Right-handed currents and heavy neutrinos

Proposal for the Report on Physics at 100 TeV

Janusz Gluza (Silesia U.)

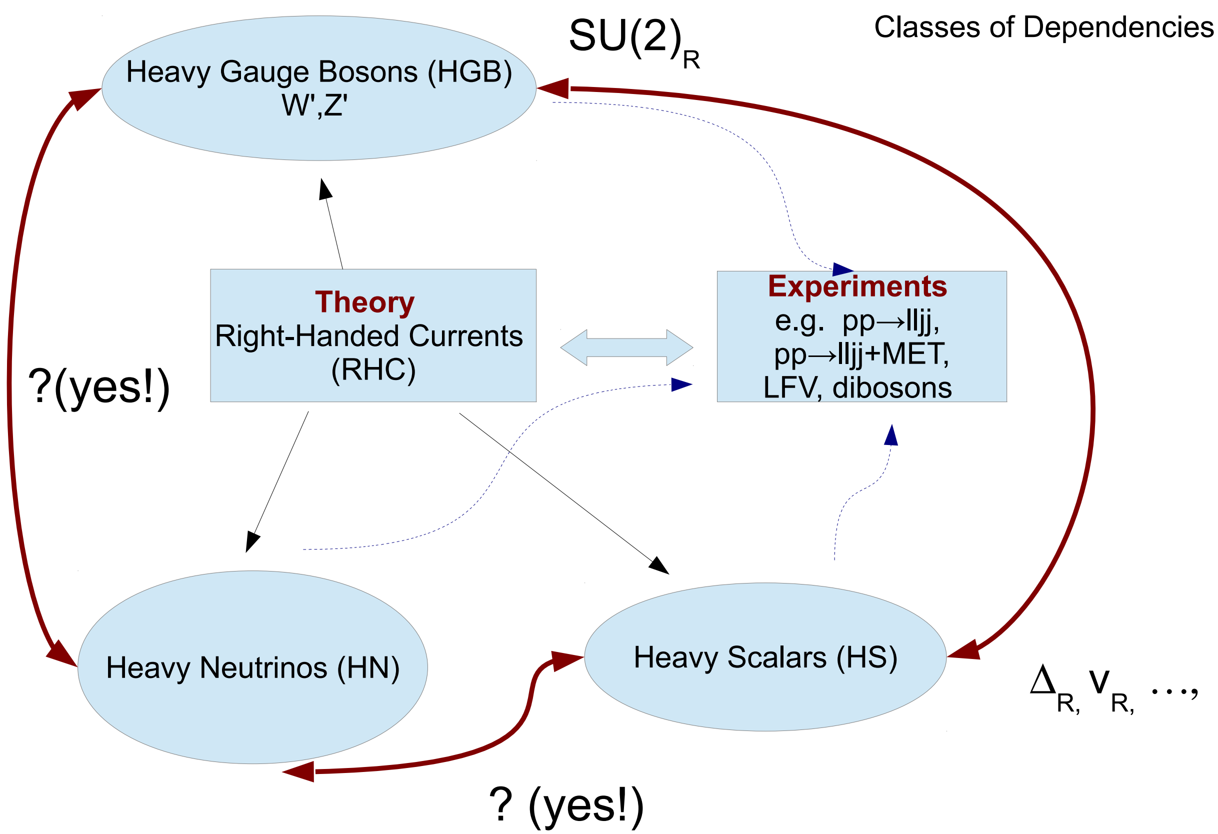
In collaboration with:

G. Bambhaniya (Ahmedabad, Phys. Res. Lab)
J. Chakrabortty, T. Srivastava (Indian Inst. Tech., Kanpur)
T. Jeliński, M. Kordiaczyńska (Silesia U.)
R. Szafron (Alberta U.)

