Presented at the "XIX Intern. Conf. on High Energy Physics", Tokyo, August 1978.

ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-78/40(P)
25 Settembre 1978

G.P. Murtas: MULTIHADRON PRODUCTION IN e^+e^- INTERACTIONS AT ADONE.

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G. P. MURTAS: MULTIHADRON PRODUCTION IN $e^+ e^-$ INTERACTIONS AT ADONE.

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The results I will talk about were obtained by three different experimental set-up at Adone in the period from the end of 1976 and June 1978.

The $\gamma\gamma 2$ [(1)] apparatus, with cylindrical telescopes of scintillation counters, optical spark chambers with lead layers in between, covers a solid angle $\Delta\Omega = 0.65 \times 4\pi$ (Fig. 1).

In Febuary 78, thes set-up was modified, as described in the following, in order to increase $\Delta\Omega$ to the value of $0.9 \times 4\pi$.

The magnetic detector MEA [(2)], filled with optical wide-gap spark chambers, has a transversal magnetic field (B = 2.5 KGs), for a solid angle $\Delta\Omega = 0.4 \times 4\pi$ (Fig. 2).

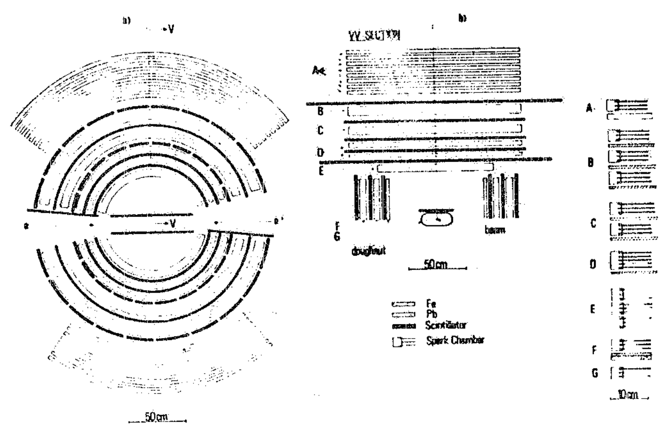

FIG. 1.

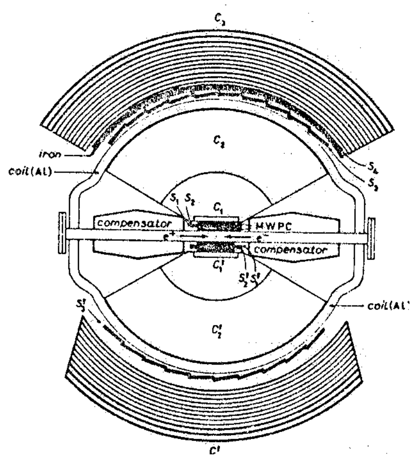

FIG. 2.

The Baryon-Antibaryon [3] set-up is a calorimeter, made of plastic and liquid scintillators, mounted longitudinally respect to the $e^+ e^-$ beam-line. The solid angle covered is $\Delta\Omega = 0.75 \times 4\pi$ (Fig. 3). The experimental set-up are described in detail in the Refs (1, 2, e 3). The people involved in these experiments are listed in Fig. 4.

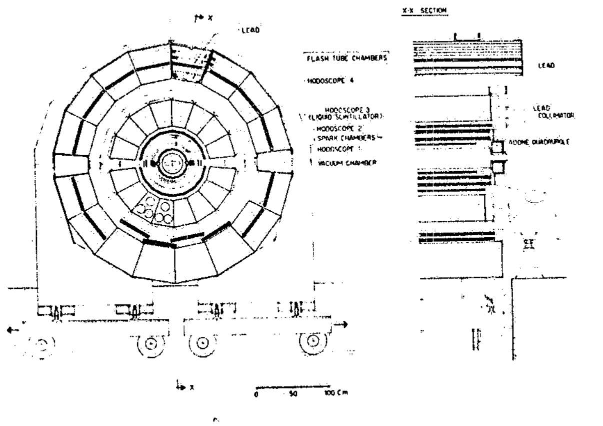

FIG. 3.

$\gamma\gamma$	MEA	$B\bar{B}$
FRASCATI-ROMA BOLOGNA	FRASCATI-MARYLAND NAPOLI-PADOVA-ROMA	FRASCATI-NAPOLI PISA-ROMA.
C BACCI	R. BERNABEI	M. AMBROSIO
R BALDINI	S. D'ANGELO	* G. BARBARINO
B BATTISTONI	B ESPOSITO	* G. BARBIELLINI
D BOLLINI	F FELICETTI	C. BEMPORAD
G CAPON	A MARINI	R. BIANCASTELLI
R DEL FABRO	P MONACELLI	G. BROSCO
G DE ZORZI	M MORICCA	M. CALVETTI
E IAROCCI	A NIGRO	* M. CASTELLANO
M MASSAI	M NIGRO	L. CERRITO
S MORIGGI	M PALLOTTA	F. COSTANTINI
G P MURTAS	L PAOLUZZI	G. GIANNINI
G PENSO	L PESCARA	F. LARICCIA
M SPINETTI	G PIANO MORTARI	G. PATERNOSTER
B STELLA	F RONGA	* S. PATRICELLI
L TRASATTI	R SANTONICO	L. TORTORA
	F SEBASTIANI	U. TROIA
	B SECCHI-ZORN	
	G.T. ZORN	

* ONLY DURING THE FIRST PART of the EXPERIMENT.

FIG. 4.

Search for Narrow Resonances.

A systematic search for narrow resonances in the mass interval 1.42-1.92 GeV has been performed with $\Delta W = 1$ MeV mass steps.

No evidence for narrow resonances was found, within the sensitivity of the present experiments.

Results for relative yields and for upper limits of $\Sigma = \int_{\Delta\omega} (\sigma - \sigma_{NR}) dw$ are given in Figs. 5, 6, σ being the cross-section in the mass interval $\Delta\omega$ and σ_{NR} the non resonant background as determined by looking outside the $\Delta\omega$ mass interval in a 25 MeV region.

$\Delta\omega$ is an energy interval of the same order of the machine spread. The total c. m. energy spread (FWHM) of Adone depends on the c. m. energy, according to the formula

$$\Gamma_\omega \text{ (MeV)} = 0.32 W^2 \text{ (GeV}^2\text{)}.$$

The maximum value for Σ obtained from $\gamma\gamma 2$ and MEA experiments is respectively 6% and 15% of the corresponding J/ψ value with 90% confidence level.

Previous results relative to 1.9 -3.1 energy interval are already published [4].

