Search for doubly-charged Higgs boson in multi-lepton final states using 36.1 fb^{-1} with ATLAS at $\sqrt{s}$ = 13 TeV

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Search for *new physics* is crucial for the ATLAS research program: Standard Model events with high p_T, isolated, **same-charge (SC) leptons** are rare, and provide a very powerful signature towards discoveries.

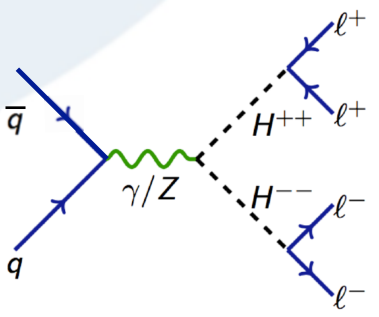


Fig. 1: H$^{\pm\pm}$ Drell-Yan pair production

Doubly Charged Higgs **(DCH)** bosons appear in many new physics models. In left-right symmetric models, a new set of scalar bosons:

$$\Delta_L = (\Delta_L{}^0,\ \Delta_L{}^+,\ \Delta_L{}^{++})$$
$$\Delta_R = (\Delta_R{}^0,\ \Delta_R{}^+,\ \Delta_R{}^{++})$$

breaks the ***$SU(2)_L \times SU(2)_R \times U(1)_{B-L}$*** symmetry, while parity is restored at the TeV scale. DCH *gives mass to neutrinos* via a Type II see-saw mechanism. DCH **production** and **decay** are shown in Fig. 1 and Fig. 2. This search assumes only $H^{\pm\pm} \rightarrow l^{\pm}l^{\pm}$ decays, where l=e,μ, allowing flavour violation.

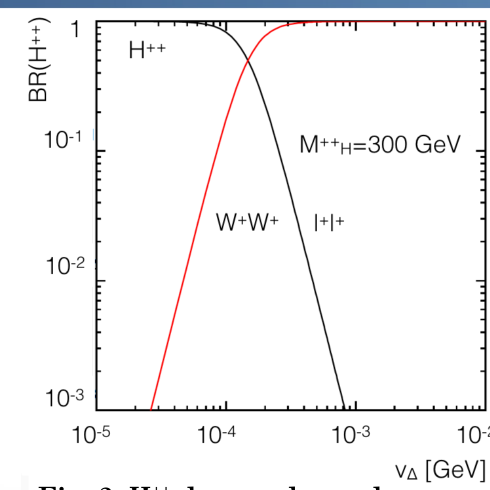


Fig. 2: H$^{\pm\pm}$ decays depend on vacuum expectation value, v$_\Delta$.

1) Analysis Regions Definition:

a)Control (CR): to fit VV (ZW,ZZ) and DY normalization;
b)Validation (VR): to validate *fakes* and *charge flip* (Sec.2);
c)Signal (SR): used to extract signal rate.

