CERN/ISRC 73-28 Add. 1
9 November 1973

PROPOSAL FOR AN EXTENSION OF THE μ-PAIR EXPERIMENT TO INCLUDE CORRELATIONS WITH THE ASSOCIATED HADRONS

G. Diambrini-Palazzi, U.J. Becker, P.J. Biggs, A. Cook,
G. Everhart, P. Goldhagen, R. Little, K. Strauch
and S.C.C. Ting

Genova-Harvard-MIT Collaboration

and

G. Bellettini, P.L. Braccini, R. Castaldi, V. Cavasinni,
T. Del Prete, P. Laurelli, G. Sanguinetti and M. Valdata

Pisa

ABSTRACT

The Genova-Harvard-MIT Collaboration and the Pisa Group have decided to join together to perform at the same time the μ-pair search, which was proposed in the previous document CERN/ISRC 73-28, and a correlation study of the associated hadrons.

1. INTRODUCTION

Correlation studies at the ISR have proved to be very valuable tools for understanding the dynamics of particle production. A few examples are easily given. Inclusive two-particle correlations have been found to be positive for small rapidity distance between particles[1]. This phenomenon appears to be a dominating feature of large multiplicity pionization events[2,3]. Single particles emitted at small angles and more specifically forward protons at $x \sim 1$ have been found to be associated with a bunch of particles emitted towards the opposite hemisphere[4,2,3]. This forward-backward long-range positive correlation is one of the most clear signatures for single diffractive events. Particle multiplicity and angular distributions in association with large p_T photons (originating from π^0 decay) have peculiar properties[5,6] which appear to carry important information on the dynamics of the process.

The virtual (time-like) photon, giving rise to the $\mu^+\mu^-$ pair, appears to be an exceedingly good probe for further improving this study. In fact, one is allowed to control separately the momentum and the energy transferred to the hadronic matter; this is not allowed in the correlation studies that one may imagine by using hadrons as probes. Investigations on hadron dynamics by use of time-like photons have already started at electron-positron storage rings. Total annihilation cross-sections into hadrons have been measured up to $q^2 = 26$ GeV^2; one-particle and two-particle inclusive studies are now in progress, and results are likely to be available within a few years for values of q^2 up to 80 GeV^2 (SPEAR II, Doris). The reaction $pp \to \gamma_V(q^2)$ + hadrons, which we are preparing to study at the ISR up to $q^2 \sim 100$ GeV^2, is connected by certain models to the two-particle inclusive annihilation $e^+e^- \to \gamma_V(q^2) \to a + b$ + hadrons. The correlation between the two reactions is based on rather general arguments of crossing of the relevant inclusive diagrams, and it is made explicit -- with similar findings -- in terms of a wide class of quark models[7]. The plateau in cross-section extending over a range of $\ln q^2$ in rapidity -- thus producing a $\ln q^2$ increase of multiplicities -- which is expected for single-particle distributions in e^+e^- annihilation, is predicted to be found as a central plateau in the single-particle distributions from the ISR reaction. Similar connections are also expected between the two-particle distributions and correlation functions measured in the two classes of experiments. These explicit predictions arise from the same family of models which produce the invariant mass behaviour of the μ-pair spectrum which stands as the basic motivation of the proposed Genova-Harvard-MIT experiment. (See Figs. 8-9 of CERN/ISRC 73-28, 1 Oct. 1973. This document will be called I in the following.)

The Pisa-Stony Brook Collaboration has been interested in correlation studies for quite some time. The relevance of these studies in connection with the production of μ-pairs was also mentioned in the Genova-Harvard-MIT proposal, doc. I. As a matter of fact it is likely that correlation data will be essential in understanding the dynamical meaning of the μ-pair spectrum itself. The present experimental set-up of the Pisa-Stony Brook group is well suited, with appreciable but not fundamental modifications, to be combined with the original set-up of Genova-Harvard-MIT. The Pisa Group and the Genova-Harvard-MIT Collaboration have therefore decided to join together to perform this combined research program.

The rest of this document describes the experimental set-up, the planned schedule of installation works and of data taking, the data acquisition, and the computer time requirements.

2. THE EXPERIMENTAL SET-UP

The layout of the experiment is shown in Fig. 1. The μ-spectrometer is as illustrated in I, except that the central counter hodoscope and the chambers are extended to cover angles from ≈ 15° to ≈ 150°. The hodoscope and chambers replace the present L-box of the Pisa-Stony Brook (PSB in the following) experiment, both in the trigger and for measuring multiplicity and directions of tracks. The left hodoscopes of PSB are left in the same positions as at present. The right hodoscopes H1R, H2R are retracted by ∿ 2.4 m and cover angles smaller than 15°. Finally H3R and H4R remain in the present positions.

