Search for MSSM from tau decaying Higgs bosons

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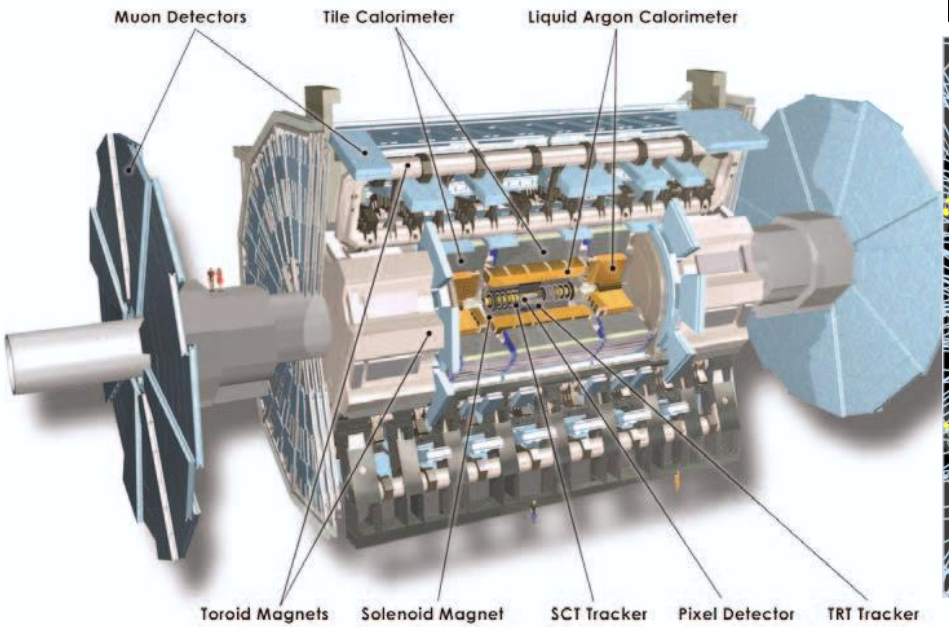
Outline

The ATLAS Experiment

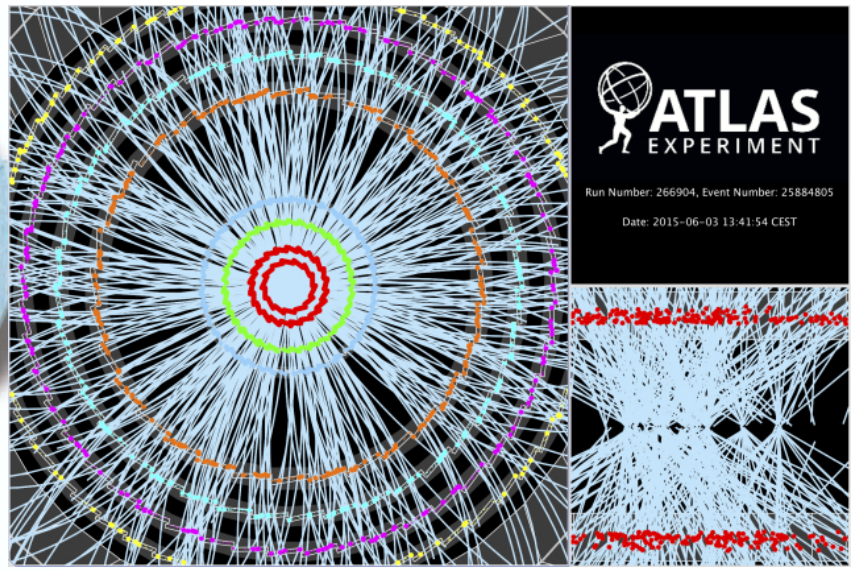
A ToroidaL ApparatuS

Show result from Run-II ATLAS

2015 data 13 TeV $3.2fb^{-1}$ $25ns^{-1}$ bunches



First stable beam, 3 June 15



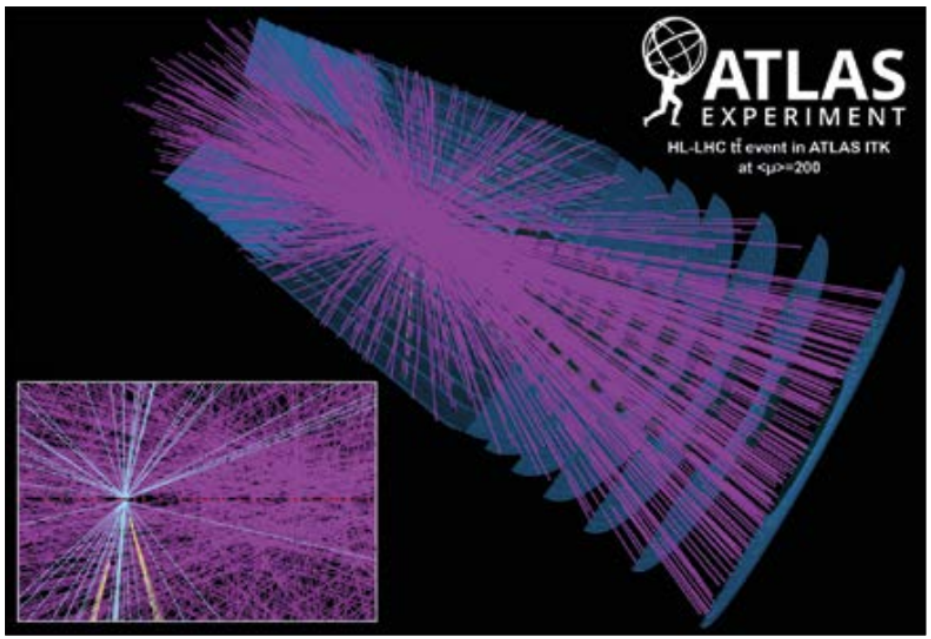
ATLAS-PHO-Event-2015-016

Upgrade

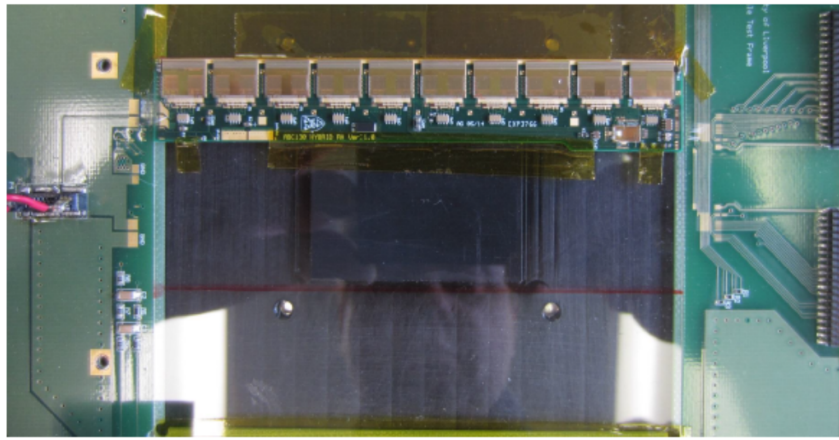
High Lumi LHC (Alex Tapper)

- By 2023 LHC delivers 300 fb^{-1}
- Detector will be changed.
- HL-LHC will deliver $\times 5$ the design luminosity.
- Very High PileUp 140–200
  $< \mu >$CERN-COURIER 56 1

