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P L E N A R Y   R E P O R T

NEUTRINO PHYSICS

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Neutrino studies proposed long ago to be performed at high energy accelerators[I-4] became now very intensive.

The results presented in my talk are mainly based on the experiments realized with the installations operated during recent two years. These set-ups and the main experimental groups working at these installations are summarized in Tables I-2. The installations to be put into operation in the near future are also mentioned.

Besides investigations carried out in the high energy neutrino beams I would like also to mention a wide neutrino program to be performed at moderate energies at the muonic factories and to remind of the underground installations for cosmic and solar neutrino studies,some of them are already available.

The characteristics of many experimental set-ups have been given at the previous conferences. Here I shall present a brief description of the FNAL I5 foot bubble chamber with an external muon identifier(EMI). The set-up of this chamber is given in Fig.I. Many exciting results were obtained recently with this bubble chamber. I shall comment on them later on.

I am going to show you the pictures of event obtained when the bubble chamber SKAT started to operate at IHEP,Serpukhov(Fig.2).Attention should be paid to favourable background conditions in the chamber. In the near future we may expect quite interesting information from this chamber for an important energy range, just between that available at Gargamelle and FNAL I5 foot bubble chamber. I am certain that at the next conferences there will be more experimental data to be obtained from the new experimental set-ups at CERN and FNAL.

When looking at Tables I-2 I often recall the words said by W.Pauli after he had suggested a hypothesis on the neutrino existence which read approximately as follows: "*To-day I have done something terrible. A theorist should never do it.I have suggested something that cannot be ever verified experimentally*". One can hardly forget these words while the I5 foot bubble chamber in an intense proton beam(IO^{I3}) and rich H_2Ne mixture provides us with pictures where almost each one contains a neutrino event. Moreover a paper entitled "Prospects for Practical Use of Neutrino Radiation in Nuclear Power"[5] has been submitted to this Conference.

For the last two years the basic trends in the neutrino studies have been the following:

I. Search for new particles(charmed particles, heavy leptons,etc.).

2. Investigations of the neutral current structure.

3. Investigations of the hadron structure and dynamics of the lepton-hadron interactions at high energies (inclusive and exclusive processes, elastic scattering,etc.)

I can prolong this list by adding the studies of the solar neutrino which are of extreme importance in order to understand not only the processes going on the Sun but the problem of the neutrino nature. Thus,the problem arises:

4. Neutrino oscillations,lepton-quark analogie,etc.

During the last two years great attention was paid to the search for new particles.Attempts were made to observe them directly. The interest in such investigations was certainly motivated, to a great extent, by the J/ψ particle discoveries, and by observation of dimuon events in the neutrino experiments. However, the physics of new particles turned out to be tightly connected with the investigations of the NC structure and lepton-hadron interactions. Indeed,since at least some of the hypothetic particles ("charmons", for instance) are to be produced from the hadronic block, one can predict the quantitative characteristics of their production onlyif the structure of hadronic block and dynamics of the lepton-hadron interactions at high energies are known. The quark-parton model in its simplest form [6-9] may be a good guide for us. But giving a very simple description of the main properties of the phenomena in the lepton-hadron interactions at low energies up to 20-30 GeV (scaling), the naive quark-parton model does not explain all the deviations from the scaling which are quite definitely observed experimentally [10]. From the theoretical viewpoint the model of free noninteracting partons needs a deeper understanding. The gauge theories with asymptotic freedom (AFGT) [11-12] are of a success in this direction.These theories are a further development of the quark-parton model, that can predict deviations from scaling behaviour of the structure functions. However the validity of these predictions for the hadronic block may be confirmed only by experiments. Therefore the solution of problems mentionedin 3. is necessary for the quantitative description of the "charm" production. Quite certainly the effects of the charmed particle production should influence the behaviour of the structure functions and anomalies in the structure functions may indicate directly to the production of new particles.

The problem of the NC structure is connected with the models involving new particles, and may serve as an important test to check these models. To a great extent the same is true for the problem of neutrino oscillations(4). Therefore search for new particles is tightly connected with all other neutrino invesigations.

I would like to note here that "new" phenomena in the neutrino beams should be interpreted in a close relation with phenomena observed in the colliding beams (noncolinear μ e pairs, the magnitude $R=\sigma(e^+e^-\to h)/\sigma(e^+e^-\to\mu^+\mu^-)$ etc.) and with those in the hadron-hadron collisions (direct leptons). In this case,however,one should be rather careful, because these phenomena may be caused not from one definite source,but have different origins. Perhaps one should not attempt to explain all the available new experimental data from one viewpoint.

At least one historical event when muon was interpreted as a particle predicted by Yukawa,and consequently many experimental results could not be brought into agreement, may serve as a good lesson for us.

Since,as was mentioned,the quantitative characteristics for the production of new hadrons should strongly depend on the strong interactions, I shall start my talk with the experimental data on the deep inelastic interactions.

I. DEEP INELASTIC SCATTERING

I.I. General Expressions for Differential Cross Sections.

It is well known that on the basis of general principles (Lorentz -invariance and locality of interactions of leptons with hadrons) the cross section for neutrino and antineutrino scattering on nucleons may be presented in the following form:

$$\frac{d^2\sigma^{\nu}}{dx\,dy}=\sigma_0\left\{q^{\nu}+\bar{q}^{\nu}(1-y)^2+K^{\nu}(1-y)\right\}$$
$$\frac{d^2\sigma^{\tilde{\nu}}}{dx\,dy}=\sigma_0\left\{\bar{q}^{\tilde{\nu}}+q^{\tilde{\nu}}(1-y)^2+K^{\tilde{\nu}}(1-y)\right\}\qquad \sigma_0=\frac{G^2ME}{\pi}\quad (I.I)$$

where x,y are the known variables: $x=\frac{Q^2}{2pq}$, $y=\frac{pq}{pk}$.

The magnitudes $q^{\nu(\tilde{\nu})}$, $\bar{q}^{\nu(\tilde{\nu})}$, $K^{\nu(\tilde{\nu})}$ are expressed with the help of the structure functions

$$q^{\nu(\tilde{\nu})}=\frac{1}{2}\left(2xF_1^{\nu(\tilde{\nu})}+x\cdot F_3^{\nu(\tilde{\nu})}\right)$$
$$\bar{q}^{\nu(\tilde{\nu})}=\frac{1}{2}\left(2xF_1^{\nu(\tilde{\nu})}-xF_3^{\nu(\tilde{\nu})}\right)\qquad (I.2)$$
$$K^{\nu(\tilde{\nu})}=F_2^{\nu(\tilde{\nu})}-2xF_1^{\nu(\tilde{\nu})}.$$

The structure functions $F_i^{\nu(\tilde{\nu})}$ in a general case may depend on the relativistic invariants Q^2 and pq (or, it is just the same for their combinations, e.g., (x,Q^2) or (x,Sy)) and they may be quite different for the neutron and proton. From general principles - a positive definiteness of the probability- there also follow the inequalities:

$$F_2^{\nu(\tilde{\nu})} \geq 2x F_1^{\nu(\tilde{\nu})} \geq x F_3^{\nu(\tilde{\nu})} . \qquad (I.3)$$

When analysing the neutrino data, additional assumptions are usually made:

a) Charge symmetry. It is assumed that the structure functions for the neutrino scattering on proton and the antineutrino scattering on neutron are the same:

$$F_i^{\nu p} = F_i^{\tilde{\nu} n} . \qquad (I.4)$$

It leads to the fact that on an isoscalar target

$$N = \tfrac{1}{2}(p+n)$$

$$F_i^{\nu N} = F_i^{\tilde{\nu} N} ; \quad q^{\nu N} = q^{\tilde{\nu} N} ; \quad \bar{q}^{\nu N} = \bar{q}^{\tilde{\nu} N} ; \qquad (I.5)$$

Assumption (I.4) is based on the fact that charged hadronic currents are mainly the components of the isotopic triplet and possess a definite G-parity (the vector current has a positive parity and the G parity for the axial current is negative). Eq.(I.4) assumes the absence of the second class currents and is violated by the current (pλ). Its validity in the Cabbibo scheme with three quarks is caused from the smallness of $\sin^2\theta_c$. Such a considerable violation of (I.4) may be expected at high energies considering the models with several heavy quarks connected asymmetrically with "u" and "d" quarks, if this asymmetry is large, to say of the order of $\cos\theta_c$. In the Glashow, Illiopoulos, Maiani [13] (GIM) scheme, when SU(4) is exact, the Eq.(I.4) is to be satisfied. However, the violation of the SU(4) symmetry (different "sea" levels for different quarks and threshold effects) may lead, as we shall see, to a considerable violation of (I.4).

b) Bjorken Scaling

According to the experimental data on the electroproduction at energies below 20 GeV, the structure functions are assumed to be dependent on the one variable "x":

$$F_i(x,Q^2) \to F_i(x) . \qquad (I.6)$$

This assumption is very important because it allows one to select in (I.I) the dependence of the differential cross section on the variable y. Moreover this dependence should be the same at all energies.

Assuming that the scaling is satisfied (it is not obligatory for the charge symmetry) one has

$$\frac{d\sigma^{\nu}}{dy} = \sigma_0 J^{\nu}\left[\tfrac{1}{2}(1+B^{\nu}) + \tfrac{1}{2}(1-B^{\nu})(1-y)^2 + L^{\nu}(1-y)\right]$$

$$\frac{d\sigma^{\tilde{\nu}}}{dy} = \sigma_0 J^{\tilde{\nu}}\left[\tfrac{1}{2}(1-B^{\tilde{\nu}}) + \tfrac{1}{2}(1+B^{\tilde{\nu}})(1-y)^2 + L^{\tilde{\nu}}(1-y)\right] \qquad (I.7)$$

where

$$J^{\nu(\tilde{\nu})} = \int_0^1 2x F_1^{\nu(\tilde{\nu})} dx ;$$

$$B^{\nu(\tilde{\nu})} = \int_0^1 x F_3^{\nu(\tilde{\nu})} dx \Big/ J^{\nu(\tilde{\nu})} ; \quad L^{\nu(\tilde{\nu})} = \int_0^1 k^{\nu(\tilde{\nu})} dx \Big/ J^{\nu(\tilde{\nu})} \qquad (I.8)$$

According to the scaling hypothesis

$$\begin{array}{ll} \text{(energy} & B^{\nu} = \text{const.} \\ \text{independent)} & B^{\tilde{\nu}} = \text{const.} \end{array} \qquad (I.9)$$

If the charge symmetry is satisfied, then

$$B^{\nu} = B^{\tilde{\nu}} . \qquad (I.10)$$

It should be noted that in fact the experimental data on electroproduction indicate to a possible dependence of the structure functions on Q^2.

c) Quark-Parton Model. Callan-Gross Relation

Since the Bjorken scaling can be expliained on the basis of the parton model, very often when processing the neutrino data one uses the Callan-Gross relation

$$F_2 = 2xF_1 . \qquad (I.II)$$

It follows from the assumption that leptons are scattered on quarks with a spin $1/2$. If (I.II) is satisfied, then $K^{\nu} = K^{\tilde{\nu}} = 0$.

Note that the violation of (I.II) leads to an existence of a longitudinal part in the deep-inelastic electroproduction $F_L = F_2 - 2xF_1$ which according to experimental data is in average I8% of the transverse part $2xF_I$. Whether the longitudinal part will decrease with the energy growth-as it takes place in the parton model with a spin of I/2- or will remain constant or even increasing should be clarified experimentally.

In the algebra of fields [14] and in the generalized vector meson dominance model [15] it is predicted that $F_I = F_3 = 0$ within the Bjorken limits, and the cross sections are to be determined by a pure longitudinal part

$$\frac{d^2\sigma^{\nu(\tilde{\nu})}}{dx\,dy} \to \sigma_0 F_L (1-y)$$

and be the same for the neutrino and antineutrino scattering.

I shall divide the experimental data into two groups: the data obtained at energies below 30-50 GeV and those above 50 GeV.

I.2 Experimental Data below 30-50 GeV

I.2.I Data of the Gargamelle Collaboration [16]

About 4000 events in the neutrino beam and about 3000 events in the antineutrino beam with E = I-I0 GeV have been obtained from the Gargamelle bubble chamber.

The results do not differ considerably from those presented at the London Conference. Fig.3 shows the results of the total cross section measurements for interactions in freon(CF_3Br) and related to one nucleon. The dependence of the cross section on energy is described with a linear fit

$$\sigma^{\nu} = (0.82 \pm 0.05) E_{\nu} \cdot 10^{-38} cm^2 GeV^{-1}$$
$$\sigma^{\bar\nu} = (0.31 \pm 0.02) E_{\bar\nu}\, 10^{-38} \qquad (I.12)$$

(For freon the ratio of number of neutrons to protons is 1.19). Normalization of the cross sections (I.12) for an isoscalar target may be done using the predictions of the simplest quark-parton model

$$\sigma^{\nu n}/\sigma^{\nu p} = \sigma^{\bar\nu p}/\sigma^{\bar\nu n} = 2 .$$

The corresponding procedure makes σ^{ν} by 3% smaller and $\sigma^{\bar\nu}$ by 3% larger.

The ratio of the cross sections $R = \sigma^{\bar\nu}/\sigma^{\nu}$ is compatible with the constant value(energy independent) within the experimental error

$$R = 0.38 \pm 0.04 \text{ */} . \qquad (I.13)$$

The constancy R satisfies the scaling requirements though, as the authors note, most of the events have low energy and do not lie in the deep-inelastic region where $Q^2 \gg M^2$ and $\nu \gg M$. Under assumption that scaling and charge symmetry are satisfied the cross section ratio is equal to

$$R = \frac{3 + A - 2B}{3 + A + 2B}$$

where
$$A = \frac{\int 2xF_1\, dx}{\int F_2\, dx} \qquad B = \frac{\int x F_3\, dx}{\int F_2\, dx} .$$

Taking into account inequalities $B \leqslant A \leqslant 1$ the mentioned ratio put the magnitude A within the following limits

$$0.87 \pm 0.1 = \frac{3(1-R)}{1 + 3R} \leqslant A \leqslant 1.$$

The obtained limitation shows how correctly the Callan-Gross relations are satisfied : when I.11 is satisfied, A=1; vice versa: from A=1 and positive definiteness of the functions F_1, F_2 there follows (I.11). At the same time it is compatible with a longitudinal part at the level observed in electroproduction. Then for the magnitude B we obtain the following limitation

$$0.87 \pm 0.1 \leqslant B \leqslant \frac{2(1-R)}{1 + R} = 0.90 \pm 0.08$$

(When condition I.11 is satisfied one has to take the upper limit for B). The closeness of the magnitude B to unity in terms of the quark-parton model shows that scattering on antiquarks gives a small contribution to the total cross section, i.e., the cross section is determined by scattering on valency quarks. However, at energies lower than 5-6 Gev there is probably an"imitation" of the scaling behaviour since the measured cross sections(in particular, for antineutrino) are saturated by two or three channels, that is, elastic scattering, single and two-pion production.

