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W.W. Ash, B. Bartoli, D. Bisello, D.C. Cheng, B. Coluzzi, E. Cuomo, B. Esposito, F. Felicetti, A. Marini, P. Monacelli, A. Mulachié, A. Nigro, M. Nigro, H. Ogren, L. Paoluzi, I. Peruzzi, L. Pescara, G. Piano Mortari, M. Piccolo, F. Ronga, E. Schiavuta, G. Schina, F. Sebastiani, V. Silvestrini, L. Trasatti, F. Vanoli and G.T. Zorn: EXPERIMENTAL STUDY OF THE NEW 3.1 GeV PARTICLE BY e^+e^- COLLISION AT ADONE.

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We present preliminary results of an investigation of electron-positron annihilation in the total C. M. energy range $\sqrt{s}$ = (3.09 - 3.112) GeV. The experiment was performed at ADONE, the Frascati e^+e^- storage ring.

Evidence for the production of the new particle of mass 3.1 GeV, first observed by the MIT group at Brookhaven[(1)], and by the Berkeley-SLAC group at SPEAR[(2)] has already been reported by the ADONE groups[(3)].

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The present letter concerns the study of the channels

(1) $e^+e^- \rightarrow e^+e^-$,

(2) $e^+e^- \rightarrow \mu^+\mu^-$,

(3) $e^+e^- \rightarrow$ many-hadrons .

A very narrow resonant behaviour of the cross section for these processes is confirmed. The total hadronic cross section integrated over energy is $\sigma_I = (4.7 \pm 1.6) \times 10^{-33}$ cm^2 GeV.

The MEA[4] experimental apparatus as shown in Fig. 1 consists of the following parts:

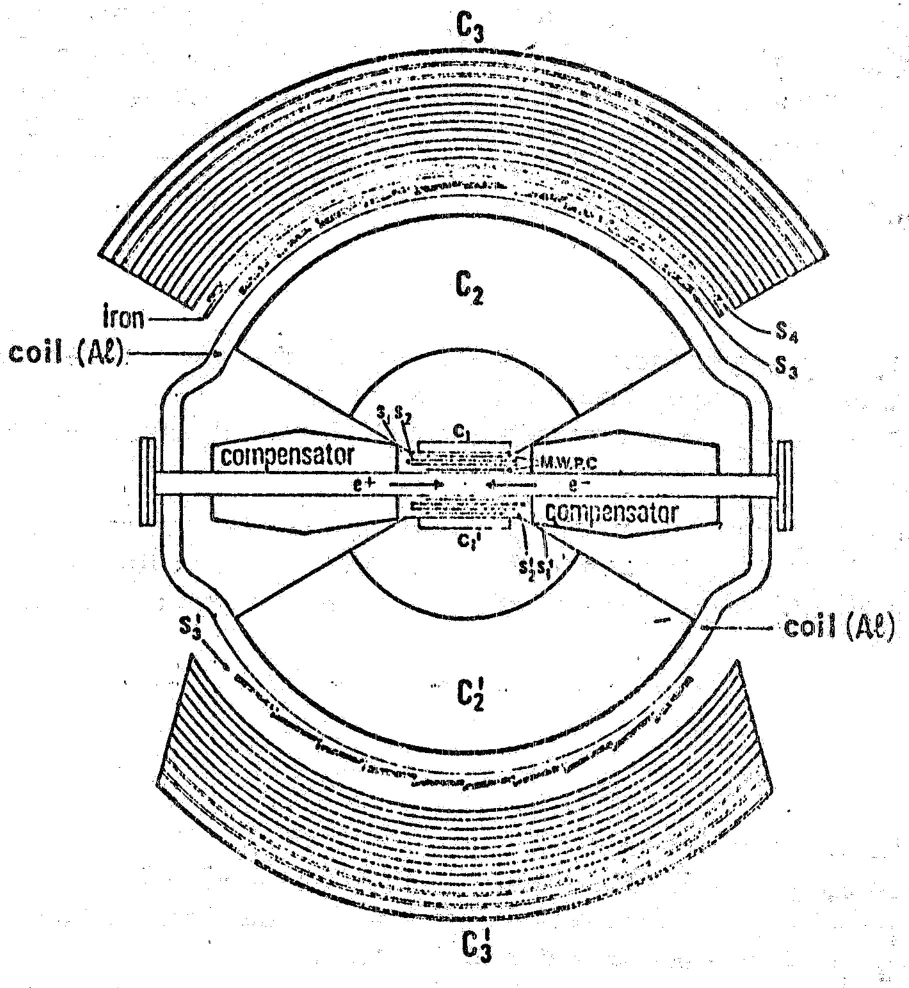

FIG. 1 - Vertical section of the experimental apparatus. C_1, C_1' are narrow gap spark chambers; C_2, C_2' are wide gap cylindrical spark chambers for momentum analysis; C_3, C_3' are thick plate spark chambers for particle identification; MWPC are multiwire proportional chambers; S_1 ... S_4 are scintillation counters.

a) A large (2 m diameter x 2 m length) solenoid with Aluminum coil mounted with its axis perpendicular to the direction of the e^+e^- beams. Two compensator magnets, covering about 50% of the beam path inside the solenoid, which reduce the magnetic field integrated along the beam path practically to zero.

b) Two 2-plane telescopes of multiwire proportional chambers (MWPC) above and below the beam path at the crossing region. These chambers have the sense wires parallel to the direction of the beams and are used both in the trigger and in the off-line geometrical reconstruction.

c) A system of optical spark chambers used for momentum analysis, which comprises two narrow gap and two cylindrical wide gap spark chambers coaxial with the solenoid, shown in Fig. 1 as C_1 and C_2 respectively. The electrodes of C_2 are made of wires in order to reduce multiple scattering and to allow viewing the sparks through the electrodes themselves. This allows to achieve complete stereo view of the tracks. As a matter of fact we use two cameras aligned with the axis of the solenoid and viewing the apparatus from opposite sides.

d) A system of 12 cylindrical thick plate narrow gap spark chambers C_3 for the detection of showers and nuclear interactions, mounted outside the magnet coil. Their total thickness is $\sim$ 6 radiation lengths and $\sim$ 1 collision length. The solid angle covered by the apparatus for point-like source is $\Delta\Omega_c \simeq 0.4 \times 4\pi\,(40^\circ \leq \theta \leq 140^\circ)$ for momentum analysis, and $\Delta\Omega_N \simeq 0.27 \times 4\pi$ for particle identification (as defined by chambers C_3, C_3'). The effect of the extended source is to lower $\Delta\Omega_c$ to about $0.09 \times 4\pi$ at $\sqrt{s} = 3.1$ GeV.

e) A scintillation counter system (S_1 to S_4) used to trigger the apparatus. In the trigger, we require at least one particle with a minimum kinetic energy of $\simeq$ 130 MeV (if pion) going in the upper part of the apparatus ($S_1 \cdot S_2 \cdot S_3 \cdot S_4$) and one particle with $\simeq$ 110 MeV going in the lower part ($S_1' \cdot S_2' \cdot S_3'$). For two prong events in order to reduce machine background some configurations (tracks with small dip angle) are rejected.

Cosmic rays are rejected by means of time of flight selection over a path length of one meter (S_1 to S_3), by requiring a suitable phase relative to the accelerator radio frequency (Δt_{RF}, see Fig. 2), and by requesting that the source-point lies within $\pm$ 5 cm from the beam line. This last rejection is achieved by making use of a fast logic signal from MWPC. The residual counting rate from cosmic rays is 1/15 min.

For each trigger an on line computer records on magnetic tape all relevant information. The selection of good events is made using both pictures and computer recorded information.

