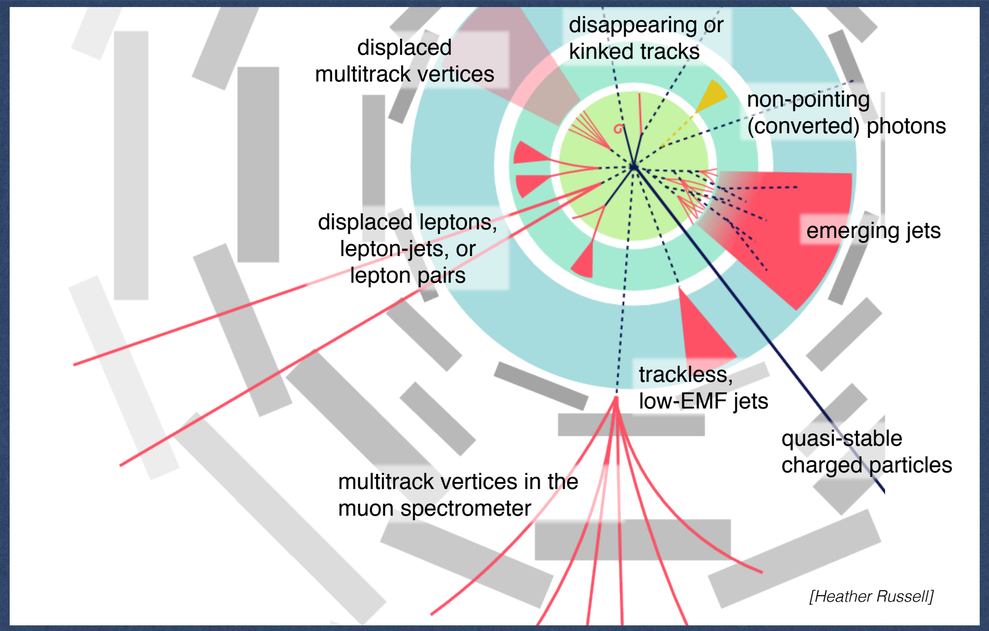


Long-lived particles and unconventional signatures at LHC

Monica Verducci - Universita' di Pisa and INFN

PANIC2021 5-10 September 2021

Lisbon (Portugal) - Virtual Conference

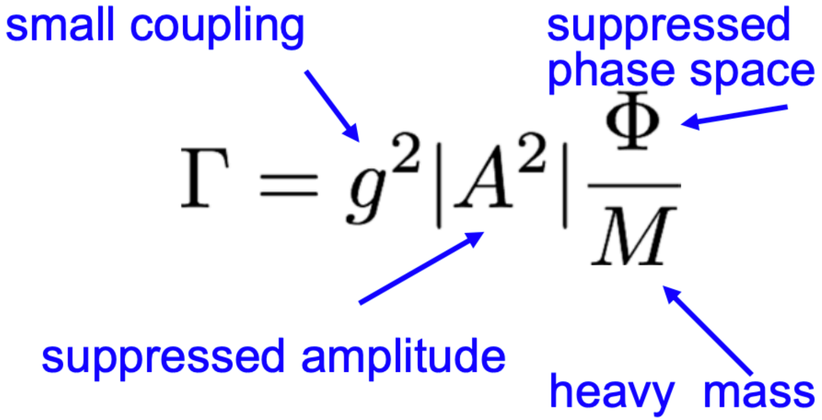
Long-Lived and Unconventional Particles

No observation of new physics at LHC: searches designed to find prompt BSM particles!

Need to design new strategies to probe BSM signals:

- new physics may manifest itself in unexpected ways, in the form of non-standard signatures,
- well-motivated theoretical scenarios foreseen long-lived particles, i.e. that the secondary vertices are macroscopically displaced with respect to the primary interaction point at which they are produced.

A wide variety of BSM models (Hidden Sectors, RPV violating decays, Split-SUSY, AMSB, GMSB, etc.) **predict the existence of Long Lived Particles (LLP),** ***new particle with long life-time*****, enabling direct measurements.**

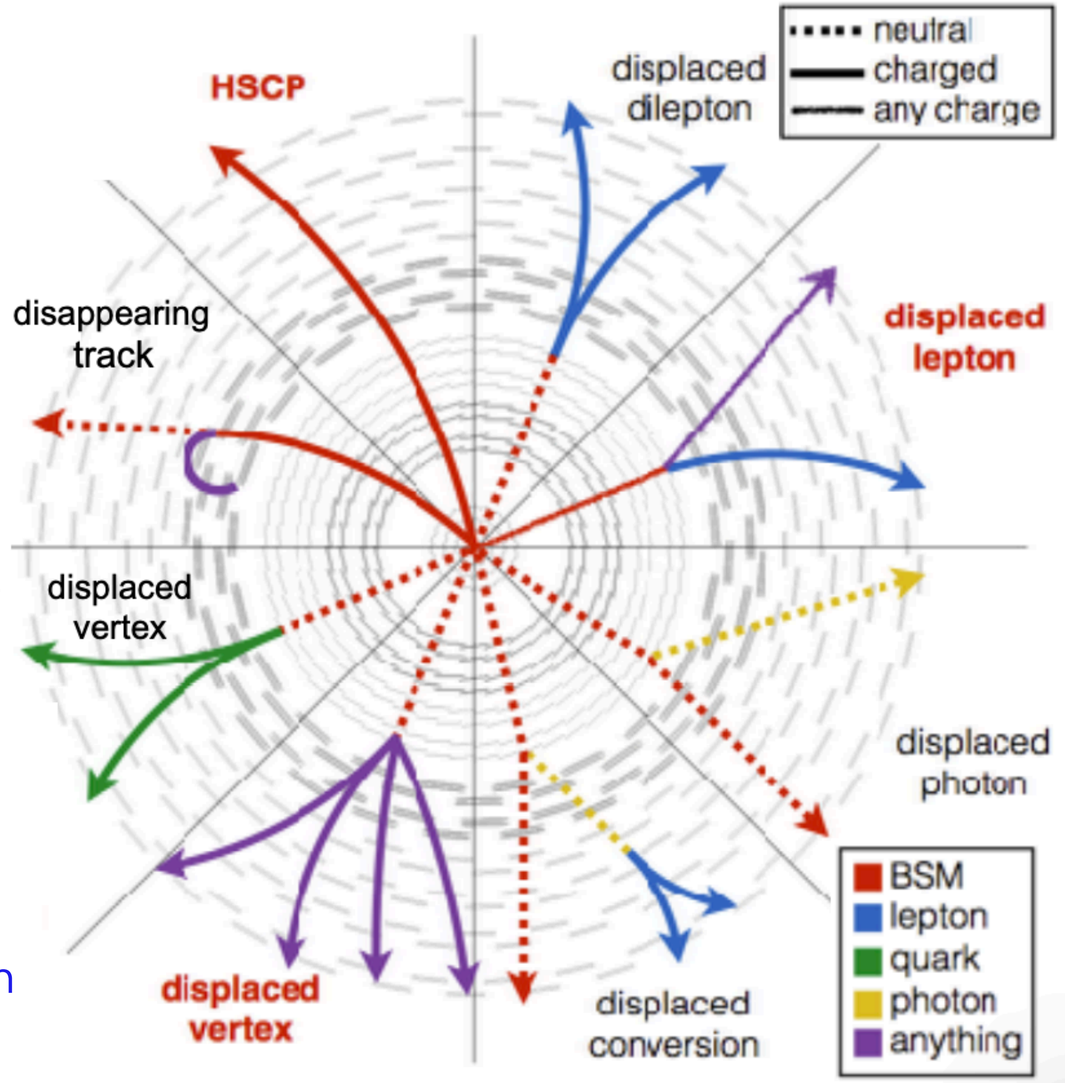


In this Talk

- Higgs Boson portal (ATLAS and CMS)
- Stopped LLP in R-Hadrons (ATLAS)
- LLP decaying insets and displaced jets (CMS)

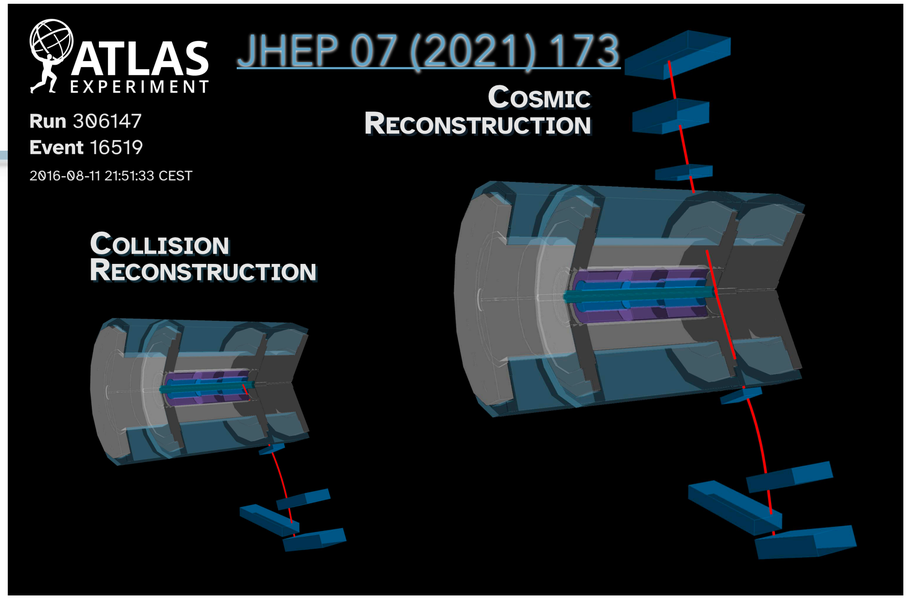
Challenges in LLP Searches

- **Unconventional signatures as long-lived particles (LLPs) have unusual and unique signatures, extremely challenging due to the non-standard final topologies.**
- The signal event reconstruction and selection, as the background estimation, use dedicated and very specialised techniques.
  - Detector-signature based search. Experimentally very diverse, depending on particles' properties (dE/dx, Time-of-flight, displaced vertex)
  - May require customised trigger and self-made objects reconstruction algorithm
  - Requires non-standard analysis strategies and tools
    - Non-standard background (cosmic-ray muons and Beam Induced background), generally data-driven estimation



Credits: J. Antonelli

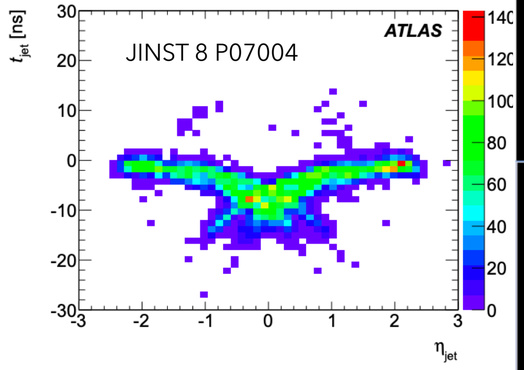
Non-Collision Backgrounds

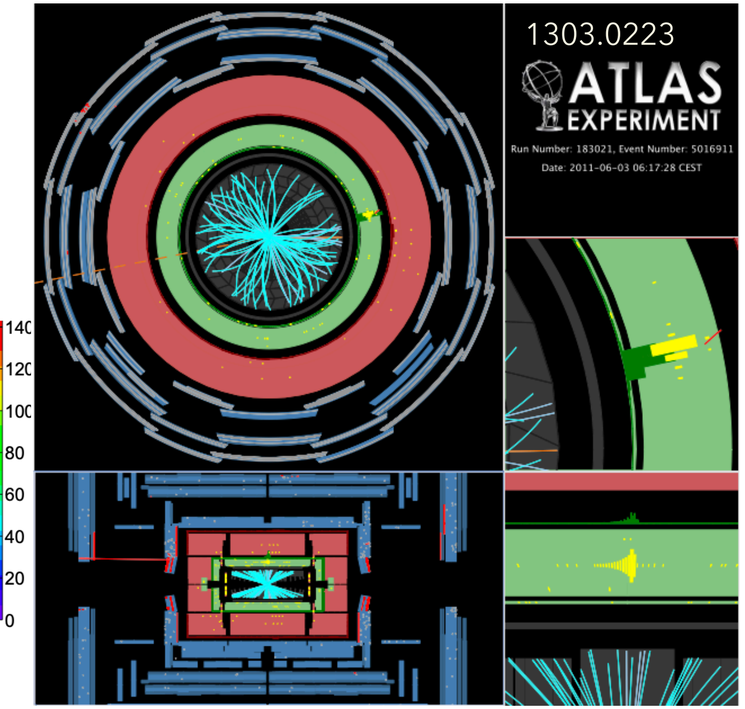


The term **non-collision backgrounds** refers to signals seen in the detector which have not been produced by normal collisions of the LHC beams.The main components are beam-induced backgrounds (BIB) and cosmic-ray showers.

These events are an important background source for searches with mostly displaced objects.

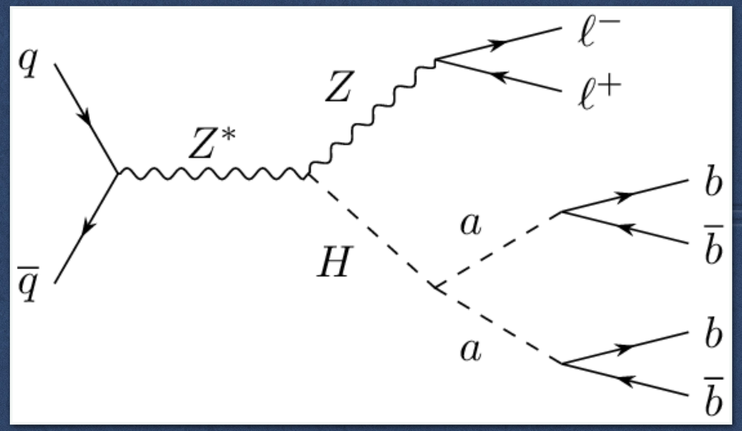
- **Cosmic-ray**
  - **trigger on EMPTY bunch** (no protons are present in the two beam in the collision window, i.e. Bunch Crossing BC)
  - Key observables: Muon track with large impact parameter, muons coming from surface (time)
- **BIB**
  - **trigger on UNPAIRED bunch**, where protons are present on one beam only per BC
  - Key observables: longitudinal energy deposition in calorimeter with wrong corrected-time

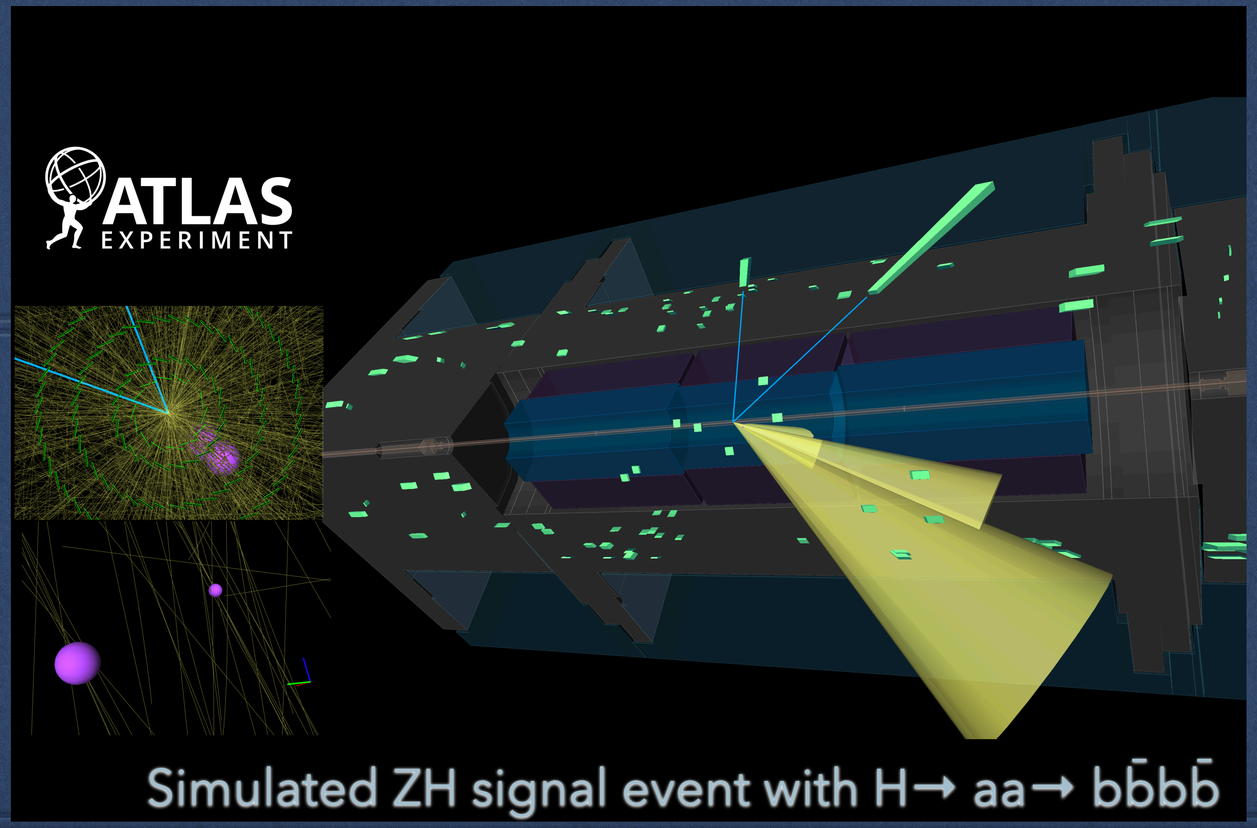




Exotic decays of the Higgs boson into long-lived particles using displaced vertices in the ATLAS inner detector

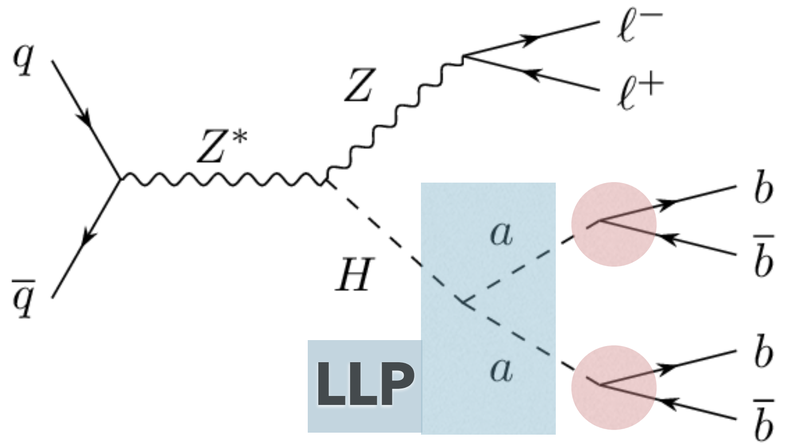
2107.06092





Exotics Higgs Boson decay to 4b

Model: Production of a Higgs boson in association with a leptonically decaying Z boson. Higgs decays into pairs of long-lived neutral particles, each decaying into a bottom quark pair.



Displaced Vertices DV

Signature predicted by BSM models where exotic Higgs decays:

- **Top-down theories:** Neutral naturalness
- **Bottom-up scenarios:** Dark sectors, SM+scalar

Benchmark signal samples

- Pseudoscalar boson a with $16 < m_a < 55$ GeV
- Life time $10\text{mm} < c\tau_a < 1\text{m}$
- Yukawa-like branching ratios:
  ⇒ $Br(a \rightarrow bb) = 100\%$

a boson is neutral and decays exclusively into b: this is not used in the analysis to enlarge the sensitivity.

Analysis Strategy

Preselection

- Lowest-threshold unprescaled single-lepton (e, μ) triggers: leptons from Z decays for high efficiency
- prompt high-p_T lepton, at least one jet with low p_T-fraction of matched tracks associated to PV.

Special processing: events are preselected when processing RAW data, then reconstructed with dedicated configuration sensitive to LLP vertices

- **dedicated tracking (Large Radius Tracking - LRT):** Standard track cuts on transverse (d^0) and longitudinal (z^0) impact parameters with respect to the IP remove displaced decay (large impact parameters). Dedicated second pass of the tracking is run on leftover hits from the standard track but **with looser cut on d^0 and z^0 algorithm.**
- **dedicated displaced vertex (DV) reconstruction:** Secondary vertex reconstruction seeded by pairs of tracks with additional cuts.

