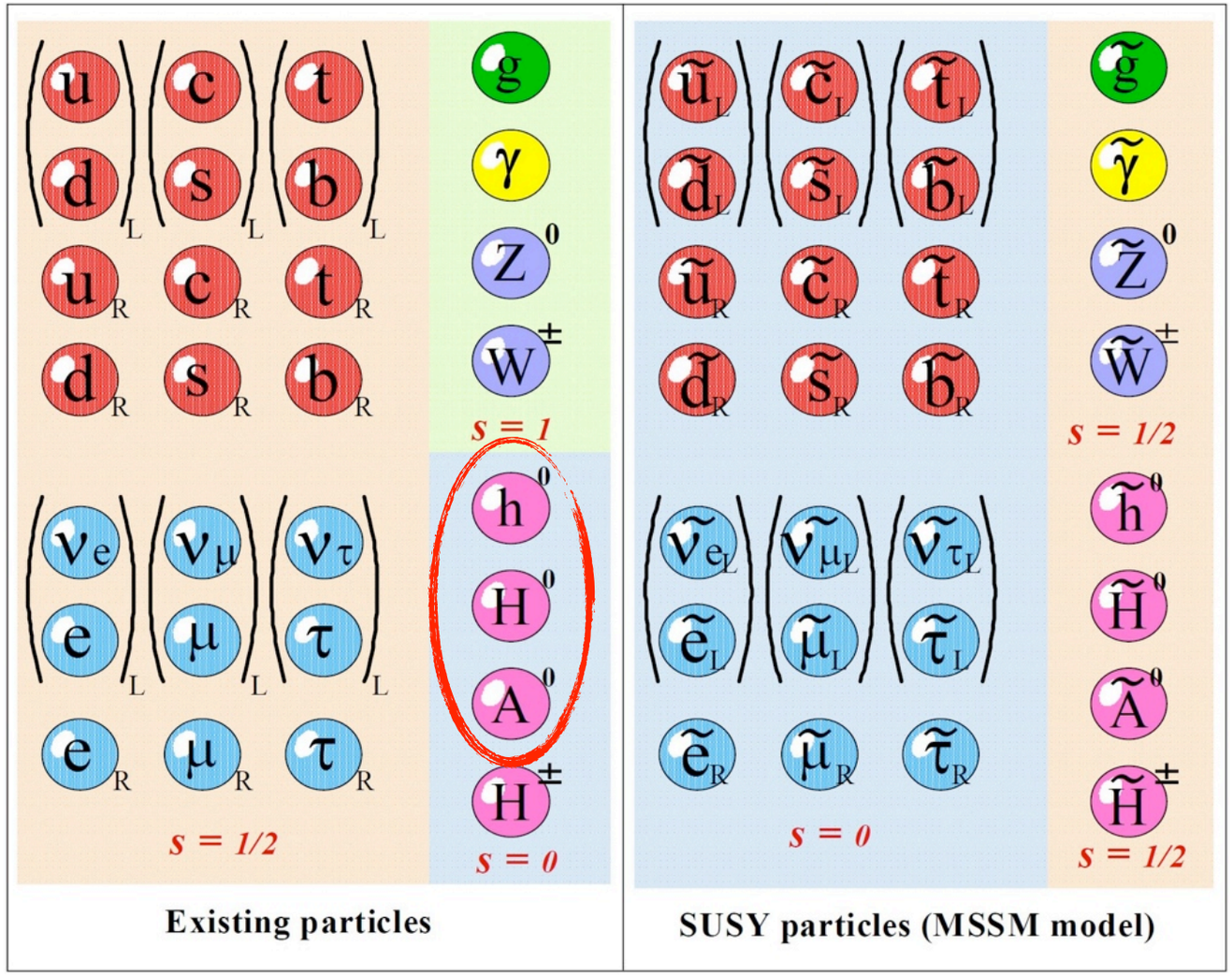
MSSM Higgs→ττ searches in ATLAS

Federico Scutti
On behalf of the ATLAS collaboration

22.07.2014
Higgs Hunting 2014
Orsay

Outline

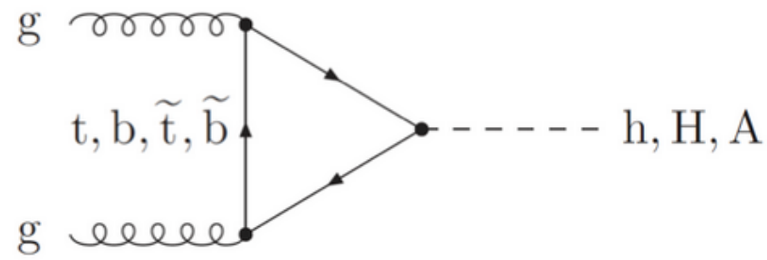
- Search for MSSM neutral Higgs bosons
- Channels:
  - Selection
  - Bkg estimation
- Exclusion limits



The neutral MSSM Higgs

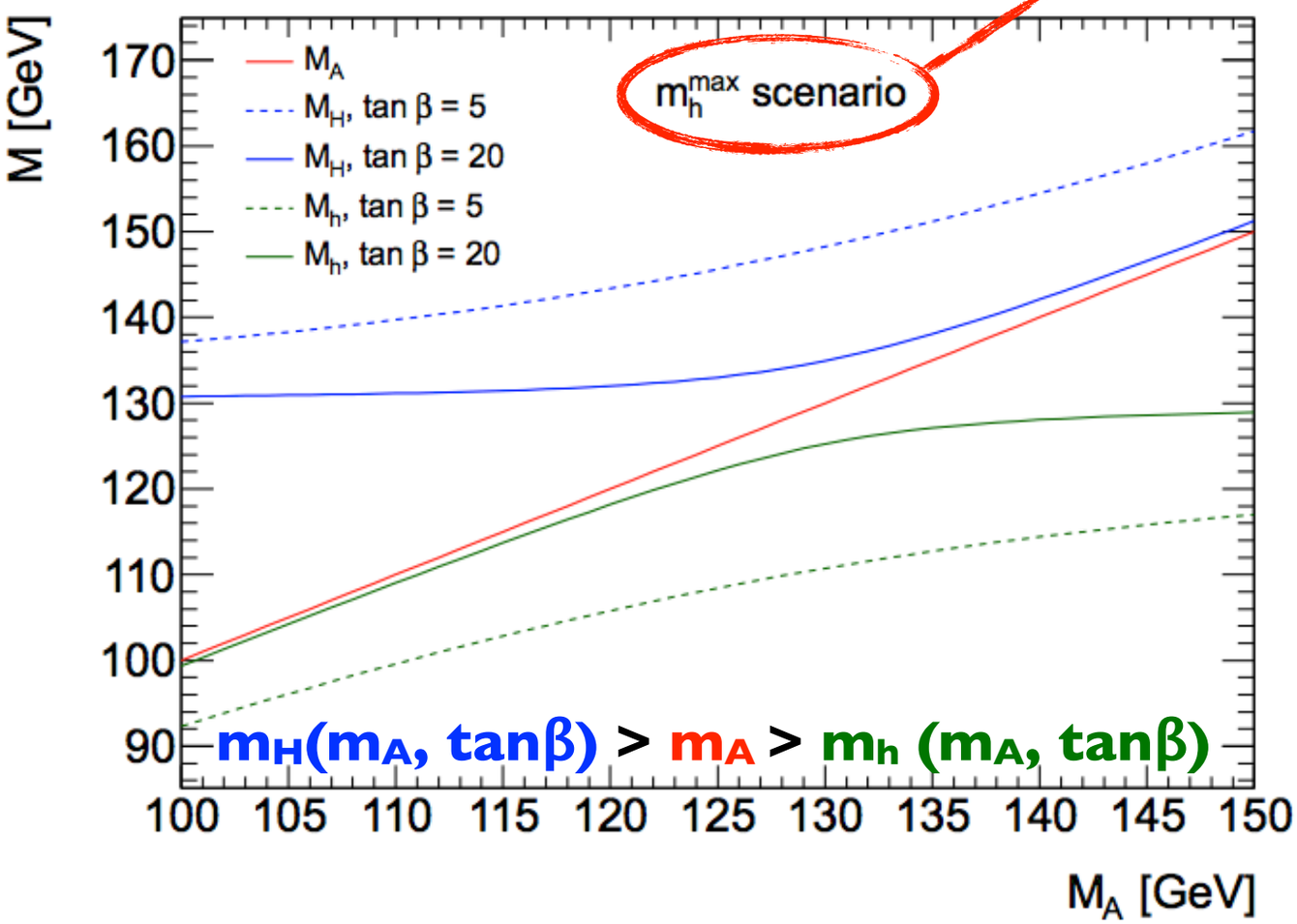
- Two CP even states: h / H
- One CP odd: A
- Free parameters at tree level: m_A , $\tan\beta$ (VEV ratio of Higgs doublets)

