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e^+e^- PAIRS PRODUCED IN $\bar{p}p$ ANNIHILATION WITH INTENSE COOLED ANTIPROTON BEAMS

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ABSTRACT

Extracted antiproton beams with intensities of more than 10^7 antiprotons per CERN PS pulse, $\Delta p/p$ of the order of $\sim 10^{-3}$, and momenta as low as 300 MeV/c, should be available at CERN around 1980. Clearly, such beams will improve by several orders of magnitude the possibilities to study e^+e^- pairs produced at rest and up to several GeV/c, via the reactions:

$$\bar{p}p \to e^+e^-$$

$$\bar{p}p \to V^0 + \text{neutrals}$$
$$\hookrightarrow e^+e^-$$

where V^0 is a vector meson.

The proton electromagnetic form factors can then be determined accurately and separately in the time-like region and the vector meson spectroscopy clarified.

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Electron-positron pairs are produced in $\bar{p}p$ annihilations directly or via real vector mesons:

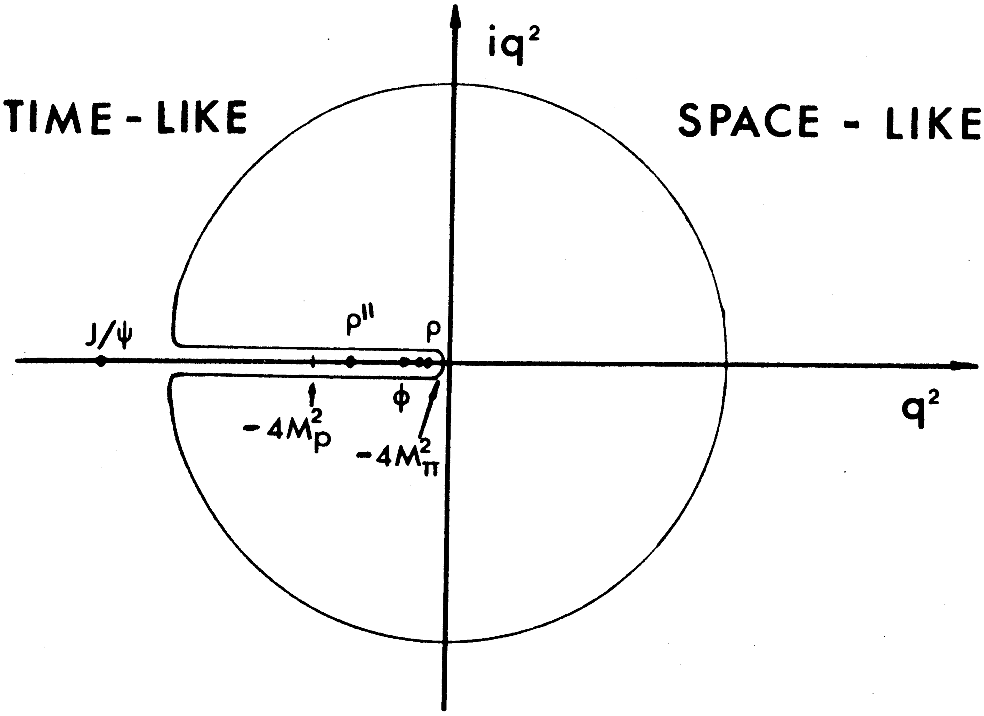
$$\begin{cases} \bar{p}p \to e^+e^- & (1) \\ \bar{p}p \to V^0 + \text{anything} & (2) \\ \quad\quad \hookrightarrow e^+e^- & \end{cases}$$

where $V^0 = \rho, \omega, \phi, \rho', \rho''$, etc.

Reaction (1) is directly related to the electromagnetic structure of the proton, which was first revealed (in 1955) and studied in ep elastic scattering experiments. Later, the enthusiasm of the theorists waned, because the poor knowledge of the asymptotic q^2 behaviour and the lack of data in the time-like region gave little hope of finding a dynamical model describing the electromagnetic form factors. For a few years, the fashion moved on to other subjects, but now, recent data in the time-like region and the expected new facilities at low and "intermediate" energies, and also at very high energies, should cause a strong revival of this fundamental field of physics.

Reaction (2) constitutes a powerful tool to study the existence and measure the width of vector mesons in the mass region 1-2 GeV/c^2, since the detection of e^+e^- pairs and the measurement of their invariant mass yield unambiguous signatures of vector mesons. A complete clarification by a systematic fine spectroscopy is needed, because many indications of structure, broad or less broad, exist in this mass region.

