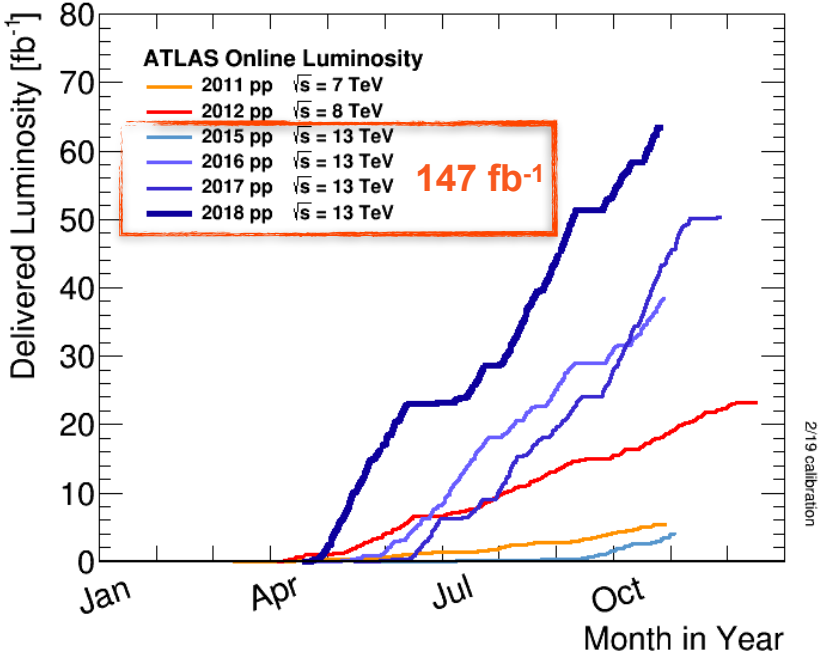
Searches for new phenomena with the ATLAS detector

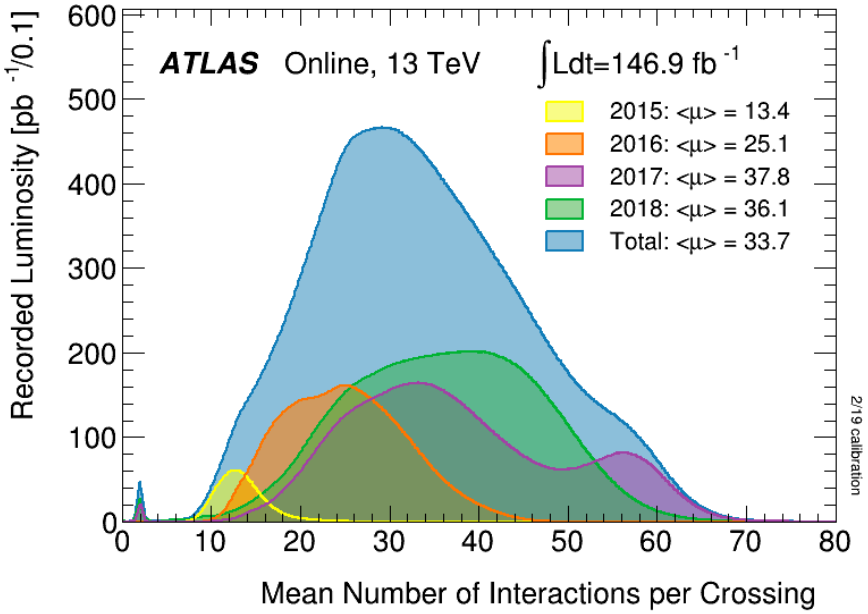
Inês Ochoa on behalf of the ATLAS Collaboration

LCWS2023 (15-19 May 2023)

Exploring LHC's Run 2 data

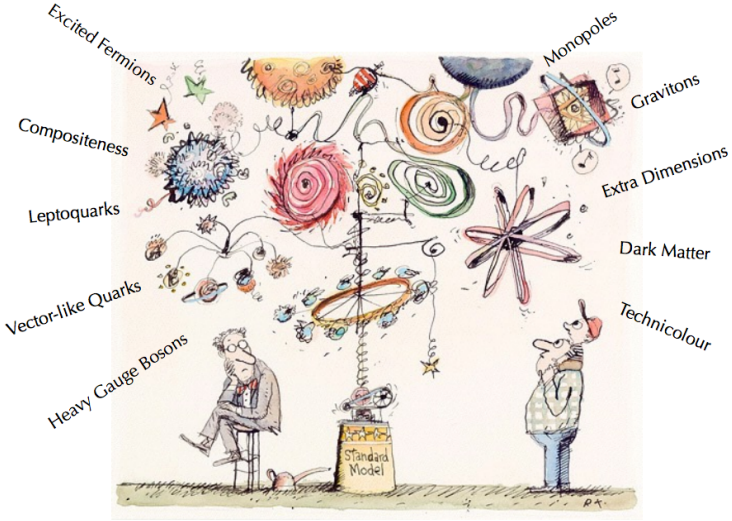
New techniques | New final states | New interpretations





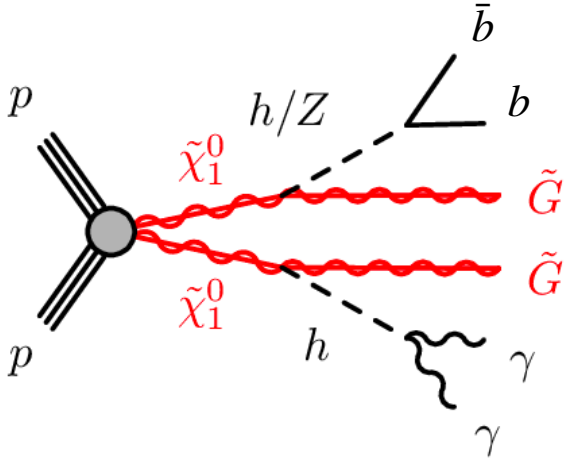
(Recent) Highlights from New Physics Searches

- Pair-produced **Higgsino** search
  - ATLAS-CONF-2023-009
- Search for **top-philic resonances**
  - arXiv:2304.01678
  - arXiv:2304.14247
- **Axion-like particles** with forward proton tagging
  - arXiv:2304.10953
- **Periodic signals** in clockwork / linear dilation models
  - ATLAS-CONF-2023-010



Higgsinos

ATLAS-CONF-2023-009



New channel:

- ✓ Excellent $\gamma\gamma$ mass resolution
- ✓ Large branching fraction $h \to b\bar{b}$

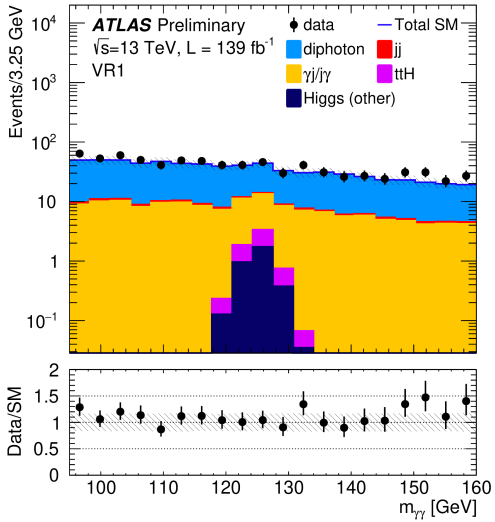
Gauge-mediated supersymmetric models

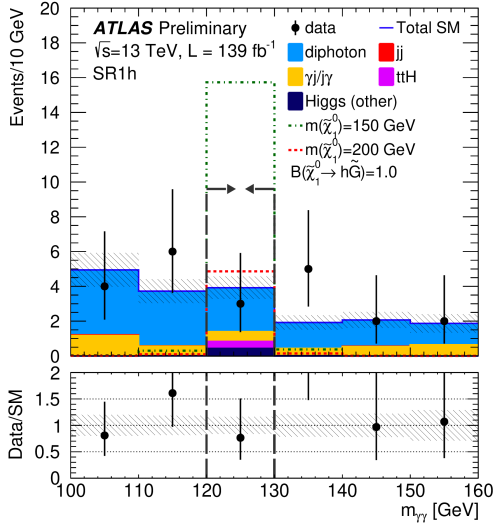
$\tilde{\chi}$ decays to a light gravitino $\tilde{G}$ via a Higgs or Z boson

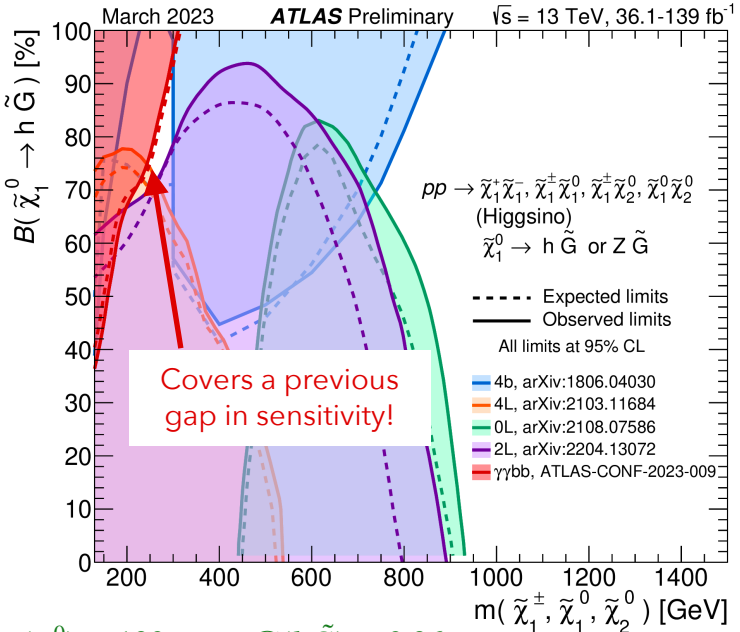
$$\mathcal{B}(\tilde{\chi}_1^0 \to h\tilde{G}) + \mathcal{B}(\tilde{\chi}_1^0 \to Z\tilde{G}) = 100\,\%$$

Pair-produced Higgsinos in $b\bar{b}\gamma\gamma$

- Three signal regions cutting on E_T^{miss} and $m_{b\bar{b}}$: lower (higher) E_T^{miss} targets low (high) $m(\tilde{\chi}_1^0)$
  - Control regions from $m_{\gamma\gamma}$ sidebands, photon identification and isolation criteria.
  - Validation regions from $m_{b\bar{b}}$ sidebands.

