

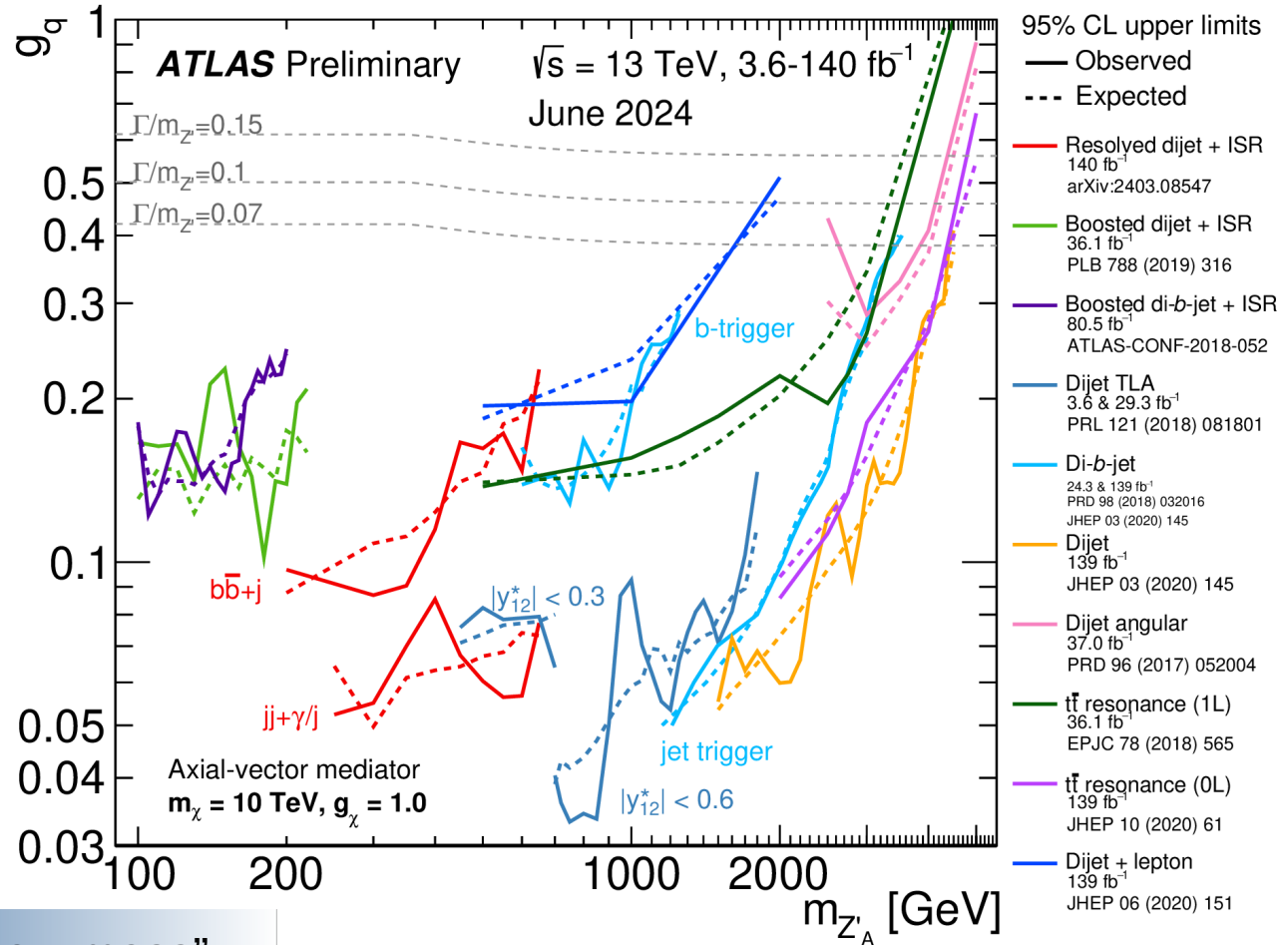
Searches for low mass BSM physics at ATLAS

Lake Louise Winter Institute 2025

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on behalf of the ATLAS Collaboration



Going to **lower** mass:
Explore **smaller** couplings
regions

- Triggering more difficult
- High momentum system boosted topologies (tau lepton and b-tagging challenging)

“Low mass”

Outline

Final states with:

- Single Resonances
 - $t \rightarrow qX$ with $X \rightarrow b\bar{b}$ JHEP 07 (2023) 199
 - $Z' + \text{Initial State Radiation}$ JHEP 01 (2025) 099 and Phys Rev D (2024) 032002
 - $H_{\text{SM}} \rightarrow Za$ arXiv:2411.16361
 - $H \rightarrow \gamma\gamma$ JHEP 07 (2023) 155
- Resonance pairs
 - $H \rightarrow aa \rightarrow \text{final states}$
- Not so “low mass” ...
 - Four leptons + $X/E_{\text{T, Miss}}$ JHEP 10 (2024) 130



