Reinterpretation of ATLAS results for exotic decay H125→$\ell\ell + E_T^{miss}$ in nMSSM

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ATLAS EXPERIMENT

ATLAS→DPF-PHENO

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https://indico.cern.ch/event/1358339/contributions/5899440/

Outline

$H \rightarrow \ell\ell + E_T^{miss}$ **RECAST**

1. Overview
   - Motivation
   - RECAST
   - REANA Tests
2. Results
   - Branching Ratio Limits
   - Sensitivity Comparisons
3. Conclusions and Next Steps

Overview: Physics Motivation

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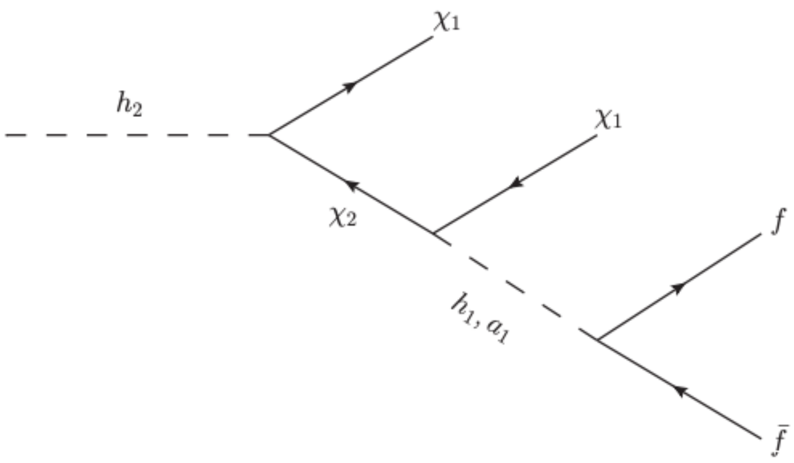
- Standard Model is great, but still have some issues:
  - Hierarchy problem
  - Galactic Center Excess[1]
- Higgs is good start point for Dark Matter searches even at weak couplings, it has relatively large branching ratio to new physics
- To address this, we consider extensions of Supersymmetry with an extra scalar particle
  - Motivated by the NMSSM in an approximate Peccei-Quinn symmetry limit
- Focus on di-tau → lepton decays



Phys. Rev. Lett. 112,221803 (2014)

Feynman diagram for signal decay channel

- In this limit, expect Higgs with following topology:

$$H \rightarrow \chi_1 \chi_2$$

$$m_{\chi 2} - m_{\chi 1} > min\{m_s, m_a\}$$

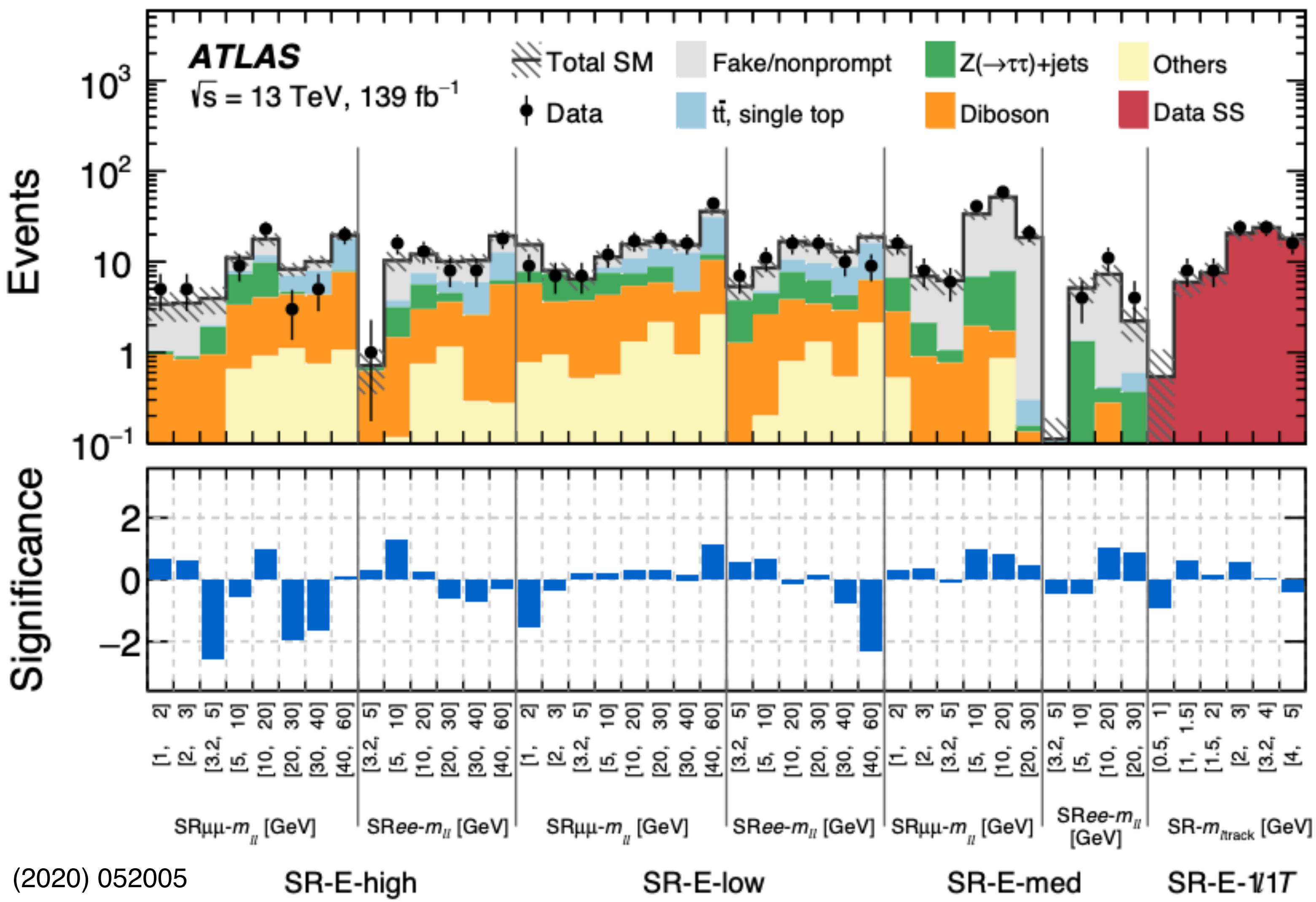
$$\chi_2 \rightarrow a\chi_1$$

[1] Phys. Rev. D 90, 115006 (2014)

Overview: RECAST

- Analysis preservation and reinterpretation framework (RECAST)
  - Preserves completed analysis (systematics, background estimations, etc.) + original virtual environment to run analysis code

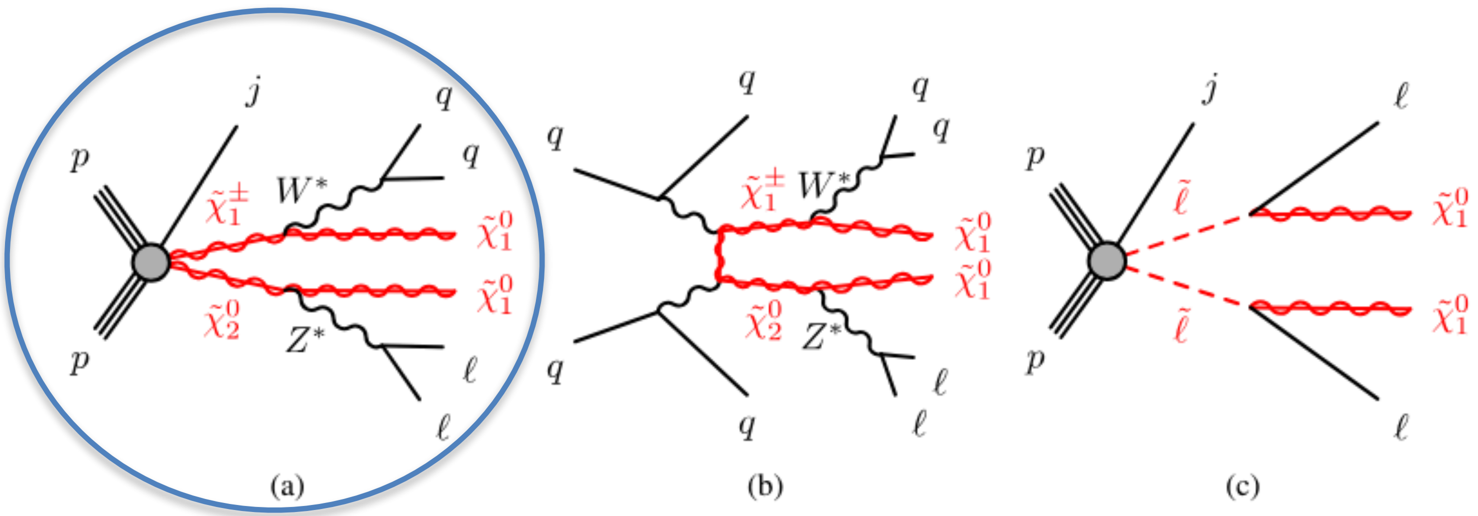
RECAST Data and BKGs



Phys. Rev. D 101 (2020) 052005

Overview: RECAST

- Can use this method because our signal partially overlaps with published ATLAS search for gauginos in a compressed-mass scenario[1]
  - Same final state (opposite sign, same flavor dilepton with significant MET)
- Our model most sensitive to electroweakino channel



