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M. Ambrosio(x), G. Barbarino(x), G. Barbiellini, A. Barletta, C. Bemporad(o), R. Biancastelli(+), G. Brosco(o), M. Calvetti(o), M. Castellano(x), F. Costantini(o)(^), G. R. Giannini(o), P. Lariccia(o), G. Paternoster(x), S. Patricelli(x), L. Tortora(x) and U. Troya(x): EVIDENCE FOR A RESONANT STRUCTURE OF THE HADRON PRODUCTION FROM e^+e^- ANNIHILATIONS IN THE 1700--1950 C. M. ENERGY REGION.

ABSTRACT: We present experimental evidence for a resonant behaviour of the hadron production from e^+e^- annihilations at the e^+e^- storage ring Adone. A Breit-Wigner fit to the enhancement present between 1800 and 1850 MeV gives the following parameters

$M = 1812^{+7}_{-13}$ MeV $\qquad \Gamma = 34^{+21}_{-15}$ MeV.

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A systematic study of the reaction

$$e^+e^- \longrightarrow \text{hadrons}$$

is under way at the e^+e^- storage ring Adone.

We report on results obtained by the "B$\bar{B}$ experiment" in the 1700-1950 MeV CM energy region during the period February-May 1977.

The experimental set-up, schematically shown in Fig. 1, is composed of four hodoscopes (from the interaction region outwards: HOD 1, 2, 3, 4) each made up of sixteen scintillation counter elements.

The system has a cylindrical symmetry around the interaction region of the e^+e^- beams and it covers a total solid angle for point like source of about $0.7 \times 4\pi$.

All counters respond linearly to the energy loss of the detected particle. The HOD 3 elements are large-thickness liquid scintillation counters (35g/ cm^2 and 0.8 R.L.); they effectively discriminate crossing particles from soft electromagnetic background by means of the calorimetric information (Γ_{FWHM}/E 20% at E = 100 MeV). Twelve of the 16 HOD 4 elements are separated from HOD 3 by 2.5 R.L. of iron-lead radiator.

Four cylindrical magnetostrictive wire chambers (4 gaps) track charged particles between HOD 1 and HOD 2.

A set of flash tube chambers, with tubes parallel to the e^+e^- beams and arranged into four double gaps, is placed in front and behind of HOD 4 and the lead radiator. The chamber system is interfaced by fiber optics to an automatic vidicon readout(1). The trigger logic allows the selection of several parallel and different trigger conditions to enable the data acquisition.

The pattern of the fired counters, their pulse height and time information, the information from the spark and flash tube chambers were all recorded on magnetic tape for each event.

The overall stability of the apparatus over long periods of time was checked by frequent calibrations by means of cosmic rays. The on-line computer made continous checks of all 207 photomultiplier H.V.'s and of the recorded time-of-flight (T.O.F.) and pulse height spectra.

All the data presented in this paper satisfy the following trigger conditions:

1) at least three charged tracks; a track is defined by elements of HOD 1, 2, 3 set in a row. The minimum energy for a pion track to trigger is $T \sim 60$ MeV.

2) A time coincidence between counter pulses and the transit of e^+e^- bunches (τ = 30 ns).

Cosmic rays are effectively rejected by a (T.O.F.) selection over a path length of about one metre. The average trigger rate was < 1/sec.

