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Update of the upper limit on m_{ν_τ} from $\tau \rightarrow 5\pi(\pi^0)\nu_\tau$ decays using 1994 data.

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Abstract

Adding the 1994 data to the 1991-93 sample, corresponding to a total of about 143,000 τ decays, the updated limit on m_{ν_τ} has been derived. It slightly improves the published value to 23.1 MeV at 95% confidence level. The sample of selected $5\pi(\pi^0)$ candidates consists now of 38 $\tau \rightarrow 5\pi\nu_\tau$ and 3 $\tau \rightarrow 5\pi\pi^0\nu_\tau$. The 94 sample is consistent with 91-93 data and with expectations from the CLEO branching ratio. The probability to have a more favourable distribution rises from 5% to 10%.

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1 Introduction

This note updates the upper limit on m_{ν_τ} using the 1994 data sample. The analysis is essentially unchanged with respect to the one published in ref. [1],[2] and described in the Aleph note [3]. Therefore in discussing the 1994 results only the changements in the analysis will be described.

2 The 1994 data

After the TSLT01 $\tau^+\tau^-$ preselection [4] the specific $5\pi^\pm$ and $5\pi^\pm\pi^0$ selections [3] were applied obtaining a sample of 15 $5\pi^\pm$ and 1 $5\pi^\pm\pi^0$ candidates. Using the values of the CLEO II branching ratios [5] the number of expected events is 23 ± 3 and 2 ± 1 (the errors include only the branching ratio uncertainty).

In addition 1 well separated background event, situated at $m_{had} = 2.15\ GeV$ and $E_{had}/E_{beam} = 0.84$, was also selected. Fig. 1 shows the position of the 17 events in the usual E_{had}/E_{beam} versus hadronic invariant mass plane.

It is clearly seen that the background event sits quite far from the allowed region, in a position where $\tau \rightarrow 3\pi\pi^0\nu_\tau$ and Z hadronic decays are expected to fake the signal.

The background event is shown in fig. 2. From the low value of the missing energy on the recoiling hemisphere (about 40 GeV of hadronic energy are measured in the calorimeters) it is possibly ascribed to a Z hadronic decay.

According to the Montecarlo prediction the number of expected background events is 0.3 from $\tau \rightarrow 3\pi\pi^0\nu_\tau$ and 0.3 from $Z \rightarrow q\bar{q}$. Both backgrounds are expected to be in the high mass region (between 2.0 and 2.5 GeV). No candidates for such background events were observed in the 1991-93 sample.

To determine the limit on m_{ν_τ} the background event was removed by lowering the cut on the signal hemisphere invariant mass from $2.5\ GeV$ to $2.0\ GeV$. This is the only change with respect to the previous analysis. It is worth noticing that the value of $2.0\ GeV$ is still 13 standard deviations (with respect to the average 5 prong resolution) above the τ mass, which is the upper limit for signal events.

The topology of the hemisphere opposite to the 5 prong decay was investigated; for the full 91-94 data sample we found: 7 electrons, 8 muons, 4 hadrons, 12 hadron-π^0, 5 hadron-$2\pi^0$, 1 hadron-$3\pi^0$ and 4 unclassified single prong decays, of which 3 low momentum ($P < 1.9\ GeV$) tracks and 1 track entering an ECAL crack.

3 Results with 1994 data only

In fig. 3 and fig. 4 a zoom of the 1994 and 1991-93 samples in the high mass region is shown. In the 1994 data only one event (labeled event 11 in fig. 4) contributes significantly to improve the limit.

The errors on the invariant mass and energy (and their correlation) for each event were evaluated following the same procedure applied in 1991-93 analysis. The nominal JULIA errors were corrected using the MonteCarlo reproduction technique [3], with about 1000 reproductions per event.

The fit with the 1994 data alone gave a 95 % confidence level upper limit of 75.7 MeV for the 1-dimensional fit, and 56.9 MeV for the 2-dimensional one.

