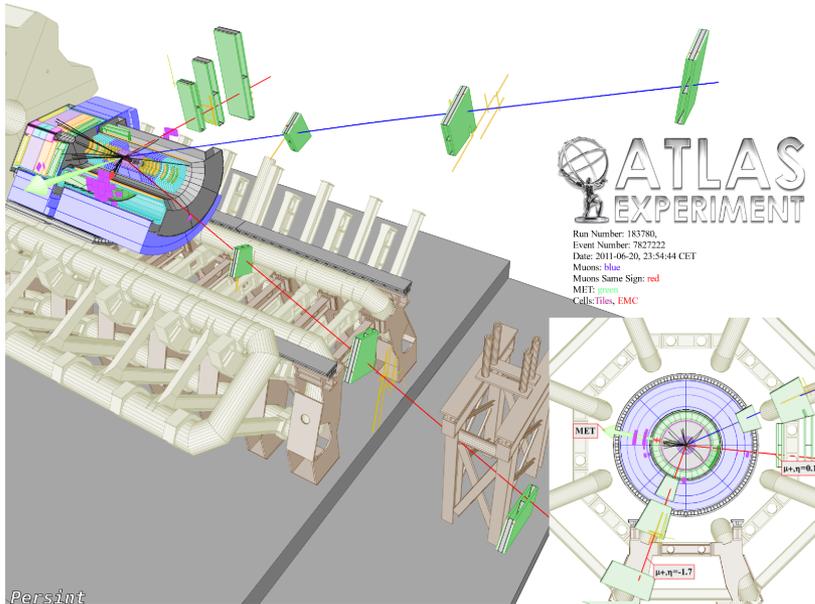


Search for new physics in the same-sign dilepton final states with ATLAS detector



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Motivation

- Many new physics models to produce same-sign leptons in the final state.
 - Supersymmetry
 - Universal extra dimensions
 - Left-right symmetric models
 - Higgs triplet models
 - Little Higgs models
 - Seesaw models
 - Vector-like quark models
- We search for inclusive same-sign leptons to minimize the model dependence.
 - JHEP12(2012)007 (arXiv:1210.4538[hep-ex])
- We also look for doubly-charged Higgs.
 - Eur.Phys.J.C72(2012)2244 (arXiv:1210.5070[hep-ex])

Tight lepton selection

- Tight criteria for **electron and muon identification**.
- Cuts on both longitudinal (z_0) and transverse (d_0) **impact parameters**.
 - $|z_0 \sin\theta| < 1\text{mm}$
 - $|d_0|/\sigma(d_0) < 3$
- **Isolation cuts**:
 - Select leptons isolated from other activity.
 - Isolation variable = sum of momentum or energy around the lepton.

Loose event selection

	Selection Criteria
Primary vertex	3 or more tracks
Same-sign pair(s)	2 or more electron(s) and/or muon(s) with same charge.
Low mass resonance removal	$M(\ell\ell) > 15 \text{ GeV}$

- 3-channels: ee , $e\mu$, $\mu\mu$
 - 2011, 7TeV data, 4.7fb^{-1}
 - Single lepton triggers were used.
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- All plots are taken from
<https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2012-13/>
<https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2012-18/>

Backgrounds

- **Prompt** backgrounds:
 - WZ, ZZ, ttbarW, ttbarZ, same-sign WW.
 - Estimated from MC simulations.
- **Charge flip** and photon conversion (electron):
 - Main source is trident events:
 - $e^+ \rightarrow e^+ \gamma \rightarrow e^+ e^+ e^-$ when this e^- carry the most of p_T of the original e^+
 - Estimated from MC simulations:
 - Drell-Yan(Z^*), ttbar, WW, Wgamma
 - Scale factor is derived by comparing to data in Z-peak region.
- **Non-prompt/Fake** backgrounds:
 - Semileptonic b and c quark decay
 - K and pi decay in flight
 - Jet faking a lepton

Fake factor method

- Data driven method to estimate the non-prompt/fake background.

