Production and radiative decay of heavy neutrinos at the Booster Neutrino Beam

Eduardo Saúl Sala, Luis Álvarez Ruso

Universidad de Valencia - IFIC

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Section 1

Introduction

Neutrino paradigm

For massive neutrinos the flavor eigenstates do not coincide with the mass eigenstates

- Mixing → Pontecorvo–Maki–Nakagawa–Sakata matrix

$$|\nu_\alpha\rangle = \sum_i U_{\alpha i} |\nu_i\rangle$$

$$\alpha = e, \mu, \tau \ ; \quad i = 1, 2, 3$$

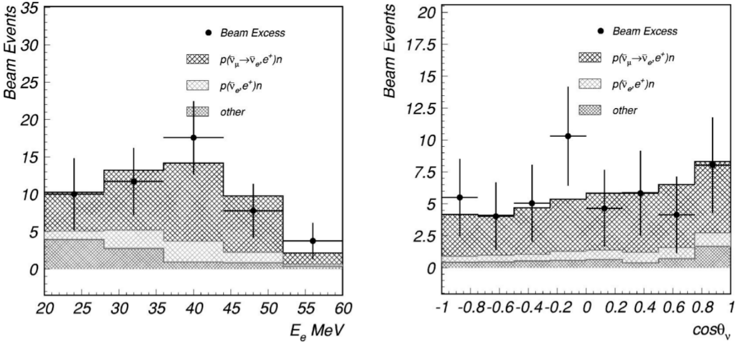
- Oscillations

$$P(\nu_\alpha \to \nu_\beta) = \sum_{k,j} U^*_{\alpha k} U_{\beta k} U_{\alpha j} U^*_{\beta j} \exp\left(-i \frac{\Delta m^2_{kj} L}{2E}\right)$$

- Questions
  - Dirac or Majorana
  - Neutrino absolute masses and Mass hierarchy
  - Sterile neutrinos
  - Values of the parameters: θ_{kj}, Δm^2_{kj} and δ_{CP}
  - **Anomalies**

Anomalies in oscillation experiments

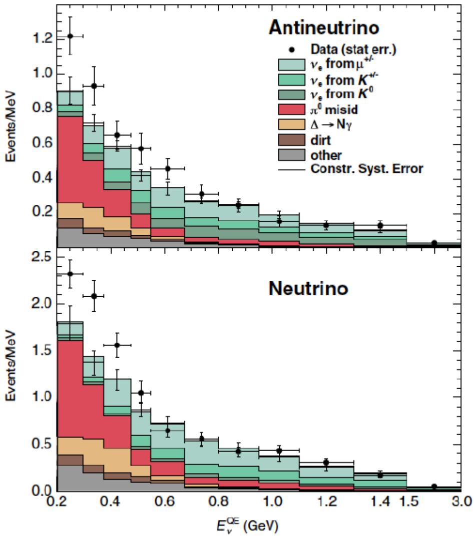
- LSND was a short baseline experiment that searched for $\overline{\nu}_e$ appearance in a $\overline{\nu}_\mu$ flux.
- An excess of $\overline{\nu}_e$ was found.



A. Aguilar et al. PRD 64.112007 (2001)

- (Originally) interpreted as $\overline{\nu}_\mu \to \overline{\nu}_e$ oscillations.

- MiniBooNE was created to make a further analysis of the LSND signal, and found and excess at low energies



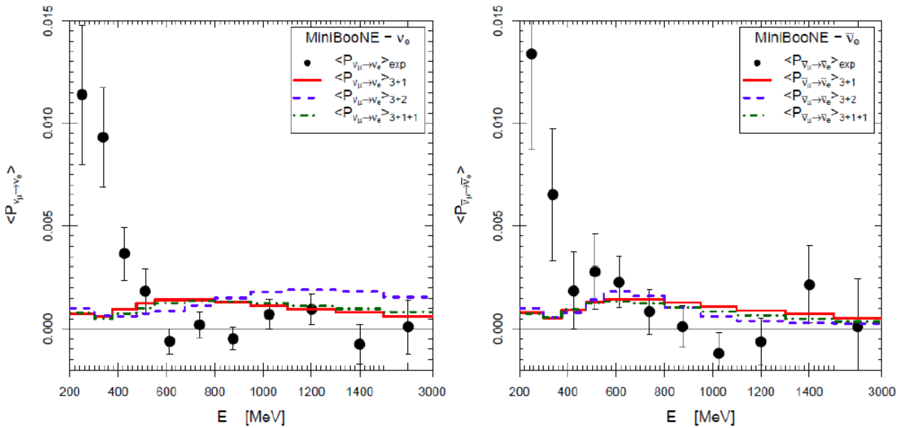
⇒ Reconstructed ν energy

$$E_\nu^{QE} = \frac{2m_n E_e - m_e^2 - m_n^2 + m_p^2}{2\left(m_n - E_e + p_e \cos\theta_e\right)}$$

⇒ e-like backgrounds

- Oscillations: not explained by 1, 2, 3 families of sterile neutrinos.

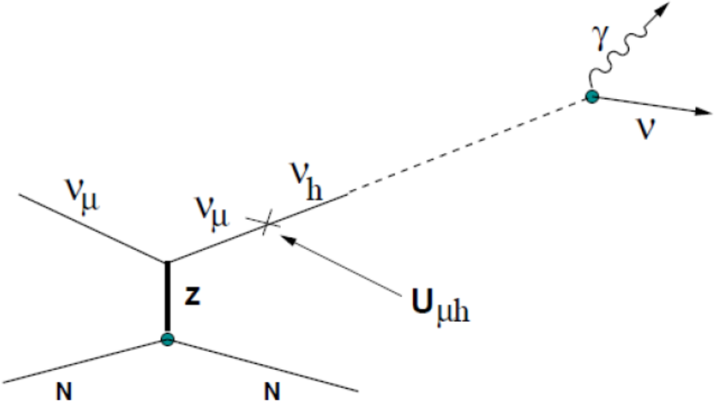
J. Conrad et al., Adv. High Energy Phys. 2013, C. Giunti et al., PRD88 (2013)



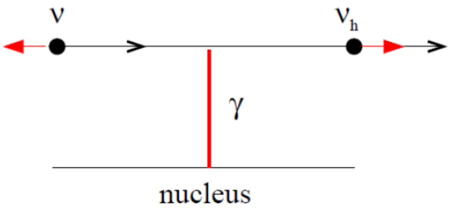
The MiniBooNE low-energy anomaly is incompatible with neutrino oscillations

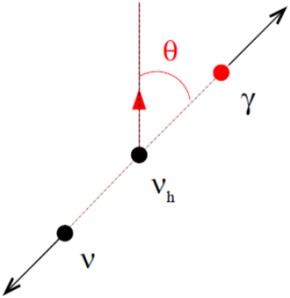
C. Giunti et al., PRD88 (2013)

- Heavy neutrinos Gninenko, PRL 103 (2009)
  - $m_h \approx 50$MeV, $|U_{\mu h}|^2 \approx 10^{-3} - 10^{-2}$, $\tau_h < 10^{-9}$s
  - Simultaneous description of both MiniBooNE and LSND anomalies.

