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A Study of $D^{*\pm}$ – Production in Z^0 Decays

The OPAL Collaboration

Abstract

In this paper an investigation of the production of $D^{*\pm}$ mesons produced in e^+e^- collisions at energies around the Z^0 pole is presented. Based on 115 $D^{*\pm}$ mesons with $x_{D^*} \equiv 2 \cdot E_{D^*}/E_{cm} > 0.2$ the properties of D^* mesons produced in the reaction $Z^0 \rightarrow c\bar{c}$ are studied. Fixing the yield and the fragmentation function of bottom quarks to the values obtained at LEP using lepton tags, an average energy fraction of the $D^{*\pm}$ mesons from primary charmed quarks of

$$< x_{c \rightarrow D^*} > = 0.52 \pm 0.03 \pm 0.01$$

is found and

$$\Gamma_{Z^0 \rightarrow c\bar{c}} \; = \; (323 \pm 61 \pm 35) \; \text{MeV}$$

is determined. The first error is the combined statistical and systematic error from this experiment, and the second the total error from other sources.

This paper is dedicated to the memory of Hans–Erhart Stier,
who died on March 25, 1991.

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1 Introduction

$D^{*\pm}$ mesons provide a powerful tool to study the production mechanism of heavy quarks. Since they contain the charm quark, D^* mesons occur almost exclusively in jets from primary bottom and charm quarks. Therefore they can be used to distinguish the original flavour of the jets which allows the study of the flavour dependence of fundamental processes.

In Z^0 decays, D^* mesons are expected from two main sources. They can be fragmentation products from primary charmed quarks coupling directly to the Z^0. This leads to D^* mesons of high $x_{D^*} \equiv 2 \cdot E_{D^*}/E_{cm}$ ($< x_{D^*} > \approx 0.5$). Those from decays of bottom particles are expected to be of somewhat lower energy ($< x_{D^*} > \approx 0.3$), providing information about the coupling of $Z^0 \rightarrow b\bar{b}$. A small number of D^* mesons could stem from a gluon splitting into a pair of charmed quarks, $g \rightarrow c\bar{c}$, yielding particles of very low x_{D^*}. This splitting is expected to be strongly suppressed due to the relatively high gluon mass required.

In this paper a measurement of D^* production in Z^0 decays using the OPAL detector at the e^+e^-collider LEP is presented. The decay channel investigated is $D^{*+} \rightarrow \pi^+ D^0 \rightarrow \pi^+(K^-\pi^+)$. In all cases the charge conjugate decay chain is also implied; subsequently, D^* will refer to both D^{*+} and D^{*-}. The high combinatorial background for the $D^0 \rightarrow K\pi$ mode can be largely suppressed by exploiting the low Q–value of the $D^* \rightarrow D^0\pi$ decay, yielding a prominent signal in an otherwise phase space suppressed kinematical region. Observed D^* mesons are used to determine the D^* fragmentation function in the process $Z^0 \rightarrow c\bar{c} \rightarrow D^* + X$ and to obtain a measurement of the partial width $\Gamma_{Z^0 \rightarrow c\bar{c}}$.

2 The OPAL Detector and Event Selection

The OPAL detector [1] has been described in detail elsewhere. It is a multipurpose detector covering almost the entire solid angle around the interaction point. Its main parts are a system of central tracking chambers inside a magnetic field of 0.435 T, an electromagnetic calorimeter, a hadron calorimeter and an outer shell of muon chambers.

For this analysis only the inner tracking chambers are used. Three sets of chambers allow an accurate determination of the vertex of the interaction and of the momenta of the charged particles. The chamber closest to the beam is the vertex chamber, extending radially from 8.5 to 24.5 cm from the interaction vertex. It has a total of eighteen layers of wires. The first twelve are used to measure the (r, ϕ) coordinate with a single hit resolution of $\sigma_{r\phi} \approx 50\mu$m, the remaining six, to determine the z-coordinate with a precision of $\sigma_z \approx 700\mu$m. The main part of the inner tracking system is a jet chamber of about 2 m in radius and of 4 m in length. It provides up to 159 measurements per track with a precision of $\sigma_{r\phi} \approx 120$ μm and $\sigma_z \approx 5$ cm . In addition the energy loss for each particle is measured with a precision of $\sigma(dE/dx)/(dE/dx) \approx 3.8$ %, allowing a good statistical separation of the various kinds of particles over a wide momentum range. A precise measurement of the z-coordinate is provided by a third set of drift chambers ("z–chambers") located at a radius of about 192 cm from the interaction point yielding up to six measurements with a single hit resolution of $\sigma_z \approx 300\mu$m. The combination of these chambers leads to $\sigma_{p_T}/p_T \approx \sqrt{0.02^2 + (0.0018 \cdot p_T/(\mathrm{GeV/c}))^2}$, where p_T is the momentum transverse to the beam direction.

The data used in this analysis correspond to an integrated luminosity of 6.6pb^{-1}, collected during the running period in 1990. The selection of multi hadronic events is based mainly on their high multiplicity and large energy deposition. In addition to the selection criteria described in [2], at least five tracks are required to be present in each event. A total of 148,071 events pass these cuts.

3 Selection of D* Mesons

This analysis is restricted to the two body decay $D^* \rightarrow D^0\pi$, where $D^0 \rightarrow K\pi$. Tracks are required to have a minimum transverse momentum of $p_T = 250$ MeV/c . Only those with an origin inside a cylinder around the main interaction vertex defined by a radius of $\mid d_0 \mid = 0.5$ cm in the plane transverse to and a distance of ± 20 cm from the interaction point along the beam direction are used. For each track, a minimum of 40 hits in the jet chamber and at least four hits in the z–chambers are required. The latter restricts the acceptance in the polar angle θ to $\mid \cos\theta \mid < 0.72$. To improve the determination of momenta all tracks in an event are constrained to a common vertex in z.

