E. Etim, A. F. Grillo, G. Pancheri-Srivastava and Y. Srivastava:
COMMENTS ON THE LEPTONIC COUPLINGS OF $\psi (3.1 \text{ GeV})$
RESONANCE.

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E. Etim\(^{(x)}\), A. F. Grillo, G. Pancheri-Srivastava and Y. Srivastava\(^{(o)}(+)\):
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ABSTRACT.

We study in detail some bounds imposed on the leptonic coupling of the recently discovered \(\psi(3, 1 \text{ GeV})\) resonance. These are based on the magnetic moment anomaly for the muon and the purely leptonic neutral current experiments. If the dip-like structure that seems to be present both in the SPEAR and in the Adone \(e^+e^- \rightarrow e^+e^-\) data is taken seriously, then a possible explanation in terms of Lee-Wick type negative metric boson is also presented.

The recently discovered \(\psi(3, 1 \text{ GeV})\) resonance\(^{(1)}\) seems to exhibit some peculiarities:

i) Under the assumption that the resonance is much narrower than the experimental energy resolution \(\Delta E \gtrsim 1.9 \text{ MeV}\), it has been estimated that \(\Gamma(\psi \rightarrow e^+e^-) \simeq \Gamma(\psi \rightarrow \mu^+\mu^-) \simeq 2 \text{ to } 5 \text{ keV and } \Gamma(\psi \rightarrow \text{hadrons}) \simeq \simeq 25 \text{ to } 60 \text{ keV}\(^{(1, 2)}\).

ii) SPEAR as well as Adone groups\(^{(2, 3)}\) reports seem to show interfe-

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rence effect in the $e^+e^-$ channel - which is destructive before the resonance. The peak in this channel seems shifted (from that seen in the hadronic channel) and the dip is $\sim 1$ MeV to the left of the peak. In the $\mu^+\mu^-$ decay channel, a dip before the peak (again approximately $\sim 1$ MeV) seems also to exist.

iii) MEA group\(^{(4)}\) at ADONE has also presented some evidence for a charge asymmetry in the $\mu^+\mu^-$ channel which appears to change sign in approximately 2 MeV around the resonance. If confirmed this would imply a strong parity violating component in the resonance decay.

If the interference effects in ii) and iii) (in the $\mu^+\mu^-$ channel) are taken at face value, we are forced to say that the spin $J$ of the resonance is $\geq 1$. Theoretically it is appealing then to entertain the possibility that $J = 1$ and that it is indeed the intermediate vector boson for neutral weak current\(^{(5)}\). But one immediately runs into severe obstacles with this nice interpretation:

a) If one accepts that $\Gamma_e$ and $\Gamma_T \ll \Delta E$, it is practically impossible to see an interference effect (dips and so on) at an energy interval comparable to $\Delta E$.

b) One obtains an enhancement instead of a dip before the resonance in the $e^+e^-$ decay channel in this scheme.

c) The sign of the charge asymmetry as given by the MEA group is opposite to that obtained with a standard V-A coupling.

Regarding point a), one possible way out is to suppose that $\Gamma_T \gg \Gamma_{\text{hadron}}$ - the rest coming mainly from decays into neutrinos. In addition, $\Gamma_{e^+e^-}$ and $\Gamma_{\mu^+\mu^-}$ also have to be much larger than the earlier estimates of $\lesssim 5$ keV. Below, we try to bound $\Gamma_{\mu^+\mu^-}$ from the $(g - 2)$ for the muon and $\Gamma_{\nu\bar{\nu}}$ from the available $e\nu$ data.

I. $(g - 2)$ for the muon.

Under the above hypothesis that the resonance is a pure V-A, one finds for the contribution to $a_\mu$. 
\[ a(\psi) \sim -\frac{4}{\pi} \frac{\Gamma(\psi \rightarrow \mu \mu)}{m_\psi} \left( \frac{m_\mu}{m_\psi} \right)^2 \sim -(1.5 \times 10^{-9}) \frac{\Gamma_\mu}{\text{keV}}. \]

If one compares the experimental data with the QED plus the hadronic contribution one finds the possible anomaly \( \Delta a_\mu \approx -(50 \times 10^{-9}) \).

