



Searches for long-lived particles and other non-conventional signatures at CMS

Michael Krohn

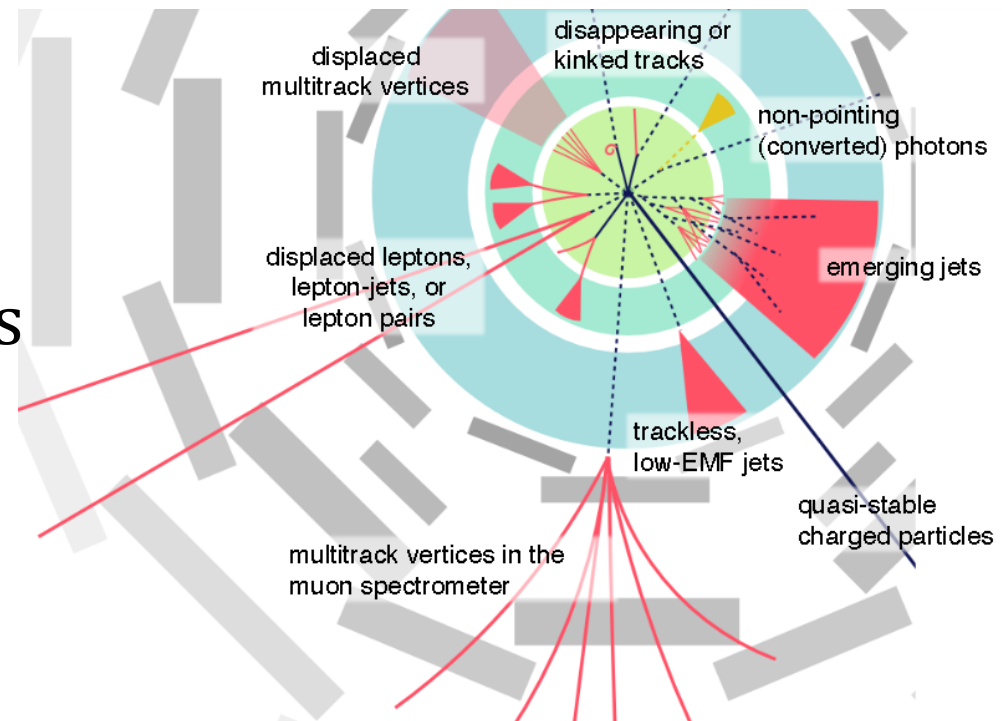
On behalf of the CMS Collaboration

Phenomenology 2019

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Motivation for Long-Lived Particles

- Numerous BSM theories predict LLPs
 - SUSY, hidden valley scenarios, dark QCD, etc.
- CMS designed to identify prompt particles
 - Triggering, data acquisition, reconstruction, and analysis techniques
- Primary backgrounds are usually ignored in prompt particle searches
 - Cosmic rays
 - Electronic noise
 - Material interactions
 - Satellite bunches
 - Beam halo

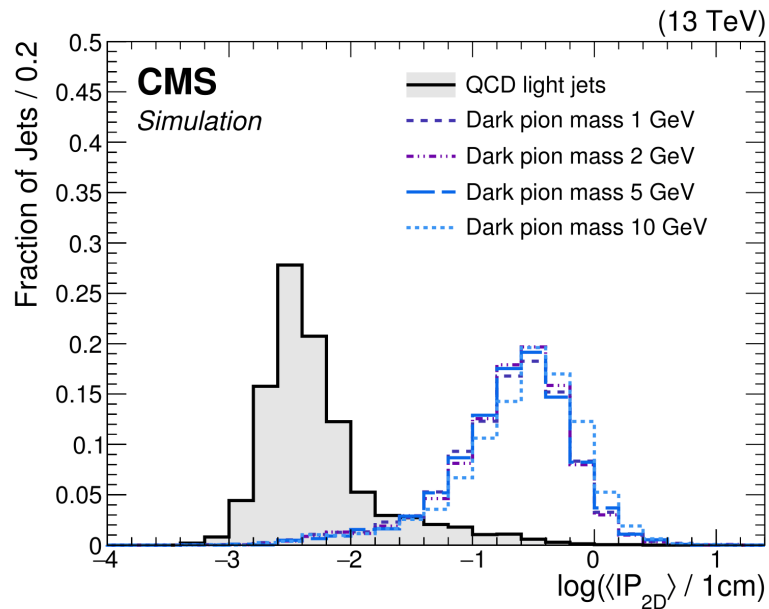


Heather Russel's LLP Workshop talk

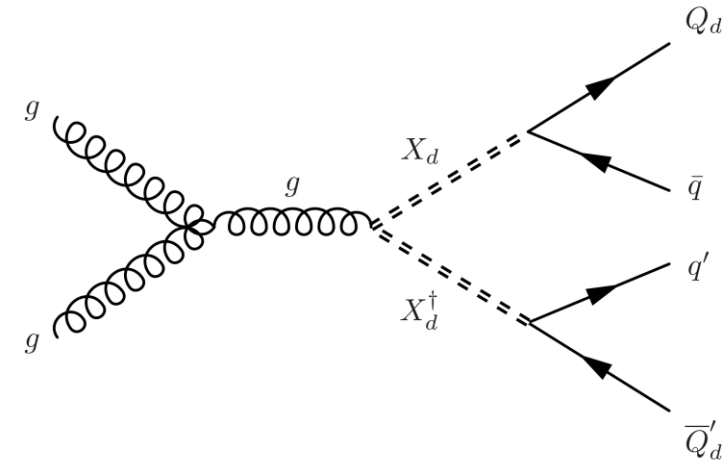
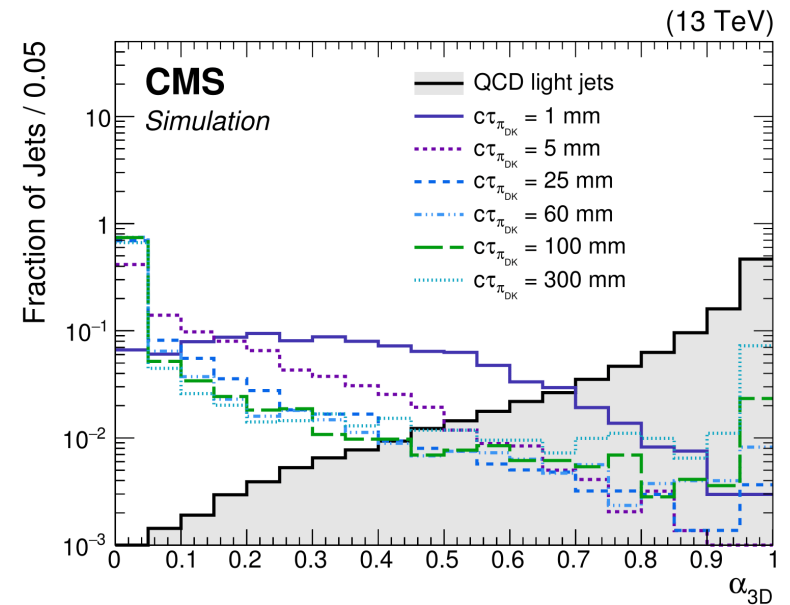
Emerging Jets

