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M E M O R A N D U M

To: Members of the SPSC
From: CERN-Hamburg-Amsterdam-Rome-Moscow (WA18) Collaboration
Subject: The case for 200 GeV narrow band neutrino beam running

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We request $3 \cdot 10^{18}$ protons of 450 GeV for narrow band beam neutrino and antineutrino runs at 200 GeV/c parent momentum in order to extend the data taken in 1978 with the WA18 detector.

1. Physics aims of the narrow band beam run

The SPSC has allocated $3 \cdot 10^{18}$ p to our experiment. Of this we have now used $1.8 \cdot 10^{18}$ protons. We would like to ask to continue running the narrow band beam at 200 GeV/c parent momentum with an addition of $3 \cdot 10^{18}$ protons on target in order to obtain a total of $\sim 5 \cdot 10^{18}$ protons, in the ratio of one to two for neutrino and antineutrino runs, as requested in our memorandum to E. Lohrmann dated 23 September 1977.

The data obtained will allow, using the novel features of the WA18 detector: (1) a more sensitive study of the strength and the structure of the neutral current than has been possible until now; (2) the first study of the structure of matter using the neutral current; (3) a sensitive search for neutral current scattering on charmed sea quarks and (4) a study of the charged current structure functions with better resolution in the scaling variables, in particular at low q^2 and at high y, than now available in other large electronic neutrino experiments.

The fine-grained calorimeter we have built allows precise measurements of the energy and of the direction of the hadron jet produced in neutrino interactions. It relies in a very essential way on the narrow band neutrino beam to obtain the neutrino energy for every event and to calculate the kinematics of inclusive neutrino reactions induced by the neutral current and by the charged current.

Several conflicting requirements have to be combined and have led us to choose 200 GeV/c as the optimum value of parent momentum; one is the event rate, compensating the lower target mass of a fine-grain calorimeter; another the resolution in the kinematical variables, which is worsened at higher beam momentum, because of the increasing parallax effect on the neutrino energy. The energy resolution of the beam is in fact proportional to the parent hadron energy, and would therefore be $\sim$ 1.6 times worse at 320 GeV than at 200 GeV.

The statistics obtained until now are given in Table 1. In order to study the structure of the neutral current and the structure functions of the nucleon we require to increase the present sample by

1. more antineutrino data
2. more neutrino data.

Event numbers as expected for the requested runs are given in Table 1, entry 2. A narrow band beam neutrino run at 320 GeV/c parent momentum as requested by others would not allow the small number of the present antineutrino statistics to be increased, would give worse resolution (see table 2) for the neutrino data, and would be a factor seven less effective per proton in increasing the present neutrino statistics (entry 2 and 3 of table 1).

2. Structure and strength of the neutral current

The chiral structure of the neutral current is not yet well determined, in particular the question of right-handed coupling of the valence quarks requires more experimental information.

The deviation of the ratio

$$\frac{d\sigma}{dy}\,(\nu\to\nu)\ /\ \frac{d\sigma}{dy}\,(\nu\to\mu^-)$$

from a constant is a direct measurement of the relative strength of right-handed and of left-handed coupling.

The improvement expected from this experiment is due to better muon recognition owing to the fine-grain structure of the calorimeter, allowing us to cut at $E_\mu > 1.0$ GeV. Instead of a 13% correction for charged current background as in the most precise published experiment, we expect a correction of approximately 2% and, hence, an error which is statistics limited. We therefore require more data at the same parent momentum.

At present there is no knowledge of the neutral current coupling of s and c quarks. The Weinberg-Salam model predicts universality of the coupling of all "up" quarks of charge + 2/3, i.e. u, c, (t), ... and of all "down" quarks of charge - 1/3, i.e., d, s, b, ... This experiment can perhaps get first results on this important question.

The effect of neutral current coupling of the s quark is expected to lead to characteristic deviations of $F_2(x)$ as measured by the charged, the neutral and the electromagnetic current. The neutral current coupling of the c quark is expected to give wrong sign muons, e.g. events with a μ^+ and a lack of p_T balance in the neutrino beam. This experiment, owing to its ability to measure the transverse momentum of hadron showers, can make a sensitive search for such events. On the basis of table 1 we expect to observe 10 events.

