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Exotic New Physics Searches

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on behalf of the **ATLAS Collaboration**

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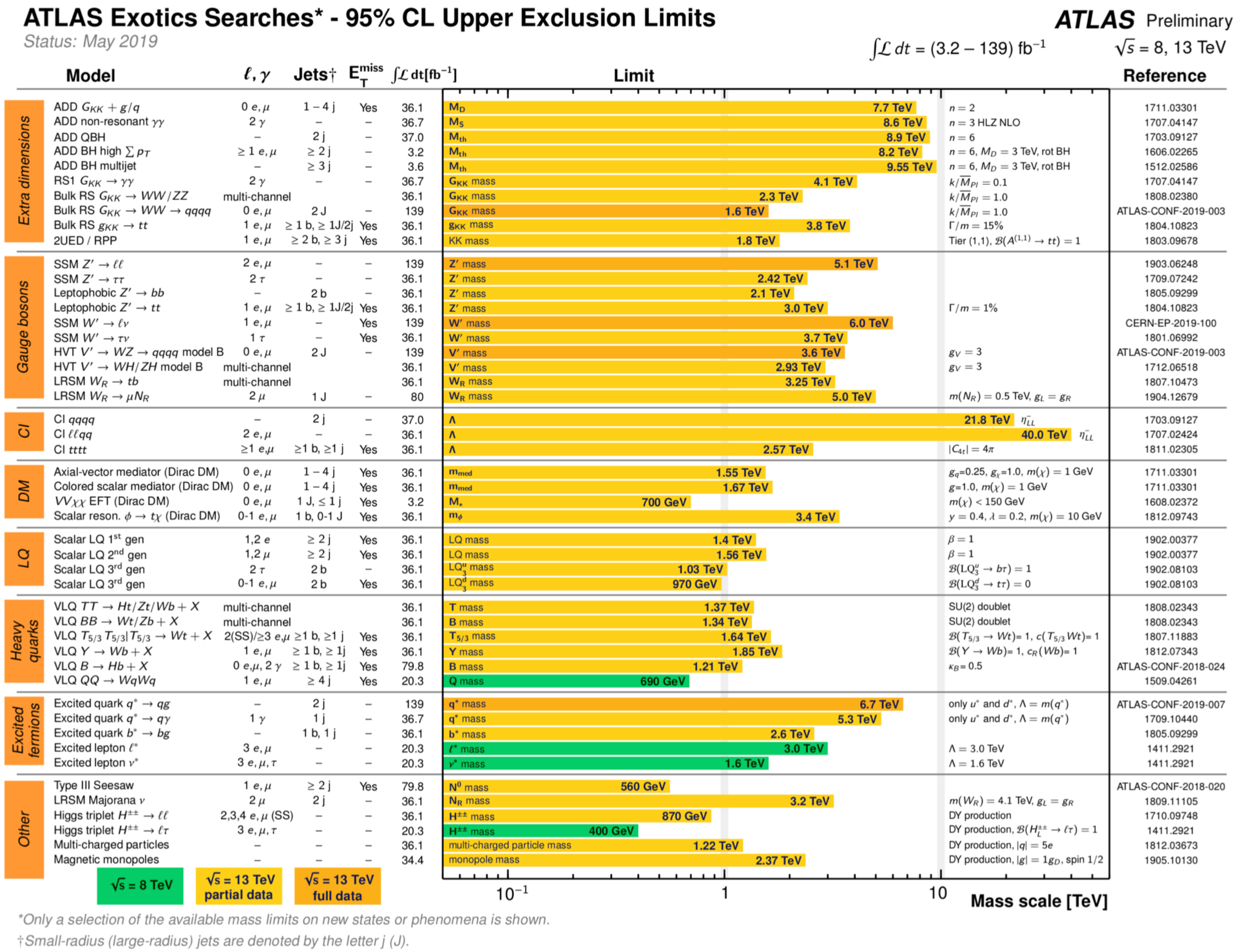
ATLAS EXPERIMENT

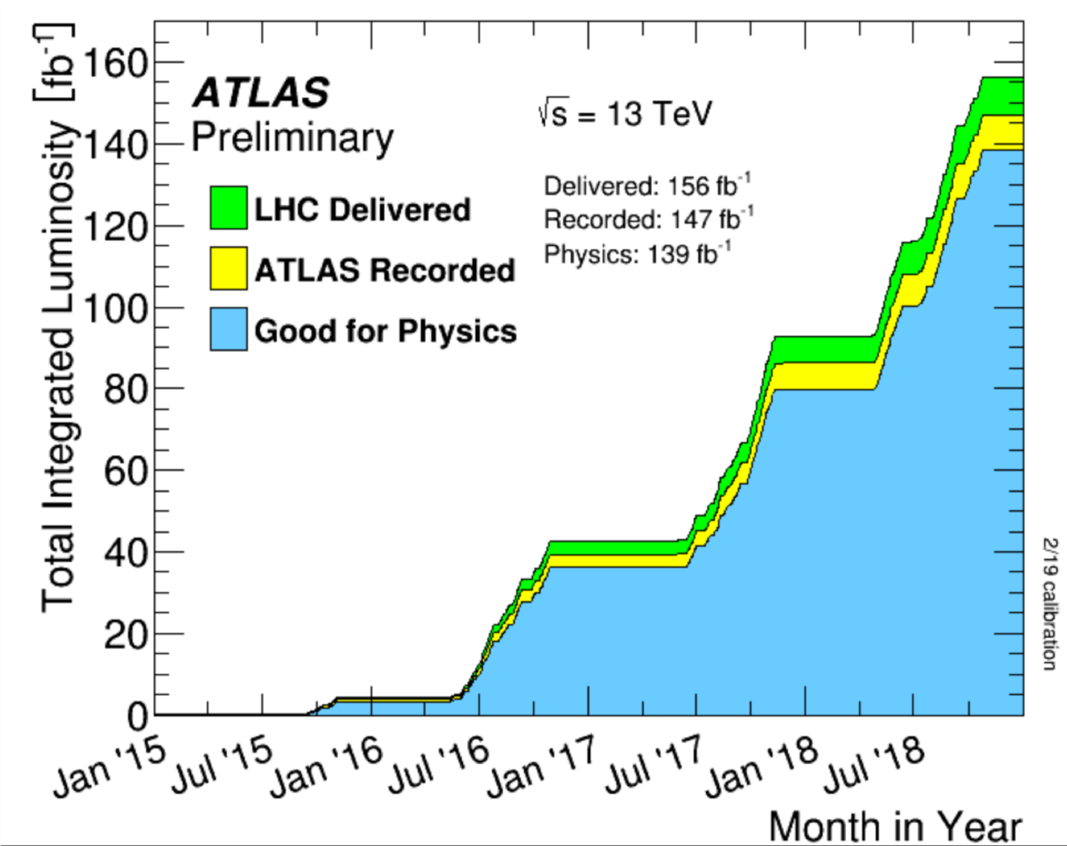
Searches

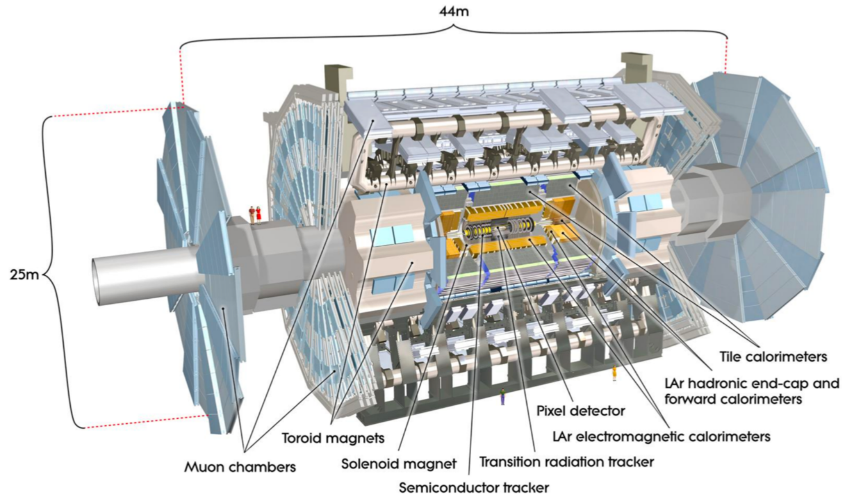
- Severely constraining the parameter space for BSM physics at the LHC.
- This talk focusses on recent updates, many with full run-2 data sets.

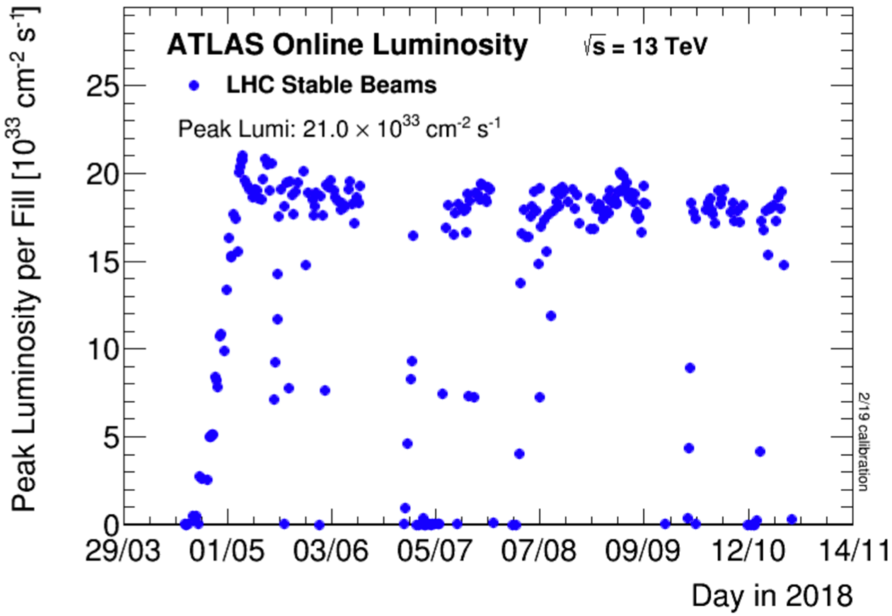


Run-2 data sample

- Run-2 data-set 139 fb^{-1} at sqrt(s)=13 TeV.
- Peak luminosity 2.1e34 cm^{-2} s^{-1}







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Di-boson resonance

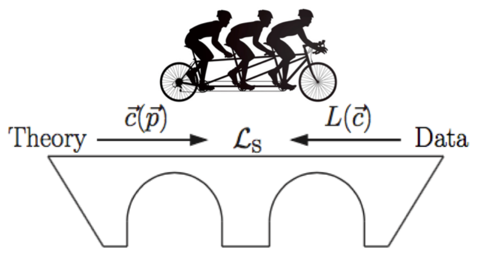
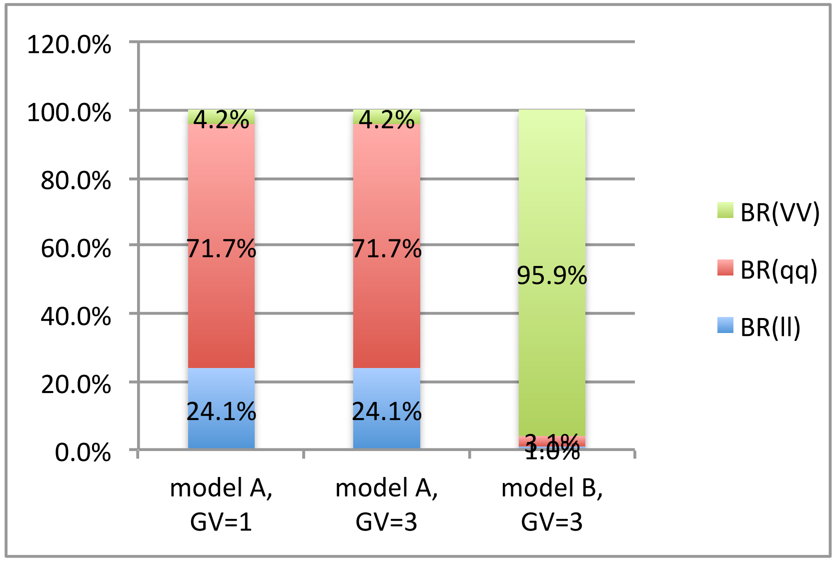
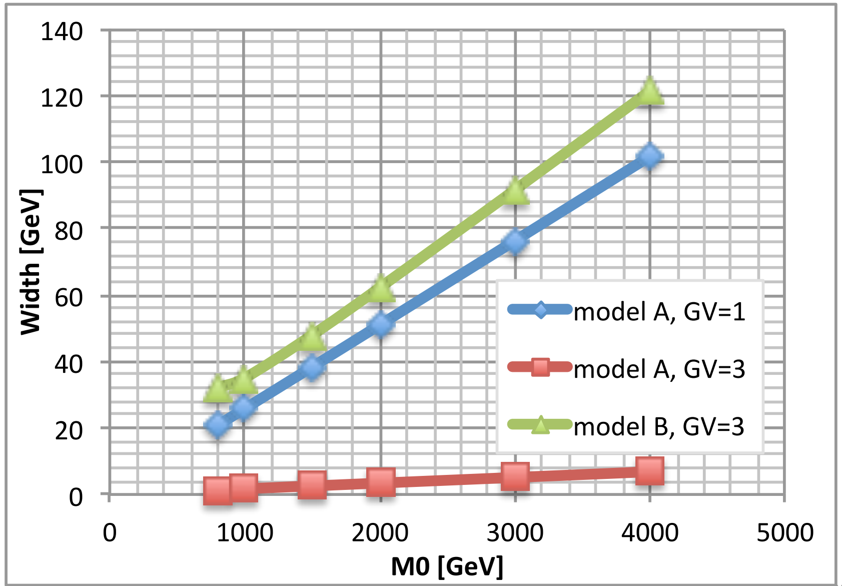


Figure 1.1: Pictorial view of the Bridge Method.