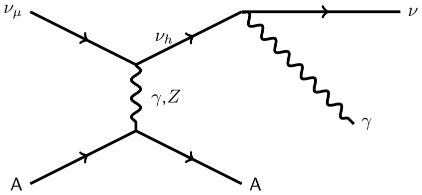


- Heavy neutrinos Gninenko, PRL 103 (2009) , Masip et al., JHEP01(2013)106
  - $m_h = 50\text{MeV}$, $\tau_h = 5 \times 10^{-9}\text{s}$, $BR\left(\nu_h \rightarrow \nu_\mu \gamma\right) = 0.01$
  - Alleviates tensions with other experiments (radiative μ capture at TRIUMF).





- We have analyzed this scenario in order to compare with MiniBooNE measurements. Also we have predicted the signal due to this kind of processes for SBN.



- On nucleons $\nu_\mu(\overline{\nu}_\mu) + \mathrm{N} \to \nu_h(\overline{\nu}_h) + \mathrm{N}$

- On nuclei
$$\nu_\mu(\overline{\nu}_\mu) + \mathrm{A} \to \nu_h(\overline{\nu}_h) + \mathrm{A} \quad \Leftarrow \text{ coherent}$$
$$\nu_\mu(\overline{\nu}_\mu) + \mathrm{A} \to \nu_h(\overline{\nu}_h) + \mathrm{X} \quad \Leftarrow \text{ incoherent}$$

- $\nu_h =$ Dirac ν with $m \approx 50$ MeV, slightly mixed with ν_μ
- A $= {}^{12}$C (MiniBooNE, CH_2), ^{40}Ar (SBN program: SBND, MicroBooNE, Icarus)

Section 2

ν_h production and decay

Electromagnetic production

In general Broggini et al., Adv.High Energy Phys (2012)

$$\mathcal{H}_{eff} = \frac{1}{2}\left\{\overline{\nu}_h \Lambda_\mu^{h\alpha} \nu_\alpha + \overline{\nu}_\alpha \gamma_0 \left[\Lambda_\mu^{h\alpha}\right]^\dagger \gamma_0 \nu_h\right\} A^\mu \qquad \alpha = e, \mu, \tau$$

Imposing Lorentz and gauge inv.

$$\Lambda_\mu^{h\alpha} = \left(\gamma_\mu - q_\mu \frac{\not{q}}{q^2}\right)\left[f_Q^{h\alpha}(q^2) + f_A^{h\alpha}(q^2) q^2 \gamma_5\right] - i\sigma_{\mu\nu} q^\nu \left[f_M^{h\alpha}(q^2) + i f_E^{h\alpha}(q^2)\gamma_5\right]$$

Choice of Masip et al., JHEP 1301 (2013)

$$\Lambda_\mu^{h\alpha} = -i\sigma_{\mu\nu} q^\nu \mu_{tr}^\alpha \left(1 - \gamma_5\right)$$

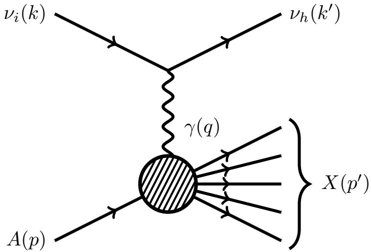
- if $\mu_{tr}^\alpha \in$ R $\Rightarrow$ CP conserved

Electromagnetic production

Effective lagrangian of the interaction, Masip et al., JHEP01(2013)106:

$$\mathcal{L}_{eff} = \frac{1}{2}\mu^i_{tr}\left[\overline{\nu}_h\sigma_{\mu\nu}\left(1-\gamma_5\right)\nu_i + \overline{\nu}_i\sigma_{\mu\nu}\left(1+\gamma_5\right)\nu_h\right]\partial^\mu A^\nu\,,$$

Inclusive process $\nu_i(k) + A(p) \to \nu_h(k') + X(p')$



$$\mathbb{i}\mathcal{M} = \frac{\mathbb{i}\,e\,\mu^i_{tr}}{2\left(q^2+\mathbb{i}\epsilon\right)}\,\overline{u}(k')\,q_\alpha\,\sigma^{\alpha\mu}(1-\gamma_5)u(k)\,\langle X|J_\mu|N\rangle\,.$$

General expression for the inclusive cross section:

$$\frac{d\sigma}{dk'^0\, d\Omega} = \frac{|\vec{k'}|}{|\vec{k}|} \frac{\alpha\, (\mu^i_{tr})^2}{16\, \pi\, q^4} L_{\mu\nu} W^{\mu\nu}$$

- Leptonic tensor

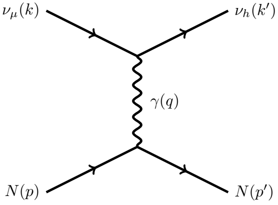
$$L_{\mu\nu} = \frac{1}{4} \,\mathrm{Tr}\left[(\not{k}' + m_h)\sigma_{\mu\alpha}(1-\gamma_5)\,\not{k}\,(1+\gamma_5)\sigma_{\nu\beta}\right] q^\alpha q^\beta$$

- Hadronic tensor

$$W^{\mu\nu} \equiv \frac{1}{2M} \left(\prod_i \int \frac{d^3 p'_i}{(2\pi)^3 2E'_i} \right) (2\pi)^3 \delta^{(4)}(k + p - k' - p') H^{\mu\nu}$$

$$H^{\mu\nu} = \overline{\sum_{\text{polar.}}} \langle X | J^\nu | N \rangle^* \langle X | J^\mu | N \rangle$$

