Searches for long-lived particles with the CMS detector

DPF 2017

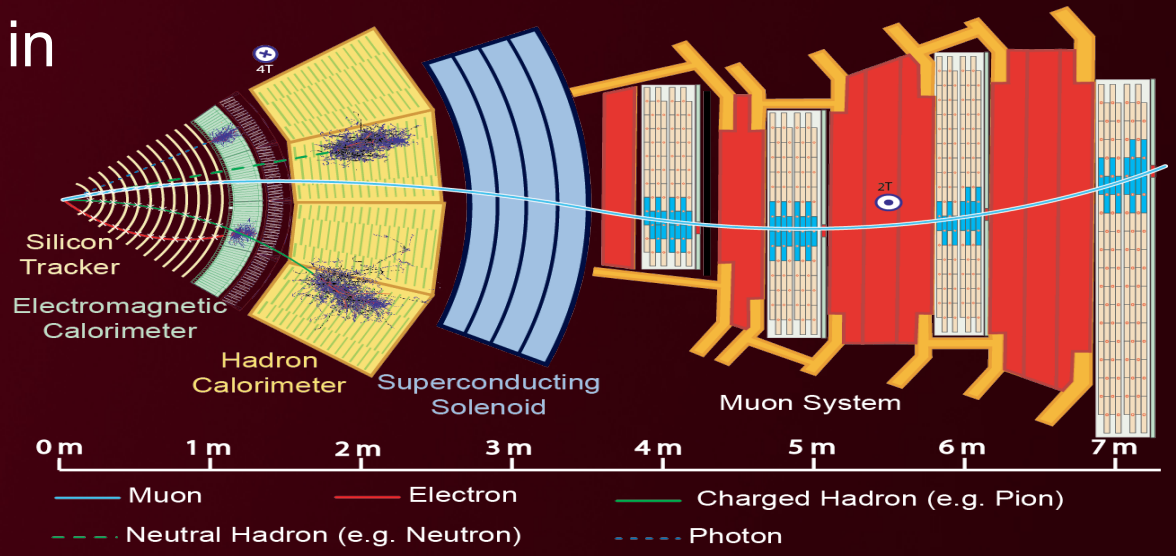
Todd Adams

Florida State University

on behalf of the CMS Collaboration

Long-lived and Non-Conventional

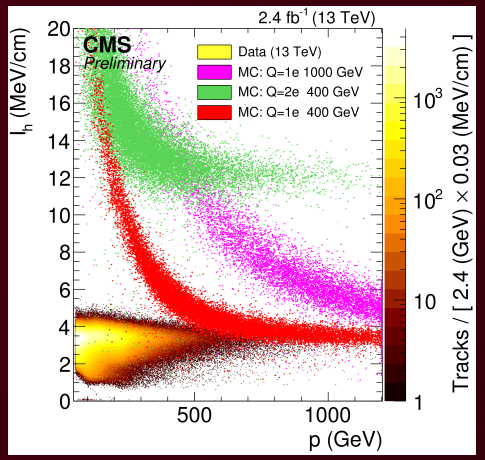
- Searches for particles that don't decay to SM particles within < 5 microns (approx.)
  - could be "stable", could have displaced decay vertex, could have out-of-time signal
- Many models
  - hidden valleys, RPV SUSY, Split SUSY, magnetic monopoles
  - small coupling, small mass splitting
- Non-standard signal in detector

