Summary WG1 (I): Pheno

S. Choubey and P. H.

WG1 @ Nufact08

- Focussed sessions…lots of discussion
- Many questions…some answers
- We learnt something about what we know and about what we do not

Why we are here ?

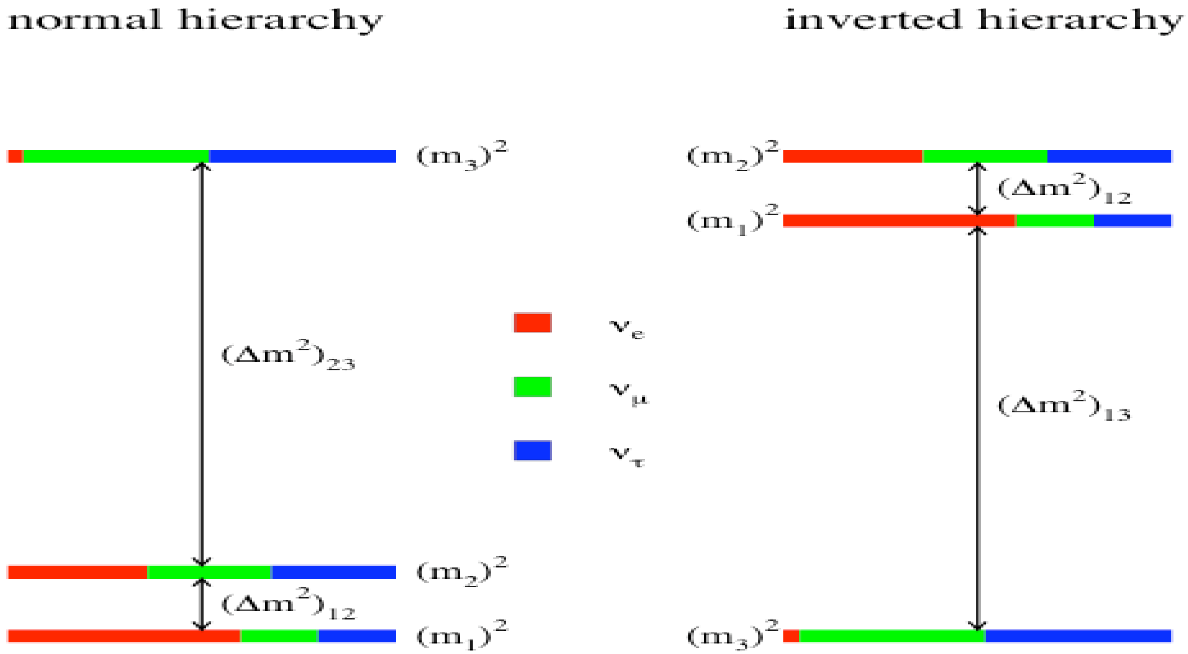
Neutrino masses imply a new physics scale Λ ? What ?

➢If $\Lambda >> v$ there is an explanation of why ν are so light

$$\mathcal{L} = \mathcal{L}_{SM} + \underbrace{\sum_i \frac{\alpha_i}{\Lambda} O_i^{d=5}}_{\nu \text{ mass}} + \underbrace{\sum_i \frac{\beta_i}{\Lambda^2} O_i^{d=6}}_{e,\mu \text{ dipole moment,etc}} + \underbrace{\ldots}_{\text{NSI}}$$

➢If $\Lambda << v$ no explanation of why ν are so light, but "hidden" sector could be related to other fundamental questions: dark matter, dark energy,...

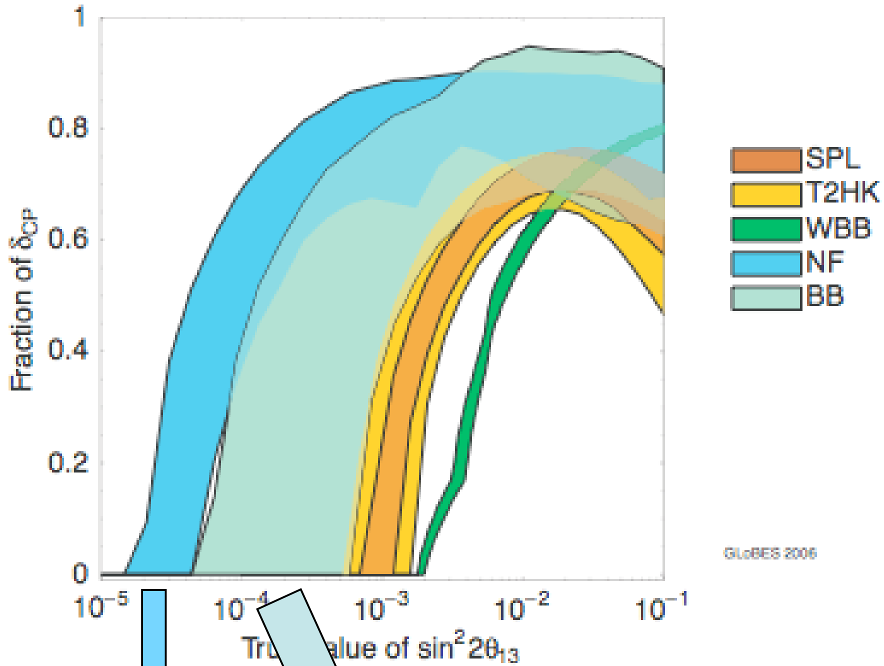
We have a good chance to learn something more about this new physics with neutrino and other flavour physics experiments by testing the Standard scenario



Masses	Angles	CP-phases
$m_1^2 < m_2^2, m_3^2$	$\theta_{12},\theta_{23},\theta_{13}$	$\delta, \alpha_1, \alpha_2$