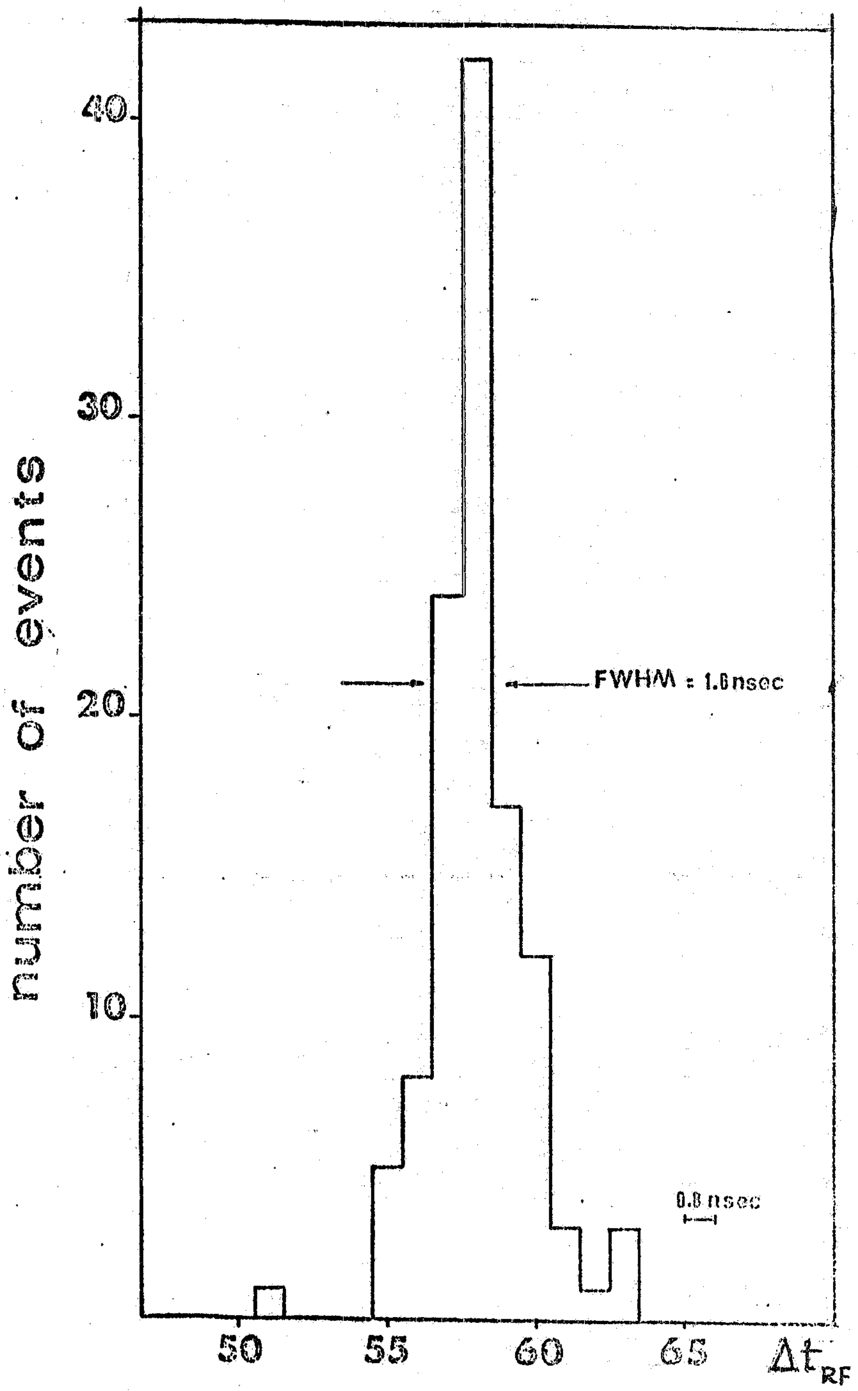

FIG. 2 - Time separation Δt_{RF} between the occurrence of the event and a timing signal from a beam pick up electrode.

