Characteristic signals of right-handed currents at future colliders

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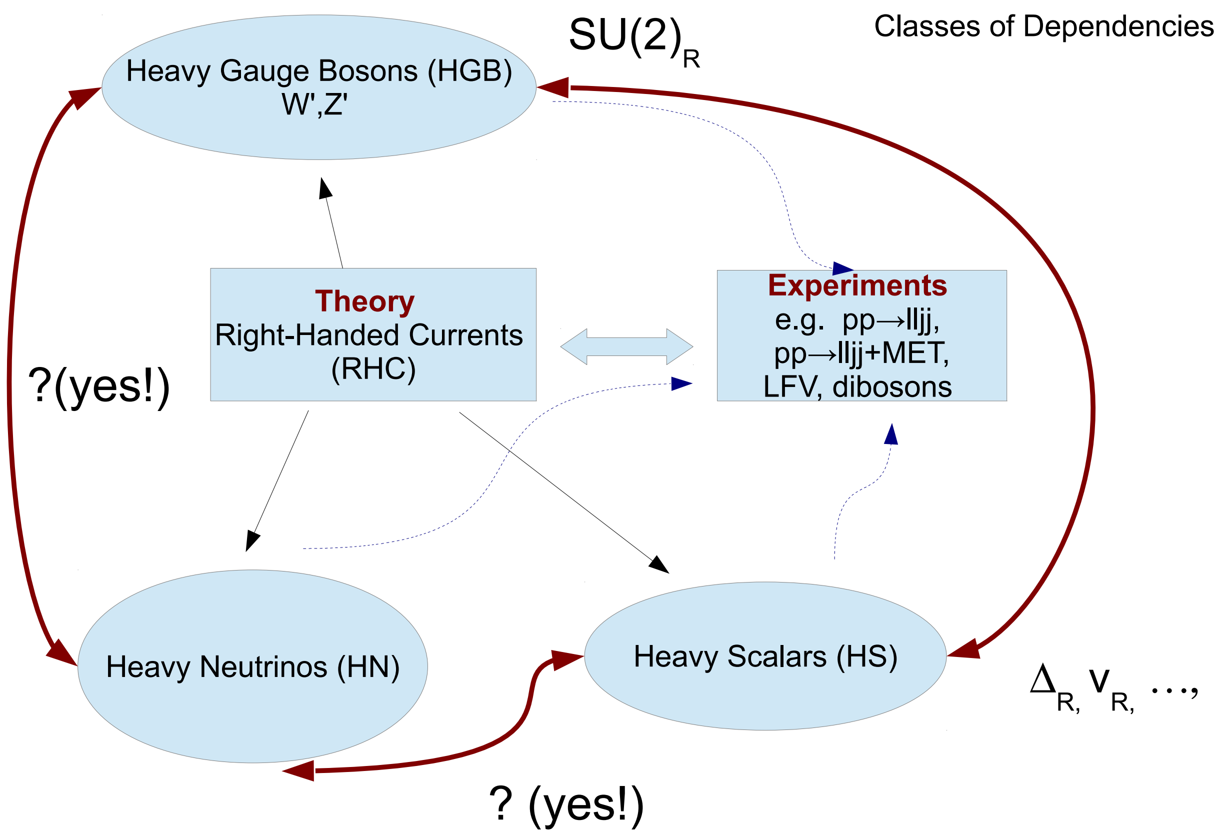
RHC includes plenty of connected issues



Studies including FCC-hh:

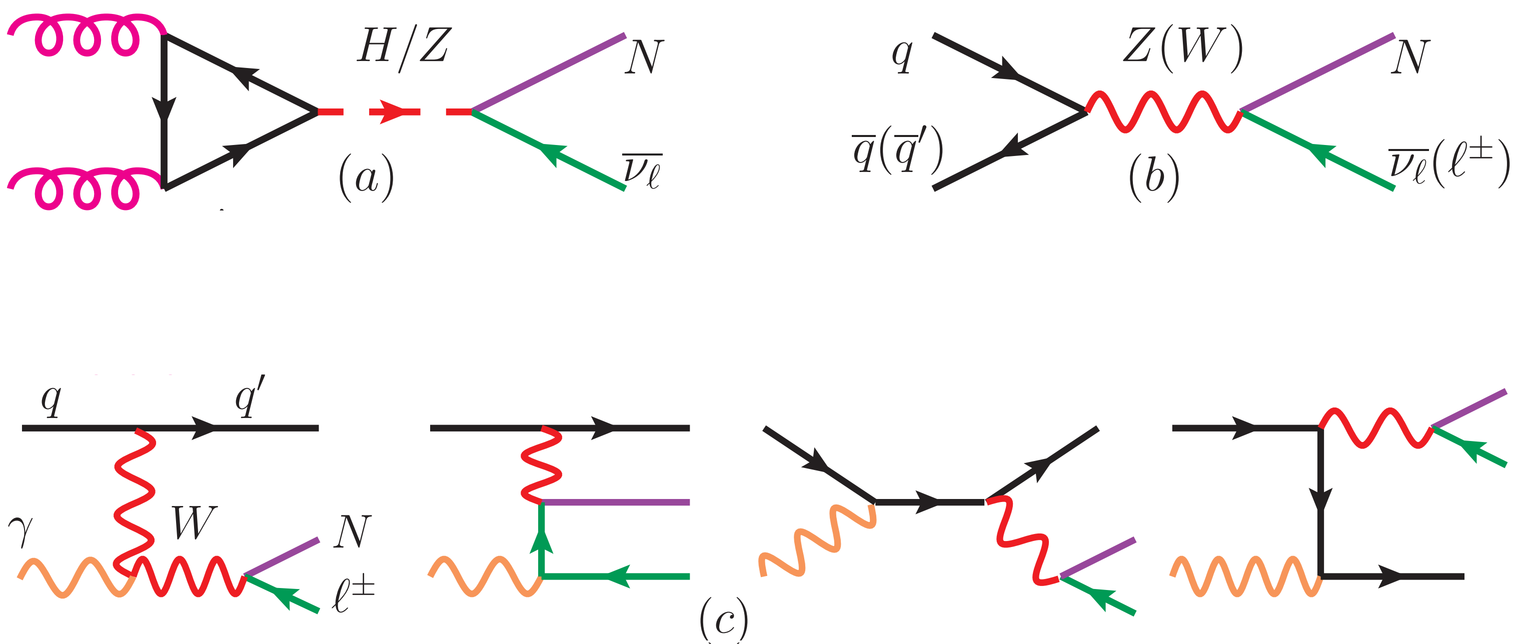
- G. Bambhaniya, J. Chakrabortty, J. Gluza, T. Jeliński and R. Szafron, "Search for doubly charged Higgs bosons through VBF at the LHC and beyond ," arXiv:1504.03999, PRD 92 (2015) 1, 015016
- G. Bambhaniya, J. Chakrabortty, J. Gluza, T. Jeliński and M. Kordiaczyńska, "Lowest limits on the doubly charged Higgs boson masses in the minimal left-right symmetric model," arXiv:1408.0774, PRD 90 (2014) 9, 095003
- J .Gluza, T. Jeliński, "Heavy neutrinos and the $pp \to lljj$ CMS data," arXiv:1504.05568, PLB 748 (2015) 125
- J. Gluza, T. Jeliński and R. Szafron, "Lepton Number Violation and 'Diracness' of massive neutrinos composed of Majorana states," arXiv:1604.01388
- FCC-hh (pre-CDR) Report: "Probing BSM Higgs Sectors at the FCC-hh", "Beyond the Standard Model physics at 100 TeV"

