Searches for R-Parity Violating Supersymmetry with the ATLAS detector

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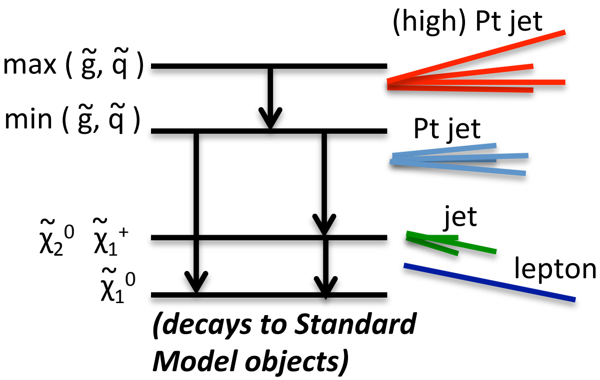
R-parity violating SUSY



R-parity conservation is added somewhat ad-hoc

RPV:

- Lepton and/or Baryon number violated, constraints from previous low energy experiments
- Strongly interacting particles, high cross sections
- LSP decays – often little or no missing momentum
- Can exploit invariant mass constraint and LSP decay properties - in general yielding rich experimental topologies
- RPV breaks the SUSY - dark matter connection

$$W_{\rm RPV} = \sum_i \mu_i L_i H_u + \sum_{i,j,k} \left(\frac{1}{2} \lambda_{ijk} L_i L_j E_k^c + \lambda'_{ijk} L_i Q_j D_k^c + \frac{1}{2} \lambda''_{ijk} U_i^c D_j^c D_k^c \right)$$

$i, j, k = (1, 2, 3)$
Label quark and lepton generations of chiral superfields

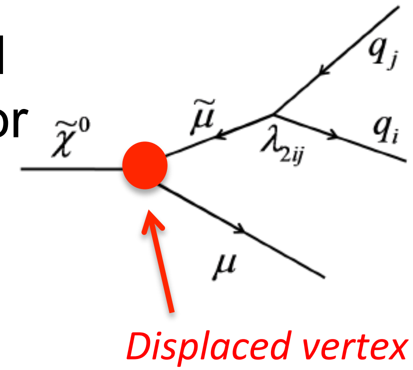
$\lambda_{ijk} = -\lambda_{jik}$, λ'_{ijk} } Responsible for lepton number violation

$\lambda''_{ijk} = -\lambda''_{ikj}$ } Responsible for baryon number violation

Analyses presented today

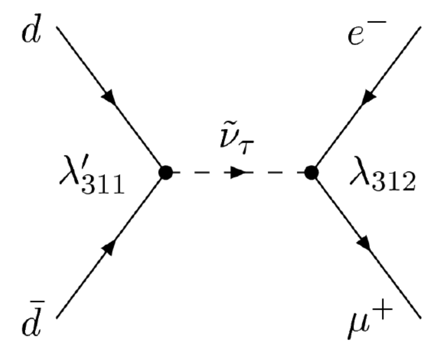
Displaced Vertex

- With λ' RPV coupling, $\tilde{\chi}^0$ decays to μ and two jets in pixel
- Muon is used for triggering, high track multiplicity good for vertex finding
- Generically sensitive to heavy long-lived particle decays to μ + jets.
- Using standard ATLAS tracking algorithms and the 2010 dataset comprising $33 pb^{-1}$ of collision data



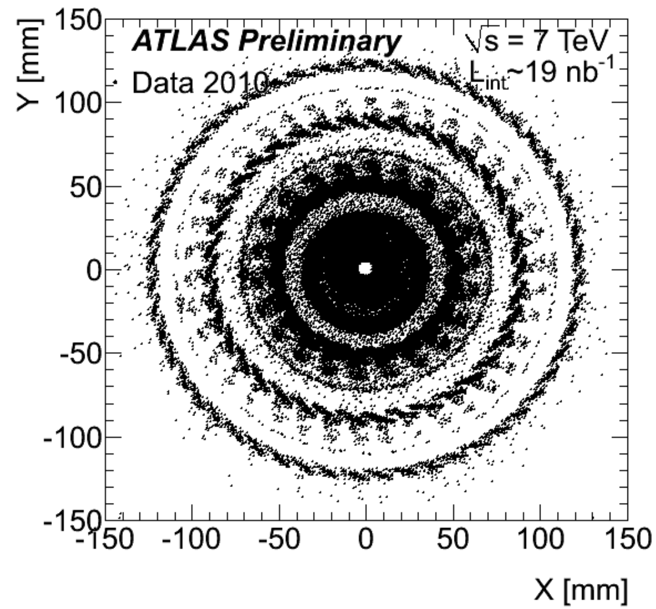
eμ resonance

- With λ' RPV coupling, resonant sneutrino (or Z') can decay into an electron-muon pair
- Use single lepton triggers and select signal candidates with exactly one high pT electron and muon
- Using $0.87 fb^{-1}$ of 2011 dataset to update analysis published in PRL analyzing 2010 data



