

# Searches for heavy long-lived charged particles with the ATLAS detector in $p$ - $p$ collisions at $\sqrt{s} = 8$ TeV

Reference: ATLAS Collaboration, JHEP 1501 (2015) 068

## Abstract

Searches for heavy long-lived charged particles (LLP) were performed on a  $19.1 \text{ fb}^{-1}$  data sample from  $p$ - $p$  collisions at  $\sqrt{s} = 8 \text{ TeV}$  collected by the ATLAS detector at the LHC. No excess is observed above the estimated background and limits are placed on the mass of the LLPs in various supersymmetric models: R-hadrons, directly produced charginos, stable sleptons produced directly or in cascade decays in GMSB and LeptoSUSY models.

## Selection

- **Event selection:** Good primary vertex & triggered by either Muon or MET trigger
- **Candidate selection:** Reconstruction quality cuts,  $p_T$ ,  $\eta$ ,  $\beta$ ,  $p$  and consistency of  $\beta / \beta\gamma$
- The candidate selection is constructed and tuned per search
- Division into signal-regions and  $\beta$ ,  $\beta\gamma$  and mass cuts per SR
- Mass cuts in all searches are model dependent (In R-hadrons also the cuts on  $\beta, \beta\gamma, p$ )

Search	Signal regions	LLP mass [GeV]	$N_{\text{cand}}$	Momentum [GeV]	$ \eta $	$E_T^{\text{miss}}$ [GeV]	$\beta$	$\beta\gamma$
Sleptons	SR-SL-2C	175-510	2	$p_T > 70$	$< 2.5$		$< 0.95$	consistency
	SR-SL-1C	175-510	1	$p_T > 70$	$< 2.5$		$< 0.85$	consistency
Charginos	SR-CH-2C	100-800	2	$p_T > 70$	$< 2.5$		$< 0.95$	consistency
	SR-CH-1LC	100-800	1	$p_T > 70$	$< 1.9$	$> 100^{***}$	$< 0.95$	consistency
	SR-CH-1C	100-800	1	$p_T > 70$	$< 1.9$		$< 0.85$	consistency
R-hadrons	SR-RH-MA	400-1700	$\geq 1$	$p > 140-200^*$	$< 1.65$		$< 0.88-0.74$	$< 2.3-1.15$
	SR-RH-FD	400-1700	$\geq 1$	$p > 140-200^*$	$< 1.65^{**}$		$< 0.88-0.74$	$< 2.3-1.15$

\*  $\Delta R_{\text{jet}, p_T > 40 \text{ GeV}} > 0.3$ ,  $\Delta R_{\text{track}, p_T > 10 \text{ GeV}} > 0.25$     \*\* only for ID+CALORIMETER candidates    \*\*\*  $\Delta\phi_{\text{LLP}, E_T^{\text{miss}}} > 1.0$

