

# Discussion

## **SINERGIA: the first two years, and the third year**

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# Experimental and theoretical study of neutrino oscillations: exploring new physics beyond the Standard Model of Elementary Particles

*Enhancing the leadership of Switzerland in neutrino physics through a coherent and coordinated action among researchers*

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Applicants: Prof. S. Antusch, Prof. A. Blondel (PI), Prof. A. Ereditato, Prof. A. Rubbia (PI), Prof. M. Shaposhnikov

**NB:** It is not all about 'oscillations', actually, but about *massive neutrinos*

**Since then (but we kind of knew):**

the Daya Bay and  $\theta_{13}$  revolution

the Higgs-and-nothing-else (ongoing) revolution

**less easy to anticipate:**

the European strategy and P5 report

the CERN neutrino platform

The main objectives of the next three years will be as follows:

1. Exploitation and analysis of T2K and NA61/SHINE data (UniBe, ETHZ, UniGe)
2. Contribution to the LAGUNA-LBNO design study and preparation of a proposal: near and far detector design, physics studies, detector R&D (UniBe, ETHZ, UniGe).
3. Study of the impact of measurements of neutrino mixing parameters, in particular the neutrino mass hierarchy, on model building beyond the Standard Model (BSM) (UniBs)
4. Sterile neutrino search, study of possibilities at the CERN LBNO facility, and comparison with other proposed facilities (EPFL).

The total request amounts to 3.2 MCHF over three years, mostly dedicated to support of researchers and students working in close collaboration on the project.

**awarded: 1.8 MCHF**

**T2K common fund, travel to shifts and T2K work**

**Manpower to all groups (fraction of 3 years for one person)**



# Theoretical motivation

Discovery of the 126 GeV Higgs boson → Triumph of the Standard Model  
The SM may work successfully up to Planck scale !

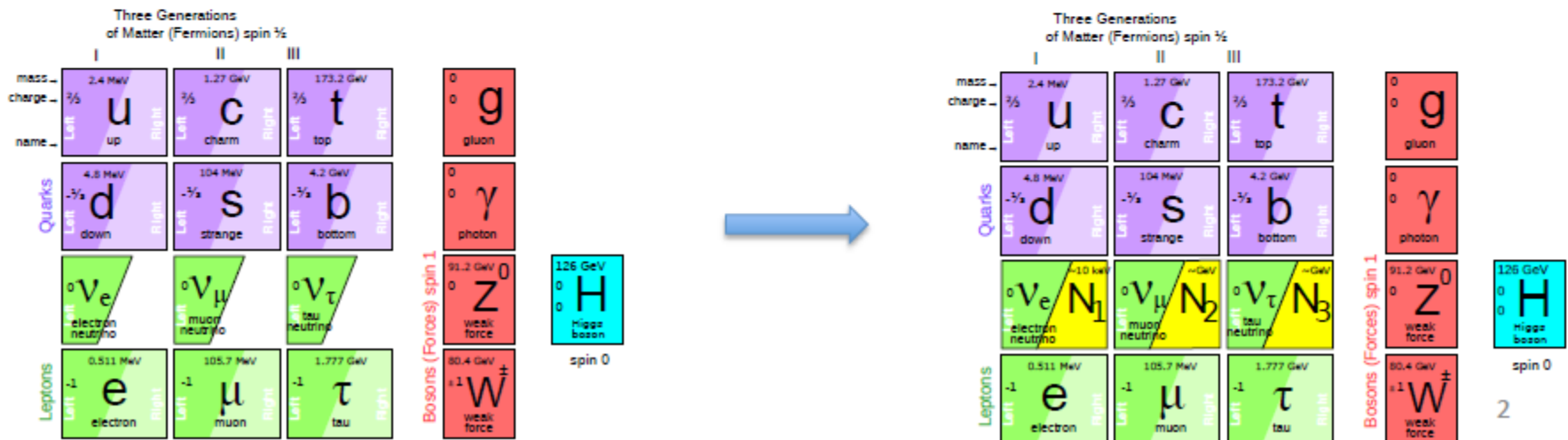
**This is a real shift in paradigm!**

SM is unable to explain:

- Neutrino masses
- Excess of matter over antimatter in the Universe
- The nature of non-baryonic Dark Matter