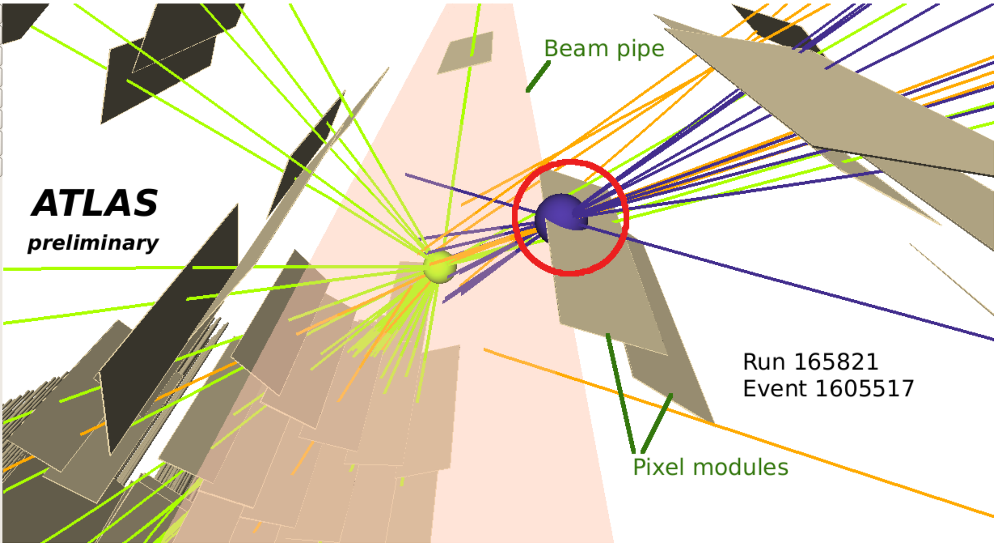
Displaced vertex: material interaction

- Dominant source of background vertices is hadronic interactions in detector material
- Generally low mass, but extra tracks could cross a real material interaction at large angle, resulting in a high-mass reconstructed vertex...



Apply a veto on material interactions

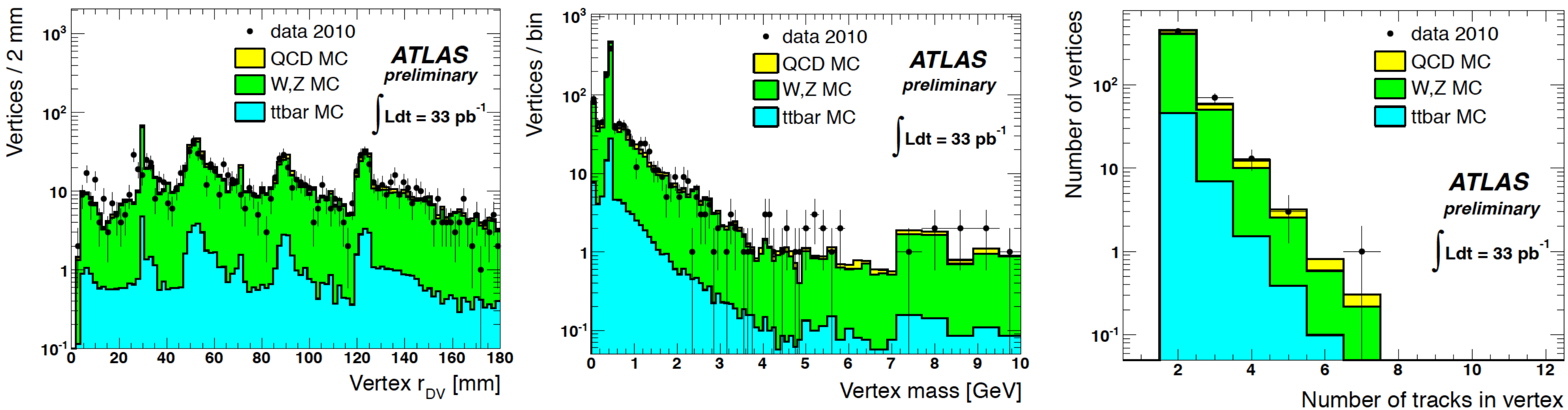
Material map of ATLAS well understood using 2010 data!



