Charged Higgs searches with the CMS experiment at the LHC

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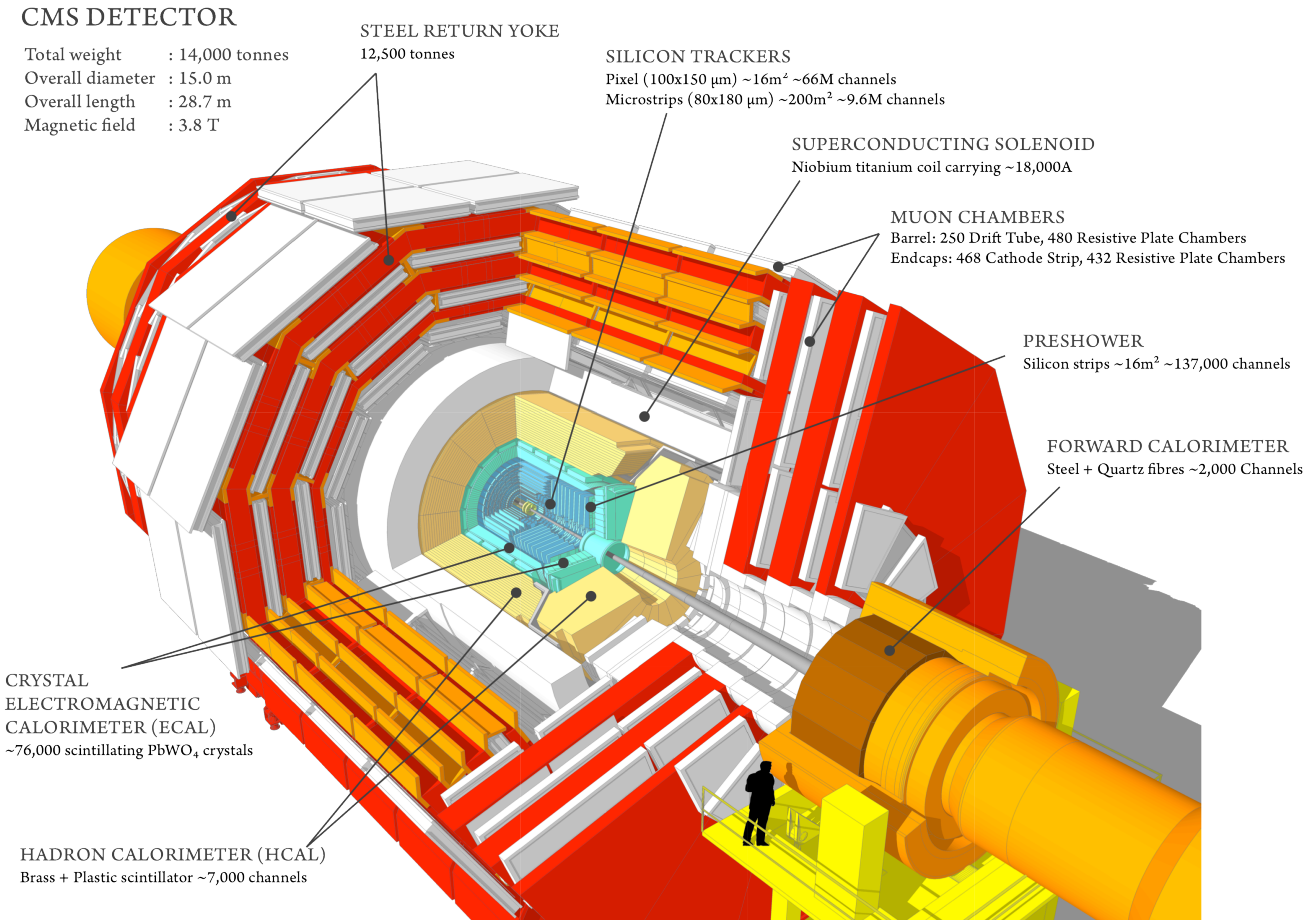
Introduction

The CMS detector

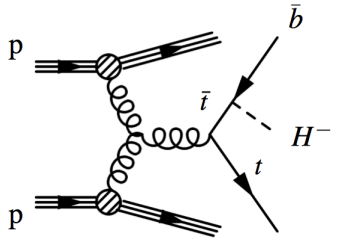


Details given by Dr. Javier Murillo this morning

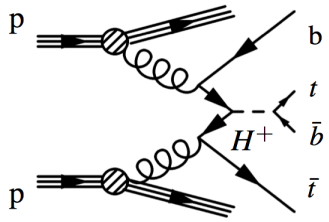
Introduction

- A simple extension of the Standard Model is the Two Higgs Doublet Model (2HDM).
- Five physical states: CP -even neutral bosons h (SM Higgs) and H, a CP –odd neutral pseudoscalar A and two charged bosons $H^{\pm}$.
- Search of $H^{\pm}$ in the high mass region is presented.

