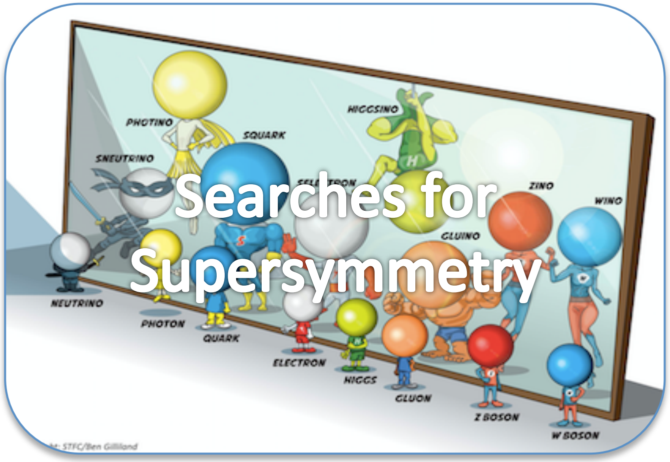
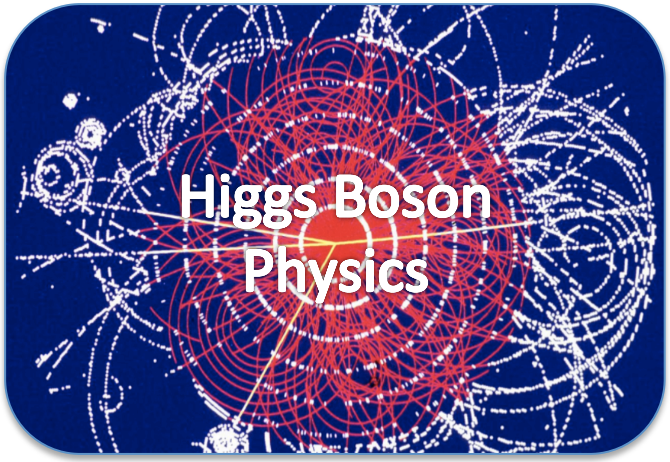
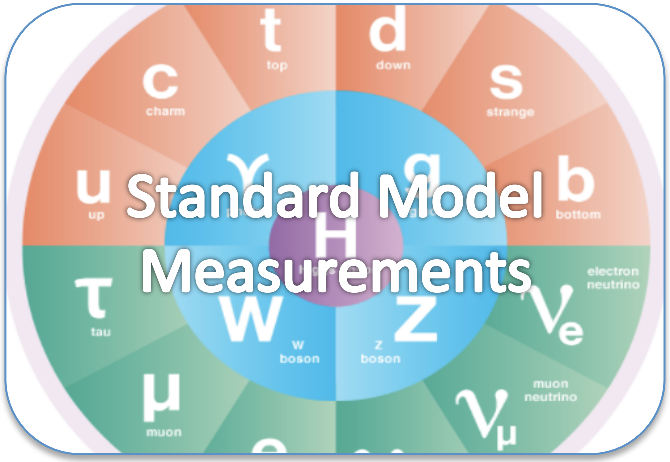
Higgs Searches and Measurements and 3rd Generation SUSY

Frederik Rühr (Albert-Ludwigs-Universität Freiburg)

Activities of the Group*

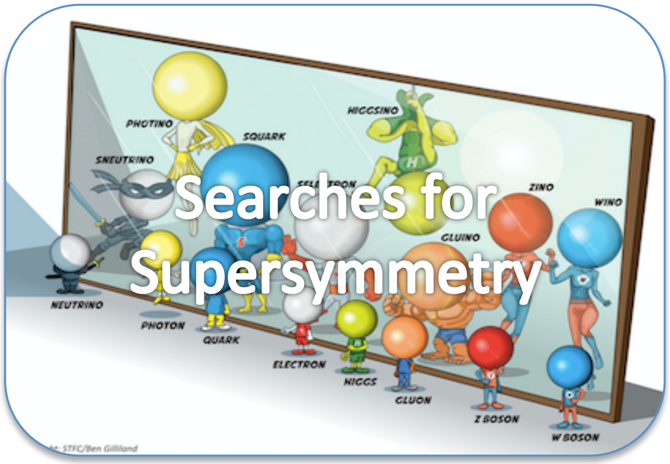






* Freiburg "Karl Jakobs" group

Activities of the Group



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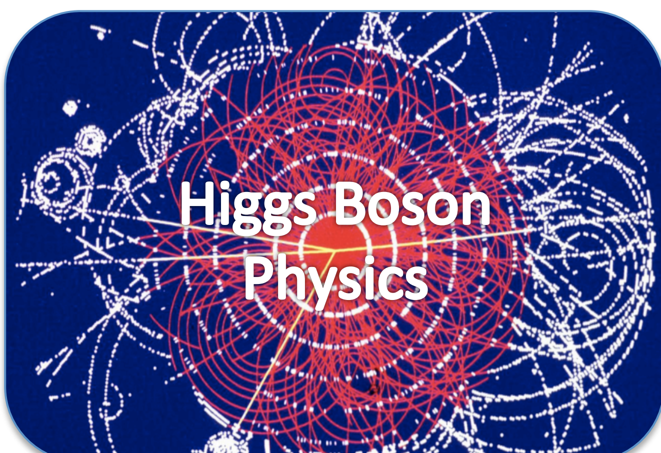
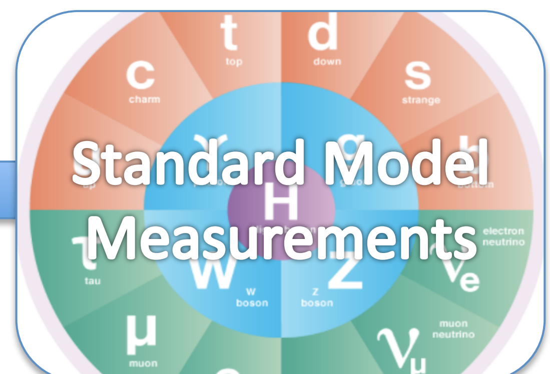
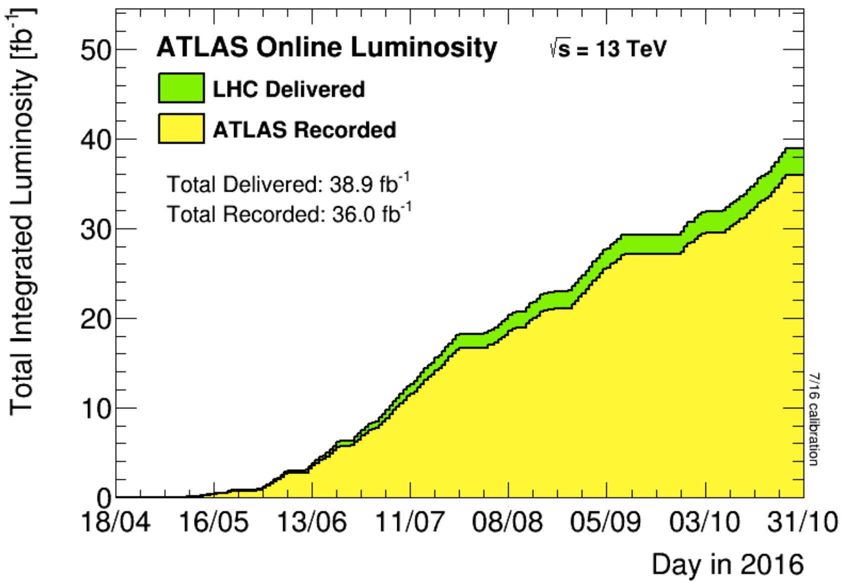
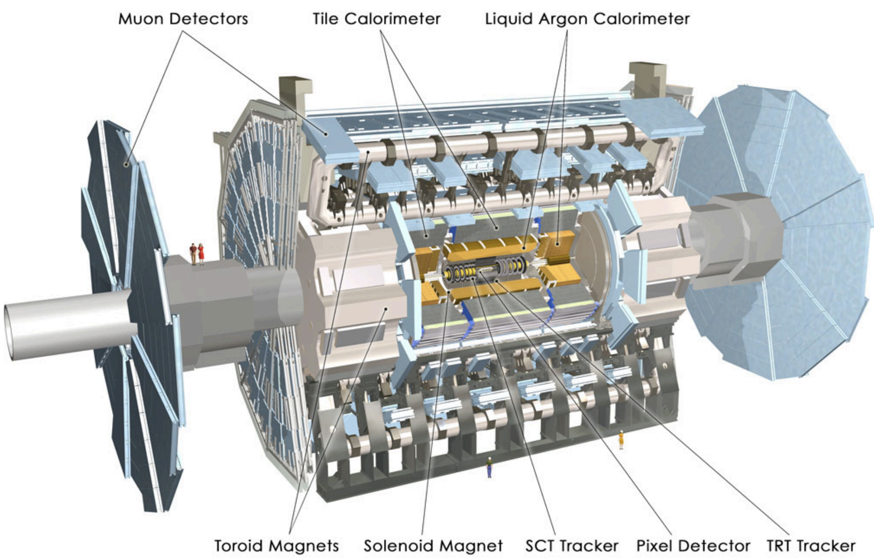