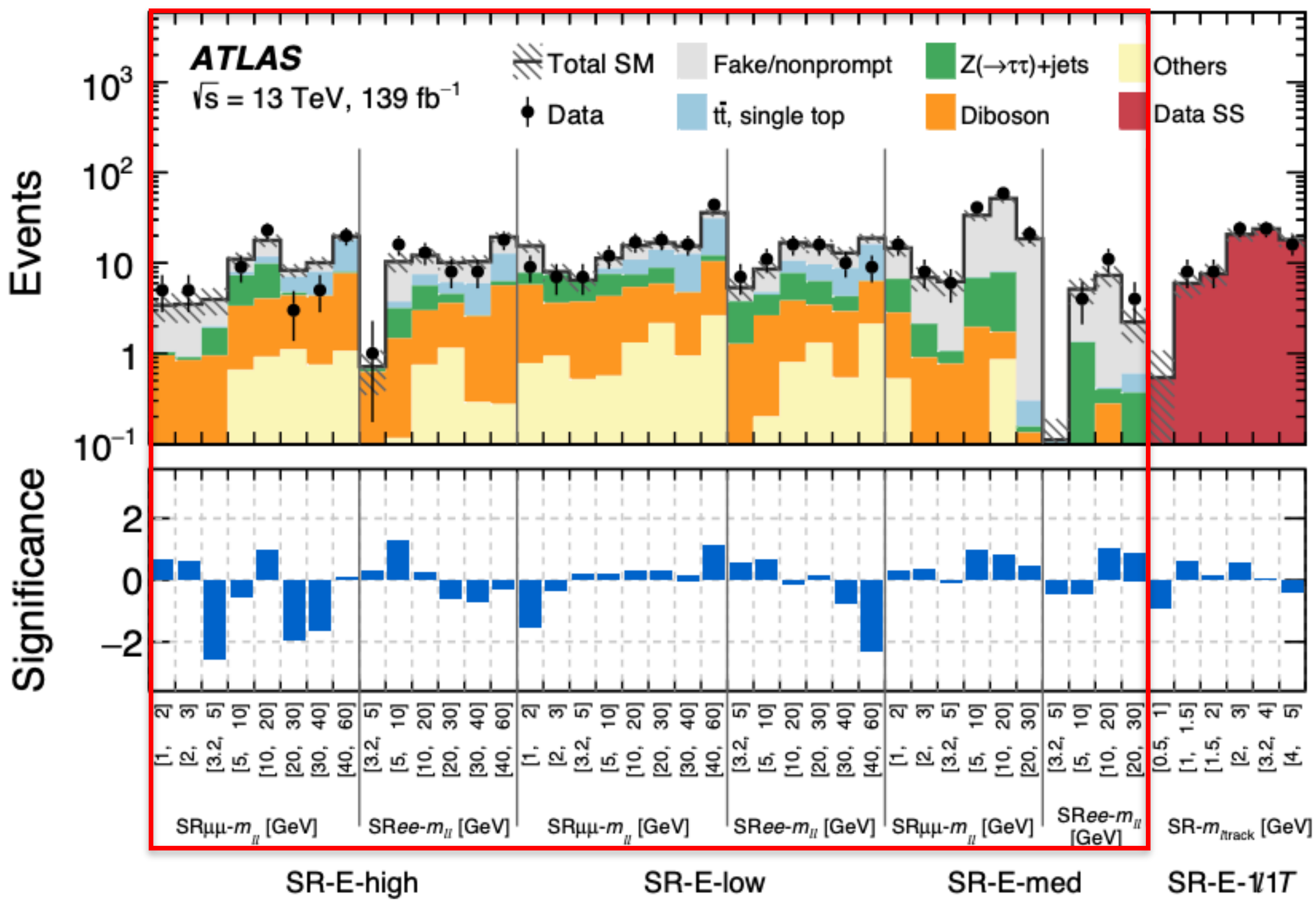
Feynman diagrams for Models investigated in published ATLAS search.
Diagrams: a) ggF electroweakino, VBF electroweakino, slepton pair production

[1] Phys. Rev. D 101 (2020) 052005

Overview: RECAST

- Have access to electroweakino and slepton pair channels from full analysis (except for 1 lep + 1 track)

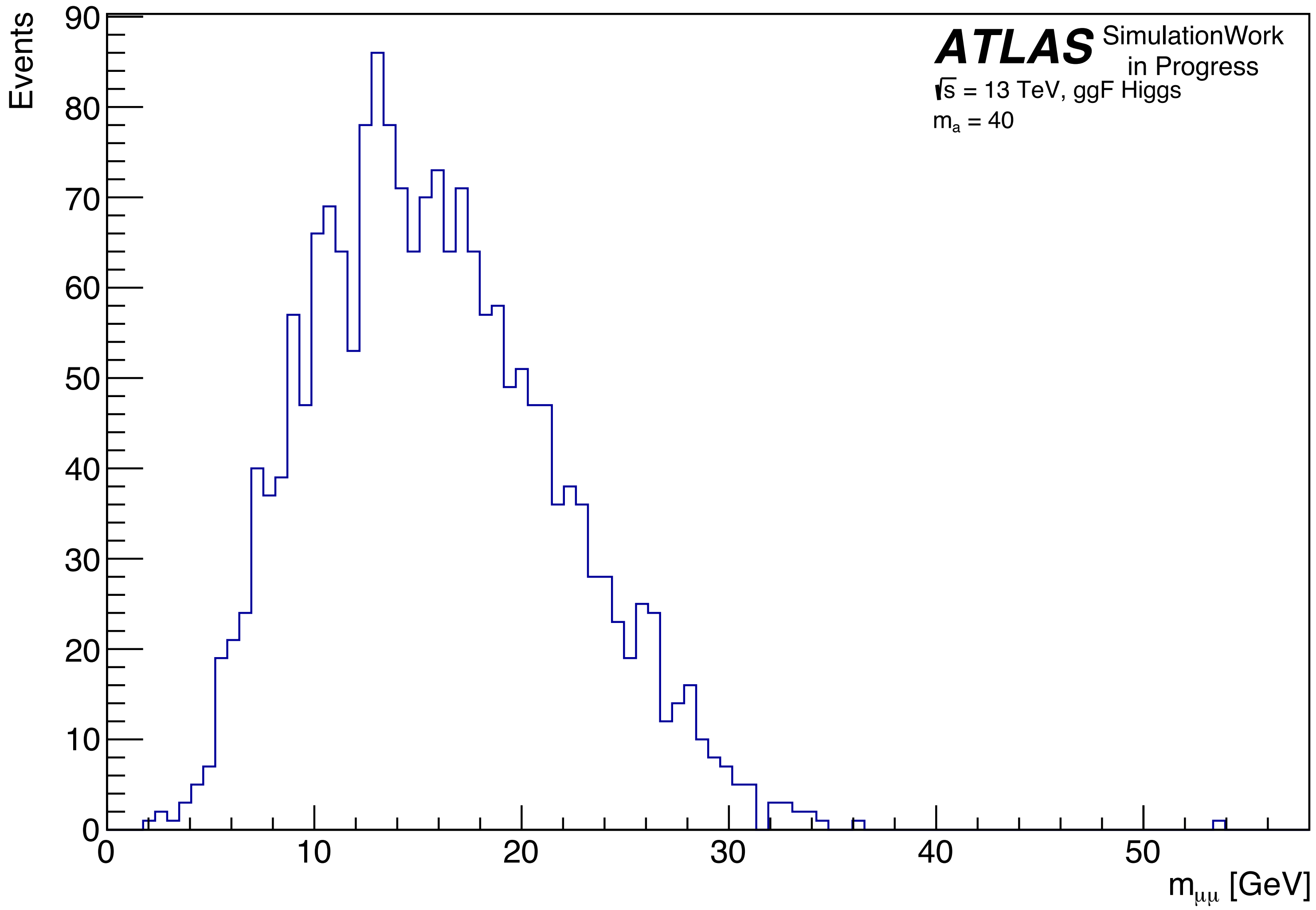
RECAST Data and BKGs



Overview: RECAST

- Now, take our signal model distributions for dimuon mass:

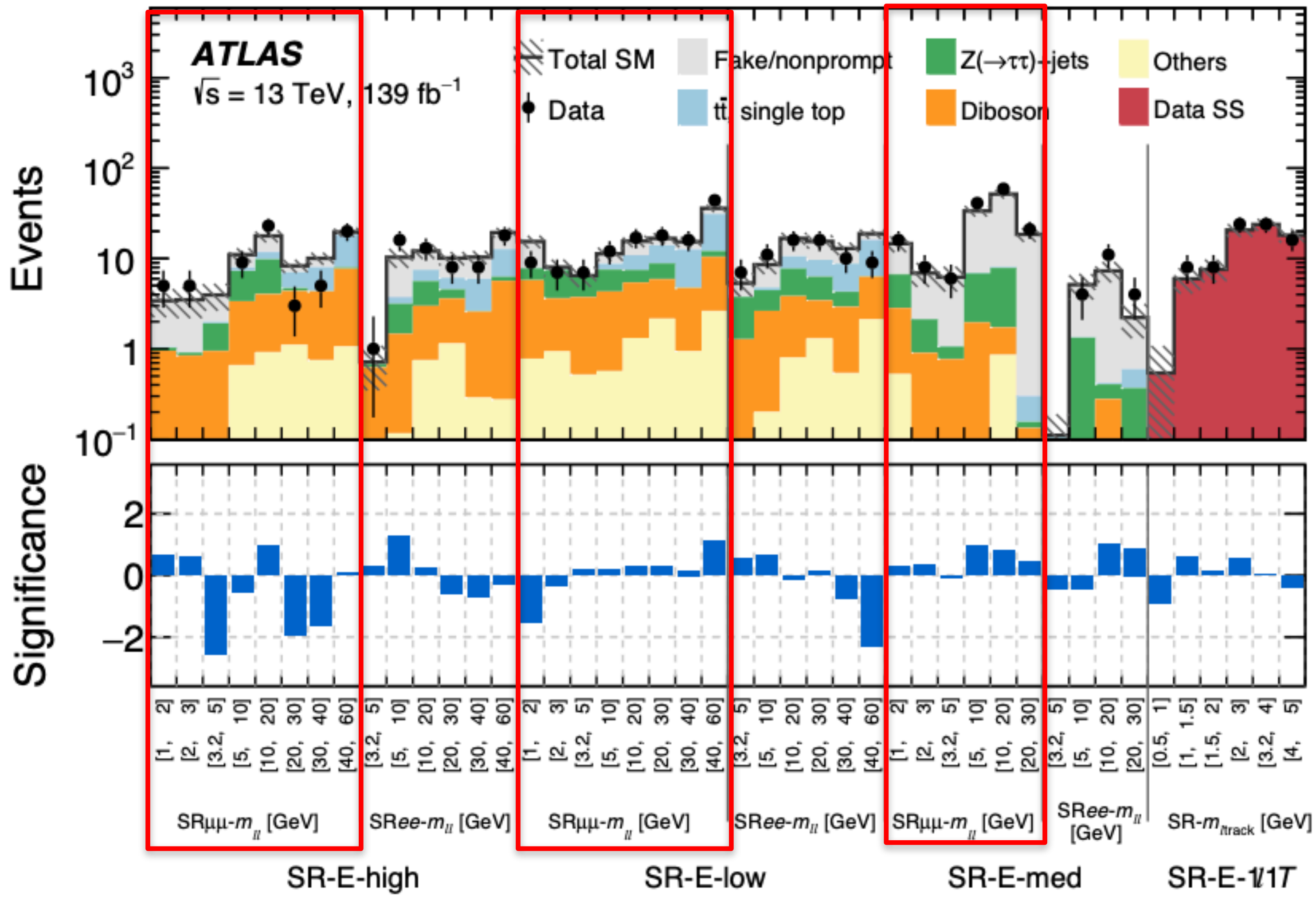
New Input Signal



Overview: RECAST

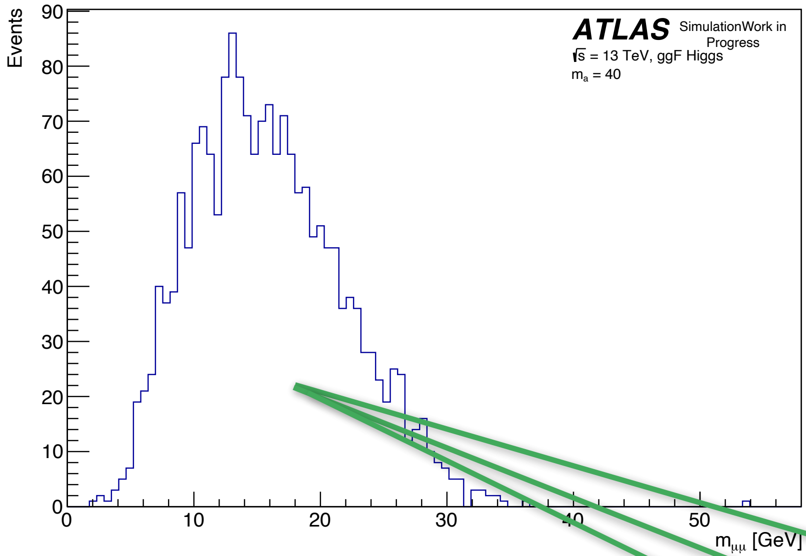
- These distributions populate these signal regions:

RECAST Data and BKGs



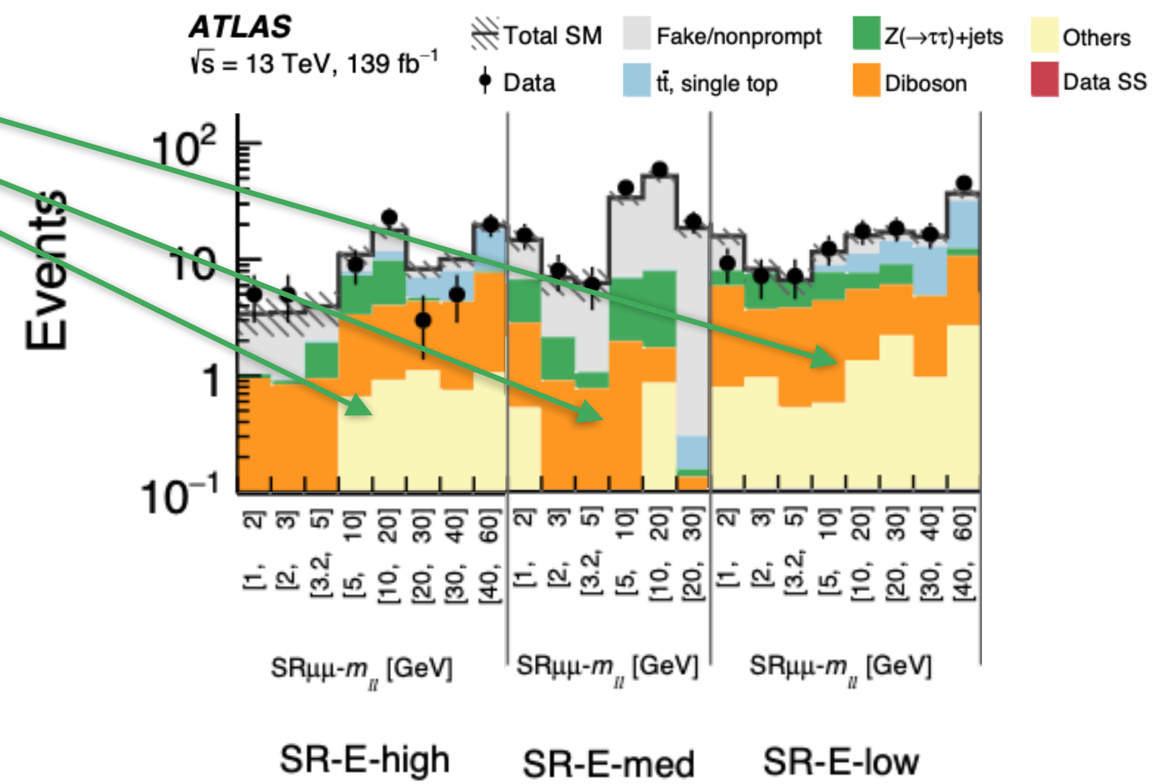
[1.] Phys. Rev. D 101 (2020) 052005

New Input



Signal populates relevant SRs of SUSY analysis, and RECAST lets us recalculate limits!

RECAST Data and BKGs

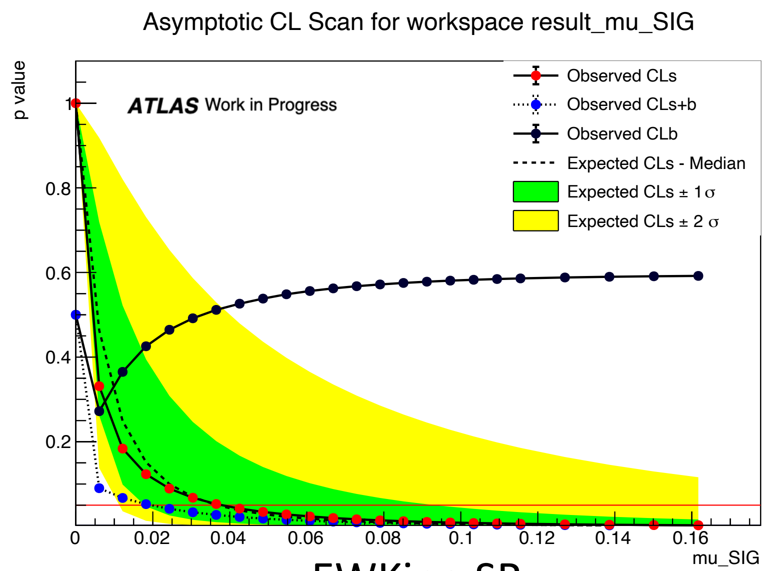


Phys. Rev. D 101 (2020) 052005

Overview: Testing REANA

- using REANA (ATLAS cloud computing software for RECAST), generated results (see below)
    - Limit on signal strength at 95% confidence level can be read from these graphs using the mu_SIG value where red line intersects with CLs lines
- Used existing VBF Higgs samples to test RECAST output
- We took an array of mass points for a and χ_2 and find the limit as a function of the a mass

