Search and prospects for BSM Higgs with the ATLAS detector

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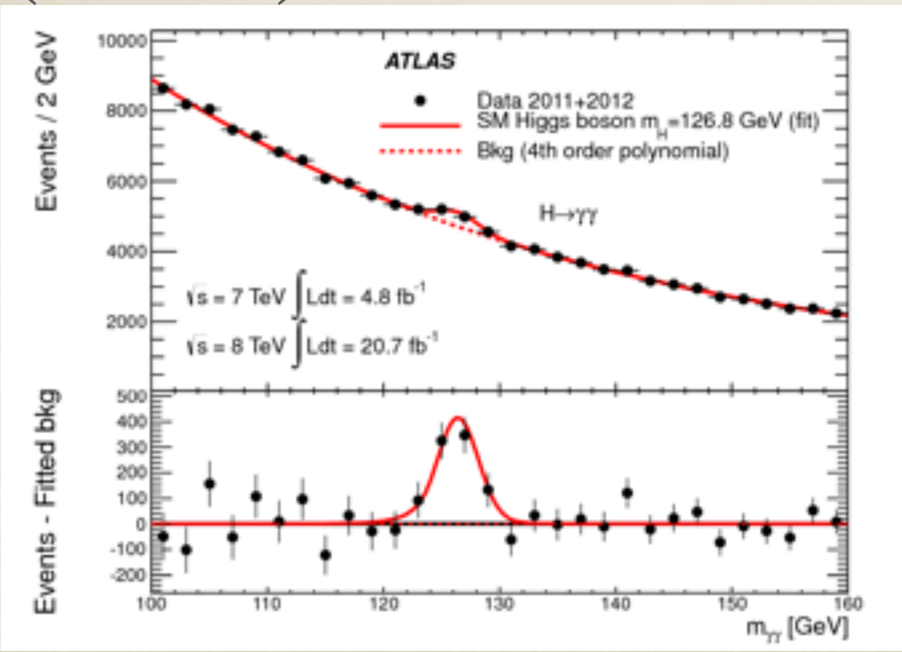
Introduction

* Almost two years ago, ATLAS and CMS announced the observation of a new boson with a mass of approximately 125 GeV.

* The properties of this newly discovered boson make a convincing case that it is a Higgs boson related to the BEH mechanism of spontaneous breaking of the electroweak (EW) symmetry.

* Yet, it remains an open question whether it is the Standard Model (SM) Higgs boson, which is a single elementary scalar particle, or one physical state of an extended scalar sector, as predicted by the two-Higgs-doublet-model (2HDM).



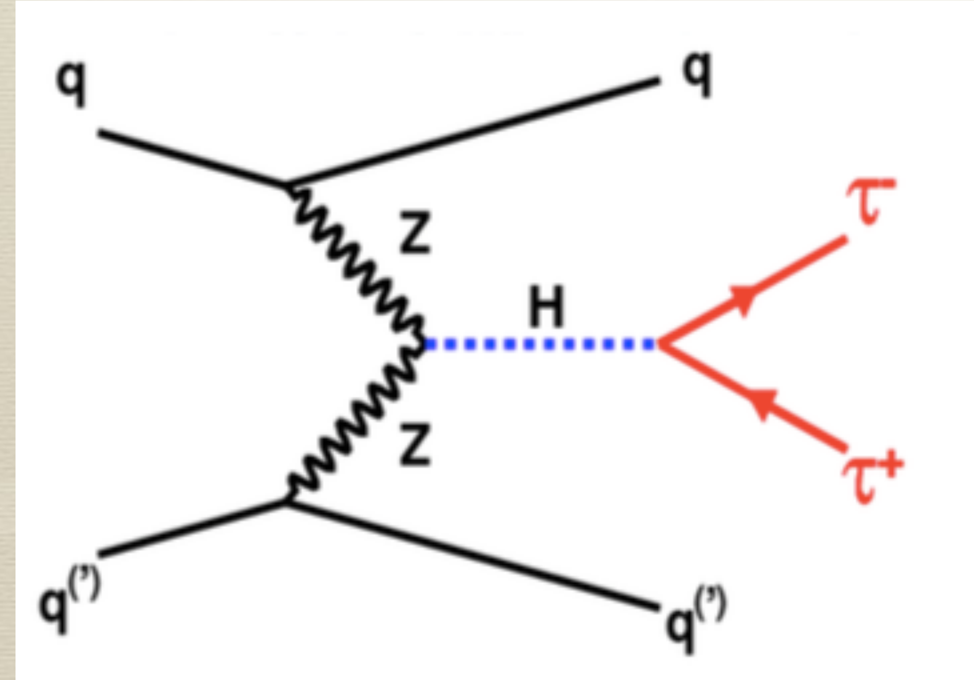
Motivation

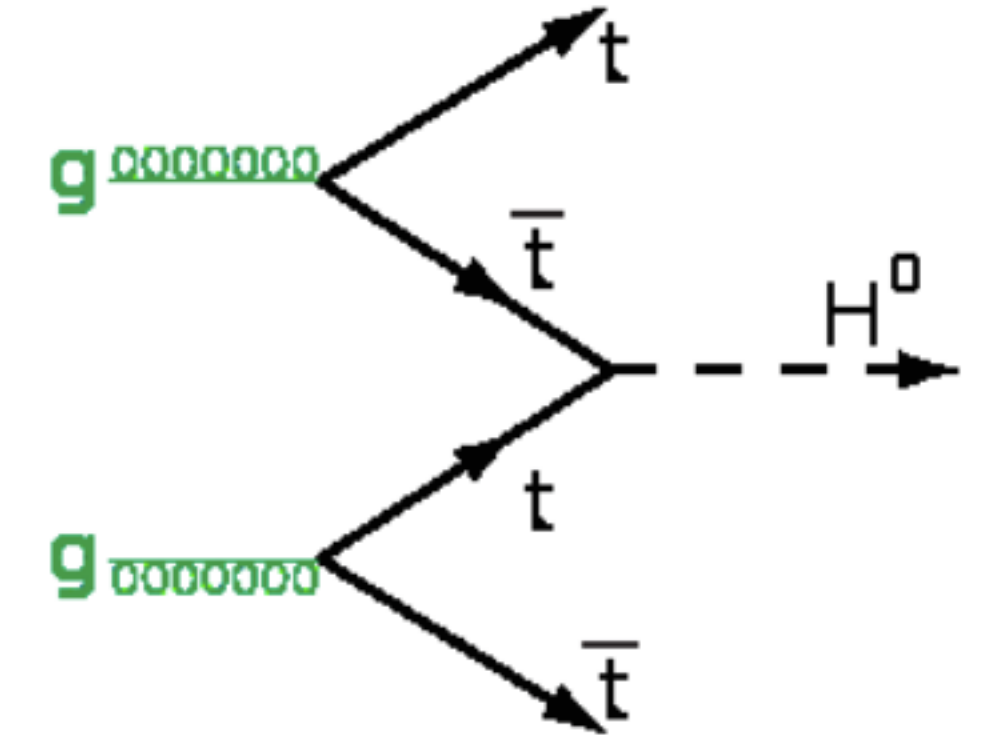
* There are various ways of trying to answer this exciting question:
  * Measurements (SM):
    * Measuring precisely the couplings to fermions and vector bosons.
    * Determining the spin/CP quantum numbers.
  * Searches (BSM):
    * Studying additional production mechanisms which are not possible in the SM (e.g. from CP-odd decay).
    * Looking for additional scalar particles (e.g. charged Higgs bosons).

Coupling measurements

* Measuring the properties and couplings of the recently-discovered Higgs boson will play an important role in the LHC physics program.

* One of the crucial aspects of these investigations is the understanding and observation of its decay to fermions, i.e H-> ττ.

