Search for displaced dileptons at the ATLAS experiment

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GEFÖRDERT VOM

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und Forschung

Max-Planck-Institut für Physik
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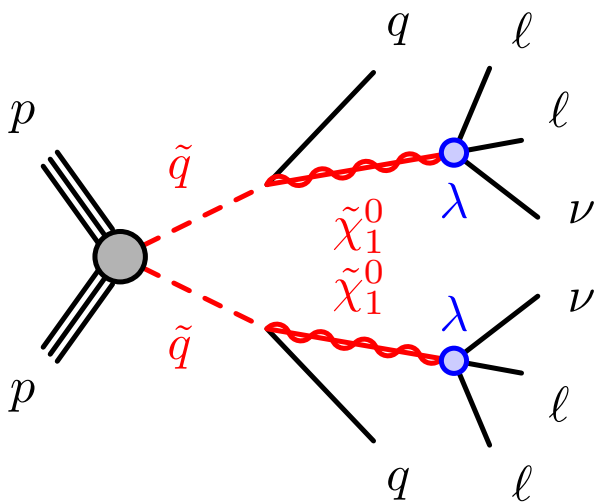
Search for displaced dileptons

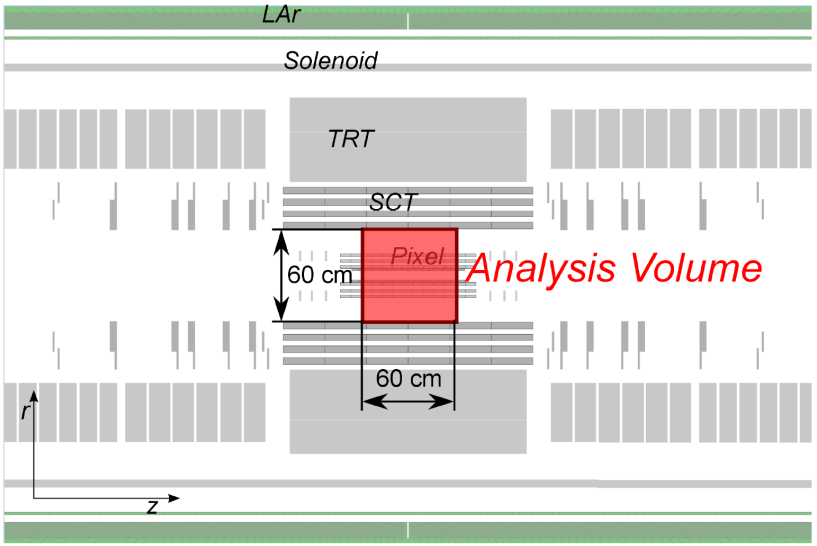
- Search for massive long-lived particles decaying to two charged leptons (e or μ)
- Experimental signature: Displaced vertices in inner detector with two lepton tracks
- Sensitive to lifetimes of about 1 ps to 1 ns
- Model independent search interpreted in a supersymmetric and a Z' model

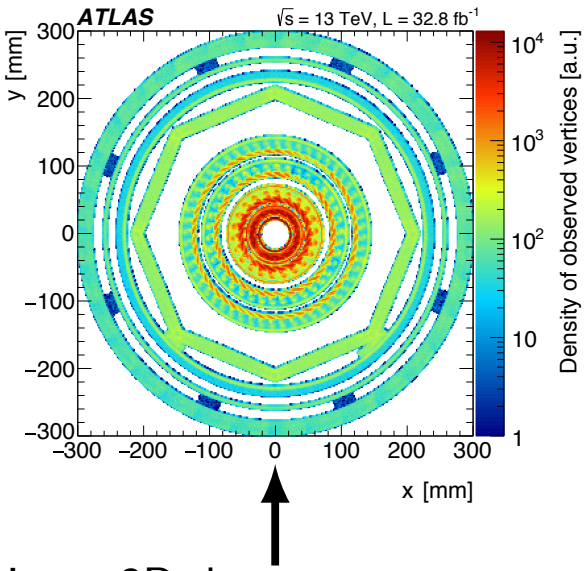
  $\rightarrow$ Focus of this talk: Supersymmetric model



