WG5 questions and plans: "Neutrinos beyond PMNS"

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Proposal from Alain and Kobayashi-san

WG5, 'Neutrinos Beyond PMNS'

TOPICS and QUESTIONS *could* cover the following :

-- general discussion, motivation and, possibly, rationalization of models beyond PMNS

-- experimental searches for right handed neutrinos

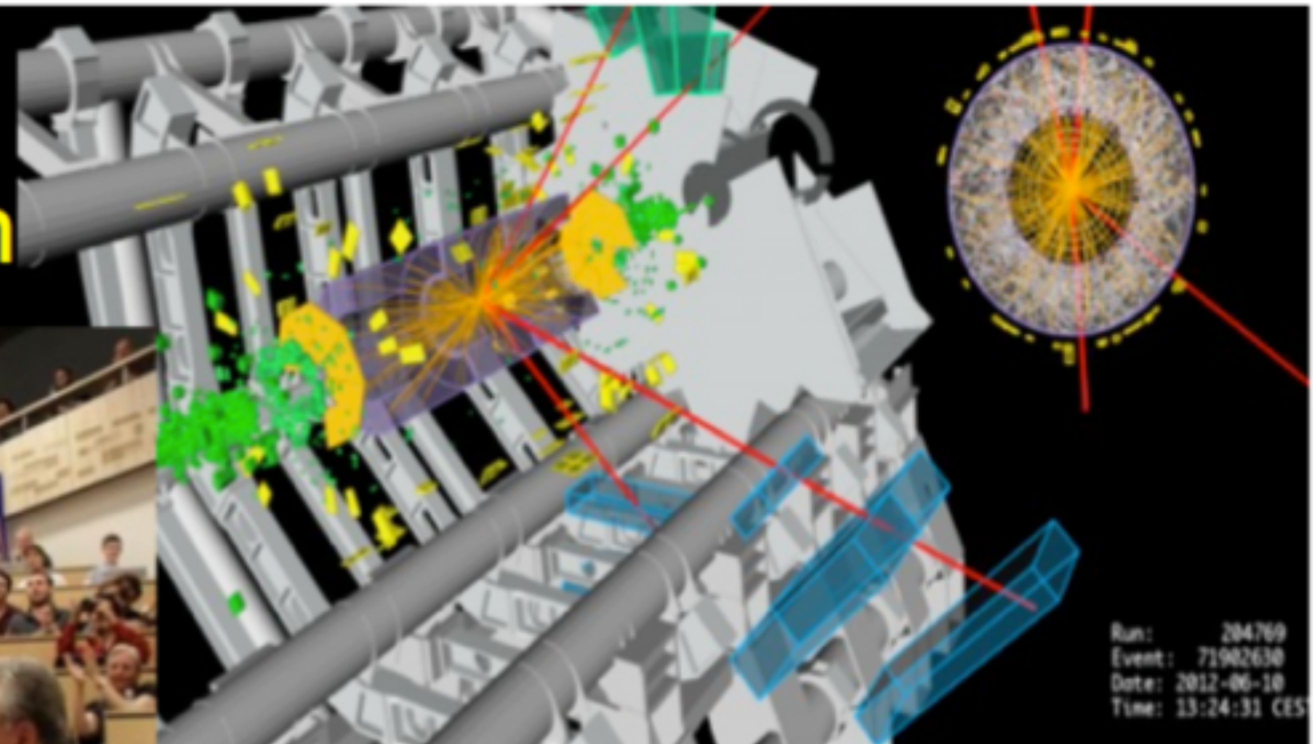
- -- nuclear decays and galactic emissions (no emphasis)
- -- short baseline oscillations
- -- observation of neutral decays in beam dump experiments and neutrino beams
- -- observation in e-e- colliders (W-W- final state)
- -- observation in Z and Higgs factories
- -- observation at hadron colliders LHC, HL-LHC and SppC and FCC-hh
- -- unification of interpretation framework

-- other beyond PMNS, NSI, etc.

Indeed emerging picture in HEP more and more supporting WG5-like studies (as Alain pointed out also in his plenary talk this morning)

…a few slides stolen from I.Shipsey's (thanks!) summary talk at ICHEP (I was not there…) follow

