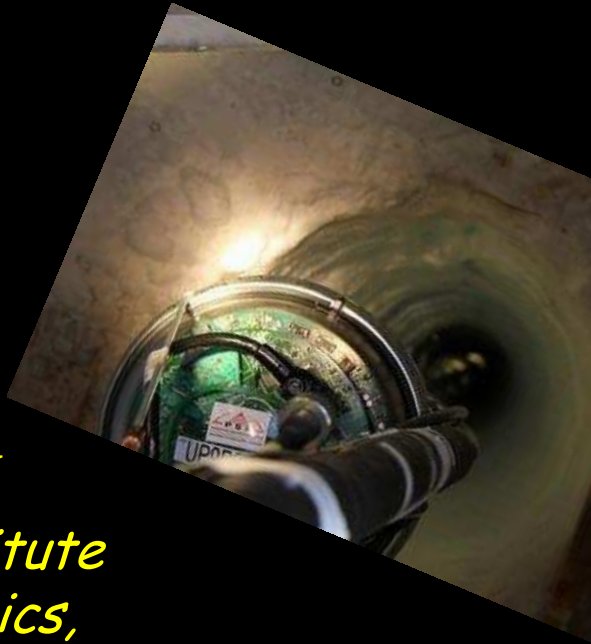


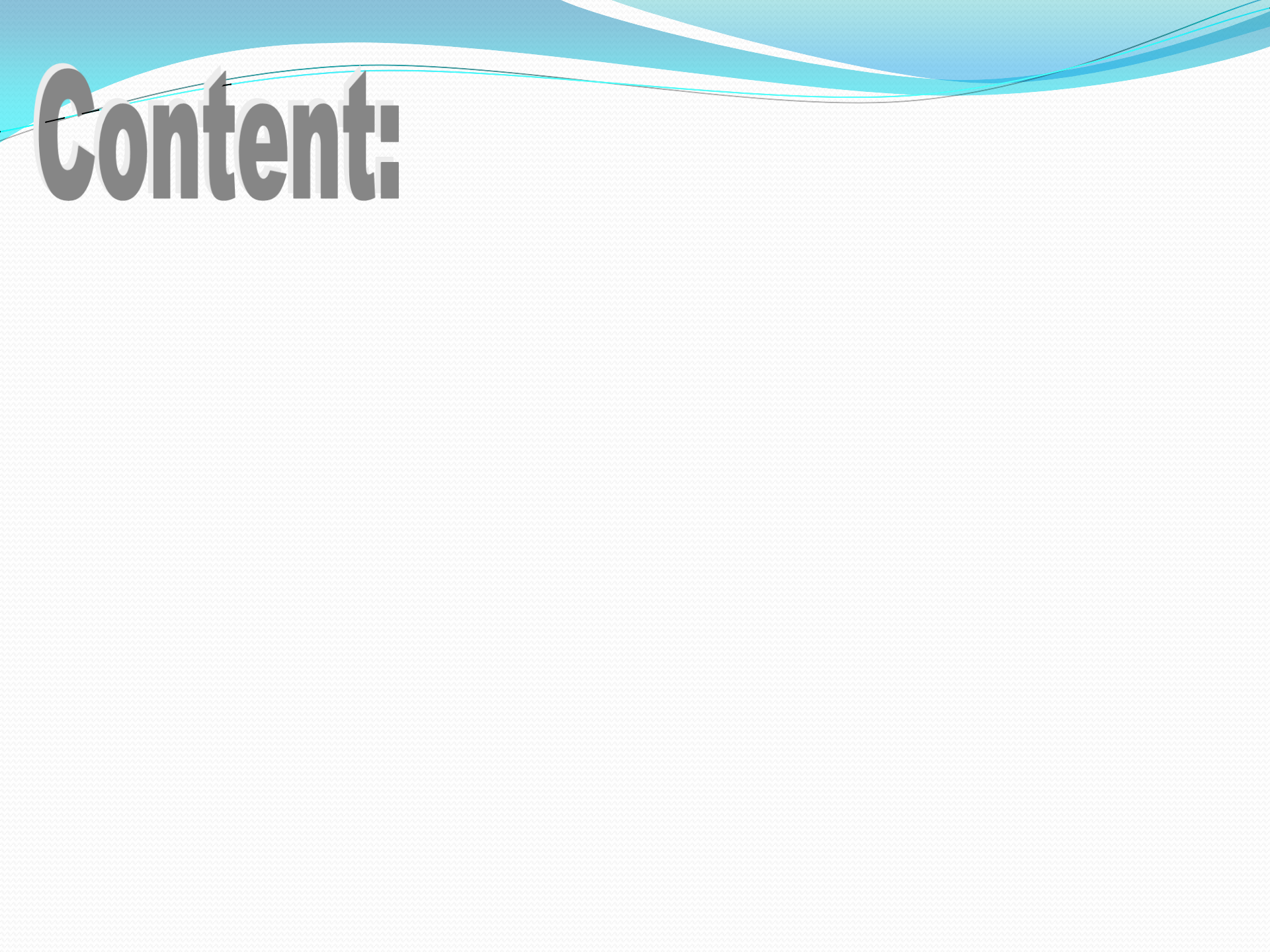
Overview on Neutrino Physics

A. Yu. Smirnov

*Max-Planck Institute
for Nuclear Physics,
Heidelberg, Germany*

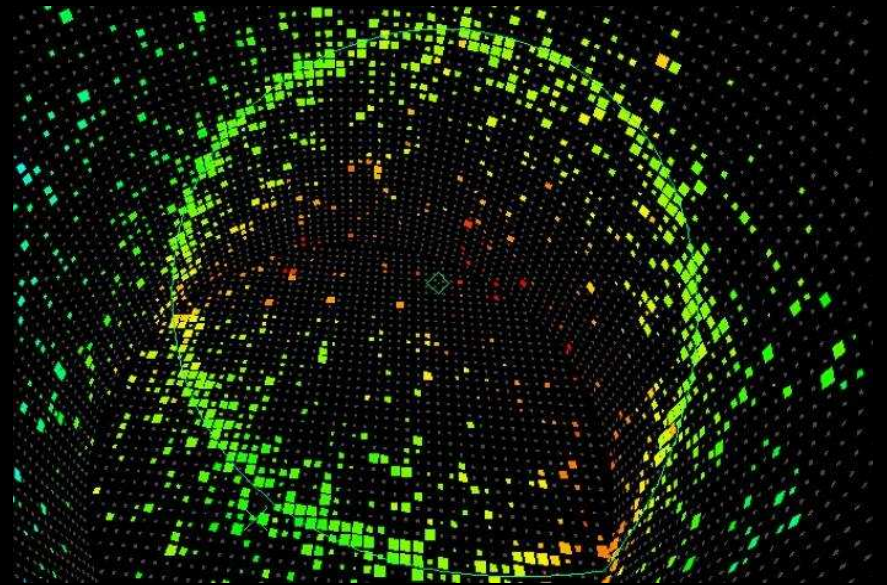


Vulcano, May 24, 2016



Content:

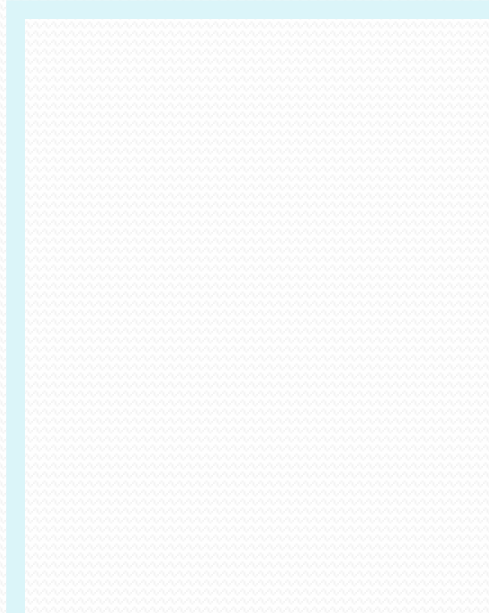
Framework: Three neutrino paradigm and beyond