	Satisfy isolation	Fail isolation
Data which satisfy signal selection	Signal region	Signal side band (Fake dominant)
Fake dominant sample	Fake which satisfy signal selection	Fake which fail isolation

- Calculate fake factors from fake dominant samples (di-jet samples).
- Fake factor = (fake which pass signal selection)/(fake which pass fake selection).
 - Fake selection = fail isolation cuts.
- Apply the fake factor to the data:
 - Count fakes in the signal sideband region.
 - Then apply the fake factor to estimate the number of fakes in the signal region.

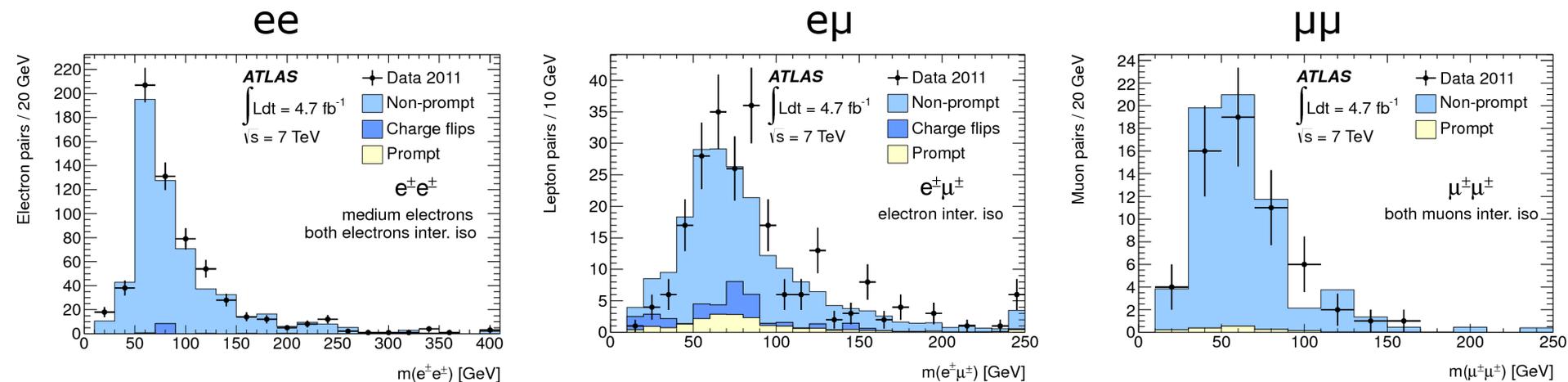
Fake factor method

	Satisfy isolation	Fail isolation
Data which satisfy signal selection	Signal region	Signal side band (Fake dominant)
Fake dominant sample	Fake which satisfy signal selection	Fake which fail isolation

- Key assumption is:
Fake factor (= the ratio of left/right) is the same both in signal like region and fake dominant sample
- This is the source of systematic errors.

