Doubly charged Higgs bosons at the FCC-hh

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AIM OF STUDIES:

Discovery of the Higgs particle at the LHC confirmed the mechanism of mass generation in the Standard Model. But that still does not eliminate the possibility of existence of models with extended scalar sectors. Those models can be constructed just by introduction of additional scalar multiplets, with or without extension of the gauge group.

Among the non-standard Higgs particles also doubly charged scalars could appear. These particles couple to leptons and can contribute to the processes violating the lepton number. The possibility of observation of these scalars is considered in the context of the Left-Right Symmetric Models which contain additional scalar triplets.

BASIC MODELS:

Following the convention $Q=Y+T_3$ it is possible to introduce to the theory triplets with Y=1, which contain neutral, singly and doubly charged scalar fields. Multiplets higher than doublets contribute to the $\rho \neq 1$ parameter. Non-standard neutral scalars can lead to FCNC.

HIGGS TRIPLET MODEL

Model with an additional triplet (Y=1):

$$\Delta = \begin{pmatrix} \frac{\Delta^+}{\sqrt{2}} & \Delta^{++} \\ \Delta^0 & \frac{\Delta^+}{\sqrt{2}} \end{pmatrix}$$

The ρ parameter (v_Δ - triplet VEV) [1]:

$$\rho = \frac{1+2\frac{v_\Delta^2}{v_\phi^2}}{1+4\frac{v_\Delta^2}{v_\phi^2}}$$

GEORGI-MACHACEK MODEL

An additional complex triplet of scalar fields with hypercharge Y=1 and one real $SU(2)_L$ triplet with Y=0.

The ρ parameter is kept to 1 due to imposing custodial symmetry. Both triplets' VEVs are equal.

To avoid FCNC, discrete Z_2 symmetry is imposed [2].

LEFT-RIGHT SYMMETRIC MODEL

Model with extended gauge group:

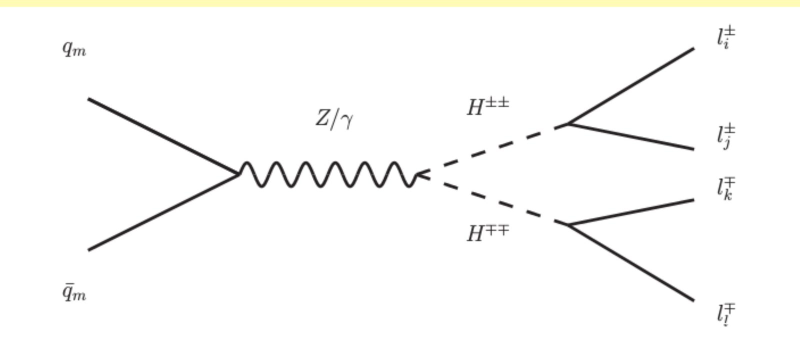
$SU(2)_R \times SU(2)_L \times U(1)_{B-L}$

In the most popular version for breaking the symmetry two additional triplets are introduced.

$\rho \approx 1$ is conserved thanks to the zero VEV value of the left-handed triplet.

To suppress the FCNC masses of neutral scalars are at the range of 10 TeV [3].

MOST RELEVANT PROCESSES IN THE MINIMAL LEFT-RIGHT SYMMETRIC MODEL:



$$pp \rightarrow H^{\pm\pm}H^{\mp\mp} \rightarrow 4l$$

Diagrams present the important ways of production doubly charged scalars at hadron colliders. The pair production and four lepton signal are especially interesting. The dominant contribution to these processes is via Z_1 and γ. Other contributions coming from s-channel H_0^0, H_0^1 and Z_2 are smaller.

$$H_{1,2}^{\pm\pm} \rightarrow l^\pm l^\pm$$
$$H_1^{\pm\pm} \rightarrow H_1^\pm W_1^\pm$$
$$H_2^{\pm\pm} \rightarrow H_2^\pm W_{1,2}^\pm$$
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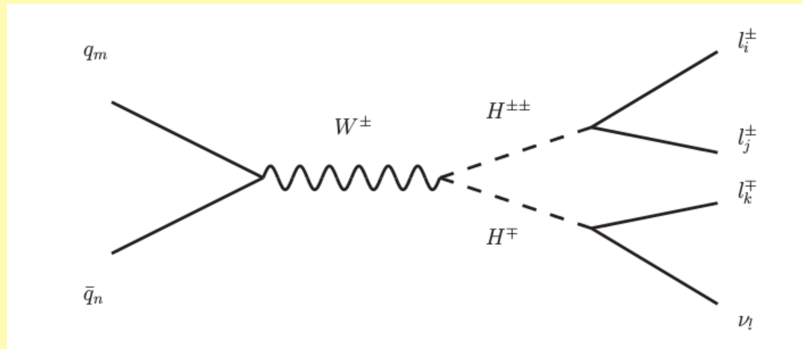