QE scattering on nucleons



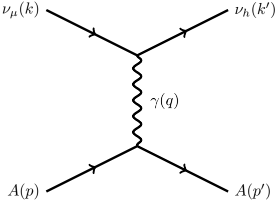
$$\frac{d\sigma}{dt} = \frac{\alpha\,(\mu_{tr}^i)^2}{4\,\left(s - M^2\right)^2\, t^2}\,\frac{1}{1-\frac{t}{4M^2}}\left(G_E^2\,R_E - G_M^2\,R_M\right),$$

G_E, G_M are the Sachs form factors

$$R_E = -\,t\left(2s + t - 2M^2\right)^2 + m_h^2\,t\,(4s+t) - 4m_h^4\,M^2$$

$$R_M = \frac{t}{4M^2}\Big[-4t\left(\left(M^2 - s\right)^2 + s\,t\right) + 2m_h^2\,t\left(2s + t - 2M^2\right) - 2m_h^4\left(t - 2M^2\right)\Big]$$

Coherent scattering on scalar nucleus



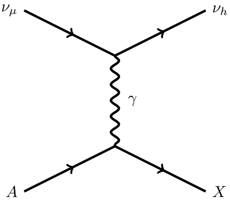
$$\frac{d\sigma}{dt} = \frac{\alpha\,(\mu^i_{tr})^2}{4\,\left(s - M_A^2\right)^2\,t^2}\,F^2\,R_E$$

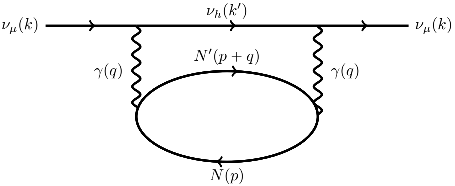
$$R_E = -t\left(2s + t - 2M_A^2\right)^2 + m_h^2\,t\,(4s + t) - 4m_h^4\,M_A^2$$

$$F(q^2) = \int d^3r\,e^{\mathbb{i}\vec{q}\cdot\vec{r}}\rho(\vec{r})$$

Incoherent scattering on scalar nucleus

Case of QE interaction with the nucleons forming the nucleus.





Nieves, Amaro, Valverde, PRC70.055503 (2004)

With the local density approximation.

$$W^{\mu\nu} = \frac{1}{\alpha}\int \frac{d^3r}{4\pi^2}\Theta(q^0)e^2\int\frac{d^3p}{4\pi^2}A^{\mu\nu}\delta\left(p^0+q^0-E\left(\vec{p}+\vec{q}\right)\right)\frac{n(\vec{p})\left(1-n\left(\vec{p}+\vec{q}\right)\right)}{4p^0\left(p^0+q^0+E(\vec{p}+\vec{q})\right)}\Theta(p^0)$$

$$A^{\mu\nu} = \mathrm{Tr}\left\{\left[\gamma^\nu F_1 - \frac{\mathbb{i}}{2M}\sigma^{\nu\alpha}q_\alpha F_2\right]\left(\not{p}+\not{q}+M_N\right)\left[\gamma^\mu F_1+\frac{\mathbb{i}}{2M}\sigma^{\mu\beta}q_\beta F_2\right]\left(\not{p}+M_N\right)\right\}$$

$$F_j = F_j(G_E, G_M)$$

Incoherent scattering on scalar nucleus

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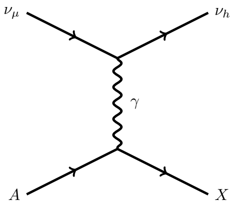

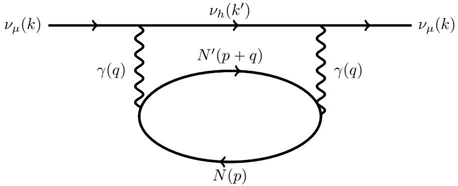

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Occupation number:

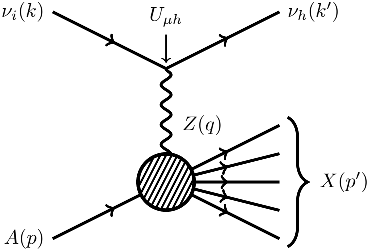
$$n(\vec{p}) = \Theta\left(k_F - |\vec{p}|\right); \qquad k_F^N(r) = \left(3\pi^2\rho^N\left(r\right)\right)^{1/3}$$

Neutral current production

Effective lagrangian of the interaction:

$$\mathcal{L}_I = -\frac{g}{2\cos\theta_W} j^\mu Z_\mu; \qquad j^\alpha = \frac{1}{2}\overline{\nu}_\mu \gamma^\alpha (1-\gamma_5)\nu_\mu,$$

Inclusive process $\nu_i(k) + A(p) \to \nu_h(k') + X(p')$,



$$\nu'_h = \cos\theta\,\nu_h + \sin\theta\,\nu_\mu,$$
$$\nu'_\mu = -\sin\theta\,\nu_h + \cos\theta\,\nu_\mu,$$

with $\sin\theta = U_{\mu h}$

$$\mathrm{i}\mathcal{M} = -\mathrm{i}\,U_{\mu h}\frac{G_F}{\sqrt{2}}\,\overline{u}(k')\gamma^\mu(1-\gamma_5)u(k)\,\langle X|J_\mu|N\rangle\,.$$

General expression for the inclusive cross section:

$$\frac{d\sigma}{dk'^0\, d\Omega} = \frac{|\vec{k'}|}{|\vec{k}|} \frac{\left|U_{\mu h}\right|^2 G_F^2}{32\,\pi^2} L_{\mu\nu} W^{\mu\nu}$$

- Leptonic tensor

$$L_{\mu\nu} = \mathrm{Tr}\left[(\not{k}' + m_h)\gamma_\mu(1-\gamma_5)\,\not{k}\,\gamma^\nu(1-\gamma_5)\right]$$

- Hadronic tensor

$$W^{\mu\nu} \equiv \frac{1}{2M}\left(\prod_i \int \frac{d^3p'_i}{(2\pi)^3 2E'_i}\right)(2\pi)^3\delta^{(4)}(k+p-k'-p')H^{\mu\nu}$$

$$H^{\mu\nu} = \overline{\sum_{\text{polar.}}} \langle X|J^\nu|N\rangle^* \langle X|J^\mu|N\rangle$$

QE scattering on nucleons

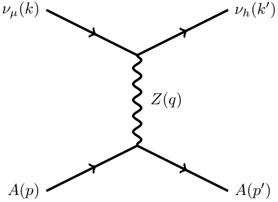
Process $\nu_\mu + N \to \nu_h + N$

$$\frac{d\sigma}{dt} = \frac{\left|U_{\mu h}\right|^2 G_F^2}{16\,\pi\, M^2\, k_0^2}\left[F_1^2\, R_1 + F_2^2\, R_2 + F_1 F_2\, R_{1\,2} + F_A^2\, R_A + F_P^2 R_P \right.$$
$$\left. + F_A F_1\, R_{A\,1} + F_A F_2\, R_{A\,2} + F_A F_P\, R_{A\,P}\right],$$