Fake control regions

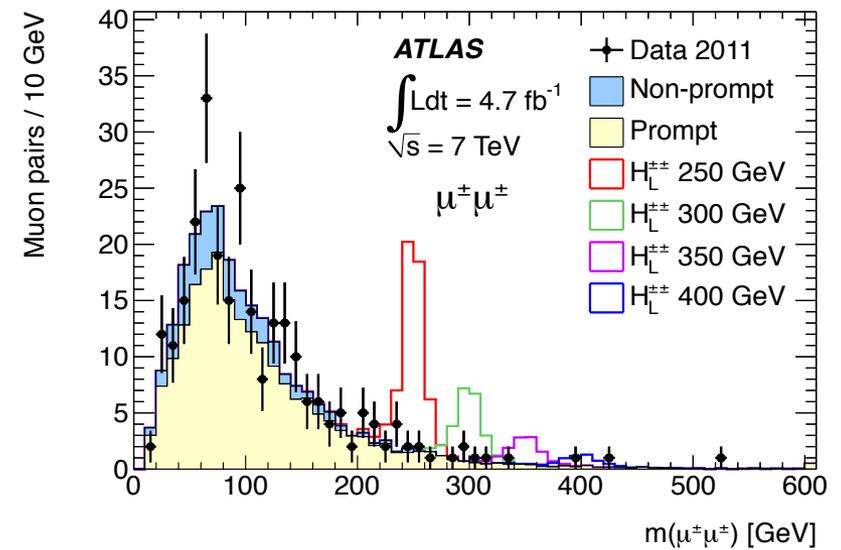
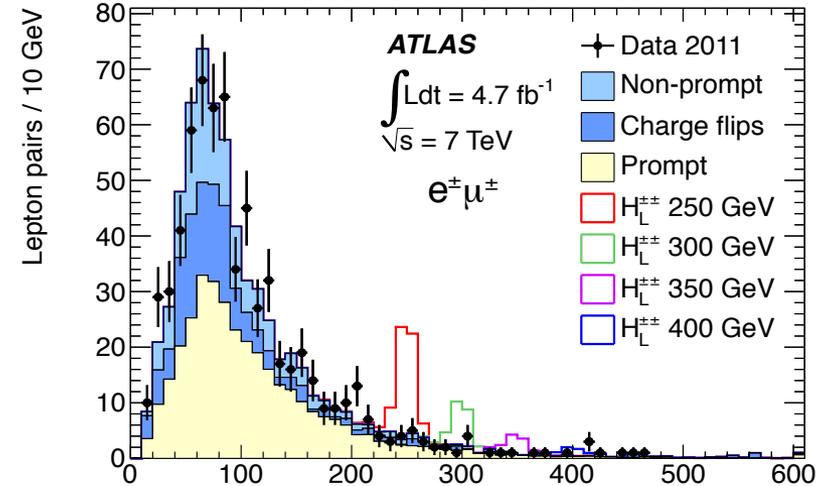
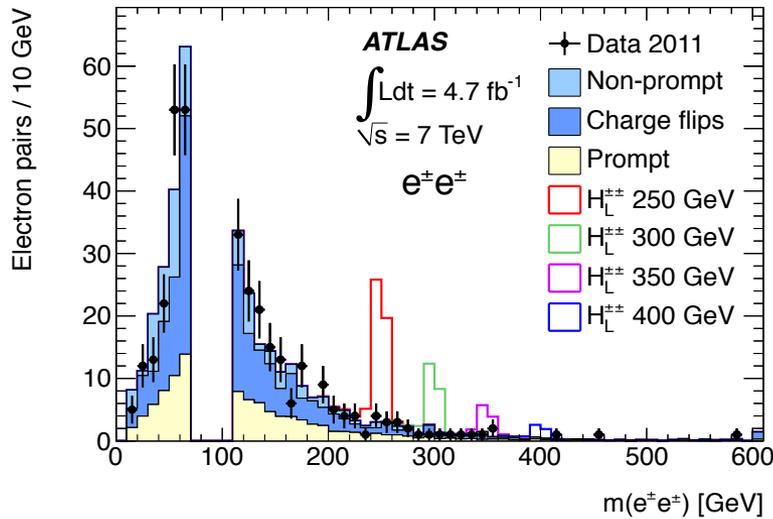
- We check the validity of our fake factor method using fake control regions.
- We select the signal sideband region dominated by non-prompt/fakes.
 - Sideband = looser particle ID, reversed impact parameter cut, reversed isolation cuts.
- Good agreement between data and expectation



Systematic Uncertainties

- Non-prompt background (Fake)
 - Limited data statistics, fake estimate : 15-100%
- Charge-flip background
 - Scale factor, MC cross section etc. : $\sim 10\%$
- Prompt background
 - Lepton ID efficiency : $\sim 3\%$
 - MC cross section : $\sim 10\%$
- Luminosity : 3.9%

