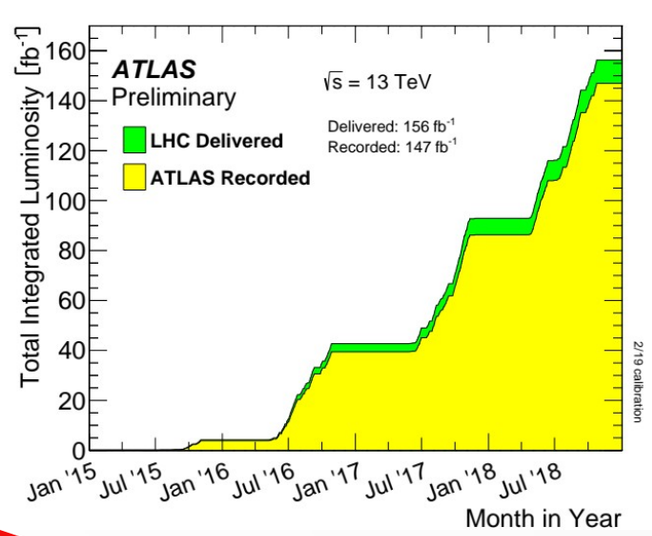
Physics with the ATLAS Experiment

Jan Kretzschmar
for the ATLAS Liverpool group
20 December 2019

The ATLAS Run 2 dataset

A unique opportunity to explore the energy frontier in diverse ways



Highlight the unique and leading contributions of ATLAS Liverpool members in the following

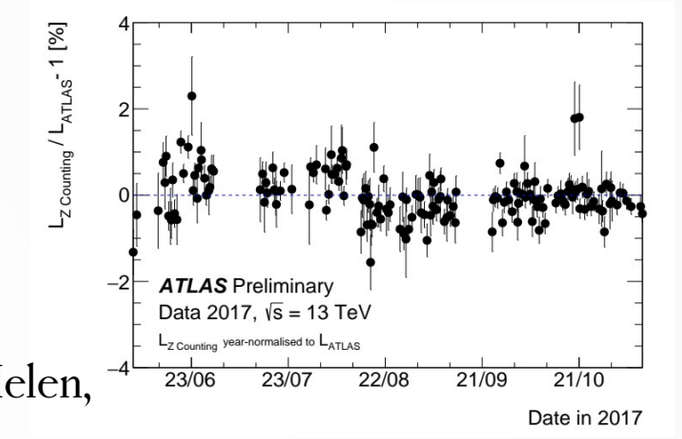
9 members of staff - Yanyan Gao left for Edinburgh (continued collaboration) - Carl Gwilliam appointed as new lecturer from Aug 2020

14 PhD students, a new PDRA starting on January 1st (Cristiano Sebastiani)

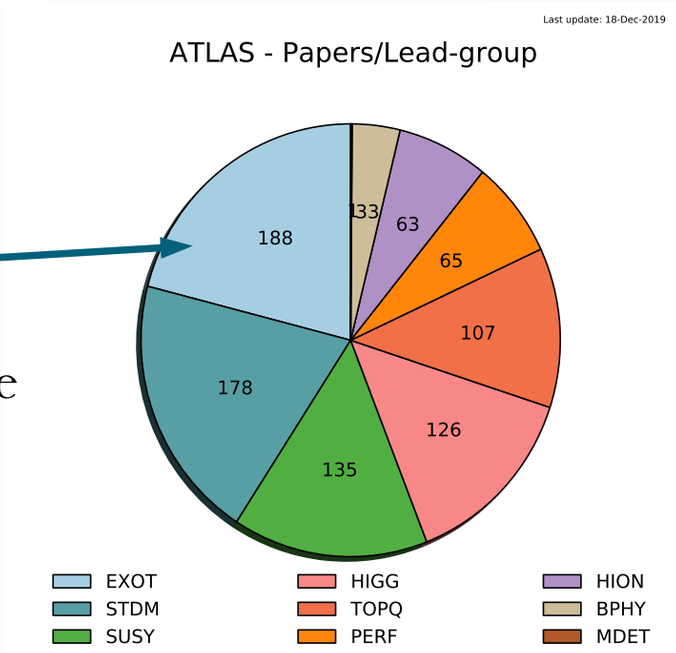
Fundamental Contributions and Leadership

- State-of-the art analyses enabled by ground work, e.g.
  - Tagging heavy-flavour jets (Nikos, Andy, Carl, Jordan (PhD))
  - Electron (Eliosa (PhD)) and Tau (Nikos) identification
  - Luminosity measurements (Uta, Jan, Michael (PhD), Harry (PhD))
  - Monte Carlo simulation (Jan, Monica, Harry (PhD))
  - Analysis software coordination (Andy)
  - SCT data acquisition, software, radiation damage, tracking simulation (Helen, Hanna (PhD)
  - Pileup simulation (Carl)

ATLAS-CONF-2019-02

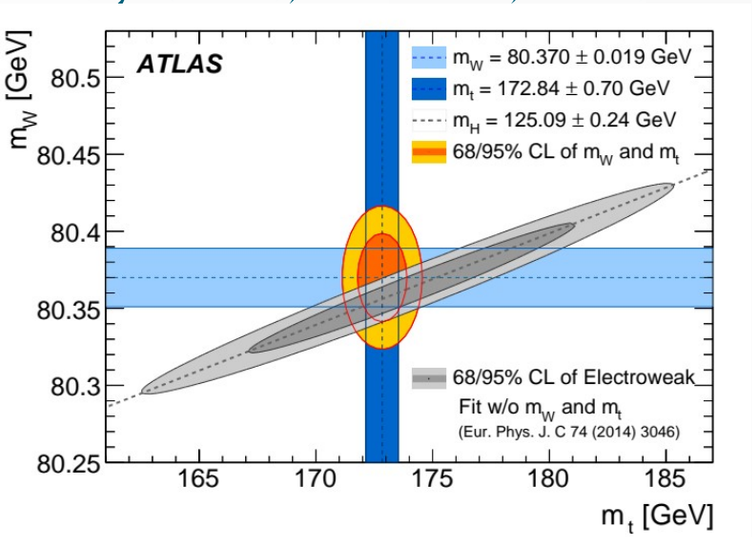


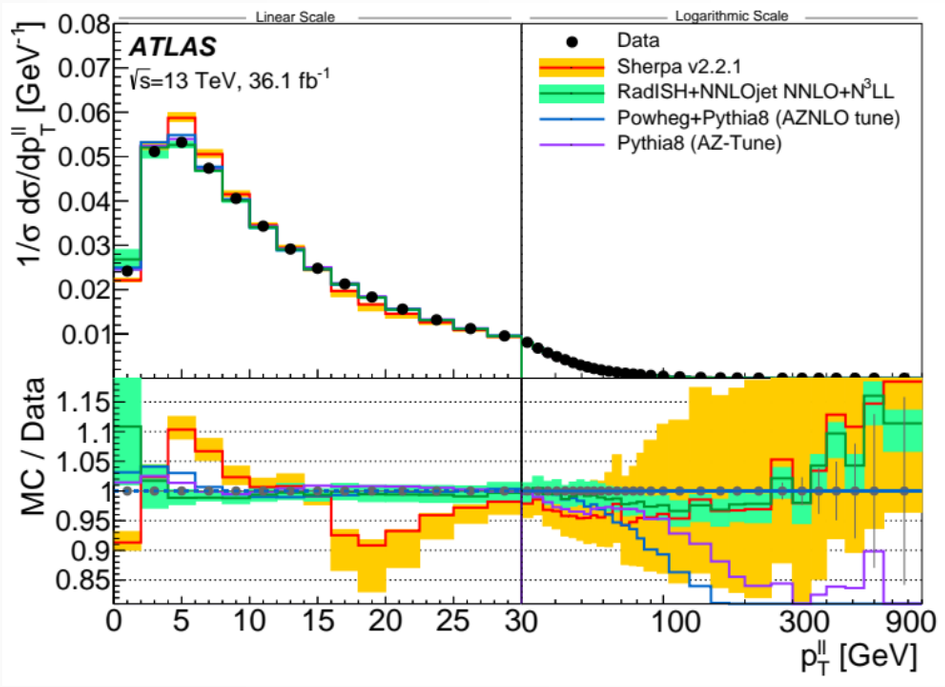
- Liverpool ATLAS members leadership positions in 2019:
  - Max: chair of Collaboration Board ("John Bercow" of ATLAS)
  - Carl: convenor of Exotic group
  - Uta: Speaker committee advisory board, Jan: Publication committee
  - Nikos: ATLAS NMSSM contact in the LHC HXSG
  - Monica: ATLAS coordinator for HL-LHC Beyond SM physics
  - Major contributions and leadership in ATLAS Upgrade → Jon's talk



Electroweak Precision Measurements (Harry (PhD), Jan Uta, Max)

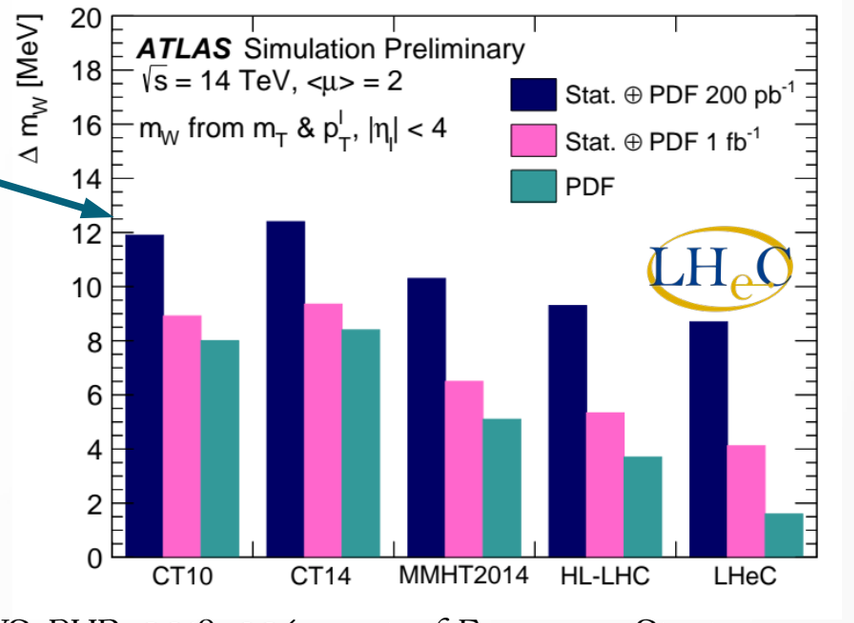
- W-boson mass important indirect constraint on new physics - but a "near impossible" measurement
- Working on supporting measurement towards $\Delta m_W \rightarrow 10$ MeV and prospect studies





