ATLAS Highlights

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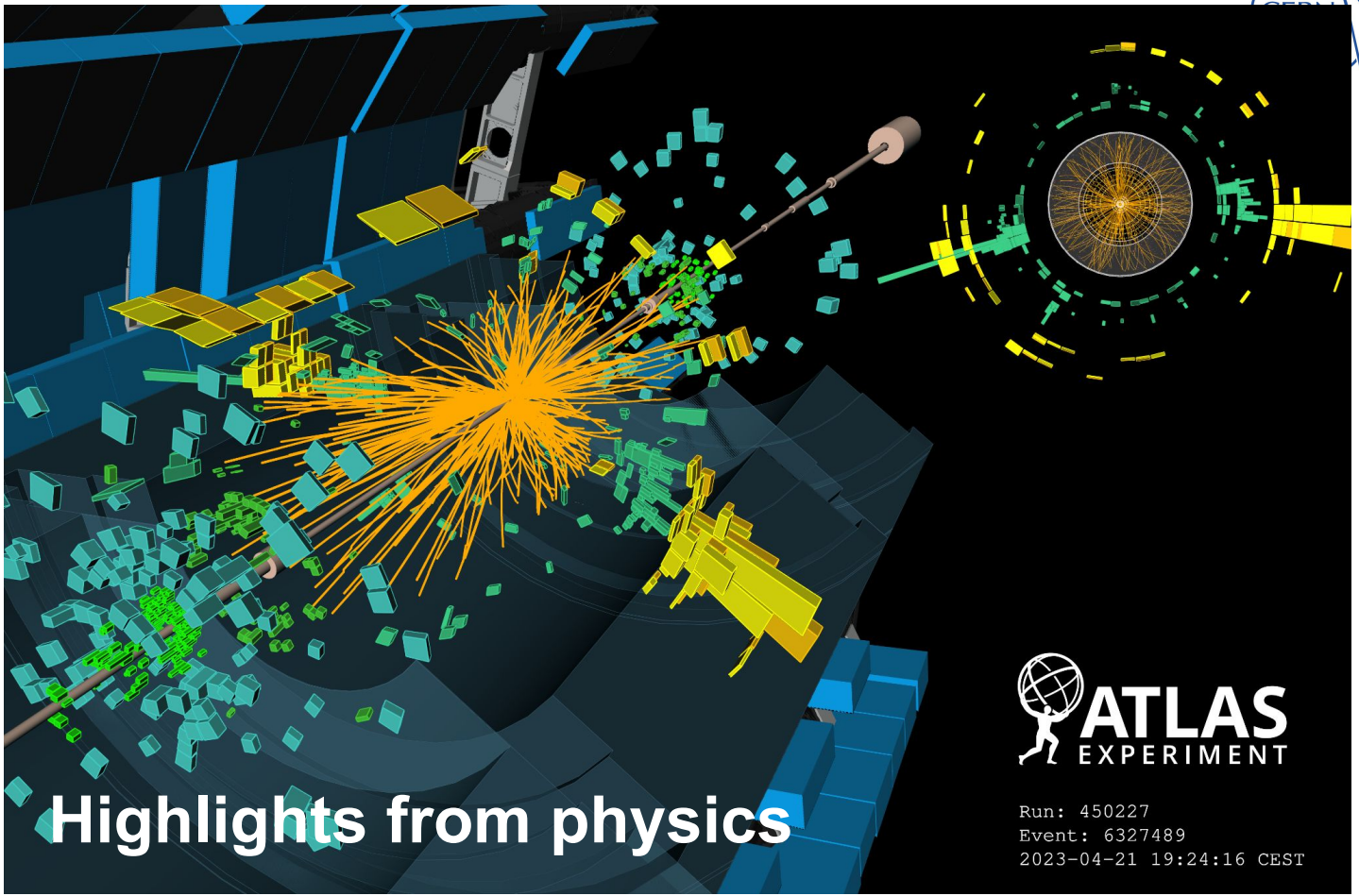
On behalf of the ATLAS Collaboration

FCPPN/L Workshop
June 11, 2024

In this talk:
A selection of new results with data from Run 1, 2, and 3!

Impressive paper output of the collaboration**:**

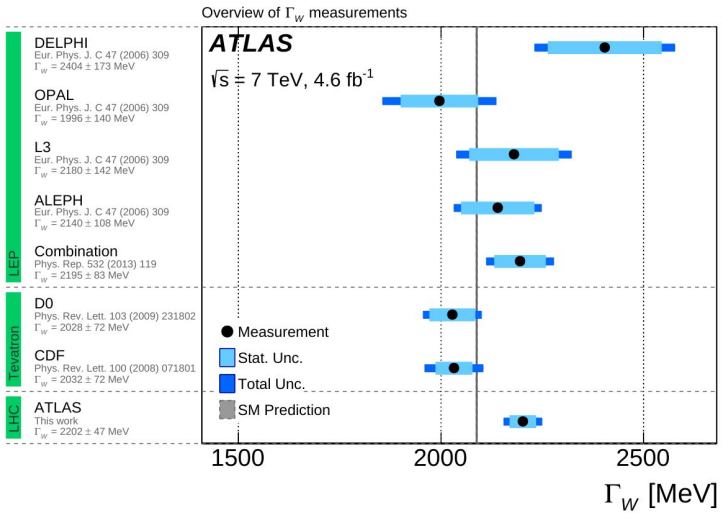
- **340 papers with full Run 2 dataset**
- **9 Run 3 papers**

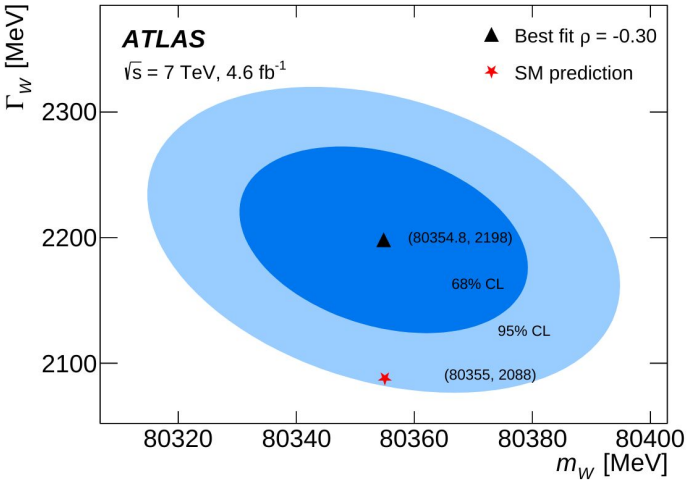


Highlights from physics

Measurement of the *W* boson mass and width

- **First measurement of the *W* width** at the LHC in combined fit with *W* mass
- Result achieved by analysing kinematic spectra of *W* decays into electrons and muons
- Most precise single-experiment Γ_W measurement to date!