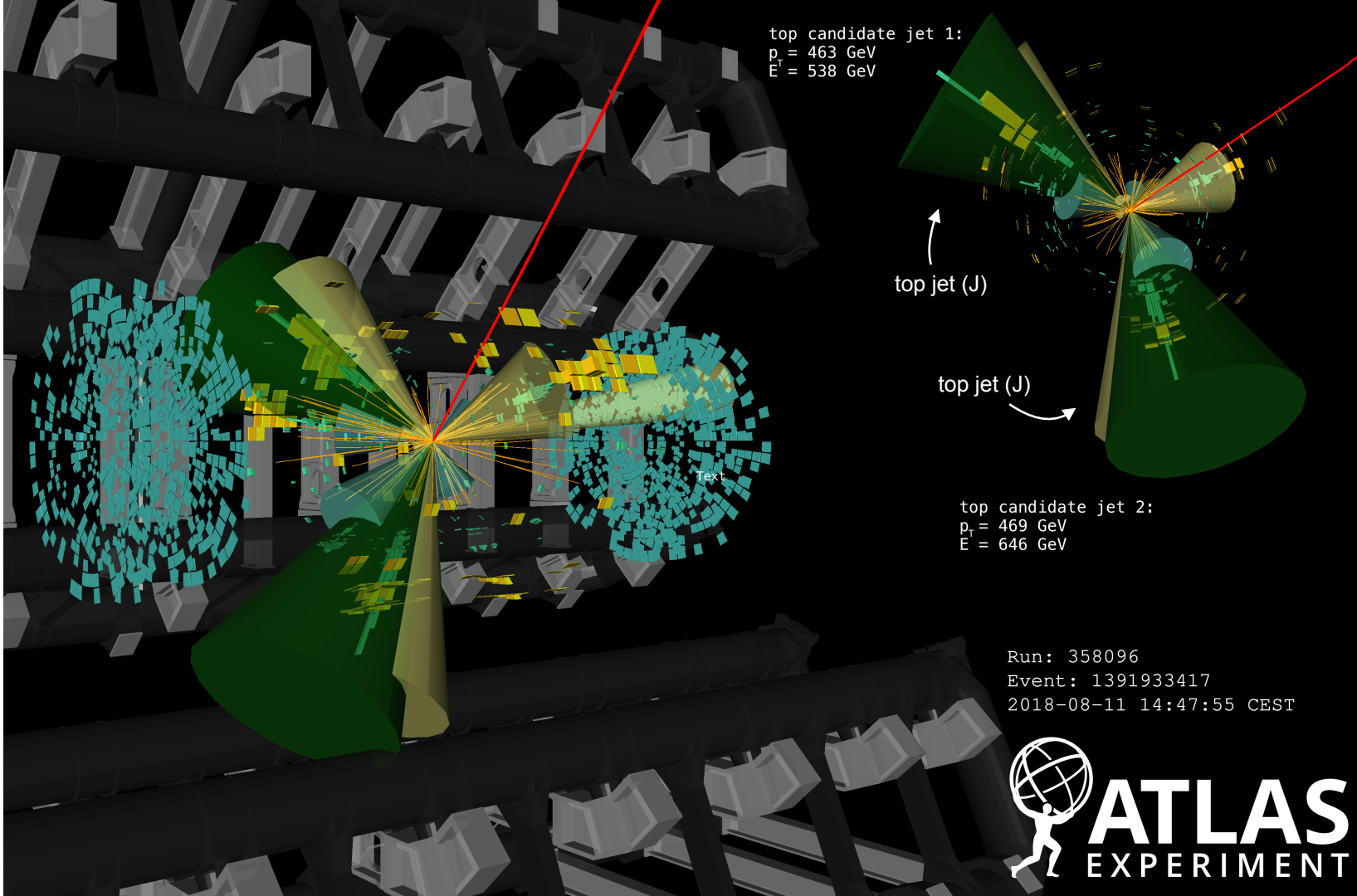






95% CL exclusion up to $m(\tilde{\chi}_1^0) = 320$ GeV, $\mathcal{B}(h\tilde{G}) = 1$ and $m(\tilde{\chi}_1^0) = 130$ GeV, $\mathcal{B}(h\tilde{G}) = 0.36$

Top-philic resonances

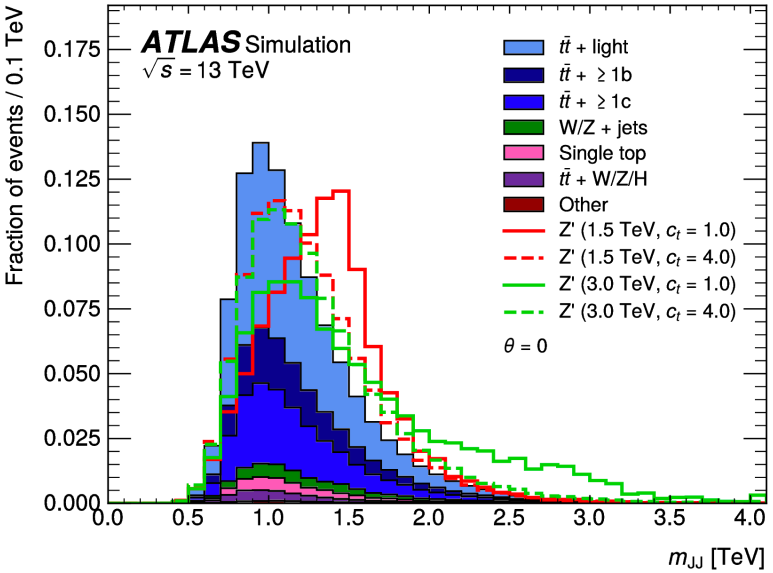


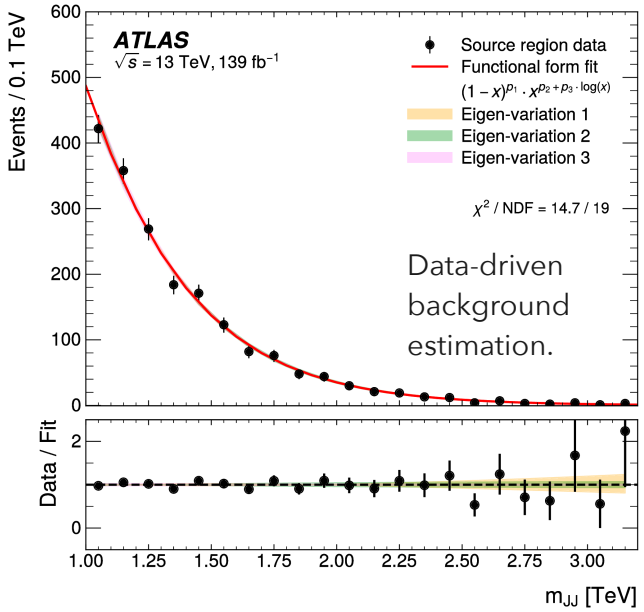
Top-philic heavy resonances

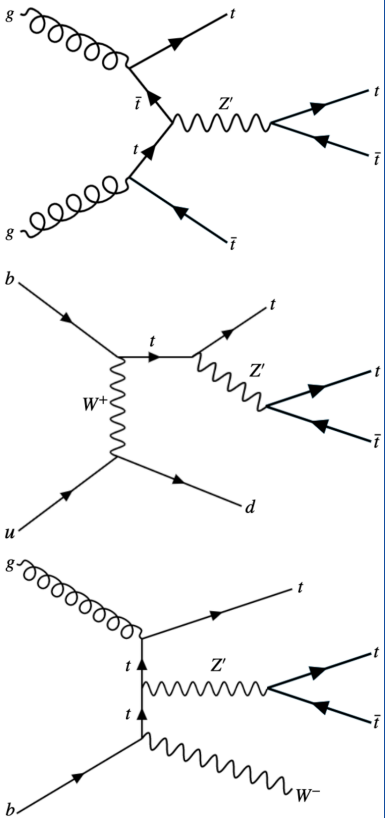
Following first observation of SM four-top production by ATLAS and CMS!

arXiv:2304.01678

- New heavy vector boson Z' that couples predominantly to top-quark.
  - Boosted hadronic tops from Z' decay reconstructed with large-radius jets (J).
  - Broad signal m_{JJ} distribution (invariant mass of top-pair system).
  - Dominant systematic from NLO top-pair modeling.