A D^0 hypothesis is tested for each combination of oppositely charged particles a and b. Kaon and pion masses are assigned to a and b respectively, and the two are used to form a particle combination P_{D^0}. At this point no attempt has been made to actually identify the particles. P_{D^0} is then combined with a third particle c, assumed to be a pion, which must have the same charge as the pion in the combination P_{D^0}.

D^0 candidates are selected by requiring that $1.79 < M(K\pi) < 1.94$ GeV/c^2 . To help suppress the combinatorial background, which becomes increasingly important at lower x_{D^*}, the isotropic decay distribution of the D^0 is used. The angular distribution of the kaons, measured relative to the direction of the D^0 candidate in the $K\pi$ rest is expected to be flat for kaons from true D^0 mesons and strongly peaked in the forward and backward direction for background events. Calling this variable θ^*, a large reduction in background is achieved by requiring $\mid \cos\theta^* \mid < 0.9$ for $x_{D^*} > 0.5$ and $\mid \cos\theta^* \mid < 0.8$ for $x_{D^*} < 0.5$. The background is further reduced by using the particle identification capability of the OPAL detector. For $x_{D^*} < 0.5$ the dE/dx measurement of the kaon candidate has to have a probability of more than 10% to agree with the expectation for a kaon.

The mass difference $\Delta M = M(K\pi\pi) - M(K\pi)$ for these events is shown in fig.1a and fig.1b for $0.2 < x_{D^*} < 0.5$ and for $x_{D^*} > 0.5$ respectively. A significant enhancement is apparent around $\Delta M = 146$ MeV/c^2 due to the D^* to D^0 transition. Assuming a Gaussian shape for the signal the peak value is found to be at 145.5 ± 0.2 MeV/c^2 , in excellent agreement with the world average values of 145.44 ± 0.06MeV/c^2[3], and with a width of 0.9 ± 0.1 MeV/c^2 . The signal in the high x_{D^*} region has very little background, whereas at lower x_{D^*} the signal–to–background ratio is close to one.

The mass distribution of the D^0 candidates for $x_{D^*} > 0.2$ is shown in fig.2, obtained from events with $0.142 < \Delta M < 0.149$ GeV/c^2 and with no requirement on $M(K\pi)$. A clear signal is visible around the nominal D^0 mass of 1.8645 ± 0.0005 GeV/c^2 [3] with a central value of 1.866 ± 0.008 GeV/c^2 and a width of 39.6 ± 6.0 MeV/c^2 . The background is significantly higher below the D^0 than above. Apart from phase space effects this is due to the presence of remnants from other, not completely reconstructed, decay modes of the D^0 . In particular, indications of a second peak are visible around $M_{D^0} = 1.6$ GeV/c^2 . A signal is expected in this region due to the $D^0 \rightarrow (K\pi)\pi^0$ transition, where the π^0 is not reconstructed. This region ($1.45 < M_{D^0} < 1.70$ GeV/c^2) is excluded in the fit to the D^0 mass distribution.

4 Determination of the D* Fragmentation Function

The background to the D* signal can be due to two sources. The dominant background is due to random combinations from decays of non charmed particles, which lead to a smooth distribution in ΔM. In addition, other D^0 decay modes are present for which only part of the decay products are associated to the D^0 , potentially contaminating the signal at lower ΔM.

Three different methods are used to determine the signal-to-background ratio. By comparing the results, the systematic error of the background subtraction is estimated.

Firstly the distribution in ΔM is fitted using $A \cdot (\Delta M - m_\pi)^B$ to describe the background plus a Gaussian around $\Delta M = 146$ MeV/c^2 to describe the signal peak, leaving A and B as well as the normalization, the central value and the width of the Gaussian as free parameters. The term m_π, the pion mass, is the minimum possible mass difference. The number of background events is obtained by integrating the background function in the range $0.142 < M_{D^*} < 0.149$ GeV/c^2 . By fitting the distributions shown in fig 1a and 1b in this way, 66 ± 4 background events are found for $x_{D^*} < 0.5$ and 8.9 ± 0.5 events for $x_{D^*} > 0.5$.

A second background estimate was obtained by following the D* search strategy with the exception of selecting a two particle combination of $2.2 < M(K\pi) < 2.6$ GeV/c^2 , above the D^0 mass. This distribution is normalized to the same number of entries as the signal distribution in the ΔM region of $0.155 < \Delta M < 0.200$ GeV/c^2 and fitted with the same background function as in method 1. A background of 65 ± 7 events is estimated for $x_{D^*} < 0.5$ and 8.3 ± 0.9 events for $x_{D^*} > 0.5$. Monte Carlo studies indicate that this method yields a good account of the true background.

In a third method two particles of equal charge are used for the $K\pi$ combination and form, together with a third track of opposite charge, a fake D* candidate. Apart from the charge assignment, cuts identical to those used in the D* search are applied. Normalizing and fitting the distribution as described above for method 2, 63 ± 3 background combinations are found for $x_{D^*} < 0.5$ and 8.9 ± 0.5 for $x_{D^*} > 0.5$. Monte Carlo studies suggest that the background is underestimated by this method due to local charge conservation in the fragmentation process [4].