Heavy neutrinos interactions

$$\begin{pmatrix} \nu_L \\ N_R \end{pmatrix} = \begin{pmatrix} U_{3\times 3} & V_{3\times n} \\ X_{n\times 3} & {K_R}^\dagger{}_{n\times n} \end{pmatrix} \begin{pmatrix} \nu \\ N \end{pmatrix}$$

$$\begin{aligned} \mathcal{L} \quad = \quad & -\frac{g_L}{\sqrt{2}} W^+_{1\mu} \overline{\nu} U^\dagger \gamma^\mu P_L \ell^- - \frac{g_L}{\sqrt{2}} W^+_{1\mu} \overline{N} V^\dagger \gamma^\mu P_L \ell^- \\ & -\frac{g_R}{\sqrt{2}} W^+_{2\mu} \overline{\nu} X^\dagger \gamma^\mu P_R \ell^- - \frac{g_R}{\sqrt{2}} W^+_{2\mu} \overline{N} K_R \gamma^\mu P_R \ell^- \\ & + \dots \end{aligned}$$

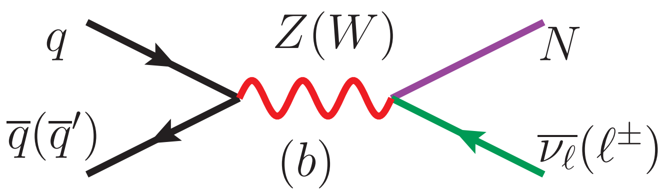
Heavy neutrinos production

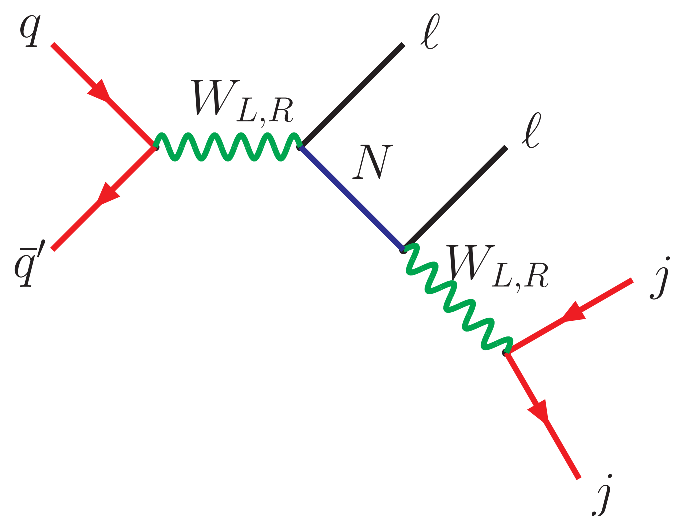


[Degrande et al., arXiv:1602.06957]

ongoing studies: estimation of the SM background and analysis of possible decay channels