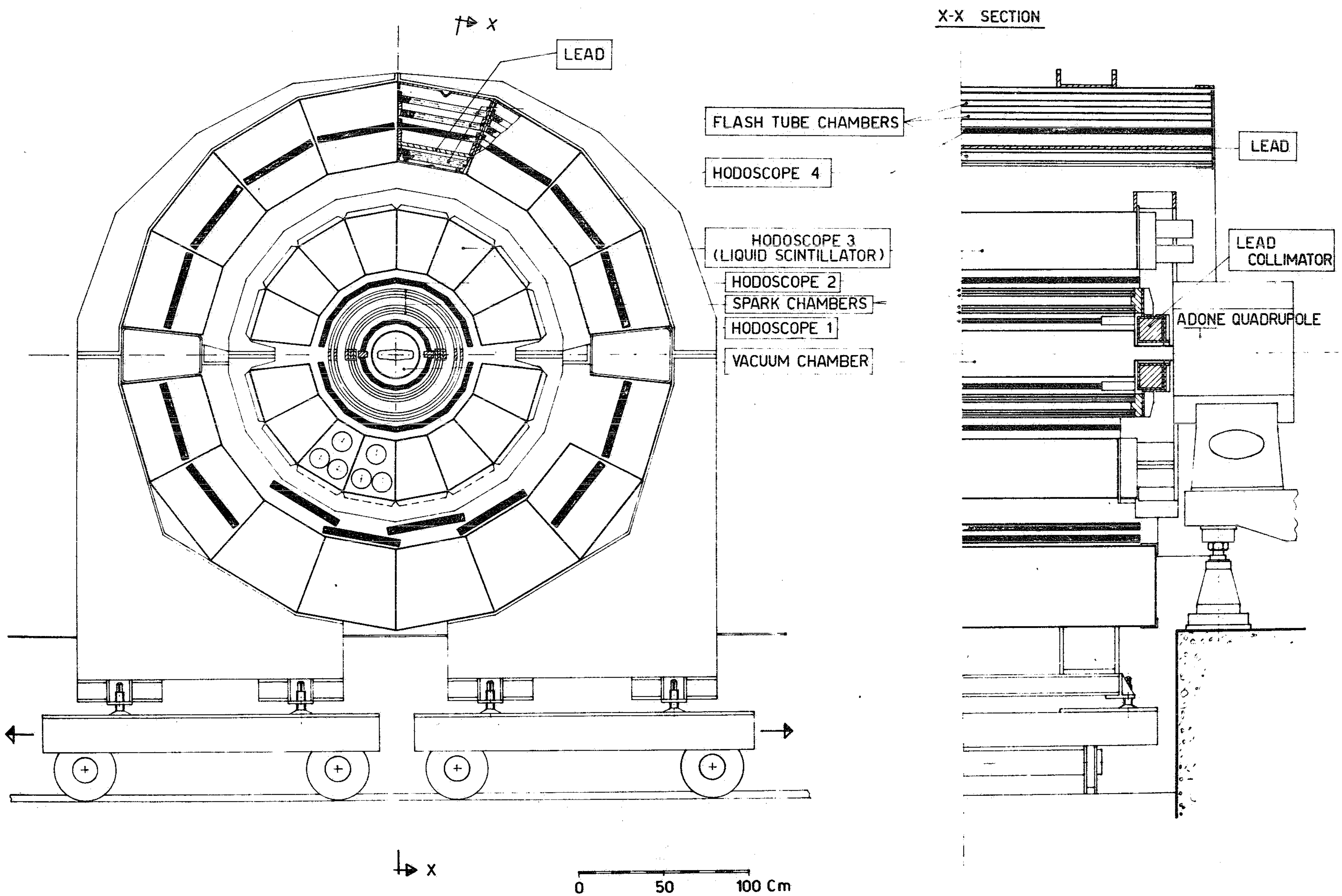


FIG. 1 - Experimental set-up

At least one fired HOD 4 element was requested off-line. The minimum energy for a pion to reach HOD 4 is T$\sim$200 MeV. The subsequent selection of hadronic events is based mainly on T. O. F. and energy loss information. The efficiency of the set-up under these conditions is of the order of 30% for a channel like $e^+ + e^- \longrightarrow 4\pi^\pm$ generated according to an invariant phase space.

The absolute luminosity of the machine was measured by the small-angle Bhabha scattering as detected by a luminosity monitor installed in the Adone straight section opposite to the one occupied by our experiment. The stability of the monitor was checked against the number of large angle e^+e^- scattering events in our apparatus and by a bremsstrahlung luminosity monitor installed close to our set-up and looking at our interaction region.

The CM energy spread of the machine is 1 MeV (FWHM) and the effective source length is 40 cm (FWHM) in the energy region explored by this experiment.