gg fusion

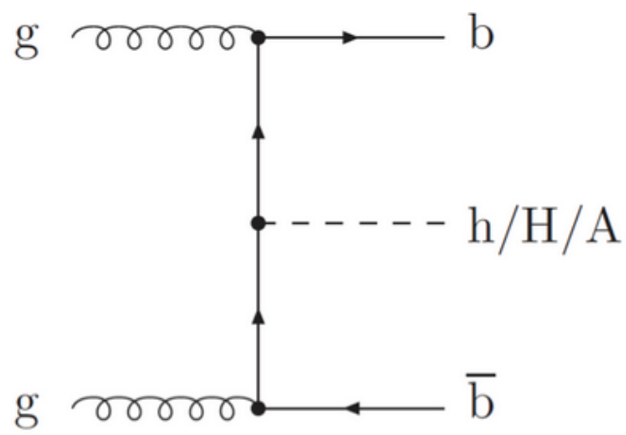


$m_{h/H/A}$ vs m_A

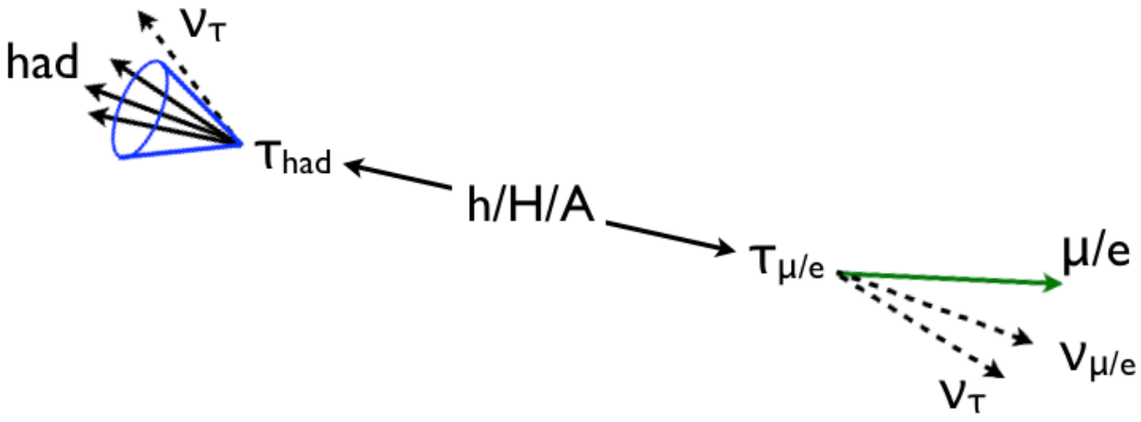
radiative corrections to m_h maximized



b-associated

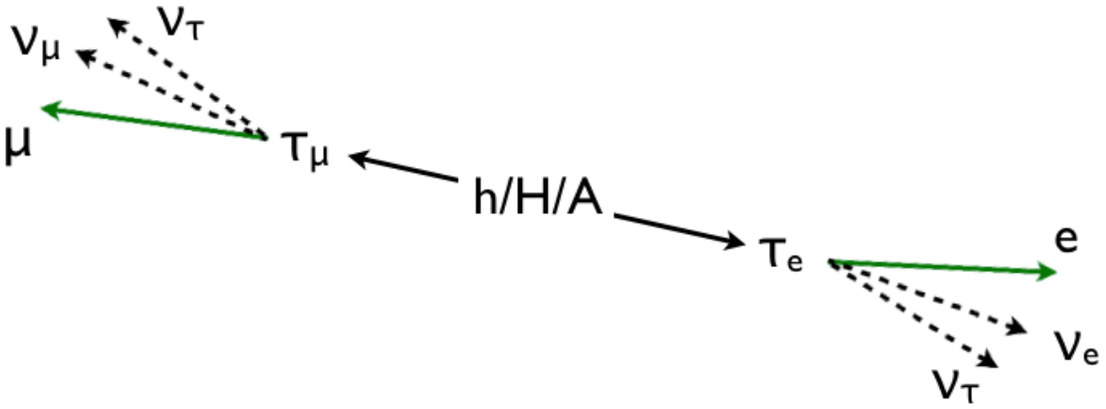


Channels and preselection



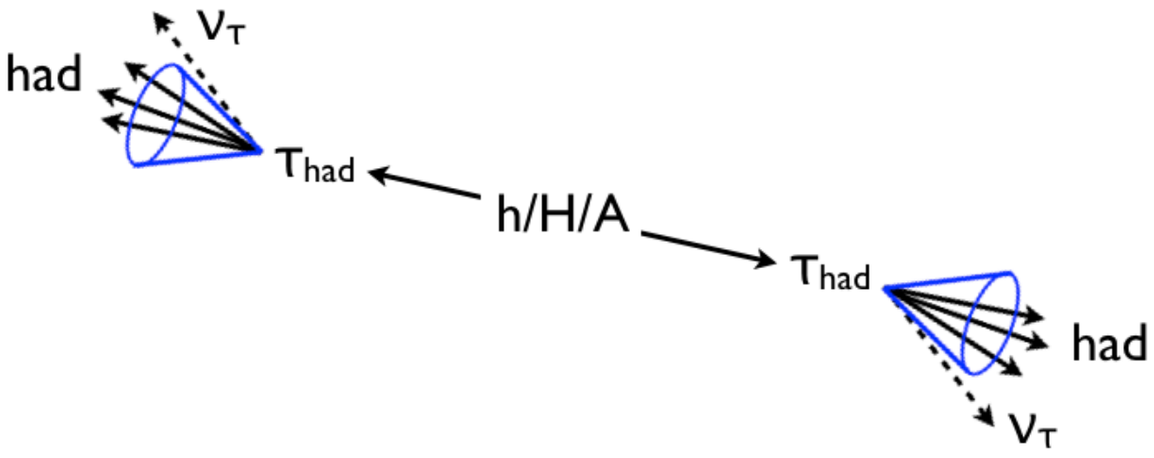
Lep-Had:

- Single-μ or single-e trigger
- One τ_{had} and one isolated e/μ (identified)
- Opposite charge between τ_{had} and e/μ



Lep-Lep:

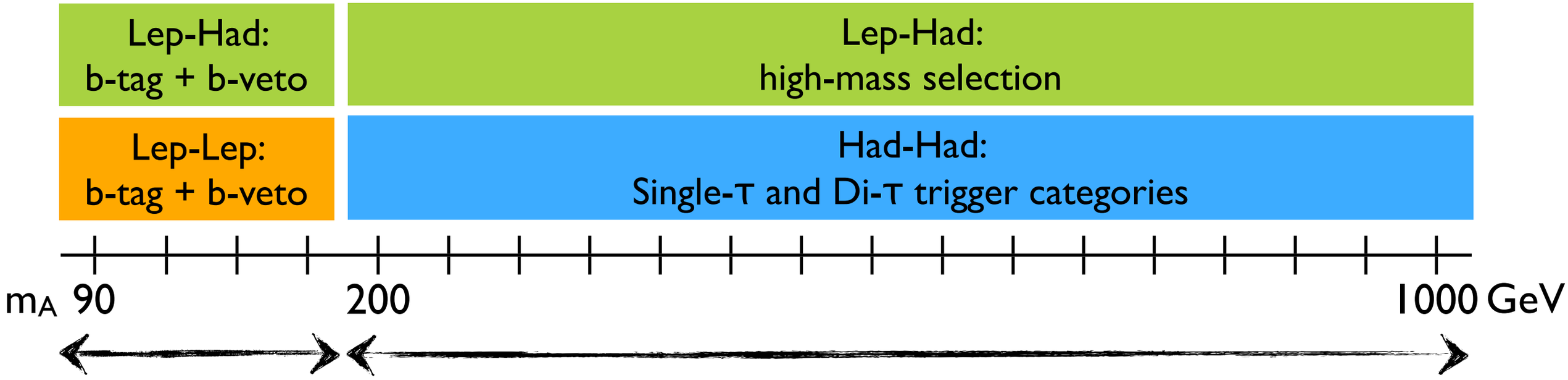
- Single-e trigger or μ+e trigger
- Isolated and identified e and μ
- Veto on τ_{had}
- Opposite charge between e and μ



Had-Had:

- At least two τ_{had} with $p_T > 50$ GeV
- Identified τ_{had}
- Opposite charge between $\tau_{had\ lead.}$ and $\tau_{had\ sub\text{-}lead.}$

Categorization and main backgrounds



dominated by:

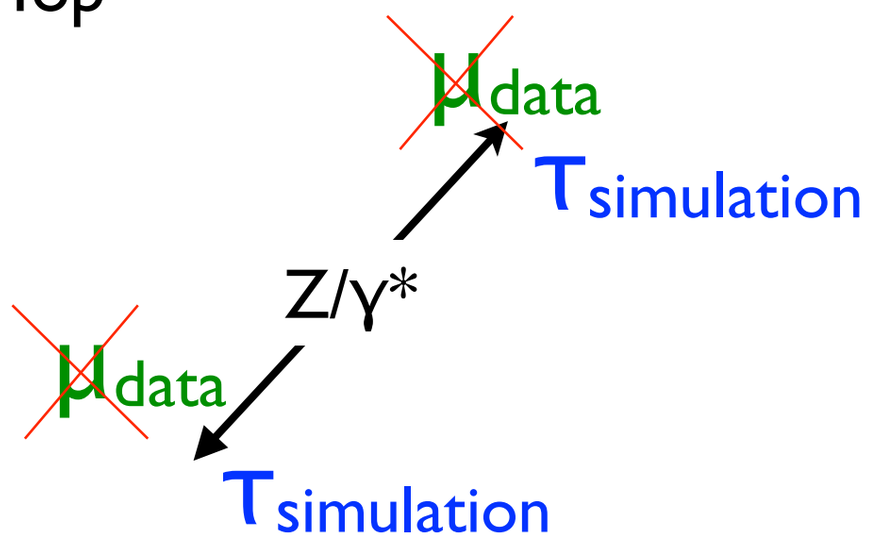
- Z/γ*→ττ
- W+jets & Top

dominated by:

- Multi-jet
- Z/γ*→ττ
- W+jets & Top

Background estimation techniques:

- Z/γ*→ττ: τ embedding in Z/γ*→μμ data events
- Multi-jet: data-driven
- W+jets & Top: from MC normalized to data



Discriminating variables:

- Lep-Had and Lep-Lep: Missing Mass Calculator algorithm
- Had-Had: $m_T^{\text{total}} = \sqrt{m_T(\tau_1,\tau_2,)^2 + m_T(\tau_1, E_{\text{T}}^{\text{miss}})^2 + m_T(\tau_2, E_{\text{T}}^{\text{miss}})^2}$

Lep-Had channel

lep=μ,e b-tag

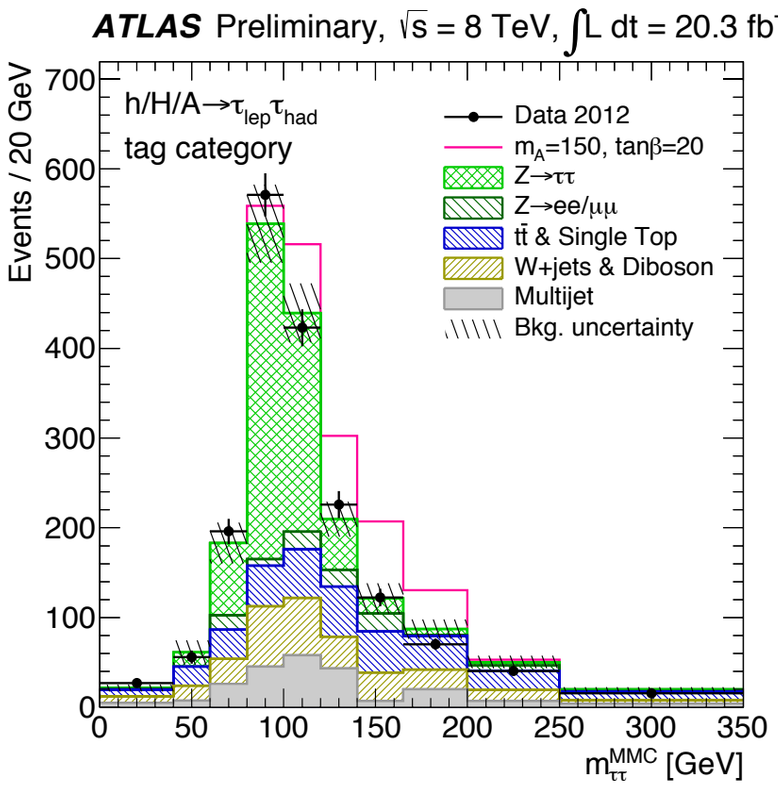
- At least one b-jet
- $m_T(lep, E_T^{miss}) < 45$ GeV

