

Physics with the ATLAS Experiment

Jan Kretzschmar
(obo the Liverpool ATLAS group)

22nd May 2026

HEP Annual Meeting



UNIVERSITY OF
LIVERPOOL

The Liverpool ATLAS Group

- 7 Academics
 - Andy, Carl (TL), Jan (DTL) ,
Monica, Nikos, Uta, Sergey (low FTE)
- 2 Physics Analysis PDRAs
 - Jordy Degens + John Anders
- 8 PhD students (+1 incoming)
 - Y1: Lennox, Oliver
 - Y2: Shirsendu, Stephen
 - Y3: Mehul
 - Y4: Bhupesh, Josh, Rob
 - Graduated: Conor, Rebecca
 - Samuel (Viva 353 days ago, PostDoc at Nikhef)
- Along with upgrade staff (see Sven's talk)



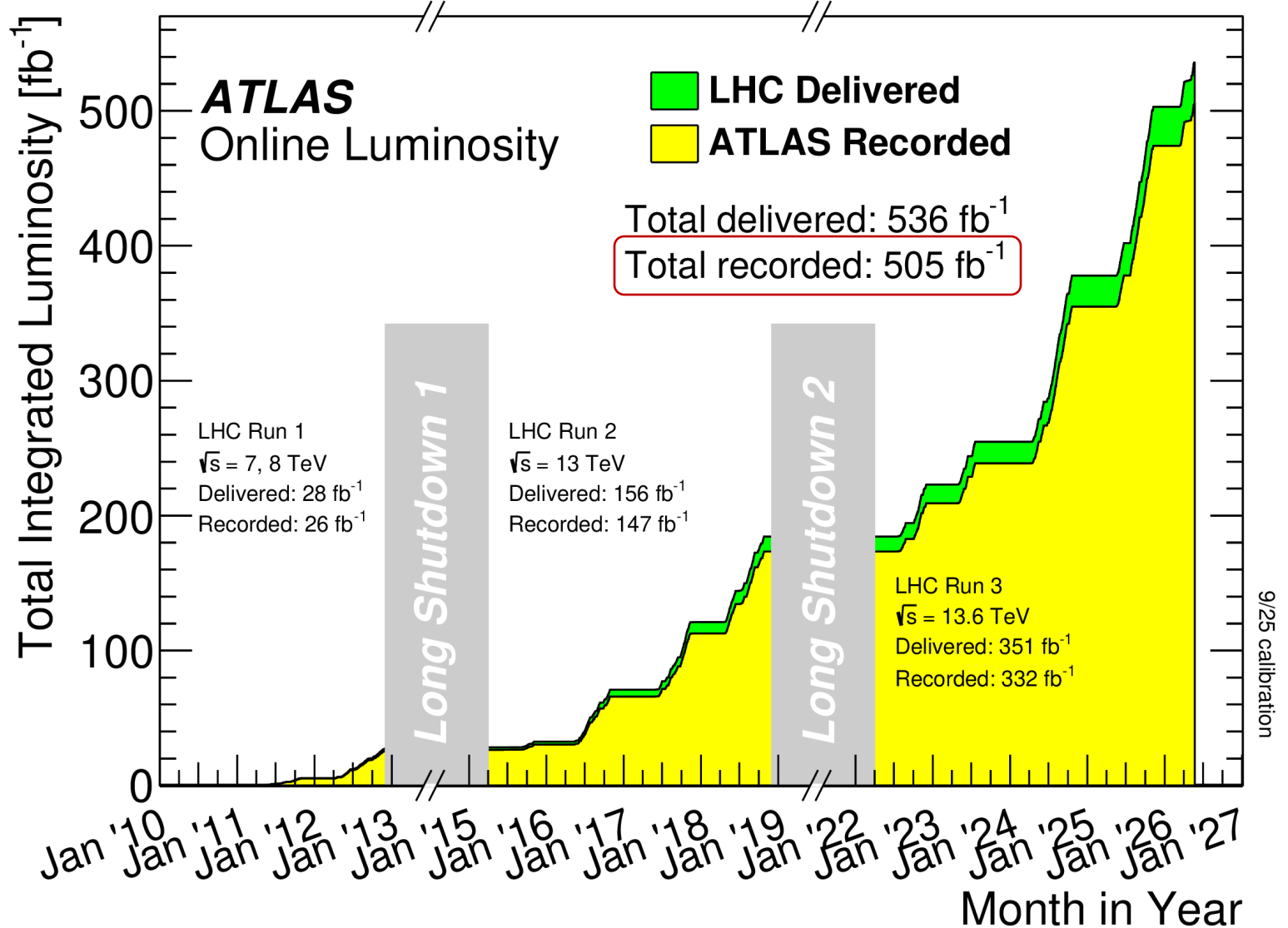
- Work on wide variety of areas in Operations, performance, physics
- Leadership across the board

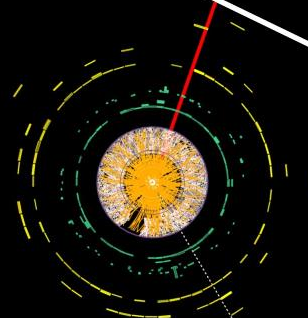
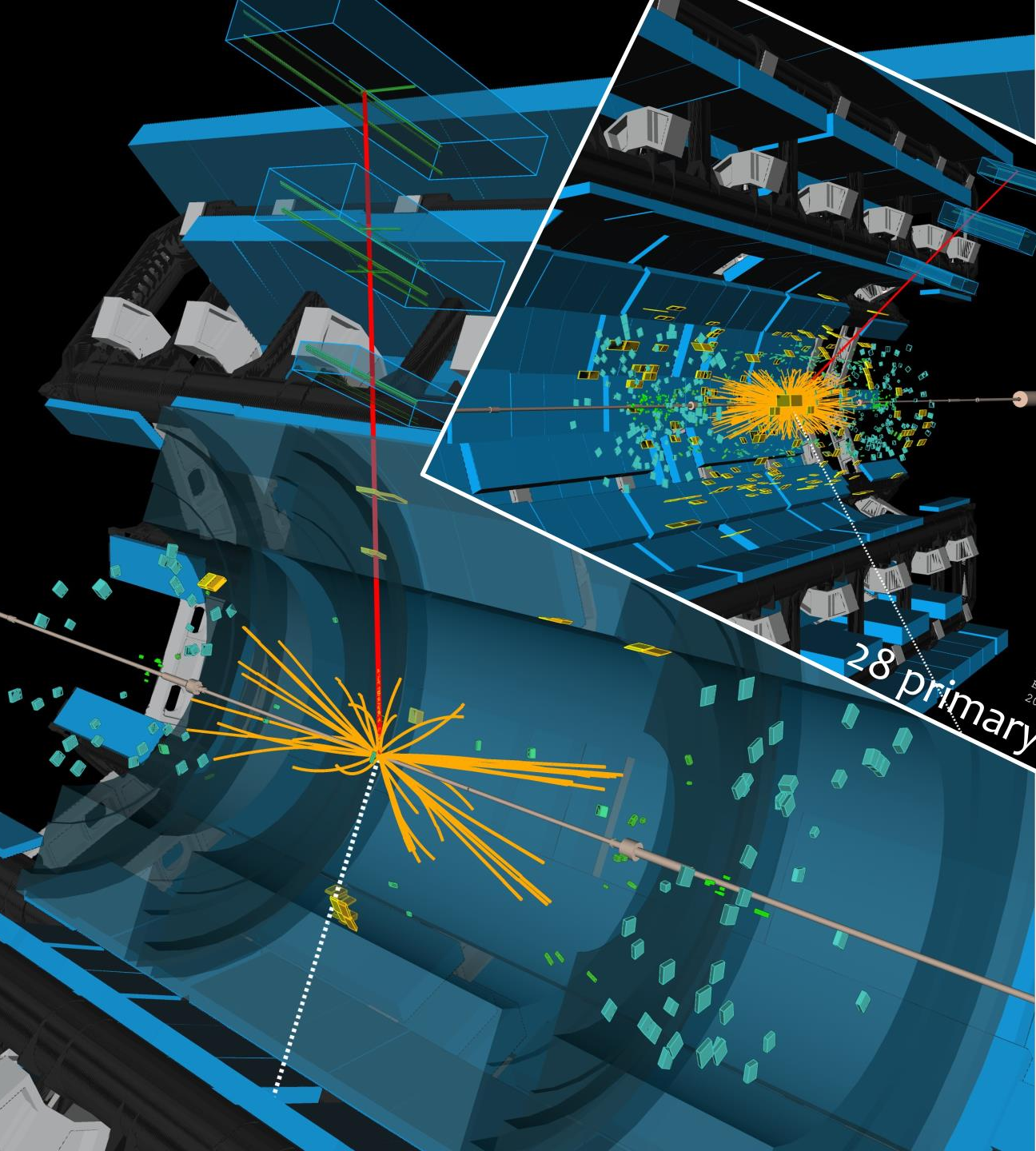
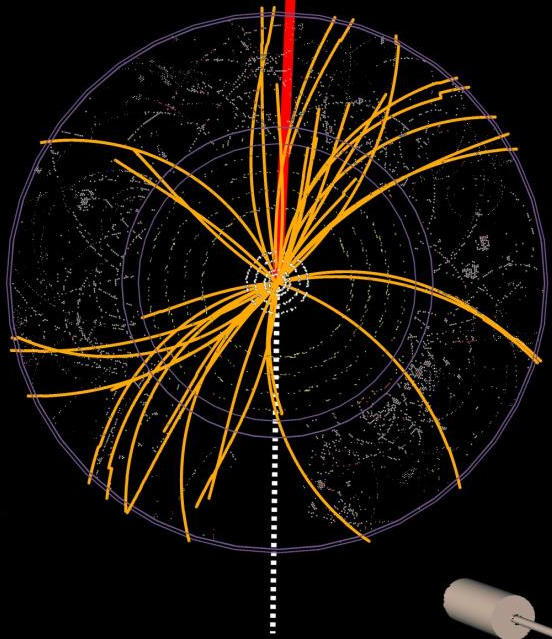
Chair of Publications Committee	Jan
ATLAS UK Spokesperson	Monica
CB chair advisor group member	Monica
Strong SUSY convener (~100)	John
ATLAS UK Higgs & DiHiggs convenor	Jordy
Speakers Committee Member	Nikos
SCT offline coordinator	John
Analysis release coordinator	Andy
Computing Resource Mgmt Board chair	Carl
Luminosity Z-counting contact	Uta
Tau Reco + ID convener (~30)	Jordy
ATLAS LHC Higgs group coordinator for extended Higgs sector + NMSSM	Nikos

