New CMS Results on Higgs in ττ, ZZ Modes

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LHC Lunch

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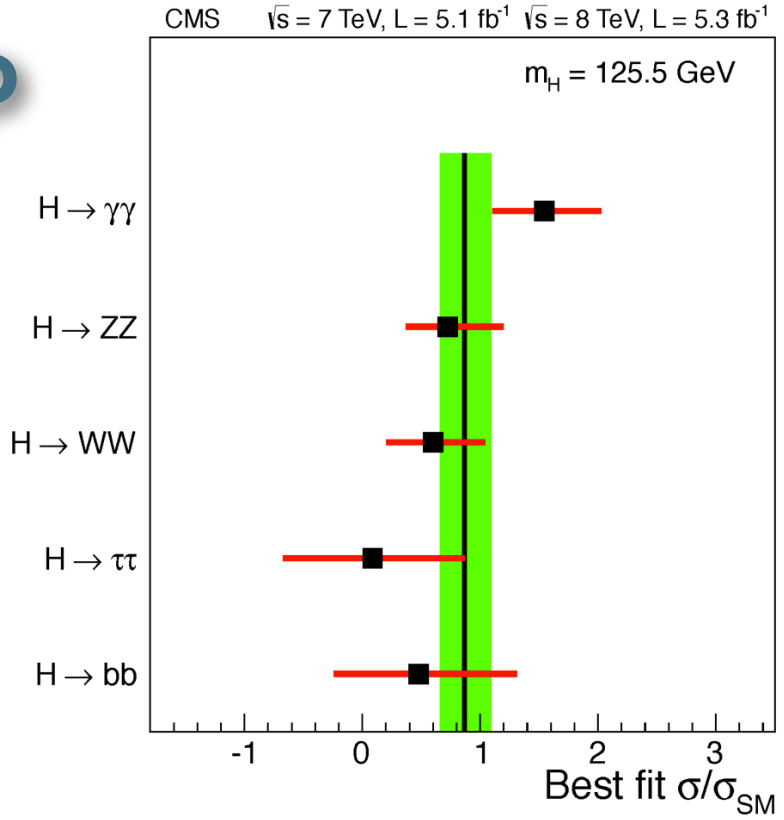
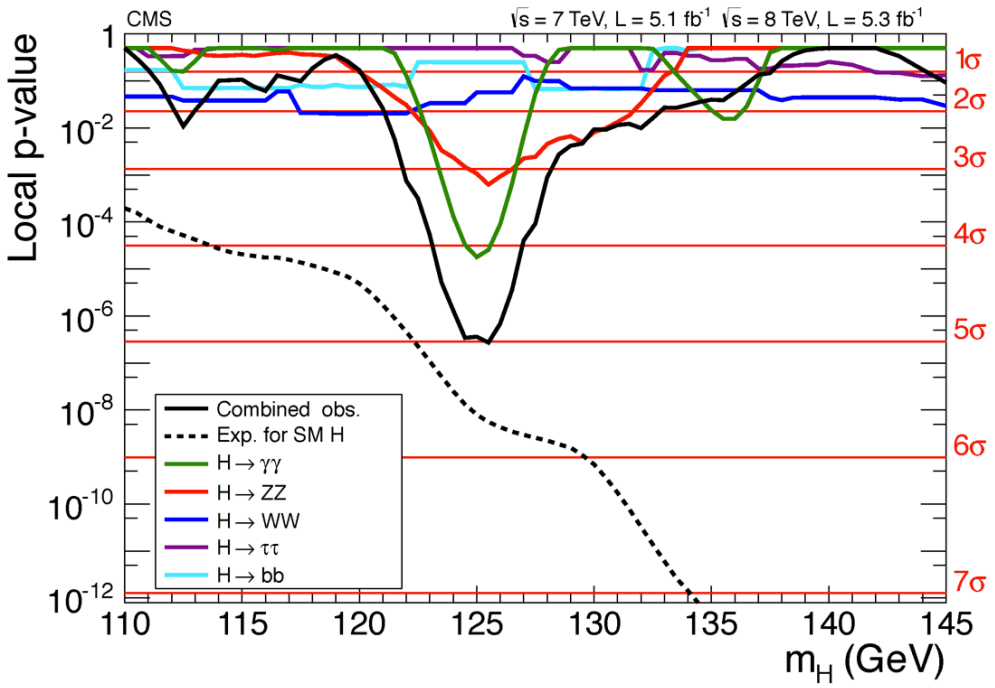
Status as of ICHEP

- Discovery of resonance at 125 GeV dominated by γγ, ZZ, and WW
- γγ mode was high
- tau and b modes were low
- much speculation!
- now showing results based on 17 fb^{-1}
- will collect > 20 fb^{-1} by the end of the year





Strategy for SM/MSSM H → ττ

- five final states:

  eτ μτ eμ ττ μμ

- SM: 3 jet categories

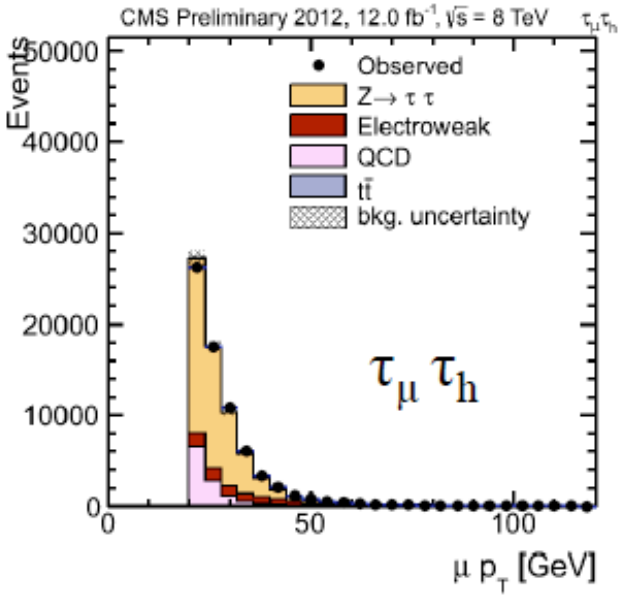
  1 jet/low p_T, 1 jet high p_T, VBF
  (use 0 jet for background constraint)

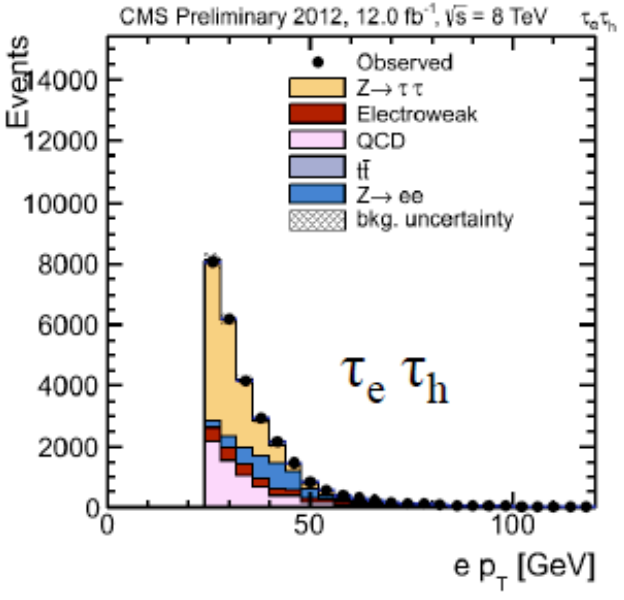
- MSSM: 2 jet categories

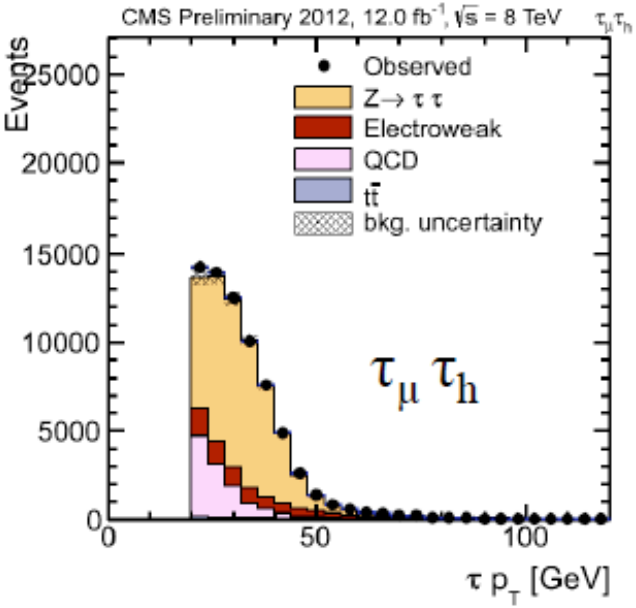
  no b tag, b tag

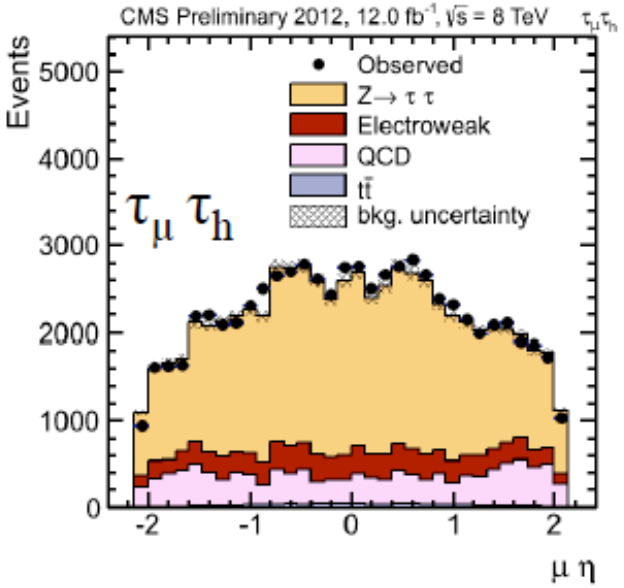
- fit fully reconstructed tau-pair mass distribution for presence of signal

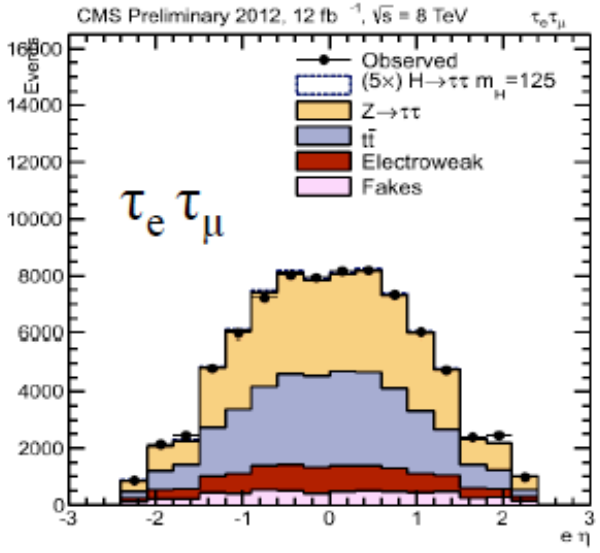
Lepton control plots

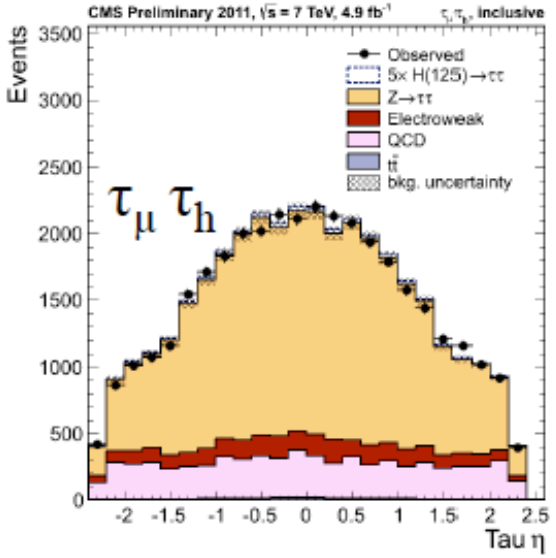






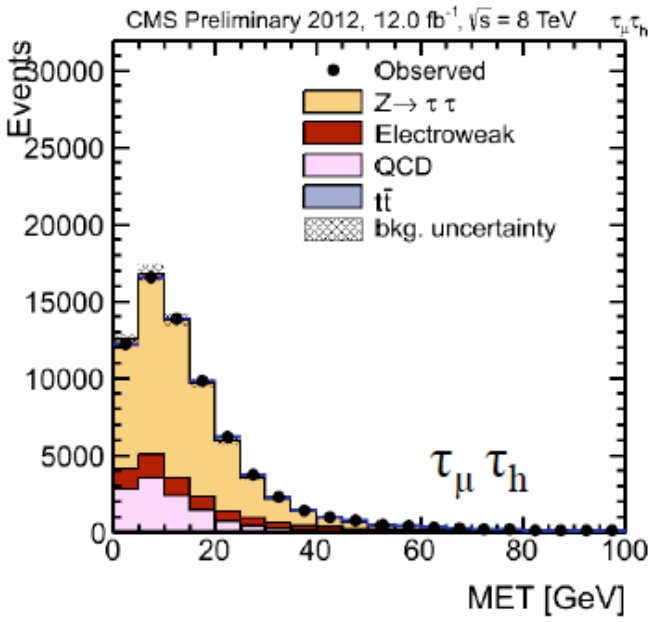


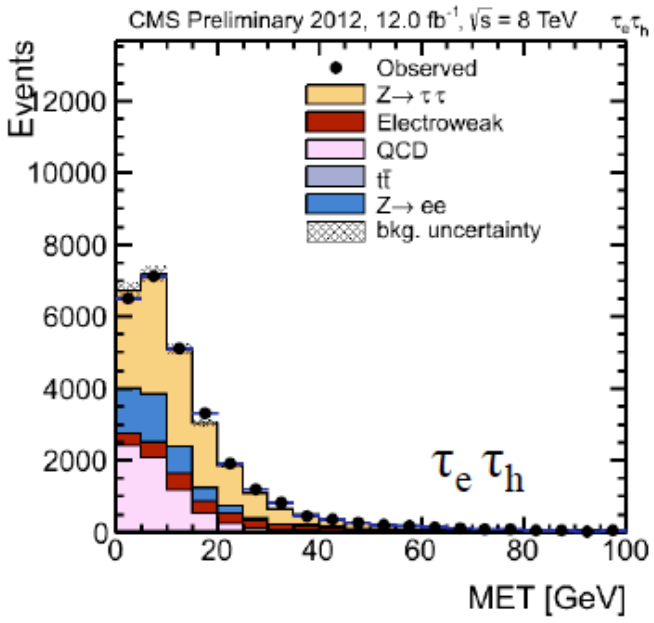


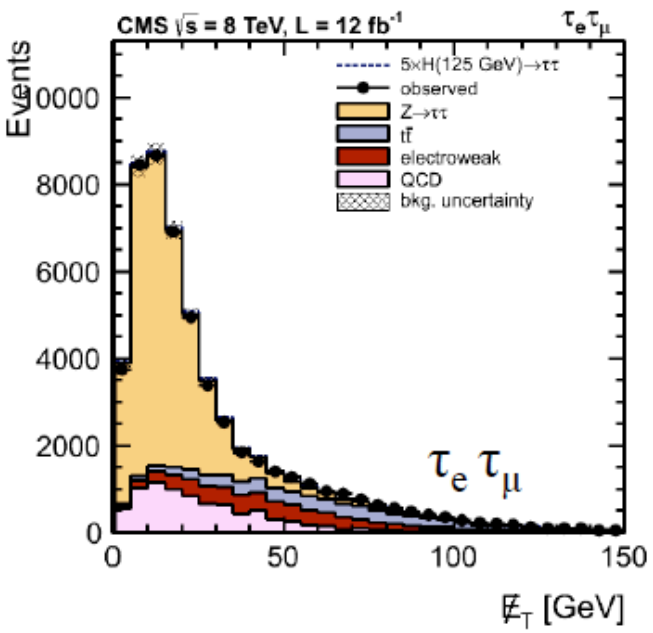


MET

- crucial to removing background (top, W+jets) and in tau pair mass reconstruction
- now use a sophisticated MVA algorithm
- all channels show good control:

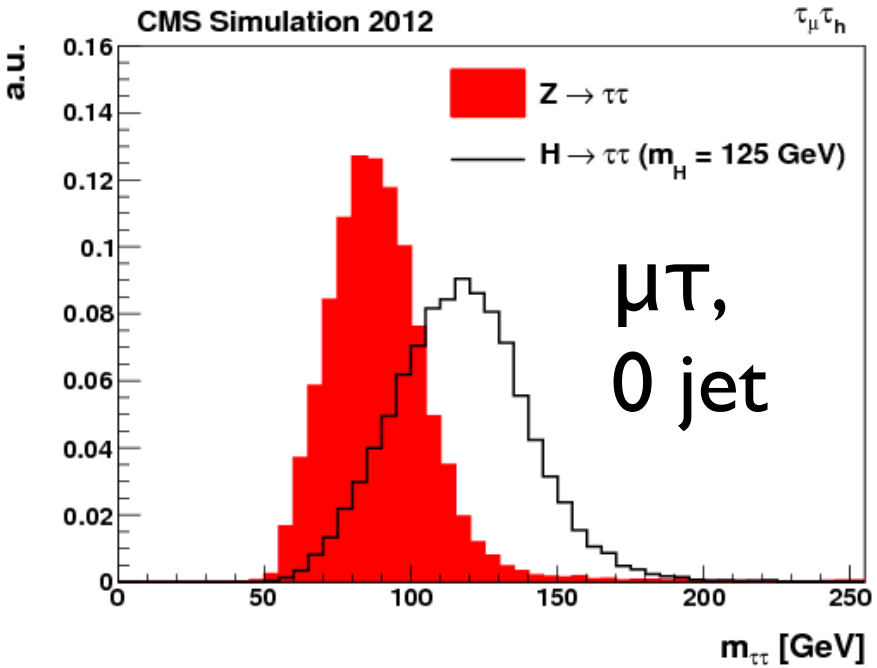






Tau Pair Mass (SVfit)

- Use all available kinematic constraints in likelihood
- Essentially we reconstruct missing neutrino energies
- Resolution ranges from about 18% at the Z mass to 25% at high mass (~300 GeV)
- Mass resolution improves when tau pair boosted: this is the reason for the 1-jet category
- Use of SVfit improves sensitivity from 1.5xSM to 1.0xSM at 125 GeV



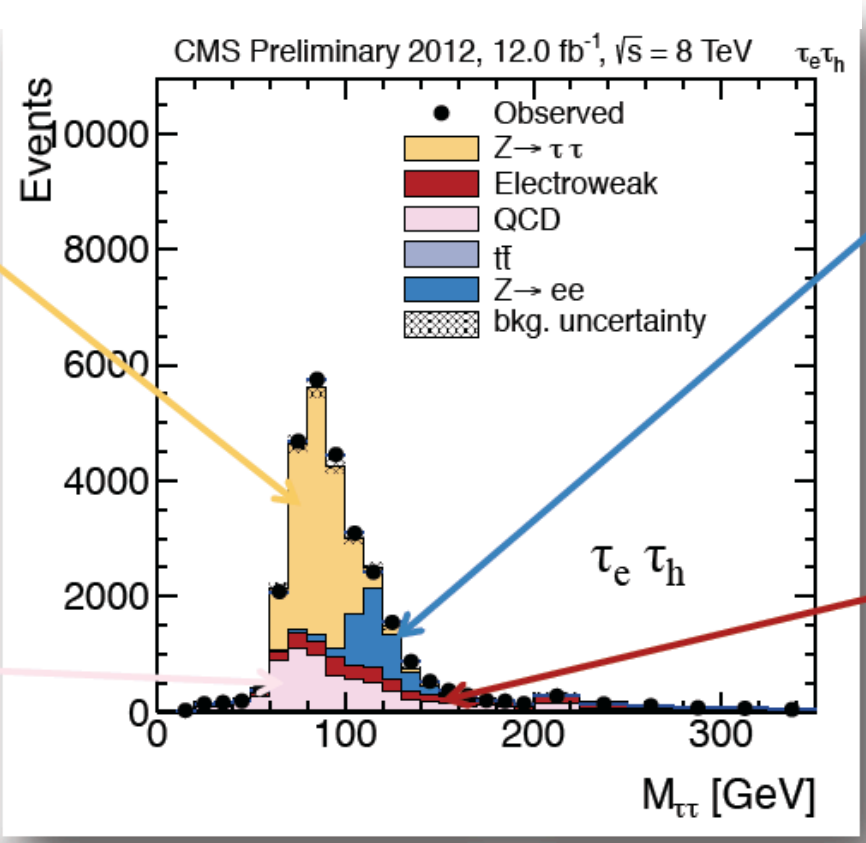
Strategy

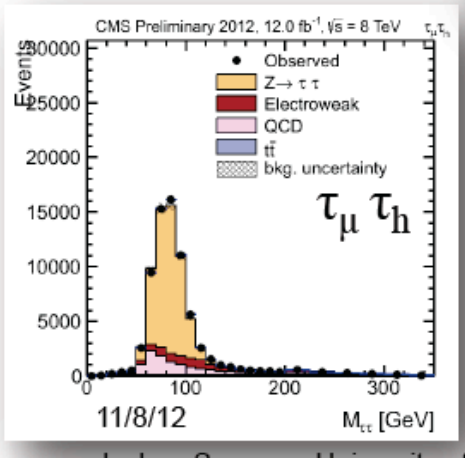
DY→ττ – Efficiency measured using τ embedded μμ events

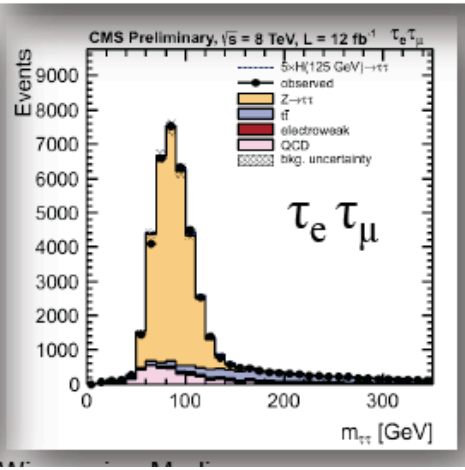
QCD – Estimated from SS data

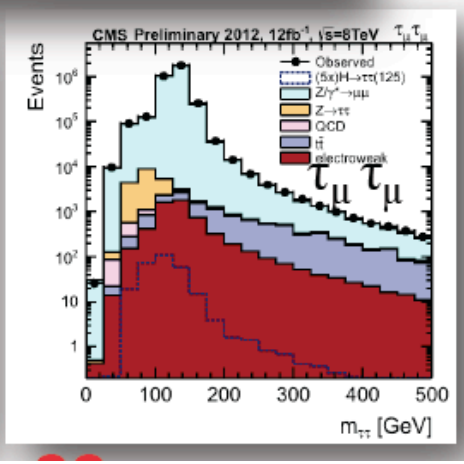
DY→ll – Taken from MC corrected for measured l→τ fake rates

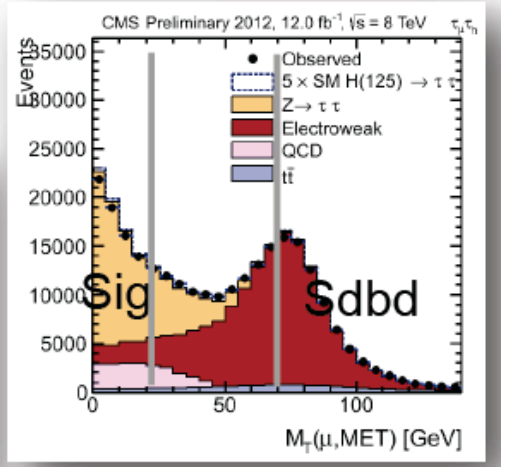
EWK – Mostly W+Jets, measured from high M_T sideband







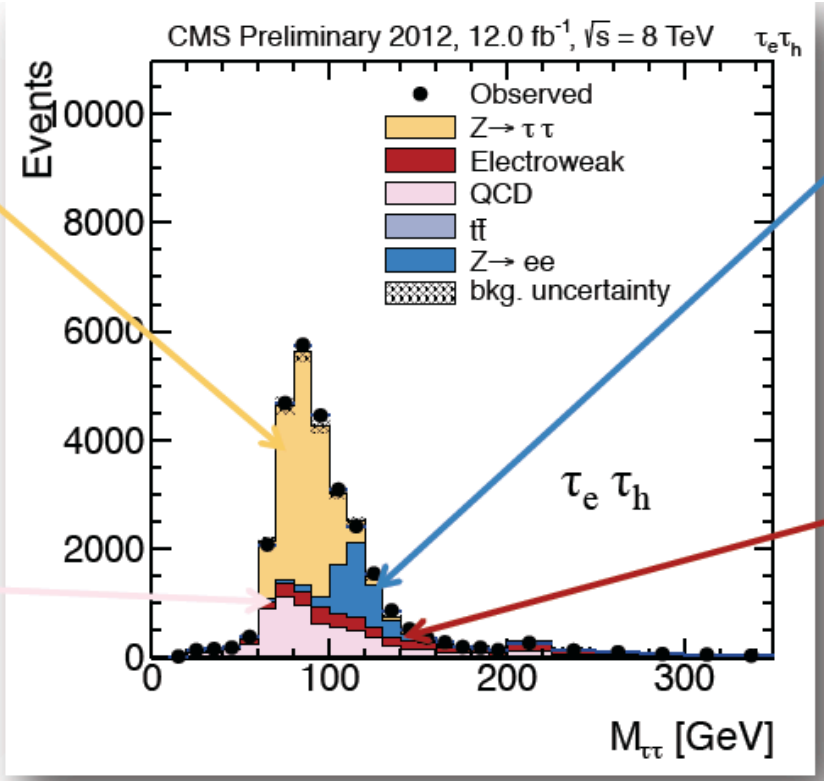




Systematics

DY→ττ – 3-10% inter-category

QCD – 10-30% per category



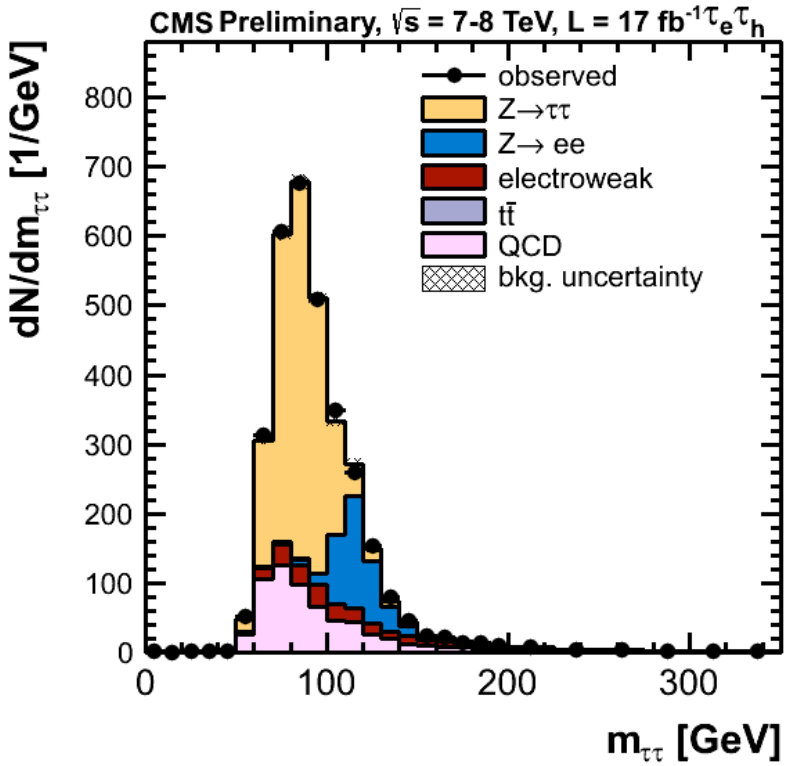
DY→ll – 20-30% per category

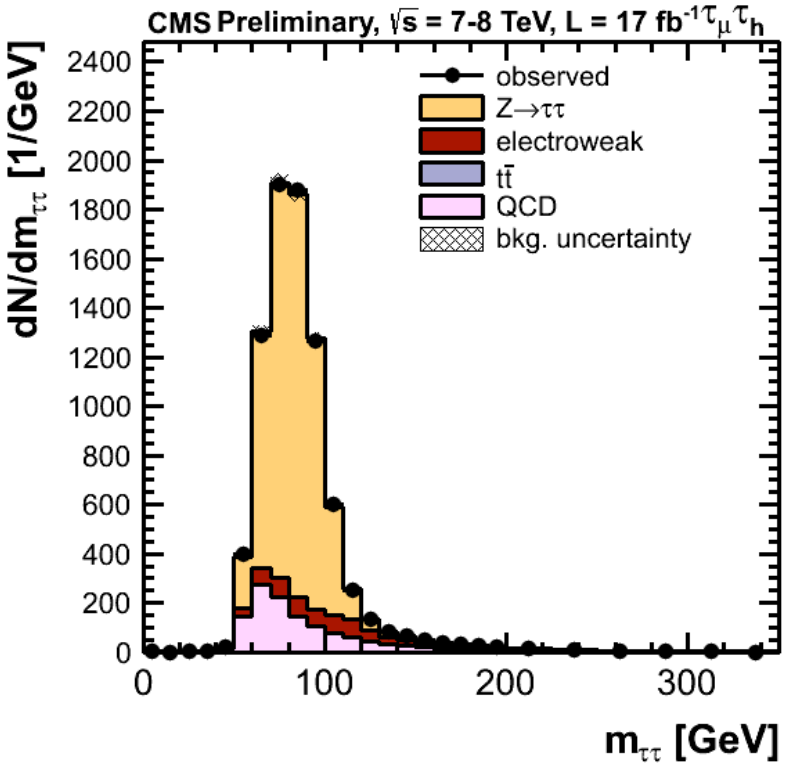
EWK –
20% in 0-Jet,
10% in 1-Jet,
10% (+stat) in VBF

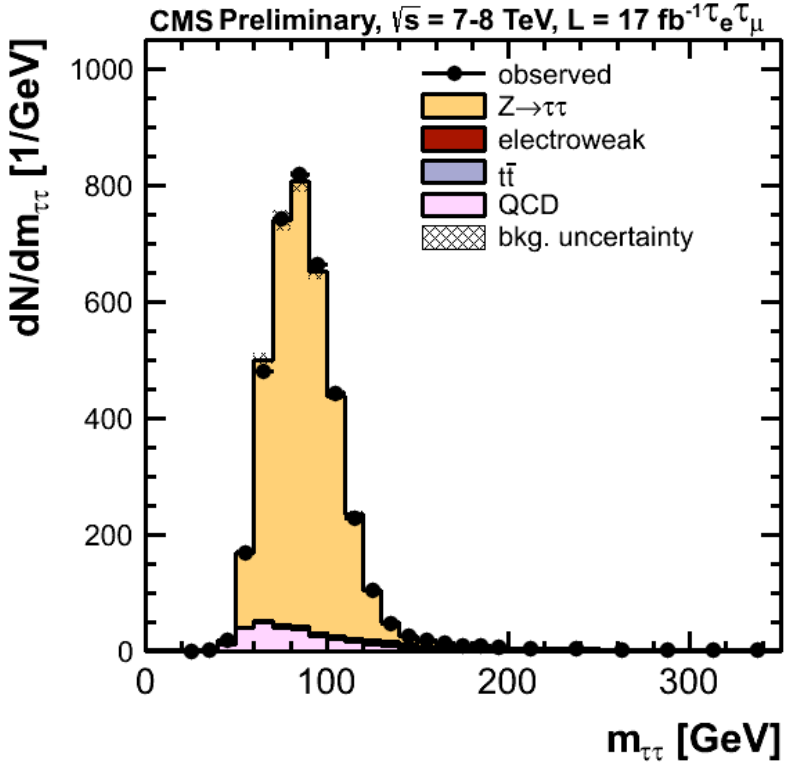
Systematic	Value	Notes
Tau ES (Shape)	3%	On Z→ττ,H; Uncorrelated between channels
Tau ID	8%	Uncorrelated between channels
Tau ID High p_T	3%	For high p_T categories, mixed for VBF
Bin-bin (Shape)	Stat	Applied in low stat categories

biggest!