Drell-Yan production & $N \to ljj$





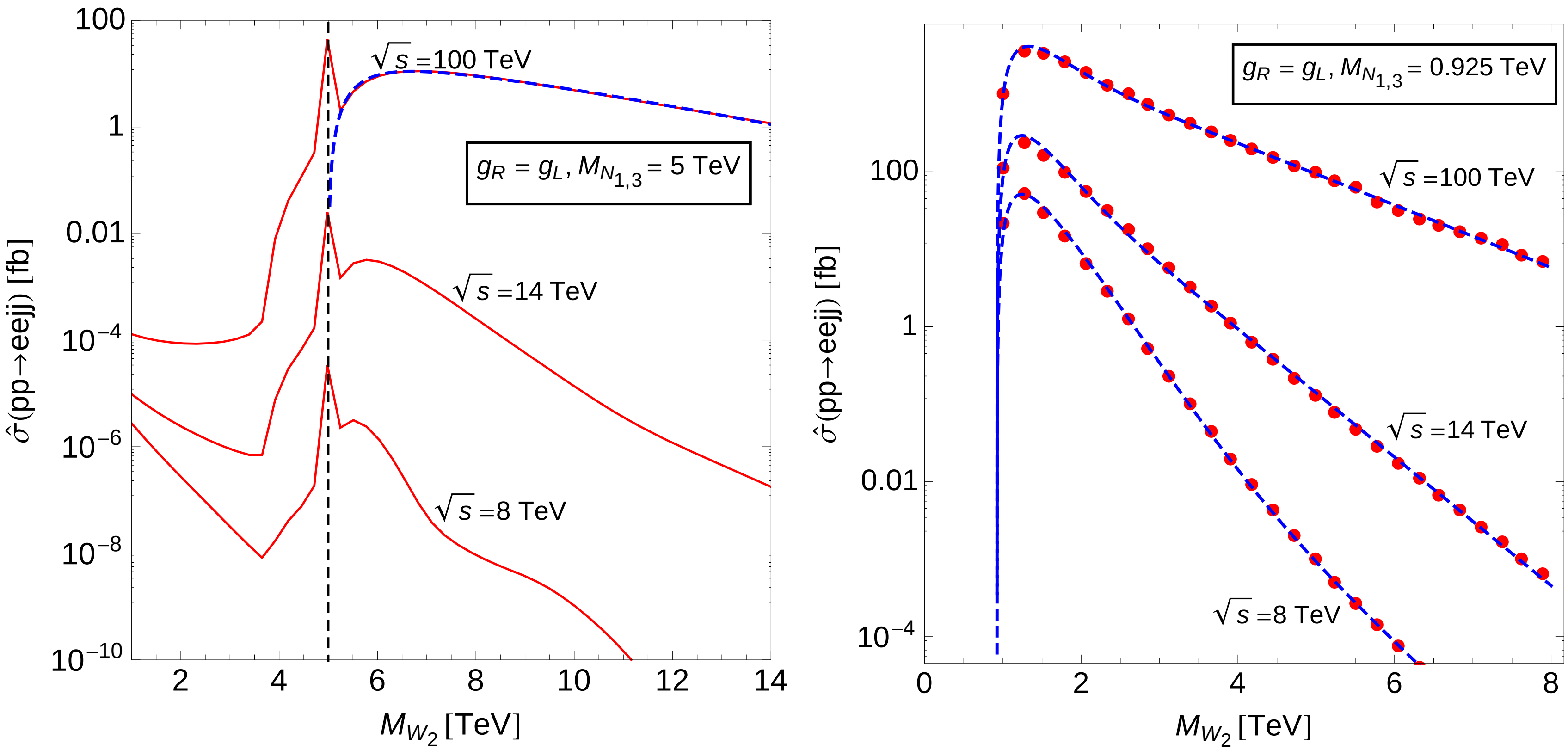
- golden channel for Majorana heavy neutrinos $\to$ SS and OS content of the dilepton signal, LFV

- no $\not{E}_T$, relatively easy to separate from the SM background

- heavy neutrino masses and mixings are crucial for interferences effects $\to$ more careful treatment of $pp \to eejj$ is needed; rough analyses can lead to overconstraining parameter space.

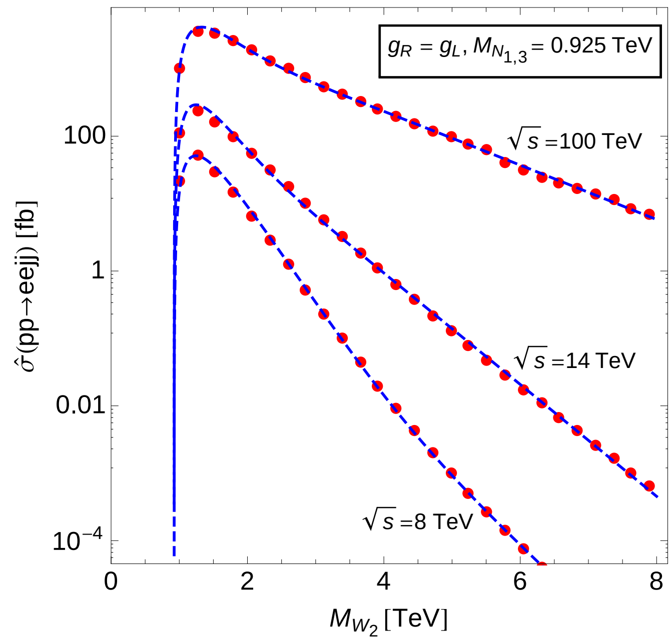
Total cross section $\sigma(pp \to eejj)$