- ATLAS published 74 papers in 2026
- Liverpool leading 6 of those (and input to many more)

Status and Operations

- Run 3 proton – proton concluded
 - Huge set of high-quality data for innovative data analyses, including ML at every level
- Still PbPb run to complete
- Many special runs: low intensity (m_W), pO, OO, NeNe, high intensity HL-LHC tests
- Many people performing control room (ID, run control) and remote (DQ, analysis, computing) shifts





$\langle \mu \rangle = 64$

ATLAS
EXPERIMENT

Run: 517403
Event: 933563292
2026-03-28 15:50:33 CEST

28 primary vertices

ATLAS
EXPERIMENT

Run: 517520
Event: 4541637302
2026-03-31 05:27:40 CEST

4 primary vertices

$\langle \mu \rangle = 3$

Status and Operations

- John coordinates the SCT offline activities
 - Crucial to keeping SCT operating with high efficiency
 - Leading final run-3 performance paper
- Uta, Jan, Josh contribute to precision lumi measurement
 - Using Liverpool-pioneered Z-counting method for rapid results independent of VdM calibration
 - Public preliminary results for 2024 + fast-feedback on 2025+2026

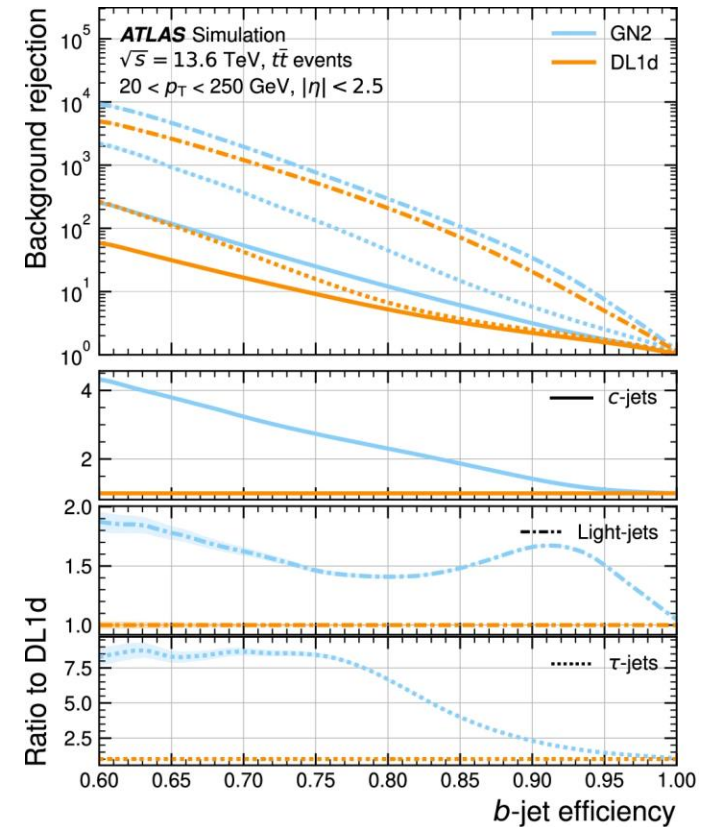
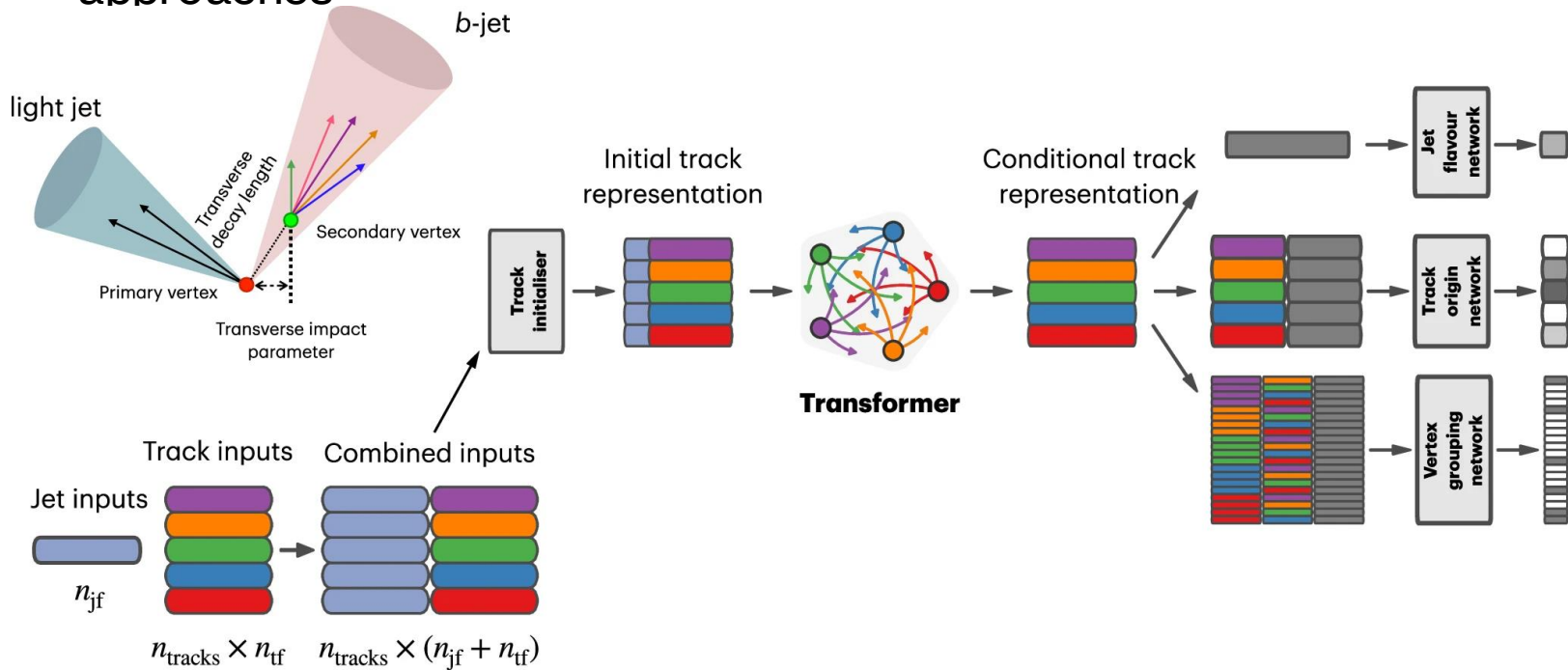
[ATL-DAPR-PUB-2025-001](#)

SCTD-2025-02



Tau and Heavy-Flavour ID

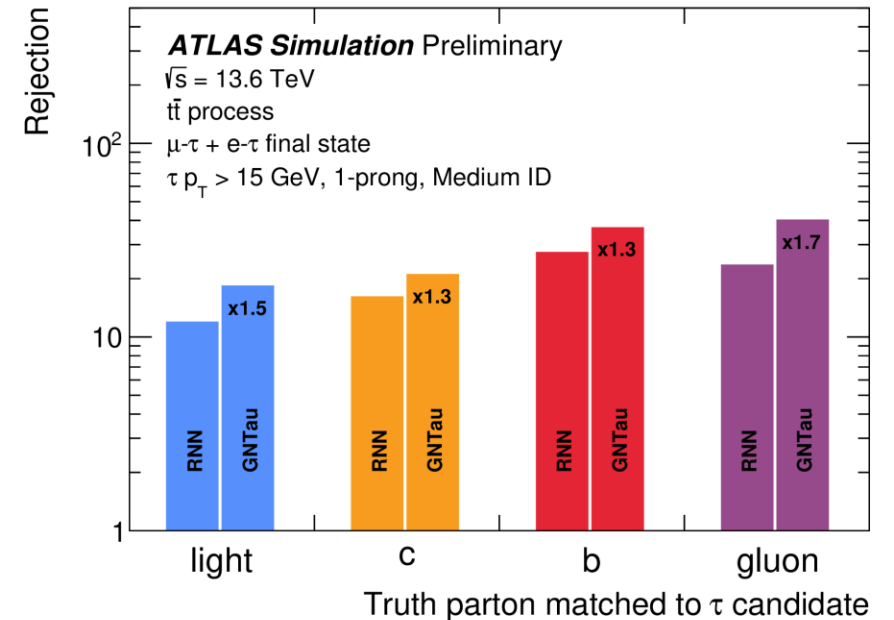
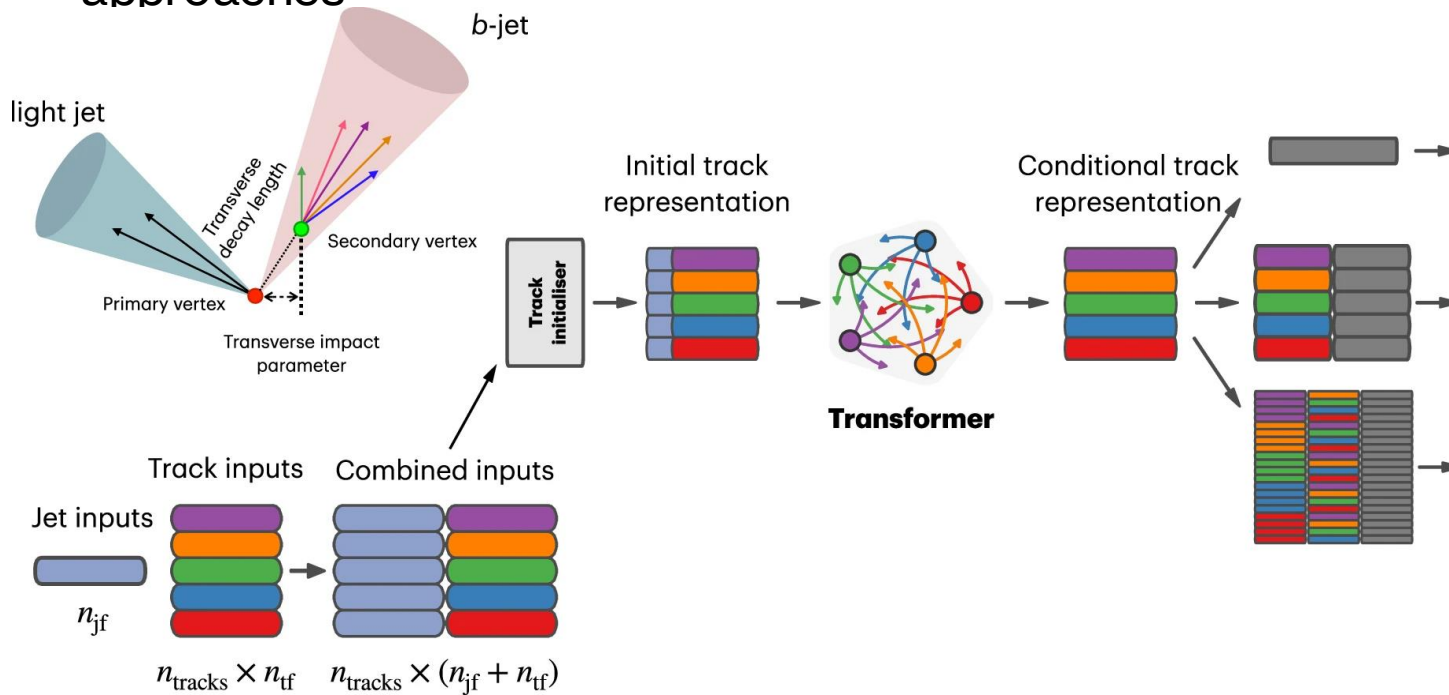
- Liverpool heavily involved third-generation taggers, key for Higgs measurements + BSM searches
- Simultaneous b/c-jet calibration (Andy, Nikos) using 1-lepton ttbar events (2 papers to be submitted)
 - Not yet at the limit: next generation GN3 will deliver yet another factor >2 improvement
- Tau reco/ID (Jordy convenor, Monica, Lennox, Mehul, Rob, Nikos): GNN with large improvements over prior approaches