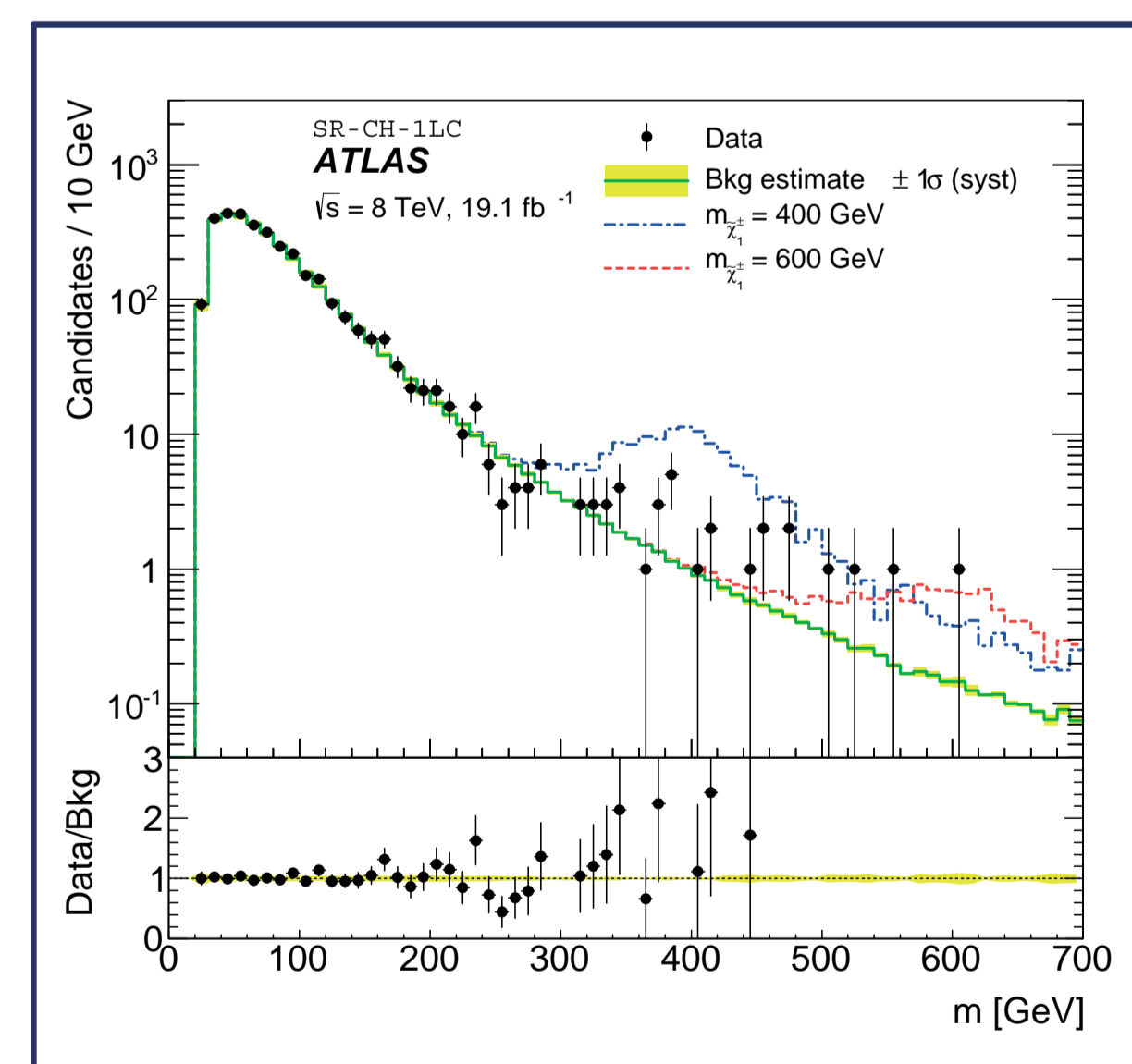
## Limits Summary

Search	Lower mass limit [GeV]
GMSB sleptons	
• $\tan \beta = 10, 20, 30, 40, 50$	440, 440, 430, 410, 385
• direct $\tilde{\ell}$ production ( $m_{\tilde{\ell}} - m_{\tilde{\tau}_1} = 2.7-93 \text{ GeV}$ )	377-335
• direct $\tilde{\tau}_1$ production	289
• $\tilde{\chi}_1^0 \tilde{\chi}_1^\pm$ decaying to stable $\tilde{\tau}_1$	537
LeptoSUSY	
• $\tilde{q}, \tilde{g}$	1500, 1360
Charginos	
• $\tilde{\chi}_1^\pm$	620
R-hadrons	
• $\tilde{g}, \tilde{b}, \tilde{t}$ (full-detector)	1270, 845 and 900
• $\tilde{g}, \tilde{b}, \tilde{t}$ (MS-agnostic)	1260, 835 and 870