0 jet


CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τe τh
observed
Z→ττ
Z→ ee
electroweak
tt̄
QCD
bkg. uncertainty
dN/dmττ [1/GeV]
mττ [GeV]


CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τμ τh
observed
Z→ττ
electroweak
tt̄
QCD
bkg. uncertainty
dN/dmττ [1/GeV]
mττ [GeV]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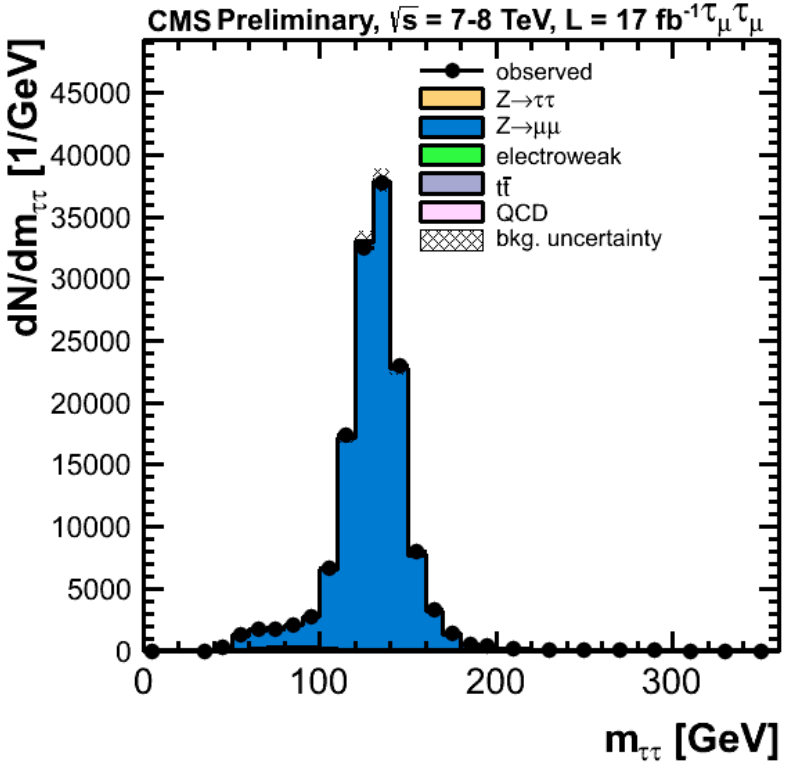
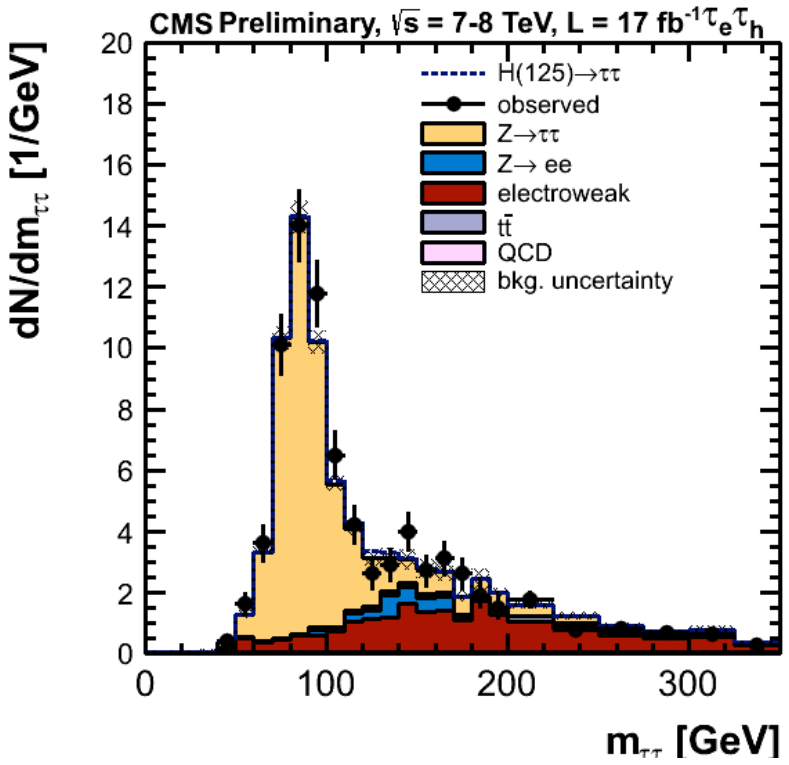
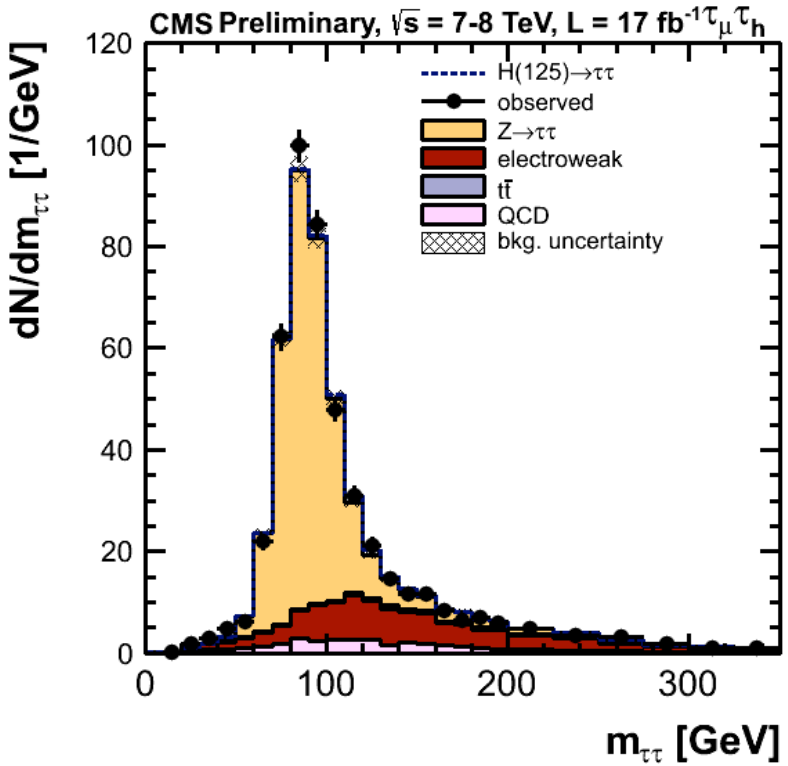

CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τμ τμ
observed
Z→ττ
Z→μμ
electroweak
tt̄
QCD
bkg. uncertainty
dN/dmττ [1/GeV]
mττ [GeV]

1 jet
low p_T


CMS Preliminary, √s = 7-8 TeV, L = 17 fb⁻¹ τe τh
H(125)→ττ
observed
Z→ττ
Z→ ee
electroweak
tt̄
QCD
bkg. uncertainty
dN/dm_ττ [1/GeV]
m_ττ [GeV]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H(125)→ττ
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QCD
bkg. uncertainty
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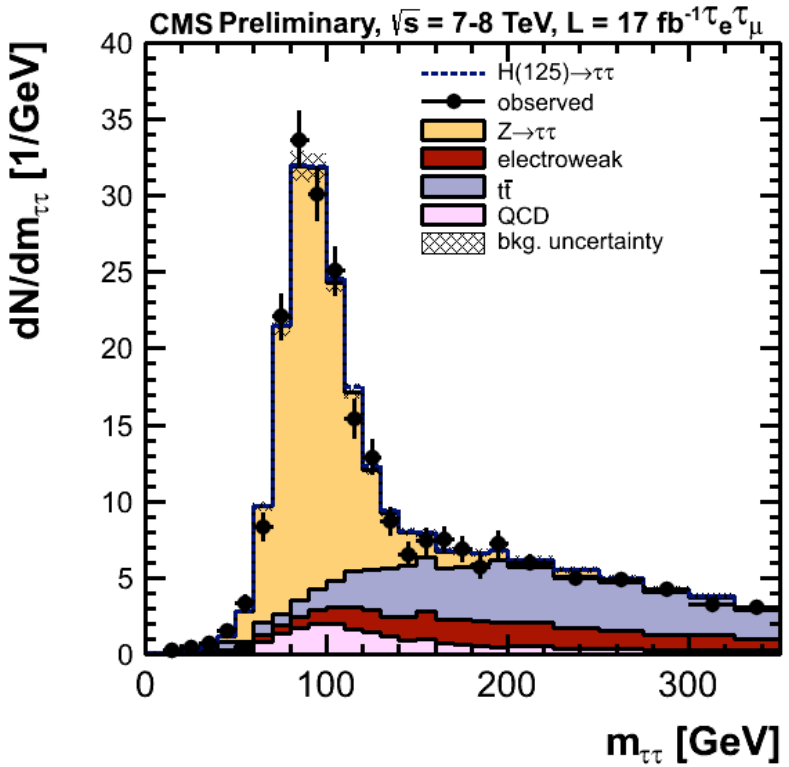
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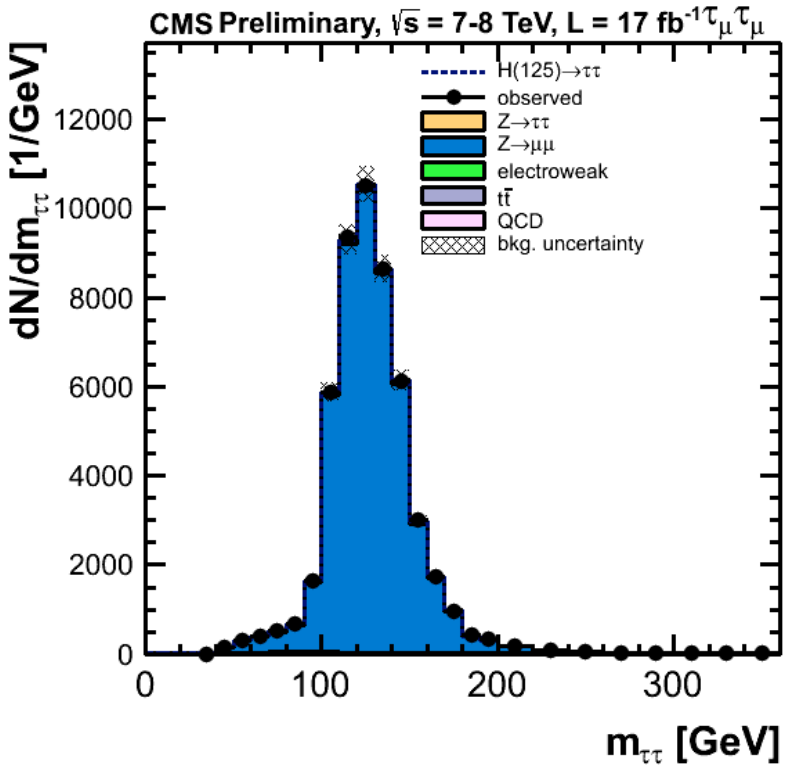
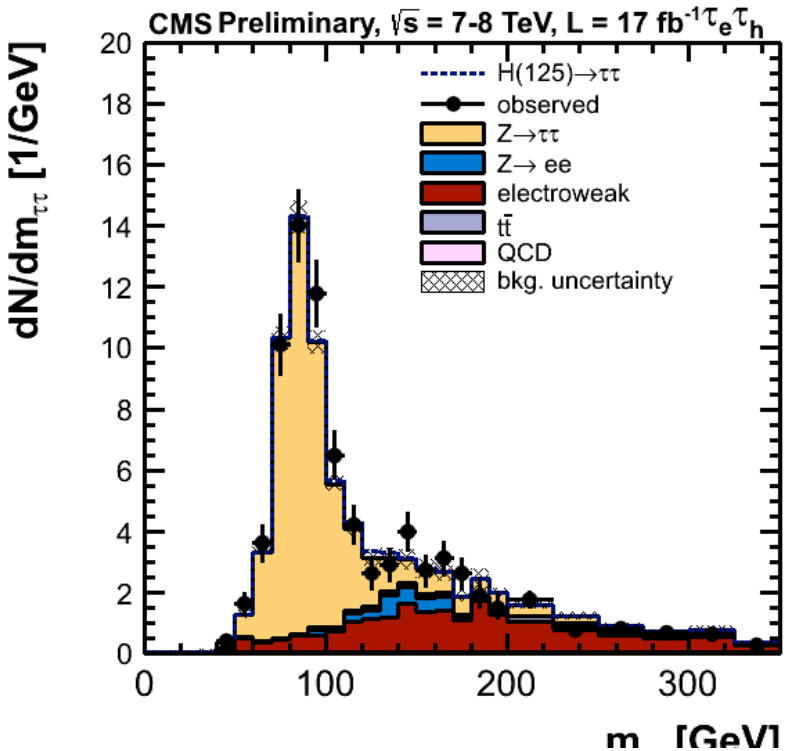

CMS Preliminary, √s = 7-8 TeV, L = 17 fb⁻¹ τμ τμ
H(125)→ττ
observed
Z→ττ
Z→μμ
electroweak
tt̄
QCD
bkg. uncertainty
dN/dm_ττ [1/GeV]
m_ττ [GeV]