The data were collected over the period February-May 1977 by multiple CM energy scans. We obtained 700 events ($\geqslant$3 C) over a total luminosity of 70 nb^{-1} .

Small contaminations due to cosmic rays and to machine background are present in the sample ($\sim$15%). They were studied by Adone runs with separated beams and by cosmic ray measurements during the Adone beam-off time.

The rate of ($\gtrsim$3 C) events after background subtraction is presented in Table I and is shown in Fig. 2a as a function of the CM energy. The experimental points are drawn at the energy values where the Adone luminosity was truly collected; no grouping of data close in CM energy was made.

TABLE I - Number of multihadron events with at least 3 charged tracks ($\gtrsim$3 C), divided by the integrated luminosity (rate), as a function of the CM energy W (MeV).

W	RATE	W	RATE
1750	11.1 $\pm$ 1.8	1830	10.4 $\pm$ 2
1770	11.7 $\pm$ 2	1835	12.7 $\pm$ 2.4
1790	12.1 $\pm$ 1.8	1840	11.7 $\pm$ 1.9
1795	9.2 $\pm$ 1.7	1850	7.6 $\pm$ 1.7
1800	7.5 $\pm$ 1.6	1870	6.7 $\pm$ 2.0
1805	5.9 $\pm$ 1.6	1880	7.5 $\pm$ 1.8
1810	6.9 $\pm$ 1.7	1900	7.2 $\pm$ 2
1815	6.7 $\pm$ 1.9	1950	7.6 $\pm$ 2.5
1820	11.1 $\pm$ 2.1	1970	4.85 $\pm$ 2.2
1825	9.0 + 1.5		

The same data are compared in Fig. 2b with the ones recently obtained, in the same channel, at the French e^+e^- storage ring DCI[7]. It is worth noting that the the DCI experimental apparatus has, like ours, a quasi-cylindrical symmetry around the e^+e^- beams and it covers a similar solid angle. The comparison is made after introducing a scale factor chosen arbitrary to take into account a possible difference between the detection efficiencies of the two experiments.

The scale for our and the DCI rates are on the left and the right hand--side of the figure.

The agreement between the two sets of data is fair at the high rate around 1750 MeV, at the low rate arond 1800 MeV and on the right of the sharp structure we noticed.

In order to test the statistical significance of the observed structure, we tried to fit all the experimental points by a straight line. The distribution of the data around the fitted constant value of 8. 7 ev/nb^{-1} gives χ^2/d. f. = = 27/18 corresponding to a confidence level C. L. =0. 09. The true level is indeed lower than this limit, since the correlation among the points carries additional information. We made the "one sample runs test"[2] to probe the randomness of the data around the average value of 8. 7 ev/nb^{-1}; this gave a C. L. well below 0. 025 for the occurrence of a fluctuation similar to that seen in Fig. 2a; therefore both the dispersion and the correlation of the experimental points make it very unlike that this effect be due to chance.

From the comparison of the average event rate at five energies between 1820 and 1840 (PEAK) and at all the other ten energies larger than 1795 MeV (BACKGROUND), we get

