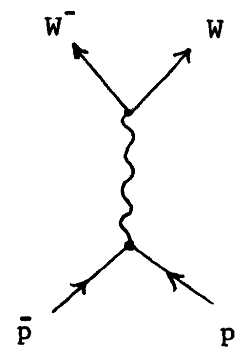
POSSIBLE USE OF COLLIDING BEAMS TO STUDY THE INTERMEDIATE BOSON

B. Thevenet
Saclay

If the intermediate boson exists, it may be possible to detect its electromagnetic production[1] in antiproton-proton annihilations, as shown on the following diagram. Its mass is unknown, but we know that it is heavier than 500 Mev because we do not observe this boson in K decay. Observation of the reaction



$$\bar{p}\, p \rightarrow W^{+}\, W^{-}$$

would enable us to measure this mass by the study of decay products of W. Indeed, its lifetime is approximately 10^{-20} seconds; it decays into $e\nu$, $\mu\nu$, 2π, 3π,... One assumes that, if its mass is much larger than the ρ mass, the more probable modes are $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$, with branching ratios almost 50%. The problem in detecting the bosons is to identify the following reactions

$$\begin{aligned} \bar{p}\, p \rightarrow W^{+}\, W^{-} \rightarrow\ & e^{\pm}\,\nu\ \ \mu^{\mp}\,\nu \\ & e\ \nu\ e\ \nu \\ & \mu\ \nu\ \mu\ \nu \end{aligned} \qquad (1)$$

and to measure directions and momenta of emitted leptons. The easier way to make this study is to concentrate on those annihilations with two

1. S. Bludman and J.A. Young, Proc. 1960 Ann. Intern. Conf. High Energy Physics Rochester, p. 564, Interscience, New York, 1960.

electrons emitted [approximately 25% of reaction (1)]. We can imagine an experimental setup of spectrometers with magnets and spark chambers to measure directions and momenta of charged particles, and Cerenkov counters with lead glass to identify the electrons by means of their electromagnetic shower production.

If the experiment is made with a stationary target, we need incident particles with very high energy; indeed, if the boson mass is 10 Gev, to obtain 20 Gev in the center of mass of the reaction (1) it is necessary to have 220-Gev antiprotons. If the experiment is made with storage rings as studied at CERN, we have 50-Gev available energy; therefore, with 10-Gev bosons, we have an energy much higher than the threshold of production and we can hope for production cross sections, not limited by phase space, to be larger than the 10^{-29} cm^2, as predicted by theory.[2] Another advantage of this technique is, as Terwilliger said,[3] that we deal with lower momenta and bigger angles than in stationary target experiments; it is specially important as particles are heavier.

Let us assume, for example, that m(W) = 10 Gev and we have an available energy of 50 Gev, either with 25-Gev colliding beams or with 1330-Gev antiprotons in collision on a stationary target. In the former case we deal with bosons of 23 Gev/c momentum whatever are their directions; in the latter, we shall have at least one very energetic boson (if the boson were emitted at 45° in the center-of-mass system, in the laboratory system it would appear with 1110 Gev/c momentum at 14 mrad) so it would be more difficult to make definite measurements of momentum and angle of the electron from boson decay.

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2. L. Van Hove, CERN Internal Report AR/Int. SG/62-11.

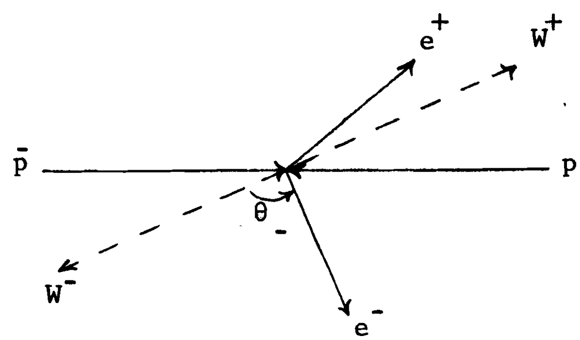
3. K.M. Terwilliger, p. 238 of this volume.

Finally, another important advantage of colliding beams for study of reaction (1) is that it would be easier to interpret and analyze the kinematics of events

$$\bar{p}\, p \rightarrow e^{+}\, e^{-}\, \nu\, \nu\, . \qquad (2)$$

Indeed, the reaction $\bar{p}\, p \rightarrow e^{+}\, e^{-}$ which has the same order of magnitude of cross section[4] as (1) will give two collinear electrons, hence will be easily discriminated from (2) by the scanning. In (2) we observe two electrons emitted at the same place.

If we assume a direction for one boson, W^{+} for example, which has decayed into an e^{+}, we can determine a mass for the boson (we assume only two-body decay). The direction of the W^{-} is opposite to that of the W^{+}; we check that, with the mass found for W, a decay electron at the angle θ_{-} would have momentum p_{e-}. This problem is soluble, but we must measure angles and momenta with great accuracy.



What event rate can be expected? K. Johnsen[5] calculated that, with the CERN storage rings, we should get 10 events/day with $\bar{p}$-p reactions of 10^{-28} cm^2. If we assume a cross section of 10^{-29} cm^2 for $\bar{p}\, p \rightarrow W^{+}\, W^{-}$, that both bosons decay in $e\nu$ and that we have an experimental setup covering 1/4 of 4π, which is possible, we obtain one detected event/10 days. The only factor which could make this experiment possible by increasing the

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4. A. Zichichi, S.M. Berman, N. Cabibbo and R. Gatto, Nuovo Cimento 24, 170 (1962).

5. K. Johnsen, CERN Internal Report AR/Int. SG/62-11.

event rate would be a cross section bigger than 10^{-29} cm^2 because we have an available energy much larger than the threshold of the reaction (1).

We can imagine another experiment, with a higher event rate, to study the neutral intermediate boson W^o. This boson could be created in a collision between any two strongly-interacting particles and, like K^o, it would have a component decaying into 2π and another decaying into 3π.[6] We could study its production in the reaction

$$p\ p \rightarrow p\ p\ W^o \quad (W^o \rightarrow \pi^+ \pi^-) .$$

The problem consists of measuring the mass spectrum of the dipion in the reaction

$$p\ p \rightarrow p\ p\ \pi^+ \pi^- .$$

If $m(W^o)$ is not very much bigger than 1 Gev, we shall be embarrassed by the presence of ρ^o and f^o which have a bigger cross section than W^o. In the CERN storage rings, Johnsen (see reference 5) calculated that p-p interactions with 10^{-36} cm^2 cross section would give 10 events/day; with a production cross section of 10^{-29} cm^2, a 2π decay rate of 1/2, and an apparatus covering 1 steradian, we could get 4×10^6 events/day, or 50 events/sec.

This then would be a conceivable experiment if the boson has a mass greater than 1.5 Gev, a limit being imposed by the overwhelming presence of f^o and ρ^o should the mass of the boson turn out to be in the 1-Gev region.

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6. R.H. Dalitz, private communication.