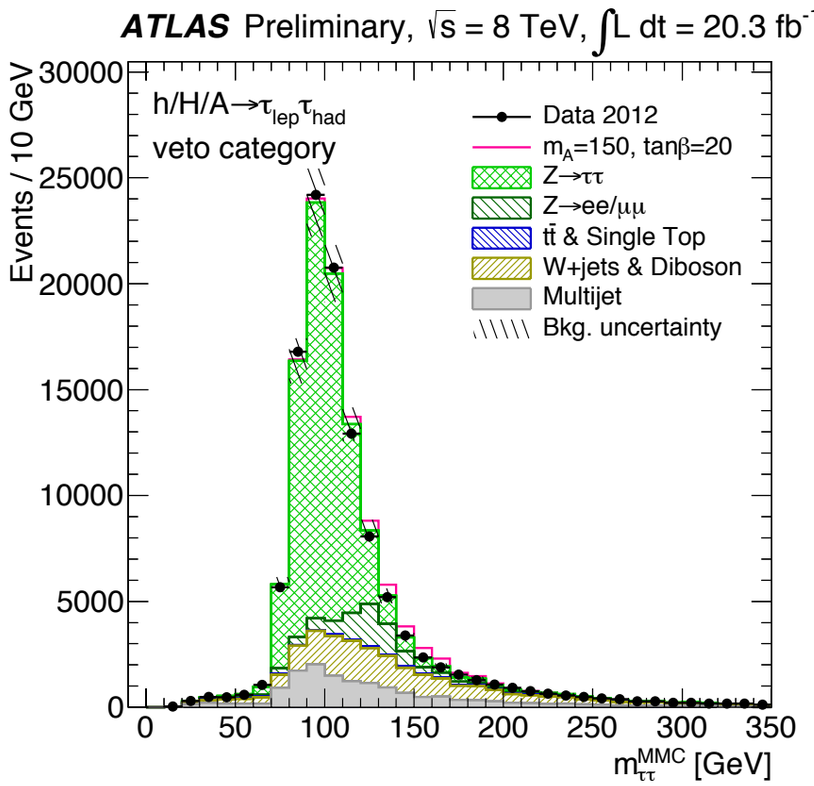
b-veto

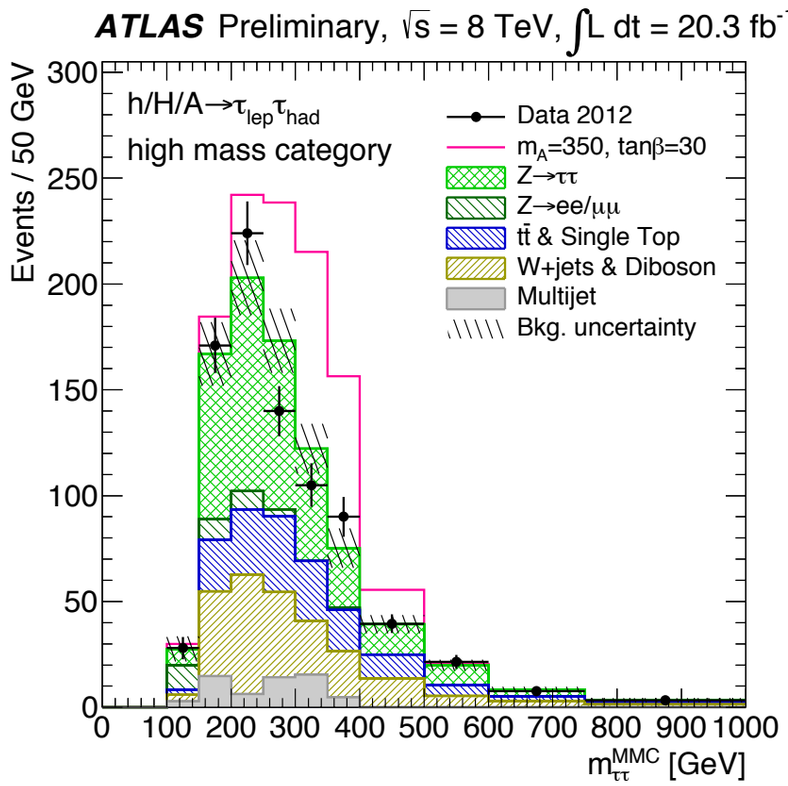
- No b-tagged jets
- $\Delta\Phi(lep,E_T^{miss})+\Delta\Phi(\tau, E_T^{miss})<3.3$
- $m_T(lep, E_T^{miss}) < 60$ GeV

high-mass

- $\Delta\Phi(lep,E_T^{miss})+\Delta\Phi(\tau, E_T^{miss})<3.3$
- $\Delta\Phi(lep,\tau) > 2.4$
- $p_T(\tau)-p_T(lep) > 45$ GeV



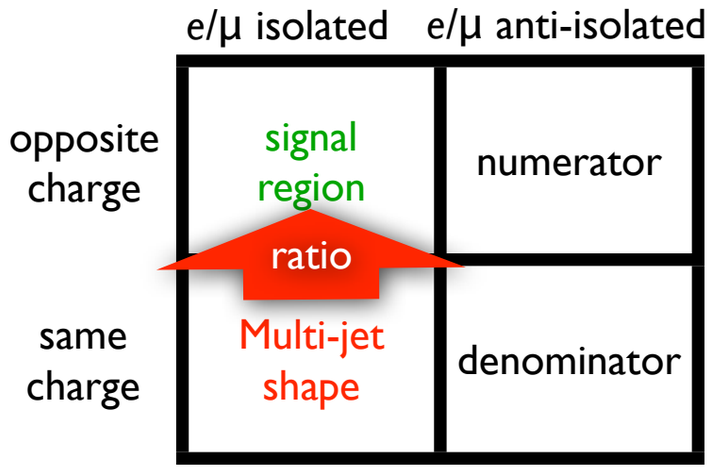




- $Z/\gamma^* \rightarrow \tau\tau$: embedding
- W+jets &:Top MC normalized to data

Multi-jet:

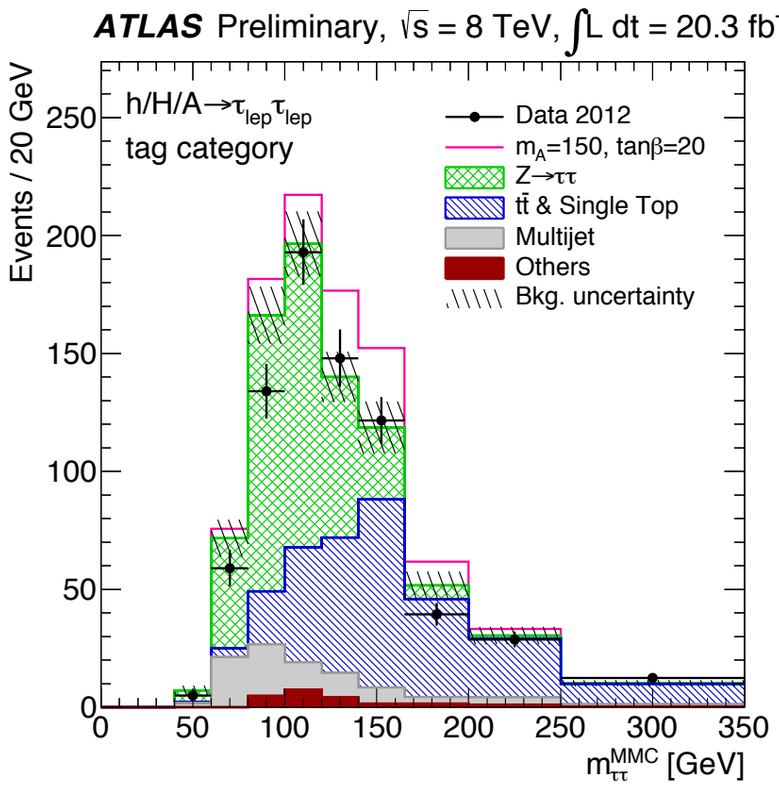
- Two dimensional sideband method
- MC subtracted from CRs



Lep-Lep channel

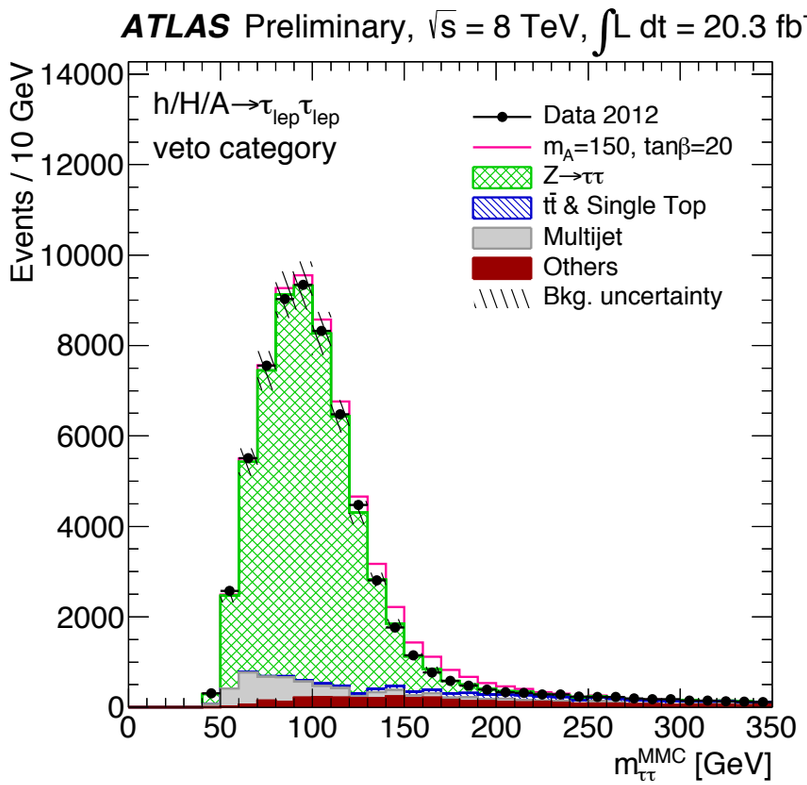
b-tag

- Exactly one b-jet
- $\cos\Delta\Phi(\mu,E_T^{miss}) + \cos\Delta\Phi(e,E_T^{miss}) > -0.2$
- $\Sigma\ |p_T(jet)| < 100$ GeV
- $|p_T(\mu)| + |p_T(e)| + |E_T^{miss}| < 125$ GeV



b-veto

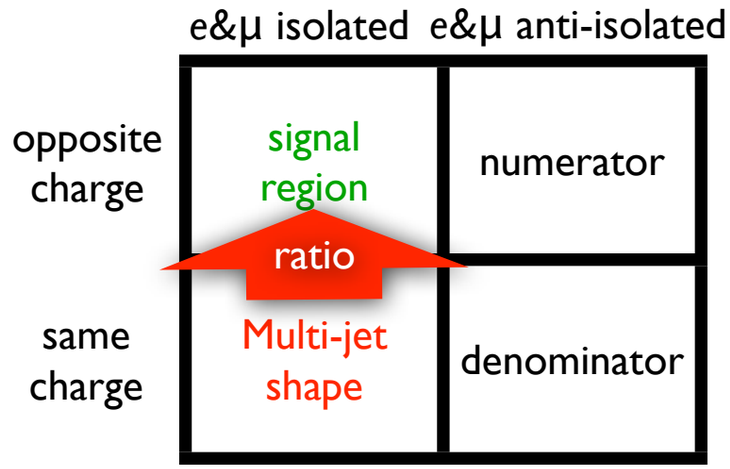
- No b-tagged jets
- $\cos\Delta\Phi(\mu,E_T^{miss}) + \cos\Delta\Phi(e,E_T^{miss}) > -0.4$



- $Z/\gamma^* \rightarrow \tau\tau$: embedding
- Top: MC normalized to data

Multi-jet:

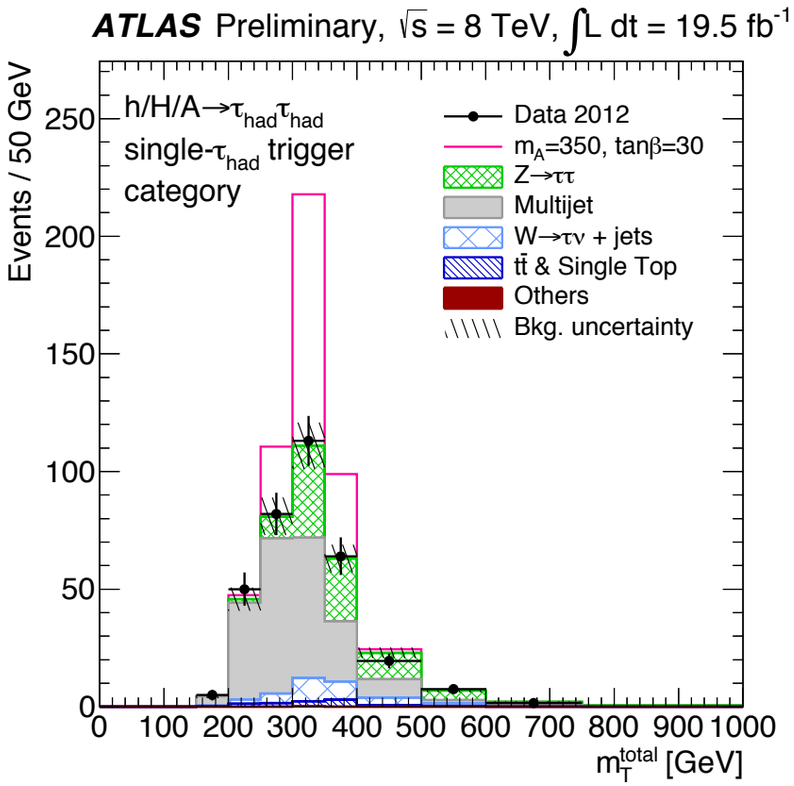
- Two dimensional sideband method
- MC subtracted from CR