MadGraph5 2.3.3 & NN23LO1 PDFs



NWA valid only for $M_{N_{1,3}} < M_{W_2} < \sqrt{s}$

Fitting dependence on M_{W_2}



Naive fit: $\sigma(pp \to eejj) = \frac{F_W(x_1)}{1+\frac{1}{18}\sum_b F_W(x_b)} a(e^{-b\mu} + ce^{-d\mu}), \quad \mu = M_{W_2}/1\,\mathrm{TeV}$

$$(8\,\mathrm{TeV}) \qquad a = 0.18 \times 10^5\,\mathrm{fb}, \quad b = 3.62, \quad c = 0.002, \quad \text{and} \quad d = 2.17,$$

$$(14\,\mathrm{TeV}) \qquad a = 1.32 \times 10^5\,\mathrm{fb}, \quad b = 3.97, \quad c = 0.016, \quad \text{and} \quad d = 1.92,$$

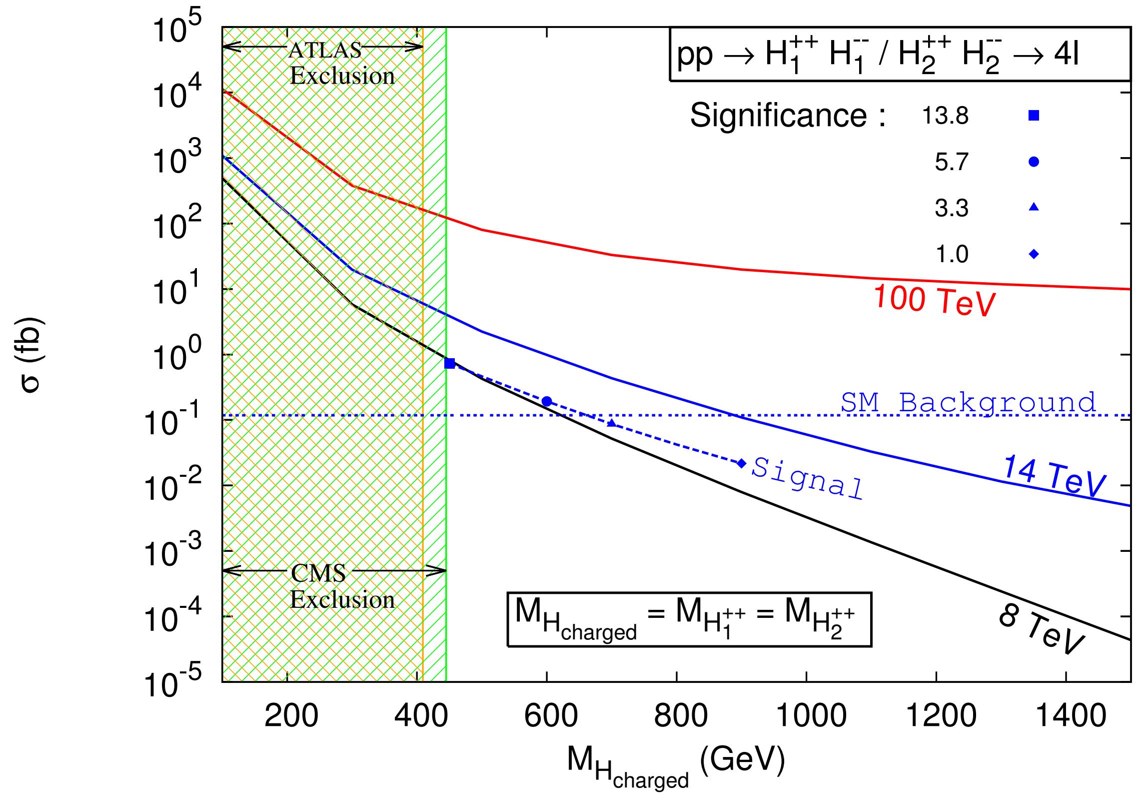
$$(100\,\mathrm{TeV}) \qquad a = 5.40 \times 10^5\,\mathrm{fb}, \quad b = 3.04, \quad c = 0.020, \quad \text{and} \quad d = 0.94.$$

