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CERN - EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/SPSC/78-41
SPSC/I 108
31 March 1978

LETTER OF INTENT

STUDY OF CHARMED HADRONS IN THE EHS

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1. INTRODUCTION

The recent neutrino beam dump experiments [1] indicate the existence of a new source of ν_e in high energy interactions of protons in a copper target. Interpreted as the hadronic production of a charmed particle, with subsequent semi-leptonic decay (e.g. $D \to K^* e\nu_e$) these results show that the cross section for the production of charmed hadrons could be in the range 100-400 μb/nucleon. A recent experiment at Fermilab [2], detecting fast μ's in a magnetic spectrometer, studying the hadron shower in a precise calorimeter, and interpreted along similar lines, gives a comparable value of the production cross section.

In the present letter of intent, we discuss the possibility of using the European Hybrid Spectrometer (EHS), [3] for the study of charmed particle production and decay at this level of cross section. We know of several other experiments aimed at similar studies, at Fermilab, and particularly at CERN, SPSC/P 95 [4]. By the time of the beginning of the operation of EHS, some new results may have arisen, to be taken into account in the design of the EHS exposure. Here, we examine briefly one mode of trigger/tagging and the corresponding event rate, and we list a number of points which we would like to study in order to prepare a detailed experiment proposal.

2. EXPOSURE

The chamber is exposed to a pion beam(*) of the highest available energy. By use of a trigger, we attempt to photograph events with charm production and decay. The trigger detects the electrons from the leptonic decay of the charmed mesons D and D^*. As charmed hadrons are expected

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(*) The available evidence on J/ψ production shows a higher cross section for incident pions than for incident protons. It is supposed that the cross sections for charmed particle production have a similar behaviour.

to be produced in pairs, the trigger based on a specific decay mode of one of the charmed hadrons, presumably gives a source of (the other) charmed hadrons, unbiased with respect to decay modes. The well-known advantages of a visual detector, (the bubble chamber with its 4-π solid angle and multi-particle detection) are enlarged by the measurement accuracy and particle identification properties of the EHS. It is hoped to identify charmed mesons and baryons, to have a glimpse at their production mechanisms, and to study their decay modes.

Two methods of selection are contemplated: based either on muon detection, to be further studied, or on electron detection. The lead-glass γ detectors of the EHS are efficient electron detectors, with the additional requirement of an incident charged particle (e.g. with simple scintillators). The discrimination between e-m and hadronic showers may be improved by the use of a relatively thin lead scintillator sandwich, in front of the lead glass, by the use of threshold Cerenkov counters, and by the use of ISIS.

The ratio (detected charmed event)/(other events), without trigger, is about 10^{-4}. We envisage to use a trigger, requesting an interaction (interaction trigger) or an interaction in the fiducial volume (fiducial volume trigger), combined with a first approximation of single electron selection (e.g. using information from IGD and FGD only) in order to reduce the picture taking to about 1/7 expansions. A more refined single electron detection is then used, on-line, to flag, say, 1/20 to 1/40 photographs. Further single electron detection (reaching 1/100 or perhaps 1/200) is done off-line using all EHS information apart from the film.

3. EVENT RATES AND ACCEPTANCES

Assuming an incident beam of 7 pions per pulse, at the highest possible energy (340 GeV/c) and a standard 20 day run of EHS giving(*) $\sim$ 60 ev/μb, a charm production cross section of 100 μb would yield 6000 events, to be found amongst $\sim 1.2\ 10^6$ inelastic interactions.

(*) Assuming an overall efficiency of 70%.

The branching ratio B_e of D mesons into final states with electrons is known [5], $B_e = 9.3 \pm 1.7\%$, corresponding to ∿ 1200 events. An ∿ equal equal number of events is expected with μ replacing e.

We have estimated, by a Monte-Carlo method, the fraction of the electrons arising from D or D^* decay that would be detected by the Intermediate Gamma Detector (IGD) and Forward Gamma Detector (FGD) and could be used as triggers. This estimation uses models for D and D^* production that are also used by the beam dump experiments to compute the total production cross section from their observations of ν_e in a limited region of phase space(*). Some results of these studies are given by fig. 1, which shows the pattern of hits of the electrons arising from D production and decay on the front planes of the IGD and FGD, and fig. 2 showing the momentum of electrons versus position in the plane of magnetic deflection, at the IGD and FGD.