- Heavy Vector Triplet
  arXiv:1402.4431v2
  - Effective Lagrangian with additional fields $V^{+,0,-}$.
  - Can tune mass, couplings to fermions and bosons.
  - Two benchmark scenarios
    - **A**: weakly coupled extended gauge symmetry
    - **B**: strongly coupled minimal composite higgs model





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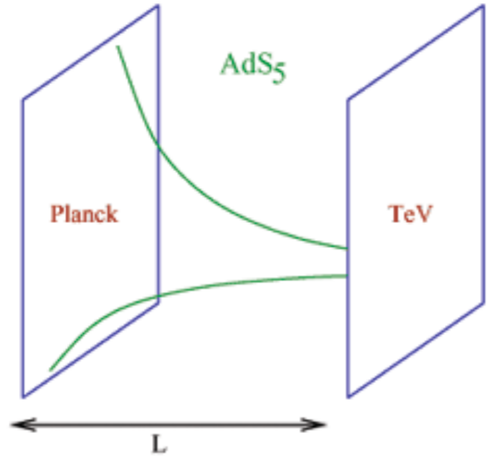
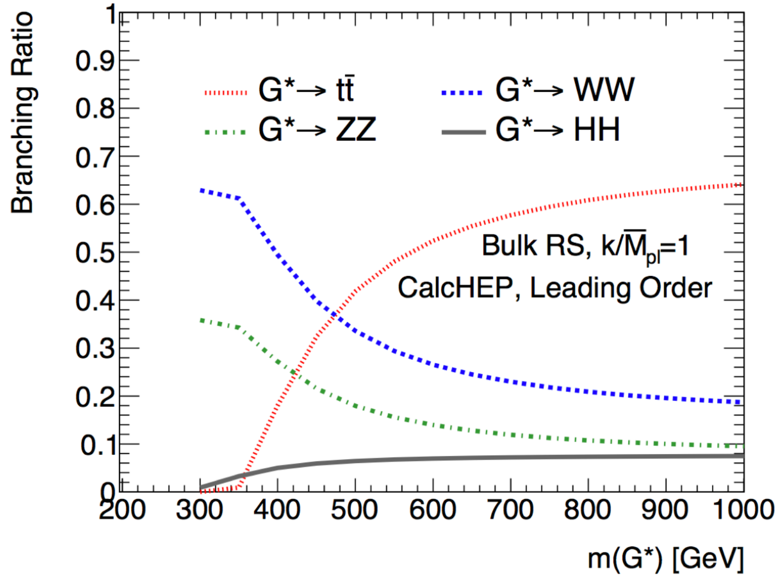
Di-boson resonance

- **"bulk" RS graviton with warped extra dimension**

  Phys.Rev.D76:036006,2007
  - Extension of KK graviton in RS1 framework with SM particles extending into the "bulk".
  - Couplings to light fermions suppressed.
  - gg fusion dominant production channel.
  - High BR of G* VV.





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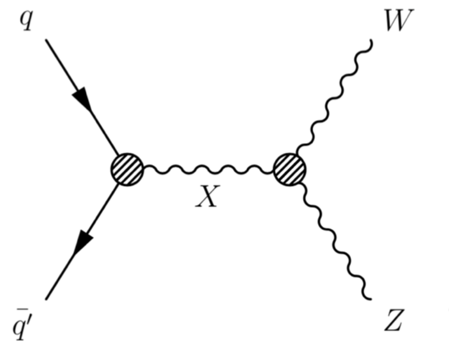
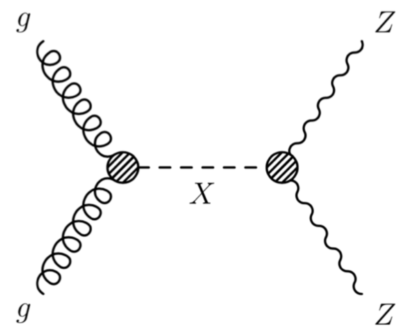
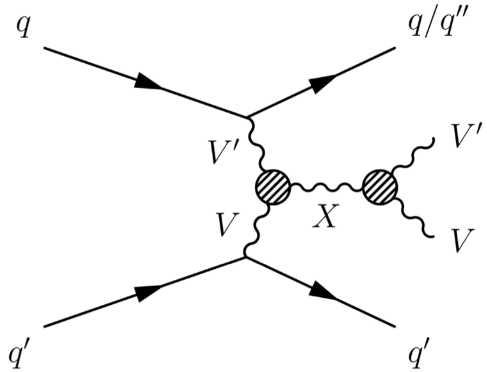
ATLAS EXPERIMENT

Narrow di-boson resonances

- **Production and decay of heavy resonances:**
  - quark-antiquark annihilation
  - gluon—gluon fusion
  - Vector Boson Fusion
- **Experimental signatures**
  - Semi-leptonic final state
    - vvqq, lvqq, llqq
  - Topologies:
    - Boosted: V->J large-R jet
    - Resolved: V->jj small-R jets
  - **fully hadronic JJ**





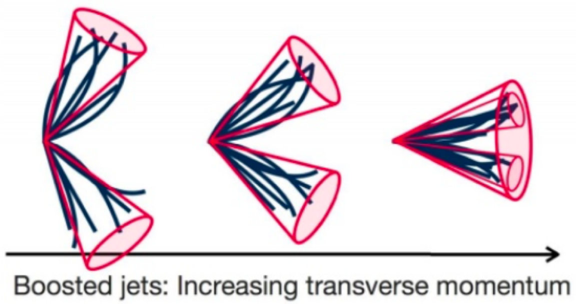


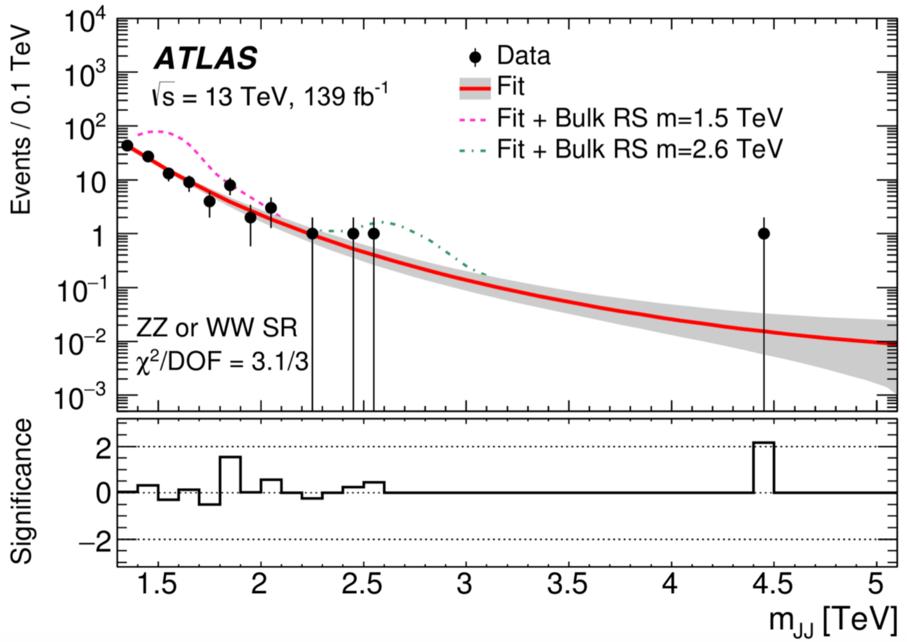
VV->JJ resonances

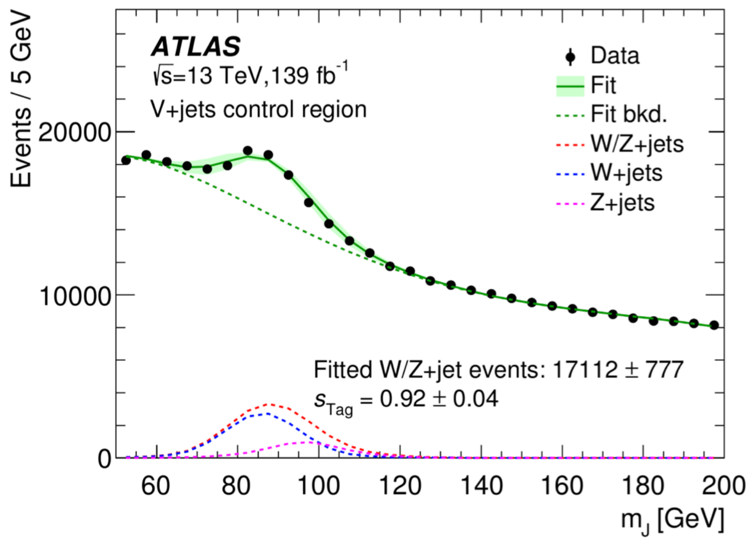
arXiv:1906.08589

sqrt(s) = 13 TeV
$L = 139\ fb^{-1}$
FS = JJ

- **Fully hadronic final state.**
  - Look for two large R jets, consistent with hadronically decaying *W* or *Z*.
  - Sensitive to resonances above about 1.4 TeV







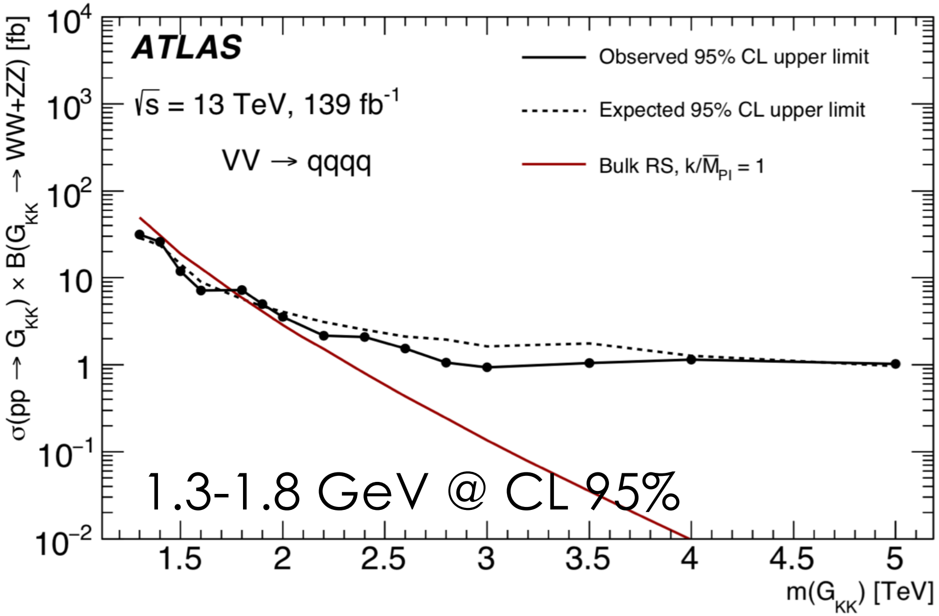
- Bump hunt in di-jet invariant mass spectrum.

