A POSSIBLE SPARK-CHAMBER EXPERIMENT WITH ANTINEUTRINOS

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(presented by G. von Dardel).

We have studied three problems which could, in principle, be investigated by a spark chamber set-up within the next two years; problems which presently cannot be tackled by a bubble chamber.

1) The measurement of the transverse component of the muon polarization (time-reversal invariance violation).

2) The high q^2 production of Λ^0 in processes where only a Λ^0 and a μ^+ are observed. For the elastic case this would be the reaction:

$$\bar{\nu} + p \rightarrow \Lambda^0 + \mu^+ \ .$$

3) The production of positrons in processes where only one electron shower is observed (μ-e universality). For the elastic case this would be the reaction

$$\bar{\nu} + p \rightarrow n + e^+ \ .$$

I. MEASUREMENT OF THE TRANSVERSE POLARIZATION OF THE μ^+

An asymmetry of the decay electron distribution, with respect to the production plane of the μ^+, produced in the reaction

$$\bar{\nu} + N \rightarrow \mu^+ + \text{anything},$$

would indicate time-reversal invariance violation in strangeness conserving weak interactions.

Berman and Veltman$^{1)}$ have calculated the corresponding transverse μ polarization by using the suggestion of Cabibbo who speculates that the time-reversal violation is due to a 90° phase between first and second-class currents.

We have taken the polarization values for B = 6 (the so-called weak electricity), from their paper, which were calculated for the elastic neutrino reaction. The polarization values have been scaled up with the ratio $\sigma(\nu)/\sigma(\bar{\nu})$ in order to obtain them for the antineutrino reaction, and a r.m.s. value, $\sqrt{\langle P^2 \rangle}$, for P was obtained by using the calculated $\bar{\nu}$ spectrum$^{2)}$ and angular distribution of the μ^+ $^{3)}$.

Assuming a homogeneous experimental set-up of $3 \times 3 \times 6$ m^3 with a density $\rho = 1$, we obtain

$$\sqrt{\langle P^2 \rangle} = 34.3\% \ .$$

The expected asymmetry is given by:

$$A = \frac{N^+ - N^-}{N} \sqrt{\langle a^2 \rangle \ \langle P^2 \rangle} \ \langle \cos \Theta \rangle ,$$

where a is the electron asymmetry parameter in μ decay and Θ is the angle between the electron momentum and the polarization vector normal to the production plane of the muon. The asymmetry A has been calculated for a lower energy cut in the electron spectrum of 30 MeV, and for vertical spark chambers.

Aiming at a 30% error on A, applying a number of geometrical corrections and considering our "stay-in" probability of 27.5%, one calculates the total number of necessary events:

$$\underline{N_{tot} \approx 14{,}000 .}$$

Not included in the evaluation of this estimate are the following corrections which eventually will have to be obtained from a calibration measurement.

a) μ scatters at end of range mistaken for an electron;

b) loss of electrons due to radiation losses and straggling (critical energy in Al = 54 MeV);

c) loss of electrons in the case of unfavourable multiple scattering;

d) loss or difficult interpretation of events due to a possibly diminished detection efficiency for electrons traversing the same gaps as the incoming μ parent;

e) admixture of background electrons when a stopping π^+ is mistaken for a stopping muon in the case of inelastic events (the decay μ cannot be observed);

f) a loss of electrons due to the difficulty of working with an extremely long sensitive time. Four μsec could, perhaps, be obtained (two μsec for the μ lifetime and two μsec for the PS pulse). However, even shorter delay times might have to be used.

For all these corrections, we have, somewhat, arbitrarily allowed a factor two in the total number of necessary events. We finally obtain:

$$\underline{N_{tot} \approx 28{,}000 .}$$

With an estimated event rate of 2 ev/hr ton, one obtains in a 25 days' run with a running efficiency of 75% and with an experimental set-up of 50 ton

$$\underline{N_{exp} \approx 44{,}000 \text{ events.}}$$

It must, however, be pointed out here that the total number of necessary events is proportional to the square of the assumed polarization value. A factor three less in polarization would require a factor ten more in the number of events and, therefore, would make the experiment for this particular geometry highly questionable, if not impossible.

The set-up one decides to use will depend on what experiment one wants to do.

A. One concentrates only on the measurement of a possible transverse component of the muon polarization. It will be somewhat more favourable to put the spark-chamber plates horizontal, parallel to the neutrino beam. One could, furthermore, divide the set-up into a cheap production and a costlier high resolution decay region (Fig. 1). Some energy resolution in the production region will, however, still be necessary (max. 10 cm Fe plates between spark chambers).