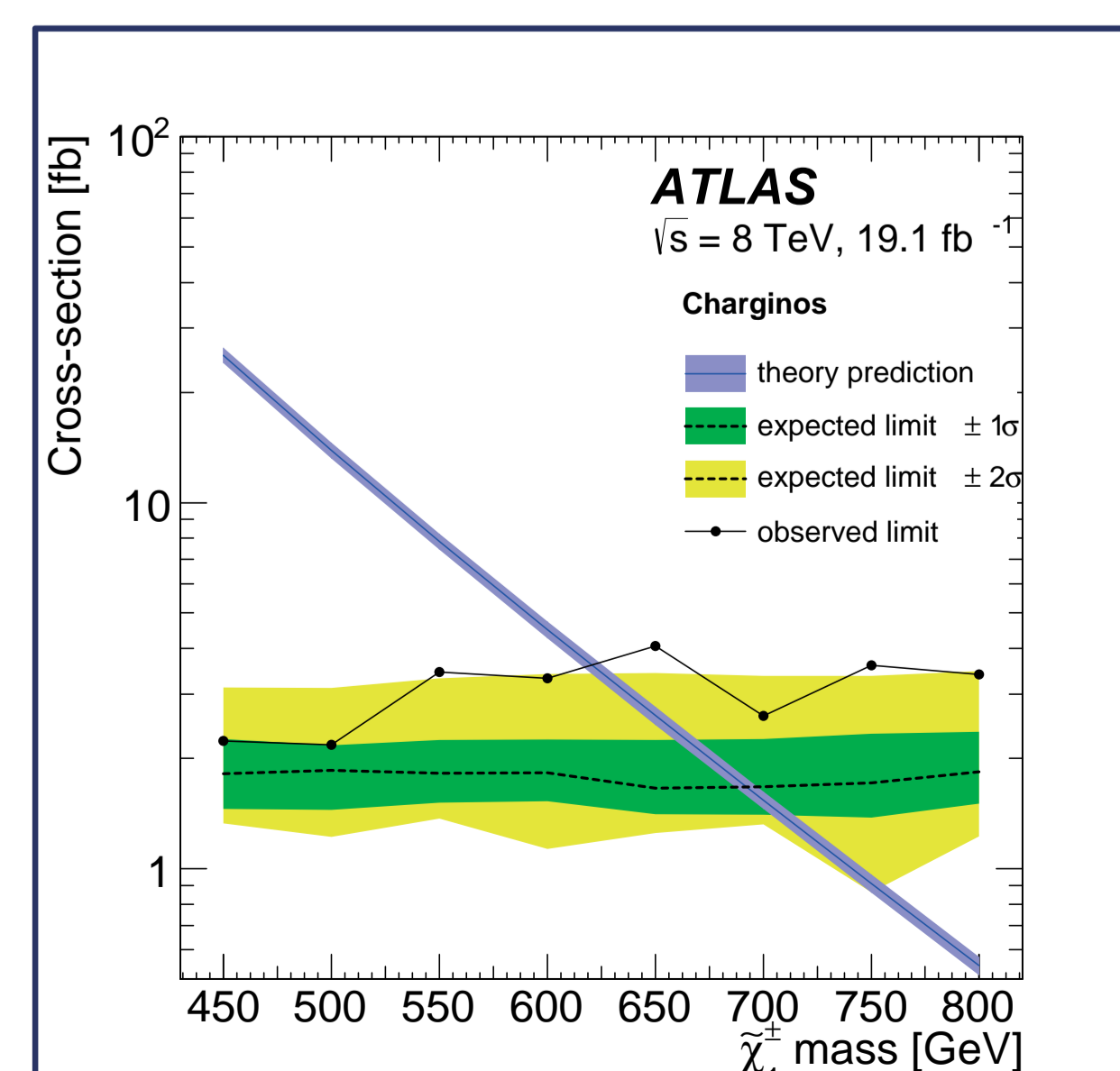
## Results & Limits on LLP cross-sections (CLs based)

### Charginos

Reconstructed mass, background estimation & expected signal:

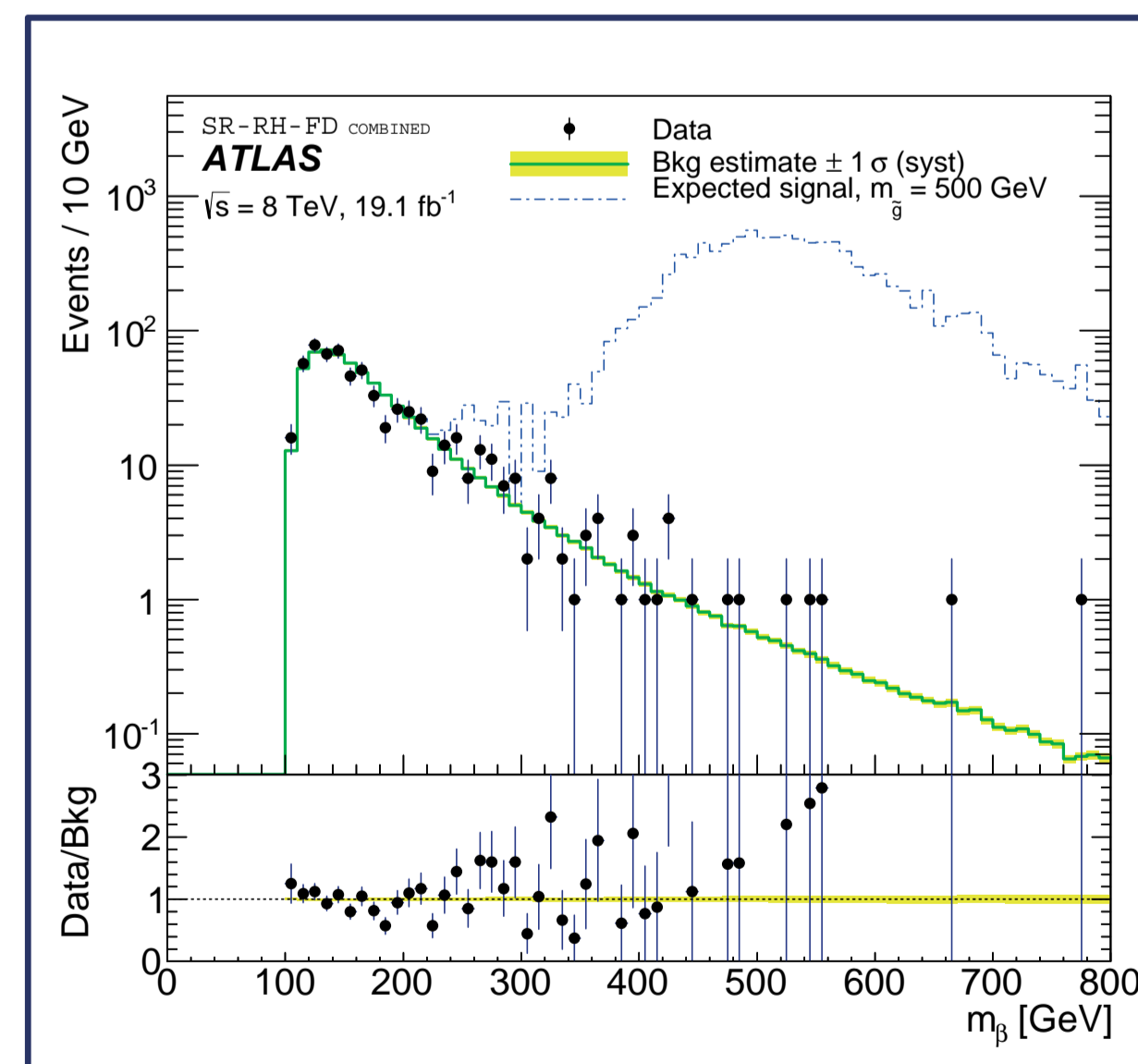


Cross-section upper limits:

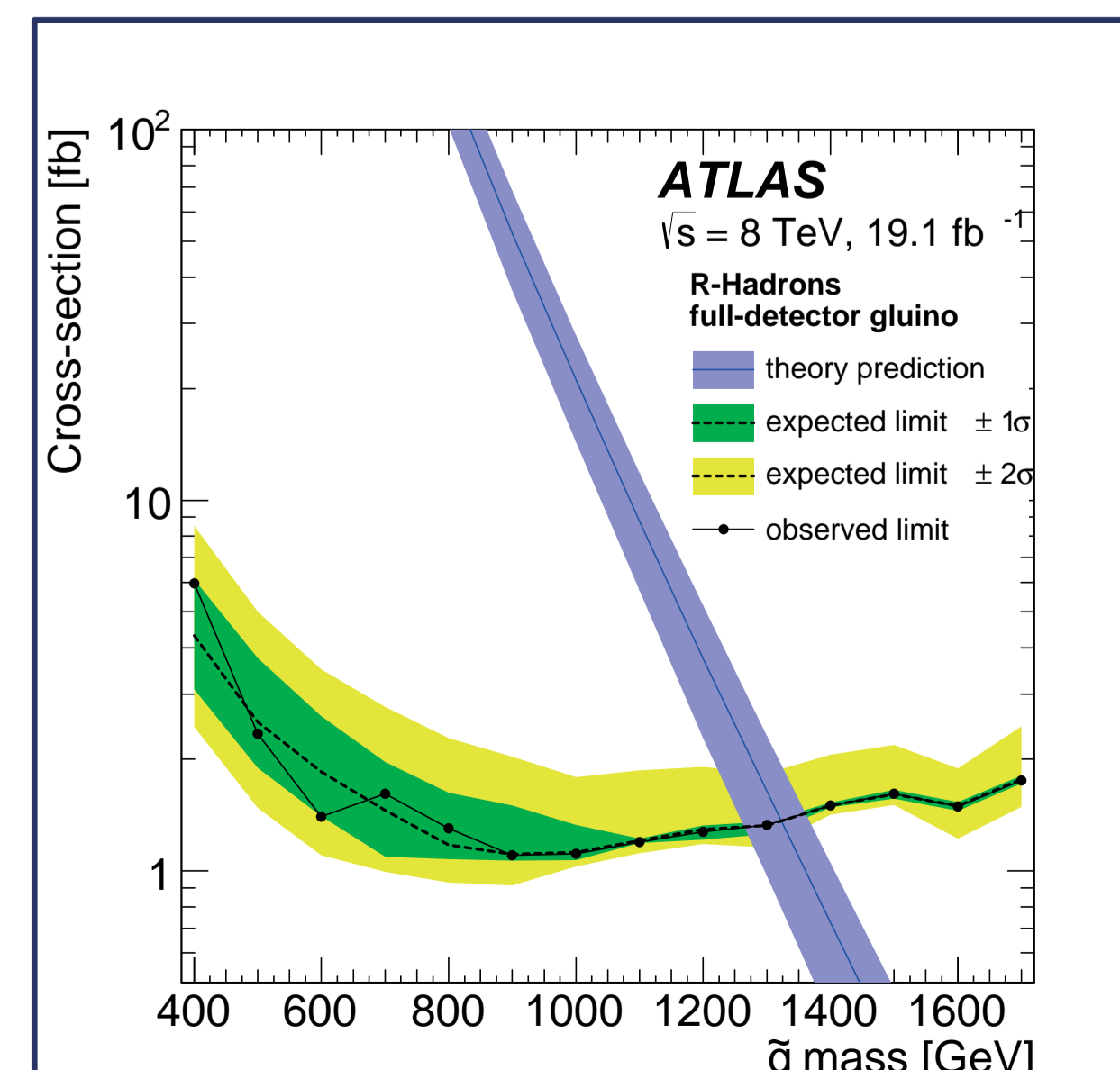


### R-hadrons

Reconstructed mass, background estimation & expected signal:



Cross-section upper limits:



## Motivation & Signal Regions

Heavy LLPs are predicted in many extensions to the Standard Model. This analysis studies different SUSY LLP scenarios where R-parity is conserved

### R-hadrons

- Long-lived  $\tilde{g}, \tilde{t}$  or  $\tilde{b}$  bound to colored SM particles to form R-Hadron
  - Cuts on  $\beta, \beta\gamma, p$  depend on LLP mass
- Signal regions:
- Full detector search (SR-RH-FD). MS info may or may not be found
  - MS-Agnostic search (SR-RH-MA). Track information from ID+Calo

### Charginos

- $\tilde{\chi}_1^\pm$  nearly mass degenerate with  $\tilde{\chi}_1^0$  (LSP)
- $\tilde{\chi}_1^\pm \tilde{\chi}_1^\pm - 33\%$  expected 2 LLPs (muon like)
- $\tilde{\chi}_1^0 \tilde{\chi}_1^\pm - 67\%$  expected 1 LLP + MET

Signal regions:

- Loose two-candidates (SR-CH-2C)
- Loose one-candidate+ MET (SR-CH-1LC)
- Tight one-candidate (SR-CH-1C)

### Sleptons

#### GMSB:

- The  $\tilde{\tau}$  is the NLSP, the  $\tilde{G}$  is the LSP
- Due to small coupling to the  $\tilde{G}$ , the NLSP is long-lived

- EW ( $\tilde{\chi}_1^\pm, \tilde{\chi}_1^0 \rightarrow \tilde{l} \rightarrow \tilde{\tau}$ ) & direct Slepton production ( $\tilde{l} \rightarrow \tilde{\tau}$  or  $DY \tilde{\tau}$ ) were considered

#### LeptoSUSY:

- $\tilde{g}/\tilde{q}$ , decaying to jets and multiple leptons to a final state with stable  $\tilde{l}$
- Two muon-like LLPs are expected

