IISN 0379-301X

UNIVERSITE LIBRE DE BRUXELLES - VRIJE UNIVERSITEIT BRUSSEL

INTER-UNIVERSITY INSTITUTE FOR HIGH ENERGIES

EVIDENCE FOR ANTINEUTRINO PRODUCTION OF D_s^* MESONS

WA59 + E180 Neutrino Collaboration

Universities of Brussels (ULB-VUB)
Pleinlaan, 2
1050 Brussels

July 1989
IIHE 89-06

EVIDENCE FOR ANTINEUTRINO PRODUCTION OF D_s^* MESONS.

WA59 + E180 Neutrino Collaboration

A. ASRATYAN[10], V.V. AMMOSOV[9], J.P. BATON[14], V.S. BURTOVOY[9], T. COGHEN[5], O. ERRIQUEZ[1], G.S. GAPIENKO[9], V.A. GAPIENKO[9], J. GUY[13], V. KAFTANOV[10], V.I. KLYUKHIN[10], V.A. KOROTKOV[9], S. KRUTCHININ[10], M. KUBANTSEV[10], I. MAKHLUEVA[10], P. MARAGE[3], D.R.O. MORRISON[4], M. NEVEU[14], J. SACTON[3], V. URALOV[10], K. VARVELL[2], W. VENUS[13], W. WITTEK[11], V.G. ZAETZ[9].

1. Dipartimento di Fisica dell'Università e Sezione INFN, I-70126 Bari, Italy.
2. University of Birmingham, Birmingham B15 2TT, UK.
3. Inter-University Institute for High Energies, ULB-VUB, B-1050 Brussels, Belgium.
4. CERN, CH-1211 Geneva 23, Switzerland.
5. Institute of Nuclear Physics, PL-30055 Cracow, Poland.
6. Nuclear Research Centre Demokritos, GR Athens, Greece.
7. LPNHE, Ecole Polytechnique, F-91128 Palaiseau, France.
8. Imperial College of Science and Technology, London, SW7 2AZ, UK.
9. Institute of High Energy Physics, Serpukhov, USSR.
10. Institute of Theoretical and Experimental Physics, Moscow, USSR.
11. Max-Planck-Institute für Physik und Astrophysik, D-8000 München 40, Federal Republic of Germany.
12. Department of Nuclear Physics, Oxford, OX1 3RH, UK.
13. Rutherford Appleton Laboratory, Chilton, Didcot, OX11 0QX, UK.
14. DPhPE, Centre d'Etudes Nucléaires, Saclay, F-91191 Gif sur Yvette, France.
15. Institute of Physics, University of Stockholm, S-11346 Stockholm.
16. Department of Physics and Astronomy, University College London, London WC1E 6BT, UK.

Abstract

Production of vector charmed strange D_s^{*-} mesons in $\bar{\nu}_\mu N$ collisions is studied using the combined data of two bubble chamber experiments.

Radiative decays $D_s^* \to \gamma D_s(1970)$ of the vector charmed strange $D_s^*(2110)$ meson (previously called F^*) were first seen in e^+e^- collisions at DESY [1,2] and in $\bar{\nu}_\mu N$ collisions in the 15-ft Bubble Chamber at Fermilab [1,3]. In this paper we pursue the study of D_s^* production by antineutrinos at a higher statistical level.

The significant increase of $\bar{\nu}_\mu N$ statistics as compared to [1,3] is achieved by merging the 15-ft Bubble Chamber data [4] with data from BEBC [5]. The merge is facilitated by the similarity of data taking conditions in the two experiments : in both cases, big bubble chambers equipped with external muon identifiers and filled with heavy neon-hydrogen mixtures were irradiated by antineutrinos produced by 400 GeV protons. A detailed comparison of the data sets has confirmed the similarity of the two charged current samples. The combined sample consists of about 22700 charged current events in $\bar{\nu}_\mu$ visible energy (E_{vis}) range 10-200 GeV ($\langle E_{vis} \rangle$ = 35 GeV, muons with momentum over 4 GeV were selected with EMI).

