New Phenomena in Subnuclear Physics

Edited by Antonino Zichichi

Part B

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Preface

In July 1975 a group of 122 physicists from 68 laboratories of 27 countries met in Erice to attend the 13th Course of the International School of Subnuclear Physics.

The countries represented at the School were: Australia, Austria, Belgium, Brazil, Canada, Chile, Denmark, France, Germany, Greece, India, Iran, Israel, Italy, Japan, Mexico, The Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, The United Kingdom, The United States of America and Yugoslavia.

The School was sponsored by the Italian Ministry of Public Education (MPI), the Italian Ministry of Scientific and Technological Research (MRST), the North Atlantic Treaty Organization (NATO), the Regional Sicilian Government (ERS) and the Weizmann Institute of Science.

The School was one of the most exciting, due to the impressive number of discoveries made not only in the field of the new particles by the MIT-BNL (reported by S. C. C. Ting) and by the SLAC-SPEAR (reported by M. Breidenbach) Groups, but also in the field of high energy neutrino interactions where Carlo Rubbia observes μ-pairs, together with bumps in the total energy of the hadronic system at $W_h \sim 4$ GeV and a discontinuity in the $\langle y \rangle$ at $E_\nu \sim 50$ GeV plus a bump at $W_{min} \simeq 4$ GeV; all these phenomena being possibly connected.

To this remarkable amount of new and exciting results it has to be added the great discovery of DORIS (reported by B. Wiik) on the first example of a new particle P_c: the highlight of the Course. Needless to say that it was too easy this year to have discussions of great interest - the atmosphere of the School being such that, even in much more sober years of meagre discoveries, it was possible to have interesting discussions.

No doubt: a new era has been opened in particle physics; and this is the first volume of it.

At various stages of my work I have enjoyed the collaboration of many friends whose contributions have been extremely important for the School and are highly appreciated. I would like to thank most warmly: Dr. N. Craigie, Mrs. M. Denzler, Dr. A. Gabriele, Mrs. C. Giusti, Mrs. H. Kirk, Miss P. Savalli, Mrs. S. Vascotto, Mrs. K. Wakley, and Miss M. Zaini for the general scientific and administrative work, and Drs. R. K. Ellis and R. Petronzio for their work as Scientific Secretaries.

A final word of acknowledgment to all those who, in Erice, Bologna and Geneva, helped me on so many occasions and to whom I feel very much indebted.

A. Zichichi

Geneva, January 1976

Contents of Part A

Contents of Part B

J PARTICLES, AND SEARCH FOR MORE LONG LIVED PARTICLES

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INTRODUCTION

There have been many theoretical speculations [1] on the existence of long lived neutral particles with a mass larger than 10 GeV/c^2 which play the role in weak interactions that photons play in electromagnetic interactions. There is, however, no theoretical justification, and no predictions exist, for long lived particles in the mass region 1-10 GeV/c^2.

Even though there is no strong theoretical justification for the existence of long lived particles at low masses, there is no experimental indication that they should not exist. Until last year no high sensitivity experiment had been done in this mass region.

There are calculations based on parton models on the production of an e^+e^- continuum from pp interactions [2]. An early experiment at the AGS [3] studied the continuum of $\mu^+\mu^-$ from p + Uranium $\rightarrow \mu^+\mu^-$ + X. This experiment gives approximately the size of $\mu^+\mu^-$ yield. In the last ten years there have been many experiments [4] at Brookhaven, at CERN I.S.R., at Fermi Lab, etc. to study the inclusive e (μ) production P+P $\rightarrow$ e(μ) + X. Again, these experiments gave no indication of a long lived particle.

My talk will consist of two parts:

1. The Discovery of the J Particle
2. The Origin of the J Particle

1. DISCOVERY OF THE J PARTICLE

The discovery of the J Particle [5,6,7] in proton-proton collisions by the MIT-BNL group at Brookhaven National Laboratory follows a decade of experiments associated with e^+e^- pair productions from hadron interactions at high energies. One learns three kinds of physics from the reaction

$$h + p \rightarrow e^+e^- + X.$$

i) Using a 7.5 GeV bremsstrahlung photon beam one can compare the e^+e^- yield with predictions of QED at large momentum transfer or small distances, $<10^{-14}$ cm [8].

