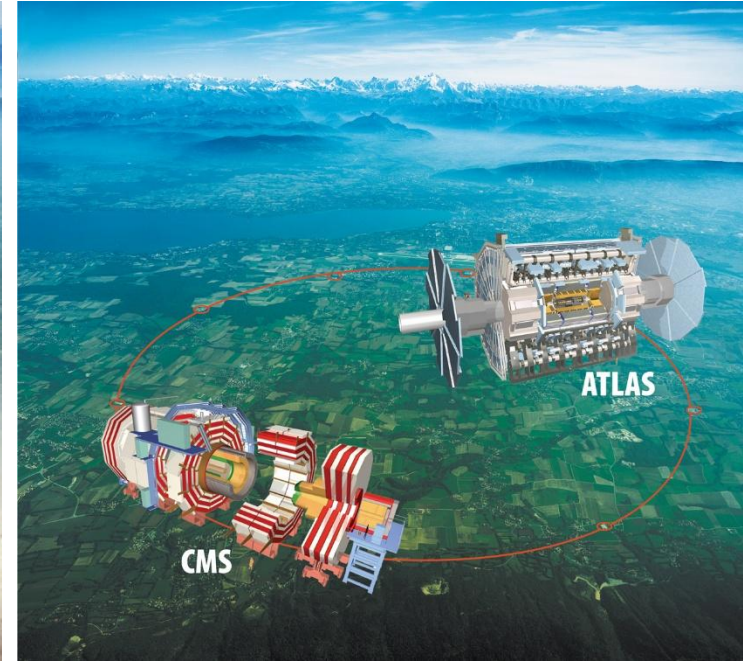
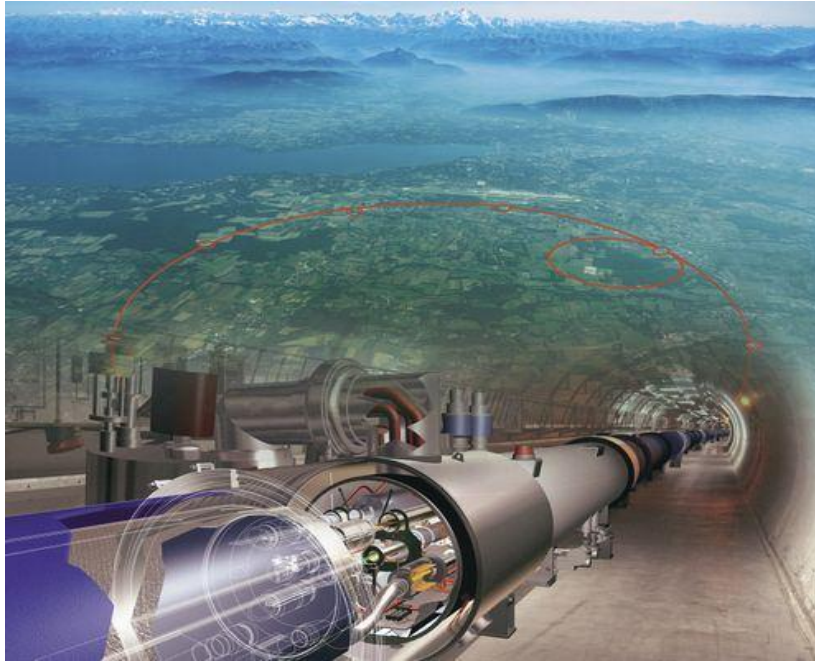


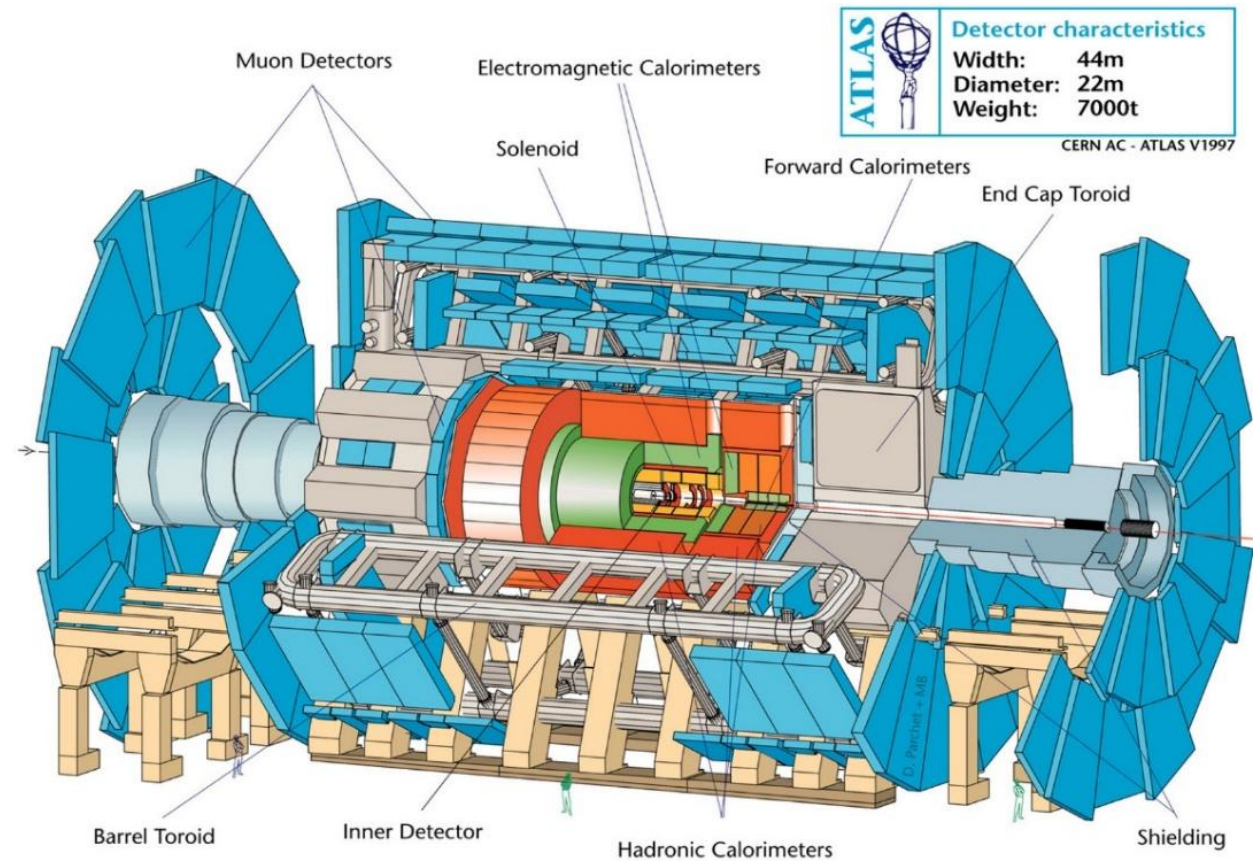
Highlights from the ATLAS Experiment

Haijun Yang (for the ATLAS Collaboration)

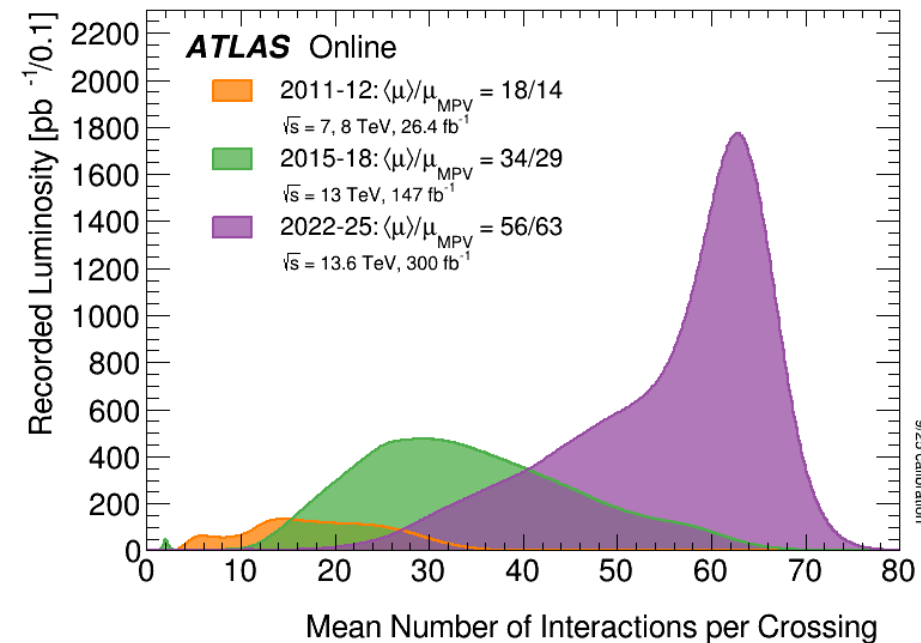
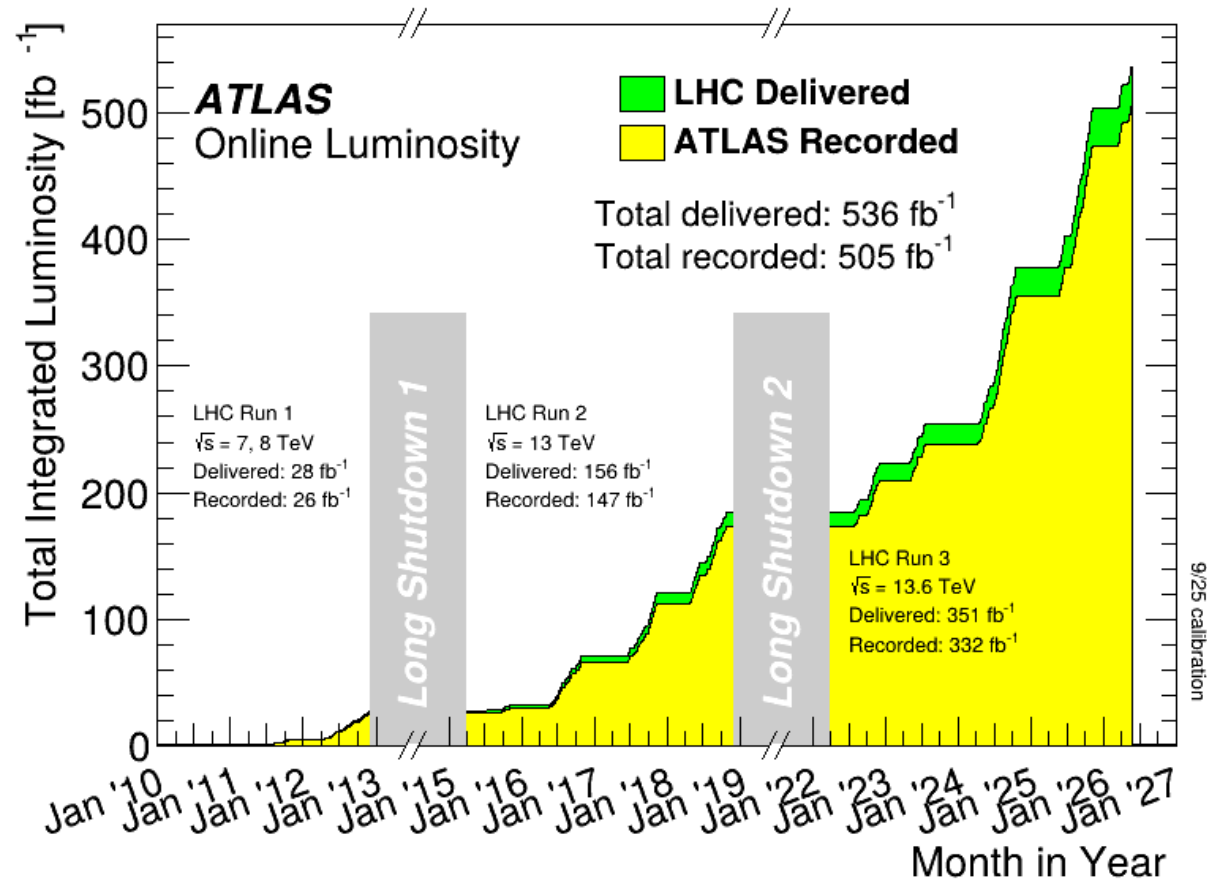
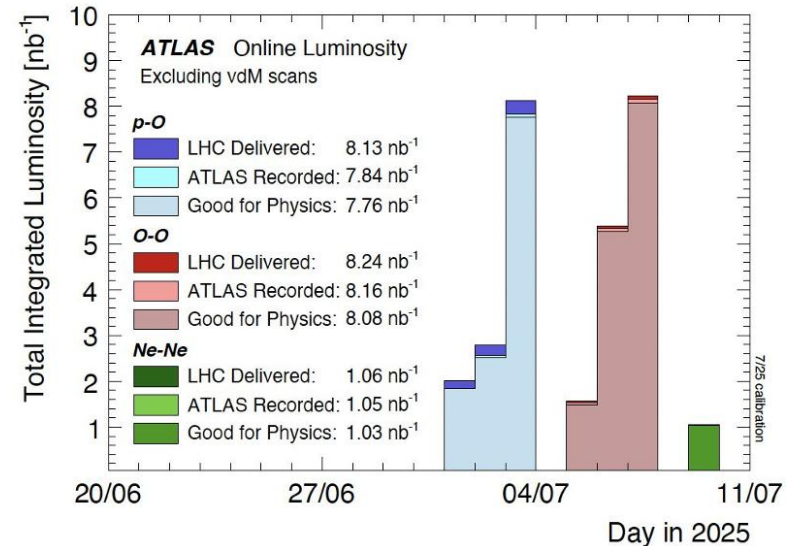


第六届中国格点量子色动力学研讨会
香港中文大学 (深圳) 2026年10月8-11

- ❖ Introduction
- ❖ Higgs, Di-Higgs, Tri-Higgs
- ❖ VBS Diboson, Triboson
- ❖ Top quark and heavy flavor
- ❖ Beyond SM Searches
- ❖ Heavy Ion & Proton-Oxygen
- ❖ Summary and Outlook



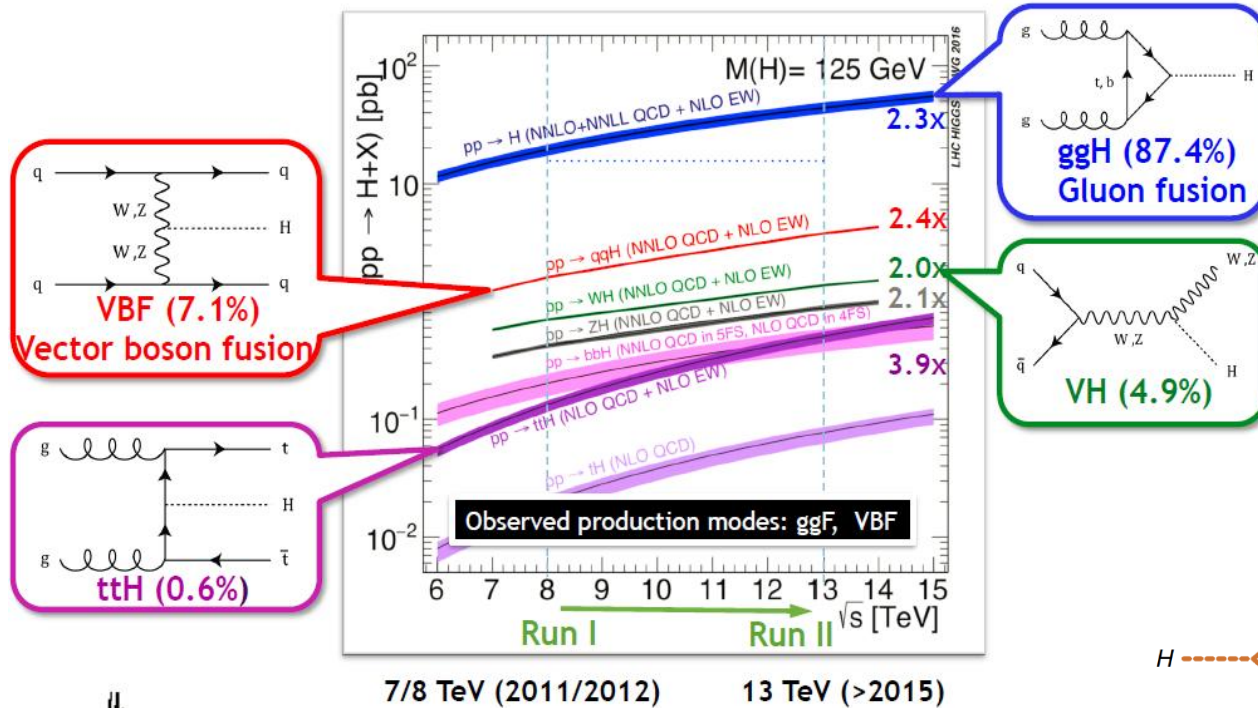
- More than **500 fb⁻¹** pp collisions data recorded by ATLAS detector
- Run3: 2022-2026 @ 13.6 TeV, 332 fb⁻¹ recorded, pile-up $\langle\mu\rangle \sim 60$**
- ATLAS recording 95% of delivered data, 94% is good for physics
- Low- μ (1.3 fb⁻¹), p-O(7.84nb⁻¹), O-O(8.16nb⁻¹), Ne-Ne (1.05nb⁻¹)



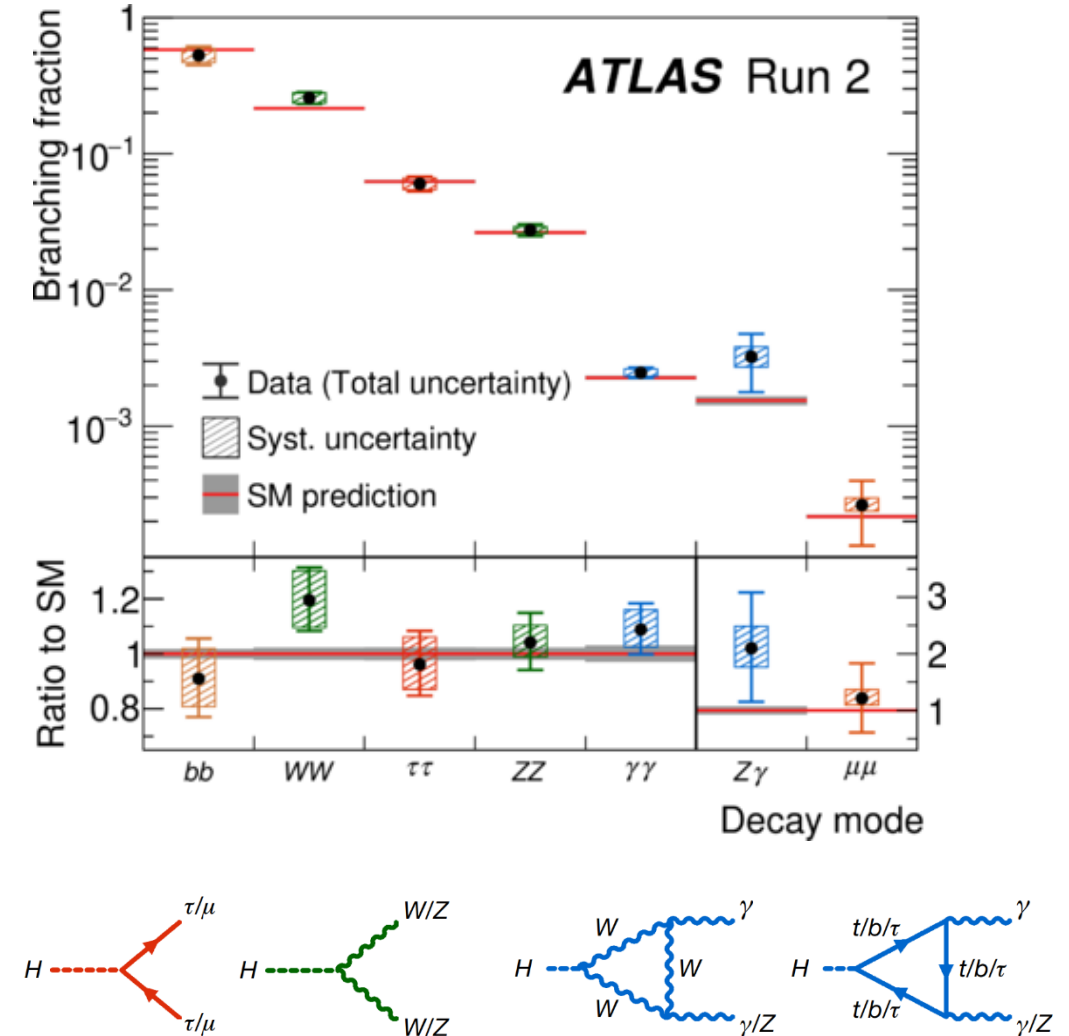
4

- Higgs productions at LHC: ggF, VBF, VH, ttH, tH
- Higgs decays: **bb, cc, $\tau\tau$, $\mu\mu$** (Yukawa coupling)
WW, ZZ, $\gamma\gamma$, $Z\gamma$ (Gauge coupling)

Higgs Production

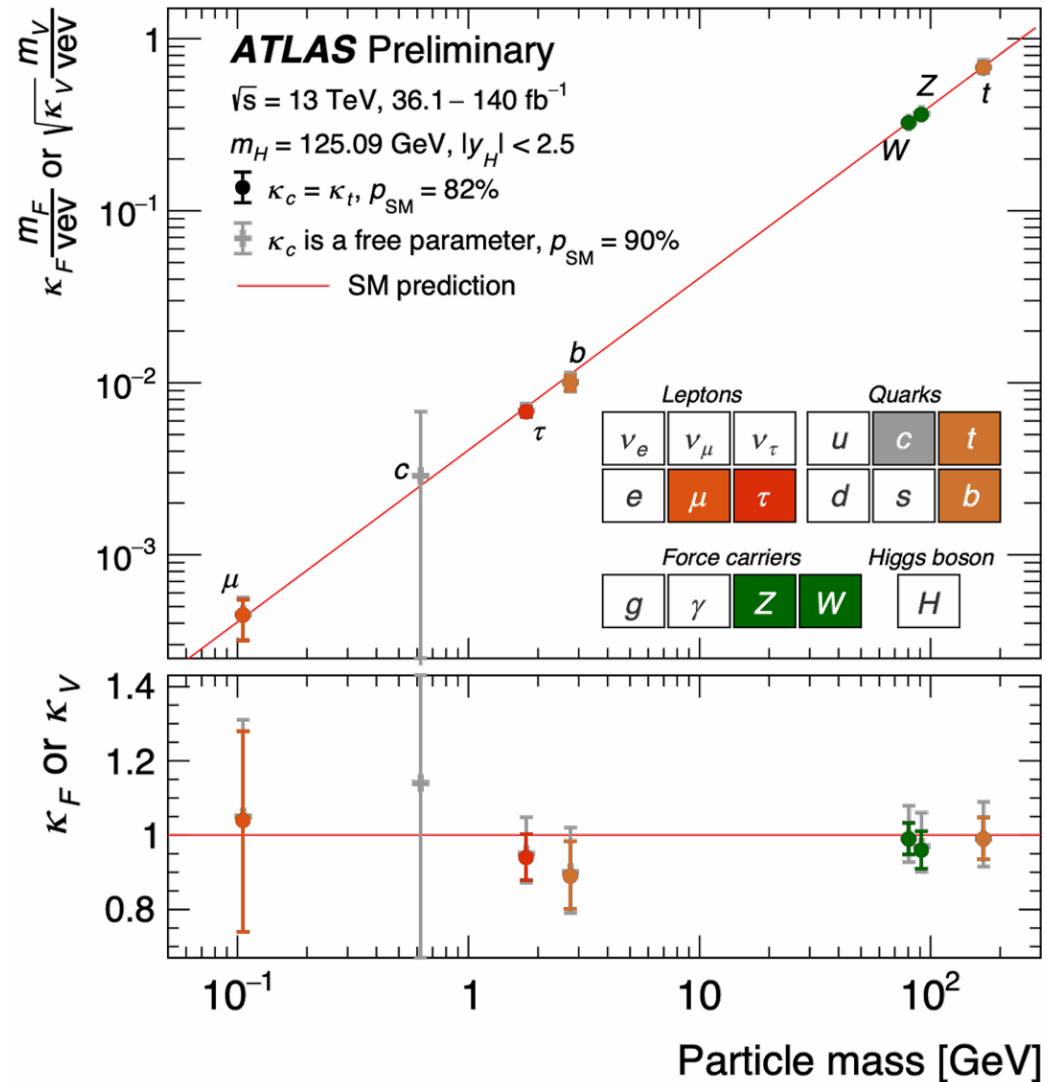


Higgs Decays



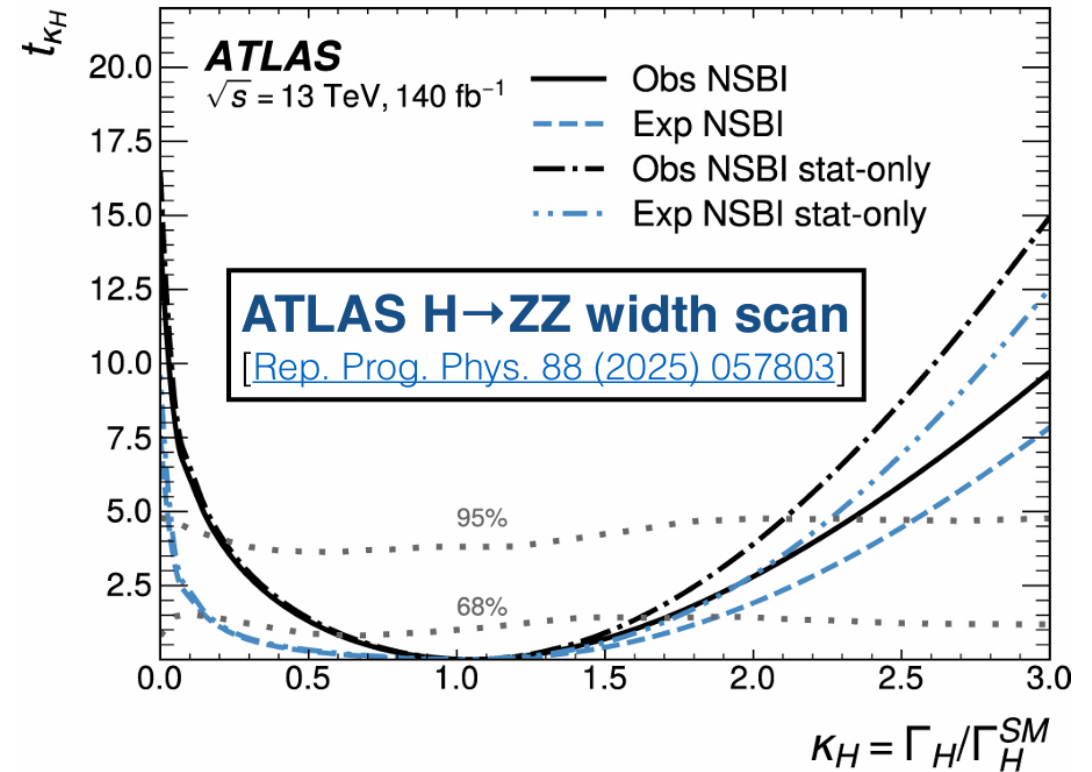
Higgs couplings agree well with SM

ATLAS: [ATLAS-CONF-2025-006](#), CMS: [arXiv:2602.18611](#)



Higgs off-shell $H \rightarrow ZZ \rightarrow 4l, 2l2\nu$:

Observed significance of 3.7σ (2.4σ exp.)