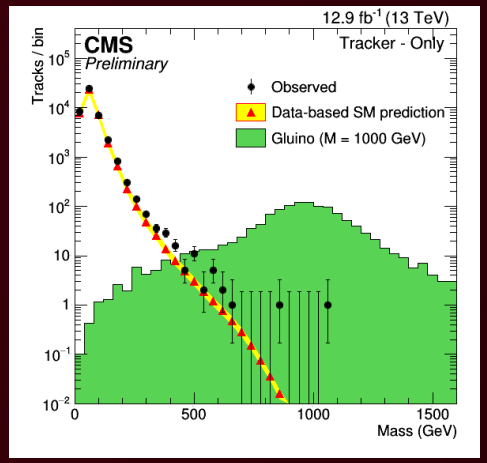


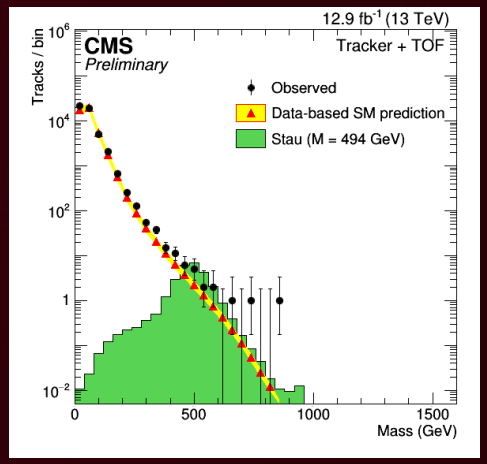
HSCPs

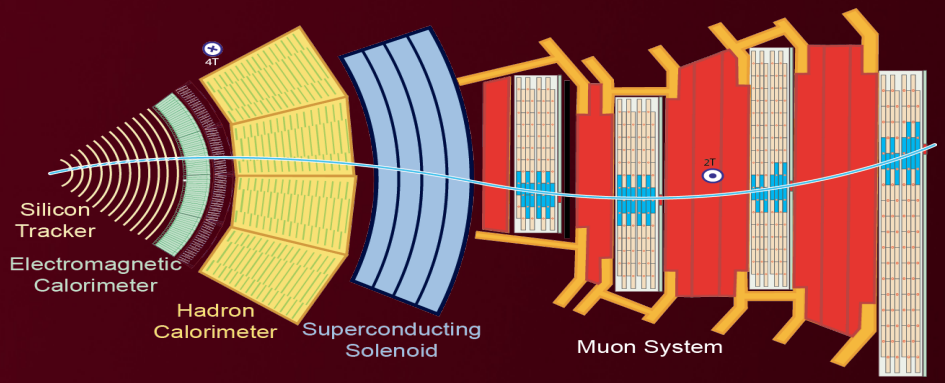
Heavy, stable, charged particles

- Massive (M > 100 GeV)
- Stable (does not decay within detector)
- Charged
- Unique signatures
  - large ionization in detector
  - long time-of-flight to outer detectors
- Lepton-like, R-hadron models