Signal regions

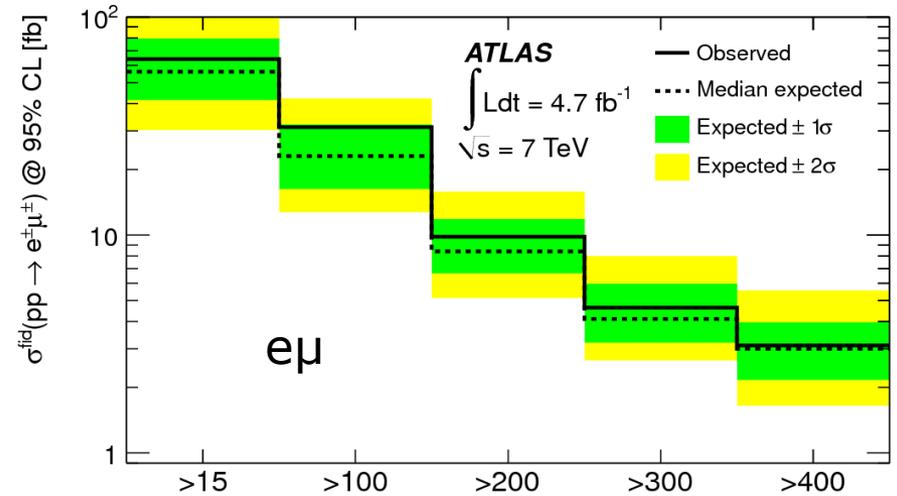
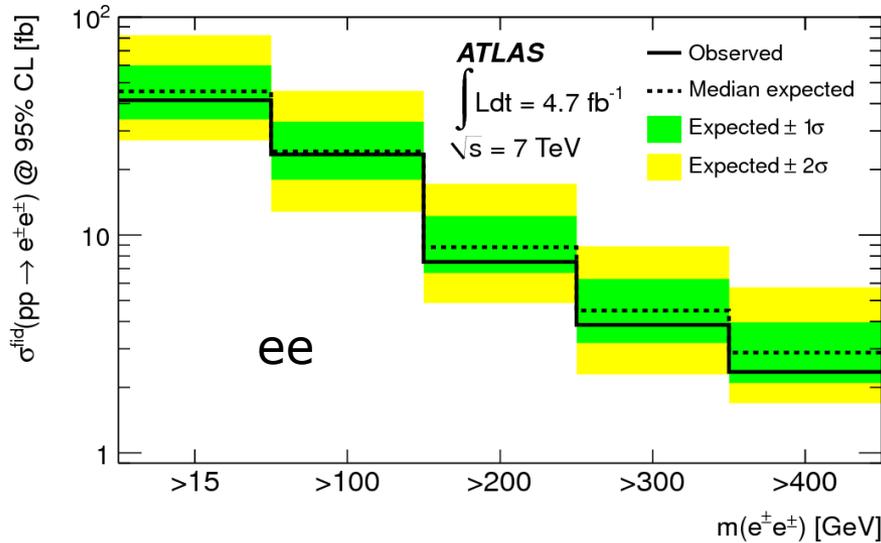


No significant deviation from expected background.
No significant bumps, no overall excess.

