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G. Abshire, M. Ambrosio, G. Barbarino, G. Barbiellini, R. Biancastelli, C. Bemporad, G. Brosco, M. Calvetti, M. Castellano, F. Cevenini, A. M. Cnops, F. Costantini, G. Finocchiaro, F. Grancagnolo, P. Lariccia, D. Owen, P. Parascandolo, G. Paternoster, S. Patricelli, E. Sassi, L. Tortora, U. Troya, F. Valerio and S. Vitale : AN UPPER LIMIT FOR THE RADIATIVE DECAY WIDTH OF THE J/ψ RESONANCE INTO $\eta'(958) + \gamma$.

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AN UPPER LIMIT FOR THE RADIATIVE DECAY WIDTH OF THE J/ψ RESONANCE INTO $\eta'(958) + \gamma$.

We present the results of a search performed at ADONE for the reaction

$$e^+ + e^- \longrightarrow J/\psi \longrightarrow \eta'(958) + \gamma.$$

No evidence was found for such a decay in a total luminosity of $146\,nb^{-1}$, integrated over a C. M. energy region around the peak of the J/ψ resonance.

We give, as a result, the following limit for the partial decay width $J/\psi \longrightarrow \eta'\gamma$

$$\Gamma_{J/\psi \to \eta'\gamma} < 0.50\ keV \qquad (90\%\ C.L.).$$

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The experimental set up, schematically shown in Fig. 1, is composed of four hodoscopes (from the interaction region outward: HOD 1, 2, 3, 4), each made up of sixteen 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 $0.75 \times 4\pi$.

All counters respond linearly to the crossing particle energy loss. The HOD 3 elements are large thickness liquid scintillation counters (35 g/cm^2); they effectively discriminate crossing particles from soft electromagnetic background by means of a calorimetric information ($\Gamma_{f.w.h.m.}/E = 20\%$ at $E = 100$ MeV). HOD 4 is separated from HOD 3 by 2.5 R.L. of lead and iron.

For detecting the high energy (1.4 GeV) monochromatic photon emitted in the $J/\psi \longrightarrow \eta'\gamma$ decay, two opposite elements of the HOD 3 normal configuration were replaced by two linear arrays of eight lead glass total absorption Č counters ($15 \times 15 \times 35$ cm^3), each subtending a solid angle, for point like source, similar to the one of a HOD 3 element.

The trigger logic asks for:

1) a photon of energy larger than 50 MeV in at least one of the Č counters;
2) at least two charged tracks; a track is defined by elements of HOD 1, 2, 3, set in a row;
3) at least one HOD 4 element fired;
4) a time coincidence between counter pulses and the transit of e^+, e^- bunches.

Cosmic rays are effectively rejected by a time of flight selection over a path length of about one meter.

The pattern of all fired counters was recorded on magnetic tape for each event together with pulse height and time informations; the average trigger rate was 2/sec.

The absolute luminosity of the machine was measured by the small angle Bhabha scattering as detected by a luminosity monitor installed in

