Charged Higgs Searches at CMS

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Seoul National University

25th Anniversary of the Rencontres du Vietnam

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ICISE

Windows on the Universe

2018

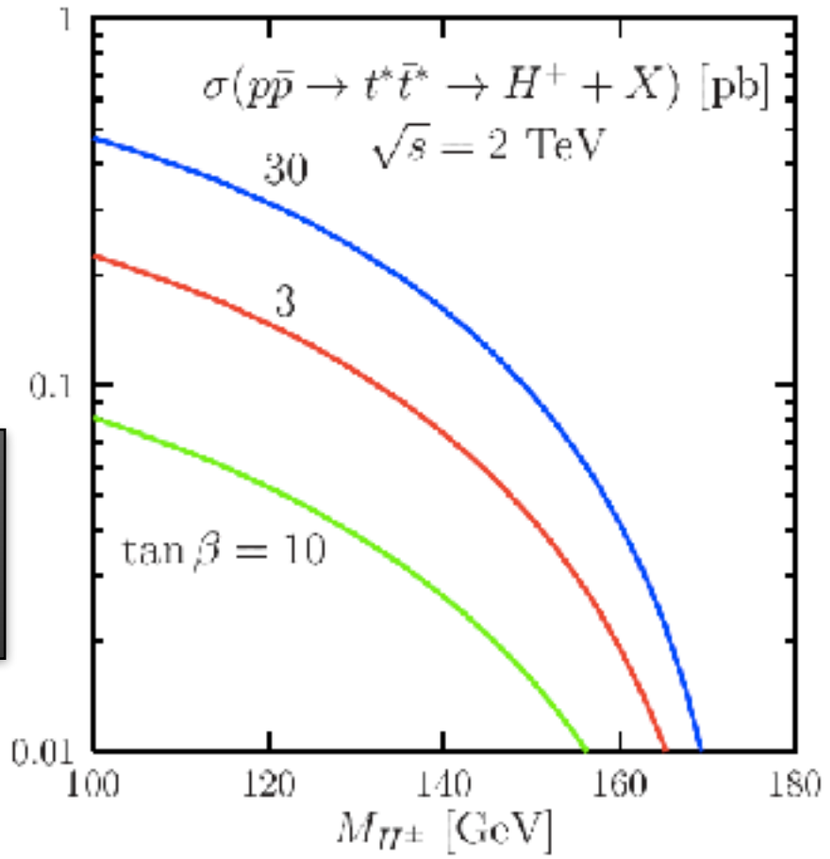
The Higgs boson and Charge

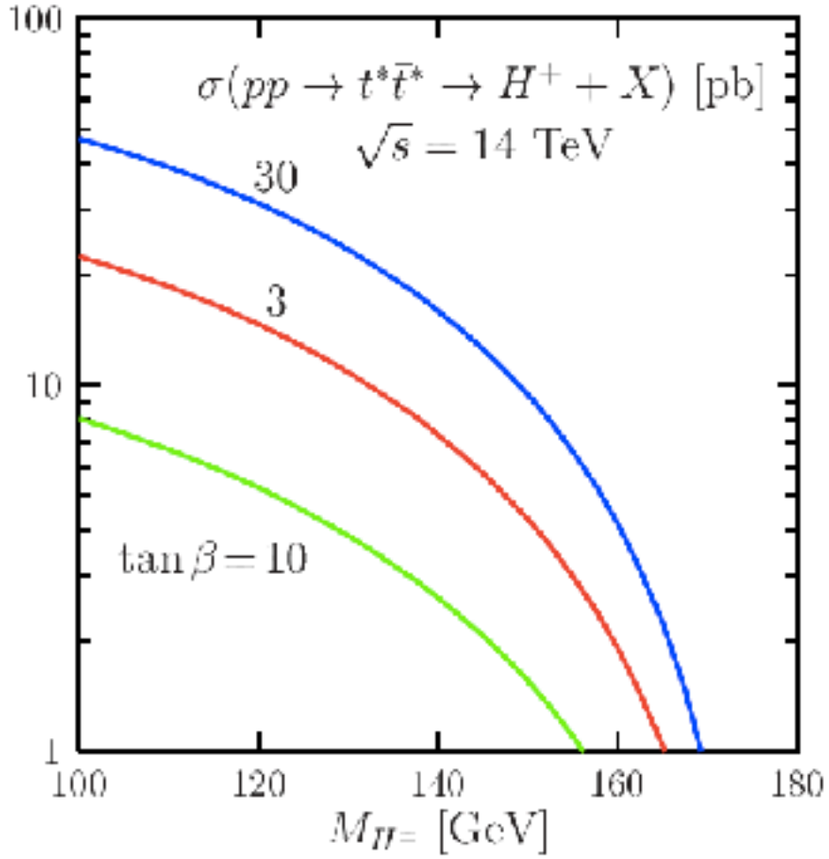
- Discovered Higgs boson at a mass of 125 GeV agrees with the standard model (SM)
  - Still unsolved questions remain in the SM and the solutions prefer extended Higgs sectors
  - Existence of the Higgs boson with charge can be a direct evidence of beyond standard model (BSM) hypotheses
- Simplest extension of the SM Higgs sector is two-Higgs-doublet model (2HDM)
  - Four different types of models depending on the coupling with each fermion type
  - Five physical Higgs bosons: h, A, H, $H^{\pm}$
  - Two independent parameters: tanβ, $m(H^{+})$ (or m(A))
  - The charged Higgs boson has been searched primarily assuming the production & decays in 2HDM
- Complex extensions available, richer Higgs phenomenology
- e.g. Georgi-Machacek model uses a complex and a real triplets additionally and gives a rise to H_5=($H_5^{\pm\pm}$,$H_5^{\pm}$,H_5^{0}) with m_5, H_3=($H_3^{\pm}$.H_3^{0}) with m_3, H_1 with m_1, and h with 125 GeV

Model	Up	Down	Electron
Type-I	Φ_2	Φ_2	Φ_2
Type-II	Φ_2	Φ_1	Φ_1
Type-X	Φ_2	Φ_2	Φ_1
Type-Y	Φ_2	Φ_1	Φ_2