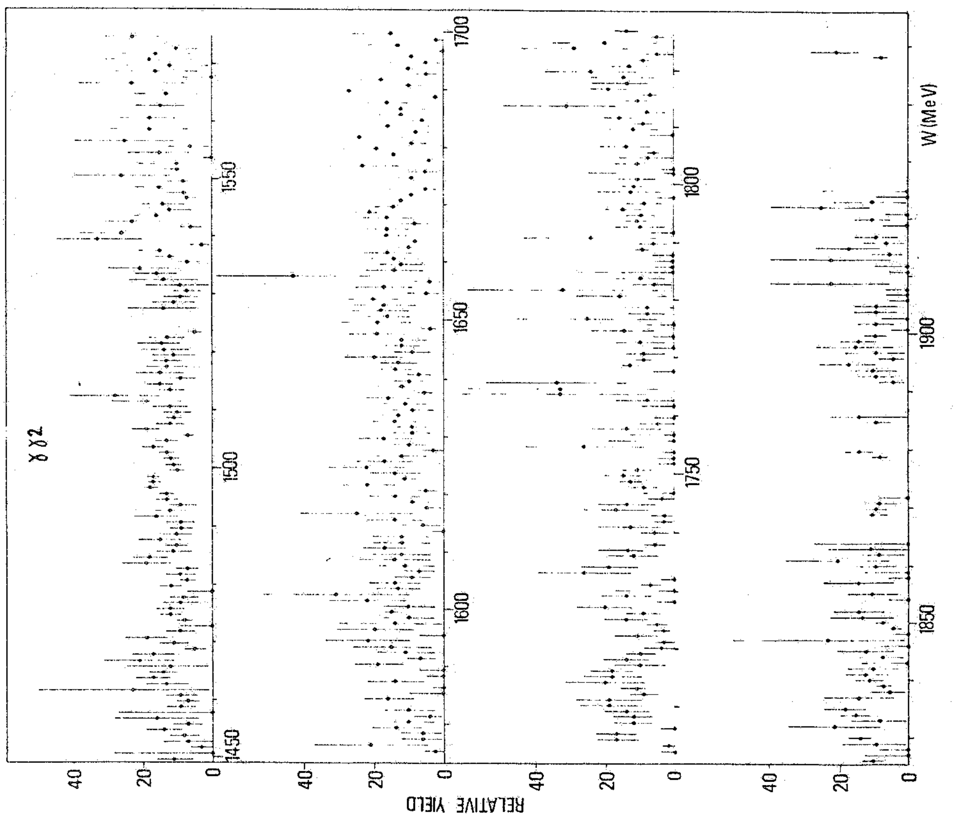

FIG. 5.

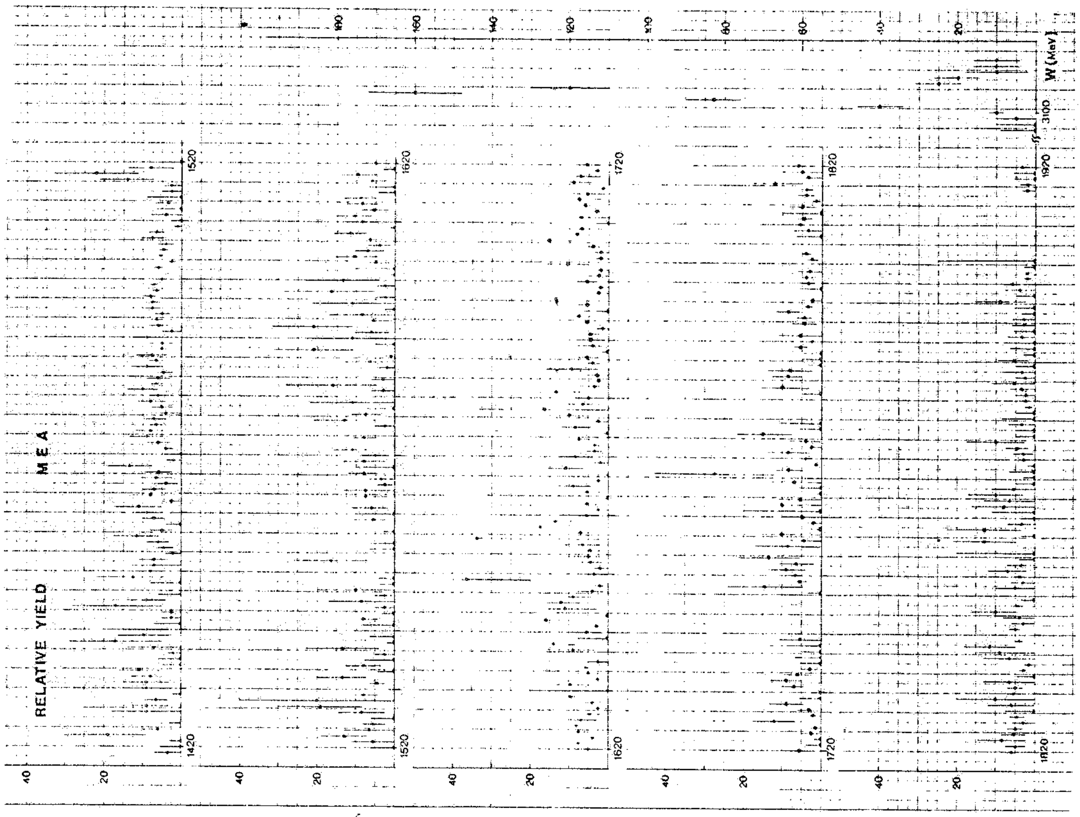

FIG. 6.

<u>1. 5 GeV region.</u>

Preliminary results for the energy region around 1. 5 GeV, were presented at the Hamburg Conference. [3]. These data seemed to show a narrow structure (Fig. 7).

Since then, new data have been taken at Adone in this energy region. The final results of the three groups concerning the multihadronic yield are shown in the Fig. 8.

Furthermore the $\gamma\gamma 2$ apparatus was modified in February 1978. A resistive tubes [5] core, around the interaction region, was added increasing the total solid angle to $\Delta\Omega = 0.9 \times 4\pi$ (for tracking) (Fig. 9).

Results obtained with the improved apparatus are shown in Fig. 10. Three energy values in the "hot" region were studied with high statistics, in order to understand the behaviour shown by the previous data (see arrows).

Such behaviour does not seem to be confirmed.

Nevertheless work is in progress to study correlations between data.