We conclude that about 20% of the electrons from $D \to K^* e \nu$ are detected by the IGD and FGD. If we also request, for the momentum p_e of the electrons, a condition (a) $p_c < 12$ GeV/c, we still detect ∿ 3% of the electrons. With a condition (b) $1.2 < p_e < 23$ GeV/c, we detect ∿ 7% of the electrons. These results were checked against other methods of acceptance calculations [6]. These figures show that the exposure will yield ∿ 85 events with detected electron.

This number of events would be increased by reconfiguring the IGD and FGD for optimum electron acceptance, and by use of the aerogel Cerenkov counters now under study.

(*) D production $\frac{d\sigma}{dx} = (1 - |x|)^n$, $n = 4$, $x = \frac{2P^*_{Lmax}}{\sqrt{s}}$

$$\frac{d\sigma}{dp_T} = e^{-1.5p_T^2}$$

D Decay $D \to K^* e \nu_e$

Other assumptions, such as $2 < n < 5$, $\frac{d\sigma}{dx} = e^{-5|x|}$,

D^* production, decays $D \to K e \nu$, $D^* \to K e \nu$ etc, do not change the overall conclusions.

4. BACKGROUND

We feel that the geometrical detection efficiencies of the previous section are reliable as a first approximation, but the background computations presented here need further study. Therefore, we indicate three different methods of background rejection, a final choice depending on the results of further investigations, which have only been initiated. We are confident, however, that a satisfactory level of background rejection can be reached. We notice that, in a bubble chamber experiment where many background events can be rejected by inspection of the photographs, the level of hardware background rejection need not be as drastic as, e.g. in the electronic experiment already quoted.

4.1 The obvious major source of background is the sequence $\pi^0 \to 2\gamma$, $\gamma \to e^+e^-$. It is expected that 1/6 of the interactions in the chamber will give an e^+e^- pair materializing in the liquid or the window with at least one electron reaching the IGD or FGD. The Dalitz pair background is expected to be $\gtrless$ 1/20 of the γ conversion background. The methods of rejection of electrons pairs under study are the following:

4.1.1 The IGD and FGD are matrices of lead-glass blocks, each giving a degree of discrimination between e-m showers (e signal), and hadron showers (h signal). Some signals are ambiguous (a). An accepted event gives a signature (ehhh...), a rejected event (eehhh...). This method can be used if the number of ambiguous events (eahhh...), (aahhh) etc. is sufficiently small. The e/h discrimination can be improved by the use, in front of each lead-glass block, of a lead scintillator sandwich.

4.1.2 The use of coincident threshold Cerenkov counters, similar to those used in SPSC/P95 would certainly give the desired e/h discrimination for $p_e < 12$ GeV (condition (a)). These counters would be inserted in the EHS instead of ISIS, or with an ISIS of reduced length.

4.1.3 The use of ISIS: according to specifications, ISIS would discriminate electrons from hadrons for $1.2 < p_e < 23$ GeV/c (condition (b)) at a confidence level of better than 90% (better than 99% for $1.3 < p_e < 12$ GeV/c), given an IGD or FGD electron signal (fig. 3).

It is not yet clear if the ISIS data can be used on-line. We note that for the present application of electron pair rejection, the knowledge of the momentum of the particle is not necessary.

4.2 Another major source of background comes from electronic hadron decays, the most serious one being Ke3. Assuming an average charged multiplicity $\langle n_{ch} \rangle = 8$, and production ratio $K/\pi = 0.08$, a reasonable estimate gives $\sim 10^3$ events of this type in the final sample.

We conclude that the single electron selection, on-line and off-line will select 10^4 pictures. Their scanning will further separate $\sim 2\ 10^3$ events for detailed measurements. Amongst these, the identification and mass resolution properties of the EHS should make it relatively easy to discriminate associated strange particle production from ~ 85 events showing genuine associated charmed particle production.