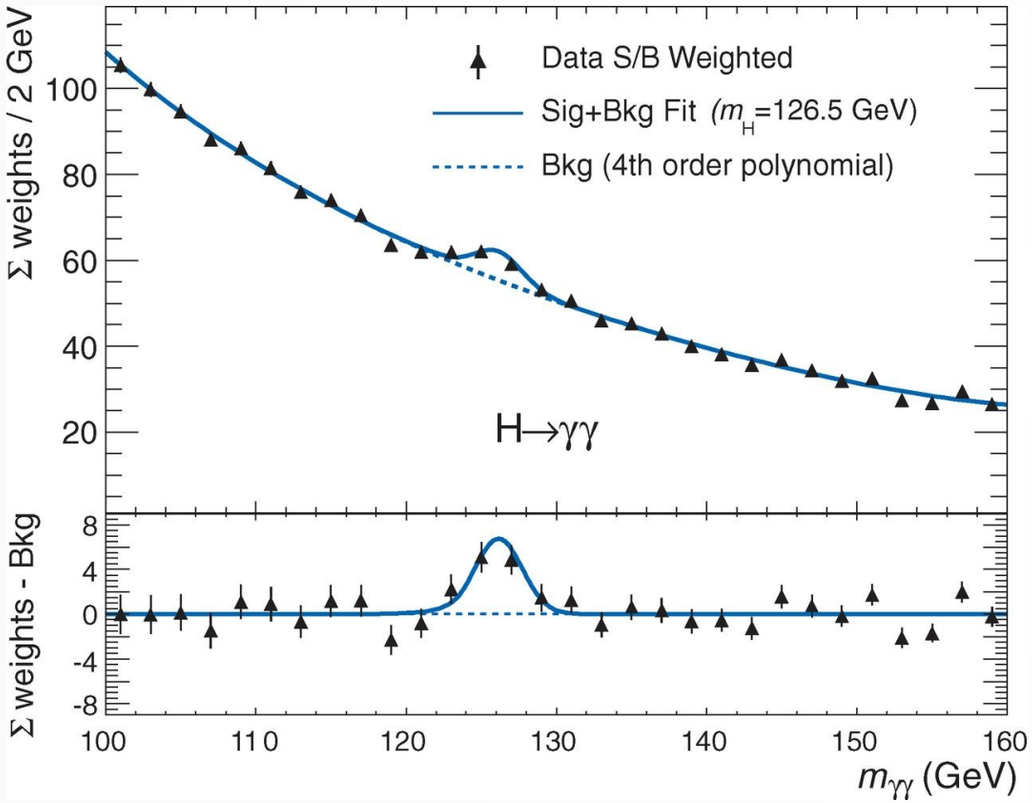
arXiv:1912.02844 (Uta (EB), Jan, Harry (Rivet, tuning))

Soon

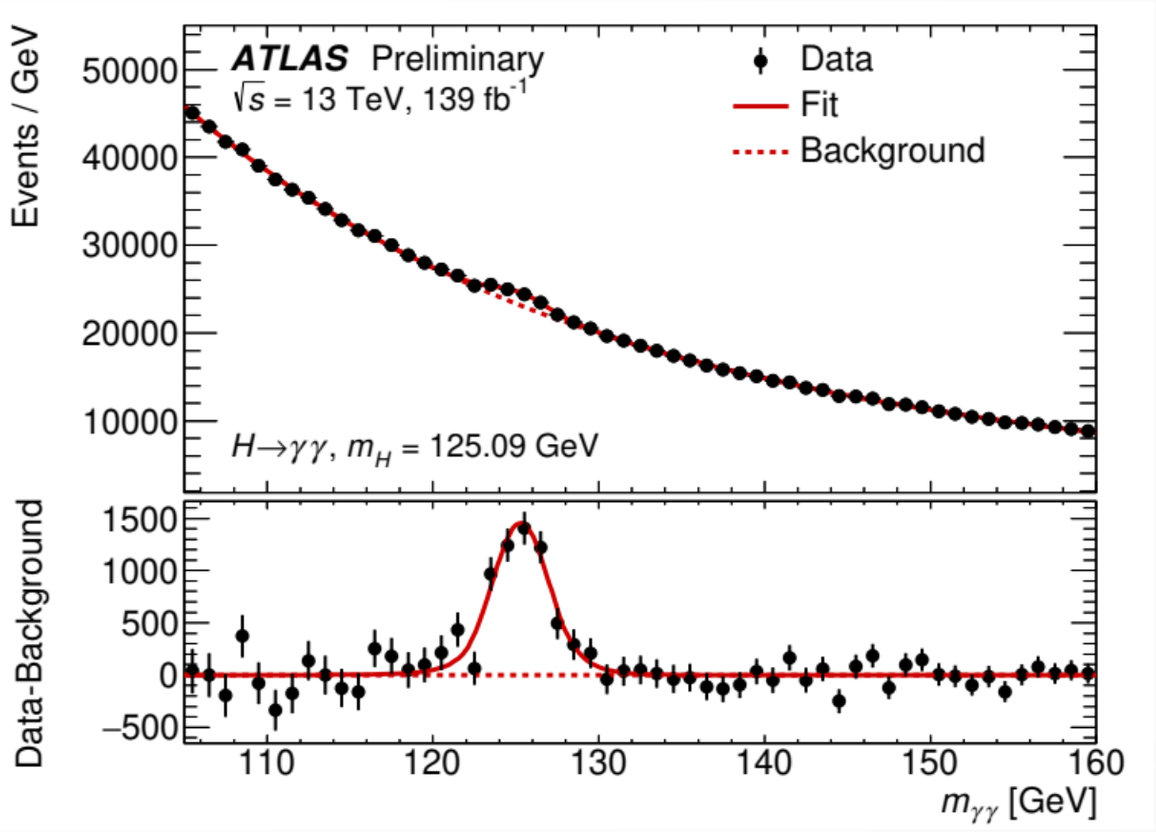


ATL-PHYS-PUB-2018-026, part of European Strategy submission for HL-LHC, arXiv:1902.04070 (Jan)