- Dark QCD model
 - Signature: 2 SM jets and 2 emerging jets

- Identifying emerging jets
 - Median of transverse IPs of associated tracks

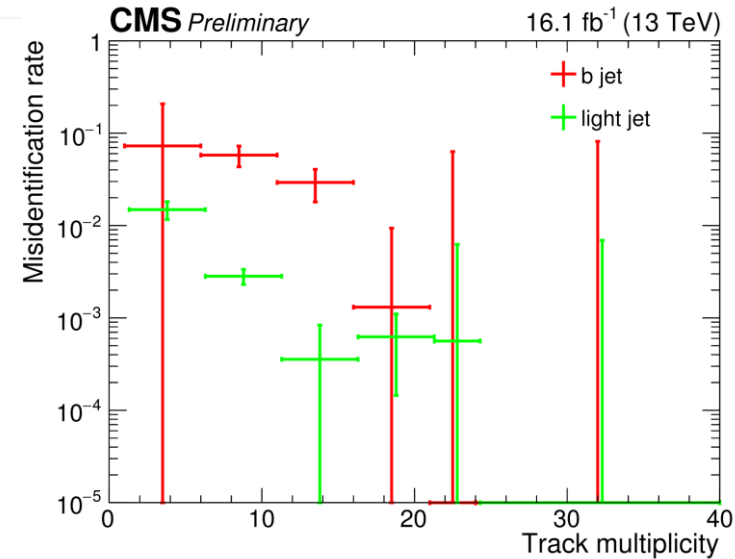
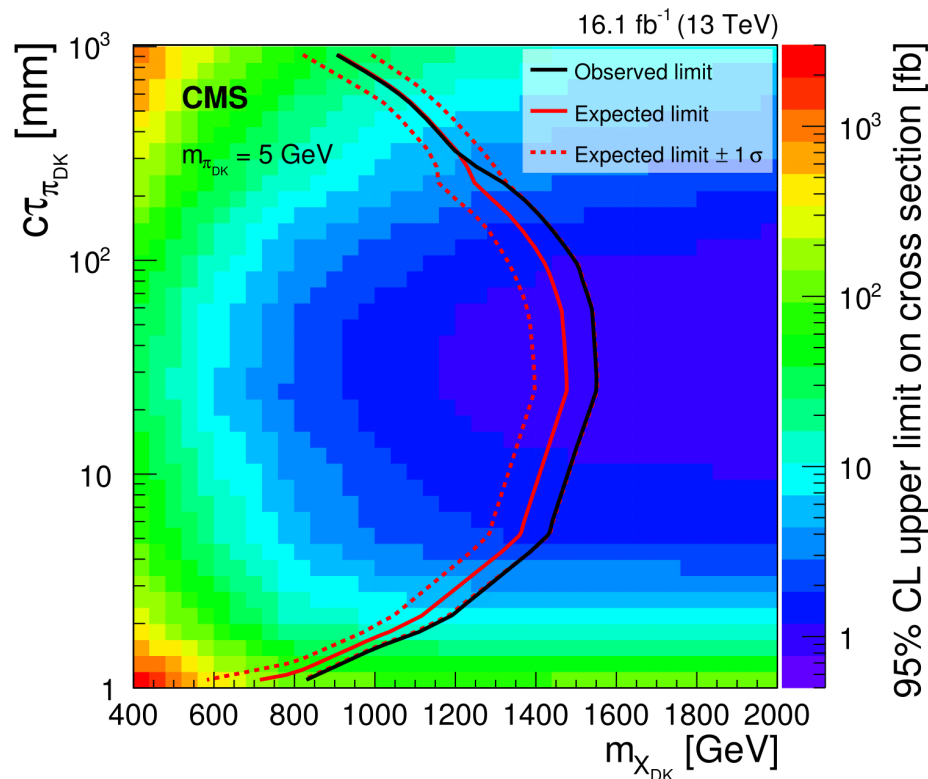


- Fraction of jet p_T associated with prompt tracks



Emerging Jets

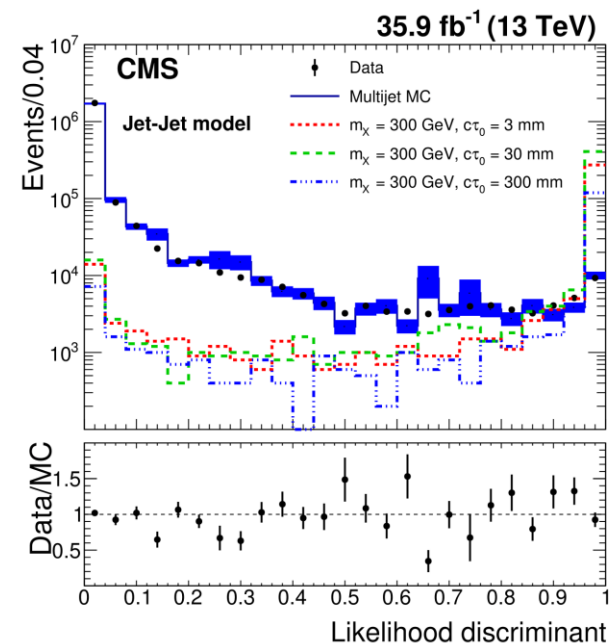
- Data driven background estimation from 4-jet sample without emerging jets
- Misidentification probability of SM jets as emerging jets



- Mediator masses excluded between 400 and 1250 GeV for decay lengths between 5 and 225 mm

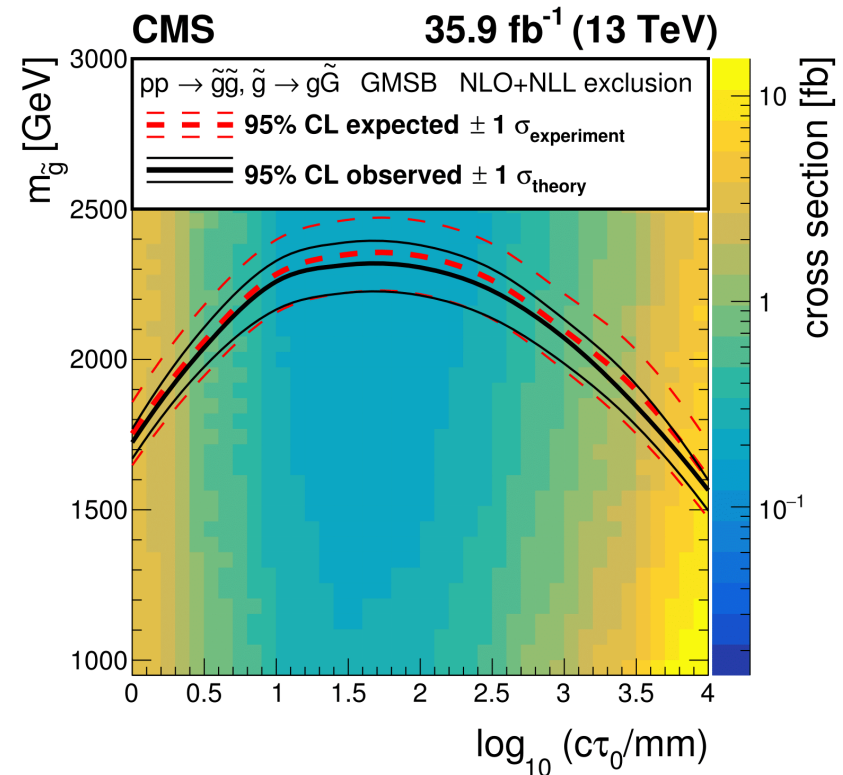
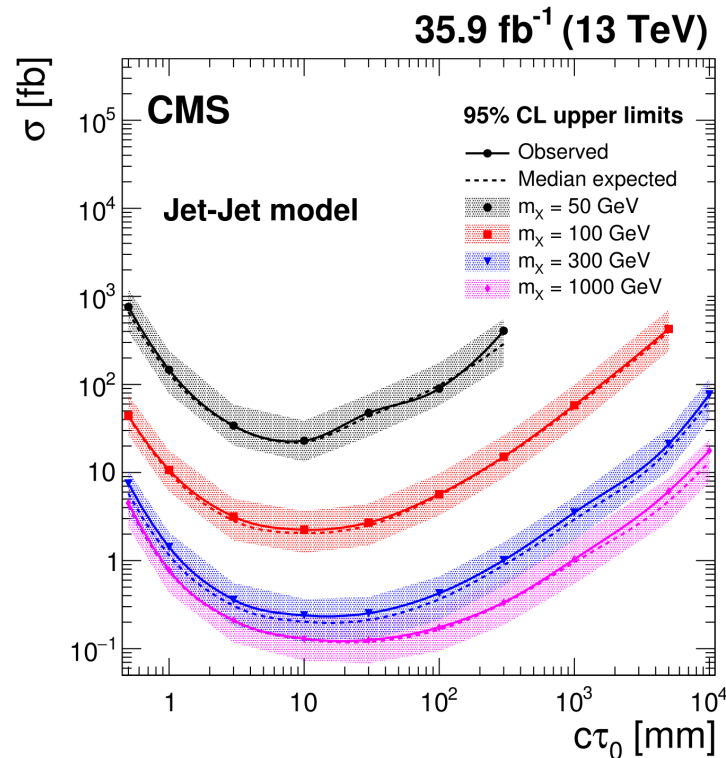
Displaced Jets