*/Normalization for isoscalar target increases R by 6%.

I.2.2 Data of the Argonne-Purdue Collaboration[17]

In the Argonne 12 foot bubble chamber with deuterium filling the CC neutrino interactions have been studied at 6 GeV[12]. $\nu_\mu p$ - $\nu_\mu n$ interactions were identified and distributed along different exclusive channels. Taken together these channels give us a picture of inclusive processes $\nu_\mu p \to \mu^- + X^{++}$ and $\nu_\mu n \to \mu^- X^+$. Total cross sections for these channels are increased linearly (even in the energy range of 0.5< E <2 GeV)that is in agreement with the CERN data.

For the ratio $R = \sigma^{\nu n}/\sigma^{\nu p}$ in the energy range above 1.25 GeV the following value has been obtained

$$R = 2.08 \pm 0.23 \qquad (I.14)$$

This value agrees with the predictions of the naive quark model according to which R=2, when neutrino are scattered on valence d-quarks.

I.2.3 Data of the FNAL-Michigan-Serpukhov-Moscow Collaboration[18]

The 15 foot bubble chamber with H_2+20%Ne filling was exposured in the antineutrino beam. Assuming equality (I.11) from the distribution in y the values of $B(x) = F_3 x/F_2$ were determined within different x intervals for 429 events. With H_2Ne filling (the ratio p/n=1.4) the value $B^{\bar\nu}$ is equal to 0.79 ± 0.06 within the energy range of 10-50 GeV.

I.2.4 Data of the ANL-Carnegie-Mellon University-Purdue Univ. Collaboration[19]

The 15 foot bubble chamber with hydrogen filling was exposured in the antineutrino beam. On the basis of 332 $\bar\nu p$ events and with y distribution it was found that $B^{\bar\nu} = 0.91 \pm 0.08 (5 < E_\nu < 30$ GeV) and $B^{\bar\nu} = 0.82 \pm 0.14$ (E > 30 GeV). Within statistics limits the data are compatible with $B^{\bar\nu} = 1$.

I.2.5 Data of the Harvard-Pennsylvania-Wisconsin-FNAL Collaboration[20,21]

On the basis of about 5000 neutrino and 2.5000 antineutrino events with y distribution the values of $B^{\bar\nu} = 0.95 \pm 0.1$ and $B^{\nu} = 0.9 \pm 0.6$ have been determined within the energy range of 10-30 GeV.

I.2.6 Data of the CalTech-FNAL Collaboration[22].

156 events coming from pion decay in the dichromatic neutrino beam with $\langle E_{\bar\nu}\rangle$= 52 Gev were found. The values $B^{\bar\nu} = 0.66^{+0.22}_{-0.26}$ were obtained from the distribution in y (the value of $B^{\bar\nu}$ for $\bar\nu$ with E = 150 GeV will be given below). The distribution in y at x <0.1 and $\langle E_\nu\rangle \simeq 50$ GeV in the

neutrino and antineutrino beams is consistent with

$$\left.\frac{d\sigma^{\nu}}{dy}\right|_{\substack{x<0.1\\ y\to 0}} = \left.\frac{d\sigma^{\tilde{\nu}}}{dy}\right|_{\substack{x<0.1\\ y\to 0}} \qquad (I.I5)$$

The indicated equality checks only the charge symmetry of the structure functions $F_2(x)$ [23].

Conclusions:

The experimental data obtained at energies below 50 Gev agree with the predictions of the

I. Charge symmetry ($B^{\nu} = B^{\tilde{\nu}}$)

2. Bjorken scaling (the parameters B^{ν} and $B^{\tilde{\nu}}$ do not change with energy within experimental errors.)

3. These data do not contradict the predictions of the parton model with the spin I/2 (A parameter is close to unity) Nevertheless the experimental errors do not exclude the existence of the longitudinal part at the level obserbed in electroproduction.

4. Closeness of the $B^{\nu(\tilde{\nu})}$ parameters to unity indicates that the momentum fraction of antiquarks ("sea") is very small in contrast with the momentum fraction of the valency quarks. This is in agreement with the equality

$$\sigma^{\tilde{\nu}N}/\sigma^{\nu N} \approx I/3 \quad \text{and} \quad \sigma^{\nu n}/\sigma^{\nu p} \approx 2.$$

I.3 DEEP INELASTIC SCATTERING ABOVE 50 GeV

I.3.I y Distribution in Antineutrino events

The experimental data indicate to a considerable change of the y distribution in antineutrino interactions at energies above 50 GeV as compared with those at lower energies. The distribution in y in antineutrino events becomes flatter and considerably differs from $(I-y)^2$. This anomaly was first discovered by the HPWF group who also indicated that events leading to a large y anomaly are concentrated in the range of large effective masses of the hadronic block W.[24] According to the HPWH data[20]

$$B^{\nu} = 0.75 \begin{smallmatrix} +0.2 \\ -0.I \end{smallmatrix} \qquad B^{\tilde{\nu}} = 0.45 \begin{smallmatrix} +0.I5 \\ -0.I0 \end{smallmatrix} \text{*/}$$

The evidence for a "flatter" distribution in y in antineutrino events was confirmed by the CalTech-FNAL group[22]. y distributions obtained in the dichromatic antineutrino beam at the average energies of 50 and I50 GeV are presented in Fig.4. It is seen that with $\langle E_{\tilde{\nu}_\pi}\rangle = 50$ Gev $B^{\tilde{\nu}} = 0.66 \begin{smallmatrix} +0.22 \\ -0.26 \end{smallmatrix}$ and with $\langle E_{\tilde{\nu}_K}\rangle = I50$ GeV $B^{\tilde{\nu}} = 0.36 \begin{smallmatrix} +0.30 \\ -0.36 \end{smallmatrix}$.

Data of the FMSM[18] group obtained in the 50-200 GeV antineutrino beam do not exclude dependence in y observed by the HPWF group. The change of the parameter $B^{\tilde{\nu}}$ at high energies evidences for a breaking of the scaling law.

Note that large y anomaly is not described by a simple quadratic polinomial in y as that would follow from (I.7) when the scaling law is satisfied (see Fig.5). This means that the structure functions are really the functions of two variables (x,Q^2) and not of one variable x. The "dip" at small y probably evidence for some threshold effects in particle production.

I.3.2 Growth of Ratio of Cross Sections $\sigma^{\tilde{\nu}}/\sigma^{\nu}$

The ratios of cross sections $\sigma^{\tilde{\nu}}/\sigma^{\nu}$ measured by HPWF group by two different methods are a clear evidence for an increase of this ratio with the energy growth (at $E > 50$ GeV)(see Fig.6). The observed growth of the cross sections is in agreement with a flatter y distribution in the antineutrino beam.

Conclusion

I. A flatter y distribution is observed in the antineutrino beam at energies above 50 GeV than at energies below 30-50 GeV. The parameter $B^{\tilde{\nu}}$ is much less than unity. In accordance with this the growth of the ratio $\sigma^{\tilde{\nu}}/\sigma^{\nu}$ is observed.

2. The observed anomaly evidences for a violation of the Bjorken scaling at transition to energies above 50 GeV. $B^{\tilde{\nu}}$ (E> 50 GeV) $\neq$ $B^{\tilde{\nu}}$ (E< 50 GeV)

3. The difference of B^{ν} and $B^{\tilde{\nu}}$ above 30-50 GeV evidence for a violation of the charge symmetry.

Some Theoretical Remarks

The last two facts, taken together, are of great importance for theoretical interpretation. However one should remember that this may be due to different reasons. The breaking of scaling law may be a problem of strong interactions and of hadron structure while the violation of charge symmetry is definitely the problem of weak interactions, that of new currents switching on.

Indeed, let us assume that the values for B^{ν} and $B^{\tilde{\nu}}$ change with energy, but the charge symmetry is not violated ($B^{\nu} = B^{\tilde{\nu}}$), and we know nothing about any other "unusual" phenomena (e.g. dileptonic events). Would a decrease of B with energy be surprising? I do not think so. Precautious scaling would be more surprising. In this sense the early Bjorken scaling could be compared with nuclear scaling observed by Y.Leksin et al.[25] in the nucleon scattering at energies of a few MeV (I am thankfull to Prof.Anisovich for the indicated analogy.) At low energies the "sea"(or multipheripheral ladder) has no time to develope, and the nuclear scaling likely reflects just the fact that nuclei consists of nucleons.

*/ The report by A.K.Mann[21] submitted later gives $B^{\nu} = 0.83 \pm 0.20$; $B^{\tilde{\nu}} = 0.4I \pm 0.I3$.

The "true" Feynman scaling accompanied by a plateau in rapidity occurs at considerably higher energies. (See the rapporteur talk by Chliapnikov) Similarly, one may think that the precautious Bjorken scaling indicates to the fact that nucleons consist of valence quarks while the "sea" is small[27]. Closeness of the ratio $\sigma^{\tilde{\nu}}/\sigma^{\nu}$ to I/3 and of $\sigma^{\nu n}/\sigma^{\nu p}$ to 2 is a quite good fit. With the neutrino energy growth we approach to the region of the true Bjorken scaling; the role of the "sea" increases, and the ratio of cross sections tends to unity. On the other hand, such an increase of the momentum fraction of the quarks from "sea" (i.e., decrease of $B^{\nu(\tilde{\nu})}$ with energy growth) is also expected in the gradient theories with asymptotic freedom (AFGT), in the vector dominance model and others. (See the rapporteur talk by V.Zakharov[28].)

However, the aforementioned remarks cannot explain the violation of charge symmetry ($B^{\tilde{\nu}} \neq B^{\nu}$) in the context of weak interaction models with Cabibbo currents (in terms of SU(3) symmetry). In order to explain the arising of charge asymmetry at high energies the additional weak currents are necessary. Thus, the violation of charge symmetry is to be attributed to the weak interactions. There exist two possibilities in this case:

a) The minimal GIM-model[13] with the forth C-quark and left-hand (LH) currents only in case when the quark "sea" is increased.

b) Schemes with right-hand (RH) hadronic currents which are strongly (of order of a unity or $\cos\theta_C$) and asymmetrically coupled with the valence u- and d-quarks.

In this sense the minimal one is the scheme with 5 quarks united into two left and one right duplet $\binom{u}{d_c}_L$, $\binom{c}{s_c}_L$, $\binom{u}{b}_R$ and lepton duplets $\binom{\nu_e}{e}_L$, $\binom{\nu_\mu}{\mu}_L$, $\binom{\nu_n}{n}_R$ containing the additional heavy charged (h) and neutral (ν_n) leptons. More sophisticated schemes of 6,8 quarks with LH and RH currents are also considered[29,30]. (See e.g. R.M.Barnett[31])

In the models with RH currents the values for $\bar{q}^{\tilde{\nu}}$ increase at energies above the threshold of production of the particles with new quarks because of the antineutrino scattering on valence quarks. This results in a flatter "y" distribution for $\tilde{\nu}$, and neutrino and antineutrino cross sections become close to each other. In these models this should lead to an evident violation of charge symmetry: the quantity B^{ν} may remain close to unity and the value for $B^{\tilde{\nu}}$ decreases. The equality (1.15) should be violeted.

Possibilities of charge symmetry violation in the models with RH currents are quite obvious. More complicated is the problem of charge symmetry violation in the GIM model. In the papers by Altarelli et al.[32] it is shown that the GIM model, the asymptotic freedom and some model assumptions on the way of restoring scaling at energies above the production threshold of charmed particles may provide an interpretation of existing experimental data on νN and $\tilde{\nu} N$ scattering. To explain how the observed charge asymmetry may appear in the GIM model I shall use the semiphenomenologiwal approach[33] (which does not assume that the increase of the quark sea is necessarily due to the asymptotic freedom). In this model the structure functions at energies above the charmed particle production threshold are of the form:

$$F_1^{\nu p} = \bar{u} + d + s + \bar{c}\,; \qquad F_1^{\tilde{\nu} n} = \bar{u} + d + \bar{s} + c$$

$$F_1^{\nu n} = u + \bar{d} + s + \bar{c}\,; \qquad F_1^{\tilde{\nu} p} = u + \bar{d} + \bar{s} + c$$

$$\tfrac{1}{2} F_3^{\nu p} = -\bar{u} + d + s - \bar{c}\,; \qquad \tfrac{1}{2} F_3^{\tilde{\nu} n} = -\bar{u} + d - \bar{s} + c$$

$$\tfrac{1}{2} F_3^{\nu n} = u - \bar{d} + s - \bar{c}\,; \qquad \tfrac{1}{2} F_3^{\tilde{\nu} p} = u - \bar{d} - \bar{s} + c$$

u, d, s, c – are the distribution fuctions of the corresponding quarks in proton.

It is seen from formula (1.16) that charge symmetry is always conserved in the function F_1 and consequently in the function F_2 (if the Callan-Gross equality is satisfied.) This equality (1.15) should take place at any values and y=0. As for the interference functions F_3 they turn out to be obviously charge asymmetrical under a natural assumption that the sea of heavy quarks in nucleon is suppressed (e.g. following the law $1/m^2$ similarly to the probability of electromagnetic pair production). Asymmetry arises due to $c(\tilde{c})$ quark production on the sea of $s(\tilde{s})$ quarks. Therefore if the sea is small, asymmetry is also small.[34] However if the role of the sea increases with energy, the charge symmetry violation in the GIM model would be considerable.

The measured quantities B^{ν} and $B^{\tilde{\nu}}$ may be expressed by way of two parameters $\mathcal{E}$ and λ

$$B^{\nu} = \frac{1+\mathcal{E}\lambda}{1+\mathcal{E}(2+\lambda)}; \quad B^{\tilde{\nu}} = \frac{1-\mathcal{E}\lambda}{1+\mathcal{E}(2+\lambda)}; \quad (1.17)$$

where $\mathcal{E}$ equals the ratio of the first moments of the sea and valent quarks

$$\mathcal{E} = \frac{\langle u+d\rangle_{sea}}{\langle u+d\rangle_{valence}}; \quad \langle u\rangle = \int_0^1 x\,u(x)\,dx; \quad (1.18)$$

and the parameter λ characterizes the suppression of the sea of s quarks as compared with the sea of u and d quarks.

$$\lambda = 2\langle s\rangle_{sea} / \langle u+d\rangle_{sea} \quad (1.19)$$

From (1.17) we obtain the relations where the parameter $\mathcal{E}$ is excluded:

$$B^{\tilde{\nu}} = B^{\nu}(1+\lambda) - \lambda \quad (1.20)$$

If we use the estimations $\lambda = 1$ and B^{ν}=0.75, then for $B^{\tilde{\nu}}$ we will obtain the value $B^{\tilde{\nu}}$=0.5 very close to the average experimental velue of $B^{\tilde{\nu}}$=0.45. But it is better to adopt for λ the values of λ =0.5 ÷ 0.6 that follow from the relations between πN and KN scattering cross sections as well as from the yield of strange particles[35]. Within rather large experimental errors the value λ =0.6 may also be brought in agreement with the measured values for B^{ν} and $B^{\tilde{\nu}}$.

