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Charm and Beauty Measurements at Fermilab Fixed Target

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ABSTRACT

Eighteen months after a successful run of the Fermilab fixed target program, interesting results from several experiments are available. This is the first time that more than one Fermilab fixed target experiment has reported the observation of beauty mesons. In this paper we review recent results from charm and beauty fixed target experiments at Fermilab.

I. INTRODUCTION

The Fermilab fixed target program is quite diverse. Several experiments have studied the production and decay of charm and beauty quark hardons during the past two fixed target runs, 1987-88 and 1990-91. These experiments will provide better understanding of the dynamics of charm and beauty production, better lifetime measurements, improved understanding of semileptonic and hardonic decays, searches for new bound states, studies of rare and forbidden decays such as B^o, $D^o \rightarrow \mu^+\mu^-$, and $D^o\bar{D}^o$ mixing. A detailed discussion of the physics of all these heavy quark production experiments is beyond the scope of this paper. These high statistics heavy quark experiments have been made possible by advances in silicon microstrip detector and data acquisition technology. All the experiments use silicon microstrip detectors to search for detached secondary vertices. Experiment E653 is a hybrid emulsion experiment measuring charm and beauty production and decay. The photoproduction of charm quark hardons has been studied by E687 and E691. E687 ran both periods and has several new results. The hadroproduction of charm has been studied by E791. B meson decays have also been reported by E672. During the last fixed target run the

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hadroproduction of beauty mesons was studied by two experiments, E771 and E789. These two experiments were planned to be the initial phase of further experiments to investigate the possibility of a high sensitivity B experiment. Experiment E771 was designed to study B production and decay by measuring B→ $J/\psi K_s$ and B→ μX. Experiment E789 studied two body decays of charm and beauty mesons in a high rate fixed target environment, and has measured dihadron decays of D° mesons and also B→ J/ψ X.

It is not possible to discuss all of these experiments in detail here, only important features of these experiments and their physics results will be discussed. Each experiment's results will be presented separately. We discuss the luminosity limitations of fixed target heavy flavor production experiments at the end of this paper.

II. Charm Production and Decay

Charmed hadron production and decay have been studied by using photon, pion and proton beams. In photoproduction, the charm pair production cross section is about 1% of the total cross section. Photoproduced charm events have low primary multiplicity, but the lack of a primary vertex can make the event reconstruction difficult. The photon beam intensity is lower than typical hadron beams.

On the other hand, in hadroproduction the charm to total cross section ratio is only about 0.1% ($30\mu b/40$ mb). The advantage of hadroproduction is the presence of a primary vertex and higher intensity beams. The total hadroproduction cross section is much larger which thus requires a selective trigger and/or a high bandwidth data acquisition system. Fig.1 shows a comparison between the photoproduction experiment E691 [1] and the hadroproduction experiment E791 [2]. The signal to background of the hadroproduction experiment is better. This figure also shows how much the capability of charm experiments has increased in about three years. In this section we will limit our discussion to the hadronic decays of charm. There are several new results on the semileptonic decays of charm which are described in detail elsewhere [3].

A. E687

Experiment E687 [4] is a high rate multiparticle spectrometer dedicated to the photoproduction of charm. The goal of the experiment is to reconstruct a large sample of charm quark decays in order to study the dynamics of heavy quark photoproduction, to study charm quark weak decays, and to study J/ψ photoproduction.

During the 1990/91 run more than 500 million events were collected. The data contains more than 10^5 fully reconstructed charm decays [5]. E687 is currently analyzing their data and has several new results. This experiment has measured the lifetime of charmed mesons and baryons more accurately than before, providing information on the relative importance of different weak decay diagrams and various modifying hadronic effects. Fig.2 shows the invariant mass plot of $\phi\pi^+$ combinations as a function of various cuts on the distance of the decay vertex from the primary vertex (L) and the error on that quantity (σ). The two peaks in the plots are the Cabibbo suppressed decay of D^+ and the Cabibbo flavored decay of the D_s^+. As the L/σ cut is increased the peak gets cleaner and the relative size of the D^+ increases due to its longer lifetime.

A comparison of the D_s lifetime from different experiments is shown in Fig.3. Due to the high statistics of E687, the new result is the most accurate and allows a comparison of the D_s and D^o lifetimes with better precision [6]. The E687 measurements give $\tau_{D_s}/\tau_{D_o} = 1.13 \pm 0.05$, suggesting that the D_s is sightly longer lived than the D^o.

Experiment E687 has also observed and measured the lifetime of the charmed baryons $\Lambda_c, \Xi_c^+, \Xi_c^o$, and Ω_c^o. Fig.4 shows the mass plot of these four charmed baryons. The lifetime measurements of charmed baryons provide important tests of theoretical models which include light quark interference effects and exchange diagrams. The measured lifetime hierarchy of charmed baryons, shown in Fig.5, is consistent with the theoretical prediction [7]. According to this model the exchange diagram and light quark interference play a significant role in the lifetime of charmed baryons. The E687 measurement of lifetimes, $\Lambda_c^+ = 0.215^{+0.025}_{-0.017} \pm 0.008 ps, \Xi_c^+ = 0.41^{+0.11}_{-0.08} \pm 0.02 ps$, and $\Xi_c^o = 0.101^{+0.025}_{-0.017} \pm 0.01 ps$, have smaller uncertainties than previous measurements by NA32.

The Cabibbo suppressed decays $D^o \rightarrow \pi^+\pi^-$ and $\Lambda_c^+ \rightarrow pK^-K^+$ have been observed by E687. Fig.6 shows the invariant mass distribution of $D^o \rightarrow K^-K^+\pi^+\pi^-$, $D^o \rightarrow K^-K^+K^-\pi^+$, and $\Lambda_c^+ \rightarrow pK^-K^+$. These decay modes contain two or three charged kaons.

The D^{**} charmed meson states, in which the relative angular momentum between the charm quark and lighter quark equals one, have also been observed by E687 [8]. These previously observed D^{**} states [9] are $D^{**o}(2460) \rightarrow D^+\pi^-$, $D^{**o}(2420) \rightarrow D^{*+}\pi^-$, and $D_s^{**+}(2536) \rightarrow D^{*+}K_s^o$. The mass difference ($M_{D^+\pi^-}$ - M_{D^+}) distribution, Fig.7, shows a pronounced peak at $\Delta M \sim 600$ MeV. This peak is due to $D^{**o}(2460)$ decaying into $D^+\pi^-$. The natural width of this peak has been calculated to be 42 ± 10 MeV. Fig.8 shows the invariant mass difference plot for $M_{D^{*+}\pi^-}$ - $M_{D^{*+}}$ with a peak at about 420 MeV. This peak is due to the $D^{**o}(2420)$ and has a natural width of 14 ± 8 MeV. Fig.9 shows the mass difference distribution of the $D_s^{**+} \rightarrow D^*K$ decay. This observed peak is due to the $D_s^{**+}(2536)$ state and has a natural width of 12 ± 6 MeV.

E687 has enough statistics to study the production dynamics (the xf and pt distributions) of the charmed hadrons and to study correlations between charm pairs.

B. E791

Experiment E791 is a charm hadroproduction experiment built reusing the same basic spectrometer as a series of charm experiments, photoproduction E691 [10] and hadroproduction E769 [11]. The goals of E791 are to collect a large unbiased charm sample in order to make precision, high statistics charm measurements and to search for rare and forbidden charm decays. Using a 500 GeV/c π^- beam incident on a segmented target, this experiment has collected over 20 billion "minimally biased" events. A high E_t trigger was made possible by the segmented nature of their electromagnetic and hadronic calorimeters. The large data set (50 Terabytes) was made with a high speed parallel data acqusition system [12].

The analysis of the E791 data is currently in progress, Fig.10 shows some of their preliminary charm signals. Based on the preliminary analysis of 10% of data, they expect to reconstruct more than 200k charm decays [2]. This large sample of charm decays will enable them to set limits on flavor changing neutral current decays of D° and search for $D^o\bar{D}^o$ mixing. The current data sample is about 20 times larger than the predecessor experiment E691.

III. Beauty Production and Decay

The recent observation [13] of large mixing of neutral B mesons suggests [14] the possibility that CP-violation could be observed in a high statistics study of B° decays. The luminosity and the small cross section at existing e^+e^- colliders severely limit the B production rate. An alternative is the detection of B decays at a high energy proton accelerator, FNAL or CERN, either in fixed target or collider mode. At proton colliders both the cross section and luminosity are high. The crucial questions to be addressed by these initial experiments are how many b's can be produced, and can one distinguish the b-decay events from the non b quark backgrounds. The large number of $b\bar{b}$ pairs produced at the Fermilab Tevatron makes it interesting to explore different methods to trigger, detect, and reconstruct both the inclusive and exclusive b quark hadrons. Experiments E653 and E672 have studied b quark production cross sections and dynamics. Experiments E771 and E789 are exploring possible ways to do high yield b quark experiments at Fermilab fixed target in order to reach CP sensitivity.

