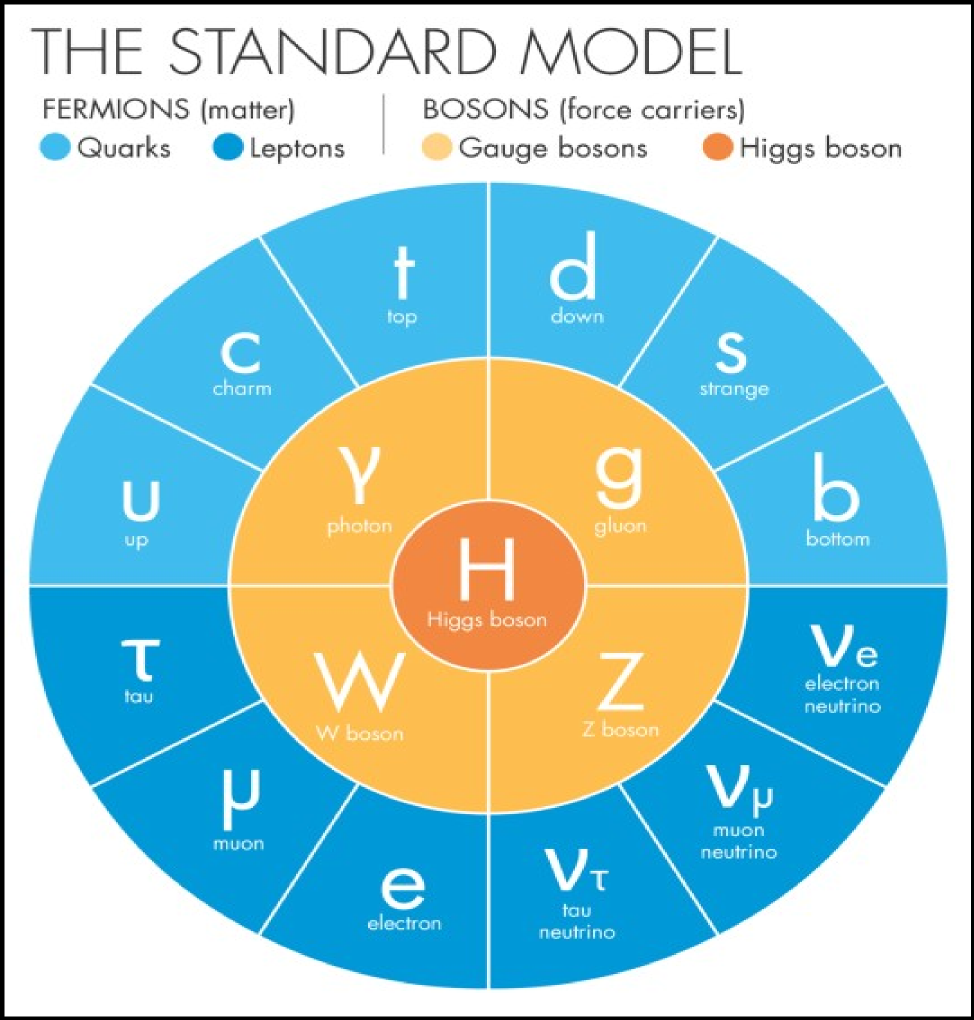
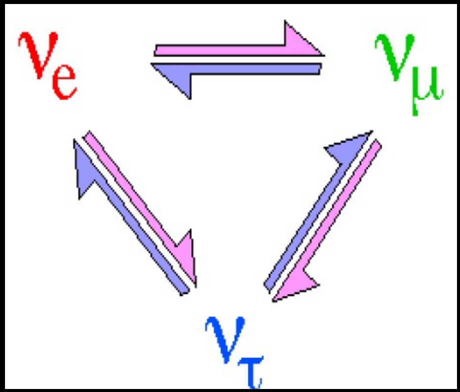
Perspectives on particle physics after LHC Run 2

J W F Valle, IFIC



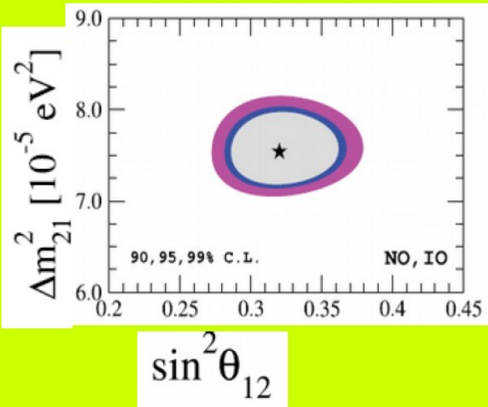
Higgs not the last brick !

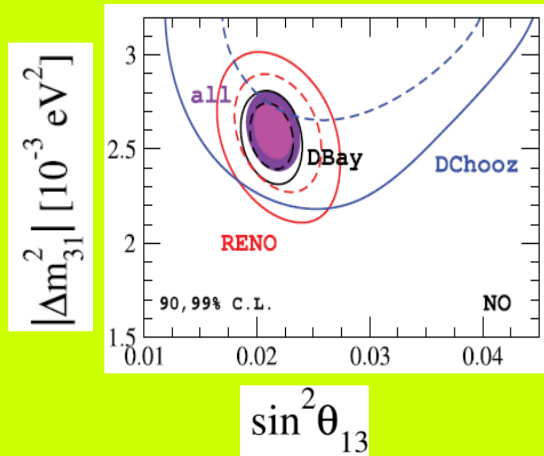


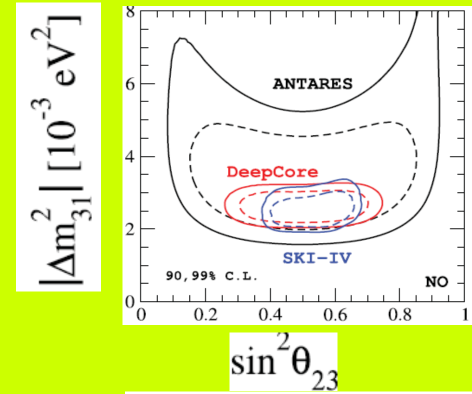
neutrino mass
flavor physics
cosmology

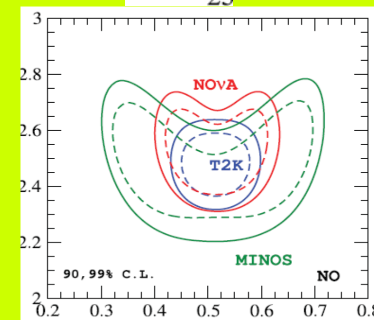
require amendment of SM ➡ new collider signatures