- Jets originating from vertices displaced up to 55 cm from the primary vertex
 - $pp \rightarrow XX$, $X \rightarrow qq$ (X = neutral scalar)
 - GMSB model with long-lived gluino ($\tilde{g} \rightarrow g\tilde{G}$)
- Dedicated displaced jet trigger
 - $H_T > 350$ GeV
 - ≥ 2 jets with $p_T > 40$ GeV, $|\eta| < 2$, ≤ 2 prompt tracks, ≥ 1 displaced track
- Background
 - Likelihood discriminant built from track, vertex, and jet information
 - Data driven estimate using control regions defined by the number of prompt tracks associated with either jet and the decay length of SV



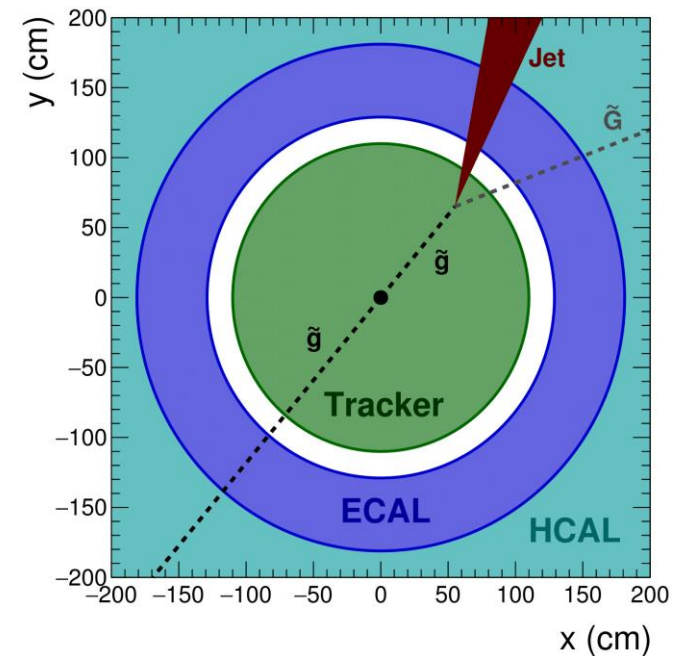
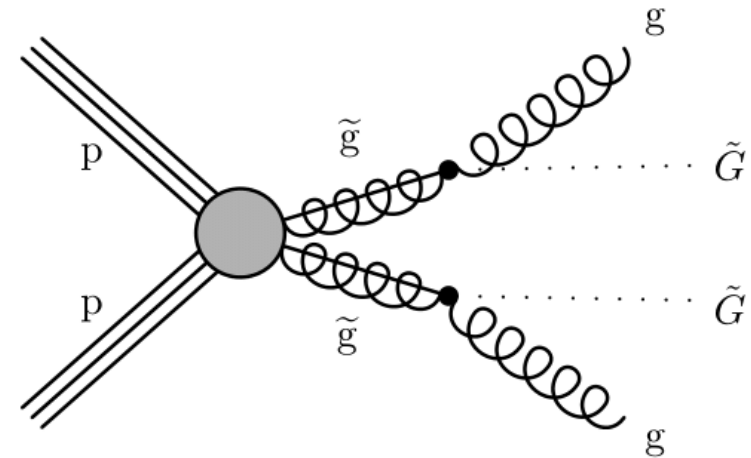
Displaced Jets

- Pair production cross sections larger than 0.2 fb excluded for $m_X > 1000$ GeV and decay lengths between 3 and 130 mm
- Gluino masses up to 2400 GeV are excluded in gluino pair production cross sections larger than 0.25 fb for decay lengths between 10 and 210 mm



Delayed Jets

- GMSB model
- Identifying delayed jets
 - ECAL timing capabilities
 - PbWO_4 crystals with Si APDs
 - Time resolution ~ 200 ps
 - Calorimeter clustering only for jet reconstruction



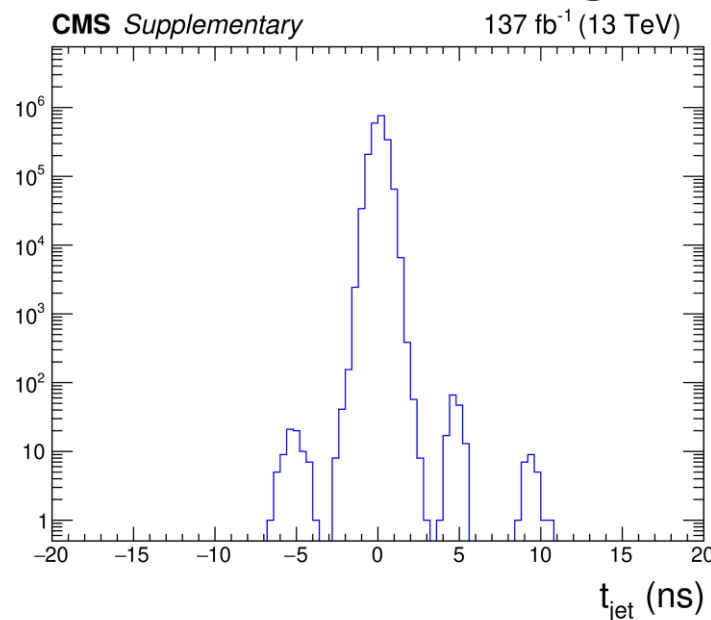
Delayed Jets

● Backgrounds estimated from data control regions

- ECAL time resolution tails
- ECAL electronic noise
- Direct APD hits
- Pileup, in-time and out-of-time
- Satellite bunches
- Beam halo
- Cosmic muons