1 jet
high p_T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H(125)→ττ
observed
Z→ττ
Z→ ee
electroweak
tt̄
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bkg. uncertainty
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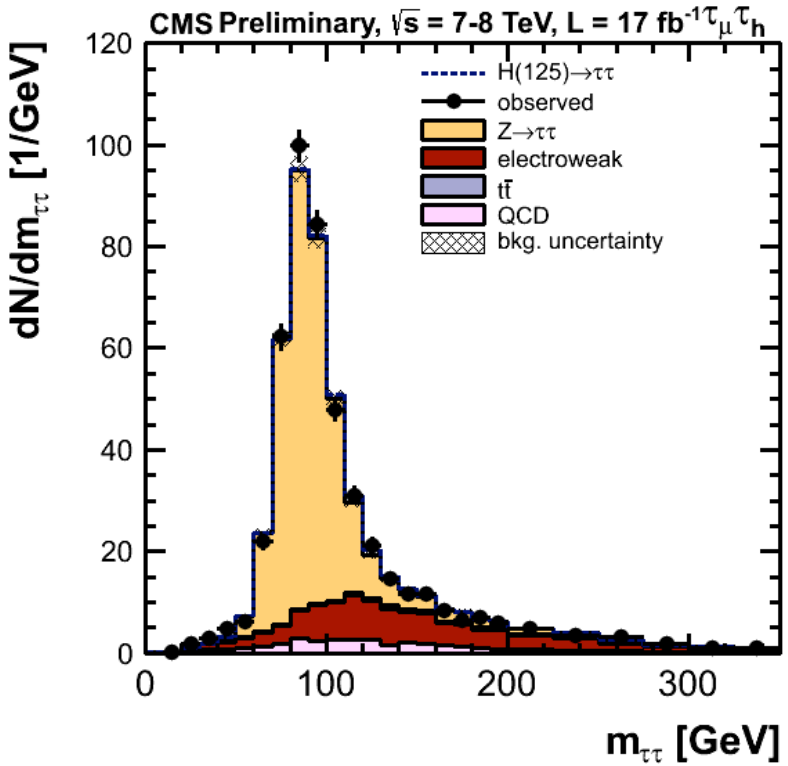
m_ττ [GeV]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H(125)→ττ
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bkg. uncertainty
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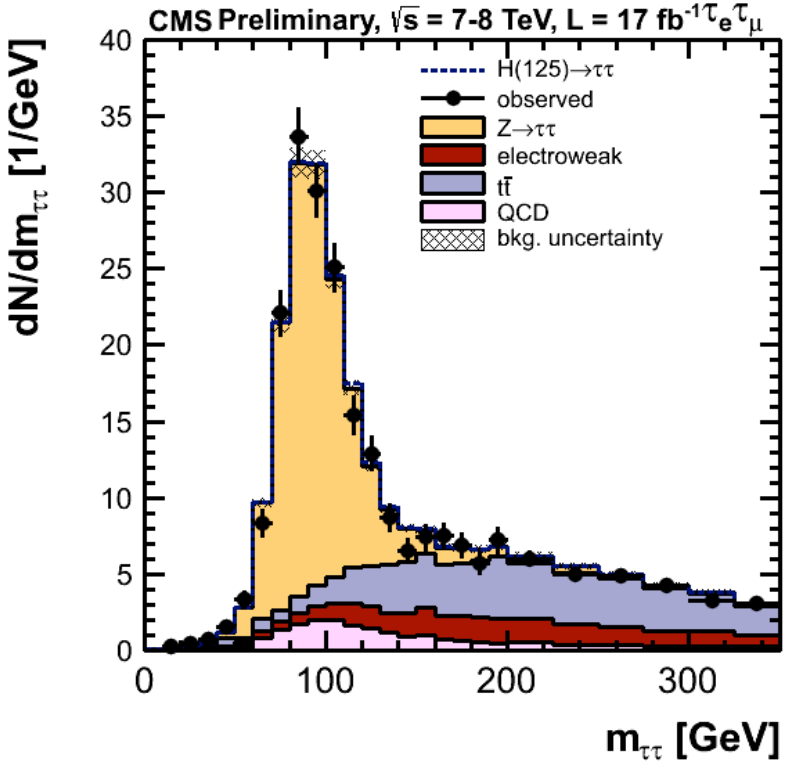
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H(125)→ττ
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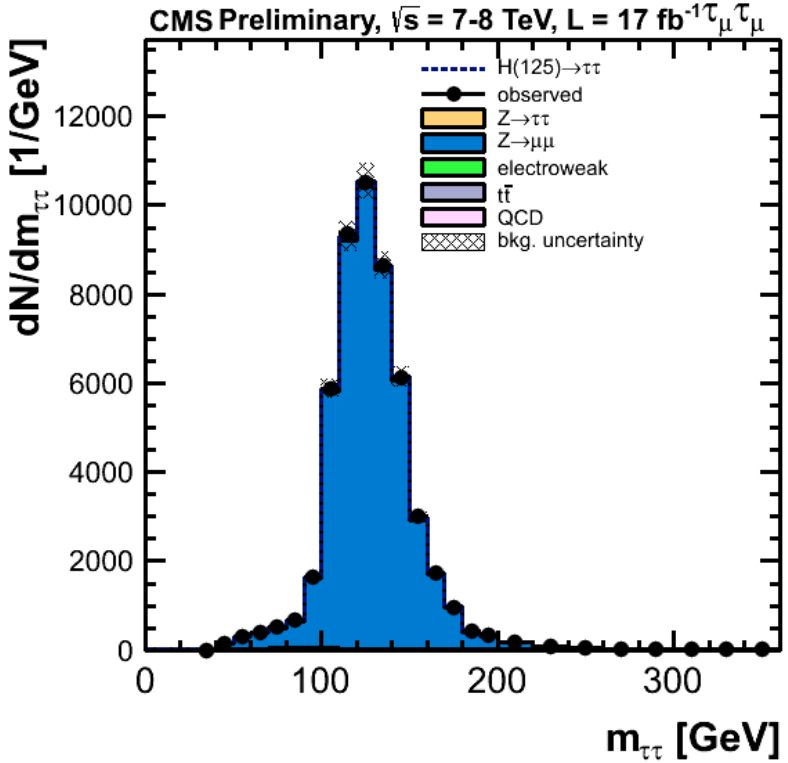
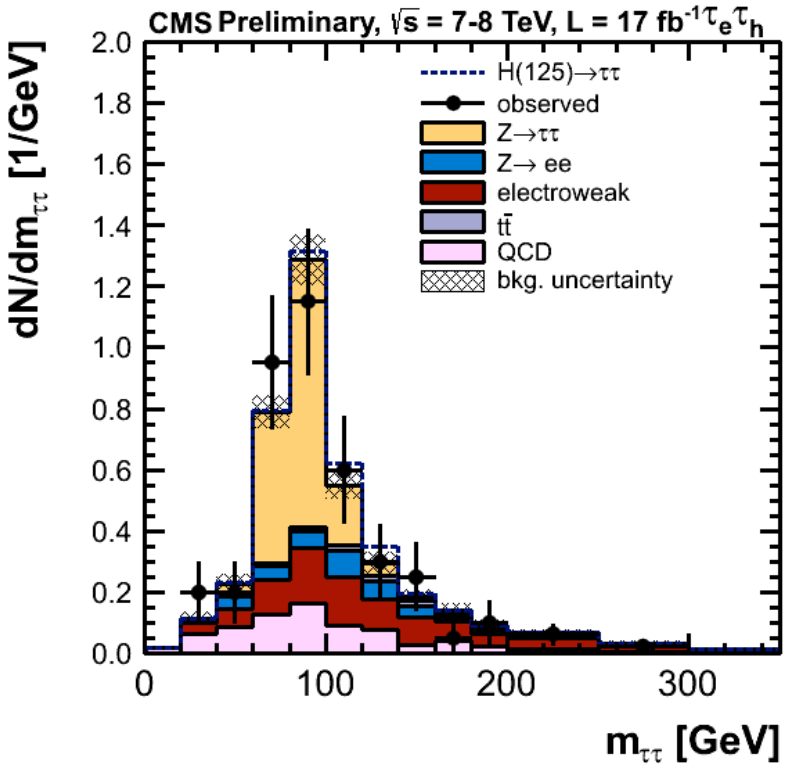
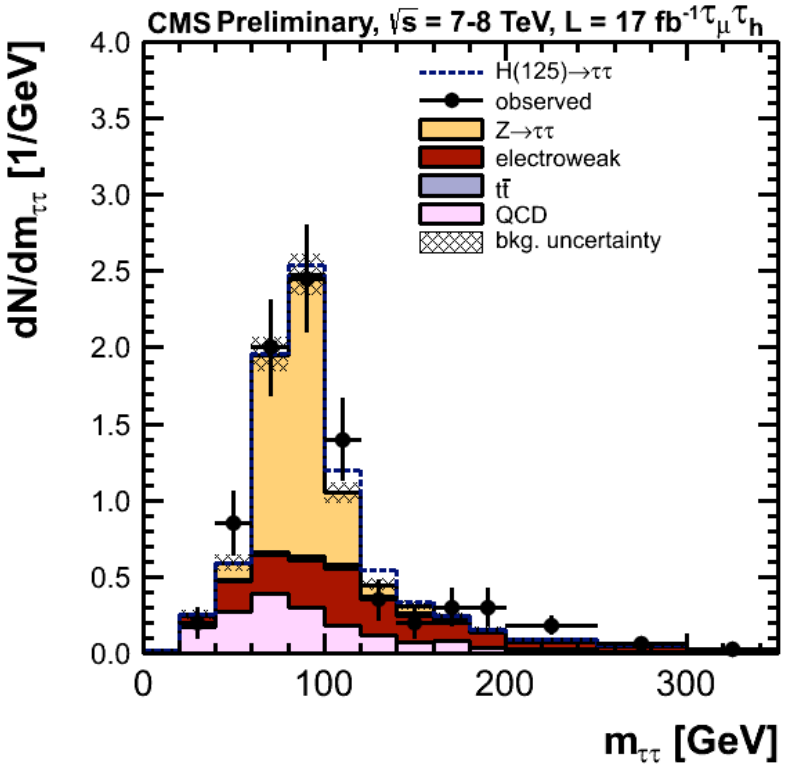

CMS Preliminary, √s = 7-8 TeV, L = 17 fb⁻¹ τμ τμ
H(125)→ττ
observed
Z→ττ
Z→μμ
electroweak
tt̄
QCD
bkg. uncertainty
dN/dm_ττ [1/GeV]
m_ττ [GeV]

VBF


CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τe τh
H(125)→ττ
observed
Z→ττ
Z→ ee
electroweak
tt̄
QCD
bkg. uncertainty
dN/dmττ [1/GeV]
mττ [GeV]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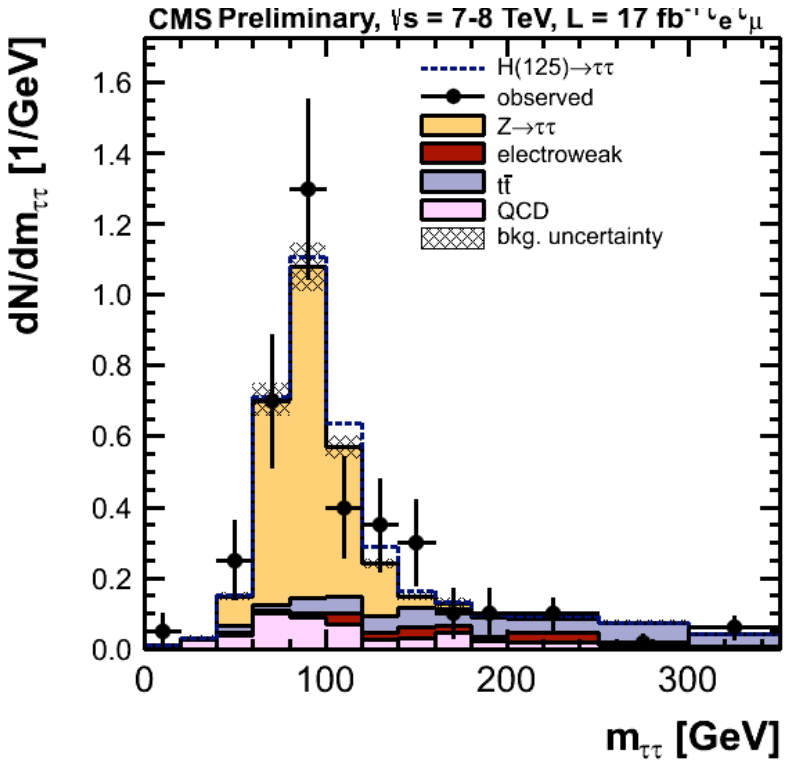
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H(125)→ττ
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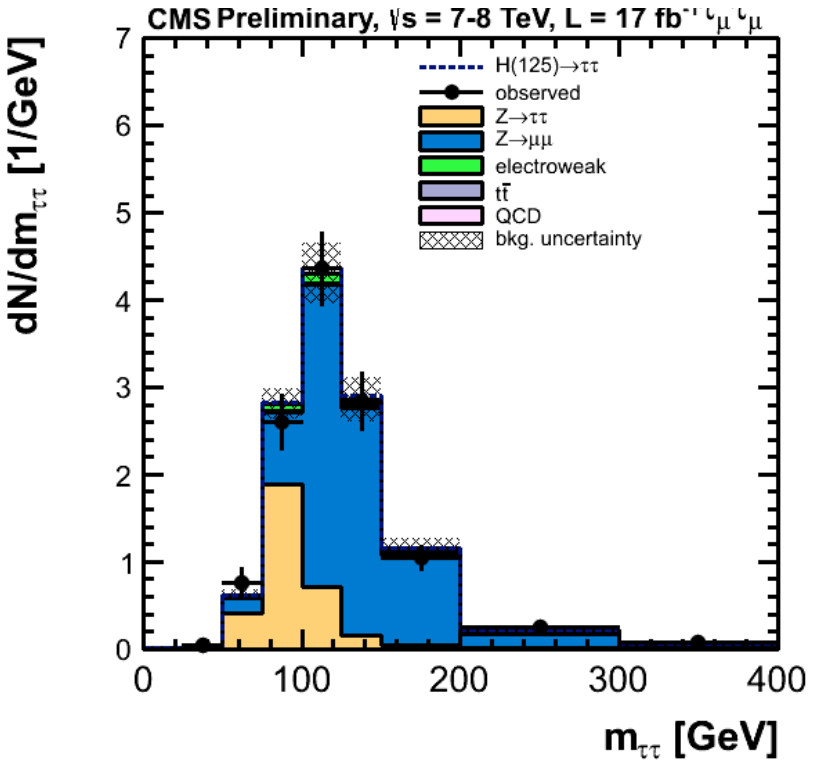
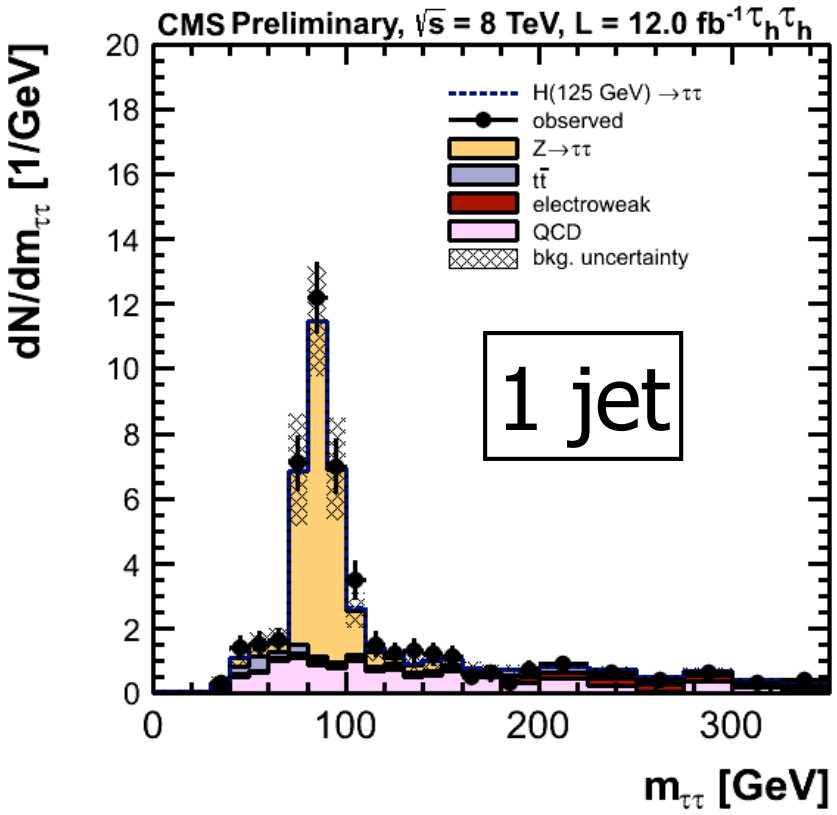
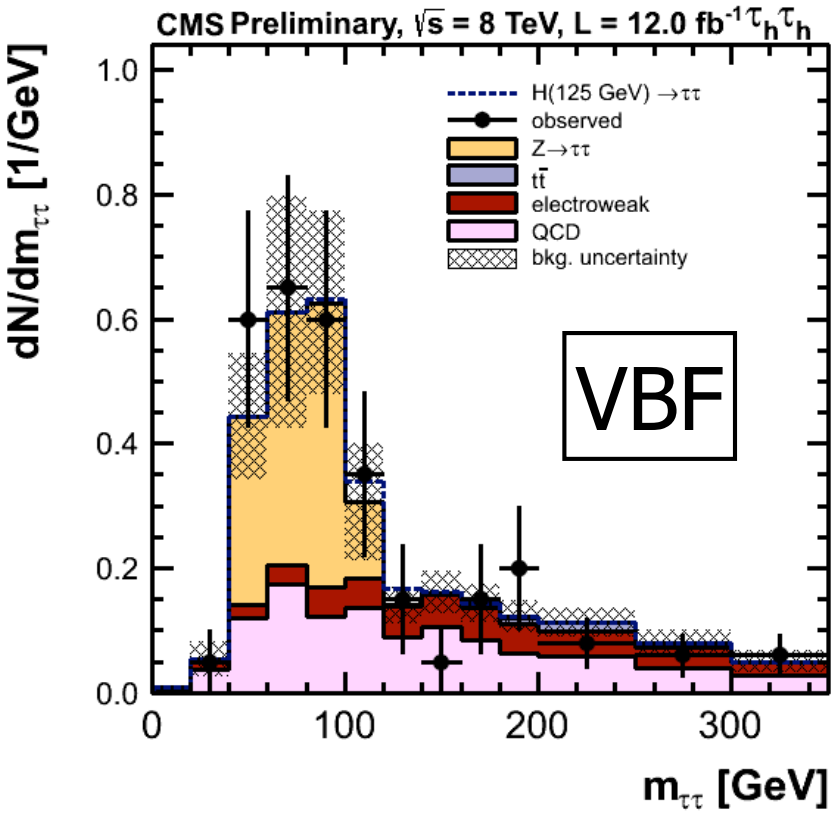
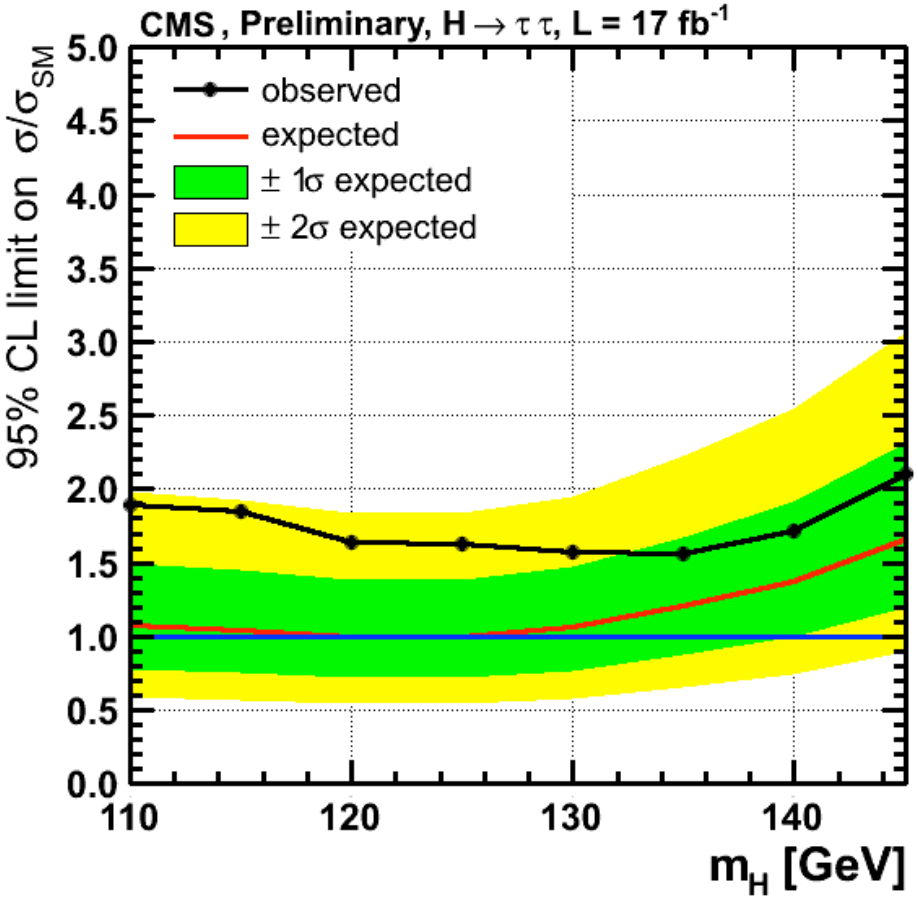

CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τμ τμ
H(125)→ττ
observed
Z→ττ
Z→μμ
electroweak
tt̄
QCD
bkg. uncertainty
dN/dmττ [1/GeV]
mττ [GeV]

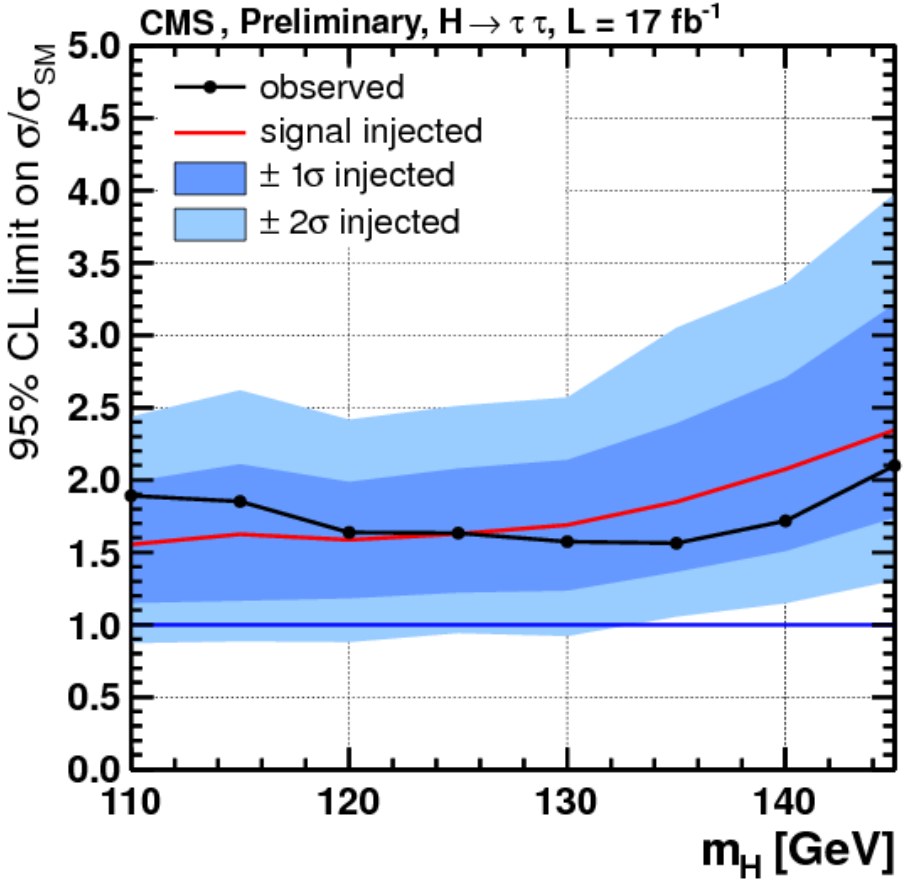
All hadronic (ττ)





