Charged Higgs searches in CMS

Andrea Carlo Marini

Massachusetts Institute of Technology

on behalf of the CMS Collaboration

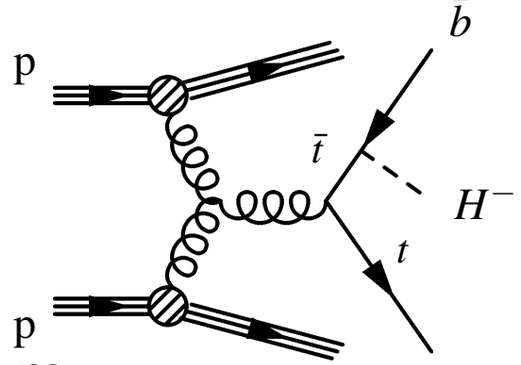
ICHEP — 6 August 2016

Introduction

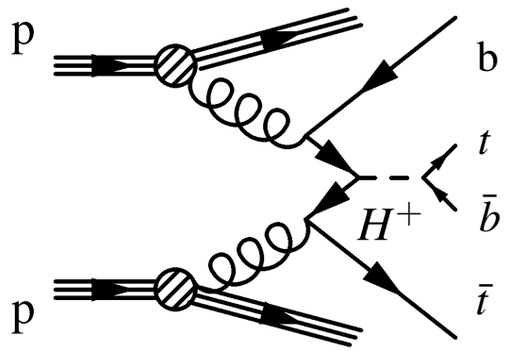
Charged Higgs bosons appear in many extensions of the SM

2HDM

- type I / type II / type Y…
- **Light**: $m_{H^\pm} < m_t - m_b$
  - $t \to H^\pm b$
  - ttbar and single top productions
  - for tanβ > 5 preferentially decays into $\tau\nu$



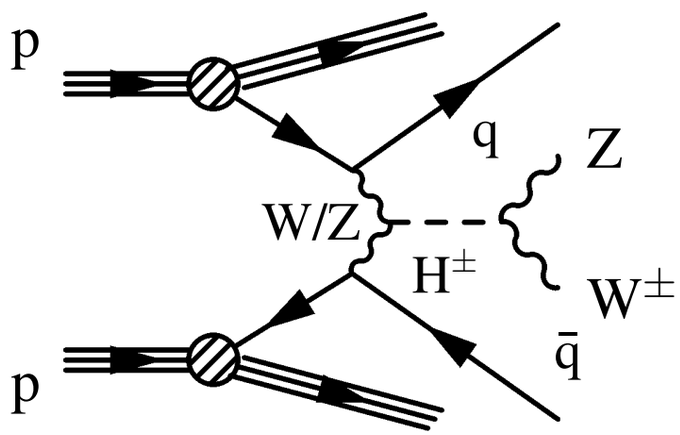
- **Heavy**: $m_{H^\pm} > m_t - m_b$
  - for very high masses $H^\pm \to tb$
  - $\mathcal{B}(H^\pm \to \tau\nu)$ ~1—10 %



Triplets models

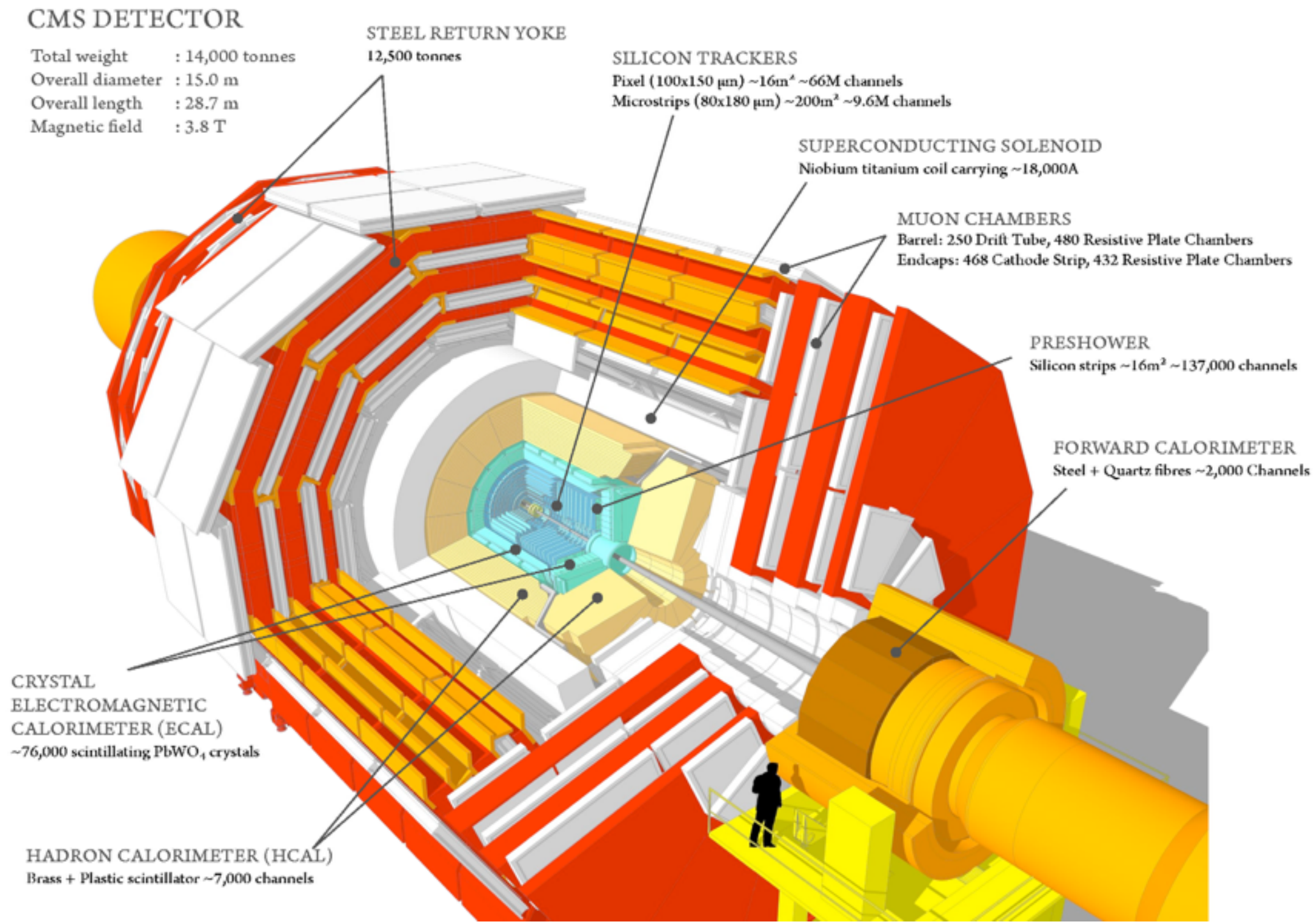
- Introduce $H^\pm WZ$ couplings at tree level
- Different phenomenology wrt nHDM

- **Georgi-Machacek:** Nucl. Phys. B 262 (1985)
  - real and complex triplet
  - free parameters: mass and sinTH