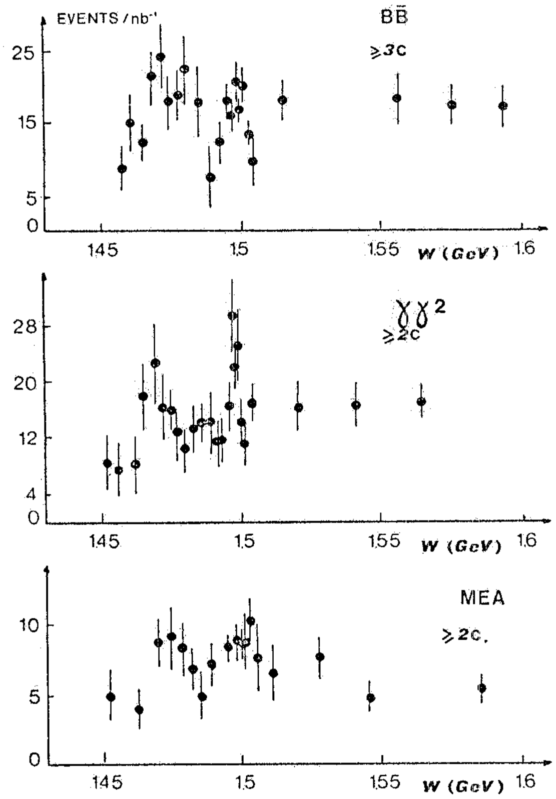

FIG. 7.

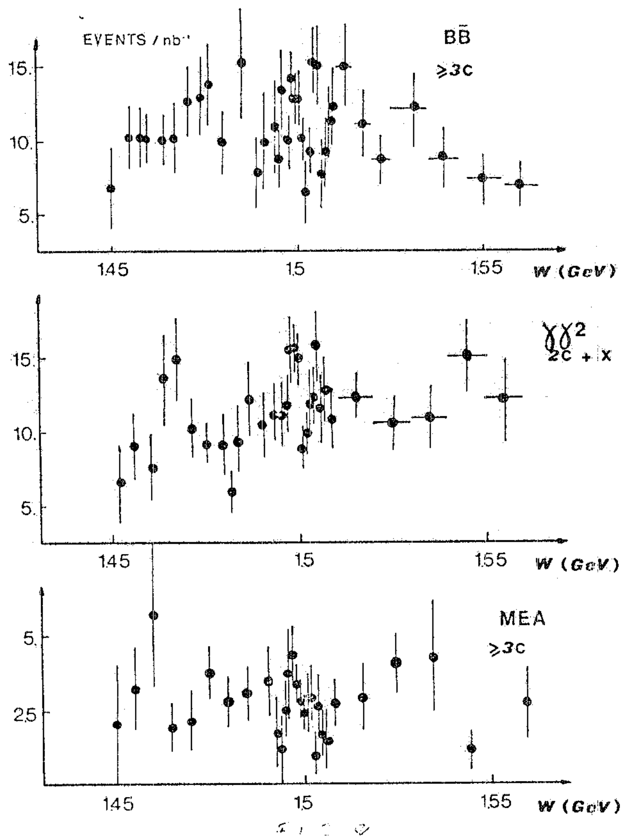

FIG. 8.

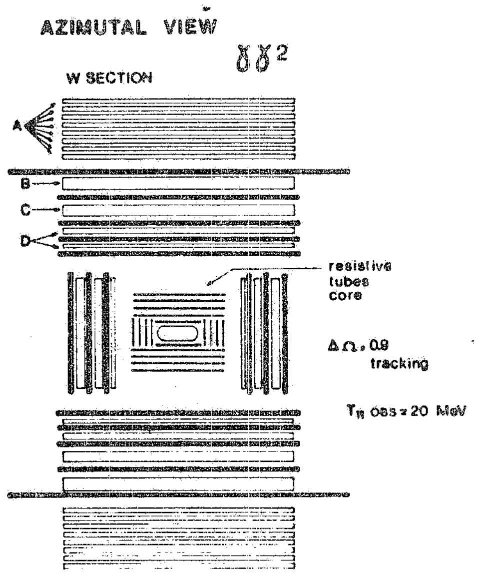

FIG. 9.

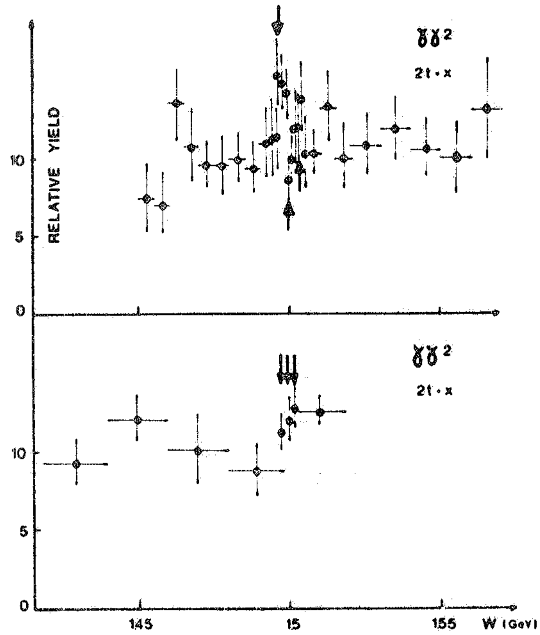

FIG. 10.

Cross sections and multiplicities.

The following assumpitions were made in order to calcultate the corss sections $\sigma[e^+ + e^- \rightarrow (n\,\pi^\pm, m\,\pi^o)]$ n, m number of charged and neutral pions:

1) All particles in the final states are π.
2) Invariant phase space momenta distribution.
3) Maximum multiplicity m + n = 6.
4) $\sigma\,(2\pi^\pm\,3\,\pi^o) = \frac{1}{2}\,\sigma\,(\,4\,\pi^\pm\,1\,\pi^o)$ is assumed from isospin considerations i. e. $\langle n\,\pi^\pm\rangle / \langle n\,\pi^o\rangle = 2$ for n + m odd.
5) Luminosity is measured by wide angle Bhabha scattering detected in the apparata.

Assumption 1) is reasonable and arguments in favour are the measured ratio: numbers of K/numbers of total particles, as measured in the MEA apparatus, Fig. 11, and the consistency checks on the penetration of the particles in the spark chambers of the $\gamma\gamma 2$ apparatus. The number of K's in the MEA apparatus is obtained from combined measurements of momentum and T. O. F., taking into account also the apparent range measurement, when available.