A. E653

Experiment E653 [15] is the first fixed target experiment to report more than one reconstructed B pair. The hybrid emulsion spectrometer used in this experiment has been described in detail elsewhere [16]. The experiment uses an active nuclear emulsion target in which both the primary interaction and short lived decays are observed. A silicon spectrometer with 18 planes of silicon microstrip vertex detectors provides tracking information for selecting events to be scanned in the emulsion. During the second run of E653, data was taken with a 600 GeV/c π^- beam. The trigger required an interaction in the target and a muon that penetrated 3900 gm/cm^2 of absorber. A total of 8.2×10^6 events, selected from 2.5×10^8 interactions, were recorded during the run. Reconstructed events with a muon of transverse momentum greater than 1.5 GeV/c were selected for scanning in the emulsion.

The first scan of the data sample yielded 9 $b\bar{b}$ pair candidates. The decay modes and topologies of these 9 pairs are shown schematically in Fig.11. There are 12 neutral and 6 charged b decays, produced in 4 neutral-neutral, 4 neutral-charged and 1 charged-charged combinations. The production x_f and p_t^2 distributions [17] are shown in Fig.12. The inclusive

x_f distribution is described by $d\sigma/dx_f = (1 - |x_f - xo|^n)$ with $n = 5.0^{+2.7+1.5}_{-2.1-0.9}$ and a positive offset $xo = 0.06^{+0.06}_{-0.07}$. The inclusive p_t^2 distribution is broader than that of charm and is described by $d\sigma/dp_t^2 = \exp(-bp_t^2)$ with b= $0.13^{+0.05}_{-0.04}$. Based on these 9 pair events, the pair production cross section, assuming a linear A dependence, is $33 \pm 11 \pm 6$ nb/nucleon [15,17], consistent with QCD predictions [18].

The measured lifetime of the 12 neutral and 6 charged beauty decays is [19] $\tau_{b^o} = 0.81^{+0.34+0.08}_{-0.22-0.02}$ ps and $\tau_{b^\pm} = 3.84^{+2.73+0.08}_{-1.36-0.16}$ ps. The combined sample lifetime is $\tau_b = 1.88^{+0.66+0.16}_{-0.45-0.07}$ ps, where the first errors are statistical and the second are systematic. A second scan of the data with a reduced p_t cut on the muon has so far yielded three more beauty pair candidates.

B. E672

Experiment E672 has investigated B→ $J/\psi X$ decays in π^- nucleon collisions at 530 GeV/c by analyzing the J/ψ vertex distribution [20]. They have reported evidence for the exclusive B decay modes B→ $J/\psi K^\pm$ and $J/\psi K^{o*}$. Experiment E672 sits behind Experiment E706 at Fermilab. The experiment triggers on final states containing two muons. This experiment uses the E706 vertex spectrometer to search for secondary J/ψ vertices in their J/ψ sample. The data was collected during the 1990 fixed target run with a 530 GeV/c π^- beam incident on a segmented Cu and Be target. About 5 million triggers were recorded during this run.

Of the 11,000 reconstructed J/ψ events, 11% have more than one vertex. About 64% of these events have a detached J/ψ vertex. A vertex fit was done for dimuon pairs in the J/ψ mass range 2.85 GeV/c^2 < $M_{\mu\mu}$ <3.35 GeV/c^2. The J/ψ vertex z-position distribution is shown in Fig.13. The target, two 0.8mm thick pieces of Cu followed by 3.71 and 1.12cm thick Be, is clearly separated in the J/ψ vertex distribution plot. They reconstruct the difference of the primary and secondary vertex in each event. Fig.14 shows the Z position difference of the primary and J/ψ vertices. The J/ψ's from the primary vertex are centered at zero, while events with a difference greater than 1 mm are J/ψ's from a secondary vertex. The false event reconstruction rate is given by the events reconstructed with a negative δZ. The sample contains 857 J/ψ events with a downstream vertex, of which only 73 events survive different selection cuts to eliminate backgrounds. The Z position of the primary and secondary vertex of the 73 events is shown in Fig.15(a,b). From Monte Carlo simulations, the estimated backgrounds are 4 ± 2 events due to false secondary vertices and 33 ± 7 due to secondary interactions.

The experiment then searched for secondary vertices in the mass free regions of the target-SSD system. They report a preliminary signal of 9 ± 3 secondary vertex J/ψ events from B decays in the mass free region. Fig.16 shows the secondary J/ψ vertex position in the y-z plane in the mass free region, with errors. Based on 9 ± 3 B→ $J/\psi X$ candidate events, the J/ψ cross section, assuming linear A dependence and a B→ $J/\psi X$ branching fraction of 1.57×10^{-3}, is $\sigma_{B\bar{B}}(X_f > 0.1) = 28 \pm 9 \pm 8$ nb/nucleon.

Experiment E672 has also searched for the exclusive B decays, B→ $J/\psi K^\pm$ and B→ $J/\psi K^{o*}$, in their sample of 73 secondary vertex J/ψ events. The experiment has no hadron identification and considers all non-muon tracks as hadrons. In three prong events with, two muons plus another track, the third track was assigned a kaon identification if it had a pt > 0.5 GeV and satisfied all other secondary vertex requirements. In four prong events, K^{o*} was observed by its decays into $K\pi$. A non-muon track in these four prong events was assigned a kaon mass if it had a momentum greater than twice the other. The combined $J/\psi K^{\pm}$ and $J/\psi K^{o*}$ invariant mass distribution is shown in Fig.17. There is an excess of events near the B mass. A background analysis using primary vertex events subjected to same cuts shows no evidence of enhancement in the B mass region.

This experiment has also measured the production of χ states. During the 1991 run, E672 collected 10 million triggers with 530 GeV/c and 800 GeV/c protons incident on Be and Cu targets.

C. E771

Experiment E771 [21] is a high rate 800 GeV proton fixed target beauty experiment using the upgraded E705 spectrometer. The main goals of the experiment are to measure the total cross section for $B\bar{B}$ production at 800 GeV, to study inclusive distributions and correlations and reconstruct exclusive B final states, measure beauty lifetimes in both exclusive and inclusive modes, and observe $B\bar{B}$ mixing. E771 has a magnetic spectrometer which follows an array of target foils and 18 planes of silicon vertex detectors. During 1990-91, experiment E771 could instrument only 60% of the original design number of silicon readout channels. In a four week running period the experiment recorded 127 million dimuon and 62 million single muon triggers.

The experiment targets 800 GeV/c protons on a distributed foil target at a 2 MHz interaction rate. Data acquisition is triggered by dimuons or single high pt muons. The data analysis from the last run is currently in progress. The dimuon invariant mass from the preliminary analysis of 10% of the data is shown in Fig.18, J/ψ and ψ' peaks are clearly resolved. The preliminary cross section for 800 GeV protons is $\sigma(J/\psi) = 339 \pm 10 \pm 74$ nb and $\sigma(\psi(2s)) = 72 \pm 16 \pm 16$ nb [21].

Using the silicon vertex spectrometer, a search for downstream J/ψ vertices has been made on about 10% of the data. Fig.19 shows one four prong event which reconstructed with a downstream vertex consistent with a B mass. This event is consistent with a B$\rightarrow J/\psi K\pi \rightarrow \mu^+\mu^- K\pi$ (non resonant) decay.

D. E789

Experiment E789 studies low multiplicity decays of neutral D and B mesons in a high rate environment. The experiment used the upgraded E605 [22], E772 [23] spectrometer used in previous experiments to detect hadron and lepton pairs with good mass resolution and high rate capability. The spectrometer was upgraded with the addition of a silicon vertex spectrometer, drift chambers, a vertex trigger processor, and an upgraded high capacity data acquisition system. The main goals E789 are to measure the B production cross section at 800 GeV via B$\rightarrow J/\psi X$ decays and to search for charmless dihadron decay modes such as B$\rightarrow \pi^+\pi^-$.

A schematic view of the E789 [24] spectrometer and its silicon vertex spectrometer is shown in Fig.20(a,b). The silicon spectrometer consists of sixteen $50\mu m$ pitch silicon strip detectors, each $5 \times 5cm^2$ in area and 300μm thick, covering an angular range of 20 to 60 mr above and below the beam axis. Unlike other fixed target experiments where a defocused beam is incident on foil targets and the silicon spectrometer intercepts the incident beam, the E789 silicon spectrometer has a beam hole. This enables the spectrometer to take a high interaction rate but reduces the acceptance. An 800 GeV proton beam was incident on one of several thin wire targets ranging from 0.1 mm to 0.3 mm high and 0.8 mm to 3 mm thick. The signals from silicon microstrips were read by DC coupled Fermilab 128 channel amplifiers [25] and LBL discriminators [26] synchronized to the accelerator RF. The electronics were designed to have 1 RF bucket (19 ns) resolution time; on average only 2 RF bucket resolution was achieved due to several limitations. The use of a thin target localizes the primary interaction vertex and greatly simplifies the offline event reconstruction.

Two different spectrometer settings were needed to span the mass regions of the D$\rightarrow h^+h^-$, B$\rightarrow J/\psi X$, and B$\rightarrow h^+h^-$ decays. A total of 1.5×10^9 events were recorded in 8×10^4 spills. The beauty data corresponds to a total of 3×10^{13} interactions. The charm setting was used to study the performance of the newly installed silicon spectrometer. The nuclear dependence of D meson production, measured with gold and beryllium targets, should give valuable insight into the origin of the J/ψ A dependence observed at the same beam energy [23]. A vertex reconstruction trigger processor was used online for the D data taking. For the beauty setting, a proton beam of 5×10^{10} protons per pulse was incident on a 3mm thick gold target yielding a 50 MHz interaction rate.