CERN, 5.10.2015, Vidyo transmission

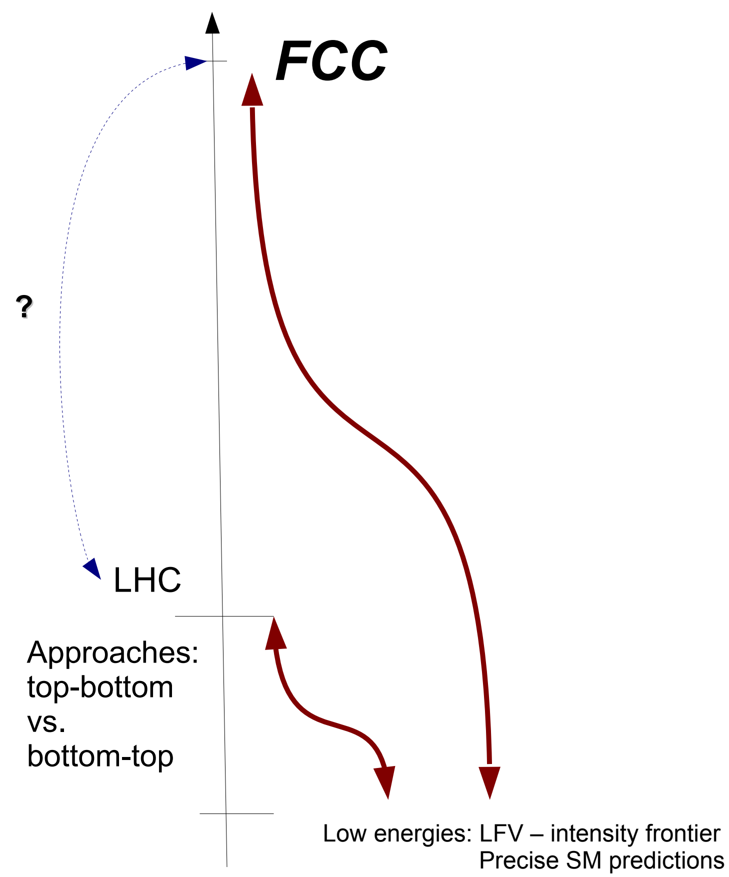
FCC-hh BSM group informal meeting, indico

RHC includes plenty of connected issues



We focus on non-supersymmetric theories

From the lowest to the high(est) energies



This talk:
$pp \to lljj$

LHC-1 excess data

A few deviations from the SM predictions in invariant mass distributions near 2 TeV:

(i) a 3.4σ excess at ∼2 TeV in the ATLAS search interpreted as a W' boson decaying into $WZ \to jj$, The mass range with significance above 2σ is ~ 1.9–2.1 TeV; the global significance is 2.5σ - see pdf.

(ii) A CMS search for jj resonances without distinguishing between the W- and Z-tagged jets, a 1.4σ excess at ∼1.9 TeV - see pdf

(iii)

a 2.8σ excess in the 1.8 – 2.2 TeV bin in the CMS search for a W' and a heavy "right-handed" neutrino, N_R, through the $W' \to N_R\, e \to eejj$ process - see pdf

(iv) a 2.2σ excess in the 1.8 – 1.9 TeV bin in the CMS search for $W' \to Wh^0$, where the SM Higgs boson, h^0, is highly boosted and decays into $b\bar{b}$, while $W \to \ell\nu$ - see pdf

(v) a $\sim 2\sigma$ excess at ~ 1.8 TeV in the CMS dijet resonance search - see pdf. The ATLAS search in the same channel has yielded only a 1σ excess at 1.8 TeV - see pdf

Theory vs experiment

Three examples:

(i) “Symmetry Restored in Dibosons at the LHC?” [Brehmer et al., arXiv:1507.00013]

(ii) “Reconciling the 2 TeV Excesses at the LHC in a Linear Seesaw Left-Right Model” [Deppisch et al., arXiv:1508.05940]