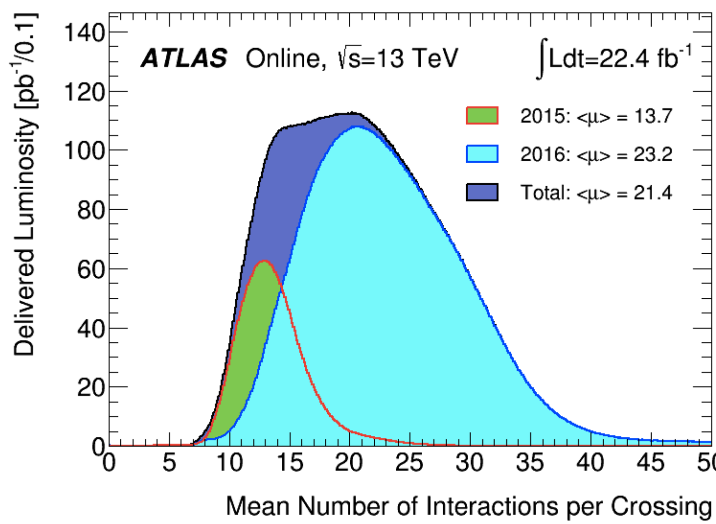


2016 LHC and ATLAS performance

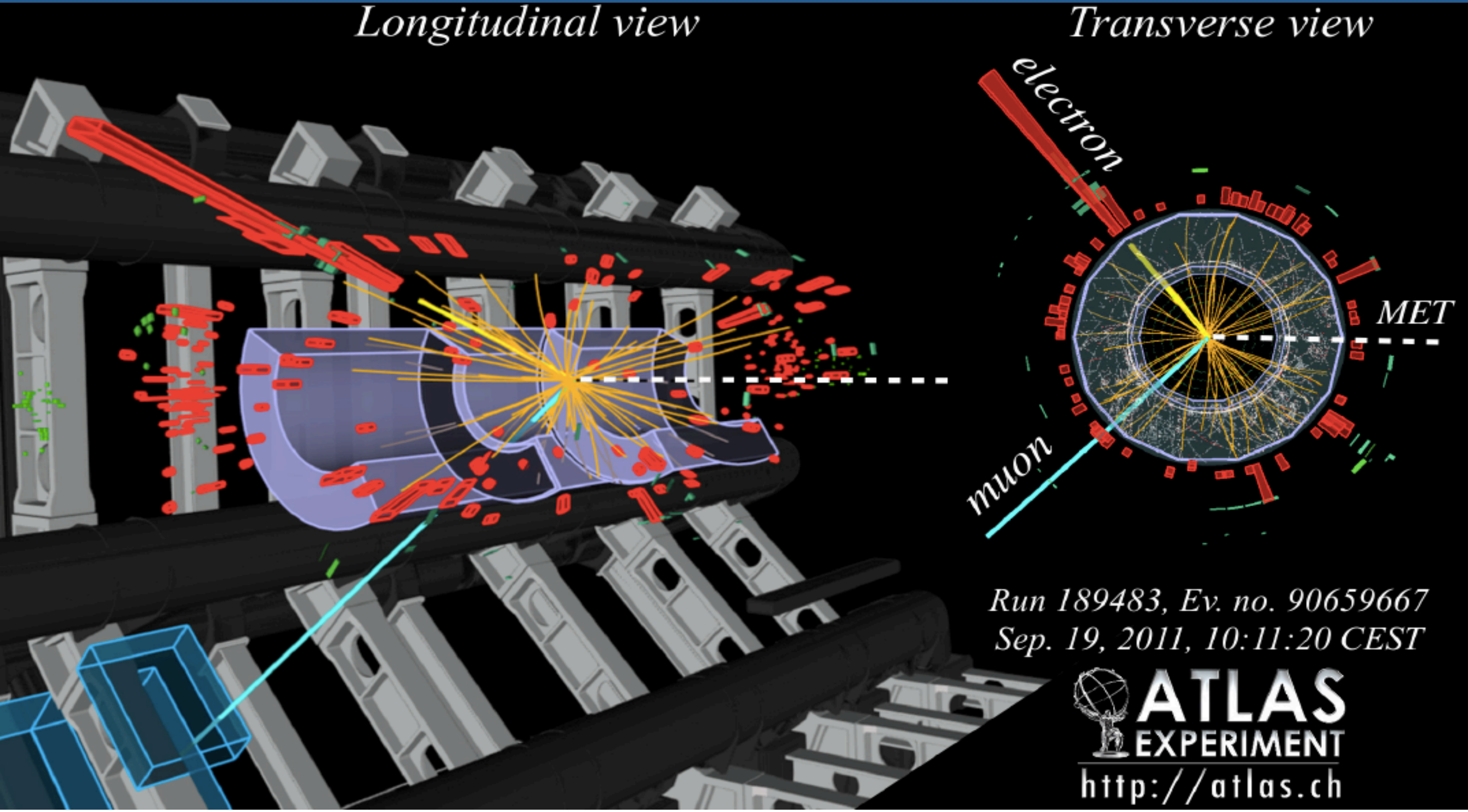
- Between 3 and 15 fb^{-1} selected by public ATLAS results
  - Depending on analysis and final state
  - For comparison: ~20 fb^{-1} at 8 TeV in 2012
- Average number of proton-proton collisions per event above Run-1 8(7) TeV value of 20.7 (9.1)