…

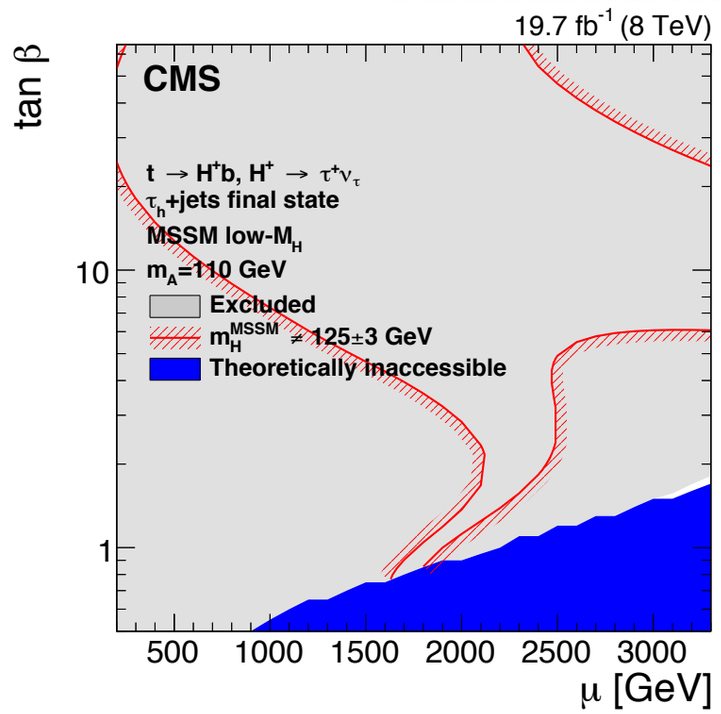
CMS Detector

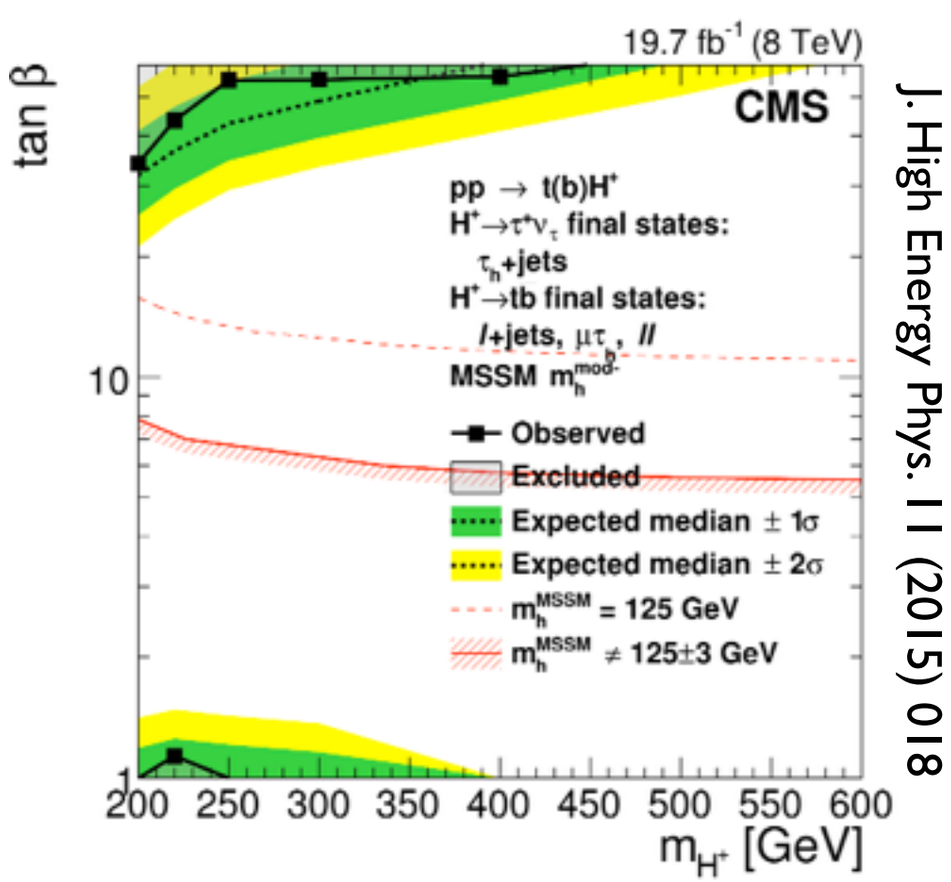


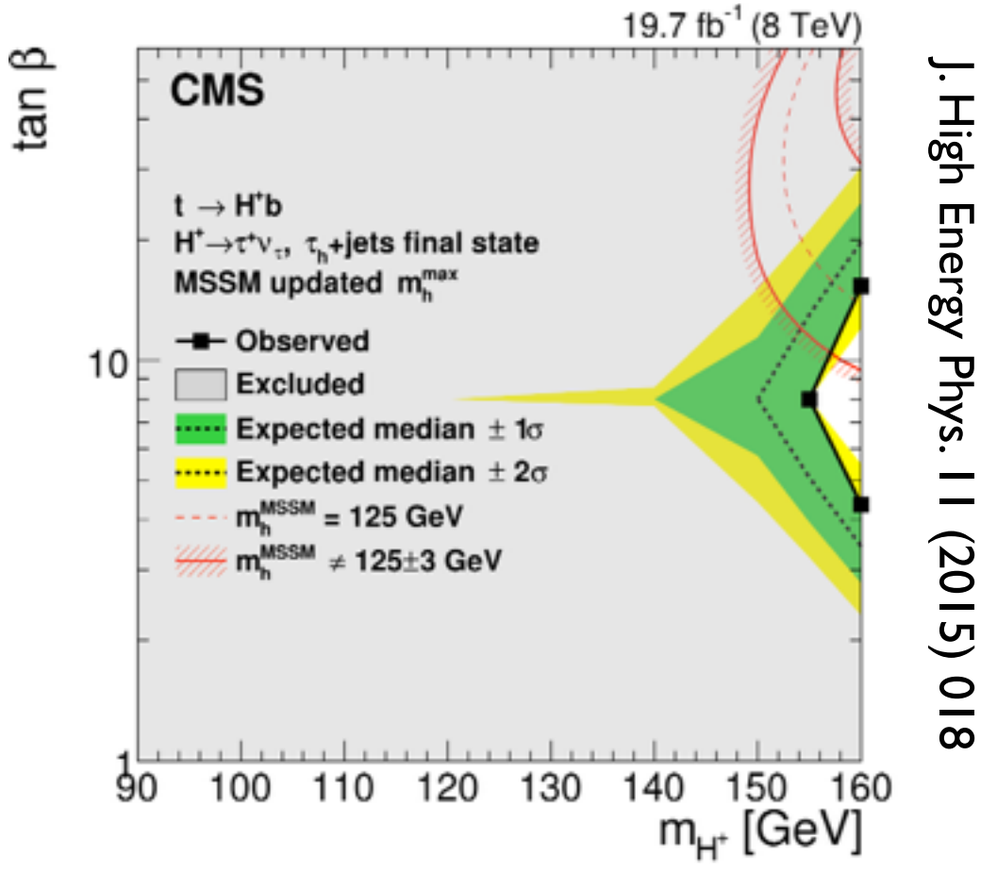
Status & Prospects

LHC-RunI legacy from CMS:

- Focus on MSSM models:
  - special case of 2HDM-typeII models
  - excluding $m_{H^\pm} < 155$ GeV (various models)
  - light-stop scenario is excluded $m_{H^\pm} < 160$ GeV
  - low mH scenario completely excluded
- High mass searches up to 600 GeV
  - MSSM models better constrained by neutral searches
  - space left at $\tan\beta < 10$ and $m_A > 350$ GeV



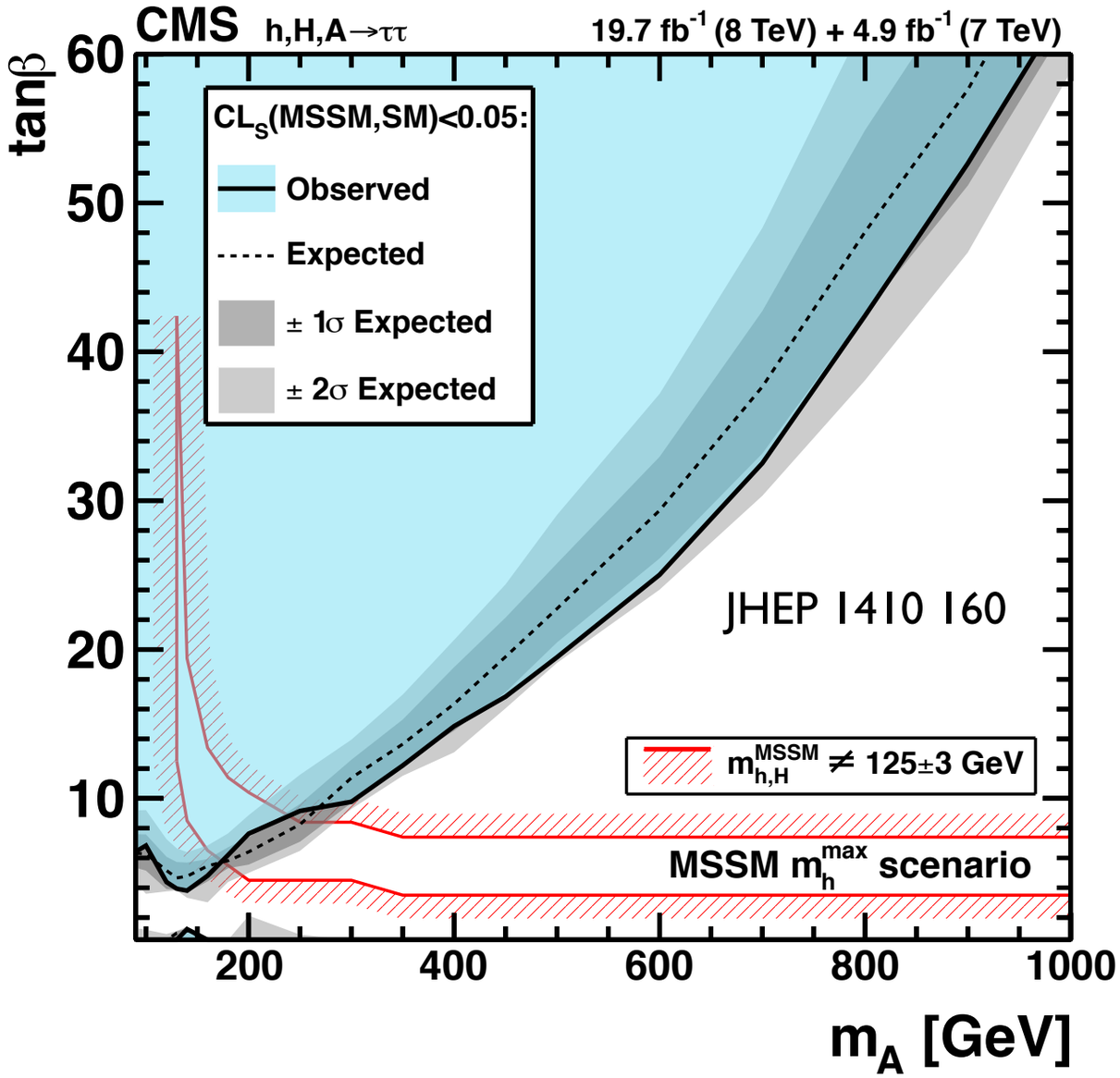


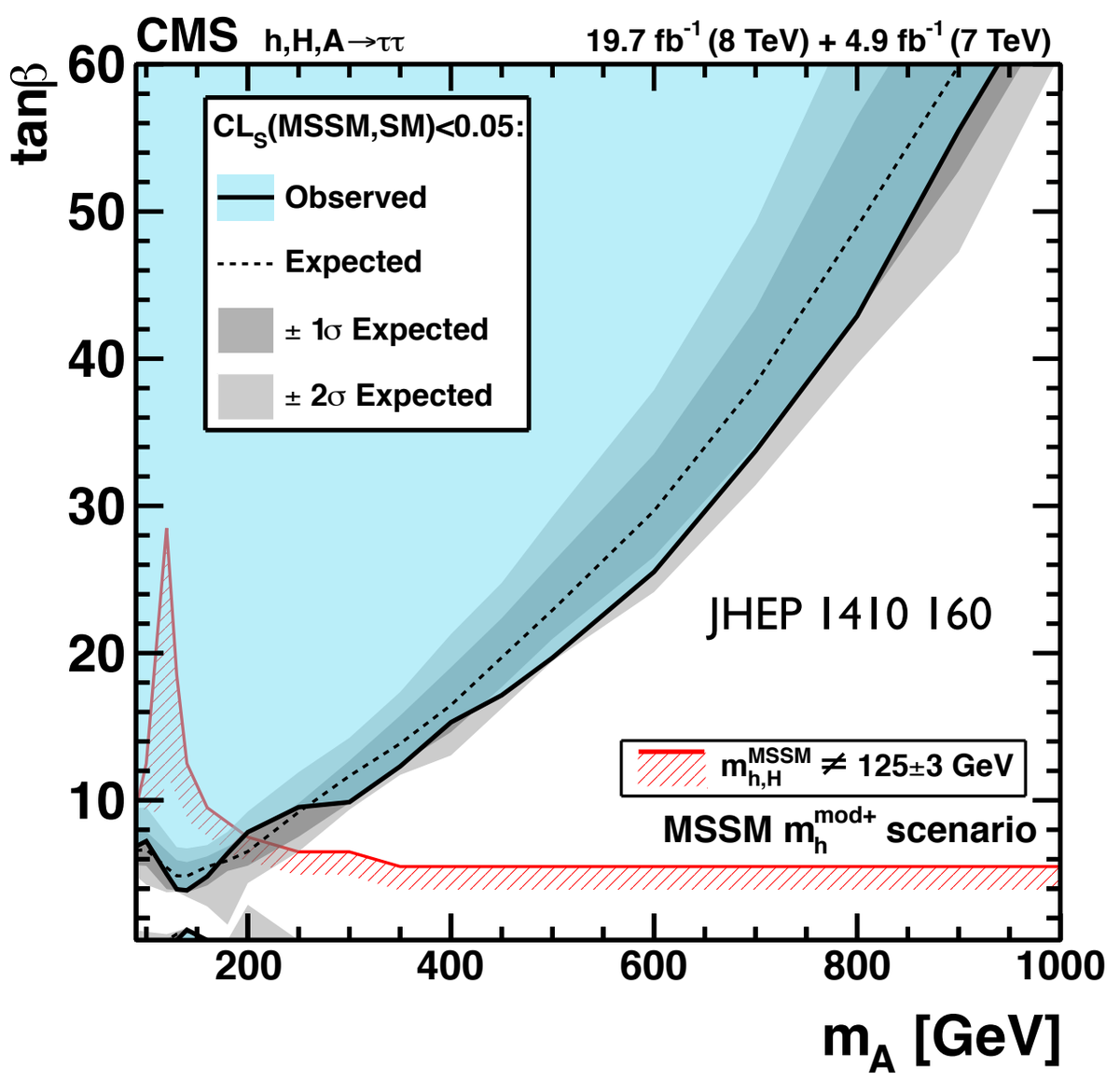


MSSM RunI

- MSSM is a special case of 2HDM-typeII
- Constrain from neutral channels h,H,A → $\tau\tau$
  - many parts of the phase space is now excluded

