INTERSECTING STORAGE RINGS COMMITTEE

PROPOSAL

OBSERVATION OF INELASTIC PROTON-PROTON COLLISIONS
AT THE ISR WITH STREAMER CHAMBERS

K. Eggert and M. Holder,
III. Physikalisches Institut, Aachen, Germany.

P. Darriulat, E. Gygi, F. Schneider and K. Tittel,
CERN, Geneva, Switzerland.

I. Derado, V. Eckardt, N. Schmitz and P. Seyboth,
Max-Planck-Institut für Physik und Astrophysik, München, Germany.
INTRODUCTION

One of the main characteristics of proton-proton collisions at very high energies is the production of a large amount of particles. At present our knowledge of the laws which underlie this particle production is quite limited, and experimental information about multiparticle events is, at best, very crude. Although it is not obvious how to extract the most suitable information from events with many degrees of freedom, there are important questions which can be solved by relatively modest experiments. Among those are the distribution of pion multiplicities and their dependence on the centre-of-mass energy and the correlations among particles in the different kinematical regions of fragmentation and pionization.

We propose to measure multiplicity and angular distributions and correlations for charged particles and gamma rays at ISR energies. In order to observe complete events, we intend to use a streamer chamber with an almost 4π-geometry around one of the field-free interaction regions at the ISR. Charged particles are well measured and distinguished from background; a high detection efficiency for γ-rays from π⁰-decays is achieved by inserting lead oxide into the streamer chambers. The relative abundance of π⁰'s in events with a given charged pion multiplicity is of interest for the understanding of the pion production. Angular measurements reflect in rapidities, the distributions and correlations of which are essential ingredients of a large variety of theories. Moreover, this detector is especially suited to handle high multiplicity events with complicated and unexpected topologies.

DETECTOR

A view of the detector is shown in Fig. 1. The bicone vacuum chamber is surrounded by two large streamer chambers to obtain maximum angular acceptance for all particles produced in the p p collisions. On each downstream side of the interaction region, two arrays of scintillation counters serve as the triggering system. These counters also allow to detect particles produced at very small angles, which emerge from the vacuum tube after the streamer chamber. The tracks in the streamer chamber are photographed directly by two cameras with a stereo angle of 15 degrees.
CHAMBERS

The bicone vacuum tube is enclosed by two double-gap streamer chambers with 25 cm gaps (see figs. 2, 3). The chambers of dimensions 270 x 130 x 50 cm³ are placed directly above and below the vacuum tubes leading into the bicone chamber. Because of the inhomogeneous electric field in the immediate vicinity of the bicone chamber, a volume of 160 x 60 x 50 cm³ has been made insensitive. The volume between the pulsed high voltage electrode and the shielding of the bicone will be filled with an insulating gas. The impedance of each streamer chamber is about 20Ω, but is distorted by the shielding of the bicone. To investigate the effect of this distortion on the visibility of tracks we have tested a model with a similar geometry. This test chamber was 2 m long, 1 m wide and had two 12.5 cm gaps. No effect on the track quality was observed in the regions which will be track sensitive in our experiment. In Fig. 4 we show a photograph of tracks taken about 10 cm in front of the distortion.

Vertical lead oxide plates can be installed in the sensitive volume for the detection of γ-rays. When the interaction region is enclosed on four sides, a good π⁰ detection efficiency is obtained.

OPTICS

Since the cameras will view the streamers end-on (parallel to the electric field) we can use direct photography. The top and bottom streamer chambers are photographed in 15° stereo over one large mirror each (see Fig. 5). The demagnification will be approximately 70 and lenses of 75 mm focal length will give sufficient depth of field up to apertures of 1:2. The size of one view on the film is about 20 x 40 mm². Views of the top and bottom chambers will be placed side by side on 50 mm film giving a length of 45 mm for each picture. Thus 14000 pictures could be taken per shift on a 650 m roll. With the chamber model described above pictures were taken at a demagnification of 70. Good photographs of tracks were obtained at an aperture of 1:2.8 when the length of the streamers was 1.0-1.5 cm.
HIGH VOLTAGE SYSTEM

We intend to use a conventional pulse generation and feeding system. For the 25 cm gap a pulse of 600 kV and 12 nsec duration is necessary to get streamers bright enough for direct photography. This pulse can be produced with a Marx generator of 750 kV output voltage. The pulse forming will be done by two Blumlein lines, one for each gap. The pulse feeding is easy to install from one side with simple adaptors. The adaptors can be constructed from aluminium of less than 0.5 mm thickness and particles travelling towards the trigger counters will not be affected. The repetition rate of the system will be 1 pulse/sec.

TRIGGERING SYSTEM

Two counter arrays are installed around each of the downstream beam pipes (see Fig. 1). The arrays are positioned 3 m (NEAR) and 6 m (FAR) from the interaction region. The NEAR array is built of 8 scintillator strips 150 x 20 cm$^2$, each equipped with 2 photomultipliers and a meantimer. An elliptical hole is cut in the two centre strips for the beam pipe. The FAR counter consists of 2 scintillator strips 50 x 35 cm$^2$. Particles from beam-beam interactions, traversing the vacuum pipe between NEAR and FAR, or their secondaries will be recorded in FAR. An angular range from 5-270 mrad is covered by the system. The streamer chamber will be triggered by a coincidence in both arms. From present experience with similar trigger systems at the ISR, we estimate a trigger efficiency of > 85% for inelastic p p events.

