ATLAS searches for R-parity violating SUSY

Vasiliki A. Mitsou (IFIC Valencia)

for the ATLAS Collaboration

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Outline

- R-parity violation (RPV) in SUSY
  - phenomenological consequences
- **Bilinear RPV – prompt LSP decays**
- **Resonant sneutrino LSP**
- Summary

Acknowledgement: Largely based on talk by
Emma Torró Pastor, SUSY2011, 28 Aug – 2 Sep 2011, Fermilab

R-parity violation

- R-parity: $R = (-1)^{3(B-L)+2s} \rightarrow R = \begin{cases} +1, \text{ for SM particles} \\ -1, \text{ for superpartners} \end{cases}$
- R-parity conservation hinted but not required by proton stability

L-number violating terms

$$W_{\not R p} = \lambda_{ijk}\hat{L}_i\hat{L}_j\hat{E}^C_k + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}^C_k + \epsilon_i\hat{L}_i\hat{H}_u + \lambda''_{ijk}\hat{U}^C_i\hat{D}^C_j\hat{D}^C_k$$

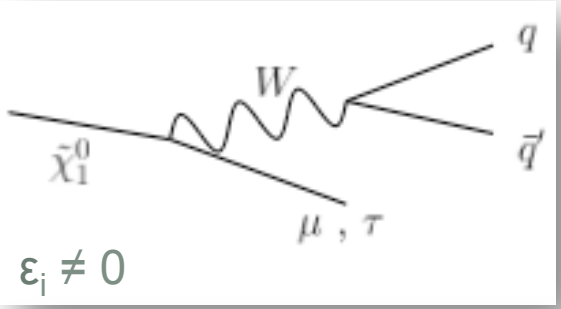
bilinear terms

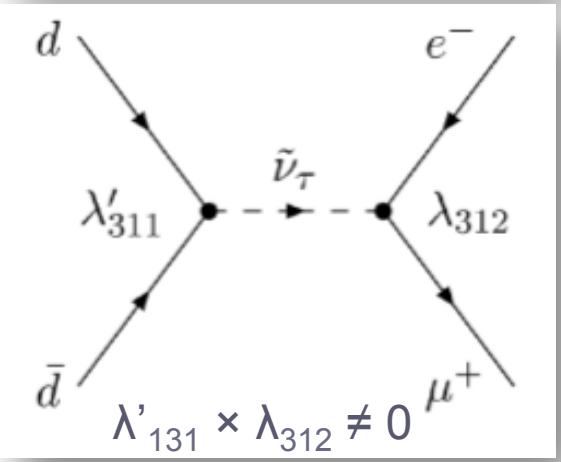
B-number violating terms

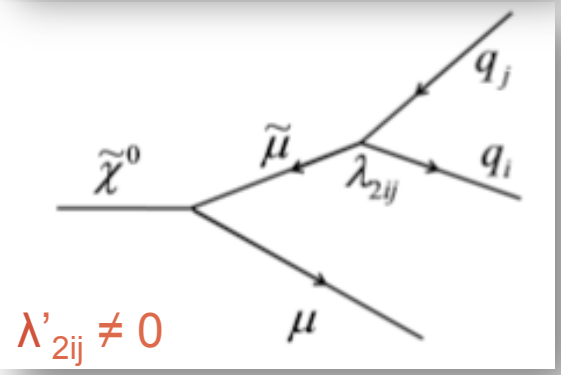
Rp conservation	Rp violation
Sparticles produced in pairs	Single sparticle production possible
Neutral and colorless LSP	LSP may be charged and/or carry color
Stable LSP → gives rise to high missing momentum	LSP decays → possibility for new signals • exploit LSP invariant mass • potentially long LSP lifetime • MET may or may not be high

ATLAS RPV SUSY analyses

- Bilinear RPV [arXiv:1109.6606]
  - $\tilde{\chi}_1^0$ LSP not stable, decaying promply to a **muon and two jets**
  - analysis optimised for Rp conserving searches requiring **exactly one muon and several jets**
  - based on **1.04 fb^{-1}** of 2011 collision data
- Resonant sneutrino LSP [arXiv:1109.3089]
  - $\tilde{\nu}_\tau$ LSP which can decay to an **electron** and a **muon**
  - search for excess in high **eμ invariant mass**
  - performed using **1.07 fb^{-1}** of 2011 collision data
- Displaced vertices [arXiv:1109.2242]
  → see Yuya Azuma's earlier talk