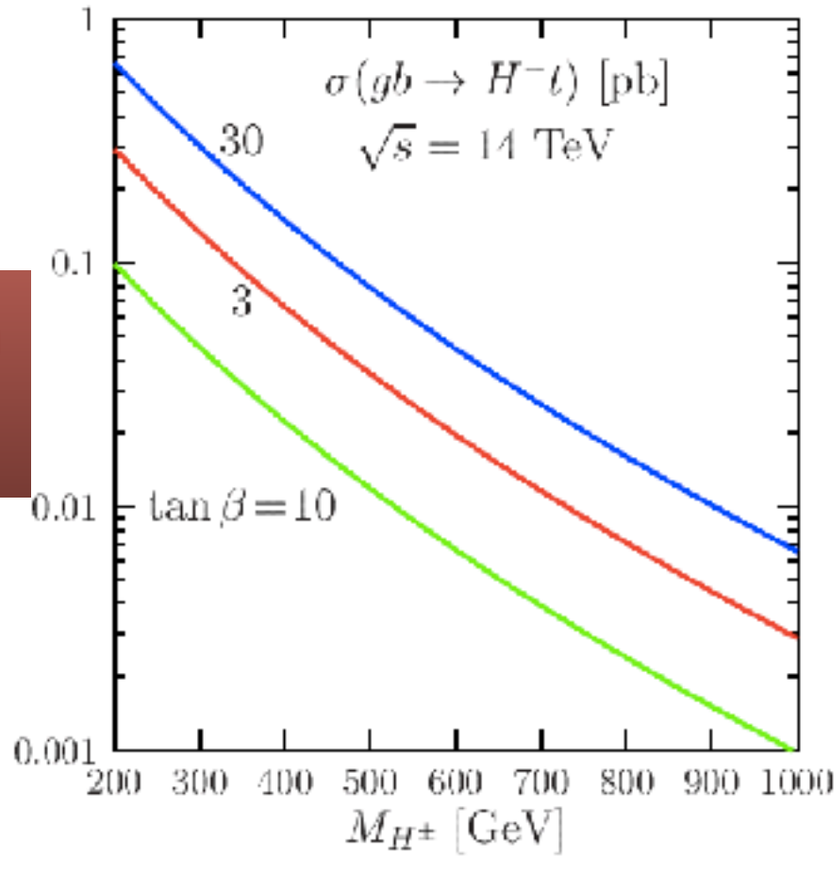
H+ Production

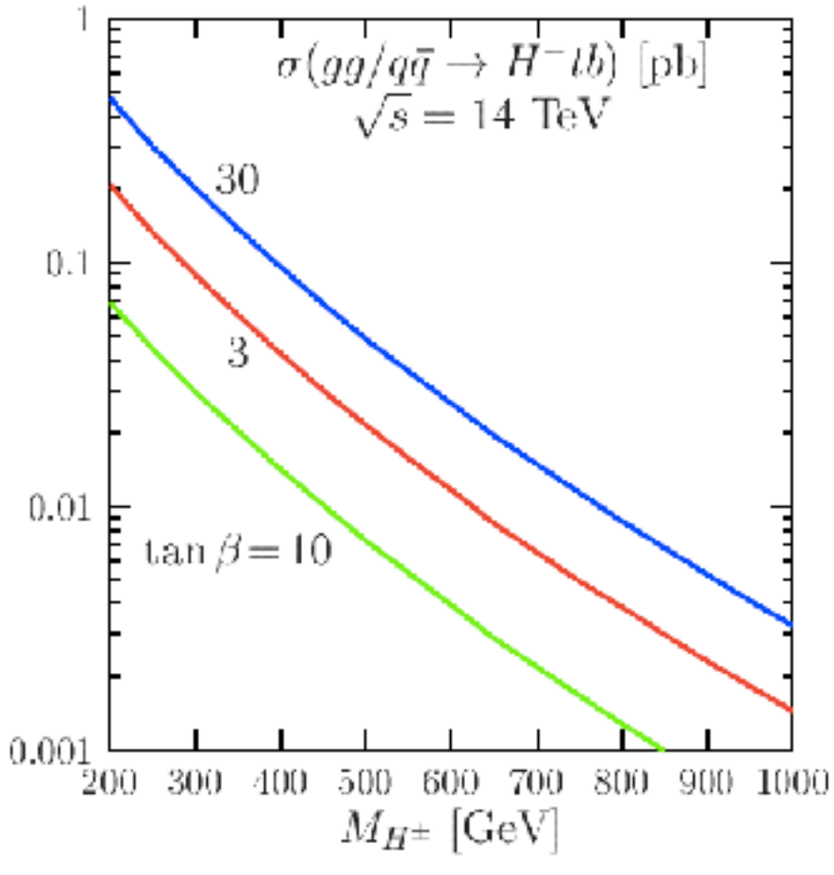
m(H+)<m(t)-m(b)
Light H+



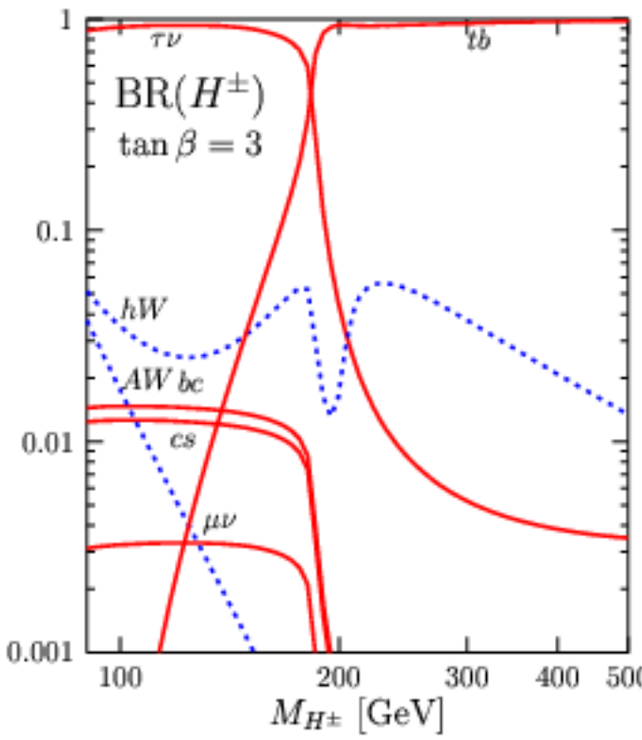


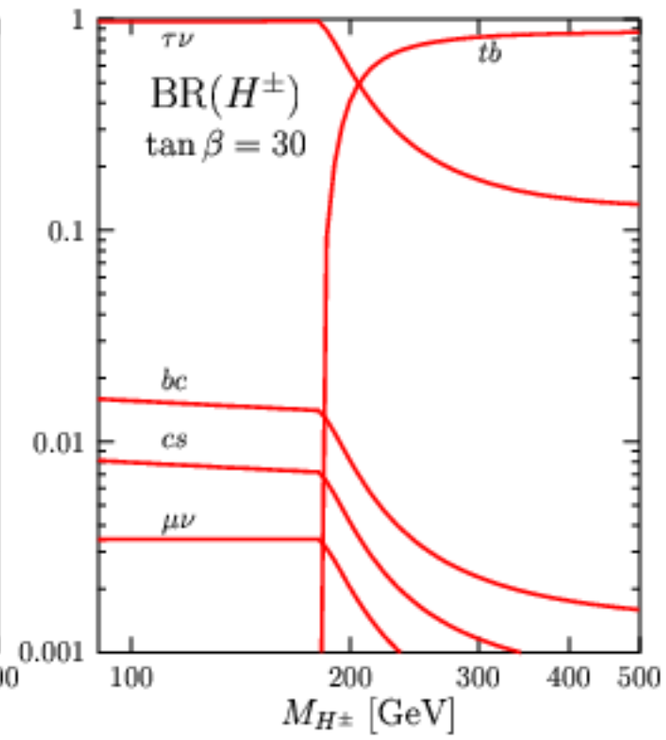
m(H+)>m(t)+m(b)
Heavy H+



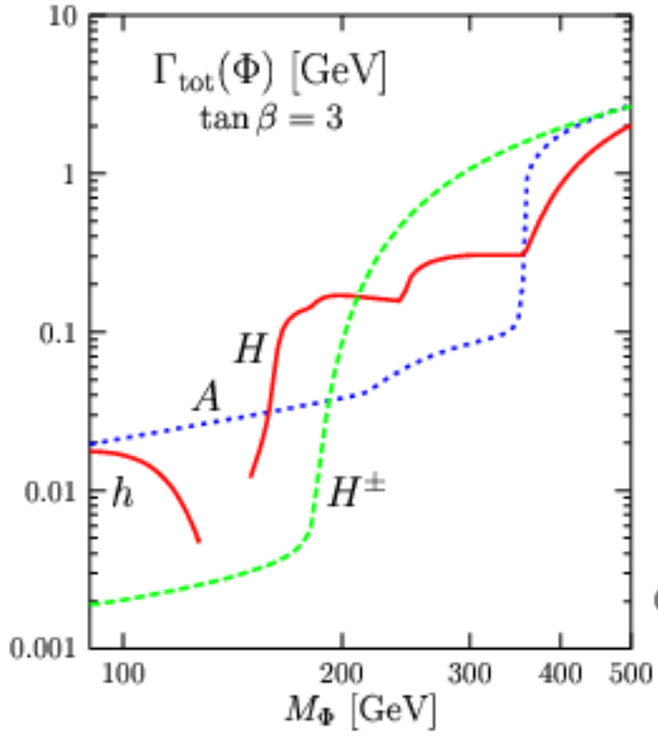


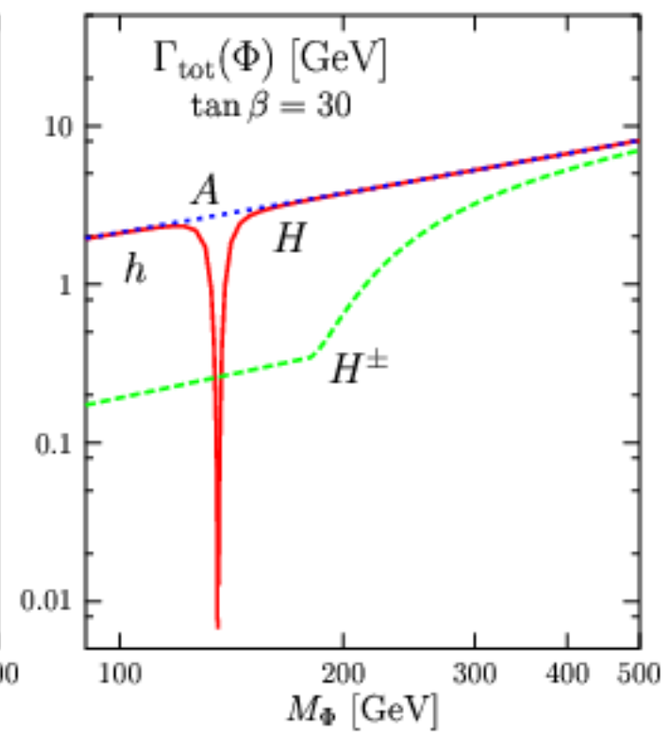
H+ Decays & Widths (MSSM)





- Various scenarios available for the 2HDM under BSM hypotheses such as minimal supersymmetric standard model
- The properties of the H^+, such as width and decays, depend on the parameters, $m(H^+)$ and $\tan\beta$

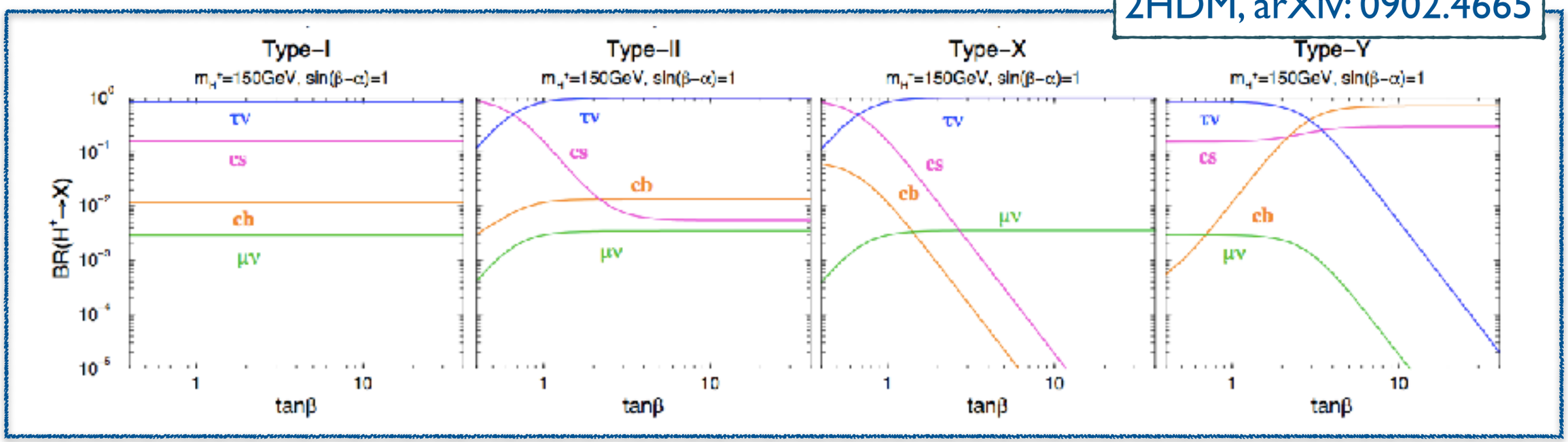




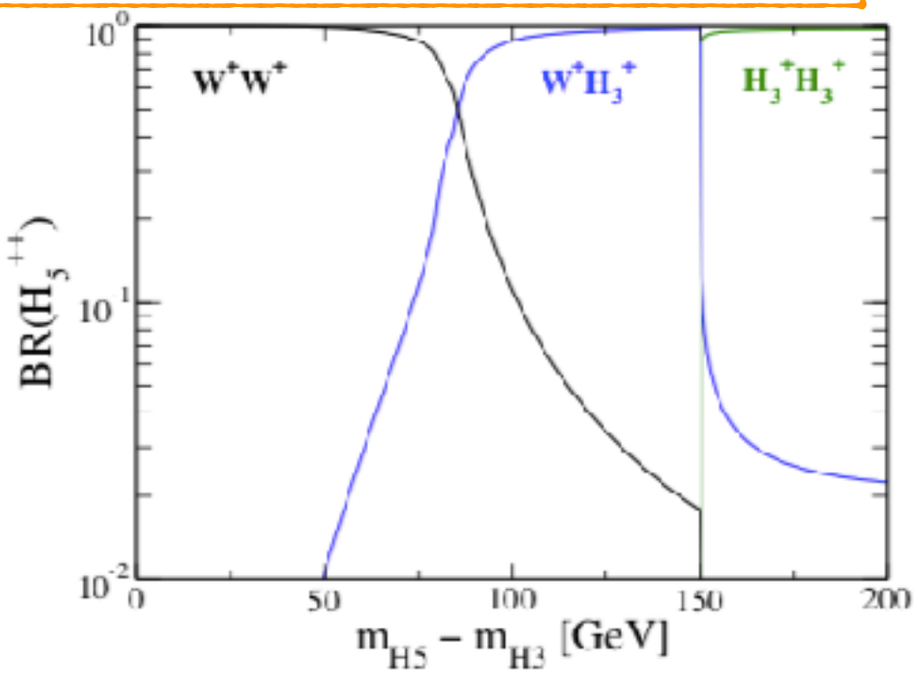
arXiv: 0901.2030

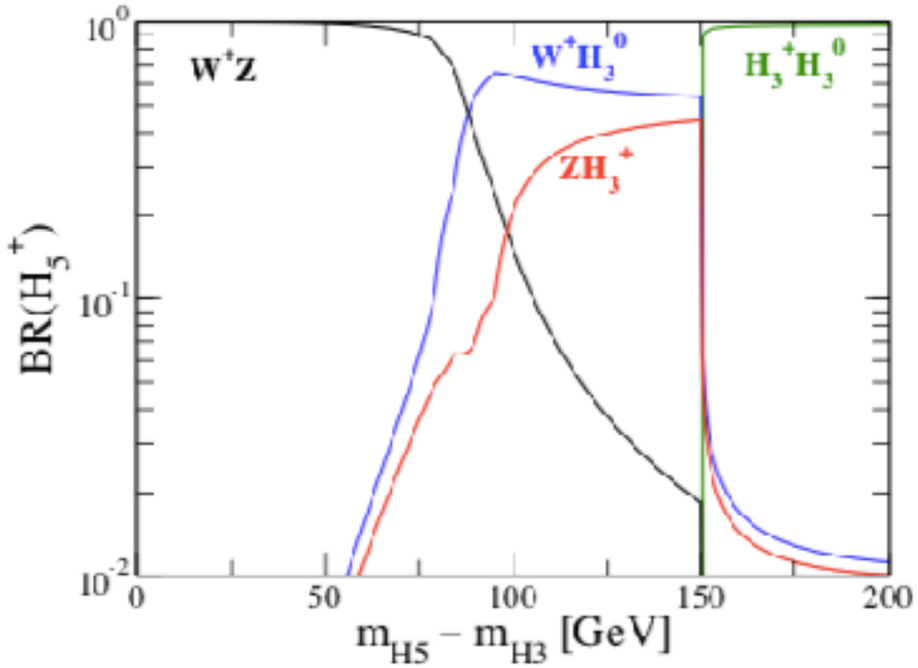
H^+ Decays for various models

2HDM, arXiv: 0902.4665



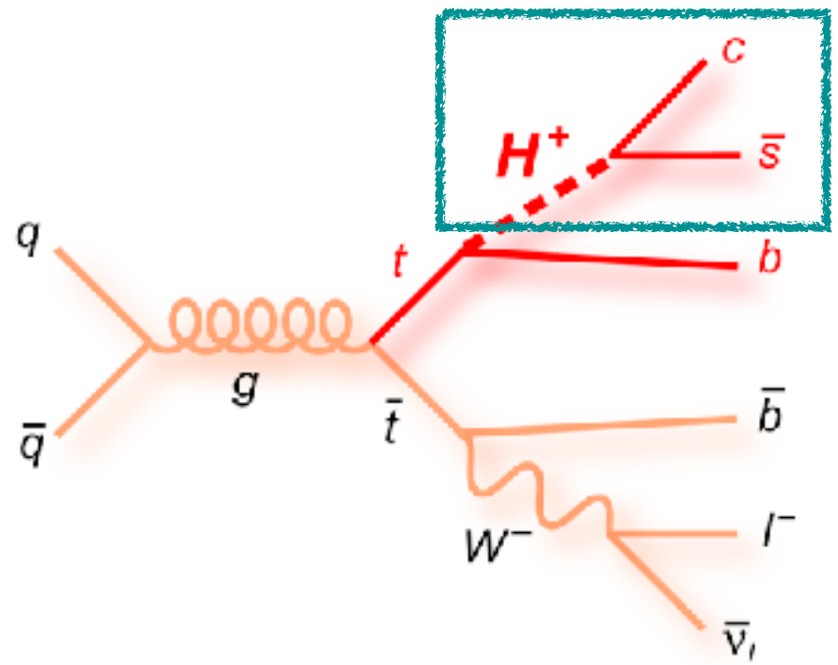
Georgi-Machacek model, arXiv: 1510.06297v2