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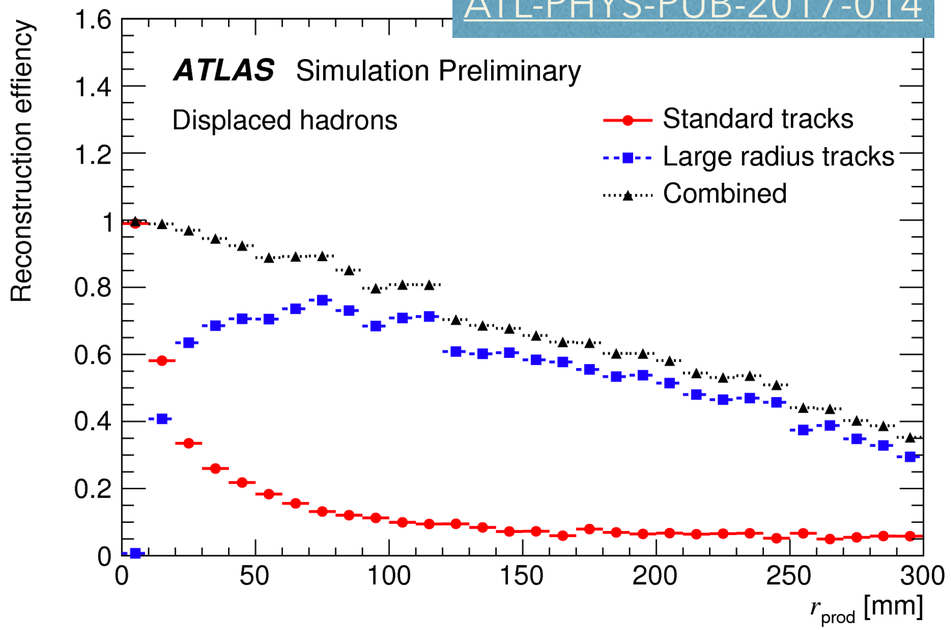

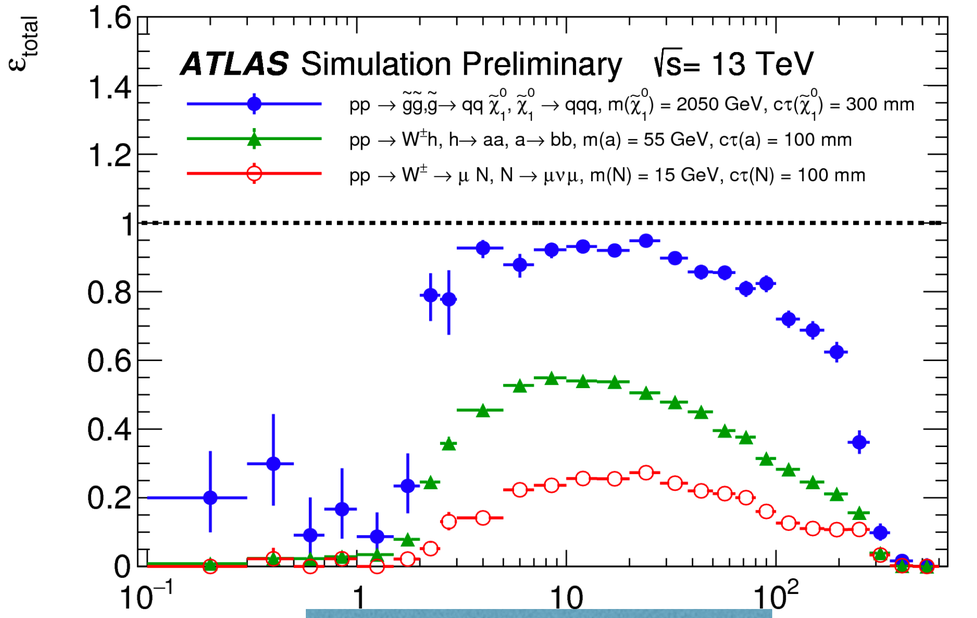

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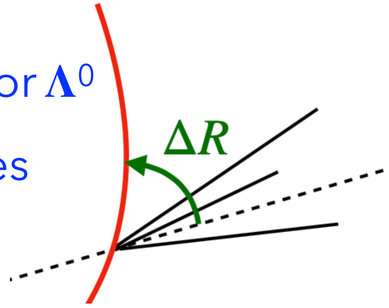
Analysis Selection

Offline Event Selection

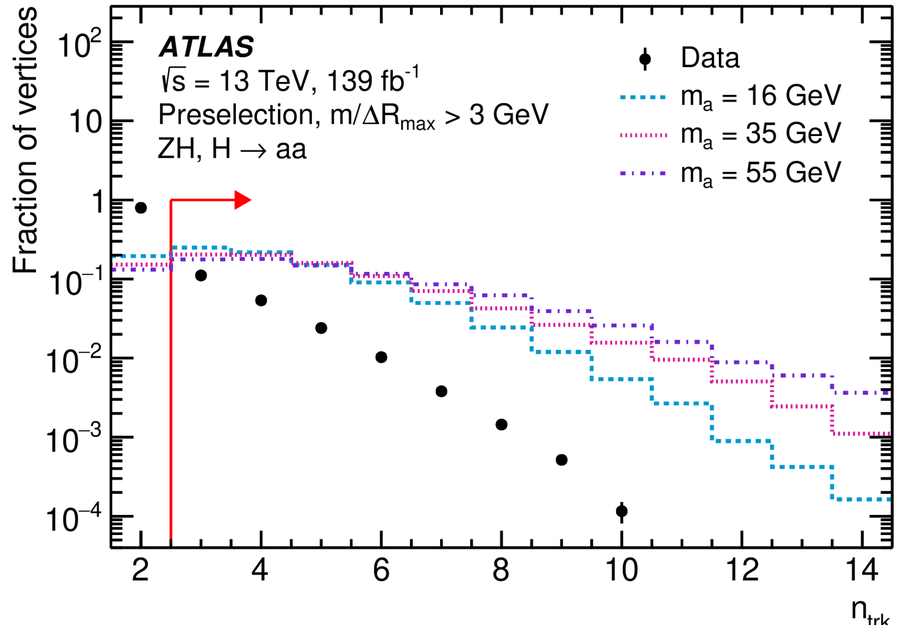
- Reconstruct Z decay:
  - two opposite-sign, same-flavour leptons
  - $66 < m_{ll} < 116$ GeV
- at least two jets $p_T > 20$ GeV

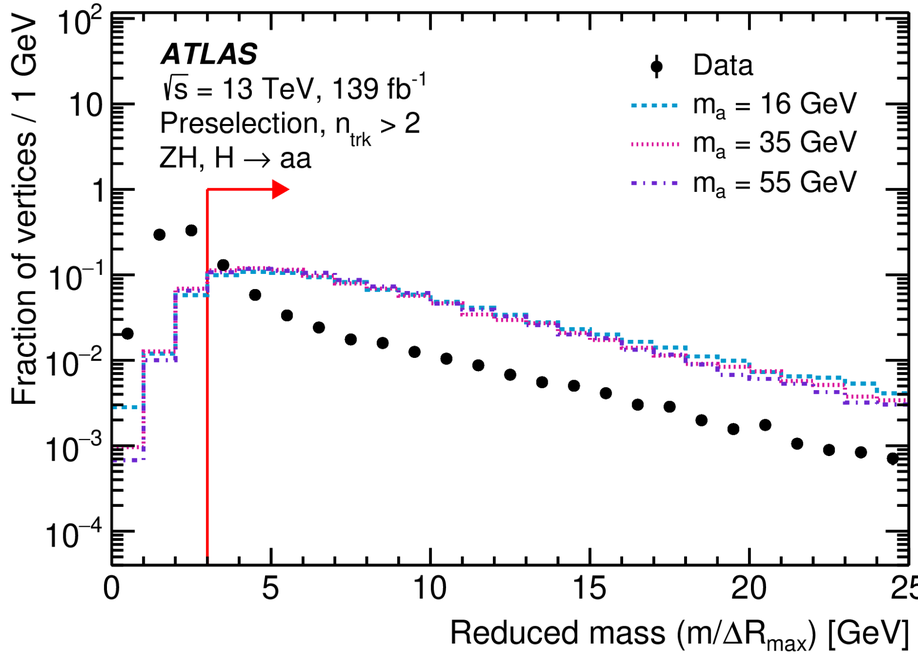
Additional cuts applied to reduce background:

- **vetoing vertices in regions with inert material** to reduce hadronic interaction
- **$n_{trk} \geq 3$** to remove metastable SM resonances as K_S^0 or Λ^0
- "Reduce mass" **$m/\Delta R_{max} > 3$ GeV** to remove vertices from random crossings
- **$\Delta R(vtx,jet) < 0.6$** to facilitate background modelling



Signal Region SR	**Control Region CR**	**Validation Region VR**
$n_{DV} \geq 2$	$n_{DV} < 2$	γ+jets vetoed leptons Photon trigger



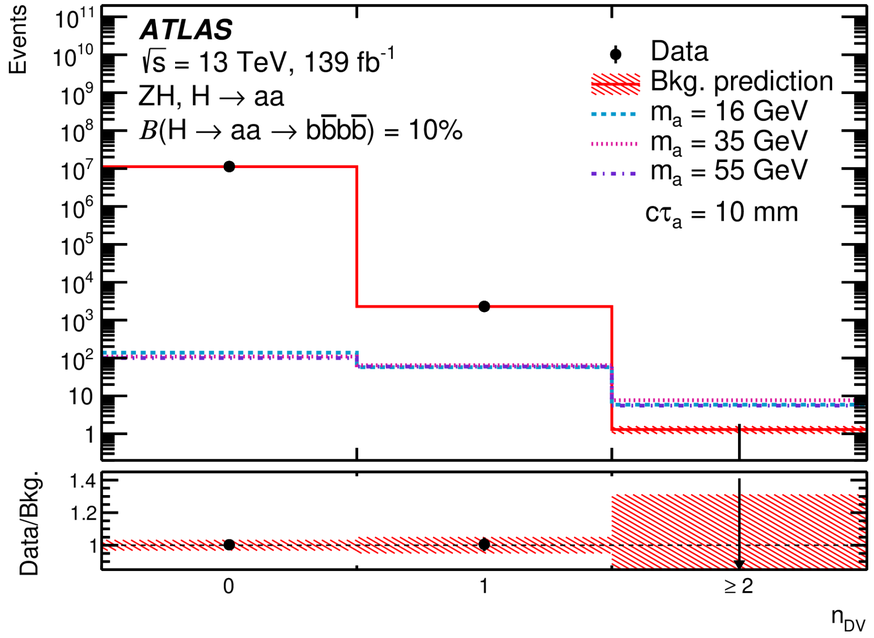


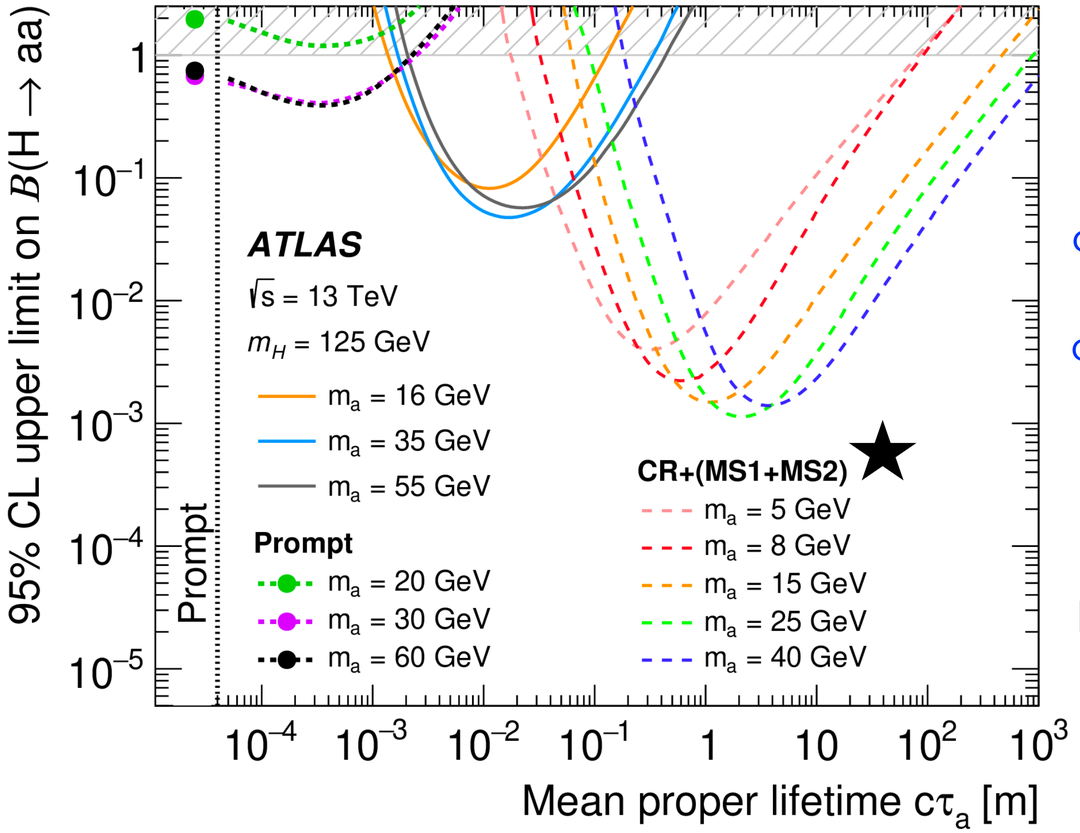
Results

Zero events observed in signal region.

Limits set for 10% branching ratios:

- m_a = 16 (55) GeV excluded 3.7 (5.4) $< c\tau_a <$ 37 (102) mm
- m_a < 40 GeV, these are the most stringent limits to date in this lifetime regime





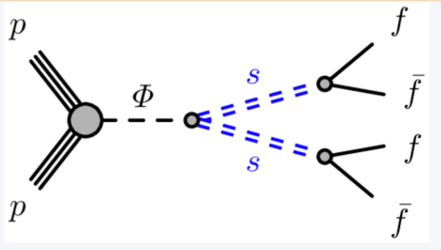
Comparison with combined results of two searches for displaced jets in the ATLAS calorimeter (CR) and muon spectrometer (MS1+MS2) (Eur. Phys. J. C 79 (2019) 481)

★ MS new result

(Displaced vertex in MS)

Higgs boson or lower/higher-mass scalar boson decays into LL neutral particles pairs, each decaying into a fermion pair.

Model excluded at 95% CL for LLP proper lifetimes ranging from 4 cm to 71.3 m.



Analysis with a dedicated trigger (Muon-Roi Cluster) and DV in MS algorithms.

Search for long-lived particles decaying in the CMS endcap muon detectors in proton-proton collisions at √s=13 TeV

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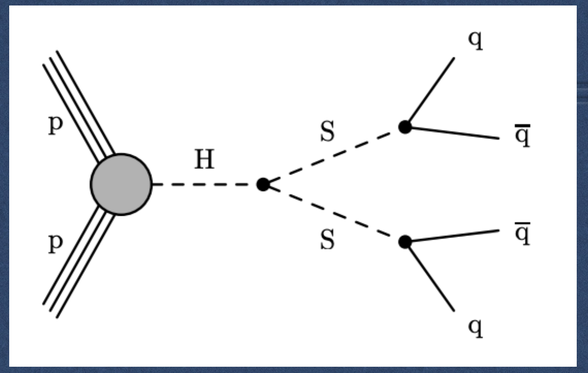
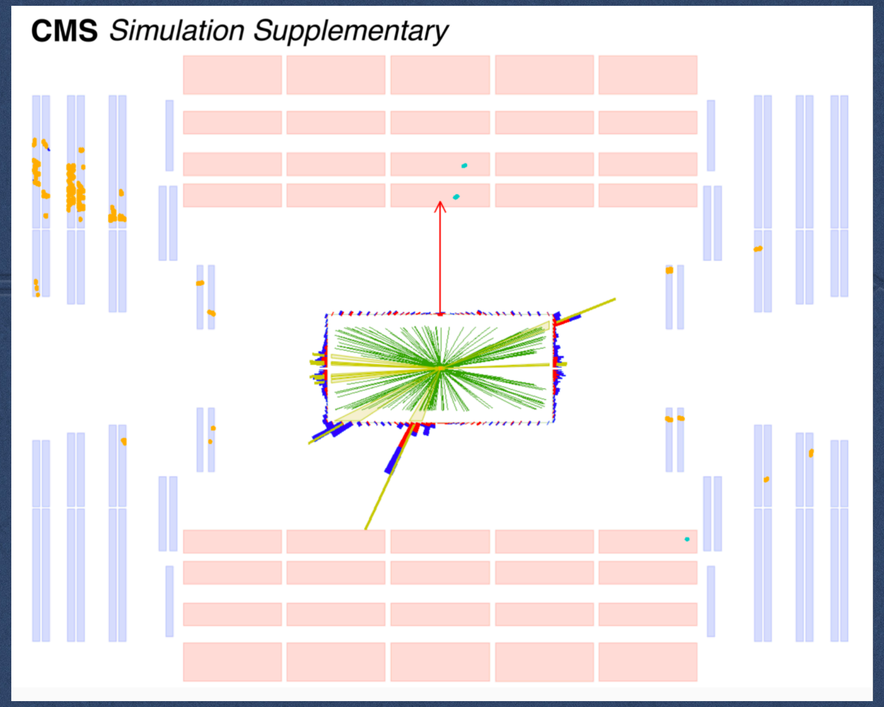
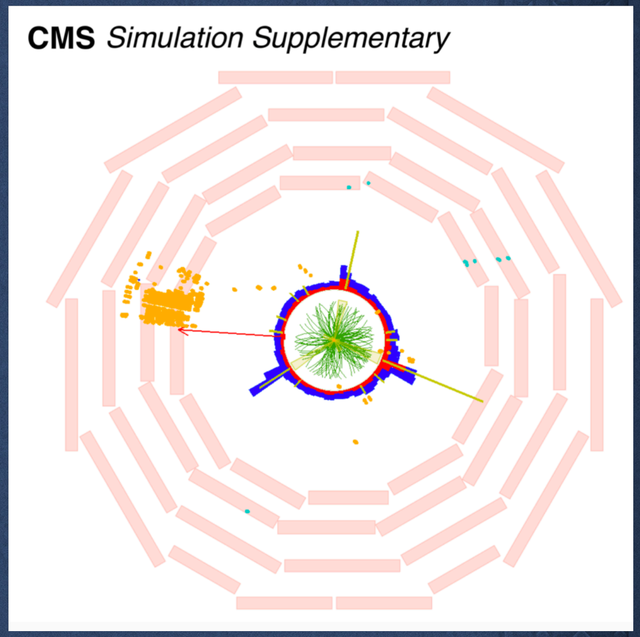


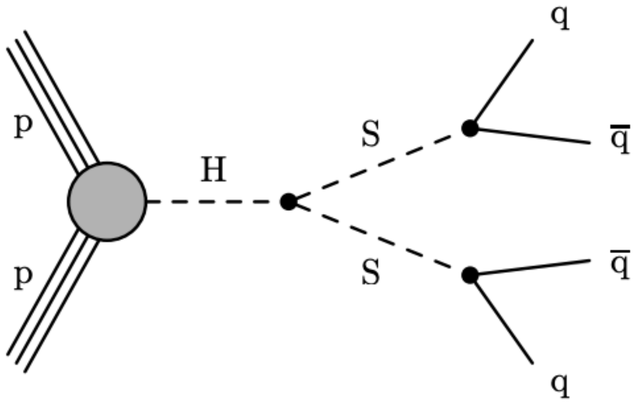




CMS Collaboration

Exotics Higgs Boson decay to pair of long-lived particles

Model: SM Higgs boson H decays to a pair of neutral long-lived scalars (S), each of which decays in turn to a pair of bottom quarks (bb), τ leptons ($\tau^+\tau^-$), or down quarks (dd).



Signature interpreted by a simplified model motivated by the twin Higgs scenario.

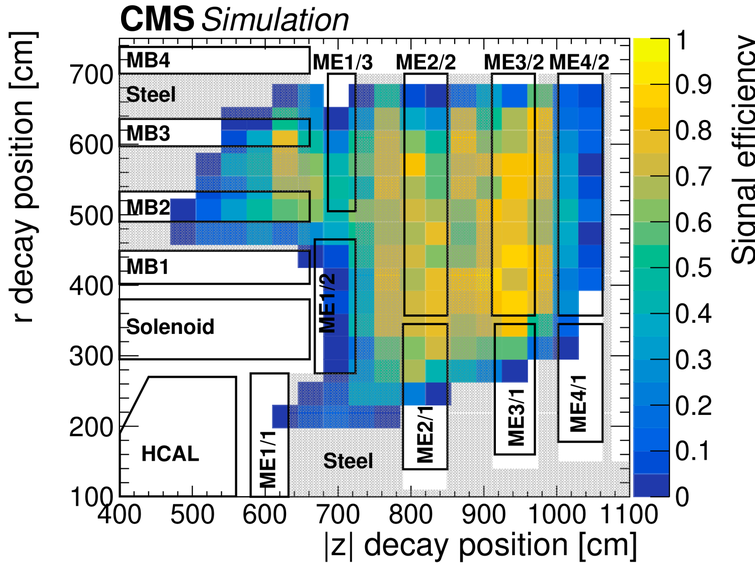
Benchmark model:

- The Higgs boson mass is set to 125 GeV
- S mass (m_S) is set to 7, 15, 40, or 55 GeV.
- Life time 1mm<cτ <100 m

This search has sensitivity to singly or multiply produced LLPs decaying to final states including hadrons, taus, electrons, or photons.

Analysis Strategy

A new technique is employed: the muon detector is used as a sampling calorimeter to identify showers produced by decays of LLPs

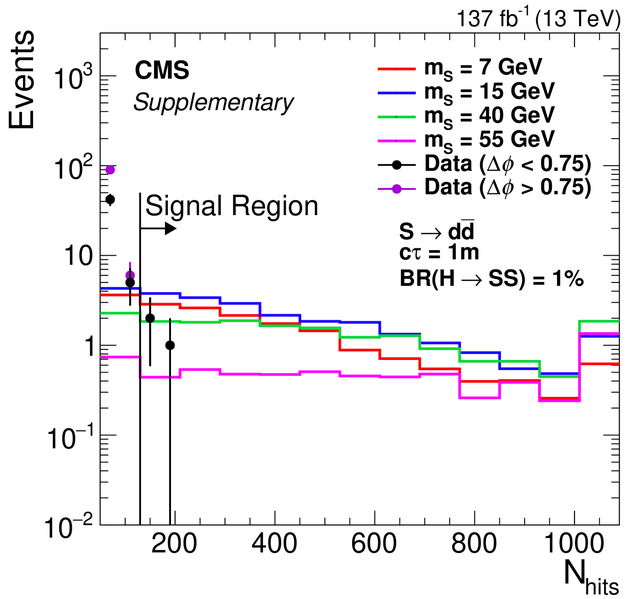


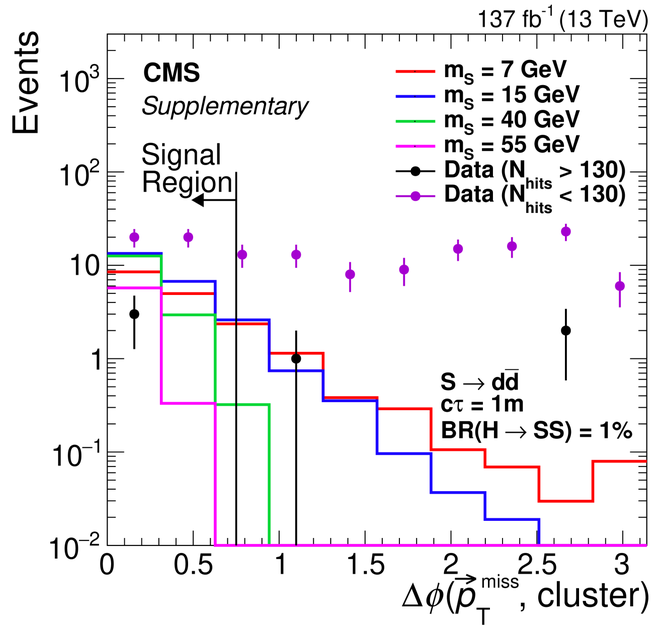
Event Selection

- triggering on events with p^{miss}_T > 120 GeV, offline p^{miss}_T > 200 GeV.
- at least one jet with p_T > 50 GeV and $|\eta| < 2.4$ (from ISR)
- Vetoed isolated electrons or muons (suppressed W and top decays)
- **Final Observables:** number of hits in the cluster Nhits>130 and the azimuthal angle between the cluster location and the p^{miss}_T , $\Delta\varphi$<0.75.

The main SM backgrounds: punch-through jets, muons that undergo bremsstrahlung, and decays of SM LLPs (neutral kaon K^0_L).