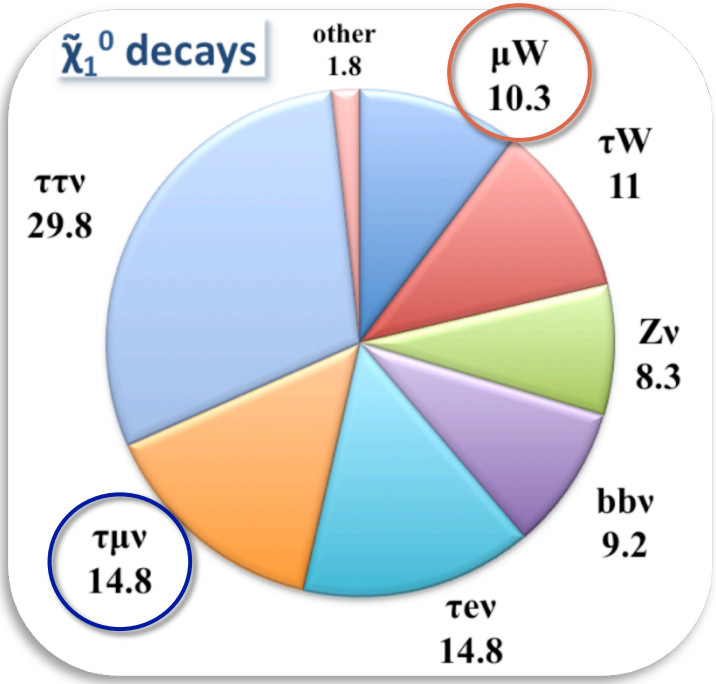


Bilinear RPV

- Bilinear R-parity violating (bRPV) terms in superpotential introduce **neutrino masses and mixings** in an natural way
- Hence RPV parameters constrained by neutrino measurements:

$$\Delta m_{atm}^2,\ \Delta m_{sol}^2,\ \tan^2\theta_{atm},\ \tan^2\theta_{sol}$$

- bRPV couplings embedded in mSUGRA
  - same cascade decay
  - LSP decays at the end
- Large variety of final states to explore
  - most of them involve leptons and taus
- Features high MET originating mainly from various LSP decays to neutrinos



Bilinear RPV: signal regions

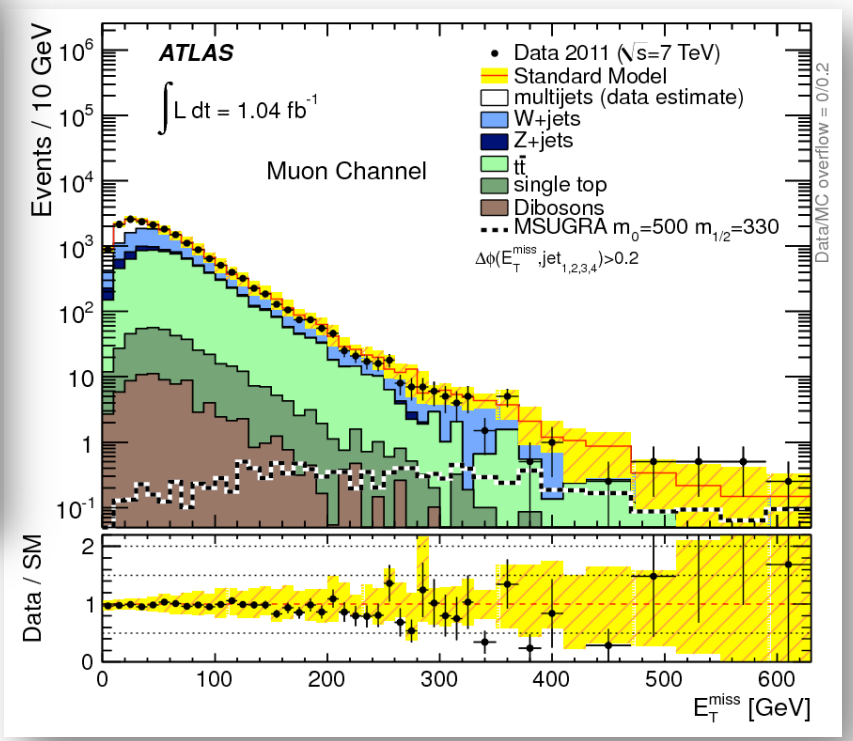
- Common event selection:
  - exactly one isolated muon with p_T > 20 GeV
  - veto for events with at least one electron with p_T > 20 GeV, aimed at avoiding overlap with other analyses
- Four signal regions requiring 3 or 4 jets with loose or tight cuts