Had-Had channel

Single-τ trigger

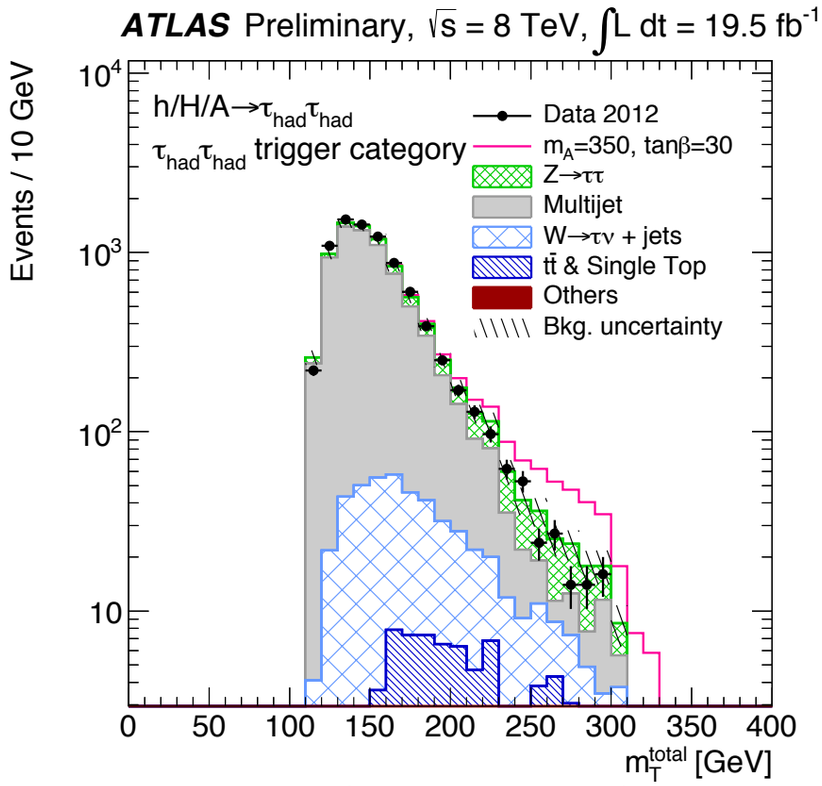
• Offline $p_T(\tau_{lead.})$ > 150 GeV



- $Z/\gamma^* \rightarrow \tau\tau$: simulation
- W+jets: MC normalized to data

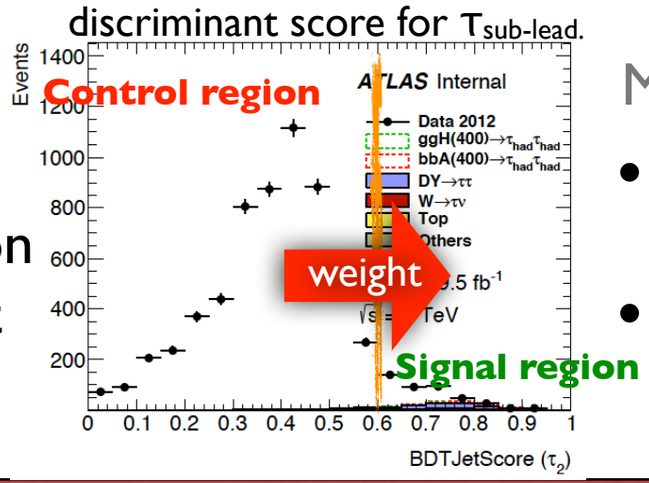
Di-τ trigger

- $p_T(\tau_{lead.})$ < 150 GeV
- Tighten τ identification
- E_T^{miss} > 10 GeV



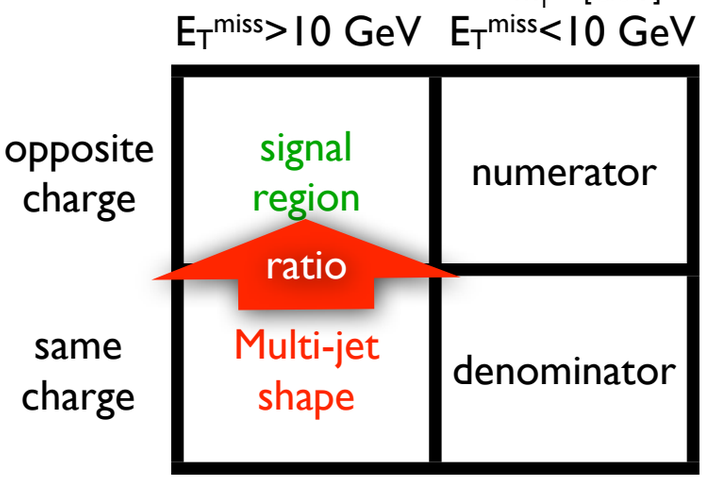
Multi-jet STT:

- weight of events failing identification
- weight from di-jet events in data



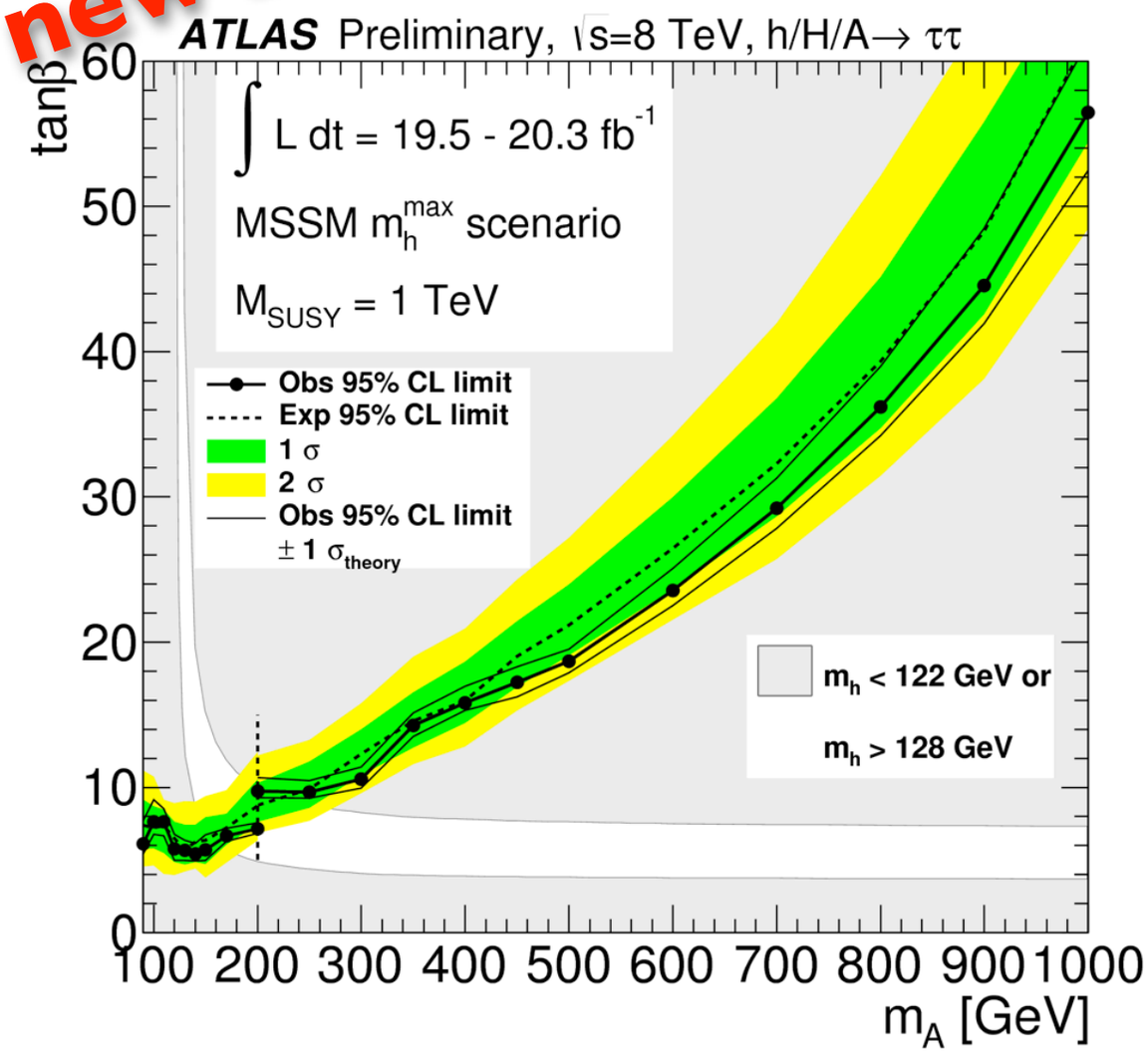
Multi-jet DTT:

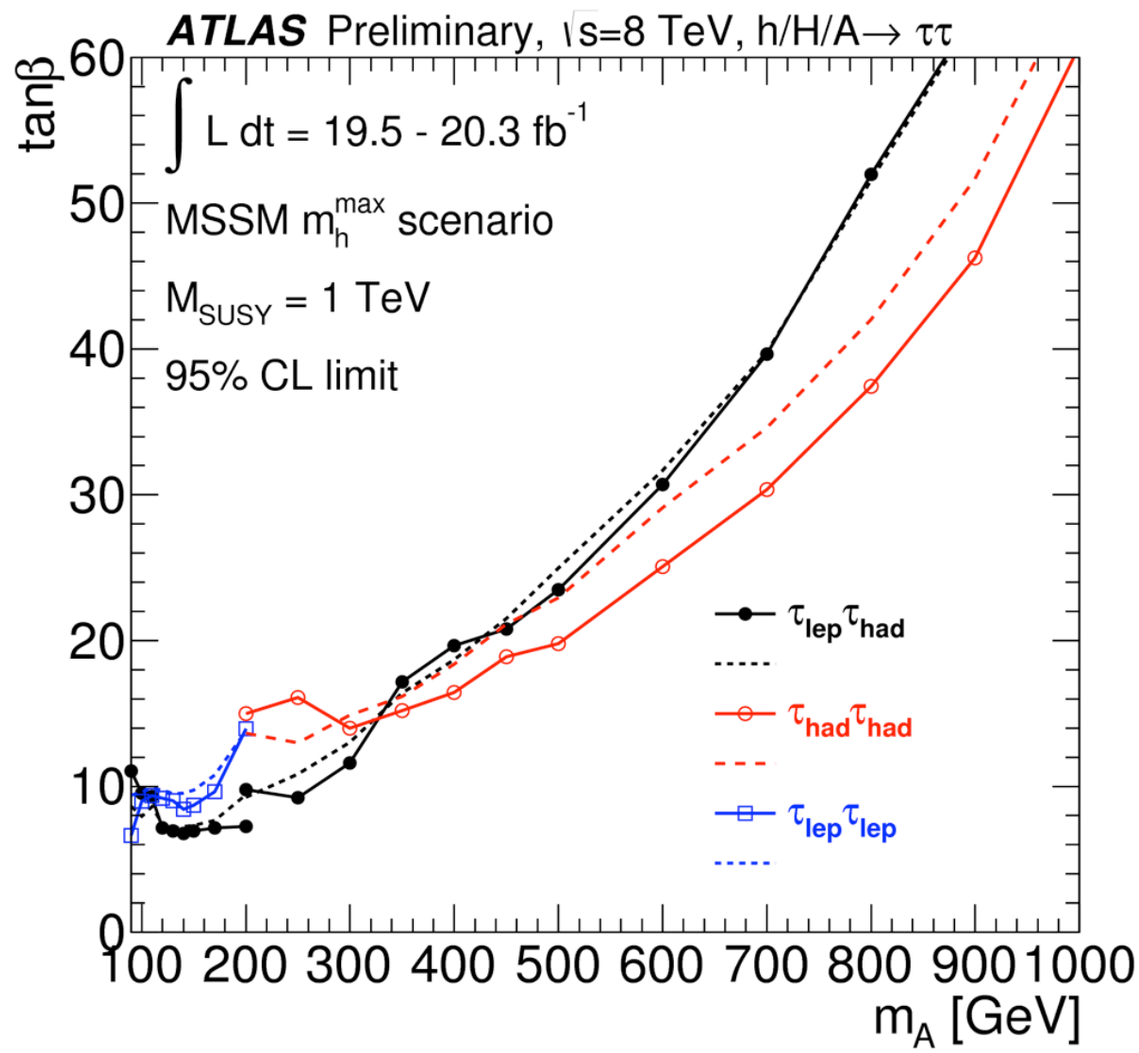
- Two dimensional sideband method
- MC subtracted from CR



Exclusion limits

new result!!!





