SEARCHES FOR BSM PHYSICS USING CHALLENGING AND LONG-LIVED SIGNATURES WITH THE ATLAS DETECTOR

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ATLAS EXPERIMENT

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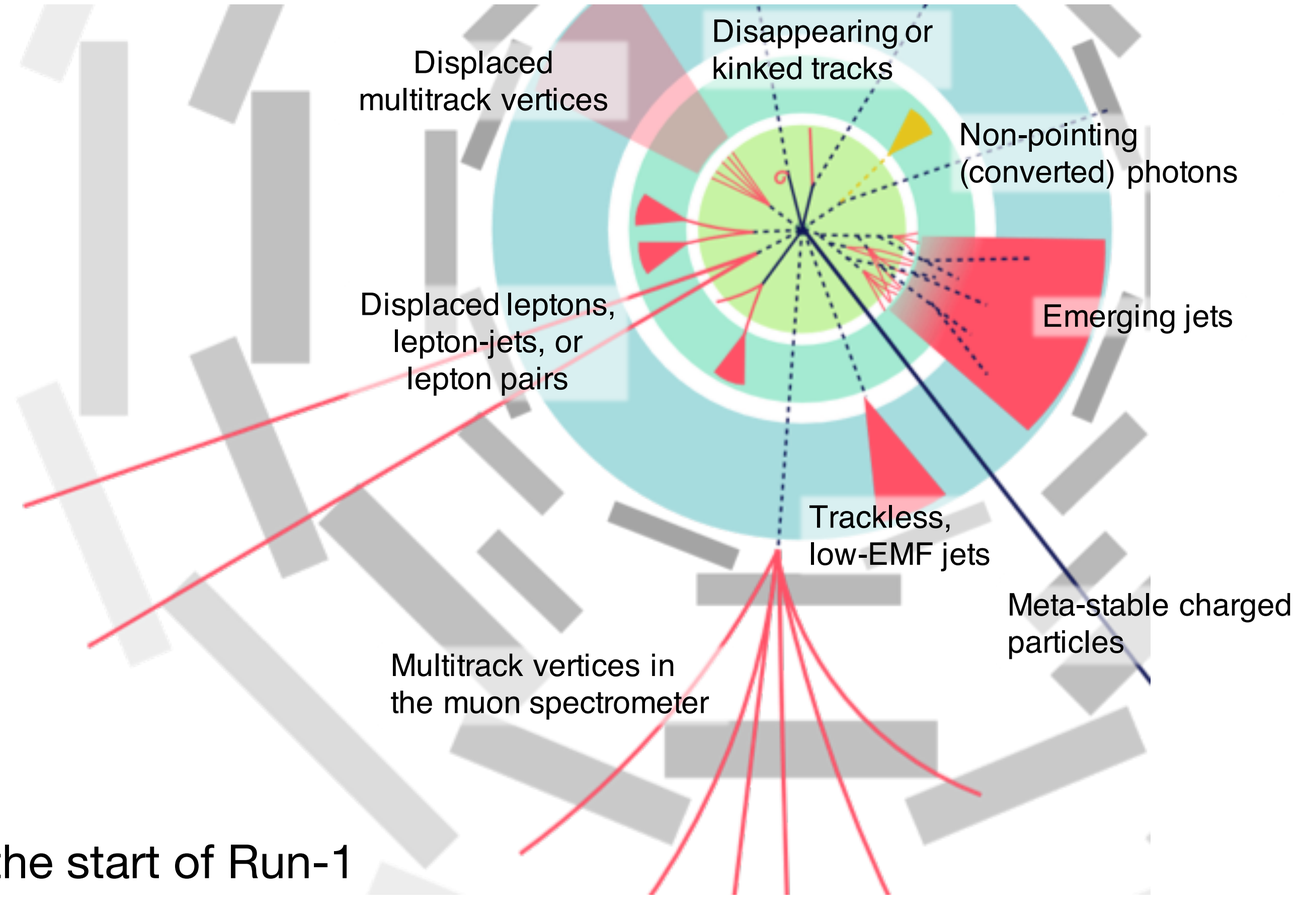
OUTLINE

signals from long-lived particles expected in several BSM extensions that can provide viable solutions for the open questions of SM

generally **occurs when decays are suppressed**: small phase space (ex. mass degeneracy in compressed SUSY models), weak couplings, energy barriers, etc. (ex. dark/hidden sectors) …

experimentally give rises to a diverse set of **unusual signatures** and **unusual backgrounds**: requiring **custom dedicated triggers and/or reconstruction strategies** …

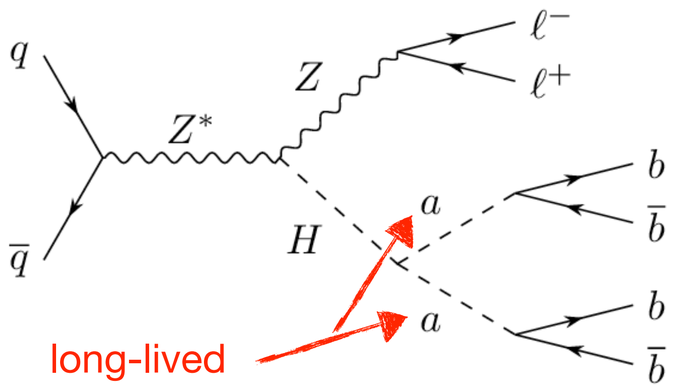


a rich program of LLP searches ongoing in ATLAS from the start of Run-1

here few examples of **recent ATLAS searches** based on the **full data statistic of Run-2** of the LHC probing different decay-lengths and signature topologies

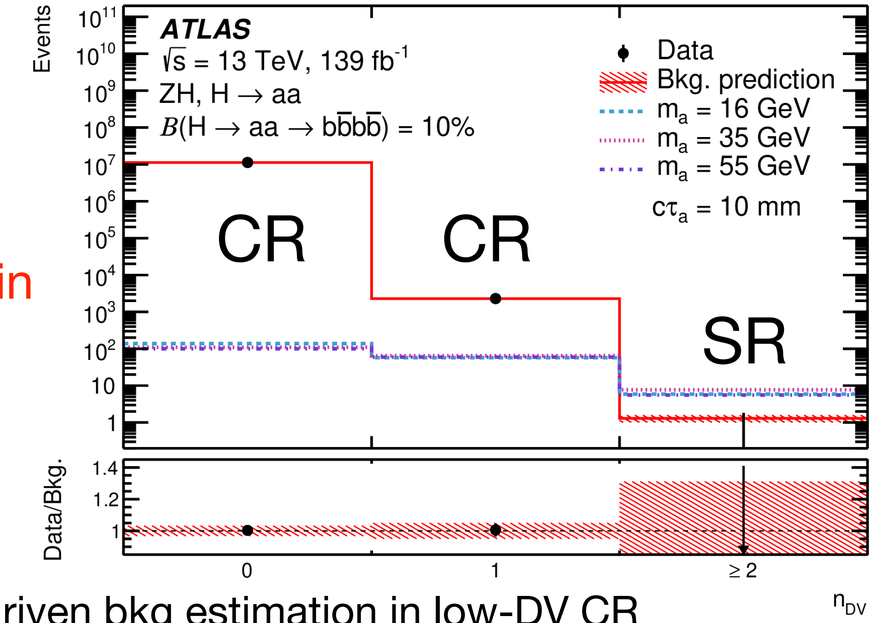
NOTE: impossible to cover in detail everything here. More details in several other ATLAS talks at SUSY 2021, and in the ATLAS public results web page: available in: https://twiki.cern.ch/twiki/bin/view/AtlasPublic