See also Timo Müller's talk yesterday on MET+jets+leptons

Selection	Signal Regions 3JL	3JT	4JL	4JT	Control Regions 3J	4J
Number of Leptons	= 1					
Lepton p_T (GeV)	> 25(20) for electrons (muons)					
Veto lepton p_T (GeV)	> 20(10) for electrons (muons)					
Number of jets	≥ 3		≥ 4		≥ 3	≥ 4
Leading jet p_T (GeV)	60	80	60	60	60	60
Subsequent jets p_T (GeV)	25	25	25	40	25	25
$\Delta\phi(\vec{\text{jet}}_i, \vec{E}_T^{\text{miss}})$	[> 0.2 (mod.π)] for all 3 (4) jets					
m_T (GeV)	> 100				40 < m_T < 80	
E_T^{miss} (GeV)	> 125	> 240	> 140	> 200	30 < E_T^{miss} < 80	
$E_T^{\text{miss}}/m_{\text{eff}}$	> 0.25	> 0.15	> 0.30	> 0.15	–	–
m_{eff} (GeV)	> 500	> 600	> 300	> 500	> 500	> 300

$$m_{\text{eff}} = p_T^{\ell} + \sum_{i=1}^{3(4)} p_T^{\text{jet}_i} + E_T^{\text{miss}}$$

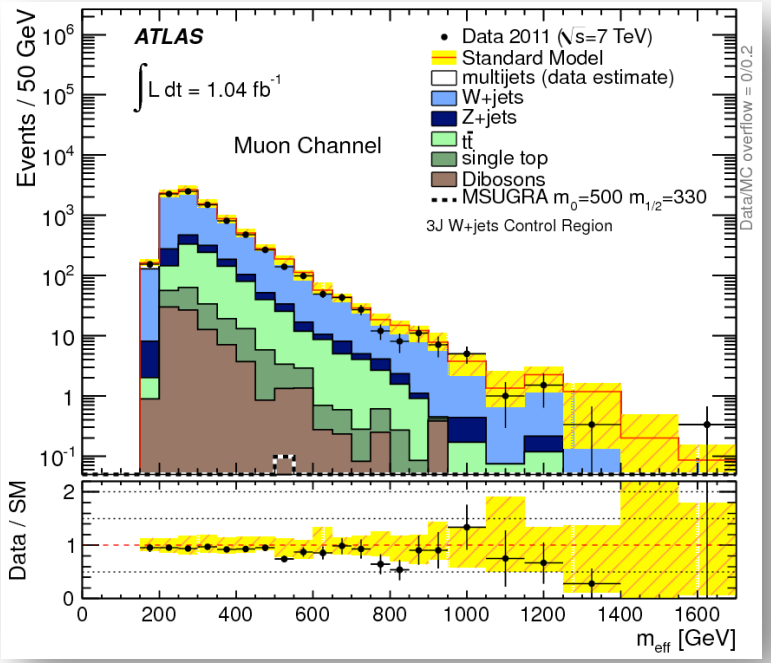
$$m_T = \sqrt{2 \cdot p_T^{\ell} \cdot E_T^{\text{miss}} \cdot (1 - \cos(\Delta\phi(\vec{\ell}, \vec{E}_T^{\text{miss}})))}$$



