UNIVERSITY OF LIVERPOOL

MSSM Higgs → ττ Searches at the ATLAS Experiment

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on behalf of the ATLAS Collaboration

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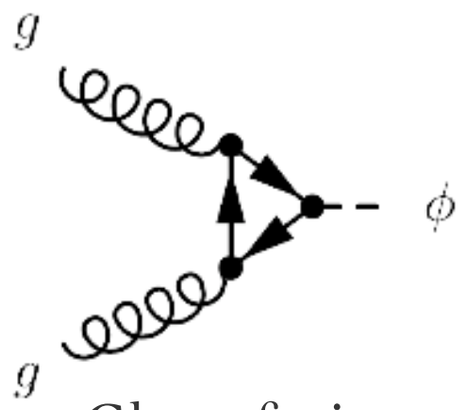
MSSM Higgs Production

Minimal Supersymmetric Standard Model requires two Higgs doublets:

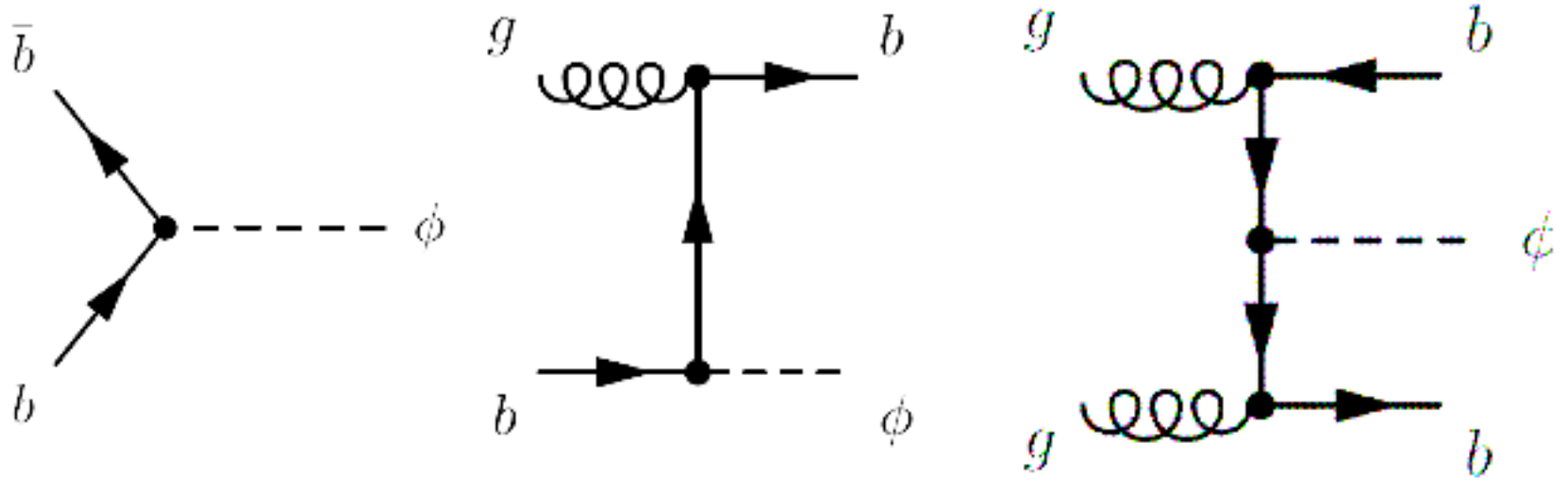
- 5 observable Higgs bosons:
  - 3 neutral (h/A/H)
  - 2 charged ($H^{\pm}$)
- Only light neutral Higgs bosons h,A,H (denoted ϕ) considered in this talk.

Example cross-sections at *7* TeV

	m_A / GeV (tan β = 20)			
	100	150	200	300
ggA	109 pb	13 pb	2.5 pb	0.2 pb
bbA	123 pb	30 pb	10 pb	1.8 pb



Gluon fusion dominant production mode when tan β < 10



Production in association with 0, 1 or 2 b-jets

Mass degeneracy further enhances cross-section (~ x2)
$m_A \lesssim 130$ GeV: $m_A \simeq m_h$; $m_A \gtrsim 130$ GeV: $m_A \simeq m_H$