The beam-beam trigger of the present PSB experiment can be preserved in the new geometry, and thus a full inclusive trigger will be available for the μ-pair search. Accurate off-line study of time-of-flight distributions will allow us to reduce the background contamination in the beam-beam sample to less than 1% [8]. This will add another important rejection criterion against background to those already mentioned in I.

In the present PSB experiment it has been found that additional rate due to δ-rays, particle conversions in vacuum pipes and counters, etc., makes an accurate multiplicity measurement very difficult. The situation would be greatly improved if one added chambers into the system to determine the direction of each track. In fact, the PSB Collaboration has made a test with an optical spark chamber placed behind hodoscope H2L at about 4 m away from the centre of the interaction region. From the result of a vertex reconstruction they obtained a clear separation of tracks which came from the interaction region and those which do not. The latter would be counted as good tracks in the hodoscopes, and would cause a substantial over-estimate of the multiplicity. This result is in agreement with that expected from a Monte Carlo calculation of the effect of secondary interactions. With this result in mind, we propose to implement the forward hodoscopes with a system of multiwire proportional chambers, in order to improve the measurements of multiplicities and angular distributions of charged particles in the forward cones. Eventually, by making use also of the central chamber and hodoscope information, the position and direction of each track will be detected with good accuracy, high efficiency, and good background rejection power over $\approx 4\pi$ solid angle.

The design of the chambers is shown in Fig. 1. Reconstruction of primary tracks and rejection of spurious ones have been shown to be feasible with a Monte Carlo calculation based on this chamber arrangement.

The dimensions of the chambers of the left and right cones are given in Table 1. Each chamber consists of three planes with 60° rotation with respect to each other. Furthermore, any two successive chambers have a 20° relative rotation. The resolution in each coordinate is 1 cm (5 wires of 2 mm spacing grouped into one amplifier).

In the region of $15° \lesssim \theta \lesssim 150°$, particles are detected by the multiwire proportional chambers C4′, C4, C4″ and by hodoscopes S′, S, S″. The hodoscope has 36 elements. Each element covers 10° in azimuthal angle. Both C4 and S are part of the μ-pair detector. Chamber C4 consists of eight rectangular chambers surrounding the bicone, with six planes in each chamber. The direction of wires in any one plane is rotated with respect to the directions of the wires in all other five planes. The wire spacing in each plane is 4 mm. Track reconstruction ambiguities are kept to a minimum owing to the large number of individual chamber modules (eight modules for C4) in this region. Because of this and of the good spatial resolution, it should in general be possible to reconstruct the vertex of interaction of the event by making use of tracks in this region. We are at the moment preparing a reconstruction program for the central region and testing it with a detailed Monte Carlo calculation. The information of the vertex will give addiiional constraint to the reconstruction of tracks in other regions. Both C4′ and C4″ consists of four chambers of three planes each. The wire resolution is 1 cm.

The sizes and number of chambers are chosen such that the average charge multiplicity (from simulation of events at 26 GeV/c-26 GeV/c ISR beam momenta) in each chamber is less than 1.5. This greatly simplifies the pattern recognition problem. In the forward direction most of the tracks enter three chambers (nine planes) with 1 cm wire resolution. In the central region, most of the tracks go through six planes of 4 mm wire spacing. For the chambers in the forward region (CH1 to CH9), we plan to make use of the experience gained by the group which has built the chambers for the SFM forward detectors[9)] at the ISR. The total material of each three-plane chamber will be about 0.9 g/cm^2, and the chamber frame thickness will be about 5 mm independent of chamber size. This enables the sensitive area of the chamber to get very close to the vacuum pipe. Also one avoids having particles traversing thick massive frames, which would be sources of abundant spurious interactions.

3. SCHEDULE OF THE EXPERIMENT AND, RUNNING TIME

The L-box of the Pisa-Stony Brook experiment will be replaced with a provisional 8,000 wire proportional chamber box during the 1974 end-of-year shutdown. These chambers are at present being used at BNL and will be carried to CERN at the end of that experiment. By the end of 1974, part of the chambers of the forward cones will also be ready and installed. During the first part of 1975 we plan to complete the installation of these chambers and to put the system in running condition. The installation of the μ detector can start in Spring 1975 and be completed in a few months. By the summer of 1975, the μ telescope should also be ready, and data taking with the complete set-up will start.