ATLAS-CONF-2014-049

Conclusions

- No excess observed...
- ... but the exclusion is very competitive and rules out a large region of the parameter space
- Stay tuned for the next round!

Thank you!

Backup

Missing Mass Calculator arXiv:1012.4686 [hep-ex]

- 6 to 8 unknowns: x,y,z components of invisible momentum from neutrino(s) in the τ decay
- invariant mass of neutrinos for leptonic decay
- only 4 equations:

$$\not{E}_{\mathrm{T}x} = p_{\mathrm{mis}_1} \sin\theta_{\mathrm{mis}_1} \cos\phi_{\mathrm{mis}_1} + p_{\mathrm{mis}_2} \sin\theta_{\mathrm{mis}_2} \cos\phi_{\mathrm{mis}_2}$$

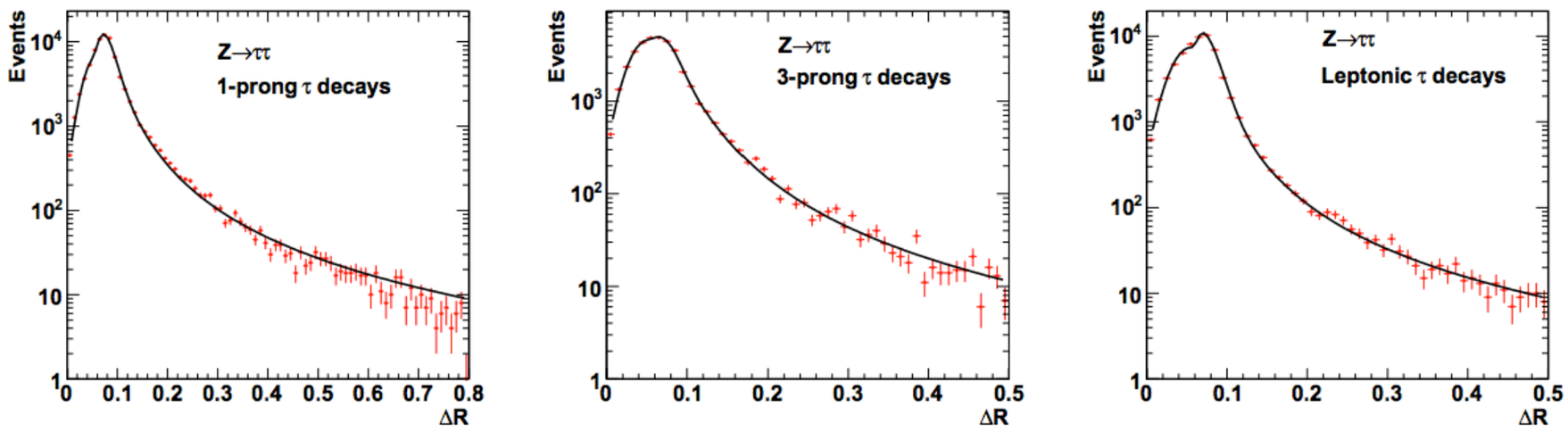
$$\not{E}_{\mathrm{T}y} = p_{\mathrm{mis}_1} \sin\theta_{\mathrm{mis}_1} \sin\phi_{\mathrm{mis}_1} + p_{\mathrm{mis}_2} \sin\theta_{\mathrm{mis}_2} \sin\phi_{\mathrm{mis}_2}$$

$$M^2_{\tau_1} = m^2_{\mathrm{mis}_1} + m^2_{\mathrm{vis}_1} + 2\sqrt{p^2_{\mathrm{vis}_1} + m^2_{\mathrm{vis}_1}}\sqrt{p^2_{\mathrm{mis}_1} + m^2_{\mathrm{mis}_1}} - 2p_{\mathrm{vis}_1}p_{\mathrm{mis}_1}\cos\Delta\theta_{vm_1}$$

$$M^2_{\tau_2} = m^2_{\mathrm{mis}_2} + m^2_{\mathrm{vis}_2} + 2\sqrt{p^2_{\mathrm{vis}_2} + m^2_{\mathrm{vis}_2}}\sqrt{p^2_{\mathrm{mis}_2} + m^2_{\mathrm{mis}_2}} - 2p_{\mathrm{vis}_2}p_{\mathrm{mis}_2}\cos\Delta\theta_{vm_2}$$

- Using PDFs of expected angular distance b/w neutrino(s) and visible decay products
- Construct globas event likelihood

$$\Delta R = \sqrt{(\eta_{\mathrm{vis}} - \eta_{\mathrm{mis}})^2 + (\phi_{\mathrm{vis}} - \phi_{\mathrm{mis}})^2}$$



- Performance highly correlated with E_T^{miss} resolution (largely influenced by jets in the event)

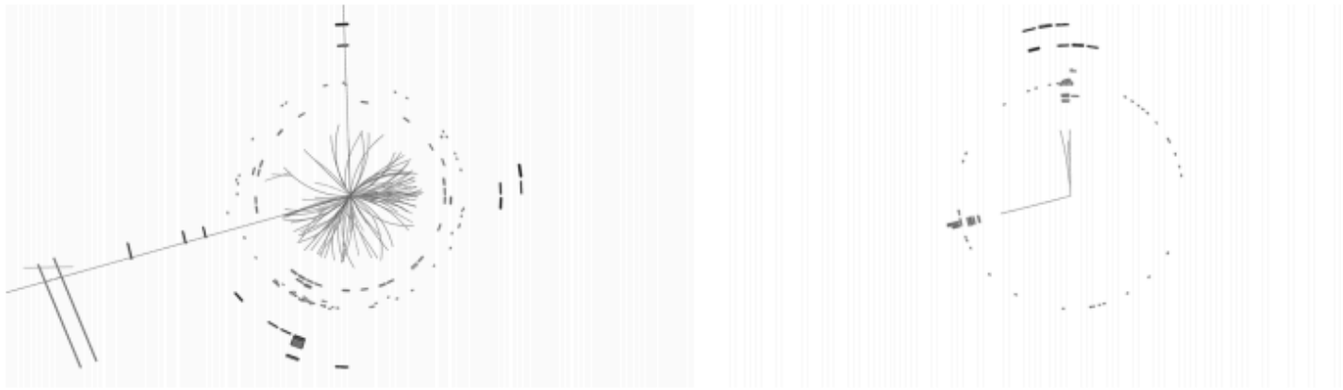
Total Transverse Mass

$$m_T^{\text{total}} = \sqrt{m_T(\tau_1, \tau_2,)^2 + m_T(\tau_1, E_{\text{T}}^{\text{miss}})^2 + m_T(\tau_2, E_{\text{T}}^{\text{miss}})^2}$$

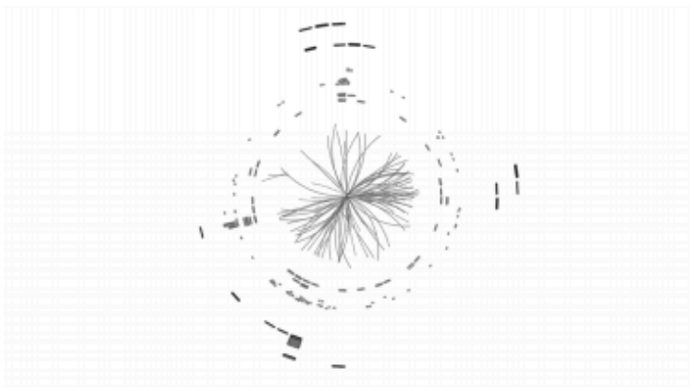
- Used in the Had-Had channel only offers better separation from Multi-jet

Embedding technique

- Selection on $Z \rightarrow \mu\mu$ events: two isolated muons with $p_T > 25$ GeV, with common primary vertex and $m_{\mu\mu} > 40$ GeV
- Muons replaced by taus at truth level: $p(\tau) = \sqrt{(E(\tau) - m_\tau)}$
- Production of simulated $Z \rightarrow \tau\tau$ events: pure τ decay with TAUOLA and PHOTOS (no UE). Truth filter applied. Processed by full ATLAS detector simulation if $p_T(e/\mu/\tau) > 15$ GeV
- Muon tracks removed from data events: $Z \rightarrow \mu\mu$ simulated with initial kinematics. Simulated calorimeter energy subtracted at cell level. Merge $Z \rightarrow \tau\tau$ event.



