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Addendum to

THE PROPOSAL TO SEARCH FOR THE NEUTRAL BOSON Z^0

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In this addendum we discuss an interesting and important by-product of our proposed set-up to search for Z^0.

In the original search for Z^0 we trigger on very large opening angle $\mu^+\mu^-$ pairs from the reaction

$$p + p \to \underset{\hookrightarrow \mu^+\mu^-}{Z^0} + X . \tag{1}$$

By requiring that both μ mesons penetrate ∿ 3 m of iron yoke of the SFM, each muon has momentum > 5 GeV. The trigger was designed to look for $Z^0 \to \mu^+\mu^-$ in the mass region $15 < m_{Z^0} < 40$ GeV.

We note that by rearranging the triggering and by adding chambers on the sides, as shown in Figs. 1 and 2, we can easily measure $\mu^+\mu^-$ pairs with smaller opening angles down to $\theta_{min} \sim 40^\circ$ and so make use of the full potential of the SFM detectors (4π Charpak chambers, hodoscopes, Čerenkov counters, lead-glass counters, etc.). We will be able to study the reaction

$$p + p \to \underset{\hookrightarrow \mu^+\mu^-}{\gamma_v} + X \tag{2}$$

in the mass range $4 < m_{\mu\mu} < 14$ GeV with 2π solid angle, and at the same time measure the structure of X with the 4π SFM detector. Of particular interest are questions such as:

a) the π, K, p ratio in X,

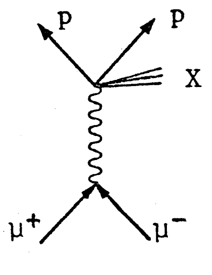
b) $\pi^0\gamma_v$, $\pi^\pm\gamma_v$, $K\gamma_v$, $p\gamma_v$ correlations,

c) a complete ∿ 4π multiplicity distribution associated with γ_v,

d) because of the transverse field of SFM, we will be able to study very forward (parallel to the beam) particles in X.

The additional side detector of Figs. 1 and 2 will increase the $Z^0 \to \mu\mu$ rate by a factor of ∿ 2.5.

The physics. The simplest way to visualize reaction (2) is to compare it with two high-energy (5-7 GeV each) μ^+ and μ^- storage rings producing collisions in a 4π detector. There one can study X in $\mu^+\mu^- \to p + p + X$ from the diagram



In parton models one uses the information on parton (antiparton) distributions obtained from deep inelastic electron scattering from SLAC [1] and νN, $\bar{\nu} N$ information from CERN [2] to estimate the functional behaviour of reaction (2). In particular the Drell-Yan model, the Kuti-Weisskopf model, and the Landshoff-Polkinghorne model[3], etc., all yield the same functional dependence of reaction (2):

$$\frac{d\sigma}{dm^2} = \frac{4\pi\alpha^2}{3m^4} F(s/m^2) \tag{3}$$

where m is the invariant mass of $\mu^+\mu^-$ and s the total ISR energy squared; $F(s/m^2)$ is a scaling function. These models all produced reasonable agreement with the measured BNL data[4].

There is no work on the structure of X in reaction (2). However, when the photon is in the space-like zone ($q^2 < 0$) in the reaction $e + p \rightarrow e + X$, there are many experiments on X [5]. These experiments have yielded the following (at W = mass of X $\approx$ 3 GeV, forward direction, $0 < |q^2| < 1$):

a) the K^+ yield increases with $|q^2|$;
b) π^+/π^- ratio increases with $|q^2|$;
c) the proton yield is independent of $|q^2|$.

It would be interesting to study X in reaction (2) and obtain K, π, p distributions and correlations.

The experiment. As shown in Figs. 1 and 2, the set-up is essentially the same as that described in CERN ISRC/73/9, Add. 1. It is slightly extended on the sides of SFM (but it is kept out of the way of cables, stands, photomultipliers, etc.). The triggering will be modified to cover a minimum opening angle of 40°. For a small portion of the detector, additional shielding will ensure that each μ meson will traverse a minimum of 2.5 m of iron. The detector will consist of drift chambers and arrays of 1 m × 3 m scintillation counters. Since the $\mu^-\mu^+$ pairs have small $p_\perp$, the triggering can be done by requiring one counter from the top yoke to be in coincidence with a counter in the bottom yoke and in coincidence with U and D counters above and below the bicone.