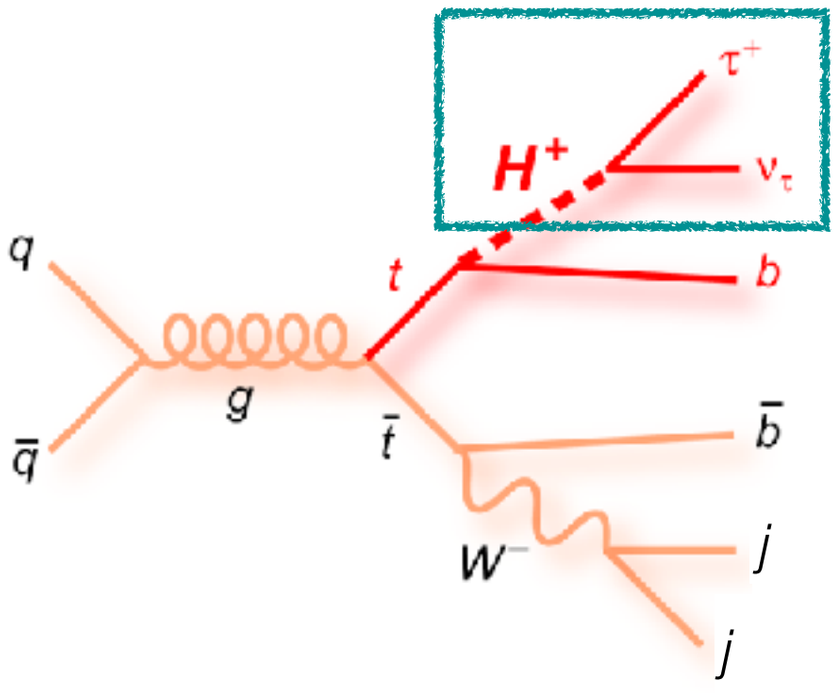


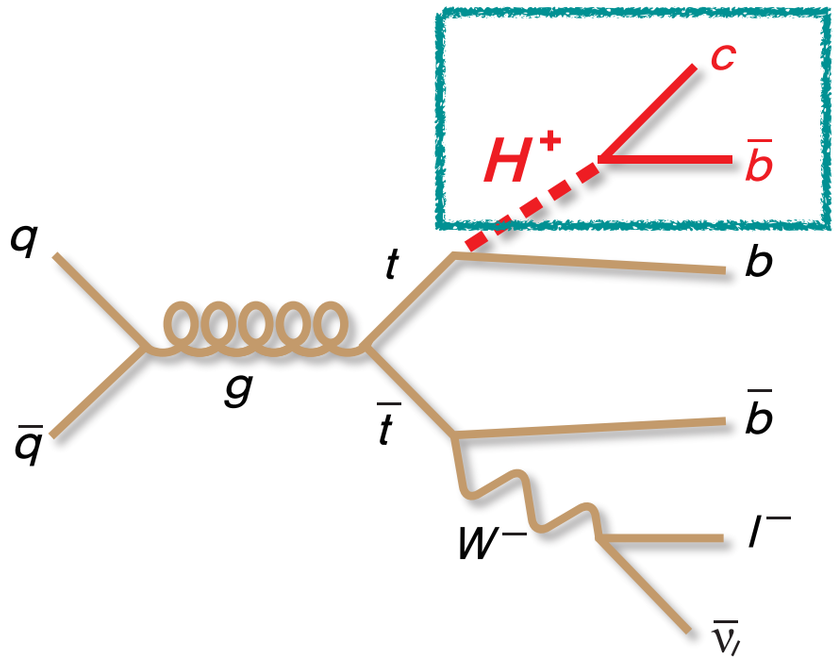


Light H^+ Searches: $80 \leq m(H^+) \leq m(t)-m(b)$

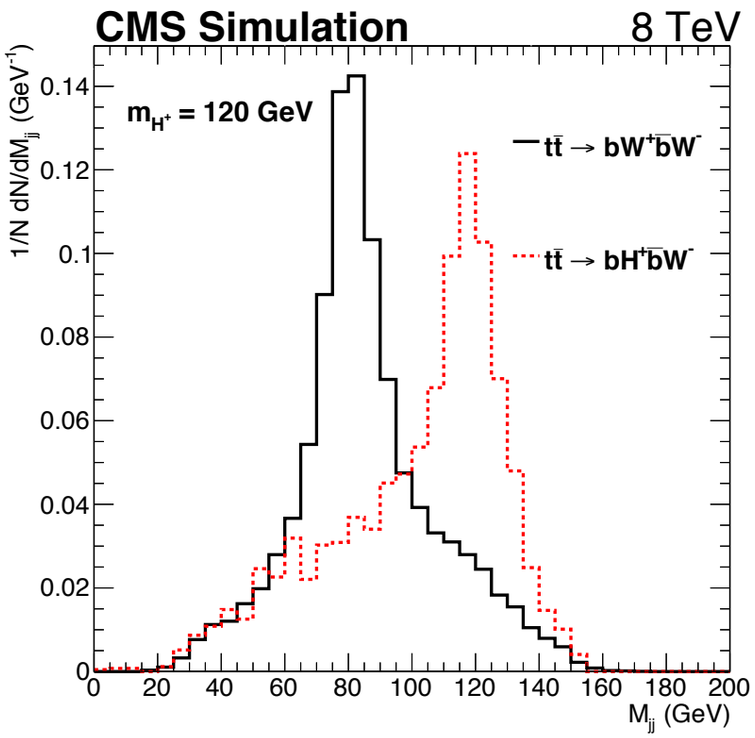
Mass below W boson excluded by LEP

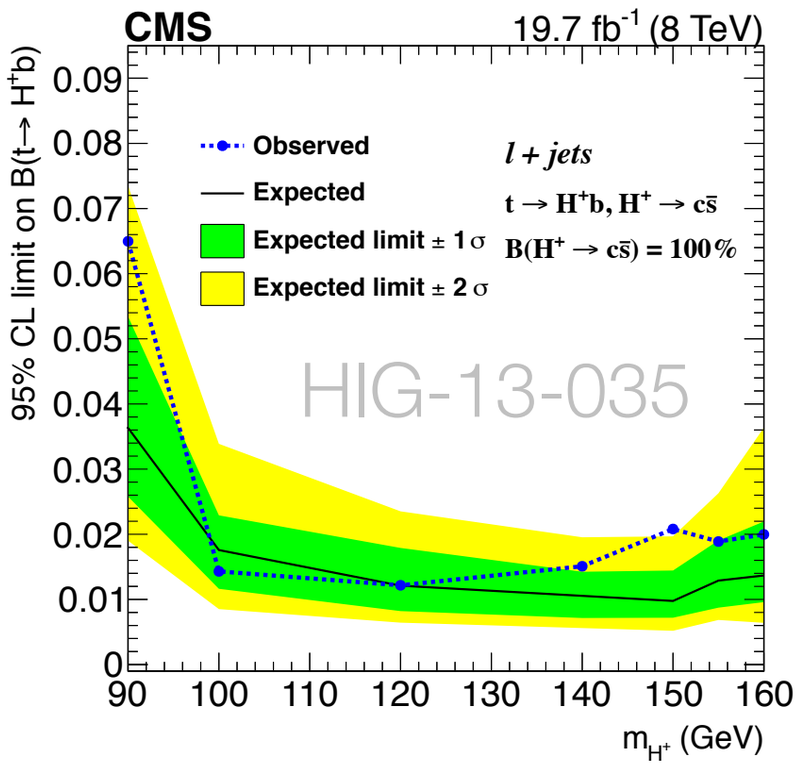




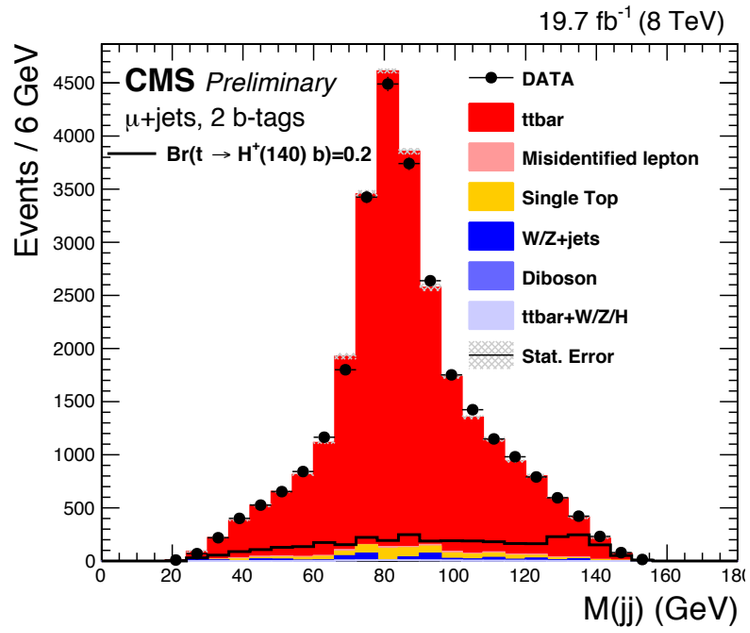