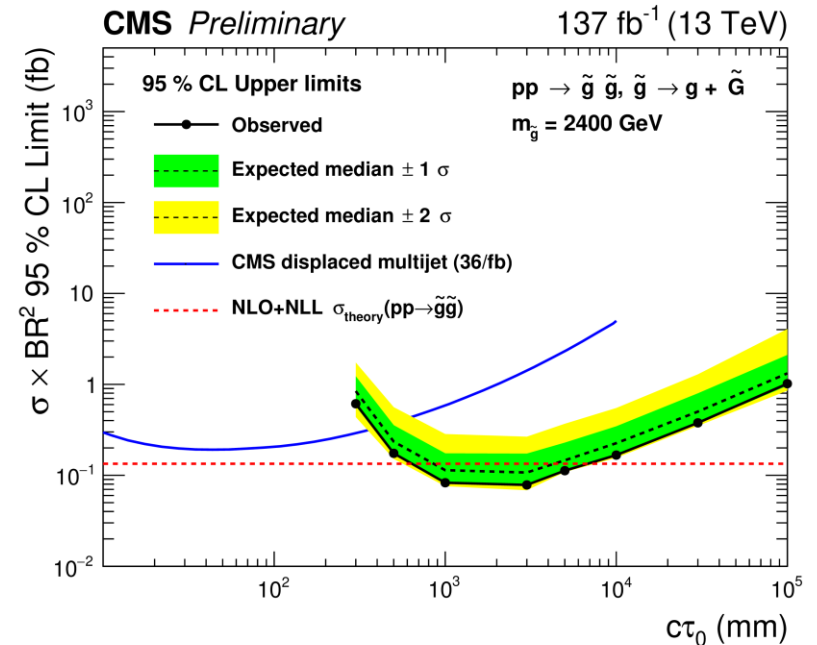
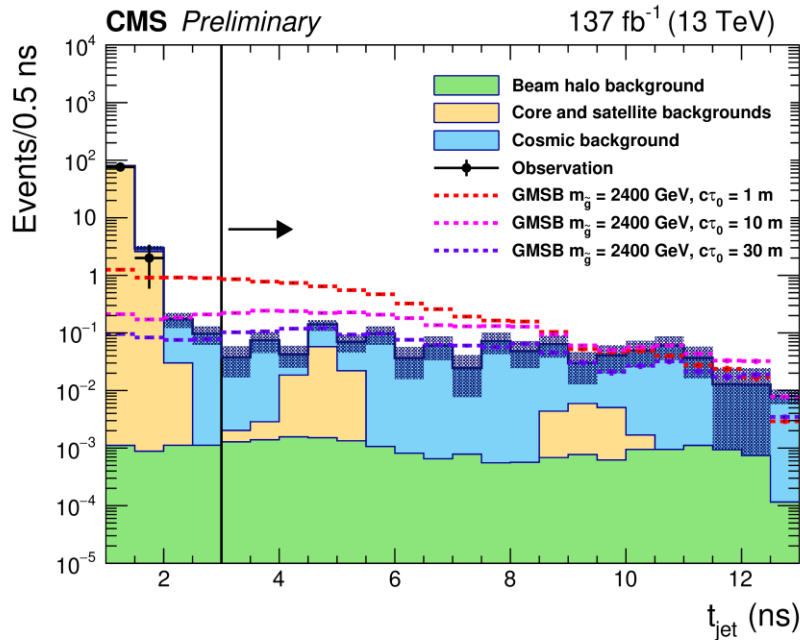
● Jet cleaning requirements

- # ECAL hits > 25
- RMS of t_{jet}
- Fraction of jet momentum from PV tracks
- Fraction of ECAL energy that can be associated with CSC segment hits



Delayed Jets

Background	Prediction
Beam halo	$0.02^{+0.06}_{-0.02}$ (stat) $^{+0.05}_{-0.01}$ (syst)
Core and satellite bunches	$0.11^{+0.09}_{-0.05}$ (stat) $^{+0.02}_{-0.02}$ (syst)
Cosmics	$1.0^{+1.8}_{-1.0}$ (stat) $^{+1.8}_{-1.0}$ (syst)

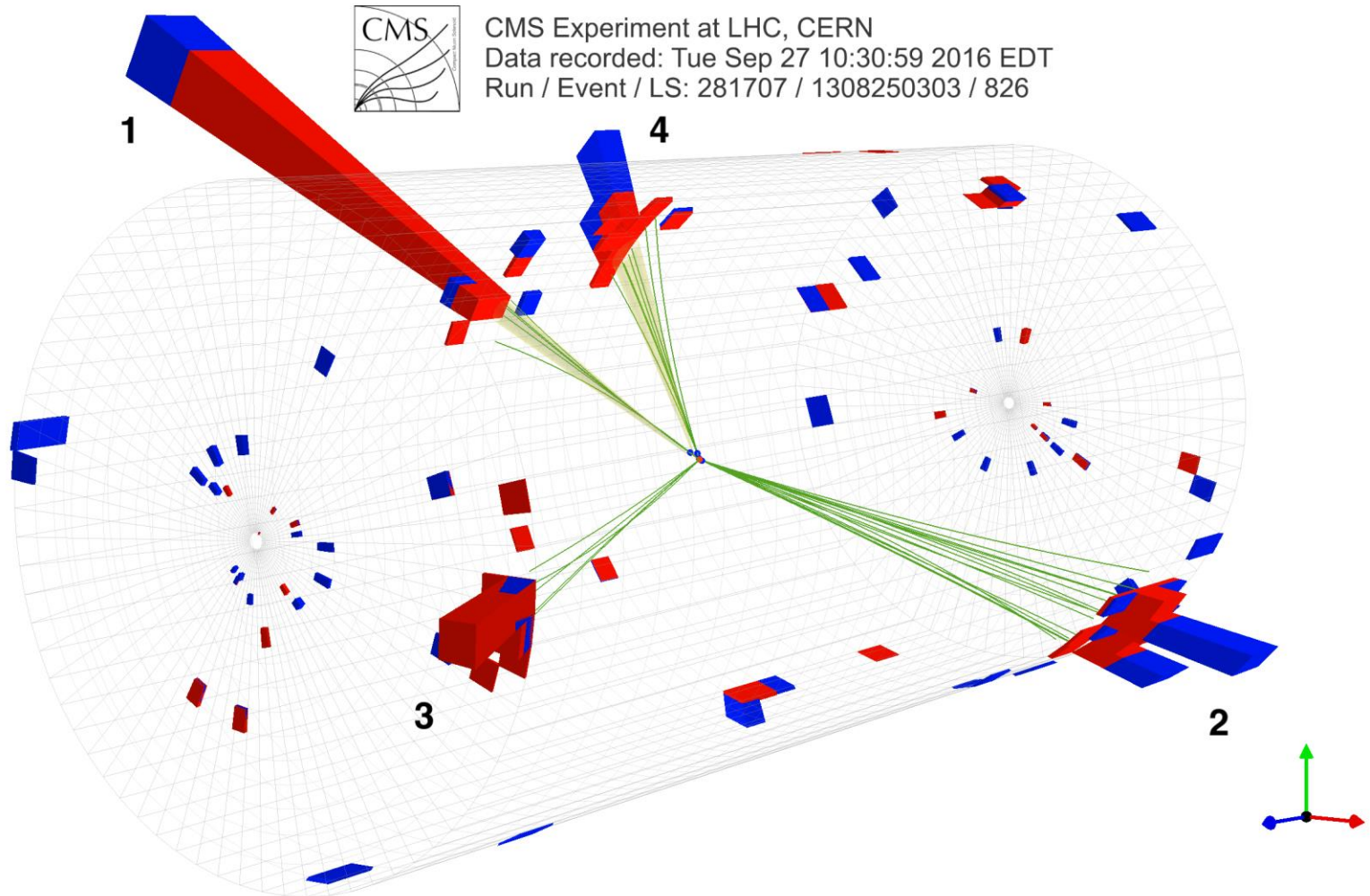


● Gluino masses below 2100 GeV are excluded for proper decay lengths between 0.3 and 30 m