3v - paradigm

v_R

Mass and Mixing



Global 3v-fit

Beyond 3v paradigm

Connections

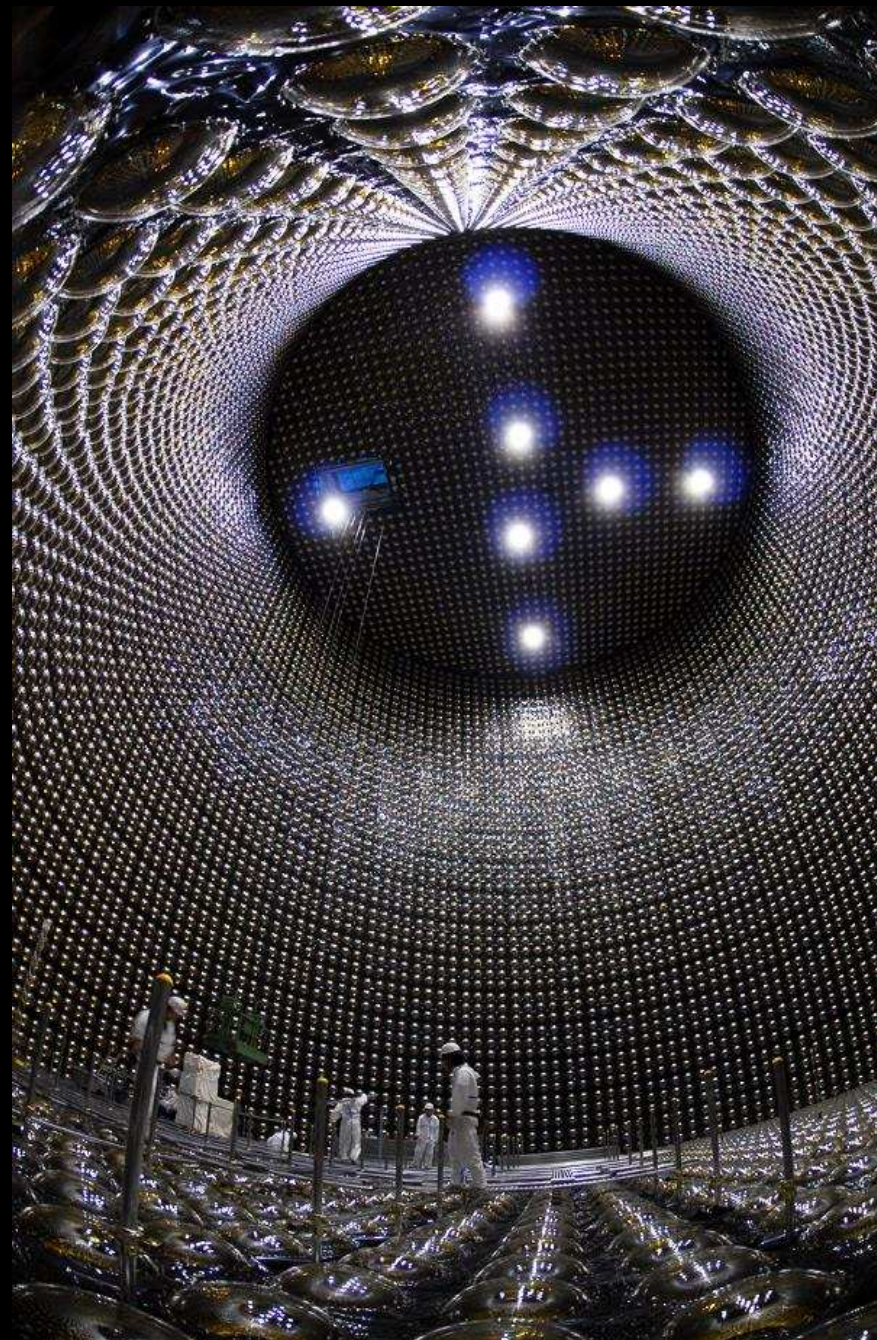
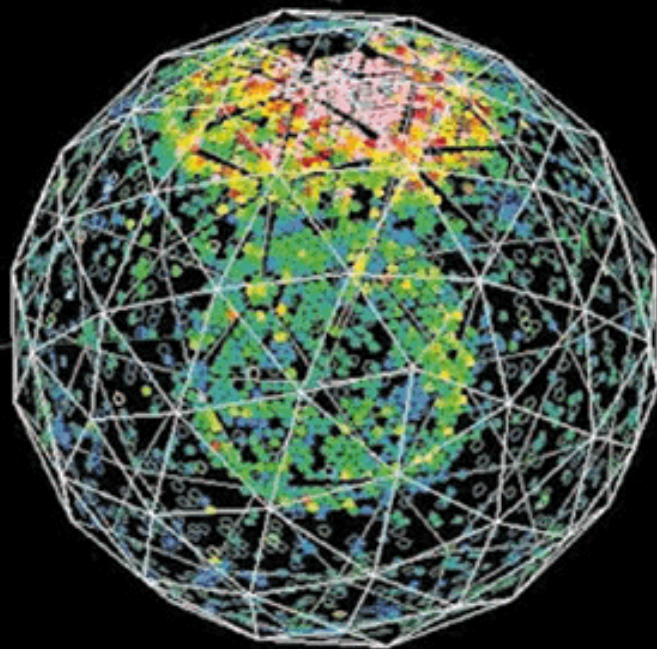