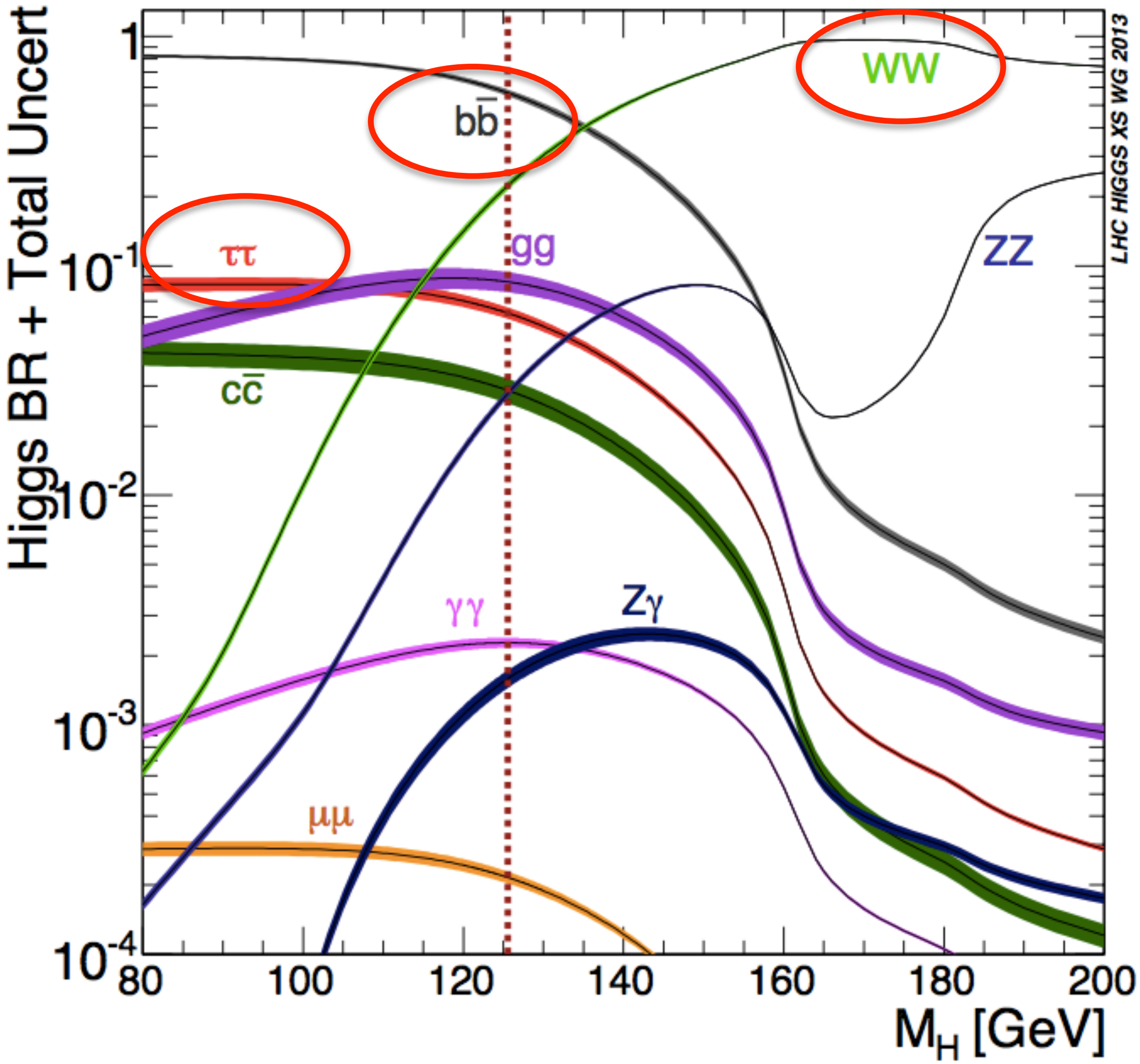


Higgs Sector

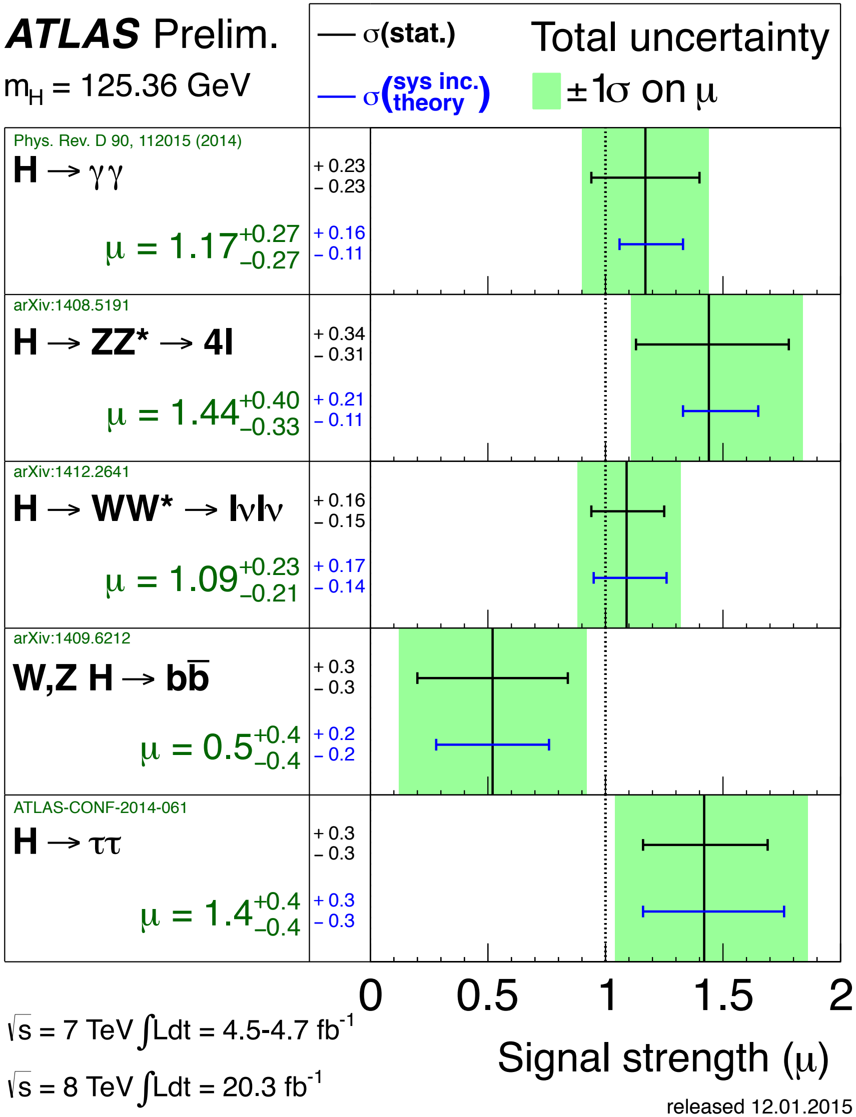


H->WW->lνlν candidate event

Decays of the Standard Model Higgs



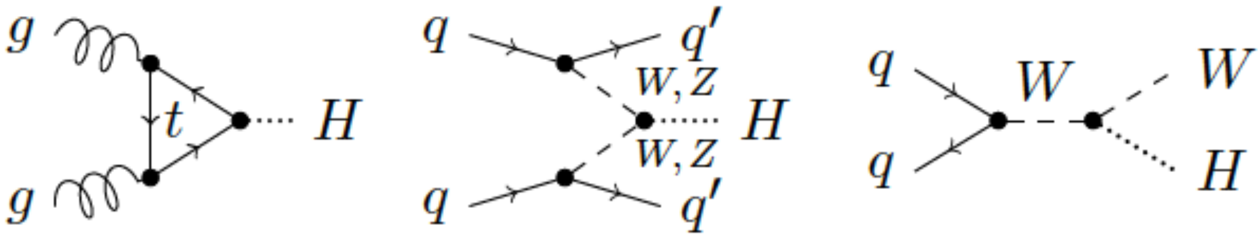
H -> WW



- H->WW important discovery channel in LHC Run-1
  - Largest event yield, but difficult backgrounds
- Conference note (ATLAS-CONF-2016-112) public with first Run-2 results
  - Statistically still very limited - using 5.8 fb^{-1}

New developments?

H -> WW - Couplings and beyond

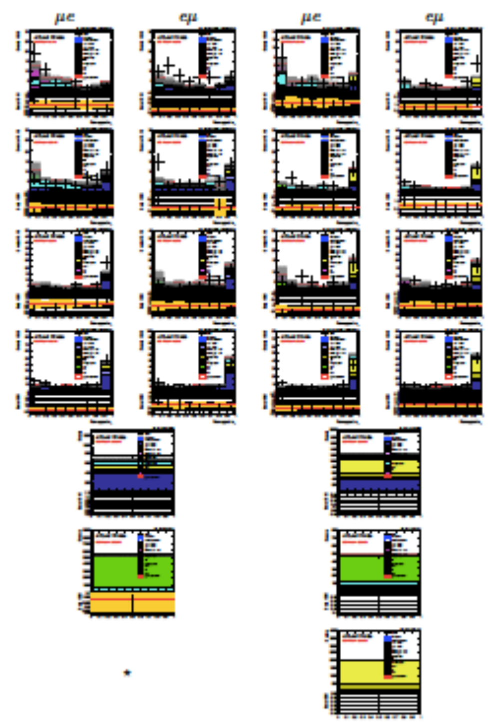


- Signal strength μ is a very simple view of the process
- Different production mechanisms and decays include different couplings (and potential beyond the Standard Model contributions)

"Higgs coupling" at the LHC:

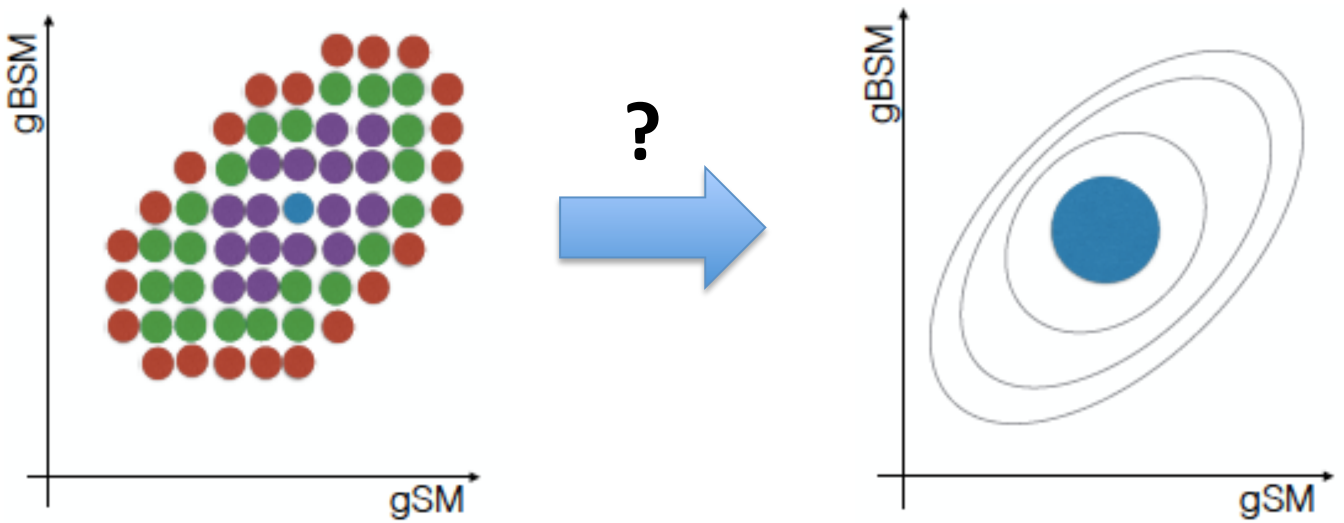
$$\kappa_W, \kappa_Z, \kappa_t, \kappa_b, \kappa_\tau, \kappa_\mu, \kappa_\gamma, \kappa_g, \kappa_H$$

- Ideally be able to scan/fit these, in the context of a complicated analysis
  - 16 signal regions, 5 control regions to constrain backgrounds, 3 external inputs



H -> WW - Morphing

- Need to predict observable distributions from a composite model
  - HEP model * soft physics * detector response * reconstruction
- Straightforward way: Grid scan