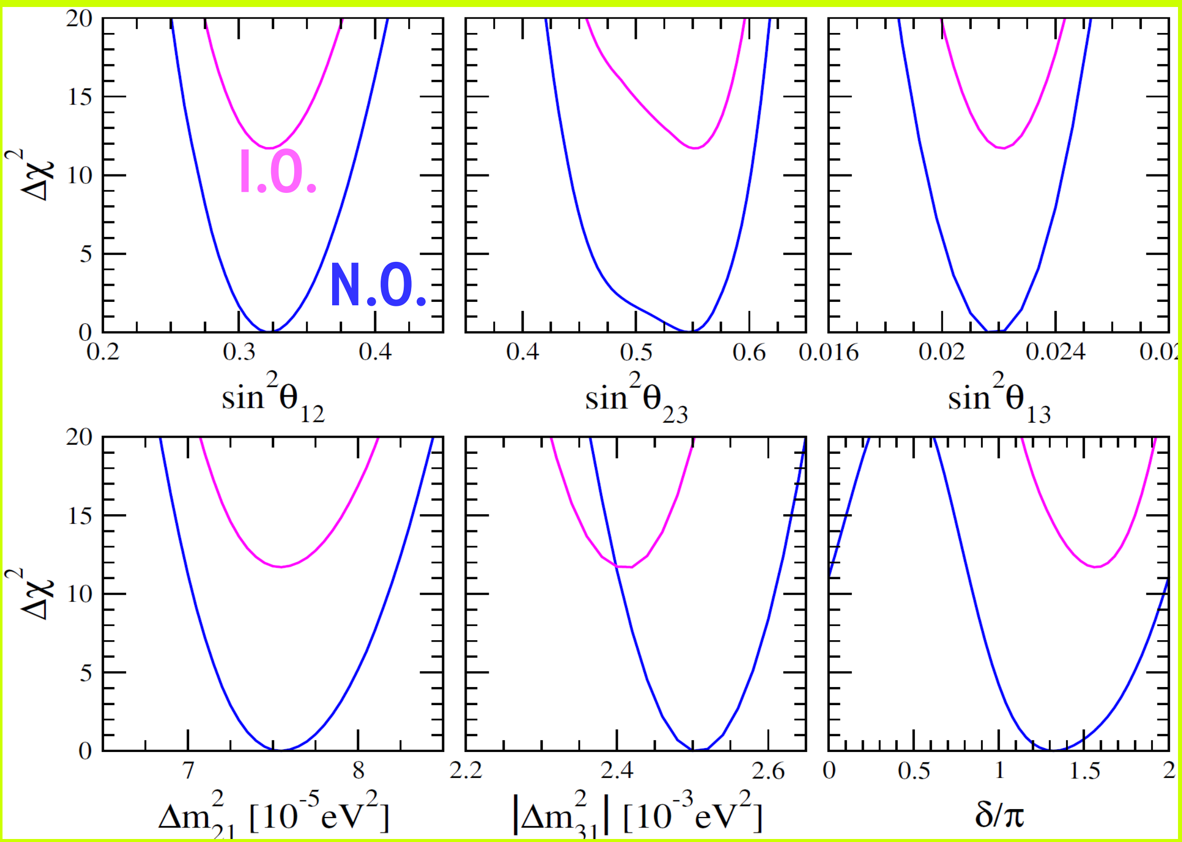
status of neutrino oscillations







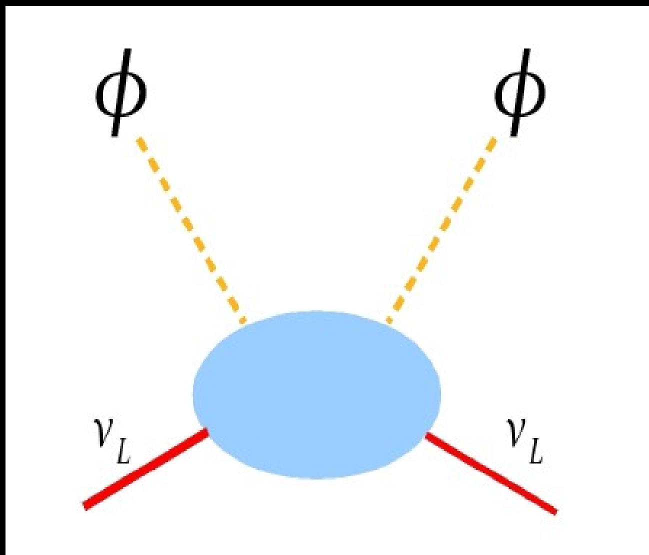


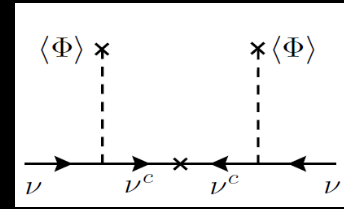


Consistent global picture

P.F. de Salas et al, PLB782 (2018) 633
https://globalfit.astroparticles.es/

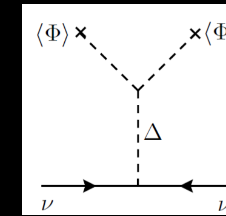
Origin of neutrino mass





TYPE I

Minkowski 77
Gellman Ramond Slansky 80
Glashow, Yanagida 79
Mohapatra Senjanovic 80
Lazarides Shafi Weterrich 81
Schechter-Valle 80 & 82



TYPE II

Schechter-Valle 80 & 82

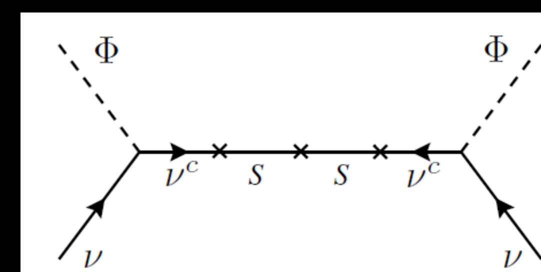
seesaw mechanism

any number of singlet R's w.r.t. L's

coefficient
mechanism
scale
flavor structure

LOW-SCALE SEESAW

Mohapatra-Valle 86
Akhmedov et al PRD53 (1996) 2752
Malinsky et al PRL95(2005)161801
Bazzocchi et al, PRD81 (2010) 051701

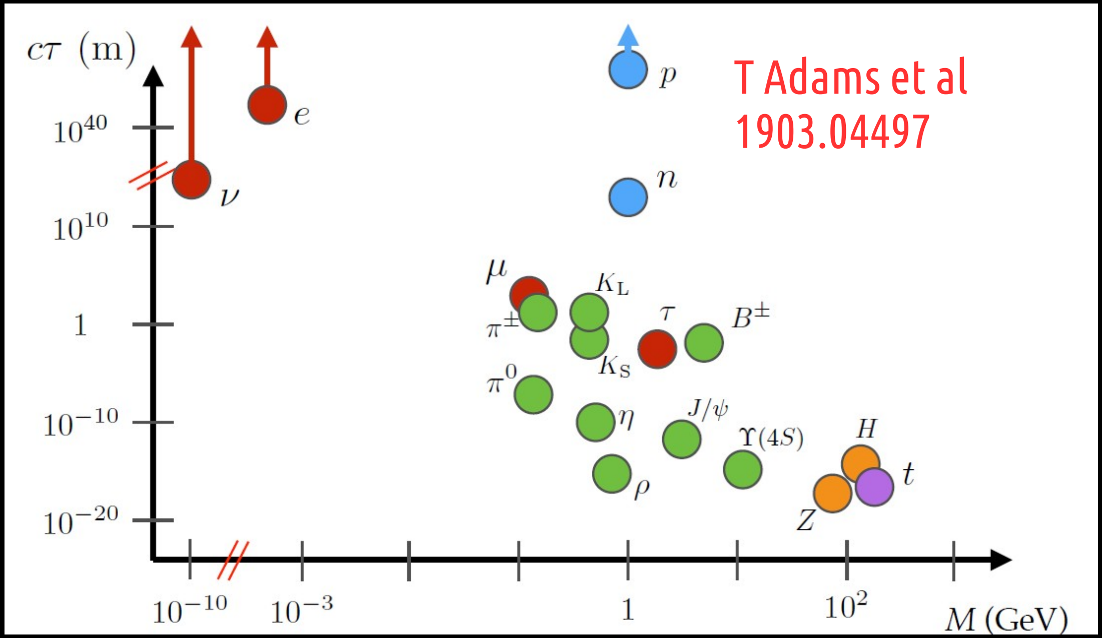


Majorana or Dirac

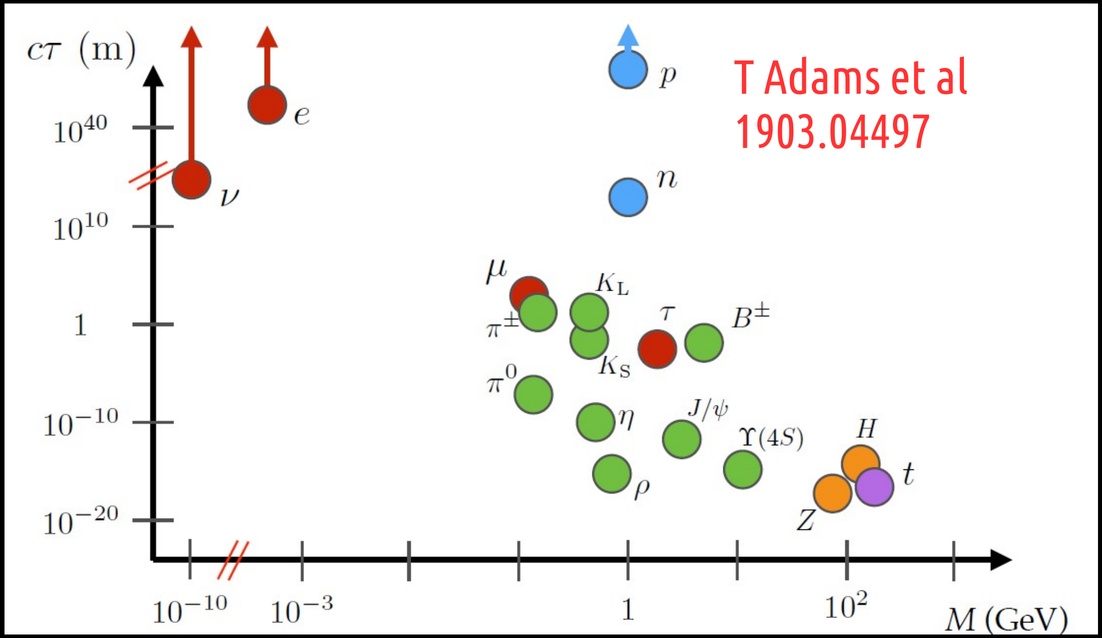
$$v_3 v_1 \sim v_2{}^2$$

EWSB

how to probe the origin of neutrino mass?