$$\kappa_H = 1.05_{-0.46}^{+0.65} \quad (1.00_{-0.84}^{+0.86}),$$

$$\Gamma_H = 4.3_{-1.9}^{+2.7} \quad (4.1_{-3.4}^{+3.5}) \text{ MeV}.$$

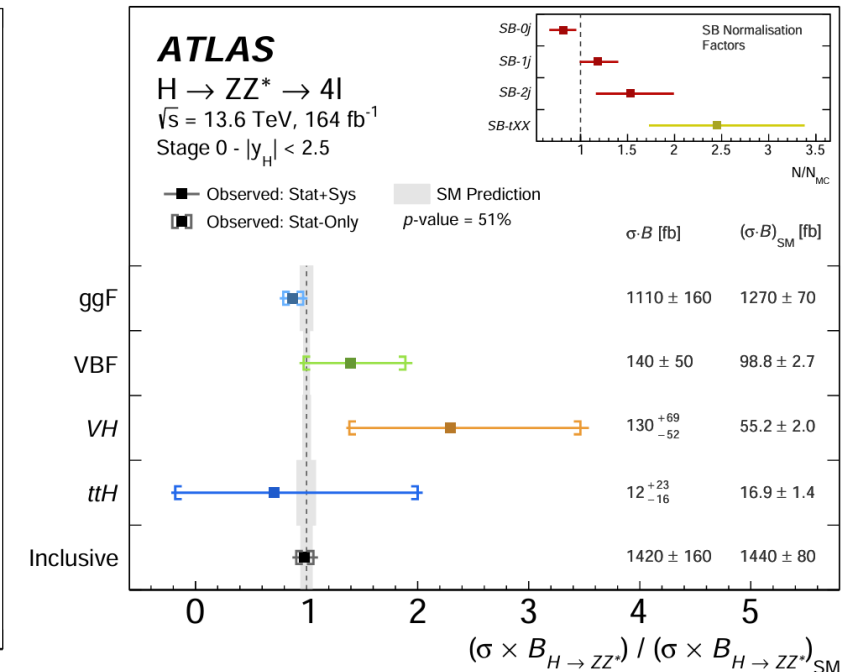
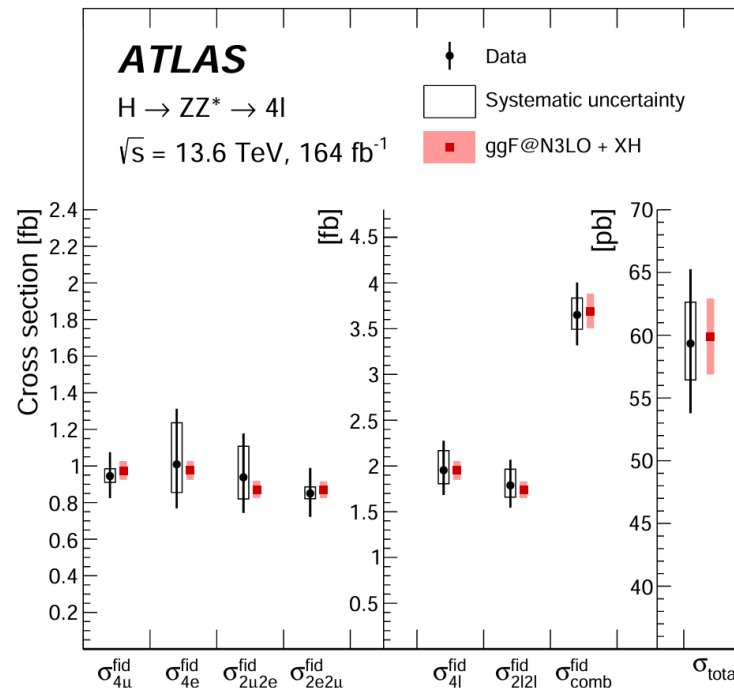
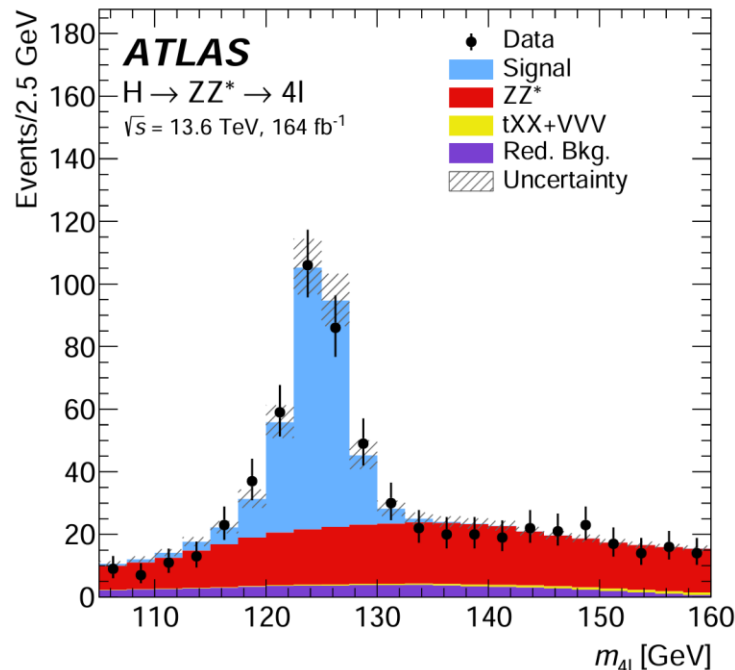
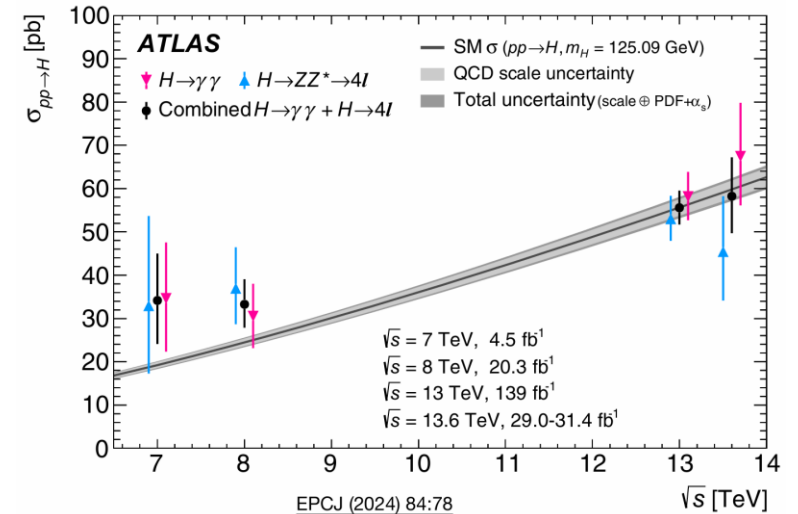
Higgs Cross Section

■ Total Higgs cross sections at different CME are consistent with SM values (13.6 TeV, $\sigma_{\text{total}}^{\text{SM}} = 59.9 \pm 3.0$ pb).

$$\sigma_{\text{total}} = 59.3 \pm 4.8(\text{stat.}) \pm 3.1(\text{sys.}) \text{ pb}$$

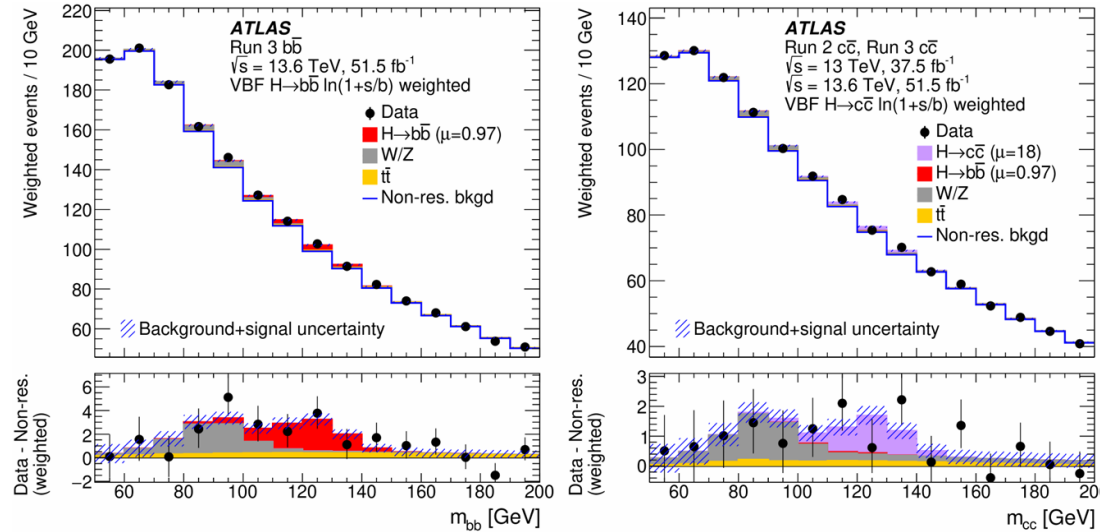
$$\sigma_{\text{fid}} \equiv \sigma \cdot \mathcal{B}(H \rightarrow ZZ^* \rightarrow 4\ell) = 3.65 \pm 0.30(\text{stat.}) {}^{+0.18}_{-0.16}(\text{sys.}) \text{ fb} = 3.65 {}^{+0.35}_{-0.33} \text{ fb}$$

$$\mu = 0.99 \pm 0.08(\text{stat.}) \pm 0.10(\text{sys.}) = 0.99 \pm 0.13$$



H → bb, cc in VH and VBF Production

Simultaneous search for H → bb and cc in VBF production using Run2 and Run3 data

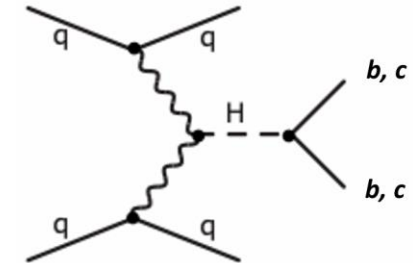


• VBF H(bb) w/ Run3

- $\mu_{bb} = 0.97 \pm 0.45(\text{stat})^{+0.35}_{-0.22}(\text{syst})$
- Significance:
 - obs (exp) = 2.0 (2.1) σ

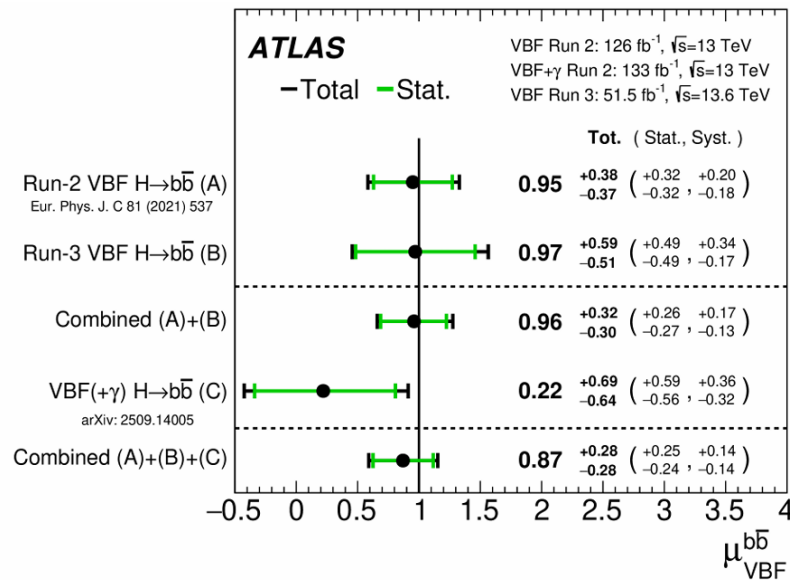
• VBF H(cc) w/ Run2+Run3

- $\mu_{cc} = 18 \pm 12(\text{stat}) \pm 7(\text{syst})$
- Upper limit @ 95% CL:
 - obs (exp) = 41 (28) x SM



PLB 877 (2026) 140279
 JHEP 04 (2025) 075
 arXiv:2511.21911
 arXiv:2509.14005

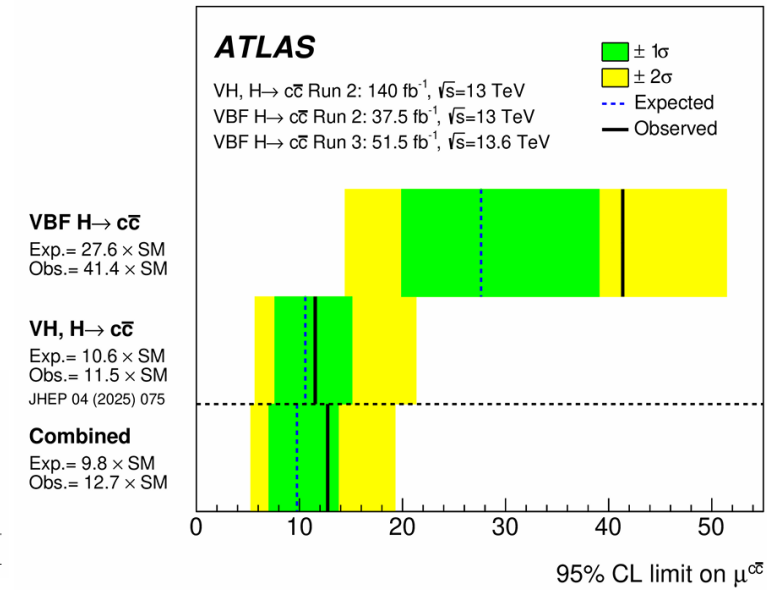
10



Significance:

- Obs (exp) = 3.2 (3.6) σ
- ⇒ Evidence of VBF H(bb) !

- Combined $\mu_{cc} = 3.3^{+5.2}_{-5.0}$
- 95% CL Upper limit on μ_{cc} :
 - obs (exp) = 12.7 (9.8) x SM

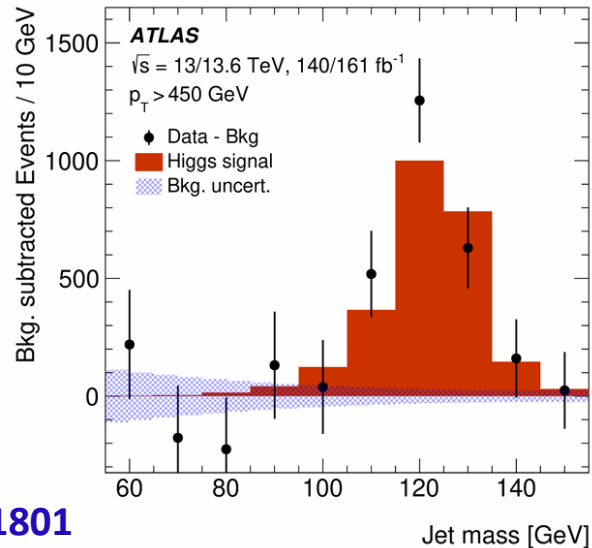


■ High- p_T Higgs is sensitive to BSM loop effects, via ggF coupling modifications.

Inclusive $H \rightarrow bb$:

- Transformer-based boosted $H \rightarrow bb$ tagger
- Improved jet mass and p_T resolution via transformer-based regression model
- $Z \rightarrow bb$ signal used to calibrate the ML
- X10 in significance compared to Run2

**Evidence for $H \rightarrow bb$
with $p_T(H) > 450$ GeV
at 3.8σ (2.5σ exp.)**

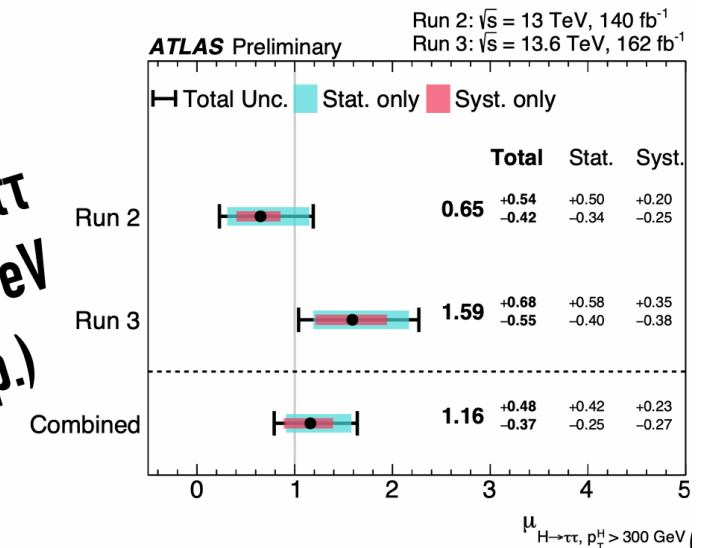


PRL 137 (2026) 071801
arXiv:2603.19369

Inclusive $H \rightarrow \tau\tau$:

- First ATLAS high- p_T $H \rightarrow \tau\tau$ analysis
- Dedicated boosted 2- τ reconstruction
- Transformer-based boosted $H \rightarrow \tau\tau$ tagger
- BDT for better S/B, used as fit variable

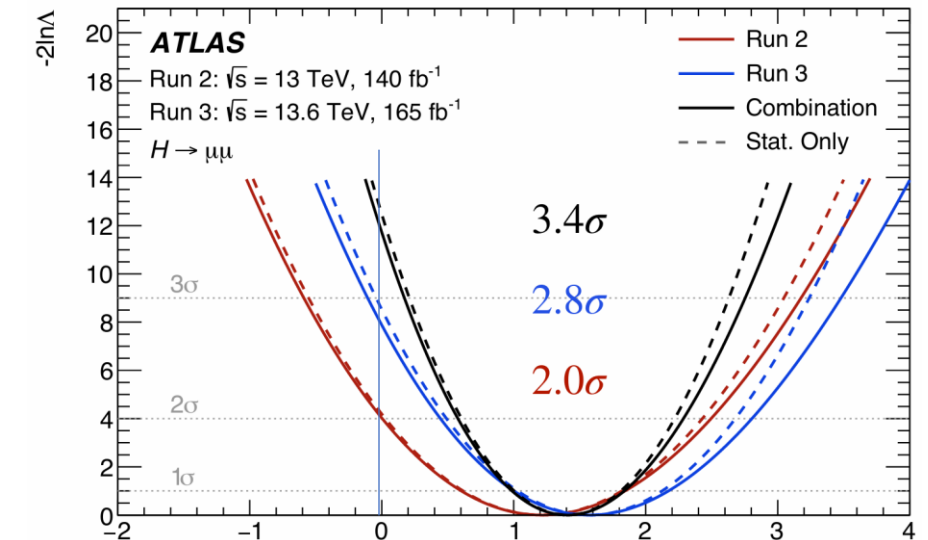
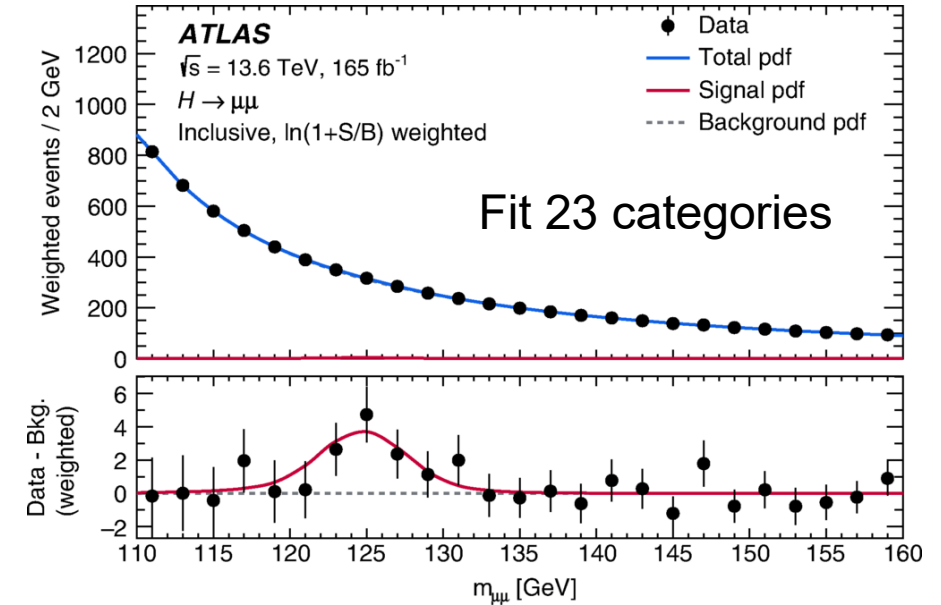
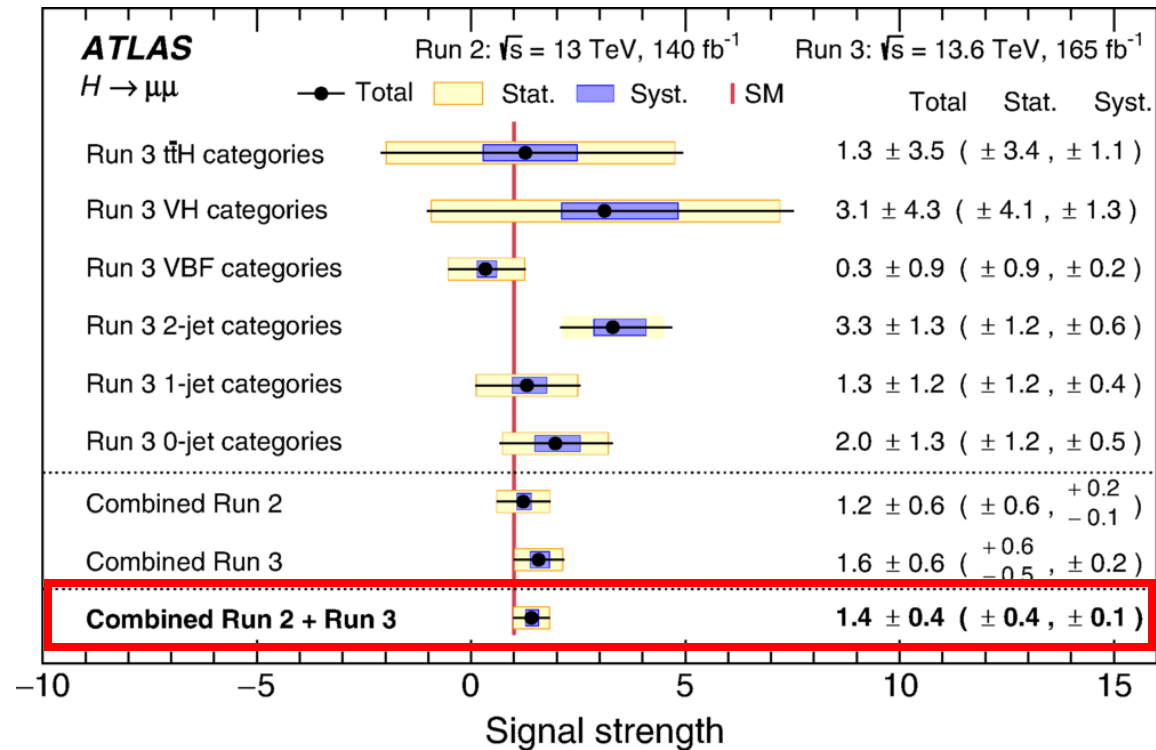
**Evidence for $H \rightarrow \tau\tau$
with $p_T(H) > 300$ GeV
at 3.8σ (3.3σ exp.)**



arXiv:2607.22193

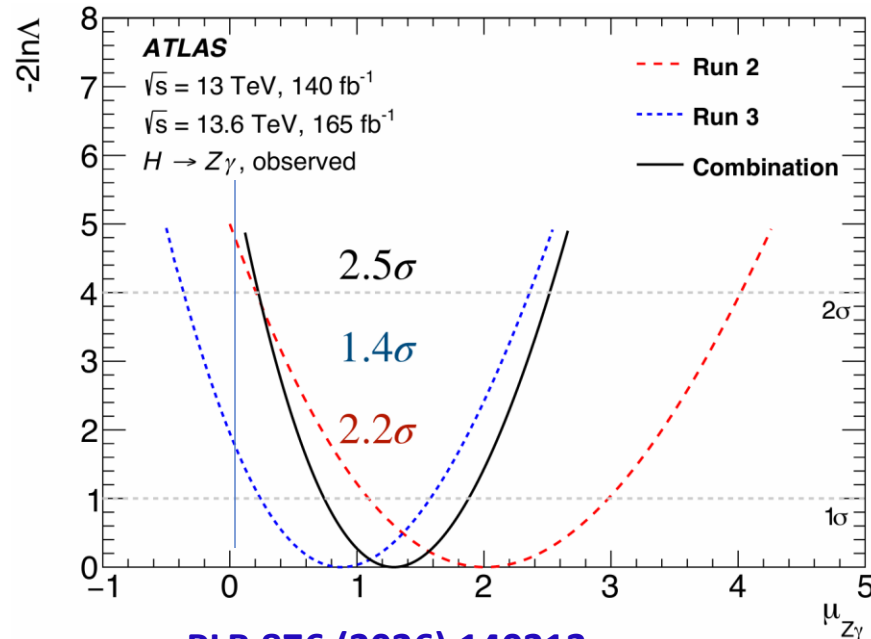
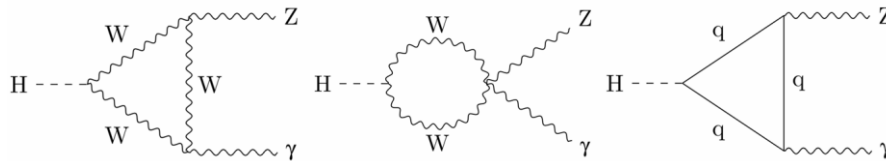
Evidence of $H \rightarrow \mu\mu$ Rare Decay

- $H \rightarrow \mu\mu$, direct probe of Higgs yukawa coupling to the 2nd generation fermions
- Challenge: Low BR $\sim 0.022\%$, S/B $\sim 10^{-3}$
- Partial Run3 (165/fb): $\mu=1.6 \pm 0.6$, 2.8σ (1.8σ exp.)
- **Run2+Run3 (305/fb): $\mu=1.4 \pm 0.4$, 3.4σ (2.5σ exp.)**

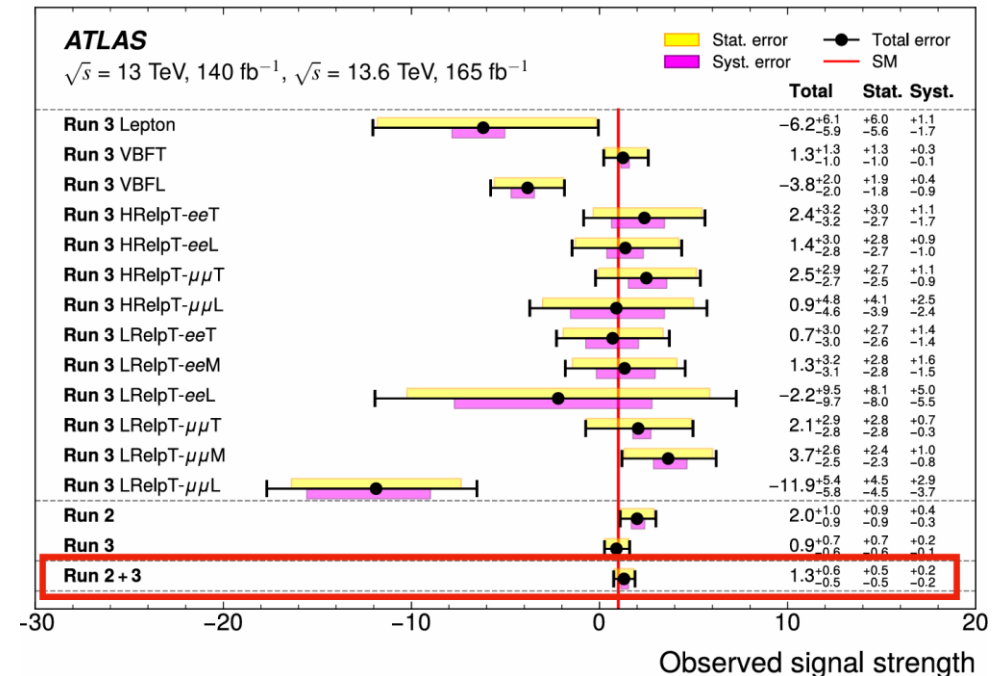
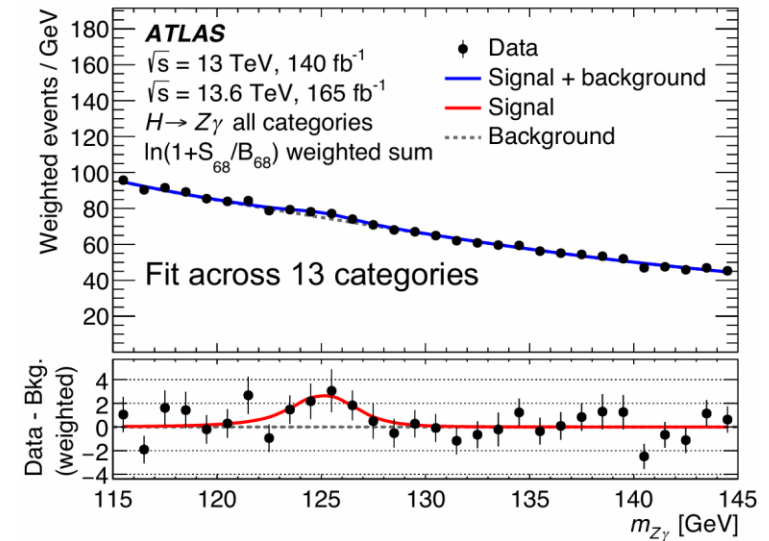


Evidence of $H \rightarrow Z\gamma$ Rare Decay

- $H \rightarrow Z\gamma$ is a loop-induced process, sensitive to probe BSM particles entering loop diagram
- Challenge: Low BR $\sim 0.15\%$, $Z \rightarrow \ell\ell$ (6.7%), S/B $\sim 10^{-3}$
- Run2 ATLAS+CMS: $\mu = 2.2 \pm 0.7$, 3.4σ (1.6σ exp.)
- Run2 + Run3 (305/fb): $\mu = 1.3 \pm 0.6$, 2.5σ (1.9σ exp.)