Final states with:

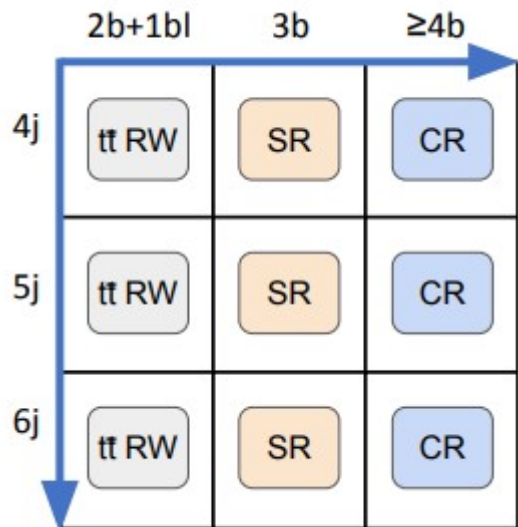
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$t \rightarrow Xq$ with $X \rightarrow b\bar{b}$

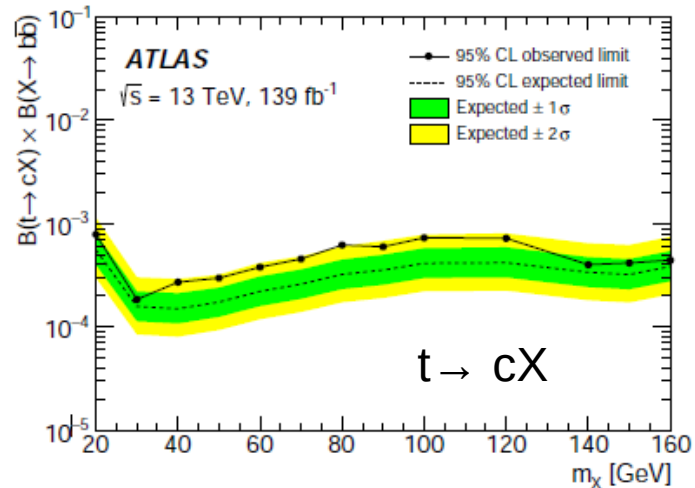
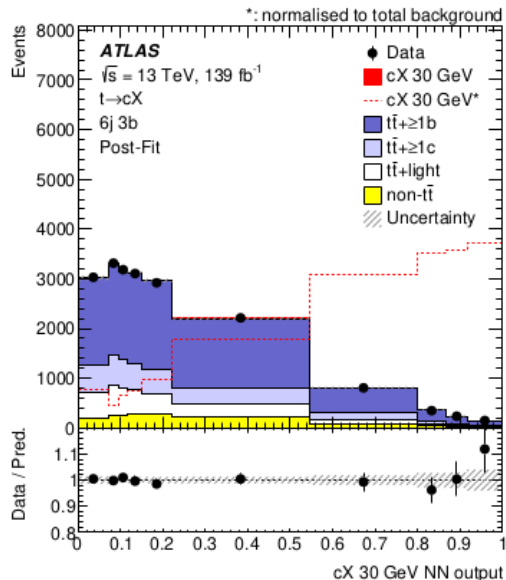
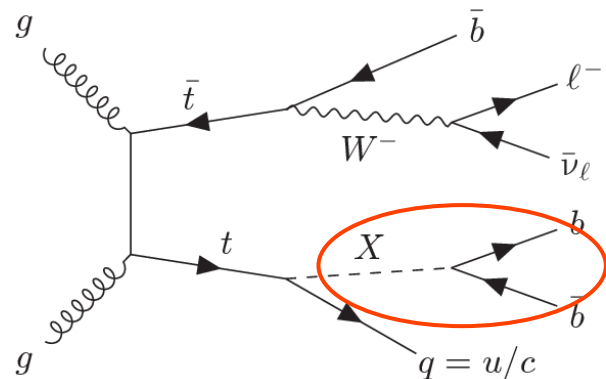
Look for X scalar (H_{BSM}) decaying in $X \rightarrow b\bar{b}$ in top pair associated process.