To isolate the radiative $D_s^{*-} \to \gamma\, D_s^-$ signal, we adopt a "semi-inclusive" approach embracing all the $\phi\pi^- X$ decays of the D_s^- meson [1,3] and not just the popular $\phi\pi^-$ mode (we estimate that $B(\phi\pi^- X) / B(\phi\pi^-) > 8$ (*)). The simple underlying idea is that the internal motion (with respect to D_s^-) of the decay ($\phi\pi^-$) system is "frozen" because of its large mass. As a result, the decay gammas which are monoenergetic in the D_s^- frame (E'_γ = 145 MeV) are nearly monoenergetic in the ($\phi\pi^-$) frame : $E'_\gamma \sim E_\gamma$. Indeed, a Monte-Carlo simulation shows that the quantity E'_γ / E_γ peaks at unity with an average smearing of ~ 0.14 for typical decays $\phi\pi^-\pi^\circ$ and $\phi\pi^-(2\pi)$.

The hadron energy was corrected for undetected neutrals using the event transverse momentum balance. To study D_s^* production, events with W_H > 2.6 GeV are selected, where W_H stands for the reconstructed mass of the hadron system (**).

(*) The calculated value of $B(\phi\rho^-)/B(\phi\pi^-)$ is ~ 6.3[6], the measured value of $B(\phi\pi^-\pi^+\pi^-)/B(\phi\pi^-)$ is ~ 0.4[7]. Sizeable $\phi\pi^-\pi^\circ$ (non-resonant), $\phi\pi^-\pi^\circ\pi^\circ$ and $\phi\pi^-(3\pi)$ contributions might also be expected.

(**) The adoption of a W_H cut well under the actual D_s^* production threshold of ~ 3.05 GeV is motivated by the smearing effects.

For each charged current event, we form the $(K^+K^-)\pi^-$ combinations with mass under 2 GeV and with m(KK) in the interval 1010-1030 MeV (the calculated mass resolution is as good as 5 MeV in the $\phi(1020)$ region). The kaon mass is combinatorially assigned to the observed charged mesons for which the kaon hypothesis is acceptable. For each combination, we plot the energy E'_γ of the registered odd gammas in the $(K^+K^-)\pi^-$ rest frame (odd gammas are those not forming $\gamma\gamma$ pairs with mass in the interval 135 ± 20 MeV which is the Gaussian width of the observed π° signal).

Since in the decay $D_s^{*-} \to \gamma D_s^-$, $D_s^- \to \phi\pi^- X$, the system $(\phi\pi^-\gamma)$ is massive enough that it remains almost at rest in the D_s^* rest frame, the fraction of D_s^{*-} energy taken by the $(\phi\pi^-\gamma)$ subsystem is ~ $m(\phi\pi^-\gamma)/m(D_s^{*-})$. Therefore the quantity

$$z' = \frac{E(\phi\pi^-\gamma)}{E_\nu - E_\mu} \cdot \frac{m(D_s^{*-})}{m(\phi\pi^-\gamma)} \qquad (1)$$

is essentially the fractional energy of the D_s^{*-} as a whole.

Shown in Fig. 1a is the E'_γ distribution for the odd gammas, for the combinations with fractional energy $z' > 0.8$. An enhancement is seen around E'_γ = 150 MeV. Its width agrees well with that expected for the radiative $D_s^{*-} \to \gamma D_s^-$ signal : the calculated rms. deviation combining the "wrong-frame" smearing and gamma momentum measurement error is ~ 30 MeV.

To probe the background, we plot the analogous E'_γ using :
i) the ϕ wings instead of the ϕ central area, i.e. $(K^+K^-)\pi^-$ combinations with m(KK) in the range 1000-1010 MeV or 1030-1040 MeV (see Fig. 1b);
ii) "fake ϕ" combinations : $(K^-K^-)\pi^+$ with the same total charge as $(K^+K^-)\pi^-$ with m(KK) in the ϕ central area 1010-1030 MeV (Fig. 1c) as well as in the ϕ wings (Fig. 1d);
iii) paired (instead of odd) gammas for both ϕ central (Fig. 1e) and sideband (Fig. 1f) areas.

None of these plots displays anything like the bump around 150 MeV seen in Fig. 1a.

