Search for displaced dileptons at the ATLAS experiment

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GEFÖRDERT VOM

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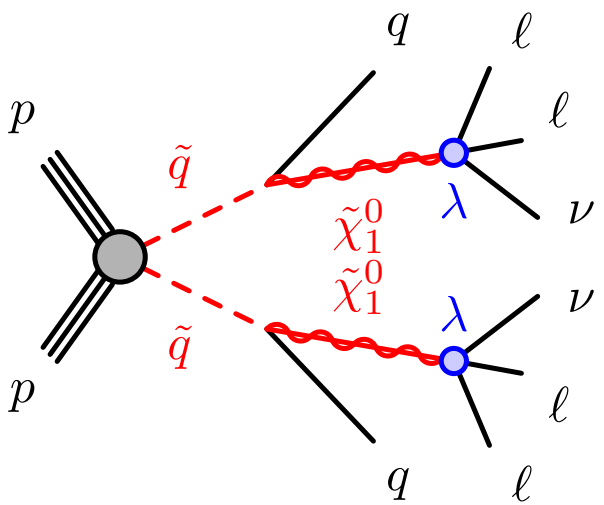
Search for displaced dileptons

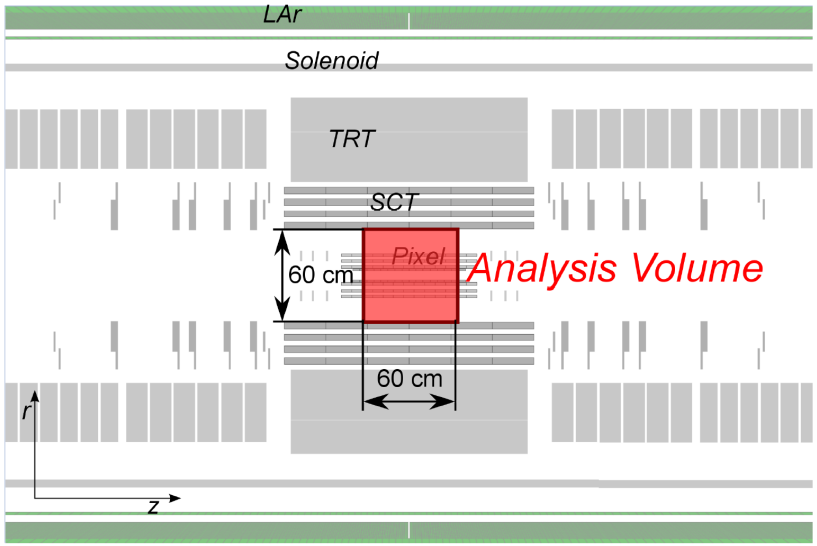
- Search for massive, long-lived particles decaying to e^+e^-, $e^\pm\mu^\mp$ or $\mu^+\mu^-$
- Experimental signature: Displaced vertices in inner detector of ATLAS
- Sensitive to lifetimes of about 1 ps to 1 ns
- Performed on 2016 data ($L = 32.8\,\text{fb}^{-1}$)
- Model independent search interpreted in a supersymmetric and a Z' model

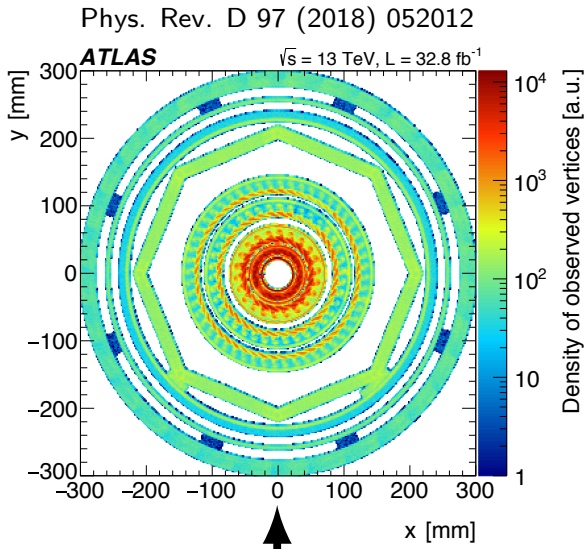
  $\rightarrow$ Focus of this talk: Supersymmetric model