MSSM Higgs Decay Modes

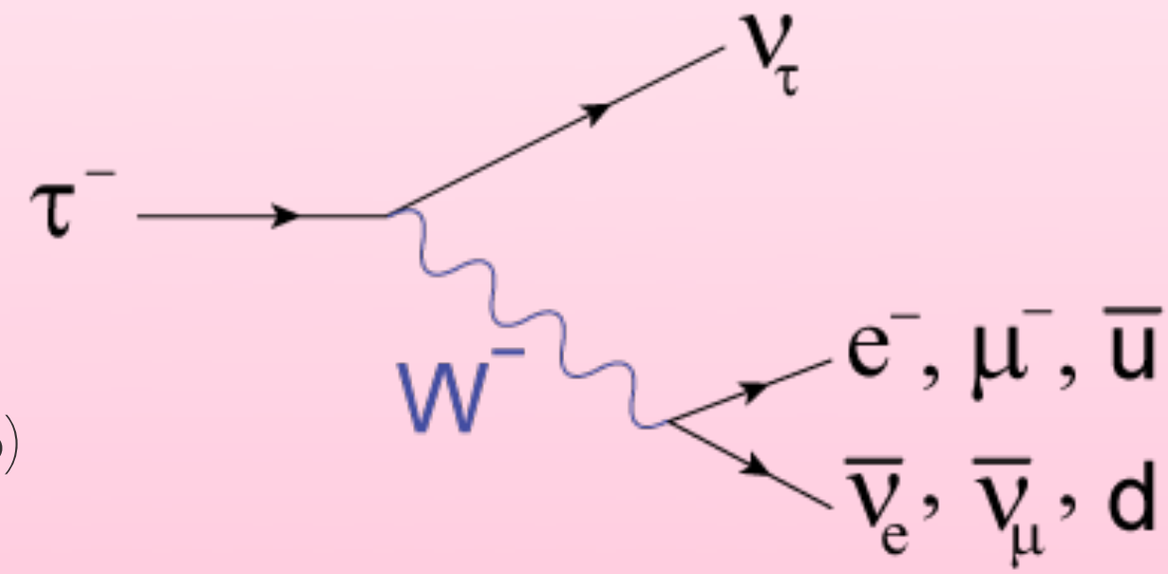
Decays to 3rd generation fermions strongly enhanced for large regions of MSSM phase space:

- BR($b\bar{b}$) ~ 90 % ⇒ Overwhelming QCD backgrounds
- BR($\tau^+\tau^-$) ~ 10 % ⇒ Need at least one lepton in the final state to trigger on
- BR($\mu^+\mu^-$) ~ 0.03 % ⇒ Very clean signature, but very low yield

<u>Higgs → ττ</u>

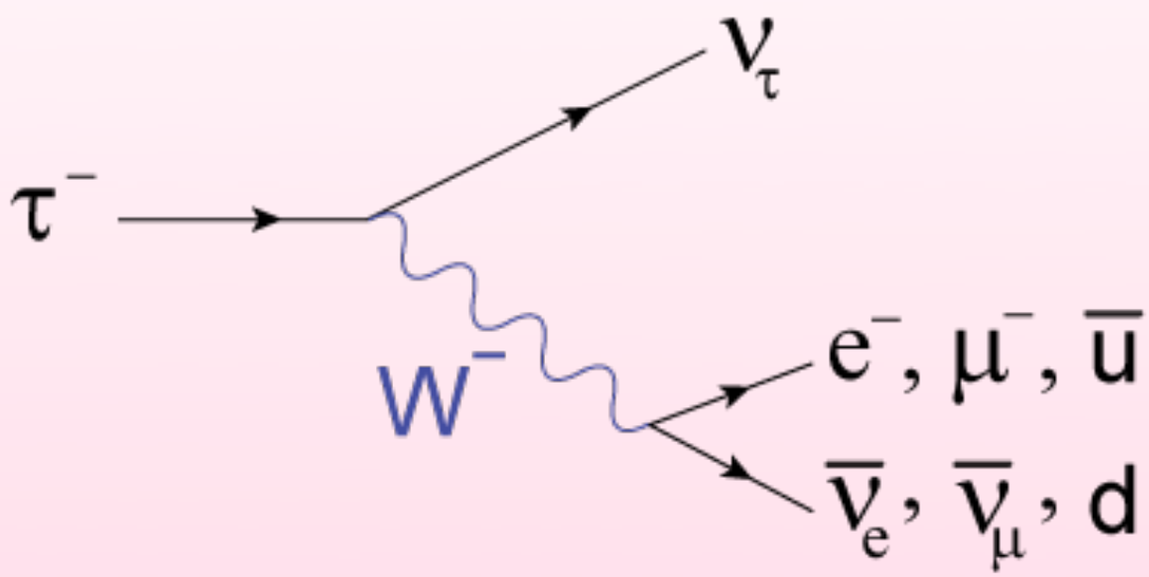
Three possible sub-channels:

- Two leptons (~12%)
- One lepton and one hadronic τ (~46%)
- Two hadronic τ's (~42%)



Difficult!!

