1b).

2.4 Cut on particle type

Needless to say, other types of particles has to be cut away:

- *Lambdas* are cut away by requirering, that the ratio between the two momenta, are not larger than 3.0.
- *Muons* are detected in the muon veto, and can therefore be cut on directly.
- *Electrons* are cut away by demanding, that the energy diposit in the LKr over the momentum is not great than 0.85 for any of the two charged tracks.

These cuts take away about 65 % of the events (see figure 2a).

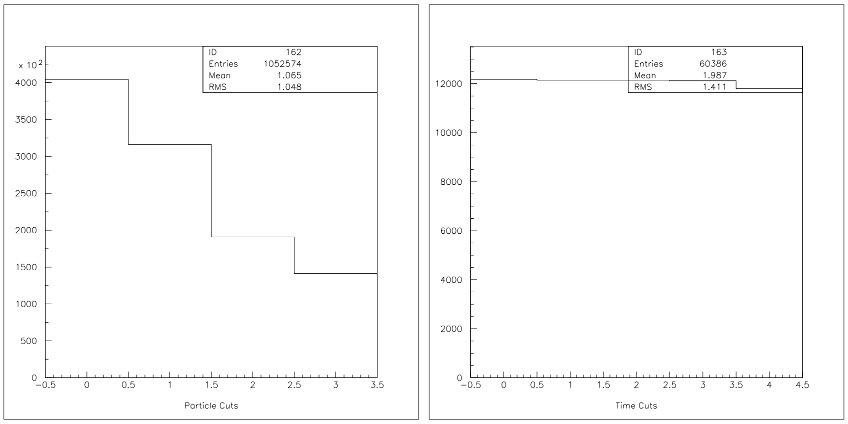

Figure 2: The efficiency of the different cuts: a) Particle cuts. b) Time cuts.

2.5 Cut on transverse momentum of pions and possible π^0

To reduce the major background from $\pi^+\ \pi^-\ \pi^0$ decays, where one photon goes undetected, a cut is made on the variable:

$$P^2_{\pi^0} \ = \ \frac{(M^2_{K^0} \ - \ M^2_{\pi^0} \ - \ M^2_c)^2 \ - \ 4M^2_{\pi^0}M^2_c \ - \ 4M^2_{K^0}(p_T)^2_c}{(p_T)^2_c \ + \ M^2_c}$$

where M_c is the invariant mass of the two pions and $(p_T)_c$ is their compined transverse momentum. This is for $\pi^+\ \pi^-\ \pi^0$ decays proportional to the squared longitudinal momentum of the π^0 in the kaon rest frame, and therefore a positive quantity. Requesting a value of $P^2_{\pi^0}$ below -0.05 reduces the background, though this is already suppressed at the trigger level, and therefore these cuts together discards only about 2 % of the events.

2.6 Cut on number of unassociated cluster

After all these initial cuts, one should be left with mostly π^+ π^- events, whit a possible extra photon. The search for these comes down to finding clusters in the LKr, where no tracks lead to - socalled unassociated clusters. When an unassociated cluster with energy higher than 1.0 GeV is found, the four momentum of a photon is reconstructed. If more than one cluster is found, the invariant mass is computed, and the event discarded if they reconstruct to the π^0–mass. These two cuts take away about 91 % of the events.

2.7 Cut on time differences

In order to insure, that the particles origins from the same event and are not accidentals, the recorded time is required to lie within certain windows. The constrains are the following:

- *Same pion time in DCH*, i.e. within 5.0 ns.
- *Same pion time in LKr*, i.e. within 6.0 ns.
- *A fixed time difference* between $t_{LKr,(\pi^+,\pi^-)}$ and $t_{DCH,(\pi^+,\pi^-)}$ of 162.3 $\pm$ 5.0 ns.
- *A fixed time difference* between $t_{LKr,\gamma}$ and $t_{DCH,(\pi^+,\pi^-)}$ of 162.3 $\pm$ 5.0 ns.

The distributions of time differences are *all beautiful gaussians*, and so these cuts only discards 9 % of the events (see figure 2b).

2.8 Cut on missing energy and kaon mass spectrum

One could now think, that the invariant mass of π^+ π^- γ would reconstruct to the kaon mass, and if there no other backgrounds than π^+ π^- π^0 and accidentals, then this would probably be true. The spektrum (see figure 3a) doesn't at all look as it is supposed to though. It has a huge background above the kaon mass from something that looks uncorrelated and only few events around the kaon mass.