We estimate that the running time of 1000 hours at beam energies of 22 GeV or more, and at an average machine luminosity of 2×10^{30} cm^{-2} sec^{-1}, which was requested in doc. I, can be obtained in one year of normal ISR operation. We therefore ask to be allowed to remain on the floor until the summer of 1976.

4. DATA ACQUISITION AND COMPUTER TIME REQUIREMENT

The present computer of PSB will store the information from the forward cones, and the PDP 11-45 computer of the MIT group will store the information from the central chambers and the μ telescope. A common flag will allow this information to be correlated. Since the event rate is expected to be low, no major problem should arise from off-line computing. We have done a Monte Carlo study of the reconstruction of tracks through the forward chambers, and we have found that the routine for primany track reconstruction and spurious track rejection can be run in a reasonable time. However, the experiment is complex enough that many auxiliary programs have to be run and many test runs will have to be taken and analysed, not only in our home Institutions but also at CERN. We feel we can safely estimate that the CERN computer time at present used by PSB (about 300 hours 660 CP time per year) will be sufficient during the full course of the experiment.

Spokesmen

G. Bellettini and S.C.C. Ting will be the spokesmen for this experiment.

Acknowledgements

We warmly thank Drs. J. Ellis and C.H. Llewellyn Smith for many interesting discussions on their theoretical ideas concerning the hadron distributions in correlation with the virtual photons.

Table 1

Sizes of chambers in the forward cones
(three wire planes in each chamber)

	No. of chambers (one above, one below the beams)	Dimension of each chamber (cm)
CH1	2	70 × 140
CH2	2	70 × 140
CH3	2	90 × 180
CH4	2	50 × 100
CH5	2	50 × 100
CH6	2	40 × 80
CH7	2	60 × 120
CH8	2	70 × 140
CH9	2	50 × 100

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Figure caption

Fig. 1 : Side view of the combined arrangement of the μ detector and hadron detector.

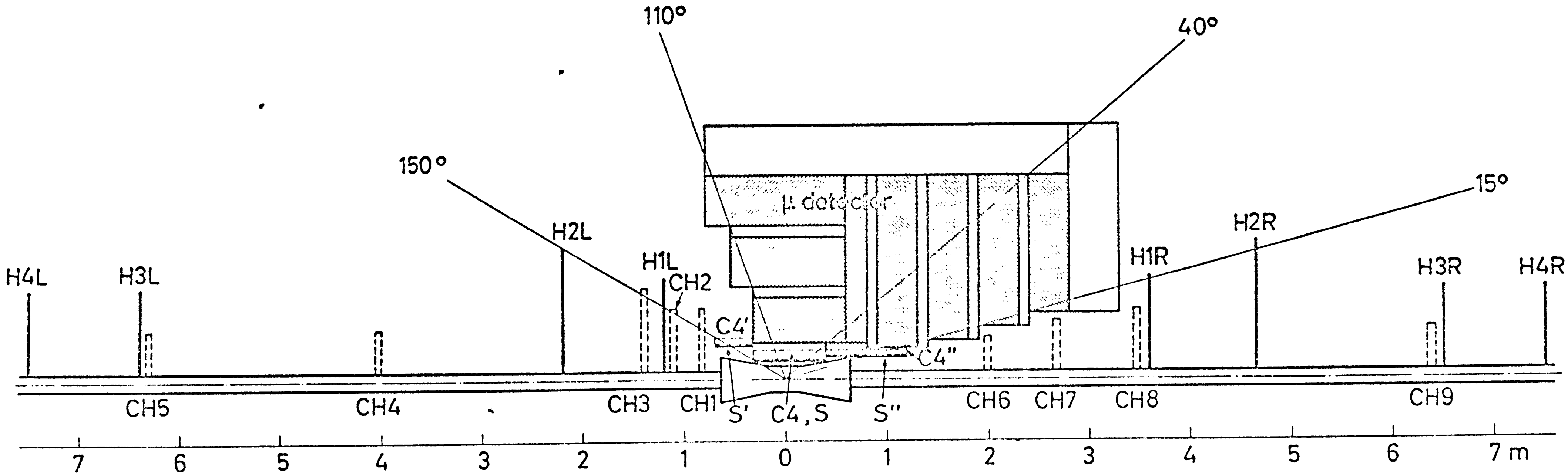

FIG 1 Side view of the combined arrangement of the μ - detector and hadron detector