The parameter $\mathcal{E}$ may be expressed through the values of B^{ν}, $B^{\tilde{\nu}}$ using formula (1.17)

$$\mathcal{E} = (1-B^{\nu}) / (B^{\nu}+B^{\tilde{\nu}}) \quad (1.21)$$

From the estimations the value is $\simeq$0.2 for the magnitude $\mathcal{E}$. One could obtain an independent estimation $\mathcal{E}$ from other considerations. Fig. 7 presents the distributions obtained in neutrino experiments at energies above 20 GeV.[18] One can note some excess at $x \lesssim 0.2$ as compared with the values for the structure functions calculated from the data on electroproduction at energies below 20 GeV. Such an excess is observed in neutrino experiments at high energies. If this excess is interpreted as an increase of the sea quark moment then for $\mathcal{E}$ we will obtain the value 20-30% in accordance with estimation (1.21).

The ratio of the cross sections

$$\frac{\sigma^{\tilde{\nu}}}{\sigma^{\nu}} = \frac{1+\mathcal{E}(4+3\lambda)}{3+\mathcal{E}(4+3\lambda)}$$

increases with the growth of $\mathcal{E}$. At $\mathcal{E}=0.2$ it is equal to $\sigma^{\tilde{\nu}}/\sigma^{\nu}=0.55$. The mean values for $\langle y\rangle_{\nu}$ and $\langle y\rangle_{\tilde{\nu}}$ are equal to

$$\langle y\rangle_{\nu} = \frac{1}{2} - \frac{\mathcal{E}}{4[3+\mathcal{E}(4+3\lambda)]}; \quad \langle y\rangle_{\tilde{\nu}} = \frac{1}{4} + \frac{3\mathcal{E}(1+\lambda)}{4[3+\mathcal{E}(4+3\lambda)]}$$

and at $\mathcal{E}\to\infty$ they monotonously tend to the same value of 0.44-0.46 (that is not very sensitive to the value for λ. At $\mathcal{E}\simeq 0.2$ $\langle y\rangle_{\tilde{\nu}}$=0.37. The values calculated for $\sigma^{\tilde{\nu}}/\sigma^{\nu}$ and $\langle y\rangle_{\tilde{\nu}}$ are in agreement with the experimental data (see fig. 6 and fig. 8).

The deviation of B^{ν} and $B^{\tilde{\nu}}$ from unity is a crucial point for the assumed consideration. The experimental data are quoted with large errors (see fig. 9). However the mean values have a tendency to decrease systematically with the energy growth. It is seen from the given Figure that the selection of experimental data into two groups (E < 50 GeV and E > 50 GeV) has an arbitrary meaning only.

An additional argument in favour of the present consideration are the data on deep-inelastic muon scattering on protons[10], where there is also an excess it $x < 0.2$ increasing with Q^2.

Conclusion

1. If the observed of charge symmetry is confirmed, then this fact will unambiguously denote that new hadronic currents should be introduced into the weak interaction scheme at high energies.

2. If further clarification of the experimental data makes it clear that at high energies the parameter B^{ν} really becomes smaller than unity then charge asymmetry may be explained in the framework of the GIM model with LH current.

3. If the parameter B^{ν} is close to unity, and charge asymmetry is observed ($B^{\tilde{\nu}} < B^{\nu}$), then one can hardly avoid introducing the models with RH currents.

2. Dileptonic Events. Search for Charmed Particles

At the previous London Conference the HPWF group presented 2 events (μ^+,μ^-) emerging from one and the same vertex in the neutrino beam.

By the present moment in already several neutrino experiments they have confirmed the production of leptonic pairs ($\mu\mu$ and μe) emerging from one vertex. It may be an evidence of production of new particle with life-time $\tau \lesssim 10^{-11}$ sec that decays in weak interaction mode.*)

In the experiments with electron detectors it was possible to select $\mu\mu$ pairs, to measure their kinematical characteristics as well as hadron energy. In the bubble chambers experiments they mainly selected μe events and managed to find accompanying hadrons for a part of these events.

2.1. Data of Electronic Detectors

2.1.1. HPWF Data/37,20/

In the experiments the events are registered with muons of different signs outgoing from one and the same vertex (in the reaction $\nu_\mu N \to \mu^-\mu^+X$ there were found 42 events; in the reaction $\tilde{\nu}_\mu \to \mu^+\mu^- x$ - 13 events). Some general properties of dileptonic events were clarified and later on they were confirmed with the results from other experiments.

1. Production cross section for leptonic pairs of different signs in antineutrino and neutrino beams were found at the 1% level from the total cross section with charged currents.

2. Leading effects:

In ν_μ beam μ^- meson is more energetic and as for $\tilde{\nu}_\mu$ beam it is μ^+ meson. The ratio of the momentum mean values in the neutrino beam is equal to $\langle p_{\mu^-}\rangle/\langle p_{\mu^+}\rangle = 6.1 \pm 0.8$*). (This ratio is confirmed by the data on $\mu^- e^+$ pairs, obtained in the BCHW experiment/38/). In the antineutrino beam: $\langle p_{\mu^+}\rangle/\langle p_{\mu^-}\rangle = 2.9 \pm 0.7$.

3. Large Inelasticity

Dileptonic events are accompanied by a considerable energy fraction transfer to hadrons. The mean value for $y = E_h/E_\nu$ is about 0.5 and the distribution $d\sigma/dy$ is of flat form for dileptonic events.

4. X -distributions for a leading muon are considerably shifted to the range of small value for X ($x \lesssim 0.2$) in the antineutrino beam. In case of the neutrino beam such a shift is smaller.

These features allow one to exclude the leptonic pair production at account of four-Fermion interaction $(\nu_\mu\mu)(\nu_\mu\mu)$, or of charged W-boson production or of heavy lepton (see figs. 10a, 10b, 10c). Process presented in fig. 10a is excluded due to the small inelasticity and leading effect (no matter how large is the force of $(\nu_\mu\mu)(\nu_\mu\mu)$ interaction). Process 10b goes on with small inelasticity and gives a leading effect for muons of opposite sign. Process 10c is excluded because of the leading effect, as

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*) Search of charmed particles in neutrino interactions were discussed long ago (see e.g. /36/).

*) This value is derived by events sampling with $p_{\mu^-} > p_{\mu^+}$ in the mixed neutrino-antineutrino beam.

it was shown by Pais and Treiman[39] independently of the form of weak interaction $(L_0\mu)(\mu\nu_\mu)$ should be $0.48 \leq \langle P_{\mu^-}\rangle / \langle P_{\mu^+}\rangle \leq 2.1$. It is obvious also that the processes shown in figs. 10 (a,b,c) do not give any explanation of the strong correlation of $\mu^- e^+$ pair with K_S^0 events observed in the bubble chambers (see below).

Many authors have treated the mechanism connected with the production of heavy hadro - lepton[40] as a possible source for leptonic pairs. This lepton was assumed to be responsible for noncolinear μe pairs in the e^+e^- colliding beams, and J/ψ , ψ' mesons were considered as a bound state of such hadro-leptons. It was assumed that leptonic pair production in ν ($\tilde{\nu}$) beams follows the scheme shown in fig.10d. It is obvious that in this mechanism there is no strong correlation between hadronic pairs and K_S^0 mesons (if no additional hypothesis are put forward) and a considerable part of energy is carried away by an invisible component three neutrinos). The latter fact seems to contradict the experiment*). Thus the hadroleptonic hypothesis cannot explain all the observed dileptonic events.

2.1.2. The observed of the dimuon production at Serpukhov accelerator

The data of the ITEP-IHEP collaboration[41]

The neutrino detector with optical spark chambers consisting of two parts: production part and magnetized iron part was used in experiments. The weight of the fiducial volume of the production part was 34 tons. There were two runs with different neutrino spectrum. In the second run the low energy part was suppressed and high energy part was enriched.

The selected dimuon candidates should have two tracks which passed more than 0.48 m of iron (0.75 GeV). Fig.11 presents the integrated distributions in visible range of the short track for neutrino run 2 . Solid curves are the Monte-Carlo predictions of background from π , K mesons. Whereas the data of run I is consistent with calculated background, one observed the excess for the run 2.

The main conclusions from this experiment are:

1. The majority of dimuon candidates is produced by neutrinos with $E_\nu > 10$ GeV.

2. Usually a considerable part of neutrino energy goes to hadrons.

3. One cannot explain the excess of 40±10 events by background within reasonable assumptions.

In the energy region $10 \leq E_\nu \leq 30$ GeV

$$\frac{\sigma(\nu N \to 2\mu + X)}{\sigma(\nu N \to \mu + X)} = \frac{N_{2\mu}(E_\mu > 0.75\,GeV)}{N_{1\mu}(E_\mu > 0.75\,GeV)}\,\frac{1}{K(E_\nu > 10\,GeV)}\cdot\frac{\varepsilon_{1\mu}}{\varepsilon_{2\mu}} = \left(1.6^{+1.2}_{-0.8}\right)10^{-2}$$

where $K(E_\nu > 10$ GeV$)$ is a fraction of events with $E_\nu > 10$ GeV, $\varepsilon_{1\mu}, \varepsilon_{2\mu}$ - efficiency for 1μ and 2μ events.

The errors take into account the uncertancies in the neutrino spectrum and efficiency for 2μ events.

4. The sensitivity of this experiment in the antineutrino beam does not allow one to make definite conclusions on the 2μ production on the level at $1\cdot 10^{-2}$ from the total cross section.

2.1.3. Theoretical Remark. Dileptonic Events and Charm

From the viewpoint of the naive quark - parton model the cross sections for neutrino-nucleon and antineutrino-nucleon scattering above the charmed particle production threshold (under condition the sea of C-quarks being suppressed in nucleon) is of the following form

*) In the HPWF experiments the average energy in dimuon events is $\langle E_{\mu^-}\rangle = (68\pm6)$ GeV $\langle E_{\mu^+}\rangle = (11\pm1)$ GeV. Putting $\langle E_{\nu_h}\rangle = \langle E_{\mu^-}\rangle$ and $\langle E_{\nu_\mu}\rangle = \langle E_{\tilde{\nu}_h}\rangle = \langle E_{\mu^+}\rangle$ (see fig.10d) one can see that the average invisible energy should be about (90±8) GeV. Taking into account that the mean visible energy is (114±4) GeV in these experimants one can obtain a total energy $\langle E_\nu\rangle_{tot} = (204\pm22)$ GeV that is larger than the total energy of a hadron beam (π, K) of 200 GeV.

$$\frac{d^2\sigma^{\nu N}}{dx\,dy} = \sigma_o x\{|(u+d)\cos^2\theta_c + 2s\sin^2\theta_c| + (\bar{u}+\bar{d})(1-y)^2 + \underline{+(u+d)\sin^2\theta_c + 2s\cos^2\theta_c}\} \quad (2.1)$$

$$\frac{d^2\sigma^{\tilde{\nu} N}}{dx\,dy} = \sigma_o x\{(u+d)(1-y)^2 + |(\bar{u}+\bar{d})\cos^2\theta_c + 2\bar{s}\sin^2\theta_c + \underline{+(\bar{u}+\bar{d})\sin^2\theta_c + 2\bar{s}\cos^2\theta_c}\} \quad (2.2)$$

where u,d,s are the distribution functions of the corresponding quarks in the proton. The underlined terms correspond to the charmed particle production. From these expressions it follows that the ratio of the charmed particle production cross section to the total cross sections for $\nu N(\tilde{\nu} N)$ scatterring may be expressed through two parameters ε and λ introduced in Section I.(formulae I.18,I.19) that,in their turn, may be expressed through the observed parameters of y-distribution[33]

$$\varepsilon = (1-B^{\nu})/(B^{\nu}+B^{\tilde{\nu}}) \quad (2.3)$$

$$\delta_{\nu} = \frac{\sigma(\nu N\to C X)}{\sigma_{tot}(\nu N)} = \frac{3\left[\sin^2\theta_c + \varepsilon(\lambda\cos^2\theta_c + \sin^2\theta_c)\right]}{3+\varepsilon(4+3\lambda)} \quad (2.4)$$

$$\delta_{\tilde{\nu}} = \frac{\sigma(\tilde{\nu} N\to \bar{C} X)}{\sigma_{tot}(\tilde{\nu} N)} = \frac{3\varepsilon(\lambda\cos^2\theta_c + \sin^2\theta_c)}{1+\varepsilon(4+3\lambda)} \quad (2.5)$$

Taking $\lambda = 0.6$ and the values $B^{\nu} = 0.7$ and $B^{\tilde{\nu}} = 0.52$ adjusted to the chosen λ (within the errors of measurements[20-21]) we obtain $\delta_{\tilde{\nu}} = 19\%$, $\delta_{\nu} = 14\%$. With leptonic branching ratio of order 10% the obtained values well agree with yield of dileptonic events within 1%. The measured parameters of y-distribition have certainly large errors. Therefore, the obtained values should be considered as roughly approximate*/. Close values of yield of charmed particles are obtained within the model described in [32].

It can be easily seen that other characteristics of dileptonic events, pointed out by the HPWF group, are also in agreement with the hypothesis of charmed particle production,i.e.:

1. From expressions (2.1) and (2.2) it is clear that y-distribution for 2 mu-events in $\tilde{\nu}$ beam should be as flat as in ν beam.

2. Since in the $\tilde{\nu}$ beam the charmed particle production goes on sea quarks only, x-distribution of the leading meson will significantly be more narrow than that of one-muon events; in the neutrino beam x-distribution of dileptonic events will be somewhat wider than that in the antineutrino beam (because part of charmed particle production goes on valence quarks).

3. The existence of the leading effects at high energies is qualitatively obvious in this model.

2.2. Further Confirmation of GIM Model

Fig. 12 present the schemes of charmed particle production in the neutrino and antineutrino beams.

Charmed particle production on the sea of strange quarks (figs. 12a and 12c) leads to the fact that dileptonic events should mainly be accompanied by a pair of strange particles (because of the smallness of $\sin^2\theta_c$). Charmed particle production on valence quark (fig. 12b) is the most important process at low energies.

