Recent Experimental Highlights from ATLAS

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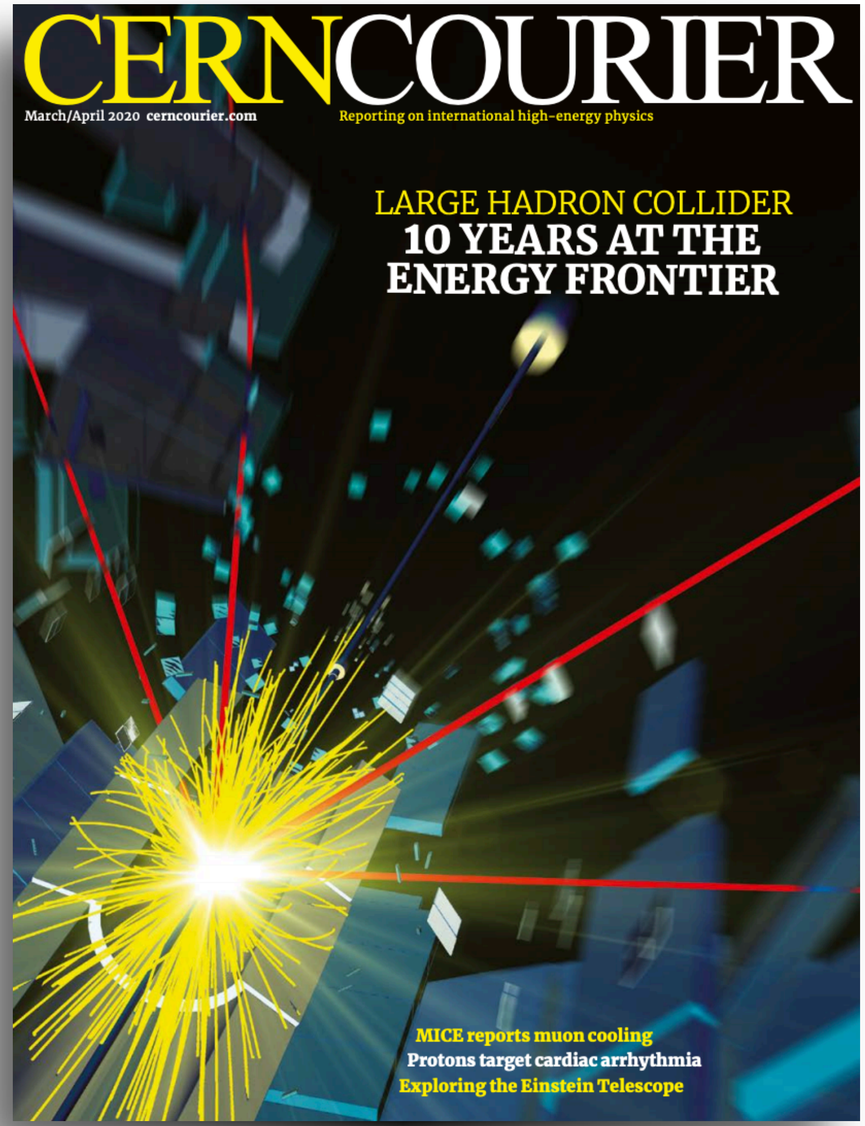
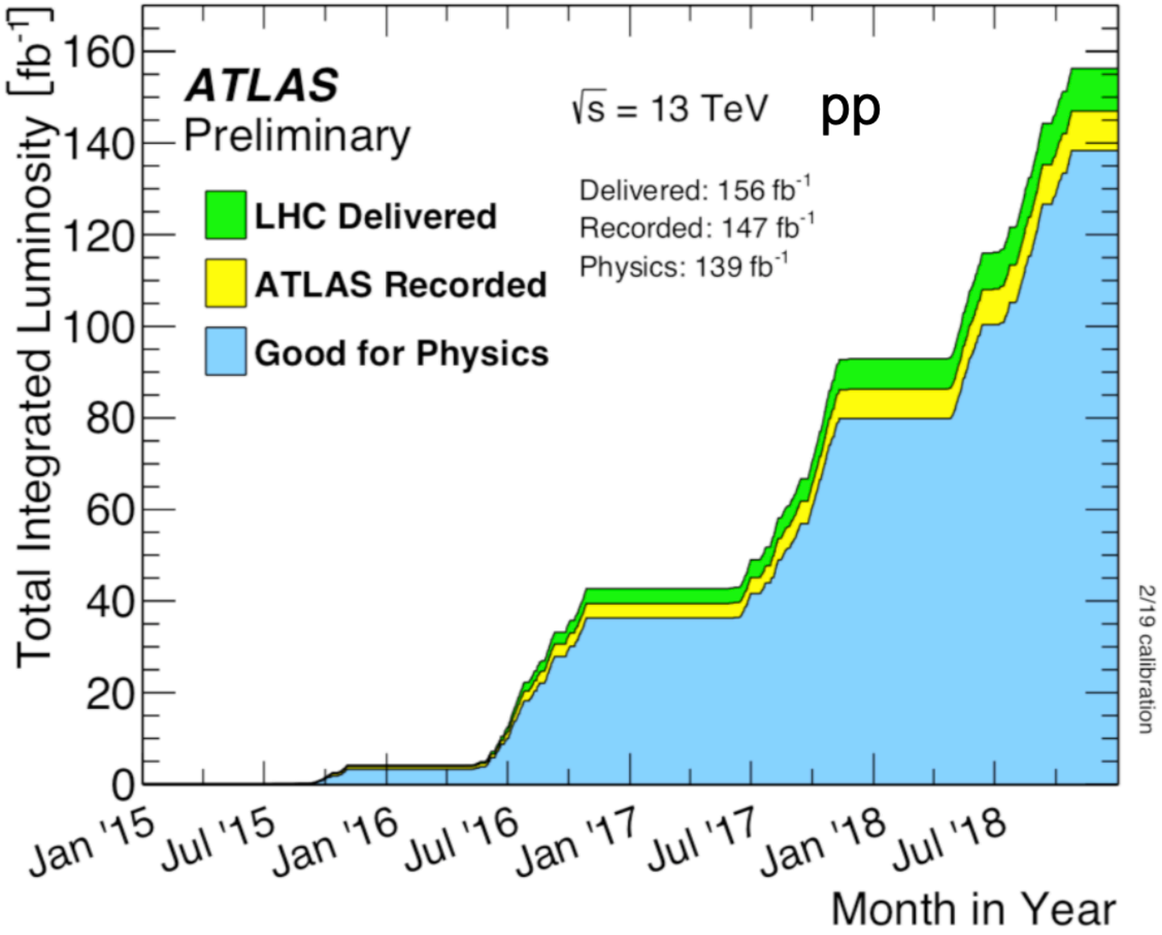
On behalf of the ATLAS collaboration
October 26 - Higgs 2020

ATLAS:10 years at the energy frontier

- The LHC has provided a unique playground for us to perform measurements that could not have been done otherwise
- Precision measurements in multiple areas
  - QCD, Top,…. Higgs
- Search for rare processes
- Search for new phenomena
- Today I will show some selected new results



LHC Run 2



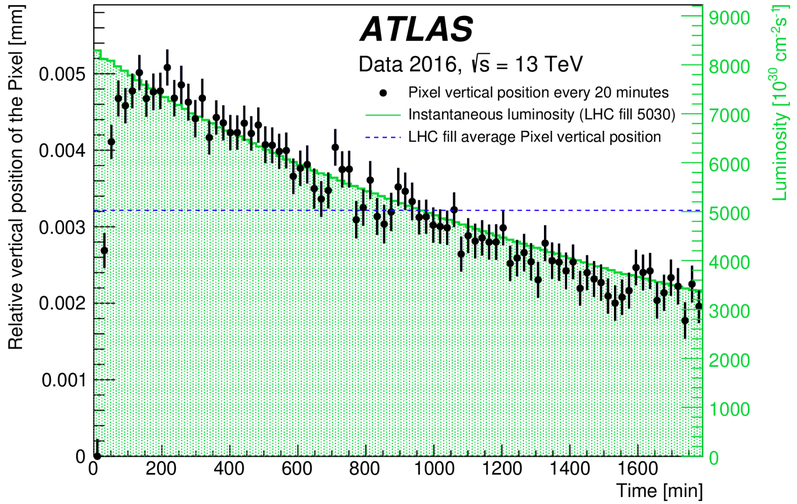
- The performance of the LHC and ATLAS in Run 2 (2015-2018) was outstanding
  - Delivered: 156 fb^{-1}
  - Recorded: 147 fb^{-1}
    (Data taking efficiency 94.2%)
  - Good for Physics: 139 fb^{-1}
    (Efficiency 94.6%, high data quality)
- Total luminosity know to precision of 1.7%
- Over 100 papers produced with Run 2 data
  - I will present some of the more recent results.

Detector Understanding & Performance

- Understanding of the detector is critical
- Reconstruction of physics objects (e, μ, τ, jets…) precisely known from careful data-driven calibrations
- Several improvements during the last year using machine learning techniques (e.g. b-tagging, τ-identification…)

Alignment of the inner detector

arXiv:2007.07624



τ-ID with RNN's

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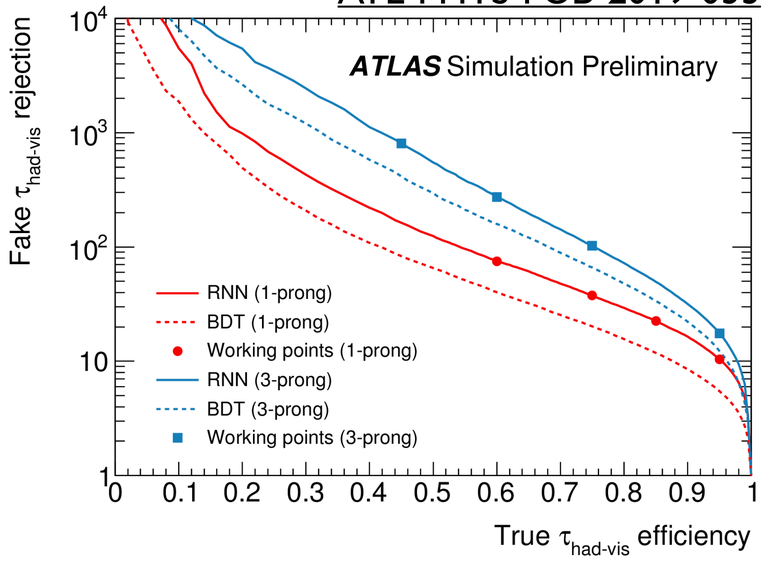
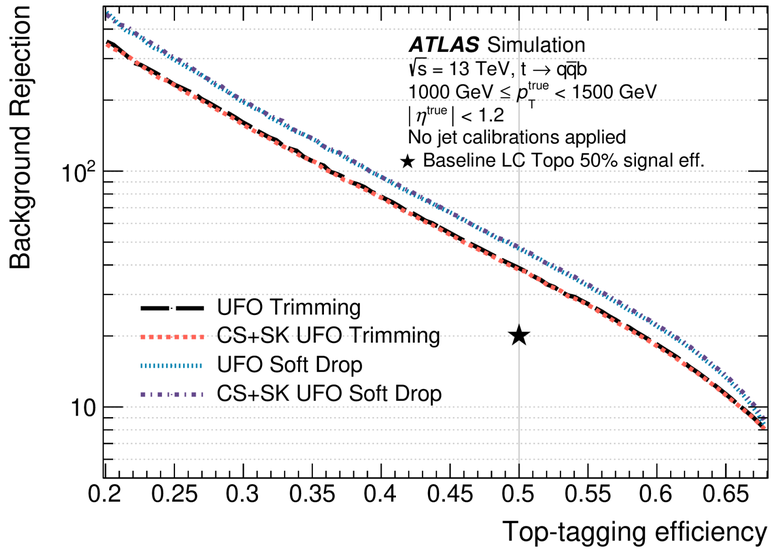