Events from the reaction $e^+e^- \rightarrow \mu^+\mu^-$ are identified using the following criteria: i) proper position of the source point; ii) correct timing with the beam-beam interaction; iii) correct time of flight in both sides of the apparatus between counters $S_1 \cdot S_2$ and S_3 ($S'_1 \cdot S'_2$ and S'_3); iv) momentum measurement; v) absence of interactions in the thick plate chambers C_3 and C'_3. Cosmic ray contamination is negligible. A study of nuclear interactions in C_3 or C'_3 of colinear events sets an upper limit of 3% on the contamination of hadronic colinear events on μ-pair production events.

Events from the reaction $e^+e^- \rightarrow e^+e^-$ must satisfy criteria from i) to iii) and in addition must show electromagnetic showers in C_3 and C'_3.

Multihadron events are required to present two non colinear tracks or more than two tracks in the wide gap chambers (C_2, C'_2), at least one track in C_3 or C'_3, and to satisfy criteria i) and ii). γ-rays with energy $E \gtrsim 100$ MeV are also seen as showers in C_3, C'_3.

The experimental results are summarized in Table I. The integrated luminosity $\mathcal{L}$ has been obtained from the measured rate of small-angle Bhabha scattering observed by the ADONE machine group in a different interaction region with a monitor whose calibration constant was obtained by comparing its rate outside the resonance with the rate of wide angle Bhabha scattering measured in our apparatus.

In columns 3 to 9 we present the total number of collected multihadron events according to their detected configurations (e.g., 2C = = two charged particles detected, $2C + \geq 1\gamma$ = two charged particles + + ≥ 1 gamma ray, ...). The corresponding numbers of colinear e^+e^- and $\mu^+\mu^-$ events are given in columns 11 and 12.

The rate for processes (1) and (2), integrated over the acceptance of the experimental apparatus are shown in Figs. 3 and 4 as functions of $\sqrt{s}$.

In order to evaluate the total multihadron cross-section, a detailed knowledge of the produced final states is needed. At present we use only the information available on the detected charged multiplicity as determined by charge recognition, and on the detected photon multiplicity. The complete momentum analysis is in progress. The average detected charged multiplicity turns out to be $\langle N_c \rangle = 3.3 \pm 0.2$. Furthermore we can set lower limits on the production of final states with at least six and eight charged pions. The ratio of the number of events with at least six (eight) charged pions to the total number of detected multihadron events is found to be $N_{\geq 6ch}/N_{tot} \geq 0.13 \pm 0.02$ ($N_{\geq 8ch}/N_{tot} \geq 0.02 \pm 0.01$).

We have evaluated with a Monte Carlo calculation the detection efficiency for a number of initial pion states (with different charged and

TABLE I

TOTAL NUMBER OF COLLECTED EVENTS.

$\sqrt{s}$ (GeV)	Integrated Luminosity $\times 10^{-33}$ (cm^{-2})	Multihadron Events								Colinear Events	
		N_{2C}	$N_{(2C+\geq 1\gamma)}$	N_{3C}	$N_{(3C+\geq 1\gamma)}$	N_{4C}	$N_{(4C+\geq 1\gamma)}$	N_{5C}	Total number of multihadrons	e^+e^-	$\mu^+\mu^-$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
3.09 - 3.112	(11.8 $\pm$ 1.2)	133	95	125	69	73	32	27	554	145	38