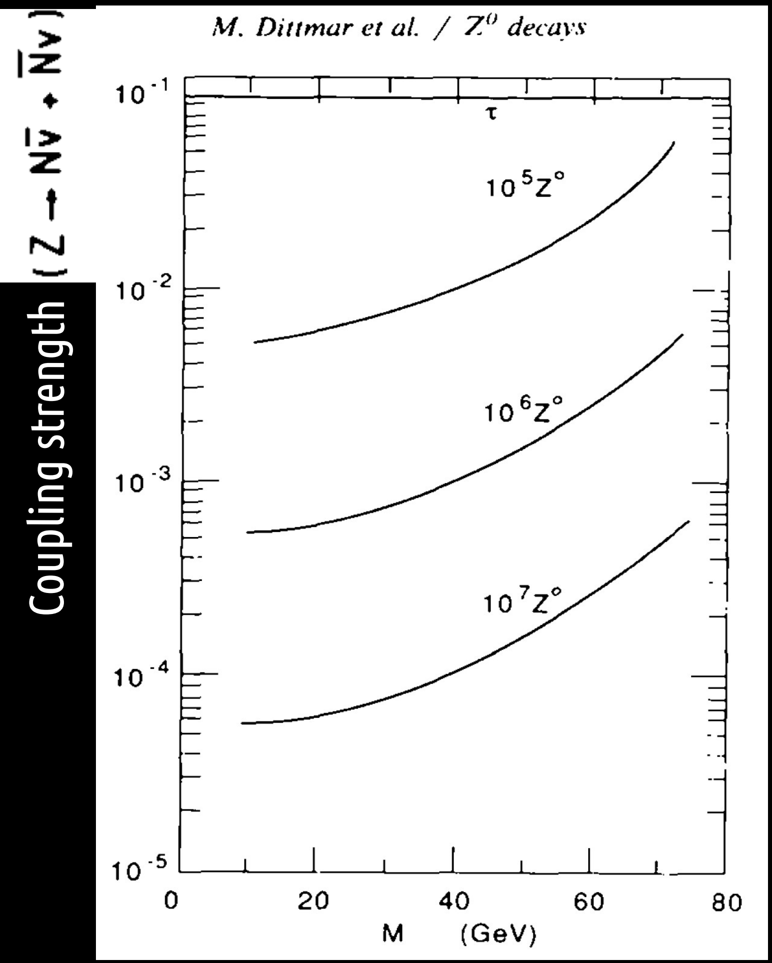
how to probe the origin of neutrino mass?



produce neutrino messengers … if light enough
measure decay vertices
decay pattern

new Higgs signatures since new Higgs couple to neutrinos

producing the messenger from SM gauge bosons



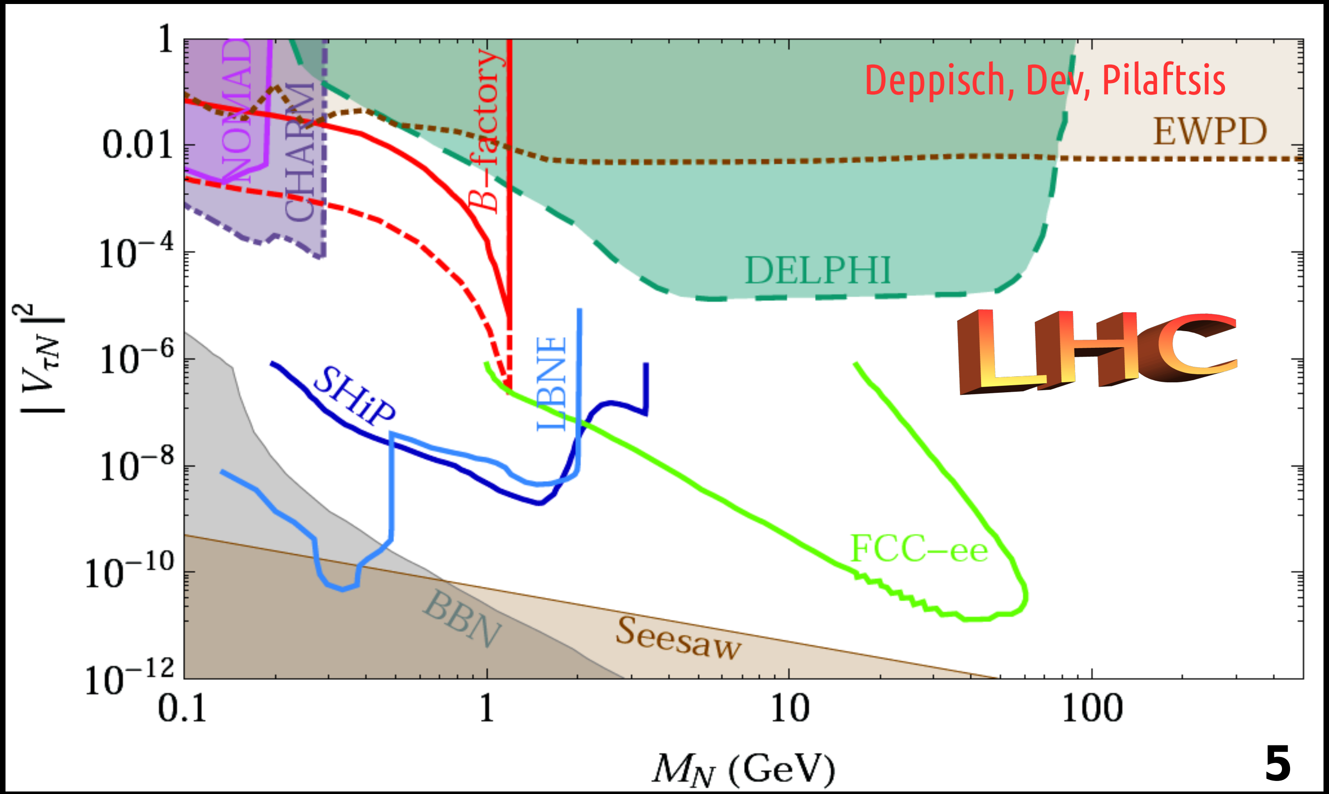
Pre-LEP days Dittmar et al Nuclear Physics B332 (1990) 1-19

Sensitivity to NHL coupling parameter as a function of the NHL mass from leptonic final states.
versus weak universality constraint
for tau type NHL neglecting family mixing.

Studies @ LEP1 & LEP2
the LHC and future colliders

CMS Phys.Rev.Lett. 119 (2017) no.22, 221802

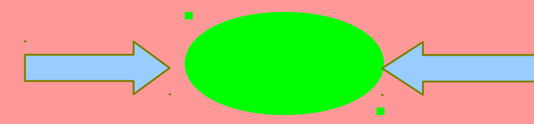
CMS Phys.Rev.Lett. 120 (2018) no.22, 221801



SUSY-MEDIATED NEUTRINO MASS

Masiero & Valle, PLB251 (1990) 273

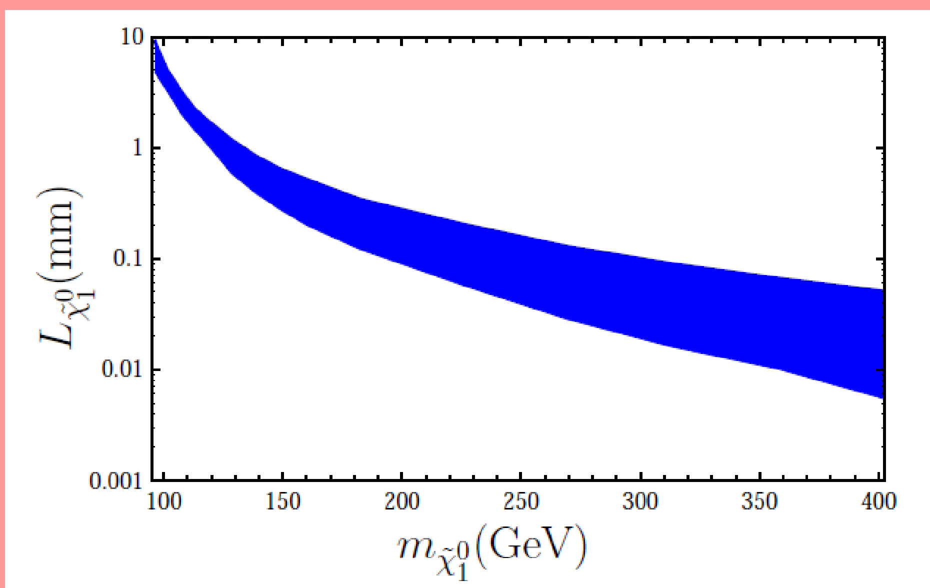
squark & gluino produced in pp
their cascade decays do not end up with LSP



De Campos et al
Phys.Rev. D86 (2012) 075001

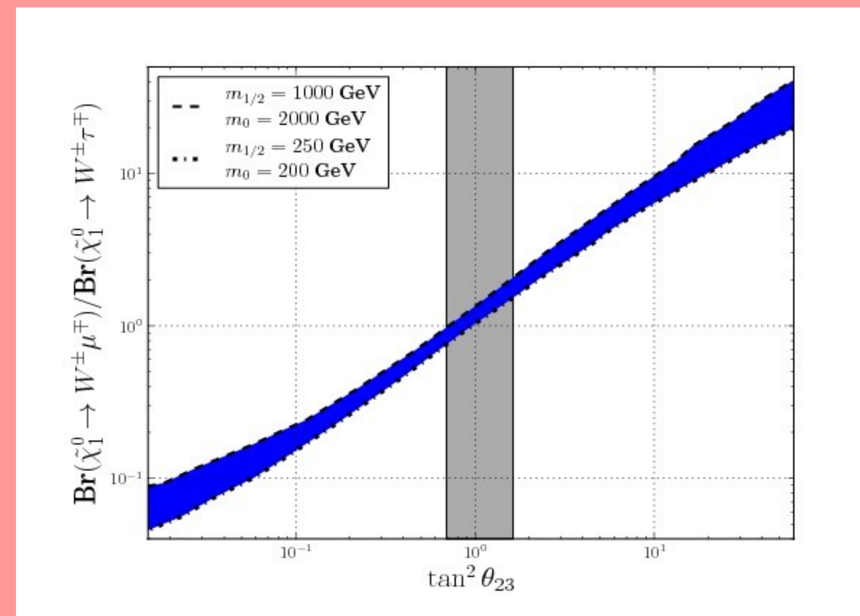
$\tilde{\chi}_1^0 \to W^{\pm} l_i^{\mp}$ $\tilde{\chi}_1^0 \to Z^0 \nu_i$

