Ant Colony Application in Sensitivy Studies

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Motivation

To efficiently verify Lorentz Invariance Violation (LIV) parameters, an adaptation of GLoBES utilizing the Ant Colony Methodology (ACM) was proposed. Neutrinos, classified as neutral leptons, exhibit flavor oscillations due to their linear combination of mass states, potentially indicating LIV at certain scales. GLoBES facilitates experiment simulation, incorporating correlations, degeneracies, non-standard physics, and modified probability engines for LIV parameters. The Ant Colony Methodology mimics ants' efficient pathfinding behavior using pheromones, aiding in optimal parameter search. The proposed methodology employs GLoBES with ACM as a tool for LIV parameters, demonstrating its superior speed and desired efficiency compared to preceding approaches concerning CPT violation and conservation in LIV parameters.

Lorentz Invariance Violation

- Halmitonian that describes oscillations is given by (1), where (2) is the Standard Oscillations and (3) is the Lorentz violation term:

$$H = H_{SM} + H_{LIV}, \tag{1}$$

$$H_{SM} = \frac{1}{2E} U \begin{pmatrix} {m_1}^2 & 0 & 0 \\ 0 & {m_2}^2 & 0 \\ 0 & 0 & {m_3}^2 \end{pmatrix} U^\dagger + \sqrt{2} G_f N_e \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \tag{2}$$

$$H_{LIV} = \begin{pmatrix} a_{ee} & a_{e\mu} & a_{e\tau} \\ a_{e\mu}* & a_{\mu\mu} & a_{\mu\tau} \\ a_{e\tau}* & a_{\mu\tau}* & a_{\tau\tau} \end{pmatrix} - \frac{4}{3} E \begin{pmatrix} c_{ee} & c_{e\mu} & c_{e\tau} \\ c_{e\mu}* & c_{\mu\mu} & c_{\mu\tau} \\ c_{e\tau}* & c_{\mu\tau}* & c_{\tau\tau} \end{pmatrix}. \tag{3}$$

- The parameters used in the present work are:

θ_{12}	θ_{13}	θ_{23}
33.45	8.62	42.1
δ_{CP}	Δm^2_{12}	Δm^2_{31}
230	7.42×10^{-5}	2.51×10^{-3}
ν time	$\bar{\nu}$ time	Detec. Mass
5.0	5.0	40