Main systematics: higher order QCD corrections (21%), cluster reconstruction and identification efficiency (6%)

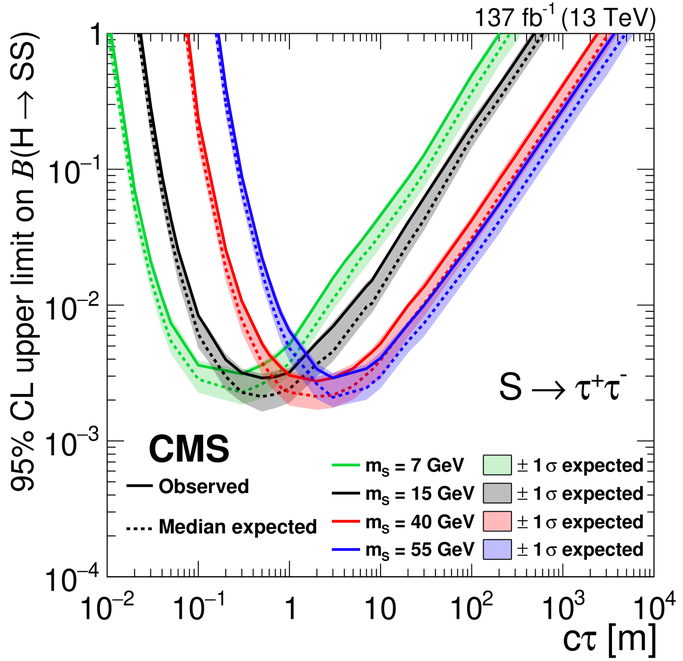


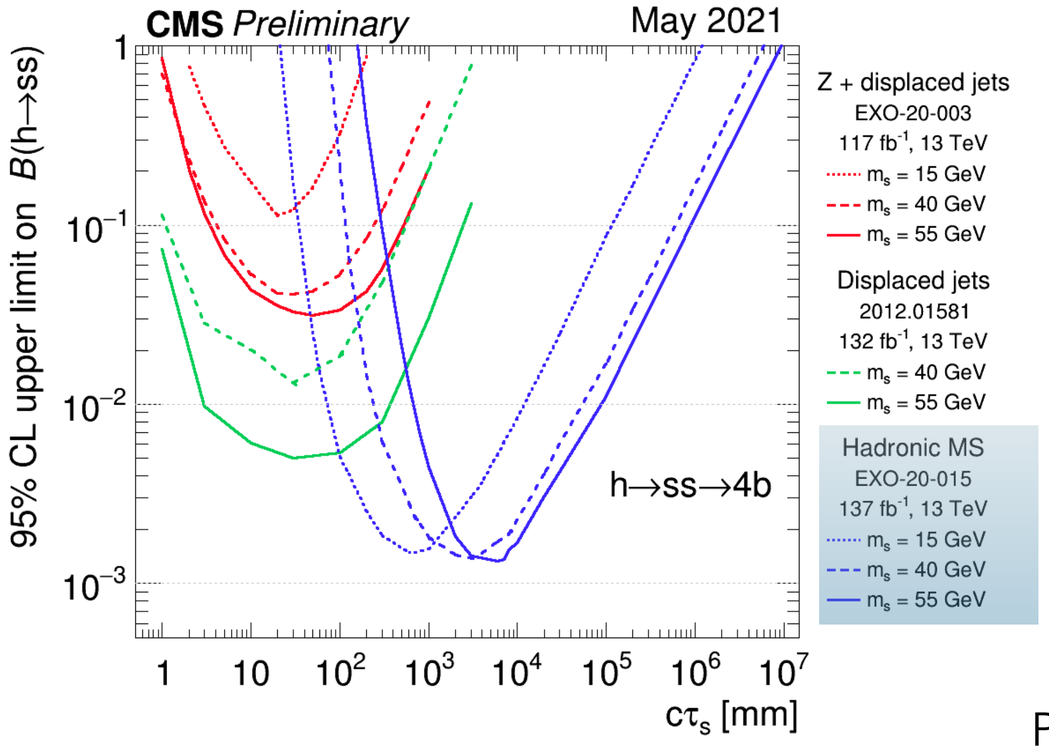


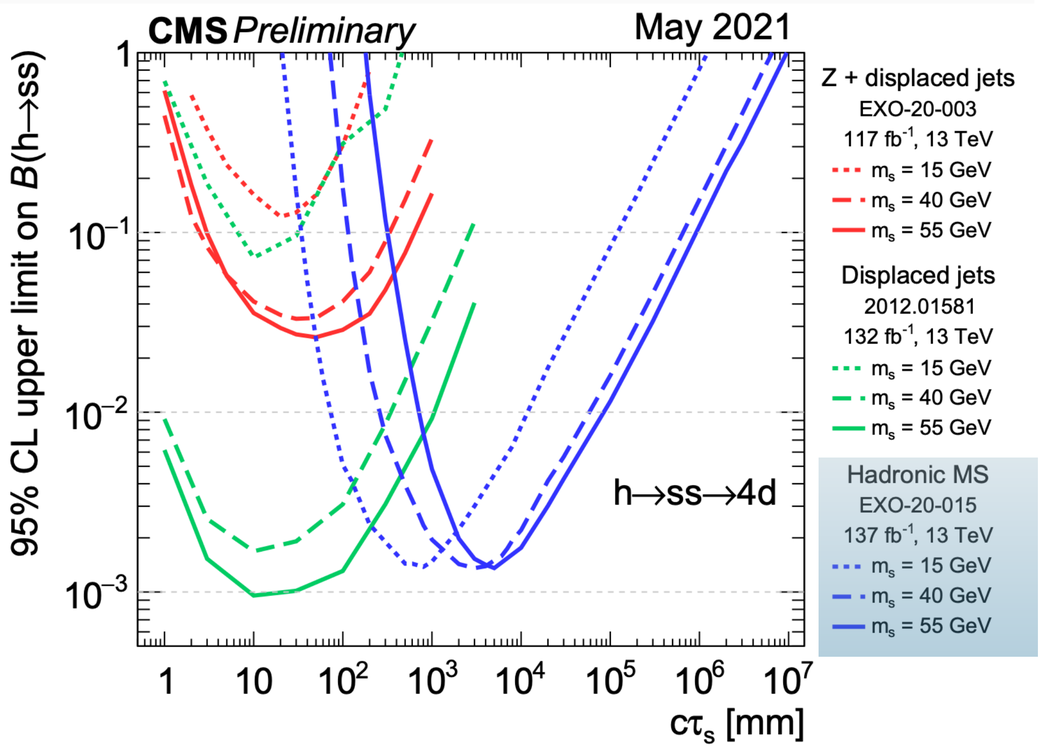
Results

Limits set on the branching fraction $\mathcal{B}(h^0 \rightarrow SS)$ as a function of $c\tau$ for the S decays. For $c\tau > 100$ m, this search outperforms the previous best limits by a factor of 6 (2) for an LLP mass of 7 (≥15) GeV

The displaced jets analysis does not have sensitivity to Higgs branching fractions less than one for long-lived scalars with a mass of 15 GeV.







Search for long-lived particles decaying to jets with displaced vertices in proton-proton collisions at √s=13 TeV

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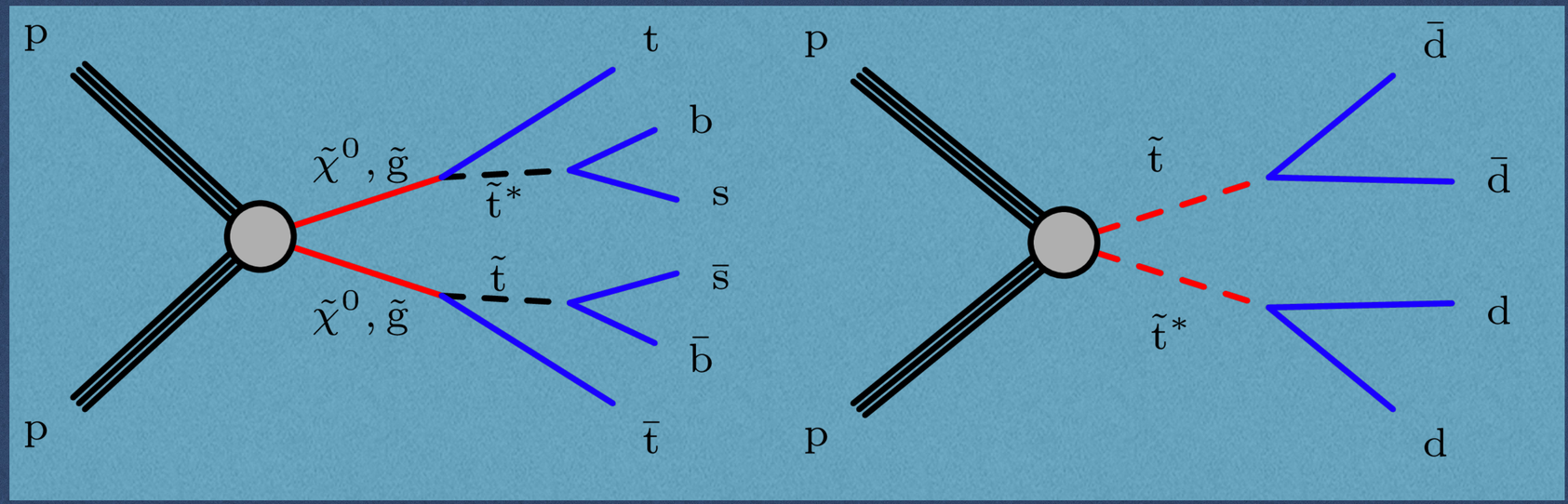
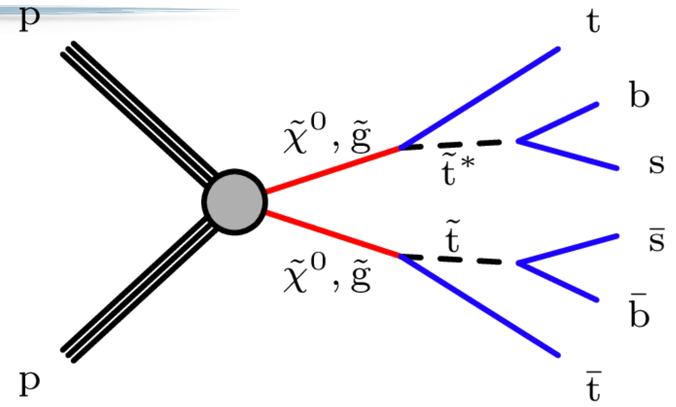


CMS Collaboration

Displaced Vertices in CMS

Model: This search targets pairs of long-lived particles with mean proper decay lengths between 0.1 and 100 mm, each of which decays into at least two quarks that hadronize to jets, **resulting in a final state with two displaced vertices.**

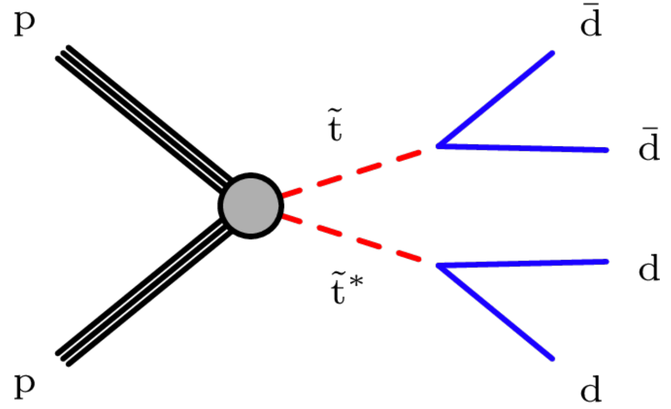
Multijets final-state



Signature interpreted by two R-parity violating supersymmetry models:

- Multijets final-state: lightest SUSY particle (LSP) is a pair of long-lived neutralino or gluino
- Dijets final-state: LSP is a pair of long-lived top squarks

Dijets final-state



Benchmark model:

- LL mass range 400–3000 GeV
- Life time 0.1mm<$c\tau_a$ <100 mm

The results may be applied to other models in which pairs of long-lived particles each decay into two or more jets in their final state

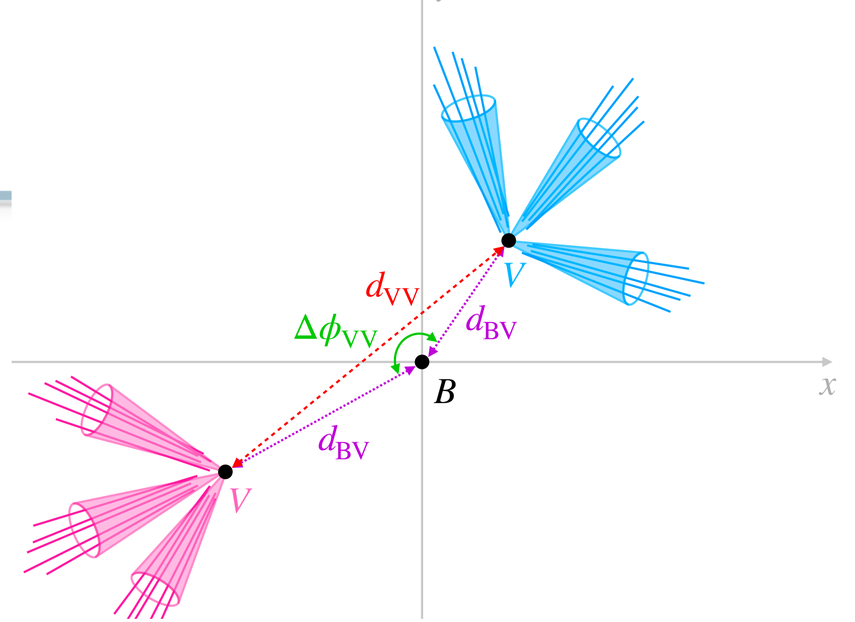
Analysis Strategy

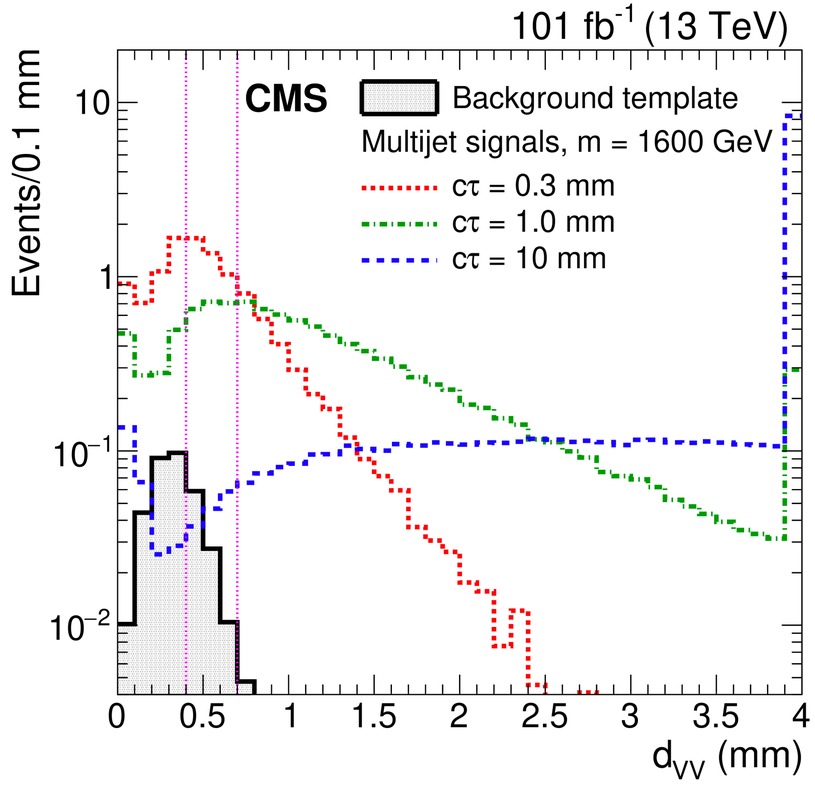
Event Selection

- Trigger requiring $H_T > 1050$ GeV, where H_T is the scalar sum of the jet p_T for jets with $p_T > 40$ GeV and $|\eta| < 2.5$
- Offline cut on $H_T > 1200$ GeV
- at least four reconstructed jets, each with $p_T > 20$ GeV and $|\eta| < 2.5$.
- Two displaced vertices
- at least five tracks per vertex in order to suppress main background from SM multijets and pair top quarks.
- Discrimating observables: distance between two vertices in the x-y plane, defined as d_{VV} , and d_{BV} distance between beam pipe and vertex

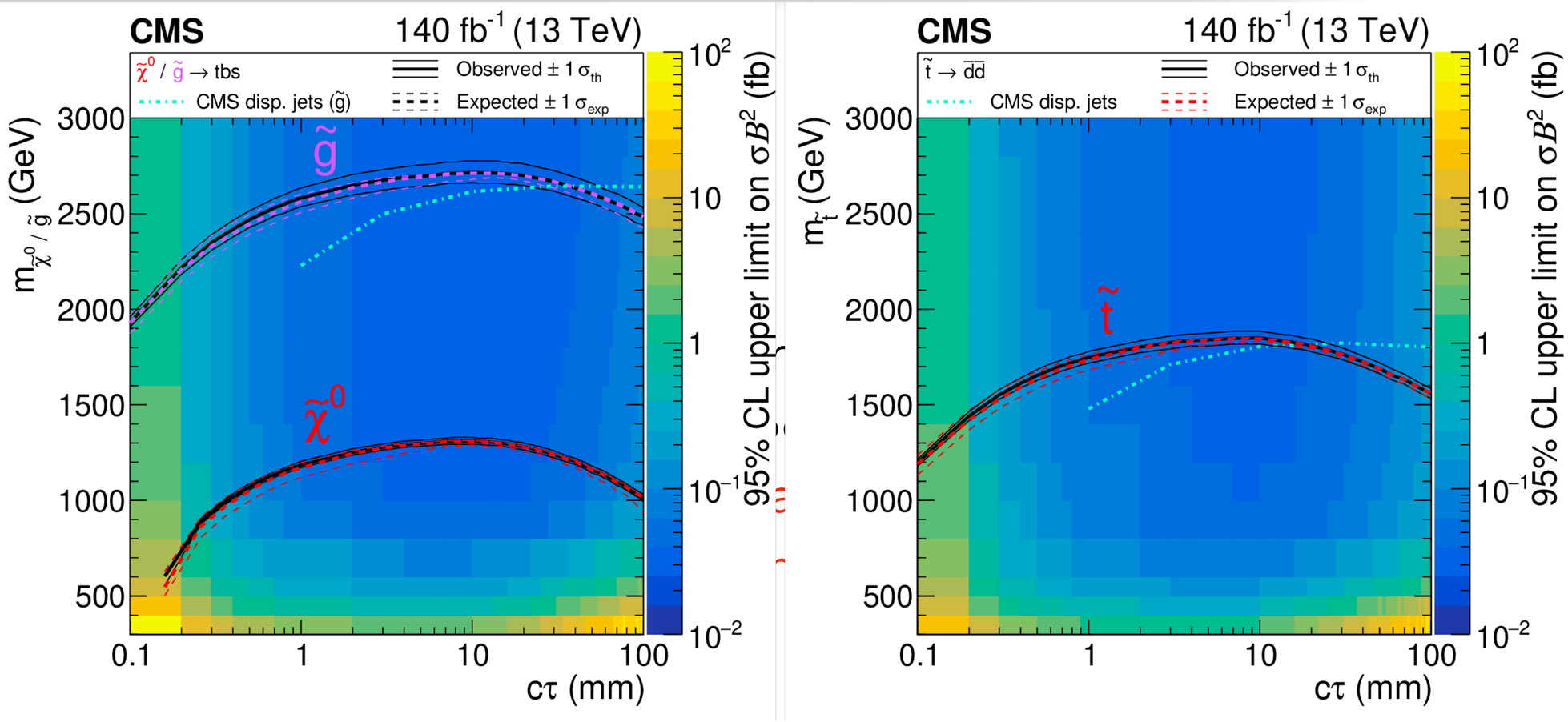
Improvements over previous results due to e.g. new technique to suppress background vertices from accidental track intersections reduces overall background by 40%.

Main systematic due to background template.