For runII results see talk from Poja Saxena





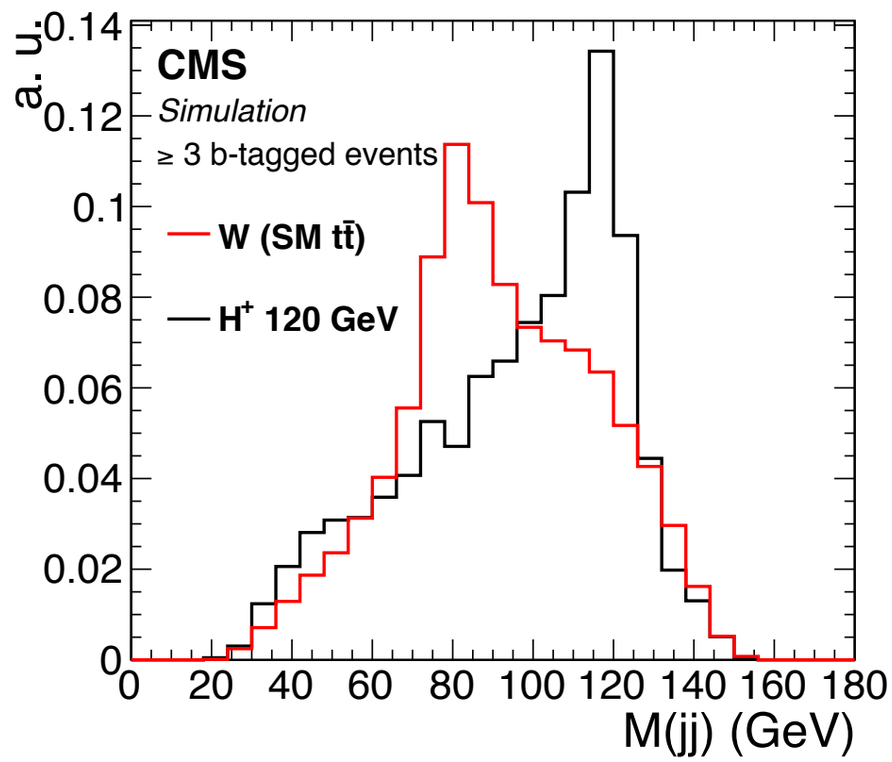
Search for $H^{\pm} \rightarrow cb$

flipped 2HDM model

Selection:

- 1 lepton: μ (e):
  - $p_T > 26$ (30) GeV
  - $|\eta| < 2.1$ (2.5)
- $N_{jets} \geq 4$ jets
- MET > 20 GeV
- $N_{b\text{-}jets} \geq 2$

NEW



Strategy:

- Fit m_{jj} of the invariant mass
- kitematic fitter to reconstruct the ttbar event
- simultaneously in two categories
  - $N_{b\text{-}jets} = 2$ (constrain tt)
  - $N_{b\text{-}jets} \geq 3$
- Assume $B(H^{\pm} \rightarrow cb) = 1$

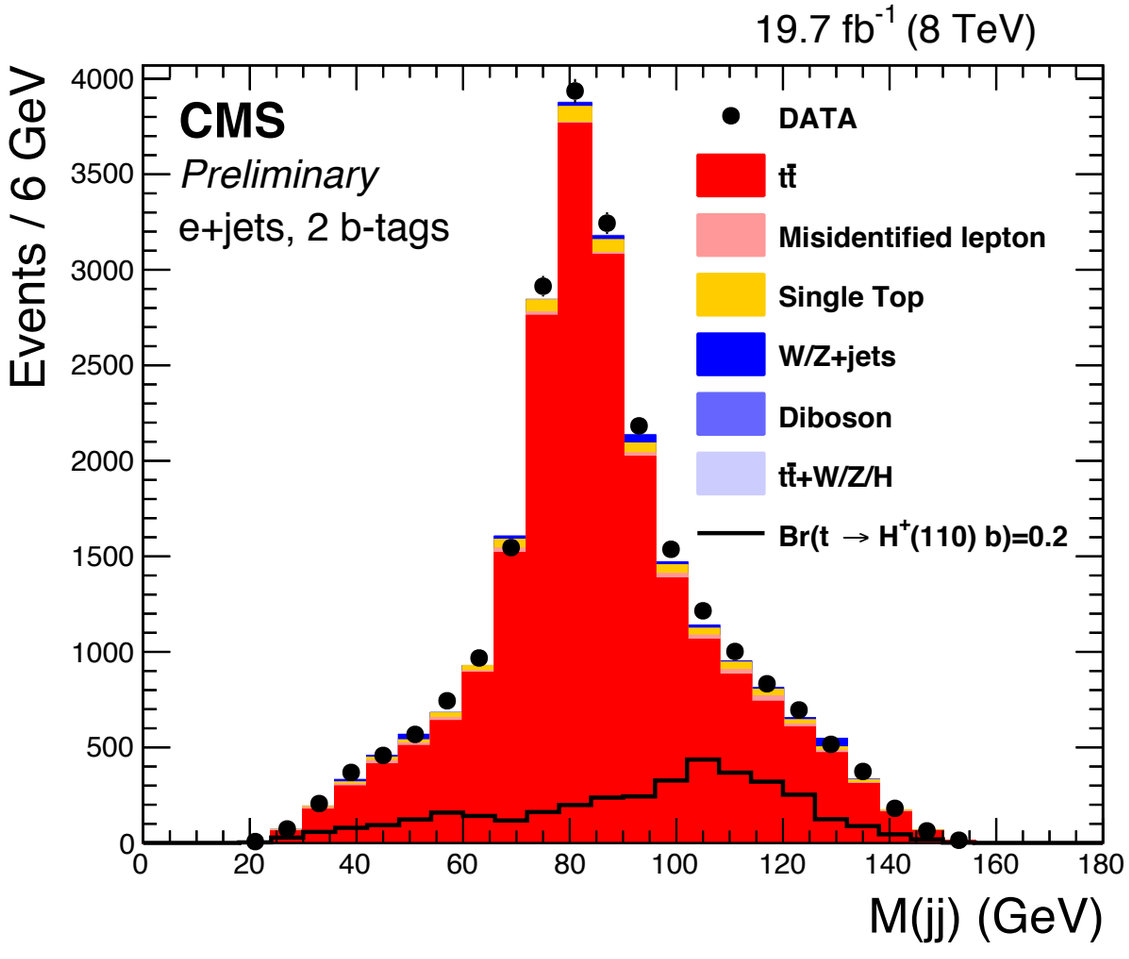
Poster:

First attempt to search for H^+ to cb in top quark decays at CMS
Geum Bong Yu

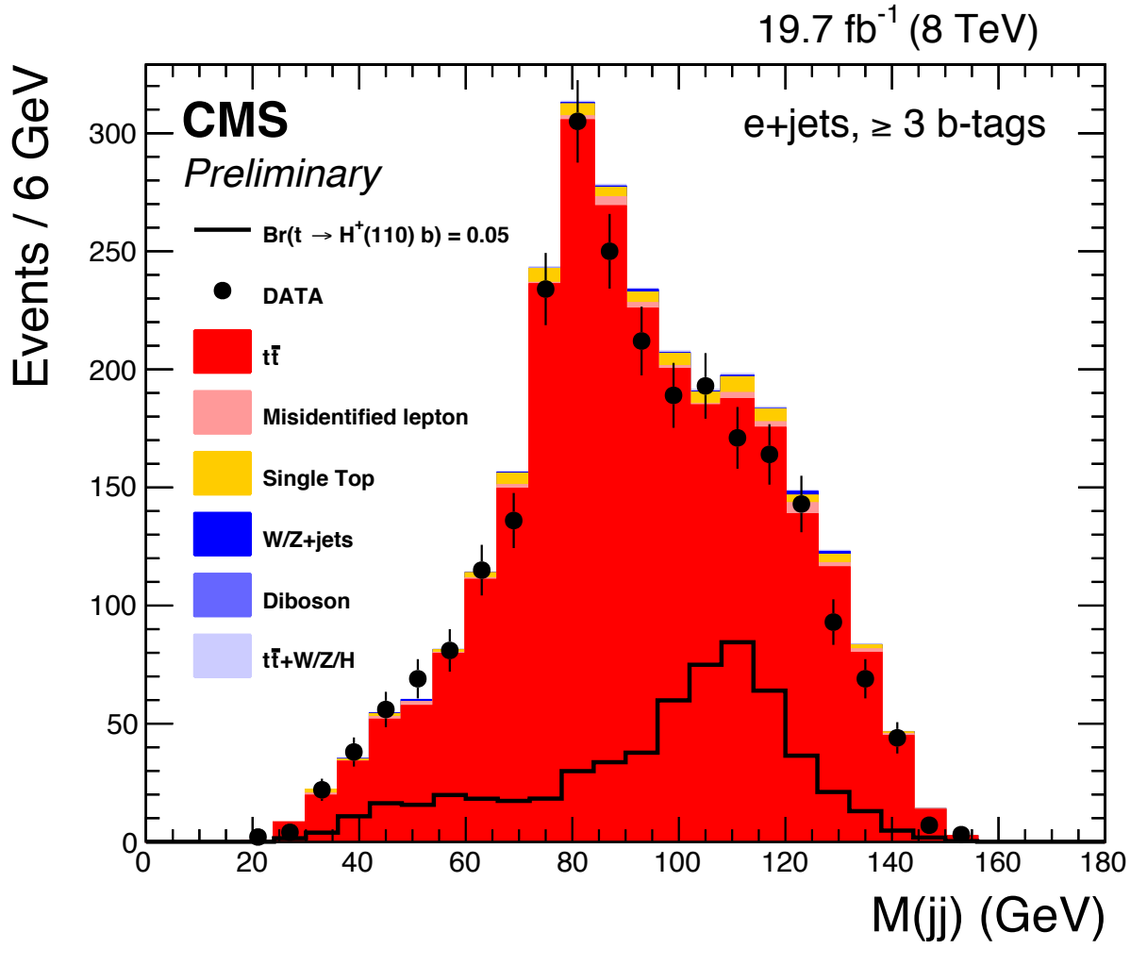
CMS-PAS-HIG-16-030

Mjj Distributions

- Left, 2-btag category (electron)
- Right, 3-btag category (electron)



