Direct Searches for New Physics @ Liverpool

Adam, Alan, Andy, Carl, Ellis, Emily, Hamish, Matt, Michael, Monica, Nikos, Sergey, Uta, Yanyan

UNIVERSITY OF LIVERPOOL

Highlights from a wide variety of direct searches for new physics carried out here at Liverpool

18th December 2017

Liverpool Christmas Meeting

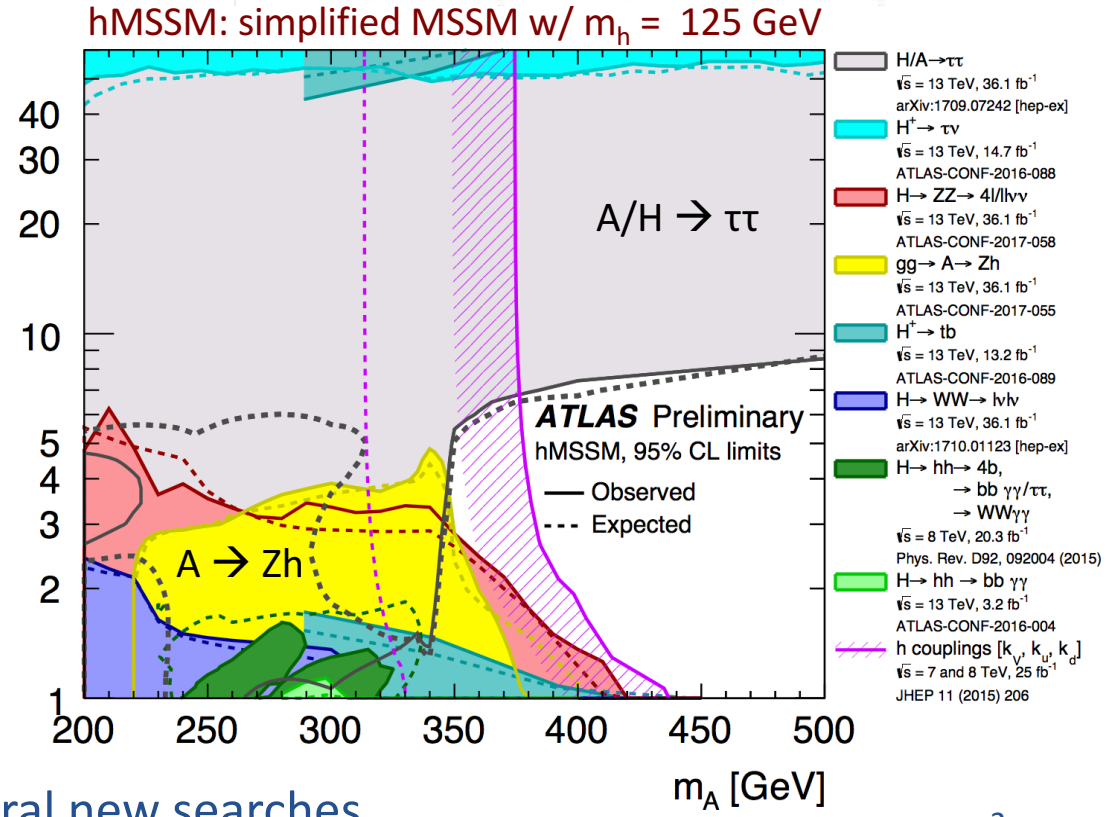
BSM Higgs

Alan, Andy, Carl, Emily, Nikos

- As newest piece of the SM, scalar sector may give first sign of new physics
  - Many BSM models predict extensions, such as additional Higgs bosons
  - 2HDM (e.g. SUSY) → 5 physical states

- Nikos is currently leading these searches as BSM Higgs group convener

- Contributed to published searches for heavy Higgs:
  - A/H → ττ
  - A → Zh → ll/vvbb



- Now working on adding several new searches …

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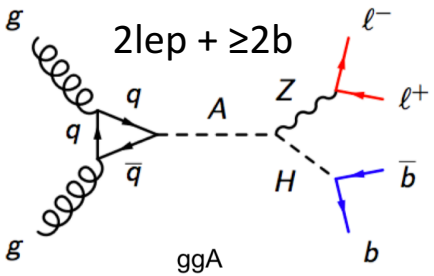
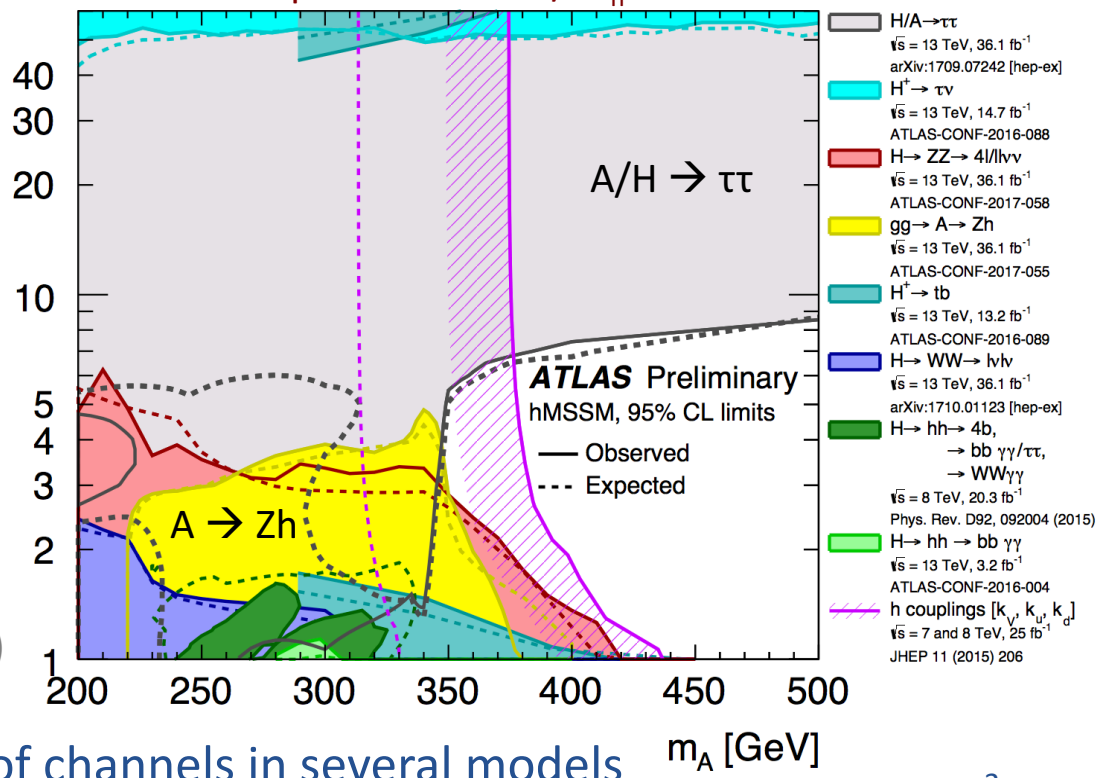
  - 2HDM (e.g. SUSY) → 5 physical states