Frontier objects

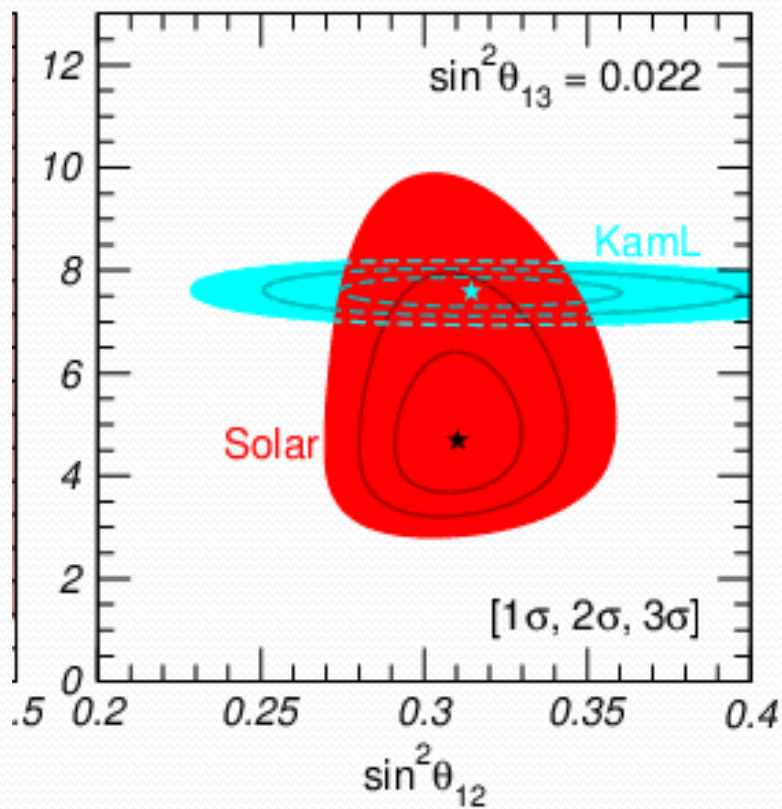
The Nobel Prize in Physics 2015

Frontier Objects

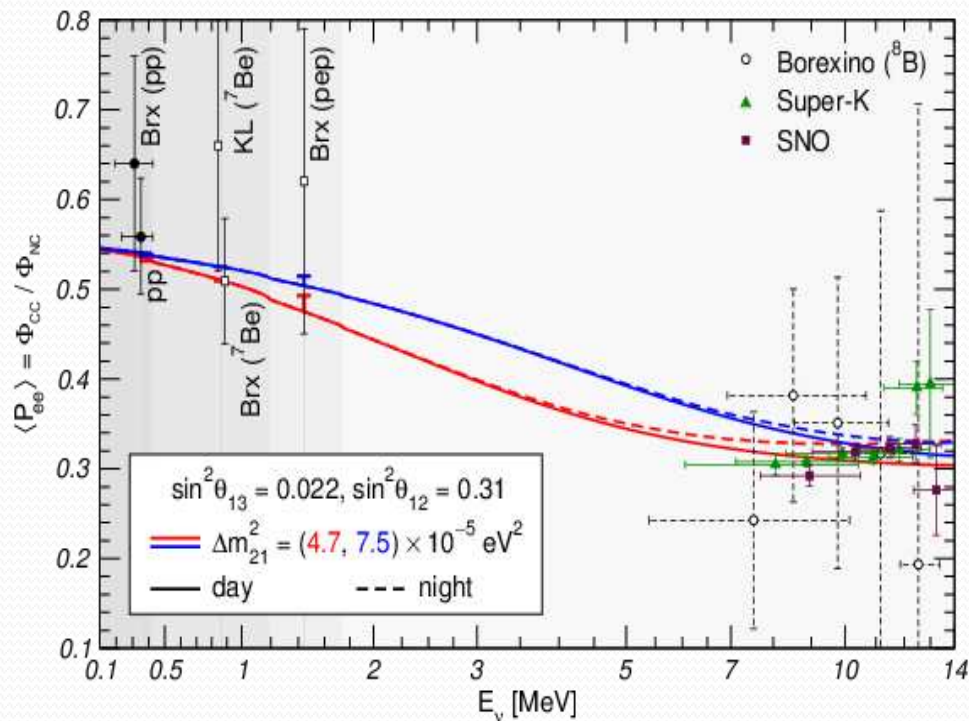


Solar neutrinos

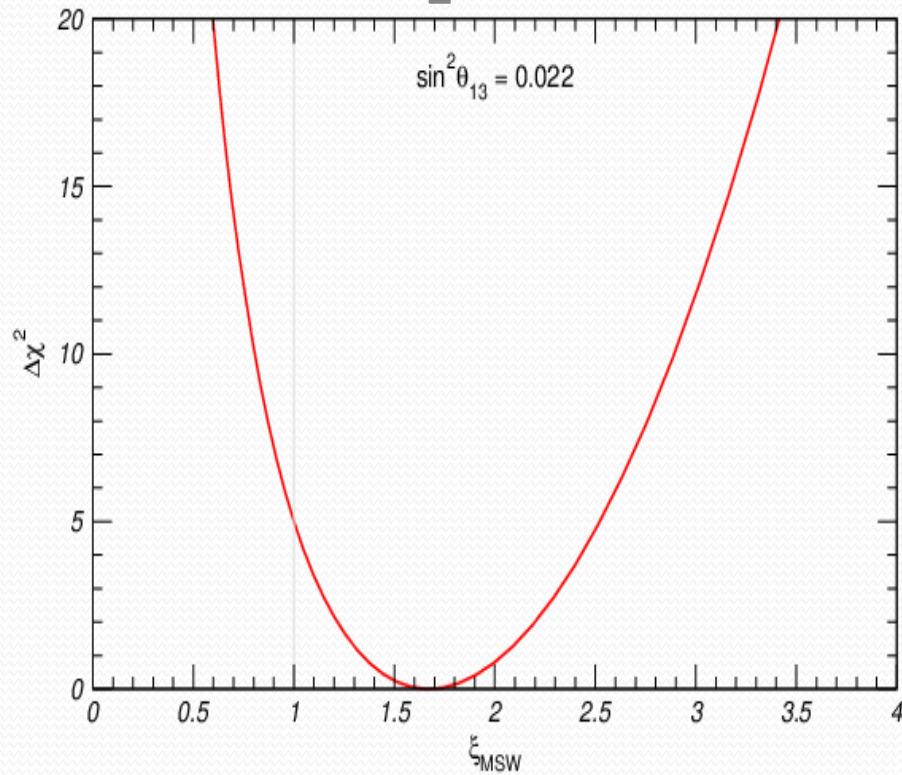
Solar vs. KamLAND



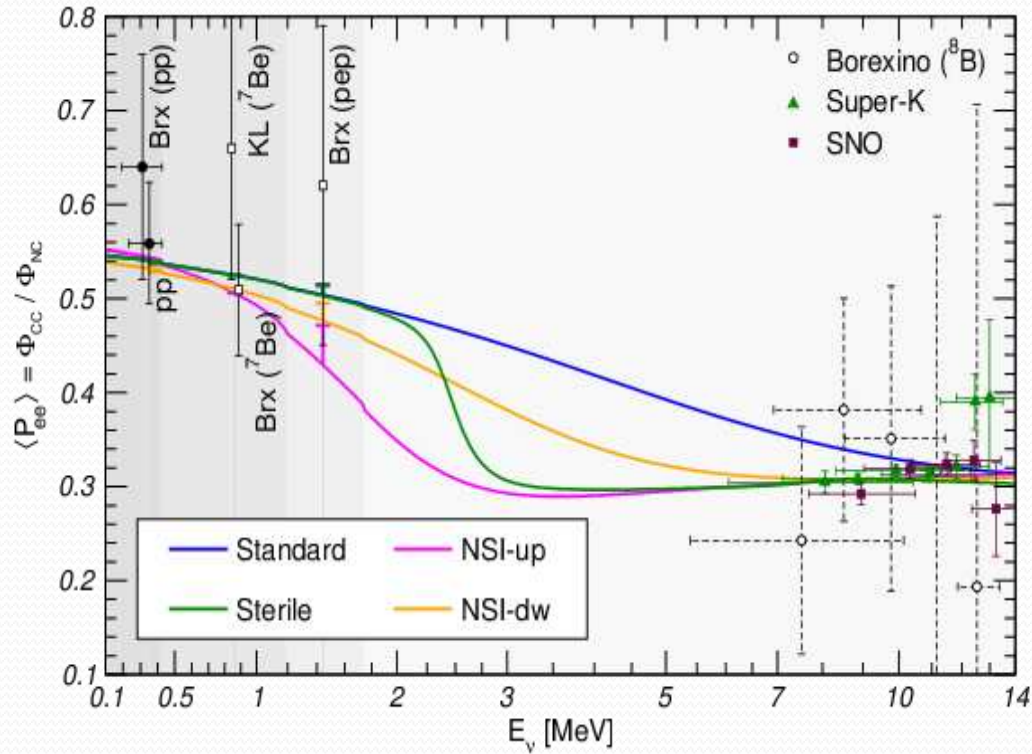
Two reasons:



Matter potential



New physics effects



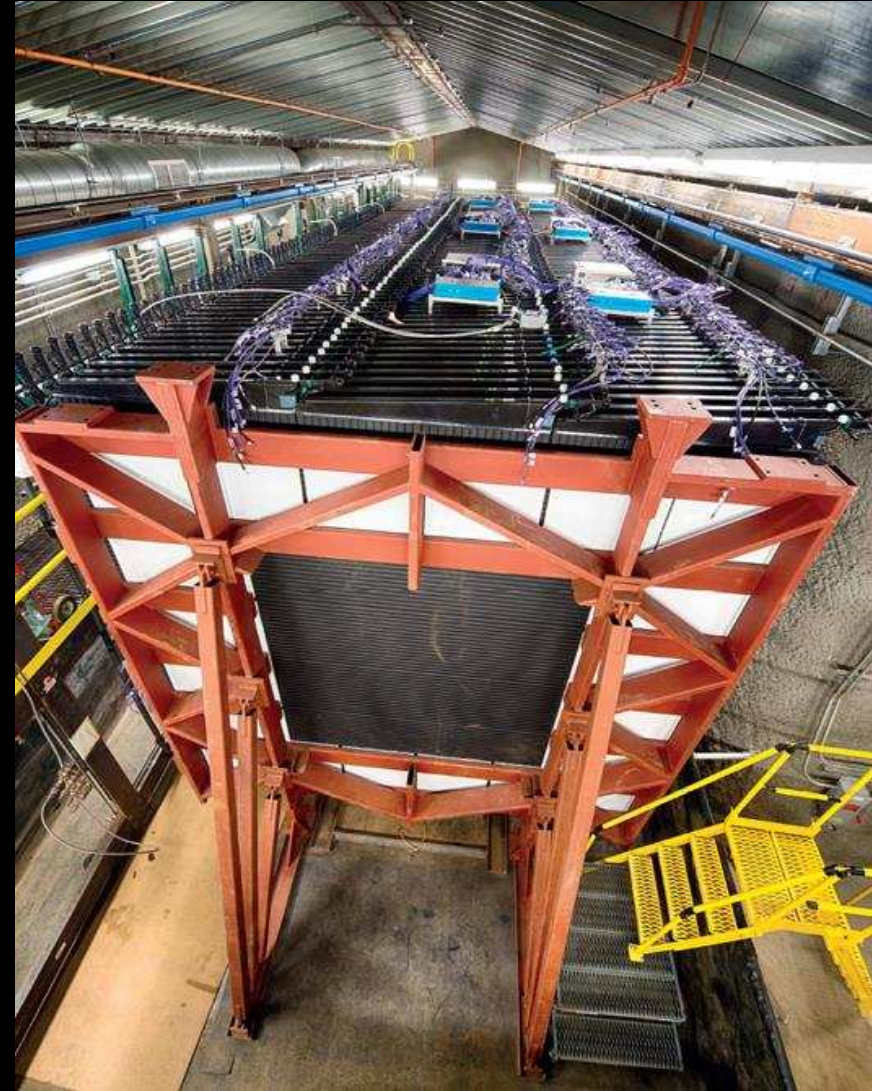
Precision measurements

Daya-Bay, RENO updates
Double CHOOZ with front
detector

T2K anti- ν

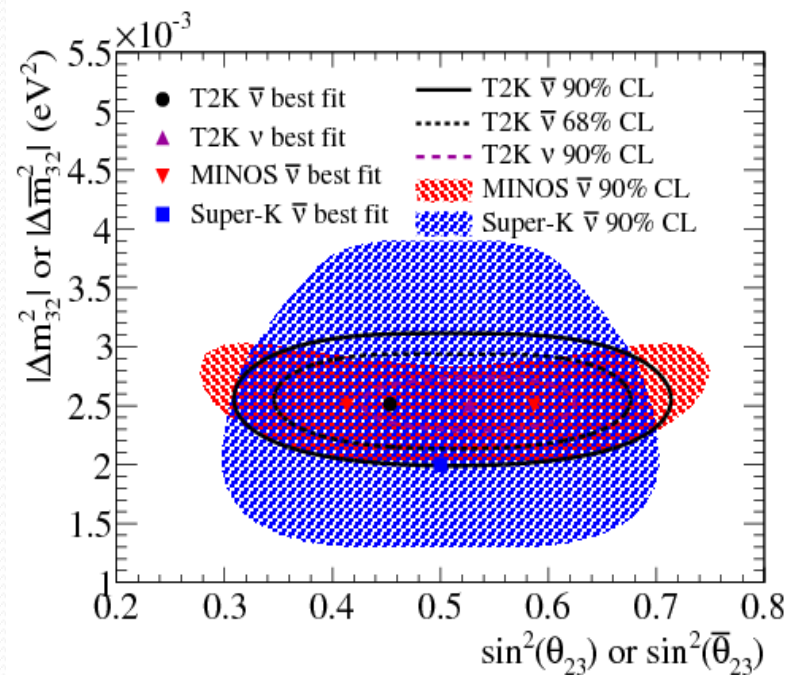
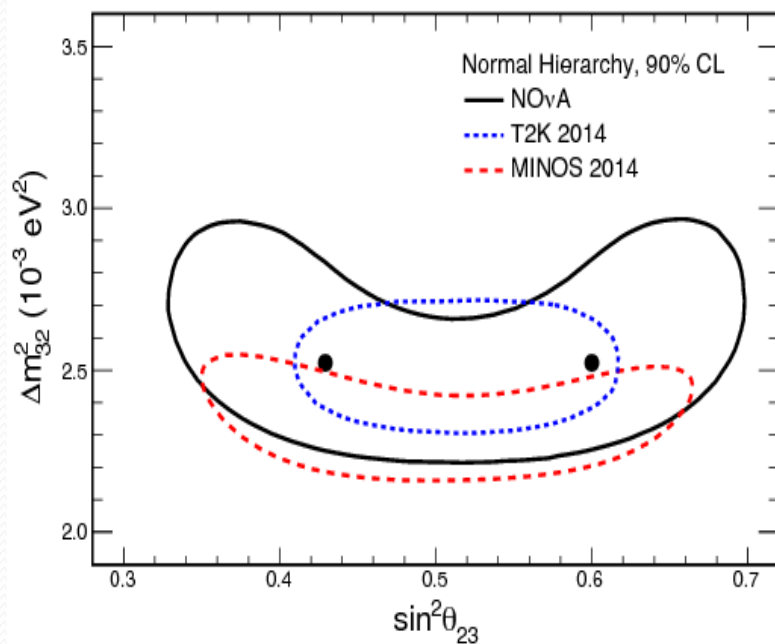
MINOS +

New players:
DeepCore, Antares



1-3 mixing

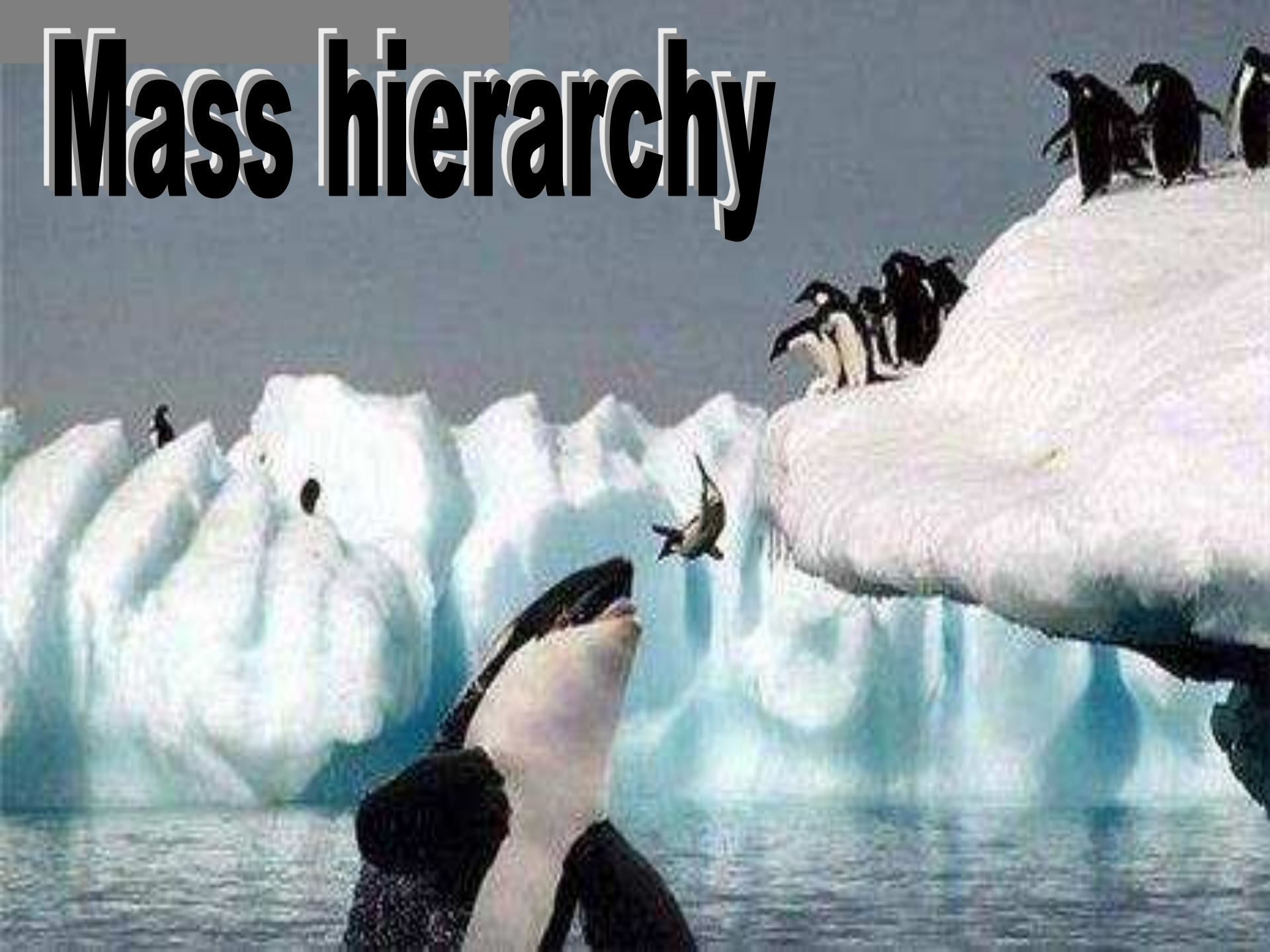
2-3 mixing





DeepCore, PINGU...

