#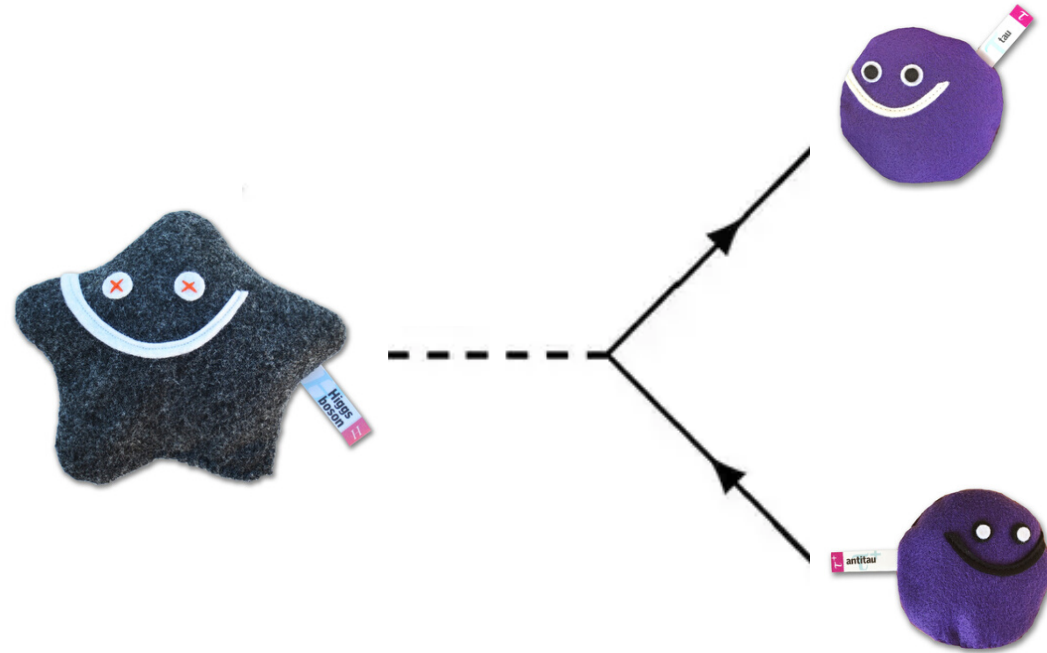 Searching for BSM Higgs and Gauge Bosons Decaying to Two Tau Leptons Using 36 fb^{-1} of Data Collected at √s=13 TeV with the ATLAS Detector

Janina Krzysiak

on behalf of ATLAS

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ATLAS
EXPERIMENT

Epiphany Conference 2020

motivation

- many BSM scenarios have an extended Higgs sector
 - Two-Higgs-Doublet Models (2HDMs) predict 5 Higgs bosons

  - Type-II 2HDM corresponds to Higgs sector of the Minimal Supersymmetric Model

- one of several extra Higgs searches at ATLAS

- Z' bosons can arise from extensions of electroweak symmetry
  - sequential standard model
  - non-universal G(221) model

production and decay

- separate by resonance production mode:

  - Higgs b-associated production → b-tag category

  - Higgs gluon-gluon fusion → b-veto category

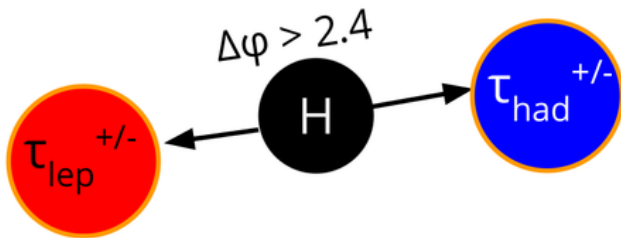 - Z' Drell-Yan production → inclusive category
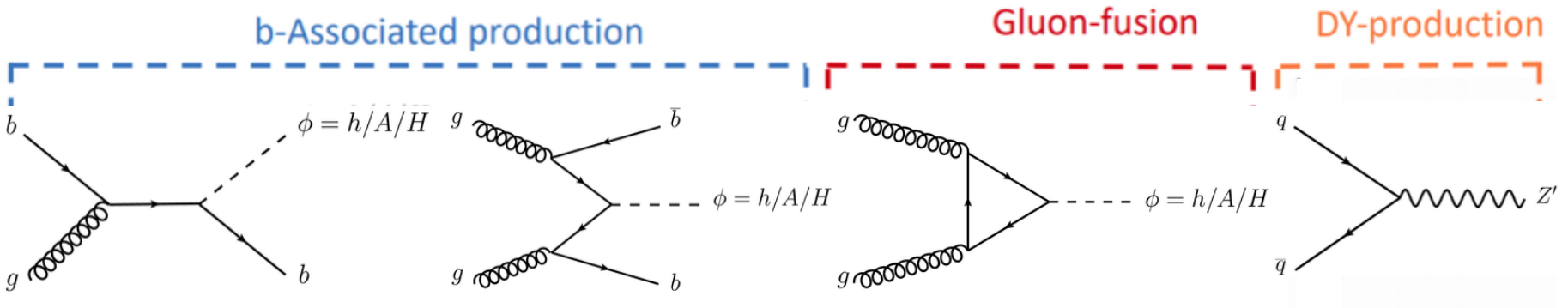
- separate by tau decay mode