$$pp \rightarrow H^{\pm\pm}H^{\mp} \rightarrow l^\pm l^\pm l^\mp \nu$$

H_0^0 H_0^1 Z_2

RESULTS: pair production and 4-lepton channel

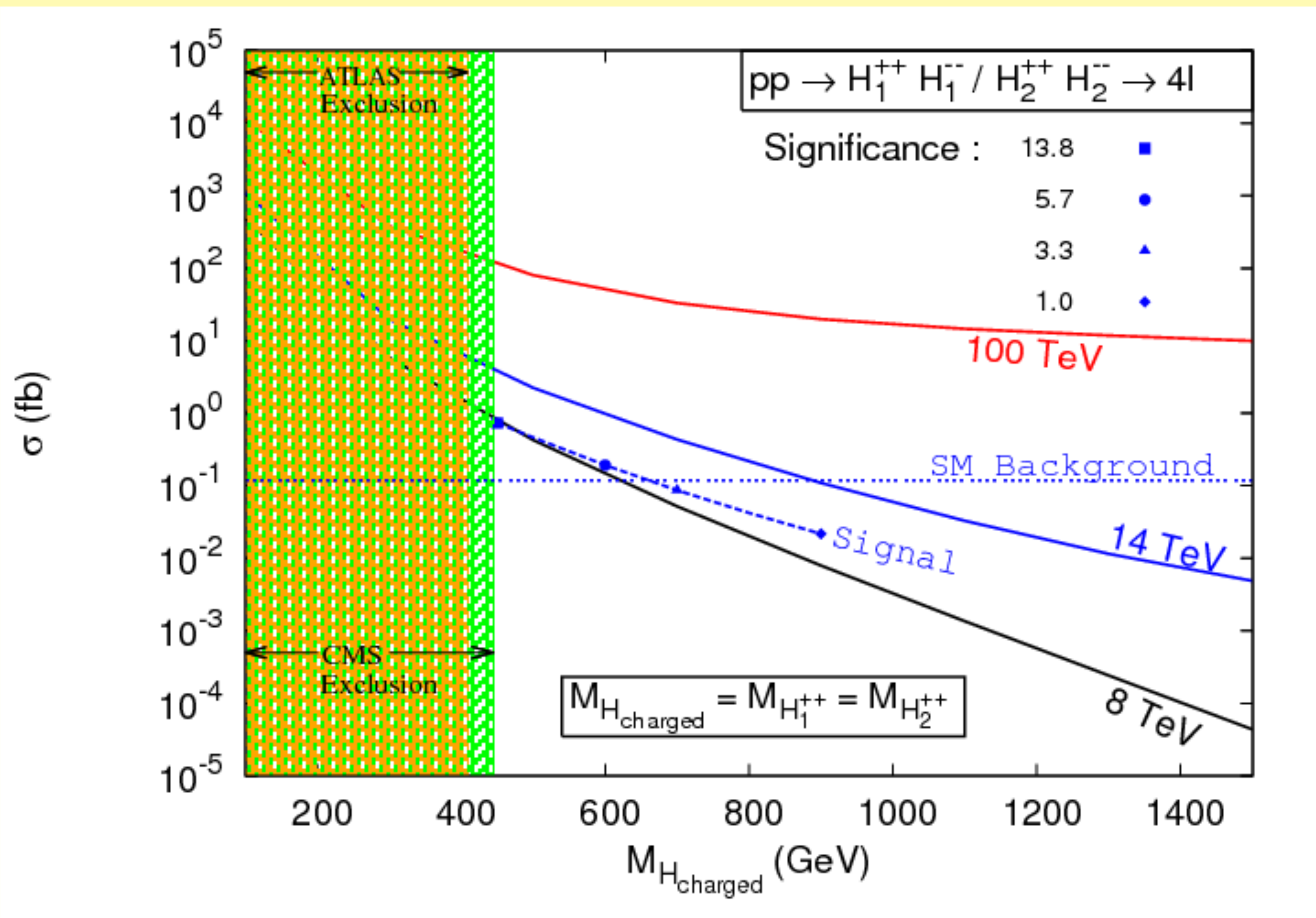

Fig. 1. Cross section for the pair production of doubly charged scalars decaying to four leptons in the MLRSM [4].