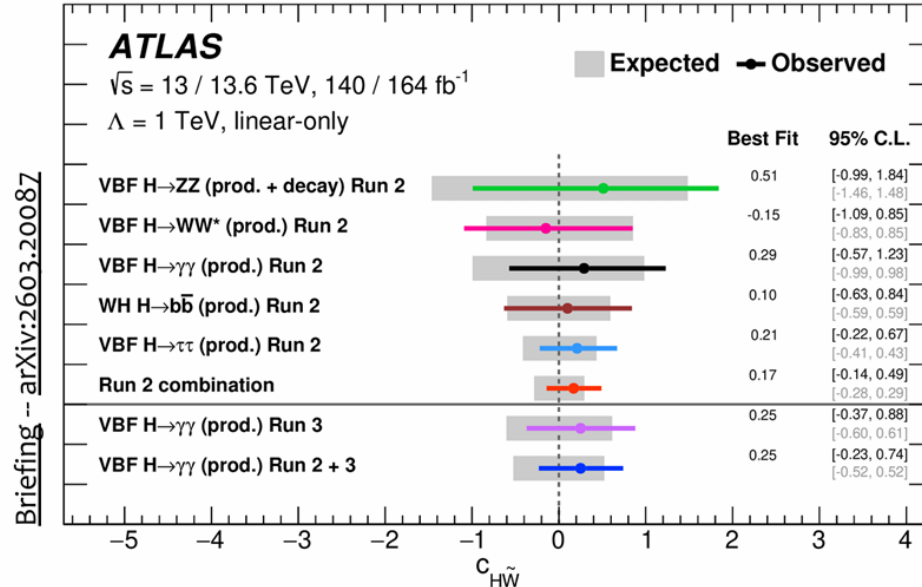


PLB 876 (2026) 140313



- CP violation (CPV) is crucial to understand matter-antimatter asymmetry in the universe, but the amount of CPV in SM (quark sector) is too small.
- Higgs boson has opened a window to search for CPV beyond the SM

CP violation in Higgs-Vector boson coupling

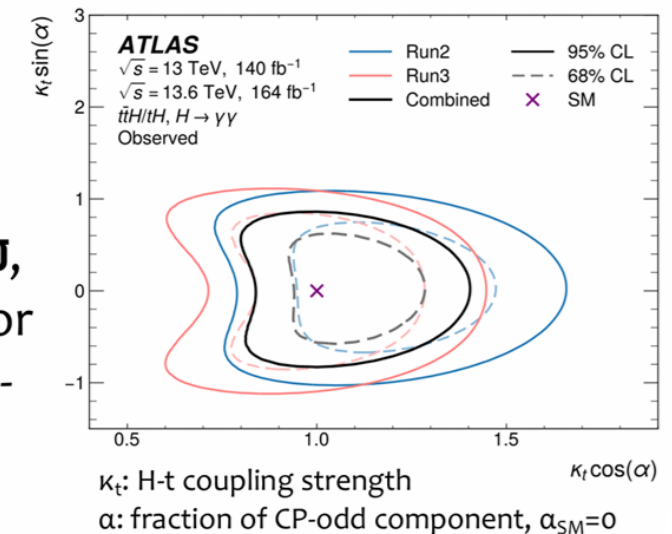


One of CP-violating SMEFT Wilson coefficients:
measured consistent with zero

arXiv:2603.20087

CP violation in H-t coupling (via $t\bar{t}H$ or tH production)

- New measurement of H-t Yukawa coupling in $H \rightarrow \gamma\gamma$ using **Run 2+Run 3 (2022-2024)** data
- Excluded $|\alpha| > 38^\circ$ at 95% CL, best direct constraint to date
- Excluded $\alpha = 90^\circ$ at 5.8σ , first $> 5\sigma$ rejection for purely CP-odd Higgs-fermion Yukawa coupling

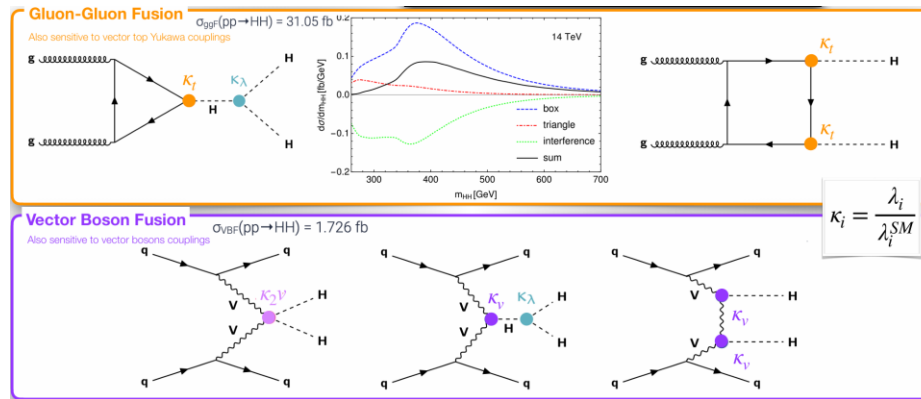


ATL-CONF-2026-002

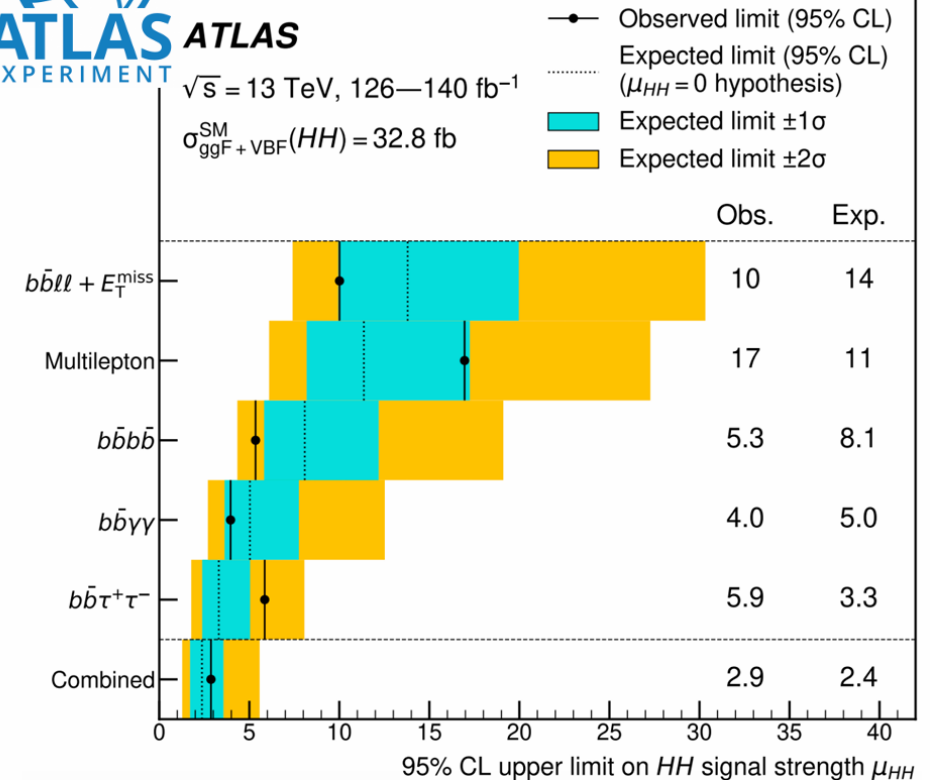
Di-Higgs Search

- The shape of the Higgs potential is still unknown
- Di-Higgs is a key process to measure Higgs self-interaction
- Challenges: very low $\sigma \sim 32.8\text{fb}$, complicated final states

$$V(H) = \underbrace{-\frac{1}{2} m_H H^2}_{\text{Higgs mass term}} + \underbrace{\lambda_3 v H^3 + \lambda_4 H^4}_{\text{Higgs self-interaction term}}$$



HH combination
Phys.Rev.Lett. 133 (2024) 101801



HH combination
Phys.Rev.Lett. 133 (2024) 101801

H+HH combination
Phys.Lett. B 843 (2023) 127745

$b\bar{b}b\bar{b}$
 $b\bar{b}\tau^+\tau^-$
 $b\bar{b}\gamma\gamma$

Multilepton

- $b\bar{b}ZZ^*$
- $VV^*VV^* (V = W, Z)$
- $VV^*\tau^+\tau^-$
- $\gamma\gamma VV^*$
- $\gamma\gamma\tau^+\tau^-$

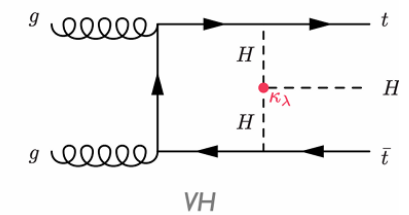
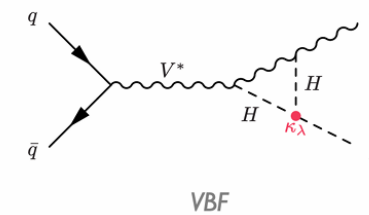
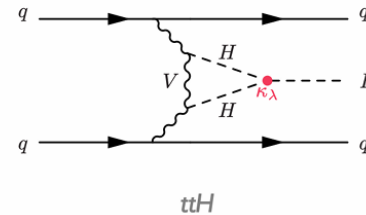
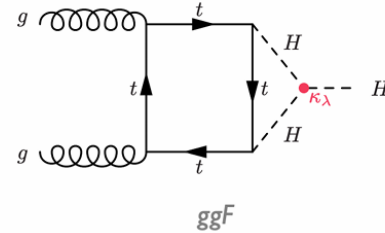
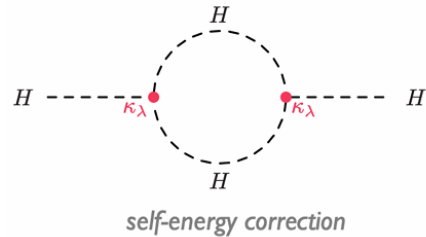
	bb	WW	$\tau\tau$	ZZ	$\gamma\gamma$
bb	34%				
WW	25%	4.6%			
$\tau\tau$	7.3%	2.7%	0.39%		
ZZ	3.1%	1.1%	0.33%	0.069%	
$\gamma\gamma$	0.26%	0.10%	0.028%	0.012%	0.0005%

"Silver bullet" channels

All combinations are based on full Run 2 luminosity, most decay channels

H+HH Combination

■ Single Higgs processes can be used to constraint κ_λ through NLO effects.



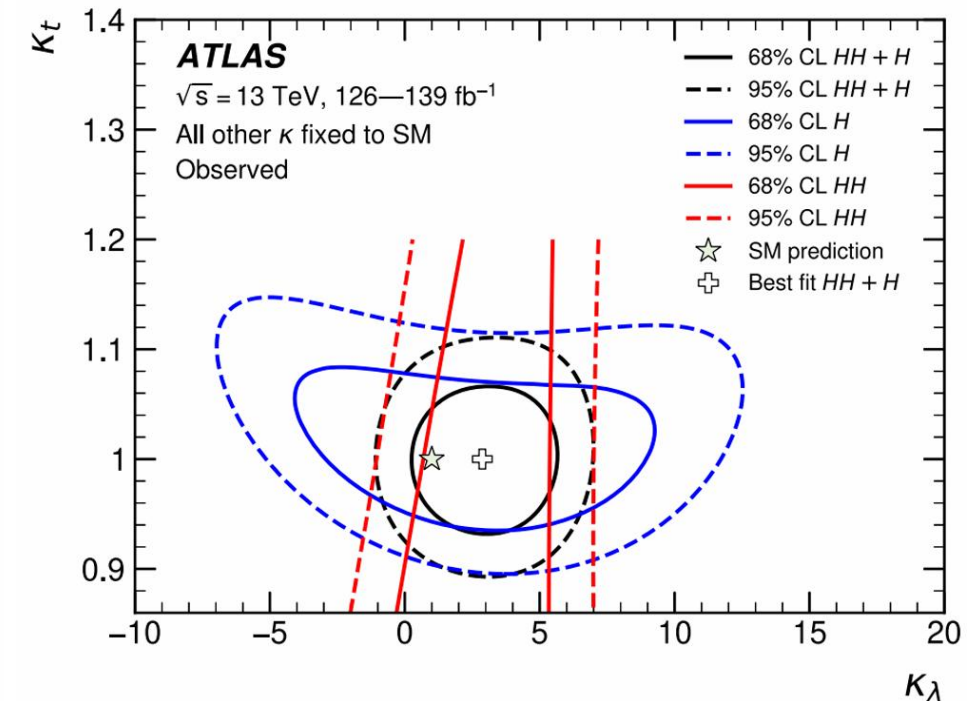
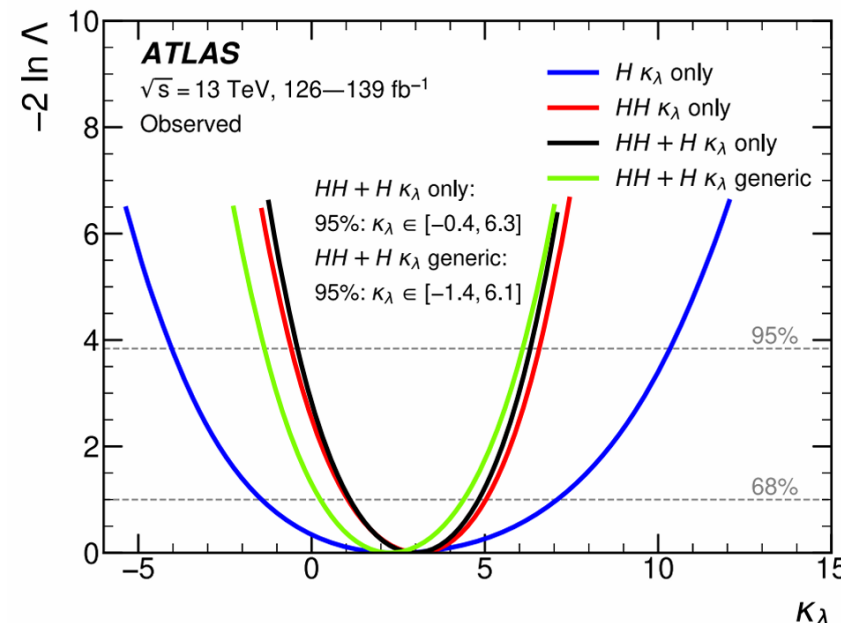
■ H+HH: combination of 7 single Higgs and 3 double Higgs channels

H+HH combination

Phys.Lett. B 843 (2023) 127745

$$-0.4 < \kappa_\lambda < 6.3 \quad (-1.9 < \kappa_\lambda < 7.6)$$

$HH \rightarrow b\bar{b}\gamma\gamma$	139
$HH \rightarrow b\bar{b}\tau^+\tau^-$	139
$HH \rightarrow b\bar{b}b\bar{b}$	126
$H \rightarrow \gamma\gamma$	139
$H \rightarrow ZZ^* \rightarrow 4\ell$	139
$H \rightarrow \tau^+\tau^-$	139
$H \rightarrow WW^* \rightarrow e\nu\mu\nu$ (ggF,VBF)	139
$H \rightarrow b\bar{b}$ (VH)	139
$H \rightarrow b\bar{b}$ (VBF)	126
$H \rightarrow b\bar{b}$ (ttH)	139

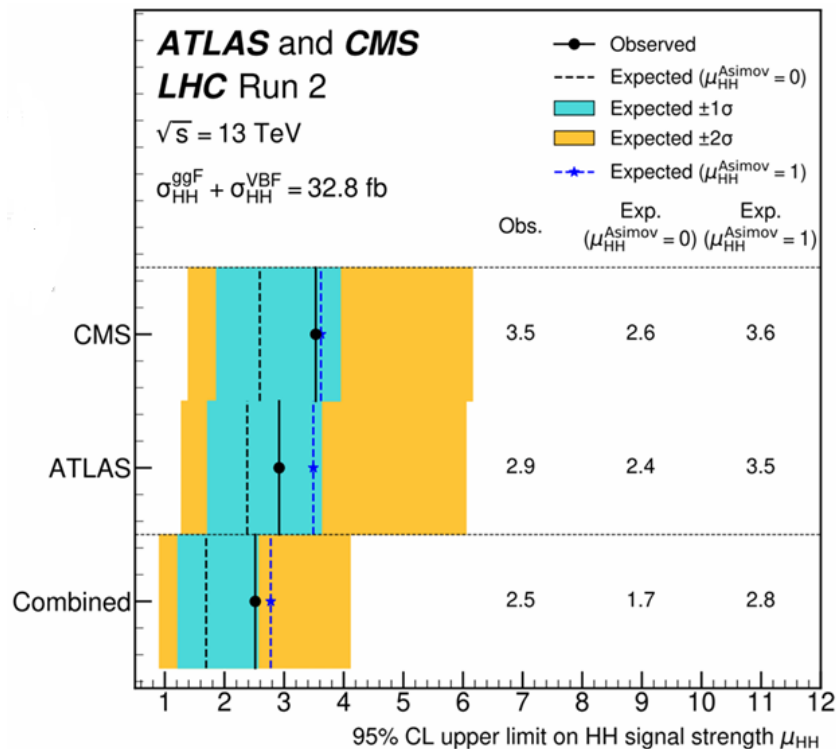


■ The best combined fit of HH signal strength at Run2

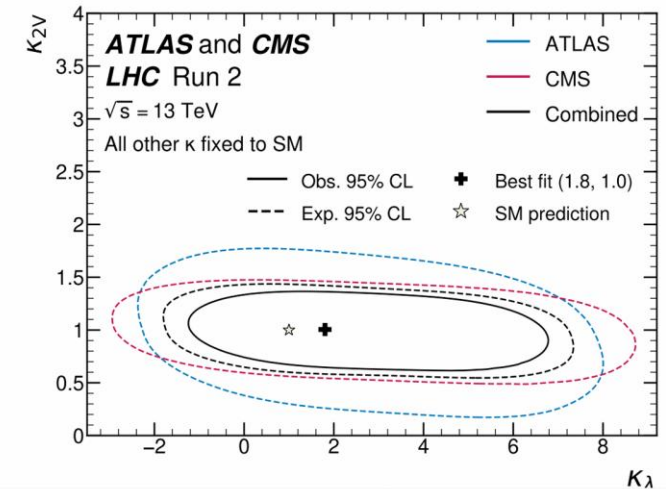
■ The observed (expected) local significance: 1.1σ (1.3σ)

$$\hat{\mu}_{\text{HH}} = 0.8^{+0.9}_{-0.7} = 0.8^{+0.7}_{-0.6}(\text{stat.})^{+0.4}_{-0.2}(\text{theory})^{+0.3}_{-0.3}(\text{exp.})$$

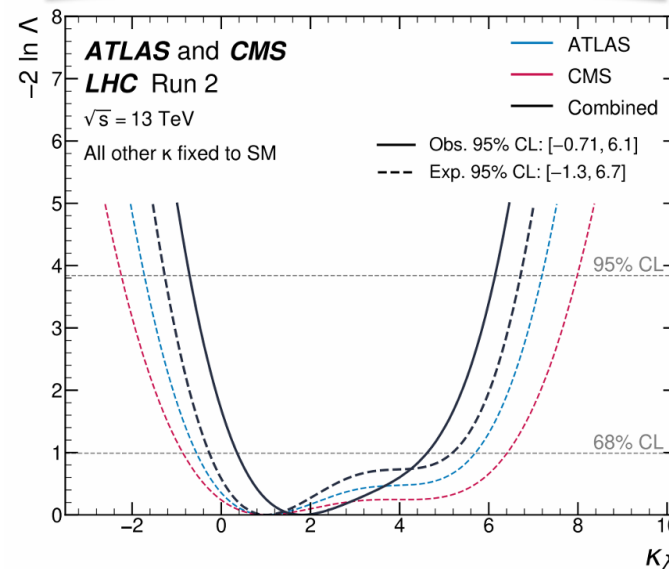
$$\hat{\mu}_{\text{HH}}^{\text{exp}} = 1.0^{+0.9}_{-0.8} = 1.0^{+0.7}_{-0.6}(\text{stat.})^{+0.5}_{-0.3}(\text{theory})^{+0.3}_{-0.3}(\text{exp.})$$



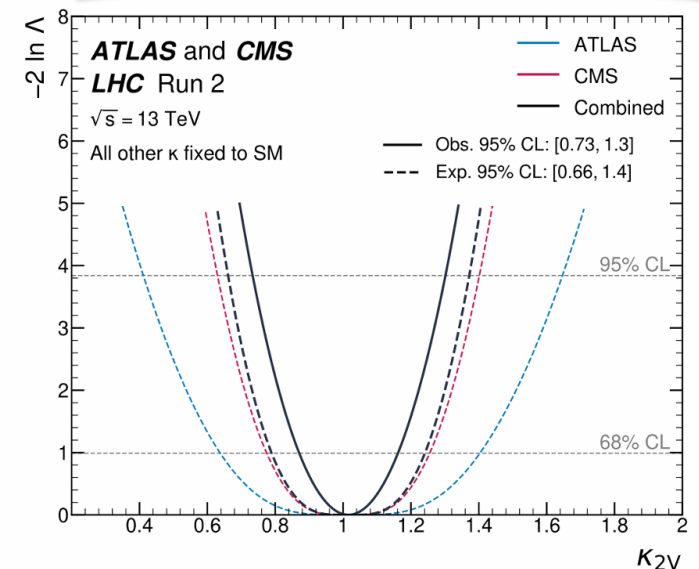
-HH combination-
CERN-EP-2026-011



$$-0.71 < \kappa_\lambda < 6.1 \quad (-1.3 < \kappa_\lambda < 6.7)$$

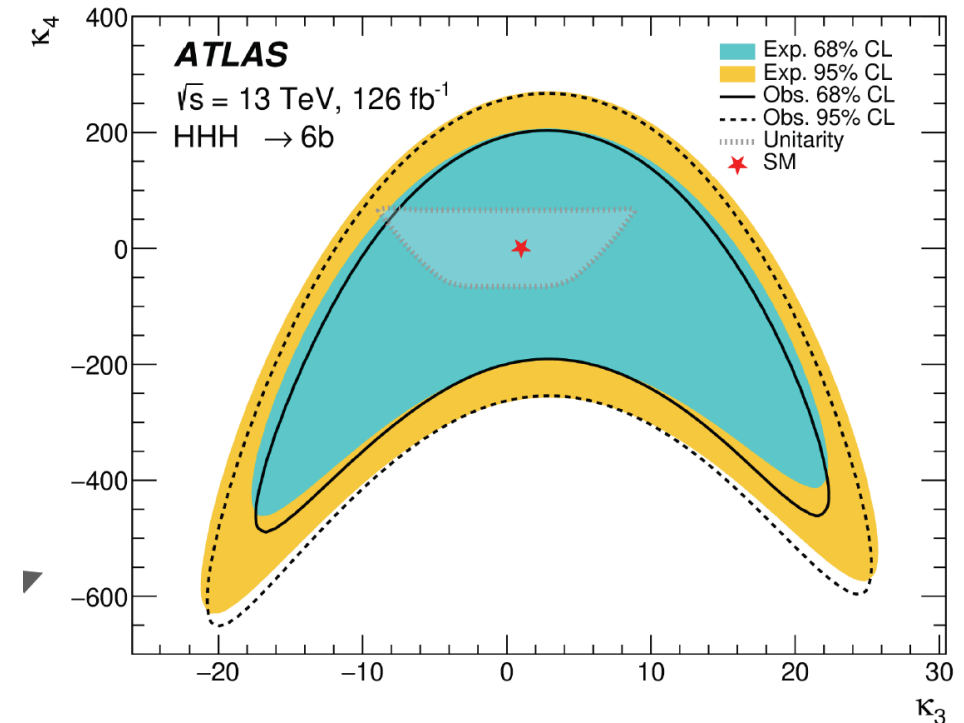
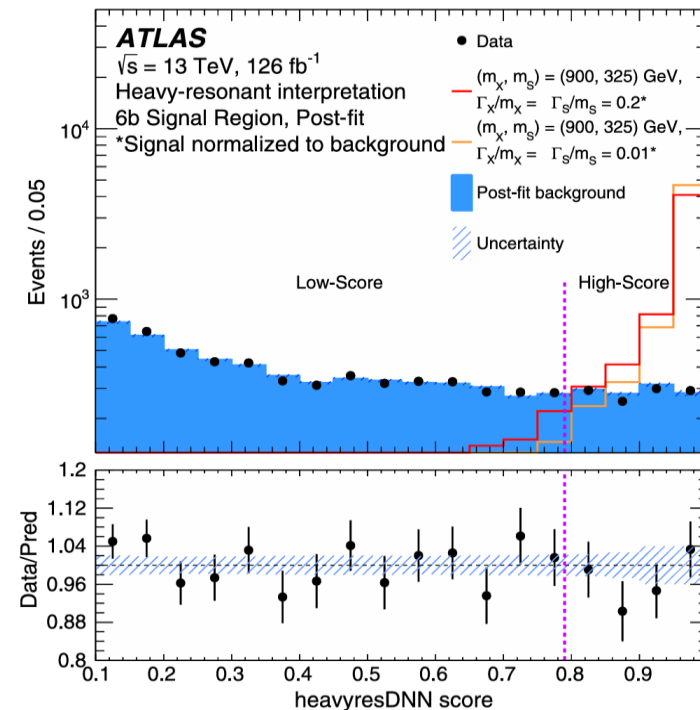
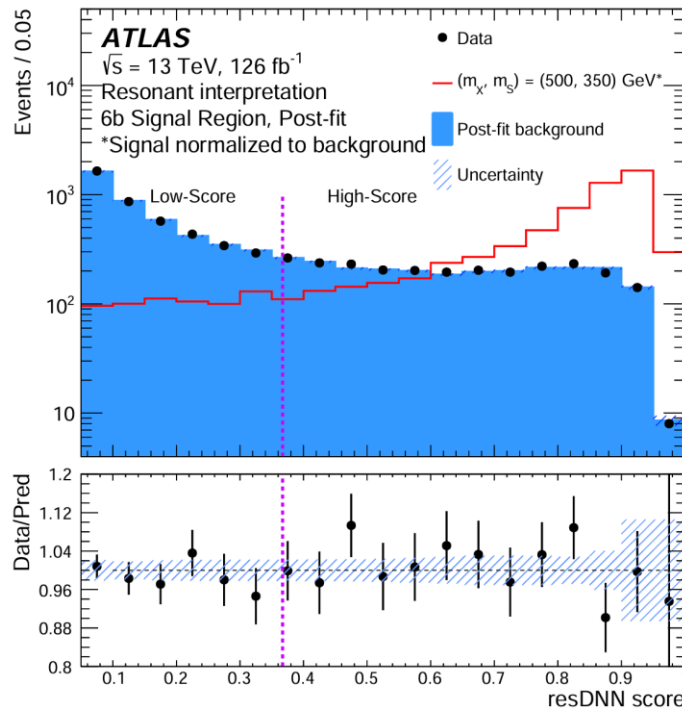
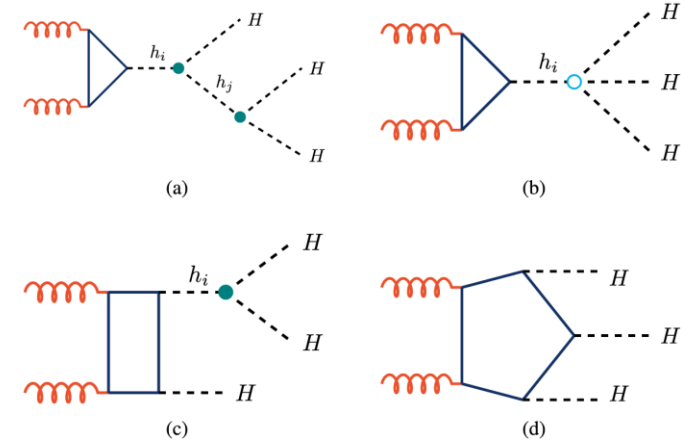


$$0.73 < \kappa_2v < 1.3 \quad (0.66 < \kappa_2v < 1.4)$$



HHH $\rightarrow$ bbbbbb Search

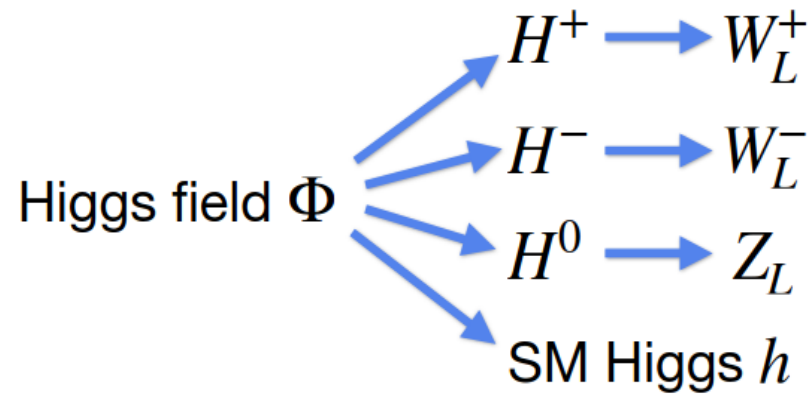
- **The 1st search of tri-Higgs** by the LHC, $X \rightarrow SH \rightarrow HHH$ (TRSM)
- Deep Neural Network (DNN) classifiers for better S/B separation
- Data-driven method to estimate major multijet background, extrapolate DNN distribution from 4b and 5b control regions.
- Set limits on trilinear (λ_3) and quartic (λ_4) Higgs self-coupling.
- **An upper limit of 59 fb is set at 95% CL.**