Selection criteria of signal region

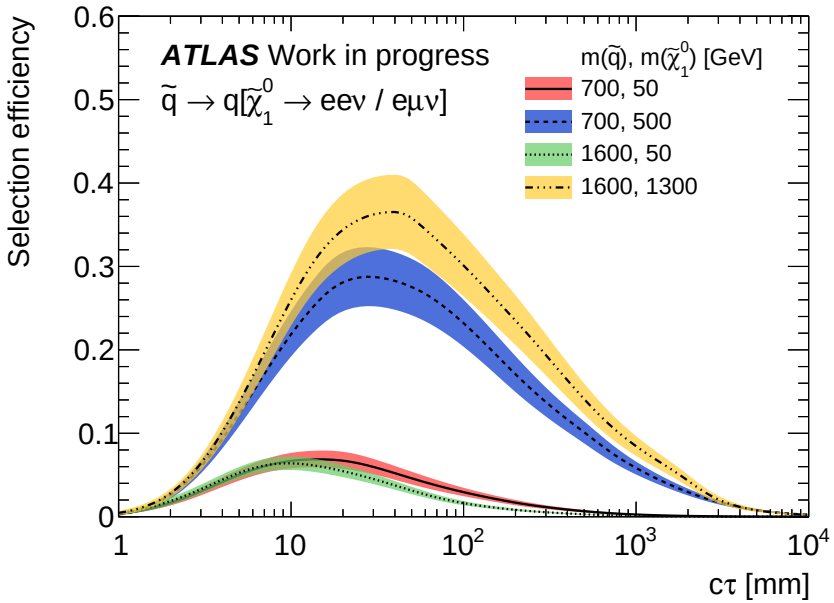
- Triggers: γ (140 GeV), $\gamma\gamma$ (50 GeV) or $\mu_{\text{MS-only}}$ (60 GeV)
- At least one displaced vertex with two oppositely charged leptons
  - Displacement: 2 mm in transverse plane to all *pp* collisions of event
  - Fiducial volume:



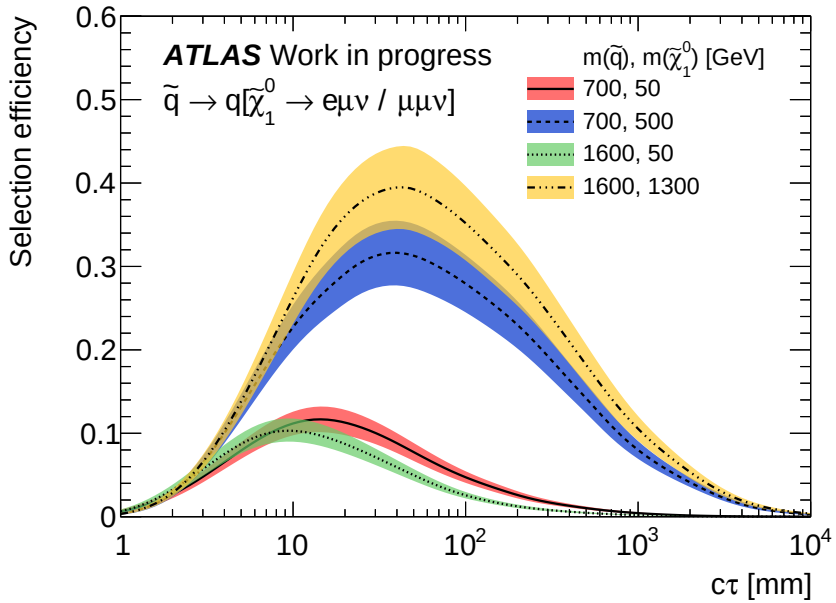


  - e^+e^- and $e^\pm\mu^\mp$ vertices inside material vetoed using a 3D detector map
  - Vertex mass > 12 GeV
  - Leptons have to pass triggers and additional kinematic cuts to ensure trigger plateau

Selection efficiency



$\mathrm{BR}(e^+e^-) = \mathrm{BR}(e^\pm\mu^\mp) = 50\%$



$\mathrm{BR}(e^\pm\mu^\mp) = \mathrm{BR}(\mu^+\mu^-) = 50\%$

- Efficiencies higher if $\mathrm{BR}(\mu^+\mu^-) > 0$ as no material veto applied
- Significantly lower efficiencies for light $\tilde{\chi}_1^0$