Assumption 2) is corroborated by Fig. 12, when the invariant $E(d^3N/dp^3)$ versus the energy E of the particles is reported, as measured in the MEA set-up in the total energy interval $1.4 < \sqrt{s} < 2.3$ GeV.

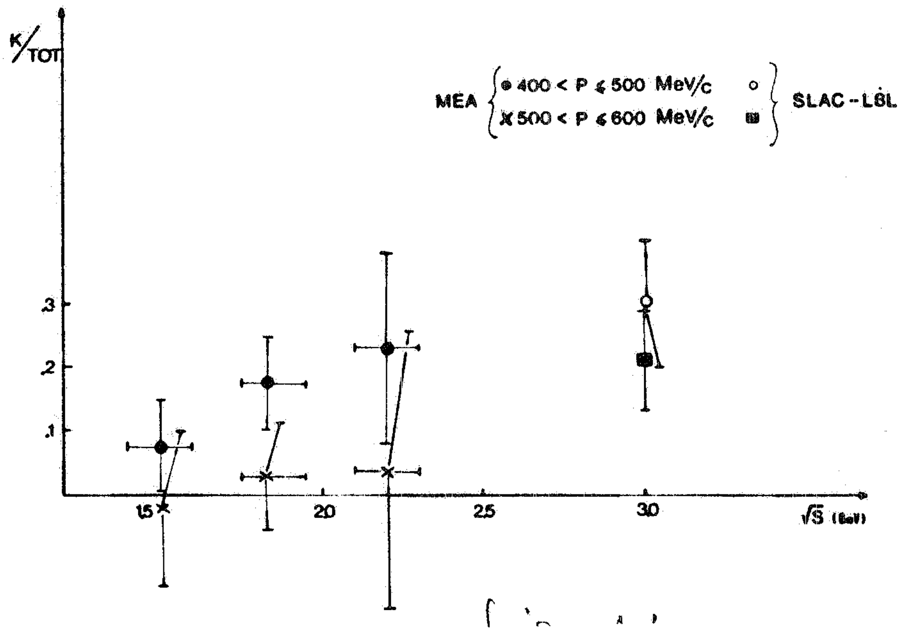

FIG. 11.

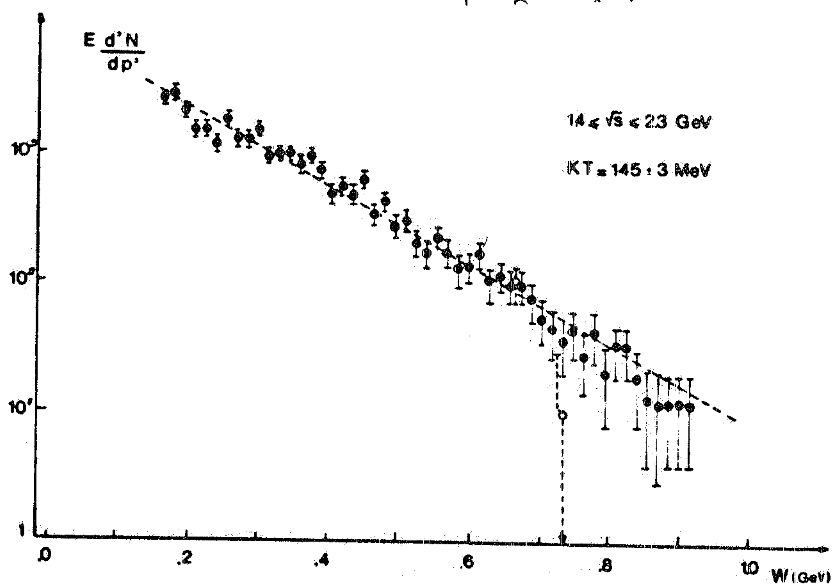

FIG. 12.

The data are well fitted by a thermodynamicae spectrum:

$$E \frac{d^3N}{dp^3} = A\, e^{-E/KT} \qquad \text{with } KT = 145 \pm 3 \text{ MeV.}$$

Similar data (6) were obtained by SLAC-LBL for $\sqrt{s} = 4.8$ GeV with KT = 190 MeV, and by DASP for $4.0 < \sqrt{s} < 5.2$ GeV with KT=185 MeV.

Fig. 13 shows the plots of (S/B) (dN/dx) versus the scaling variable $x = 2E/\sqrt{s}$ as measured by MEA in three energy intervals $1.4 \leq \sqrt{s} \leq 1.6$, $1.75 \leq \sqrt{s} \leq 1.95$, $2.1 \leq \sqrt{s} \leq 2.3$ GeV.

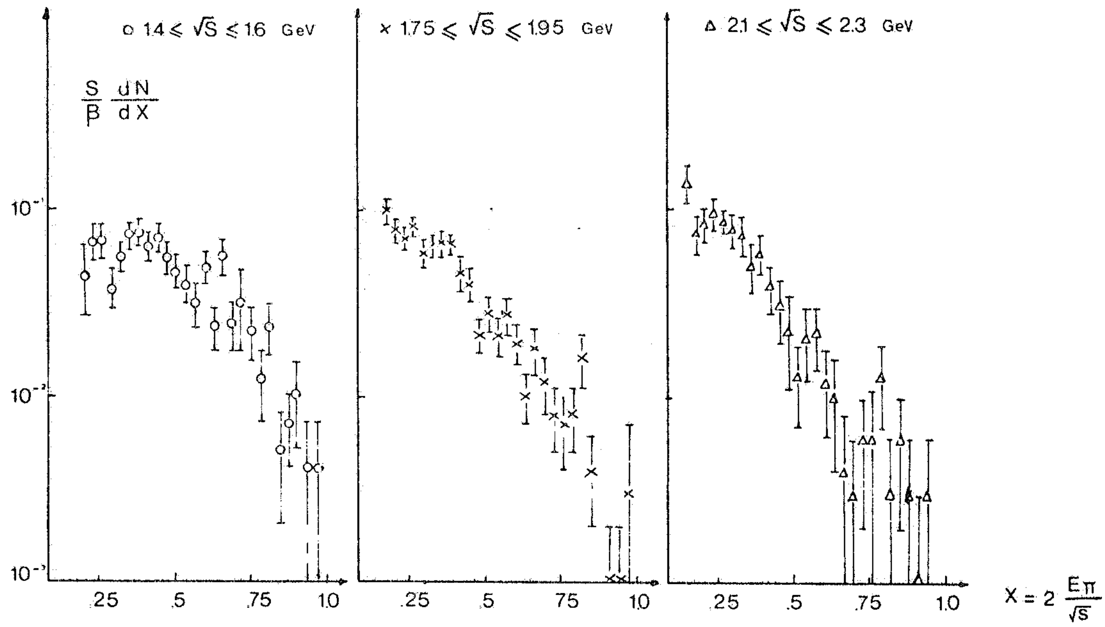

FIG. 13.

