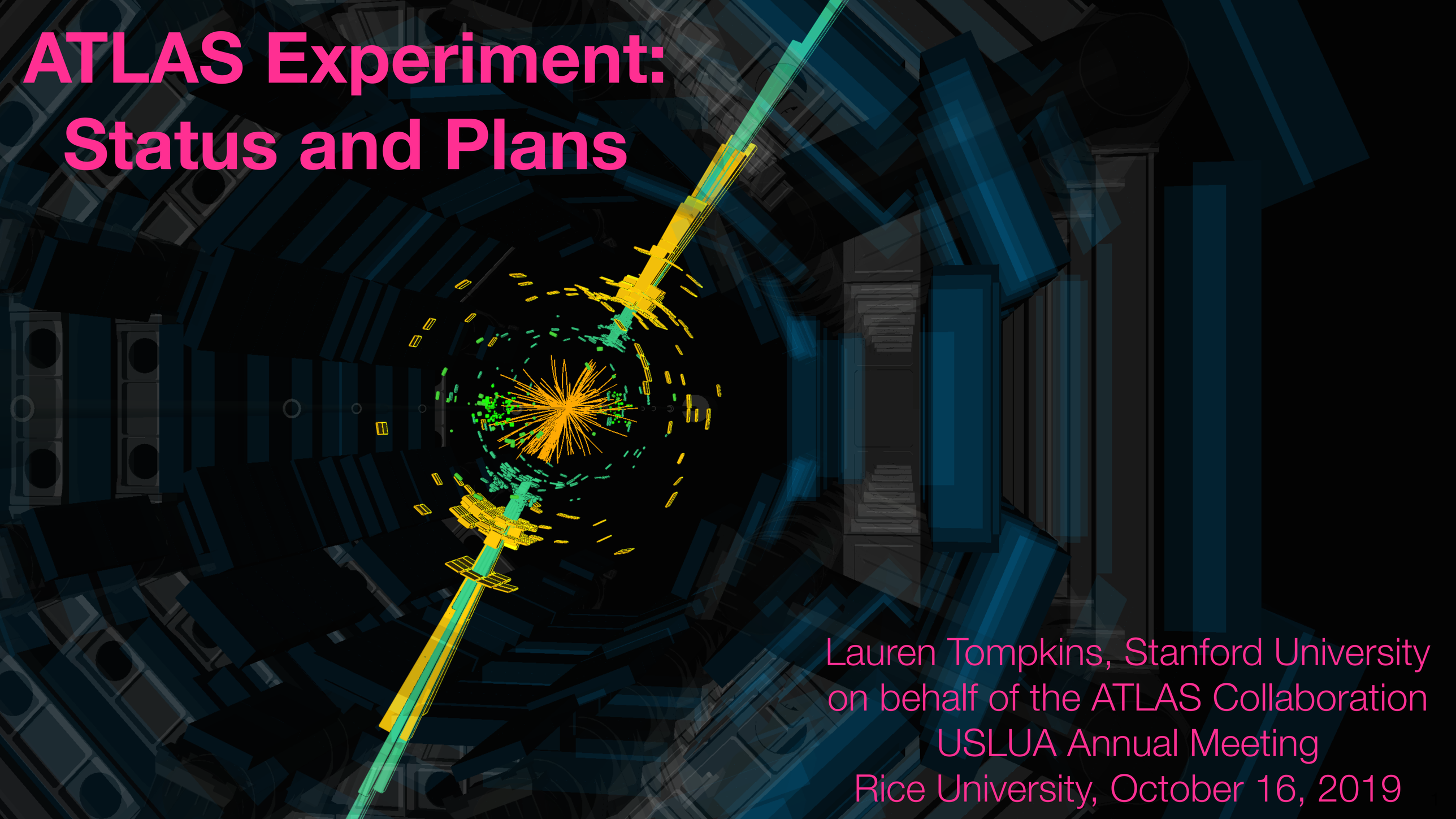
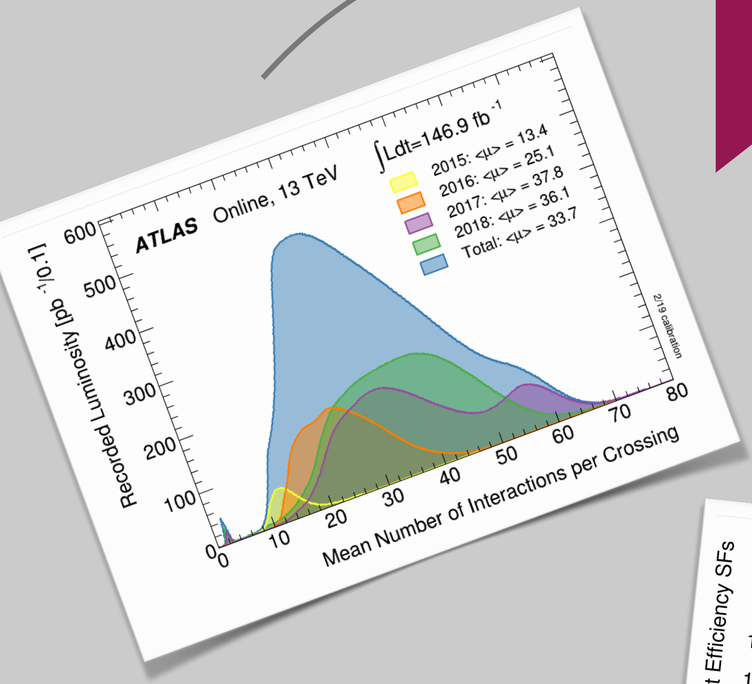
# ATLAS Experiment: Status and Plans

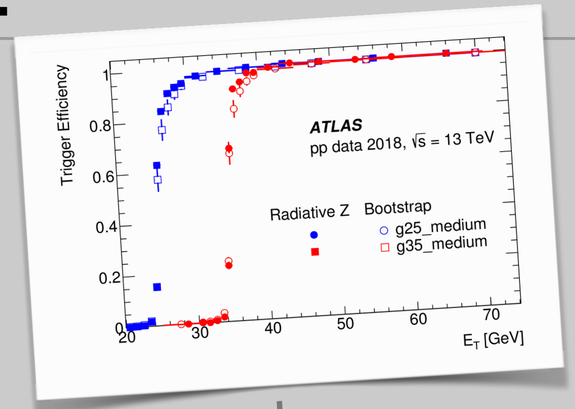


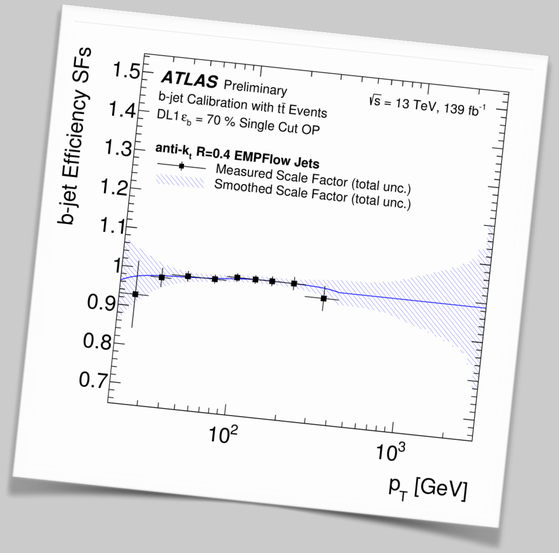
Lauren Tompkins, Stanford University
on behalf of the ATLAS Collaboration

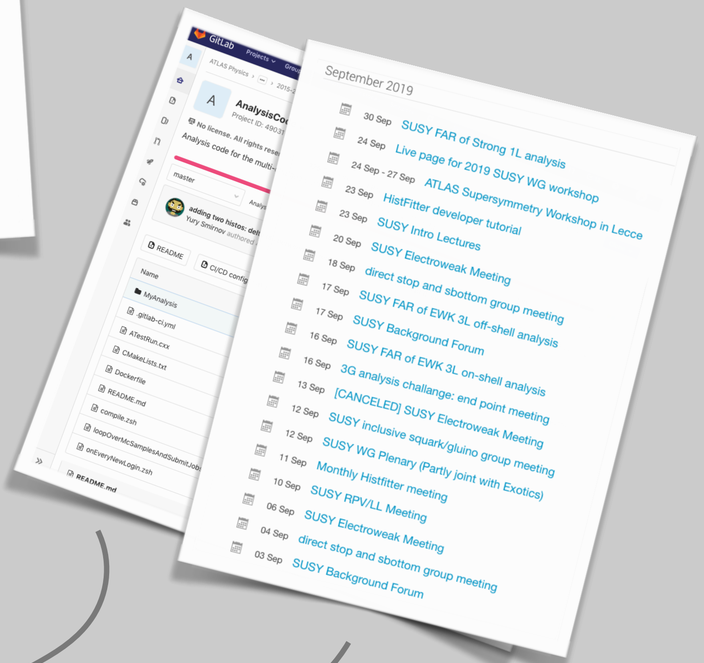
USLUA Annual Meeting
Rice University, October 16, 2019

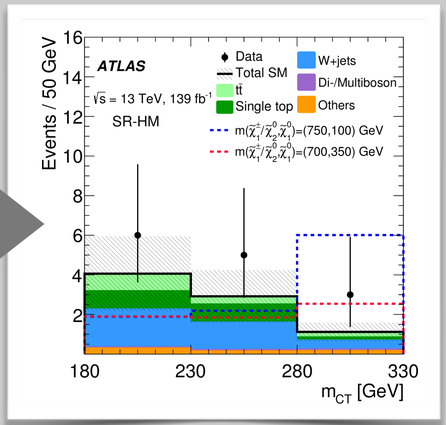
# Since the last USLUA Meeting…



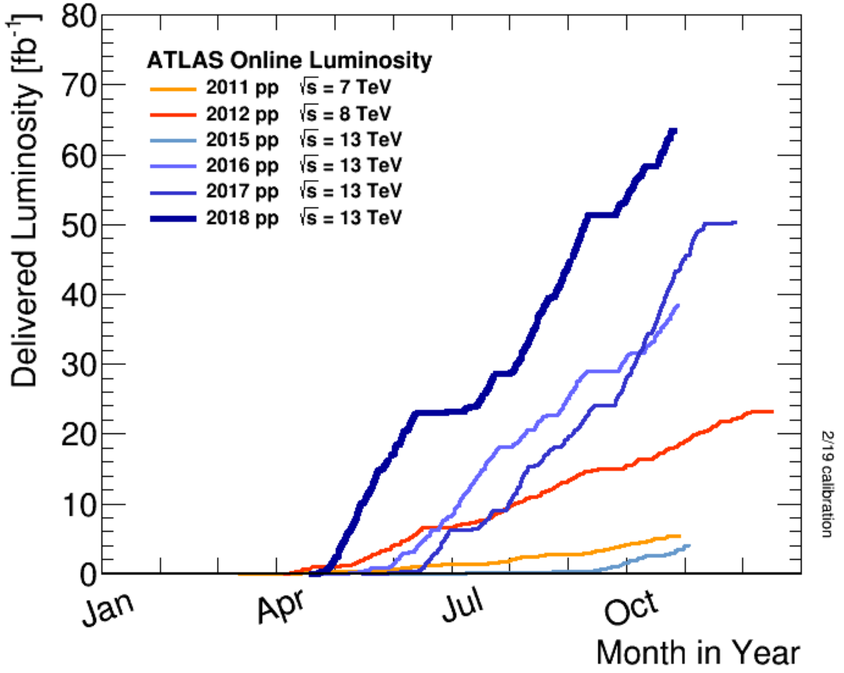



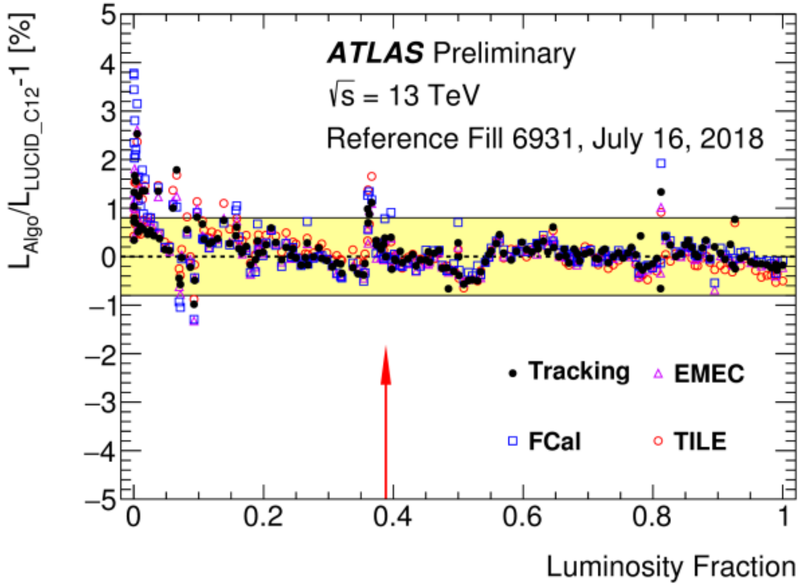



# Run II by the numbers

- Proton-proton @ 13 TeV:
  - 156 fb$^{-1}$ delivered, 147 fb$^{-1}$ recorded (94%), ***139 fb$^{-1}$ good for physics*** (95%)
  - Luminosity uncertainty: 1.7%



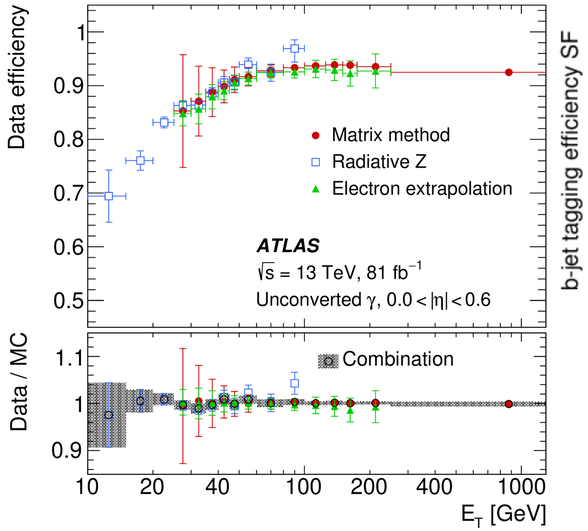




- Other datasets:
  - 1.80 (1.76) nb$^{-1}$ delivered (collected) of Pb-Pb in 2018
  - Pb-p and Pb-Pb datasets in 2016 and 2015
  - High β* and other dedicated runs for soft QCD measurements
- Rich datasets going into Long Shutdown!

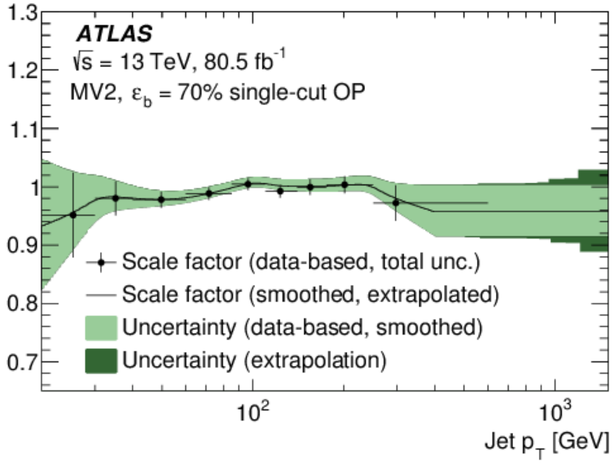
# The nitty gritty work

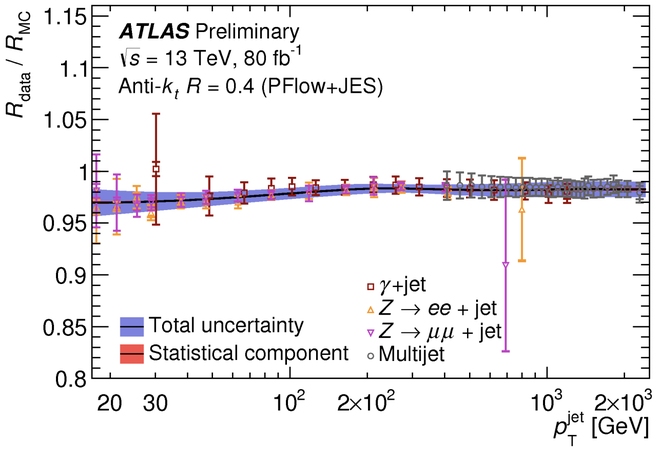
- Full Run II results deserve the best calibrations and smallest uncertainties…
  - Sub-percent electron & photon energy uncertainties, <~10% efficiency uncertainty over wide η, $p_T$ range [arXiv:1908.00005].
  - Few % uncertainty on b-tagging efficiency [arXiv: 1907.05120].
  - Jet energy scale uncertainty of a few percent
  - Muon reconstruction efficiency known to few per-mille

arXiv:1908.00005




arXiv: 1907.05120



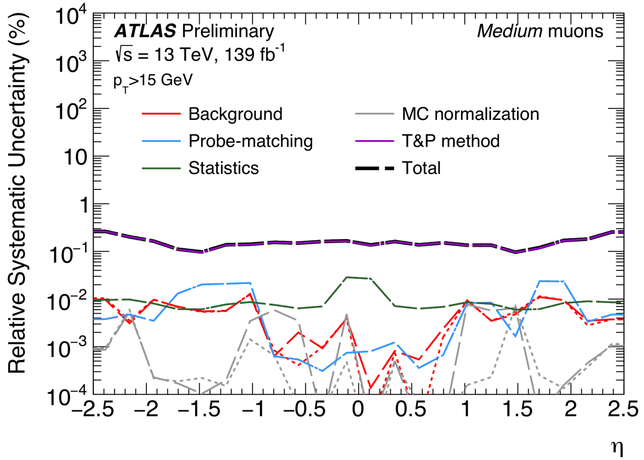
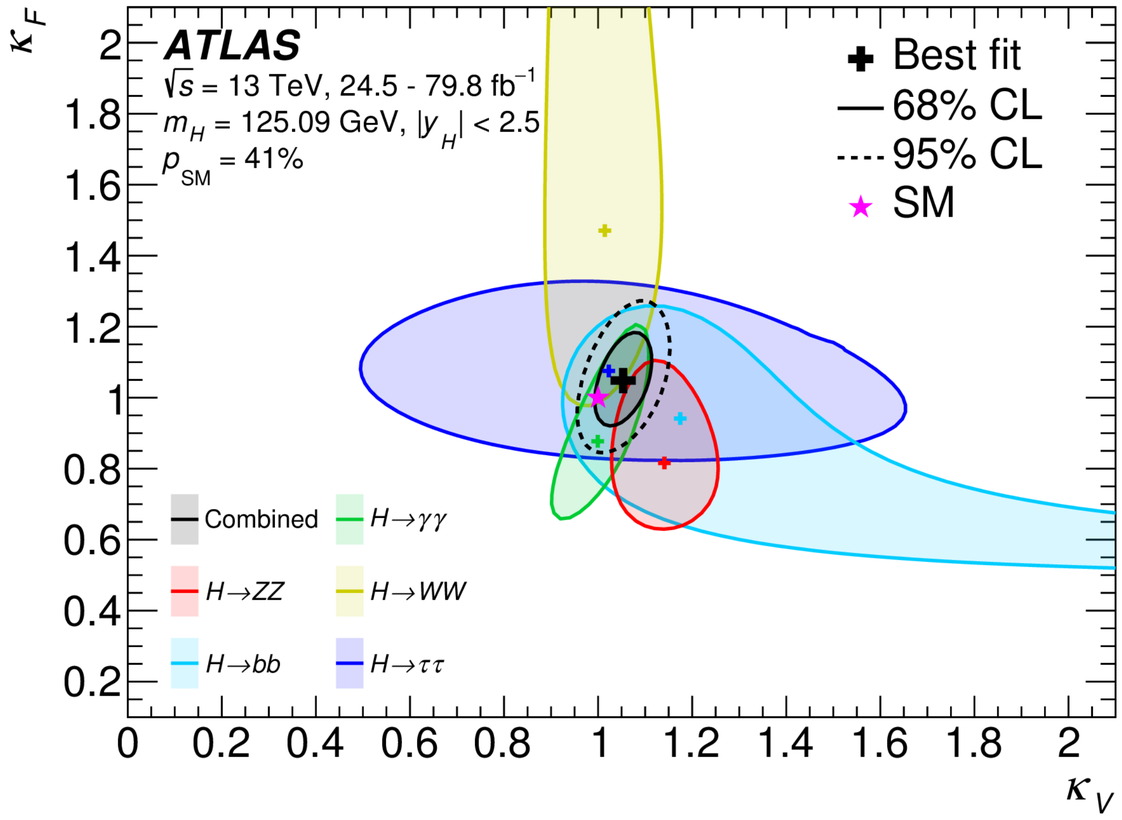



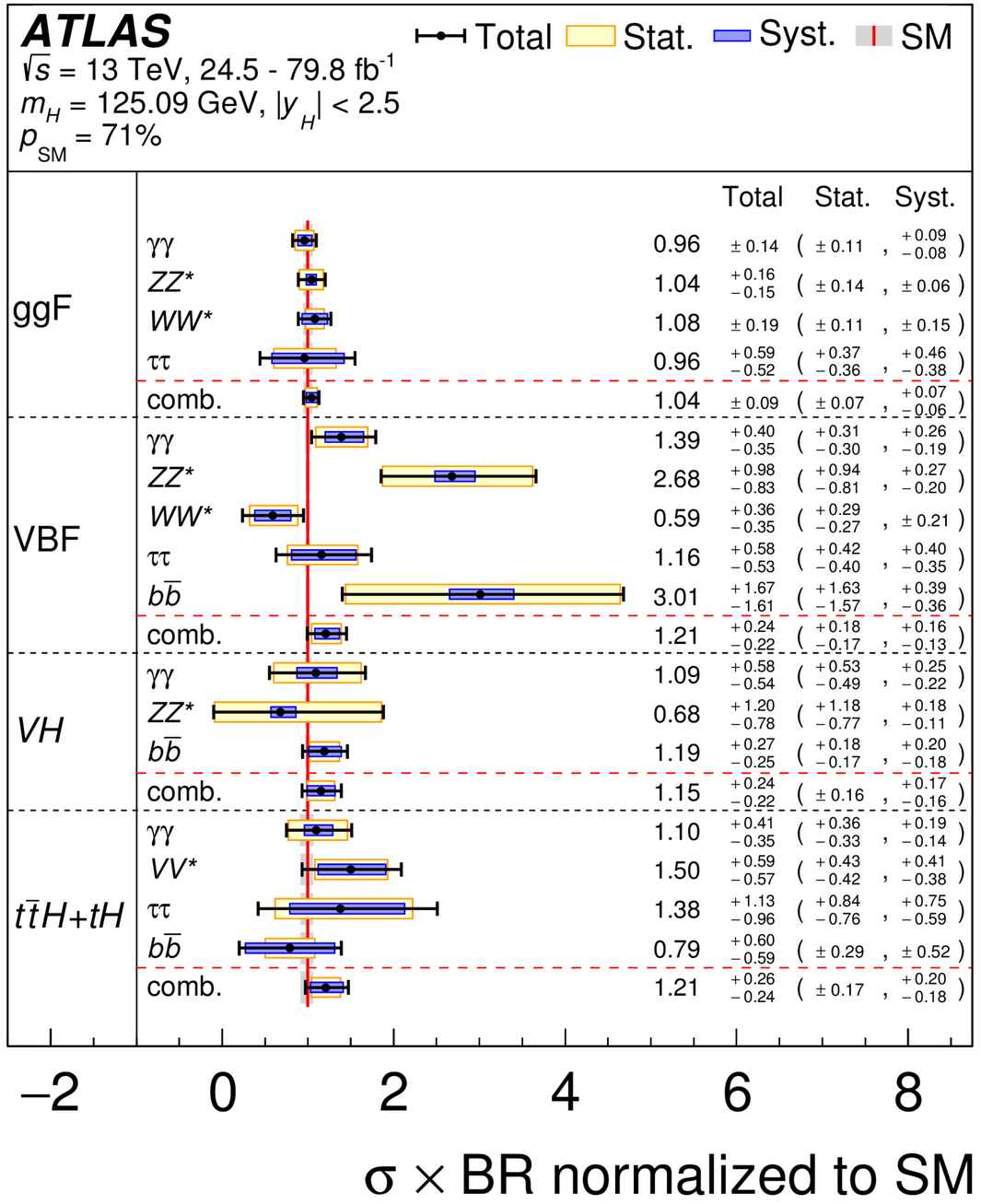

Image credit

# Higgs Headliner

- Major effort to assemble unified picture of Run II Higgs measurements with up to 80 fb$^{-1}$ of data [arXiv:1909.02845]