Mass hierarchy



**Mass
hierarchy**

Further advance
important by itself

**Theoretical
implications**

Phenomenology

**Supernova
neutrinos**

**Atmospheric
neutrinos**

bb0n decay

LBL

Solar neutrinos

Cosmology



MH: what is behind?

Race for the mass hierarchy

Matter effect
on 1-3 mixing
Oscillations, conversion

Precise
measurements
of Δm^2
at reactors

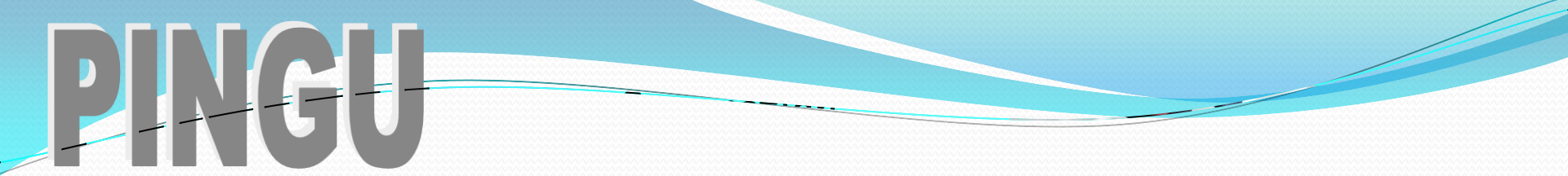
Cosmology
 Σm
Double beta
decay m_{ee}

Atmospheric
neutrinos

LBL
experiments

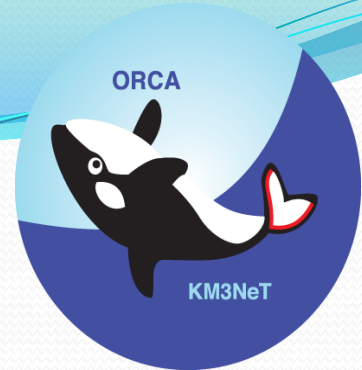
Supernova
neutrinos

PINGU
ORCA
INO



PINGU

ORCA





Smeared distributions

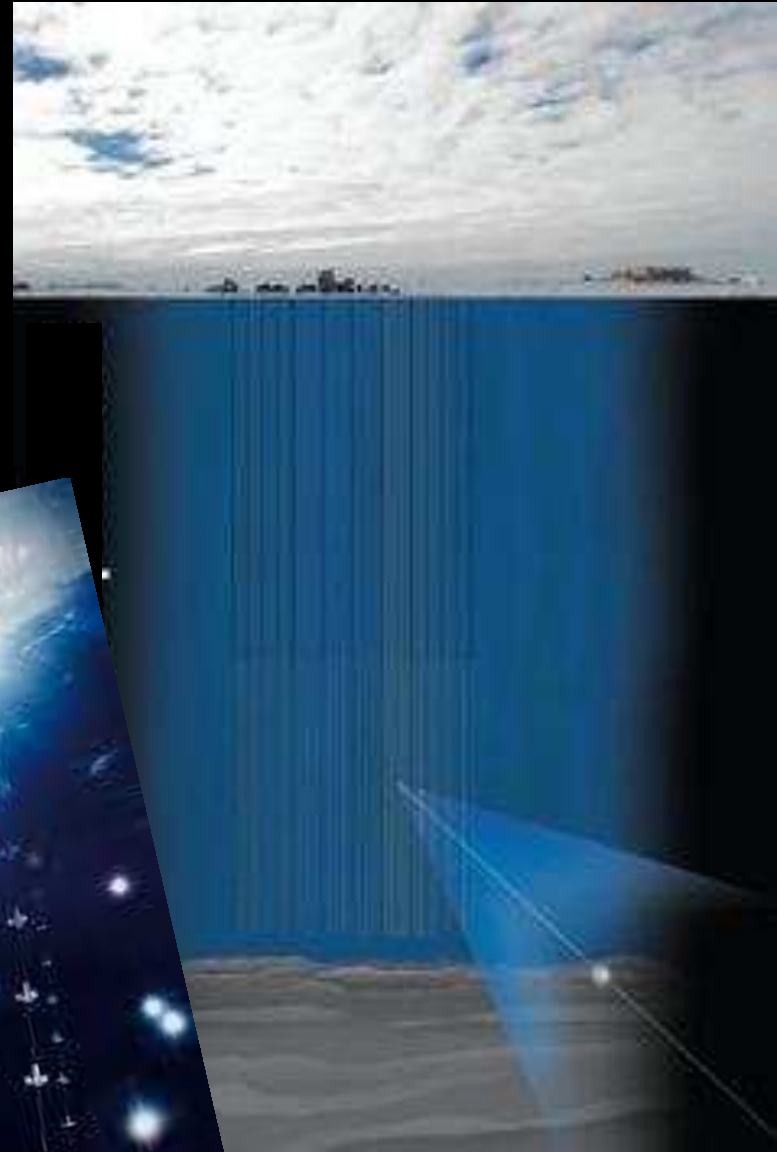
Determination of mass ordering



JUNO

CP-violation

The first glimpses?



**Leptonic
CP-phase**

Theory

**Cosmic
neutrinos**

**Long
Baseline**

**Atmospheric
neutrinos**

Predicting CP-phase?

Neutrino beams

$0\nu\beta\beta$ -decay

Cosmology

NOvA results



Measuring CP-phase

Global fit

T2K + NOvA + reactors

J-PARC- SK

Dedicated experiments

J-PARC- HK

DUNE LBNF

ESS

Alternative?



