Drell-Yan $H_5^{\pm\pm} \to W^{\pm}W^{\pm} \to$ like-sign leptons

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ATLAS Collaboration, "Search for anomalous production of prompt same-sign lepton pairs and pair-produced doubly charged Higgs bosons with $\sqrt{s} = 8$ TeV pp collisions using the ATLAS detector," 1412.0237 (JHEP 2015). 20.3 fb^{-1}

Measured like-sign dilepton fiducial cross section.

In good agreement with SM prediction $\Rightarrow$ set limits on anomalous production cross section.

Doubly-charged Higgs interpretation assumed $H^{\pm\pm} \to \ell^\pm \ell^\pm$ (dilepton resonance) – not useful for GM model.

Theorist recasting: $\mu^\pm\mu^\pm$ channel provides strongest limit.

Selection cuts: same-sign dilepton pair with
$p_T^{\ell_1} > 25$ GeV, $p_T^{\ell_2} > 20$ GeV, $|\eta| < 2.5$, $M_{\ell\ell} > 15$ GeV.
Events with an opposite-sign same-flavour dilepton pair with $|M_{\ell^+\ell^-} - M_Z| < 10$ GeV rejected.

Kanemura, Kikuchi, Yagyu & Yokoya, "LHC Run-I constraint on the mass of doubly charged Higgs bosons in the same-sign diboson decay scenario," 1412.7603

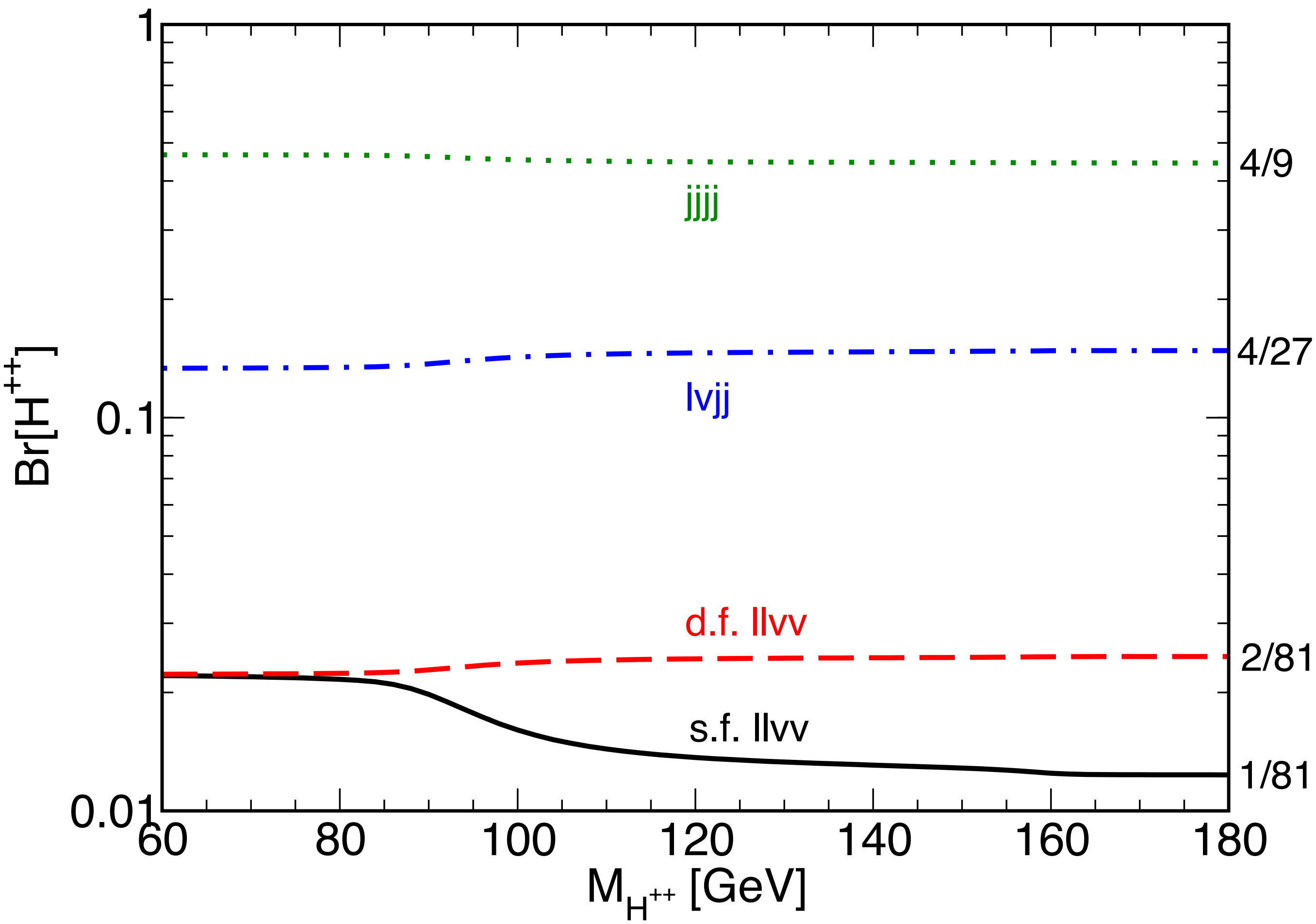
Recast the ATLAS result in the context of the Higgs Triplet Model $(\phi^+, \phi^0) + (\chi^{++}, \chi^+, \chi^0)$.