Longitudinal Polarized VBS

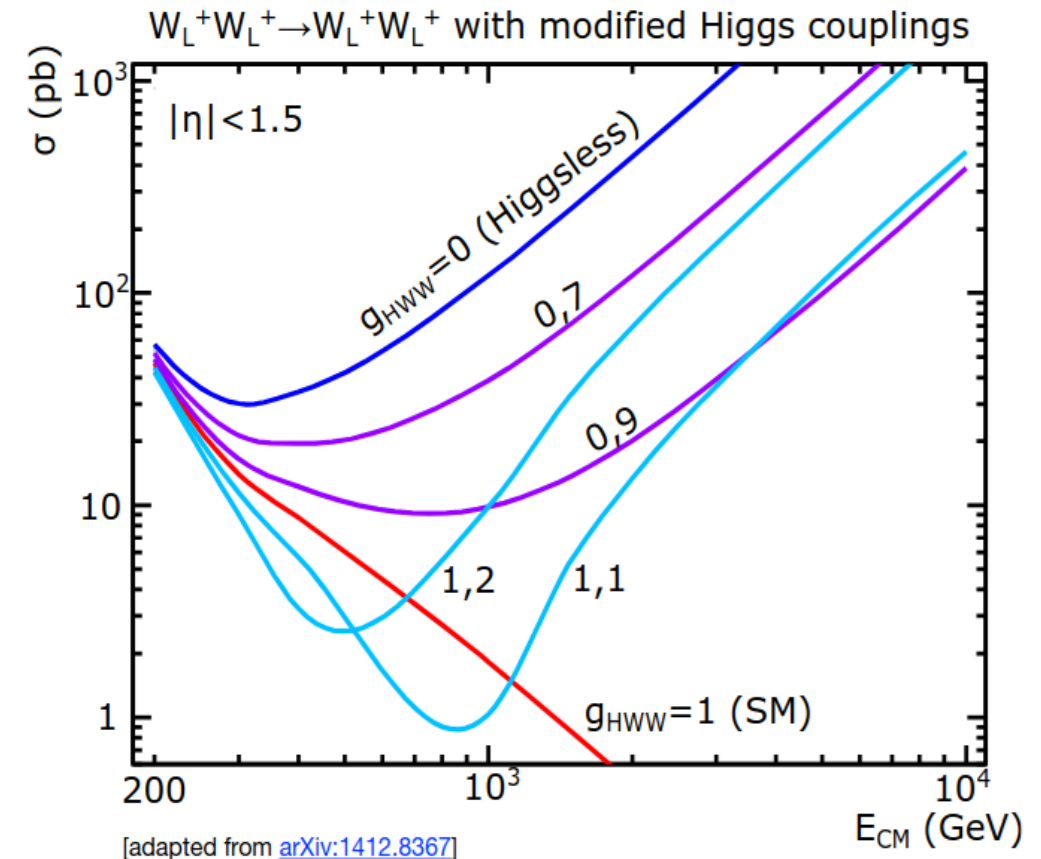
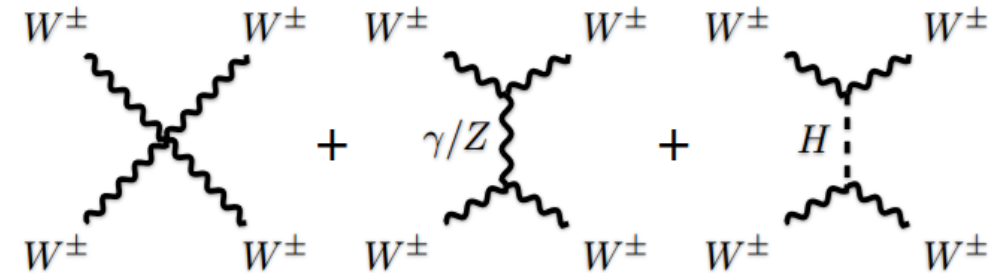
Importance of $W_L^\pm W_L^\pm \rightarrow W_L^\pm W_L^\pm$

- Higgs Goldstone bosons result in longitudinal polarized vector bosons:



- Longitudinal $W_L^\pm W_L^\pm \rightarrow W_L^\pm W_L^\pm$ would **violate unitarity if Higgs coupling deviates from SM prediction**

➡ $W_L^\pm W_L^\pm \rightarrow W_L^\pm W_L^\pm$ is a **unique opportunity to probe electroweak symmetry-breaking**



➤ Two-stage DNN analysis strategy:

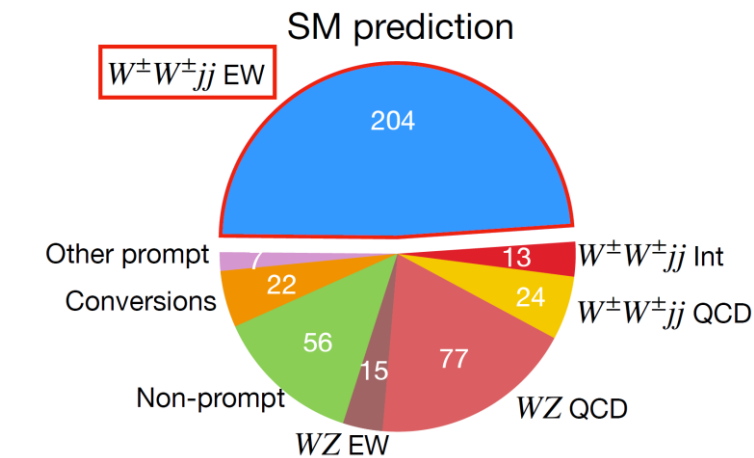
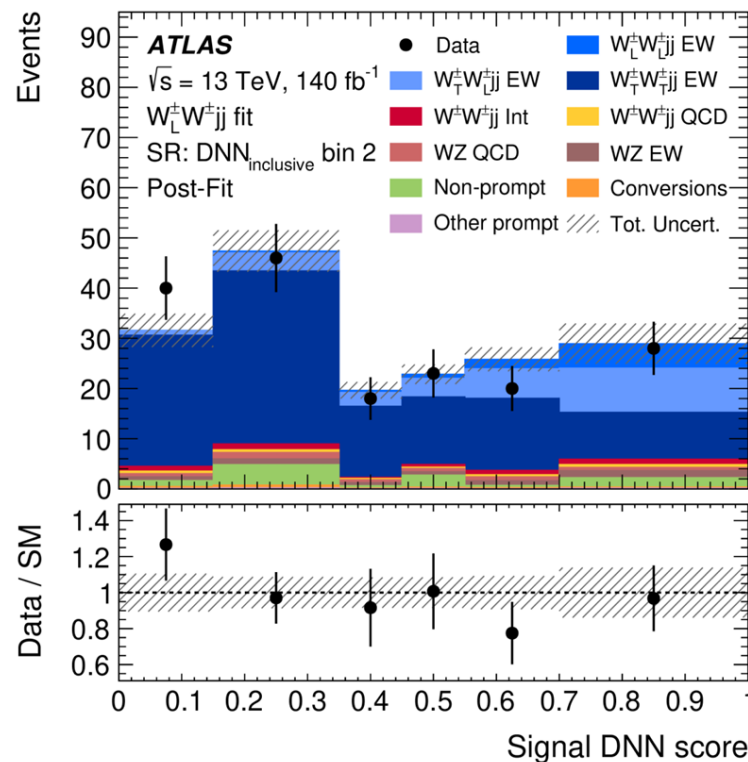
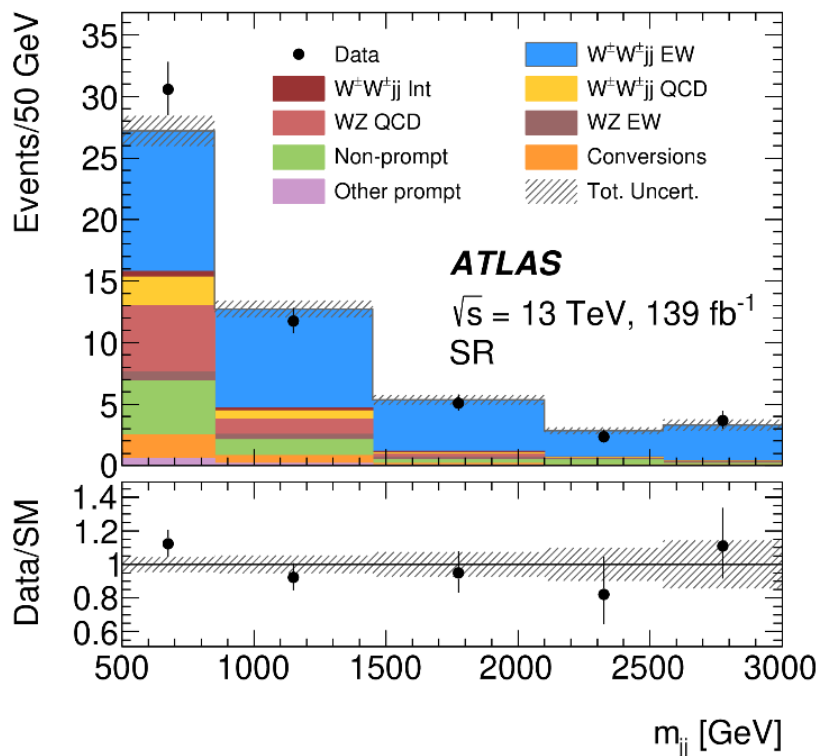
- ❑ $\text{DNN}_{\text{inclusive}}$: inclusive EW ssWW vs backgrounds
- ❑ $\text{DNN}_{\text{polarization}}$: polarization separation for $W_L W_L$ vs. $W_T W$, $W_L W$ vs. $W_T W_T$

➤ **First evidence for ≥ 1 longitudinally polarized W boson: 3.3σ (4σ exp.)**

➤ Upper limit for doubly-longitudinal $W_L W_L$ components: 0.45 fb (95% CL)

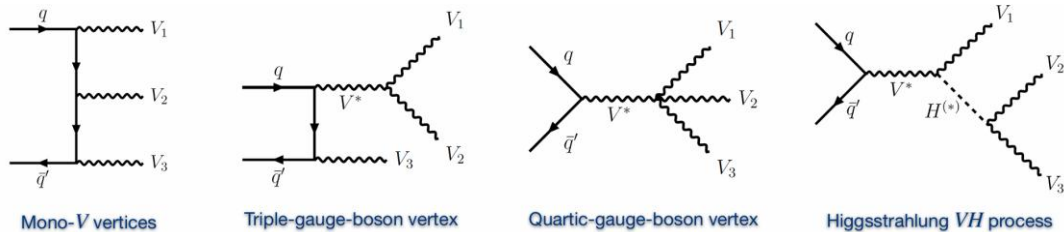
204 signal:

- LL: 10%
- LT: 21%
- TT: 69%

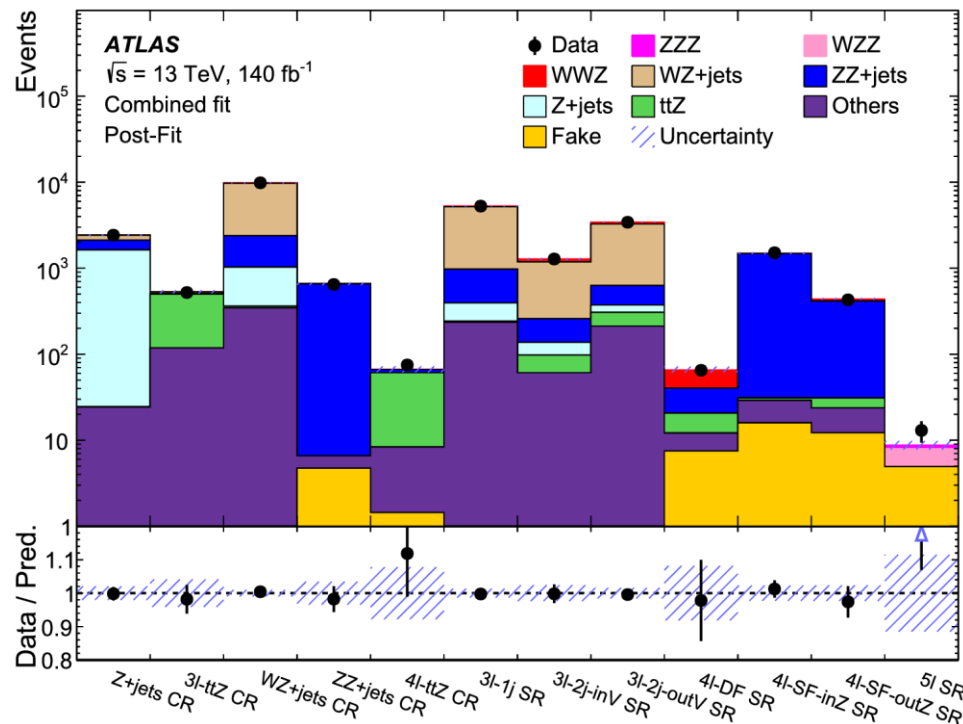


Process	Predicted $\sigma\mathcal{B}$ (fb)	Measured $\sigma\mathcal{B}$ (fb)
$W_L^\pm W_L^\pm jj$	0.29 ± 0.07	$0.01 \pm 0.21(\text{tot})$
$W_T^\pm W^\pm jj$	2.56 ± 0.64	$3.39 \pm 0.35(\text{tot})$
$W_L^\pm W^\pm jj$	1.18 ± 0.29	$0.88 \pm 0.30(\text{tot})$
$W_T^\pm W_T^\pm jj$	1.67 ± 0.40	$2.49 \pm 0.32(\text{tot})$

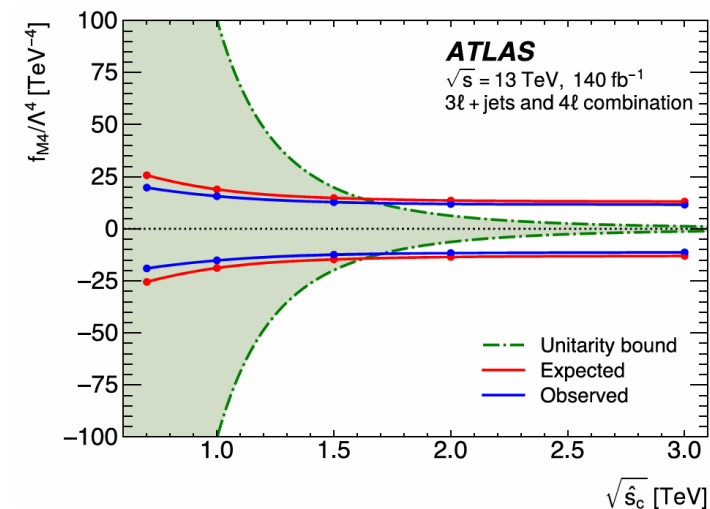
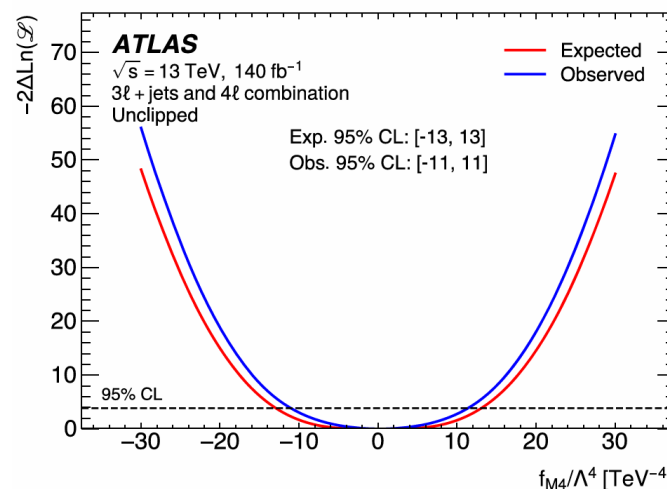
➤ **ATLAS observed VVZ 6.4σ (exp 4.7σ) using 140 fb^{-1} Run-2 data at 13 TeV**



Process	Signal strength	Cross section (fb)	Observed (expected)
VVZ	$1.43 \pm 0.20(\text{stat.})^{+0.21}_{-0.19}(\text{syst.})$	$660^{+93}_{-90}(\text{stat.})^{+88}_{-81}(\text{syst.})$	$6.4 (4.7) \sigma$
WWZ	$1.33 \pm 0.28(\text{stat.})^{+0.21}_{-0.17}(\text{syst.})$	$442 \pm 94(\text{stat.})^{+60}_{-52}(\text{syst.})$	$4.4 (3.6) \sigma$
WZZ	$2.13^{+1.18}_{-0.96}(\text{stat.})^{+0.76}_{-0.41}(\text{syst.})$	$200^{+111}_{-91}(\text{stat.})^{+65}_{-37}(\text{syst.})$	$2.8 (1.6) \sigma$



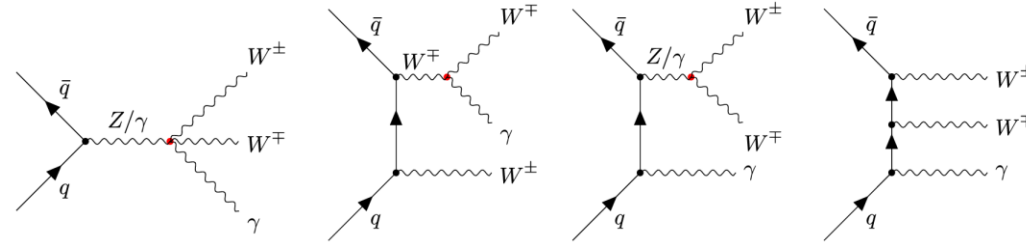
Coefficient	Expected limit [TeV^{-4}]	Exp. $\sqrt{\hat{s}_c}$ [TeV]	Observed limit [TeV^{-4}]	Obs. $\sqrt{\hat{s}_c}$ [TeV]
f_{M2}/Λ^4	$[-18, 17]$	1.2	$[-19, 19]$	1.2
f_{M3}/Λ^4	$[-28, 29]$	1.5	$[-28, 29]$	1.5
f_{M4}/Λ^4	$[-14, 14]$	1.6	$[-12, 12]$	1.7
f_{M5}/Λ^4	$[-11, 11]$	2.1	$[-9.1, 9.3]$	2.2



Tri-boson: $WW\gamma$ Observation

➤ **First observation of $WW\gamma$ with significance of 5.9σ (6σ exp.)**

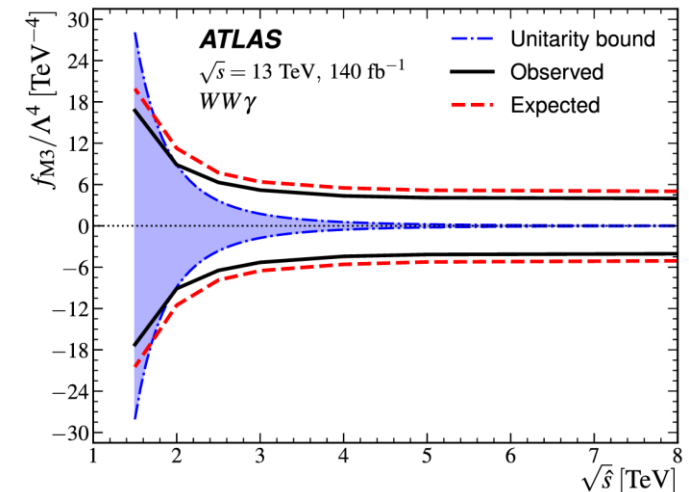
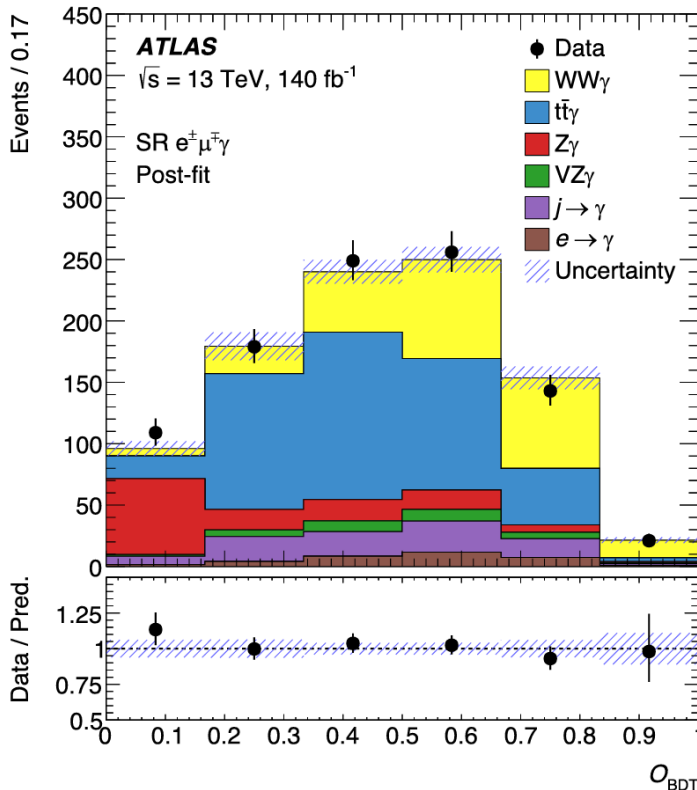
➤ **Measured fiducial cross-section:**
 6.2 ± 0.8 (stat.) ± 0.6 (syst.) fb
 consistent with SM (6.1 fb)



	SR $e^\pm \mu^\mp \nu \bar{\nu} \gamma$
$WW\gamma$	250 ± 40
$VZ\gamma$	31 ± 6
$Z\gamma$	119 ± 7
$t\bar{t}\gamma$	422 ± 34
$j \rightarrow \gamma$	89 ± 34
$e \rightarrow \gamma$	34 ± 5
Total	941 ± 29
Data	957

➤ **Constraints on Wilson coefficients of 13 dim-8 EFT operators via anomalous quartic gauge couplings (aQGC):**

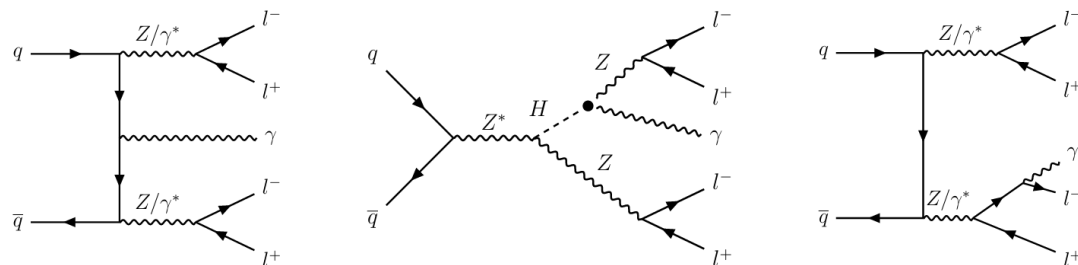
EFT operator	Expected 95 % CI [TeV^{-4}]	Observed 95 % CI [TeV^{-4}]
f_{M0}/Λ^4	$[-8, 8]$	$[-6, 6]$
f_{M1}/Λ^4	$[-13, 13]$	$[-10, 10]$
f_{M2}/Λ^4	$[-3.1, 3.1]$	$[-2.5, 2.5]$
f_{M3}/Λ^4	$[-5, 5]$	$[-4, 4]$
f_{M4}/Λ^4	$[-8, 8]$	$[-6, 6]$
f_{M5}/Λ^4	$[-6, 6]$	$[-5, 5]$
f_{M7}/Λ^4	$[-26, 26]$	$[-21, 21]$
f_{T0}/Λ^4	$[-1.4, 1.4]$	$[-1.1, 1.1]$
f_{T1}/Λ^4	$[-1.7, 1.7]$	$[-1.4, 1.3]$
f_{T2}/Λ^4	$[-4, 4]$	$[-3.1, 3.0]$
f_{T5}/Λ^4	$[-1.1, 1.1]$	$[-0.9, 0.9]$
f_{T6}/Λ^4	$[-1.3, 1.3]$	$[-1.1, 1.1]$
f_{T7}/Λ^4	$[-3.0, 3.0]$	$[-2.4, 2.4]$



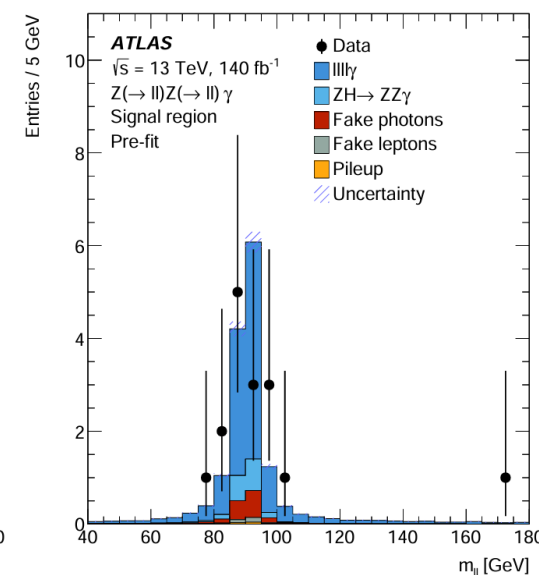
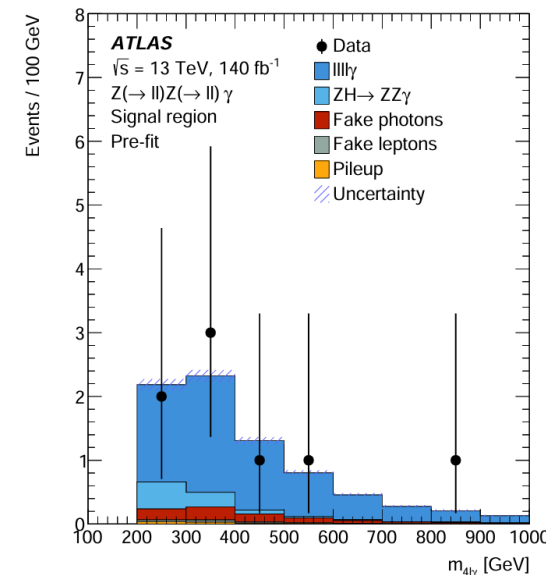
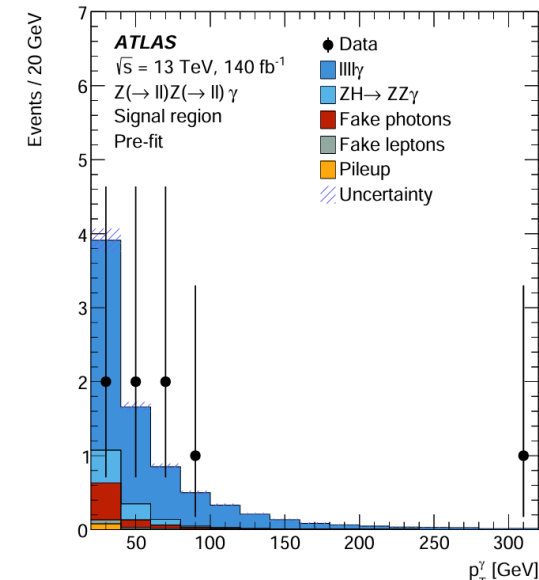
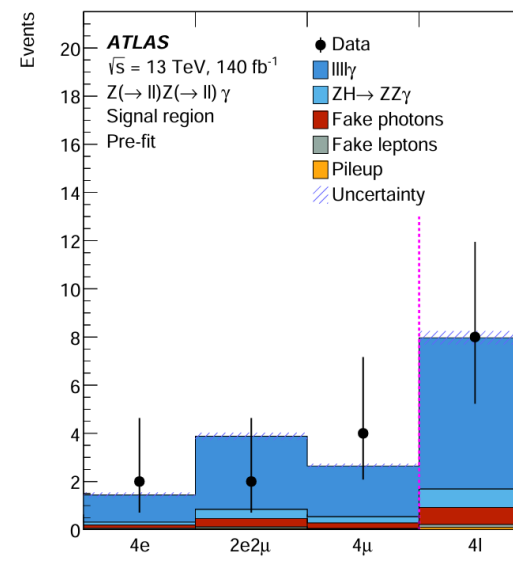
Tri-boson: ZZγ evidence

- $ZZ\gamma \rightarrow 4l+\gamma$ has high S/B ratio (~ 7)
- **Evidence of $ZZ\gamma \rightarrow 4l+\gamma$ (observed 4.4σ)**

$$\sigma_{ZZ\gamma} = 0.144^{+0.064}_{-0.051} \text{ (stat.) } ^{+0.007}_{-0.005} \text{ (syst.) fb}$$



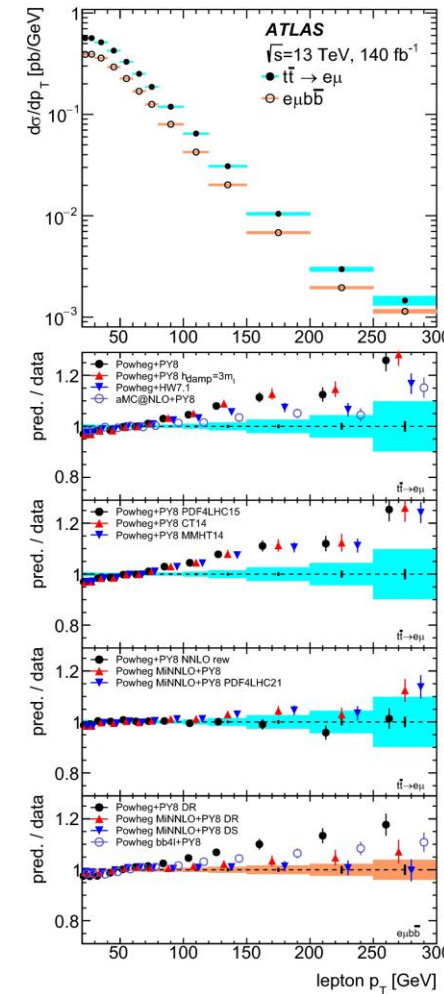
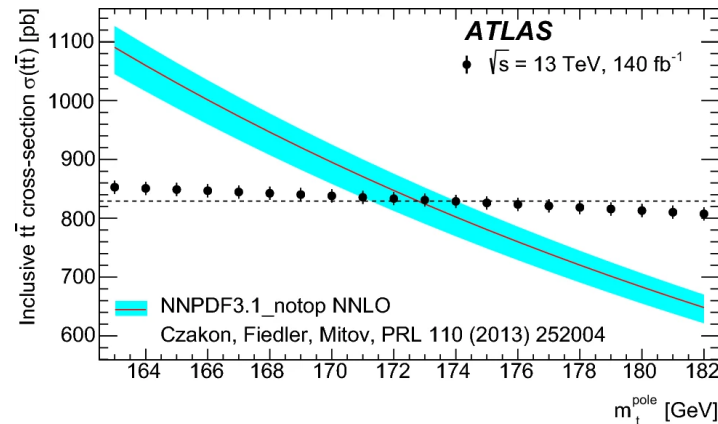
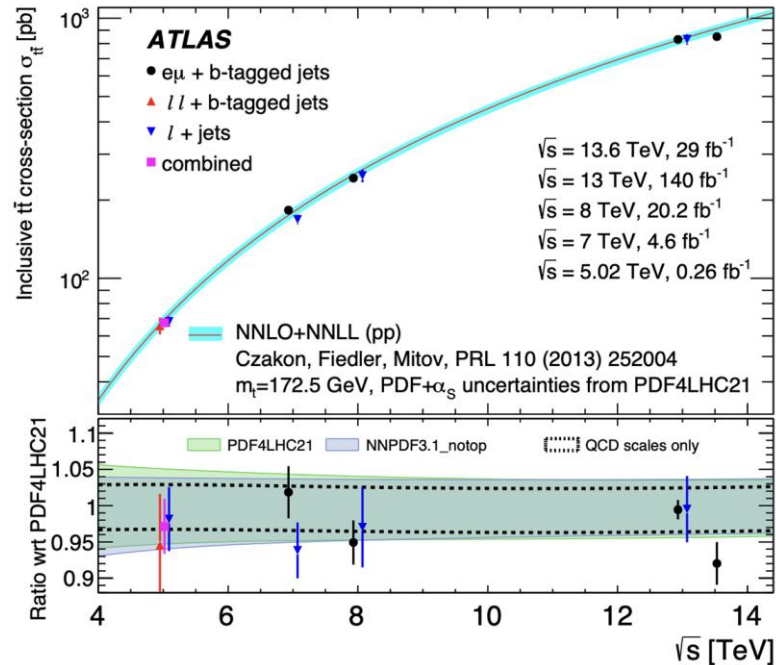
	Number of events
SHERPA 2.2.11 $4\ell\gamma$	6.28 ± 0.09 (stat.) ± 0.18 (syst.)
POWHEG+PYTHIA8 $ZH \rightarrow ZZ\gamma$	0.76 ± 0.03 (stat.) ± 0.03 (syst.)
Signal	7.04 ± 0.09 (stat.) ± 0.18 (syst.)
Fake photons	0.71 ± 0.02 (stat.) ± 0.13 (syst.)
Fake leptons	0.12 ± 0.02 (stat.) ± 0.08 (syst.)
Pileup	0.09 ± 0.002 (stat.) ± 0.02 (syst.)
Total background	0.92 ± 0.03 (stat.) ± 0.15 (syst.)
N_{tot} prediction	7.96 ± 0.09 (stat.) ± 0.23 (syst.)
N_{tot} data	8