Signal regions:

- Loose two-candidates (SR-SL-2C)
- Tight one-candidate (SR-SL-1C)

## Analysis Strategy

Track information is used to calculate the candidate mass:  $m = \frac{p}{\beta\gamma}$ :

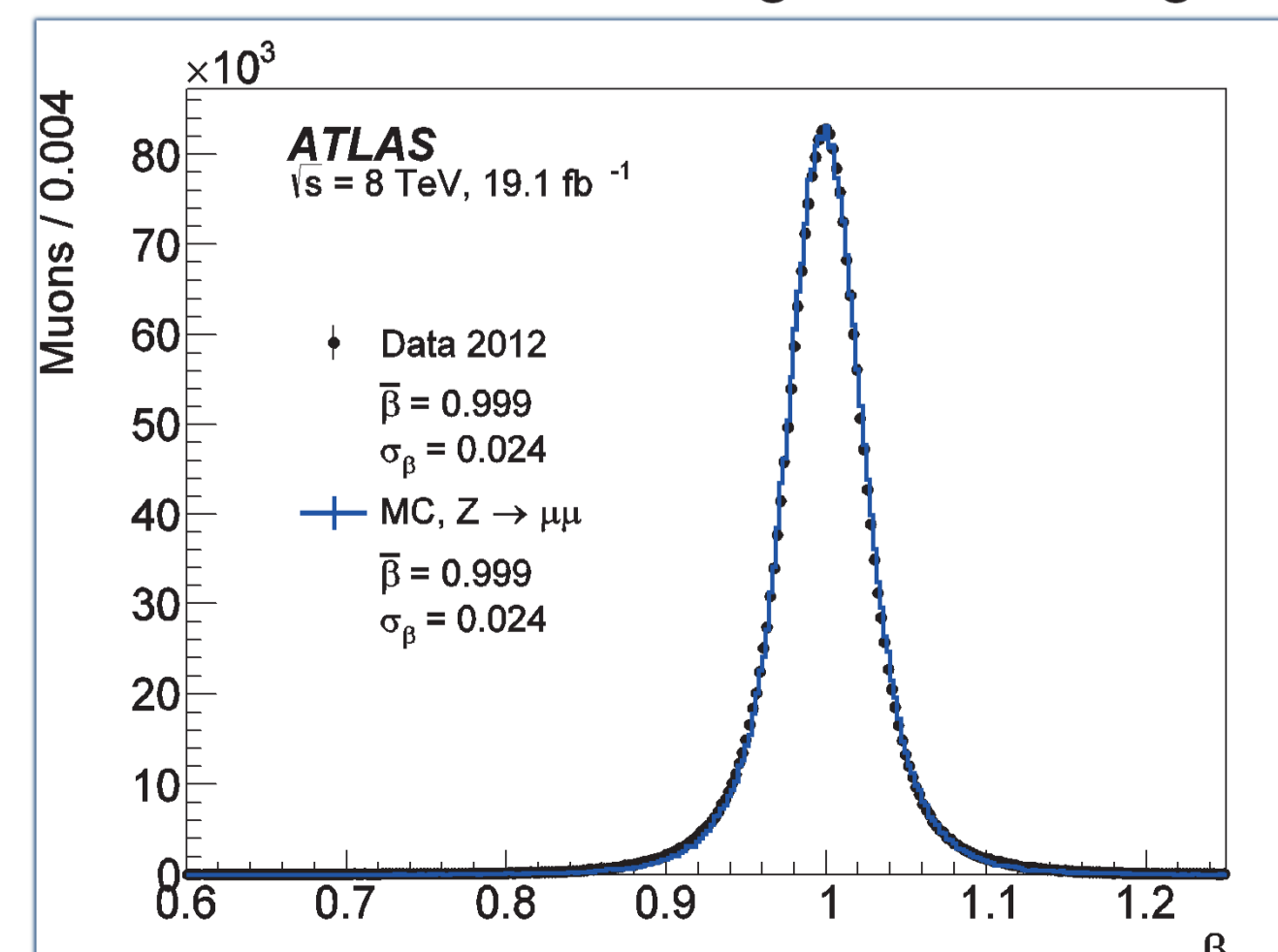
- $p$  derived from the candidate track
- $\beta$  calculated from measured ToF
- $\beta\gamma$  deduced from Pixel  $dE/dx$