Results

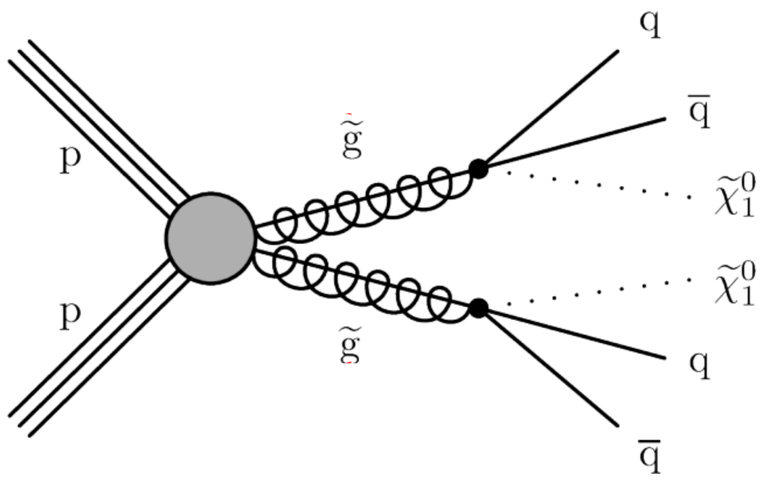


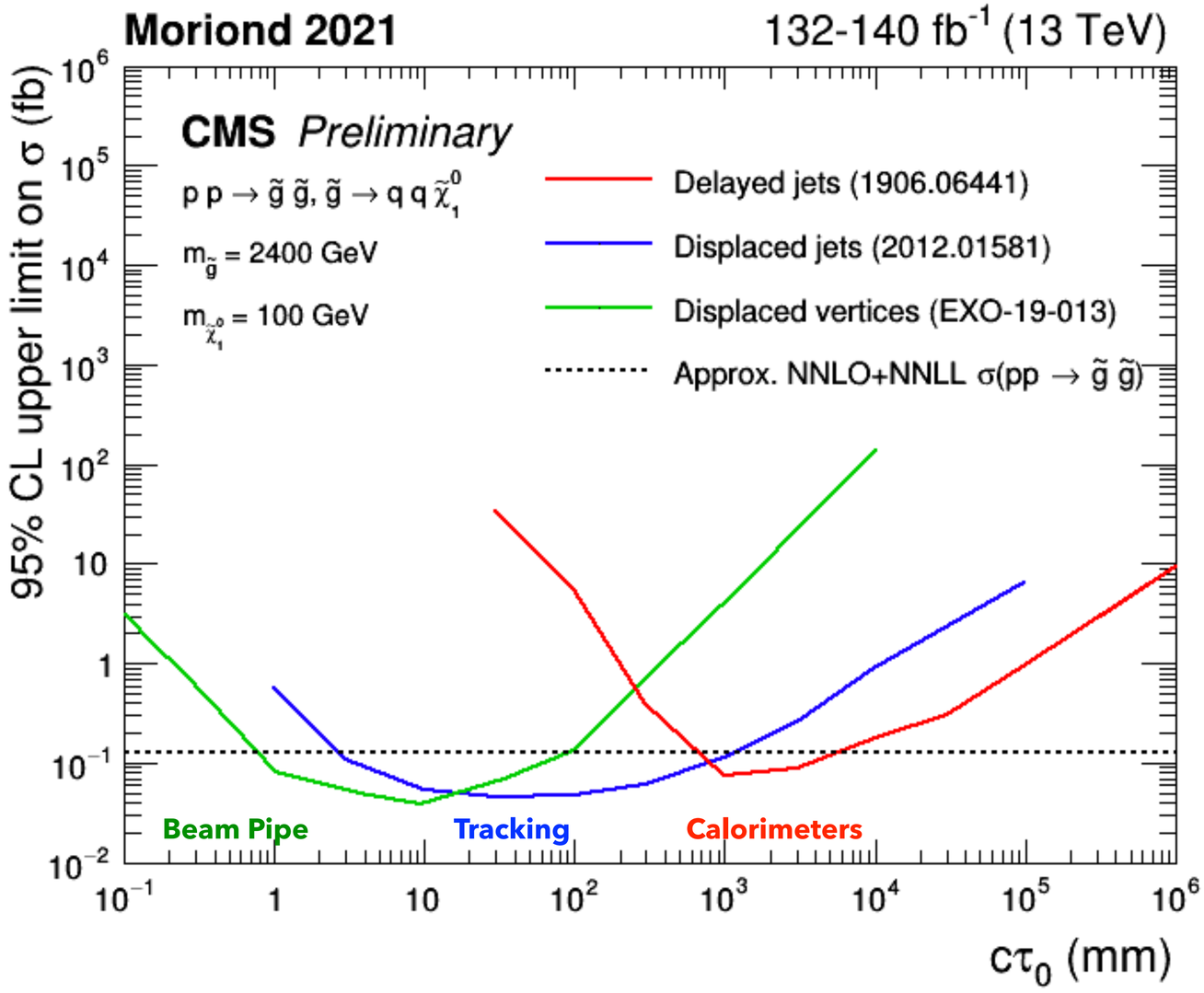
For the long-lived gluino, neutralino, and top squark in the **RPV models** described, pair-production cross sections larger than 0.08 fb are excluded for masses between 800 and 3000 GeV and mean proper decay lengths between 1 and 25 mm.

Complementary results

Extend lifetime coverage using “mini-split" SUSY benchmark models with different decay position

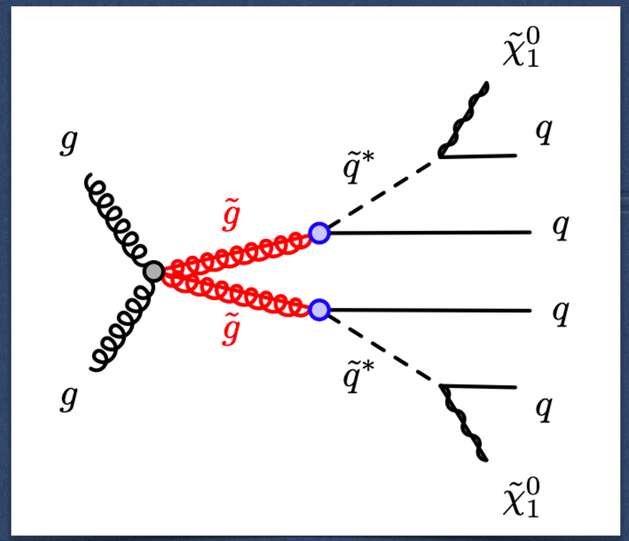
- Assuming a 100% branching fraction for the gluino to decay into a quark-antiquark pair and the lightest neutralino





A search for the decays of stopped long-lived particles at √s=13 TeV with the ATLAS detector

JHEP 07 (2021) 173

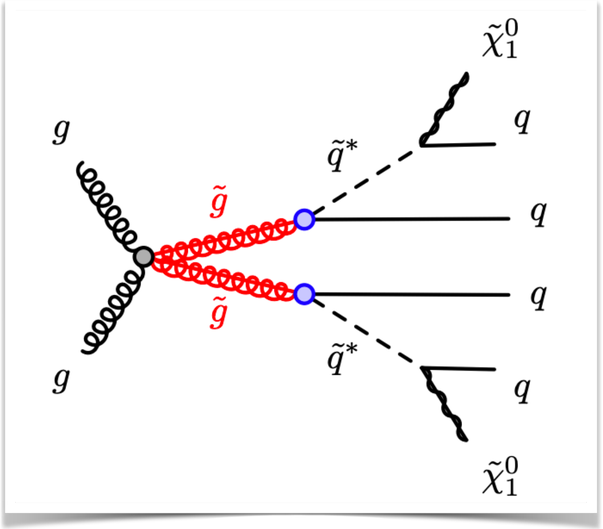


ATLAS
EXPERIMENT

Stopped Long-Lived Particle

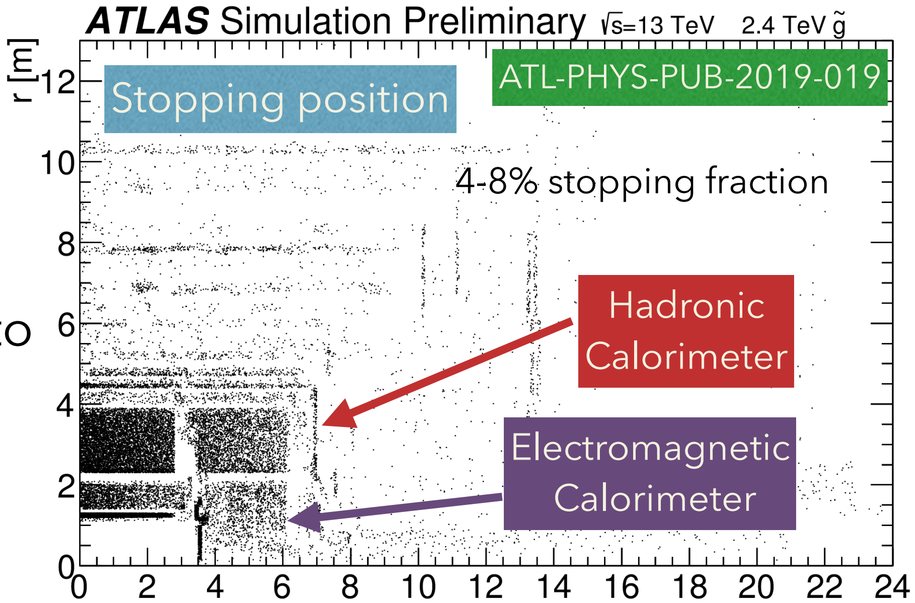
Model: Production of a gluino that interacts with the strong nuclear force and form a composite state called an R-hadron.

Signature predicted by "mini-split" SUSY models, where a large mass difference between SUSY particles induces a large lifetime for the gluino.



Benchmark signal samples:

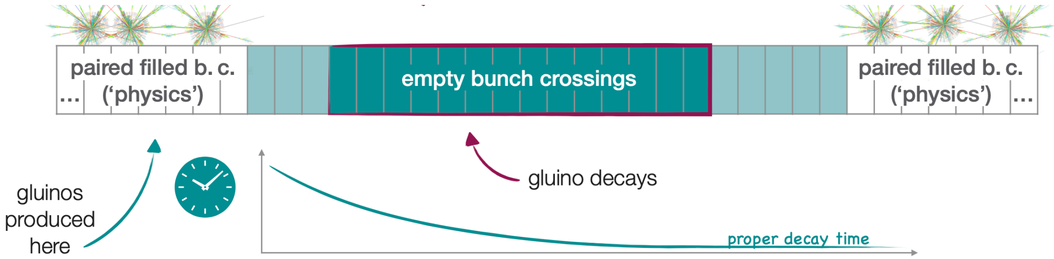
- R-hadrons lifetimes from μs to years
- Revised simulation: Overlay randomly collected data events to model spurious detector activity [documented here]



Analysis Strategy

This analysis looks for energetic sprays of hadrons entering the calorimeter systems of the ATLAS detector during "empty bunch crossings" – time intervals in which no proton collisions are expected from the LHC.

- This "late" dataset leads to a unique style of data analysis and non-standard backgrounds as **cosmic muons** and **BIB.**



Credits: S.Morgenstern

Event Selection

- Trigger on jets in empty bunch crossings
  - MET > 50 GeV, jet pT > 55 GeV
- Offline: leading jet pT > 150 GeV, PV and muon veto
- Two signal regions:
  - **jet |η| < 0.8 (SRC), jet |η| < 2.4 (SRInc)**

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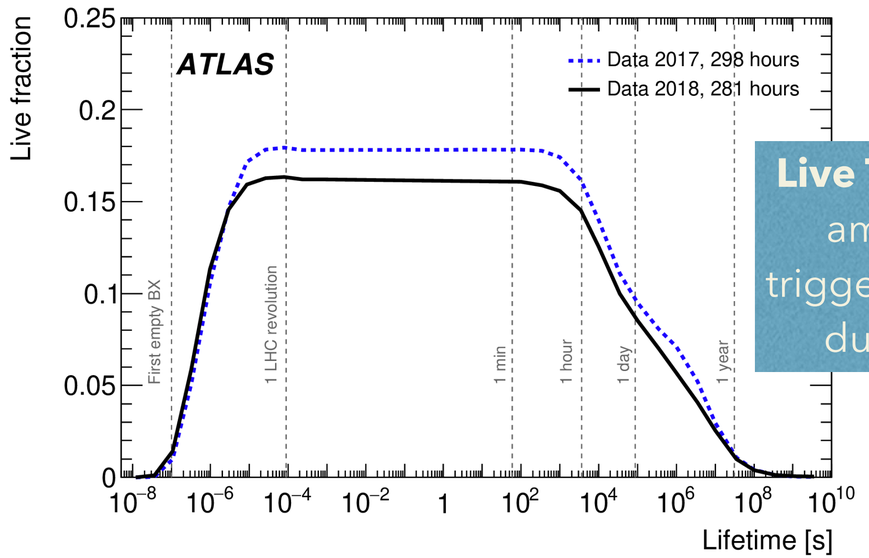
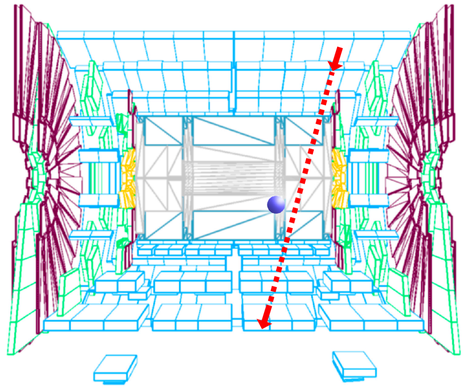
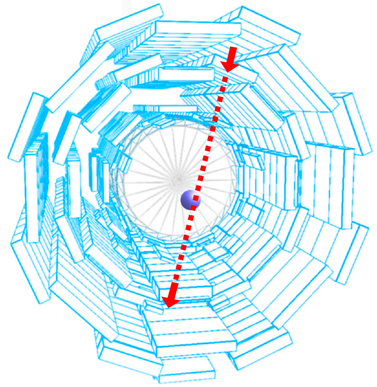


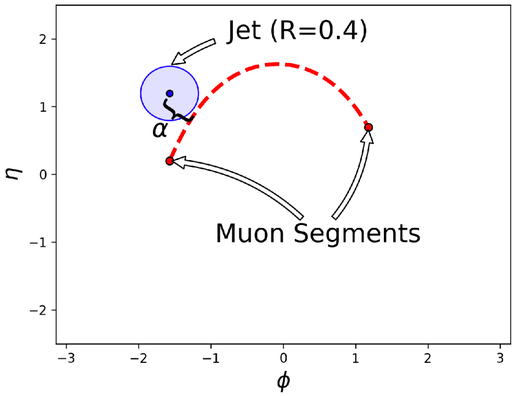
Live Time: total amount of trigger-able time during run

Signal ∝ luminosity and live time.
Background ∝ live time

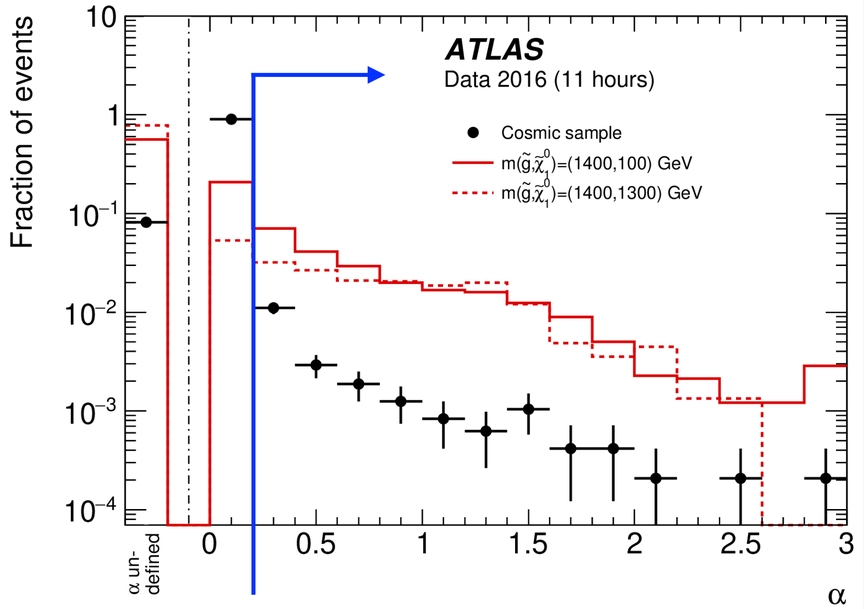
Main Backgrounds





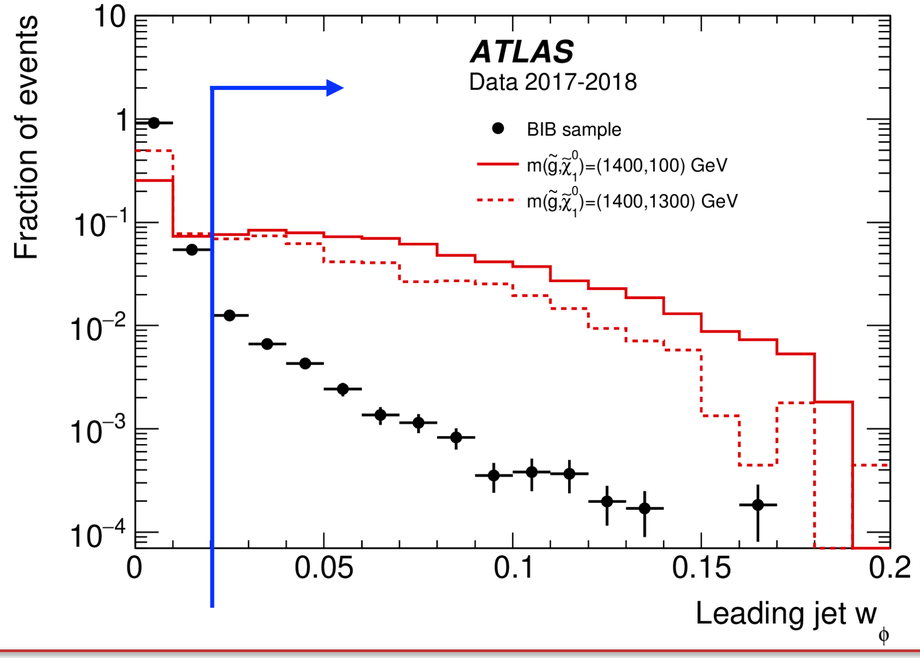


- Cosmic muons leave high energy deposition close to its track.
  - Require a muon track
  - **Reject events with $\alpha < 0.2$**



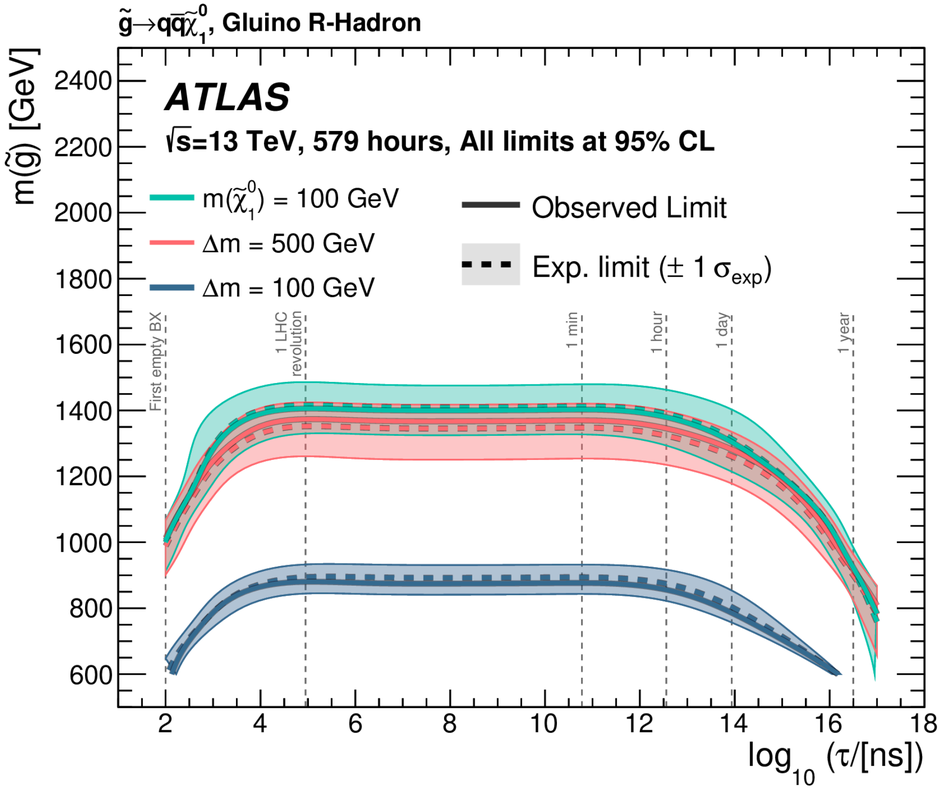
- BIB gives narrow calorimeter energy deposits parallel to beam direction
  - **Reject event with w_Φ <0.02**

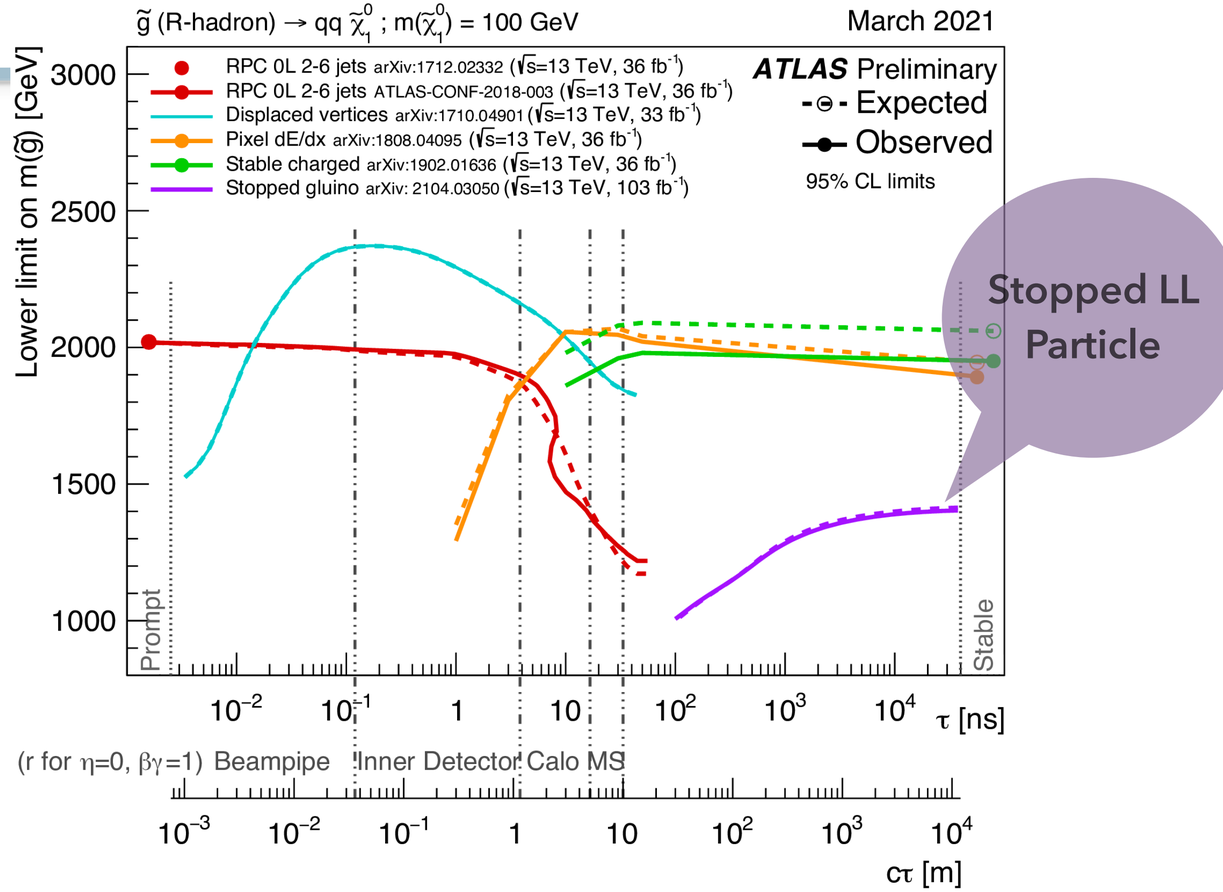
$$w_\phi = \frac{\sum_i p_T(i) \cdot |\Delta\phi(\text{jet}, i)|}{\sum_i p_T(i)}$$



Results

Exclude gluino masses up to 1.4 TeV in the lifetime interval (~10^{-5} to 10^{3} s) and up to 1.0 TeV for lifetimes of 100 ns and lifetimes up to 10^{7} s





Constraints on gluino R-hadron decaying into a gluon or light quarks and a neutralino with mass of 100 GeV in the mass-lifetime plane.