[Nat Commun 17, 541 \(2026\).](#)

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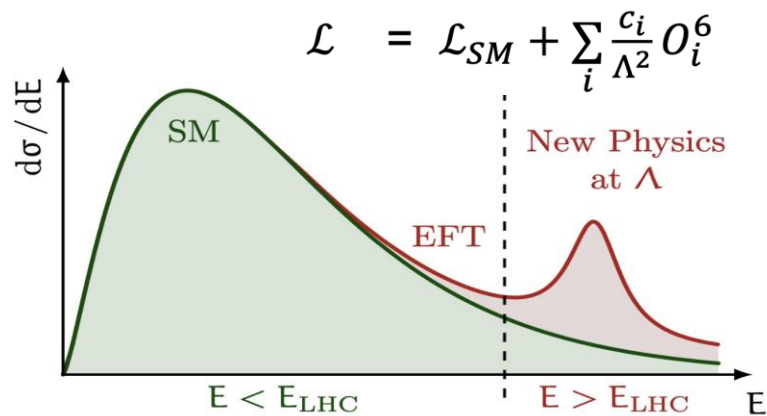
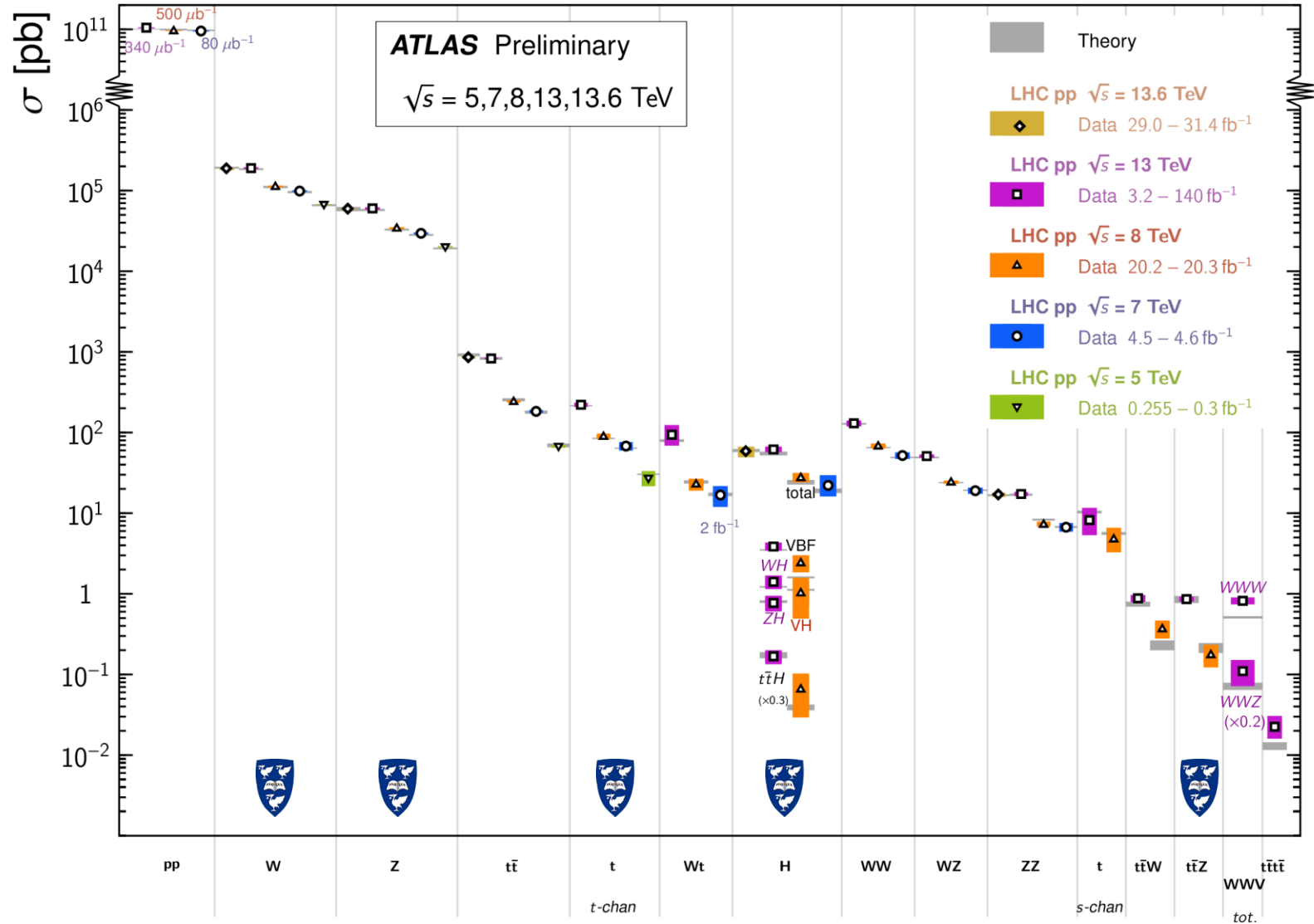
[Nat Commun 17, 541 \(2026\).](#)

Standard Model Measurements

- LHC - the "everything" factory
- Precision measurements enable understanding the SM and testing for small BSM deviations

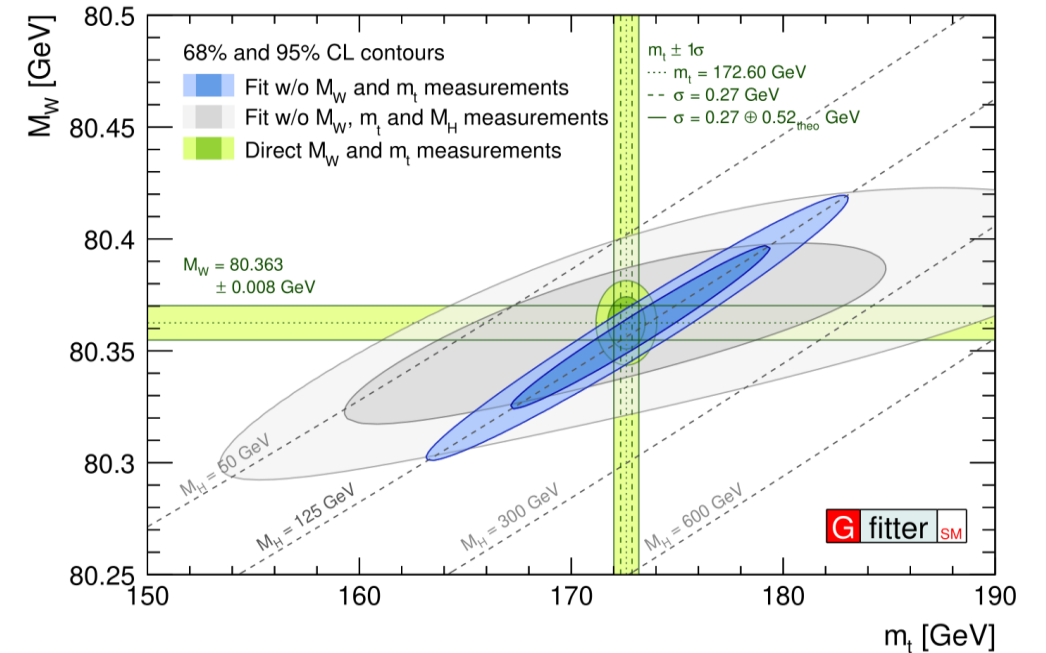
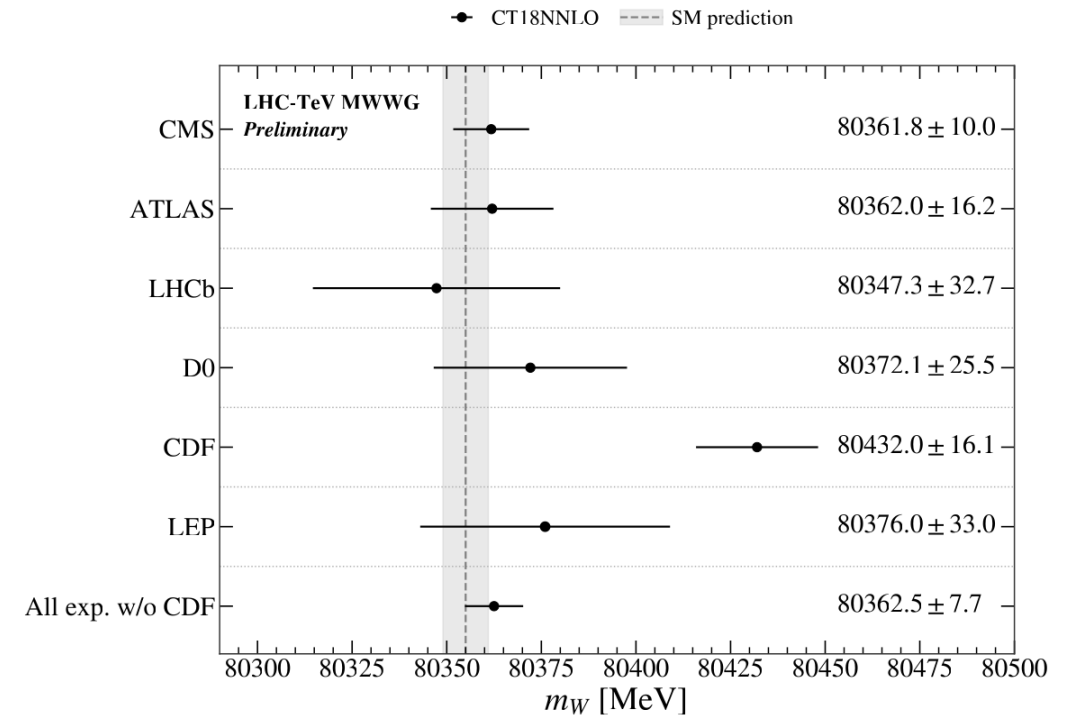
Standard Model Total Production Cross Section Measurements