τ-Decay Characteristics



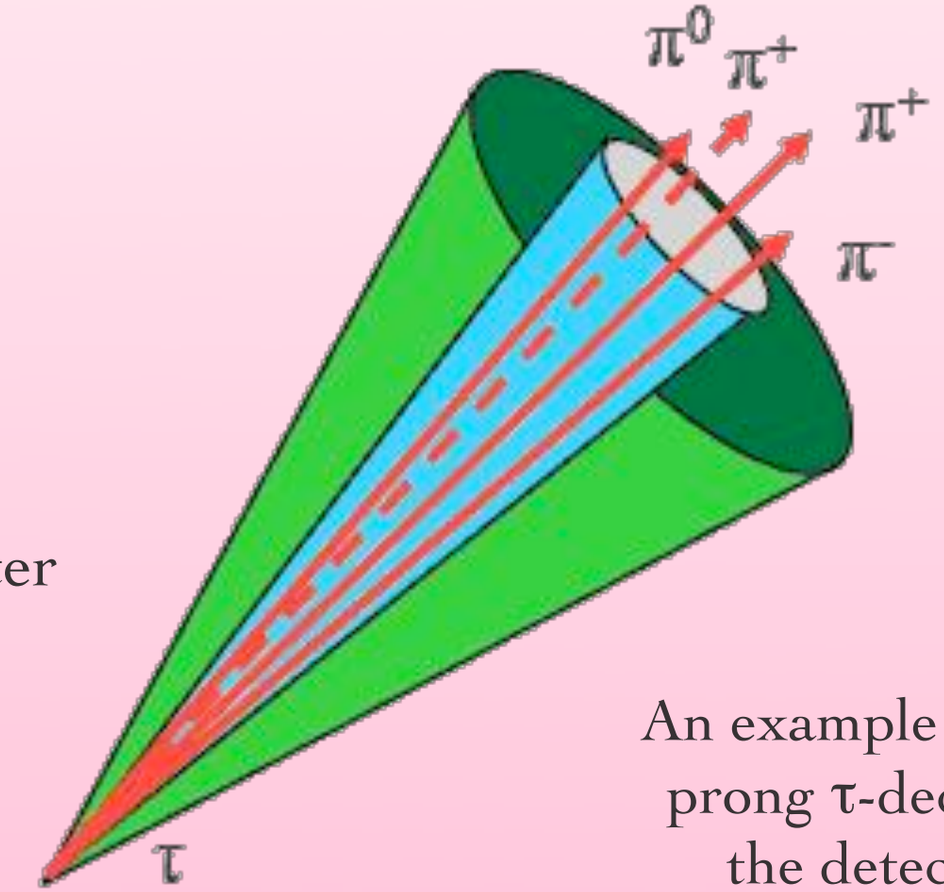
$BR(\tau \rightarrow e/\mu + \nu_\tau + \nu_{e/\mu}) \simeq 35\%$

$BR(\tau \rightarrow jets + \nu_\tau) \simeq 65\%$

Missing E_T always present due to neutrinos.

Hadronic τ-jets:

- Well collimated
- Low multiplicity
- Deposits in both hadronic and EM calorimeters.
- One or three tracks matching the calorimeter deposition.



Courtesy of NBI

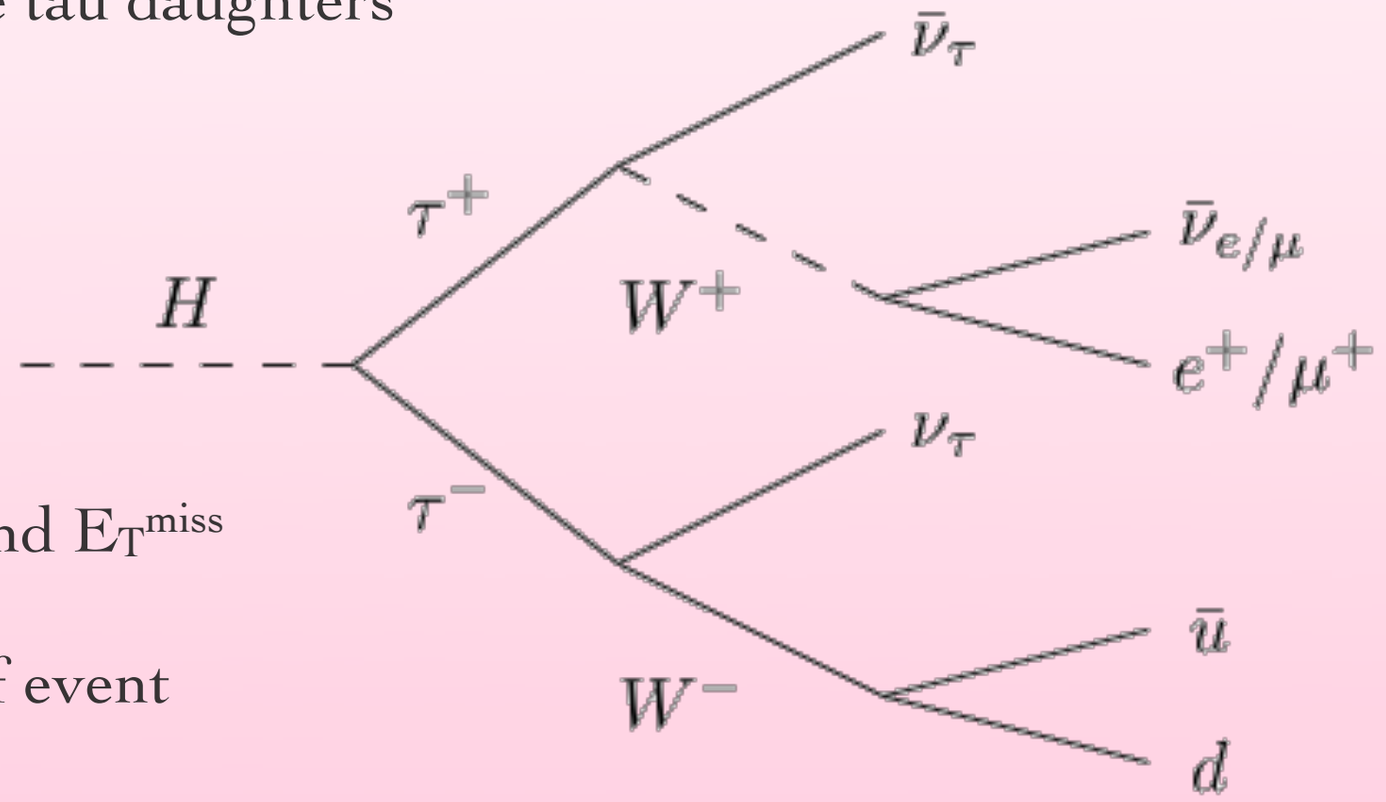
An example of a 3-prong τ-decay in the detector