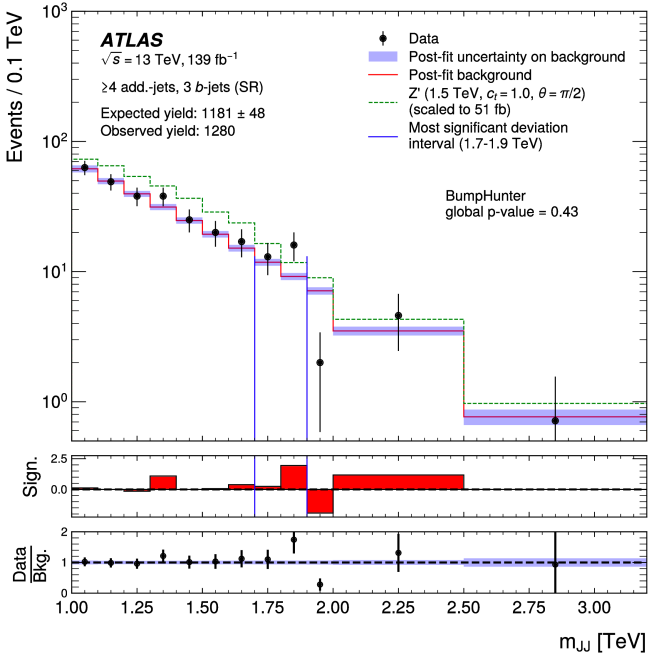


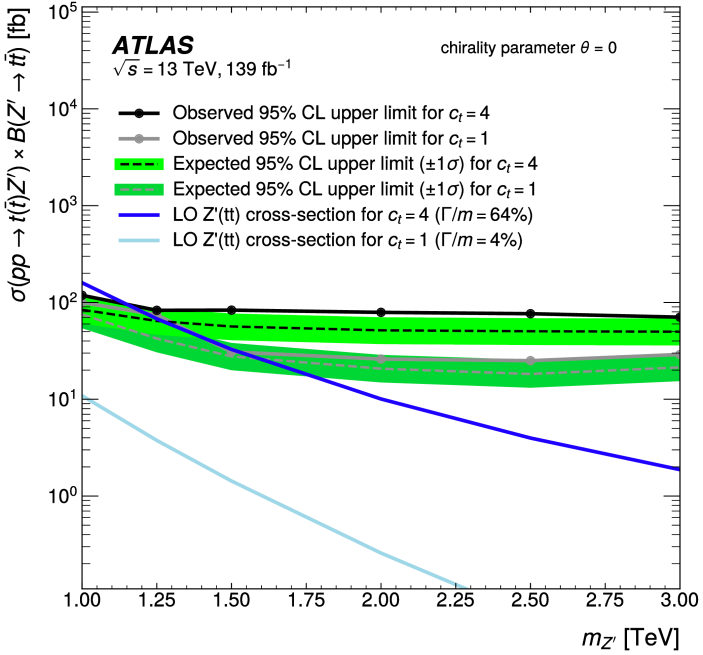


arXiv:2304.01678

Top-philic heavy resonances

- Minimal model-dependence search using *BumpHunter* to fit m_{JJ}: no significant deviations observed.
- CLs limits considering simplified Z' signal model.



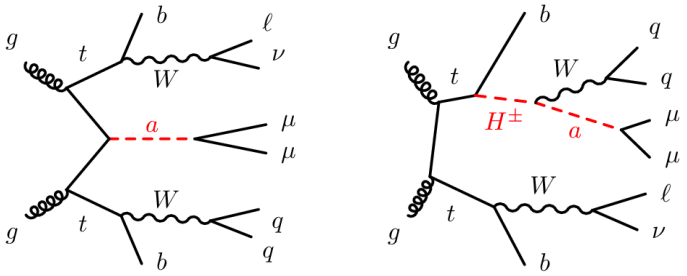


Observed (expected) limits range from 21 (14) fb to 119 (86) fb depending on the choice of model parameters

Top-philic light resonances

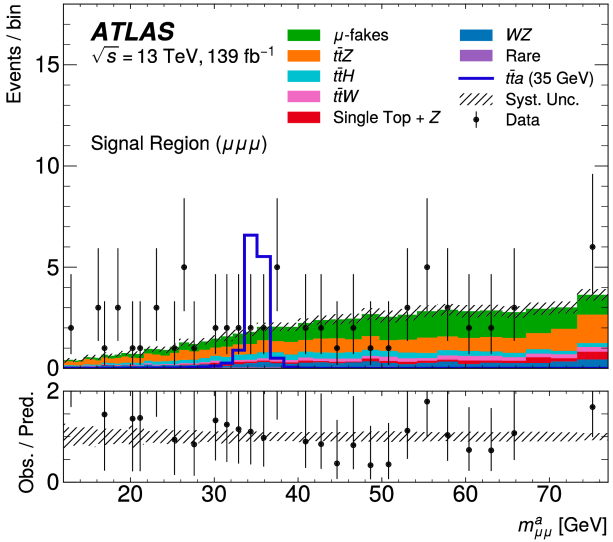
$a \to \mu\mu$ search

arXiv:2304.14247

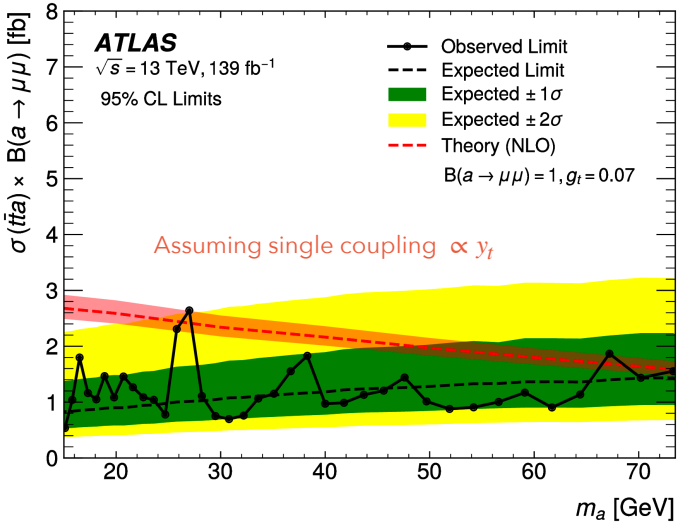


- Final state signature with three leptons $e\mu\mu$ or $\mu\mu\mu$ and jets.
- $12\ \text{GeV} < m_{\mu\mu} < 77\ \text{GeV}$ (for rejecting Υ and Z decays).
- Event categorisation by #muons, #jets, #b-jets and $m_{\mu\mu}$.

Excellent mass resolution from muon-pair.

