1. INTRODUCTION

The UA5 detector had its first chance to take data at the SPS/Collider during Period 7 of last year. During the runs of 21-22 October and 5-10 November a total of 60,000 triggers were obtained from which \( \sim 16,000 \) good pp events resulted. Data taking lasted \( \sim 40 \) hours and utilized the very low luminosity, typically \( \sim \text{few} \ \cdot 10^{20} \ \text{cm}^{-2} \ \text{s}^{-1} \) on average, of the Collider at an early stage of operation. The UA5 detector including trigger was tested and largely set up using coating proton bunches, and performed throughout without major fault.

First results based on measurements of a sample of about 350 complete events, comprising a total of \( \sim 17,000 \) primary tracks, were presented at the pp seminar held in CERN on 20 November. Simultaneously, two papers were submitted for publication covering pseudorapidity distributions and charged multiplicity distributions. Data presented at the Madison Conference held from 10-12 December included first results on charged particle correlations and on \( \gamma \)-production, as well as some details of the technical aspects of the UA5 detector performance.

Measurement and analysis of events has since proceeded at all the laboratories of the collaboration, with a total of 2500 completely measured events now on DST. These events have been enriched by a pre-measurement scan so that the fraction of high multiplicity (say \( n_{ch} > 50 \)) events available has been increased from the "normal" 4% to 8% of the total sample. Measurements of e.m. showers observed in the streamer chambers have also allowed a study of photon production. This has enabled a first search of the high multiplicity component for any sign of the "Centauro" phenomenon.

A brief summary of the main physics results follows.

There follows an account of the technical improvements to UA5 currently being made by the addition of new detectors and a new vacuum chamber, and of the preparations for the next data-taking which it is hoped will take place later in 1982 during the M/D sessions of Period 4.
Prospects for utilizing 900 GeV pulsed operation of the Collider in 1983 for a second exploratory experiment are then briefly mentioned.

2. SUMMARY OF PHYSICS RESULTS FROM UA5 SO FAR

2.1 Charged particle production [2],[3]

Analysis of complete events up to the highest multiplicities has been carried out, successfully adapting the procedures developed at the ISR, from which data have now been published [6].

The pseudorapidity ($\eta = -\ln \tan \theta/2$) distribution over the range $|\eta| < 5$ was determined; the central pseudorapidity density was found to be $3.0 \pm 0.1$ for non-diffractive events, consistent with a linear extrapolation from FNAL and ISR data. The width of the observed $\eta$ distribution as expressed by the FWHM had grown by 2 units going from ISR to Collider energy, whereas the separation of the two beam particles in rapidity has increased by 4.6 units: a conventional cylindrical phase space model of low $p_T$ hadron production could accommodate this by, for example, increasing $(p_T)$ from $\sim 350$ MeV/c to $\sim 500$ MeV/c.

A value of $27.4 \pm 2.0$ was obtained for $(n_{ch})$ of produced hadrons, which agrees nicely with that predicted by a fit of the form $s + b \ln s + c \ln^2 s$ to ISR and FNAL data. Suggestions that $(n_{ch})$ might be growing as fast as $s^{1/4}$ or higher from ISR to Collider energies could be ruled out. The $n_{ch}$ distribution over all rapidities was consistent with KNO scaling within the limitations of statistics.

More recent measurements confirm and clarify with better statistics these first results within systematic errors.

2.2 Photon distributions [4,5]

About 7000 e.m. showers produced by conversions of primary produced photons in the vacuum chamber, and 700 e.m. showers produced in lead glass plates inside the streamer chamber, have been analysed. The pseudorapidity distribution of photons over almost the complete range $|\eta| < 5$ has been obtained, and compared with that for charged particles. The mean number of photons per event, $(n_{\gamma})$, is $31 \pm 2$, about 10% higher than $(n_{ch})$. The excess can be understood in terms of a contribution from $K_2 \rightarrow 2\pi^0$, and possibly also from $\pi$-meson production.

The correlation between $(n_{\gamma})$ and $n_{ch}$ has been obtained in the form $(n_{\gamma}) = (5.0 \pm 2.0) + (0.82 \pm 0.10) n_{ch}$. The $s$-dependence of the ratio $(n_{\gamma})/(n_{ch})$ has also been studied over the ISR to Collider energy range.

2.3 Centauro search [5]

The above study of e.m. showers lends confidence to our ability to obtain reliable data on photon production from the UA5 detector, and events of the
highest charged multiplicity have been successfully analysed. The UA5 Collaboration is therefore in a good position to search for the Centauro phenomenon, in which a small number of cosmic ray events of very high multiplicity ($n_{ch} \sim 75$) were observed to have a seeming absence of produced photons as well. One may assume that these anomalous cosmic ray events were produced by a primary of $\sim 1500$ TeV (deduced from the observed total energy of an event) in collision with an atmospheric nucleon, to provide a basis of comparison with Collider energy data.

