# FINAL PROJECT SUMMARY FOR DoE/HEP DE-FG02-95ER40911

## Data Analysis of the LSND for $\pi^o \to \nu\bar{\nu}$ Search

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The Department of Physics at Southern University participated in the Liquid Scintillator Neutrino Detector experiment (LSND). The grant was provided by the Department of Energy, Office of High energy Physics (DoE/HEP) under the contract number DE-FG02-95ER40911.

This report contains the salient features of the activities and achievements obtained through this grant. The total amount of grant for the nine (9) year duration was $251,000.

We analyzed both Decay-in-Flight (DIF) neutrino oscillations and $\pi^0 \to \nu_\mu\bar{\nu}_\mu$ decay. In the DIF analysis, we came up with the idea of looking at the charged-current reaction exciting the ground state of $^{12}N$ with a life-time of 15.9 ms. We wrote the section on this search in the LSND "famous" paper, "Results on $\nu_\mu \to \nu_e$ Oscillations from Pion Decay in Flight Neutrinos", C. Athanassopoulos, et al.; Phys. Rev. C. 58, 2489, (1998). This analysis was the topic of a 1998 MS thesis for the first graduate, Anthony K. Cochran, of the MS program established in 1996. Tony spend eight months at Los Alamos working on LSND. He was supported by LANL through their Office of Diversity program. Tony is now at Clark-Atlanta University working on his Ph.D.

We also took the lead in analyzing the LSND data for a search for the conventionally forbidden decay of neutral pion to two neutrinos. We wrote a paper on this analysis and this paper was published in Physical Review Letters in March of 2004. "Search for Decay in LSND " L.B. Auerbach, R.L. Burman, D.O. Caldwell, E.D. Church, A.K. Cochran, J.B. Donahue, A.R. Fazely, G.T. Garvey, R.M. Gunasingha, R.L. Imlay, G. Kahrimanis, W.C. Louis, R. Majkic, A. Malik, K.L. McIlhany, W.J. Metcalf, G.B. Mills, D. Rupnik, V.D.

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Sandberg, D. Smith, R.F. Somodi, I. Stancu, W.D. Strossman, M. Sung, R. Tayloe, G.J. VanDalen, W. Vernon, N. Wadia, D.H. White, S. Yellin, H. Yi (LSND Collaboration) Phys. Rev. Lett. Volume 92, Number 9 (2004) 1774-1777hep-ex/0310060. I must emphasize that the entire idea and work for this paper were from Southern University and this PRL constitutes one only four PRL from the entire LSND collaboration.

We now briefly discuss the importance of this paper. The observation of the decay $\pi^o \rightarrow \nu\bar{\nu}$ would imply new interesting physics. The pion has zero spin and odd intrinsic parity, that is $J^P = 0^-$; it is represented by a wave function which has the space transformation properties under inversion and rotation of a pseudo-scalar. The pion decay with a hadronic state of $J^P = 0^-$ to vacuum, $J^P = 0^+$ can only be achieved by axial vector (A) or pseudo-scalar (P) operators. Momentum and angular momentum conservation require that the decay $\nu$ and $\bar{\nu}$ possess the same helicity. If Majorana neutrinos exist, then neutrinos are identical to anti-neutrinos, or if the neutrino is massive, then the neutrino will not always respect the observed rule. A- and P-interaction favor leptons with opposite and same helicity, respectively. Therefore, in A-interaction the un-favored helicity $-\beta$ is proportional to $(1 - \beta)$ and in the P-interaction the decay rate is proportional to $(1 + \beta)$. This implies that A-interaction forbids $\pi^o \rightarrow \nu\bar{\nu}$ decay for massless neutrinos and that P coupling maximizes decay rate for neutrino with zero mass. If the neutrino mass is not zero and the $Z^0$ couples to the right-handed neutrino with standard weak-interaction strength, the branching ratio $B(\pi^o \rightarrow \nu\bar{\nu})$ has a maximum value of $3 \times 10^{-9}$ at $m_\nu = 55 MeV/c^2$; the upper limit $m_{\nu_\tau} \leq 18.2 MeV/c^2$ implies that $B(\pi^o \rightarrow \nu\bar{\nu}) < 5.2 \times 10^{-10}$ [1]. It is noteworthy that a BR of $\approx 10^{-14}$ for the $\pi^o \rightarrow \nu\nu\gamma$ within the Standard Model is allowed.

This analysis was the topic for two MS theses here at Southern, Rodica Somodi and Hai Yi.

We believe that our contribution to LSND was substantial and we were very successful to fulfill our obligations with respect to our commitments to this contract.

# References

[1] H. ALbrecht *et. al.*, Phys.Lett. B 202, 149 (1988).