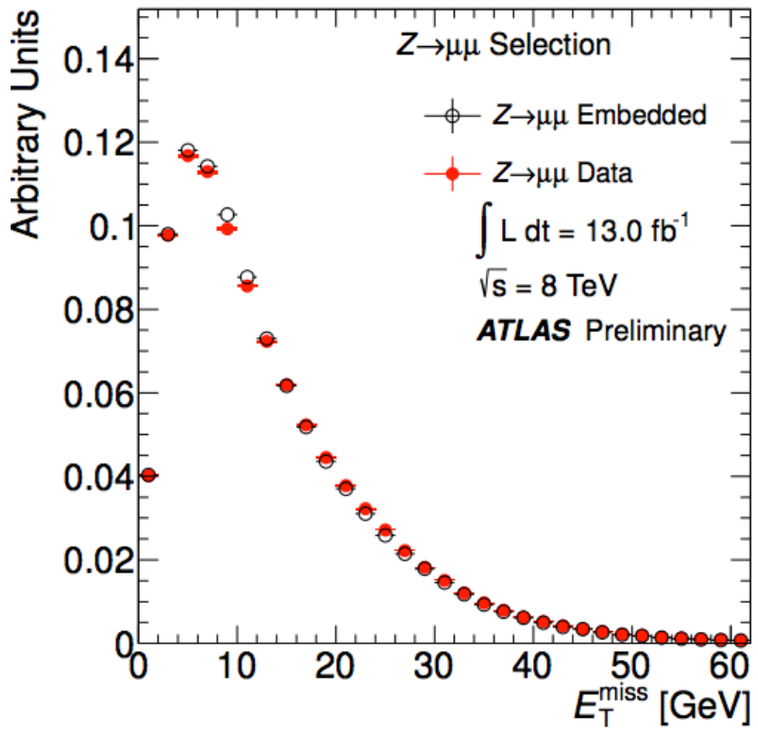
(a) data event (b) *mini event*



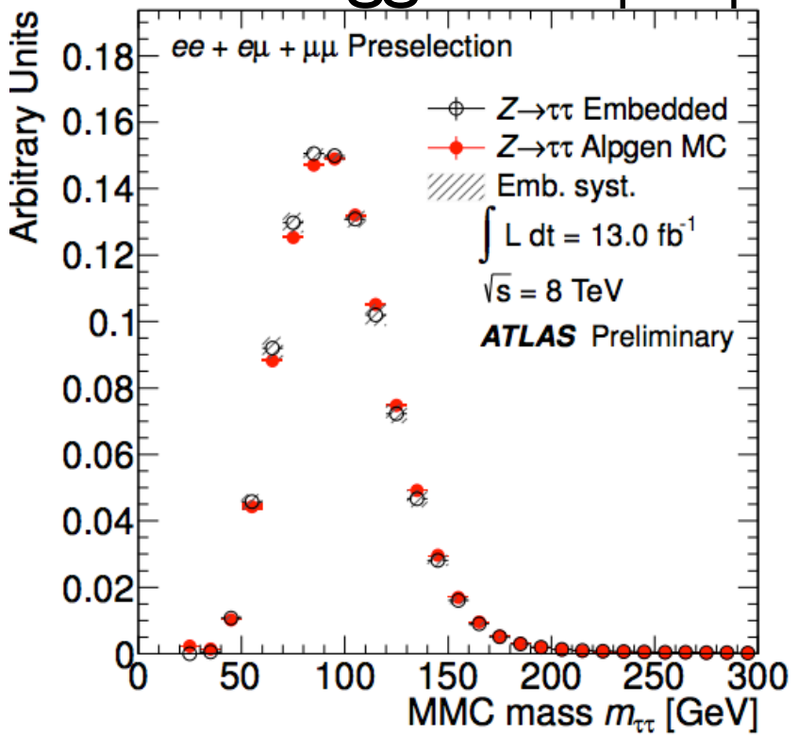
(c) embedded event

Embedding technique (ATLAS-CONF-2012-160)

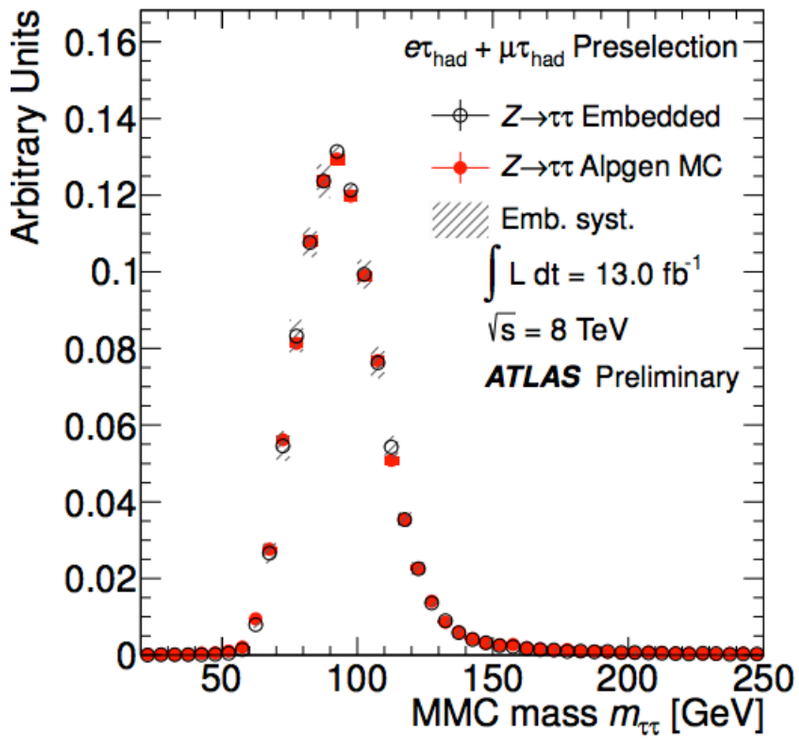
E_T^{miss}



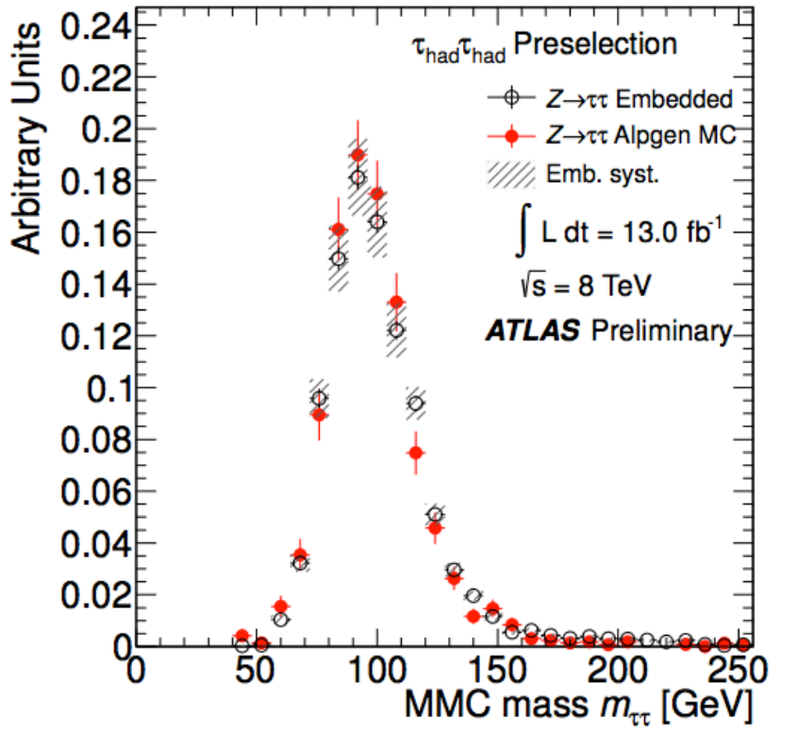
SM Higgs → $\tau_{lep}\tau_{lep}$



SM Higgs → $\tau_{lep}\tau_{had}$



SM Higgs → $\tau_{had}\tau_{had}$

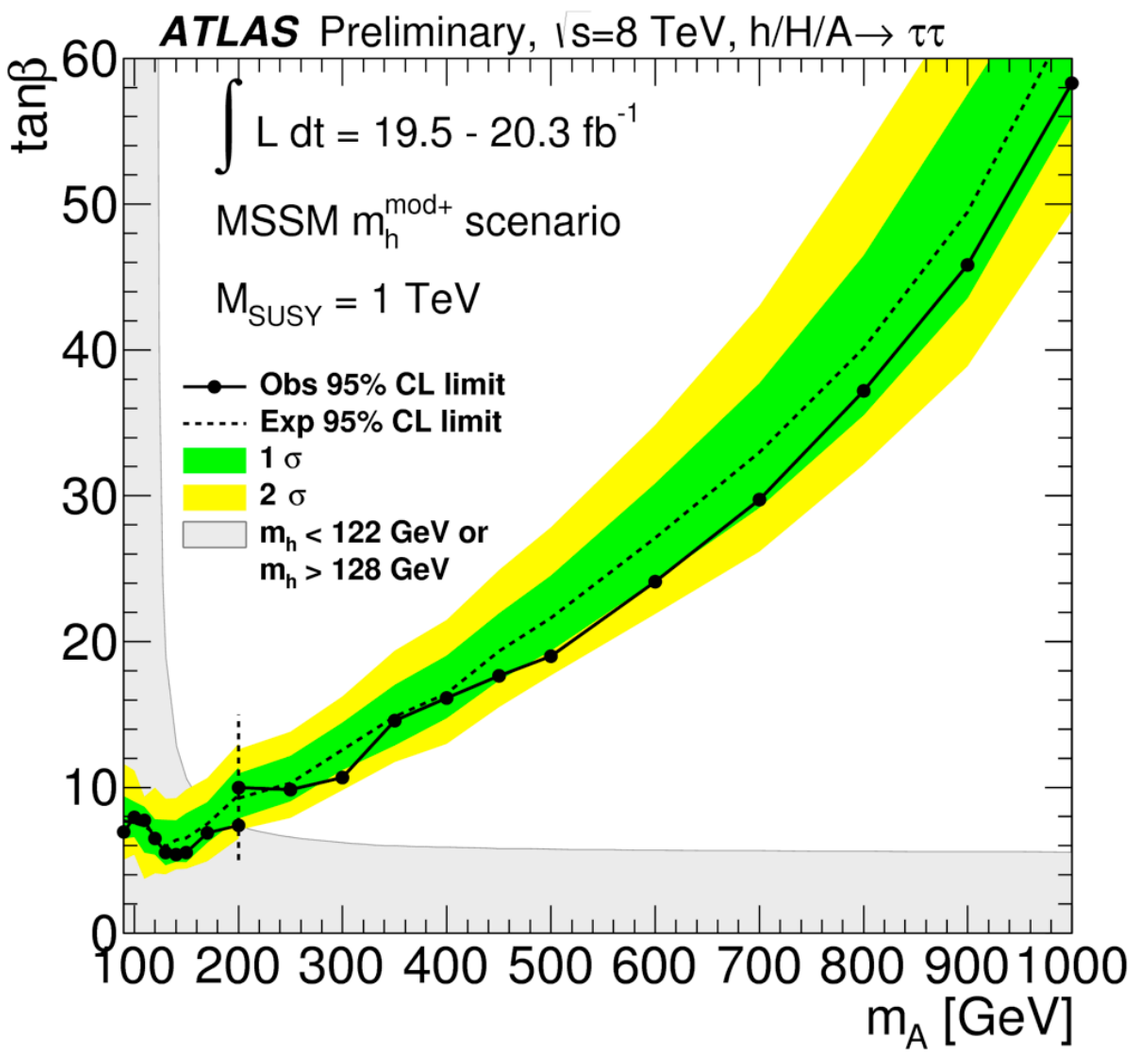


Alternative scenarios arXiv:1302.7033v1 [hep-ph]