F_1, F_2, F_A, F_P are the weak nucleon form factors for neutral currents.

$$R_1 = - m_h^2(2s+t) + 2(M^2-s)^2 + 2st + t^2$$
$$R_2 = \frac{1}{8M^2}\left[-4m_h^4 M^2 + t^2(m_h^2 + 8M^2 - 4s) - t(m_h^2 + 2M^2 - 2s)^2\right]$$
$$R_{1\,2} = 2t^2 - m_h^2(m_h^2 + t)$$
$$R_A = m_h^2(4M^2 - 2s - t) + 2M^4 - 4M^2(s+t) + 2s^2 + 2st + t^2$$
$$R_P = \frac{m_h^2\, t\,(t - m_h^2)}{2M^2}$$
$$R_{A\,1} = R_{A\,2} = 2t(2s + t - m_h^2 - 2M^2)$$
$$R_{A\,P} = 2m_h^2(t - m_h^2)$$

Coherent scattering on scalar nucleus



$$\frac{d\sigma}{dt} = \frac{\left|U_{\mu h}\right|^2 G_F^2}{32\,\pi\, M_A^2\, k_0^2} F_W^2 \left(m_h^4 - m_h^2(4s+t) + 4\left[\left(M_A^2 - s\right)^2 + st\right]\right)$$

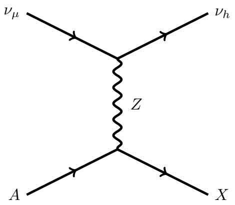
F_W is te weak form factor of the nucleus,

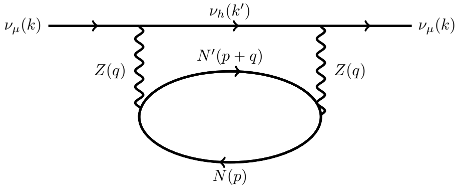
$$F_W(Q^2) = \frac{F_p(Q^2)\left(1 - 4\sin^2\theta_W\right) - F_n(Q^2)}{2}$$

$$F_N(q^2) = \int d^3r\, e^{\mathbb{i}\vec{q}\cdot\vec{r}} \rho_N(\vec{r})$$

Incoherent scattering on scalar nucleus

Case of QE interaction with the nucleons forming the nucleus.





Nieves, Amaro, Valverde, PRC70.055503 (2004)

With the local density approximation.

$$W^{\mu\nu} = \frac{1}{4\pi}\int d^3r\,\theta(q^0)\int \frac{d^3p}{4\pi^2} A^{\mu\nu}\delta\left(p^0 + q^0 - E\left(\vec{p}+\vec{q}\right)\right)\frac{n(p)\left(1 - n\left(\vec{p}+\vec{q}\right)\right)}{p^0\left(p^0 + q^0 + E(\vec{p}+\vec{q})\right)}\theta(p^0)$$

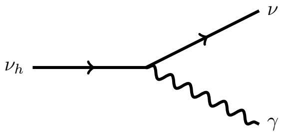
$$A^{\mu\nu} = \mathrm{Tr}\left\{\left[\gamma^\nu F_1 - \frac{i}{2M}\sigma^{\nu\alpha}q_\alpha F_2 + \gamma^\nu\gamma_5 F_A - \frac{q^\nu}{M}\gamma_5 F_P\right]\left(\not{p} + \not{q} + M_N\right)\right.$$
$$\left.\times\left[\gamma^\mu F_1 + \frac{i}{2M}\sigma^{\mu\beta}q_\beta F_2 + \gamma^\mu\gamma_5 F_A + \frac{q^\mu}{M}\gamma_5 F_P\right]\left(\not{p} + M_N\right)\right\}$$

Antineutrino production

- **Electromagnetic production**
  The antisymmetric part of $L_{\mu\nu}$ changes sign but $W_{\mu\nu}$ is symmetric → same results as neutrino electromagnetic interaction.

- **Neutral current production**
  The antisymmetric part of $L_{\mu\nu}$ changes sign:
  - QE scattering with nucleons → change of sign in the antisymmetric terms.
  - Coherent scattering with scalar nucleus → same result as neutrino neutral current scattering.
  - Incoherent scattering with scalar nucleus → change of sign in the antisymmetric terms.

Decay of the heavy sterile neutrino



- $m_h \sim 50$ MeV
- $\tau \sim 5 \times 10^{-9}$ s

$$\frac{d\Gamma}{d\cos\theta_\gamma} = \frac{(\mu^i_{tr})^2\, m_h^3}{32\pi}\,(1 \pm \cos\theta_\gamma)\,; \qquad \left\{ \begin{array}{l} EM+ \\ NC- \end{array} \right.$$

- θ_γ is the angle of the photon respect the ν_h spin direction.
- Electromagnetic production flips quirality $\rightarrow \nu_{hR}$
- Neutral current production keeps quirality $\rightarrow \nu_{hL}$
- At high energies (~ 1 GeV) contributions of other helicity components are negligible.

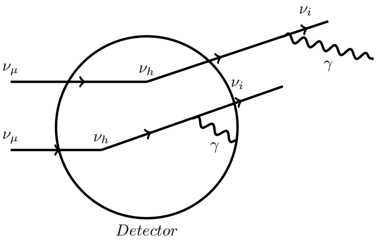
Number of photons inside the detector,

$$N_\gamma = \frac{M_{det}}{V_{det}} N_A N_{POT} \sum_t f_t \int dE_\nu \, \phi(E_\nu) \int dk_0' d\cos\theta_h d\varphi_h \frac{d\sigma}{dk_0' d\cos\theta_h d\varphi_h} \int d^3 r \, P$$

$$P(k_0', r, \theta, \varphi, \theta_h, \varphi_h) = 1 - e^{\frac{-\Delta l}{\lambda}}$$

$$\lambda = \tau_0 \, c \, \frac{k_0'}{m_h} \sqrt{1 - \frac{m_h^2}{(k_0')^2}}; \qquad \tau_0 = \frac{1}{\Gamma}$$

We can calculate the energy and the angular distributions of the photons:



Section 3

Results

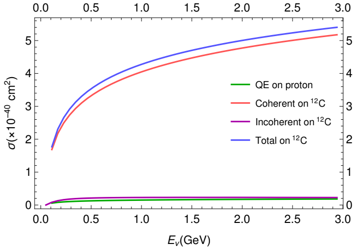
Parameters

Choice of parameters from M. Masip et al, JHEP 1301 (2013):

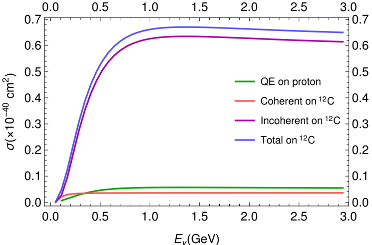
- Mass of the heavy neutrino, $m_h = 50$ MeV
- Mixing angle, $|U_{\mu h}|^2 = 3 \times 10^{-3}$
- Lifetime, $\tau_h = 5 \times 10^{-9}$s
- Branching ratio, $BR_i = \frac{(\mu_{tr}^i)^2}{\sum_i (\mu_{tr}^i)^2} \rightarrow BR_\mu = 10^{-2}$

ν_h production cross sections

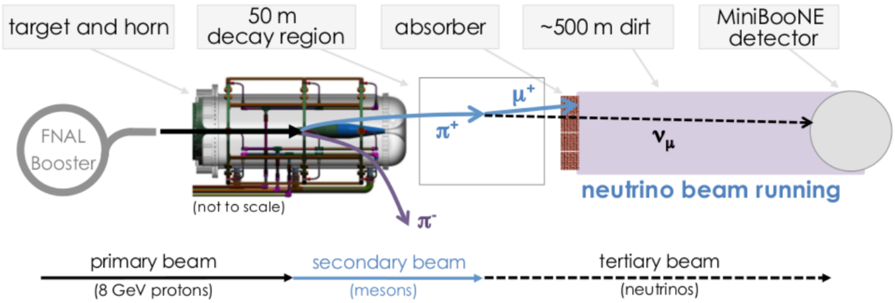
- EM: dominated by the coherent mechanism



- NC: dominated by the incoherent mechanism



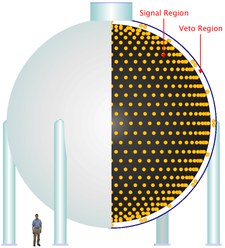
MiniBooNE

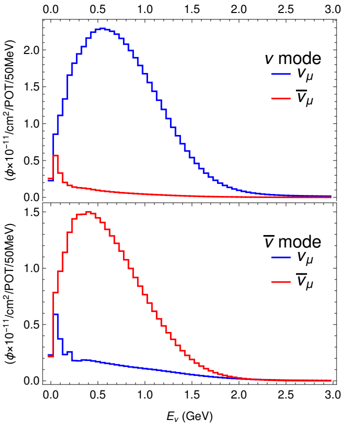


- Fermi National Accelerator Laboratory is a with 149 m of diameter.
- A 8 GeV protons beam is generated in FNAL and focused to a beryllium target.
- A secondary beam of mesons is produced and filtered with magnetic fields

MiniBooNE

- Cherenkov detector.
- Spherical tank with 12.2 m of diameter.
- 806 tons of mineral oil, CH_2.
- MiniBooNE measurements were made with:
  - 6.46×10^{20} POT in neutrino mode.
  - 11.27×10^{20} POT in antineutrino mode.





Aguilar-Arevalo et al, PRD 79 (2009)

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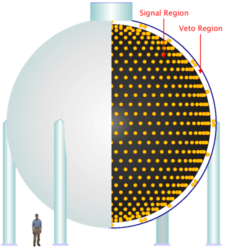
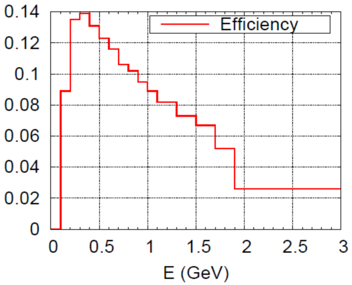
MiniBooNE Detector

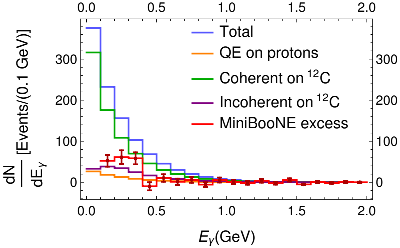


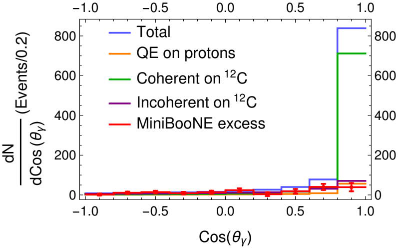


`http://www-boone.fnal.gov/for_physicists/data_release`

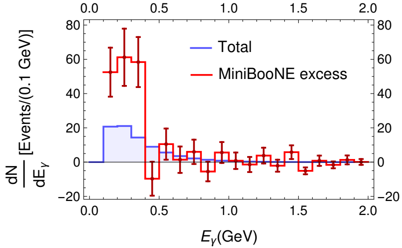
Neutrino mode

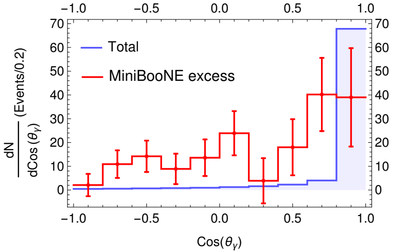
- Energy and angular distributions





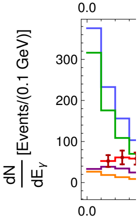
- Energy and angular distributions with efficiency