The Higgs Boson - From discovery to measurements

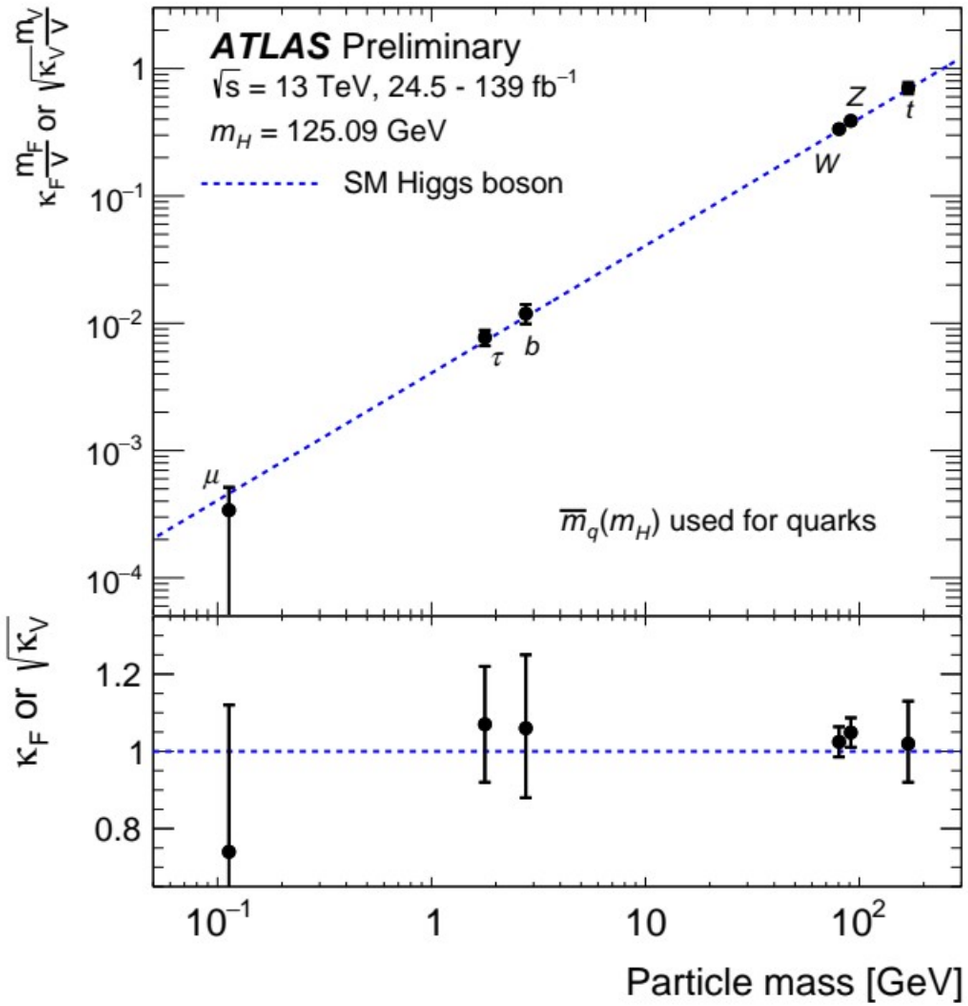


Summer 2012



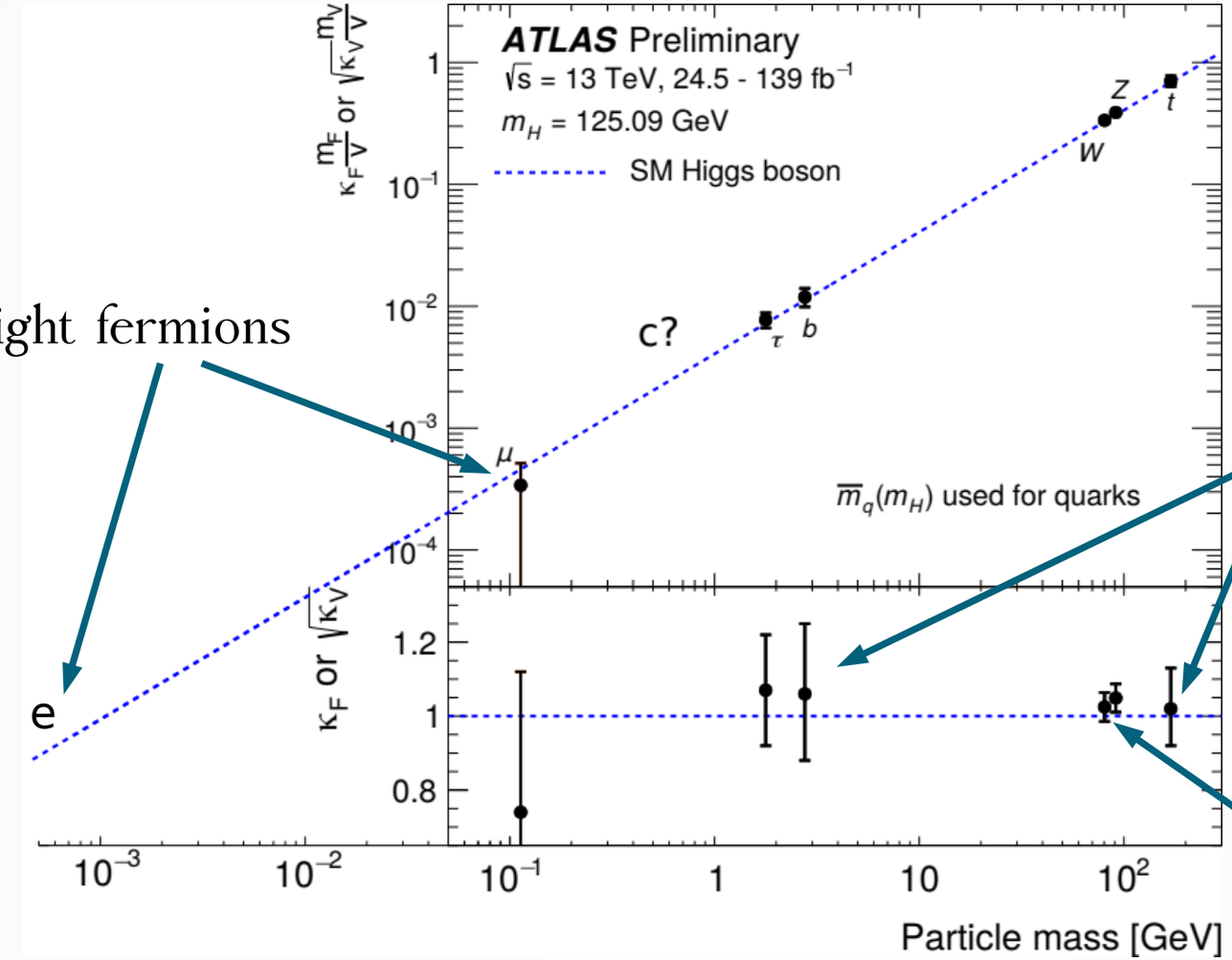
Summer 2019

The Higgs Boson - From discovery to measurements



State-of-the-art characterisation of the Higgs Boson arXiv:1909.02845

The Higgs Boson – Back to discoveries?



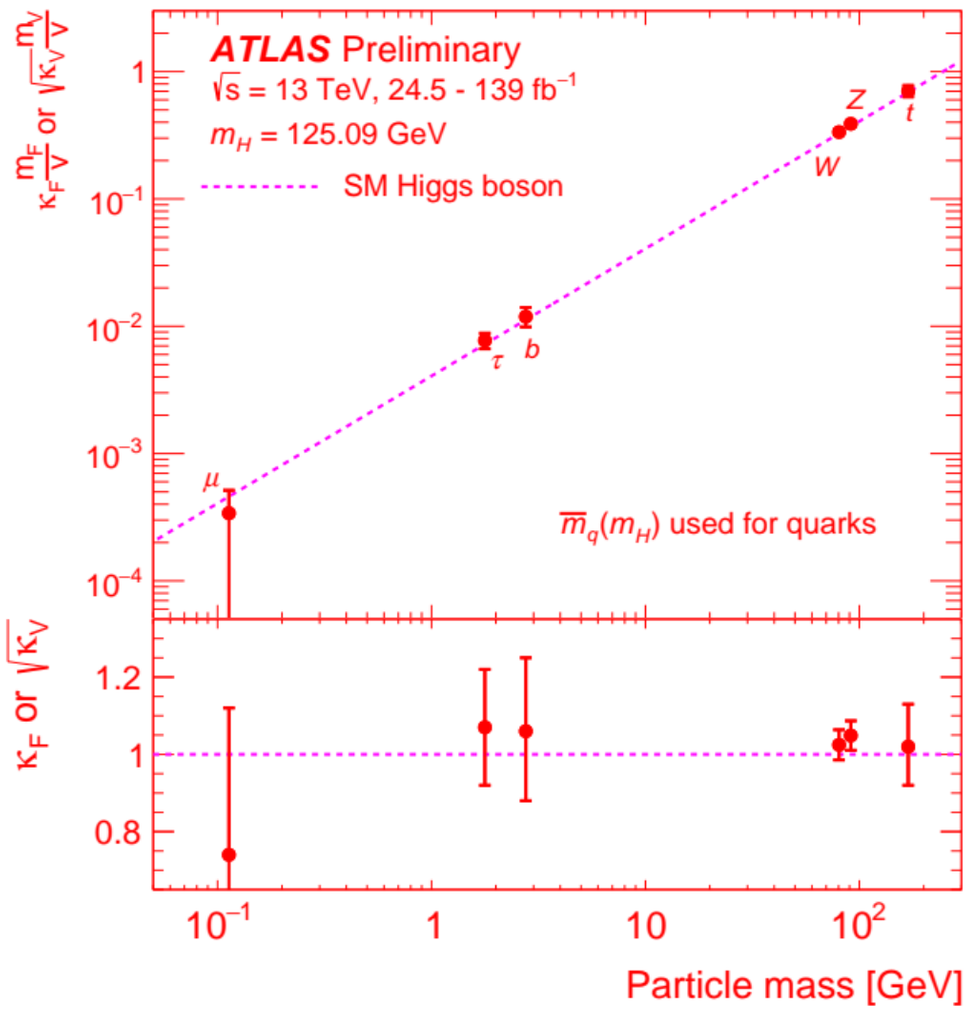
Frontier: light fermions

Just beyond observation: heavy fermions

"Precision" era: ~5%

Leading Liverpool contributions to many SM Higgs analyses and their review:
Andy (bb, μμ, ee), Monica (ttH), Jan (γγ, μμ, ee), Uta (γγ), PhD: Hanna (μμ, ee)

The Higgs Boson – Back to discoveries?



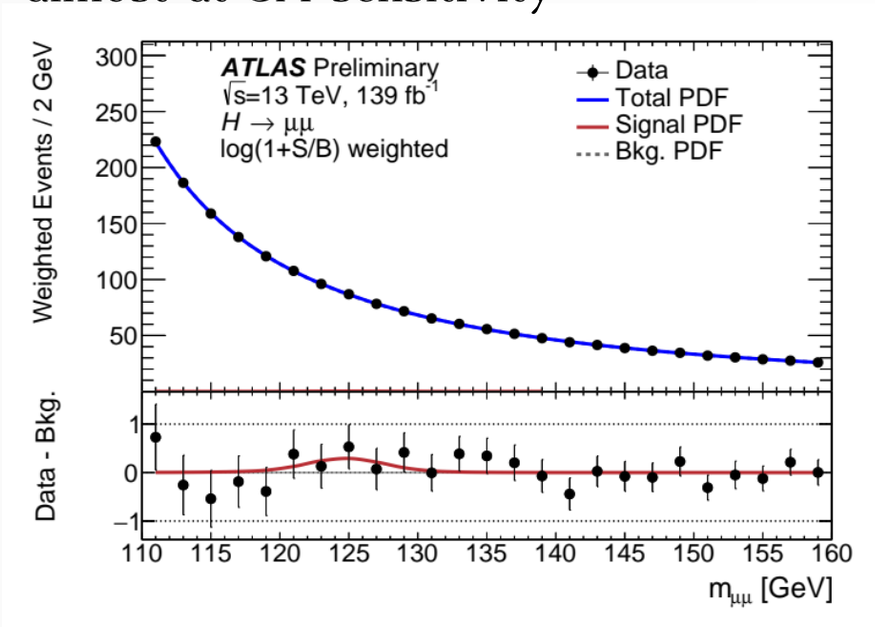
Use the Higgs boson as "tool" for direct discovery of physics beyond the SM

