Search for doubly charged Higgs with ATLAS at √s=13 TeV
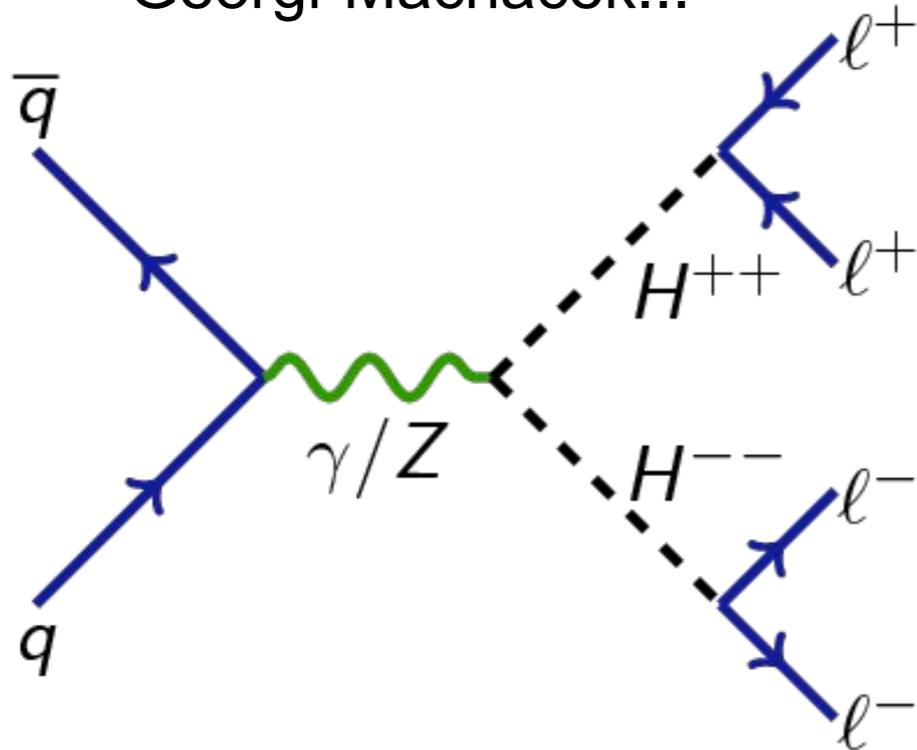
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Partikeldagarna, Stockholm, 2017

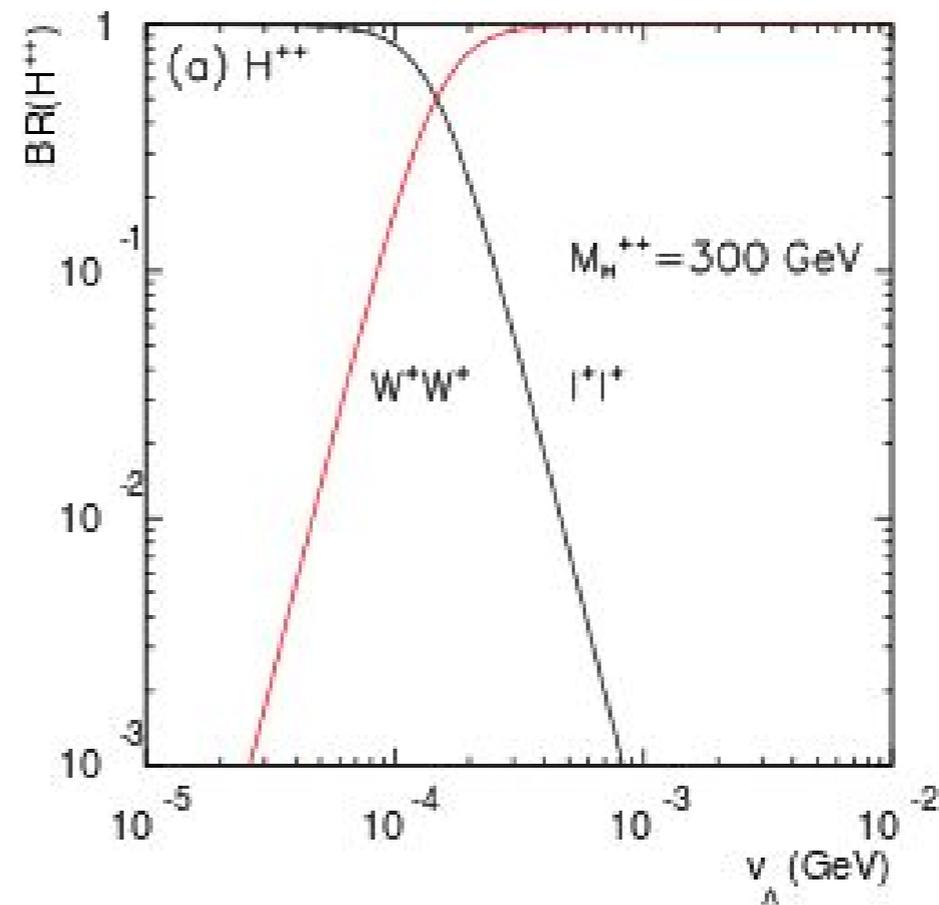# Motivation

- SM events with high pT, isolated, same-charge leptons are rare, and provide a very powerful signature towards discoveries.
- Doubly charged Higgs in many BSM theories, usually by adding a scalar triplet to the SM.
    - left-right symmetric models
    - the little Higgs model
    - type II seesaw
    - Zee-Babu
    - Georgi-Machacek...

Drell-Yan pair production of $H^{\pm\pm}$

$H^{\pm\pm}$ decays depend on vacuum expectation value v_Δ

Search overview

- The search uses the *pp* data sample corresponding to 36.1 fb⁻¹ of integrated luminosity collected in 2015 and 2016 by the ATLAS detector at the LHC at √s=13 TeV.
- Searching for H$^{\pm\pm}$ in multi-lepton final states, Drell-Yan production only, with v$_\Delta$=0
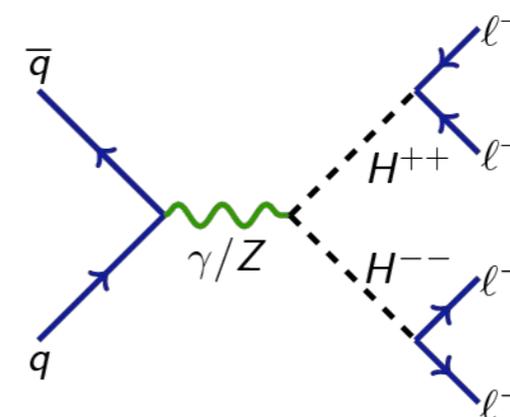
$$\Gamma(H^{\pm\pm} \to \ell^\pm \ell'^\pm) = k \frac{h_{\ell\ell'}^2}{16\pi} m(H^{\pm\pm})$$

- This analysis studies the case where H$^{\pm\pm}$ decays only into light leptons:

$$\sum_{\ell,\ell'} \mathrm{Br}(H^{\pm\pm} \to \ell^\pm \ell'^\pm) + \mathrm{Br}(H^{\pm\pm} \to X) = 100\%$$

where *X* accounts for decays into particles not directly considered in the selection of the analysis or outside the acceptance.