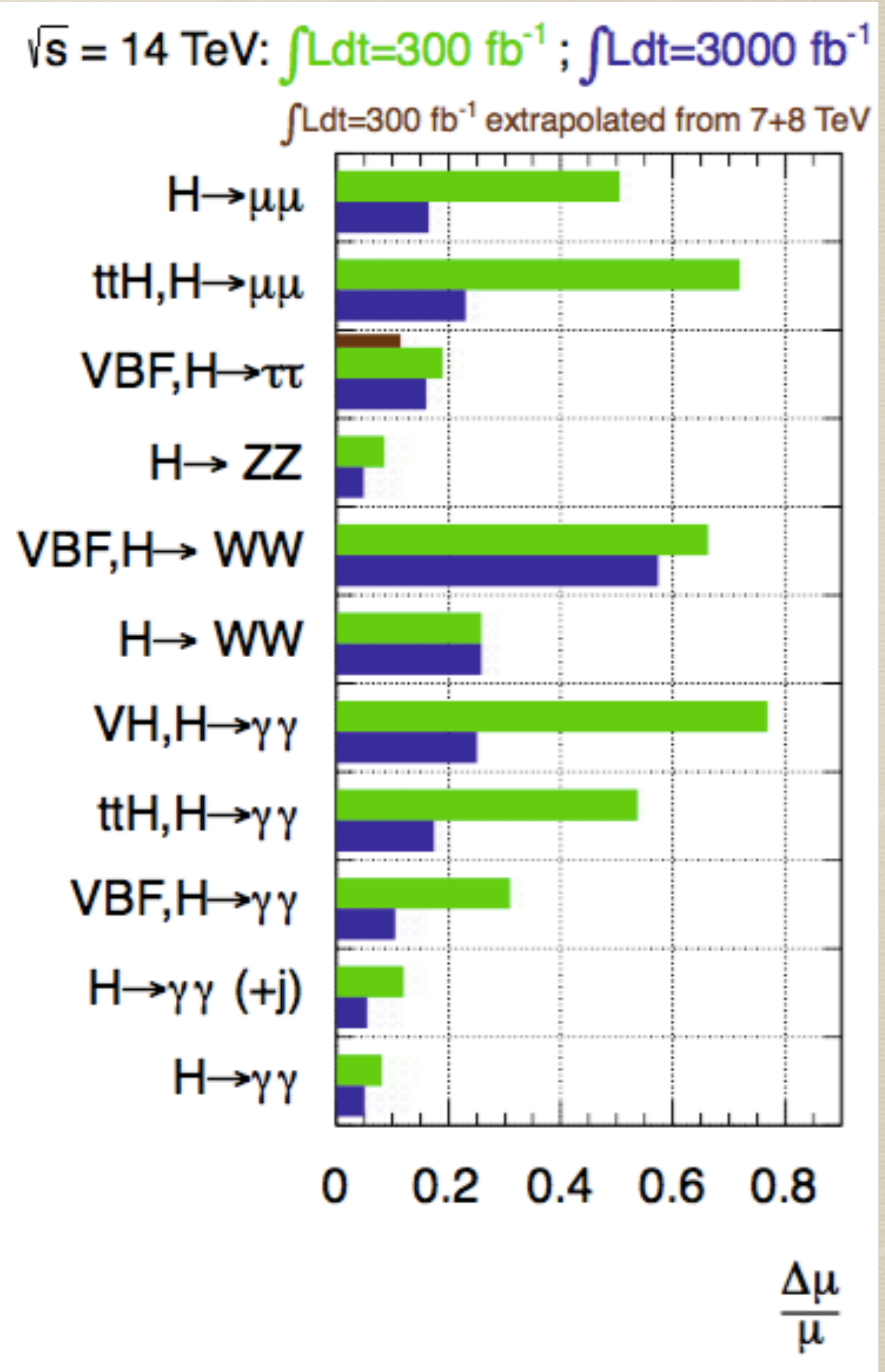




Uncertainty on the signal strength

- The precision of the cross section times branching ratio measurements (relative to the expected SM ones, i.e. signal strength) is conventionally expressed in terms of the relative uncertainty in the ratio to the Standard Model expectation, $\Delta\mu/\mu$.

- These signal strength measurements are then interpreted in terms of Higgs boson couplings.



CP studies prospects

* During the ES studies, the need for future CP measurement was arise.
* Having a vector boson coupling in either the initial or final state is most likely projecting only to the CP even component of the Higgs.
* Using ttH, H->ff, fermion Yukawa couplings appears both in the initial and final states – no CP suppression is expected.
* H->bb,ττ suffer from reconstruction problems at high luminosities. ttH,H->μμ can be easily reconstructed.
* Unfortunately, the number of expected events for 3000 fb^{-1} is not sufficient for a significant discrimination beyond the ~ 1σ level, assuming a SM Higgs signal rate.

Additional Higgs searches

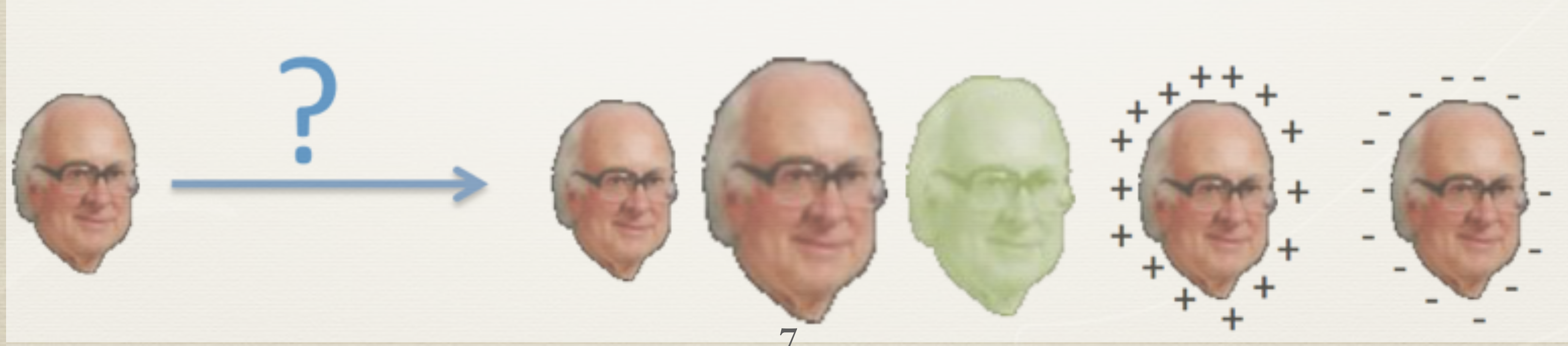
* Standard Model (SM):
  One doublet of Higgs, only one neutral Higgs boson.

* SM needs to be extended:
  ν mass, dark matter...

* Fermions (leptons and quarks) come in three generations, why only one Higgs doublet?

* In many extensions of the SM:
  Prediction of two complex Higgs doublets (2HDM).

* Five physical states: $H^{+}, H^{-}, h^{0}, H^{0}, A^{0}$.

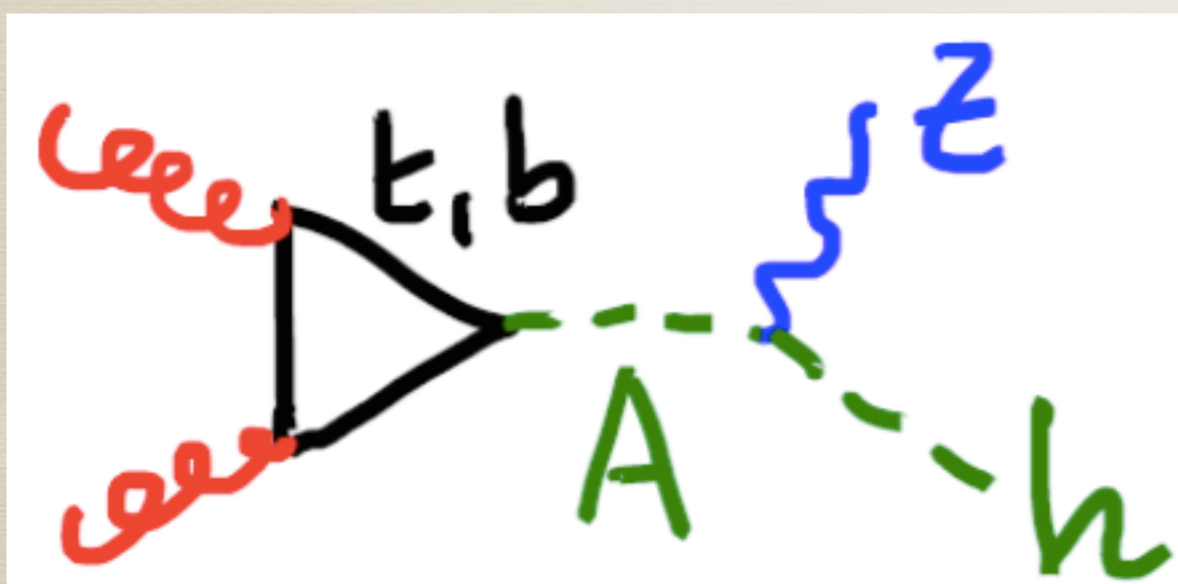


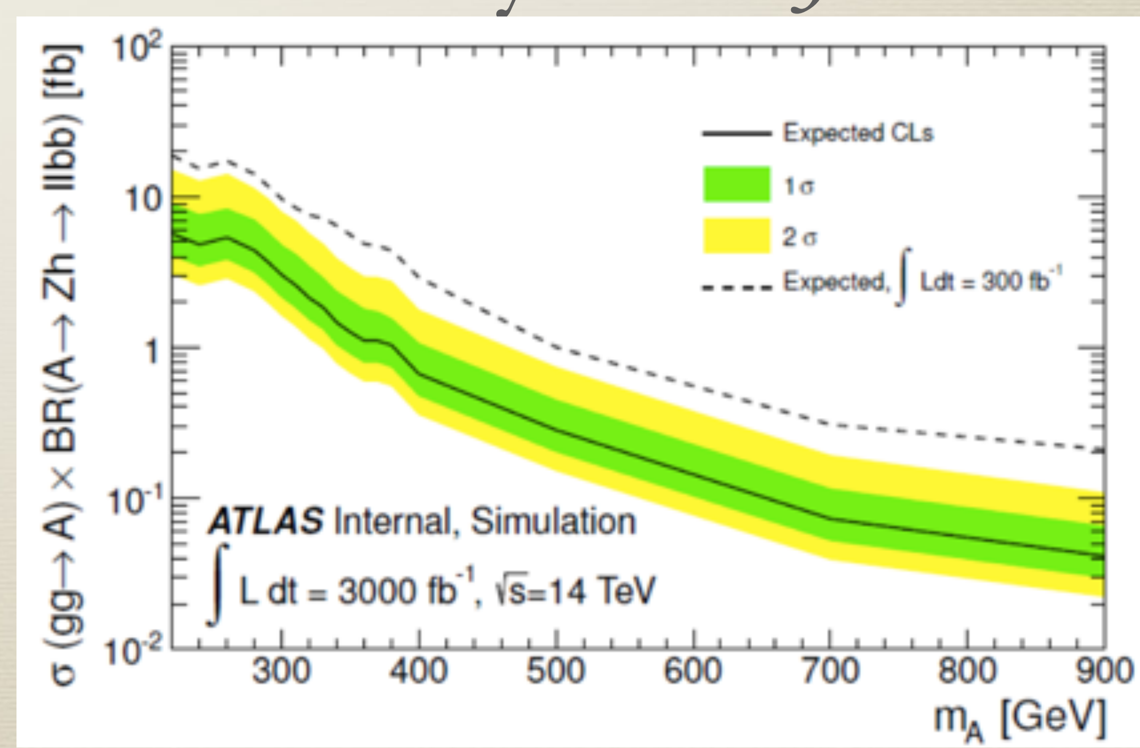
A→Zh

- The production of the heavy CP-odd particle A, is mainly through gluon-gluon fusion (ggF) for large parts of the 2HDM parameter space.