The total $\mu^-\mu^+$ detector has a 2π solid angle; the hadron detector can be the complete 4π SFM detector.

To calculate the yield, we use the formula of Jaffe and Primack (checked independently by Paschos and Llewellyn-Smith$^{6)}$ for $d\sigma^2/dm^2dQ_y$, where Q_y is the γ_v momentum in the incident beam direction. We used a Monte Carlo program to calculate the yield of $\mu^+\mu^-$ as a function of mass, taking into account loss of energy and multiple scattering as described in Add. 1. The result is shown in Fig. 3, based on 10^{31} cm^{-2} sec^{-1} luminosity and 100 days of parasite running. As seen, we will obtain about 5000 events: This event rate implies that we will be able to do the following:

1) To parasite with the high $p_\perp$ extension of experiment R410. In that experiment, three banks of hodoscopes, separated by 2 m each, give a total of 4 m of flight path and enable one to distinguish π, K, p below 1 GeV with a total solid angle of $\sim$ 2 sr. The large solid angle available, together with the 100 channel time-of-flight system, implies that almost every $\mu^-\mu^+$ event will have a π or a K being measured simultaneously.

2) To parasite with other high-intensity, low-rate experiments which have Čerenkov counters in the forward region or large solid angle lead-glass counters, large gas-Čerenkov counters, etc.

Background calculations. As discussed in Add. 1, the cosmic-ray background can be rejected by time of flight and by requiring a $\mu^+\mu^-$ opening angle $< 177°$.

The dotted line in Fig. 3 is the estimate of $\pi,K \rightarrow \mu$ background where we have used the $\pi^0\pi^0$ data in the central region from the CCR group$^{7)}$. We have scaled this data with measured $p_\parallel$ dependence$^{8)}$ and integrated over the acceptance. We have assumed the number of K^-K^+ pairs = the number of $\pi^+\pi^-$ pairs = the number of $\pi^0\pi^0$ pairs.

It should be noted that the π,K yield increases quickly with decreasing angle with respect to the beam direction. To keep the background to the 10% level of Fig. 3, we have applied a different cut-off angle θ_c for different mass regions. For 4 GeV $\leq m_{\mu\mu} <$ 6 GeV, $\theta \geq 20°$, and for 6 GeV $\leq m_{\mu\mu} <$ 14 GeV, $\theta \geq 30°$. Figure 3 is the composite result of such a procedure.

As mentioned in Add. 1, we have used the empirical program of Ranft to estimate the hadron showers. With a minimum of 2.5 m of iron as shielding, the calculated hadron showers are much less than the decay corrections. To further reduce the shower contribution, we can put additional absorber between the drift chambers.

We note that the $\mu\mu$ detector we propose is very similar to the detectors used at BNL [9] and CERN [10], where one measures the branching ratio of $\rho \to \mu^-\mu^+/\rho \to \pi\pi \approx 10^{-4}$ from the reaction $\pi + N \to \mu^+\mu^- + X$ where both groups have successfully obtained a $\pi\pi/\mu\mu$ rejection of $\sim 10^{-7}$. Both groups measured the particle trajectories before 2.0-3.0 m of iron shielding and identified $\mu\mu$ pairs with detectors behind the iron. For our experiment we need a π,K rejection of $\sim 10^{-6}$ only.

The mass resolution for low mass pairs was calculated as in Add. 1 and typically $\Delta m/m \approx 10\%$.

Requirement from ISR. We intend to run this experiment in parasitic mode with other experiments. We have had many conversations with ISR supporting groups and potential users of the SFM. So far, all our requests are compatible with other experiments.

REFERENCES

1) H. Kendall, Rapporteur's Talk, Int. Conf. on Electromagnetic Interactions, Cornell, 1971.

2) CERN-Gargamelle-Collaboration. V. Brisson, 16th Int. Conf. on High-Energy Physics, Chicago-Batavia, 1972 (NAL, Batavia, 1973), Vol. 3, p. 195.

3) J.D. Drell and T.M. Yan, Phys. Rev. Letters 25, 316 (1970).
J. Kuti and V.F. Weisskopf, Phys. Rev. D4, 3418 (1971).
P.V. Landshoff and J.C. Polkinghorne, Phys. Letters 40 B, 463 (1972).

4) J.H. Christenson et al., Phys. Rev. Letters 25, 1523 (1970).

5) G. Wolf, DESY 72/61, 1972 and D. Luke, private communication.