Physics potential ISS report

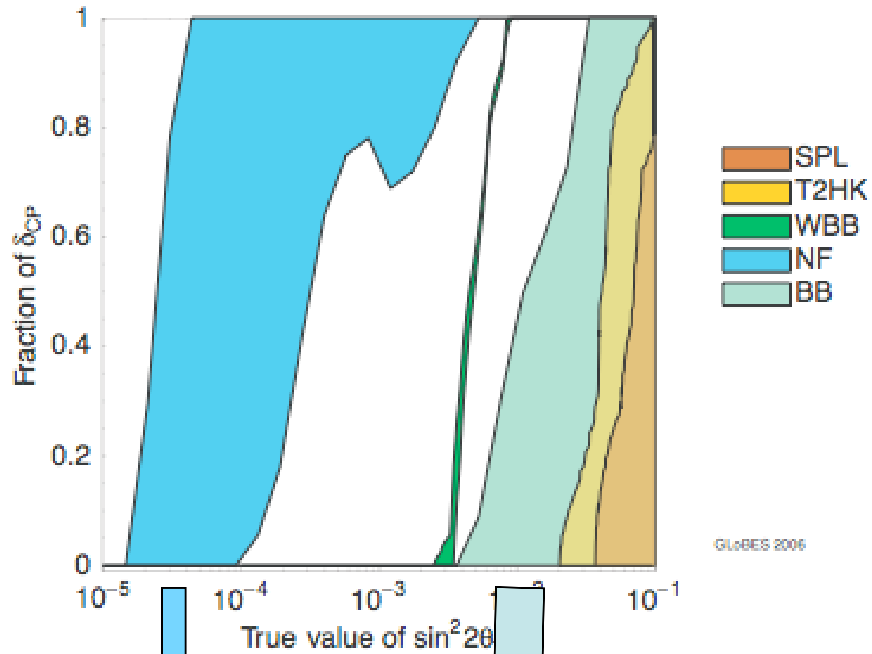
CP phase



One baseline!

Two baselines!

Hierarchy



Lower energy

Higher energy

Upgrading β-beams

To improve on the hierarchy larger E, L needed:

Li/B at γ=350 : $E_{max} \sim \gamma E_0$

New detector technology…

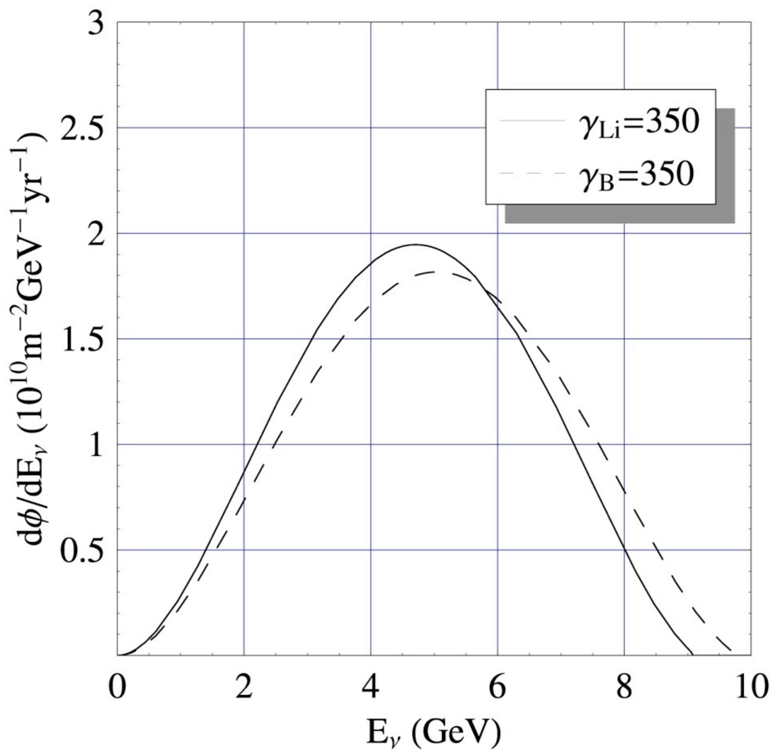
MIND, TASD detector …

less mass

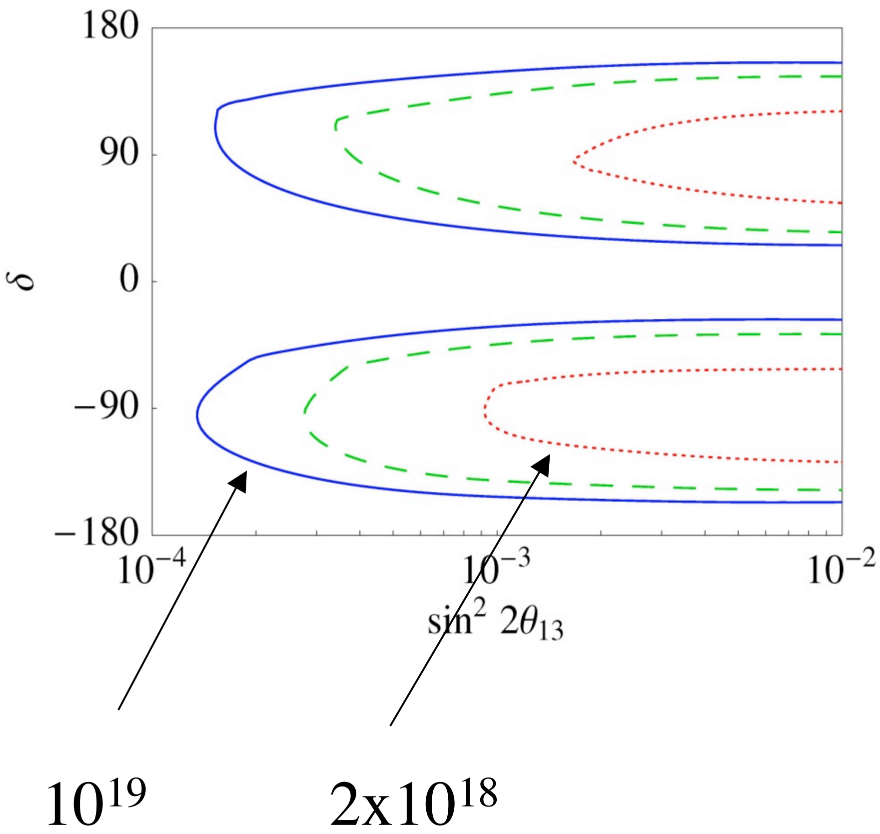
Two baselines:

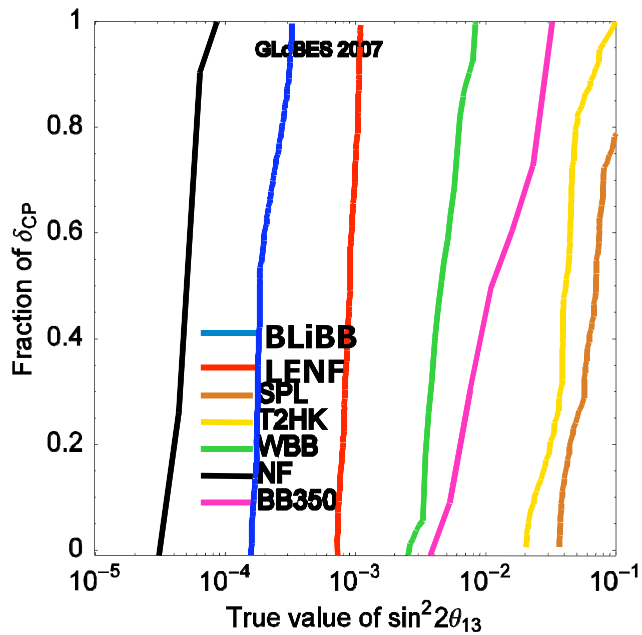
L=7000km magic

L=2000km peak



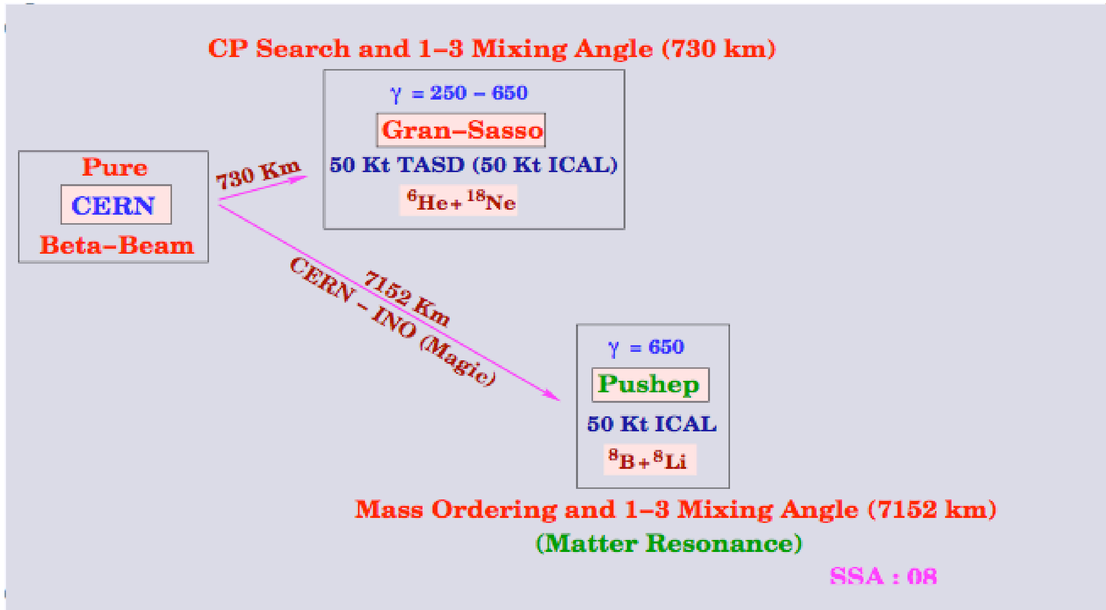
@MIND type detector





Fernández-Martínez

10^{19} needed ballpark for this game !

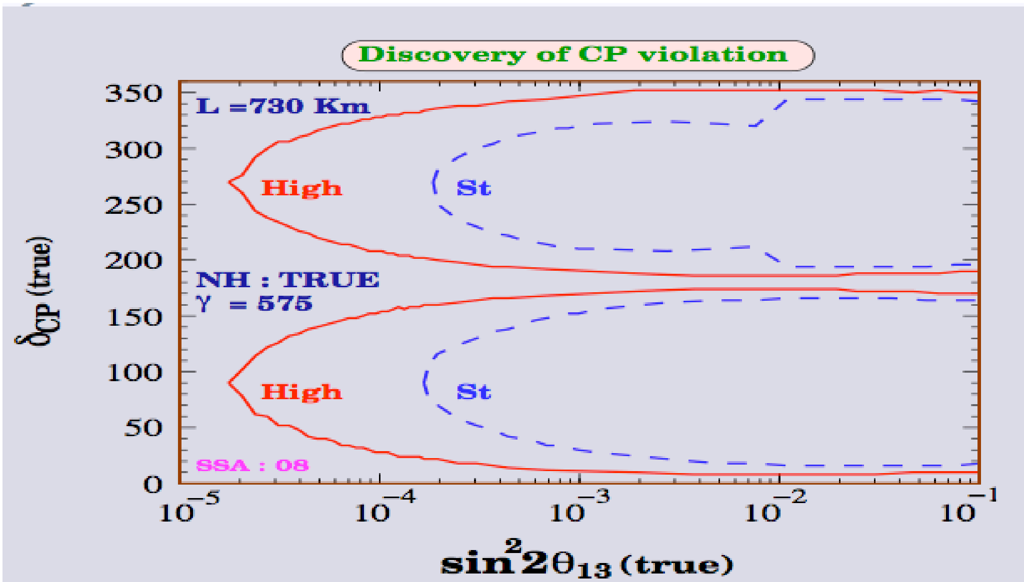


Agarwalla

700km+7000km

Even larger γ

Unbeatable!



β–beam $\gamma = 350$ and/or 10^{19} ions…

Are we crazy ?

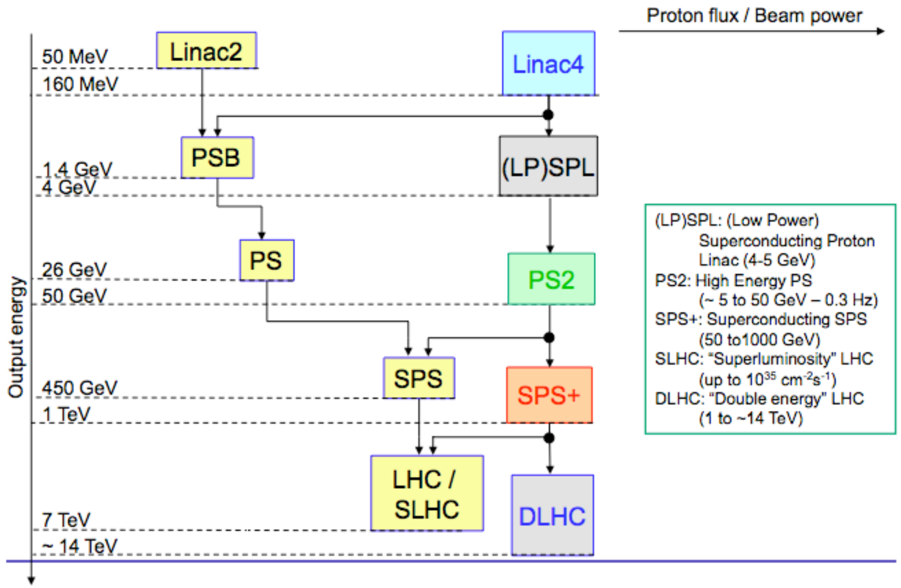
It seems not (completely) yet… from joint session WG1-WG3