Production: Drell-Yan (fixed by gauge coupling & H^{++} mass)
(a) $pp \to H^{++}H^{--}$
(b) $pp \to H^{++}H^{-}$ Assumed $m_{H^\pm} = m_{H^{\pm\pm}}$
(c) $pp \to H^{+}H^{--}$

$$\sigma_{\rm fid}(\mu^\pm\mu^\pm) = \left[\sigma_a \cdot \left\{2\epsilon_a - \epsilon_a^2 \mathcal{B}_{\mu\mu}\right\} + \sigma_b \cdot \epsilon_b + \sigma_c \cdot \epsilon_c\right] \cdot \mathcal{B}_{\mu\mu},$$

Details of the production cross section (NLO K-factor) and interference effects* in the decay BRs (important for $m_{H^{++}} <$ 160 GeV), are described in detail in
Kanemura, Kikuchi, Yagyu & Yokoya, 1407.6547

*Below the WW threshold, same-flavour leptons can come from either of the Ws, leading to an interference term. Need full $H^{++} \to 4f$ branching ratios simulation.



Kanemura, Kikuchi, Yagyu & Yokoya, 1407.6547

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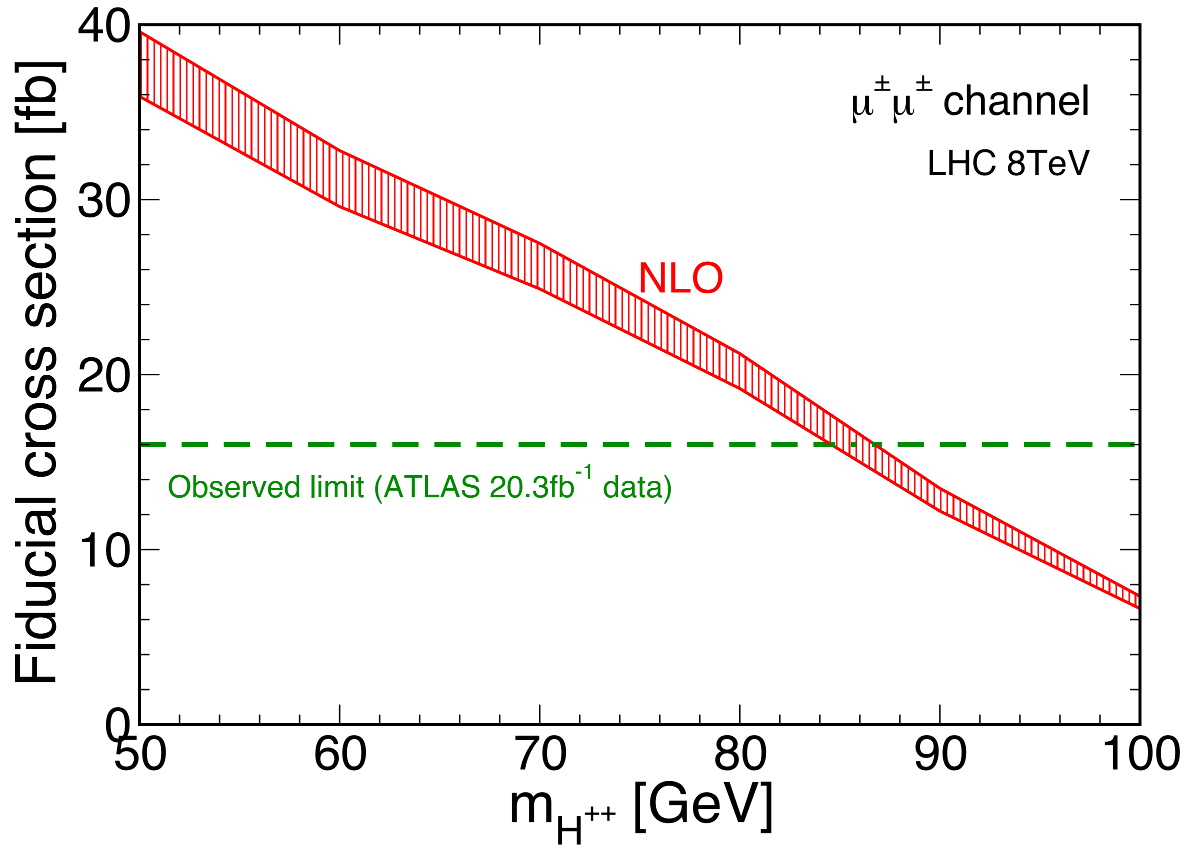
$m_{H^{\pm\pm}}$	50	60	70	80	90	100	[GeV]