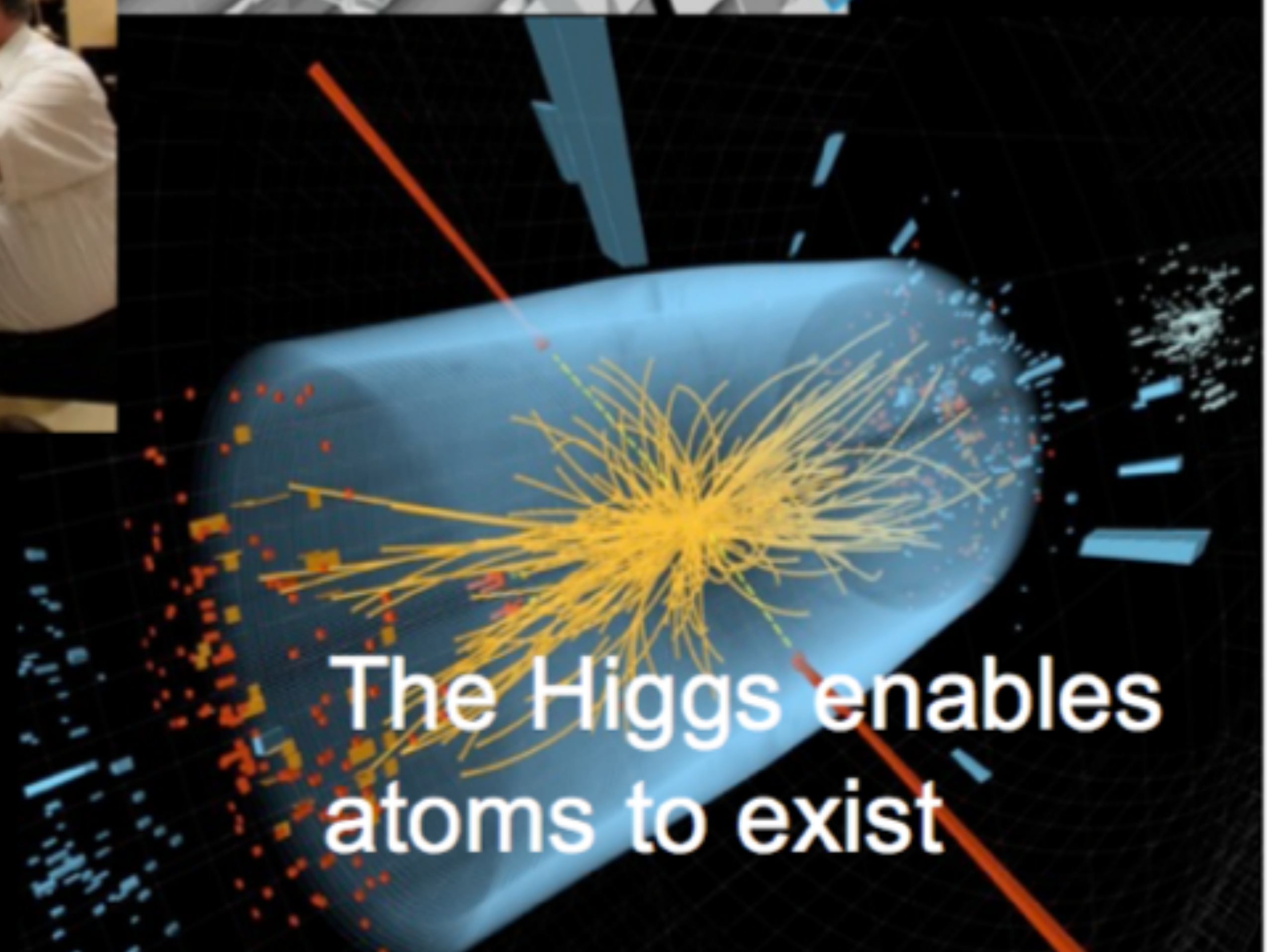
2012.7.4
discovery of Higgs boson



theory : 1964

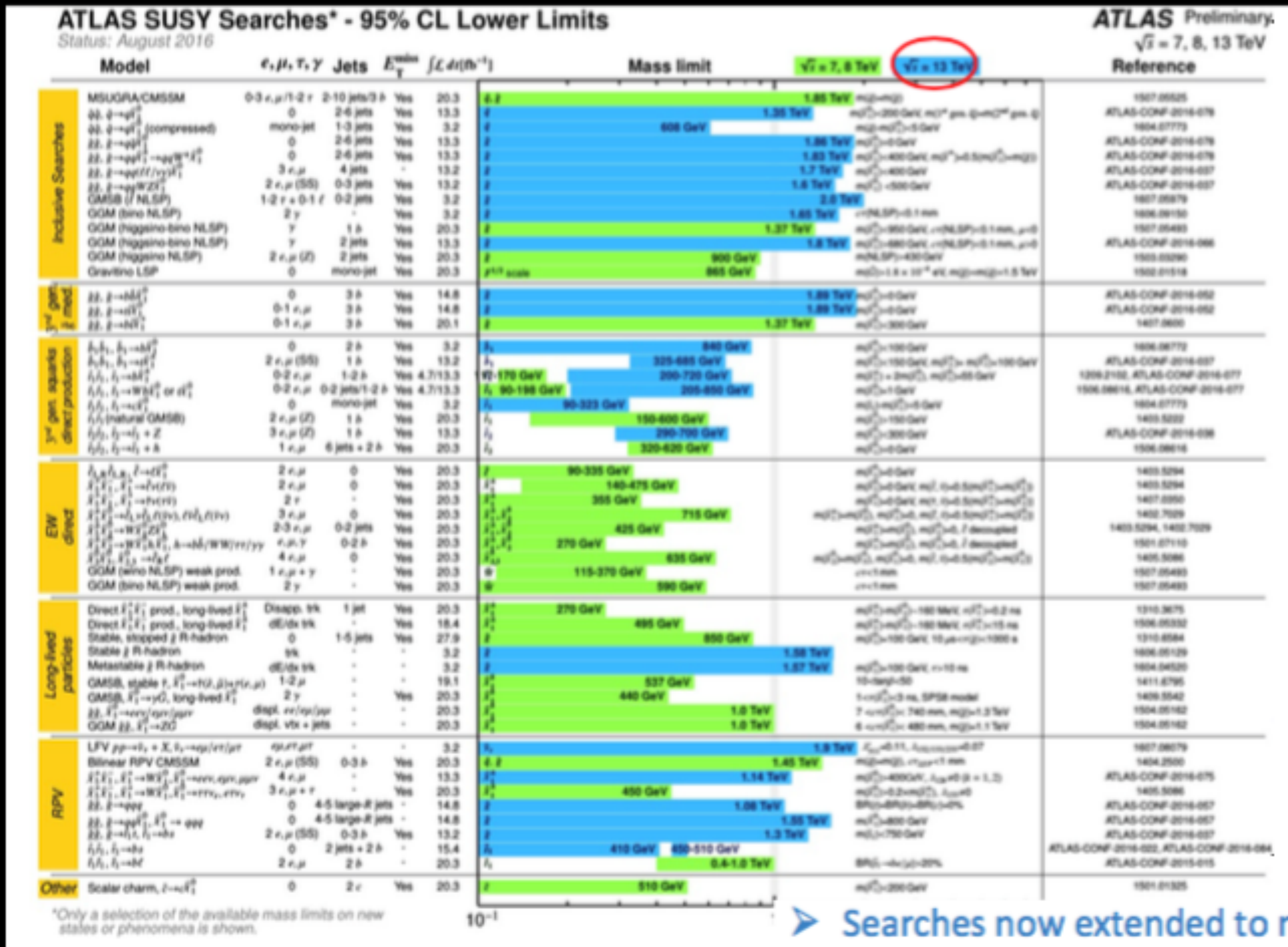
design : 1984

construction : 1998



However…

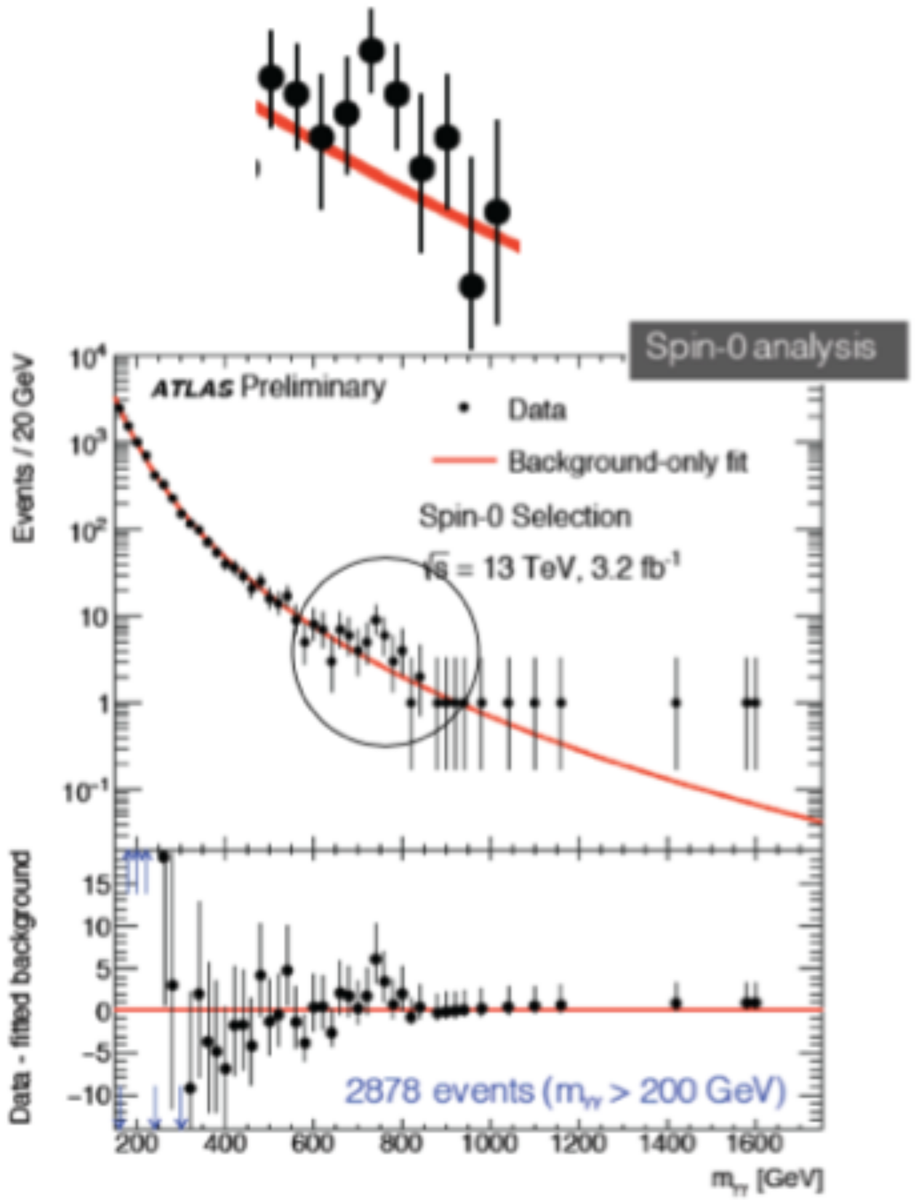
Run 2 SUSY Searches

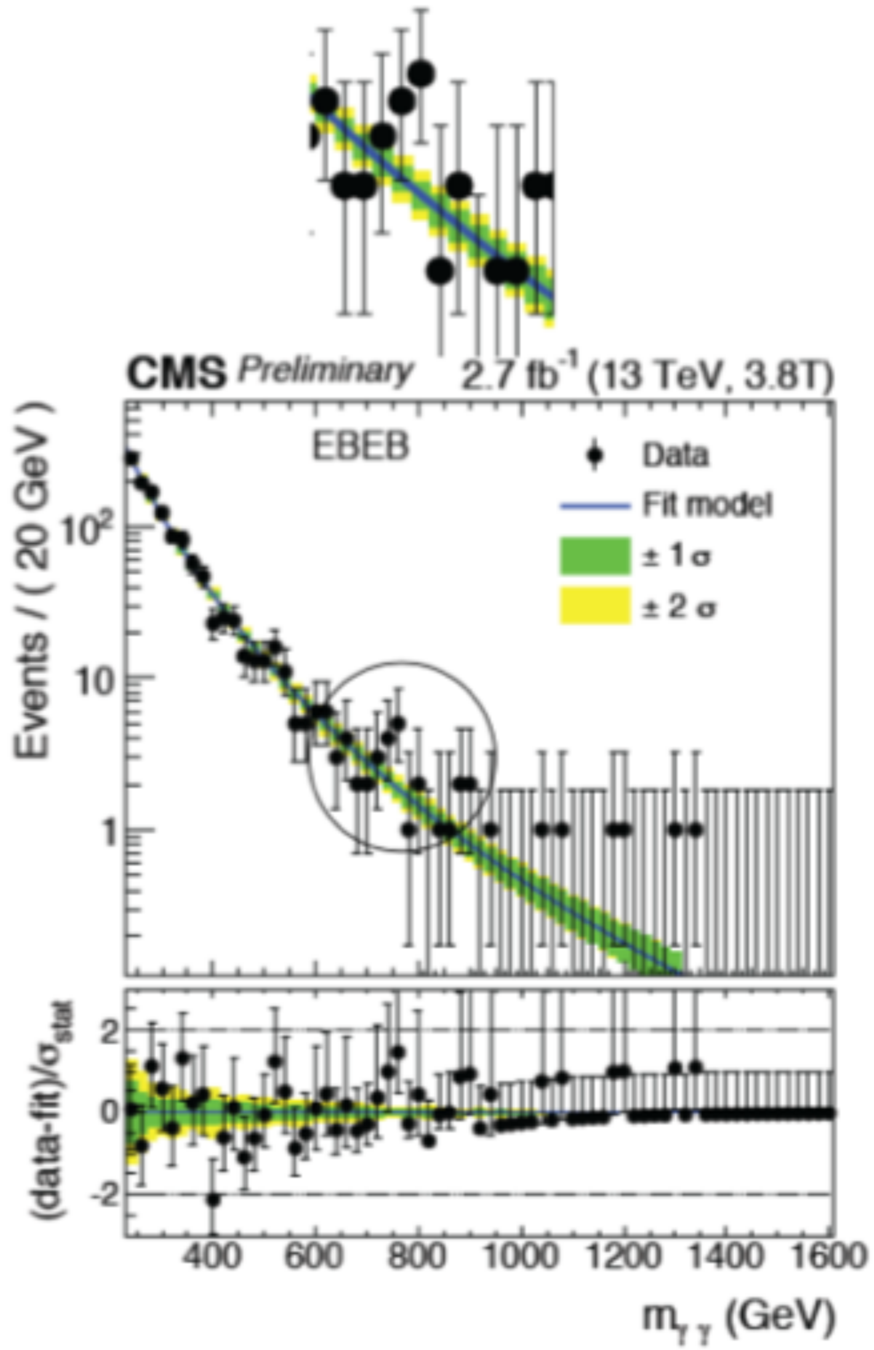


- Searches now extended to more challenging scenarios
  - Electroweak production, compressed mass spectra, …