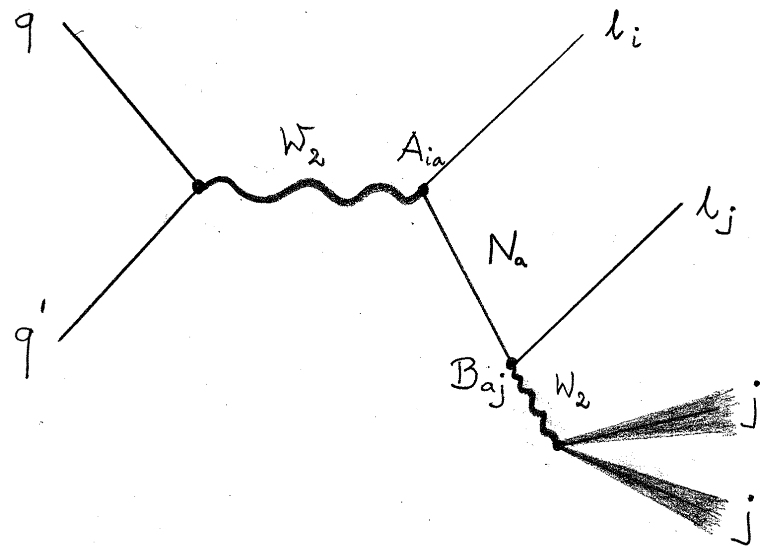
(iii) “Unified explanation of the $eejj$, diboson and dijet resonances at the LHC” [Bhupal Dev and Mohapatra, arXiv:1508.02277]

In (ii) linear see-saw is favorable, in (iii) inverse see-saw is favorable over type I see-saw

What is surprising about CMS data on $pp \to lljj$?

1. Ratio of opposite-sign (OS) $pp \to e^{\pm}e^{\mp}jj$ to the same-sign (SS) $pp \to e^{\pm}e^{\pm}jj$ leptons:

$$r_{CMS} = \frac{N_{SS}}{N_{OS}} = \frac{1}{13},$$

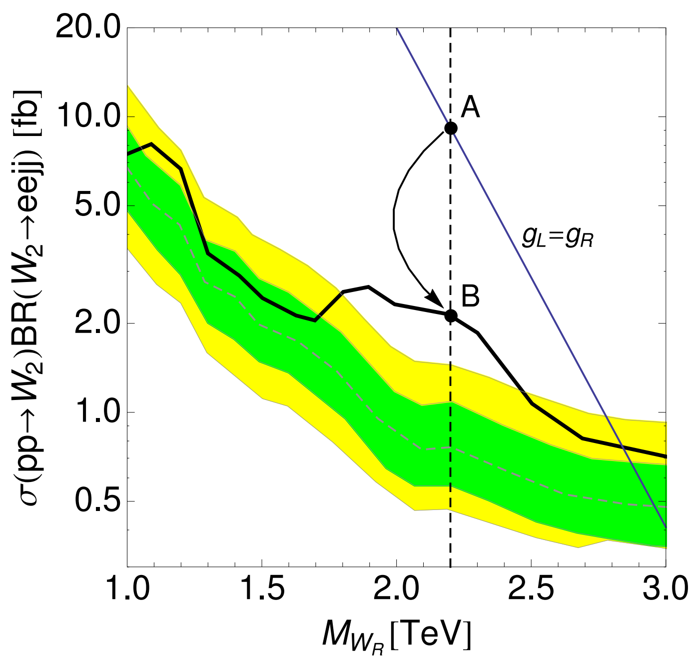


Almost no lepton number violation! Dirac/Pseudo-Dirac heavy neutrinos

In addition:

2. No excess in the $\mu\mu$ channel

3. Overall excess in $eejj$ production (point B), interpreted by CMS with $g_L = g_R$ (point A)



ATLAS case!

Only SS leptons considered - assumption of Majorana neutrinos

Keung, Senjanovic 1983 paper ...

How to explain CMS excess data with/without RHC?

- supersymmetric models,...

- RHC, $A \to B$: $g_R < g_L$

- RHC, $A \to B$: take into account interferences among neutrino states

Our point of view:

'Heavy neutrinos and the $pp \to lljj$ CMS data," JG and T. Jeliński, PLB **748** (2015) 125, e-Print: arXiv:1504.05568

All the above facts can be reconciled with data if RHC with heavy neutrinos with CP phases and mixings are taken into account (CMS takes in analysis degenerate heavy neutrinos, without mixings and CP phases),

$$\begin{aligned} \mathcal{L} \quad &\supset \quad \frac{g}{\sqrt{2}} \sum_{a=1}^{3} \overline{\nu}_a \gamma^\mu P_L (U_{PMNS})_{aj} l_j W^+_{1\mu} + \text{h.c.} \\ &+ \quad \frac{\tilde{g}}{\sqrt{2}} \sum_{a=1}^{3} \overline{N}_a \gamma^\mu P_R (K_R)_{aj} l_j W^+_{2\mu} + \text{h.c.} \end{aligned}$$