arXiv:1909.02845

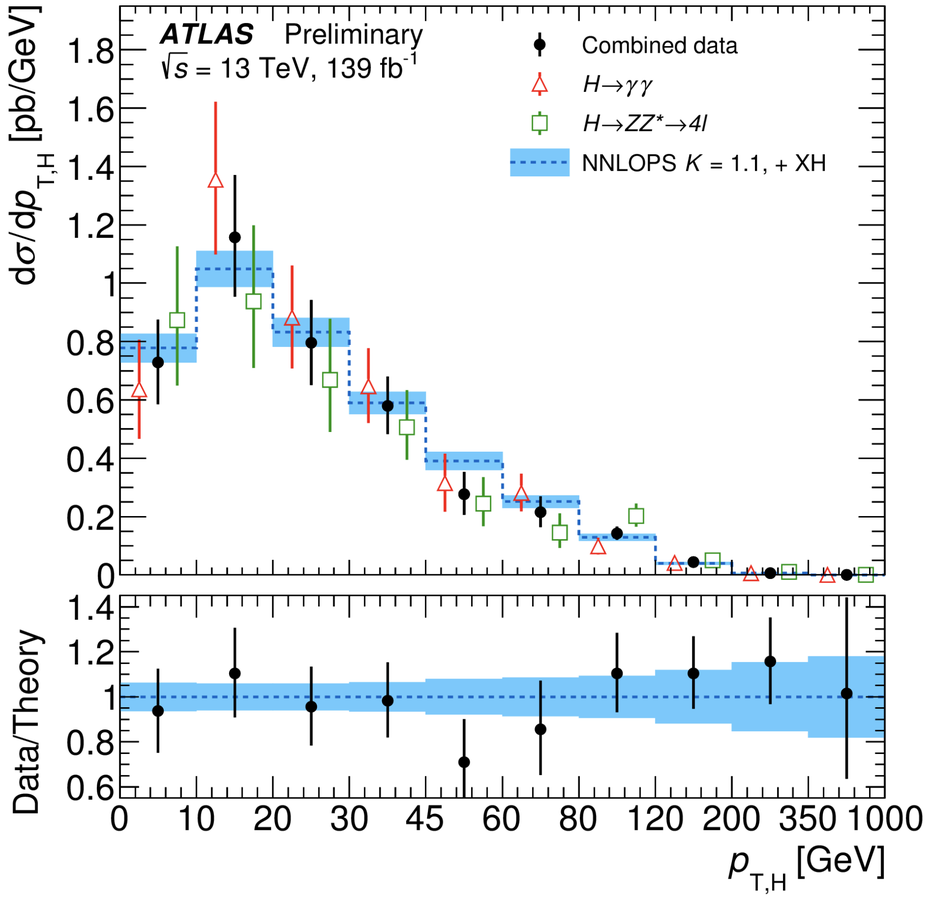


# Full Run II Higgs Measurements

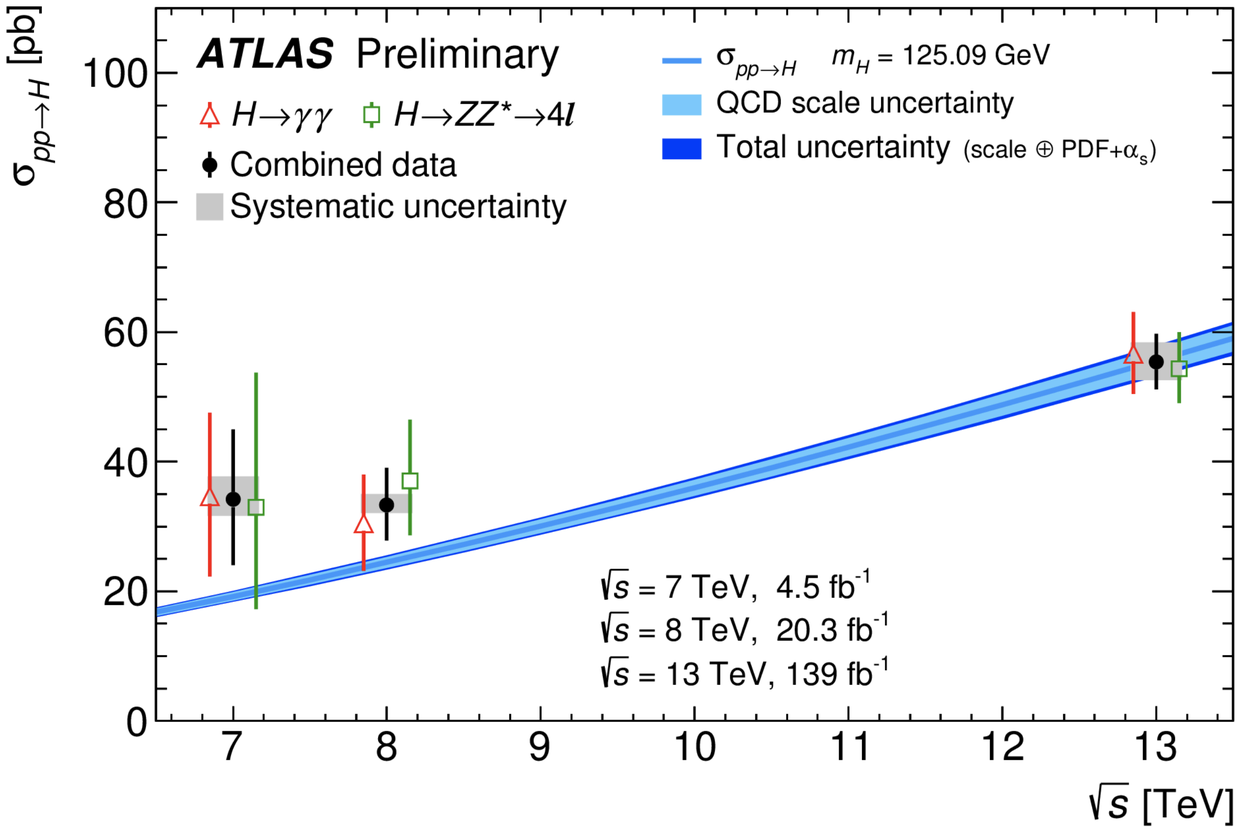
- Full dataset used in γγ,ZZ channels for differential measurements, good agreement with state-of-the-art QCD calculations within uncertainties

$$\sigma(pp \to H) = 56.7^{+6.4}_{-6.2}(\gamma\gamma), 54.4^{+5.6}_{-5.4}(4l), 55.4^{+4.3}_{-4.2}(\text{comb.})\ \text{pb}$$

$$\sigma(pp \to H) = 55.6 \pm 2.5\ \text{pb}\ (\text{NLO} - \text{N3LO QCD}, \text{NLO EW})$$

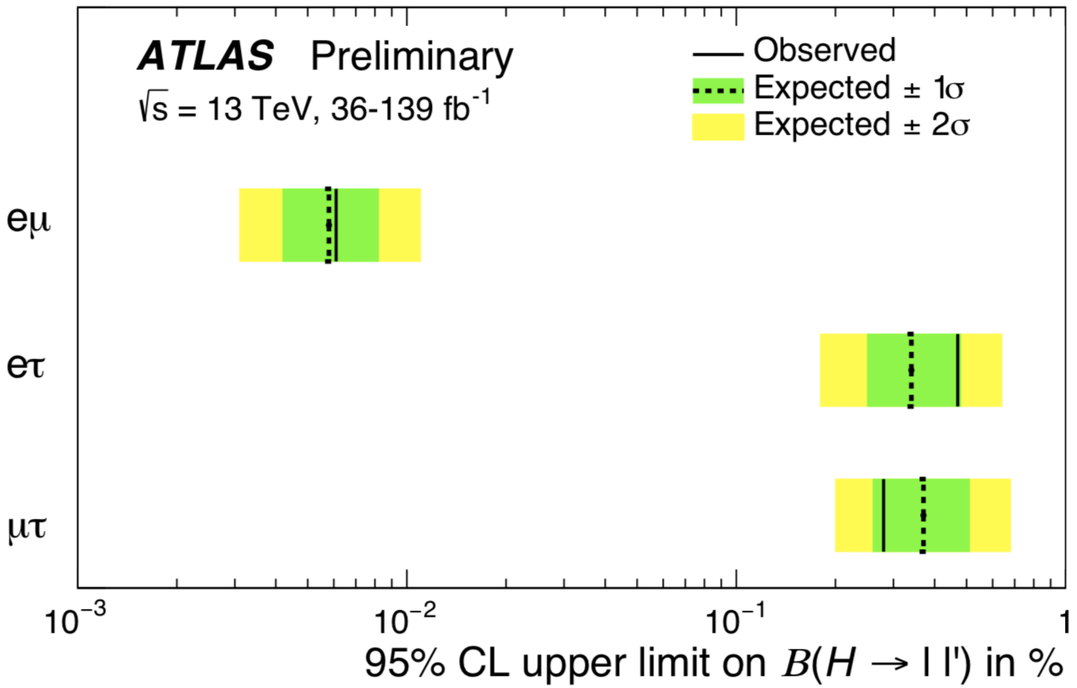



ATLAS-CONF-2019-032

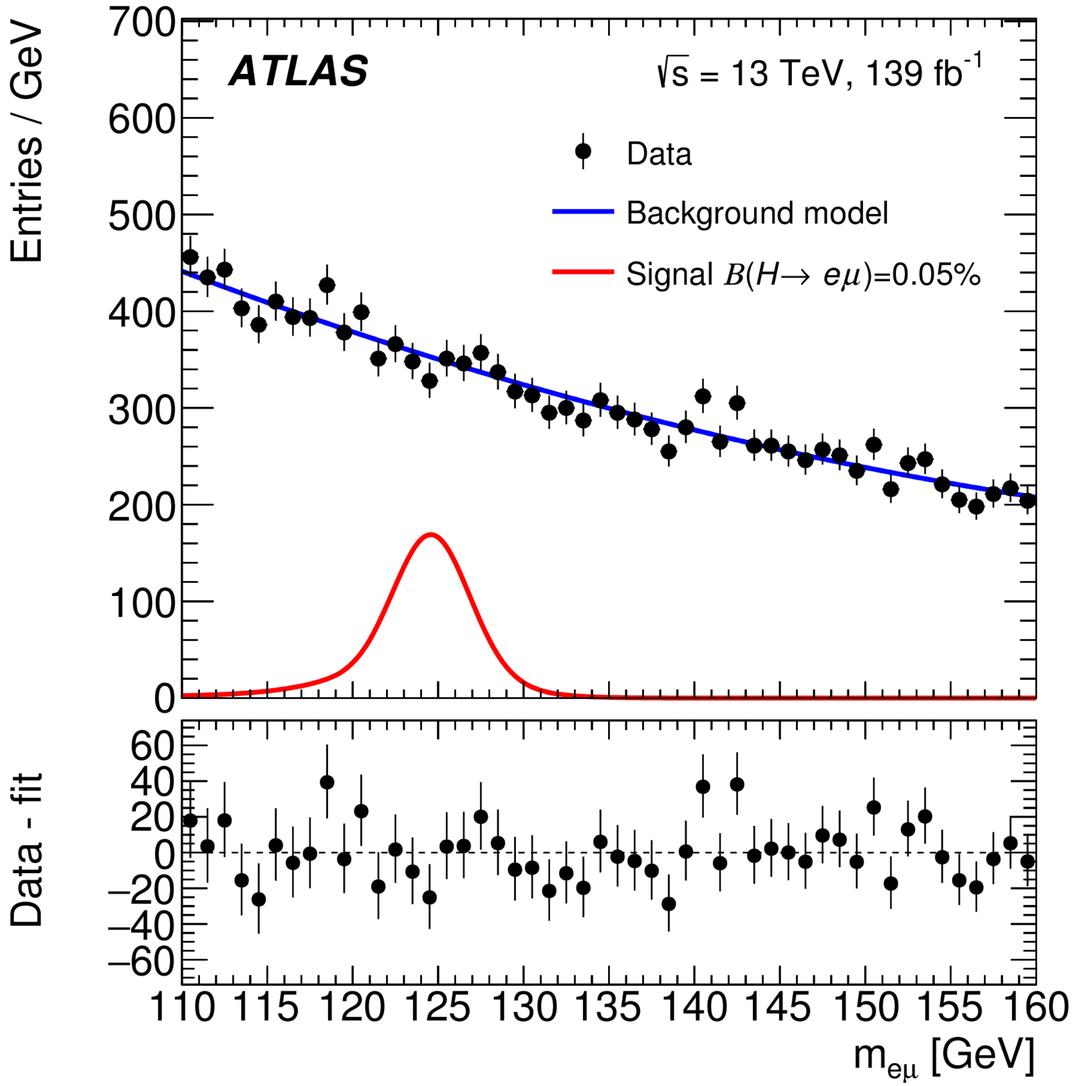


# Lepton Flavor Violating Higgs Decays

- Full Run-II searches for H→eμ [arXiv:1909.10235]
  - Br( H→eμ) < 6.1x10$^{-5}$ ;
  - (Also limits on Br( H→ee) < 3.4x10$^{-4}$)
- New tau results with 36 fb-1:
  - Br( H→eτ, H→μτ) < 4.7 x10$^{-3}$, 2.8 x10$^{-3}$ [arXiv:1907.06131]

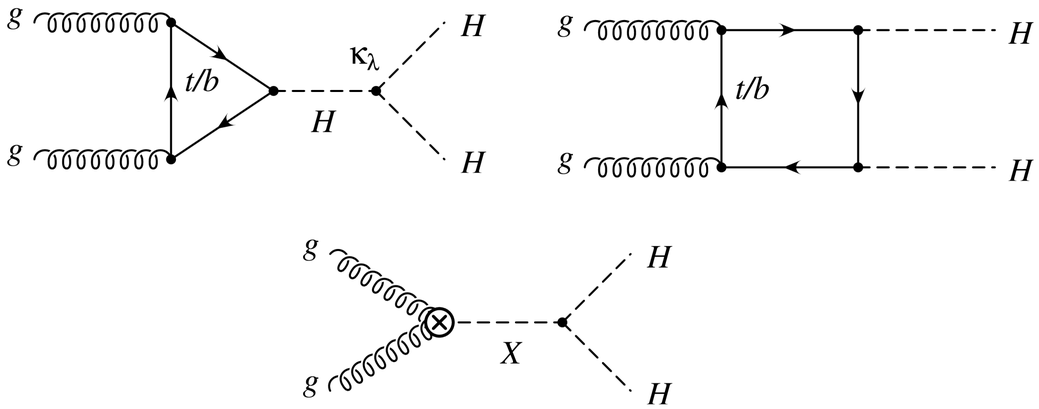



arXiv:1909.10235

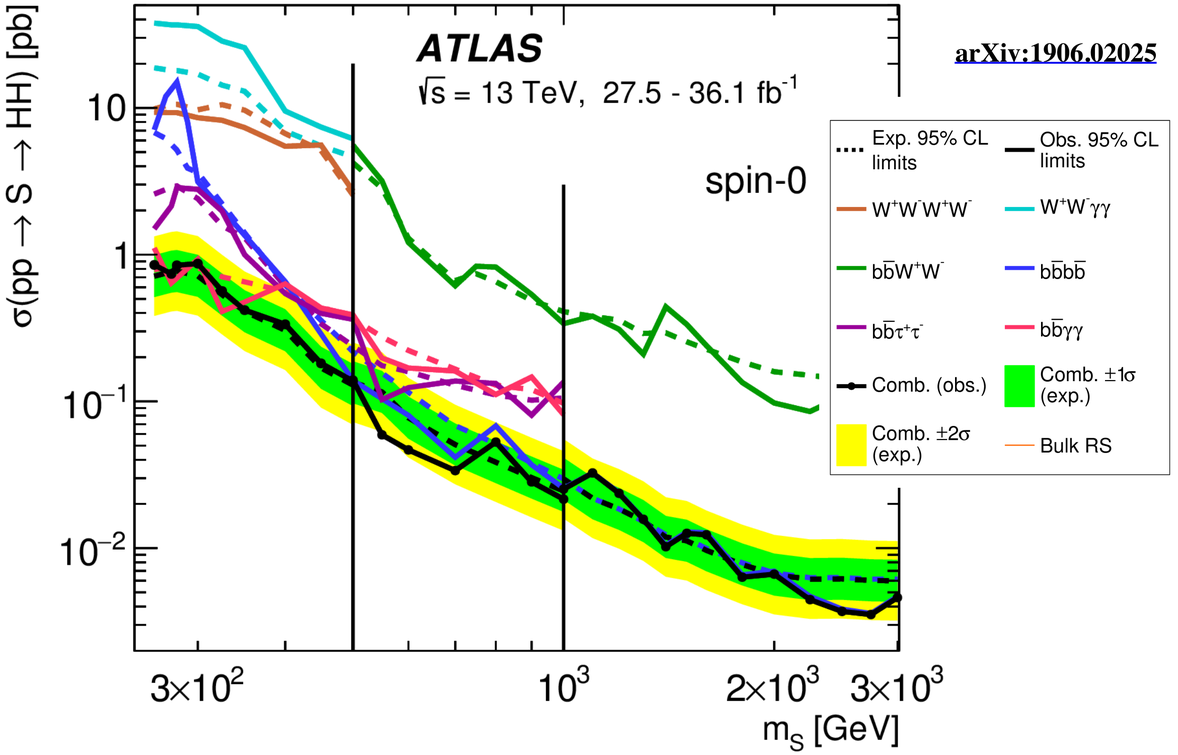


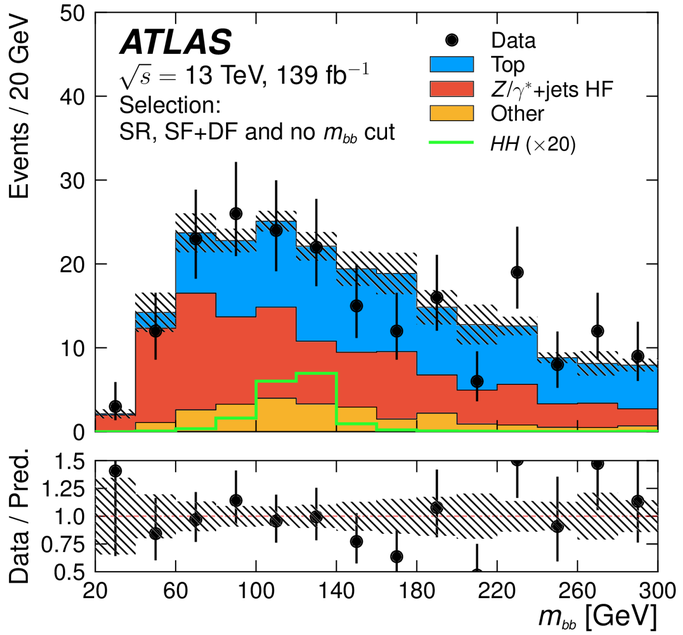
# Di-Higgs Searches

- Di-Higgs searches provide powerful constraints on BSM physics
  - Initial Run II searches combined to put 6.9xSM limit on non-resonant HH production [arXiv:1906.02025]




- bbWW channel updated to full Run II dataset
  - Upper limit of $1.2^{+0.4}_{-0.3}$ pb (40xSM) for this single channel [arXiv:1908.06765]

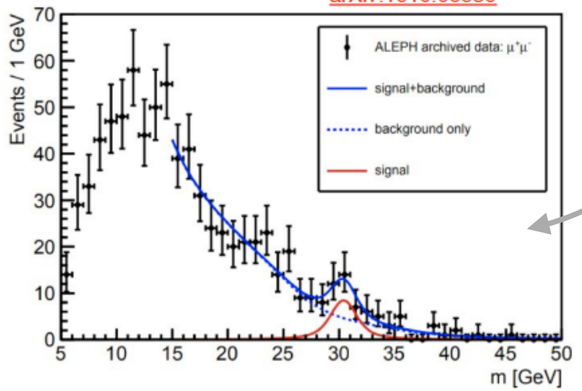



arXiv:1908.06765

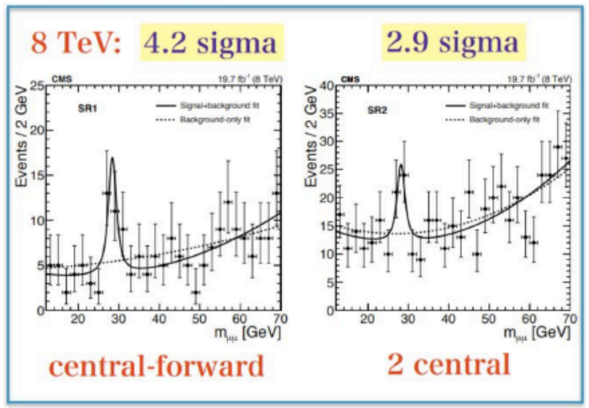
# Investigating the Aleph $m_{\mu\mu}$ fluctuation

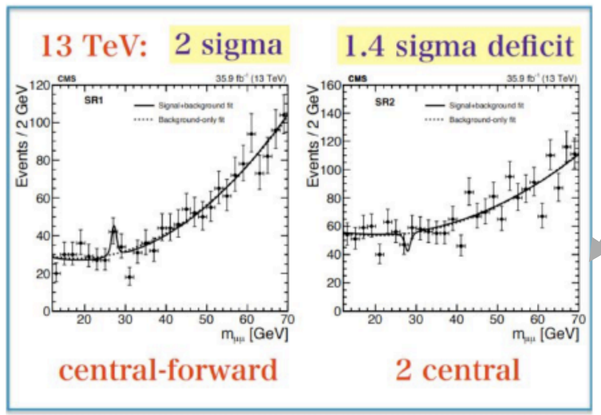
arXiv:1610.06536

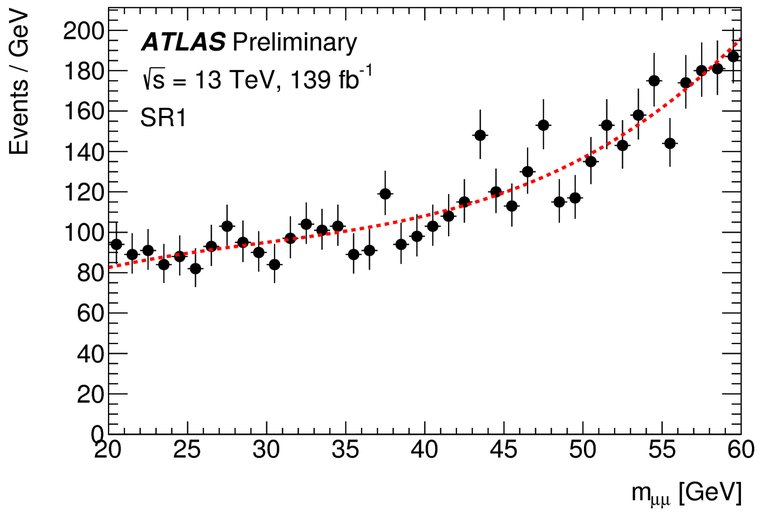


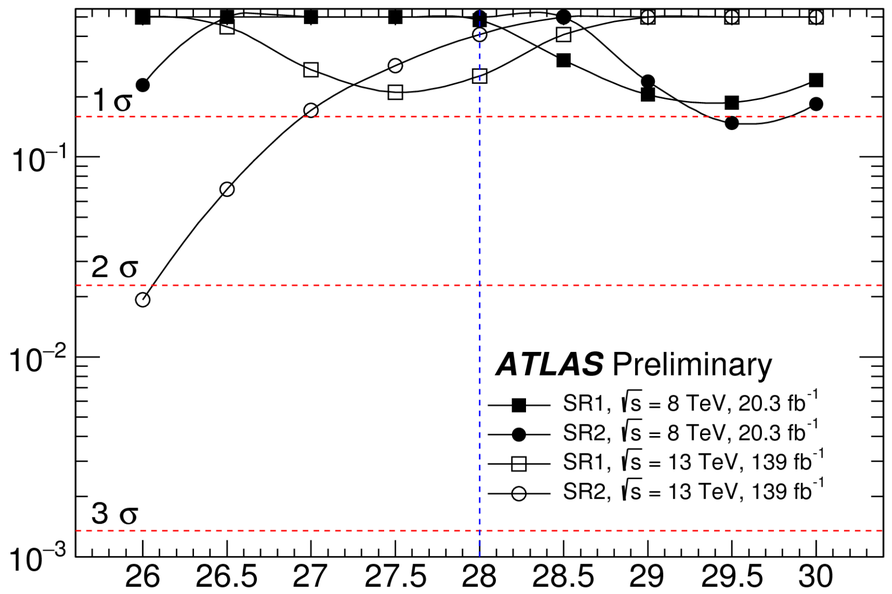

- Aleph data found 5(2.6)σ local(global) sig. for a 30 GeV $m_{\mu\mu}$ resonance in events with b-jets
- CMS analysis shows 1.4σ deficit to 4.2σ local excess @ 28 GeV
  - ATLAS analyzed full Run II data and finds no excess [ATLAS-CONF-2019-036]

JHEP **11** (2018) 161



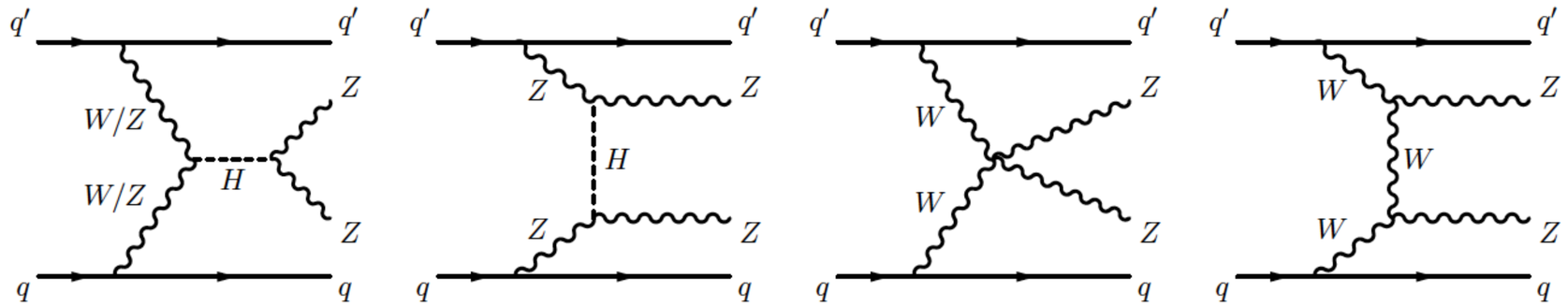

ATLAS-CONF-2019-036

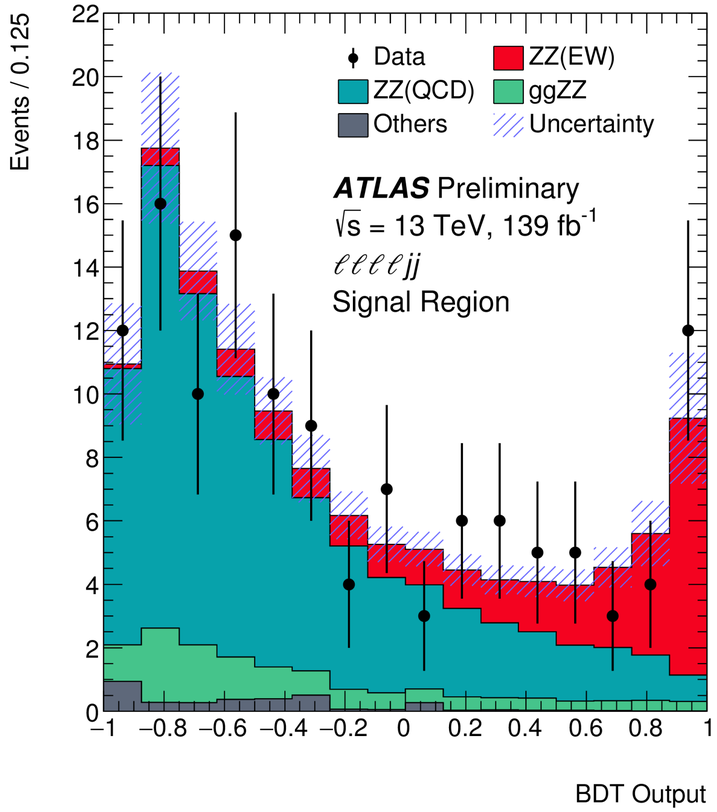
# Many more Higgs results!