Lightest neutralino decay length



measurement of neutrino mass

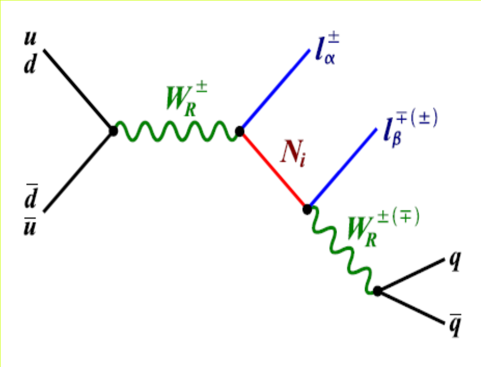
Lightest neutralino decay correlates with atm angle



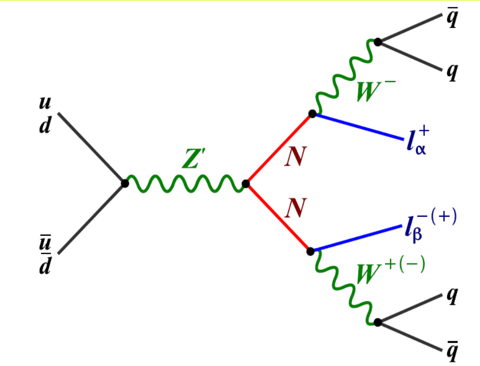
measurement of neutrino angles

PROBING NUS @ LHC

producing the messenger from new gauge portal



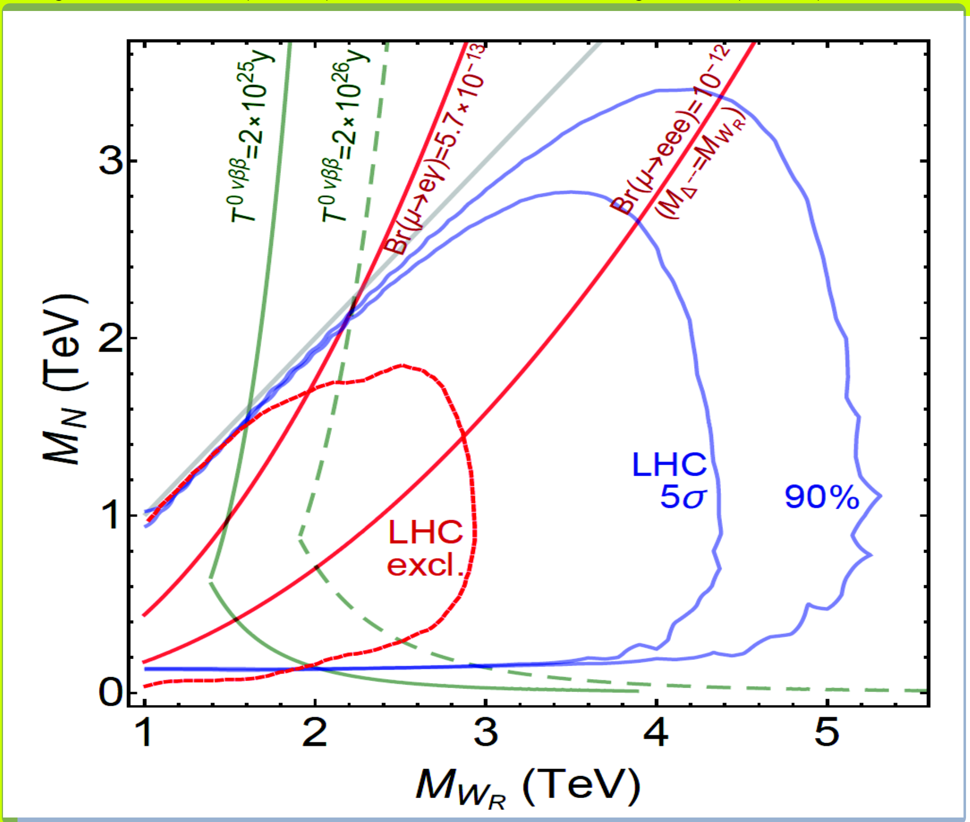
extended LR EW theory



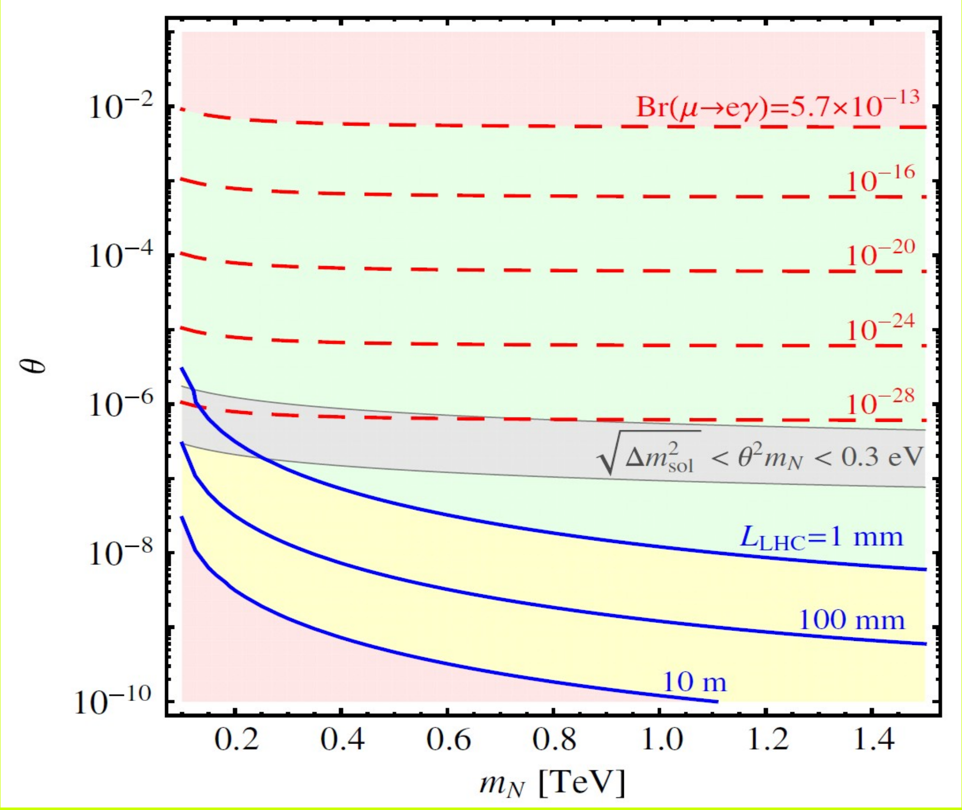
LFV just at high energies?

ATLAS JHEP 1901 (2019) 016

Phys.Rev. D86 (2012) 055006 & New J.Phys. 17 (2015) 075019



Phys.Rev. D89 (2014) 051302



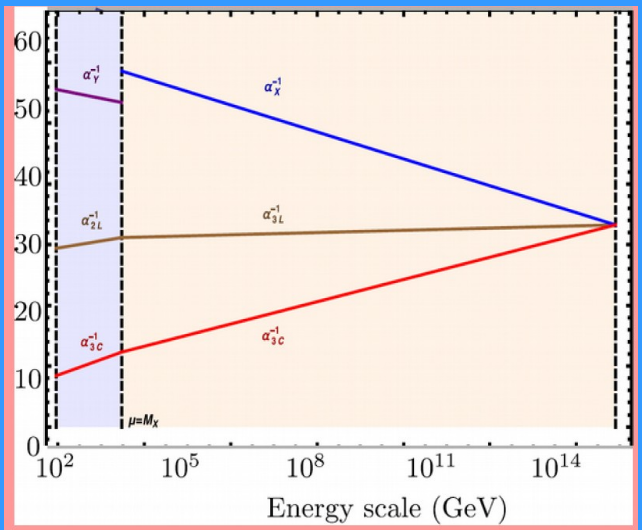
producing the messenger from 331 gauge bosons