4 The full 1991-94 data sample

Adding the 1994 selected events to the 1991-93 data a final sample of 38 $5\pi^\pm$ and 3 $5\pi^\pm\pi^0$ candidates was obtained. The number of expected events from the CLEO branching ratio is 51 ± 6 for the $5\pi^\pm$ and 6 ± 2 for the $5\pi^\pm\pi^0$. The disagreement between the number of observed and expected $5\pi^\pm$ events is at the 1.3σ level. However the error on the expected events does not contain any systematics from the selection efficiency.

Performing the fit on this sample a limit of $m_{\nu_\tau} < 37.2$ MeV for the 1-dimensional fit and $m_{\nu_\tau} < 22.3$ MeV for the 2-dimensional one was obtained. A resume of the fit results for the different samples is reported in table 1.

Data sample	m_{ν_τ} 95% CL limit 1d	m_{ν_τ} 95% CL limit 2d
1991-93	37.8 MeV	23.0 MeV
1994	75.7 MeV	56.9 MeV
1991-94	37.2 MeV	22.3 MeV

Table 1: Fit results for the different data samples.

The same sources of systematics considered in the previous analysis were considered again.

For what concerns the background, as the level in the *sensitive region* remains negligible, no change was applied (i.e. the amount of background is considered to be negligible).

The systematics on resolution and calibration of the energy and of the mass were determined using the $D^0 \to K^-3\pi^\pm$ and $D^0 \to K^-\pi^+$ decays. In fig. 5 the invariant mass spectra of $D^0 \to K^-3\pi^\pm$ decays are plotted for the four years separately, while in fig. 6 the $D^0 \to K^-\pi^+$ spectrum is plotted for the 1992-1993 and 1994 periods. No significant difference with respect to the previous results was observed, so that the same systematics variations as in [1] were applied.

In table 2 the systematics for the 2-dimensional fit with the 1991-93 and the 1991-94 samples are reported. Practically, seen the poor improvement apported by 1994 data, the systematics remain unchanged (at the first digit level).

The spectrum in invariant mass has been compared with the expectations from different models. In fig.7 the $5\pi^\pm$ data are compared with the *phase space* and $a1 - 2\pi$ model prediction. At this level of statistics is not yet possible to decide in favor of one of the two; however the $a1 - 2\pi$ one seems to describe better the data.

The so called luck factor [4], evaluated with the full sample and the $a1 - 2\pi$ model, rose to 10% with respect to the of 1991-93 value of 5%.

In table 3 a comparison between the amount of events in the high mass region for different experiments is reported.

[4]it is a statistical estimator giving the probability to have a distribution in the E_{had}/E_{beam} versus hadronic invariant mass plane as lucky as or more lucky than the one observed in data in terms of m_{ν_τ} limit

systematic source	variation	2d var. 91-93 (MeV/c^2)	2d var. 91-94 (MeV/c^2)
Mass offset	0.5 MeV	0.2	0.2
Energy offset	12 MeV	0.2	0.2
Mass & Energy offsets	100% correlation	0.3	0.3
Mass resolution	20%	0.2	0.2
π^0 energy	1%	< 0.1	< 0.1
Resolution function	MC consistency	0.6	0.6
τ mass	0.3 MeV	0.2	0.2
E_{beam} calibration	6 MeV	0.1	0.1
E_{beam} spread	37 MeV	0.3	0.3
Background	$5\pi^\pm$ class. as $5\pi^\pm\pi^0$	0.3	0.3
total		0.8	0.8

Table 2: Systematics sources and variation for the 2-dimensional fit and the 91-93 and 91-94 data samples

Experiment	$M_h > 1.7\ GeV/c^2/Tot.$	Fraction(%)
CLEO $5\pi^\pm$	3/60	5.0 ± 2.8
CLEO $3\pi^\pm 2\pi^0$	4/53	7.5 ± 3.6
ARGUS $5\pi^\pm$	3/20	15 ± 8
ALEPH $5\pi^\pm$	3/38	7.9 ± 4.2
OPAL $5\pi^\pm$	1/5	20 ± 18
HRS $5\pi^\pm$	0/5	0
Mark II $5\pi^\pm$	1/3	33 ± 27
Average 5π	15/184	8.2 ± 2.0

Table 3: Comparison of the number of events in the high mass region for different experiments.