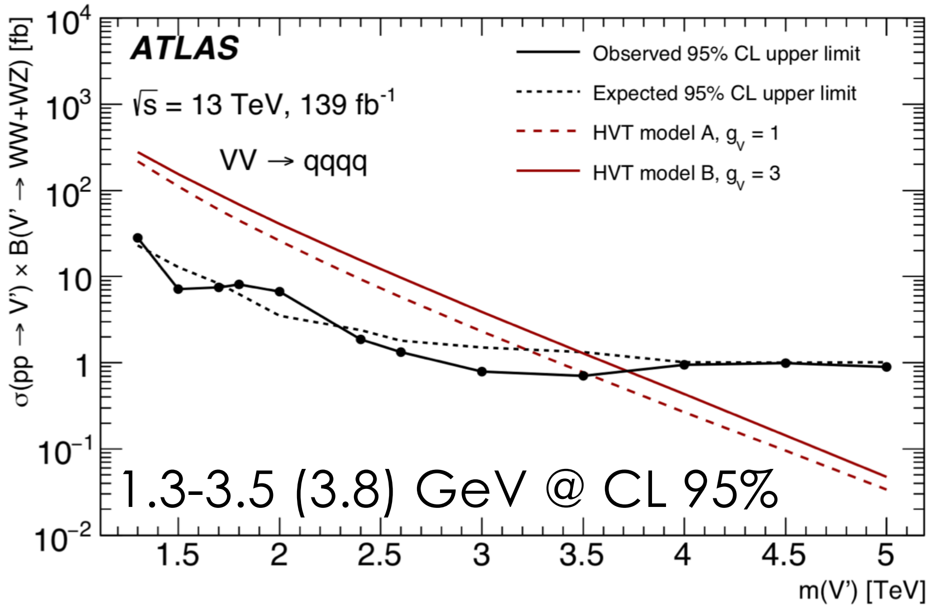
VV->JJ resonances

arXiv:1906.08589

- **No excess observed**
- **Limits** on HVT (spin-1) Graviton models (spin-2)
- Competitive limits compared to combination of 36fb^{-1} analysis on (all channels). arXiv:1808.02380

Model	Signal Region	Excluded mass range [TeV]
HVT model A, $g_V = 1$	WW	1.3–2.9
	WZ	1.3–3.4
	$WW + WZ$	1.3–3.5
HVT model B, $g_V = 3$	WW	1.3–3.1
	WZ	1.3–3.6
	$WW + WZ$	1.3–3.8
Bulk RS, $k/\overline{M}_{\rm Pl} = 1$	WW	1.3–1.6
	ZZ	none
	$WW + ZZ$	1.3–1.8

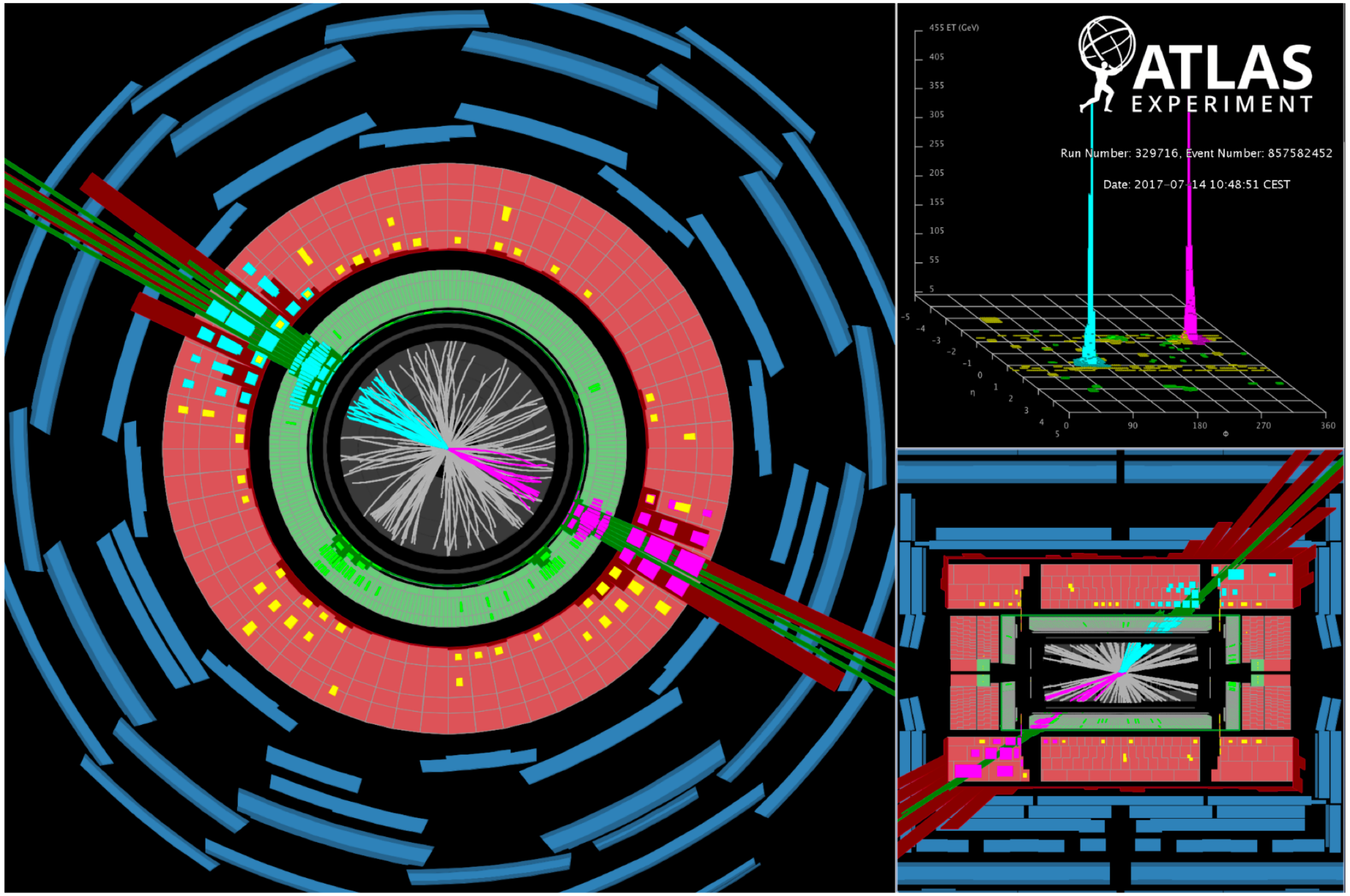




arXiv:1910.08447

Di-jet

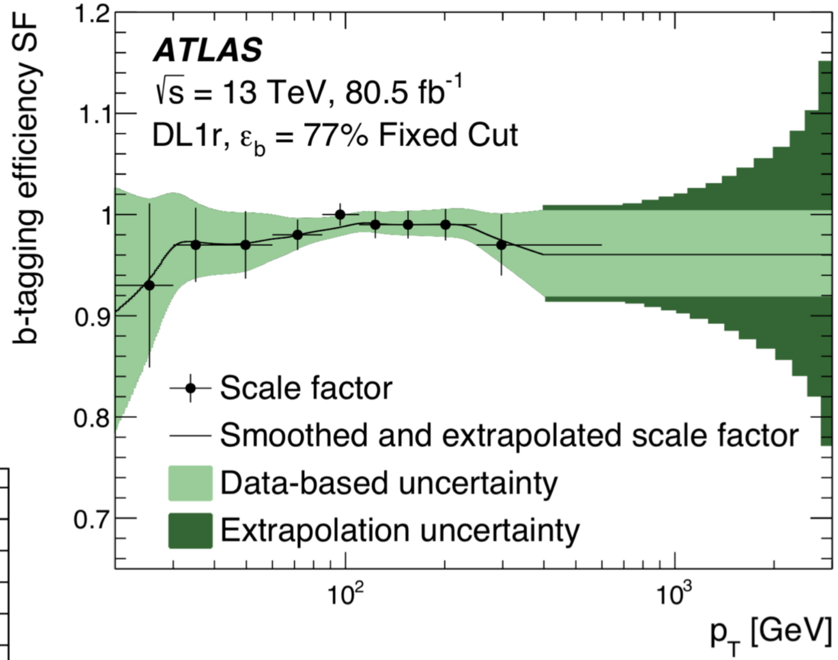
- Search for di-jet resonances.
- Full Run-2 data-set, 139fb^{-1}
- Inclusive di-jet search and dedicated di-b-jet signature.

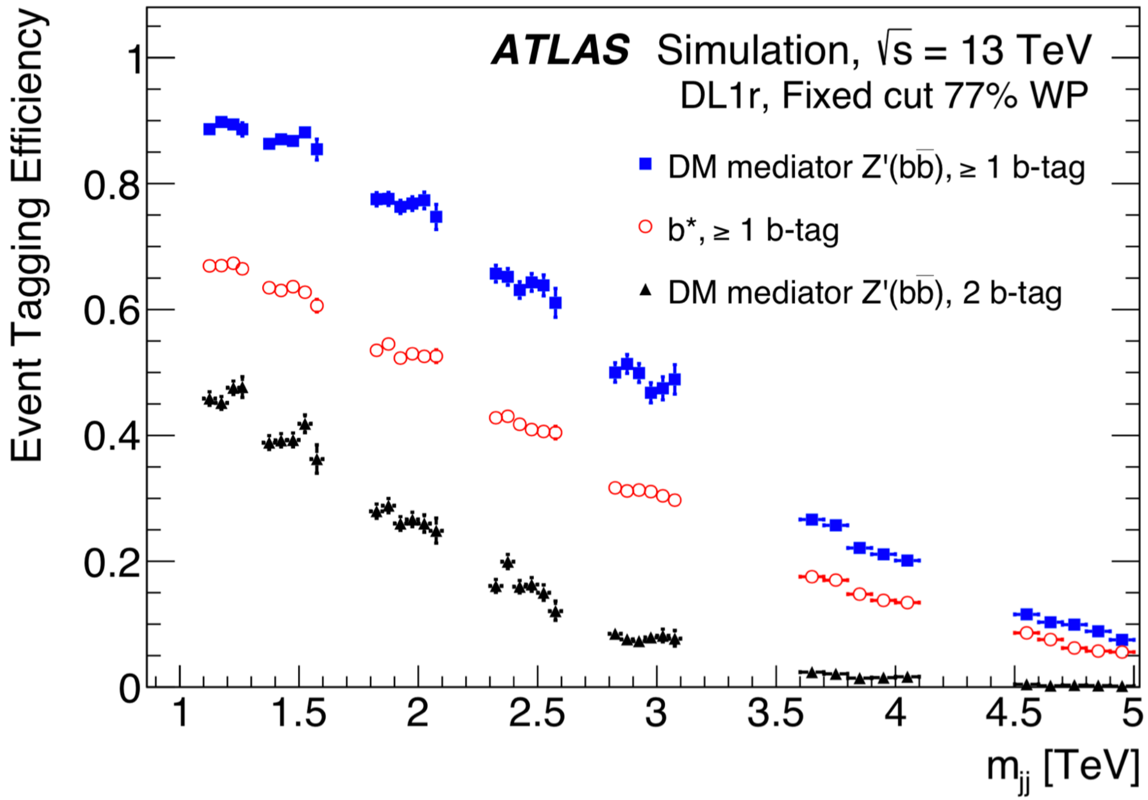


dijet event with m_{jj}=9.5 TeV

Di-jet

- **Improved b tagging:** **b-jets** identified with deep-learning neural networks, operating point ε_b=77% (for *tt* events).
- Correction factors for $\varepsilon_b(p_t)$ derived from data and MC.



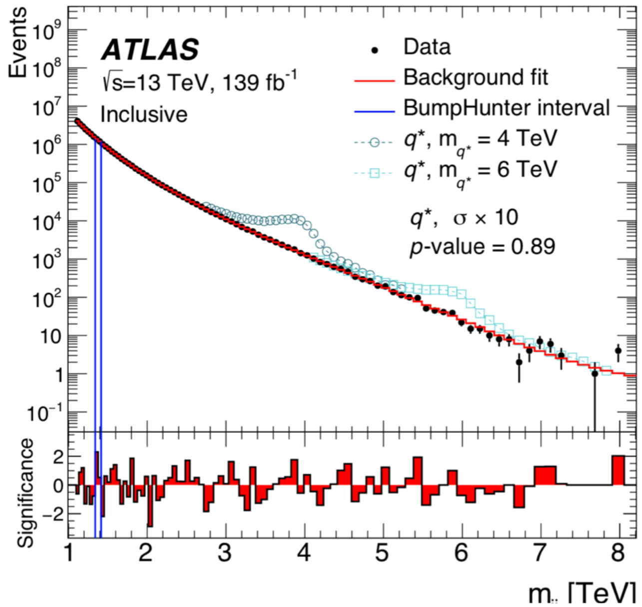


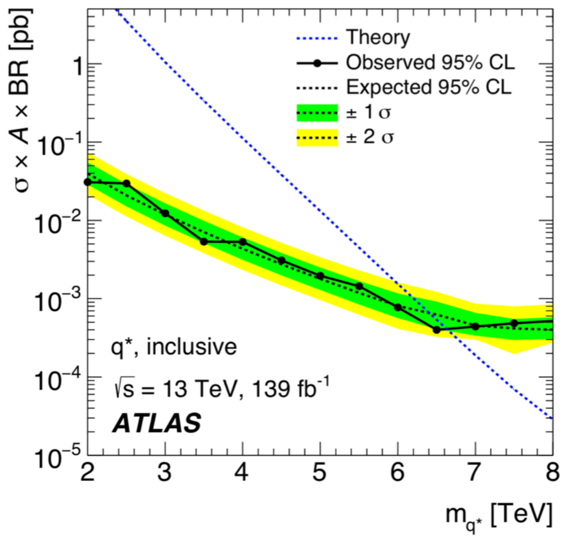
- Event tagging efficiency mass and model dependent.
- Reduce dominant QCD background by cutting on rapidity separation of jets.