$$\text{PEAK} = 10.4 \pm 0.8 \ \text{ev/nb}^{-1}$$

$$\text{SIGNAL} = 3.6 \pm 1.0 \ \text{ev/nb}^{-1}$$

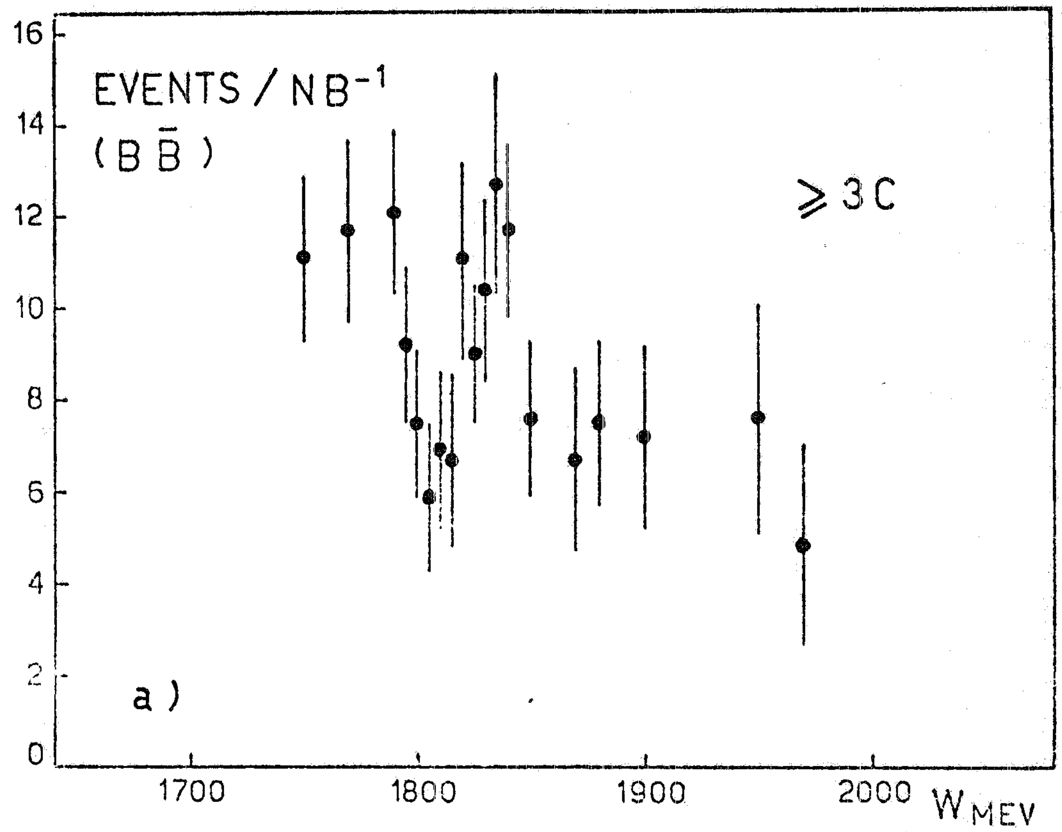
$$\text{BACKGROUND} = 6.8 \pm 0.6 \ \text{ev/nb}^{-1}$$

The existence of a new structure in the energy ragion we studied is demonstrated within 3. 6/1. 