Results: σ_{95}/σ_{SM}

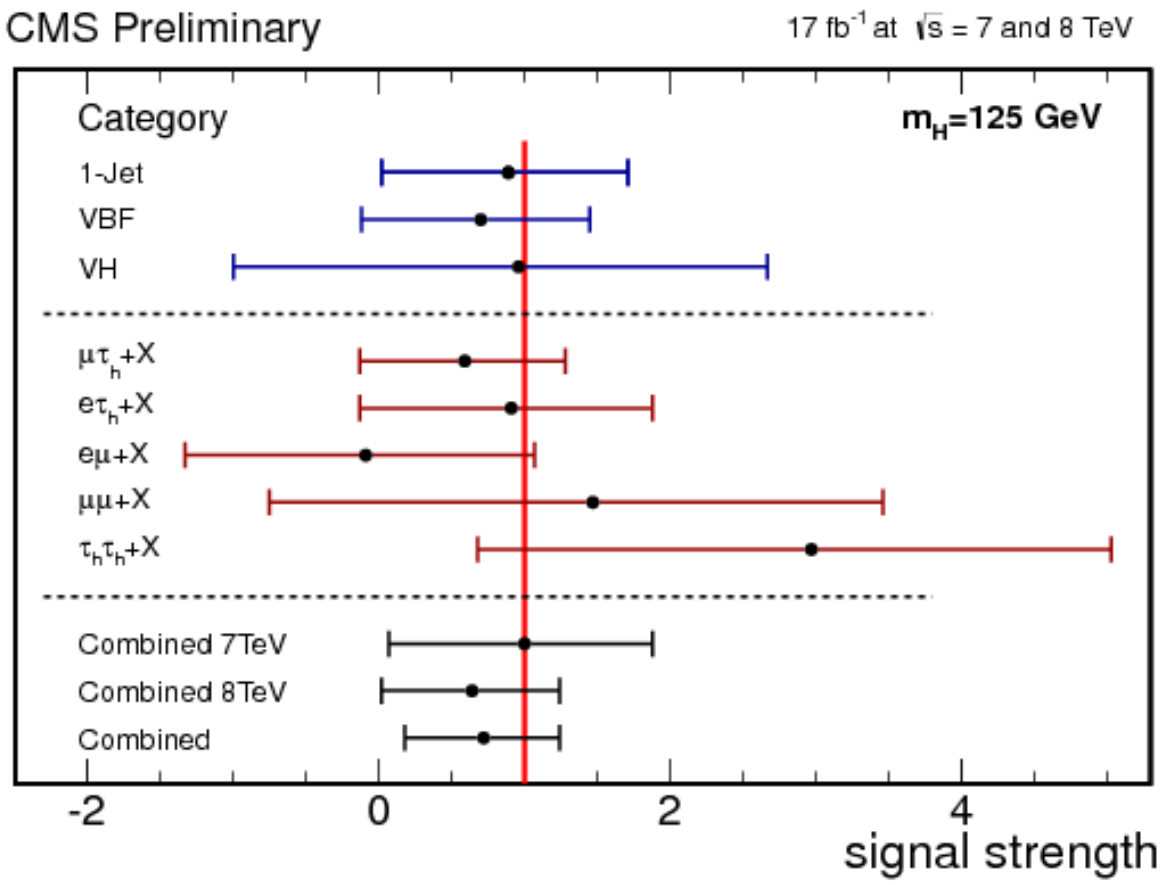




Expected band: no signal

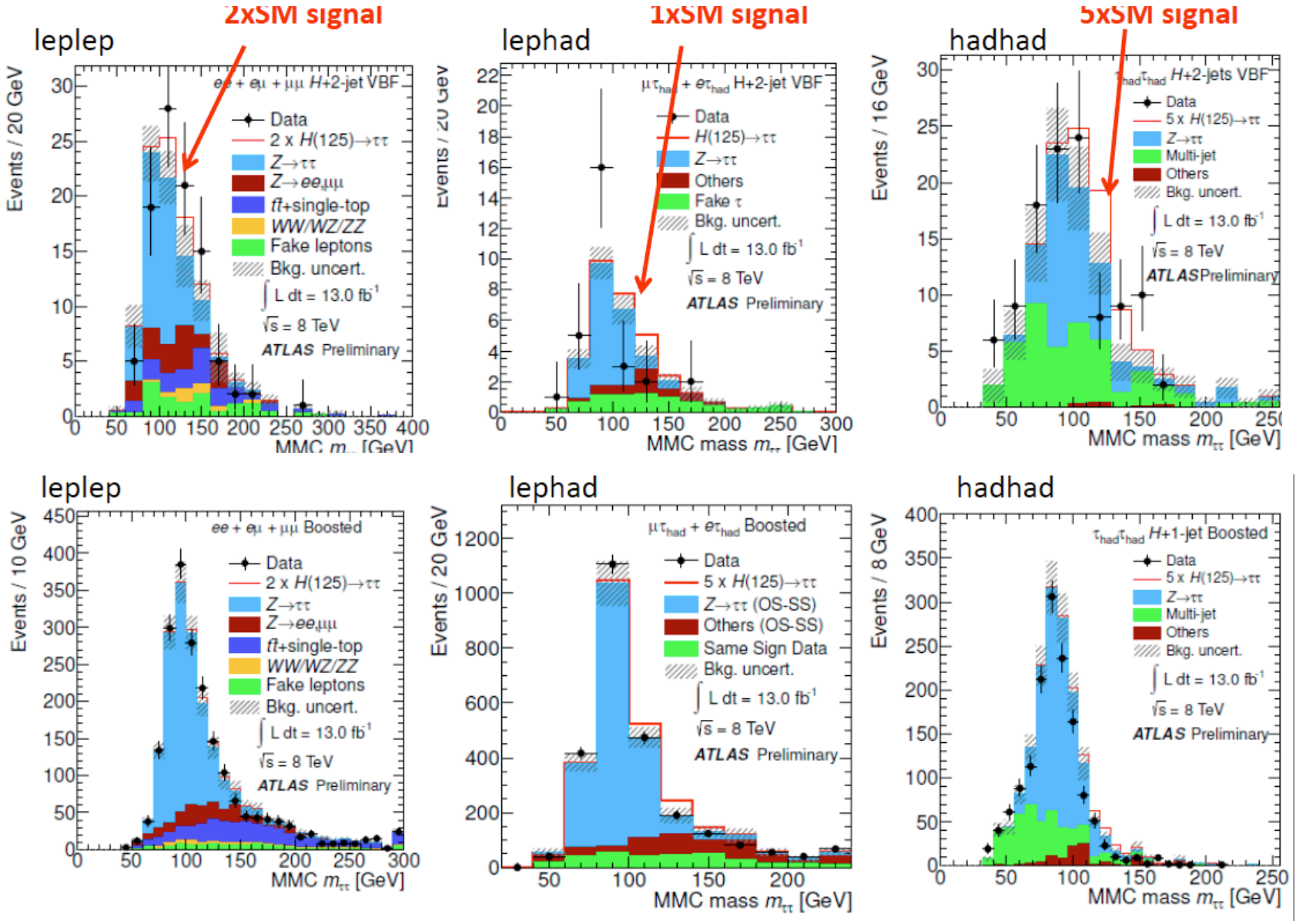
Expected band: signal at 125 GeV

Results: signal strength

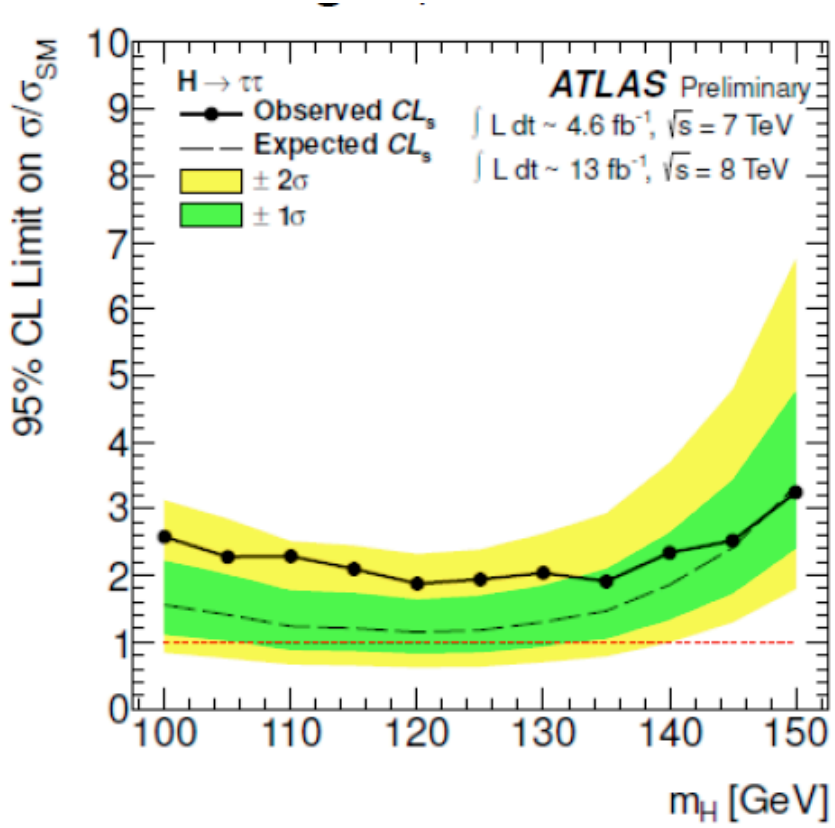


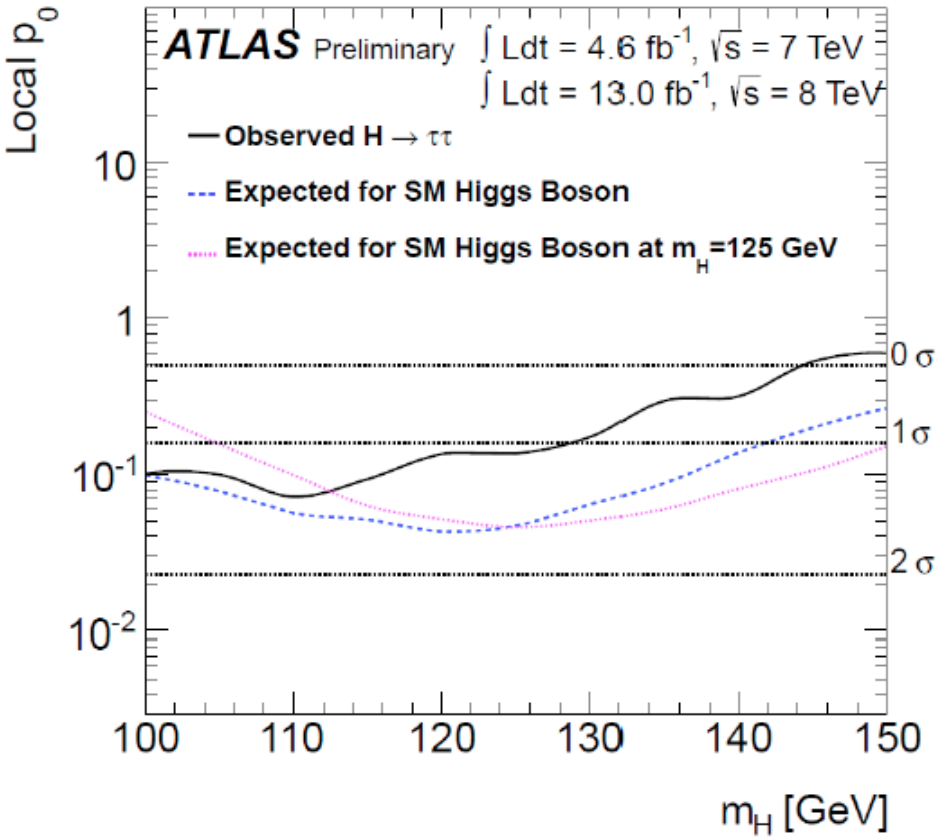
Combined: $\mu = 0.7 \pm 0.5$

ATLAS result from HCP



ATLAS result from HCP





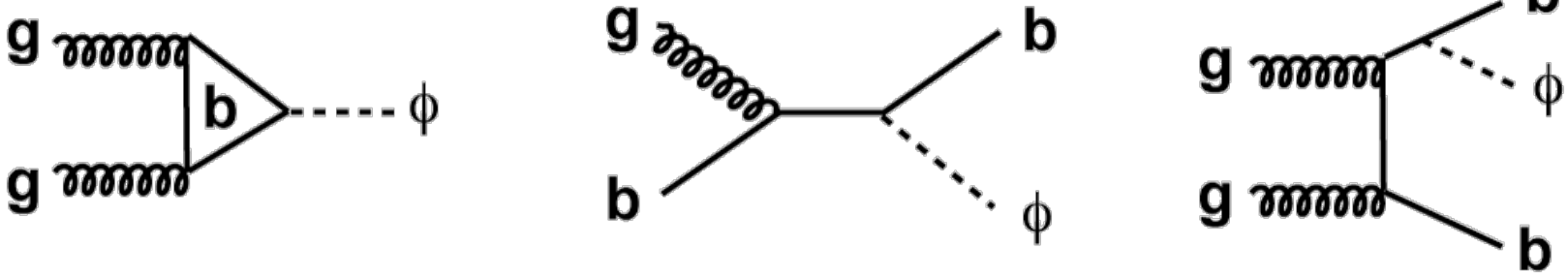
Expected:1.2xSM (μ=0) **Observed:1.9xSM**

Expected:1.7σ (μ=1) **Observed:1.1σ**

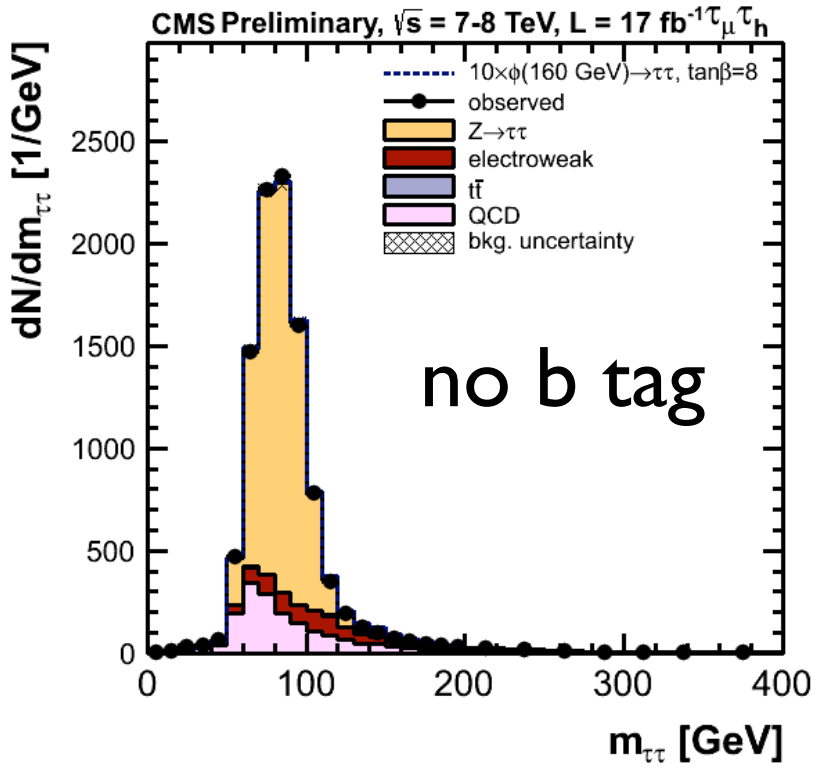
Best fit value of Signal Strength (μ) is 0.7 ±0.7

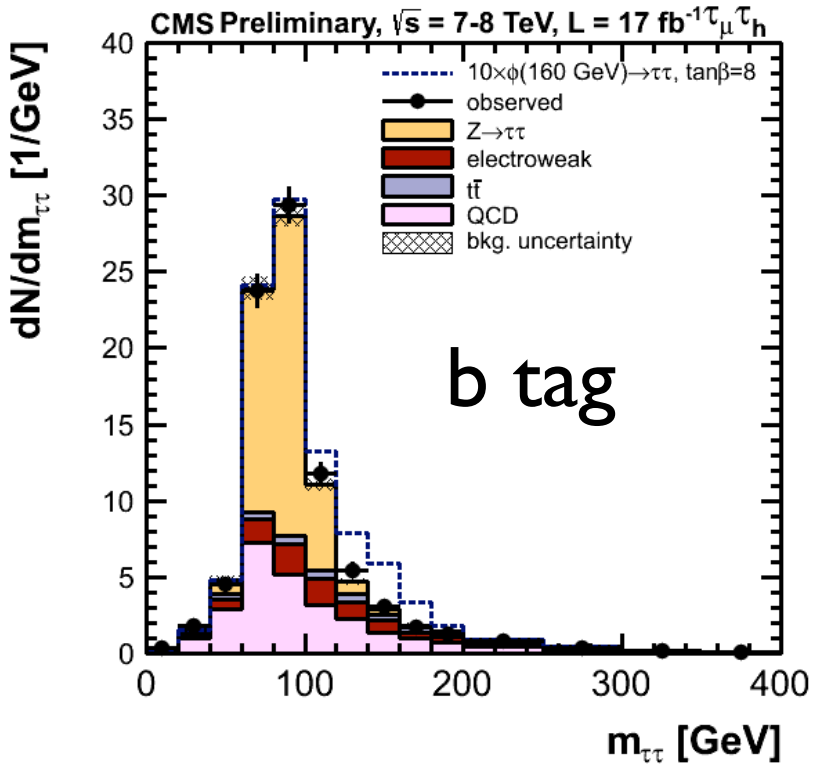
Conway's combination for ττ: μ = 0.7 ± 0.4

MSSM h/A/H → ττ



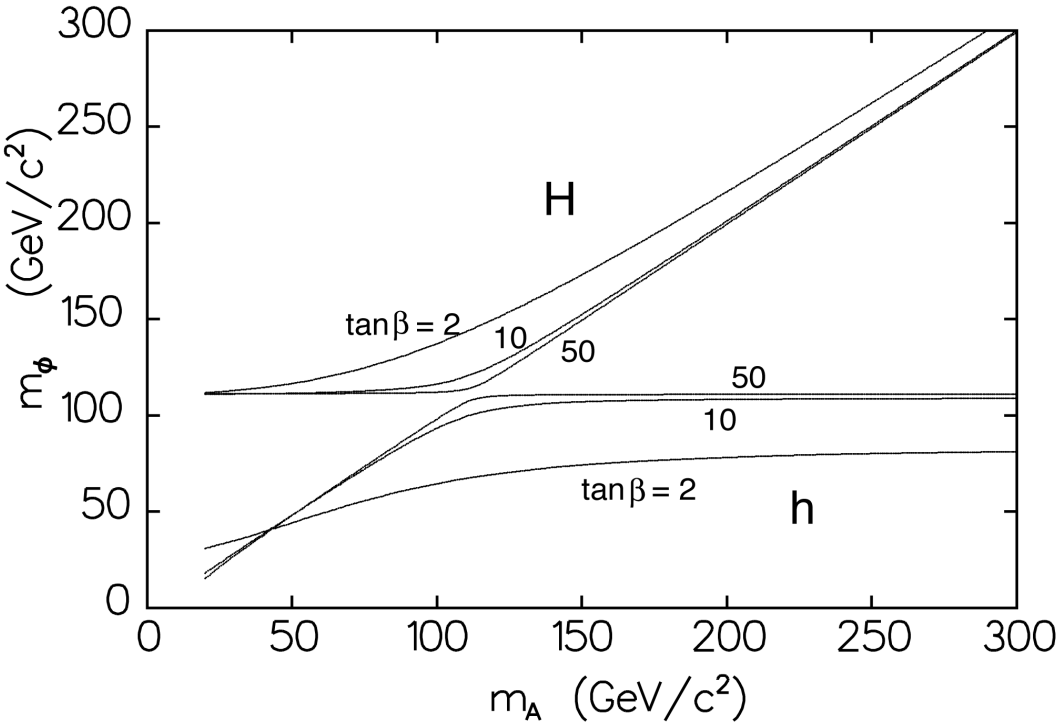
- production diagrams all proportional to $\tan^2\beta$
- can get a b-tagged jet in the final state
- use two categories: no-b-tag and b-tag



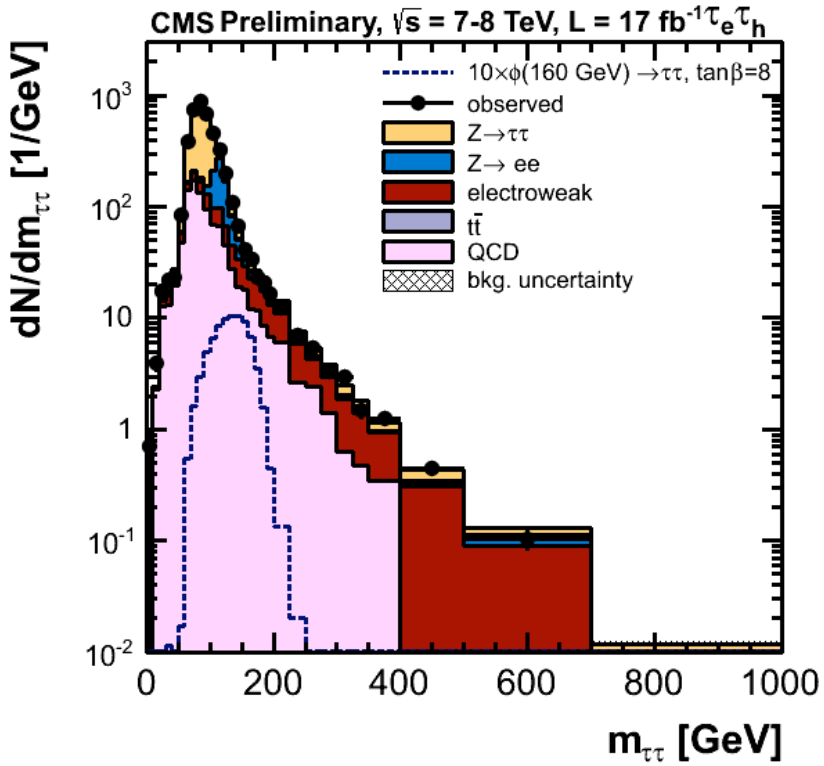


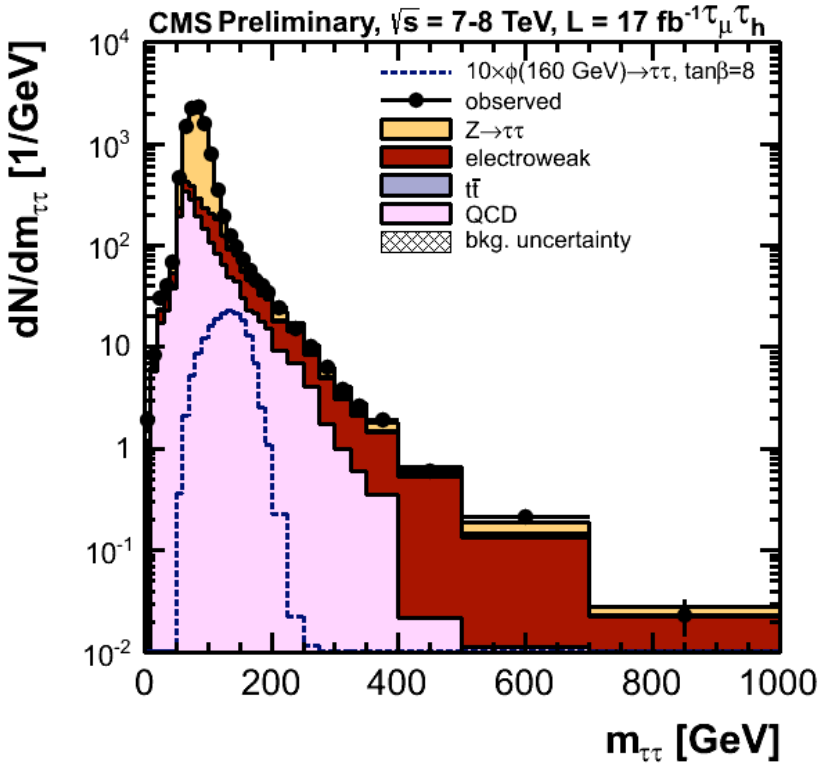
Mass fitting for MSSM

- at any mA tanβ point, have three Higgs states contributing
- We make an appropriate mixture of h, A, and H and fit the observed mass spectrum for all three
- ignore 125 GeV state - let data decide what it is and if it's there
- mass resolution is much greater than the difference in h masses at larger values of m_A