HSCP Searches

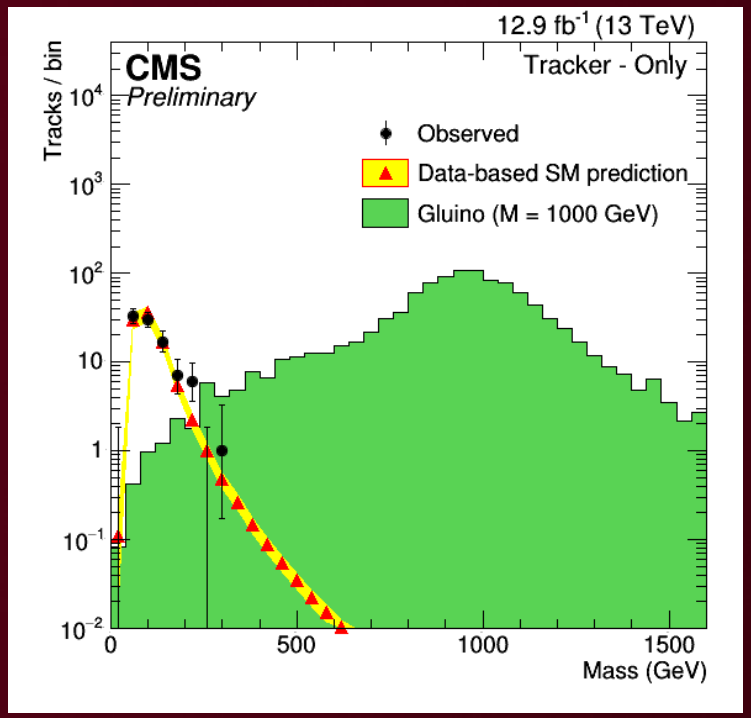
Two related searches

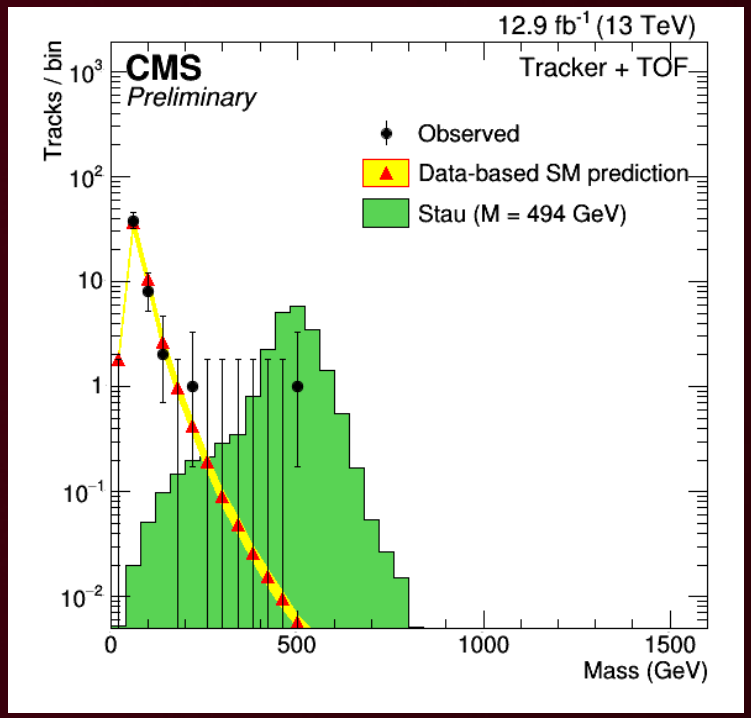
Tracker dE/dx

- Sensitive to HSCPs that don't make it to muon system

Tracker dE/dx + muon TOF

- HSCPs traversing full detector



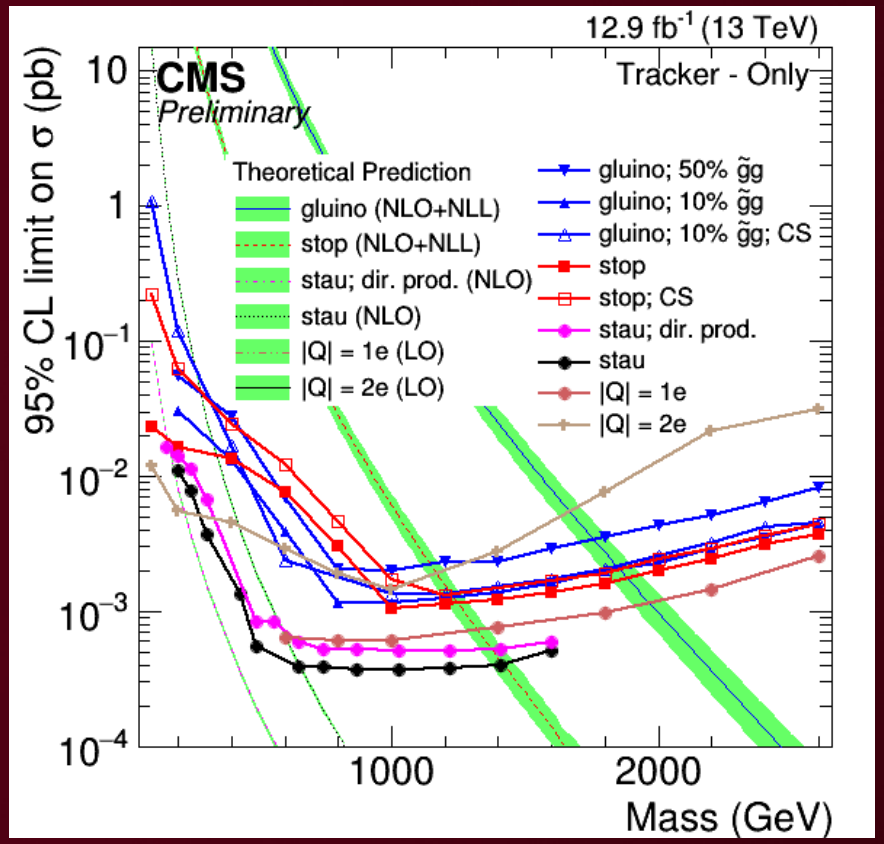


Mass calculated from dE/dx

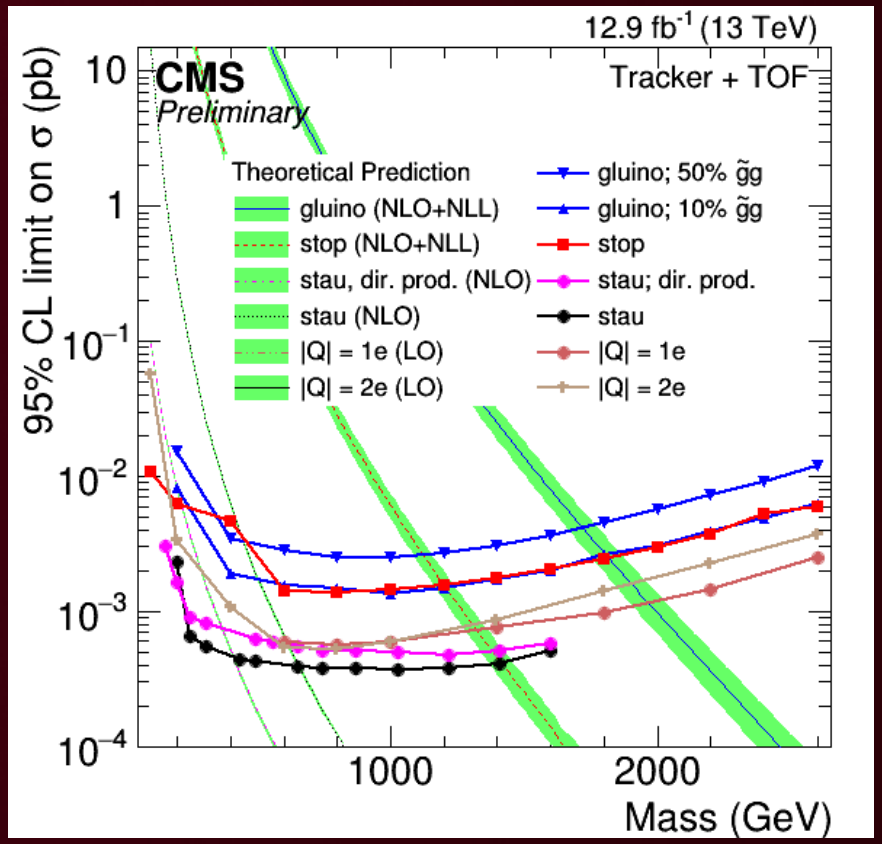
HSCP Results

Observations consistent with expectation

Tracker dE/dx



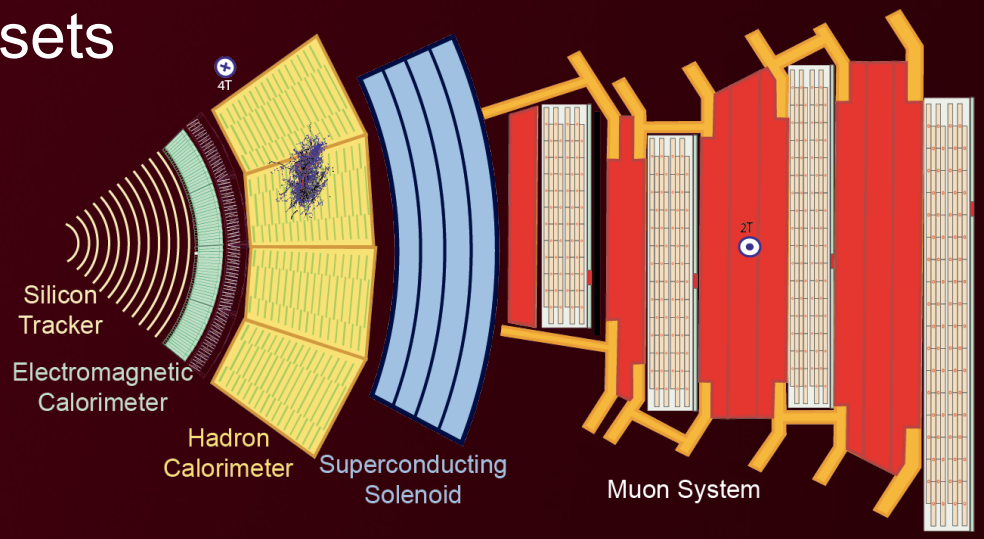
Tracker dE/dx + muon TOF



EXO-17-036

Stopped Particles

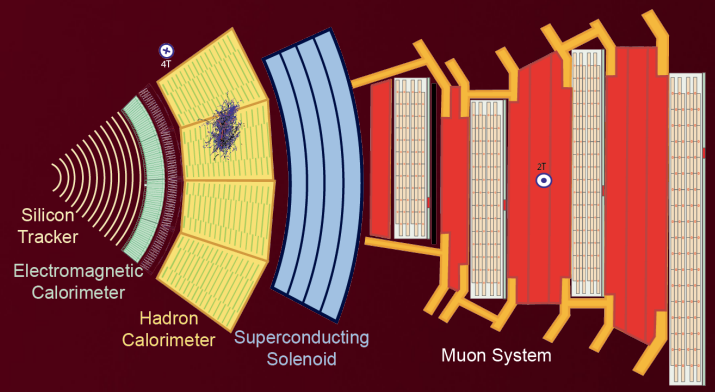