- The expected limits on the s*BR of the A to Zh. The green and yellow are 1 and 2 σ errors, respectively.

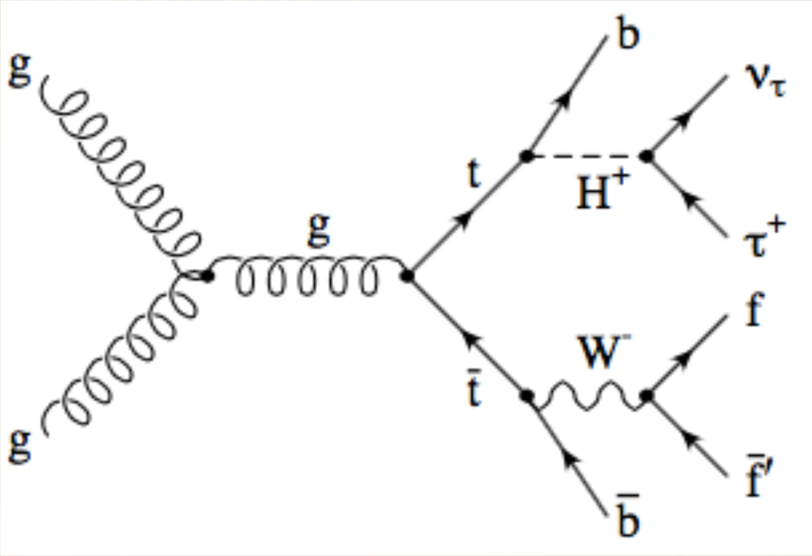
- The systematic uncertainties are estimated by a flat 30%.

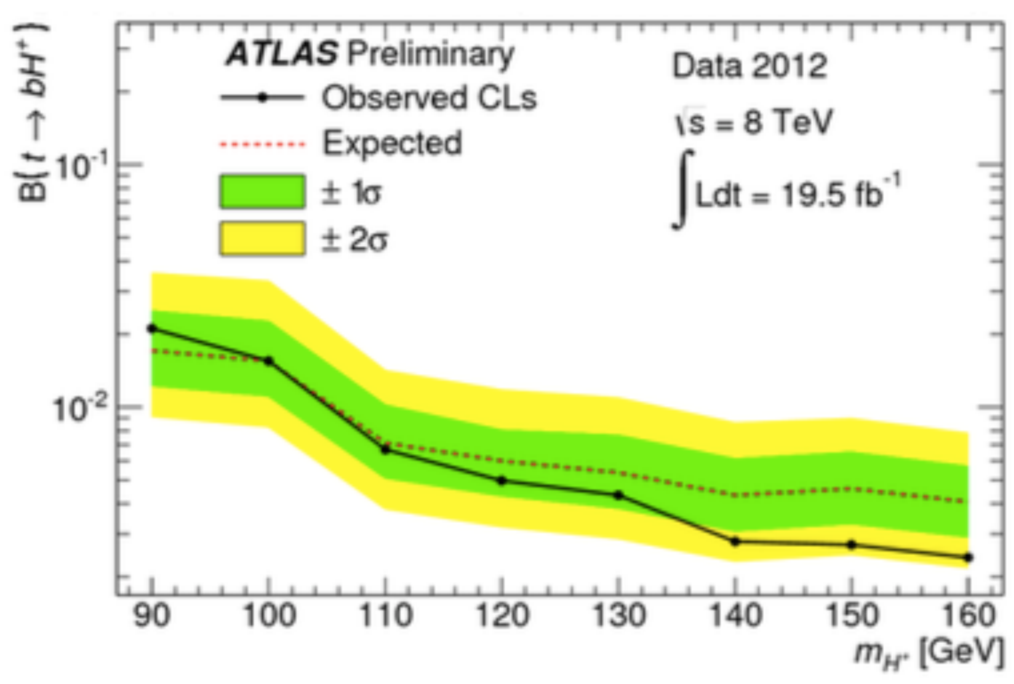


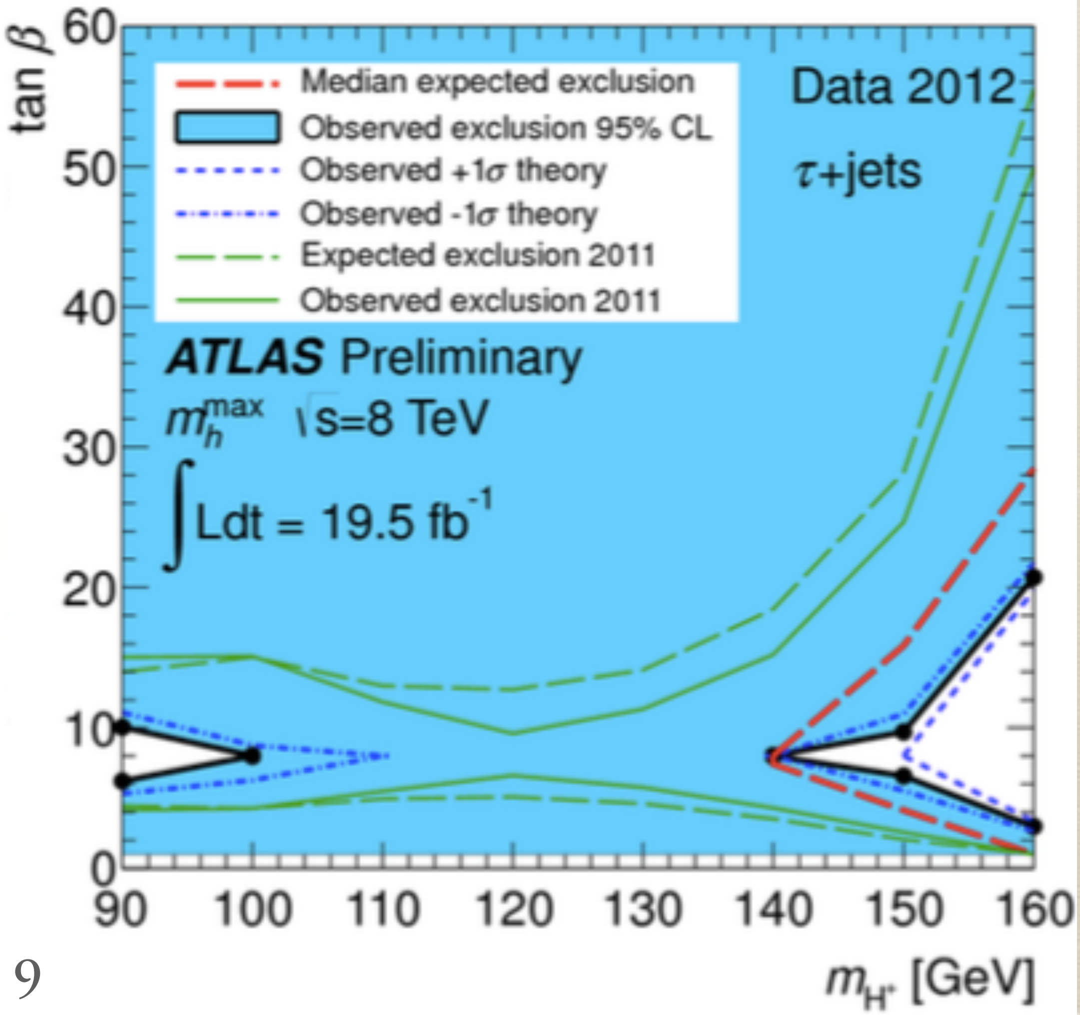


Charged Higgs searches

- Light charged Higgs:
  - In most of the extensions for most of the parameters space, the dominant decay will be to τν.
  - Both the τ and the top can decay hadronically or leptonically.