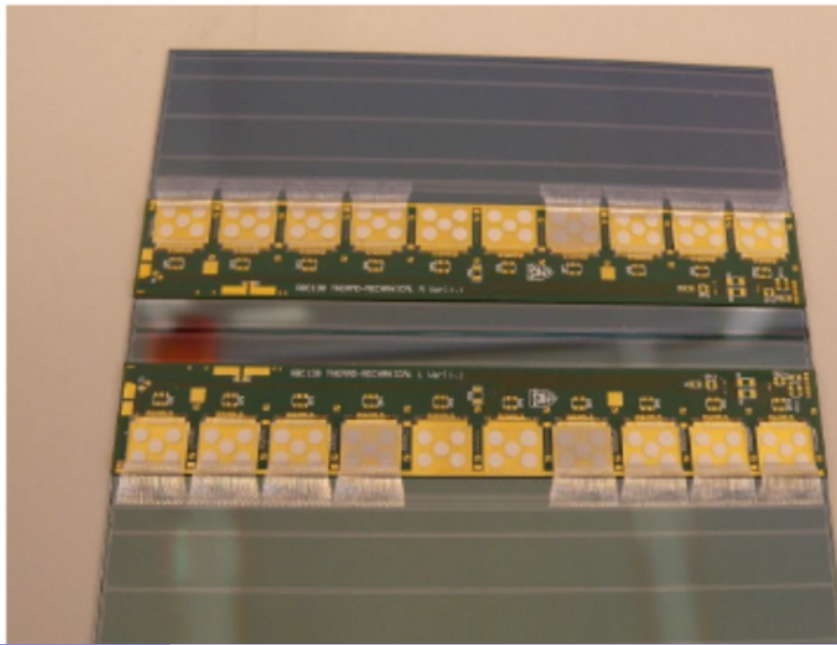
Si Tracker to replace TRT



- Prototype strip module
  CERN-LHCC-2015-020



- Sheffild Mechanical module
  Shef 1



ATLAS and the Higgs Boson

... in agreement with Standard Model

New boson observed in 2012

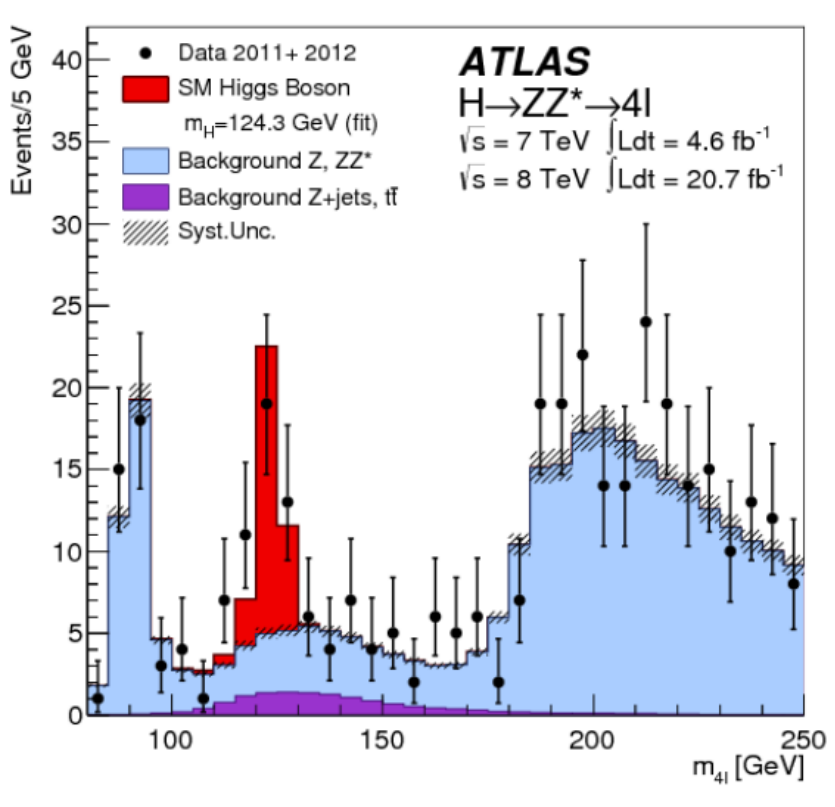
- σ, BR and couplings of H show no deviation from SM within uncertainties

New physics?

- Higgs doublet solely responsible for EW symmetry breaking?
- Is Higgs sector minimal or extended? (BSM)

Four lepton channel

ATLAS-PHO-EVENTS-2013-002



Presenting results for search of a MSSM heavy Higgs boson (Run-II)

2HDMs

Motivated extension: two Higgs fields break EW symmetry (H_u, H_b)

$$\rho = m_W/(m_Z \cos\theta_W) \to 1$$

- 2HDM cases
  - Degenerate $|m_H - m_A| < m_Z$
  - Hierarchical $|m_H - m_A| > m_Z$
    $A^0 \to ZH^0$
- Simplified CP-conserving case
  - Described by
    $[M_\phi, \tan\beta, \cos(\beta - \alpha)]$

5 Higgs Bosons

h	Light
H^0	Heavy
$H^\pm$	Charged
A	pseudoscalar

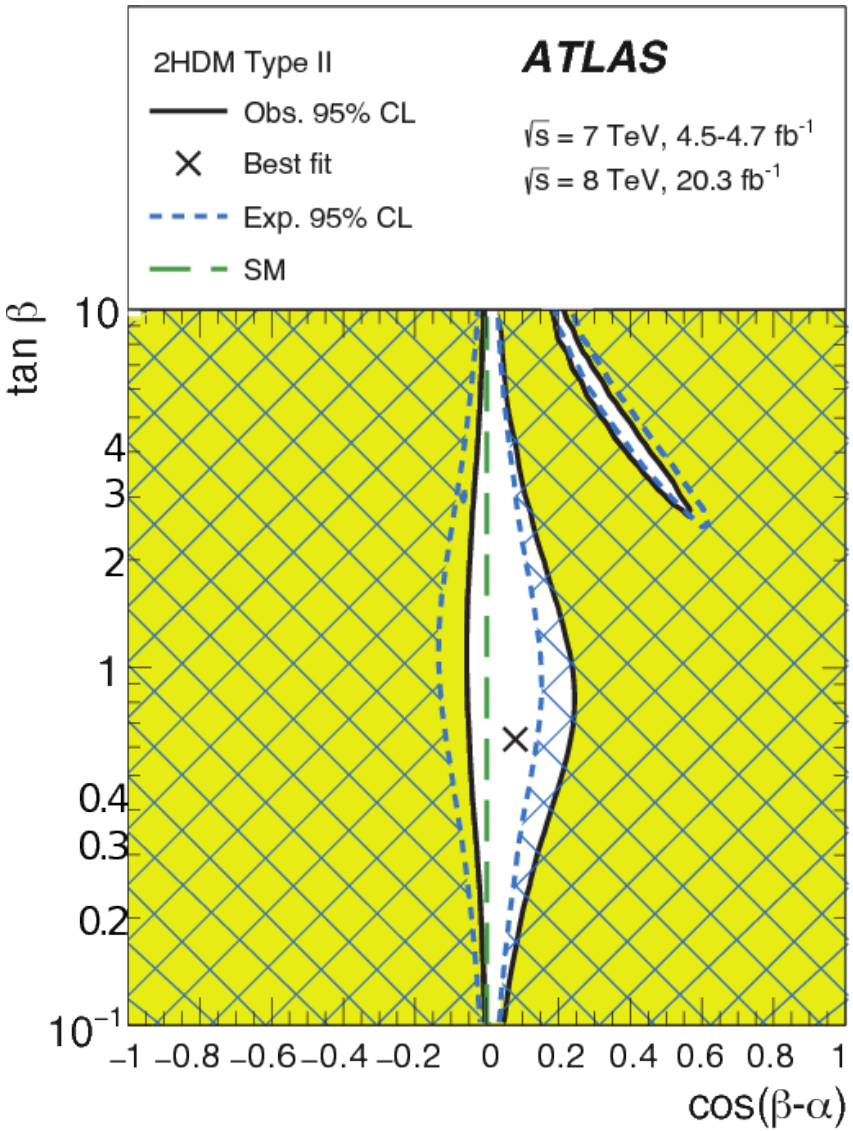
Coupling scale factor	Type I	Type II	Type III	Type IV
κ_V	sin(β - α)	sin(β - α)	sin(β - α)	sin(β - α)
κ_u	cos(α)/sin(β)	cos(α)/sin(β)	cos(α)/sin(β)	cos(α)/sin(β)
κ_d	cos(α)/sin(β)	-sin(α)/cos(β)	cos(α)/sin(β)	-sin(α)/cos(β)
κ_l	cos(α)/sin(β)	-sin(α)/cos(β)	-sin(α)/cos(β)	cos(α)/sin(β)

The coupling scale factor of the Higgs boson h to vector bosons, up and d quark, and lepton of each type expressed as ratios relative to the SM-Higgs couplings.