RECAST Output Example

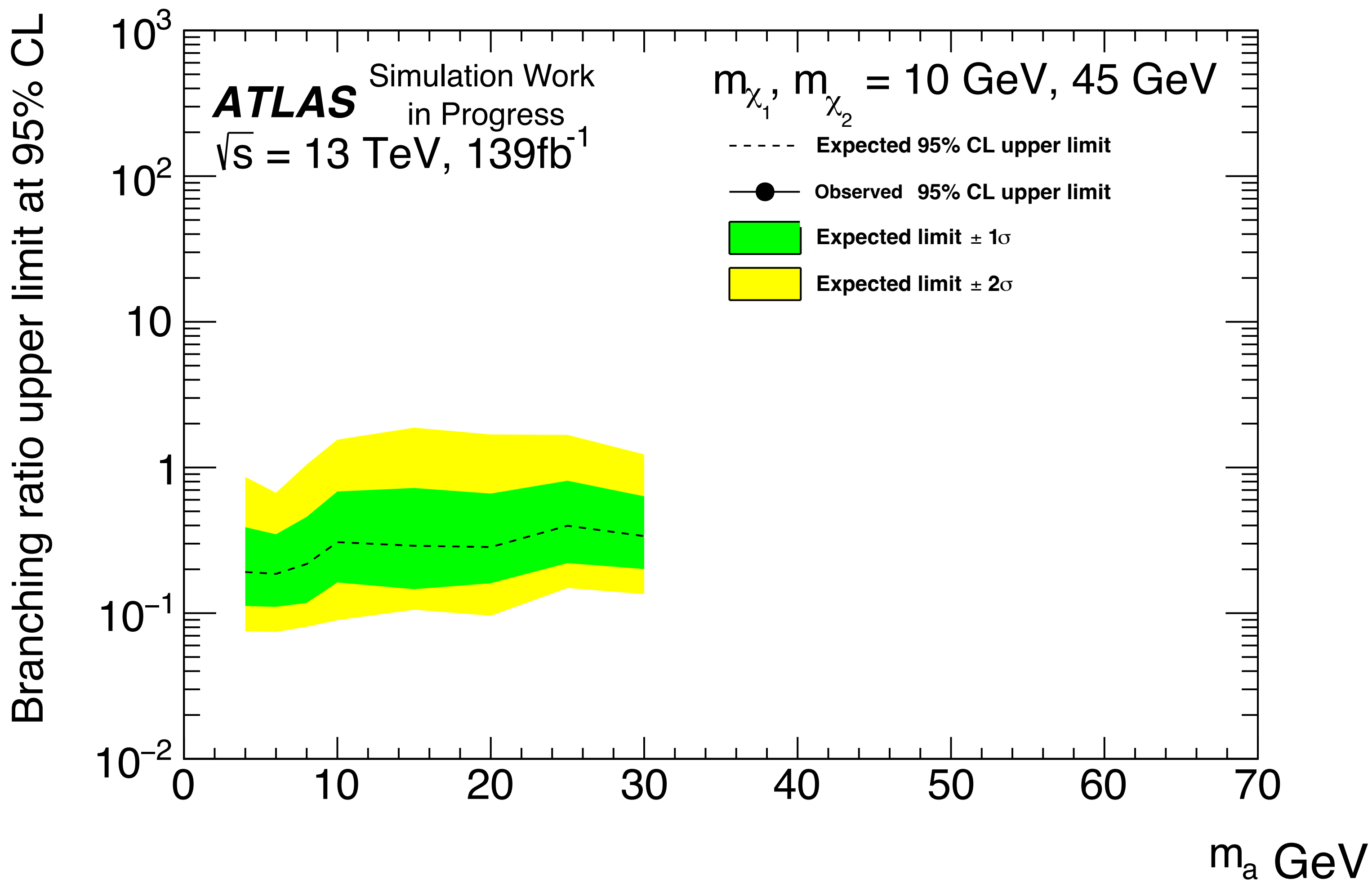


EWKino SR

Observed limit is ~ .04

Results: Branching Ratio Limits

- Observed mild excess around these masses for model independent limit in original analysis
- further investigation currently underway for our signal

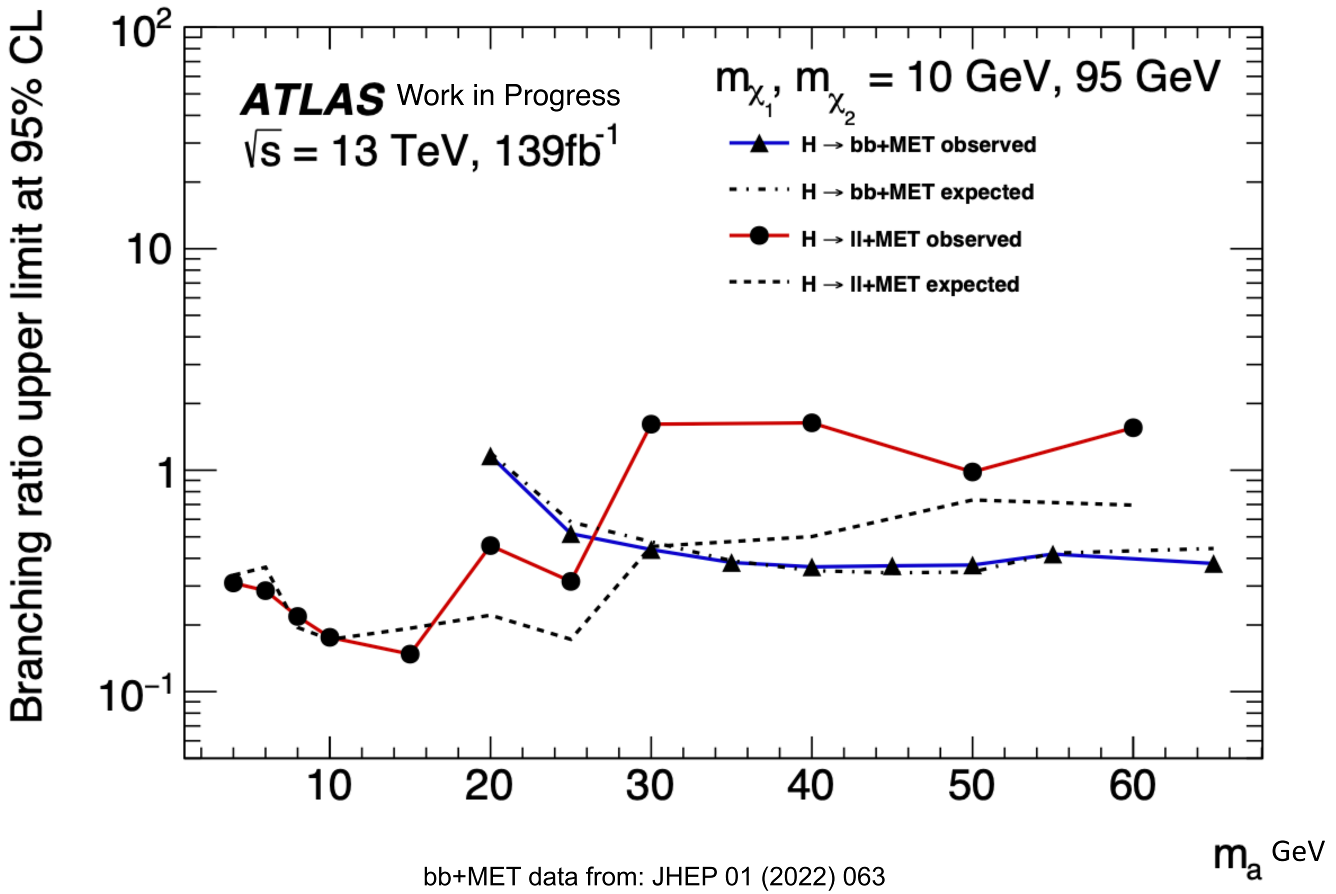


Results: Sensitivity Comparisons

Here, compare the model-independent results on the branching ratio to the previous bb + MET analysis.

- ○ Br($a \rightarrow \tau\tau$) vs Br($a \rightarrow bb$) is model dependent on factors like $tan(\beta)$