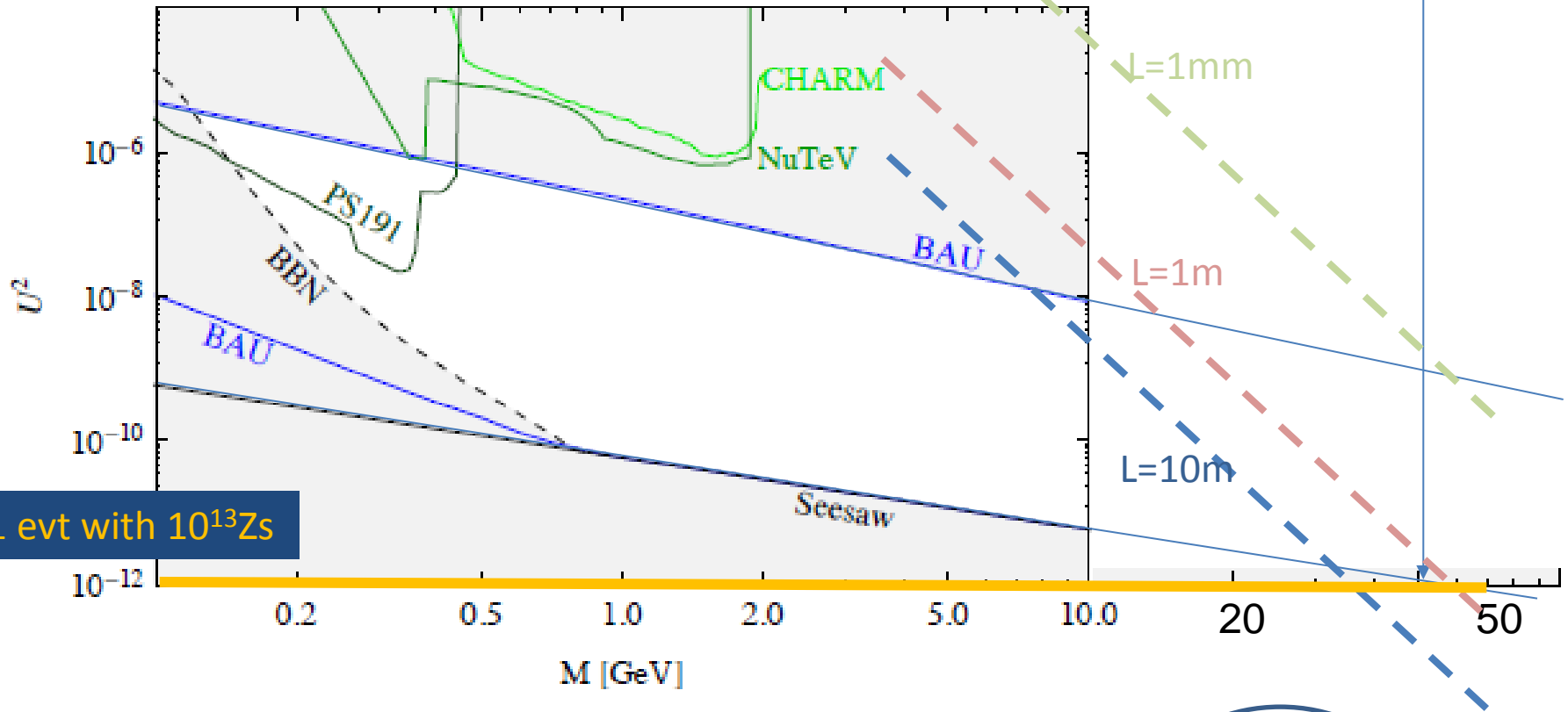
All three issues can be solved by adding three new fundamental fermions, right-handed Majorana **Heavy Neutral Leptons (HNL):  $N_1, N_2$  and  $N_3$**