Two options $t \rightarrow uX$ and $t \rightarrow cX$ (FCNC process)

Use pDNN to distinguish sig vs bkg

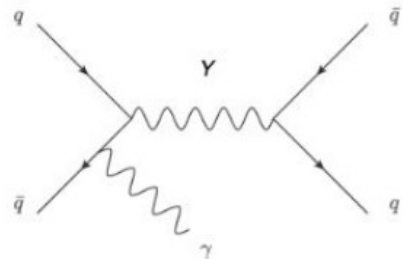


Multijet events with multi b-jets



Dijet + ISR

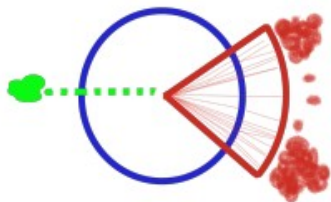
JHEP 01 (2025) 099



Phys Rev D 110 (2024) 032002

Boosted Regime:

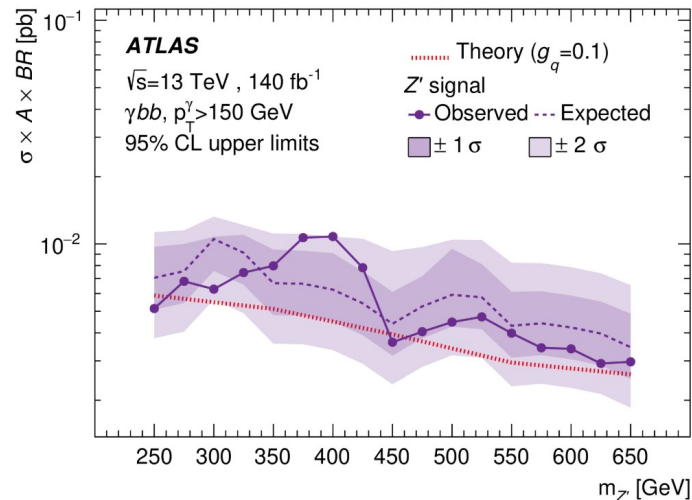
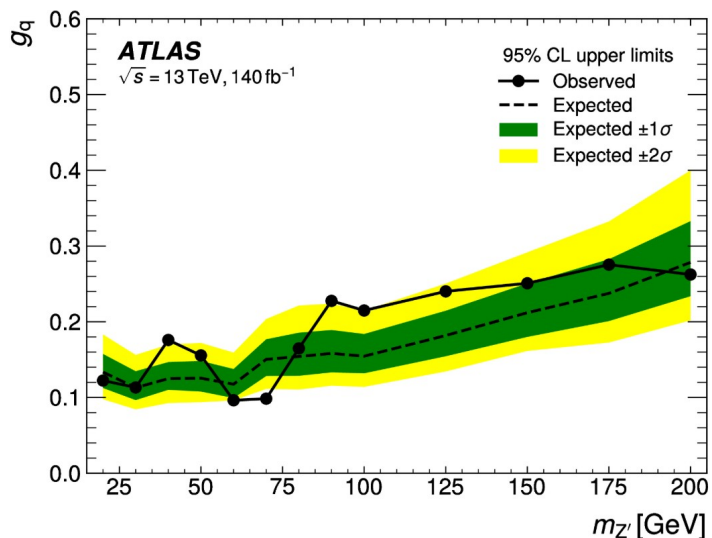
Single hard photon (>150 GeV) trigger
 One large $R=1$ jet (back to back)
 → huge QCD background
 Signal regions defined by D_2 and η_γ



Resolved Regime:

standard bump-hunt search on dijet mass spectrum (m_{jj} or m_{bb}) → $p_{T,\gamma} > 150$ GeV or $P_{T,J1} > 475$ GeV
 background estimated from functional fit to data
 → search for narrow width signals (width/mass $< 15\%$)
 optimise event selection, aiming simultaneously at:

- smoothly falling background shape
- increase S/B ratio



$H_{SM} \rightarrow Za$

Observed (Expected) limit BR($H \rightarrow$ invisible) is 10.7 (7.7)% from PLB 842 (2023) 137963

arXiv:2411.16361

Search for a light resonance produced in association with a Z boson from SM higgs decays

- Mass range 0.5-4 GeV, focusing at low masses
 - a decays hadronically, reconstructed as a single jet (large boost)
 - Z leptonic decays
 - Background mainly from Z + jets
- Targeting 2HDMS(s) or ALP

