Lepton Number Violation

and the

Baryon Asymmetry of the Universe

Heinrich Päs

PASCOS 2017 - Madrid

Why is Lepton Number Violation interesting ?

Why is LNV interesting ?

Why is a non-zero ν mass physics beyond SM ?

EITHER - OR

$m_D \overline{\nu_L} \nu_R$

$m_M \overline{\nu_L^c} \nu_L$

$m_M \overline{\nu_R^c} \nu_R$ OR ~~$m_M \overline{\nu_R^c} \nu_R$~~

LNV

LNV
e.g.
Seesaw-I
[Minkowski'77]

New Symmetry, e.g. Lepton Number

Lepton Number (Violation) is at the core of the link between ν mass & physics beyond SM!

Key Message

0vBB Decay

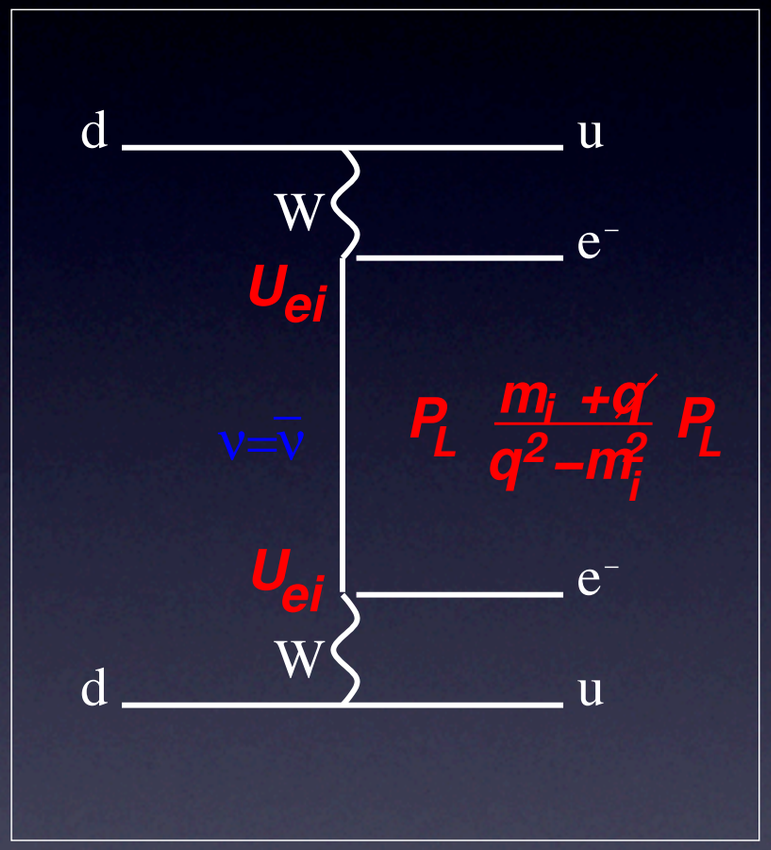
LHC

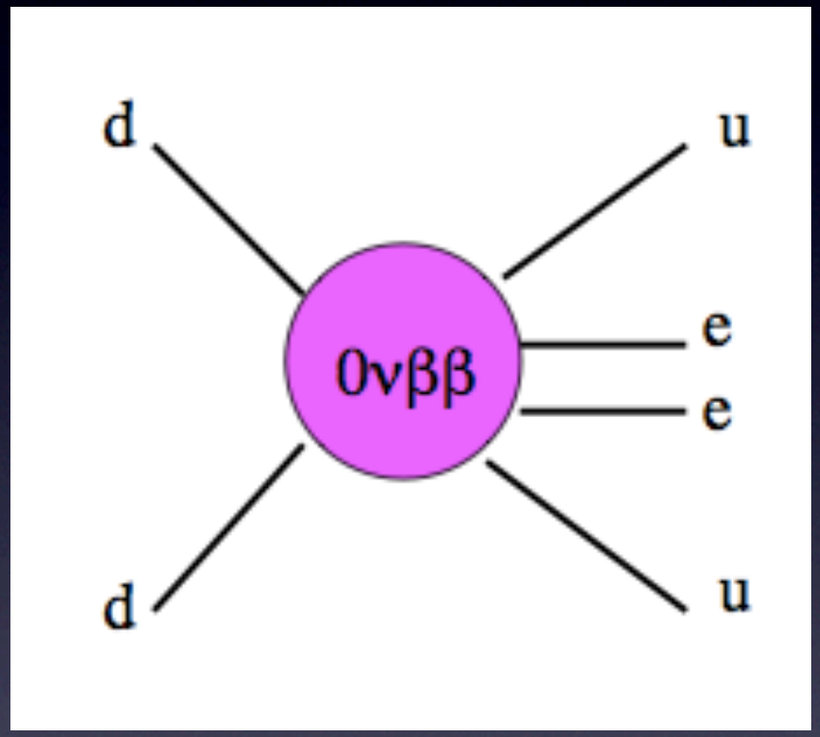
Lepton Number Violation

Baryon Asymmetry of the Universe

Probing LNV

Most prominent: 0νBB decay



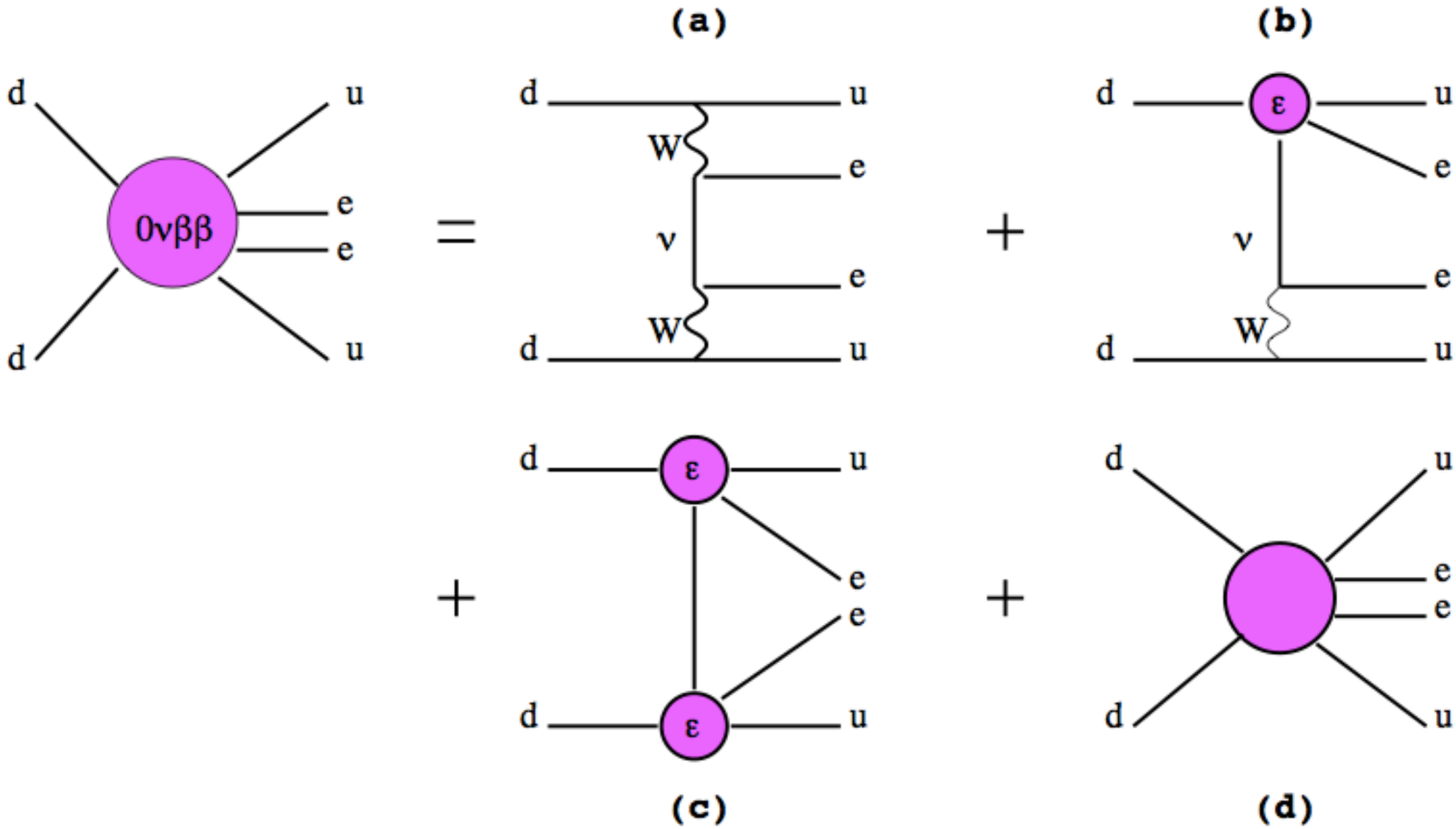


~ m_ν

"Mass Mechanism"