  - lep-had and had-had channels

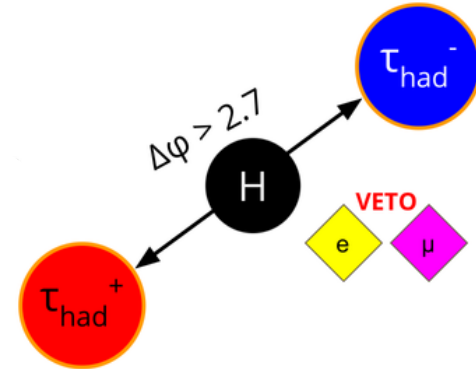 - skip lep-lep - very little improvement in

    sensitivity

3
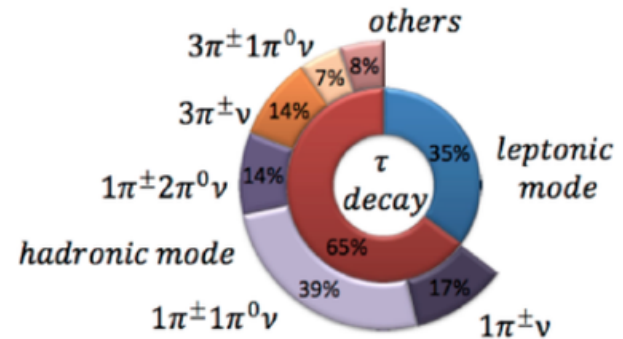
event selection

lep-had

- single-lepton trigger (40-120 GeV depending on data-taking period)
- leptonic tau:
  - matched to trigger
  - isolation criteria
- hadronic tau:
  - medium ID (BDT score)
  - pT>25 GeV and |η|<2.7
- $m_T(\text{lep}, \text{MET}) =$
  $= \sqrt{2p_T^{\text{lep}} \cdot \text{MET}(1 - \cos\Delta\phi(\text{lep}, \text{MET}))} < 40$ GeV
- 80< m_{vis} <110 GeV veto for e-had

had-had

- single-tau trigger (80, 125, 160 GeV depending on data-taking period)
- leading tau:
  - matched to trigger
  - pT > trigger pT + 5 GeV
  - medium ID (BDT score)
- subleading tau:
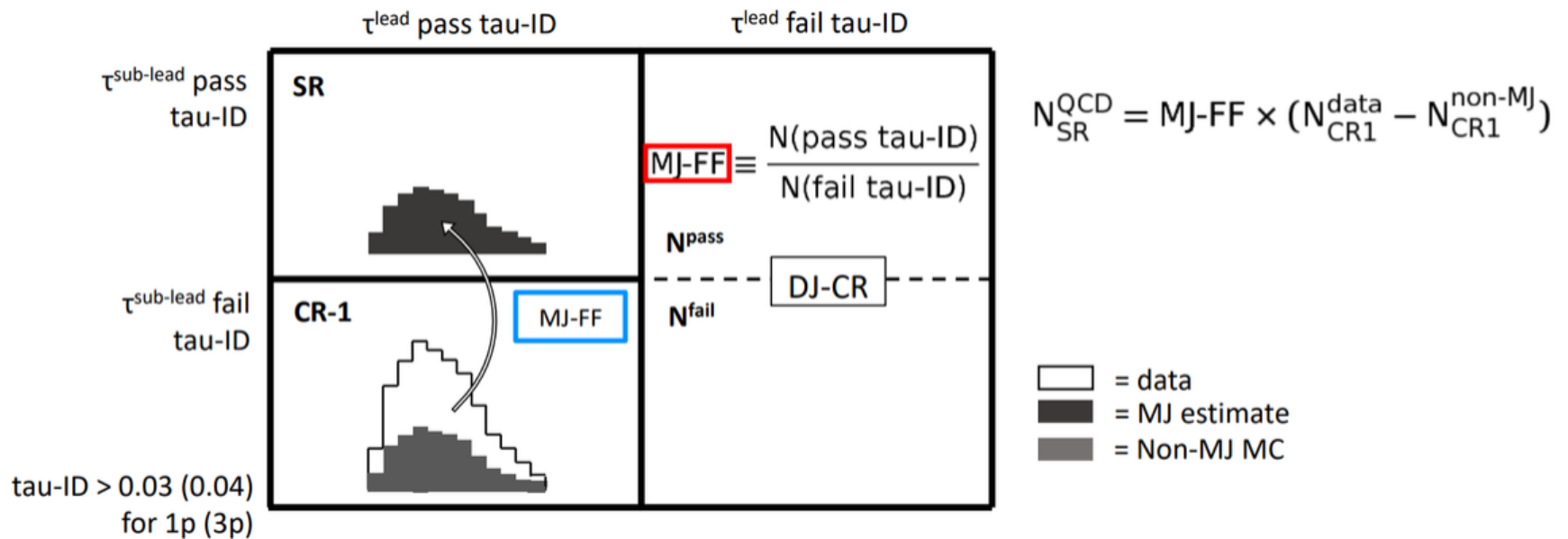 - pT>65 GeV
  - loose ID (BDT score)

4

backgrounds: had-had

- Monte Carlo with data-driven jet→τ fake rates:
    - Drell-Yan Z/γ*→ττ (two real taus)
    - W→τν+jets (one real tau, one fake tau)
    - single top quark, ttbar
    - diboson
    - W→lν+jets
    - Z→ll+jets

- data-driven method:
    - QCD multijet (jet→τ fakes)