- A → ZH → llbb (H ≠ h125)
  - Relax mass degeneracy
    - Allowing $m_A > m_H$
  - First time by ATLAS



  - Can explain matter asymmetry via EWBG
  - Alan's thesis topic (see talk)

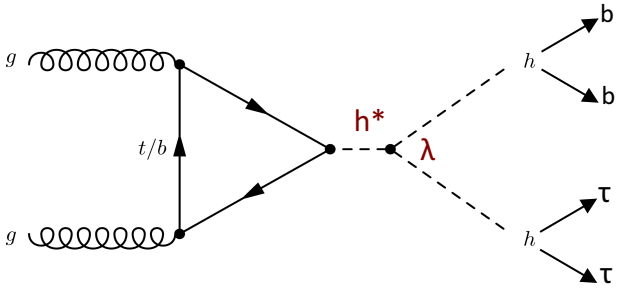


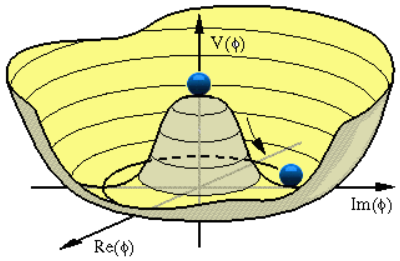
- Working on full combination of channels in several models

Di-Higgs hh → bbττ

Carl, Emily

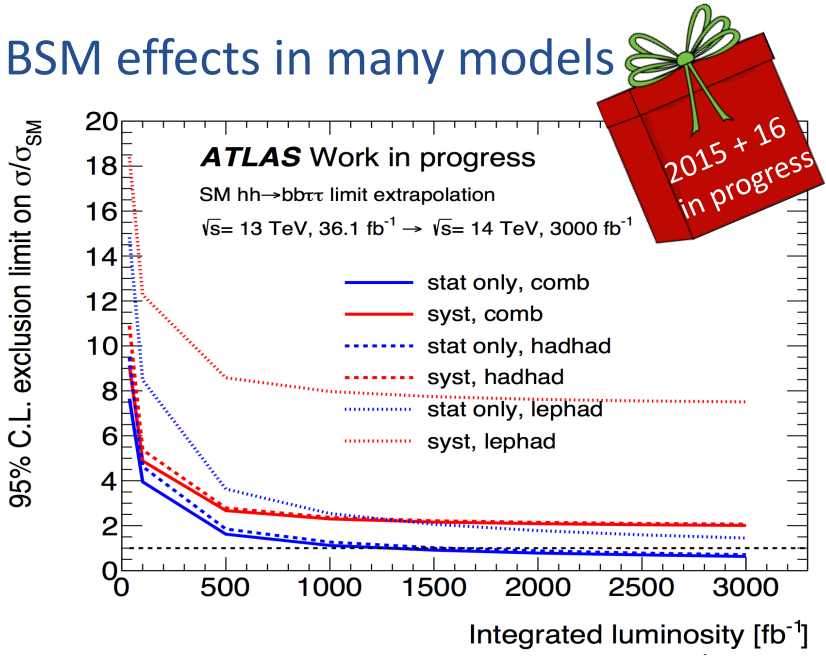
- SM h-pair production can measure self-coupling (λ) and reconstruct potential
  - Crucial test of Higgs mechanism and EWSB





$$V = \frac{m_h^2}{2}h^2 + \underbrace{\frac{m_h^2}{2v}}_{\lambda}h^3 + \frac{m_h^2}{2v^2}h^4$$

- Very small in SM (≈34 fb^{-1}) but sensitive to BSM effects in many models
  - Non-resonant enhancement
    - Compositeness, Heavy top partners
  - Resonant production
    - Additional scalars, Gravtions
- hh → bbττ most sensitive non-res channel
  - Lep-had is Emily's thesis topic (see talk)
- Longer term can be sensitive to SM alone!
  - Investigate deep learning improvements



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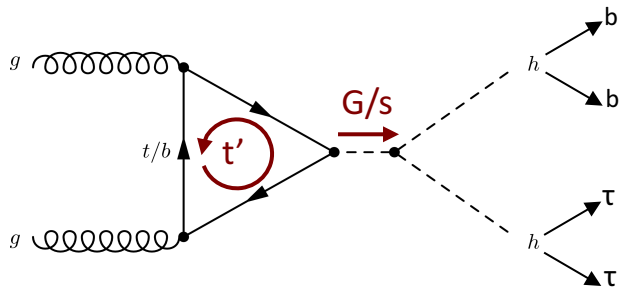

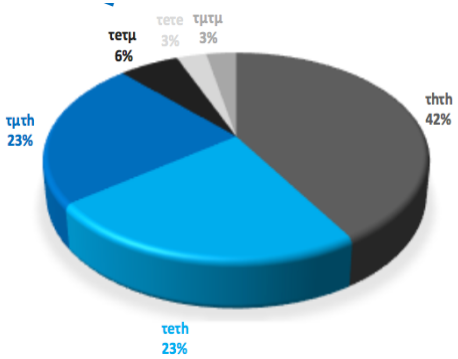

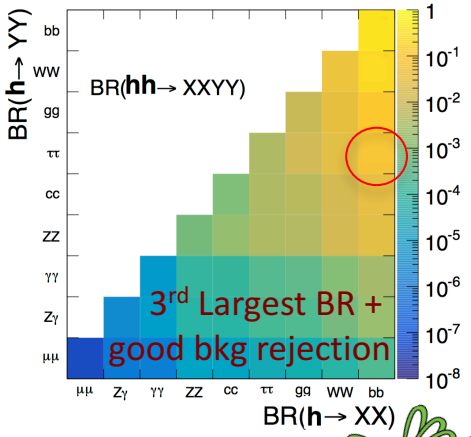

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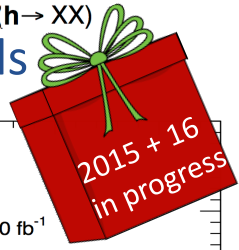