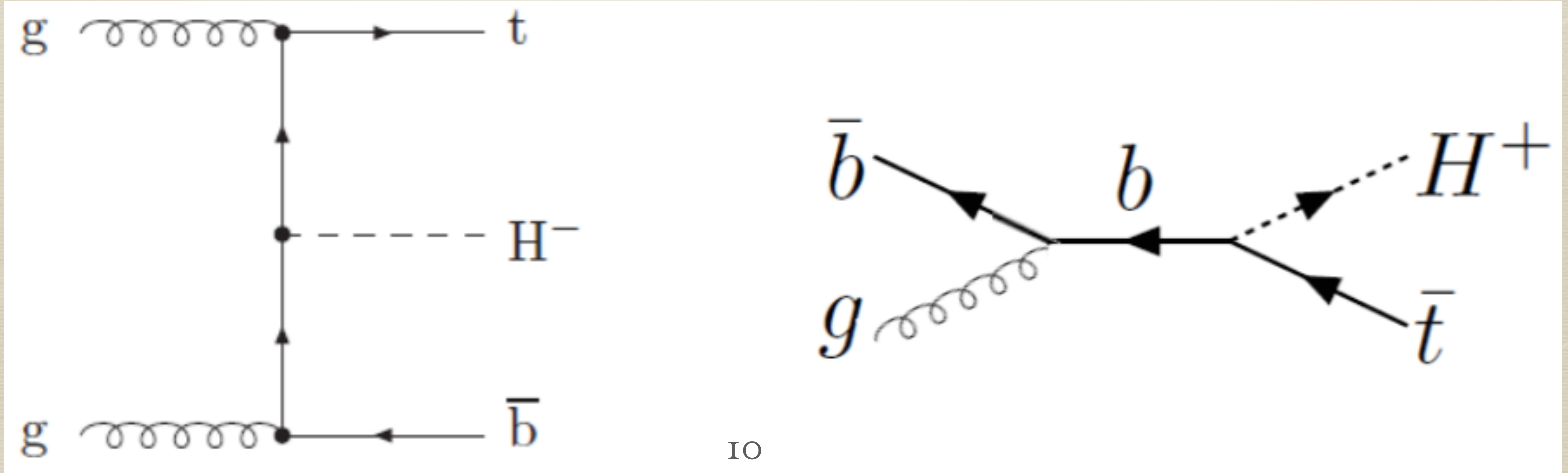




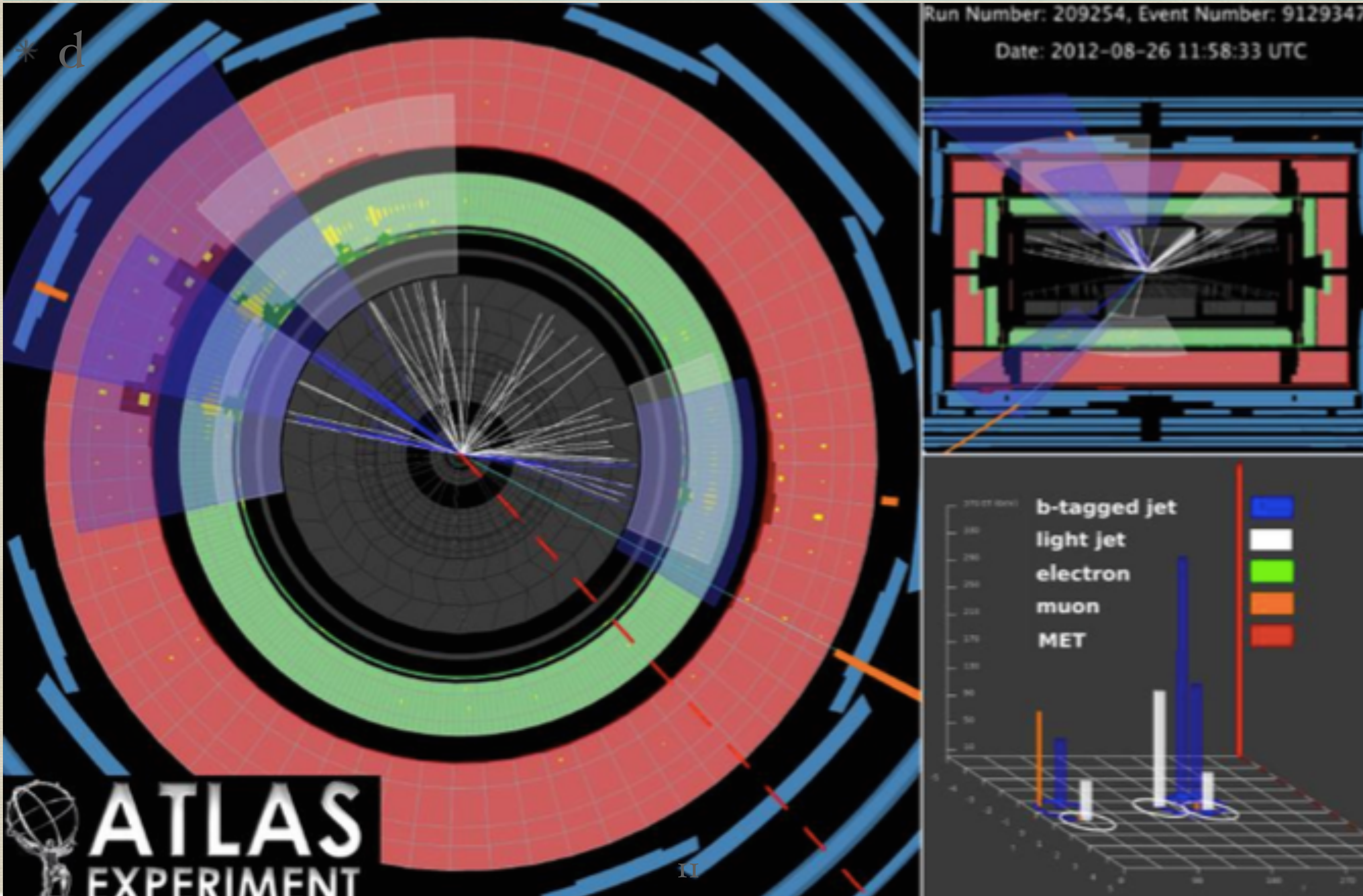


Charged Higgs searches

* Heavy charged Higgs:
    * Once the tb threshold is opened, tb decay become the dominant channel.
    * Very complicated analysis, complex final state, ambiguity in objects assignment, lacking proper theoretical description (signal modelling, ttbb xs…) etc.



Charged Higgs candidate



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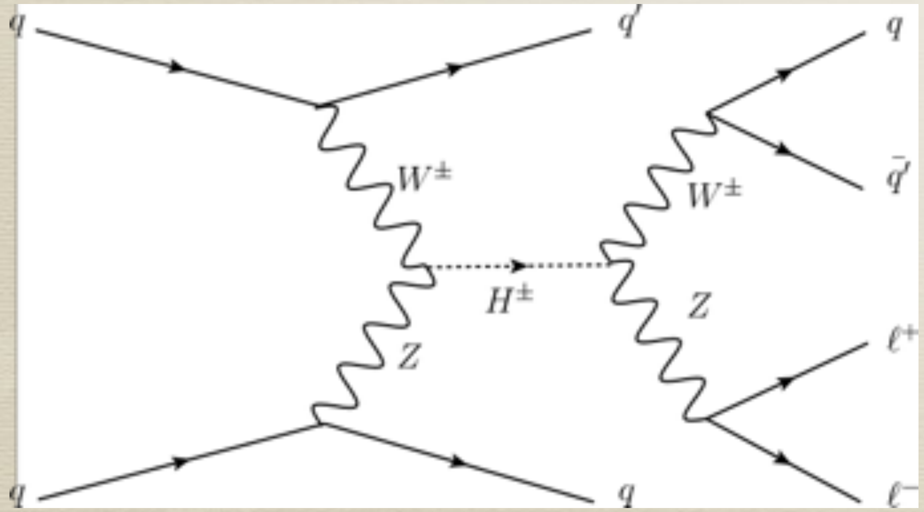
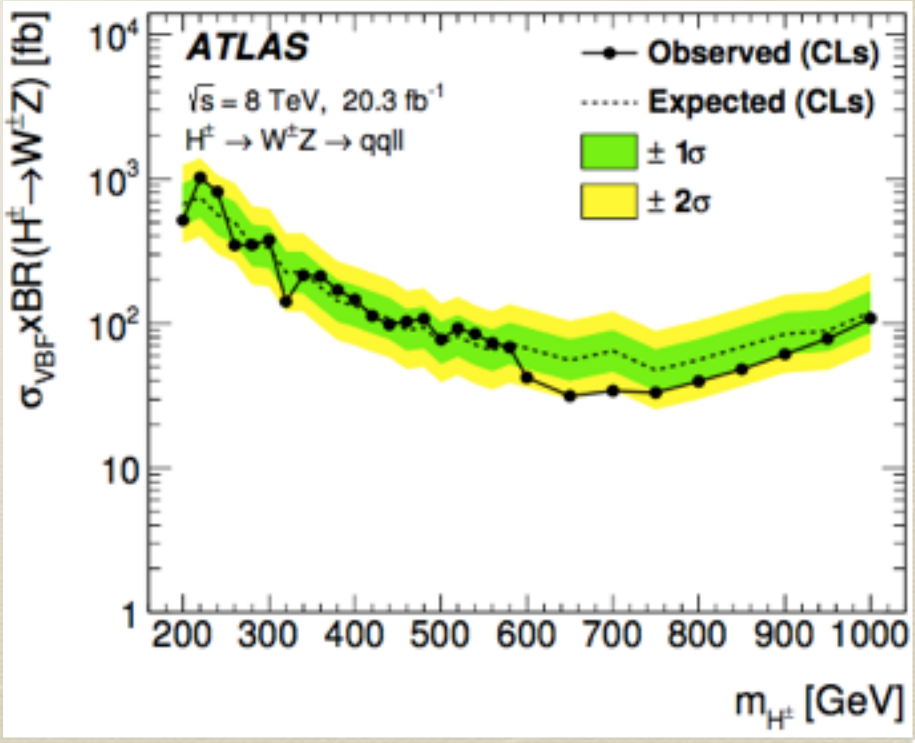
Charged Higgs searches

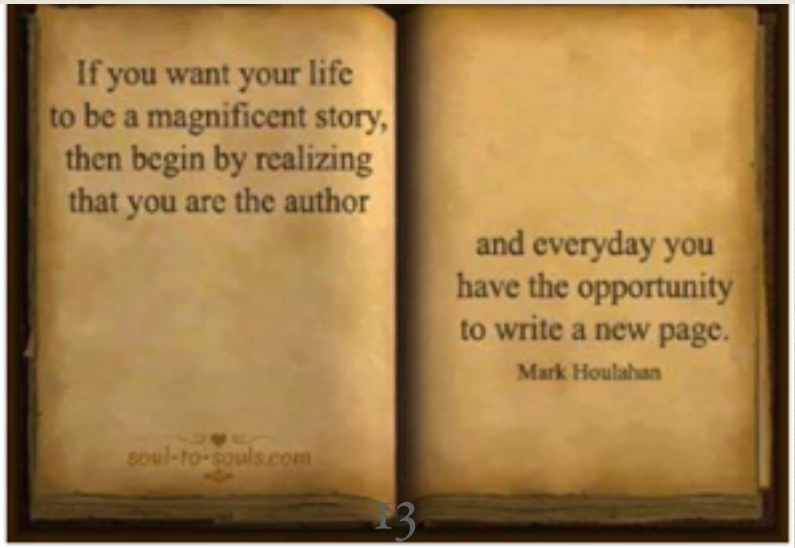
- $H^{\pm} \rightarrow W^{\pm} Z$:
  - First search for charged Higgs in VBF production.
  - This coupling ($H^{\pm}W^{\pm} Z$) appears at loop level in 2HDM but can be dominant decay in Higgs triplets models.
  - Narrow resonance expected- None seen.