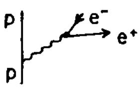
ii) One can study the e^+e^- decay of photon-like particles with spin 1 and negative parity and charge conjugation, such as the ρ, [9] ϕ, [10] ω, [11] and ρ' [12] and measure the coupling strengths between photons and massive photon-like particles [13]. One can also study the production mechanisms of these photon-like particles produced by photons.

iii) Search for additional particles which decay to e^+e^- from $pp \rightarrow e^+e^- + X$ or $pp \rightarrow \mu^+\mu^- + X$.

1.1 <u>Design Considerations</u>

To perform a high sensitivity experiment, detecting narrow width particles over a wide mass region, we make the following four observations:

i) Since the e^+e^- comes from photon decays, the yield of e^+e^- is lower than hadron pairs ($\pi^+\pi^-$, K^+K^-, pp, K^+p, etc.) by a factor



$$\frac{\alpha^2}{m^4} F^2 (m^2) \approx 10^{-6}.$$

The factor α^2 comes from the virtual photon decay, m^{-4} is the photon propagator and $F(m^2)$ the form factor of the target proton, where m is the invariant mass of the e^+e^- pair.

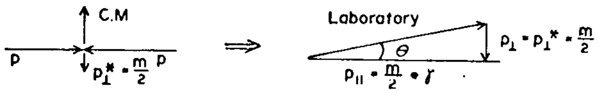
ii) Because of (i) one must design a detector which can stand a high flux of hadrons to obtain a sufficient yield of e^+e^- pairs.

iii) The detector must be able to reject hadron pairs by a factor $\sim 10^6 - 10^8$.

iv) In choosing the best kinematic region to detect the decay of new particles, one notes that at high energies, inclusive production of ρ, π and ω from p-p interactions can all be described in the c.m. system by a dependence of the form

$$\frac{d^3\sigma}{dp_{\parallel}^{*} dp_{\perp}^{*2}} = \frac{a e^{-bp_{\perp}^{*}}}{E^{*}} , \quad \text{independent of } p_{\parallel}^{*} ,$$

where $p_{\parallel}^{*}$, $p_{\perp}^{*}$ and E^{*} have their usual meaning.



Thus the maximum yield will occur when the particle is produced at rest in the center of mass. If we look at the 90° decay of the e^+e^- pair, we note that they emerge at an angle $\theta = \arctan\left(\frac{1}{\gamma}\right) = 14.6°$ in the lab system for an incident proton energy of 28.5 GeV, independent of the mass of the decaying particle.

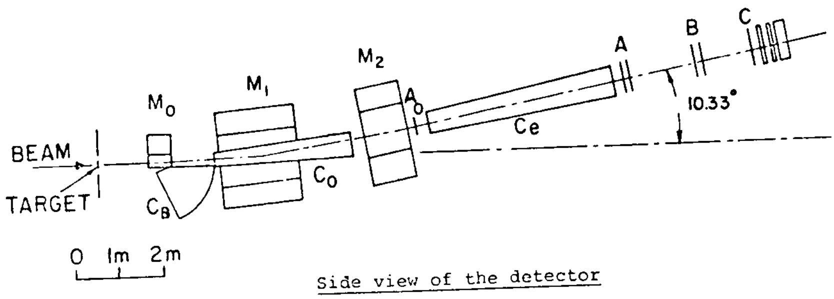
1.2 Experimental Set-Up

Figure 1 shows the plan and side views of the spectrometer and detectors. Bending is done vertically to decouple angle (θ) and momentum. The field of the magnets in their final location was measured with a three dimensional Hall probe at a total of 10^5 points C_B, C_o and C_e are gas threshold Cerenkov counters. C_B is filled with isobutane at 1 atm., C_o is filled with hydrogen at 1 atm. and C_e is filled with hydrogen at 0.8 atm. A_o, A, B and C are proportional wire chambers with 2 mm spacing and a total of 4,000 wires on each arm. Behind chambers A and B are situated two planes of hodoscopes, 8x8, for improved timing resolution.