- Able to probe the region below 20 GeV for the first time!
- Obs (Exp) Limits are approximately a factor of 2 worse in the range 20 GeV < ma < 60 GeV



bb+MET data from: JHEP 01 (2022) 063

Next Steps: Sensitivity in mumu

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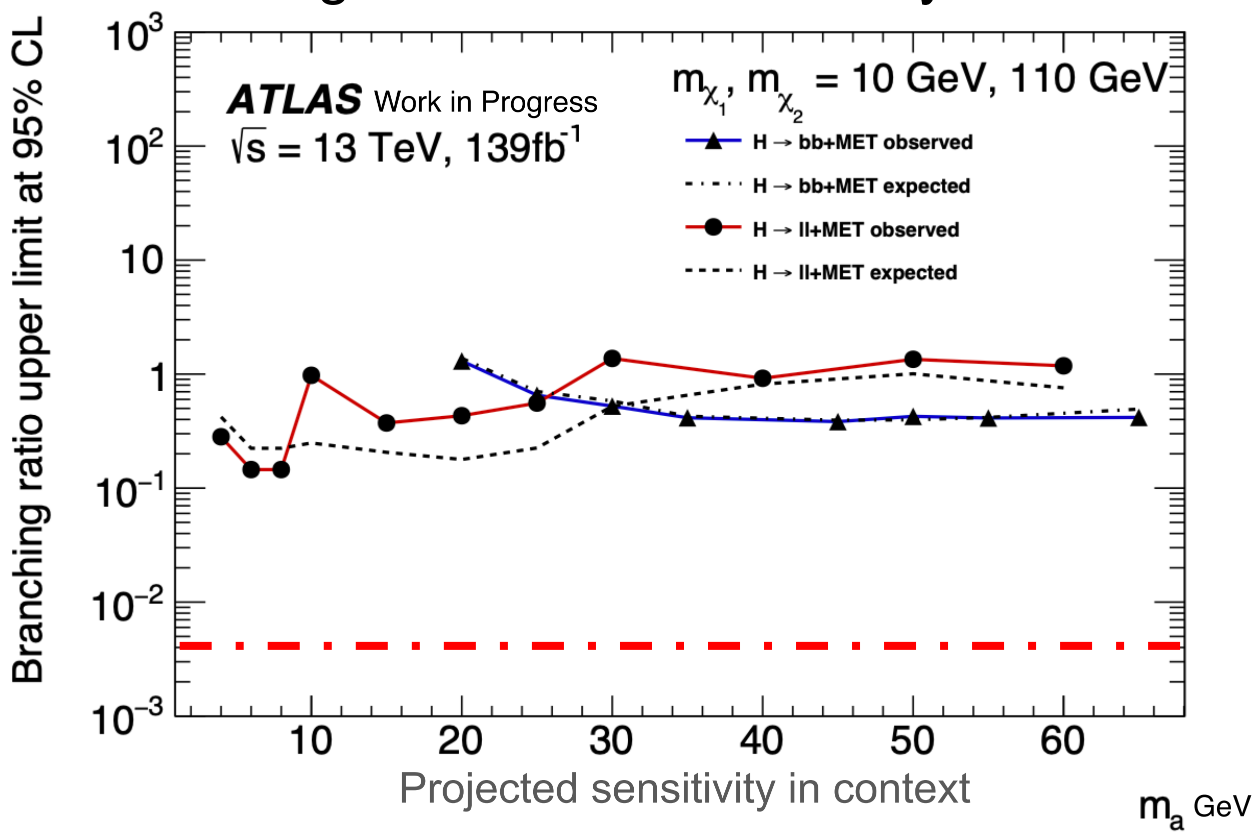
- Able to run some select VBF mumu points through RECAST:
  - Observed (Expected) limits on Br(H→(ℓℓ+MET))
    - ma = 3 GeV, mχ2 = 120 GeV: 0.031 (0.033)
- Quick estimate sensitivity for ggF mumu points:
  - Scale by ratio of VBF acceptance to ggF acceptance and ratio of respective cross sections
  - For ma = 4 GeV, mχ2 = 110 GeV ~ .0030 (.0032)
  - For ma = 20 GeV, mχ2 = 110 GeV ~ .0027 (.0029)
- Looking at 1-2 order of magnitude better sensitivity!



Projected sensitivity in context

Final Conclusions and Next Steps

With RECAST,

- able to quickly and efficiently calculate limits **without** dedicated analysis.
- Able to probe m_a < 20 GeV for the first time

We are working on:

- a second sample request for μμ channel to investigate excess, given the excellent sensitivity of this channel.
- Calculating model dependent limits

This work will continue with the goal of an internal PUB note.
Many thanks to Ben, Chris, Tae for their continued support.

Questions?

Backup: SR Definitions

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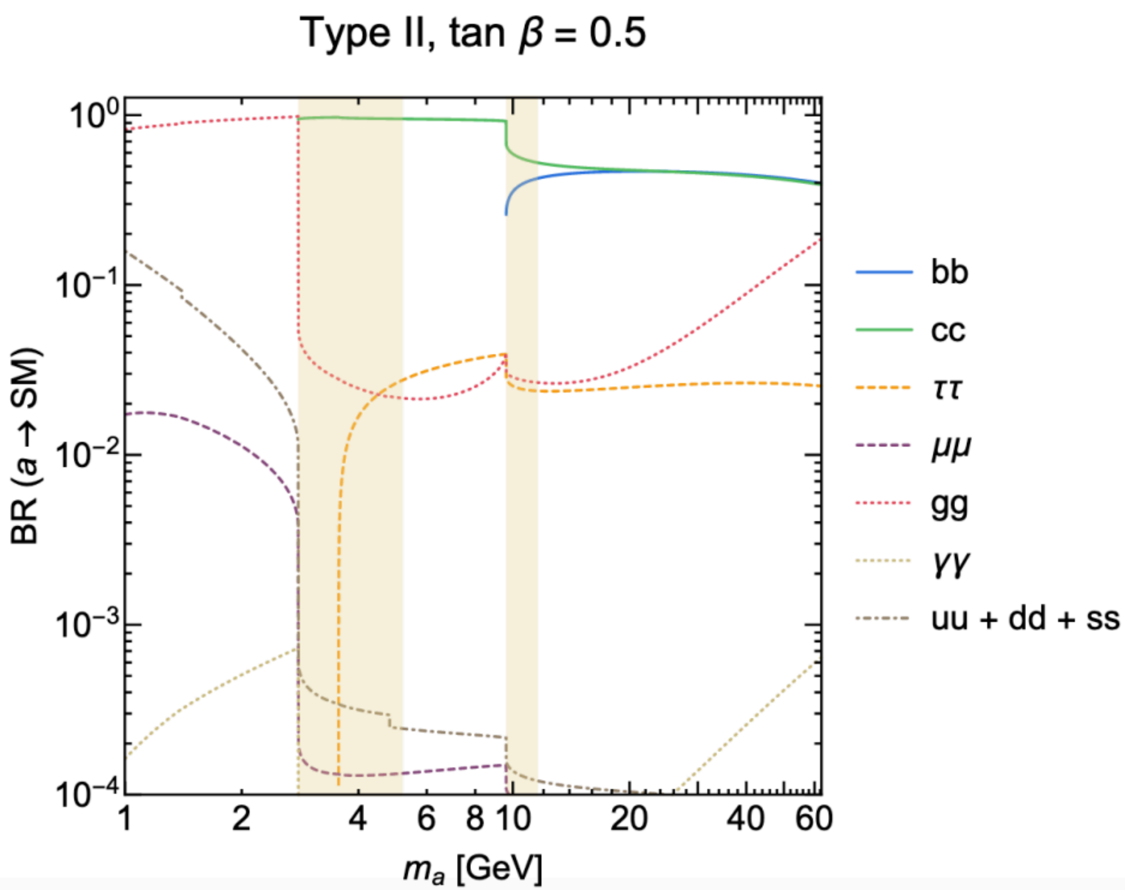
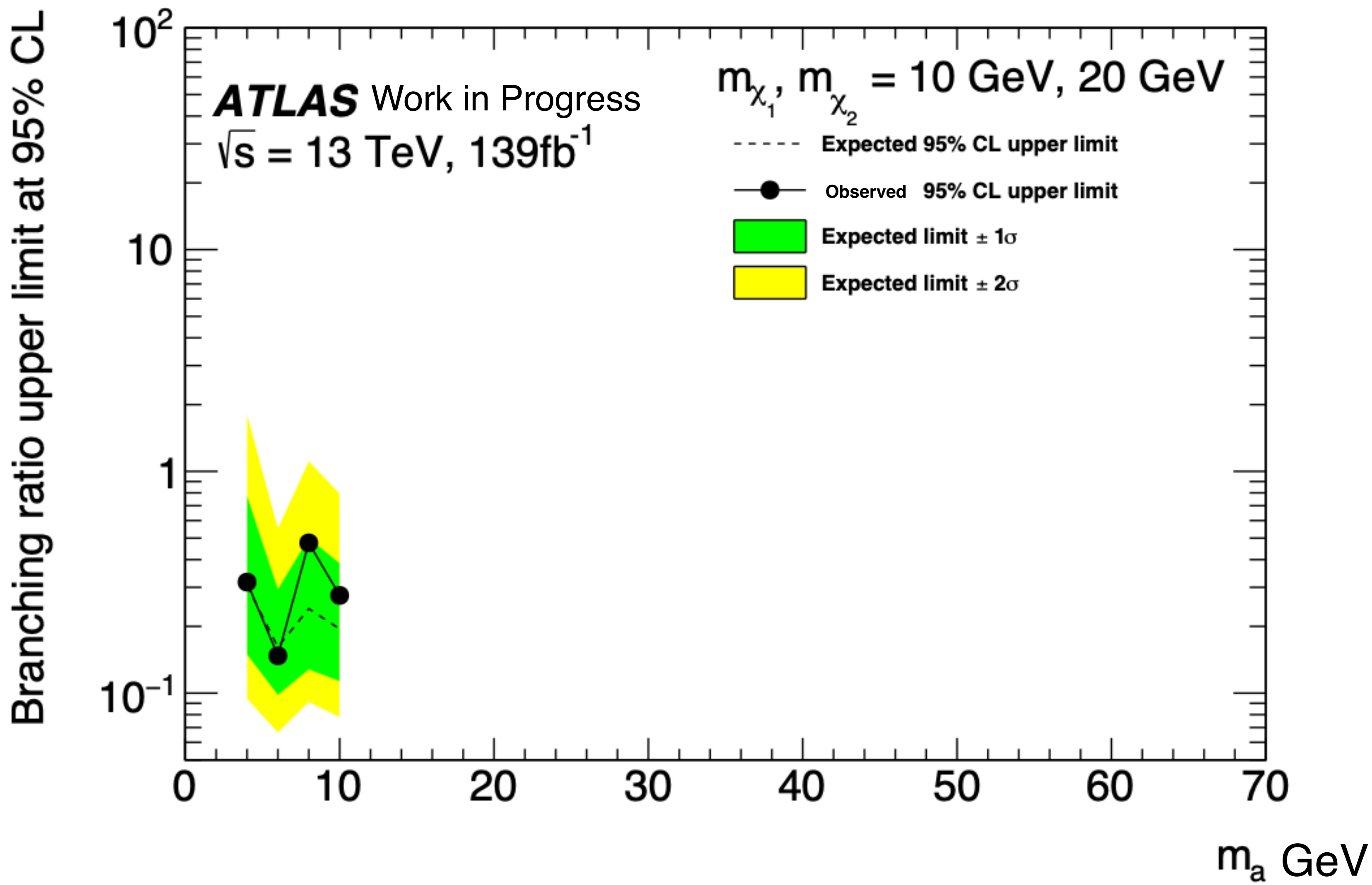
Variable	Electroweakino SR requirements			
	SR-E-low	SR-E-med	SR-E-high	SR-E-1ℓ1T
E_T^{miss} [GeV]	[120, 200]	[120, 200]	>200	>200
E_T^{miss}/H_T^{lep}	<10	>10	$\cdots$	>30
$\Delta\phi(\text{lep}, \mathbf{p}_T^{miss})$	$\cdots$	$\cdots$	$\cdots$	<1.0
Lepton or track p_T [GeV]	$p_T^{\ell_2} > 5 + m_{\ell\ell}/4$	$\cdots$	$p_T^{\ell_2} > \min(10, 2 + m_{\ell\ell}/3)$	$p_T^{track} < 5$
M_T^S [GeV]	$\cdots$	<50	$\cdots$	$\cdots$
$m_T^{\ell_1}$ [GeV]	[10, 60]	$\cdots$	<60	$\cdots$
R_{ISR}	[0.8, 1.0]	$\cdots$	$[\max(0.85, 0.98 - 0.02 \times m_{\ell\ell}), 1.0]$	$\cdots$