Singer, Valle, Schechter, Phys.Rev. D22 (1980) 738

motivations

families = # colours

new road to unifiction

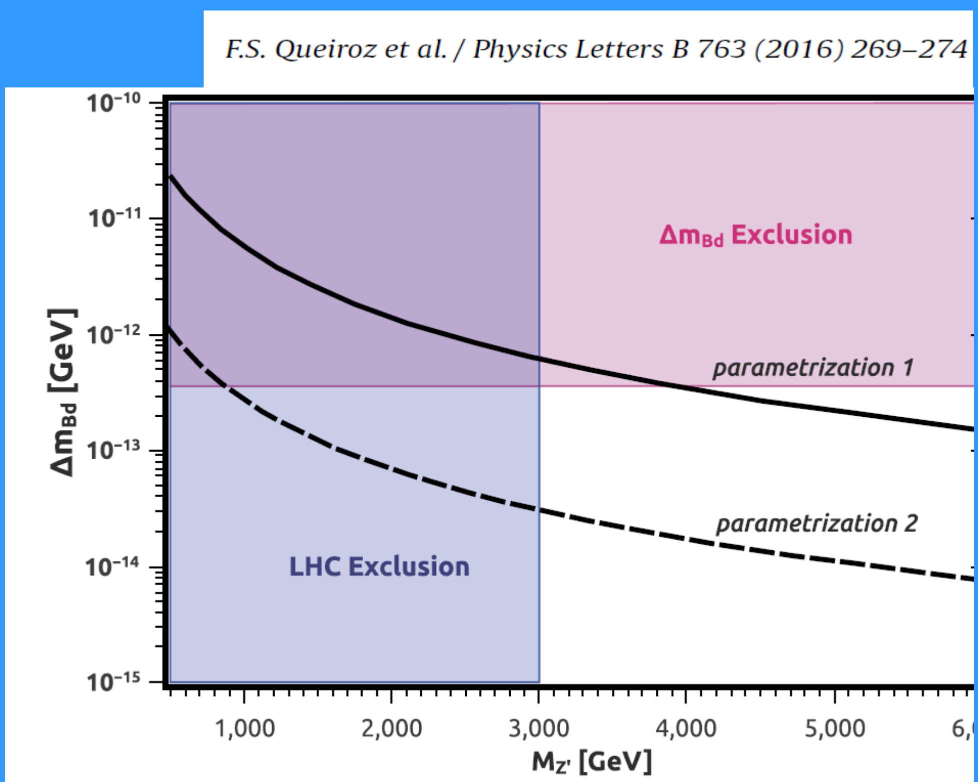


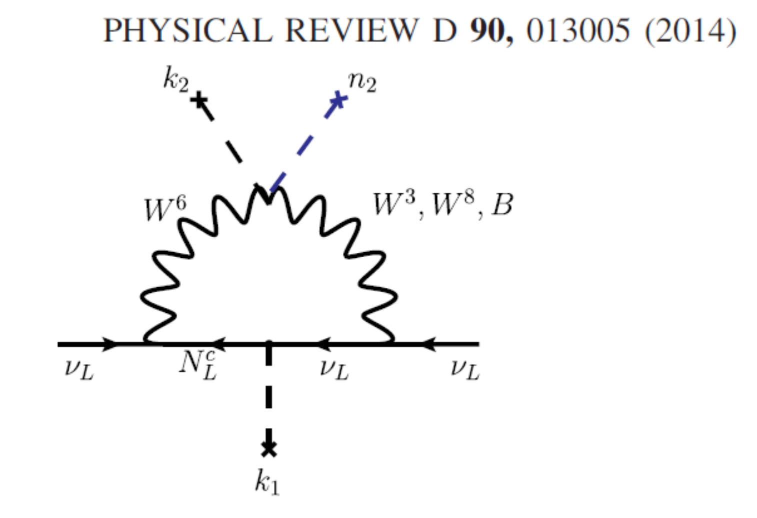
Boucenna et al Phys. Rev. D 91, 031702 (2015)

Deppisch et al Phys.Lett. B762 (2016) 432

radiative neutrino masses

gauge origin of neutrino mass





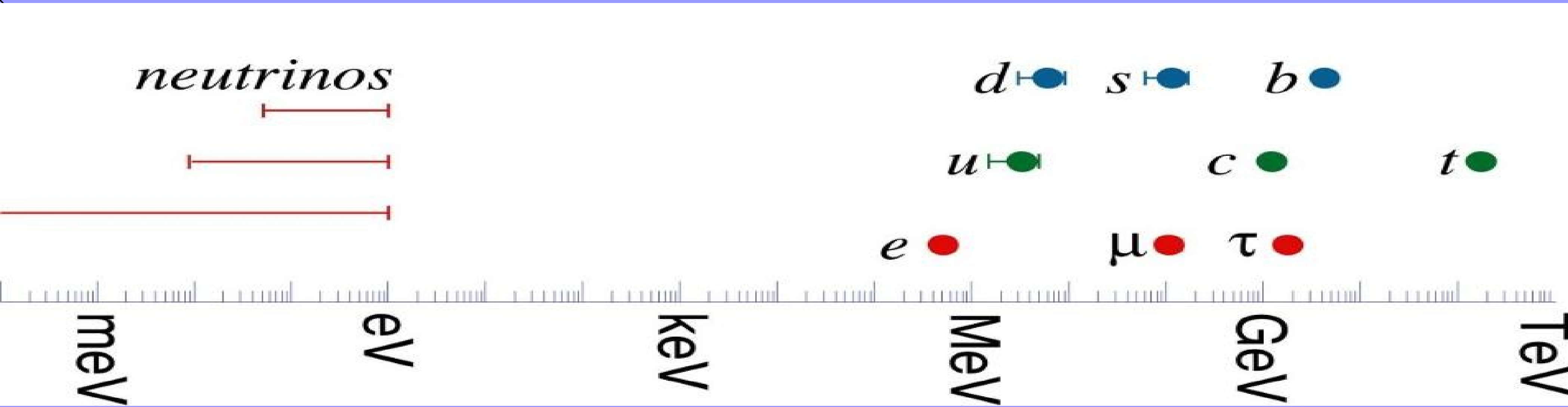
Boucenna, Morisi, JV Phys.Rev. D90 (2014) 013005 take home message: go for detecting messengers with DV & measuring angles @ high energies

neutrinos lie at the center of particle physics, e.g

- flavor problem
- EWSB

neutrinos lie at the center of cosmology, e.g.

- dark matter



from oscillations to flavor problem

charged fermion masses

Morisi et al — Phys.Rev. D84 (2011) 036003

King et al — Phys. Lett. B 724 (2013) 68

Morisi et al — Phys.Rev. D88 (2013) 036001

Bonilla et al — Phys.Lett. B742 (2015) 99

Reig, Valle & Wilczek — Phys.Rev.D98 (2018) 095008

Golden Q-L unification

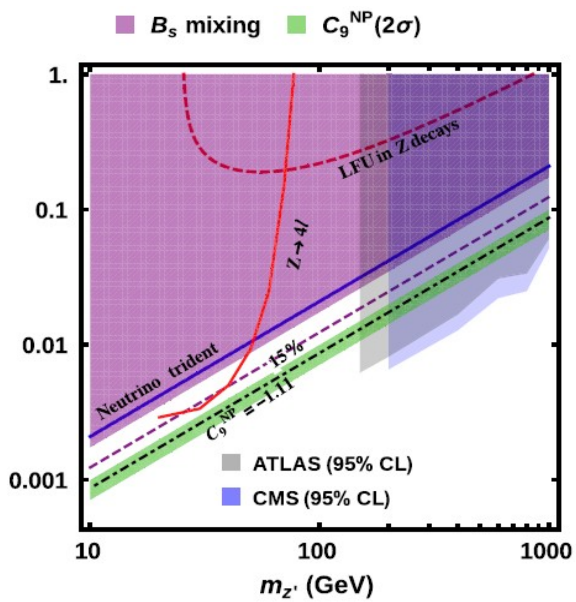
$$\frac{m_\tau}{\sqrt{m_e m_\mu}} \approx \frac{m_b}{\sqrt{m_d m_s}}$$

understanding of CKM

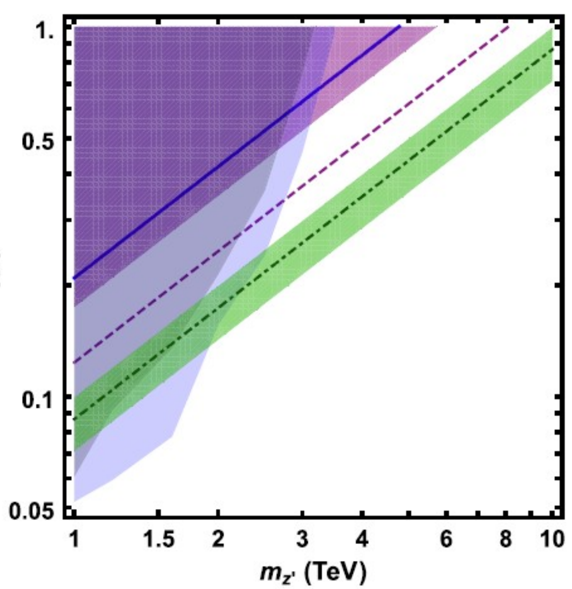
R_K :

Phys.Rev. D98 (2018) 095002

$U(1)_{B_3-3L_2}$ gauge symmetry as a simple description of $b \to s$ anomalies



ATLAS/CMS versus LHCb



Are the B decay anomalies related to neutrino oscillations?

