SOLMITZ : Well, I asked Maglic about this, but I think this is going to be very difficult, because in the cases selected here, the antiproton has the high momentum, and the proton has very low momentum, and so there is very little available path length for scattering, and very little analyzability. On the other hand, the cases where the antiproton has the low momentum and the proton has the high momentum are much rarer. As you saw, the angular distribution was peaked in that way, so I think experimentally with this amount of data Maglic did not think this was feasible.

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# ANTIPROTON EXPERIMENTS IN A HYDROGEN BUBBLE CHAMBER

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I will present five experiments performed by the group of J. Button, P. Eberhard, G. R. Kalbfleisch, J. Lannutti, S. Limentani, G. Lynch, B. Maglic, M. L. Stevenson, and Nguyen-h-Xuong.

## 1. A SEARCH FOR $\pi-\pi$ RESONANCE IN ANTIPROTON ANNIHILATIONS AT 1.65 BeV/c

In a recent paper Cerulus considered the effect of a strong $J=1$, $T=1$ pion-pion resonance in antiproton-proton annihilation within the framework of the statistical model [1].

Cerulus' approach consists in dealing with the two resonant pi's as with a single particle—an isobar of mass equal to 3 or 4 pion masses and having the above mentioned quantum numbers. He calls this particle $\sigma^{\pm}$. The interaction volume (the only parameter of the original Fermi theory) is taken to be :

$$\Omega_0 = \frac{4}{3}\pi\left(\frac{\hbar}{m_R c}\right)^3$$

for both $\pi$'s and $\sigma$'s, while the results turn out to be quite insensitive to variations of the $K$-meson interaction volume (between $\Omega_0$ and $^1/_{30}\ \Omega_0$).

Of all the consequences of Cerulus' calculations, the most promising one for an experimental test seemed to be the shape of the energy or momentum spectrum for particles produced in the annihilations yielding 2 visible prongs. This theoretical spectrum is shown in Fig. 1 for annihilations at rest and $m_\sigma = 3$ or 4 $m_\pi$. The bulk of the spectrum at low energy is due to annihilations in which one or more neutral particles are produced, while the peak at the high end of the spectrum should come from the pion emitted in the process :

$$\bar{p}+p\rightarrow\sigma^{\pm}+\pi^{\mp}$$

(The $\sigma^{\pm}$ would then decay into $\pi^{\pm}+\pi^0$ in a time of the order of nuclear times.)

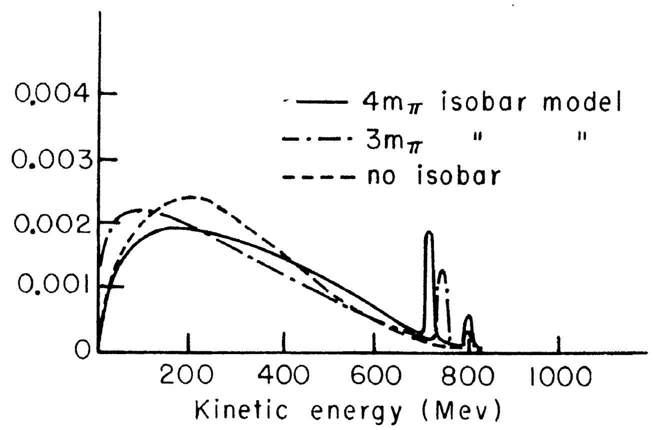

**Fig. 1** Theoretical spectrum for particles produced in annihilations yielding two prongs, for $m_\sigma = 3$ or 4 pion masses.

The available antiproton film from the 72-inch hydrogen bubble chamber was taken at 1.65 BeV/c. Calculations are being done to see how the theoretical spectrum must be modified at this energy. There is about a 25% change in total energy available in the c.m. system with respect to the at-rest case.

The main problem related to the measurement of the spectrum is the elimination of the background. This is due to several sources:

*(a)* $\pi^-$ interactions—both elastic and inelastic scatters of the $\pi^-$ component of the beam.

*(b)* $\bar{p}$-$p$ elastic scatters.

*(c)* $\bar{p}$-$p$ inelastic scatters.

*(d)* misinterpretation of $K$'s as $\pi$'s, and consequent distortion of the c.m. spectrum.

*(a)* This difficulty is taken care of by a fortunate feature of the beam: the momentum spectra of antiprotons and pions are different enough that a discrimination is possible. These spectra are shown in the paper of J. Button et al. on the reaction $\bar{p}+p\rightarrow\bar{\Lambda}+\Lambda$ (Session S3). In the present sample no event was accepted that had an incident momentum less than 1620 Mev/c.

*(b)* Events in which the recoil stopped in the bubble chamber could be eliminated on the scanning table, while all other 2-prongs were measured and checked for coplanarity and energy and momentum balance.