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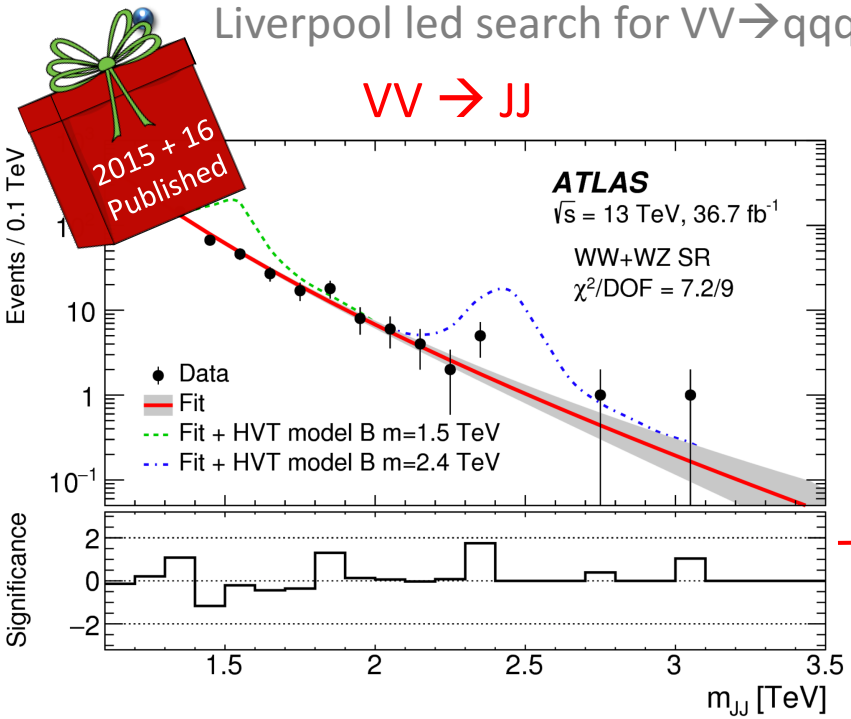
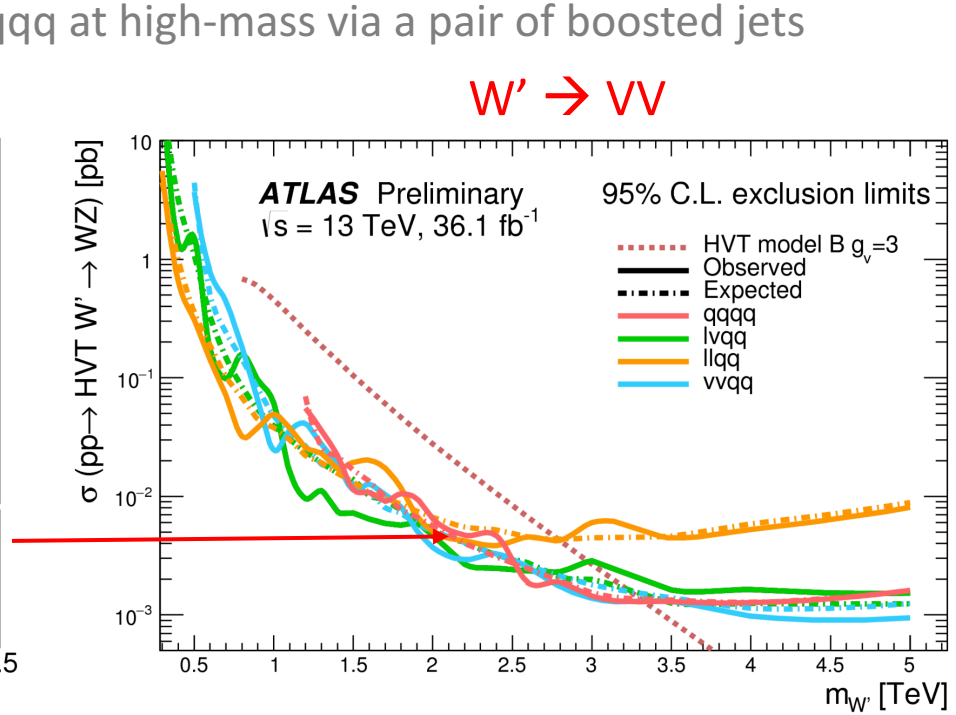
BSM Resonances

Carl, Ellis, Michael, Uta, Yanyan

- Beyond additional Higgs, we are searching for generic new heavy particles
  - Probing many BSM models: new scalars (2HDM), vectors (HVT), tensors (RSG)
    - HVT = simplified phenomenological model with triplet of heavy vectors ($W^{\pm}$,Z^0)
- Carl was Exotics Dibosons & Multileptons group convener
  - Liverpool led search for VV→qqqq at high-mass via a pair of boosted jets