Thus, in absence of any other cancelling contribution, \( \Gamma_\mu \approx 100 \text{keV} \). If instead of V-A, one had pure V coupling (like in the "charm" or "color" classifications) the bound is much worse, i.e. \( \Gamma^{(V)}_\mu \approx 175 \text{keV} \). Note that in this case \( a^{(V)}_\mu \) is opposite in sign.

II. Elastic e\( \nu \) and e\( \bar{\nu} \) scattering.

Regarding some speculations which admit of the possibility that the neutrino decay modes may be anomalously large (for example, as large as \( \sim 700 \text{keV} \)), we present some bounds which rule out this way of escape. Our observations stem from considering \( \nu_\mu e^- \) and \( \bar{\nu}_\mu e^- \) elastic scattering, for which experimental bounds exist. Adler and Tuan\(^7\) have given expressions for these cross-sections taking into account the experimental cuts. In terms of the \( e^+e^- \) and \( \nu_\mu \bar{\nu}_\mu \) decay widths, these cross-sections become (in the pure V-A form):

\[ \sigma (\bar{\nu}_\mu e^- \rightarrow e^- \bar{\nu}_\mu) \simeq (0.053) \left( \frac{\Gamma_e \Gamma_{\nu_\mu}}{\text{keV}^2} \right) (0.035 \times 10^{-41} \text{cm}^2 \frac{E_{\bar{\nu}_\mu}}{\text{GeV}}), \]

\[ \sigma (\nu_\mu e^- \rightarrow e^- \nu_\mu) \simeq (0.16) \left( \frac{\Gamma_e \Gamma_{\nu_\mu}}{\text{keV}^2} \right) (0.054 \times 10^{-41} \text{cm}^2 \frac{E_{\nu_\mu}}{\text{GeV}}), \]

to be compared with CERN Gargamelle results

\[ (0.03) \times 10^{-41} \text{cm}^2 \frac{E_{\bar{\nu}_\mu}}{\text{GeV}} < \sigma (\bar{\nu}_\mu e^- \rightarrow e^- \bar{\nu}_\mu) < (0.3) \times 10^{-41} \text{cm}^2 \frac{E_{\nu_\mu}}{\text{GeV}} \]
4.

\[ \sigma(\nu_\mu e^- \rightarrow e^- \nu_\mu) < 0.26 \times 10^{-41} \text{ cm}^2 \text{ E}_{\nu}/\text{GeV}. \]

Thus, one obtains

\[ 18 \approx \Gamma_e \Gamma_{\nu_\mu} \approx 30 \text{ keV}^2. \]

Experimentally, from \( \gamma\gamma \) group at Adone, \( \Gamma_e > 2.4 \text{ keV} \), which limits

\[ \Gamma_{\nu_\mu} < 12.5 \text{ keV}. \]

Similar bounds can also be obtained for \( \Gamma_{\nu_e} \). Saturating the experimental upper bound

\[ \sigma(\bar{\nu}_e e^- \rightarrow e^- \bar{\nu}_e) < (1.3 \times 10^{-41} \text{ cm}^2)(\text{E}_{\nu}/\text{GeV}), \]

we obtain

\[ \Gamma_{\nu_e} \lesssim 20 \text{ keV}. \]

These bounds are not much different for Weinberg-Salam type models. Thus, the total decay width cannot be substantially increased by appealing to the neutrino channels.

**Conclusion**

As discussed previously, taking the dip which is seen in the \( e^+ e^- \) data about 1 MeV below the peak at its face value, one is led to demand a large total width which however cannot now be attributed to known leptonic channels. The problem of the destructive interference before the resonance can be partially understood provided one employs a negative metric boson of the Lee-Wick type. Also, the charge asymmetry in \( \mu^+ \mu^- \) channel as observed requires one to relax the pure V-A structure and thus give up chirality. Lastly the possibility of spin other than 1 is still open. We hope to return to these problems elsewhere.
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(5) - The possibility of identifying this resonance as the mediator of weak interactions has been independently suggested by G. Altarelli, N. Cabibbo, L. Maiani, G. Parisi, R. Petronzio (University of Roma preprint); J. Sakurai, UCLA preprint; D. Weingarten (University of Rochester preprint); and S. Okun (Private communication).


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