**$\nu$ MSM: T.Asaka, M.Shaposhnikov PL B620 (2005) 17**



# Decay length

Interesting region  
 $|U|^2 \sim 10^{-9}$  to  $10^{-12}$  @ 50 GeV



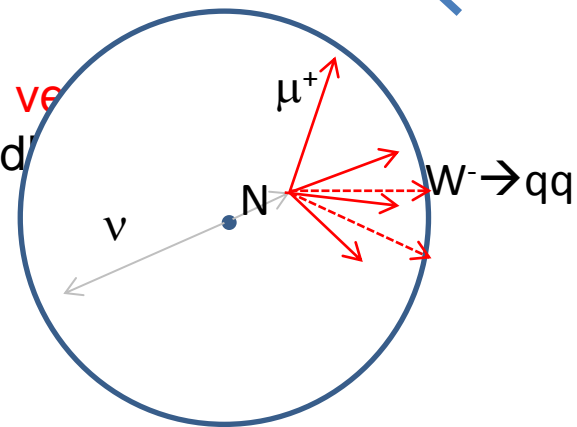
~1 evt with  $10^{13}$ Zs

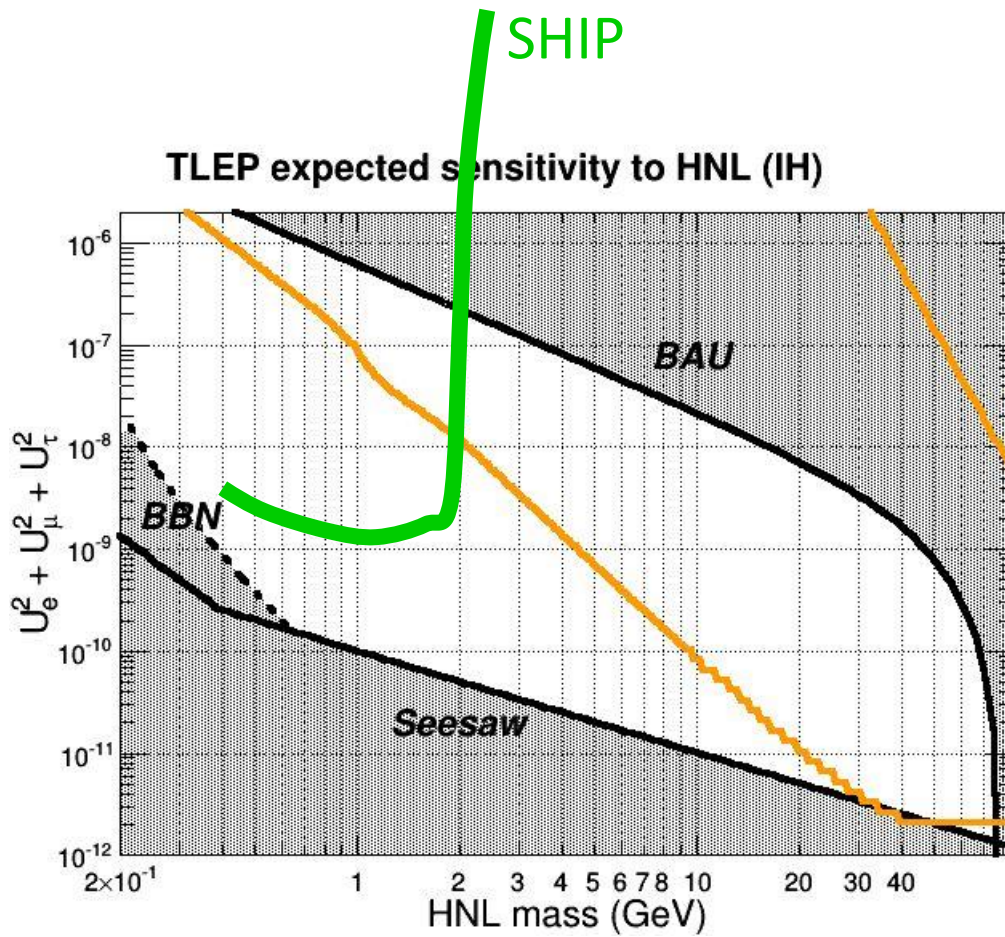
heavy neutrino mass  $\sim M$

a large part of the interesting region will lead to detached vertices

...  $\rightarrow$  very strong reduction of background

Exact reach domain will depend on detector size and details of displaced vertex efficiency & background





$N_Z = 10^{13}$

$N_Z = 10^{13}$   $100\mu m < L < 5m$

*Elena Graverini, Nicola Serra*

## A short recall of where we stand

### External events:

the Daya Bay and  $\theta_{13}$  revolution

the Higgs

the European strategy, ICFA neutrino panel, P5

### Internal events

T2K cross-section paper, 5 sigma app., disappearance, sterile analysis

T2K upgrade proposals: WAGASCI, nuPRISM

T2HK proposal to JPARC PAC submitted. EU-HyperK meetings. TITUS.

NA61/SHINE : 2007 papers , 2009 analysis almost finished for tT, LT

2010 needs manpower! next is numi target, possibly miniBOONE?

LBNO status : EOI submitted, WA105 approved, C2PY not, but

invitation to submit LBNF proposal to Fermilab in early 2015

Sterile neutrino search at Fermilab (microboone) soon to start

LAr1-ND extension

SHIP proposal

**WE ARE ASKED TO PRODUCE A WHITE PAPER ON  
NEUTRINOS IN SWITZERLAND BY ~NOVEMBER**

Also FCC study (relationship to neutrinos!)



## Complementarity

### -1- HyperK is the natural continuation to T2K

We have invested in NA61, and in the near detectors of T2K

It is the most sensitive proposal for the observation of CP violation in neutrino oscillations

and for a large part of underground physics

(proton decay, atmospheric, solar and supernovae neutrinos)

.... and the most straight-forward technology

### -2- it is not complete however and there is a physics case

for a complementary experiment that would determine

unambiguously the value of  $\delta_{CP}$  and the mass hierarchy,

complete the observations of oscillations involving tau

leptons and matter effects  $\rightarrow$  {LBNO; LBNE} .

This requires a more sensitive technology (Liq. Argon) , in need

of R&D and experience (and probably a longer time scale)

The path is not unique and includes focused R&D (WA105)

and application + experience on running experiments (microboone)

## A few important questions:

We have many excellent ways to go in front of us.

We need to streamline enough to have impact

... but not too much so that we don't end up painting ourselves in a corner.

### 1. make best return on investment and acquired competence on NA61/T2K

NA61 results, 2010 and further use? (NUMI, BOONE, LBNF) (we can't drop this!)

T2K analysis

T2K upgrades **if** justified (e.g. WAGASCI?)

*T2HK follow up and project*

### 2. make best use of R&D excellence and investments

CERN neutrino platform, WA105

MICE-EMR-babyMIND

Single phase LArg → microboone

Double Phase LArg → **LBNF** (*relation with T2HK?*)

### 3. make best use of SINERGIA «beyond the 3 active neutrinos»

SHIP, FCC-ee etc...

**PRIORITIES?**