0 standard deviations(*) corresponding to a confidence level C. L. = 4 10^{-4}.

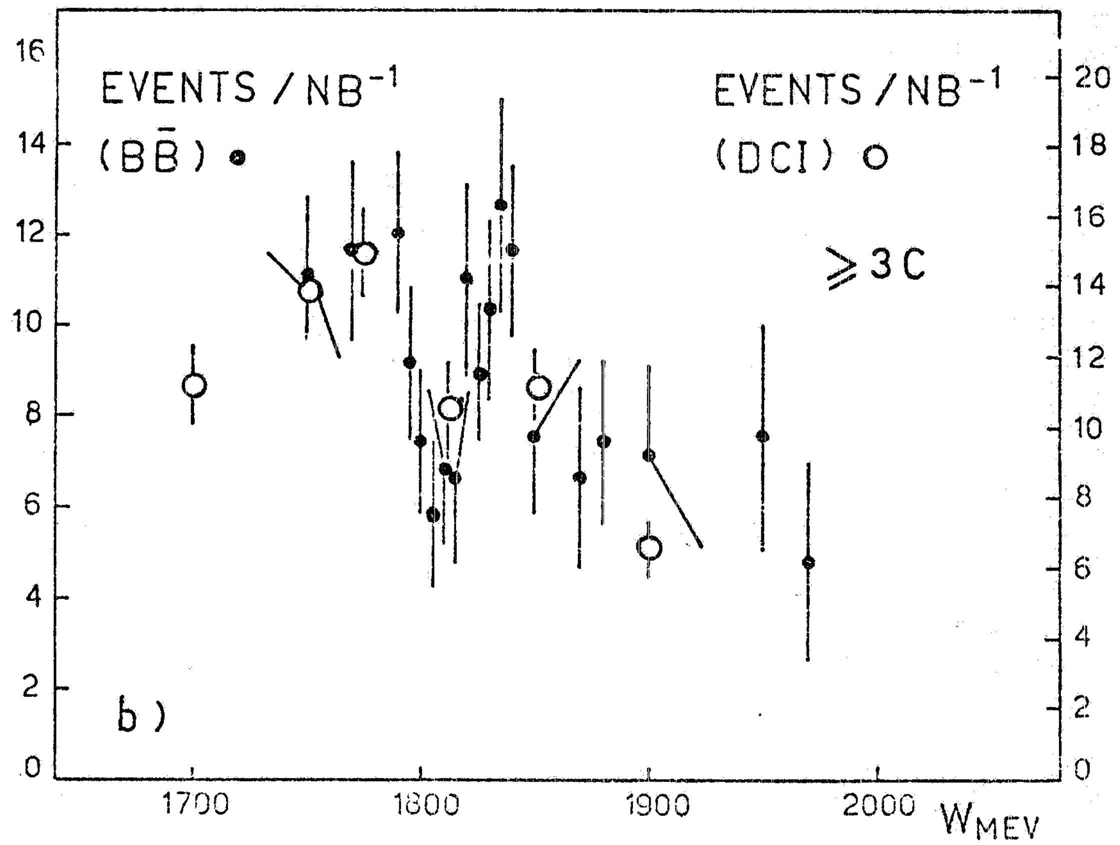
The observed enhancement is a candidate for one of the known vector meson recurrences which, by extended vector dominance[3] and symmetry schemes, should be located in the energy interval explored by this experiment.