Optimisation of large-R jet reconstruction and W/Z/H/top-tagging

arXiv:2009.04986

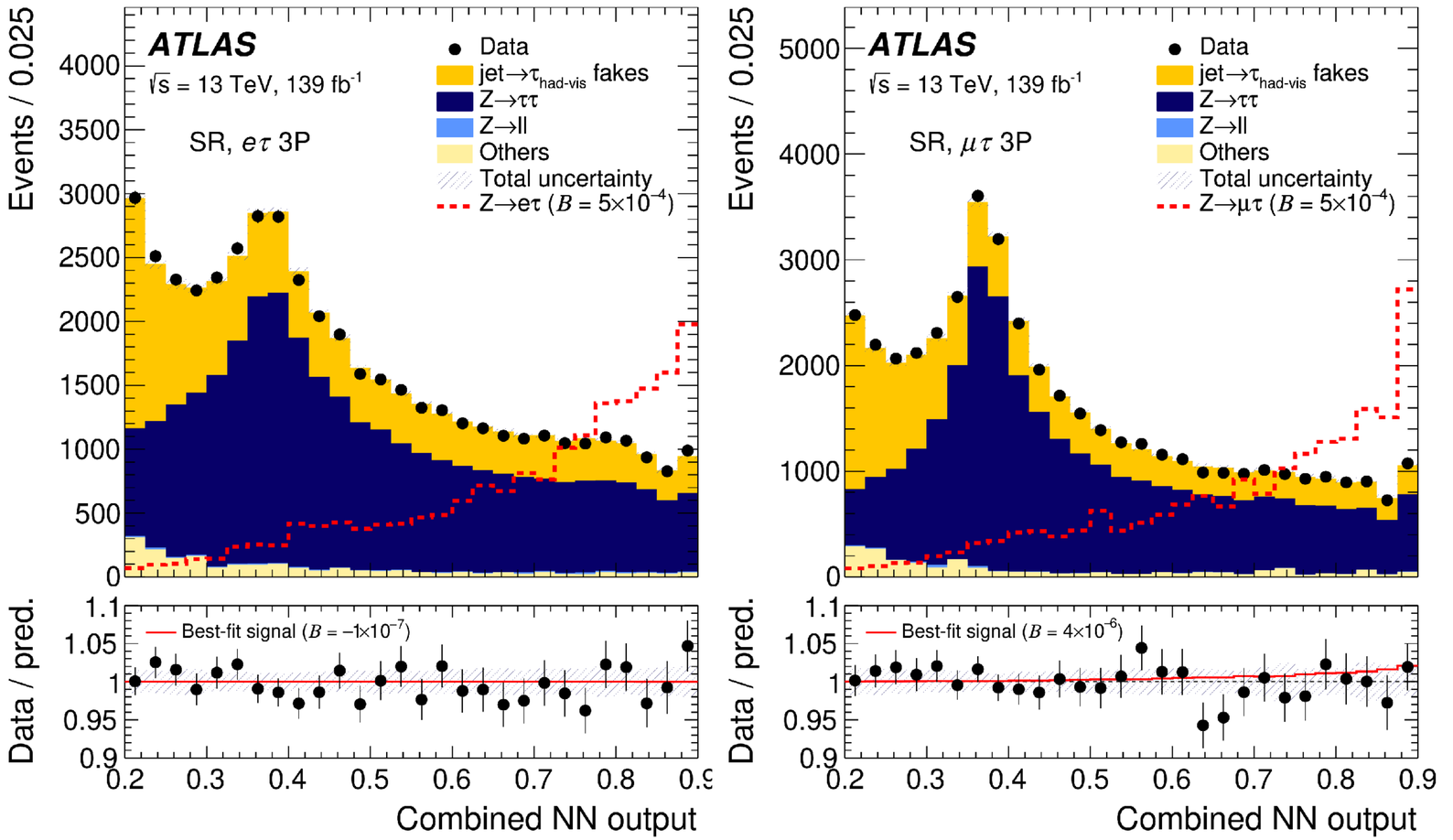


Tests of the Standard Model

Lepton flavour violation: Z→eτ/μτ

arXiv:2010.02566

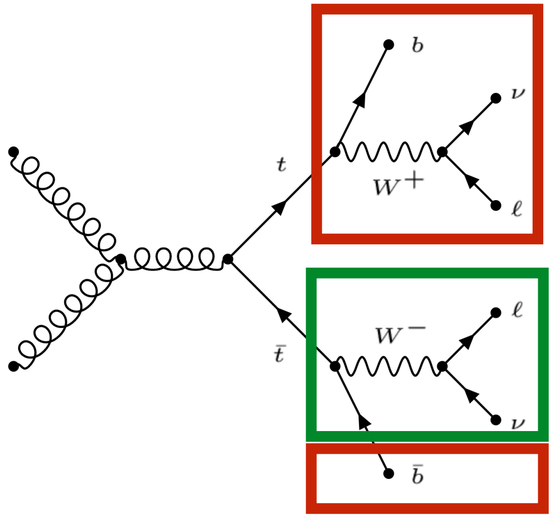
- LFV forbidden in SM
  - Neutrinos are known to oscillate but charged LFV would be an unambiguous sign of new physics
- Use large LHC Z boson (8×10^9) sample to search for Z→lτ with hadronic tau
  - Utilise significantly improved RNN tau ID
- Main backgrounds are Z→ττ and W+jets
  - Z→ττ corrected to ATLAS differential cross section
  - Jet→τ fakes from data-driven fake rate
- Utilise multi-class NN to separate S and B
- Most stringent BR limits for unpolarised τ's (surpassing LEP):
  - BR(Z→eτ) < 8.1 (8.1)×10^{-6} obs (exp)
  - BR(Z→μτ) < 9.5 (6.1)×10^{-6} obs (exp)

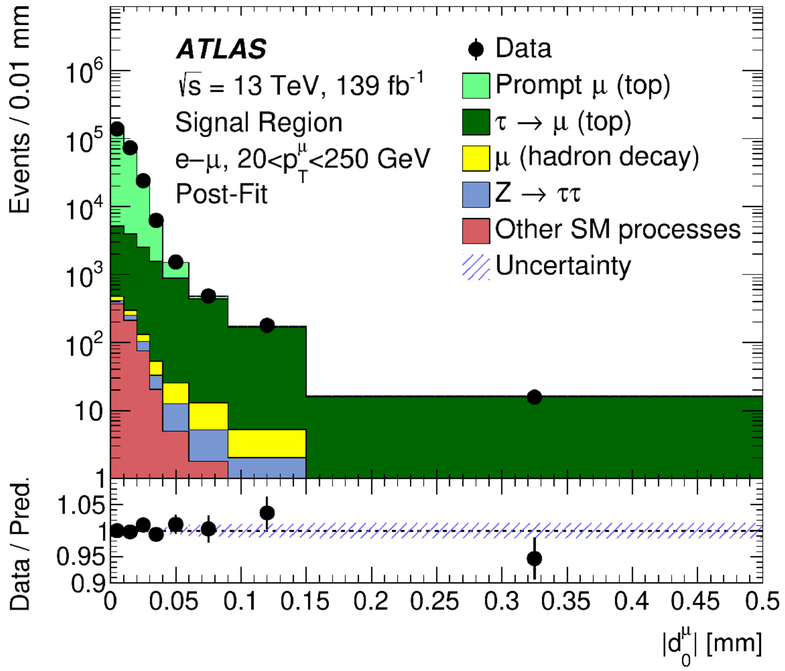


Lepton-flavour universality in W decays

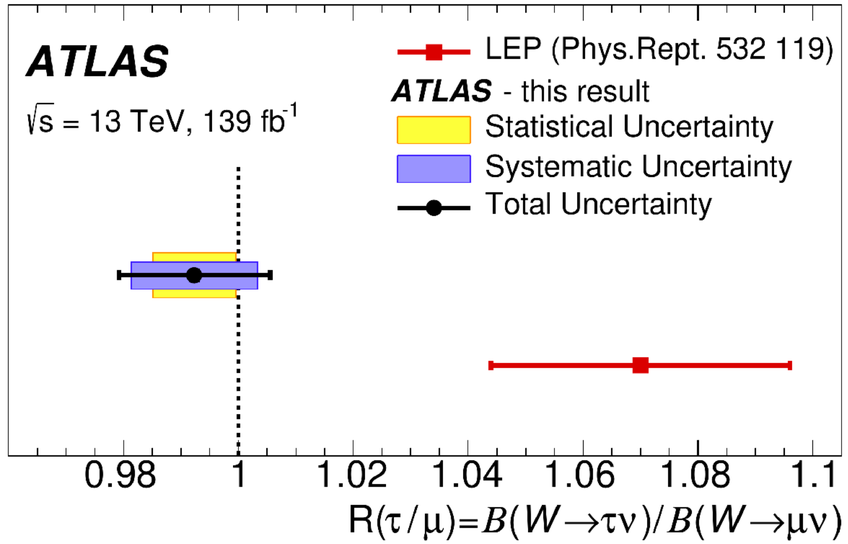
- Use abundant tt produced at ATLAS (~275M) as a source of unbiased W bosons
  - One W decays leptonically (trigger event) + 2 b-tag jets
  - Other W is ~unbiased
- Measure ratio of prompt (W→μν) to softer, delayed muons from tau decays (W→τν→μνvv)

- Partially motivated by long-standing 2.7σ LEP deviation (Phys. Rept. 532 (2013) 119):
  - R = BR(W→τν) / BR(W→μν) = 1.070 ± 0.026





arXiv:2007.14040



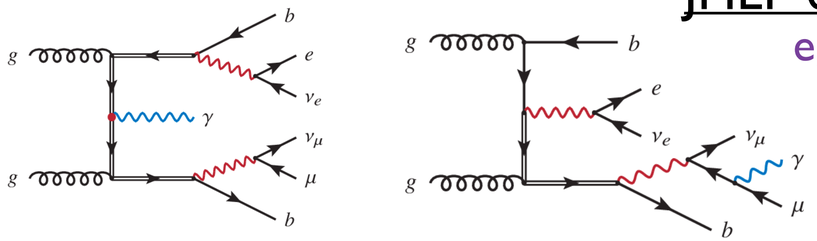
- New results improve precision by a factor of 2
  - R = BR(W→τν) / BR(W→μν) = 0.992 ± 0.013

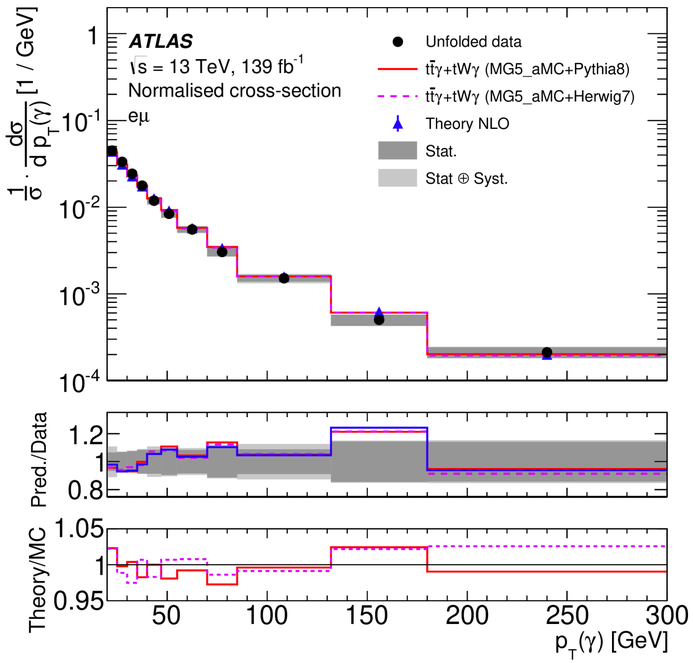
Associated ttγ + tWγ production and ttZ production

- Measurement have direct access to coupling of the heaviest SM particle to electroweak gauge bosons
  - Differential cross-section is sensitive to e.g. BSM physics in EWSB
- Good agreement of the SM predictions with the measured inclusive, fiducial and differential cross sections