The various background estimates are consistent within the different x_{D^*} ranges. For the final background calculation the first method is used. The variations between the different estimates are taken into account by assigning a systematic uncertainty of 10% of the signal for $0.2 < x_{D^*} < 0.5$ and of 2% for $0.5 < x_{D^*} < 0.65$. For $x_{D^*} > 0.65$ the systematic error caused by the background subtraction method is negligible. The signal and background yields are listed in table 1 for several intervals of x_{D^*}.

Apart from the combinatorial background from decays of non charmed particles, genuine charm decays other than $D^* \to \pi K\pi$ can also contaminate the signal. Incompletely measured D^0 and D^* decay modes like $D^0 \to \rho^+ K^-$ and $D^+ \to \pi^+ K^{*0}$ can contribute when the $K\pi$ combination falls into the selected mass interval. Background from higher multiplicity D^0 and D^+ decays leaking into the signal region is estimated to contribute fewer than three combinations at the current statistics. Monte Carlo studies show, that background due to the exchange of the kaon and the pion assignment for the D^0 candidate is negligible.

To determine the efficiency $\varepsilon(x_{D^*})$ of the D* selection the generated and retained D* yields are compared using the JETSET V7.2 Monte Carlo [5] [1] followed by a full simulation of the OPAL detector

[1] Hereafter referred to simply as JETSET.

[6]. The parameters used in the Monte Carlo are those optimized by OPAL [7]. Within the regions of $0.2 < x_{D^*} < 0.5$ and $x_{D^*} > 0.5$, the efficiency shows no dependence on x_{D^*}. For the low x_{D^*} region the efficiency is $\varepsilon = 0.152 \pm 0.006$; for $x_{D^*} > 0.5$, $\varepsilon = 0.219 \pm 0.006$ (statistical error only). The difference for the two x_{D^*} regions is due to the looser selection criteria $x_{D^*} > 0.5$.

Systematic uncertainties in the efficiency calculation may be due to misrepresentations of the detector in the simulation. Several checks were performed to estimate their size. The width of the D^0 signal and the transition peak in the data and in the simulation were compared. The values of 36.2 MeV/c^2 (M_{D^0}) and of 0.95 MeV/c^2 (ΔM) in the simulation are in good agreement with the data. The sensitivity of the observed D^* yield to the applied cuts was compared between the data and the Monte Carlo simulation and was found to be in good agreement. Since the statistics of the observed D^* mesons are low, the abundant K^0_s production is used to identify potential systematic problems in the mass reconstruction. Based on more than 20,000 observed $K^0_s \to \pi^+\pi^-$ decays, the following main contributions to the systematic error of the corrected D^* yield due to potential misrepresentations of the detector in the simulation are considered: uncertainties in the mass resolution (3%), the matching to the z-chamber (7%), and the $\cos\theta$ dependence of the efficiency (5%). An additional error of 5% is introduced for the intervals of $x_{D^*} < 0.5$ to account for uncertainties in the efficiency of the dE/dx measurement. Combining these errors the systematic error introduced by the determination of the efficiency is 10% for $x_{D^*} < 0.5$ and 9% for $x_{D^*} > 0.5$.

The observed yield is converted into an efficiency corrected distribution of

$$\frac{1}{N_{\text{hadron}}} \cdot \frac{dN(D^* \to \pi K \pi)}{dx_{D^*}}$$

for $0.2 < x_{D^*} < 1.0$. The results are listed in table 1 and displayed in fig.3. As expected from the arguments given in the introduction the x_{D^*} distribution is very hard compared to the x distribution of all final particles.

Using JETSET, it is found that $17 \pm 5\%$ of all D^* mesons are expected below $x_{D^*} = 0.2$. The error on this number is dominated by uncertainties in the fragmentation function. The Monte Carlo predicts that these D^* mesons are mostly from $b\bar{b}$ events, but contributions from gluon splitting into $q\bar{q}$ are included as well. Incorporating this correction the measurement is translated into a total inclusive yield of D^* mesons of

$$\frac{\Gamma_{Z^0 \to D^* + X}}{\Gamma_{Z^0 \to \text{hadrons}}} \cdot B(D^* \to \pi + D^0 \to \pi(K\pi)) = (5.00 \pm 0.66 \pm 0.65) \cdot 10^{-3},$$

where the first error is statistical and the second systematic. For the D^* and D^0 branching ratios the Particle Data Group value [3] of

$$B(D^* \to D^0\pi \to \pi K \pi) = 0.0204 \pm 0.0020$$

is used. This leads to

$$\frac{\Gamma_{Z^0 \to D^* + X}}{\Gamma_{Z^0 \to \text{hadrons}}} = 0.245 \pm 0.045 \pm 0.024.$$

Here the statistical and the systematic error of the total inclusive D^* yield are combined in quadrature into the first quoted error and the second error is due to the uncertainty introduced by the $D^* \to \pi K \pi$ branching ratio. As always in this paper, both charge conjugate modes are included in the quoted numbers.

5 The Charm Fragmentation Function and the Branching Ratio $B(Z^0 \to c\bar{c})$

As mentioned in the introduction, the observed x_{D^*} distribution has contributions from both charm and bottom quarks coupling directly to the Z^0. The yield depends on

- the fractions
$$F_c = \frac{\Gamma_{Z^0 \to c\bar{c}}}{\Gamma_{Z^0 \to \mathrm{Hadrons}}}$$
and
$$F_b = \frac{\Gamma_{Z^0 \to b\bar{b}}}{\Gamma_{Z^0 \to \mathrm{Hadrons}}};$$
- the fragmentation functions of the charm and bottom quarks;
- the product branching ratio $P_{q \to D^*}$ of a quark species q to turn into a D^* and the D^* to decay into $\pi(K\pi)$.