Ice Cube

Deep Core

**PINGU
ORCA**

Mass hierarchy

**Super-PINGU
-ORCA**

MICA

CP violating phase



Neutrino masses: Scales and nature



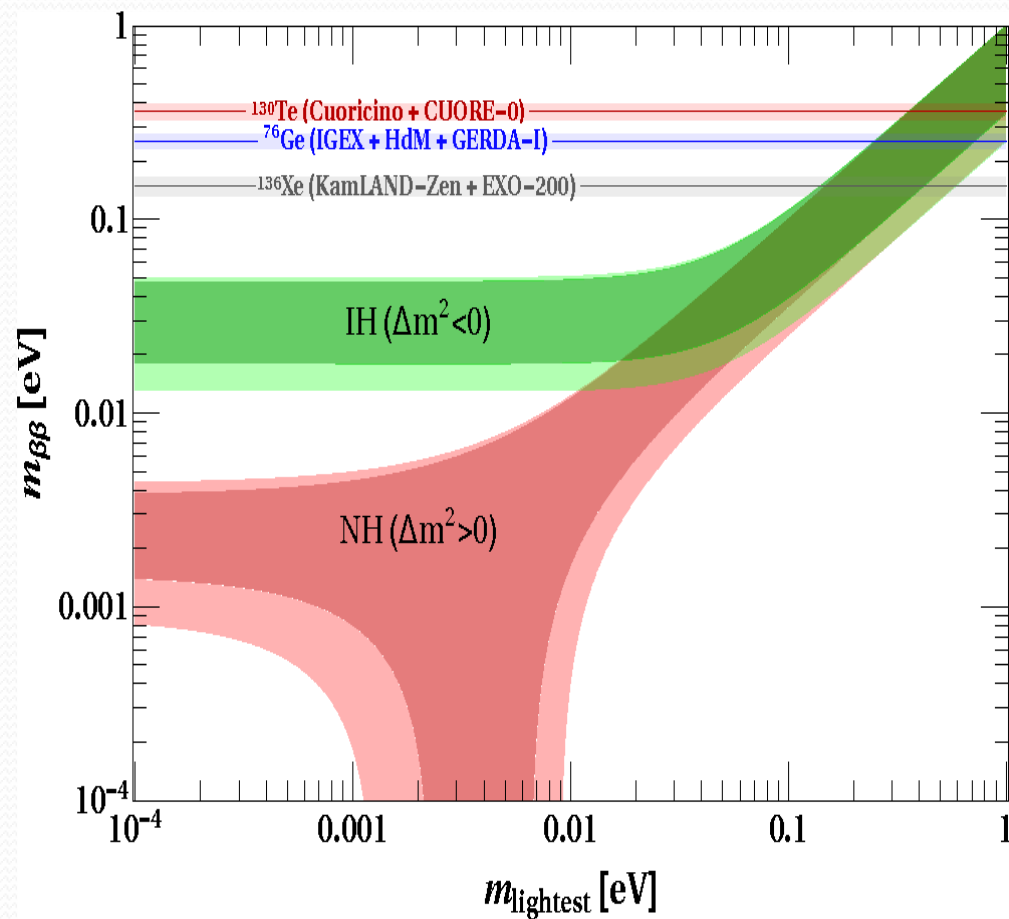
KATRIN 2016

Cosmology

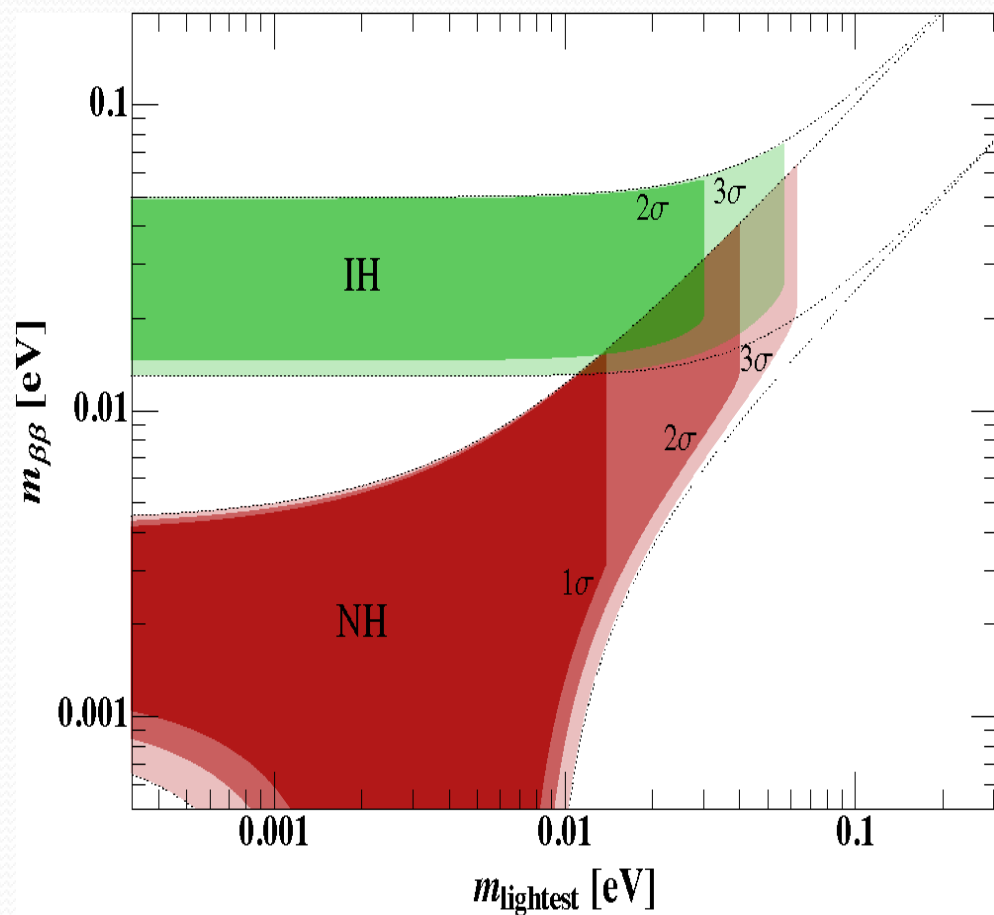
KamLAND Zen

If LHC see will see nothing....