  - Can expect many more after end of 2016 data taking!
- Mass limits (in simplified model spectra!)
  - pushed to about 1.9 TeV (gluinos) and 900 GeV (top squarks); limits on EW production even for small mass differences

Some hopes…

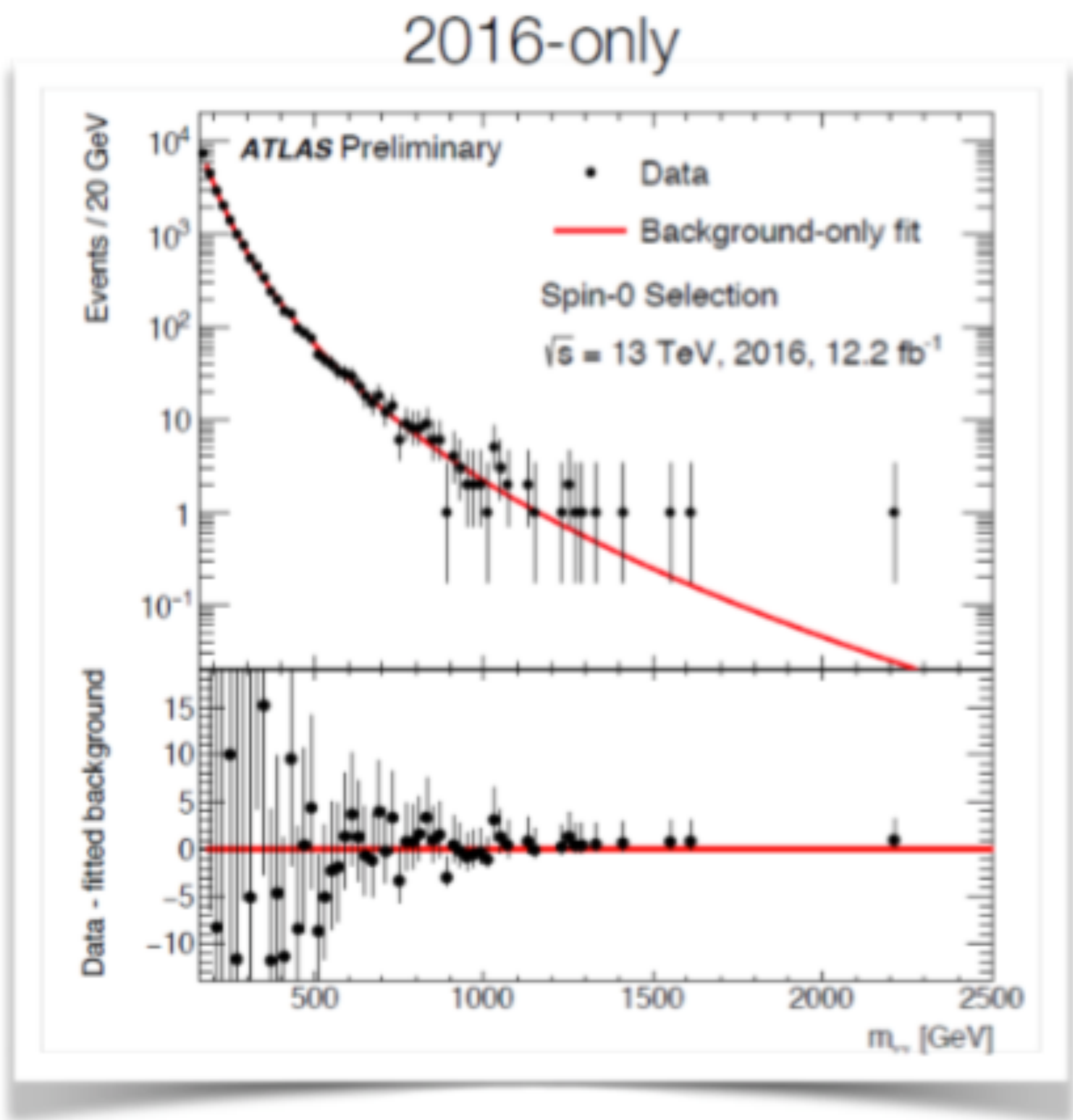
ATLAS and CMS searches for di-photon resonances

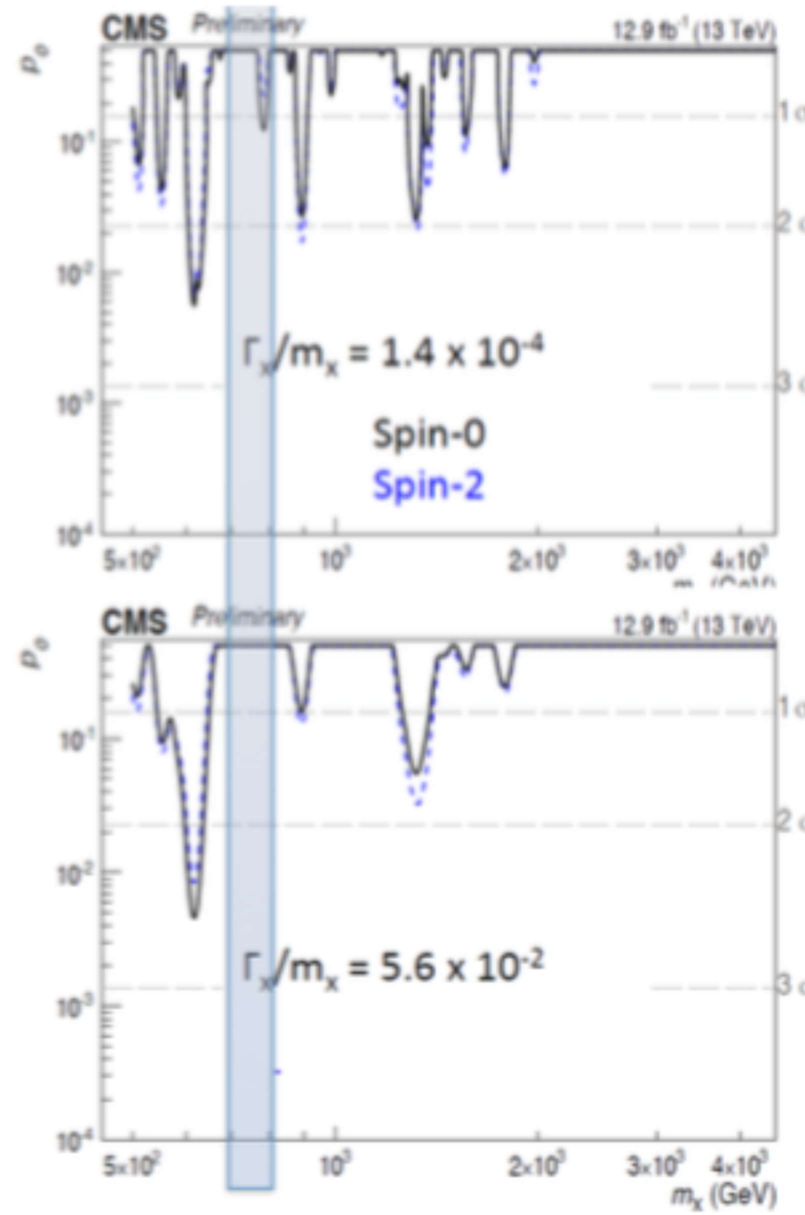




not realized…

New data @ ICHEP 2016:

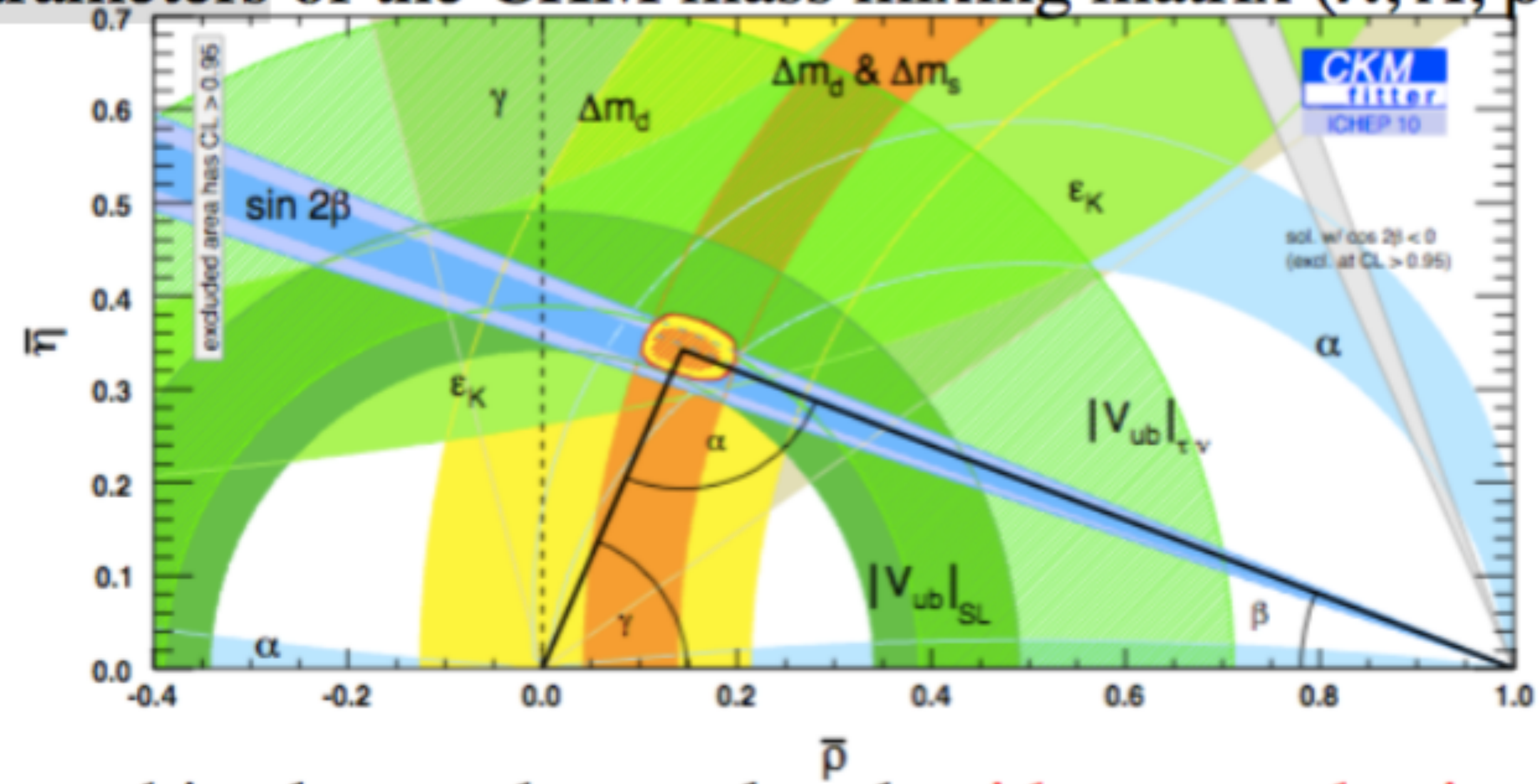




Quark flavor physics

Triumph of the CKM description

- All the flavour changing processes are described by the four parameters of the CKM mass mixing matrix (λ, A, ρ, η)



- From this plot, we know already either new physics energy scale is >> TeV (far beyond LHC) or the flavour structure of new physics is very special.

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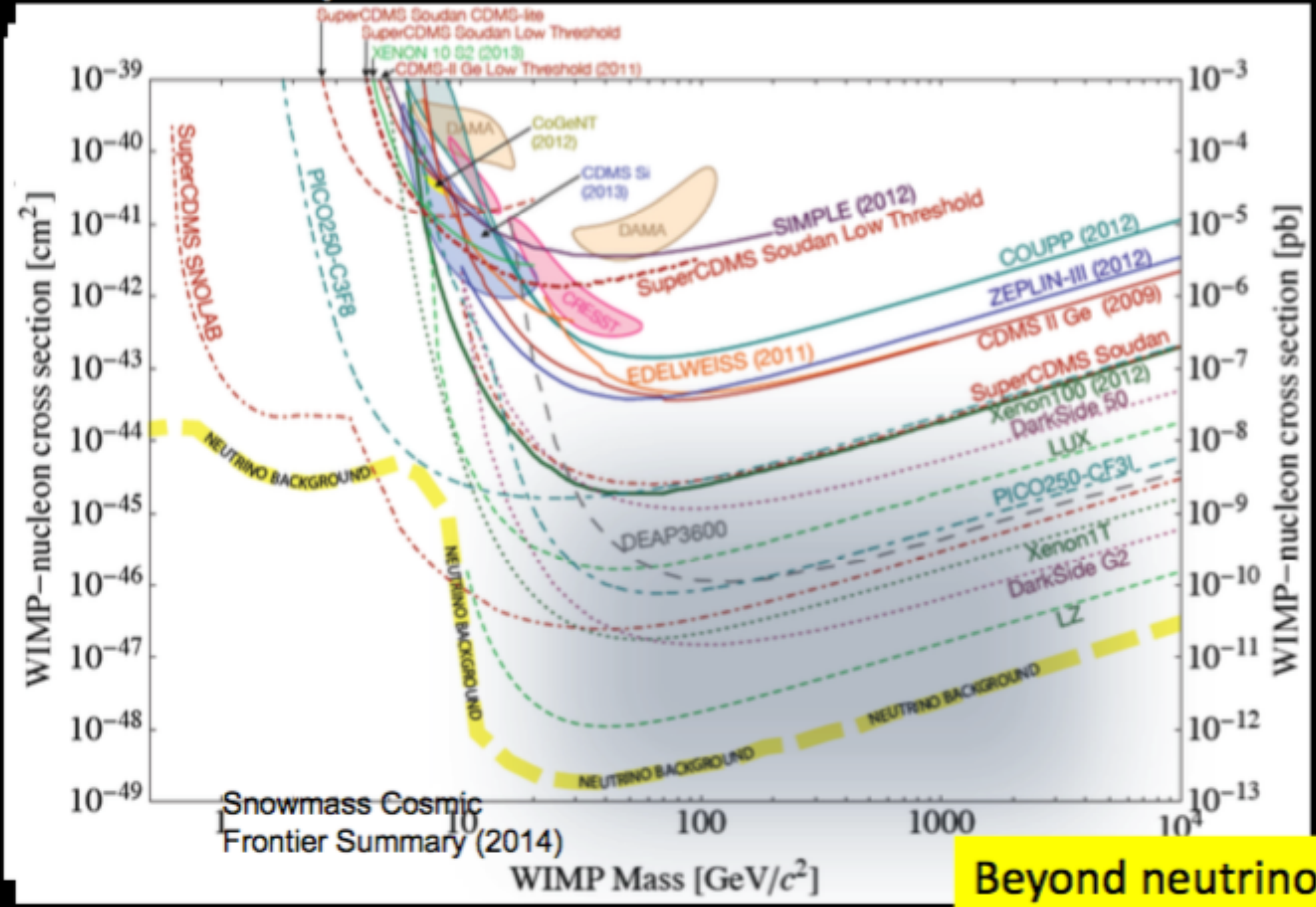
DIRECT DETECTION: STATUS AND PROSPECTS

- Since 2010, sensitivity improved by ~100 (for m ~ 100 GeV)
- Further improvements by 2-3 orders of magnitude expected by a suite of experiments world-wide



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Beyond neutrino floor directional detection needed

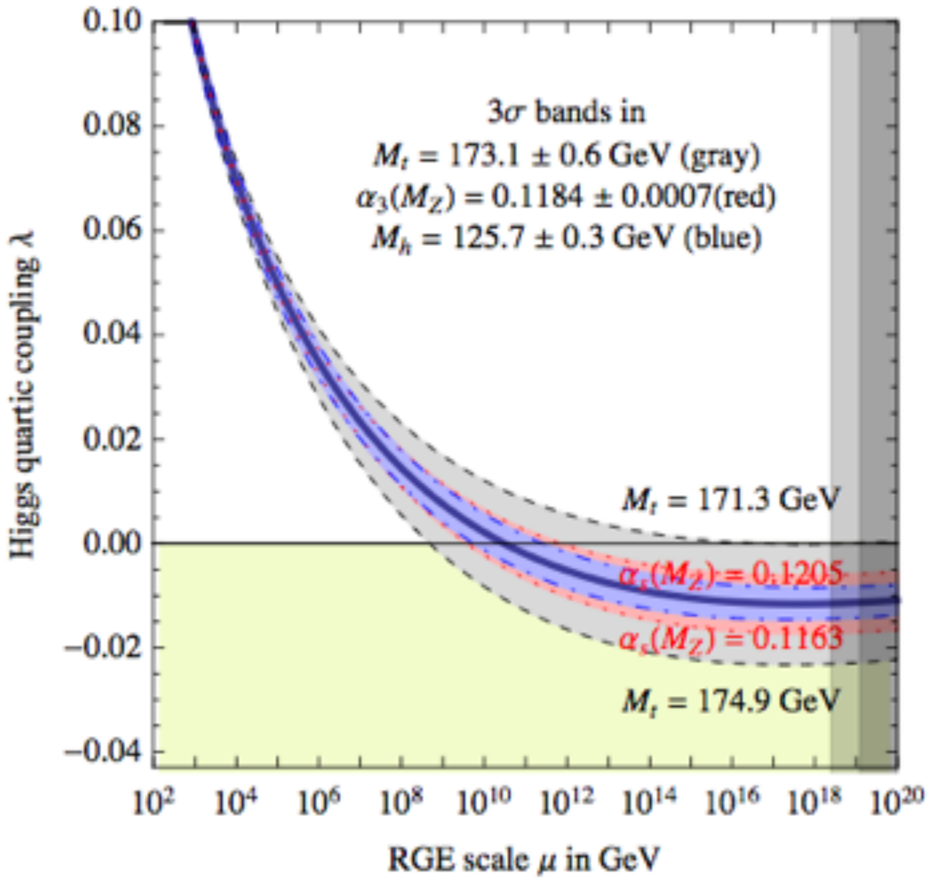
So what?