6) R. Jaffe and J. Primack, Nuclear Phys. B, to be published.
E. Paschos and C. Llewellyn-Smith, private communication.

7) F.W. Büsser et al., Int. Conf. on New Results from Experiments on High-Energy Particle Collisions, Vanderbilt University, Nashville 26-28 March, 1973.

8) B. Alper et al., CERN preprint, to be published in Phys. Letters, and G. Giacomelli, private communication.

9) B.D. Hyams et al., Phys. Letters 24 B, 634 (1967).

10) A. Wehmann et al., Phys. Rev. Letters 17, 1113 (1966). For more work on hadron attenuation see: A. Citron et al., Nuclear Instrum. Methods 32, 45 (1965) and M. Tannenbaum, Nevis-132 (1965).

Figure captions

Fig. 1 : End view of $\mu^-\mu^+$ detector.

Fig. 2 : Side view of the detector.

Fig. 3 : Solid line is events from reaction (2) according to Jaffe. The dotted line is the $\pi K \rightarrow \mu$ background.

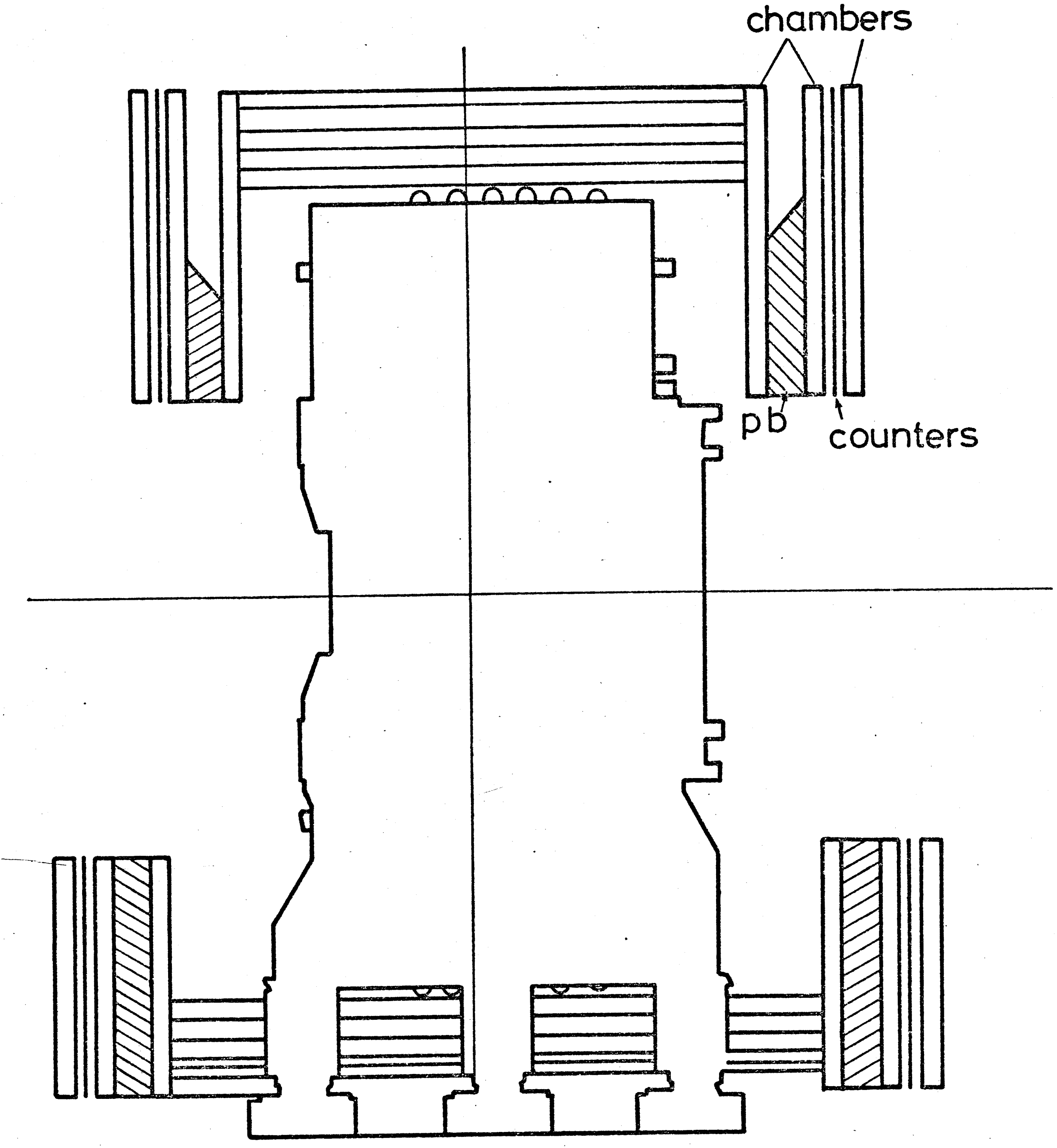


FIG.1

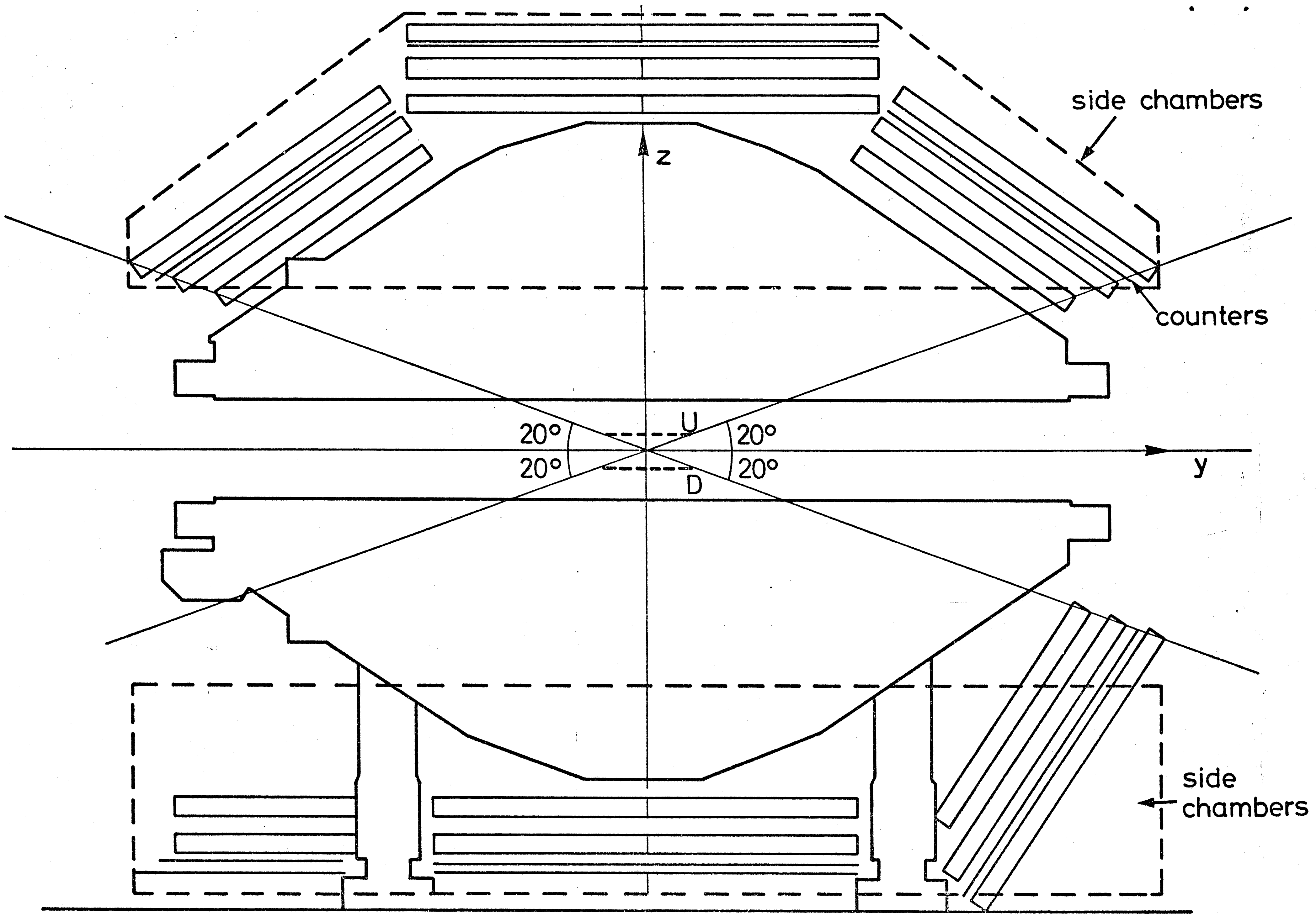


FIG. 2

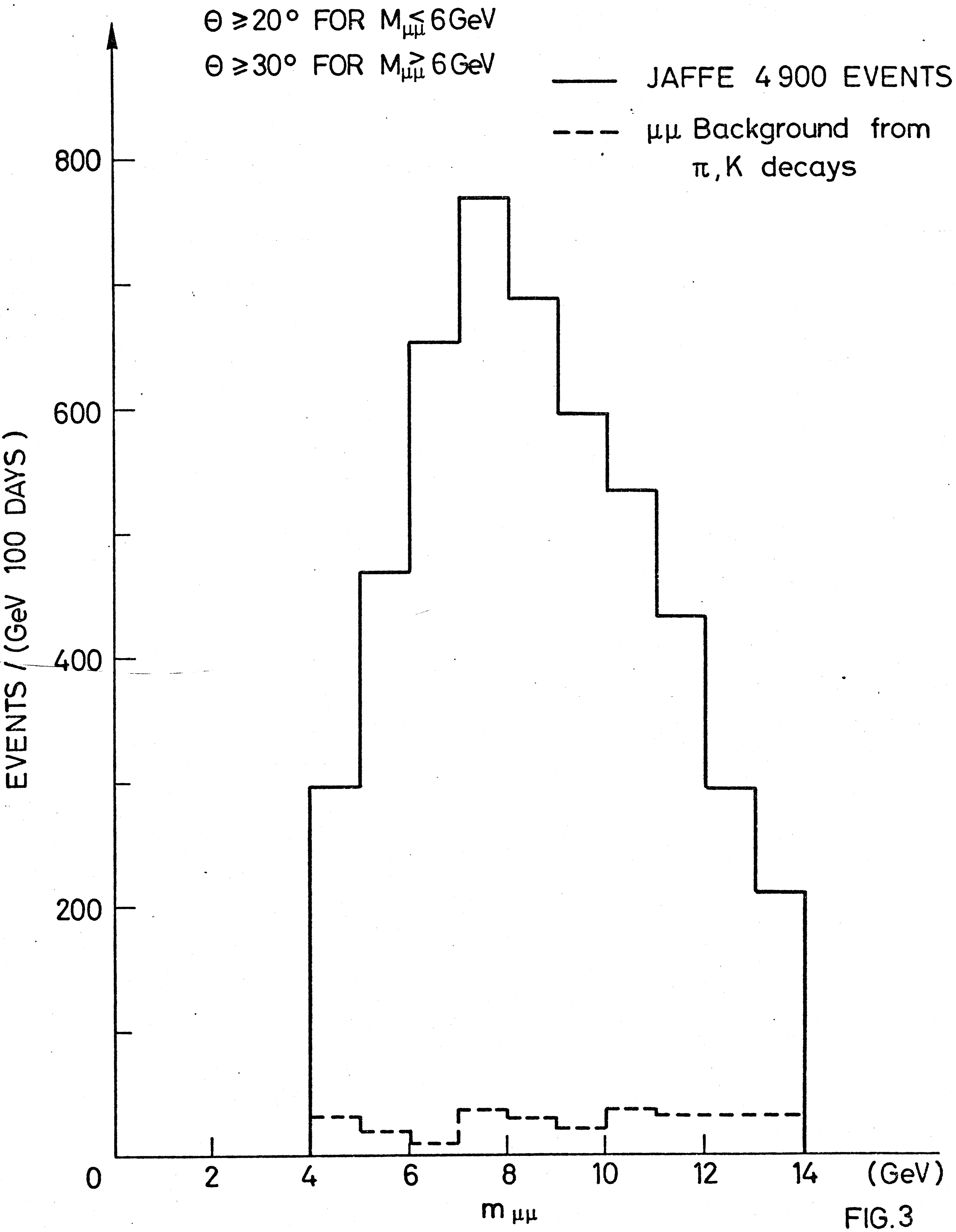

Θ ≥ 20° FOR M_μμ ≤ 6 GeV
Θ ≥ 30° FOR M_μμ ≥ 6 GeV
JAFFE 4 900 EVENTS
μμ Background from π, K decays
EVENTS / (GeV 100 DAYS)
800
600
400
200
0
2
4
6
8
10
12
14
(GeV)
m μμ

FIG.3