backgrounds: lep-had

- Monte Carlo:
  - Drell-Yan Z/γ*→ll,ττ
  - top quark, ttbar
  - diboson

  (true lepton and either true tau or lepton→τ fake)
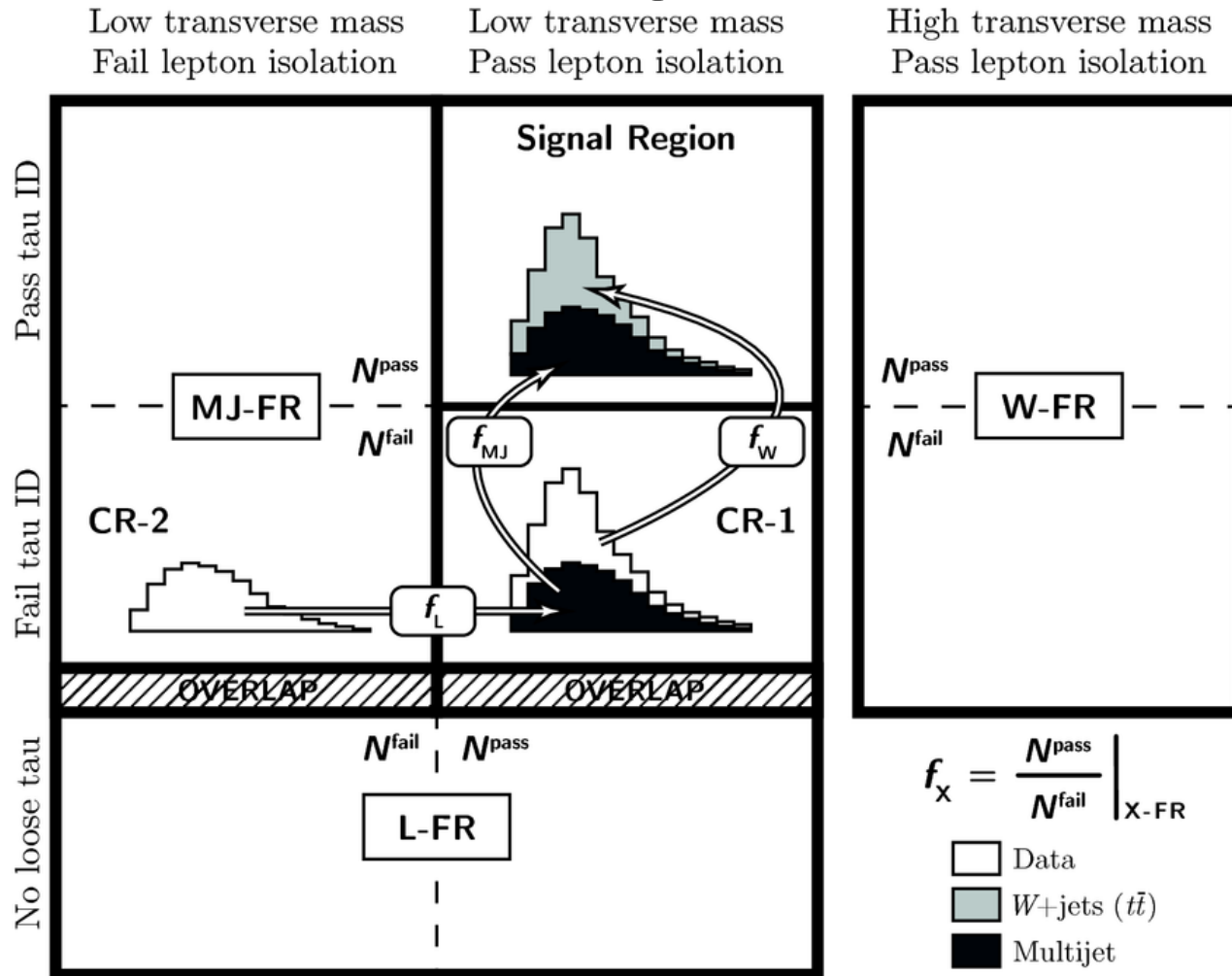

- data-driven method:
  - QCD multijet (lepton and tau faked by jets)
  - W+jets (true lepton, jet→τ fake; b-veto category)
  - ttbar (true lepton, jet→τ fake; b-tag category)

data-driven background estimation for had-had

$$N_{SR}^{QCD} = MJ\text{-}FF \times (N_{CR1}^{data} - N_{CR1}^{non\text{-}MJ})$$

$$MJ\text{-}FF \equiv \frac{N(\text{pass tau-ID})}{N(\text{fail tau-ID})}$$

→ fake factors are binned in subleading tau pT

data-driven background estimation for lep-had

→ multijet fake factors are binned in leptonic tau pT
→ W+jets/tt fake factors are binned in hadronic tau pT

systematic uncertainties

- for Monte Carlo:
  - theoretical cross-section calculation
  - luminosity, pile-up uncertainty
  - efficiency of reconstruction, identification, triggering algorithms
  - energy scale and resolution of e, μ, τ, (b-)jets, MET

- for data-driven background estimates:
  - fake factors: limited size of fake regions, background subtraction

fit model

- parameter of interest: signal strength

$$\mu = \frac{(\sigma \times BR)_{\text{observed}}}{(\sigma \times BR)_{\text{predicted}}}$$

- final discriminant:

$$m_{\mathsf{T}}^{\text{tot}} = \sqrt{m_{\mathsf{T}}^2(\tau_1, \tau_2) + m_{\mathsf{T}}^2(\mathsf{MET}, \tau_1) + m_{\mathsf{T}}^2(\mathsf{MET}, \tau_2)}$$

- fit function: likelihood function constructed as the product of Poisson probability terms (one for each bin in $m_{\mathsf{T}}^{\text{tot}}$)

- simultaneous fit in (lep-had,had-had)x(b-veto,b-tag) $m_{\mathsf{T}}^{\text{tot}}$ histograms