Fig. 14 shows the average number of hadrons obtained from $\gamma\gamma$ 2 and the similar $\sqrt{s}/\langle E_\pi \rangle$ values obtained from MEA, $\langle E_\pi \rangle$ being the average pion energy.

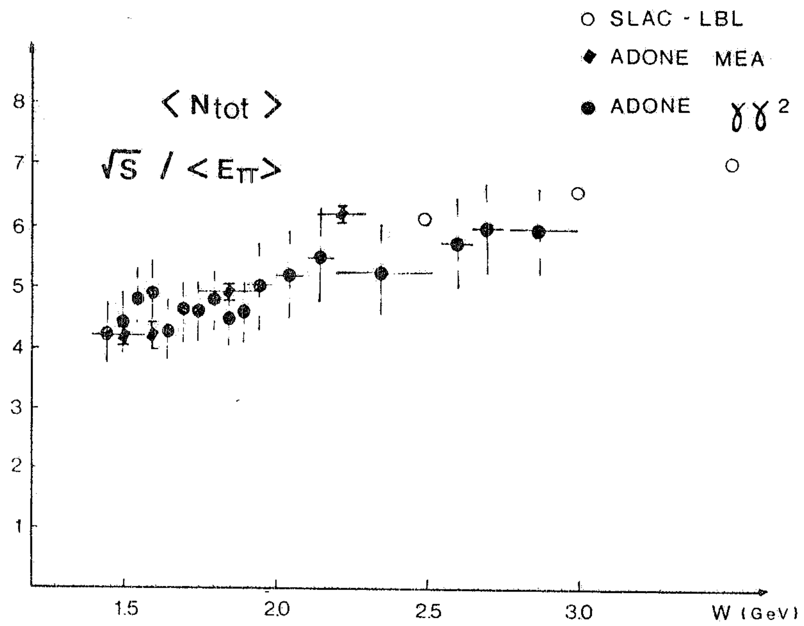

FIG. 14.

Fig. 15 shows charged and neutral multiplicities. Data obtained from SLAC-LBL [7] are also reported.

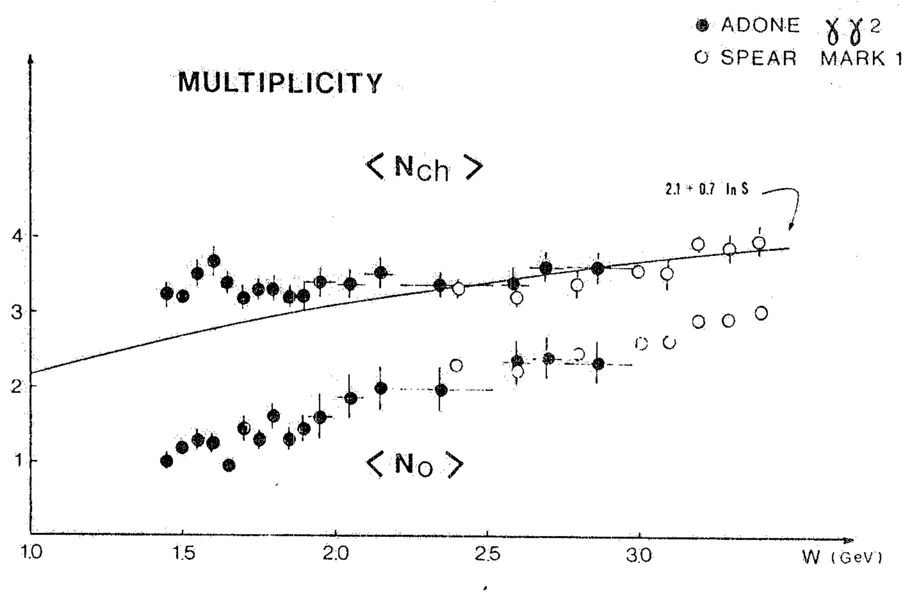

FIG. 15.

It is clear that the ratio <Nch>/<No> is rapidly increasing when the total energy W decreases (Fig. 16).

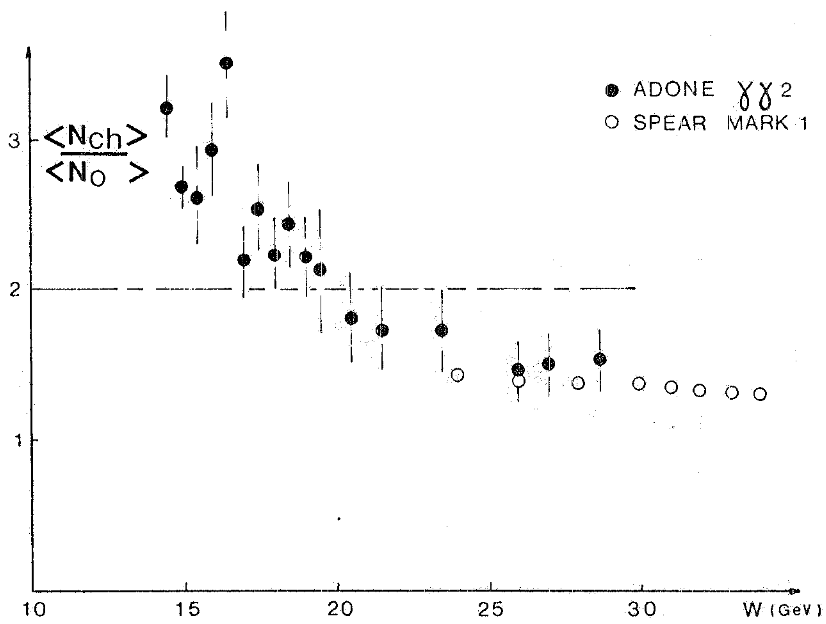

FIG. 16.

The energy behaviour of the ratio R= $\sigma_{tot}/\sigma_{\mu\mu}$ is shown in Fig. 17 for c. m. energies up to 3 GeV obtained by $\gamma\gamma 2$ and MEA Fig. 17 includes also results obtained by other Laboratories, in prticular results from Novosibirsk are mediated with the hypothesis that $\sigma(\pi^+\pi^-\pi^o) = 0$, $(4\pi^\pm \; n\pi^o) = 0$, as presented at Tblisi Conference [9]. Only statistical errors are reported, systematical uncertainties on $\gamma\gamma$ data are quoted to be of the order of ~20%.