- Charged Higgs production:



Light: $m_{H^{\pm}} < m_t - m_b$

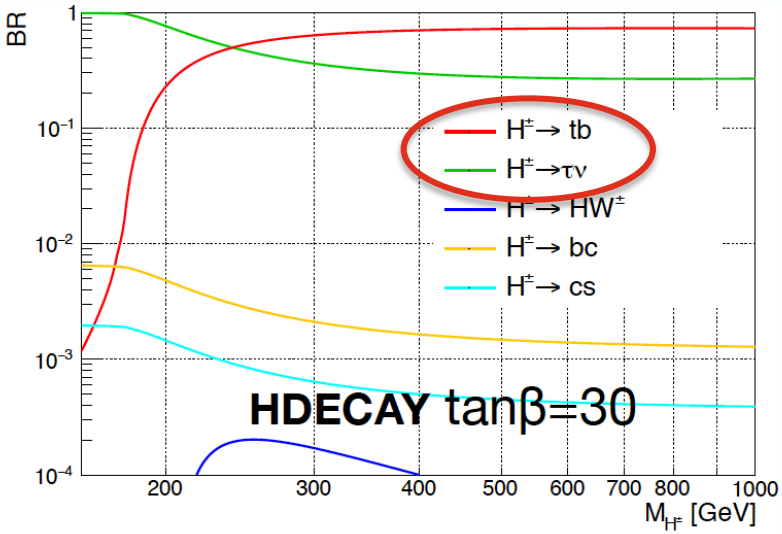


Heavy: $m_{H^{\pm}} > m_t - m_b$

- Only high mass region considered.

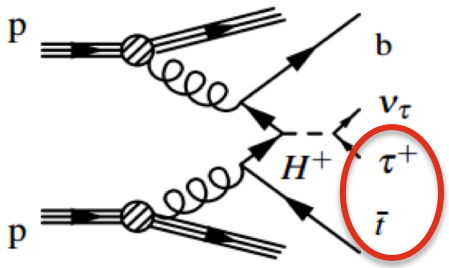
- Decay modes:

Main channels: $H^{\pm} \rightarrow \tau\nu$ and $H^{\pm} \rightarrow tb$.



Charged Higgs searches

$H^{\pm} \rightarrow \tau\nu$

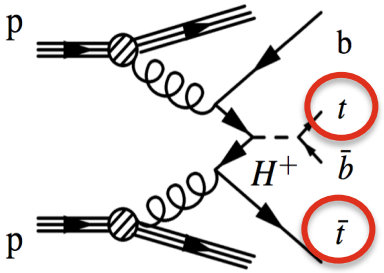


Final states:

- Full hadronic: $\tau_h \rightarrow$ jets.
- Single lepton: $\tau_l \rightarrow l\nu_l$ + jets, l = e, μ.
- Dilepton: $ll'\nu_l\nu_{l'}$ + jets.

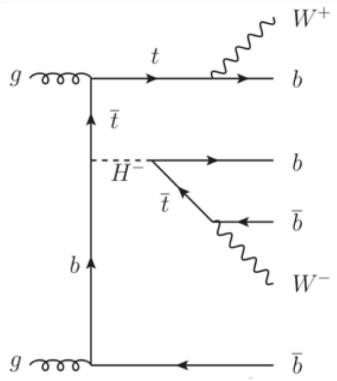
- Leptonic search in close agreement with the tb final state.

$H^{\pm} \rightarrow tb$



Final states:

- Single lepton: $l\nu_l$ + jets, l = e, μ.
- Dilepton: $ll'\nu_l\nu_{l'}$ + jets.
- Full hadronic: jets.