Sofiane M. Boucenna [a], José W.F. Valle [b], Avelino Vicente [b,c,*]

Predicting lepton flavor violation in B meson decays

Phys.Lett. B750 (2015) 367-371

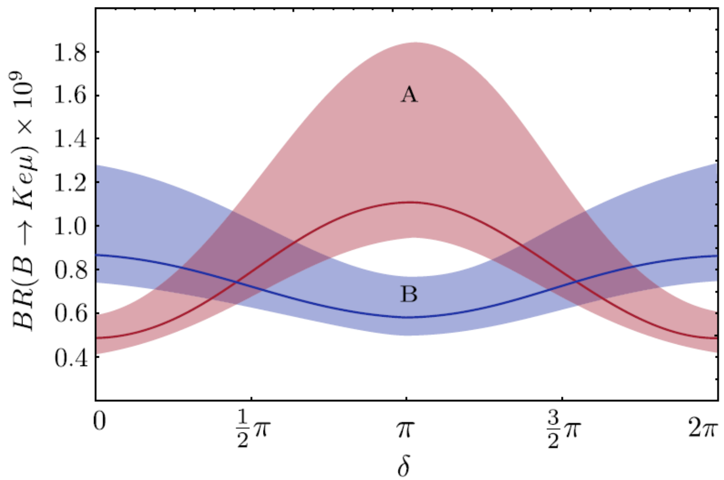
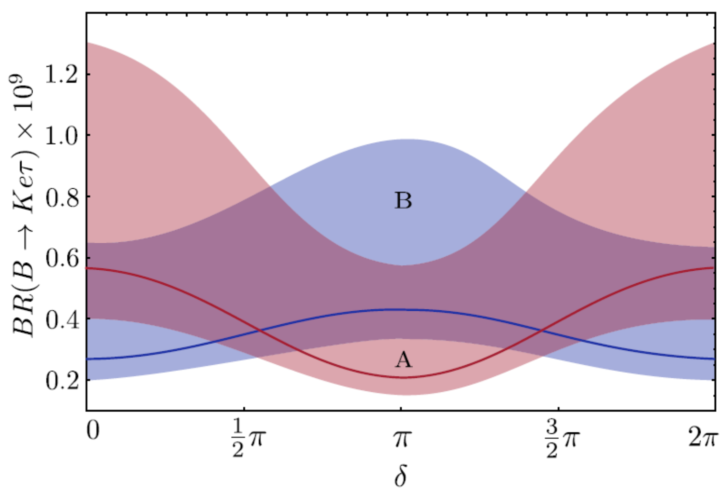
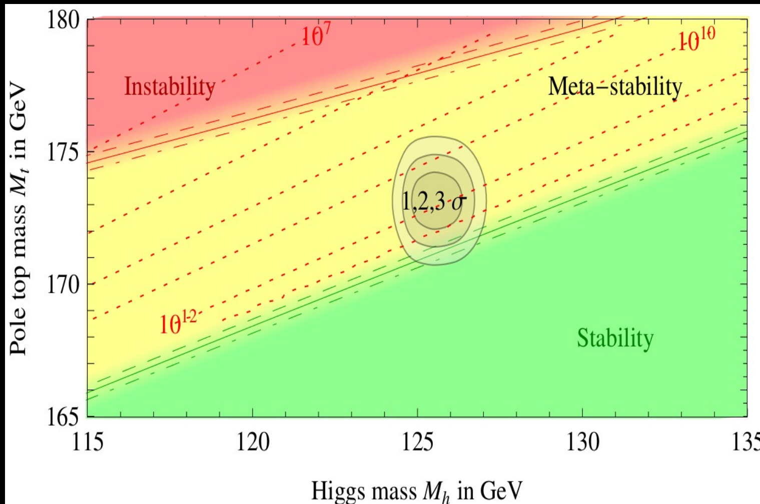


Fig. 1. The branching ratio of the decay $B \to Ke\mu$ versus the CP violating phase δ in scenarios A and B. The bands are obtained by taking the leptonic mixing angles within their 1σ range w.r.t. the best-fit value (solid line) [26].

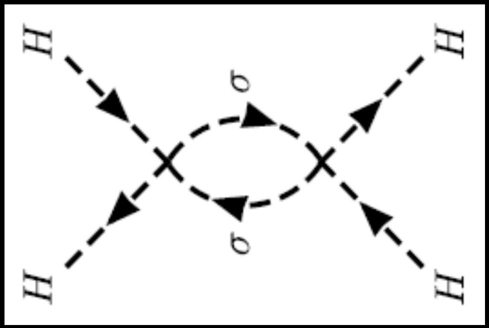




From Degrassi et al: JHEP 1208 (2012) 098

neutrinos make the EW vacuum stable again

Phys.Rev. D92 (2015) 075028

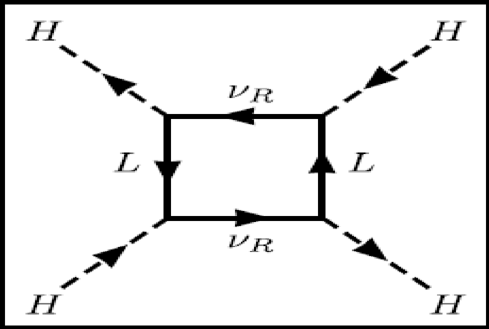


Higgs searches **Bonilla et al**

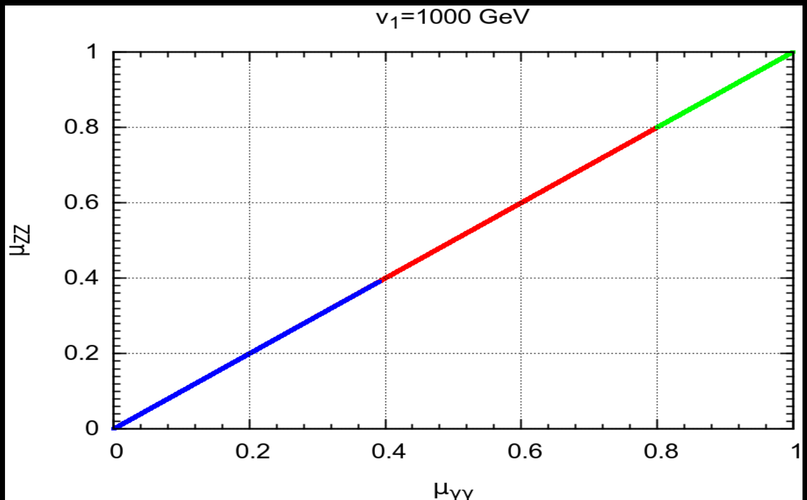
Phys.Lett. B756 (2016) 345-349

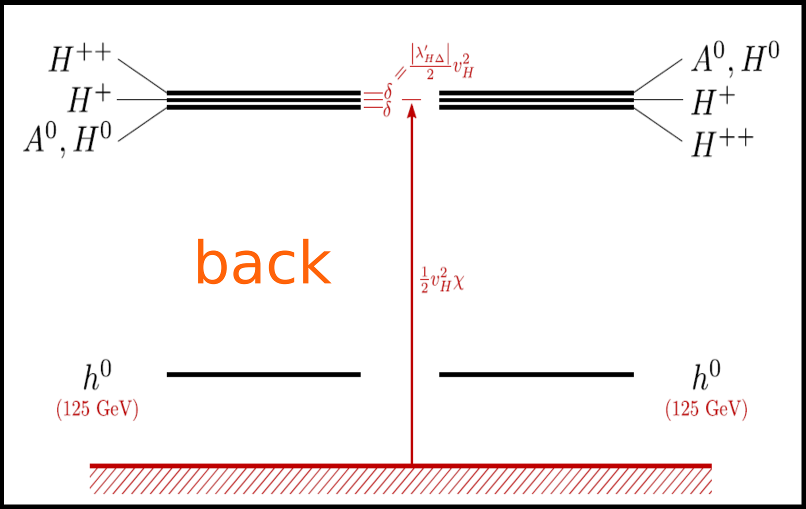
New J. Phys. 18 (2016) 033033

Phys.Rev. D91 (2015) 113015



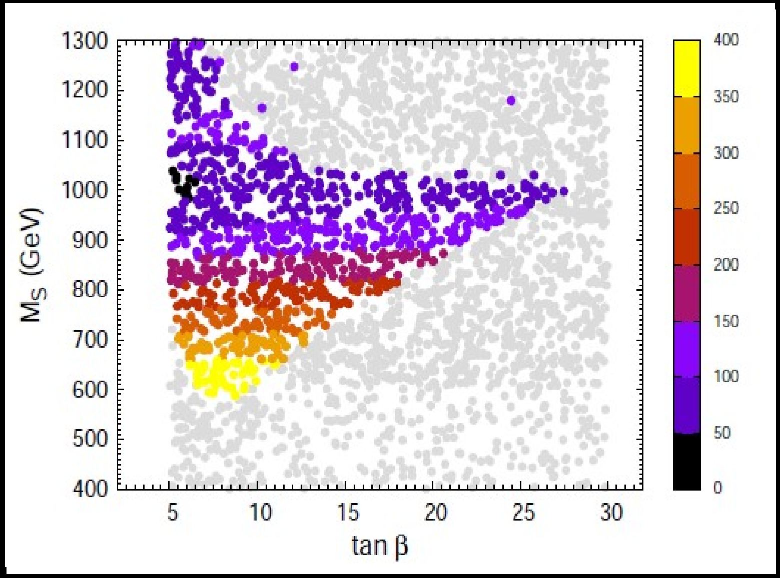
benchmark for EW studies @ colliders





SUSY WIMP as COLD DARK MATTER

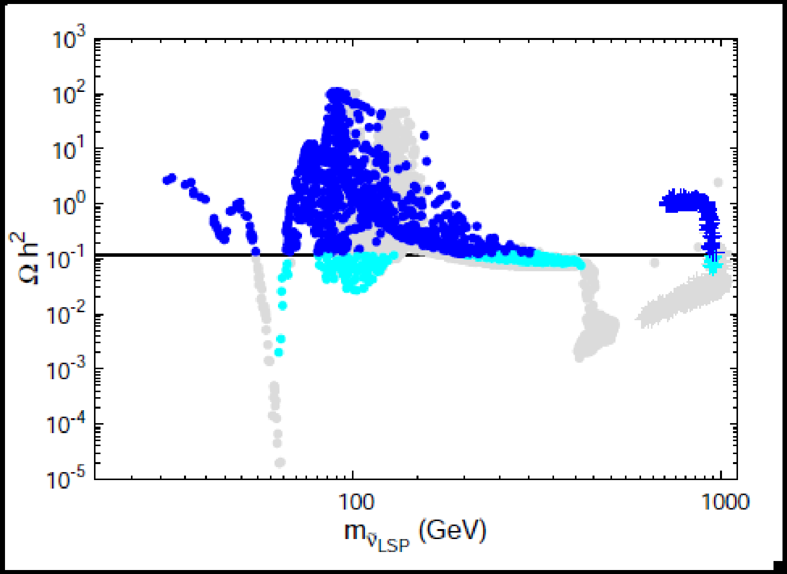
If neutrinos get mass from SUSY inverse seesaw spectrum can change so ...