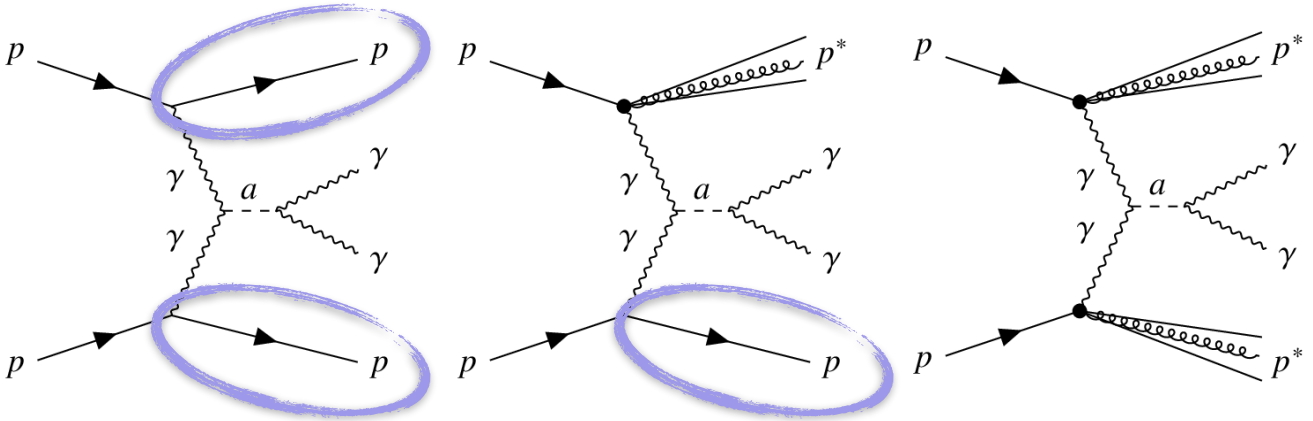


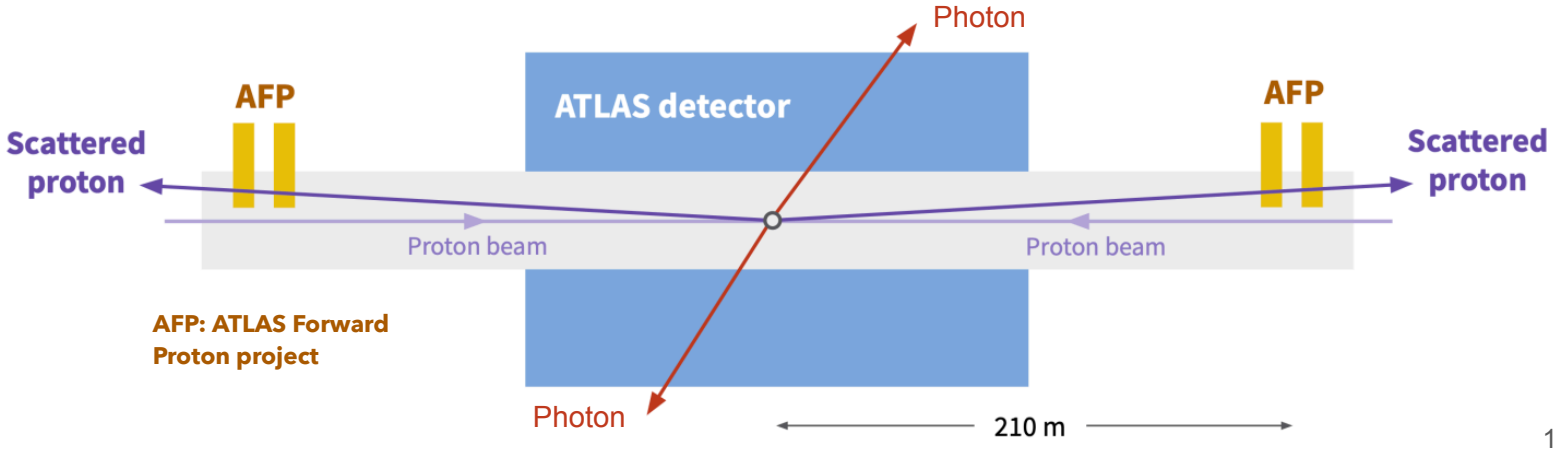
Smallest p-value is 0.008 at $m_a = 27\ \text{GeV}$



Axion-like particles

arXiv:2304.10953

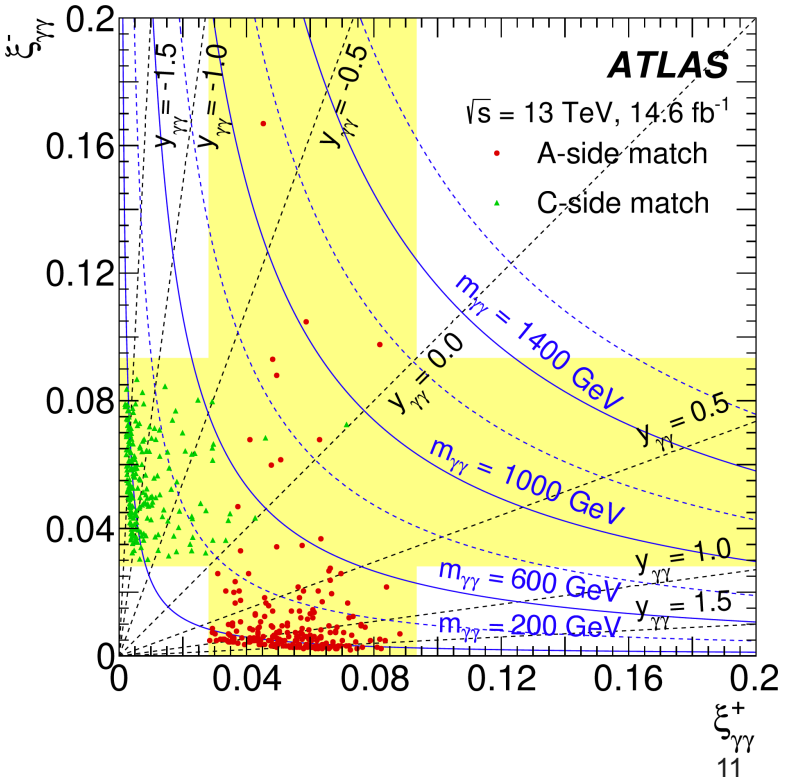




arXiv:2304.10953

Axion-like-particles with the ATLAS Forward Proton (AFP) detector

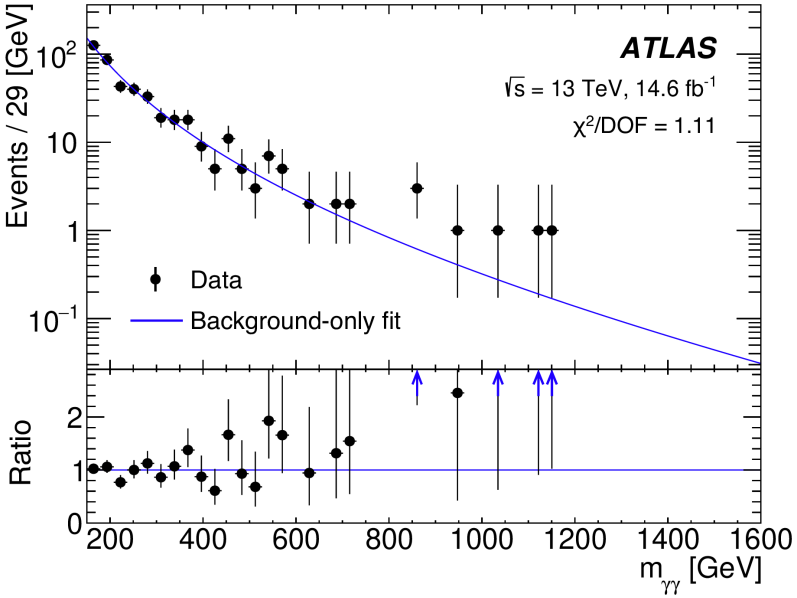
- Fractional energy loss of a scattered proton can be inferred from AFP tracks and beam optics:
  $\xi_{\mathrm{AFP}} = 1 - E_{scattered}/E_{beam}$
- Same quantity can be calculated independently from central photons: $\xi^{\pm}_{\gamma\gamma} = (m_{\gamma\gamma}/\sqrt{s})e^{\pm y_{\gamma\gamma}}$
- Acceptance for mass range 150 - 1600 GeV.
- Exclusive and single-dissociative processes account for 60% (40%) and 40% (60%) of selected signal in range $m_{\gamma\gamma} < 500$ $(m_{\gamma\gamma} \geq 500)$ GeV.

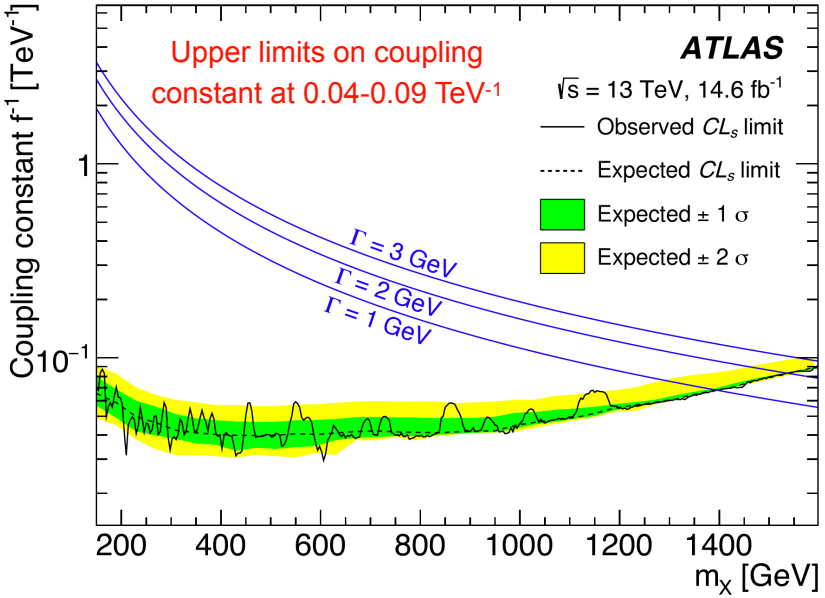


Axion-like-particles with the ATLAS Forward Proton (AFP) detector

arXiv:2304.10953

- A total of 441 events are observed in the target mass range (no event passed matching for AFP stations on both sides of ATLAS).
  - Most significant excess at 454 GeV (local significance of 2.51σ).