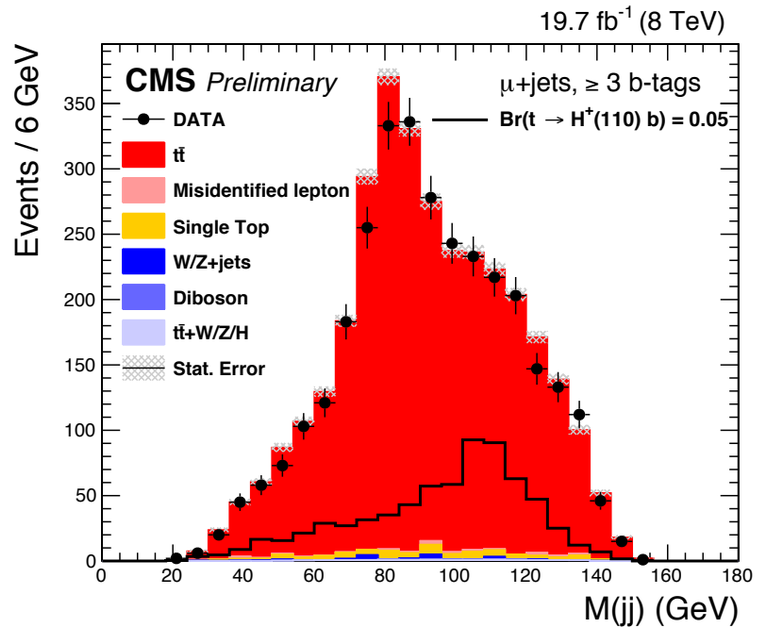
$H^+ \rightarrow cs$ @ 8 TeV

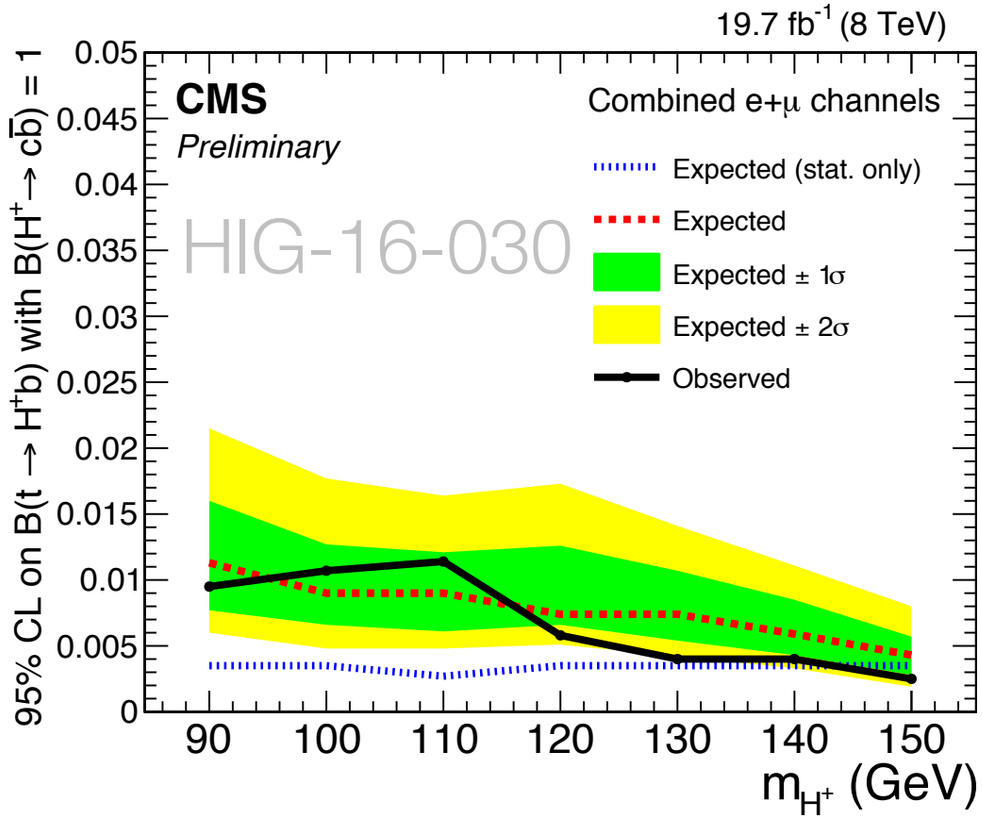




$H^+ \rightarrow cb$ @ 8 TeV

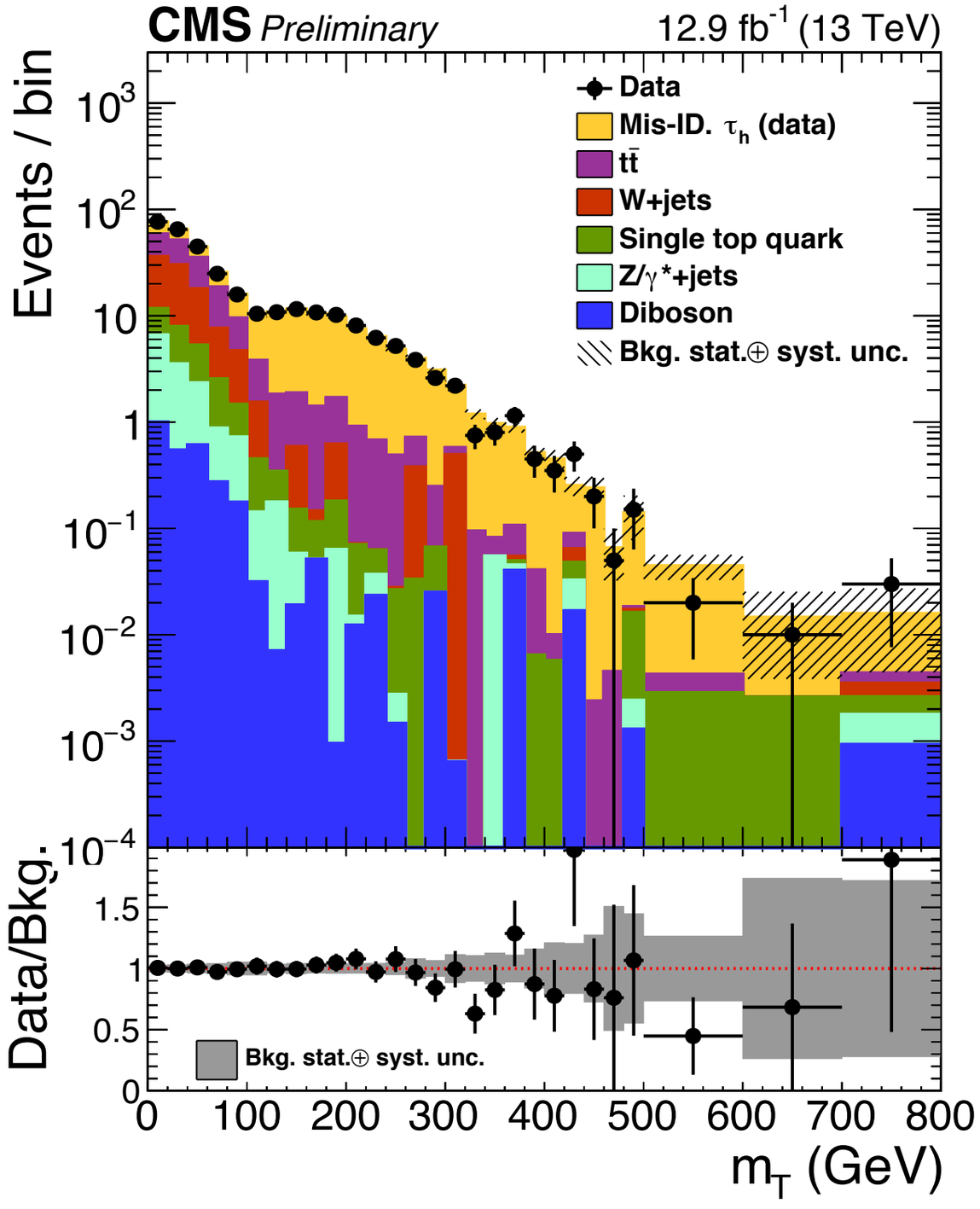






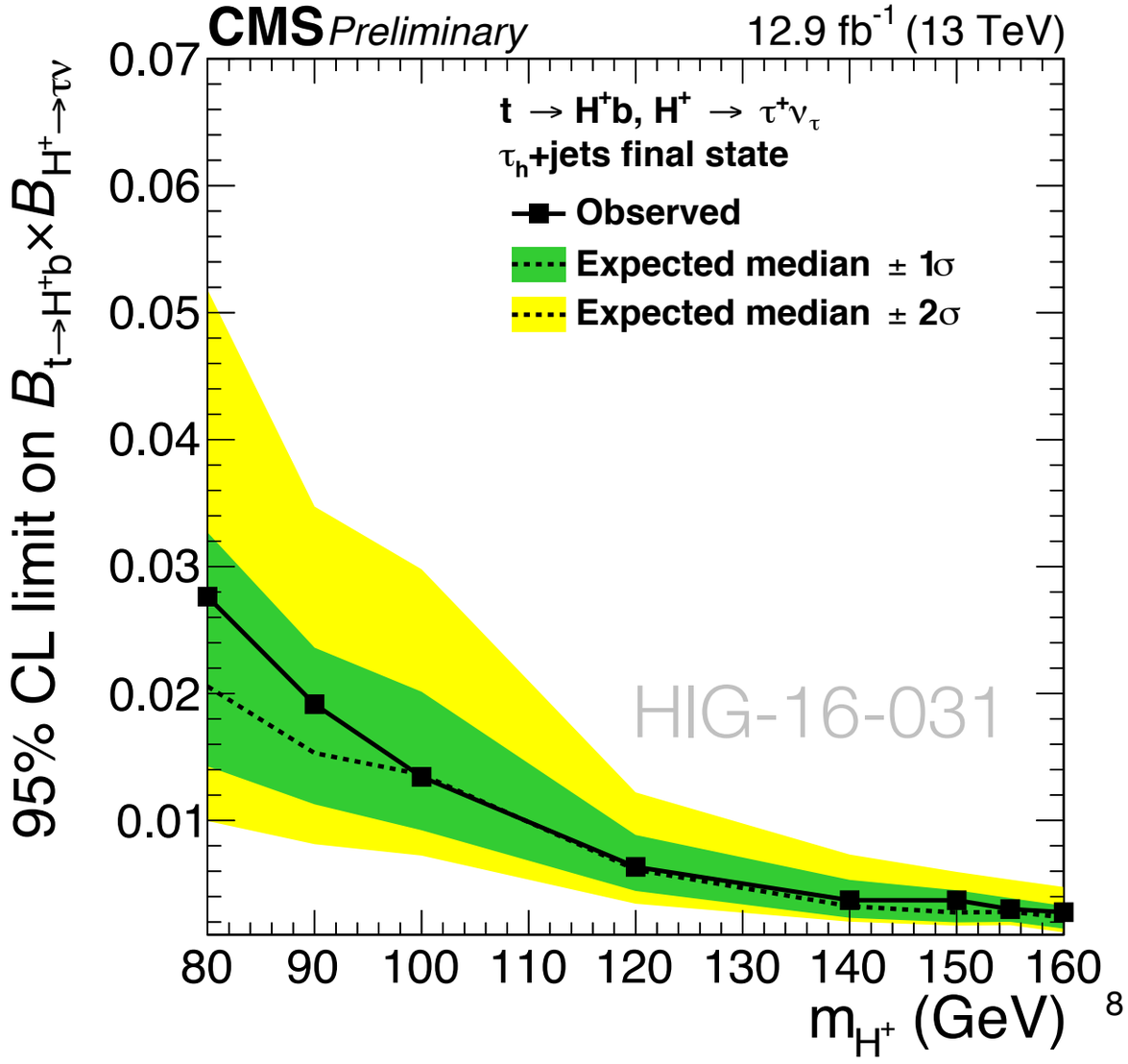
Use dijet mass discrepancy between W and H+ in fully reconstructed tt events