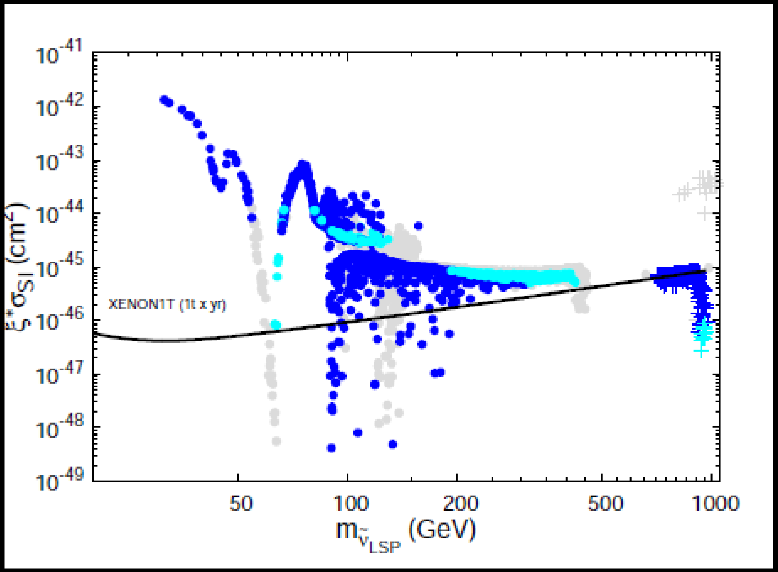


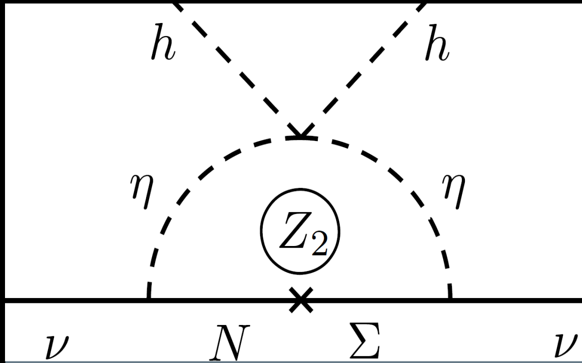
LSP is SNEUTRINO-like
instead of neutralino ..

Arina et al PRL101 (2008) 161802
Bazzocchi et al PRD81 (2010) 051701

De Romeri, Patel, Valle arXiv:1808.01453



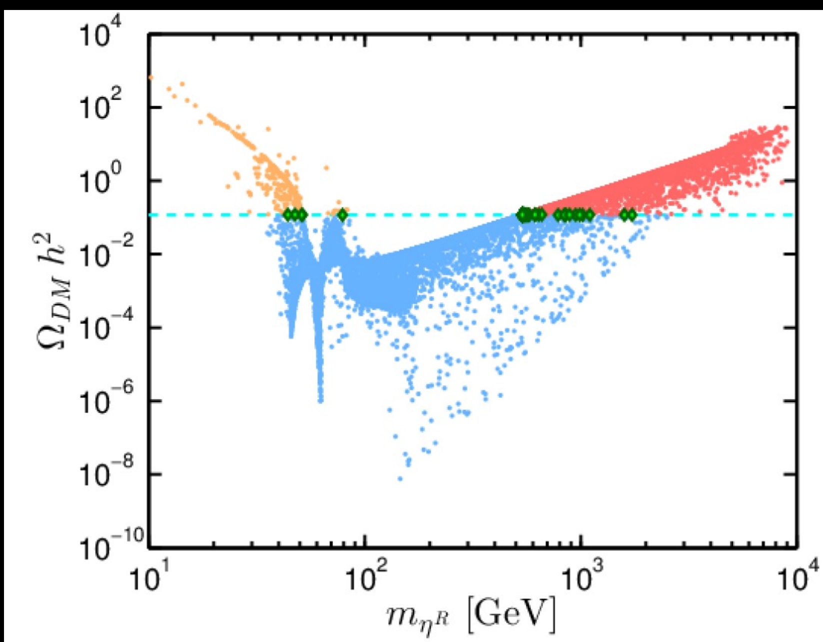


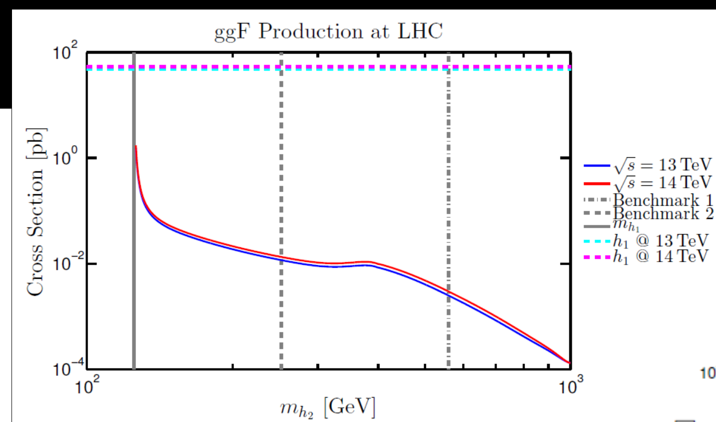


WIMP dark matter as radiative neutrino mass messenger

E Ma 2006 "scotogenic"
Hirsch et al JHEP 1310 (2013) 149
Merle et al JHEP 1607 (2016) 013
Diaz et al JHEP 1708 (2017) 017

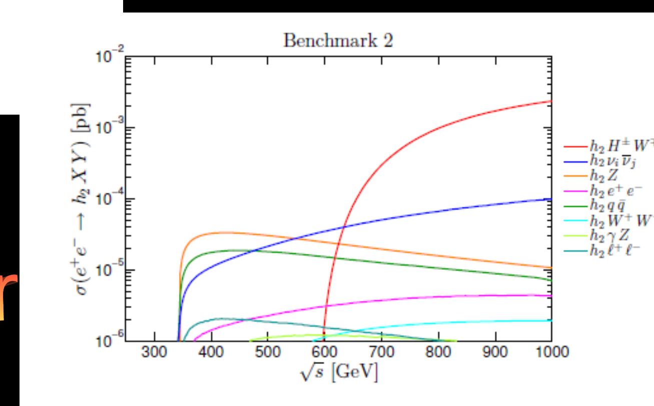
within collider reach?