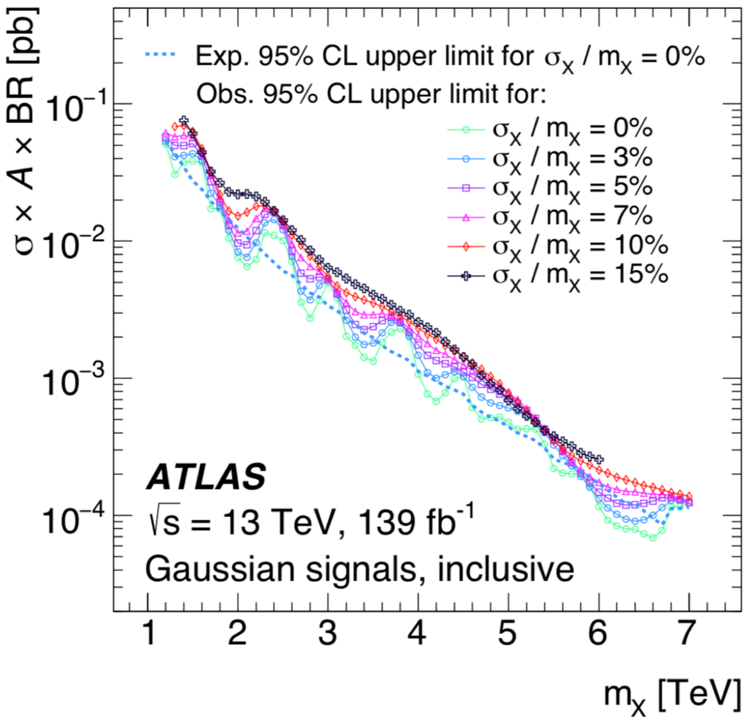
arXiv:1910.08447

Di-jet

- SM Di-jet mass spectrum described with parametric function and validated with data-driven methods.
- For b-tagged jets CR are defined with inverted b-tag requirements.
- Quantify significance of any access with *bump-hunter*.
- No excess found.
- Set limits on BSM models & Gaussian signals







Di-jet

- No excess found, set limits on BSM models.

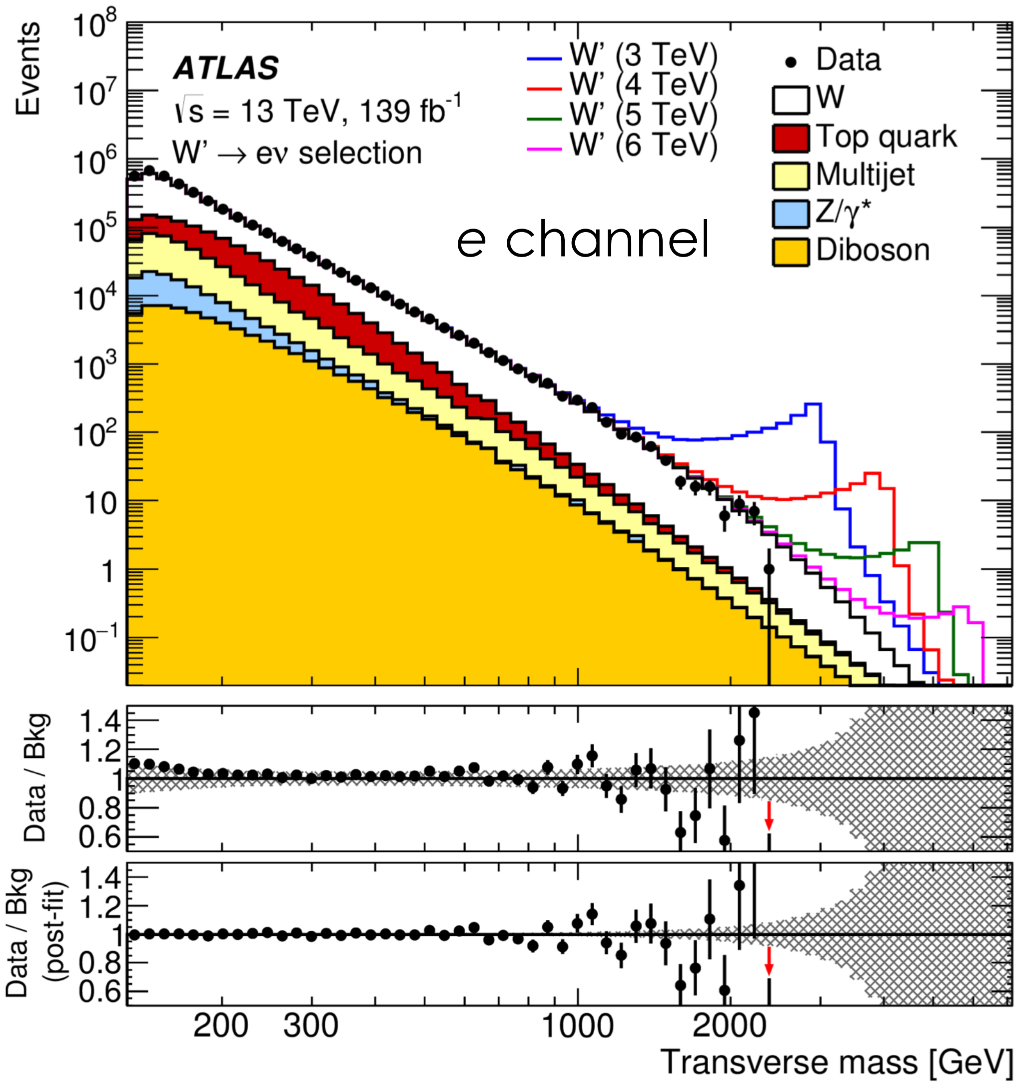
Table 2: The lower limits on the masses of benchmark signals at 95% CL.

Category	Model	Lower limit on signal mass at 95% CL	
		Observed	Expected
Inclusive	q^*	6.7 TeV	6.4 TeV
	QBH	9.4 TeV	9.4 TeV
	W'	4.0 TeV	4.2 TeV
	W^*	3.9 TeV	4.1 TeV
	DM mediator Z', $g_q = 0.20$	3.8 TeV	3.8 TeV
	DM mediator Z', $g_q = 0.50$	4.6 TeV	4.9 TeV
$1b$	b^*	3.2 TeV	3.1 TeV
$2b$	DM mediator Z' $g_q = 0.20$	2.8 TeV	2.8 TeV
	DM mediator Z', $g_q = 0.25$	2.9 TeV	3.0 TeV
	SSM Z',	2.7 TeV	2.7 TeV
	graviton, $k/\overline{M}_{\mathrm{PL}} = 0.2$	2.8 TeV	2.9 TeV

Phys. Rev. D 100 (2019) 052013
DOI: 10.1103/PhysRevD.100.052013

W'

- Search for resonances in transverse mass mT (*) in lepton (e, μ) + MET channel.
- Full Run-2 data-set, 139fb-1
- Acceptance between 79% and 44% depending on channel and W' mass.
  - high pT muon selection optimised.
- No excess observed, limits on W' models.



(*)

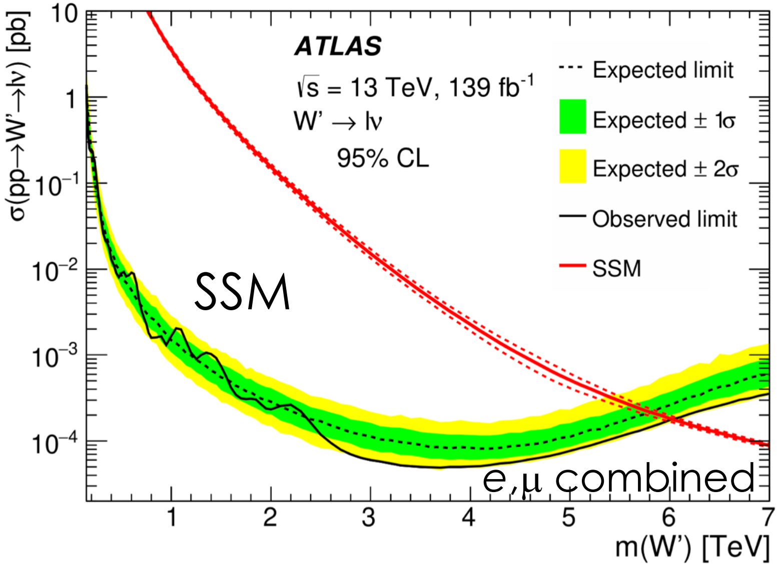
$$m_T = \sqrt{2\, p_T\, E_T^{\text{miss}}\, (1 - \cos\phi_{\ell\nu})}$$

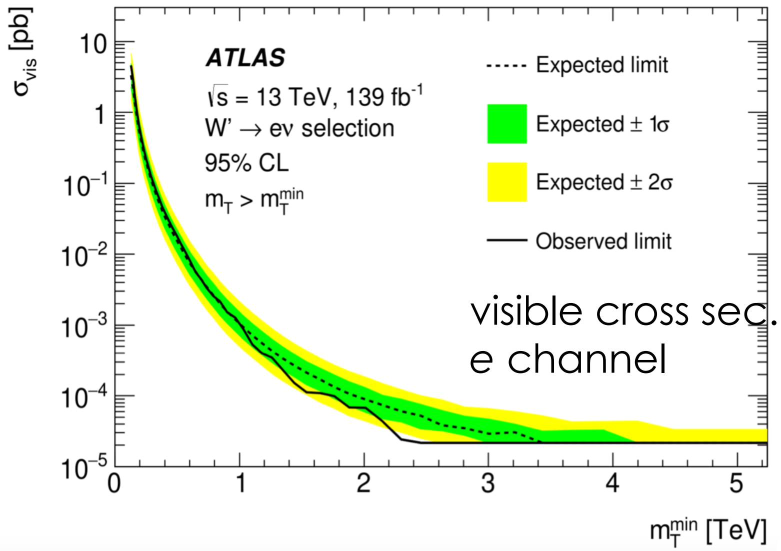
Phys. Rev. D 100 (2019) 052013
DOI: 10.1103/PhysRevD.100.052013

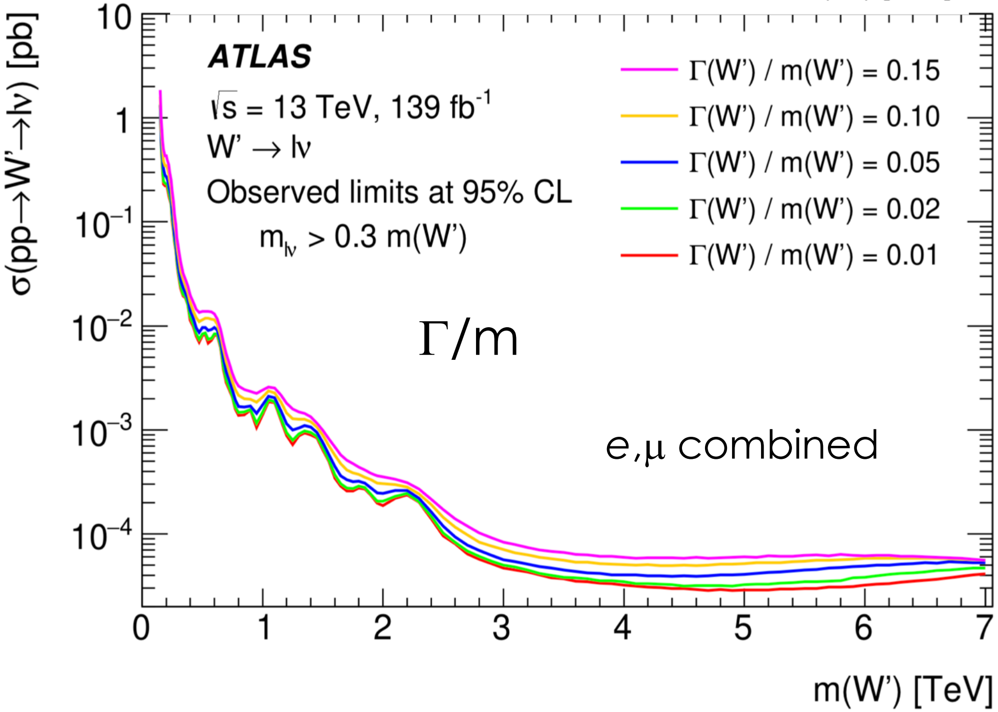
W'

	$m(W')$ lower limit [TeV]	
Decay	Observed	Expected
$W' \to e\nu$	6.0	5.7
$W' \to \mu\nu$	5.1	5.1
$W' \to \ell\nu$	6.0	5.8

- **Limits on**
  - SSM model W' (6.0 TeV observed, 5.8 TeV expected)
  - Varying Γ/m ratios (1% to 15%)
  - Visible cross section above m_T threshold.