Displaced vertex selection

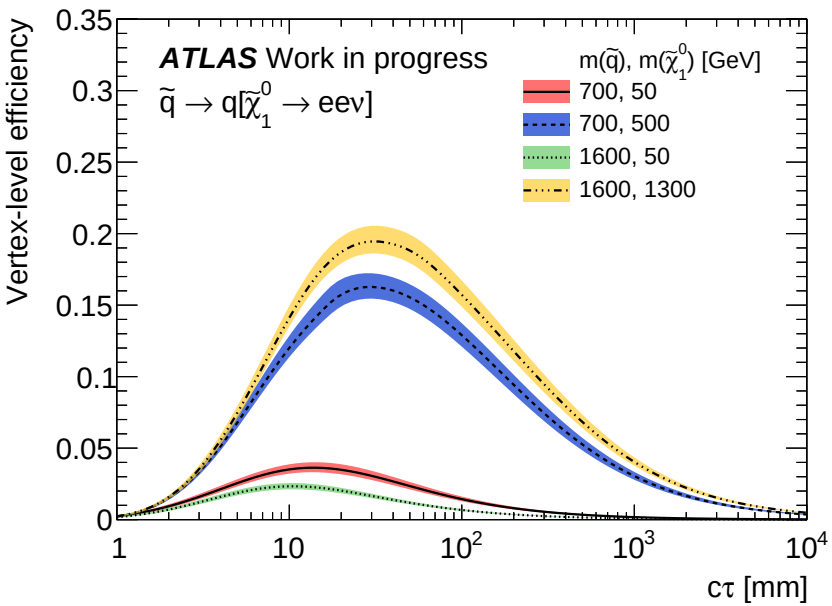
- Displaced vertex (DV) with two oppositely charged leptons
  - Displacement: 2 mm in transverse plane to all pp collisions of event
  - Fiducial volume:



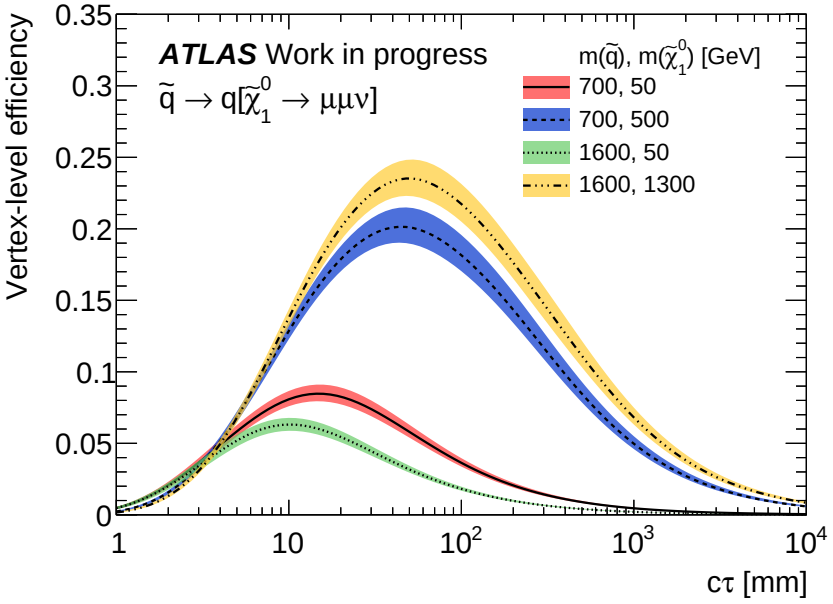


  - e^+e^- and $e^\pm\mu^\mp$ vertices inside material vetoed using a 3D detector map
  - $m_{\mathrm{DV}} > 10\,\mathrm{GeV}$
  - Lepton tracks: $p_{\mathrm{T}} > 10\,\mathrm{GeV}$
  - Match of DV to at least one trigger required: γ (140 GeV), $\gamma\gamma$ (50 GeV) or μ (60 GeV)