To check the use of these plots to estimate the background, we simulated them using live events but "fake" gammas. The $(KK)\pi$ system was selected as described before; each of the remaining charged pions was then taken as a neutral pion and allowed to decay randomly into two gammas (5 times to increase statistics). The distributions thus obtained were very similar to each other, as well as to the distributions shown in Fig. 1b-d. This confirms that the shape of the background in Fig. 1a is adequately reproduced by the sum of the "live" background plots in Fig. 1b-d.

The sum of these last three distributions [E'_γ plots for $(K^+K^-)_W\pi^-$, $(K^-K^-)_\phi\pi^+$, and $(K^-K^-)_W\pi^+$, where the subscript "ϕ" stands for the ϕ central mass area, "W" for the wings)] is normalised to the E'_γ distribution in the $(K^+K^-)_\phi\pi^-$ plot over the interval $0 < E'_\gamma < 1000$ MeV with the bump region $100 < E'_\gamma < 200$ MeV excluded. The background subtraction(*) performed separately for three z′ bins (0.4-0.6, 0.6-0.8, and over 0.8) yields the z′ dependence of the enhancement, shown in Fig. 2 (excess per bin). The effect is seen only in the high-z area ($z > 0.8$), where the excess amounts to (24.9 ± 7.0) events. With due account taken of the $\phi \to K^+K^-$ branching fraction and relevant registration efficiencies, this translates into D_s^* production rate times $D_s^- \to \phi\pi^- X$ branching relative to all charged current events of

$$\frac{N(D_s^{*-} \to \gamma D_s^-,\ D_s^- \to \phi\pi^- X)}{N(CC)} = (4.3 \pm 1.2)*10^{-3} \qquad (2)$$

Since the $D_s^- \to \phi\pi^-$ branching fraction is ~ 0.04 [8] and, according to our estimate, $B(\phi\pi^- X) / B(\phi\pi^-) > 8$, this suggests D_s^{*-} production at a one percent level.

Comparison with neutrino-emulsion data [9] shows that the D_s^* mesons are produced at appreciably higher z values than the D^* mesons. This strongly suggests a different production mechanism, such as vector meson dominance as indeed predicted back in 1975 by Arbusov, Gerstein and Folomeshkin [10]. The fact that the bulk of the signal lies under

(*) In the bump region $100 < E'_\gamma < 200$ MeV, one must count the contributing gammas rather than just the entries. In the bump region of the $(K^+K^-)_\phi\pi^-$ plot with $z' > 0.8$ (see Fig. 1a), there are 50 entries but only 39 contributing odd gammas.

$Q^2 = 4\ GeV^2$ ($\simeq$ mass squared of the D_s^*), as shown in Fig. 2, is compatible with this assumption.

Acknowledgements.

We are indebted to our colleagues at Fermilab and Michigan University for their contribution to the E180 experiment.