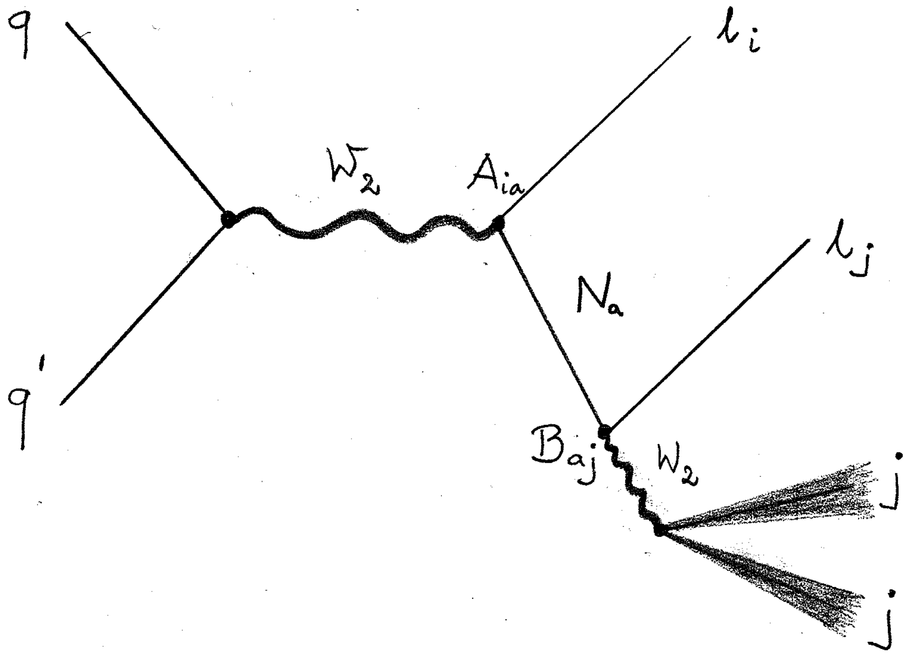
e.g.

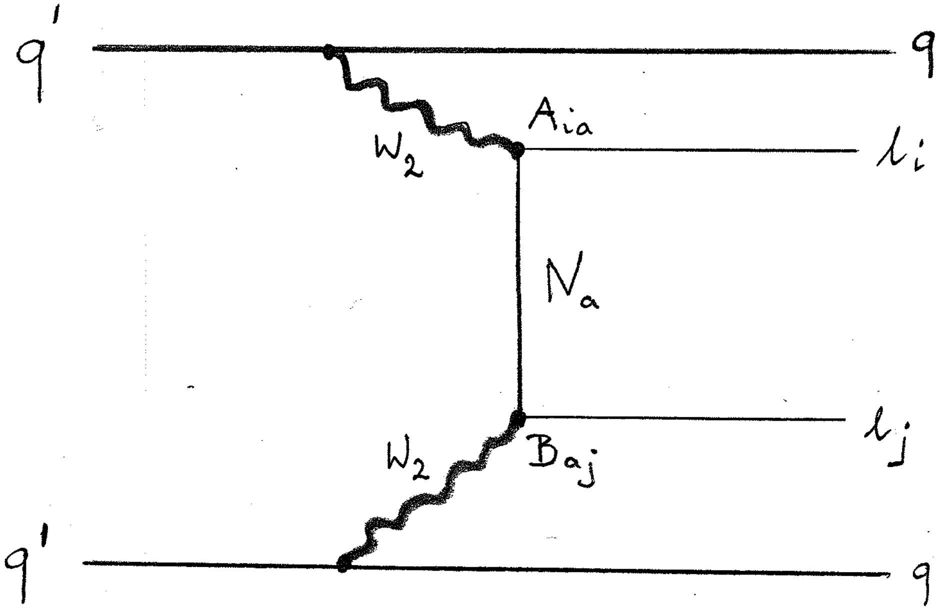
$$M_{N_{1,3}} = 0.925\,\text{TeV}, \quad M_{N_2} = 10\,\text{TeV}, \quad K_R = \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13} \\ 0 & 1 & 0 \\ -e^{i\phi_3}\sin\theta_{13} & 0 & e^{i\phi_3}\cos\theta_{13} \end{pmatrix}.$$

$$\mathcal{L}_{\mathcal{RHC}} \quad = \quad \overbrace{\left(\cos\theta_{13}\overline{N}_1 - e^{i\phi_3}\sin\theta_{13}\overline{N}_3\right)}^{N_{eff}} \frac{\tilde{g}}{\sqrt{2}} \gamma^\mu P_R (K_R)_{aj} l_j W^+_{2\mu}$$