*(c)* It is important to notice that contamination from this source would affect the low energy part of the spectrum and not the critical tail region.

One needs to concern oneself only with reactions of the type;

$$\bar{p}+p\rightarrow\bar{p}+p+\pi^0 \qquad (1.1)$$

$$n+p+\pi^- \qquad (1.2)$$

$$\bar{p}+n+\pi^+ \qquad (1.3)$$

the percentage of events giving two or more pions beings small. These belong to the one-constraint class and and can therefore in principle be identified and eliminated through the kinematic analysis performed by the KICK computer program. At present the $\chi^2$ distribution is not quite satisfactory; however, there seems to be a higher probability of getting spurious fits (from events in which two or more neutral particles are produced) than not getting fits in the correct assumption. All 24 events giving fits reactions (1.1), (1.2), or (1.3) with $\chi^2\leq 10$ were eliminated from the present sample. A few true annihilations (again, not in the critical region) were probably discarded in this way.

*(d)* The theoretical spectrum includes particles coming from all possible 2-charged prong channels. However, it is generally impossible to tell $K$'s from $\pi$'s at this energy. Consequently a deformation will be introduced in the c.m. spectrum through Lorentz transformations based on a pion mass assumption for all prongs.

To correct for this effect, the spectrum of $K_1^0$ as measured in the course of a different research project, was transformed to the c.m. both under the correct and the incorrect mass assumption; the difference properly weighted, could be used to correct the charged spectrum; however the shift turned out to be not very significant with the available statistics, and the correction was therefore neglected at this time.

The resulting experimental spectrum, as obtained from only 135 2-prong stars, is shown in Fig. 2. The position of the expected peak is indicated by the arrow. Better statistics and the theoretical calculation at the right energy are needed and planned.

It is to be remarked that the energy of the pion produced opposite to the resonating pair is far from the resonating region, and should therefore not disturb the other two.

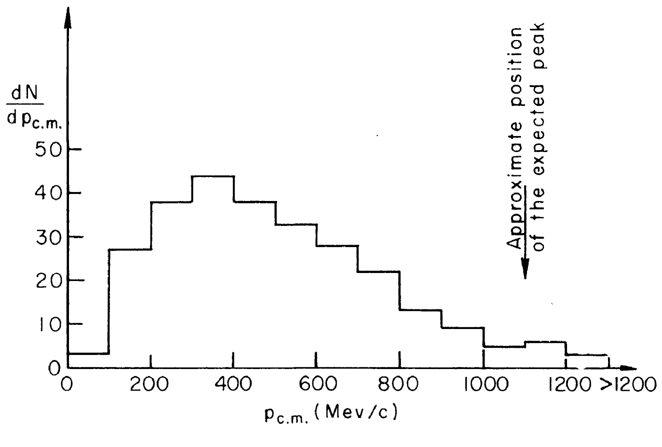

**Fig. 2** Experimental spectrum for two pronged stars.

## 2. SEARCH FOR A HEAVY NEUTRAL MESON IN HIGH-ENERGY ANTIPROTON INTERACTIONS

The existence of a heavy neutral meson was postulated by Nambu [2] in an attempt to explain the nucleon electromagnetic structure. More recently Chew [3] has suggested that a three-pion resonance or even a bound state may have the same characteristics as the Nambu $\rho^0$ meson.

The properties of this particle or resonant state are:

Isotopic Spin = 0
Spin = 0
Parity = odd
Mass $\leq 3m_\pi$
Life-time $\sim 10^{-20}$ sec.

Decay modes, as suggested by Nambu, are:

$$\begin{aligned} \rho^0 &\to \pi^0+\gamma \\ &\to 2\pi^0+\gamma \\ &\to \pi^+ + \pi^- + \gamma . \end{aligned}$$

Decay into leptons should also be possible, but at a much slower rate.

This new state should explain the large radius of the isotopic scalar form factor of the nucleon; further, it should give rise to a short-range nuclear force perhaps related to the hard repulsive core of potential theory. In antinucleon-nucleon annihilations, as suggested by several authors [4], a bound state or resonance could explain high pion multiplicities without the large volume necessary in the usual statistical theory.

In the film from the recent antiproton experiment at 1.6 BeV/c, done with the 72-inch hydrogen bubble chamber, two classes of events were examined for evidence of a heavy neutral particle or three-pion resonance. These were annihilations into two charged pions and annihilations into four charged pions. Inelastic and charge-exchange scatterings were also among the events examined, but were too few in number to be useful for analysis.