EXOTIC HIGGS DECAYS TO LLP: H→aa→4b

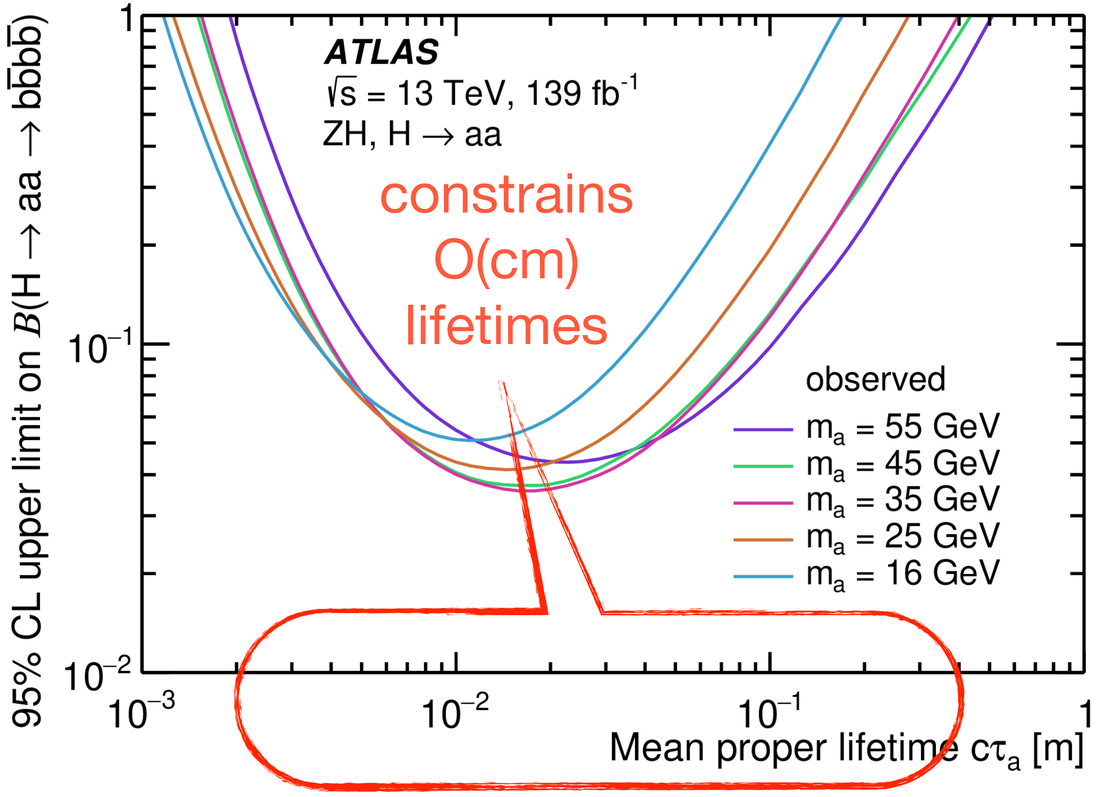


- the 125 GeV Higgs boson can act as communicator with BSM sectors
- exploit ZH production: trigger on leptons, large BR to b-quarks
- use "**large-radius tracking**" with **loser track-to-vtx association to reconstruct displaced vertices**
- require ≥2 jets, with leading b-jets matched to DVs

no excess in SR observed in 139/fb



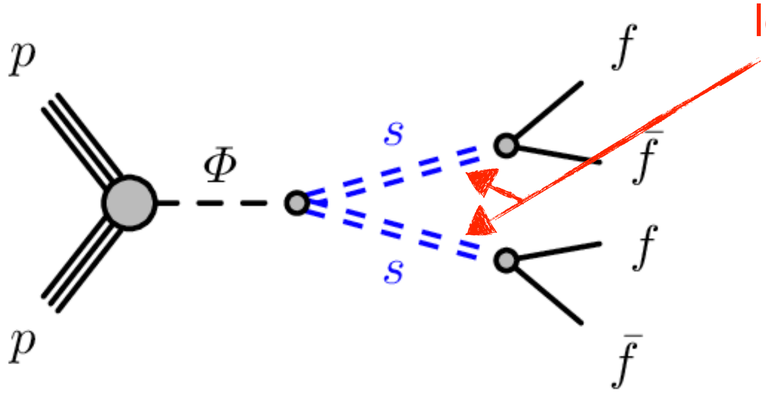
- full data-driven bkg estimation in low-DV CR
- systematic uncertainty dominated by non-standard tracking/vertexing (2-12%)



arXiv:2107.06092 (submitted to JHEP)

DISPLACED VERTICES IN THE MUON SPECTROMETER

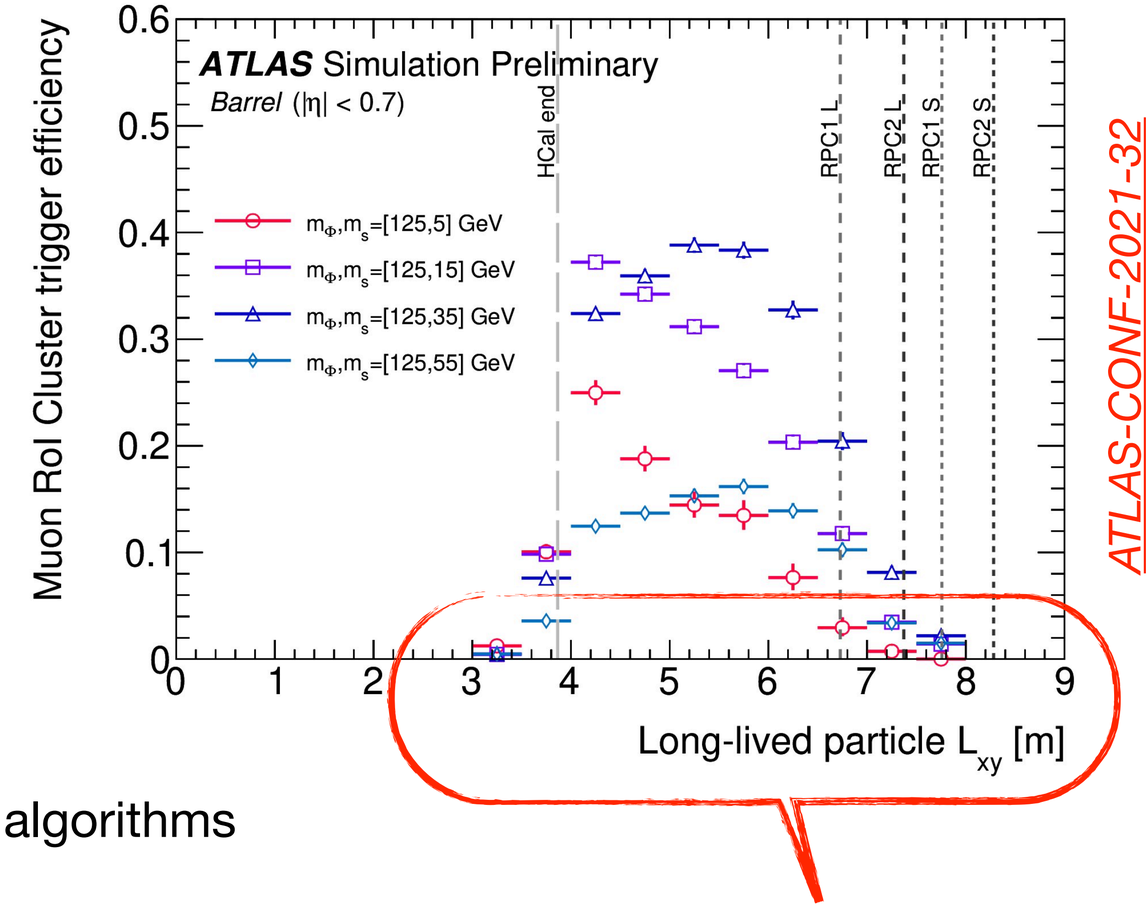
- produced by neutral LLPs that travel undetected the whole ATLAS detector and decay in SM particles near on in the muon spectrometer
- simplified **benchmark model: hidden valley** with hidden scalars are produced by a scalar (higgs-like) particle communicator:



long-lived due to the weak coupling to SM

- **strategy:** search for signatures with a pair of displaced multitrack vertices in the muon spectrometer
- exploit ATLAS **dedicated trigger** and **vertexing in the MS** algorithms

JINST 8 (2013) P07015 , *JINST 9 (2014) P02001*



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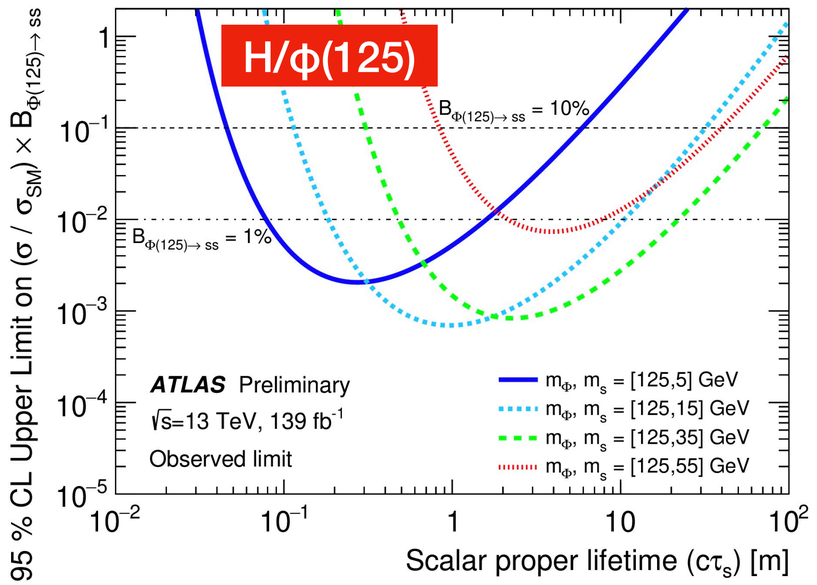
good acceptance for a broad range of O(m) decay lengths

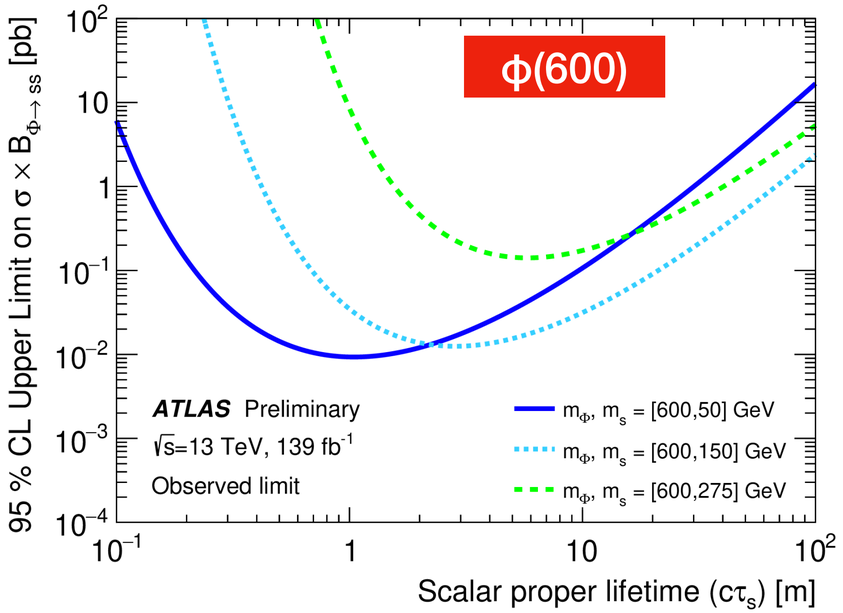
- **selection:** two isolated MS vertices, matched to triggering cluster(s) and separated by ΔR>1 to ensure not coming from the same background activity
- **backgrounds:**
  - dominant: punch-through QCD jets (data-driven estimation)
  - smaller contribution from non-collision events (electronic noise, cosmic-ray muons, beam-induced background)
- **total systematic uncertainty in average 15%**, dominated by lifetime extrapolation (0-30%), modelling of trigger efficiency (20-25%), and vertex reconstruction efficiency (10-15%)

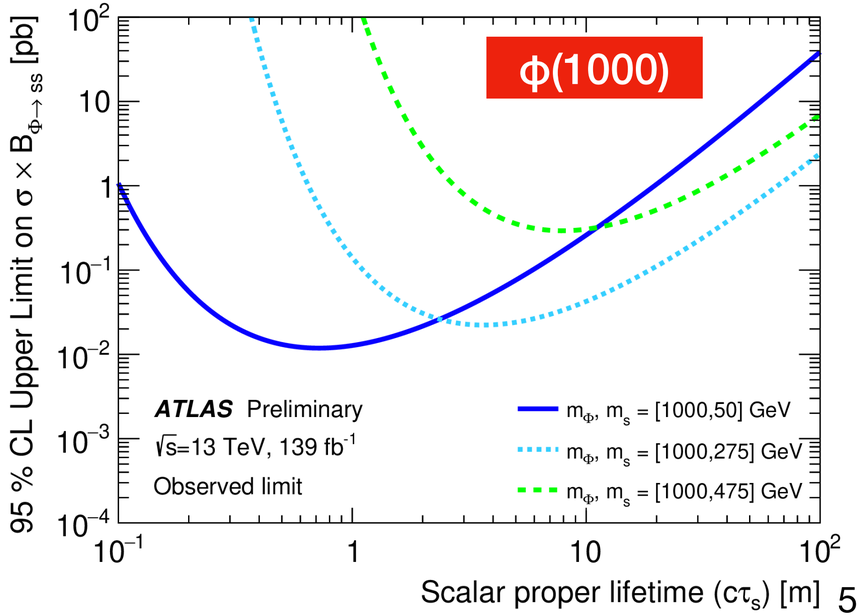
Observed events in **139 fb^{-1}** of pp collisions: **0 events**