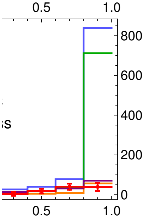




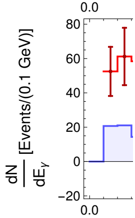
Neutrino mode

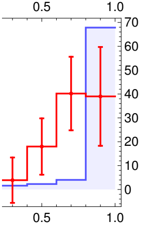
- Energy and an

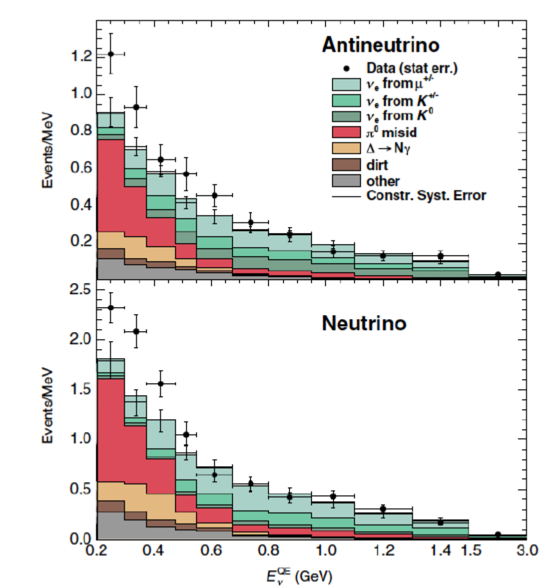




- Energy and an

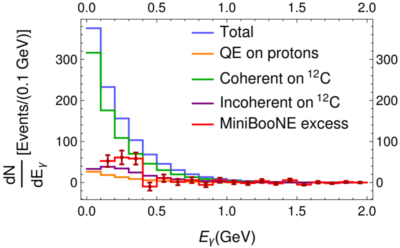


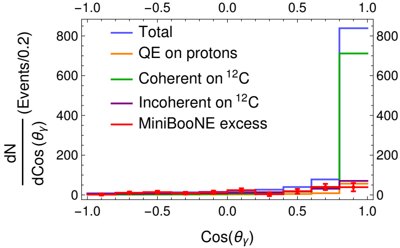




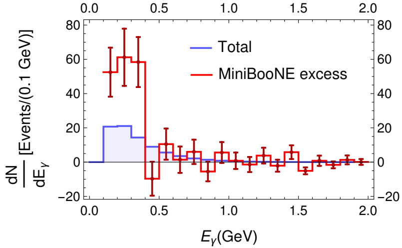
Neutrino mode

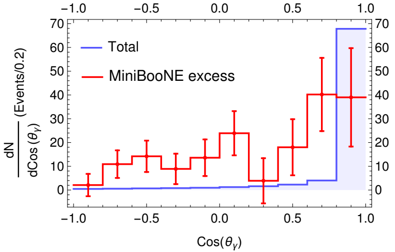
- Energy and angular distributions





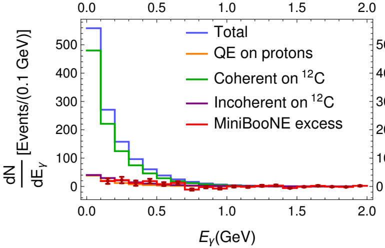
- Energy and angular distributions with efficiency

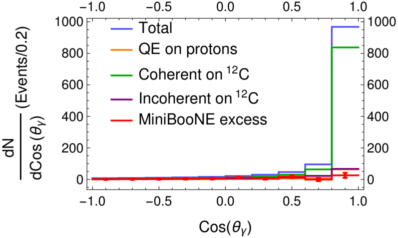




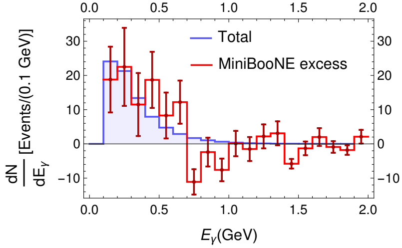
Antineutrino mode

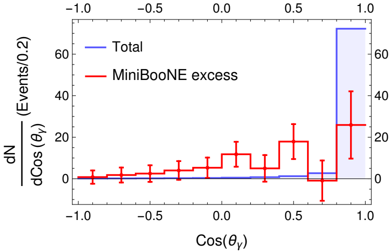
- Energy and angular distributions





- Energy and angular distributions with efficiency





Parameters

Choice of parameters from M. Masip et al, JHEP 1301 (2013):

- Mass of the heavy neutrino, $m_h = 50$ MeV
- Mixing angle, $|U_{\mu h}|^2 = 3 \times 10^{-3}$
- Lifetime, $\tau_h = 5 \times 10^{-9}$s
- Branching ratio, $BR_i = \frac{(\mu_{tr}^i)^2}{\sum_i (\mu_{tr}^i)^2} \rightarrow BR_\mu = 10^{-2}$
- does not explain the MiniBooNE excess of events $\Rightarrow \chi^2/\text{DoF} = 127/54$

Parameters and limits

LSND compatible limits for the parameters by Gninenko, PRD 83, 015015 (2011):

- Mass of the heavy neutrino, m_h:
  - Lower bound: $m_h \geqslant 40$ MeV → KARMEN experiment.
  - Upper bound: $m_h \leqslant 80$ MeV → LSND ν_h production suppressed by phase space factor.
- Mixing angle:
  - Lower bound: $|U_{\mu h}|^2 \geqslant 10^{-3}$ → muon lifetime.
  - Upper bound: $|U_{\mu h}|^2 \leqslant 10^{-2}$ → LEP experiments $Z \to \nu\nu_h$ decay
- Lifetime:
  - Upper bound: $\tau_h \leqslant 10^{-8}$s → Gninenko LSND results

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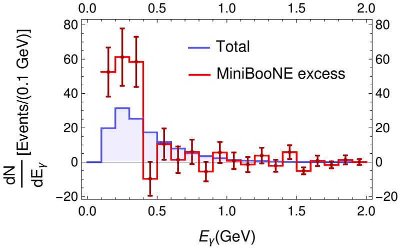
  - Upper bound: $\tau_h \leqslant 10^{-8}$s → Gninenko LSND results

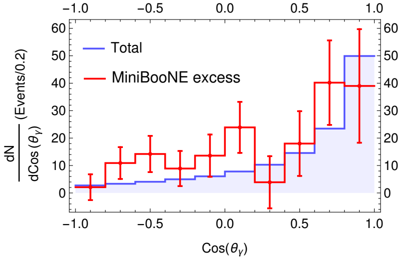
Our fit: χ^2/DoF $= 101/54$

- $m_h = 68.6$ MeV
- $|U_{\mu h}|^2 = 10^{-2}$
- $\tau_h = 2.5 \times 10^{-9}$ s
- $BR_\mu = 8.4 \times 10^{-4}$ ⇔ EM ν_h production strongly suppressed