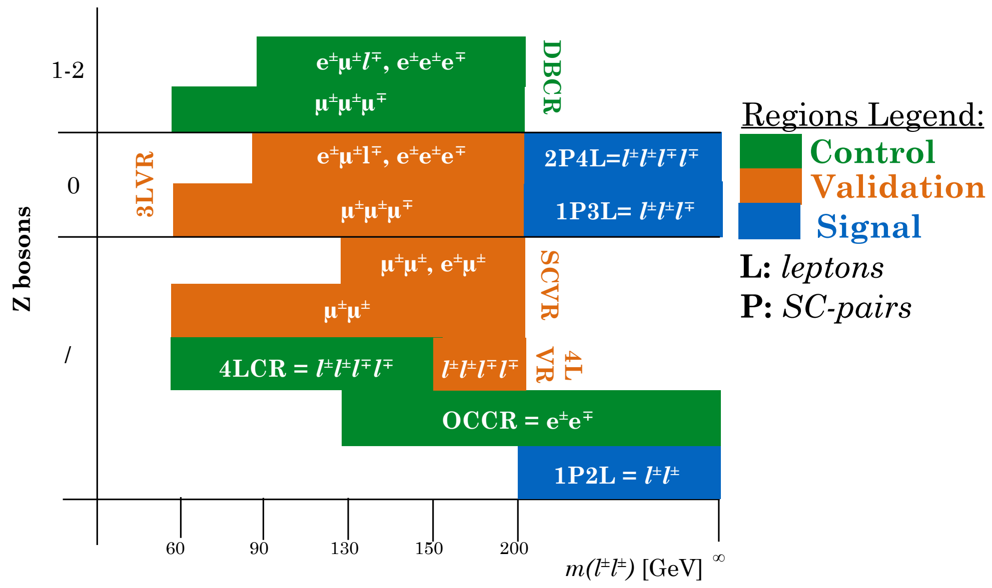


Fig. 3: Overview of the selection of all analysis regions.

2) Background Estimation:

• **Prompt** leptons from SM processes (mainly *VV*, *ttV*) taken from MC simulation.

• ***Fakes,*** non-prompt leptons from hadron decay or mis-identified jets, are estimated with the *fake-factor(FF)* method. FF measured using di-jet events, with low missing E$_T$, and validated in VRs.

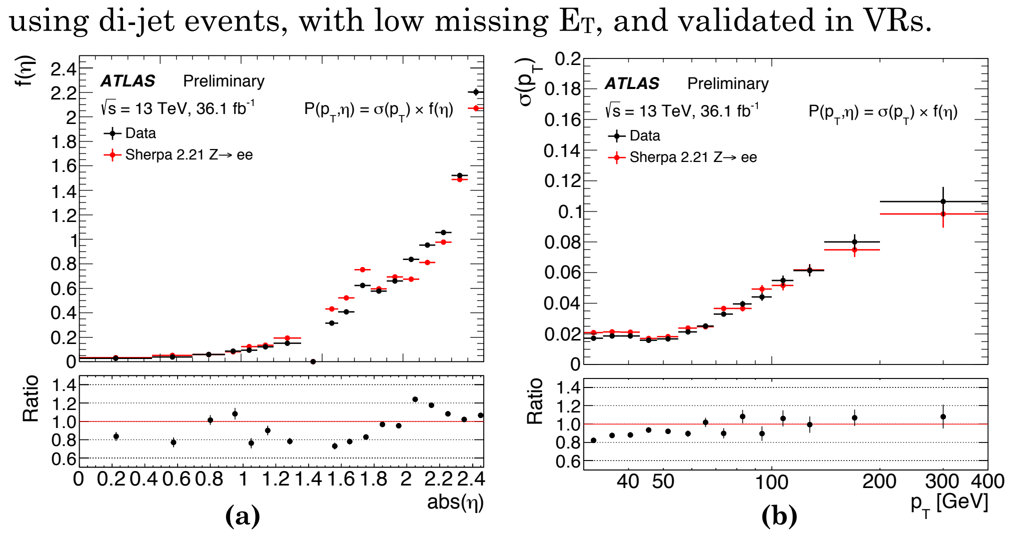


Fig. 4: CF probability $P(p_T,\eta) = \sigma(p_T) \times f(\eta)$: (a) η and (b) p_T dependences.

• ***Charge Flip (CF)*** probability, defined as $P(p_T,\eta)=\sigma(p_T)\times f(\eta)$, is measured in a $Z/\gamma^* \rightarrow ee$ sample through a likelihood fit. P(p_T,η) is applied as a 1D×1D parametrization of electron η and p_T (Fig.4). *Correction-factors* derived as the ratio between data/MC and applied to simulated CF electrons.

3) Systematic Uncertainties:

✤*Fakes:* alter event and jet kinematic cuts, MC normalization, sample statistics.
✤*CF:* finite statistics of the sample used to estimate the CF rates.
✤*Experimental:* reconstruction, particle identification, isolation and trigger efficiency, lepton calibration.
✤*Theory:* cross-section, PDF, EW scale.

Impact of systematic uncertainties in CR/VR/SRs in Fig.5.