The two-prong interactions sought were:

$$\bar{p}+p\to\pi^+ + \pi^- + \rho^0,\ \rho^0\to\pi^0+\gamma \text{ or } 2\pi^0+\gamma \tag{2.1}$$

$$(\bar{p}+p\to\bar{p}+p+\rho^0)$$

$$(\bar{p}+p\to\bar{n}+n+\rho^0).$$

The four-prong events of interest were:

$$\bar{p}+p\to\pi^+ + \pi^- + \rho^0,\ \rho^0\to\pi^+ + \pi^- + \gamma \tag{2.2}$$

$$\bar{p}+p\to\pi^+ + \pi^- + \pi^+ + \pi^- + \rho^0,\ \rho^0\to\pi^0+\gamma \text{ or } 2\pi^0+\gamma$$

$$(\bar{p}+p\to\bar{p}+p+\rho^0,\ \rho^0\to\pi^+ + \pi^- + \gamma). \tag{2.3}$$

Interactions expected to contribute heavily to the background for the two-prong events were:

| | |
|---|---|
| $\bar{p}+p\to\pi^+ + \pi^- + 2\pi^0$ | ~ 1200 events (or 30% of all 2-prong annihilations) |
| $\to\pi^+ + \pi^- + 3\pi^0$ | ~ 1000 |
| $\bar{p}+p\to K^\pm + \pi^\mp + K^0$ | ~ 200 |
| $\to K^\pm + \pi^\mp + K^0 + \pi^0$ | ~ 300 |
| $\bar{p}+p\to\bar{p}+p$ | ~ 1100 indistinguishable from annihilations without fitting. |
| $\pi^- + p\to\pi^- + p$ | ~ 2100 indistinguishable from annihilations. |
| $\bar{p}+p\to\bar{p}+p+\pi^0$ | ~ 350 |
| $\to\bar{p}+\pi^+ + n$ | ~ 350 |
| $\to\bar{p}+\pi^- + \bar{n}$ | ~ 350 |

Predictions are based on the statistical model and other studies of this experiment.

Interactions which were troublesome background for the four-prong events were:

| | |
|---|---|
| $\bar{p}+p\to\pi^+ + \pi^- + \pi^+ + \pi^-$ | ~ 1000 events |
| $\bar{p}+p\to\pi^+ + \pi^- + \pi^+ + \pi^- + \pi^0$ | ~ 3000 |
| $\bar{p}+p\to\pi^+ + \pi^- + \pi^+ + \pi^- + 2\pi^0$ | ~ 1500 |

The experimental technique utilized was the plotting of a "missing-mass spectrum" for the two-prong and also for the four-prong events. This was done by using IBM computer programs to calculate:

$$MM = [(\Delta E)^2 - (\Delta p)^2]^{\frac{1}{2}},$$

where $\Delta E$ is the difference in energy and $\Delta p$ is the difference in momentum between the $\bar{p}+p$ initial state and the charged particles of the final state. Analysis of the two-prong events had the advantage of better resolution of the expected $\rho^0$ peak near $MM = 3m_\pi$ from the background spectrum, but the disadvantage of association with many types of background interactions yielding ambiguous fits and spurious values of $MM$.

As indicated above, estimates could be made of the expected $MM$ peak at one pion mass. The background continuum for events with two or more neutrals was calculated roughly by assuming secondaries to be only pions, energy to be equally distributed, and total momentum of missing neutrals to be $\sim 0$ in comparison with their total energy. The missing-mass spectrum was also obtained by exact phase-space calculation with the assumption of massless particles except at the end-points of the spectrum. The weighting of various pion multiplicities was determined with the usual statistical-model assumption of equal weighting of available I-spin states.

Reactions (2.1) and (2.3) were treated as described above, with the use of all visible secondaries to calculate $MM$. Reaction (2.2) required the use of one $\pi^+-\pi^-$ pair as directly-produced secondaries; thus, each event yielded four $MM$ results for each possible $\pi^+-\pi^-$ combination. For this reaction (2.2), the existence of a resonance in $MM$ would be reflected strongly in the associated "non-resonant" pair; the latter would cause some distortion of the $MM$ spectrum near the peak.

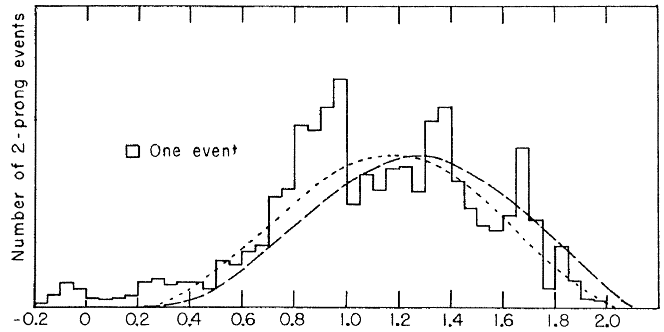

**Fig. 3** Missing-mass spectrum for annihilation events with two visible prongs (reaction (2.1) of article). The istogram represents a total of 311 events. The dashed curve is the estimate of the spectrum for $\bar{p}+p \rightarrow \pi^- + \pi^+ + n\pi^0$ with the assumption of the equipartition of energy, etc., the dotted curve is the result of phase-space calculations with massless particles (except at the extremes of the curve). Events with one neutral pion should constitute only a few percent of the 2-prongs. The reactions $\bar{p}+p \rightarrow K^+ + \pi^- + K^0$ or $K^- + \pi^+ + K^0$ very likely contribute to distortions in the region of 800 MeV.