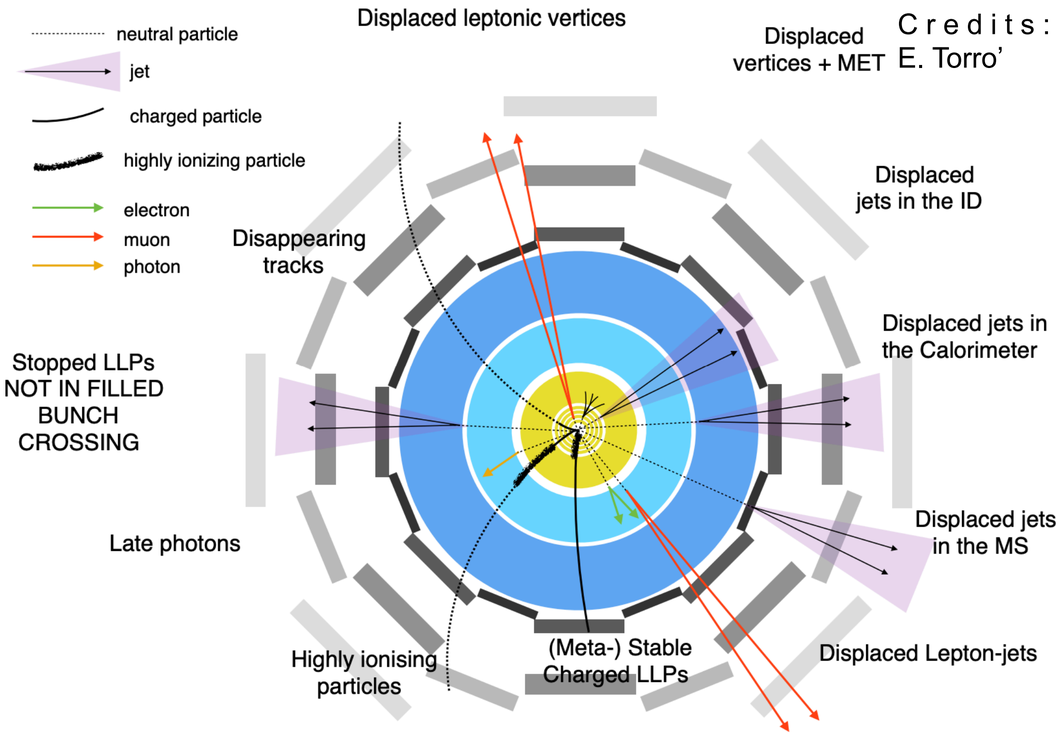
Conclusions

Searches for long-lived particles provide a nice playground for both theorists and experimentalists.

- The unconventional searches are extremely challenging, requiring:
  - **Self-made objects reconstruction and triggers**
  - **non-standard analysis strategies and tools**
  - **Non-standard backgrounds**

Both ATLAS and CMS conduct a rich and coherent program of unconventional searches to test different signatures and models

- The results presented explored full Run-2 LHC Data Taking 2015-2018 data
  - **no significant deviation observed**
- Great effort to extend our experimental reach in Run3!



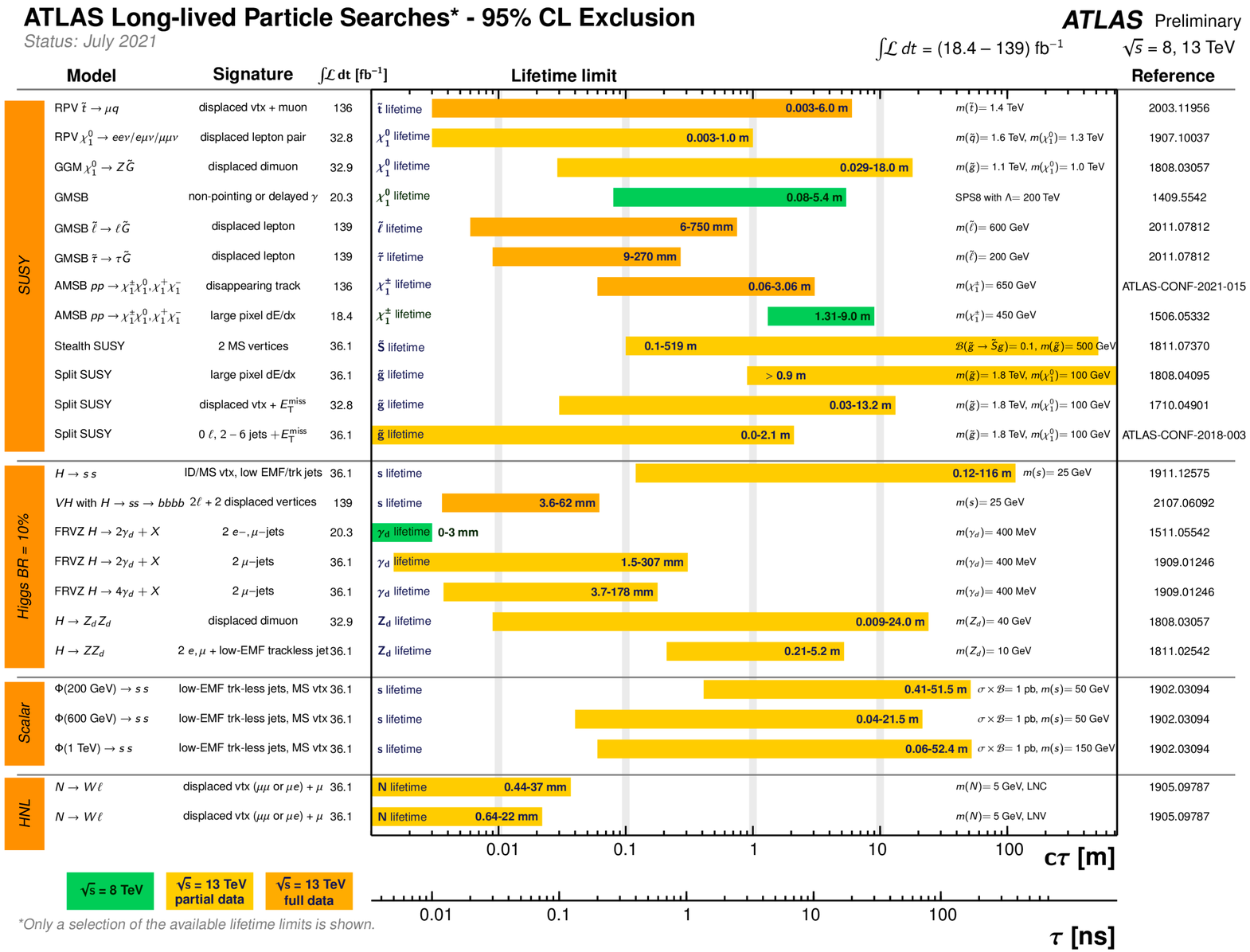
Public Results

- **All ATLAS public results:**
- ATLAS: https:/twiki.cern.ch/twiki/bin/view/AtlasPublic/WebHome
- CMS: http://cms-results.web.cern.ch/cms-results/public-results/publications/

- **EXOTICS specific results:**
- ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults
- CMS: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO

- **SUSY specific results:**
- ATLAS: https:/twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults
- CMS: http://cms-results.web.cern.ch/cms-results/public-results/publications/SUS/index.html

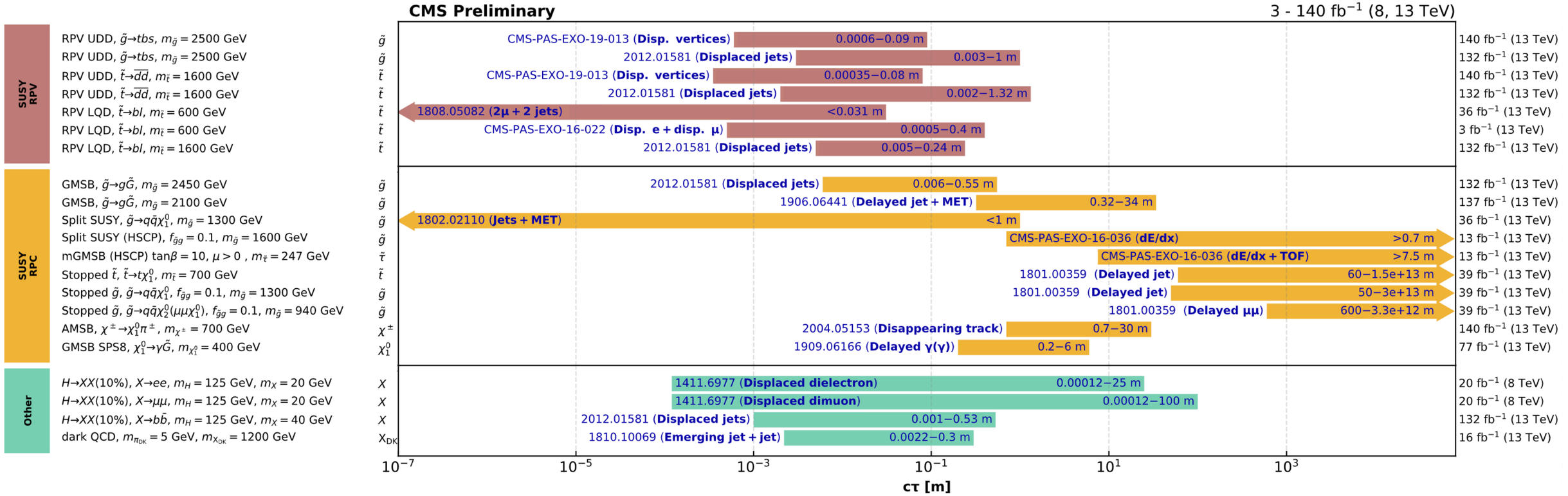
Summary Plots



*Only a selection of the available lifetime limits is shown.

Summary Plots

Overview of CMS long-lived particle searches



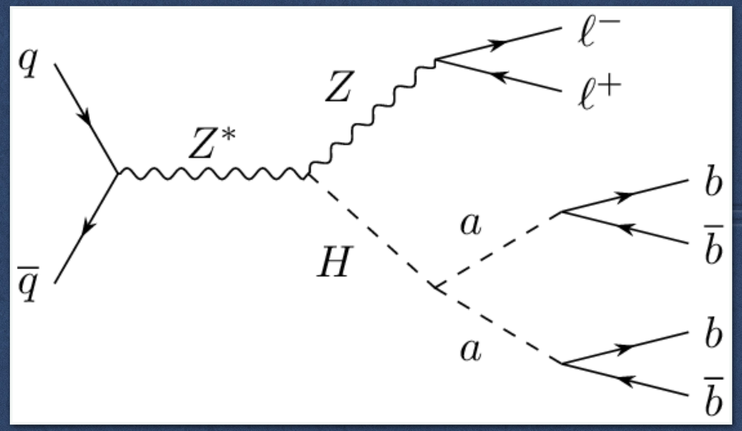
Moriond 2021

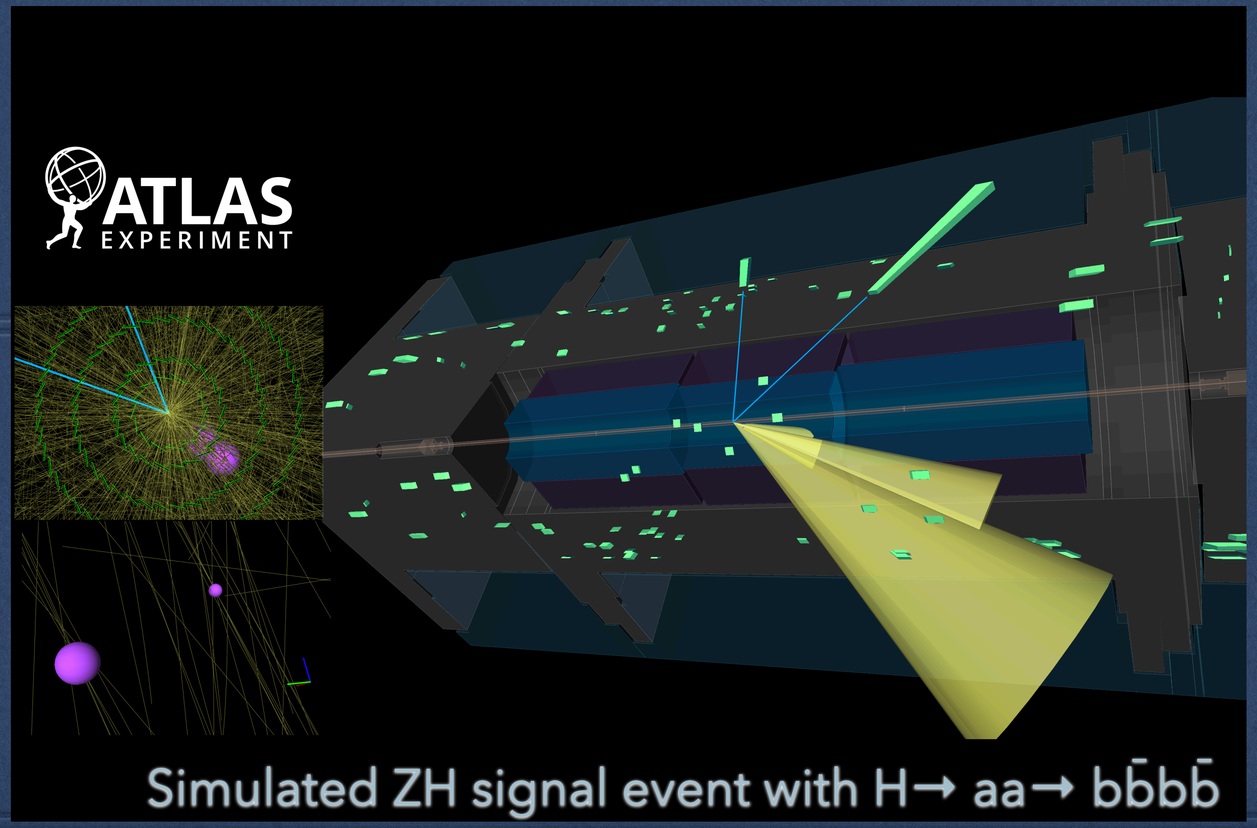
Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included). The y-axis tick labels indicate the studied long-lived particle.

Backup

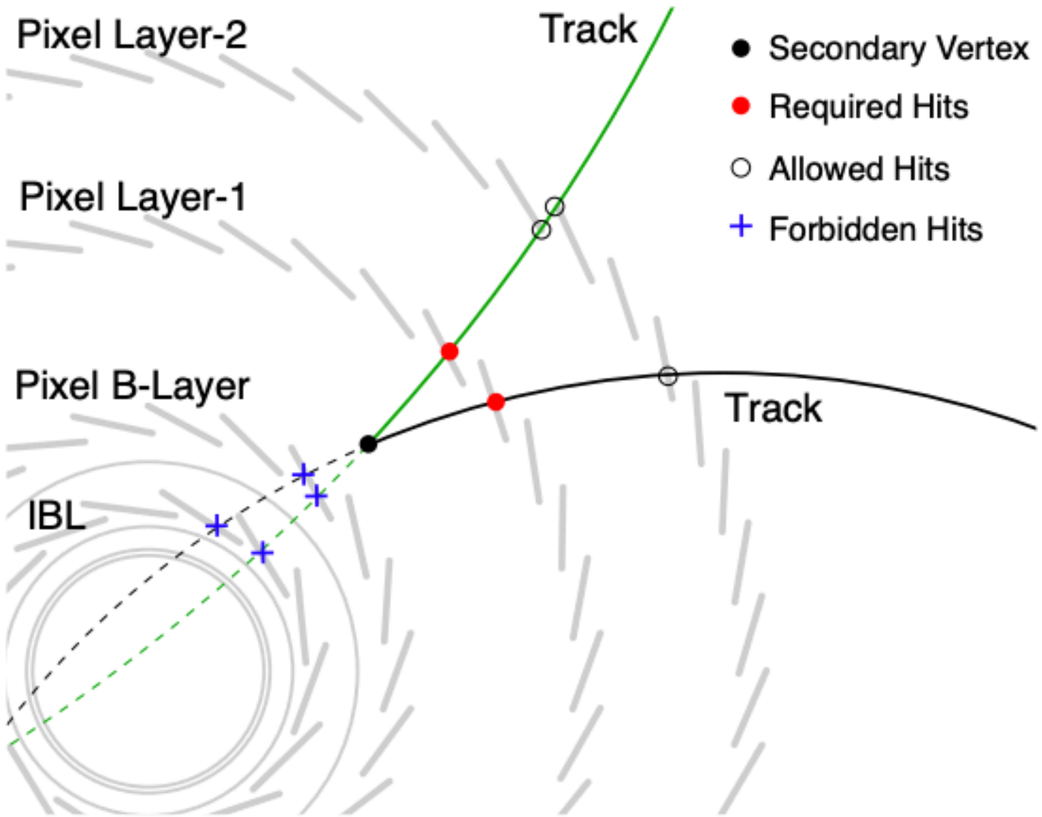
Exotic decays of the Higgs boson into long-lived particles using displaced vertices in the ATLAS inner detector

2107.06092





Displaced Vertex: quality cuts

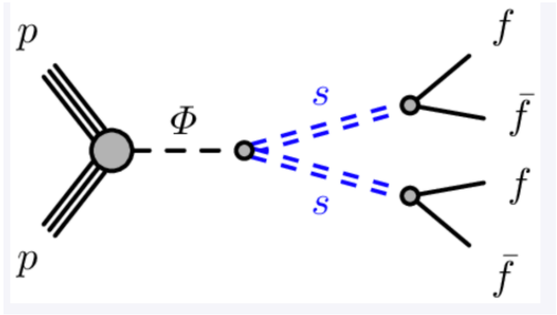


Selection type	Requirement
Track pruning	$\lvert d_0^{\mathrm{DV}}\rvert < 0.8$ mm
	$\lvert z_0^{\mathrm{DV}}\rvert < 1.2$ mm
	$\sigma(d_0^{\mathrm{DV}}) < 0.1$ mm
	$\sigma(z_0^{\mathrm{DV}}) < 0.2$ mm
Vertex preselection	$\chi^2/n_{\mathrm{DoF}} < 5$
	$r < 300$ mm
	$\lvert z\rvert < 300$ mm
	pass material veto
Vertex selection	$n_{\mathrm{trk}} > 2$
	$m/\Delta R_{\mathrm{max}} > 3$ GeV
	$r/\sigma(r) > 100$
	$\max(\lvert d_0\rvert) > 3$ mm
	$\Delta R_{\mathrm{jet}} < 0.6$

Displaced vertex in MS

Model: Production of a Higgs boson or lower/higher-mass scalar boson decays into long-lived neutral particles pairs, each decaying into a fermion pair.

Interpret model: Scalar portal Model

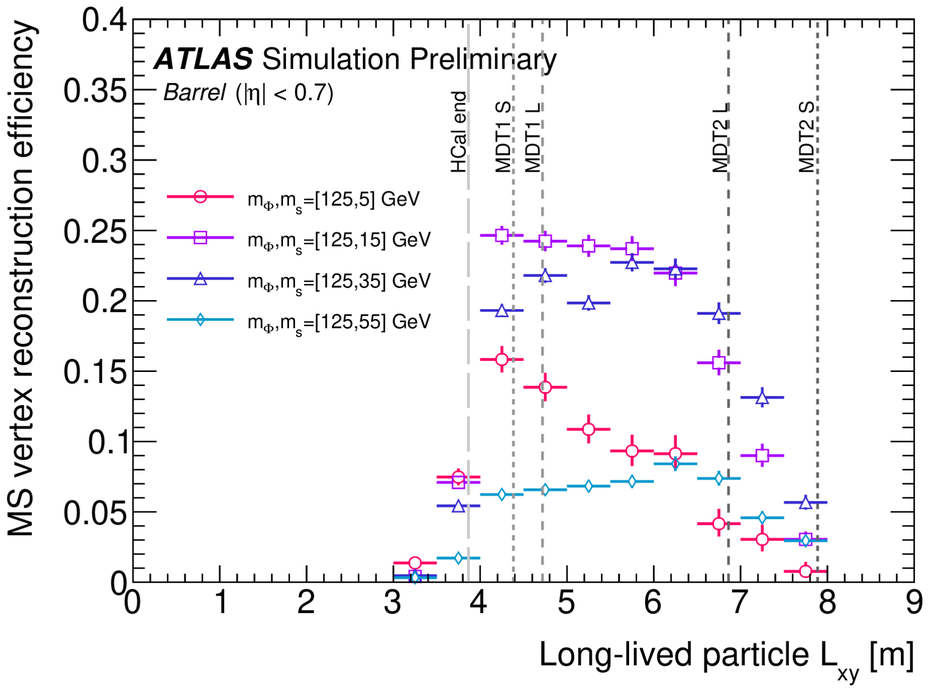


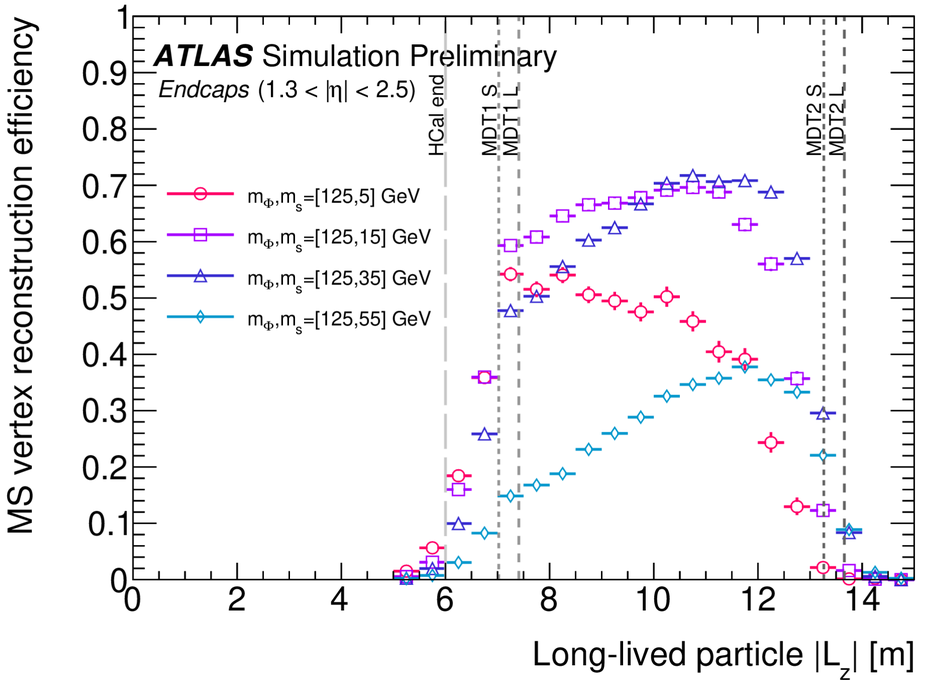
Benchmark signal samples

- Pseudoscalar boson a with 5<ms <475 GeV
- Life time 0.1m<cτs <6m
- Yukawa-like branching ratios to fermions