Event from a jet-trigger data sample, where a high-mass vertex (circled) is the result of an apparently random, large-angle intersection between a track and a low-mass hadronic-interaction vertex produced in a pixel module. The beampipe and some pixel modules are shown

Comparison with Monte Carlo

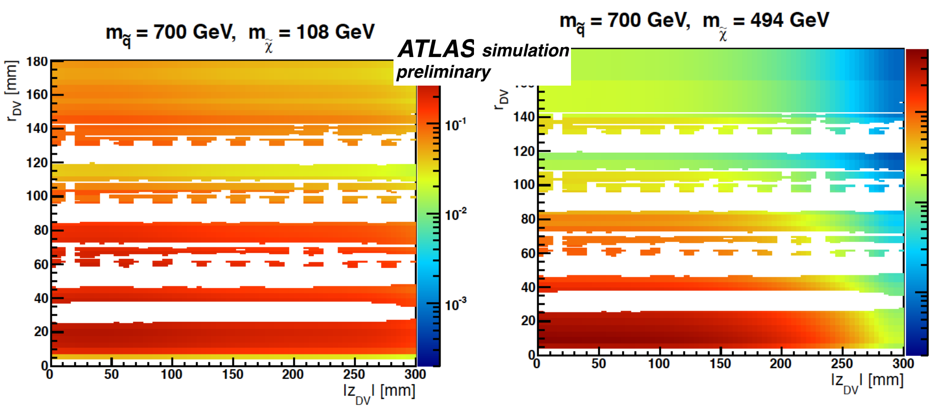
- Loosen selection to compare data with simulation
  - Allow 2-track vertices and demand an offline μ
  - Vertex mass<10GeV (orthogonal to signal region)



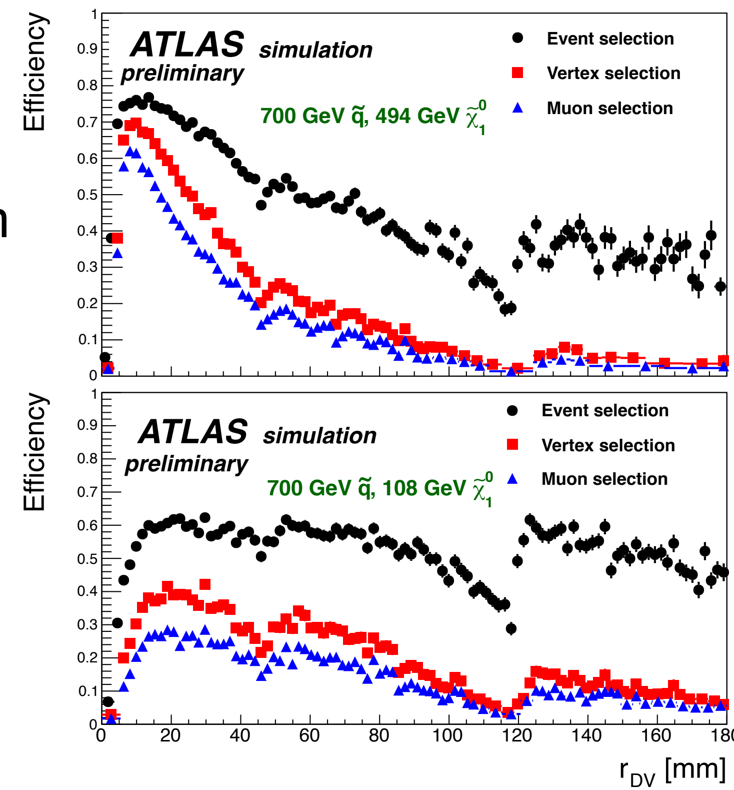
Good agreement in shape and yield provides confidence in simulation

Signal Efficiency

- Define efficiency as number of truth-matched vertices passing selection cuts divided by number of true neutralino decays, as a function of decay position.
- Require vtx within 3mm of true position (use errors from vertex fit), ≥ 2 tracks from reco vtx to be matched with true tracks from neutralino decay.



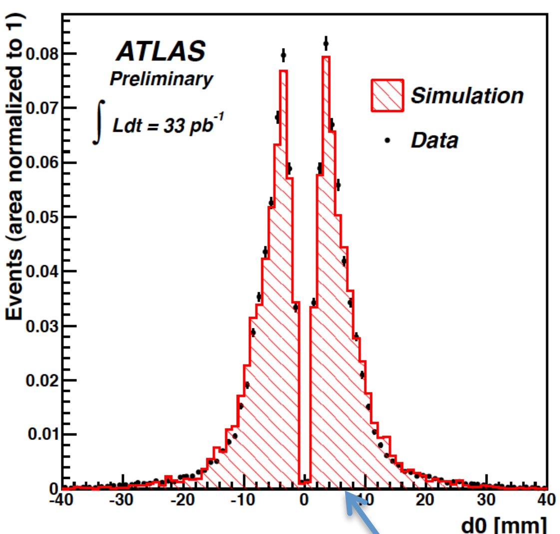
- Use signal Monte Carlo to get 2d efficiency map in rDV vs |zDV| for each signal point considered