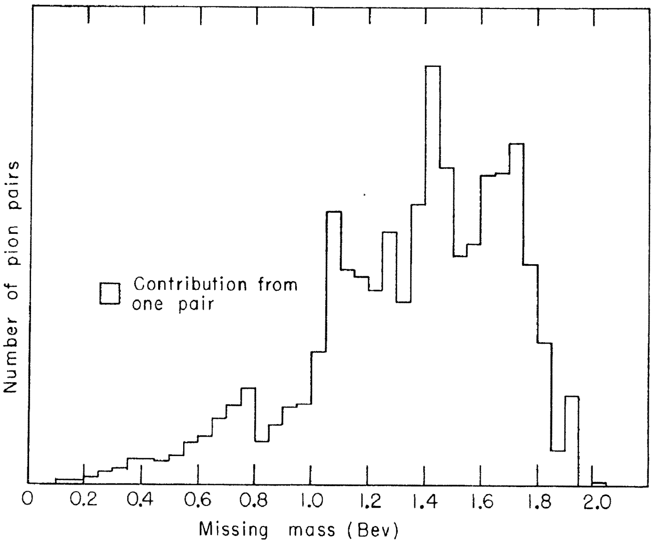

**Fig. 4** Missing-mass spectrum for $\pi^+\pi^-$ pairs of 4-prongs annihilation events (reaction (2.2)). The total number of pairs is 172. This distribution should differ somewhat from that of Fig. 1 because of the different charge states considered. (Also any resonance effect would distort the background continuum.)

Experimental results plotted as idiograms are given with the approximate theoretical curves in Figs. 3, 4, and 5. Useful data on four-prongs came from 65 events; two-prong results are from 310 events.

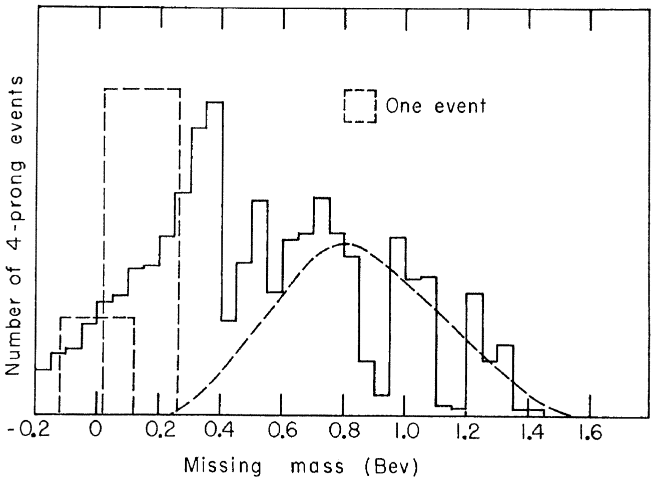

**Fig. 5** Missing-mass spectrum for 4-prong annihilation events (reaction (2.3). The number of events plotted is 65. The dashed curves represent rough estimates of the background with 0, 1, and $n$ neutral pions; the last assumes equipartition of energy, etc. The slight peaking near 350 MeV could be the result of poor energy resolution (the uncertainty in $MM$ being on the average 120-150 MeV), contamination by $K$-pair annihilations, and inaccuracy of the theoretical curve.

## 3. THE ANNIHILATION OF ANTIPROTONS INTO TWO AND ONLY TWO MESONS

A search has been carried out for the reactions:

$$\bar{p}+p\rightarrow\pi^{+}+\pi^{-} \quad \text{and} \quad (3.1)$$

$$\bar{p}+p\rightarrow K^{+}+K^{-} \quad (3.2)$$

among the approximately 21,000 interactions of 1.61±0.03 BeV/c antiprotons in the 72″ hydrogen bubble chamber. Neither of these reactions has ever been observed in previous antiproton experiments. The fact that these cross sections are small is consistent with the predictions of the Fermi statistical model. If one adjusts the interaction volume to obtain an average pion multiplicity of 5.0, the statistical model predicts that only one annihilation in 700 will result in two charged pions, and corresponding to an average pion multiplicity of 5.2 the prediction is only one such event in 1000 annihilations. Thus, the statistical model predicts that in our approximately 10,000 annihilations into pions we should see on the order of 10 annihilations into two charged pions.