Event Selection

- MuonROI Cluster Trigger
- at least one PV with two tracks with p_T > 500 MeV
- At least one MS DV matching the muon-ROI trigger cluster
- Cuts on muon hits and isolation criteria





MS Selection Criteria

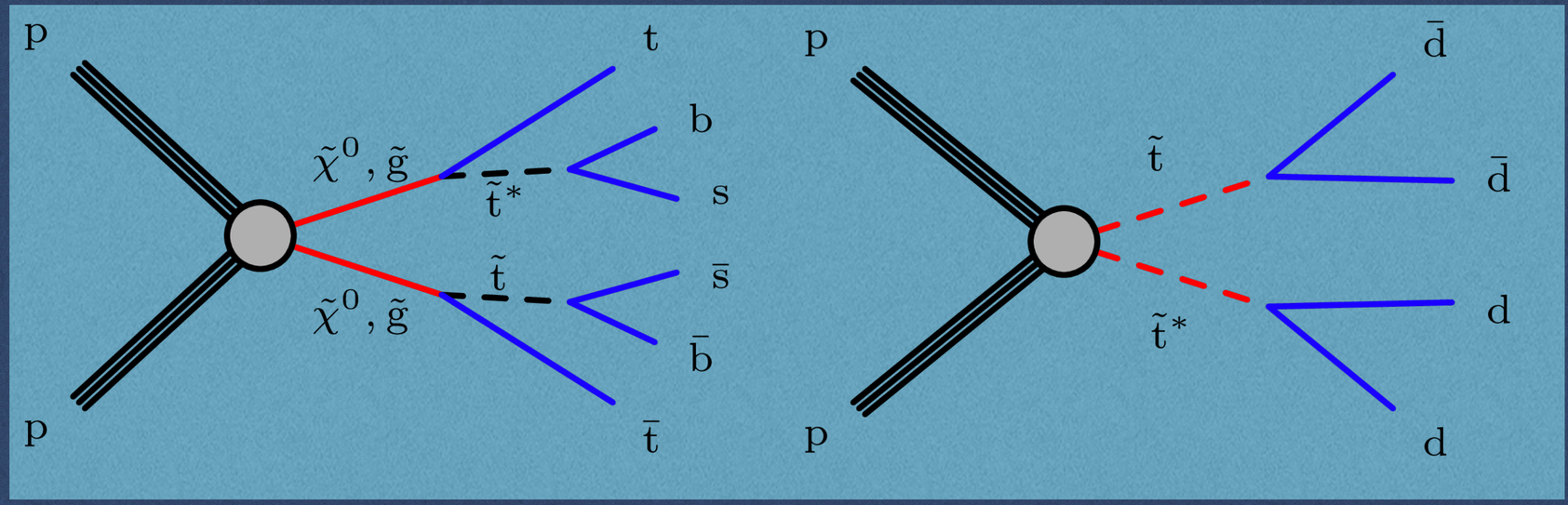
Event passes Muon RoI Cluster trigger
Event has a PV with at least two tracks with $p_{\mathrm{T}} > 500$ MeV
Event has at least one MS DV
MS DV matched to the triggering muon-RoI cluster ($\Delta R(\mathrm{DV}, \mathrm{RoI\ cluster}) < 0.4$). In the case of two muon-RoI clusters, the second vertex should be matched to the second cluster.
$300 \leq n_{\mathrm{MDT}} < 3000$

Barrel	*Endcaps*
MS DV with $\lvert\eta_{\mathrm{vx}}\rvert < 0.7$ MS DV with $3\,\mathrm{m} < L_{xy} < 8\,\mathrm{m}$ $n_{\mathrm{RPC}} \geq 250$	MS DV with $1.3 < \lvert\eta_{\mathrm{vx}}\rvert < 2.5$ MS DV with $L_{xy} < 10\,\mathrm{m}$ and $5\,\mathrm{m} < \lvert L_z\rvert < 15\,\mathrm{m}$ $n_{\mathrm{TGC}} \geq 250$

Isolation requirements	Barrel	Endcaps
High-p_{T} track isolation ($p_T > 5$ GeV)	$\Delta R > 0.3$	$\Delta R > 0.6$
Low-p_{T} track isolation ($\Sigma p_{\mathrm{T}}(\Delta R < 0.2)$)	$\Sigma p_{\mathrm{T}} < 10$ GeV	$\Sigma p_{\mathrm{T}} < 10$ GeV
Jet isolation	$\Delta R > 0.3$	$\Delta R > 0.6$

Search for long-lived particles decaying to jets with displaced vertices in proton-proton collisions at √s=13 TeV

2104.13474



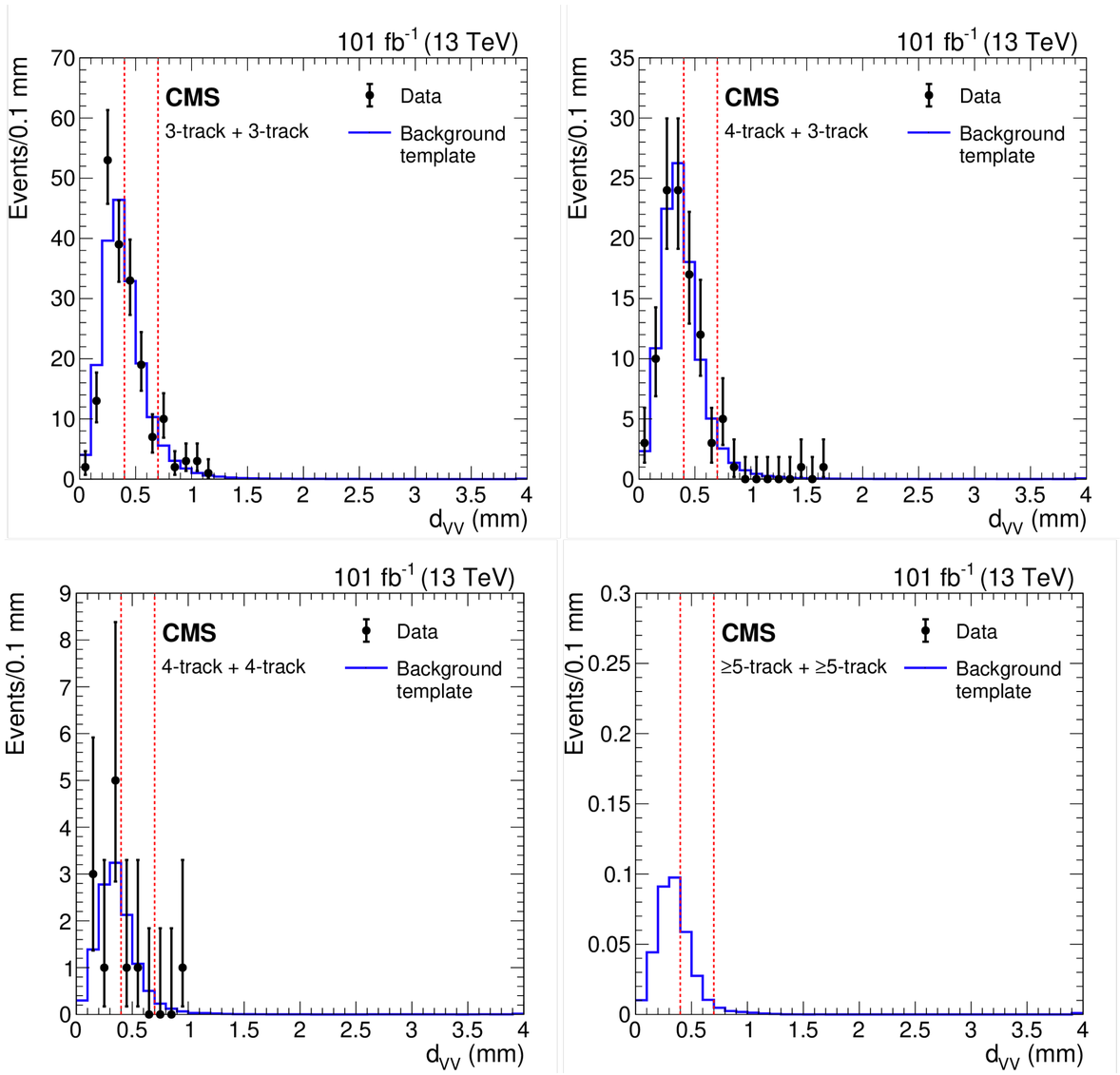
CMS Collaboration

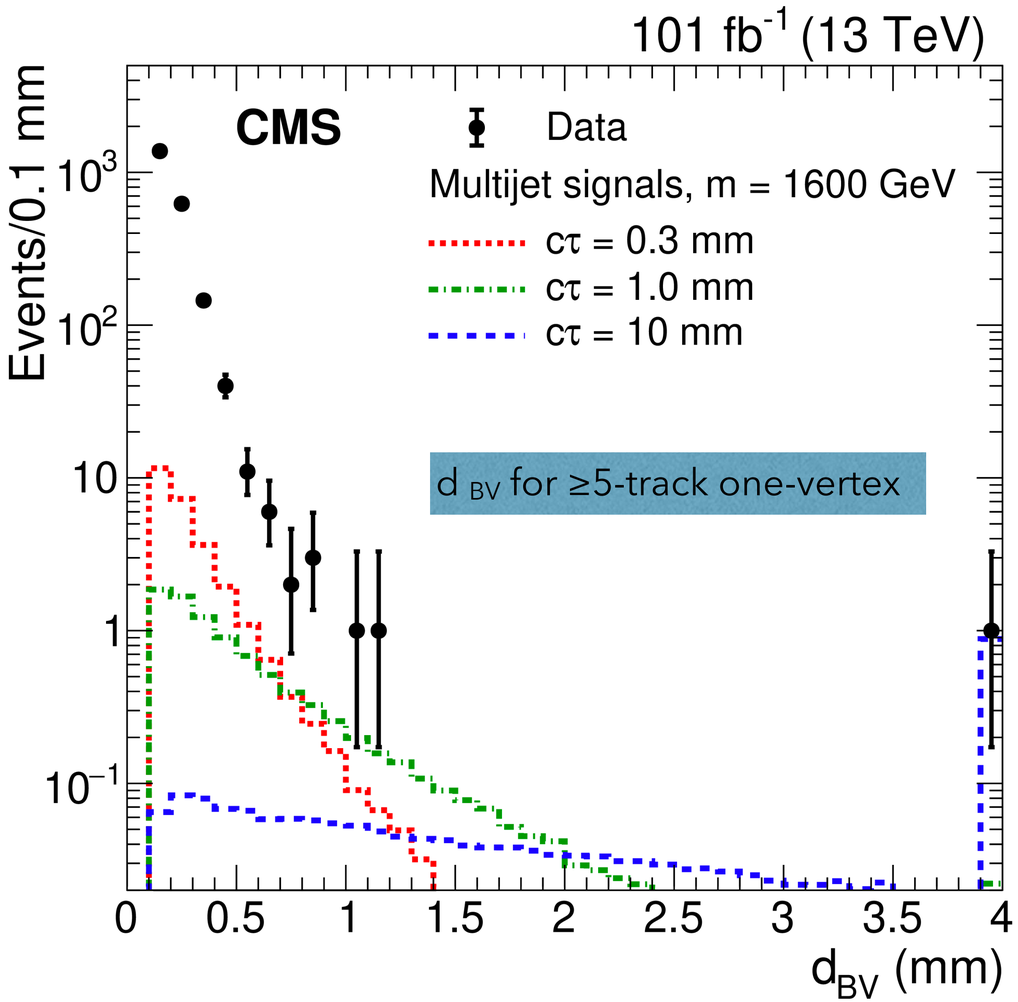
Systematics

Systematic effect	Dijet uncertainty (%)	Multijet uncertainty (%)
Vertex reconstruction	11–41	1–36
PDF uncertainty	1–8	1–8
Integrated luminosity	2–3	2–3
Jet energy scale	5	5
Jet energy resolution	2	2
Pileup	2	2
Trigger efficiency	1	1
Changes in run conditions	1	1
Total	13–42	7–36

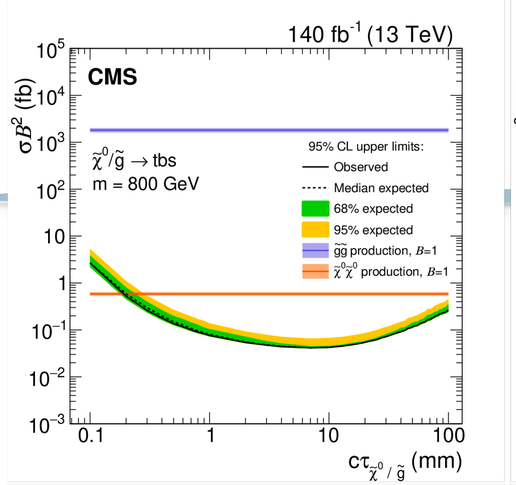
	Systematic uncertainty (%)		
Systematic effect	0–0.4 mm	0.4–0.7 mm	0.7–40 mm
Closure in 3-track control sample	10	14	50
$\geq$5-track template normalization factor	24	24	24
Difference from 3-track vertices to $\geq$5-track vertices:			
Modeling of vertex pair survival efficiency	9	20	25
Modeling of $\Delta\phi_{VV}$	3	6	6
Variation of b quark fraction	1	3	6
Variation of b tagging correction factors	0.5	0.5	1
Total	28	35	61

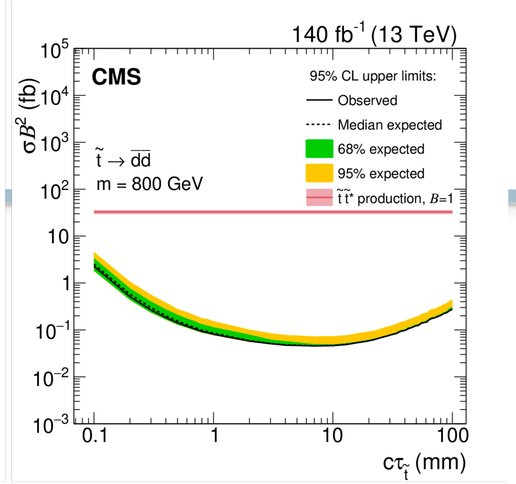
Background Template

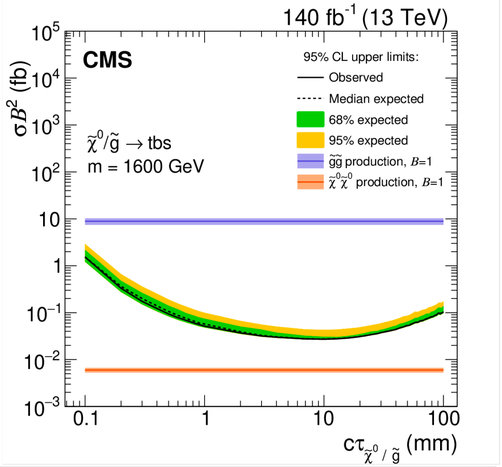


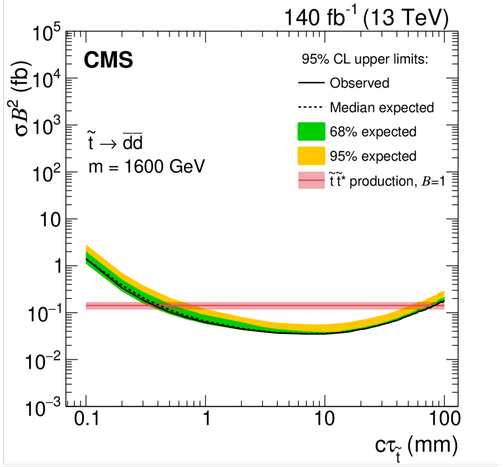


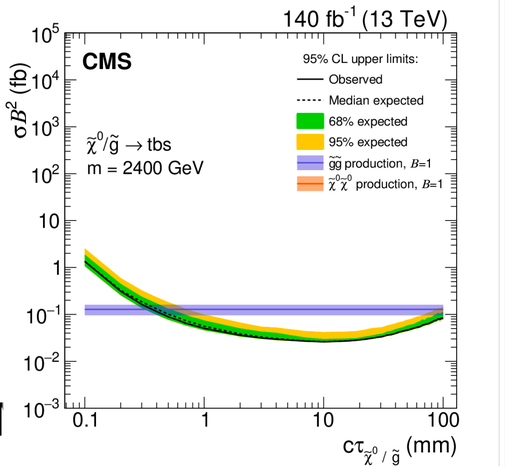
Limits

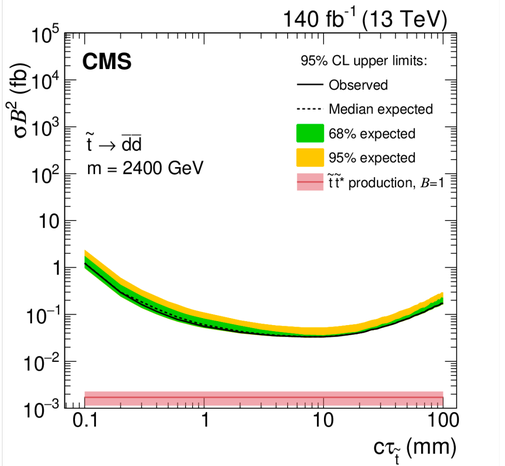

140 fb^{-1} (13 TeV)
CMS
$\tilde{\chi}^0/\tilde{g} \to tbs$
m = 800 GeV
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{g}\tilde{g}$ production, B=1
$\tilde{\chi}^0\tilde{\chi}^0$ production, B=1
σB^2 (fb)
$c\tau_{\tilde{\chi}^0/\tilde{g}}$ (mm)

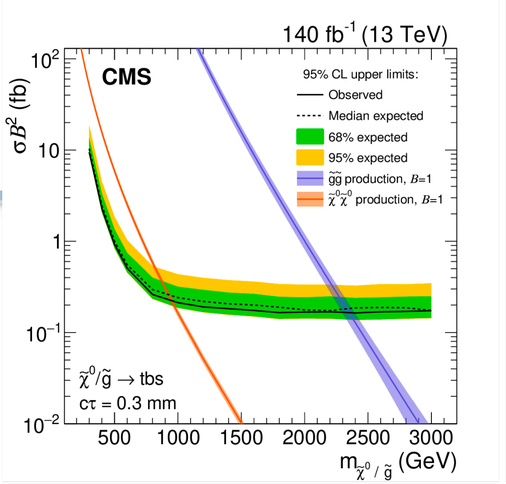

140 fb^{-1} (13 TeV)
CMS
$\tilde{t} \to \bar{d}\bar{d}$
m = 800 GeV
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{t}\tilde{t}^*$ production, B=1
σB^2 (fb)
$c\tau_{\tilde{t}}$ (mm)

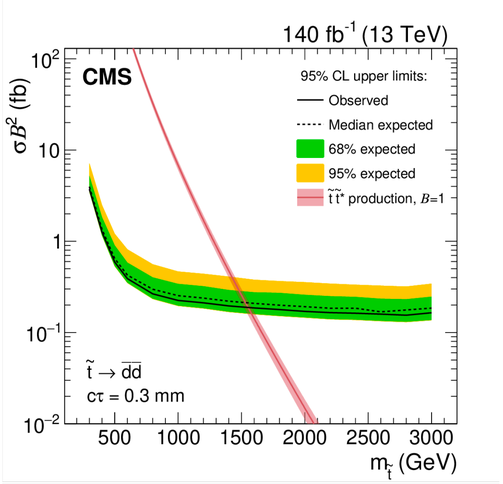

140 fb^{-1} (13 TeV)
CMS
$\tilde{\chi}^0/\tilde{g} \to tbs$
m = 1600 GeV
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{g}\tilde{g}$ production, B=1
$\tilde{\chi}^0\tilde{\chi}^0$ production, B=1
σB^2 (fb)
$c\tau_{\tilde{\chi}^0/\tilde{g}}$ (mm)

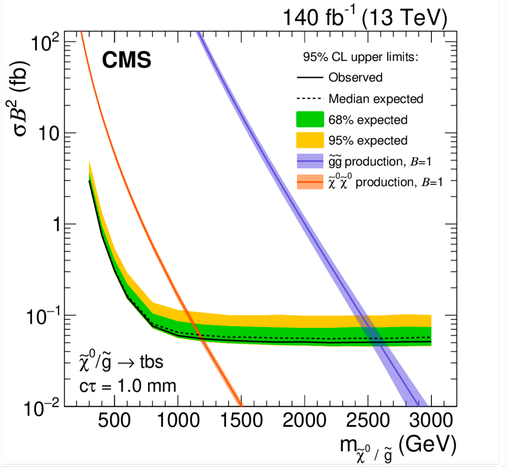

140 fb^{-1} (13 TeV)
CMS
$\tilde{t} \to \bar{d}\bar{d}$
m = 1600 GeV
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{t}\tilde{t}^*$ production, B=1
σB^2 (fb)
$c\tau_{\tilde{t}}$ (mm)

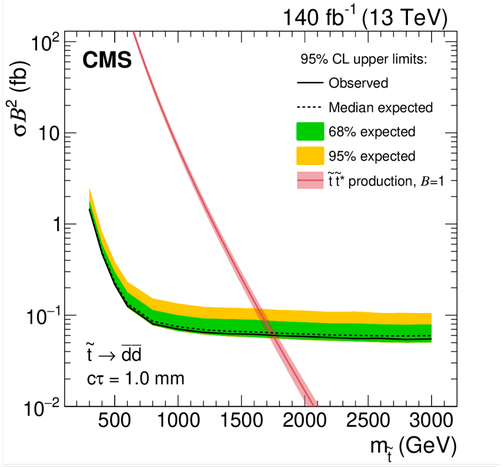

140 fb^{-1} (13 TeV)
CMS
$\tilde{\chi}^0/\tilde{g} \to tbs$
m = 2400 GeV
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{g}\tilde{g}$ production, B=1
$\tilde{\chi}^0\tilde{\chi}^0$ production, B=1
σB^2 (fb)
$c\tau_{\tilde{\chi}^0/\tilde{g}}$ (mm)