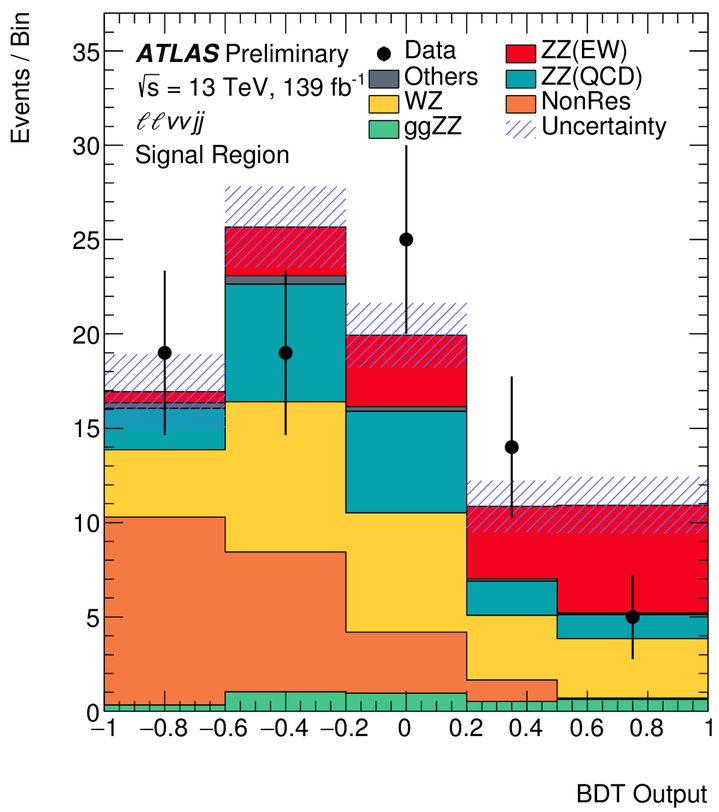
| Short Title | Journal Reference | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| Search BSM H(125)->emu lepton flavor violating decay and H(125)->ee | Submitted to PLB | 23-SEP-19 | 13 | 139 $fb^{-1}$ | Documents \| 1909.10235 \| Inspire Internal |
| h(125) combination cross-sections, couplings | Submitted to Phys. Rev. D | 06-SEP-19 | 13 | 80 $fb^{-1}$ | Documents \| 1909.02845 \| Inspire Internal |
| HH->bb WW-> bblvlv | Submitted to PLB | 19-AUG-19 | 13 | 139 $fb^{-1}$ | Documents \| 1908.06765 \| Inspire Internal |
| Search BSM H(125)->tau l (l=e,mu) lepton flavor violating decay | Accepted by PLB | 13-JUL-19 | 13 | 36.1 $fb^{-1}$ | Documents \| 1907.06131 \| Inspire Briefing \| Internal |
| Search BSM bH H->bb | Submitted to PRD | 05-JUL-19 | 13 | 27.8 $fb^{-1}$ | Documents \| 1907.02749 \| Inspire Internal |
| Combination h(125)h(125) | Submitted to PLB | 05-JUN-19 | 13 | 36.1 $fb^{-1}$ | Documents \| 1906.02025 \| Inspire Internal |
| H(125)->invisible combination | Phys. Rev. Lett. 122 (2019) 231801 | 10-APR-19 | 7 , 8 , 13 | 5 $fb^{-1}$, 20 $fb^{-1}$, 36 $fb^{-1}$ | Documents \| 1904.05105 \| Inspire Internal |
| VH(125), H->WW | Phys. Lett. B 798 (2019) 134949 | 24-MAR-19 | 13 | 36.1 $fb^{-1}$ | Documents \| 1903.10052 \| Inspire Internal |
| VH(125) H->bb STXS | JHEP 05 (2019) 141 | 11-MAR-19 | 13 | 80 $fb^{-1}$ | Documents \| 1903.04618 \| Inspire Internal |
| Summary of searches for mediator-based dark matter and scalar dark energy models | JHEP 05 (2019) 142 | 03-MAR-19 | 13 | 36 $fb^{-1}$ | Documents \| 1903.01400 \| Inspire Internal |
| Measurement of the 4 lepton invariant mass distribution at 13 TeV with the ATLAS detector | JHEP 04 (2019) 048 | 15-FEB-19 | 13 | 36 $fb^{-1}$ | Documents \| 1902.05892 \| Inspire Rivet \| HepData \| Internal |
| Search BSM bH with H-> mu mu | | | | | |
| Search for flavor-changing neutral current t to Hq with H->b-bbar and | | | | | |
| Search BSM H->HH->4W and HH->4W | | | | | |
| H(125) -> tau tau | | | | | |
| Search BSM H->HH->bb WW and HH->bb WW | | | | | |

| Short Title | Document Number | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| Self-coupling constraints from single and double Higgs measurements | ATLAS-CONF-2019-049 | 03-OCT-19 | 13 | 80 $fb^{-1}$ | Documents \| Internal |
| H(125) H-> tau tau spin/CP studies | ATLAS-CONF-2019-050 | 02-OCT-19 | 13 | 36.1 $fb^{-1}$ | Documents \| Internal |
| H(125) combination differential cross-sections gamma gamma and 4l | ATLAS-CONF-2019-032 | 11-JUL-19 | 13 | 139 $fb^{-1}$ | Documents \| Briefing \| Internal |
| H(125)->gammagamma differential cross sections | ATLAS-CONF-2019-029 | 11-JUL-19 | 13 | 139 $fb^{-1}$ | Documents \| Briefing \| Internal |
| VBF HH to 4b | ATLAS-CONF-2019-030 | 11-JUL-19 | 13 | 126 $fb^{-1}$ | Documents \| Internal |
| Search H(125)->mumu | ATLAS-CONF-2019-028 | 11-JUL-19 | 13 | 139 $fb^{-1}$ | Documents \| Briefing \| Internal |
| H(125)->4l STXS and differential cross sections | ATLAS-CONF-2019-025 | 09-JUL-19 | 13 | 140 $fb^{-1}$ | Documents \| Briefing \| Internal |
| ttH(125) H->gammagamma | ATLAS-CONF-2019-004 | 18-MAR-19 | 13 | 139 $fb^{-1}$ | Documents \| Briefing \| Internal |
| Low mass boosted di-b-jet resonances with an extra jet | ATLAS-CONF-2018-052 | 26-NOV-18 | 13 | 80 $fb^{-1}$ | Documents \| Internal |

# Electroweak Sector: Vector Boson Scattering in ZZjj



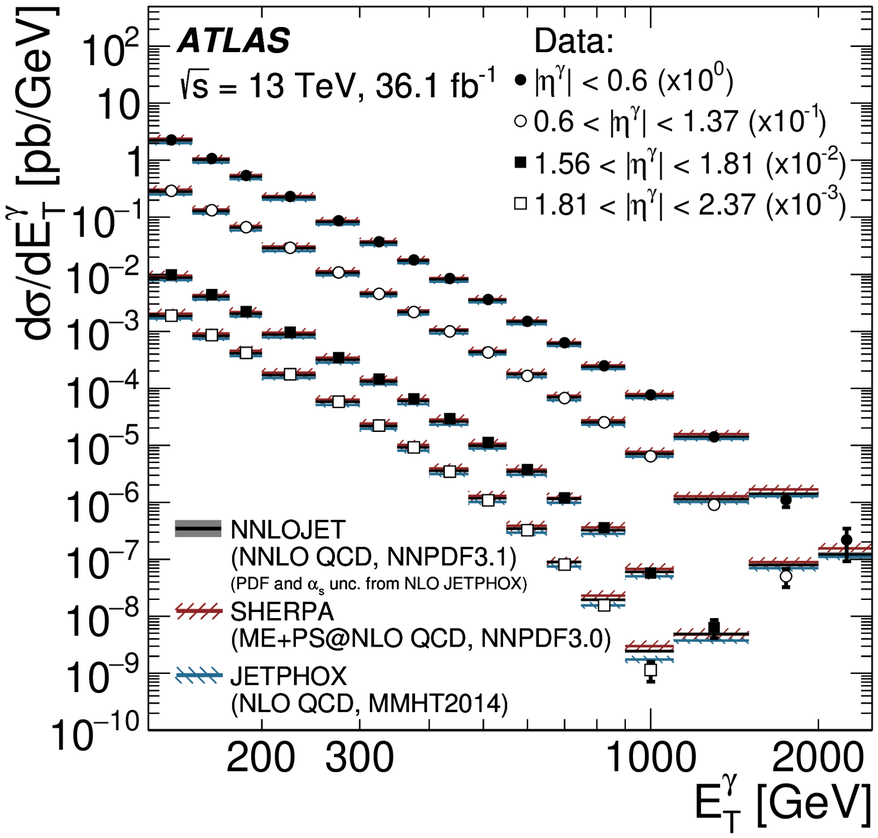

- Observed ZZjj EWK production!
  - σ(obs) = 0.82±0.21 fb
  - σ(pred) = 0.61±0.03 fb
- All VVjj channels have > 5σ significance (V = W,Z)
  - 13 TeV Zγjj result and full Run II differential Zγ also available [ATLAS-CONF-2019-034, ATLAS-CONF-2019-039]

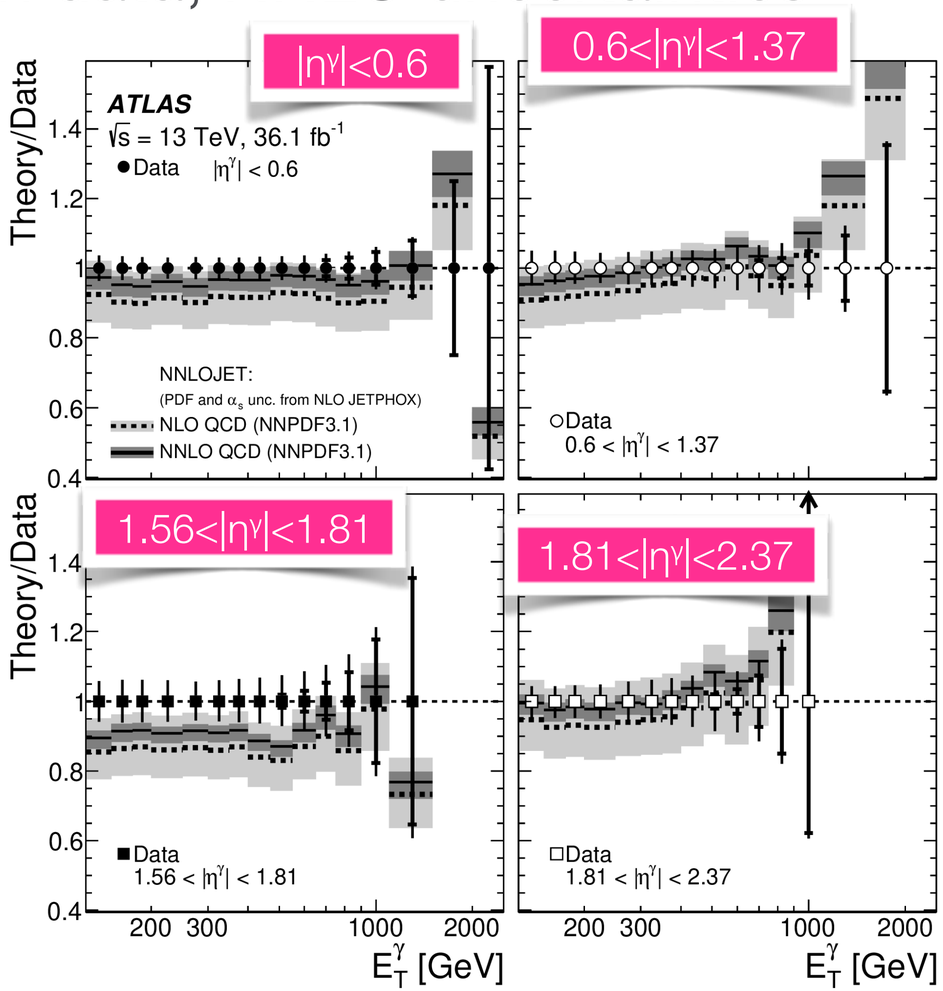
| | $\mu_{\mathrm{EW}}$ | $\mu_{\mathrm{QCD}}^{\ell\ell\ell\ell jj}$ | Significance Obs. (Exp.) |
|---|---|---|---|
| $\ell\ell\ell\ell jj$ | $1.54 \pm 0.42$ | $0.95 \pm 0.22$ | 5.48 (3.90) $\sigma$ |
| $\ell\ell\nu\nu jj$ | $0.73 \pm 0.65$ | - | 1.15 (1.80) $\sigma$ |
| Combined | $1.35 \pm 0.34$ | $0.96 \pm 0.22$ | 5.52 (4.30) $\sigma$ |

ATLAS-CONF-2019-033

# Measurements Sensitive to pQCD

- Measurement of inclusive photon production up to $E^{\gamma}_{T}$ ~1 TeV with < 10% experimental & theoretical uncertainties [arXiv:1908.02746]
- Excellent NLO & NNLO agreement with data; NNLO uncertainties comparable to data uncertainties

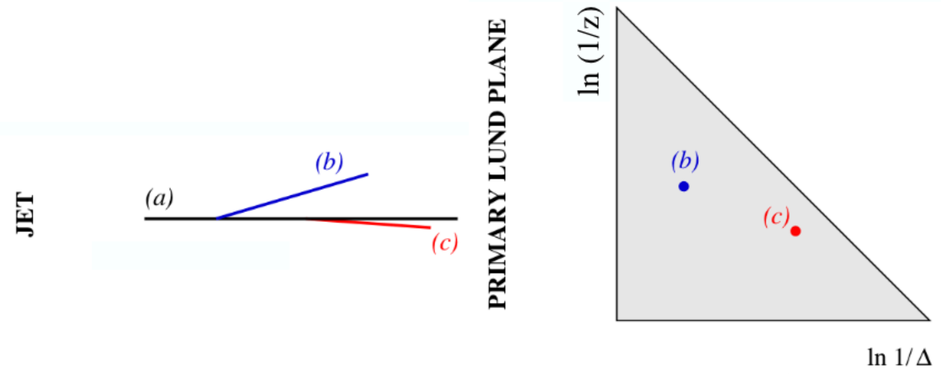


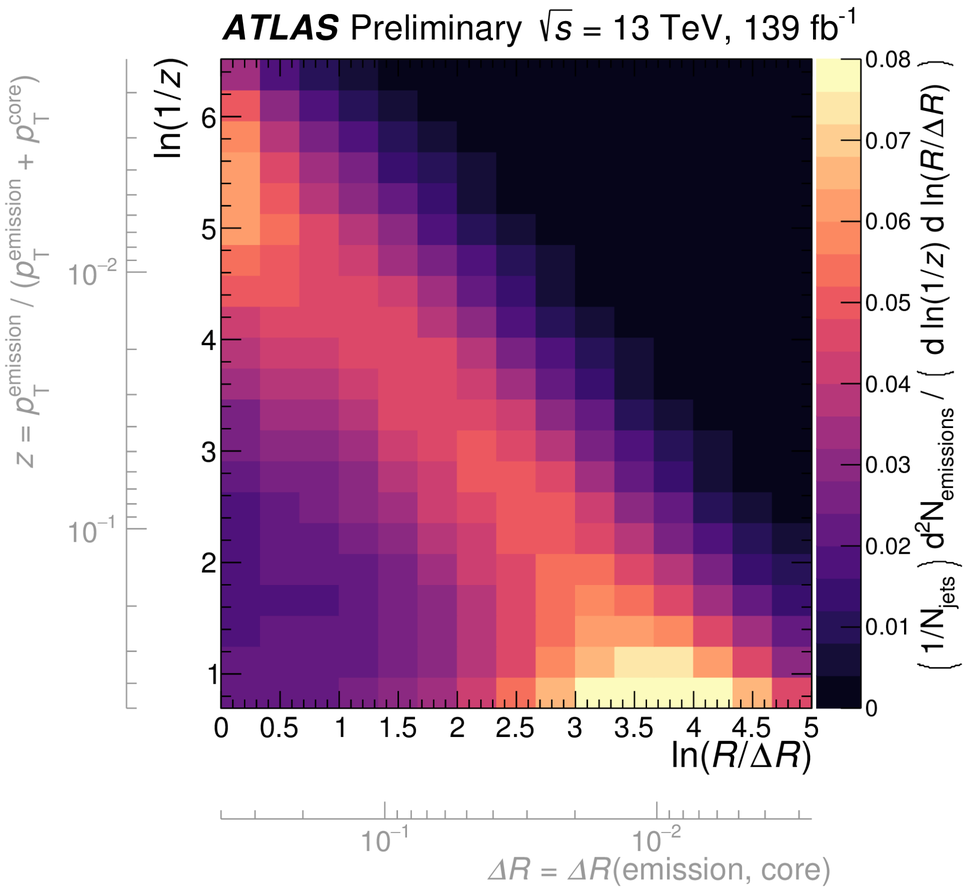



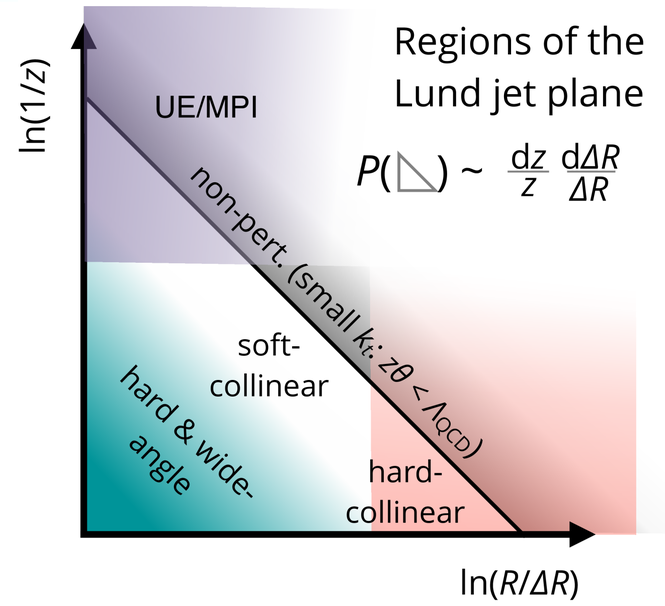

arXiv:1908.02746

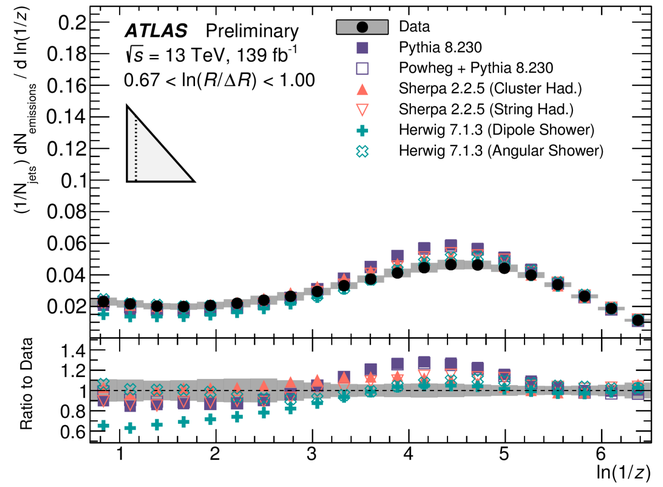
# Multiscale Dynamics: Lund Plane

- New proposal to represent internal structure of jets*:
  - Lund Plane: ln(1/z) vs ln(1/θ)
- Recluster jet using Cambridge/ Aachen alg, plot history
- Utilize tracks associated to anti-kT (R = 0.4) jets, recluster with C/A, plot history
- Powerful test of MCs against shower and hadronization history
  - Can distinguish perturbative and non-perturbative effects in same measurement
- Can be used in ML-based jet discriminants




* J. High Energ. Phys. (2018) 2018

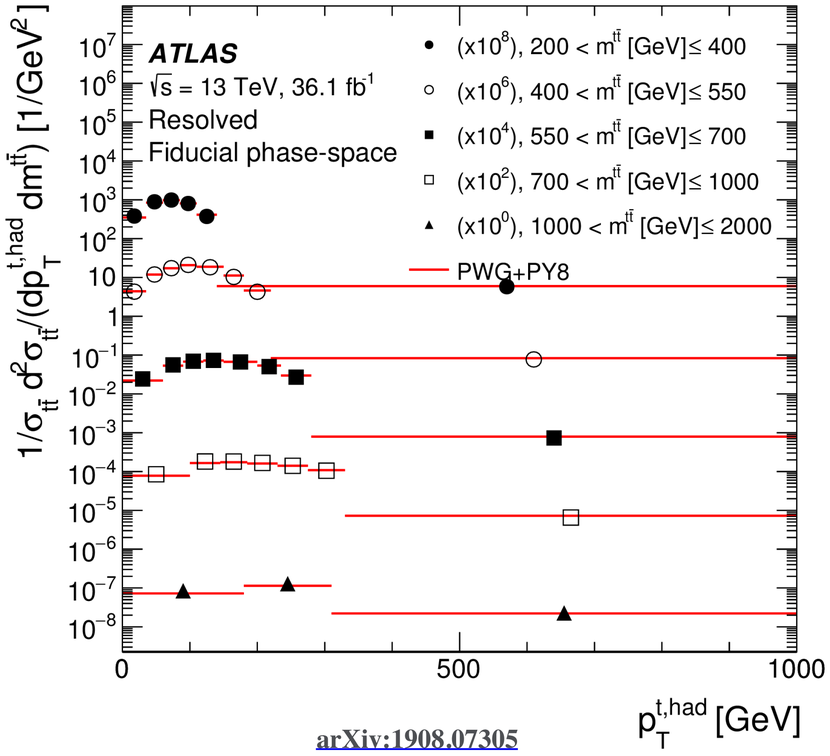
# Many more Standard Model results!