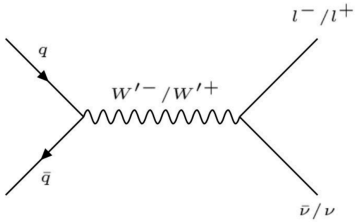


- We're working on full combination of these channel along with leptonic V' …

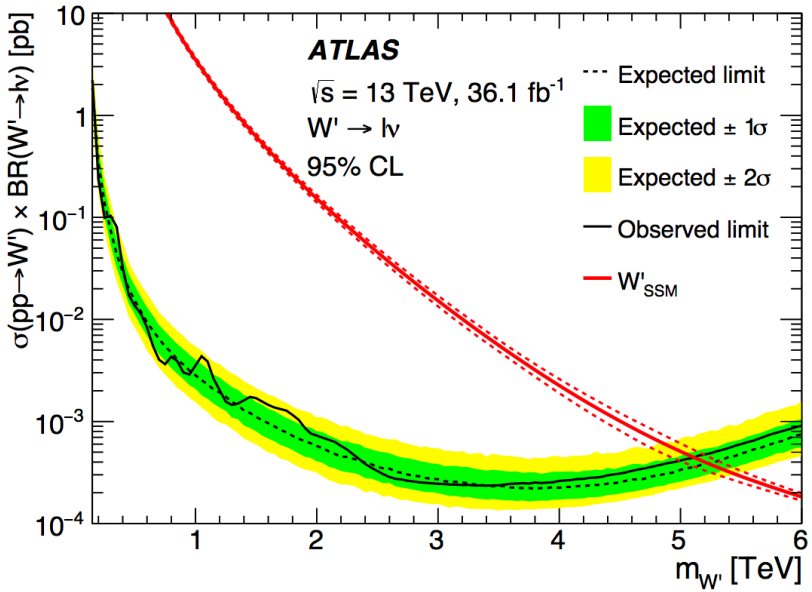
New W'/Z' gauge boson

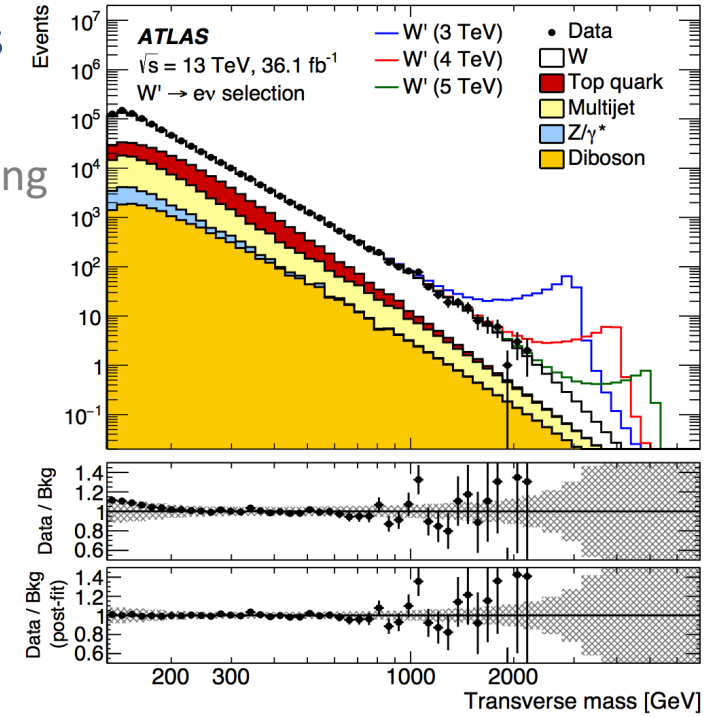
Carl, Ellis, Michael, Uta

- Extended gauge sector gives new spin-1 bosons
- W': search for lepton + E_T^{miss}
  - e-channel is Ellis' thesis topic; Michael continuing
  - Limits pushed to very high mass

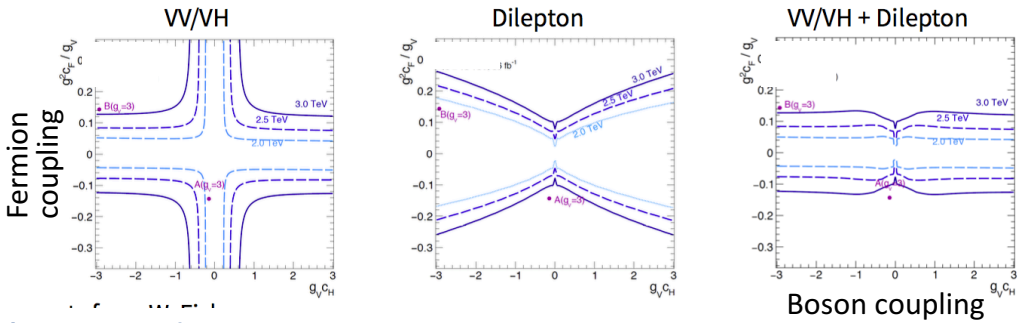


Decay	$m_{W'}$ lower limit [TeV] Expected	Observed
$W' \to e\nu$	5.1	5.2
$W' \to \mu\nu$	4.7	4.5
$W' \to \ell\nu$	5.2	5.1





- Complementary to VV/VH



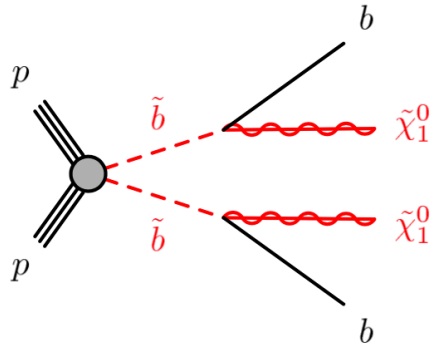
- Also contributed to Z' → ll via background PDF uncertainties

SUSY: Sbottom/Stop

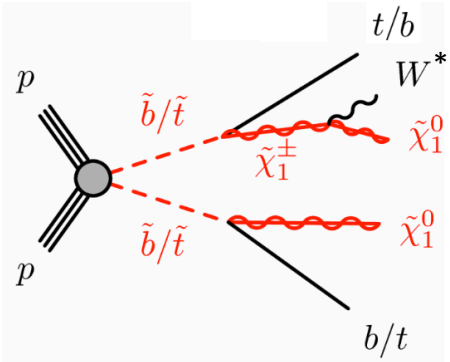
John, Hamish, Monica

- Naturalness suggests 3rd gen squarks are lightest coloured SUSY particles
  - Maybe significantly lighter than others and pair-produced with large rate at LHC

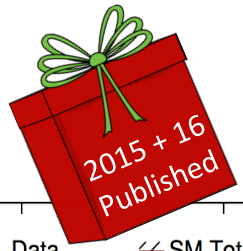
Decay to χ^0 LSP directly
→ 0 lep, ≥2 b-jets, E_T^{miss}