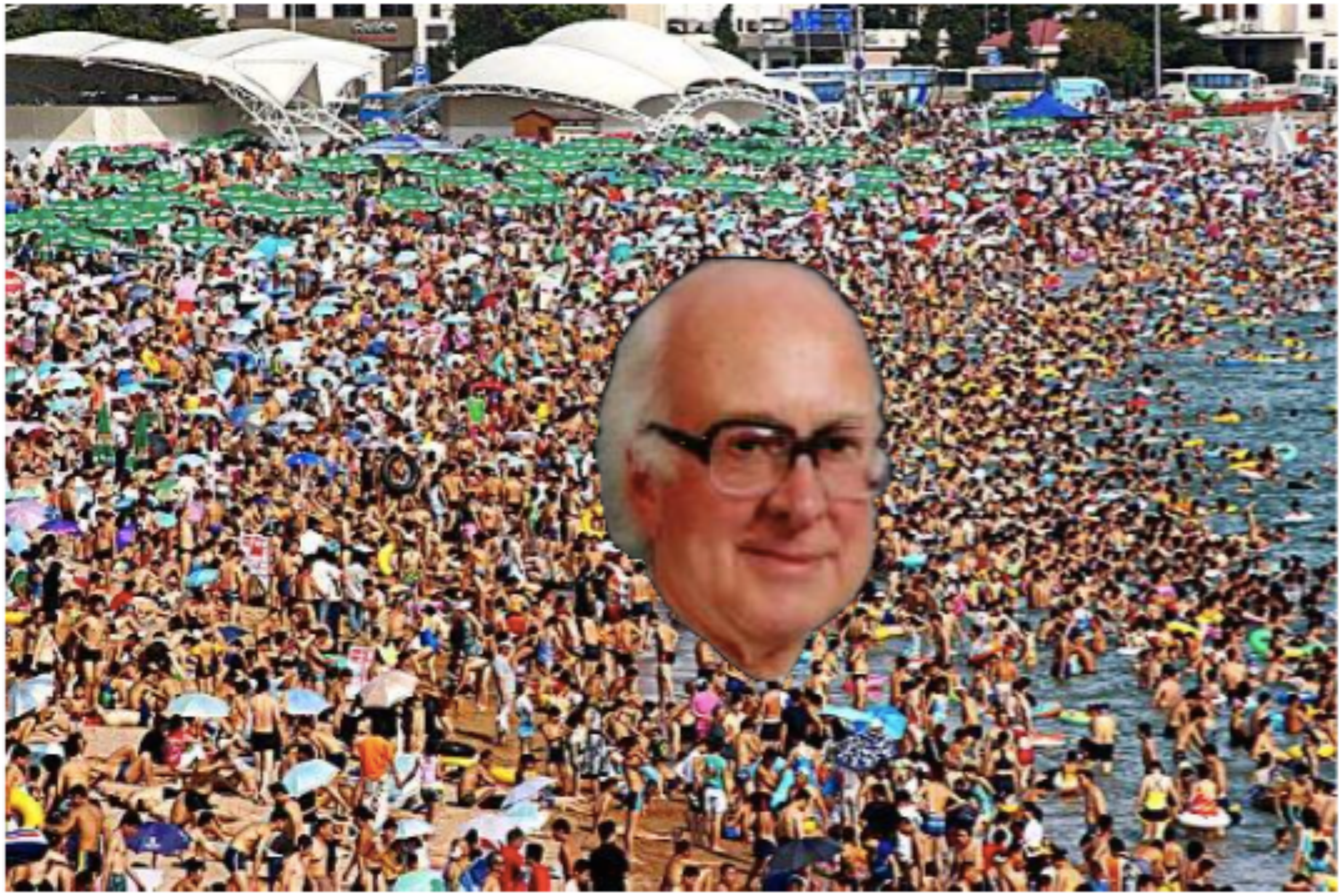
Summary

* LHC has already written a new page in our physics text book!
* We have discovered a new scalar particle, which has all the characteristics of a Higgs boson.
* Hopefully it's a first of its kind.
* BUT, the real fun has just began with doubling of the energy at the LHC searching and hopefully finding new particles, new physics, more pages in nature's book.



Next year presentation

Next year presentation

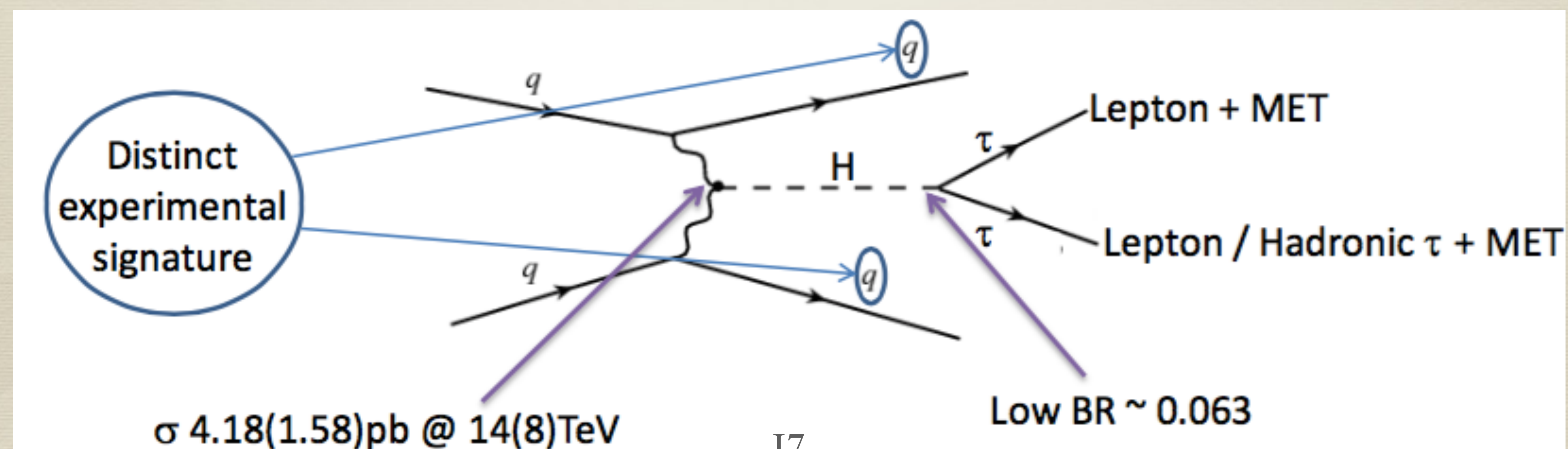


BackUp

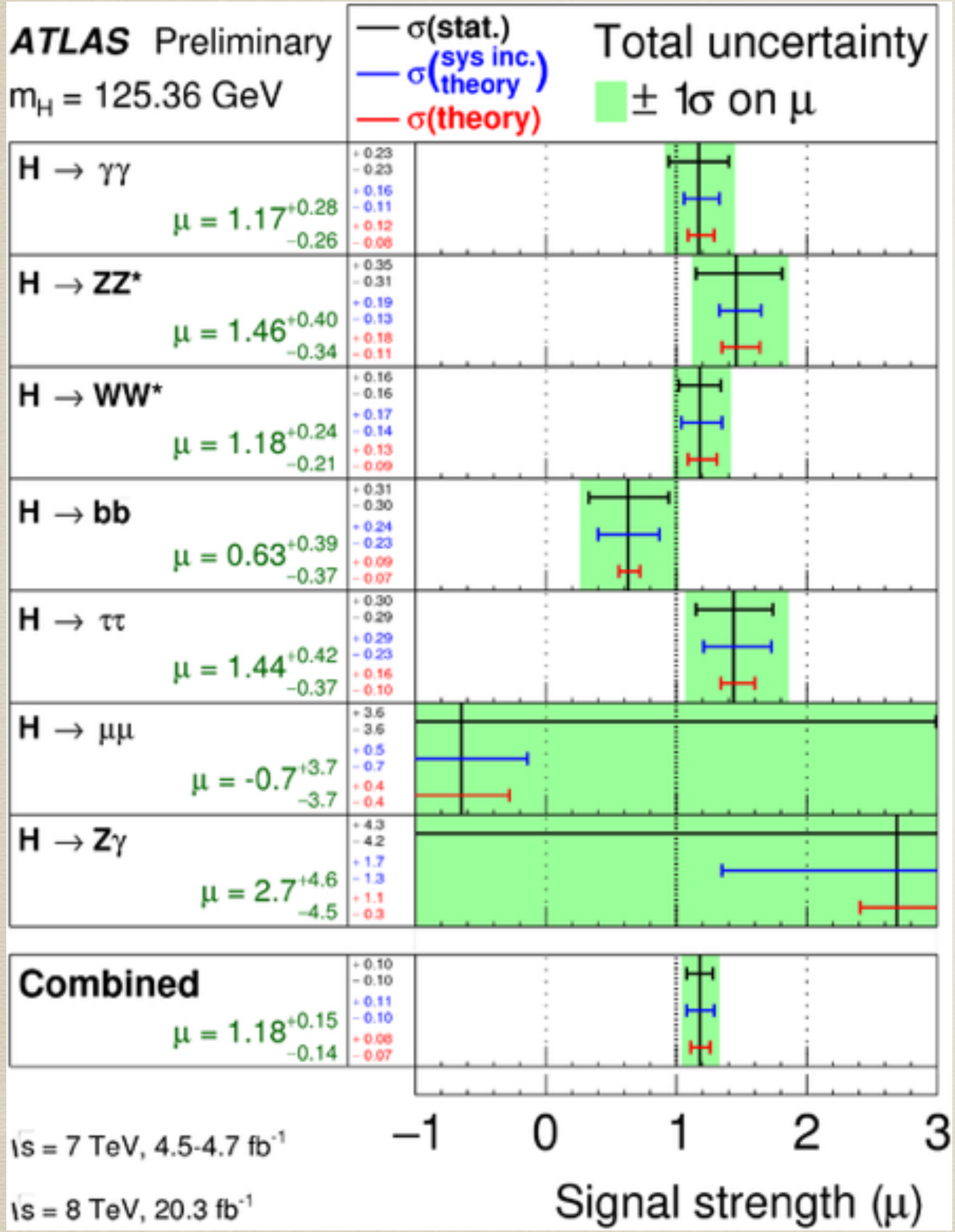
Coupling measurements

* Measuring the properties and couplings of the recently-discovered Higgs boson will play an important role in the LHC physics program.