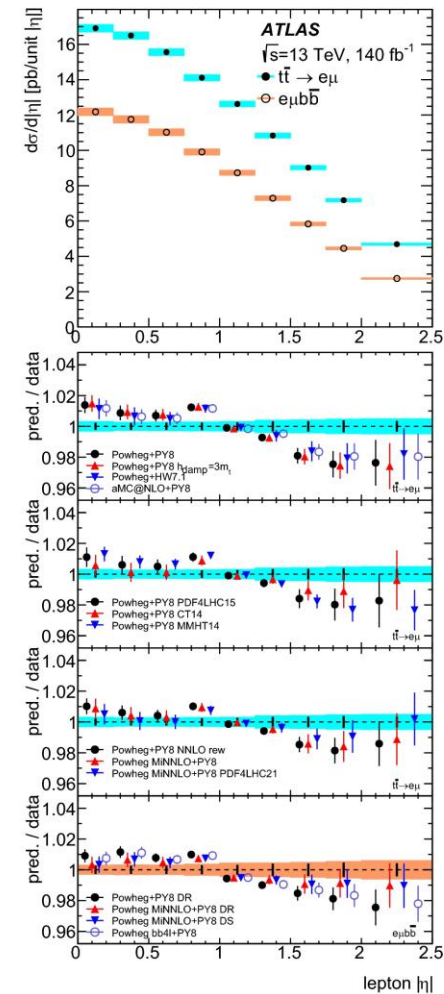
Top Pair Production

- Inclusive cross section: $\sigma_{t\bar{t}} = 829.3 \pm 1.3 (stat) \pm 8.0 (syst) \pm 7.3 (lumi) \pm 1.9 (beam) pb$
- Consistent with NNLO+NNLL, precision limited by systematics and luminosity uncertainties.
- Top pole-mass extraction using NNPDF3.1_notop NNLO:

$$m_t^{pole} = 172.8_{-1.7}^{+1.5} GeV$$



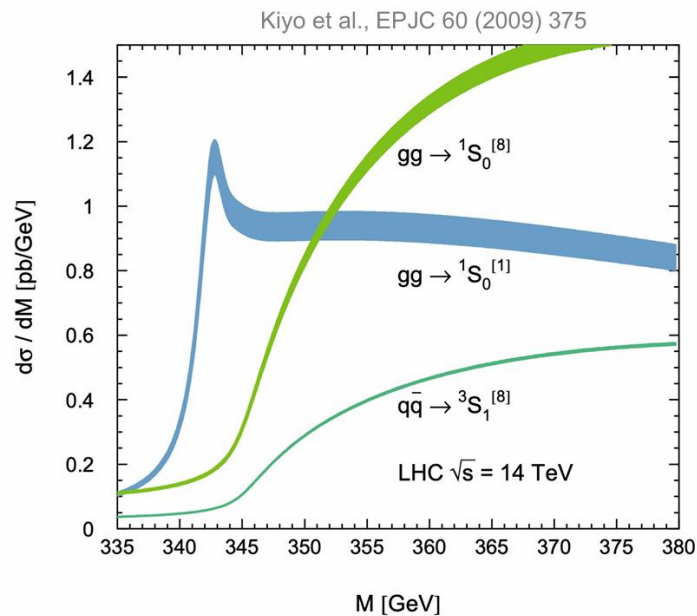
(a)



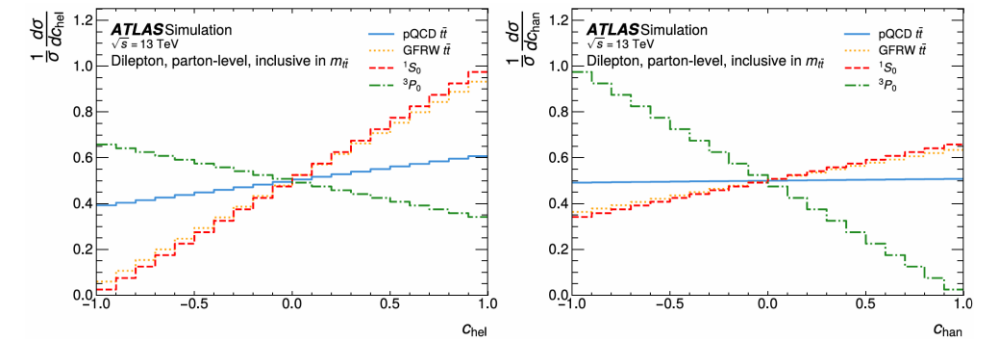
(b)

Differential cross section
in $e\mu$ final states

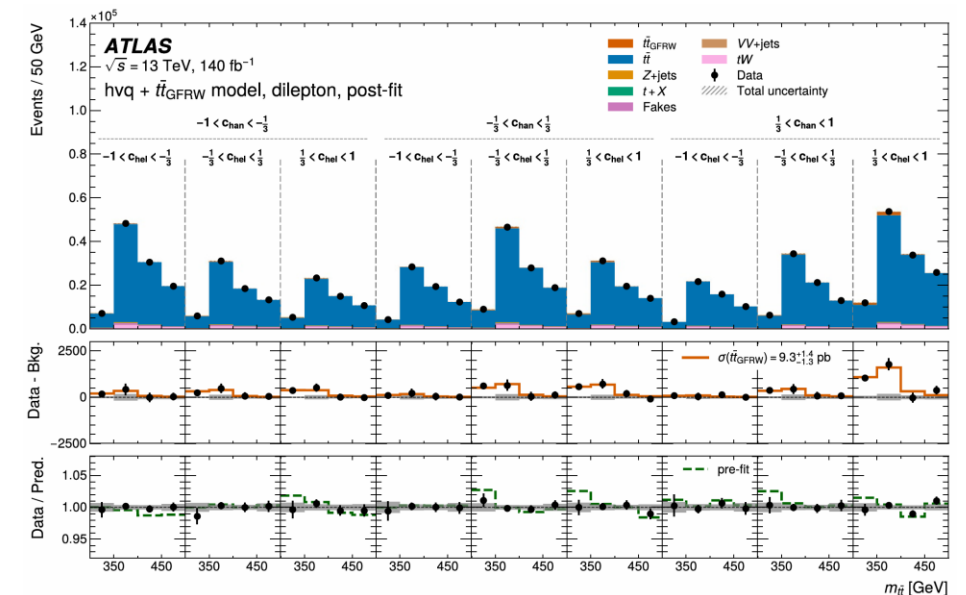
- $t\bar{t}$ quasi-bound-state provide a stringent probe of NRQCD.
- $t\bar{t}$ cross section enhancement near threshold (~ 345 GeV), $\sim 45\%$ larger than SM prediction (6.43pb)
- $\sigma(t\bar{t}_{\text{GFRW}}) = 9.3^{+1.4}_{-1.3} \text{ pb} = 9.3^{+1.1}_{-1.0} (\text{stat.}) \pm 0.8 (\text{syst.}) \text{ pb}$
- **The baseline model without $t\bar{t}$ quasi-bound-state contribution is excluded with 8σ (6σ expected)**
- Overall statistically dominated, $t\bar{t}$ GFRW modelling, pQCD modelling are major sources of uncertainty



Category	Impact
$t\bar{t}_{\text{GFRW}}$ modelling	6.9%
pQCD $t\bar{t}$ modelling	4.7%
JES pile-up	1.5%
b -tagging	1.3%
⋮	
Total syst. uncertainties	8.8%
Total stat. uncertainties	11%



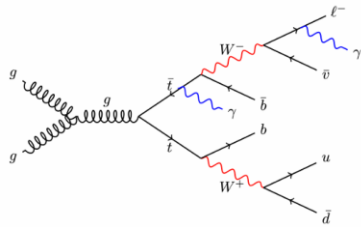
9 orthogonal signal regions based on angular variables



Rare Top-Associated Productions

■ tt + diphoton (observation)

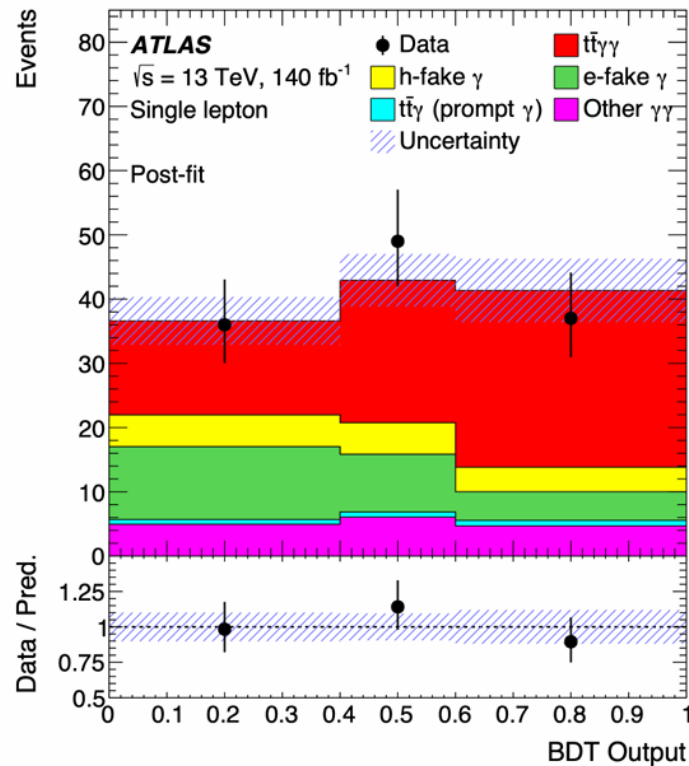
PLB 874 (2026) 140195



Fiducial cross section

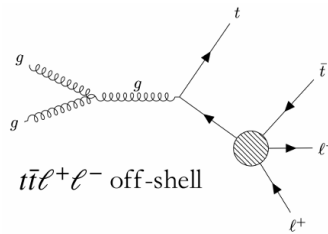
$$\sigma_{\text{fid}}(t\bar{t}\gamma\gamma) = 2.42^{+0.58}_{-0.53} \text{ fb}$$

Observed significance = 5.2σ



■ tt + dilepton (evidence)

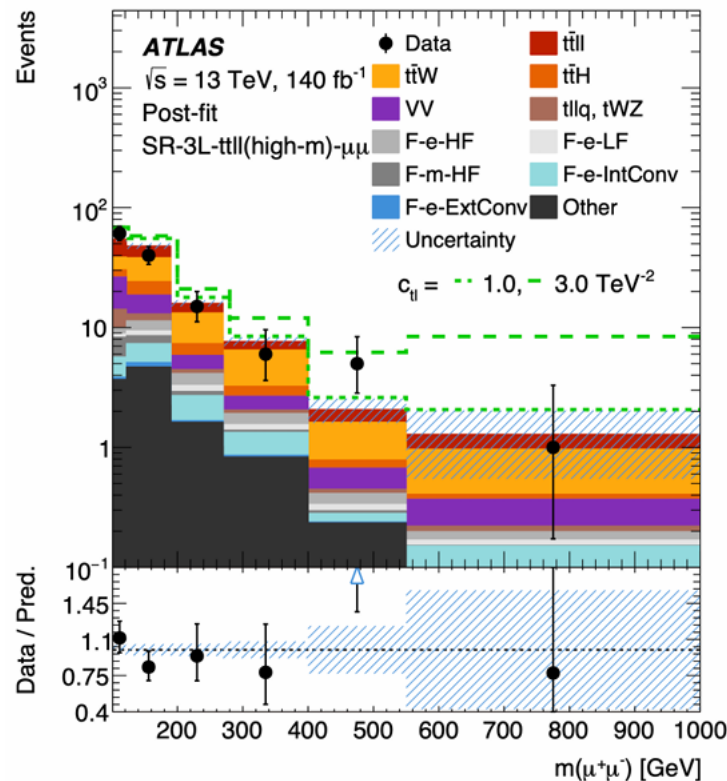
EPJC 85 (2025) 1434



SM signal strength

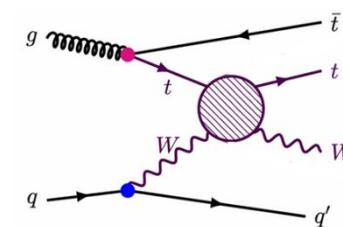
$$\mu(t\bar{t}\ell^+\ell^-) = 1.0^{+0.4}_{-0.4}$$

significance = $2.9 (2.8)\sigma$



■ tt + Wj (no excess)

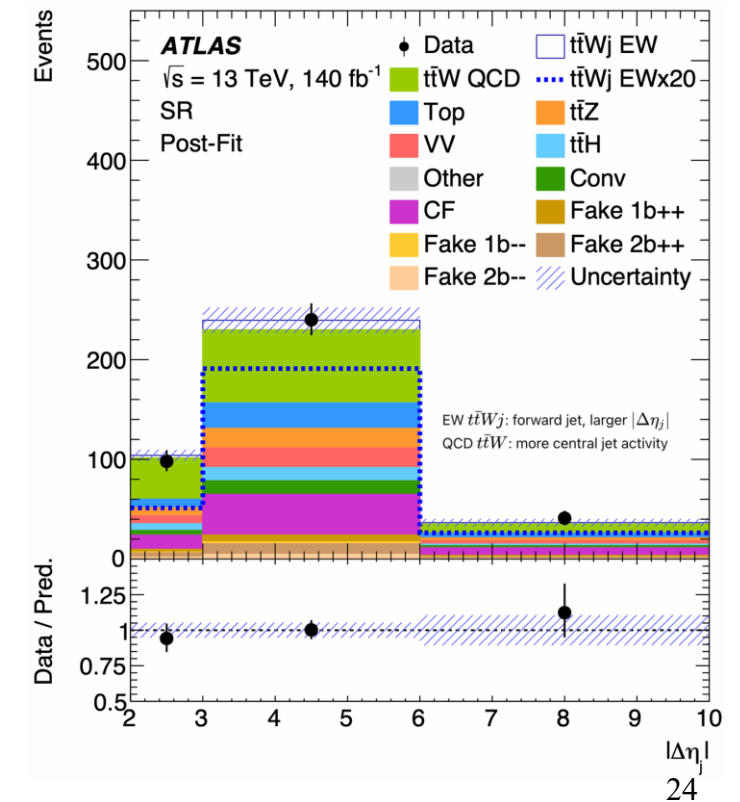
PRD 114 (2026) 012001



$$\mu_{\text{EW}} t\bar{t}Wj = 0.9^{+2.4}_{-3.0}$$

$$\sigma_{\text{EW}}^{95\% \text{ CL}} t\bar{t}Wj < 251 \text{ fb}$$

Expected : 230 fb



Observation of B_c^{*+} and $X(6900)$

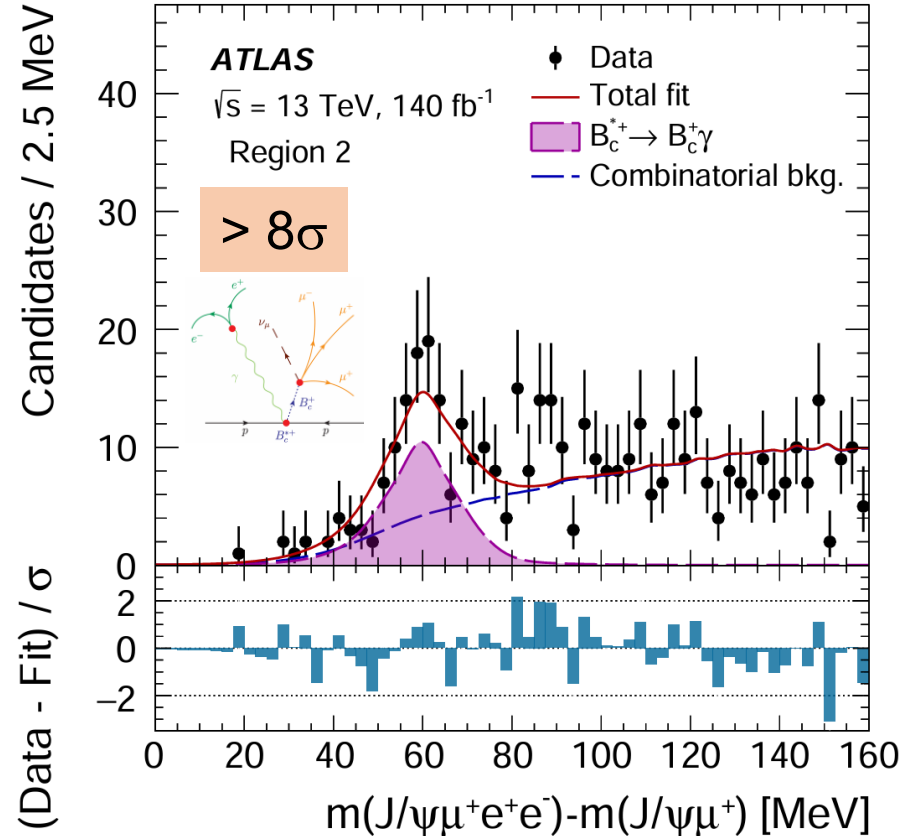
■ Observation of meson $B_c^{*+} \rightarrow B_c^+ \gamma$

arXiv:2605.16228 (PRL)

$$B_c^+ \rightarrow J/\psi \mu^+ \nu_\mu X$$

$$\Delta m_{B_c^{*+}} = 64.5 \pm 1.4 \text{ (stat.)}_{-1.4}^{+1.0} \text{ (syst.) MeV}$$

$$m(B_c^{*+}) = 6339.0 \pm 1.4 \text{ (stat.)}_{-1.4}^{+1.0} \text{ (syst.)} \pm 0.3 (m_{B_c^+}) \text{ MeV}$$



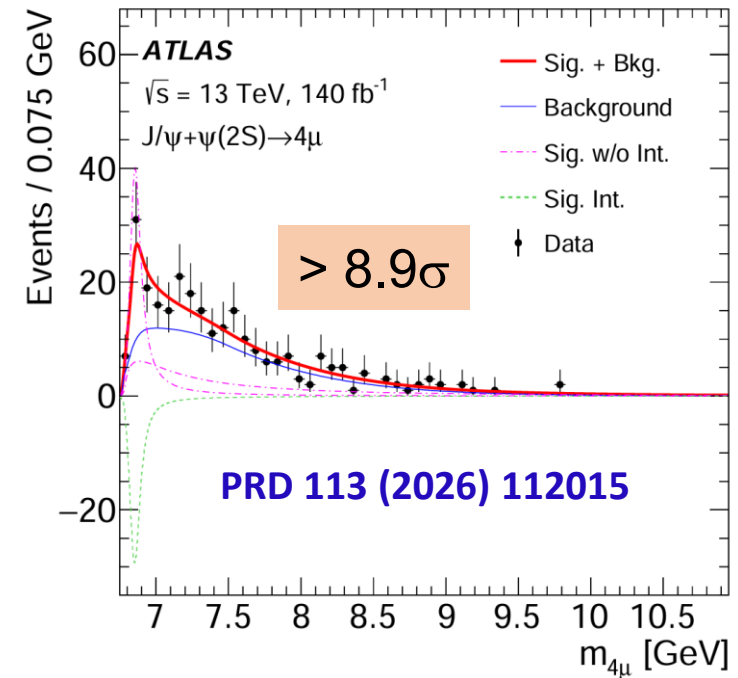
■ Observation of $X(6900) \rightarrow J/\psi + \psi(2S) \rightarrow 4\mu, 4\mu + 2\pi$

$$m / \text{GeV} \quad 6.860 \pm 0.023 \pm 0.010$$

$$\Gamma / \text{GeV} \quad 0.082 \pm 0.032 \pm 0.015$$

$$R \quad 1.08 \pm 0.20_{-0.09}^{+0.40}$$

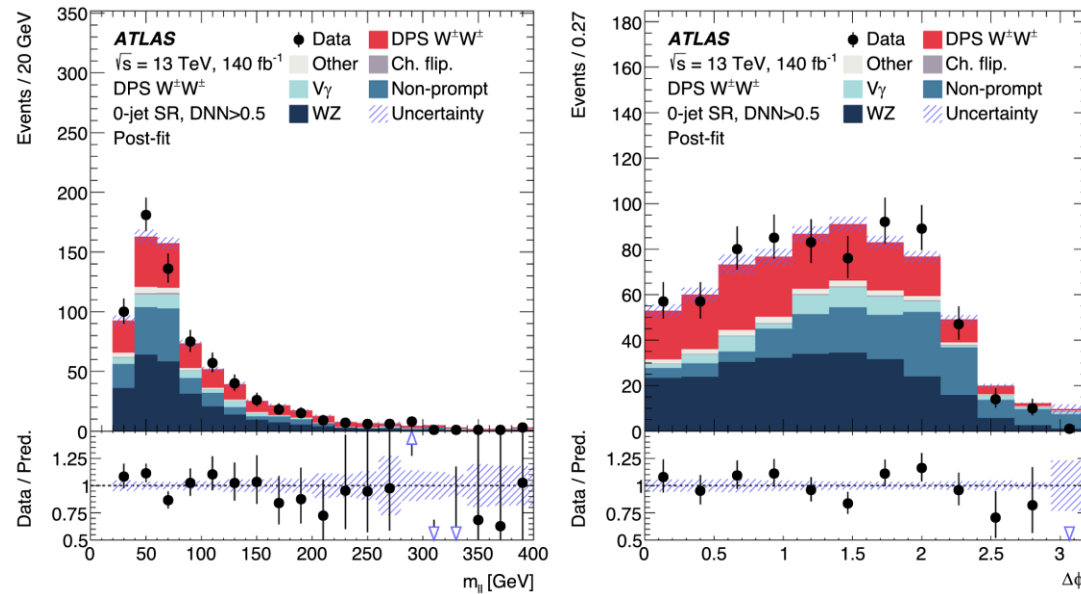
$$R = \Gamma_{X(6900) \rightarrow J/\psi + \psi(2S)} / \Gamma_{X(6900) \rightarrow \text{di-}J/\psi}$$



→ Hadronic decay amplitudes constrain tetraquark quantum numbers and couplings in LQCD, while LQCD spectra are needed to distinguish compact tetraquarks from charmonium molecules.

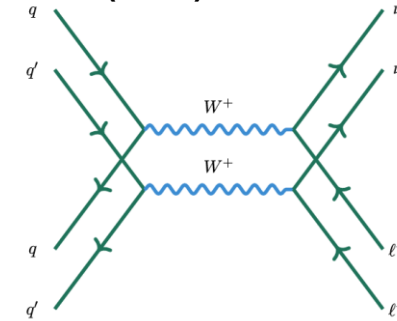
Observation of DPS in ssWW

- Study of double-parton scattering (DPS) is crucial to understand internal structure of colliding hadrons including the correlation effects among partons.
- ssWW provides a clean DPS signature, observed 8.8σ with Run2 data (140fb^{-1}) σ_{eff} is $10.6 \pm 1.8 \text{ mb}$

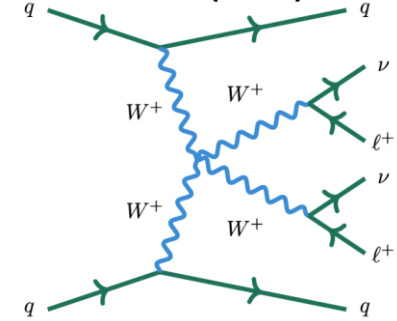


→ σ_{eff} provides experimental boundary condition for lattice LaMET calculations of double parton distributions (DPD) which is the key non-perturbative input connecting lattice QCD with multi-parton interactions at the LHC.