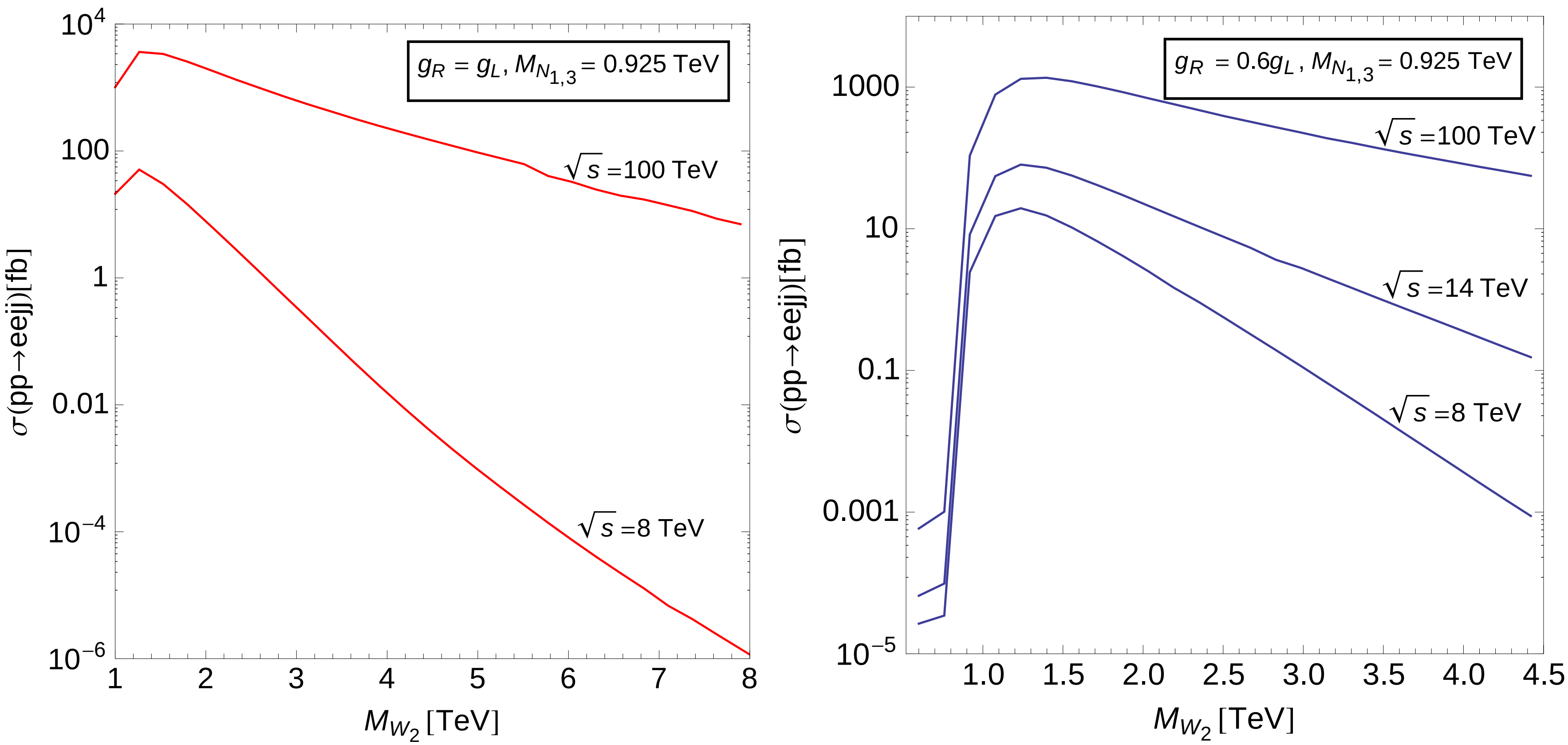
There is no a problem with $\mu \to e\gamma$ here (zero or very small K_{R12} elements).