Signal efficiency



e^+e^-



$\mu^+\mu^-$

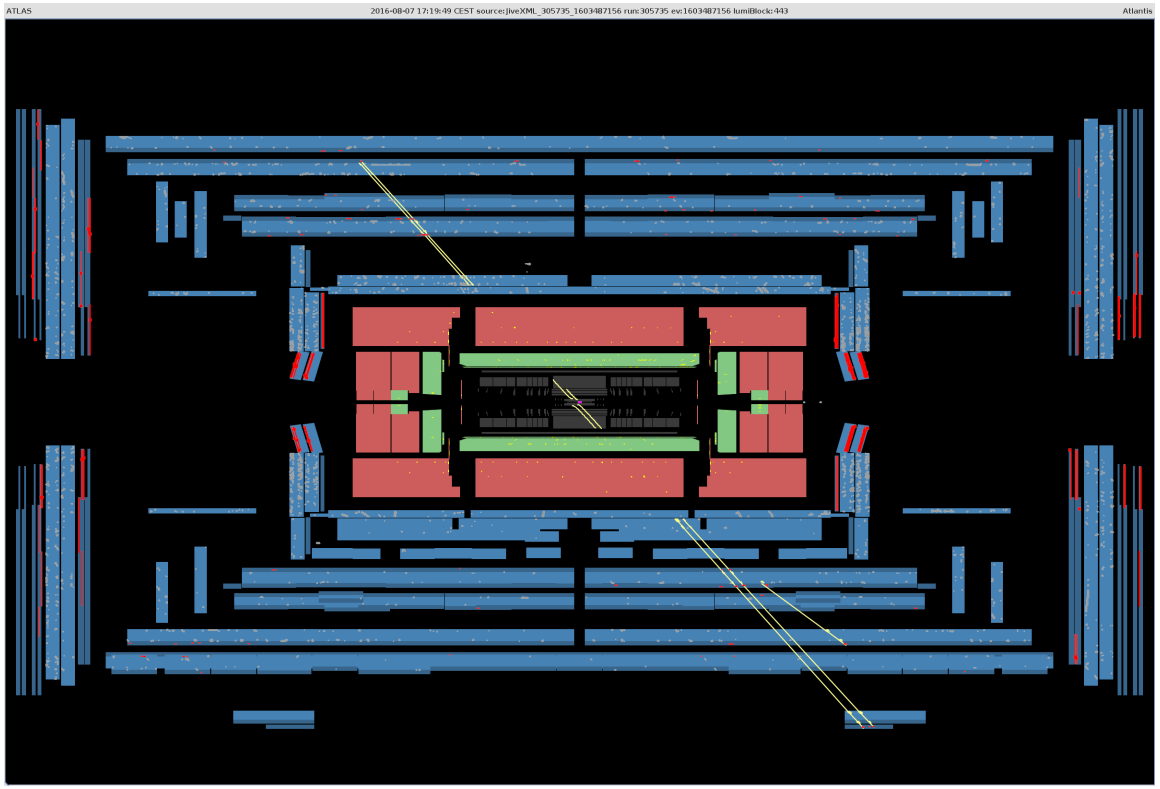
- Boosted vertices (light $\tilde{\chi}_1^0$) challenging to reconstruct
- Efficiencies significantly larger for $\mu^+\mu^-$ than for e^+e^- due to missing material veto

Background sources

- Selection criteria suppress background to very small levels

  $\rightarrow$ Goal for estimates: Get order of magnitude right
- Cosmic muons: $\mathcal{O}(10^{-1})$
  - Cosmic muons sometimes reconstructed as a back-to-back muon pair
  - Events with back-to-back lepton pairs rejected to suppress this background
- Random crossings of two leptons (ie. Standard Model background): $\mathcal{O}(10^{-3})$
  - Badly reconstructed / fake leptons can randomly cross and form a vertex
  - Various processes contribute: $b\bar{b}$, $t\bar{t}$, low mass processes (esp. J/Ψ) and many more