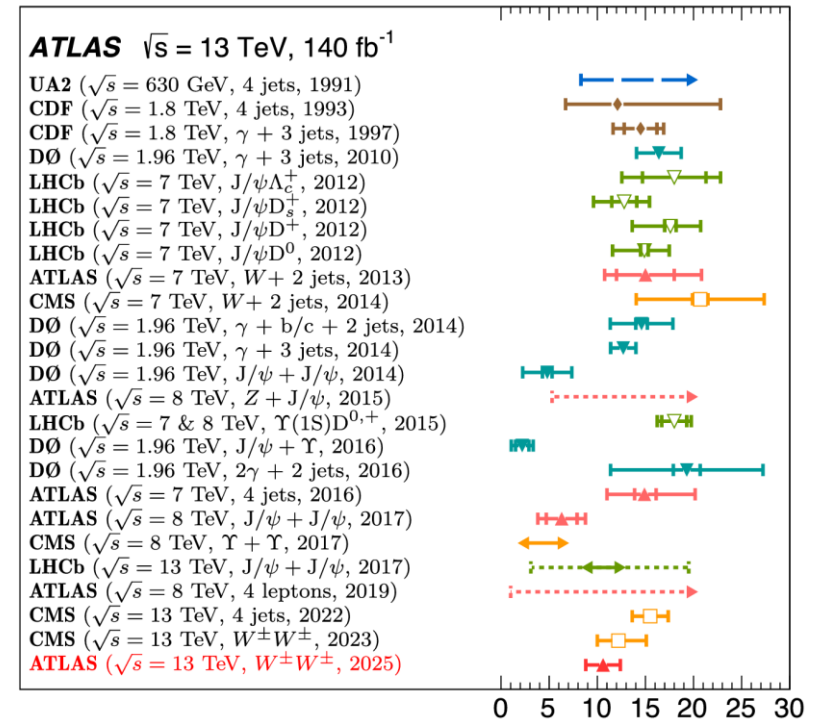
Double Parton Scattering (DPS)



Single Parton Scattering (SPS)



Experiment (energy, final state, year)



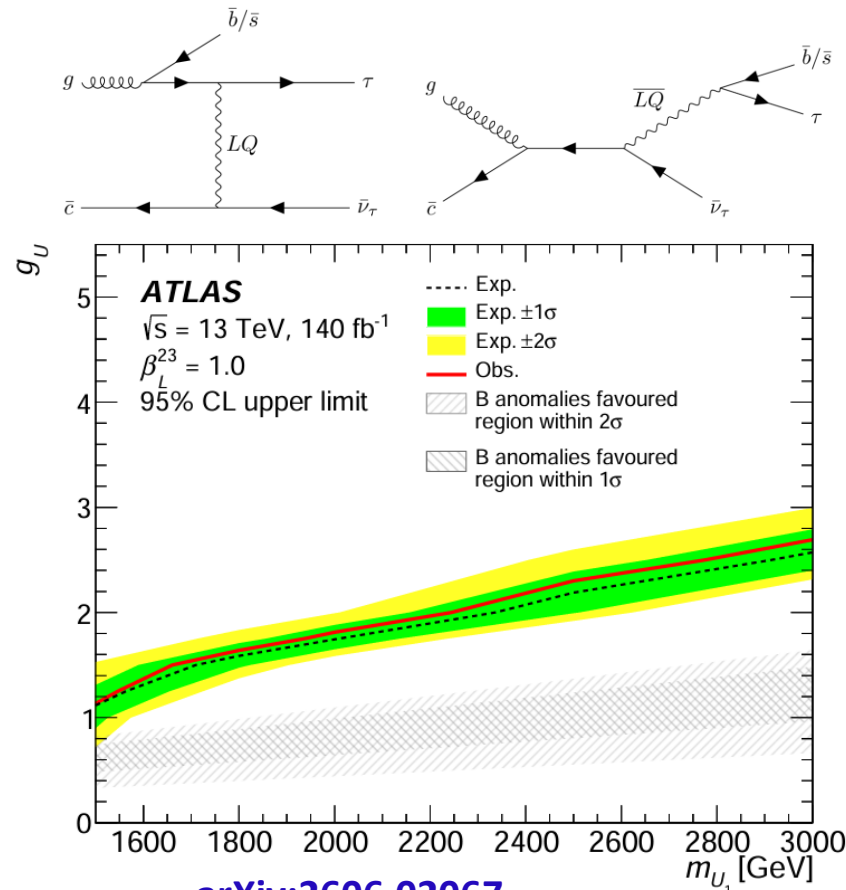
PLB 870 (2025) 139892

$\sigma_{\text{eff}} [\text{mb}]$

■ Search for leptoquark with τ -lepton

Signal is described by 3 parameters: m_{U_1} , g_U and β_L^{23}

No signal is observed, limits are set on couplings in benchmark U_1 vector-leptoquark model at 95%CL:



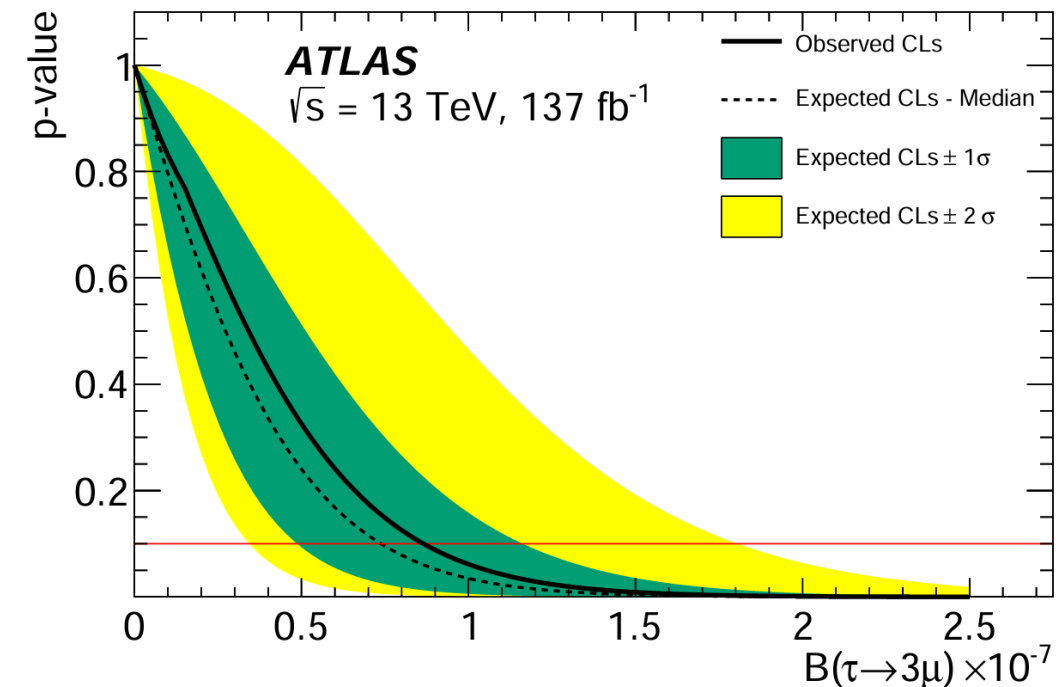
■ Search for LFV $W \rightarrow \tau \nu \rightarrow 3\mu \nu$

Any observation of LFV would be evidence of BSM

No signal is observed, the best-fit signal strength:

$$B(\tau \rightarrow 3\mu) = (1.5 \pm 4.0) \times 10^{-8}$$

$$B(\tau \rightarrow 3\mu) < 8.7 \times 10^{-8} (7.5 \times 10^{-8}) \text{ at } 90\% \text{ CL}$$

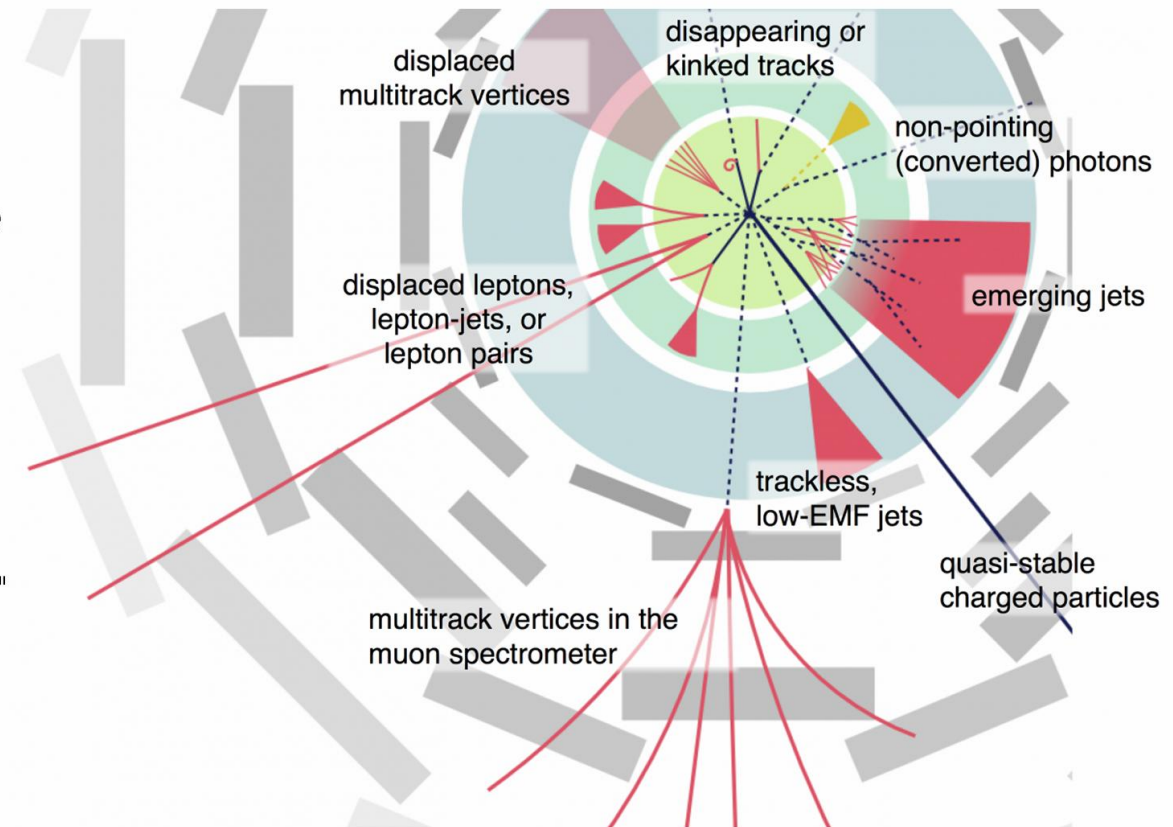


PLB 880 (2026) 140748

arXiv:2603.18099

- The long-lived particle (LLP) regime probes particles with decay lengths, supported by theories including LFV, cascade decays through heavy mediators and RPV SUSY etc.
- ATLAS enables sensitive search for LLPs with decay length ($c\tau$) around $10^{-4} \sim 10$ m.

- **Displaced vertices of oppositely charged leptons**
"Search for long-lived particles using displaced vertices of oppositely charged leptons in 140 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ with the ATLAS detector"
 Submitted to: Phys. Lett. B: [Arxiv: 2601.05664](#)
- **Displaced Decays with Missing Transverse Momentum**
"Search for displaced decays of long-lived particles in events with missing transverse momentum in $\sqrt{s} = 13 \text{ TeV}$ $p p$ collisions with the ATLAS detector"
 Submitted to: JHEP: [Arxiv: 2603.12051](#)
- **Displaced vertices and Displaced Muons**
"Search for massive, long-lived particles in events with displaced vertices and displaced muons in pp collisions at $\sqrt{s} = 13.6 \text{ TeV}$ with the ATLAS experiment"
 Submitted to Phys. Lett. B: [Arxiv: 2603.01991](#)
- **Search for emerging jets (Run 2)**
"Search for emerging jets in $p p$ collisions at $\sqrt{s} = 13 \text{ TeV}$ with the ATLAS experiment"
 Submitted October 14, 2025: [Arxiv: 2510.12347](#)
- **Search for emerging jets (Run 3)**
"Search for emerging jets in $p p$ collisions at $\sqrt{s} = 13.6 \text{ TeV}$ with the ATLAS experiment"
 Physics, Vol. 88 (2025) 097801: [Arxiv: 2505.02429](#)



Graphics by Heather Russell

■ LLP: DV + MET

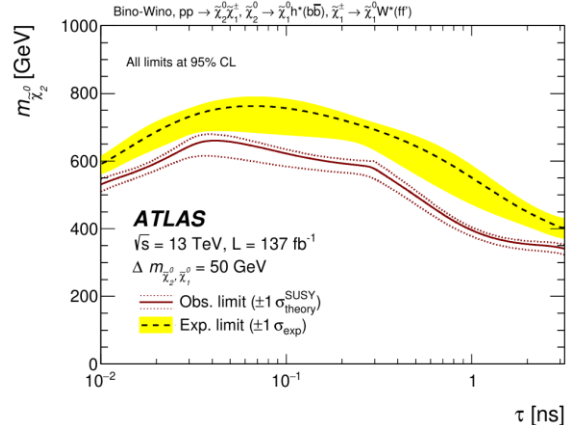
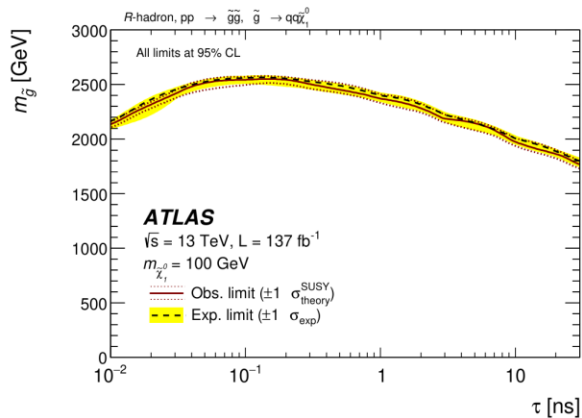
JHEP 08 (2026) 016

Four models: Gluinos R-hadron

Neutralinos Bino-Wino coannihilation

Higgsinos decaying to axinos

Higgs portal model: light pseudoscalars

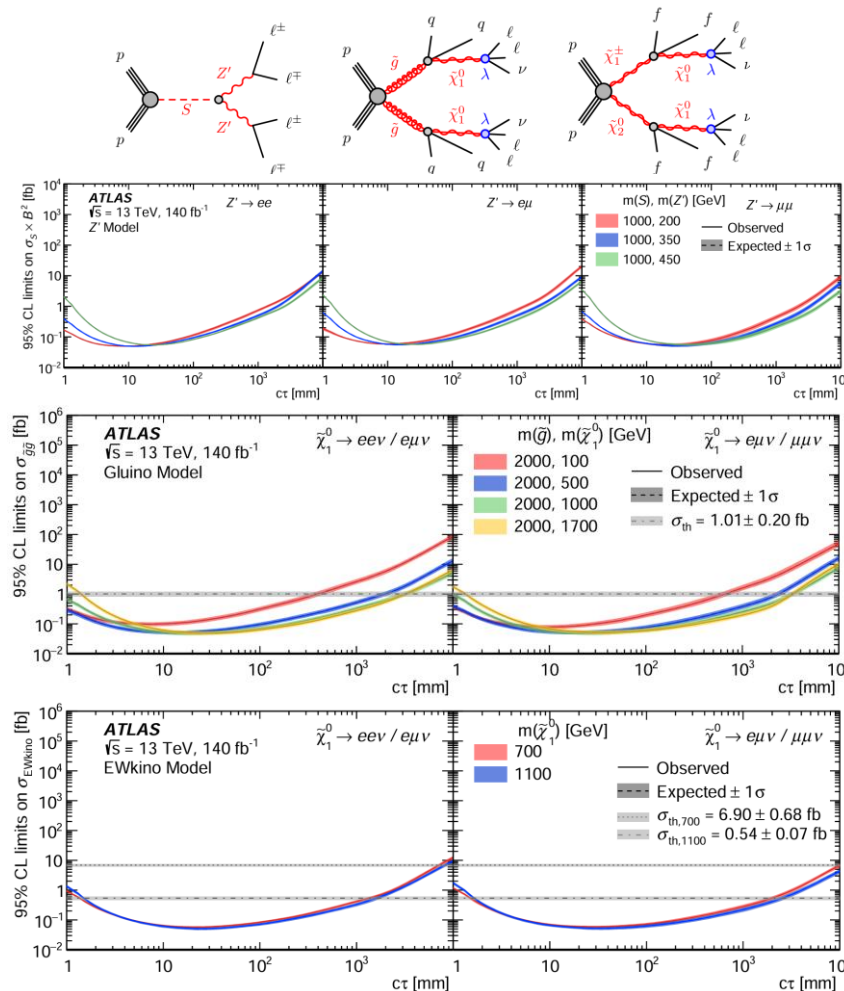


■ LLP: DV + leptons

PLB 878 (2026) 14097

Z' , Gluino and Electroweakino models

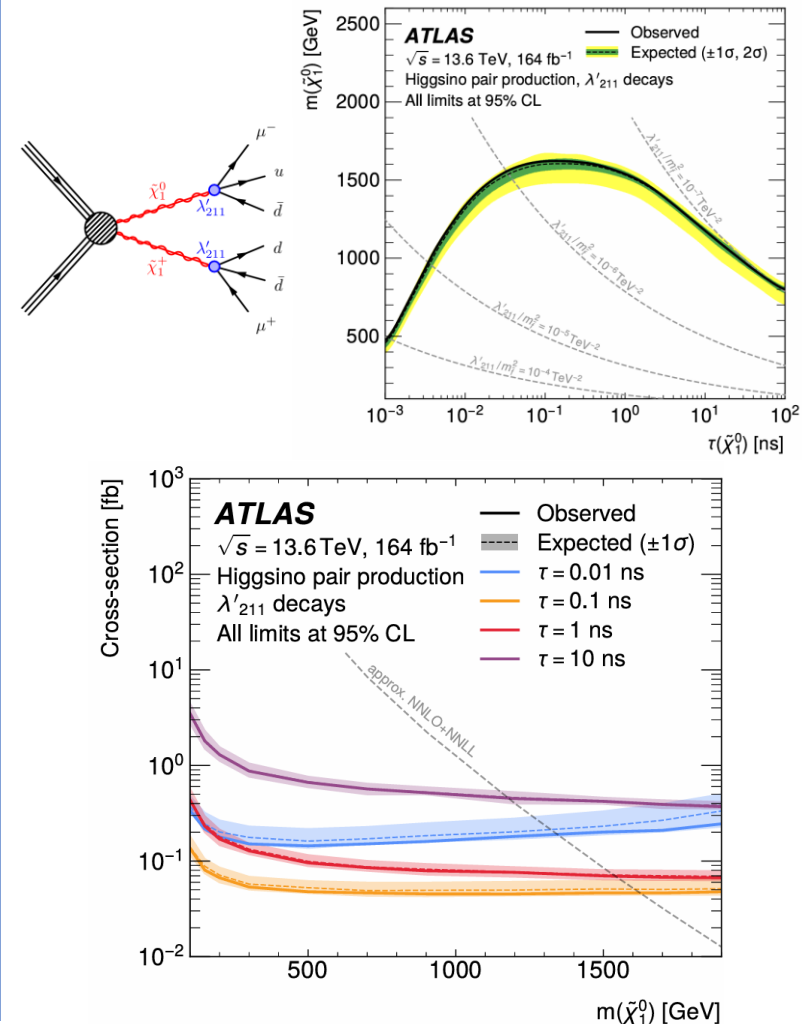
Cross section limits with $c\tau$ (1-10000) mm



■ LLP: DV + Muons

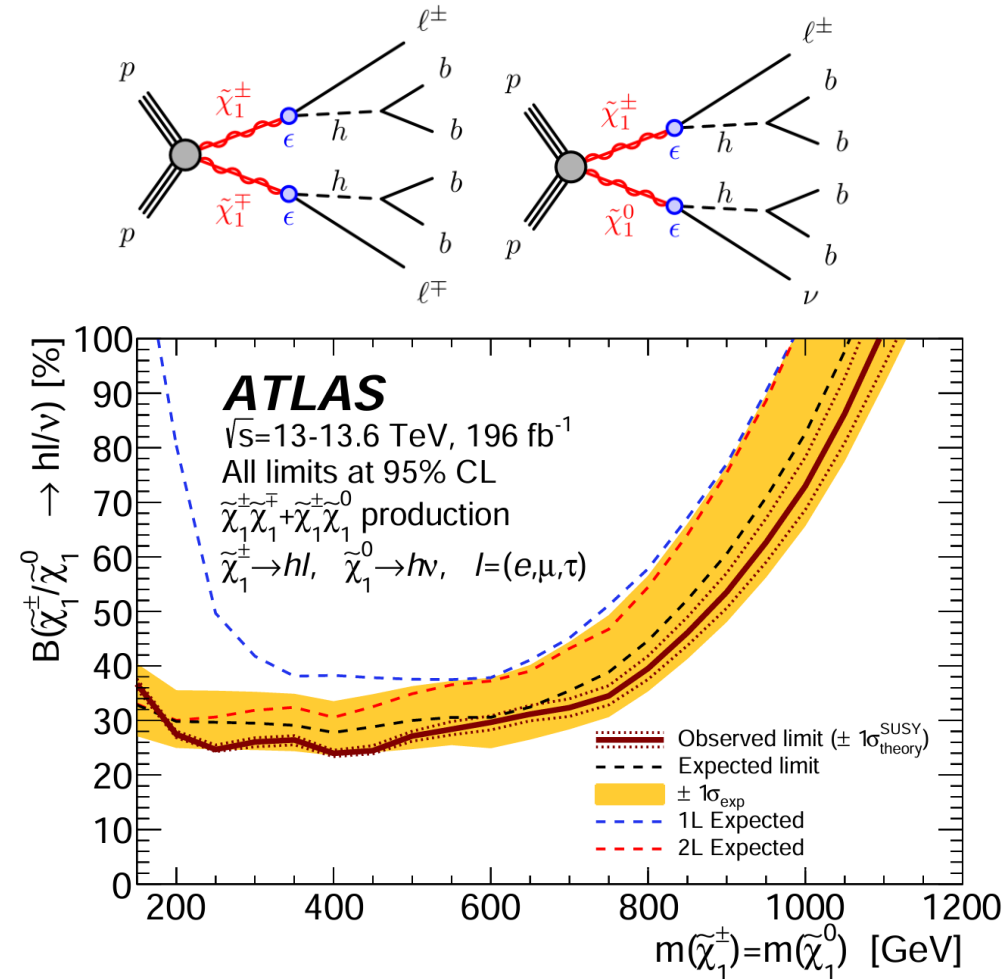
PLB 878 (2026) 140509

RPV SUSY model: higgsino pair production



Search for RPV Chargino and Neutralinos

Charginos and neutralinos (via Higgs decay) with masses between 150 and 1100 GeV are excluded at 95% CL.

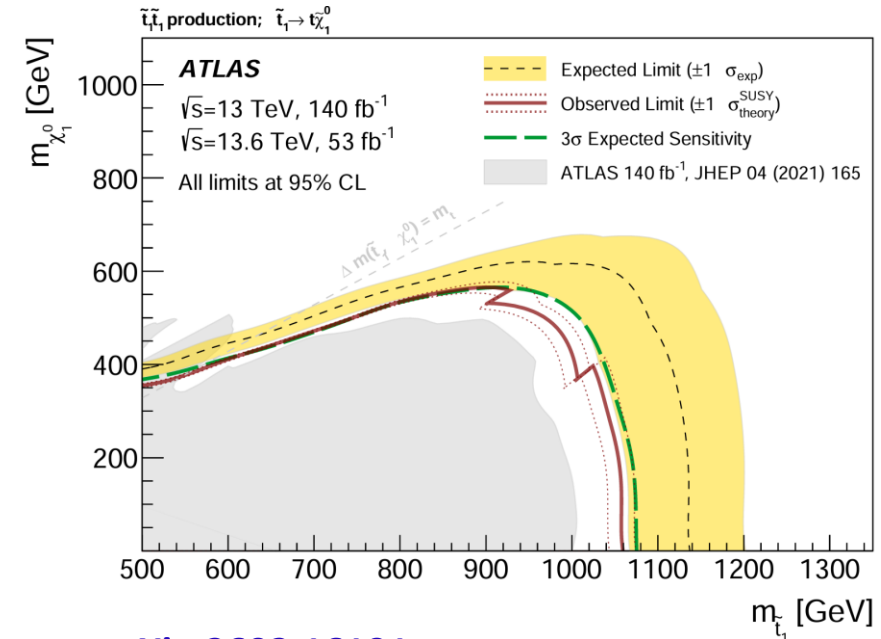
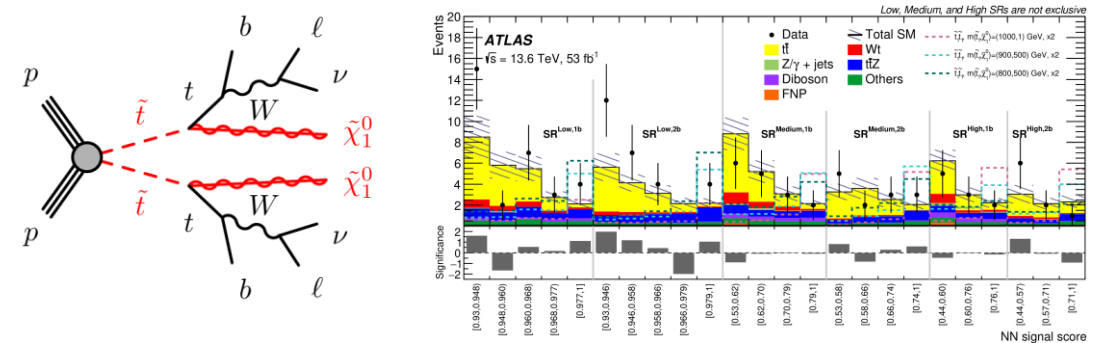


PRD 114 (2026) 052007

Search for pair of top squarks

Top squark mass limits improving 10%: $>1060\text{ GeV}$ at 95% CL

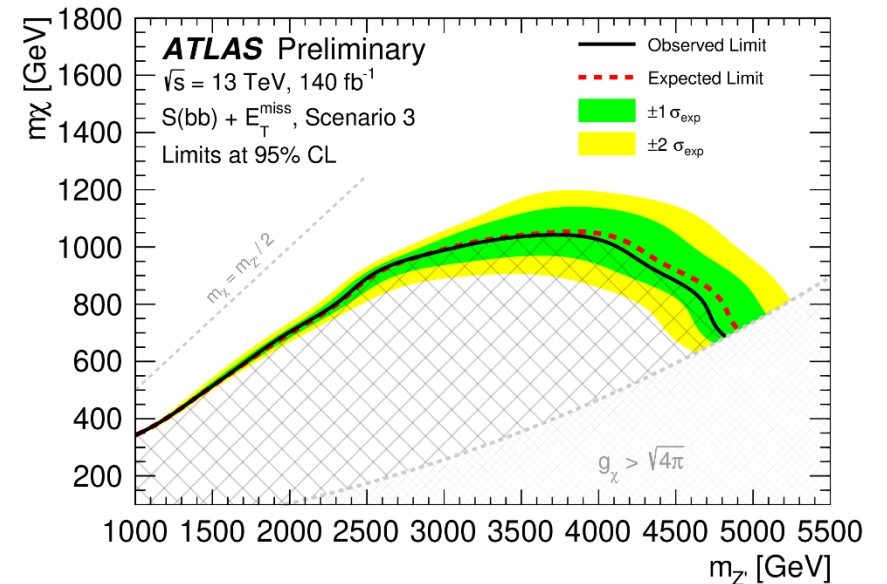
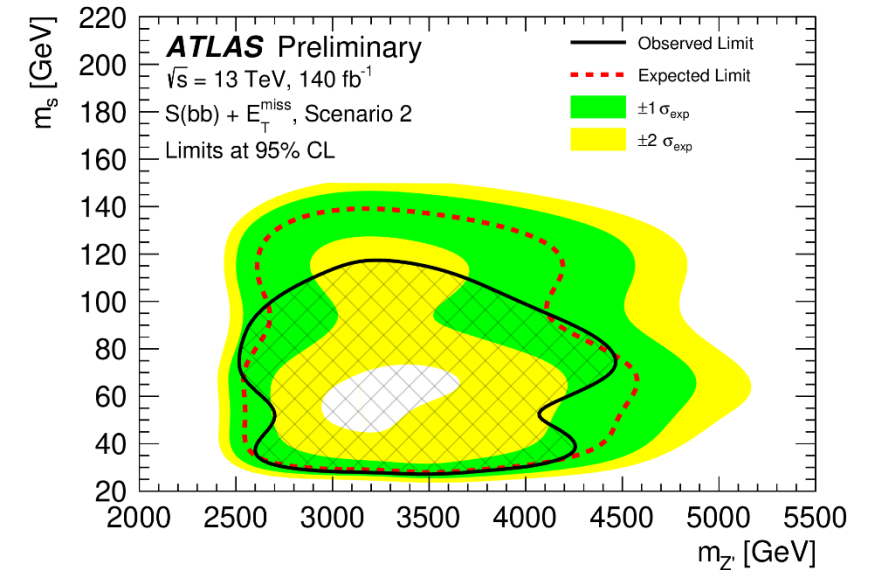
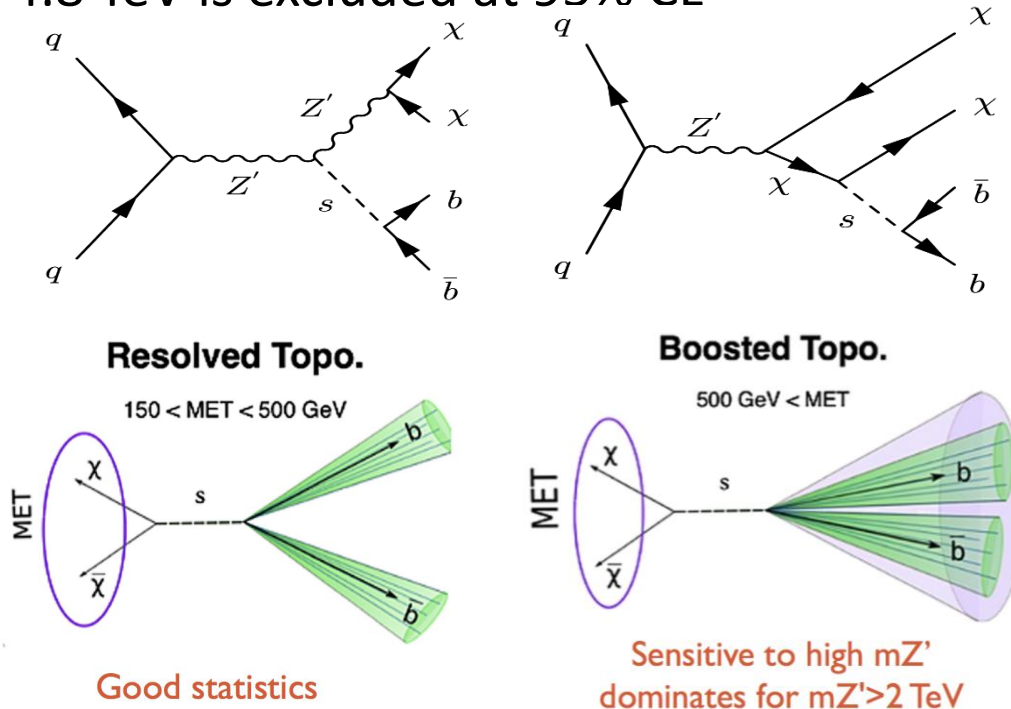
Neutralino mass: $>560\text{ GeV}$ for $m(\tilde{t}_1)$ of 900 GeV at 95% CL