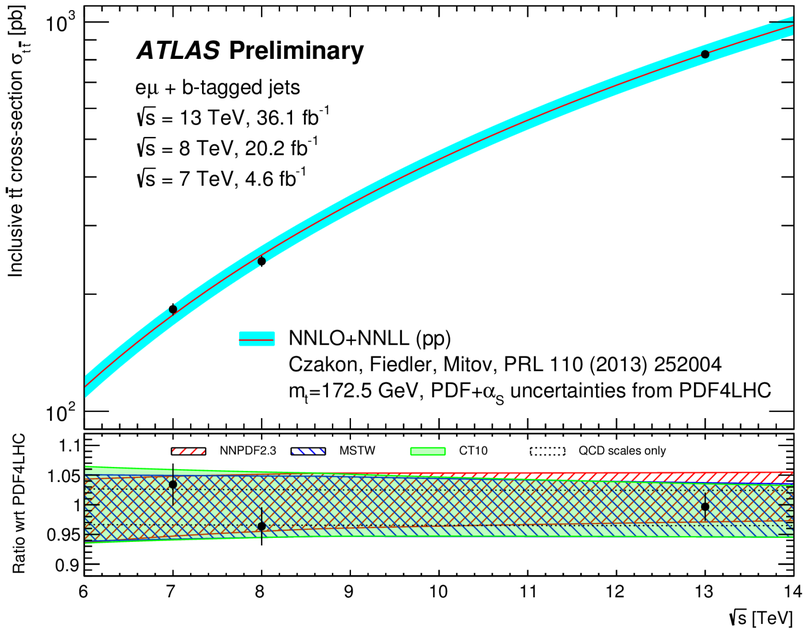
| Short Title | Journal Reference | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| Measurement of the inclusive isolated-photon cross section at 13 TeV | Accepted by JHEP | 07-AUG-19 | 13 | 36 $fb^{-1}$ | Documents \| 1908.02746 \| Inspire Internal |
| KS and Lambda production in ttbar events at 7 TeV | Submitted to EPJC | 25-JUL-19 | 7 | 5 $fb^{-1}$ | Documents \| 1907.10862 \| Inspire Internal |
| High transverse momentum Z(->bb) + photon production at 13 TeV | Submitted to PLB | 16-JUL-19 | 13 | 36.1 $fb^{-1}$ | Documents \| 1907.07093 \| Inspire Internal |
| Z boson in association with jets cross sections at 8 TeV | Accepted by EPJC | 15-JUL-19 | 8 | 20.3 $fb^{-1}$ | Documents \| 1907.06728 \| Inspire HepData \| Internal |
| W and Z cross sections at 2.76 TeV | Submitted to EPJC | 08-JUL-19 | 2.76 | 4 $pb^{-1}$ | Documents \| 1907.03567 \| Inspire Internal |
| Properties of Jet Fragmentation using Charged Particles with the ATLAS detector at sqrt{s } = 13 TeV | Phys. Rev. D 100 (2019) 052011 | 21-JUN-19 | 13 | 32.9 $fb^{-1}$ | Documents \| 1906.09254 \| Inspire Internal |
| Same-sign WW cross section at 13 TeV | Accepted by PRL | 07-JUN-19 | 13 | 35 $fb^{-1}$ | Documents \| 1906.03203 \| Inspire HepData \| Internal |
| Measurement of Underlying Event in Z Boson Events at 13 TeV | Eur. Phys. J. C 79 (2019) 666 | 23-MAY-19 | 13 | 3.2 $fb^{-1}$ | Documents \| 1905.09752 \| Inspire Internal |
| Measurement of the vector Boson scattering of VV final states in the Semileptonic decay channel | Phys. Rev. D 100 (2019) 032007 | 19-MAY-19 | 13 | 35 $fb^{-1}$ | Documents \| 1905.07714 \| Inspire Internal |
| ZZ production with two charged leptons and two neutrinos in the final state at 13 TeV | Accepted by JHEP | 17-MAY-19 | 13 | 36 $fb^{-1}$ | Documents \| 1905.07163 \| Inspire Internal |
| Measurement of differential W+W- production cross sections in proton-proton collisions at 13TeV with the ATLAS detector | Accepted by EPJC | 10-MAY-19 | 13 | 35 $fb^{-1}$ | Documents \| 1905.04242 \| Inspire HepData \| Internal |
| W cross section and W+/W- asymmetry at 8 TeV | Accepted by EPJC | 11-APR-19 | 8 | 20.2 | Documents \| 1904.05631 \| Inspire HepData \| Internal |
| Observation of light-by-light scattering in 2018 5.02 TeV Pb+Pb | Phys. Rev. Lett. 123 (2019) 052001 | 06-APR-19 | 5.02 /NN, 5.02 /NN | .5 $nb^{-1}$, 1 $nb^{-1}$ | Documents \| 1904.03536 \| Inspire HepData \| Briefing \| Internal |
| Evidence for WVV production at 13 TeV | Accepted by PLB | 25-MAR-19 | 13 | 80 $fb^{-1}$ | Documents \| 1903.10415 \| Inspire HepData \| Internal |
| Measurement of the jet shapes at 13 TeV | | | | | |
| Measurement of the 4 lepton invariant mass distribution at 13 TeV with t | | | | | |
| Precision WZ cross sections and polarisation at 13 TeV | | | | | |
| Scalar leptoquarks pair search and differential cross-section measureme + jet events | | | | | |

| Short Title | Document Number | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| Z gamma VBS at 13 TeV | ATLAS-CONF-2019-039 | 07-AUG-19 | 13 | 36.1 $fb^{-1}$ | Documents \| Internal |
| Lund Plane measurement with charged particles | ATLAS-CONF-2019-035 | 24-JUL-19 | 13 | 140 $fb^{-1}$ | Documents \| Internal |
| Observation of electroweak production of two jets in association with a Z-boson pair | ATLAS-CONF-2019-033 | 12-JUL-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Z(-->ll) gamma cross section at 13TeV | ATLAS-CONF-2019-034 | 12-JUL-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Inclusive single diffractive dissociation cross-section of pp collisions at 8 TeV | ATLAS-CONF-2019-012 | 09-APR-19 | 8 | 24.11 $nb^{-1}$ | Documents \| Internal |

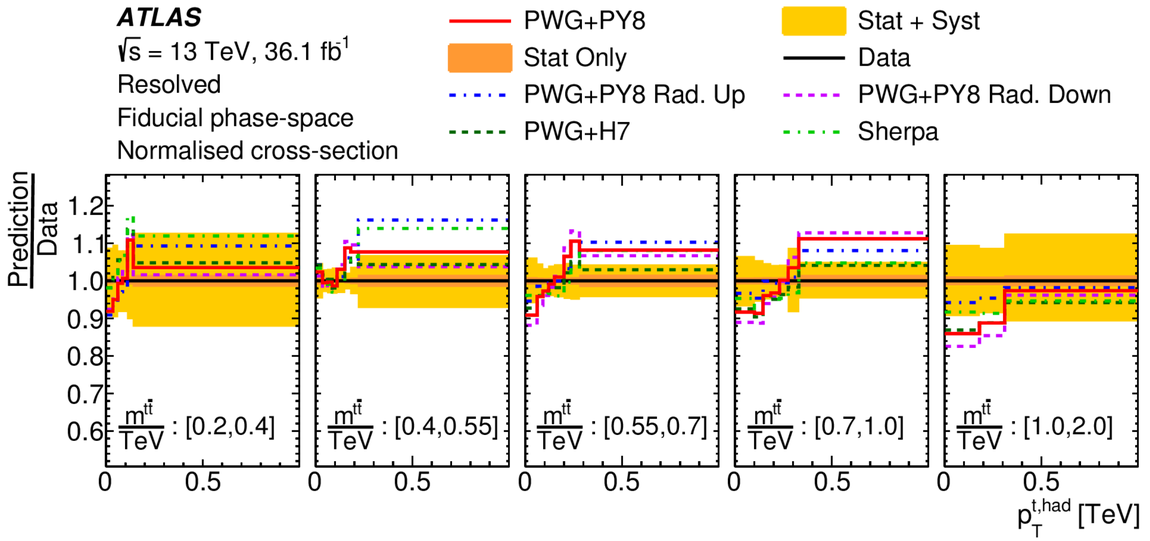
# Precision Top Physics

- Lepton + jets 13 TeV dataset used to measure precise top quark differential distributions in wide phase space (including boosted!)[arXiv:1908.07305]
- eμ dilepton 13 TeV dataset used to measure $\sigma_{tt}$ to 2.4%! $\sigma_{t\bar{t}} = 826.4 \pm 3.6\,(\text{stat}) \pm 11.5\,(\text{syst}) \pm 15.7\,(\text{lumi}) \pm 1.9\,(\text{beam})\,\text{pb}$
  - Also used to extract pole mass, differential distributions [ATLAS-CONF-2019-041]




$$m_t^{\text{pole}} = 173.1^{+2.0}_{-2.1}\,\text{GeV}$$

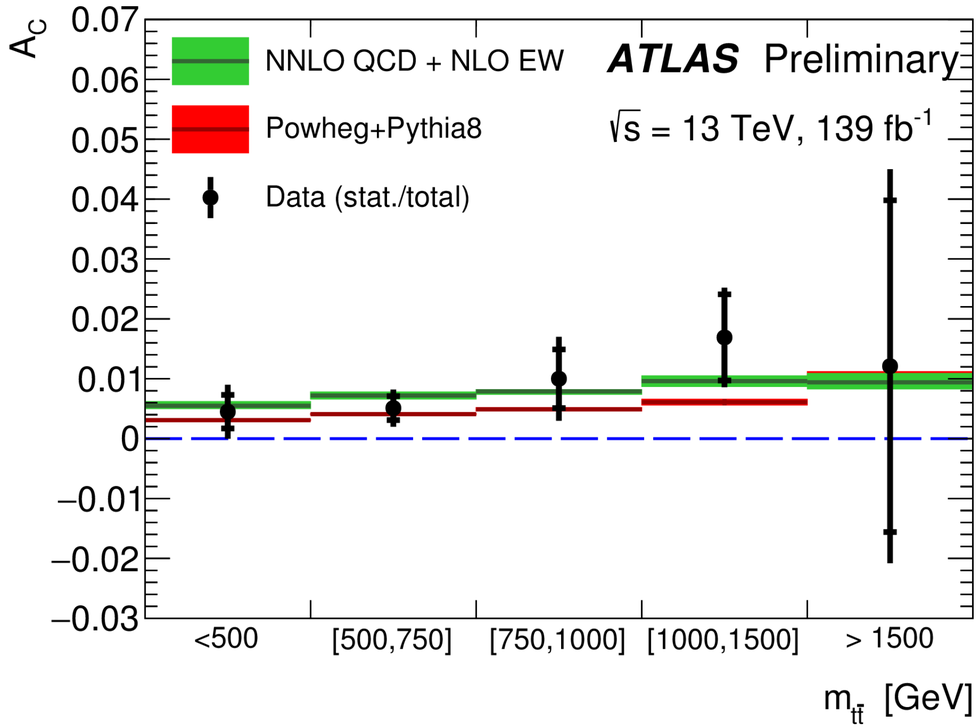


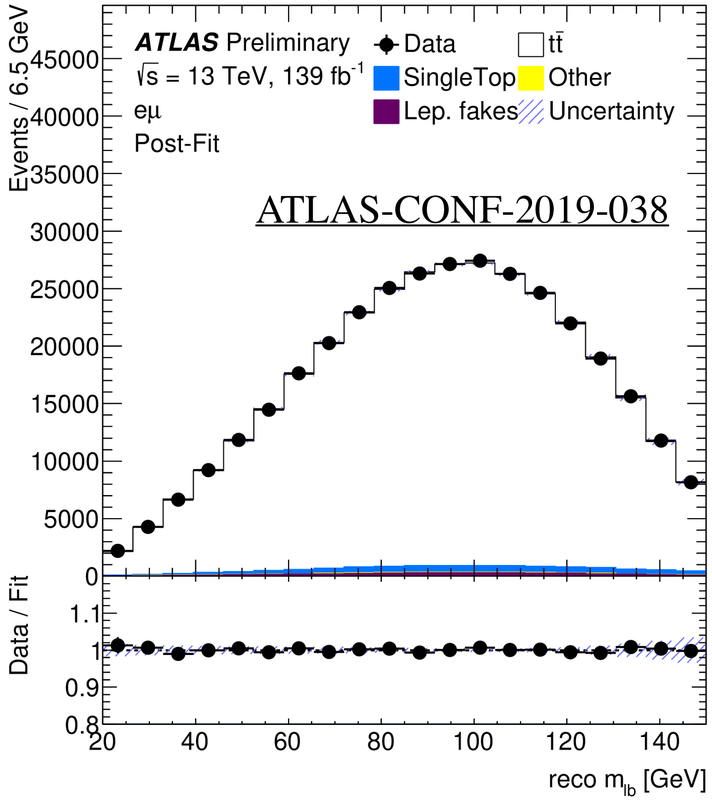
# Full Run II Top Results

- Measured charge asymmetry, defined as

$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)} \qquad \Delta|y| = |y_t| - |y_{\bar{t}}|$$

  - Good agreement with NNLO pred, puts tight limits on dim 6 BSM operators [ATLAS-CONF-2019-026]




- Used very pure dilepton sample to directly measure top width $\Gamma_t = 1.94^{+0.52}_{-0.49}$ GeV , in agreement with 1.322 GeV SM prediction
  - Sensitive to BSM contributions, relatively model independent

# Many more Top results!

| Short Title | Journal Reference | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| Search for FCNC tqgamma in single top | Submitted to PLB | 22-AUG-19 | 13 | 80 $fb^{-1}$ | Documents \| 1908.08461 \| Inspire Internal |
| Differential ttbar cross-sections in lepton+jets with 36 fb-1 | Submitted to EPJC | 20-AUG-19 | 13 | 36 $fb^{-1}$ | Documents \| 1908.07305 \| Inspire Internal |
| KS and Lambda production in ttbar events at 7 TeV | Submitted to EPJC | 25-JUL-19 | 7 | 5 $fb^{-1}$ | Documents \| 1907.10862 \| Inspire Internal |
| Measurement of the top-quark mass using ttbar+1jet events at 8 TeV | Submitted to JHEP | 06-MAY-19 | 8 | 20.3 $fb^{-1}$ | Documents \| 1905.02302 \| Inspire Internal |
| Spin correlation measurement at 13 TeV | Submitted to EPJC | 18-MAR-19 | 13 | 36 $fb^{-1}$ | Documents \| 1903.07570 \| Inspire Internal |
| Measurement of the jet shapes at 13 TeV | JHEP 08 (2019) 033 | 07-MAR-19 | 13 | 36 $fb^{-1}$ | Documents \| 1903.02942 \| Inspire HepData \| Internal |
| ATLAS+CMS combination of Run 1 single top measurements and extraction of Vtb | JHEP 05 (2019) 088 | 18-FEB-19 | 8 | 20 $fb^{-1}$ | Documents \| 1902.07158 \| Inspire Internal |
| Measurement of ttV in multilepton final states using 36.5fb-1 at 13 TeV | Phys. Rev. D 99 (2019) 072009 | 11-JAN-19 | 13 | 36 $fb^{-1}$ | Documents \| 1901.03584 \| Inspire Internal |
| Search for flavor-changing neutral current t to Hq with H->b-bbar and tautau at 13 TeV | JHEP 05 (2019) 123 | 30-DEC-18 | 13 | 36 $fb^{-1}$ | Documents \| 1812.11568 \| Inspire Internal |
| Measurement of the ttbar+gamma cross section at 13 TeV | Eur. Phys. J. C 79 (2019) 382 | 04-DEC-18 | 13 | 36 $fb^{-1}$ | Documents \| 1812.01697 \| Inspire Internal |
| Measurement of the ttbb cross section at 13 TeV | JHEP 04 (2019) 046 | 29-NOV-18 | 13 | 36 $fb^{-1}$ | Documents \| 1811.12113 \| Inspire HepData \| Internal |
| 4 top quark search with 1 or 2 leptons | Phys. Rev. D 99 (2019) 052009 | 06-NOV-18 | 13 | 36 $fb^{-1}$ | Documents \| 1811.02305 \| Inspire Briefing \| Internal |

| Short Title | Document Number | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| Top quark mass using soft muon tags | ATLAS-CONF-2019-046 | 27-SEP-19 | 13 | 36 $fb^{-1}$ | Documents \| Internal |
| Observation of tZq single top at 13 TeV | ATLAS-CONF-2019-043 | 23-SEP-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| ttgamma cross section in emu channel | ATLAS-CONF-2019-042 | 22-SEP-19 | 13 | 140 $fb^{-1}$ | Documents \| Internal |
| Measurement of the ttbar production cross-section in the lepton+jets channel at 13 TeV | ATLAS-CONF-2019-044 | 22-SEP-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Top width measurement in dilepton ttbar | ATLAS-CONF-2019-038 | 02-AUG-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Inclusive and lepton differential cross-sections in dilepton ttbar with 36 fb-1 | ATLAS-CONF-2019-041 | 04-AUG-19 | 13 | 36 $fb^{-1}$ | Documents \| Internal |
| Measurement of ttbar charge asymmetry at 13 TeV in l+jets | ATLAS-CONF-2019-026 | 09-JUL-19 | 13 | 139 $fb^{-1}$ | Documents \| Briefing \| Internal |

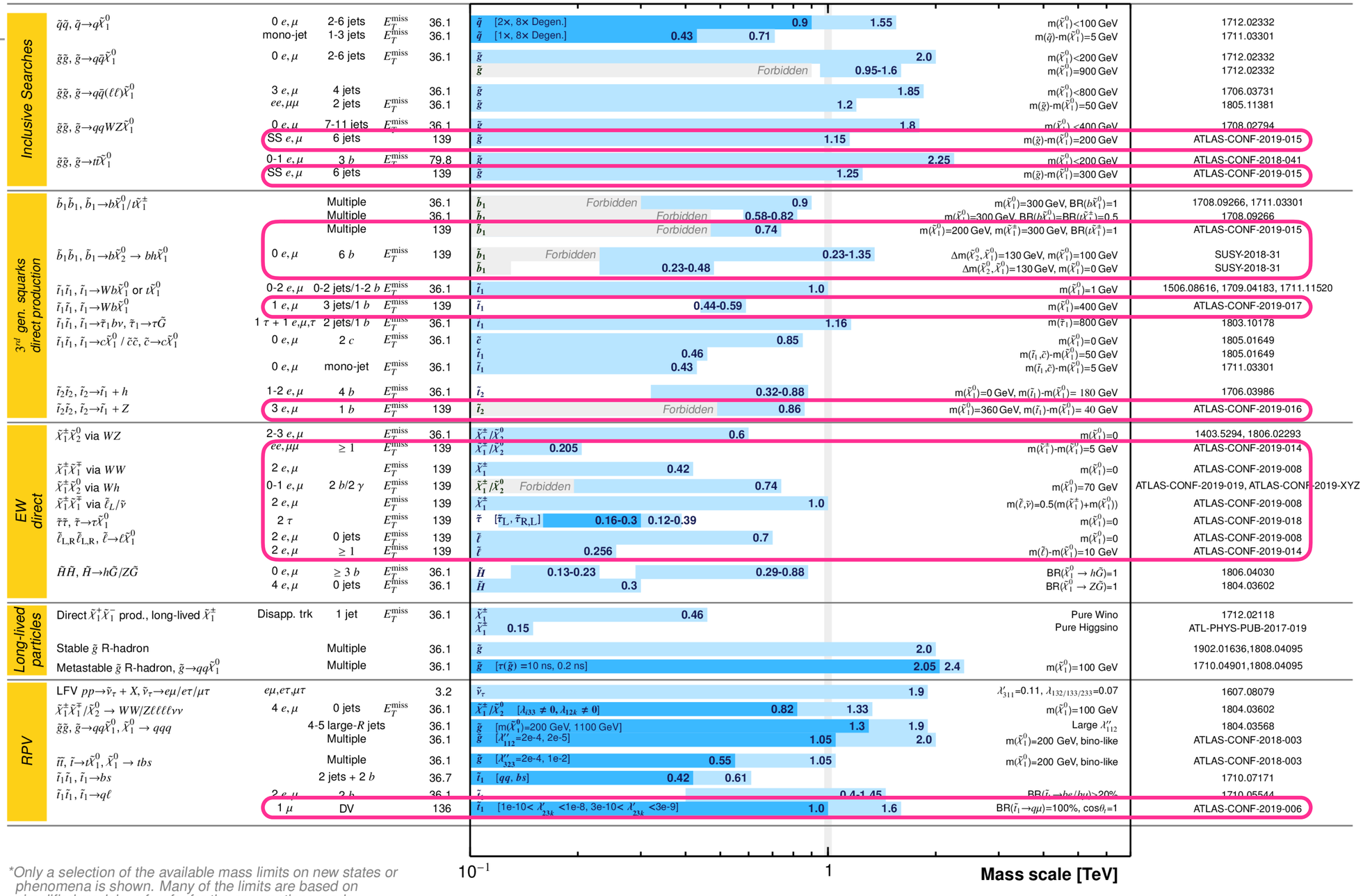
# SUSY

## ATLAS SUSY Searches* - 95% CL Lower Limits

*July 2019*

**ATLAS** Preliminary

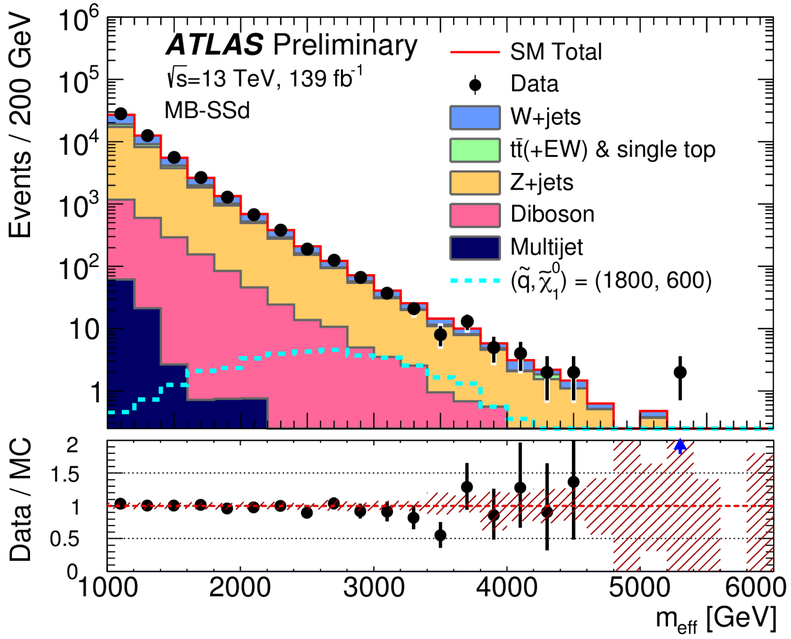
$\sqrt{s}$ = 13 TeV

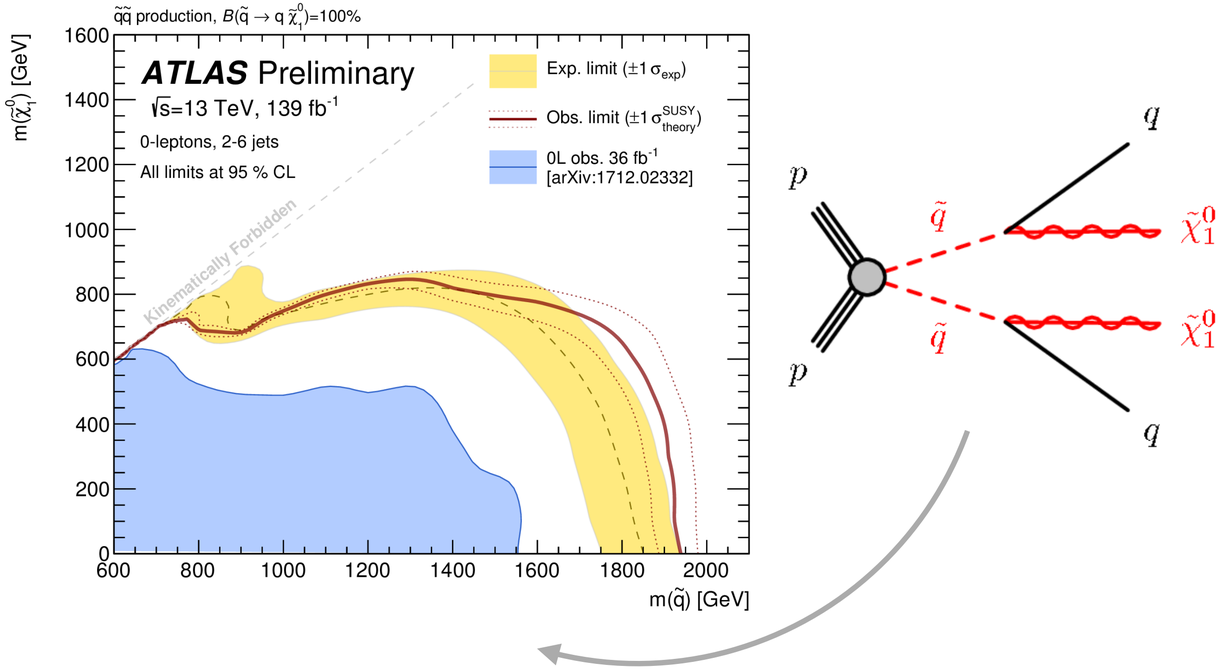


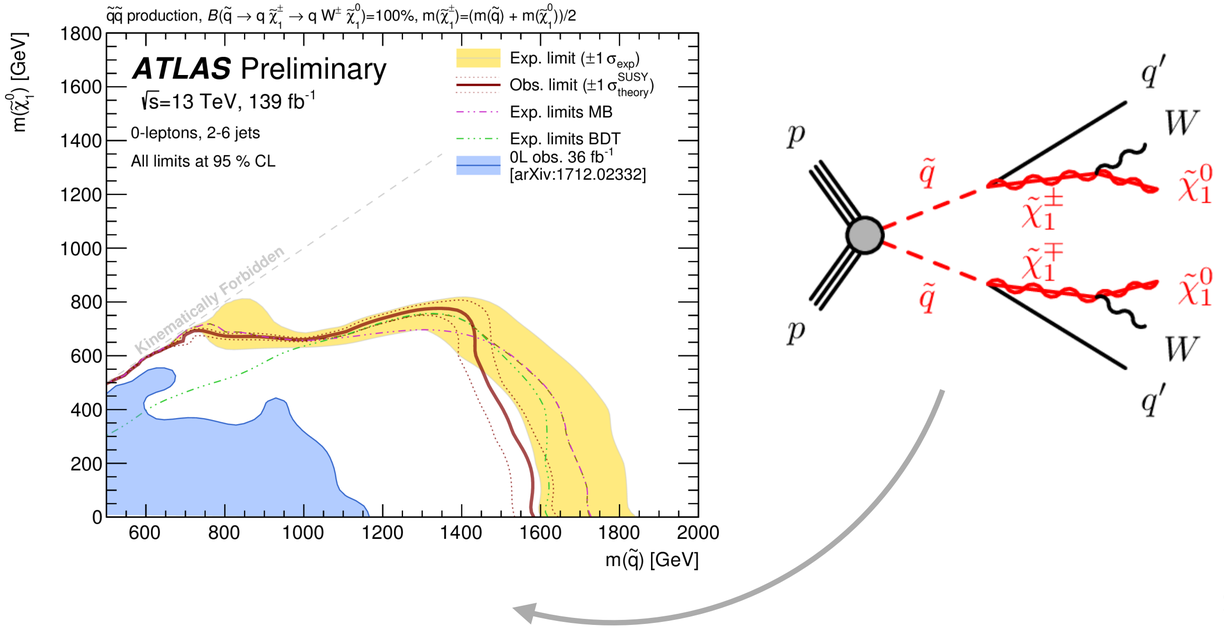

**Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.*

# SUSY Strong Production

- Comprehensive search for all hadronic final states of squarks & gluinos in R-parity conserving simplified scenarios
  - Cut-based and BDT approaches combined for maximum sensitivity
  - Model independent results also presented