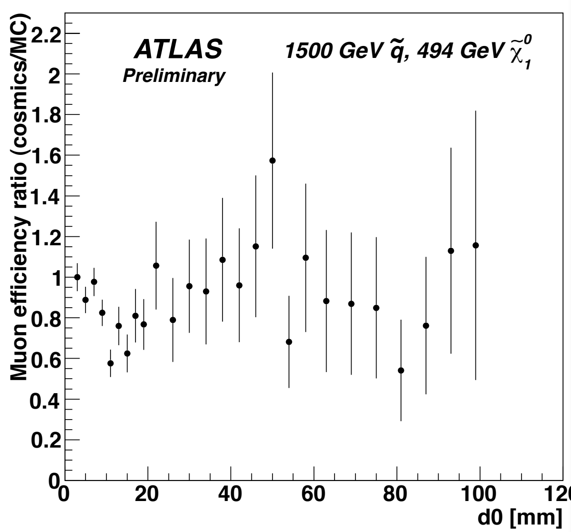


Material veto not applied here

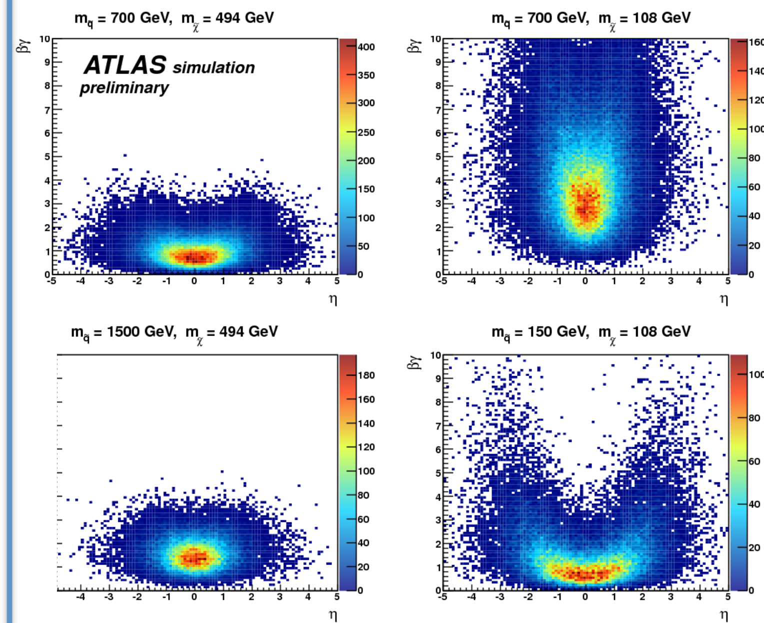
Muon eff. corrections and MC decays

- Take ratio of d0 distribution of cosmic muons to that from background Monte Carlo
- Use this to apply event-by-event correction and remake 2D efficiency maps
- Mapping of muon d0 to vertex radius used we apply systematic 3.5->8%



