ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА
2011. Т. 42. ВЫП. 4

IS THERE ANY «LSND ANOMALY»?

A. Bolshakova
(for the HARP–CDP Group)*

*The members of the HARP–CDP group are: A. Bolshakova, I. Boyko, G. Chelkov, D. Dedovich, A. Elagin, D. Emelyanov, M. Gostkin, A. Guskov, Z. Kroumchtein, Yu. Nefedov, K. Nikolaev, and A. Zhemchugov from the Joint Institute for Nuclear Research, Dubna, Russian Federation; F. Dydak and J. Wotschack from CERN, Geneva, Switzerland; A. De Min from the Politecnico di Milano and INFN, Sezione di Milano–Bicocca, Milan, Italy; V. Ammosov, V. Gapienko, V. Koreshev, A. Semak, Yu. Sviridov, E. Usenko, and V. Zaets from the Institute of High Energy Physics, Protvino, Russian Federation.

ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА
2011. Т. 42. ВЫП. 4

IS THERE ANY «LSND ANOMALY»?

A. Bolshakova
(for the HARP–CDP Group)*

The LSND Collaboration reported a 3.8σ excess of $\bar{\nu}_e$ over background. In this experiment, 800 MeV protons were dumped into a water target. LSND experimentalists interpreted this excess as evidence for $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillations, which led to the hypothesis of the existence of «sterile» neutrinos. LSND's claim was not confirmed by the MiniBooNE Collaboration, so the origins of the LSND result were never clarified. The data from the HARP–CDP group on pion production by 800 MeV protons are used in an independent calculation of LSND's $\bar{\nu}_e$ background. The pion production by neutrons which had been ignored in LSND's calculations is also taken into account. We conclude that LSND's claim of a 3.8σ excess cannot be upheld.

PACS: 14.60.Pq; 95.55.Vj

INTRODUCTION

The LSND experiment reported an anomalous 3.8σ excess of $\bar{\nu}_e$, interpreted as $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation with $\Delta m^2 \approx 1$ eV^2 [1]. This result has not been confirmed by other experiments until today. The MiniBooNE experiment was designed to check the «LSND anomaly». They performed a search for $\nu_\mu \rightarrow \nu_e$ oscillations, but no signal was found [2]. The recent results from a search for $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillations are consistent with an event excess, however low statistics make it difficult to interpret these results as a confirmation of the LSND result [3]. Therefore, the «LSND anomaly» remains an unsolved puzzle in neutrino physics. It is considered of such an interest that a new experiment [4] has been proposed recently at CERN to test the LSND observation.

THE HARP–CDP RE-EVALUATION OF THE LSND BACKGROUND

In the HARP experiment, pion productions with a 1.5 GeV/c proton beam impinging on various target materials, including water and copper, were measured

*The members of the HARP–CDP group are: A. Bolshakova, I. Boyko, G. Chelkov, D. Dedovich, A. Elagin, D. Emelyanov, M. Gostkin, A. Guskov, Z. Kroumchtein, Yu. Nefedov, K. Nikolaev, and A. Zhemchugov from the Joint Institute for Nuclear Research, Dubna, Russian Federation; F. Dydak and J. Wotschack from CERN, Geneva, Switzerland; A. De Min from the Politecnico di Milano and INFN, Sezione di Milano–Bicocca, Milan, Italy; V. Ammosov, V. Gapienko, V. Koreshev, A. Semak, Yu. Sviridov, E. Usenko, and V. Zaets from the Institute of High Energy Physics, Protvino, Russian Federation.

(see Fig. 1). These measurements were used to cross-check the calculation of LSND's $\bar{\nu}_e$ background. Only the data from the HARP large-angle spectrometer, analyzed by the HARP–CDP group, were used [5, 6].

Two independent simulation programmes have been developed, and give consistent results. Hadron production has been simulated by Geant4 [7] and FLUKA [8] codes, and then adjusted to the HARP–CDP data. Pion production by neutrons has been tuned according to the results of other experiments [9, 10]. To demonstrate our understanding of the LSND geometry, the LSND procedure of calculation of the neutrino fluxes has been «emulated» in our simulation using