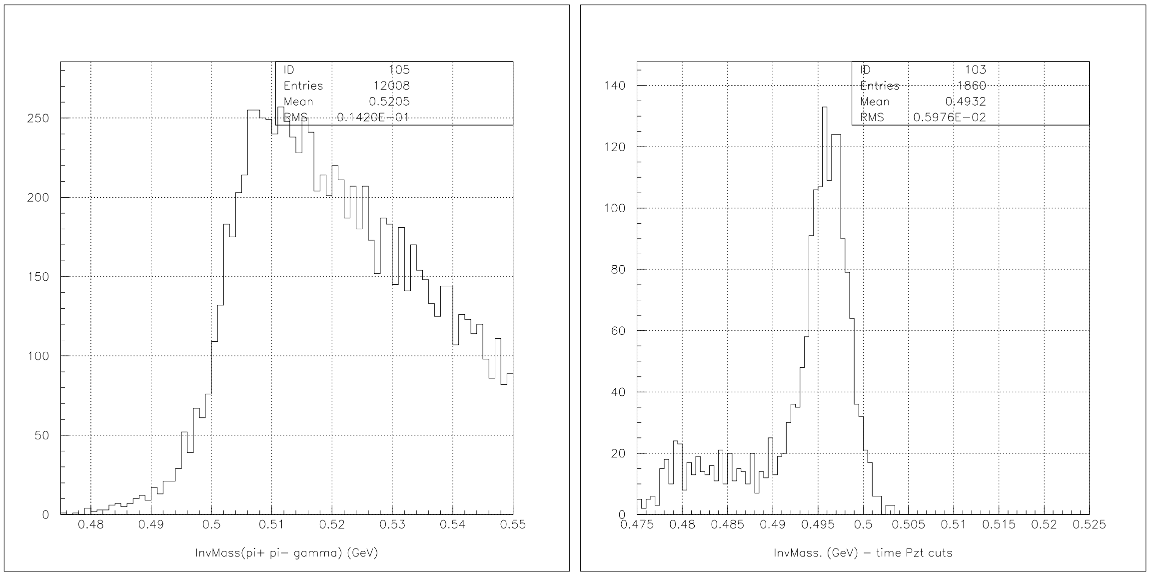

Figure 3: a) Invariant mass of π^+ π^- γ before cut on missing energy and kaon mass. b) Invariant mass of π^+ π^-. The tail to the left is from π^+ π^- γ events.

However, looking at the corresponding plot of the π^+ π^- invariant mass (see figure 3b) shows, that most of the events indeed shouldn't have an extra photon in order to reconstruct to the kaon. The plot has a tail indicating missing energy, i.e. π^+ π^- γ events, and so a cut demanding the π^+ π^- invariant mass to be below 491.0 MeV[2)] is made.

The final cut is fitting to the kaon mass. One accepts only events where the invariant mass of π^+ π^- γ equals the kaon mass plus minus 15.0 MeV; a mass window which fully contains the

[2)] This value was determined only by inspection of the π^+ π^- invariant mass plot, and should be investigated further with a Monte Carlo.

eccential data. The resulting spectrum is shown in figure 4 below. It is beautifully fitted with a gaussian and hits the kaon mass within errors.

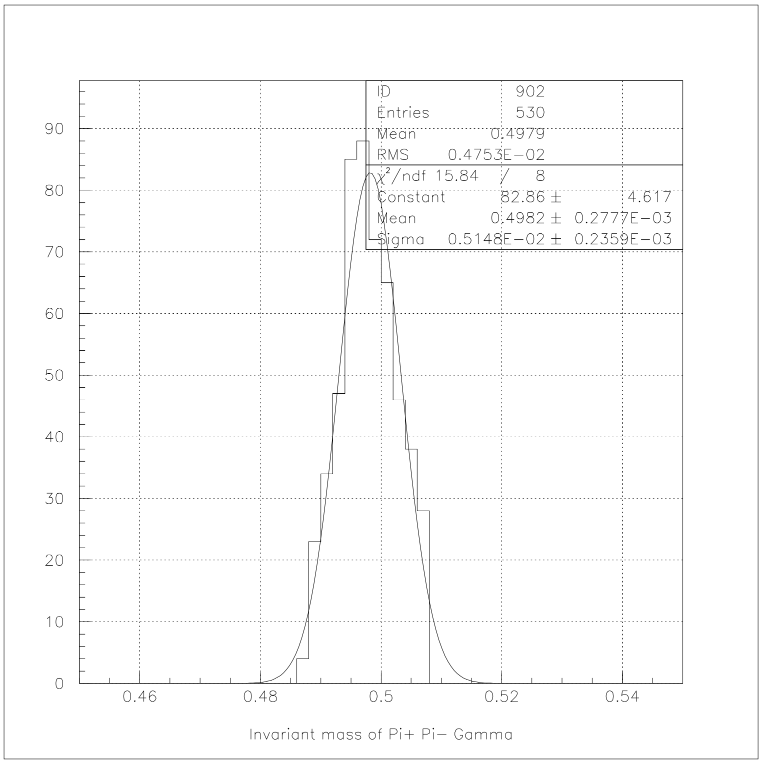

Figure 4: Invariant mass of $\pi^+ \ \pi^- \ \gamma$ after all cuts.

2.9 Additional possible cuts

An additional cut that could be applied to a later piece of code, is to look for missing transverse momentum. If the two charged pions are not back to back in the detector, this might imply a photon. Furthermore, assuming reconstruction to the kaon mass, one should be able to predict an area in the LKr where the photon hit, and an unassociated cluster can then be searched for. However, this approach should not be taken before a proper kaon mass spectrum is obtained, since it involves assuming reconstruction to the kaon mass.

3 Results and conclusions

It is though still highly suspecious, that the momentum of the photon in the kaon rest frame does not have the same distribution in different directions. While p_x and p_y have the same distribution and are nicely centered around 0.0 MeV, p_z has about half the width and is shifted to the forward direction, that is towards positive momentum. An initial thought could be, that the Lorentz transformation isn't correct, but it has been tested thouroughly

References

[1] Simultaneous Measurement of K_S and K_L Decays into $\pi^+ \ \pi^- \ \gamma$, The E731 Collaboration, Physical Review Letter, 26th April 1993.

[2] Rare Kaon Decays, Peter Buchholz and Burkhard Renk.