Expected events from background (data-driven): **0.32 ± 0.05 events**

exclusion for different communicator mass and LLP proper lifetime and masses







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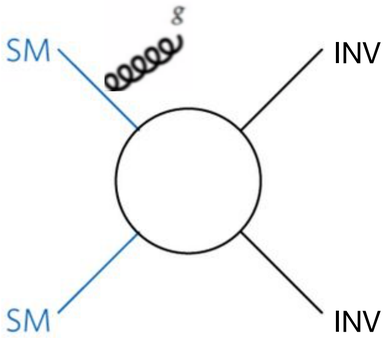
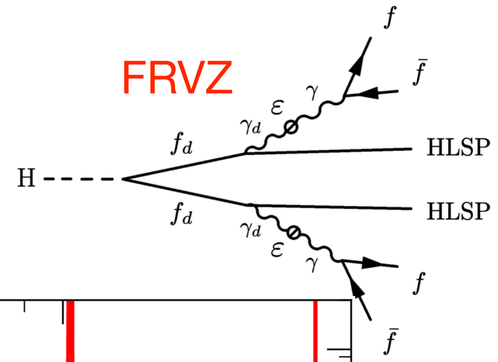
EXOTIC HIGGS DECAYS TO LLP: USING MONO-JET SIGNATURES

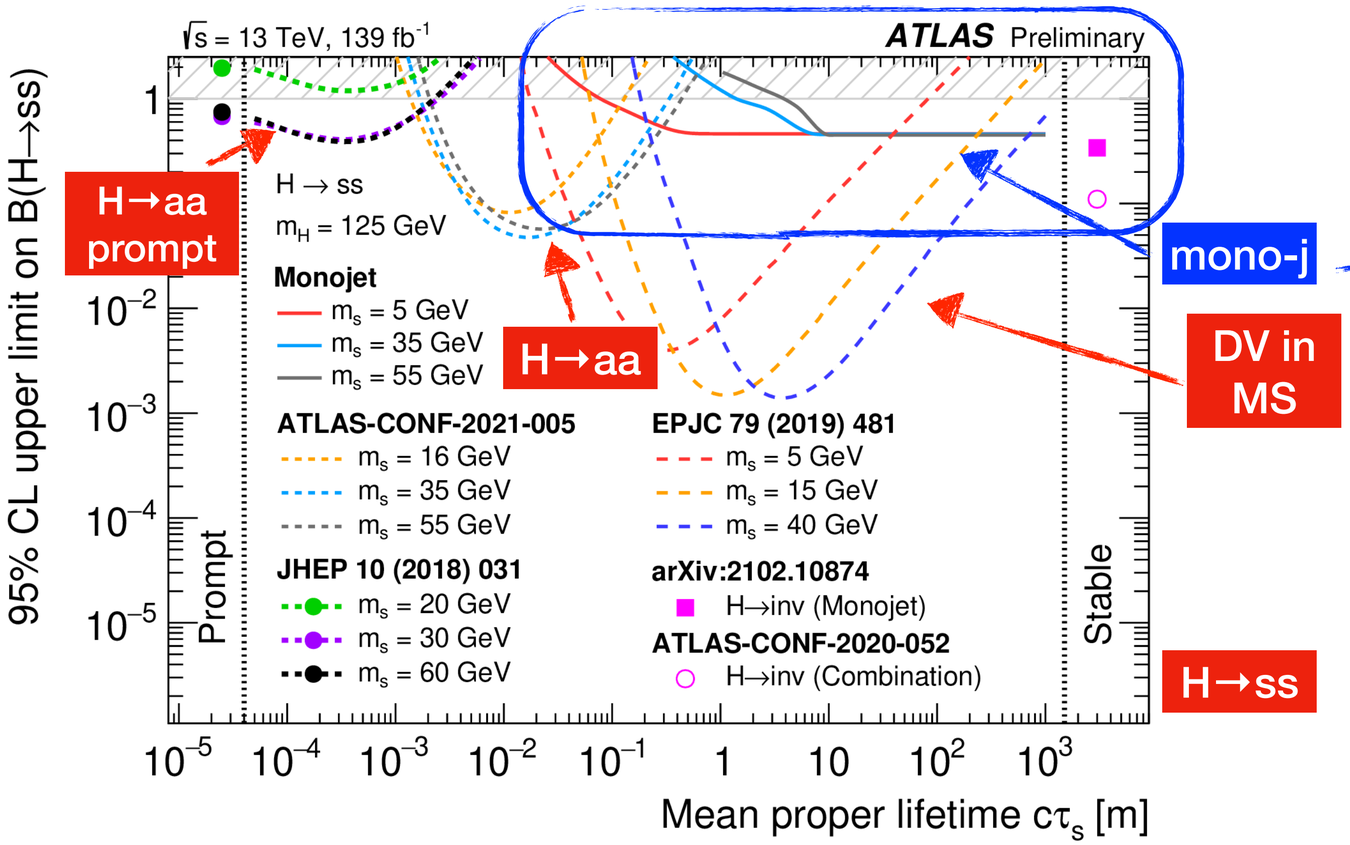


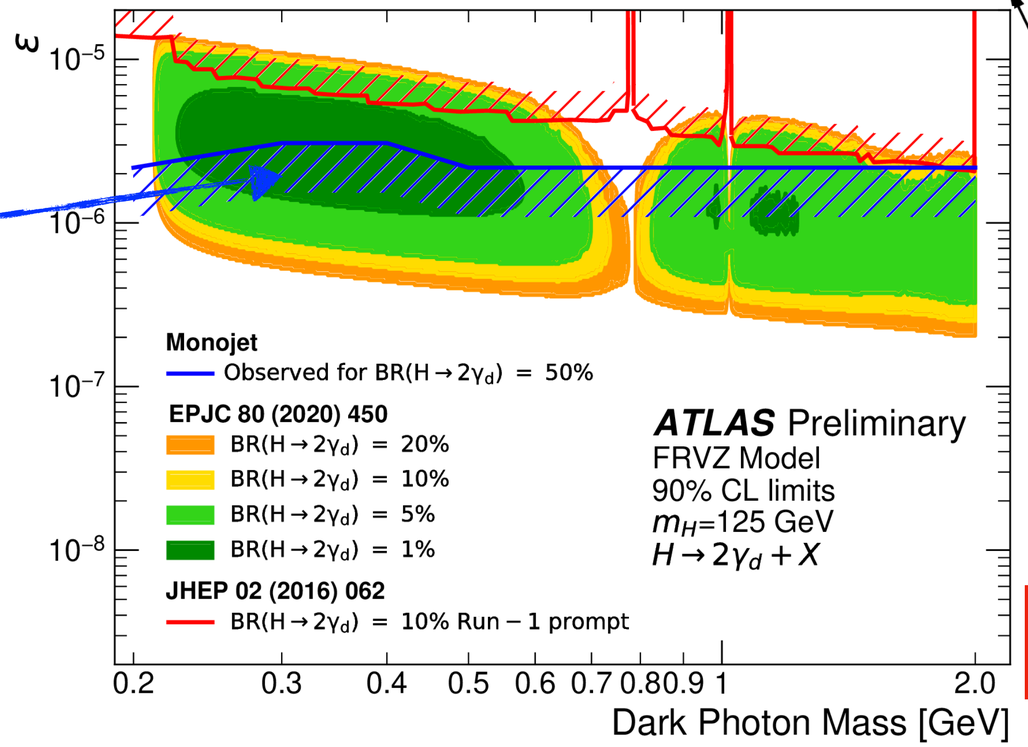
- **reinterpretation** of ATLAS mono-jet search developed for DM searches based on the RECAST framework
- allows to use BKG predictions of the original analysis to test new physics models, and to include systematic detector-related uncertainties for the signal samples
- extend LLP searches to cases in which LLPs decay outside ATLAS sensitive volume