$H^+ \to \tau\nu$ @ 13 TeV

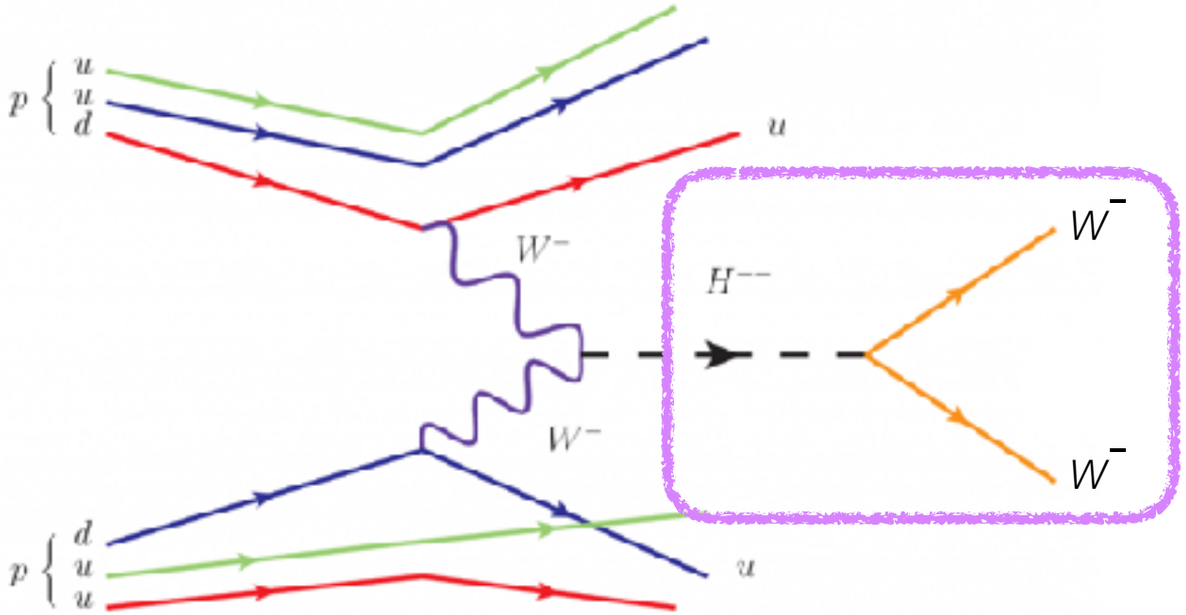


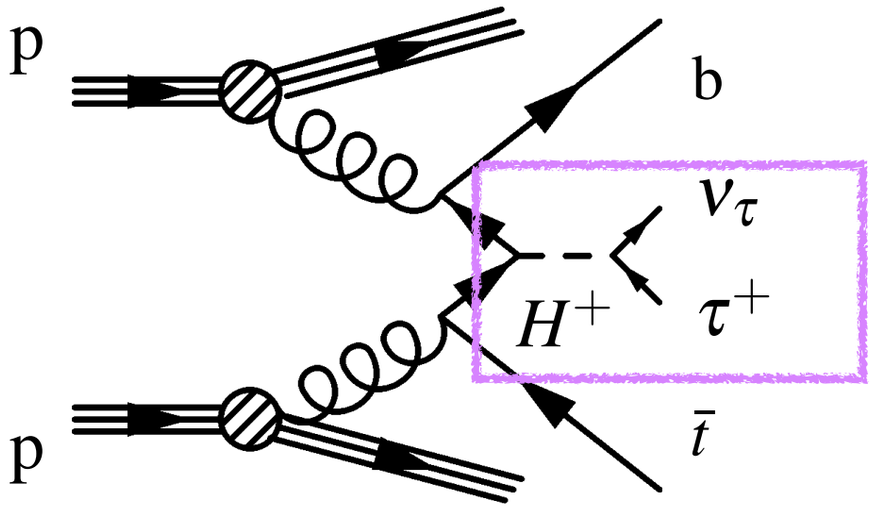
Reconstruct the transverse mass & extract the charged Higgs boson signal

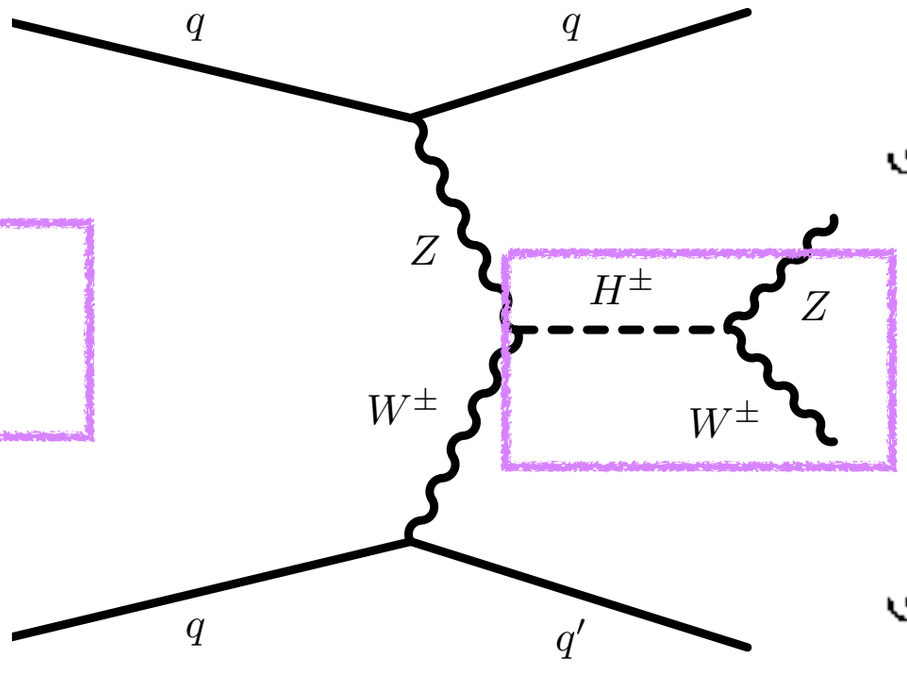
$$m_{\mathrm{T}}^2 = 2 \cdot p_{\mathrm{T}}^{\tau^{\mathrm{h}}} |\vec{\not{E}_T}| (1 - \cos\Delta\phi(\vec{\not{E}}_{\mathrm{T}}, \tau^{\mathrm{h}}))$$