MSSM H → ττ Event Selection

- Exactly two of e/μ (di-lepton channel)

OR

- Exactly one e/μ and exactly one hadronic τ (lepton-hadron channel)
- Charge correlation between visible tau daughters
- Missing E_T (from neutrinos)



<u>For background rejection:</u>

- Transverse mass between lepton and E_T^{miss}
  - Rejects W+jets background
- Requirements on jet multiplicity of event
  - Rejects top backgrounds
- At least one b-tagged jet (associated production)

OR

- No b-jets (gluon-fusion production channel)

Backgrounds

Dominant backgrounds to MSSM analysis are $Z \rightarrow \tau\tau$, W + jets & t-tbar.

$Z \rightarrow \tau\tau$ (+ jets)

- Irreducible.
  - True di-tau final state.
  - Similar kinematics.
- Important for low mass scenarios, where signal falls on tail of Z-peak.

$W \rightarrow e/\mu/\tau_l + \nu$ (+ jets)

- Large production cross-section.
- Real lepton + missing E_T.
- Jets in event fake hadronic tau.

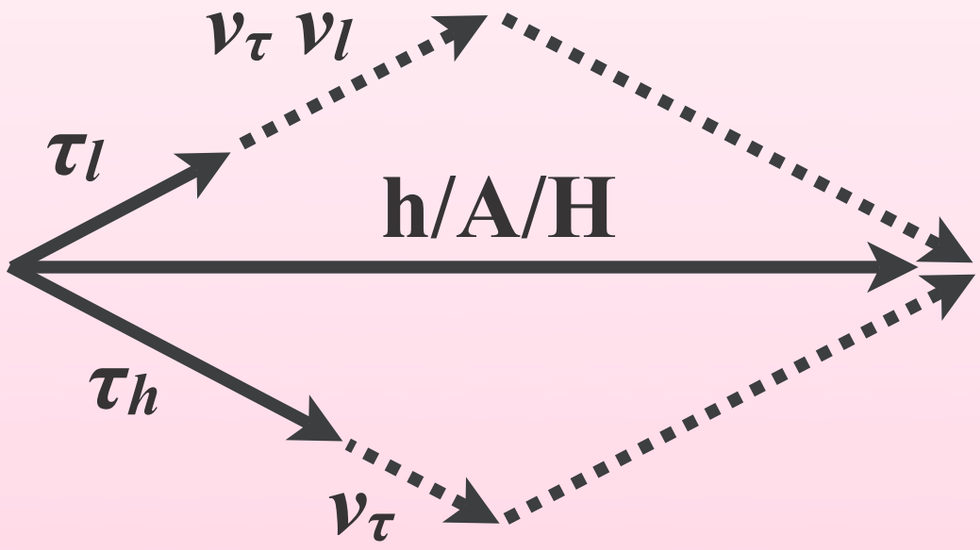
ttbar

- tt → WbWb (W's → e/μ/τ+ν or jets).
  - Possibility to have real leptons and/or hadronic taus in the final state.
    - Hadronic jets (from W-decay) fake taus.
    - b-jets in signal and background.
    - Leptons from b-decay.
- More significant as $m_{h/A/H}$ increases.

Others include $Z \rightarrow ll$ (+ jets), $W \rightarrow \tau_h\nu$ (+ jets), QCD.
Single top was previously considered negligible, due to it's small cross-section, but shown to be significant (up to ~30% of ttbar's), esp at higher $m_{h/A/H}$.