- Energy loss can result in HSCP stopping within detector
- Particle decays at a much later time
- Search for
  - decay in calorimeter
  - decay in muon system
- Require decay when no colliding beams present
- Combined 2015+2016 datasets
- Backgrounds
  - cosmic rays
  - beam halo
  - detector noise

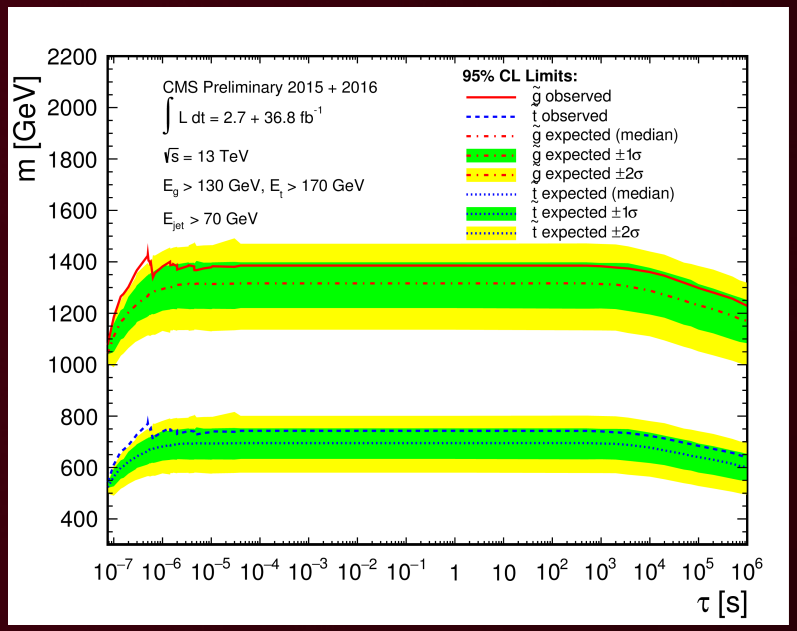


Calorimeter Signature

large energy deposition in calorimeter

- E(jet) > 70 GeV
- Out of time with collisions (≥2 bunch crossings from proton bunches)
- Backgrounds scaled from vetoed events
- Two signal models: gluinos and stops