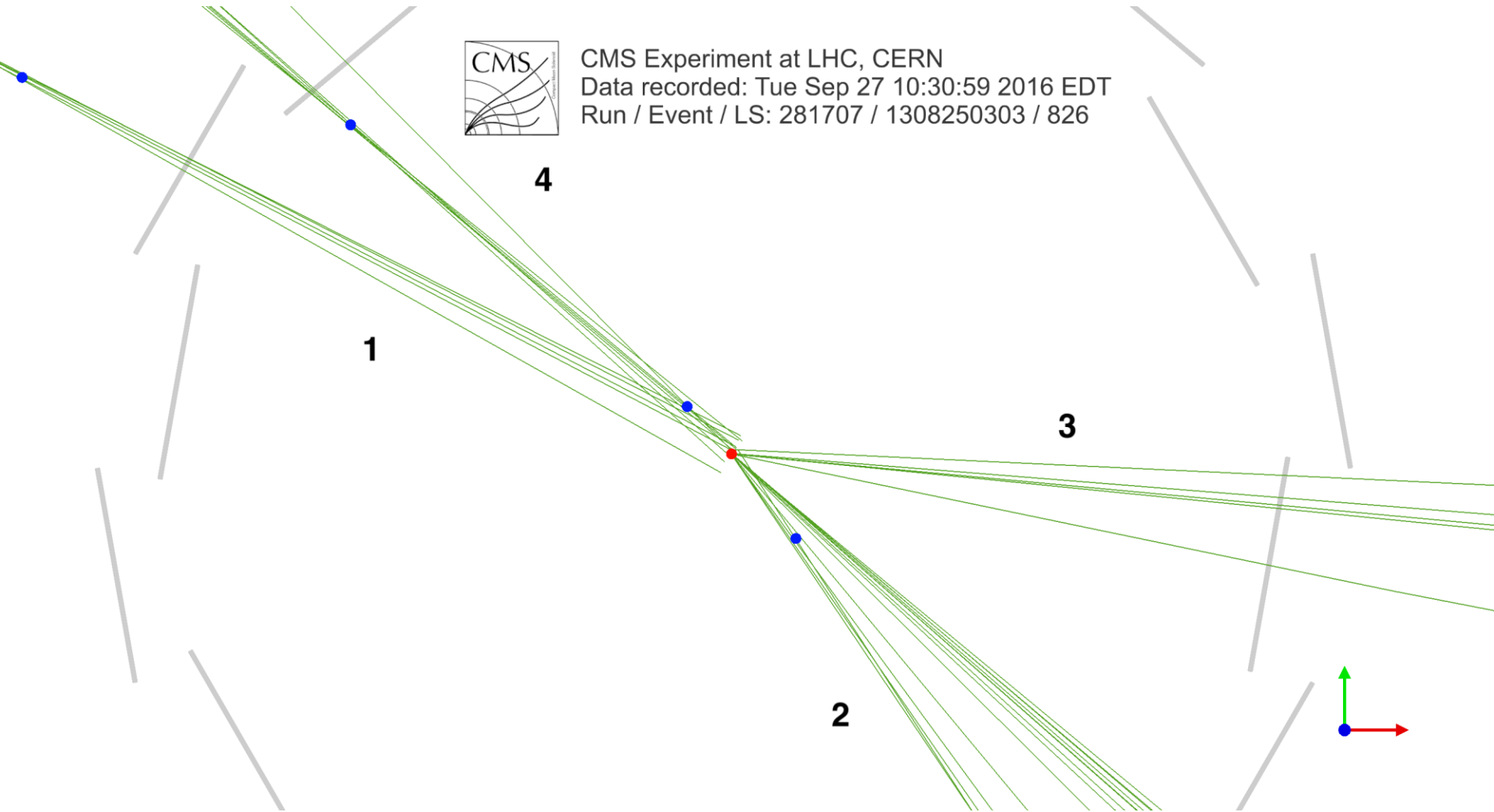
Conclusion

- Searches for long-lived particles and unconventional signatures are underway
- More full Run 2 analyses will be published soon
- Triggers, data acquisition, reconstruction techniques and analysis strategies are being developed for unconventional signatures
- HL-LHC upgrades will assist in allowing more unconventional signatures to be looked for