The number of observed events is not sufficient to allow the determination of all these quantities with reasonable precision from this analysis. Instead we use the values for the bottom branching ratio and for the fragmentation function of bottom hadrons as measured previously at LEP [8, 9, 10, 11]. The $P_{q \to D^*}$ are taken from measurements at lower energy.

The fragmentation function of bottom and charm quarks is parametrized by [12]

$$d(x) = \frac{N}{x \cdot [1 - \frac{1}{x} - \frac{\epsilon}{1-x}]^2}. \quad (1)$$

In the case of the bottom quark, eq.(1), with $\epsilon = \epsilon_b$, is used as the primordial fragmentation function of the b quark, which is evolved to generate the spectrum of bottom hadrons. With the appropriate B hadron decay distribution this leads to the effective fragmentation function $d'_{b \to D^*}(x_{D^*})$. For the fragmentation function of D^* from charm quarks, the observed x_{D^*} distribution is directly parametrized using eq.(1). It should be noted that the $D^{**} \to D^*\pi$ decay will contribute to the D^* sample at the 10% level [13] and will soften the measured fragmentation. Neglecting contributions from $g \to c\bar{c}$, the observed x_{D^*} distribution is given by

$$f(x_{D^*}) \;=\; 2 \cdot [F_c \cdot P_{c \to D^*} \cdot d_{c \to D^*}(x_{D^*}) + F_b \cdot P_{b \to D^*} \cdot d'_{b \to D^*}(x_{D^*})]. \quad (2)$$

Taking the weighted average of $F_b \cdot B(b \to \mu)$ [9, 10, 11], and using $B(b \to \mu) = 0.115 \pm 0.009$, which is a weighted average of the Particle Data Group value and a recent LEP measurement [3, 9], yields $F_b = 0.215 \pm 0.018$.

The product branching ratio $P_{b \to D^*}$ is derived mostly from previous experimental data. It has contributions from B_u, B_d and B_s:

$$P_{b \to D^*} = (p_u + p_d) \cdot P_{B_{u,d} \to D^*} + p_s \cdot P_{B_s \to D^*}.$$

Here the p_i are the respective fractions of bottom particles B_i with quark flavors $i = (u, d, s)$, and $P_{B_{u,d} \to D^*}$ is the inclusive product branching ratio $B(B_{u,d} \to D^* + X) \cdot B(D^* \to \pi D^0) \cdot B(D^0 \to K\pi)$, and $P_{B_s \to D^*} = B(B_s \to D^* + X) \cdot B(D^* \to \pi D^0) \cdot B(D^0 \to K\pi)$. For the p_i we adopt the values obtained from jets in e^+e^- collisions at 10 and 30 GeV : $p_u + p_d$=0.8±0.05, p_s=0.13±0.05 [4]. The inclusive branching ratio $P_{u,d \to D^*}$ has been measured at the $\Upsilon(4S)$ [14]. To take into account possible non B decays of the $\Upsilon(4S)$ this measurement has been scaled down by 5% and an additional systematic error of 5% has been assigned to it [15]. This gives $P_{B_{u,d} \to D^*} = (6.9 \pm 1.5) \cdot 10^{-3}$.

The decay $B_s \to D^* + X$, from which $P_{B_s \to D^*}$ could be determined, has not yet been observed. To estimate its contribution the decay $B_{u,d} \to D_s + X$, measured to have a branching ratio of 0.125 ± 0.035 [3], is used as an analogy. About 2/3 of this branching ratio is expected to be due to the W→ $c\bar{s} \to D_s$ decay, whose equivalent W→ $c\bar{d} \to D^*$ in the B_s case is Cabbibo suppressed. The remaining 1/3 is due to the sea contribution and has to be corrected for the p_d/p_s ratio. The B_s branching ratio is finally estimated as $P_{B_s \to D^*} = (1.8 \pm 0.8) \cdot 10^{-3}$. Combining this number with the branching ratio $B(D^* \to \pi K \pi)$, the product branching ratio for b-quarks into D^* mesons is found to be $P_{b \to D^*} = 0.0058 \pm 0.0013$ or $F_b \cdot P_{b \to D^*} = (1.24 \pm 0.30) \cdot 10^{-3}$.

The x_{D^*} distribution of bottom hadrons is obtained from the JETSET Monte Carlo and cross checked by changing the decay tables to those in EURODEC [16]. Both were found to be in good agreement. As input to the Monte Carlo program the fragmentation parameter $\epsilon_b = 0.006 \pm 0.004$ as measured at LEP [8, 10, 11] is used. The function $d'_{b \to D^*}(x_{D^*})$ for D^* mesons from bottom quarks is parametrized by

$$d'_{b \to D^*}(x_{D^*}) = A \cdot exp(\frac{-(x_{D^*} - B)^2}{C}) \cdot (1 + D \cdot x_{D^*} + E \cdot x^2_{D^*} + F \cdot x^3_{D^*}). \qquad (3)$$

The six parameters A-F are determined by a fit to the Monte Carlo distribution. The function is plotted in fig.3. It was checked that the D^* momentum distribution, as simulated in JETSET is compatible with the spectrum measured at the $\Upsilon(4S)$ [14]. Again this was cross checked using the EURODEC decay tables.

A maximum likelihood fit to the D^* candidate events is performed with the function:

$$\begin{aligned} \mathcal{L}(x_{D^*}, d_c(x_{D^*}), P_{c \to D^*}) &= [F_b \cdot P_{b \to D^*} \cdot d'_b(x_{D^*}) + F_c \cdot P_{c \to D^*} \cdot d_c(x_{D^*}) \ ] \\ &\quad + f_{background}(x_{D^*}). \end{aligned} \qquad (4)$$

Here $f_{background}(x_{D^*})$ describes the background. It is obtained by a fit of an exponential function to the measured background values listed in table 1. The two parameters determined in the fit are $P_{c \to D^*}$ and $< x_{c \to D^*} >$.