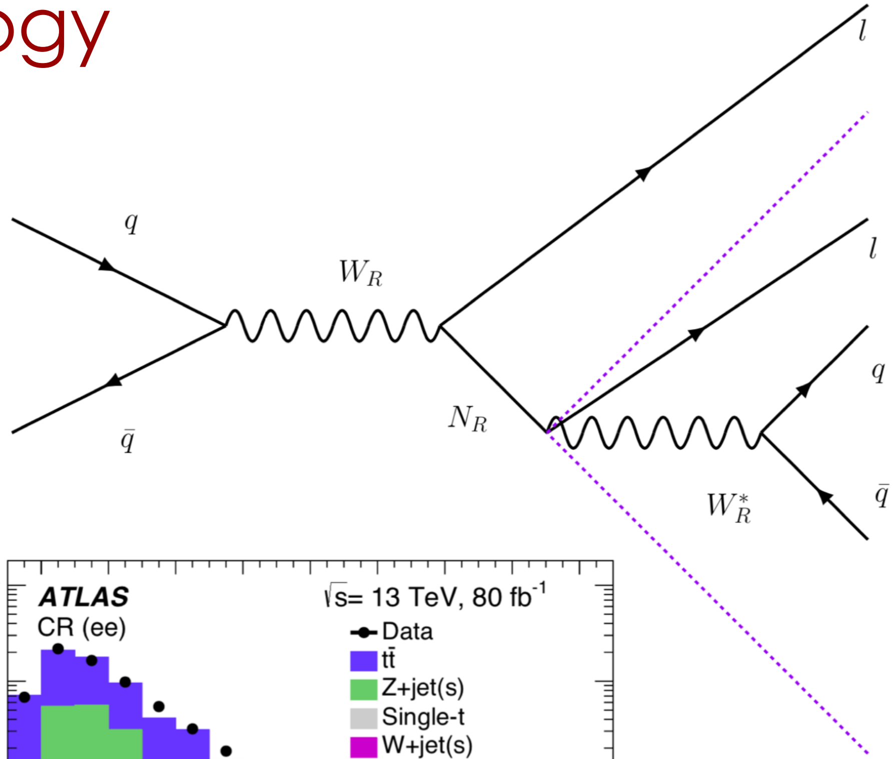


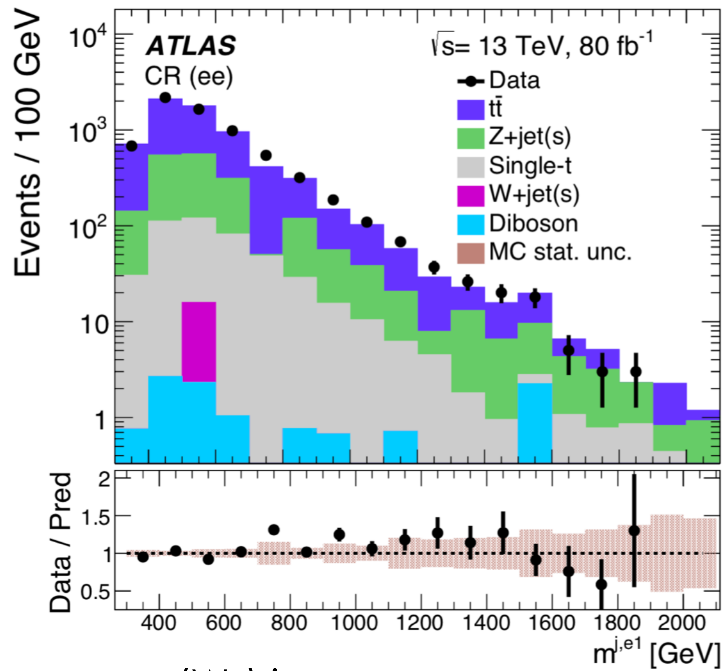




Heavy Neutrino search in boosted topology

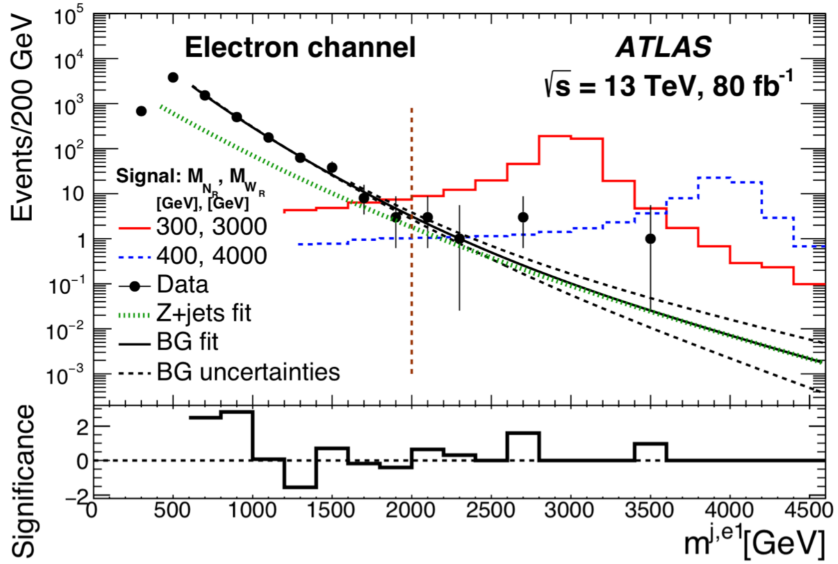
- Seesaw mechanism to explain neutrino masses, models predict right-handed heavy W'_R and a heavy neutrino N_R.
- This search for $m(W_R) >> m(N_R)$.
  - N_R boosted decay.
  - Signature same isolated lepton and fat-jet + embedded lepton, same flavour.
  - Observable $m_{inv}(J, l_1, l_2)$:

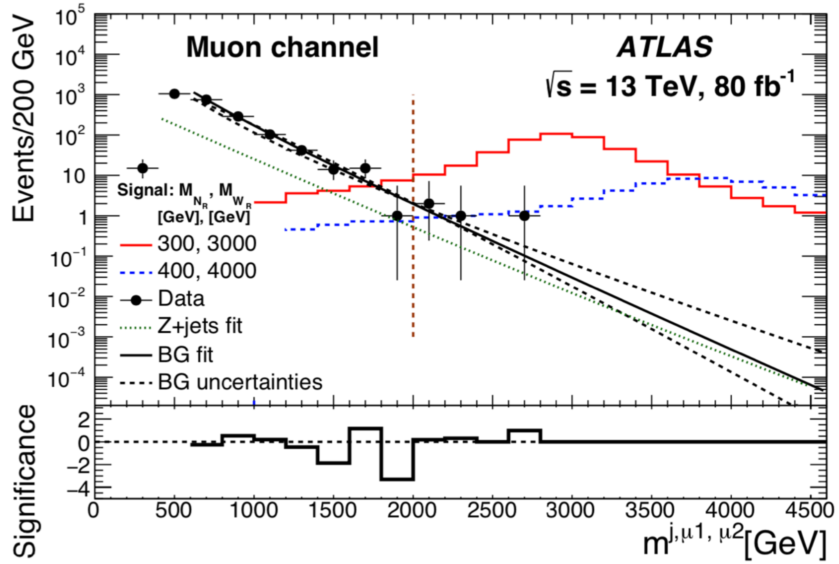




$m(W_R)$ in control region < 2TeV

Heavy Neutrino search in boosted topology





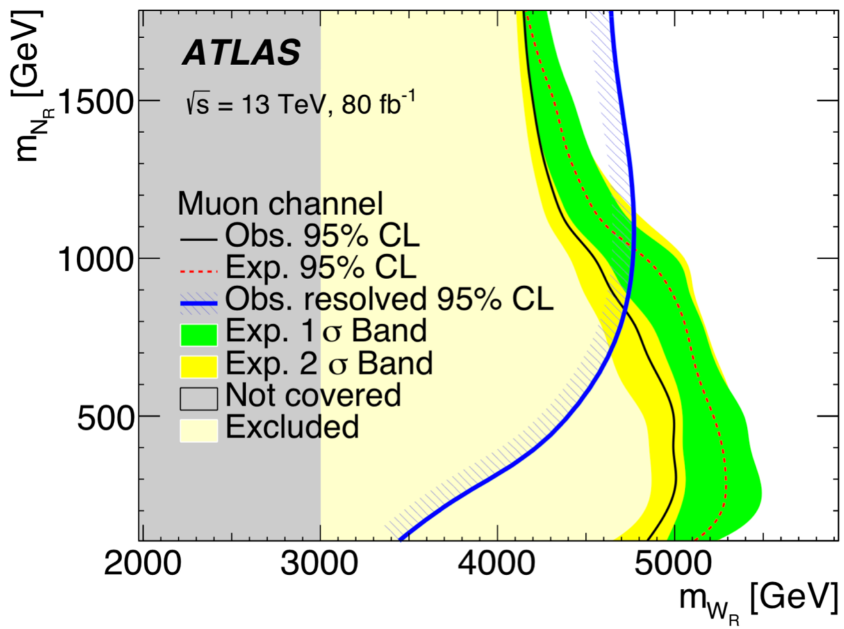
- Event count in signal region consistent with background expectation.
- Derive mass limits on N_R and W_R.

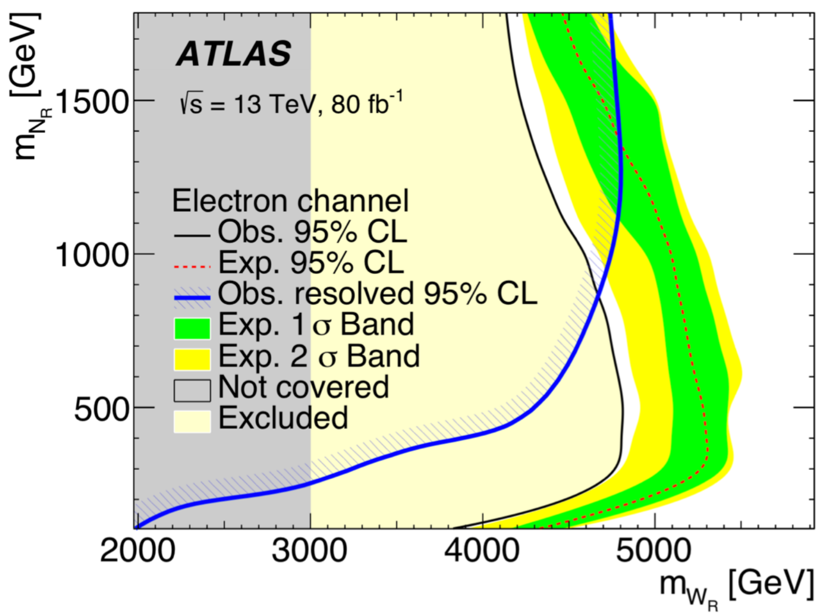
	Electron Channel	Muon Channel
Signal (m_{W_R} = 3 TeV, m_{N_R} = 150 GeV)	346^{+48}_{-75}	411^{+36}_{-48}
Signal (m_{W_R} = 3 TeV, m_{N_R} = 300 GeV)	471^{+42}_{-69}	429^{+29}_{-40}
Signal (m_{W_R} = 4 TeV, m_{N_R} = 400 GeV)	66^{+6}_{-10}	57^{+4}_{-4}
Expected background	$2.8^{+0.5}_{-0.7}$	$1.9^{+0.5}_{-0.7}$
Observed events	8	4
Significance	2.4σ	1.2σ
p-value	0.0082	0.12

Phys. Lett. B 798 (2019) 134942

Heavy Neutrino search in boosted topology

- Derive mass limits on N_R and W_R.
  - **m(W_R) > 4.8 TeV (e- channel)**
  - **m(W_R) > 5.0 TeV (μ- channel)**
- Complementary results to previous analysis using resolved jets.