Backup

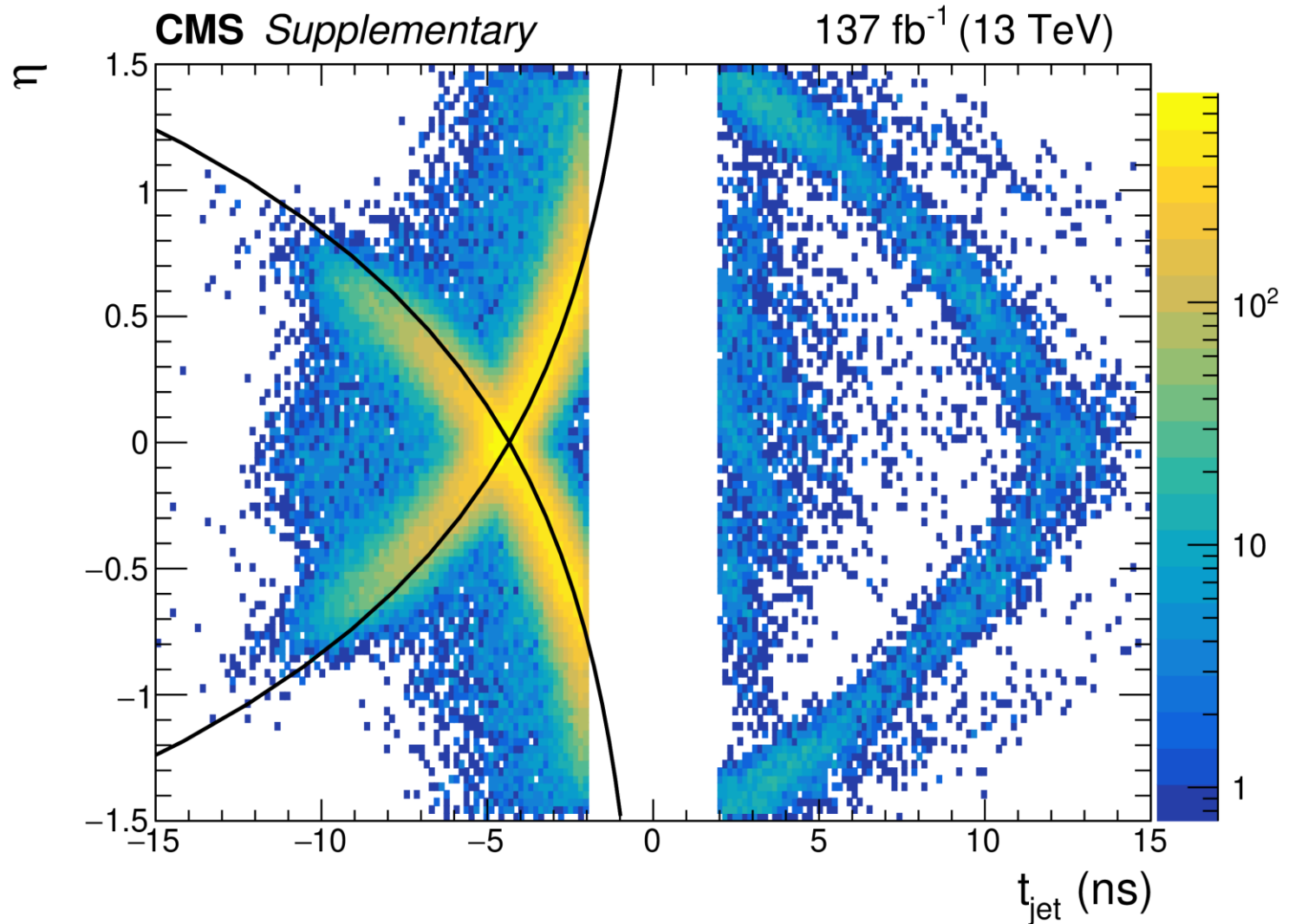


Emerging Jets



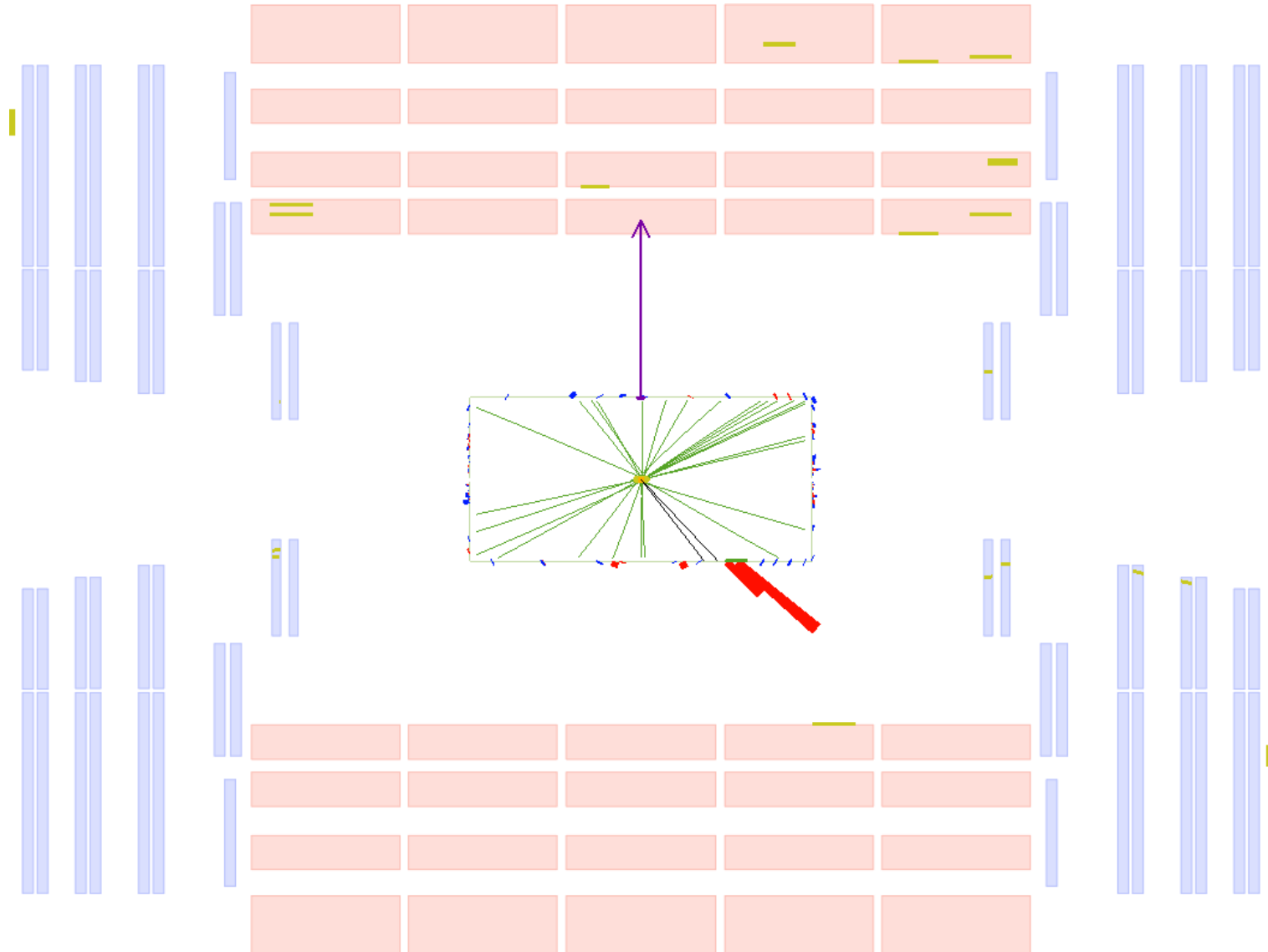
Delayed Jets

● Beam halo muon



Delayed Jets

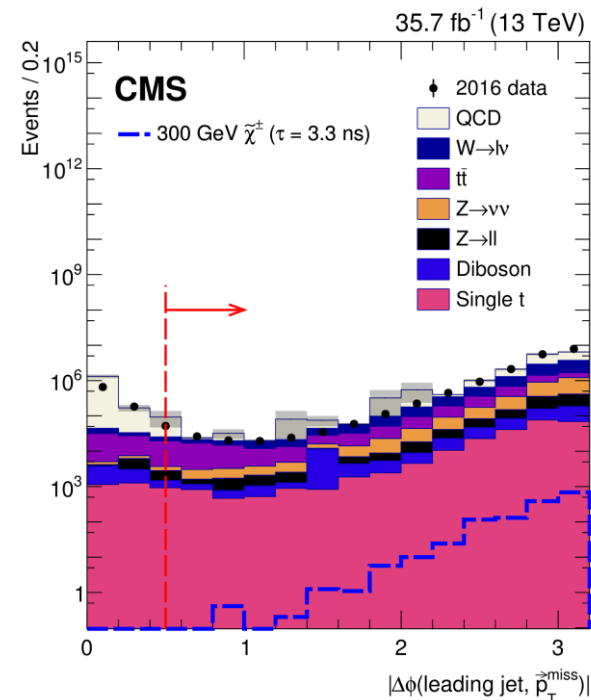
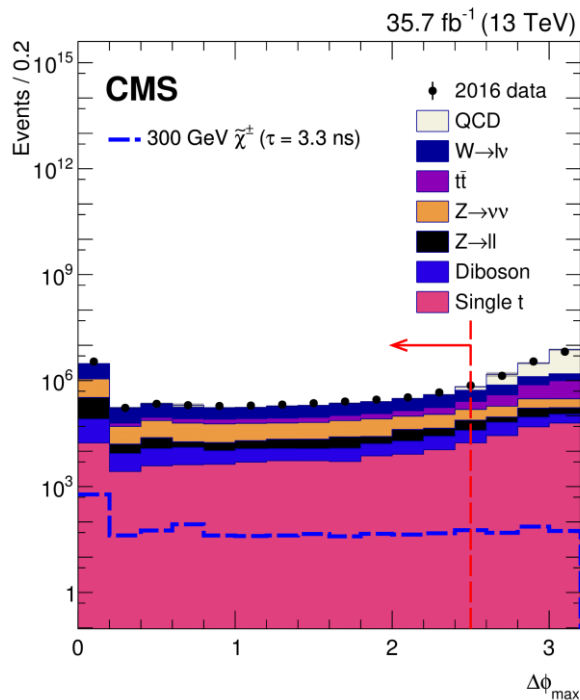
● Beam halo muon