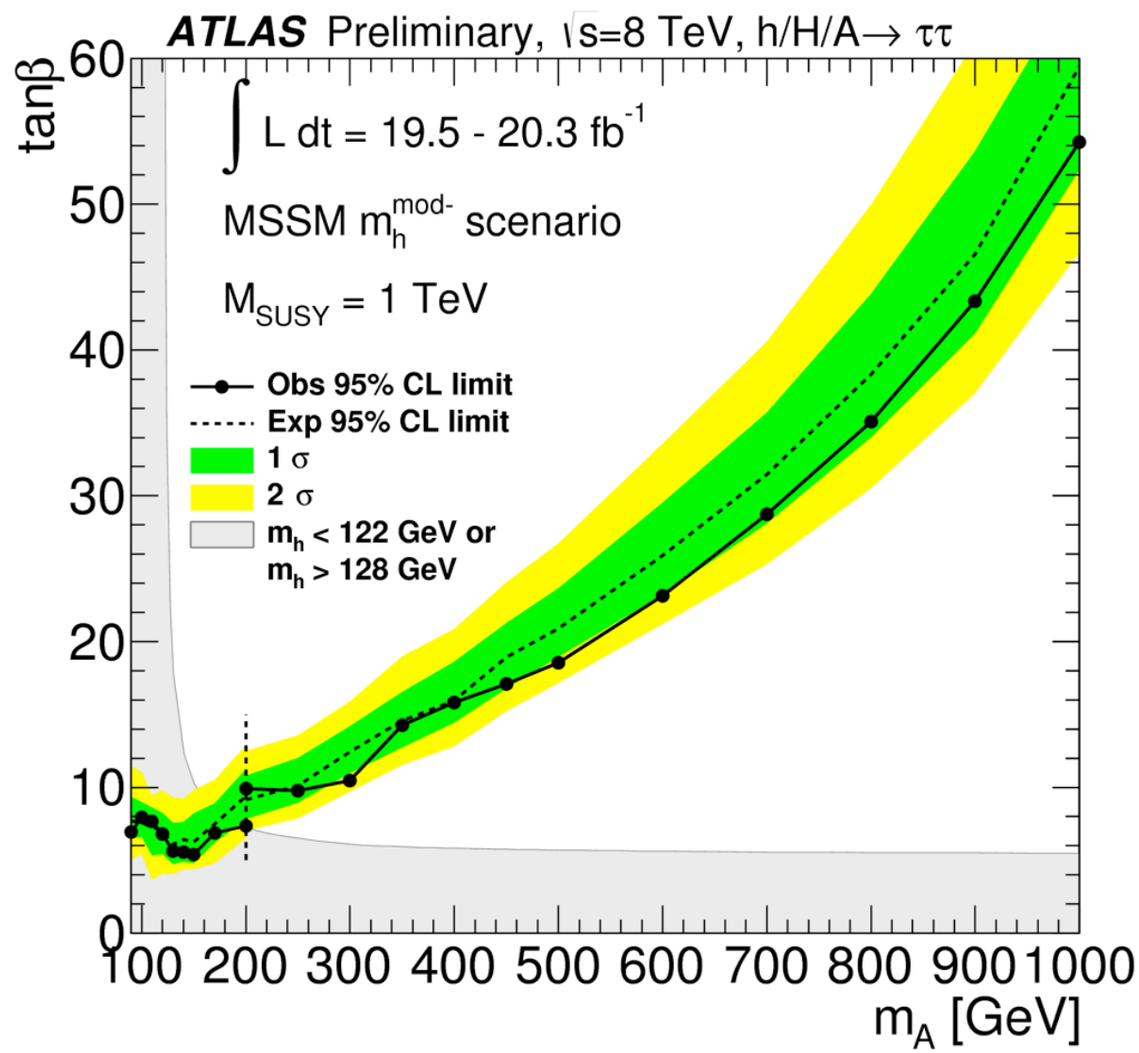
Parameter	m_h^{max}	$m_h^{\text{mod+}}$	$m_h^{\text{mod-}}$	*light stop*	*light stau*	τ*-phobic*	*low-*M_H
m_t	173.2	173.2	173.2	173.2	173.2	173.2	173.2
M_A	varied	varied	varied	varied	varied	varied	110
$\tan\beta$	varied	varied	varied	varied	varied	varied	varied
M_{SUSY}	1000	1000	1000	500	1000	1500	1500
$M_{\tilde{l}_3}$	1000	1000	1000	1000	245 (250)	500	1000
$X_t^{\text{OS}}/M_{\text{SUSY}}$	2.0	1.5	-1.9	2.0	1.6	2.45	2.45
$X_t^{\overline{\text{MS}}}/M_{\text{SUSY}}$	$\sqrt{6}$	1.6	-2.2	2.2	1.7	2.9	2.9
A_t	Given by $A_t = X_t + \mu\cot\beta$						
A_b	$= A_t$	$= A_t$	$= A_t$	$= A_t$	$= A_t$	$= A_t$	$= A_t$
A_τ	$= A_t$	$= A_t$	$= A_t$	$= A_t$	0	$= A_t$	$= A_t$
μ	200	200	200	350	500 (450)	2000	varied
M_1	Fixed by GUT relation to M_2						
M_2	200	200	200	350	200 (400)	200	200
$m_{\tilde{g}}$	1500	1500	1500	1500	1500	1500	1500
$M_{\tilde{q}_{1,2}}$	1500	1500	1500	1500	1500	1500	1500
$M_{\tilde{l}_{1,2}}$	500	500	500	500	500	500	500
$A_{f\neq t,b,\tau}$	0	0	0	0	0	0	0

Alternative scenarios (I)

m_h^{mod+}

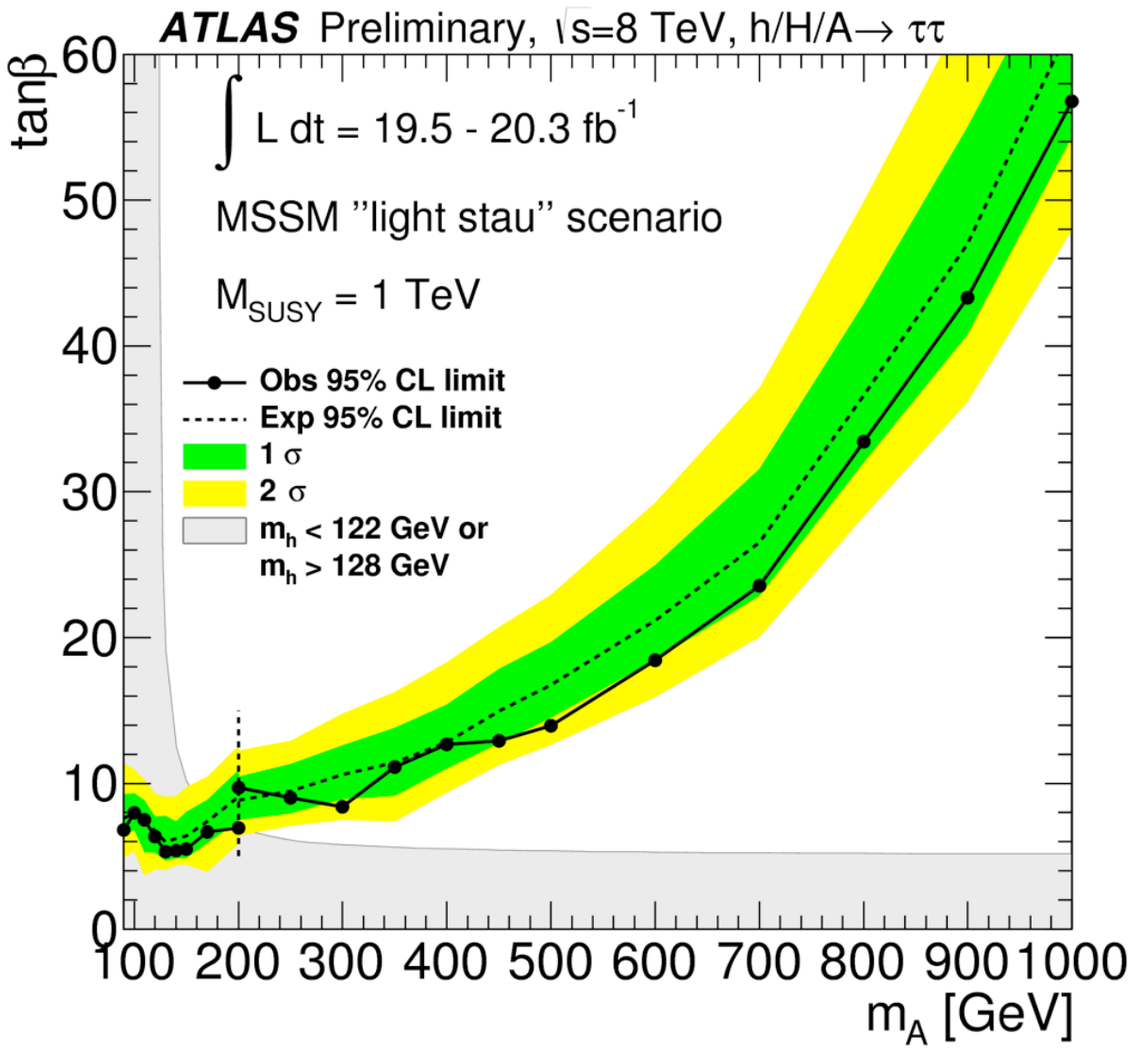


m_h^{mod-}

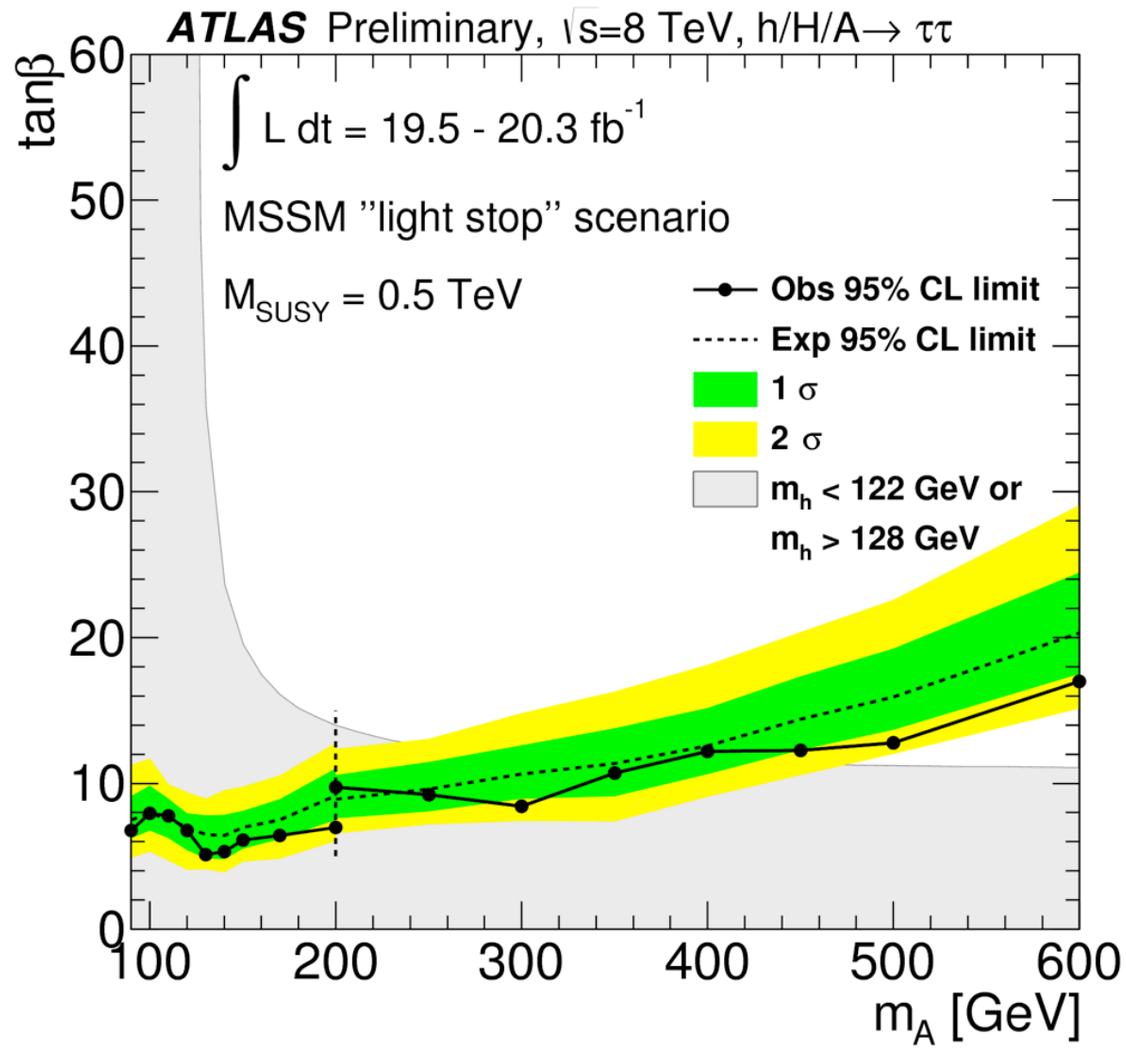


Alternative scenarios (II)