Mass Reconstruction

- Use the collinear approximation to reconstruct the invariant mass of the di-tau pair.
  - Assume that the tau decay products are collinear to the tau direction.
  - Good approximation when the parent particle is heavily boosted.



$$M_{\tau\tau} \approx \frac{M_{lh}}{\sqrt{x_{\tau_l} x_{\tau_h}}}$$

Fraction of tau momentum carried by visible daughter

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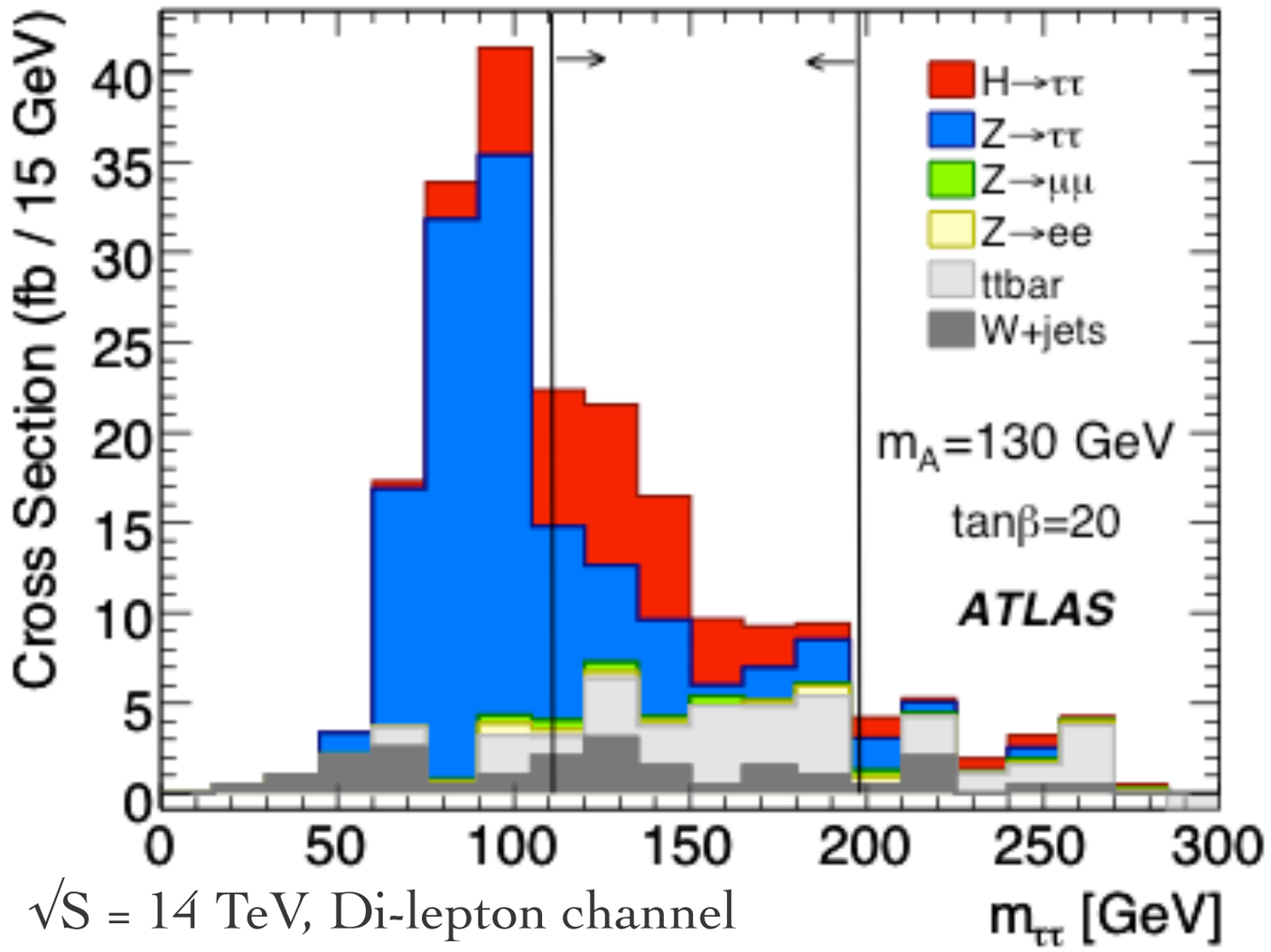
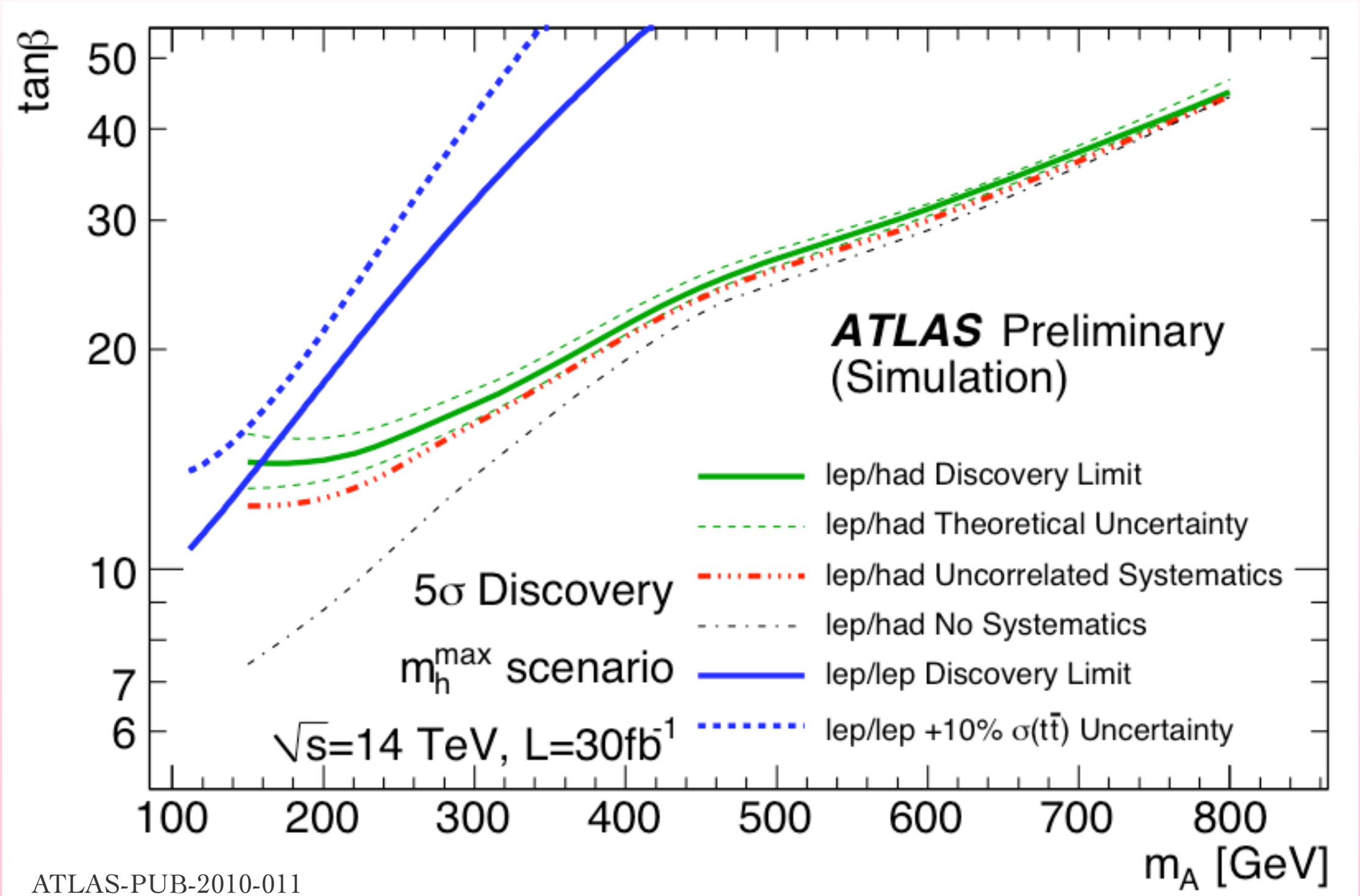