The background estimation for all searches is based on data:

- Mostly  $\mu$ 's of high- $p_T$  and miss-measured  $\beta$
- Elimination of possible correlation between  $p$  and  $\beta$  by division into  $\eta$  regions
- Estimated per search per signal region

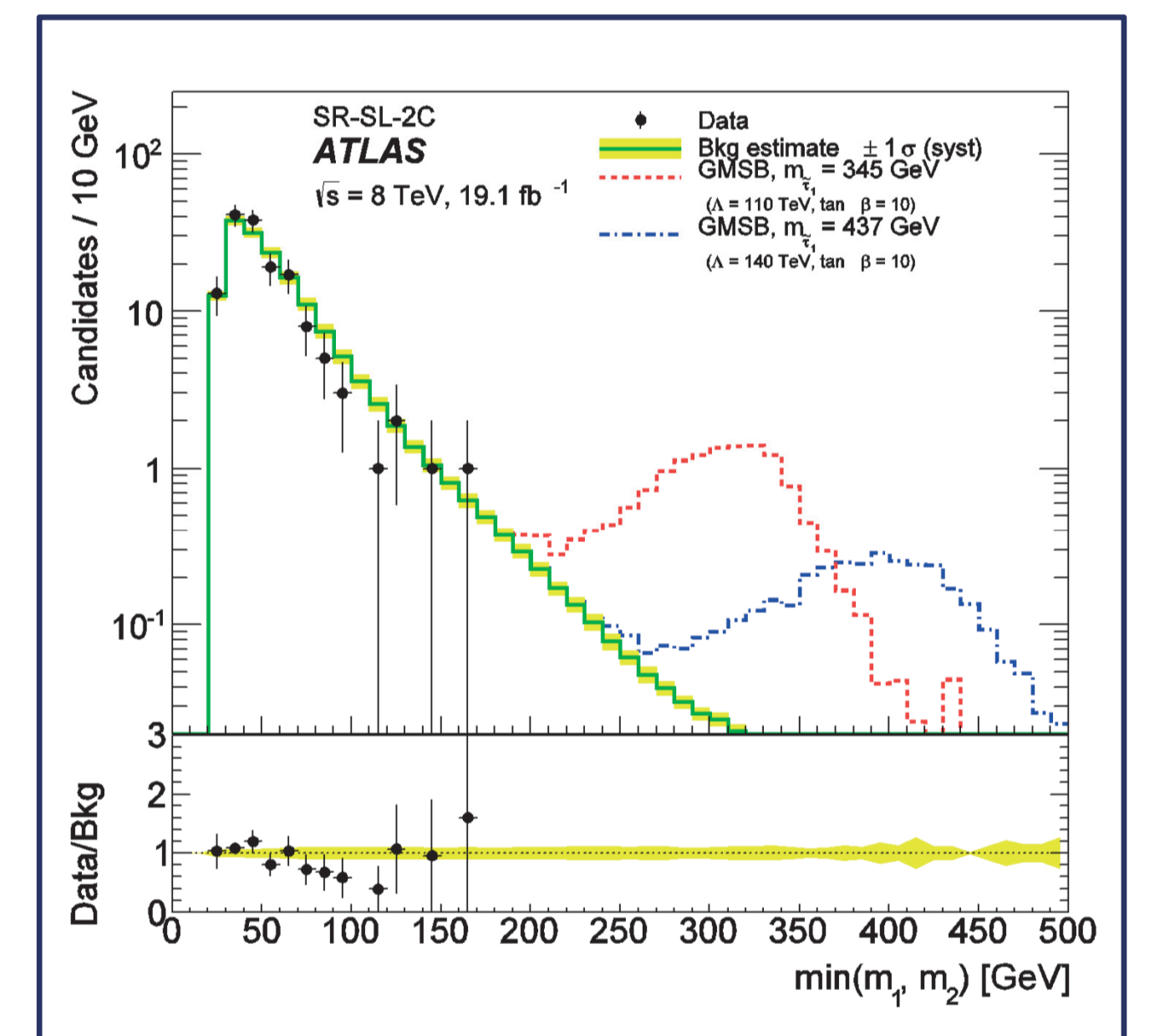
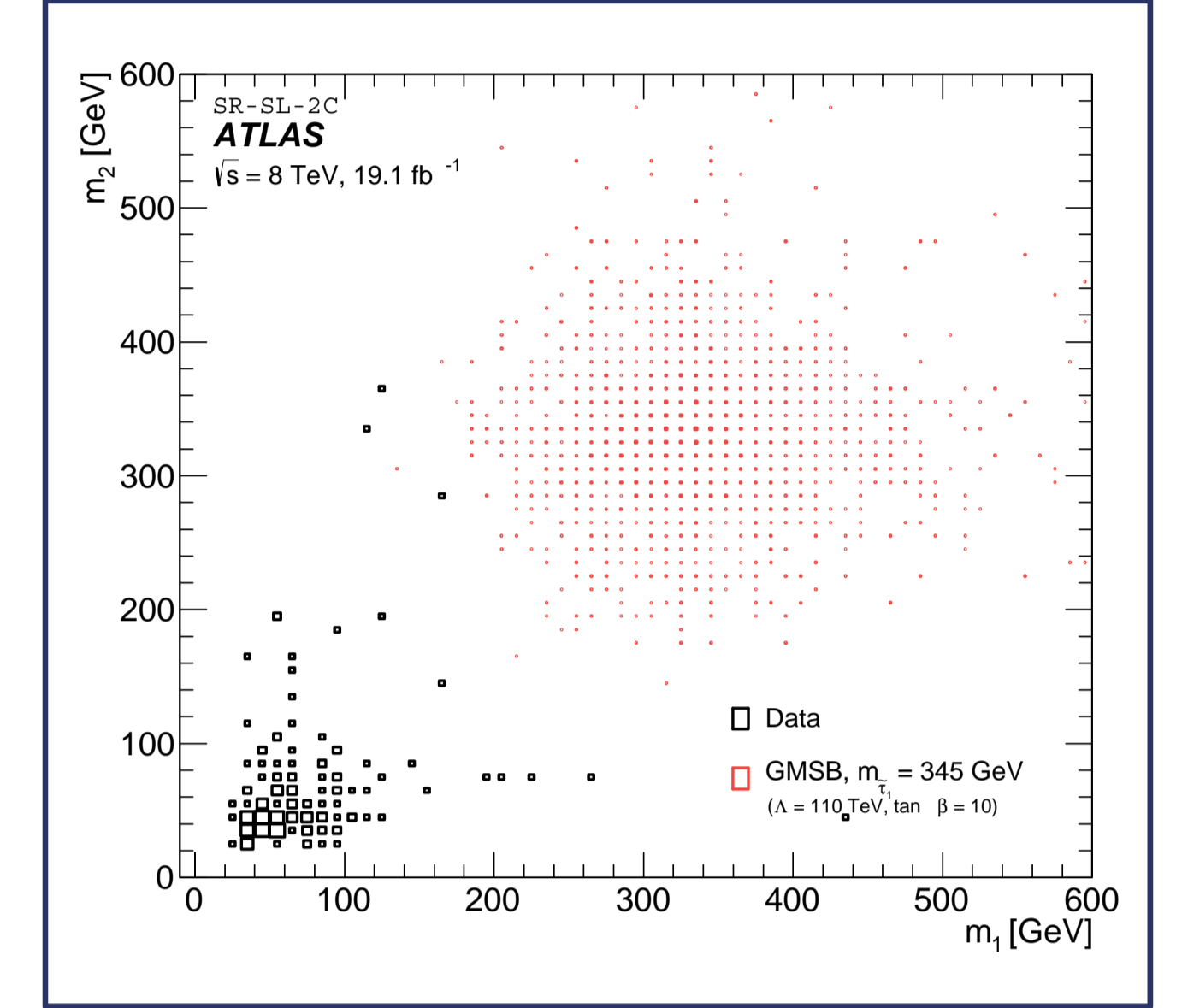
### $\beta$ Estimation

- ToF deduced from hits on the track (Tile+Lar, RPCs and MDTs)
- Correction to the hit-times for:
  - LHC-ATLAS phase difference (per run)
  - Offsets by detector element
- Smearing of hit-times in MC according to calibrated hit-times distribution in  $Z \rightarrow \mu\mu$  data (checked with  $Z \rightarrow \mu\mu$  MC)
- Individual sub-detector  $\beta$  measurements are combined in a weighted average



## Sleptons

Reconstructed mass, background estimation & expected signal:



Cross-section upper limits:

