The multiplicity results are shown in Figures 4 and 5 for the two beam energies. These are based upon the results of the "polymeter" analysis which surrounds the beam interaction region. These multiplicities are only for those events which have a hadron passing through our spectrometer. We found that although the polymeter covers 99% of the solid angle, about 30% of our events had an odd number of charged particles whereas one would expect an even number. Studies of the e^+e^- final state data showed that there was less than a 10% chance of getting an extra track through some background, so we have tentatively concluded that there are some inefficiencies in the polymeter, probably in the regions of the support wires. The graphs shown are for the data when it is forced to have an even number of charged particles by adding one particle to each "odd" event. The effect of this on the average multiplicity was not large, and we believe the numbers given on the figure for this quantity are good to about ±.5. Since our solid angle coverage is large for the polymeter, we believe that the

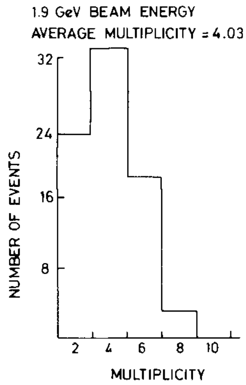

Fig. 4

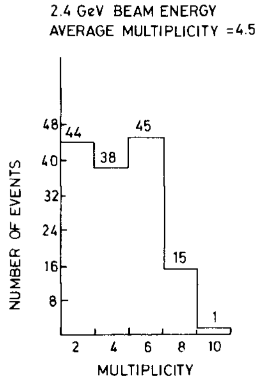

Fig. 5

agreement between our multiplicities and those found by other groups who assumed a phase space angular distribution for hadrons represents fairly strong evidence against any theory which predicts a particle distribution rising steeply at small angles, unless that rise begins at less than 10 degrees.

Finally, we would like to point out that an experiment has been approved to set up in July 1975, using substantially the same apparatus at the increased SPEAR energy of about 3.6 GeV per beam.

FORM FACTORS AND LOW ENERGY DYNAMICS IN e^+e^- ANNIHILATION

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The contributions presented at this conference in this domain are characterized by increased accuracy within the existing models which corresponds closely to similar developments on the experimental side. The main subjects covered are:

- rigorous properties of the pion form factor (sum rules, bounds, zeroes)
- developments of the (restricted and extended) VDM models.
- detailed analyses of quasi-body reactions.

Concerning the pion form factor the essential new result is the derivation by BONNEAU, GRUNBERG, MARTIN, PHAM and TRUONG[1] of inequalities which are independent of the number of zeroes and do not require the polynomial bound. In particular they obtain the sum rule

$$(1) \qquad I \equiv \frac{2\mu}{\pi} \int_{4\mu^2}^{\infty} \frac{\log|F_\pi(s)|\,ds}{s\sqrt{s-4\mu^2}} \geq 0$$

which was previously established within the polynomial bound and the hypothesis of a finite number of zeroes. Saturating (1) for $4\mu^2 \le s \le 0.3$ GeV^2 using the experimental results on $\pi^- p \to n + e^+e^-$ and for 0.3 GeV$^2 \le s \le 2.$GeV^2 using $e^+e^- \to \pi^+\pi^-$, they get the sum rule:

$$\frac{2\mu}{\pi}\int_{2.}^{\infty} \frac{\log|F_\pi(s)|\,ds}{s\sqrt{s-4\mu^2}} \ge -0.33 \pm 0.11$$

This gives a lower bound for the high energy behaviour of the time like form factor; for example if on average $|F(s)| \simeq \frac{a}{s^n}$, then $n \le 1.2 \pm 0.3$.

CRONSTROM(2,3) and independently DUBNICKA and MESHCHERYAKOV(4) use

(1) and

(2) $$J \equiv \int_{4\mu^2}^{\infty} \frac{\log|F_\pi(s)/F_\pi(4\mu^2)|\,ds}{(s-4\mu^2)^{3/2}} \ge 0$$

(obtained with the polynomial bound and the hypothesis of a finite number of zeroes) in order to look for the existence of zeroes (real zeroes for $s < 4\mu^2$ or complex conjugate pairs); the equalities in (1) and (2) hold in the absence of such zeroes. (2) is less sensitive than (1) to the unknown high energy behaviour but the experimental uncertainties on the low energy part do not allow in my opinion the drawing of a definite conclusion up to now; various fits done by these authors give $2\mu J$ varying from 0.20 to 1.19 and these results have also to be compared with the different earlier analysis by Roos, which lead to the absence of zeroes.