Primary production	Secondary production	Signal
I. $H_1^+ H_1^-$	$\ell^+\ell^-\nu_L\nu_L$	$\ell^+\ell^- \oplus MET$
–	$\ell^+\ell^-\nu_R\nu_R$	depends on ν_R decay modes
–	$\ell^+\ell^-\nu_L\nu_R$	depends on ν_R decay modes
II. $H_2^+ H_2^-$	$\ell^+\ell^-\nu_L\nu_L$	$\ell^+\ell^- \oplus MET$
–	$\ell^+\ell^-\nu_R\nu_R$	depends on ν_R decay modes
–	$\ell^+\ell^-\nu_L\nu_R$	depends on ν_R decay modes
III. $H_1^{++} H_1^{--}$	–	$\ell^+\ell^+\ell^-\ell^-$
–	$H_1^+ H_1^+ H_1^- H_1^-$	See I
–	$H_1^\pm H_1^\pm H_2^\mp H_2^\mp$	See I & II
–	$H_2^+ H_2^+ H_2^- H_2^-$	See II
–	$W_i^+ W_i^+ W_j^- W_j^-$	depends on W's decay modes
IV. $H_2^{++} H_2^{--}$	–	$\ell^+\ell^+\ell^-\ell^-$
–	$H_2^+ H_2^+ H_2^- H_2^-$	See II
–	$H_1^\pm H_1^\pm H_2^\mp H_2^\mp$	See I & II
–	$H_1^+ H_1^+ H_1^- H_1^-$	See I
–	$W_i^+ W_i^+ W_j^- W_j^-$	depends on W's decay modes
V. $H_1^{\pm\pm} H_1^\mp$	–	$l^\pm l^\pm l^\mp \nu_L$
VI. $H_2^{\pm\pm} H_2^\mp$	–	$l^\pm l^\pm l^\mp \nu_L$
VII. $H_1^\pm Z_i, H_1^\pm W_i$	–	See I & Z_i, W_i decay modes
VIII. $H_2^\pm Z_i, H_1^\pm W_i$	–	See II & Z_i, W_i decay modes
IX. $H_1^\pm A$	–	See I
X. $H_2^\pm A$	–	See II