$\sigma_{\rm tot}^{\rm NLO}(pp \to H^{++}H^{--})$	8.52	3.57	1.93	1.16	0.744	0.501	[pb]
$\sigma_{\rm tot}^{\rm NLO}(pp \to H^{++}H^{-})$ $[m_{H^\pm} = m_{H^{\pm\pm}}]$	10.6	4.47	2.36	1.40	0.891	0.598	[pb]
$\sigma_{\rm tot}^{\rm NLO}(pp \to H^{+}H^{--})$ $[m_{H^\pm} = m_{H^{\pm\pm}}]$	6.71	2.73	1.40	0.803	0.498	0.326	[pb]
$\mathcal{B}(H^{\pm\pm} \to \mu^\pm\mu^\pm\nu\nu)$	2.22	2.21	2.19	2.16	1.98	1.61	[%]
$\epsilon_A(pp \to H^{++}H^{--})$	5.1	9.9	16.	21.	23.	23.	[%]
$\epsilon_A(pp \to H^{++}H^{-})$	4.9	9.9	15.	21.	22.	23.	[%]
$\epsilon_A(pp \to H^{+}H^{--})$	4.7	9.7	15.	21.	23.	22.	[%]
$\sigma_{\rm fid}(pp \to \mu^\pm\mu^\pm + X)$ $[m_{H^\pm} = m_{H^{\pm\pm}}]$	37.7	31.2	26.2	20.2	12.8	6.98	[fb]

Acceptance efficiencies from LO MadGraph5 simulation.

Kanemura, Kikuchi, Yagyu & Yokoya, "LHC Run-I constraint on the mass of doubly charged Higgs bosons in the same-sign diboson decay scenario," 1412.7603



Shaded band: $\pm 5\%$ uncertainty on NLO DY xsec

Set limit $m_{H++} \gtrsim 84$ GeV in HTM.