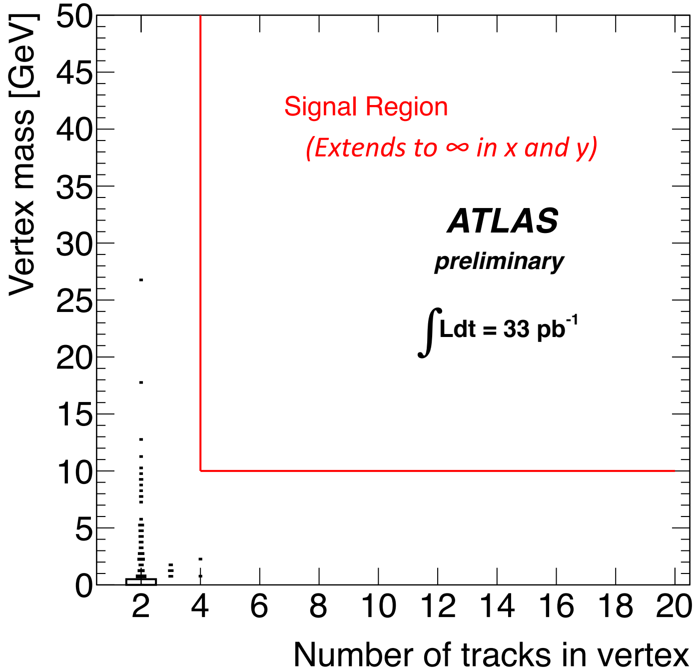


Compare d0 from minimum bias data and simulation



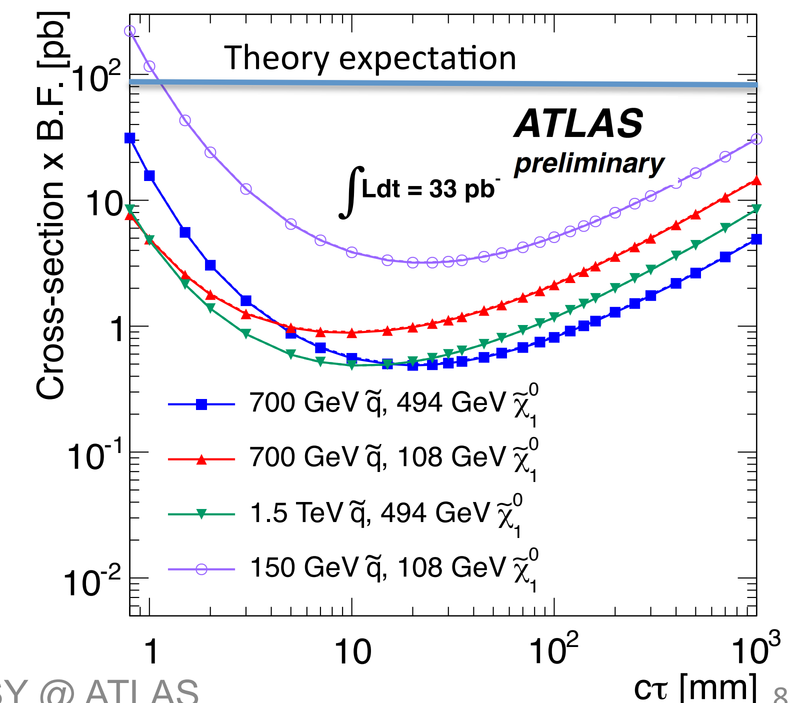
- Decay position (wrt to primary vertex) in z and r determined from decay length and η
- Distribution varies for each signal sample due to the boost

Displaced vertex results



- Signal region defined in terms of vertex mass and Ntracks in Vtx. Find zero events, use CLs with one-sided profile-likelihood as test statistic.
- Each $c\tau$ treated as number counting experiment with errors on ε,lumi and background as nuisance parameters