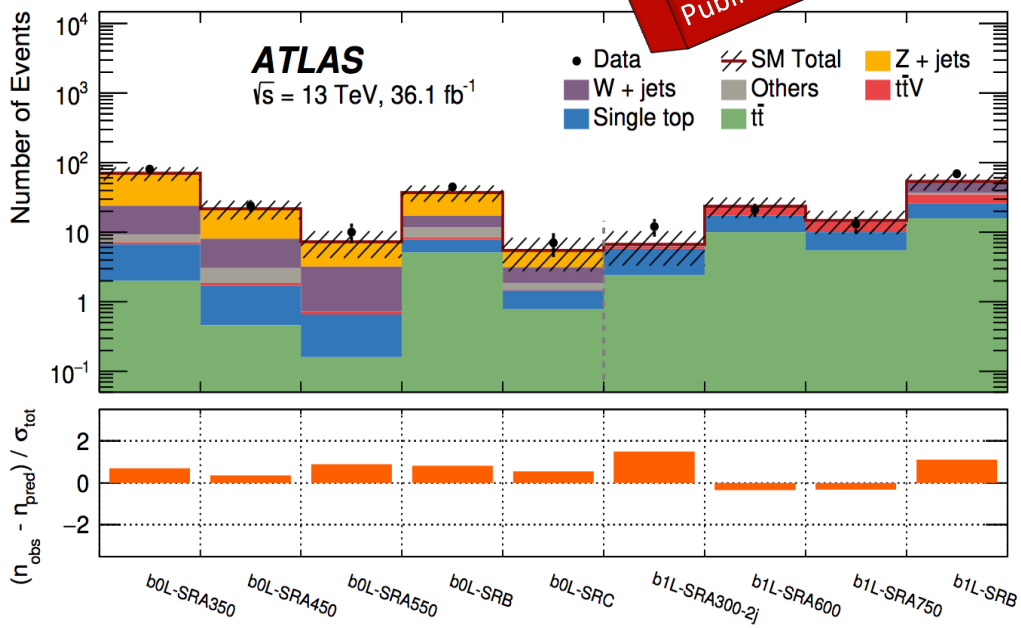


Mixed decay to χ^0 via W^*
→ 0,1 lep, ≥2 b-jets, E_T^{miss}



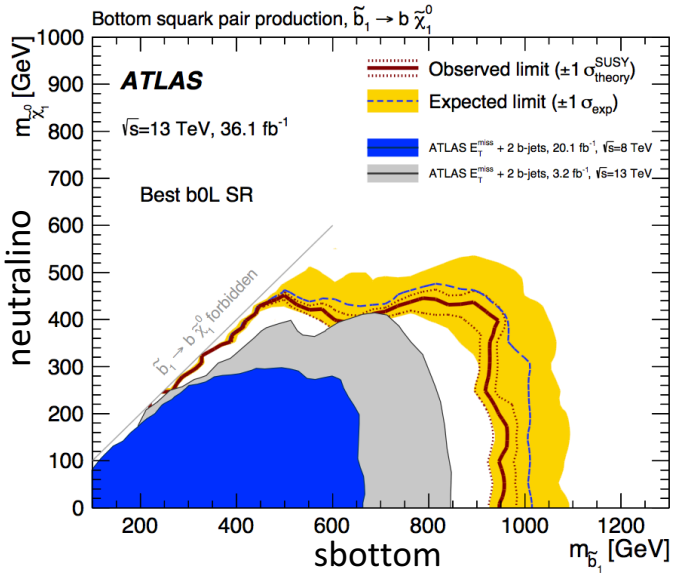
- Original analyses limited to simple decays
- Extended to look at more complicated decays
  - Split into 9 SRs
  - John's thesis!

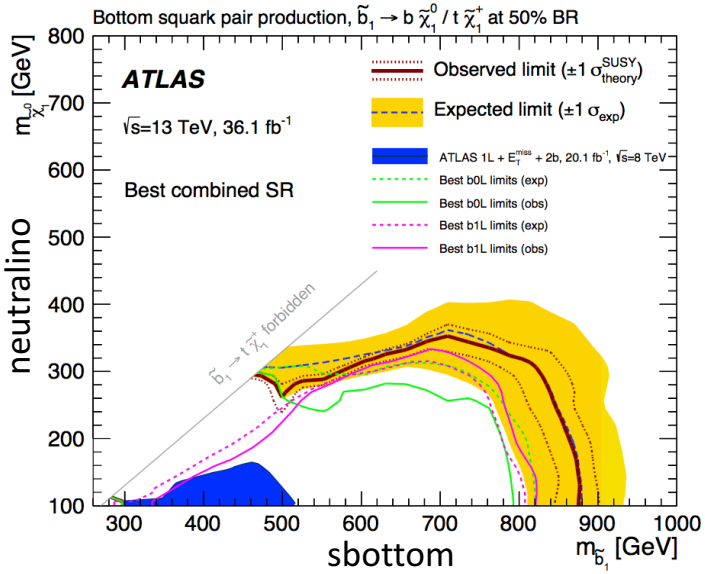




SUSY: Sbottom/Stop + EWK

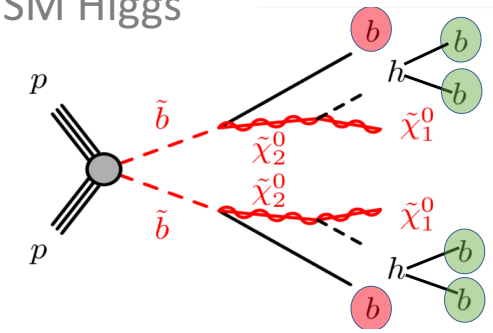
John, Hamish, Matt
Monica, Yanyan





- Hamish looking at more complicated decays
  - Sbottom decay via SM Higgs

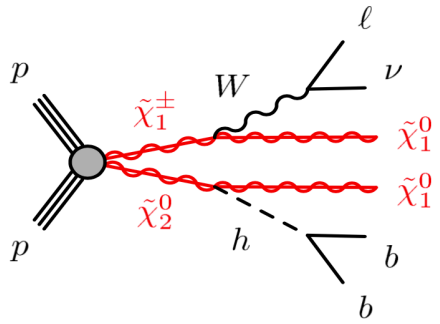
≥4 b-jets
+ E_T^{miss}



Electroweak SUSY

- Given limits on strong-production of 1st/2nd gen squarks of >1 TeV + 3rd Gen limits, direct EW gaugino production maybe dominant @ LHC

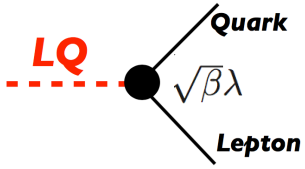
- Neutralino + chargino pair
  - 1 lep, E_T^{miss}, 2 b jets, < 4 jets with 3 SRs for different mass splittings
  - Part of Matt's thesis
    - (see talk)