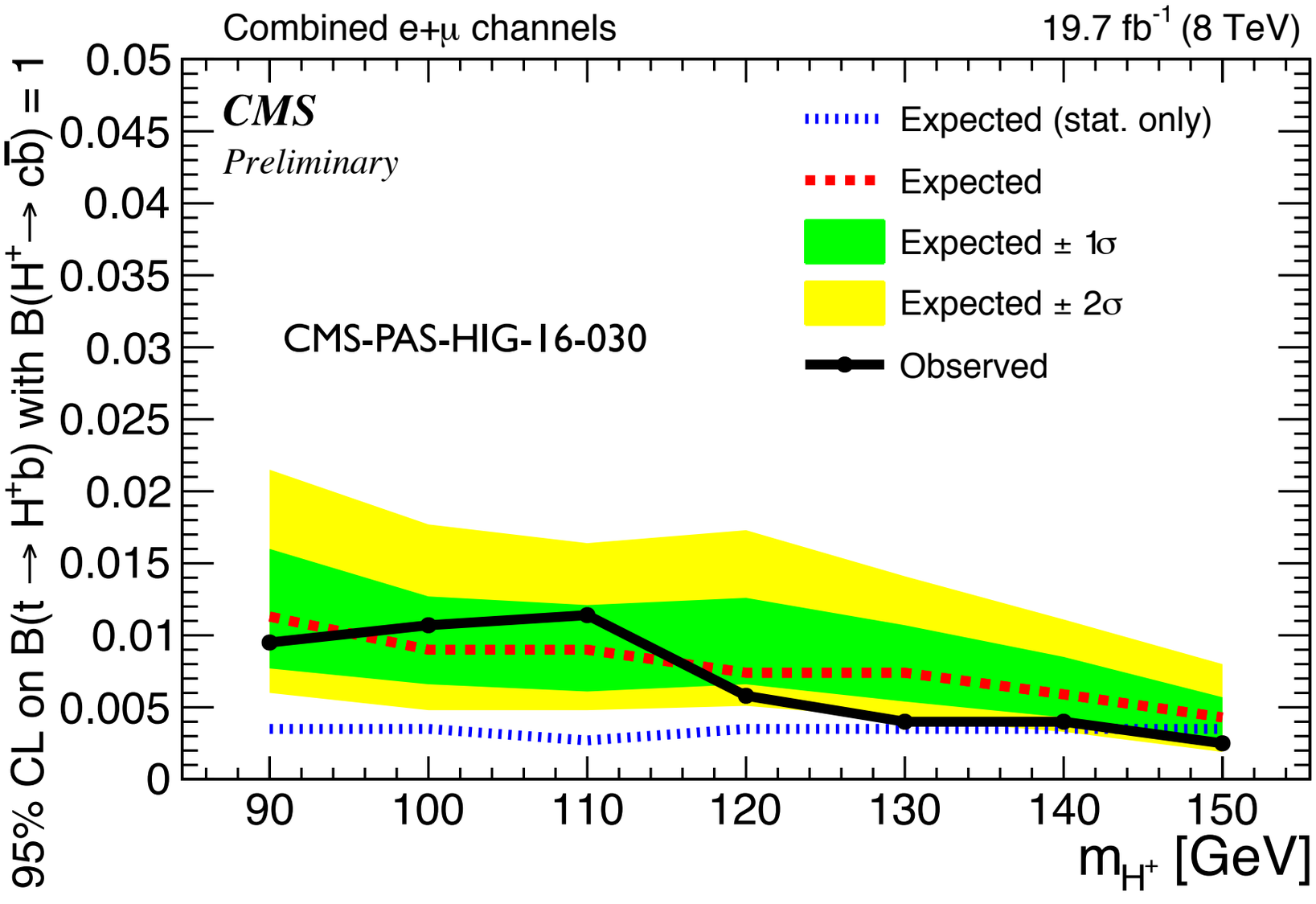
CMS-PAS-HIG-16-030



CMS-PAS-HIG-16-030

Results

- Setting limits on the $B(t \to H^{\pm} b)$ assuming $B(H^{\pm} \to cb) = 1$
- data agree with the SM

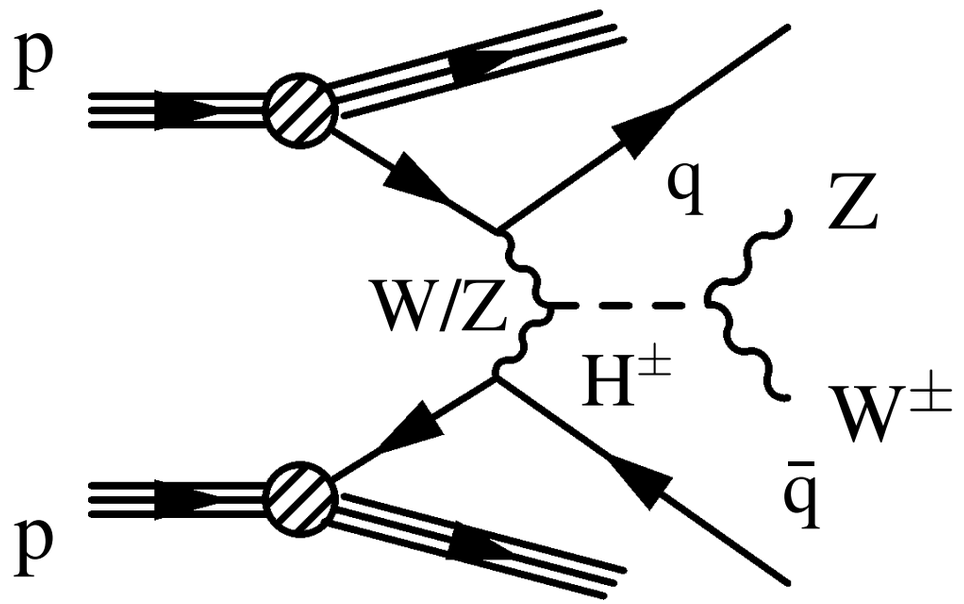


Run II

$H^{\pm} \rightarrow WZ$ in VBF signature

NEW

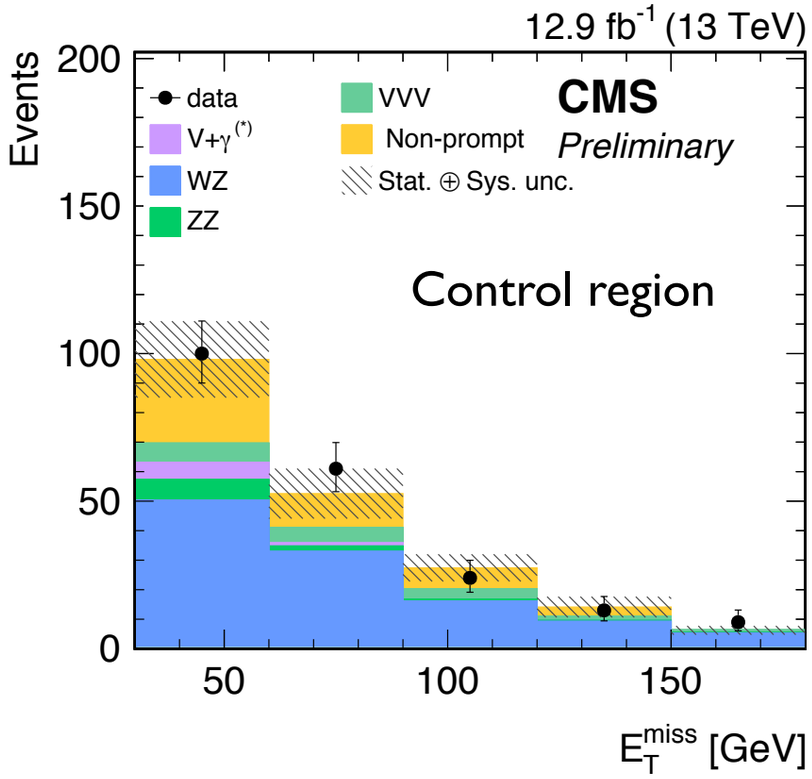
- 3 leptons (μ, e)
  - p_T > 20, 10, 20 GeV
  - |η| < 2.4 (2.5) electrons (muons)
- 2 jets
  - p_T > 30 GeV
  - |η| < 5
- MET > 30 GeV
- One Z:
  - Opposite sign same flavor leptons
  - $|m_{\ell\ell} - m_Z| < 15$ GeV
- VBF:
  - $m_{jj} > 500$ GeV
  - $\Delta\eta(j,j) > 2.5$
- anti b-tag