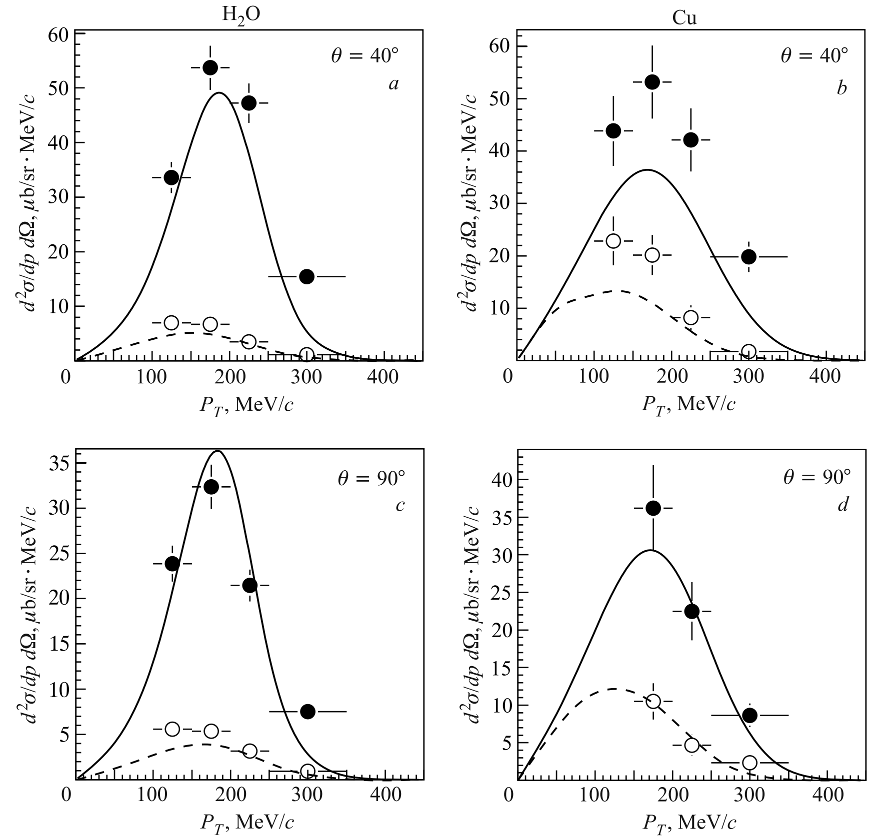

Fig. 1. Inclusive cross sections of pion production by $+1.5$ GeV/c protons on water (a, c) and copper (b, d) as a function of p_{T}, for the polar angle 40° (a, b) and 90° (c, d). The black circles correspond to π^+, and the open circles to π^-, measured by HARP–CDP. Pion production cross sections calculated according to the LSND parameterization are also shown for π^+ (solid line) and π^- (dashed line)

LSND's pion production parameterization [11, 12]. A comparison of results of simulations based on Geant4 and FLUKA, and obtained from LSND «emulation», is shown in Fig. 2.

According to the simulation, a contribution of higher pion generations, which were not taken properly into account by LSND, is found significant, especially in the case of π^- production (see Fig. 3). It is largely explained by pion production by neutrons, which had been ignored in LSND's calculations.

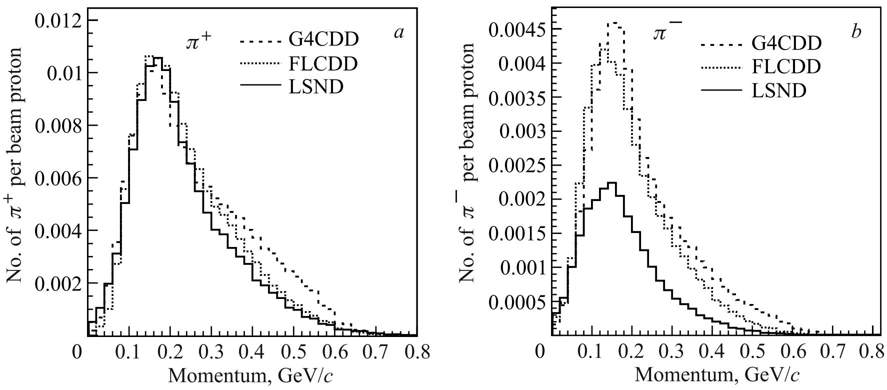

Fig. 2. The numbers of π^+ (*a*) and π^- (*b*) per incoming +1.5 GeV/*c* proton as a function of momentum. The results of simulations based on the Geant4 and FLUKA codes, adjusted to experimental data, are compared with the LSND «emulation»