All of the approximately 13,000 two-prong events (including elastic scattering, annihilation, inelastic scattering, and pion events) were investigated on the scanning table and all but 125 of them were eliminated. These were measured on the Franckenstein measuring projector and kinematically analyzed. Of these all but 25 were eliminated as possibilities for reaction (3.1) and all but 8 were eliminated as possibilities for reaction (3.2). On the basis of this, definite upper limits of 1 in 400 and 1 in 1000 can be stated for the fraction of antiproton annihilations at 1.61 BeV/c which go to reactions (3.1) and (3.2) respectively.

Unfortunately, in most cases the identification of these events is not unique. Although it is almost always possible to separate those events which fit reaction (3.1) from those which fit reaction (3.2), in most of the cases the possibility that the reaction is:

$$\bar{p}+p\rightarrow\pi^{+}+\pi^{-}+\pi^{0} \quad (3.3)$$

cannot be definitely eliminated. All of the events which fit reaction (3.2) also fit reaction (3.3). Of the 25 candidates for reaction (3.1), 15 appear to be genuine ones, and of the 8 candidates for reaction (3.2), 6 appear genuine. Until the systematic errors in the analysis of 72″ bubble chamber film are better understood than they are at present, and until further studies are made of the likelihood of three-body annihilations faking two-body annihilations within our experimental errors, these numbers are only tentative. A few of the events which fit reaction (3.1) strongly favor it over reaction (3.3) and for two of them all reactions other than (3.1) are completely ruled out. So we feel confident in saying that we have observed cases of the annihilation of antiprotons into two pions.

## 4. COMPARISON OF HIGH-ENERGY ANTIPROTON ANNIHILATIONS WITH STATISTICAL-MODEL PREDICTIONS

The distribution of pion multiplicities in antiproton annihilations has been fitted at low energies with various models by the adjustment of a volume parameter. The original Fermi theory required a volume $\Omega = 10$ (in units of a sphere with radius of the pion Compton wavelength). Two other models have been considered, the Fermi statistical annihilation modified by a pion-pion interaction and the Koba-Takeda core-and-cloud annihilation process [5]. The volumes required for these models are much smaller and give predictions of *K*-meson abundance more consistent with experiment.

Events observed in the recent antiproton experiment with the 72-inch hydrogen chamber yielded the prong distributions shown in Figs. 6 and 7 for antiproton momenta 1.6 and 2.0 BeV/c. Corrections were made for background $\pi^{-}+p$ events and for antiproton charge-exchange and elastic scatters. The proportion of pion to antiproton interactions was determined by counting delta rays (of energy greater than the maximum produced by antiprotons) on interacting tracks.

Extensive calculations of Lorentz-invariant phase-space integrals have been made [6] and compared with experimental data at 1.05 BeV/c [7]. A volume $\Omega = 8$ for the Lorentz-invariant theory (or a volume $= 10$ for the non-invariant theory) was used to fit multiplicity distributions at this momentum (2100 MeV in the c.m. system). However, a volume $= 5$ in the invariant theory is found necessary to give results in good agreement with the 1.6 BeV/c and 2.0 BeV/c experiments. Experimental values for the ratio of 6-prong to 4-prong events are plotted and compared with statistical-model predictions for various $\Omega$ in Fig. 8.

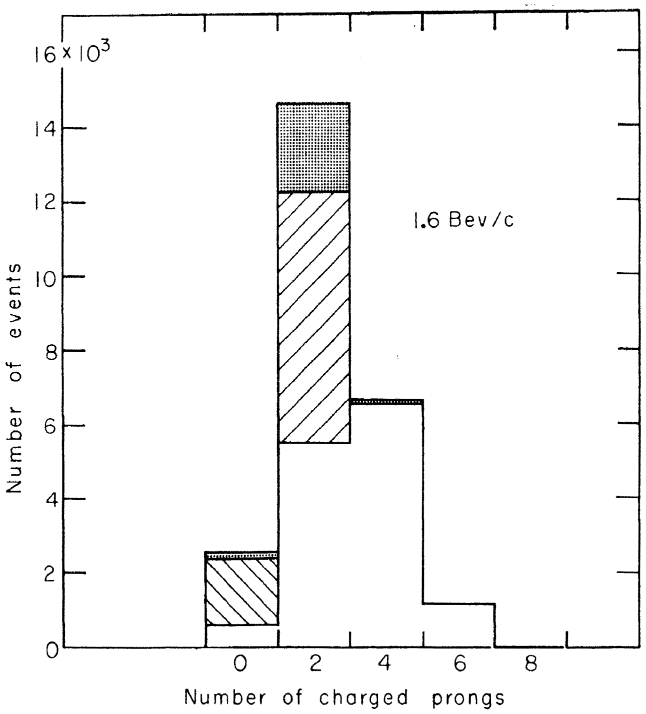

**Fig. 6** Multiplicity of charged prongs in annihilation events at an antiproton momentum of 1.6 BeV/c. The shaded areas represent the estimated number of $\pi^- + p$ interactions; the cross-hatched areas are antiproton charge-exchange and elastic scatters.