Disappearing Track

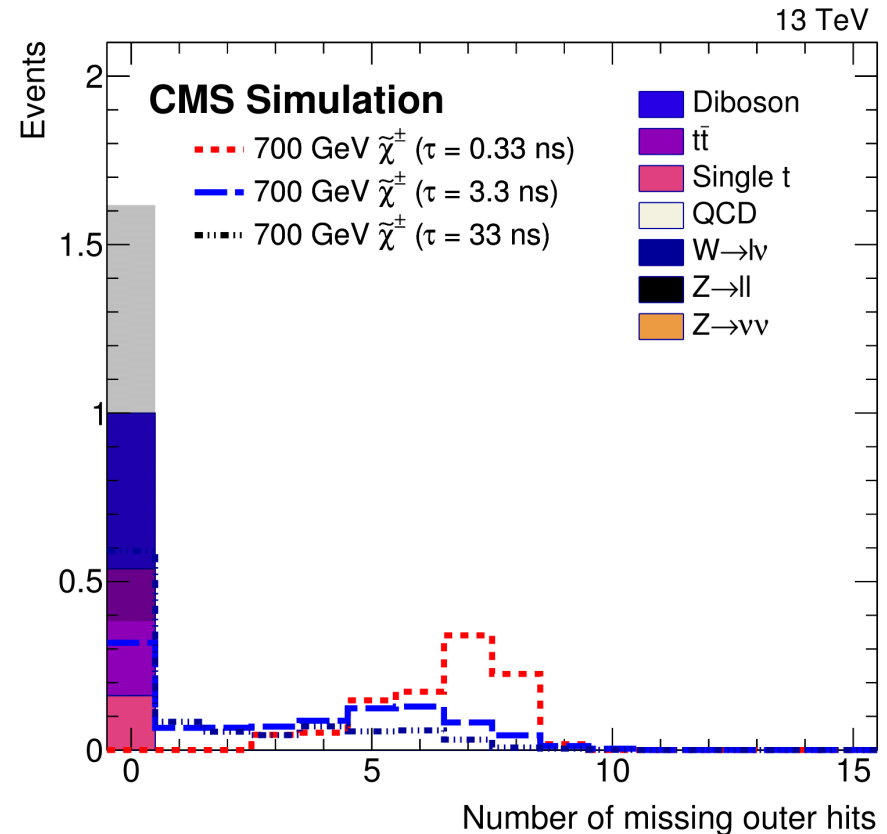
- Anomaly-mediated supersymmetry breaking models
 - χ_1^\pm (NLSP) is nearly mass-degenerate with χ_0 (LSP)
 - Produces a track that disappears after crossing a few tracker layers
- Select signal events using ISR jet
 - Reduce QCD background using angle cuts between jets and missing

p_T



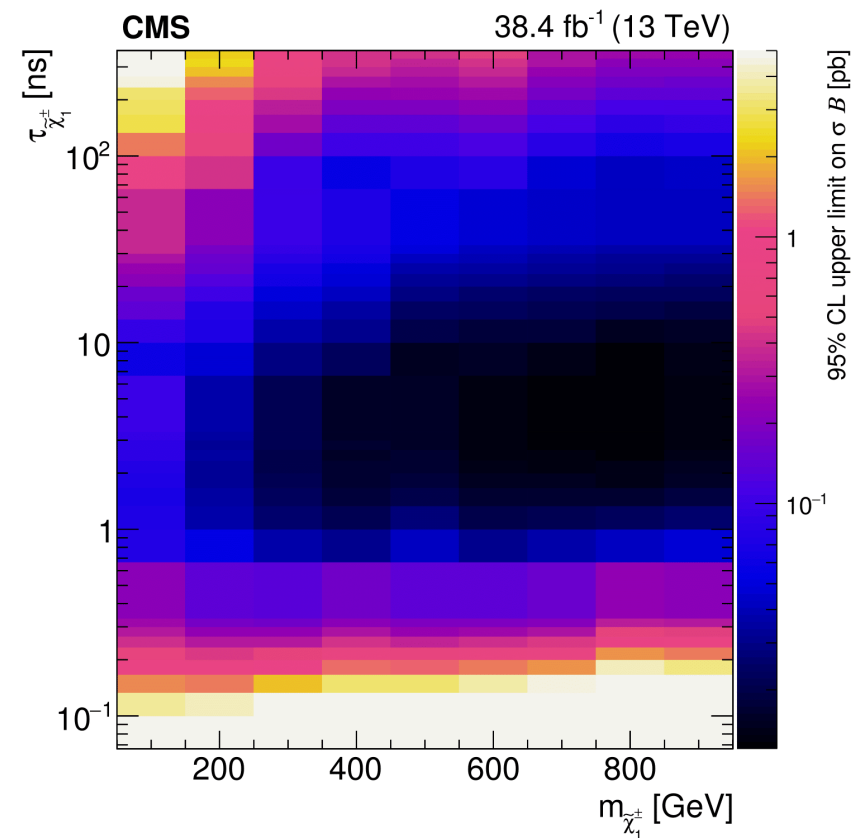
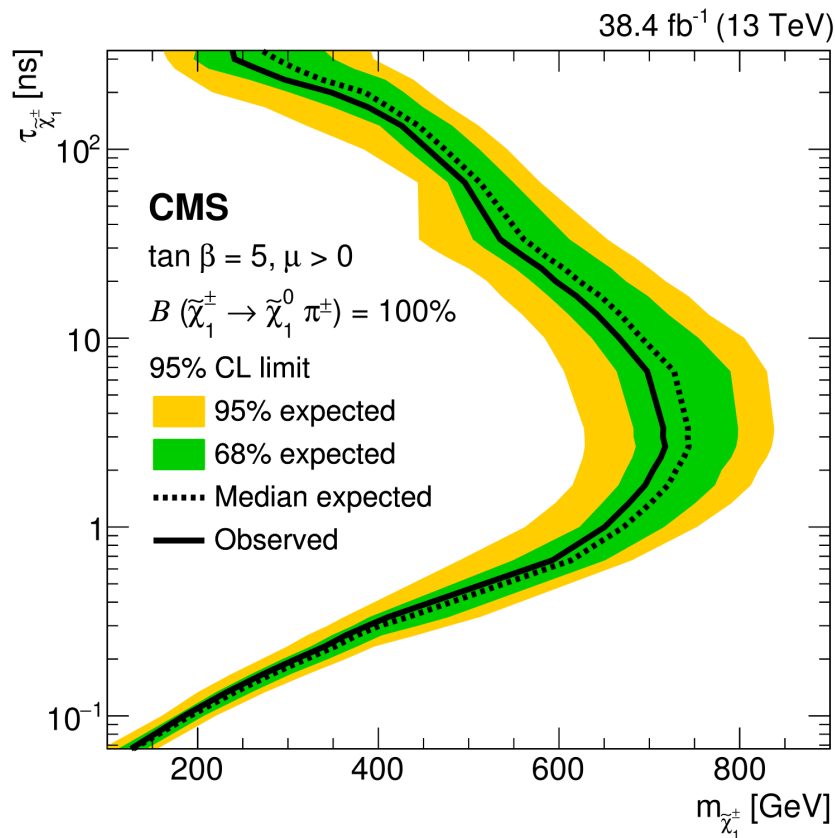
Disappearing Track

- Reconstructing small tracks
 - Require 3 hits in pixel detector and 7 hits overall in tracker
 - No missing inner hits
 - No hits in the outer layers
 - Strict impact parameter requirement
- Backgrounds estimated using data control regions
 - Spurious tracks from random hits
 - Charged leptons that fail lepton ID



Disappearing Track

- Limits set for lifetimes between 0.1 and 100 ns
 - $\tilde{\chi}_1^\pm$ with masses up to 715 (695) GeV are excluded for a lifetime of 3 (7) ns