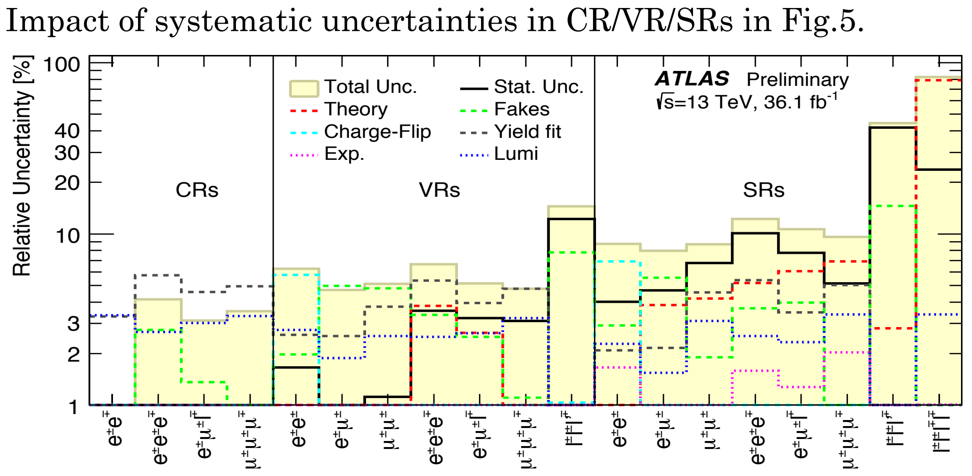


Fig. 5: Relative unc. on the total background yield estimation after fit.

4) Fit Procedure and Results:

How: implementing a maximum-likelihood fit of the $m(l^{\pm}l^{\pm})$ distribution.
Background predictions and systematics from **CRs** are validated in **VRs** and extracted to **SRs**.

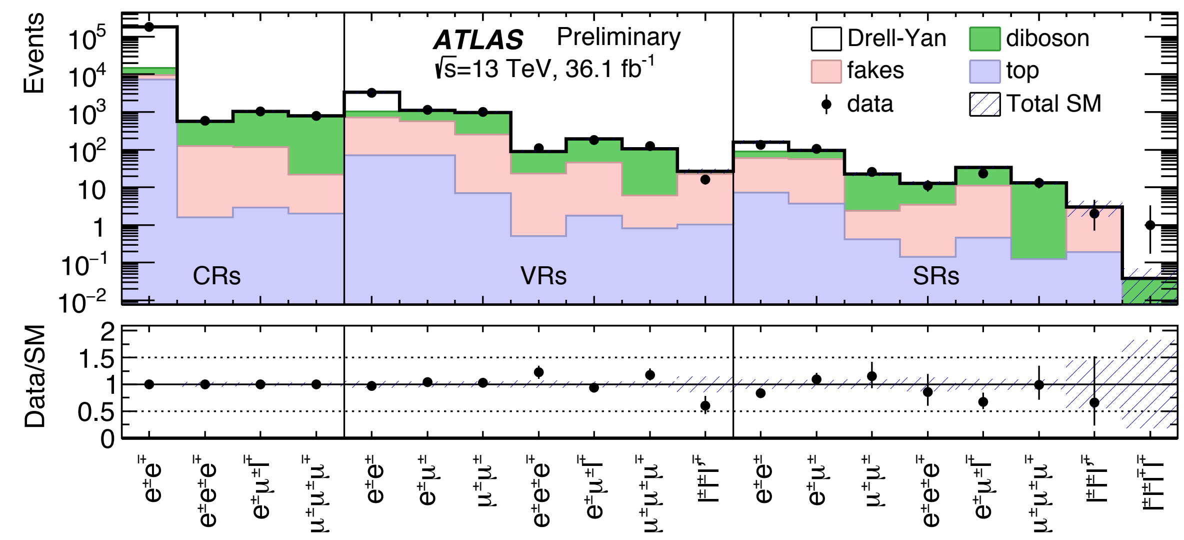


Fig. 6: Post-fit regions. Good agreement between data/MC observed.