The ALEPH data are in a neutral position with respect to luck. It has to be reminded that such a comparison is significant only in the limit in which the selection efficiency is independent of the invariant mass.

Including the systematics the final result is :

- $m_{\nu_\tau} < 40.1$ MeV at 95% confidence level for the 1-dimensional fit
- $m_{\nu_\tau} < 23.1$ MeV at 95% confidence level for the 2-dimensional fit

5 Conclusions

The 1991-93 measurement of the m_{ν_τ} upper limit as been updated adding 1994 data. As expected it improved only slightly to $m_{\nu_\tau} < 23.1$ MeV at 95% confidence level. The increase in statistics showed no inconsistency with respect to the published analysis and rose the *luck factor* at a 10% level.

6 Acknoledgements

It is a pleasure to thank V. Ciulli who kindly provided the sample of $D^0 \to K^- 3\pi$.

References

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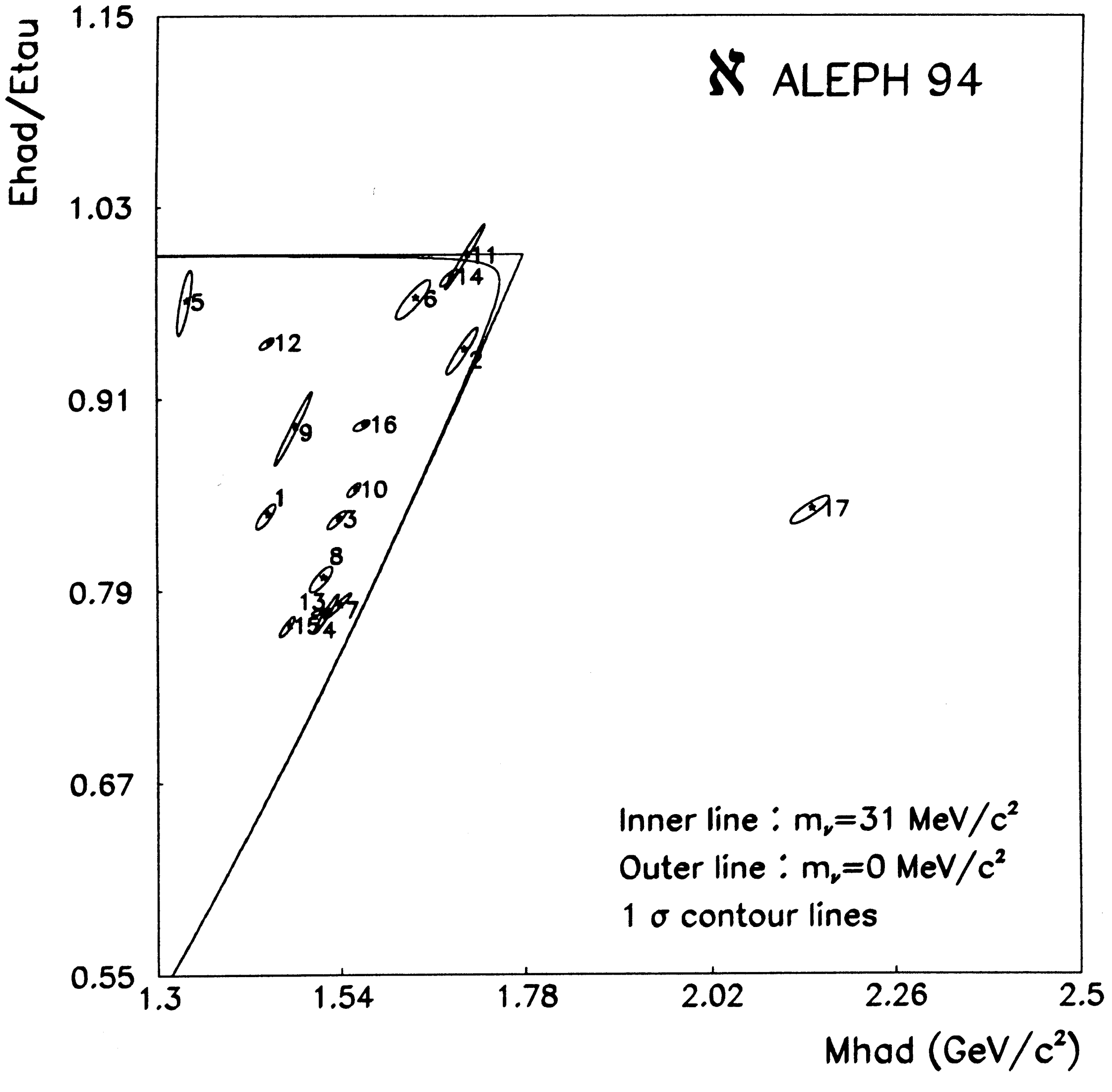