post-fit plots

lep-had
b-veto

lep-had
b-tag

had-had
b-veto
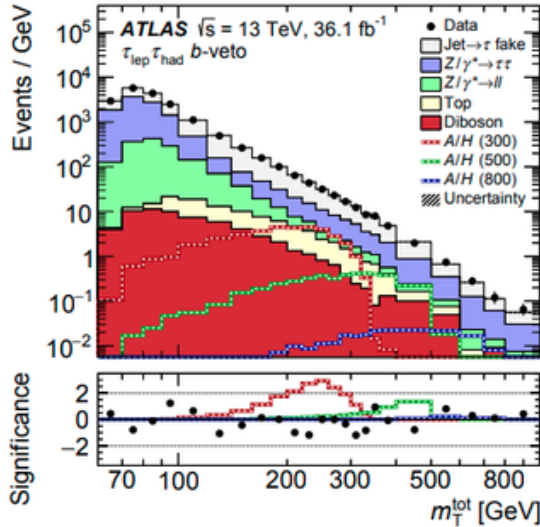
had-had
b-tag

(a) $\tau_{lep}\tau_{had}$ *b*-veto category
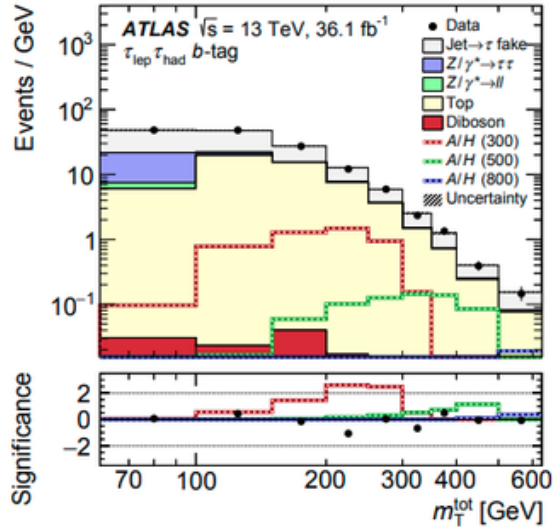
(b) $\tau_{lep}\tau_{had}$ *b*-tag category
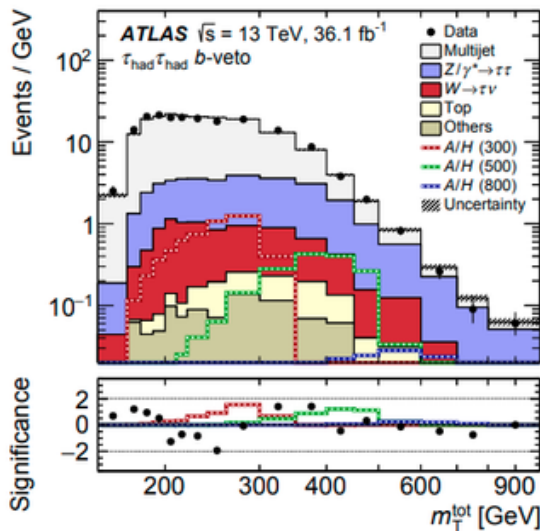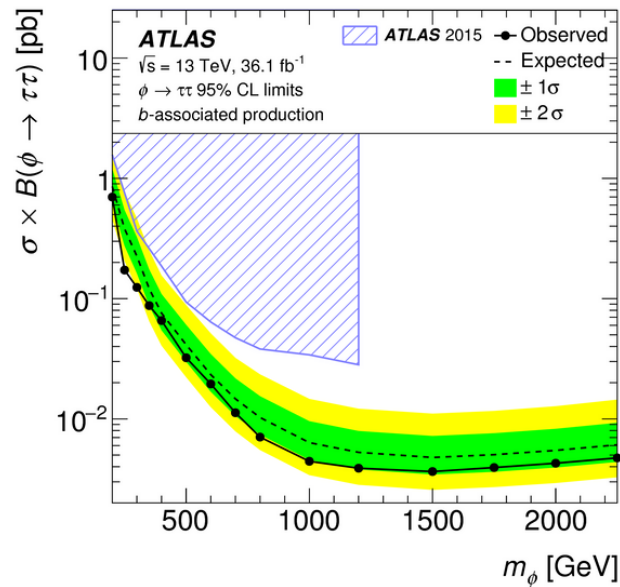
(c) $\tau_{had}\tau_{had}$ *b*-veto category
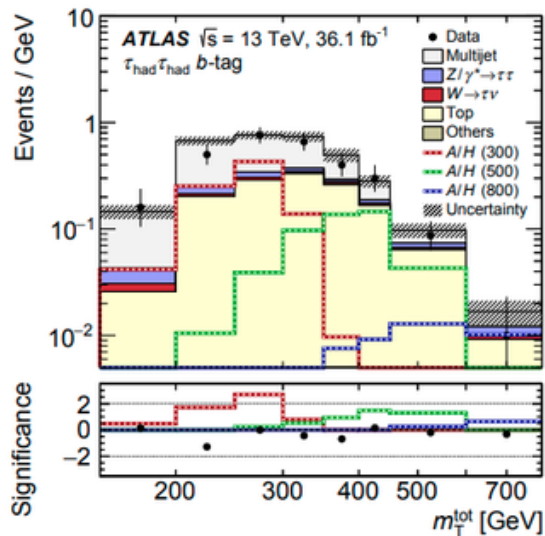
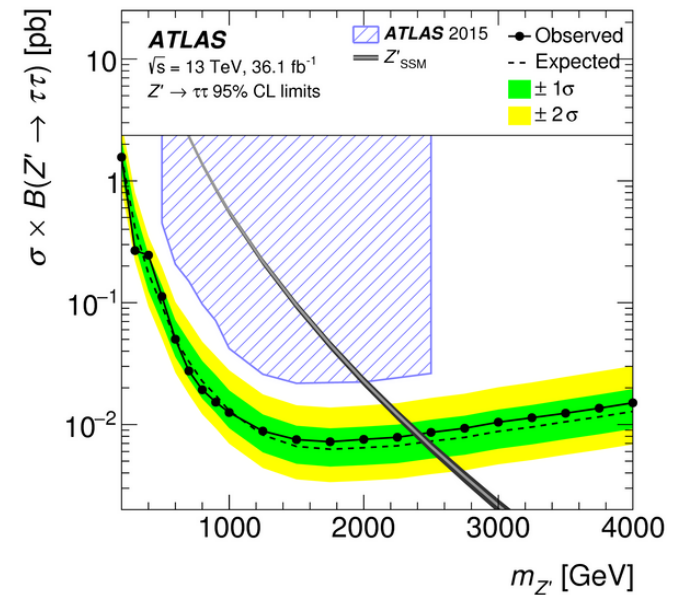(d) $\tau_{had}\tau_{had}$ *b*-tag category