Two NP scenarios probed:

- H→ two long-lived (pseudo)scalars → 4f
- Light Dark-photons (FRVZ model): H→dark-sector + γ_d→γ via kinetic mixing (ε)







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DISAPPEARING TRACKS

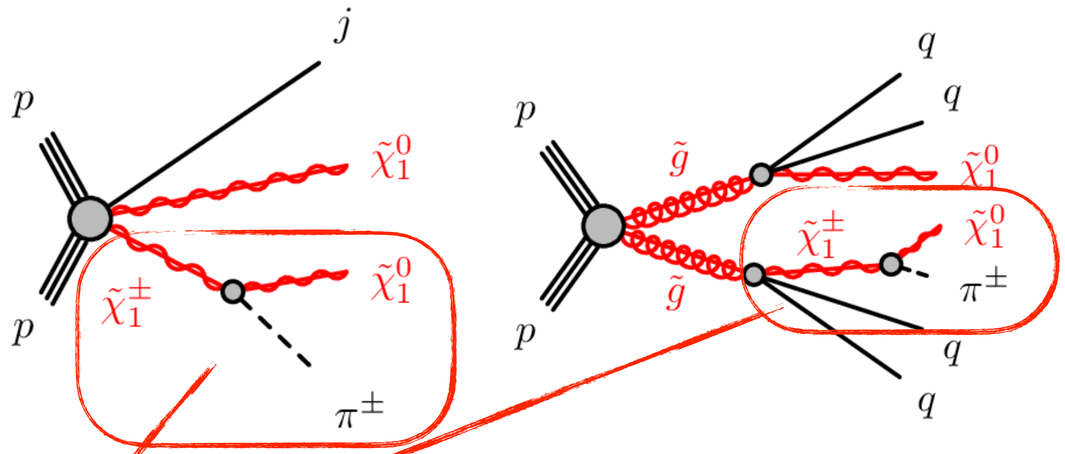
see Emily Thompson's and Paul Gessinger's talks at this conference for details

SUSY models with compressed scenarios predict lightest chargino nearly degenerate with lightest neutralino (LSP), resulting in long chargino lifetimes

Striking experimental signature: with charged pion too soft to be reconstructed (~100 MeV) that leads to chargino that "disappear"

New ATLAS search with full Run-2 dataset (136/fb @13 TeV)

probe both EW and Strong productions



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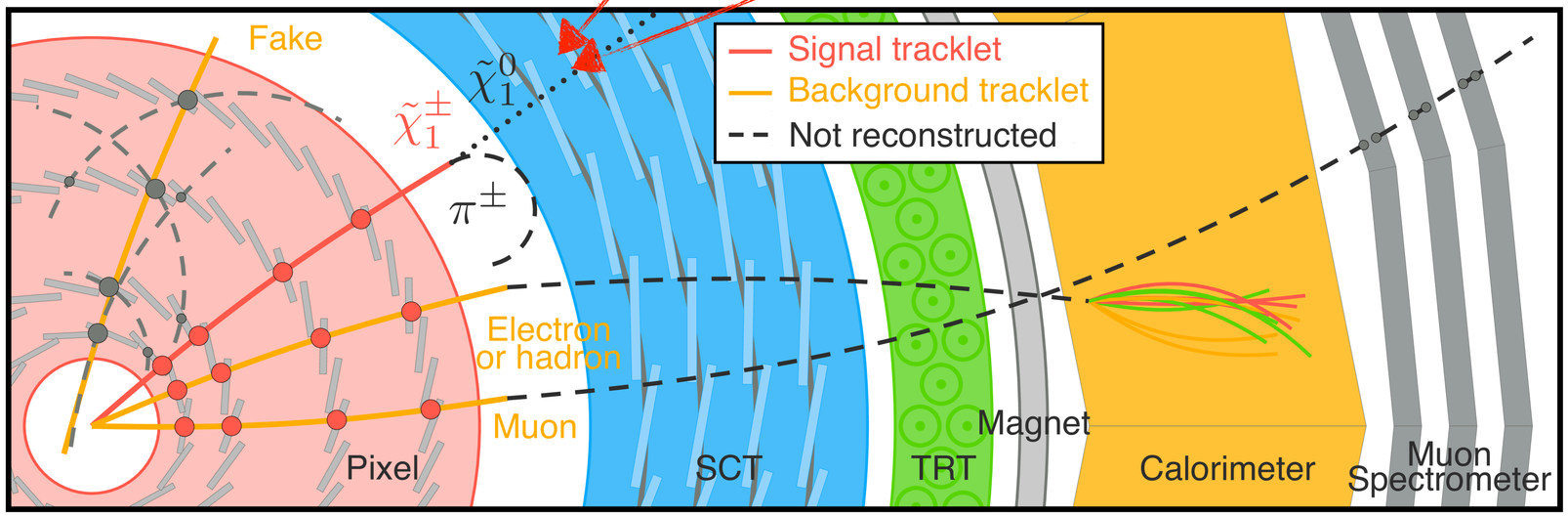


Use a dedicate trigger (MET) and modified ID tracking

Search for tracks (Pixel Tracklets) with:
- 4 inner silicon detector well measured
- veto data with activity on upstream SCT/TRT and Calorimeter activity

