Neutrino Physics: an Open Window on Fundamental Physics and the Evolution of the Universe

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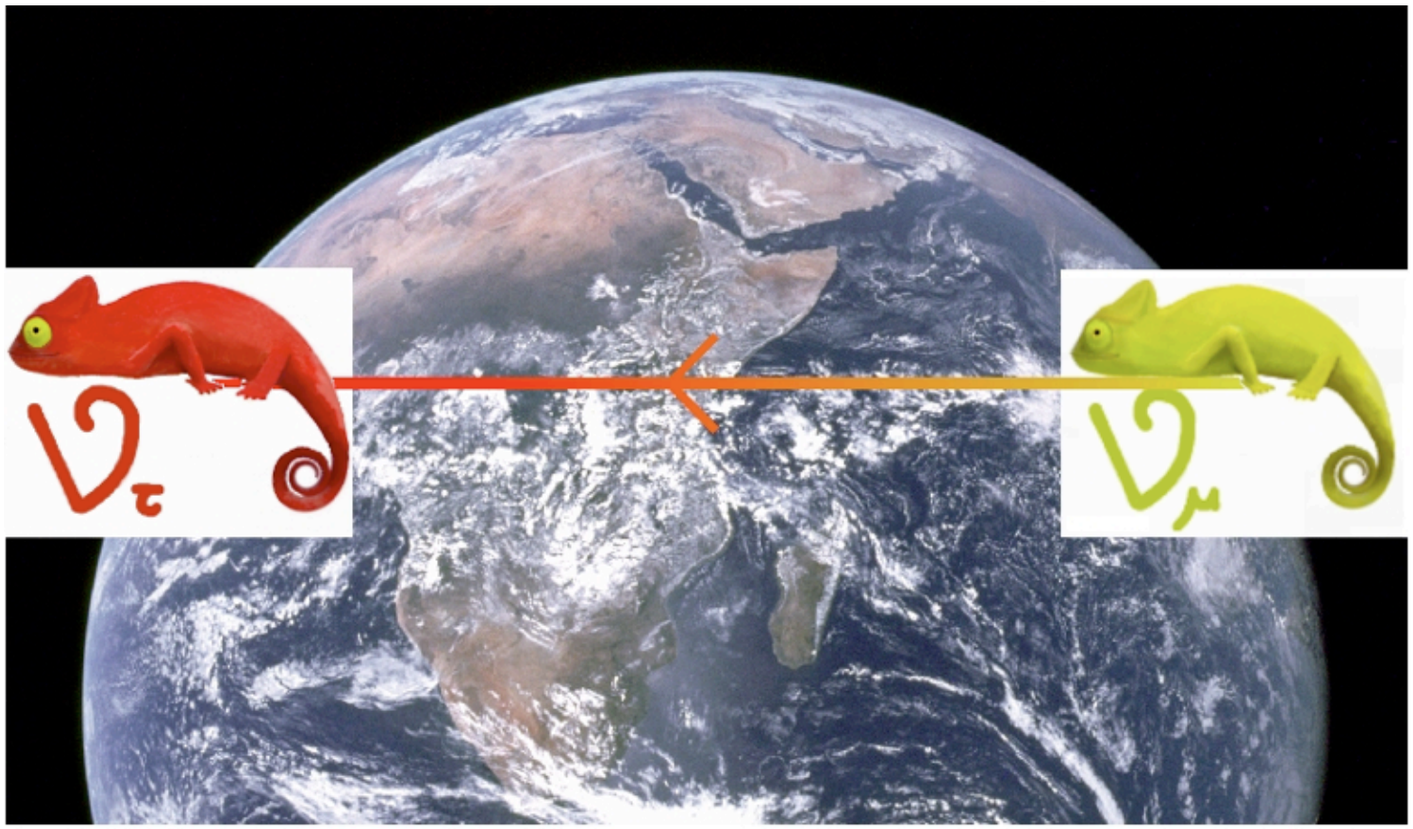
The Pioneering Age of Neutrinos:

neutrino hypothesis and their discovery (1930-1997)

The Golden Age of Neutrinos:

evidence of neutrino oscillations (1998-2006)

Neutrinos are chamaleon particles



They imply that neutrinos have mass and mix!

First evidence of physics Beyond the SM.