5. CONCLUSION

We expect the following data acquisition and reduction:

-	EHS run	20 days
-	Expansions	$7\ 10^6$
-	Photographs	10^6
-	Tagged photographs	$5\ 10^4$
-	Photographs to be scanned	10^4
-	Photographs to be measured	$2\ 10^3$
-	Charmed particle events	85

6. TOPICS FOR FURTHER STUDY

- Discrimination between e-m and hadronic showers in IGD and FGD Improvements by lead scintillator sandwiches and Cerenkov. Use of ISIS.
- Study of on-line capability of ISIS.
- Detailed design of electron detection system, optimization of the configuration.
- Detailed investigation of signal and background.
- Possible use of the high magnification camera.
- Combination of this experiment with others during the same data taking.
- Muon detection system.

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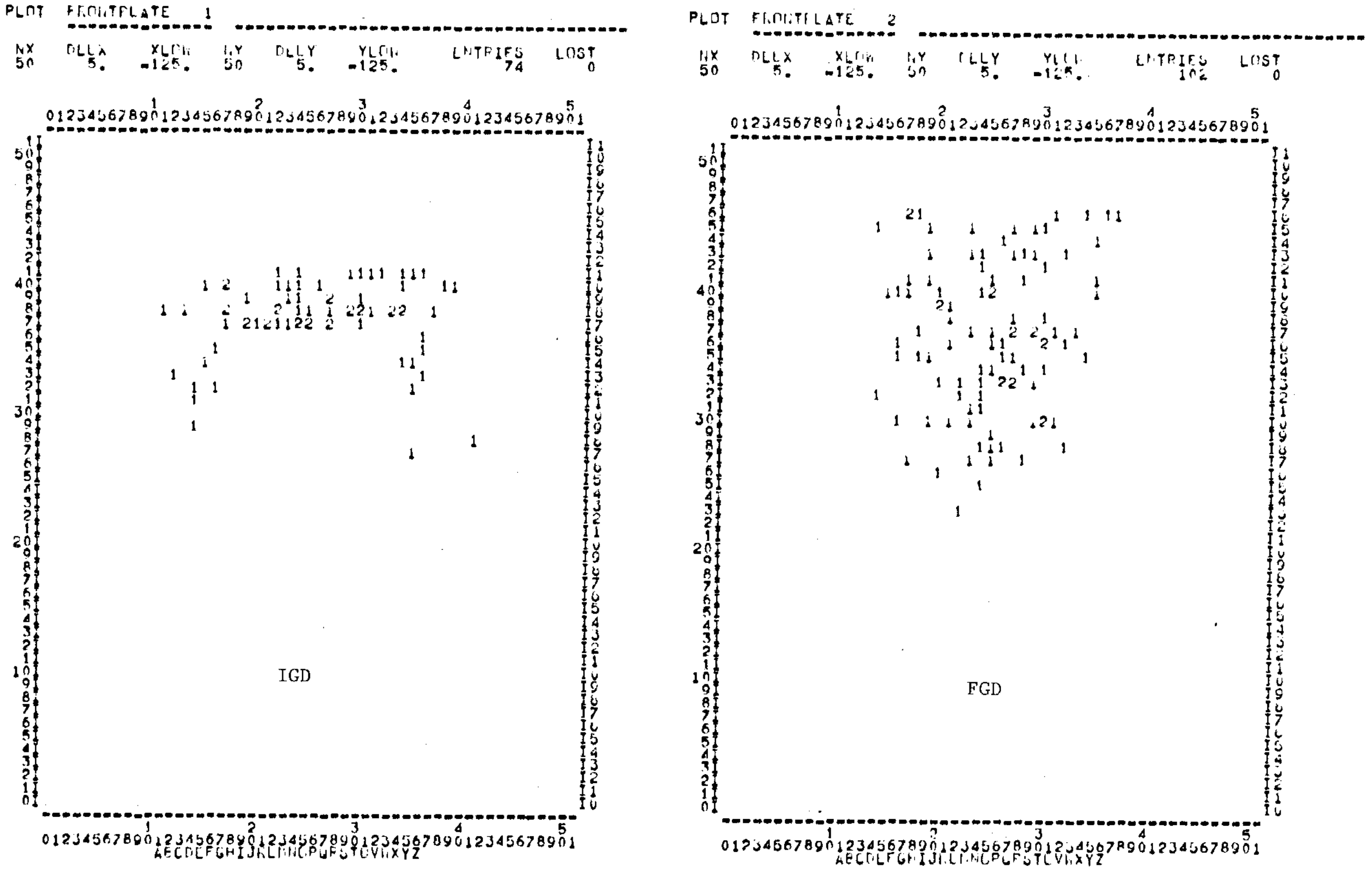

Fig. 1 The vertical scale is y in centimeters and in steps of 5 cm. The horizontal scale is z in centimeters and in steps of 5 cm.