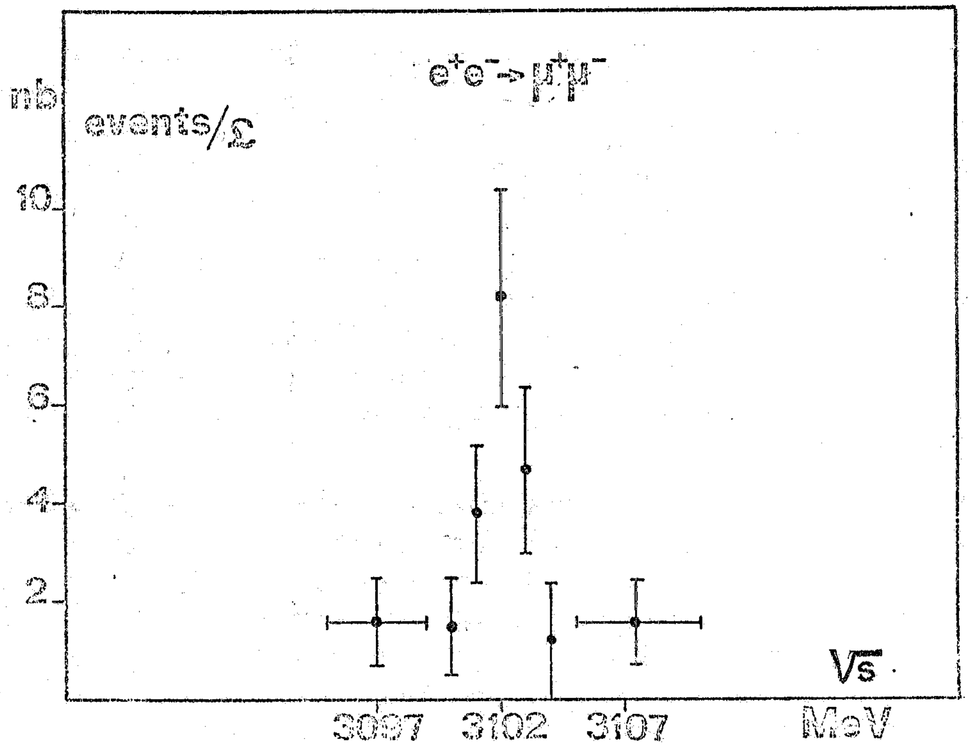

FIG. 3 - $e^+e^- \longrightarrow \mu^+\mu^-$ rate integrated over the acceptance of the experimental apparatus vs $\sqrt{s}$.

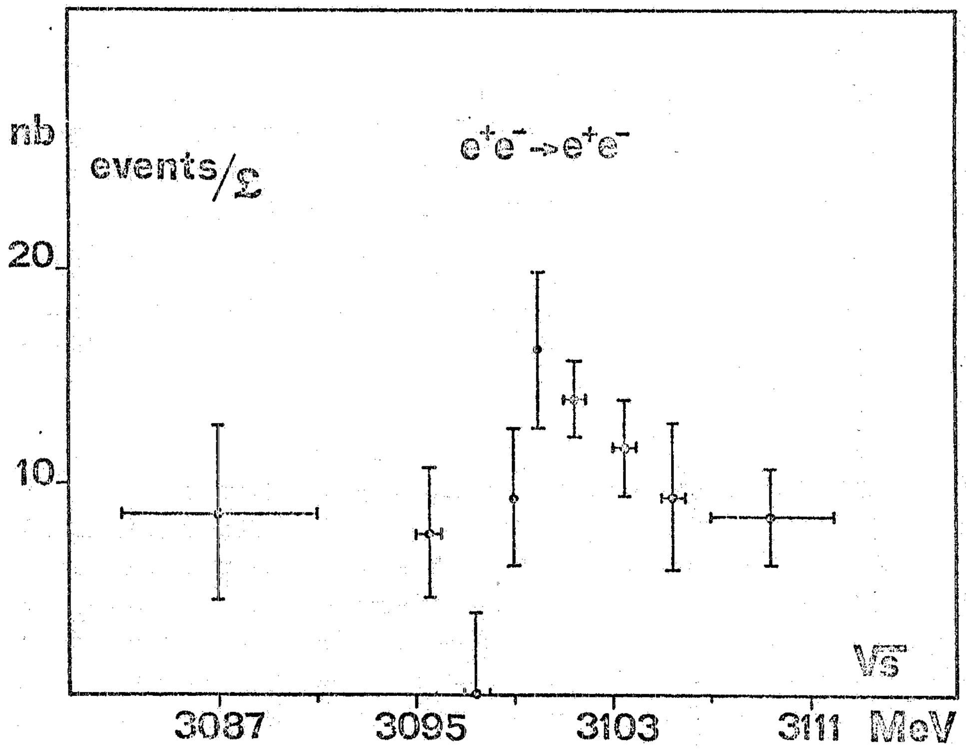

FIG. 4 - $e^+e^- \longrightarrow e^+e^-$ rate integrated over the acceptance of the experimental apparatus vs $\sqrt{s}$.