- m(H$^{\pm\pm}$) ∈ [250, 1300] GeV
- submitted to EPJC, https://arxiv.org/abs/1710.09748

Analysis regions

constrain backgrounds in the fit

validate backgrounds

Region / Channel	Control Regions			Validation Regions			Signal Regions		
	OCCR	DBCR	4LCR	SCVR	3LVR	4LVR	1P2L	1P3L	2P4L
electron ch.	$e^\pm e^\mp$	$e^\pm e^\pm e^\mp$		$e^\pm e^\mp$	$e^\pm e^\pm e^\mp$		$e^\pm e^\pm$	$e^\pm e^\pm e^\mp$	
mixed ch.	-	$e^\pm \mu^\pm \ell^\mp$	$4\ell^\pm$	$\ell^\pm \ell'^\pm$	$e^\pm \mu^\pm \ell^\mp$ $\ell^\pm \ell^\pm \ell'^\mp$	$4\ell^\pm$	$\ell^\pm \ell'^\pm$	$e^\pm \mu^\pm \ell^\mp$ $\ell^\pm \ell^\pm \ell'^\mp$	$4\ell^\pm$
muon ch.	-	$\mu^\pm \mu^\pm \mu^\mp$		$\mu^\pm \mu^\pm$	$\mu^\pm \mu^\pm \mu^\mp$		$\mu^\pm \mu^\pm$	$\mu^\pm \mu^\pm \mu^\mp$	
mass range [GeV]									
$m(\ell^\pm \ell^\pm)$ electron ch.	$[130, 2000]$	$[90, 200)$		$[130, 200)$	$[90, 200)$		$[200, \infty)$	$[200, \infty)$	
$m(\ell^\pm \ell^\pm)$ mixed ch.	-	$[90, 200)$	$[150, 200)$	$[130, 200)$	$[90, 200)$	$[60, 150)$	$[200, \infty)$	$[200, \infty)$	$[200, \infty)$
$m(\ell^\pm \ell^\pm)$ muon ch.	-	$[60, 200)$		$[60, 200)$	$[60, 200)$		$[200, \infty)$	$[200, \infty)$	
selection									
b-jet veto	✓	✓	✓	✓	✓	✓	✓	✓	✓
Z veto	-	inv.	-	-	✓	-	-	✓	✓
$\Delta R(\ell^\pm \ell^\pm) < 3.5$	-	-	-	-	-	-	✓	✓	-
$p_T(\ell^\pm \ell^\pm) > 100$ GeV	-	-	-	-	-	-	✓	✓	-
$\sum |p_T(\ell)| > 300$ GeV	-	-	-	-	-	-	✓	✓	-
$\Delta M / \bar{M}$ cut	-	-	-	-	-	-	-	-	✓