Status: June 2024



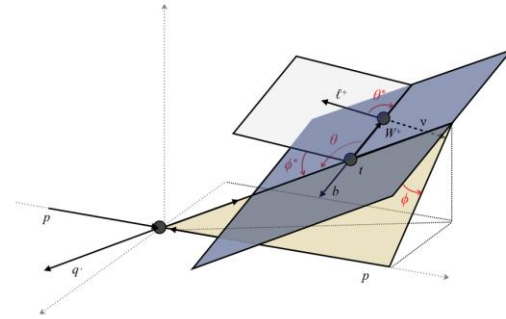
W-boson mass

- One most precisely calculated quantities in the SM
 - Unique test of SM consistency + probe for new particles/forces
 - New, preliminary world combination for PDG2026 (Jan)
- Long standing Liverpool leadership in ATLAS analysis (Jan, Uta, Josh's PhD with electron calibration)
 - Precision of 10 MeV for ATLAS combination of Run 1 result with new low-pileup Run 2

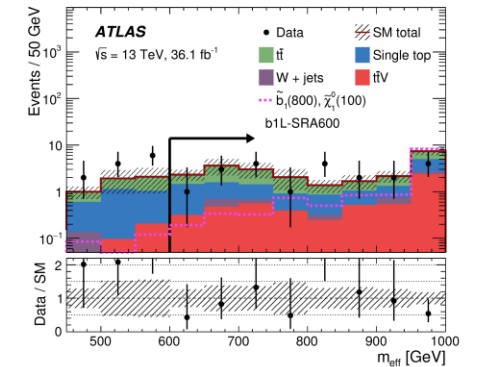
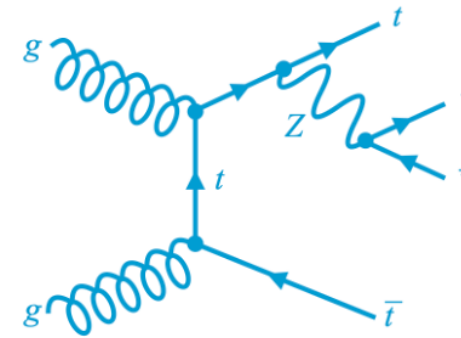
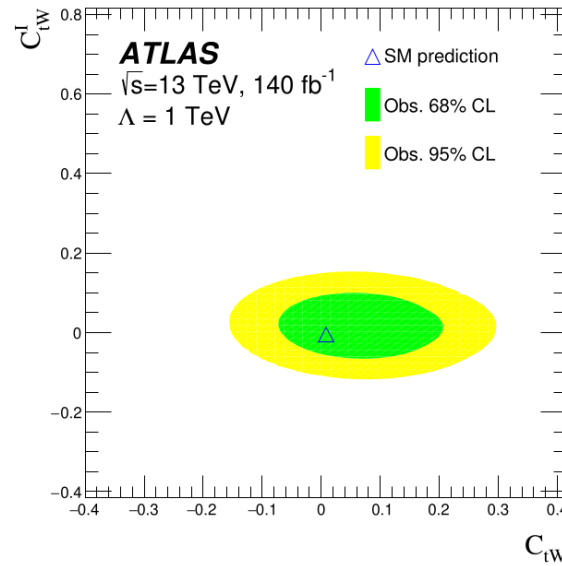
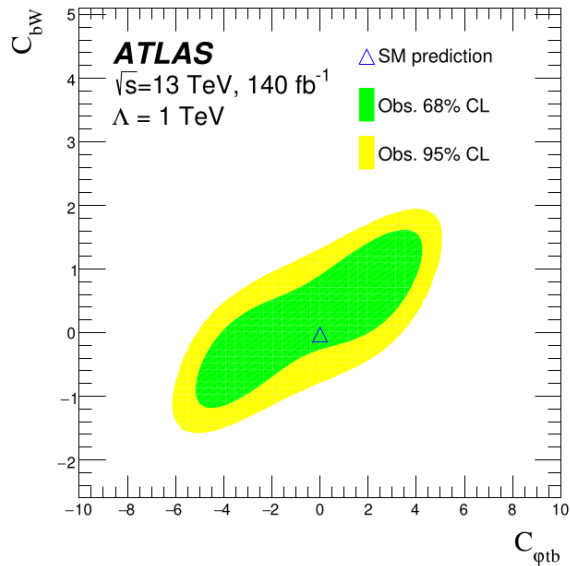


Top-quark Measurements

- Heaviest SM particle provides unique access to bare quark and can only be produced at the LHC
- "4-angle" t-channel single top analysis (Jordy's thesis) [arXiv:2510.23372](https://arxiv.org/abs/2510.23372)



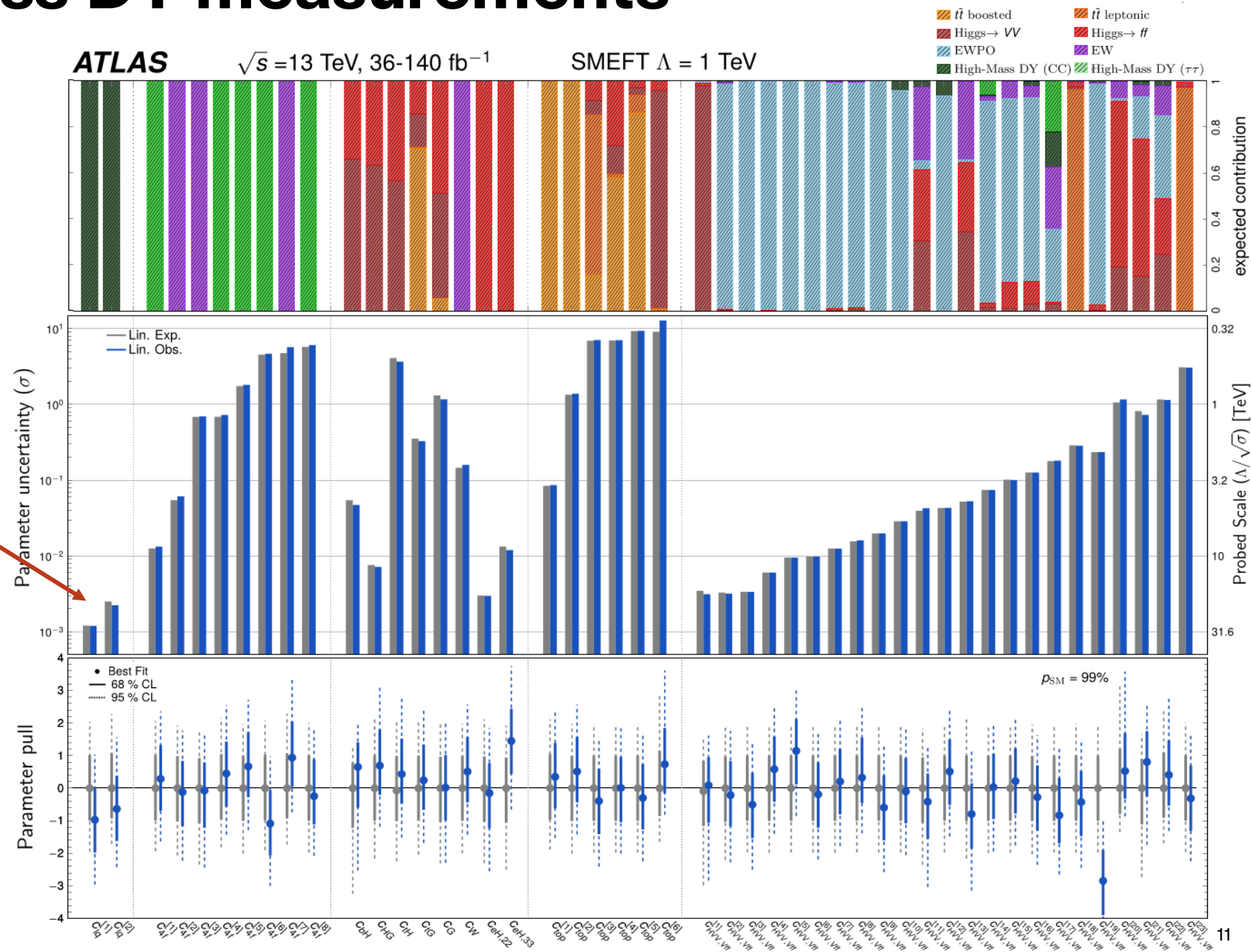
- ttZ cross-section in $Z \rightarrow \nu\bar{\nu}$ channel (John)
- Major background to many SUSY searches but has not yet been measured directly
- Cross-section analysis benefits from large $Z \rightarrow \nu\bar{\nu}$ BR c.f. $Z \rightarrow e\bar{e}, \mu\bar{\mu}$