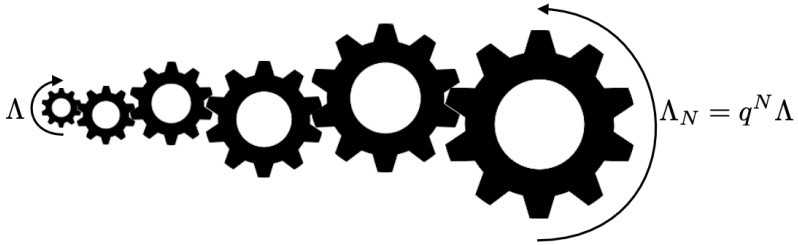




Periodic signals

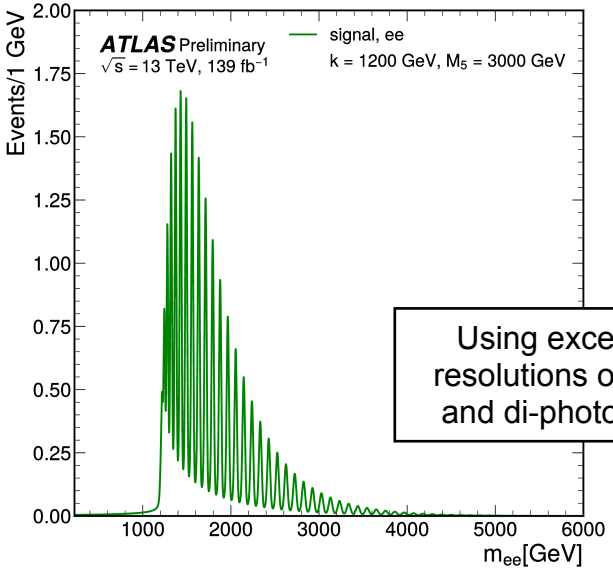
JHEP02(2017)036

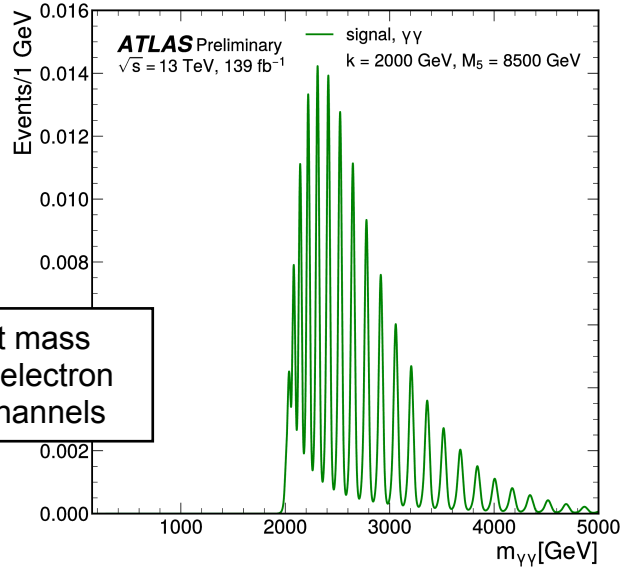
ATLAS-CONF-2023-010



Clockwork / Linear Dilaton (CW/LD) scenario

Towers of gravitons with small splittings in mass and negligible intrinsic widths



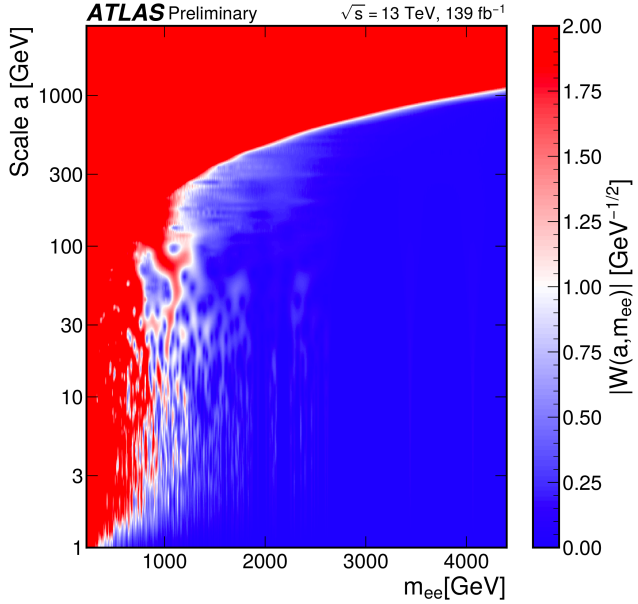


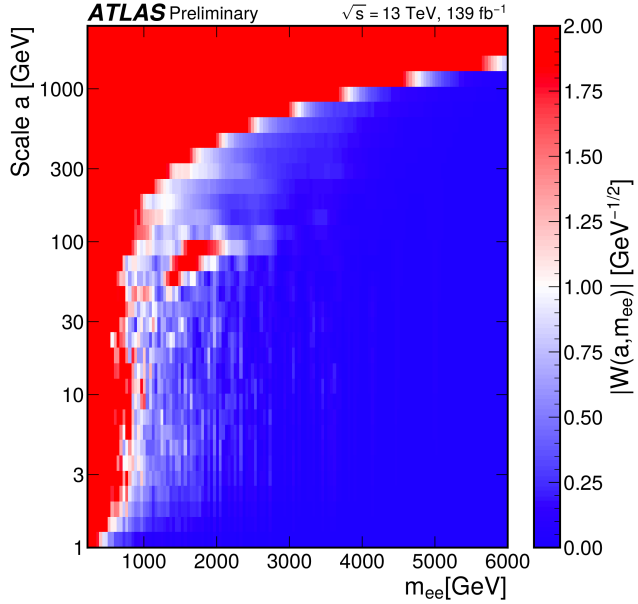
Using excellent mass resolutions of di-electron and di-photon channels

Periodic signals

- **Strategy**: continuous wavelet transformations to obtain mass vs frequency maps
  - Classifier NN to search for CW/LD models and auto-encoder for generic periodic excesses

Signal region data



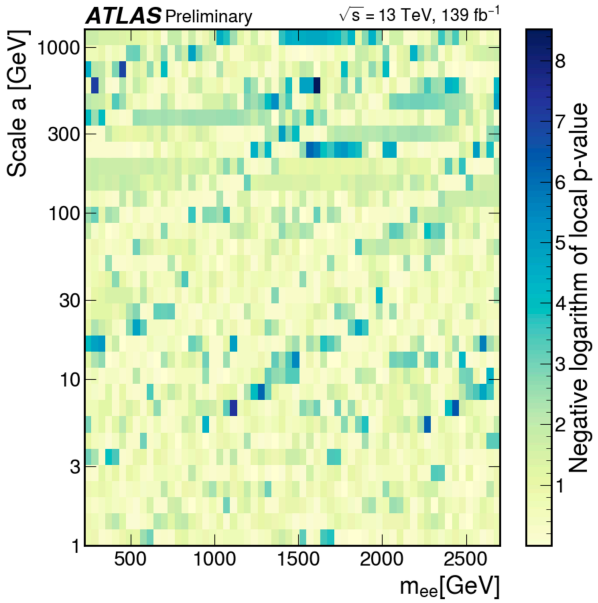


Injected signal at k=1200 GeV, M5=3000 GeV (coarser binning)

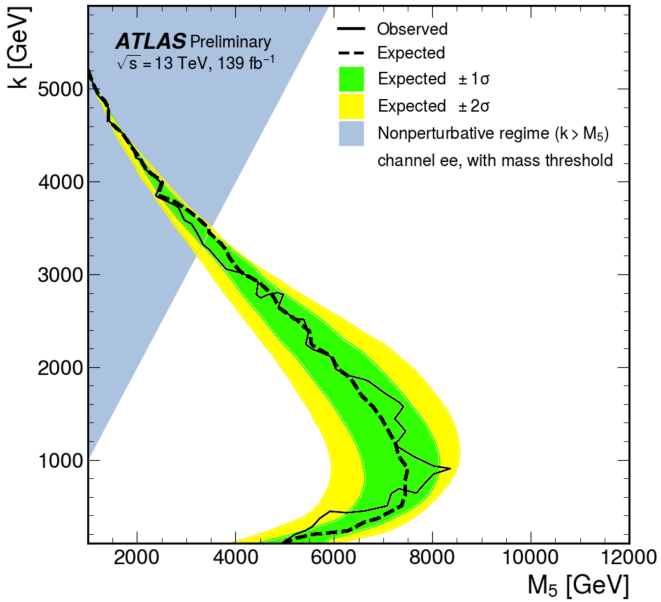
Periodic signals

- **Strategy**: continuous wavelet transformations to obtain mass vs frequency maps
  - Classifier NN to search for CW/LD models and auto-encoder for generic periodic excesses

-log(local p-values) in generic search

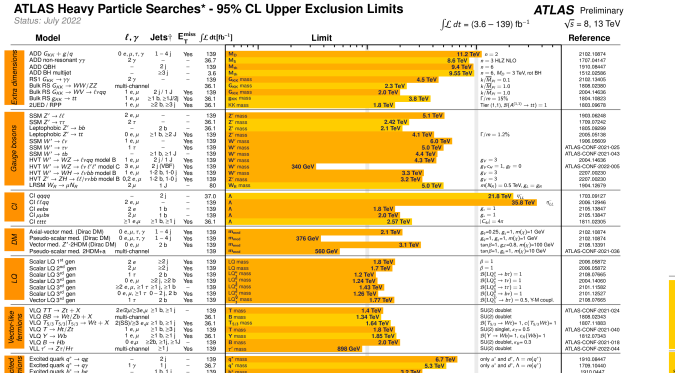


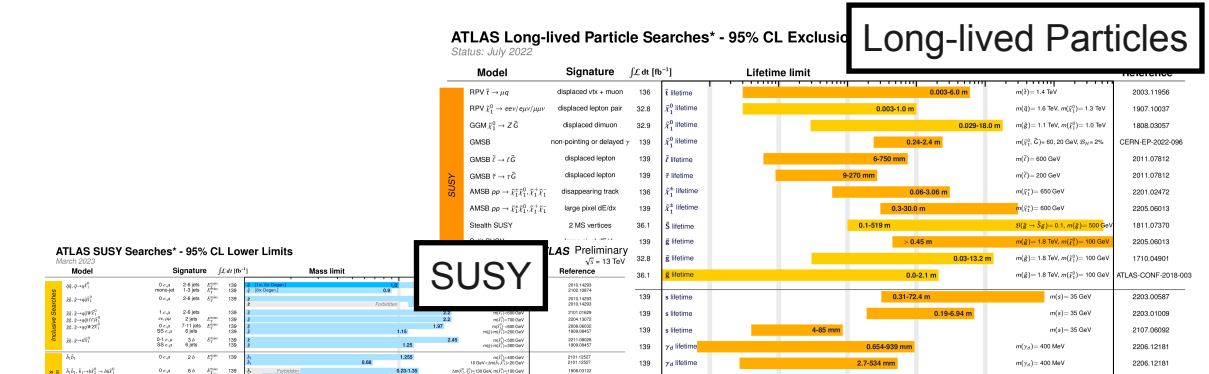
Exp. and obs. exclusion limits for CW model in k-M_5 space