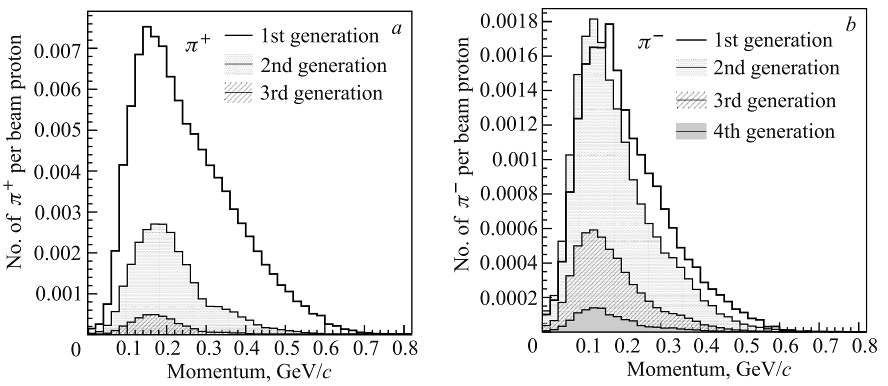

Fig. 3. The numbers of π^+ (*a*) and π^- (*b*) from different generations per incoming $+1.5$ GeV/*c* proton are shown, as predicted by the FLUKA code adjusted to experimental data

Neutrino fluxes from muon decay at rest: the HARP–CDP simulation results compared with the results published by LSND [1]

	LSND (runs 1993–1995)	LSND «emulation»	Geant4 + exp. data	FLUKA + exp. data
π^-/π^+	—	0.20	0.38	0.35
$\bar{\nu}_\mu$, $\mathrm{PoT}^{-1}\cdot\mathrm{cm}^{-2}$	$0.8\cdot10^{-9}$	$0.60\cdot10^{-9}$	$0.78\cdot10^{-9}$	$0.76\cdot10^{-9}$
$\bar{\nu}_e$, $\mathrm{PoT}^{-1}\cdot\mathrm{cm}^{-2}$	$0.65\cdot10^{-12}$	$0.59\cdot10^{-12}$	$0.96\cdot10^{-12}$	$0.88\cdot10^{-12}$

Comparing the LSND «emulation» and our best estimate based on Geant4 and FLUKA, adjusted to the experimental data, one can «measure» the effect of improved pion production simulation on the estimate of the neutrino fluxes. Results of our calculations are shown in the Table. It is demonstrated that the larger part of the background of LSND's $\bar{\nu}_\mathrm{e}$ signal was underestimated by nearly a factor of 1.6. The causes were too small cross section of pion production by protons and the neglect of pion production by neutrons, which, unlike protons, predominantly produce π^- rather than π^+. We conclude that the claim of a 3.8σ significance of the LSND anomaly cannot be upheld.

REFERENCES

1. *Aguilar A. et al.* // Phys. Rev. D. 2001. V. 64. P. 112007.
2. *Aguilar-Arevalo A. et al.* // Phys. Rev. Lett. 2007. V. 98. P. 231801; *Aguilar-Arevalo A. et al.* // Phys. Rev. Lett. 2009. V. 102. P. 101802.
3. *Aguilar-Arevalo A. et al.* // Phys. Rev. Lett. 2010. V. 105. P. 181801.
4. *Baibussinov B. et al.* hep-ex/0909.0355.
5. *Ammosov V. et al.* // Nucl. Instr. Meth. A. 2008. V. 588. P. 294.
6. *Ammosov V. et al.* // Nucl. Instr. Meth. A. 2007. V. 578. P. 119.
7. *Agostinelli S. et al.* // Nucl. Instr. Meth. A. 2003. V. 506. P. 250; *Allison J. et al.* // IEEE Trans. Nucl. Sci. 2006. V. 53. P. 270.
8. *Battistoni G. et al.* // AIP Conf. Proc. 2007. V. 896. P. 31–49; *Fasso A. et al.* CERN-2005-10. 2005. INFN/TC-05/11. SLAC-R-773.
9. *Oganesian K. O.* // JETP. 1968. V. 54. P. 1273.
10. *Baturin V. N. et al.* // JETP Lett. 1979. V. 30. P. 86.
11. *Burman R. L. et al.* // Nucl. Instr. Meth. A. 1990. V. 291. P. 621; *Burman R. L. et al.* LANL Report LA-1502-MS. 1988; *Burman R. L. et al.* FZK Report FZKA-5599. 1995.
12. We thank *M. Sung* for providing the LSND parameterization; the programme code is available at http://hep.phys.lsu.edu/sung/lsnd/beammc/index.html