JHEP 09 (2020) 049

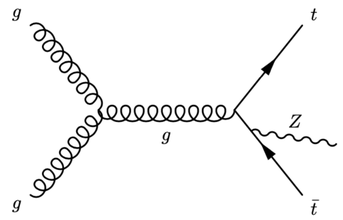
e,μ, γ final states

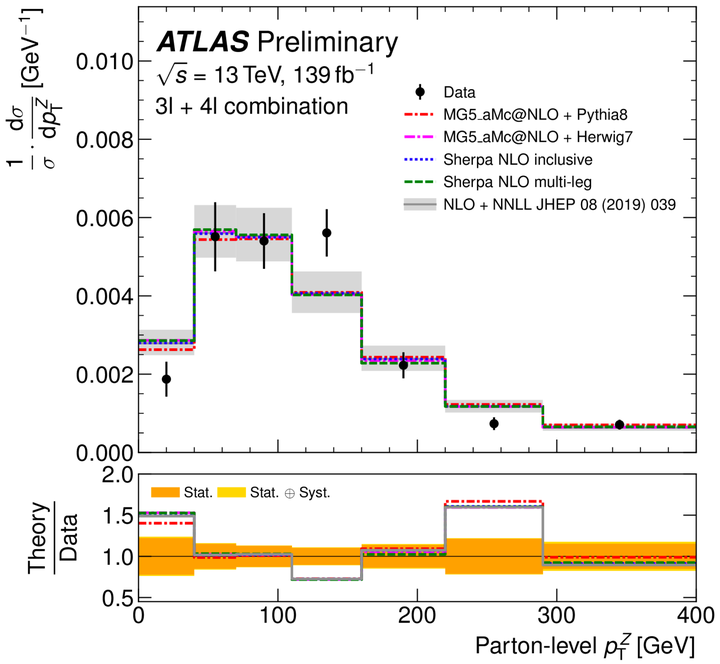




ATLAS-CONF-2020-028

3 and 4 lepton final states

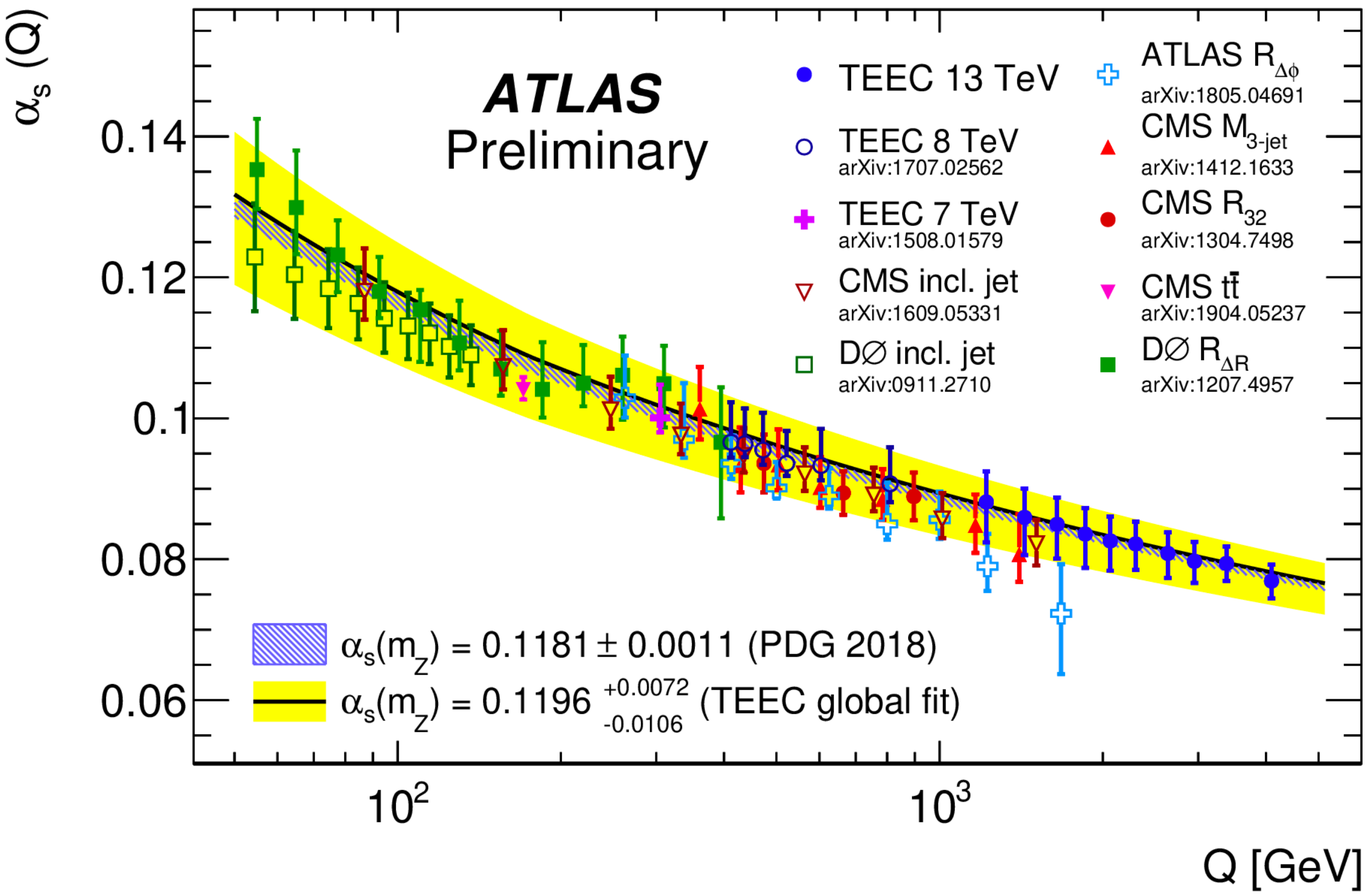




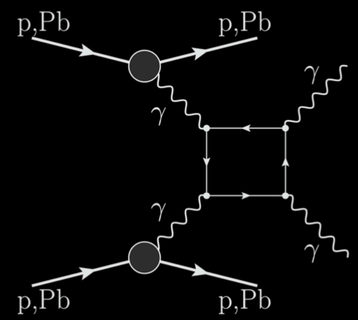
QCD

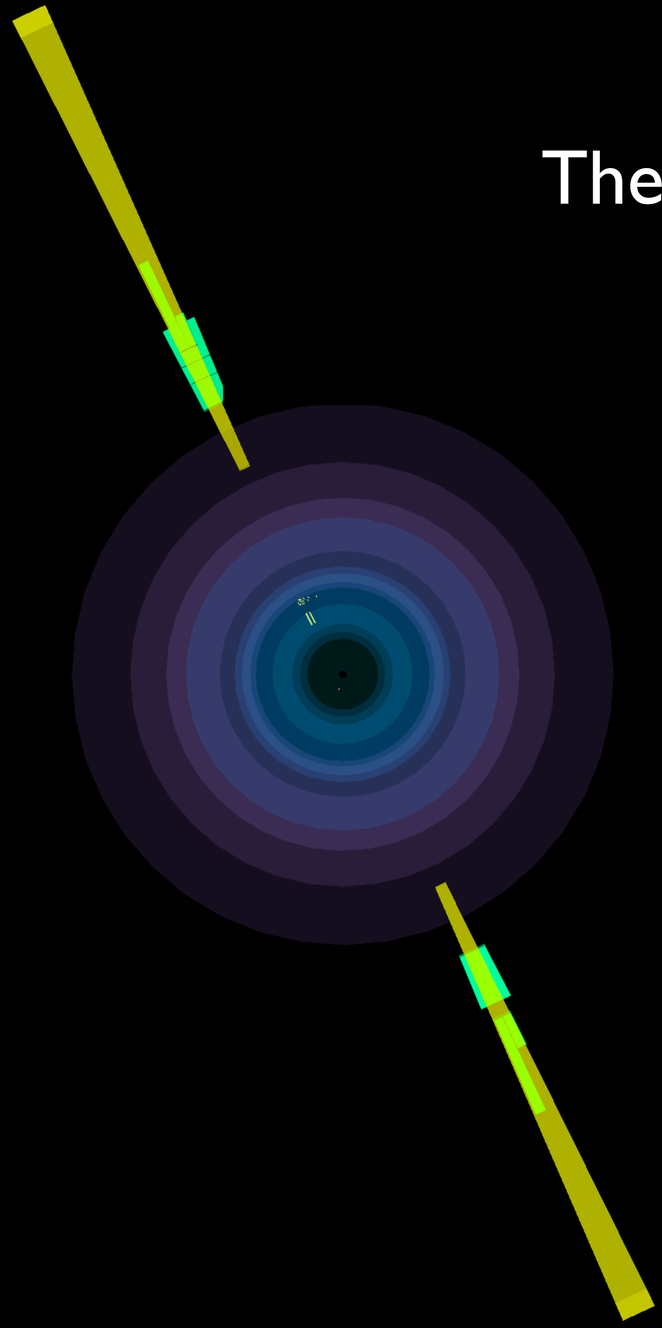
ATLAS-CONF-2020-025

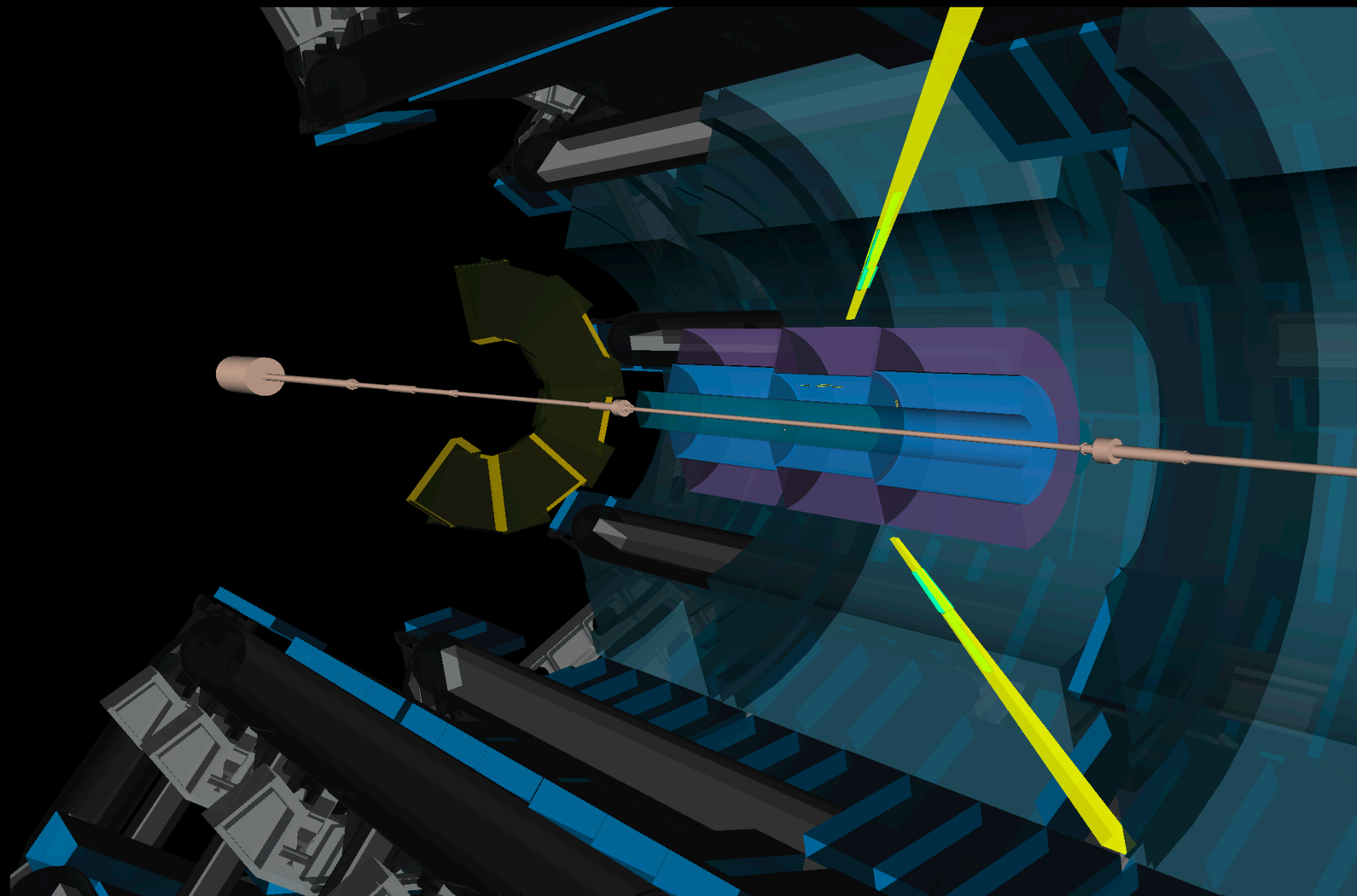
- New measurement of α_s from Transverse Energy-Energy Correlations (TEEC) in multi-jet events (based on NLO calculations)
- $\alpha_s(m_Z) = 0.1196 \pm 0.0004$ (exp) $^{+0.0072}_{-0.0105}$ (theo)