- Measurement including EFT interpretation by the end of the year

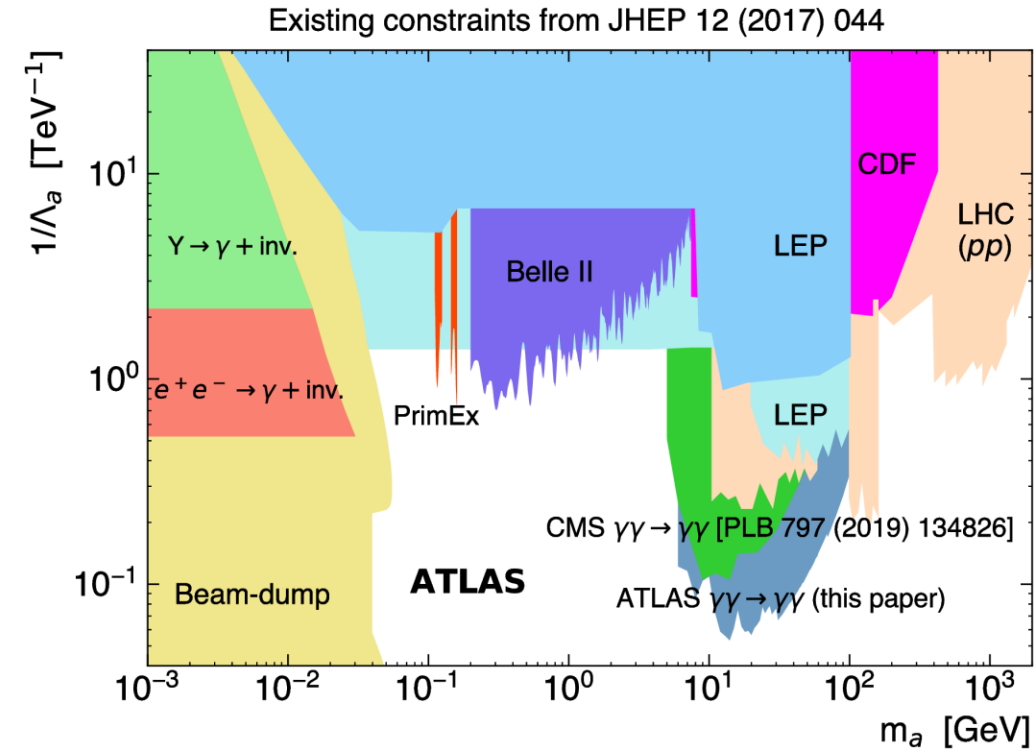
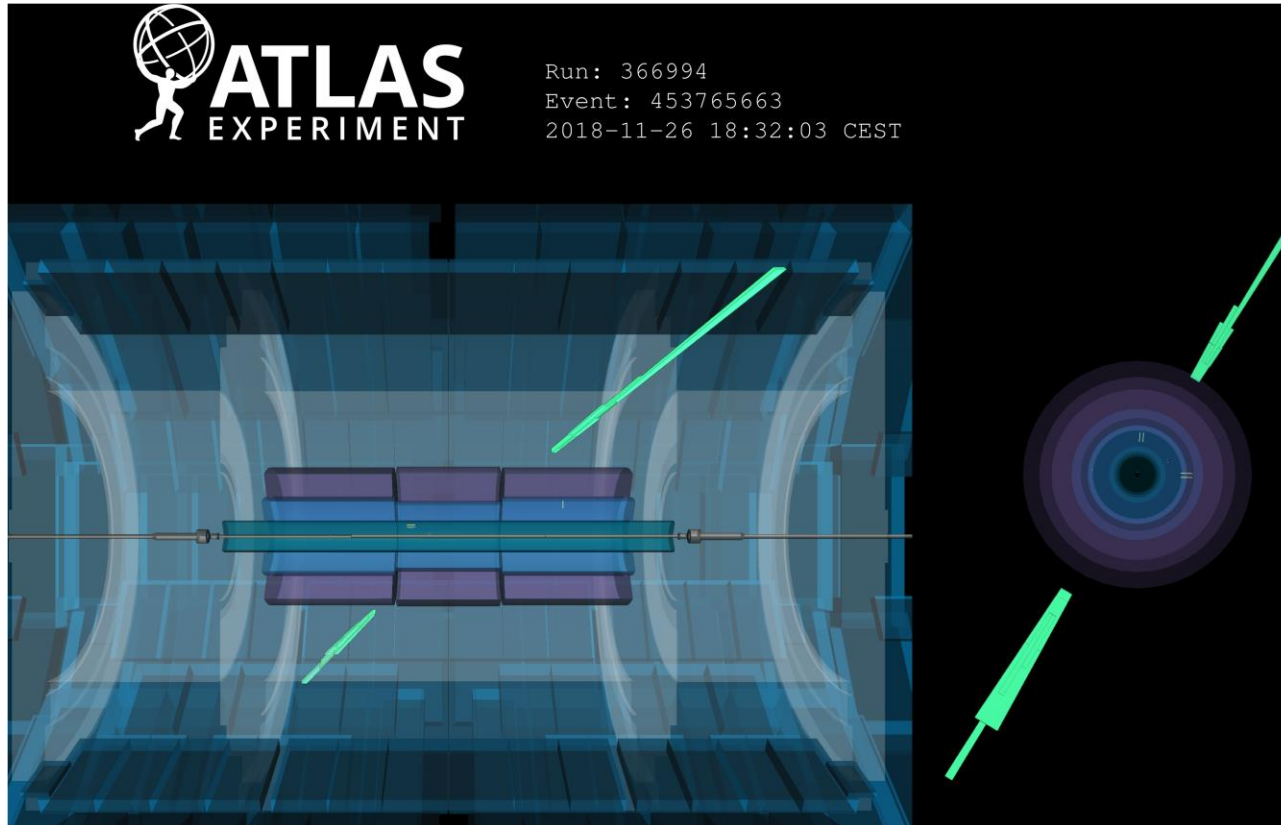
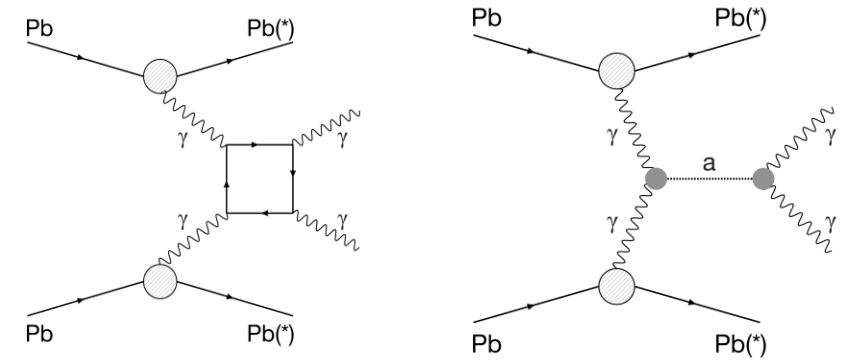
High and low mass DY measurements

- Recent ATLAS 'global' EFT [arXiv:2604.21670](https://arxiv.org/abs/2604.21670) exploits among others the novel CC high mass DY measurement
- Ongoing Low-mass DY measurement unique probe of QCD (to be published soon)