The model was qualitatively approved by the BCHW[38] experiment and by the data of Gargamelle[42] and BNL[43].

2.2.1. Gargamelle Data[42]

Among 22500 neutrino with charged current events with the visible energy $E_{\nu} > 3$ GeV there were found 3 $\mu^- e^+ V^0$ events with the selection criterium $p_e > 200$ MeV. Their characteristics are enumerated in the Table. Fig.13 presents one of the events. Their characteristics and a total set of events, including electrons and positrons are given in the report by P.Musset[42] alongside with the estimations for the expected background level. The probability that the three $\mu^- e^+ V^0$ events are the background is equal to $2\cdot 10^{-4}$.

A strict correlations between positron and V^0- particle production has been established. Since the mean fraction of V^0- events in usual

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*/ Using the CalTechFNAL data (see sec.I.2.6) at $\langle E_{\tilde{\nu}}\rangle = 50$ GeV $B^{\nu} = 0.66^{+0.22}_{-0.26}$ and $\lambda = 0.54$, then by formulae (I.20),(I.21),(2.3)- (2.5) one derives $B^{\tilde{\nu}} = 0.80^{+0.12}_{-0.20}$; $E = 0.14^{-0.08}_{+0.03}$;

$$R = \frac{\sigma^{\tilde{\nu}}}{\sigma^{\nu}} = 0.48^{-0.10}_{+0.13} \quad \delta_{\tilde{\nu}} = 0.15^{-0.07}_{+0.03}$$

$$\delta_{\nu} = 0.10^{-0.03}_{+0.03}$$

CC interactions is 1.3% then if $V^0_{\bar{e}}$ particle production is noncorrelated one should have observed 230 $\mu^- e^+$ events, but there are only 16 events observed). The calculations of yield of charmed particles /44,45/ are by order of magnitude consistent with the observed number of events.

2.2.2. BCHW Data/38/

The FNAL 15 foot bubble chamber with neon hydrogen filling and external muon identifier was exposured in the neutrino beam. As a result 5000 C.C events were obtained.

15 $\mu^- e^+$ events have been found, 13 events out of them have the positron energy above 0.8 GeV. The detection efficiency for positron with $E_{e^+} > 0.8$ GeV is (48 ± 7)% and is almost independent of the positron energy. 90% of $\mu^- e^+$ events may be referred to C.C. events.

For the ratio $\sigma(\mu^- e^+ X)/\sigma(\mu^-)$ they obtain the following estimation $\sigma(\mu^- e^+ X)/\sigma(\mu^-) = \frac{1}{f}(0.63 \pm 0.21)\%$ where f - is the spectrum fraction e^+ with the energy more than 0.8 GeV. It is possible that $f \approx 1/2$.

The expected background is estimated as 1 event (0.7 of events from the asymmetric Dalitz pairs $\nu N \to \mu^- \pi^0 X$, $\pi^0 \to e^+ (e^- \gamma)$ and 0.3 of the events from K_{e3} decay).

There is a very strong correlation of $\mu^- e^+$ pairs with V^0 events: from 15 events 7 are accompanied by $K^0_S \to \pi^+ \pi^-$ (in one of these events there is also $K^0_S \to 2\pi^0$) 2 are accompanied by $\Lambda \to p\pi^-$; 2 events with K^0_S/Λ (K^0_S and Λ are not distinguished) and 4 events are without V^0 prongs (in one event there is $K^0_S \to 2\pi^0$) There are events with stopping K^+. Such a strong correlation is quite consistent with the hypothesis on the appearance of leptonic pairs in charmed particle production in the framework of the GIM model (fig.12).

Taking into account K^0_S detection efficiency and assuming that $\langle N(K^0_S)\rangle = \langle N(K^0_L)\rangle$ the mean multiplicity of neutral K mesons is

$$\langle N_{K^0} \rangle = 1.54 \pm 0.58,$$

i.e. within experimental error it is compatible with 1 or it may be even less. However if they refer two ambiguous K^0_S/Λ events to the events with K^0_S then they will obtain the value of $\langle N_{K^0} \rangle = 2 \pm 0.6$ and for the total multiplicity of kaons (under condition that $\langle N_{K^\pm} \rangle = \langle N_{K^0} \rangle$) the value $\langle N_{K^\pm_0} \rangle$ will be 4 ± 1.2). Proceeding from all the reasons above the authors come to a conclusion that K meson multiplicity in $\mu^- e^+$ events is anomalously large.

Still before putting forward any hypothesis on the possible nature of this effect one should have rich statistics as within the limits of the available statistics there is a probability that the obtained results are compatible with $\langle N_{K^\pm_0} \rangle \lesssim 2$ following from the schemes presented in figs. 12-12a.

As for the other characteristics of pairs (xy distributions in fig. 14) they are in good agreement with the expected properties of leptonic pairs from the charmed particle decay. Y-distribution is compatible with a flat one. In x-distribution 6 events out of 15 are within the range $X > 0.2$ that is also compatible with the estimations of the valence quark contribution $\delta_v \approx (30\text{-}40\%)$. The leading effect is very distinct: $\langle P_{\mu^-} \rangle / \langle P_{e^+} \rangle = 6.1$.

The distribution of dileptonic events over the visible energy shows the absence of the threshold effects above 10-20 GeV (see fig.15). P_T-distribution (P_T is the P_{e^+} momentum component orthogonal of the plane $\nu_\mu \mu^-$) does not differ from hadronic distribution (see fig. 14c). This fact and the absence of the threshold effect indicate to a possible small mass of charmed particles. The observed smallness of the average value for P_T is very important for the search for charmed particles in colliding e^+e^- beams. A very high cut off over the momentum ($P_e > 0.6$ GeV/c) adopted at SPEAR may cut off a very large fraction of lepton decays of charmed particles.

Assuming that half of the observed $K_S^0 \to \pi^+\pi^-$ events is related to the decay of charmed particles the authors estimate the probability of their semileptonic decays as: $\frac{c \to e^+ x}{c \to all} \to 0.17(1 \pm 0.4)$. The authors pointed out that two of the events e^+K_S might be in neutral currents.

2.2.3. FMSM Data (FNAL-Michigan-Serpukhov-Moscow) /46/

In the antineutrino exposure of the FNAL 15 foot bubble chamber (H_2+21%Ne) there was found one μ^+e^- event, that additionally contains 4 positive and 2 negative tracks and a photon (P_X = 32 GeV/c, P_{μ^+} =17.1 GeV/c P_{e^-} =1.2 GeV/c, X_μ =0.07, y_μ =0.5). At 90% confidence level the upper limits for the production cross section of μ^+e^- pair are $\sigma(\mu^+e^-X)/\sigma(\mu^+) \lesssim 1\%$ $\sigma(\mu^+e^-V^0X)/\sigma(\mu^+) \lesssim 0.6\%$. The expected background from $\nu_e N$ scattering when a positive hadron is identified as μ^+ is 0.3 events. The background from the asymmetric Dalitz pairs and from e^+e^- pairs is 0.1.

2.2.4. Conclusion

All the data on dileptonic events, that is:

1) The relative value of the effects,

2) kinematical characteristics,

3) the presence of strange particle are compatible with the four quarks GIM model. From comparison of the data of BCHW and IHEP-ITEP it is clear that intensive production of charmed particles starts at the energies of the order of 10 ÷20 GeV.

2.3. Problems on Leptonic Pairs with the Same Sign

The works on the dileptons of the same sign are not submitted to this conference.

In the HPWF experiment/37/ (see Sec. 2.1.1) 7 $\mu^-\mu^-$ pairs were observed alongside with the muons of opposite sign. These pairs are referred by the authors to neutrino interactions and 3 $\mu^+\mu^+$ pairs observed in the same experiment to antineutrino interactions. The ratio of the production cross sections for $\mu^-\mu^-$ and $\mu^-\mu^+$ is estimated to be

$$\sigma(\mu^-\mu^-X)/\sigma(\mu^-\mu^+X) \simeq (0.1 \pm 0.05)$$

Various hypothesis are used to interpret theoretically production of muons of an identical sign (see e.g./47/):

1. In the models with several quarks the muons with identical sign may arise from the cascade (transition of heavier quarks into the lighter ones).

2. One could attach the processes $D^0 \rightleftarrows \bar{D}^0$ to explain the appearance of the second muon with a "wrong" sign. In the standard GIM model the probability of such processes is strongly suppressed/48/.

However in the multiquark vector-like theories the transitions like $D^0 \rightleftarrows \bar{D}^0$ may go on with a noticable probability.

3. Within the framework of a standard GIM model one may attempt to explain dimuon events with identical signs by pair charmed particle production with further leptonic decay of one of the charmed particles.

In this case the ratio $R^{--} = \sigma(\mu^-\mu^-X)/\sigma(\mu^-)$ should have been $R^{--} = \langle n_c \rangle Br(C)$ where $\langle n_c \rangle$ is the everage number of charmed particles produced in a block of strong interaction. At $R^{--} \approx 10^{-3}$ and the branching ratio BR(c)$\sim$10% the magnitude $\langle n_c \rangle$ should be about 10^{-2}.

This value is just at the point of becoming contradictary with the experimental data. Indeed if one assumes that direct leptons observed in nucleon-nucleon collisions are produced from the charmed particle decays, then in strong interactions the ratio μ/π should be equal to

$$\mu/\pi = \frac{\langle n_c \rangle Br(C)}{\langle n_\pi \rangle} \approx \frac{R^{--}}{\langle n_\pi \rangle} \approx \frac{10^{-3}}{\langle n_\pi \rangle}$$

At the energies of about 100 GeV this ratio should be about 3.10^{-4} that seems to be higher than the observed value for direct leptons.

However one cannot exclude the fact that muon multiplicity $\langle n_c \rangle$ in deep inelastic neutrino scattering on nucleons may be higher than in the strong interaction processes at the same value of $S = W^2$.

Possible leptonic triplets are a characteristic feature of the pair production as well as of the multiquark models with cascade leptonic decays. At the present level of statistics one should not neglect such a possibility.

Some authors propose to consider the production of heavy charged and neutral leptons (see work /49, 50/) as a source for muon pair with identical sign. Pati and Salam/51/ considered the production and successive decay of integer charged colour gluons and quarks as two new mechanisms of appearance of multileptonic events (in particular, of muons of the same charge in νN scattering). However, the production of leptons of the same sign at the above mentioned level of cross section should be further confirmed experimentally.

2.4. Search for the hadronic mode of charmed particle decay

A number of experiments with the bubble chambers (7' BNL, Gargamelle, 15' FNAL, 12'ANL) were carried out with the aim to search for hadronic mode of charmed particles decay produced from neutrino interaction.

The search for particles with new quantum numbers was performed in two directions:

a) an evident violation of $\Delta S = \Delta Q$ rule in neutrino interaction;

b) the presence of narrow resonances in the invariant mass of $\Lambda + n\pi$, $K^0_s + n\pi$, $K^0_s p$ etc., systems. (See mini-report by Yu.Ryabov/52/).

2.4.1. Study of $\Delta S = -\Delta Q$ event in the BNL 7 foot chamber /43/

In the neutrino exposure 1086 CC events were obtained in the neutrino exposure, among them 10 have strange particles of V^0 type in the final state. One of the ten events is the following interaction $\nu_\mu p \to \mu^- \Lambda^0 \pi^+ \pi^+ \pi^+ \pi^-$ ($\Delta S = -\Delta Q$), where all observed particles are identified. The invariant hadronic mass $(\Lambda^0 \pi^+ \pi^+ \pi^+ \pi^-)$ M=2.426+0.013 GeV. The latest calculations for the probability that this event was caused from the background (associated production of ΛK^0_L with K^0_L along ν_μ) gives $3 \cdot 10^{-5}$. According to the GIM model such an event might be interpreted as charmed barion production (with the suppression by the Cabibbo factor $\sin^2\theta_c$) and as a decay along the hadronic channel (see fig. 12b). Rough estimation /44-45/ does not contradict such a hypothesis.

2.4.2. Search for narrow resonances in the systems $\Lambda + n\pi$, $K + n\pi$, $K + p$

The search for narrow resonances was performed with the chamber "Gargamelle" and the FNAL 15 foot chamber (the BHFM collaboration/12/)/53/ No evident characteristics were detected in mass spectra at the present level of statistics (taking into account the background of a usual strange particle pair production). A large yield of the known resonance $\Sigma^*(1385)$ was observed by both groups. In the experiment/53/ $\sigma(\nu N \to \Sigma^*(1385))/\sigma^{\nu}_{tot} \approx 4\%$. The question arises, if resonance $\Sigma^*(1385)$ is the decay product of charmed baryons.

2.4.3. Distribution of strange particles as a function of the invariant hadron mass in $\tilde{\nu}$ beam

The experiments with antineutrino give certain advantages for charmed particles search in their hadronic decay mode . Since "y"-distribution for production of usual and strange particles (on valence quarks) is to be falling and that of charmed particles is flat, the events with decaying charmed particle should give an excess at large invariant masses of the hadron block. The production of strange particles in $\tilde{\nu}_\mu$ beam was studied in paper/54/. The yield of V^0 particles as a function of the invariant mass W

of the hadron block is given in fig. 16. Data do not contradict the fact that in the distribution of V^0 events on the invariant hadron mass for $W > 5$ GeV there is an excess over the distribution normalized for all CC events (see fig.17). To make more definite conclusions the statistics should be increased.

2.5. Prospects of search of charmed particles in photoemulsions

One of "experimentum-crucis" which proves that the decay of new particles is due to the weak interaction and makes it possible to define their lifetime is a direct observation of the charmed particle decay in flight. The photoemulsion technique which allows one to define the paths of order of 10μ seems to be very promising especially in neutrino experiments. In this case number of events is not large, but the technique used with the help of spark and bubble chambers allows one to reduce scanning time. At present few experiments of the photoemulsion irradiated in neutrino beams are carried out.

3. Neutral currents

After the London conference many experimental and theoretical investigations were devoted to the study of neutral currents. The experimental works submitted to this conference give an essential contribution to understanding of neutral currents. I shall present the results of these works as follows:

1) Pure lepton currents.

2) Elastic scattering $\nu_\mu p$ and $\tilde{\nu}_\mu p$.

3) Reactions of single production $\nu_\mu N \to \nu_\mu N' \pi$; $\tilde{\nu}_\mu N \to \tilde{\nu}_\mu N' \pi$

4) Total cross sections and inclusive processes.

3.1. Pure lepton currents: the processes $\nu_\mu e \to \nu_\mu e$, $\tilde{\nu}_\mu e \to \tilde{\nu}_\mu e$, $\tilde{\nu}_e e \to \tilde{\nu}_e e$

3.1.1. "Gargamelle" experiment [42,55]

A general feature of the reactions with lepton currents is the appearance of a single electon at small angle towards the neutrino.