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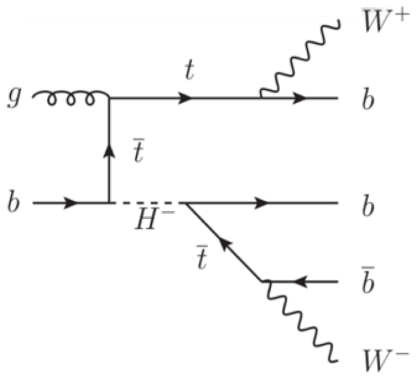

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$H^{\pm} \rightarrow \tau\nu$: full hadronic

CMS-PAS-HIG-16-031

Dominant backgrounds

- Backgrounds are estimated from Monte Carlo and data (QCD).

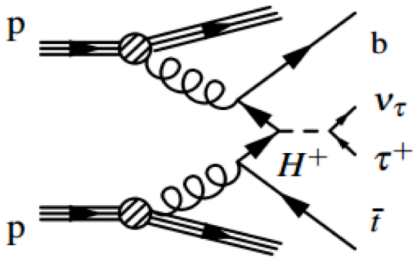
Process	Cross section (pb)
W+jets: $W \rightarrow l\nu_l$ + gluons.	61527
TTbar: $t \rightarrow bW \rightarrow bl\nu_l$ (T and Tbar)	831
Drell Yan + jets: leptons + jets	6025
Diboson (WW, WZ, ZZ): leptons + jets	5 - 50
Single top: $t \rightarrow bW \rightarrow bl\nu_l$	30 - 100
QCD: jets accounted as fake τ's.	Data driven

- Fake τ background:
  - Data driven QCD with the ABCD method.
  - Estimated in a QCD rich region, orthogonal to the signal region.

$H^{\pm} \rightarrow \tau\nu$: full hadronic

Object definition and selection

CMS-PAS-HIG-16-031



Trigger
- τ, $p_T > 90$ GeV
- MET > 110 GeV

≥ 1 τ
- $p_T > 60$ GeV
- $|\eta| < 2.1$
- Leading track $p_T > 30$ GeV
- Decay mode: 1 prong
- ID: byLooseCombinedIsolation
- Isolation < 2.5

≥ 3 jets
- $p_T > 30$ GeV
- $|\eta| < 4.7$
- Loose ID
- Jet energy corrections

MET
- MET > 100 GeV
- MET filters and corrections applied

≥ 1 b-jet
- $p_T > 30$ GeV
- $|\eta| < 4.7$
- Combined Secondary Vertex (CSV)

Lepton veto
- μ, e
- $p_T > 10$ (15) GeV
- $|\eta| < 2.5$
- Loose ID criteria

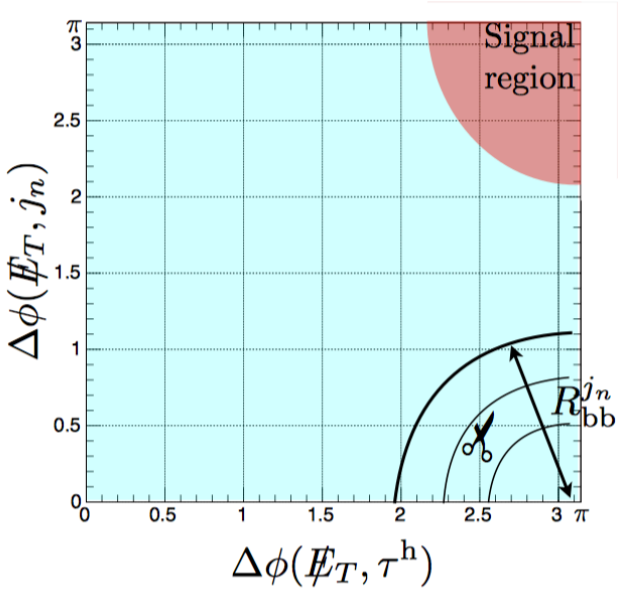
$H^{\pm} \rightarrow \tau\nu$: full hadronic

