Search for supersymmetry with displaced dileptons at the ATLAS experiment

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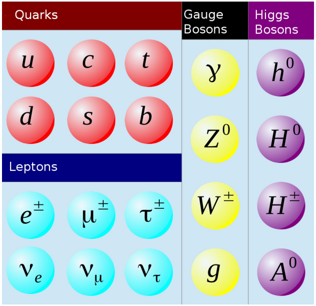
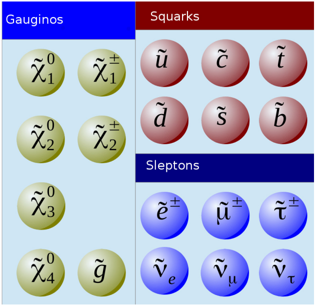
Supersymmetry

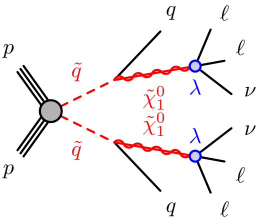
- Symmetry between fermions and bosons
- Every Standard Model particle gets superpartner
- Spin differs by 1/2
- Minimal supersymmetric Standard Model:



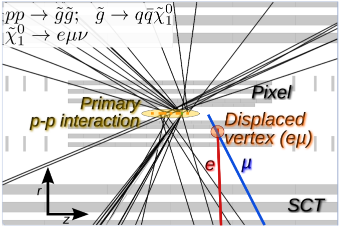


Search for displaced dileptons

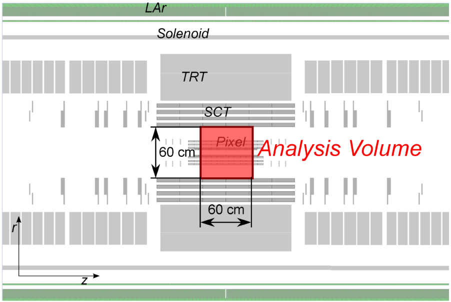
- Search for massive long-lived particles decaying to two charged leptons (e or μ)
- Experimental signature: Displaced vertices in the inner detector with two leptons
- Sensitive to lifetimes of about 1 ps to 1 ns
- Model independent search interpreted in supersymmetric models

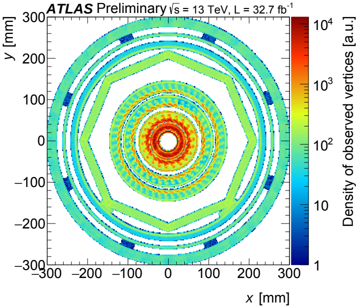


Example of a R-parity violating model

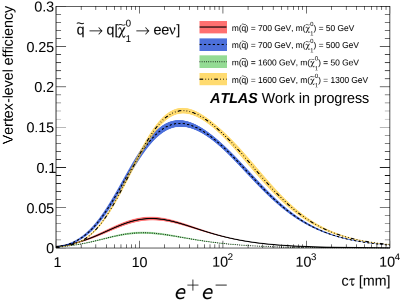


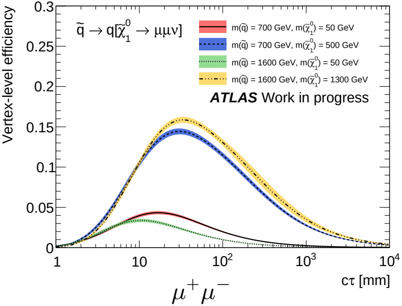
- Displaced vertex with two oppositely charged leptons (e^+e^-, $e^\pm\mu^\mp$ or $\mu^+\mu^-$)
  - Displacement: 4 mm in transverse plane to all *pp* collisions of the brunch crossing
  - Fiducial volume:





  - Vertices inside detector material are vetoed
  - Invariant mass $m_{\mathrm{DV}} > 10\,\mathrm{GeV}$





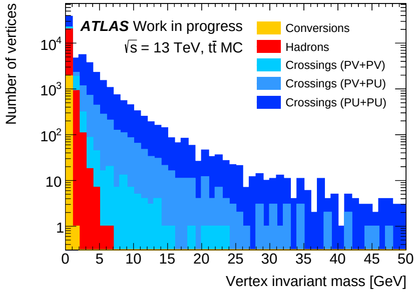
- Total vertex selection efficiency always below 20%

  → Main efficiency loss from vertex reconstruction efficiency ($\approx$ 20 - 30%)

- Significantly higher efficiencies if the long-lived particle ($\tilde{\chi}_1^0$) heavy

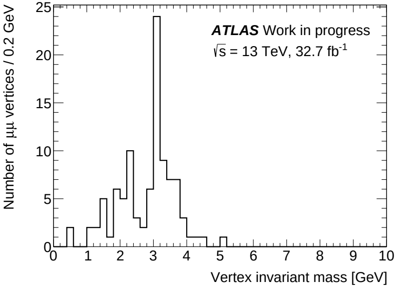
  → More energy to trigger on

Background sources of displaced vertices



- Plot shows origin of displaced vertices with two tracks in a $t\bar{t}$ Monte Carlo sample
- Mostly vertices without leptons
- Random crossing of tracks dominant background for $m_{\mathrm{DV}} > 10\,\mathrm{GeV}$