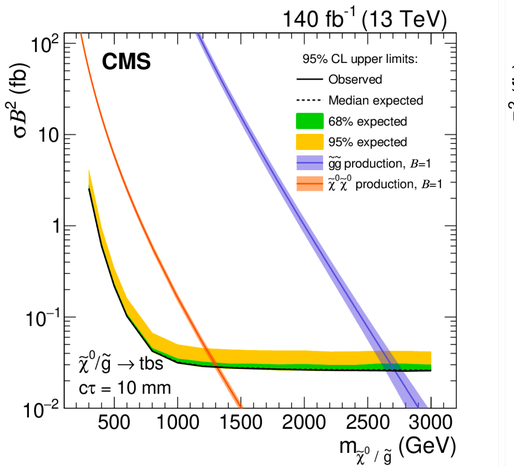

140 fb^{-1} (13 TeV)
CMS
$\tilde{t} \to \bar{d}\bar{d}$
m = 2400 GeV
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{t}\tilde{t}^*$ production, B=1
σB^2 (fb)
$c\tau_{\tilde{t}}$ (mm)

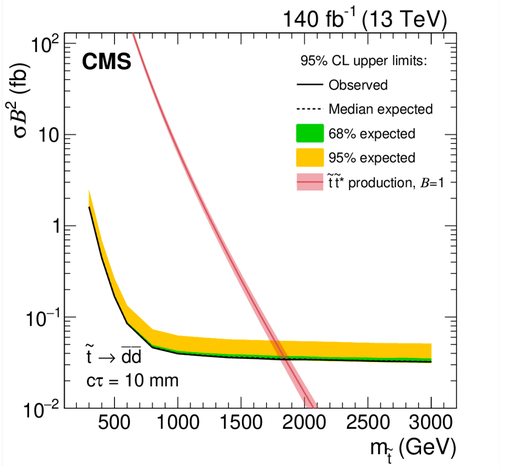

140 fb^{-1} (13 TeV)
CMS
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{g}\tilde{g}$ production, B=1
$\tilde{\chi}^0\tilde{\chi}^0$ production, B=1
$\tilde{\chi}^0/\tilde{g} \to tbs$
$c\tau$ = 0.3 mm
σB^2 (fb)
$m_{\tilde{\chi}^0/\tilde{g}}$ (GeV)


140 fb^{-1} (13 TeV)
CMS
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{t}\tilde{t}^*$ production, B=1
$\tilde{t} \to \bar{d}\bar{d}$
$c\tau$ = 0.3 mm
σB^2 (fb)
$m_{\tilde{t}}$ (GeV)


140 fb^{-1} (13 TeV)
CMS
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{g}\tilde{g}$ production, B=1
$\tilde{\chi}^0\tilde{\chi}^0$ production, B=1
$\tilde{\chi}^0/\tilde{g} \to tbs$
$c\tau$ = 1.0 mm
σB^2 (fb)
$m_{\tilde{\chi}^0/\tilde{g}}$ (GeV)

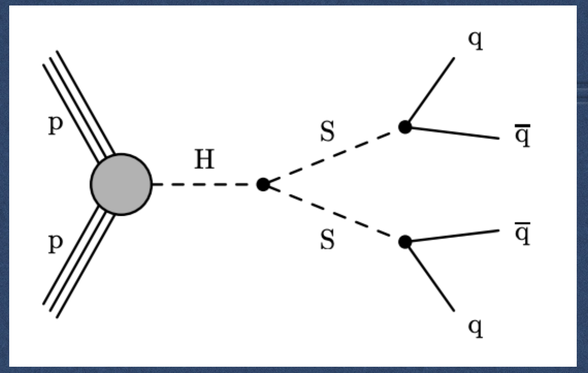

140 fb^{-1} (13 TeV)
CMS
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{t}\tilde{t}^*$ production, B=1
$\tilde{t} \to \bar{d}\bar{d}$
$c\tau$ = 1.0 mm
σB^2 (fb)
$m_{\tilde{t}}$ (GeV)

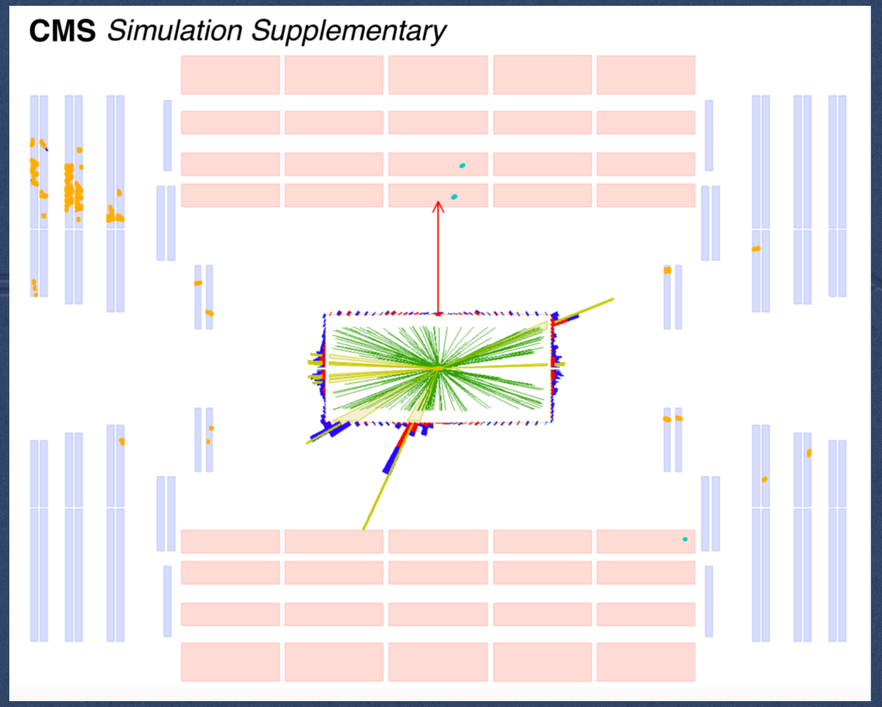

140 fb^{-1} (13 TeV)
CMS
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{g}\tilde{g}$ production, B=1
$\tilde{\chi}^0\tilde{\chi}^0$ production, B=1
$\tilde{\chi}^0/\tilde{g} \to tbs$
$c\tau$ = 10 mm
σB^2 (fb)
$m_{\tilde{\chi}^0/\tilde{g}}$ (GeV)

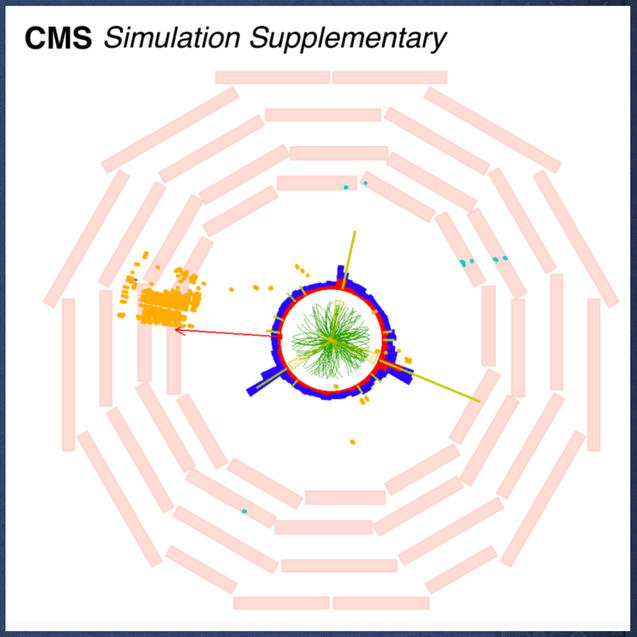

140 fb^{-1} (13 TeV)
CMS
95% CL upper limits:
Observed
Median expected
68% expected
95% expected
$\tilde{t}\tilde{t}^*$ production, B=1
$\tilde{t} \to \bar{d}\bar{d}$
$c\tau$ = 10 mm
σB^2 (fb)
$m_{\tilde{t}}$ (GeV)

Search for long-lived particles decaying in the CMS endcap muon detectors in proton-proton collisions at √s=13 TeV

2107.04838

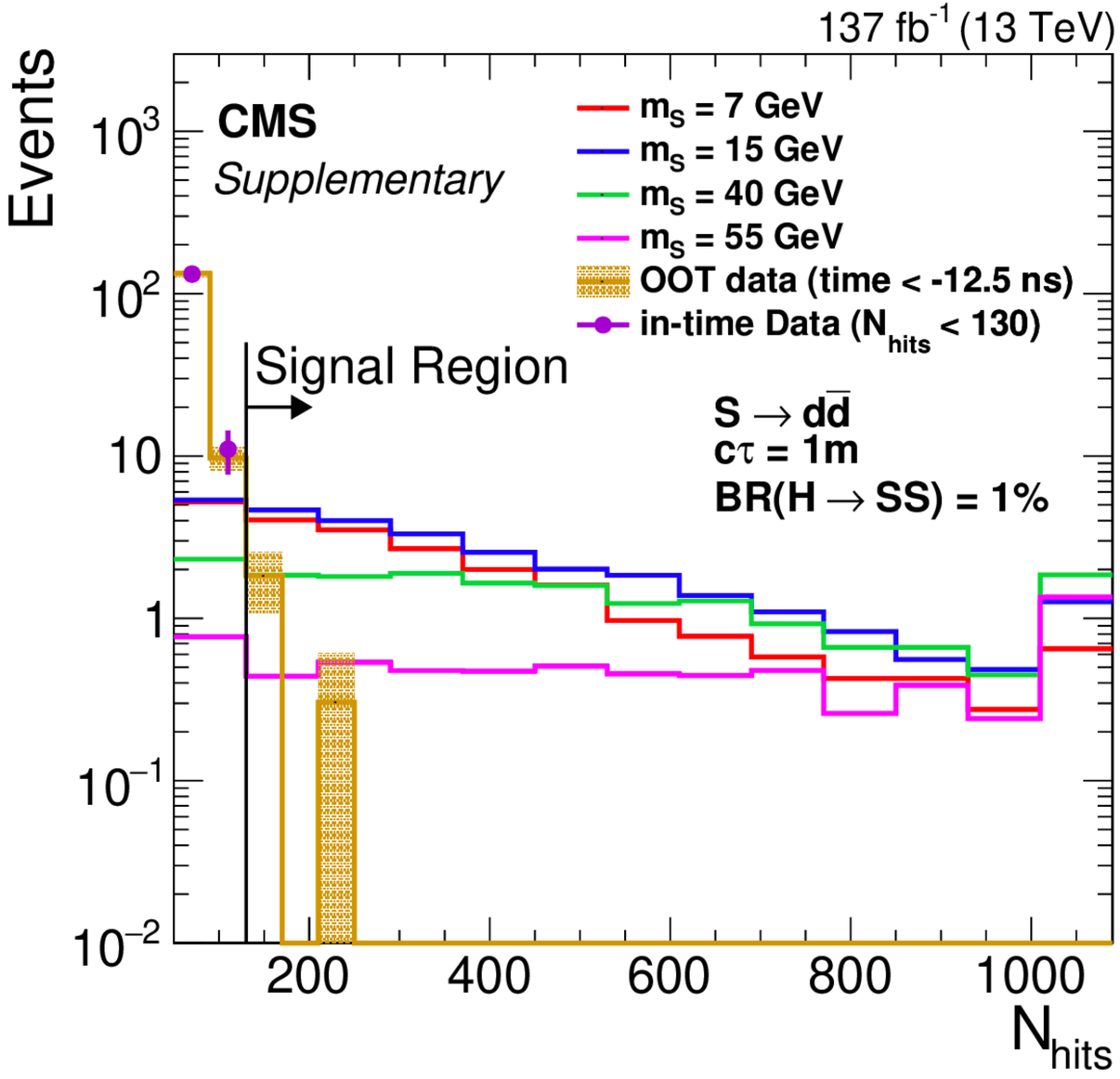


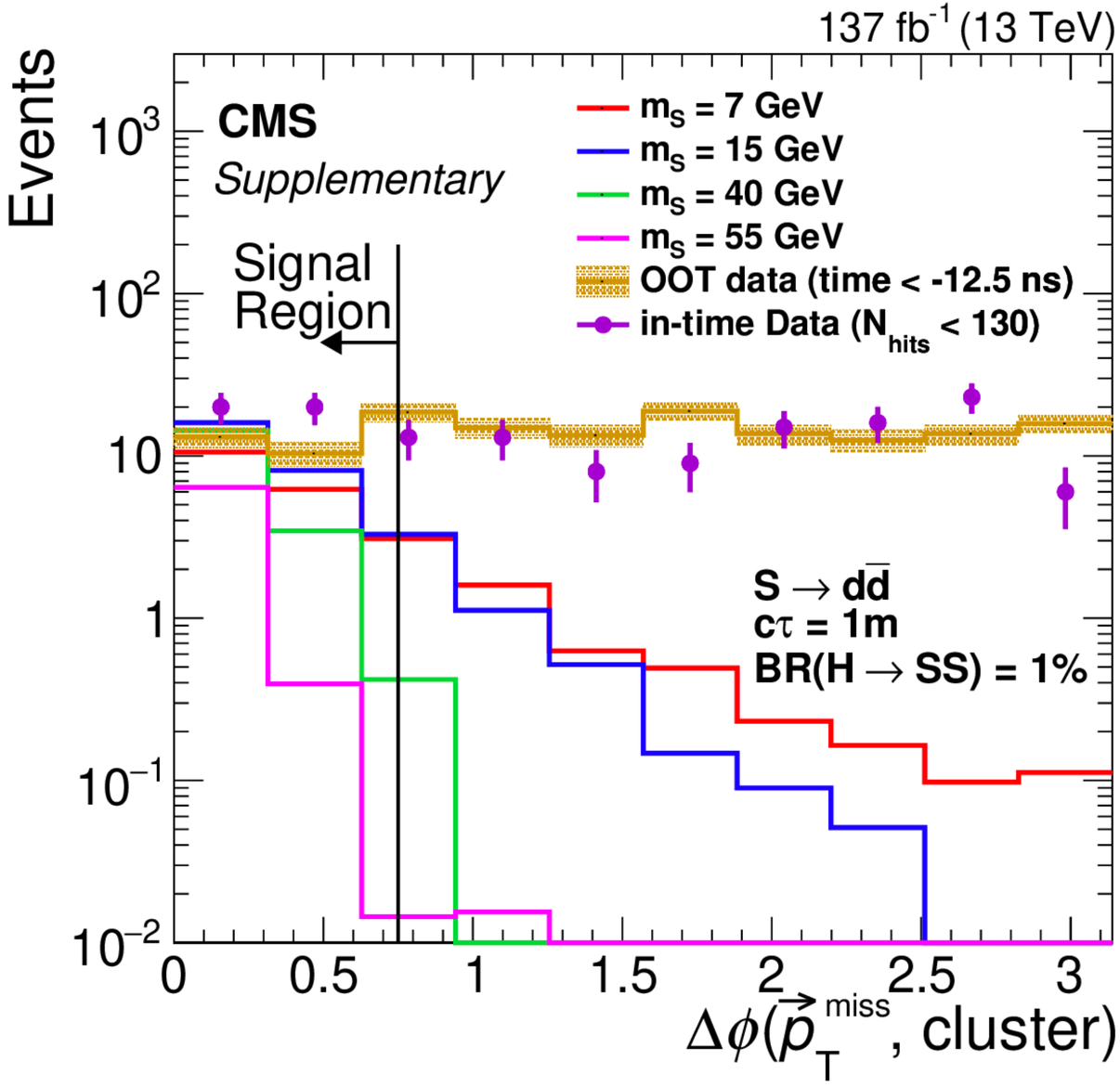




CMS Collaboration

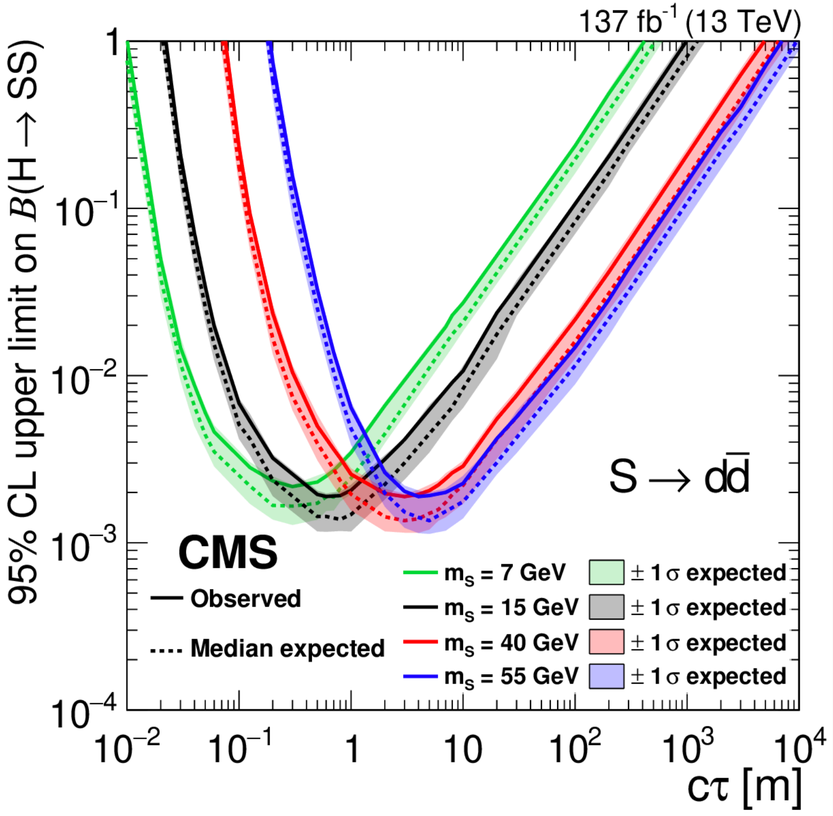
In-Time Out-of -Time

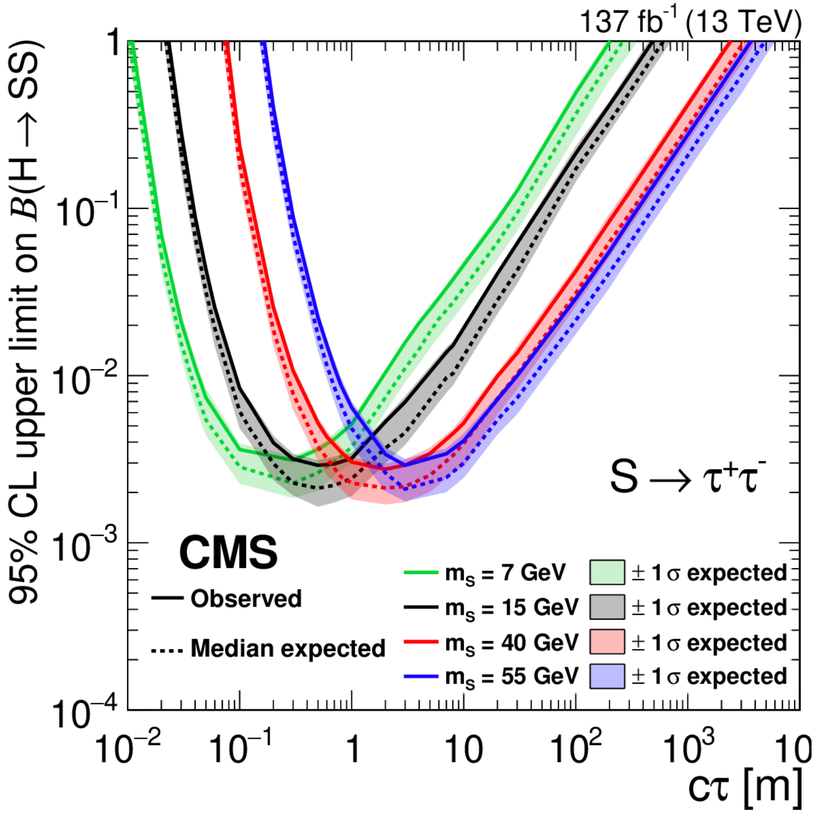


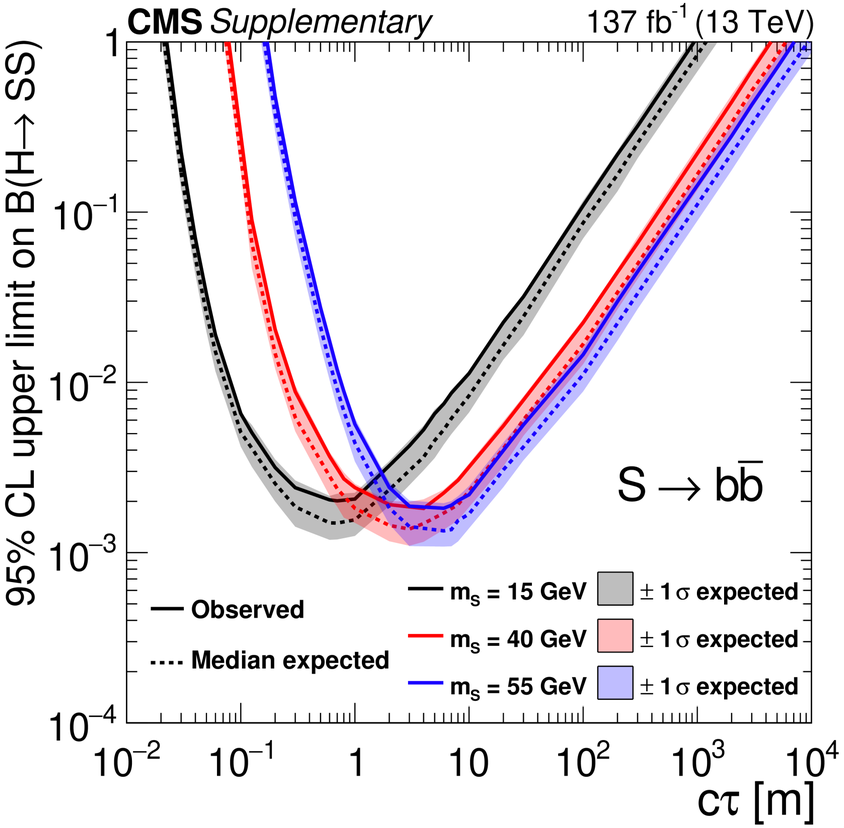


Results

Limits set on the branching fraction $\mathcal{B}(h^0 \rightarrow SS)$ as a function of $c\tau$ for the S decays







A search for the decays of stopped long-lived particles at √s=13 TeV with the ATLAS detector