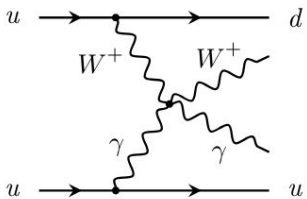


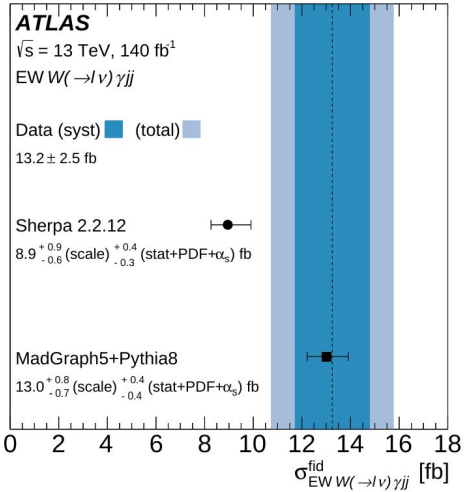
- Result consistent with SM predictions within 2σ
- $\Gamma_W = 2202 \pm 32 \pm 34$ MeV (SM: 2088 ± 1 MeV)

arXiv:2403.15085, Physics briefing

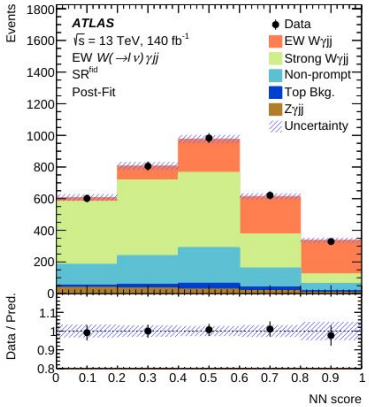
Electroweak $W\gamma jj$ production

- Observation of the electroweak production of a W boson and a photon in association with two jets
  - Sensitive to the quartic gauge boson couplings via VBS!
- Fiducial and differential cross section measurement

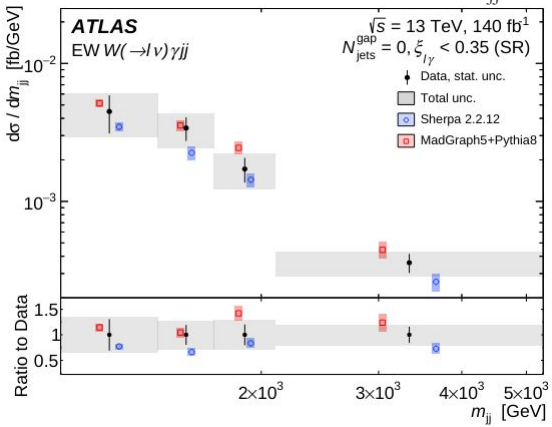




Neural networks deployed to separate especially strong from EW Wγjj production



Differential cross section as function of invariant mass m_{jj}

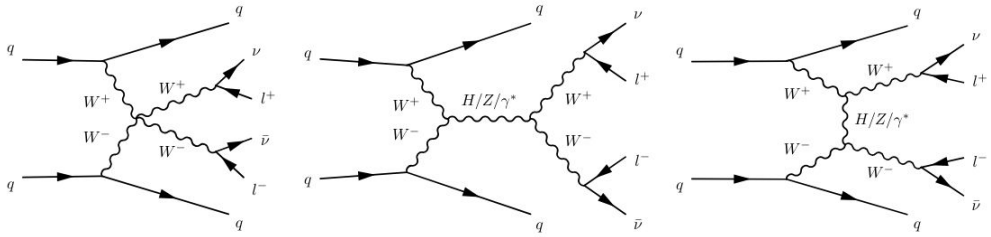


- Observed significance of the electroweak $W\gamma jj$ process > 6σ
- Measured fiducial cross section σ_{EW} = 13.2 ± 2.5 fb consistent with LO predictions
- Differential cross sections measured as function of six kinematic variables

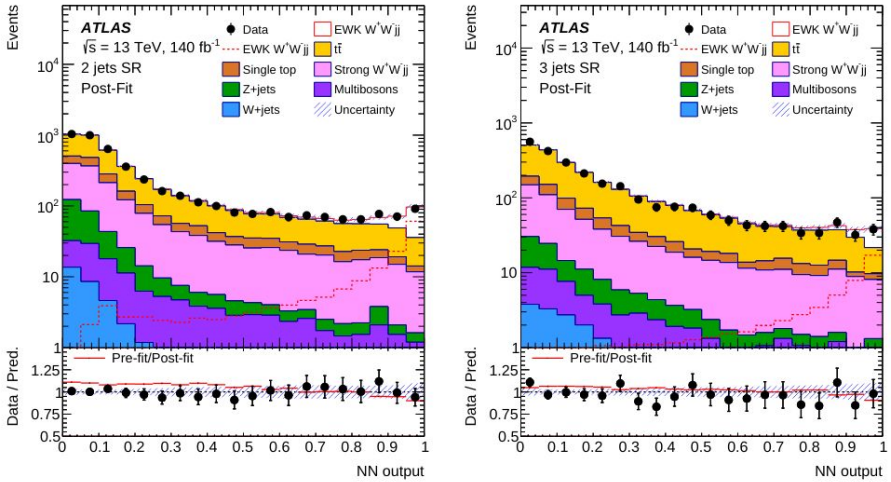
arXiv:2403.02809

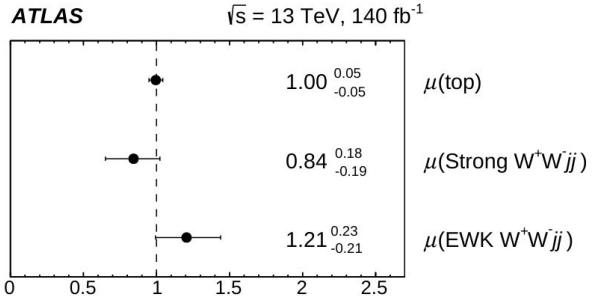
Electroweak W^+W^-jj production

- Observation of W^+W^- in association with jets
- Fiducial cross section measurement
- Different lepton flavor final states selected