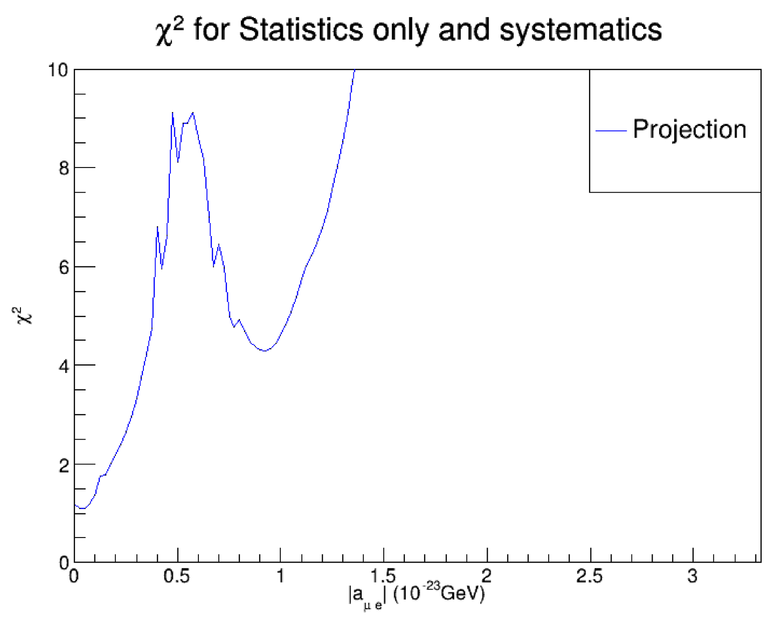
Methodology

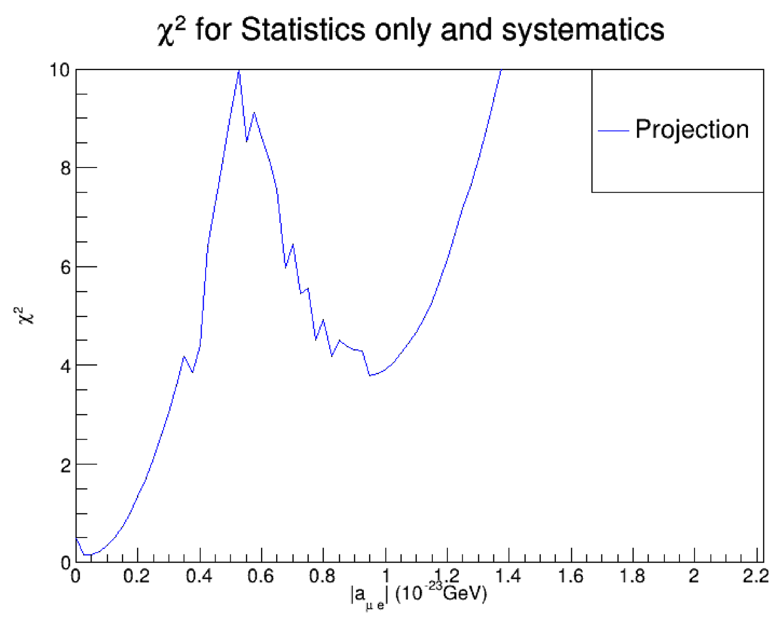
This work aims to validate ACM as a tool for LIV parameter verification and efficient limit simulation in a brisk time, and, for this, an algorithm that incorporates the GLoBES software with the ACM was applied. First of all, some GLoBES parameters, as well as some ACO parameters, are defined. In our case, the number of iterations, the number of ants, their iterations before death, their step size, the grid size, the decay and deposit rate for pheromones, and the LIV values are defined. In the best solution, the defined values are 1000, 10, 25, 7, 100, 0.02, and 1.1, respectively.

A k-cluster of ants is initialized at a predetermined location within a grid characterized by dimensions W×H×D. Subsequently, the process commences with initializing pheromone concentrations across all grid locations, set to a constant value of 0.01. The heuristic calculation initiates with the evaluation of χ^2 within a 3×3×3 grid. Following this, the pheromone levels are considered to inform the heuristic, thereby determining the probability of ant selection for each position. After ant selection, pheromone deposition occurs within a grid defined by the cube of the step size, with diminishing strength relative to the distance from the source, contingent upon the quality of the solution obtained. Thereafter, matrix updates incorporate pheromone evaporation and decay mechanisms.

With the ACO algorithm running occurs the marginalization of the values of θ_{23}, δ_{CP}, and the phase, ϕ, for each LIV parameter. The LIV parameters considered are $a_{e\mu}$ and $c_{e\mu}$.