arXiv:2603.16191

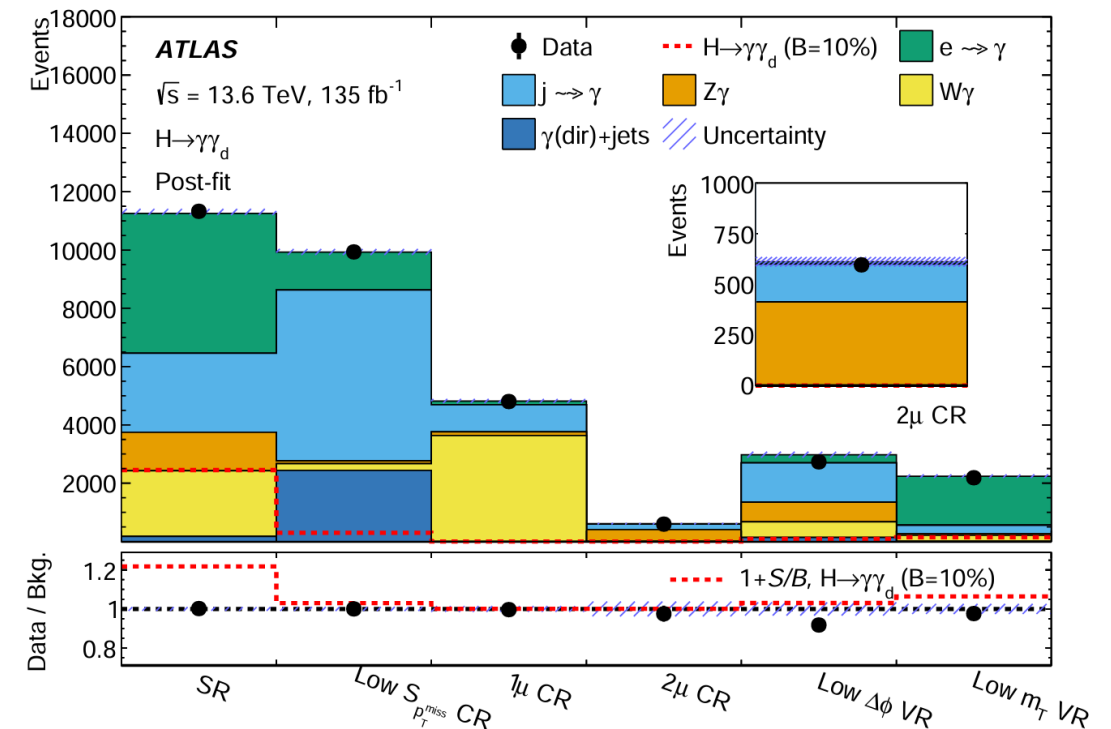
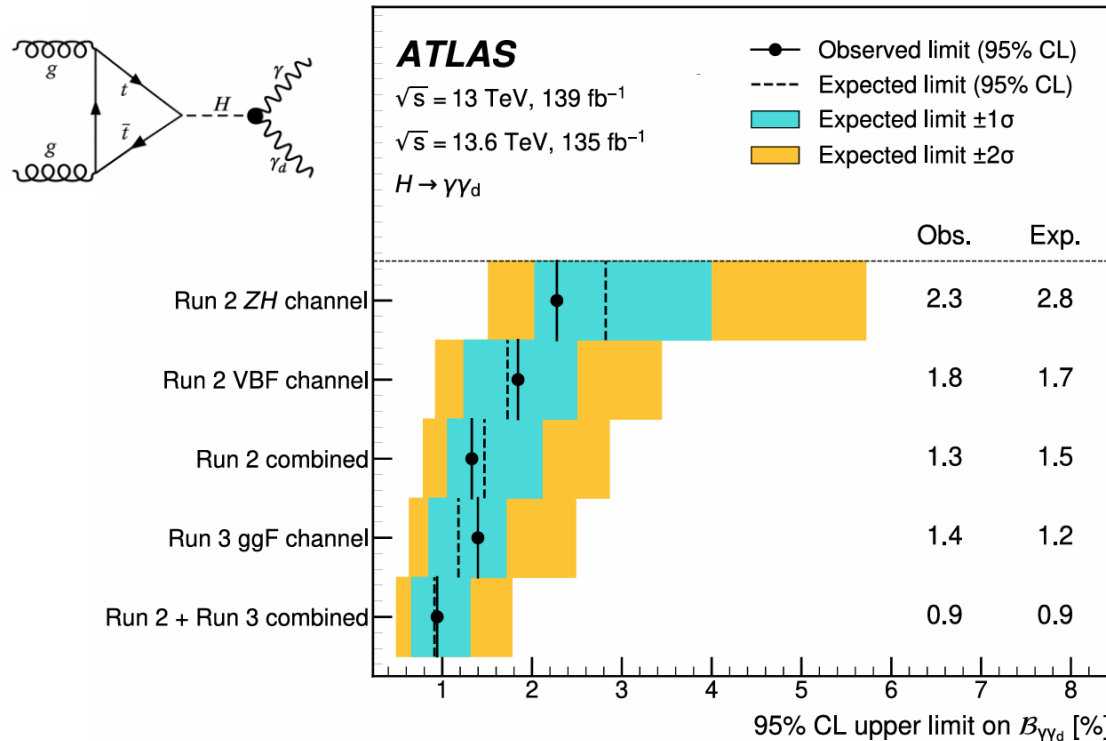
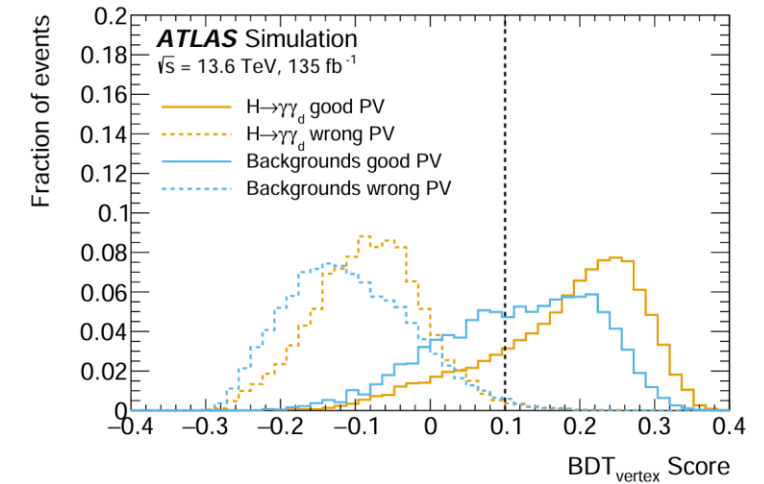
Hunting for New Particles

- Search for dark Higgs boson (s) in Z' mediator model
- Dxbb to improve b-tagging calibration efficiency
- Best limit on dark Higgs search which satisfy observed cosmological constraint on freeze-out relic density $\Omega h^2 = 0.1200 \pm 0.0012$ [PLANCK218]
- Dark Higgs mass between [30,150] GeV with Z' mass up to 4.8 TeV is excluded at 95% CL



Hunting for New Particles

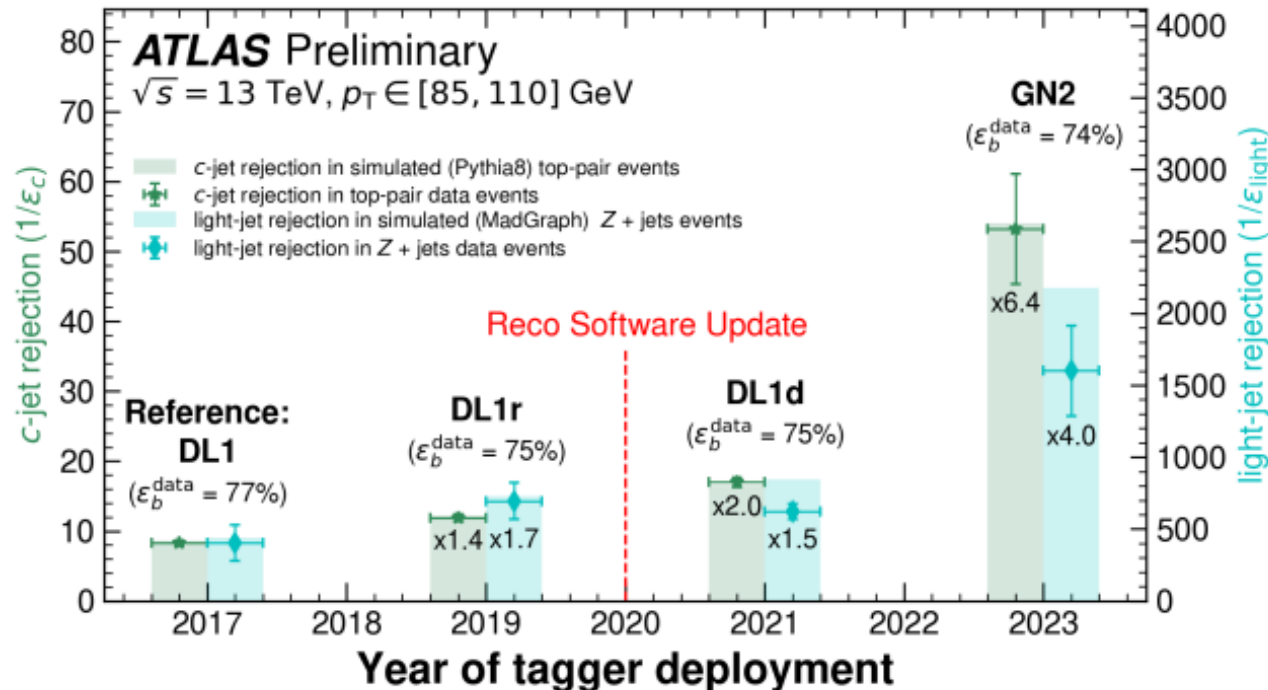
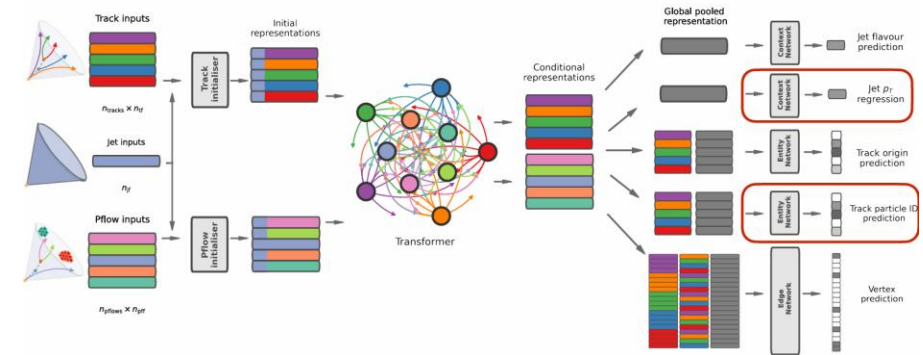
- Search for dark photon in Higgs decays ($ggF\ H \rightarrow \gamma\gamma_d$)
- Predicted as the gauge boson of dark U(1) group in hidden sector
- Dedicated new trigger improve acceptance x2 – Run3 (2023+2024)
- Primary vertex with dedicated BDT_{vertex}
- Observed (exp.) upper limit on BR ($H \rightarrow \gamma\gamma_d$): 0.9% (0.9%) at 95%CL



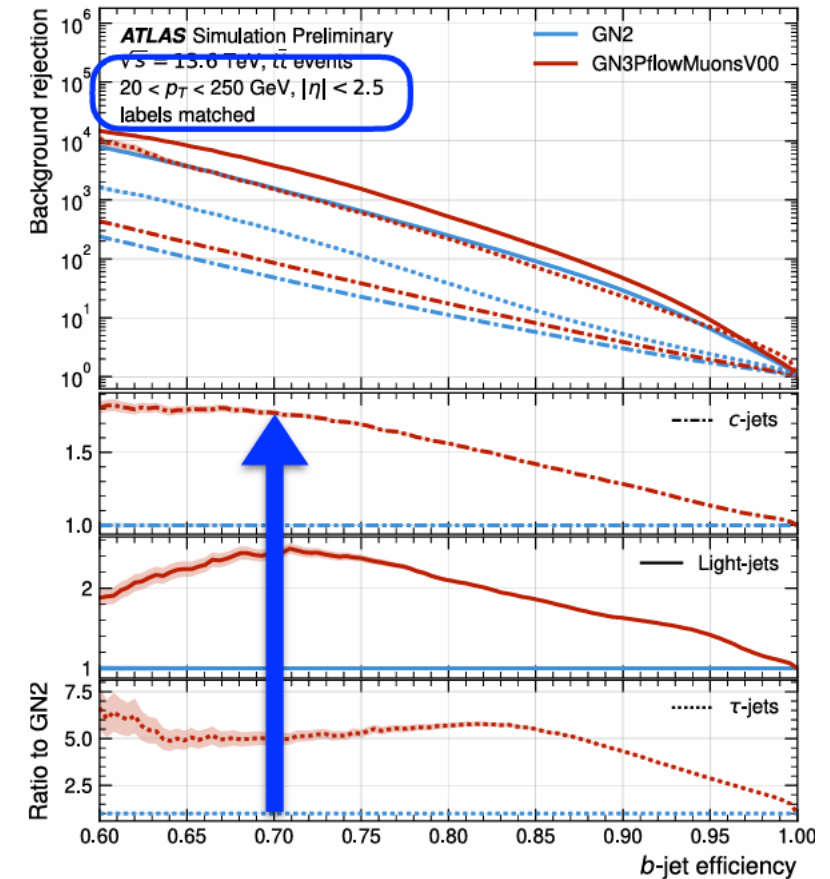
Transforming Flavor Tagging: GN2 → GN3

Briefing: ATLAS enters a new era of jet flavour tagging – powered by AI

- GN3 combines inputs from jets, tracks (with looser selection), charged/neutral PFO with dedicated initialisation network before a transformer encoder
- Jet flavor classification for b/c/ud/s/g-jet with 4 auxiliary tasks
- For a given b-jet signal efficiency, significant improvement for background rejection



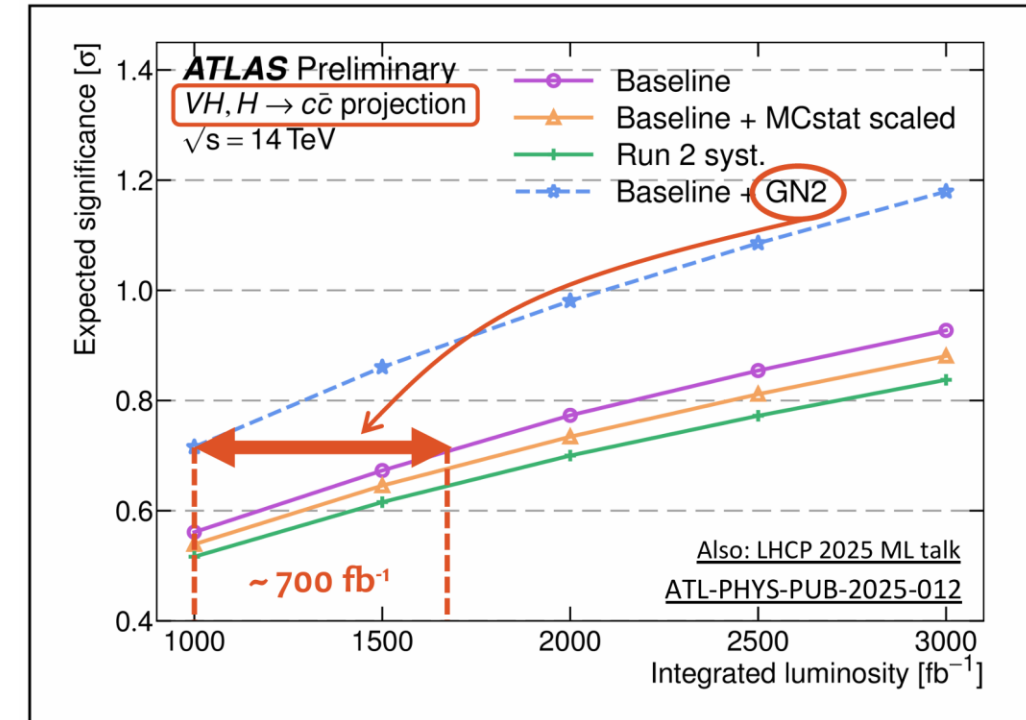
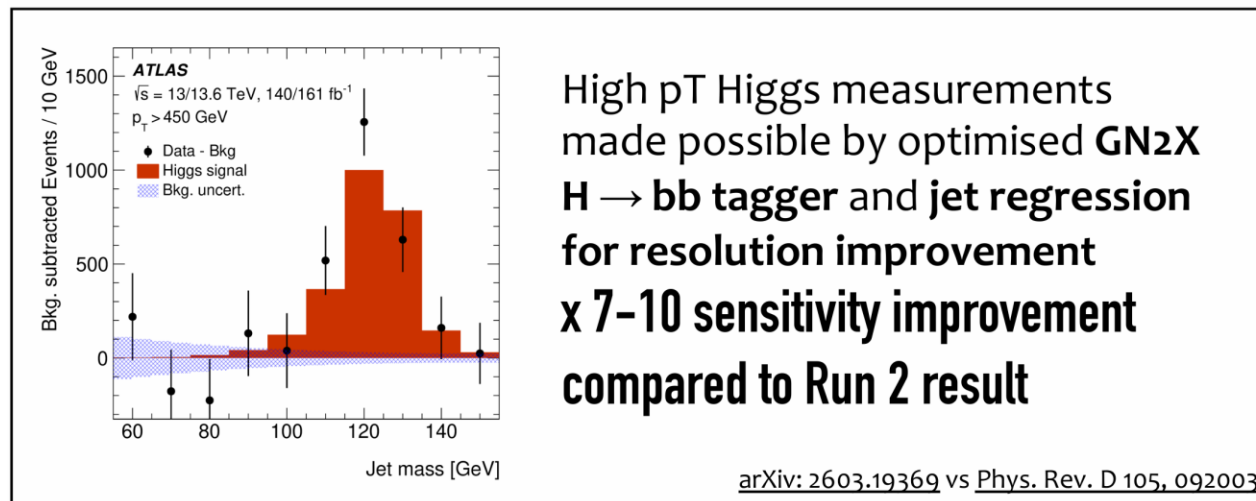
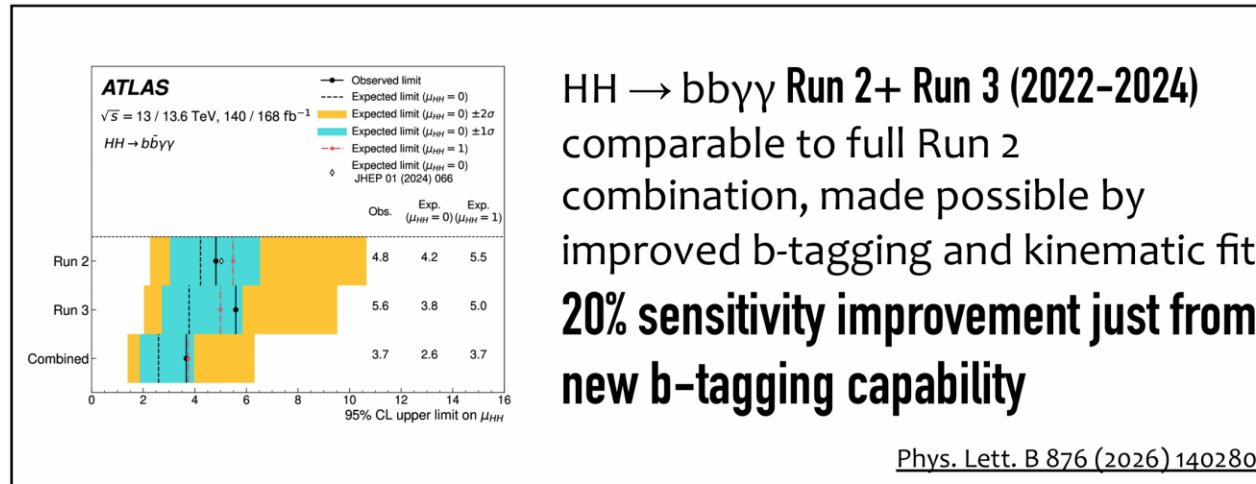
Nature Communication 17 (2026) 541



ATL-PHYS-PUB-2026-001

Impact of Flavor Tagging

Improved sensitivity for better flavor tagging: $HH \rightarrow bb\gamma\gamma$, VH ($H \rightarrow bb, cc$)



3.8 σ (2.5 σ exp.) **PRL 137 (2026) 071801**

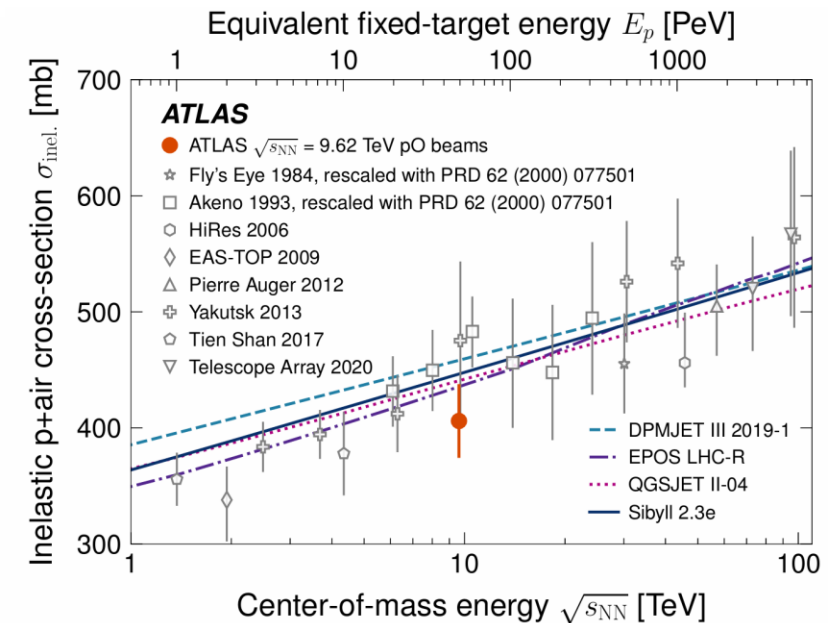
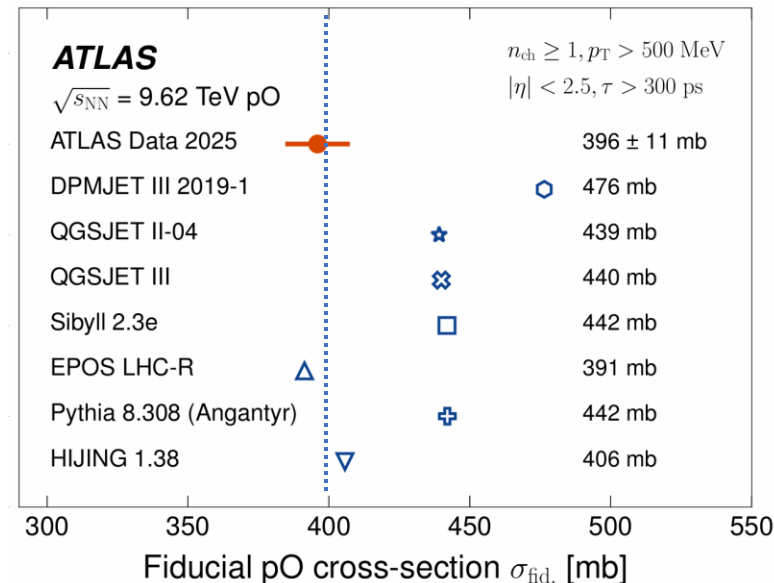
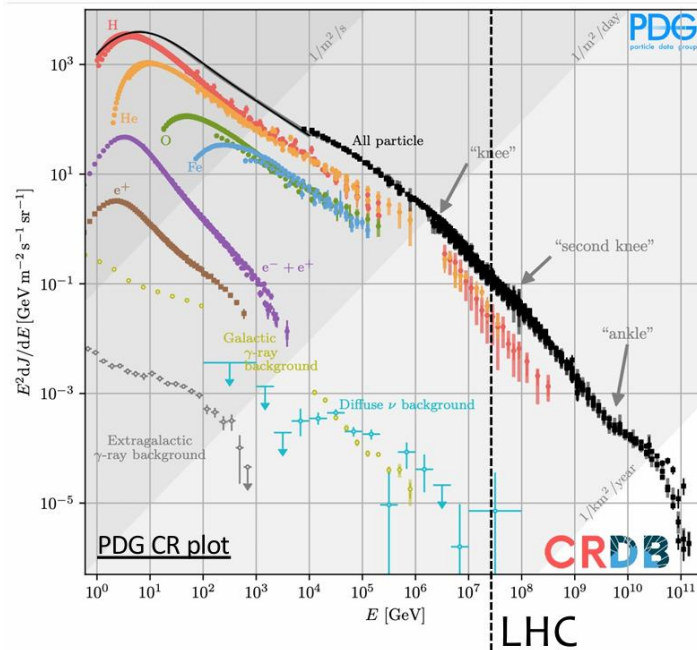
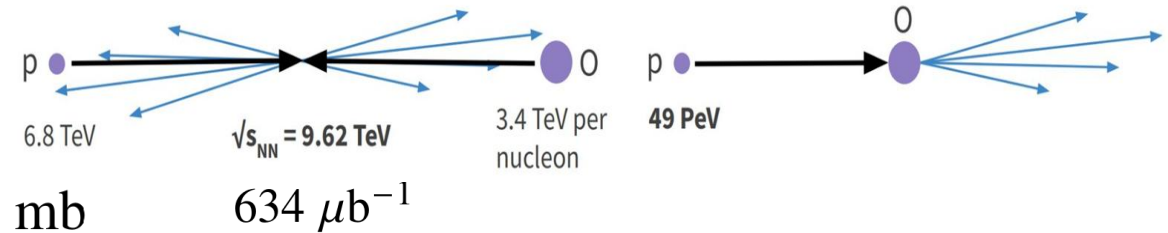
Improved sensitivity for same luminosity, or a data-size booster!

Also: keeps HEP computationally cutting-edge, attracting talent and innovation

- Revealing origins of cosmic rays is a crucial goal in astro-particle physics
- First collider measurement mimicking cosmic-ray atmospheric interactions
- Fiducial p-O (6.8+3.4TeV) cross section consistent with MC (EPOS LHC-R and HIJING)

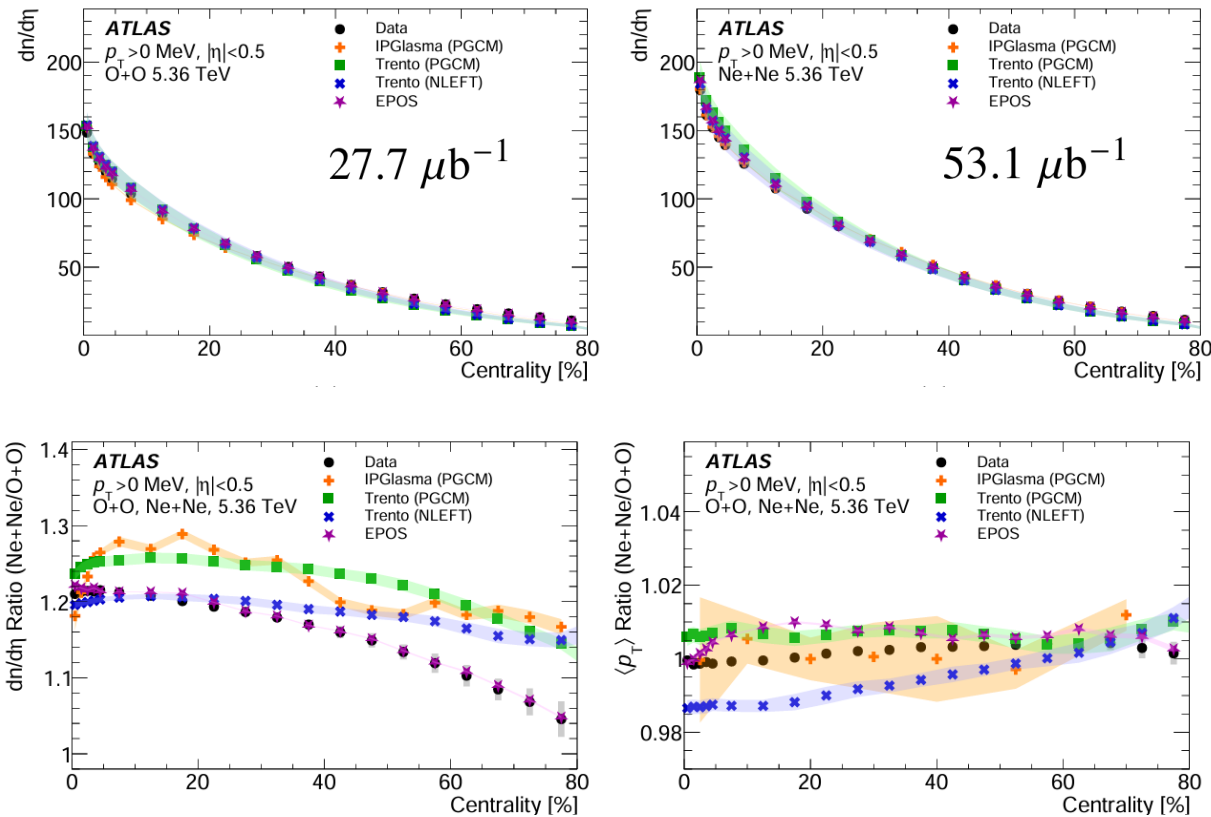
$$\sigma_{\text{fid.}}^{pO} = 396 \pm 6 \text{ (exp.)} \pm 9 \text{ (lumi.) mb}$$

$$\sigma_{\text{inel.}}^{p+\text{air}} = 406 \pm 6 \text{ (exp.)} \pm 9 \text{ (lumi.)} \pm 28 \text{ (th.) mb}$$



Centrality dependence of $dn/d\eta$ or $\langle p_T \rangle$

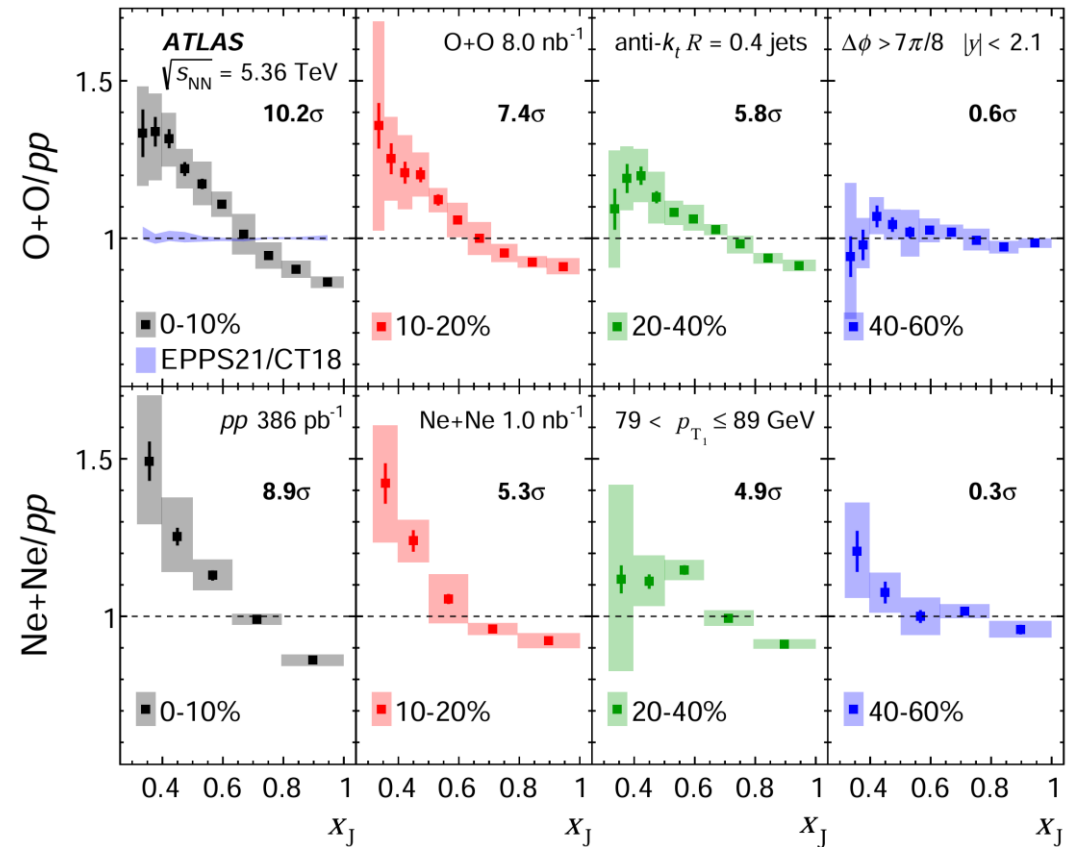
- ✓ Particle multiplicity rises towards central collisions
- ✓ $dN/d\eta$ ratio: models comparable in central collisions
- ✓ $\langle p_T \rangle$ ratio: models predictions within 1-2% of data.



arXiv:2606.20257

Observation of centrality-dependence p_T imbalance

- ✓ Centrality-dependent dijet p_T imbalance $x_J = \frac{p_{T2}}{p_{T1}}$
- ✓ Large deviations from pp ref in central collisions
- ✓ New regime for path-length dep. of jet quenching



arXiv:2606.20463

- **Data:** Successful Run3 collected 332 fb^{-1} at 13.6 TeV, more results are coming
- **AI/ML:** GN transformer flavour tagger greatly enhances physics sensitivity
- **Higgs:** Precise cross-section, couplings and width; rare decays $H \rightarrow \mu\mu$ (3.4σ), $H \rightarrow Z\gamma$ (2.5σ); tight limits on Higgs self-coupling κ_λ and Higgs CPV
- **Diboson/VBS:** First 3.3σ evidence of at least one longitudinal WW scattering; tribosons $WW\gamma/VVZ$ observed, strong SMEFT aQGC constraints
- **Top & heavy flavour:** Observation of toponium quasi-bounding state; new mesons B_c^{*+} , X(6900), double-parton-scattering (DPS) etc.
- **BSM:** No SUSY/LLP/dark particle excess
- **HION:** p-O/O-O/Ne-Ne collision for cosmic/jet-quenching studies

Thanks for your attention, please stay tuned !