A neural network is used to separate the signal from top quark and strong W^+W^-jj production



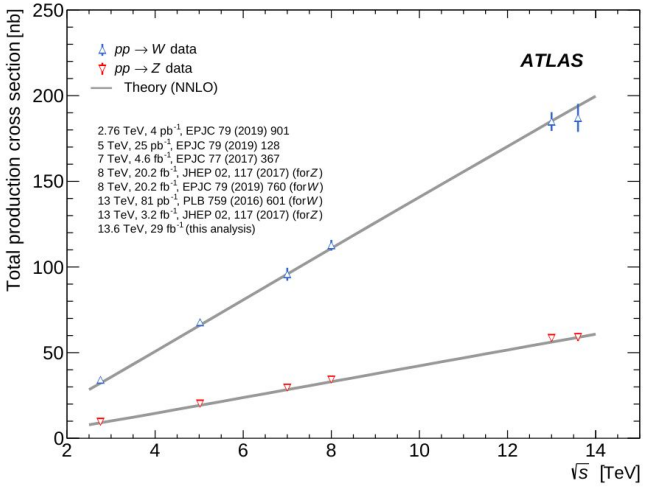


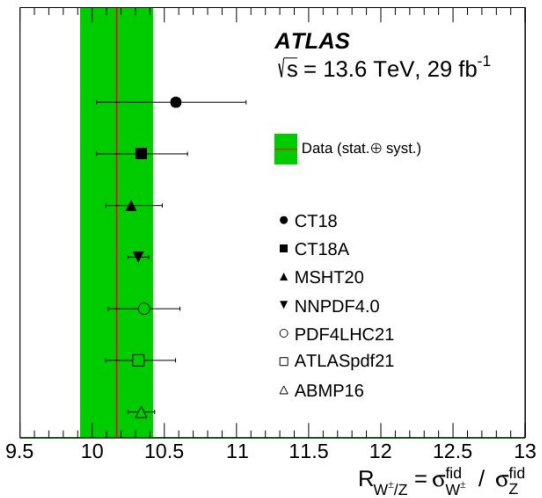
- Significance of 7.1σ observed
- Measured cross section 2.7 ± 0.5 fb consistent with theoretical prediction
- Dominant uncertainty from limited data sample

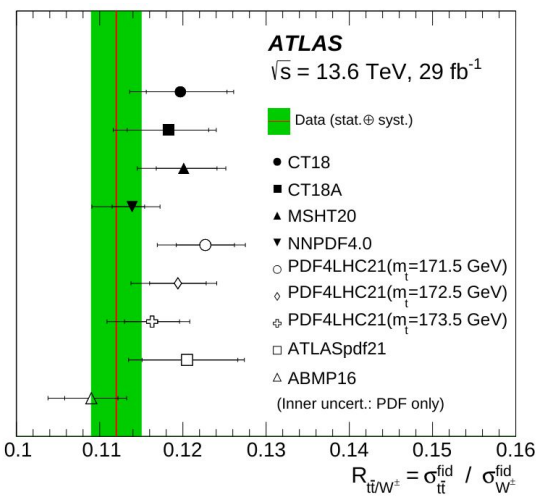
arXiv:2403.04869

W and *Z* production cross section measurement (Run 3 data!)

- Fiducial and total $W^{\pm}$ and *Z* boson cross sections measurement
- …and their ratios and the ratio of top-antitop pair and *W* boson fiducial cross sections







- *W* and *Z* boson cross sections are **in good agreement with the SM predictions**
- top-antitop over *W* boson fiducial cross section ratios slightly overestimated by some theoretical predictions
  - Consistent with Run 3 top-antitop cross-section measurement

Measured fiducial cross section values

- $W^{+} \rightarrow \ell^{+} \nu = 4250 \pm 150$ pb
- $W^{-} \rightarrow \ell^{-} \bar{\nu} = 3310 \pm 120$ pb
- $Z \rightarrow \ell^{+} \ell^{-} = 744 \pm 20$ pb

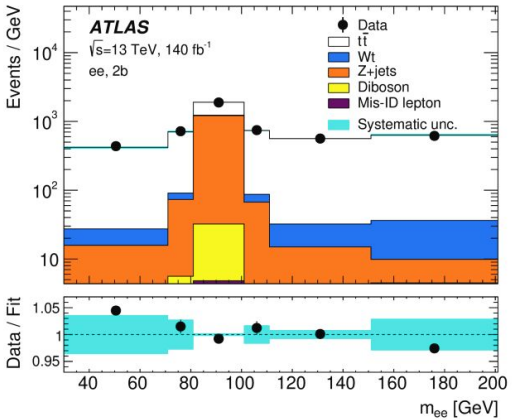
arXiv:2403.12902, Physics Briefing

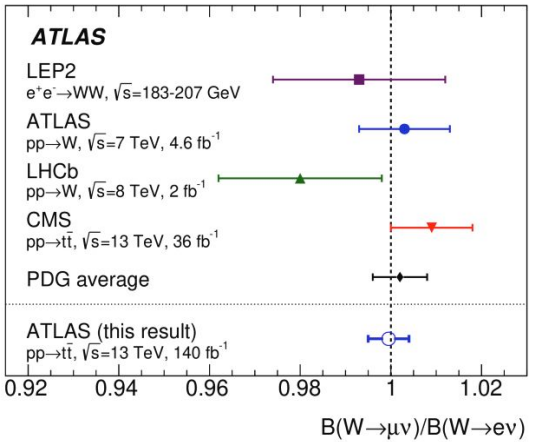
Probing lepton universality

- Lepton universality from W bosons from top-antitop pair decays measured by evaluating ratio $R_W^{\mu/e}$
- **Challenge**: Collect unbiased W sample
  - Systematic uncertainty be reduced by making a simultaneous measurement of the analogous ratio $R_Z^{\mu\mu/ee}$

$$R_{WZ}^{\mu/e} = \frac{R_W^{\mu/e}}{\sqrt{R_Z^{\mu\mu/ee}}} = \frac{\mathcal{B}(W \to \mu\nu)}{\mathcal{B}(W \to e\nu)} \cdot \sqrt{\frac{\mathcal{B}(Z \to ee)}{\mathcal{B}(Z \to \mu\mu)}}$$