2HDM in Run-I

- *H* Coupling Measurements

arXiv:1502.04478v2



- Direct Searches (A→ Zh)

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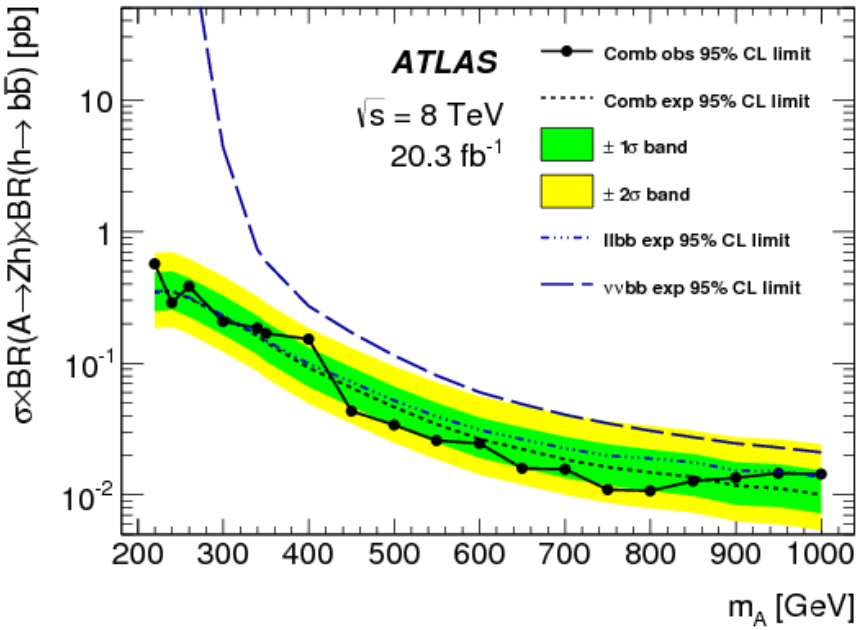
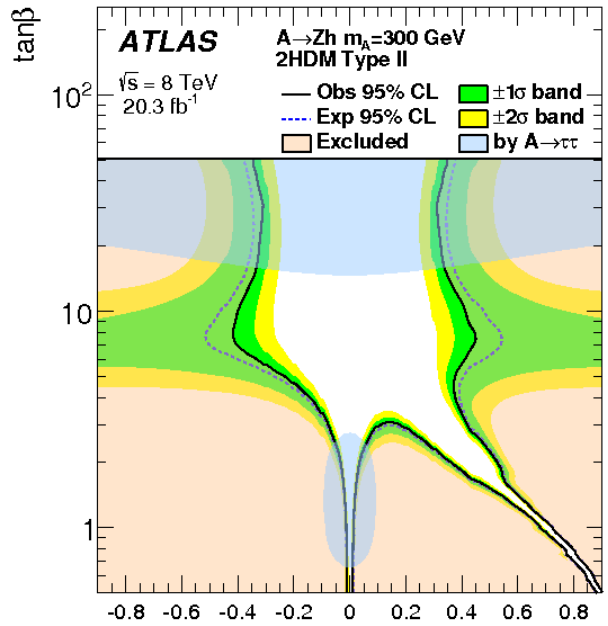




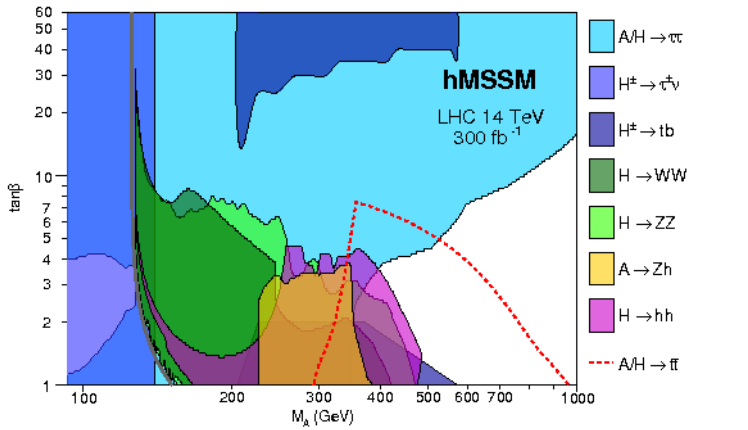
Minimal Supersymmetric SM

MSSM

- SUSY in 2HDM (Type-II)
- Described by

$$(M_\phi, \tan\beta)$$

JHEP 1506 (2015)



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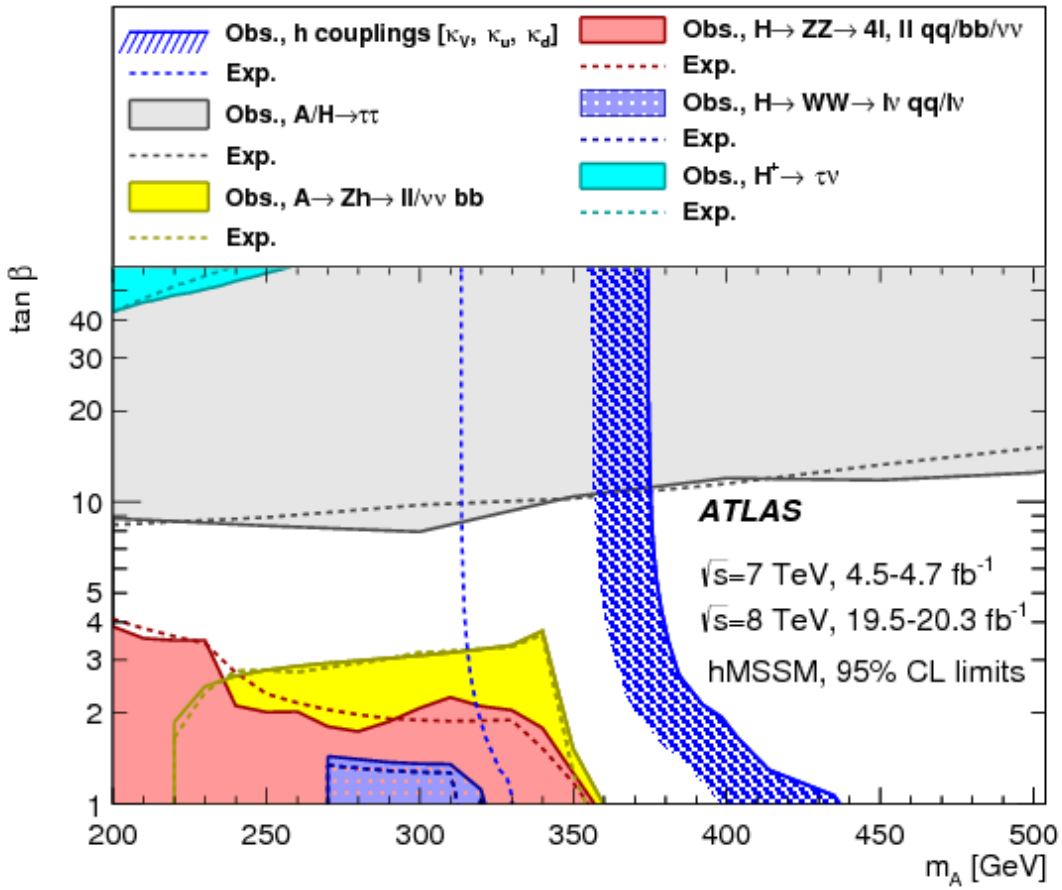
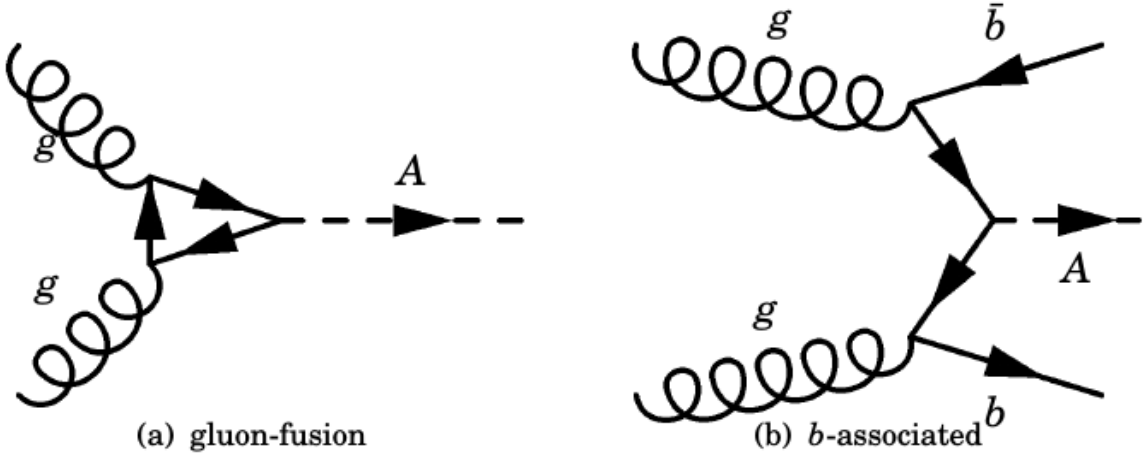