Figure 1: 1994 selected event in the E_{had}/E_{beam} versus hadronic invariant mass plane; the event labeled 5 is the $\tau \rightarrow 5\pi\pi^0$ candidate, the event labeled 17 is the background event.

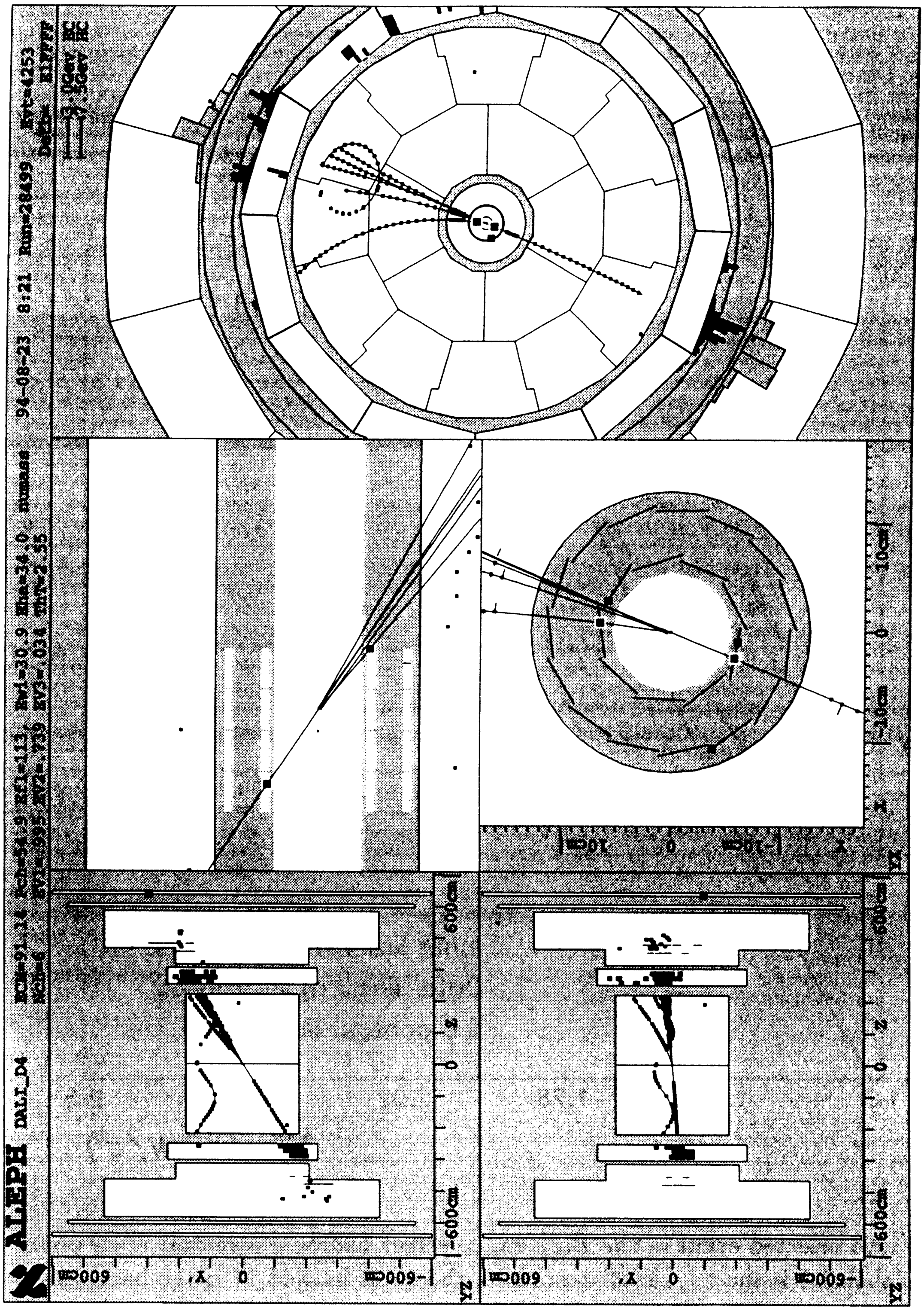

Figure 2: The background event candidate to be a hadronic Z decay. On the recoling hemisphere about 40 GeV of hadronic energy are measured in the calorimeters.