11

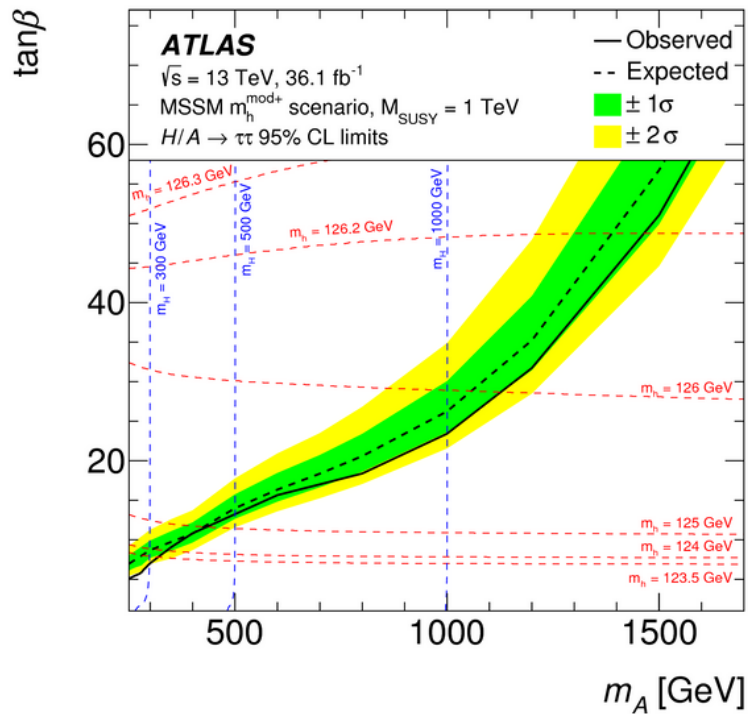# *model-independent limits*
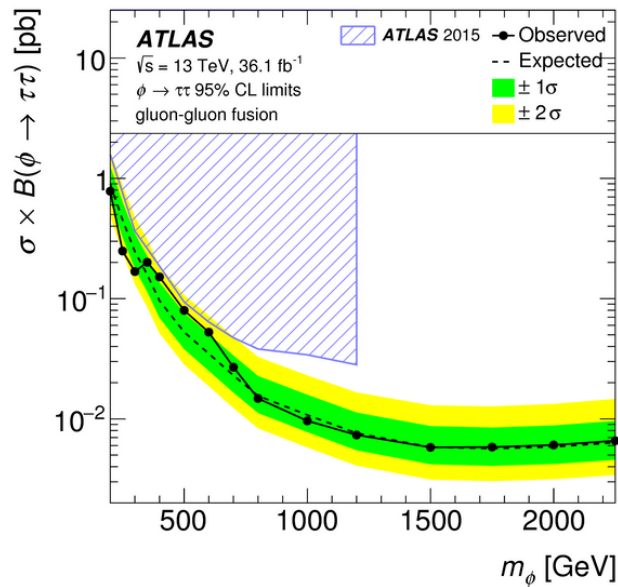
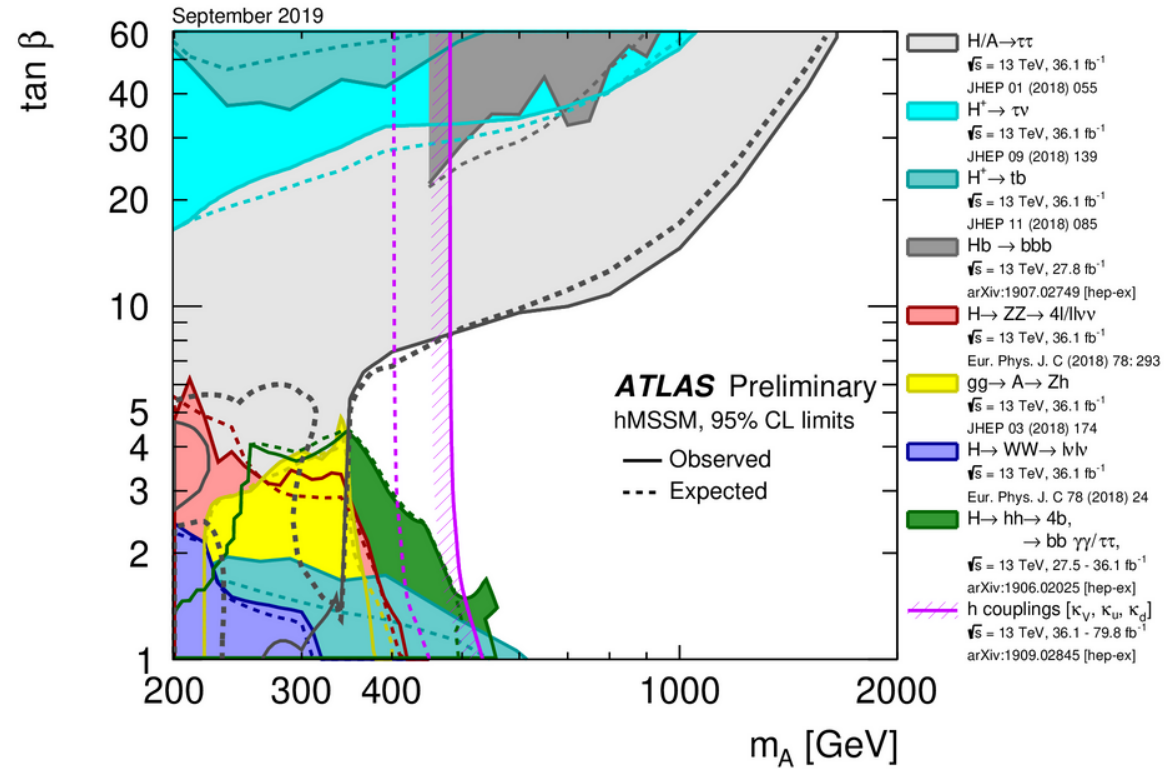Higgs gluon-gluon fusion