From the fit the following values for the D^* mesons from primary charmed quarks for the full x_{D^*} range are obtained:

$$\begin{aligned} P_{c \to D^*} \cdot F_c &= (1.36 \pm 0.23 \pm 0.11 \pm 0.10) \cdot 10^{-3} \\ < x_{c \to D^*} > &= 0.52 \pm 0.03 \pm 0.01 \pm 0.01. \end{aligned}$$

For each value the first error is statistical only, the second one reflects the systematic error as listed in table 1 due to uncertainties in the efficiency calculation and the background subtraction. The third error is the systematic uncertainty of the bottom contribution, estimated by varying the parameters of the bottom fragmentation independently within their errors and by using both JETSET and EURODEC decay tables. The corresponding χ^2 is 6.0 for three degrees of freedom.

To check the consistency of the result, F_c is fixed at its Standard Model value and only $< x_{c \to D^*} >$ is allowed to vary in the fit, yielding $< x_{c \to D^*} > = 0.53 \pm 0.02 \pm 0.01 \pm 0.01$. The results for $< x_{c \to D^*} >$, both from the full fit and from the fit with fixed F_c, are lower at the 2σ level than previous measurements at lower energies [17, 18, 19], where $< x_{D^*} >= 0.59 \pm 0.02$. This behaviour is expected from QCD scaling violations [12, 20].

The fit result is converted into a fraction $\Gamma_{Z^0 \to c\bar{c}}/\Gamma_{Z^0 \to \mathrm{hadrons}}$ using $P_{c \to D^*} = (7.3 \pm 0.6) \cdot 10^{-3}$ as obtained from e^+e collisions at center of mass energies around 30 GeV [4, 18, 19]:

$$\frac{\Gamma_{Z^0 \to c\bar{c}}}{\Gamma_{Z^0 \to \mathrm{hadrons}}} = 0.186 \pm 0.035 \pm 0.020.$$

For $\Gamma_{Z^0 \to \mathrm{hadrons}} = 1.739 \pm 0.017$ GeV , as obtained from this experiment [2, 21], this corresponds to

$$\Gamma_{Z^0 \to c\bar{c}} = (323 \pm 61 \pm 35) \quad \mathrm{MeV}.$$

All errors due to this experiment have been combined into the first quoted error, all others into the second one. This value is in good agreement with the Standard model prediction of $296^{+4.5}_{-4}$ MeV for top masses between 90 and 230 GeV/c^2 and Higgs masses between 10 and 1000 GeV/c^2 [22]. It also compares well with the measurements obtained by other methods [10, 11, 23].

The results were also used to estimate the fractions of D^* mesons coming from primary charmed quarks for various x_{D^*} intervals. As seen from table 1 the fraction of primary charmed quarks is about 75% for $x_{D^*} > 0.5$.

6 Summary

Using the full statistics available from the 1990 data taking period at LEP with the OPAL detector 115 charged D^* mesons have been identified in the channel $D^* \to D^0\pi \to \pi K\pi$. From an analysis of their momentum distribution, the partial width Z^0 into $c\bar{c}$ is determined to be $\Gamma_{Z^0 \to c\bar{c}} = (323 \pm 61 \pm 35)$MeV. The average D^* energy fraction is $< x_{c \to D^*} >= 0.52 \pm 0.03 \pm 0.01$, which is about 10% lower than measurements at energies around 30 GeV in agreement with expectations from QCD. The first error quoted is the combined statistical and systematic error due to this experiment, the second one the error from other sources.

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Table 1. D^* yield and corrections.

x_{D^*}	$N_{D^*}^{obs}$	N_{backgr}	$N_{D^*}^{corr}$	syst. err.	$f_{c\bar{c}}$
0.20–0.35	32.5±9.6	51.5	214±63	± 32	0.27±0.11
0.35–0.50	17.2±5.7	14.8	113±38	± 17	0.49±0.13
0.50–0.65	43.4±7.0	5.6	198±33	± 19	0.72±0.09
0.65–0.80	17.1±4.5	2.9	78±21	± 7.4	0.87±0.05
0.80–1.00	4.5±2.2	0.4	21±10	± 2.0	0.95±0.04