* One of the crucial aspects of these investigations is the understanding and observation of its decay to fermions, i.e $H \to \tau\,\tau$.



Coupling measurements



2HDM

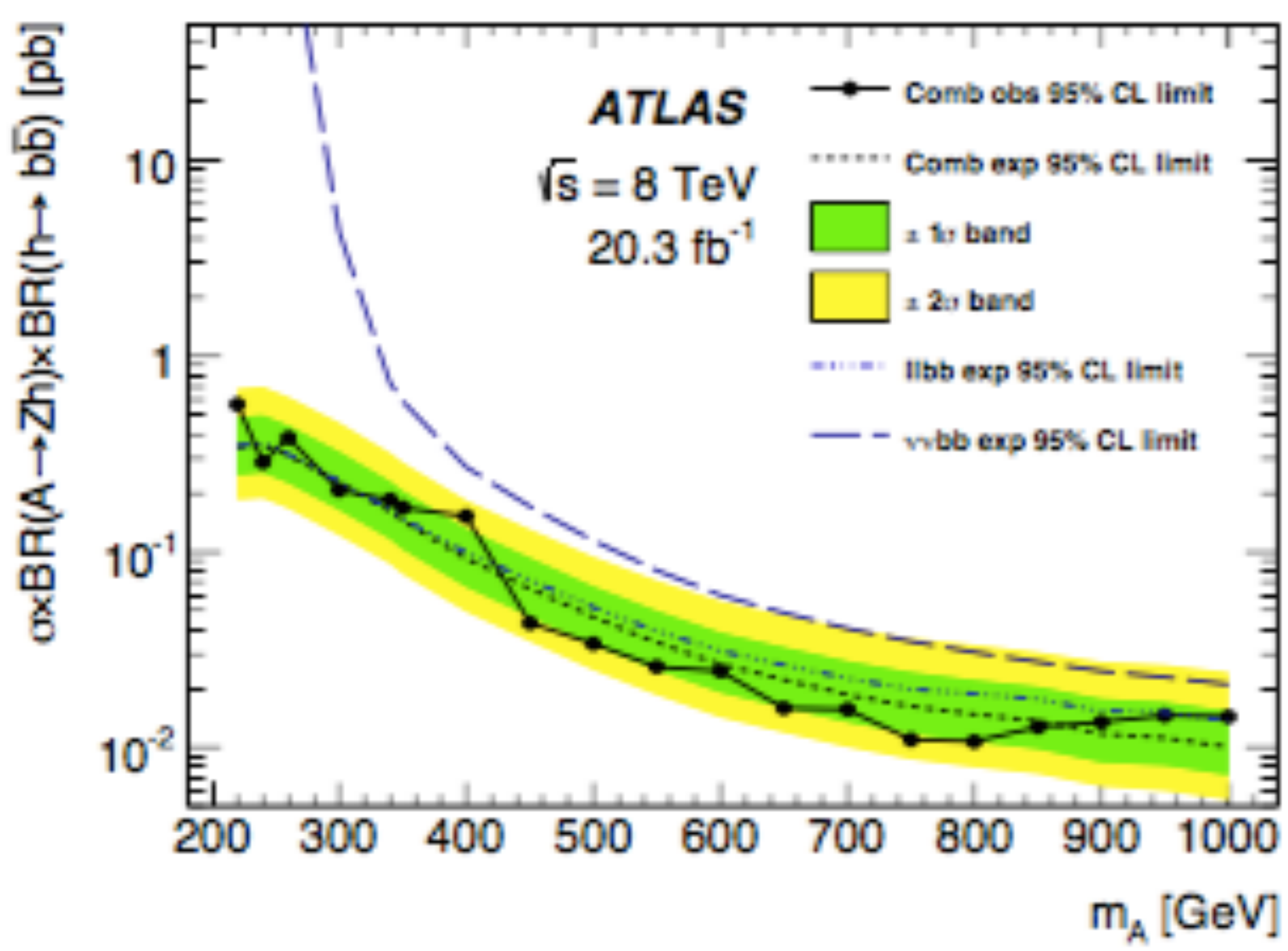
- Charged Higgs coupling to fermions: $m_{fermions}$, tanb.
- Strongest coupling is to third generation fermions.

$$\mathcal{L}_{H^\pm} = -H^+ \left(\frac{\sqrt{2} V_{ud}}{v} \bar{u} \left(m_u X P_L + m_d Y P_R \right) d + \frac{\sqrt{2} m_\ell}{v} Z \bar{\nu}_L \ell_R \right) + \mathrm{H.c.}$$

$$\tan\beta = \frac{v_u}{v_d}$$

	Type I	Type II	Lepton-specific	Flipped
X	$\cot\beta$	$\cot\beta$	$\cot\beta$	$\cot\beta$
Y	$\cot\beta$	$-\tan\beta$	$\cot\beta$	$-\tan\beta$
Z	$\cot\beta$	$-\tan\beta$	$-\tan\beta$	$\cot\beta$

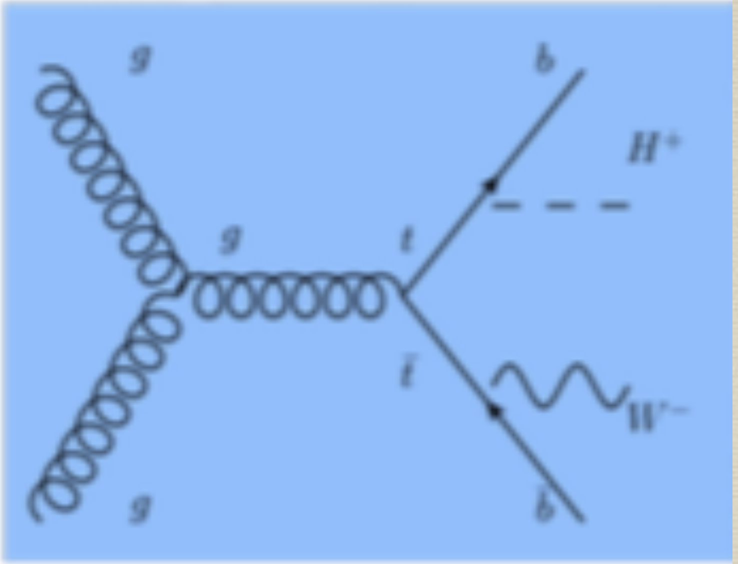
A→Zh

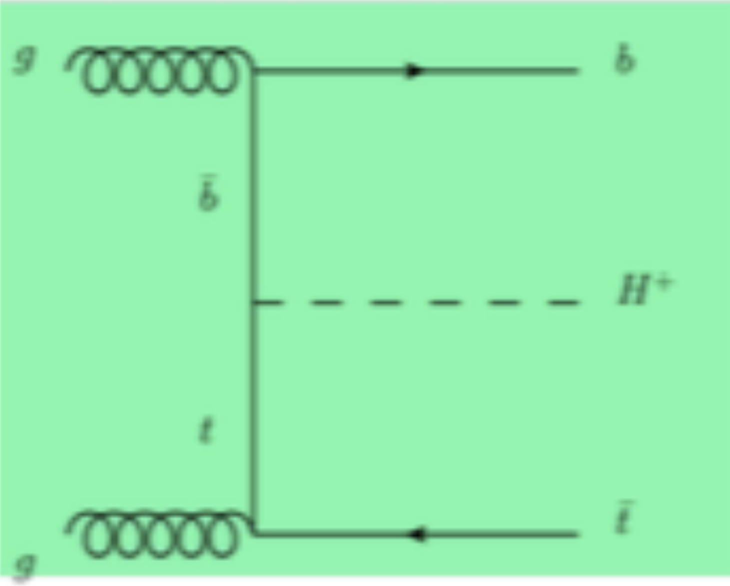


(b) $A \to Zh,\ h \to bb$

$H^{\pm} \to \tau\nu$ (τ+jets): Event Selection

- 8TeV study using light [heavy] production mechanism [ATLAS-CONF-2013-090].
- τ+MET trigger
- Hadronic τ, $p_T > 40$ GeV
- e/μ veto
- 4 [3] jets, >= 1 b-tag
- $E_T^{miss} > 65$ [80] GeV
- $\frac{E_T^{miss}}{0.5 \cdot \sqrt{\Sigma p_T^{PV\,trk}}} > 13$ [12] GeV$^{1/2}$