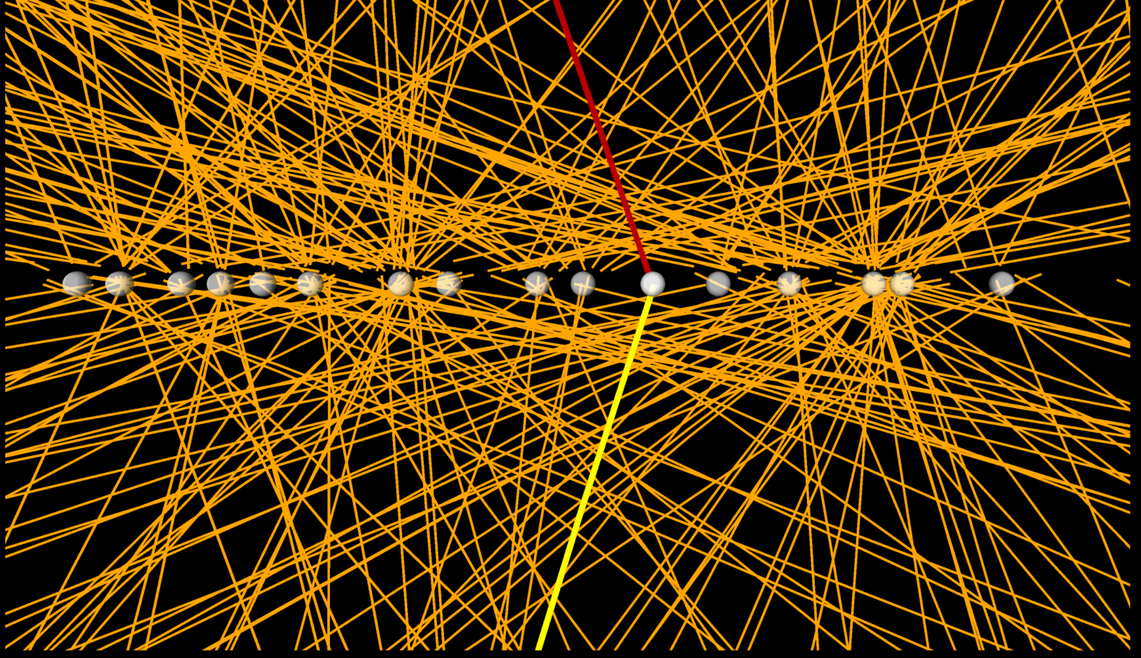


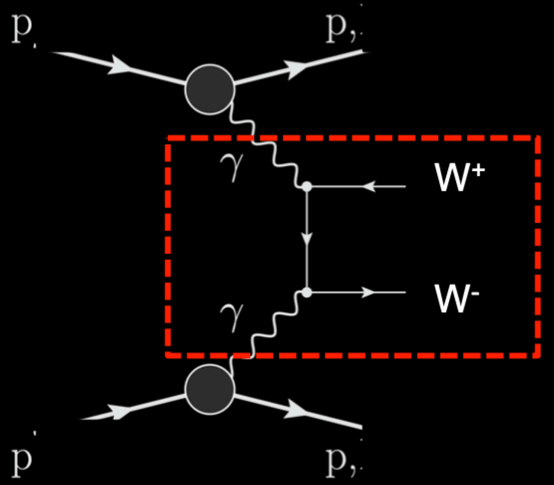
The Large Photon Collider










p
p
γ
W+
W-
γ
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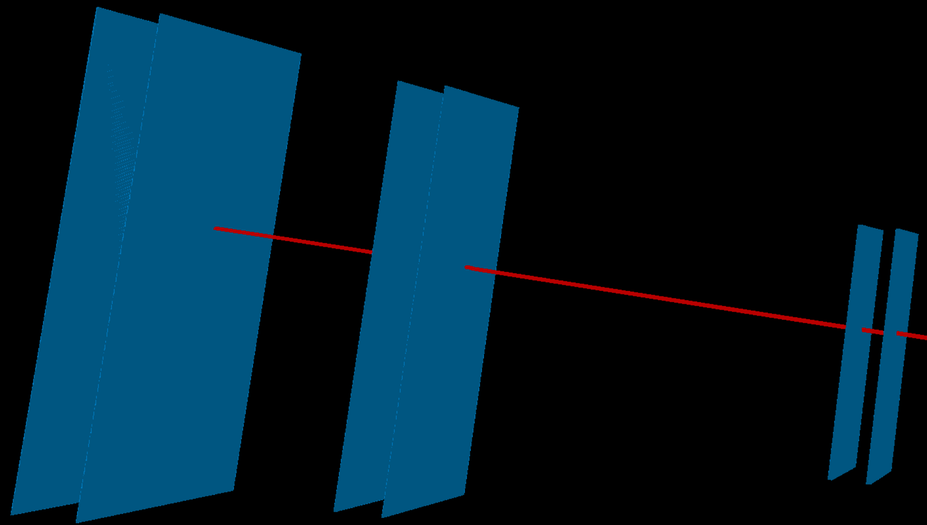
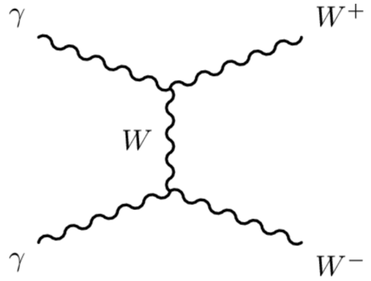
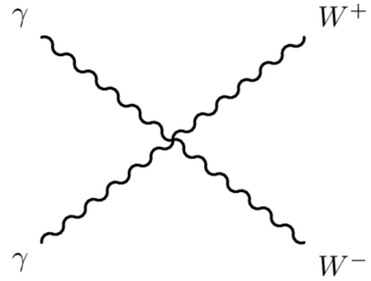


Observation of γγ→WW

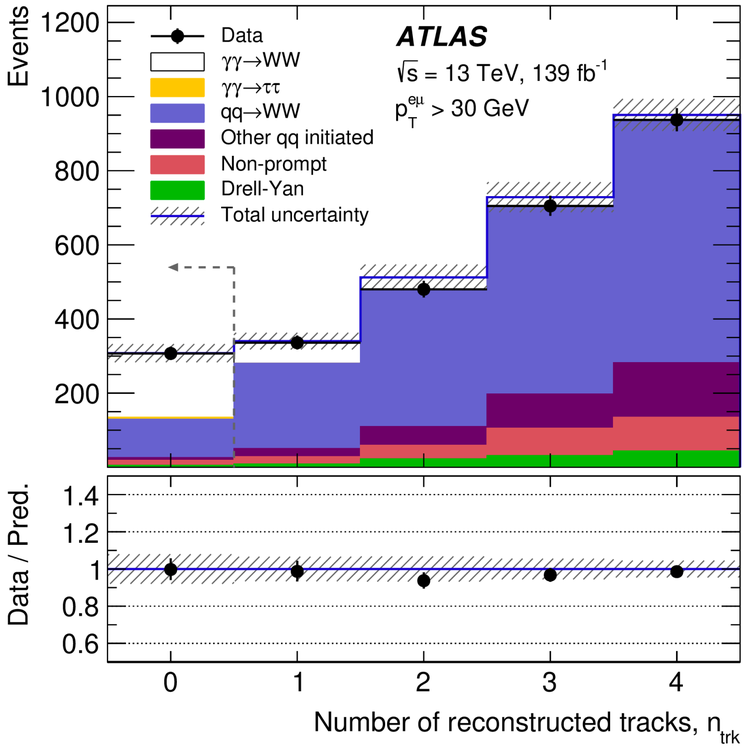
arXiv:2010.04019

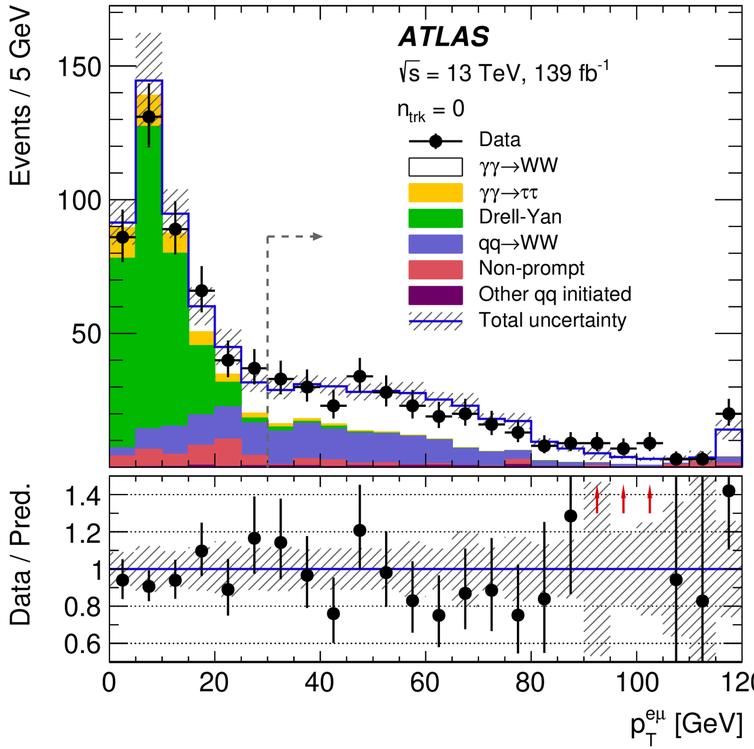
- Following the on from the evidence seen in Run 1 by ATLAS and CMS
- Production through trilinear and quartic gauge-boson interactions (Born level)
  - Test of gauge structure of the SM, sensitive to anomalous gauge-boson interactions





- Search for WW→eνμν signature
  - e-μ vertex,
  - p_T^{ll} > 30 GeV,
  - no add. charged particle activity



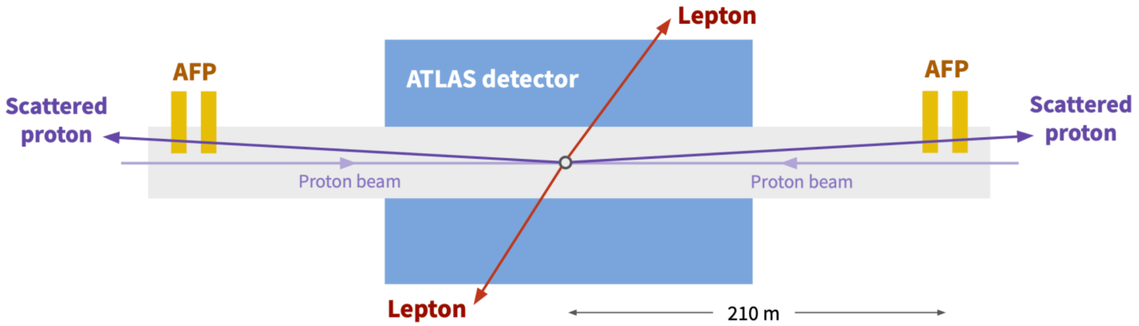


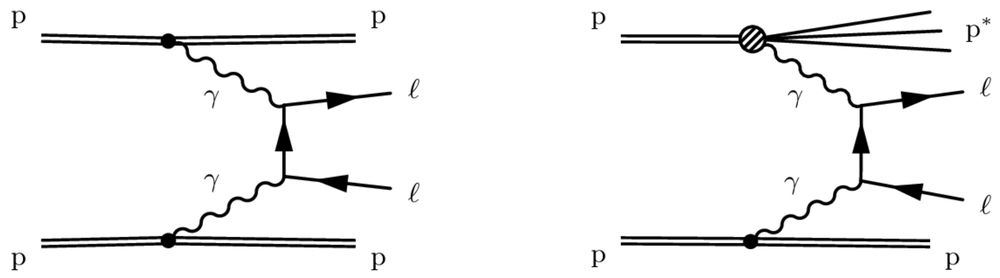
- σ_{fid} = 3.13 ± 0.31 (stat) ± 0.28 (syst) fb
  - Consistent with theoretical predictions
- Obs. (exp.) significance: 8.4σ (6.7σ)

Observation of AFP-tagged γγ→ll

arXiv:2009.14537

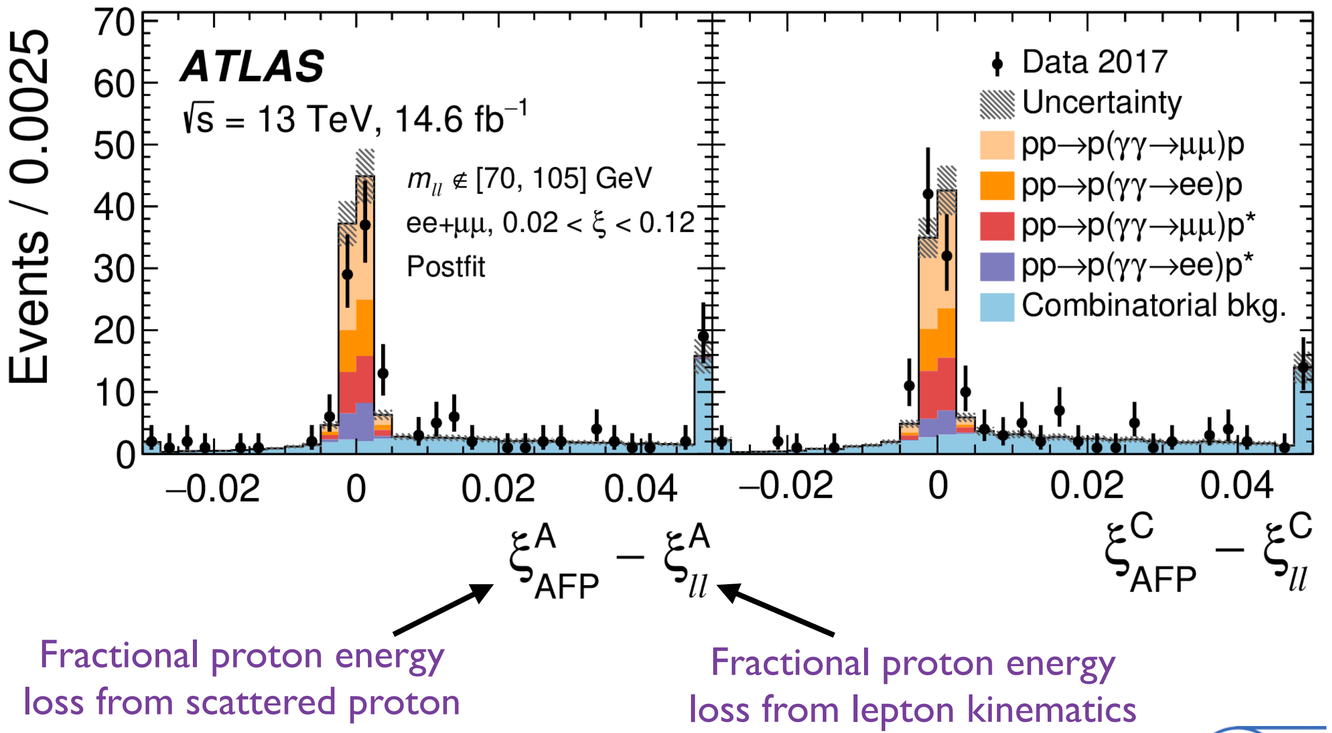
- Forward scattering of incident protons is a key prediction of photon fusion
  - Measured in ATLAS Forward Proton spectrometer (AFP)





