# RADIATIVE CORRECTIONS IN NEUTRINO-DEUTERIUM SCATTERING

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The Sudbury Neutrino Observatory (SNO) [1] will utilize the interaction of $^8$B solar neutrinos with deuterium in heavy water to measure the total neutral-current (NC) cross-section in the reaction

$$\nu_x + d \rightarrow p + n + \nu_x. \tag{1}$$

Also to be measured is the charged-current (CC) cross-section in the reaction

$$\nu_e + d \rightarrow p + p + e^-. \tag{2}$$

Since the NC reaction is independent of neutrino flavour, the ratio of the number of charged-current to neutral-current events, $N_{CC}/N_{NC}$, will be a powerful indicator of the presence of neutrino oscillations. A measurement of this ratio is a primary goal for the SNO experiment. A secondary experiment that could provide an independent check is to measure the shape of the recoil spectrum in the CC reaction. A distortion in the electron spectrum from that expected in standard weak-interaction theory could also suggest neutrino oscillations. The likely measured signals are the first moment, $\langle T_e \rangle$, and possibly the second moment, $\langle T_e^2 \rangle$, of the recoil electron's kinetic energy, where the averages are taken over the electron spectrum for a detection threshold set at $T_{\rm min} = 5$ MeV.

Bahcall, Krastev and Lisi [2, 3] have given values for the SNO observables, $\langle T_e \rangle$, $\langle T_e^2 \rangle$ and $N_{CC}/N_{NC}$ for the standard solar model with no neutrino oscillations, and for a number of cases representing various neutrino-oscillation scenarios. The shift in SNO observables with each scenario is a measure of the discriminatory ability of the SNO detector to uncover new physics.

In the analysis so far the role that radiative corrections might have on the cross-sections of Eqs. (1) and (2) has not been considered. However, one might expect it to be reasonably small. In weak-interaction studies, the correction to the total decay rate is typically at the few percent level. Indeed, in considering the energy dependence of the electron spectrum and the SNO observables, we find radiative corrections have a negligible impact on the shape test and an almost negligible 0.5% effect on the ratio $N_{CC}/N_{NC}$. This analysis, however, assumes the internal bremsstrahlung photon emitted in the charge-current reaction, Eq. (2), has not been detected. In principle, the SNO detector can measure these bremsstrahlung photons. If we make a very schematic assumption that the efficiency of photon detection equals the efficiency of electron detection, then the analysis simplifies significantly and we find that the impact of radiative corrections on the $N_{CC}/N_{NC}$ observable is increased to a 3.7% effect. If, for example, the error that has been assigned to the $N_{CC}/N_{NC}$ observable from such causes as counting statistics, uncertainties in the neutrino spectrum, and the energy resolution and absolute energy calibration of the SNO detector represents one standard deviation, then the change in this observable caused by the inclusion of radiative corrections is found to be about

one standard deviation. This is not sufficient to spoil the discriminatory test that could, for example, distinguish between neutrino oscillations and no neutrino oscillations in the $N_{CC}/N_{NC}$ observable. However, it is sufficient that if an analysis were to be inverted, namely, the SNO observable is used to determine the parameters of a neutrino-oscillation scenario then the value of the parameters will depend on whether radiative corrections have been considered or not. So photon detection with the SNO detector may become an interesting issue.

## References


[1] SNO Collaboration, G.T. Ewan *et al.*, "Sudbury Neutrino Observatory Proposal," Report No. SNO-87-12, 1987 (unpublished)

[2] J.N. Bahcall and E. Lisi, Phys. Rev. D **54**, 5417 (1996)

[3] J.N. Bahcall, P.I. Krastev and E. Lisi, Phys. Rev. C **55**, 494 (1997)