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Backgrounds

Prompt	**Non-prompt**	**Charge-flip**
real prompt leptons: Z(W/Z), tt(W/Z), W$^\pm$/Z	● real e or μ from non-prompt decays, e.g. from heavy flavored mesons ● jets mis-reconstructed as electrons	oppositely charged leptons with charge mis-ID: Z/γ*, tt, tW , W$^\pm$W$^\mp$
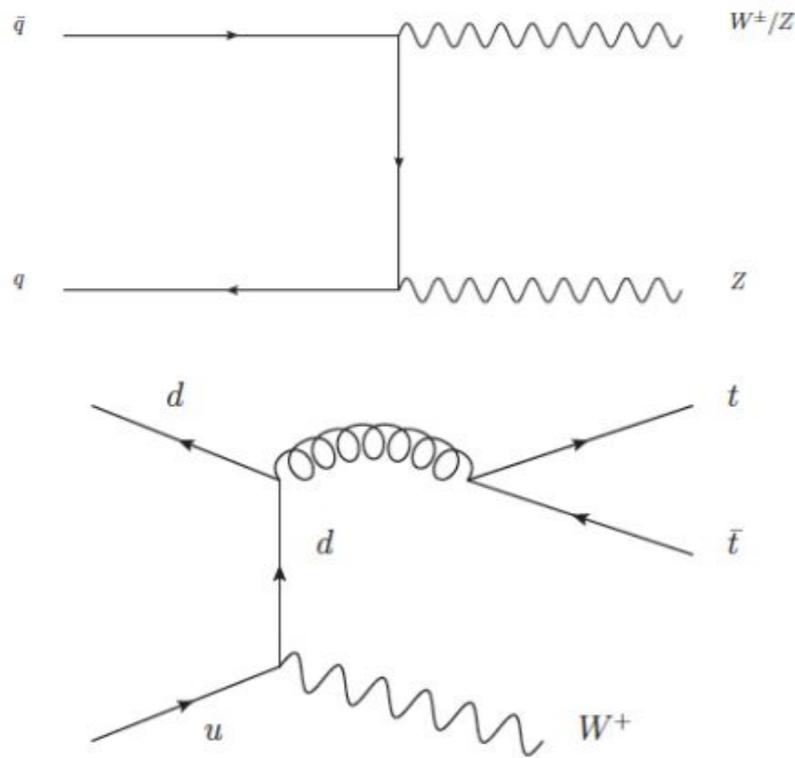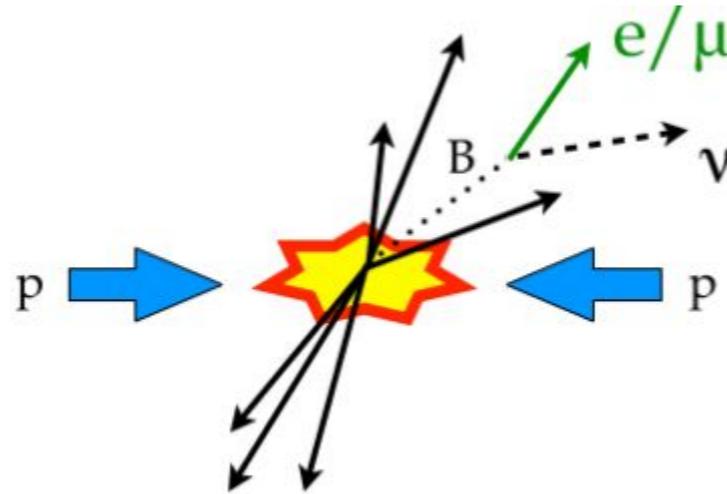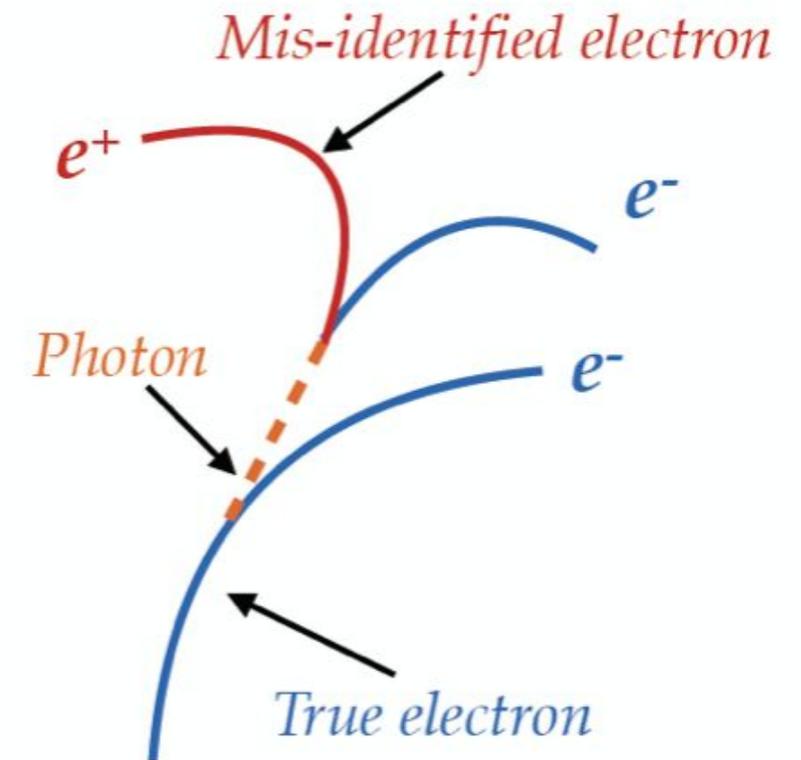
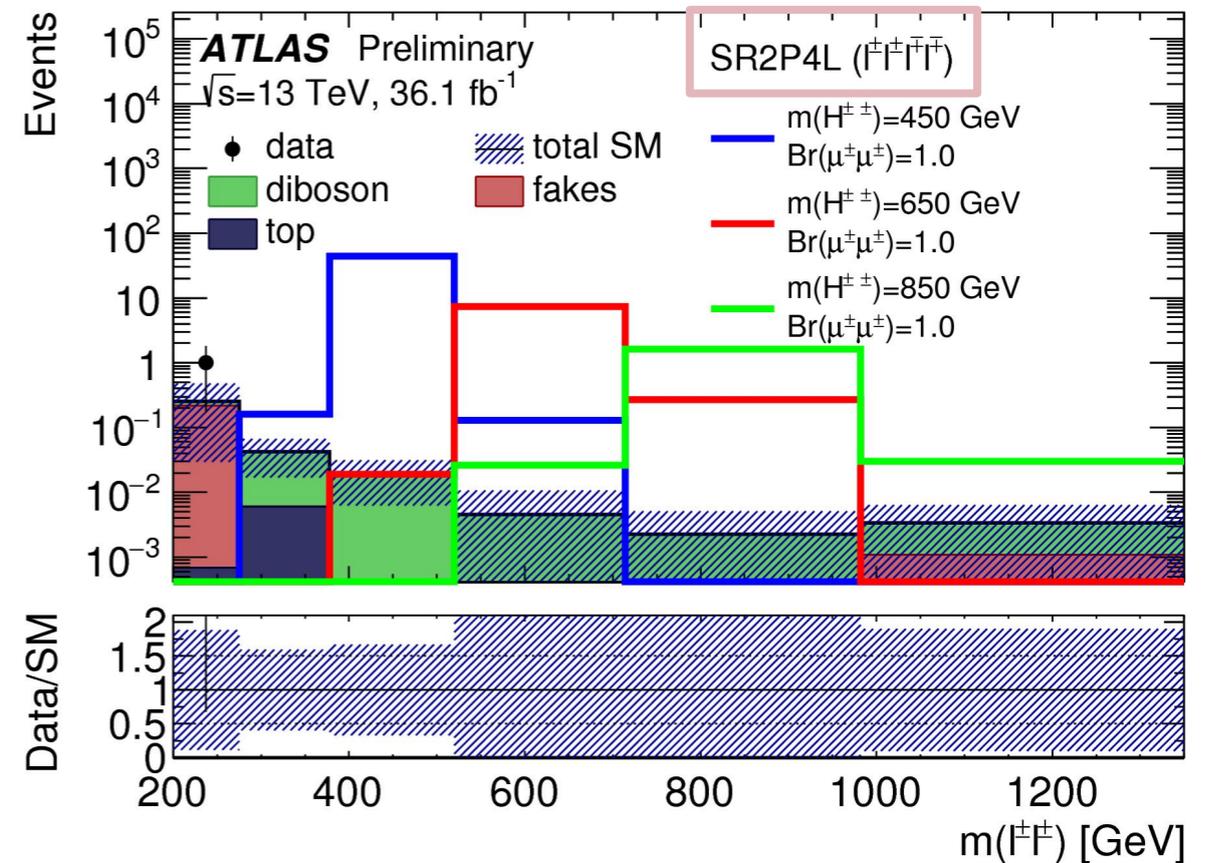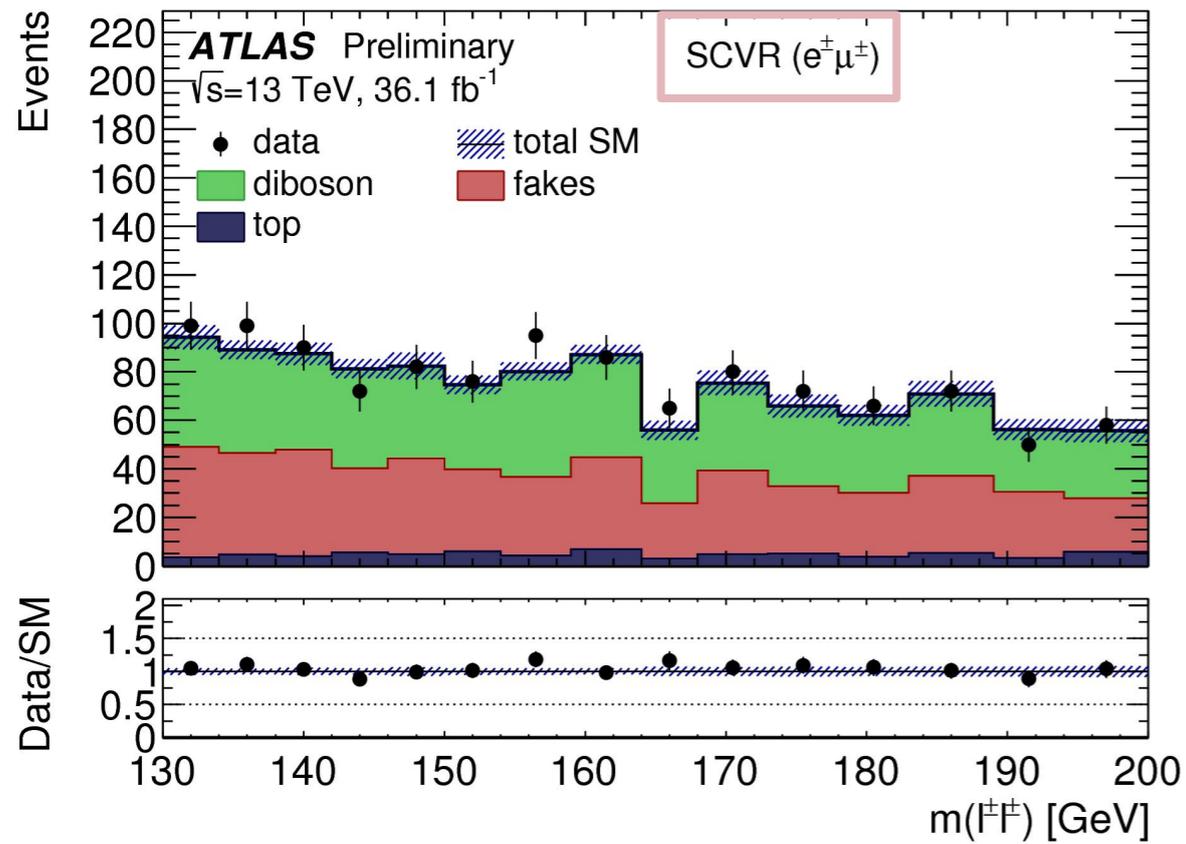| estimated with simulation	data-driven estimation with the fake factor method	charge-flip probability measured in a Z→ee sample with a likelihood fit