No NP anywhere! Also, naturalness is now severely challenged.

Of course we should continue all searches at LHC (and beyond), flavour, direct dark matter etc. with vigour!

Still the peculiar Higgs mass suggest that, even in absence of NP, the Universe is metastable.

SM could well be valid up to Planck scale (and we could maybe forget about fine tuning problems)



JHEP 1312 (2013) 089

But…

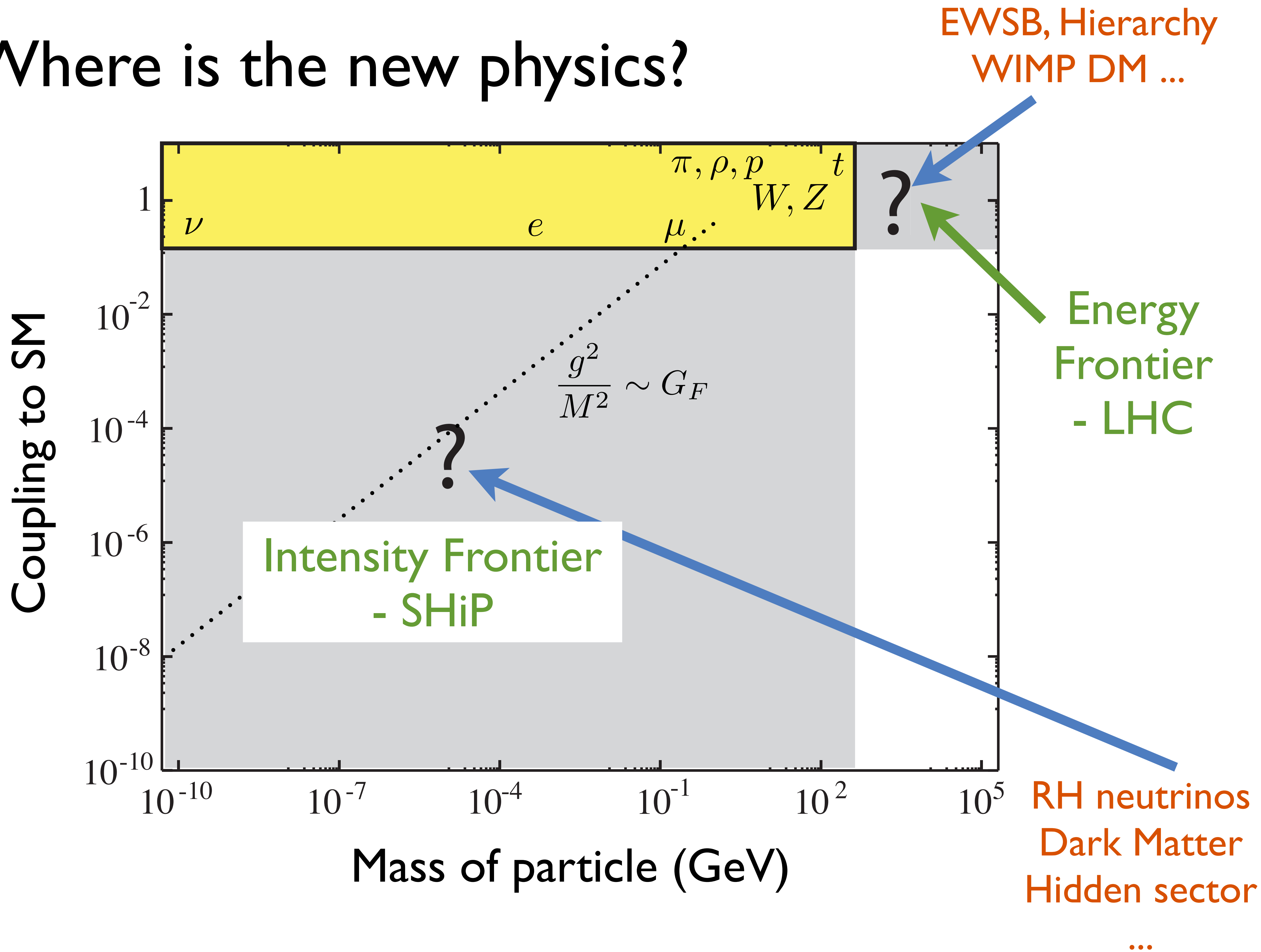
… we have at least to explain some experimental facts:

neutrino oscillations

baryogenesis

dark matter (+inflation, dark energy…)

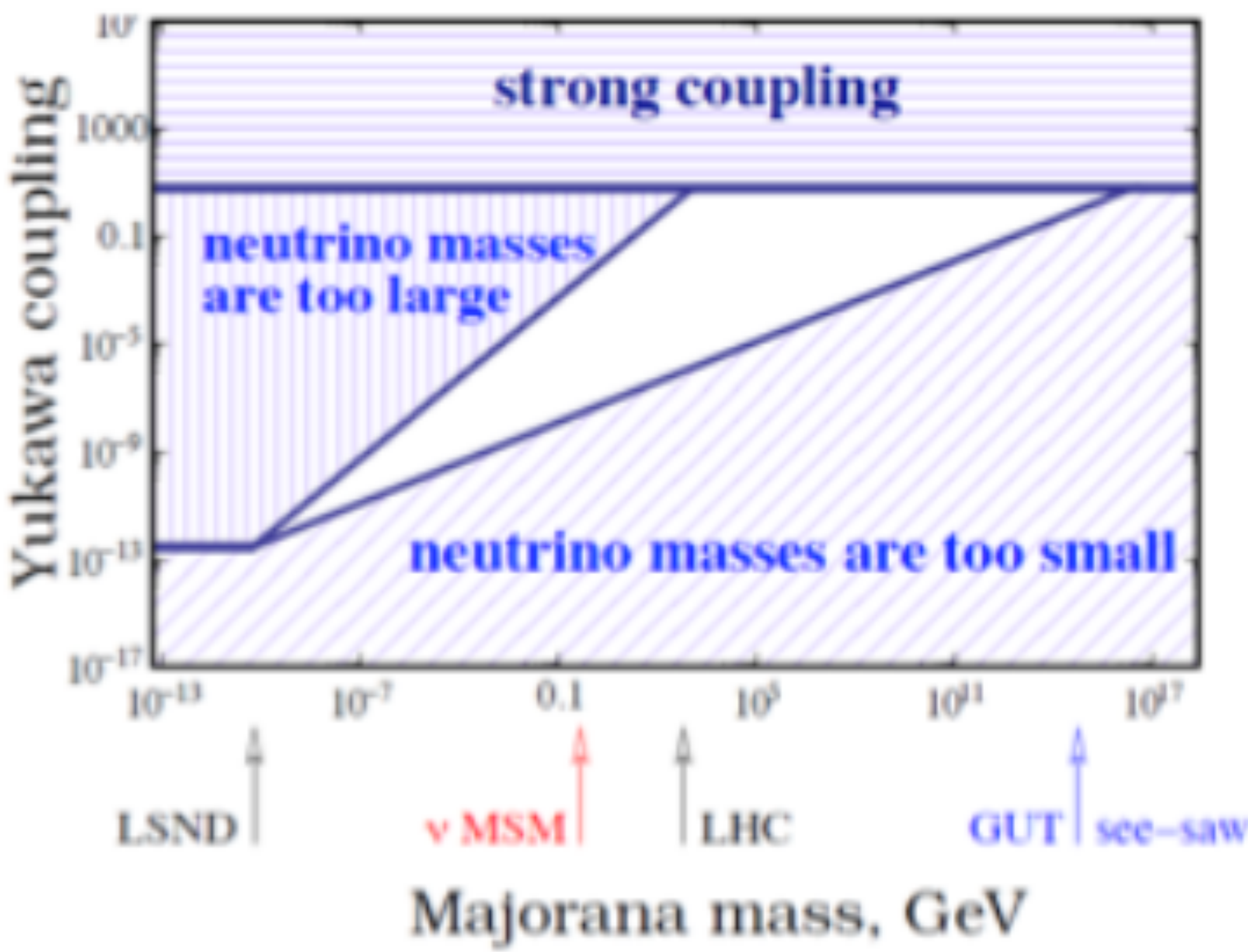
Where is the new physics?



consequences of neutrino oscillations

Where does the ν mass come from?