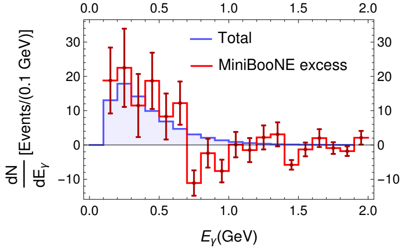
Fitted parameters

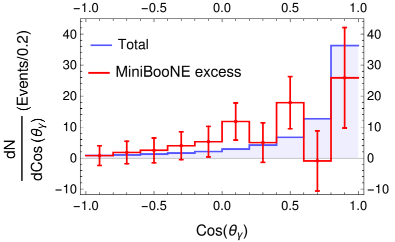
- Neutrino mode



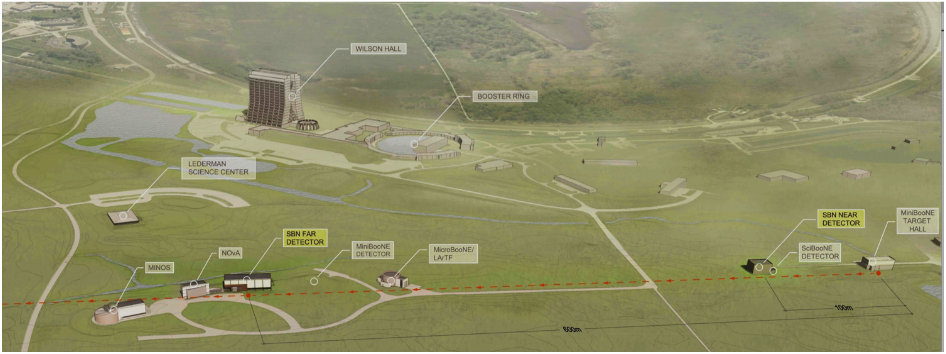


- Antineutrino mode



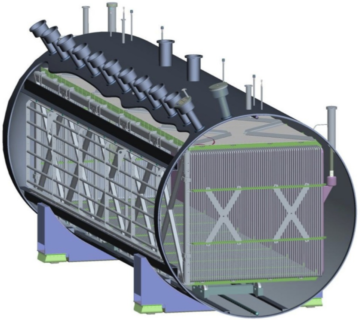


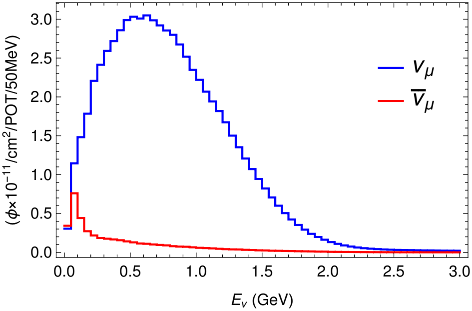
SBN


WILSON HALL
BOOSTER RING
LEDERMAN SCIENCE CENTER
SBN FAR DETECTOR
NOvA
MINOS
MiniBooNE DETECTOR
MicroBooNE/ LArTF
SBN NEAR DETECTOR
SciBooNE DETECTOR
MiniBooNE TARGET HALL
100m
600m

MicroBooNE

- LArTPC detector (large liquid argon time projection chamber).
- TPC of 2.3 m × 2.6 m × 10.4 m.
- Cylindrical deposit with 170 tons of liquid argon (active mass: 86.6 tons).
- Same L/E as MiniBooNE approx.
- Run plan of 6.6×10^{20} POT.

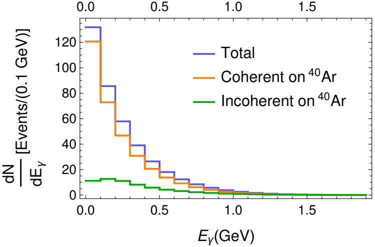


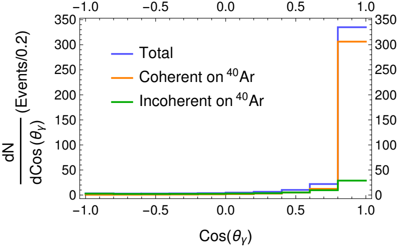


Zarko Pavlovic, private communication.

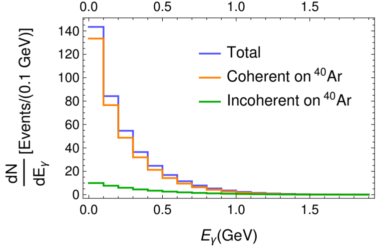
MicroBooNE, parameters of Masip et al.