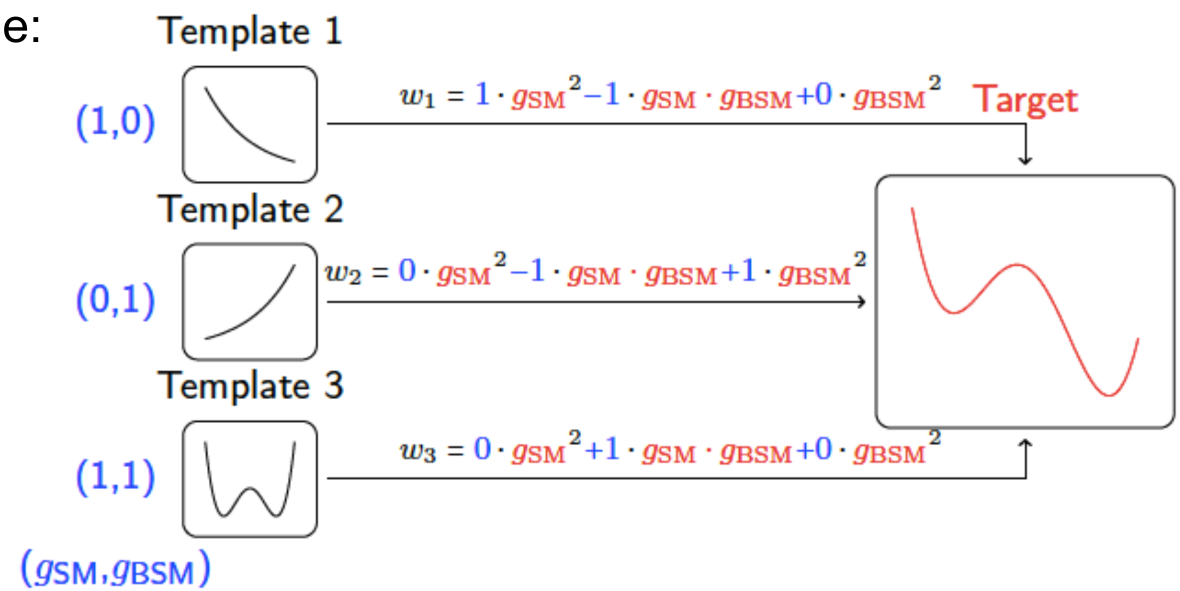
- For more than one coupling, many samples needed even for very rough granularity
  - Can one turn the grid scan into continuous function?

H -> WW - Physics inspired morphing

- Template morphing applicable if matrix element factorizes

$$|\mathcal{M}(\vec{g})|^2 = \underbrace{\left(\sum_{x\epsilon p,s} g_\alpha \mathcal{O}(g_\alpha)\right)^2}_{\text{production}} \cdot \underbrace{\left(\sum_{x\epsilon d,s} g_\alpha \mathcal{O}(g_\alpha)\right)^2}_{\text{decay}}$$

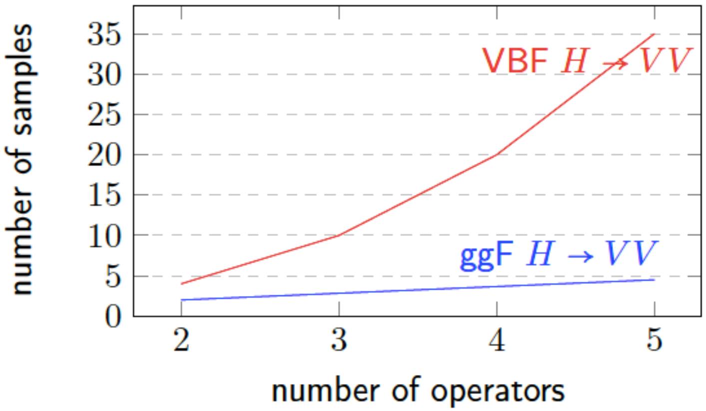
  - Model cross-section at arbitrary point as linear interpolation of templates, example:



$$T_{\text{target}}(g_{SM}, g_{BSM}) = \underbrace{(g_{SM}{}^2 - g_{SM} \cdot g_{BSM})}_{=w_1} T_{i,\text{input}}(1,0) + \underbrace{(g_{BSM}{}^2 - g_{SM} \cdot g_{BSM})}_{=w_2} T_{i,\text{input}}(0,1) + \underbrace{+ g_{SM} \cdot g_{BSM}}_{=w_3} T_{i,\text{input}}(1,1)$$

H -> WW

- For higher dimensional basis, there is still a significant number of input samples required for e.g. VBF H->WW
  - Significant effort goes into finding optimal minimal fixed sample basis



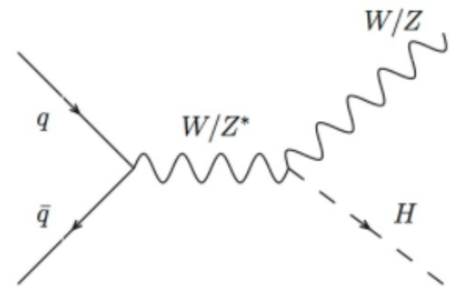
- Computing resources unfortunately bottleneck for many analyses
  - Detector simulation of samples is an expensive component
- Use matrix element reweighting to get input samples
  - Why morph afterwards if reweighting is used already?
  - Morphing creates distributions on the fly during a fit - running over millions of events while reweighting computationally too expensive

- **Stay tuned for 13 TeV data Higgs coupling measurements**
- **Property analysis techniques are under heavy development**

H -> bb - Status

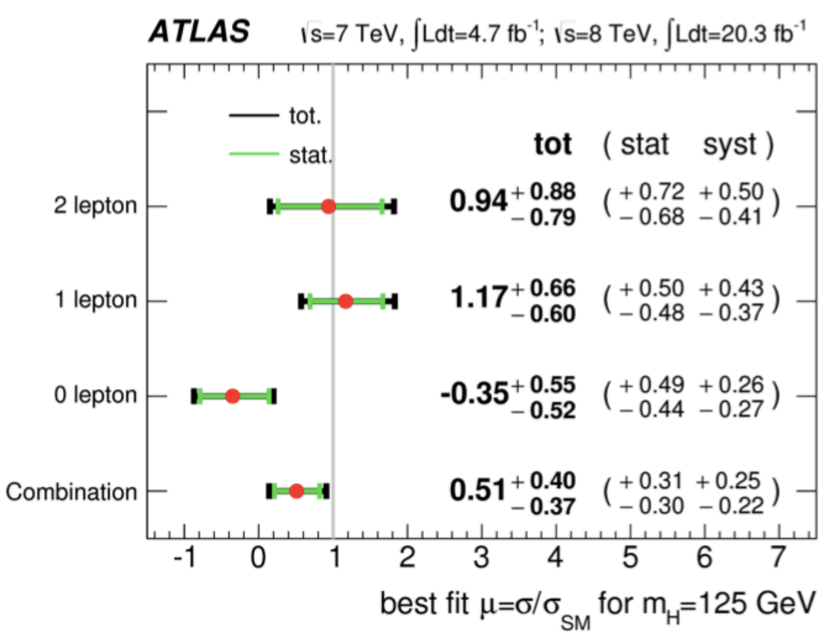
- Large number of e.g. ggF H->bb events are produced @LHC
  - **Practically impossible to distinguish from QCD background**