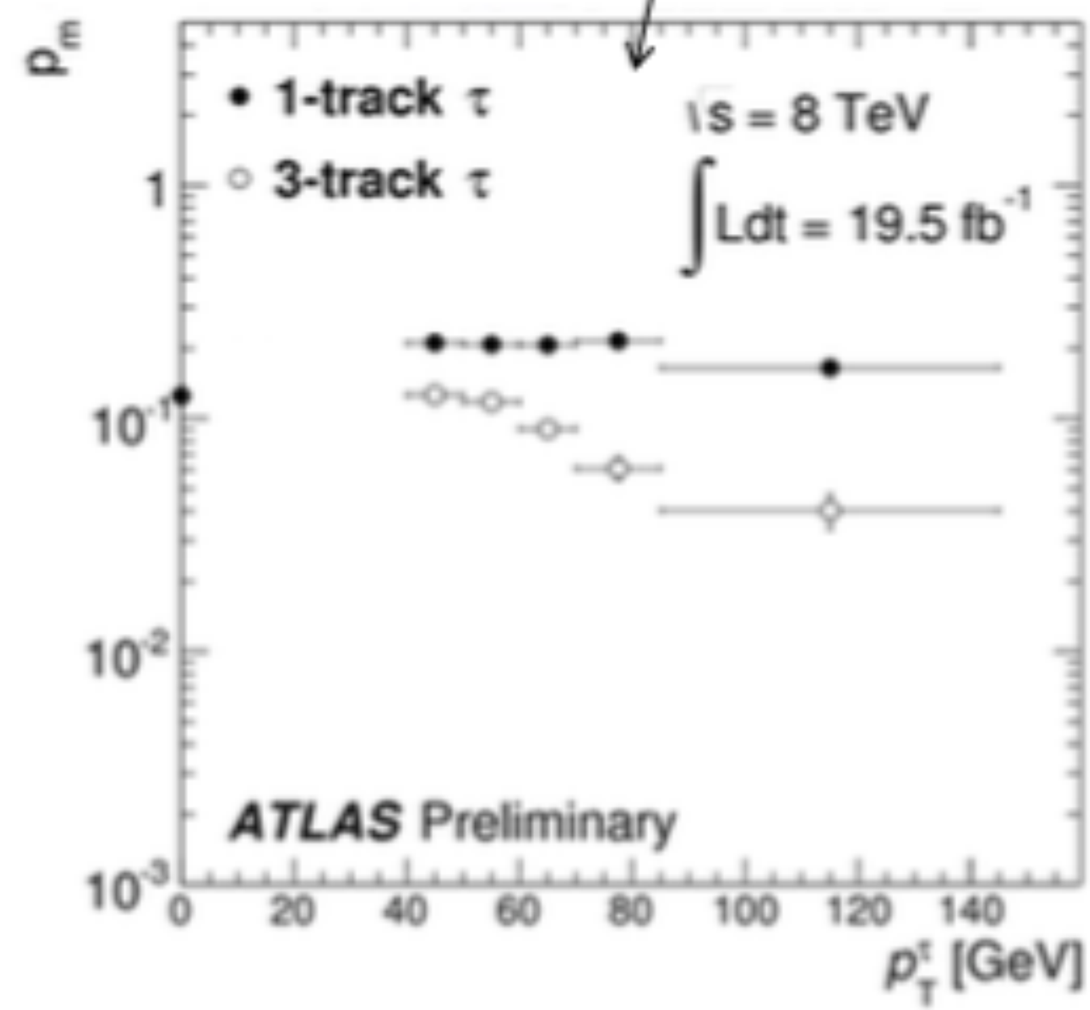


H±→τν (τ+jets): Background Estimation

- Jet → τ misID: Matrix method
  - Multi-jet background
  - W+jets, ttbar with “fake” taus