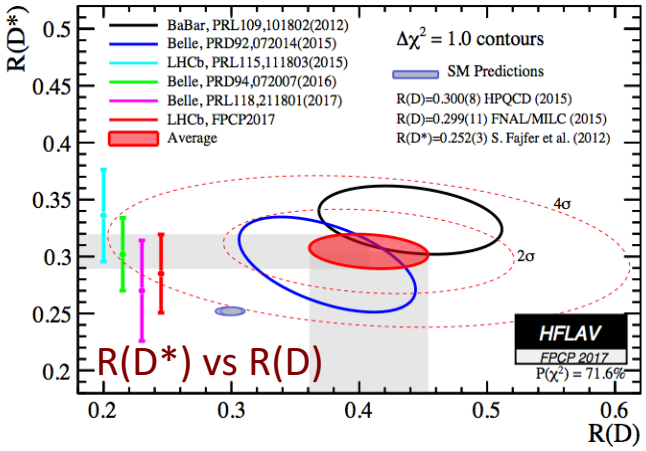
Leptoquarks

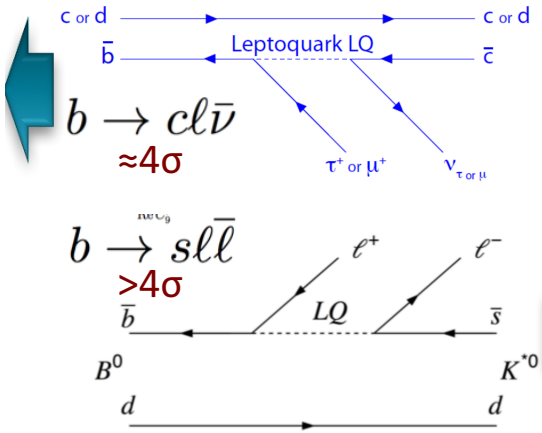
Adam, Andy, Carl, Emily, Monica

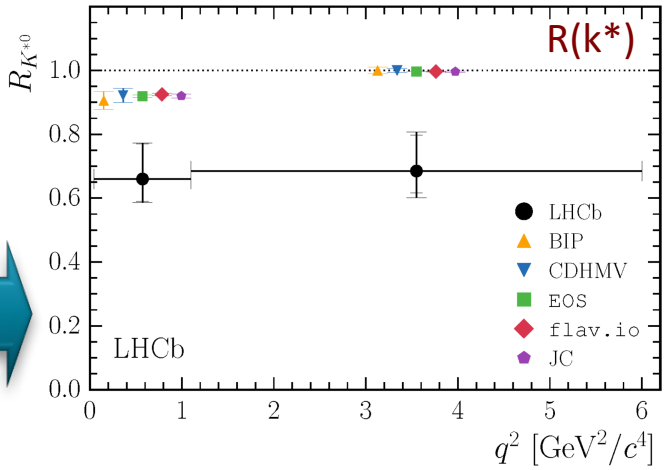
- Leptoquarks are colour-triplet bosons with fractional charge
  - Carry both L + B number → unify leptons & quarks



- They are hot topic recently since they could explain several B-meson excesses

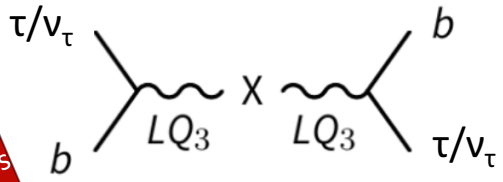






- Search for LQ pair-production since less dependent on yukawa coupling λ

- Currently searching for 3rd generation LQs
  - Depending on β can decay to τ/ν_τ + b (or t)
  - Modify hh to search for LQ_3LQ_3 → bτbτ
  - sbottom reinterpreted for LQ_3LQ_3 → bν_τbν_τ



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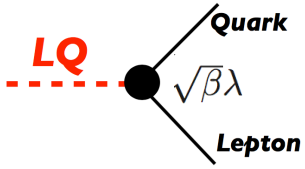

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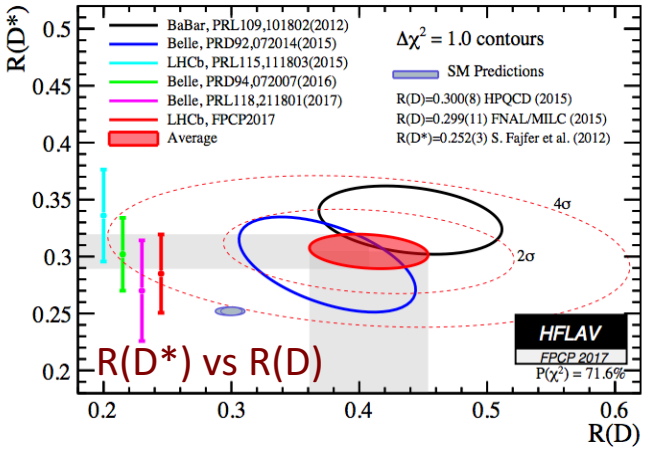
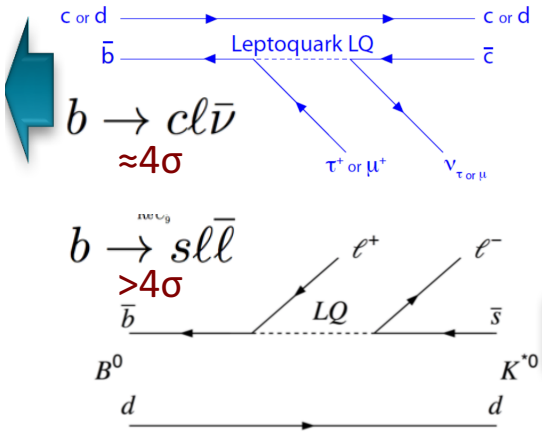
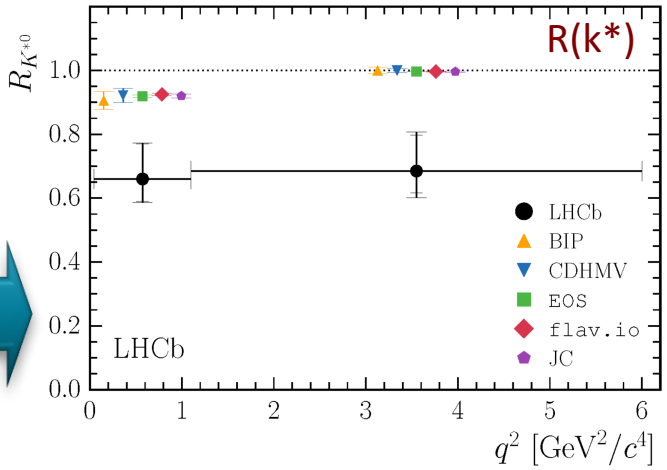
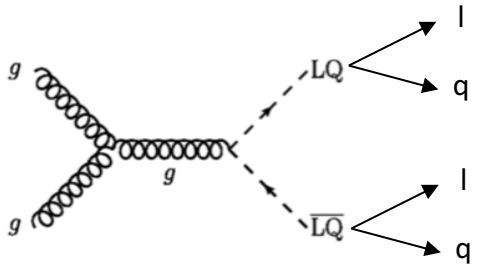