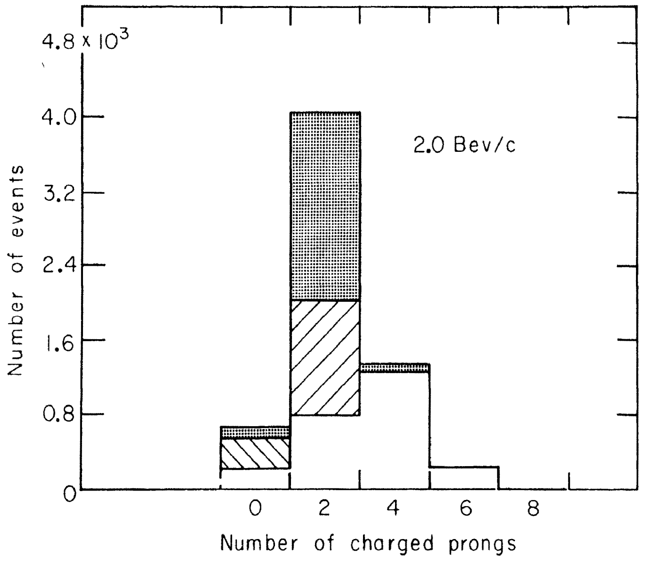

**Fig. 7** Multiplicity of charged prongs in annihilations at 2.0 BeV/c. Shaded and cross-hatched areas have the same interpretation as in Fig. 6.

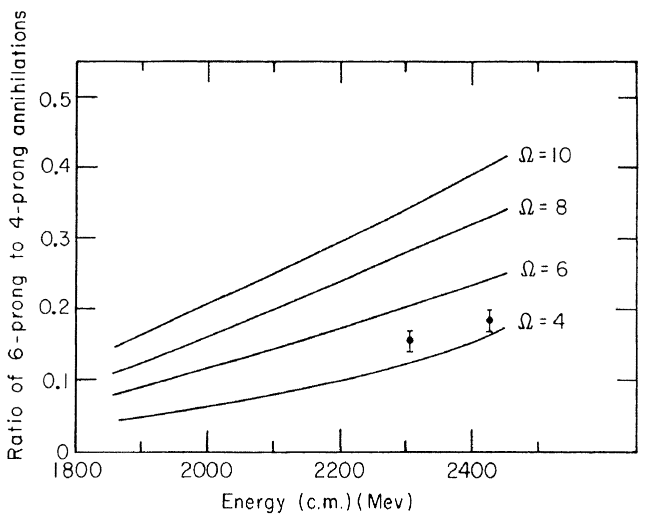

**Fig. 8** Ratio of 4-prong annihilation events vs. c.m. energy. Calculations were done with Lorentz-invariant phase space for a Fermi-type interaction.

The average multiplicity in annihilations increases quite markedly with energy in the Fermi theory; however, because of the smaller annihilation volume, the Koba-Takeda theory predicts only a very slight increase. Experimental values for average multiplicity obtained by Goldhaber, Silberberg, et al[7] at 1.05 BeV/c and by the authors at 1.61 and 1.99 BeV/c (2100, 2305, and 2430 MeV in the c.m. system) are plotted in Fig. 9. Comparison is made with multiplicity vs. energy curves obtained from Fermi-model calculations (Lorentz-invariant, but without correction for Lorentz contraction due to motion of the

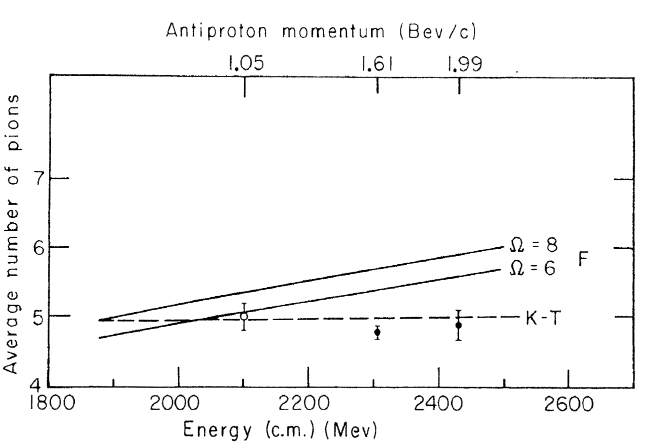

**Fig. 9** Energy dependence of average pion multiplicity. Solid lines are results of calculation with a Lorentz-invariant Fermi model; the dotted line was obtained from the Koba-Takeda model.[5] The point at 2100 MeV represents data of Goldhaber et al[4]; the points at higher energy are results of the experiment reported here.

antiproton) and from Koba-Takeda calculations. (Total multiplicities were obtained from charged-prong multiplicities through multiplying the latter by 1.51, a factor given by Pais' calculations with equal weighting of various I-spin states [8]). Evidently the higher-energy multiplicities are in much better agreement with the Koba-Takeda than with the Fermi model.