$$N^{Tight}_{misidentified} = \frac{p_m}{(p_{real} - p_m)} p_r N^{Loose} - N^T$$

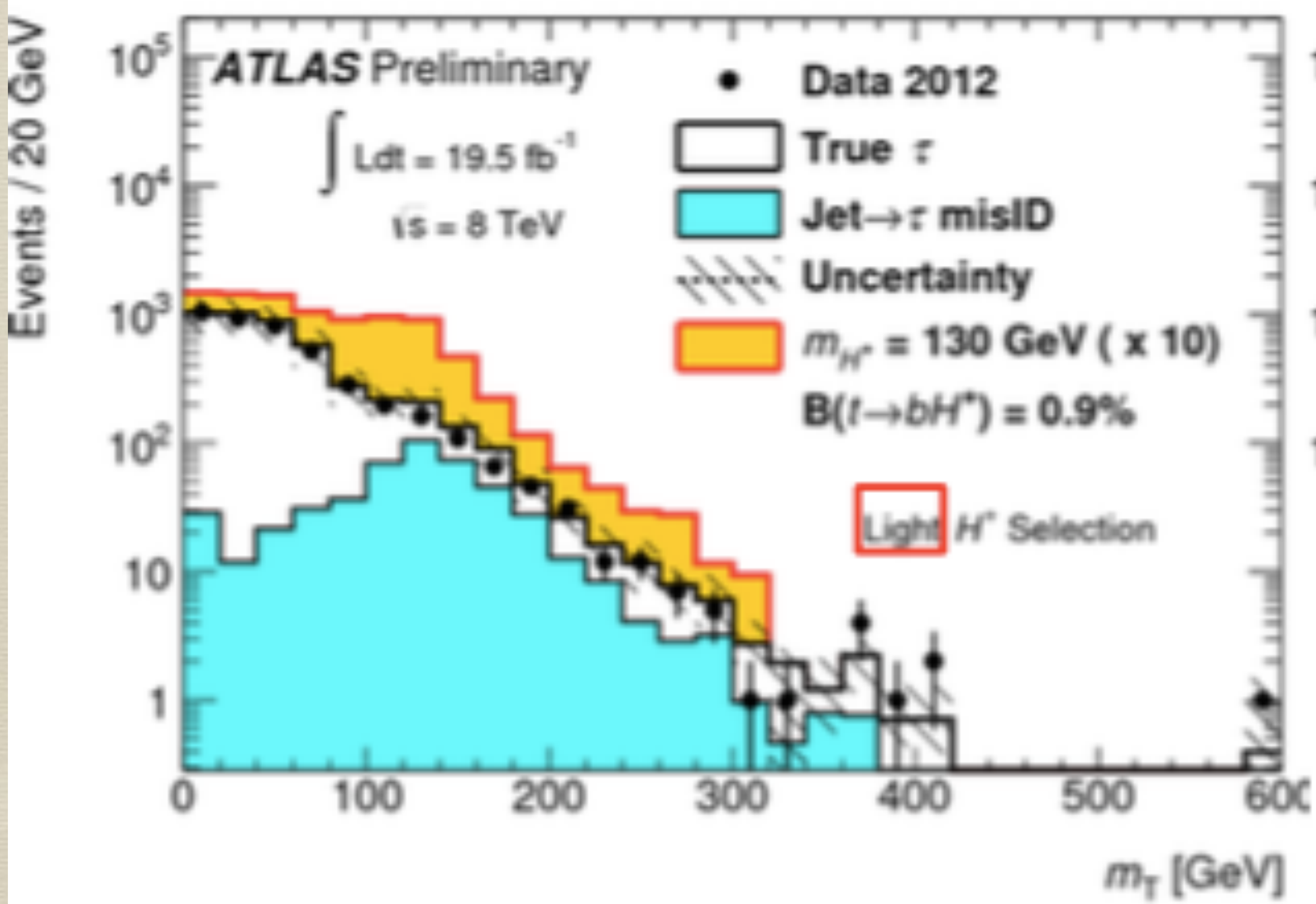
From simulation

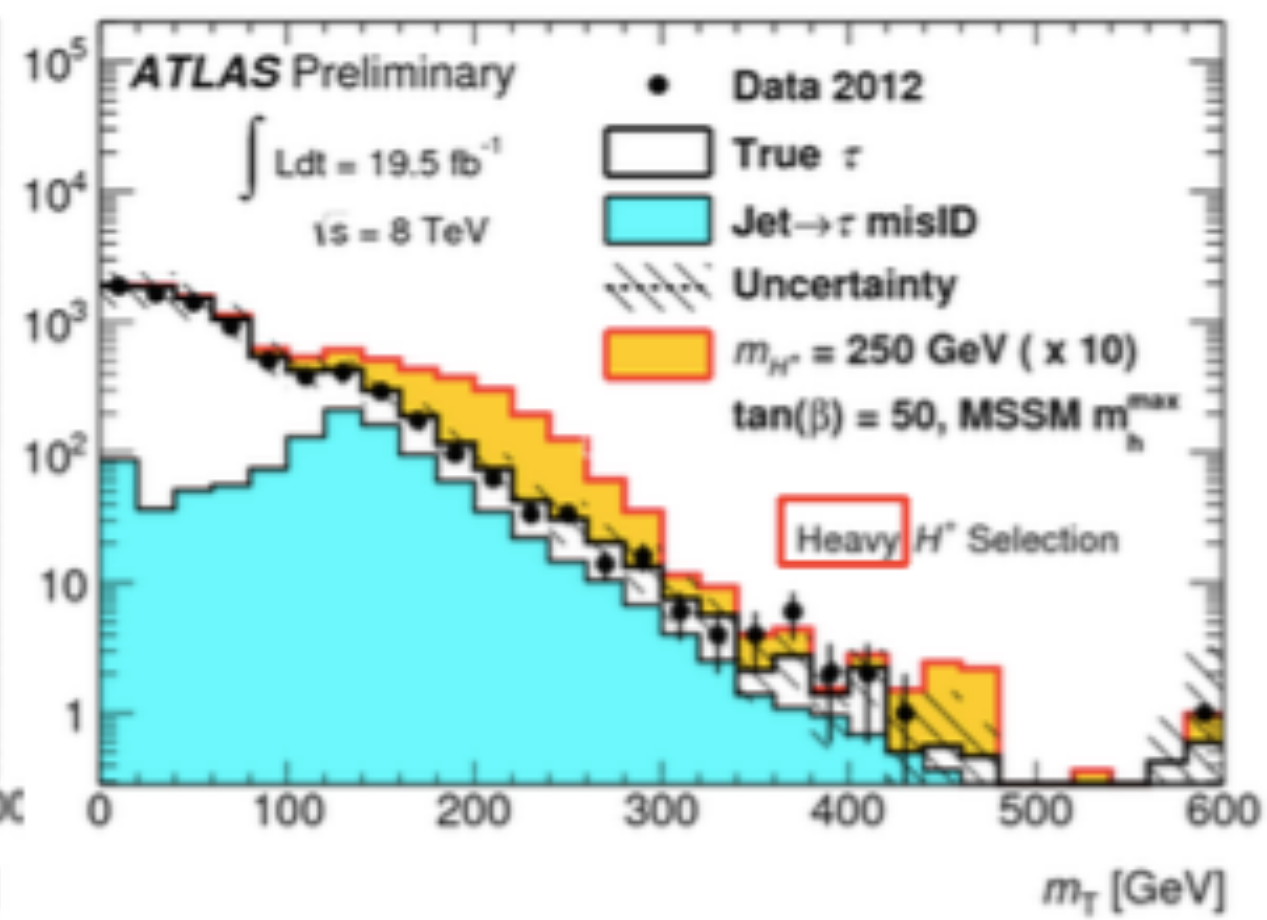


- Lepton → τ misID:
  - Simulation, with data-driven corrections
- Events with true τ:
  - Simulation, verified in control regions

H±→τν (τ+jets): Results

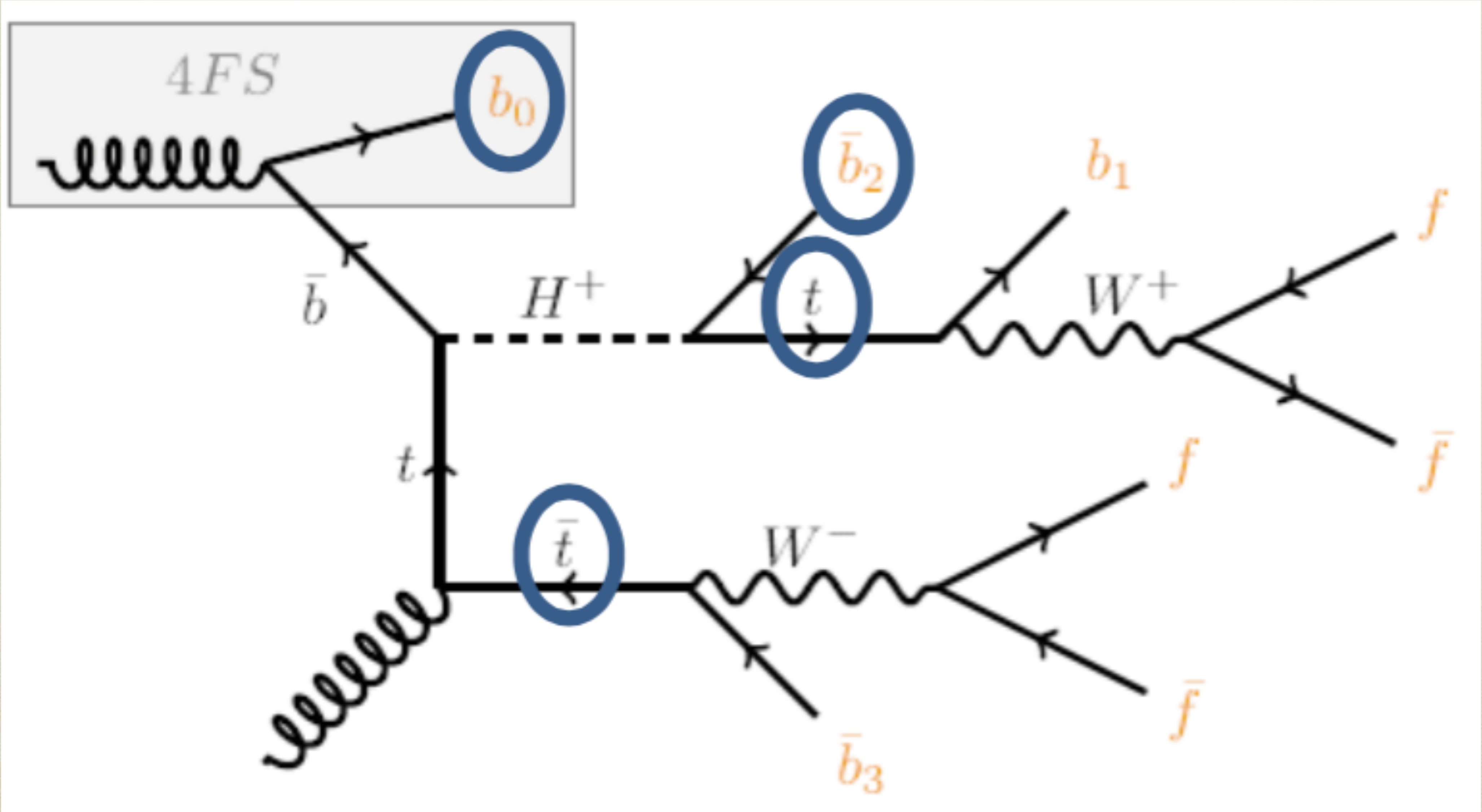
- Final discriminant: $m_{\mathrm{T}} = \sqrt{2p_{\mathrm{T}}^{\tau}E_{\mathrm{T}}^{\mathrm{miss}}(1-\cos\Delta\phi_{\tau,\mathrm{miss}})},$
- No sign of H±
  good agreement with SM-only prediction…
  →set limits!





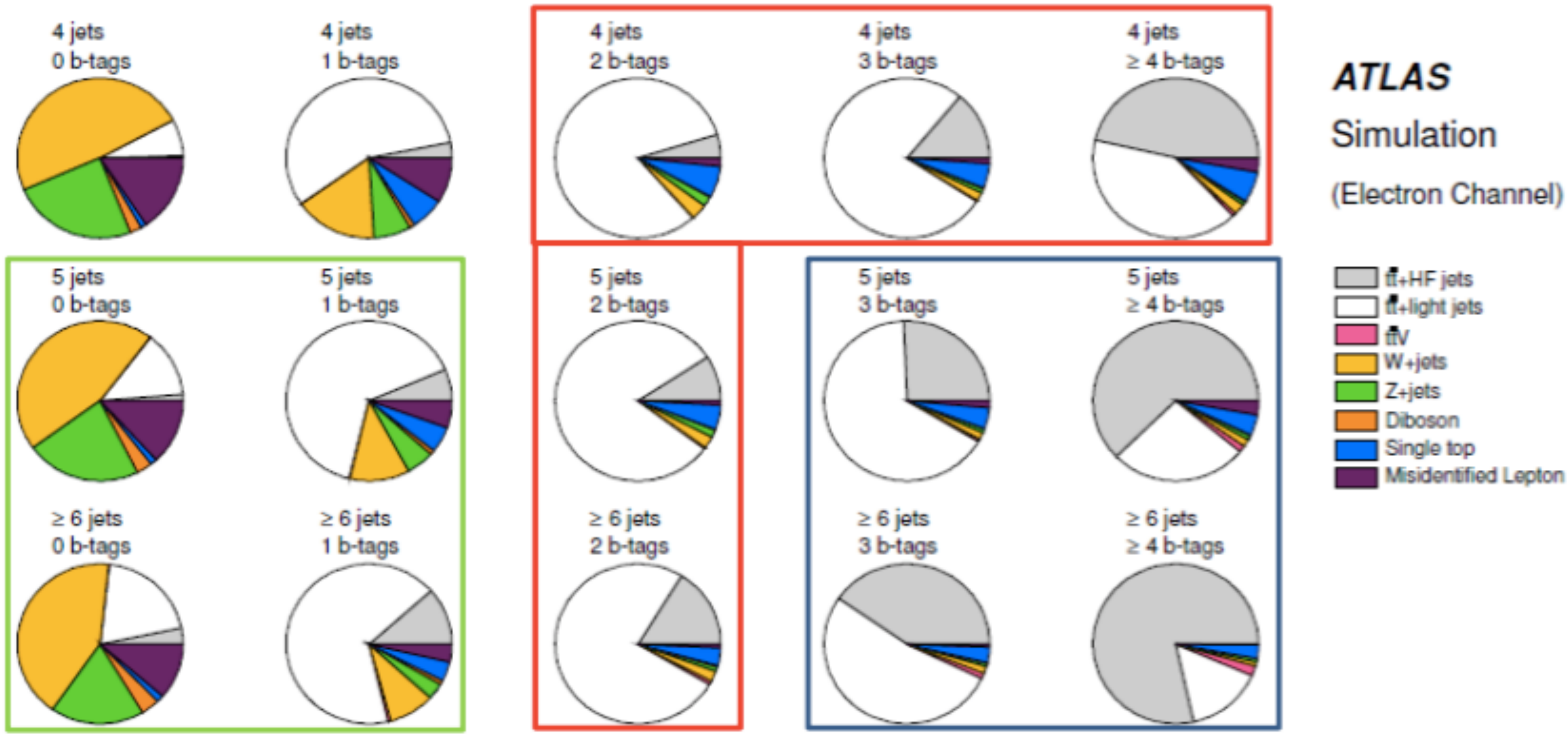
Charged Higgs searches

* Heavy charged Higgs:



Charged Higgs searches

- Classification of event topologies by N(jets) and N(b-jets) for background.
- Defining signal, control and validation regions.



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