  $\to$ Reason: Reduced trigger and reconstruction efficiencies

Background sources

- Selection criteria significantly suppress background
- Random crossings of two leptons:
  - Uncorrelated leptons from different processes randomly cross and form a vertex
  - $b\bar{b}$, $t\bar{t}$, low mass processes (esp. J/Ψ) and many more
- Cosmic muons:
  - Cosmic muon sometimes reconstructed as a back-to-back muon pair
  - Background suppressed by cosmic veto

Data-driven estimation of random crossings

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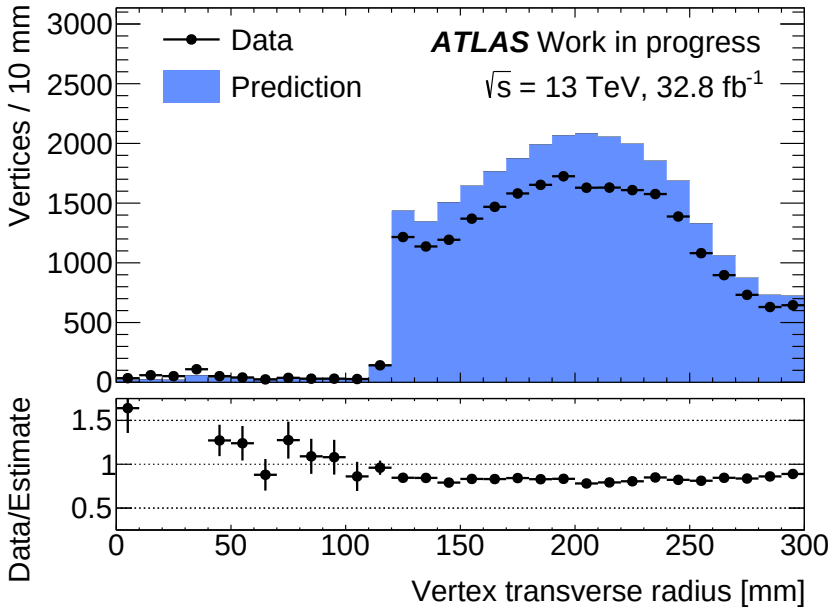
- Count number of vertices $N(\text{Vx})$ passing signal region criteria
- Calculate crossing probability $p_{\text{xing}} = \frac{N(\text{Vx})}{N_{\text{sampled}}(\ell\ell)}$
- Estimate $= N_{\text{obs}}(\ell\ell) \cdot p_{\text{xing}}$