Carl, Monica, Andy, Nikos, Uta, Jan

PhDs: Hamish, Matt, Eloisa, Alessandro, Alan, Emily, Jordan, Joseph

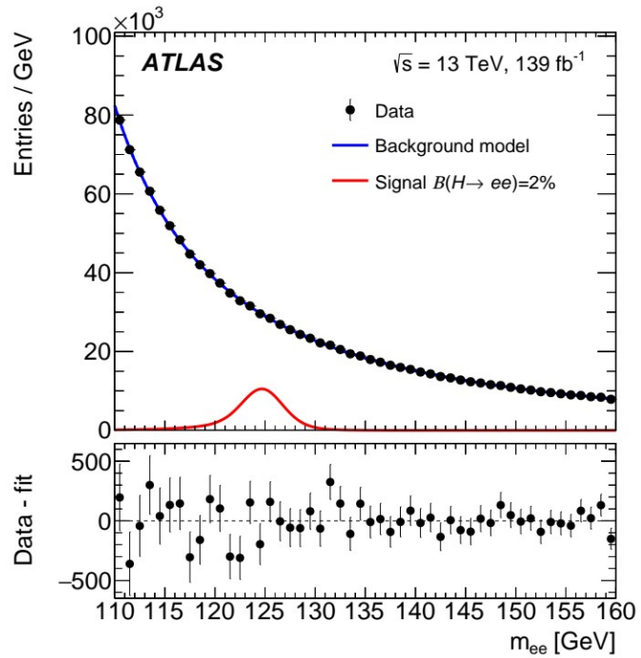
Higgs frontier: light leptons and flavour violation

Br(H → μμ)/exp. SM = 0.5 ± 0.7
- almost at SM sensitivity

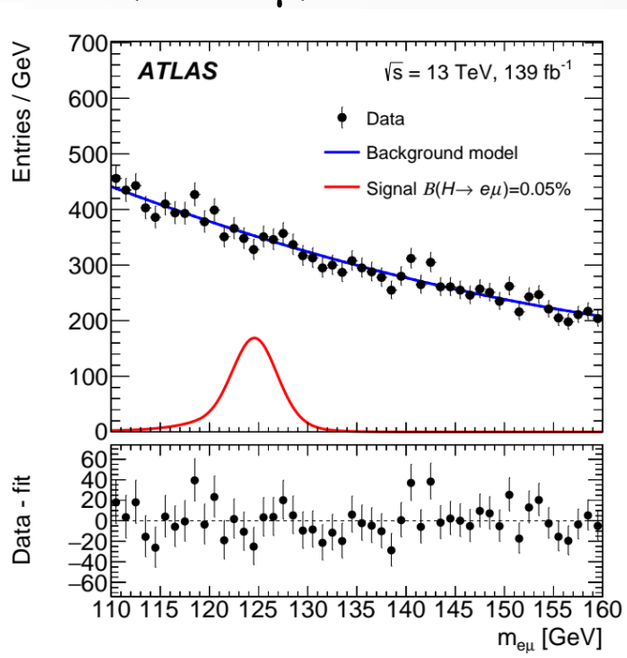


ATLAS-CONF-2019-028 (Jan, Andy, Hanna (PhD))

Br(H → ee) < 3.6·10⁻⁴



Br(H → eμ) < 6.1·10⁻⁵



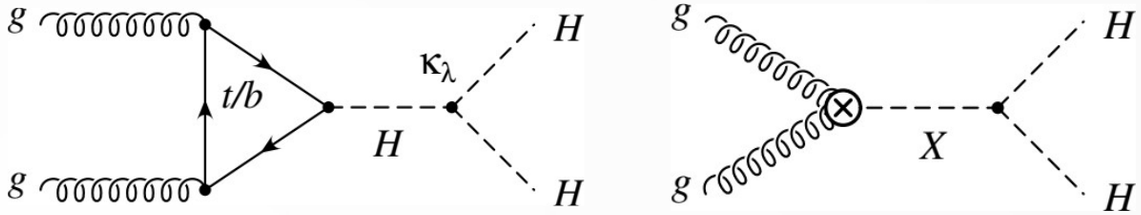
Phys. Lett. B 801 (2020) 135148 (Andy, Jan, Hanna (PhD))

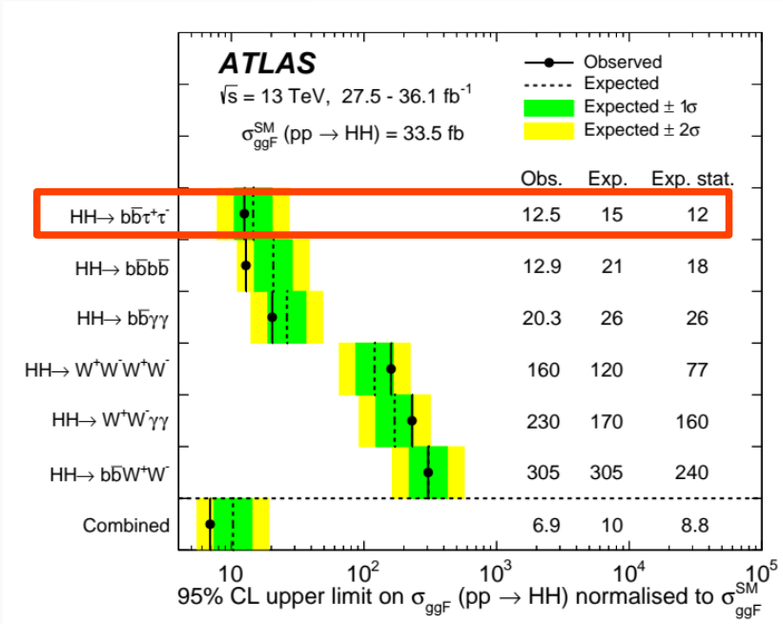
- Among the first ATLAS Higgs analyses on full Run 2 dataset; world-leading sensitivity
- Results on lepton-flavour violating decays complement low-energy precision studies
- Work ongoing on eτ, μτ channels (Uta, Carl, Joseph (PhD))

Higgs-boson Pair Production

- Exploring the Higgs potential + search for new resonances X

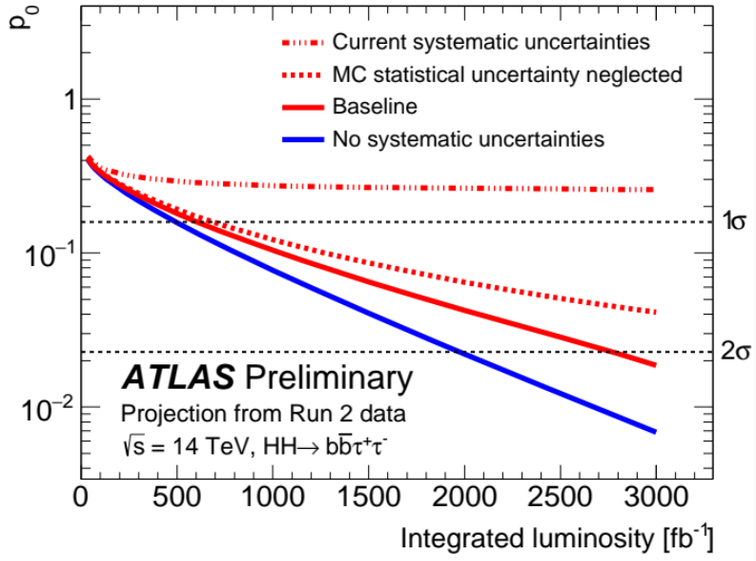
$$\mathcal{L} = \tfrac{1}{2}\left[(\partial_\mu - igA_\mu)(v+h)(\partial^\mu + igA^\mu)(v+h)\right] + \tfrac{1}{2}\mu^2(v+h)^2 - \tfrac{1}{4}\lambda(v+h)^4 - \tfrac{1}{4}F^{\mu\nu}F_{\mu\nu}.$$





Phys. Lett. B 800 (2020) 135103 (Carl, Nikos, Andy, Emily (PhD))

Higgs-boson pair-production potential at HL-LHC

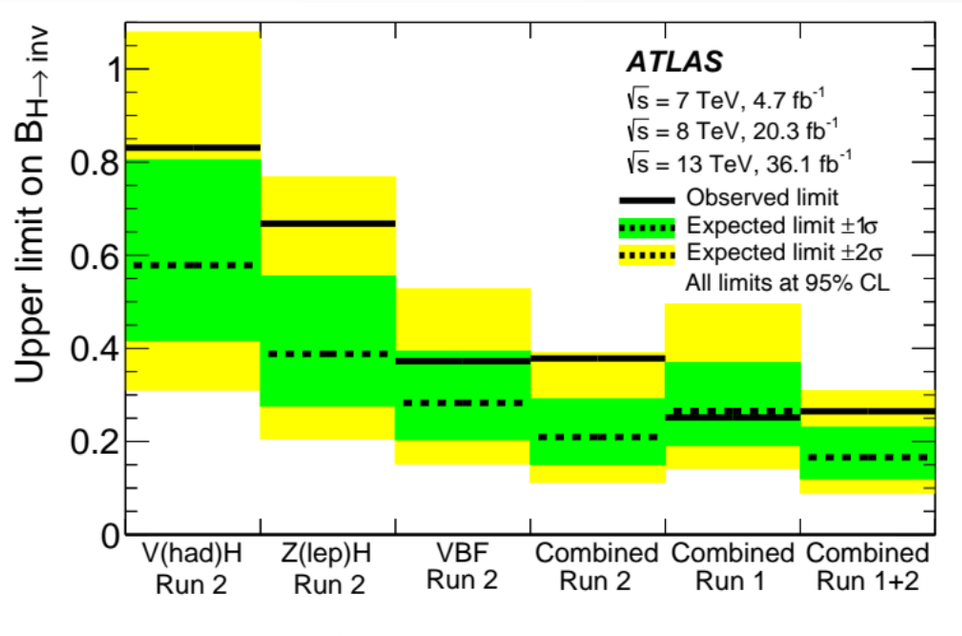


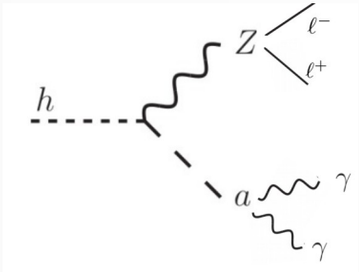
ATL-PHYS-PUB-2018-053, part of European Strategy submission for HL-LHC, arXiv:1902.00134 (Carl)