The information from the counters can also be used to correct for particles not detected in the streamer chamber at very small angles. Particles hitting the three top and bottom strips of NEAR are also seen in the streamer chamber.

PERFORMANCE OF THE DETECTOR

We have estimated the acceptance of the detector with the help of a model of p p inelastic collisions at ISR energies. The parameters of the model are adjusted to reproduce the rapidity and transverse momentum
distributions observed in inclusive ISR measurements both for charged pions and for protons (ignoring the very forward diffraction peak). Correlations among produced pions are taken from the Chew-Pignotti model and pion charges are attributed at random with the constraint that they should add to zero. The acceptance of the detector for charged particles is calculated by counting how many charged prongs are observed in the streamer chambers with a track length larger than 10 cm. In the case of 22 GeV/c colliding beams 36% of the protons and 87% of the pions fall in this category. Most other particles travel further downstream and cross the wall of the elliptical pipe with a high probability of interaction, making a multiplicity measurement in the very forward direction extremely difficult. However we use the information of the forward scintillators (FAR), which barely overlap the streamer chamber acceptance, by accounting for one or two additional particles depending on whether one or both of them have fired. This brings up the efficiency for proton detection above 90%. Generated and observed multiplicity distributions for charged particles are compared in Figure 6 for 22 GeV/c colliding beams. A summary of the acceptance calculation is given in Table 1.

We now give an estimate of the \( \pi^0 \) detection efficiency of our experiment. As shown in Fig. 7a the interaction region is surrounded on four sides by lead oxide plates of 1 radiation length thickness, separating the sensitive volume of the streamer chambers into an inner and outer region. With the proposed arrangement the geometric detection efficiency for photons can be calculated. Only photons with production angles <30 mrad are lost entirely. In a Monte Carlo calculation we generated a set of \( \pi^0 \) with a Poisson distribution of average 5 and a distribution in rapidity like that of the charged \( \pi^+ \)'s described above. The resulting observed distribution of photons is shown in Fig. 7b. Using the geometric efficiencies we obtain the distribution shown as dots in Fig. 7b. We conclude that we can measure the \( \pi^0 \) multiplicity distribution and its correlation with the charged multiplicity with our detector.

To eliminate background we will require all tracks from an event to extrapolate to a common interaction point. We used Monte Carlo events
generated according to the model described above to investigate our measuring accuracy. Allowing for scattering in the vacuum chamber walls and assuming 3 measured points on each track with reconstruction errors like those observed in previous streamer chamber experiments under similar conditions ($\Delta X = \Delta Y = 0.5 \text{ mm}, \Delta Z = 1.5 \text{ mm}$, where $Z$ is parallel to the optical axes) we find errors of $\Delta X \simeq 0.2 \text{ cm}, \Delta Y \simeq 0.5 \text{ cm}, \Delta Z \simeq 0.5 \text{ cm}$ for the reconstructed interaction point. The lack of momentum measurement and particle identification makes it in principle impossible to transform the observed distributions to the pp centre-of-mass system. However, due to its slow movement in the ISR frame ($\beta \sim 0.15$), and under the assumption of limited transverse momentum, we can estimate centre-of-mass rapidities and azimuthal angles within $\pm 0.2$ and $\pm 5^\circ$ respectively over much of the angular range.

REQUEST

We are asking to take 200,000 pictures distributed over the usual ISR energies. These could be taken in 2 months running. In addition we are asking for one month to check our detector.

We require a thin-wall bicone vacuum chamber of the usual type available in the ISR department. The intersection region I-7 seems to be most suitable for the installation of the experiment. It is free of other equipment and would allow easy installation of the cameras in the trench. Moreover it can be equipped at small cost, since the necessary electronics can be installed in the generator building nearby and can be connected to the detector through the underground tunnel. Should I-7 not be available, the experiment could also be run in one of the other intersection regions.

We would like to install the detector during the shut-down period at the end of 1972. The analysis of the pictures will take about 6 months.
Table 1

Acceptance for charged particles (excluding elastic and quasi-elastic scattering)

<table>
<thead>
<tr>
<th>Beam momentum (GeV/c)</th>
<th>15</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of pions observed in the streamer chambers</td>
<td>90%</td>
<td>87%</td>
</tr>
<tr>
<td>Proportion of protons observed in the streamer chambers</td>
<td>54%</td>
<td>36%</td>
</tr>
<tr>
<td>Proportion of protons counted in the forward (FAR) counters</td>
<td>44%</td>
<td>60%</td>
</tr>
<tr>
<td>Overall acceptance</td>
<td>92%</td>
<td>90%</td>
</tr>
</tbody>
</table>
FIGURE CAPTIONS

1. Artist view of the detector. The front half of the top chamber has been cut out to show the bicone vacuum chamber. One of the NEAR arrays is visible in the back.

2. Front view of the streamer chamber body.

3. Side view of the streamer chamber body.

4. Multitrack exposure of the test chamber in a region located 10 cm away from the distortion.

5. Schematic layout of the mirror system.

6. Generated and reconstructed multiplicities for charged particles.

7. Generated and reconstructed multiplicities for gamma rays.
CHARGED MULTIPLICITY

$(22 + 22 \text{ GeV/c})$

- • observed
- □ generated

**Fig. 6**

**NUMBER OF EVENTS**

**MULTIPLICITY**

- 0 1000 2000

- 2 4 6 8 10 12 14 16
Observation of $\gamma$-rays

1 rad. length PbO

$\gamma$-pairs generated from $\pi^0$'s
--- observed $\gamma$-pairs
• corrected $\gamma$-pairs

Fig. 7