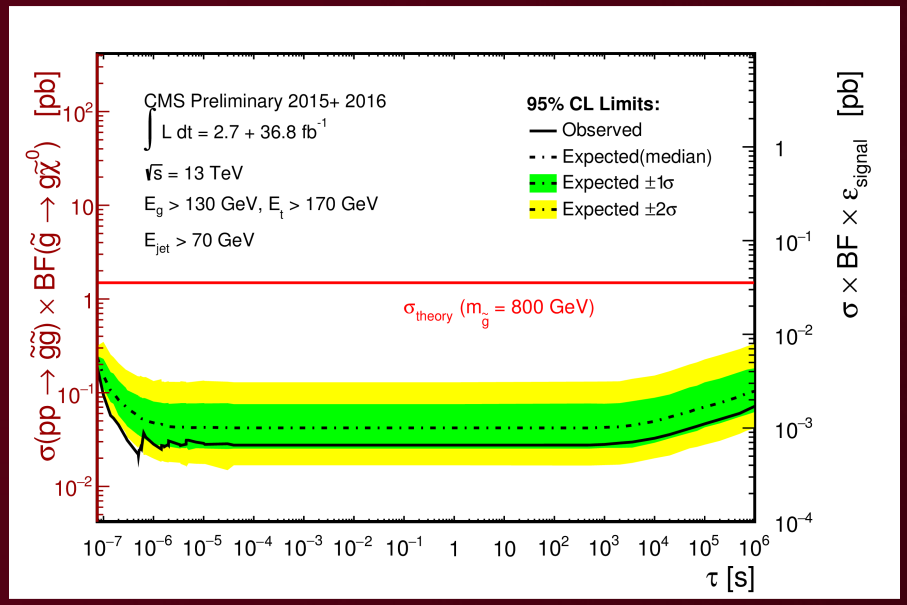


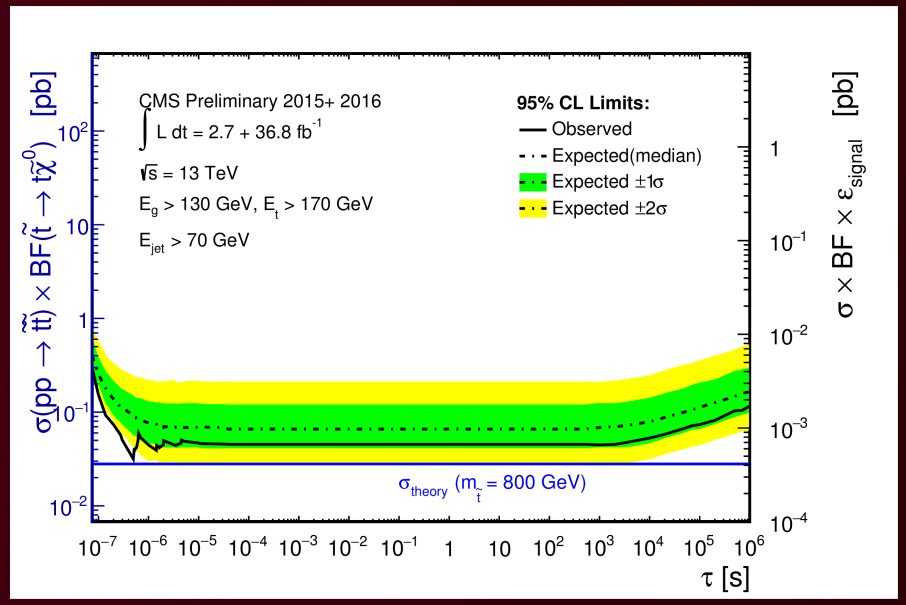


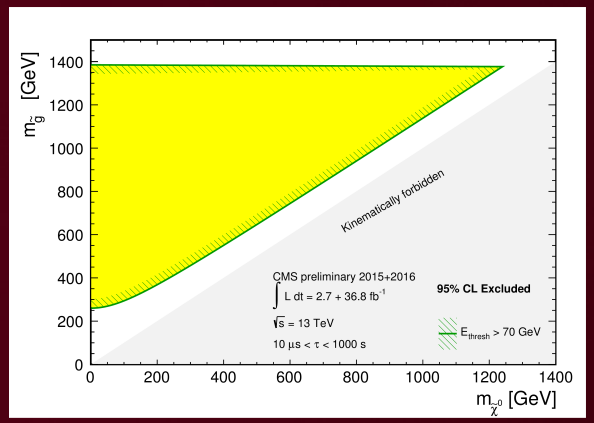
Period	Livetime (hrs)	Noise	Cosmics	Halo	Total	Observed
2015 control	-	$0.3^{+2.4}_{-0.3}$	1.7 ± 0.6	0	-	2
2015	135	$0.4^{+2.9}_{-0.4}$	2.6 ± 0.9	1.1 ± 0.1	$4.1^{+3.0}_{-1.0}$ (the median is 6.2)	4
2016 control	-	$0^{+2.2}_{-0}$	2.5 ± 0.9	0	-	2
2016	586	$0^{+9.8}_{-0}$	8.8 ± 3.1	2.6 ± 0.2	$11.4^{+10.3}_{-3.1}$ (the median is 17.4)	13