- World-leading sensitivity, esp. through $b\tau b\tau$ analysis by Liverpool, work on full Run 2 Analysis (Carl, Nikos, Jordan (PhD))
- Work on full Run 2 A→ZH (Nikos, Alan (PhD)

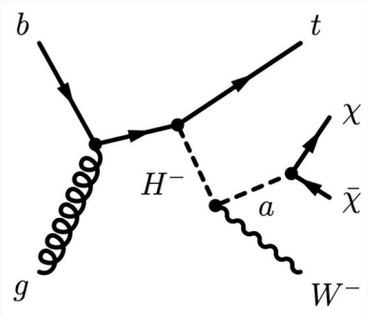
Higgs bosons as Portal to Dark Matter

- Direct constraints on Br(H→invisible) < 20% - significant room for coupling to new physics
- The group is covering a wide variety of different signatures

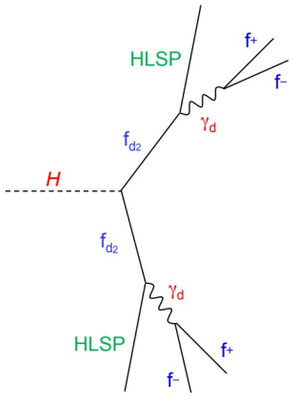




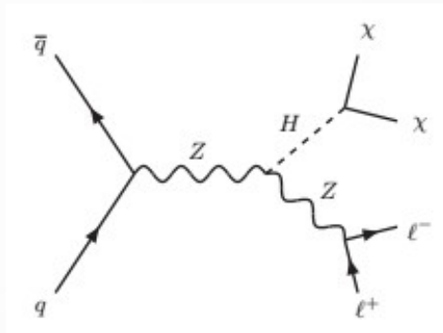
Axions from Higgs decays:
Nikos, Sergey, Adam R. (PhD)



Dark matter with top-quarks:
Monica, Matt (PhD), Hamish (PhD)

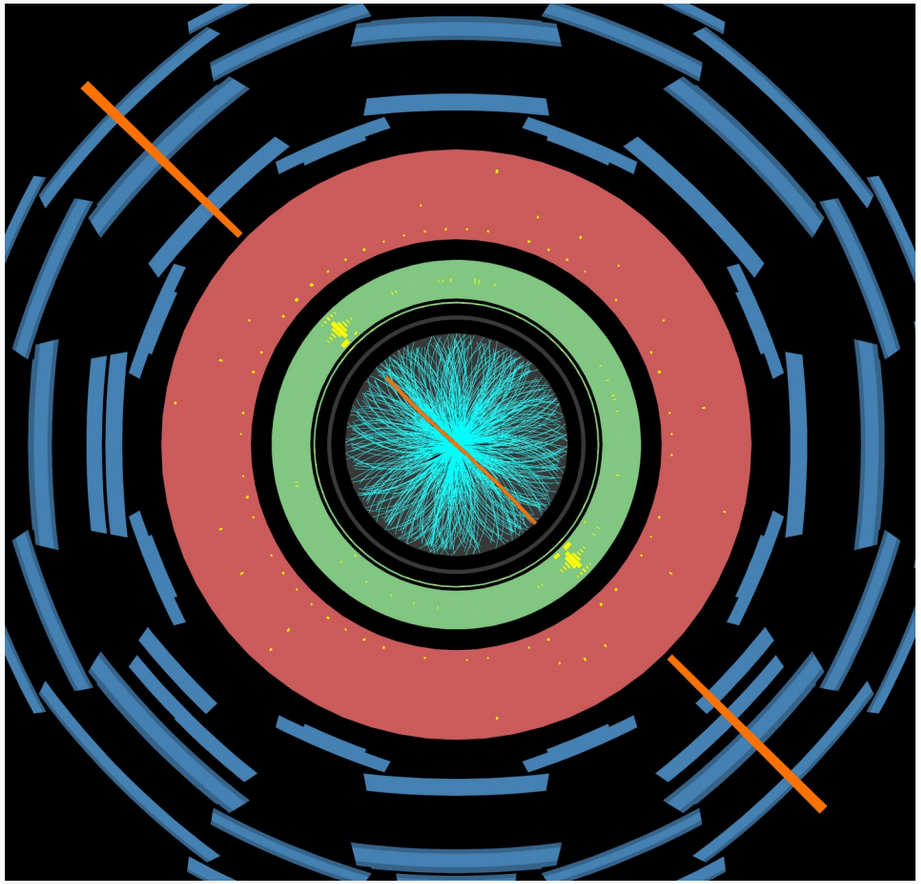


Dark photons from Higgs decays:
Monica, Alessandro (PhD)



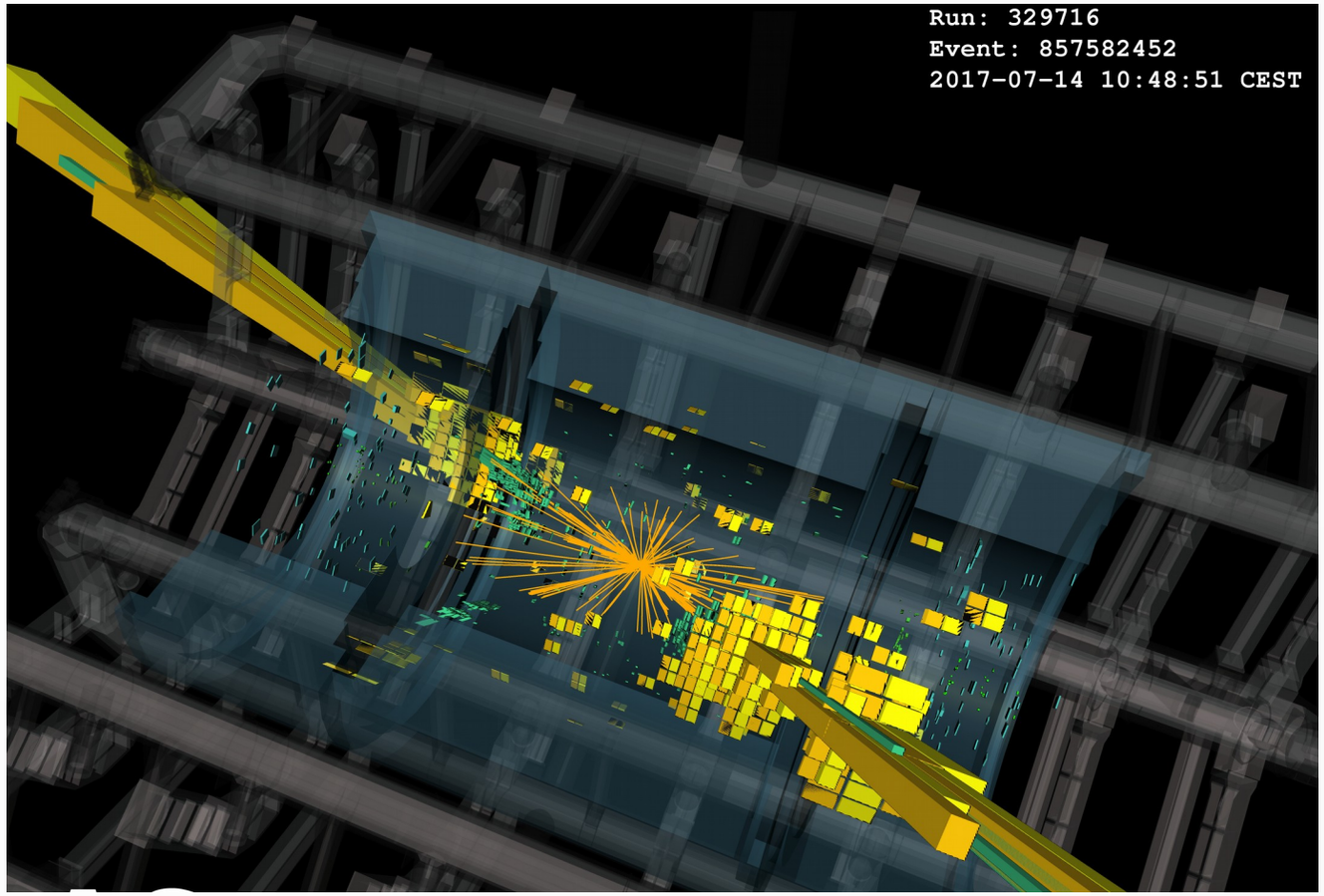
Higgs to Dark matter/invisible:
Monica, Andy, Eloisa (PhD)