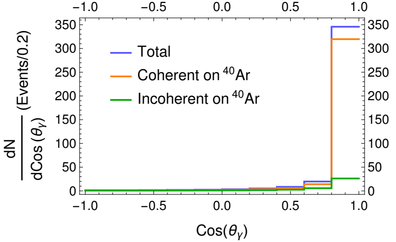
- Neutrino mode





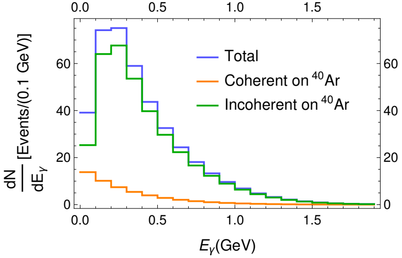
- Antineutrino mode

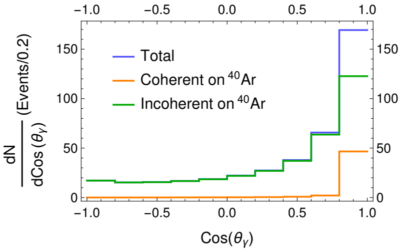




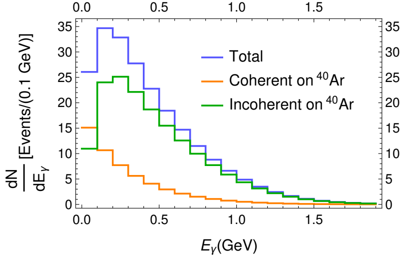
MicroBooNE, fitted parameters

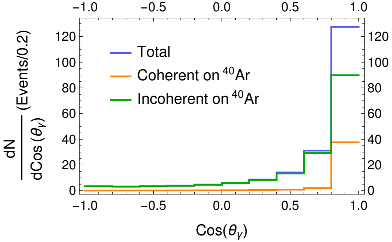
- Neutrino mode



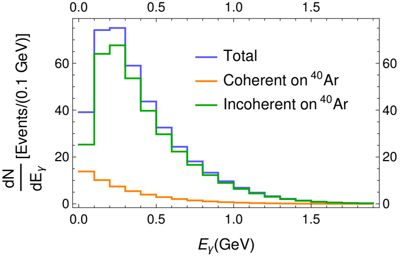


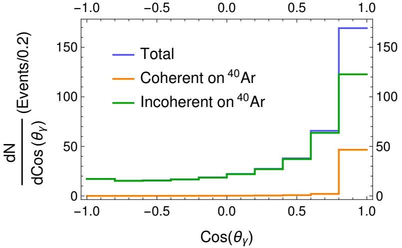
- Antineutrino mode



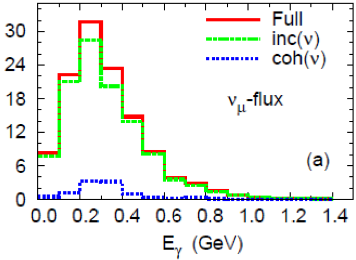


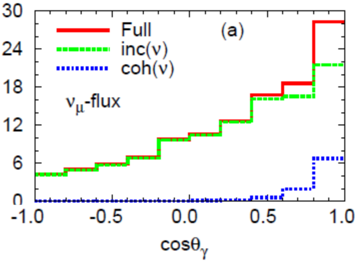
- Neutrino mode





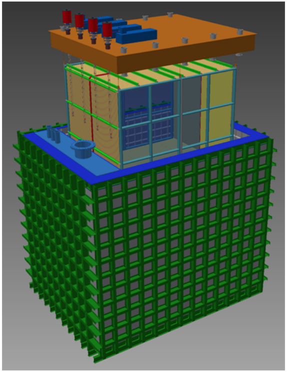
- Prediction for SM predominant photon emission from $\Delta(1232) \to n\gamma$, Wang, Alvarez-Ruso, Nieves, PRC89.015503 (2014)

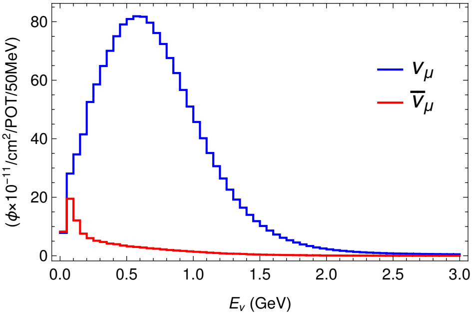




LaR1-ND

- LArTPC detector (large liquid argon time projection chamber).
- TPC of 5 × 4 × 4 m.
- Active mass: 112 tons.
- Run plan of 6.6×10^{20} POT.

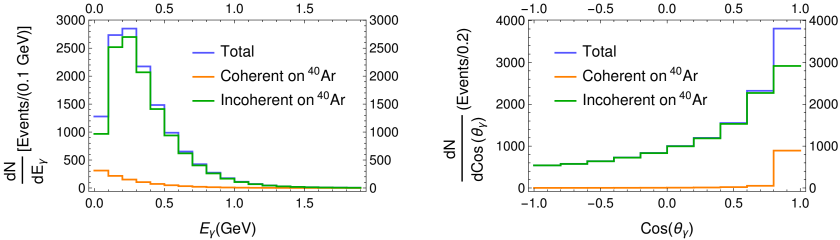




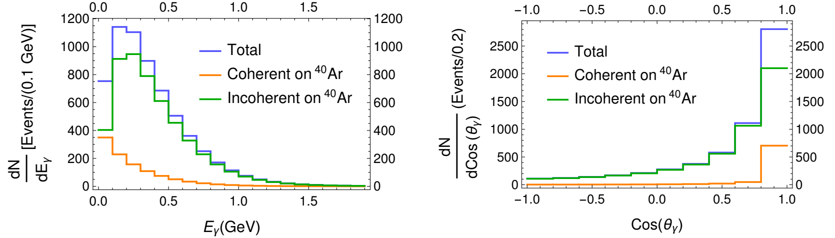
Zarko Pavlovic, private communication.

LaR1-ND, fitted parameters

- Neutrino mode

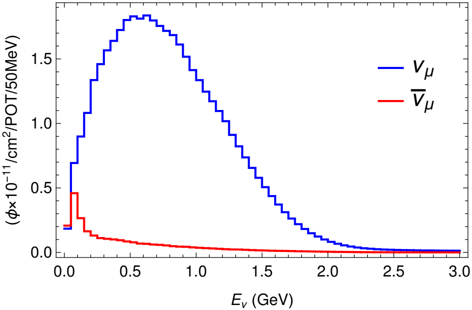


- Antineutrino mode



ICARUS

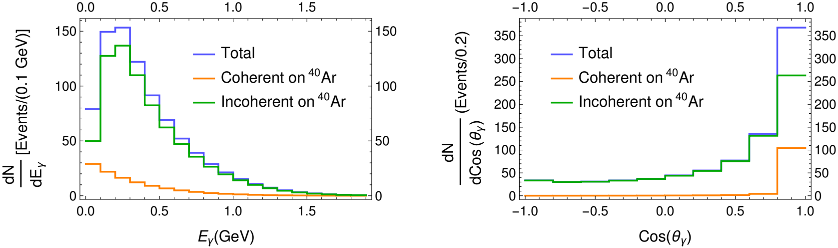
- LArTPC detector (large liquid argon time projection chamber).
- TPC of 18 × 3 × 2 m.
- 2 TPC of 238 tons.
- Run plan of 6.6×10^{20} POT.



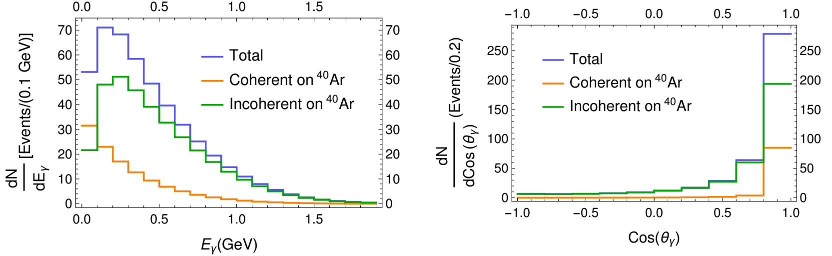
Zarko Pavlovic, private communication.

At each TPC of ICARUS, fitted parameters

- Neutrino mode



- Antineutrino mode



Section 4

Conclusions

Conclusions

- The origin of MiniBooNE anomaly is still not understood.
- Production and radiative decay of heavy sterile neutrino could be a solution.
- We have made an analysis of this scenario using our understanding about neutrino interactions with matter.
- In the range of parameter values consistent with LSND anomaly this scenario does not fully describe MiniBooNE anomaly, but could be sizable contribution.
- We can predict the impact in SBN measurements and test the model.

Thank for your attention!