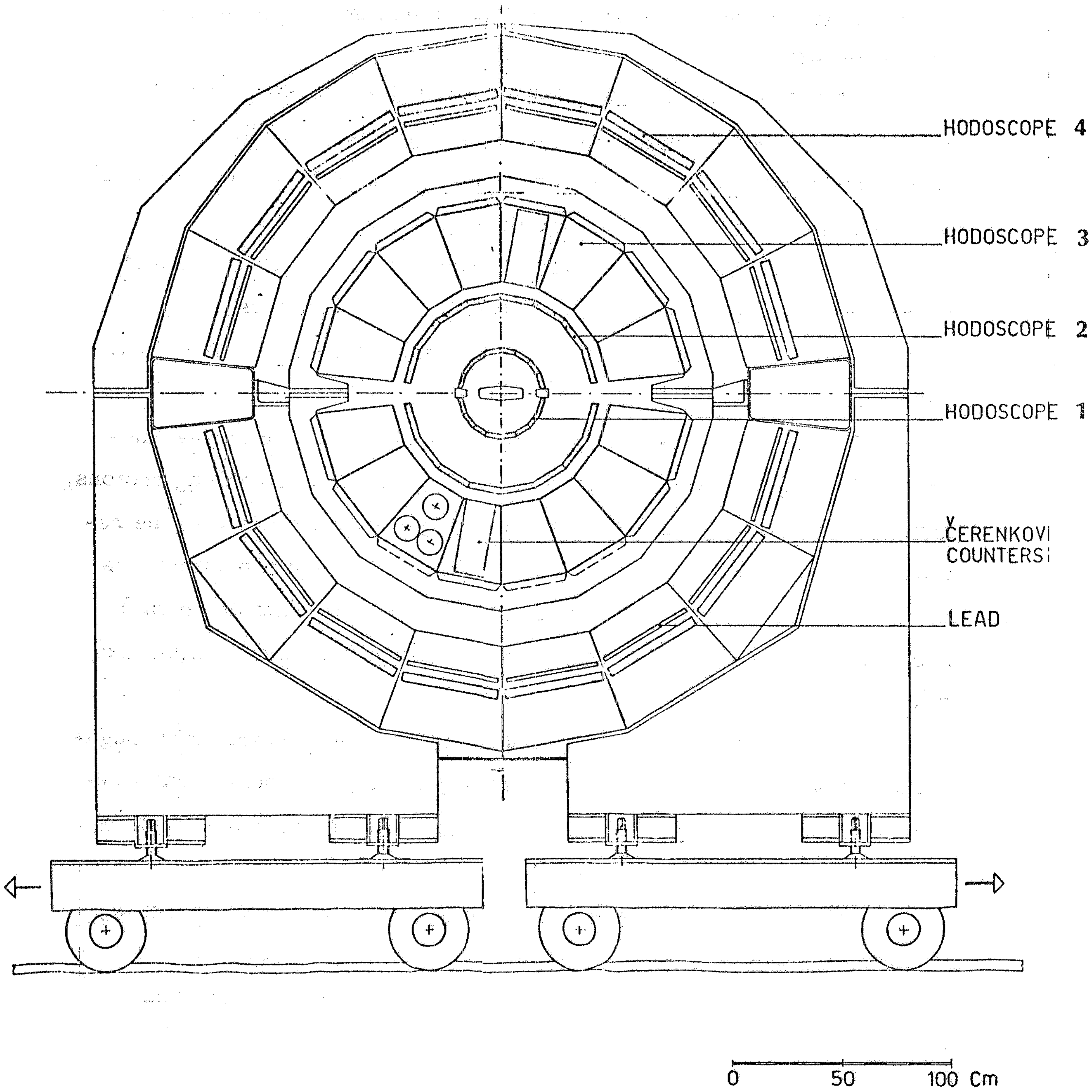

FIG. 1 - End view of the experimental set-up.

the ADONE straight section opposite to the one occupied by our set-up and by a double bremsstrahlung luminosity monitor installed close to our experiment.

The lead glass shower counter is the heart of the experiment as far as the detection and measurement of monochromatic photons from J/Ψ decays is concerned; we want therefore to discuss some of the points related to the behaviour of this device.

Each $\check{C}$ counter was separately calibrated at CERN by a test beam in which electrons were identified by gas $\check{C}$ counters.

The counter linearity was checked up to 2 GeV; the fractional resolution $\Gamma_{f.w.h.m.}/E$ was 14% at E = 1 GeV.

The absolute calibration of the $\check{C}$ counters, in their final mechanical assembly, was repeated at ADONE by bremsstrahlung photons, generated in the collision of the circulating electron beam with the residual gas present in the interaction region where our experiment is located; the photons could be tagged by a small scintillation counter positioned in the ADONE magnet adjacent to the machine straight section.

The variation of the response of the $\check{C}$ shower detector throughout the experiment was traced continuously on line; we periodically recorded the $\check{C}$ pulses induced by low energy α sources, mounted on NaI crystals in optical contact with each lead glass.

An additional absolute $\check{C}$ calibration and a check of the luminosity monitor absolute calibration were provided by the process $e^+ + e^- \rightarrow$ $\rightarrow e^+ + e^-$, at the J/Ψ C.M. energy and lower, whose e^+, e^- pairs were detected by the two opposite $\check{C}$ arrays.