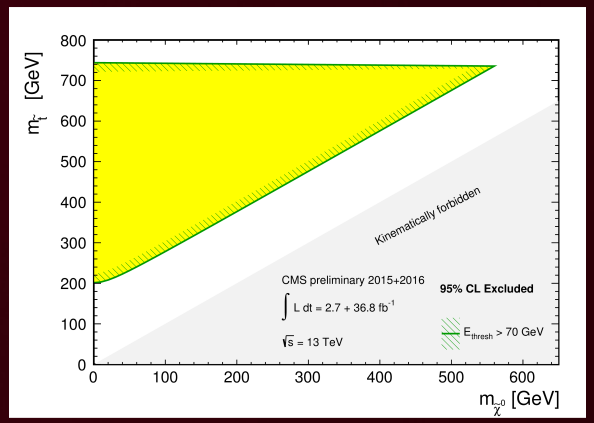
Calorimeter Signature

no excess observed









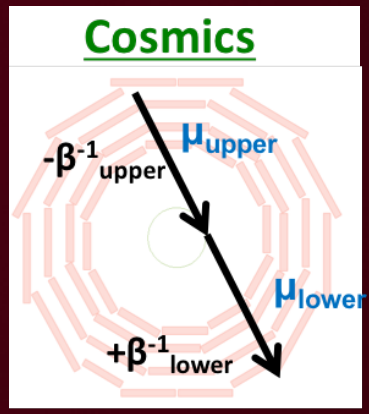
EXO-16-004

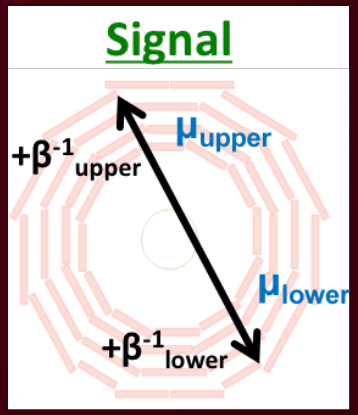
NEW RESULT

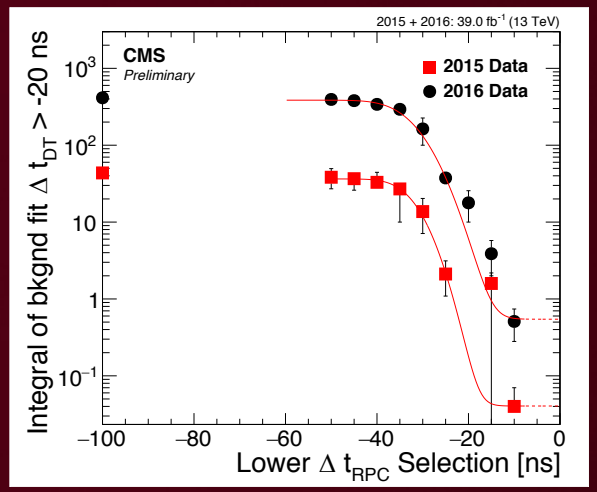
Muon Signature

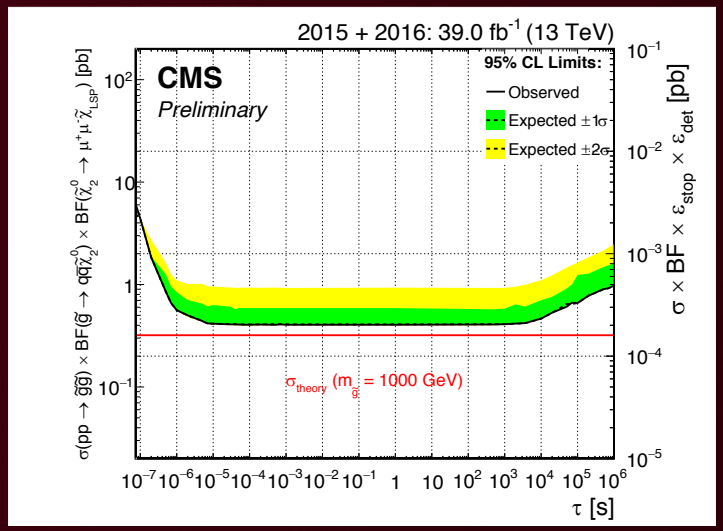
muons from decay

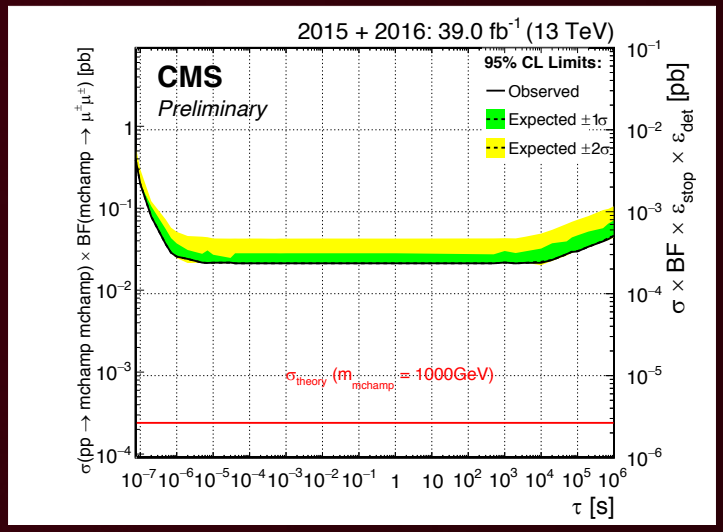
- Require two muon tracks
  - upper and lower part of detector
  - $\Delta t = t_{upper} - t_{lower}$
- Background: extrapolate timing difference
- Two signal models: gluinos and |Q| = 2e
- No events observed