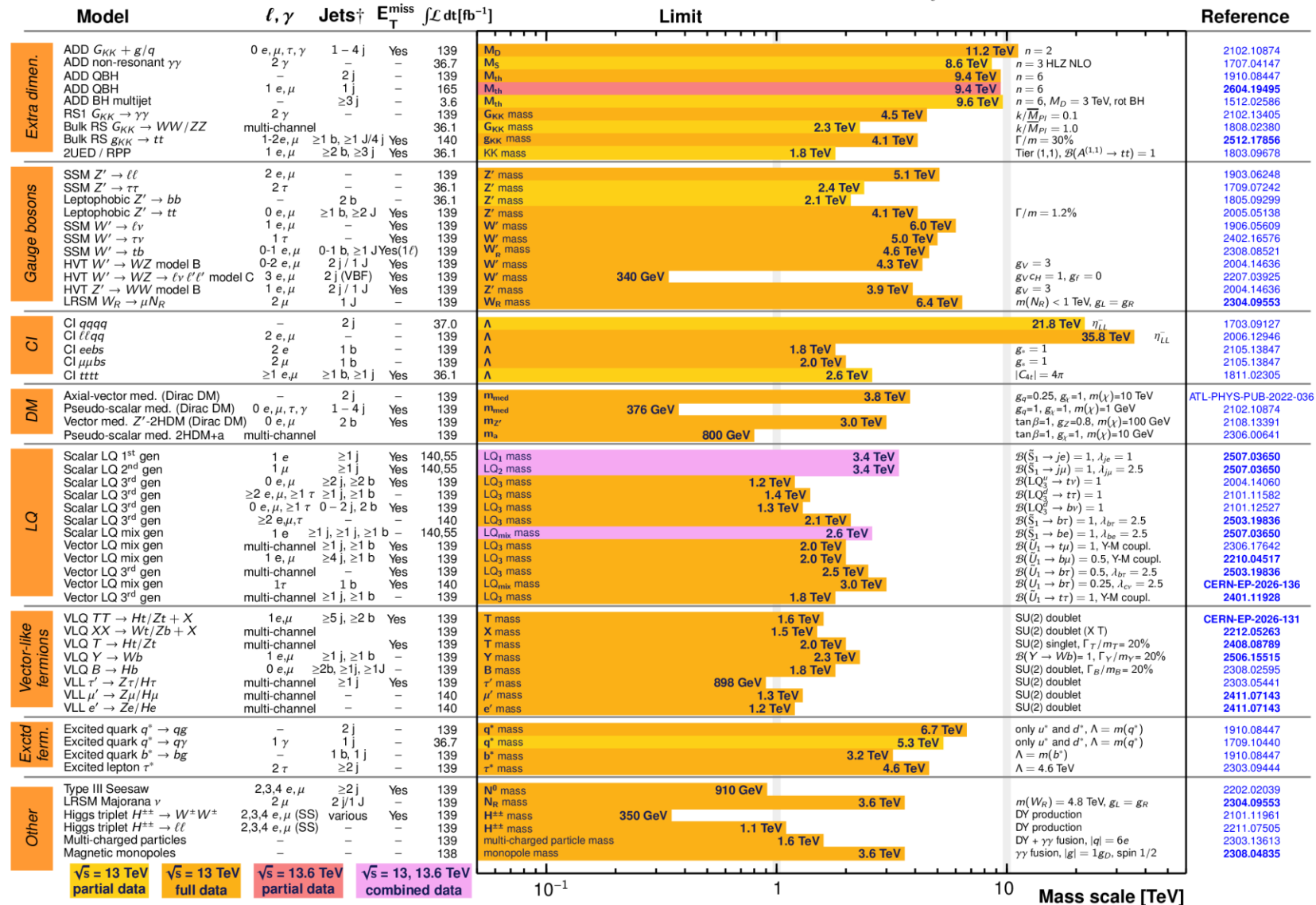
Heavy Particle Searches

ATLAS Heavy Particle Searches* - 95% CL Upper Exclusion Limits

Status: Spring 2026

ATLAS Preliminary

$$\int \mathcal{L} dt = (3.6 - 195) \text{ fb}^{-1} \quad \sqrt{s} = 13, 13.6 \text{ TeV}$$

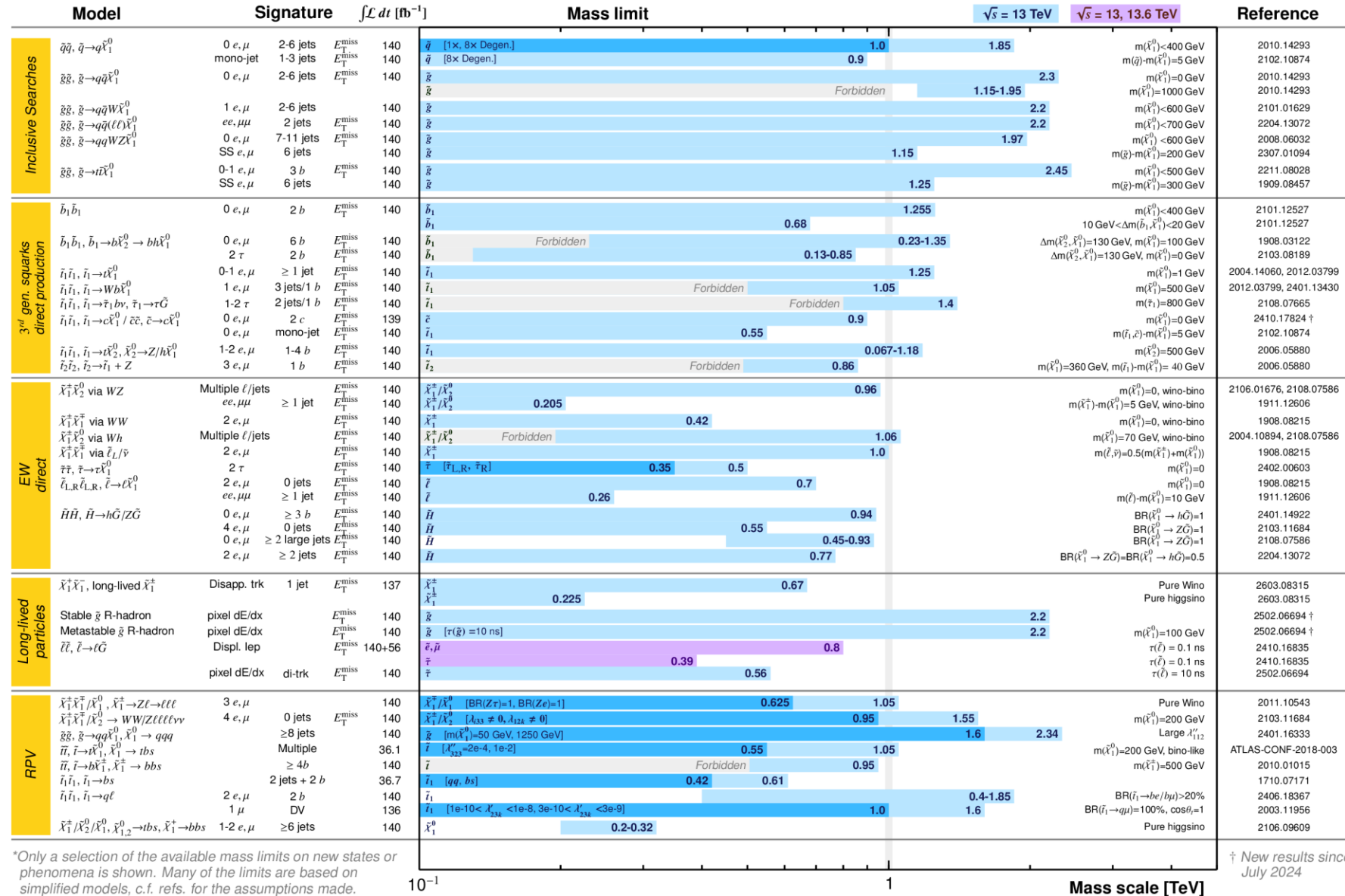


*Only a selection of the available mass limits on new states or phenomena is shown.

[†]Small-radius (large-radius) jets are denoted by the letter j (J).

ATLAS SUSY Searches* - 95% CL Lower Limits

ATLAS Preliminary $\sqrt{s} = 13, 13.6 \text{ TeV}, 36\text{-}196 \text{ fb}^{-1}$ March 2026



*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

† New results since July 2024

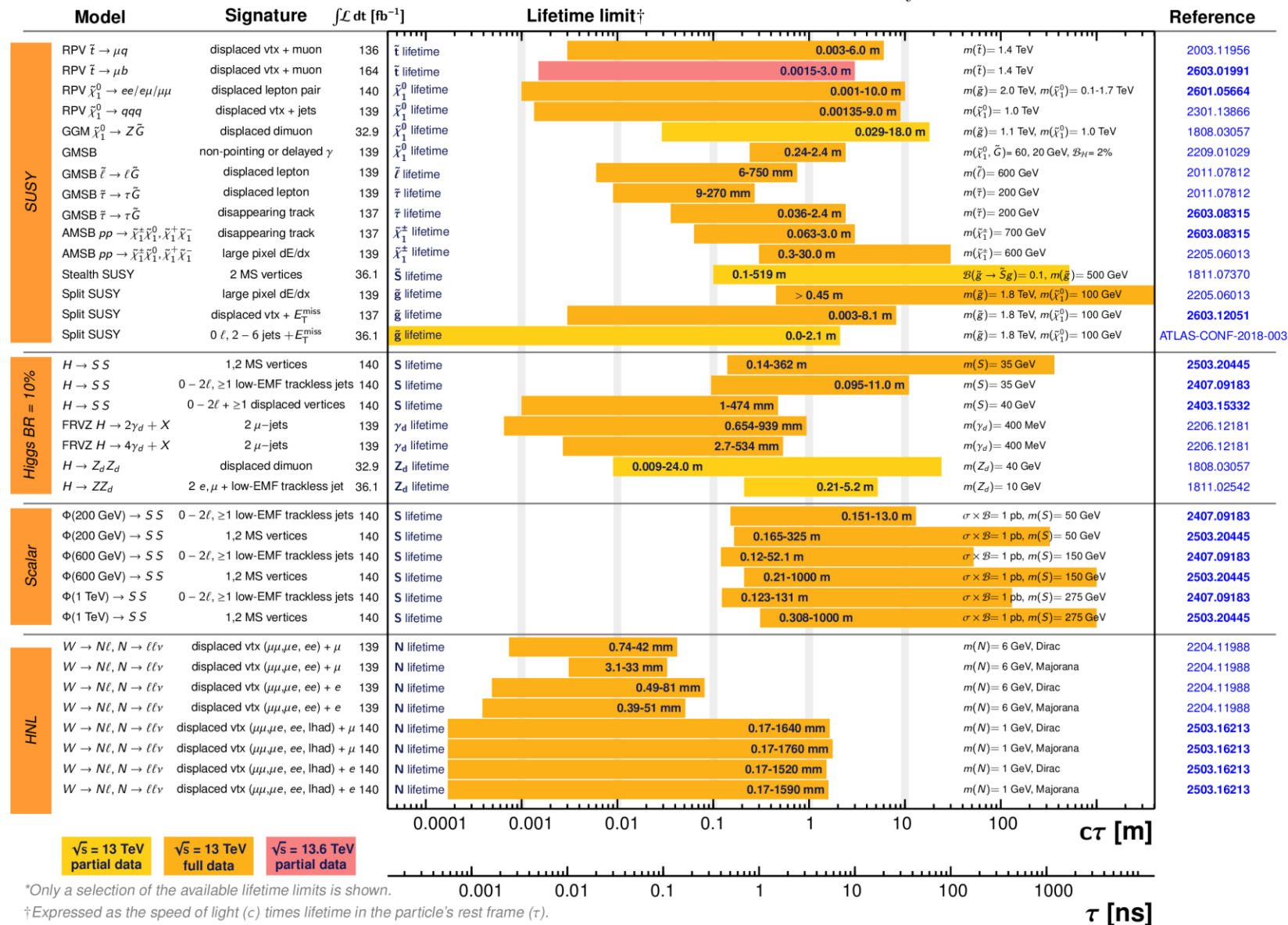
LLP Searches

ATLAS Long-lived Particle Searches* - 95% CL Exclusion

Status: Spring 2026

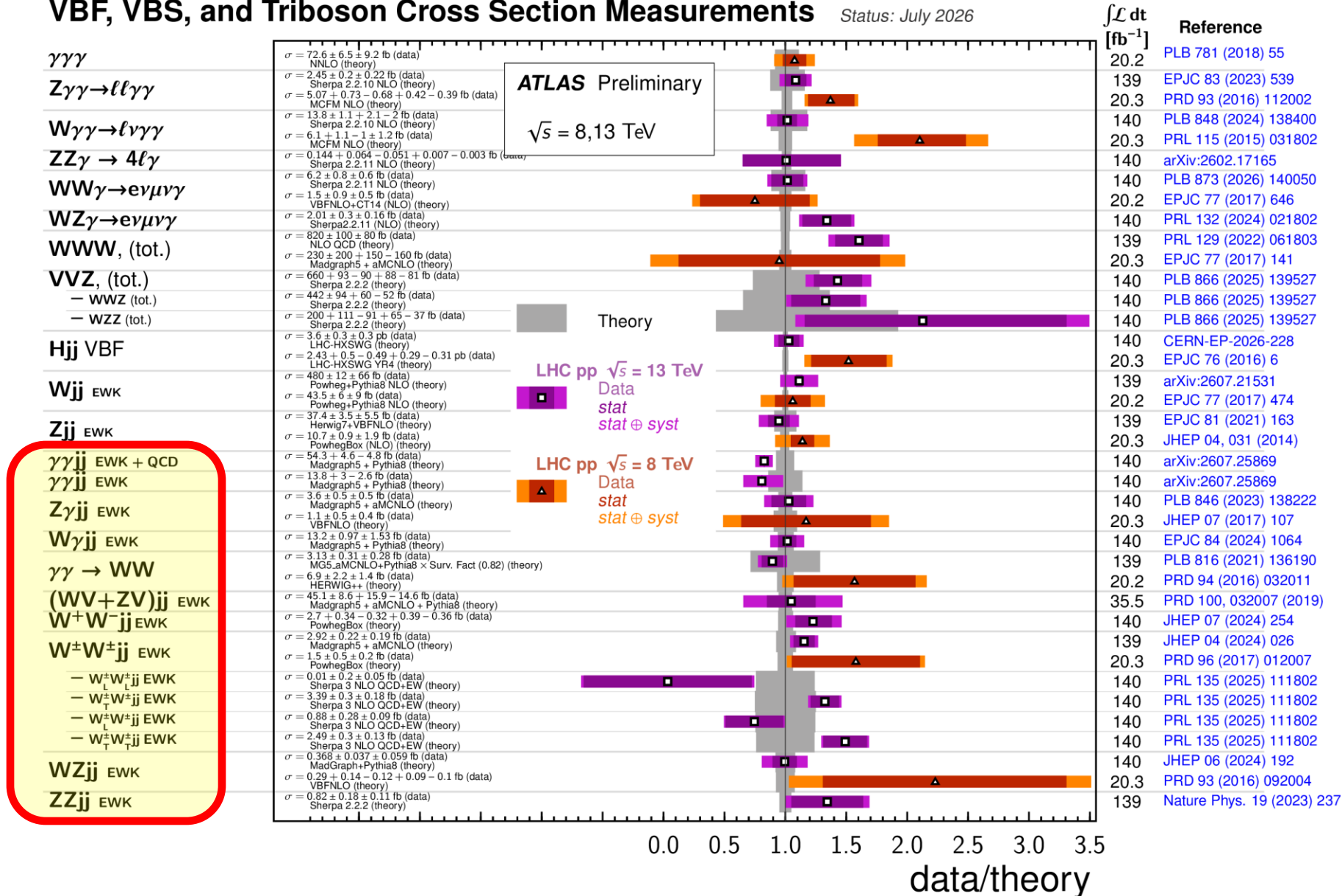
ATLAS Preliminary

$$\int \mathcal{L} dt = (32.9 - 164) \text{ fb}^{-1} \quad \sqrt{s} = 13, 13.6 \text{ TeV}$$



VBF, VBS, and Triboson Cross Section Measurements

Status: July 2026



- **Effective Field Theory (EFT)**, SM (Wilson coefficients $f_i = 0$) + BSM operators

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{f_i^{(6)}}{\Lambda_i^2} O_i^{(6)} + \sum_j \frac{f_j^{(8)}}{\Lambda_j^4} O_j^{(8)} + \dots$$

f : Wilson coefficients

Λ : Scale of new physics ($\sim \text{TeV}$)

$O^{(6)}$: Dimension-6 operators

$O^{(8)}$: Dimension-8 operators

- Constrain BSM operators via anomalous TGC or QGC.

- Dim-6 operators affect Triple-Gauge-Couplings (TGCs) at low energy
 - Dim-8 operators control Quartic-Gauge-Couplings (QGCs) at high energy
- Eboli-Gouzevitch basis: Tensor (T-) / Scalar (S-) / Mixed (M-) operators

- SM predicts QGCs that contain at least two charged W: $WWWW$, $WWZZ$, $WW\gamma\gamma$, $WWZ\gamma$

- QGCs with pure neutral bosons ($ZZZZ$, $ZZZ\gamma$, $ZZ\gamma\gamma$, $Z\gamma\gamma\gamma$, $\gamma\gamma\gamma\gamma$) are SM-forbidden

Anomalous QGCs serve as a powerful probe for new physics BSM.

The aQGC altered with dimension-8 operators are shown with X.

	$WWWW$	$WWZZ$	$ZZZZ$	$WW\gamma Z$	$WW\gamma\gamma$	$ZZZ\gamma$	$ZZ\gamma\gamma$	$Z\gamma\gamma\gamma$	$\gamma\gamma\gamma\gamma$
O_{S0}, O_{S1}	X	X	X						
O_{M0}, O_{M1}, O_{M7}	X	X	X	X	X	X	X		
$O_{M2}, O_{M3}, O_{M4}, O_{M5}$		X	X	X	X	X	X		
O_{T0}, O_{T1}, O_{T2}	X	X	X	X	X	X	X	X	X
O_{T5}, O_{T6}, O_{T7}		X	X	X	X	X	X	X	X
O_{T8}, O_{T9}			X			X	X	X	X

$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \sum_{k=0}^1 \frac{f_{S,k}}{\Lambda^4} O_{S,k} + \sum_{i=0}^7 \frac{f_{M,i}}{\Lambda^4} O_{M,i} + \sum_{j=0,1,2,5,6,7,8,9} \frac{f_{T,j}}{\Lambda^4} O_{T,j}$$

- Contribution of operators with Gauge boson field

$$O_{T,0} = Tr[W_{\mu\nu} W^{\mu\nu}] \times Tr[W_{\alpha\beta} W^{\alpha\beta}],$$

$$O_{T,1} = Tr[W_{\alpha\nu} W^{\mu\beta}] \times Tr[W_{\mu\beta} W^{\alpha\nu}],$$

$$O_{T,2} = Tr[W_{\alpha\mu} W^{\mu\beta}] \times Tr[W_{\beta\nu} W^{\nu\alpha}],$$

$$O_{T,5} = Tr[W_{\mu\nu} W^{\mu\nu}] \times B_{\alpha\beta} B^{\alpha\beta},$$

$$O_{T,6} = Tr[W_{\alpha\nu} W^{\mu\beta}] \times B_{\mu\beta} B^{\alpha\nu},$$

$$O_{T,7} = Tr[W_{\alpha\mu} W^{\mu\beta}] \times B_{\beta\nu} B^{\nu\alpha},$$

$$O_{T,8} = B_{\mu\nu} B^{\mu\nu} B_{\alpha\beta} B^{\alpha\beta},$$

$$O_{T,9} = B_{\alpha\mu} B^{\mu\beta} B_{\beta\nu} B^{\nu\alpha}.$$

- Contribution of operators with covariant derivatives only (Scalar field):

$$O_{S,0} = [(D_\mu \Phi)^\dagger (D_\nu \Phi)] \times [(D^\mu \Phi)^\dagger (D^\nu \Phi)],$$

$$O_{S,1} = [(D_\mu \Phi)^\dagger (D^\mu \Phi)] \times [(D_\nu \Phi)^\dagger (D^\nu \Phi)],$$

$$O_{S,2} = [(D_\mu \Phi)^\dagger (D_\nu \Phi)] \times [(D^\nu \Phi)^\dagger (D^\mu \Phi)].$$

- Contribution of both operators with covariant derivatives and field strength tensors field):

$$O_{M,0} = Tr[W_{\mu\nu} W^{\mu\nu}] \times [(D_\beta \Phi)^\dagger (D^\beta \Phi)],$$

$$O_{M,1} = Tr[W_{\mu\nu} W^{\nu\beta}] \times [(D_\beta \Phi)^\dagger (D^\mu \Phi)],$$

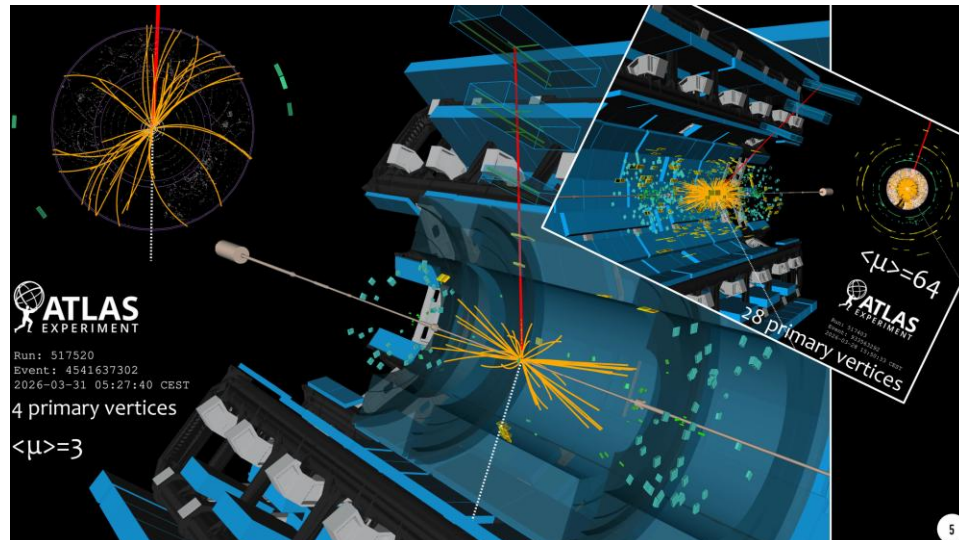
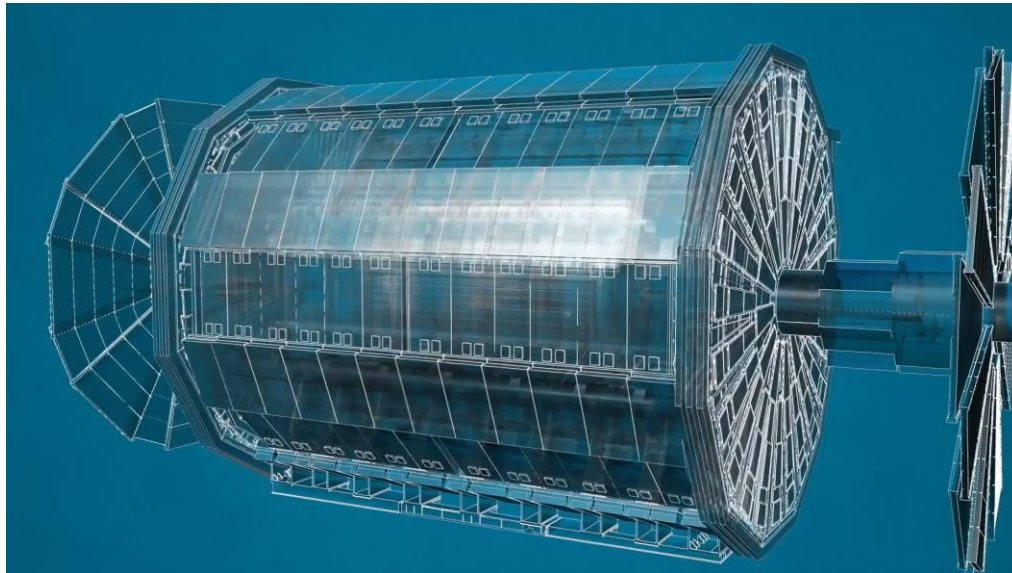
$$O_{M,2} = [B_{\mu\nu} B^{\mu\nu}] \times [(D_\beta \Phi)^\dagger (D^\beta \Phi)],$$

$$O_{M,3} = [B_{\mu\nu} B^{\nu\beta}] \times [(D_\beta \Phi)^\dagger (D^\mu \Phi)],$$

$$O_{M,4} = [(D_\mu \Phi)^\dagger W_{\beta\nu} (D^\mu \Phi)] \times B^{\beta\nu},$$

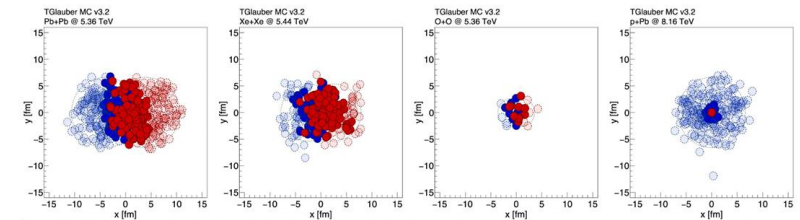
$$O_{M,5} = [(D_\mu \Phi)^\dagger W_{\beta\nu} (D^\nu \Phi)] \times B^{\beta\mu} + h.c.,$$

$$O_{M,7} = [(D_\mu \Phi)^\dagger W_{\beta\nu} W^{\beta\mu} (D^\nu \Phi)].$$



Why light ions?

- Bridge between large (Pb+Pb) and small (pp, p+Pb) systems
 - Is QGP production and evolution smooth with transverse size down a proton?
 - Increasing role of viscosity & fluctuations as size shrinks
- Direct probe of nuclear structure
 - α -clustering structure of ^{16}O
 - Elongated ("bowling-pin") deformation of ^{20}Ne
- New testing ground for jet quenching
 - Path-length dependence of energy loss
 - Central O+O $\approx$ cleaner geometry than peripheral Pb+Pb



2