neutral multiplicities), leading to various observed configurations (i. e. 2C, 2C + $\geq 1\gamma$, 3C, 3C + $\geq 1\gamma$, ...). Phase space momentum distribution (P.S.) has been assumed. The trigger efficiencies are found to be in the range 0.06 - 0.12 for channels like $e^+e^- \to 2\pi^+2\pi^-$, $2\pi^+2\pi^-\pi^o$, $2\pi^+2\pi^-2\pi^o$, $2\pi^+2\pi^-3\pi^o$, $3\pi^+3\pi^-\pi^o$, $4\pi^+4\pi^-$.

The experimental ratio R_γ of the number of events with at least one photon detected to the total number of multihadron events is found to be $R_\gamma = 0.33 \pm 0.02$. This value of R_γ and the predictions of our MonteCarlo calculation indicate that the production of final states with one π^o is favoured with respect to final states in which two or more π^o's are produced.

The observed angular distribution for configurations in which three and four charged particles are detected is somewhat different from the one calculated with the Monte Carlo program. This suggests the existence of correlation effects among the produced particles. In spite of this moderate inconsistency, we have deduced from our P.S. Monte Carlo calculation an average detection efficiency $\epsilon = 0.09 \pm 0.03$ for multihadron events. In Fig. 5 the $e^+e^- \to$ multihadron rate integrated over the acceptance of the experimental apparatus is plotted vs $\sqrt{s}$.

The mass resolution is determined by the energy spread of the beams. In Adone, at $\sqrt{s} \simeq 3.1$ GeV, this spread is $\Gamma_{2E} = 3$ MeV (FWHM)[5].

The total multihadron cross section σ_H (Fig. 6) integrated over the energy interval $\sqrt{s} = 3.099 - 3.107$ GeV is found to be $\sigma_I = (4.7 \pm 1.6) \times 10^{-33}$ cm^2.GeV. The error quoted includes a 30% estimated uncertainty due to the detection efficiency calculation.

As far as the nature of this particle is concerned it is difficult, at present, to make any definite statement. In particular, a detailed study of the $e^+e^- \to \mu^+\mu^-$[6] channel may be relevant for the understanding of its properties.

We wish to thank the ADONE machine group for the excellent performance of the accelerator, which made this experiment possible. The help of both the OFTA group of G. Di Stefano and his coworkers and of the Mechanical Engineering group was unvaluable in the design and setting up of the apparatus. We also thank the Film Developing Service, Mrs. Morani from the Film Scanning Service, and all people from inside and outside the Laboratory who contributed to the success of this experiment.

We are grateful to G. Altarelli, C. Bernardini, N. Cabibbo, M. Greco, L. Maiani, G. Parisi and Y. Srivastava for many stimulating discussions and suggestions.

