# Neutrinos: an open window on Fundamental physics and the Evolution of the Universe

04 October 2009

European Strategy for Future Neutrino Physics
CERN

**Silvia Pascoli**

IPPP – Durham University

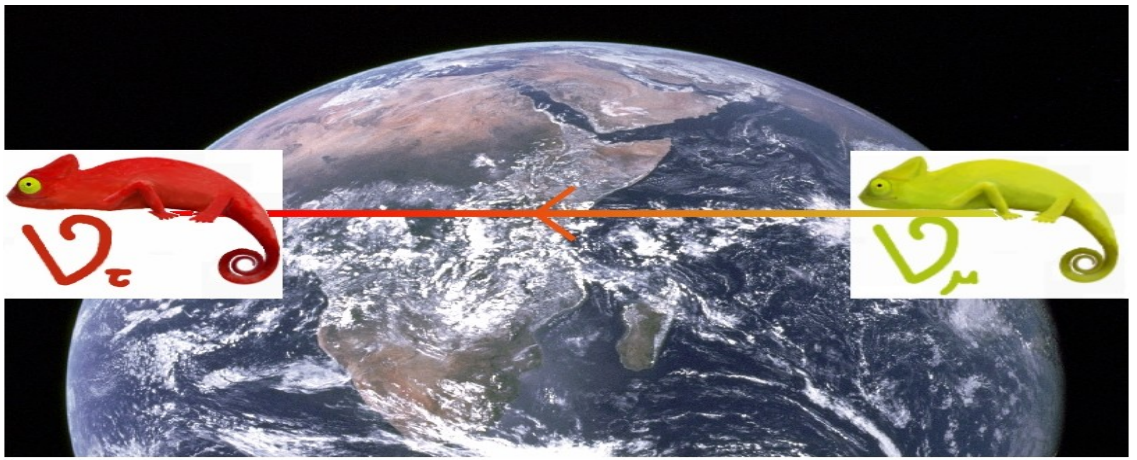
The **Pioneering Age** of Neutrino Physics:

Neutrino hypothesis and its discovery (1930 – 1997)

The **Golden Age** of Neutrino Physics:

Evidence of neutrino oscillations (1998-2006)

**Neutrino oscillations**: neutrinos are **chameleon** particles.



**They imply that neutrinos have mass and they mix!**

**First evidence of physics beyond the Standard Model.**

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

**3. What are the values of neutrino masses and mixing?**

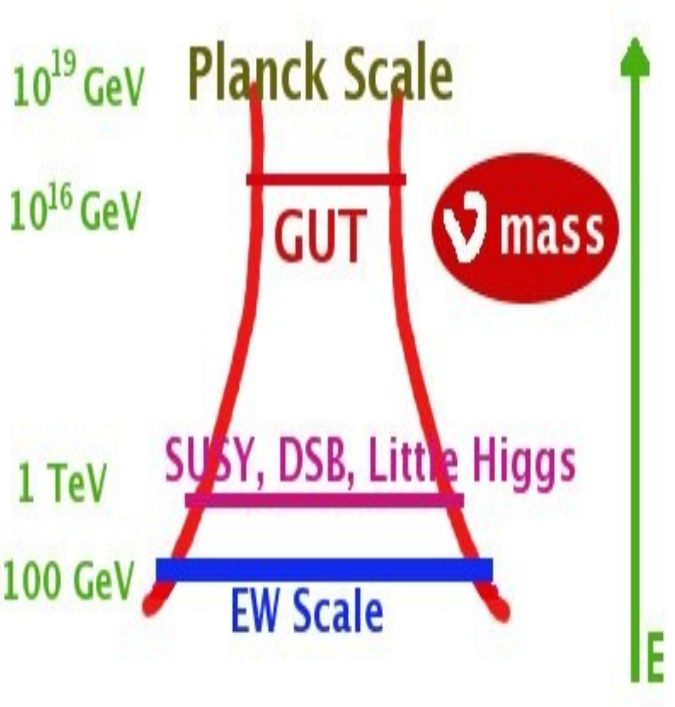
**4. Are there sterile neutrinos? Is the standard picture right?**

A wide experimental program is going to address these questions in the future.

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

- Open window on the **Physics beyond the SM at scales**, possibly, not otherwise reachable, which is responsible for neutrino masses.

- another perspective on the **problem of flavour**.




This information is **complementary** with the one which comes from flavour physics experiments and from colliders.