- Dark Matter, hierarchy, naturalness
- Many different benchmarks

focus on hMSSM ($m_h = 125$GeV)

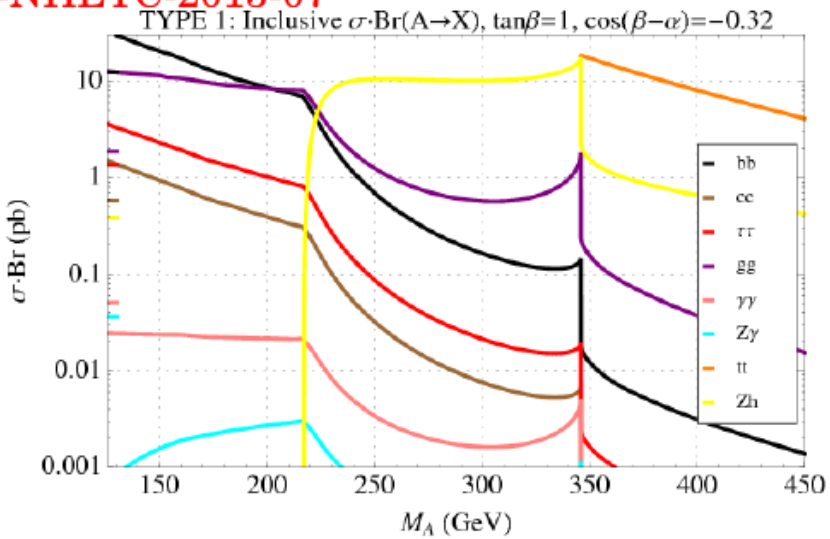
Motivation (XSs and BRs)

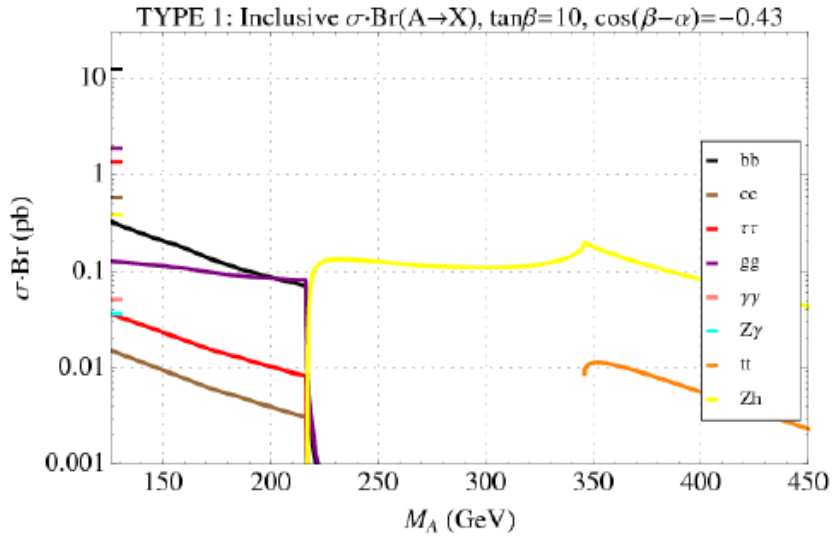
- Gluon fusion is dominant form of production
- b-associated production particularly important for large tanβ.