CMS-PAS-HIG-16-027

Background & Signal Extraction

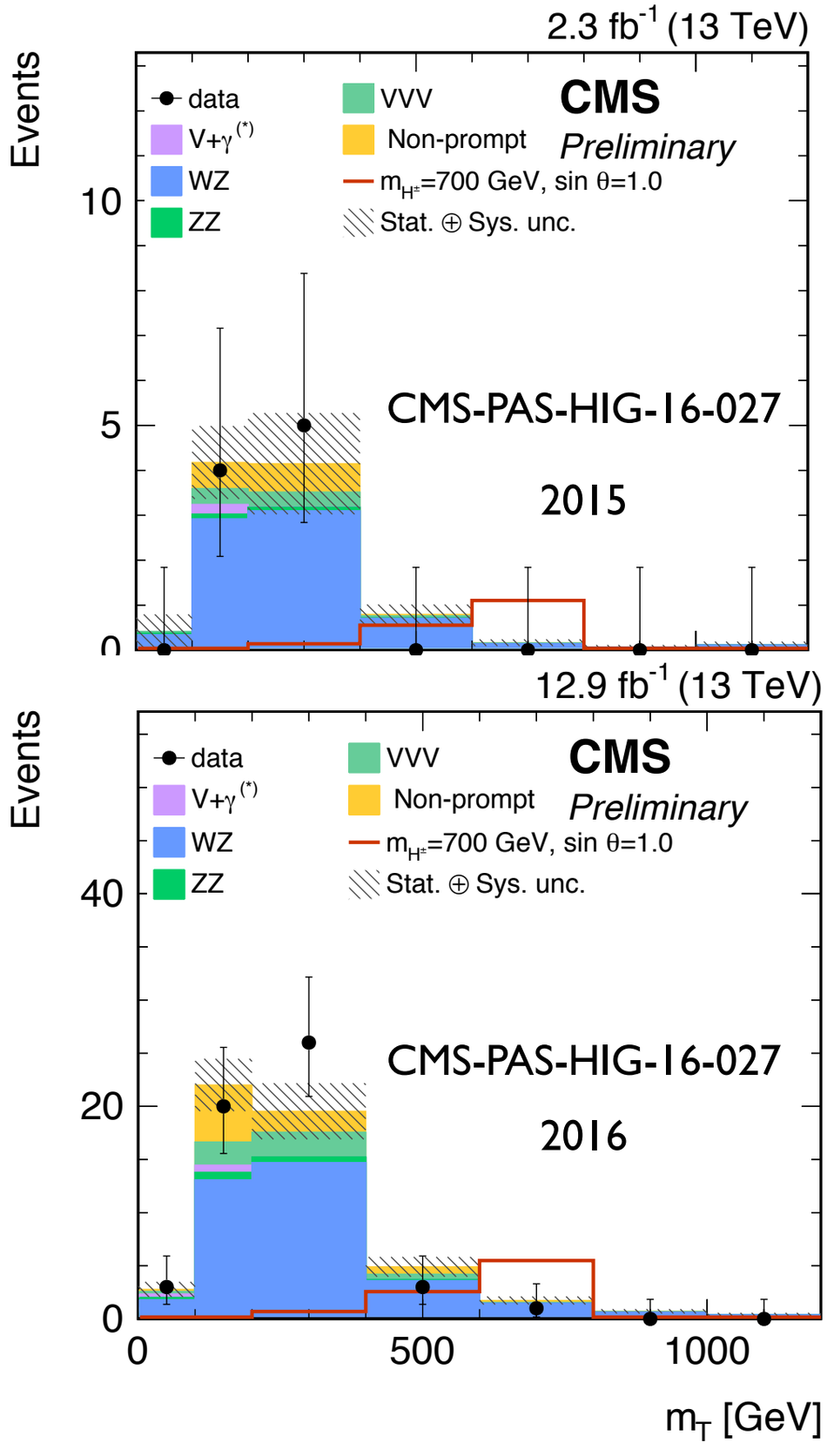
- Non prompt background:
  - data-driven



- m_T (massive particles)

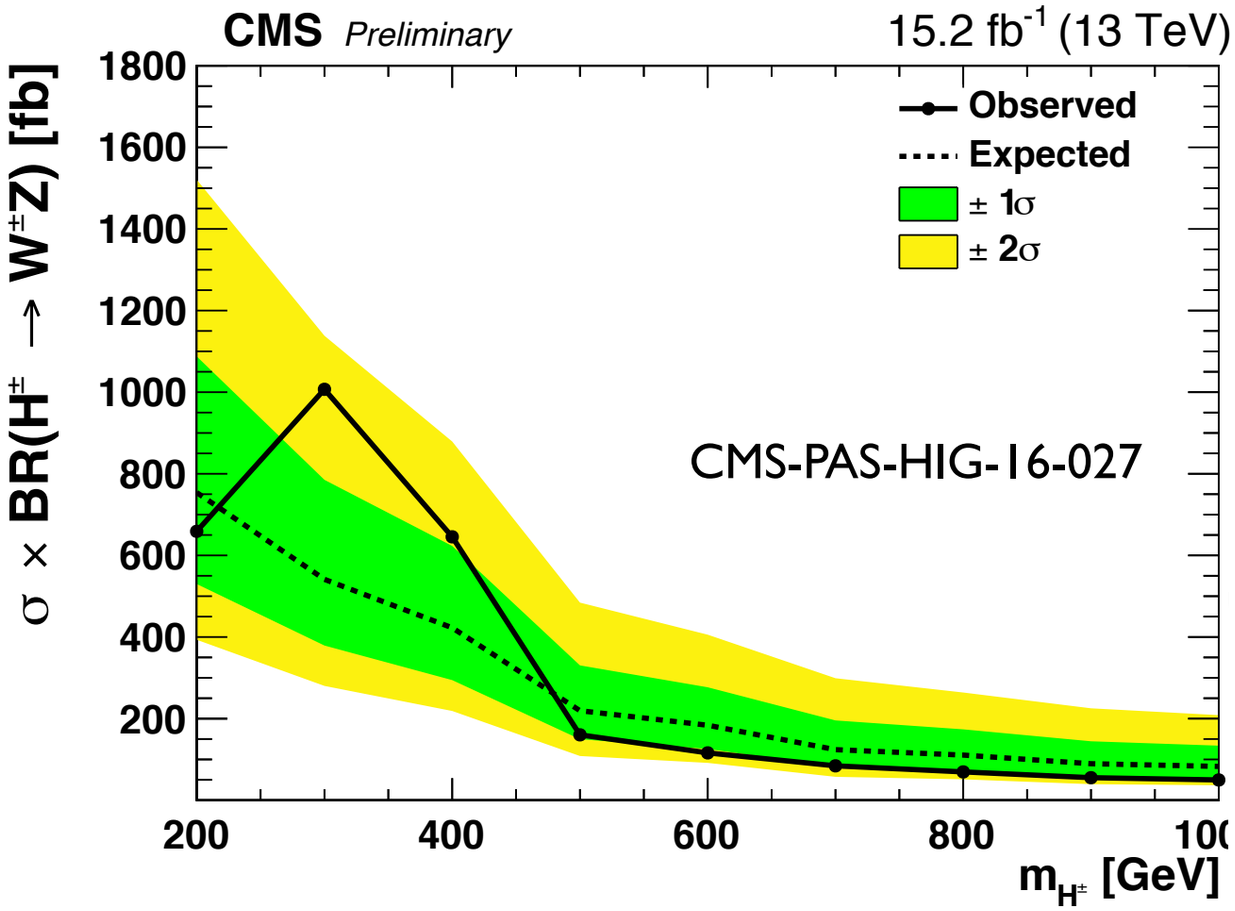
$$M_T(WZ) = \sqrt{(E_T^Z + E_T^W)^2 - (\bar{p}_T^Z + \bar{p}_T^W)^2}$$