The Precision Era of Neutrinos:

Hunting for neutrino masses, mixing and their origin (2006-)

With the discovery of neutrino oscillations, a new perspective has opened on neutrino physics with compelling questions which await their answer:

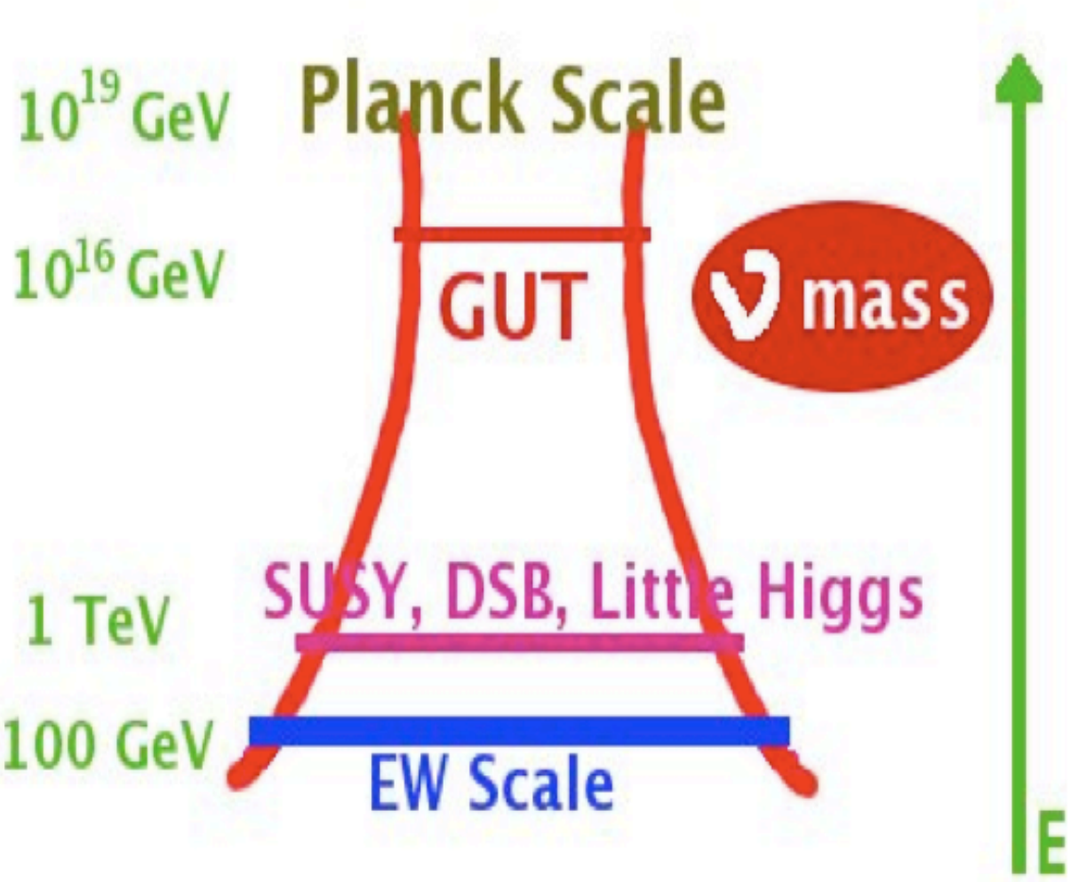
1. What is the nature of neutrinos?
2. What are the values of neutrino masses and mixing?
3. Is CP violated in the leptonic sector?
4. Do sterile neutrinos exist? Is the standard picture right?

A wide experimental program is going to address these questions.

Neutrino physics provides information on the fundamental laws of Nature and on the evolution of the Universe.

- Open window on Physics beyond the Standard Model, possibly at scales not directly reachable otherwise (but low energy models exist).