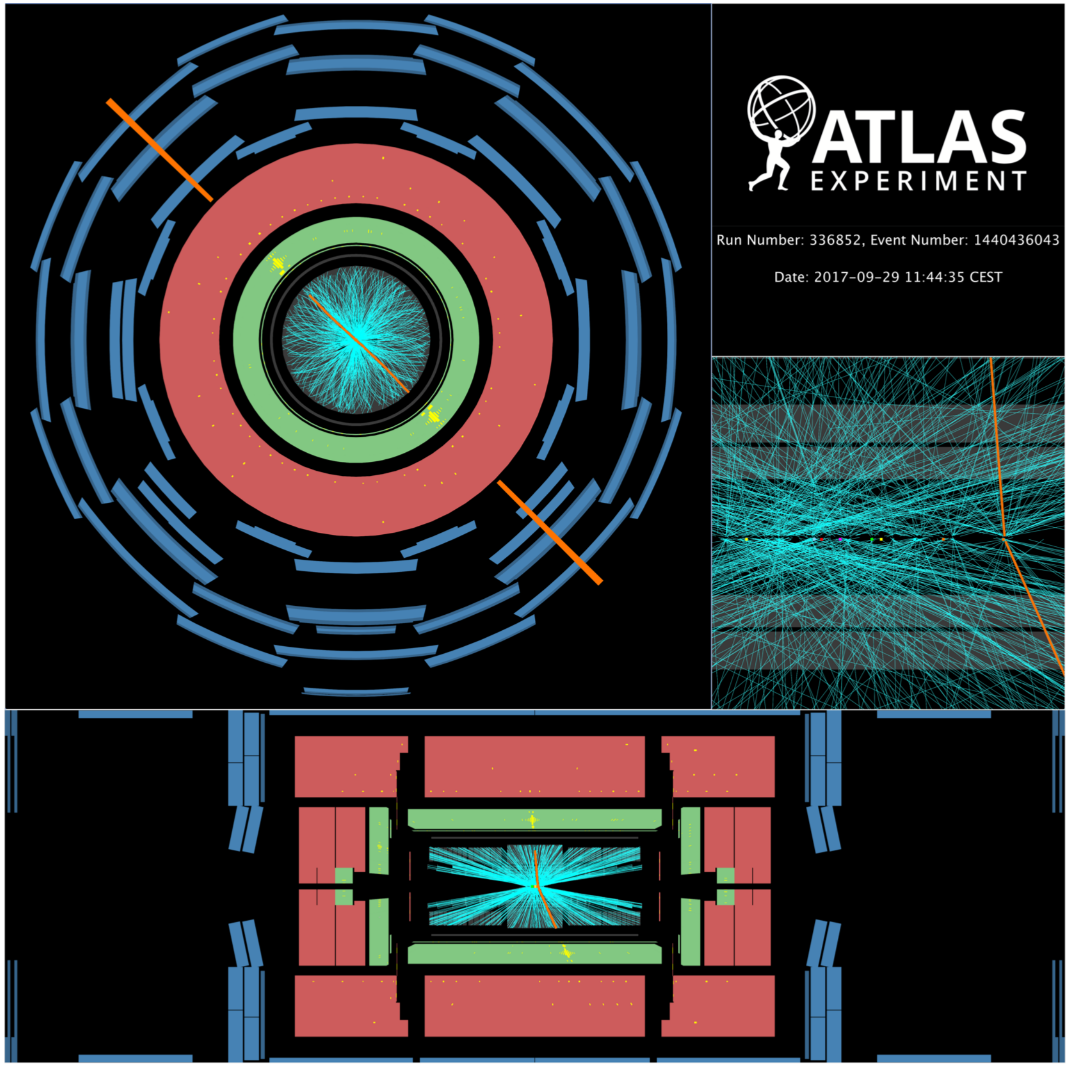




arXiv:1903.06248

Z'

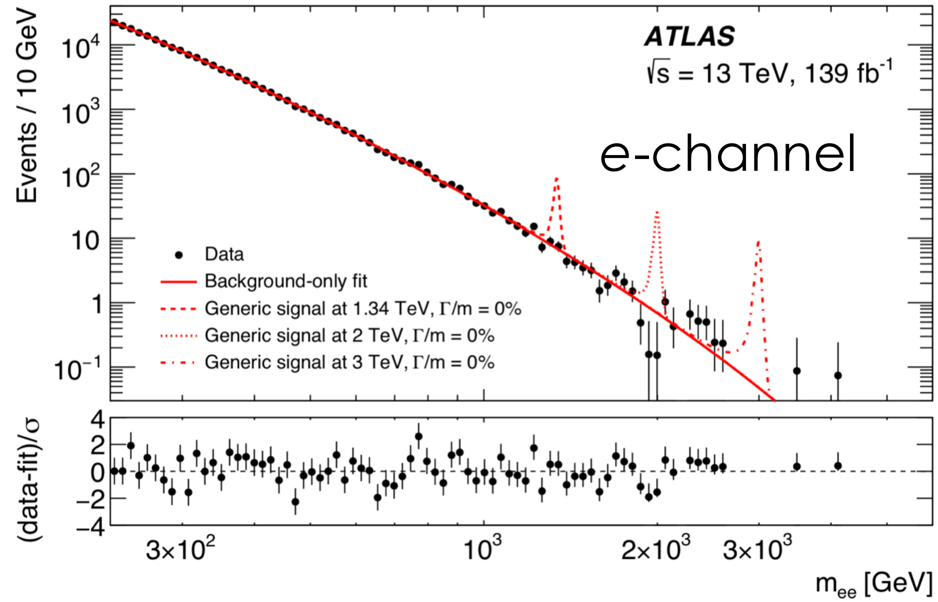
- Search for **narrow resonances** in the dilepton (electron or muon) invariant **mass spectrum**
- Signal models:
  - **generic Breit-Wigner signals**
  - **Z'** (ψ, X, SSM), **Heavy Vector Triplet** model
- Selection of two high p_T isolated leptons.

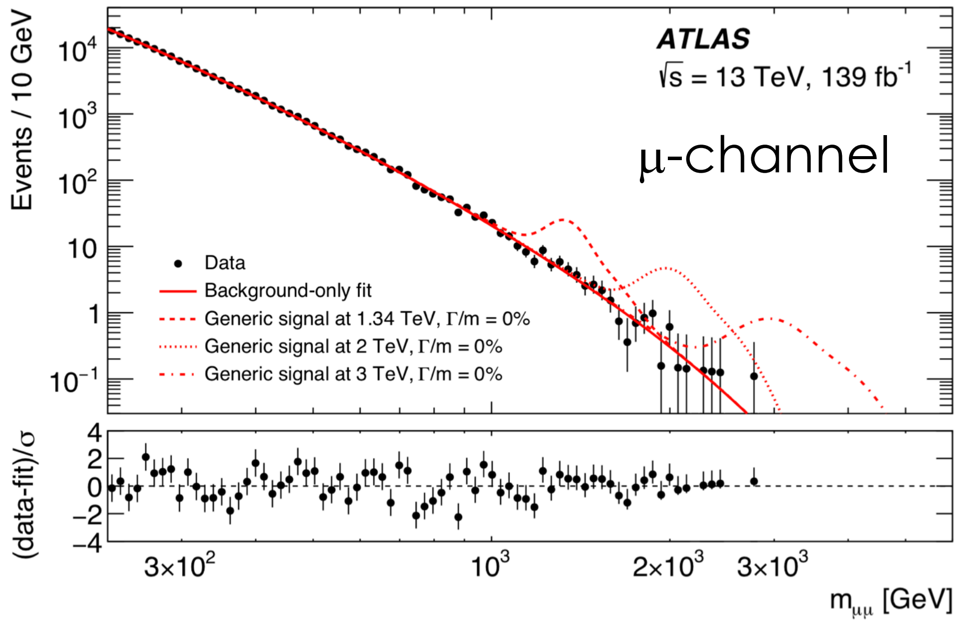


m_{ee} = 4.06TeV

Z'

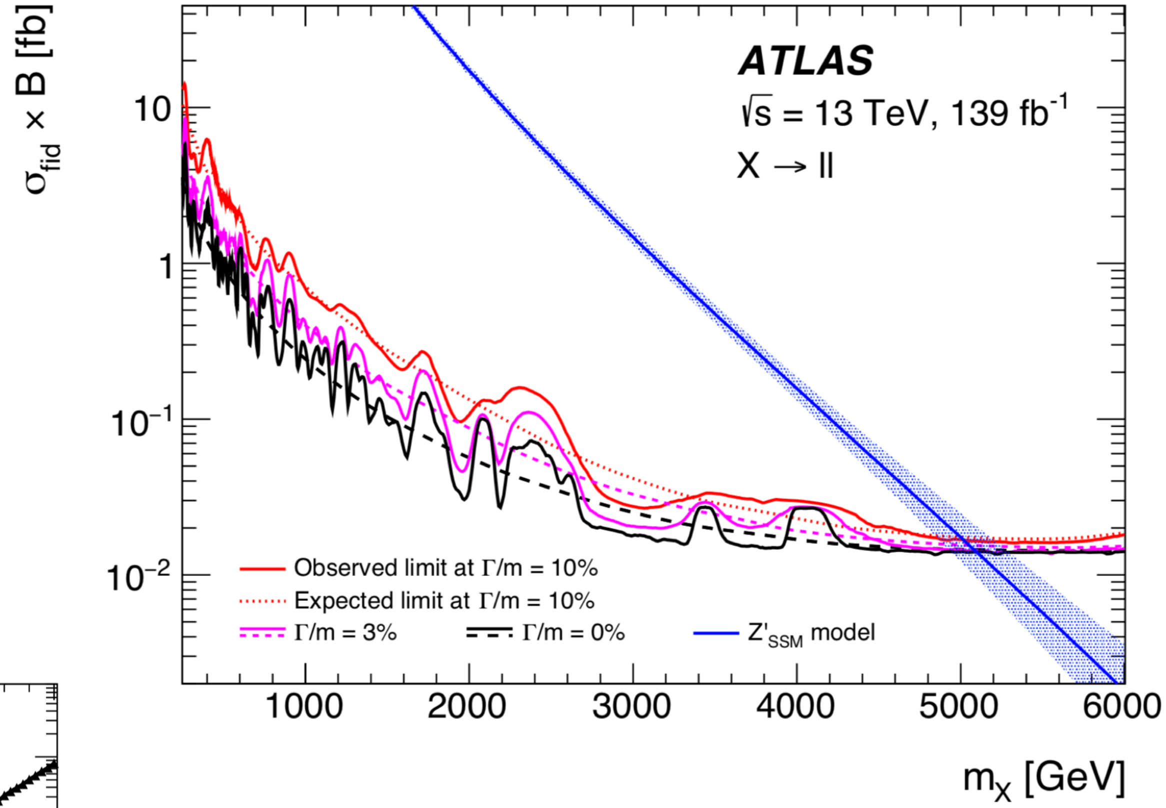
- Improvements in lepton reconstruction.
  - Improved ECAL cell-clustering.
  - ID and muon tracking alignment.
- Main background Drell-Yan Z production.
- Background estimation with fit, functional form determined from template fits.
- Dominant uncertainty:
  - "spurious signal"/background modelling.
  - Electron ID, muon quality

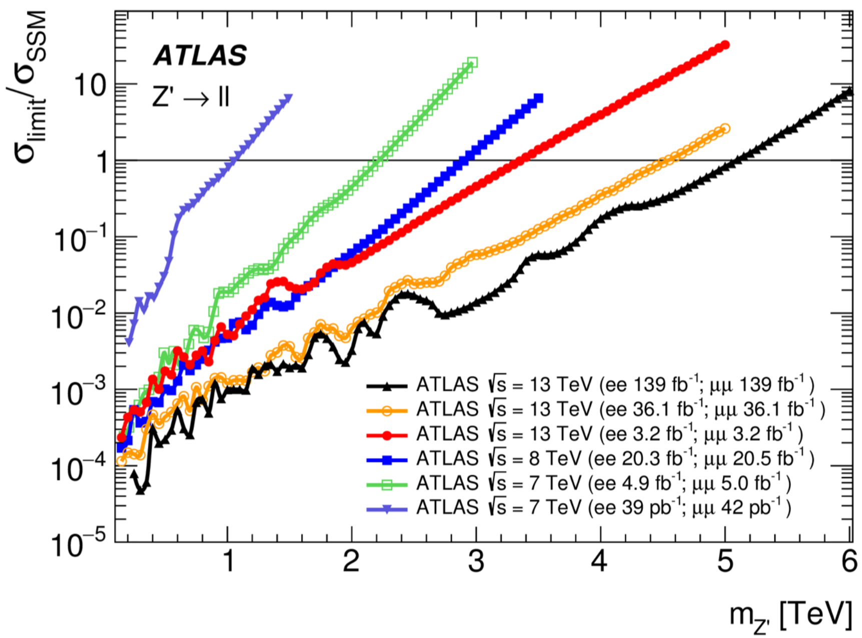




Z'

- Better limits compared to previous studies
  - data-set increased 4 fold
  - optimization of lepton reconstruction