With similar techniques GESHKENBEIN, IOFFE and SHIFMAN have been able to constrain the high energy behaviour of the proton form factors in the time-like region using the present experimental data in the space - and time-like region; a $^1/S^2$ fall-off requires at least two zeroes which could correspond

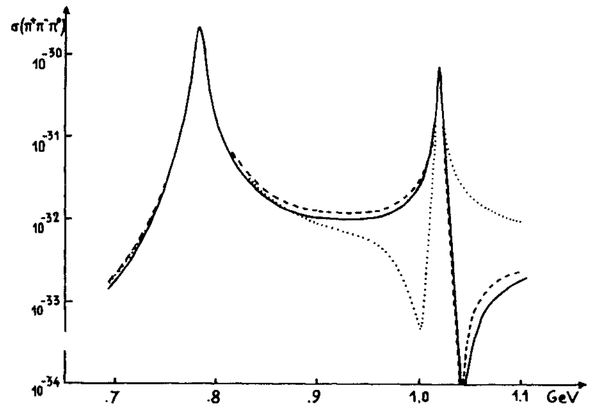

Fig. 1 Cross section for $e^+e^- \to \pi^+\pi^-\pi^0$ in the vector dominance model of abstract 24.

to higher vector mesons; an exponential fall-off is also allowed.

The restricted ρ, ω, ϕ dominance model has been developed(5,6) in order to take into account the various annihilation chanels, in particular the implications of the energy dependence of the width $m\Gamma_V(s)$. The vector meson propagators become

$$\Delta_V(s) = (m_V^2 - s)\left[1 - (m_V^2 - s)\, G_V(s)\right] - im\Gamma_V(s)$$

where $G_V(s)$ is the real part of a dispersion integral over $m\Gamma_V(s) \equiv \sum_i m\Gamma_{V\to i}(s)$, i being all the channels coupled to V. In the ω, ϕ case this expression results from the diagnalization of a matricial propagator which leads to a mixing angle having an imaginary part which is not completely negligible for $s \ge m_\phi^2$. These formulas predict the VDM amplitudes in modulus and in phase and in particular nice interference shapes in the region where two vector mesons overlap, for example near, below or above the ϕ in the reactions $e^+e^- \to 3\pi$, K^+K^- , K^oK^o , $\pi\gamma$ and $\eta\gamma$. The opening of higher channels in $m\Gamma_V(s)$ (multipions, heavy pairs ...) induce structures in $G_V(s)$ and therefore in each of these amplitudes (for example in $F_\pi(s)$) which are not necessarily connected with the existence of higher vector mesons.

Concerning interference shapes an interesting feature of the electromagnetic $\rho - \omega$ mixing has been noticed by ACHASOV, KOZHEVNIKOV and SHESTAKOV[7] the interference effect should be much more pronounced in the $\pi^+\pi^-$ mass spectrum of $e^+e^- \to \pi^+\pi^-\pi^o$ than in direct $e^+e^- \to \pi^+\pi^-$ because of the relative importance of the ω amplitude as $g_{\gamma\pi\omega}/g_{\gamma\pi\rho} \simeq 3$ instead of $g_{\gamma\omega}/g_{\gamma\rho} \simeq \frac{1}{3}$.

The possible existence of higher vector meson nonets has also been considered[5] using as inputs the data concerning $\rho'(1.3) \to \pi\pi$, $\pi\omega$ and $\rho''(1.6) \to \pi\pi, \pi\omega, \rho\varepsilon$. With a Veneziano spacing $m_V^2 n = m_V^2 o + n$, SU_3 and an ideal nonet structure, partial and total width of the members $\rho^{(n)}$, $\omega^{(n)}$, $\phi^{(n)}$ and $K^{*(n)}$ are predicted. Higher terms ($n > 2$) are supposed to satisfy simple recursion rules. On the other hand BOHM, JOOS and KRAMMER[8,9] obtain the vector mesons as $q\bar{q}$ Bethe - Salpeter bound states; there are no odd daughters ($n = 1, 3, \ldots$) in this model but the spectrum of the even ones is degenerate (1ρ, $3\rho''$, $5\rho^{(4)}$...); the coupling constants predicted by this model (in particular the pion form factor) are in good agreement with experiment.

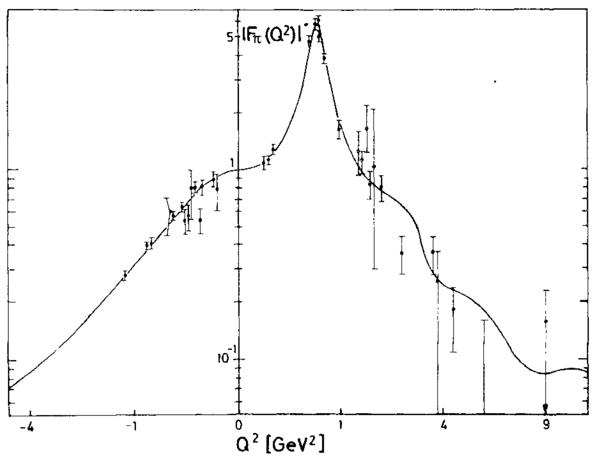

Fig. 2 Comparison of pion form-factor from the model of Bohm, Joos and Krammer (abstract 188) with data.