➡ Associated Higgs production, e.g. H + W/Z

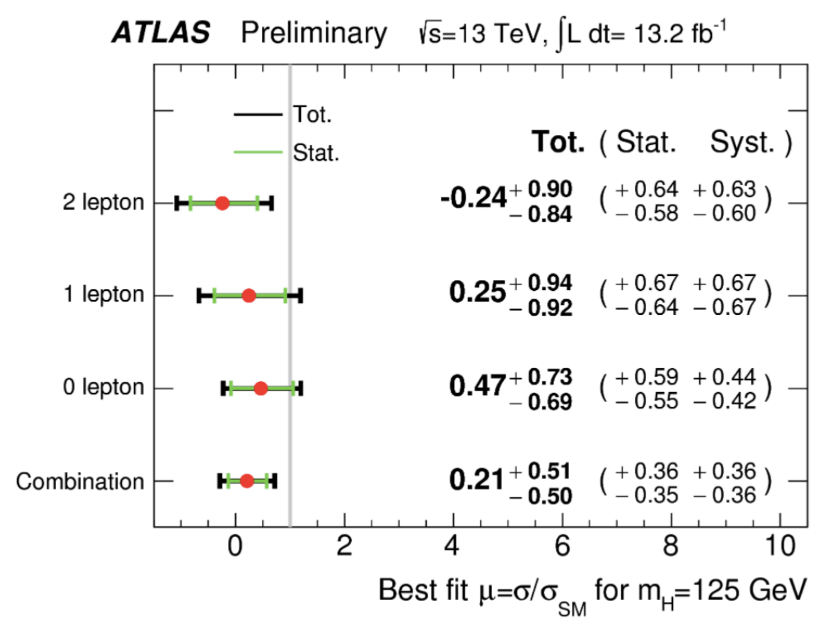


- **No discovery yet**

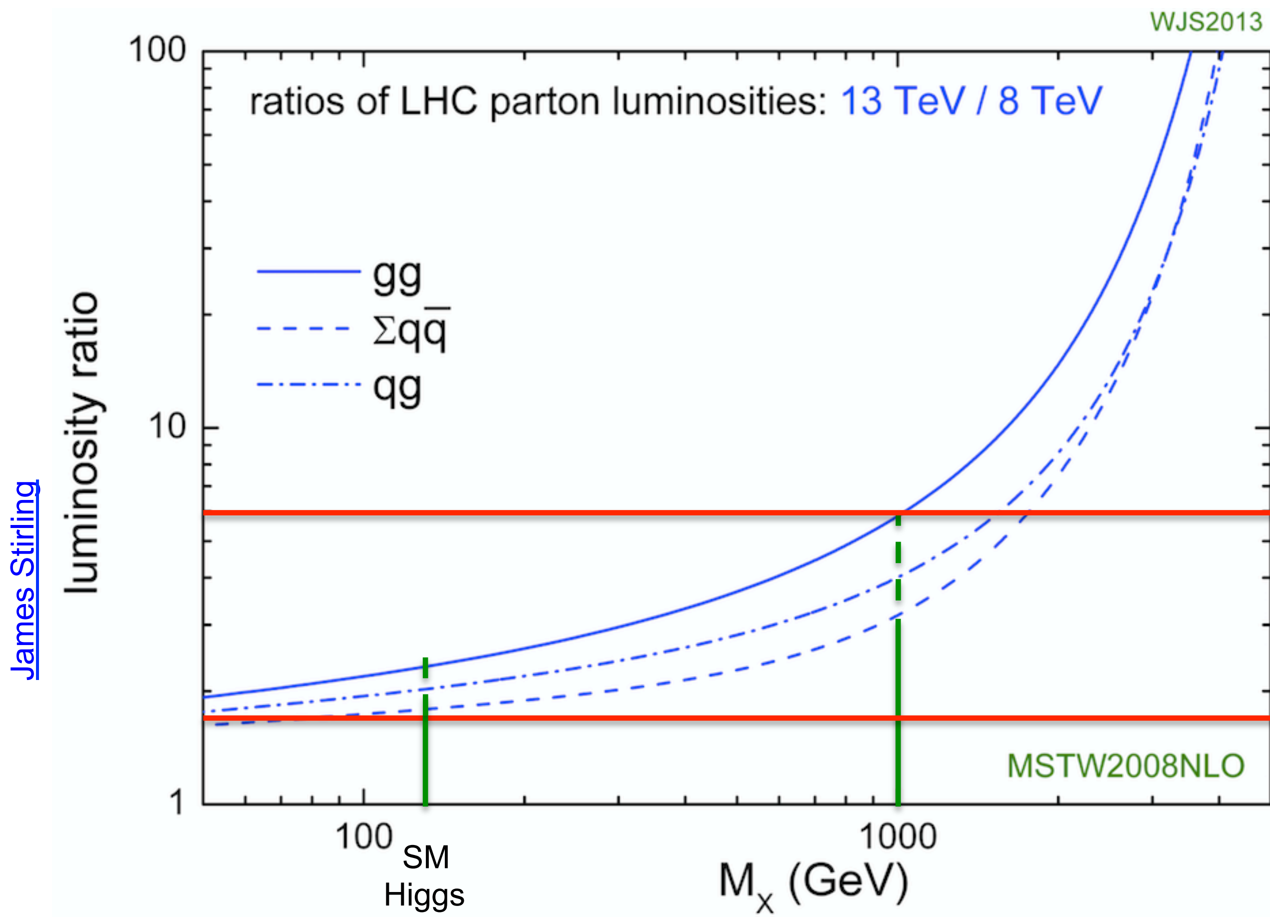
Run-1 Status



Run-2 Status



Physics potential of 2015+2016 data



SM Higgs

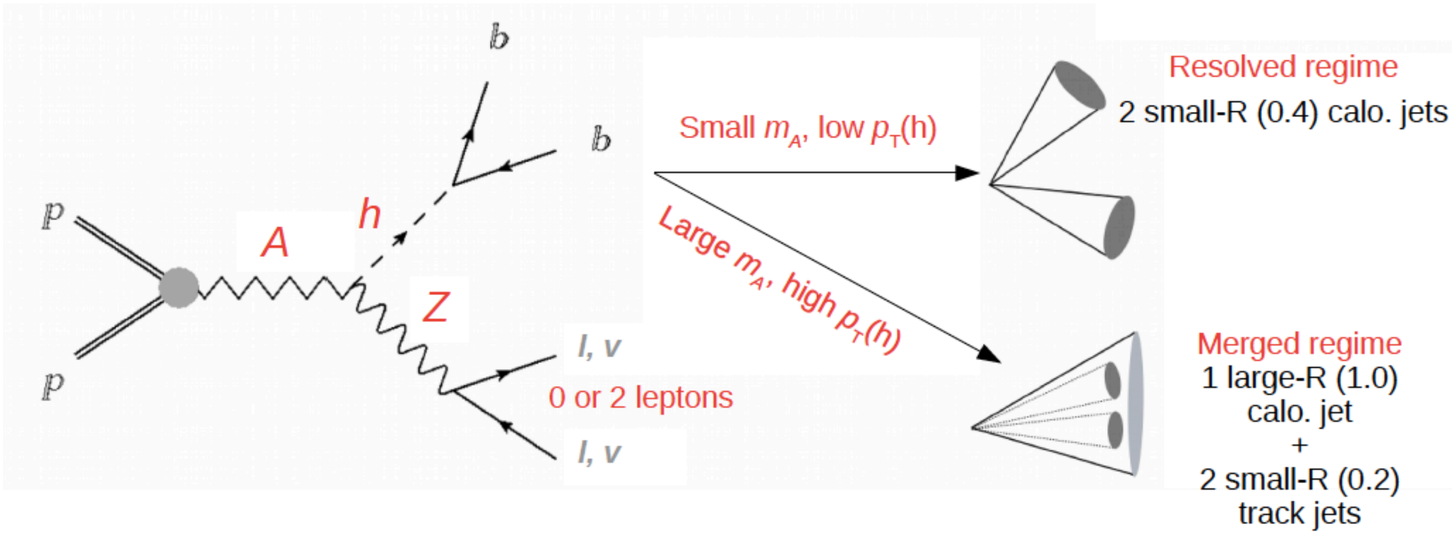
Heavy Higgs

Data at 8 TeV: 20 fb^{-1} (Run-1)
Data* at 13 TeV: 3-13 fb^{-1} (Run-2)

* Analyzed for current public results

Ratios to match Run-1 number of events

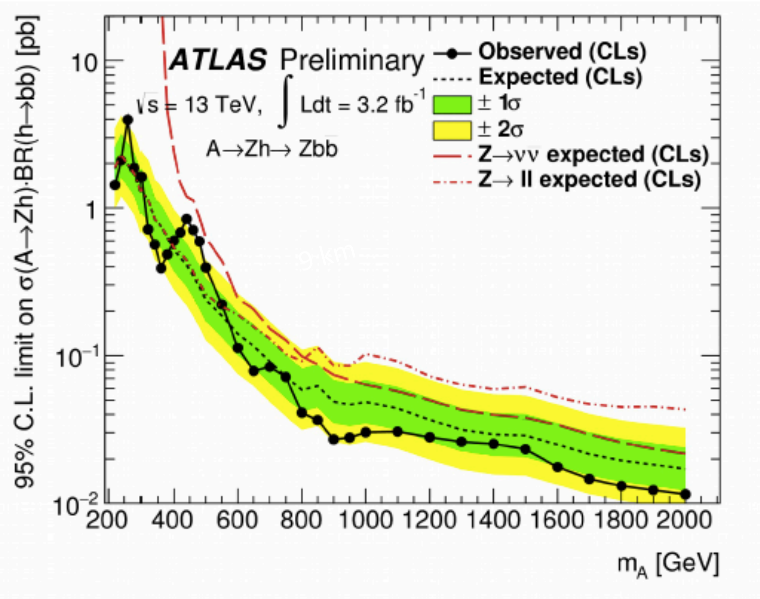
A->Z+h->νν/ll+bb

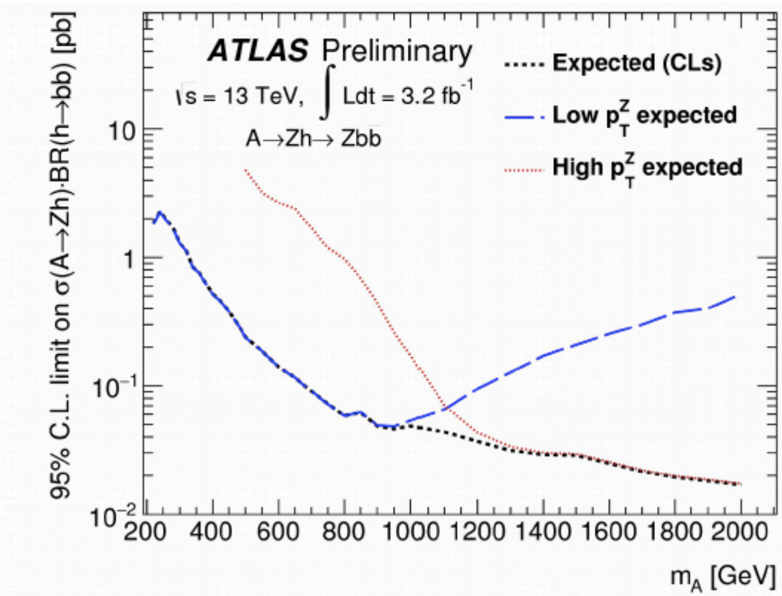


- Search for a CP-odd, pseudoscalar Higgs boson A decaying to a SM-like Higgs boson h and a Z boson in a Two-Higgs-Doublet model