Fig.21 shows the E789 dihadron mass spectra for the charm data sample. The D$^o \rightarrow \pi^+K^-, \bar{D^o} \rightarrow K^+\pi^-$ and $D^o, \bar{D^o} \rightarrow \pi^+\pi^-, K^+K^-$ decays are clearly visible in this figure. Information from the ring imaging Cherenkov detector has not been used in this analysis for π/K identification. Fig.22 shows the D^o lifetime distribution obtained by making a side band subtraction at the D^o peak. The estimated D^o lifetime is 0.41 $\pm$ 0.03 ps consistent with other published measurements [27]. The nuclear dependence of D production was also measured in this experiment by measuring D^o production from Be and Au targets. The preliminary value of α is 1.02 ± 0.06. Analysis of the D$\rightarrow$ dilepton mode data is in progress. E789 is expected to set a 90% C.L. upper limit of 5×10^{-6} for D$\rightarrow e^+e^-, \mu^+\mu^-$, and e$\mu$.

The dimuon mass spectrum from a preliminary analysis of data at the beauty mass setting is shown in Fig.23. These events are required to have silicon tracks but no vertex cut is applied. There are approximately 50k J/ψ and 600 ψ' events in this sample. Requiring that the impact parameters for both muon tracks are greater than 150μm and that the decay vertex is between 0.7 cm and 5.0 cm yields the dimuon mass spectra in Fig.24a. A J/ψ peak is clearly visible. These 24 events are candidate events for B$\rightarrow J/\psi X \rightarrow \mu^+\mu^- X$ decays. Backgrounds caused by silicon tracking errors are estimated by selecting events with an apparent vertex upstream of the target, $-5.0cm < Z_{vert} < -0.7cm$, see Fig.24b. The Z_{vert} symmetry of the silicon tracking is confirmed using a dihadron data sample, where no signal is expected to be observed. A more detailed analysis, currently underway, using a different silicon tracker should confirm the b signal and allow the calculation of the b production cross section. This experiment is also studying B$\rightarrow$ $J/\psi X \rightarrow e^+e^-X$, B$\rightarrow$ $\mu^+\mu^-, e^+e^-, e\mu, h^+h^-$ decays. Extrapolating from the current yield, the full sample should provide about 75 reconstructed B$\rightarrow$ $J/\psi X$ events. Assuming no decays are observed after all cuts, a 90% confidence level upper limit for rare decays of about 1.0×10^{-4} should be obtained.

V. Limitations of Fixed Target heavy quark experiments

This is a controversial topic; opinions vary considerably. It is not directly related to the topic of this paper, but is an important issue at this workshop. The experiences gained from the current experiments are the best guide to future high rate beauty experiments. At 800 GeV, the beauty production cross section is predicted to be about 10 nb compared to 40 mb of total cross section. The experiment must be capable of handling a very high trigger rate and must find a very small signal in a very large background. There are two major types of background. The first is due to the copious production of light hadrons at the primary vertex. The second arises from pairs of long lived particles, each decaying at different distances downstream of the target. Accurate multiple vertex reconstruction in the presence of these two backgrounds is extremely difficult, especially when the soft pions from either source multiple scatter in the silicon detectors.

The silicon detector can be placed either in the beam (E771), or very close to the beam (E789), to accept the maximum number of B decays. To accumulate high statistics these experiments must run at a high interaction rate, which results in very high track rates in the silicon and radiation damage of the silicon detectors. The high track density makes it difficult to correctly identify tracks, one must devise a very sophisticated and highly segmented vertex spectrometer to reduce this problem. Besides the hard and soft tracks produced in the target, there are tracks present in the events which are due to the decay of long lived strange and charmed hadrons. Such tracks, paired with a misreconstructed primary vertex track, yield fake downstream vertices. The high rate of tracks also limits the capability of the downstream charged particle spectrometer. Experiment E789, which has a very limited acceptance (about 1%), was rate limited in almost all of its detectors. One must deal with higher rates if one increases the angular acceptance to achieve higher statistics or broaden the physics potential. It is not enough to simulate the signal to claim the potential of an experiment. In designing future experiments, we must use the backgrounds and hit density information gathered in recent runs to estimate realistically the signal to background ratios.

It is my impression that doing a high rate, high yield beauty experiment with Fermilab fixed target beams is difficult. It might be possible to do an experiment to measure the cross section, lifetime, production dynamics, with reasonable statistics and to observe some rare decays in a long run. It is unlikely that a Fermilab fixed target B experiment will be able to reach CP sensitivity by only the same means that have been very successful for present Charm experiments. On the other hand it does appear that an order of magnitude over current charm statistics can be achieved in a newly designed charm experiments [28].

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I would like to thank C. N. Brown for much assistance and the opportunity to give this talk. I would also like to thank the different collaborations, and specifically J. N. Butler and P. Garbincius (E687), J. A. Appel and M. V. Purohit (E791), R. Lipton (E653), A. Zieminski (E672), and L. Spiegel (E771) for providing their data.

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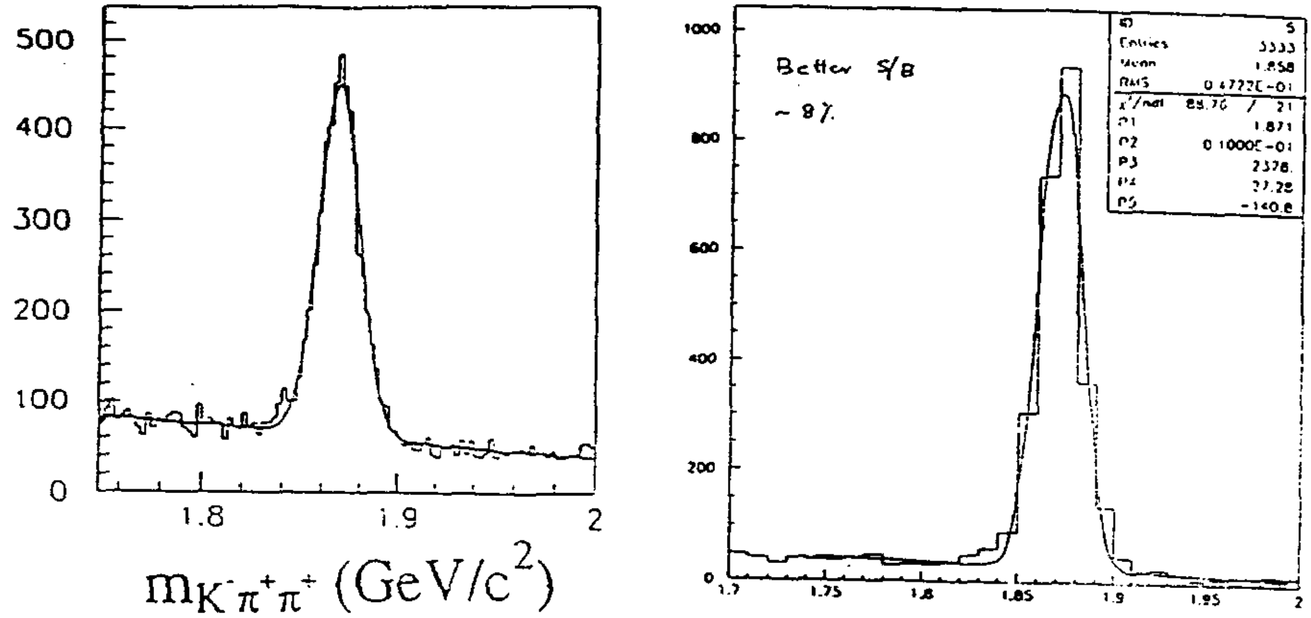

Fig. 1 Comparision between photoproduction (E691) and hadroproduction (E791) of charm experiments.

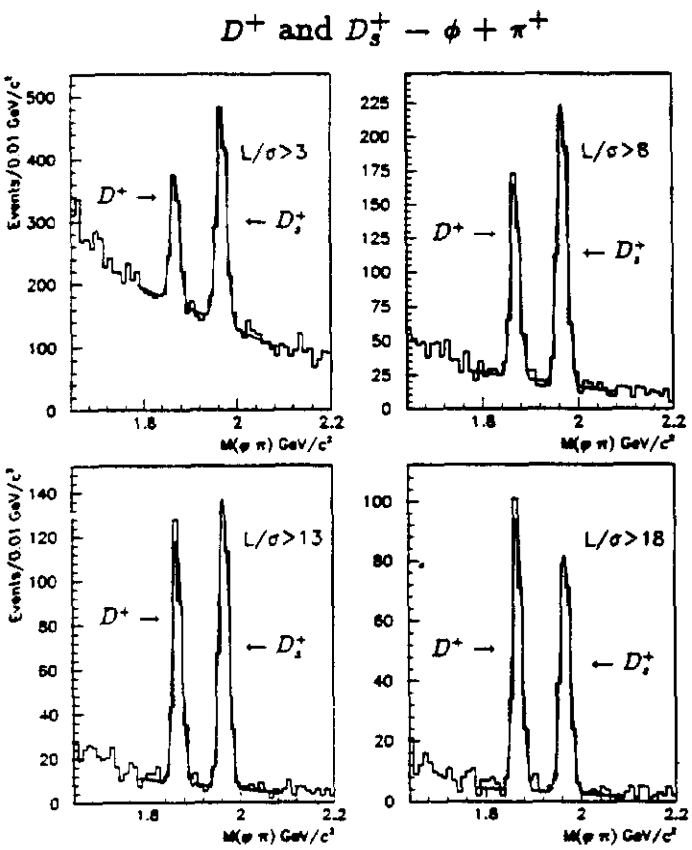

Fig. 2 Invariant Mass distributions for $\phi\pi$ combination, subject to various detachment cuts.