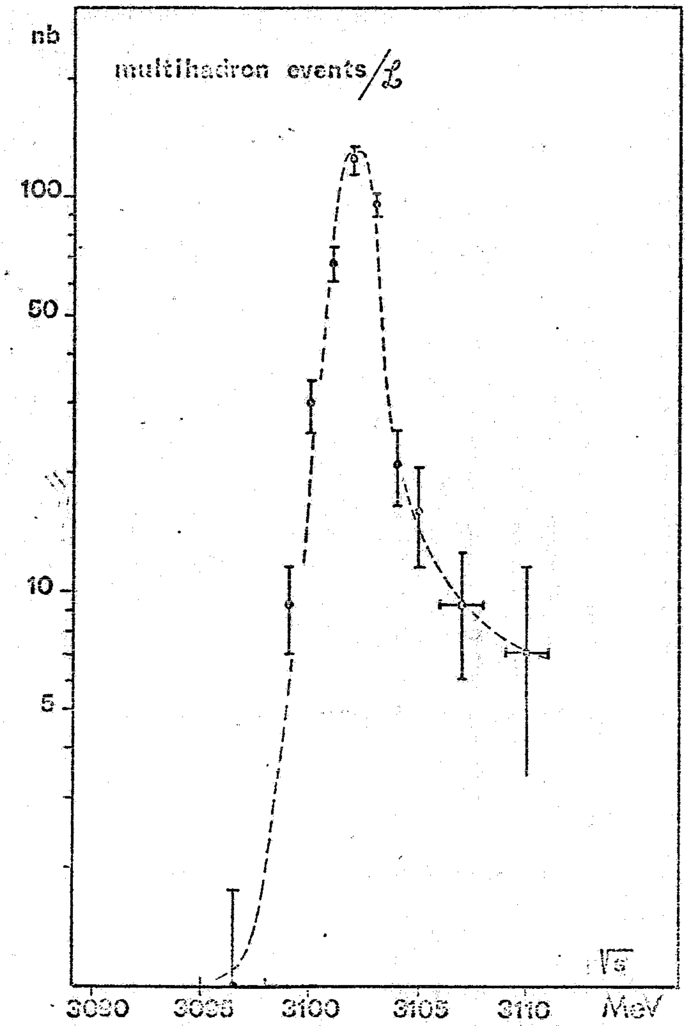

FIG. 5 - $e^+e^- \longrightarrow$ many-hadronsrate integrated over the acceptance of the experimental apparatus vs $\sqrt{s}$.

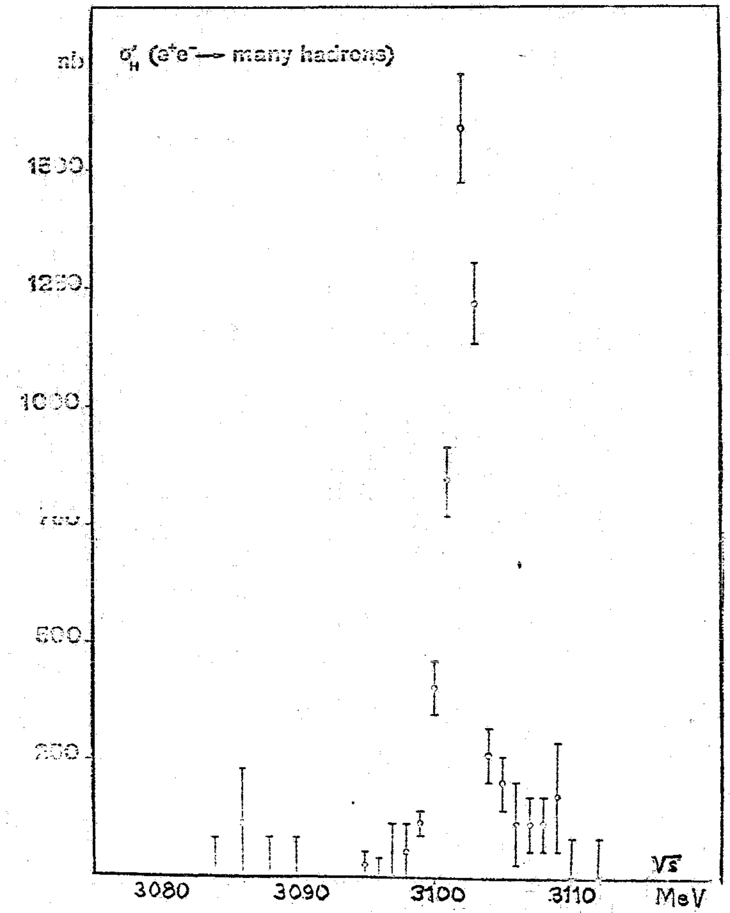

FIG. 6 - Total cross section $_H$ for the reaction $e^+e^- \longrightarrow$ many hadrons vs $\sqrt{s}$. The errors are statistical only.

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