Invariant mass distributions
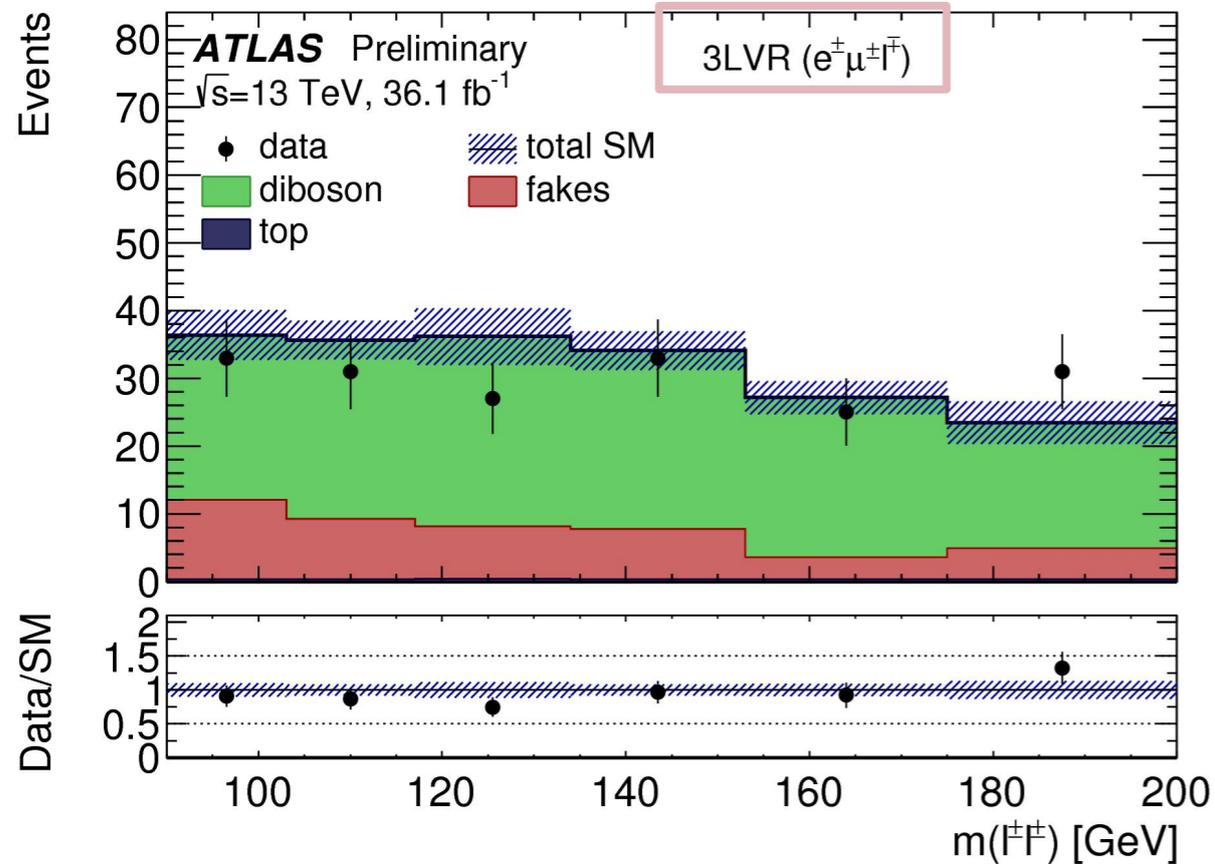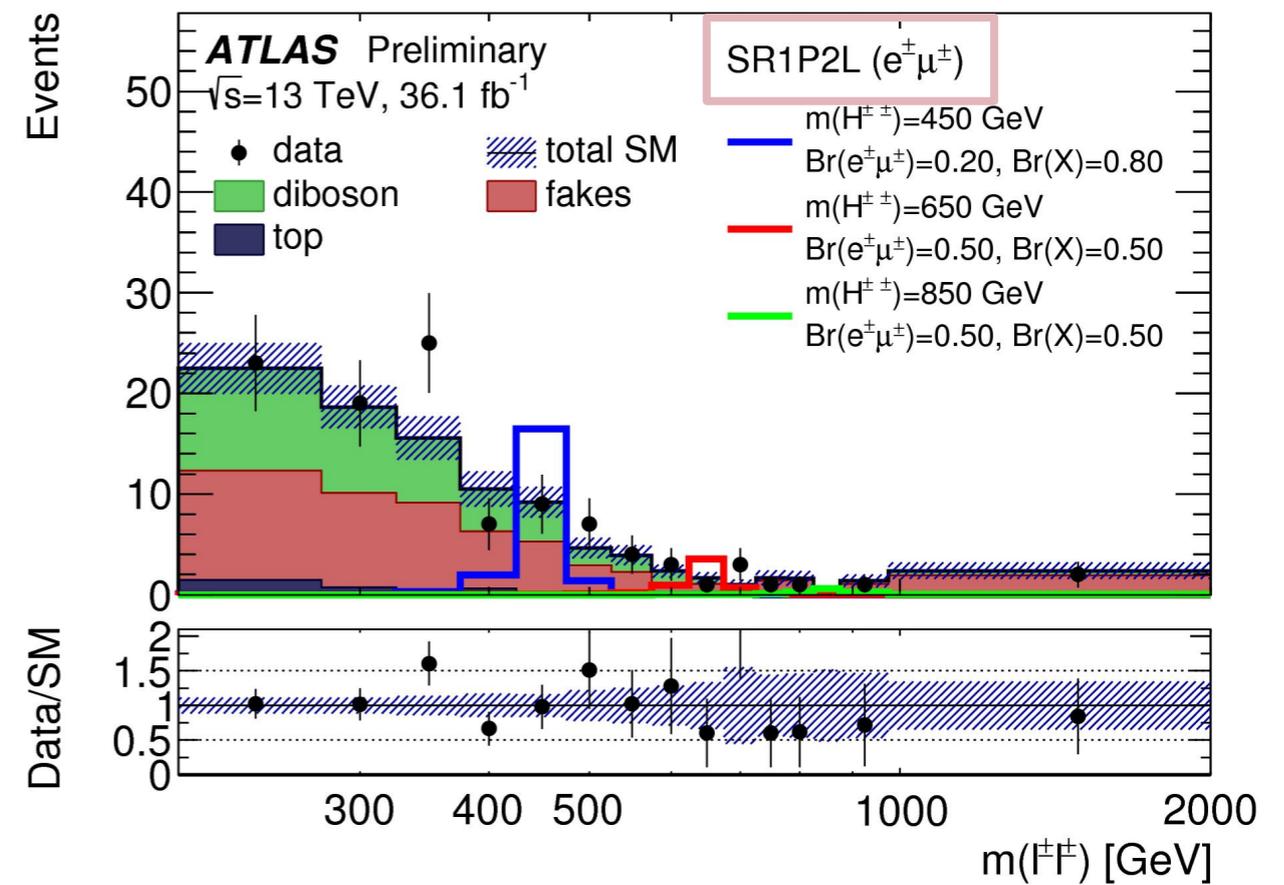
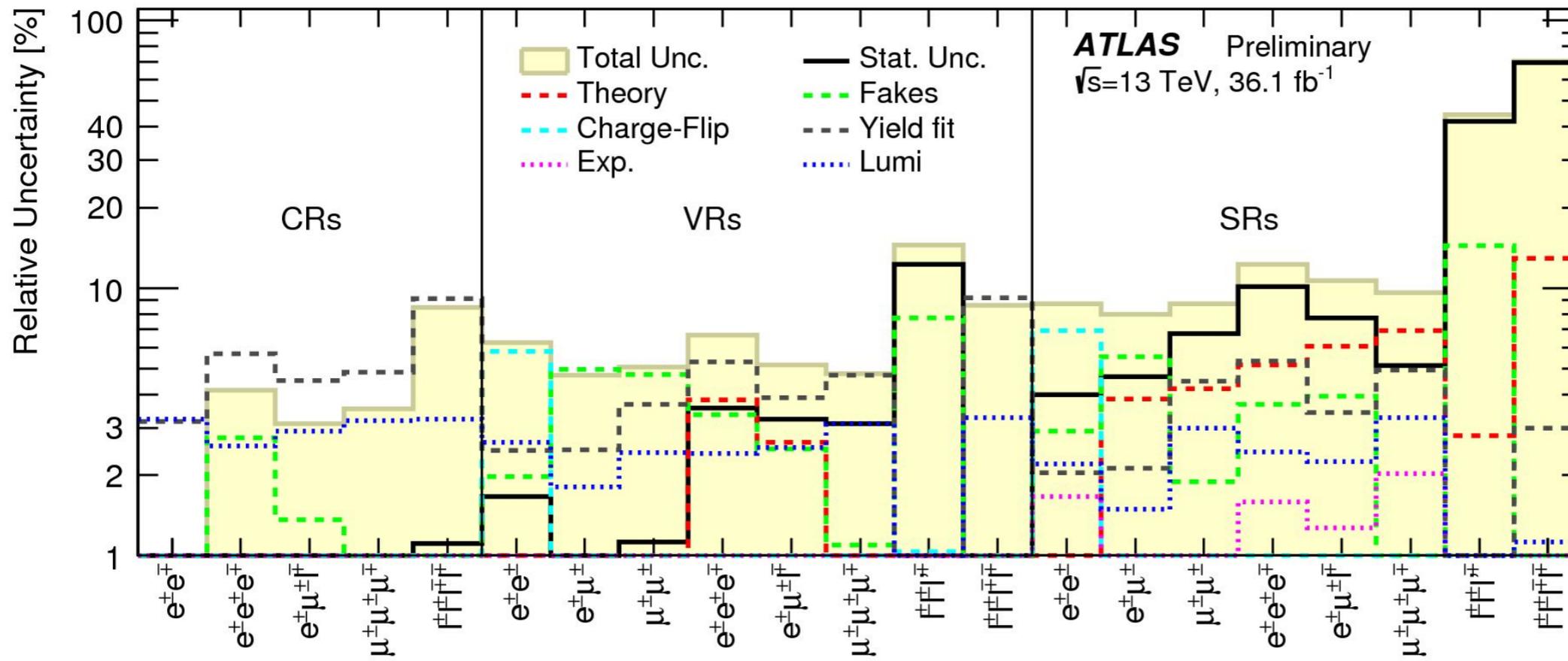# Fit