Going from vertical to horizontal spark-chamber plates might let us gain a factor two in the number of necessary events. An additional factor of three could equally be obtained due to the far superior stay-in probability for this set-up, as compared to a homogeneous set-up for which the stay-in probability has been calculated. The experiment would, therefore, just be possible in the case of a two to three times smaller polarization value.

In principle, the set-up can be triggered every burst of the PS. To reduce the number of photographs, one could trigger the set-up by counters placed at the end of the production region and because only stopping muons are required; one could think of some anti-coincidence arrangement to avoid triggering whenever the track leaves the set-up. It must, however, still be verified how the possible occurrence of multiple discharges, which are usually observed along a small angle incident track, would effect the measurement of back-going electrons.

B. The electron asymmetry could perhaps be measured more elegantly with a digitized spark chamber as designed by Krienen$^{4)}$. The principle is shown in Fig. 2. As immediate advantages, one could quote:

1) less geometry loss due to crossed-plate arrangement, i.e. no preferred geometry;
2) greater density, $\rho = 1.5$;
3) no multiple discharge possible;
4) no photography.

However, the number of cores involved, $\sim 10^5$, makes the mounting of the experimental set-up expensive and time consuming.

C. A set-up, in which also strange particles and electrons are to be measured, must have vertical spark-chamber plates perpendicular to the neutrino beam. A possible set-up has been sketched in Fig. 3. A small low resolution production region has been added in front in order to utilize better the first part of the thin plate set-up. The magnet at the end could consist simply of two magnetized iron plates as in the old neutrino experiment. It serves to get the μ^+/μ^- ratio from the essentially kaon-born high-energy neutrinos. (The knowledge of this ratio will be useful to estimate the e^- background in the e^+ measurement.)

The set-up should be triggered at every burst of the machine; we can therefore expect in 25 days of running

$$\sim 2 \cdot 10^6 \text{ photos}$$

with a photo/event ratio of ~ 50. However, we could move the film every two to three bursts without much danger to superimpose events. The scanning and measuring will have to be done with some automatic device.

II. Λ^0 PRODUCTION

We select events having only a muon and a V particle.

All possible checks, as coplanarity and transverse momentum balance, will be made whenever possible in order to eliminate background and some of the inelastically produced events.

We assume a Λ^0 of energy > 200 MeV to be measurable. One can then estimate under the assumption of a branching ratio for the elastic reaction:

$$\frac{\bar{\nu} + P \to \Lambda^0 + \mu^+}{\bar{\nu} + P \to n + \mu^+} = 0.03 ,$$

and with the restriction that the decay must take place at least 4 cm from the vertex, one should observe $\gtrsim$ 100 measurable Λ^0 events if one uses the above-mentioned production figures.

Three background sources have been investigated:

a) associate production of Λ^0 K_2^0 with K_2^0 leaving the experimental set-up before decaying;
b) inelastic production of K_1^0 simulating a Λ^0;
c) neutron stars in the reaction $N + n \to n + P + \pi^-$.

These background sources have been estimated to contribute a maximum of 10- 20% to the expected elastically produced Λ^0 rate.

Other background contributions, quite generally inelastic production with pion absorption inside the nucleus, Σ^0 and Σ^- production with internal charge exchange, are important, but somewhat less than in the old neutrino experiment$^{5)}$ for $\Delta S = 0$, as we are dealing here with the higher momentum transfer part of the Λ^0 production. The difficulty of estimating the importance of this background is inherent to all experiments performed with complex nuclei; the Λ^0 measurement should, therefore, be considered essentially as a "pilot" experiment for exploring the Λ^0 production at large q^2.

III. e^+ PRODUCTION BY $\bar{\nu}_e$

Single electron showers with no other visible particles will be defined as elastic in precisely the same way as in the old neutrino experiment$^{5)}$. We expect ~ 120 e^+ events in using the above-mentioned total production rate, and about 40 confusable e^- events from the neutrino background. This background could be estimated from the μ^+/μ^- ratio as a function of q^2. Electron and positron events can be treated together at least for high ν energies.

Together with some 40 elastic e^- events observed in the CERN neutrino experiment so far, we could make a better check of the electron-muon universality.

REFERENCES

1) S.M. Berman and M. Veltman, Physics Letters **12**, 275 (1964).
2) S. van der Meer, CERN 63- 37.
3) Y. Yamaguchi, CERN 61 - 2.
4) F. Krienen, CERN 64 - 44.
5) CERN Neutrino spark chamber group, Physics Letters **13**, 80 (1964).

FIGURE CAPTIONS

Figure 1 :	Sketch of one unit of a possible experimental set-up for the measurement of the transverse muon polarization.
Figure 2 :	Principle of a digitized spark chamber of high density.
Figure 3 :	Sketch of a possible experimental set-up with which all the problems discussed in this paper could be investigated.