Bilinear RPV: background

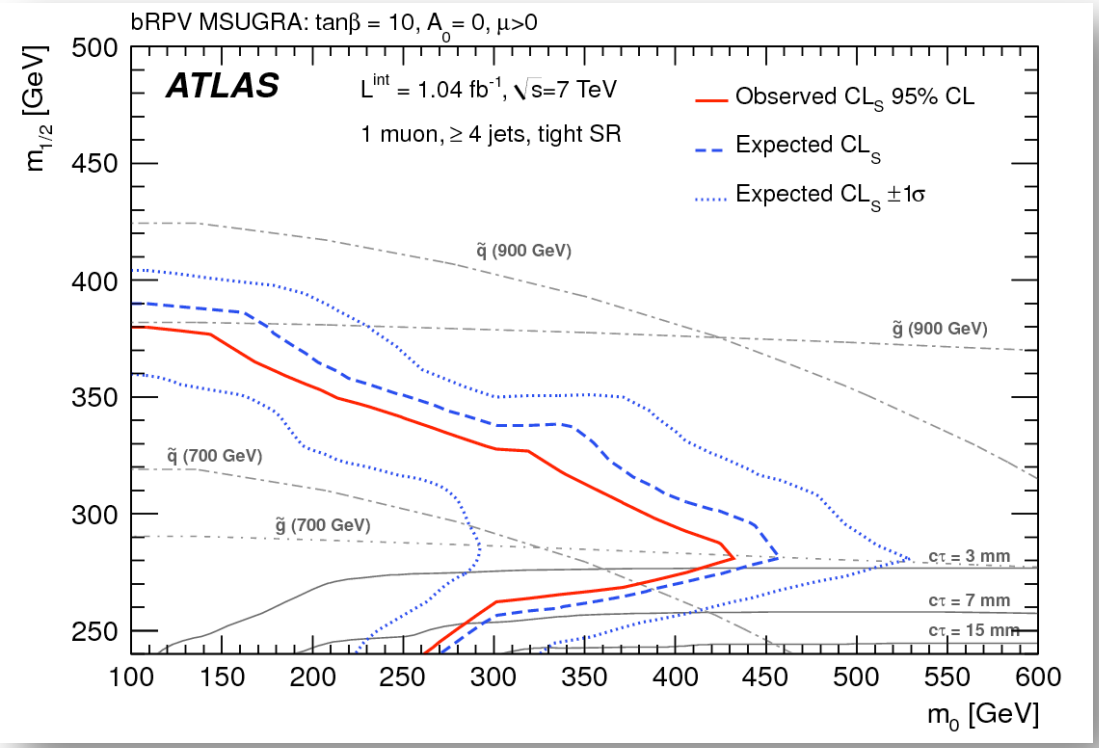
- Separate control regions for 3-jet & 4-jet selections
  - same lepton and jets requirements as in the corresponding signal region
- Final determination of background done through simultaneous likelihood fit of control regions to account for cross contamination
- MC simulation prediction of backgrounds in signal regions validated by checking additional control regions
- Possible contamination from atmospheric muons found to be negligible
- Background from single top and dibosons found to be small
- Systematic uncertainties: dominated by theoretical uncertainties (20 – 30%); rest less than 15%

Control region:	W+jets	Top
$\Delta\varphi(\text{jet}_i, E_T^{\text{miss}})$	> 0.2	
m_T	40 GeV < m_T < 80 GeV	
E_T^{miss}	30 GeV < E_T^{miss} < 80 GeV	
M_{eff} [GeV]	> 500 (3J) ; > 300 (4J)	
#selected jets tagged as b-jets	0	≥ 1



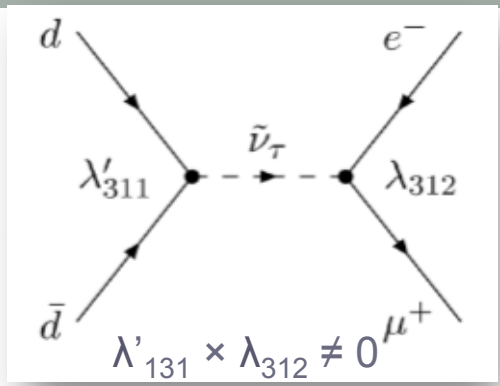
Bilinear RPV: results

- No excess of events observed!
- 95% CL exclusion limits in the 4JT SR for mSUGRA bRPV