- σ * detector acceptance * ε <0.09pb @95% Confidence level



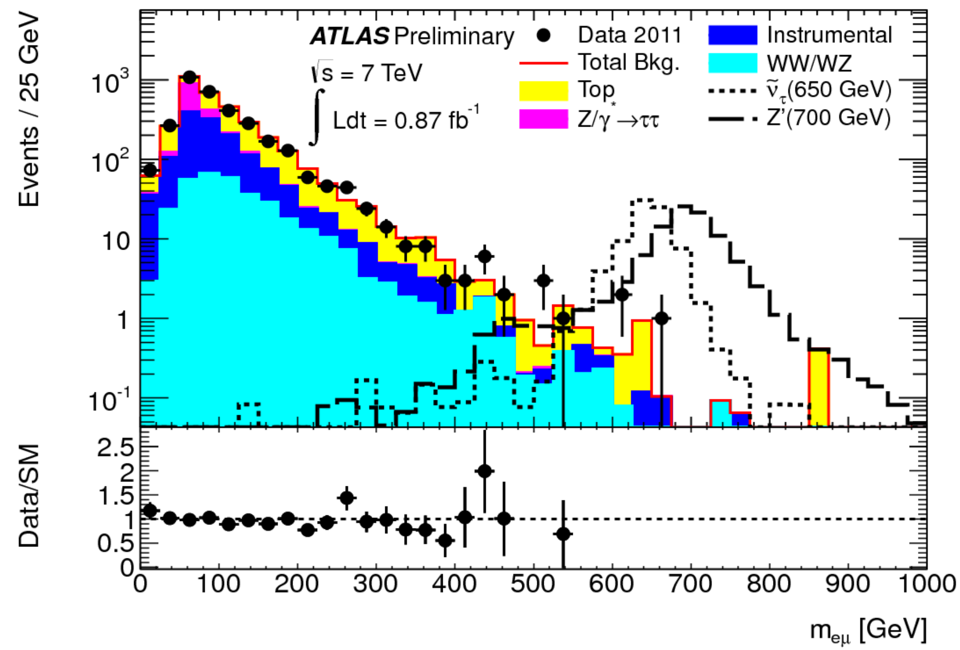
eμ resonance search

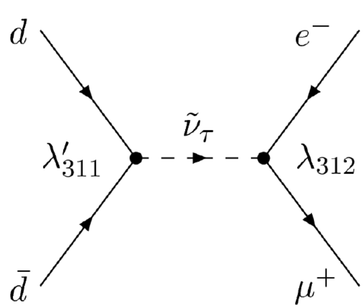
- Resonant sneutrino can decay into an electron-muon pair
- Exactly one electron and one muon selected (used to trigger)
- At least one Primary Vtx with 3 tracks > 500 MeV
- Isolation cuts on electron/muon and jet cleaning
- Background from $t\bar{t}$, $Z\tau\tau$, Wt, WW, WZ, ZZ rely on Monte Carlo simulation
- Instrumental backgrounds:
  - Photon - due to EM cluster randomly matching with a inner detector track (negligible). Background due to electron from photon conversion, estimated using MC (small)
  - Jets - from QCD and W/Z+jets are estimated with matrix method directly from the data

eμ resonance

- Final states with sneutrino decaying to electron and muon with opposite charge
- Constraint on sneutrino and Z' with LFV

Process	Num. of events
$Z/\gamma^* \rightarrow \tau\tau$	614±53
$t\bar{t}$	1281 ± 168
WW	318 ± 24
Single top	125 ± 17
WZ	18.2 ± 1.9
$W/Z+\gamma$	67 ± 11
Jet instrumental background	984 ± 105
Total background	3408 ± 230
Data	3338



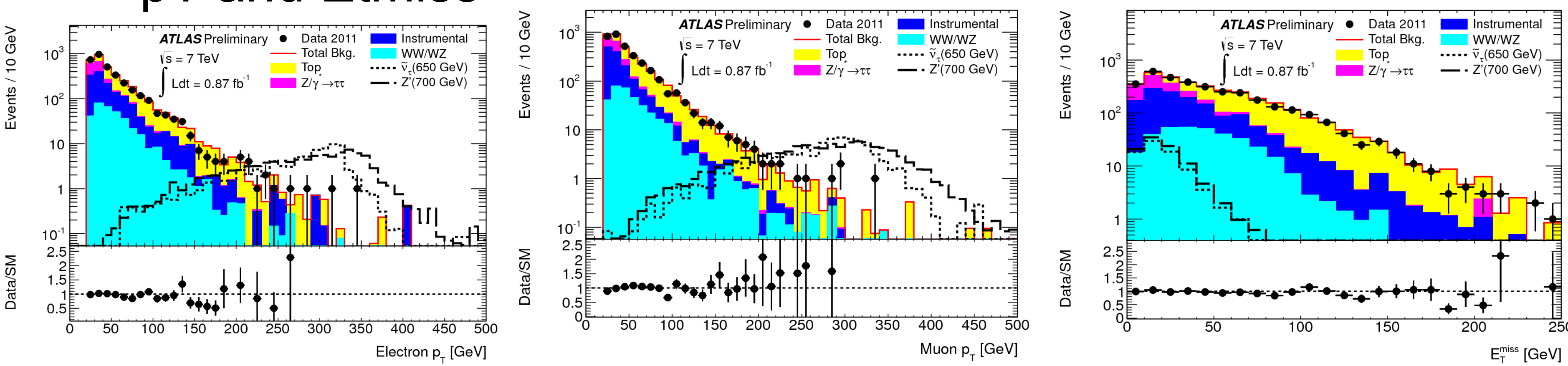


Changes compared to 2010 ATLAS analysis:

- ✓ Use 4x4 matrix to estimate W+jets and QCD background directly from data
- ✓ Lepton p_T >25GeV, increased due to trigger, larger backgrounds and pile-up effects
- ✓ ~25 times more data used (now 0.87fb^{-1})

eμ resonance

- Plot kinematic distributions to compare the data/MC
- Shape and yield of events studied as a function of lepton pT and Etmiss

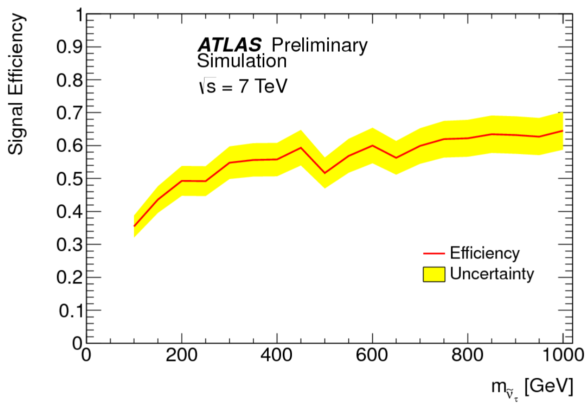


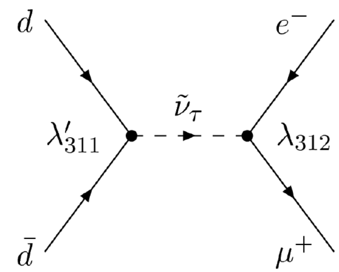
- Increasingly tighten cut on $m_{e\mu}$ – good agreement
- No deviation from the SM prediction when considering higher mass regions only