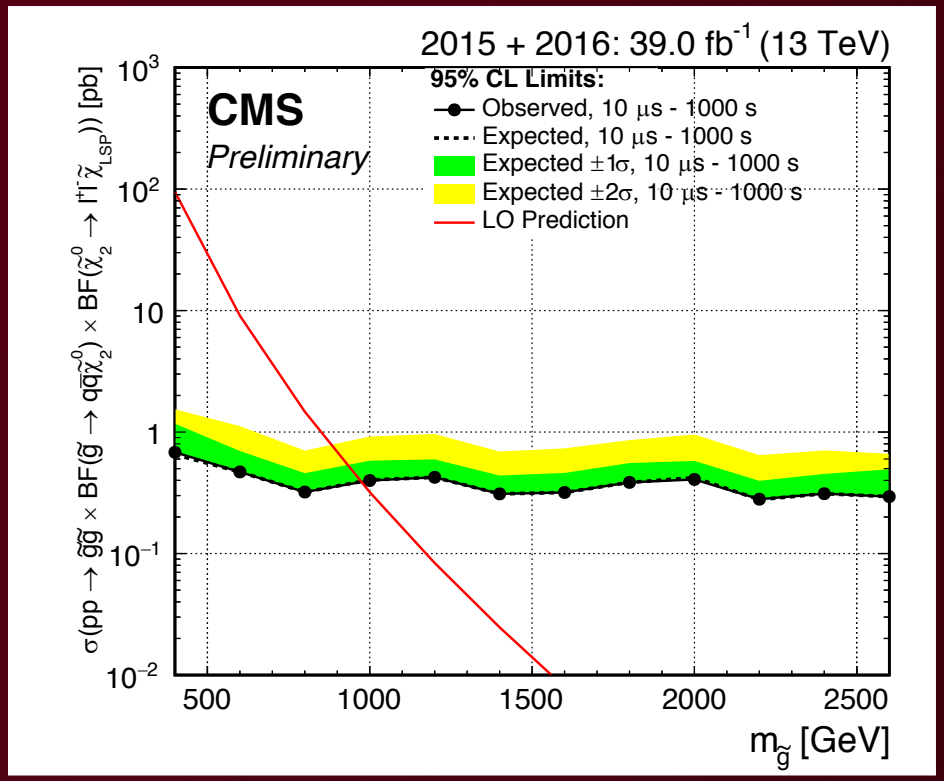




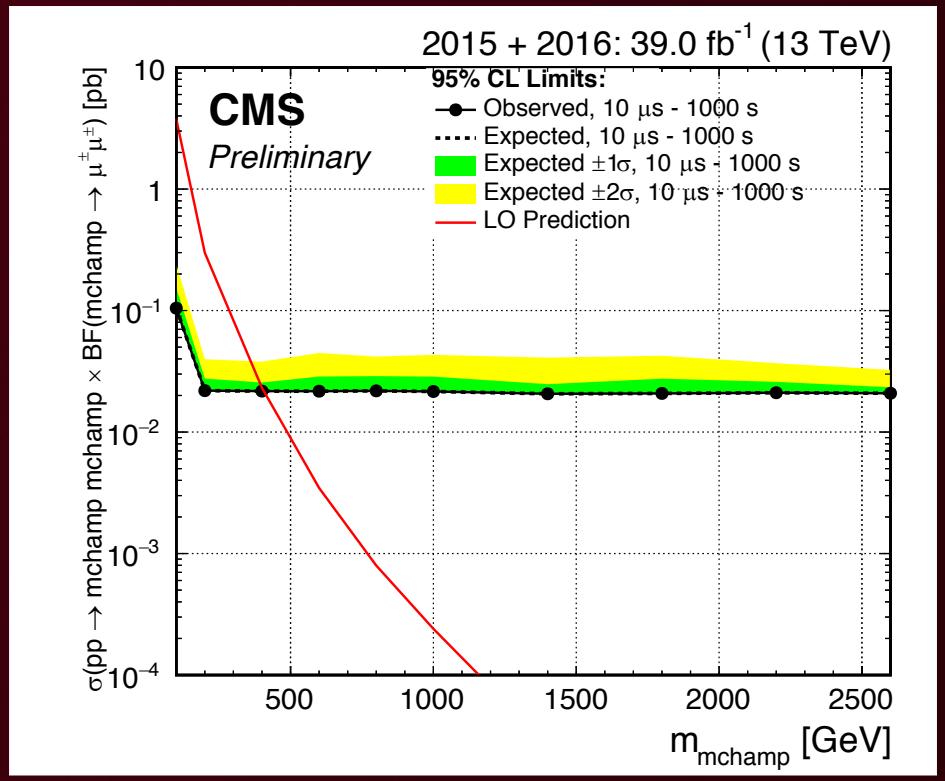


Delayed Muons

Gluino



|Q| = 2e

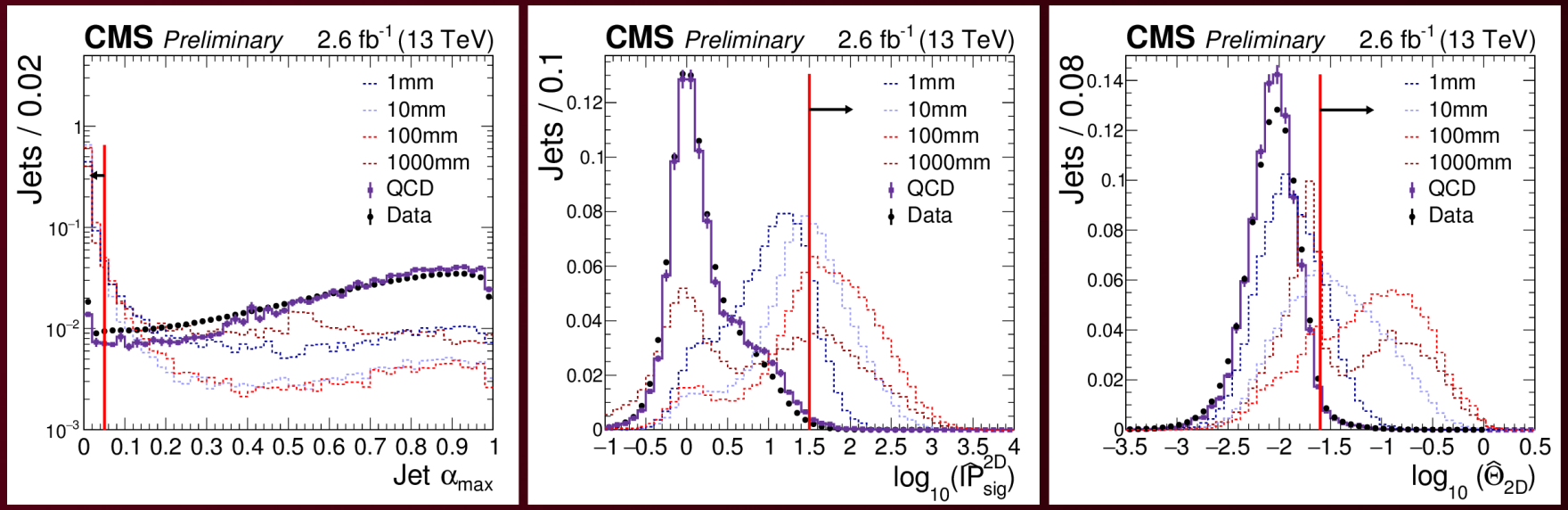


EXO-17-004

Displaced Vertices

Decay to Jets

- Search for long-lived neutral particles decaying into one (or more jets)
- Several models
  - $X^0 \rightarrow jj$ (X^0 pair produced)
  - stop $\rightarrow b\ell$ (ℓ = e, μ, τ) (stop pair produced)
- Displaced jet tagging
- Require 2 or more tagged jets

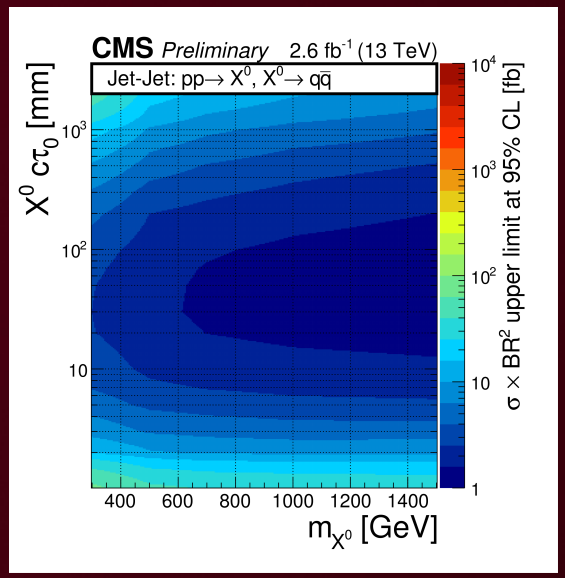


Displaced Jets

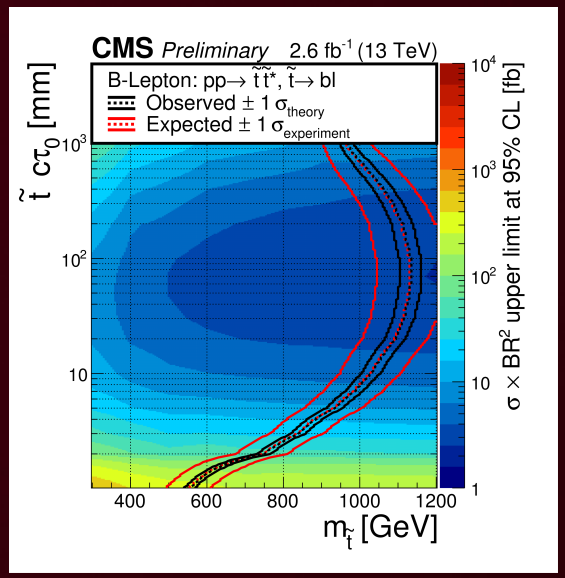
No excess found

- $N_{tag} = 2$
  - Observed: 1 event