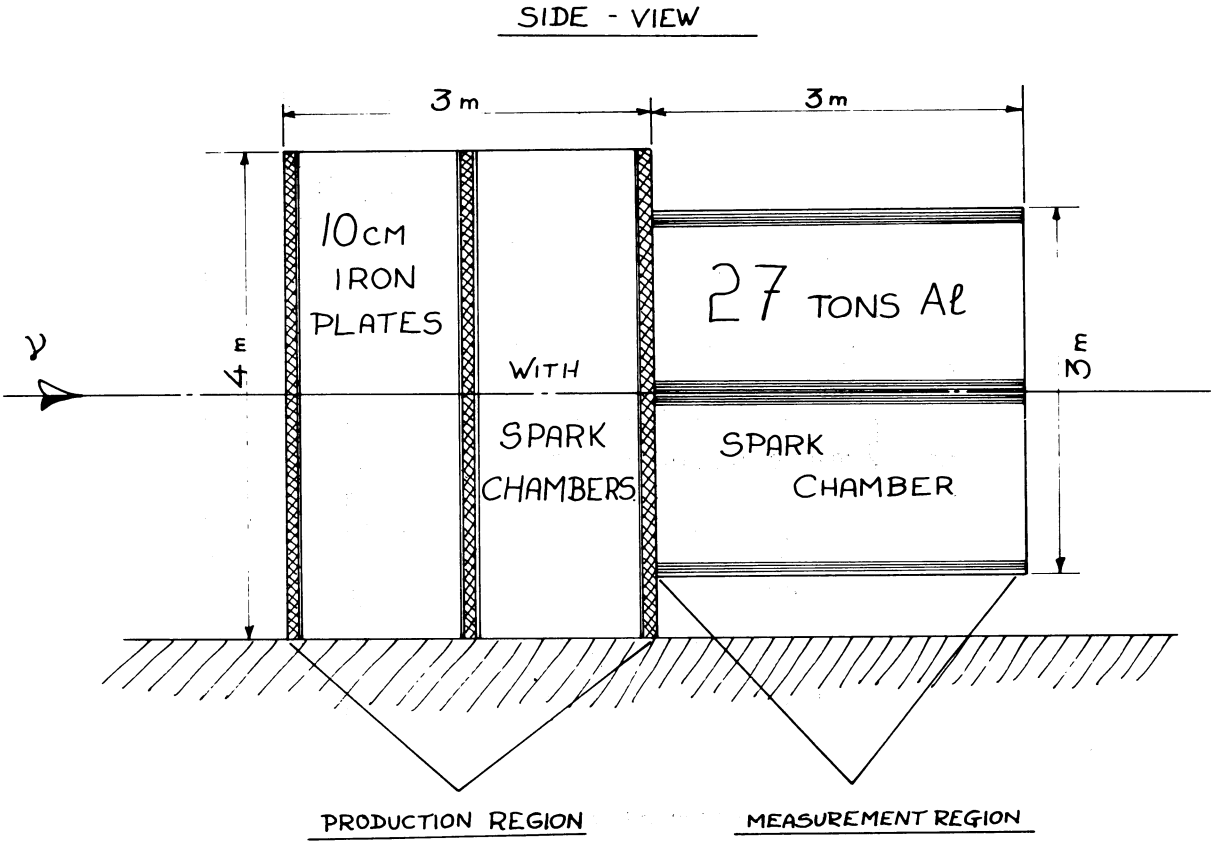
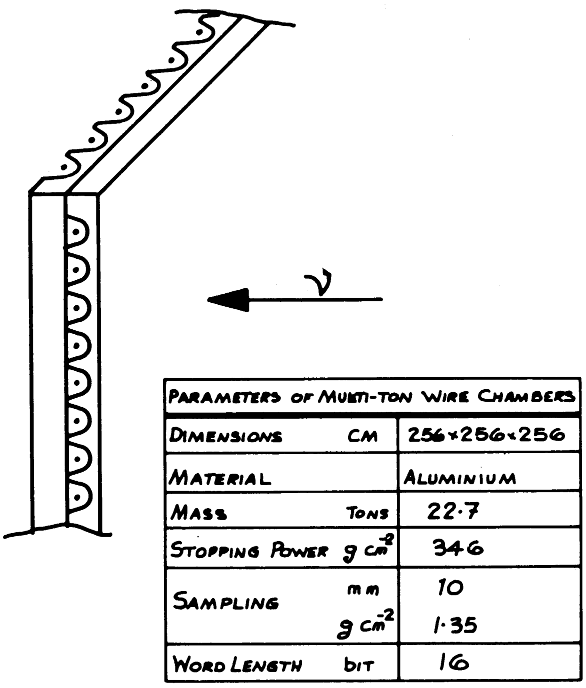