No excess observed (Fig.6): setting 95% CL limits. One event of type $e^+\mu^+e^-\mu^-$ (Fig.7) observed in 2P4L SR compatible with background only hypothesis for $ZZ \rightarrow e^+e^-\mu^+\mu^-$ production.

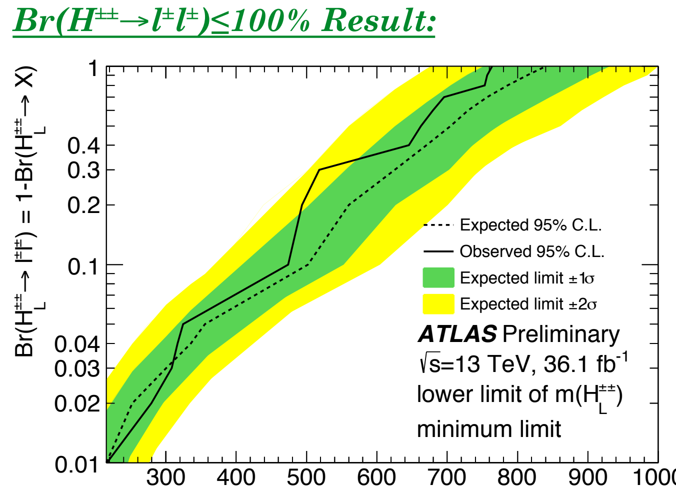
5) Exclusion Limits:

Scanning over branching ratio (Br) combinations:

$$Br(H^{\pm\pm} \rightarrow e^{\pm}e^{\pm}) + Br(H^{\pm\pm} \rightarrow e^{\pm}\mu^{\pm}) + Br(H^{\pm\pm} \rightarrow \mu^{\pm}\mu^{\pm}) + Br(H^{\pm\pm} \rightarrow X) = 100\%$$

X are final states that do not have any impact on the signal yield in SRs.

$Br(H^{\pm\pm}\rightarrow l^{\pm}l^{\pm}) \leq 100\%$ Result:



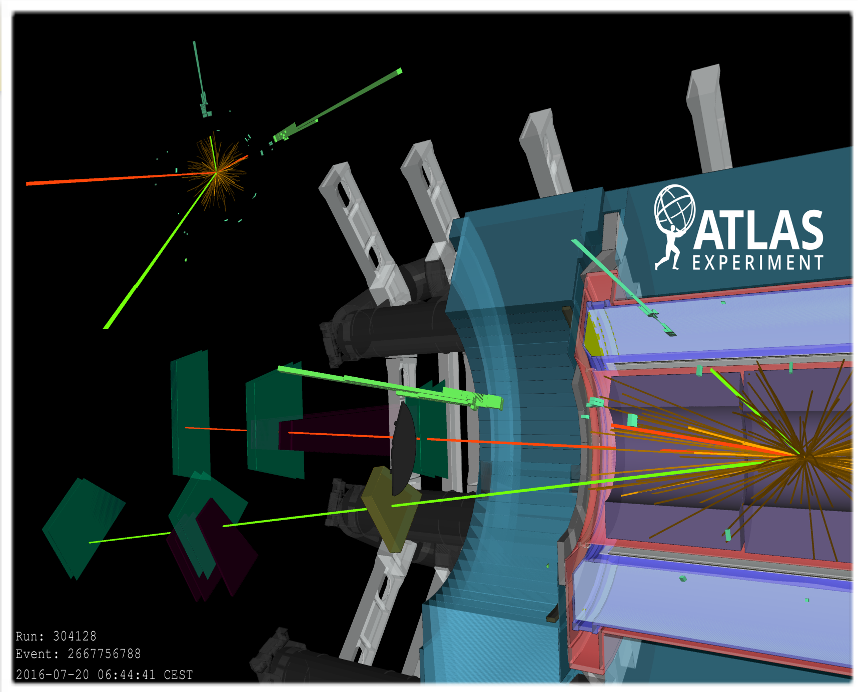


Fig. 7: event display of the event observed in 2P4L SR. The SC invariant masses are 228 GeV and 207 GeV, while the OC ones are 163.09 GeV for e$^+$e$^-$ and 78.89 GeV for $\mu^+\mu^-$.