Electrons and photons, hitting the $\check{C}$ counter entrance surface, produce showers whose energy might either be fully contained in one or two $\check{C}$ cells, or might partially be lost across the planes limiting the $\check{C}$ matrix.

In the first two cases the electron/photon energy is correctly measured, in the last case the energy spill out is normally signalled by HOD 3 and 4 elements adjacent to the Č matrices ; only rarely and for small energy spills, the adjacent counters do not fire.

The phenomenon has been extensively studied and it is clearly visible in the electron and positron energy spectra associated with wide angle e^+, e^- events. (Fig. 2 a, b)(*).

From a practical point of view, the energy spill-out is assimil able to a Č counter energy resolution worse than the one measured under conditions of full shower containment; as a consequence, in the search for the 1.4 GeV monochromatic photons, one has to accept events associated with lower energy gammas, down to a minimum E_c. To set a proper E_c value, we decided to use the energy distribution for $e^\pm$ of known nominal energy, obtained from the process $e^+ + e^- \rightarrow e^+ + e^-$ at the J/ψ C.M. energy and lower; this experimental distribution is the refore shaped by the normal fluctuations of the Č light and of the photo multiplier response and by the effects of the energy spills.

After introducing a correction for the $e^\pm$ energy loss in the material in front of the shower counter, we assume that the $e^\pm$ energy distribution is similar to the one generated by photons of equal energy.

We believe that this hypothesis can be safely made in setting E_c, because Bhabha events have an angular distribution which tends to pro duce somewhat higher spills than the ones associated with the $J/\psi \rightarrow \rightarrow \eta' \gamma$ decays; moreover, the radiative effects, present in e^+, e^- scattering, produce low energy tails in the $e^\pm$ spectra.

In preparing the energy distribution associated with showers, induced both by electrons and by photons, it is convenient to treat sepa rately the events in which energy spills were signalled by adjacent coun ters. The experimental resolution is better for showers with total containment, as was expected.

To accept 90% of all photons of energy equal to 1.4 GeV, E_c has been set at 1.0 GeV (see Fig. 2).

The fact that a photon has to convert in order to produce Č light, has been taken into account, in the calculation for the photon detection