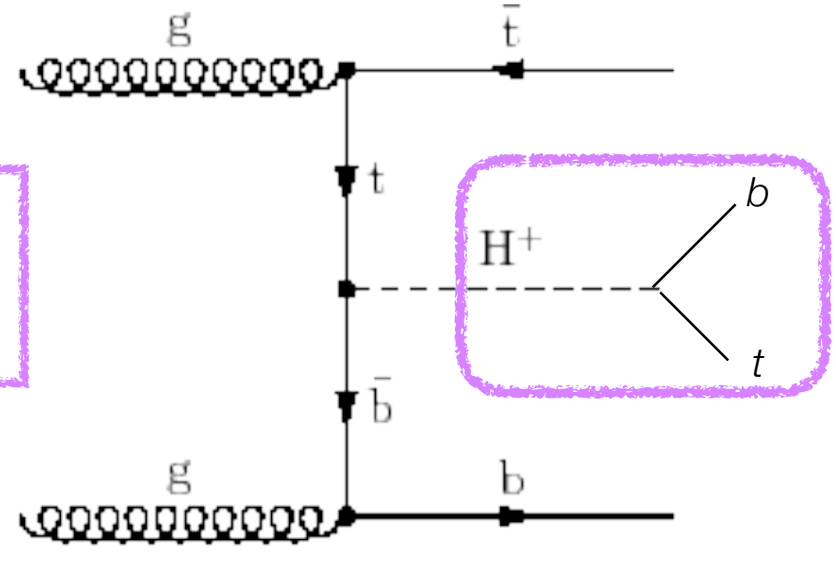


Heavy H^+ Searches: $m(H^+) \geq m(t)$

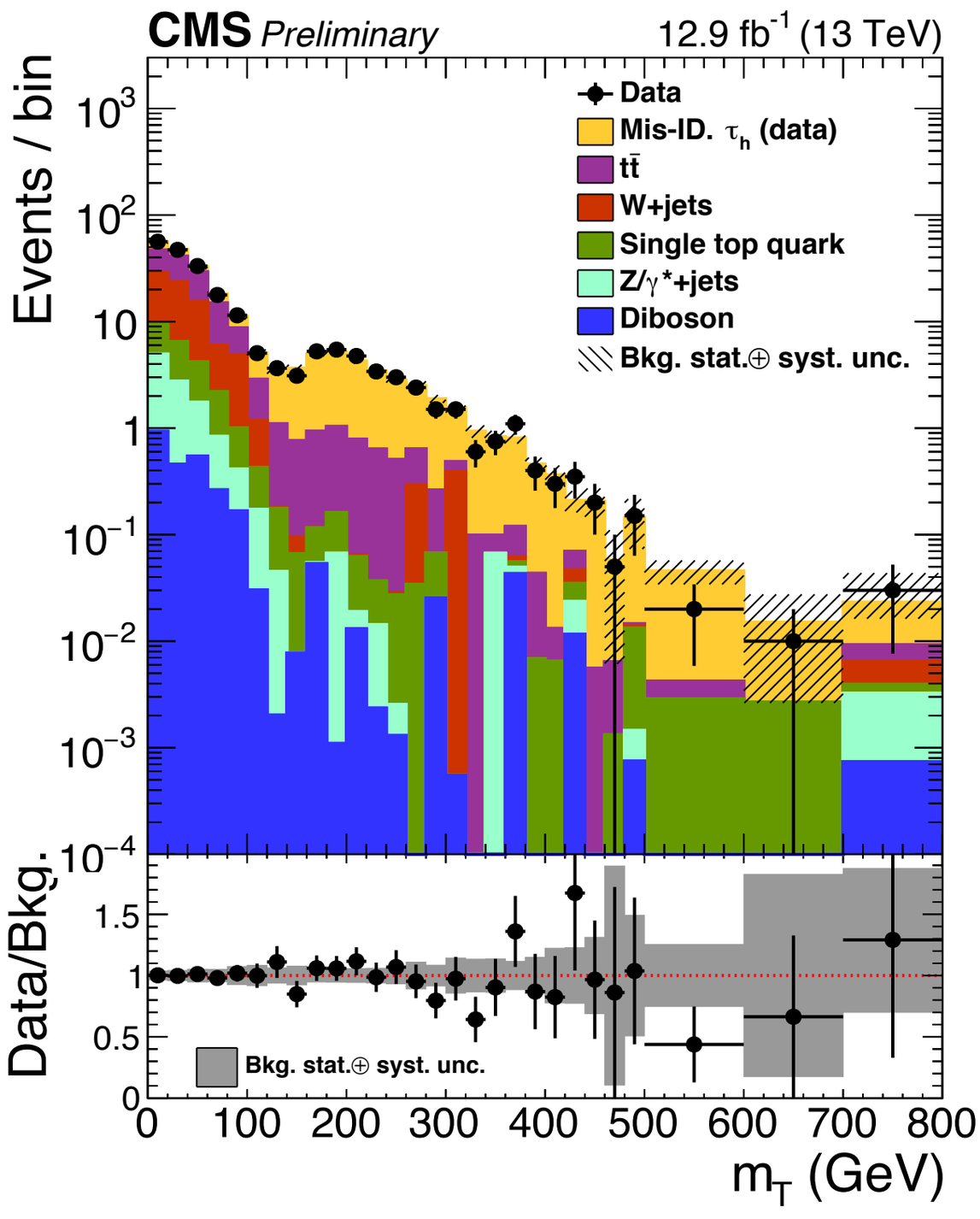








$H^+ \rightarrow \tau\nu$ @ 13 TeV



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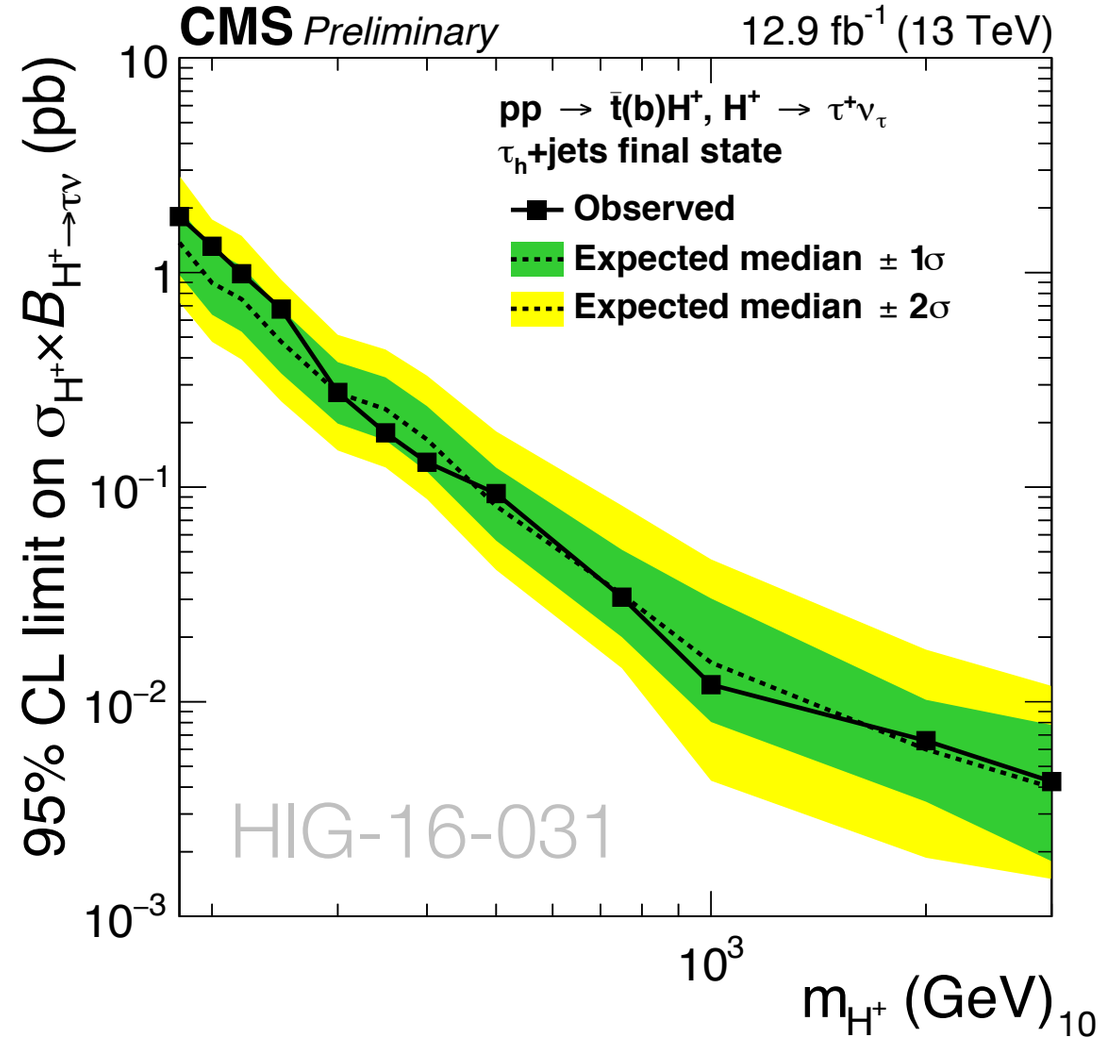
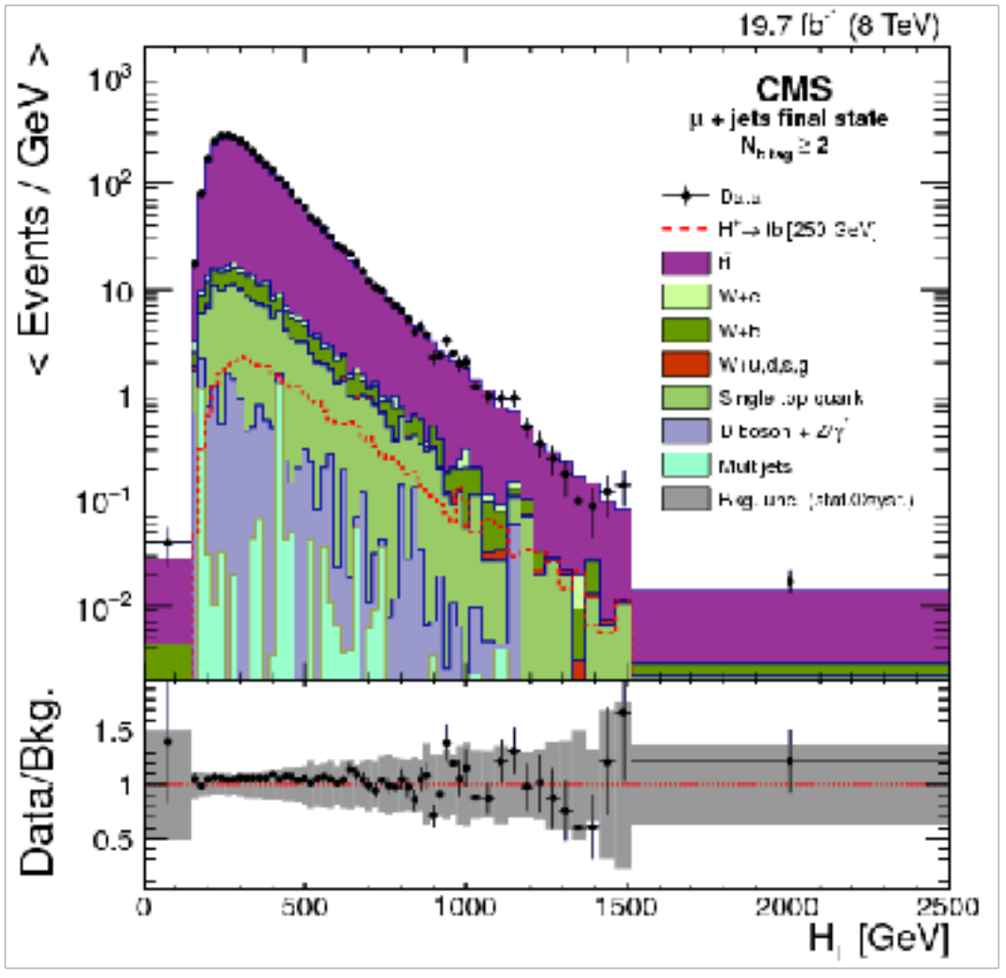
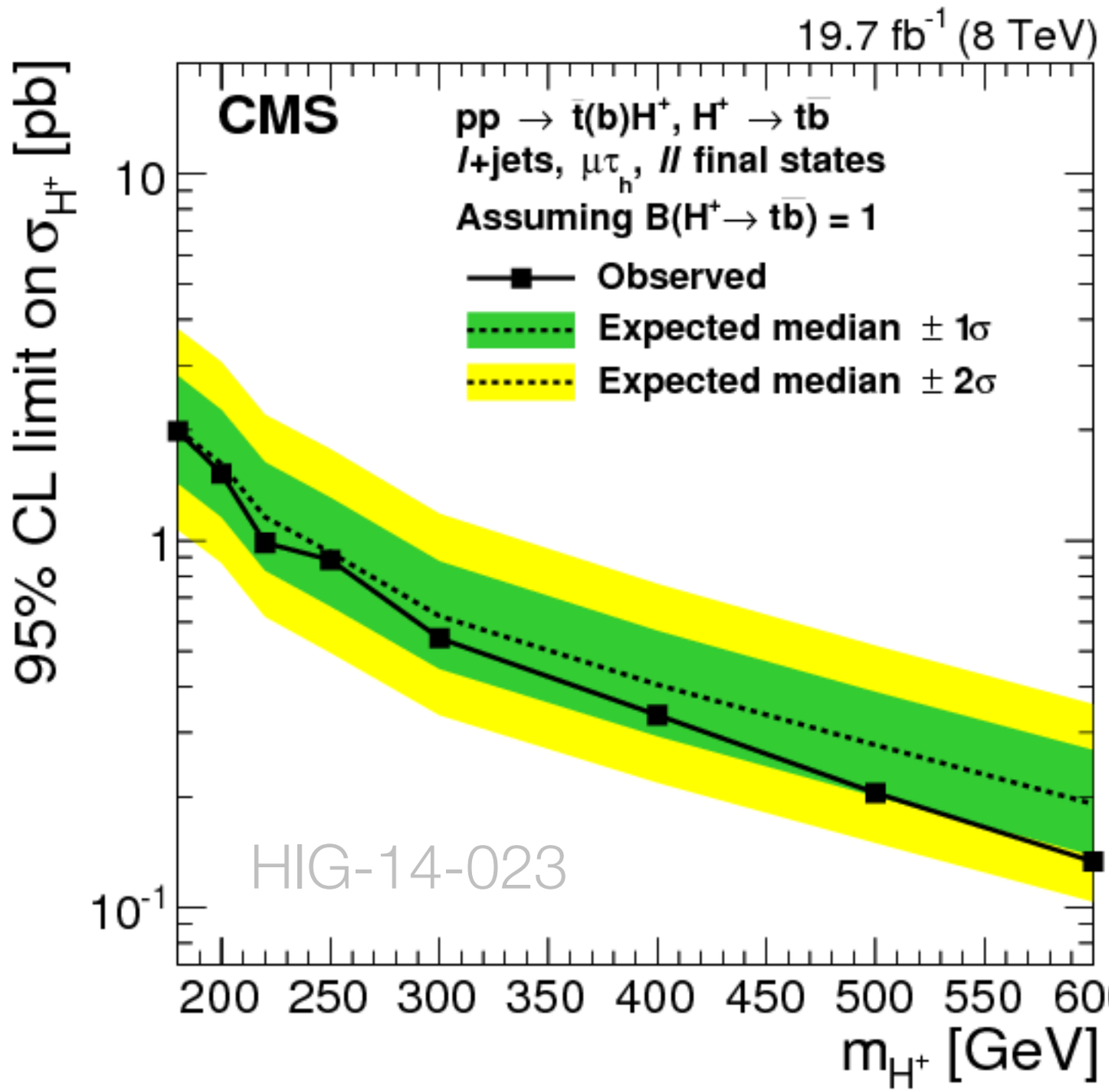


$H^+ \rightarrow tb$ @ 8 TeV

- Combining the results obtained from three different final states
- H+ signal is extracted based on the kinematic distributions of each channel