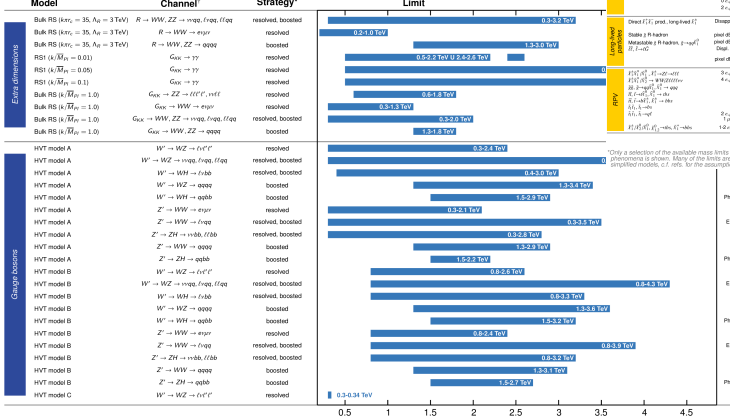


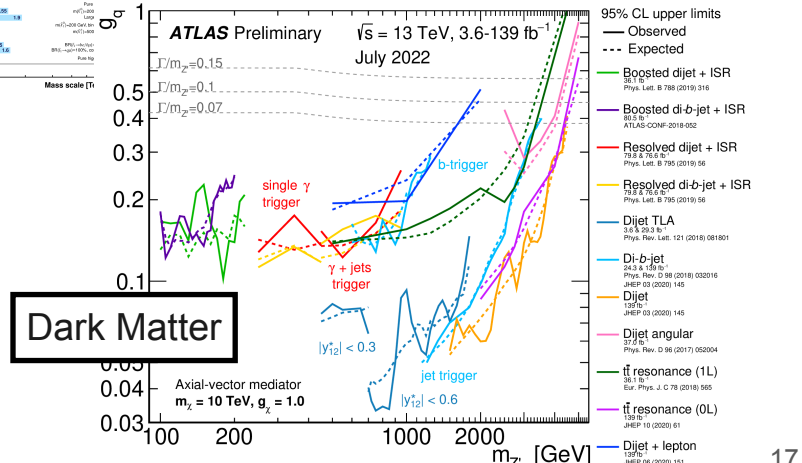
- No significant deviations are observed in data.
- Limits are set for the parameters in the CW/LD model (gravity scale M_5 and turn-on mass *k*)

Summary









Long-lived Particles

SUSY

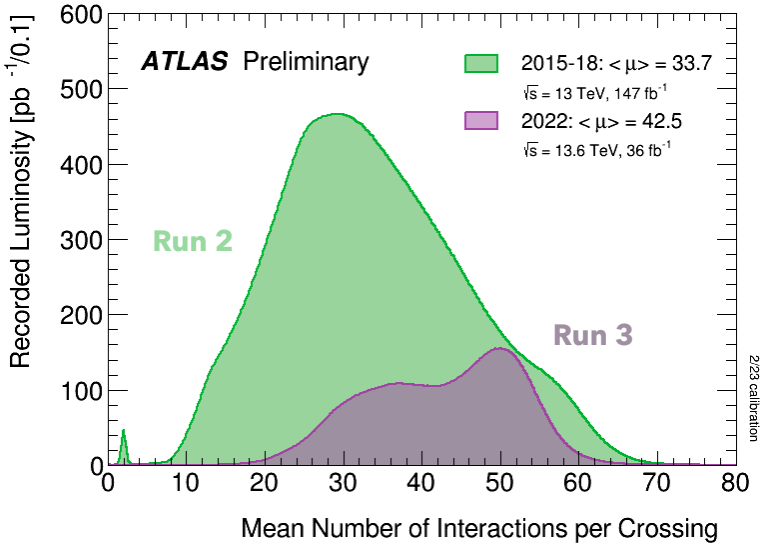
Heavy and light resonances

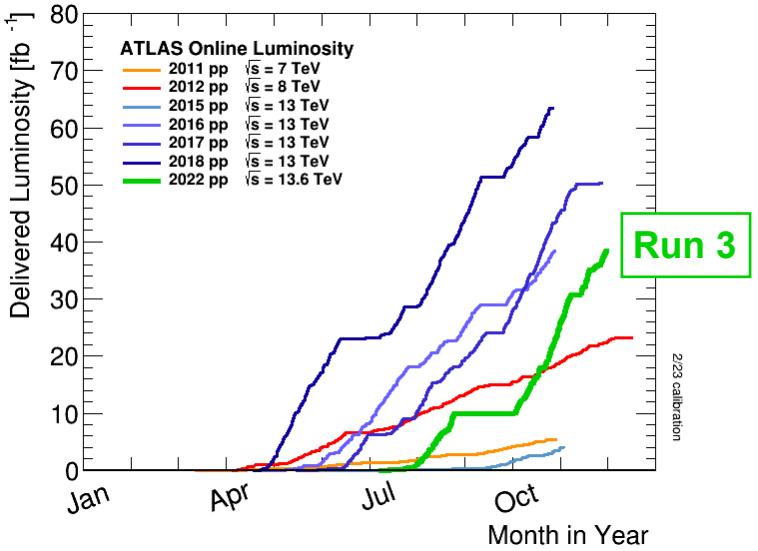
Dark Matter

https://atlaspo.cern.ch/public/summary_plots/

Summary

- A **vast program of searches for new physics** is taking place in ATLAS.
- We continue to develop new analysis ideas and methods to **fully explore the Run 2 data**, as we prepare to collect twice as much data during Run 3 at √s=13.6 TeV.



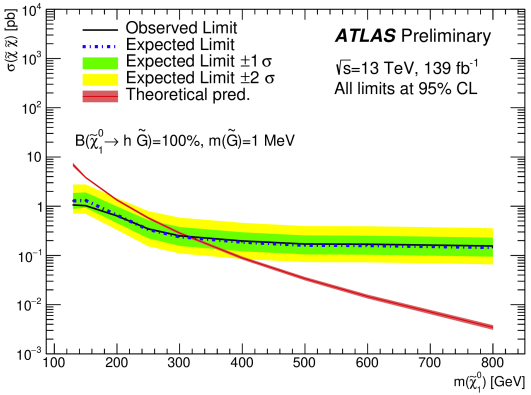


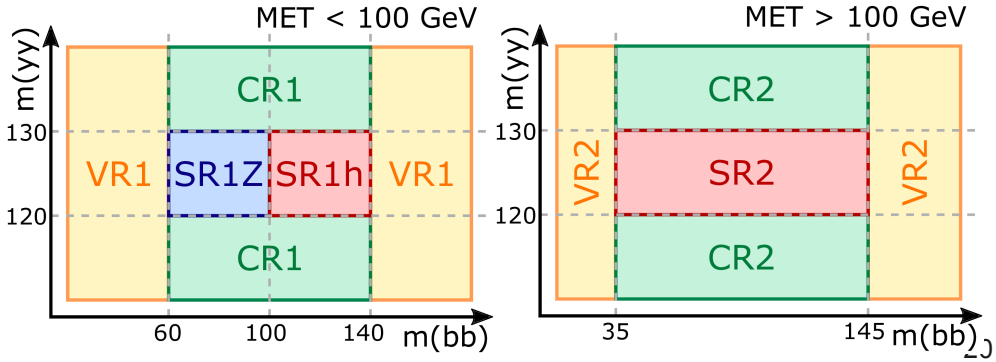
Thank you for your attention!