Fig. 8: minimum limit obtained for each Br(H$^{\pm\pm}\rightarrow$l$^{\pm}$l$^{\pm}$) from the limits in which H$_L^{\pm\pm}$ only decays to e$^{\pm}$e$^{\pm}$, e$^{\pm}\mu^{\pm}$ or $\mu^{\pm}\mu^{\pm}$ pairs. Each decay channel has comparable sensitivity.

$Br(H^{\pm\pm}\rightarrow l^{\pm}l^{\pm})=100\%$ Result:

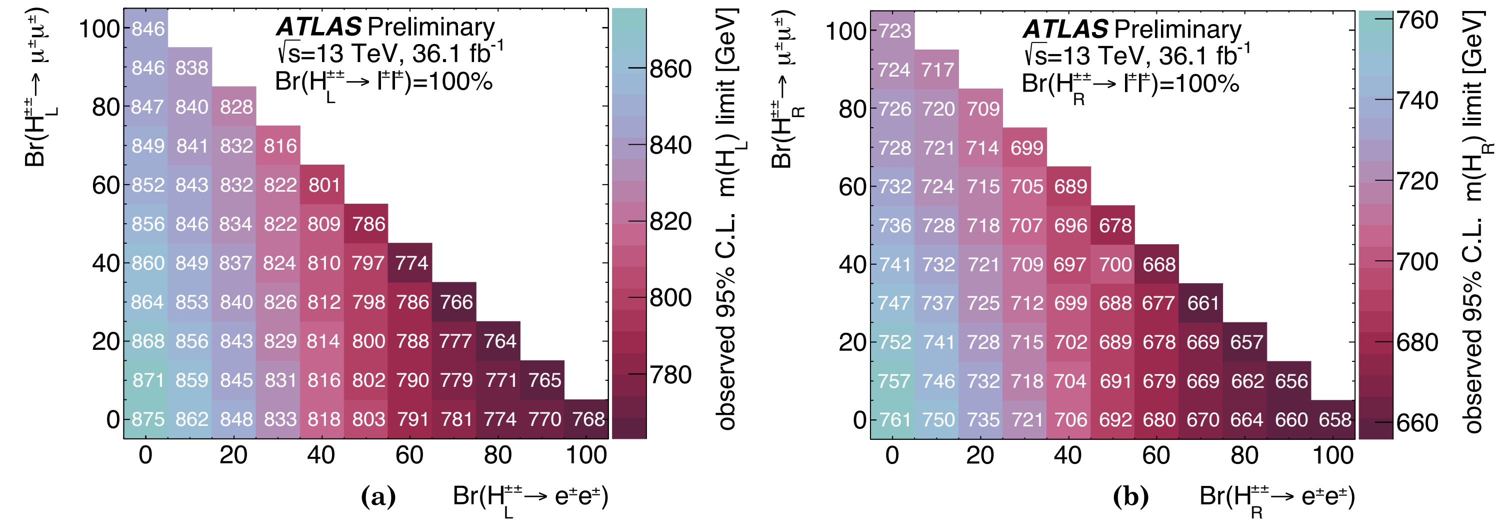


Fig. 9: 2D grid of observed lower mass limit for H$^{\pm\pm}_L$ (a) and H$^{\pm\pm}_R$ (b) for any combination of Br(H$^{\pm\pm}\rightarrow$l$^{\pm}$l$^{\pm}$)=100%. Fit performed varying Br(H$^{\pm\pm}\rightarrow$l$^{\pm}$l$^{\pm}$) from 10% to 100% in steps of 10%.

Observed limits at 95% CL on $H_L^{\pm\pm}$ mass vary from 770-870 GeV (850 GeV expected) and from 660-760 GeV (730 GeV expected) for $H_R^{\pm\pm}$, under $Br(H^{\pm\pm}\rightarrow l^{\pm}l^{\pm})$=100% assumption.

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