Fit performed using double ratio. Uncertainties on electron and muon efficiencies cancel!





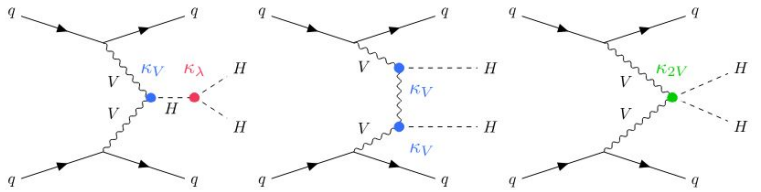
$R(\mu/e) = 0.9995 \pm 0.0045$

- Confirming SM at 0.5% level!
  - Improves single-experiment precision by factor of two!
- Adds to previous ATLAS $R(W \to \tau/\mu)$ result (Nature Physics 17, 813 (2021))

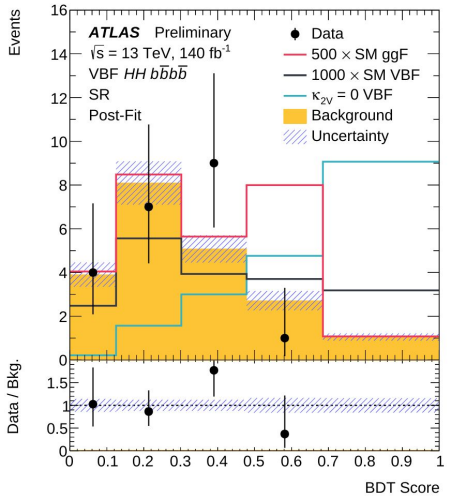
arXiv:2403.02133, Physics Briefing

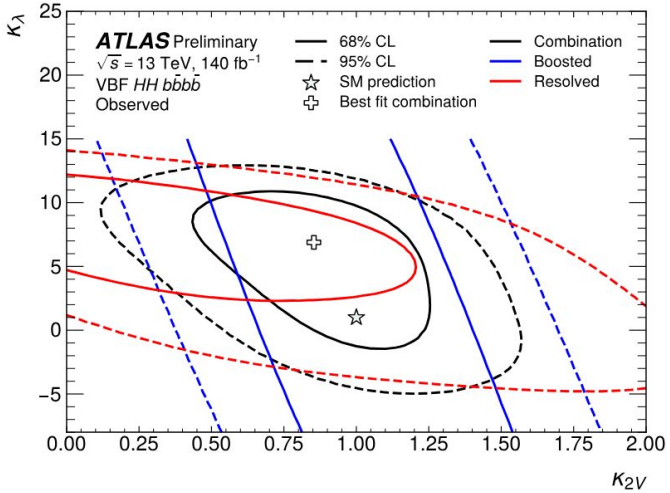
DiHiggs searches

- Search for boosted Higgs pair production via VBF in the *bbbb* final state
- Search sensitive to the **anomalous quartic couplings κ_{2v}** between two vector bosons and two Higgs bosons



BDT score used to separate signal from background



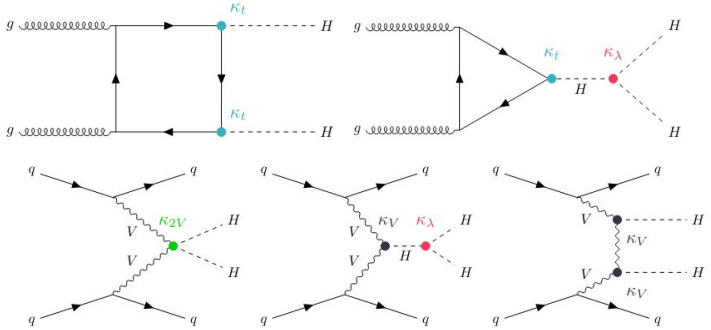


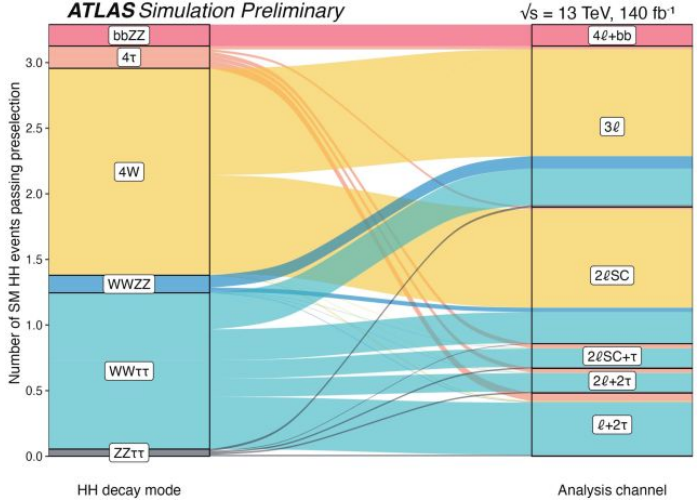
- Data agree with background only hypothesis
- Constraints when combining boosted and resolved results $0.55 < \kappa_{2V} < 1.49$
- $\kappa_{2V} = 0$ excluded with an observed significance of 3.8σ
- Statistically limited analysis