One remarkable possibility: see-saw mechanism (type I) with one/two/three massive and sterile Majorana-type neutrinos



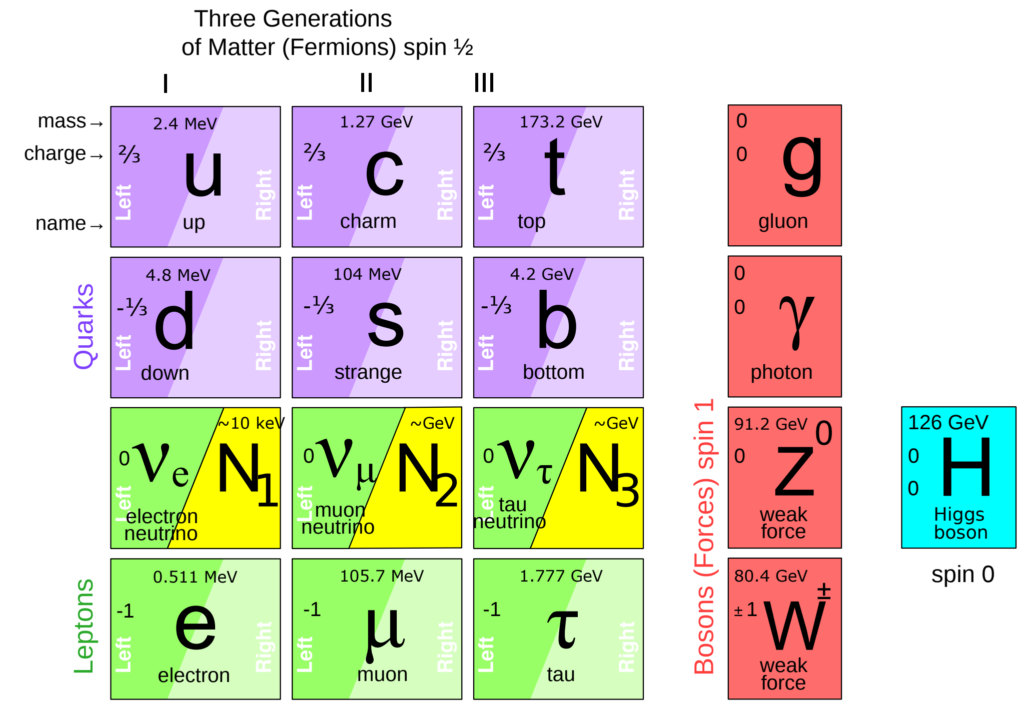
The neutrinos can come in rescue!

An example:

3 Majorana (HNL) partners of ordinary ν, with $M_N<M_W$

In a peculiar parameter space νMSM explains:

neutrino masses (see-saw), baryogenesis (via lepto-genesis) and DM (N_1)!

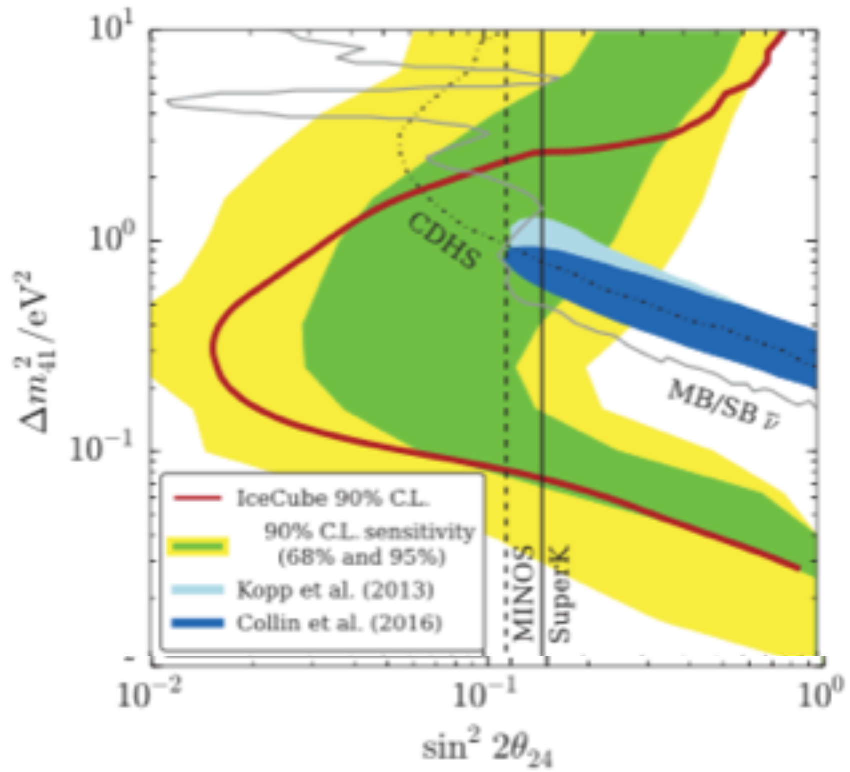


*νMSM: T.Asaka, M.Shaposhnikov PL **B620** (2005) 17*
M.Shaposhnikov Nucl. Phys. B763 (2007) 49

Questions and issues addressed by the WG5 this year

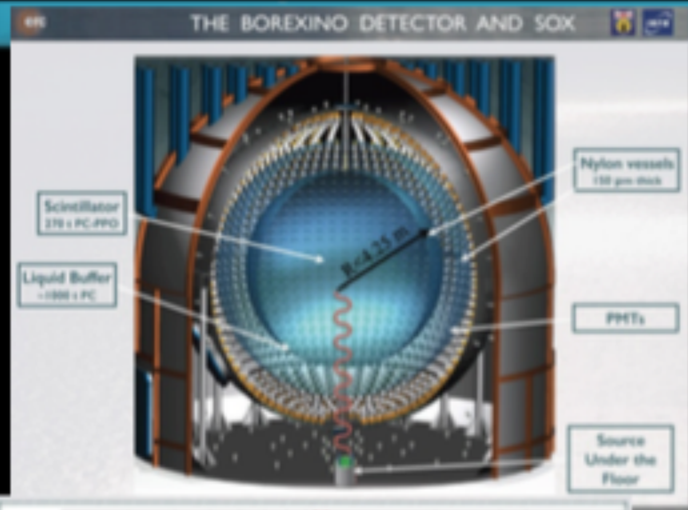
Status of PMNS matrix, unitarity and hints of a 4th neutrino. Can we test the unitarity of the PMNS matrix at neutrino oscillation experiments?

Steriles at eV: the new ICECUBE and MINOS results. how global fits include this?what models are still viable?