Higgs b-associated production

Z' Drell-Yan

MSSM interpretations

MSSM m_h^{mod+} scenario

hMSSM scenario
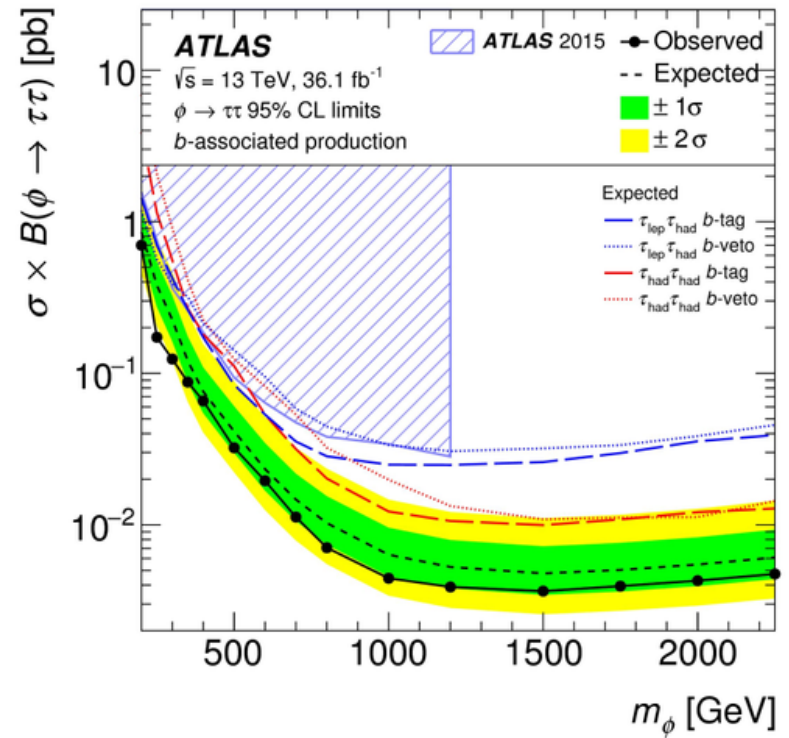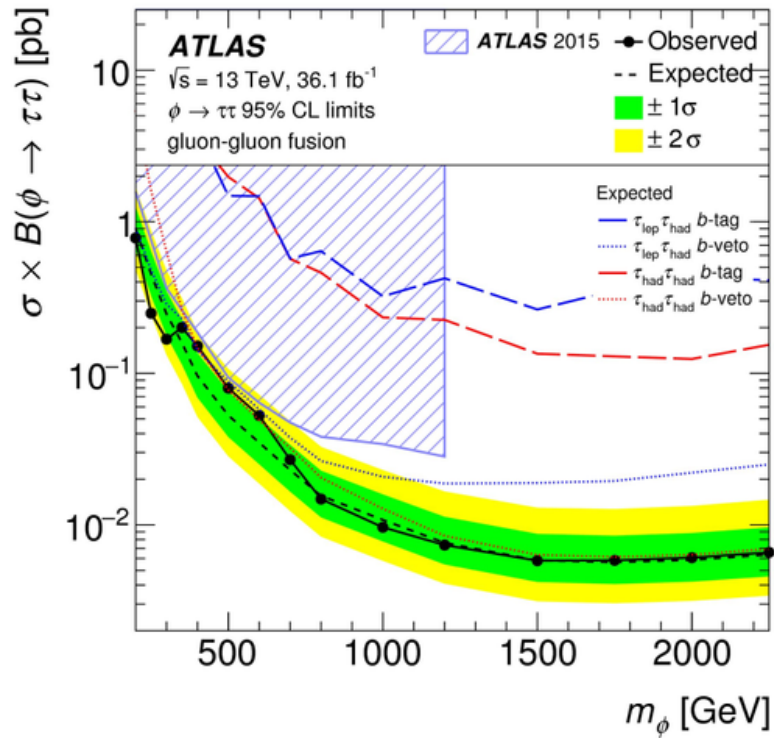
Z' interpretation
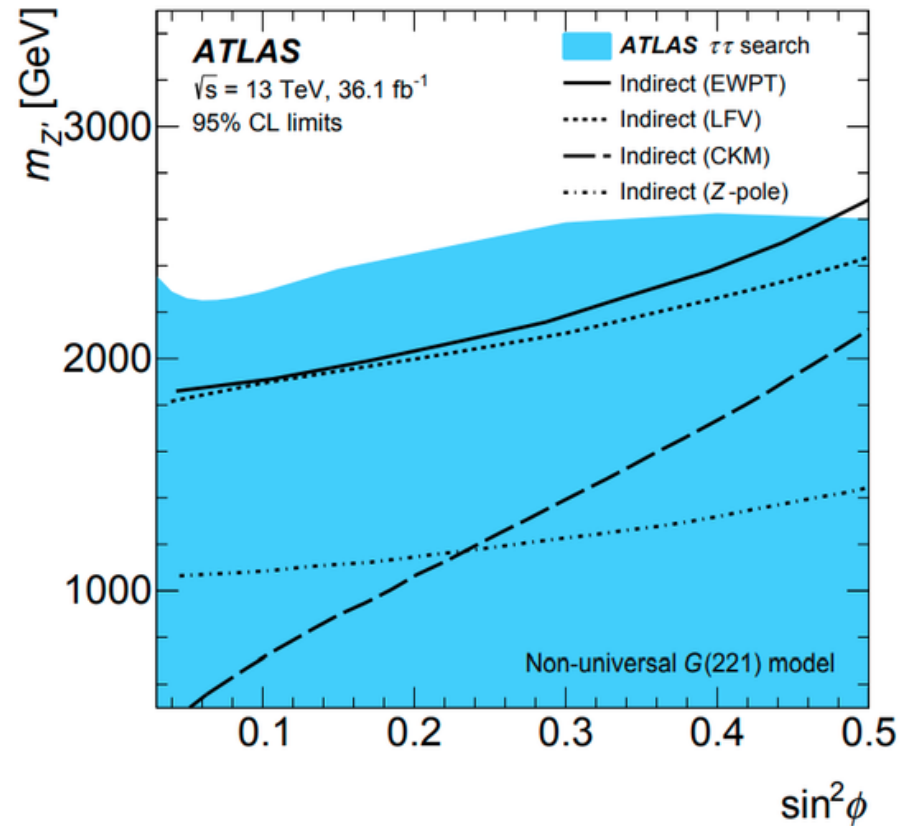
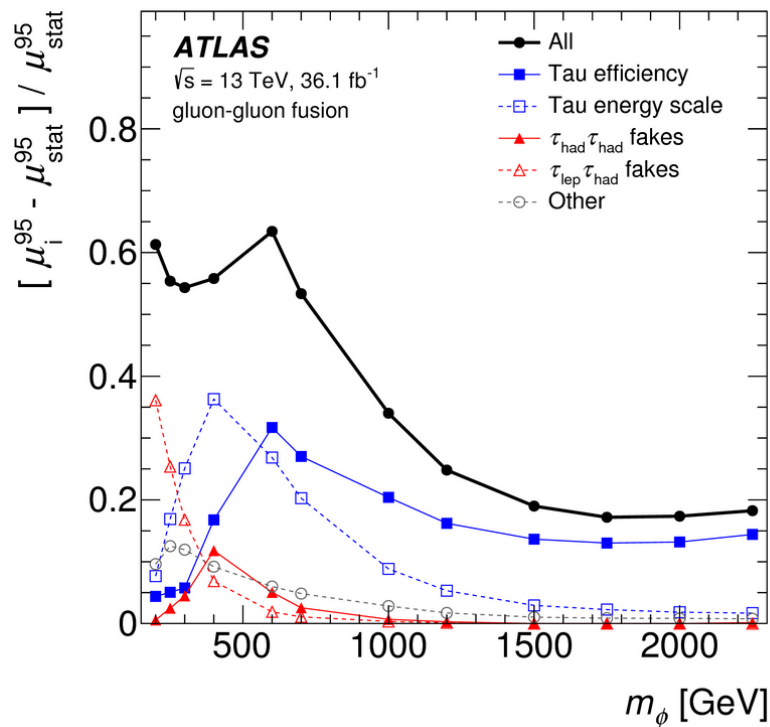non-universal
G(221) model