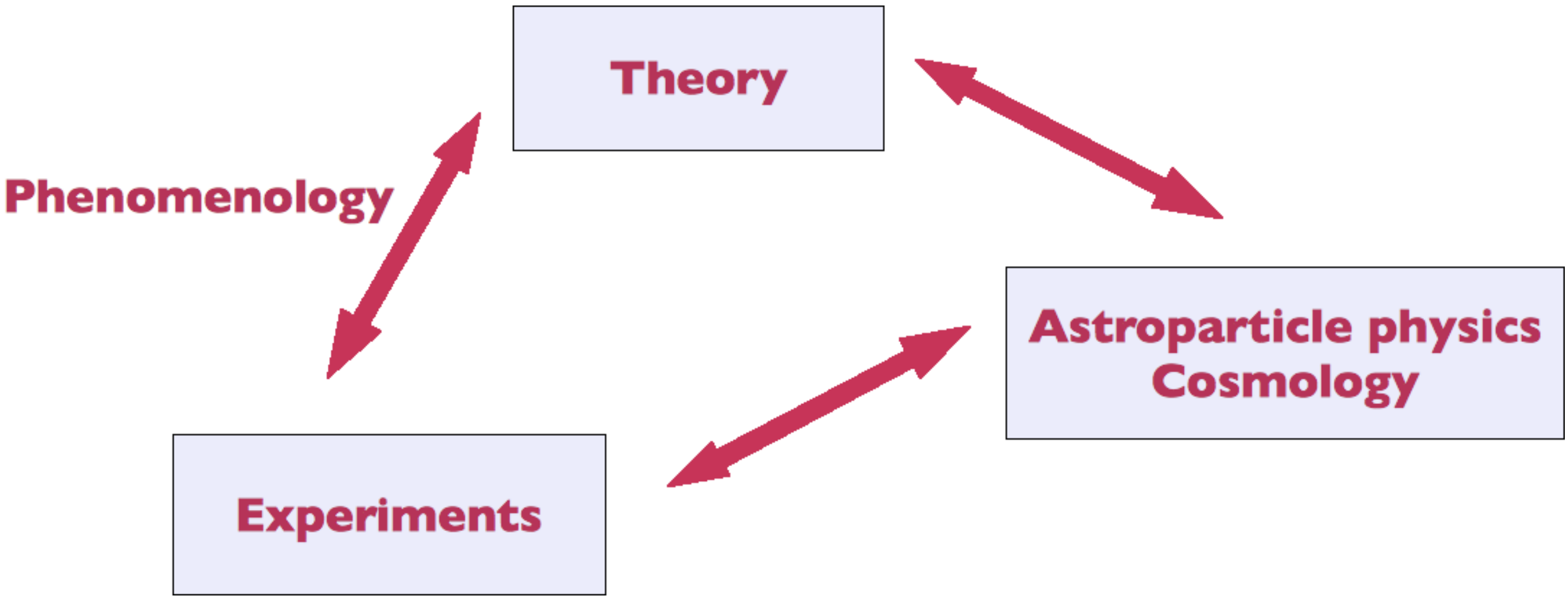
- Another perspective on the problem of flavour.



This information is complementary with the one from collider and other flavour experiments.

Neutrinos are unique:

- a new window on the physics beyond the SM
- a different perspective on the flavour problem



Question 1
Different scenarios for large/small theta13?

In the next few years, we will test if theta13 is large with DoubleCHOOZ, RENO, Daya Bay, T2K (NOvA). We could find that sin^2 2 theta13>0.01 or not. The searches for CP-violation and the matter hierarchy depend on theta13.

What are the best facilities in the scenarios of large/small theta13?
Should we inform the choice depending on theta13?
For large theta13, are there physics motivations for a high-precision facility?

Question 2
European coordination: LAGUNA, EUROnu, IDS-NF

Do we need to involve more closely the theory neutrino community? Efforts are taking place within current projects (e.g. NuFlavour workshop, June 2009 at Cosener's House).

Different neutrino activities are taking place in parallel in Europe: CNGS, LAGUNA, EUROnu, IDS-NF, Betabeams. Each of these studies has a different perspective but strong overlap.

Do we need a dialogue and eventually a coordination? How can we achieve it?

Question 3
Need or not for coordination/dialogue at the international level?

On the same timescales as a future neutrino program in Europe we will have

- T2K and its possible upgrades
- US program: NOvA, LBNE (and a neutrino factory?)

Should EU define its own neutrino program?
Should it talk with Japan and/or US?
How to achieve an international dialogue?

Question 4
LBL versus other particle physics experiments

LBL experiments can search for CPV and the mass hierarchy and can test the three-neutrino scenario.
Other experiments search for
- the neutrino nature (neutrinoless bb-decay),
- lepton flavour violation (mu-e gamma and muon conversion)
- collider physics (which provides information on the physics at the TeV energy scale).

What are the synergies and complementarities?
We need to establish clearly the physics case for different experiments and how they are related.
What are the common experimental issues?

Do we need a dialogue at different levels?

- theory vs experiments,
- accelerator vs astroparticle neutrinos (e.g. EUROnu and LAGUNA),
- oscillations vs non-oscillation experiments (LFV),
- neutrinos vs other particle physics experiments,
- neutrinos and CERN,
- EU vs Japan and US (and Asia).

How to achieve a **EU neutrino oscillation roadmap**? **Can we do it within the present neutrino projects**? **Do we need a specific committee/panel** which includes all the various neutrino activities and interfaces with Japan/US and with other particle physics communities?

From a theoretical point of view we need to understand:

1. What is the origin of neutrino masses? Which is the energy scale at which they arise? What are the particles of the new theory and the new interactions?

2. What is the theory of flavour? Why do we have mixing? What is the connection, if any, with the quark sector?

In order to answer these questions, from a phenomenological point of view, we need to know:

1. What is the nature of neutrinos (Majorana vs Dirac)?

2. Is the charge/parity (CP) symmetry broken?

3. What are the values of neutrino masses (absolute mass scale and the type of mass hierarchy)? and mixing with precision(theta13, theta23)?

4. Are there sterile neutrinos? Is the standard picture correct (NSI, violation of unitarity...)?