PHYS. REV. D 101, 052005 (2020)

Backup: Why tau?

Branching ratios for high/low $tan(\beta)$ for Type-II 2HDM





ATLAS Work in Progress
√s = 13 TeV, 139fb-1
mχ1, mχ2 = 10 GeV, 20 GeV
Expected 95% CL upper limit
Observed 95% CL upper limit
Expected limit ± 1σ
Expected limit ± 2σ
Branching ratio upper limit at 95% CL
ma GeV

Backup: Branching Ratio Limits:

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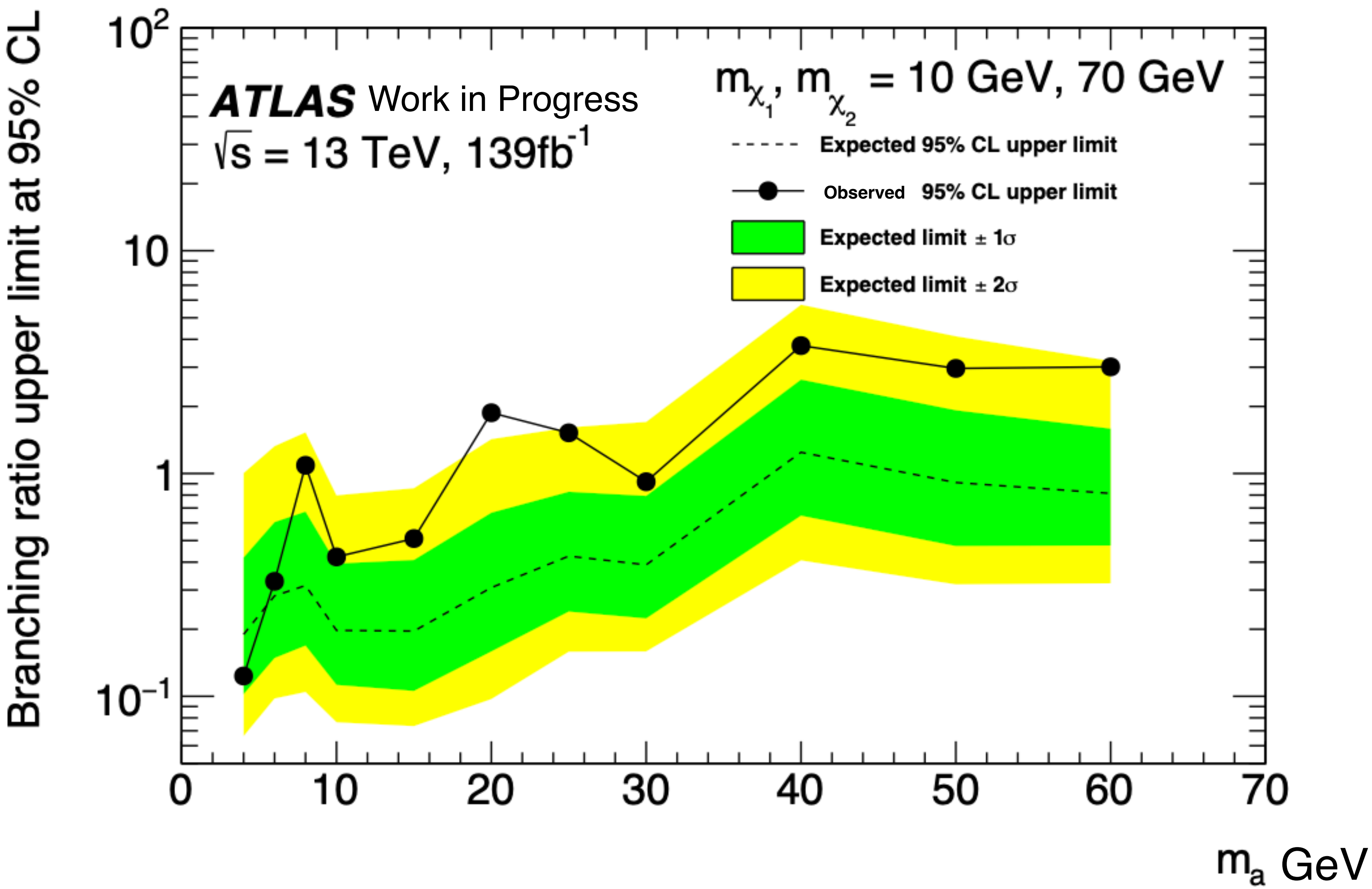
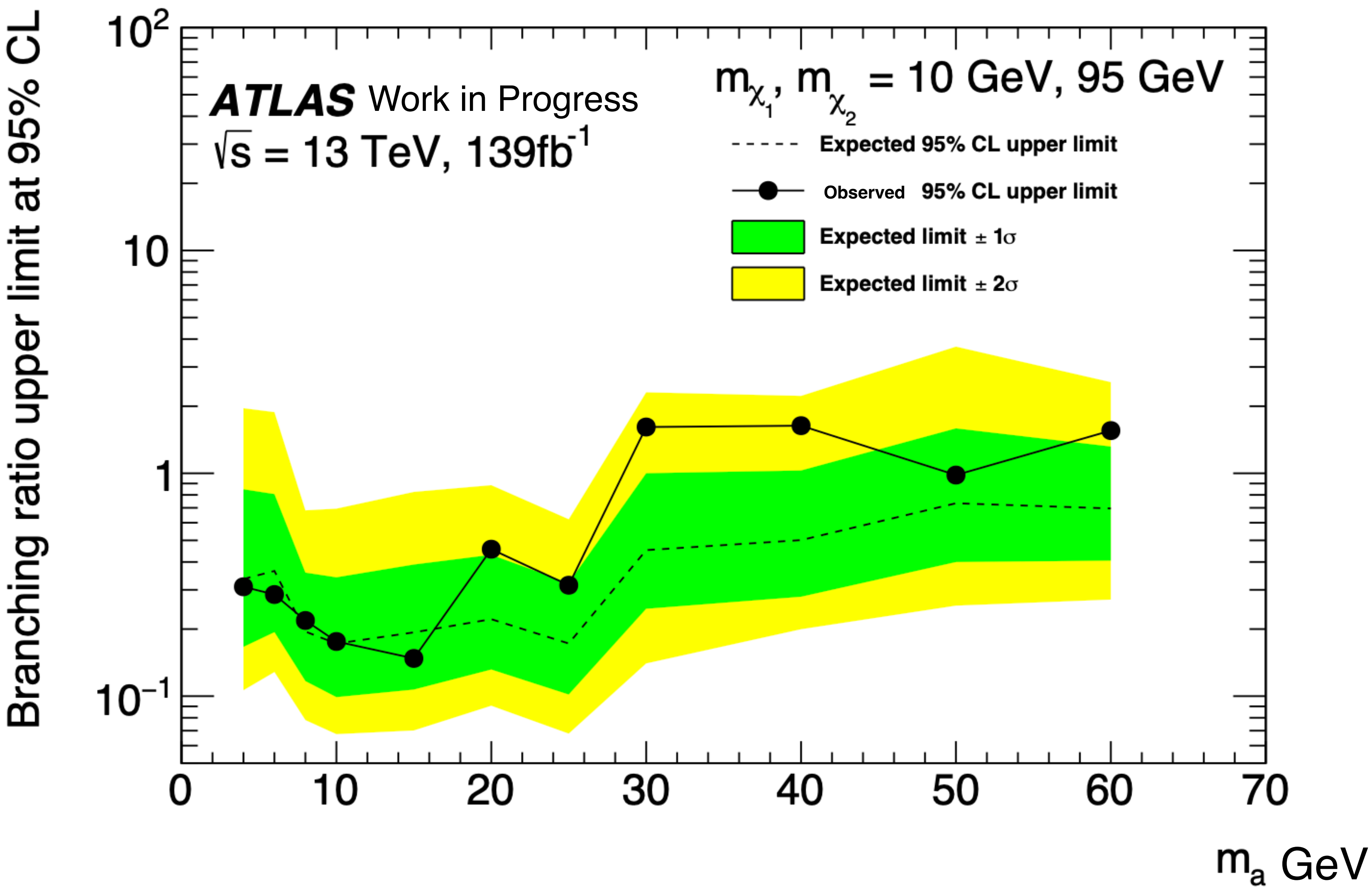