By changing ions we change end-point energy E_0

Physics-reach scaling law:
$$\frac{N_\beta^{(1)}}{N_\beta^{(2)}} \simeq \left(\frac{E_0^{(1)}}{E_0^{(2)}}\right)^2 , \quad \frac{\gamma^{(1)}}{\gamma^{(2)}} \simeq \frac{E_0^{(2)}}{E_0^{(1)}}$$

Or γ/N_β duality…

It could indeed fit in LHC upgrades…



STAGE	1	2	3	4
DESCRIPTION (*new accelerator*)	*Linac4* PSB PS SPS	*Linac4* PSB *PS2 or PS2+* (& PS) SPS	*Linac4* *SPL* *PS2 or PS2+* SPS	*Linac4* *SPL* *PS2 or PS2+* *SPS+*
Performance of LHC injectors (SLHC)	+ Ultimate beam from PS	++ Ultimate beam from SPS	++ Maximum SPS performance	+++ Highest performance LHC injector
Higher energy LHC	-	-	-	+++
beam	-	-	++ (~150 ^{6}He)	++ (~350 ^{6}He)
Factory	-	-	+++ (~5 GeV prod. beam)	+++ (~5 GeV prod. beam)
k,	-	~150 kW beam at 50 GeV	~400 kW beam at 50 GeV	~400 kW beam at 50 GeV
EURISOL	-	-	+++	+++

If the $$$ machines are there, probably one can do something about other difficulties...

- x10 ion production
- Decay ring
- Activation issues...

⇨ Greenfield scenarios will be considered within the new EuroNu design study (to the extent that manpower permits)

Downgrading β-beams

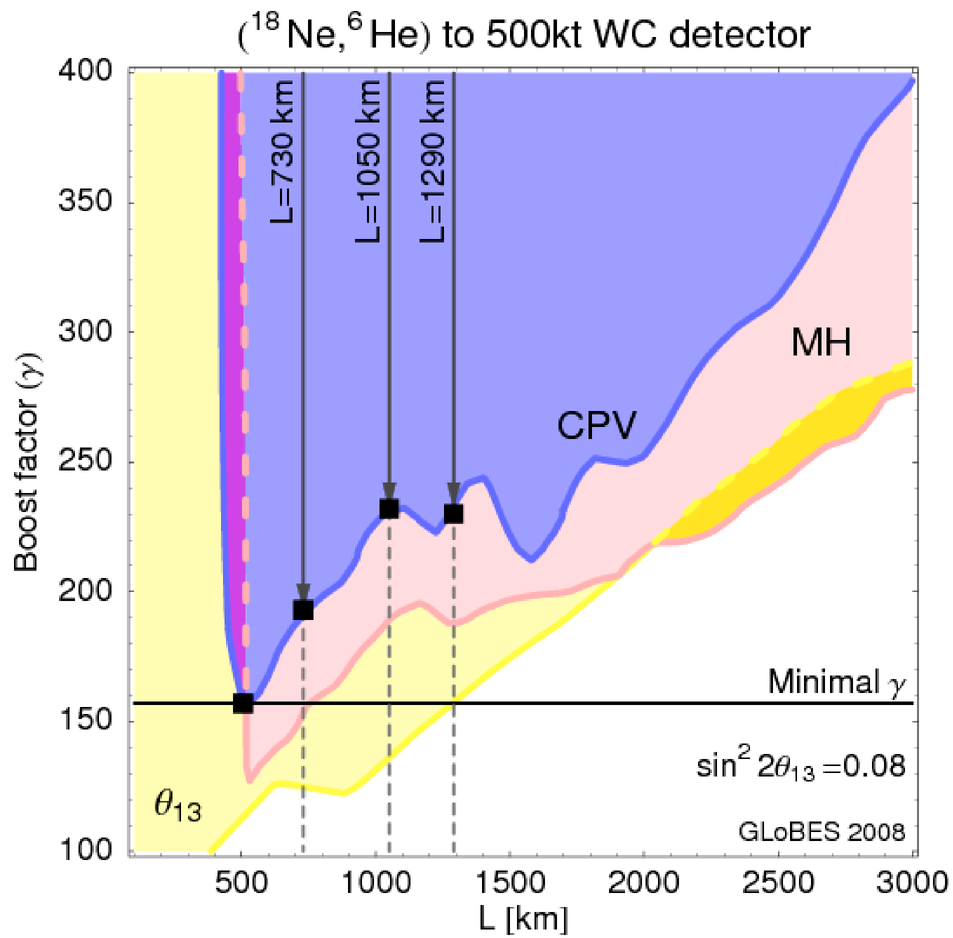
What if θ_{13} is large (ie within 90% D-Chooz reach) ?

W. Winter`s wish list and question

- 5σ independent confirmation of $\theta_{13} > 0$
- 3σ mass hierarchy determination for any (true) δ_{CP}
- 3σ CP violation determination for 80% (true) δ_{CP}

What is the minimal β–beam for that?

Winter



Standard γ=350, He/Ne β-beam seems to be near optimal but not a particularly downgraded version therefore…

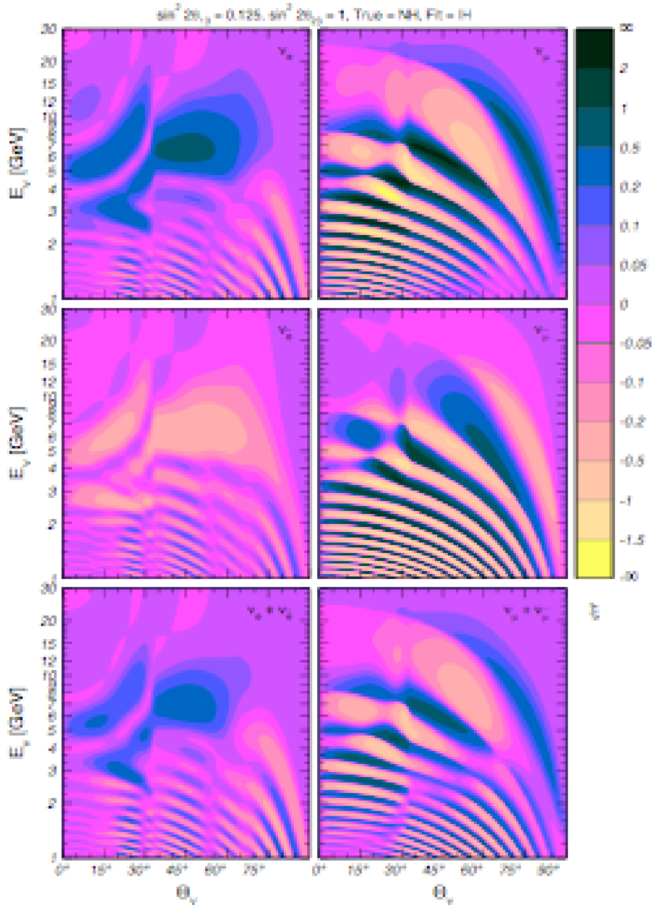
Other physics with 100Kton-> Megaton detectors ?