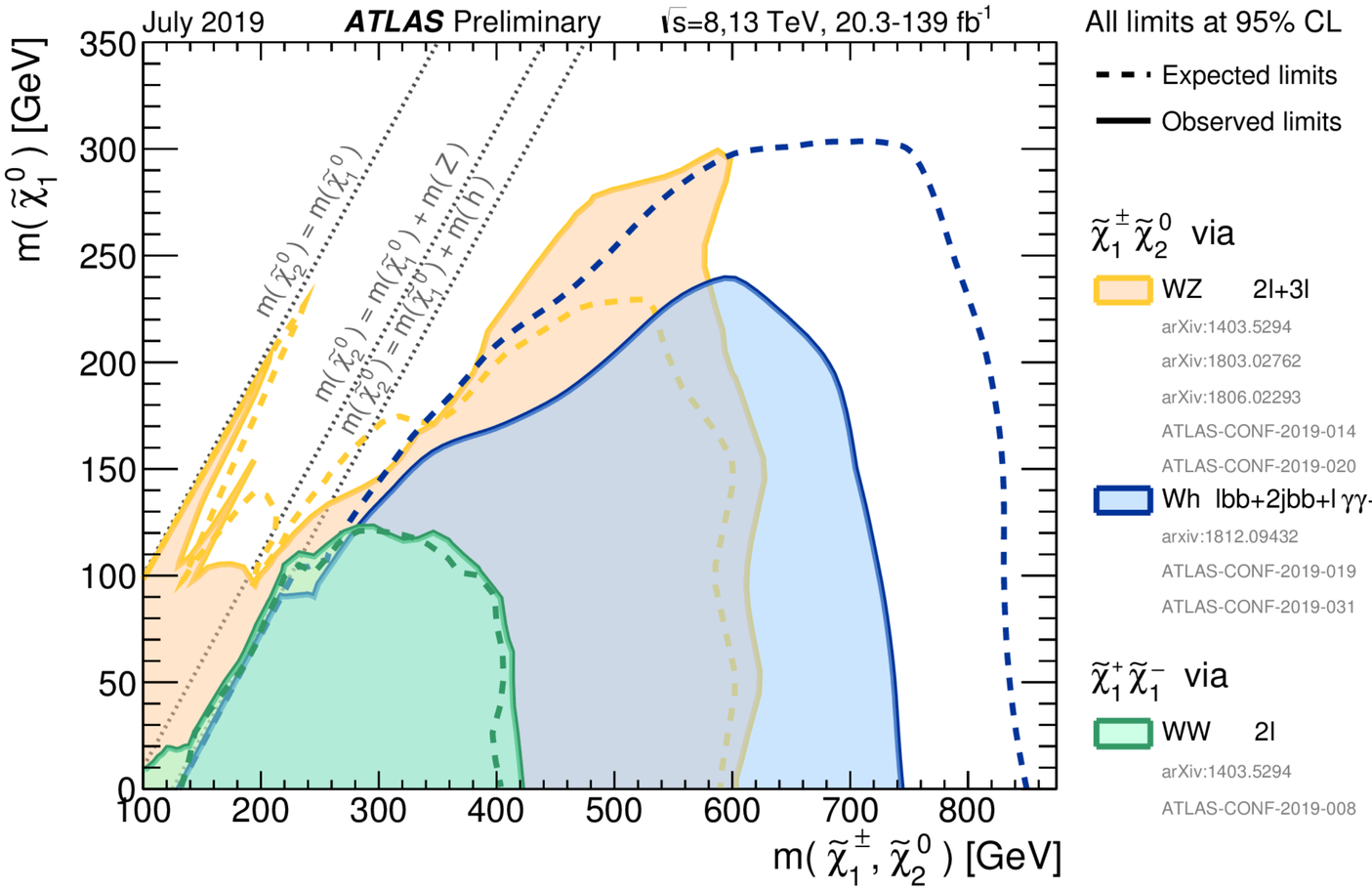


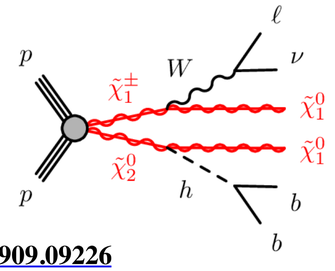



# SUSY EWK Production

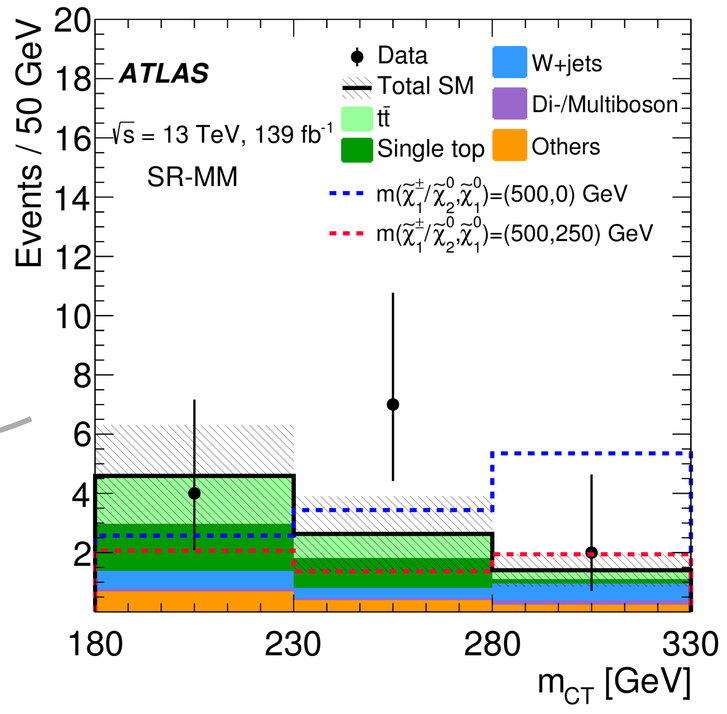
- If squarks and gluinos are very heavy then may only have access to charginos and neutralinos
  - Low cross-section final states dominated by leptons + MET, sometimes “extras” like Higgs




$$m_{CT} = \sqrt{2p_T^{b_1}p_T^{b_2}(1+\cos\Delta\phi_{bb})},$$




arXiv:1909.09226



# Many more SUSY results!

| Short Title | Journal Reference | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| Chargino-neutralino pair; Higgs boson in final state, 2 b-jets and 1 lepton | Submitted to EPJC | 19-SEP-19 | 13 | 139 $fb^{-1}$ | Documents \| 1909.09226 \| Inspire Internal |
| Stop pair, sbottom pair, gluino pair; two same-sign leptons or three leptons | Submitted to JHEP | 18-SEP-19 | 13 | 139 $fb^{-1}$ | Documents \| 1909.08457 \| Inspire Internal |
| Chargino pair, slepton pair; 2 leptons | Submitted to EPJC | 21-AUG-19 | 13 | 139 $fb^{-1}$ | Documents \| 1908.08215 \| Inspire Internal |
| Sbottom; b-jets | Submitted to JHEP | 08-AUG-19 | 13 | 139 $fb^{-1}$ | Documents \| 1908.03122 \| Inspire Internal |
| Gluino pair, squark pair; displaced vertex with lepton pairs | Submitted to PLB | 23-JUL-19 | 13 | 32.8 $fb^{-1}$ | Documents \| 1907.10037 \| Inspire HepData \| Internal |
| Spin correlation measurement at 13 TeV | Submitted to EPJC | 18-MAR-19 | 13 | 36 $fb^{-1}$ | Documents \| 1903.07570 \| Inspire Internal |
| Summary of searches for mediator-based dark matter and scalar dark energy models | JHEP 05 (2019) 142 | 03-MAR-19 | 13 | 36 $fb^{-1}$ | Documents \| 1903.01400 \| Inspire Internal |
| Searches for 3rd generation Leptoquarks | JHEP 06 (2019) 144 | 21-FEB-19 | 13 | 36 $fb^{-1}$ | Documents \| 1902.08103 \| Inspire Internal |
| Gluino pair, squark pair, stop pair, R-hadron; pixel ionisation, calorimeter and muon timing | Phys. Rev. D 99 (2019) 092007 | 05-FEB-19 | 13 | 36.1 $fb^{-1}$ | Documents \| 1902.01636 \| Inspire HepData \| Internal |
| Chargino-neutralino pair; Higgs boson in final state | Phys. Rev. D 100 (2019) 012006 | 22-DEC-18 | 13 | 36 $fb^{-1}$ | Documents \| 1812.09432 \| Inspire HepData \| Internal |
| Displaced jets in muon system | Phys. Rev. D 99 (2019) 052005 | 18-NOV-18 | 13 | 36 $fb^{-1}$ | Documents \| 1811.07370 \| Inspire HepData \| Internal |

| Short Title | Document Number | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| Gluino pair; squark pair; gluino-squark; 0-lepton | ATLAS-CONF-2019-040 | 05-AUG-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Soft b-hadron tagging for compressed SUSY scenarios | ATLAS-CONF-2019-027 | 11-JUL-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Chargino-neutralino pair; Higgs boson in final state, 2 photons | ATLAS-CONF-2019-019 | 17-MAY-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Chargino-neutralino pair; 3 leptons, weak-scale mass splittings | ATLAS-CONF-2019-020 | 19-MAY-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Stop pair; 1-lepton | ATLAS-CONF-2019-017 | 19-MAY-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Chargino-neutralino pair, slepton pair; soft leptons | ATLAS-CONF-2019-014 | 19-MAY-19 | 13 | 139 $fb^{-1}$ | Documents \| Briefing \| Internal |
| Stop pair; Z boson | ATLAS-CONF-2019-016 | 17-MAY-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Staus; taus | ATLAS-CONF-2019-018 | 17-MAY-19 | 13 | 139 $fb^{-1}$ | Documents \| Briefing \| Internal |
| Stop pair, long-lived; displaced vertex and displaced muon | ATLAS-CONF-2019-006 | 18-MAR-19 | 13 | 136 $fb^{-1}$ | Documents \| Internal |

# Exotics

## ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

*Status: May 2019*

**ATLAS** Preliminary

$\sqrt{s}$ = 8, 13 TeV

$\int \mathcal{L}\, dt$ = (3.2 – 139) fb$^{-1}$

| | Model | $\ell, \gamma$ | Jets† | $E_T^{miss}$ | $\int \mathcal{L}\, dt$[fb$^{-1}$] | Limit | | Reference |
|---|---|---|---|---|---|---|---|---|
| Extra dimensions | ADD $G_{KK} + g/q$ | 0 $e, \mu$ | 1 – 4 j | Yes | 36.1 | $M_D$ 7.7 TeV | $n = 2$ | 1711.03301 |
| | ADD non-resonant $\gamma\gamma$ | 2 $\gamma$ | – | – | 36.7 | $M_S$ 8.6 TeV | $n = 3$ HLZ NLO | 1707.04147 |
| | ADD QBH | – | 2 j | – | 37.0 | $M_{th}$ 8.9 TeV | $n = 6$ | 1703.09127 |
| | ADD BH high $\sum p_T$ | ≥ 1 $e, \mu$ | ≥ 2 j | – | 3.2 | $M_{th}$ 8.2 TeV | $n = 6$, $M_D = 3$ TeV, rot BH | 1606.02265 |
| | ADD BH multijet | – | ≥ 3 j | – | 3.6 | $M_{th}$ 9.55 TeV | $n = 6$, $M_D = 3$ TeV, rot BH | 1512.02586 |
| | RS1 $G_{KK} \to \gamma\gamma$ | 2 $\gamma$ | – | – | 36.7 | $G_{KK}$ mass 4.1 TeV | $k/\overline{M}_{Pl} = 0.1$ | 1707.04147 |
| | Bulk RS $G_{KK} \to WW/ZZ$ | multi-channel | | | 36.1 | $G_{KK}$ mass 2.3 TeV | $k/\overline{M}_{Pl} = 1.0$ | 1808.02380 |
| | Bulk RS $G_{KK} \to WW \to qqqq$ | 0 $e, \mu$ | 2 J | – | 139 | $G_{KK}$ mass 1.6 TeV | $k/\overline{M}_{Pl} = 1.0$ | ATLAS-CONF-2019-003 |
| | Bulk RS $g_{KK} \to tt$ | 1 $e, \mu$ | ≥ 1 b, ≥ 1J/2j | Yes | 36.1 | $g_{KK}$ mass 3.8 TeV | $\Gamma/m = 15\%$ | 1804.10823 |
| | 2UED / RPP | 1 $e, \mu$ | ≥ 2 b, ≥ 3 j | Yes | 36.1 | KK mass 1.8 TeV | Tier (1,1), $\mathcal{B}(A^{(1,1)} \to tt) = 1$ | 1803.09678 |
| Gauge bosons | SSM $Z' \to \ell\ell$ | 2 $e, \mu$ | – | – | 139 | $Z'$ mass 5.1 TeV | | 1903.06248 |
| | SSM $Z' \to \tau\tau$ | 2 $\tau$ | – | – | 36.1 | $Z'$ mass 2.42 TeV | | 1709.07242 |
| | Leptophobic $Z' \to bb$ | – | 2 b | – | 36.1 | $Z'$ mass 2.1 TeV | | 1805.09299 |
| | Leptophobic $Z' \to tt$ | 1 $e, \mu$ | ≥ 1 b, ≥ 1J/2j | Yes | 36.1 | $Z'$ mass 3.0 TeV | $\Gamma/m = 1\%$ | 1804.10823 |
| | SSM $W' \to \ell\nu$ | 1 $e, \mu$ | – | Yes | 139 | $W'$ mass 6.0 TeV | | CERN-EP-2019-100 |
| | SSM $W' \to \tau\nu$ | 1 $\tau$ | – | Yes | 36.1 | $W'$ mass 3.7 TeV | | 1801.06992 |
| | HVT $V' \to WZ \to qqqq$ model B | 0 $e, \mu$ | 2 J | – | 139 | $V'$ mass 3.6 TeV | $g_V = 3$ | ATLAS-CONF-2019-003 |
| | HVT $V' \to WH/ZH$ model B | multi-channel | | | 36.1 | $V'$ mass 2.93 TeV | $g_V = 3$ | 1712.06518 |
| | LRSM $W_R \to tb$ | multi-channel | | | 36.1 | $W_R$ mass 3.25 TeV | | 1807.10473 |
| | LRSM $W_R \to \mu N_R$ | 2 $\mu$ | 1 J | – | 80 | $W_R$ mass 5.0 TeV | $m(N_R) = 0.5$ TeV, $g_L = g_R$ | 1904.12679 |
| CI | CI $qqqq$ | – | 2 j | – | 37.0 | $\Lambda$ 21.8 TeV | $\eta_{LL}^-$ | 1703.09127 |
| | CI $\ell\ell qq$ | 2 $e, \mu$ | – | – | 36.1 | $\Lambda$ 40.0 TeV | $\eta_{LL}^-$ | 1707.02424 |
| | CI $tttt$ | ≥1 $e,\mu$ | ≥1 b, ≥1 j | Yes | 36.1 | $\Lambda$ 2.57 TeV | $\lvert C_{4t}\rvert = 4\pi$ | 1811.02305 |
| DM | Axial-vector mediator (Dirac DM) | 0 $e, \mu$ | 1 – 4 j | Yes | 36.1 | $m_{med}$ 1.55 TeV | $g_q$=0.25, $g_\chi$=1.0, $m(\chi) = 1$ GeV | 1711.03301 |
| | Colored scalar mediator (Dirac DM) | 0 $e, \mu$ | 1 – 4 j | Yes | 36.1 | $m_{med}$ 1.67 TeV | $g$=1.0, $m(\chi) = 1$ GeV | 1711.03301 |
| | $VV\chi\chi$ EFT (Dirac DM) | 0 $e, \mu$ | 1 J, ≤ 1 j | Yes | 3.2 | $M_*$ 700 GeV | $m(\chi) < 150$ GeV | 1608.02372 |
| | Scalar reson. $\phi \to t\chi$ (Dirac DM) | 0-1 $e, \mu$ | 1 b, 0-1 J | Yes | 36.1 | $m_\phi$ 3.4 TeV | $y = 0.4$, $\lambda = 0.2$, $m(\chi) = 10$ GeV | 1812.09743 |
| LQ | Scalar LQ 1$^{st}$ gen | 1,2 $e$ | ≥ 2 j | Yes | 36.1 | LQ mass 1.4 TeV | $\beta = 1$ | 1902.00377 |
| | Scalar LQ 2$^{nd}$ gen | 1,2 $\mu$ | ≥ 2 j | Yes | 36.1 | LQ mass 1.56 TeV | $\beta = 1$ | 1902.00377 |
| | Scalar LQ 3$^{rd}$ gen | 2 $\tau$ | 2 b | – | 36.1 | $LQ_3^u$ mass 1.03 TeV | $\mathcal{B}(LQ_3^u \to b\tau) = 1$ | 1902.08103 |
| | Scalar LQ 3$^{rd}$ gen | 0-1 $e, \mu$ | 2 b | Yes | 36.1 | $LQ_3^d$ mass 970 GeV | $\mathcal{B}(LQ_3^d \to t\tau) = 0$ | 1902.08103 |
| Heavy quarks | VLQ $TT \to Ht/Zt/Wb + X$ | multi-channel | | | 36.1 | T mass 1.37 TeV | SU(2) doublet | 1808.02343 |
| | VLQ $BB \to Wt/Zb + X$ | multi-channel | | | 36.1 | B mass 1.34 TeV | SU(2) doublet | 1808.02343 |
| | VLQ $T_{5/3}\,T_{5/3}/T_{5/3} \to Wt + X$ | 2(SS)/≥3 $e,\mu$ | ≥1 b, ≥1 j | Yes | 36.1 | $T_{5/3}$ mass 1.64 TeV | $\mathcal{B}(T_{5/3} \to Wt) = 1$, $c(T_{5/3}Wt) = 1$ | 1807.11883 |
| | VLQ $Y \to Wb + X$ | 1 $e, \mu$ | ≥ 1 b, ≥ 1j | Yes | 36.1 | Y mass 1.85 TeV | $\mathcal{B}(Y \to Wb) = 1$, $c_R(Wb) = 1$ | 1812.07343 |
| | VLQ $B \to Hb + X$ | 0 $e,\mu$, 2 $\gamma$ | ≥ 1 b, ≥ 1j | Yes | 79.8 | B mass 1.21 TeV | $\kappa_B = 0.5$ | ATLAS-CONF-2018-024 |
| | VLQ $QQ \to WqWq$ | 1 $e, \mu$ | ≥ 4 j | Yes | 20.3 | Q mass 690 GeV | | 1509.04261 |
| Excited fermions | Excited quark $q^* \to qg$ | – | 2 j | – | 139 | $q^*$ mass 6.7 TeV | only $u^*$ and $d^*$, $\Lambda = m(q^*)$ | ATLAS-CONF-2019-007 |
| | Excited quark $q^* \to q\gamma$ | 1 $\gamma$ | 1 j | – | 36.7 | $q^*$ mass 5.3 TeV | only $u^*$ and $d^*$, $\Lambda = m(q^*)$ | 1709.10440 |
| | Excited quark $b^* \to bg$ | – | 1 b, 1 j | – | 36.1 | $b^*$ mass 2.6 TeV | | 1805.09299 |
| | Excited lepton $\ell^*$ | 3 $e, \mu$ | – | – | 20.3 | $\ell^*$ mass 3.0 TeV | $\Lambda = 3.0$ TeV | 1411.2921 |
| | Excited lepton $\nu^*$ | 3 $e, \mu, \tau$ | – | – | 20.3 | $\nu^*$ mass 1.6 TeV | $\Lambda = 1.6$ TeV | 1411.2921 |
| Other | Type III Seesaw | 1 $e, \mu$ | ≥ 2 j | Yes | 79.8 | $N^0$ mass 560 GeV | | ATLAS-CONF-2018-020 |
| | LRSM Majorana $\nu$ | 2 $\mu$ | 2 j | – | 36.1 | $N_R$ mass 3.2 TeV | $m(W_R) = 4.1$ TeV, $g_L = g_R$ | 1809.11105 |
| | Higgs triplet $H^{\pm\pm} \to \ell\ell$ | 2,3,4 $e, \mu$ (SS) | – | – | 36.1 | $H^{\pm\pm}$ mass 870 GeV | DY production | 1710.09748 |
| | Higgs triplet $H^{\pm\pm} \to \ell\tau$ | 3 $e, \mu, \tau$ | – | – | 20.3 | $H^{\pm\pm}$ mass 400 GeV | DY production, $\mathcal{B}(H_L^{\pm\pm} \to \ell\tau) = 1$ | 1411.2921 |
| | Multi-charged particles | – | – | – | 36.1 | multi-charged particle mass 1.22 TeV | DY production, $\lvert q\rvert = 5e$ | 1812.03673 |
| | Magnetic monopoles | – | – | – | 34.4 | monopole mass 2.37 TeV | DY production, $\lvert g\rvert = 1g_D$, spin 1/2 | 1905.10130 |