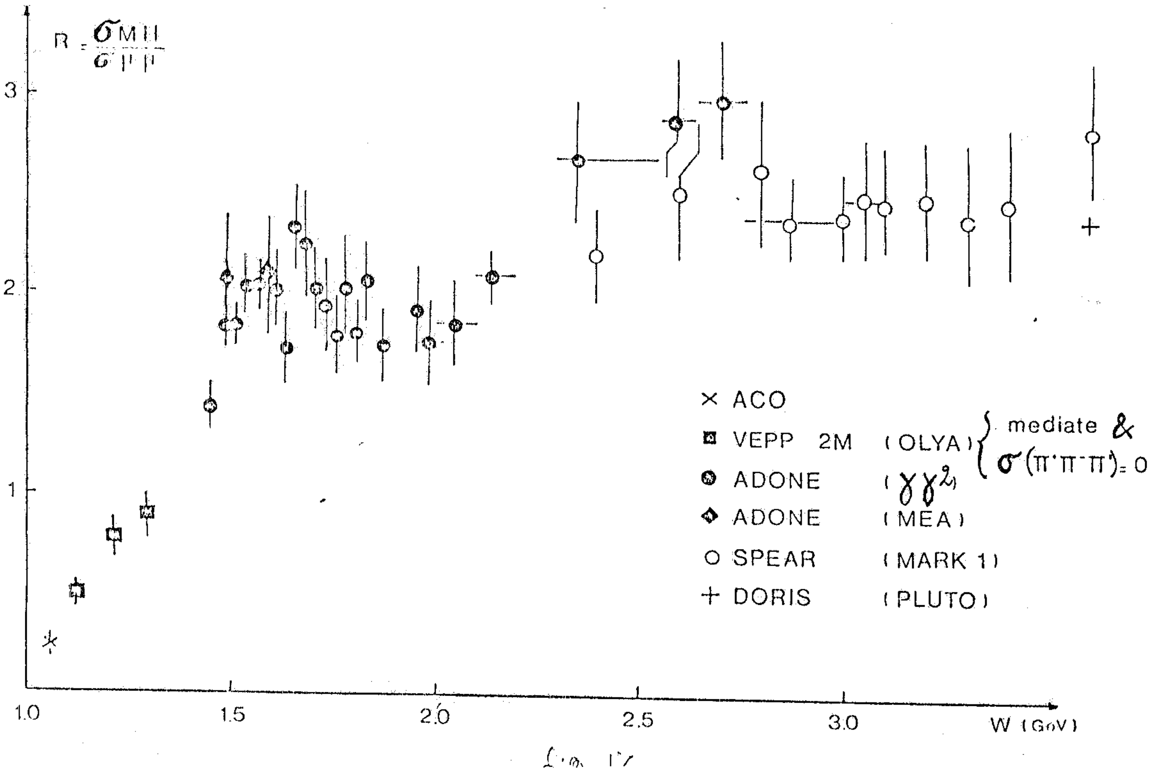

FIG. 17.

Final state with an even number of pions, G^+, are strongly preferred. Cross sections with odd number of pions, G^-, are about 1/10 of the corresponding value of G^+ states, as shown in Fig. 18 and are in a qualitiative agreement with SU_3 predictions.

The cross section $\sigma(e^+ e^- \to 4\pi^\pm)$ shows a large resonant behaviour if data of different experiments, ACO, OLIA, $\gamma\gamma 2$, MEA, MARK 1 are plotted together as show Fig. 19. A fit made with <u>ONLY ONE</u> Breit-wigner distribution:

$$\sigma = \frac{12\pi}{S} \frac{M_v^2 \; \Gamma_v \; \Gamma_{ee}}{(S - M_v^2)^2 + M_v^2 \Gamma^2} \quad , \quad \Gamma_v = k \frac{(s - M_o^2)^{3/2}}{\sqrt{s}} \quad ;$$

gives

$$M_V = 1649 \pm 23 \text{ MeV},$$
$$M_o = 890 \pm 20 \text{ MeV},$$
$$\Gamma_{ee} = 3.1 \pm .2 \text{ KeV},$$
$$K = .48\ 10^{-3} \pm .04\ 10^{-3},$$

the Γ_{FWHM} is = 500 ± 50 MeV.

These results are in rough agreement with previous results obtained in Adone [10].

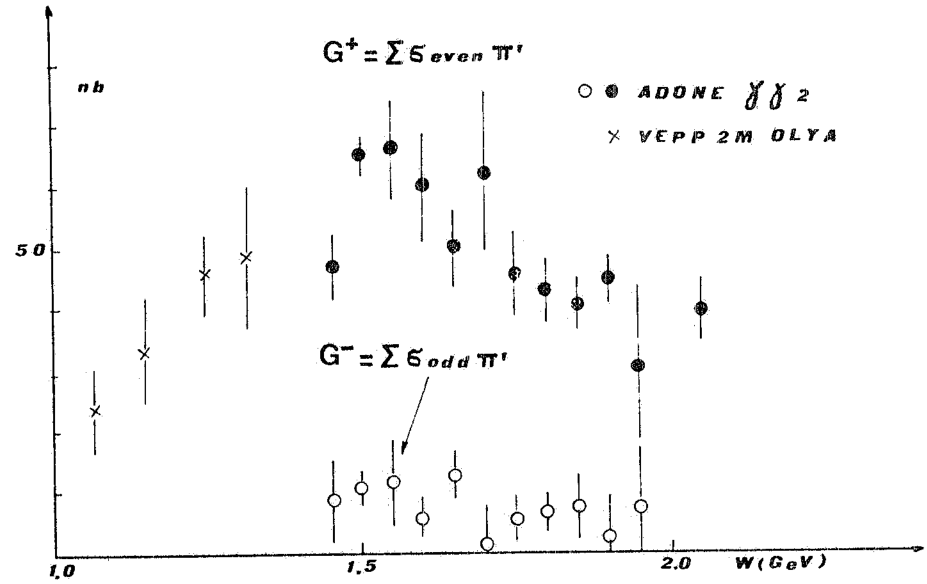

FIG. 18.