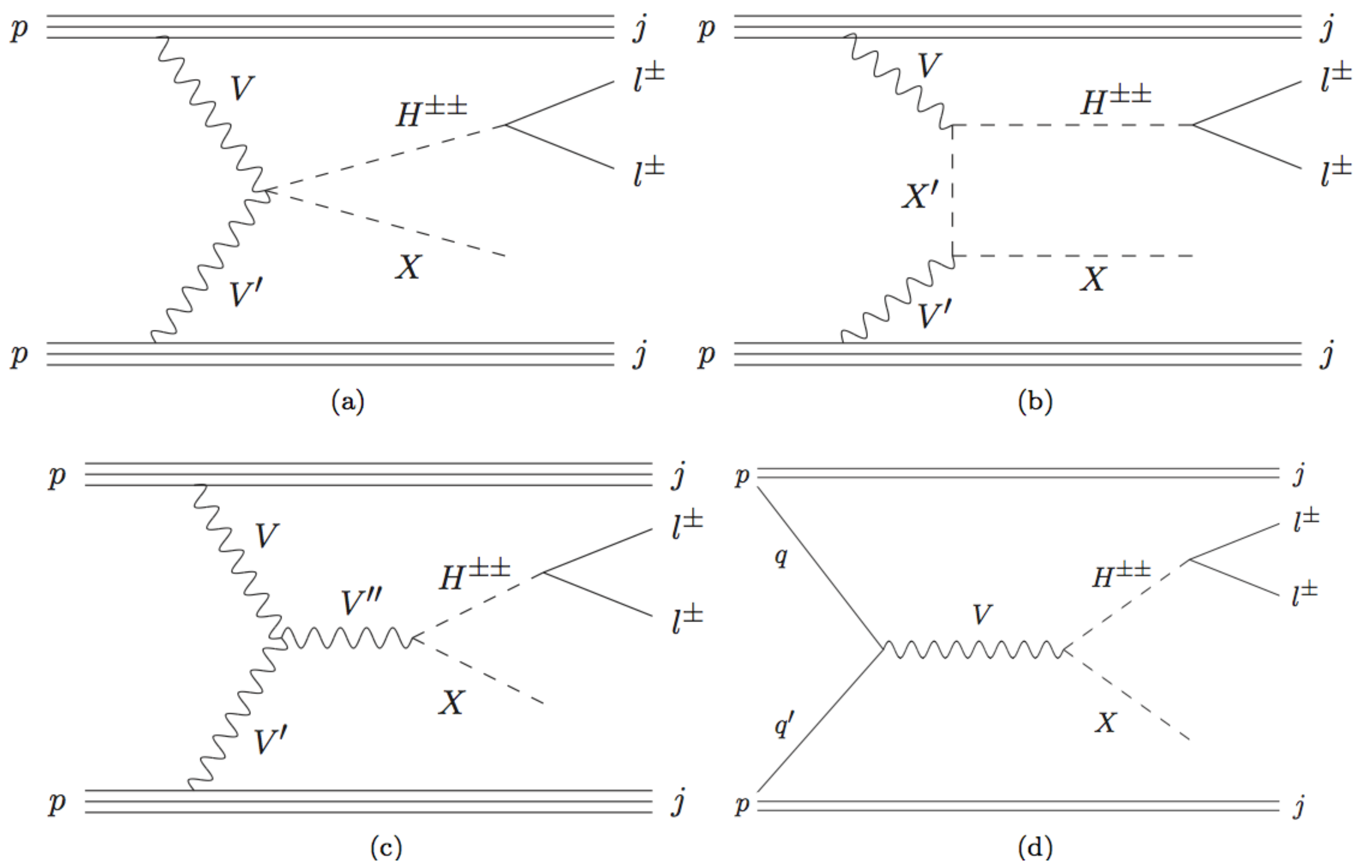
Doubly charged Higgses production (Drell-Yan)

$$m_{H^{\pm\pm}_{1,2}} = 600 \text{ GeV}:$$

$$\sigma(pp \to H^{++}_{1,2} H^{--}_{1,2} \to l_i{}^+ l_i{}^+ l_j{}^- l_j{}^-) \quad = \quad 0.144(0.9498) \text{ fb for } \sqrt{s} = 8(14) \text{ TeV}.$$