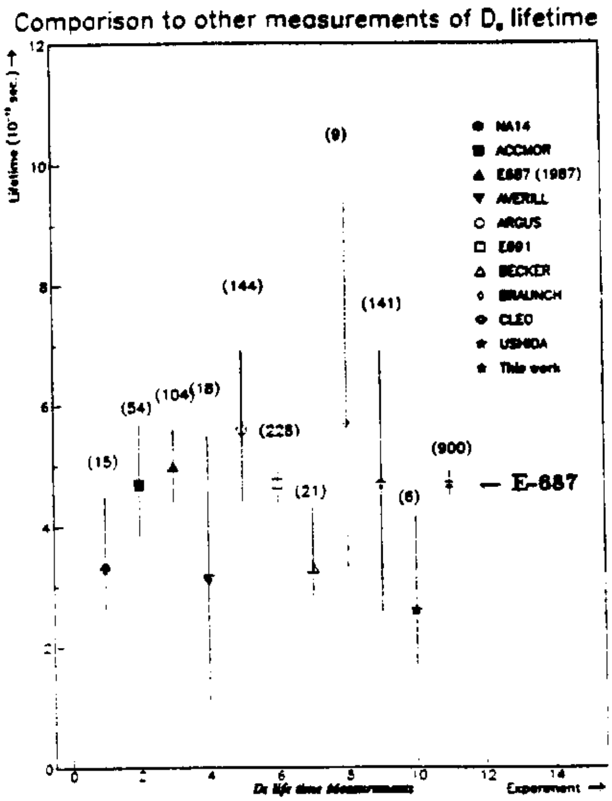

Fig. 3 World data of the D$_s$ lifetime.

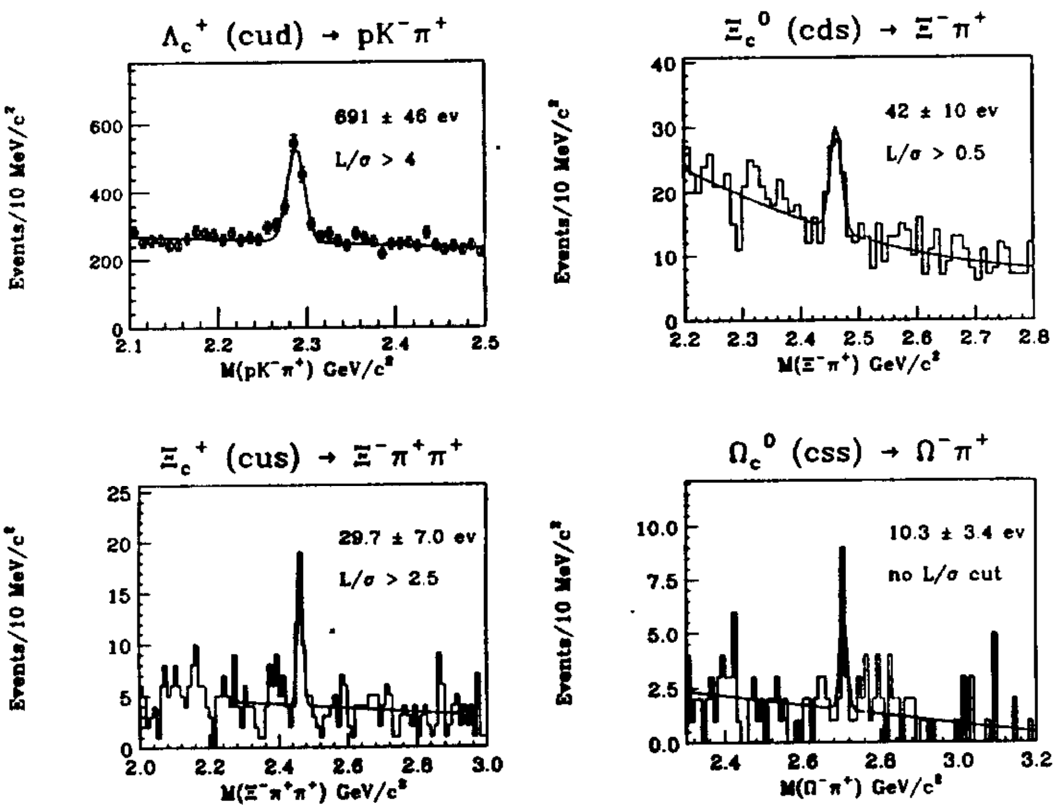

Fig. 4 Signal of four Charmed baryons.

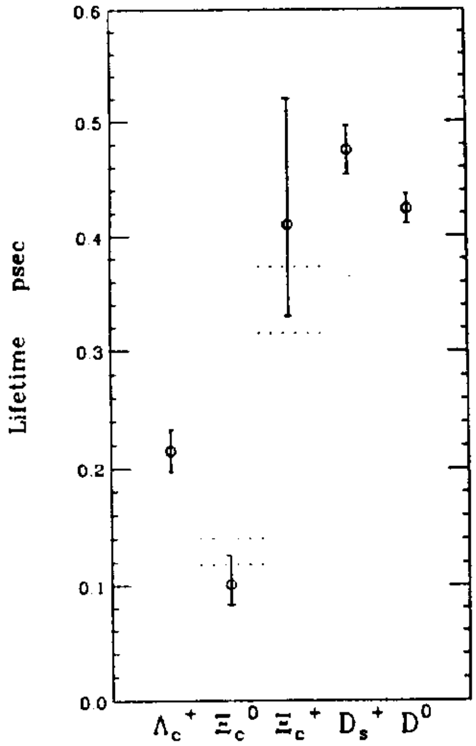

Fig. 5 Lifetime hierarchy for charmed baryons and theoretical predictions (dotted region)

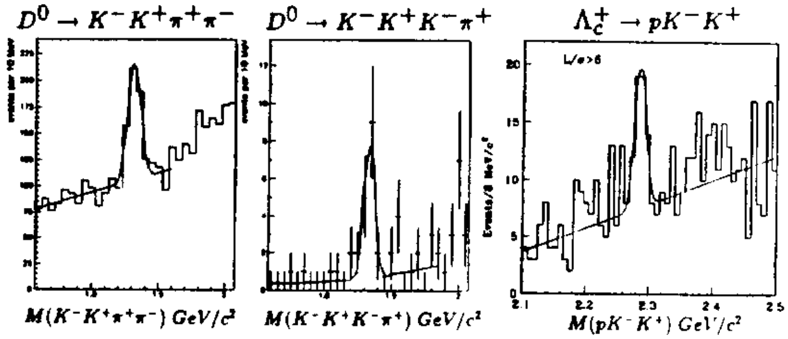

Fig. 6 Invariant Mass distributions for $K^-K^+\pi^+\pi^-$, $K^-K^+K^-\pi^+$, and pK^+K^-.

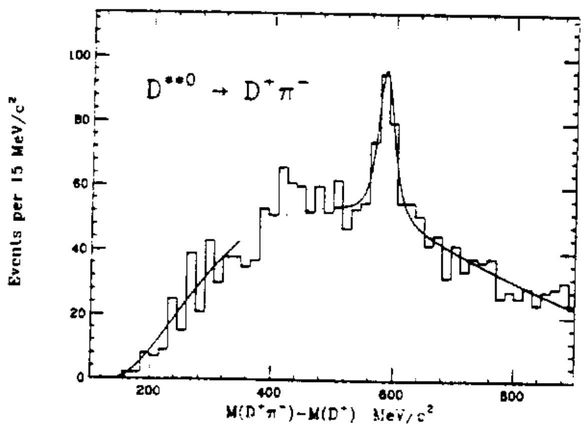

Fig. 7 Invariant Mass distributions for $M_{D^+\pi^-} - M_{D^+}$. The peak is due to $D^{**o}(2460)$.

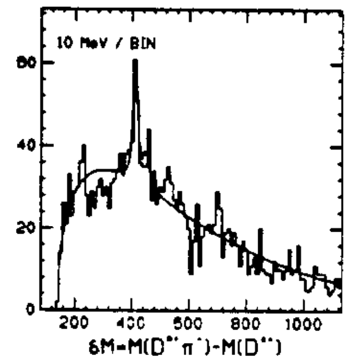

Fig. 8 Invariant Mass distributions for $M_{D^{*+}\pi^-} - M_{D^{*+}}$. The peak is due to $D^{**o}(2420)$.