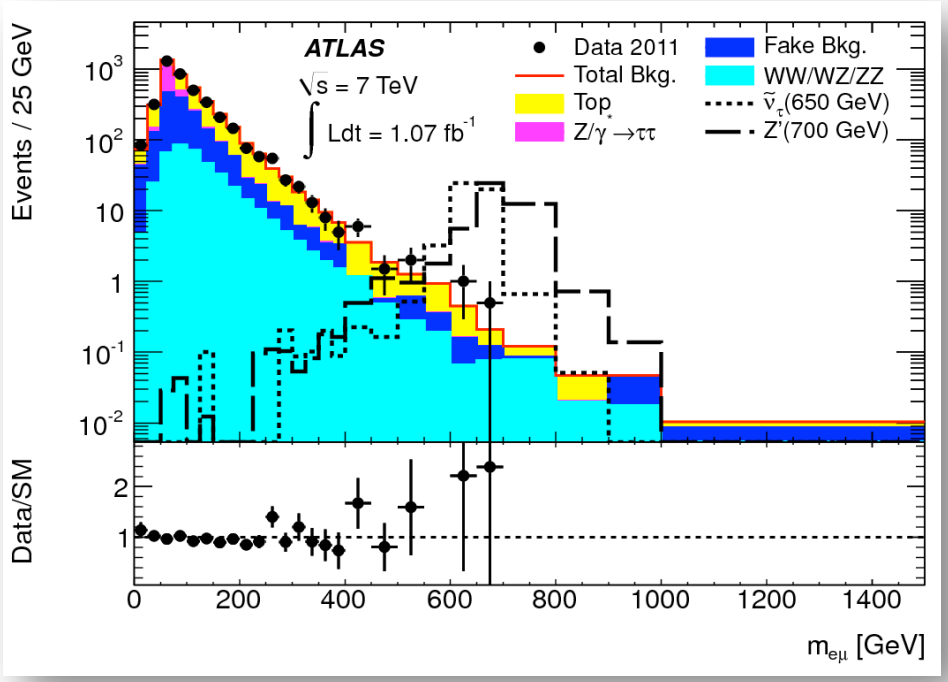


Muon channel		
Signal region	Observed	Fitted background
3JL	58	64 ± 19
3JT	11	13.9 ± 4.3
4JL	50	53 ± 16
4JT	7	6.0 ± 2.7

eμ resonance: analysis



- Search for an excess in high eμ invariant mass
- Clean signal: look for exactly one isolated **electron** and exactly one isolated **muon** with opposite charge and p_T > 25 GeV
- Low SM background in the high $m_{e\mu}$ region due to:
  - processes which can produce electrons and muons in the final state
  - instrumental bkg: photons or jets in the final state reconstructed as leptons