Behind the C chamber there are two orthogonal banks of lead glass counters of three radiation lengths each, the first containing twelve elements, the second thirteen, followed by one horizontal bank of lead lucite shower counters, seven in number, each ten radiation lengths thick, to further reject hadrons from electrons and improve track identification.

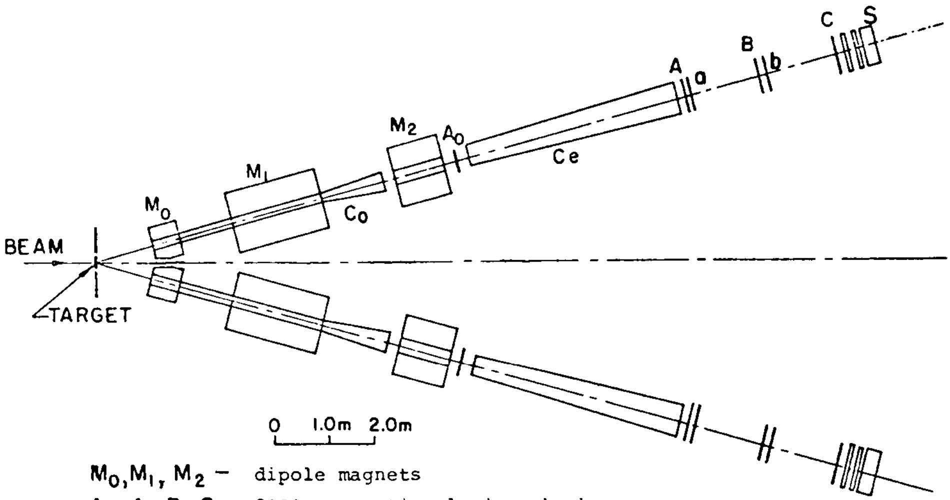
The following are the unique features of this experiment:

i) To obtain a rejection against hadrons of 10^8 or better, the two gas Cerenkov counters in each arm, C_o and C_e



Side view of the detector

Fig. 1b



M_0, M_1, M_2 — dipole magnets

A_0, A, B, C — 8000 proportional wire chambers

a, b — 8x8 hodoscopes

S: — 3 banks of pb-glass shower counters

C_B, C_0 C_e — gas cerenkov counters

Plan view of the detector

Fig. 1a

(Fig. 2a, b) are filled with hydrogen and made with thin mylar windows to reduce knock-on and scintillation effects. The counters are painted black inside and are decoupled by the strong magnetic fields of M_1 and M_2, so that knock-on electrons produced in C_o do not enter C_e and only electrons along the beam trajectory will emit Cerenkov light which is focussed onto the photomultiplier tube. Special high gain, high efficiency phototubes of the type RCA C31000M were used so that the counters C_o and C_e can be operated at 100% efficiency with very low voltage. The counter C_o collects an average of 9 photoelectrons. To ensure the voltage was set on a single electron and not on e^+e^- pairs from π^o's, which would give ~18 photoelectrons, the counter C_o was filled with He and the location of the single photoelectron peak was found (Fig. 2c).

ii) To be able to handle a high intensity of 2×10^{12} protons per pulse with consequent single arm rates of ~20 MHz, there are eleven planes of proportional wires ($2 \times A_0$, 3xA, 3xB, and 3xC) rotated 20^o with respect to each other as shown in Fig. 3a to reduce multitrack ambiguities. To ensure the chambers have a 100% uniform efficiency at low voltage (Fig. 3b) and a long life time in the highly radioactive environment, a special Argon-Methylal mixture at 2^o C was used.

iii) To reduce multiple scattering and photon conversion, the material in the beam is reduced to a minimum. The front and rear windows of C_o are 125 μm thick respectively, both mirrors of C_o and C_e are made of 3 mm black lucite and hodoscopes are 1.6 mm thick.