A search for possible candidates among our data is in progress, and limits for the occurrence of such events will be given.

2.4 Kaon production

We are investigating the production of kaons using $K_L^0$, $K_S^0$, and $K^\pm$ decays observed in the streamer chamber. The probabilities for visible decay in the chamber volume are roughly 9% for $K_S^0$, 2% for $K_L^0$, and 10% for $K^\pm$. In a sample of $\sim 1100$ events measured and carefully checked on the scanning table we have found $\sim 180$ $K^\pm$ decays, $\sim 80$ $K_S^0$ decays and 17 $K_L^0$ decays. After correction these correspond to a $K/\pi$ ratio of around 15%. In the case of $K_S^0$ decays we can reconstruct the momentum of the decaying particle from the decay angles, and make a direct estimate of $\langle p_T \rangle$ for kaons. An independent check of $\langle p_T \rangle$ can be made from the relative rates of $K^\pm$ and $K_S^0$ decays. Both methods at present indicate a fairly high value of $\langle p_T \rangle$, around 650 MeV/c. The c.m. decay distribution of $K_S^0$ shows a deviation from uniformity, from which we expect to estimate the rate of $\Lambda/\bar{\Lambda}$ production. Further checks on the data quality and backgrounds are expected to be finished shortly.

2.5 Charged and neutral particle correlations

Correlations between charged particles of positive and negative c.m.s. pseudo-rapidity have been analysed. In order to separate possible short-range and long-range correlations a gap of two units has been introduced to study the latter. For the short-range correlation measured over two adjacent bins in rapidity, we find a strength of about the same value as observed at ISR energies, indicating that resonance production has not changed significantly by going from ISR to Collider energies. The even more interesting result is that the charged particles are equally strongly correlated when a gap of two units is introduced, so excluding correlations resulting from "normal" resonances. This can be looked at in the following way. If one requires a large (small) multiplicity in a certain region of rapidity the tendency to observe a large (small) multiplicity in an adjacent bin of rapidity and a bin further away is about equally high.

Studies of such aspects are progressing.
2.6 Jet studies

An investigation of the structure of events, particularly those of high multiplicity, is in progress looking for evidence of hadron jet formation. In the absence of a specific jet trigger this requires a careful statistical analysis, with particular attention to the problem of background from secondary particles. These and related more detailed investigations will be greatly facilitated by the additions to our detector described in the next section, followed by more data-taking.

The measurement and analysis of the data from the first Collider run will be completed during summer 1982.

3. IMPROVEMENTS TO UA5 DETECTOR

Our last report (31 July 1981) for the Cogene meeting of the SPSC described plans to build a neutral hadron detector (NHD) and a high multiplicity trigger (HMT). These devices are now in the final stages of construction, having been funded by the Collaboration.

3.1 NHD

The first half of this device will be delivered to a test beam in the East Hall at the end of March. The second half is to arrive about a month later. Commissioning and calibration, along the lines [7] of that carried out on one of the 10 modules of the full device last summer will then proceed until mid-July.

Meanwhile the NHD support structure (for ~ 30 tons) and all cabling will be assembled in ECX4 together with the UA5 detector before Period 3 starts, and the NHD itself will be brought along the tunnel, put in place, and cabled during the shut-down (19 July-2 August) before Period 4.

It is planned to use the NHD both as a passive detector and as a triggering device, during data-taking which, it is hoped, will take place in Period 4. The likely performance of the NHD is summarized in the report to last year's SPSC Cogene meeting, and in ref. [7].

3.2 HMT

This device is designed to facilitate a detailed study of high multiplicity events to which the 47 solid angle and high multitrack efficiency of the UA5 streamer chamber detector is extremely well suited. In order to allow an almost bias free enrichment of large multiplicity events we have therefore designed a small wire chamber consisting of 160 Al tubes of 2.5 mm diameter and a length of 60 cm. The detector fits closely around the SPS vacuum chamber covering about five units in rapidity with an azimuthal resolution of a few degrees.
A prototype of the detector has been successfully tested at the synchrocyclotron in February. The efficiency of the detector was found to be compatible with 100% and a good time resolution of 20–25 ns was achieved. The final detector is now under construction and will be ready in April, together with all the electronics necessary. It is the idea to have the EMT installed in ECX4 for Period 3 in order to profit from any coasting proton bunches for final tests under realistic conditions.

3.3 Beryllium vacuum chamber

The major limitation to the extraction of high-quality data at the Collider is the existing steel beam pipe. We have found that at least 60% of our events showed effects of secondary interactions (mostly $\gamma$ conversions) that either partially or completely prevented track measurements for $|\eta| \geq 3$ units, necessitating corrections to the data. A study of the improvement to be expected from a 2 mm thick Be vacuum chamber indicated that an order of magnitude reduction in background is likely. This should dramatically increase the analysing power of the UA5 detector: for example, in jet studies with high multiplicity events the chance of jet-like configurations of background tracks would be nearly eliminated.