selection

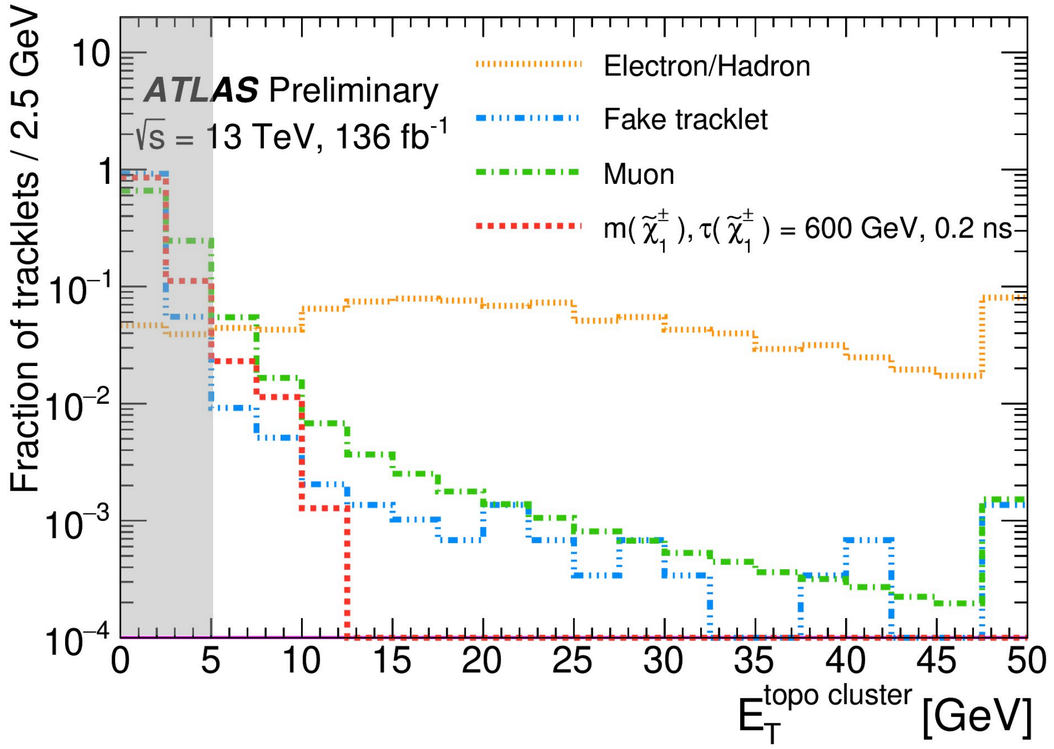
- data-driven background estimates in dedicated CR
- syst. uncertainties: bkgd O(1-7%), sig O(15%)

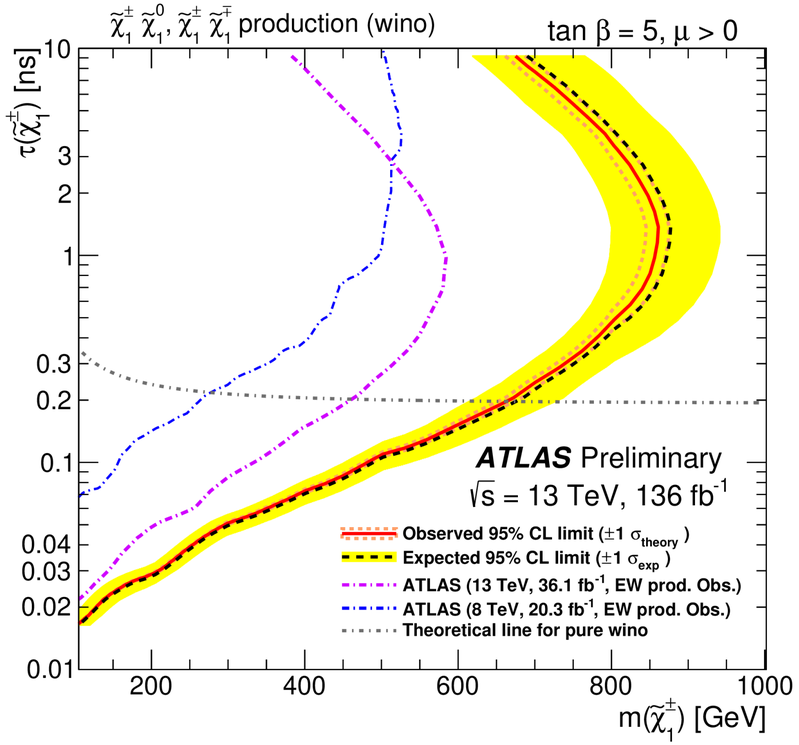
Signal region	Electroweak production	Strong production
Number of electrons and muons	0	
Number of pixel tracklets	≥ 1	
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 200	> 250
Number of jets (p_{T}> 20 GeV)	≥ 1	≥ 3
Leading jet p_{T} [GeV]	> 100	> 100
Second and third jet p_{T} [GeV]	–	> 20
$\Delta\phi_{min}^{\mathrm{jet}-E_{\mathrm{T}}^{\mathrm{miss}}}$	> 1.0	> 0.4

	Electroweak channel	Strong channel
	High-$E_{\mathrm{T}}^{\mathrm{miss}}$ SR	
Fake	2.6 ± 0.8	0.77 ± 0.33
Hadron	0.26 ± 0.13	0.024 ± 0.031
Electron	0.021 ± 0.023	0.004 ± 0.004
Muon	0.17 ± 0.06	0.049 ± 0.018
Total Expected	3.0 ± 0.7	0.84 ± 0.33
Observed	3	1

136/fb

calorimeter energy found within ΔR<0.2 of the pixel-tracklet





most stringent limits on pure winos or higgsinos

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see for details Emily Thompson's talk at this conference

STOPPED LL-PARTICLES

Meta-stable R-hadrons predicted in many BSM models: split-SUSY, Extra-Dimensions, GMSB, …

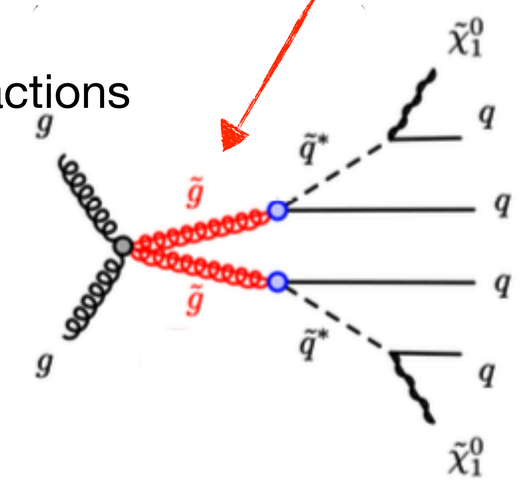
Common signature largely model independent:

- massive bound states (R-hadrons) which may stop in the detector due to material interactions and then decay a significant time later
- **benchmark model:** long-lived gluinos in Split-SUSY models

Analysis strategy:

- look for energetic jets in hadron calorimeter in "empty" bunch crossing of LHC

meta-stable for low Δm, high $m_{\tilde{q}}$



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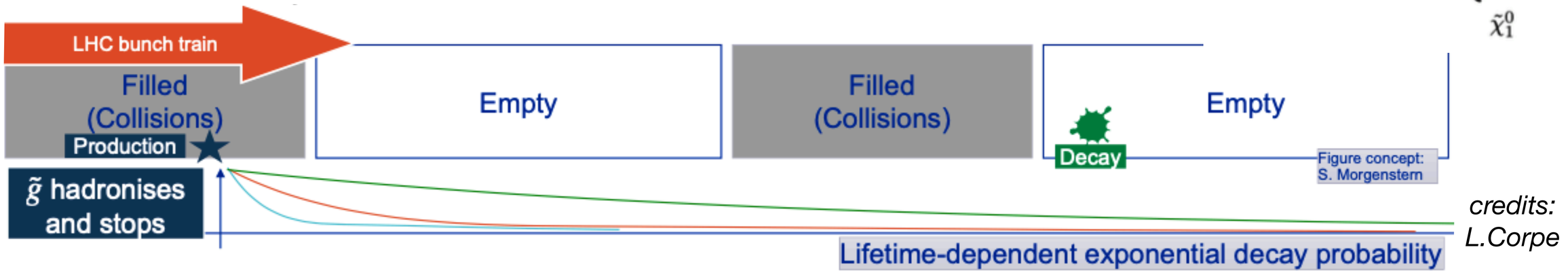
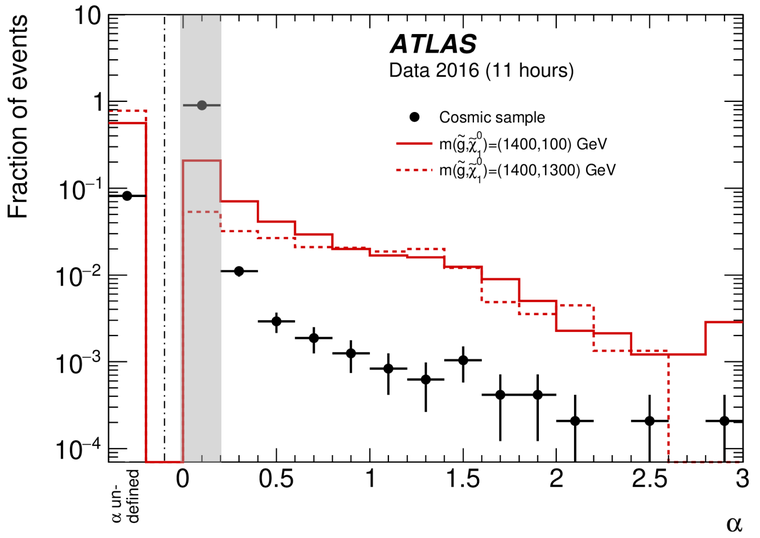


credits: L.Corpe

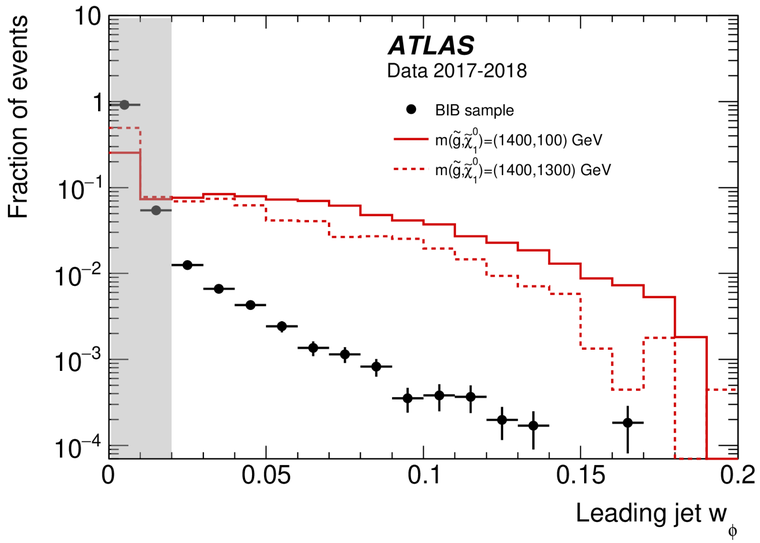
sensitivity depends on both **integrated luminosity** (signal production) and **"live time"** (time in which the trigger actively select events in empty bunch crossing

Dataset: 2017+2018
49.0/fb filled BXs, 298h empty BXs
62.1/fb filled BXs, 281h empty BXs

Data-driven BG analysis



Cosmics:
- studied in a dedicated cosmic run w/o beam in 2016
- **α:** geometrical distance between leading jet and candidate cosmic track
- veto small values

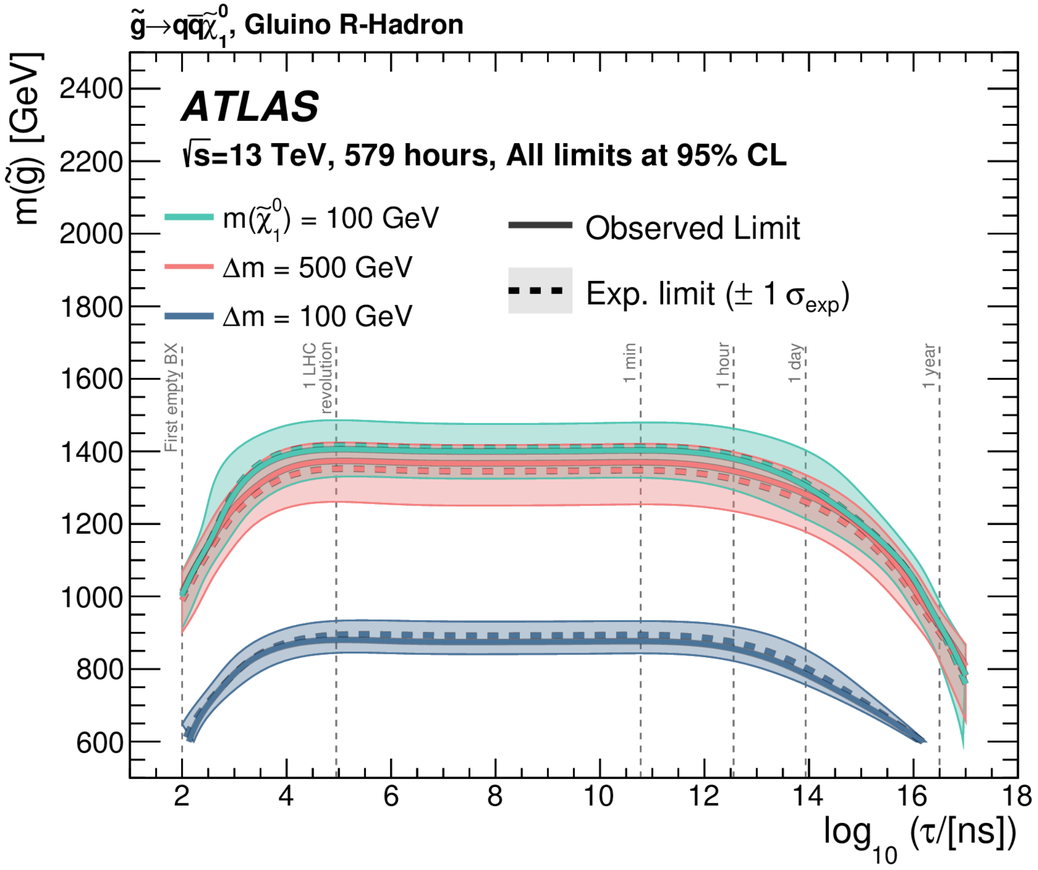


Beam Induced BG:
- studied in unpaired BXs (protons in one side only)
- **W_ϕ:** width of jet in ϕ
- veto small values

residual contamination estimated in CRs

no evidence of signals in ATLAS data

limits from leading jet p_T fit in search regions and extrapolated using calculated live-time as a function of lifetime