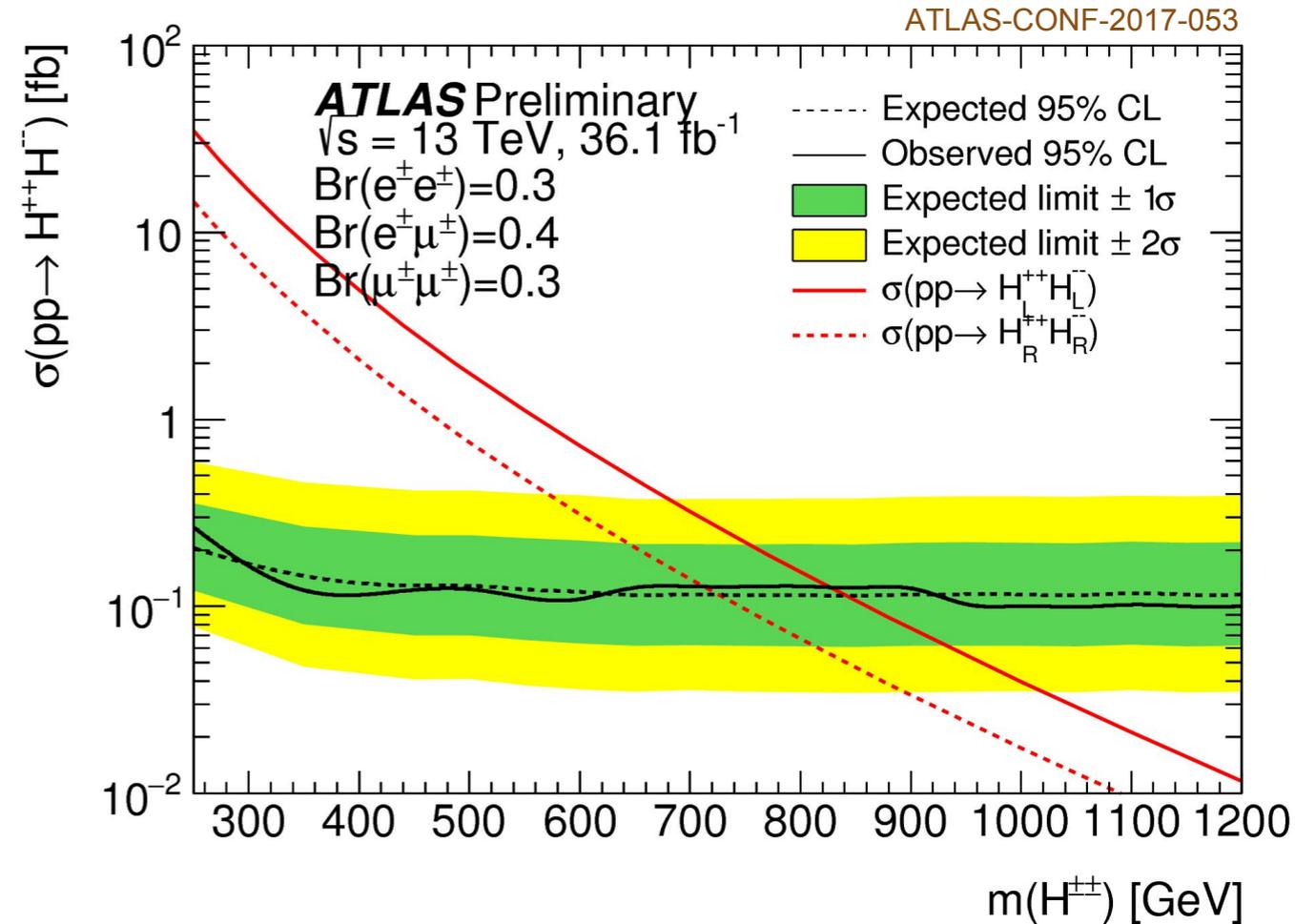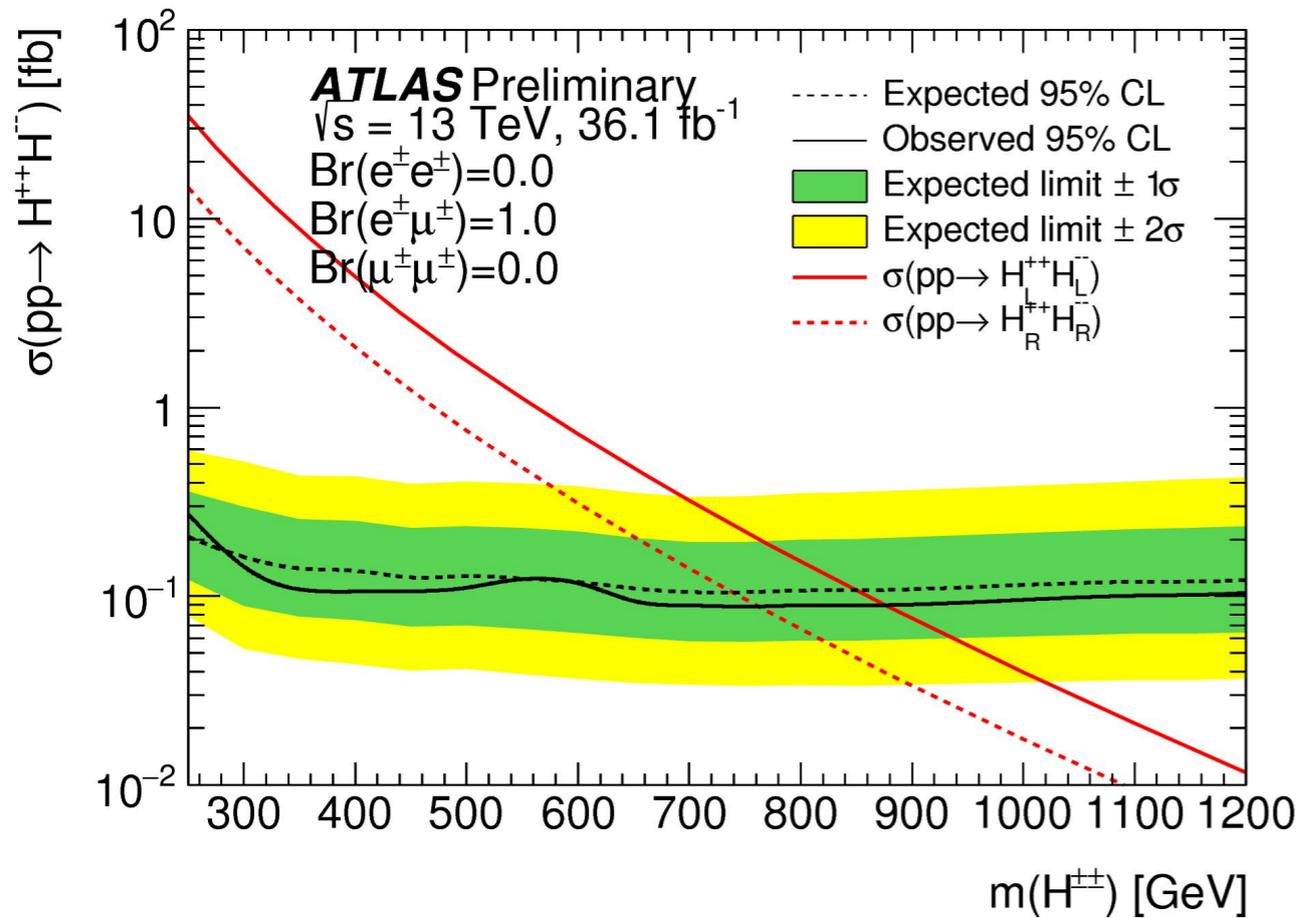## a maximum-likelihood fit of the invariant