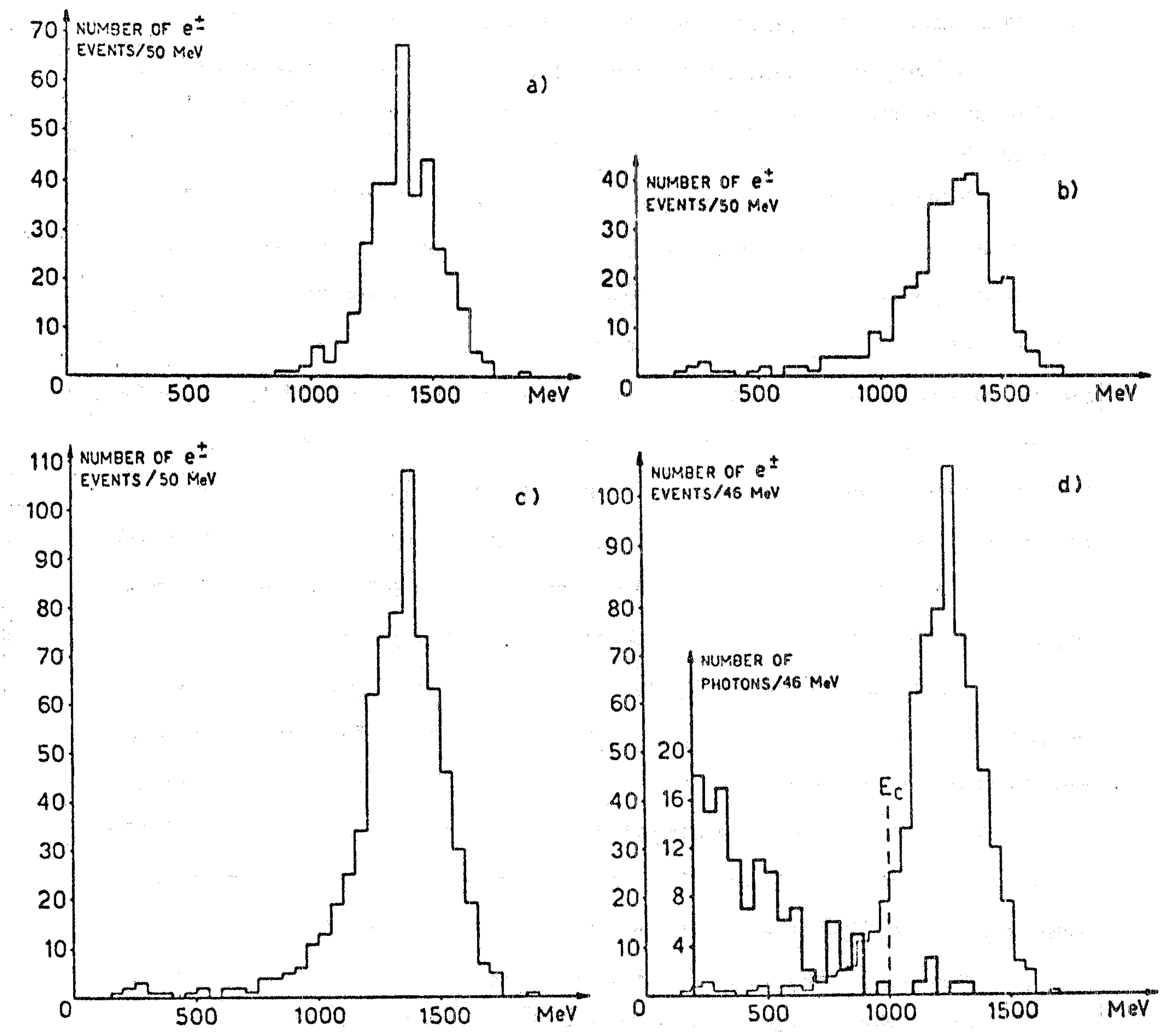

FIG. 2 - Electron energy distribution from the process $e^+ + e^- \rightarrow e^+ + e^-$ obtained at J/ψ C.M. energy and lower. The data are plotted as if all were taken at the J/ψ C.M. energy.

a) Energy distribution in the case of no energy spill-out;
b) Energy distribution in the case of energy spill-out;
c) Sum of a) + b);
d) Simulated 1.4 GeV photon energy distribution obtained by shifting the electron energy distribution by a proper factor (e.g. the factor is 1.4/1.55 for electrons collected at the J/ψ C.M. energy). Shown is the experimental photon energy distribution and the energy cut E_c.

efficiency, by the requirement of a minimum gamma ray path of 2 R. L. in the lead glass.

The analysis of the experiment was performed as follows. A Montecarlo calculation gave the detection efficiencies for the decay

$$J/\psi \longrightarrow \eta' + \gamma, \quad \eta' \longrightarrow \pi^+ \pi^- + \text{anything}$$

under various assumptions (efficiency of the order of 1%); effects like : nuclear interactions of secondary particles, energy losses, multiple scattering, detector granularity, etc. were taken into account. Similar Montecarlo calculations provided the detection efficiencies for decay channels like $J/\psi \rightarrow \eta\gamma$, $J/\psi \rightarrow \rho^0\pi^0$, $J/\psi \rightarrow \omega\eta$, which are among the possible sources of background in the present experiment.

As predicted by the Montecarlo calculation, the events whose pions were associated with a high energy photon in the opposite hemisphere, frequently sent (about 35% probability) a particle to one of the Č array elements. The Č counter must then be fully efficient to detect even low energy pions.

The pulse height distribution of the Č counter associated with crossing cosmic ray muons, the setting employed for the Č discriminator threshold and the β versus light output curve for lead glass, were such that the Č detector was fully efficient to pions (or muons) with $T_\pi > 80$ MeV ; we calculated a correction to the $\eta'\gamma$ detection efficiency, due to the possible nuclear interactions of pions before emitting light sufficient to cross the discriminator threshold, plus a correction due to the energy cut on the pion spectrum from the $J/\psi \rightarrow \eta'\gamma$ decay (6.5%).

We selected two-track events associated withat least one photon of energy larger than 200 MeV and with an energy loss larger than 30 MeV in each HOD 3 element ; this sample is dominated by hadronic J/ψ decays ; the requirement of two and only two tracks, selects 90% of all the detected $\eta'\gamma$ final states.