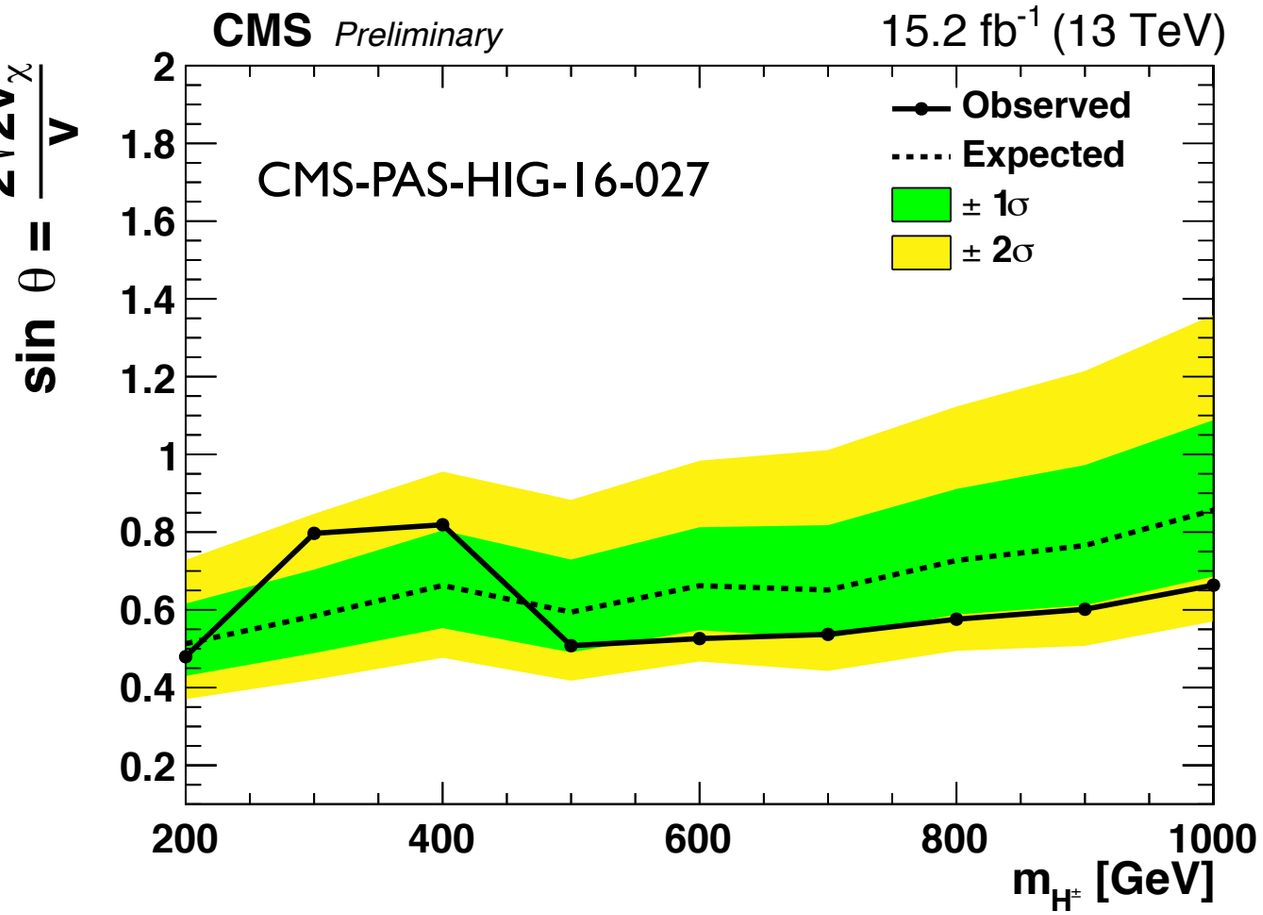
CMS-PAS-HIG-16-027



Cross section limits

- 95% CL limits (CL_s criterion) on the production cross section





- Limits on the parameters, in the G-M model

Summary

- The search using 8TeV data for the production of $H^{\pm} \rightarrow cb$ has been presented for the first time

- The first results on charged higgs searches in CMS using RunII data has been presented
  - $H^{\pm} \rightarrow WZ$ (VBF)

- So far, limits agree with SM expectations

- A lot of data are being and will be delivered by the LHC
  - New results will come out soon
  - stay tuned!

Backup

VBF WZ

- Systematics

Source	Signal	WZ	VVV	Zγ	ZZ	Non-prompt
Luminosity	2.7-6.2	—	2.7-6.2	2.7-6.2	2.7-6.2	—
Lepton efficiency	4.0	—	4.0	4.0	4.0	—
Lepton momentum scale	1.0	1.0	1.0	1.0	1.0	—
Jet momentum scale	2.0 - 5.0	8.0	6.0	30.0	13.0	—
$E_{\mathrm{T}}^{\mathrm{miss}}$ resolution	5.0	1.7	1.0	—	7.0	—
B-tagging	2.0	—	2.0	2.0	2.0	—
WZ normalization	—	21-23	—	—	—	—
Non-prompt normalization	—	—	—	—	—	30-81
GM uncertainties	8	—	—	—	—	—

Table 1: Relative systematic uncertainties in the estimated signal and background yields, in units of percent

- Systematics (see PAS for the full list)

Table 4: List of rate systematic uncertainties for e+jets (μ+jets) channel H^+ signal samples for 2 b-tagged (up) and ≥ 3 b-tagged (down) region.

H^+ mass (GeV)	90	100	110	120	130	140	150
2 b-tags							
B-tagging SF (b/c)	1.3(1.3)%	1.2(1.3)%	1.3(1.2)%	1.2(1.2)%	1.5(1.4)%	1.6(1.7)%	2.1(2.1)%
B-tagging SF (light/gluon)	0.1(0.1)%	0.1(0.1)%	0.1(0.1)%	0.2(0.1)%	0.1(0.1)%	0.1(0.1)%	0.1(0.1)%
Pileup reweight SF	0.3(0.4)%	0.8(0.3)%	0.8(0.2)%	0.1(0.4)%	0.4(0.1)%	0.4(0.1)%	1.2(0.2)%
3 b-tags							
B-tagging SF (b/c)	5.7(5.7)%	5.8(5.7)%	5.7(5.8)%	5.7(5.8)%	5.7(5.7)%	5.7(5.7)%	5.6(5.7)%
B-tagging SF (light/gluon)	0.3(0.3)%	0.2(0.3)%	0.2(0.3)%	0.2(0.3)%	0.3(0.2)%	0.3(0.4)%	0.7(0.4)%
Pileup reweight SF	0.6(0.4)%	0.7(0.1)%	0.3(0.1)%	0.7(0.1)%	0.5(0.3)%	0.1(0.1)%	0.7(0.4)%

Table 5: List of rate systematic uncertainties of e+jets (μ+jets) channel $t\bar{t}$ and non-$t\bar{t}$ samples.

	$t\bar{t}$,2b	$t\bar{t}$, $3b_{nor}$	$t\bar{t}$, $3b_{high}$	non-$t\bar{t}$,2b	non-$t\bar{t}$, $3b_{nor}$	non-$t\bar{t}$, $3b_{high}$
B-tagging SF (b/c)	3.6(3.6)%	5.7(5.7)%	5.7(5.7)%	3.0(2.9)%	4.4(4.0)%	4.3(4.0)%
B-tagging SF (light/gluon)	0.2(0.2)%	2.8(2.7)%	2.8(2.7)%	1.7(1.9)%	2.3(3.2)%	2.3(3.2)%
Pileup reweight SF	0.3(0.5)%	0.3(0.7)%	0.3(0.7)%	0.7(1.3)%	0.3(0.4)%	0.4(0.3)$