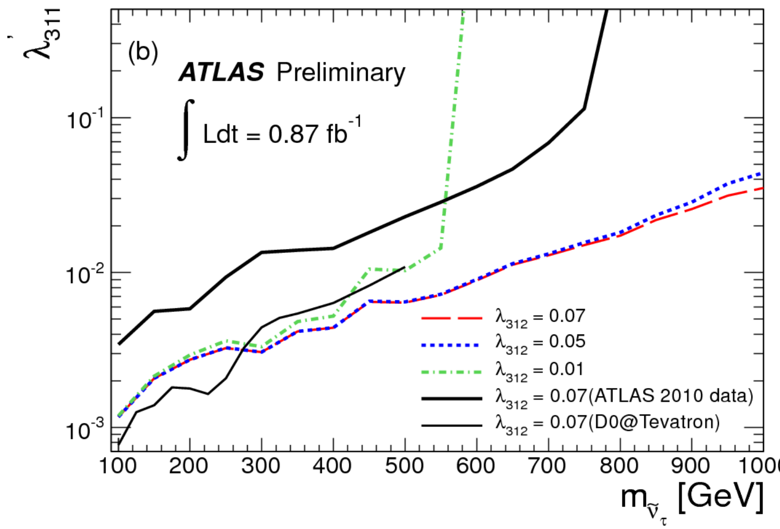
$m_{e\mu}$	Data	SM prediction
> 200 GeV	224	236 ± 21
> 250 GeV	119	111 ± 11
> 300 GeV	51	55 ± 6
> 350 GeV	29	30 ± 4
> 400 GeV	18	14.2 ± 2.2
> 450 GeV	9	8.2 ± 1.5
> 500 GeV	7	5.3 ± 1.1
> 550 GeV	3	3.4 ± 0.8
> 600 GeV	3	2.2 ± 0.7
> 650 GeV	1	0.9 ± 0.4
> 700 GeV	0	0.8 ± 0.4

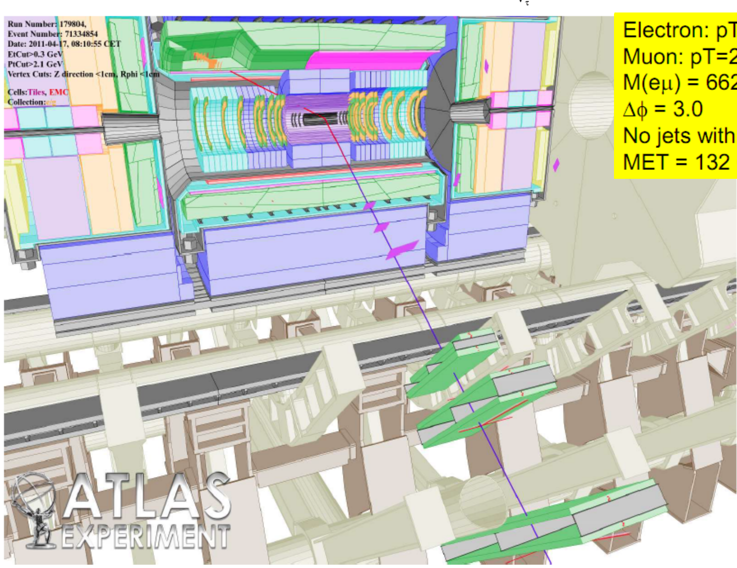
eμ resonance - limits

- Acceptance x ε varies from 36% (100GeV) to 65%(1TeV)
- For a 100GeV(1TeV) sneutrino the limit on cross-section x BR is 130(11)fb
- These results are 7(14) times better than previous results