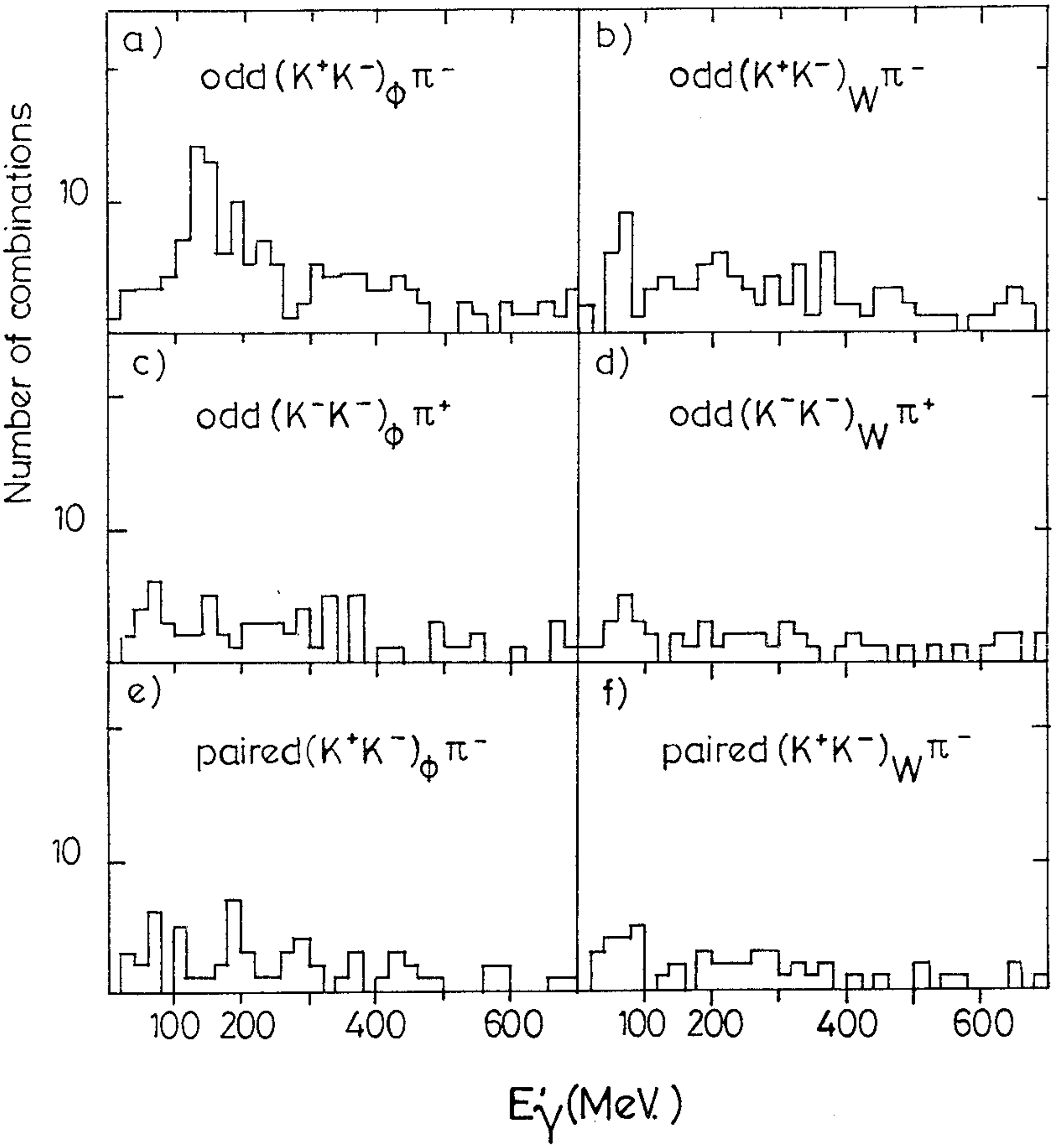
References.

1. A. Silverman, rapporteur talk, XXII International Conference on High Energy Physics (Leipzig 1984).
2. H. Albrecht et al., Phys. Lett. 146B, 25 (1984).
3. A.E. Asratyan et al., Phys. Lett. 156B, 441 (1985).
4. P.A. Goritchev et al., Yad. Fiz. 39, 626 (1984).
5. W. Wittek et al., Z. Phys. C40, 231 (1988).
6. M. Bauer, B. Stech, and M. Wirbel, Z. Phys. C34, 103 (1987).
7. J.C. Anjos et al., Phys. Rev. Lett. 60, 897 (1988).
8. A. Chen et al., Phys. Rev. Lett. 51, 634 (1983).
9. N. Ushida et al., Phys. Lett. 121B, 292 (1983).
10. B.A. Arbuzov et al., Yad. Fiz. 21, 1322 (1975).

Figure captions.

Fig. 1 : energy of the odd gammas E'_γ for the $(K^+K^-)\pi^-$ combinations with m(KK) in the ϕ central area (a) and in the ϕ wings (b); for the $(K^-K^-)\pi^+$ combinations with m(KK) in the ϕ central area (c) and in the ϕ wings (d); paired gammas for the $(K^+K^-)\pi^-$ combinations with m(KK) in the ϕ central area (e) and in the ϕ wings (f). All the plots are for $z' > 0.8$.

Fig. 2 : z' dependence of the signal for : (a) all Q^2 (full circles), (b) $Q^2 < 4$ GeV^2 (open circles).



