CERN/ISRC/79-7
ISRC/P100
28 February 1979

PROPOSAL FOR A FIVE-FOLD INCREASE IN THE ACCEPTANCE OF R-108 FOR ELECTRON PAIRS

A.L.S. Angelis[3], H.J. Besch[1], L. Camilleri[1], T.J.Chapin[4], R.L. Cool[4], J.T. Linnemann[4], N. Phinney[3], R.W. Rusack[2], A.M. Segar[3], M.J. Tannenbaum[4], J.M. Yelton[3].

CERN[1]-Columbia[2]-Oxford[3]-Rockefeller[4] Collaboration

I. - INTRODUCTION.

The CERN-Columbia-Oxford-Rockefeller (CCOR) collaboration proposes, in this document, a modification of their apparatus that would extend the detection of electrons, γ's and π^0's to nearly the whole azimuth, to complement the full azimuth charged particle detection now available. This would result in an increase in the acceptance for high mass e^+e^- pairs by a factor of 5. Furthermore, the ability to detect γ's and π^0's over a much larger angular region is clearly beneficial to the study of jets, and also provides the possibility for a total neutral energy trigger.

Specifically, the physics objectives for the improved detector are the following :

1) Search for "Toponium" or any other high mass state decaying into e^+e^- before PETRA, CESR and PEP sweep the field. The sensitivity is 2% of the Υ cross-section for 10 detected events.

2) Systematics of Lepton Pair Production. As well as the cross-section, the transverse momentum and rapidity distributions as a function of mass will be measured for the continuum, the Υ and any new resonances. The $\langle p_T \rangle_{e^+e^-}$ as a function of $m_{e^+e^-}$ is now predicted by QCD and constitutes a test of the theory. We emphasize that the ISR is the only accelerator where this measurement can be made.

3) Search for Jets Balancing the Transverse Momentum of a High p_T Lepton Pair. Our present data indicate that 10% of the high mass e^+e^- pairs will have $p_T > 3$ GeV/c. If this large p_T is balanced by a quark or gluon jet, the jet will be clearly seen in the improved detector.

4) Search for χ (?) States. For those $\Upsilon(9.5)$ which may be produced with an associated γ ray by a cascade decay from a χ state

$$\chi(?) \rightarrow \Upsilon + \gamma \quad \Big\lfloor \rightarrow e^+e^- \ ,$$

over 50% of the associated γ rays will be detected in the modified apparatus.

5) Improved Measurement of Jets Produced along with a High p_T π^0. The full azimuthal coverage for both neutral and charged particles greatly improves the acceptance for tri-jet configurations. It also allows the unbiased study of the angular distribution of secondaries in a total neutral energy trigger.

II. - THE APPARATUS.

The present apparatus consists of a superconducting solenoid containing four double-gap drift chambers DC1 - DC4. Outside the coil are two arrays of lead glass counters and two MWPC's with cathode strip read out. The lead glass arrays used for the detection of electrons each subtend $\pm 33^o$ in azimuth (ϕ) and $\pm 38^o$ in polar angle (θ). After a considerable effort we feel that the different components of the apparatus are now well understood. In particular the hardware reliability of the drift chambers has been considerably improved and, in software, a thorough understanding of the time-distance relation permits us to achieve resolutions of 0.3 mm. It is clear to us that the major improvement that can be made in the detector is to increase its acceptance for the detection of electrons and photons.

It is not possible to extend substantially the lead glass arrays due to the presence of the return yoke above and below the coil. It is therefore proposed to remove those sectors of DC4 that are not in the lead glass acceptance and to replace them by lead-scintillator shower counters for the detection of electrons, γ's and π^0's. The chambers being modular, the removal of some of the sectors poses no big problem. The increase in acceptance thus achieved for e^+e^- pairs is a factor of 5 over the present apparatus.