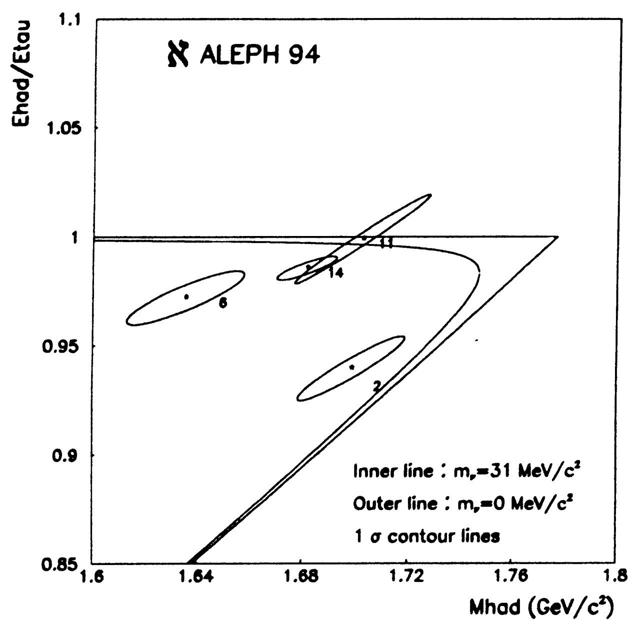

Figure 3: 1994 selected events in the E_{had}/E_{beam} versus hadronic invariant mass plane in the high mass and high E_{had}/E_{beam} region.

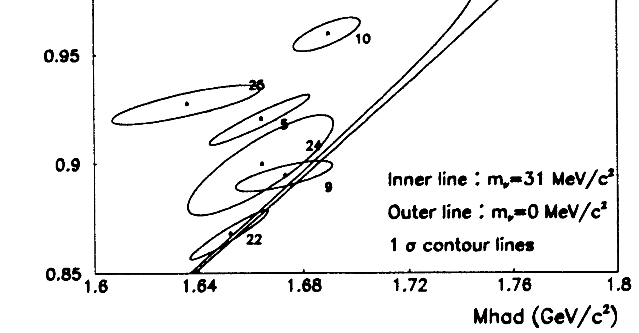

Figure 4: 1991-93 selected events in the E_{had}/E_{beam} versus hadronic invariant mass plane in the high mass and high E_{had}/E_{beam} region.