(a) gluon-fusion (b) b-associated

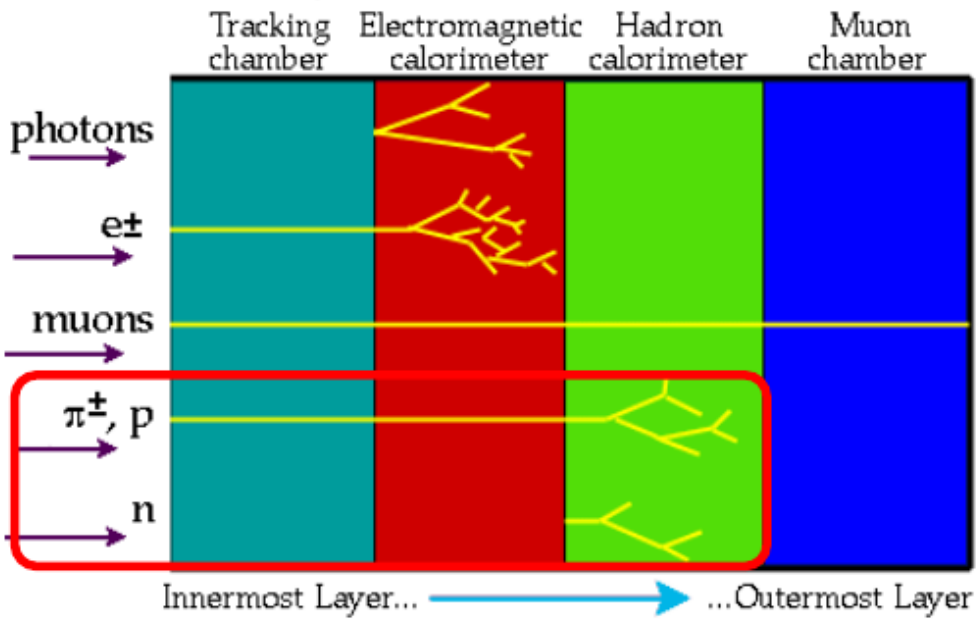
RU-NHETC-2013-07

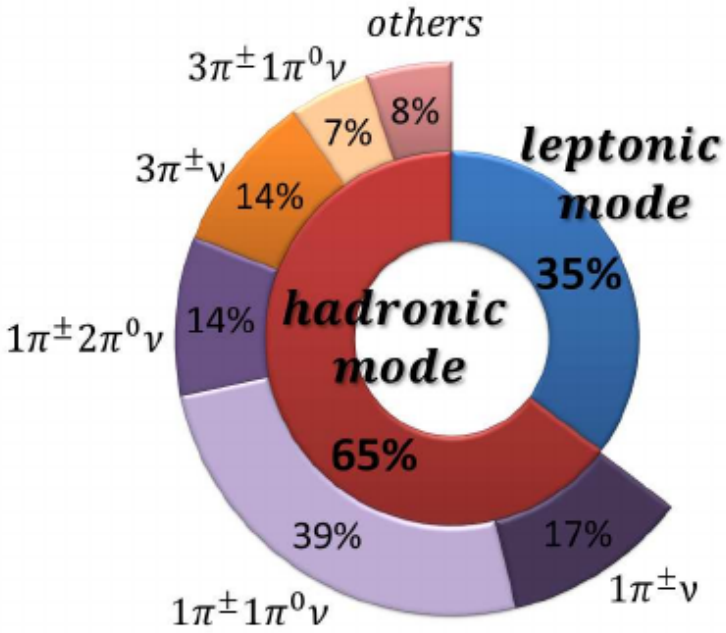




Tau Leptons in ATLAS

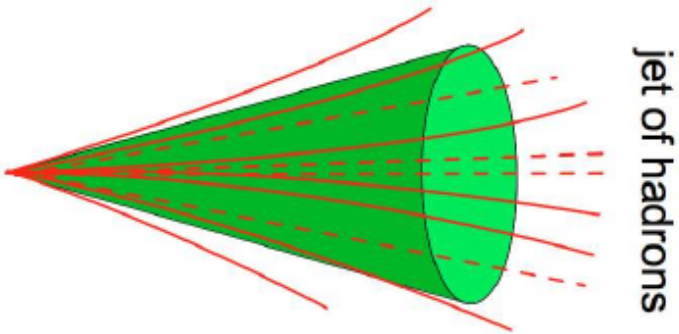
Different decays in ATLAS detector:



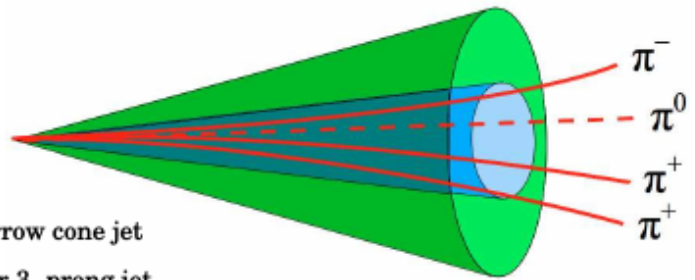


Taus never make the inner-detector (can only look at decays) ATLAS-CONF-2013-064

Non-Tau Jet



Tau Jet



- Narrow cone jet
- 1- or 3- prong jet
- BDT and e-veto

Object Selection

- Focus on lep-had and had-had resonant decays.
- Two similar but different (backgrounds) analysis are combined.
- Common object selection

Use all of ATLAS

Electrons	15 GeV	$\mid \eta \mid < 2.47^{\dagger}$	loose + isolation
Muons	15 GeV	$\mid \eta \mid < 2.5$	loose + isolation
Jets	anti-k_t algo	$\Delta R < 0.4$	Used for MET
Tau (visible decay)	20 GeV	$\mid \eta \mid < 2.5^{\dagger}$	BDT selection

- MET: negative vector sum of p_T + soft term (Benjamin Brunt).
- Remove overlaping objects

taus over jets	$\Delta R < 0.2$
e/μ over jets	$\Delta R < 0.4$
e/μ over taus	$\Delta R < 0.2$
μ over e	$\Delta R < 0.2$

[†]Transition region excluded:$1.37 < \mid \eta \mid < 1.52$

Event Selection for Lep-Had

Triggers

Medium ele	$p_T > 24$ GeV
Loose ele	$p_T > 120$ GeV
Isolated μ	$p_T > 20$ GeV
Non Iso μ	$p_T > 50$ GeV

Lepton

n = 1	Medium ID
$p_T > 30$ GeV	trigger match

Tau lepton

Medium ID $p_T > 30$ GeV

Choose leading tau

- Opposite charge
- $\Delta\phi(\tau, \ell) > 2.4$
- $m_T(\ell, MET) < 40$ or
  $m_T(\ell, MET) > 150^{\dagger}$ GeV
- Reject
  $80 < m_{vis}(e, \tau) < 110$ GeV

Event Selection for Had-Had

Trigger

- Single tau trigger
  $p_t > 120$ GeV

- $\Delta\phi(\tau, \tau) > 2.7$
- Opposite sign

Tau Leptons

leading τ	trigger match medium $p_T > 135$ GeV
subleading τ	loose $p_T > 55$ GeV

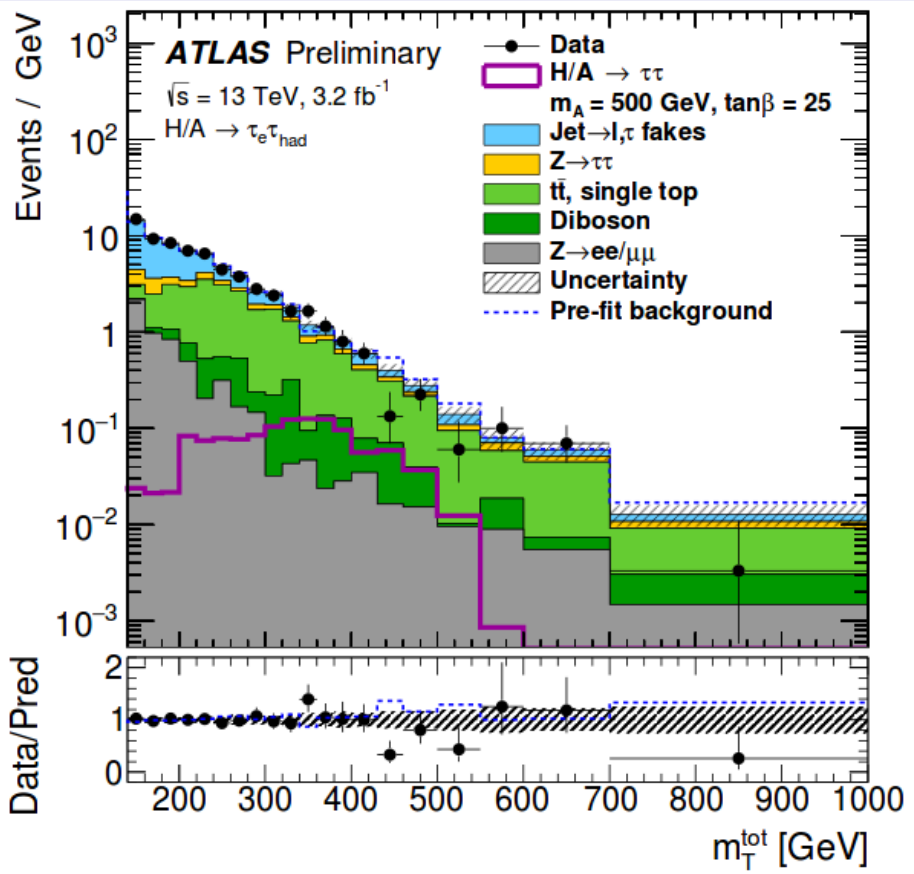
Di-tau mass reconstruction (Lep-Had and Had-Had)

$$m_{\mathrm{T}}{}^{\mathrm{TOT}} = \sqrt{m_{\mathrm{T}}{}^2(\mathrm{MET}, \tau_1) + m_{\mathrm{T}}{}^2(\mathrm{MET}, \tau_2) + m_{\mathrm{T}}{}^2(\mathrm{MET}, \tau_2)}$$