HEL & Rentala, "All the generalized Georgi-Machacek models," 1502.01275

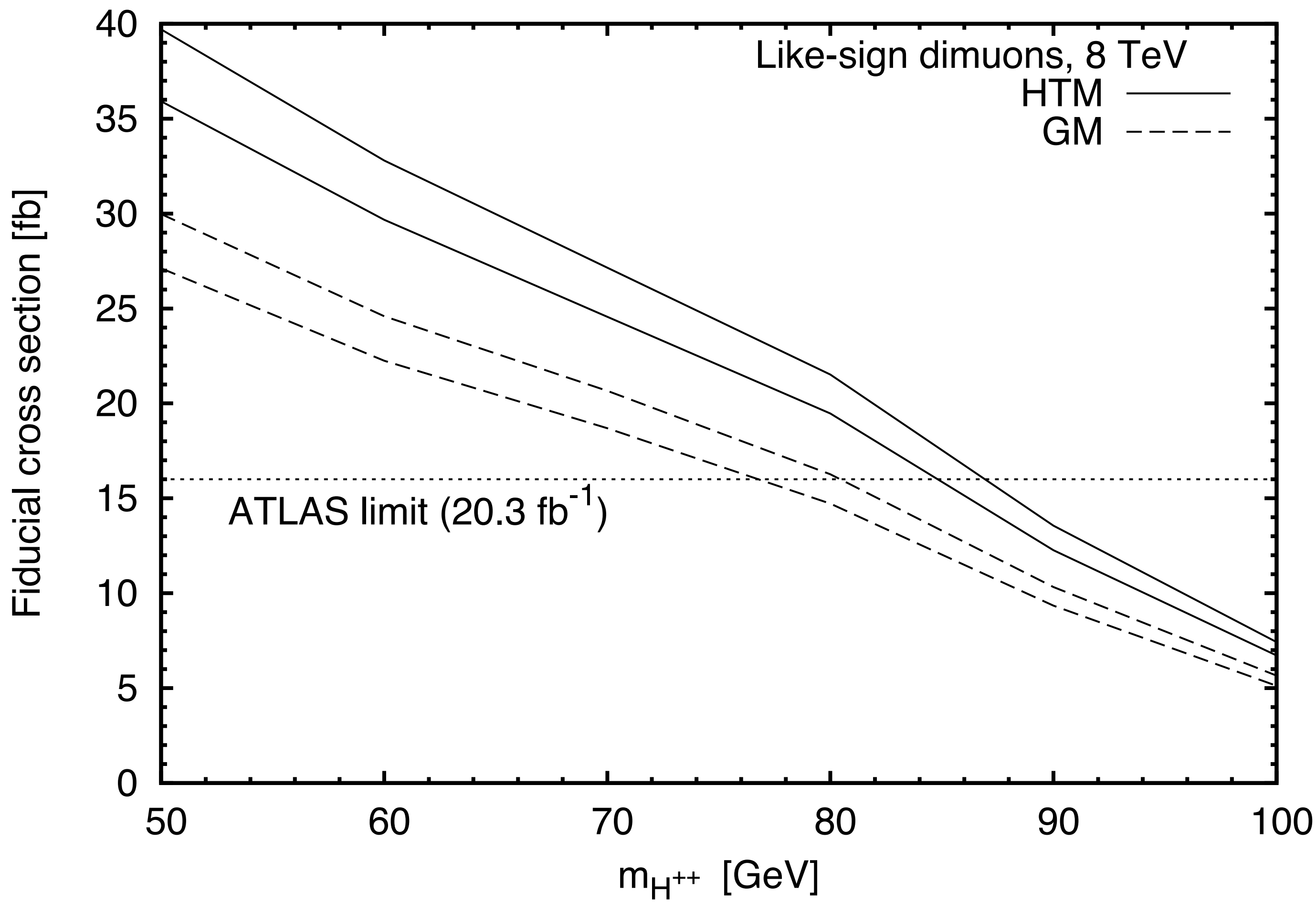
Reinterpreted HTM recasting in the GM model.
Simple relation of cross sections:

$$\sigma_{\mathrm{tot}}^{\mathrm{NLO}}(pp \to H_5^{++} H_5^{--})_{\mathrm{GM}} = \sigma_{\mathrm{tot}}^{\mathrm{NLO}}(pp \to H^{++} H^{--})_{\mathrm{HTM}},$$
$$\sigma_{\mathrm{tot}}^{\mathrm{NLO}}(pp \to H_5^{\pm\pm} H_5^{\mp})_{\mathrm{GM}} = \frac{1}{2}\sigma_{\mathrm{tot}}^{\mathrm{NLO}}(pp \to H^{\pm\pm} H^{\mp})_{\mathrm{HTM}}.$$

$m_{H^\pm} = m_{H^{\pm\pm}}$ guaranteed by custodial symmetry.

Everything else that we needed was provided already by Kanemura, Kikuchi, Yagyu & Yokoya, 1412.7603

HEL & Rentala, "All the generalized Georgi-Machacek models," 1502.01275



Set limit $m_{H^{++}} \gtrsim 76$ GeV in GM model.

HEL & Rentala, “All the generalized Georgi-Machacek models,” 1502.01275

Subtleties:

- We ignored contributions to the $H^{\pm\pm}$ production cross section from Drell-Yan $pp \to H_5^{\pm\pm} H_3^{\mp}$ (depends also on m_3), VBF $\to H^{\pm\pm}$ (rate proportional to s_H^2), and $pp \to H \to H_5^{\pm} H_5^{\mp}$ (requires $m_H > 2m_5$). These would make the exclusion stronger, but introduce dependence on additional model parameters.

- We assumed $m_3 > m_5$ so that BR($H_5^{\pm\pm} \to W^{\pm} W^{\pm}$) = 1. This is safe because LEP searches for charged Higgs decaying to fermions excludes $H_3^{\pm}$ up to masses higher than 76 GeV (hep-ex/0107031).