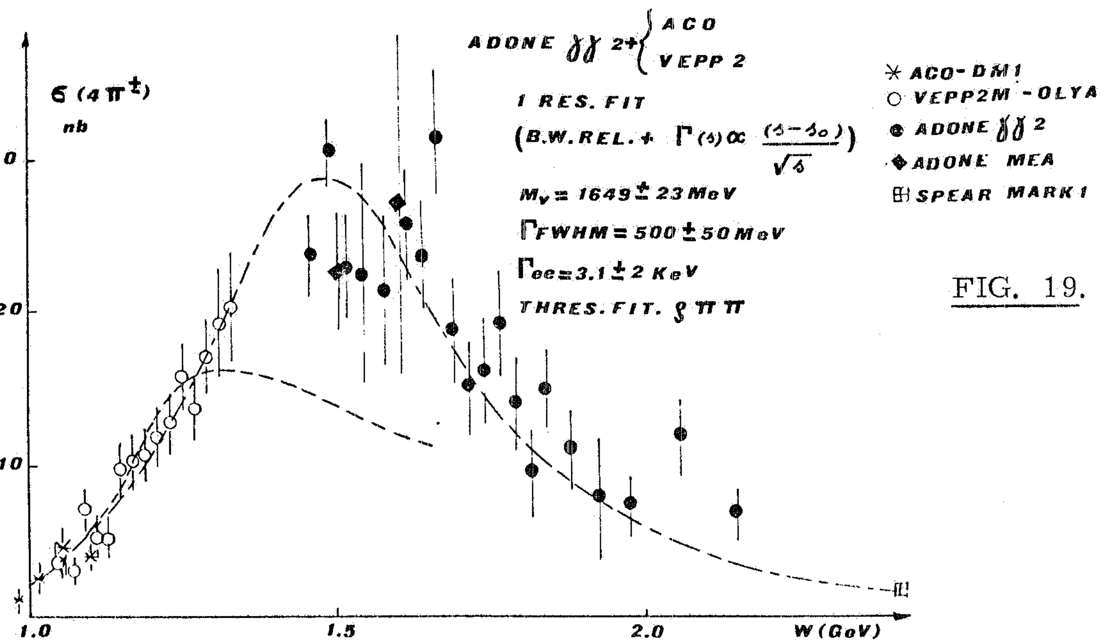

FIG. 19.

Work is in progress in the MEA experiment to look for the cross section $\sigma(\varrho\pi\pi)$. In fact preliminary results on the invariant mass spectrum of the neutral system of two pions show a peak in the region of the ϱ mass (Fig. 20).

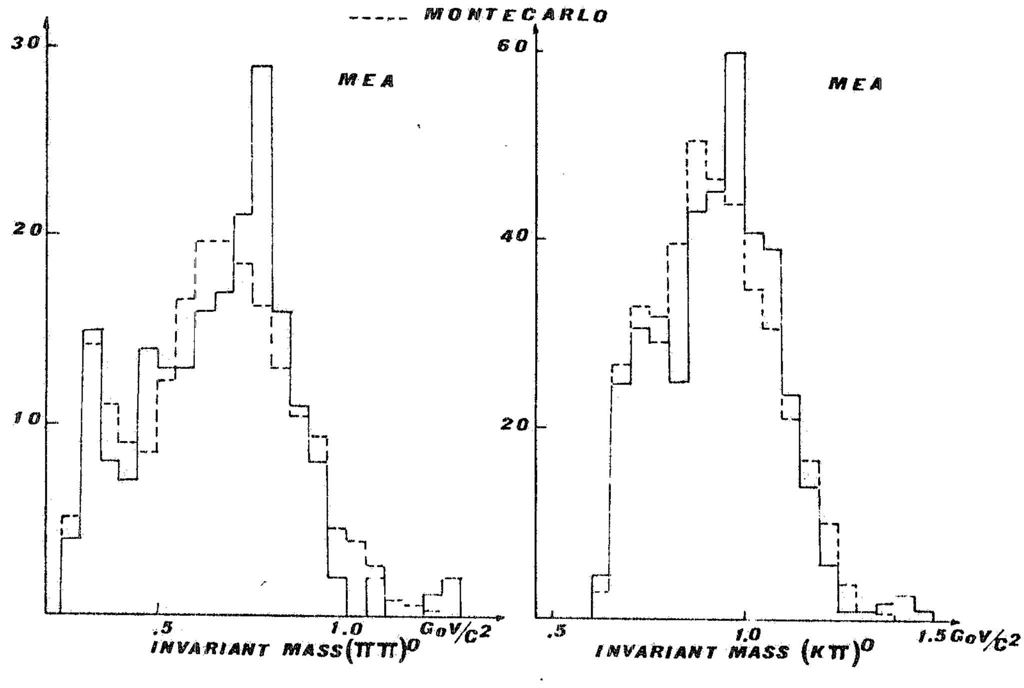

FIG. 20.

The cross section $\sigma(2\pi^{\pm} 2\pi^{0})$ ($\simeq \sigma(2\pi^{\pm} \gg 2\pi^{0})$) shows a diffe-rent behaviour respect to the $\sigma(4\pi^{\pm})$ at low energies ($1 \div 1.4$ GeV) Fig. 21, 22).

Probably a $\varrho \rightarrow \omega\pi$ is responsible of this different behaviour.

Smaller cross sections ($\sigma(4\pi^{\pm} 1\pi^{0})$, $\sigma(4\pi^{\pm} 2\pi^{0})$, $\sigma(2\pi^{\pm} 1\pi^{0})$ are also reported in Fig. 23, 24.

Work is in progress to check the various cross sections (especial ly for $\pi^{+}\pi^{-}\pi^{0}$) with kinematical reconstructions of the events, when available.

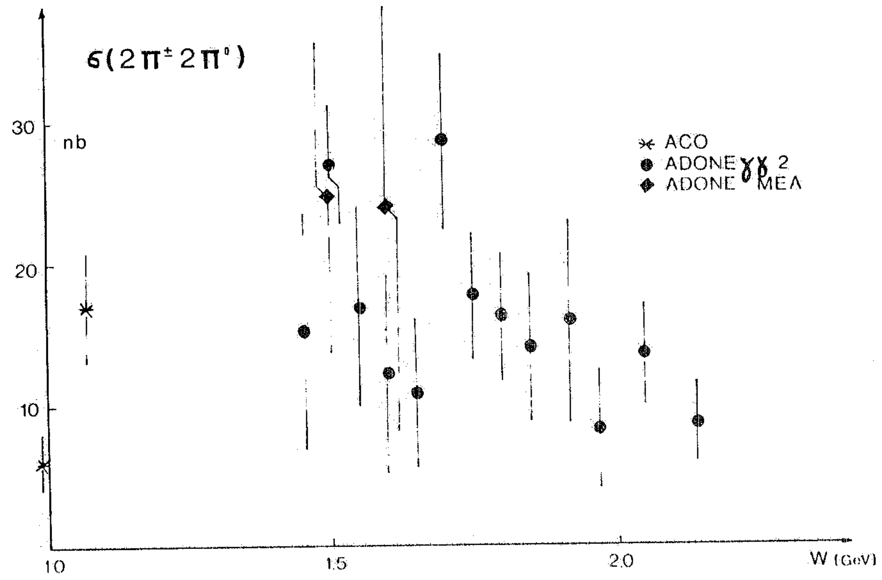
σ(2π±2π°)
nb
30
20
10
ACO
ADONE γγ2
ADONE MEA
1.0
1.5
2.0
W (GeV)

FIG. 21.