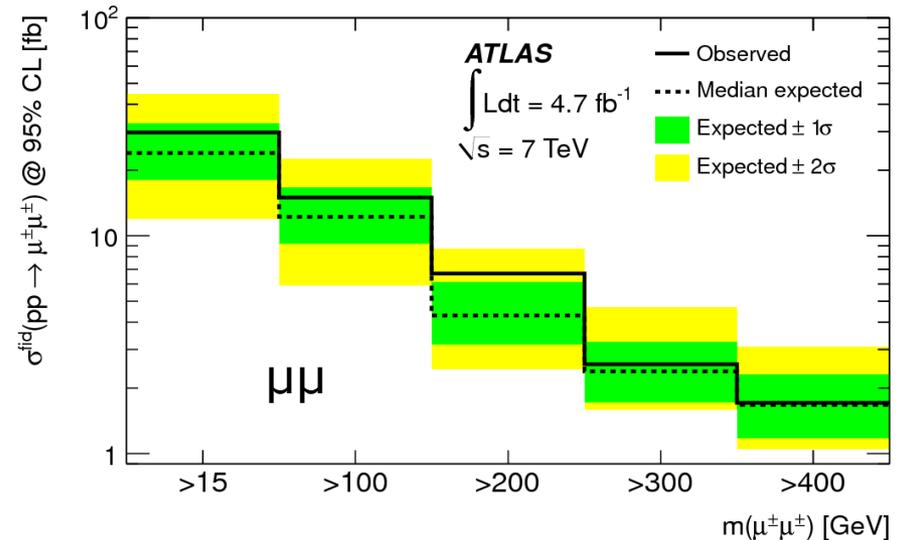
Fiducial cuts

- We set fiducial cuts to reduce model dependence in selection efficiency.
- Fiducial cuts are the same cuts as the selection cuts but with truth variables (so that theorists can reproduce cuts).
- Efficiency variation between different models gets smaller after fiducial cuts.
- We take the lowest efficiency to be conservative.
 - ee: 43%, $e\mu$: 55%, $\mu\mu$: 59%