In the experiment 3 events were found identified with the reaction $\tilde{\nu}_\mu e \to \tilde{\nu}_\mu e$ (at kinematic cutoff $0.3\ \mathrm{GeV} < E_e < 2\ \mathrm{GeV}$, $\theta_e < 5^\circ$). The basic sources of the background are evaluated as follows:

a) neutral currents with production of π^0 gave 0.24 events;

b) inverse β-decay $\nu_e n \to p e^-$: 0,07 events;

c) electron neutrino scattering (taking into account the expected cross section $\tilde{\nu}_e e$) 0.12 events.

The total background is (0.43 ± 0.13) events. The probability of imitating of the found 3 events by the background is 1%. The authors gave the following value of the cross section:

$$\sigma(\tilde{\nu}_\mu e) = \left(0.1^{+0.21}_{-0.09}\right) E_{\tilde{\nu}_\mu} \cdot 10^{-41}\ \mathrm{cm^2\,GeV^{-1}}$$

During the neutrino exposure one event was detected satisfying the accepted selection critiria. The limit on the cross section of the reaction $\nu_\mu e \to \nu_\mu e$

$$\sigma(\nu_\mu e) \leq 0.26\ E_{\nu_\mu} \cdot 10^{-41}\ \mathrm{cm^2\,GeV^{-1}}$$

was found.

The interpretation of both the reactions within the Salam-Weinberg model (S-W) gives the following bounds: $0.1 \leq \sin^2\theta_W \leq 0.4$

3.1.2. Aachen-Padova Experiment [56,57]

A neutrino detector consisting of 141 aluminium spark chambers with the dimensions 2 x 2 m^2 was used in the experiment. 12 backward chambers were alternated with iron, working as a muon identifier. The weight of the operational effective volume was 19 T.

Electrons with energy $0.2 < E_e < 2$ GeV and the angle $\theta_e < 5^\circ$ were detected. As a result:

$\nu_\mu e$: 25 candidates; 11.8-background; 13.2±5.3 effect; $\tilde{\nu}_\mu e$: 19 candidates; 29 background; 16.1±4.5 effect.

After introducing the corrections for the kinematic cut off the following values for the cross sections have been obtained:

$$\sigma(\nu_\mu e) = (0.24 \pm 0.12)\, E_{\nu_\mu}\, 10^{-41}\, cm^2\, GeV^{-1}$$

$$\sigma(\tilde{\nu}_\mu e) = (0.54 \pm 0.17)\, E_{\tilde{\nu}_\mu}\, 10^{-41}\, cm^2\, GeV^{-1}$$

The ratio is $\sigma(\nu_\mu e)/\sigma(\tilde{\nu}_\mu e) = 0.44 \pm 0.26$. Professor Faissner noticed that the obtained values differ more than by 10 standard deviations from (V-A) variant of the interaction $\nu_\mu (\tilde{\nu}_\mu)$ with electrons (since for (V-A) variant

$\sigma(\nu_\mu e)/\sigma(\tilde{\nu}_\mu e) = 3$)

The interpretation in terms of S-W model gives the following limitations

$\sin^2\theta_W > 0.32$ for the cross section ratio

$\sin^2\theta_W = 0.58 \pm 0.09$ for the both channels.

3.1.3. The $\tilde{\nu}_e e$ scattering

The group led by Reines has observed the anti-neutrino scattering on electrons at the "Savannah River" reactor. (Data are presented in the mini-rapporteur talk by professor Faissner/57/, see also /58/). Data on pure lepton currents are given in Table III.

3.2. Elastic Scattering on Neutrino and Antineutrino on Protons

The CIR and HPW experiments were devoted to the study of neutrino elastic scattering on protons. In HPW experiment they also investigated antineutrino elastic scattering on protons. Both experiments were performed in the BNL beams (maximum of the neutrino energy spectrum is 1.2 GeV).

3.2.1. CIR Experiment/59/

The detector consisted of 20-25 spark chambers, alternated with the scintillation counters. To reduce the most dangerous neutron background the detector installed far from the shielding and any other big objects that could be neutron source. Neutrino and neutron events were identified by time of flight (up to the momenta 1.5 GeV).

After having scanned 170.000 pictures 92 candidates for quasi-elastic processes with charged currents $\nu_\mu n \to \mu^- p$ were found alongside with 55 candidates for the elastic process $\nu_\mu p \to \nu_\mu p$ with neutral currents. The events with proton momentum larger than 550 MeV ($Q^2 > 0.3$ GeV^2) and the angle above 25° were selected. These selection criteria allowed one to decrease the role of nuclear effects and of the background from np charge exchange. After selection there remained 77 candidates for quasielastic (CC) process and 38 candidates for elastic (NC) process. A possible background for the quasielastic process (from $\nu_\mu N \to \mu^- N' \pi$) is about 2 events according to the authors' estimations. As for the elastic process there are additional sources of the background, connected with neutrons (10 events) and with quasielastic events in which the muon at large angle was not detected (6 events). The total background comes to 19 events.

After background subtraction we obtain:

$$R^\nu = \frac{\sigma(\nu_\mu p \to \nu_\mu p)}{\sigma(\nu_\mu n \to \mu^- p)} = 0.23 \pm 0.09; \quad 0.3 < Q^2 < 1\ GeV^2$$

3.2.2. HPW Experiment/60/

The detector consists of containers with liquid scintillator CH_2 that is looked through with a system of photomultipliers (calorimeter). The total number of bloks is 12 and the weight is 33 T. Between the backward blocks there are installed coordinate detectors i.e., drift chambers. The set-up is surrounded by counters switched into anticoincidence mode. The common length is 6.4 m (12 nuclear lengths, or 6 radiation lengths).

The events with one charged track being completely within the detector are identified. The angles and kinematic energy of proton are measured, thus the event kinematics is reconstructed very well (CC fit). The protons are selected from pions by the difference in their range.

The authors point out the advantage of the neutrino active shielding used in the experiment. The space distribution for the event vertex exhibited the smallness of the neutron background. The number of candidates for elastic process with neutral current is 30 events in the neutrino beam and 22 events in the antineutrino beam. At the same time they investigated quasielastic scattering $\nu_\mu n \to \mu^- p$ and $\tilde{\nu}_\mu p \to \mu^+ n$. The full flux in the antineutrino exposure was about 2 times larger than that in the neutrino one. The expected background is presented in the Table IV. The results are:

$$R^{\nu} = \frac{\sigma(\nu_\mu p \to \nu_\mu p)}{\sigma(\nu_\mu n \to \mu^- p)} = 0.17 \pm 0.5 \qquad 0.3 < Q^2 < 0.9\,GeV^2$$

$$R^{\tilde{\nu}} = \frac{\sigma(\tilde{\nu}_\mu p \to \tilde{\nu}_\mu p)}{\sigma(\tilde{\nu}_\mu p \to \mu^+ n)} = 0.2 \pm 0.1$$

(errors are only statistical)

The results on quasielastic processes with charged currents obtained by the authors are in agreement with the earlier experiments. In the present experiment $\sigma(\nu_\mu n \to \mu^- p)/\sigma^{\nu}_{tot} = 0.25 \pm 0.03$ while this ratio is 0.24 ± 0.02 from the 7 foot BNL bubble chamber experiment.

The value for R^{ν} is also in agreement with the CIR results. However it is very important to know both R^{ν} and $R^{\tilde{\nu}}$ as it will help us to clarify the space structure current. There are 23 events of the $\nu_\mu p \to \nu_\mu p$ reaction. If neutrino currents have had the space structure S, P or pure V then with account of the ratio of neutrino and antineutrino fluxes, one may expect 40 events of $\tilde{\nu}_\mu p \to \tilde{\nu}_\mu p$. Still in the experiment they have obtained 14 events from this reaction.

Estimating the ratio of the cross sections for quasielastic reactions $\tilde{\nu}_\mu$ and ν_μ with CC currents ($M_A^{CC} = 0.9$) to be 0.3 they will obtain

$$\frac{\sigma(\tilde{\nu}_\mu p \to \tilde{\nu}_\mu p)}{\sigma(\nu_\mu p \to \nu_\mu p)} = \frac{R^{\tilde{\nu}}}{R^{\nu}} \cdot \frac{\sigma(\tilde{\nu}_\mu p \to \mu^+ n)}{\sigma(\nu_\mu n \to \mu^- p)} = 0.35 \pm 0.2$$

In case of a purely vector version, this ratio should be equal to 1. This result indicates to parity nonconservation in neutral currents. As is seen, the multiquark models that give a pure vector variant for the neutral currents are excluded by this experiment. The models where the neutral current is explained by a large electromagnetic radius $\nu_\mu(\tilde{\nu}_\mu)$ have been excluded as well.

When interpreting the results in terms of SW model, the authors have obtained:

$$\sin^2\theta_W = 0.3^{+0.05}_{-0.1}$$

Data on elastic scattering of $\nu_\mu(\tilde{\nu}_\mu)$ on protons are given in Table 1V. A theoretical analysis of data on the elastic scattering is presented in papers [61,62].

3.3. Single Pion Production

Single pion production induced by neutral currents were studied by several collaborations. Below we report the data presented at the Tbilisi conference and at neutrino conference in Aachen.

3.3.1. "Gargamelle" data [42,55]

The ratios

$$R^0 = \frac{\sigma(\nu_\mu p \to \nu_\mu p \pi^0) + \sigma(\nu_\mu n \to \nu_\mu n \pi^0)}{2\sigma(\nu_\mu n \to \mu^- p \pi^0)}$$

$$\bar{R}^0 = \frac{\sigma(\tilde{\nu}_\mu p \to \tilde{\nu}_\mu p \pi^0) + \sigma(\tilde{\nu}_\mu n \to \tilde{\nu}_\mu n \pi^0)}{2\sigma(\tilde{\nu}_\mu p \to \mu^+ n \pi^0)}$$

were measured.

120 thousands pictures were obtained for each of the beams. In the antineutrino exposure a booster increasing the intensity of the proton beam by a factor of 3 was used. In the neutrino beam 367 CC and 137 NC events of single pion production were observed, while in the antineutrino 212 CC and 146 NC events, respectively. Taking into account all the corrections the following values were obtained:

$$0.1 < R^0 < 0.2$$
$$0.26 < \bar{R}^0 < 0.44$$

Single pion production provides information about isotopic properties of neutral currents.

If only the transition $\Delta T=0$ were allowed, the ratio of pion yields from the target with the same number of protons and neutrons will be:

$$\pi^0 : \pi^- : \pi^+ = 1 : 1 : 1$$

The experiment gives:

$\pi^0/\pi^- = 1.4 \pm 0.2$ for neutrino and

$\pi^0/\pi^- = 2.1 \pm 0.4$ for antineutrino.

Comparing these values with those expected for freon $\pi^0/\pi^- = 0.9$ one can see that purely isoscalar neutral current is experimentally excluded.

3.3.2. Data of the collaboration Aachen-Padova /63/

The ratios were studied with the electron detector by the collaboration Aachen-Padova (see 3.1.2). At the conference in Aachen the following values were presented:

$$R^0 = 0.40 \pm 0.06$$
$$\bar{R}^0 = 0.61 \pm 0.10$$

At our conference one more ratio is presented:

$$\frac{\sigma(\tilde{\nu}N \to \tilde{\nu}N\pi^0)}{\sigma(\nu N \to \nu N\pi^0)} = 0.51 \pm 0.12$$

This result indicates to parity violation in neutral currents. The ratio $R^0/\bar{R}^0 = 0.66 \pm 0.15$ allows one to obtain(Adler et al./64 /) $\sin^2\theta_W = 0.4 \pm 0.1$ (see also/65/).

3.3.3. Data of CIR/59/

The detector used by the collaboration is described in sec. 3.2.1. The development of 500 thousands of neutrino and 300 thousands of antineutrino pictures, gives: 157NC (ν), 22NC($\tilde{\nu}$), 511CC (ν), 35CC($\tilde{\nu}$)events of single pion production. As a result

$$R^0 = 0.17 \pm 0.04$$
$$\bar{R}^0 = 0.39 \pm 0.18$$

These values are in good agreement with "Gargamelle" data.

3.4. Total Cross Sections and Inclusive Processes

3.4.1. "Gargamelle" data/66,42/

A brief discussion of the principles of particle identification and neutral current events selection criteria from "Gargamelle" chamber is given in paper/55/. This paper also contains the results given below.

Considering the corrections due to the background and to incorrectly identified events, one obtains:

$$R^{\nu} = \frac{\sigma^{NC}(\nu)}{\sigma^{CC}(\nu)} = 0.25 \pm 0.03, \quad R^{\tilde{\nu}} = \frac{\sigma^{NC}(\tilde{\nu})}{\sigma^{CC}(\tilde{\nu})} = 0.56 \pm 0.07$$

Taking into account the effects of the kinematic cutoff on the basis of a simple parton model, the authors have :

$$R^{\nu}_{corr} = 0.25 \pm 0.04$$
$$R^{\tilde{\nu}}_{corr} = 0.39 \pm 0.06$$

The results are in agreement with the S-W model:

$$\sin^2\theta_W = 0.31 \pm 0.07 \text{ (from } R^{\nu})$$
$$\sin^2\theta_W = 0.33^{+0.17}_{-0.10} \text{ (from } R^{\tilde{\nu}})$$

General estimate:

$$\sin^2\theta_W = 0.33 \pm 0.05$$

3.4.2. Data of CITF/67/

More than 3 thousands neutrino events were obtained including about 500 events in antineutrino beam. The kinematic cut was $E_h > 12$ GeV. The results agree with those of the previous collaboration:

$$R^{\nu} = 0.24 \pm 0.02$$
$$R^{\tilde{\nu}} = 0.34 \pm 0.02$$

that in terms of the S-W model gives:

$$\sin^2\theta_W = 0.33 \pm 0.05$$

The dichromatic beam allows the distribution over hadron energy to be used instead of y-distribution. Pure S or P variants contradict the experimental data.

3.4.3. HPWF experiment/21,68/

The collaboration presented new data on R^{ν} and $R^{\tilde{\nu}}$ corrected due to higher statistics received in a sufficiently pure antineutrino beam.

The events with $E_h > 4$ GeV were registed. The results of all four exposures are given in

Table V. Taking into account the selection criterion of $E_h > 4$ GeV and assuming that there are only V and A variants, the authors receive a more appropriate variant for neutral current (V-0.8A). Data indicate to parity violation.

Data on the total cross sections are in agreement with the predictions of the Salam-Weinberg model.