Precision in Heavy Ion collisions

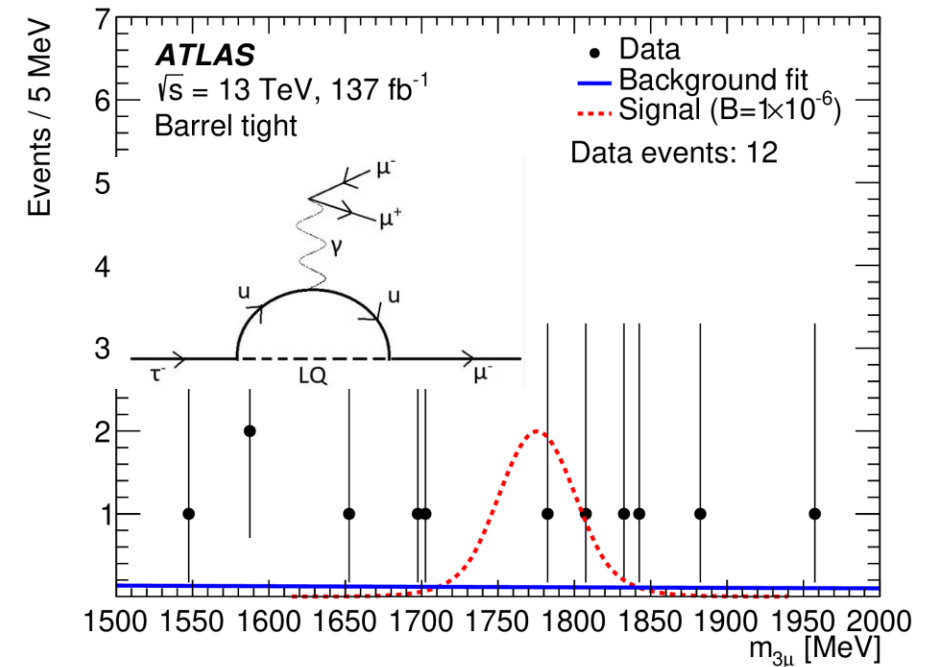
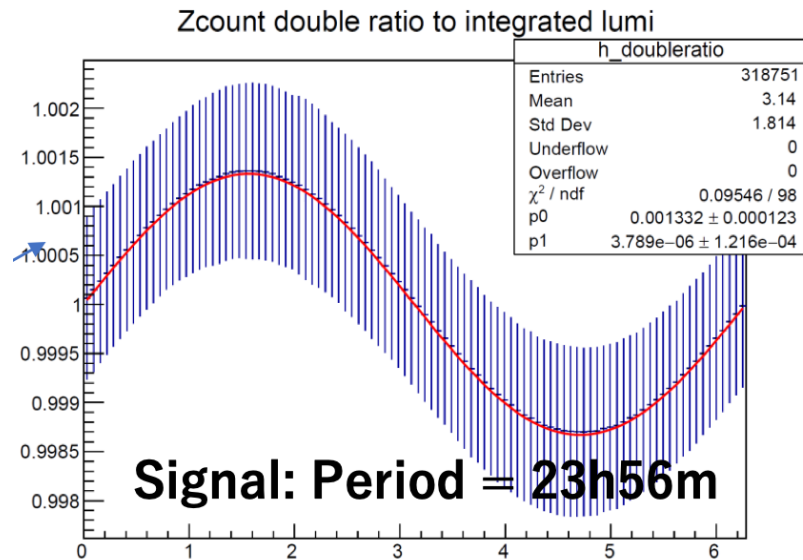
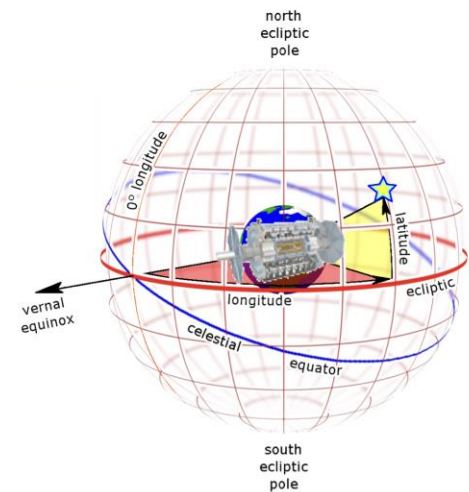
- Relativistic heavy-ion beams are intense source of photons
- ATLAS reported first observation of the Light-by-Light process in 2019 and then set limits on axion production ([JHEP03\(2021\)243](#))
- Nikos, Monica, Shirsendu working on analysis of the new Run 3 data



Precision and rare processes

- Searches for Lorentz + CPT invariance violation
 - Non-isotropic background field leads to time-dependent periodic modulations
 - Uta initiated novel time-dep. $Z \rightarrow \mu\mu$ measurement
 - Build on SM expertise and Z-counting lumi
 - Aiming to be one of the first full Run 2+ Run 3 papers

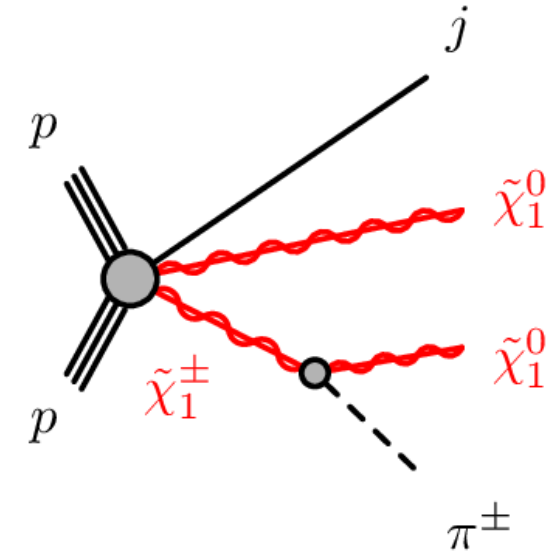
- Search for cLFV $\tau \rightarrow 3\mu$ (Carl, Conor, Jan)
 - Flavour not a fundamental symmetry of SM, model-indep. NP probe at negligible SM rate
 - Tau limits 10^4 less stringent than muon
 - Conor's PhD thesis result published: Improvement factor 5 over previous ATLAS result



arXiv:2603.18099

SUSY and Leptoquarks

- Small mass-splitting between SUSY particles can lead to unusual signatures such as Disappearing tracks
 - John leading this analysis to conclusion recently, effort driven by Liverpool (incl. Monica and PhD students)
- Further SUSY searches to explore uncovered SUSY phase space progressing: $tb+MET$, compressed sleptons (John)
- For the Leptoquark search ($b\bar{b}t\tau$) see Mehul's talk (w/ Monica, Andy)



ATLAS - Run 2 Disappearing Track Search [2603.08315]

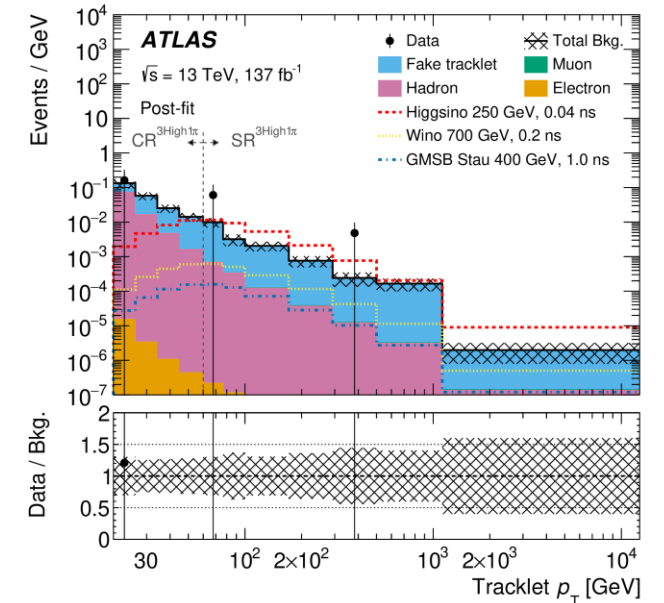
Search for SUSY scenarios with light electroweakinos

- Long-lived chargino decaying within the innermost layers of ATLAS
 - Reconstructed as a "tracklet" (short track) using additional tracking from 3- or 4-hits
- Also sensitive to stau production with long-lived decays (GMSB, CMSSM)
- Follow-up to previous Run 2 analysis

Four Signal Regions defined with an ISR selection and require the presence of a tracklet

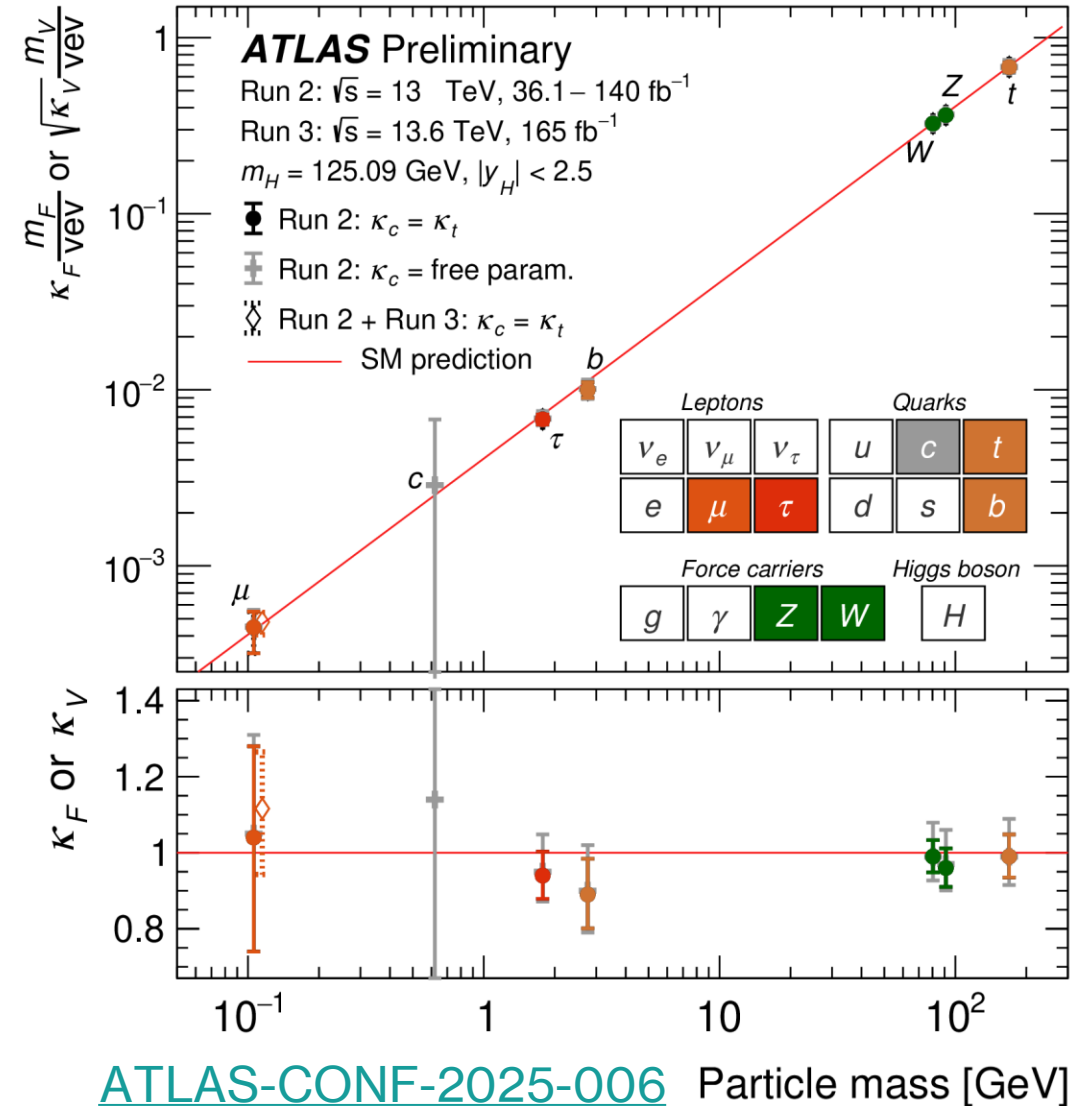
- Improvements from previous analysis:
 - Two SRs with hits in only three-layers (very short tracklets)
 - BDT to reconstruct low-energy charged pions