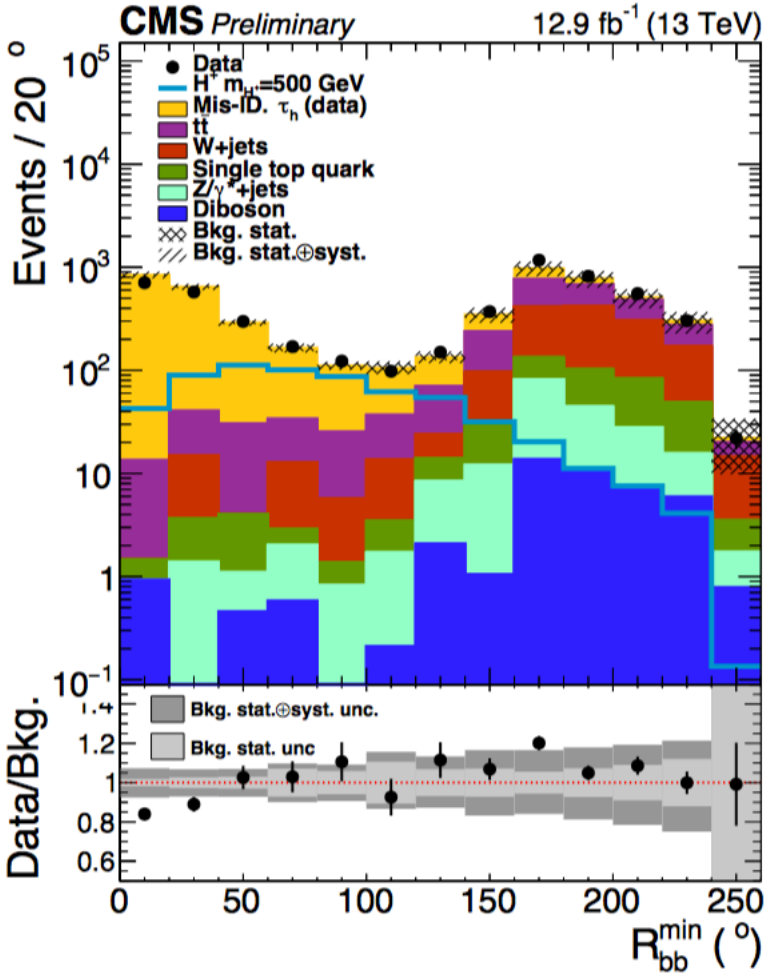
CMS-PAS-HIG-16-031

Angular cuts

Rejection multijet events with τ_h and MET back-to-back.

- $R_{bb}^{min} = \min_{j \in j_1..j_3} \sqrt{\Delta\phi(\not{E}_T, j)^2 + (\pi - \Delta\phi(\tau^h, \not{E}_T))^2}$
- $R_{bb}^{min} > 40°$





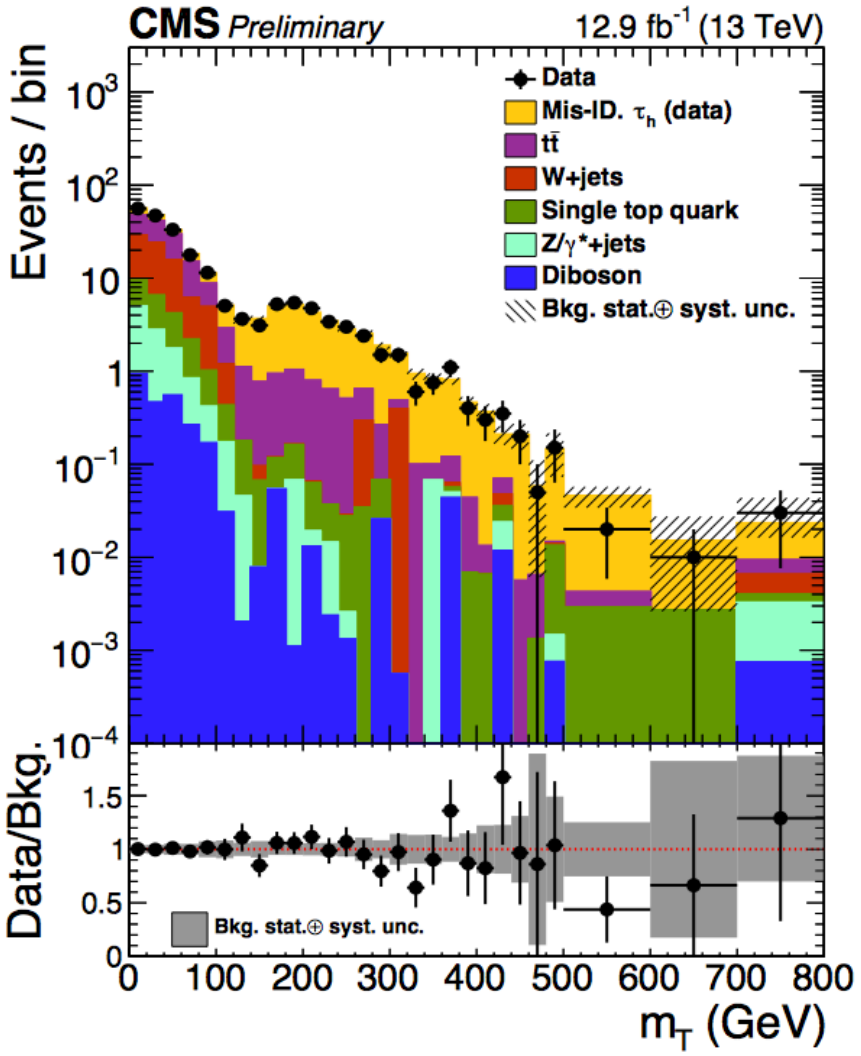
$H^{\pm} \rightarrow \tau\nu$: full hadronic