The occurence of broad states raises obviously the question of mixing, -between members of the same degenerate daughter in the quark model, - or between members of different daughters in any case. As an example we have treated[5] the $\rho - \rho'(1.3)$ case in which a complex mixing angle is required in order to fit correctly the experimental results on $e^+e^- \to \pi\pi$ and $\pi\omega$; solutions with different inputs of initial states ($m_{\rho'} = 1.3$, first daughter) or ($m_{\rho'_o} = 1.6$, second daughter) giving both $m_{\rho'} \simeq 1.3$ are equally probable. Precise experimental results in clean exclusive channels like $\pi\pi$, 3π, K^+K^-, $K^o\bar{K}^o$, $\pi\gamma$ or $\eta\gamma$ with complete analyses of interference phenomena are required in order to disentangle the complex superposition of higher vector mesons.

The three body production amplitudes $\gamma_V \to bcd$ have been related by ACTOR[10] to the s-channel helicity amplitudes $\gamma_V + b \to c+d$, with an explicit kinematical treatment of the resonance dominance $\gamma_V \to b+R_{\to c+d}$ in the cases $R = \varepsilon$, A_1, f and N^*.

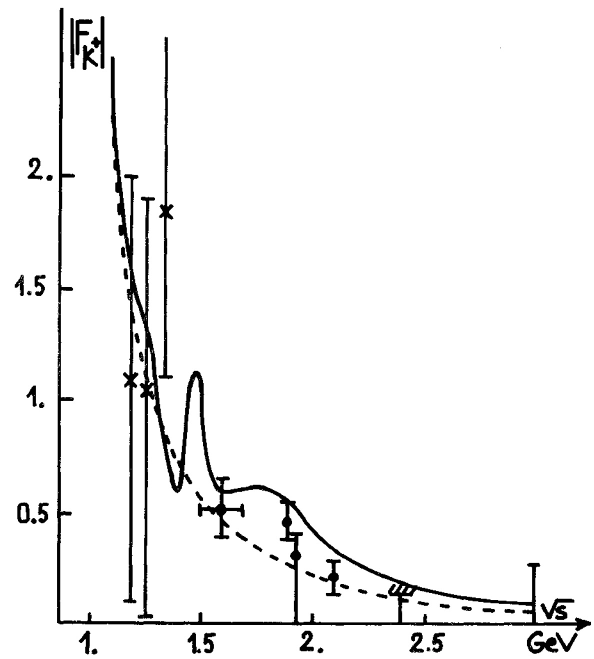

Fig. 3 Charged K meson form factor of abstract 24 compared with the data.

Independently HIRSHFELD, KRAMER and SCHILLER[11] have treated in a similar way the reactions $e^+e^- \to N\bar{N}\pi$ and calculated the cross-sections using the multi-polar analysis of the electroproduction $\gamma_V+N_1 \to N_2+\pi$. The results are of course very sensitive to the type of $\gamma_V NN^*$ form factors which are used; in the most favourable case (with VDM form factors) the cross-section appears to be of the order of several nb between 2 and 4 GeV.

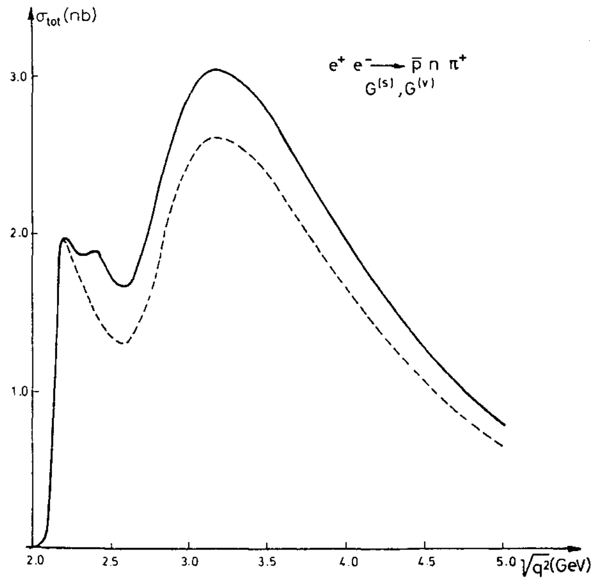

Fig. 4 Cross-section for $e^+e^- \to \bar{p}\ n\ \pi^+$ computed by Hirshfeld, Kramer and Schiller (abstract 306).

From these contributions and from my personal feeling I am sure that there is still much physics to be learned from low and medium energy e^+e^- annihilation. The accurate measurement of the pion form factor in particular below the ρ is of primary importance for analyticity tests. Strong and electromagnetic mixing between vector meson states as well as amplitude interferences in exclusive channels will give a lot of new constraints on models and symmetry schemes that hadronic collisions or other electromagnetic processes have not been able to give. In addition the search for higher vector mesons and the analyses of quasi-two-body production open to the e^+e^- collisions the field of the resonance physics in a much cleaner way than in hadronic collisions, due to the $J^{PC} = 1^{--}$ constraint and the knowledge of the production mechanism.

A good knowledge of the low and medium energy e^+e^- annihilation mechanism could be the unique way of understanding how the spectacular high energy results arise (dominance of some particular channels or couplings, well-defined superpositions of vector mesons or new interactions or particles ...) but we refer for such discussions to the report by J. ELLIS at this Conference.

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