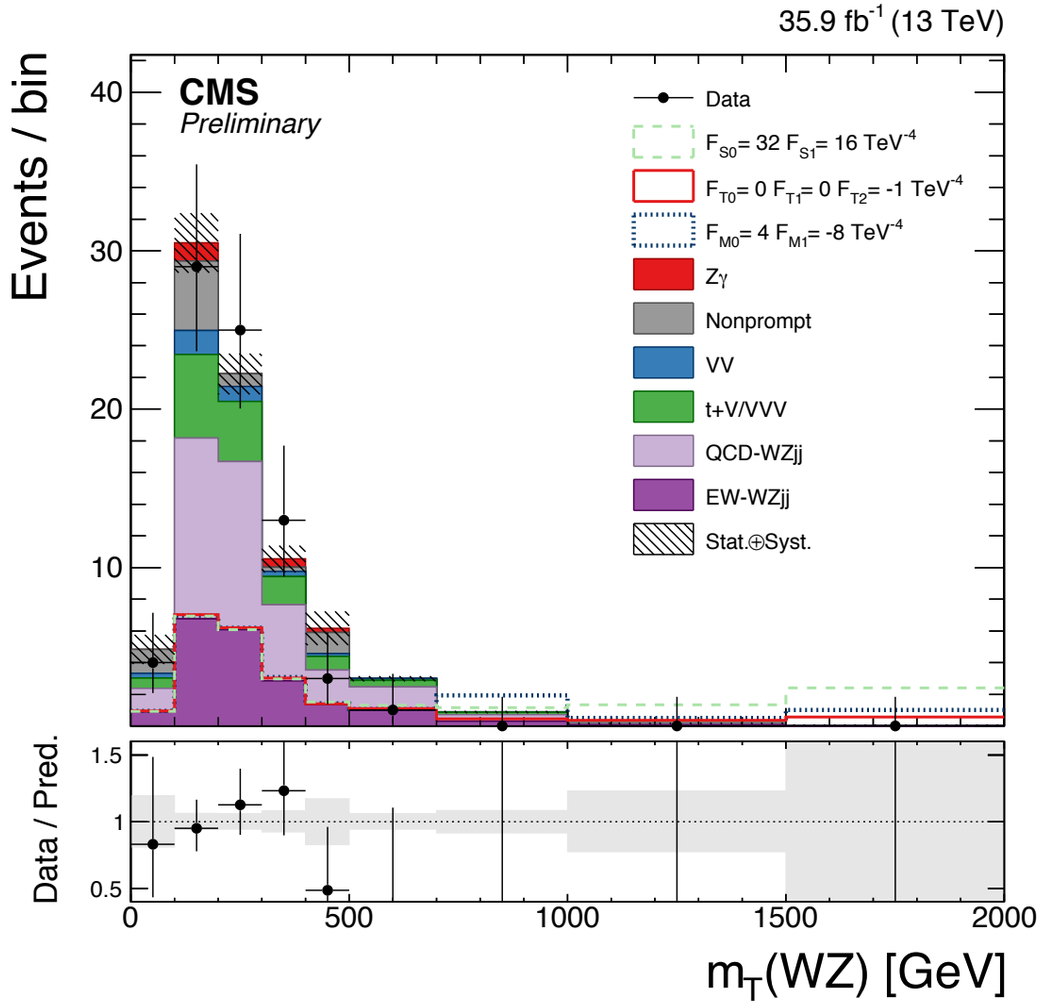


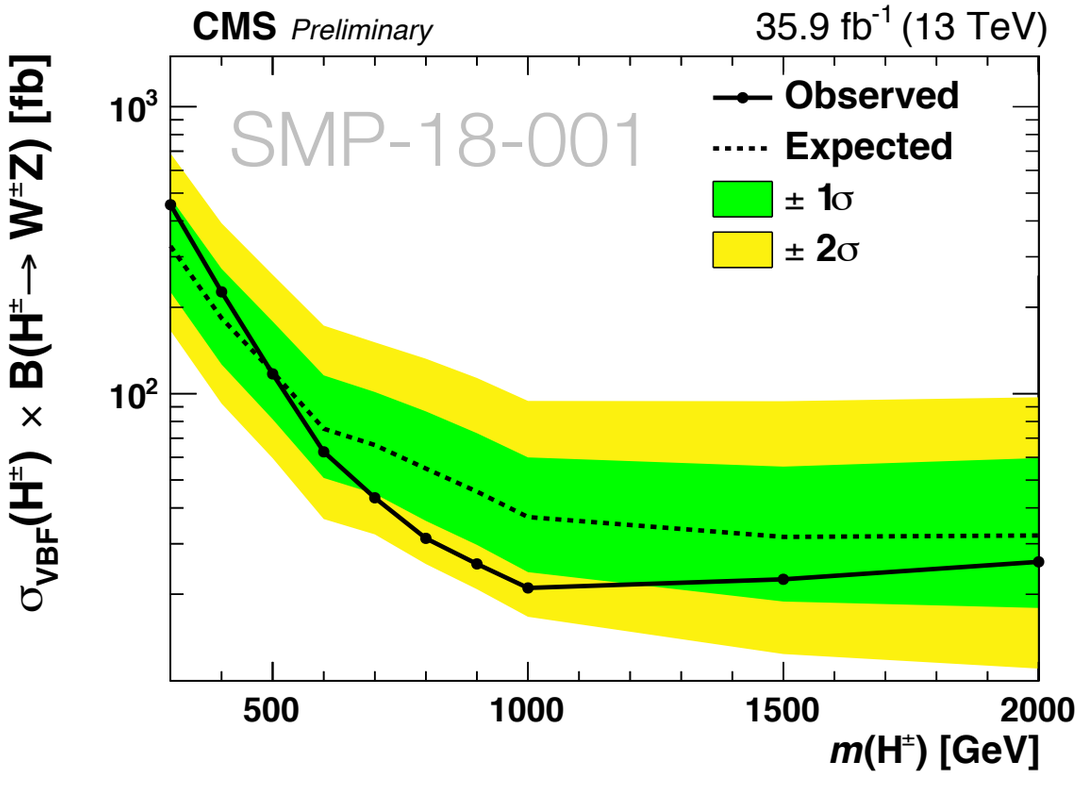
$H^+ \rightarrow WZ$ @ 13 TeV

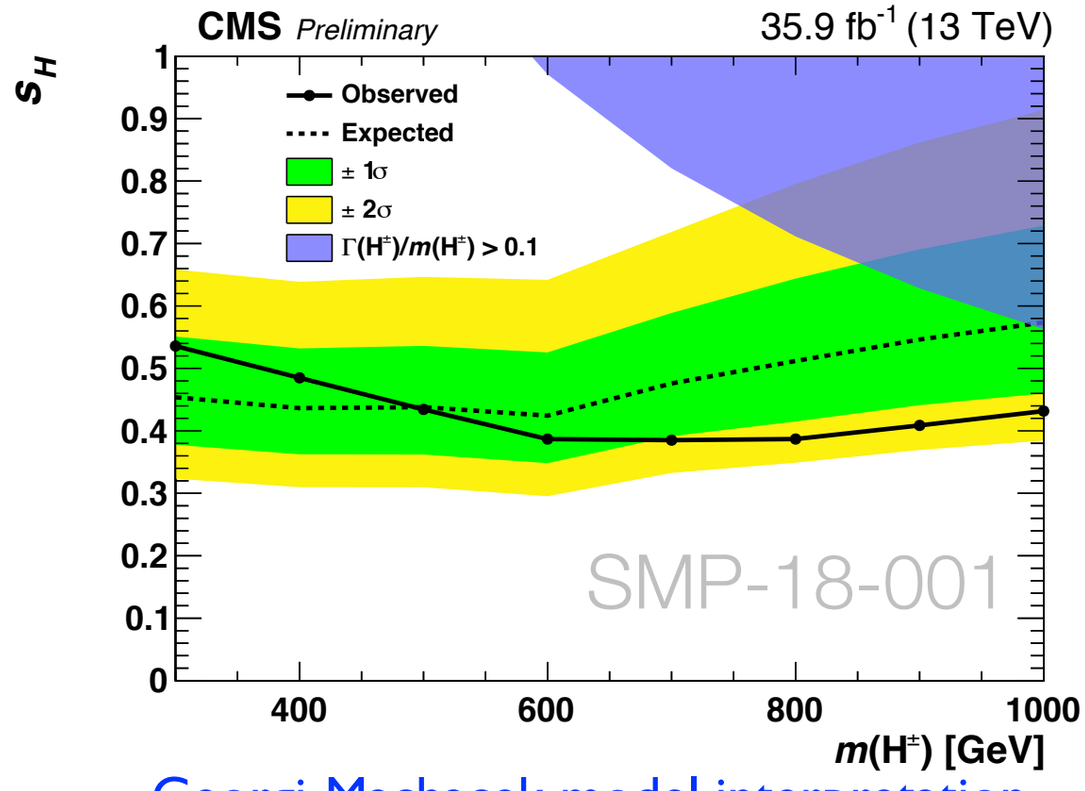
- WZ → 3leptons & two jets
- Reconstruct transverse mass of WZ and extract the signal

$$m_{\mathrm{T}}(\mathrm{WZ}) = \sqrt{(E_{\mathrm{T}}(\mathrm{W}) + \mathrm{E}_{\mathrm{T}}(\mathrm{Z}))^2 - (\mathbf{p}_{\mathrm{T}}(\mathrm{W}) + \mathbf{p}_{\mathrm{T}}(\mathrm{Z}))^2}$$

$$\sigma(\mathrm{VBF} \to H_5) = s_H^2 \sigma_1(\mathrm{VBF} \to H_5), \quad s_H \equiv \sin\theta_H = \frac{2\sqrt{2}\, v_\chi}{v}$$