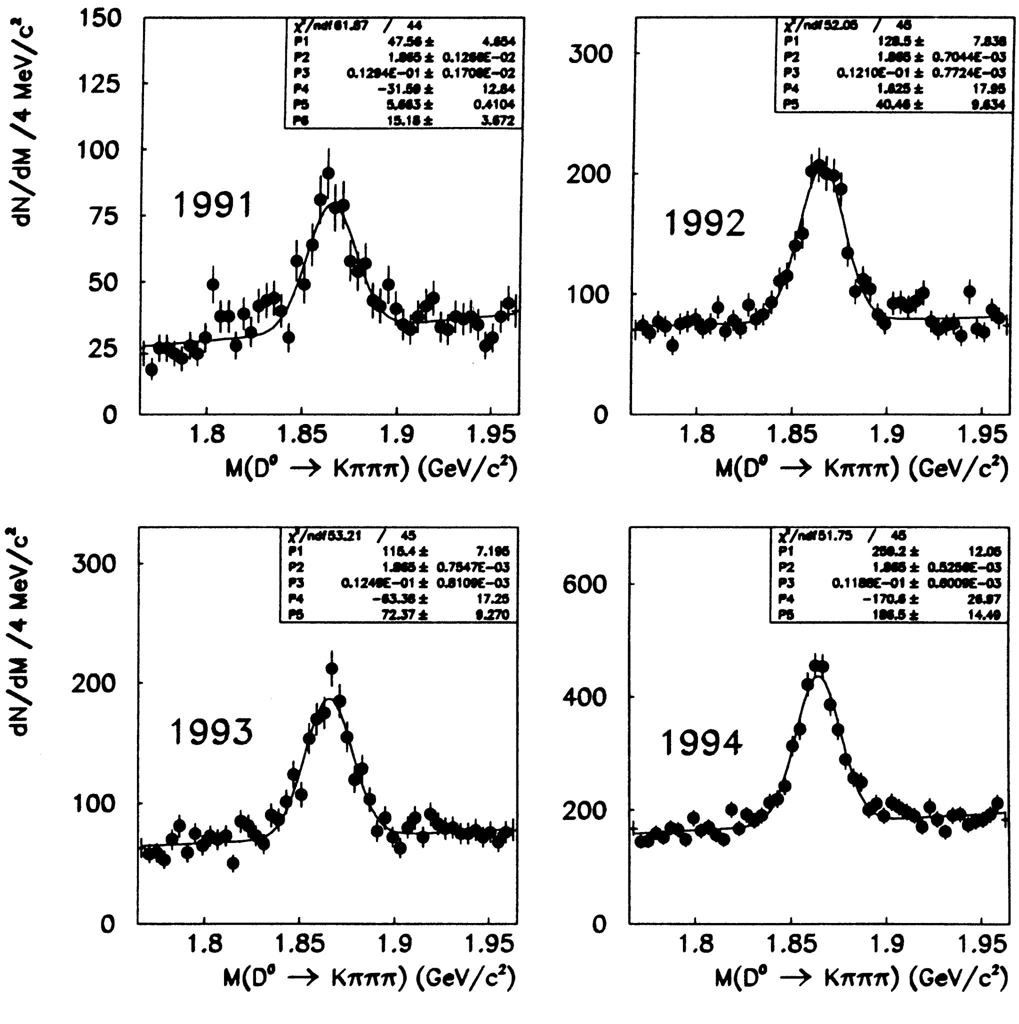

Figure 5: Invariant mass spectrum of the decay $D^0 \to K^- 3\pi$ in the data for each year; the spectra are fitted with a gaussian for the signal and a simple polynomial for the background.