$10^{-1}$ 1 10 **Mass scale [TeV]**

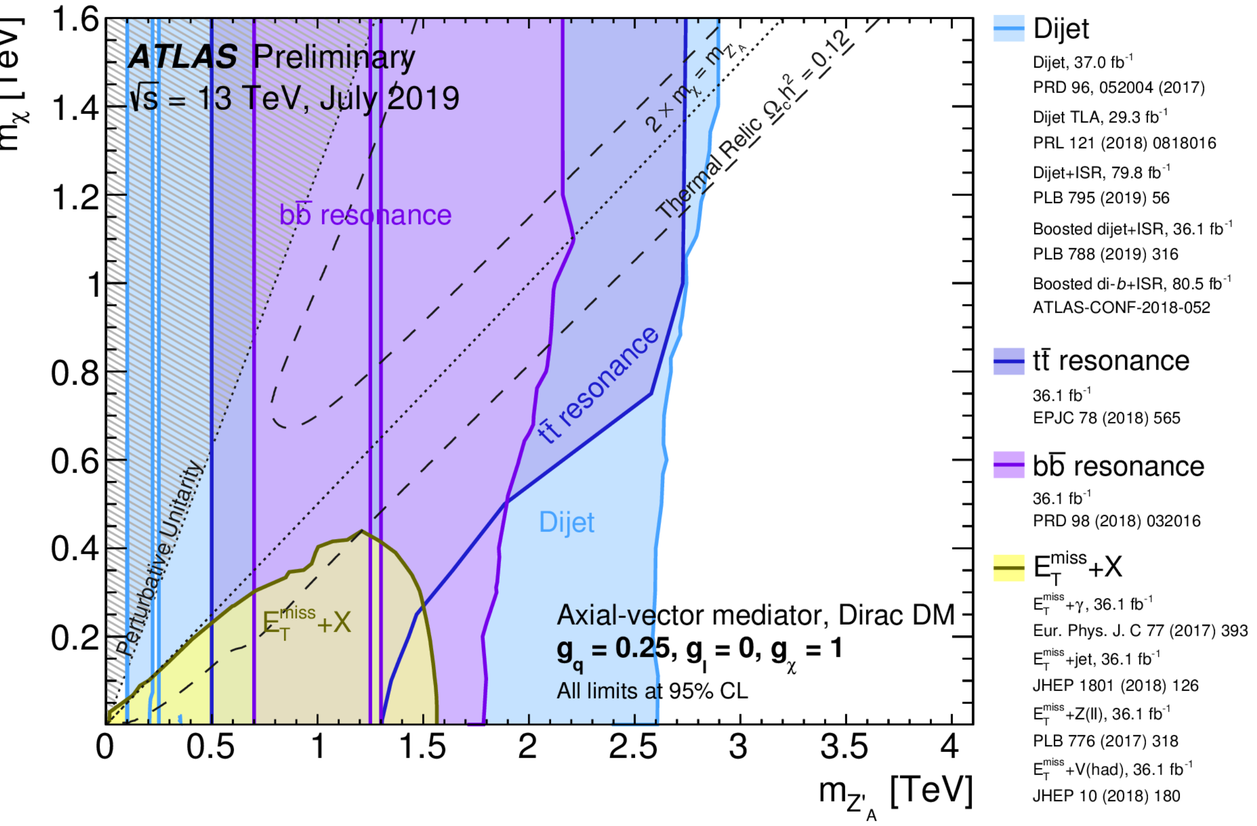
$\sqrt{s}$ = 8 TeV | $\sqrt{s}$ = 13 TeV partial data | $\sqrt{s}$ = 13 TeV full data

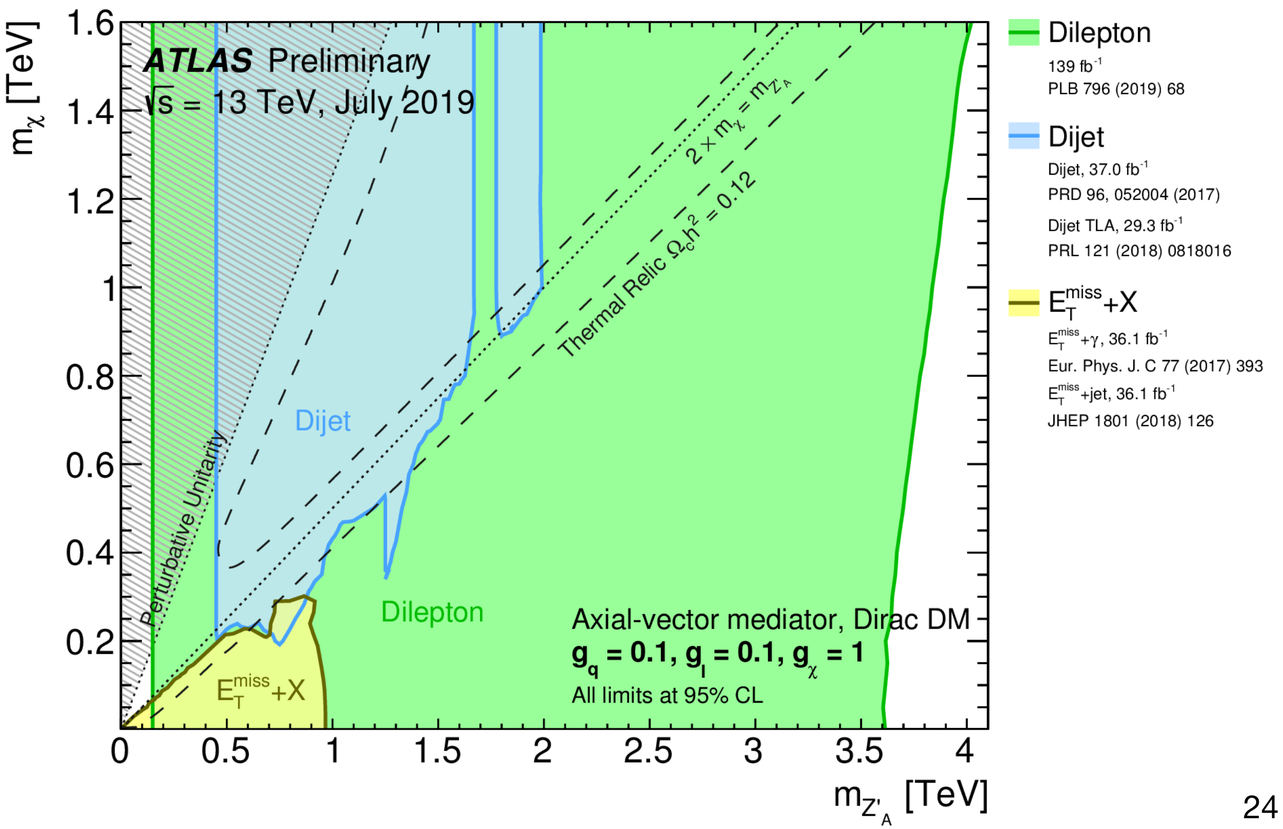
*Only a selection of the available mass limits on new states or phenomena is shown.

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

# Dark Matter Searches

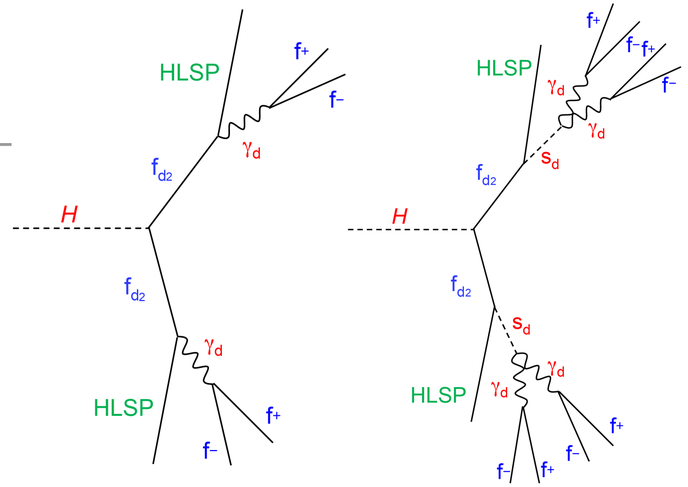
- Simple assumptions on leptophilic and leptophobic dark matter scenarios narrowing parameter space for DM at LHC
  - Axial-vector mediators exclude to 2.6(3.6) TeV for leptophobic(philic) DM
  - Vector mediators exclude to 2.6 TeV for leptophobic DM



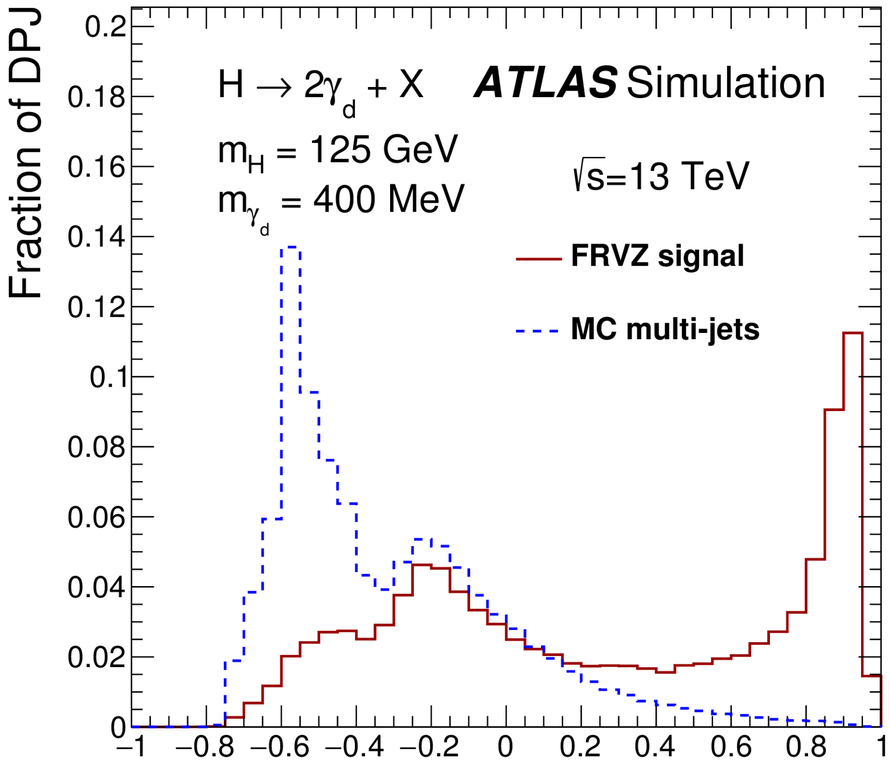



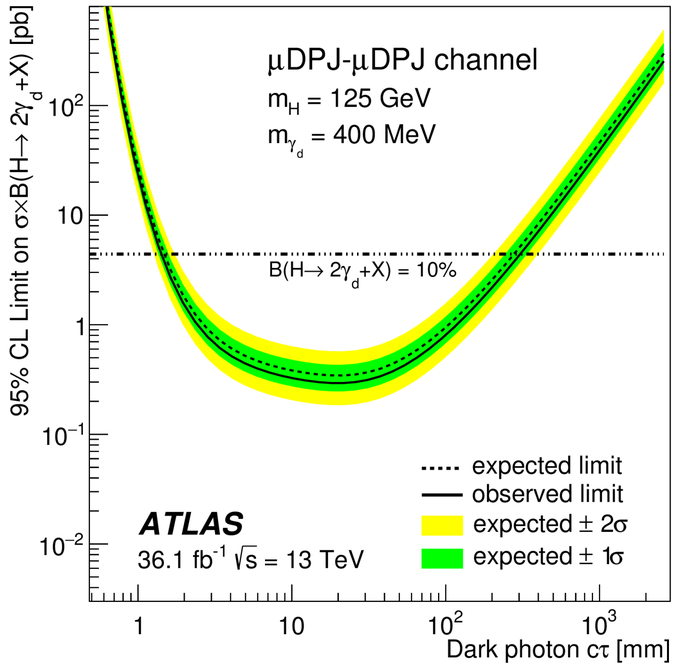
# Dark Sectors: Displaced Lepton Jets

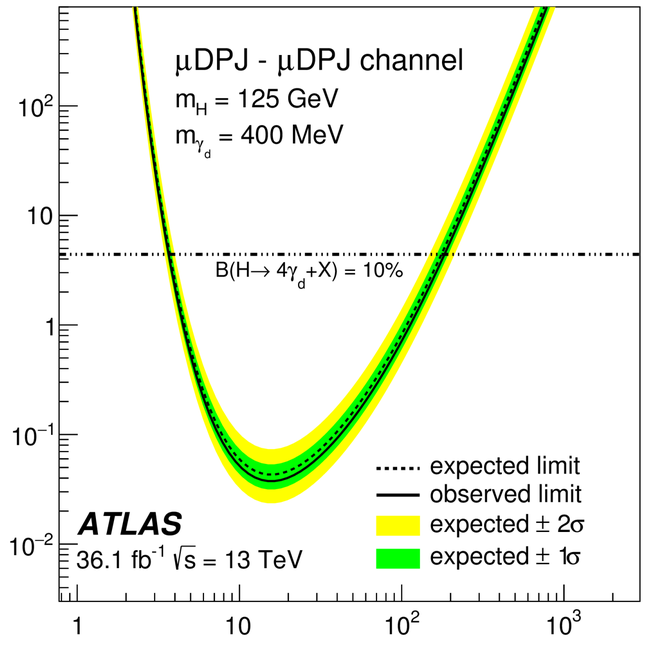
- If there exists a complex dark sector it could couple to the higgs and mix with the SM through a dark photon
  - Search for displaced lepton jets from dark photon decays
  - Set limits based on dark photon cτ, mass and mixing parameter to the SM [arXiv:1909.01246]




arXiv:1909.01246



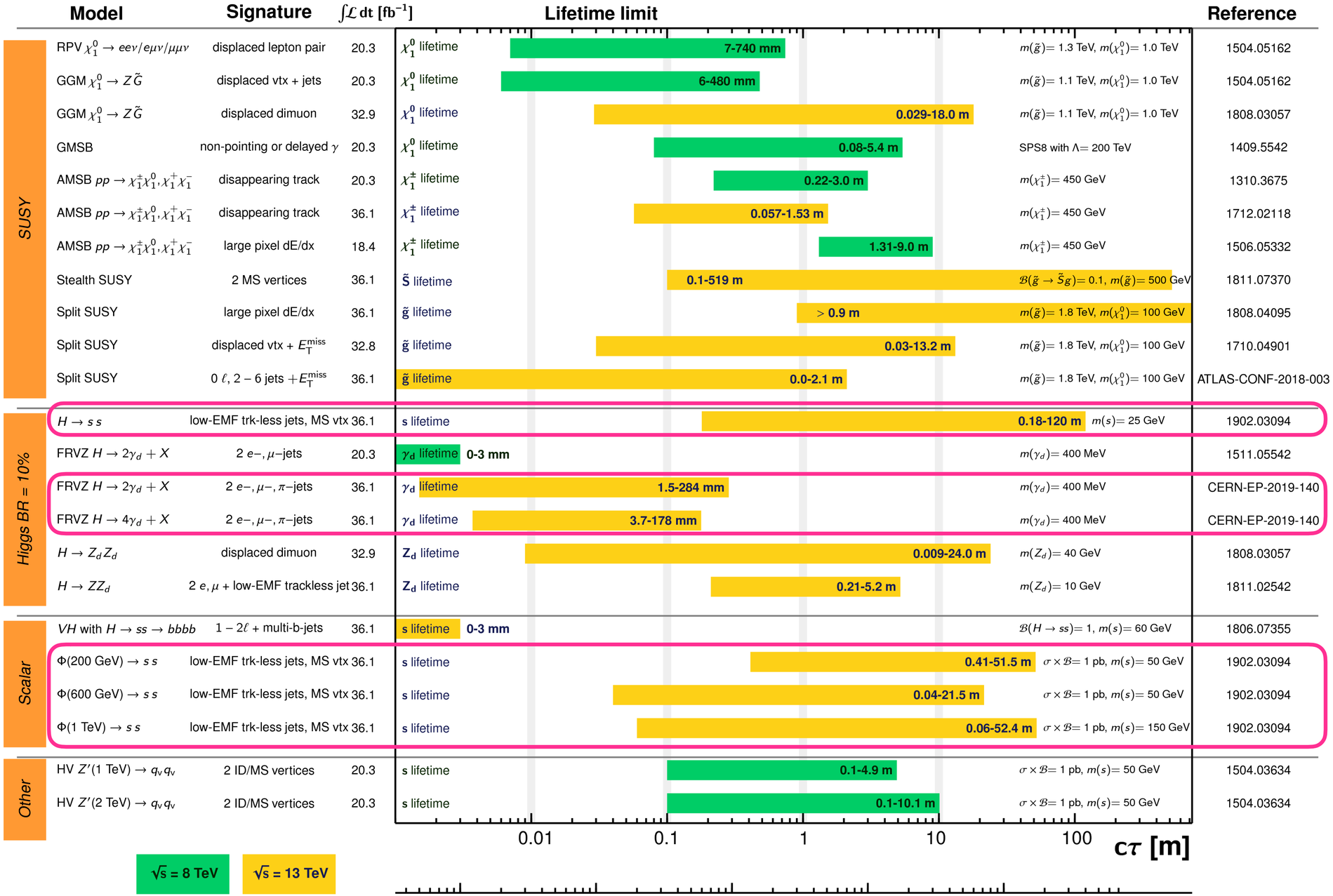



# ATLAS Long-lived Particle Searches* - 95% CL Exclusion

*Status: July 2019*

**ATLAS** Preliminary

$\int \mathcal{L}\, dt$ = (18.4 – 36.1) fb$^{-1}$ $\sqrt{s}$ = 8, 13 TeV

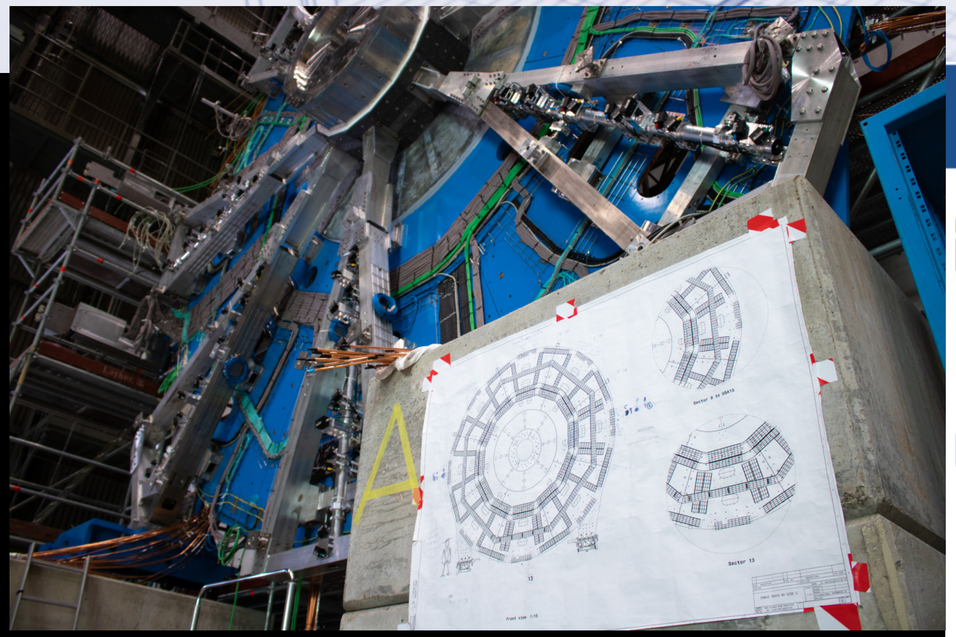



*Only a selection of the available lifetime limits is shown.

# Many more Exotics results!

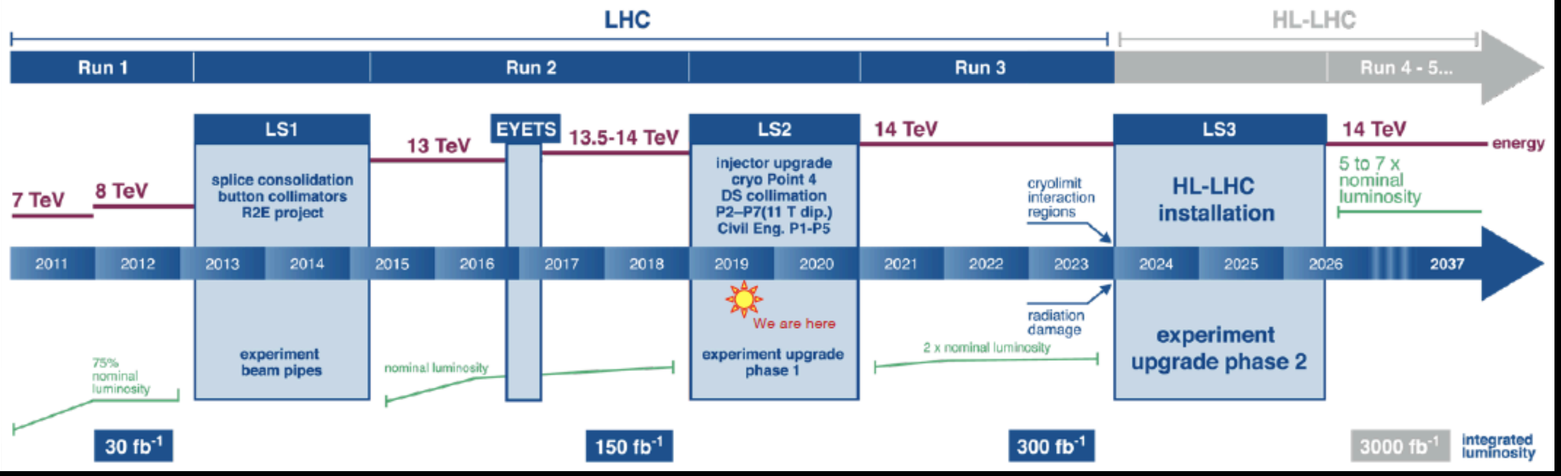
| Short Title | Journal Reference | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| Search for displaced lepton-jets | Submitted to EPJC | 03-SEP-19 | 13 | 36 $fb^{-1}$ | Documents \| 1909.01246 \| Inspire HepData \| Internal |
| Gluino pair, squark pair; displaced vertex with lepton pairs | Submitted to PLB | 23-JUL-19 | 13 | 32.8 $fb^{-1}$ | Documents \| 1907.10037 \| Inspire HepData \| Internal |
| lepton + MET resonance search | 10.1103/PhysRevD.100.052013 | 13-JUN-19 | 13 | 139 $fb^{-1}$ | Documents \| 1906.05609 \| Inspire HepData \| Internal |
| Search for excited electrons | Eur. Phys. J. C 79 (2019) 803 | 07-JUN-19 | 13 | 36 $fb^{-1}$ | Documents \| 1906.03204 \| Inspire HepData \| Internal |
| Search for highly ionising particles/monopoles | Submitted to PRL | 24-MAY-19 | 13 | 36 $fb^{-1}$ | Documents \| 1905.10130 \| Inspire HepData \| Briefing \| Internal |
| Prompt and Displaced Heavy Neutral Lepton Search | Accepted by JHEP | 23-MAY-19 | 13 | 36 $fb^{-1}$ | Documents \| 1905.09787 \| Inspire Internal |
| Heavy Neutrino search in boosted topology | Phys. Lett. B 798 (2019) 134942 | 29-APR-19 | 13 | 80 $fb^{-1}$ | Documents \| 1904.12679 \| Inspire HepData \| Internal |
| H(125)->invisible combination | Phys. Rev. Lett. 122 (2019) 231801 | 10-APR-19 | 7 , 8 , 13 | 5 $fb^{-1}$, 20 $fb^{-1}$, 36 $fb^{-1}$ | Documents \| 1904.05105 \| Inspire Internal |
| Dilepton Resonance Search | Phys. Lett. B 796 (2019) 68 | 14-MAR-19 | 13 | 139 $fb^{-1}$ | Documents \| 1903.06248 \| Inspire HepData \| Briefing \| Internal |
| Summary of searches for mediator-based dark matter and scalar dark energy models | JHEP 05 (2019) 142 | 03-MAR-19 | 13 | 36 $fb^{-1}$ | Documents \| 1903.01400 \| Inspire Internal |
| Search for top - anti-top resonances in the hadronic final state | Phys. Rev. D 99 (2019) 092004 | 26-FEB-19 | 13 | 36 $fb^{-1}$ | Documents \| 1902.10077 \| Inspire Internal |
| Searches for 3rd generation Leptoquarks | JHEP 06 (2019) 144 | 21-FEB-19 | 13 | 36 $fb^{-1}$ | Documents \| 1902.08103 \| Inspire Internal |
| Search for displaced hadronic jets in the calorimeter | Eur. Phys. J. C 79 (2019) 481 | 08-FEB-19 | 13 | 33 $fb^{-1}$ | Documents \| 1902.03094 \| Inspire Internal |
| Gluino pair, squark pair, stop pair, R-hadron; pixel ionisation, calorimeter and muon timing | Phys. Rev. D 99 (2019) 092007 | 05-FEB-19 | 13 | 36.1 $fb^{-1}$ | Documents \| 1902.01636 \| Inspire HepData \| Internal |
| Scalar leptoquarks pair search and differential cross-section measurements in dilepton or dimuon + jet events | | | | | |
| Resolved low mass dijet resonance search with IS | | | | | |
| Search for MET plus a single top quark | | | | | |

| Short Title | Document Number | Date | √s (TeV) | L | Links |
|---|---|---|---|---|---|
| VBF HH to 4b | ATLAS-CONF-2019-030 | 11-JUL-19 | 13 | 126 $fb^{-1}$ | Documents \| Internal |
| Dijet resonance search | ATLAS-CONF-2019-007 | 17-MAR-19 | 13 | 139 $fb^{-1}$ | Documents \| Internal |
| Low mass boosted di-b-jet resonances with an extra jet | ATLAS-CONF-2018-052 | 26-NOV-18 | 13 | 80 $fb^{-1}$ | Documents \| Internal |