Backup

Pair-produced Higgsinos in $b\bar{b}\gamma\gamma$

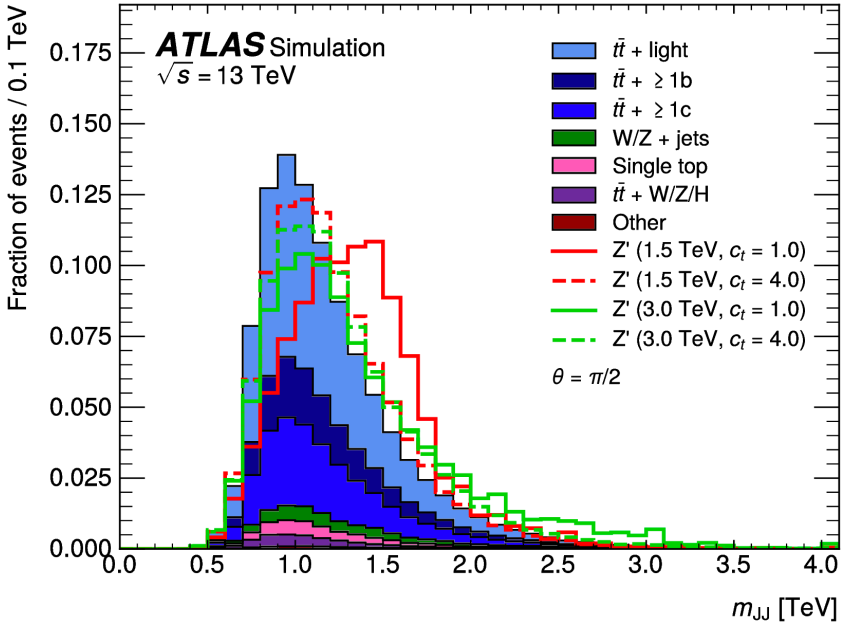
Channel	SR1h	SR1Z	SR2
Observed events	3	5	2
Total SM events	3.9 ± 0.6	6.4 ± 1.0	1.7 ± 0.7
$\gamma\gamma$ events	2.5 ± 0.5	3.7 ± 0.7	0.88 ± 0.26
γj events	0.47 ± 0.28	0.8 ± 0.5	0.24 ± 0.15
$j\gamma$ events	0.088 ± 0.014	0.27 ± 0.04	0.00 ± 0.6
jj events	< 0.01	0.07 ± 0.05	$0.22^{+0.24}_{-0.22}$
ttH events	0.41 ± 0.04	0.297 ± 0.025	0.27 ± 0.06
Higgs (other)	0.40 ± 0.08	1.22 ± 0.26	0.064 ± 0.011
$\langle \epsilon\sigma \rangle^{95}_{\text{obs}}$ [fb]	0.03	0.04	0.03
S^{95}_{obs}	4.8	5.5	4.8
S^{95}_{exp}	$5.4^{+2.2}_{-1.5}$	$6.7^{+2.6}_{-1.8}$	$4.6^{+1.6}_{-0.8}$
$p(s = 0)$	0.50	0.50	0.43

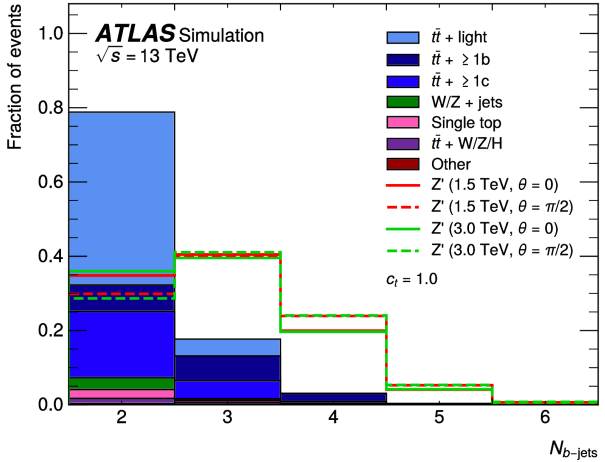


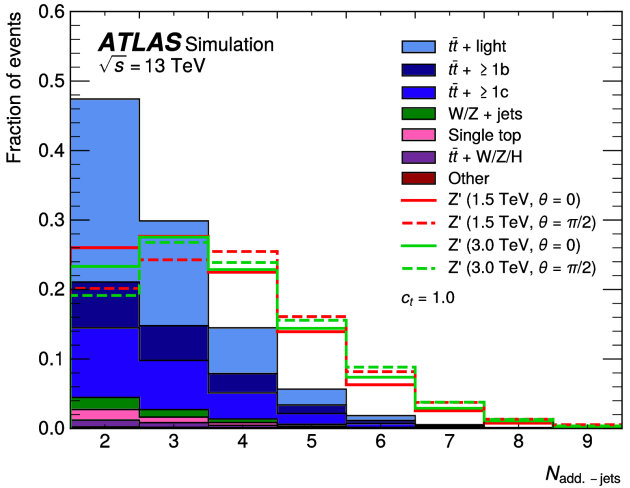


arXiv:2304.01678

Top-philic heavy resonances



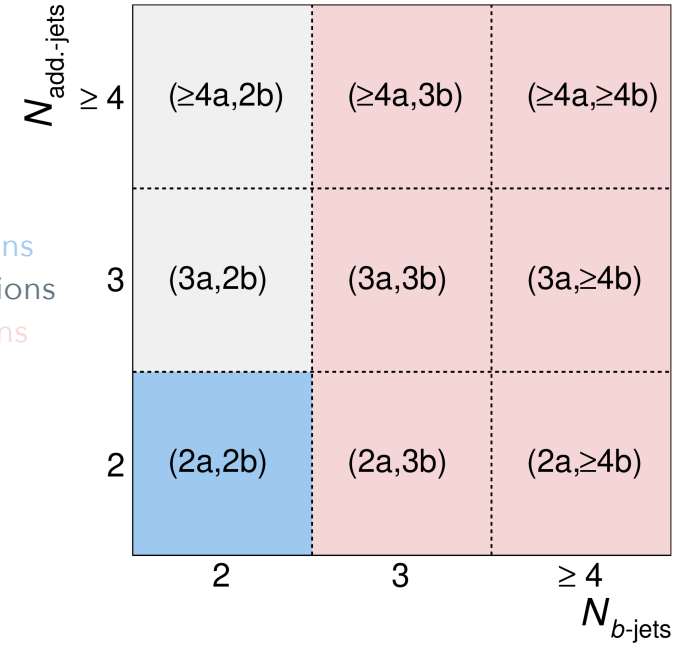




arXiv:2304.01678

Top-philic heavy resonances

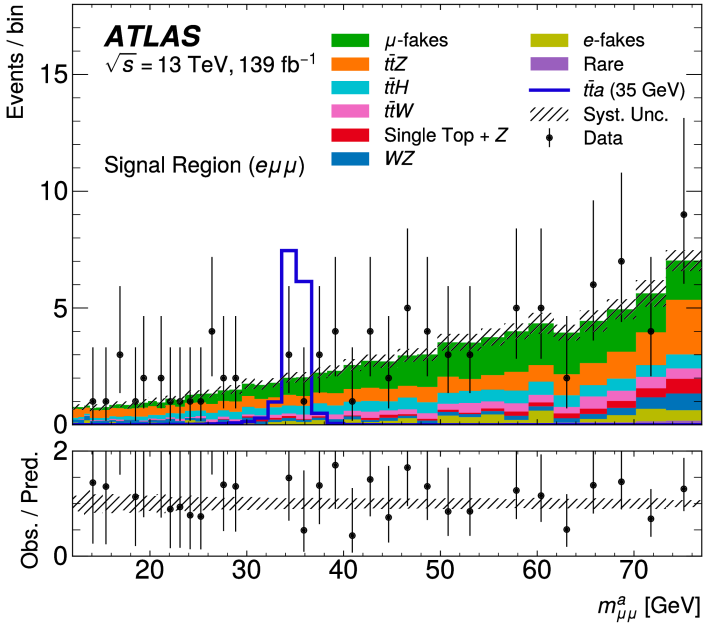
Source regions
Validation regions
Signal regions



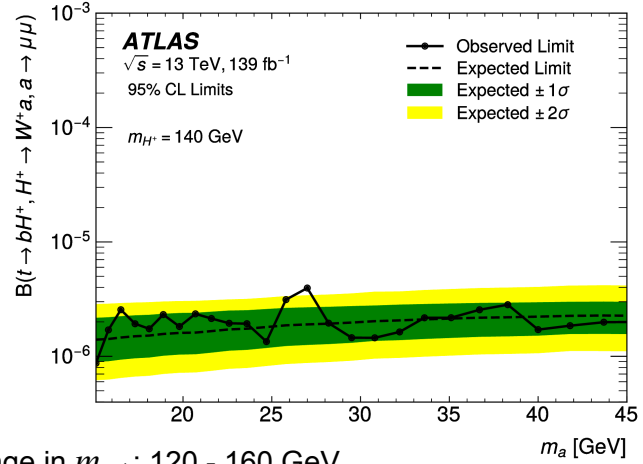
Uncertainty categories	Relative contribution to the total uncertainty [%]	
	1.5 TeV $c_t = 1$	3 TeV $c_t = 4$
$t\bar{t}$+jets modelling	78	87
Jet energy scale and resolution	40	46
Functional fit and extrapolation	41	23
Signal bias	35	7.3
Statistical uncertainty on signal MC	26	19
Single-top-quark modelling	11	8.9
Flavour tagging	9.4	9.8
Minor backgrounds modelling	6.9	5.3
Other uncertainties	1.5	2.1
Luminosity	0.2	2.0
Total systematic uncertainty	95	96
Statistical uncertainty	32	29

arXiv:2304.14247

Top-philic light resonances



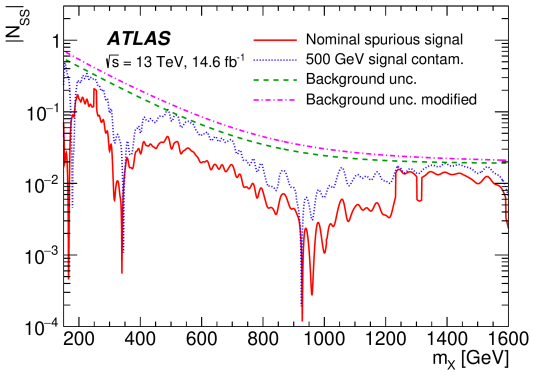
	Signal Regions		on-Z Control Region		$t\bar{t}$ Control Region
Channel	$e\mu\mu$	$\mu\mu\mu$	$e\mu\mu$	$\mu\mu\mu$	$e\mu\mu$
Binning	$m^a_{\mu\mu}$	$m^a_{\mu\mu}$	n_{jets}, $n_{b\text{-jets}}$	n_{jets}, $n_{b\text{-jets}}$	$p_{\text{T}}^{\mu,\text{fake}}$
$n_{\text{electrons}}$	1	0	1	0	1
n_{muons}	2	3	2	3	2
$m_{\mu\mu}$ [GeV]	$12 < m^a_{\mu\mu} < 77$	$12 < m^a_{\mu\mu} < 77$ and $m^{\text{other}}_{\mu\mu} < 77$ or > 107	$77 < m^a_{\mu\mu} < 107$	$77 < m^a_{\mu\mu} < 107$ or $77 < m^{\text{other}}_{\mu\mu} < 107$	$12 < m^a_{\mu\mu} < 77$
	-		-		-
n_{jets}	≥ 3				1 or 2
$n_{b\text{-jets}}$	≥ 1				1