3.5. Conclusion

1. Parity violation in neutral currents is established. This can be concluded from single pion production, the experiments on neutrino and antineutrino elastic scattering on protons and the total cross section for muonless events. The experiment excludes all pure S, P, V, A, T variants.

2. The existence of terms with isotopic spin $T \geq 1$ (from the charge ratio π^-/π^0 in single pion production) was established in neutral current.

3. All data on neutral currents do not contrudict the Salam-Weinberg model with value $\sin^2\theta_W = 0.3 \div 0.4$.

4. It is necessary, without keeping any model, to make a complete experimental study of spacial and isotopic structure of neutral currents (like for β-decay). Within V and A variants the study of deep inelastic muonless ν and $\tilde{\nu}$ scattering on protons and neutrons as well as of inclusive channels with the production of vector mesons $\nu(\tilde{\nu})N \to \nu(\tilde{\nu})N\rho^0$, $\nu(\tilde{\nu})N \to \nu(\tilde{\nu})NA_1$ and so on /69/ (for these reactions in C.C. currents see ref. /53/) may appear to be necessary at high energies. I should like to mention that important problems concerning the structure of neutral currents may be solved when studying nuclear level excitations using the neutrino at low and intermediate energies /70-72/ (since the levels of light nuclei are characterized by definite values of spin, isospin and parity). Uncertainties in nuclear matrix elements can in many cases be eliminated by experimental determination of the corresponding matrix elements from electromagnetic transitions. Since the matrix elements are big, the search in nuclear transitions for the isoscalar A-variant (which is not present in the S-W model) seems to be realistic. /72/

3.6. Additional remarks: Neutral currents in astrophysics

A great importance of the processes due to neutral currents was pointed out by B. Pontecorvo as 1962. /73/ The emission of $\nu\tilde{\nu}$ pairs owing to neutral currents is important in cooling of neutron stars and so on /74,75/

However, the most promising were neutral currents in explosions of supernovas. It was expected that owing to the coherent effect in neutrino scattering on nuclei, for isotopic scalar interactions /76,77/ ($\sigma \sim A^2$) the neutrino flux from the collapsing iron core of a star may blow off a star's shell /78-80,75/. For this purpose S-variant of neutral currents may be especially favourable. /81/ However, the calculations, taking into account a selfconsistent development of hydrodynamics collapse, showed that in fact, there is no such a blowing off of a shell. /82/ The explosion of supernova with a simultaneous production of a neutronstar may essentially be due to the ignition of thermonuclear reaction caused from scattering in the shell of a degenerated carbon-oxygen star /83/.

4. Neutrino Properties

4.1. Neutrino mass

The theory of the two-component (longitudinal) neutrino with zero mass was important for the discovery of the V-A theory of weak interactions. However, after the V-A theory was established, it become unnecessary to consider the neutrino be distinct among other leptons (since their polarization in weak interactions according to V-A theory is equal to $-v/c$ and at energies $E_\ell \gg m_\ell$ does not actually differ from -I). Therefore, a more accurate experimental determination of the upper limit on the neutrino mass seems to be very important. In the paper of IHEP submitted to this conference /84/ the new upper limit on the electron mass neutrino

$$m_{\nu_e} \leqslant 35\ eV \quad \text{at} \quad 90\%\ C.L$$

is found from the analysis of tritium β-spectrum, which is twice better than the existing one. I should like to mention that the experimental upper limit on the muonic neutrino mass is: $m_{\nu_\mu} < 0.65$ Mev *)

4.2 Quark-Lepton Analogy

From the experimental evidence of the charmed particle existence and from the gauge theories one may trace a deep analogy between quarks and leptons. Historically it is just this analogy that made the basis for introducing charmed quark[90/] (see also [9I/]). A success of the GIM model allows one to assume that the mixing of states is extended to leptons also. Such a viewpoint was developed by S.M.Bilen'ky and B.Pontecorvo[92/] (see also [93/]). The absence of strange changing neutral currents in the first order in the weak interactions and their appearence in the second order are shown in the GIM model due to the fact that "u" quark is assigned to a weak doublet with the combination $n_0 = d\cos\theta_c + s\sin\theta_c$, and "c" quark with the orthogonal combination $\lambda_\theta = -d\sin\theta_c + s\cos\theta_c$.

*) A better upper limit give cosmological data. According to the model of not Universe the number of relict neutrino should in order of magnitude be close to the number of relict photons with temperature $\theta \approx 3^\circ K$, i.e. $n_\nu \sim 10^3 cm^{-3}$ /85/. On the other hand, the Hubble constant and age of the Universe give the estimate on the upper limit of the energy density (including an "unobserved" component) $\rho < 10^{-28} gcm^{-3}$ $10^{-4} GeVcm^{-3}$. For the upper limit m_{ν_μ} it follows $m_{\nu_\mu} < 10^2 ev$ First such an estimate was made in paper /86/ and further in papers /87,88/. Another cosmological upper limit for m_{ν_μ} is based on the M.A Markov idea /89/ that the neutrino with $m_{\nu_\mu} \neq 0$ may be accumulated in the galaxy cluster and determine their "hidden" masses (G.Marx).

According to [/92,93/] an analogous situation may occur for leptons also: an electron can be assigned to a weak doublet with the combination $\nu_e = \nu_1 \cos\theta + \nu_2 \sin\theta$ and muon with the orthogonal combination $\nu_\mu = -\nu_1 \sin\theta + \nu_2 \cos\theta$ (where ν_1 and ν_2 are the four-component particles with definite masses m_1, m_2). With such a structure of weak lepton doublets the "asymmetric" neutral currents (for instence $\mu \to e + \gamma$ etc), are induced by higher orders of perturbation theory and are very small[/ 94/]. The mixing of states results in oscillations in neutrino beams reminding the oscillations $K^0 \rightleftarrows \bar{K}^0$ in neutral kaon beams. For instance at sufficiently large distances from the muon neutrino source there may appear the electron neutrino. The oscillation length in this case is equal to $L = \frac{4\pi p}{|m_1^2 - m_2^2|}$ (where p is the neutrino momentum). From the experimental data the authors[/95 /] estimate $|m_1 - m_2| \leqslant 1 eV$. Thus, the upper limit $m_{\nu_e} < 35\ eV$ in this scheme is simultaneously that on the value of mass m_{ν_μ}

4.3. Neutrino oscillations

The study of possible oscillations in neutrino beams gives an extremely sensitive method of investigation of the neutrino nature. Depending on mixing of different neutrinos, lepton charge violation and the existence of other types of neutrinos (besides ν_e, ν_μ) different types of oscillations may occur[/96,97/]

The sensitivity of the method is due to the fact that the oscillation effects are proportional to the transition amplitudes (not to their squares).

*) The possibility of oscillations in neutrino beams was discussed long ago[/98 /] (the first detailed theory was presented by V.N.Gribov and B.M.Pontecorvo[/99 /]).

Experimental search for neutrino oscillations seems to be realistic for all known neutrino sources (reactors, accelerators) and by estimates /95/ may provide upper limits for $|m_1 - m_2|$ of order of $10^{-1} \div 10^{-2}$ eV. A still more sensitive method which can provide the limit $|m_1 - m_2| < 10^{-6}$ eV is detection of a flux of solar neutrinos. For this purpose the Ga - Ge method is very perspective allowing detection of neutrino from the reaction $pp \rightarrow D e^+ \nu_e$ /100/. The intensive of neutrino from the hydrogen reaction is related to luminosity of the sun and may be calculated with high accuracy (of course, if a possible cyclic decrease in yield of thermonucleon reaction on the sun during the time of order of 10^6 years is not taken into account). From the experiments of Davis /101/, though the registered signal is lower than the expected one, one cannot make any definite conclusions on neutrino oscillations since the expected intensily of detected neutrino depends on solar models and is not known with sufficient accuracy.

Concluding Remarks

I. It is obvious that new particles decaying in the weak interaction are detected in the neutrino experiments. A strong correlation of two-lepton events with strange particles is in good agreement with the production and decay of charmed particles in the GIM model.

2. The nature of scaling breaking is still unclear. If it is due to strong interactions, the observed phenomena also not contradict the minimal GIM model. For its explanation one does not need to introduce many-quark schemes and right-handed currents. However, the existing data do not exclude an opposite viewpoint.

3. It was found that the neutrino interactions with neutral currents violate the spatial parity and contain the terms with $\Delta T \geqslant 1$. On the whole these interactions do not contradict the predictions of the S-W model with $\sin^2\theta_W = 0.3 \div 0.4$. For further investigation of neutral currents it is important to observe the effects of parity non-conservation in atomic transitions.

4. Using the data from the colliding $e^- e^+$ beams indicating the existence of heavy leptons, one should expect the complication of the simplest models and search for new phenomena in neutrino interactions. In this connection the experiments of the type "Beam dump" and observations of neutrino oscillations may be important.

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Table II.

Electronic Neutrino Detectors

Accelarator	Collaboration	Neutrino energy	Physics	Experimental set-up	Target weight	Future plans
CERN PS E_p=28 GeV	Aachen-Padova	2-10 GeV	$\nu_\mu(\bar\nu_\mu)e$ NC($\nu\pi^0 N$)	141 bigap Al spark chambers	22T f.v.	
BNL E_p=31 GeV	Harvard-Pennsylvania-Wisconsin	1-2 GeV	$\nu_\mu p$ $\bar\nu_\mu p$	liquid scintillation modules, drift chambers	33T f.v.	
	Columbia-Illinois-Rockefeller-BNL	1-2 GeV	$\nu_\mu p$ NC ($\nu\pi^0 N$)	Al spark chambers, scintillation counters	20T f.v.	
IHEP E_p=70GeV	ITEP(Moscow) IHEP(Serpukhov)	5-30 GeV	2μ	spark chambers Fe target plates	34T f.v.	$\nu_\mu e$ NC Al spark chambers scintillation counters
FNAL E_p=400 GeV	Harvard-Pennsylvania-Wisconsin-Fermilab	20-300 GeV	CC NC 2μ	liquid scintil.modules spark chambers muon spectrometer	60T f.v.	2μ 1000 Fe target large acceptance-spectrometer
	Caltech-Fermilab	50,150 GeV narrow band beam	NC CC 2μ	Fe target plates, spark chambers muon spectrometer	140T total	NC,CC,2μ wide band beam larger acceptance
CERN SPS E_p=400 GeV	CERN-Dortmund-Heidelberg-Saclay	50-300 GeV dichromatic beam		Fe fine-grained calorimeter,toroidal magnets, drift chambers	1400 T total	CC $n\mu$ ($n\geq2$)
	CERN-ITEP-Hamburg-Rome	100-300 GeV dichromatic beam		target calorimeter iron frames muon spectrometer	170T total	NC $\nu_\mu e$

BC & LABORATORY	GROUP	CHAMBER FILL	VIS VOLUME & TARGET MASS	X_0 (cms)	H (KGS)	BEAM	• E_p (GeV)	E_ν (GeV)	$E_{\nu\,peak}$ (GeV)
GGM, CERN	GGM	CF_3Br	7m³, 10T	11	20	ν	26	1-16	2
						$\bar\nu$		1-14	2
12', ANL	AP	H_2, D_2	16m³, -17	990		ν	12.4	.5-6	~1
7', BNL	BNL	H_2, D_2	6m³, -0.4T	990	25	ν	28	1-18	2
15' FNAL	BHFM	H_2	28m³, -1.7T	990	21,30	ν	300,400	5-250	~15
	ACM	H_2	28m³, -1.7T	990	21, 30	$\bar\nu$	300,400	5-200	~22
	BCHW	H_2+Ne(20%)	28m³, -11T	~110	30	ν	300	5-200	~15
	FMMS	H_2+Ne(20%)	28m³, -11T	~110	30	$\bar\nu$	300	5-200	~20
	CB	H_2+Ne(64%)	28m³, -28T	~40	30	ν	400	5-250	~15
		H_2+Ne(64%)	28m³, -28T	~40	30	$\bar\nu$	400	5-250	~22
SKAT, IHEP		CF_3Br	6 m³, -9T	11	20-25	ν, $\bar\nu$	70	2-30	~5
BEBC		H_2, D_2, Ne	[illegible]		35	ν,$\bar\nu$	400	5-250	15-20 and narrow band

AP ANL - PURDUE
ACM ANL - CARNEGIE - MELLON - PURDUE
BCHW LBL - CERN - HAWAII - WISCONSIN
BHFM LBL - HAWAII - FNAL - MICHIGAN
CB COLUMBIA - BNL
FMMS FNAL - MICHIGAN - MOSCOW - SERPUKHOV

Table III.

Purely leptonic currents

Gargamelle:

	Number of events	Background	Kinemat. cut	σ (E $\cdot10^{-42}$) $cm^2 GeV^{-1}$	$\sin^2\theta_W$ = X
$\bar\nu_\mu$	3	0.43±0.13	0.3 < E_e < 2 (GeV) θ_e < 5°	$1.0^{+2.1}_{-0.9}$	0.1 ≤ X ≤ 0.4
ν_μ	(1)			≤ 2.6	

Aachen-Padova:

$\bar\nu_\mu$	19	2.9	0.2 < E_e < 2 θ_e < 5°	5.4±1.7	x = 0.58±0.09
ν_μ	25	11.8		2.4±1.2	

$$\frac{\sigma(\bar\nu_\mu e)}{\sigma(\nu_\mu e)} = 0.44\pm0.26 \quad x > 0.32$$

Paissner:
G.G.M and A-P
United : $\sigma(\bar\nu_\mu e) = (3.2\pm1.4)E\cdot10^{-42} cm^2 GeV^{-1}$ x = 0.44±0.10

Reines et al .

1.5 < E_e < 3 (MeV) $\sigma(\bar\nu_e e)$ = 4.7±1.4
3 < E_e < 4.5 (MeV) $\sigma(\bar\nu_e e)$ = 9.2±2.4
} $\sigma(\bar\nu_e e)$ = 5.8±1.4, X = 0.35±0.07

Table IV.

Elastic scattering $\nu_\mu p$, $\tilde{\nu}_\mu p$

beam B.N.L.