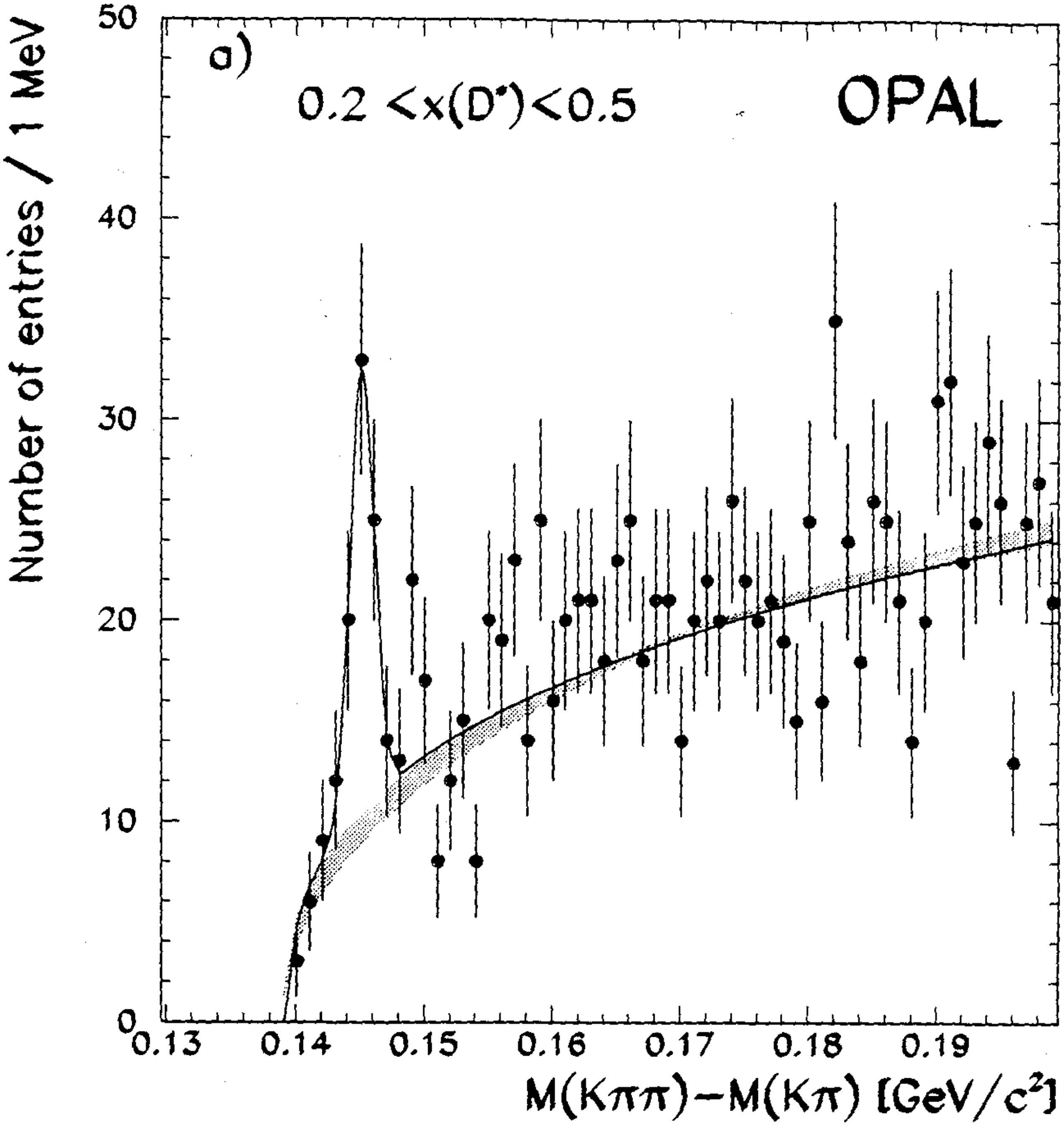
The observed and corrected D^* yields are listed for various intervals of x_{D^*}. The error quoted for $N_{D^*}^{obs}$ includes the statistical errors for the number of events and the background fit. The systematic error takes into account contributions from the uncertainty in the efficiency calculation and variations between different methods of background determination. In the last column $f_{c\bar{c}}$ denotes the fraction of D^* mesons from primary charmed quarks as derived from the fit described in section 5.

Figure Captions

Fig.1 Observed distribution of $\Delta M = M(P_{D^*}) - M(P_{D^0})$ for: (a) $0.2 < x_{D^*} < 0.5$; (b) $x_{D^*} > 0.5$. The line shows the result from a fit of a Gaussian distribution for the signal over a smooth background (see text). The shaded area in (a) indicates the range of the different background estimates.

Fig.2 Observed distribution of $M(P_{D^0})$ for $x_{D^*} > 0.2$ and $0.142 < M(P_{D^*}) < 0.149 \mathrm{GeV}/c^2$. The line shows the result of a fit of a Gaussian distribution plus a second order polynomial. The area below the D^0 peak, indicated by a dashed line in the plot, is excluded from the fit (see text).

Fig.3 Total D^* yield $\frac{1}{N_{had}} \cdot \frac{dN(D^* \to \pi K \pi)}{dx_{D^*}}$. The error bars displayed are statistical errors only. Also shown is the D^* contribution from Z^0 decays into bottom quarks (dotted line), derived as explained in the text and the fitted contribution from $Z^0 \to c\bar{c}$ (dashed line). The solid line shows the combined contribution from b and c quarks.



a)
0.2 <x(D*)<0.5
OPAL
Number of entries / 1 MeV
M(Kππ)−M(Kπ) [GeV/c²]
0
10
20
30
40
50
0.13
0.14
0.15
0.16
0.17
0.18
0.19