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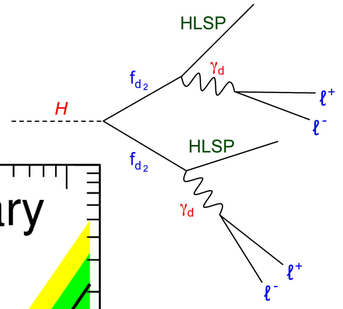
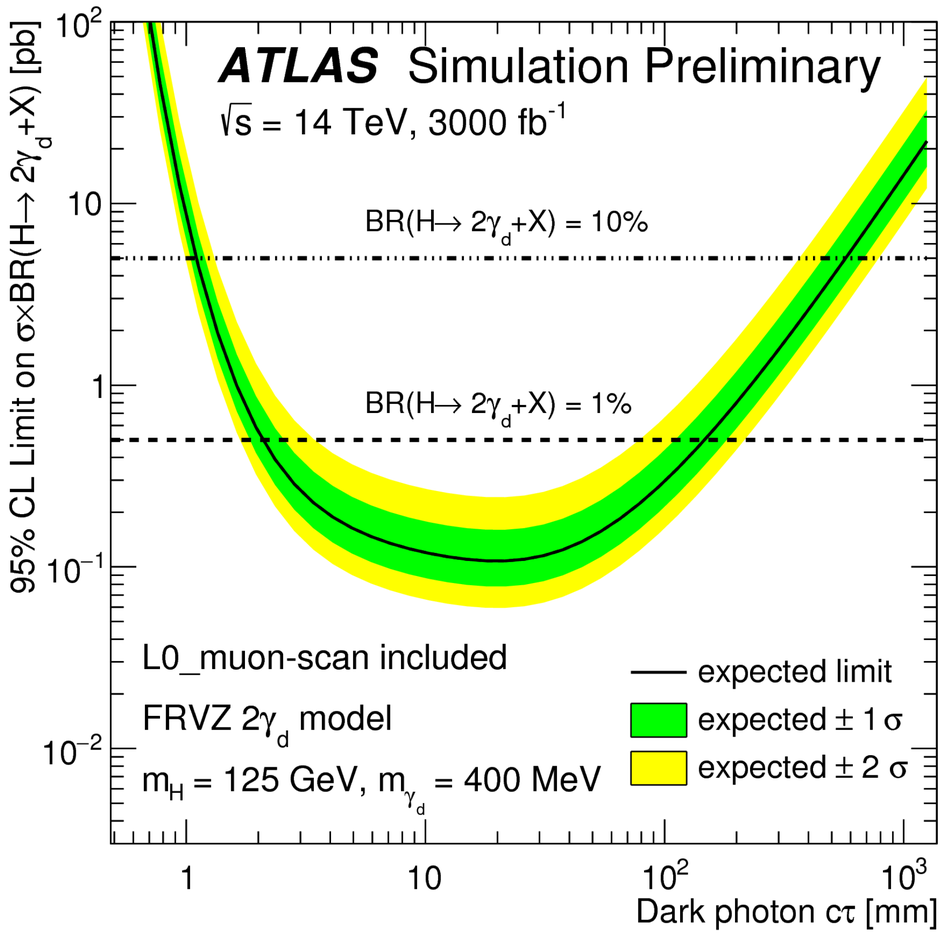
gluinos masses excluded up to 1.4 TeV for lifetimes in the 10μs to 1day range

PERSPECTIVES@HL-LHC

DISPLACED DARK-PHOTONS





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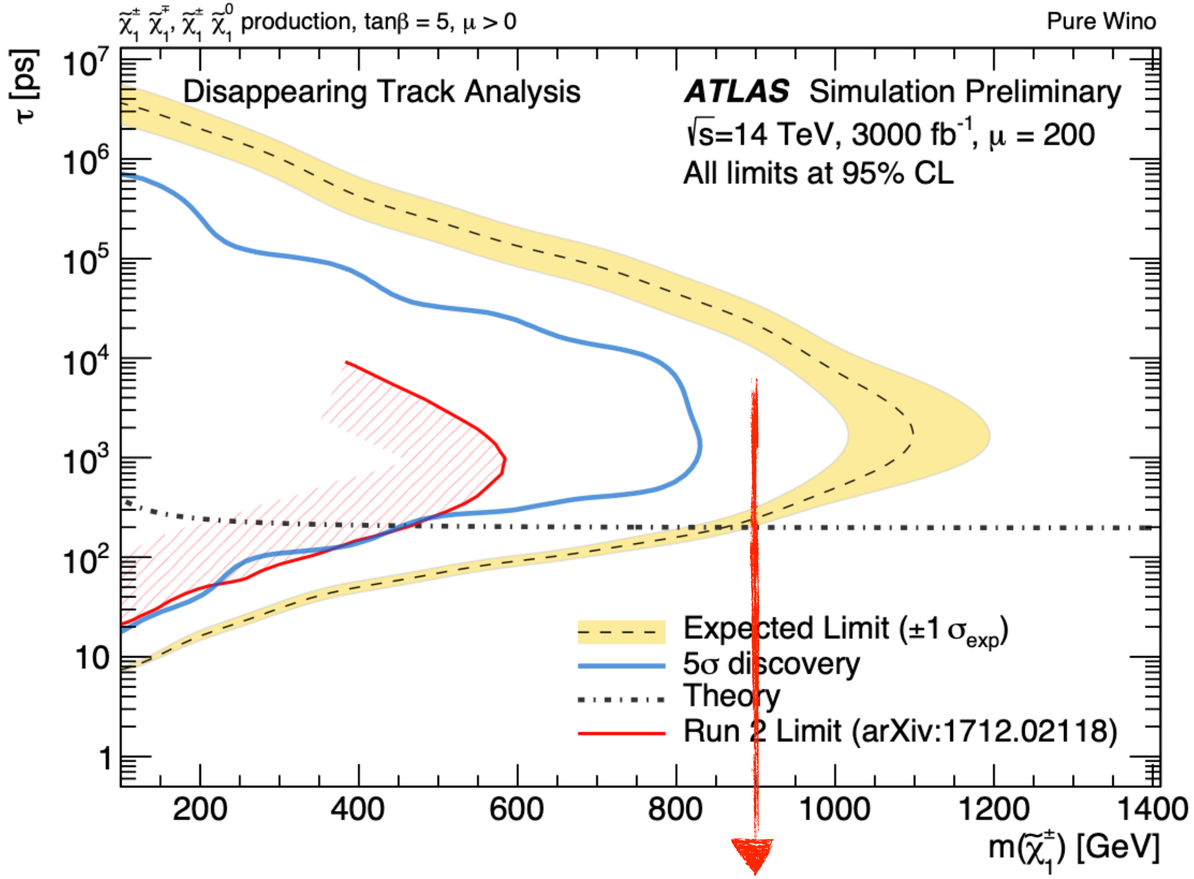
DISAPPEARING TRACKS 2018 - projection



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2018 projection conservative,
at the end of Run-2 we are already here!

SUMMARY AND CONCLUSION

- The ATLAS collaboration is pushing forward an intense research program in search of new physics effects from new exotic particles with long lifetimes producing unusual signatures
  - **several new results based of the full Run-2 data statistic**
  - **expand the exploration of possible physics BSM by checking all our blind spots**

- **No evidence of NP from several searches up to now, but …**
  - powerful constraints set on a variety of different benchmarks and simplified models
  - **more searches in complementary channels are in preparation and much more to come** in Run 3 and HL-LHC (300, 3000 fb-1), with many regions still unexplored and substantial space available for surprises & discoveries!