Summary and future results

- 2015+2016 data, results published in JHEP

- no new resonance found, but new limits set

- currently getting ready to publish results with full Run 2 (2015-2018) data, following the same analysis strategy

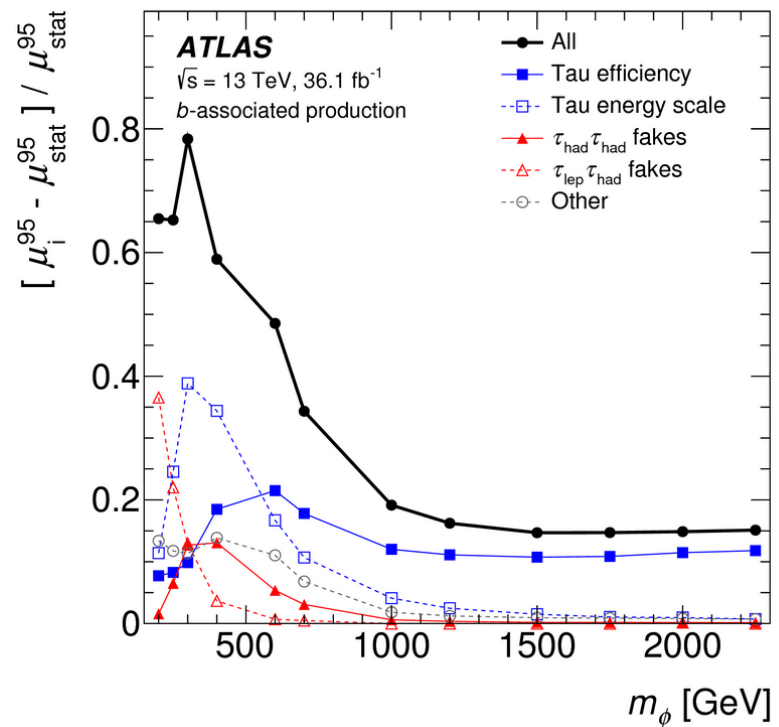- next: Run 2 legacy paper with improvements

