Title

AN ATTEMPT TO DETECT^ -MESON PAIRS FROM 322 MEV BREMMSSTRAHLUNG

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It has been suggested that high energy photons should create pairs of μ-mesons, either by an electromagnetic process (since it is thought probable that the μ-meson is a Dirac particle), or by virtue of recent considerations of Wentzel[1]. J. Steinberger suggested one might look for the effect using the Berkeley Sychrotron.

The total yield of such pairs is given by:

$$n \int_{E_0}^{E_{max}} \sigma(E) \; \frac{dF(E)}{dE} \; dE$$

where n is the number of nuclear centers per unit area, E_0 is the threshold, E_{max} is 322 Mev, $\frac{dF(E)}{dE}$ is the total photon spectrum, and $\sigma(E)$ is the cross section for pair production. In our computations we have assumed the cross section to be of the form: $\sigma(E) = \sigma_0 \left(\frac{E-E_0}{m_\mu c^2}\right)^2$. For electromagnetic pair production,[2] as an example, σ_0 is 0.085 $\bar{\phi}$ where $\bar{\phi}$ is $\frac{1}{137}\left(\frac{Z e^2}{m_\mu c^2}\right)^2$ (using the μ mass instead of the electron mass). Using this value for a 1 inch CH_2 target gives 4.6×10^{-11} pairs per e.q. and for 1/4 inch lead: 2.3×10^{-9} pairs per e.q., where the number of equivalent quanta (e.q.) is the total energy in the beam divided by the maximum photon energy (322 Mev). The beam used for this experiment was on the order of 2×10^9

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[1] Wentzel, Phys. Rev. 79, 710 (1950).
[2] Heitler, The Q.M. Theory of Radiation (Oxford).

e.q. per minute.

The experimental apparatus, consisting of two scintillation counter telescopes and associated electronics, is shown in Figs. 1 and 2. The liquid scintillator is 0.5 percent of terphenyl in xylene enclosed in glass cylinders 4" dia. x 1.25" and 3" dia. x 0.5" (for the anticoincidence) with thin windows for a pair of 1P21 photomultipler tubes. The use of two photo tubes per scintillator greatly flattened the geometric pulse height distribution and raised the electron signal rate by a factor of five without raising the noise appreciably.

Each meson channel was adjusted to count π^{+-}-mesons (by means of the μ-electron decay) with maximum efficiency, and the result of this was found to be in good agreement with the work of Steinberger and Bishop[3].

CH_2 and Cu targets were used for 90° observations and CH_2 for 135°.

The number of pairs one would expect to count can be calculated as follows:

$$\text{No.} = n\,(\Omega)^2 \quad (D)^2 \quad C\,\eta \int Q(E)\;\sigma(E)\;\frac{dF(E)}{dE}\,dE$$

where Ω, the solid angle subtended by each counter telescope at the target, is squared if we assume the angular distribution of the μ's to be random and spherically symmetric; D is the fraction of the decay electrons accepted by the delayed electron gates; C is the fraction of the μ^--mesons which give a decay electron in carbon; η is the counter efficiency for seeing the μ-electron decay; and Q(E) accounts for the small part of the total energy spectrom of the μ pairs which will be accepted by the counters.

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[3] Steinberger and Bishop, Phys Rev <u>78</u>, 993 (1950).

This includes two effects, since the energy acceptance of the crystals limits the total energy of the pair and also, the manner in which the total energy is split. The last factor greatly reduces the number of pairs detected.

For the electromagnetic theory, for example, where the energy splitting distribution (for small μc^2) is fairly flat, reasonable values for these quantities give the following results:

1×10^{-16} pairs per e.q. in CH_2 at 90°

5×10^{-15} pairs per e.q. in Pb at 90°

These rates are impossibly small, and the angular distribution for this process is probably somewhat forward, so it was decided to look for other modes of μ-pair production at 90° and 135° where the background conditions are decidedly better. It is assumed that these processes would have a reasonably spherically symmetric angular distribution.

The results of several bombardments are as follows:

Target	Angle (lab)	Total counts	Calculated accidentals
Cu	90°	1 per 10^9 e.q.	1.4 per 10^9 e.q.
CH_2	90°	1 per 5.6×10^{10} e.q.	0.17 per 5.6×10^{10} e.q.
CH_2	135°	1 per 2.5×10^{11} e.q.	2.2 per 2.5×10^{11} e.q.

To observe a real counting rate of this order of magnitude would mean that a process, similar to electromagnetic production, would have to have a cross section 2×10^5 larger than the electromagnetic cross section. Both of the CH_2 results give an upper limit on the total μ-pair yield which is 3 percent of the (experimental) π^+ yield. A previous value of 2 percent has been given by Peterson, Gilbert, and White,[4] as a byproduct of their

[4] Peterson, Gilbert, and White, Phys Rev (in Press) and UCRL-703 Rev.

investigations of photo-meson production using photographic plates. The background with a Cu target was too high to make an estimate possible.