  $N_{\text{obs}}(\ell\ell) =$ Number of lepton pairs observed in data

Random crossings of non-leptonic tracks



- Performance of estimation procedure tested with **non-leptonic** tracks

  → Many orders of magnitude larger data sample than that of leptons

- Data and prediction agree within 20%

  → Great success for this simple method

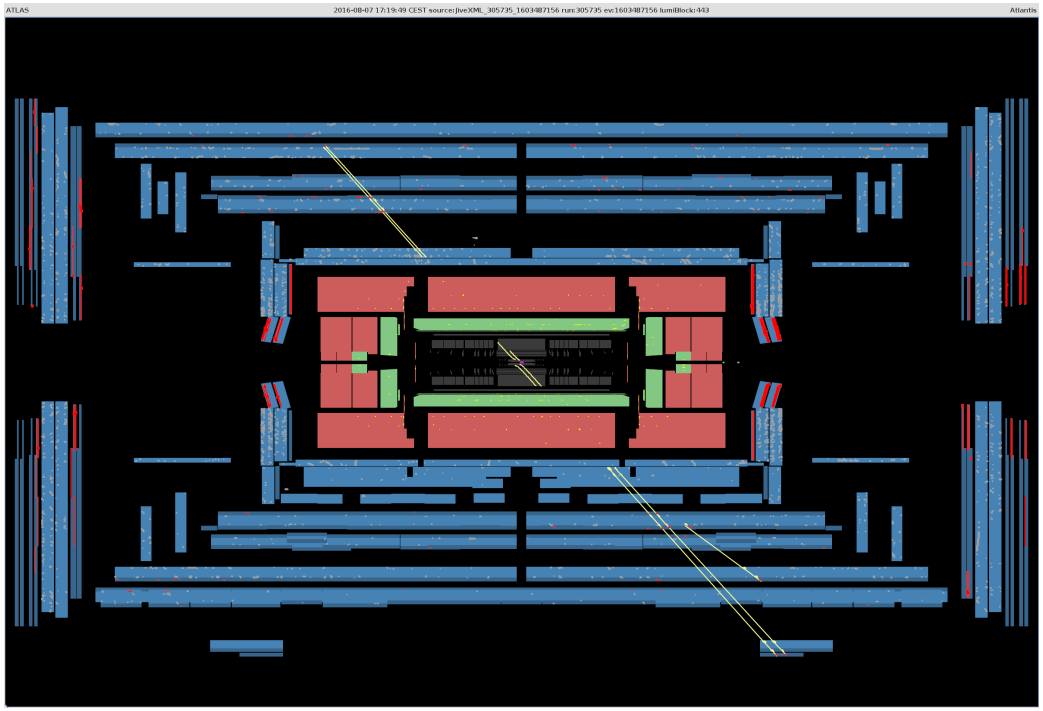
Random crossings of leptons

Channel	$N(\ell\ell)$	$p_{\text{xing}}/10^{-5}$	Estimate$/10^{-4}$
ee	21	1.2	2.6
$e\mu$	10	7.0	7.0
$\mu\mu$	9	15.9	14.3

- $N(\ell\ell)$ and p_{xing} are very small
- Muons have significantly larger crossing probabilities than electrons
- Signal region estimate: $(2.4 \pm 0.5\ (\text{stat.}) \pm 1.8\ (\text{syst.})) \cdot 10^{-3}$ events

  $\rightarrow$ Negligible compared to cosmic muon background

Cosmic veto



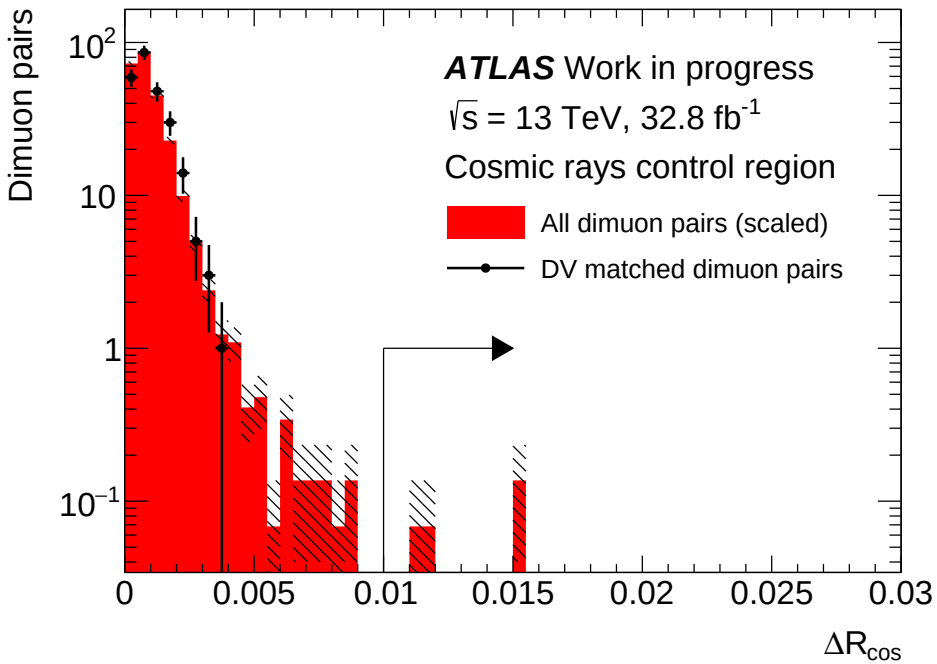
- Cosmic muons sometimes reconstructed as back-to-back muon pairs:

  $\rightarrow \Delta R_{\text{cos}} = \sqrt{(\eta_1 + \eta_2)^2 + (|\Delta\phi| - \pi)^2} \approx 0$