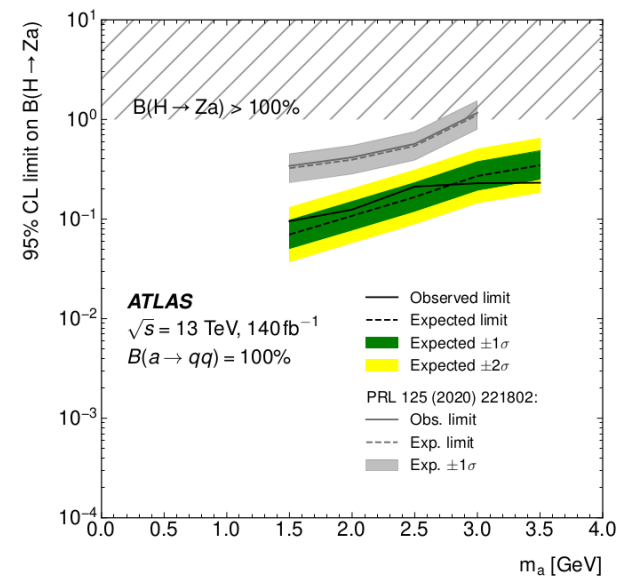
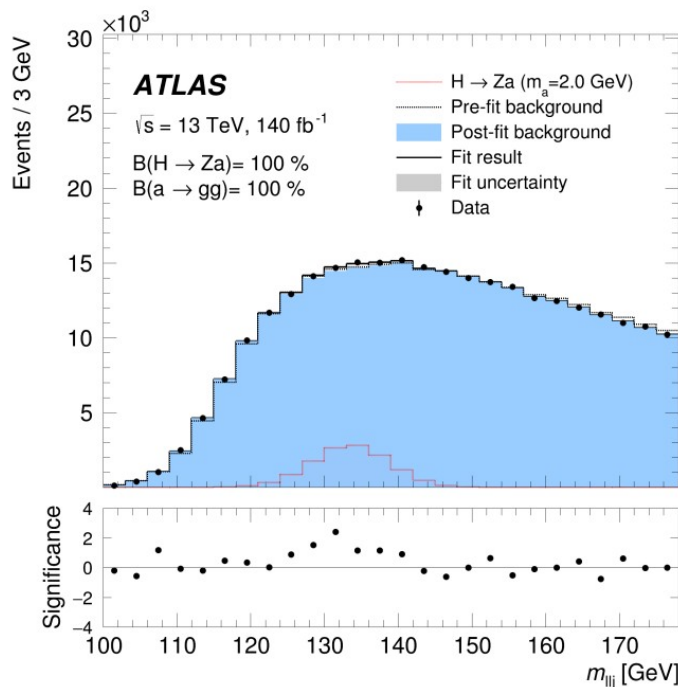
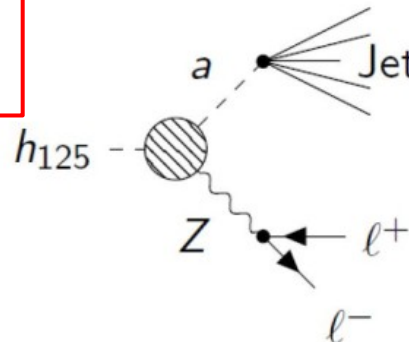
Background reweighting



$m(a)$ regression



Signal vs background classification

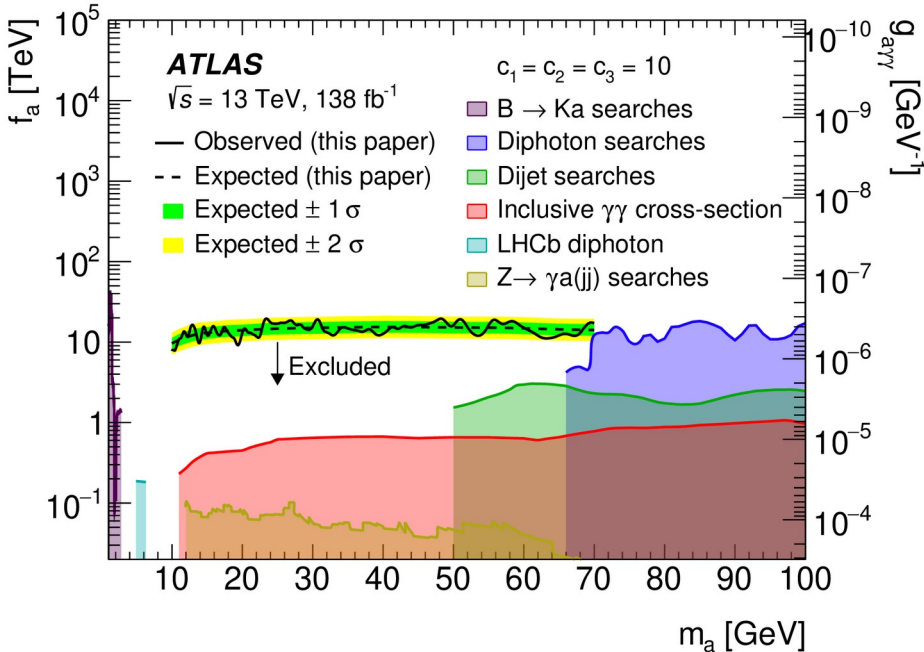
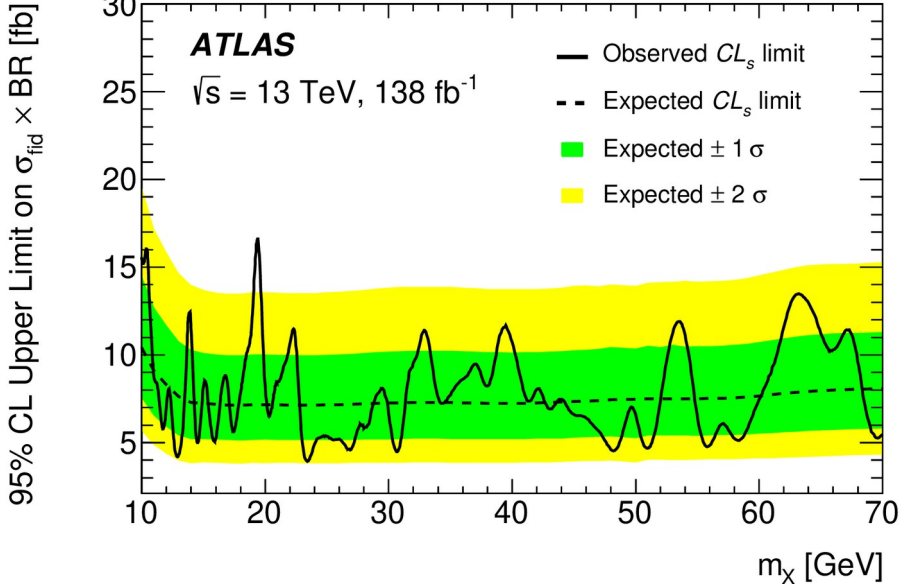