- σ_{fid} (ee+p) = 11.0 ± 2.6 (stat) ± 1.2 (syst) ± 0.3 (lumi) fb
- σ_{fid} (μμ+p) = 7.2 ± 1.6 (stat) ± 0.9 (syst) ± 0.2 (lumi) fb
- Obs. significance: well above 5σ for both (ee) and (μμ)
  - Results are in agreement with the SM prediction

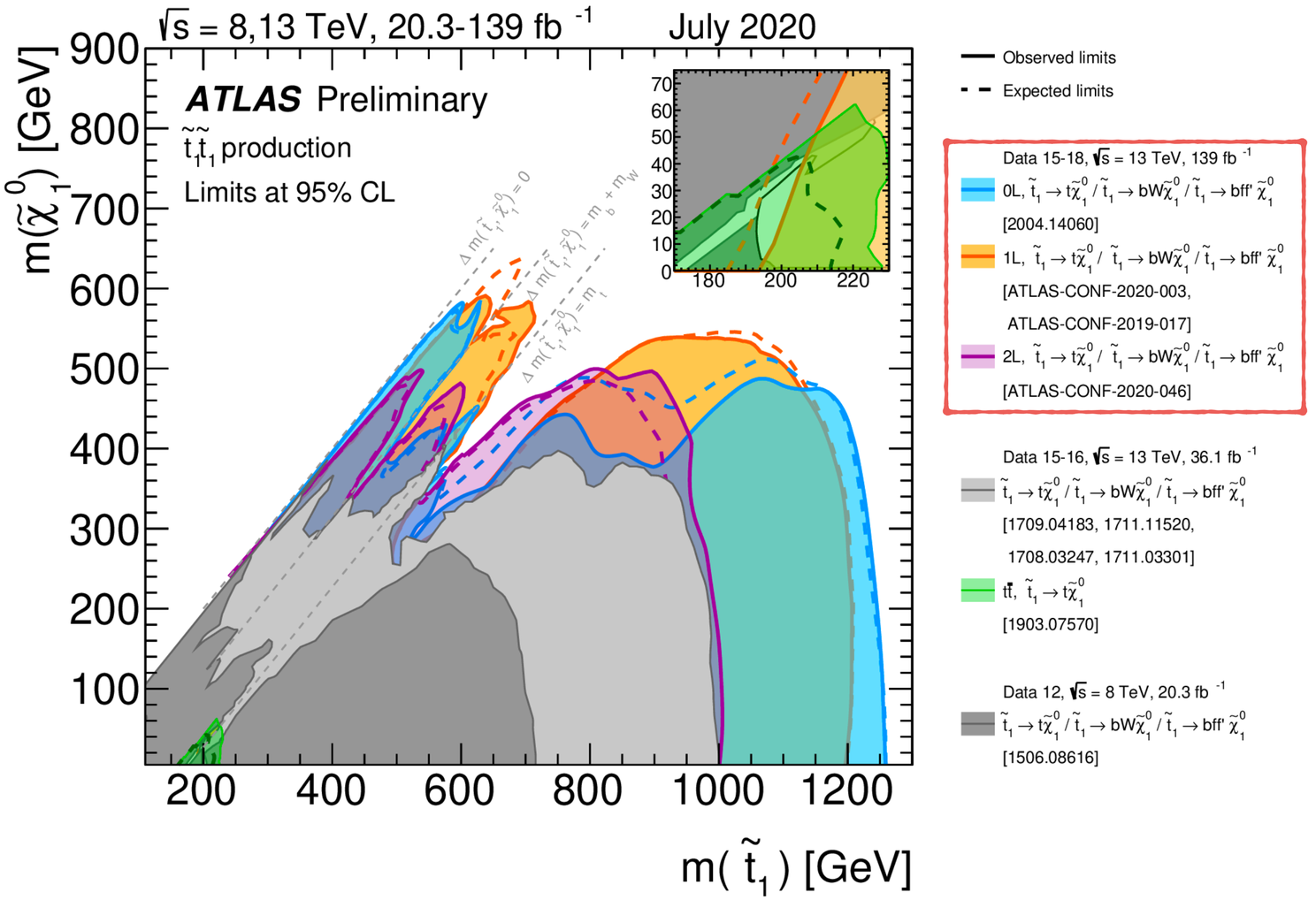
- First cross-section measurement using proton-tagging in photon-fusion processes at the LHC



Searches for Physics beyond the Standard Model

Search for physics beyond the SM

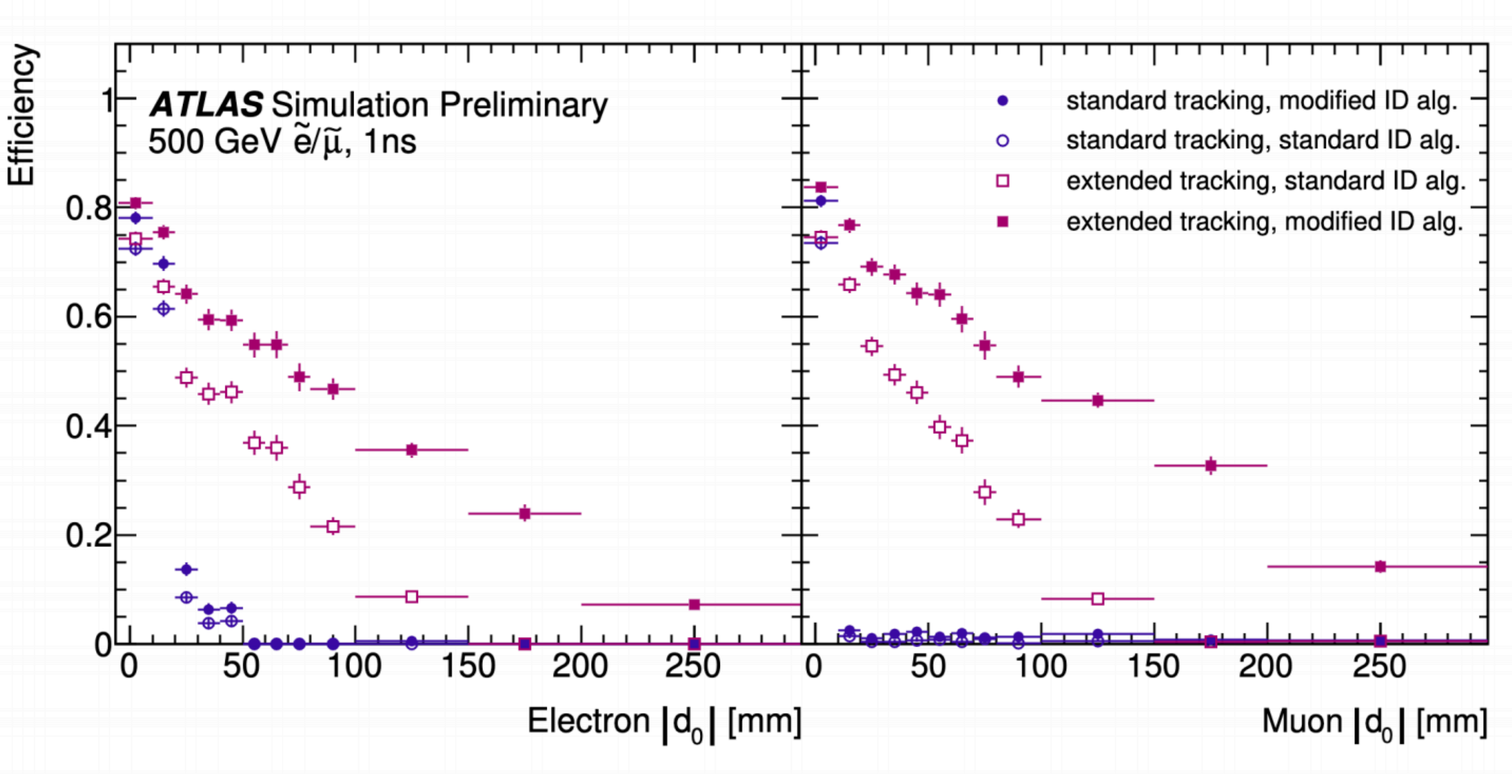
- Many searches performed and more are ongoing
  - No signal yet
  - Limits continue to improves with new reconstruction techniques and analysis strategies
  - Also extending to phase spaces with challenging experimental signatures
- e.g. Stop production limits
  - Analyses with 0,1,2 lepton final states increase limits
  - Improves the limits in the difficult compressed region, where the decay products have very low transverse momentum



Tackling challenging BSM signatures

- Huge phase space of possible BSM signatures!
  - Some require specialised reconstruction e.g. non-prompt particle decays
- Unconventional signature are often harder to be mimicked by the SM
  - Mains backgrounds normally originate from detector and reconstructions effects, cosmic muons, etc
  - Can allow us to probe small cross sections
  - Signature focused searches can be applied to many BSM models
- A focus for future search results is to ensure that they can be simply interpreted in additional models accurately