## 5. ANTIPROTON-PROTON INELASTIC CROSS SECTIONS AT 1.61 BeV/c

The following four reactions constitute the inelastic antiproton-proton interactions which produce one pion

$$\bar{p}+p\rightarrow\bar{p}+p+\pi^0 \qquad (5.1)$$

$$\rightarrow\bar{p}+n+\pi^+ \qquad (5.2)$$

$$\rightarrow n+\bar{n}+\pi^0 \qquad (5.3)$$

$$\rightarrow\bar{n}+p+\pi^- \qquad (5.4)$$

We have measured the cross section for reactions (5.1) and (5.2) for antiprotons of 1.61±0.03 BeV/c. By charge conjugation invariance reactions (5.2) and (5.4) must have equal cross sections. Reaction (5.3) is difficult to observe alone, but all measurements of the charge exchange cross section have included this reaction. Because many antiprotons annihilate into 2 charged pions plus several neutral pions ($\bar{p}+p\rightarrow\pi^++\pi^-+n\pi^0$), it is extremely difficult to analyze a random sample of 2 prong events. Therefore, we have analyzed only those events in which the negative secondary produces a 4 or 6 prong event. A 6-prong secondary event is certain to be an annihilation of an antiproton. Almost all secondary 4-prong events are also annihilations. Since the few 4-prong events which are produced by pions can have at most one neutral associated pion, they can be identified by kinematic analysis.

In a total of 21,000 $\bar{p}$ interaction events in the 72-inch hydrogen bubble chamber, there were 400 connected events of this type. A careful scanning table measurement of these permitted us to eliminate almost all the elastic events. The Franckenstein measuring projector was used to measure the 50 remaining candidates for the inelastic reactions. Kinematic analysis of these (supplemented by ionization measurement of the positive track for a few events) yielded

22 of $\bar{p}+p\rightarrow\bar{p}+p+\pi^0$
17 of $\bar{p}+p\rightarrow\bar{p}+n+\pi^+$
1 which fits either reaction.

The remaining 10 events are $\bar{p}p$ elastic or $\pi^-p$ events.

In order to calculate the cross section for this inelastic process it is necessary to weight each event with the reciprocal of the average probability that a $\bar{p}$ from such an event will produce a 4 or 6 prong annihilation in the 72-inch chamber. After weighting, the estimate for the number of events is

| | |
|---|---|
| for reaction (5.1) | 274±60 |
| for reaction (5.2) | 215±55 |
| for either (5.1) or (5.2) | 11 |

After correcting for efficiency and making use of the known antiproton-proton total cross section, we obtained

$$\sigma(\bar{p}+p\rightarrow\bar{p}+p+\pi^0) = 1.5\pm0.4\text{mb}$$

$$\sigma(\bar{p}+p\rightarrow\bar{p}+n+\pi^+) = 1.1\pm0.3\text{mb}$$

A statistical model calculation predicts the ratio : [9] 4:5:4:5 for reactions (5.1):(5.2):(5.3):(5.4). The isobaric model predicts the ratio : [10] 2:1:2:1. Our results for reactions (5.1) and (5.2) are intermediate between the predictions of these two models.

We did not find any event of the type $\bar{p}+p\rightarrow\bar{p}+p+\pi^++\pi^-$ in which the antiproton annihilated in a 4 or 6 prong event. This places an upper limit of about 0.1 mb for the cross section for this reaction.

If either the isobaric model or the statistical model with no interference is assumed, the cross sections for reactions (5.1) and (5.3) are equal. On the basis of this assumption the total inelastic cross section is

$$\sigma_{\text{inelastic}} = 5.1\pm1 \text{ mb}$$

We note that this value is small compared to the nucleon-nucleon inelastic cross sections. These cross sections are :

$$
\begin{aligned}
21\pm 1\text{mb for} \quad & p+p\rightarrow p+p+\pi^0\\
& \rightarrow p+n+\pi^+\\
\text{and } 24\pm 4\text{mb for} \quad & n+p\rightarrow n+p+\pi^0\\
& \rightarrow n+n+\pi^+\\
& \rightarrow p+p+\pi^-
\end{aligned}
$$

as observed by Batson et al. [11]

Using the above values and the measurements of T. F. Elioff et al [12] for the inelastic (plus annihilation) cross section, we determine the antiproton annihilation crosssection at 1.61 BeV/c as

$$\sigma_{\text{annihilation}} = \sigma_{(\text{inelastic+annihilation})} - \sigma_{\text{inelastic}}$$

$$= (56\pm 3)-(5\pm 1) = 51\pm 3 \text{ mb.}$$

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## DISCUSSION

WATTENBERG: I am curious as to why I do not see on your next to the last slide the $\pi^0$ showing up as a missing mass, in the $\pi^+ + \pi^- + \pi^0$ events.