(i) Atmospheric data for free: must be included in all analyses!

Eg. Hierarchy :

Maltoni

ν_e



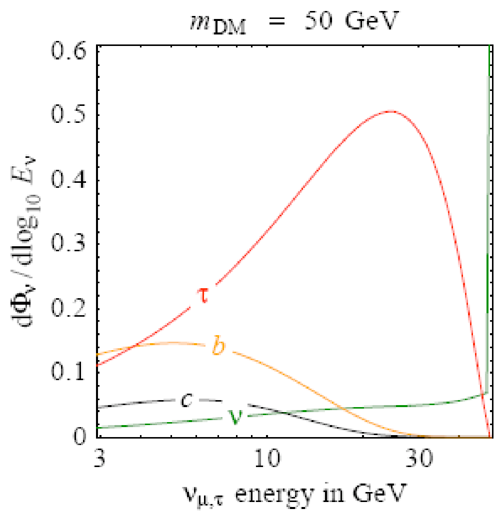
ν_μ

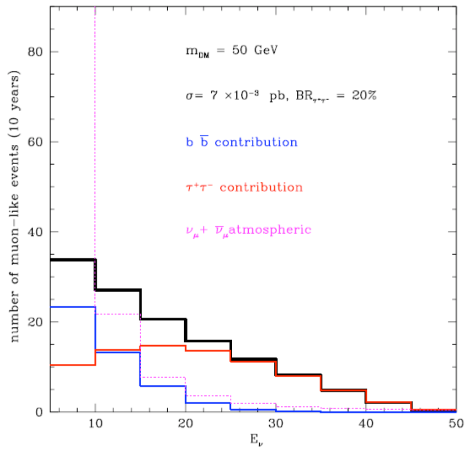
Optimization of WC analysis is foreseable and most welcome!

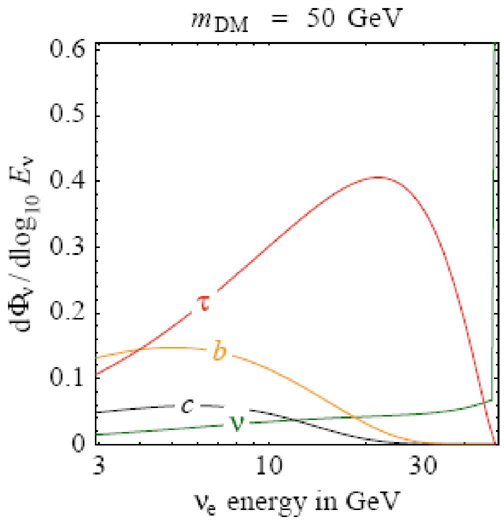
(ii) Solving dark-matter degeneracies

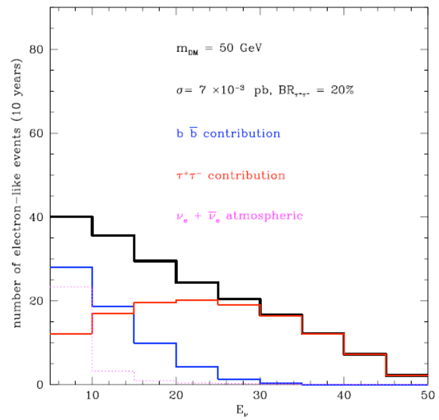
Neutrino spectra at MIND from dark matter annihilation can discriminate between decay channels