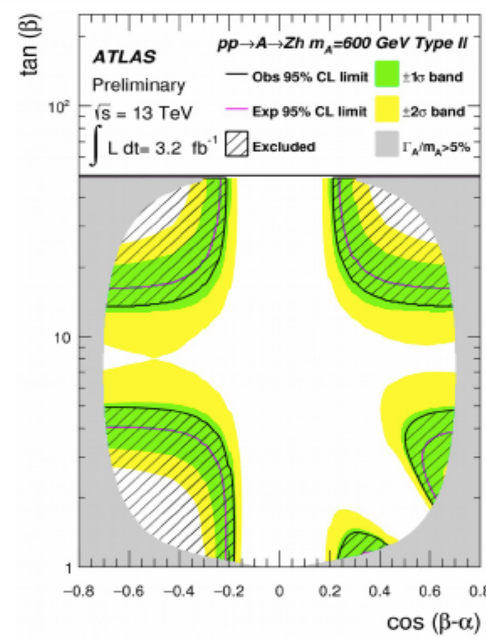
- General analysis design
  - Split data whether charged leptons or neutrinos in final state
  - Define signal regions in m_{bb}, two control regions each to constrain ttbar and Z+heavy flavor background
- First Run-2 result public in spring 2016 with 2015 data only
  - Multiple improvements, including added "merged" category

A->Z+h->νν/ll+bb



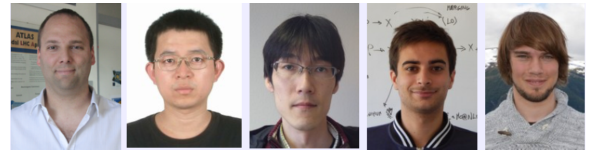


- No significant excess found, derive constraints on mass and cross-section x BR of particle A
- 2-lepton vs. 0-lepton (MET) channels and resolved vs. boosted selection excel in different mass ranges

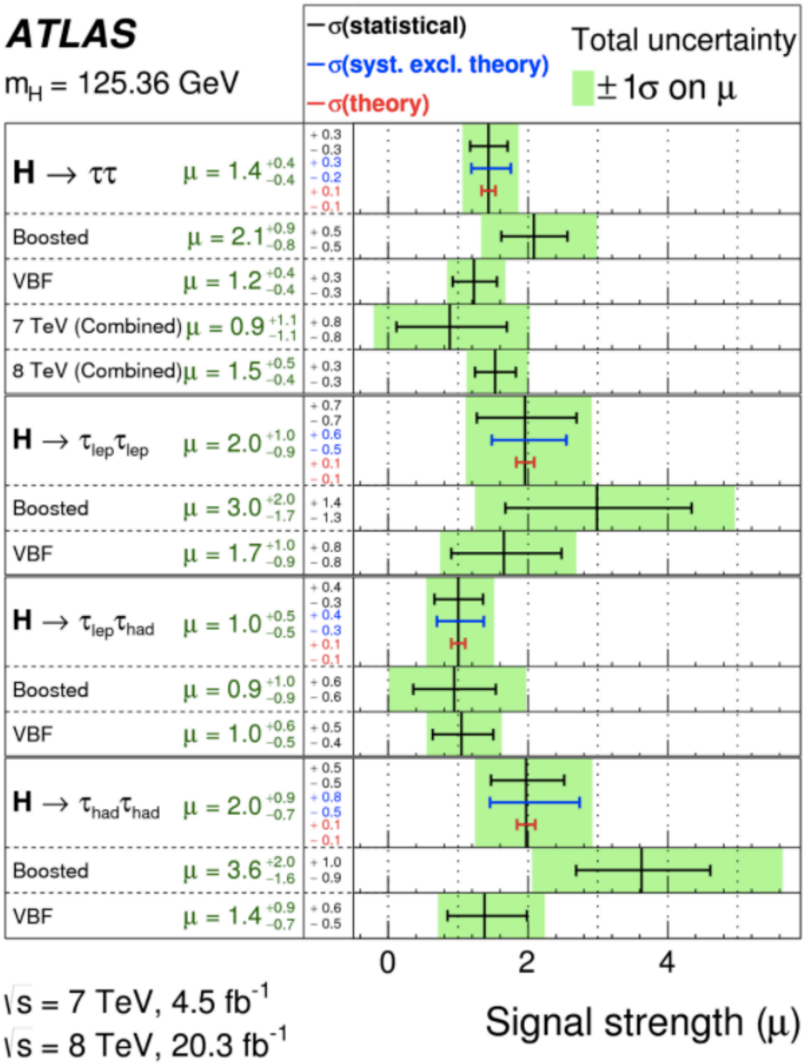


- Constraints in two Higgs doublet model close to Run-1 results - **with only 3 fb^{-1}**
- **~10 times more data being analyzed**

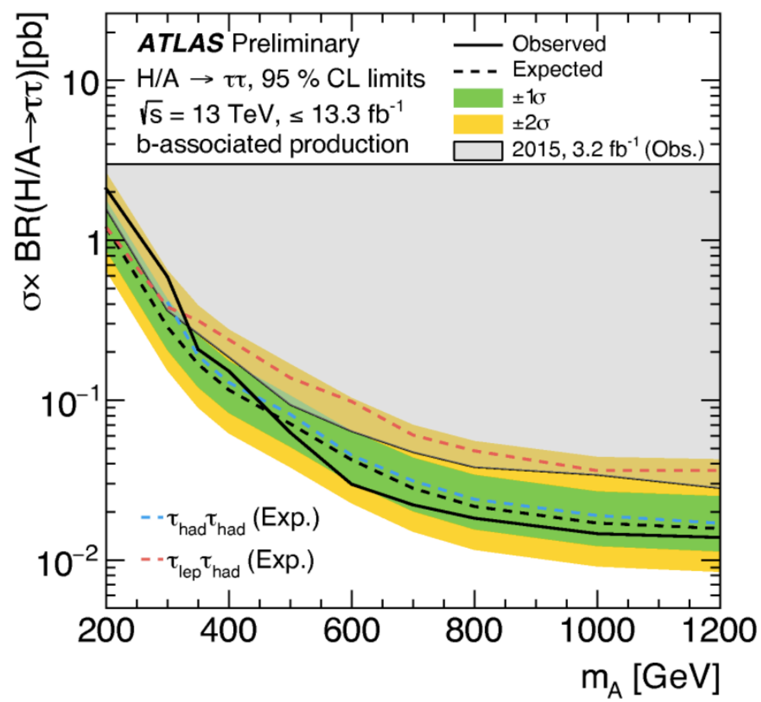
H->ττ



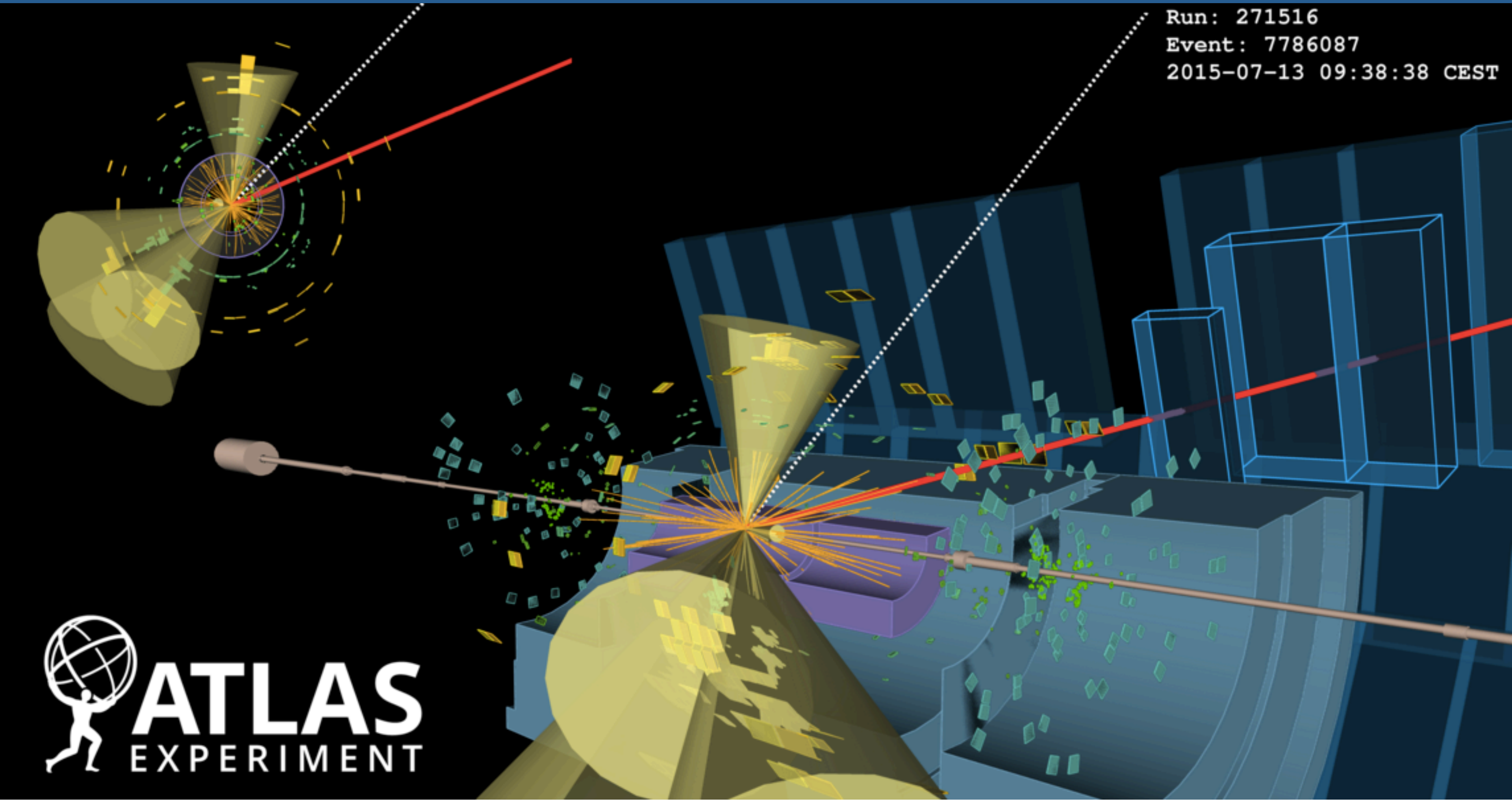
- Likewise, both heavy Higgs search as well as “rediscovery” in Run-2 being worked on