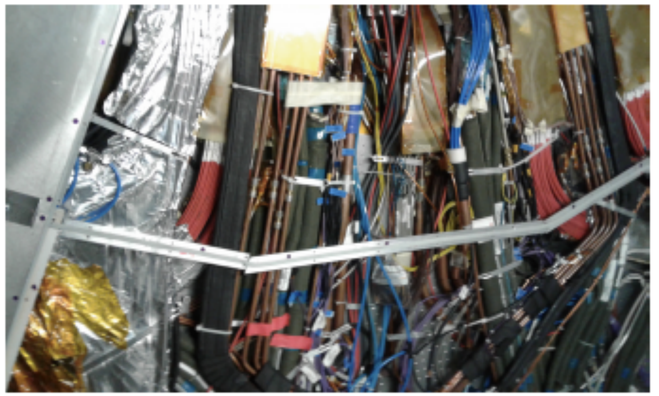
## LHC / HL-LHC Plan

HiLumi HL-LHC PROJECT

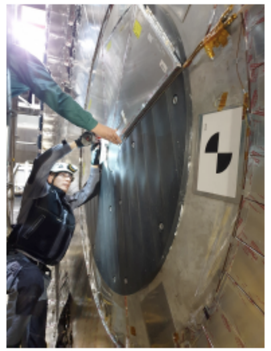


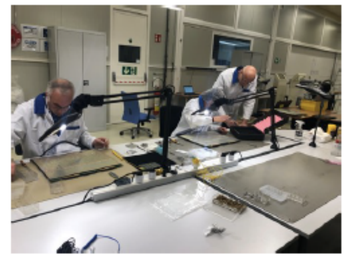
# LS2 Work

- Large program of consolidation: fixing leaks, replacing old parts, etc.
  - E.g., TRT gas change due to leakage, replacement of pixel opto-boards, cooling connections replaced for calorimeters, muon gas leak repairs
  - Significant maintenance to technical networks and general infrastructure
- Phase II Upgrades demonstrator & prep work:
  - Tile calorimeter electronics demonstrator installed
  - MDT replacement options studied



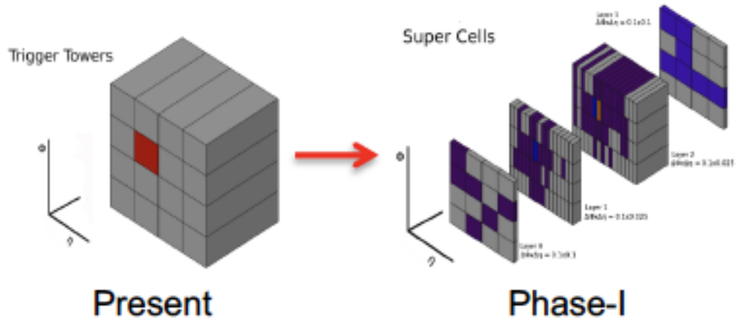
View of the Inner Detector, after opening of end plate (March 2019)





# Phase I Upgrades

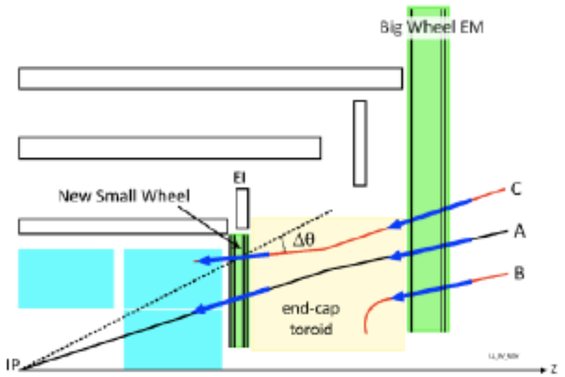
- Liquid Argon Calorimeter Electronics improved to provide higher granularity information to trigger system



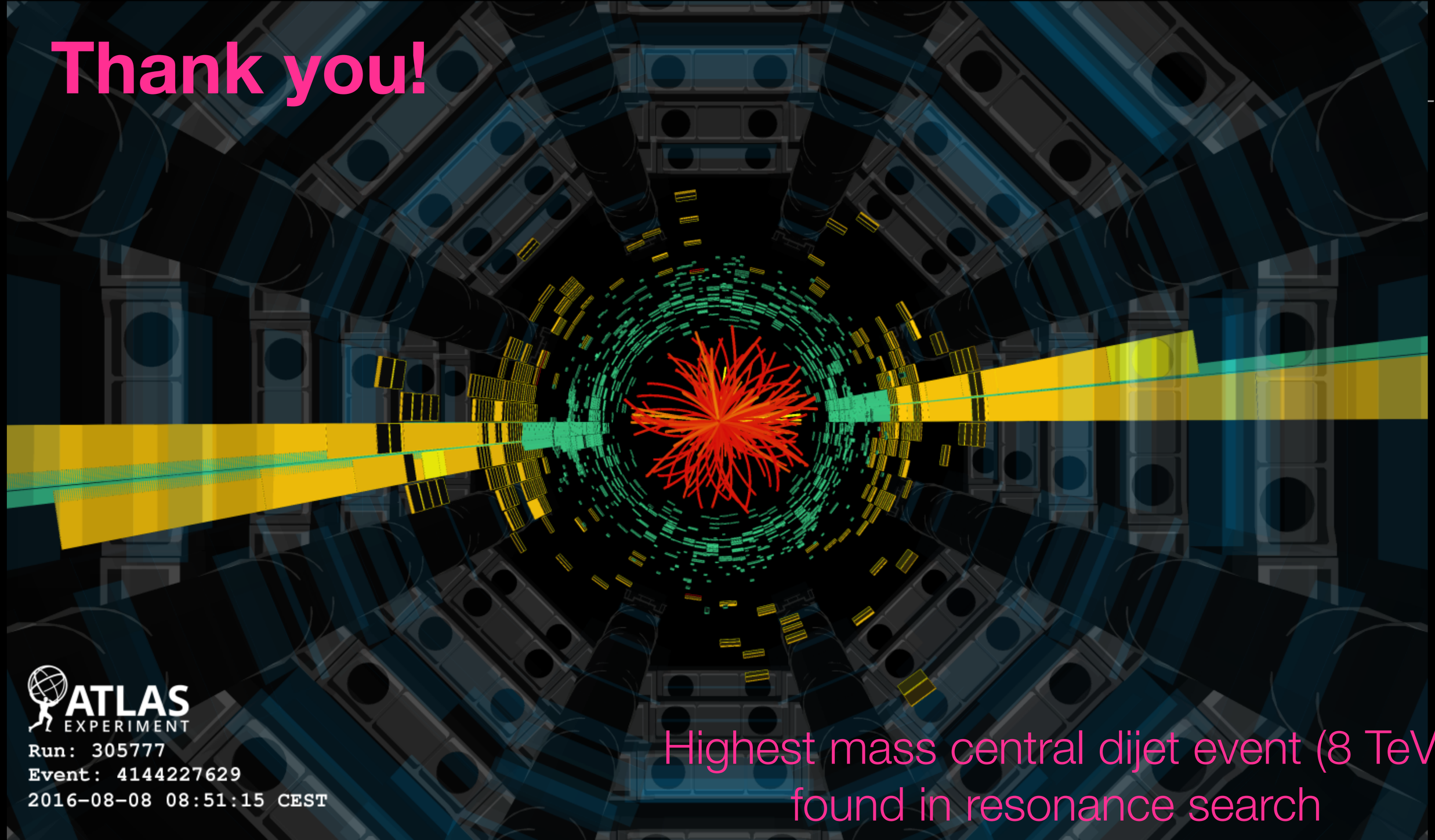

- Level 1 Calorimeter trigger completely redesigned to exploit LAr granularity and new muon electronics


- TDAQ Readout System completely redesigned: FELIX

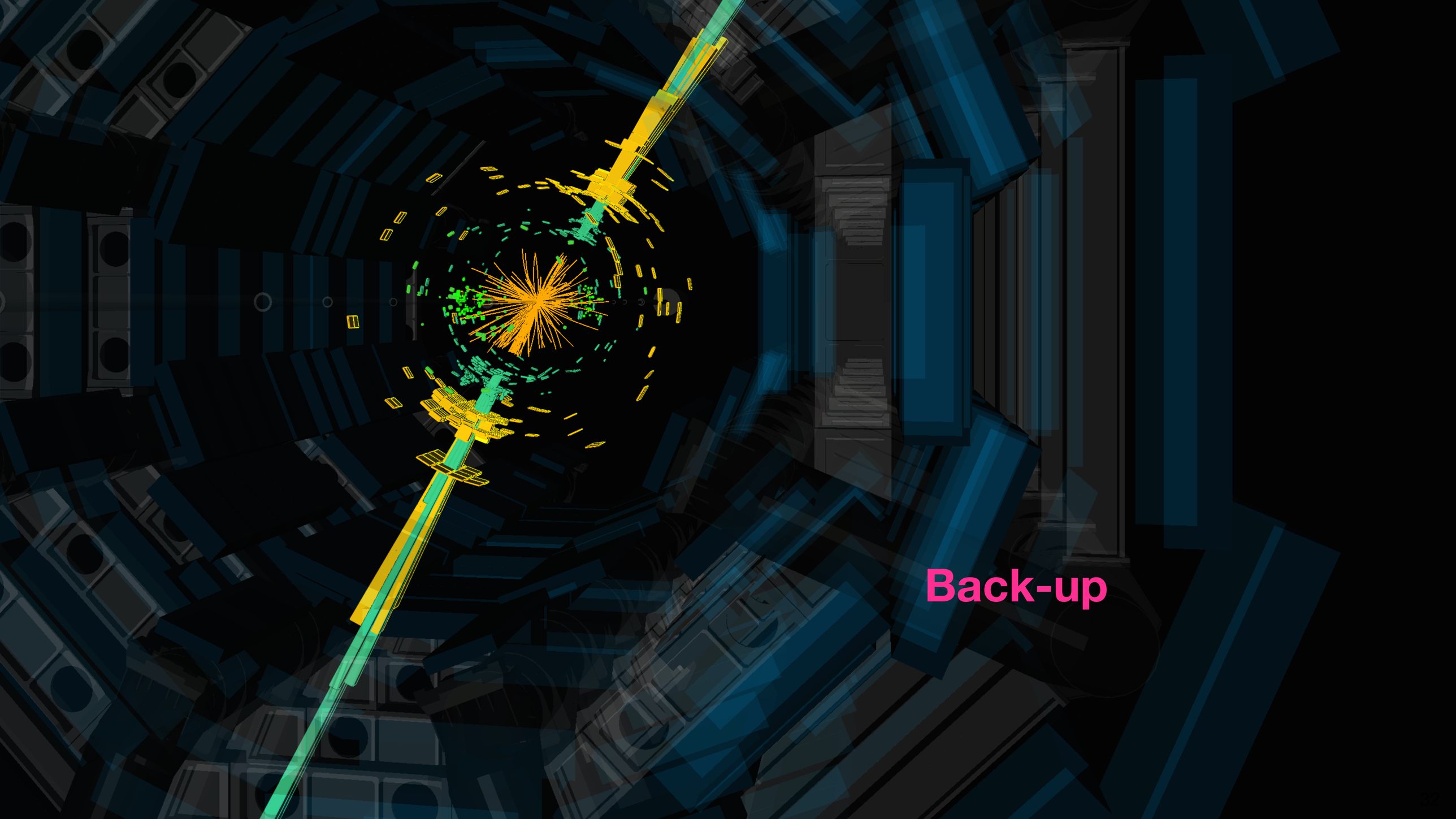
- Planned installation of New Small Wheel: completely new muon inner endcap