mass distribution
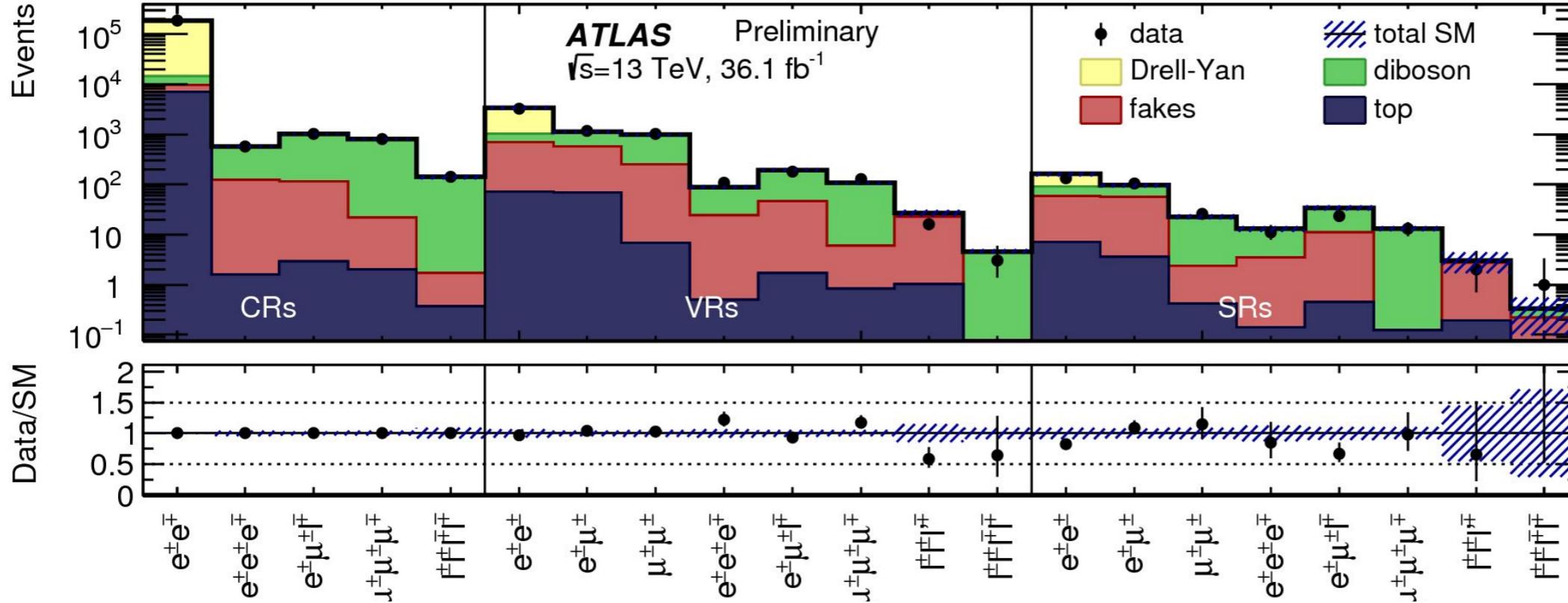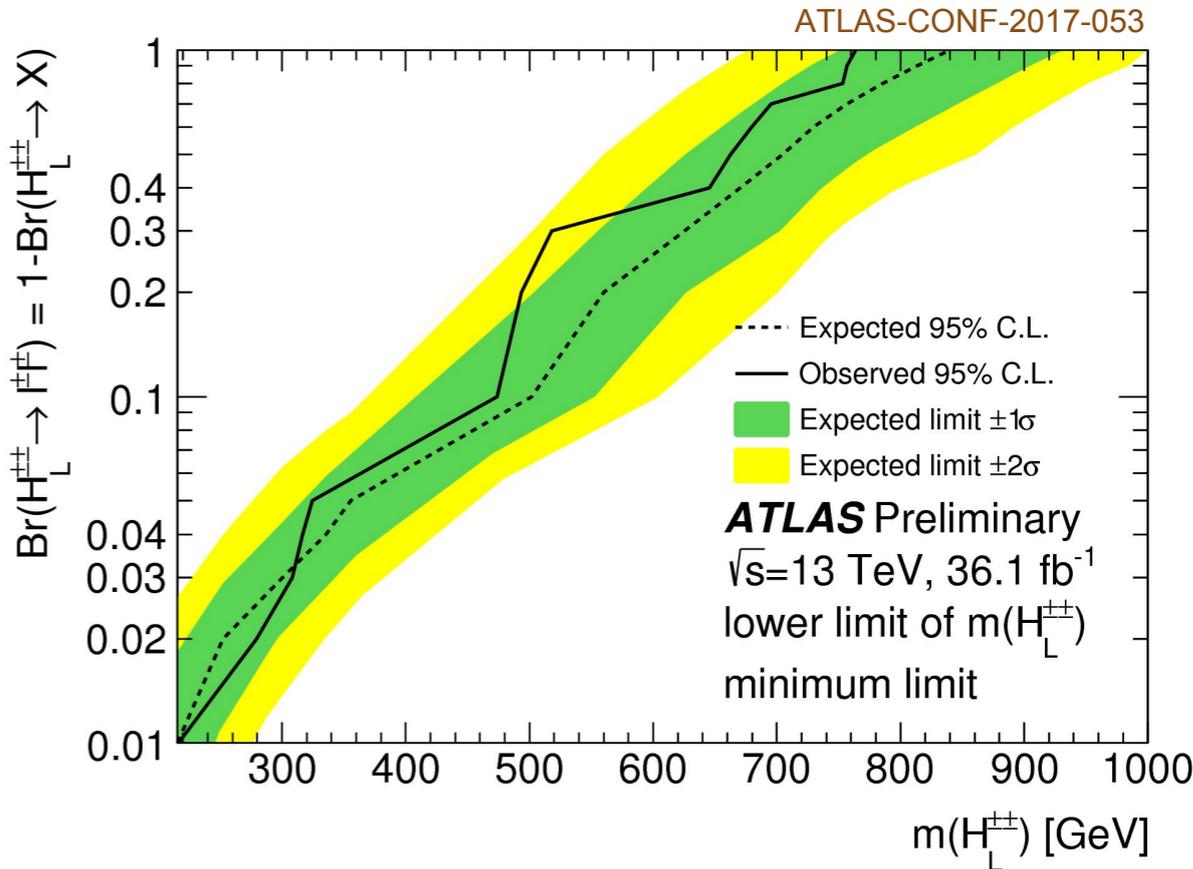
post-fit regions