Fiducial cross section limits

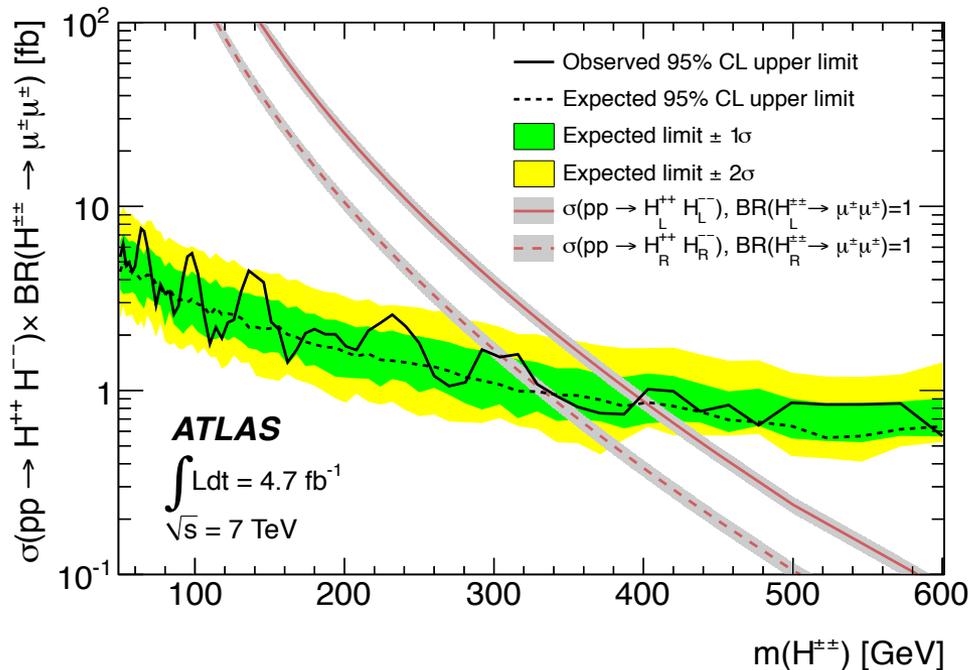


- $\mu\mu$ is the best channel



Limits on doubly-charged Higgs

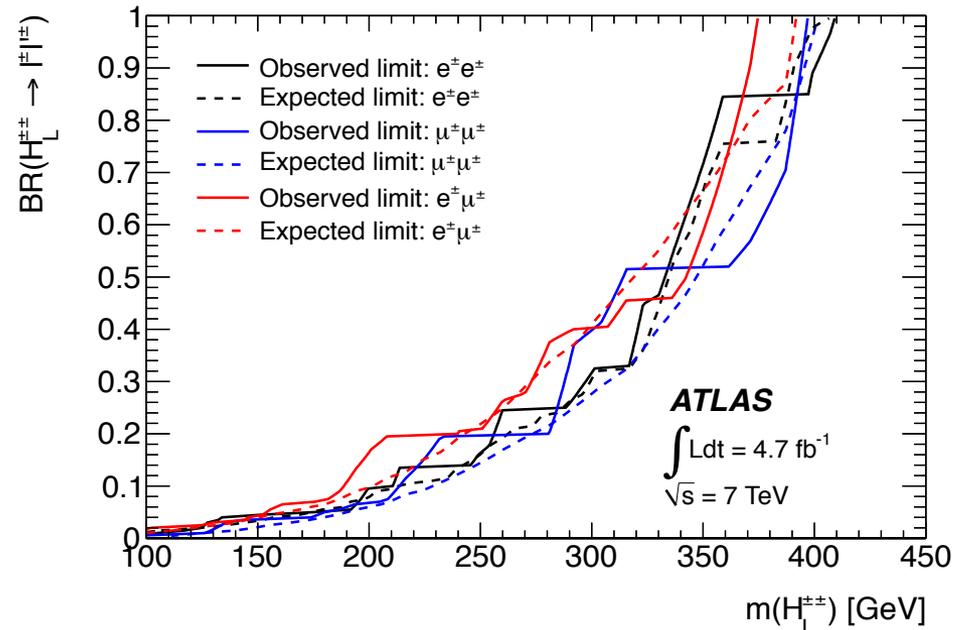
- Doubly charged Higgs can be pair produced:
 - $pp \rightarrow H^{++}H^{--}$
- Doubly charged Higgs decays to two same-sign leptons: $H^{++} \rightarrow |^+|^+$



$\mu\mu$ -channel

Mass limits vs Branching Ratio

$BR(H_L^{\pm\pm} \rightarrow \ell^\pm \ell'^{\pm})$	95% CL lower limit on $m(H_L^{\pm\pm})$ [GeV]					
	$e^\pm e^\pm$		$\mu^\pm \mu^\pm$		$e^\pm \mu^\pm$	
	exp.	obs.	exp.	obs.	exp.	obs.
100%	407	409	401	398	392	375
33%	318	317	317	290	279	276
22%	274	258	282	282	250	253
11%	228	212	234	216	206	190