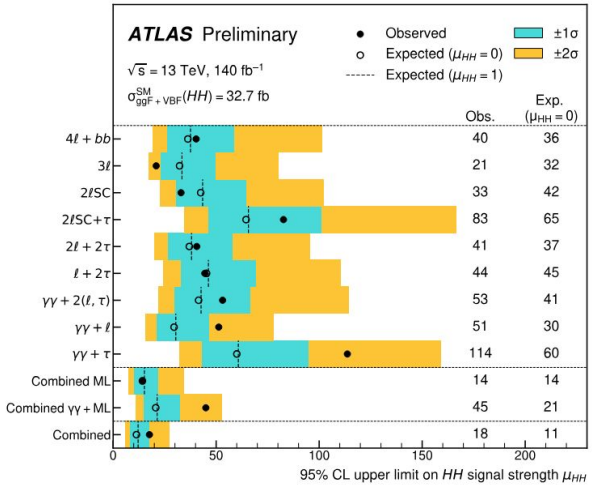
ATLAS-CONF-2024-003

DiHiggs searches

- Search for Higgs pair production in final states with leptons, taus and photons
  HH→ bbZZ, 4V, VVττ, 4τ, γγVV, γγττ
  - **Explored for the first time in ATLAS!**
- BDT scores are used to separate signal from background



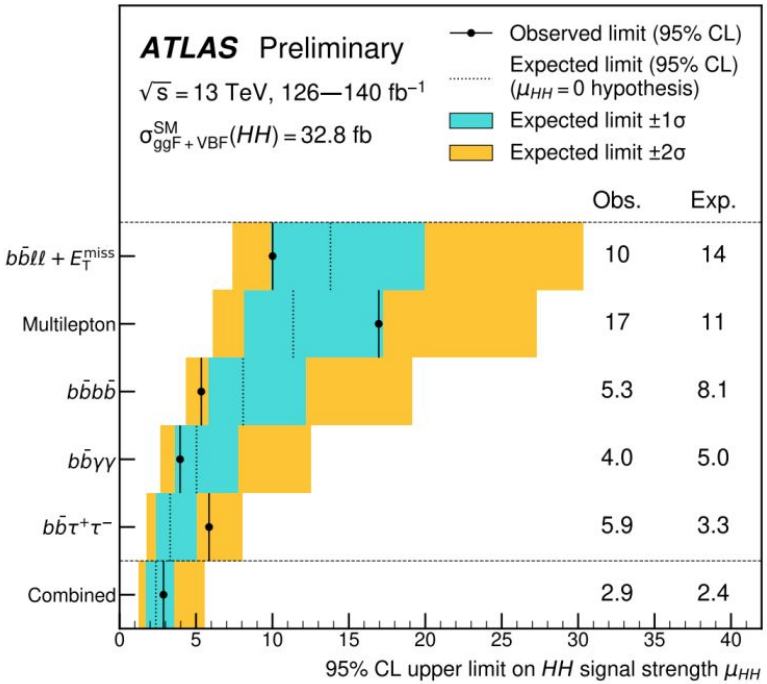




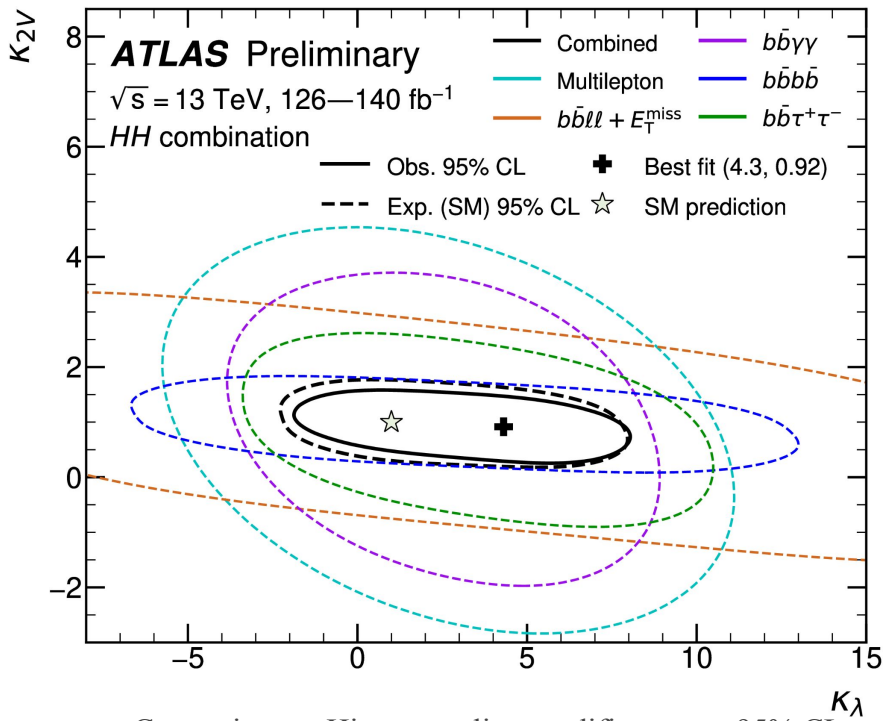
- Observed limits of 18 times the SM prediction are set on the *HH* signal strength μ
- Statistically limited analysis