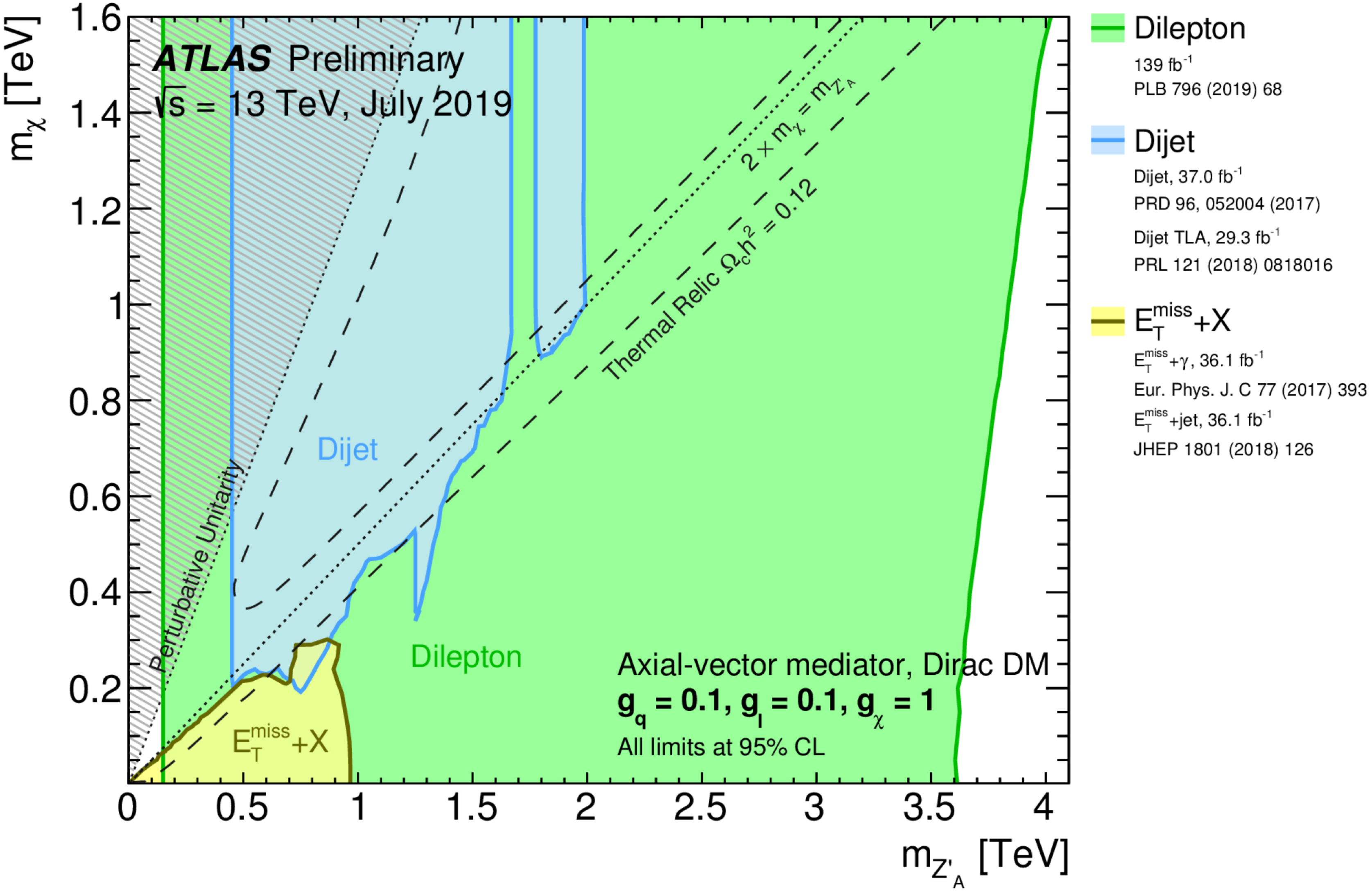




Model	Lower limits on $m_{Z'}$ [TeV]					
	ee		$\mu\mu$		$\ell\ell$	
	obs	exp	obs	exp	obs	exp
Z'_{ψ}	4.1	4.3	4.0	4.0	4.5	4.5
Z'_{χ}	4.6	4.6	4.2	4.2	4.8	4.8
$Z'_{\rm SSM}$	4.9	4.9	4.5	4.5	5.1	5.1

Dark Matter Summary

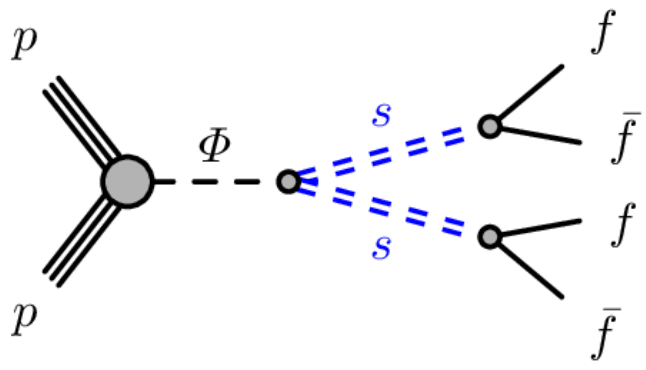
- Summary plot including di-jet (37fb^{-1}), di-lepton and E_T miss.

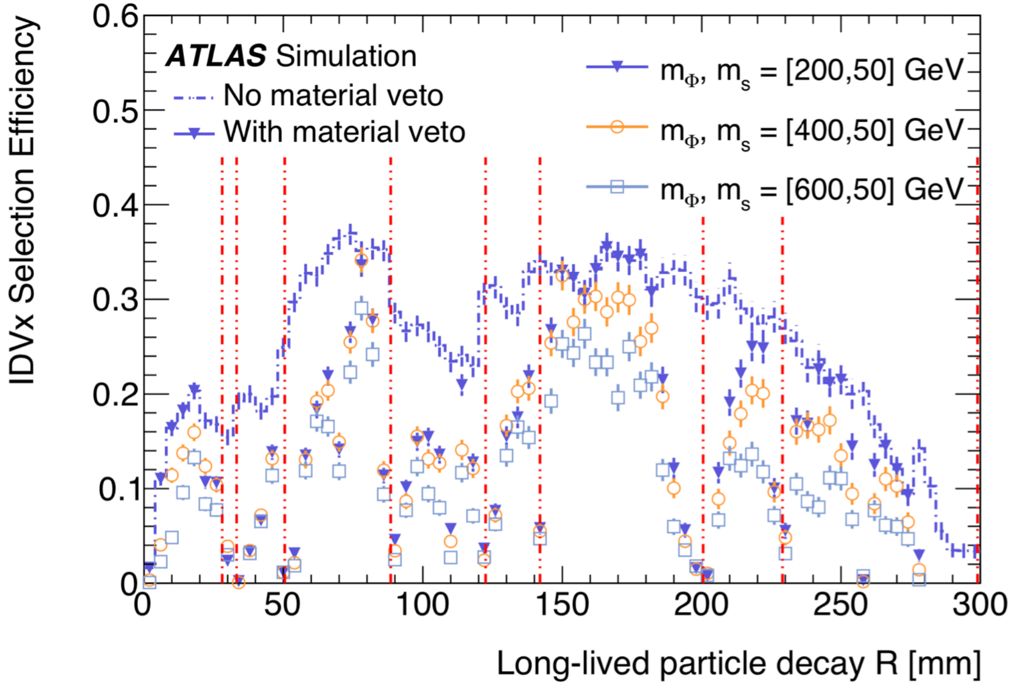


arXiv:1911.12575

Displaced jets

- Search for long-lived particles, predicted by many BSM models (eg. SUSY, hidden sector, neutral naturalness)
- Datase 33fb^{-1} at 13 TeV.
- Topology: one *s* decay in ID, and one *s* decay in muon spectrometer (MS).
  - s decay preferable to *bb*, *cc* ,$\tau\tau$
  - Use special reconstruction methods, dedicated trigger chains.
  - Sensitive for O(cm) < cτ O(m).
- Main backgrounds:
  - ID: material interactions
  - MS: Multi-jet, punch through

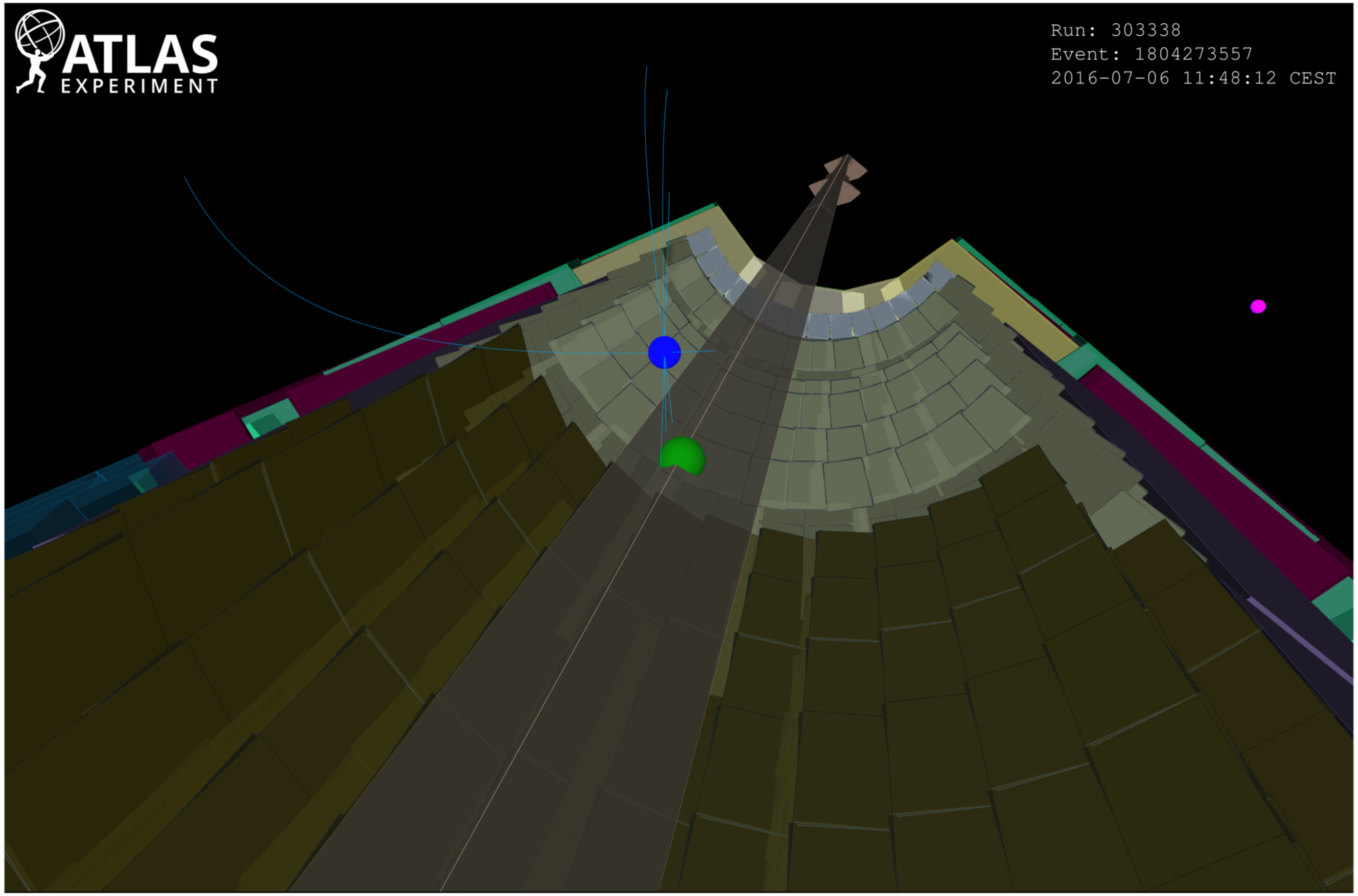




arXiv:1911.12575

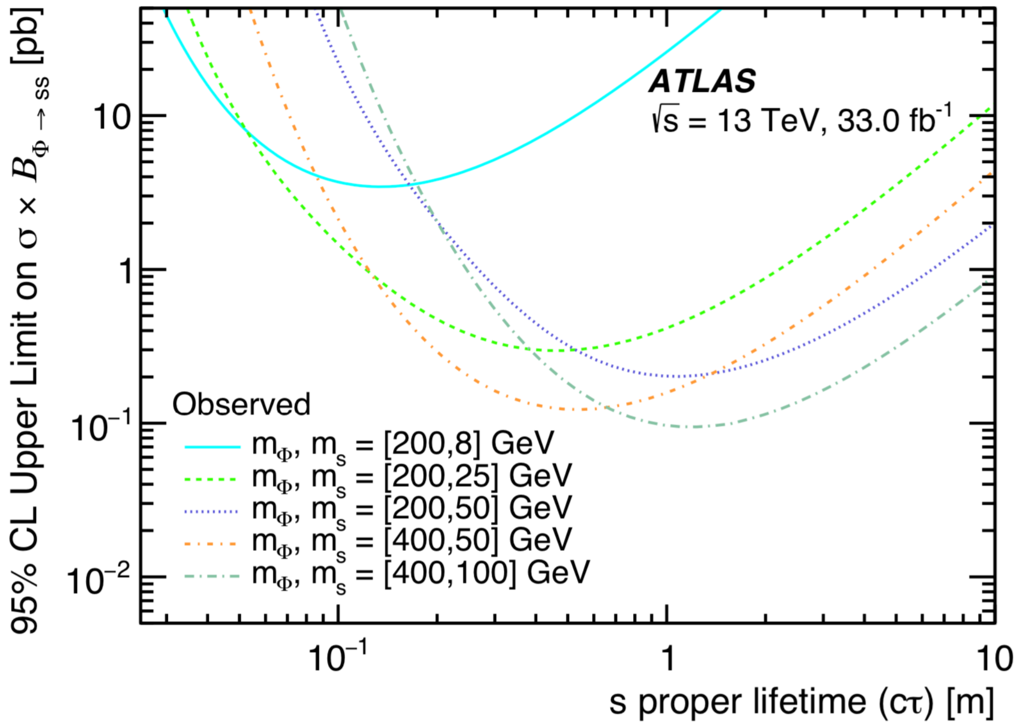
Displaced jets

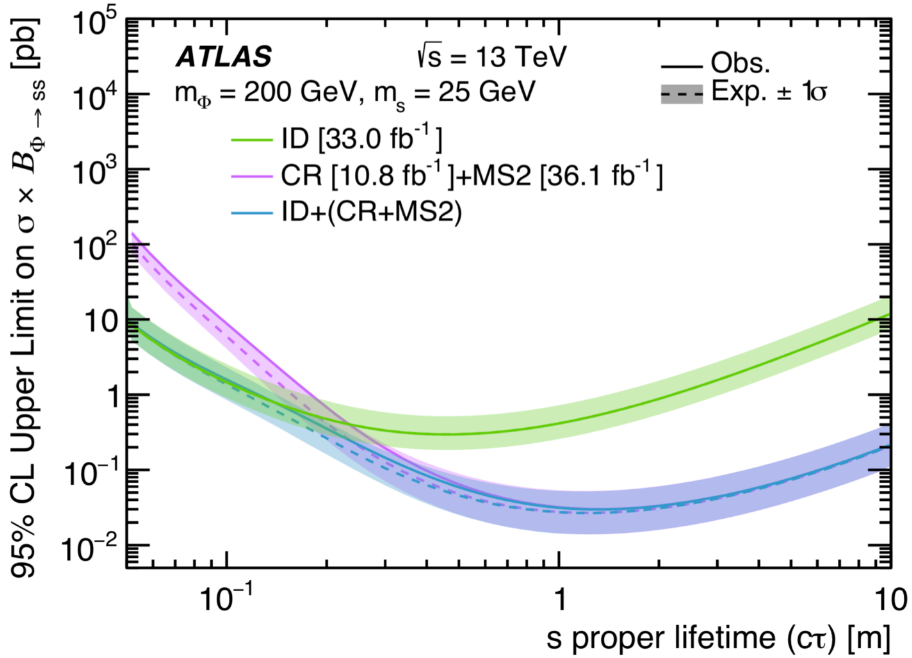
- Background estimated from data with CR: 1.2 ± 0.2 (stat) ± 0.3 (sys)
- Main signal systematic from displaced vertex reco.
- Observe 1 event passing all signal criteria in data.