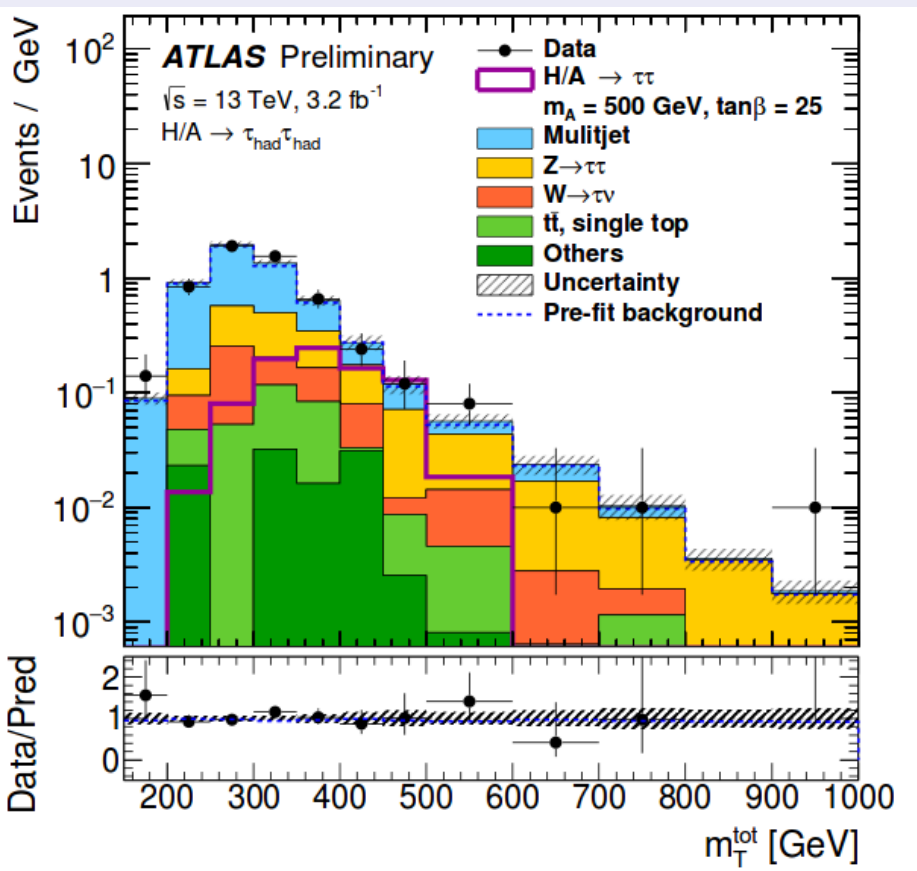
Background estimation and final distributions

- Fake-Factor used for jets faking taus: QCD & W+jets(Lep-Had)
- Fake-Rates applied to simulated backgrounds.
  ATLAS-CONF-2015-061