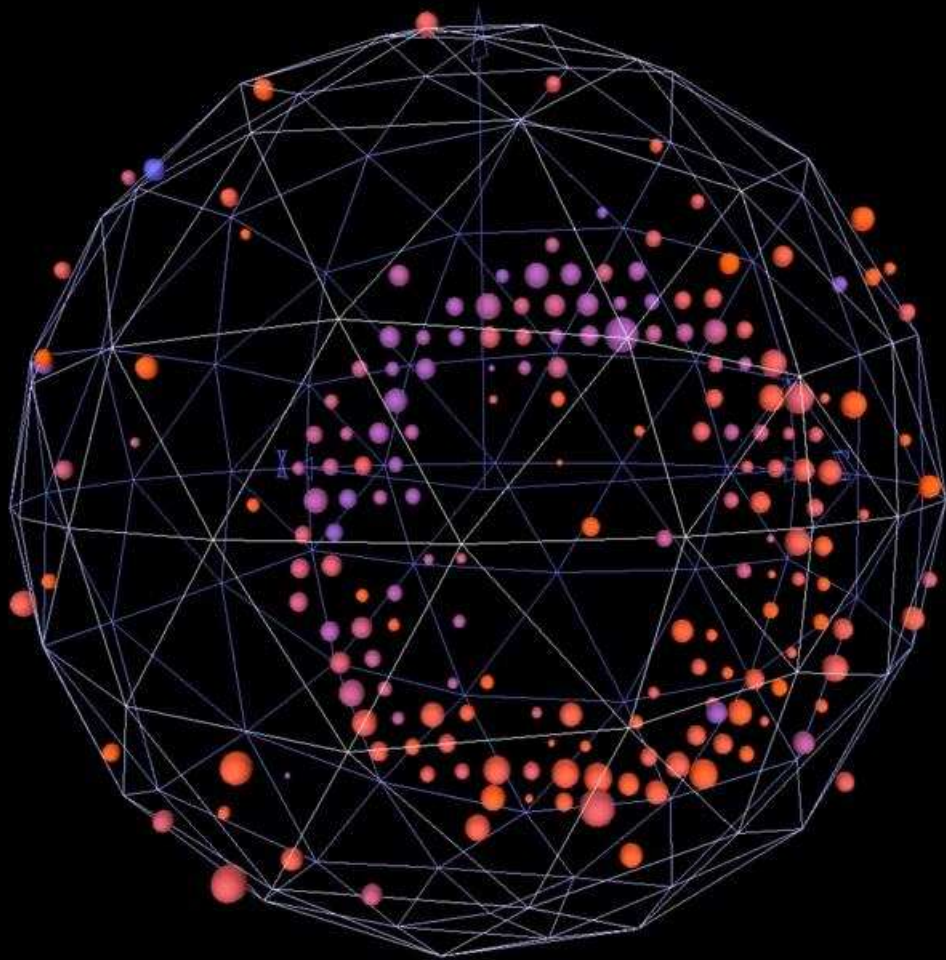
Double beta decay



Neutrinoless $\beta\beta$ - decay and cosmology



Sterile Neutrinos



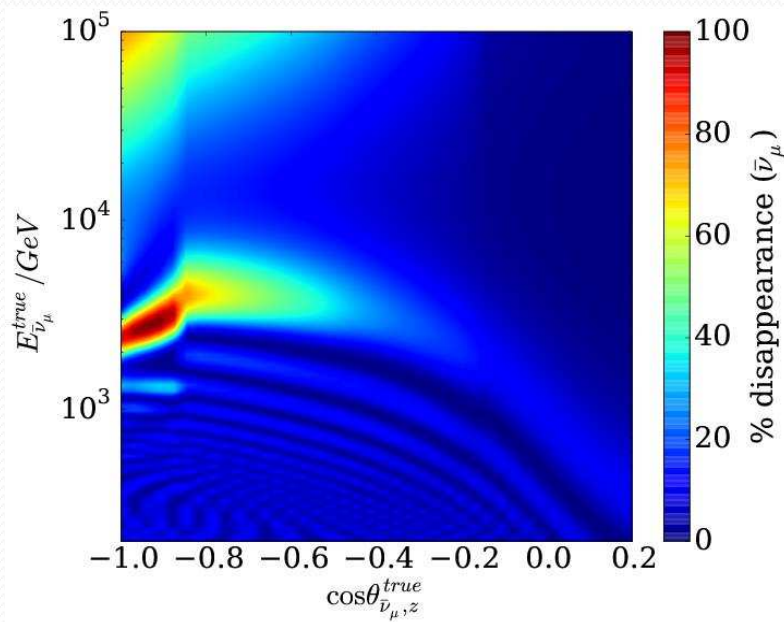
eV scale sterile neutrinos

Motivation:

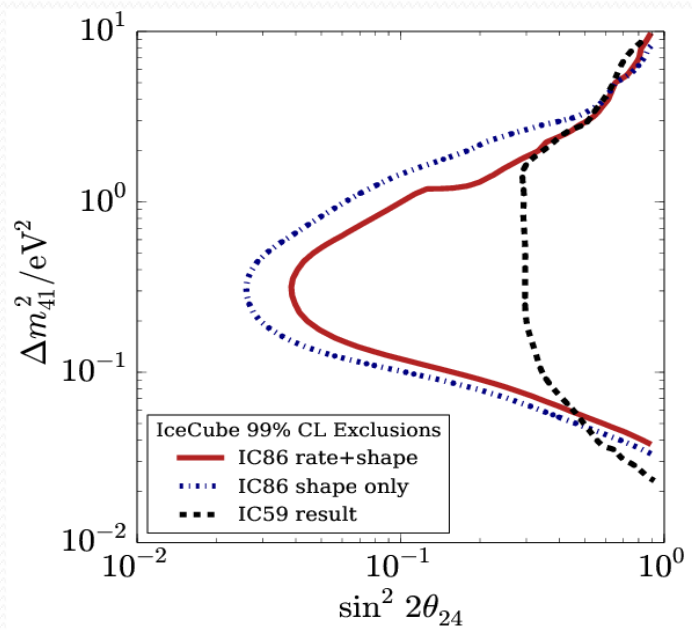
Phenomenology:

Theory:

IceCube searches for sterile neutrinos

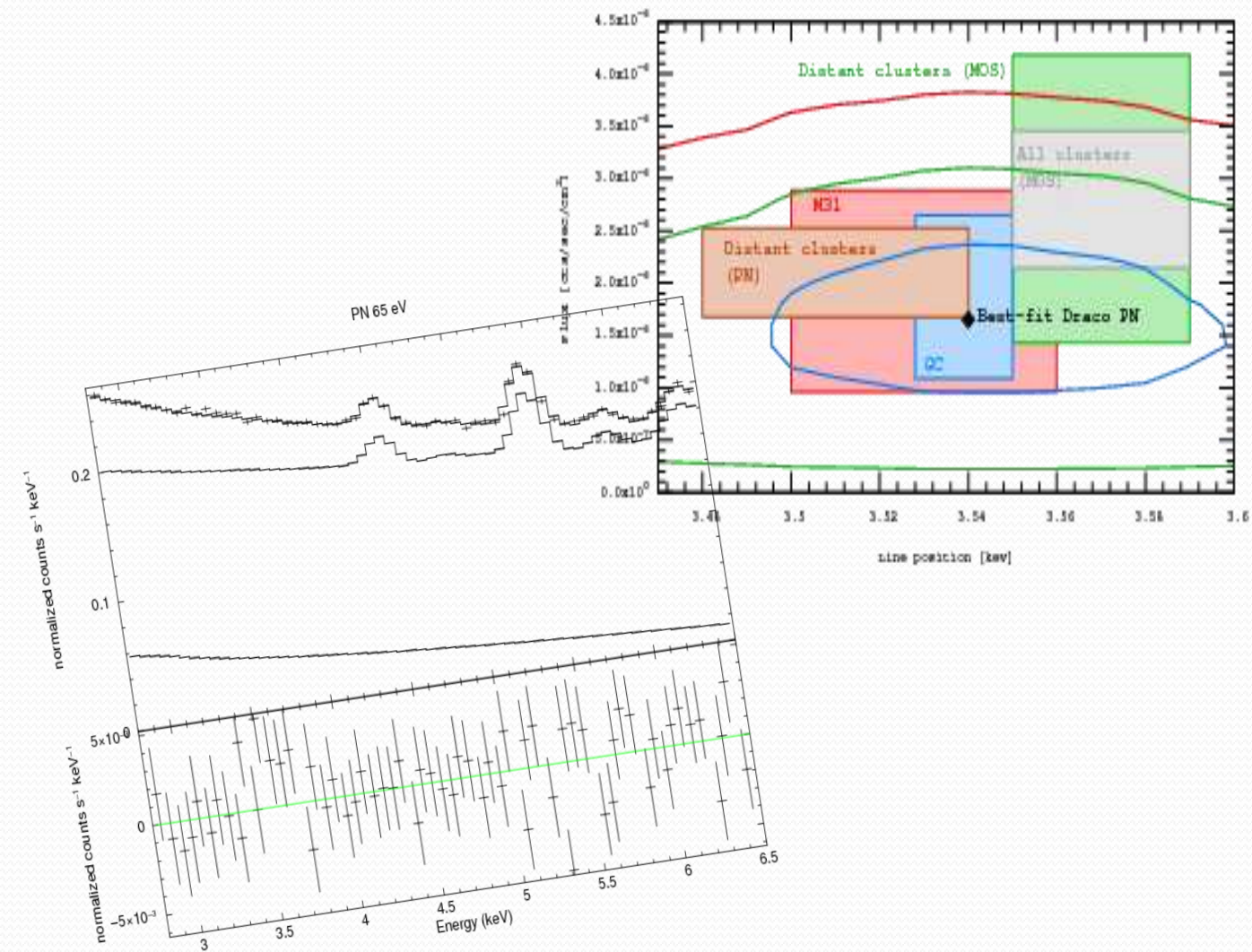


IC bounds

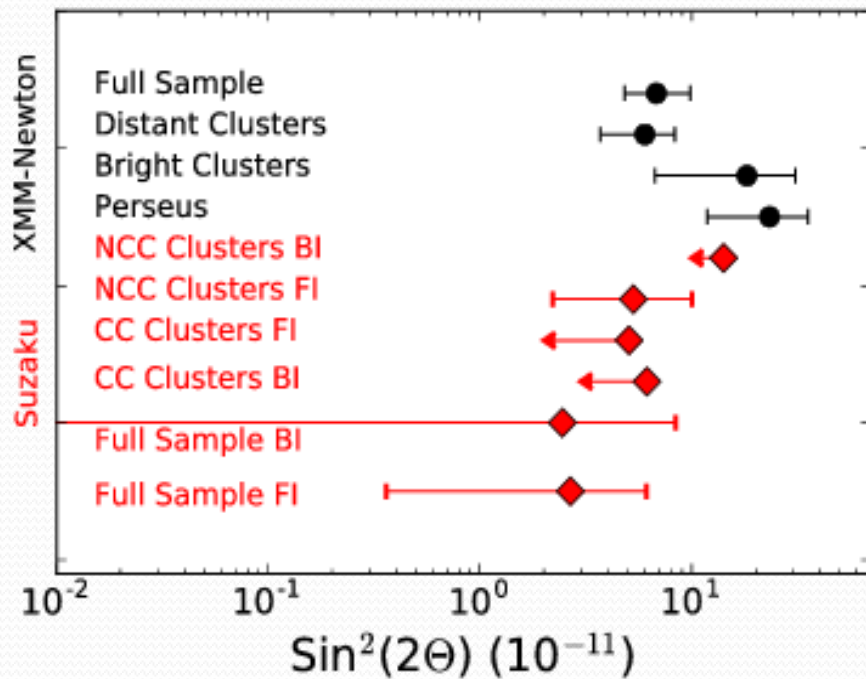


WDM sterile neutrino ?