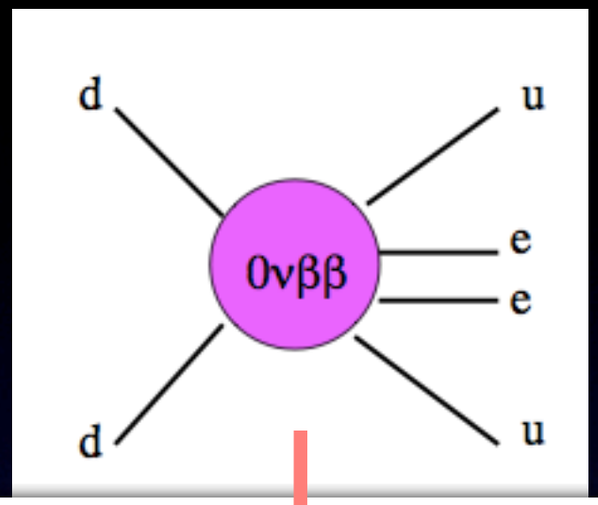
General Case

0νBB Decay



[HP, Hirsch, Kovalenko, Klapdor-Kleingrothaus, PLB 1999 & 2001]

0νBB - LHC Complementarity



pointlike @ nuclear Fermi momentum $O(r_N^{-1})$~100 MeV

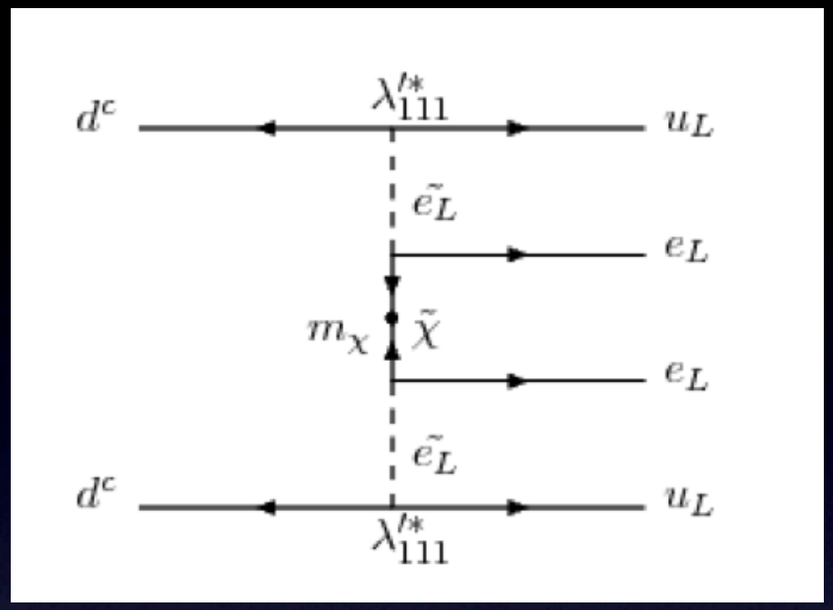
d = 9 operator

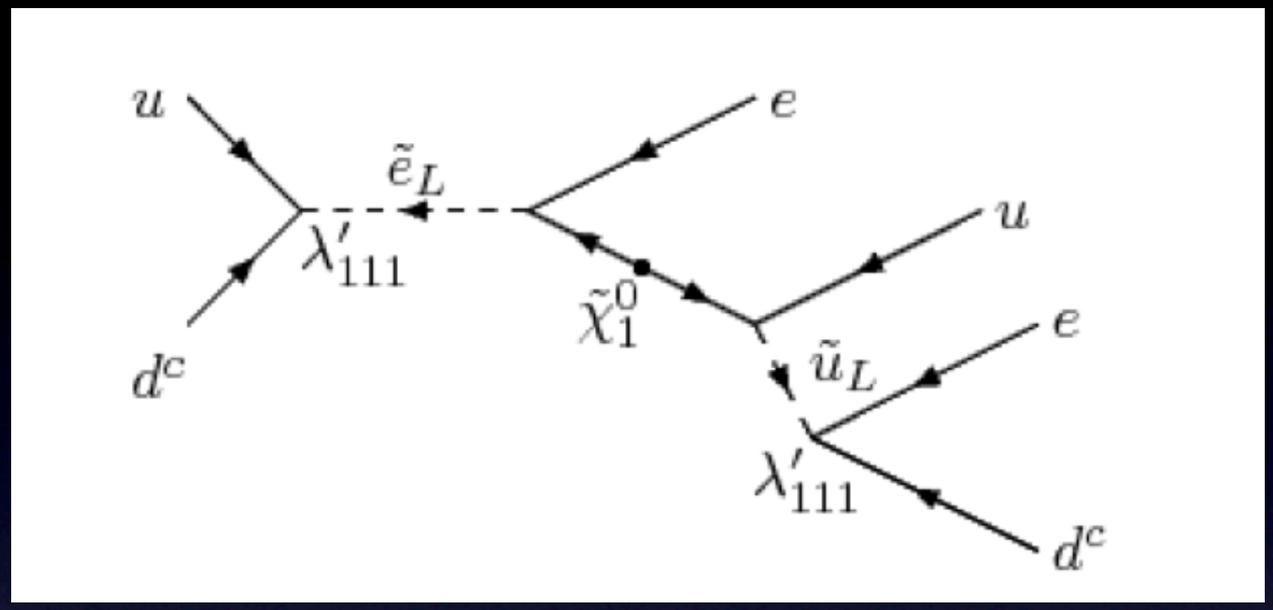
TeV scale particles

New Physics @ the LHC!

0νBB - LHC Complementarity!