Displaced Vertices and Unconventional Signatures



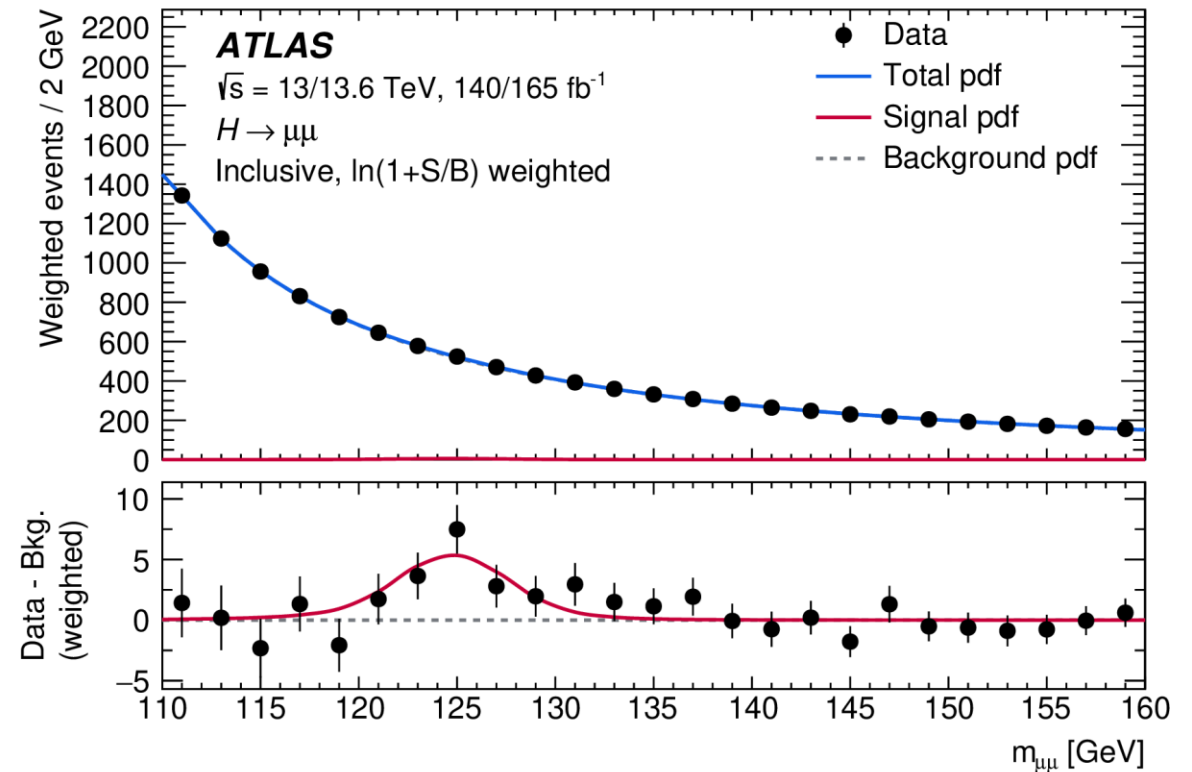
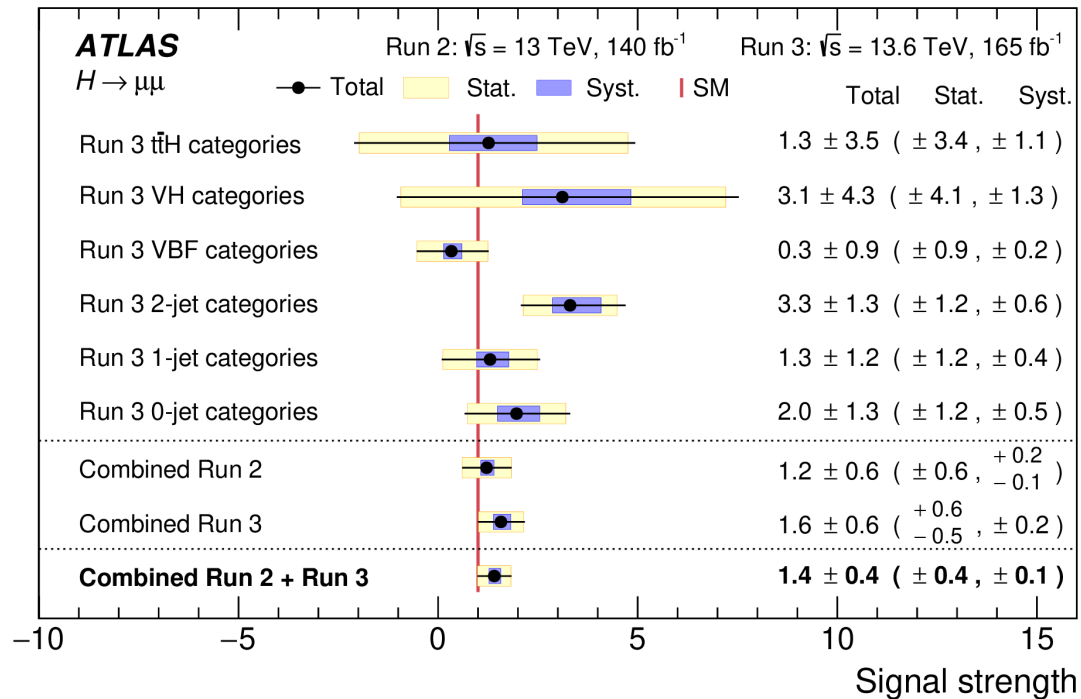
Higgs

- The Higgs boson is central to the standard model
 - Key to understanding EWSB and evolution of Universe
 - Constrains any new physics getting mass from Higgs
- Have made huge progress since discovery
 - Measured mass to < 0.1%
 - 125.11 ± 0.11 GeV
 - First measurement of width
 - $4.5^{+3.3}_{-2.5}$ MeV (SM: 4.1 MeV)
 - Couplings to heaviest particles constrained at 5-10%, second generation the new frontier



$H \rightarrow \mu\mu$

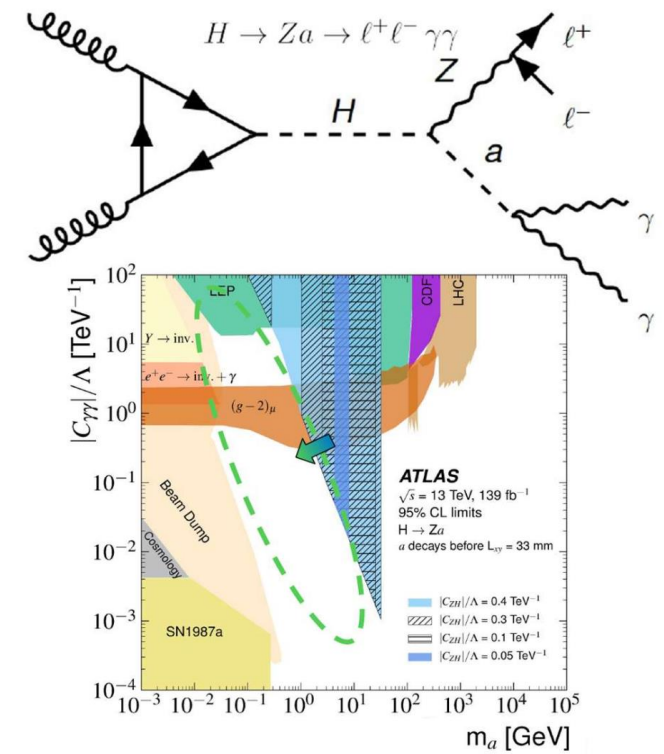
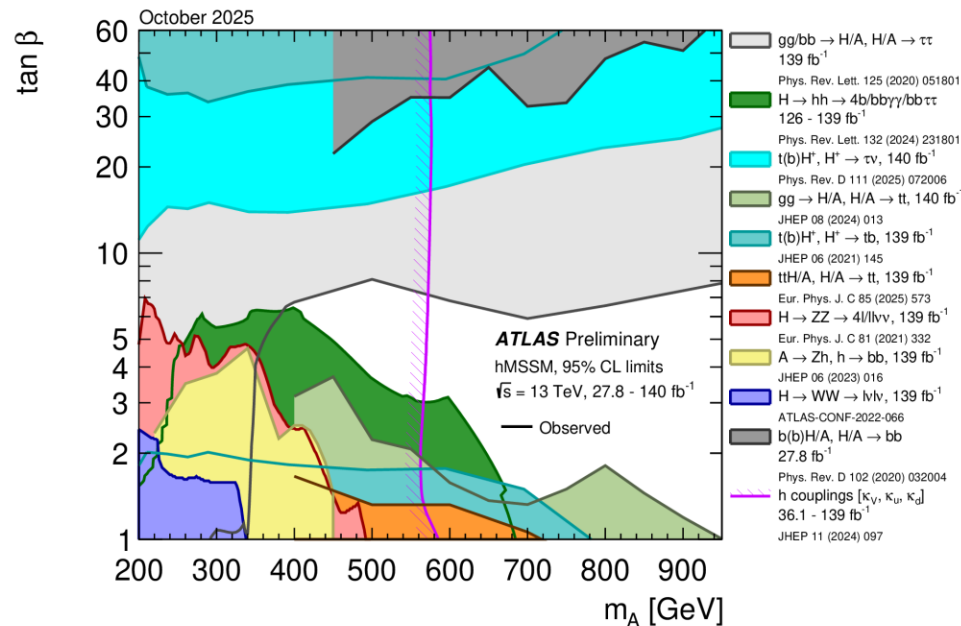
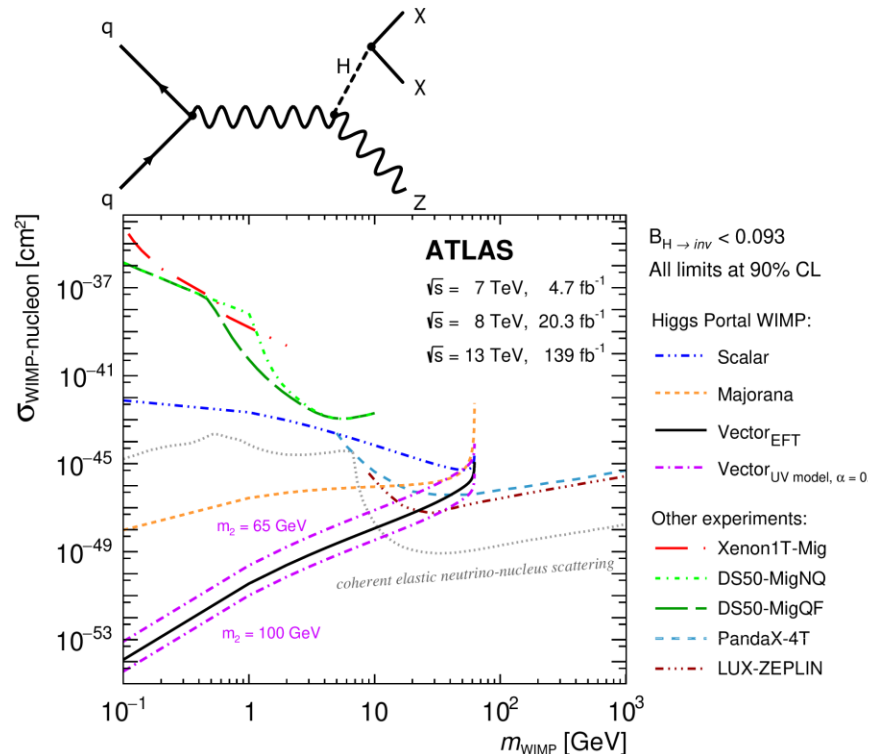
- 3σ evidence with Run-2 + half of the Run 3 (Jan)
- Aiming for 5σ observation with full run-3 data from combined ATLAS+CMS