Palomares-Ruiz



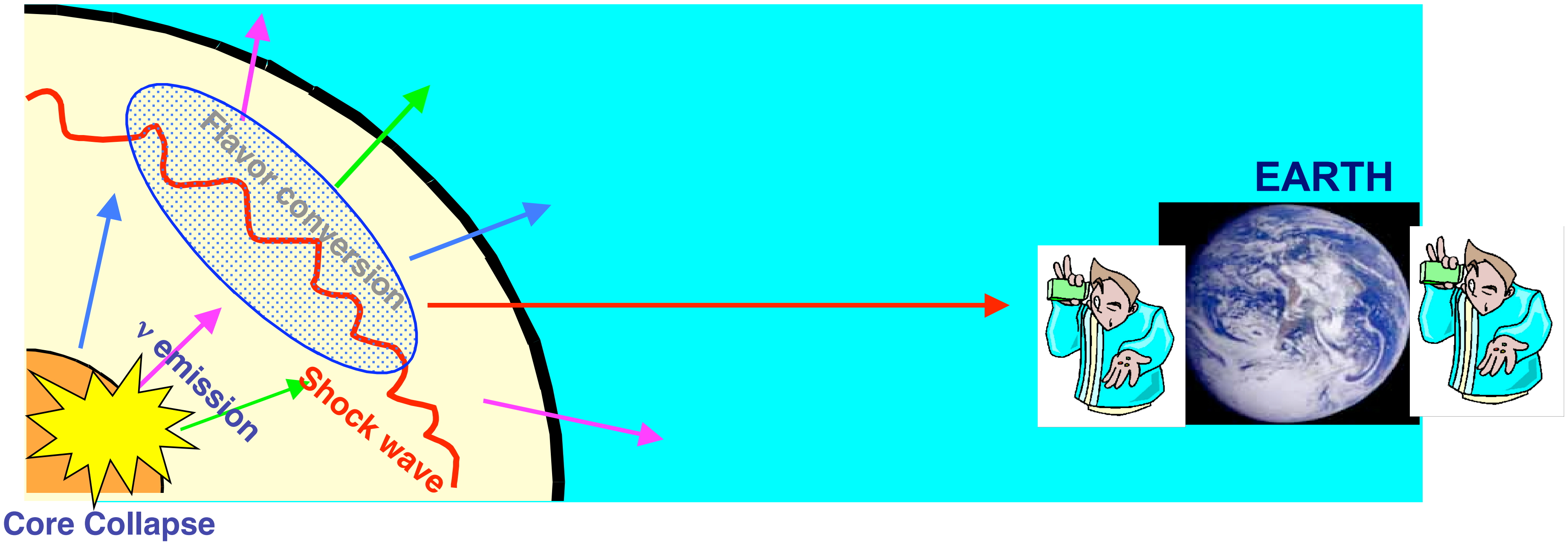






(iii) Supernova neutrinos

Mirizzi



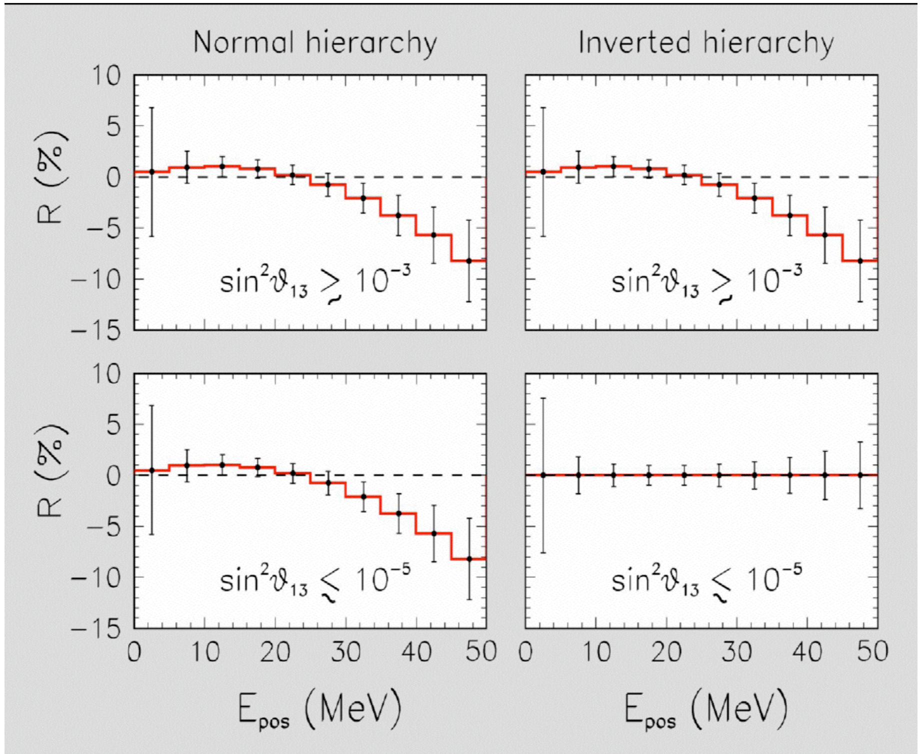
- **Claim:** Maybe possible to determine neutrino mass hierarchy at extremely small θ_{13} using galactic supernova neutrinos.

- **Effect:** Crucially dependence on the mass hierarchy of <u>collective neutrino oscillations</u> in SN

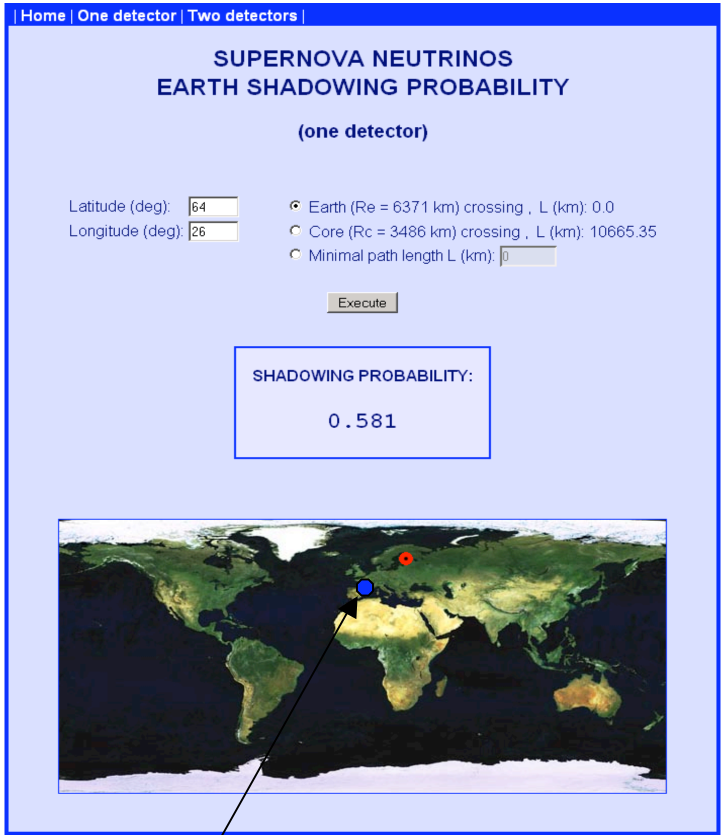
- **Strategy:** Using Earth matter effect to diagnose collective SN neutrino flavor transitions

(iii) Supernova neutrinos mass hierarchy at small θ_{13}

Galactic SN @ 10 kpc by 2003(15): Ratio of spectra in two 0.4 Mton WC detectors, one shadowed by the Earth, the other not



Mirizzi



Canfranc's shadowing prob=0.568

More on the downgraded LE Nufact

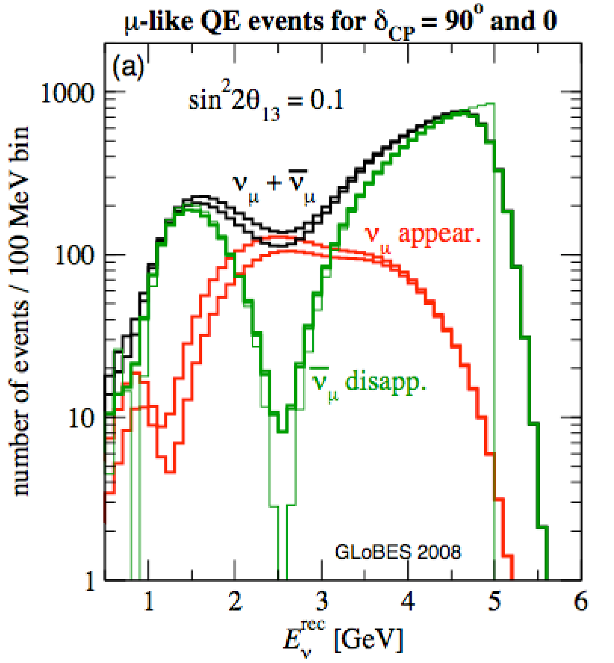
$N_\mu = 10^{21}\ y^{-1}$ E_μ = 5GeV L= 1290 km

Huber

What if we used a non-magnetized detector ?