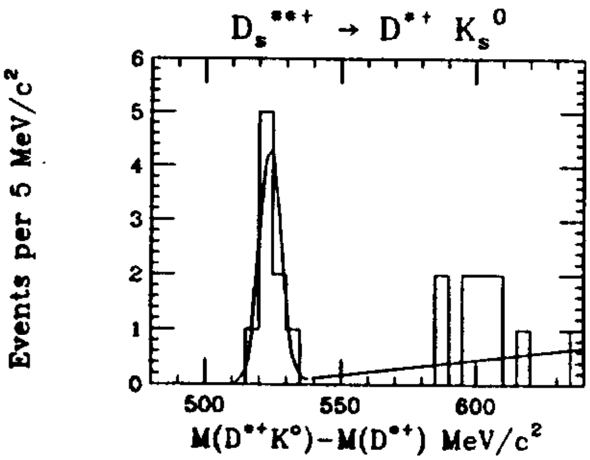

Fig. 9 Invariant Mass distributions for $M_{D_s^{*+}} - M_{D^{*+}}$. The peak is due to $D_s^{**+}(2536)$.

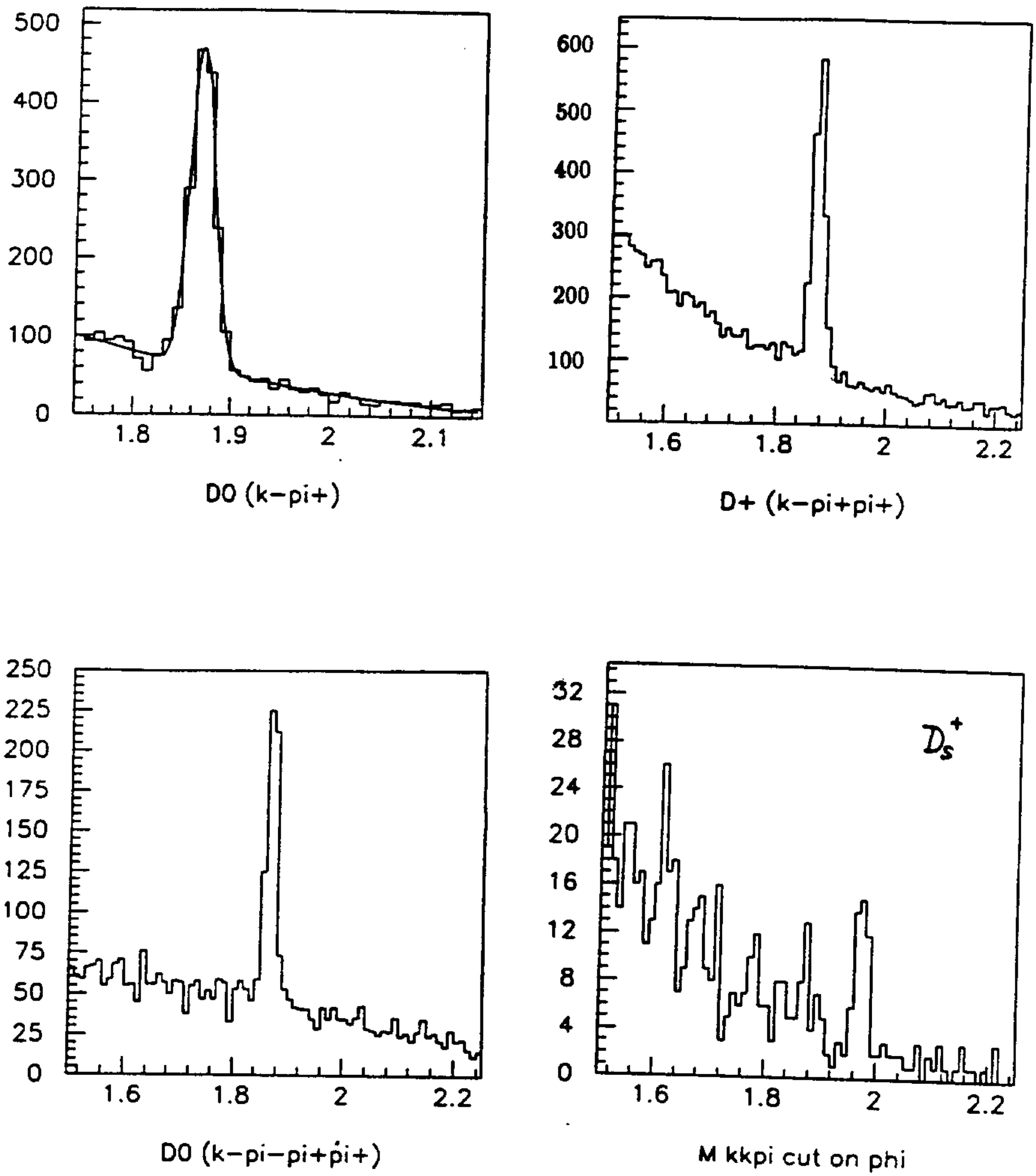

Fig. 10 Preliminary mass distribution from E791.

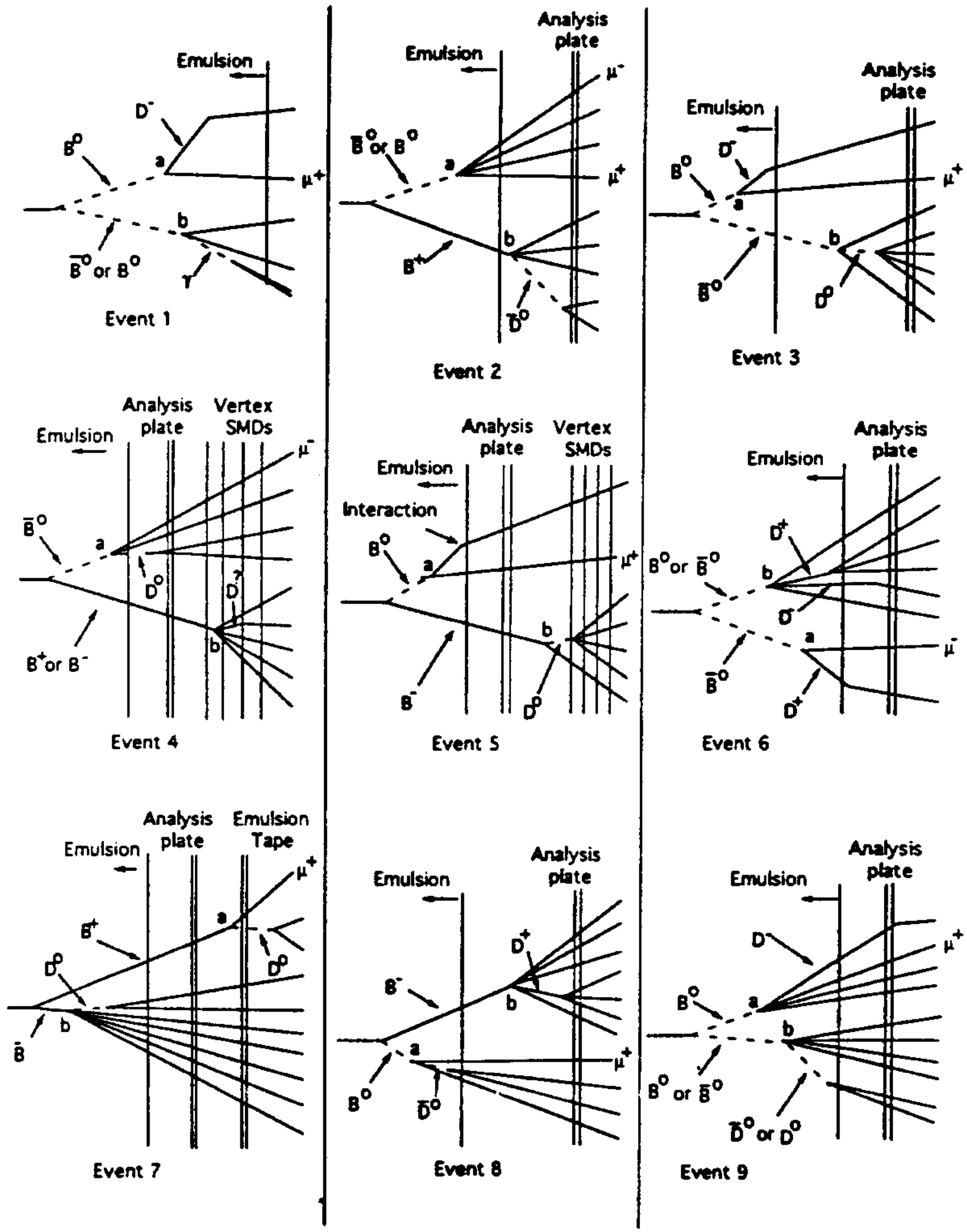

Fig. 11 Decay modes and topologies of 9 $B\bar{B}$ pairs.