		N.of events	Background	Ratio	Cut
C.I.R.	$\nu_\mu p$	38	$\nu_\mu N \to \mu N \pi$: 2 $np \to np$: 10 $\nu_\mu n \to \mu^- p$: 6 19	$\frac{\sigma(\nu_\mu p \to \nu_\mu p)}{\sigma(\nu_\mu n \to \mu^- p)}$ R =0.23± 0.09	$0.3 < q^2 < 1$ GeV^2 $\theta > 25°$
HPW	$\nu_\mu p$	30	$\nu_\mu p \to \nu_\mu p \pi^0$: 2 $\nu_\mu n \to p \mu^-$: 2 $np \to np$: 3 7	$\frac{\sigma(\nu_\mu p \to \nu_\mu p)}{\sigma(\nu_\mu n \to \mu^- p)}$ R =0.17± 0.05	$0.3 < q^2 < 0.9$ Gev^2
HPW	$\tilde{\nu}_\mu p$	22	$\tilde{\nu}_\mu n \to \tilde{\nu}_\mu p \pi^-$: 1 $\tilde{\nu}_\mu p \to \tilde{\nu}_\mu p \pi^0$: 1 $np \to np$: 6 8	$\frac{\sigma(\tilde{\nu}_\mu p \to \tilde{\nu}_\mu p)}{\sigma(\tilde{\nu}_\mu p \to \mu^+ n)}$ R =0.2± ±0.1	$0.3 < q^2 < 0.9$

$$\frac{\sigma(\tilde{\nu}_\mu p \to \tilde{\nu}_\mu p)}{\sigma(\nu_\mu p \to \nu_\mu p)} = 0.35 \pm 0.2 \qquad \text{(HPW)}$$

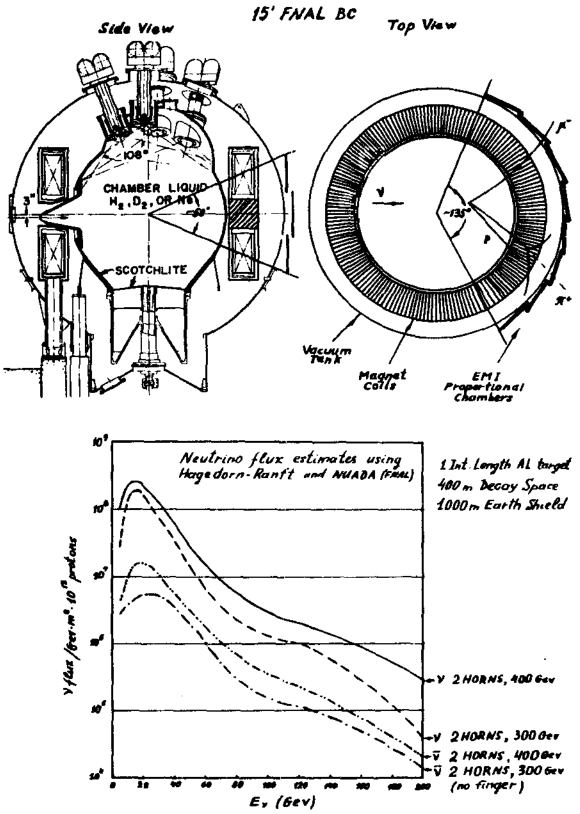

Fig.1.

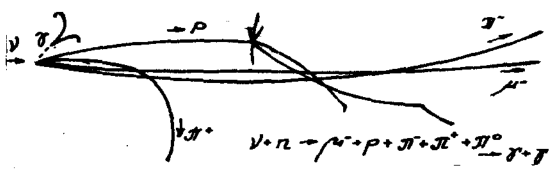

Fig.2a.

Table V

Total cross section $\nu_\mu N \to \nu_\mu X$; $\tilde{\nu}_\mu N \to \tilde{\nu}_\mu X$

a) Gargamelle :

	$E_{\nu(\tilde{\nu})}$	NC+CC+AS	Kinemat. cut	$R_{\nu(\tilde{\nu})} = \frac{\sigma(NC)}{\sigma(CC)}$	$R^{cor.}_{\nu(\tilde{\nu})}$	$\sin^2\theta_W = X$
ν_μ	1–12	433	$E_h > 1$ GeV	$R_\nu = 0.25 \pm 0.03$	$R^\nu = 0.25 \pm 0.04$	$x = 0.33 \pm 0.05$
$\tilde{\nu}_\mu$	GeV	469		$R_{\tilde{\nu}} = 0.56 \pm 0.07$	$R^{\tilde{\nu}} = 0.39 \pm 0.06$	

b) C.I.T.F. dichrom. beam: $\langle E_\nu \rangle_\pi = 52$ GeV; $\langle E_\nu \rangle_K = 146$ Gev :

	N. of events	Cut		
ν_μ	~ 2.800	$E_h > 12$ GeV	$R_\nu = 0.24 \pm 0.02$	$X = 0.33 \pm 0.05$
$\tilde{\nu}_\mu$	~ 400		$R_{\tilde{\nu}} = 0.34 \pm 0.02$	

Pure S or P   not good fit

c) H.P.W.F.

Beam	$\frac{N_{\mu^-}}{N_{\mu^-} + N_{\mu^+}}$	N.of events N.C.	N.of events C.C.	$R_{\nu(\tilde{\nu})} = \frac{\sigma(NC)}{\sigma(CC)}$
Pure ν $\langle E_\nu \rangle = 53$ Gev	0.94	266	857	$R_\nu = 0.31 \pm 0.06$
Mixed $\langle E_\nu \rangle = 78$	0.83	158	599	$R_\nu = 0.24 \pm 0.06$
$\langle E_\nu \rangle = 85$	0.86	300	1042	$R_\nu = 0.29 \pm 0.04$
Pure $\tilde{\nu}$ $\langle E_{\tilde{\nu}} \rangle = 41$ Gev	0.27	69	198	$R_{\tilde{\nu}} = 0.39 \pm 0.10$
	(V – 0.8 A)	best fit		

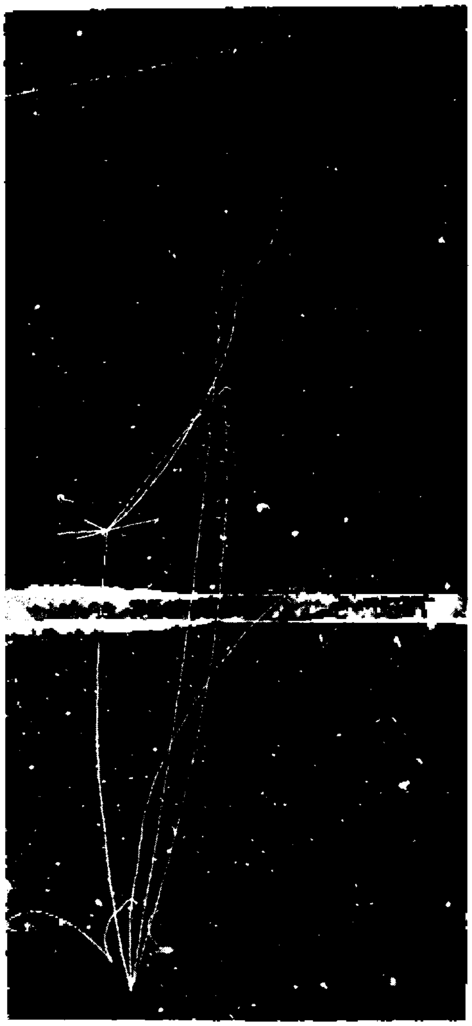

Fig.2b.

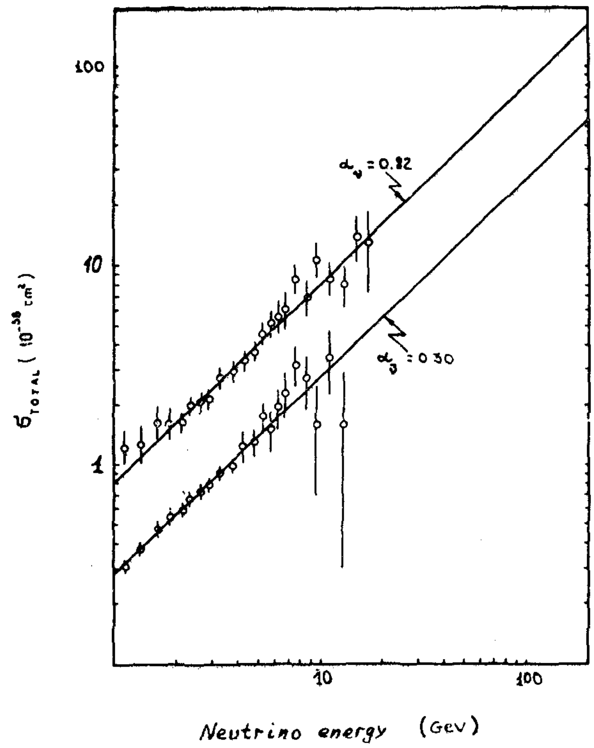

Fig.3.

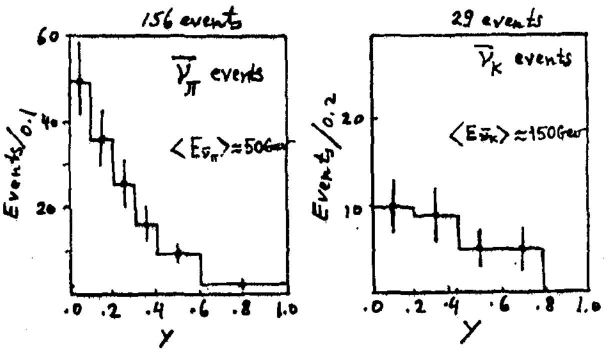

Fig.4.

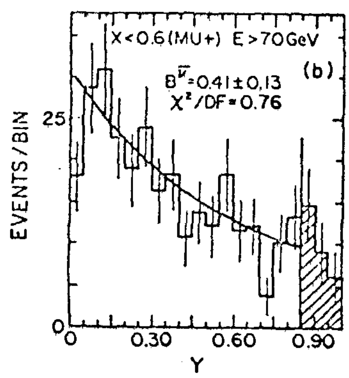

Fig.5.

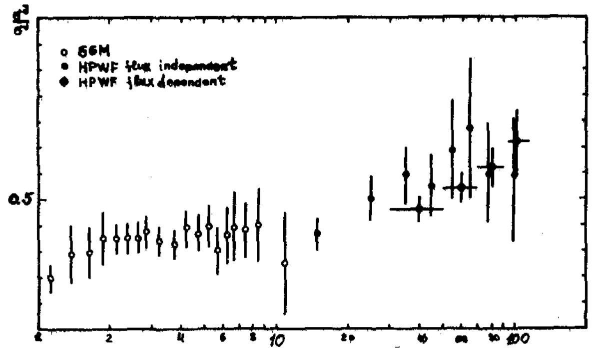

Fig. 6.

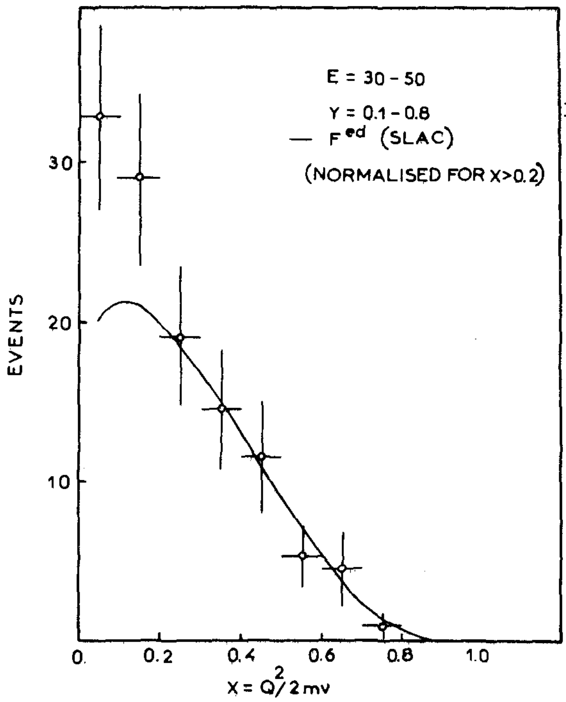

Fig.7.

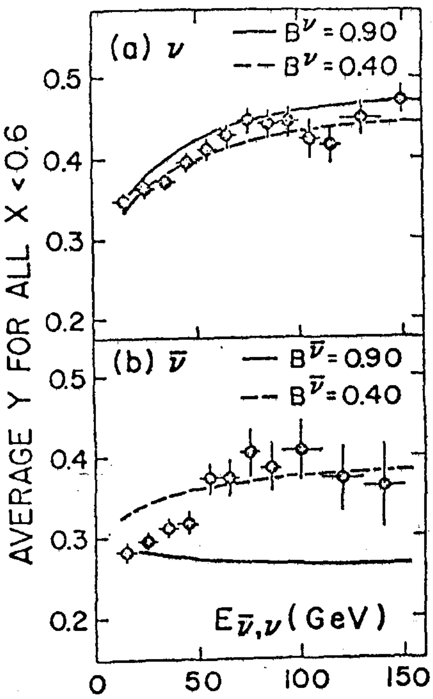

Fig.8.

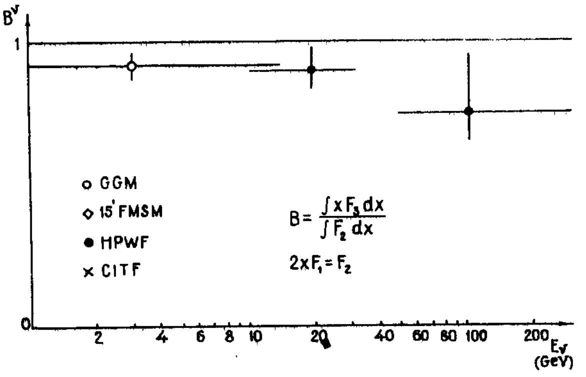

Fig.9a.

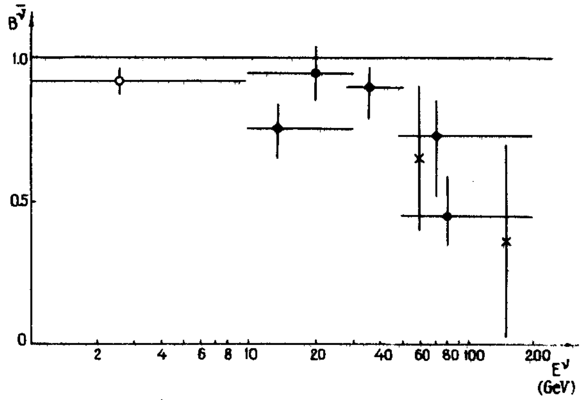

Fig.9b.

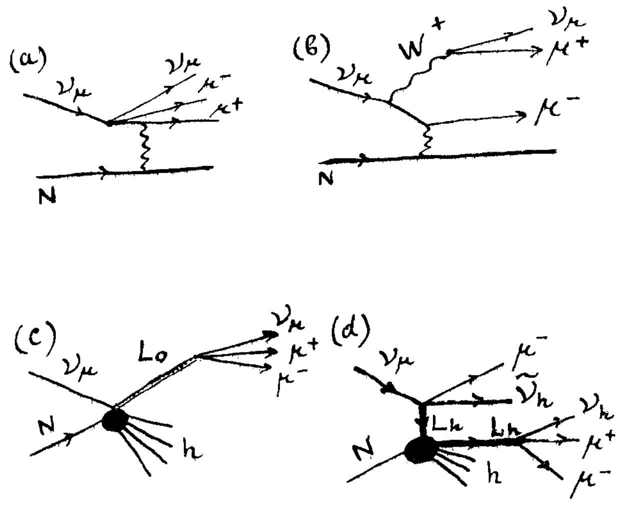

Fig.10.