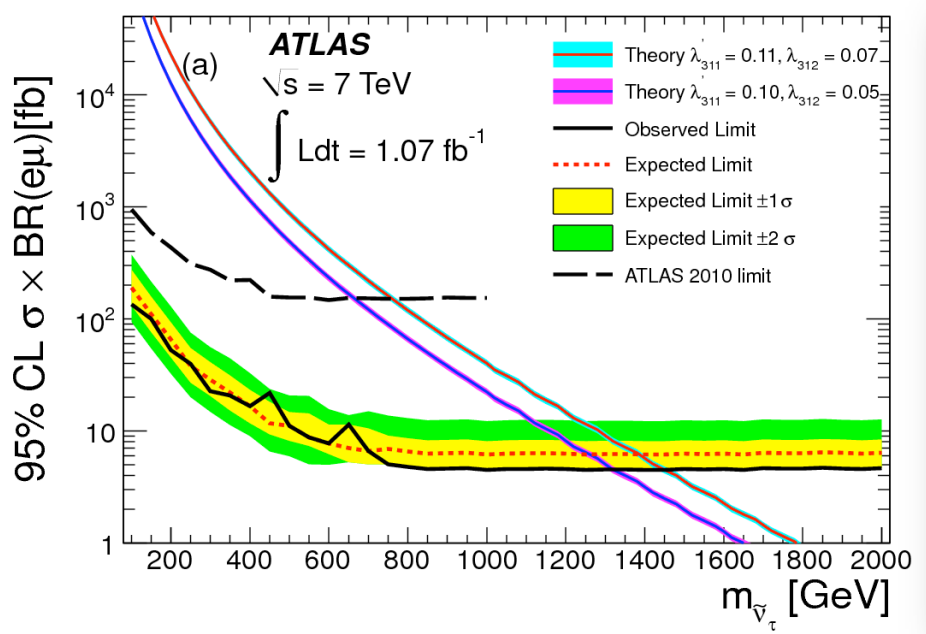


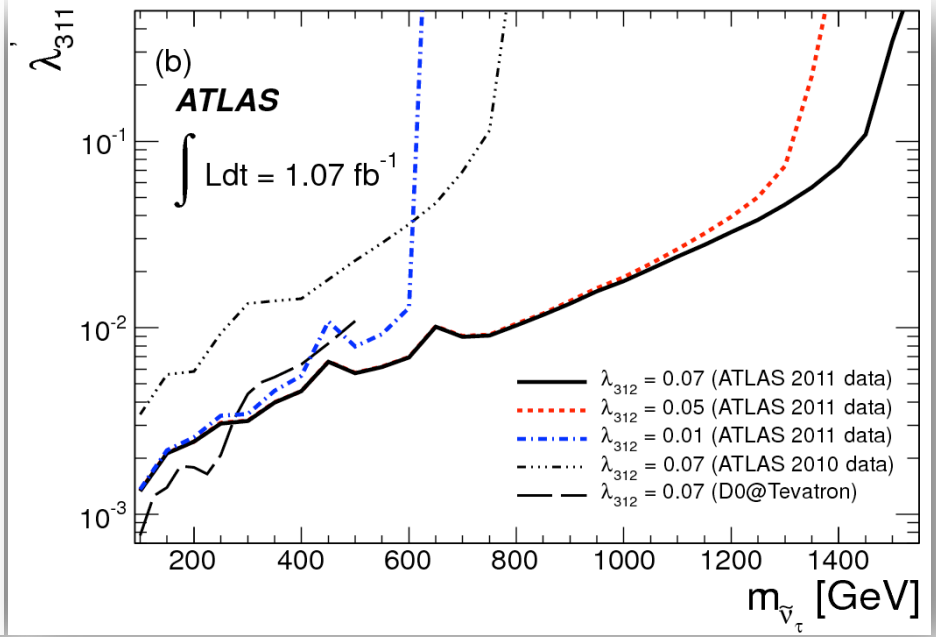
Process	Number of events
$t\bar{t}$	1580 ± 170
Jet fake	1180 ± 120
$Z/\gamma^* \rightarrow \tau\tau$	750 ± 60
WW	380 ± 31
Single top	154 ± 16
$W/Z + \gamma$	82 ± 13
WZ	22.4 ± 2.3
ZZ	2.48 ± 0.26
Total background	4150 ± 250
Data	4053

