FIRST PROTON–ANTIPROTON COLLISIONS IN THE CERN SPS COLLIDER

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Received 6 November 1981

Protons and antiprotons have been stored simultaneously in the CERN SPS for several hours. Their interactions at 540 GeV in the centre-of-mass system have been observed by three different experiments.

The CERN antiproton project (fig. 1) has been described in recent papers [1,2]. Antiprotons, produced in a target by 26 GeV protons from the CERN Proton Synchrotron (PS) are collected at 3.5 GeV/c, stored and stochastically cooled in the antiproton accumulator ring (AA). After about one day of collecting and cooling, the antiprotons are injected into the PS, accelerated up to 26 GeV and then transported to the

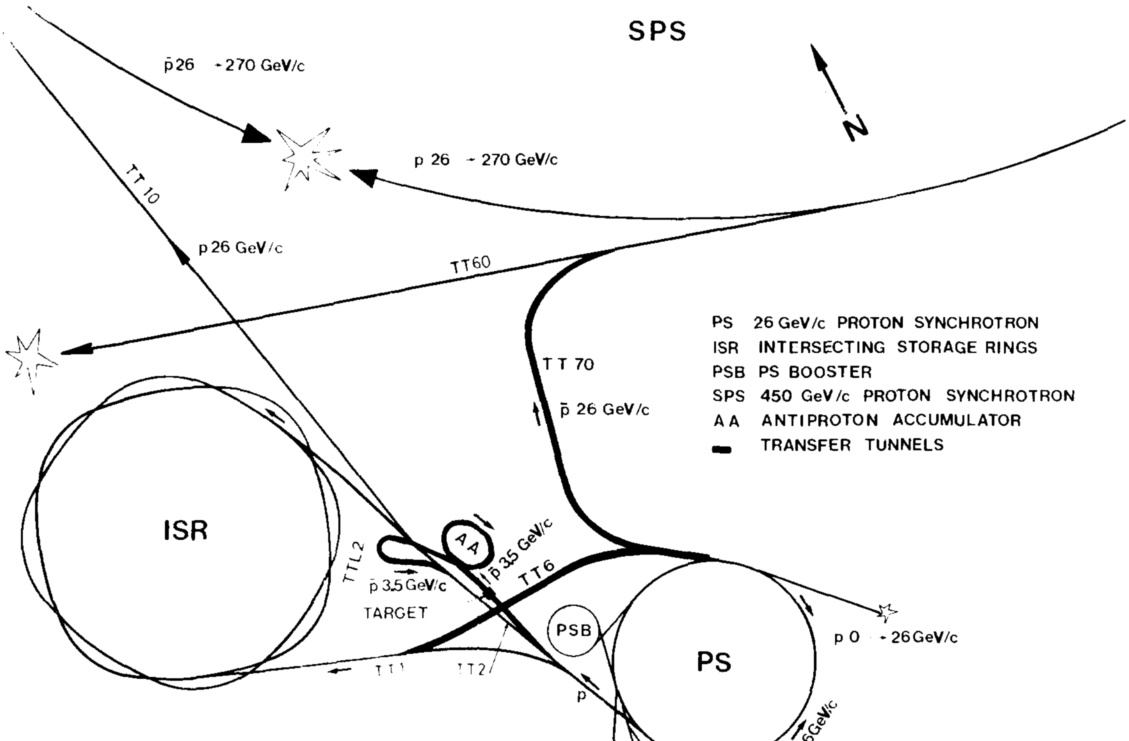

Fig. 1. Layout of the CERN p–p̄ complex.

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CERN Super Proton Synchrotron (SPS), where they are further accelerated up to 270 GeV together with counterrotating protons. Commissioning of the SPS as p–$\bar{p}$ collider started in June 1981 after a shutdown of one year needed to modify the SPS ring for this additional mode of operation and to construct two underground experimental areas.

We can now report successful storage of protons and antiprotons at 270 GeV with lifetimes of several hours. Typically two bunches of 5×10^{10} protons each were colliding against one bunch of about 10^9 antiprotons, giving an initial luminosity of 2×10^{25} $cm^{-2}s^{-1}$ per interaction point in these first runs.

Proton–antiproton collisions have been observed in both experimental areas. Fig. 2 shows the tracks of outgoing particles produced by a 540 GeV p–$\bar{p}$ collision as seen by the UA5 streamer chambers. The UA5 detector [3] consists of two 6 m long streamer chambers, situated immediately above and below the beam pipe and triggered by external planes of scintillation hodoscopes. From an analysis of previous background runs and from the fact that larger numbers of tracks emerge in both directions from a vertex, which lies inside the region where the bunches are known to cross, it is concluded that the event shown results from a beam–beam interaction.

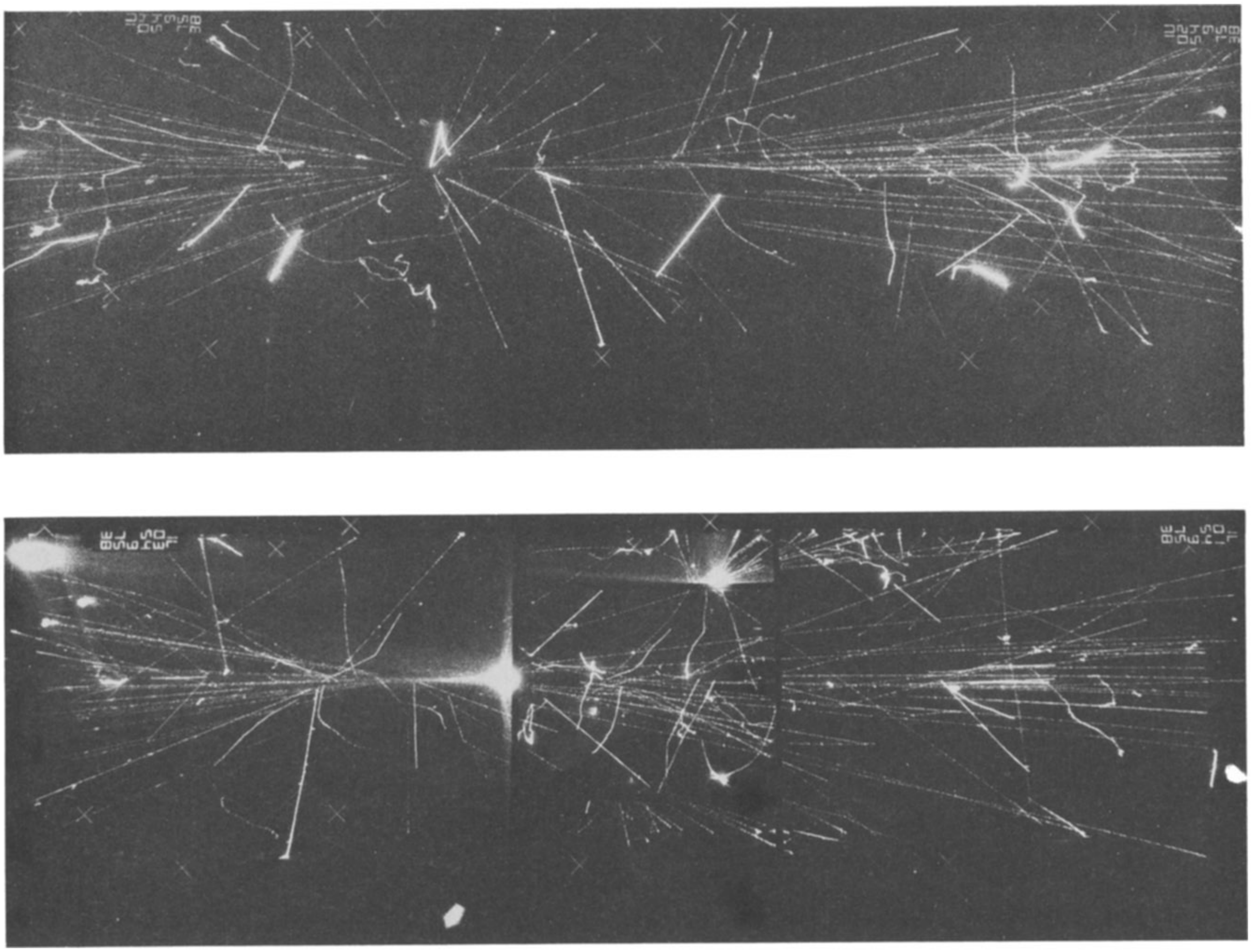

Fig. 2. Photograph of a p–$\bar{p}$ event as seen by the upper and lower UA5 streamer chambers. The chambers are mounted immediately above and below the beam pipe, so as to observe tracks down to less than 1° production angle. The sensitive volume per chamber is $6 \times 1.25 \times 0.5\ m^3$.