The modified set up is shown in Fig. 1. The shower counters are divided into 2 arrays, each array being itself divided azimuthally into 18 counters. A counter consists of 17 layers of 4 mm thick scintillator interleaved with layers of 5 mm lead for a total of 15 radiation lengths. The first four layers of scintillators are read separately in order to reject hadrons by the early shower development technique. The light produced in the scintillator is collected by light guides going through holes in the magnet pole pieces to phototubes located outside the magnet.

Both ends of the counters are read.

It has been shown experimentally [1] that the amount of light produced in shower counters of the type described here is unaffected by placing them in a magnetic field. Each counter is 150 cm long and the position of a shower along the counter is obtained from a comparison of the time of arrival of the pulses at the two ends and also as a check, from a comparison of the pulse heights at the two ends.

Modifications to the present vacuum chamber in I-1, which contains support rods in the acceptance of the new shower counters, have been discussed with the ISR division, and can be made in time.

III. - PERFORMANCE OF THE SHOWER COUNTERS.

A prototype counter is currently being built and will be tested at the PS in early March. Final results on the performance of the counter will have to wait until then. However, an estimate of the performance can be obtained from the literature.

a) Energy resolution. It is hoped to achieve an energy resolution [2] of $\sigma(E)/E = \pm 0.14/\sqrt{E}$ (E in GeV) which would yield a FWHM of $\Delta M = 1$ GeV/c^2 at the upsilon and 1.4 GeV/c^2 at a mass of 20 GeV/c^2. These numbers are comparable to the resolution achieved by the present experiment. An advantage of the shower counters inside the solenoid is that the resolution is not affected by energy loss in the coil.

b) Shower position. The azimuthal position of the shower is obtained directly. The position of the shower along the length of the counter is obtained by the difference in time of arrival of the signals at the photomultipliers at the two ends. A positional accuracy of $\pm$ 3 cm has been achieved with a similar counter [3].

IV. - BACKGROUND REJECTION.

The backgrounds to the e^+e^- experiment come from three sources :

a) spatial overlaps of a charged particle with a π^0

b) conversions, either internal (Dalitz) or external, of photons from π^0 or η decay and

c) charged hadrons which interact in the shower detector simulating an electron.

The raw rates for these processes - before applying any rejection criteria - are 4%, 8%, and 2% respectively of the π^0 rate, per particle. The presence of the magnetic field allows us to reduce the first 2 backgrounds to ½% and 2% simply by requiring that the momentum of the candidate electron as measured in the drift chamber roughly match the energy deposited in the shower detector. It should be noted, however, that such a requirement has almost no effect on background c), which at 2% per particle is the major background of the present experiment.

For the region of the proposed apparatus already covered by the current experiment, these rejections are unaltered since no changes are made. For the regions subtended by the new shower detectors, the momentum resolution of the tracking system will be worse by a factor of ~ 2. We have investigated the effect of this deterioration using our present data and find only a 10% increase in background.

The rejection against charged hadrons, the major background at present is considerably improved by the double sampling of the new shower counters. Tests of a similar double sampling configuration using lead glass [4] yielded rejection factors against charged hadrons of the order of 1000 per particle, whereas, the present configuration of lead glass and large pulse height in the B-counter only yields an overall factor of 100 per particle. Thus, for the new configuration we expect that background c) will be reduced by an additional factor of 100 overall.

V. - ACCEPTANCE AND EVENT RATES FOR e^+e^- PAIRS.

The angular acceptance of the lead glass and shower counter arrays are listed in Table I. The geometrical acceptance of the modified apparatus for the detection of e^+e^- pairs has been calculated as a function of mass and is plotted in Fig. 2, together with the acceptance of the present apparatus. The assumptions used in the calculation are

a) Mean p_T at production, $< p_T > = 1.6$ GeV/c.

b) x_F distribution given by

$$\frac{dn}{dx_F} = (1 - |x_F|)^{5.3}$$

c) Isotropic decay in the e^+e^- rest frame.

The acceptance is 37% at the Υ and 54% at a mass of 25 GeV/c^2. This is a gain of 5.5 and 4.3 respectively over the present apparatus.