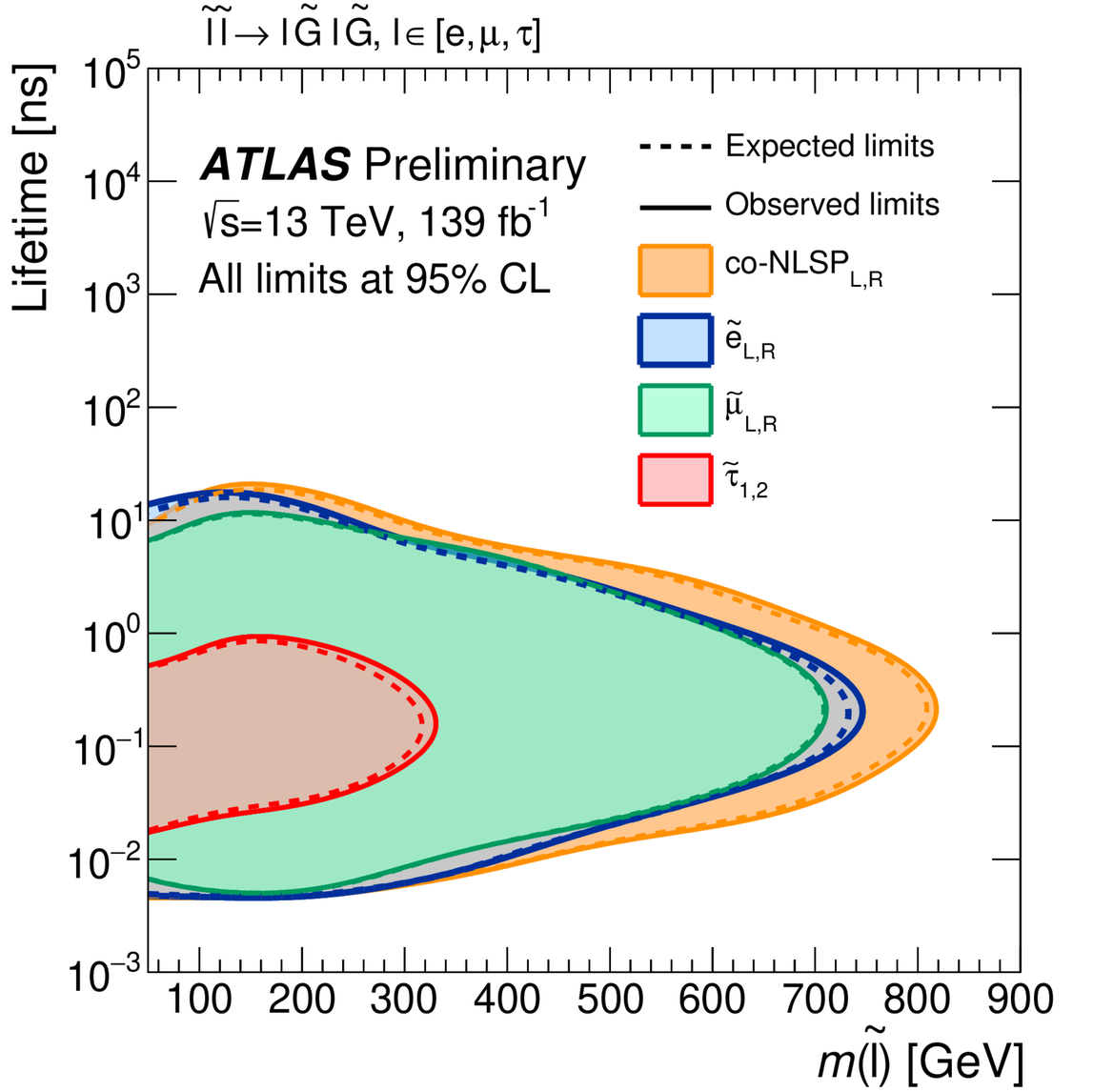
ATLAS-CONF-2020-051

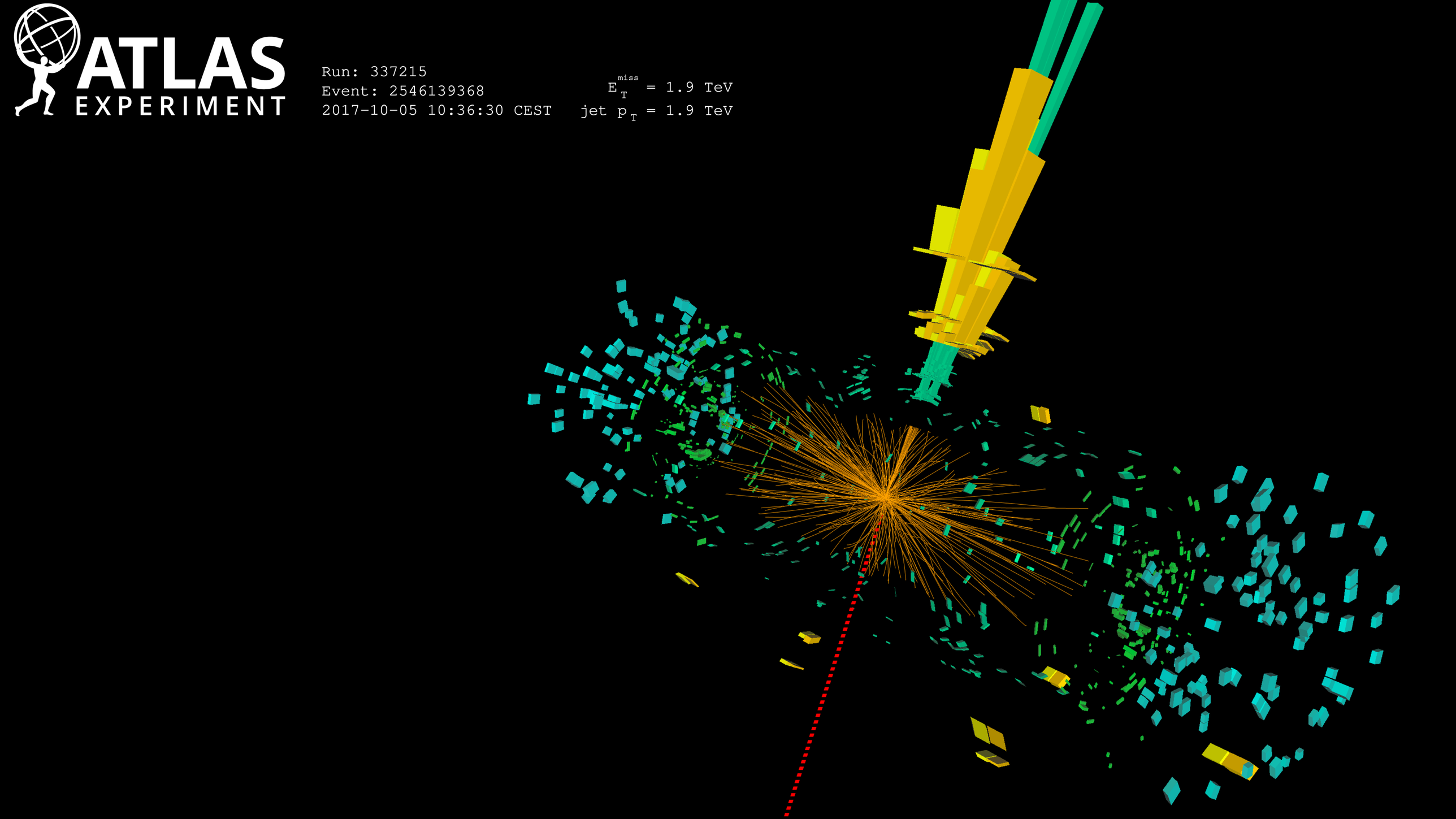


Long Lived Particle Searches

ATLAS-CONF-2020-051

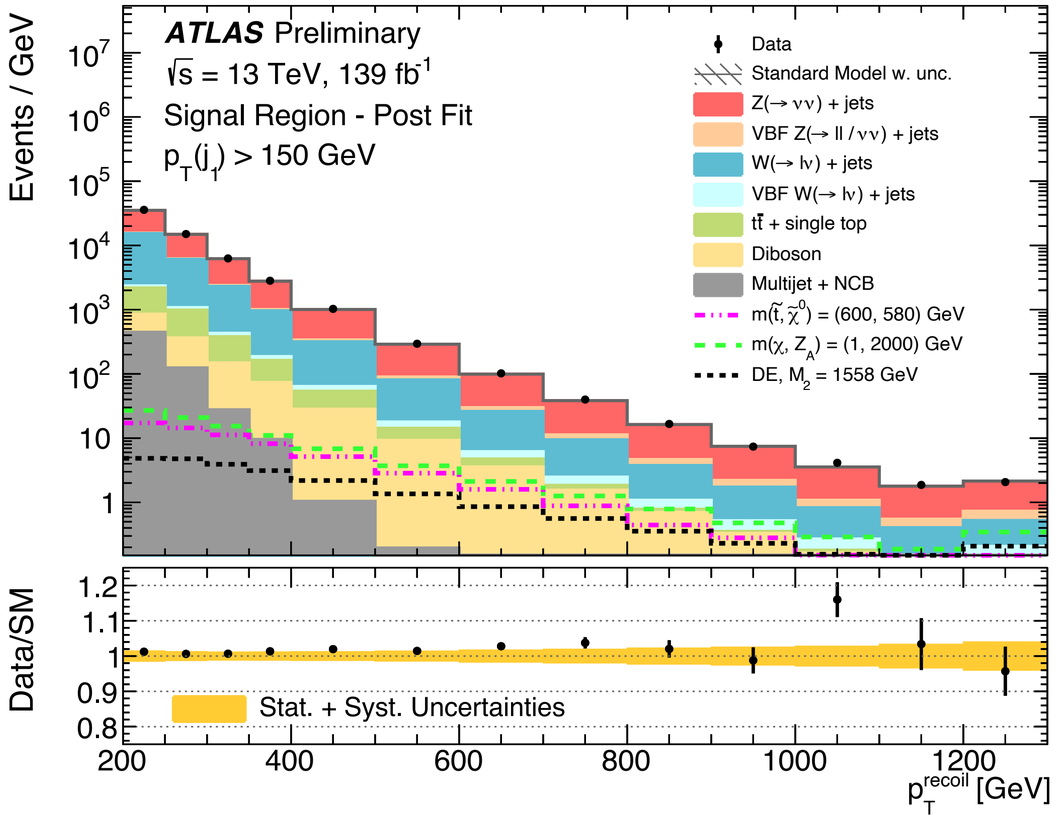
- Search for two leptons with high p_T and high d_0
  - Unique sensitivity to pair-produced sleptons in GMSB SUSY at the LHC
- LSP gravitino, suppressed decay with no secondary vertex
  - Last limits at ~90 GeV from LEP (Eur.Phys.J.C46:307-341,2006)
  - First LHC analysis to target this model with this signature and improve the limit
- Expect < 1 event per signal region, observe 0 — no SUSY here either
- Exclude huge range of phase space previously under-explored
  - slepton up to 800 GeV in co-NSLP scenarios for 0.1ns



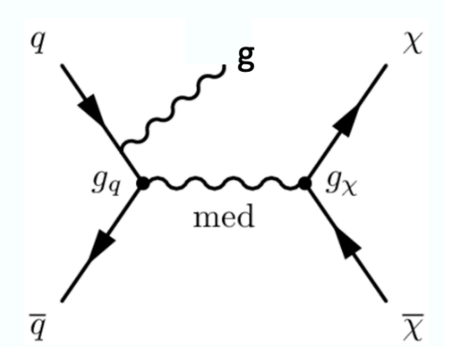

ATLAS
EXPERIMENT
Run: 337215
Event: 2546139368
2017-10-05 10:36:30 CEST
E_T^{miss} = 1.9 TeV
jet p_T = 1.9 TeV

Monojet Searches

ATLAS-CONF-2020-048



- Signature: An energetic jet recoiling against E_T^{miss} provides a model independent probe for dark matter
  - Require at least one jet (E_T >150) GeV, and E_T^{Miss} >200 GeV (Reduced thresholds)
  - Veto leptons (now also including taus)

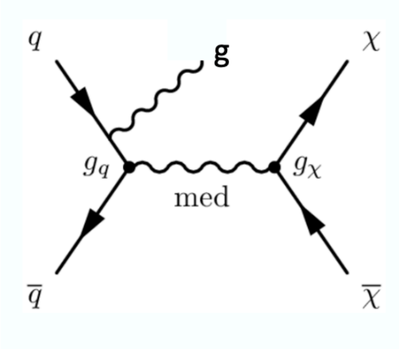


- Backgrounds
  - Z→νν & W→lν+jets constrained from 1/2 lepton PRs
  - 2x reduction of theory systs. via improved calculations of W/Z+jets which now have NNLO QCD and NLO EW corrections
  - Final Uncertainty 1-4% a precision search

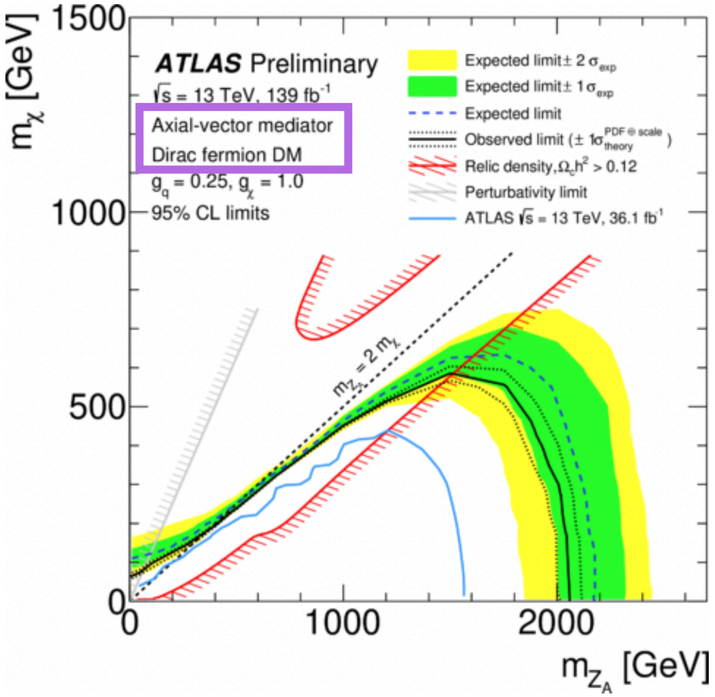
Monojet searches: Dark Matter

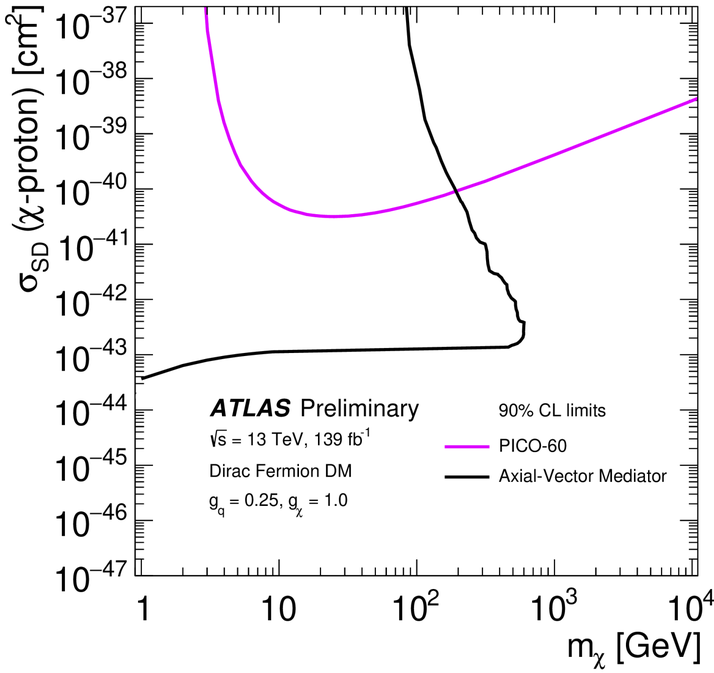
ATLAS-CONF-2020-048

- Limits on many models (compressed SUSY, extra dimensions etc.),
- e.g. A simplified models where DM couples to SM particles via spin 0/1 mediator