One of the two tracks is requested to be in line with or adjacent to one of the fired HOD 4 elements ; this means that one of the two tracks (if it is a pion) has energy $T_\pi > 160$ MeV ; the other track has $T_\pi > 75$ MeV.

$J/\psi \rightarrow \eta'\gamma$ candidates were finally selected by adding to the previously listed requirements the ones of having a photon of energy larger than $E_c = 1.0$ GeV and of having both tracks in the hemisphere opposite to the photon direction (93% probability). We were left with six events whose associated photon energies are shown in Fig. 2. Although , as already mentioned, background contributions might be present from $J/\psi \rightarrow \rho^0\pi^0, \omega\eta, \eta\gamma$, etc. here we interpret all the six events as being only due to $J/\psi \rightarrow \eta'\gamma$ decays. A number of corrections were applied to the Montecarlo calculated detection efficiency before deducing from the data a limit for the integrated $\sigma(e^+e^- \rightarrow J/\psi \rightarrow \eta'\gamma)$ cross section ($\sigma_{\eta'\gamma}$) : photon conversion before the $\check{C}$ counter anticoincidence (12 %), trigger dead time (5%), photon energy spectrum cut ($\sim 10\%$), etc.

To extract the useful integrated luminosity, from the one measured by the Bhabha luminosity monitor, we used the experimental J/ψ hadronic excitation curve as obtained through the same $\eta'\gamma$ trigger and by weaker off-line conditions : events with two or more tracks in any direction and photon energy larger than 200 MeV.

The final result can be stated in the form :

$$\int \sigma_{\eta'\gamma}\, dW < 135 \quad \text{nb} \cdot \text{MeV} \qquad (1)$$

after applying radiative corrections[1].

In addition to the $J/\psi \rightarrow \eta'\gamma$ decay, the most important channel contributing to the observed number of events, the decay $J/\psi \rightarrow \rho^0\pi^0$, has a known decay width[2]. It is therefore possible to estimate the expected contribution from such a background in our apparatus ; we evaluated $N_{\rho^0\pi^0} \sim 3.5$ events.

By considering the possible statistical fluctuations of this number, a new value for the limit on the integrated $\sigma_{\eta'\gamma}$ cross section can be derived:

$$\int \sigma_{\eta'\gamma}\, dW < 85 \qquad \text{nb} \cdot \text{MeV} \qquad (2)$$

From (2) and by use of the known J/ψ hadronic integrated cross section and J/ψ hadronic width, we set a limit for the partial decay width $\Gamma_{J/\psi \to \eta'\gamma}$:

$$\Gamma_{J/\psi \to \eta'\gamma} < 0.50 \qquad \text{keV} \quad (90\%\ \text{C.L.}).$$

This result improves a previous limit determined at ADONE[3]. A similar result has been obtained by the DESY DASP Collaboration[4]. It is important to know that since in the present experiment we select events which have two-tracks associated with at least one high energy photon, we are in the position to set upper limit for other J/ψ decay channels[5]. E.g. in the case of the $J/\psi \to \omega\eta$:

$$\int \sigma_{\eta\omega}\, dW < 500 \qquad \text{nb} \cdot \text{MeV}$$

from which:

$$\Gamma_{J/\psi \to \eta\omega} < 3.0 \qquad \text{keV} .$$

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FOOTNOTE AND REFERENCES. -

(*) - The peak position of the electron energy distributions is shifted relatively to the electron nominal energy; the shift is larger in case of detected energy spills (Fig. 2b). We interpret the shift as due to a combination of energy spills and energy losses in the material in front of the Č counters. Small energy spills, not detected by adjacent counters, are probably present also in Fig. 2a. A small error in the absolute calibration of the Č counters (a few per cent) is also possible.

(1) - M. Greco et al., Nuclear Phys. B101, 234 (1975).

(2) - Review of Particle Properties, Rev. Mod. Phys. 48, 1 (1976).

(3) - R. Baldini-Celio et al., Phys. Letters 58B, 475 (1975).

(4) - B. H. Wiik, DESY Report 75/37 (1975).

(5) - G. Abshire et al., submitted to Lett. Nuovo Cimento.