Electron Channel



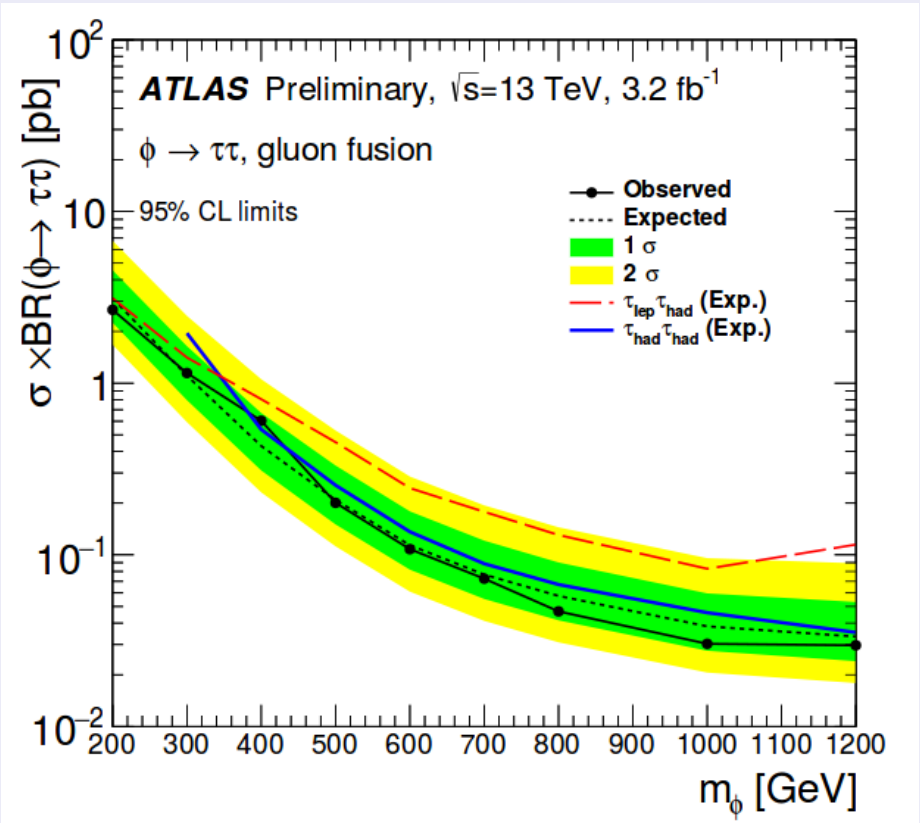
Hadronic Channel



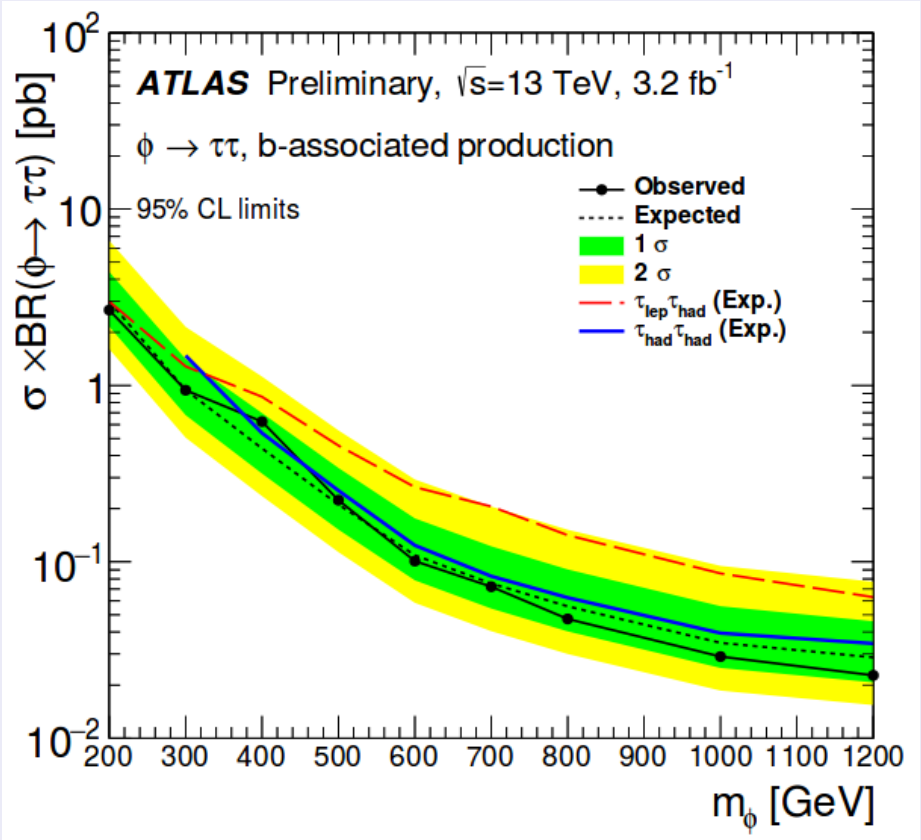
Limits

ATLAS-CONF-2015-061

gluon-fusion



b-associated



Exclusion Limits

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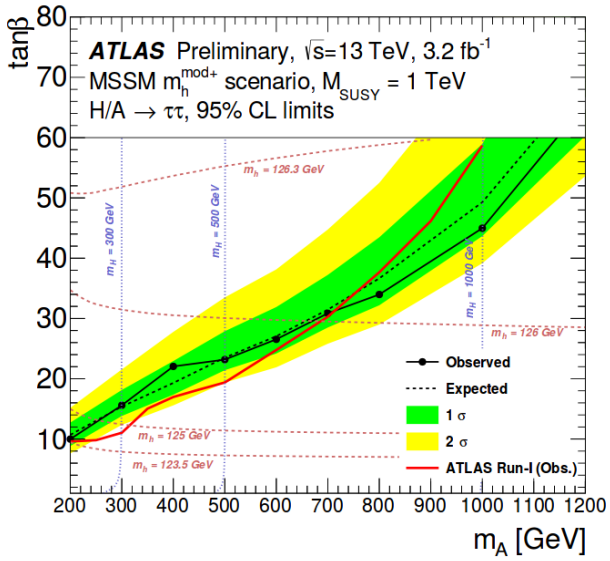
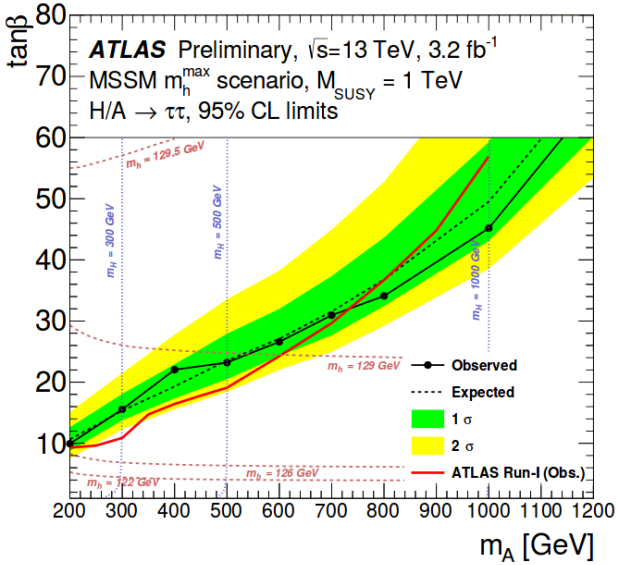
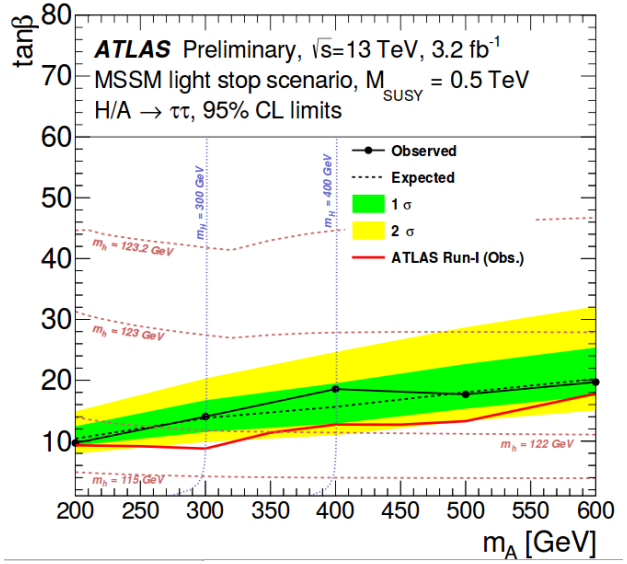
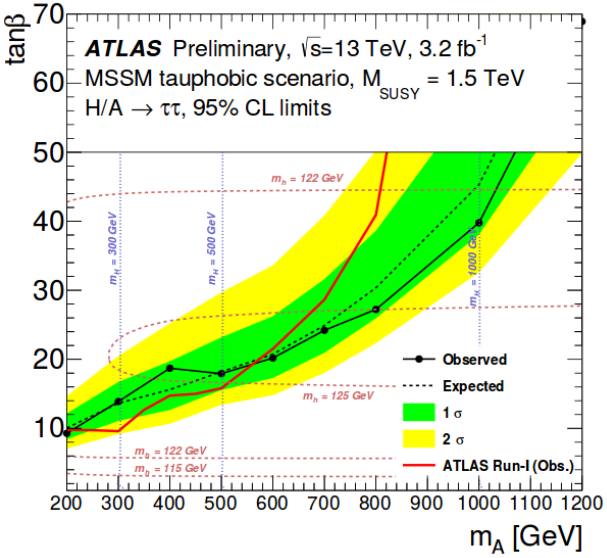
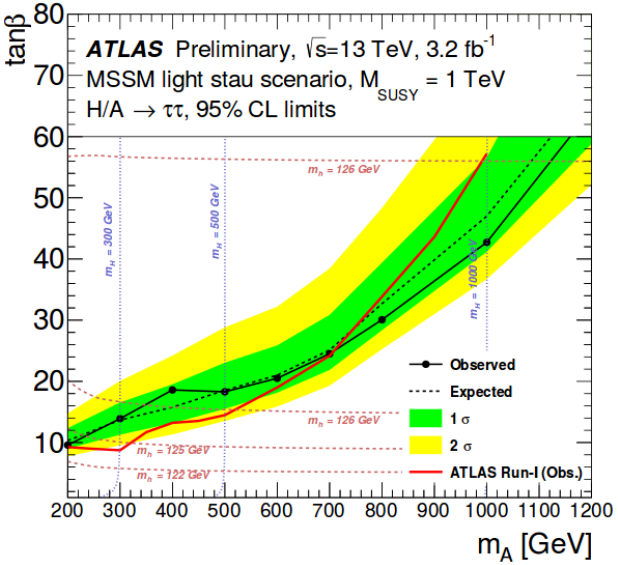
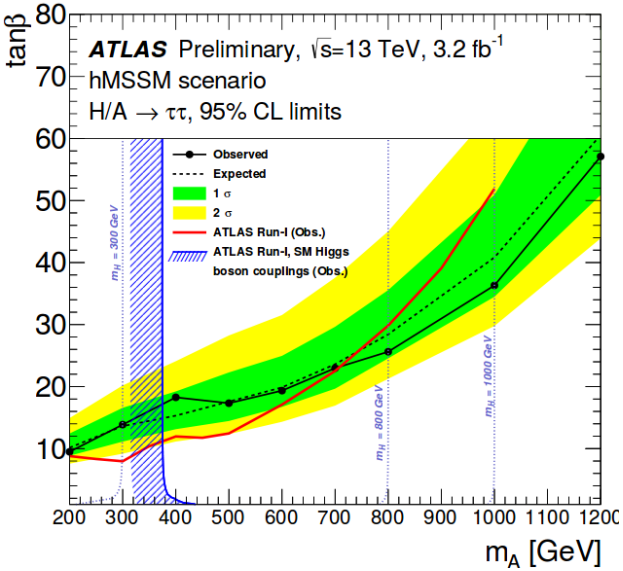