Behavior of the solution

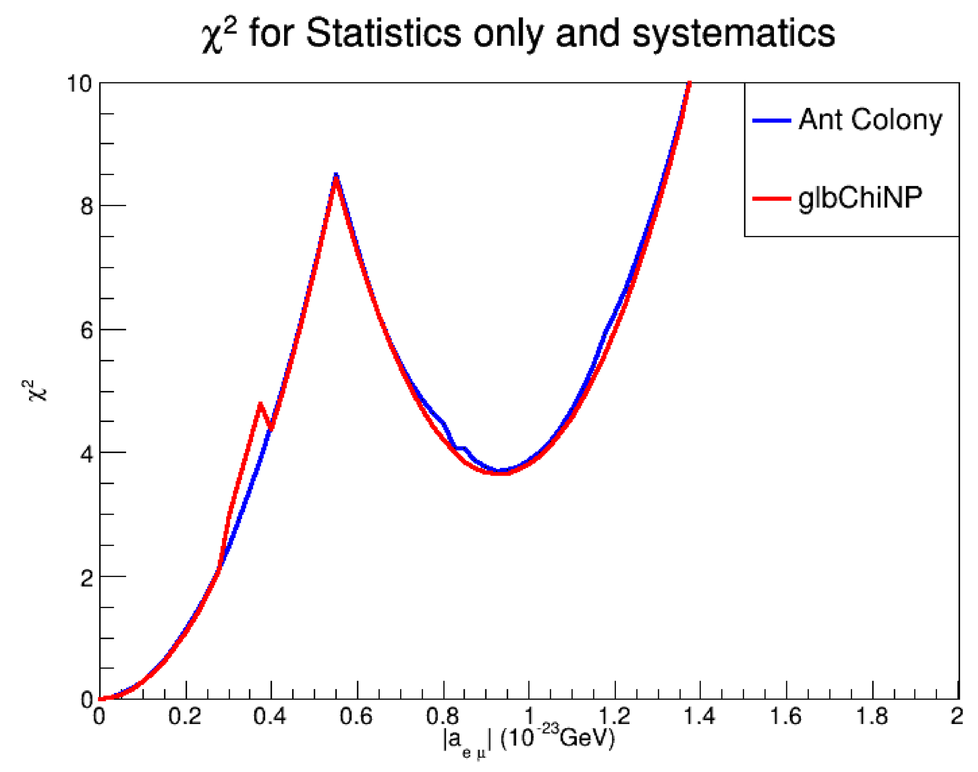




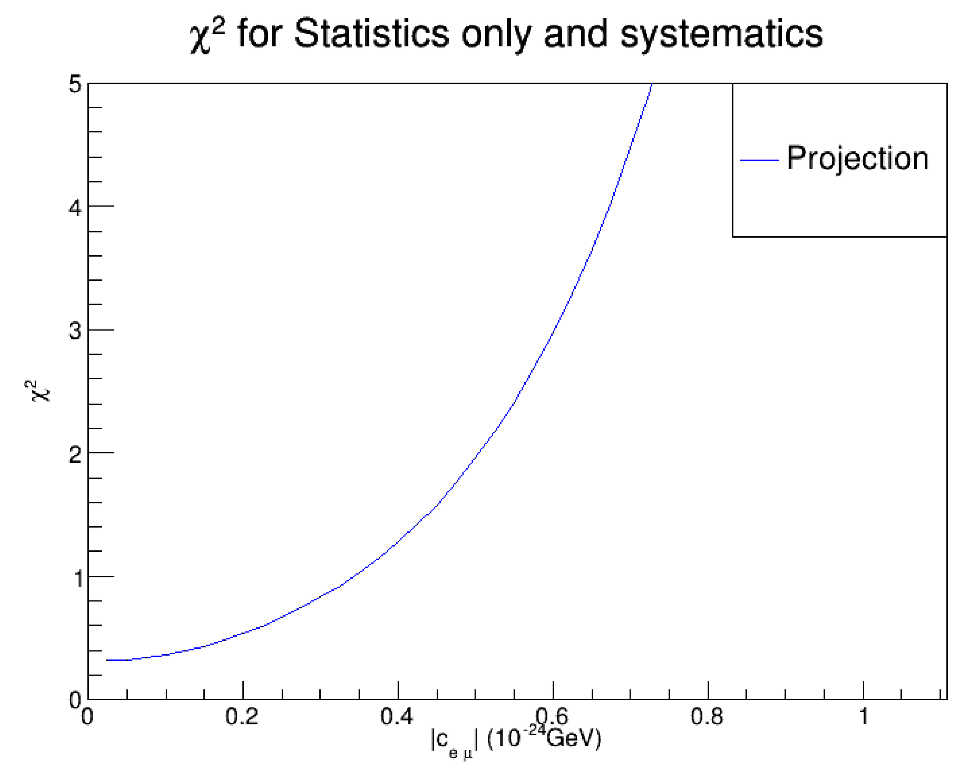
Utilizing Ant Colony Optimization (ACO) to derive solutions introduces inherent stochasticity in ant movements, leading to variability in solution outcomes across multiple executions. However, due to significant advancements in the speed of simulation facilitated by ACO, this variability is not considered problematic but rather a factor to be duly considered.

Results

In the forthcoming figure, a comparative analysis delineates the approximation of χ^2 employing the globes **glbChiNP** method using a global minimum depicted in red. Additionally, the blue curve represents the exploration of CPT-violating Lorentz invariance violation (LIV) parameters individually via an ant colony algorithm.



This next figure we can se the graph for the CPT-conserving LIV parameters considered individually.



Conclusions

- The proposed methodology employs the ACM as a tool for LIV parameters, demonstrating its superior speed and desired efficiency compared to preceding approaches.
- Future advancements and refinements in the ACM methodology present promising avenues for conducting more extensive and profound research.

KEY REFERENCES

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MORE INFORMATION

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