The thickness of one piece of Beryllium target is 1.8 mm and the nine pieces are each separated by 7.5 cm so that the particles produced in one piece and accepted by the spectrometer do not pass through the next piece.

iv) To reduce photon and neutron contamination the location of all the hodoscopes and lead glass counters are such

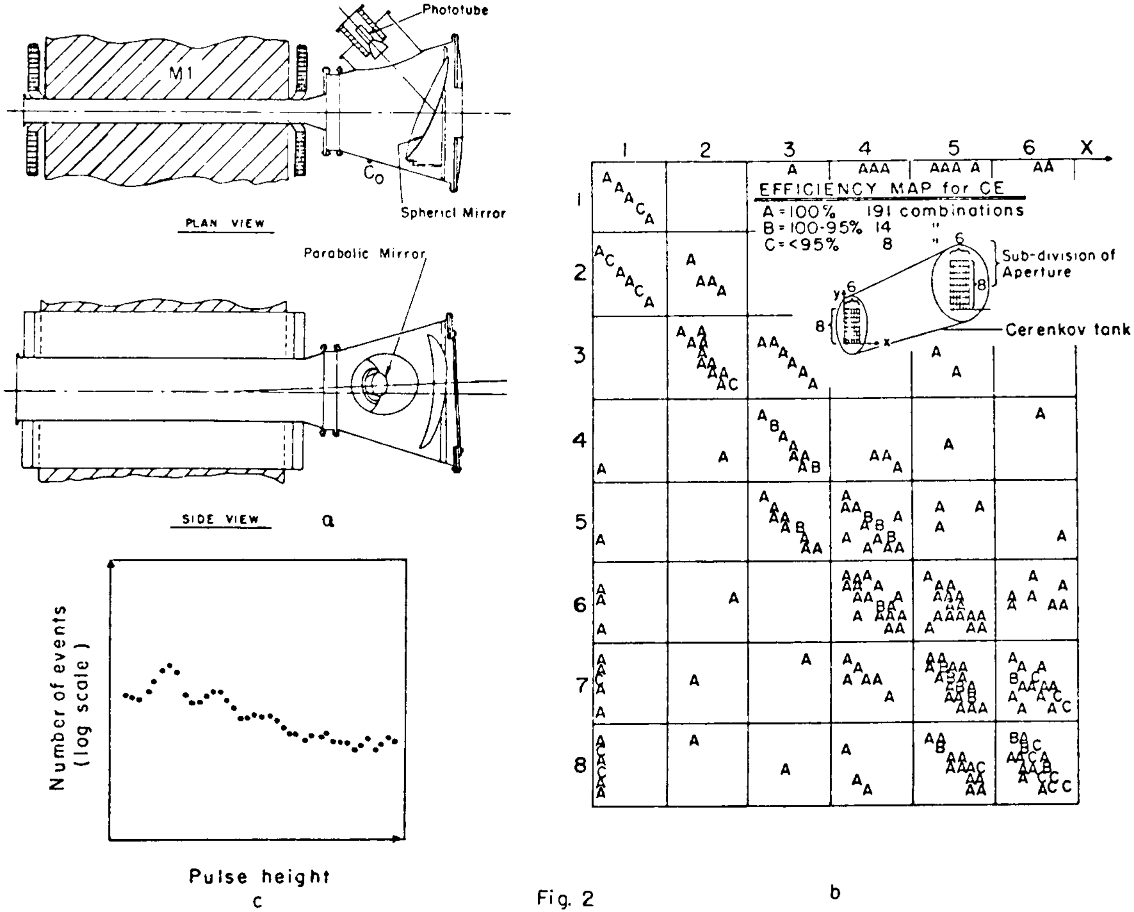
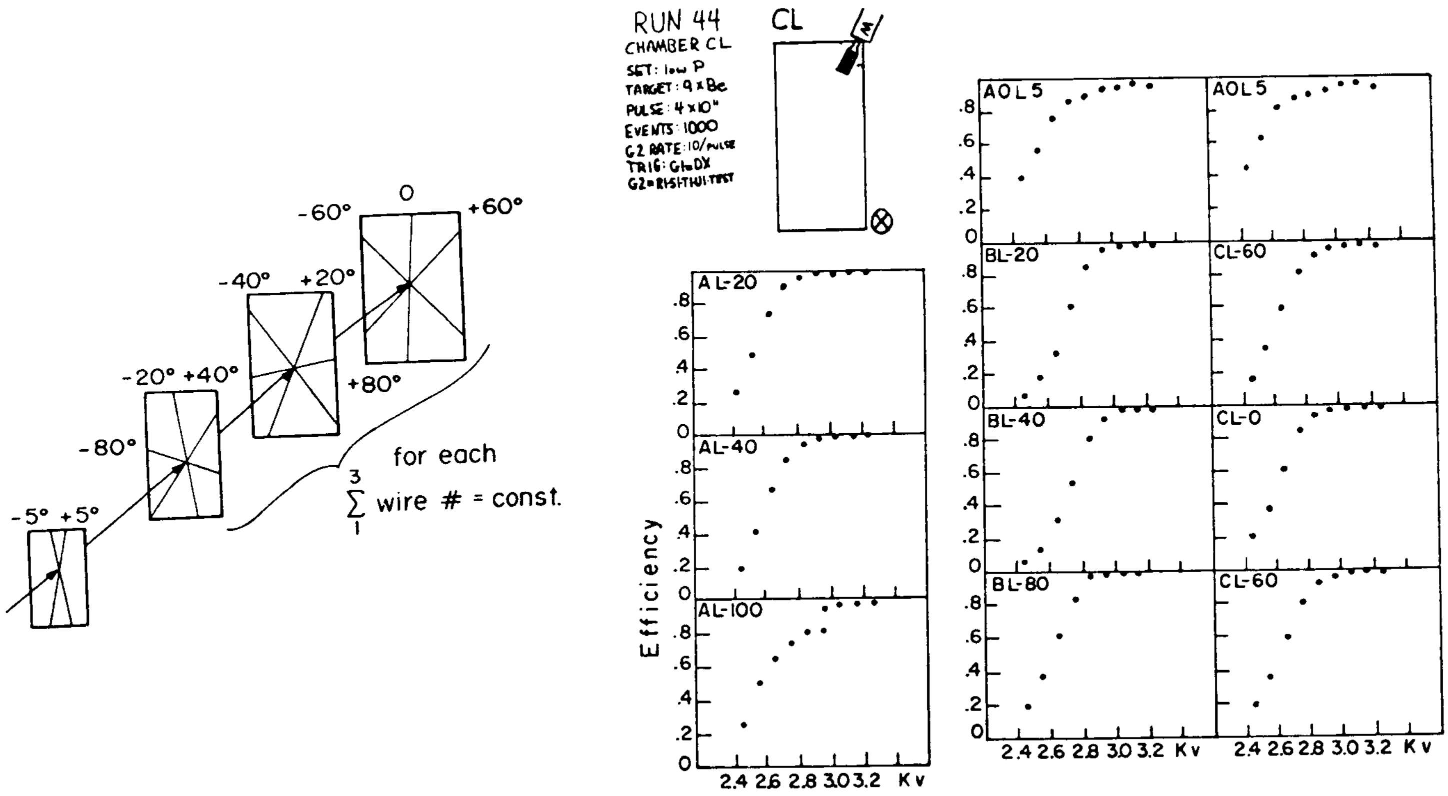


Fig. 2

a. Plan and side view of the C_O counter shown in its location in the experiment.
b. Mapping of the efficiency of the C_e counter over its whole phase space. The letters on the plot refer to efficiencies measured for trajectories between the corresponding points marked on the grid at each end of the counter.
c. Pulse height spectrom from the photo tube (RCA C31000M) of the C_O Cerenkov counter. Clearly visible are the one, two or three photoelectron peeks.



a b

Fig. 3

(a) Relative orientation of the planes of wires in the proportional chambers.

(b) Efficiency of all the wire planes as a function of the applied voltage. The position where this measurement was made is indicated by the sketch in the top left hand corner.