0vBB @ LHC: Example RPV SUSY

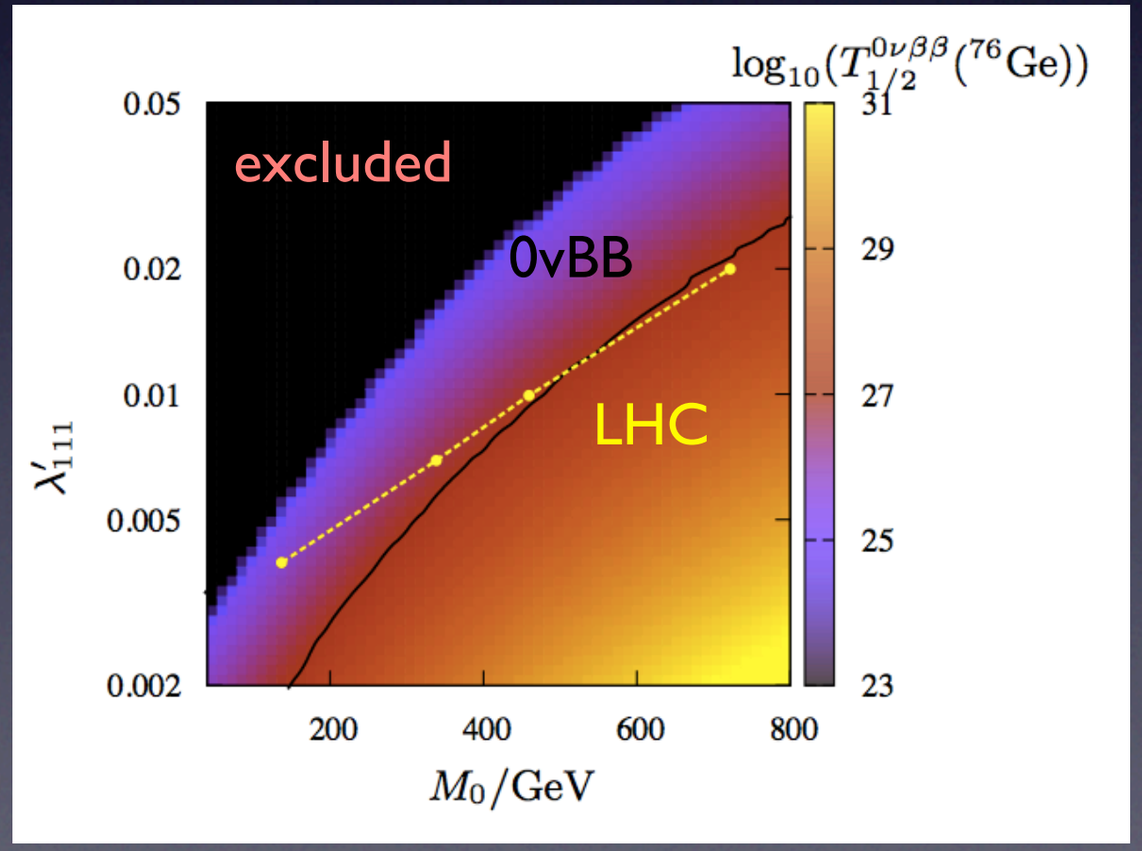




Like-Sign Di-Lepton Signal:
10 fb^{-1}, $\sqrt{s}$ = 14 TeV
SM + SUSY Background

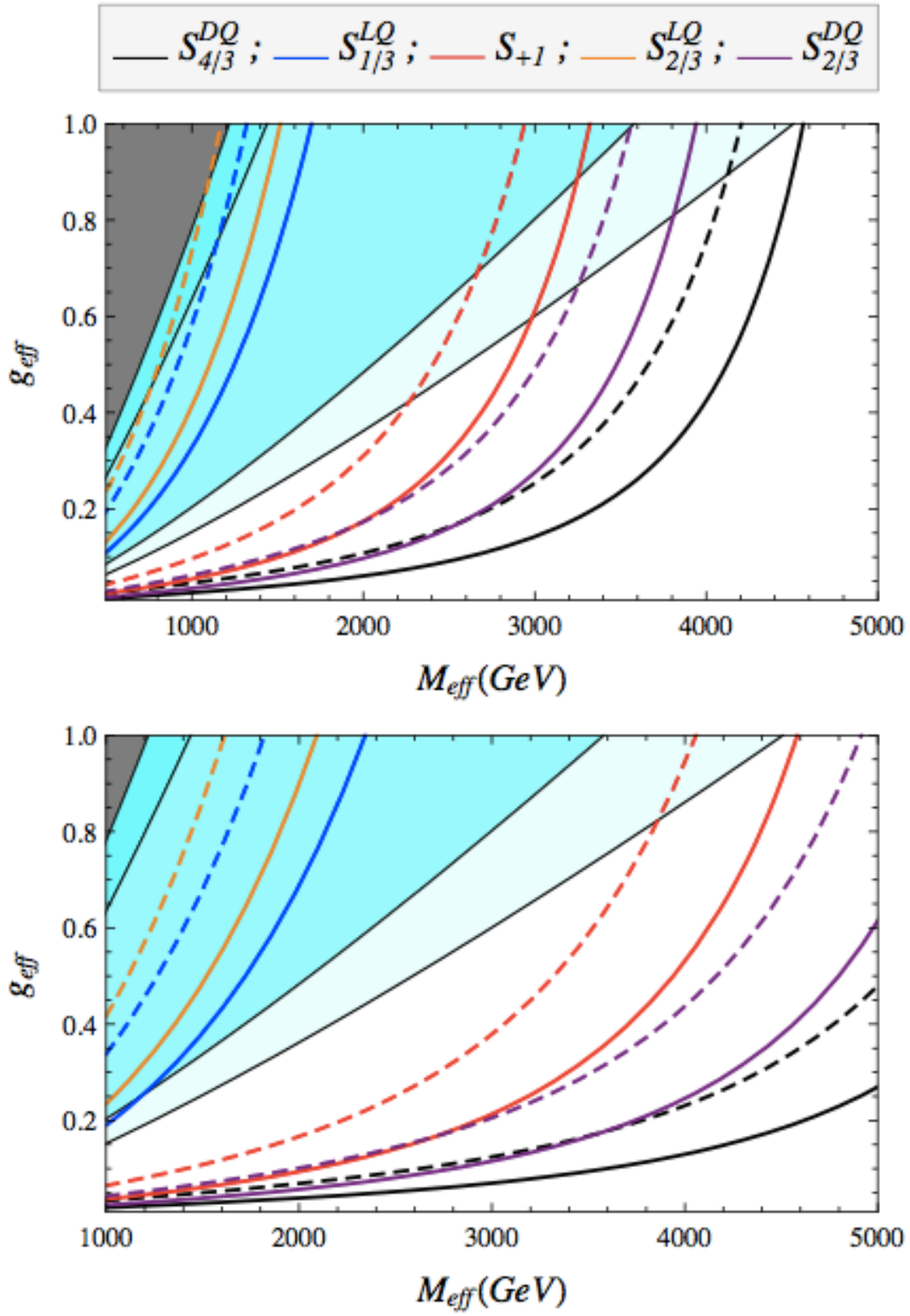
$$M_{1/2} = 300\ \text{GeV} + 0.6 M_0$$

[Allanach, Kom, HP, PRL 2009]



0νββ versus LHC SSD at $\sqrt{s}$ = 14 TeV

m_ψ = 200 GeV



m_ψ = 1 TeV

0νββ - grey & blue areas:

present bound, $T_{1/2}>10^{26}$y
(smallest rate operator)
$T_{1/2}>10^{26}$y, $T_{1/2}>10^{27}$y
(largest rate operator)

$$\mathcal{A}^{0\nu\beta\beta} \propto \frac{g_1 g_2 g_3 g_4}{m^2_{S_i} m_{\psi_q} m^2_{S_j}} \equiv \frac{g^4_{eff}}{M^5_{eff}}.$$

LHC: curved lines
dashed: $Br^{eff}(S \to eejj)=10^{-2}$
solid: $Br^{eff}(S \to eejj)=10^{-1}$

[Helo, Hirsch, Kovalenko, HP, 2013]

0νββ vs LHC sensitivities

→ with the exception of Leptoquarks:

LHC more sensitive than 0vBB Decay !

0vBB signal → LHC signal