Cosmic veto

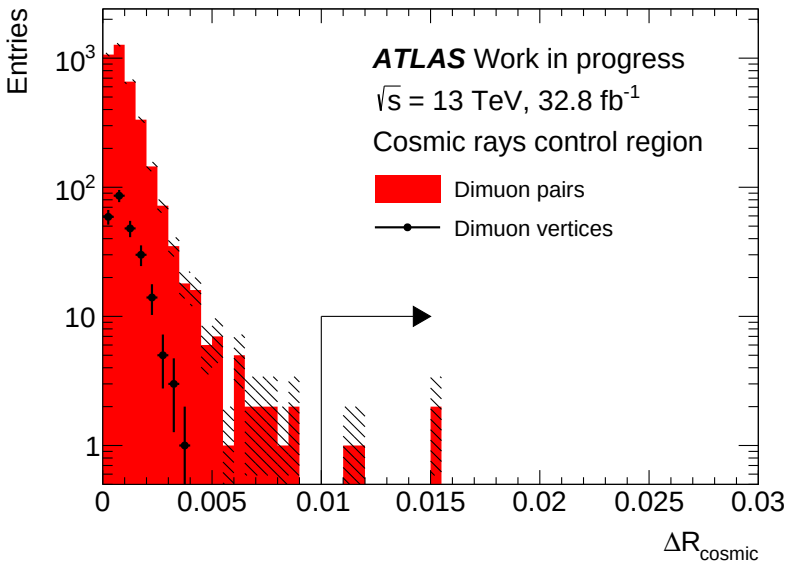


- Cosmic muons sometimes reconstructed as back-to-back muon pairs:

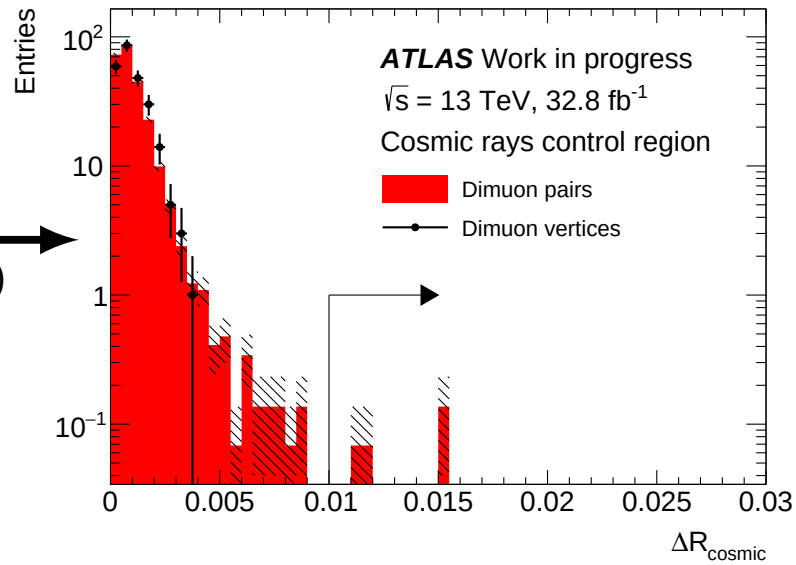
  $\rightarrow \Delta R_{\text{cosmic}} = \sqrt{(\eta_1 + \eta_2)^2 + (|\Delta\phi| - \pi)^2} \approx 0$

- Cosmic veto: Reject events with lepton pairs failing $\Delta R_{\text{cosmic}} > 0.01$

Cosmic background estimation



Scale N(Pairs)



- Study ΔR_{cosmic} distributions of $\mu^+\mu^-$ pairs and vertices in data
- Distribution of vertices vanishes before signal region cut of $\Delta R_{\text{cosmic}} = 0.01$
- Idea: Use distribution of pairs to extrapolate vertex distribution to signal region

  $\rightarrow$ Rescale distribution of pairs by $\int_0^{0.004} N(\text{DV}) / \int_0^{0.004} N(\text{Pairs})$
- Estimate: 0.27 ± 0.14

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- Estimate $= N(\ell\ell) \cdot p_{\text{xing}}$

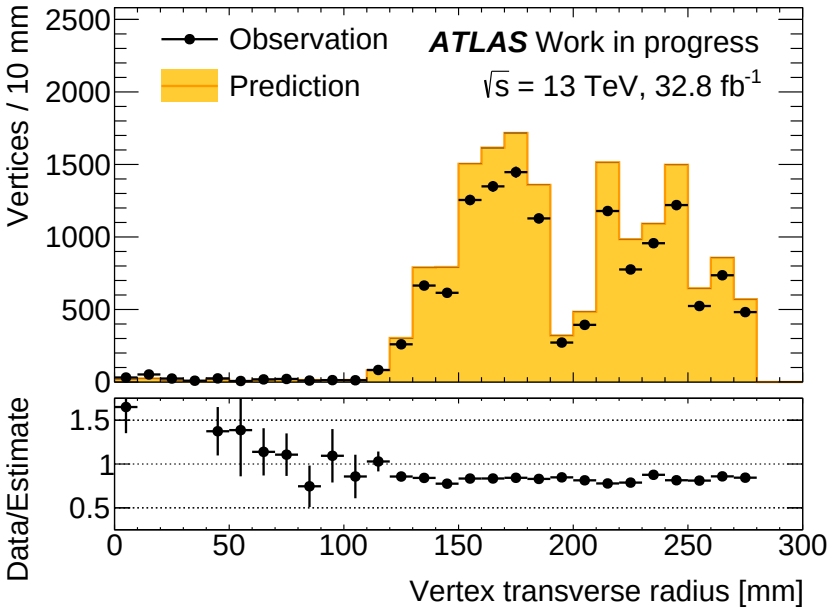
  $N(\ell\ell) =$ Number of lepton pairs observed in data