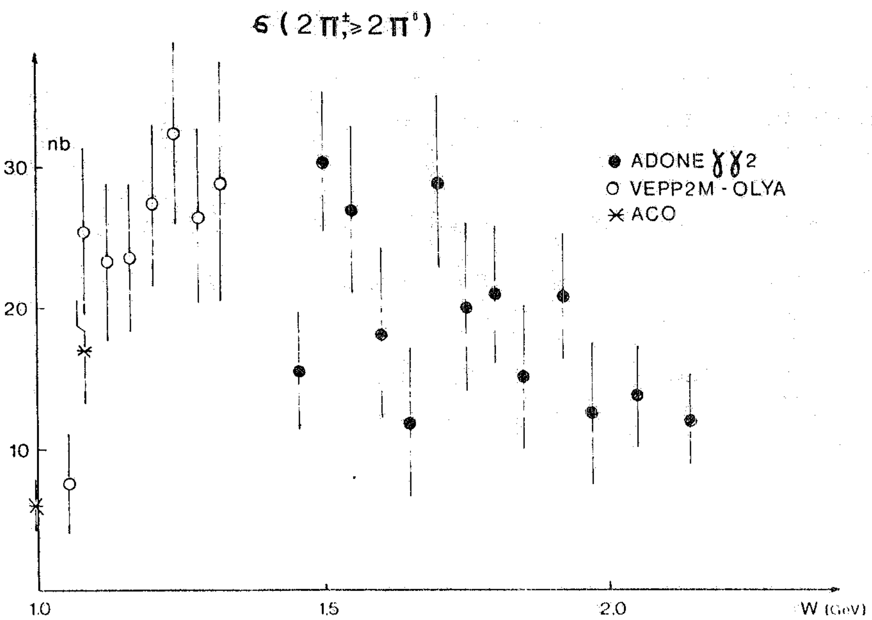
σ(2π±,≥2π°)
nb
30
20
10
ADONE γγ2
VEPP2M - OLYA
ACO
1.0
1.5
2.0
W (GeV)

FIG. 22.

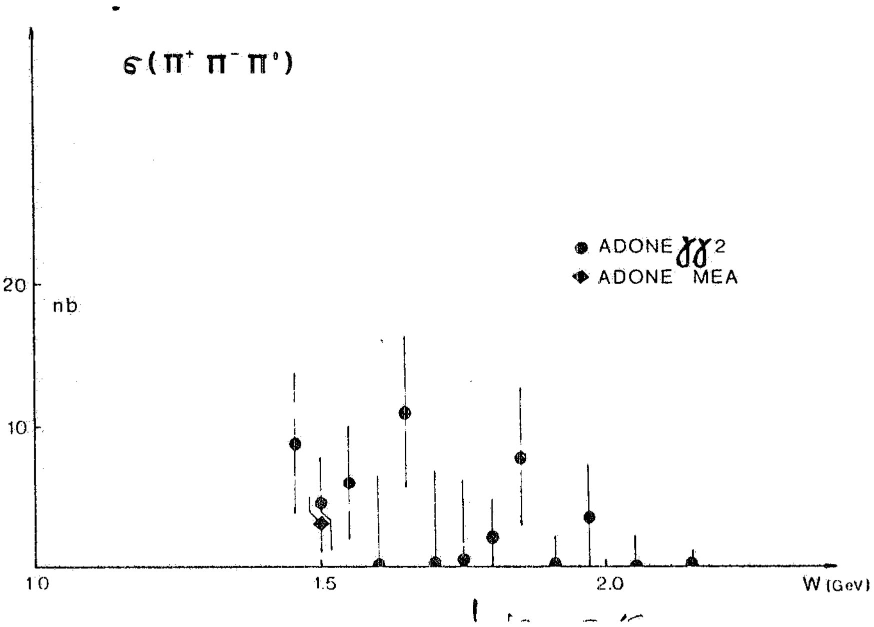
σ(π⁺ π⁻ π°)
ADONE γγ2
ADONE MEA
20
nb
10
1.0
1.5
2.0
W (GeV)

FIG. 23.

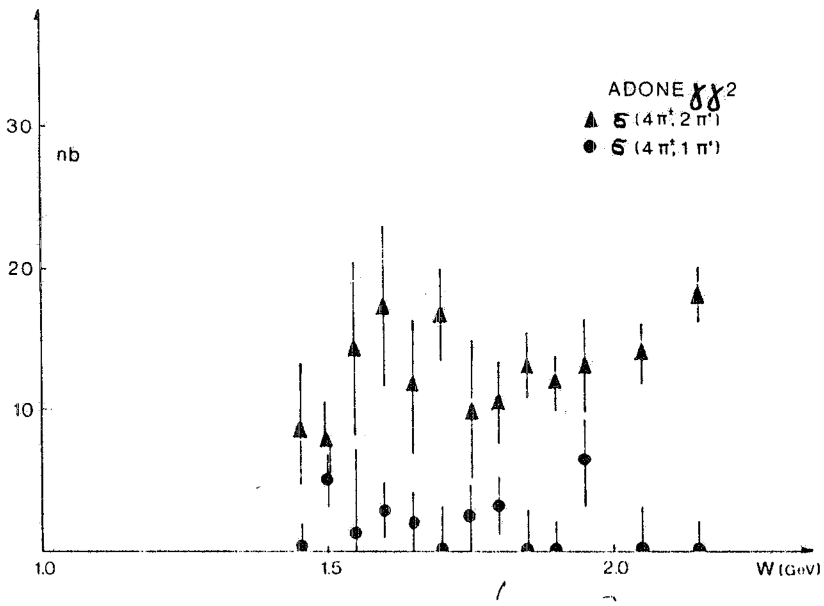
ADONE γγ2
σ (4π±, 2π°)
σ (4π±, 1π°)
30
nb
20
10
1.0
1.5
2.0
W (GeV)

FIG. 24.

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