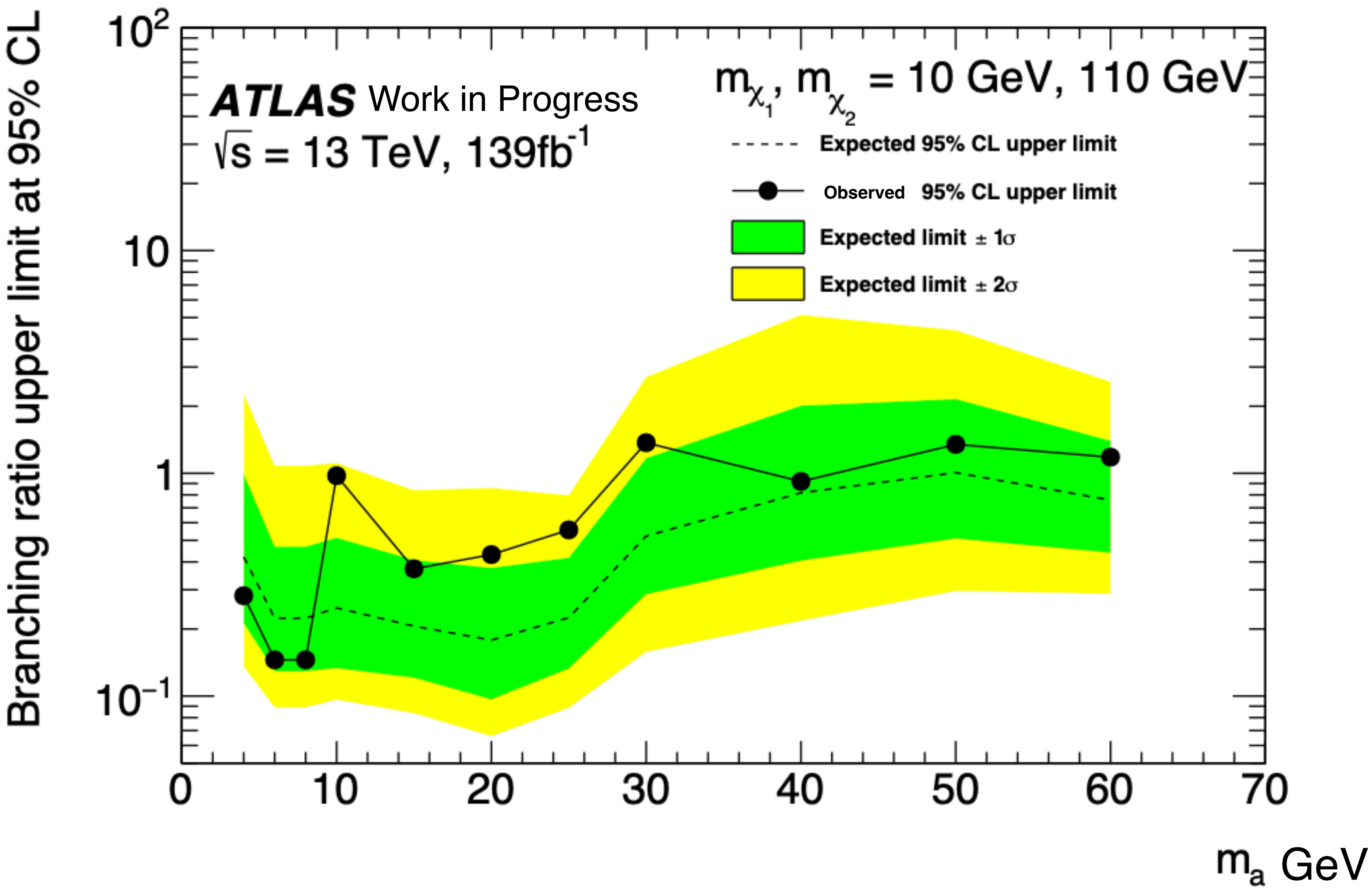
Backup: Branching Ratio Limits:

Brandani



Backup: Branching Ratio Limits:

Brandani



ee mm

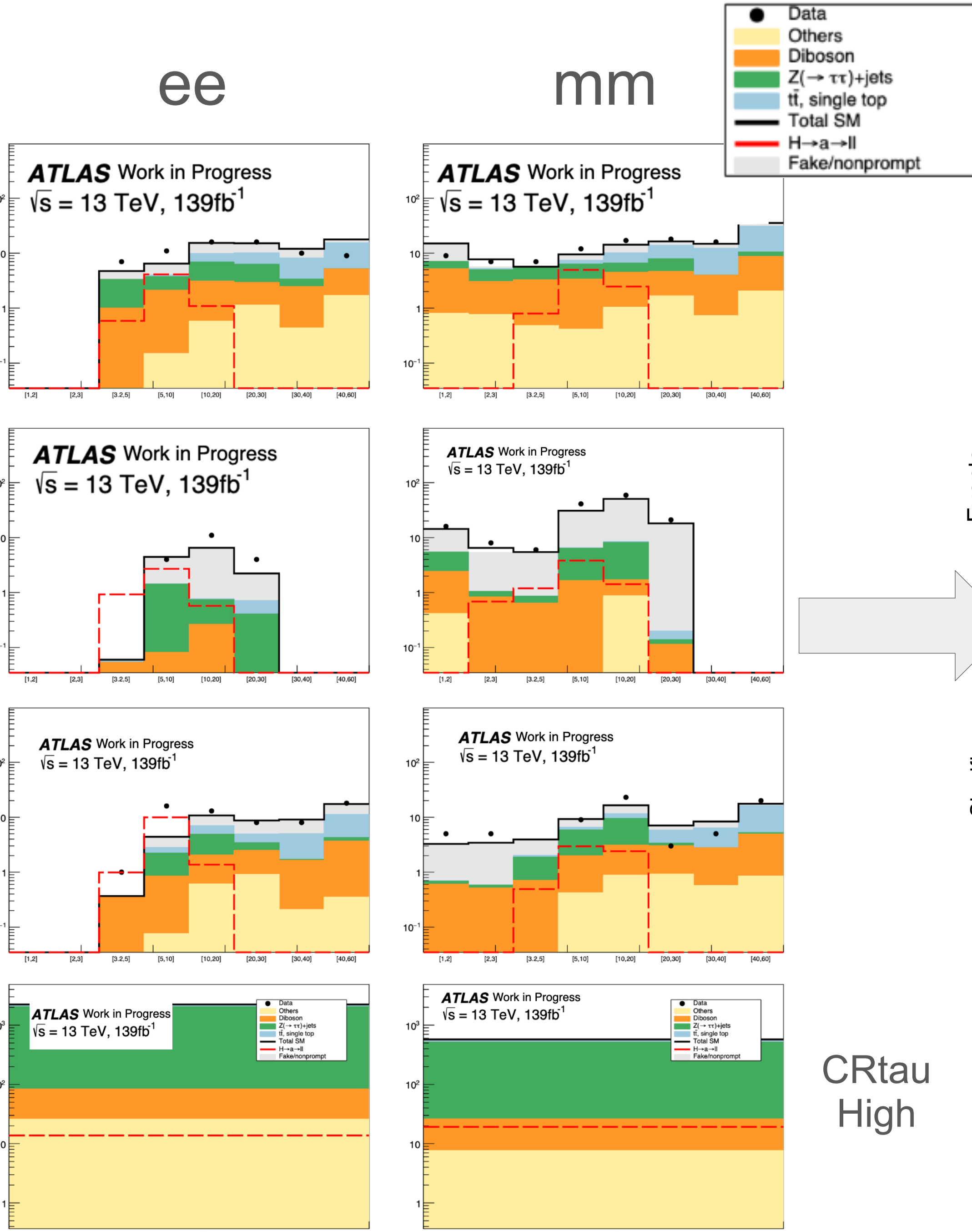
SR-E-low

SR-E-m

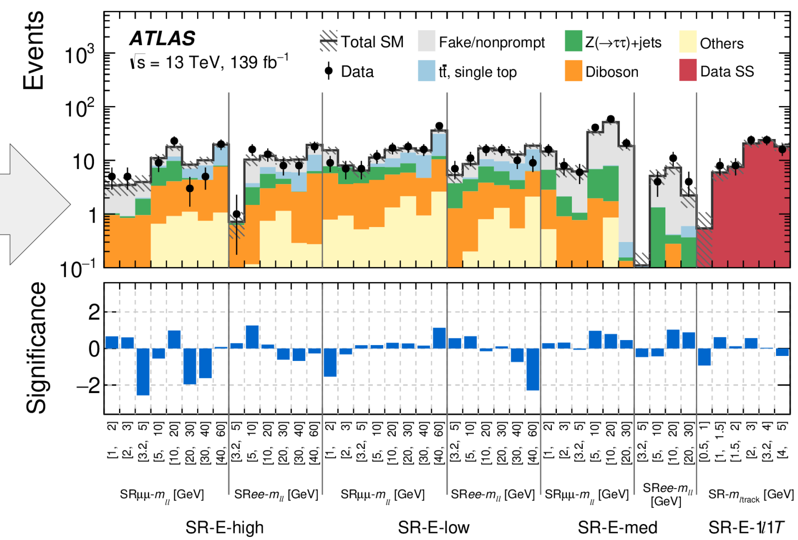
SR-E-hi

CRtau Low

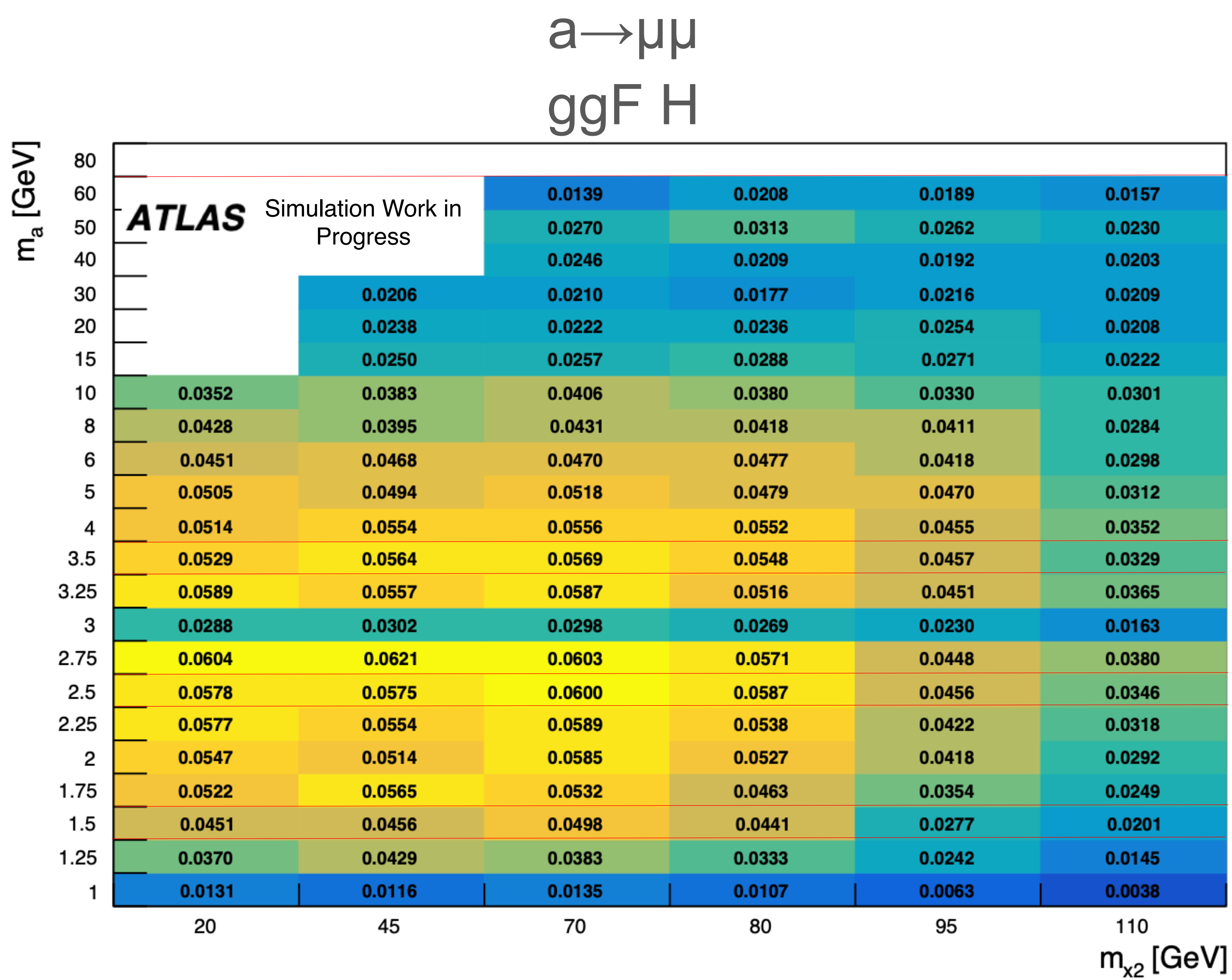
CRtau High



Goal to format these pre/postfit yields into summary plots as in the original paper



- Acceptance scan in m_a vs. m_{χ_2} for new μμ samples



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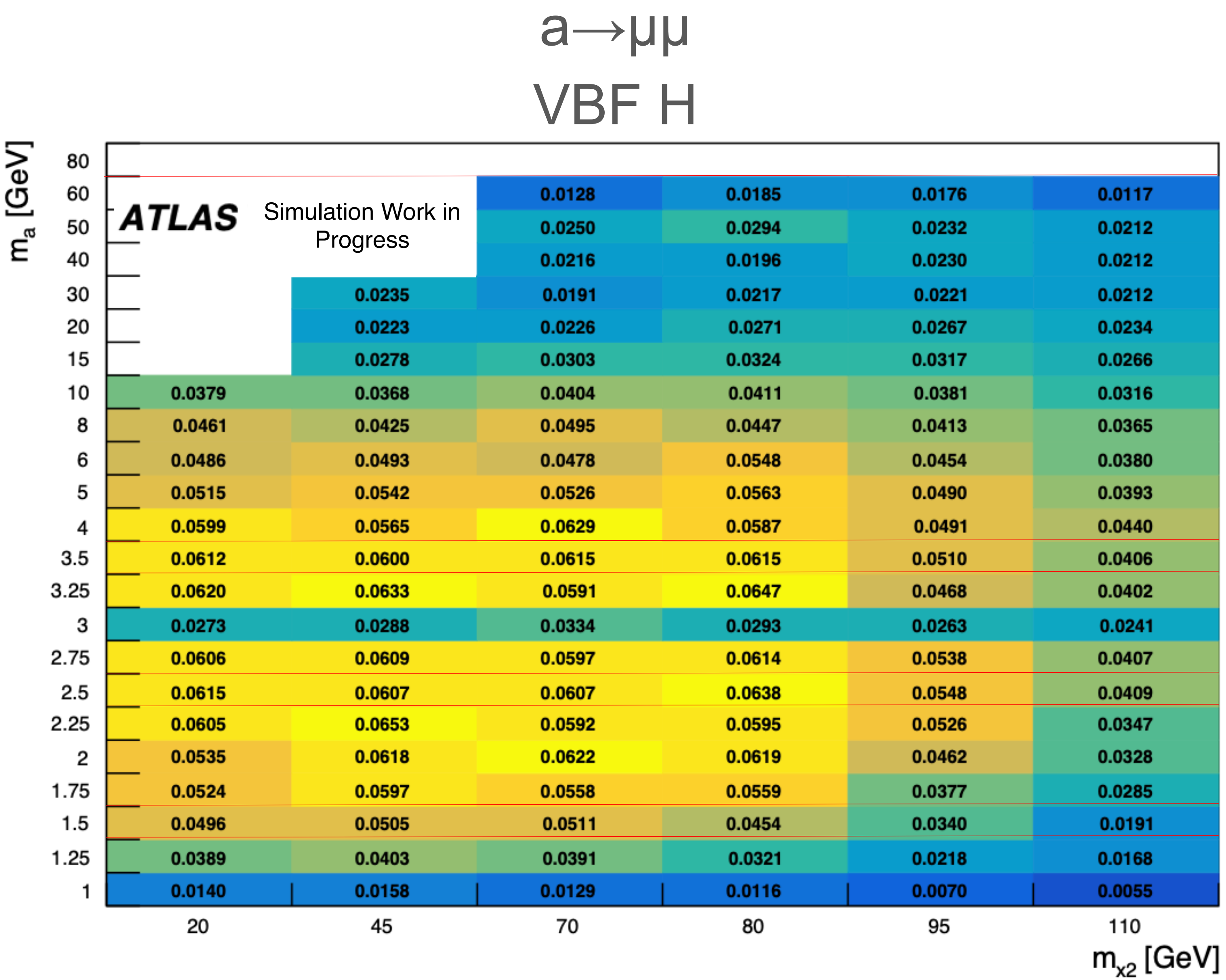

Backup: Sensitivity in mumu

Observed (Expected) limits on Br(H→(ℓℓ+MET))

mχ1 = 1 GeV	mχ2 = 6 GeV	mχ2 = 62 GeV	mχ2 = 63 GeV	mχ2 = 120 GeV
ma = 1 GeV	X	0.0091 (0.017)	X	X
ma = 2 GeV	X	X	0.0082 (0.0050)	X
ma = 3 GeV	0.0089 (0.0091)	X	0.0072 (0.0070)	0.031 (0.033)