Fig. 1



PARAMETERS OF MULTI-TON WIRE CHAMBERS		
DIMENSIONS	CM	256×256×256
MATERIAL		ALUMINIUM
MASS	TONS	22·7
STOPPING POWER	$g\ cm^{-2}$	346
SAMPLING	mm	10
	$g\ cm^{-2}$	1·35
WORD LENGTH	bit	16

Fig. 2

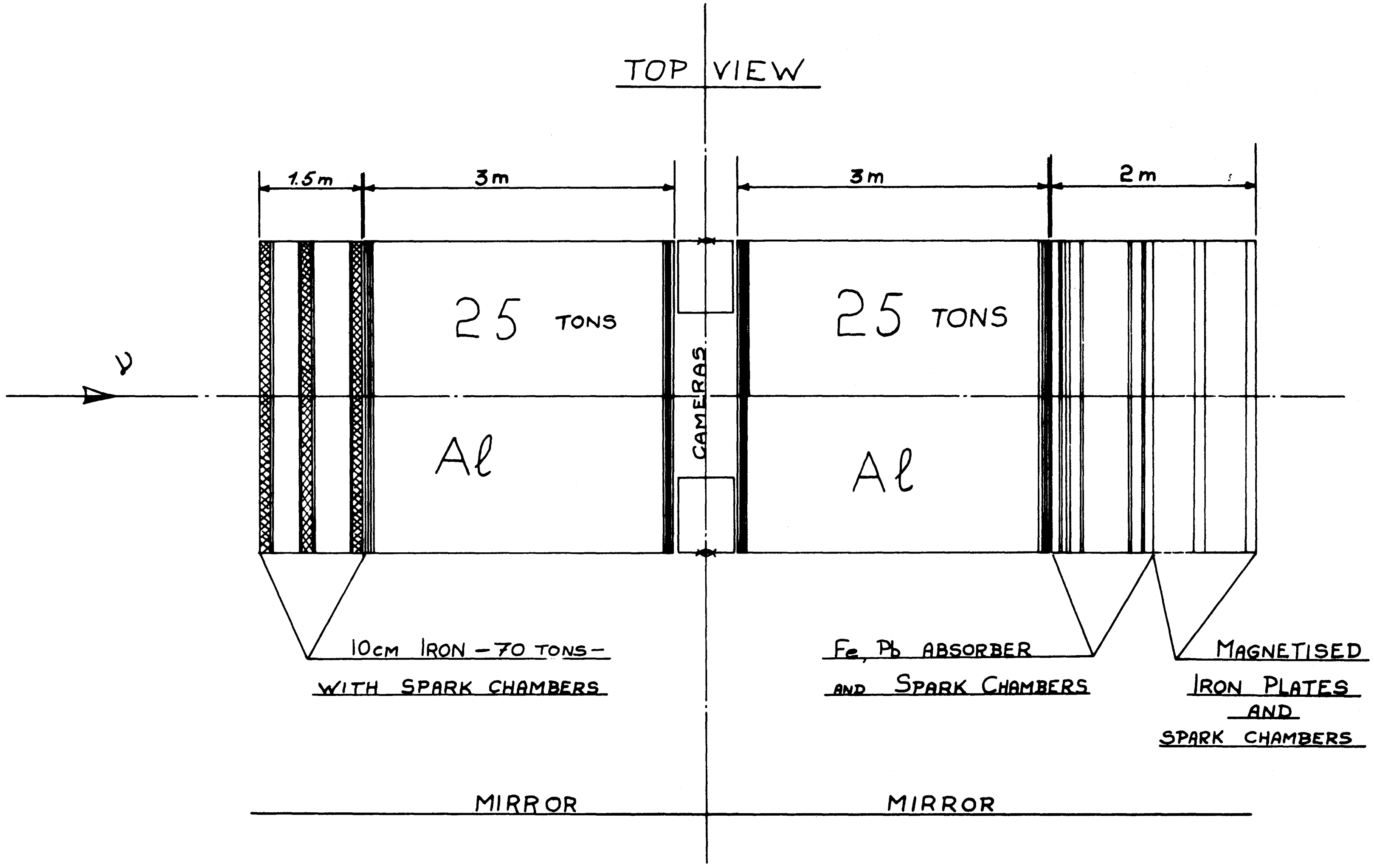

TOP VIEW
ν
1.5m
3m
3m
2m
25 TONS
Al
CAMERAS
25 TONS
Al
10cm IRON – 70 TONS –
WITH SPARK CHAMBERS
Fe, Pb ABSORBER
AND SPARK CHAMBERS
MAGNETISED
IRON PLATES
AND
SPARK CHAMBERS
MIRROR
MIRROR

Fig. 3