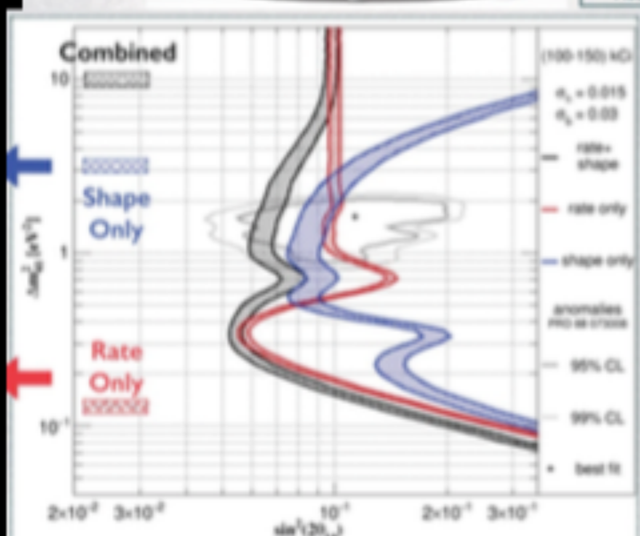


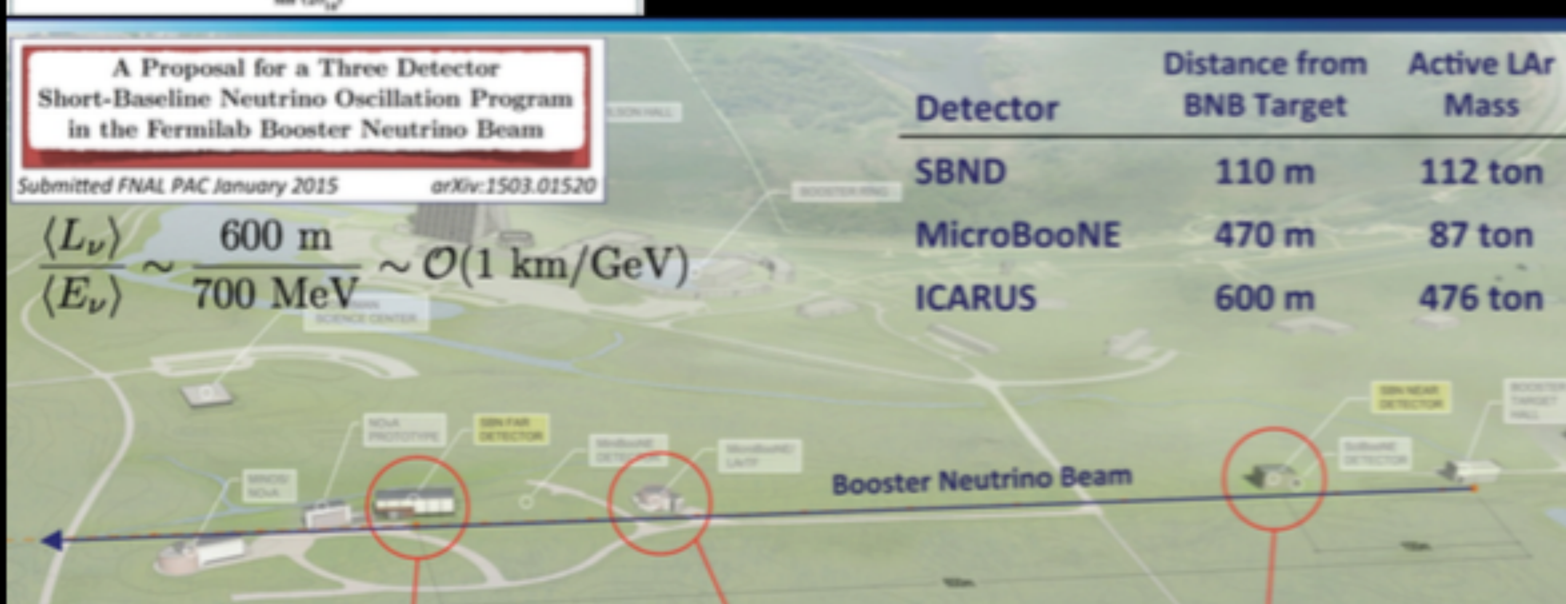
many coming experiments and planned!!!! what is their peculiarity? is there a rationale behind all of them?

Next Generation sterile neutrino experiments are almost ready



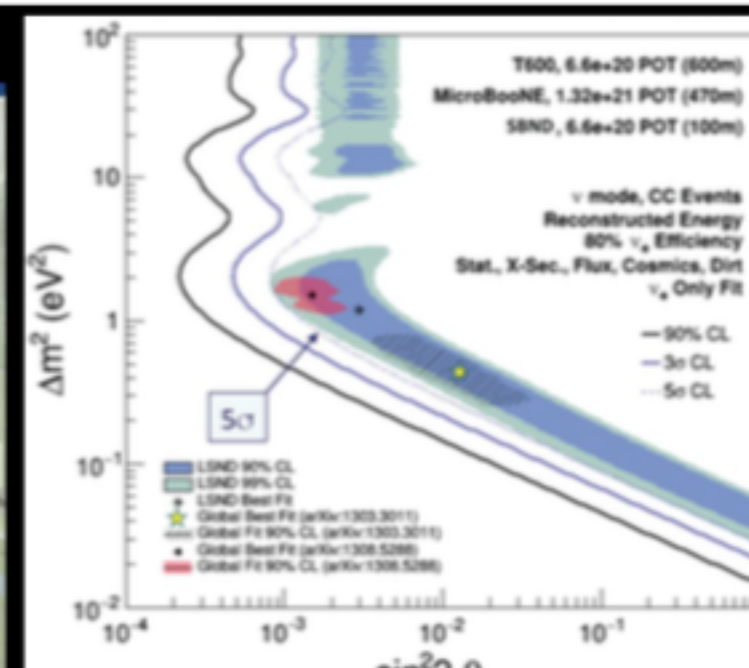
Experiment	Reactor Power/Fuel	Overburden (mwe)	Detection Material	Segmentation	Optical Readout	Particle ID Capability
DANSS (Russia)	3000 MW LEU fuel	~50	Inhomogeneous PS & Gd sheets	2D, ~5mm	WLS fibers.	Topology only
NEOS (South Korea)	2800 MW LEU fuel	~20	Homogeneous Gd-doped LS	none	Direct double ended PMT	recoil PSD only
nuLat (USA)	40 MW ^{235}U fuel	few	Homogeneous ^{6}Li doped PS	Quasi-3D, 5cm, 3-axis Opt. Latt	Direct PMT	Topology, recoil & capture PSD
Neutrino4 (Russia)	100 MW ^{235}U fuel	~10	Homogeneous Gd-doped LS	2D, ~10cm	Direct single ended PMT	Topology only
PROSPECT (USA)	85 MW ^{235}U fuel	few	Homogeneous ^{6}Li-doped LS	2D, 15cm	Direct double ended PMT	Topology, recoil & capture PSD
SoLid (UK Fr Bel US)	72 MW ^{235}U fuel	~10	Inhomogeneous ^{6}LiZnS & PS	Quasi-3D, 5cm multiplex	WLS fibers	topology, capture PSD
Chandler (USA)	72 MW ^{235}U fuel	~10	Inhomogeneous ^{6}LiZnS & PS	Quasi-3D, 5cm, 2-axis Opt. Latt	Direct PMT/ WLS Scint.	topology, capture PSD
Stereo (France)	57 MW ^{235}U fuel	~15	Homogeneous Gd-doped LS	1D, 25cm	Direct single ended PMT	recoil PSD





$$\frac{\langle L_\nu \rangle}{\langle E_\nu \rangle} \sim \frac{600 \text{ m}}{700 \text{ MeV}} \sim \mathcal{O}(1 \text{ km/GeV})$$

Detector	Distance from BNB Target	Active LAr Mass
SBND	110 m	112 ton
MicroBooNE	470 m	87 ton
ICARUS	600 m	476 ton



Room 1: WG1+WG5 Sterile Neutrinos

Chairperson: Walter Marcello Bonivento (INFN Cagliari)

10:45 11:15 - **Impact of sterile neutrinos on CP and mass hierarchy at long baselines**
Sanjib Kumar Agarwalla (Bhubaneswar University, India)

11:15 11:45 - **eV Scale Sterile at LBL & SBL (Exp.)**
Roxanne Guenette (University of Oxford)

11:45 12:15 - **eV Scale Sterile at SBL (Exp.)**
Alessandro Minotti (CEA Saclay)

Room 1: WG1+WG5 Sterile neutrinos and Unitarity of the PMNS matrix

Chairperson: Mattias Blennow (Royal Institute of Technology, Stockholm)

13:30 14:00 - **Results of the Search for Sterile Neutrinos with IceCube**
Ben Jones (University of Texas at Arlington)

14:00 14:30 - **Non-Unitarity of the PMNS matrix**
Mark Ross-Lonergan (IPPP Durham University)

14:30 15:00 - **Neutrino Oscillations in Matter with Direct and Indirect Unitarity Violation in the Lepton Mixing Matrix**
Shu Luo (Xiamen University)

Friday August 26th

Room 5: WG5 Neutrinos Beyond PMNS (Non Standard Interactions / Unitarity of the PMNS matrix)

Chairperson: Jordi Salvado (IFIC, Valencia)

Friday August 26th

15:30 16:00 - **Testing the Direct and Indirect Unitarity Violation at a Neutrino Factory**
Jian Tang (Sun Yat-Sen University, Guangzhou)

Room 4: WG4+WG5 New physics and lepton flavor violating observables

Chairperson: Michael Schmidt (The University of Sydney)

Thursday August 25th

15:30 16:00 - **Global constraints on Seesaw neutrino mixing**
Josu Hernandez (IFT UAM, Madrid)

What is the relation between CPV in sterile neutrino decays, CP of PMNS matrix and leptogenesis?