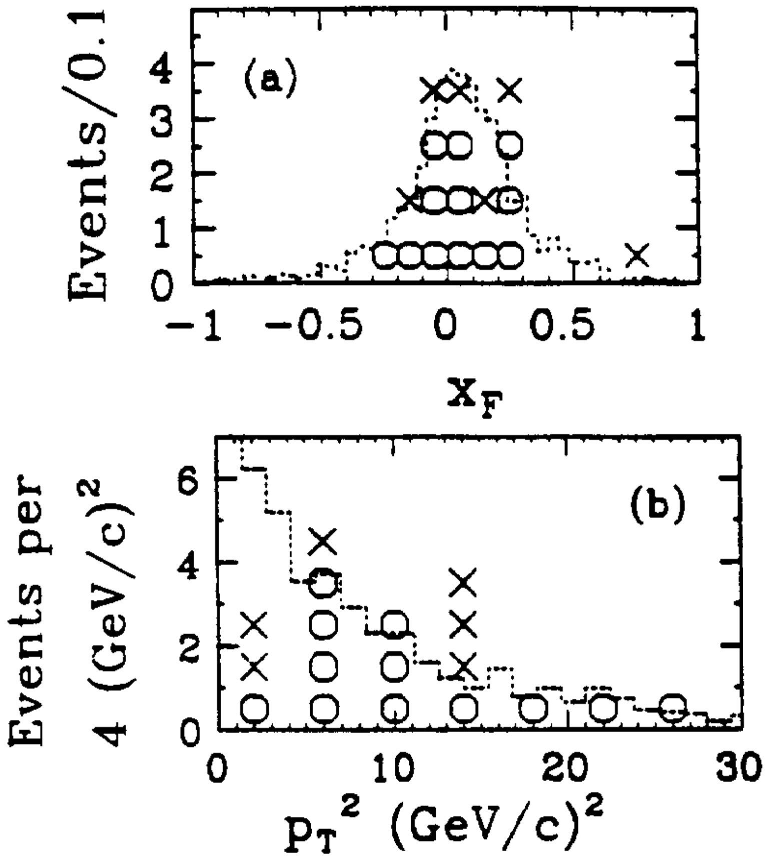

Fig. 12 a) Histogram of inclusive xf for 6 neutral(circles) and 6 charged (crosses) beauty mesons. The dashed histogram is simulation with n=5.0 and x_o = 0.06.

b) Histogram of inclusive pt^2. The dashed histogram is a simulation with b=0.13.

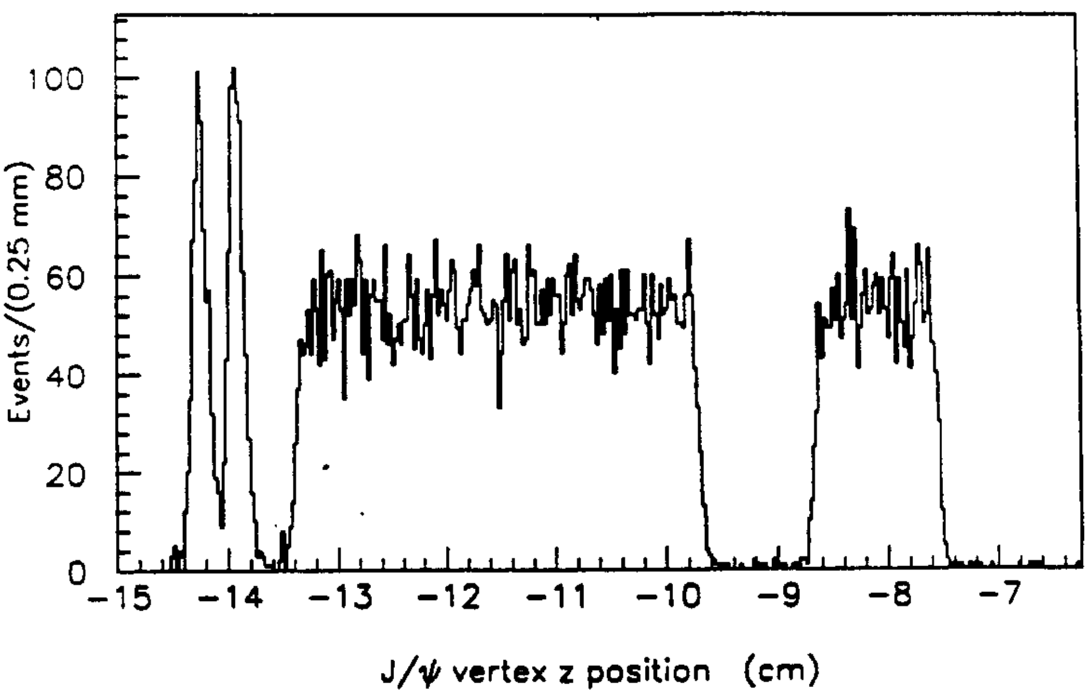

Fig. 13 Reconstructed J/ψ Z vertex position from E672.

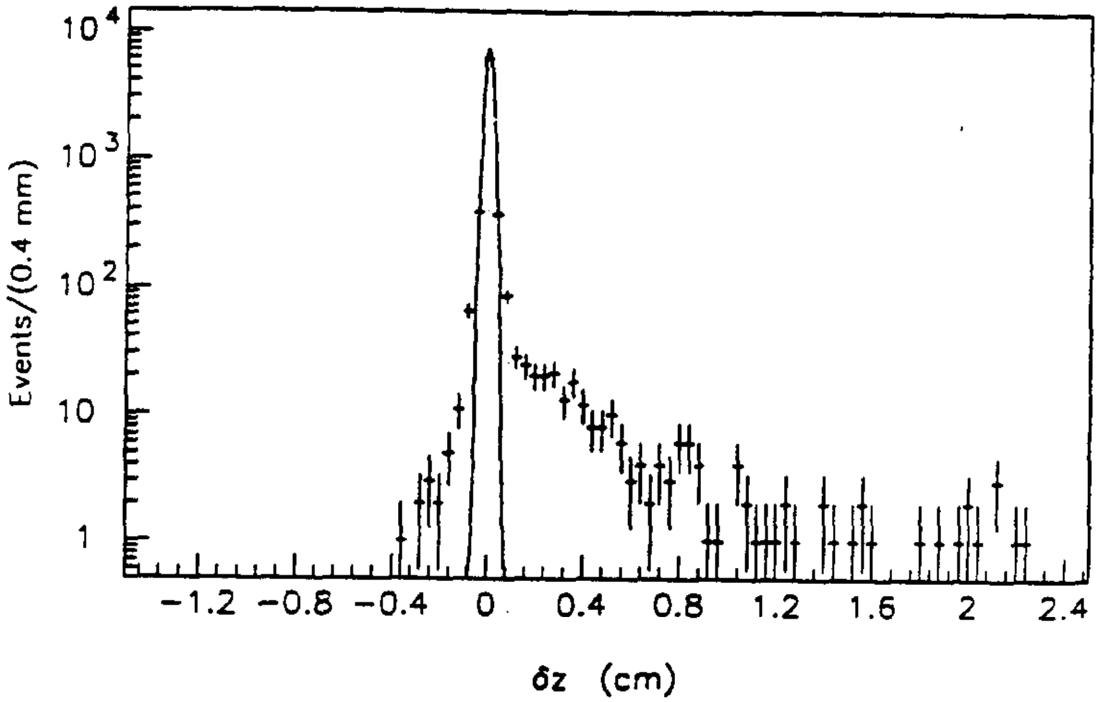

Fig. 14 Difference between primary vertex Z position and J/ψ vertex Z position.

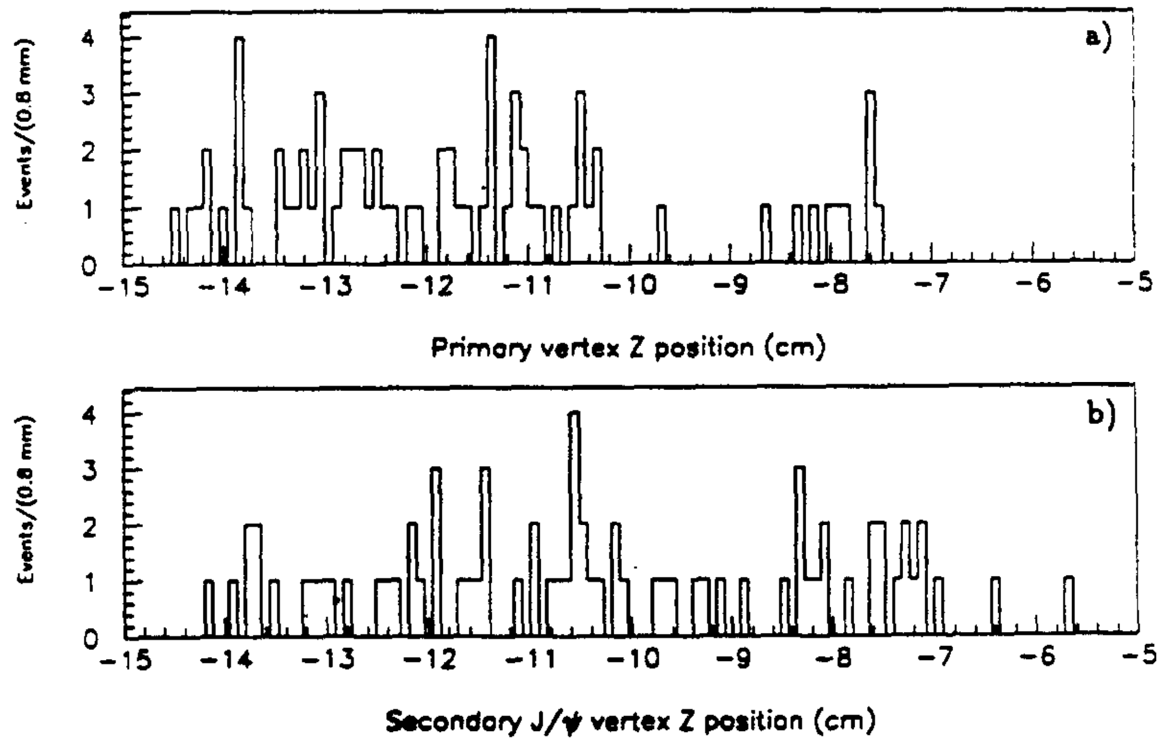

Fig. 15 a) Primary vertex position for events with a secondary J/ψ vertex.
b) Secondary J/ψ vertex position for these events.