RESULTS: branching ratio for Z_2 boson

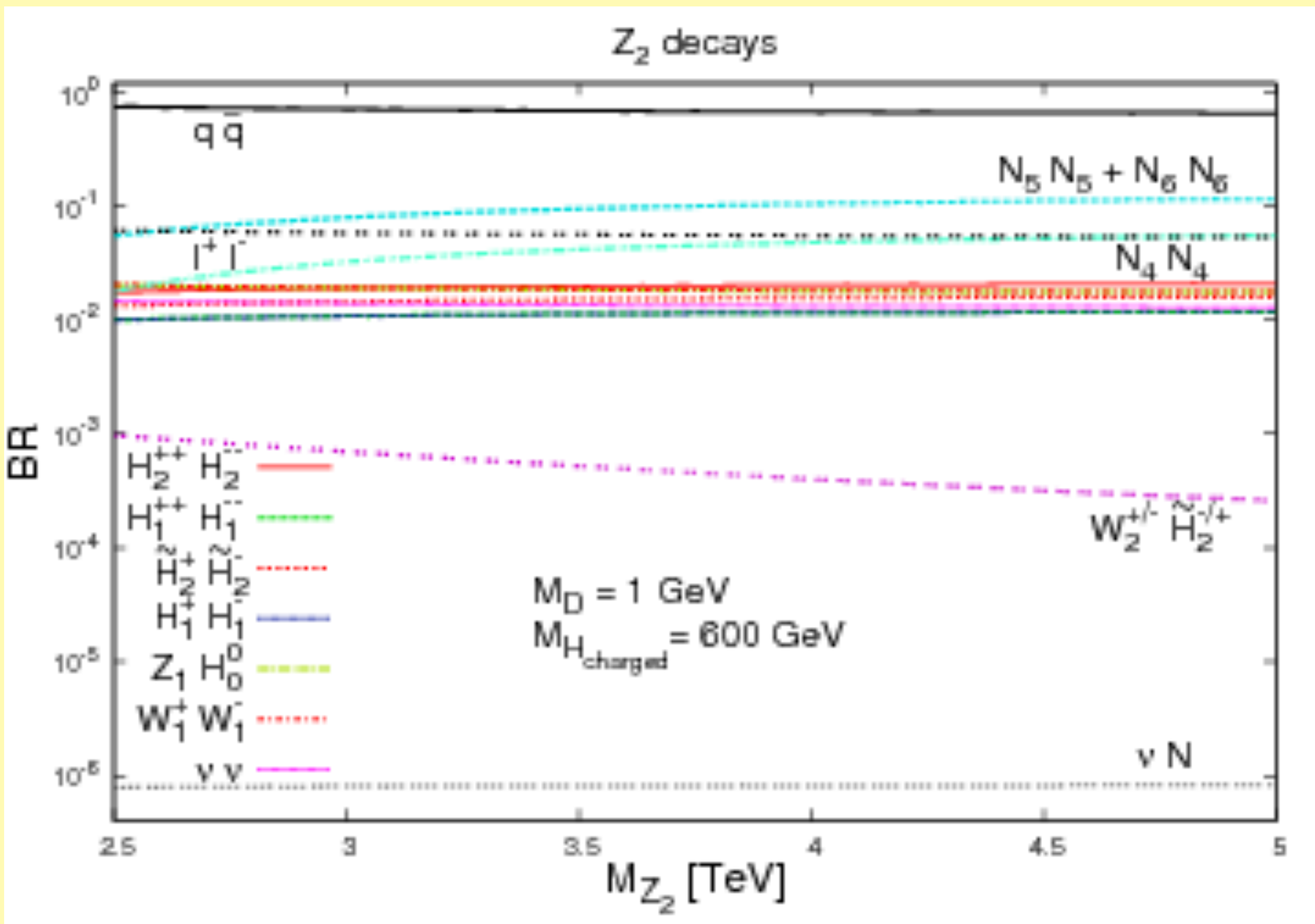

Fig. 2. Branching ratio for Z_2 boson decay with relatively light charged scalars [5]. Channels with pair of doubly charged H^{++} contribute to the decay rate at a percentage level.

CONCLUSIONS AND OUTLOOK:

Experimental discovery of the Higgs boson at the LHC proved validity of the mass generation mechanism in the Standard Model. However, we still have a freedom to create extensions of the SM model and to introduce more complex Higgs sectors with additional scalar particles. We intend to investigate processes where lepton flavour numbers can be violated, both at high energy hadron collisions and at low energies, focusing on models containing additional triplets of scalar fields.

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