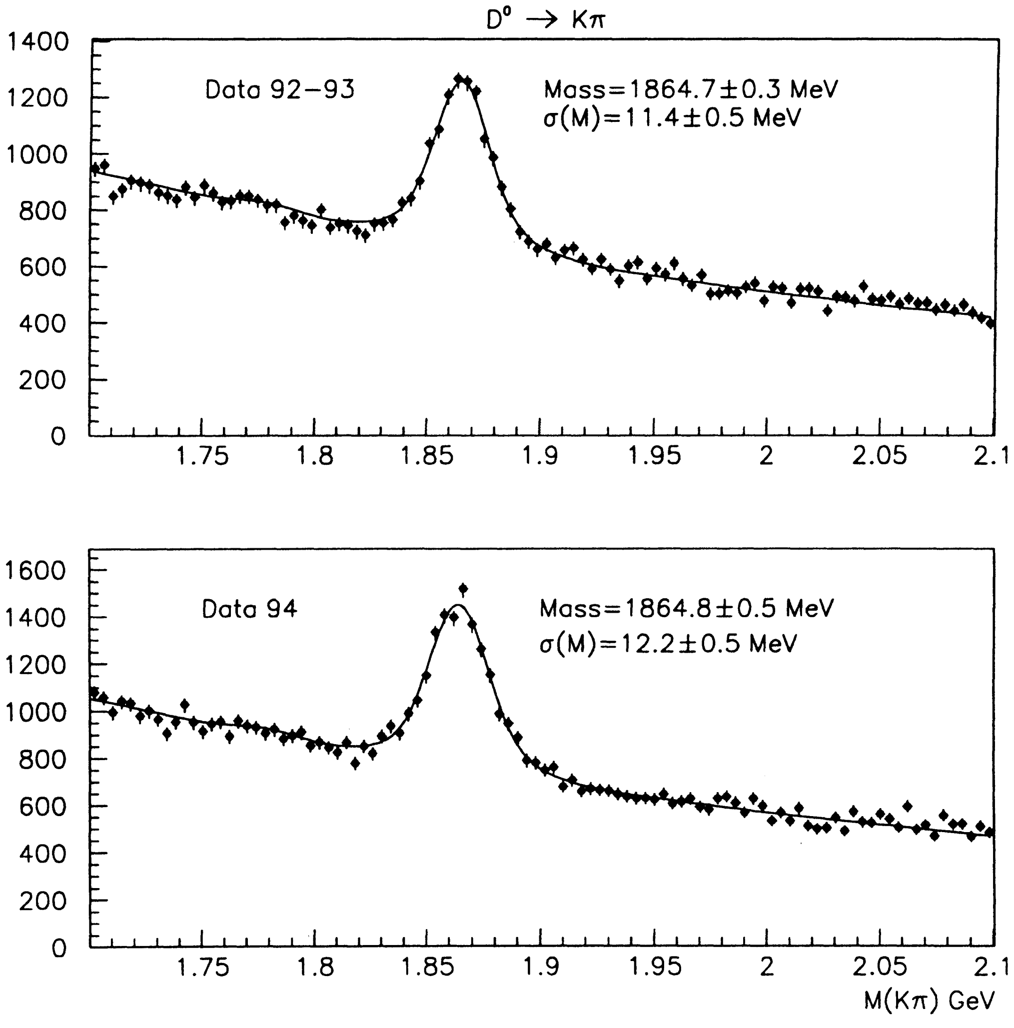

Figure 6: Invariant mass spectrum of the decay $D^0 \to K^-\pi^+$ in the data for the 1992-1993 and 1994 samples.