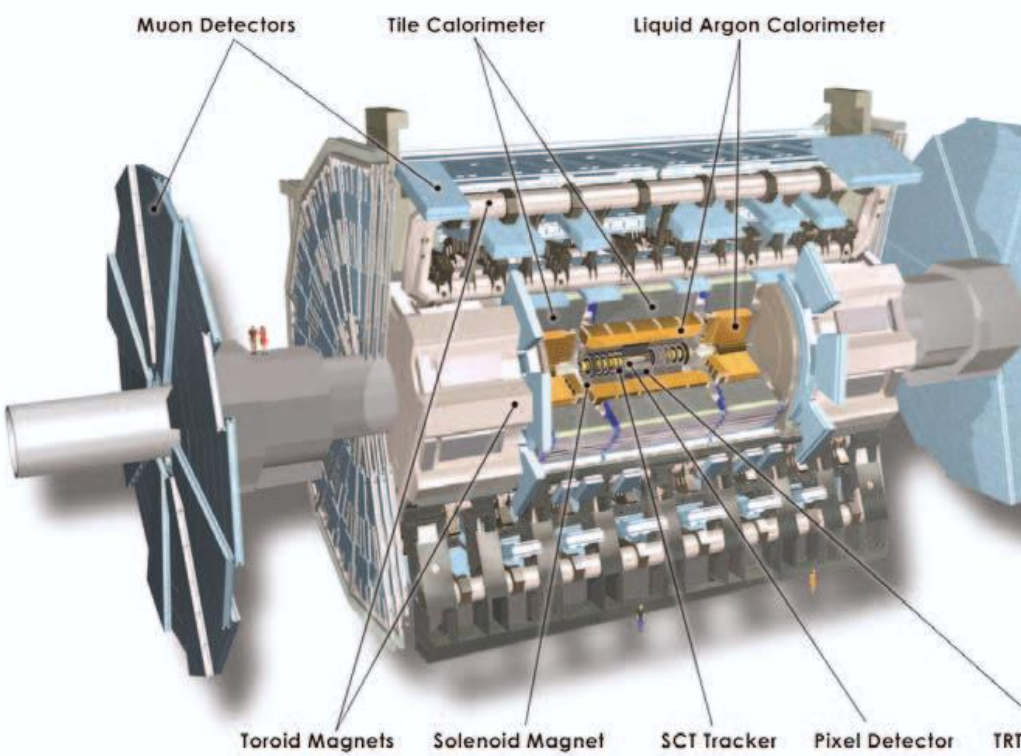
Conclusion

- Benchmark scenarios are used in ATLAS to probe 2HDM and MSSM models.
- These scenarios can be probed via H coupling, or direct resonant searches.
- Direct searches used to exclude large regions of phasespace.
- Can be used in combination with other analysis to exclude large ranges.
- Heavy resonance $\phi \rightarrow \tau\tau$ search was conducted and interpreted in several MSSM scenarios.

The ATLAS Experiment

A ToroidaL ApparatuS

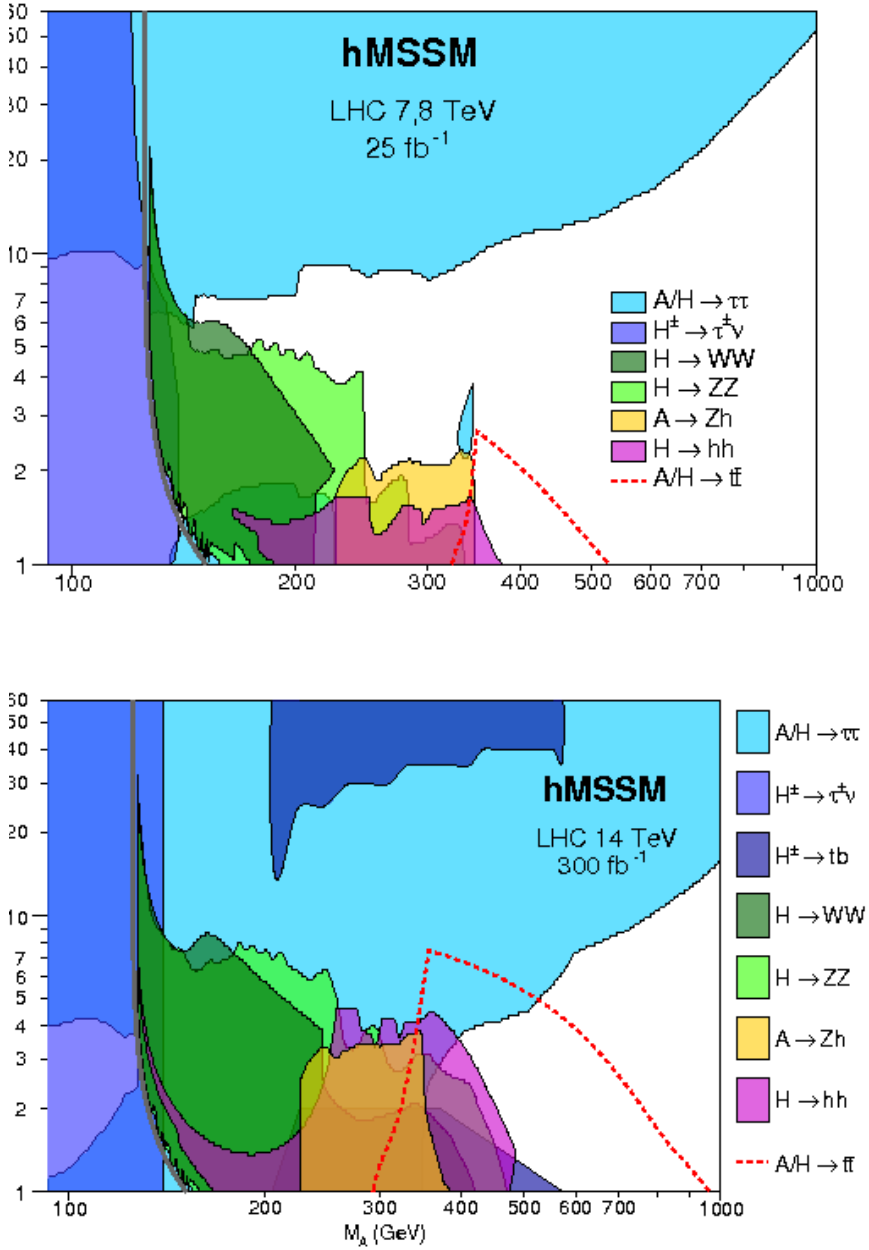
- Diameter 25 m; Length : 46 m
- Barrel toroid length 26 m
- Overall weight 7.000 tonnes
- ~ 100 million electronic channels
- ~ 3.000 km of cables
- Sub-Detectors
  - Inner Detector, Calorimeters, Muons, Forward detectors
- Computing Grid and DATA quality



BSM Combinations

JHEP 1506 (2015)

- LHC projections of high mass Higgs searches show promise for exclusion of large amounts of the hMSSM phasespace.



- Fake Factor Method
  - Background dominated by jet misidentied as τ_{vis}
    - Fake Factor Method

$$FF = N(pass - tau - ID)/N(fail - tau - ID)$$

Lep-Had	Had-Had
$\text{FF} = \text{FF(W)} \times r_W + FF(QCD) \times r_{QCD}$	FF(QCD)
Applied to anti-tau events	anti-sub-leading-tau

Fake Rates

- Fake Rate in MC processes not modelled well.
  - Calculated in CR.
  - Applied to non truth matched taus.

Systematics

- Theoretical XS uncert. for MC (PDF,scale variation)
- Detector Uncrtainties
  - Taus, Electron, Muon: trigger, Reco, ID, energy scale
  - JES, JER
  - MET + soft-term
- FakeFactor LH
  - Contamination in W+jets CR
  - Difference in q/g jet fakes in CR/SR
  - Taken from MC
- FakeFactor HH
  - Statistical Uncert of difference between SS/OS FF
- Top MC p_T uncert.
- W+jet norm. uncert. from Sherpa/Powheg.
- Signal: PDF, final state radiation, renormalization, etc.