Dilepton vertices from hadron decays



$\mu\mu$ vertices

- Validation region on data with inverted mass cut: $m_{\mathrm{DV}} < 10\,\mathrm{GeV}$
- Most $\mu\mu$ vertices from displaced J/ψ particles of B-hadron decays
- No dilepton vertex with $m_{\mathrm{DV}} > 5.2\,\mathrm{GeV}$ observed

  $\rightarrow$ Background from hadron decays negligible

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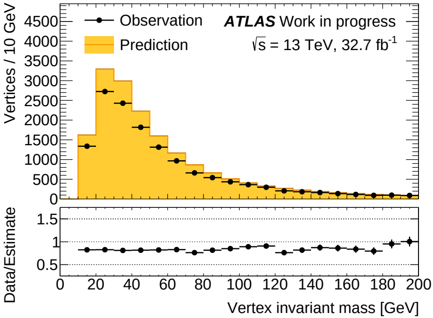
  - Calculate crossing probability $p_{\text{xing}} = \frac{\text{Number of vertices found in this procedure}}{\text{Number of lepton pairs used}}$
  - Estimate: Number of lepton pairs in data $\times$ p_{xing}

- Validation region: Same procedure using vertices with two non-leptonic tracks
- Very similar vertex selection as in signal regions
- Prediction agrees within 20% to observation:

	VR
Number of track pairs	1.1×10^8
Avg. crossing prob.	1.6×10^{-4}
Predicted vertices	17953
Observed vertices	14788

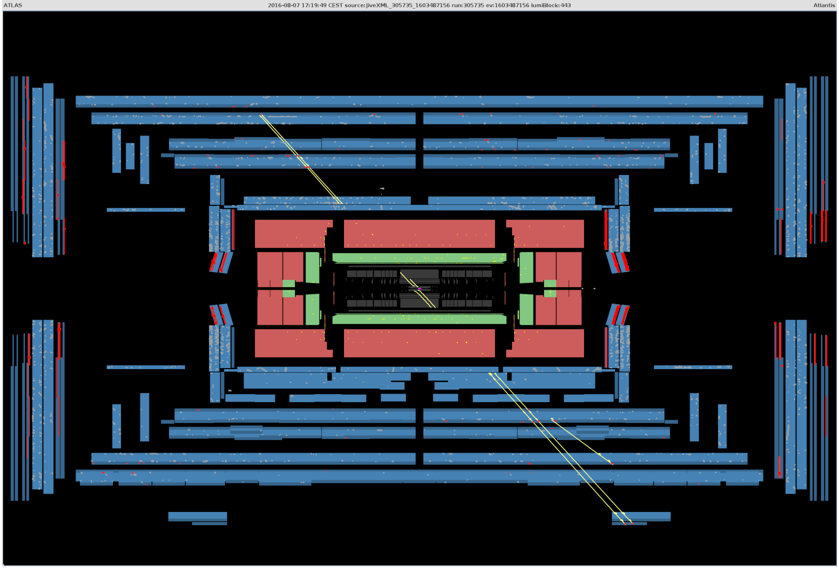


SR	$N_{vx}^{est}/10^{-4}$
ee	$1.1 \pm 0.3\ \text{(stat.)}\ ^{+0.3}_{-0.5}\ \text{(syst.)}$
$e\mu$	$6.3 \pm 2.0\ \text{(stat.)}\ ^{+1.4}_{-2.3}\ \text{(syst.)}$
$\mu\mu$	$5.8 \pm 2.4\ \text{(stat.)}\ ^{+1.3}_{-3.8}\ \text{(syst.)}$

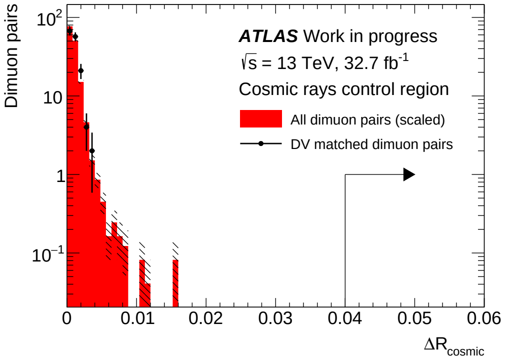
- Random crossing background is of order 10^{-4} for all SRs

  $\rightarrow$ Any vertex observed would hint for a signal
- One of the smallest backgrounds estimated for an ATLAS search
- Total uncertainties on the estimates not larger than 80%

Event display of a dicosmic event



- Cosmic muon sometimes reconstructed as a back-to-back muon pair
- Back-to-backness: $\Delta R_{\text{cosmic}} = \sqrt{(\eta_1 + \eta_2)^2 + (|\Delta\phi| - \pi)^2}$
- Veto cosmic muons in signal regions by requiring: $\Delta R_{\text{cosmic}} > 0.04$
- Invert cosmic veto to study back-to-backness of cosmic muons:



Summary

- Model-independent search for displaced vertices with two leptons
- Interpreted in supersymmetric models
- Dominant background from random crossings of leptons
- Data-driven estimate of random crossings
- Background is of order 10^{-4} for all SRs
- Potential signal can be identified very clearly in data