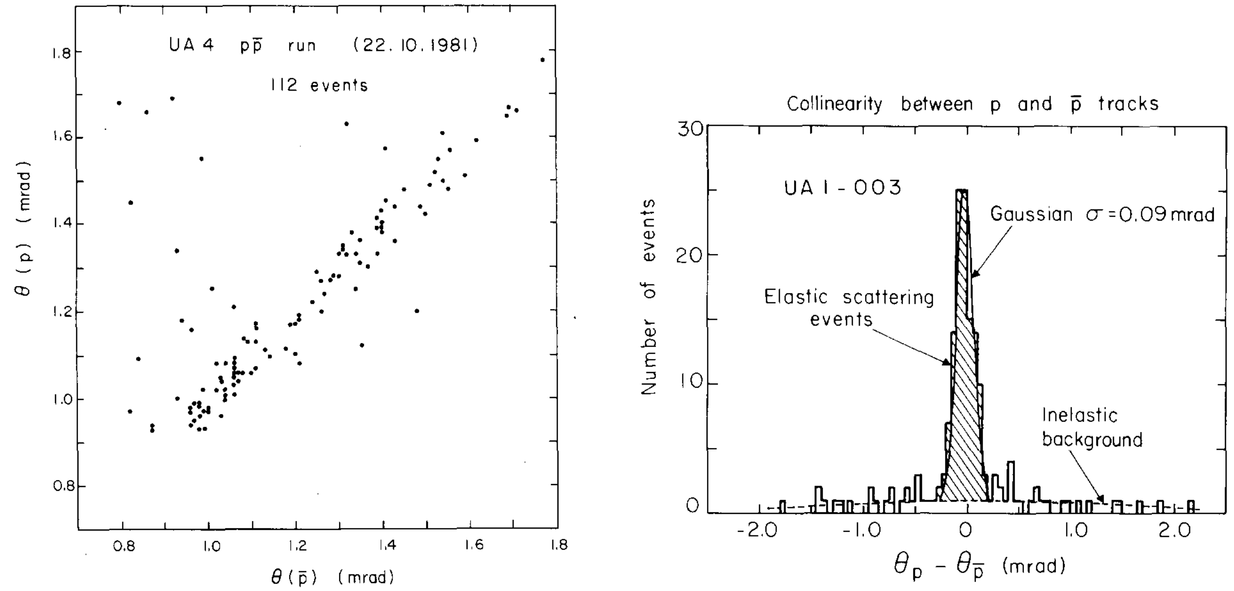

Fig. 3. p–p̄ elastic scattering events. (a) Distribution of proton versus antiproton scattering angles for 112 events observed by experiment UA4. (b) Distribution of the measured difference of the p and p̄ scattering angles for 168 events observed by experiment UA1.

Further evidence for beam–beam interactions is given by a clear signal of p–p̄ elastic scattering observed by two collaborations UA1 [4] and UA4 [5] in both interaction areas. The experimental set-up is similar for the two experiments. Drift chamber telescopes are placed symmetrically some 20 m (UA1) or 40 m (UA4) away from the crossing point to observe trajectories of particles scattered in the angular range 1–2 mrad. Tracks measured in the telescopes are extrapolated through the machine quadrupoles back to the interaction region to obtain the scattering angles θ_p and $\theta_{\bar{p}}$. Figs. 3a and 3b show plots of elastic scattering angles measured by experiments UA4 and UA1 respectively. The clear grouping of events around the line $\theta_p = \theta_{\bar{p}}$ in fig. 3a and the sharp peak at $(\theta_p - \theta_{\bar{p}}) = 0$ in fig. 3b correspond to collinear, i.e. elastic events. The background signal from inelastic events is relatively low because of the momentum filtering effect of the machine quadrupoles between the interaction point and each telescope.

The SPS is the first proton machine which uses a small number of short bunches (~0.5 m) to maximize the rate of p–p̄ collisions around the centre of the detectors. In such a machine it is necessary to reduce the noise in the radiofrequency system to an extremely low level to limit the diffusion of particles out of the buckets with a corresponding reduction in lifetime of the luminosity. The recent results indicate that this problem can be overcome in the SPS.

Another problem related to the use of tightly bunched bems is the maximum beam–beam tune shift tolerable in the head-on collisions of bunched proton and antiproton beams. In the p–p̄ collisions reported here, the beam–beam space-charge tune-shift of the antiproton bunch induced by each of the two counter-rotating proton bunches has been calculated to be 2.5×10^{-3}. No evidence of a catastrophic loss or emittance growth has been recorded at this level, although more detailed measurements are needed before final conclusions can be drawn.

In these preliminary runs, no attempt was made to achieve a high luminosity. Within the limits of the beam–beam tune shift already obtained, it should be possible to increase the p̄-intensity by a factor 50 in the near future. Furthermore, the application of the low beta scheme which has already been successfully tested with protons, should increase the luminosity by nearly another factor 50.

The further development of the p–p̄ colliding beam facility towards its design luminosity of 10^{30} cm^{-2}s^{-1}

will require the storage of up to six bunches, each with an intensity of about 10^{11} particles, in both beams stored in the SPS.

References

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