High-mass resonances



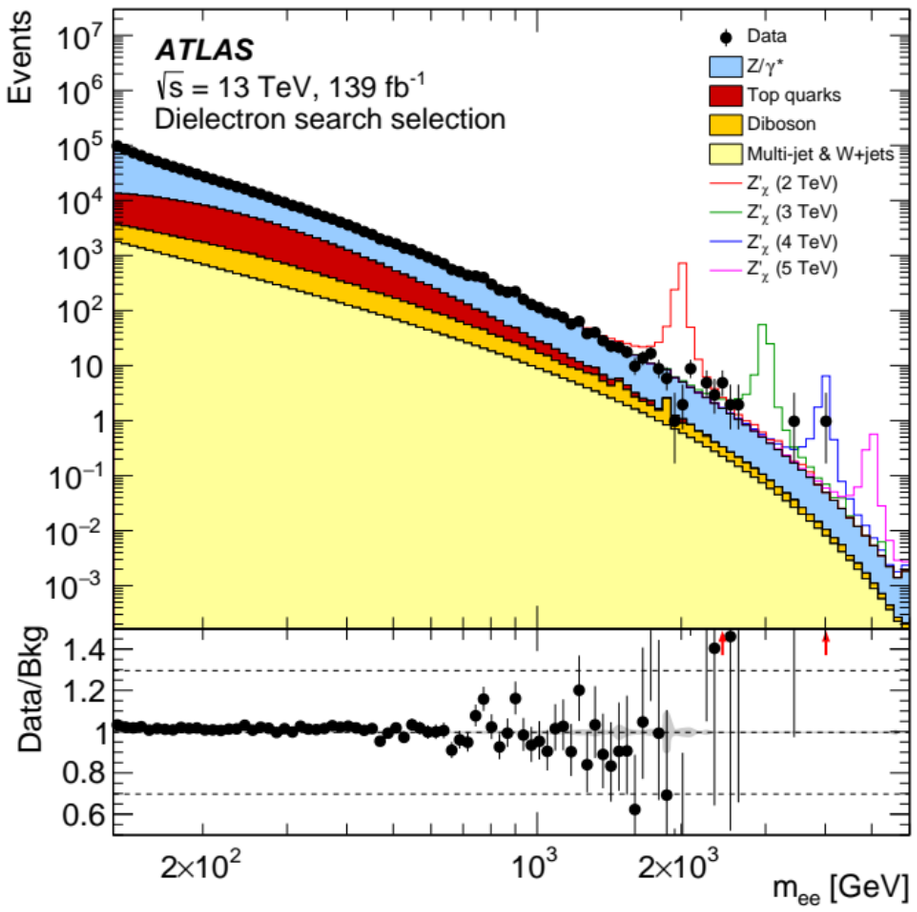
Di-electron event m_{ee}=4.1 TeV

Di-jet event m_{jj}=9.5 TeV



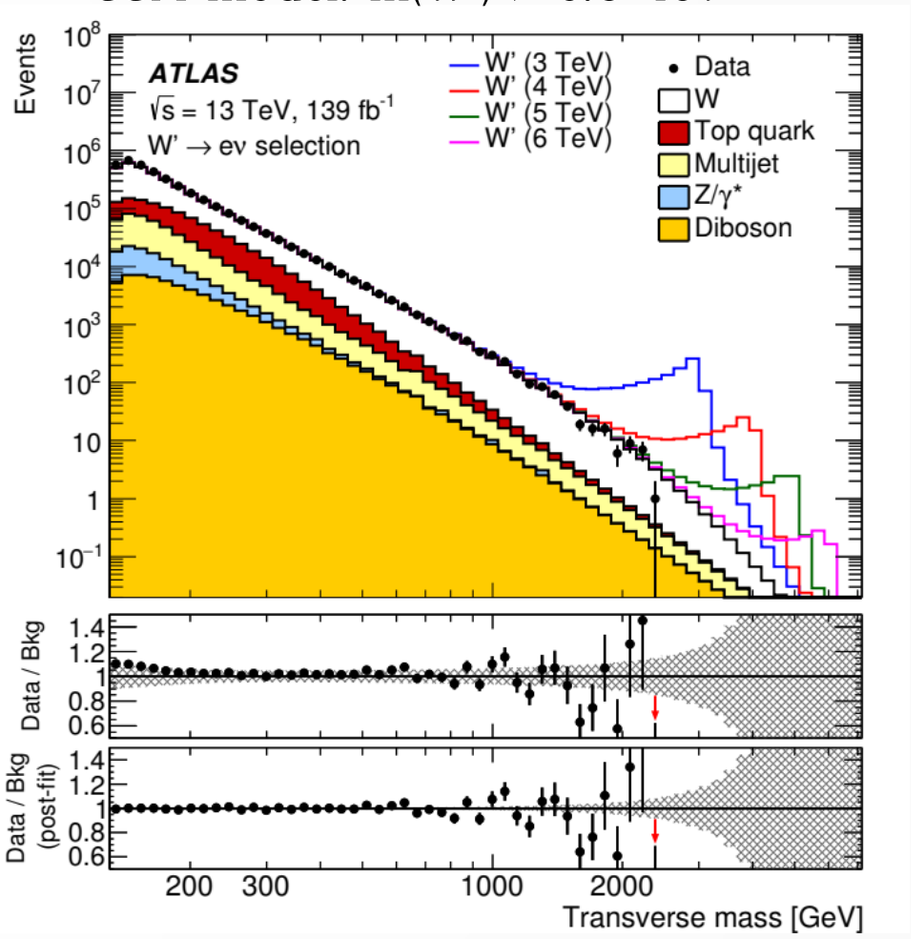
High-mass resonances

SSM model: m(Z') > 5.1 TeV



Phys. Lett. B 796 (2019) 68 (Uta)

Liverpool lead on electron channel
SSM model: m(W') > 6.0 TeV

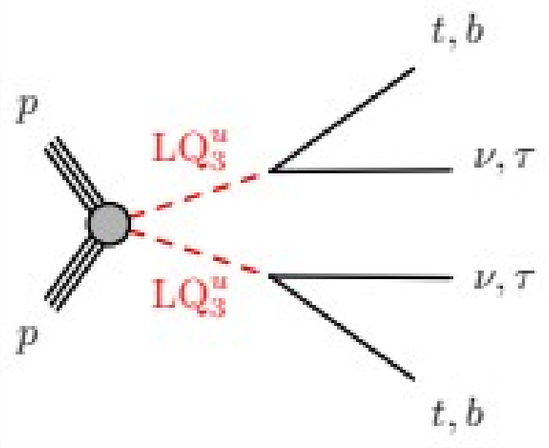


Phys. Rev. D 100 (2019) 052013 (Uta, Michael (PhD))

- Extending analyses to search for non-resonant signals, measure high-mass cross sections, EFT analysis (Uta, Jan, PhD: Michael, Ricardo)

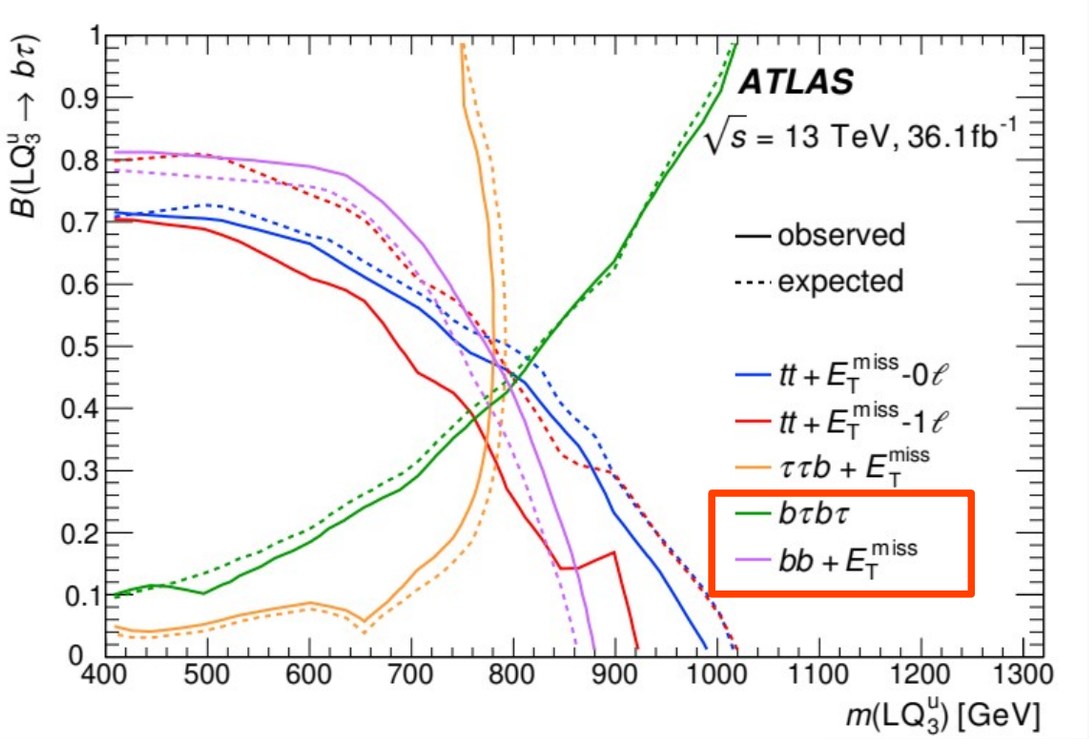
Leptoquarks

- Connection of lepton and quark sector?
  3rd generation LQs may provide explanation for flavour anomalies



- Summary paper with world-leading sensitivity and strong Liverpool contributions on $b\tau b\tau$ and $bb+E_T^{miss}$

- Work ongoing on LQ analyses including 1st & 2nd and & 3rd generations as well as first time mixed LQ (Andy, Monica, Adam J. (PhD)