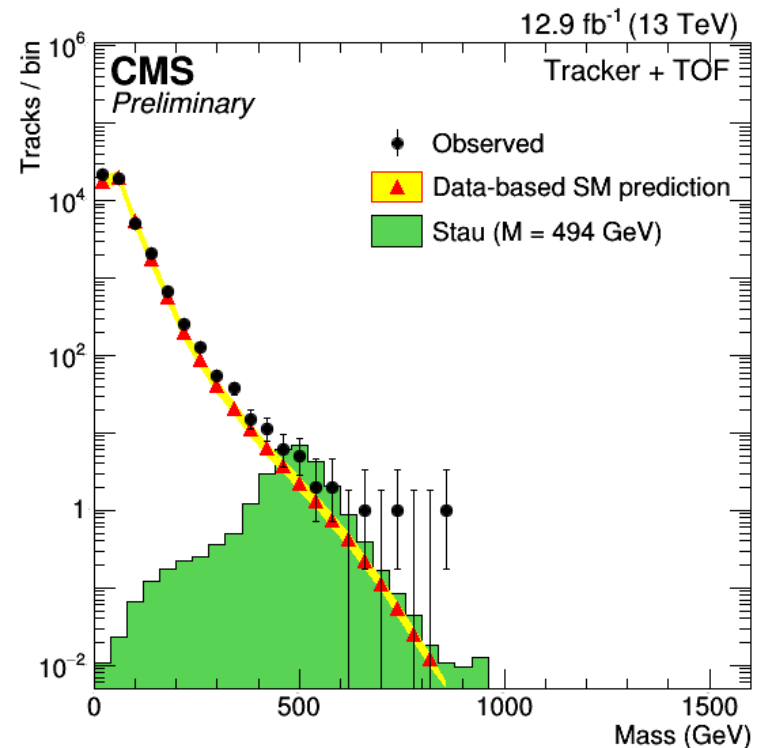
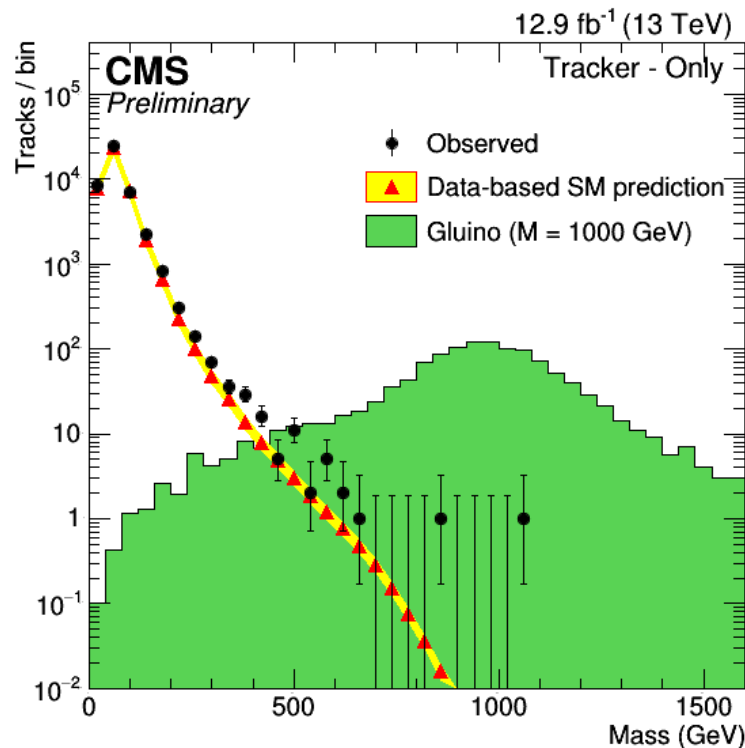
Heavy Stable Charged Particles

- HSCPs have large ionization energies, $\frac{dE}{dx}$, and long time of flights (TOF)
 - Two analysis techniques used
 - Tracker-only
 - Tracker + TOF
- Benchmark models
 - Split SUSY scenarios with R-hadrons that are stable
 - Stuas from mGMSB
 - Modified Drell-Yan production with long lived lepton-like fermions

Heavy Stable Charged Particles

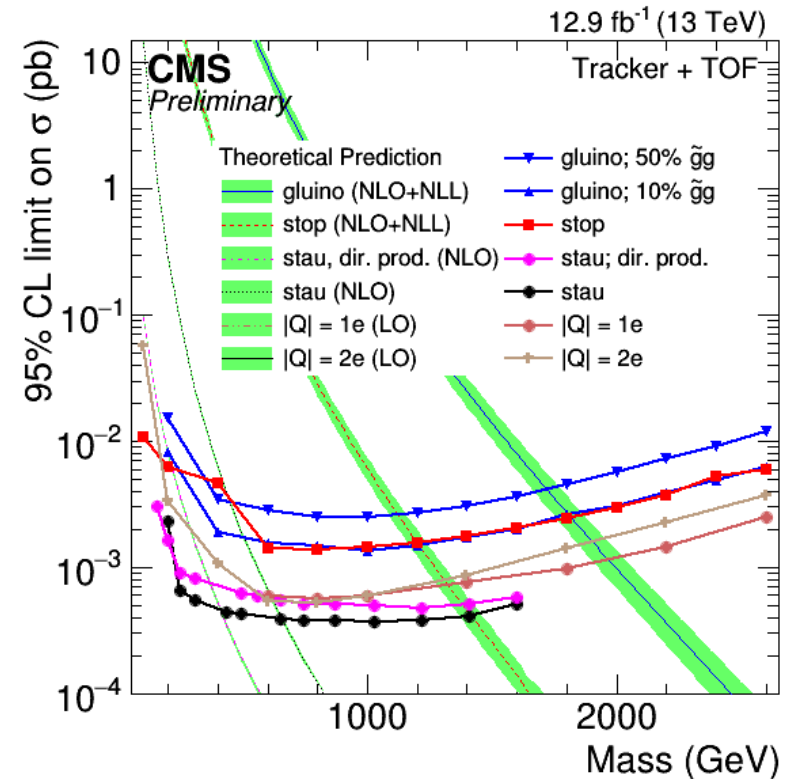
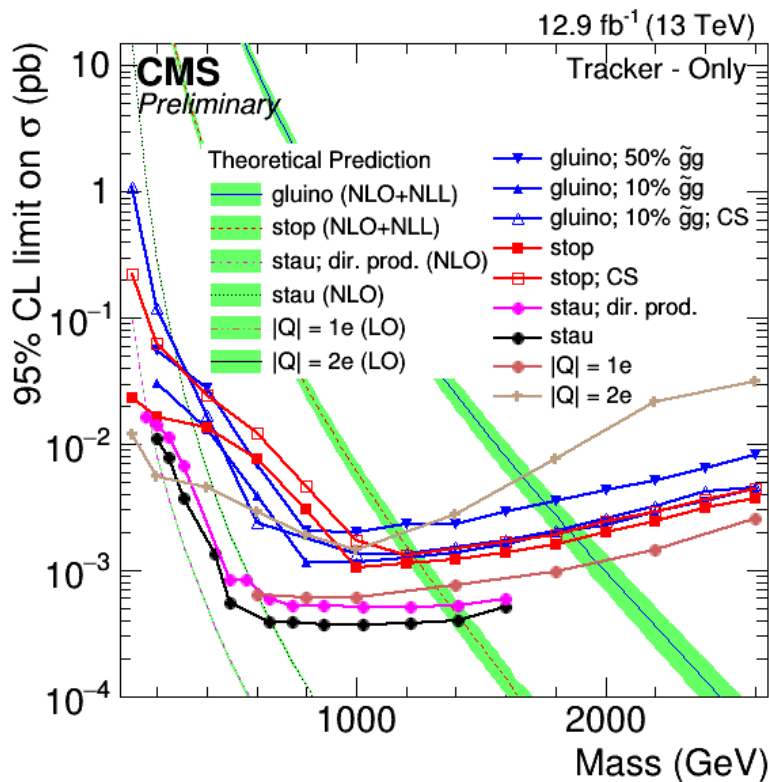
● Background estimation

- Tracker-only: ABCD method based on p_T and $\frac{dE}{dx}$
- Tracker+TOF: Extended ABCD method based on p_T , $\frac{dE}{dx}$, and $\frac{1}{\beta}$



Heavy Stable Charged Particles

- Split SUSY gluino masses below 1850 GeV excluded
- Stau masses below 660 GeV excluded for GMSB
- DY signals with $|Q| = 1e(2e)$ excluded below 730 (890) GeV



CMS LLP Summary of Results

CMS long-lived particle searches, lifetime exclusions at 95% CL

