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M E M O R A N D U M

To: J. Lefrançois (SPSC Chairman)

From: CERN-Dortmund-Heidelberg-Saclay-Warsaw (WA1) Collaboration

Subject: Precision measurement of $\sin^2\theta_W$ in semileptonic νFe interactions

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1. Introduction

The upgrading programme for the WA1 detector as approved by the SPSC in 1979 and implemented by early 1982 improved the detector in three ways: The smaller plate thickness of 2.5 cm Fe instead of 5 cm improves the hadron energy resolution, the new scintillator structure gives better spatial information on the hadron shower, and the shorter distance between two drift chambers (50 cm Fe instead of 75 cm) allows the identification of shorter muon tracks than before.

One of the motivations for this upgrading of the detector pointed out in the proposal was the possible improvement in measurements of the neutral current to charged current cross-section ratio for neutrinos, R_ν, which still provides the most precise method for measuring the weak-electromagnetic mixing angle $\sin^2\theta_W$.

We feel that a precise measurement can be done with this upgraded detector and ask the SPSC to include this experiment in their deliberations for 1984.

2. Physics case

The weak mixing angle θ_W is an important parameter of electroweak gauge theories. A precise measurement of this constant is not only important in its own right, but bears upon predictions of grand unified models, and may allow, for the first time, an experimental check on second order electroweak radiative corrections, by comparing the actually measured mass of the Z^o to its value predicted in the lowest order approximation*).

The CERN-Dortmund-Heidelberg-Saclay (CDHS)Collaboration has in the past made important contributions to the measurement of $\sin^2\theta_W$: In 1977, the value $\sin^2\theta_W = 0.24 \pm 0.02$ was published, which was quite different from the then commonly accepted value $\sin^2\theta_W \sim 0.35$. Recently, a second measurement has been completed, giving the presently most precise value on $R_\nu = (\frac{NC}{CC})_\nu = 0.300 \pm 0.005 \pm 0.005$, which in turn will yield the most precise value of $\sin^2\theta_W$, with an experimental error of ± 0.012. The publication is in preparation.

We feel that the error on $\sin^2\theta_W$ could be reduced further by carrying out a dedicated neutral current experiment, optimising the running conditions of the beam and the detector. A first analysis of the error sources has convinced us that an improvement by more than a factor of 2 is possible in the error of $\sin^2\theta_W$, as measured in semileptonic reactions of neutrinos with Fe nuclei. A precision determination of $\sin^2\theta_W$ within ± 0.005 seems within reach, with practically no investment in new equipment.

In a contribution to the SPS Fixed Target Workshop held in December 1982, C. Llewellyn-Smith pointed out that for the extraction of $\sin^2\theta_W$ from semileptonic neutrino interactions the errors due to strong interactions are small for an isoscalar target. Theoretical uncertainties are not an obstacle to measuring $\sin^2\theta_W$ to ± 0.005 in such an experiment.

3. Method

The best systematic accuracy for measuring the ratio of neutral to charged-current events in deep inelastic νFe reactions can be obtained in a narrow-band beam exposure.

In order to maximize the flux of neutrinos, a parent momentum of $\sim$160 GeV/c with 450 GeV/c proton targeting appears optimal, in conjunction with minor modifications of the neutrino beam line**). On the basis of the

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*) This argument is, to our knowledge, due to Marciano and Sirlin, and Llewellyn-Smith.

**)We thank A. Grant for a preliminary design of this narrow-band beam.

observed event numbers in the 1978 neutrino 200 GeV/c NBB exposure, about 5×10^{18} protons on target would be required (i.e. an exposure of 100 days with 1×10^{13} protons on target per burst), in order to achieve a sufficiently small statistical error. The beam would have to be extracted in a fast-slow resonance mode ($\sim$0.5 ms FWHM).

Special care must be taken to measure correctly the background due to charm production in the target and the proton beam dump, and due to the decay of π, K before selection in sign and momentum. The optimum fraction of time for background measurement (~15%) must be spent, with a specially installed hadron absorber located before the decay tunnel, and proper parent flux normalization.

A detailed document on the proposed experiment is in preparation and will be submitted to the SPSC before the September meeting.

4. Beam requirements

The quoted number of protons corresponds to roughly what might be available in one calendar year. We propose to carry out this experiment in 1984, after the completion of the forthcoming WBB run.