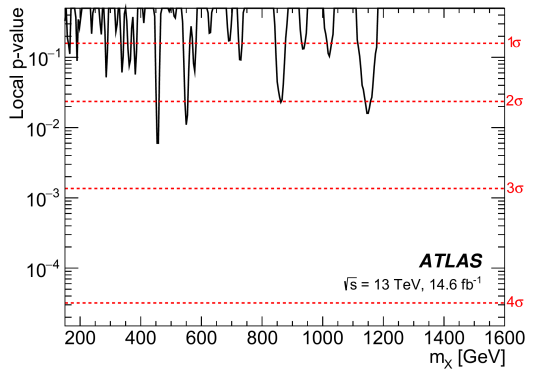


Search range in m_{H^+}: 120 - 160 GeV

arXiv:2304.10953

Axion-like-particles with the ATLAS Forward Proton (AFP) detector

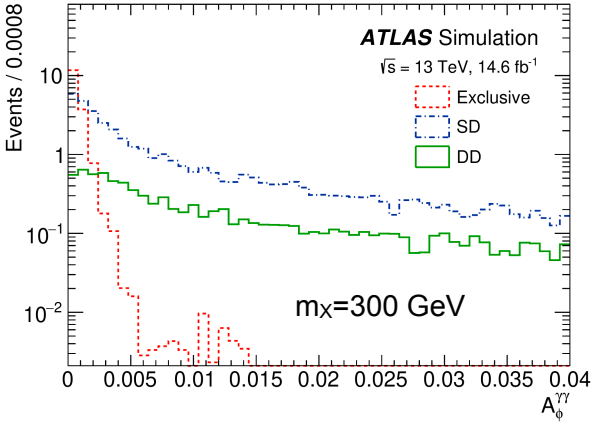


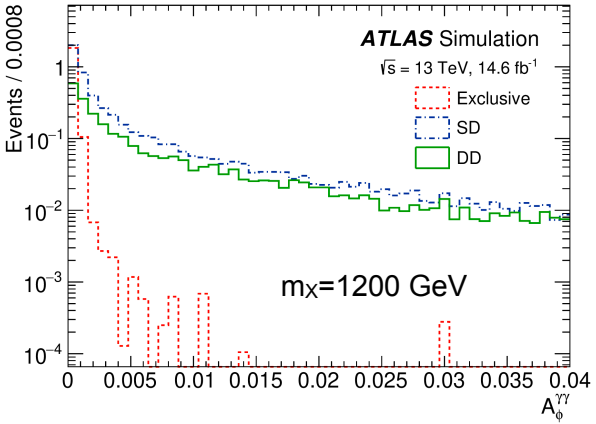


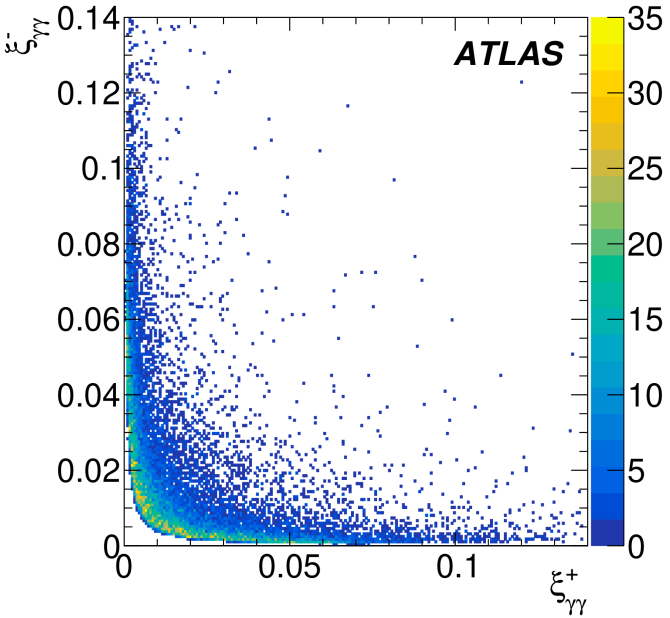
Source	Uncertainty
Signal yield uncertainty	
Pile-up reweighting	$^{+2.7}_{-2.6}$%
Luminosity	±2.4%
Photon identification efficiency	$^{+1.6}_{-1.5}$%
Photon isolation efficiency	±1.9%
Beam optics between ATLAS central and AFP detectors	$^{+0.8}_{-3.4}$%
AFP global alignment	$^{+10.0}_{-8.6}$%
Proton reconstruction efficiency	$^{+3.0}_{-2.2}$%
Showering in the AFP	$^{+0.0}_{-6.6}$%
Background modelling (mass-dependent)	±(0.02–0.7) events
Signal modelling	
Photon energy resolution	$^{+14.1}_{-4.8}$%
Photon energy scale	±(0.5–1.0)%
Signal cross-section uncertainty	
Soft survival factor (exclusive process)	±2%
Soft survival factor (single-dissociative process)	±10%
Soft survival factor (double-dissociative process)	±50%

Axion-like-particles with the ATLAS Forward Proton (AFP) detector

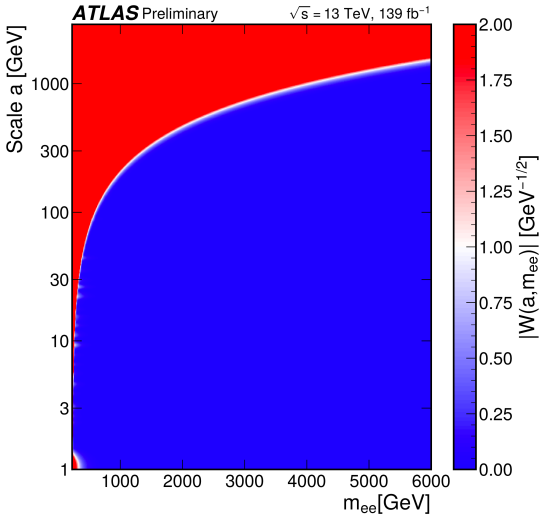
arXiv:2304.10953

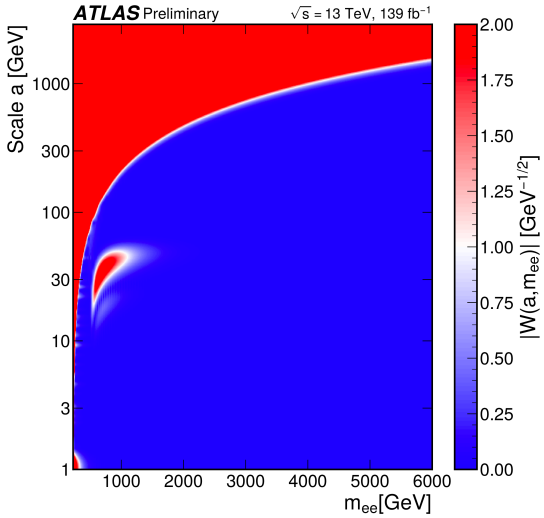


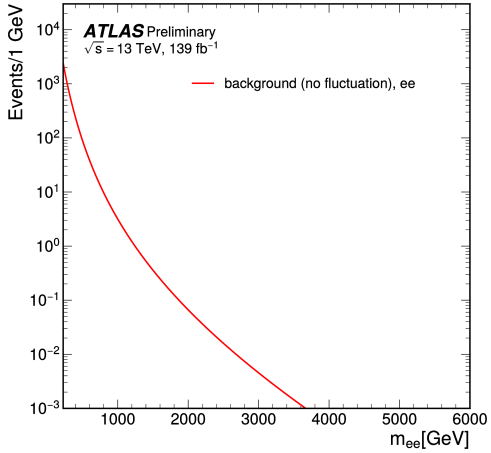


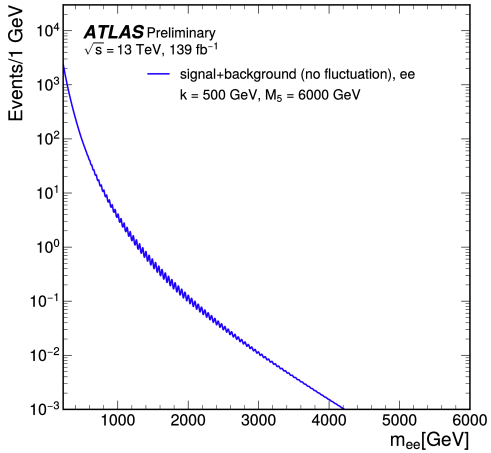


Periodic signals









Periodic signals