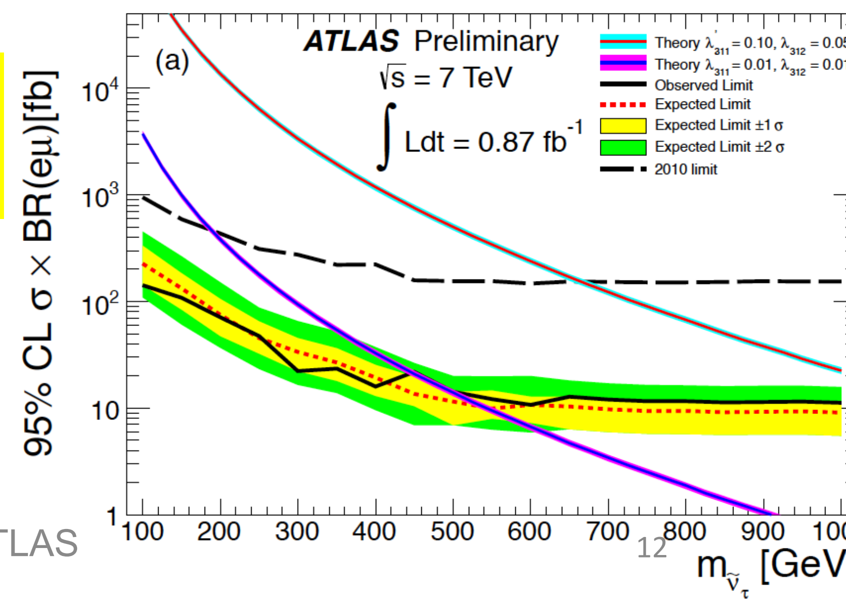






Electron: pT=341 GeV, η = -1.17, ϕ=0.91
Muon: pT=216 GeV, η = 0.14, ϕ=-2.36
M(eμ) = 662 GeV
Δϕ = 3.0
No jets with pT>30 GeV
MET = 132 GeV

Highest mass eμ candidate



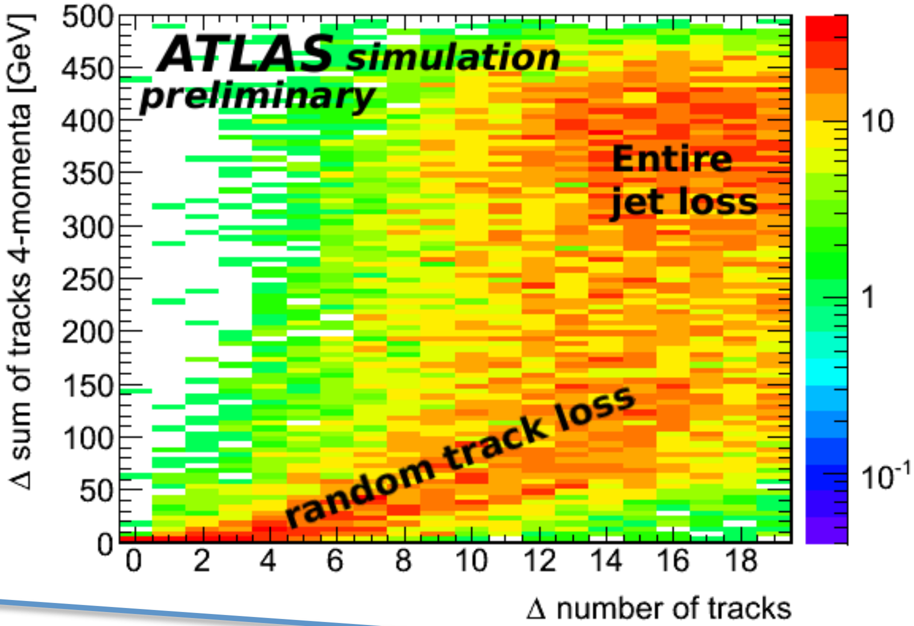
Summary

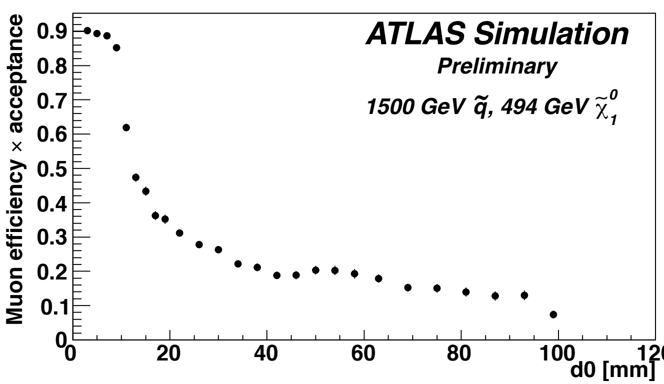
- ATLAS is extremely active in the search for R-parity violating SUSY
- Presented two analyses constraining:
  - Displaced vertices
  - eμ resonances from sneutrino decay
- No excess beyond the expected background is observed, the limits set are the most stringent to date

extras

Additional distributions for DV search

- X-axis shows number of true tracks with pT>1GeV, |η|<2.5 and |d0|>2mm, from neutralino NOT reconstructed
- Y-axis is difference between total invariant mass of reconstructed tracks from neutralino decay and total invariant mass of true tracks
- Sometimes we miss a whole jet





- Muon efficiency with respect to d0 in signal Monte Carlo
- Our inefficiency drops considerably for muons produced much further away from the interaction region