For this reason the UA5 Collaboration, with the technical support of SPS Division, has ordered$^{a)}$ a prefabricated Be chamber, of which the total length of Be is 4.7 m, that will cover the rapidity range out to $\eta = 5.1$. Provided the delivery date of 21 May is adhered to, there is a good chance it can be installed on the UA5 detector before the start of Period 3. The importance of installing this desirable (and expensive) piece of equipment before the next phase of data-taking is clear. That it will provide a useful test of similar chambers for LEP is also apparent.

4. PREPARATIONS AND PLANS FOR DATA-TAKING IN 1982

As well as the work on new detectors and components described in the previous section, the plan for the main UA5 detector consisting of streamer chambers and power supplies, optics and triggering counters is as follows:

- 26 April–21 May: reassembly and testing in ECA4;
- 1–9 June: move into ECX4; preparation of vacuum chamber;
- 10 June–19 July: during Period 3, set up and test trigger, EMT with coasting protons;
- 19 July–2 August: introduce NHD, final cabling and checks;
- 3 August–9 September: preparing for data-taking during $p\bar{p}$ M/D in Period 4;
- 10 September–8 October: data-taking during Period 4 M/D.

$^{a)}$ From Electrofusion Corporation, Menlo Park, California. The 370 kSFr cost of the Be chamber has been shared between the Collaboration and CERN EF and SPS Divisions.
To give some flexibility and allow for maintenance or repairs it would be nice if two sessions of data-taking were allowed in Period 4.

The following physics objectives can be foreseen, of course subject to the results of the analysis of data already in progress. A total of 50–60,000 triggers, which in view of the improvements in luminosity\(^a\) should yield at least 95% good \(p\bar{p}\) events, divided perhaps as follows:

a) 15,000 triggers with previous minimum bias trigger to reproduce results of first run, plus
   - evaluate HMT;
   - study high multiplicity events without background (Be pipe);
   - NHD used passively for energy measurement of charged hadrons and gammas over \(|\eta| \leq 1\), identification of neutral hadrons, jet studies, etc.;
   - improved Centauro search, etc.

b) 10–15,000 triggers with HMT in trigger
   - detailed search for jet-like phenomena (bias-free) in high multiplicity events, correlation studies, etc.;
   - NHD used passively as above.

c) 10–15,000 triggers with NHD used as \(E_T\) trigger
   - detailed study of resulting events, jet studies, etc.;
   - possible inclusion of neutral hadron trigger.

The analysis of this hadron physics data will be carried out in 1982–83. The existing measurement facilities in the Collaboration will be sufficient and will be kept fully utilized. Software development for off-line data analysis in connection with the new detectors is under way.

5. **POSSIBLE 900 GeV COLLIDER OPERATION**

A proposal \(^b\) has been made to use a scheme for pulsed SPS operation that, with a successful installation of the new SPS transformers to give 450 GeV/c flat-top later this year, could later be utilized to produce \(p\bar{p}\) collisions at 900 GeV c.m. energy with \(\approx 25\%\) duty factor. The scheme would exploit a cyclic variation of the stored beam momentum between 450 GeV/c and a lower momentum which might be 100 GeV/c. Physics data could thus be taken at 900 GeV and interleaved with data at 200 GeV in the same run, though of course with low luminosity since the low-\(\beta\) scheme is excluded.

\(^a\) A value of \(\approx 10^{25} \text{ cm}^{-2} \text{ s}^{-1}\), corresponding to intermediate-\(\beta\), would be sufficient.
UA5 regards this opportunity as a highly desirable and logical extension of its first exploratory physics studies at 540 GeV. New thresholds might be opened, for example, the equivalent laboratory energy of 430 TeV is now nearer the 2 1000 TeV of cosmic ray experiments at which the Centauro events were claimed to have been seen.

6. CONCLUSION

We believe we have shown that the UA5 Collaboration can generate physics results at the Collider quickly and of good quality covering a large range of hadron physics topics. Analysis of the data from our first run at the Collider will be completed this summer. Some additions are being made that will considerably increase the power and scope of the detector. We request that further running time be granted, during preferably two M/D sessions of Period 4, to enable data on about 50-60 K triggers to be taken. The Collaboration will be ready to start analysis of this new data as soon as it is produced.

REFERENCES

[8] J.G. Rushbrooke, Proposal for achieving p$\bar{p}$ collisions at up to 1 TeV c.m. energy by means of cyclic variations of stored beam energy in the SPS Collider, CERN-EP/82-6 (1982).