ATLAS-CONF-2024-005, Physics Briefing

Legacy Run 2 *HH* combination



New combination of updated **diHiggs** searches using full Run 2 dataset



Constraints on Higgs coupling modifiers set at 95% CL

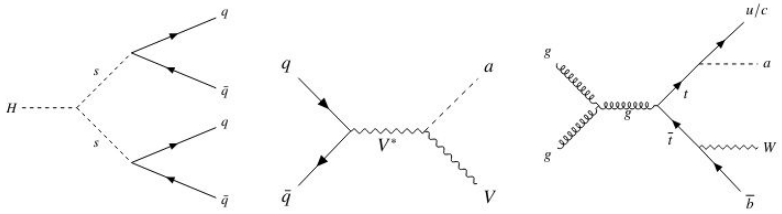
$-1.2 < \kappa_\lambda < 7.2$

$0.57 < \kappa_{2V} < 1.48$

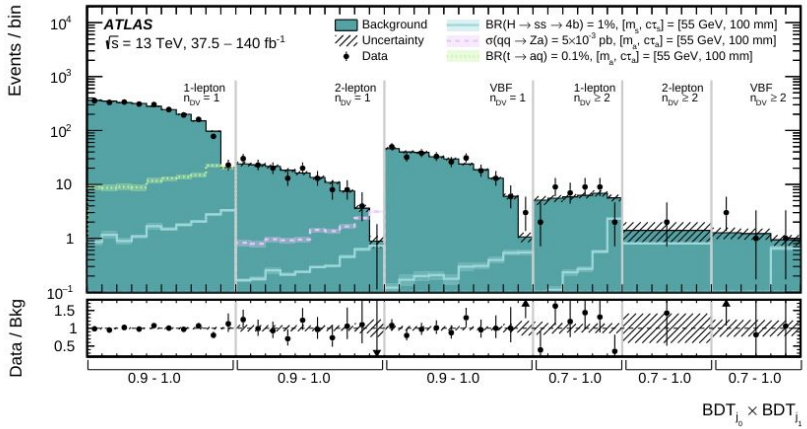
ATLAS-CONF-2024-006

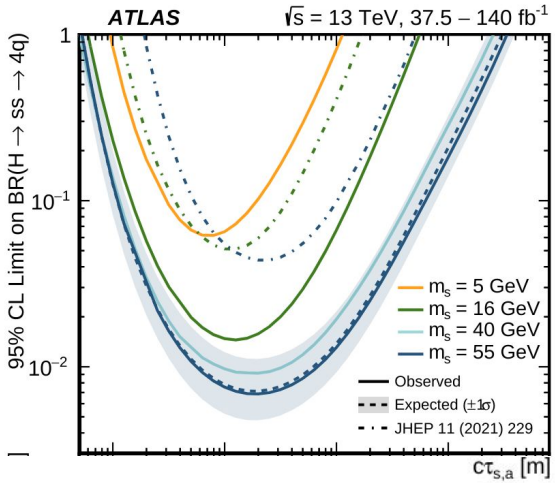
Light long-lived particles (LLPs) using displaced vertices

- LLPs ($c\tau \gtrsim 100\,\mu$m) with 5 GeV < m_s < 55 GeV that decay hadronically targeted
  - Possible with **improved track reconstruction pass** for large impact parameter tracks!
- All Higgs production modes included!
- Benchmark models from exotic Higgs decays to axion-like particles (ALPs) considered



Product of two BDT discriminants used to distinguish events with displaced from those with prompt jets





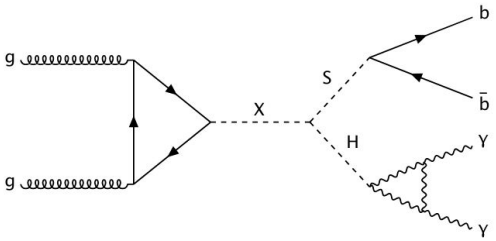
- No significant excess beyond the SM is observed
- Most stringent constraints to date on Higgs BR for $m_s < 40$ GeV and $1 < c\tau_s < 100$ mm!

arXiv:2403.15332

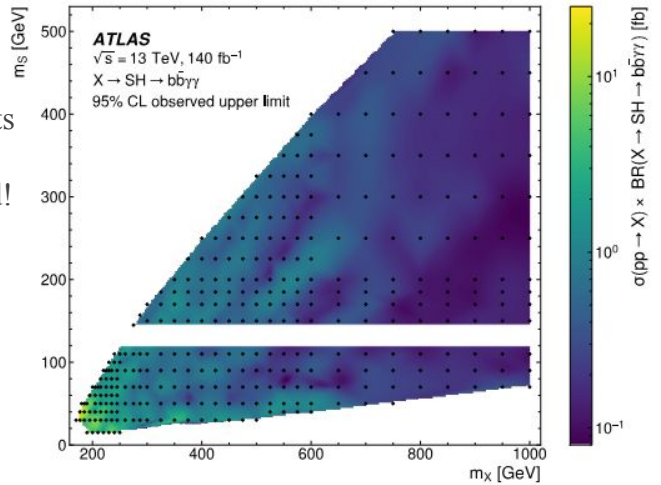
Heavy Higgs

Search for a heavy scalar X decaying into another scalar S and a Higgs boson H

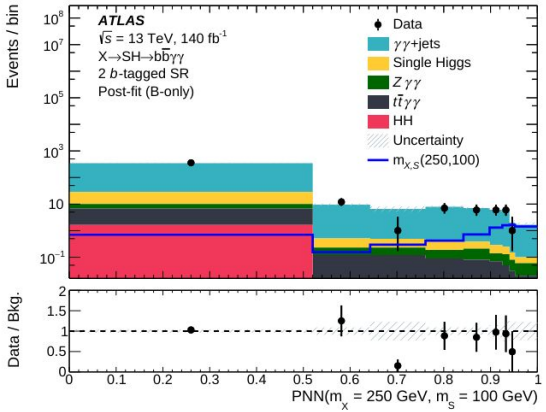
$X \rightarrow S(\rightarrow bb)H(\rightarrow \gamma\gamma)$

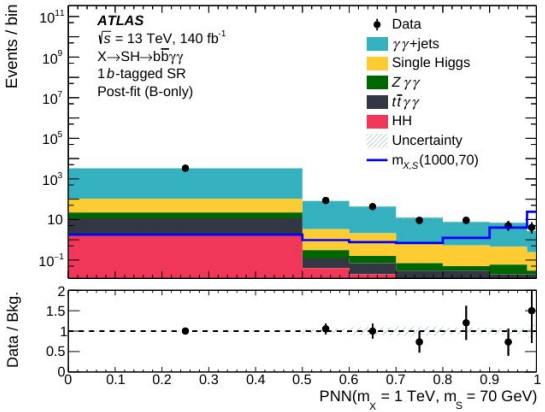


For setting limits 359 (m_X, m_S) pairs are probed!