Room 5: WG5 Neutrinos Beyond PMNS (Dark Matter / Astrophysical Neutrinos)

Chairperson: Enrique Fernandez-Martinez (UAM, Madrid)

Tuesday August 23rd

14:30 15:00 **discussion lead by M.Drewes and J.Salvado**

Link between steriles and LFV

Room 4: WG4+WG5 New physics and lepton flavor violating observables

Chairperson: Michael Schmidt (The University of Sydney)

16:00 16:30 - **Electric dipole moments of charged leptons with sterile fermions**
Takashi Toma (LPT, Orsay)

16:30 17:00 - **Conversions of Bound Muons: LFV from Doubly Charged Scalars**
Tanja Geib (Max Planck Institute for Physics, Munich)

Thursday August 25th

Link between steriles and $0\nu2\beta$ relation with leptogenesis

$0\nu2\beta$: detection? how? when will we be able to know if Dirac and Majorana? complementarity of different planned experiments

Room 5: WG5 Neutrinos Beyond PMNS (Neutrinoless Double Beta Decay: Experiments)

Chairperson: Marco Drewes (TU Munich, Garching)

13:30 14:00 - **Searching for Neutrinoless Double Beta Decay with Bolometers (CUORE/CUPID)**
Ke Han (Shanghai Jiao Tong University)

14:00 14:30 - **The Status of NEXT**
Ben Jones (University of Texas at Arlington)

Thursday August 25th

14:30 15:00 - **Search for neutrinoless-double-beta decay with EXO-nEXO**
Guofu Cao (Institute of High Energy Physics CAS, Beijing)

Room 5: WG5 Neutrinos Beyond PMNS (Neutrinoless Double Beta Decay: Theory)

Chairperson: Pasquale di Bari (University of Southampton)

10:45 11:15 - **Review on theoretical and experimental prospects on Neutrinoless Double Beta Decay**
Stefano Dell'Oro (INFN Gran Sasso Science Institute, L'Aquila)

11:15 11:45 - **On neutrinoless double beta decay in the nuMSM**
Hiroyuki Ishida (Shimane University, Matsue)

Thursday August 25th

:h

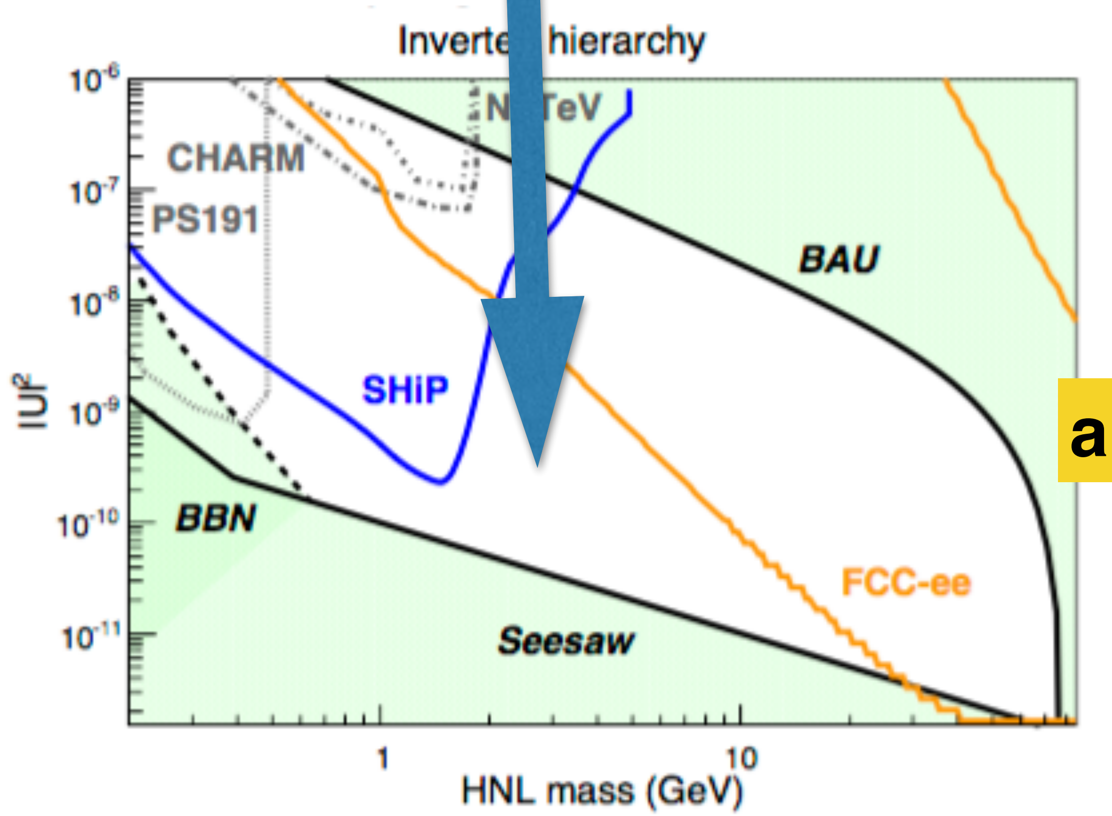
Steriles at MeV and above:

how can we improve existing limits with running or upcoming experiments?
how the new proposed projects (e.g. SHiP and FCC) fit into this picture?

Could we cover one day all the "interesting" parameter space, at least within some minimal models?

what technologies we have to push in order to do that?

What about less constrained models?



(c) Decay length 0.01-500 cm, 10^{13} Z^0

arXiv:1411.5230v2

Room 3: WG3+WG5 New Physics and Accelerators

Chairperson: **Takahashi Nakadaira**

Wednesday August 24th

10:40 11:10	-	**Accelerator developments for SHiP and FCC** Linda Stoel (CERN, Geneva)
11:10 11:40	-	**Search for massive neutrinos at LHCb and discovery potential of the FCC** Marcin Chrzaszcz (University of Zurich)
11:40 12:10	-	**Physics and Experimental Development towards IsoDAR@KamLAND** Jose Alonso (MIT, Cambridge)

NSI in neutrino experiments:

are there any viable models that can give large NSI without entering in conflict with bounds from charged leptons?

what is the best way to probe new interactions in production, detection and propagation of neutrinos?

are neutrino oscillation experiments enough, or are there better experiments to do this?

Room 5: WG5 Neutrinos Beyond PMNS (Non Standard Interactions / Unitarity of the PMNS matrix)

Chairperson: Jordi Salvado (IFIC, Valencia)

Friday August 26th

16:00 16:30 - **Will atmospheric neutrino experiment at Hyper-Kamiokande see non-standard interaction effects?**
Osamu Yasuda (Tokyo Metropolitan University, Hachioji)

16:30 17:00 - **Viable models for large Non-Standard neutrino interaction**
Yasaman Farzan (Institute for research in fundamental sciences, Tehran)

Room 1: WG1+WG5 Non Standard Interactions and Steriles

Chairperson: Roxanne Guenette (University of Oxford)

Monday August 22nd

15:30 16:00 - **Non-Standard neutrino interactions at running reactor and beam-based neutrino oscillation facilities**
David Vanegas Forero (Virginia Tech, Blacksburg)

16:00 16:30 - **New Physics Searches at ESSnuSB**
Mattias Blennow (Royal Institute of Technology, Stockholm)

16:30 17:00 - **New Physics Searches at DUNE**
Kevin Kelly (Northwestern University, Evanston)

Flavour models:

can we test flavour models by measuring the value of the CP phase? can we definitely rule out certain types of flavour models? which ones?

are there other ways to do this? what signatures should we be looking for?

Room 5: WG5 Neutrinos Beyond PMNS (Flavor Models / Dark Matter)

Chairperson: Sanjib Agarwalla (Institute of Physics, Bhubaneswar)

10:40 11:10 - **Lepton mixing from the interplay of the alternating group A55 and CP**
Andrea Di Iura (Università Degli Studi Roma Tre)

11:10 11:40 - **Mass limit for light flavon in neutrino flavor model**
Yusuke Shimizu (Hiroshima University)

Tuesday August 23rd

Room 5: WG5 Neutrinos Beyond PMNS (Neutrinoless Double Beta Decay: Theory)

Chairperson: Pasquale di Bari (University of Southampton)

Thursday August 25th

11:45 12:15 - **Leptonic CP Violation Predictions from Discrete Flavour Symmetry Approach**
Arsenii Titov (SISSA, Trieste)

Dark matter/astro neutrinos:

are sterile neutrinos a viable dark matter candidate? under which conditions? how could they be produced in the early universe? are we sensitive to a possible dark matter decay through astrophysical neutrino signals?

what other models of New Physics can give interesting signatures at Icecube? what type of signatures should we be looking for? are there any models of New Physics that can give a sizable deviation for the flavor ratios with respect to the SM prediction?

Room 5: WG5 Neutrinos Beyond PMNS (Flavor Models / Dark Matter)

Chairperson: Sanjib Agarwalla (Institute of Physics, Bhubaneswar)

11:40 12:10 - **Sterile Neutrino Dark Matter Production from Scalar Decay**
Michael Schmidt (University of Sydney)

Room 5: WG5 Neutrinos Beyond PMNS (Dark Matter / Astrophysical Neutrinos)

Chairperson: Enrique Fernandez-Martinez (UAM, Madrid)

13:30 14:00 - **IceCube Events from Heavy DM decays through the Right-handed Neutrino Portal**
Yong Tang (Korea Institute for Advanced Study, Seoul)

14:00 14:30 - **New Physics in Astrophysical Neutrino Flavor**
Jordi Salvado (Instituto de Fisica Corpuscular, Valencia)

Tuesday August 23rd

All summarised by the plenaries!

Plenary Session #7: WG5 related Session
Chairperson: Sanjib Agarwalla (Institute of Physics, Bhubaneswar)

08:30 08:55	-	**The seesaw mechanism in neutrino oscillations** Enrique Fernandez-Martinez (UAM, Madrid)
08:55 09:20	-	**keV sterile neutrinos: theoretical and experimental prospects** Marco Drewes (TU Munich)
09:20 09:45	-	**Heavy neutrino searches from MeV to TeV** Elena Graverini (Zurich University)
09:45 10:10	-	**Searches for dark sector particles at neutrino experiments** Dave Mc Keen (University of Washington, Seattle)

Dark sector particles and dark Matter detection in neutrino experiments (accelerators and astrophysical probes)

do we need dedicated experiments or we can derive constraints from neutrino experiments only?