CMS-PAS-HIG-16-031

Signal extraction

- $H^{\pm}$ invariant transverse mass reconstruction: possible as MET only coms from $H^{\pm}$.
- Signal is extracted from m_T.

$$m_T^2 = 2 \cdot p_T^{\tau^h} |\vec{\not{E}}_T| \left(1 - \cos\Delta\phi(\vec{\not{E}}_T, \tau^h)\right)$$



Systematics

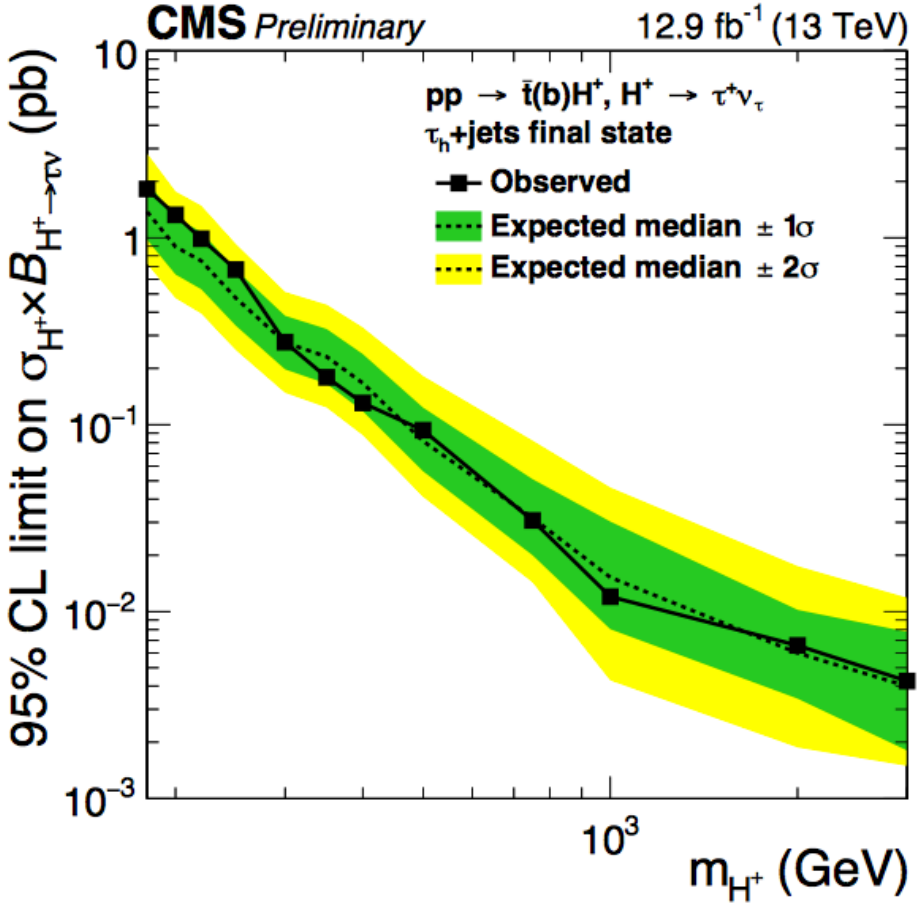
- Luminosity.
- Tau ID, p_T and energy scale.
- Trigger SF/eff. Uncertainties.
- MC normalization and statistical uncertanties.
- Pileup.
- Btag and lepton scale factors, etc.

$H^{\pm} \rightarrow \tau\nu$: full hadronic

CMS-PAS-HIG-16-031

Model independent limits

- Based on ICHEP 2016 dataset.
- Luminosity 12.9 fb^{-1}.