post-fit background uncertainty

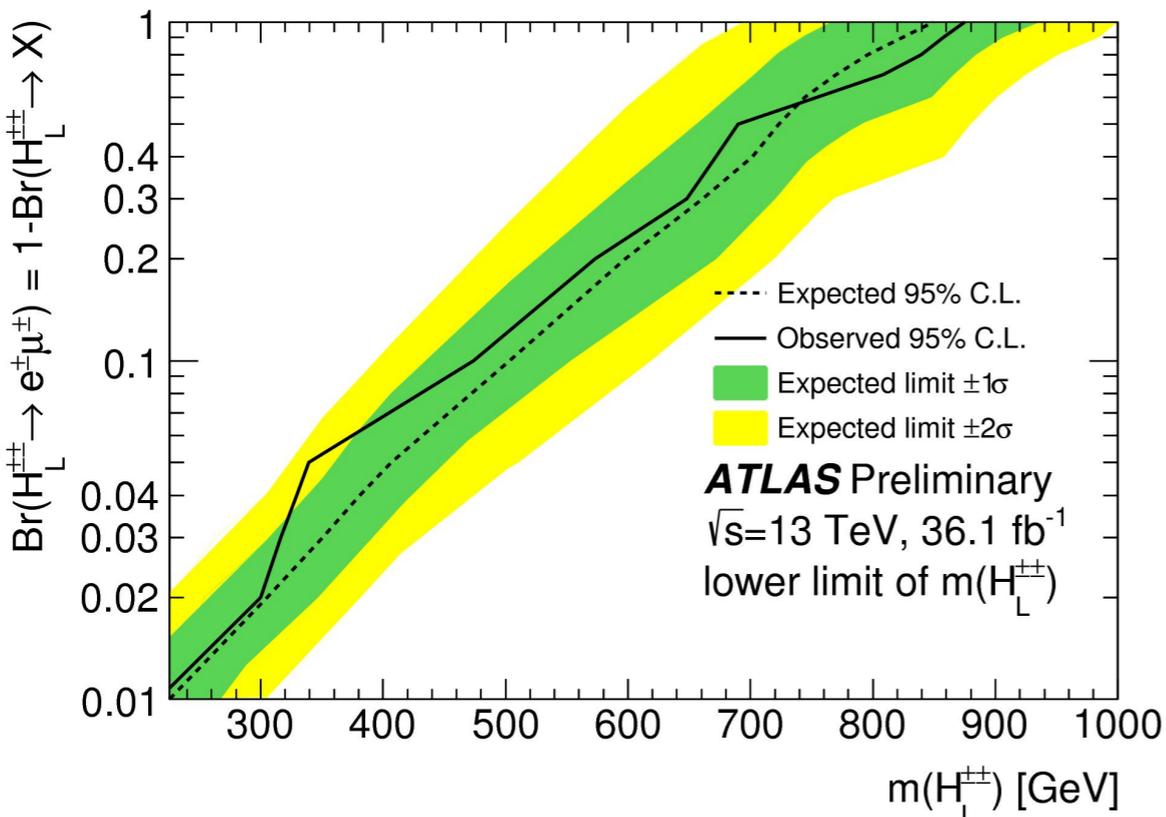# Upper limits on the cross-section

Upper limit on the cross-section for pp→ H$^{\pm\pm}$H$^{\mp\mp}$ in the fit for several branching ratio working points

Lower limits on $H_L^{\pm\pm}$ mass

Expected and observed lower limit on $H_L^{\pm\pm}$ mass for all branching ratio combinations that sum to 100%.

Lower limits on $H_L^{\pm\pm}$ mass

$H_L^{\pm\pm}$ decays only into electron-muon pairs and "X", where "X" does not enter any of the SRs

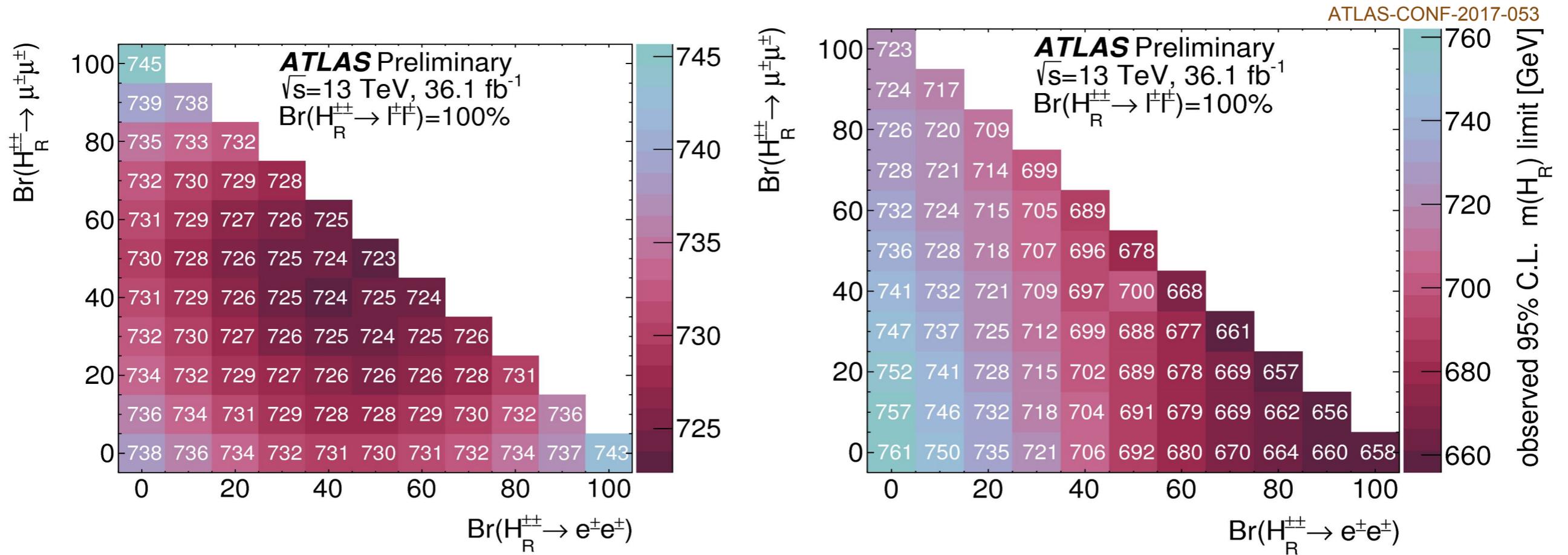the minimum observed and expected limit

Summary

- The ATLAS detector at LHC has been used to search for **doubly charged Higgs bosons** in the **same-charge dilepton** invariant mass spectrum at high values.

- The search scans through various $H^{\pm\pm}$ BRs in several exclusive signal regions.

- No significant evidence of signal was observed.

- Limits on the production cross-section and the lower limit on $m(H^{\pm\pm})$ were derived.

- Observed lower limits on $m(H^{\pm\pm}_L)$ vary from **770 GeV to 870 GeV** for $BR(H^{\pm\pm}_L \to \ell^\pm \ell^\pm)=100\%$ and are **>450 GeV** for $Br(H^{\pm\pm}_L \to \ell^\pm \ell^\pm)>10\%$ for any combination of partial BRs.