SOLMITZ: The reason for that, I believe, is that if you do statistical model calculations, for the multiplicity, then the two prong are really dominated by two or three or four extra $\pi^0$'s. I think the dominant mode is three extra $\pi$'s, so that one extra $\pi^0$ is probably not very prominent, and may also be partially washed out just by experimental resolution. Actually, I forgot to mention the experimental resolution; it is something on the order of plus or minus 100 MeV on the mass scale. It is not very significant.

LINDENBAUM: I think the really more interesting parts of the non-annihilation meson production would be the energy spectra of the nucleons and antinucleons and the pions which should be studied in addition to the branching ratios. Now of course you would probably need much more events than you have there.

SOLMITZ: Would you? I am not sure.

LINDENBAUM: Well, you could start to do something with what you have but I think it would be interesting to pursue the investigation especially if you get a chance to do so in the course of other work. If you neglect the additional effects due to the nucleon—antinucleon interaction, and the presence of the annihilation reaction, one can hope that at least in those cases which do not involve annihilation the meson production proceeds via production of nucleon isobars and anti-isobars which predominantly decay outside the range of mutual force, and that in these processes, you can approximately hope that the characteristics of the pion production are the same as in nucleon-nucleon collisions in equivalent $T$ states. For example, you have here with single pion production via the $T = J = {}^3/_2$ isobar just $T = 1$, with two pions you would have $T = 0$ as well, and we can make very definite predictions for the spectra on the basis of the *p-p* and *p-n* interactions. One prediction for example, is that the nucleon and the antinucleon, say at one BeV incident energy, should show in the center of mass system a peak at 90 MeV and the $\pi$ spectrum should be identical with the $\pi$ spectrum in the *p-p* production. I think that no one would say that this would or would not work, but it would at least provide a clue to see to what extent it does work in non-annihilation meson producing events. You could then have a handle on separating the parts that come from the meson cloud and the parts that come from the annihilation, in the reductions involving annihilation.

SOLMITZ : This is all the data we have in which there is a subsequent antiproton annihilation, and if there is something very striking then may be it might show up in this many events. I will tell them to look for it.

BREIT : I would like to ask what mass the test for $J = 1$, $T = 1$, was aimed at, and also, what degree of likelihood is there that the mass you looked for is not there. I was not able to correlate the two graphs very well. The theoretical graph showed peaks that were rather high, on the right end and then the experimental one, off hand, looked as if the experiment indicated there was not much chance of a particle. Yet, that was not your opinion, so I am confused.

SOLMITZ : With $J = 1$, $T = 1$, Cerulus calculated by doing a Monte Carlo phase space calculation, with three $\pi$ masses, and 4 $\pi$ masses. Those two peaks that you saw were three $\pi$ masses and four $\pi$ masses, and even a large change like that did not change the position of the peak very much. In the experimental plot there was no sign of a peak in that region at all.

BREIT : So really what you meant to say was that it spoke against the suggestion.

SOLMITZ : That is right, but on the other hand, since the area of the peak was only a few per cent, and there were something on the order of 250 events, by statistical fluctuations, it can not really be ruled out. We have not yet ruled it out, but the experimental curve spoke against it.

BREIT : Did the theoretical calculations include the possibility of a reasonably short life of that particle? That would produce some diffuseness in the result.

SOLMITZ : No, as I remember that paper, it was just a particle of a given mass.

BREIT : So then it really does not rule out the possibility.

SAKURAI : If the mass of the $\rho^0$ meson is greater than three pion masses, then the dominant decay mode of the $\rho^0$ should be $\pi^+ + \pi^- + \pi^0$. Now, have you looked into any correlation among the three pions?

SOLMITZ : No correlations have been looked at, and I think unless you know what you are looking for, it is a very, very difficult problem, because you have so many events with very high multiplicity, four and six prong events, and unless you really have some idea of what you are looking for, I think it is very hard to really find real effects. For one thing, you cannot tell easily on the basis of kinematics how many extra $\pi^0$'s are given off.

EKSPONG : I have been given a comment by H. Pilkuhn, now at Stockholm University, saying that if annihilation of antiproton-proton into two *K*-mesons only is observed, then it follows that the *K*-mesons do not obey the “ wrong ” statistics, that means they obey Bose-Einstein statistics. It was speculated, I think, last year that *K*-mesons could obey the “ wrong ” statistics. Pilkuhn has shown that on the basis of assuming equal parities of $K$ and $\overline{K}$, assuming conservation of parity $P$, and charge parity $C$, then the observation of this process you just reported shows the *K*-mesons to obey Bose-Einstein statistics.