Also limits for $B(a \rightarrow gg) = 100\%$

X → γγ

Gap at low masses in γγ resonant searches [arXiv: 1702.02152](https://arxiv.org/abs/1702.02152)
→ Poorly explored region ~5 to ~80 GeV

Low mass $10\text{GeV} < M_x < 70\text{GeV}$
Additional selection $P_t^{\gamma\gamma} > 50\text{ GeV}$ to reduce trigger simulation uncertainties for collimated photon
Background template: $\gamma\gamma$ (from MC) + yj (data driven)
→ analytical function



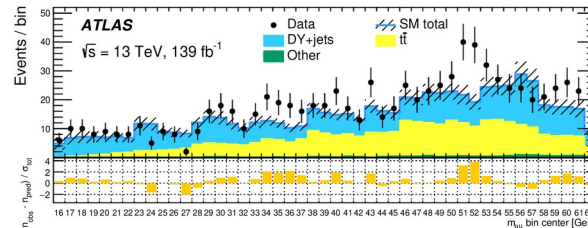
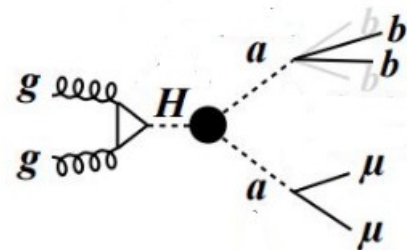


Final states with:

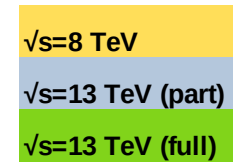
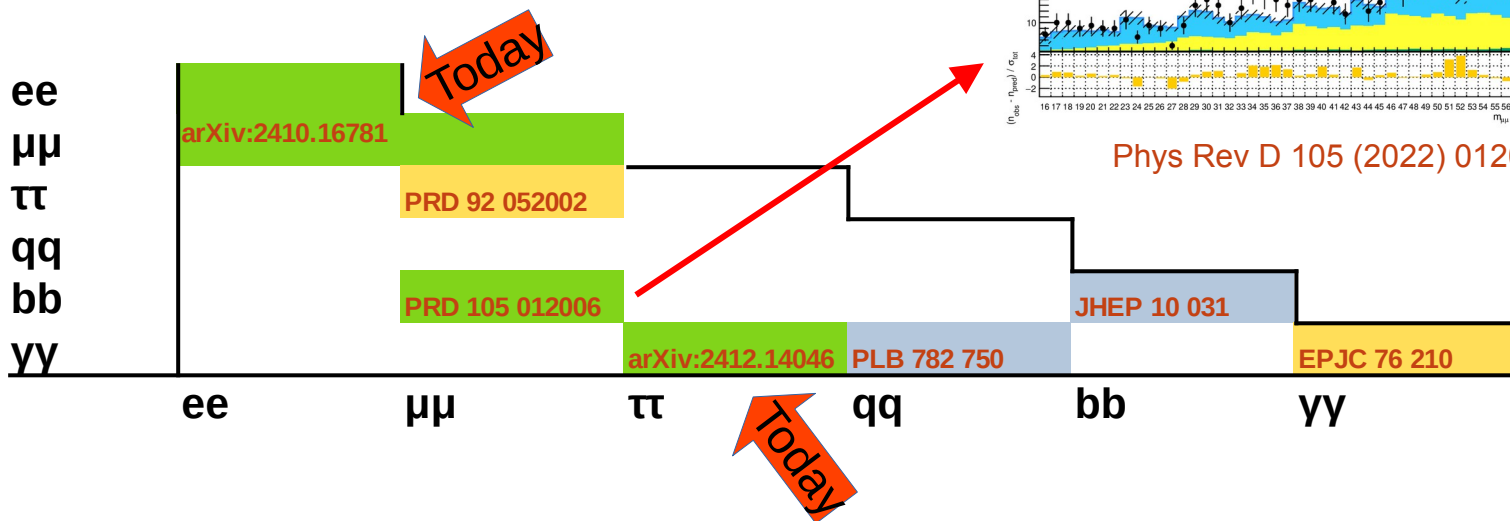
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Resonance Pairs