light-stau

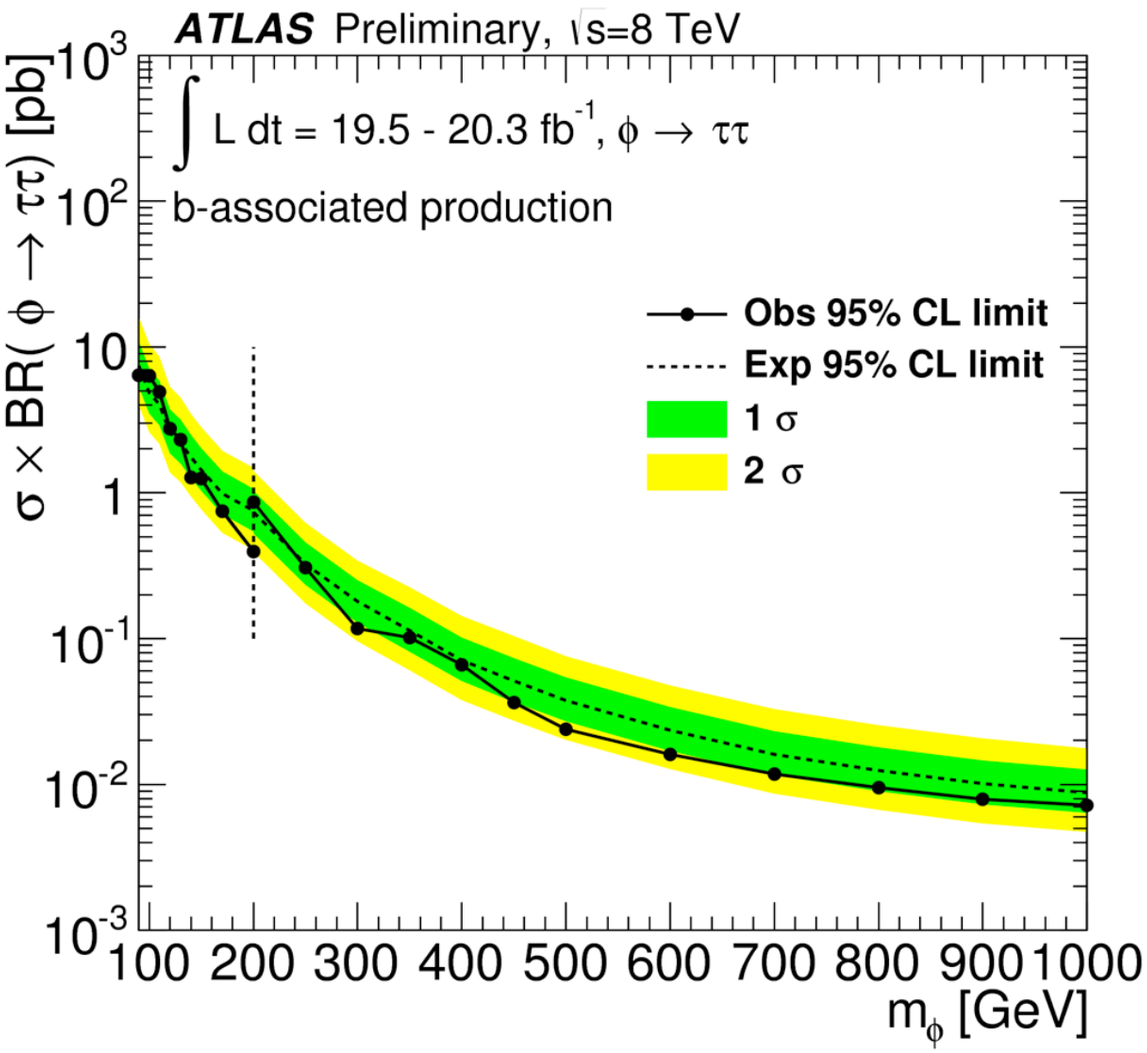


light-stop

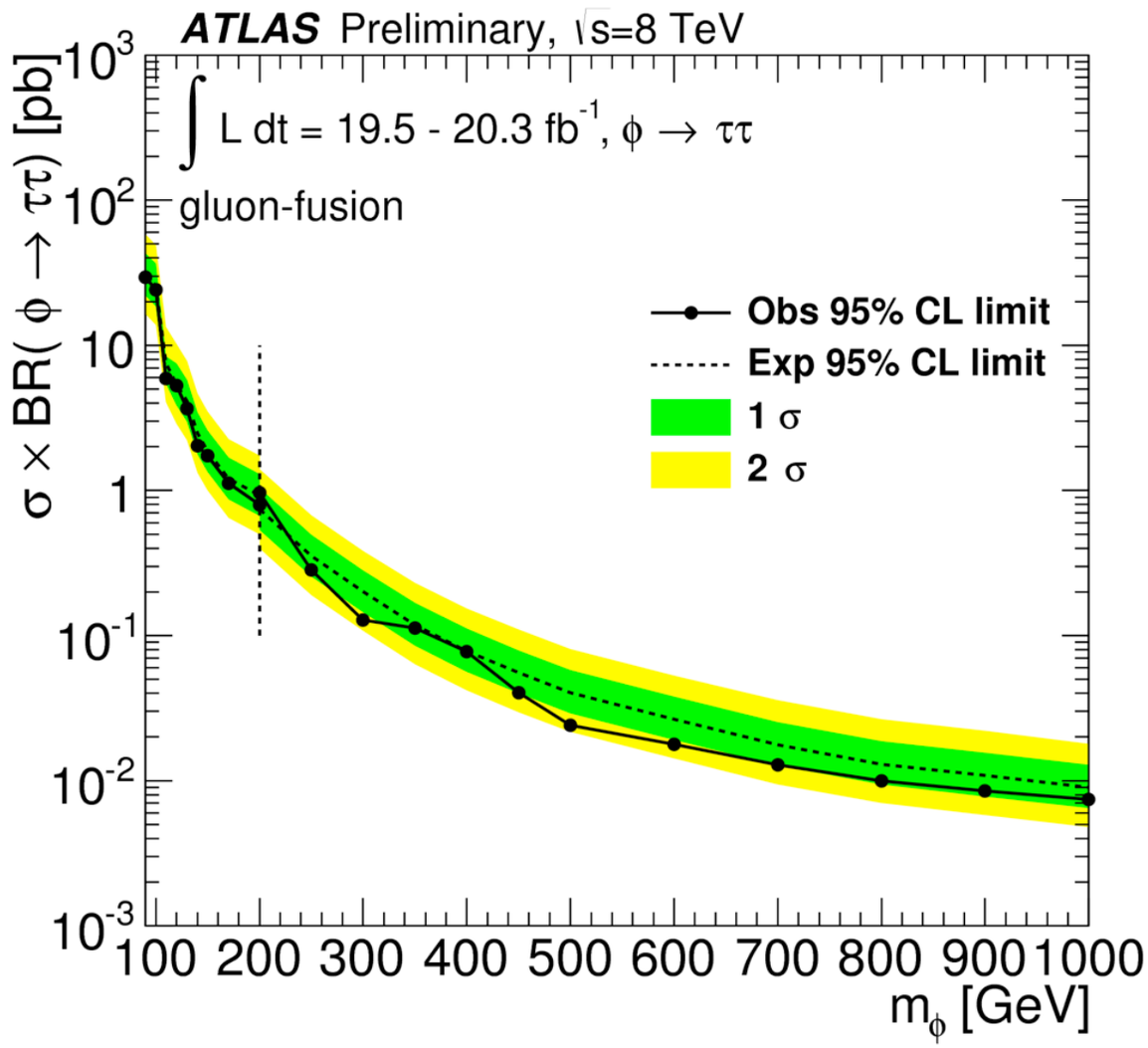


Model independent limits

bb-associated

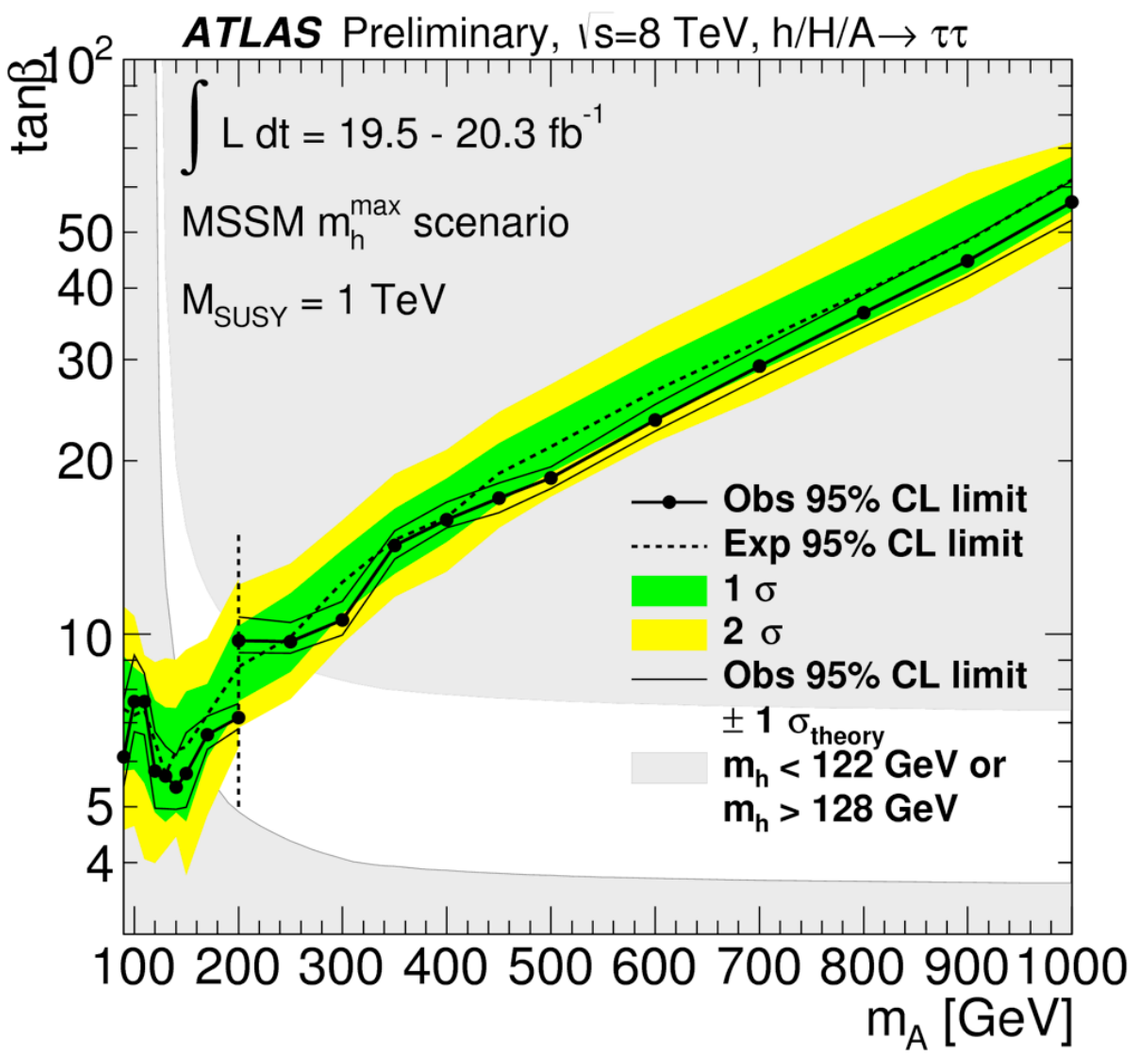


gg-fusion



ATLAS vs CMS

ATLAS-CONF-2014-049



CMS-PAS-HIG-13-021