The latest e^+e^- mass spectrum of R-108 obtained with an integrated luminosity of $8 \times 10^{37} cm^{-2}$ accumulated over 1600 hours of running is shown in Fig. 3. A total of 42 events observed in the Υ region (8.75 → 11.0 GeV/c^2) and 10 events are detected above 11 GeV/c^2. Scaling up the number of events in Fig. 3 to a 3000 hour run with the increased acceptance yields 430 upsilons and 80 events above 11 GeV/c^2. We would like to emphasize that this experiment requires the highest possible luminosity at $\sqrt{s}$ = 62 GeV.

VI. - JET STUDIES WITH A HIGH p_T π^0 AND A HIGH p_T e^+e^- TRIGGER.

The proposed modification does not interfere with the high p_T π^0 trigger using the lead glass. In fact, the modified detector is substantially improved for the study of jets. The added shower counters provide detection of π^0's and γ's over the whole azimuth thus complementing the detection of charged particles by the drift chambers. A more complete study of 2-jet and possibly 3-jet events is thus made possible. The added detector also allows a total neutral trigger. The price to be paid is a worsening of the charged particle momentum resolution by about a factor of 2 in the azimuthal region of the shower counters due to the removal of DC4 in that region. However, when studying jets pointed to the lead glass most of the tracks above 1 GeV/c are still contained in the angular region where DC4 remains, because of the strong azimuthal correlations [5].

VII. - TIME SCALE OF THE MODIFICATION.

The collaboration feels strongly that in order for the modification to be worthwhile, the experiment must be run before the long shut down of 1980. The reasons for this are :

a) The mass region above the Υ is now being explored by PETRA, soon to be joined by PEP, and it is therefore the last opportunity for the ISR to discover any possible new e^+e^- resonances in this region (toponium, middleonium etc...)

b) Beyond the 1980 shut down, the very high integrated luminosity

necessary to the study of e^+e^- pairs at 20 GeV/c^2 will not be available for two reasons :

i) the storing of antiprotons in the ISR part of the time

ii) the possible incompatibility of the steel low-β with the superconducting low-β. At best, if they are compatible, the gain in luminosity in I-1 over a standard region would be a factor of 1.5 instead of the present 2.1.

It has been ascertained that the scintillator could be delivered by the end of April. Central Workshop estimates that the counters could then be ready by the end of June.

We therefore are aiming to install the new detectors in the July September shut-down of 1979 during which time it is also planned to recalibrate the lead glass. This would give almost a year's running before the long shut-down of 1980.

REFERENCES

1) H. Jensing, Diplomarbeit, Hamburg 1977.
The counters tested were the ones used in the PLUTO detector at DORIS.

2) Proposal to search for new particles CERN/SPSC/78-144.

3) A Large Area Modular Electromagnetic Shower Detector for the CERN Intersecting Storage Rings, M. Basile et al.
(Submitted to Nucl. Instr. and Methods).

4. B.J. Blumenfeld et al., Nucl. Instr. and Methods 97 (1971) 427.

5. CCOR Collaboration, "Recent Results on Correlations and Jets in High Transverse Momentum p-p Collisions at the CERN ISR, submitted to the XIX International Conference on High Energy Physics, Tokyo, Japan - August 1978.

TABLE I

Angular Acceptance of Lead Glass

and Shower Counter Arrays

DETECTOR	NUMBER OF ARRAYS	$\Delta\theta$ EACH ARRAY	$\Delta\phi$ EACH ARRAY
Lead Glass	2	76	67
Shower counter	2	100	104

Figure captions.

Fig. 1 : The modified detector viewed along the beams.

Fig. 2 : The acceptance of the present detectors (R-108) and modified detectors calculated according to the assumptions described in the text.

Fig. 3 : The e^+e^- mass spectrum obtained in R-108. The spectrum for same charge events, a measure of the bakcground, is also shown.