- Less than 10% of muon pairs reconstructed as displaced vertices

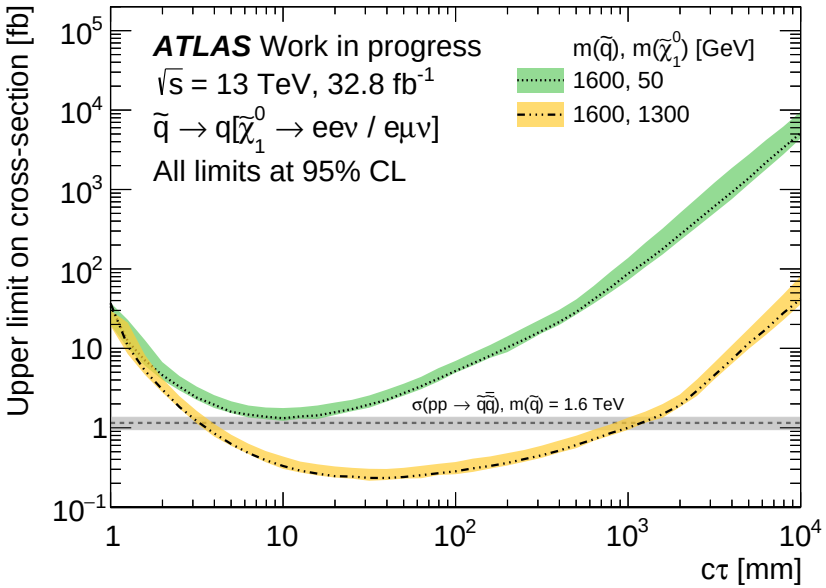
- Cosmic veto: Reject events that have lepton pairs with $\Delta R_{\text{cos}} < 0.01$

Cosmic background estimation



- Study ΔR_{cos} distributions of $\mu\mu$ pairs and vertices in data
- Vertex distribution vanishes at $\Delta R_{\text{cos}} = 0.004$
- Distribution of pairs used to extrapolate vertex distribution to signal region
- Estimated background: $0.27 \pm 0.14\ (\text{stat.}) \pm 0.1\ (\text{syst.})$ events

Expected cross section limits



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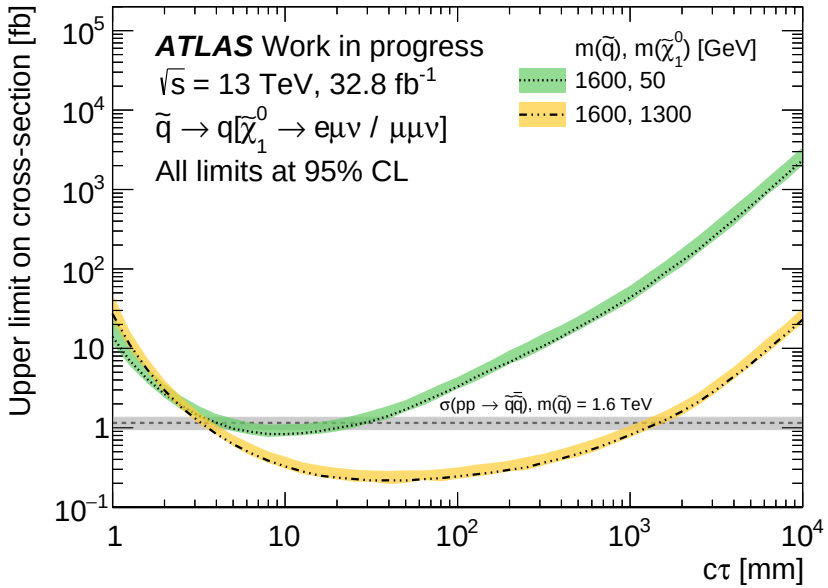

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- Upper limits at 95% CL for $m(\tilde{q}) = 1.6\,\mathrm{TeV}$
- $m(\tilde{\chi}_1^0) = 1.3\,\mathrm{TeV}$: Lifetimes between 3 mm and 1 m excluded
- $m(\tilde{\chi}_1^0) = 50\,\mathrm{GeV}$: No constraints for $\mathrm{BR}(\mu^+\mu^-) = 0$

Summary

- Search for displaced vertices with two oppositely charged leptons
- Model independent search
- Signals: Supersymmetric model with long-lived $\tilde{\chi}_1^0$ and long-lived Z' model
- Dominant background contribution from cosmic muons
- Very small background of 0.3 events