



Search Strategy for Long-Lived Particles that Decay to ee , $e\mu$ or $\mu\mu$ with ATLAS

K.K. Gan
The Ohio State University

On behalf of ATLAS Collaboration

May 16, 2024



Outline

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- Background Estimates
- Systematic Uncertainties
- Summary

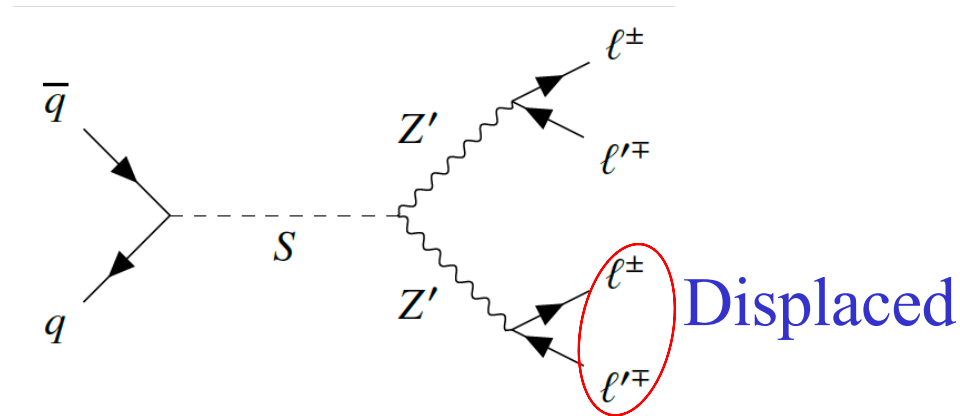


Introduction

- No evidence of beyond Standard Model particles in extensive searches by ATLAS and CMS
 - ⇒ search for long-lived particles is of particular interest
- ATLAS searches in pp collisions at $\sqrt{s} = 13$ TeV
- Integrated luminosity: 140 fb^{-1}
 - ◆ update of previous analysis based on 32.8 fb^{-1}
Phys. Lett. B 801, 135114 (2020)



Models Investigated

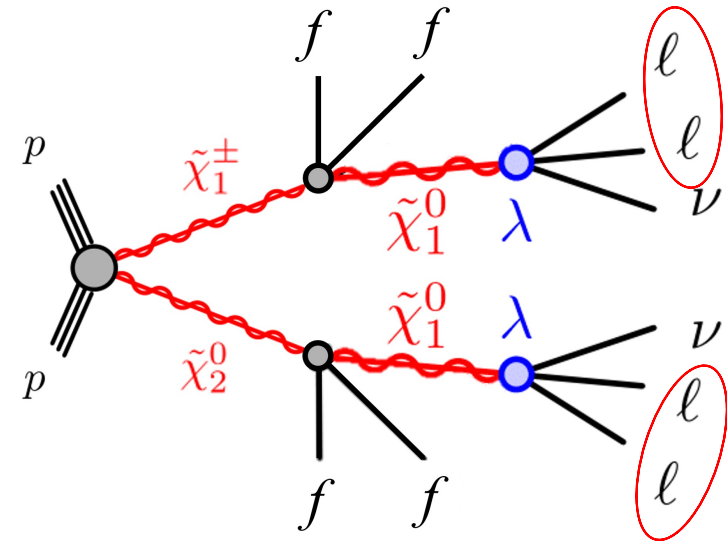
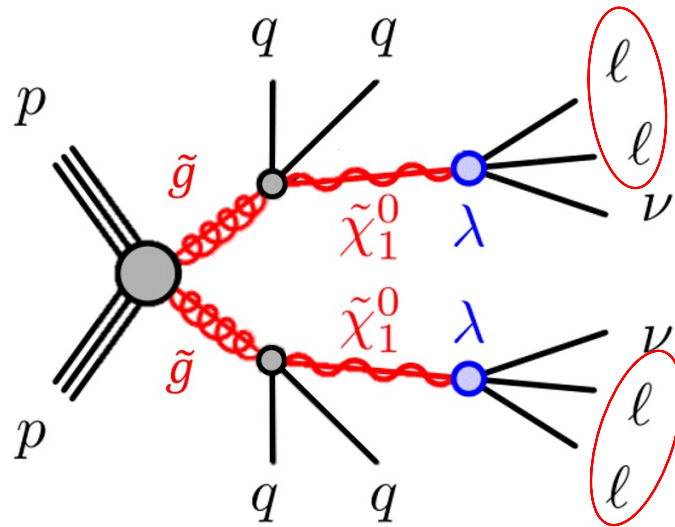


- Previous toy model: Drell-Yan production of Z'
 - ◆ known problem: Z' produced in $q\bar{q}$ interaction would also decay predominately into $q\bar{q}$ and hence excluded
 - ⇒ new model with a scalar decaying to two Z'
 - Z' can decay to lepton pair or dark matter