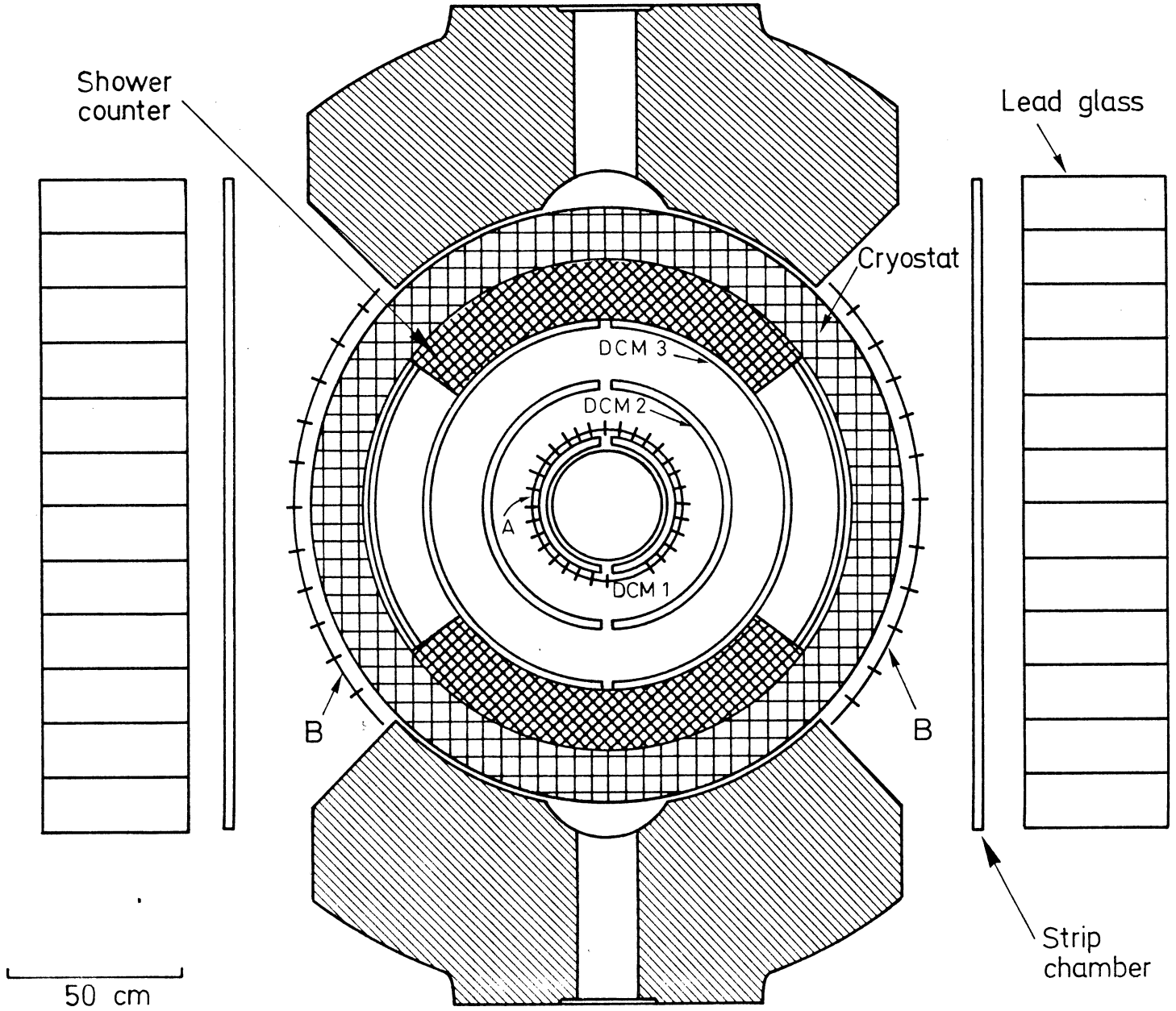

Shower
counter
Lead glass
Cryostat
DCM 3
DCM 2
A
DCM 1
B
B
Strip
chamber
50 cm

FIG. 1

FIG. 2.