- e.g. Axial-vector mediator
- Model assumptions:
  - Neutral, spin-1 particle acts as mediator
  - DM assumed to be Dirac fermion
- Five parameters:
  - Masses of the mediator and DM particle
  - g_l : coupling to all lepton-flavours
  - g_X: coupling to DM
  - g_q: flavour-universal coupling of Z' boson to all quarks





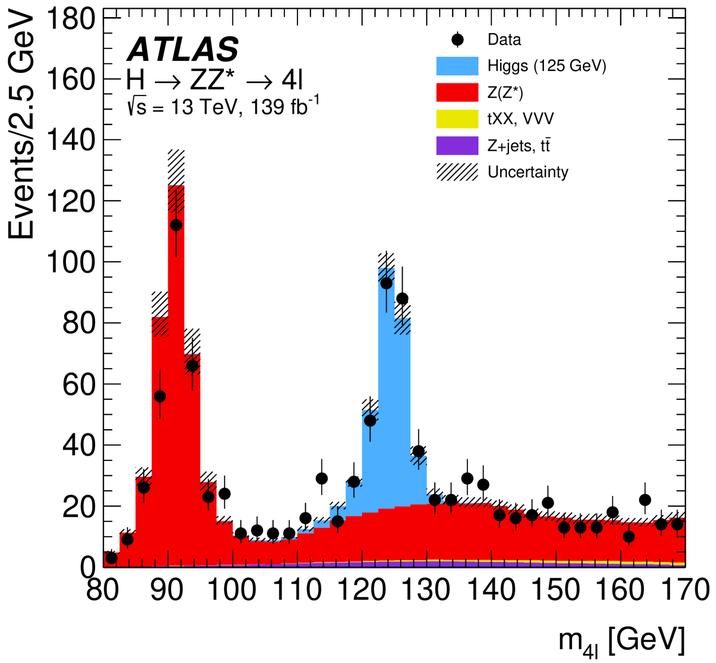
Mediator masses up to 2 TeV excluded for low m_X
- Significant improvement over previous limits

Higgs Boson Physics

- I don't want to ruin the fun so I won't say much
- Many production and decay modes are well established
- (Double) Differential measurements, STXS, properties and searches for rarer decay

H→ZZ→4l

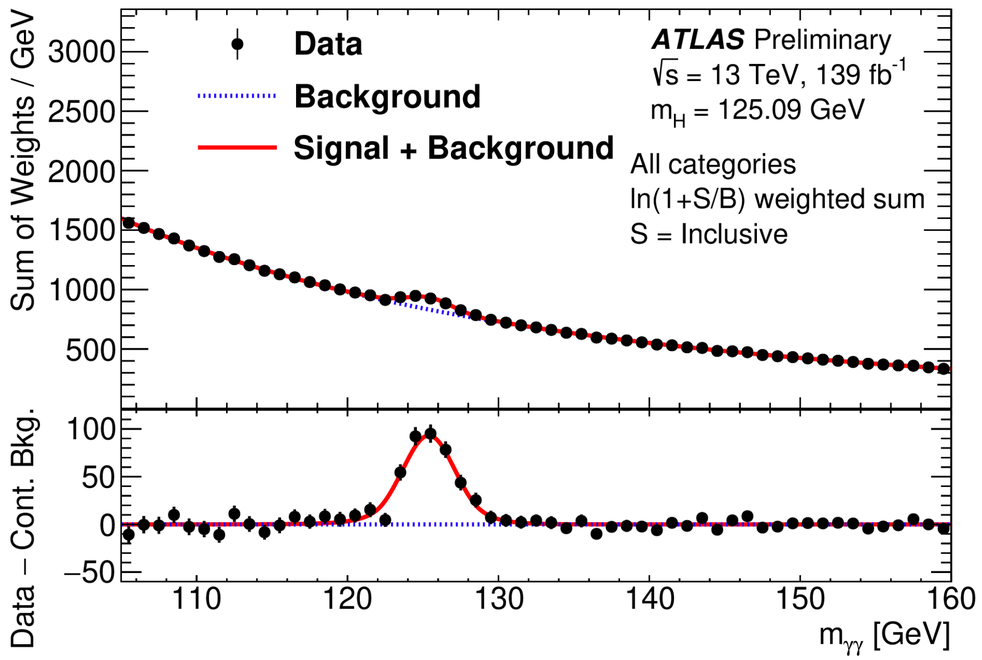
Eur. Phys. J. C 80 (2020) 941



$\sigma = 53.5 \pm 4.9$ (stat) ± 2.1 (syst) pb
$\sigma_{SM} = 55.7 \pm 2.8$ pb

H→γγ

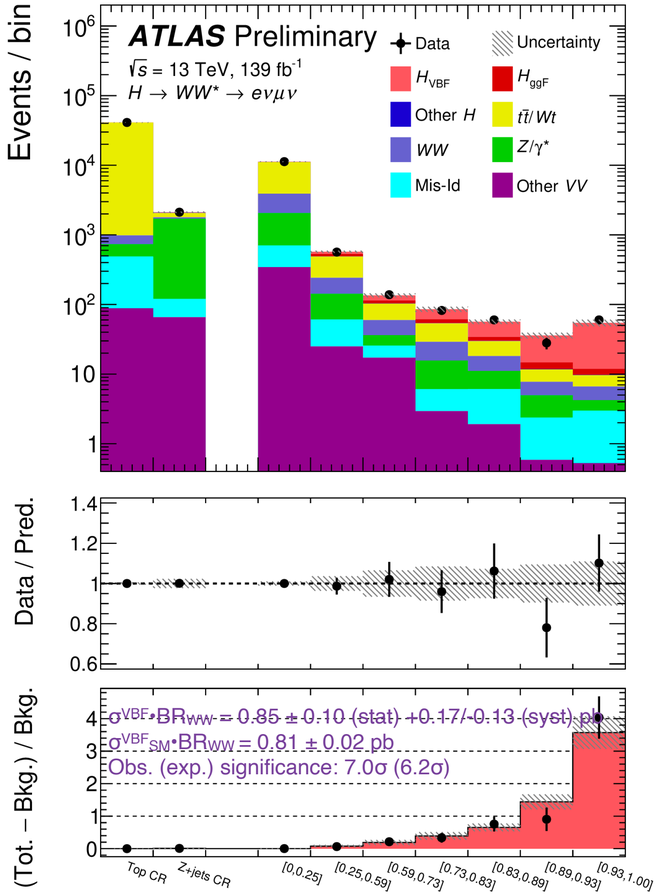
ATLAS-CONF-2020-026



$\sigma \cdot BR_{\gamma\gamma} = 127 \pm 7$(stat) ± 7(syst) fb
$\sigma_{SM} \cdot BR_{\gamma\gamma} = 116 \pm 5$ fb

H→WW

ATLAS-CONF-2020-045

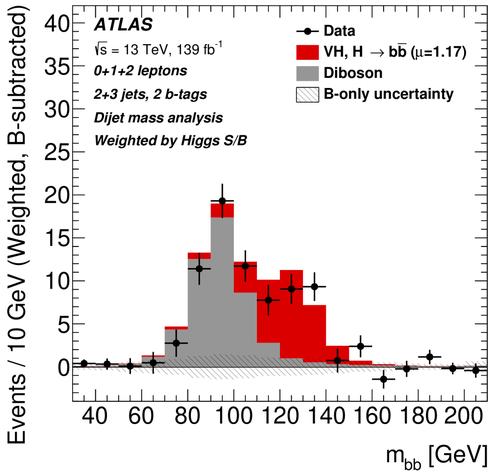


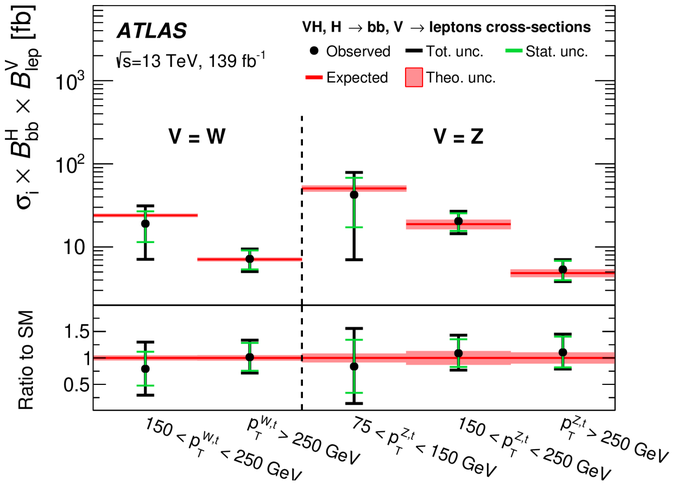
VH H→bb

- Not a rarer decay but a more difficult one
- Two analyses used to maximise the phase-space studied
  - Resolved for low and medium Higgs p_T
  - Boosted for high Higgs p_T
- Clearly establishes coupling to 3rd generation fermions

Resolved

arXiv:2007.02873

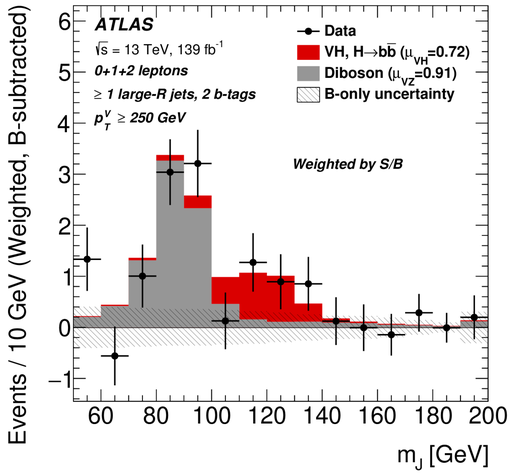


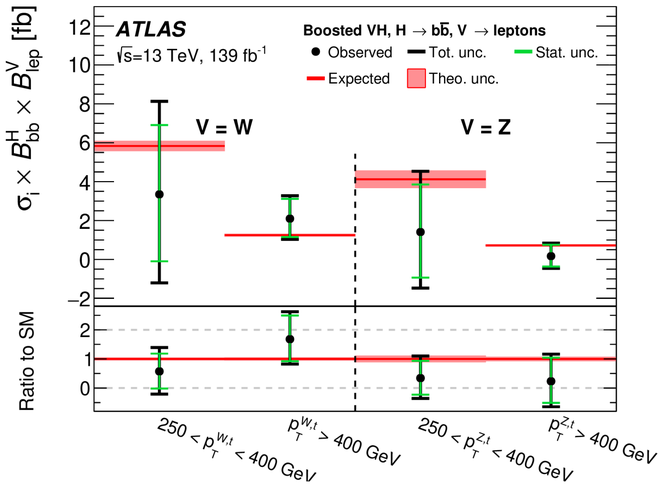


Signal strength: $\mu = \sigma_{obs} / \sigma_{SM}$
$\mu_{VH}(bb) = 1.02\ ^{+0.12}_{-0.11}\ (stat)\ ^{+0.14}_{-0.13}\ (syst)$
Obs. (exp.) significance (ZH): 5.3σ (5.1σ)