  - Expected: 1.09 ± 0.16
- $N_{tag} \geq 3$
  - Observed: 0 events
  - Expected: (4.9 ± 1.0) x 10^{-4}

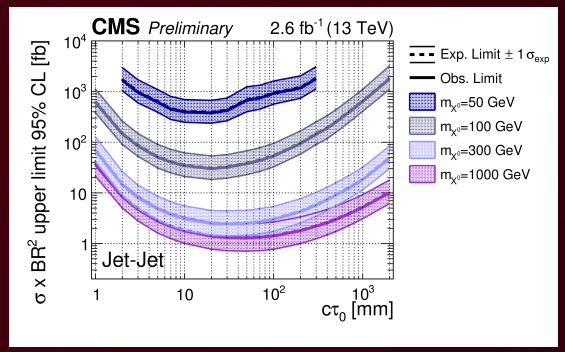
EXO-16-003

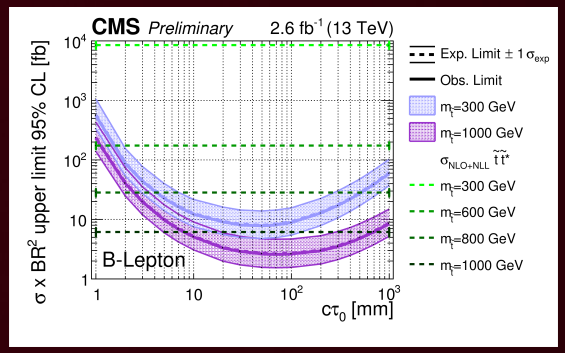


Jet-Jet model



b-lepton model





Searching Far and Wide…

Summary

- CMS has performed a wide range of searches for long-lived and non-conventional signatures
  - displaced leptons, delayed photons, disappearing tracks, fractionally charged particles, multiply charged particles
- Signature based searches offer significant discovery potential
- Challenging analyses
- New techniques under development
- http://cms.cern/