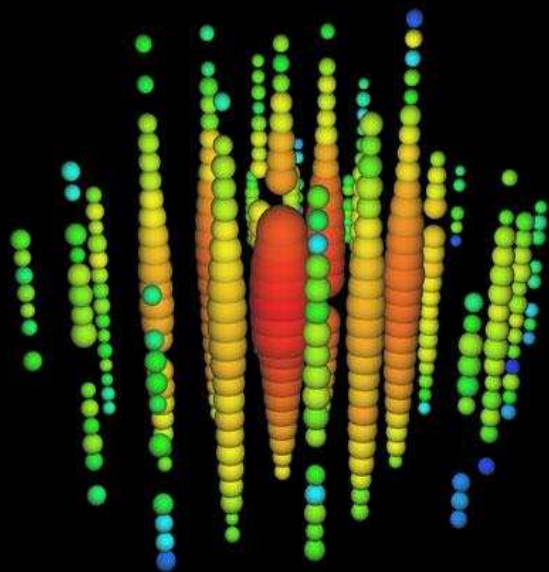
3.5 keV γ -line



More bounds



Cosmic Neutrinos



Cosmic neutrinos

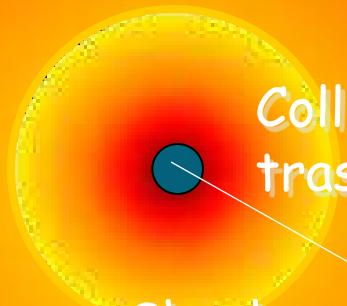


Cosmic neutrinos

The background of the slide features a series of smooth, flowing, wavy lines in various shades of blue and white, creating a sense of movement and depth. The lines are layered, with some appearing in the foreground and others receding into the background, giving the overall design a three-dimensional feel.

Bigger than “big bird”

Supernova neutrinos



Collective flavor transformation

Shock wave effect on conversion

MSW flavor conversion inside the star

Propagation in vacuum

Oscillations inside the Earth

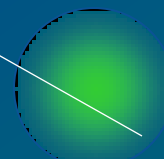
With known 1-3 mixing all MSW transitions are adiabatic

Collective neutrino flavor conversion ; More and more complications. Toy models.

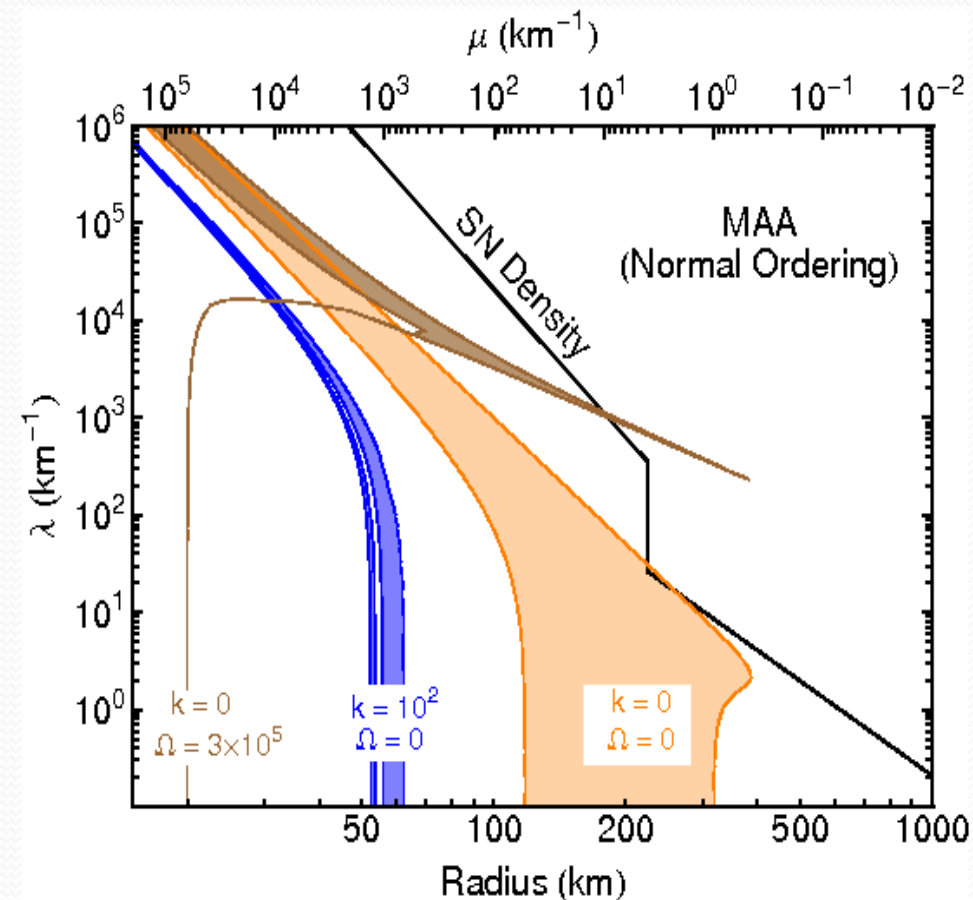
Instabilities in flavor evolution: develop or suppressed?

Spatial and temporal instabilities

Determination of the mass hierarchy



Supernova neutrinos



Behind neutrino mass



A framework



...continued

Two kinds of new physics

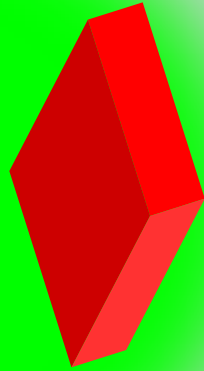
Set-up

Patrick Ludl A.S

CKM

Neutrino

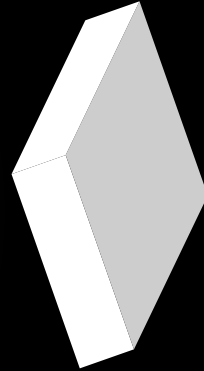
SM $\rightarrow$
SO(10)



G_{Yukawa}

Visible
sector

G_{basis}



Portal

G_{basis}

G_{portal}

fermions $\{1_S^i\}$
bosons $\{1_H^j\}$

G_{hidden}

Hidden
sector

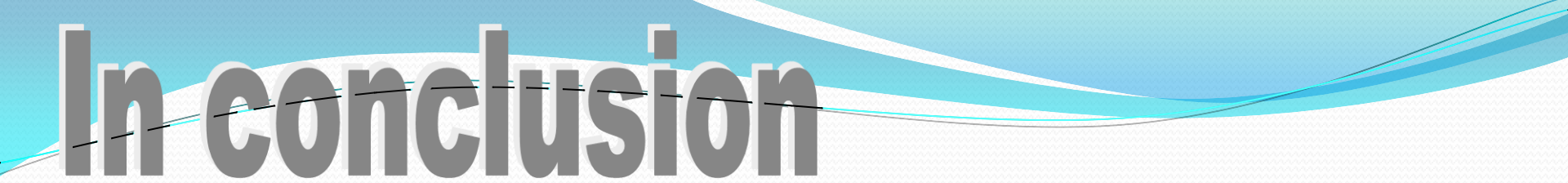
Scheme

The header features a decorative design with several wavy lines in shades of blue and white. A red dashed line runs diagonally across the top right corner.



Schemes

In conclusion





General relation

Setup