A first χ^2 fit using a straight line and two Breit -Wigner and a second fit using a straight line, two Breit- Wigner and their mutual interference are shown in Fig. 2c, d; they gave the parameters presented in Table II.

(*) If expressed in terms of the fluctuations of the "BACKGROUND" contribution alone, this corresponds 6 "BACKGROUND" standard deviations.



EVENTS / NB^{-1}
(B $\bar{B}$)
≥ 3C
a)
16
14
12
10
8
6
4
2
0
1700
1800
1900
2000
W$_{MEV}$



EVENTS / NB^{-1}
(B $\bar{B}$)
EVENTS / NB^{-1}
(DCI)
≥ 3C
b)
16
14
12
10
8
6
4
2
0
20
18
16
14
12
10
8
6
4
2
0
1700
1800
1900
2000
W$_{MEV}$

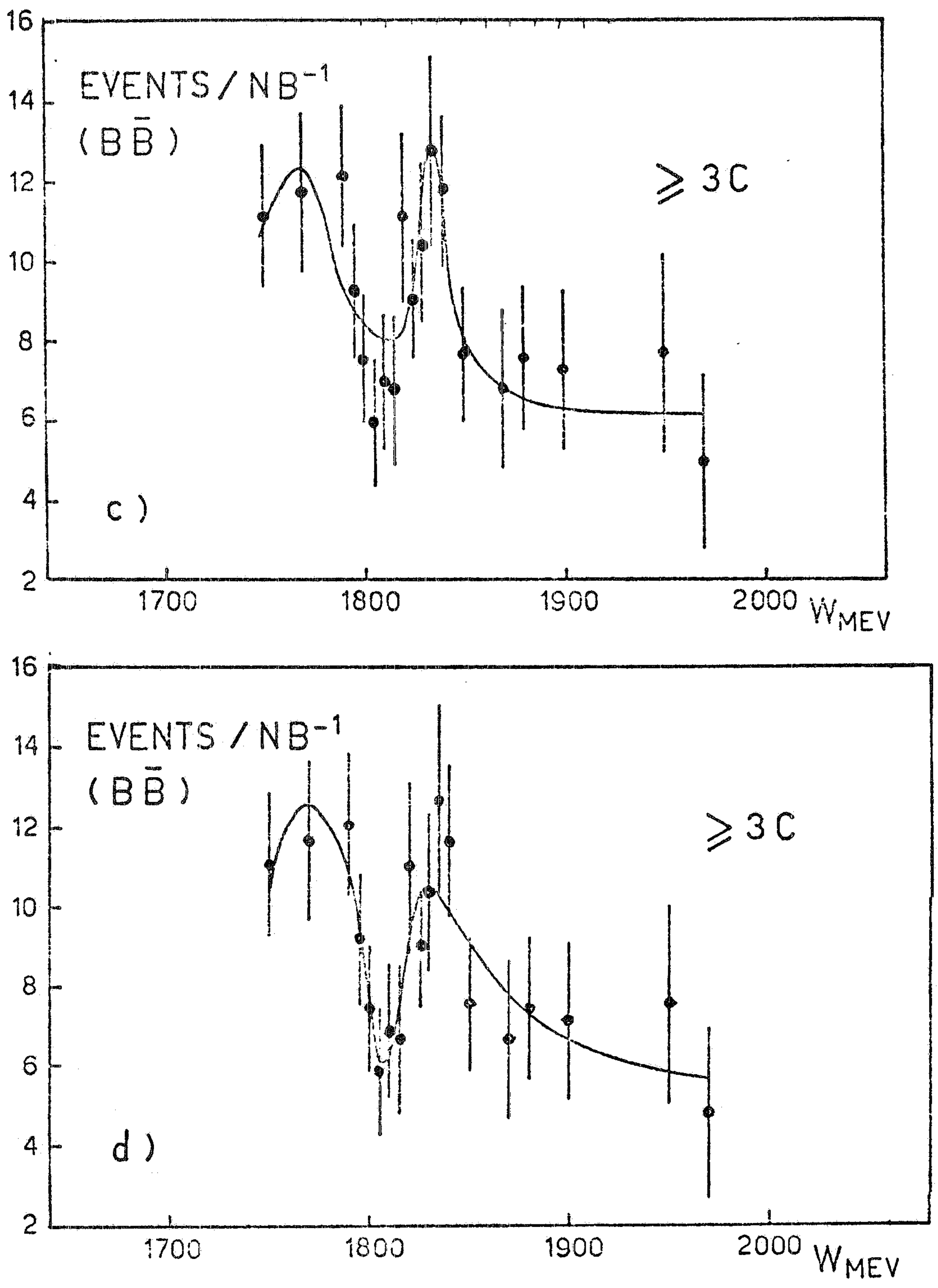


FIG. 2 - Number of multihadron events with at least 3 charged tracks ($\geq$ 3 C), divided by the integrated luminosity (rate) as a function of the CM energy W.
a) rate as determined by our "B$\bar{B}$ experiment" ; b) comparison of the rates as determined by our "B$\bar{B}$ experiment" (left scale) and by the "DCI experiment" (right hand scale). The bars on the DCI data give the statistical errors ; c) our experimental data and a fit by a straight line and two Breit-Wigner ; d) our experimental data and a fit by a straight line, two Breit-Wigner and their interference term.

TABLE II - Values of the parameters obtained by the χ^2 fits and by using:
1) one straight line, two Breit-Wigner.
2) one straight line, two Breit-Wigner and their interference term. The quoted errors correspond to a χ^2 increment of one unit.

	(1)	(2)
M_1	1836^{+3}_{-3} MeV	1812^{+7}_{-13} MeV
Γ_1	13^{+3}_{-2} MeV	34^{+21}_{-15} MeV
M_2	1765^{+14}_{-38} MeV	1792^{+31}_{-14} MeV
Γ_2	47^{+25}_{-20} MeV	79^{+77}_{-29} MeV
χ^2/d. f.	8. 8/11	6. 1/9

The second fit was attempted because we wanted to consider the possibility that two nearby structures with one or more common decay channels might interfere with each other.

If true this would reproduce a situation evoking the one of $\varrho - \omega$ (4)(5) or $\phi - \omega$ (6) interference.

It is worth nothing that the position in mass of the new possible resonance is very much dependent on the interference term. Although the second set of parameters is preferred and the curve fits the dip at 1805 MeV better, the question about the existence of the interference term cannot be settled at the present stage.

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