Boosted

arXiv:2008.02508





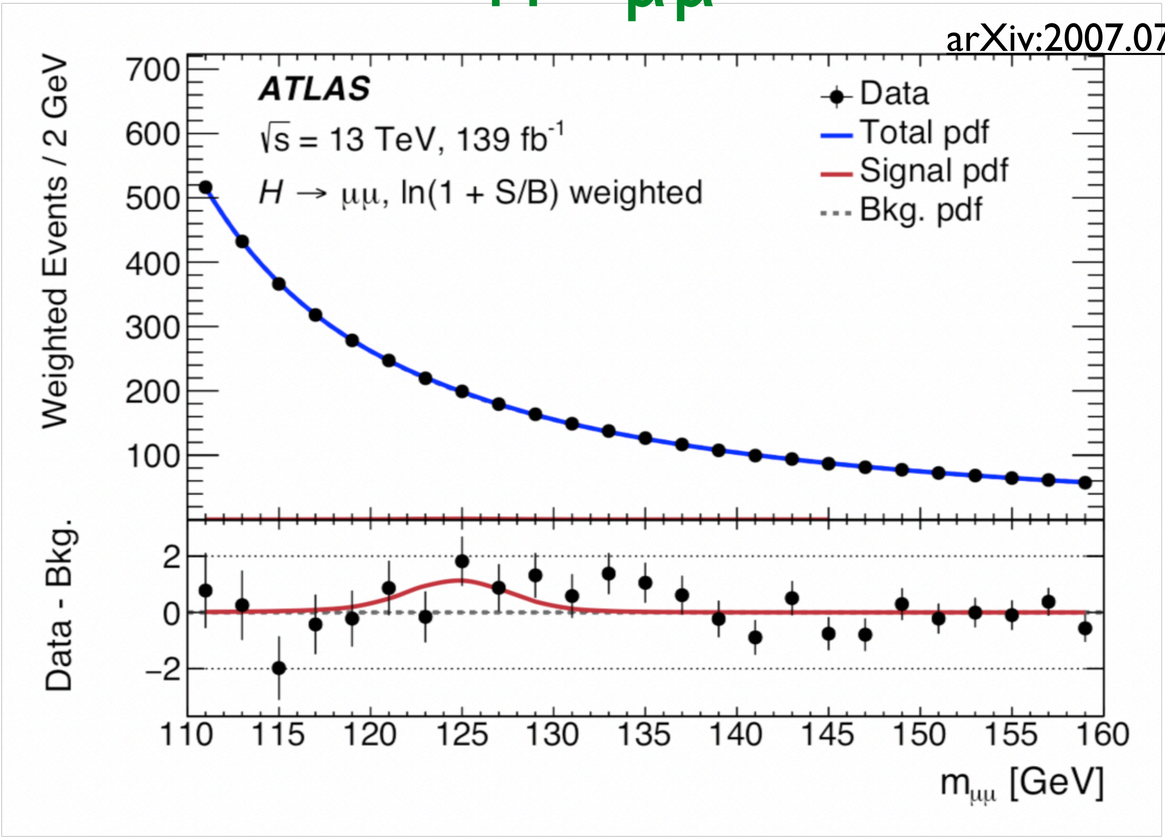
$\mu_{VH}(bb) = 0.72\ ^{+0.39}_{-0.36}$
Obs. (exp.) significance (ZH): 2.1σ (2.7σ)

Rare decays

- Important to test the Yukawa sector as well all possible Higgs decay paths

H→μμ

arXiv:2007.07830



Best fit signal strength: μ = 1.2 ± 0.6
Obs. (exp.) significance: 2.0σ (1.7σ)

H→Zγ

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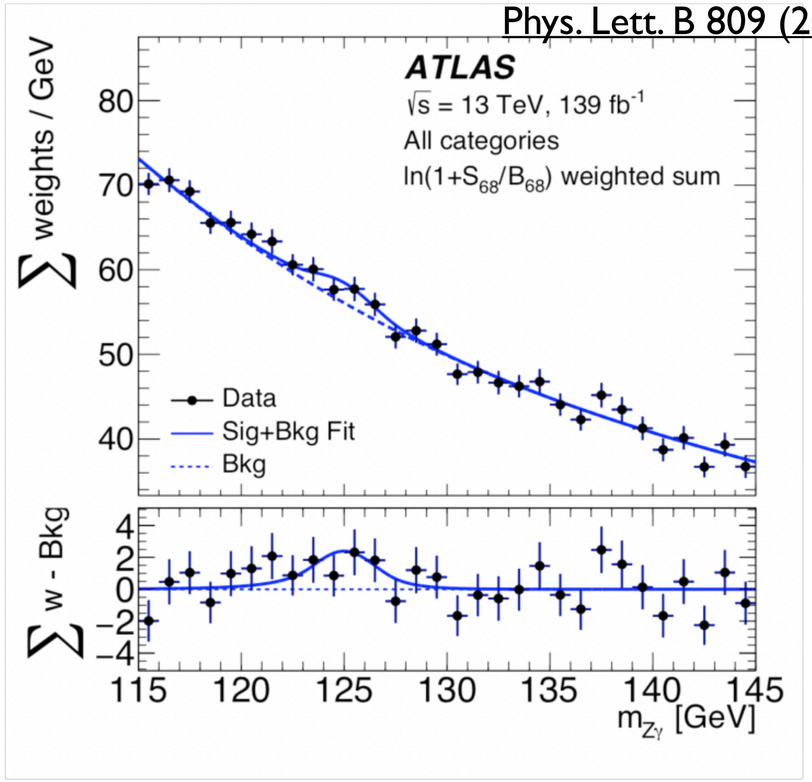


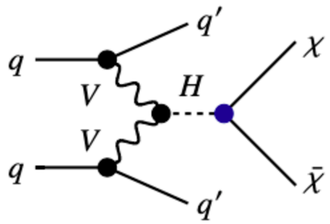
Best fit signal strength: $\mu_{Z\gamma}$ = 2.0 ± 0.9 (stat) +0.4/-0.3 (syst)
Obs. (exp.) significance: 2.2σ (1.1σ)

Run 3 and beyond essential to increase sensitivity

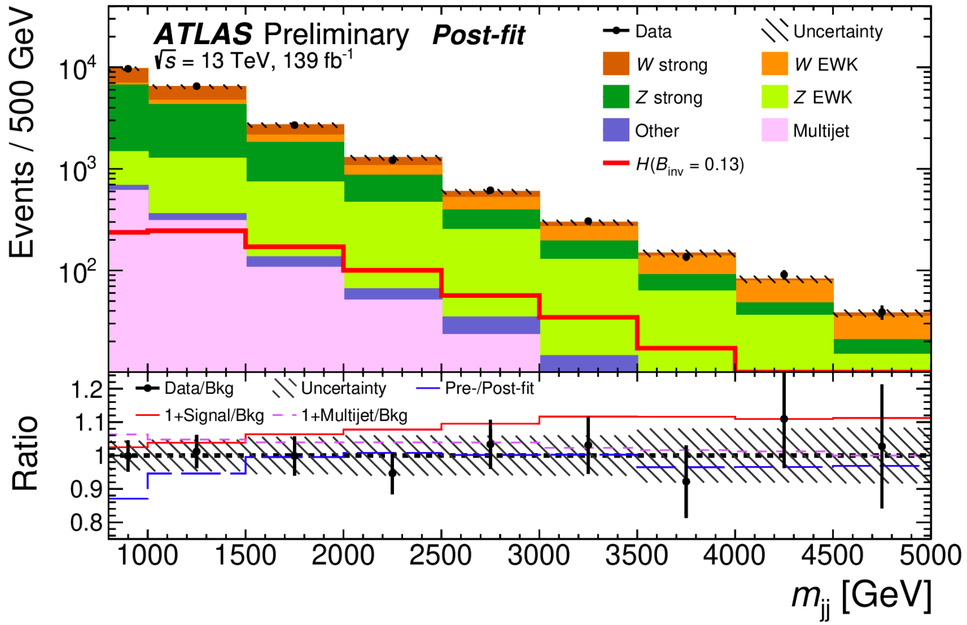
VBF H→invisible

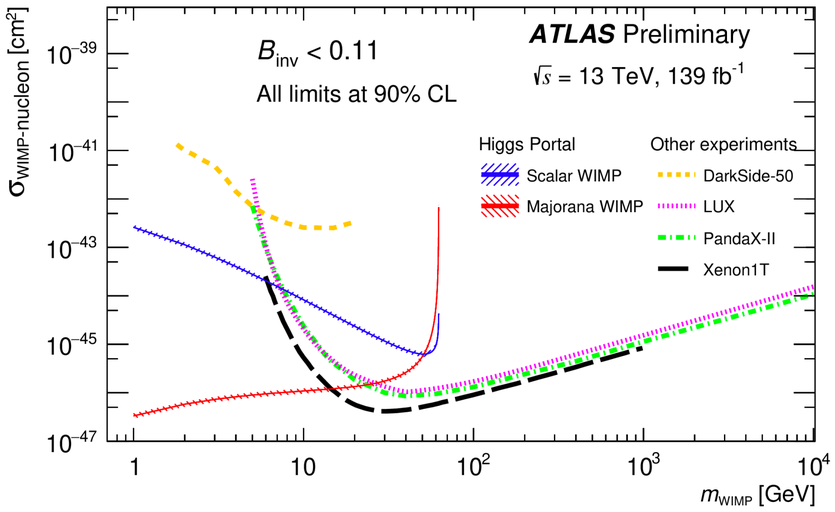
ATLAS-CONF-2020-008

- Direct search for Higgs decaying into invisible
  - Suitably small in the SM that any single would be evidence of New physics
- In the VBF channel the invisible Higgs boson decays can be tagged selecting 2 forward jets and missing transverse momentum



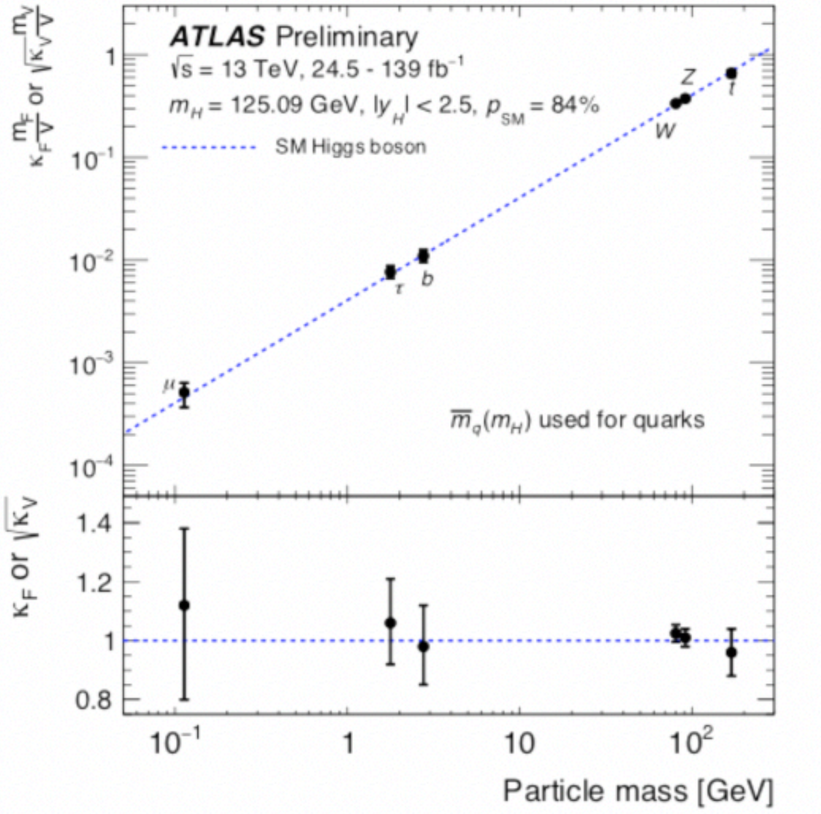
- Both the observed and expected upper limits on the branching fraction of its decay into invisible particles are derived to be 0.13 at 95% confidence level
- Dark Matter interpretation (Higgs portal models)





Summary & Outlook

- ATLAS continues probing the Standard Model with new measurements and searches with the full run-2 dataset
  - These would not be possible without the continued development of our understanding of the detector and improved combined performance improvements and novel analysis techniques.
- Standard model continues to prove unbelievably predictive but with improvement measurements and searched hopefully we find a few inconsistencies
- Much more still to come from the Run 2 dataset some of which you hear about this week!
- ATLAS Collaboration is working hard to prepare for run-3
  - Hardware:
    - LS2 activities on track following restart
    - Phase-I installation and commissioning, including NS
  - Software:
    - Implementation of reconstruction for new detectors
    - Significant improvements in CPU, memory & disk usage



Useful links

- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ResultswithData2018
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults

Future

- Many searches and measurements utilising the Full Run-2 dataset in the pipeline
  - Many utilising new or improved methods
- Run 3 promises to double the size dataset and preparations are ongoing
  - Many detector receiving some TLC during the shutdown
  - Improve higher granuanilty L1 trigger for the calorimeter will be available in Run-3
  - Largest upgrade is the NSW which will lower the fake trigger rate in the muon system
    - NSW-A on track for installation in ATLAS in spring 2021
    - NSW-C: Chamber production continuing and target installation in Oct'21 still possible
  - Many Improved to both the online and offline software
    - Migration to a multithreaded software
    - Large improvement in the event reconstruction time allowing for more specialised event reconstruction to be run on all events —> More diverse physics searches possible!