eμ resonance: results

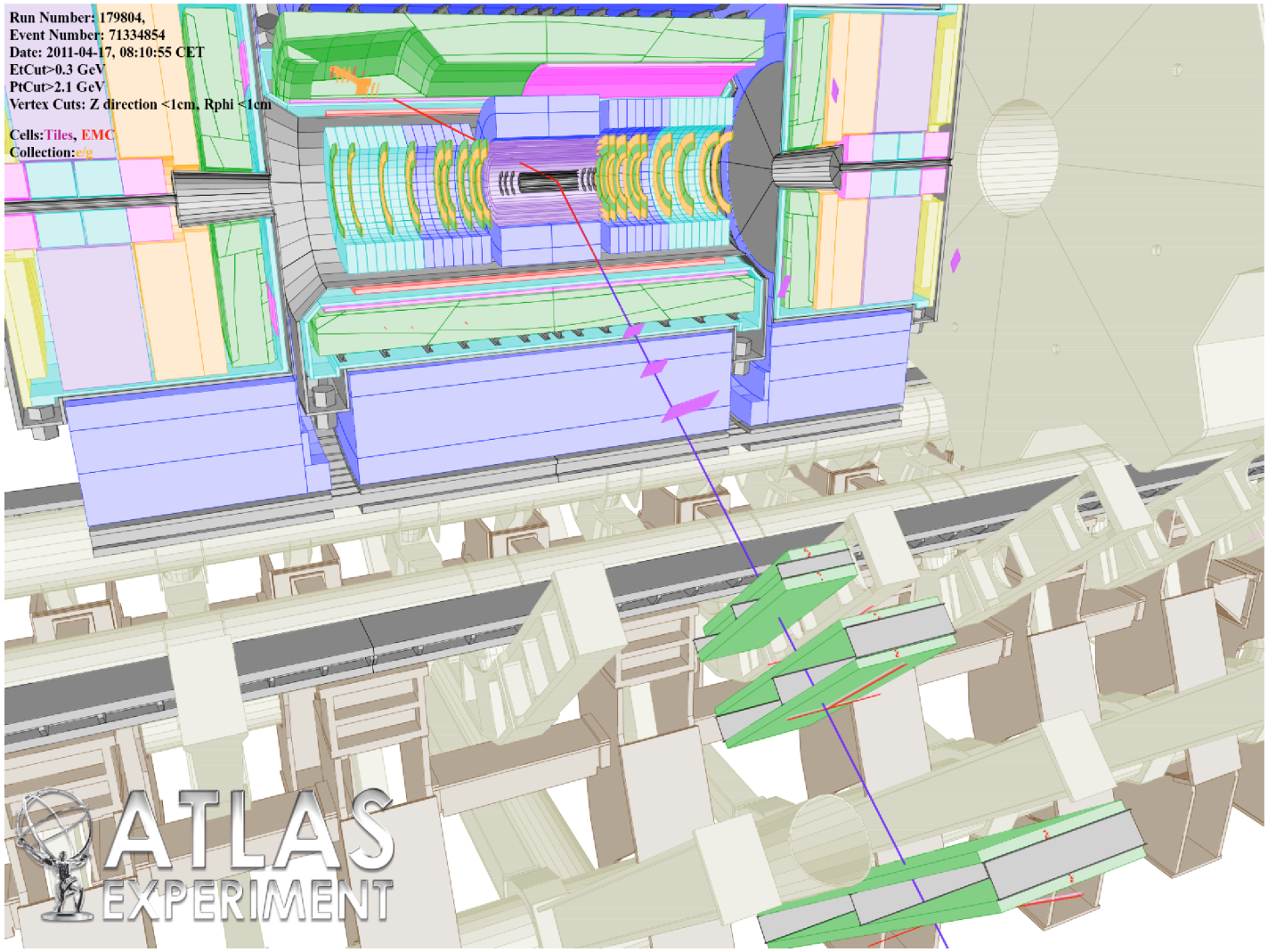
- 95% CL upper limits on $\sigma(pp \rightarrow \tilde{\nu}_\tau) \times BR(\tilde{\nu}_\tau \rightarrow e\mu)$ as a function of $m_{\tilde{\nu}}$
- Mass limits obtained are twice as high than previous ATLAS results using 35 pb^{-1} of data [PRL106,251801,2011]
- Tau sneutrinos with a mass below 1.32 (1.45) TeV are excluded, assuming coupling values $\lambda'_{311} = 0.10$ & $\lambda_{312} = 0.05$ ($\lambda'_{311} = 0.11$ & $\lambda_{312} = 0.07$)

- 95% CL upper limits on the λ'_{311} couplings as a function of $m_{\tilde{\nu}}$ for three values of λ_{312}
- Limits on λ'_{311} are better than D0 results for sneutrino mass > 270 GeV assuming λ_{312}=0.07





eμ pair with highest $m_{e\mu}$ = 662 GeV



Conclusions

- ATLAS results in searches for RPV SUSY presented
  - good understanding of detector performance & physics objects have been demonstrated, which are essential for these analysis
  - background processes well under control
- Limit setting for two different scenarios within RPV
  - sneutrino decaying to eμ resonances and bilinear RPV
  - no significant deviations from SM observed so far
  - exclusion limits set have been extended to wider parameter-space ranges
  - limits presented are the most stringent to date