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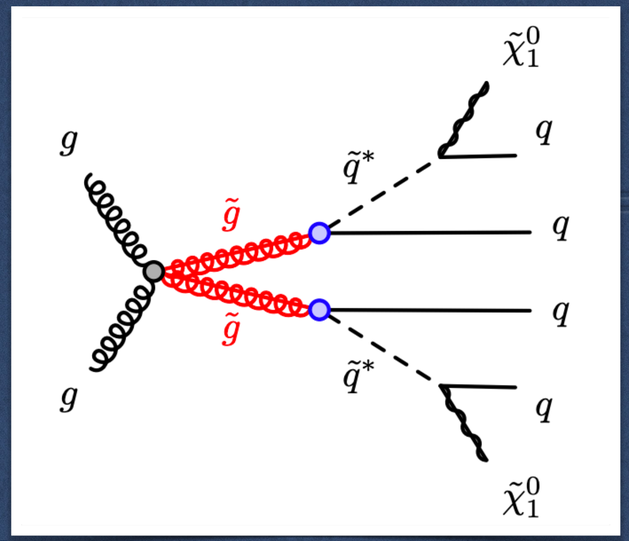
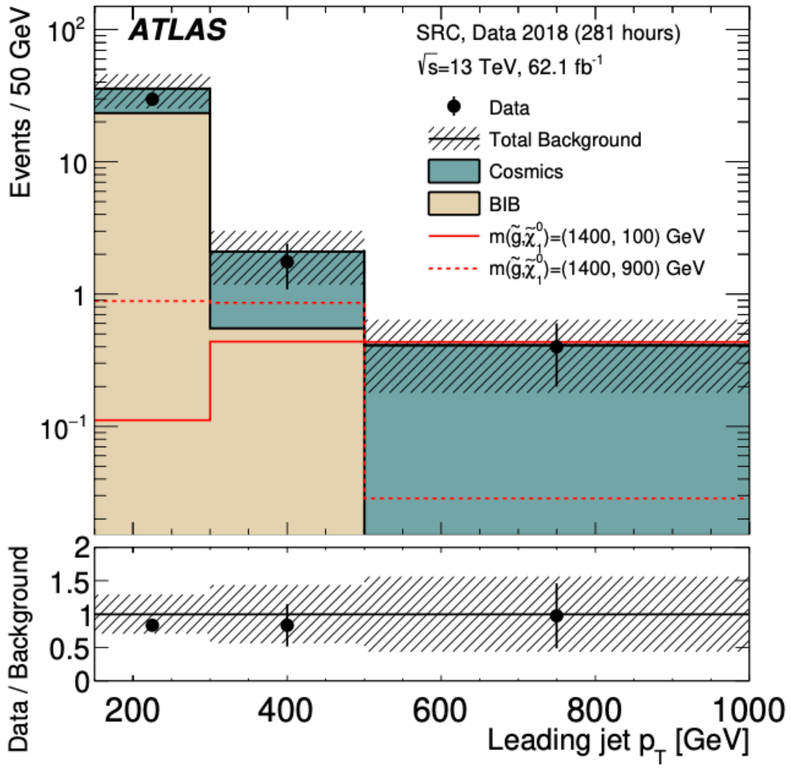


ATLAS
EXPERIMENT

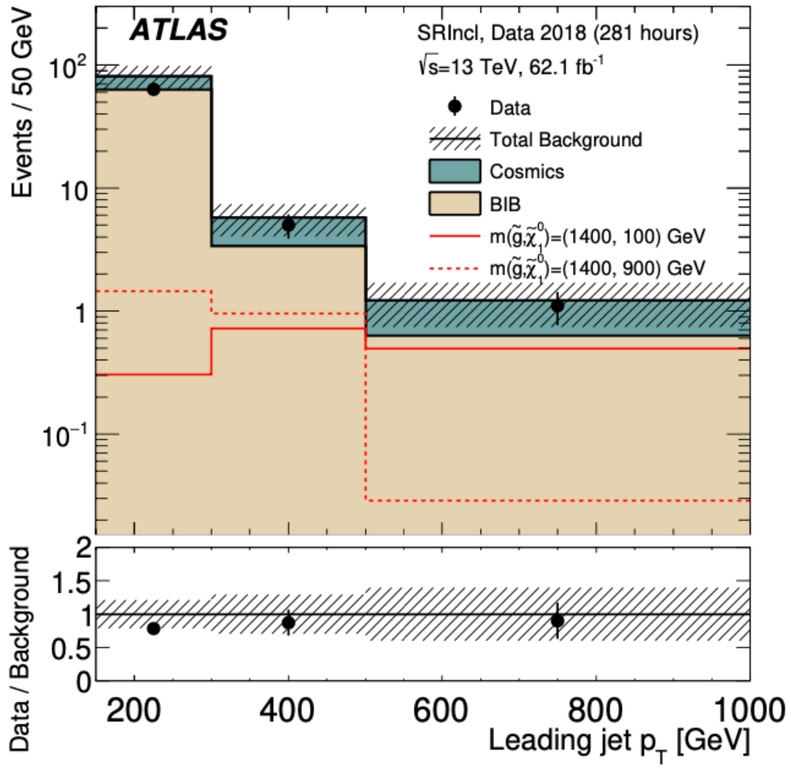
Signal Regions

Region	Data sample	Number of muons	Leading jet p_T [GeV]	α	Leading jet w_ϕ	Leading jet $\lvert\eta\rvert$
Central signal region						
SRC	Search sample	0	150–300 300–500 > 500	> 0.2	> 0.02	< 0.8
Inclusive signal region						
SRIncl	Search sample	0	150–300 300–500 > 500	> 0.2	> 0.02	< 2.4

SRC: $|\eta| < 0.8$



SRInc: $|\eta| < 2.4$



The ATLAS detector (HL-LHC Upgrade)

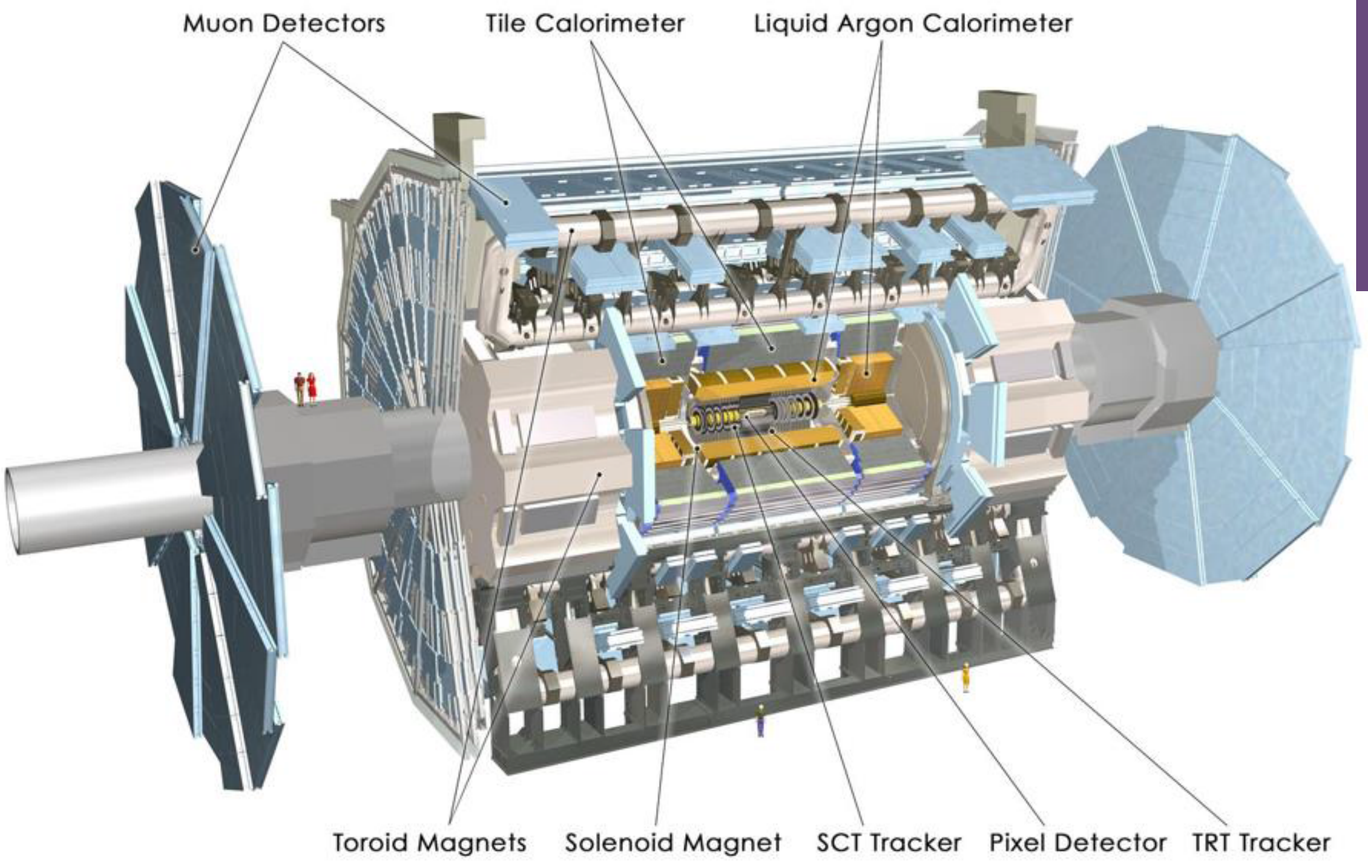
TDAQ upgrade

➔Increased latencies and rates

Proposals for adding in forward regions a muon tagger and a timing detector

Inner Detector: full replacement by a all-silicon one ($165m^2$), extending up to $|\eta|=4$
At most 1.75 X_0

Muon readout and trigger upgrades.
New Barrel trigger layer.
New end cap inner Muon station (nSW) (Phase I)

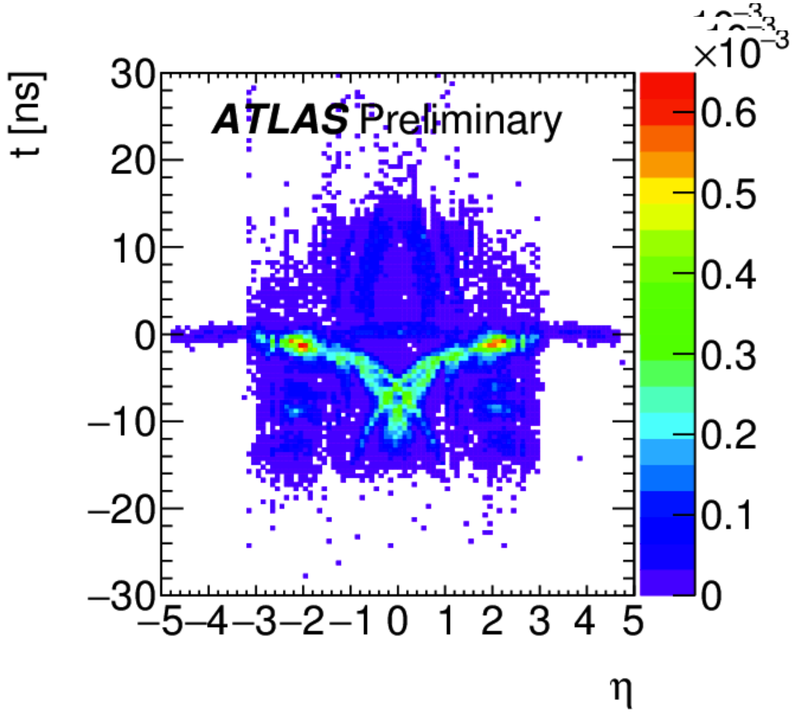


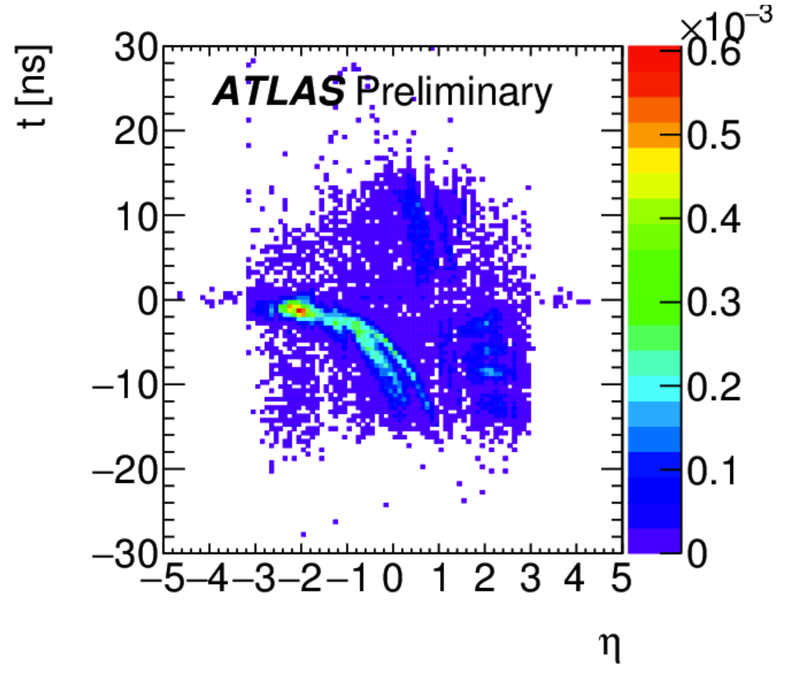
ATLAS Detector Upgrade for HL-LHC

LArg: new FrontEnd and BackEnd electronics for faster readout
High granularity LAr (PhaseI)
Tile Calorimeter : upgrade of electronics and HV distribution

BIB in ATLAS

Interactions between beam protons and beam collimators upstream of the IP are a source of **high-momentum muons, denoted beam-induced-background (BIB) muons**, that can enter the ATLAS detector nearly parallel to the beam axis. Most MS tracks and jets generated by this process are identified and rejected.





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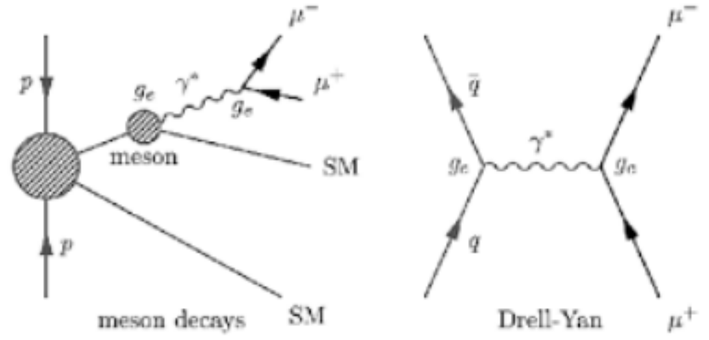
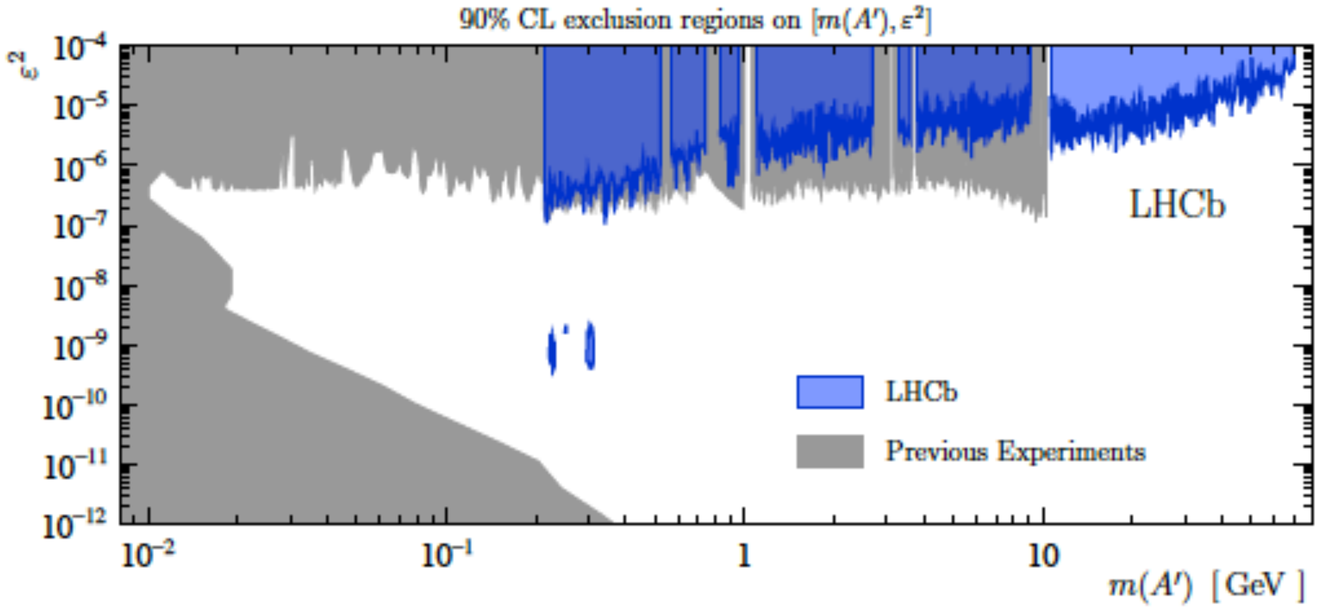
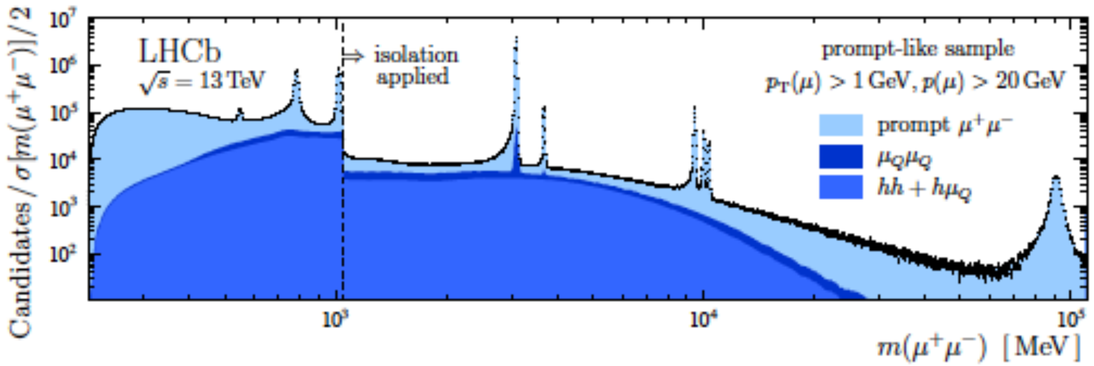
Dark Photons

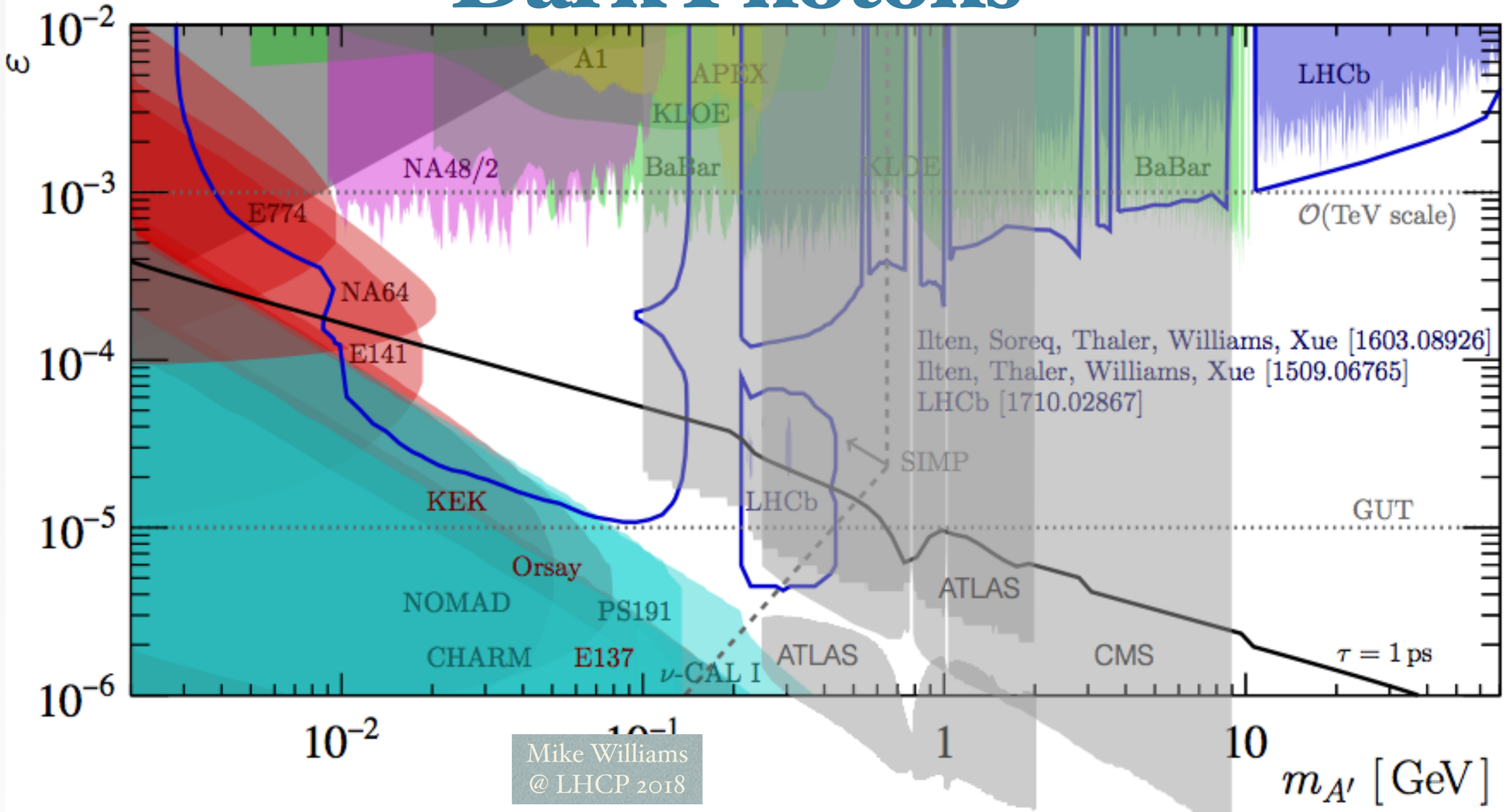
- **Inclusive search for Dark Photons (A') in μμ only with LHCb 2016 dataset**
  - The model predicts A' light, produced as γ*
  - Two searches: prompt and displaced muons
- Large fraction in forward region, very soft pT. Online reconstruction of candidates, no pre-scale down to threshold 2mμ. Isolation cut applied above 1 GeV/c.
- Backgrounds from same sign μ, fits to IP x2







Dark Photons



Mike Williams
@ LHCP 2018

ATLAS/CMS limits shown here assume B(H→$f_D f_D$)=10%.

ATLAS [1511.05542] (see also 1505.07645,CONF-2016-042), CMS [PAS-HIG-16-035].