- Stay tuned for Run-2 SM results
- Two iterations of BSM Higgs->ττ already public



Search for Supersymmetry



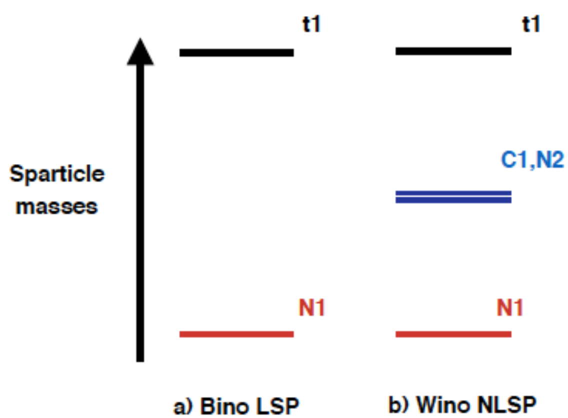
Event with two top quark candidates and a missing transverse momentum of 470 GeV

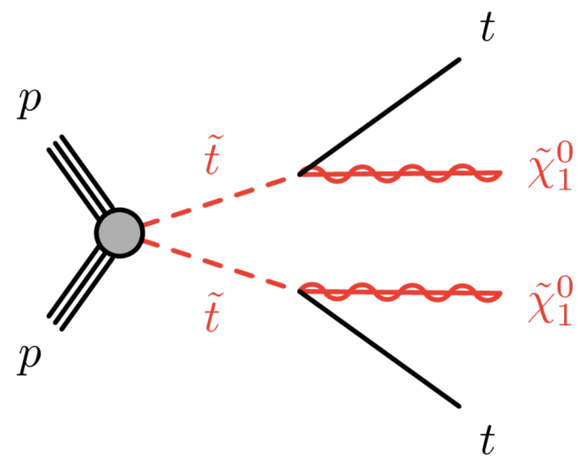
Looking for stops

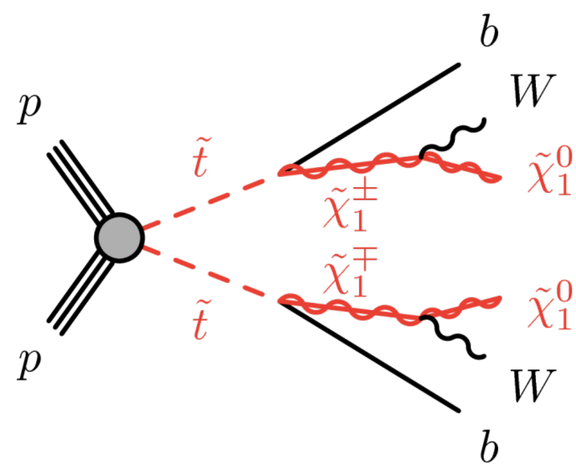
- Low mass of supersymmetric (SUSY) partners of top quarks (stops) well motivated from theory - stops are special!
- Constraints on stops are much weaker than on partners of light quarks and gluons
  - missing t-channel production via Gluino exchange

- Focus on “simplified models”
  - Assume a limited number of sparticles in reach, all others very heavy
  - Result of one analysis = one building block to test full models

  == Benchmarks

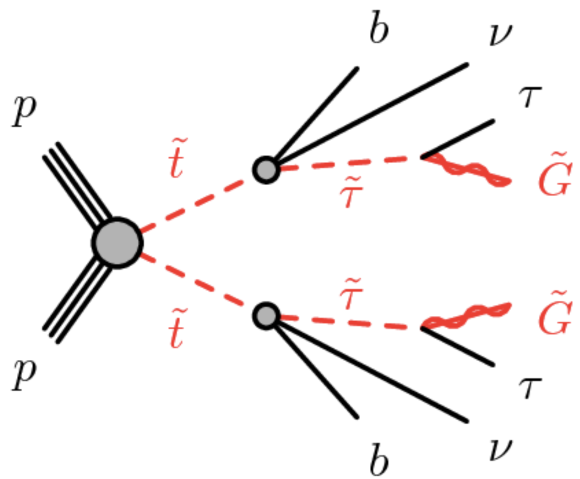


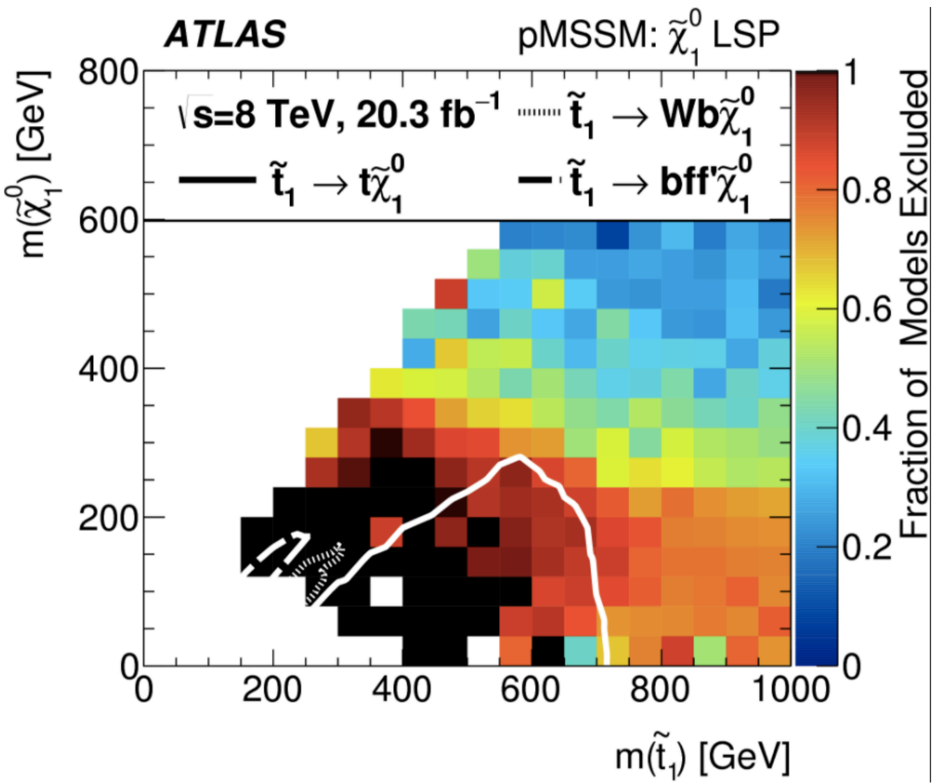




Looking for stops

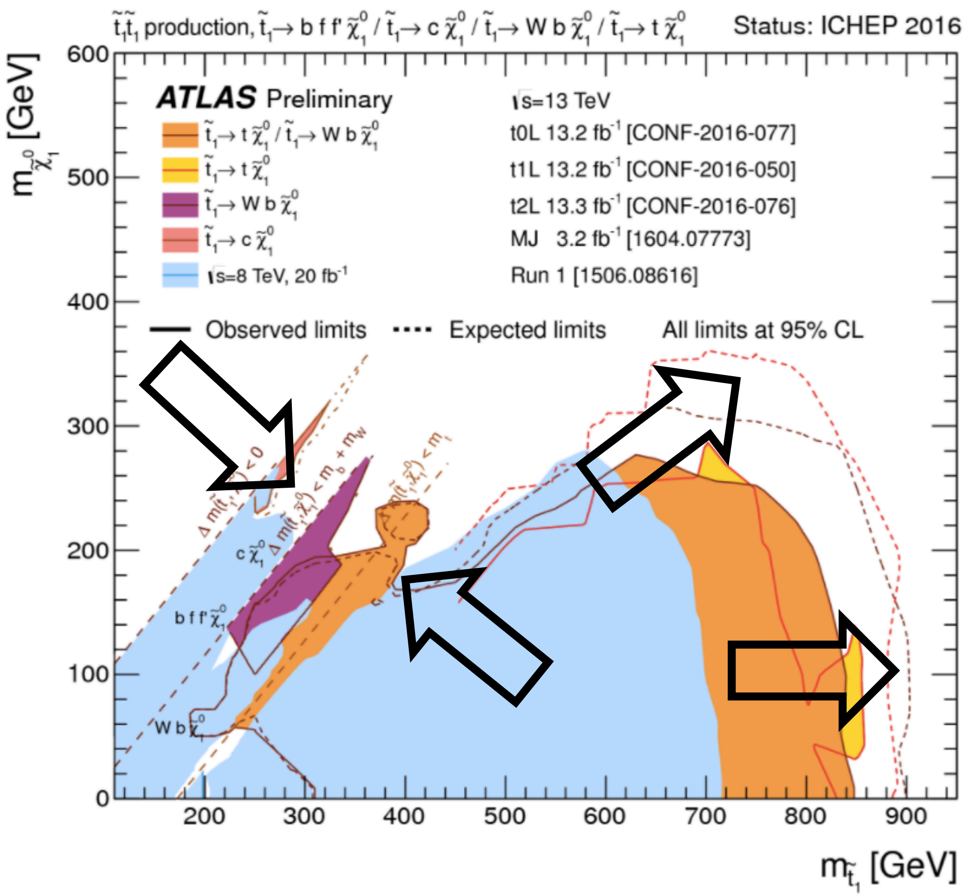
- End of Run-1 focus of team was pair production of stops in fully hadronic final states and final states including one lepton (e/μ)
- ATLAS did pMSSM scan during LHC long shutdown 1, checking ~300000 model points
- A large fraction of models surviving constraints in the region "excluded" for simplified models had τ-leptons in the final state
    - Joined the effort in Run-2