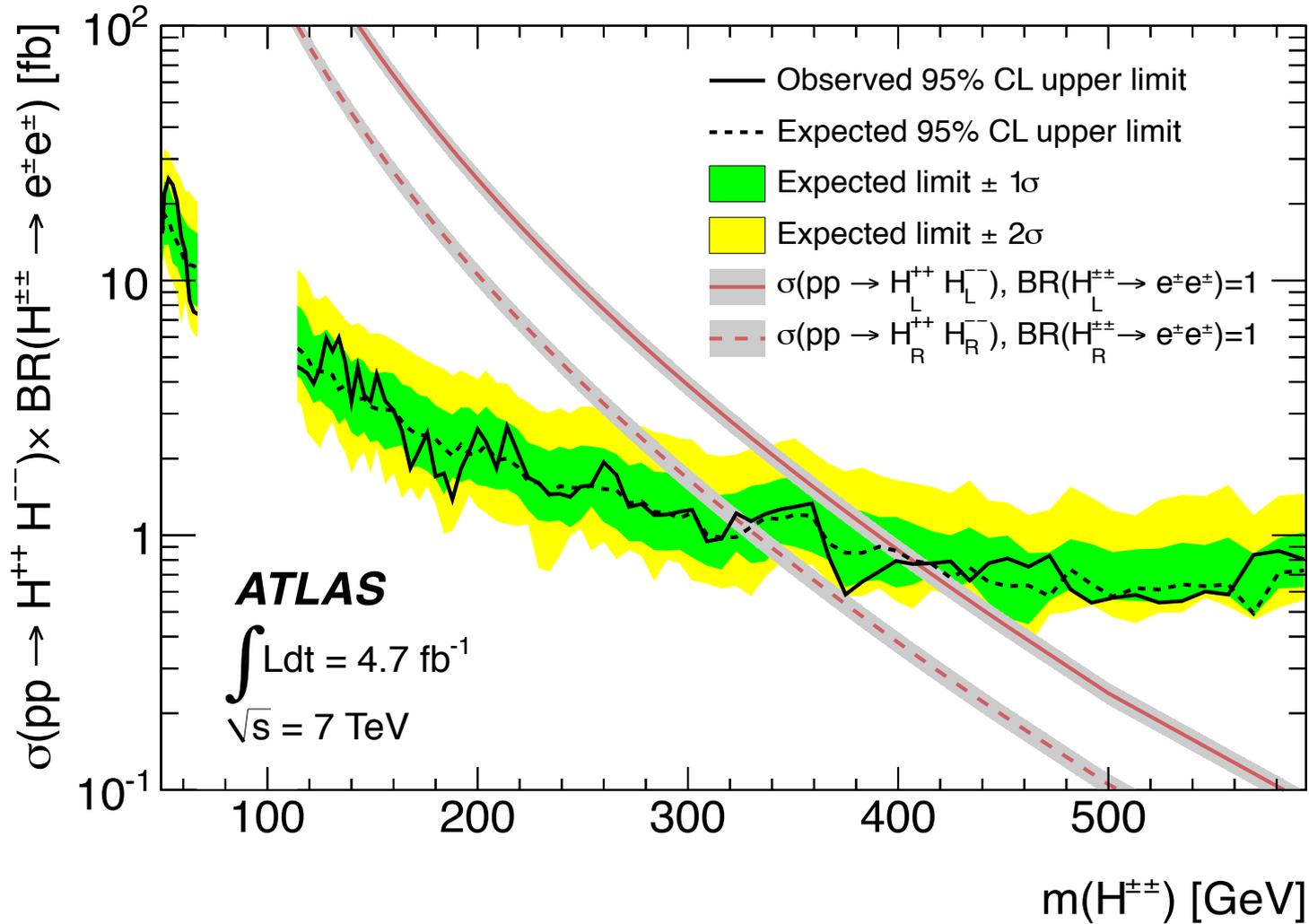
Conclusion and prospects

- Same-sign dilepton final states are searched.
- Good estimates for the main backgrounds:
 - Prompt, charge-flip, non-prompt/fake
- No excess is observed and fiducial cross section limits are set.
 - As a function of dilepton mass.
- Doubly-charged Higgs mass limits are set.
 - Best mass limits as of 2013
- 2012, 8TeV, 20 fb⁻¹ data is under analysis. Results will be made public in July.
 - Big improvements are expected; sensitivity in the doubly-charged Higgs mass increase by $\sim 100\text{GeV}$.

Back up: Tight lepton selection

	Electron	Muon
Particl ID etc.	isEM tight++	Staco muon, Charge: $Q_{ID} = Q_{MS}$
Leading p_T	25 GeV	25 GeV
Subleading p_T	20 GeV	20 GeV
Eta	$ \eta < 2.47$, excluding $1.37 < \eta < 1.52$	$ \eta < 2.5$
Impact parameter	$ z_0 \sin\theta < 1\text{mm}$	$ z_0 \sin\theta < 1\text{mm}$
	$ d_0 /\sigma(d_0) < 3$	$ d_0 < 0.2\text{mm},$ $ d_0 /\sigma(d_0) < 3$
Track isolation	$ptcone30/E_T < 0.1$	$ptcone40/p_T < 0.06$
Calo isolation	$Etcone20 <$ $3 + 0.037(E_T - 20)$	
Overlap removal	$\Delta R(e, \mu) > 0.05$ $\Delta R(e, jet) > 0.40$	$\Delta R(\mu, jet) > 0.40$

Back-up: ee-channel



Back-up: $e\mu$ -channel