Test of estimation procedure

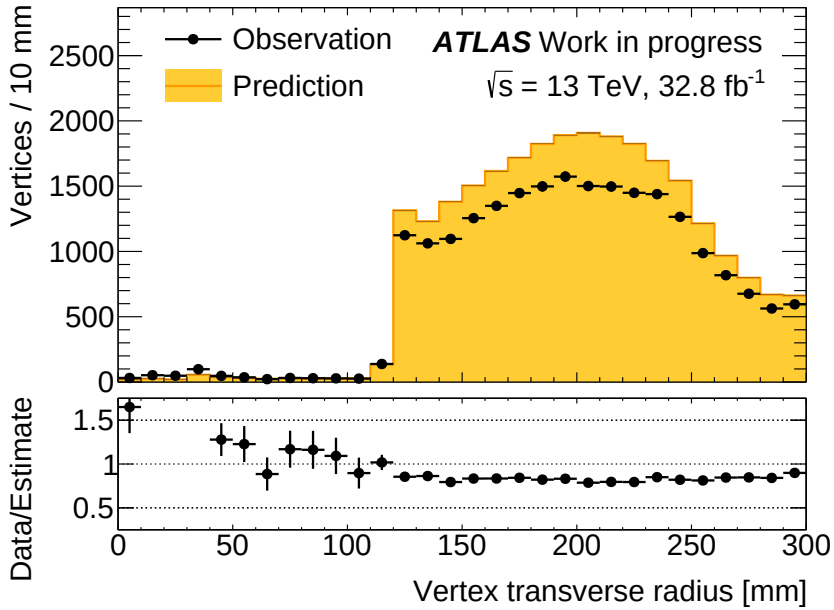
- Goal: Evaluate precision of random crossing estimation
- Idea: Perform same procedure as for signal region (SR) but with non-leptonic tracks
  $\rightarrow$ Very high statistics
- Differences to SR estimate: No opposite charges and no trigger matching
- Results:

	With material veto	Without material veto
Number of pairs in data	1.0×10^8	
Avg. crossing probability	1.6×10^{-4}	2.6×10^{-4}
Predicted vertices	16288	26085
Observed vertices	13564	21780
Overestimate	20.1 %	19.8 %

Random crossings of non-leptonic tracks



With material veto



Without material veto

- 20% overestimate in both cases
  - Estimation works equally well with and without material veto
  - Sufficient precision since only order of magnitude important
- Underestimate for low radii due to remaining background of hadron decays