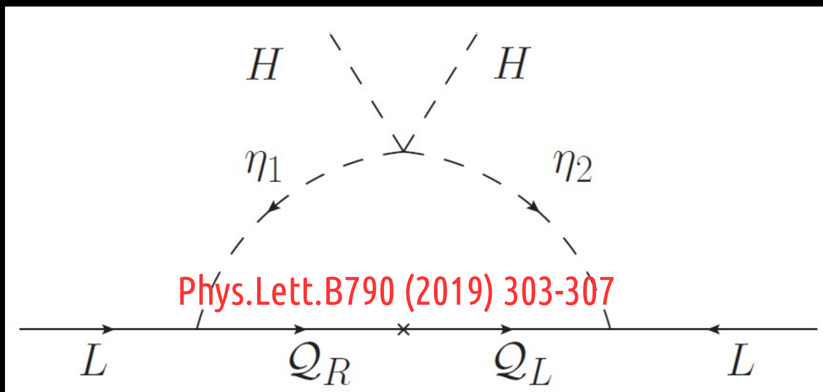
LHC

linear collider



many variants, e.g. Phys.Lett. B762 (2016) 214-218

dark matter as bound-state of neutrino mass messenger



beyond LHC

De Luca, Mitridate, Redi, Smirnov, Strumia

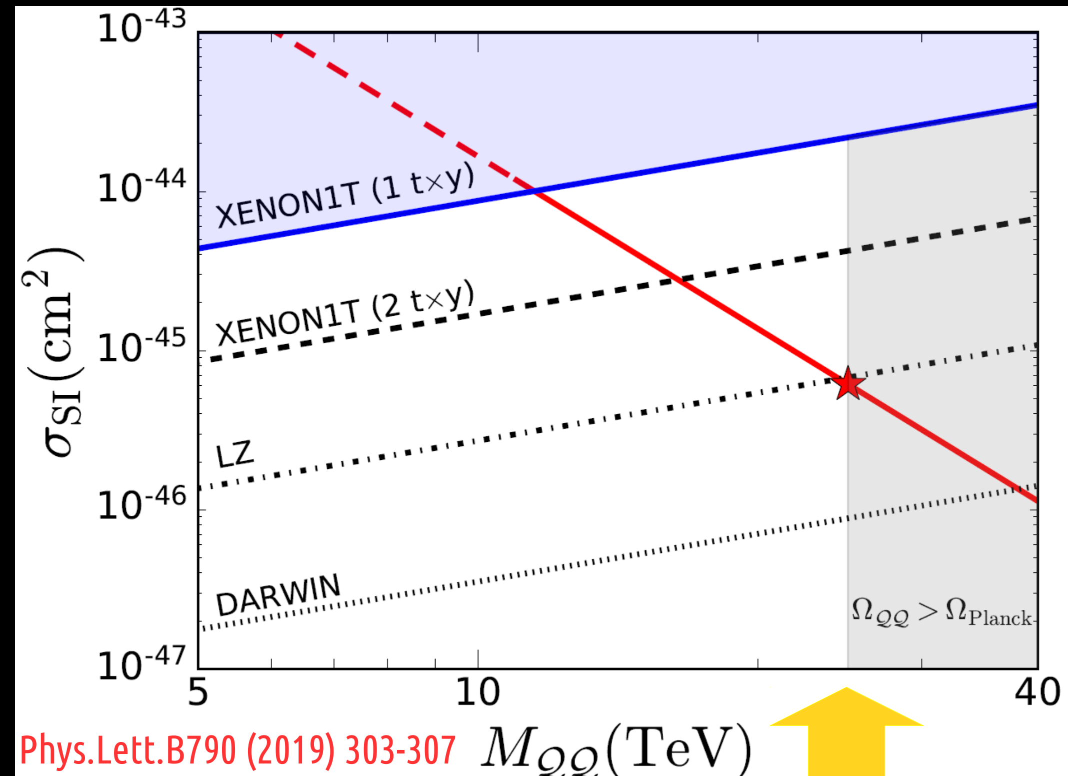


FIG. 2. Spin-independent cross section as a function of $M_{QQ} = 2M_Q$ (red). The star represents the mass required for a thermal bound state 25 TeVdark matter. Lower values can be probed by direct searches, the current bound is indicated in blue, while the black lines (dashed, dotted and dot-dashed) correspond to future sensitivities.

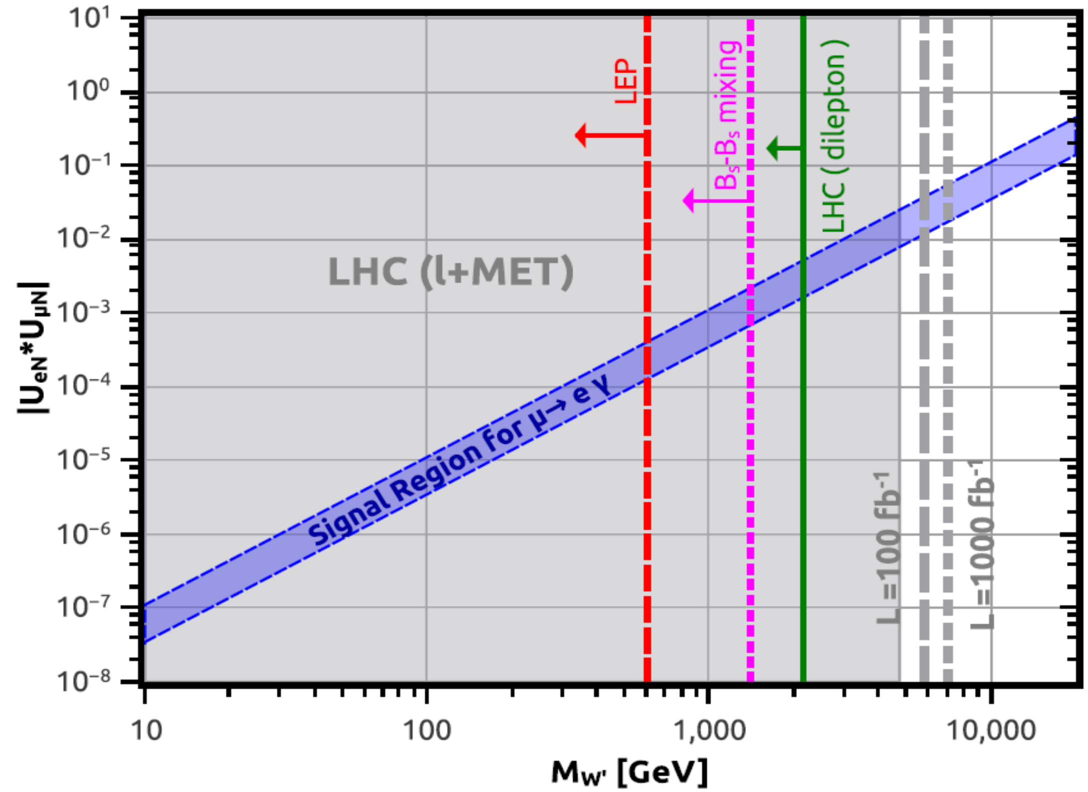
Phys.Rev. D97 (2018) 115032

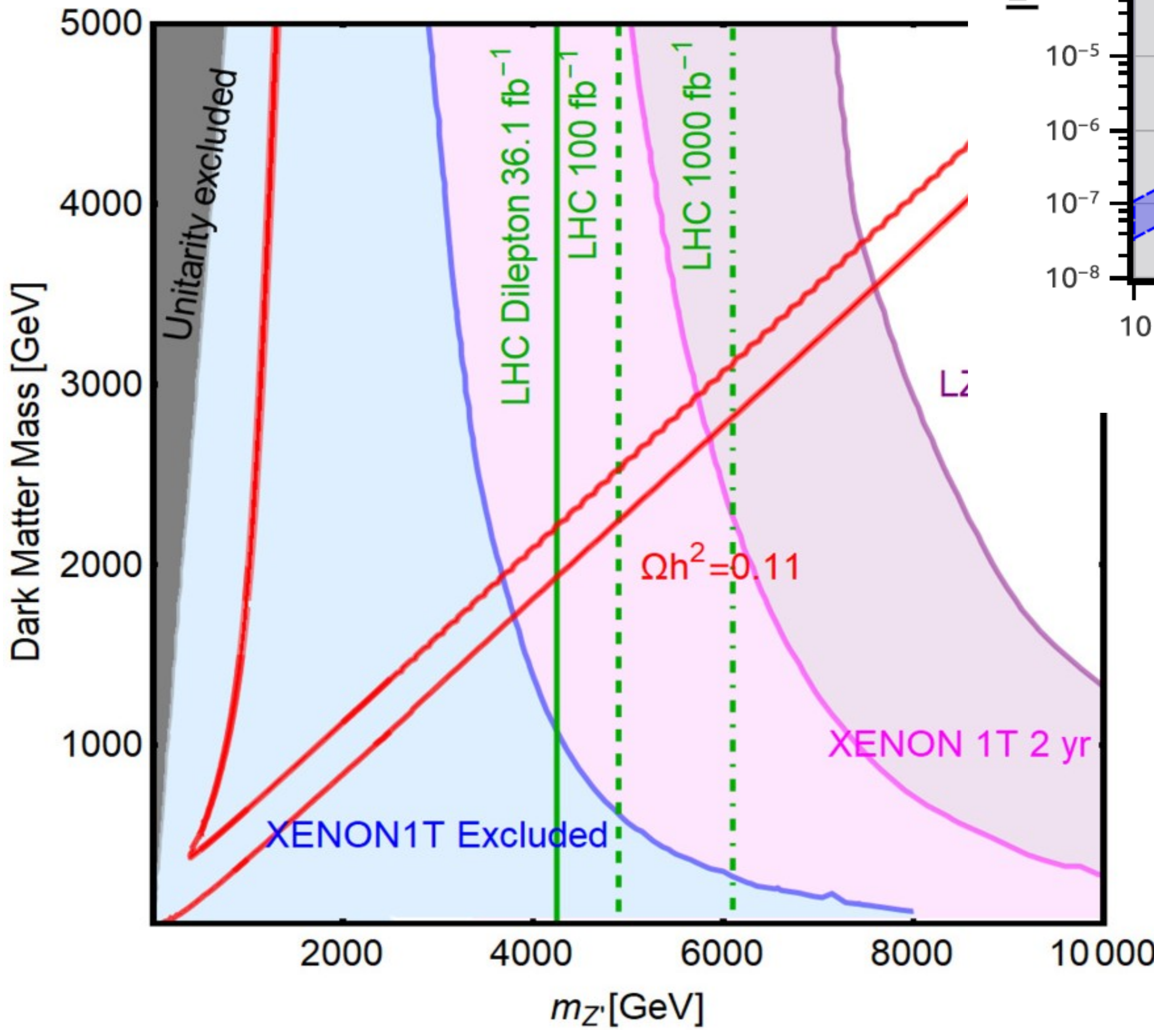
DM stability from Diracness

Matter-parity as a residual gauge symmetry: Probing a theory of cosmological dark matter

3-3-1-1 EW extension

Alves et al Phys.Lett. B772 (2017) 825–83
Dong et al JHEP 1804 (2018) 143
Dong et al Phys.Rev. D99 (2019) 055040





interplay with LHC, LFV, etc

decaying Gravitino dark matter

decays suppressed by Planck mass & smallness of m-nu

$$\Gamma = \Gamma(\tilde{G} \to \sum_i \nu_i \gamma) \simeq \frac{1}{32\pi} |U_{\tilde{\gamma}\nu}|^2 \frac{m_{\tilde{G}}^3}{M_P^2}$$

chosen to fit neutrino osc. data

Restrepo et al
PRD85 (2012) 023523

relic abundance
+ LHC searches

excluded by gamma
line searches @
Egret & Fermi-LAT