Addressing topologies with pairs of BSM particles decaying in various final states



Phys Rev D 105 (2022) 012006



$H_{SM} \rightarrow aa \rightarrow \gamma\gamma \tau_h \tau_h$

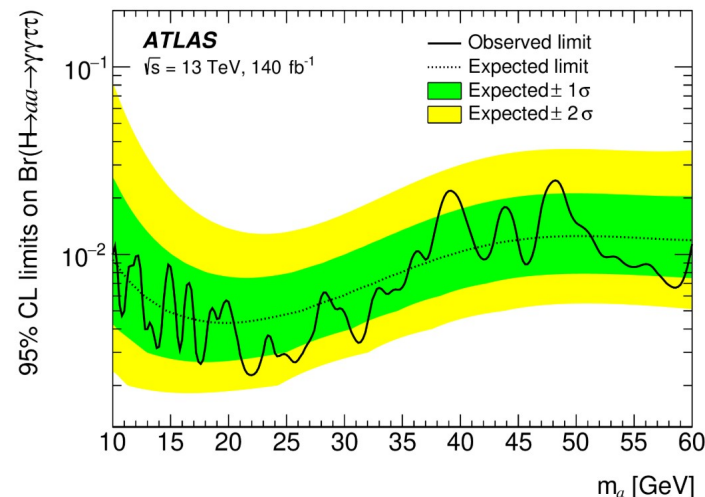
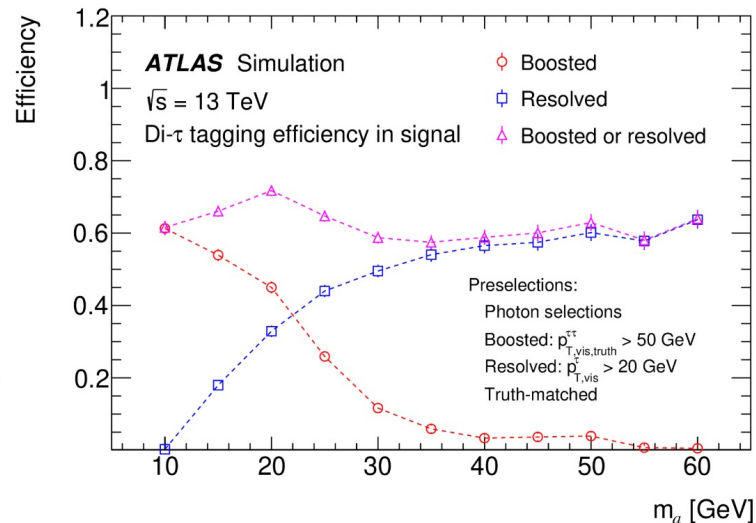
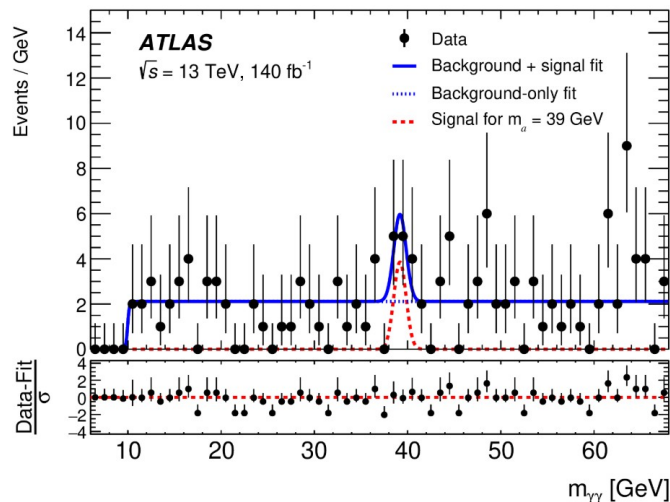
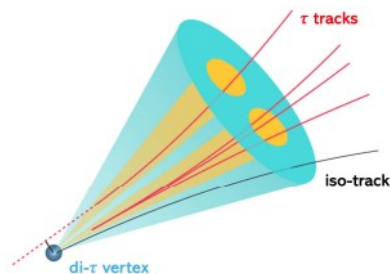
Based on $X \rightarrow \gamma\gamma$ search
 → In addition two hadronically decaying taus (boosted)