Parameterised neural networks for signal discrimination in resolved and boosted decays



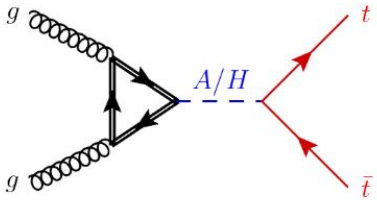


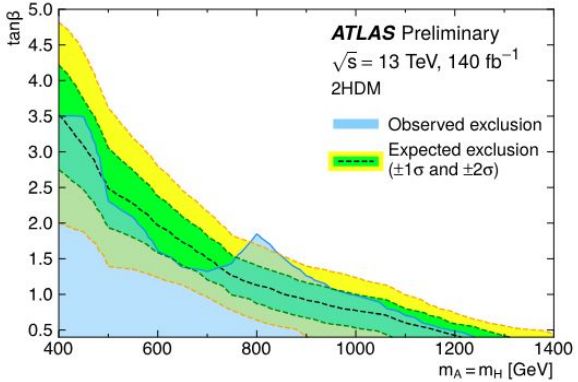
- No significant excess above the expected background is found
- Earlier LHC searches expanded to lower masses m_S and m_X
- Upper limits range from 39 fb to 0.09 fb
  - Excluding small CMS excess at (m_X, m_S) = (650,90) GeV

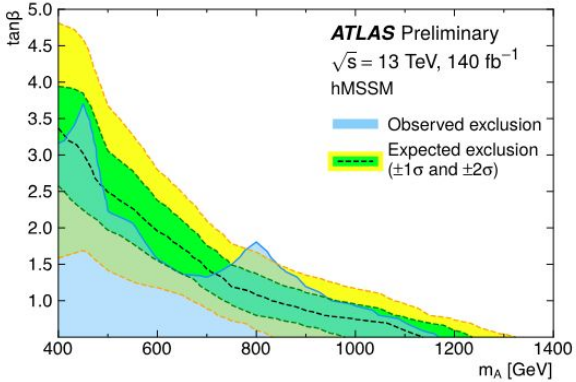
arXiv:2404.12915, Physics Briefing

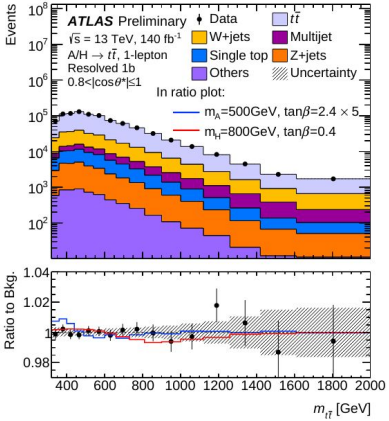
Heavy Higgs

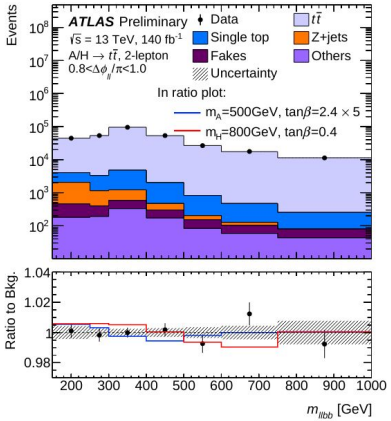
Search for heavy scalar H or pseudo-scalar A decaying into a top pair in a semi- or fully leptonic final state