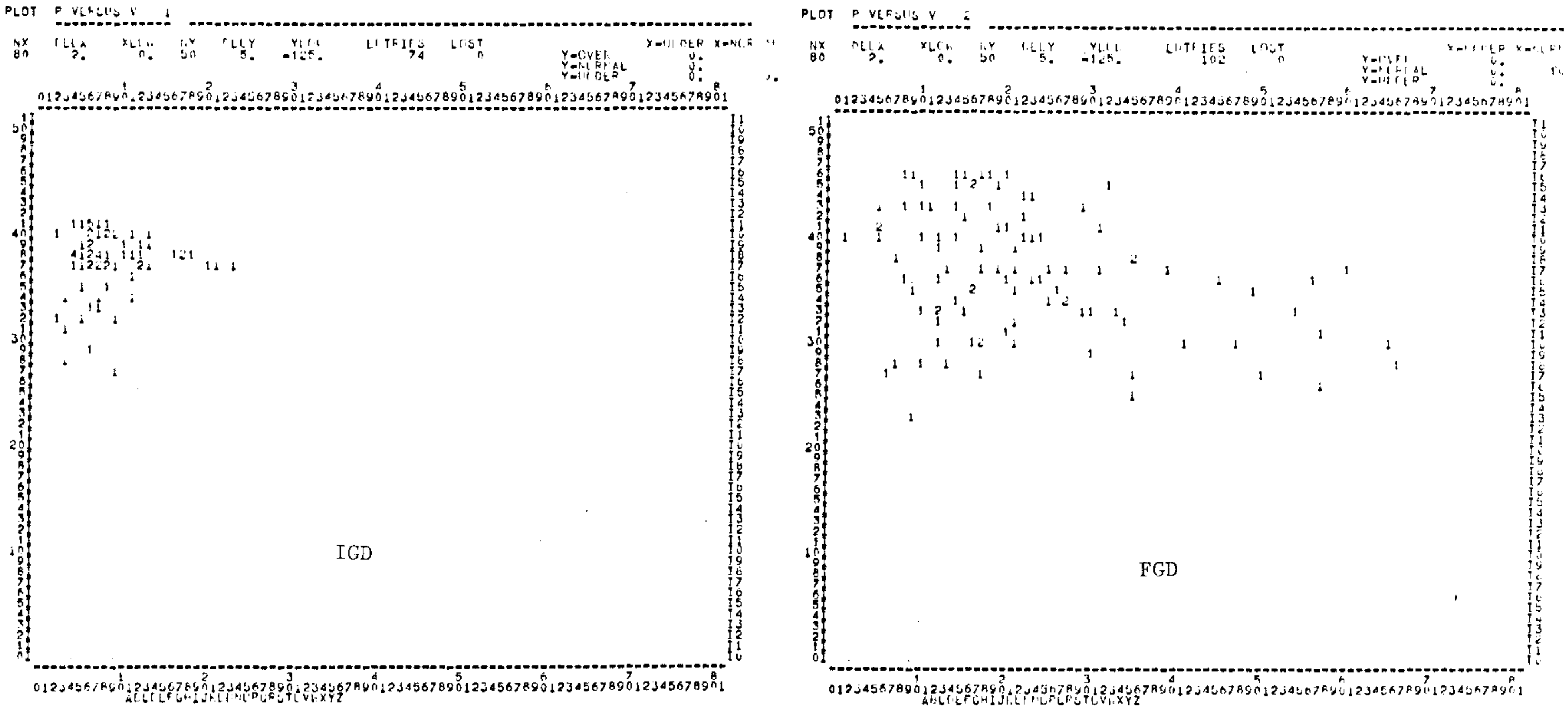

Fig. 2 The vertical scale is y in centimeters and in steps of 5 cm. The horizontal scale is p in GeV/c in steps of 2 GeV/c.

FIGURE 3

Relative ionisation versus momentum for electrons and hadrons in ISIS. The 90% and 99% confidence level boundaries are marked for electron discrimination, assuming a 1:5:1 flux for e:π:p, a reasonable assumption for events with an IGD or FGD electron signal.