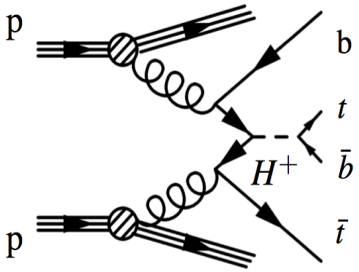


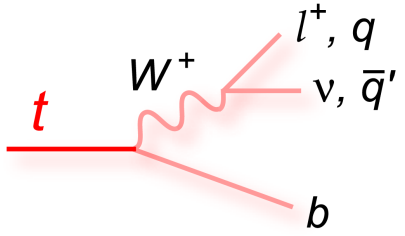
$H^{\pm} \rightarrow tb$: analysis strategy

Event categorization

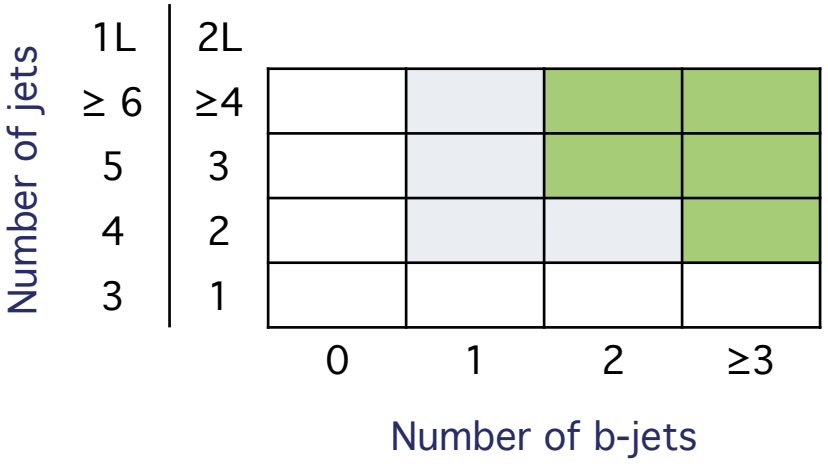
Lepton categories

- Single lepton (1L):
  - 1 e, 1 μ.
  - $N_{jets} \geq 4$, $N_{b\text{-jets}} \geq 1$.
- Dilepton (2L):
  - 2 e, 2 μ, 1 e + 1 μ.
  - $N_{jets} \geq 2$, $N_{b\text{-jets}} \geq 1$.





- Further categorization based on the number of jets and b-jets.

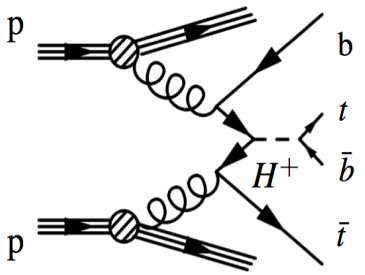


- Dominant background: TTbar.
- Simultaneous fit in both SR and CR among all the categories (1MU, 1EL, 2MU, 1MU1EL, 2EL):
  - CR = H_T shape distribution: scalar sum of the jets p_T.
  - SR = BDT (Boosted Decision Tree) shape distribution: Multivariate Analysis (MVA) Technique.

$H^{\pm} \rightarrow tb$: analysis strategy

Object definition and selection (1L/2L)

Lepton
- μ (e)
- p_T > 30 (35) GeV
- |η| < 2.4
- Tight ID for leading lepton.
- Loose ID for the second lepton and p_t cuts.
- Mini - isolation < 10 (40) % p_T.



MET
- MET > 30 GeV
- MET filters and corrections applied.

≥ 4 (2) jets
- p_T > 40 GeV
- |η| < 2.4
- ΔR (l,j) > 0.4
- Loose ID criteria.

≥ 2 b-jets
- Combined Second Vertex (CSV).

τ_h veto
- p_T > 20 GeV
- |η| < 2.3
- Loose ID.

Conclusions and perspectives

$H^{\pm} \rightarrow tb$

- Analysis is converging, aiming for EPS conference (July).
- Full hadronic final state analysis is already starting.

$H^{\pm} \rightarrow \tau\nu$

- The results for the full hadronic final state with 12.9 fb^{-1} of 2016 data.
- Aim approval with full 2016 dataset this Autumn.

- Combination:
  - Both τν and tb decay channels in all the final states.
  - Set model dependent limits for the production of Charged Higgs.