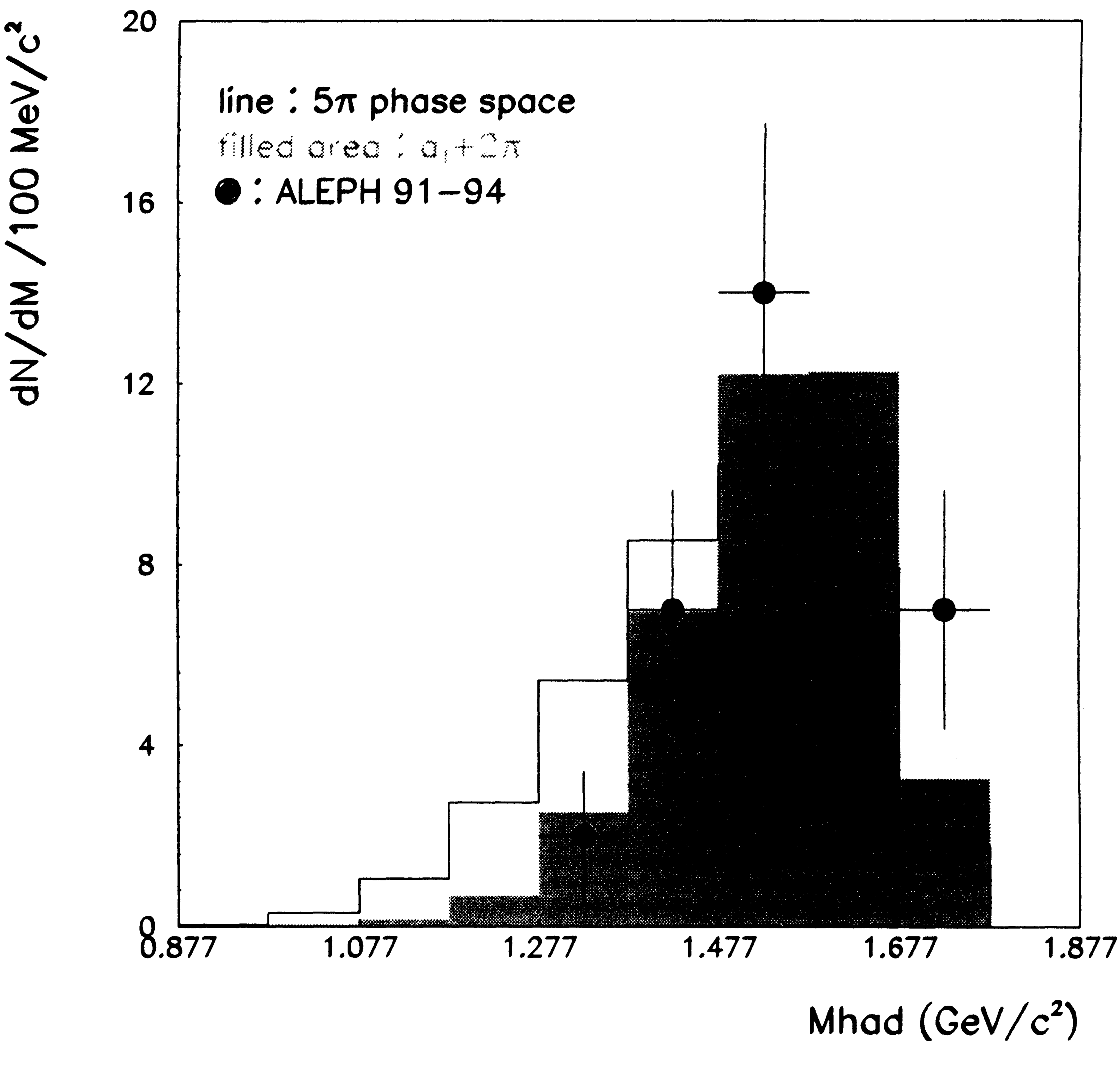

Figure 7: Invariant mass spectrum of the 1991-94 data compared with the full phase space and $a1 - 2\pi$ models.