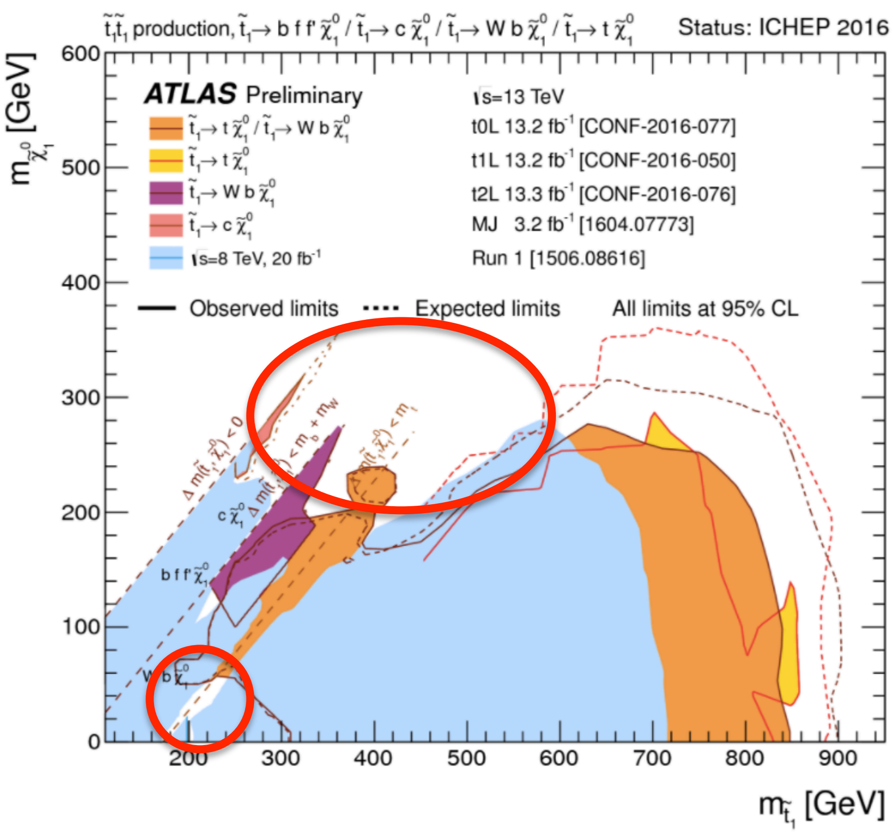
Stops - Run-2 Status

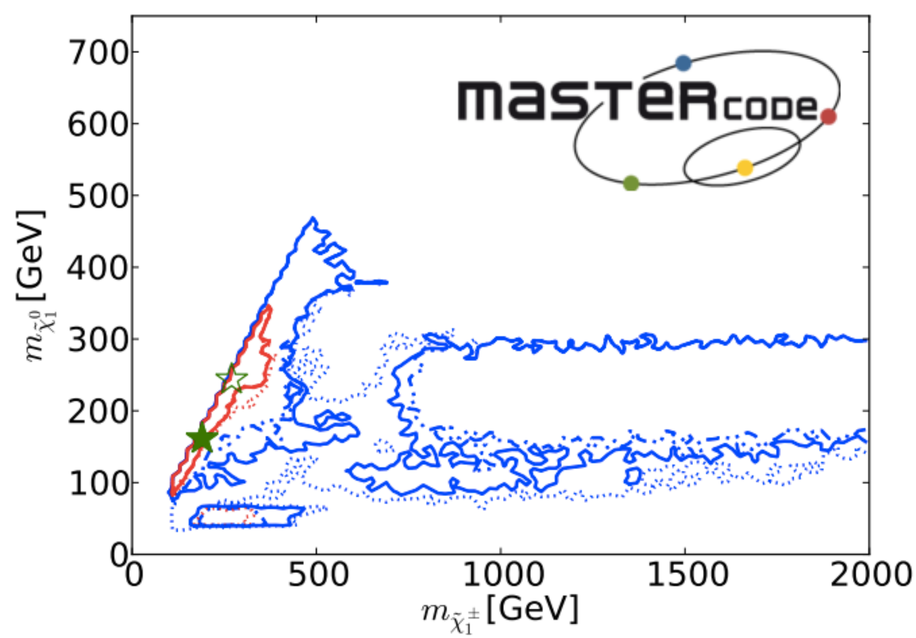
- No significant excess above Standard Model backgrounds observed in any channel
- The two areas of focus stay the same
  - Extend coverage to higher masses/lower production cross-sections
  - Try to "plug holes"



SUSY - Remaining Refuges

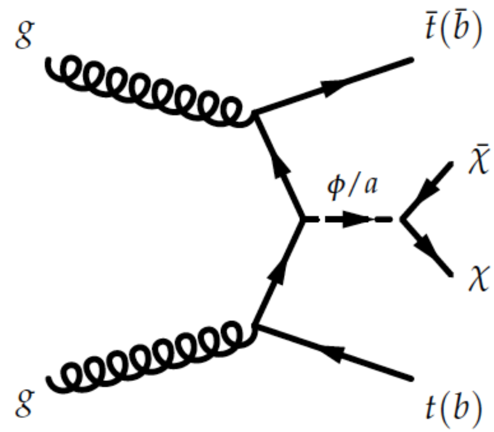
- “Natural” Supersymmetry under tension from LHC data
  - Even for light stops, interesting corners remain

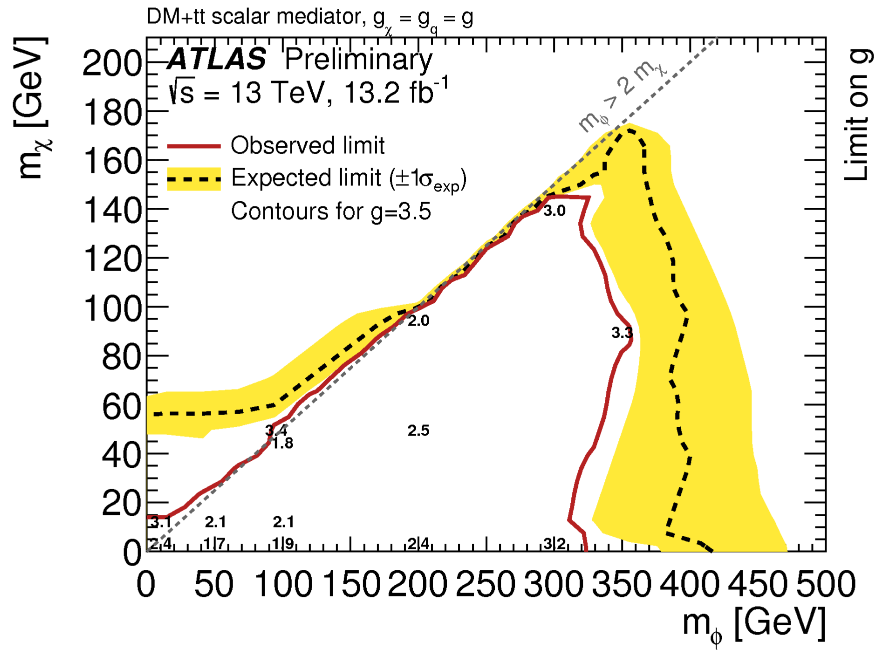




Dark Matter interpretation of SUSY searches

- With SUSY "naturalness" under pressure, is low scale SUSY worth the "effort"?
- SUSY searches have been re-interpreted in the context of simple Dark Matter models
- Run-2: Dedicated signal regions attached to searches for SUSY, sharing techniques, background estimates, …
    - Looking for Dark Matter + heavy flavor production





Summary

- Freiburg group has three main areas of emphasis for early ATLAS Run-2 data analysis
    - **Higgs -> WW**
    - **Higgs -> fermions**
    - **Searches for Supersymmetry (stops)**
  - In Higgs sector, searches for heavy Higgs had priority at first due to favorable parton luminosity ratios of 13 to 8 TeV
- Typically a factor of 3 to 10 more data already recorded and being analyzed
  - **Stay tuned - Rencontres de Moriond are just around the corner**