No LHC signal → no 0vBB signal

- OR-

0vBB is Long Range (e.g. mass-mechanism)

→ how to find out?

“Falsifying Leptogenesis at the LHC”

[F. Deppisch, J. Harz, M. Hirsch, PRL 112 (2014) 221601]

“Falsifying Leptogenesis at the LHC”

- LNV @ LHC
- Lower bound on washout of Lepton Number Asymmetry
- No out-of-equilibrium condition in early universe!

LNV and BAU

But EVEN WORSE: consider Sphalerons

Leptogenesis:

~~B-L~~ + ~~B+L~~

ν_R decay + Sphalerons

↓

B Asymmetry

In Reverse:

~~B-L~~ + ~~B+L~~

e.g. LHC + Sphalerons

↓

B washout

LNV and BAU

Large LNV @ LHC (or elsewhere) will washout ANY pre-existing Baryon Asymmetry, irrespective of the Baryogenesis mechanism (Leptogensis, etc...)

Original Paper: [Fukugita, Yanagida, 1990]

"Sphaleron induced Baryon Number Non-conservation and a constraint on Majorana neutrino masses"

Also:

[Gelmini, Yanagida, 1992] keV-bound on ν mass

[Klapdor-Kleingrothaus, Kolb, Kuzmin, 1990] Bound on sneutrinos

[Hollenberg, HP, Schalla, 2011] Bound on 4th generation neutrinos

[...many others]

Conclusions I

0vBB

- OR -

Long range mechanism e.g. m_ν

Short range mechanism

LNV @ LHC

[Deppisch, Harz, Hirsch, Huang, HP, 2015]

Low-Scale Baryogenesis

also detectable @ LHC?
"2 for one"

Conclusions II

High scale baryogenesis → ~~LNV @ LHC~~ → If 0vBB

↓

Mass mechanism

m_ν

↓

Very probably high scale origin of m_ν

[Deppisch, Harz, Hirsch, Huang, HP, 2015]

Summary

0vBB →

- EITHER -

LNV@LHC → Low scale Baryogenesis, "2 for 1"

- OR -

very probably high-scale origin of m_ν

(like vanilla type-I seesaw + leptogenesis)

[Deppisch, Harz, Hirsch, Huang, HP, 2015]

Loopholes exist and should be checked!

(Flavor restriction, conserved charges, etc...)

[Deppisch, Harz, Hirsch, 2014; Antaramian, Hall, Rasin, 1994, work in progres...]