The present experimental situation of the proton electromagnetic form-factors is summarized in Fig. 1. In the time-like region, only three older limits of CERN[1)] and BNL[2)] and three more recent measurements at ADONE[3)] and CERN[4)] exist. A tentative fit with six vector mesons is shown, but clearly many more constraints in the time-like region are necessary to determine a fit. Let us recall why the time-like region is particularly important for the determination of the analytical function $F(q^2)$. Nucleon form factors are boundary values of analytic functions in the complex q^2 plane with a cut along the real axis from $-4m_\pi^2$ to $-\infty$.



$F(q^2)$ is a real function in the space-like region and above $-4m_\pi^2$. The determination of $|F(q^2)|$ along the cut, in particular in the time-like region, determines $F(q^2)$ in the whole of the complex plane. So, precise measurements in the time-like region and over a wide q^2 range are needed. Moreover, in order to obtain $|G_E|$ and $|G_M|$ separately (they are strictly equal only at threshold), we need angular distributions of the electrons, i.e. high statistics.

Only a jump of several orders of magnitude in the interaction rates can bring about a decisive contribution in this field. Since present e^+e^- colliding rings do not yield high statistics for the process:

$$e^+e^- \rightarrow \bar{p}p$$

and, in particular, are unable to go to small q^2 (below ≈ 4.3 GeV/c^2) near the threshold, the best expectation comes from $\bar{p}p$ with the future high-intensity cooled antiproton source.

The SPS $\bar{p}p$ collider project should be operational in 1981. It uses antiprotons produced around 3.5 GeV/c on an external target by 26 GeV protons of the PS. A d.c. operated antiproton accumulator (AA) ring of ≈ 50 m diameter and ultra-high vacuum (≈ 10^{-10} Torr) will allow continuous stochastic cooling both longitudinally and transversely. The RF system then captures a fraction of the stack, accelerates it out to the extraction orbit from which it is transferred to the PS and re-accelerated to 26 GeV before extraction and injection in the SPS.

In the AA or in the PS the accumulated cooled $\bar{p}$ beam can be decelerated when the SPS is not used for $\bar{p}p$ physics. It can then be extracted at any desired energy and brought into the PS South Hall, where a low-energy antiproton ring (LEAR) will allow stretching, further deceleration, stochastic and electron cooling, extraction at all momenta from ≈ 300 MeV/c up to ≈ 2 GeV/c, or collisions with a proton beam or with the protons of a H_2 jet target.

In any case, in 1981 we can expect to have extracted antiproton beams with a $\Delta p/p \lesssim 10^{-3}$, practically no contamination, and an intensity of ≈ 3×10^6 $\bar{p}$/sec or ≈ 2×10^{11} $\bar{p}$/day between ≈ 300 MeV/c and several GeV/c.

Table 1 shows the rates which can be expected for reaction (1) with such a beam hitting a liquid hydrogen target.

Table 1

Event rate for $\bar{p}p \rightarrow e^+e^-$ with 2×10^{11} $\bar{p}$/day on a liquid hydrogen target

$\bar{p}p$ [GeV/c]	q^2 [(GeV/c)^2]	σ [nb]	Target length [cm]	$N_{e^+e^-}$/day
0	-3.52	$B_{e^+e^-} = 3 \times 10^{-7}$	5	60 000
0.3	-3.61	50	10	4 000
1.0	-4.3	4	50	1 700
2.5	-6.8	≈ 0.07	100	50

The rate at rest has to be compared with the rate 3 e^+e^-/day possible in present antiproton beams (m_{14}, 1976).

The rates in the table were calculated using our measured data at rest and at 0.3 GeV/c, ADONE's result at 1 GeV/c, and the pessimistic value obtained from our tentative fit at 2.5 GeV/c. This table shows the q^2 range in the time-like region, where accurate measurements and angular distributions can be obtained.

Furthermore, a study of reaction:

$$\bar{p}d \to \bar{p}p + n$$
$$\hookrightarrow e^+e^-$$

should allow a determination of $|G_E|$ and $|G_M|$ below the threshold of the time-like region [up to $q^2 \approx -3.2$ $(GeV/c)^2$].

An experimental set-up used to study reaction (1) will require a very high rejection power against hadrons at the level of the electronic trigger and a good energy resolution. The same set-up can be used to detect reaction (2). In fact the rates expected for reaction (2) with $\bar{p}$ at rest are of the order of 10^4 e^+e^-/day. An energy resolution of $\approx$ 1% would yield a resolution on the V^0 mass of $\simeq$ 20 MeV/c^2. These features lead to the choice of a rotative double-arm magnetic spectrometer.