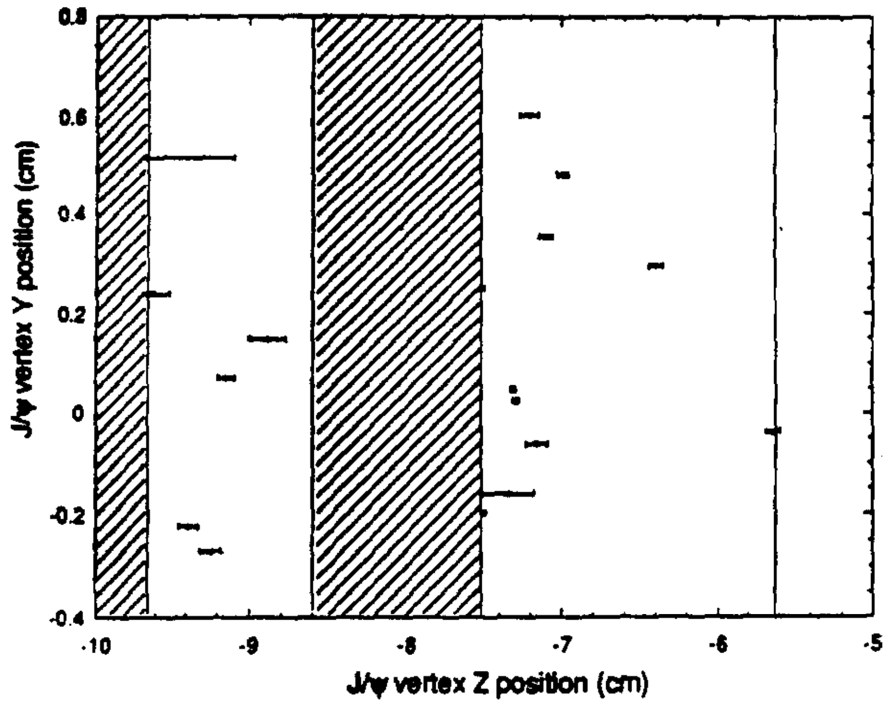

Fig. 16 Distribution of secondary vertices in material free region around the target.

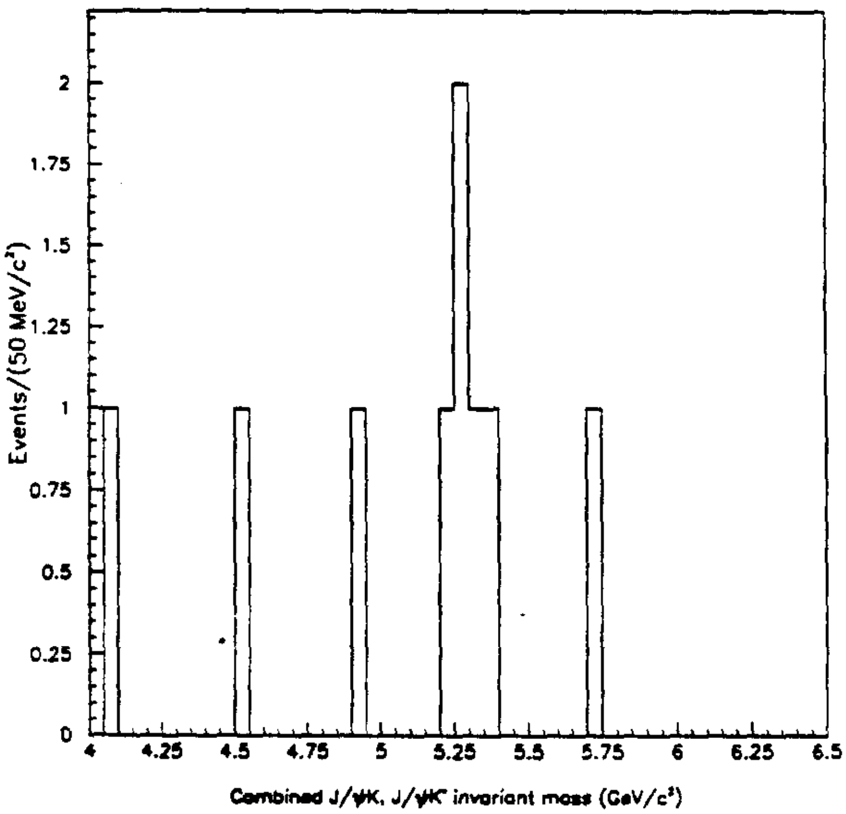

Fig. 17 Combined $J/\psi K^*$ and $J/\psi K$ invariant mass distribution (GeV/c^2).

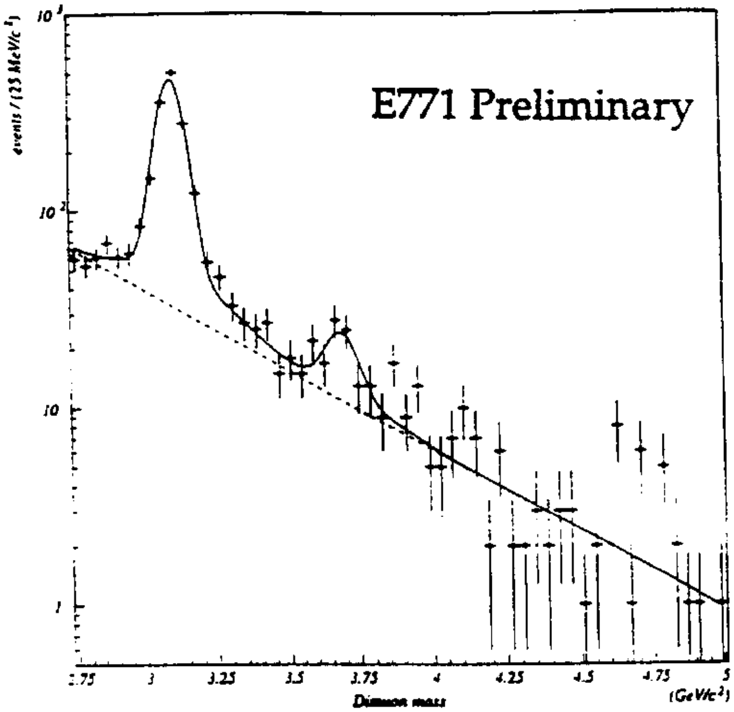

Fig. 18 Dimuon invariant mass distribution from the preliminary analysis of 10% of data.

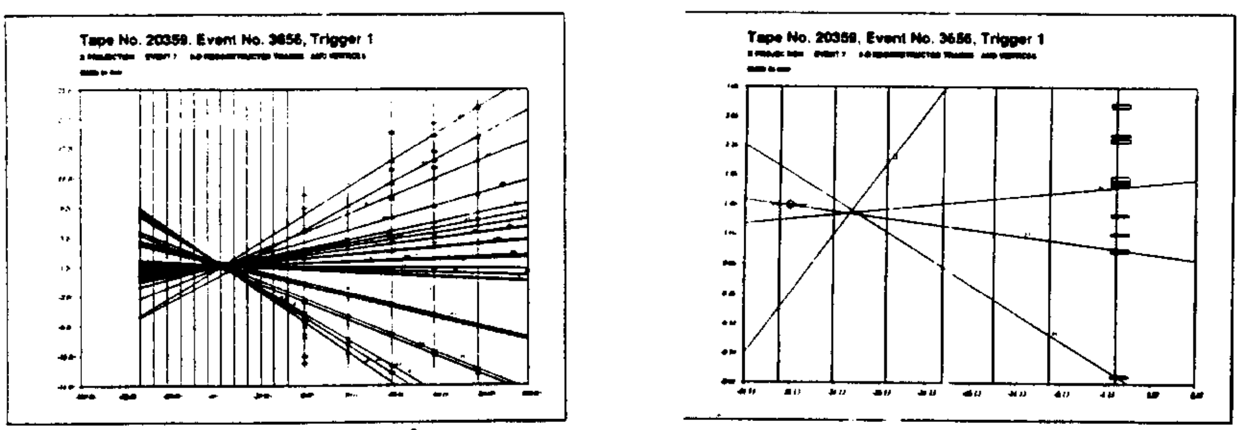

Fig. 19 Candidate B event.