Due to $E_{T, Miss}$ $m(\tau\tau)$ not used in fit
 Only in event selection (BDT)

→ only $m(\gamma\gamma)$ in fit

Main background:

- Irreducible $\gamma\gamma$ (includes also $\tau\tau$ fakes)
- Reducible γj and $j j$

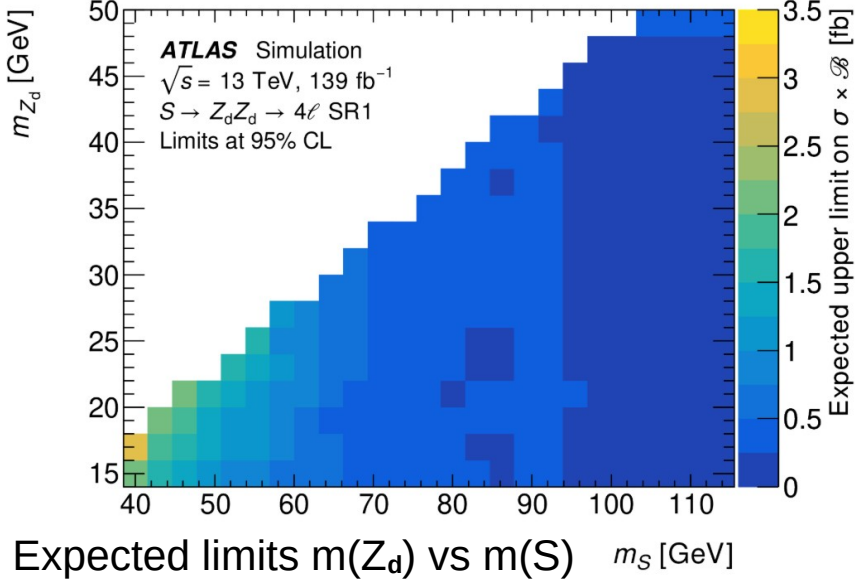
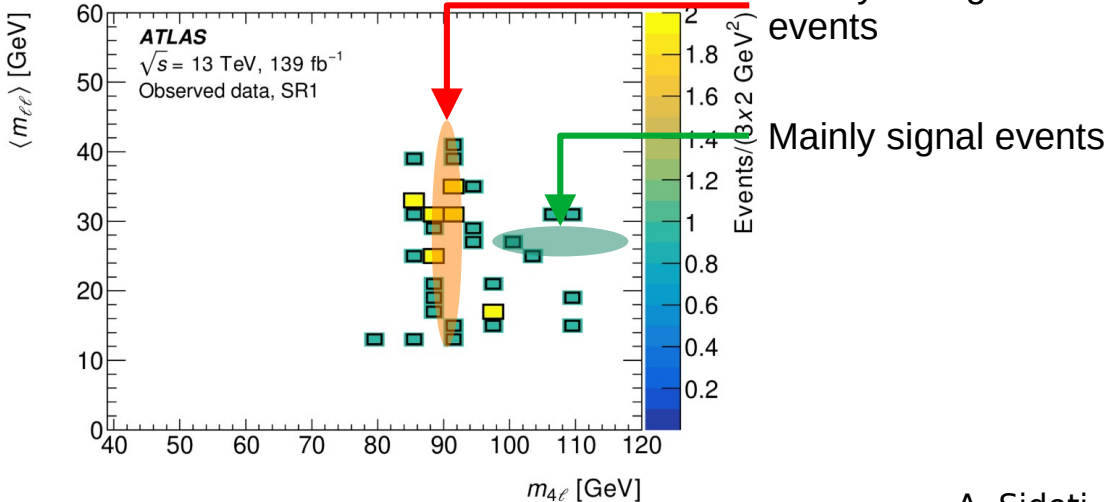
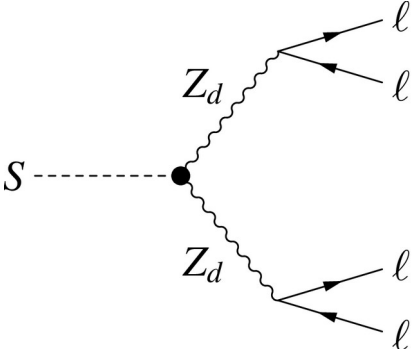