Displaced jets

- Derive limits on (σ BR) on various signal masses.
- Orthogonal to MS and ID only analyses.

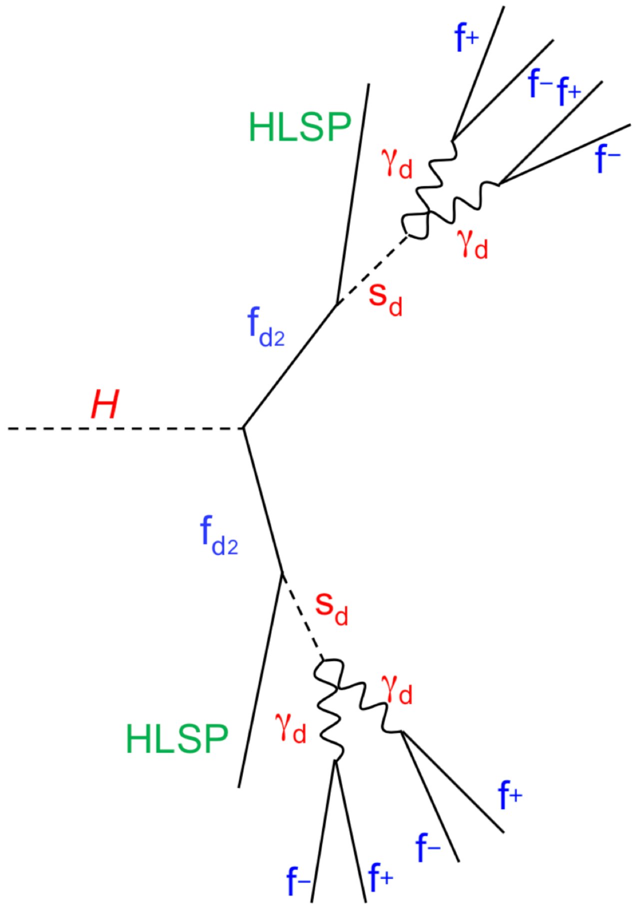




- Combination with MS and ID only analyses improves limits.

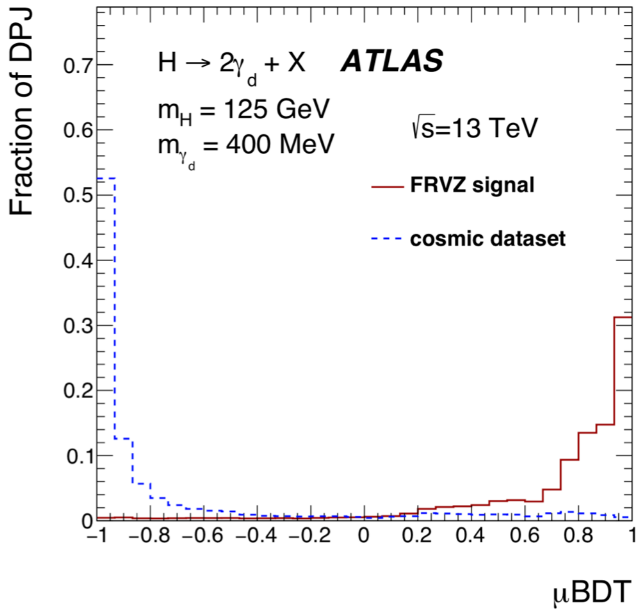
Collimated fermion jets

- Search for long-lived dark photons produced from the decay of a Higgs boson or a heavy scalar boson.
- Dataset 36fb^{-1} at 13 TeV.
- Decaying into displaced collimated Standard Model fermions (leptons or hadrons).
- Improved background rejection makes fully hadronic channel accessible.

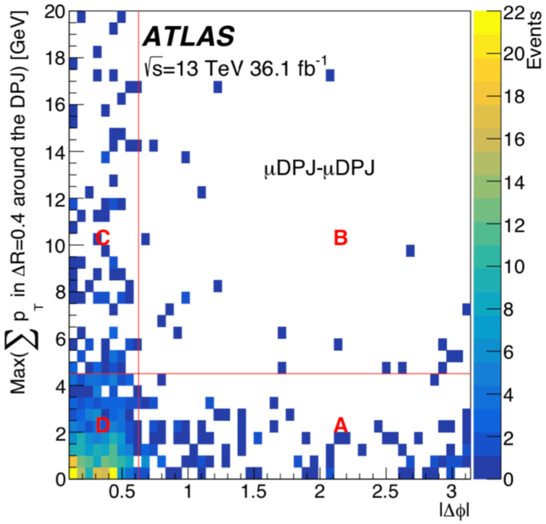


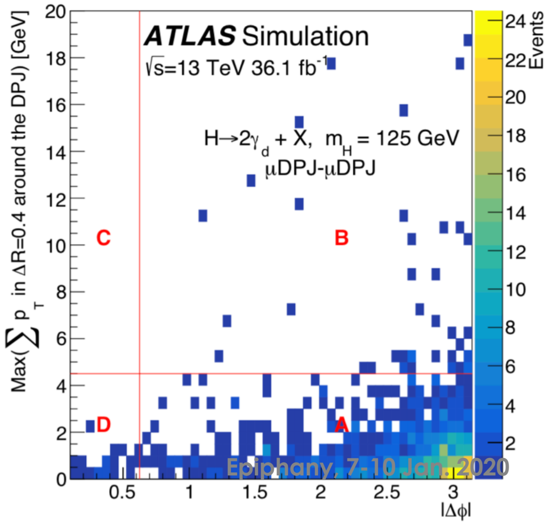
Collimated fermion jets

- Dark Photon signature searched for in outer calorimeter/MS
  - muons: look for 2 close by muons in MS
  - hadrons/electrons: look for jets with large Had/EM ratio.



- Selection based on BDT on DP jet candidate:
  - muonic jet, main background cosmics.
  - hadronic jet, main background multijet production.
- Data driven background estimation with CR.



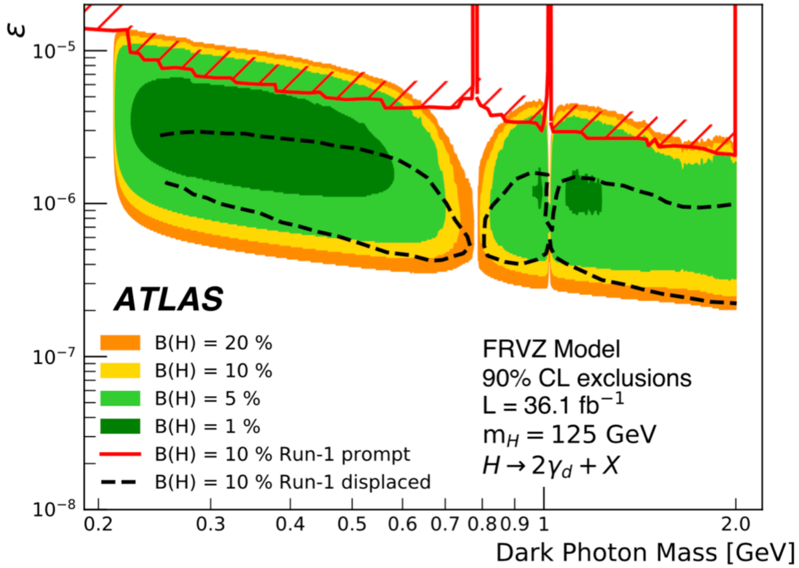


arXiv:1909.01246

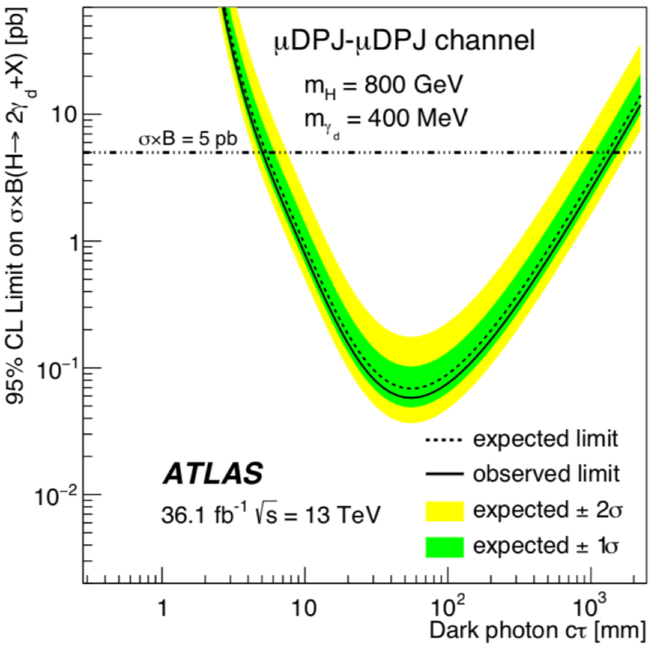
Collimated fermion jets

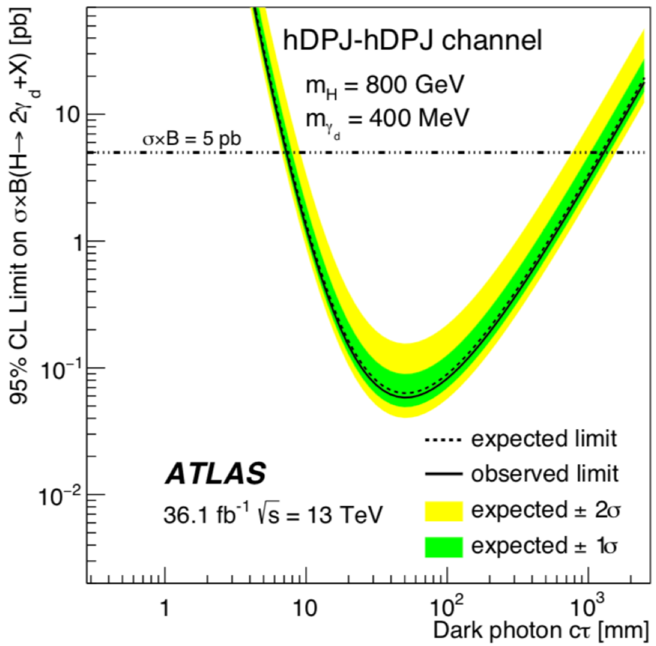
- No excess observed.
  - Limits on kinetic mixing parameter ε vs dark photon mass.

$$\tau \propto \left(\frac{10^{-4}}{\epsilon}\right)^2 \left(\frac{100\ \text{MeV}}{m_{\gamma_\text{d}}}\right)$$



  - Limits on production cross section times BR.





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ATLAS EXPERIMENT

Summary

- Discussed a few recent updates:
  - VV->JJ resonances (arXiv:1906.08589)
  - Di-jet resonances (arXiv:1910.08447)
  - W' (arXiv:1906.05609)
  - Heavy neutrino (arXiv:1904.12679)
  - Z' (arXiv:1903.06248)
  - Displaced jets (arXiv:1911.12575)
  - Collimated fermion jets (arXiv:1909.01246)
- Many more results with different final states expected with the full run-2 dataset.
- Run-3 increase centre-of-mass energy and luminosity.
  - Exploit upgrades in detector and trigger capabilities!
- Awaiting the unexpected!