√S = 14 TeV, Di-lepton channel

Discovery Potential



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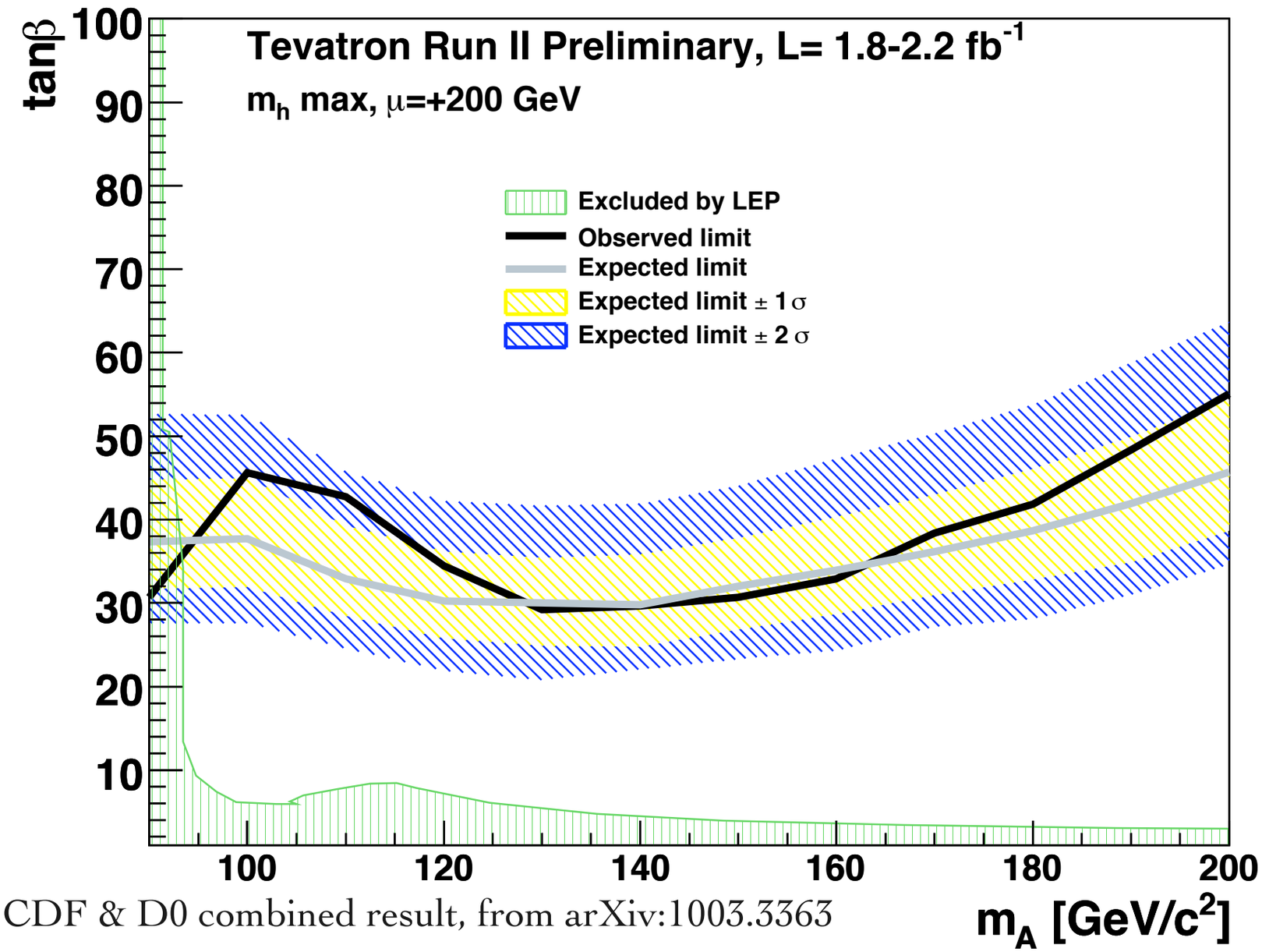
Latest Tevatron Results