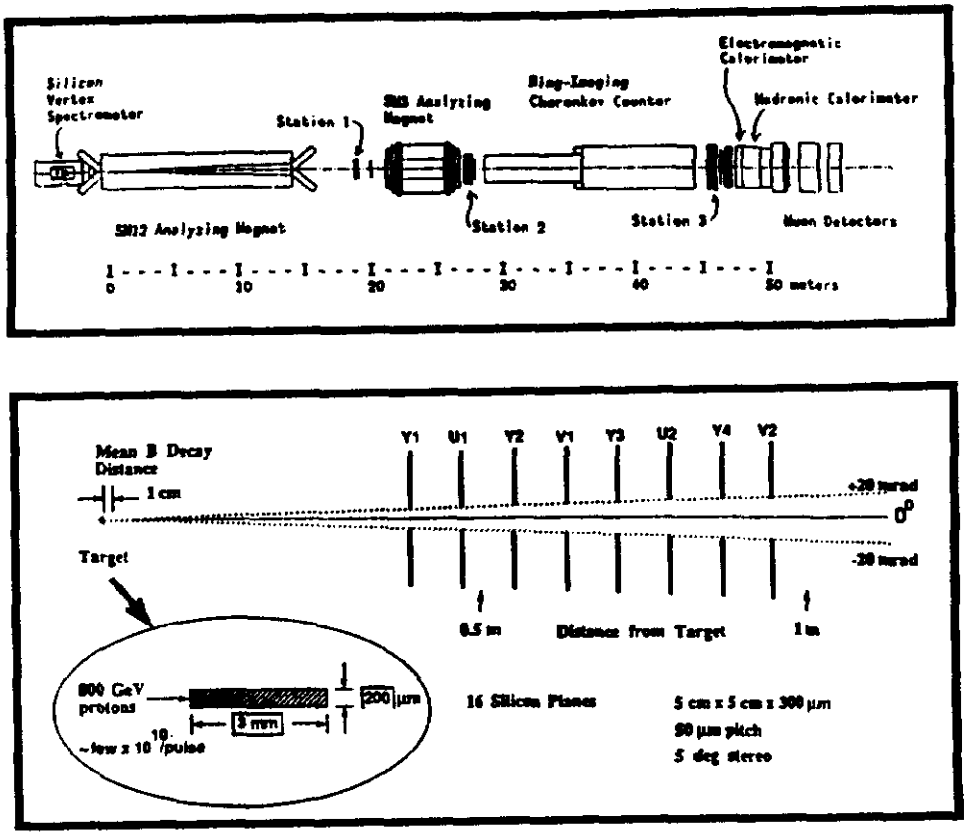

Fig. 20 A schematic view of E789 spectrometer and silicon vertex spectrometer.

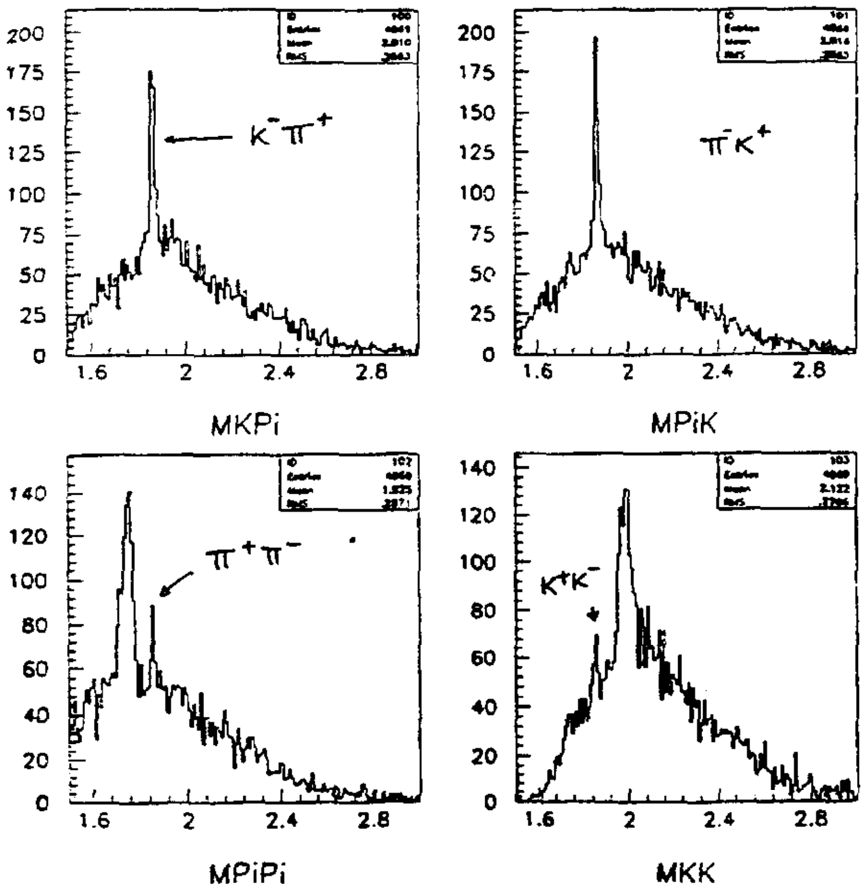

Fig. 21 Mass spectra for dihadron events reconstructed with various assumption for the hadron species.

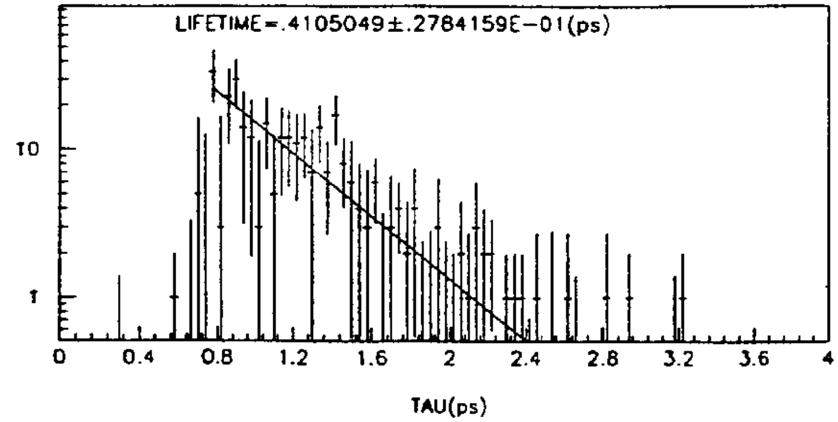

Fig. 22 D° lifetime distribution.

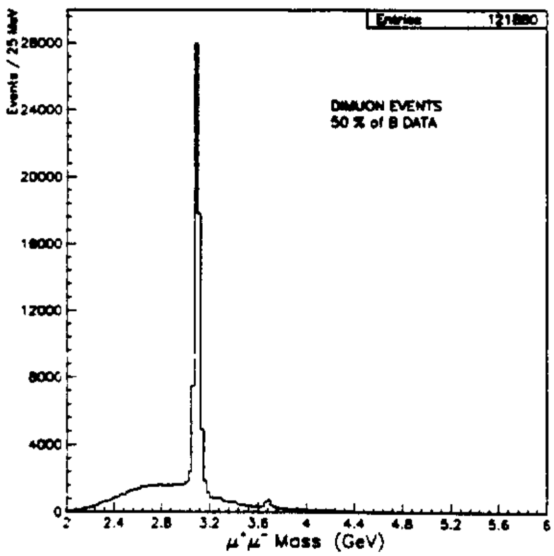

Fig. 23 Mass Spectrum for dimuon events (50% of the data).

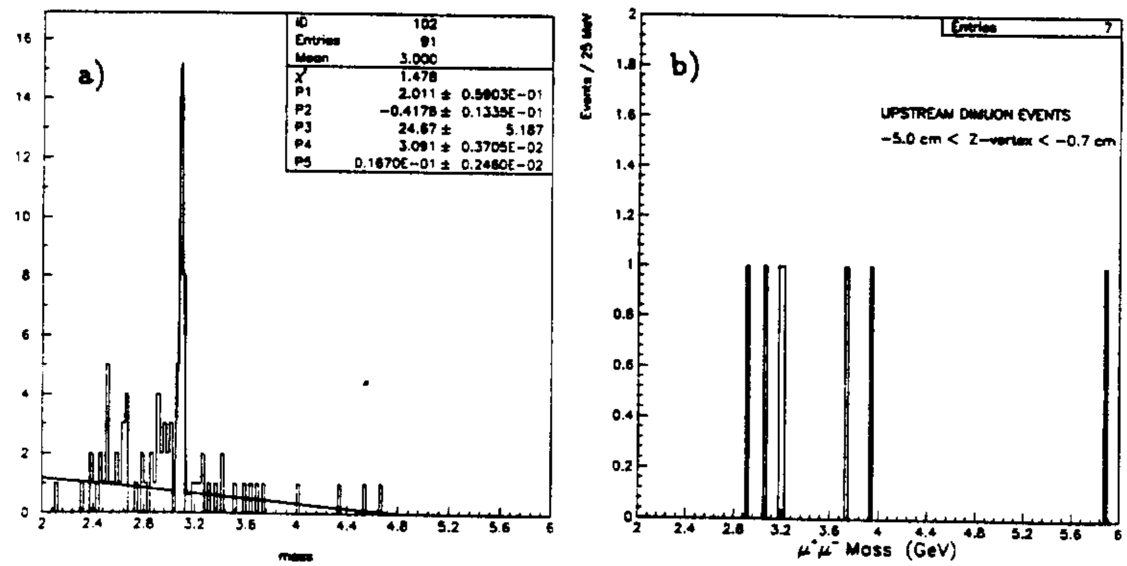

Fig. 24 Mass spectra for dimuon events passing a) downstream Z vertex cuts b) upstream Z vertex cuts.