Table 1

Narrow Band Beam Event Rates of WA18

After Fiducial Cuts

beam	period	protons on target	CC	NC
1. Present statistics of CHARM Collaboration				
ν 200 GeV	P6B, 8(1978)	$0.57 \cdot 10^{18}$	8600	2600
$\bar{\nu}$ 200 GeV	P7, 8(1978)	$1.20 \cdot 10^{18}$	4700	1600
2. Statistics of CHARM Collaboration from requested runs in 1979 for $3 \cdot 10^{18}$ protons of 450 GeV				
ν 200 GeV	P5, 6(1979)	$1 \cdot 10^{18}$	18800	5600
$\bar{\nu}$ 200 GeV	P5, 6(1979)	$2 \cdot 10^{18}$	9800	3400
3. Events expected for CHARM from a 320 GeV narrow band beam run				
ν E_ν < 200 GeV	P5, P6	$3 \cdot 10^{18}$	7100	2100
ν E_ν > 200 GeV	1979		7100	2100

Table 2

Ratio of Resolution in x and y at 320 GeV and 200 GeV Parent Momentum

1) Δx (320 GeV)/Δx (200 GeV)

$\bar{y}$ \ $\bar{x}$	0.1	0.3	0.5	0.7	0.9
0.1	0.62	0.85	0.90	0.92	0.94
0.3	1.2	0.95	0.80	1.0	1.0
0.5	1.4	1.3	1.2	1.0	1.2
0.7	1.4	1.2	1.3	1.2	1.3
0.9	1.5	1.3	1.3	1.2	1.4

2) Δy (320 GeV)/ Δy (200 GeV)

$\bar{y}$	0.1	0.3	0.5	0.7	0.9
Δy	1.1	1.3	1.4	1.4	1.4

There exist at present no direct tests of quantum number selection rules of the neutral current. In this experiment we can perform a sensitive search for isoscalar axial-vector contributions which would lead to a non-zero intersect of $d\sigma/dq^2$ in the limit $q^2 \to 0$.

3. <u>The structure of matter seen by neutral, charged and electromagnetic currents</u>

The structure functions xF_1 (x, q^2), F_2 (x, q^2) and xF_3 (x, q^2) can be determined directly by forming sums and differences of appropriately weighted neutrino and antineutrino cross sections, both for charged and for neutral currents, and the first two also in muon scattering experiments for the electromagnetic current. To obtain them with some precision requires good statistics both for neutrino and for antineutrino cross-sections.

For the first time there is therefore the possibility to compare these structures. Of course, if we ask theoretical physicists they claim that these structures can be rigorously calculated. It is for this reason that an experimental test is now crucial. Indeed, some characteristic deviations of F_2 (x, q^2) are expected in these models. The measurement, however, will reveal whether there exist other, unexpected differences, e.g. due to new particle production, to propagator effects of the Z^0 or some other non-locality peculiar to neutral currents.

4. <u>Study of charged current structure functions</u>

We expect to make specific contributions to the study of structure functions and their q^2 dependence. It is of course true that our detector, owing to its fine-grain calorimeter, has smaller density and therefore lower event rate. However, it has been stressed before that the limits may not be set by statistical errors but by systematic uncertainties and by resolution effects. In this experiment, owing to its ability to measure shower directions, we can make a kinematical fit to optimize the measurement of charged current events. In the narrow band beam we measure, for charged current events, the following seven variables: neutrino energy, hadron energy, muon momentum and two muon and hadron angles, while we need only four to determine the kinematics. Hence, the equations of energy and momentum conservation can be used to make a better estimate of the kinematic variables which satisfy these equations. A comparison of Δx and Δy as determined with and without the fit is shown in table 3. The improvement over other existing experiments is considerable and should allow sensitive measurements, e.g. at low q^2, at high y and at low x.

Table 3

Comparison of Resolutions Δx and Δy at E_ν = 200 GeV

With and Without Kinematical Fit in Charged Current Events

1. Δx

with fit

y \ x	0.2	0.4	0.6	0.8
0.2	.05	.09	.10	.10
0.4	.04	.06	.09	.09
0.6	.04	.06	.08	.09
0.8	.03	.07	.09	.09

without fit

y \ x	0.2	0.4	0.6	0.8
0.2	.06	.12	.13	.13
0.4	.05	.09	.13	.11
0.6	.05	.08	.11	.13
0.8	.04	.08	.10	.11

2. Δy

with fit

y \ x	0.2	0.4	0.6	0.8
0.2	.02	.02	.02	.02
0.4	.03	.02	.02	.02
0.6	.03	.03	.02	.02
0.8	.02	.02	.02	.02

without fit

y \ x	0.2	0.4	0.6	0.8
0.2	.02	.02	.02	.02
0.4	.04	.04	.04	.04
0.6	.06	.05	.05	.05
0.8	.07	.07	.06	.06

5. Conclusions

The considerable investment in a new electronic neutrino experiment using a fine-grained calorimeter requires to be backed up by sufficient event numbers. Although other experiments have already run in the narrow band beam at 200 GeV/c for $4 \cdot 10^{13}$ protons this experiment has not. We request allocation of $3 \cdot 10^{18}$ protons for further 200 GeV/c narrow band beam running to complete the approved WA18 program before the shutdown. The final data sample offers some unique and novel possibilities to study the structure and the strength of the neutral current and of possible non-locality effects up to mass ranges of 30 GeV.

A corresponding run at 320 GeV/c parent momentum would not give more anti-neutrino data, would be a factor seven less effective per proton for increasing our neutrino sample, and would suffer from worsened resolution.