# Thank you!

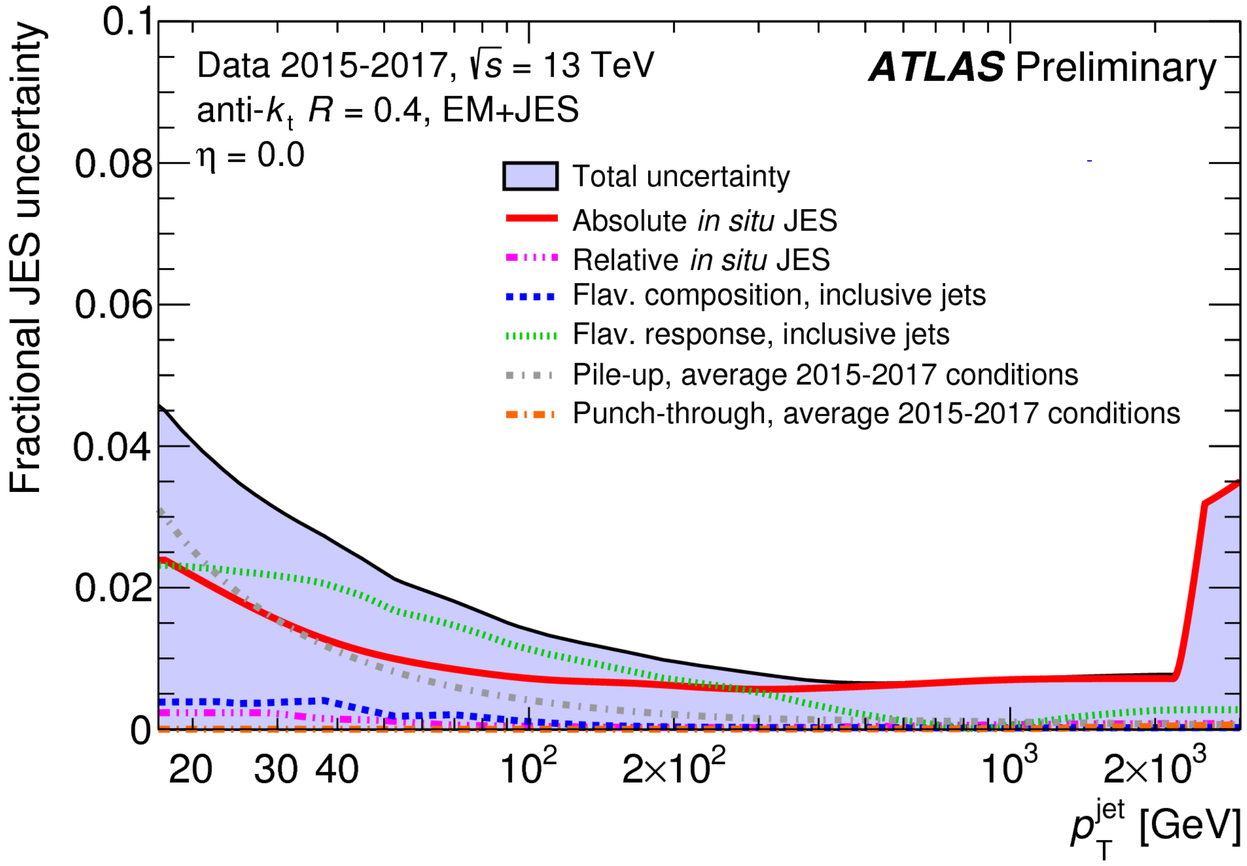


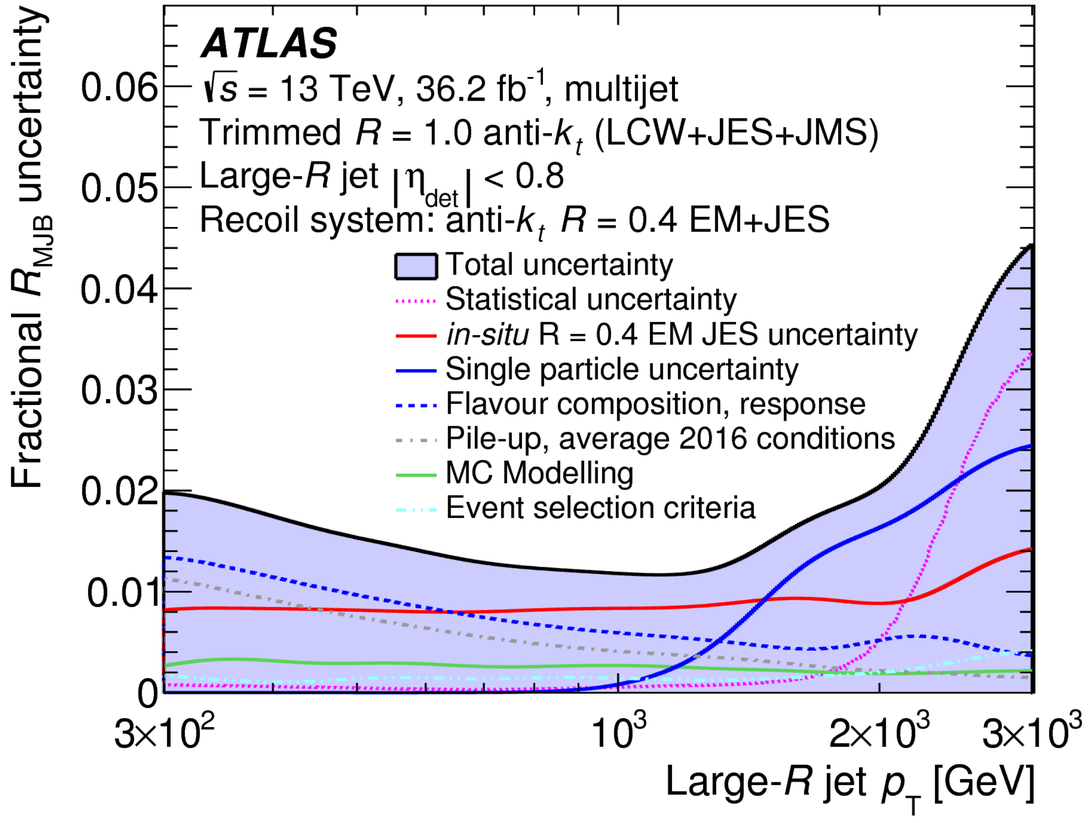

Highest mass central dijet event (8 TeV) found in resonance search


Back-up

# Jet Energy Scale: ATLAS

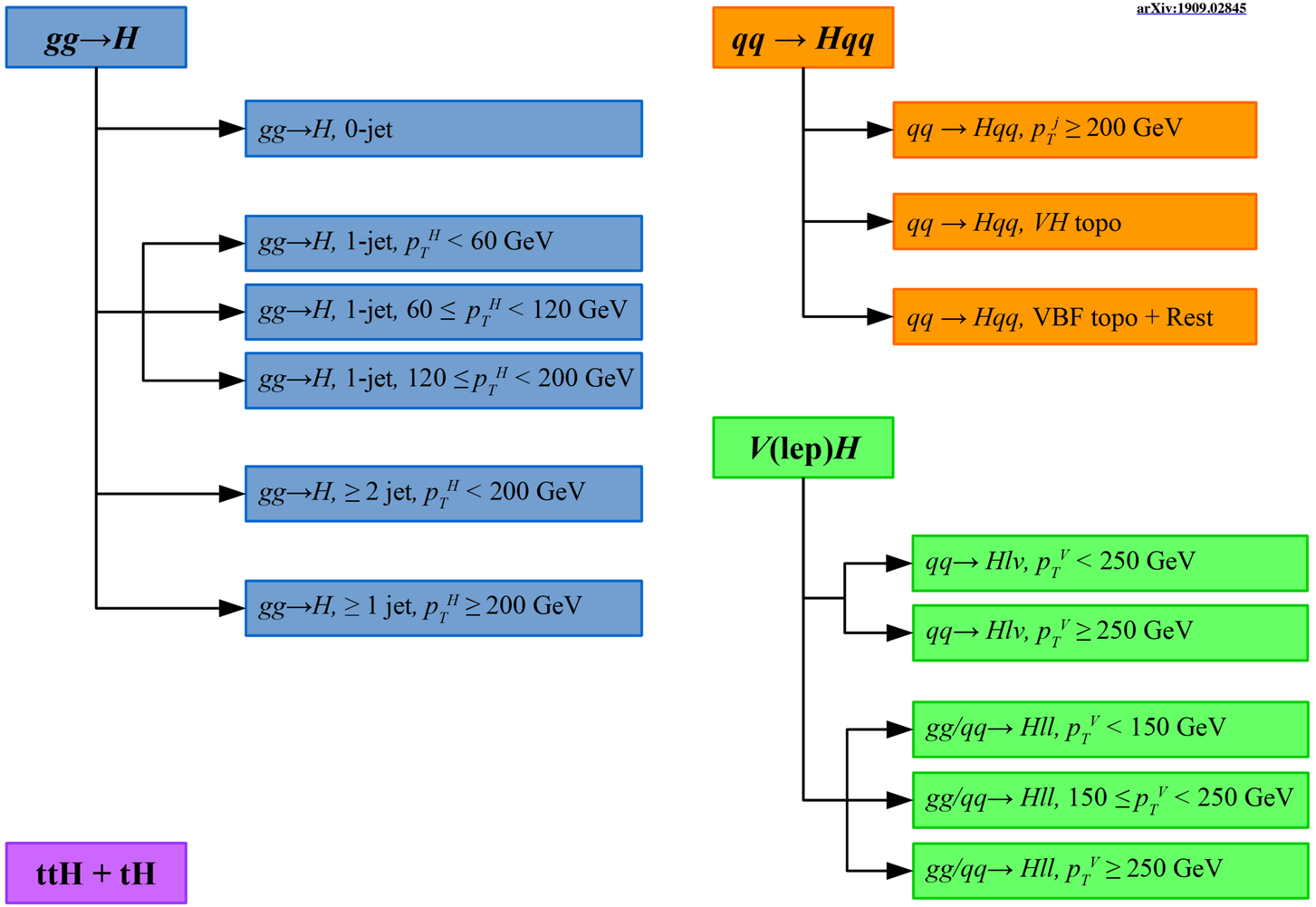
JETM-2018-006
ATLAS-CONF-2017-063



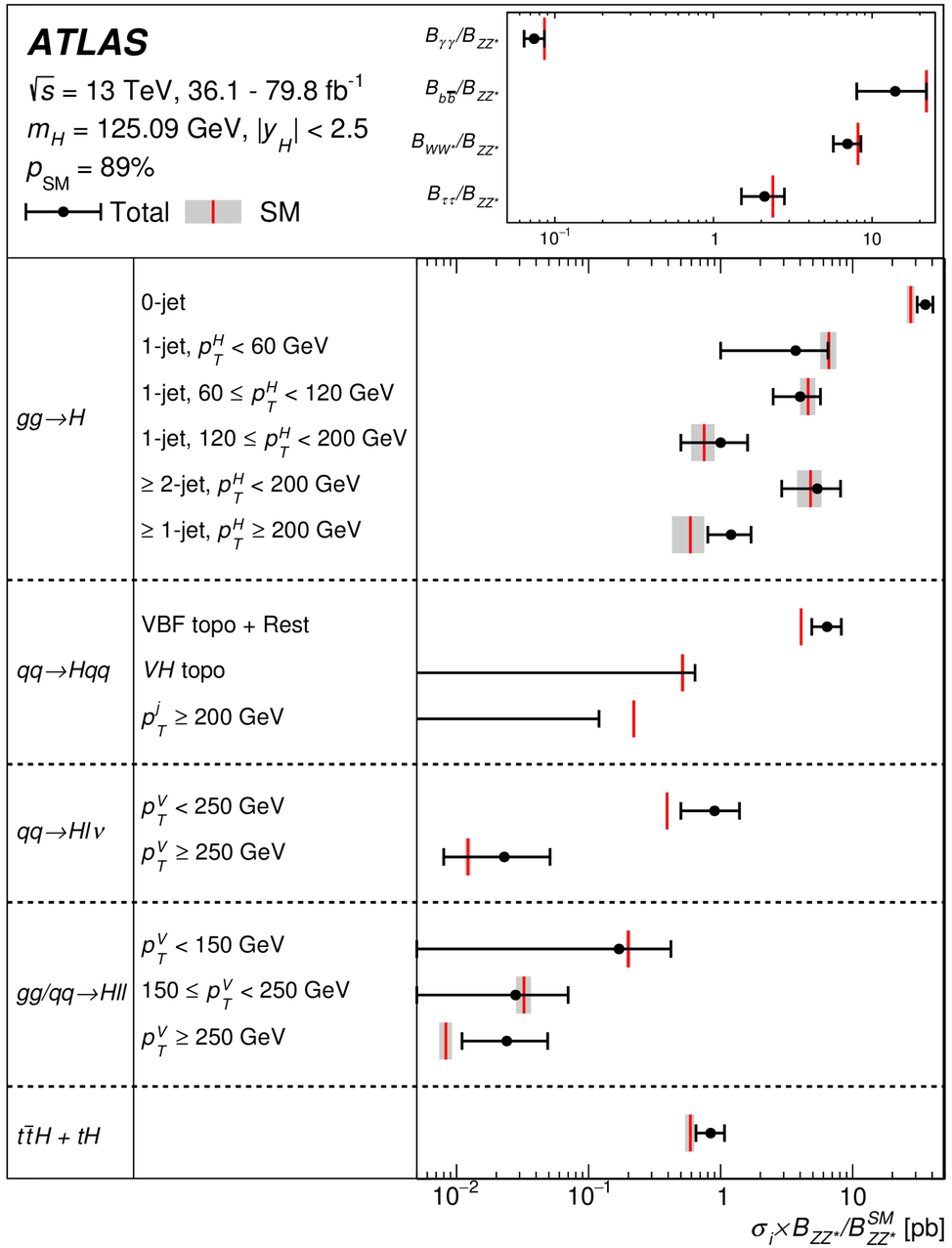



# STXS Cross-Sections

arXiv:1909.02845



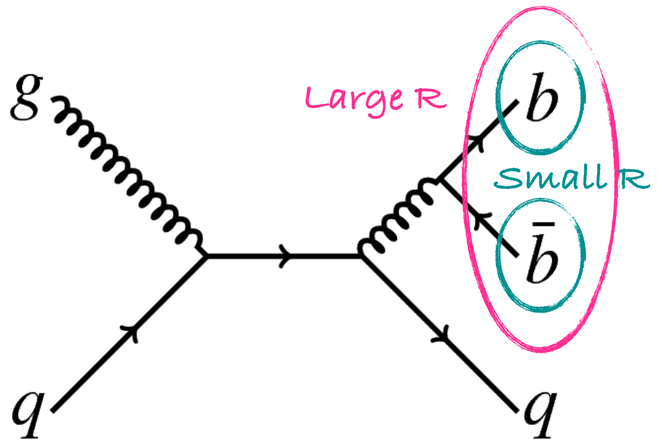

arXiv:1909.02845

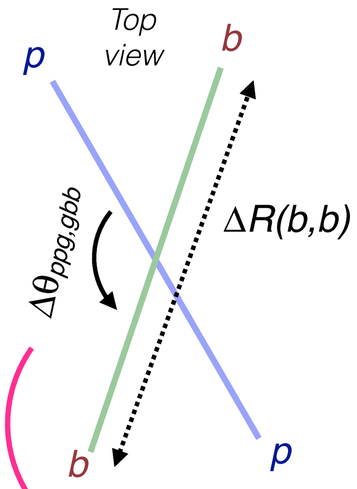


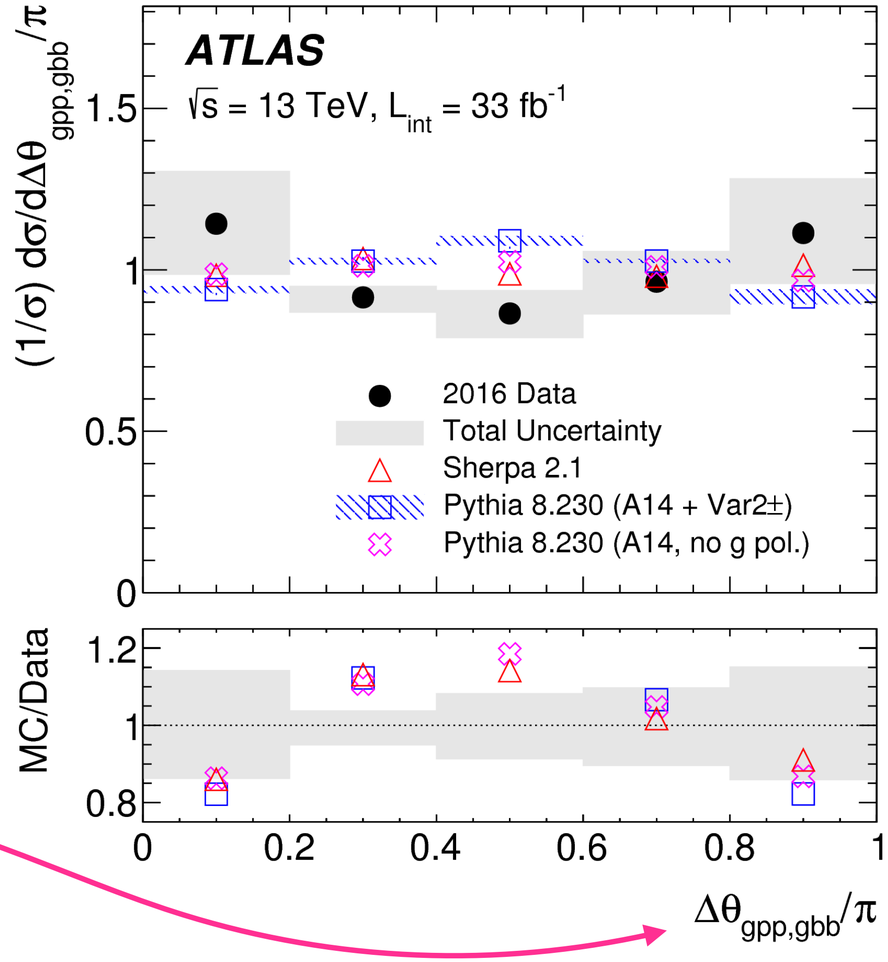
Phys. Rev. D 99 (2019) 052004

# Multiscale Dynamics: Gluon splitting

- Select sample rich in g➛bb by large radius jet with 2 small radius sub-jets, at least 1 b-tag
  - Probe quantities related to b-b system



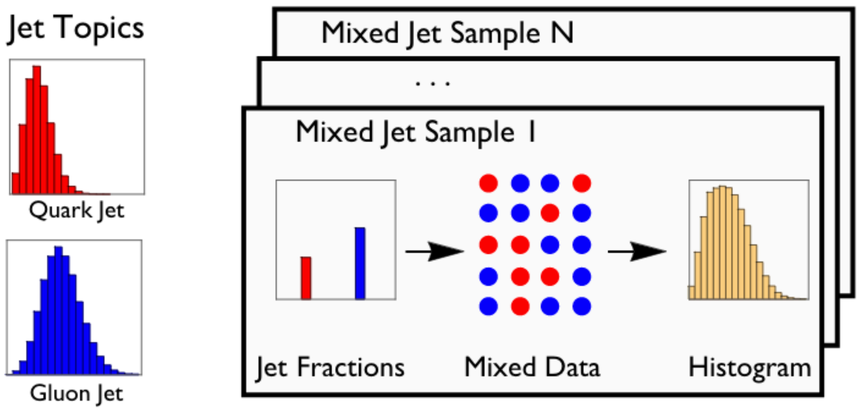



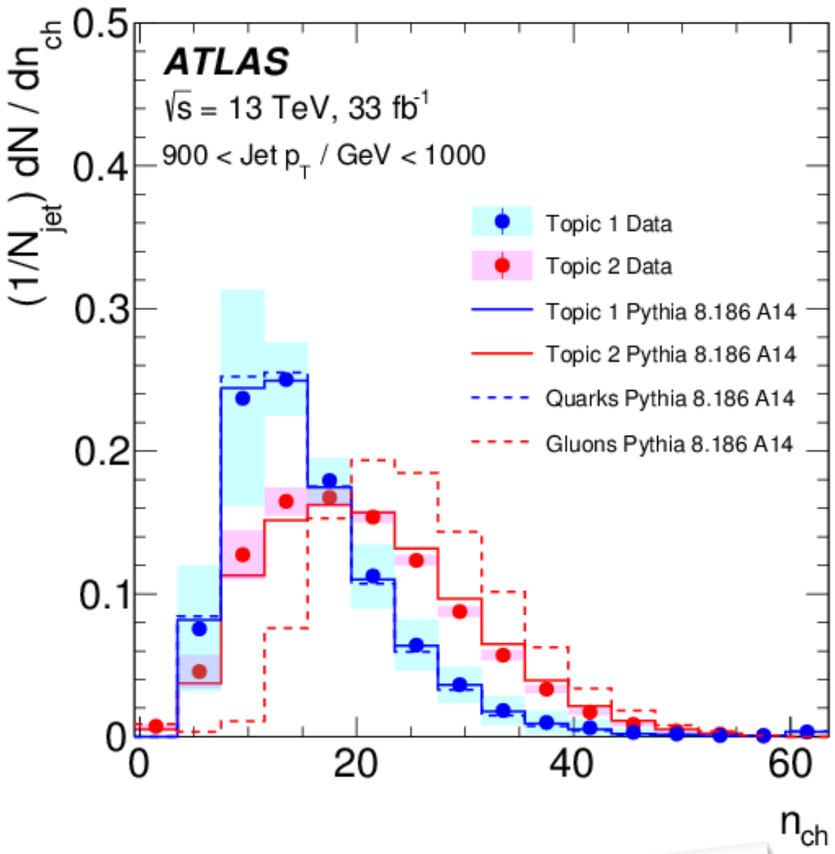

- Data shows significant deviation from models in angle related to gluon polarization (largely unconstrained from prior data)

# Multiscale Dynamics: Jet Constituent Characteristics

- By exploiting the fact that forward jets tend to be quark dominated, can extract *in situ* quark & gluon distributions
  - Utilize ML technique, topic modeling, to extract distributions without dependence on MC models




Phys. Rev. Lett. 120, 241602 (2018)




- Paper has detailed comparisons of jet fragmentation quantities in forward and central regions, compares q/g distributions extracted with MC fractions to N$^3$LO predictions

Data topic 2 (gluon-*like*) matches topic 2 extracted from MC, but not parton matched MC due to some quark contamination

# Q/G Jet Extraction

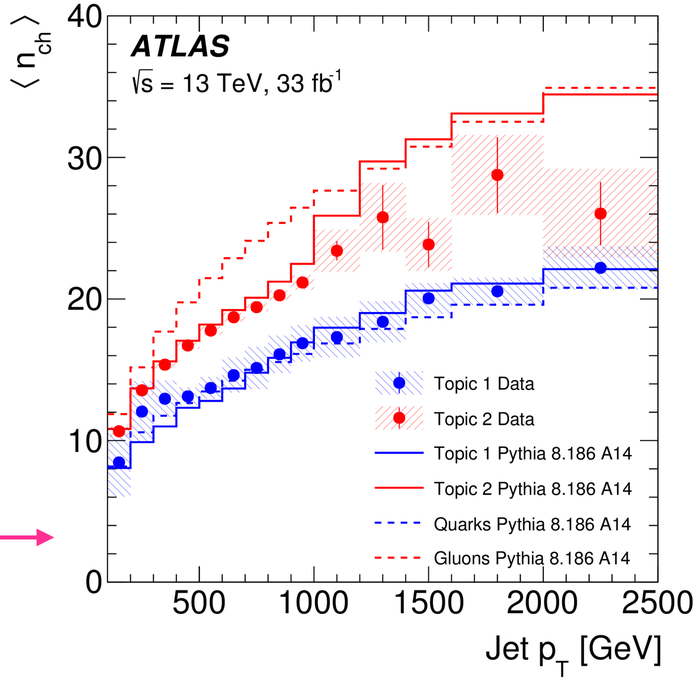
arXiv:1906.09254

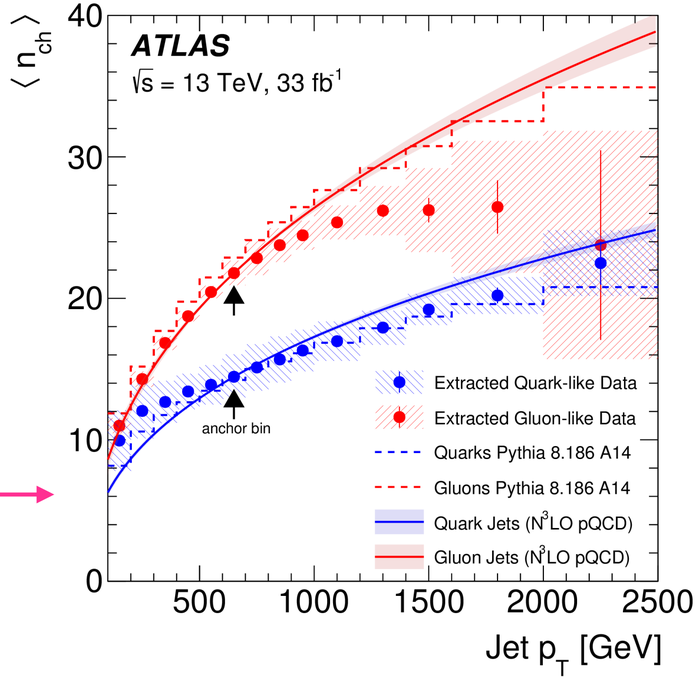
- Topics converge to quark/gluon definitions in the case that there are some bins in the dataset which are purely quark or purely gluon
  - Basically true for quarks, not quite true for gluons, but converges at high pT
  - Only true for Nch
- Extraction relying on MC fractions shows good agreement with N3LO at low pT, diverges at high pT
  - Used for Nch & fragmentation variables

$$h_i^{T_1} = \frac{h_i^f - \left(\min_j\{h_j^f/h_j^c\}\right) \times h_i^c}{1 - \min_j h_j^f/h_j^c},$$

$$h_i^{T_2} = \frac{h_i^c - \left(\min_j\{h_j^c/h_j^f\}\right) \times h_i^f}{1 - \min_j h_j^c/h_j^f}.$$

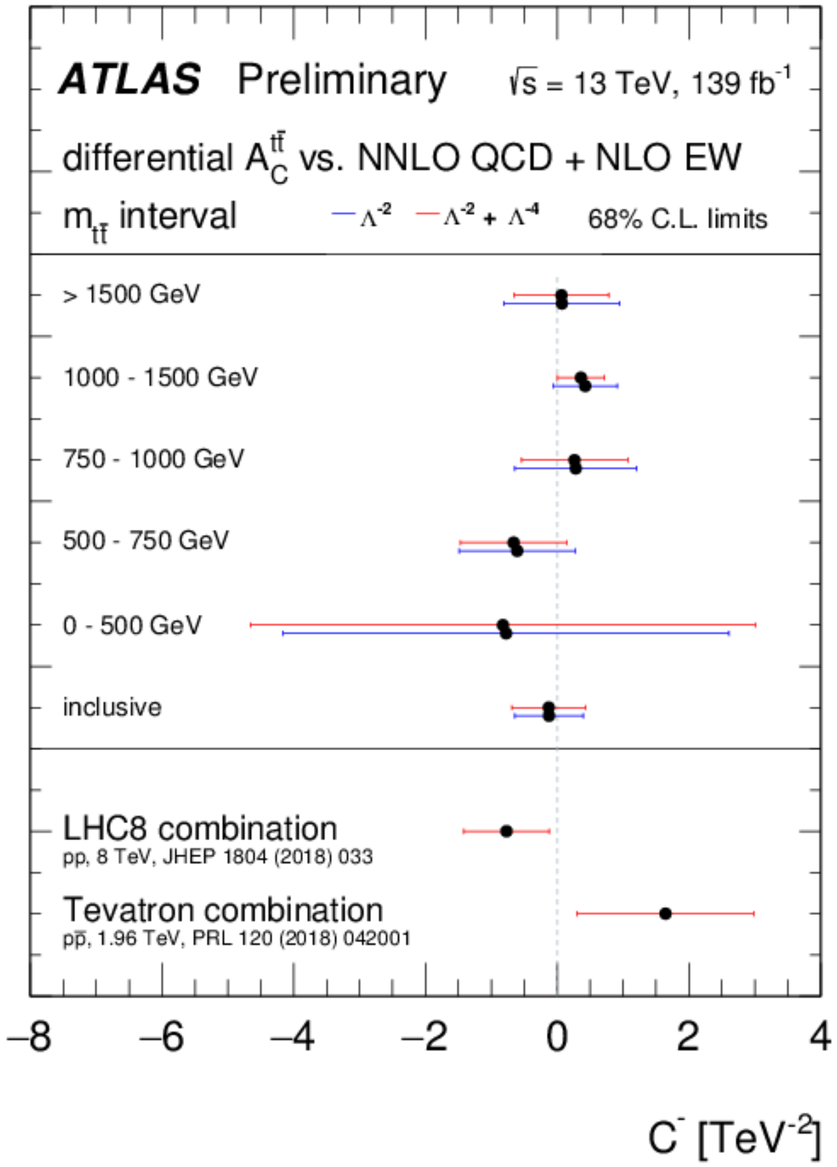
$$h_i^f = f_q^f h_i^q + (1 - f_q^f) h_i^g,$$
$$h_i^c = f_q^c h_i^q + (1 - f_q^c) h_i^g,$$

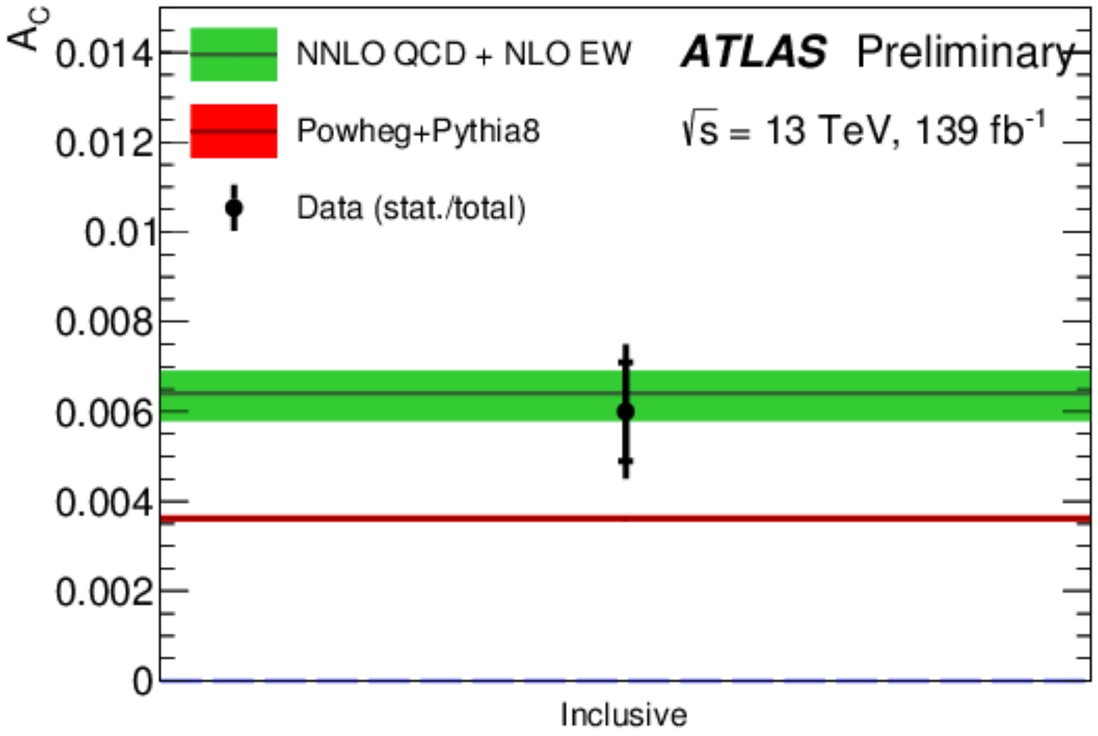


# Top Charge Asymmetry

ATLAS-CONF-2019-026

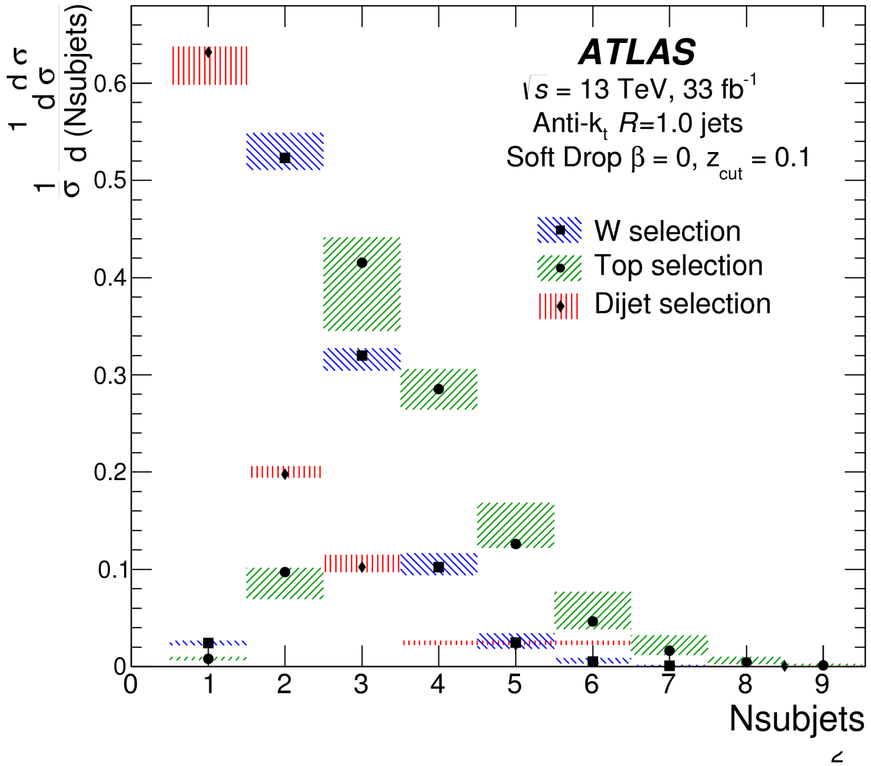


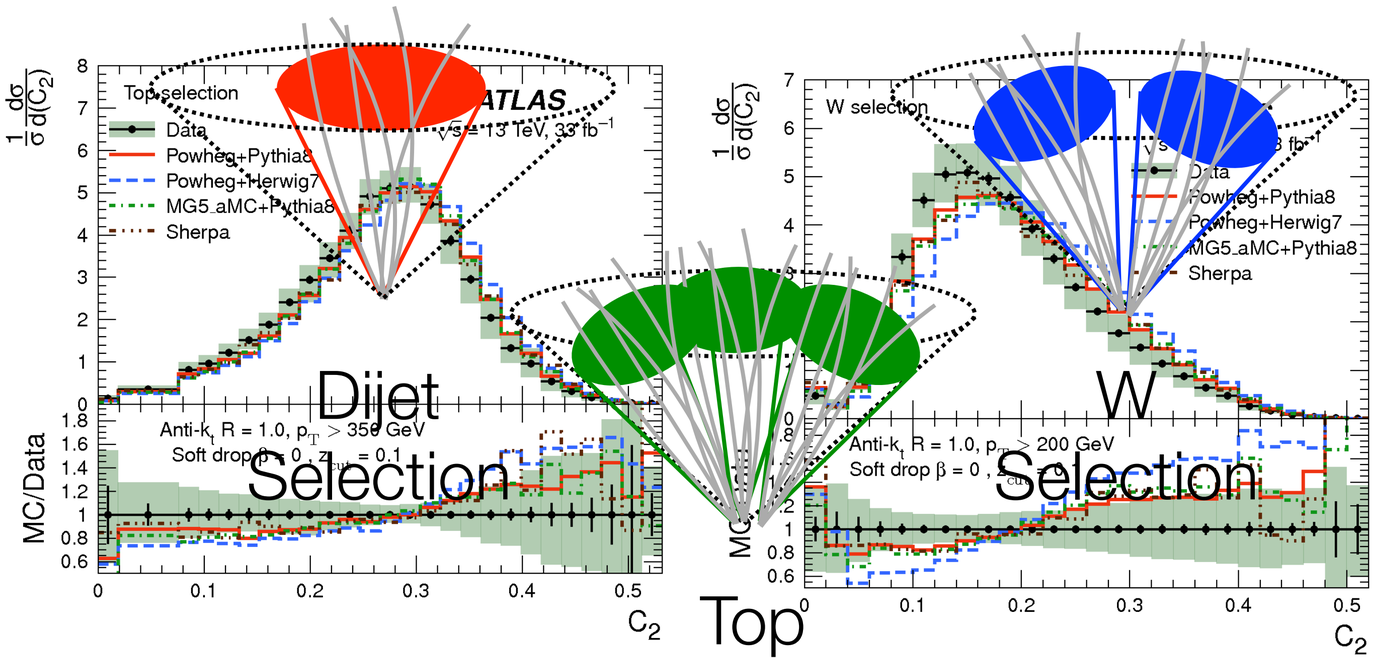



# Multi-scale: Jet production

arXiv:1903.02942

- ATLAS selects hadronic top, W and dijet events and compares jet substructure variables for data and standard generators




Dijet Selection

W Selection

Top Selection

C2 ref