WC, LAr become alternatives…

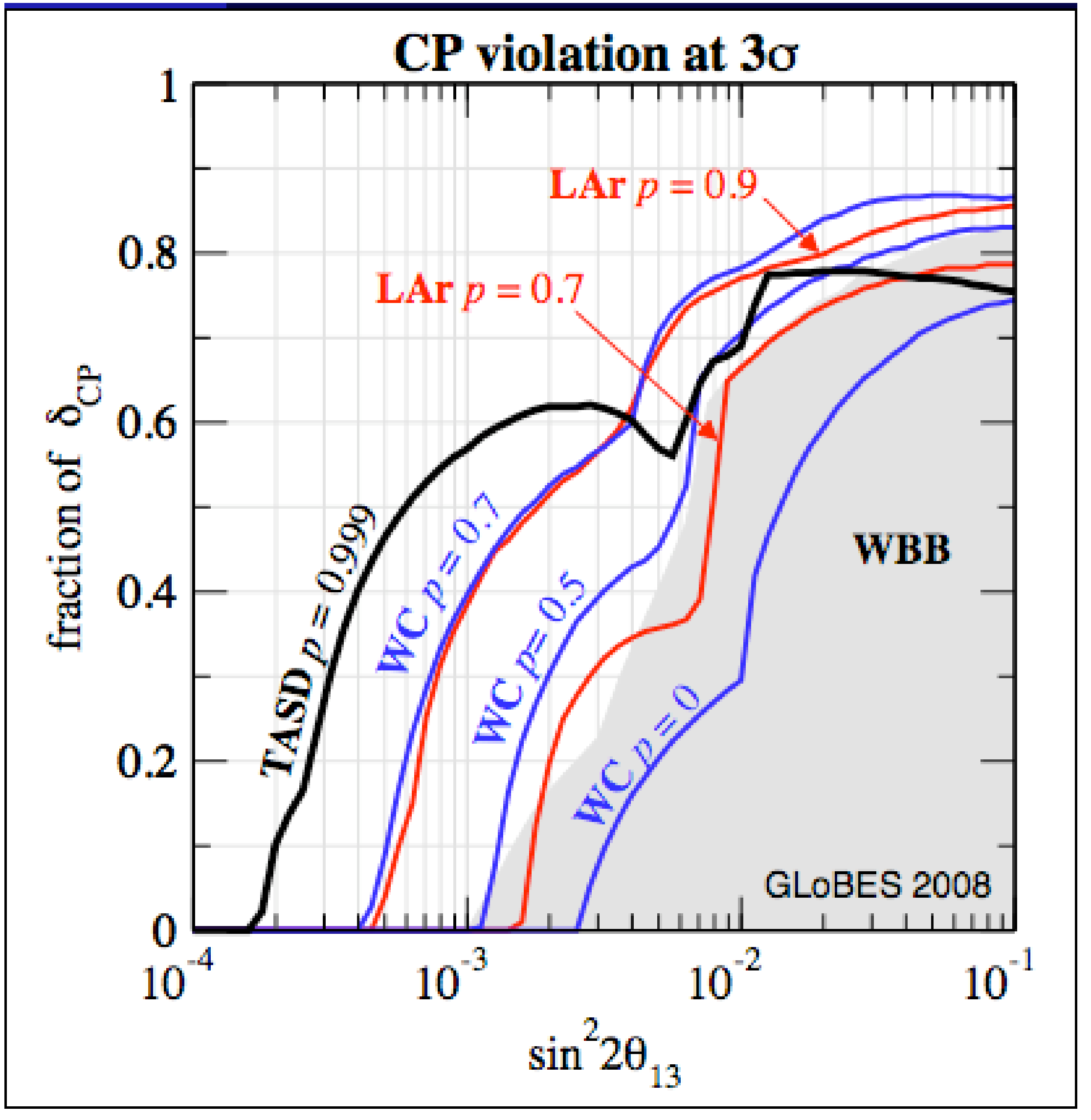
Discrimination between ν/ν still possible to some extent:



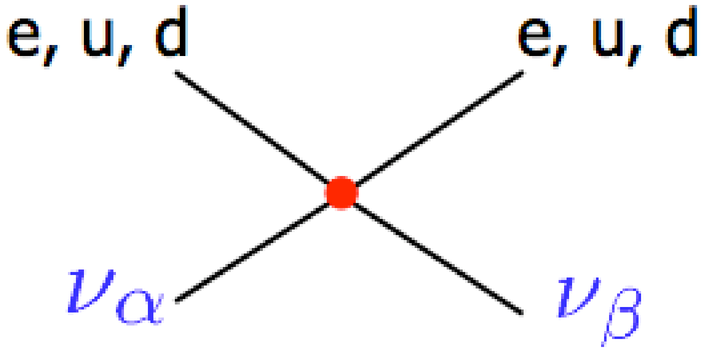
But also:

- μ decay vs. capture
- Angular dependence
- n tagging

Some more GloBES curves…



Non-standard ν interactions



$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{\alpha_i}{\Lambda} O_i^{d=5} + \sum_i \frac{\beta_i}{\Lambda^2} O_i^{d=6} + \ldots$$