backup
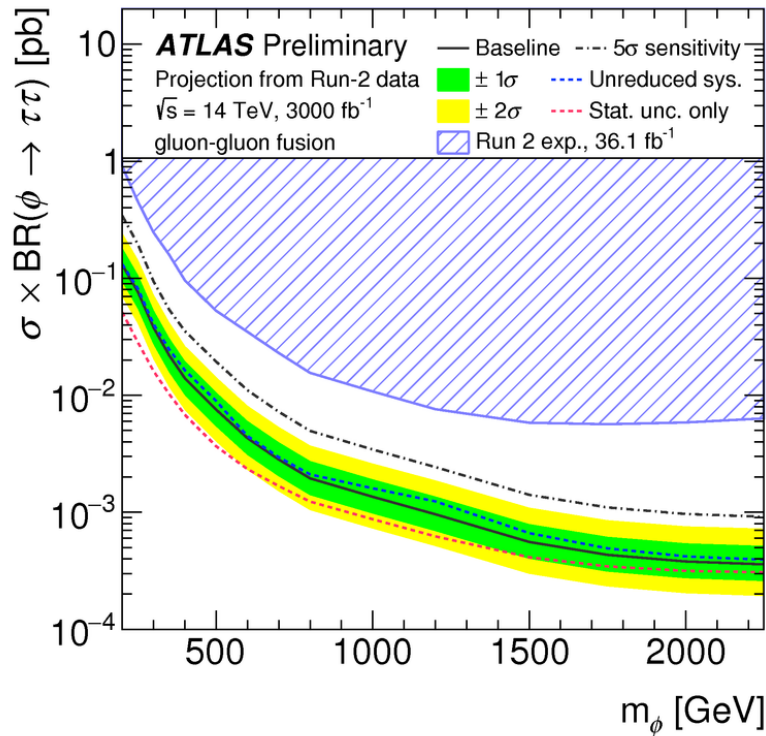
Limits by channel

systematic uncertainties

gluon-gluon
fusion

b-associated
production

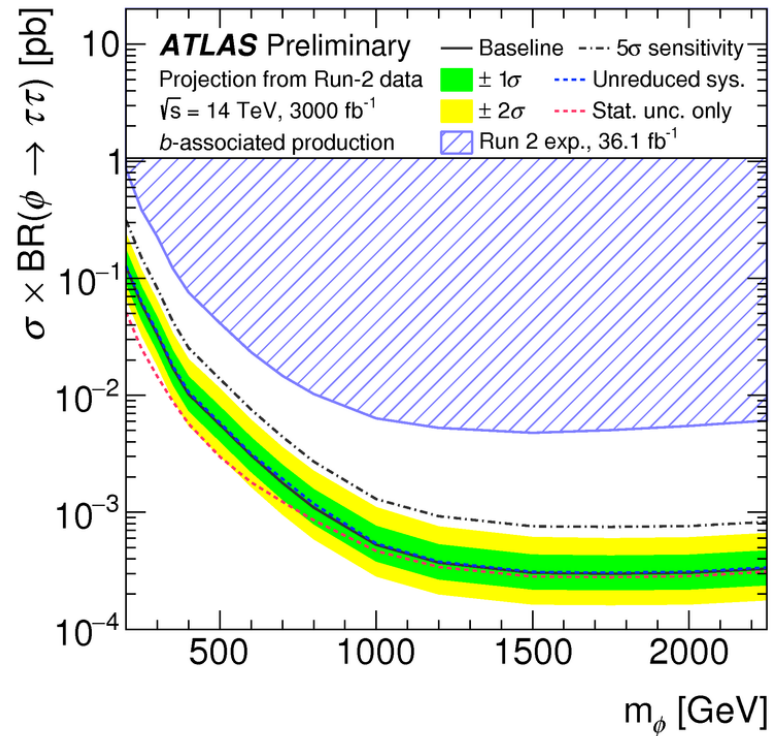# *HL-LHC projection*

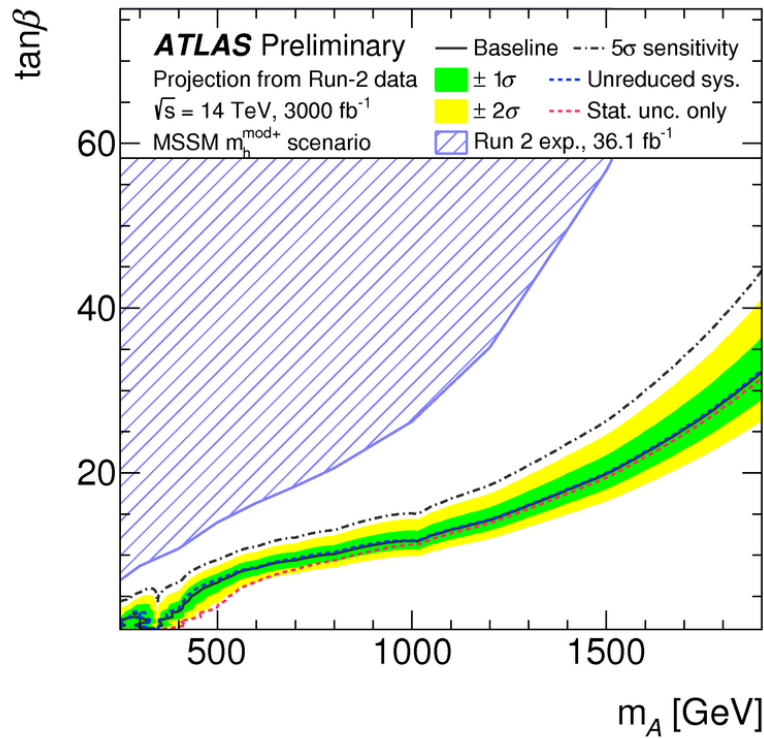gluon-gluon
fusion

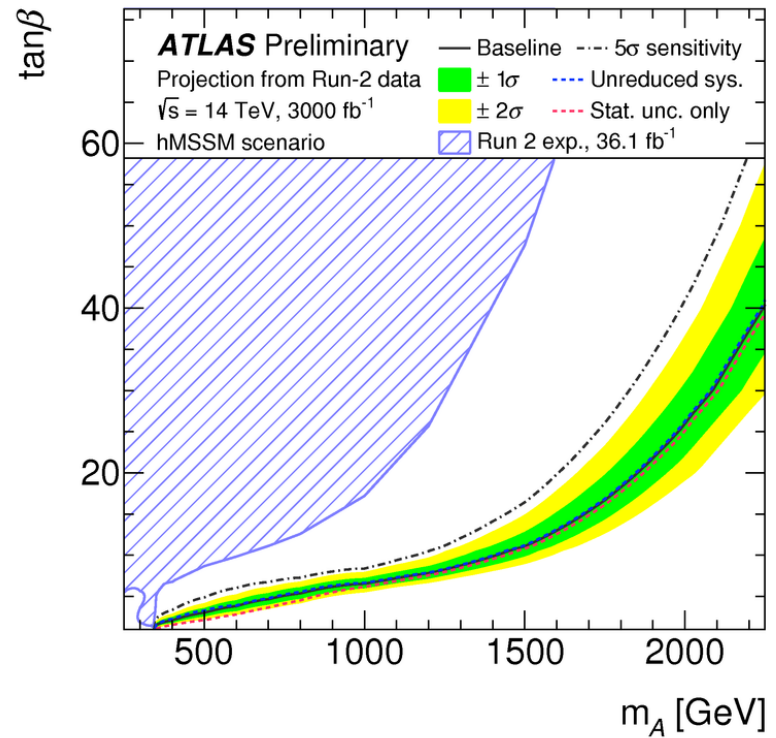b-associated
production

HL-LHC projection

MSSM $m_h^{\mathrm{mod}+}$
scenario

hMSSM
scenario