CDF & D0 combined result, from arXiv:1003.3363

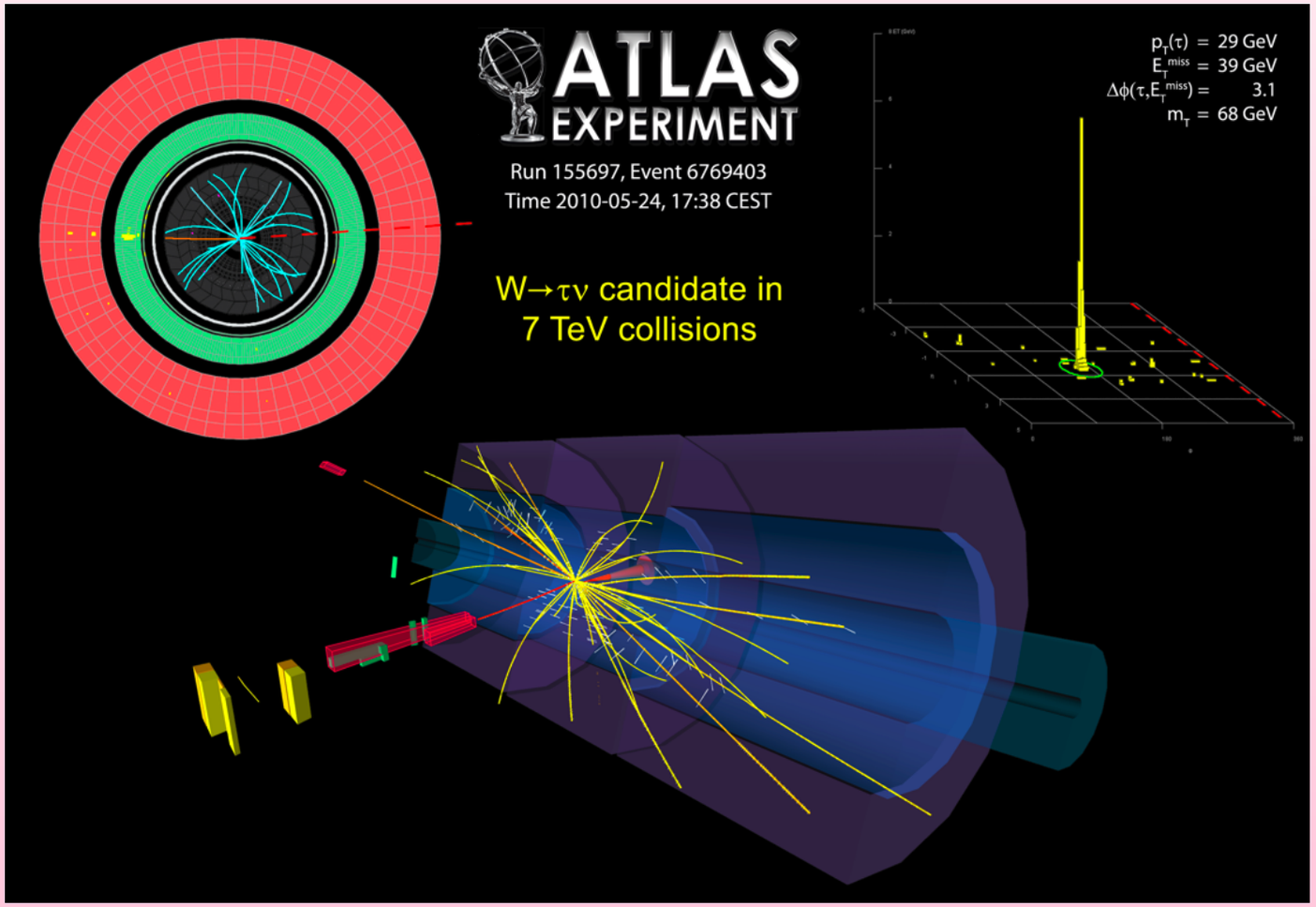
- Preliminary estimates show ATLAS can expect to be able to exclude a large region of the MSSM phase space with data from the 2010-2011 run (expect 1 fb^{-1}).
  - Push to lower tan β and higher m_A than Tevatron.