0 tag


CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τe τh
10×φ(160 GeV) →ττ, tanβ=8
observed
Z→ττ
Z→ ee
electroweak
tt̄
QCD
bkg. uncertainty
dN/dmττ [1/GeV]
mττ [GeV]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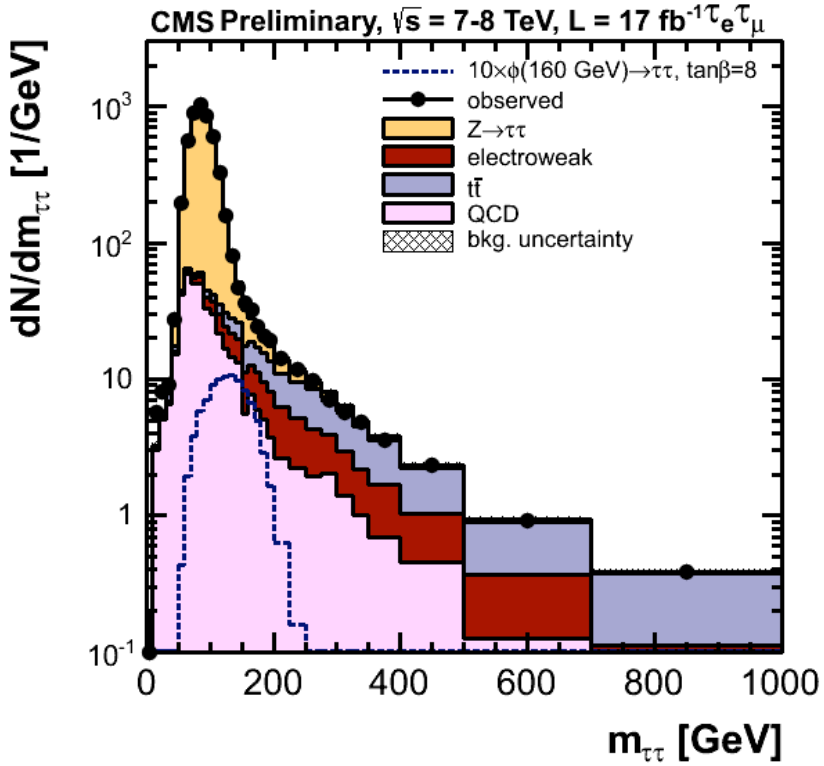
CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τe τμ
10×φ(160 GeV)→ττ, tanβ=8
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electroweak
tt̄
QCD
bkg. uncertainty
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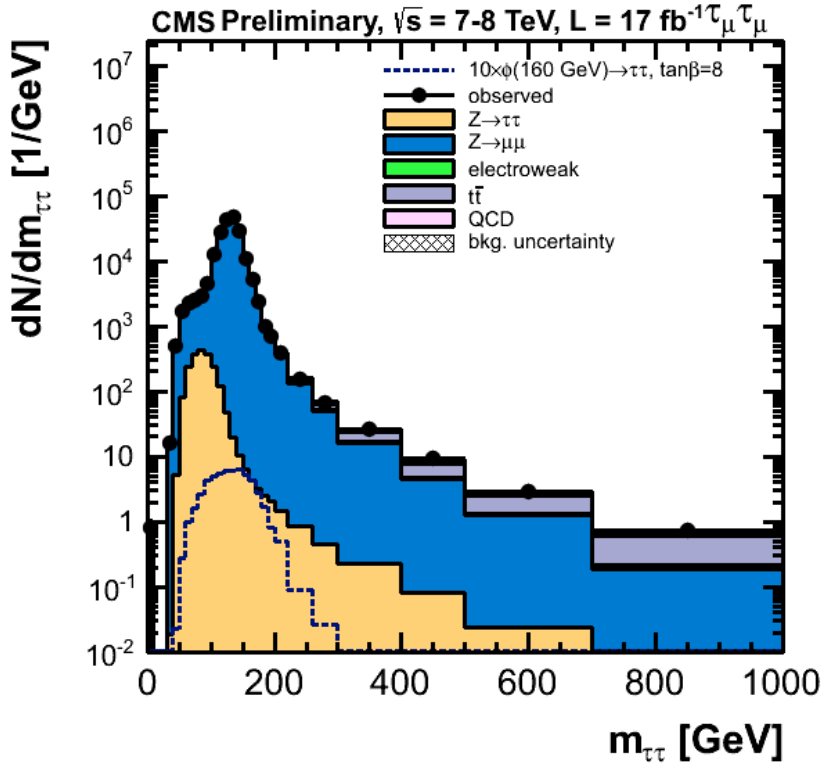
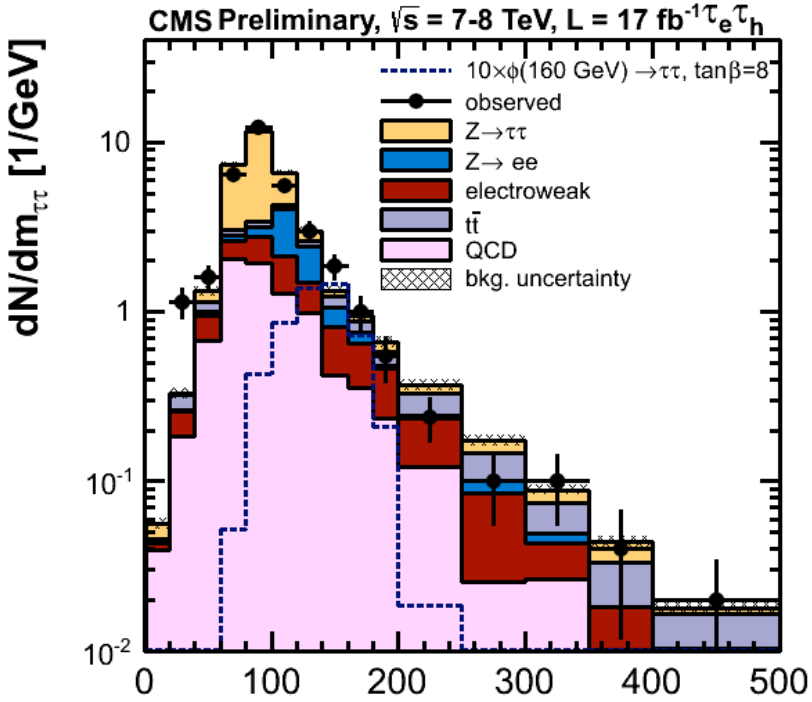
mττ [GeV]


CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τμ τμ
10×φ(160 GeV)→ττ, tanβ=8
observed
Z→ττ
Z→μμ
electroweak
tt̄
QCD
bkg. uncertainty
dN/dmττ [1/GeV]
mττ [GeV]

b tag


CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τe τh
10×φ(160 GeV) →ττ, tanβ=8
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tt̄
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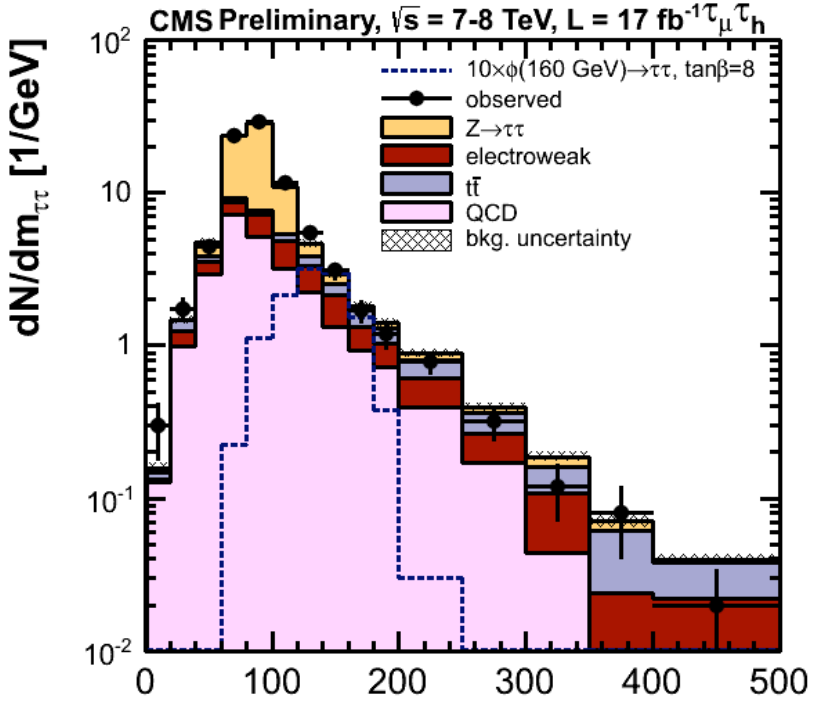
bkg. uncertainty
dN/dmττ [1/GeV]
mττ [GeV]


CMS Preliminary, √s = 7-8 TeV, L = 17 fb-1 τμ τh
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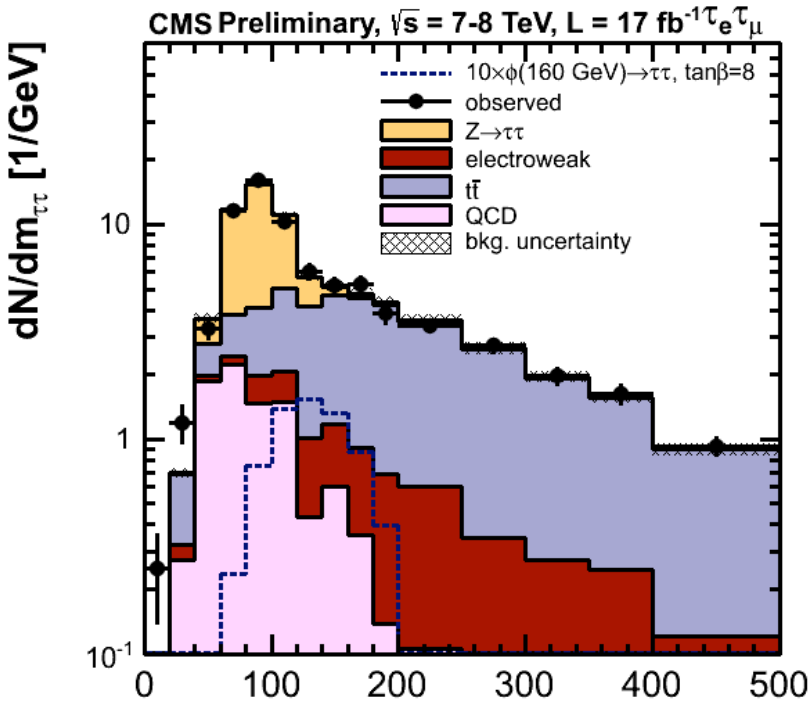
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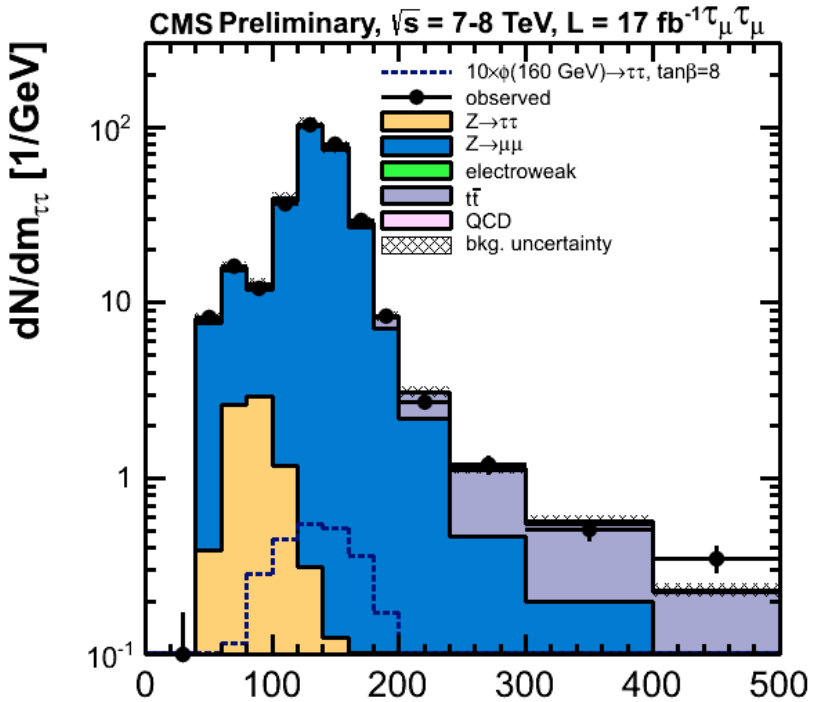
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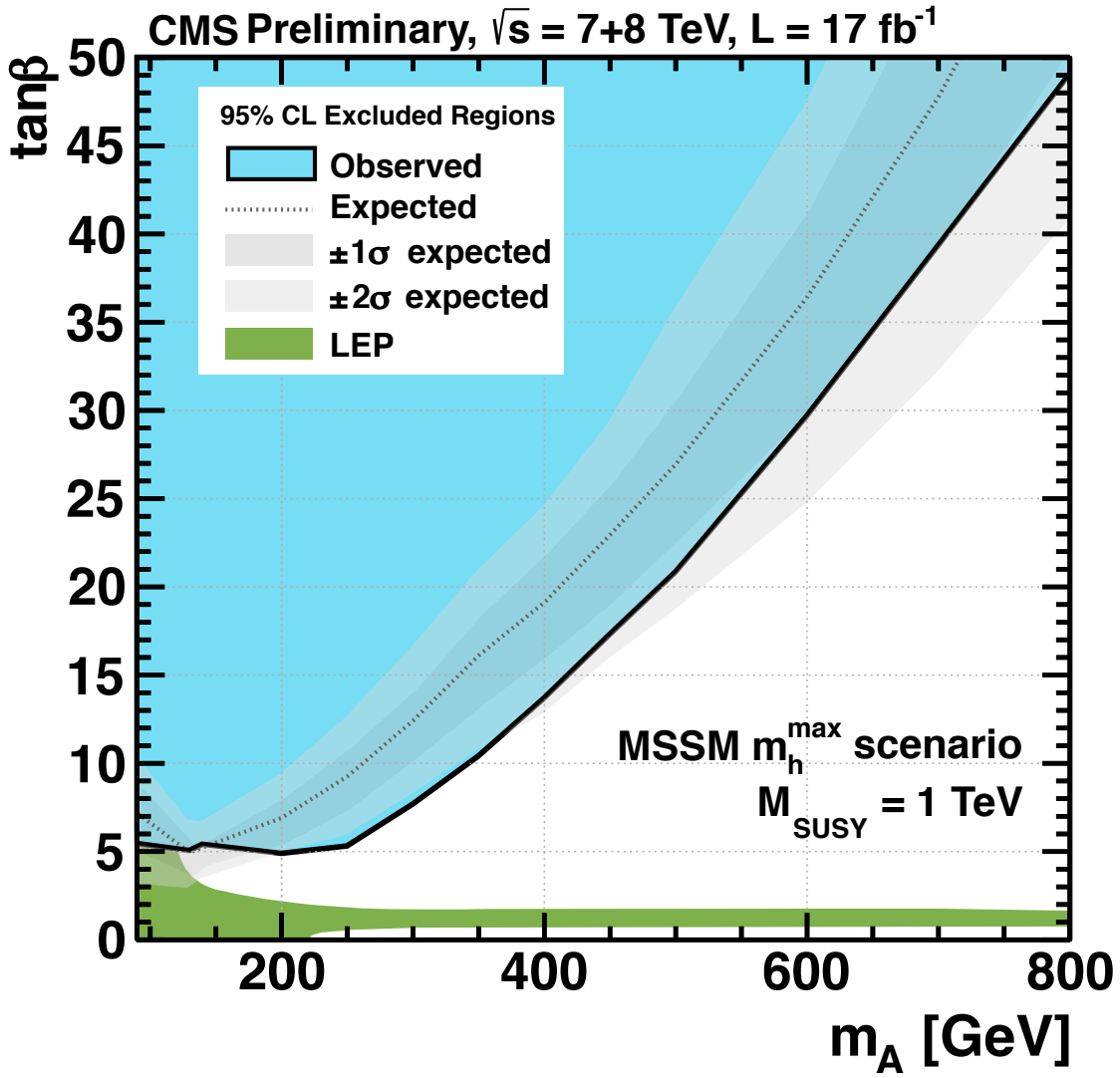
10×φ(160 GeV)→ττ, tanβ=8
observed
Z→ττ
Z→μμ
electroweak
tt̄
QCD
bkg. uncertainty
dN/dmττ [1/GeV]

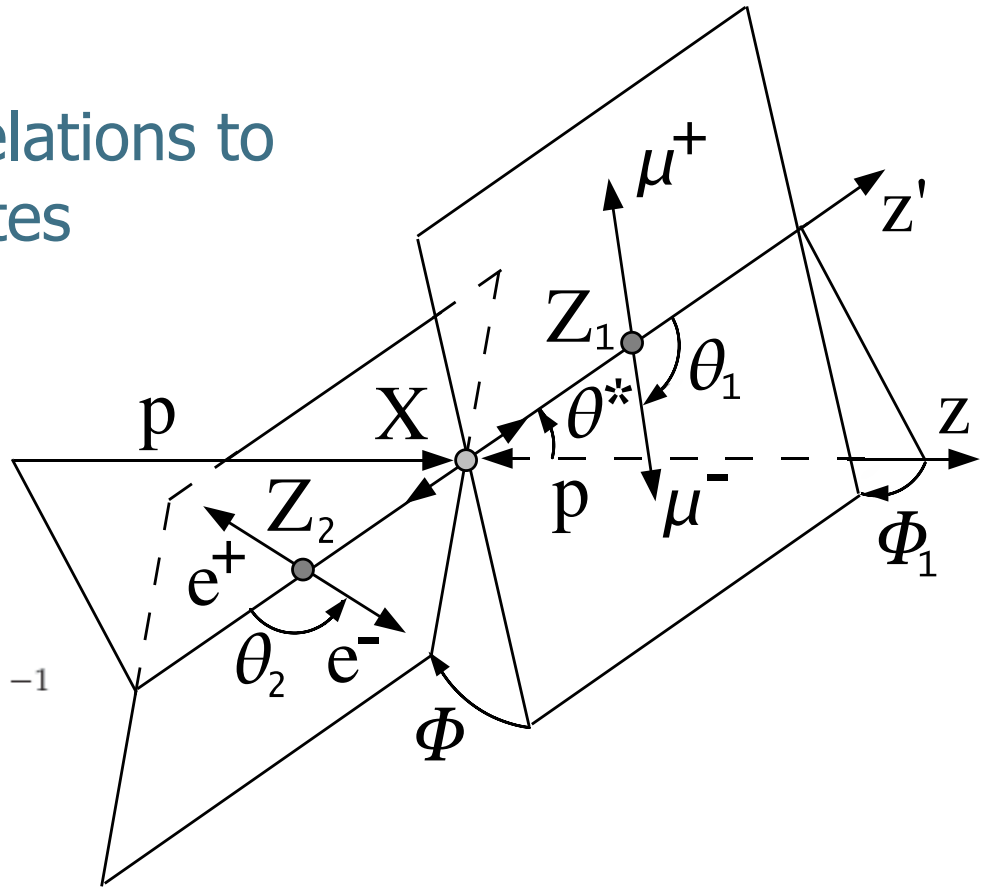
Result: tanβ versus m_A



No sign of excess anywhere!