- Search for LQ pair-production since less dependent on yukawa coupling λ

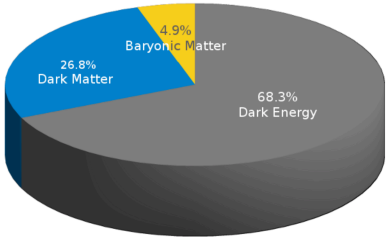
- Adam will look for 1st + 2nd gen LQs with full run-2
  - Signature: 2 lep + 2 jets
  - Include possibility of cross-gen decays e.g. eb, μb for the first time



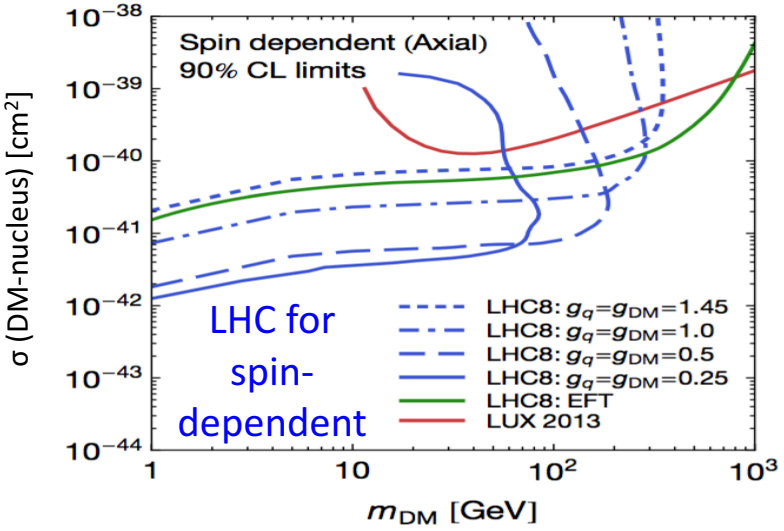
Dark Matter

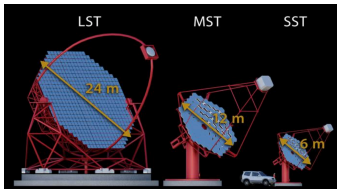
Andy, Carl, Monica, Sergey

- Nature of DM is one of the major open questions
  - Makes up about 27% of the universe
  - One favoured candidate is a WIMP
    - Natural link due to “WIMP Miracle”



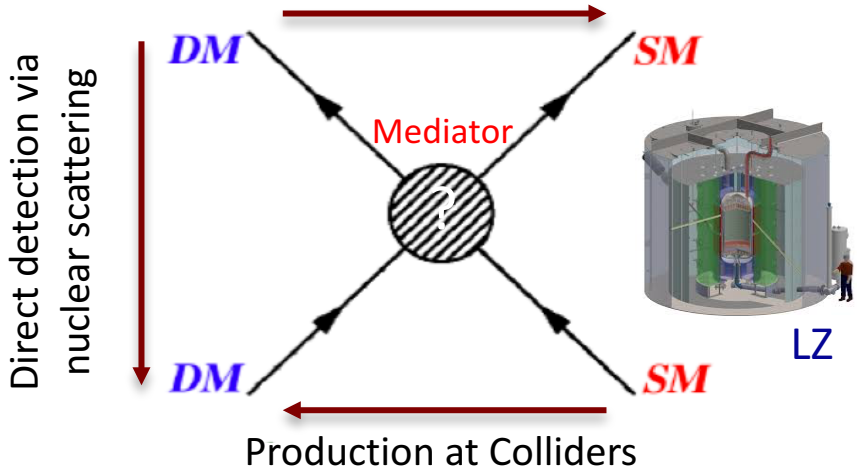
- Complementary detection methods:





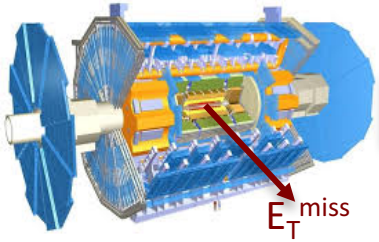
CTA

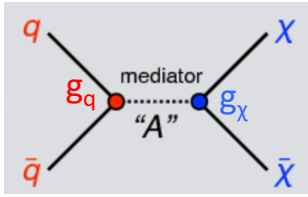
Indirect detection via annihilation



LZ

ATLAS

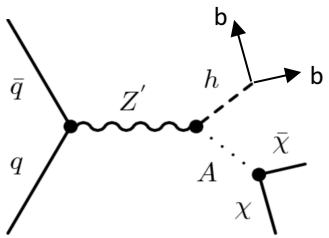




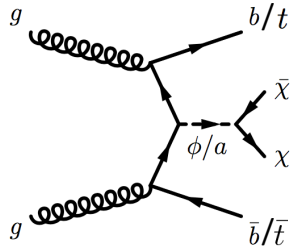
Simplified mediator models

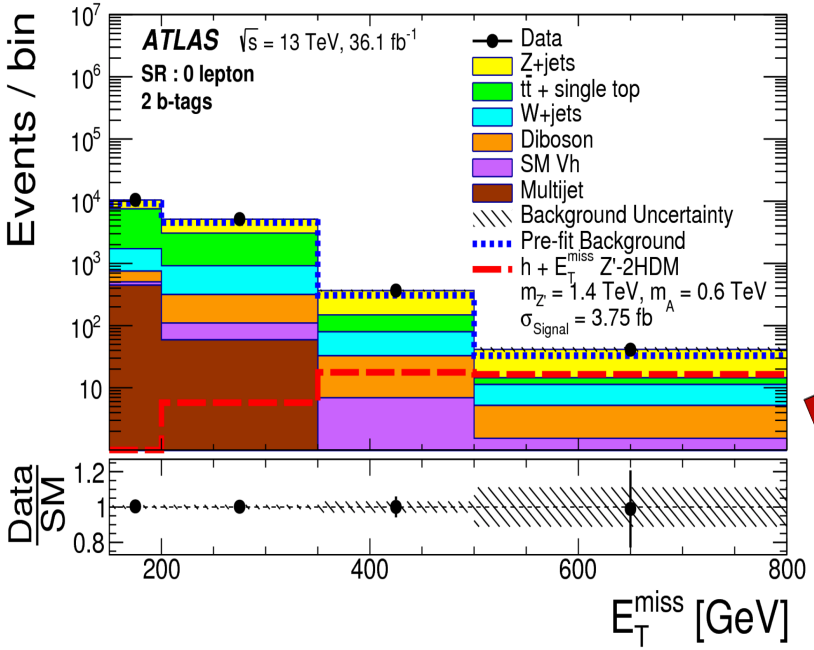
Mono-H DM + HF

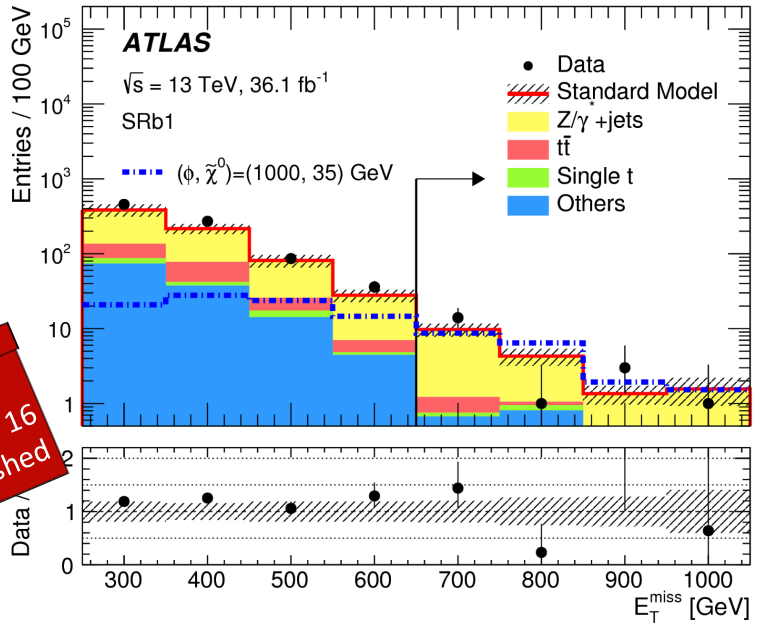
- DM recoils against Higgs
  - Potential unique DM-SM probe
  - 2 b-jets from h + large E_T^{miss}
  - Fit m_{bb} spectrum in E_T^{miss} bins



- DM in association with general HF
  - b-flav DM can explain Fermi-LAT
  - b: E_T^{miss} + ≥2 b-jet
  - t: E_T^{miss} + ≥2 b-jets + 2lep or ≥4 jets







- Limits in terms of vector mediator or (pseudo) scalar mediator
  - Future: axions in h → Za or h → aa (g-2?), Zh, h→ inv and h → $\gamma_d \gamma_d$ (GTAs)

Mono-H DM + HF

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  - Potential unique DM-SM probe
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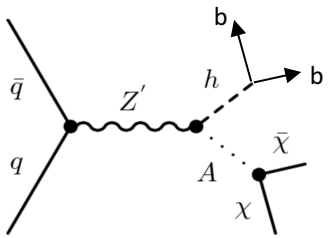

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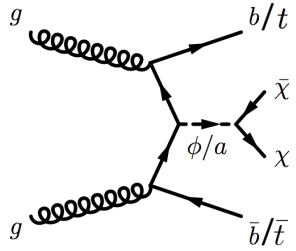

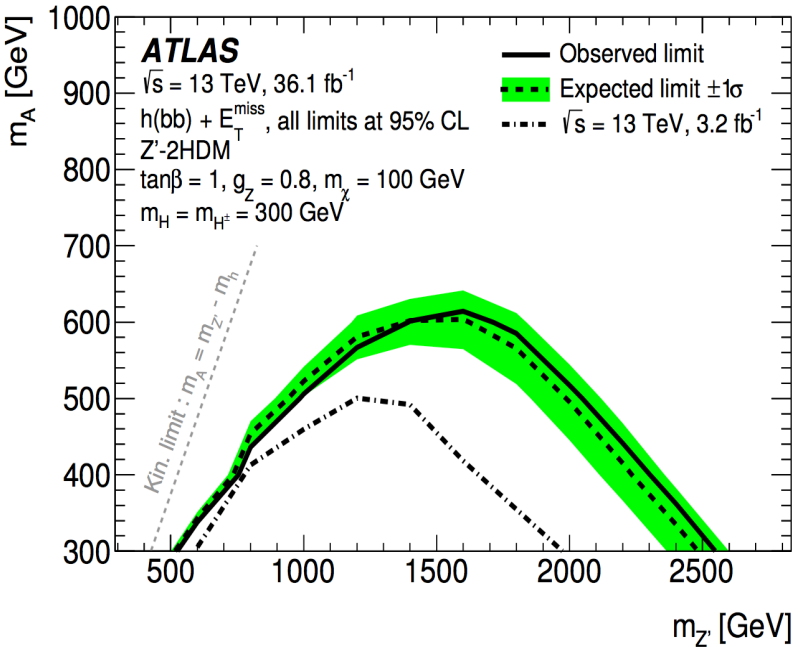

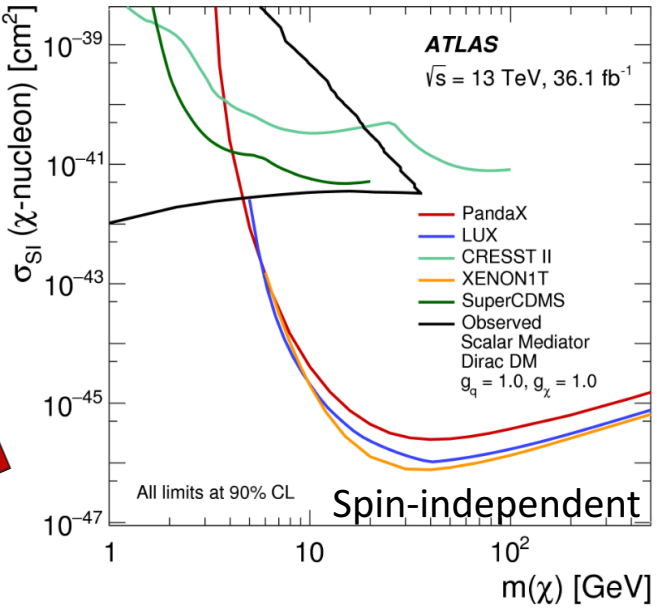

- Limits in terms of vector mediator or (pseudo) scalar mediator
  - Future: axions in h → Za or h → aa (g-2?), Zh, h→ inv and h → $\gamma_d \gamma_d$ (GTAs)

Summary

- Liverpool ATLAS lead a large range of direct new physics searches
  - Covering a wide variety of interesting and timely BSM models
  - Exploiting links with other Liverpool experiments
- Published 8 papers on 2015+16 dataset this year
  - Further 7 in the pipeline for early next year
  - Still in progress so can't show them here
    - But saw most of them in the student talks
- Continue these areas with full run 2 data, with new searches/techniques
  - Focus on BSM Higgs, SUSY + dark matter, leptoquarks, generic resonances