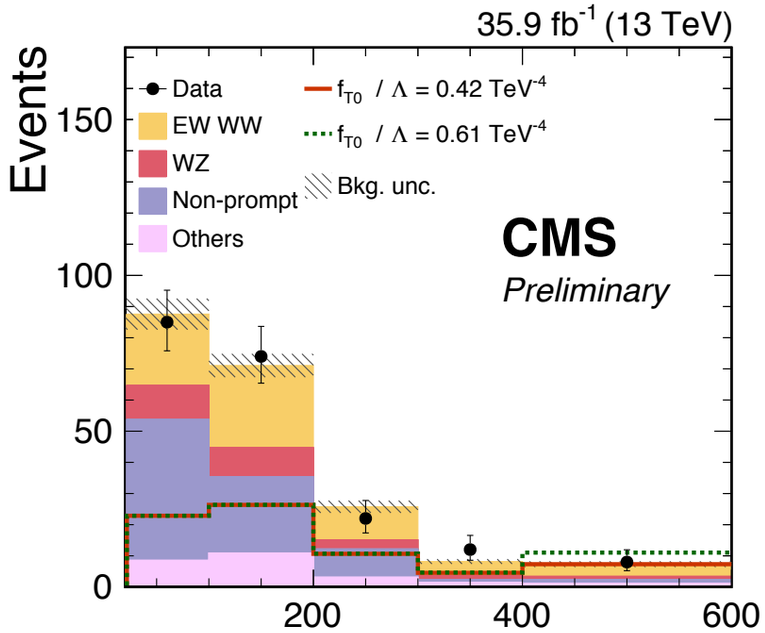


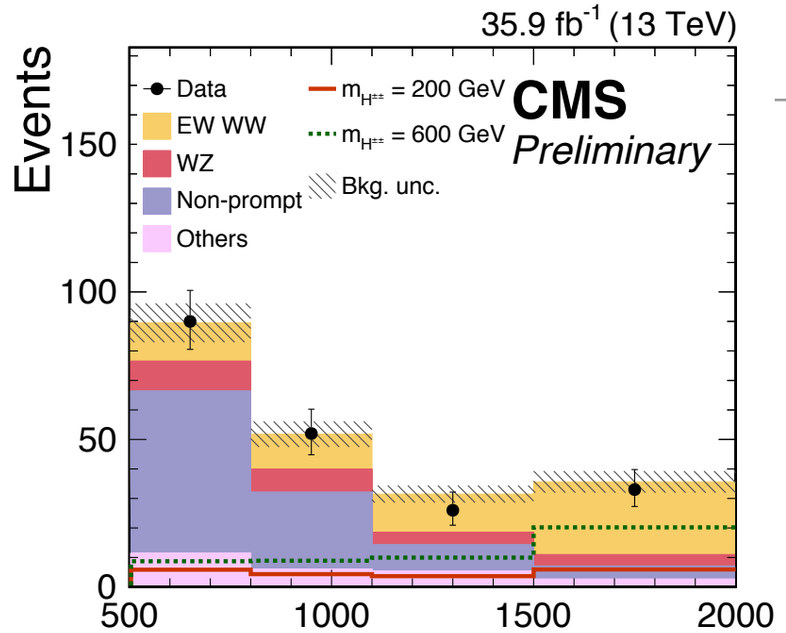




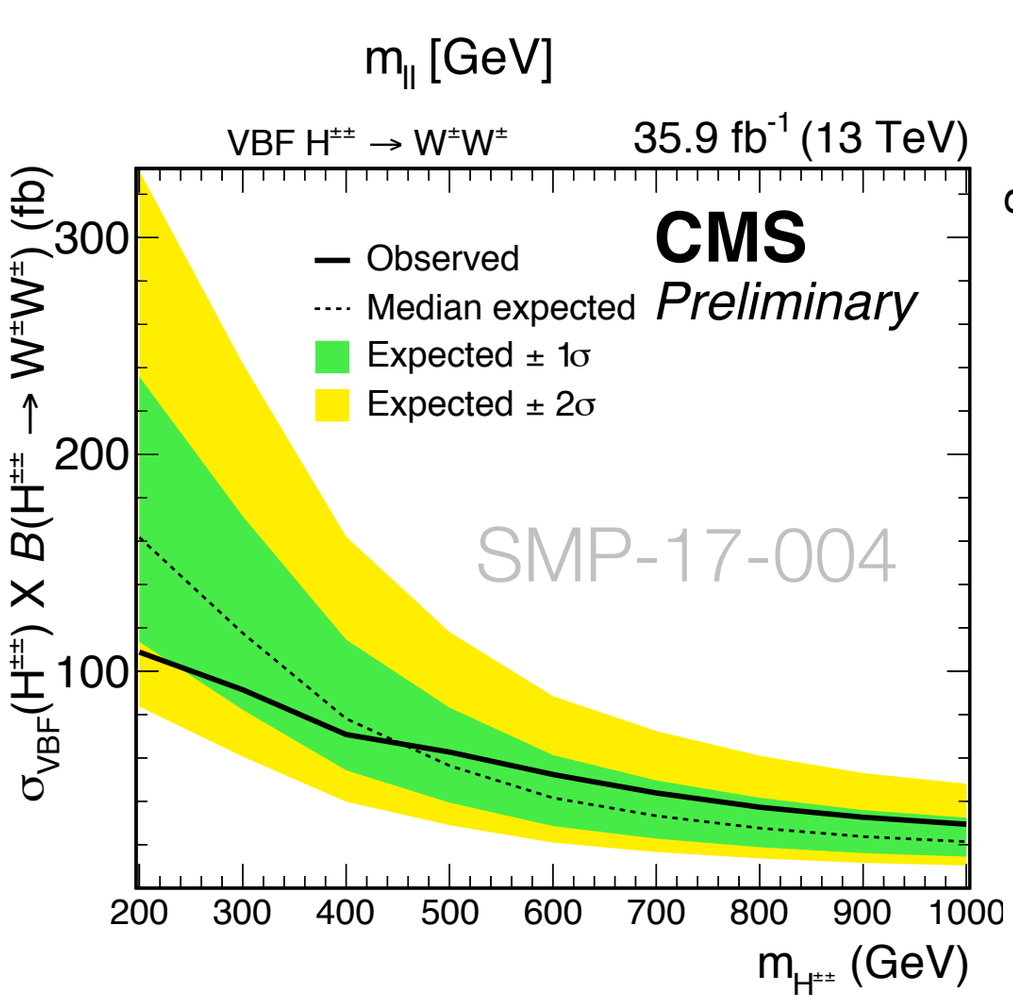
Georgi-Machacek model interpretation

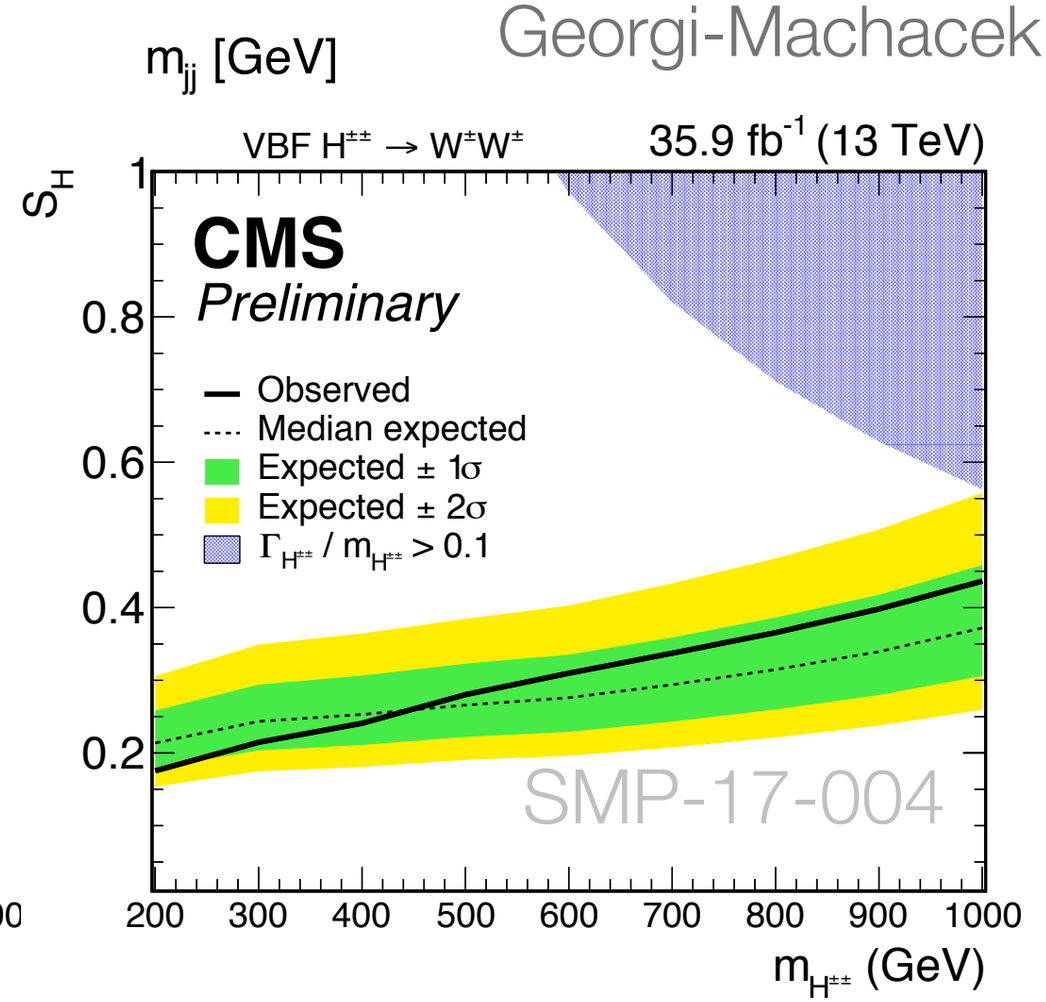
H^{++}→WW @ 13 TeV





- Two isolated same-sign leptons, p_T^{miss}>40 GeV, two ak4 jets
- Simultaneous fits on m_{ll} & m_{jj} 2D distribution and m_{jj} in WZ control region for H$^+$ signal extraction
- Limits interpreted in the Georgi-Machacek model





Summary

- Since the discovery of the SM-like Higgs boson, interest in the new physics search has grown
  - The charged Higgs boson is a must-be particle in the most BSM theories
- CMS searches performed for the most dominant production and decay modes of the $H^{+(+)}$ in the extended Higgs sector, but no observation is reported
- Updates with improvements as well as searches in a new channel are ready to be public soon. Stay tuned!

Thank you!
Cảm ơn bạn!

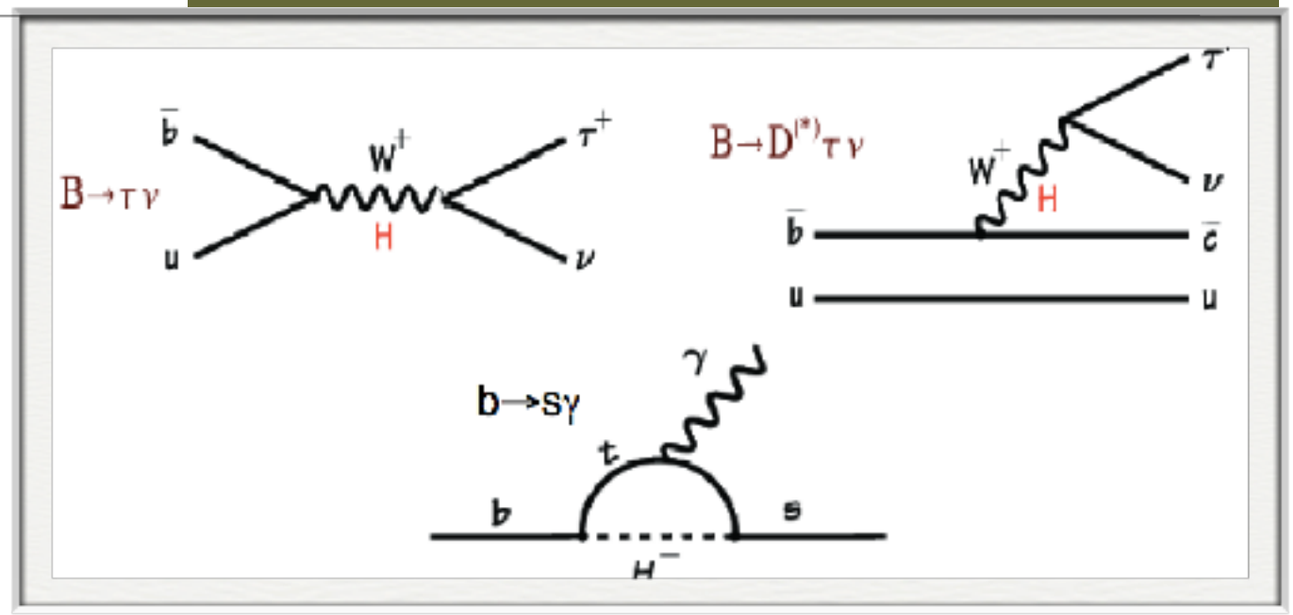
Backup

Charged Higgs (H^+) boson

Indirect H^+ search

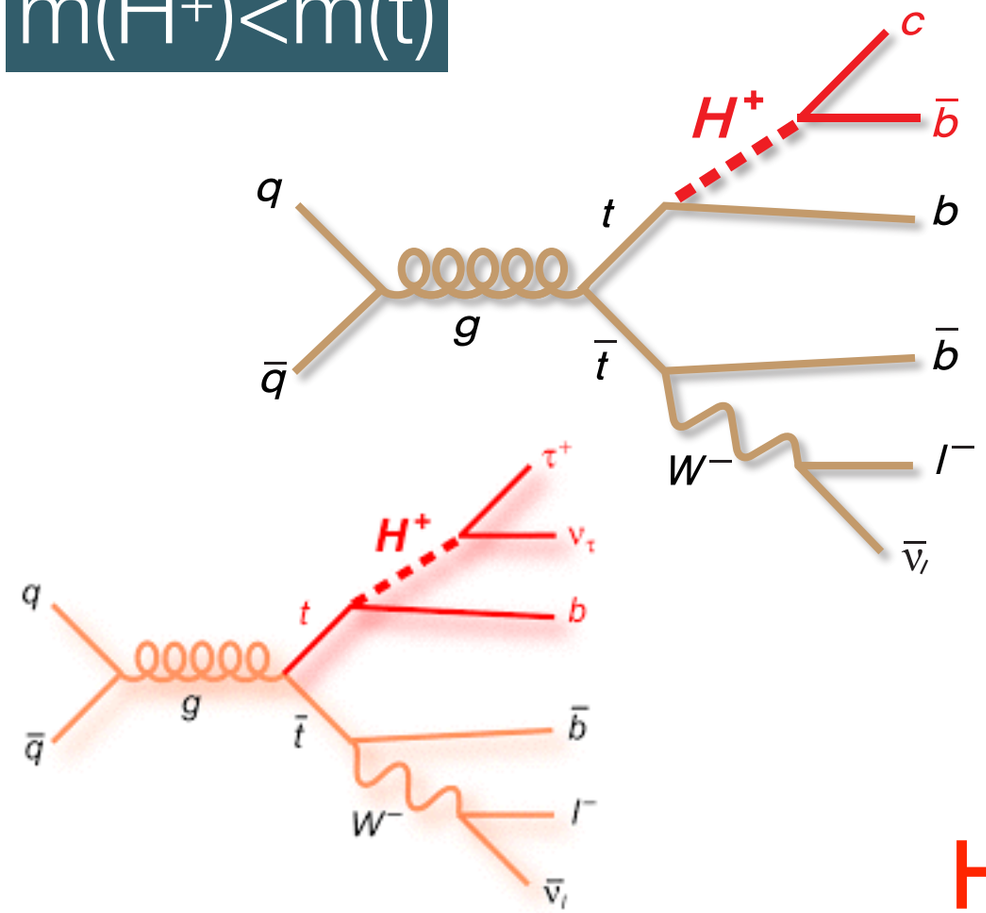
H^+ contribution @ B-factory

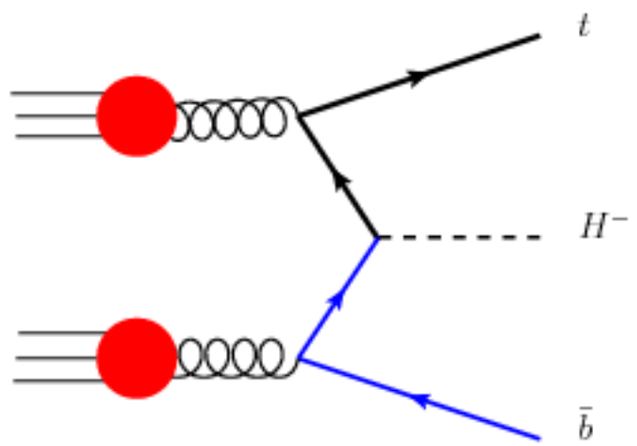
- H^+ can add a contribution to the processes that W boson takes part in

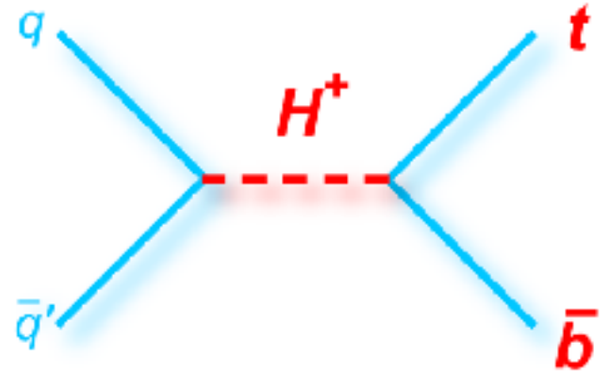


Light H^+ search

$m(H^+)<m(t)$







$m(H^+)>m(t)$

Heavy H^+ search