Current Activities

- Current ATLAS effort focused on estimating background contributions from data.
  - QCD in particular not well known from Monte Carlo (need huge statistics).
    - Tuning and testing methods to provide a clean sample of QCD which can then be used to model the background shape.
  - Obtain estimate of $Z \rightarrow \tau\tau$ background shape by selecting clean sample of $Z \rightarrow \mu\mu$ events from data, and then embedding simulated taus in place of muons.

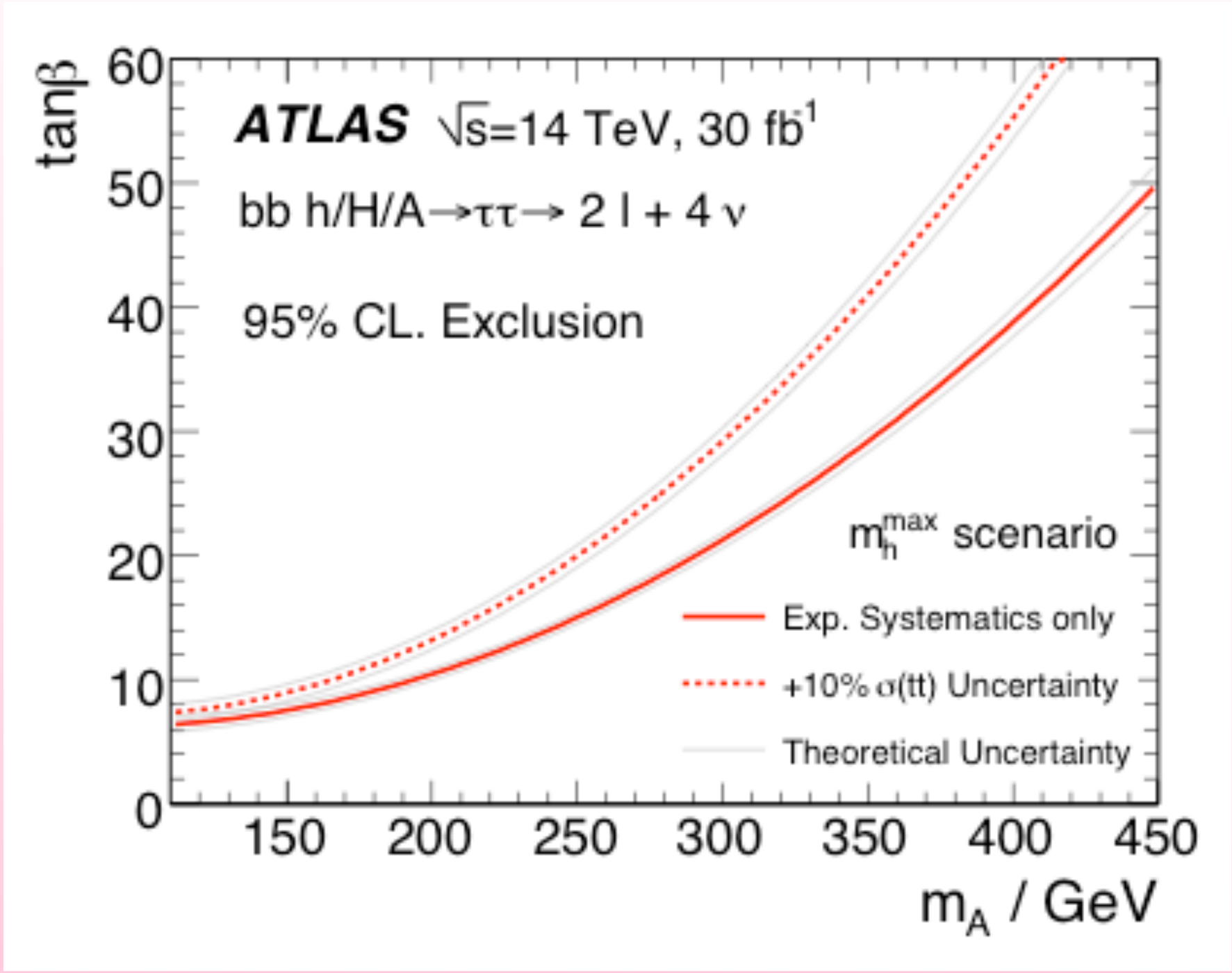
- Tau identification and b-tagging being validated and improved with first ATLAS data
  - Study analysis performance using latest algorithms.

- Now starting to see first tau candidates in ATLAS data!



Back Up

Exclusion Potential



- Results for long term prospects (30 fb^{-1} at 14 TeV), di-lepton channel only.

Discovery Prospects (Long Term)