Number of combinations
a)
odd $(K^+K^-)_\phi\pi^-$
b)
odd $(K^+K^-)_W\pi^-$
c)
odd $(K^-K^-)_\phi\pi^+$
d)
odd $(K^-K^-)_W\pi^+$
e)
paired $(K^+K^-)_\phi\pi^-$
f)
paired $(K^+K^-)_W\pi^-$
10
10
10
100 200 400 600
100 200 400 600
E'_γ(MeV.)

Fig. 1

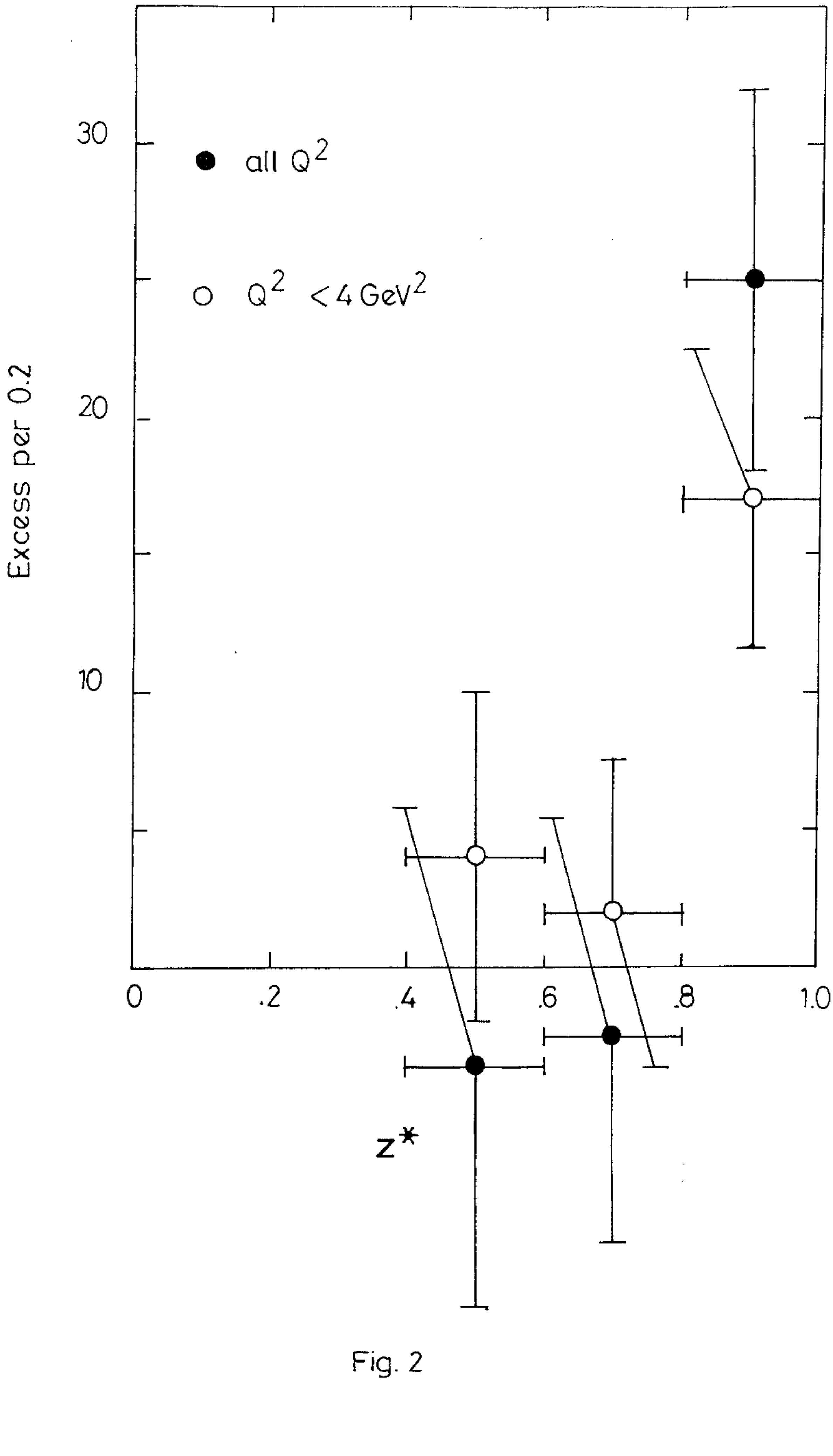


Fig. 2