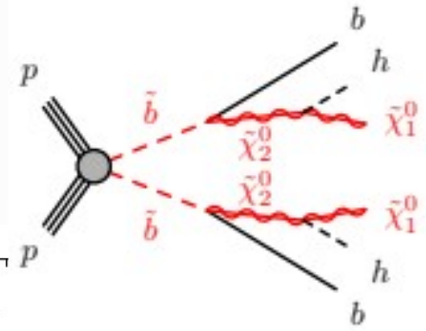


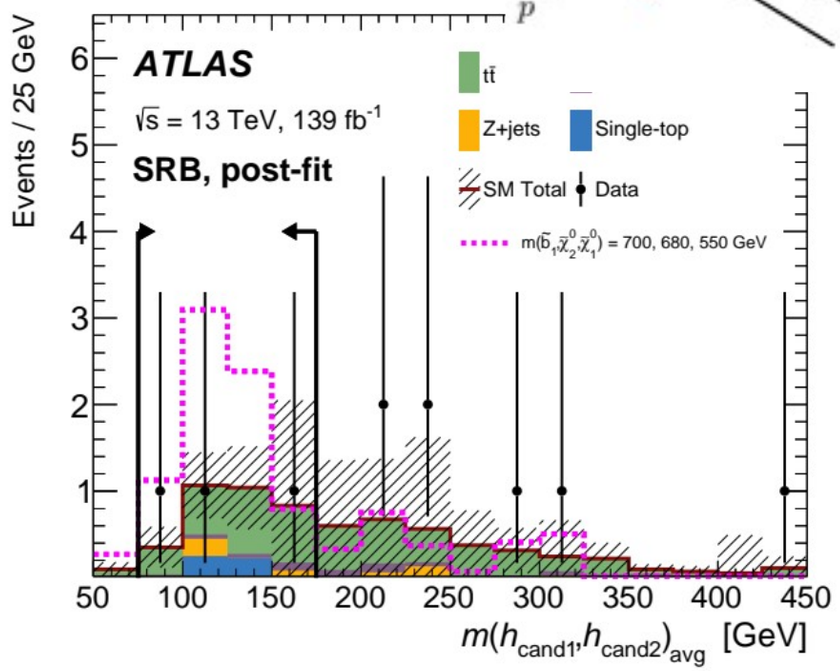
JHEP 06 (2019) 144 (Carl, Andy, Monica, Emily (PhD))

Supersymmetry

- A lot of activity on searches for SUSY: framework for searches with signatures typical of Beyond SM theories, candidate for Dark Matter
- Starting up: signatures with disappearing tracks (Helen, Monica, James (Phd)

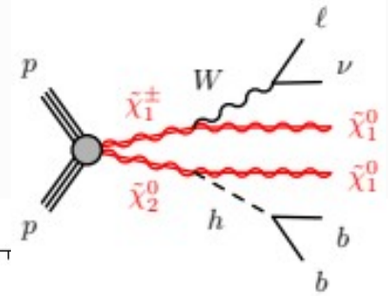
Sbottom decaying to final states with Higgs bosons

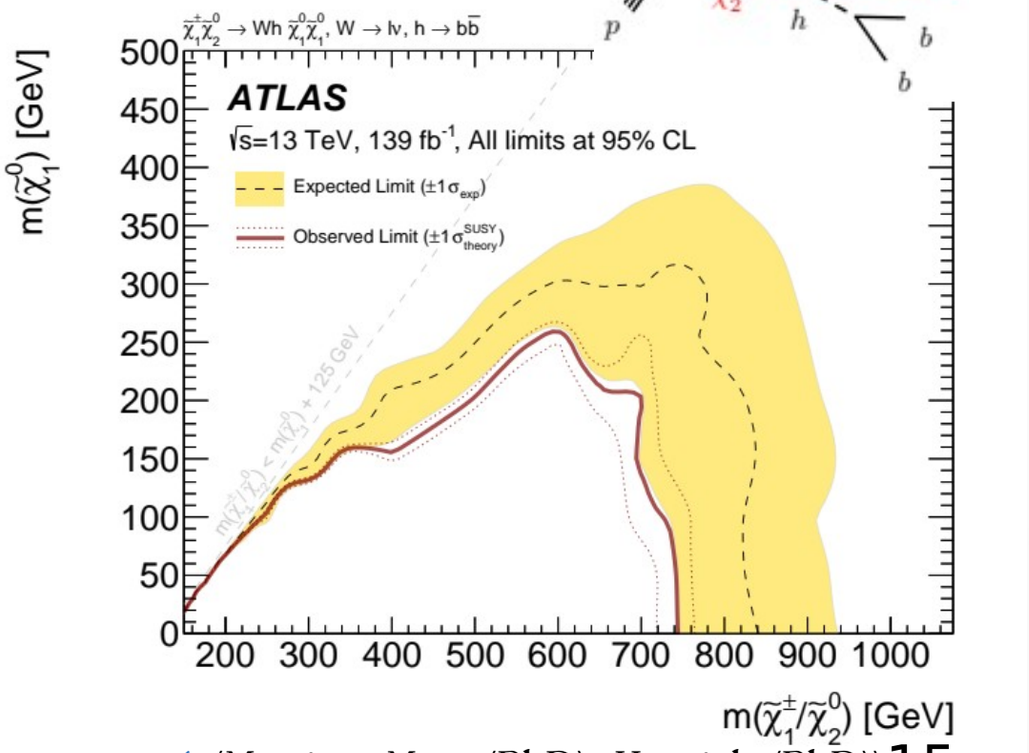




JHEP 12 (2019) 060 (Monica, Hamish (PhD))

Chargino-Neutralino production decaying to WH

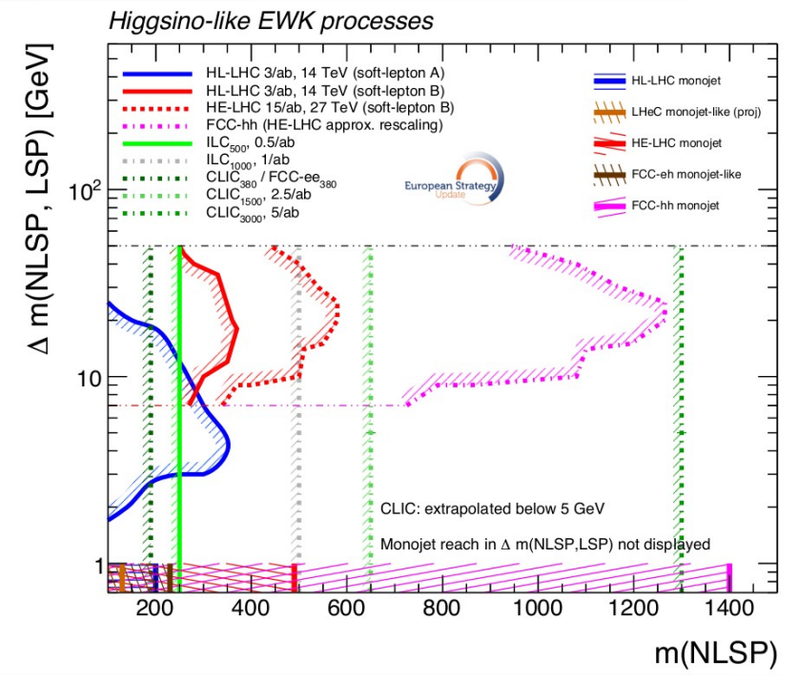


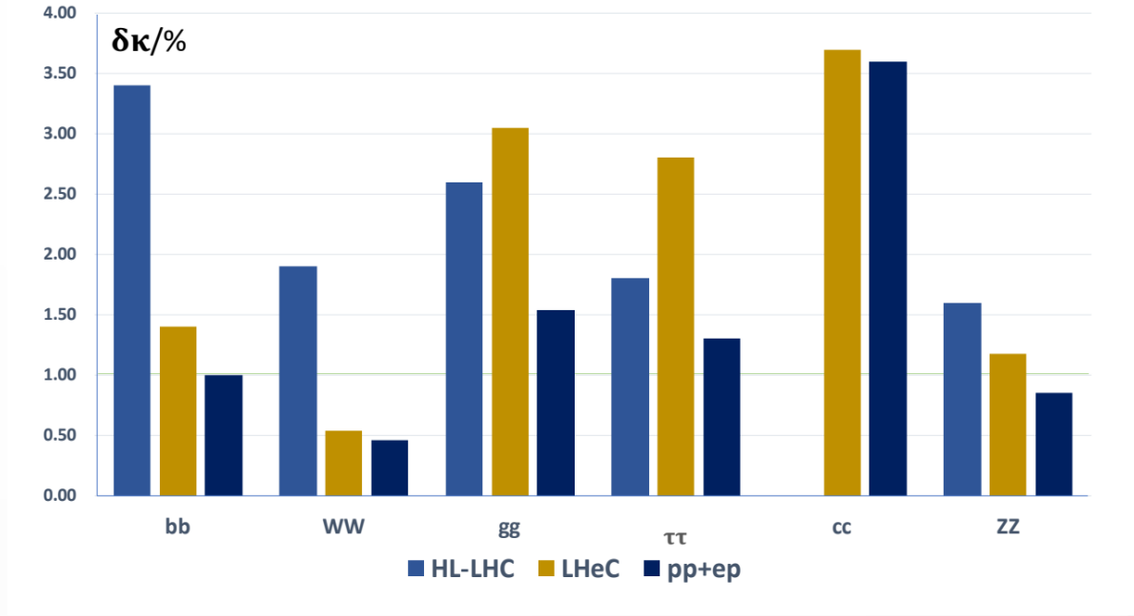


arXiv:1909.09226 (Monica, Matt (PhD), Hamish (PhD))

European Strategy and Future Collider Prospects

- LHeC: Project Leader Max, Convenors: Monica, Uta
  - Involvement of 5 UK institutes;
  - Collaboration on PERLE with Daresbury, Orsay, CERN, Jlab and others
- Vital contributions from Liverpool on physics studies for HL-LHC, HE-LHC and LHeC:
  - BSM report arXiv:1812.07831: Monica, Carl, Matt (PhD), Yanyan (now Edinburgh), Hamish (PhD)
  - SM report arXiv:1902.04070: Jan
  - Higgs report arXiv:1902.00134: Carl, Nikos
- Convenors for "Granada Meeting" and work on "Briefing Book" arXiv:1910.11775: Monica, Uta