Muon-pair detection could be easily added to such a set-up and obviously all $\bar{p}p$ annihilations yielding gamma-rays could also be studied.

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REFERENCES

1) M. Conversi, T. Massam, Th. Muller and A. Zichichi, Nuovo Cimento 40, 690 (1965).

2) D.L. Mertill, B.C. Barish, D.G. Fong, R. Gomez, J. Pine and A.V. Tollestrup, Phys. Rev. 184, 1415 (1969).

3) M. Castellano, G. Di Giugno, J.W. Humphrey, E. Sassi Palmieri, G. Troise, U. Troya and S. Vitale, Nuovo Cimento 14, 1 (1973).

4) G. Bassompierre, G. Binder, P. Dalpiaz, P.F. Dalpiaz, G. Gissinger, S. Jacquey, C. Peroni, M.A. Schneegans and L. Tecchio, Phys. Letters 68B, 477 (1977).

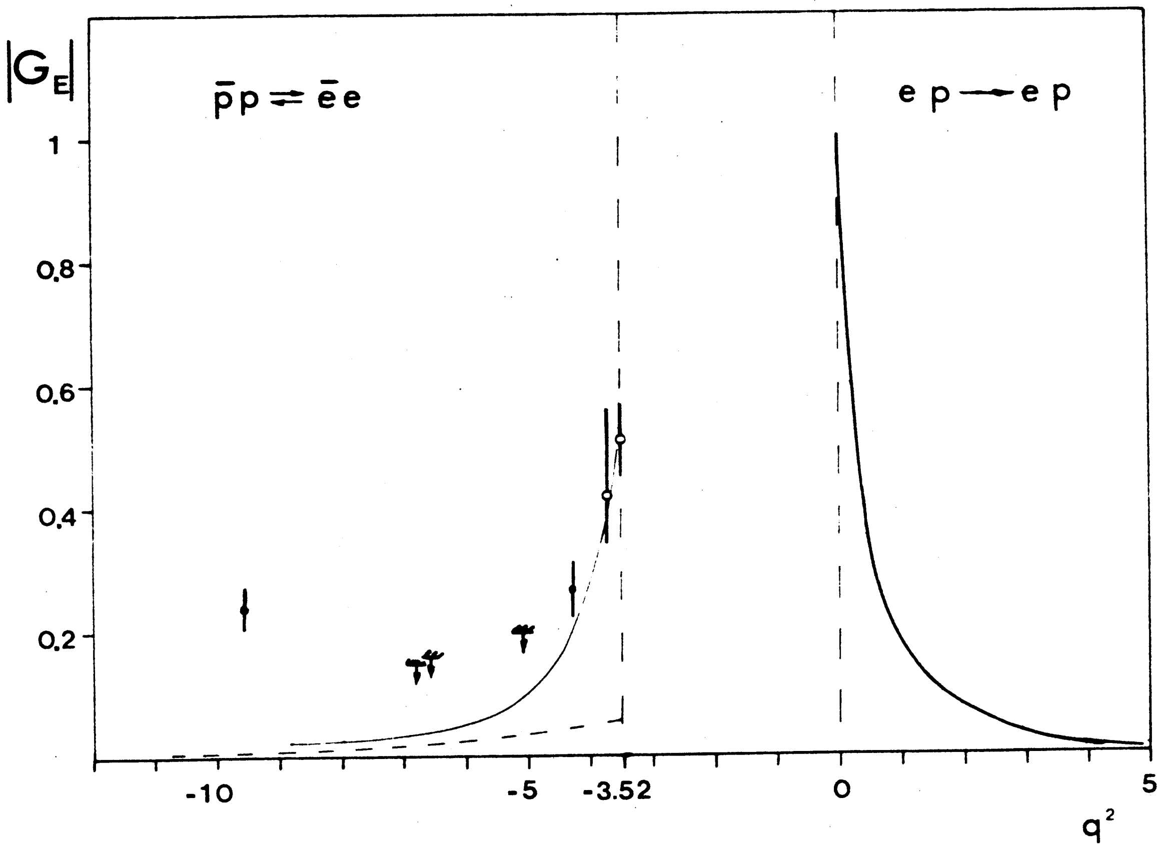

Fig. 1 Experimental situation of the proton electromagnetic form factors