- **Models of neutrino masses and mixing** by **G. Altarelli**
- **Neutrino masses at the TeV scale and LHC signatures** by **A. Strumia**
- Discussion on theoretical aspects of neutrino mass generation and flavour problem by **G. Ross**

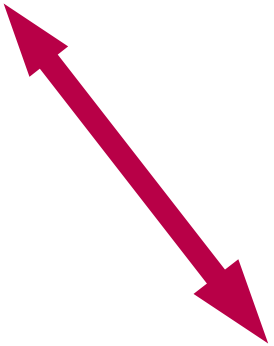
- **Neutrino phenomenology** by **T. Schwetz**
- Discussion by **P. Hernandez**

- **Neutrino physics in the era of precision experiments** by **B. Gavela**
- Discussion by **S. T. Petcov**

- **The connection of neutrino physics with astrophysics and cosmology** by **S. Hannestad**
- Discussion by **A. de Rujula**

## Experiments

- Long baseline oscillations
- Non-acc. oscillation experiments
- Neutrinoless double beta decay
- Direct mass searches



## Phenomenology

## Astroparticle physics Cosmology

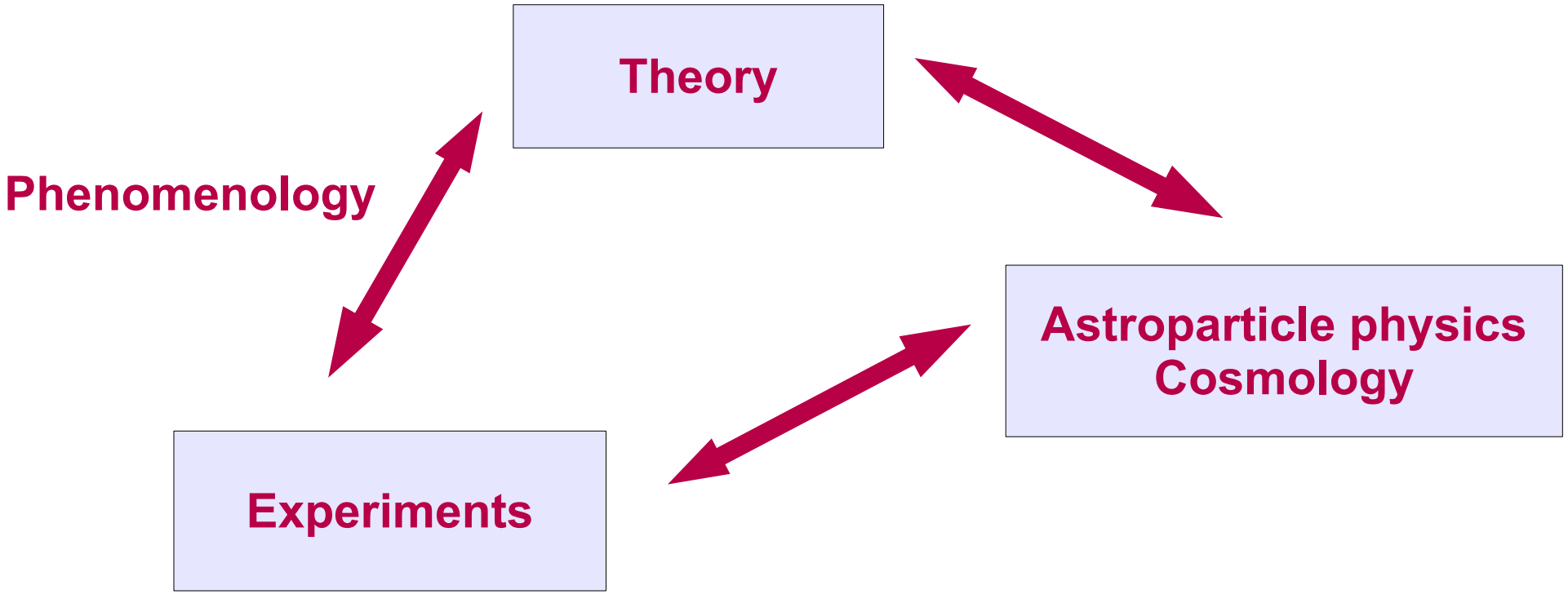
- Constrain neutrino properties
- Study evolution of Universe

## Theory

- Origin of neutrino masses BSM
- Flavour problem

# The **Diamond Era** of Neutrinos:
## much harder but much brighter than before.

**Neutrinos are unique**: they provide
- a **new window** on physics beyond the Standard Model;
- a **different perspective** on the flavour problem.



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...)?**