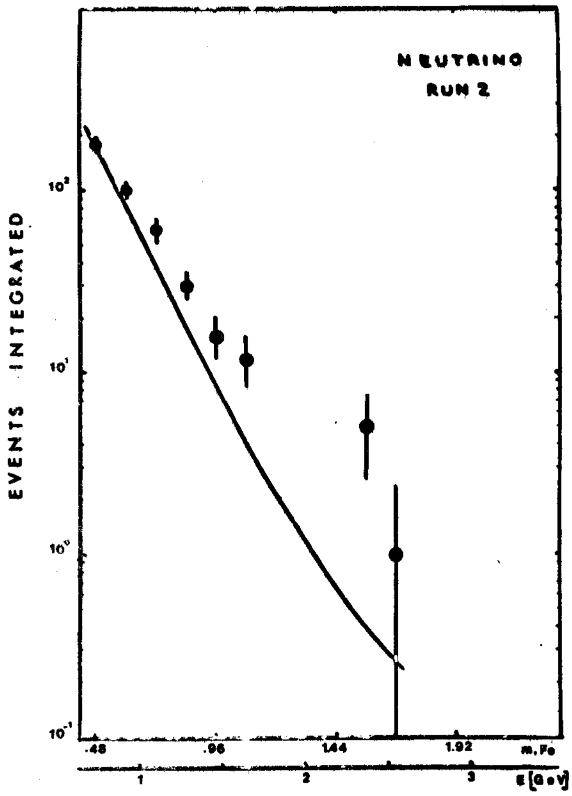

Fig.11.

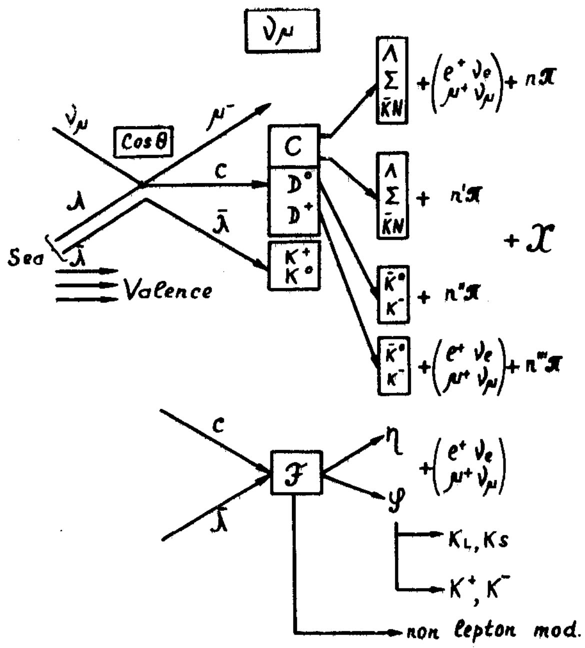

Fig.12a.

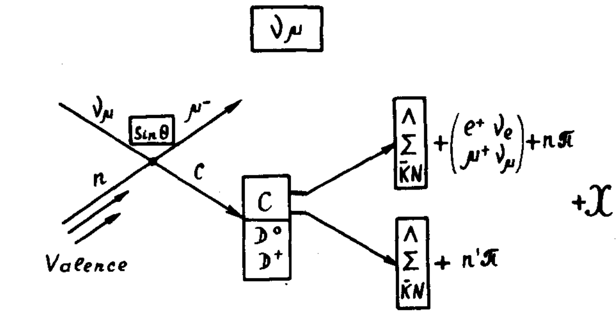

Fig.12b.

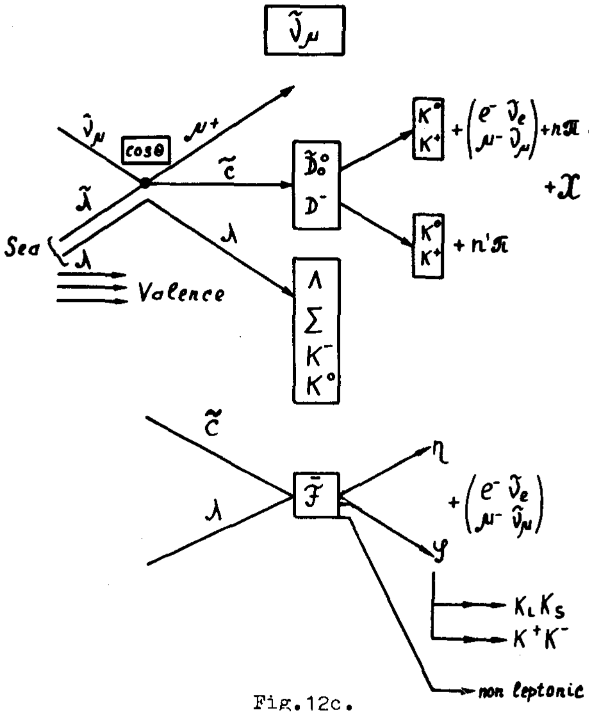

Fig.12c.

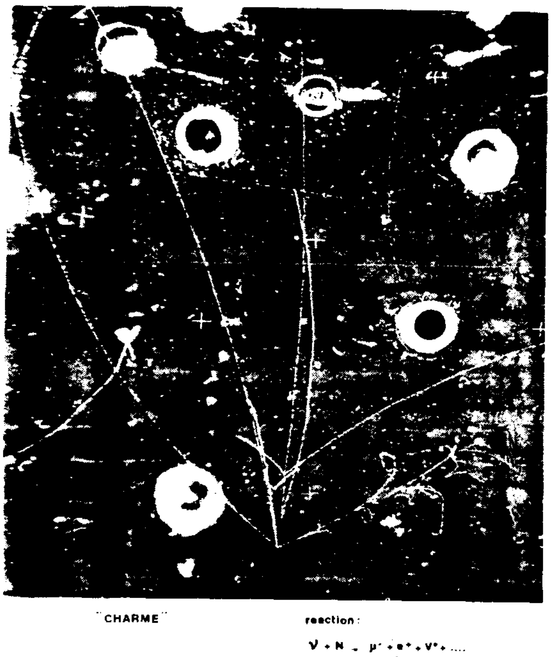

Fig.13.

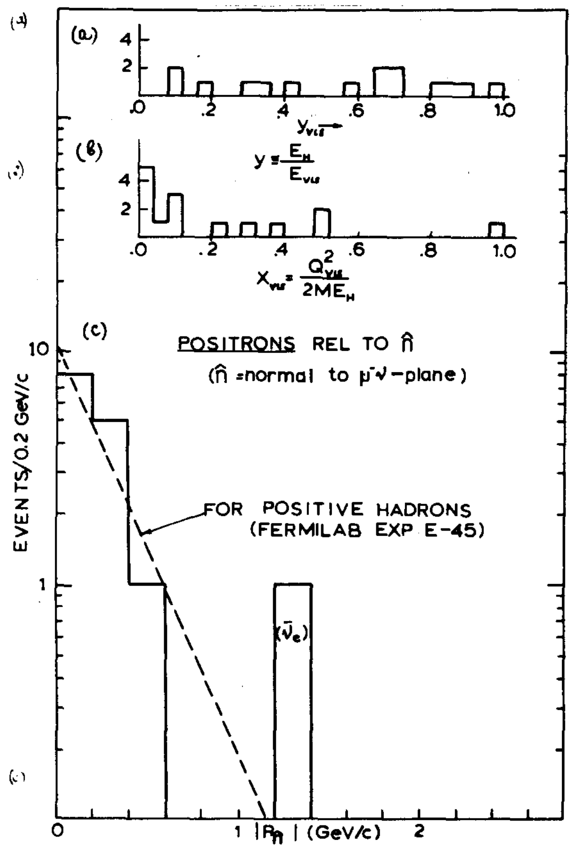

Fig.14.

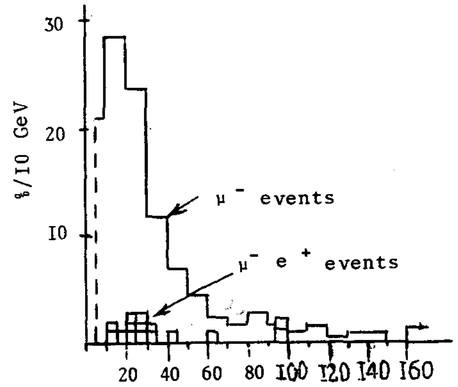

Fig.15.

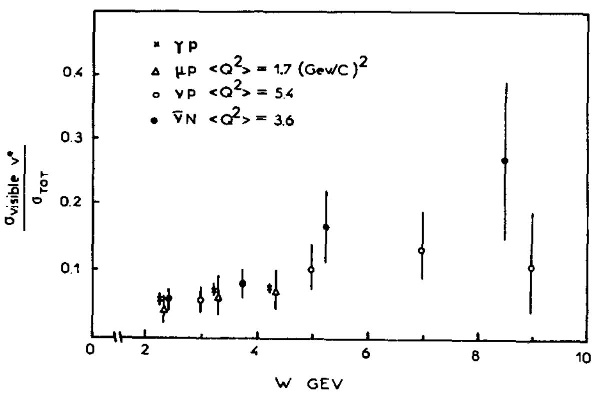

Fig.16.

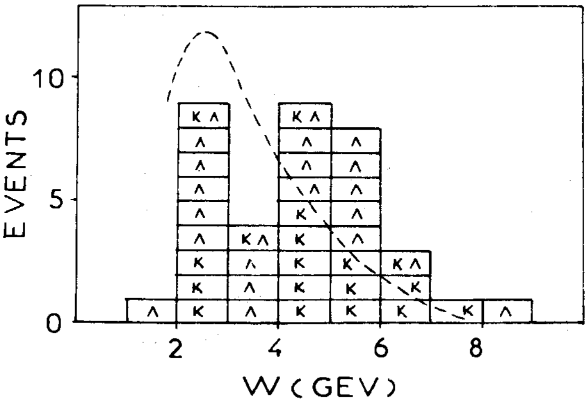

Fig.17.

PARALLEL SESSION ON LEPTON PRODUCTION
IN HADRON INTERACTIONS

ANOMALOUS LEPTON PRODUCTION IN COLLISIONS OF HADRONS

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University of Munich, FRG

Introduction

Direct (or prompt) leptons are those leptons which are produced within experimental resolution at the interaction point conventionally excluding leptons from residual decays of long-lived parents (kaons, hyperons) or Dalitz-decays. Whether these leptons are "anomalous" depends on whether their sources are of conventional or of novel type.

In this report a brief survey of the available data on direct leptons is given. Contributions from electromagnetic and weak decays will be discussed. Unless stated otherwise units of energy and momentum are always in GeV and GeV/c.

Published results or results presented by other speakers have been treated very briefly. For details see the original papers, ref. /1/ or the invited talks.

Survey of available data on direct leptons

1) Leptons with large transverse momenta and large CM-angles:

a) CERN-Columbia-Rockefeller-Saclay /2/ ($e^{\pm}$, $\vartheta^{*} = 90°$, $p_{\perp} = 0.6-5.0$, $\sqrt{s} = 23-62$). The data, shown in Fig. 1 for $\sqrt{s} = 52$, suggest an increase of e/π with $\sqrt{s}$. At medium $p_{\perp}$

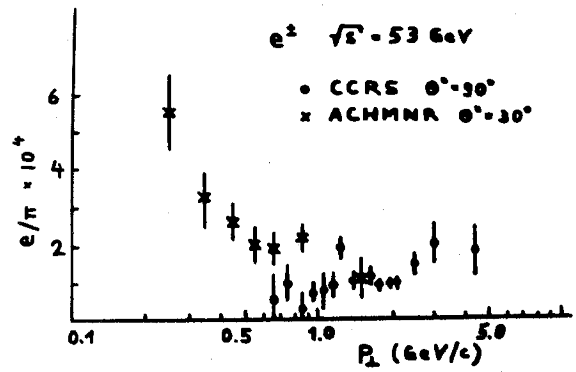

Fig. 1.
e/π at $\sqrt{s}$ =52 GeV, ref. 2,7.

(1.3-1.6) electrons are more frequent($e^{+}/e^{-} = 0.79 \pm 0.12$).

b) Chicago-Princeton /3/ ($\mu^{\pm}$, $\theta^{*} = 90°$, $p_{\perp} = 1.5-5.5$, $\sqrt{s} = 23, 27$): $\mu/\pi = (1.1 \pm 0.2) 10^{-4}$, no variation with target material (Be, Cu, W) or lepton charge. Preliminary new data at $\sqrt{s} = 27$ show a rise with $p_{\perp}$ [$\mu/\pi = (1.3 \pm 0.15) 10^{-4}$ at $p_{\perp} = 3$, $\mu/\pi = (2.3 \pm 0.2) 10^{-4}$ at $p_{\perp} = 5$].

c) Columbia-FNAL /4/ ($e^{\pm}$, $\mu^{\pm}$, $\theta^{*} = 90°$, $p_{\perp} = 1.8-4.0$, $\sqrt{s} = 23$) : Measurements on Be for $e^{\pm}$ and $\mu^{\pm}$ show no difference [$e/\pi = (0.8 \pm 0.2) 10^{-4}$, $\mu/\pi = (1.0 \pm 0.2) 10^{-4}$].

d) Chicago-Harvard-Pennsylvania-Wisconsin /5/ ($\mu^{\pm}$, $\theta^{*} = 45°-95°$, $p_{\perp} = 1.0-2.2$, $\sqrt{s} = 10-20$): Measurements with a low Z target (mainly C) show no energy dependence (see Fig.4).

e) Moscow-Serpukhov /6/ ($\mu^{\pm}$, $\theta^{*} = 59°-79°$, $p_{\perp} = 1.9-3.2$, $\sqrt{s} = 8.0-11.5$): Two methods have been used. Both agree only if $\mu^{+}/\mu^{-} \simeq 1.2$ [$\mu^{+}/\mu^{-} = 1.20 \pm 0.10$ at $\sqrt{s} = 11.5$, $\mu^{+}/\mu^{-} = 1.22 \pm 0.16$ at $\sqrt{s} = 9.7$. The ratio μ/π shows a clear threshold effect between 8.0 and 11.5 (see Fig.4) and it does not change with target material (Be, Cu) nor $p_{\perp}$.