[Phys. Rev. Lett. 135 \(2025\) 231802](#)

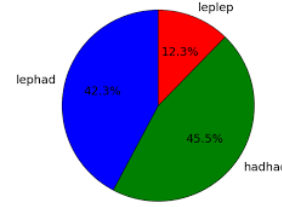
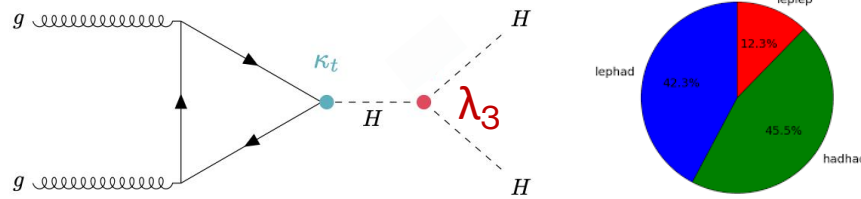
Higgs Searches

- Wide array of searches using the Higgs boson as a 'tool'
- Higgs decay to invisible particles, could connect to dark matter: Andy, Monica, Stephen working on the ZH channel
- Also ongoing: High-mass $H \rightarrow ZZ$ search
- Many BSM theories include an extended Higgs sector: Run 3 search for $A \rightarrow Zh \rightarrow llbb$ (Nikos)
- Axion-like particles in Higgs decays (Rebecca, Monica, Nikos, John, Oliver): exploring long-lived ALPs with Run 3 data



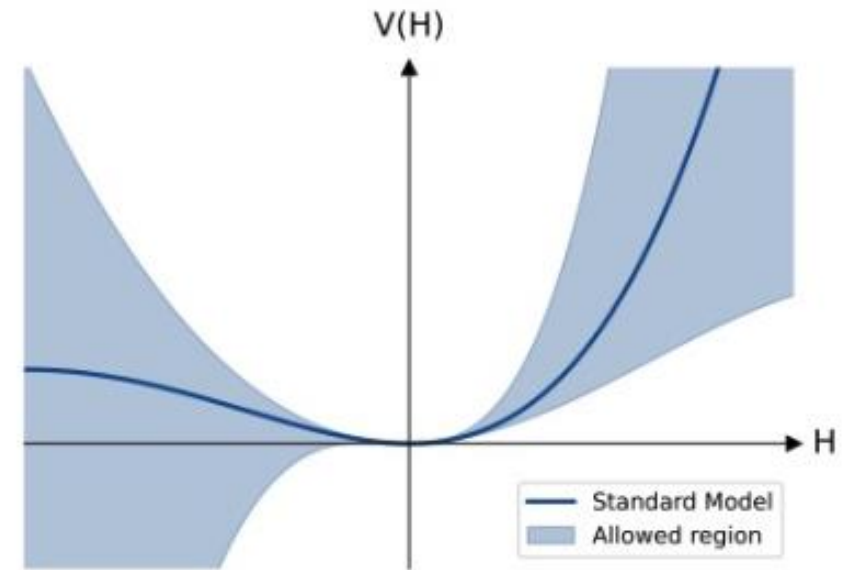
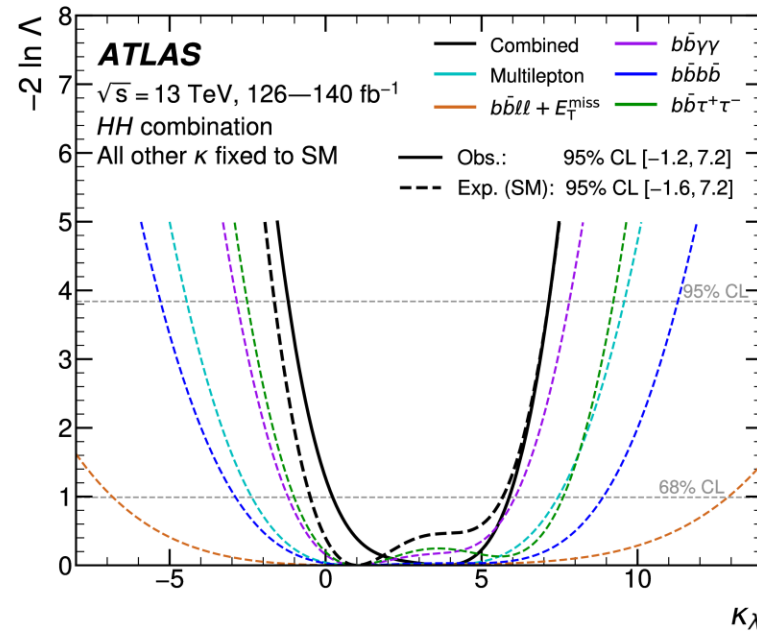
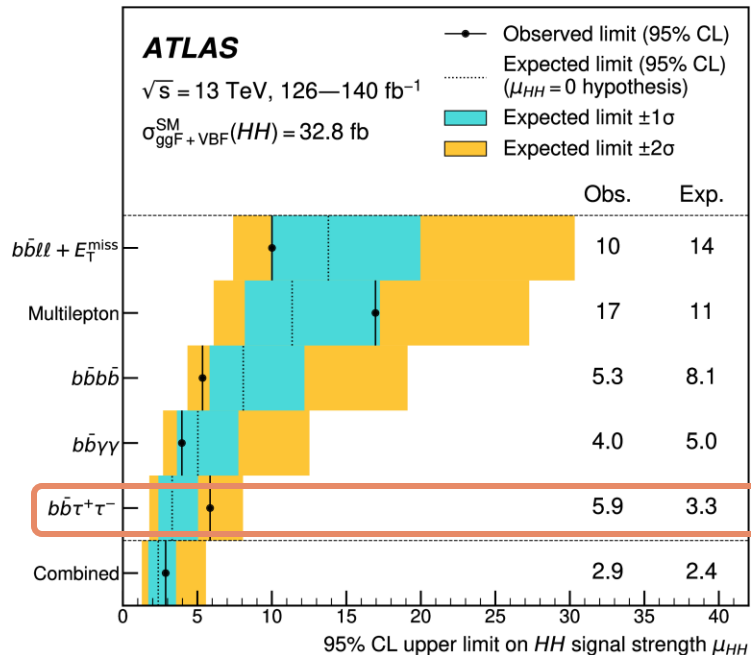
Di- and Tri-Higgs

$$V(h) \simeq \frac{1}{2}m_H^2 h^2 + \lambda v h^3 + \frac{1}{4}\lambda h^4 + \dots$$



- Di-Higgs production probes H self-coupling but $\sigma_{HH} \approx 1/1000$ of σ_H
- Liverpool has been a driving force in $HH \rightarrow bb\tau\tau$
- Currently working on Run-2+3 (Carl, Jordy, Bhupesh, Lennox)
 - Public result in summer 2026 + 3σ evidence with full run-2+3

	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%



Conclusion

- ATLAS continues to perform vibrant and dynamic research covering a huge spectrum
 - From precise measurements to searches for new physics in unexplored phase space
- Detector performed well at extreme pile-up conditions (factor 2-3 beyond design)
 - Coupled with significant ML-enabled improvements in simulation and reconstruction
- Collected excellent Run 3 data set with factor 3 increase in luminosity
 - Wealth of new results that form the long-term legacy of the LHC
- Liverpool plays a central role across ATLAS, recognised by several leadership roles
- With the HL-LHC just round the corner, we have only just scratched the surface of physics results
 - Liverpool playing a key role in ensuring ATLAS is ready to make the most of this (Sven)

< ATLAS Collaboration

2025 Breakthrough Prize in Fundamental Physics

For detailed measurements of Higgs boson properties confirming the symmetry-breaking mechanism of mass generation, the discovery of new strongly interacting particles, the study of rare processes and matter-antimatter asymmetry, and the exploration of nature at the shortest distances and most extreme conditions at CERN's Large Hadron Collider.

Andreas Hoecker (CERN, spokesperson 2021 to 2025) accepted the prize on behalf of the collaboration. The \$1 million (of the \$3 million prize) allocated to ATLAS was donated to the CERN & Society Foundation for grants to doctoral students from member institutes to spend research time at CERN.