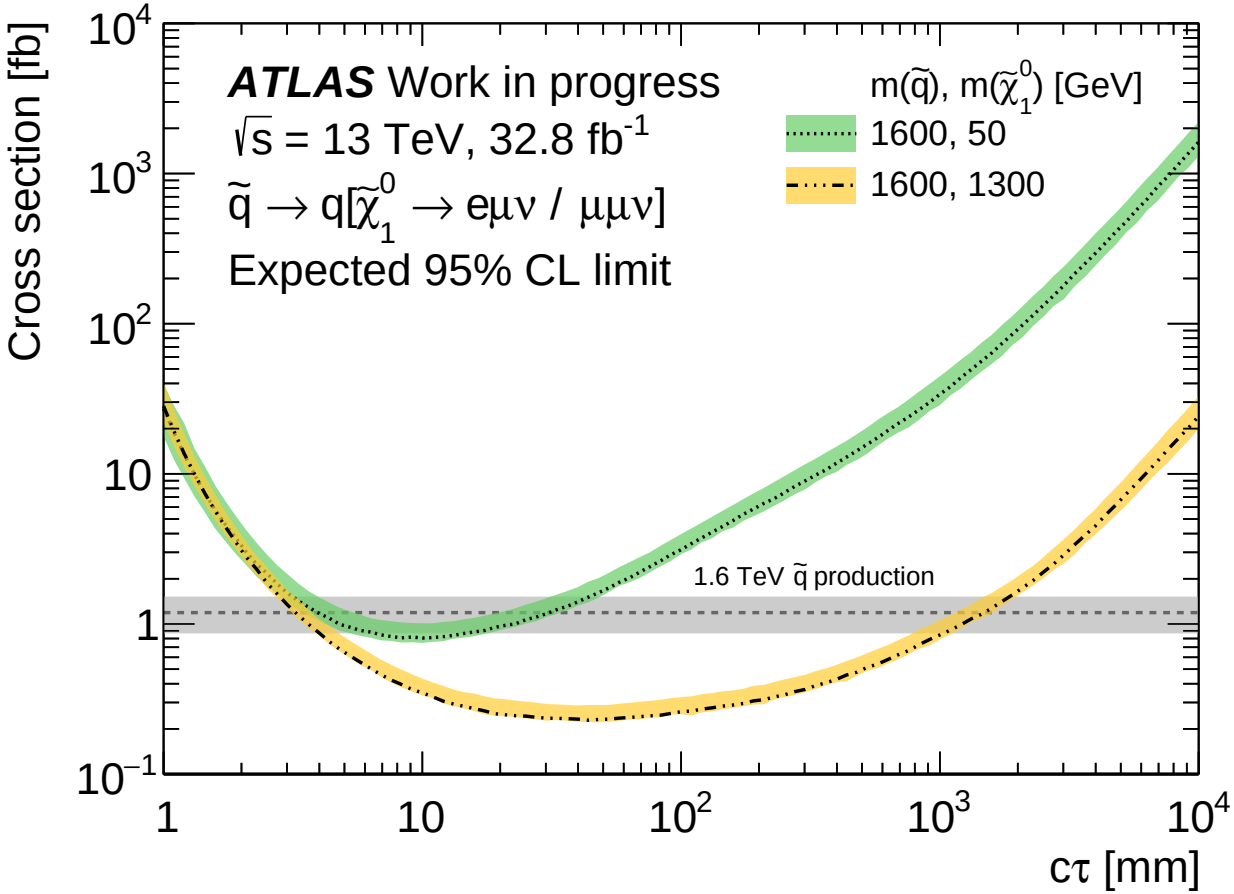
  $\rightarrow$ Small effect and not relevant for dilepton case

Random crossings of leptons

Channel	$N_{\ell\ell}$	$p_{\text{xing}}/10^{-5}$	$N_{vx}^{est}/10^{-4}$
ee	21 ± 4.6 (stat.)	1.3 ± 0.1 (stat.)	2.7 ± 0.6 (stat.)
$e\mu$	10 ± 3.2 (stat.)	7.0 ± 0.2 (stat.)	7.0 ± 2.2 (stat.)
$\mu\mu$	9 ± 3.0 (stat.)	15.9 ± 0.3 (stat.)	14.3 ± 4.8 (stat.)
SR			24.0 ± 5.3 (stat.)

- Electrons have lower crossing probabilities than muons
- Probability especially high for $\mu^+\mu^-$ due to missing material veto
- Random crossing background is of order 10^{-3}
- Negligible compared to cosmic muon background

Expected cross section limits



- $\mathrm{BR}(\tilde{\chi}_1^0 \to e\mu\nu) = \mathrm{BR}(\tilde{\chi}_1^0 \to \mu\mu\nu) = 0.5$
- Everything below dashed horizontal line excluded

Summary

- Search for displaced vertices with two oppositely charged leptons
- Model independent search
- Signals: $\tilde{q}$ model with R-parity violating decay of $\tilde{\chi}_1^0$ and long-lived Z' model
- Dominant background from cosmic muons
- Background is of order 10^{-1}
- Expected model independent 95% CL cross section limit: 0.09 fb
- Potential signal could be identified very clearly in data