<https://scipost.org/SciPostPhys.5.4.036/pdf>



Models Investigated



- Replace $\tilde{q}\tilde{q}$ production by $\tilde{g}\tilde{g}$ with larger cross-section
⇒ better sensitivity
- Electroweak production is new



Challenge in Long-Lived Particle Search

- Standard ATLAS trigger + track/vertex reconstruction are designed for particles originated near pp collision region
 - ◆ need special triggers without using inner tracker information
 - loose enough without producing too much data
 - γ : $P_T > 160$ GeV
 - 2γ : $P_T > 60$ GeV
 - μ : $P_T > 60$ GeV and $0 < |\eta| < 1.05$
 - using muon chamber only
 - ◆ need to recover tracks not originated near pp collision region
 - Large radius tracking (LRT) + vertexing



Large Radius Tracking

- special tracking program to recover tracks with large impact parameters not found by standard tracking program
 - ◆ use hits not used by the standard tracking

Allow tracks with larger impact parameters

Reconstruction Phase	Requirement	Standard	Large Radius
Forward tracking	Min. p_T (MeV)	500	900
	Max. η	2.7	5.0
	Max. d_0 (mm)	10	300
	Max. z_0 (mm)	250	1500
Clustering	Min. unshared Si hits	6	5
	Max. shared Si modules	1	2
	Min. Si hits	7	7
	Seed extension	Combinatorial	Sequential
Back-tracking	Min. p_T (MeV)	1000	—
	Max. d_0 (mm)	100	—

Require less silicon hits



Vertex Requirements

- track not allowed to have pixel hits smaller than the vertex radius
- must have nearby pixel or strip hits at larger radius
- vertex cannot be inside disabled pixel module
- no vertex with electron in pixel/strip modules or structure
- candidate tracks must match to trigger and pre-selection objects



Background

- no standard model process can produce heavy lepton pair with displaced vertex
- two potential backgrounds
 - ◆ cosmic ray
 - ◆ two random leptons forming a displaced vertex

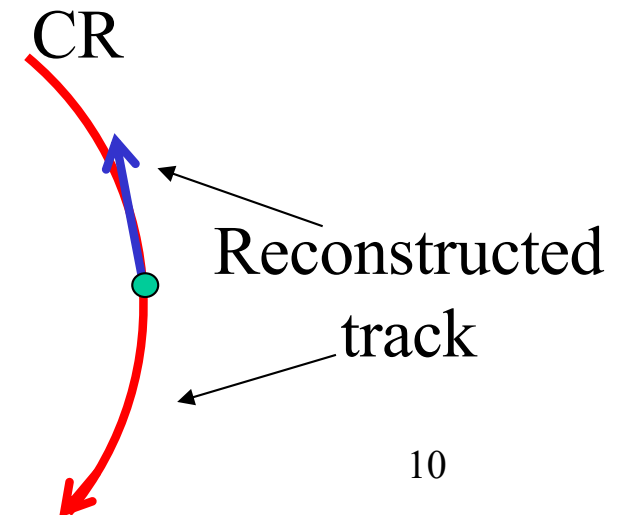


Cosmic Ray Veto

- one segment of cosmic ray could be reconstructed in opposite direction
 - ⇒ two opposite signed track forming a detached vertex
 - ◆ two tracks separated in ϕ by π
 - ◆ two tracks of opposite η
 - ⇒ CR veto:

$$\Delta R_{\text{cos}} = \sqrt{(\Delta\phi - \pi)^2 + (\Sigma\eta)^2} < 0.01$$

- ◆ estimate the background by fitting the distribution and extrapolate into the signal region





Random Crossing Background

- select one lepton from one event and combine with a lepton from a different event
- calculate probability for forming detached vertex
 - ◆ calculation is CPU intensive because probability $\sim 10^{-7}$
 - ◆ need to reconstruct several hundred million events/channel
- multiple this by number of lepton pairs in data to predict number of vertices from random crossing
- validated with high statistics without the lepton requirement



Systematic Uncertainties

- tracking and vertexing efficiency for LLP
 - use $K_s \rightarrow \pi\pi$
 - K_s can be reconstructed using standard or large radius tracking
 - number of K_s is not well simulated by MC
 - ⇒ normalize number of K_s found in data with standard tracking to MC
 - ⇒ compare number of K_s found in data with large radius tracking to MC as a function of transverse decay radius
- Other systematic uncertainties are estimated from data using Z bosons with “tag-and-probe”



Summary

- Presented search strategy for long-lived particles that decay into two oppositely charged leptons: ee , $e\mu$, $\mu\mu$
 - ◆ requiring a detached vertex in the inner tracking volume greatly suppresses the SM background
 - ◆ vertices from random crossing of tracks comprise large source of background but is small and estimated from data
 - ◆ cosmic ray background is even smaller and estimated from data
- Stay tuned...