Figure 1a

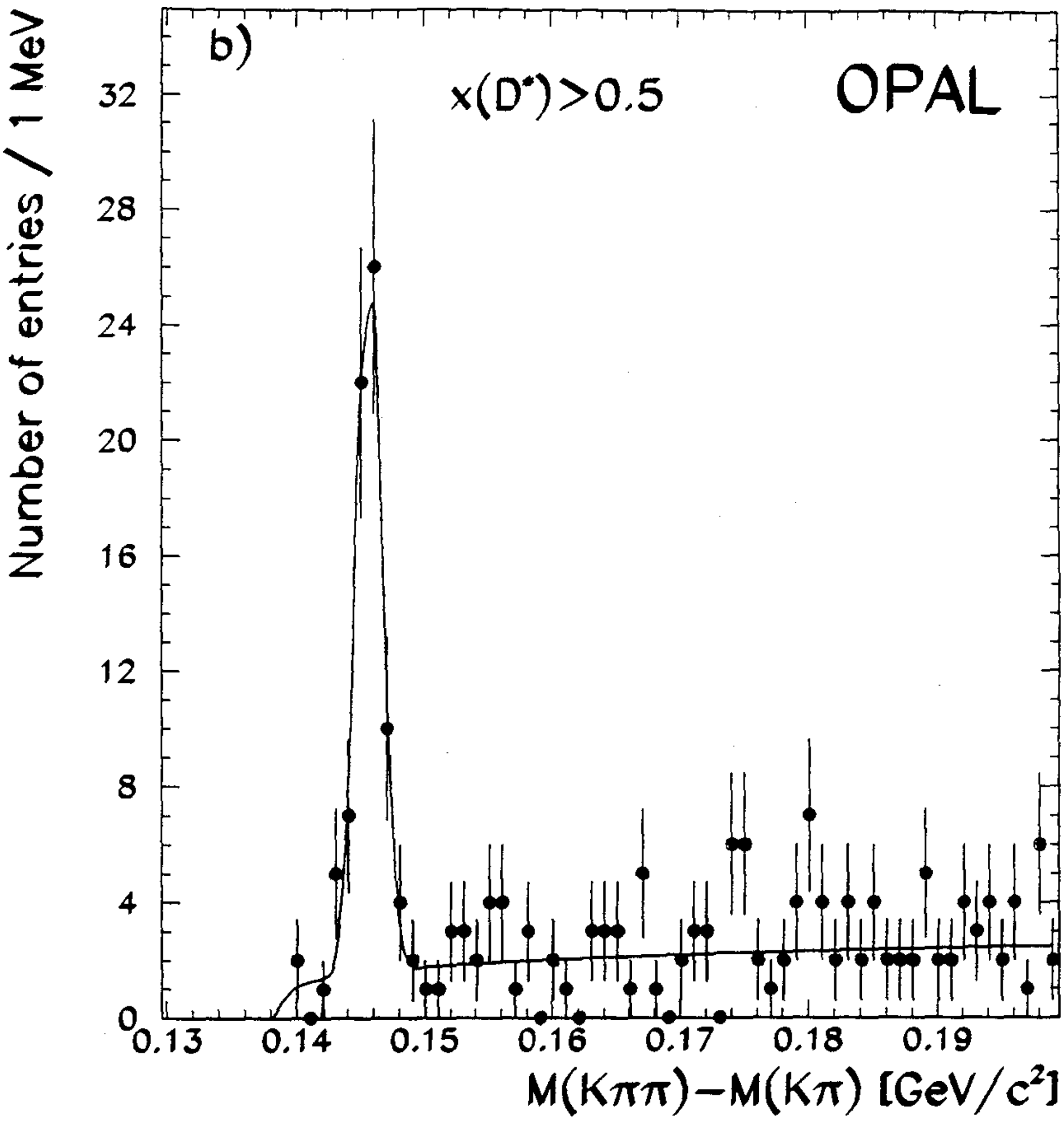
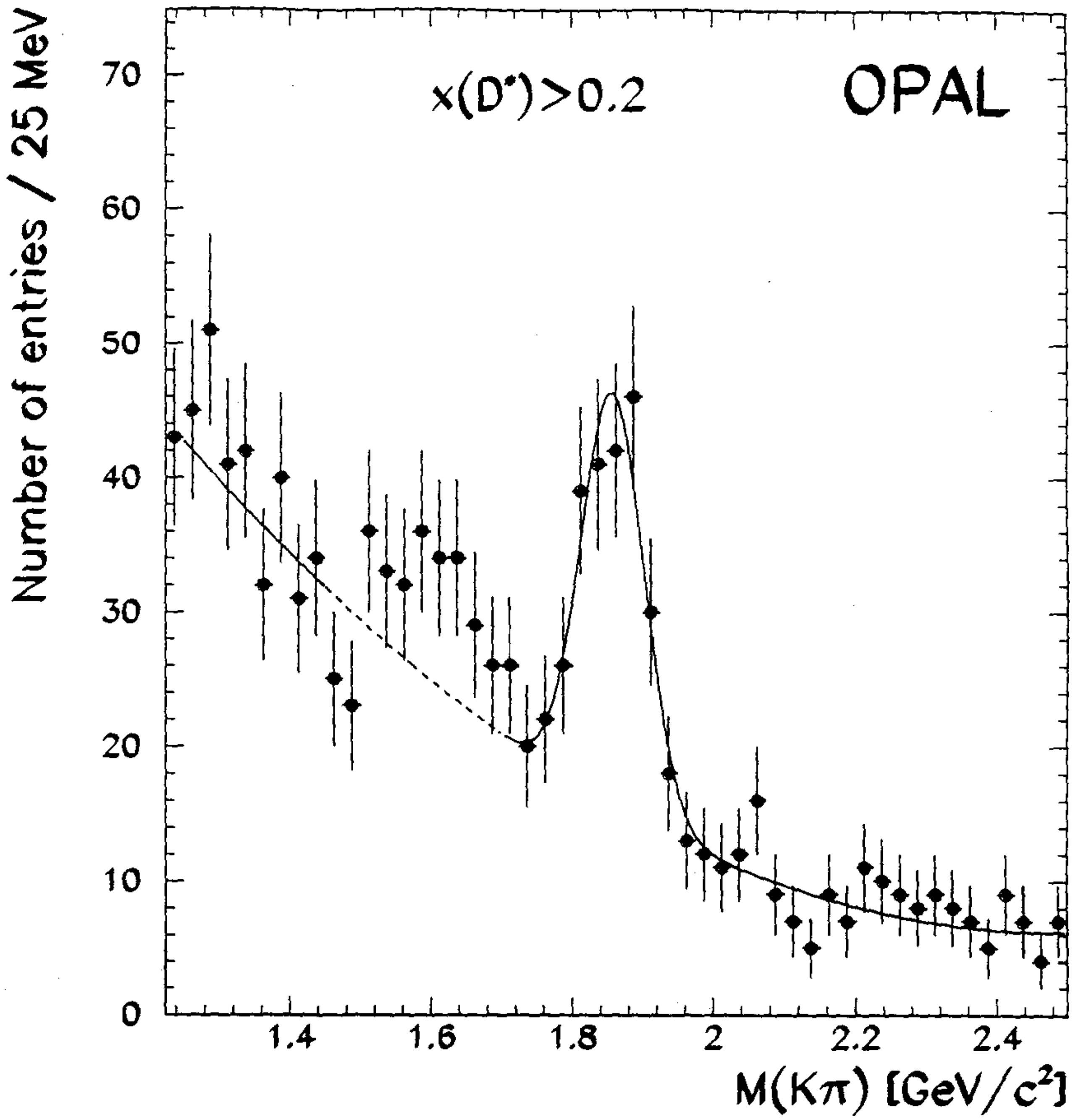
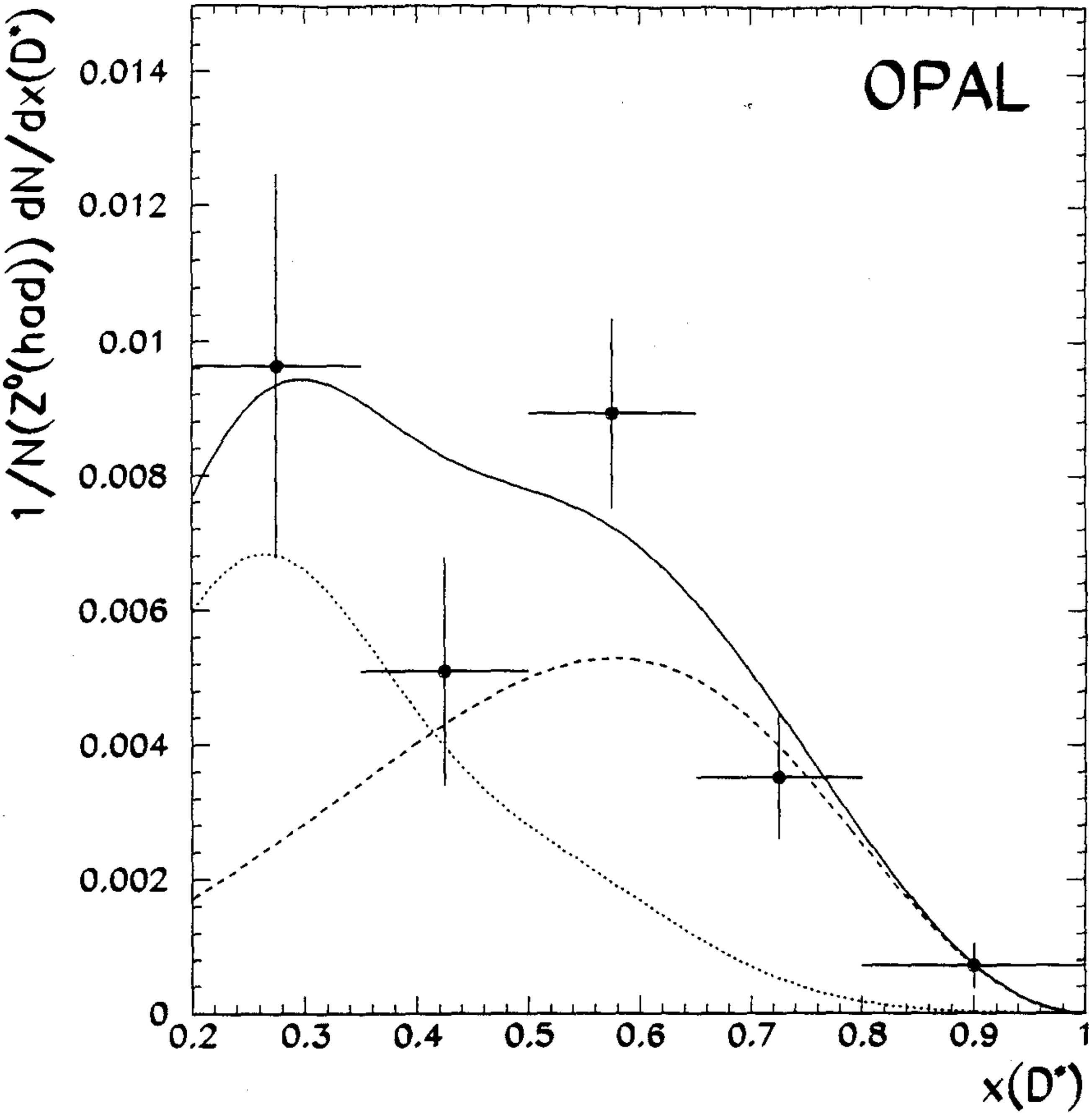

b)
x(D*)>0.5
OPAL
Number of entries / 1 MeV
M(Kππ)−M(Kπ) [GeV/c²]
0
4
8
12
16
20
24
28
32
0.13
0.14
0.15
0.16
0.17
0.18
0.19

Figure 1b



x(D*)>0.2
OPAL
Number of entries / 25 MeV
M(Kπ) [GeV/c²]
0
10
20
30
40
50
60
70
1.4
1.6
1.8
2
2.2
2.4

Figure 2



OPAL
1/N(Z⁰(had)) dN/dx(D*)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
x(D*)

Figure 3