- Observed lower limits on $m(H^{\pm\pm}_R)$ vary from 670 GeV to 760 GeV for $BR(H^{\pm\pm}_R \to \ell^\pm \ell^\pm)=100\%$ and are >320 GeV for $Br(H^{\pm\pm}_R \to \ell^\pm \ell^\pm)>10\%$ for any combination of partial BRs.
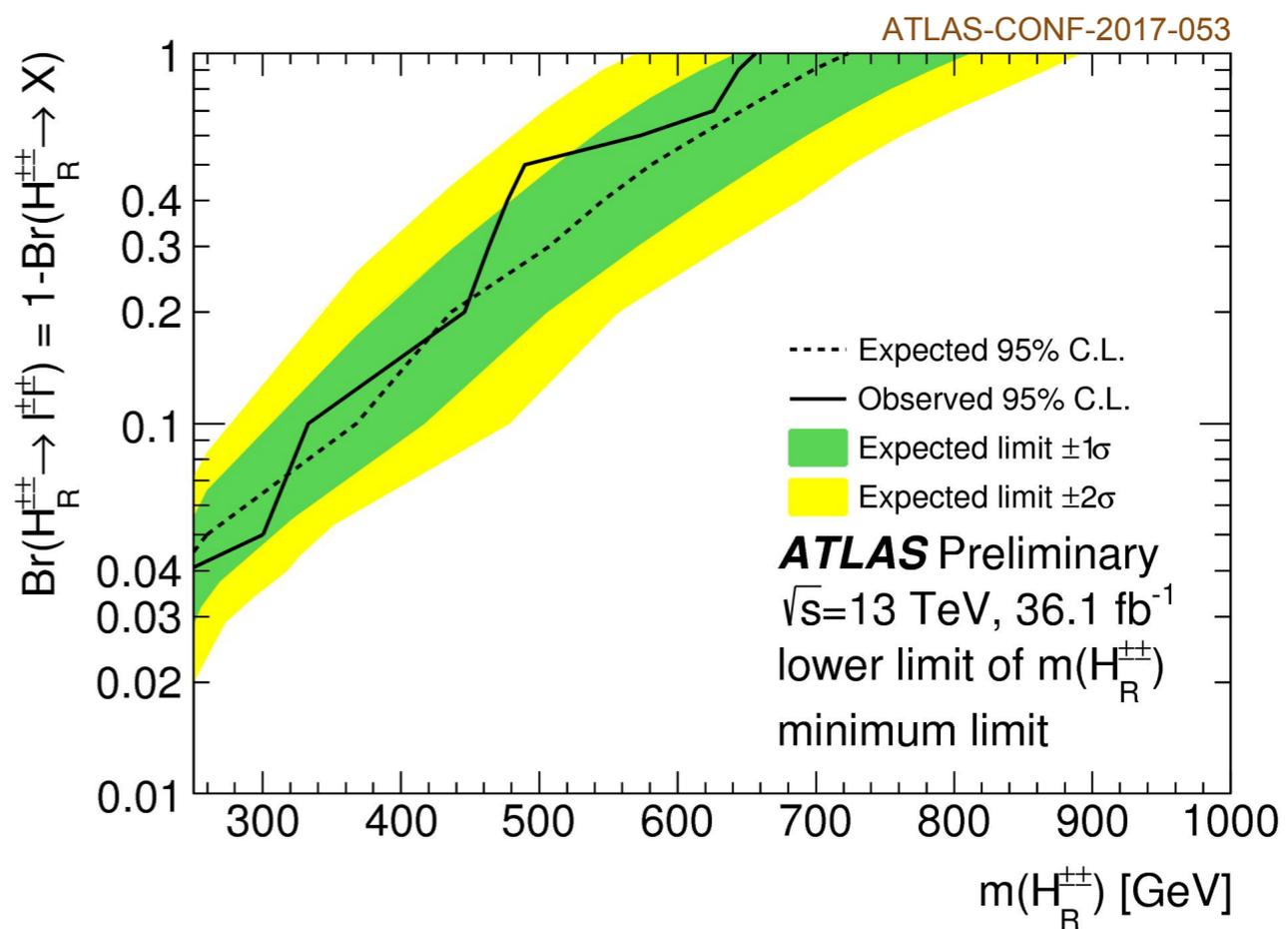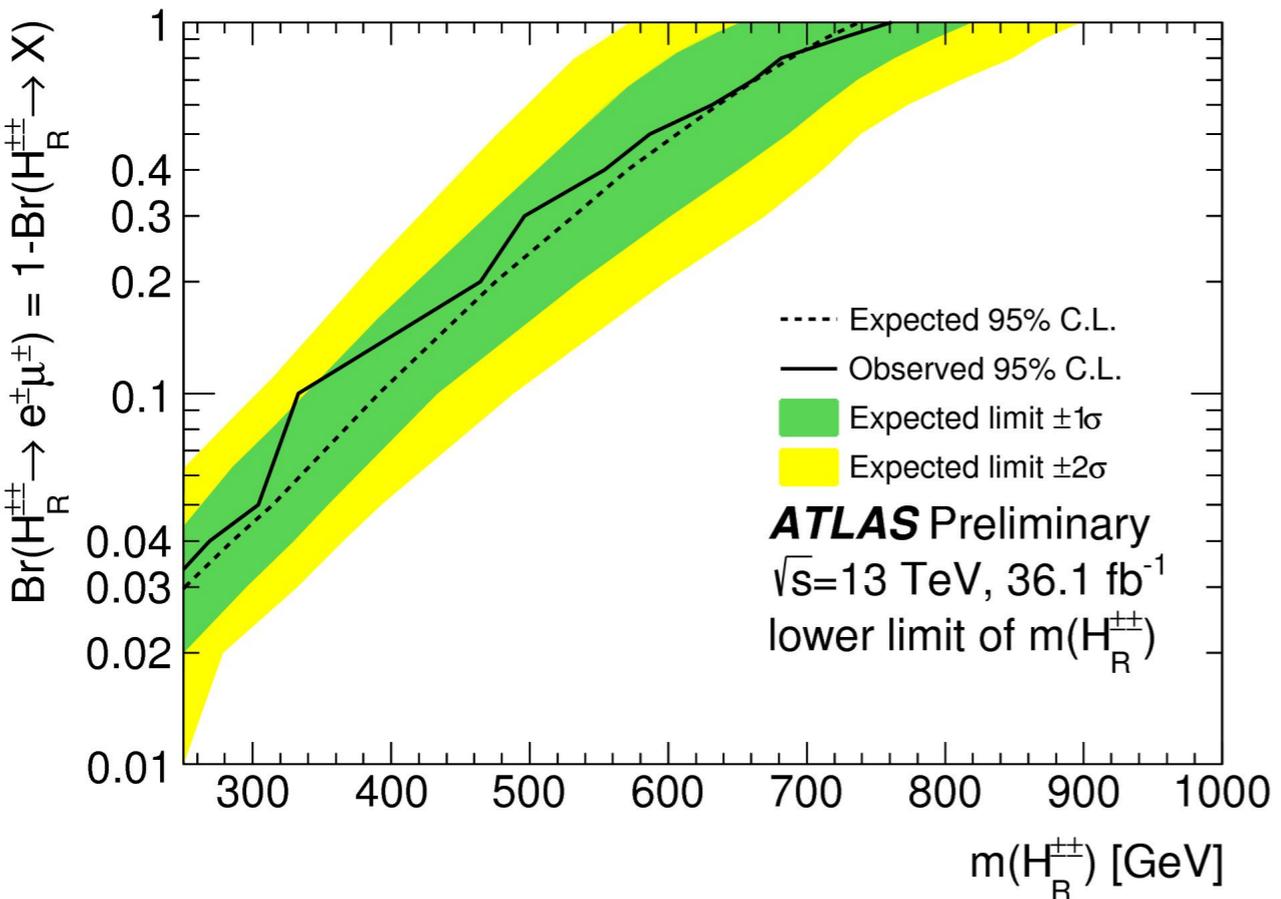
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Backup slides

Lower limits on $H_R^{\pm\pm}$ mass

Expected and observed lower limit on $H_R^{\pm\pm}$ mass for all branching ratio combinations that sum to 100%.

Lower limits on $H_R^{\pm\pm}$ mass

$H_R^{\pm\pm}$ decays only into electron-muon pairs
and "X", where "X" does not enter any of the SRs

the minimum observed and expected
limit

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