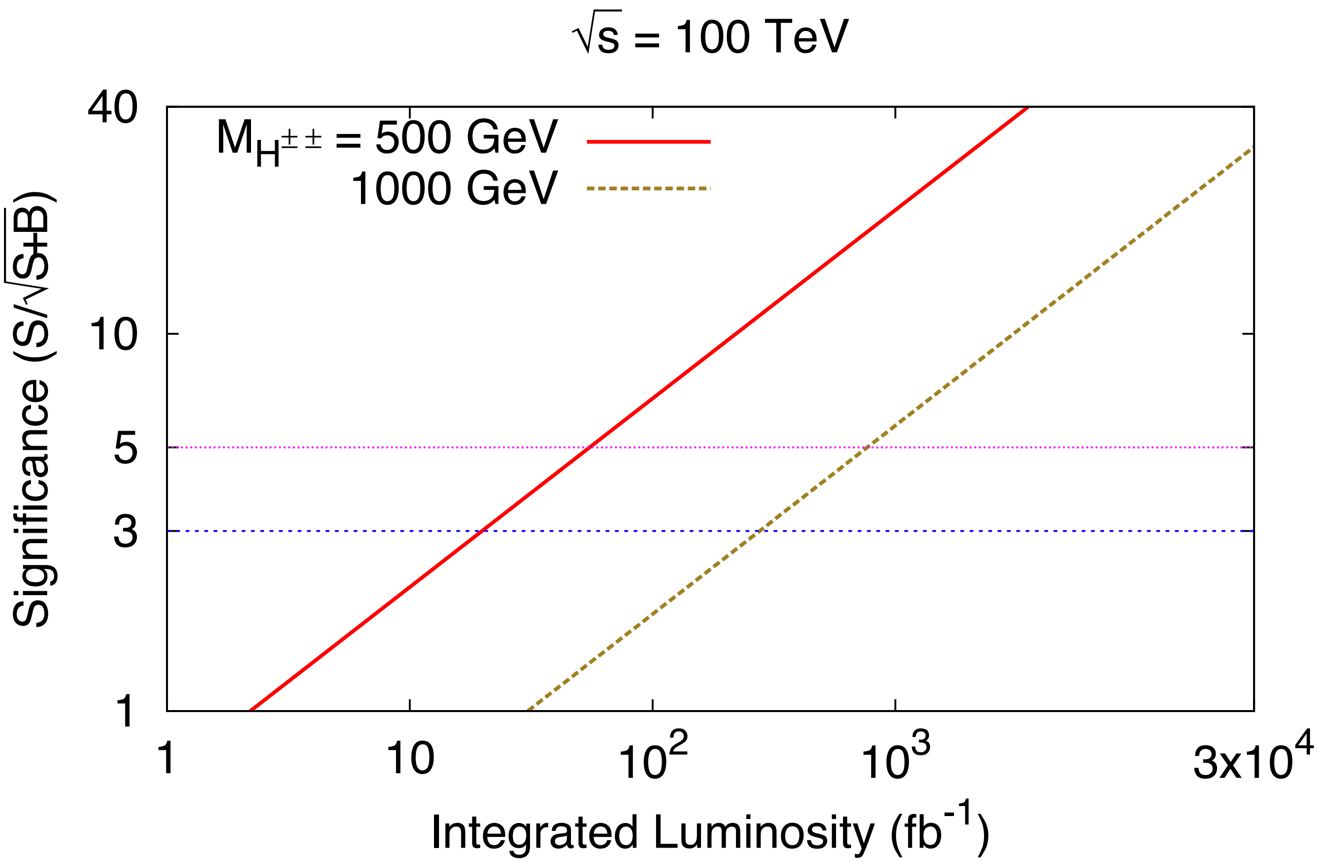


Doubly charged Higgs bosons production (Vector Boson Fusion with 2 jets)



Need for dedicated search channels for tagged forward jets.

Doubly charged Higgs bosons production (Vector Boson Fusion with 2 jets)



FCC-hh dedicated DELPHES card used which includes the basic isolation and selection criteria.

Summary

- Discovery of $W_2^{\pm}$, $H^{\pm\pm}$ or N_i would be something incredibly new and would define new directions in physics (e.g. issue of supersymmetry)

- FCC-hh opens up a very wide range of $W_2^{\pm}$, $H^{\pm\pm}$ or N_i masses which can be explored