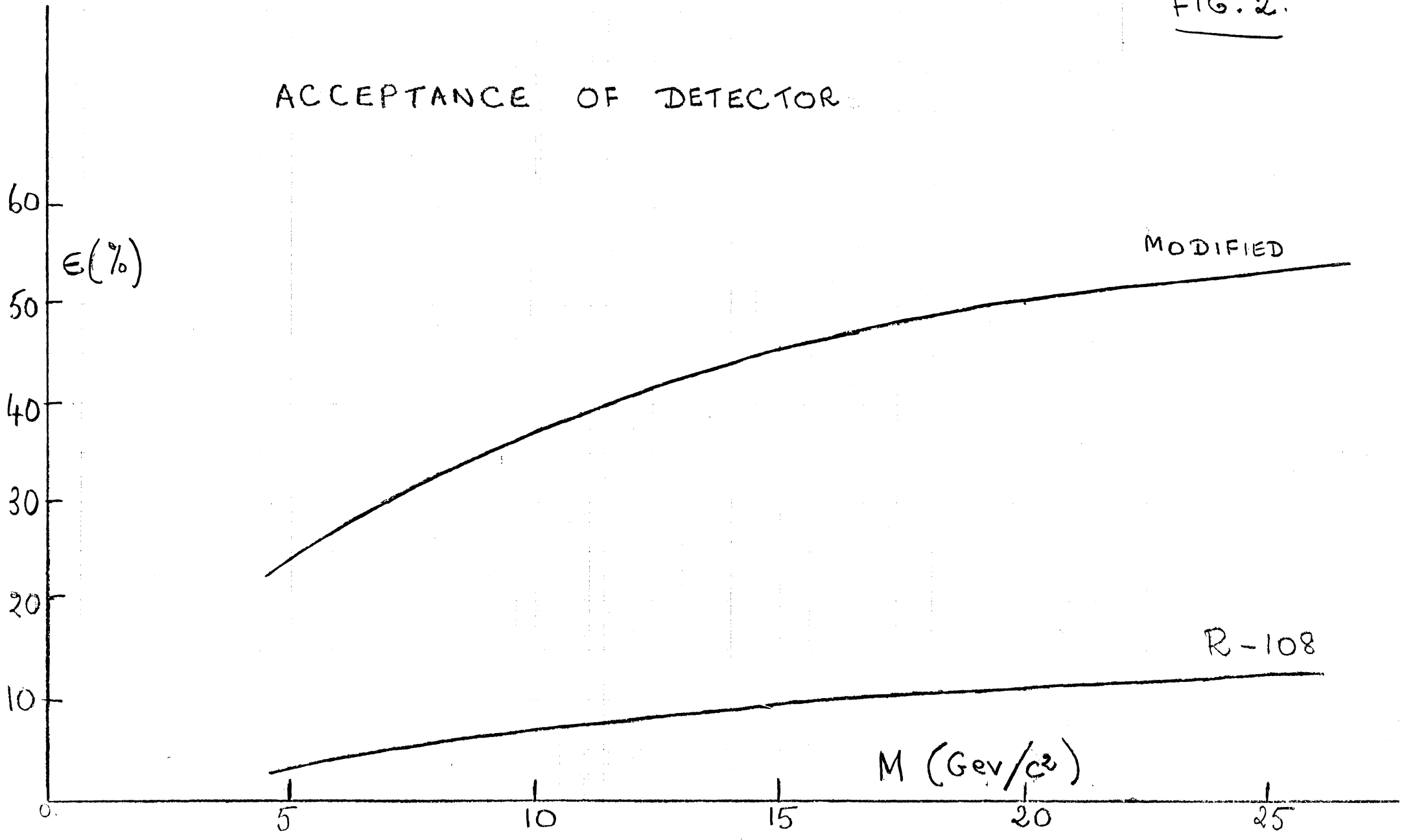
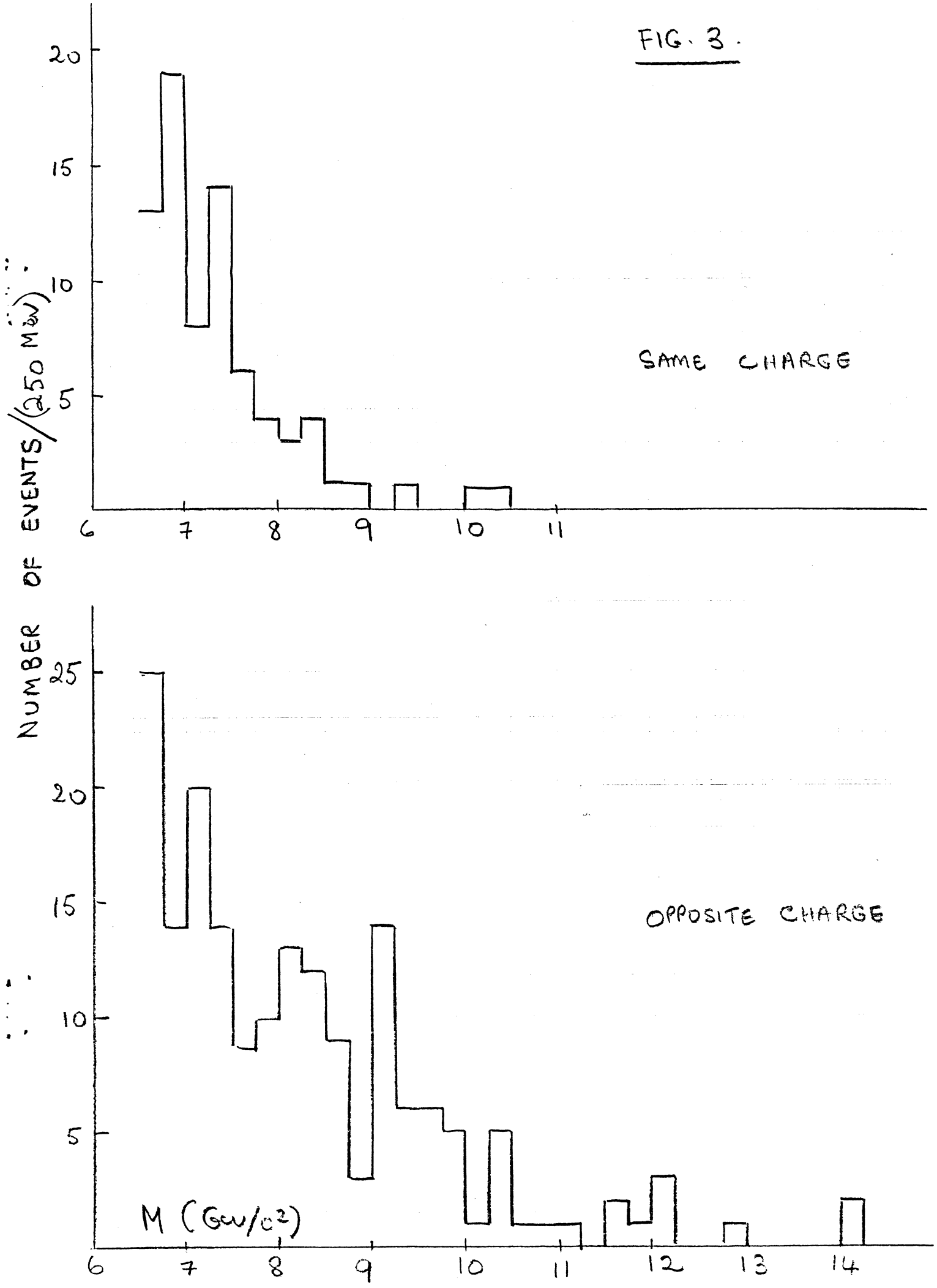

ACCEPTANCE OF DETECTOR
60
50
40
30
20
10
0
ε(%)
MODIFIED
R-108
M (Gev/c²)
5
10
15
20
25

FIG. 3.


NUMBER OF EVENTS/(250 MeV)
20
15
10
5
6
7
8
9
10
11
SAME CHARGE
25
20
15
10
5
6
7
8
9
10
11
12
13
14
M (GeV/c²)
OPPOSITE CHARGE