S → Z_dZ_d → 4 leptons

Searching for additional dark Z in eeee, μμμμ or eeμμ pairs

→ Two m_{4l} invariant regions 15 < m_{4l} < 115 GeV and 130 < m_{4l} < 800 GeV

Dominant background ZZ* → 4l from MC
Z+jets and tt smaller contribution estimated from data

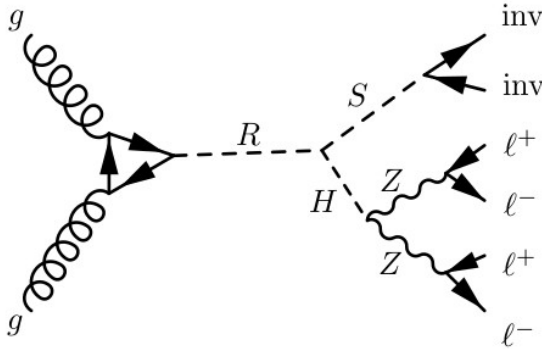




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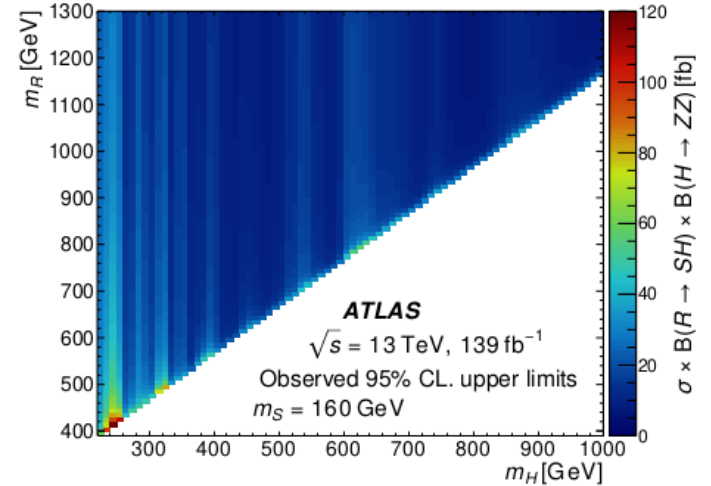
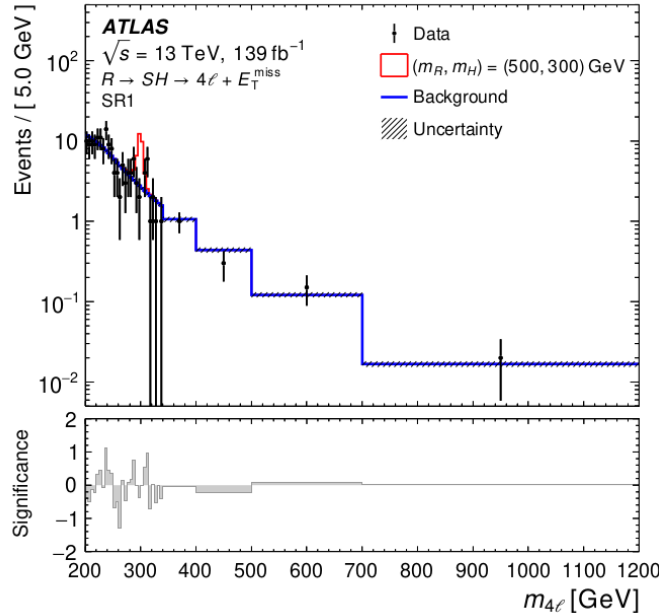
Four leptons + X/E_{T, Miss}



R(CP-even) in [390,1300] GeV
 H(CP-even) in [220,1000] GeV
 m(S) set at 160 GeV

Final state from resonance +
 H → ZZ → 4 leptons (M_{4ℓ} > 200 GeV)

Three SR according to n_{jet}
 multiplicity, E_{T, Miss} and P_T^{4ℓ}





Summary

- ▶ Beyond Standard Model Physics can hide at **low mass** with **small couplings**
- ▶ Large integrated luminosity → Exploit the largest datasets ever collected by LHC at the highest center of mass energy
- ▶ Improving reconstruction and analysis techniques enhances BSM searches sensitivity
- ▶ Run3 data are being studied
- ▶ Some intriguing discrepancies to be followed up in Run3