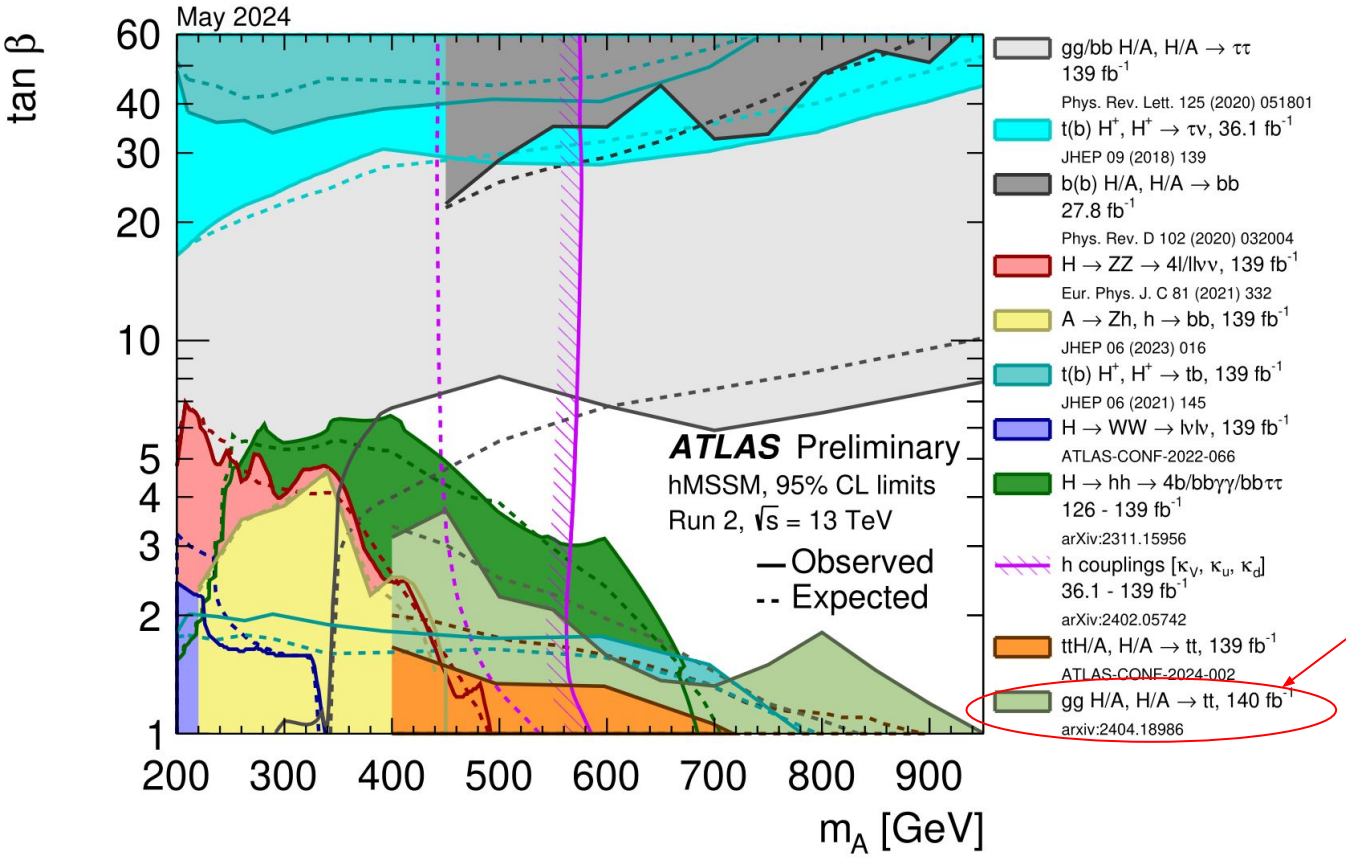




- No significant deviation from SM is observed
- **Most stringent constraints on the 2HDM** and **hMSSM** parameter space **for high m_A and low tanβ** to date

arXiv:2404.18986

Heavy Higgs summary plot



Excluded regions of [m_A, tanβ] plane excluded in the hMSSM via direct searches for heavy Higgs bosons

- *gg H/A , H/A→ tt* adds to exclusion at low tanβ!

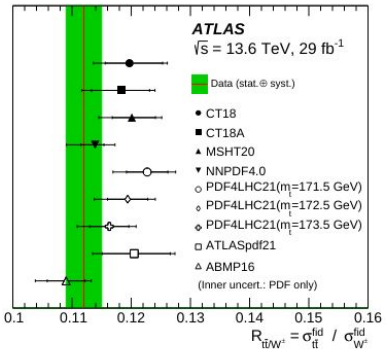
ATL-COM-PHYS-2024-195

We try to keep up the sustained rich physics production and high profile results!

Thank you!

W and *Z* production cross section measurement (2022 data!)

- Fiducial and total *W*± and *Z* boson cross sections, their ratios and the ratio of top-antitop quark pair and *W*-boson fiducial cross sections are measured in proton–proton collisions
  - *ttbar* over *W*-boson fiducial cross-section ratios are slightly overestimated by some of the theoretical predictions



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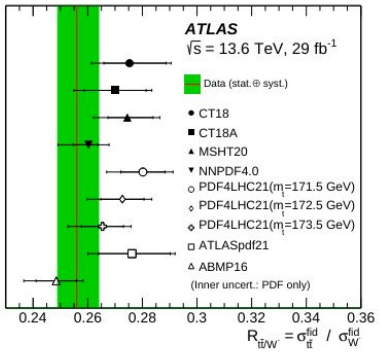

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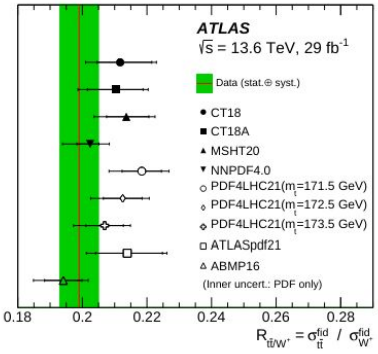
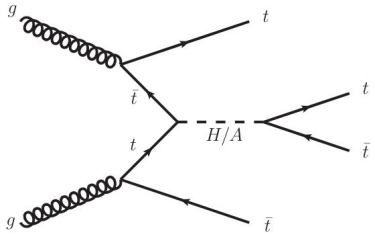


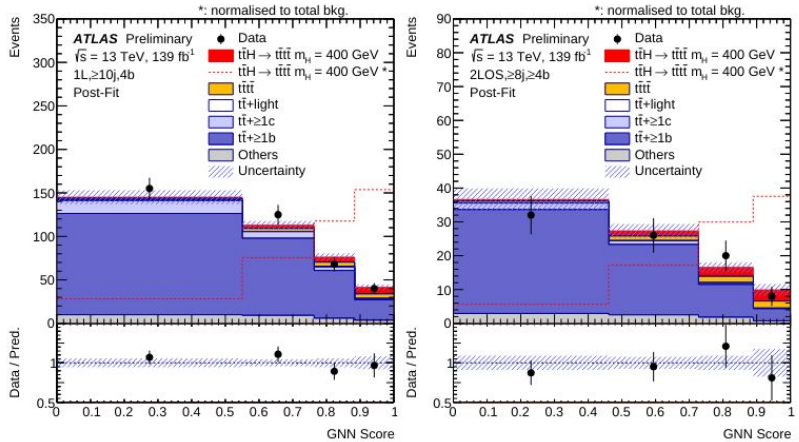
arXiv:2403.12902

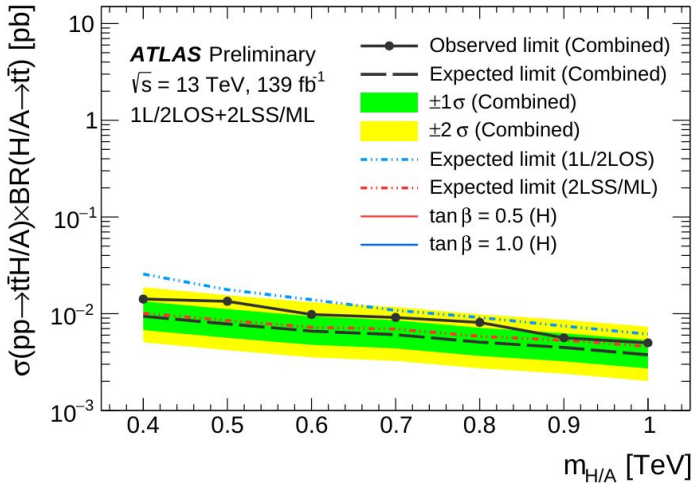
Heavy Higgs

Search for a heavy scalar H or pseudo-scalar A predicted by 2HDM in association with a top pair, with the H/A decaying to a top pair and opposite sign leptons in the final state



GNN is used to optimise the signal-background discrimination





- Results combined with previous search from ATLAS with multilepton final states
- Combined observed limit ranges from 14.2 fb at $m_{A/H}$ of 400 GeV and 5.0 fb at 1000 GeV