Also problem with neutrinoless doubly beta decay can be avoided (destructive interferences)



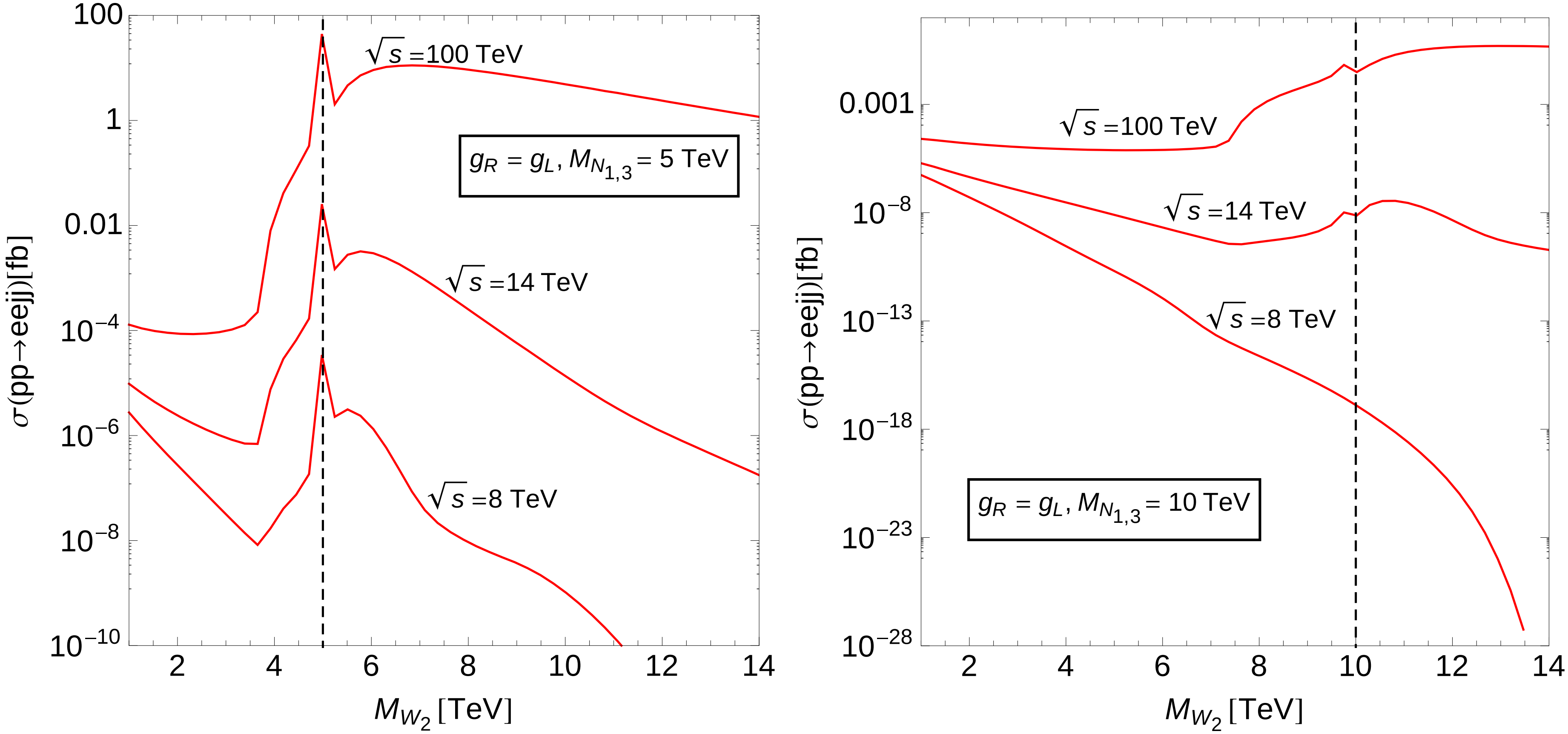


Preliminary plots, proposal for BSM section of the Report on Physics at 100 TeV



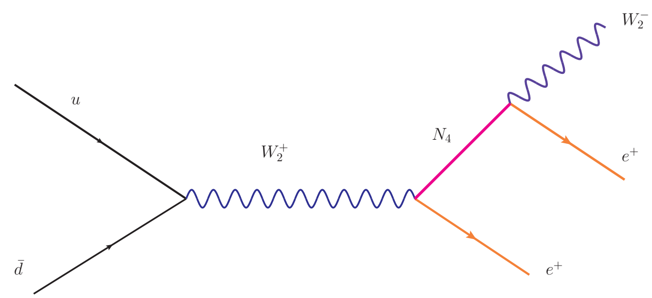
1. What about 33 TeV option?
2. We plan to tweak predictions next weeks: Cuts, Significance, other flavours,...

Preliminary plots, proposal for BSM section of the Report on Physics at 100 TeV



Remark, models consistency, radiative corrections

"Left-Right Symmetry at LHC and Precise 1-Loop Low Energy Data", J. Chakrabortty et al, JHEP 1207 (2012) 038

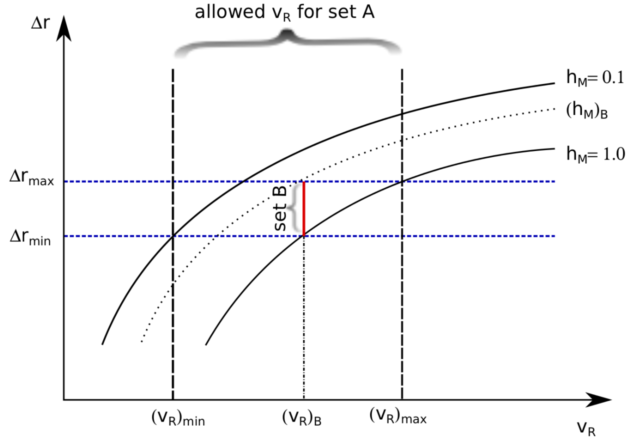


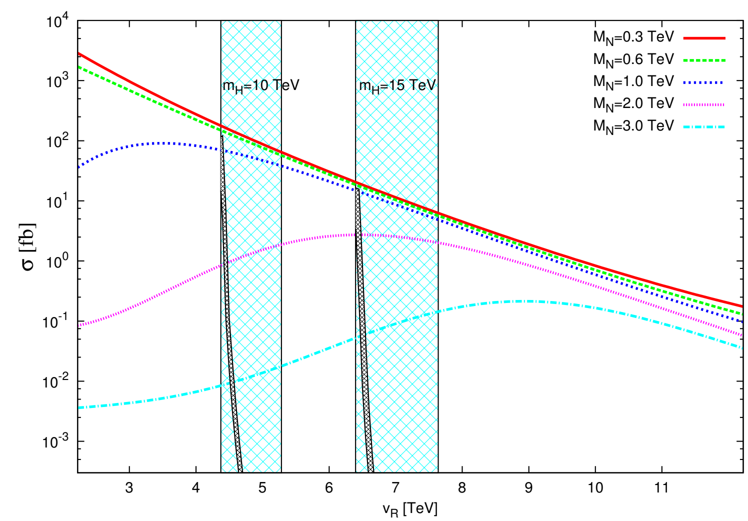
Muon decay constrain parameter space of a model

$$\frac{G_F}{\sqrt{2}} = \frac{e^2}{8(1 - M_W^2/M_Z^2)M_W^2}(1 + \Delta r[M_N, M_H, M_{W_2}]).$$

⇒ calculate Δr in LR
⇒ do the matching with SM
⇒ compare with data
M. Czakon, J. Gluza,M. Zrałek, Nucl. Phys. **B573** (2000) 57 and
M. Czakon, J. Gluza, J. Hejczyk, Nucl. Phys. **B642** (2002) 157-172.

Corrections narrow parameter space, $\sqrt{s} = 14$ TeV





$pp \to eeW_2$

Summary

$pp \to lljj$

- We are ready for preparing and delivering updated analysis for the "smoking-gun" $pp \to lljj$ process at 100 TeV, taking into account
  1. Knowledge on heavy neutrino sector in various scenarios for neutrino masses and mixings (e.g. see-saw, inverse see-saw)
  2. Low energy constraints
  3. Various RHC scenarios (e.g. $g_R \neq g_L$)