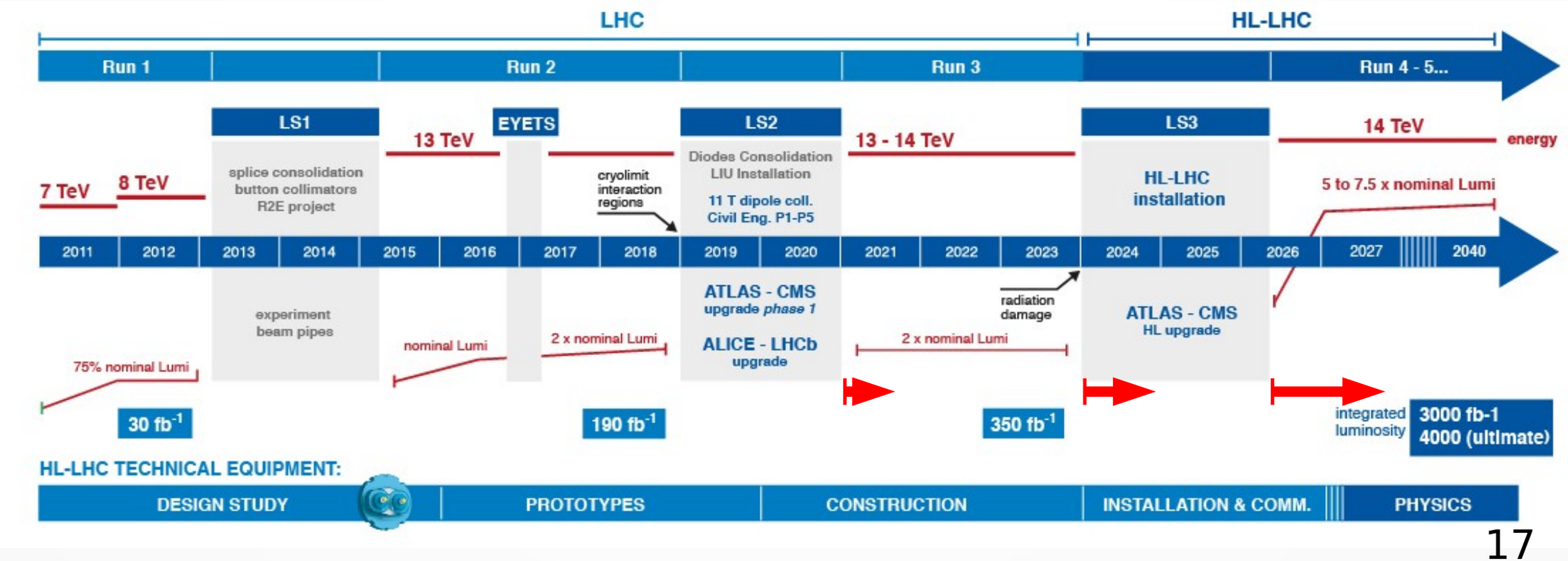




LHeC White Paper (to appear, Uta, Monica, Max)

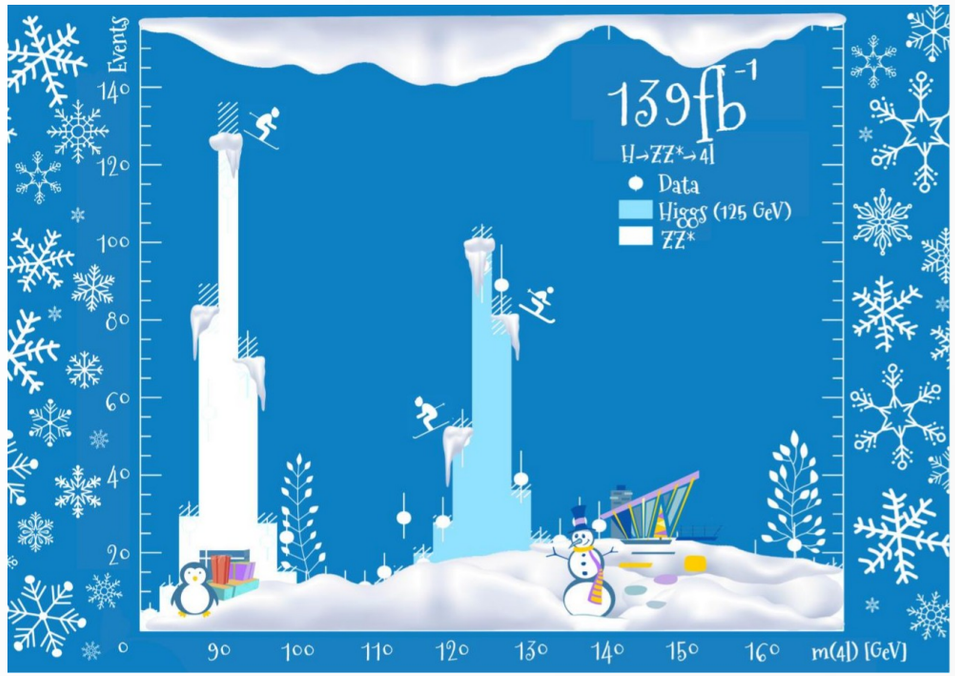
Upgrades and High-Luminosity LHC

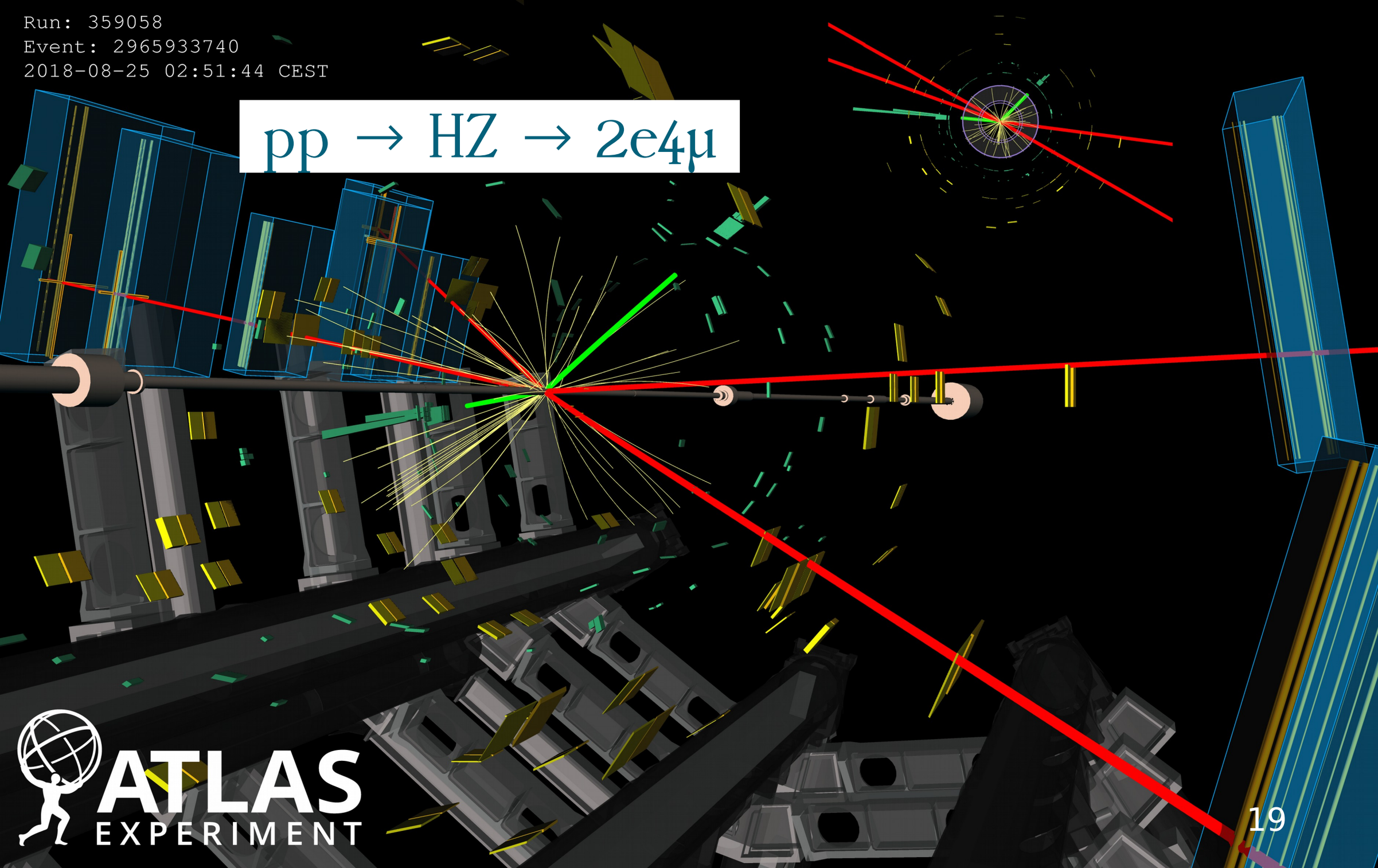
- Currently in "Long shutdown 2" (LS2) with intense upgrade activities (ATLAS: Muon New "Small" Wheel, Trigger) - extended to mid 2021
- Extend Run 3 by one year: more data, more time to prepare HL-LHC
- Extend "Long Shutdown 3" by one year: HL-LHC to start mid 2027



Summary

- 2019 was a very active year for ATLAS physics and Liverpool group members make leading contributions to high-profile publications – at world-leading precision or sensitivity
- We have made leading contributions to the European Strategy process to shape the future of collider physics
- We would also like to thank the computing team for their essential support of our activities
- Merry Christmas!

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2018-08-25 02:51:44 CEST
pp → HZ → 2e4μ
ATLAS
EXPERIMENT