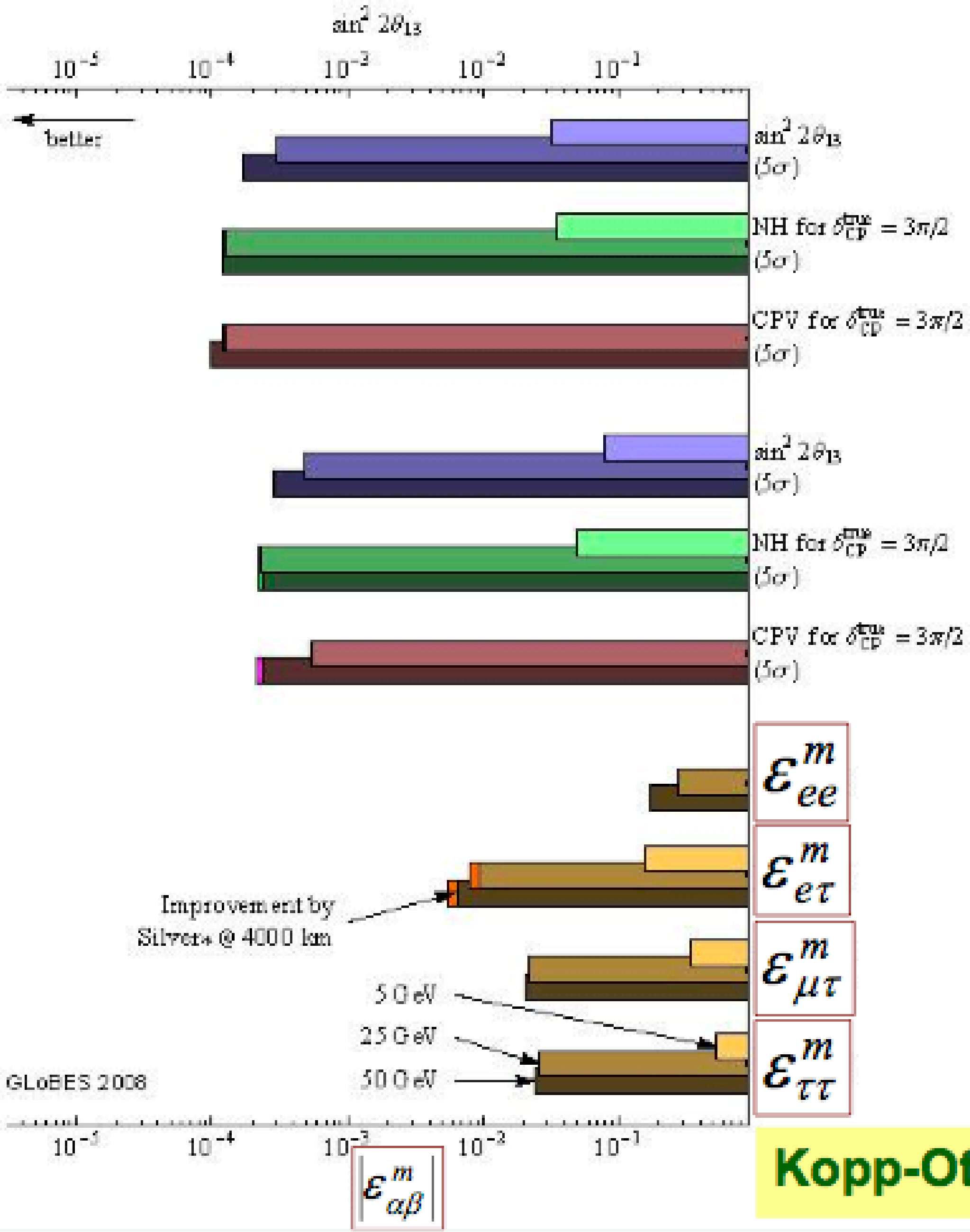
Eg: d=8 $\quad \bar{f}\left(H^\dagger \gamma^\rho P_L L_\beta\right)\left(\overline{L}_\alpha \gamma_\rho P_L H\right) f$

- First preliminary SK analysis on the subject ! Mitsuka
- Future constraints from Opera Esteban-Pretel,Blennow
- Future constraints from Nufact Uchinami, Ota's poster

If combining baselines was necessary to resolve degeneracies in the 3ν family case, it is even more important if there are NSI…

Sensitivity at ν factory

Statistical + systematic errors + some correlations of errors + some correlations of errors



$\sin^2 2\theta_{13}$ reach
no NSI

$\sin^2 2\theta_{13}$ reach
fit including $\epsilon^m_{e\tau}$

$|\epsilon^m_{\alpha\beta}|$ reach (@3σ)

Kopp-Ota-Winter, 0804.2261v1 [hep-ph]

It will be important to continue exploring what type of generic new physics the future facilities could access:

- Non-standard interactions
- Low see-saw scale: EW, or even lower
- Exotic explanations of LSND, dark matter, dark energy

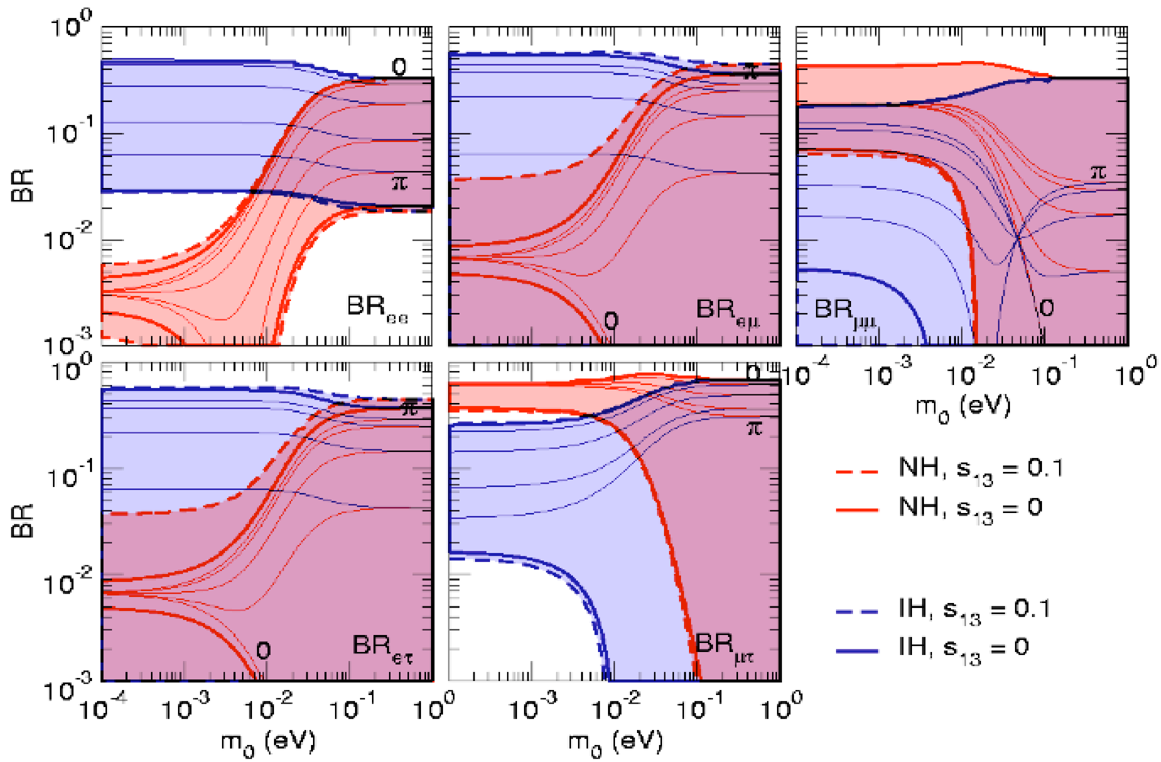
We could expect that the old faithfull ν will continue to bring in surprises…

One example...

Garayoa

See-saw II:Pair-production of charged triplet scalars at LHC

$BR(H^{++} \to l_a^+ l_b^+) \sim |M_{ab}|^2$



LHC, ν oscillation physics complementarity !