The relatively high accidental rate is inherently due to the electron singles rate flooding the wide gates necessary to receive the decay electron. Any possible improvement should therefore include a means of drastically reducing the electron singles rate. A possible means of doing this would be to shield the electron counters from the target. A faster coincidence for the μ-mesons would only be of partial help as it was found that approximately 1/4 of the coincidences formed were real. It should be noted that the accidental rate will go theoretically as the 4^{th} power of the beam intensity. Experimentally this variation was verified.

Another major problem is that of how to make a practical increase in the energy acceptance of the counters without detrimentally increasing the accidental rate. Other improvements should be noted; such as a higher beam energy (although multiple π production might hinder this); an improved β gate; and generally refined electronics. It can be seen, using reasonable factors for these improvements, that while the μ-pair/π^+ ratio could be improved, the electromagnetic pair production yield would be far from reached.

It is a pleasure to acknowledge the guidance of Dr. E. McMillan on this project, and some helpful discussions with J. Steinberger and A. S. Bishop. We also thank Geo. McFarland and the Synchrotron Crew for their assistance; John Barale, Al Stripeika, and Vern Ogren for their invaluable help with the complex electronics; and Harry Powell who did the glasswork for the counters.

Information Division
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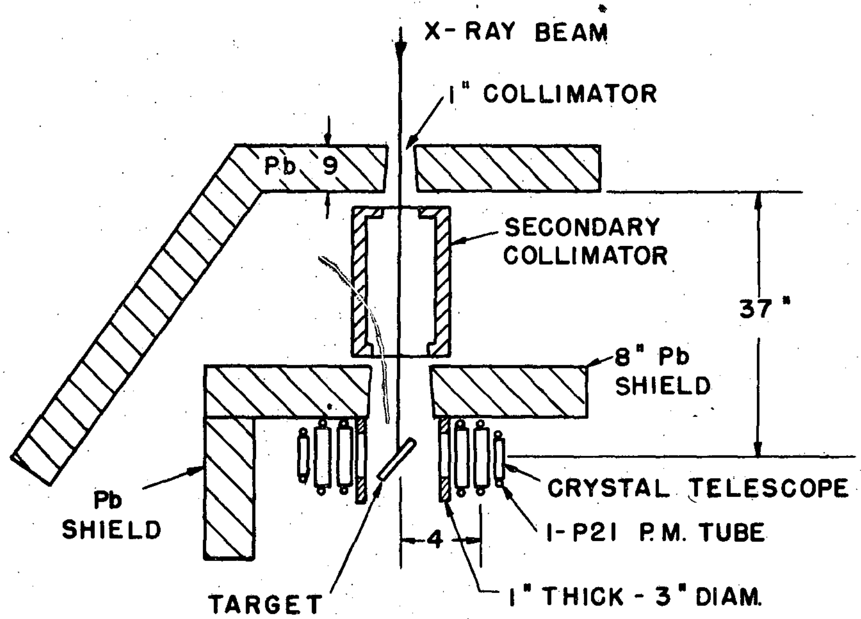
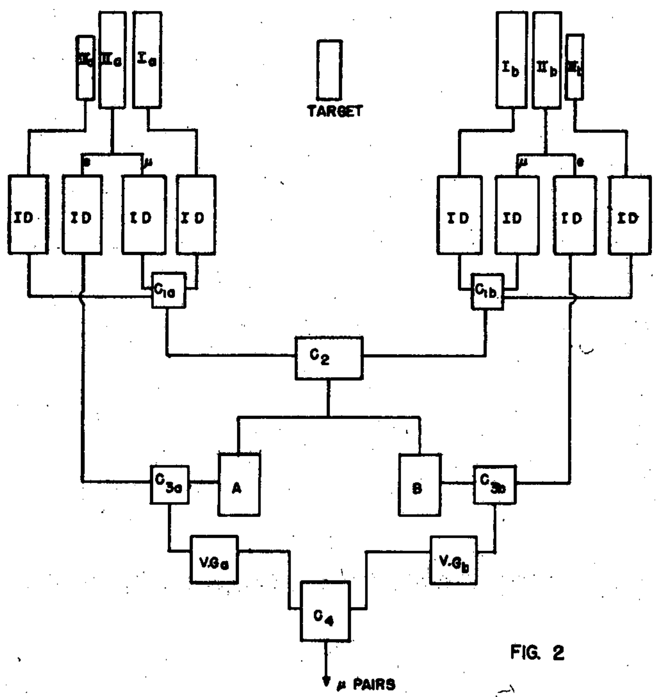


90° GEOMETRY

FIG. 1

MU 1439

ELECTRONICS ARRANGEMENT



I, II, III a & b – 3 CRYSTAL TELESCOPE

I.D. – INVERTER DISCRIMINATORS

μ – MESON PULSE

e – ELECTRON PULSE

C_{1a}, C_{1b} – COINCIDENCE-ANTICOINCIDENCE UNIT

C_2 – PAIR COINC. $\tau \sim 10^{-7}$ SEC

C_{3a}, C_{3b} – ELECTRON-GATE COINC. $\tau \sim 10^{-7}$

C_4 – FINAL COINC. $\tau = 10^{-7}$

A, B – 4 CHANNEL – 2 μS TANDEM GATE MAKER

VG_a, VG_b – PULSE WIDENER

FIG. 2

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