SM H→ZZ→4ℓ

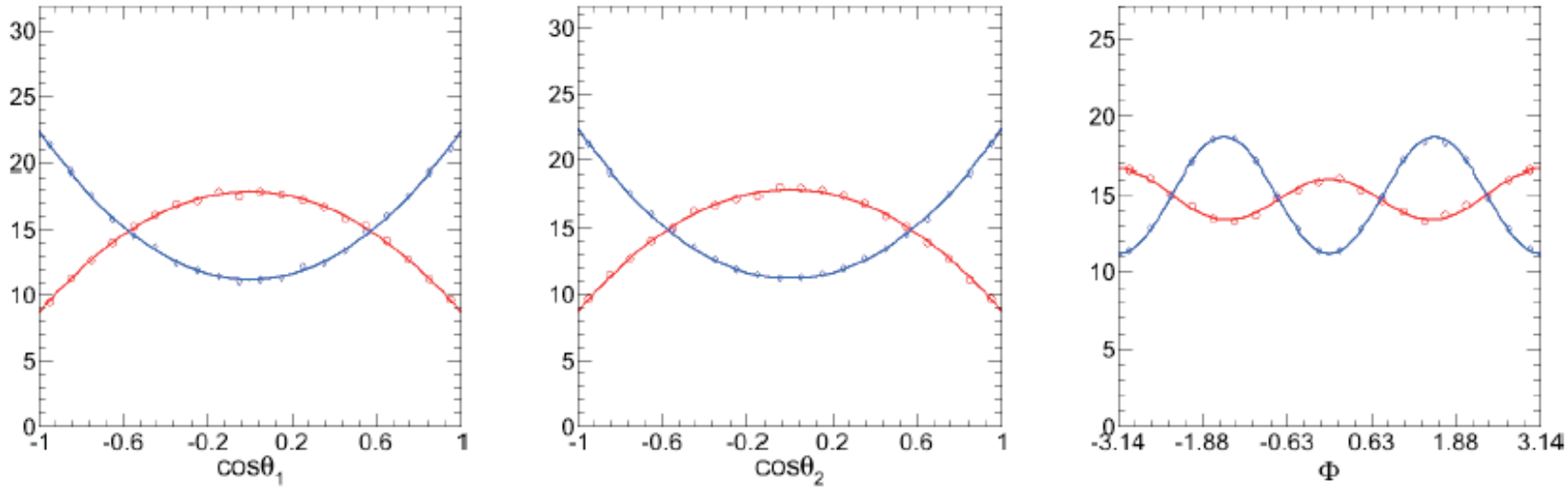
- one of the two golden modes for discovery and Higgs mass measurement
- can use the angular correlations to distinguish Higgs from continuum ZZ background
- can also use angular correlations to distinguish spin/parity states
- use "MELA" technique:
  Matrix Element
  Likelihood Analysis



$$\mathrm{KD} = \frac{\mathcal{P}_{\mathrm{sig}}}{\mathcal{P}_{\mathrm{sig}} + \mathcal{P}_{\mathrm{bkg}}} = \left[1 + \frac{\mathcal{P}_{\mathrm{bkg}}(m_1, m_2, \vec{\Omega}|m_{4\ell})}{\mathcal{P}_{\mathrm{sig}}(m_1, m_2, \vec{\Omega}|m_{4\ell})}\right]^{-1}$$

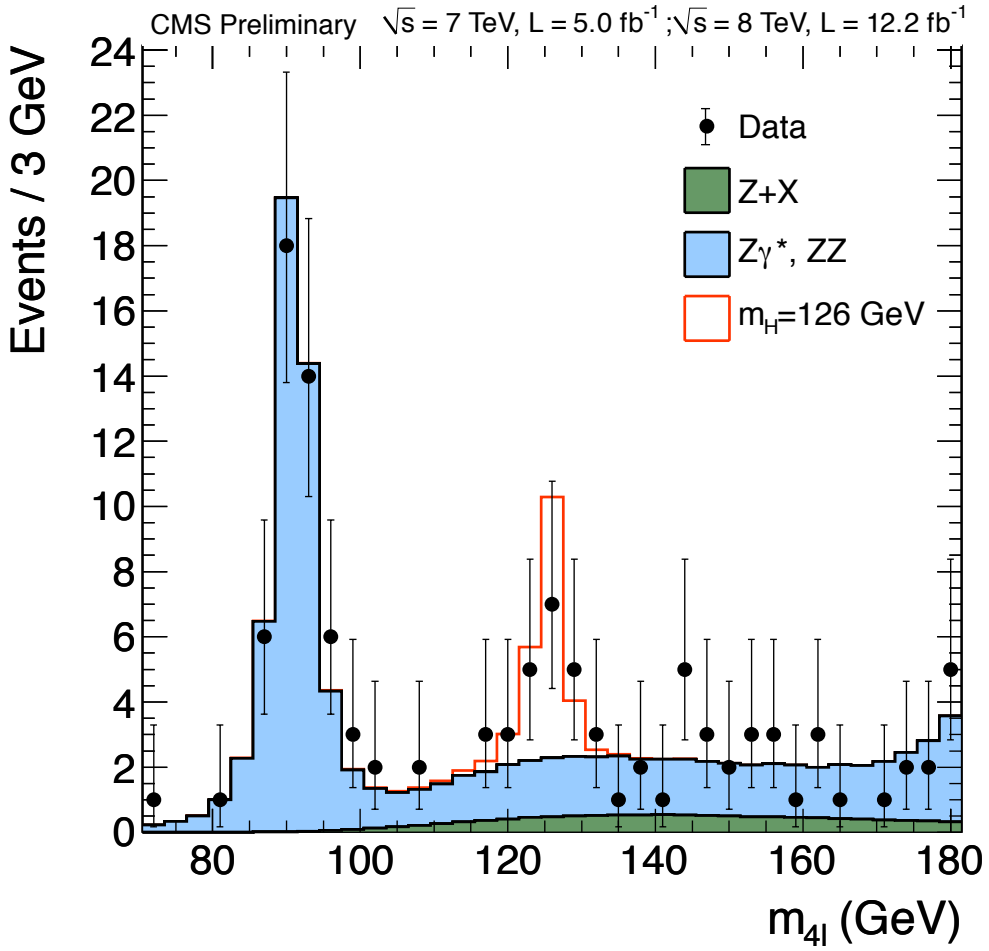
SM H→ZZ→4ℓ

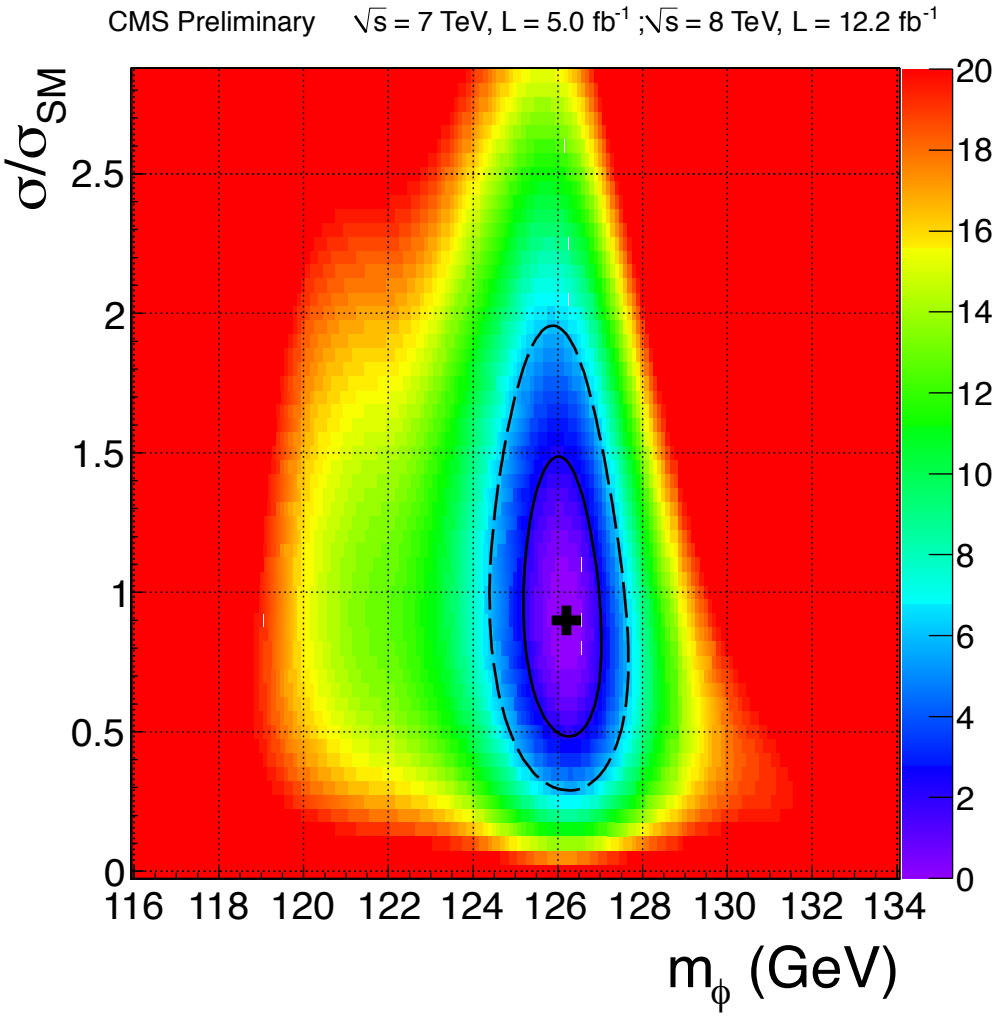
Example: scalar (0^+) versus pseudoscalar (0^-)



- we first perform fit in sig/bkg MELA to "rediscover" the boson and measure mass etc.
- then we perform fits in 2D: sig/bkg MELA versus scalar/pseudoscalar MELA

SM H→ZZ→4ℓ





- μ = 0.8 ± 0.3 (significance 4.5σ)
- mass = 126.2 ± 0.6 ± 0.2 GeV

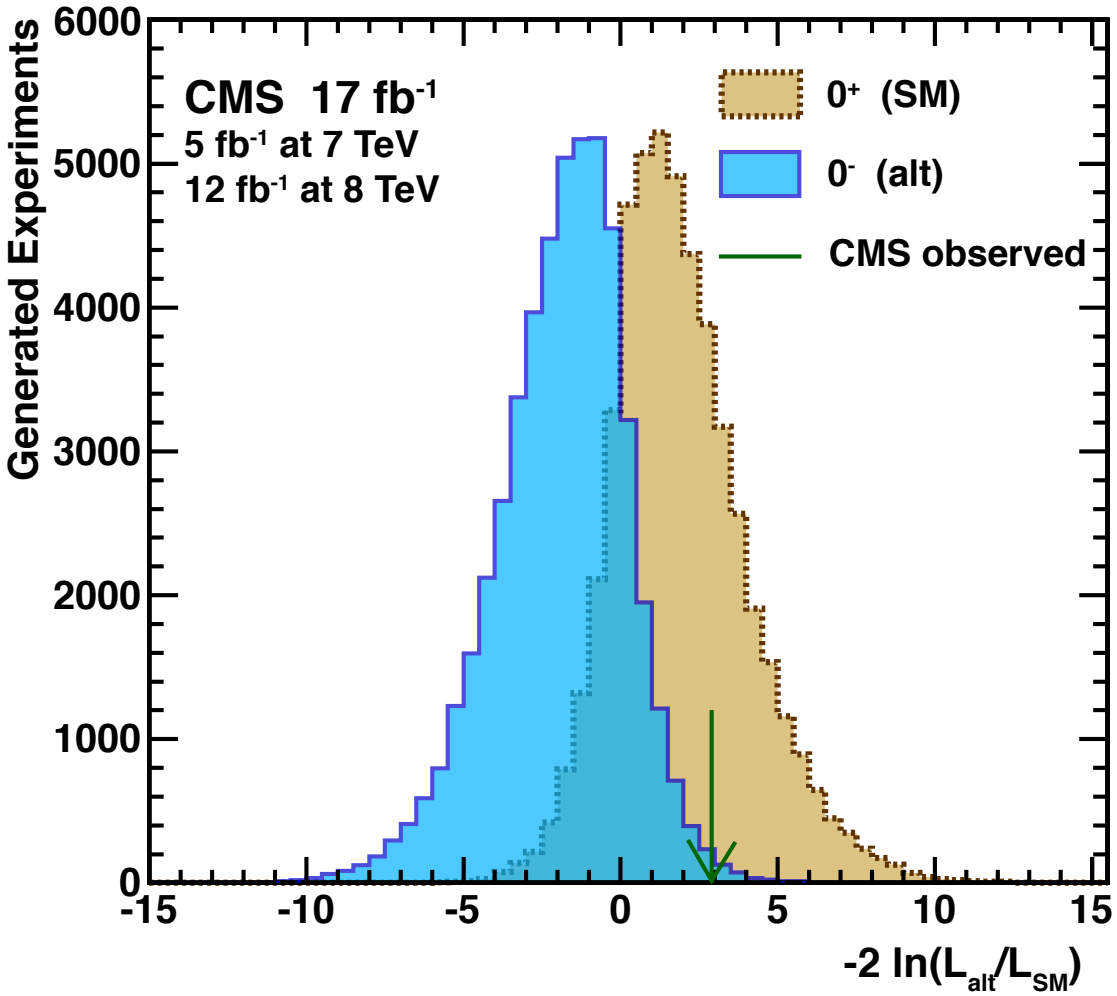
Summary

- we have new results for the search for SM $H \rightarrow \tau\tau$ from CMS (0.7 ± 0.5) and ATLAS (0.7 ± 0.7)
- new MSSM exclusion bounds down to quite low $\tan\beta$; analysis remains statistics limited
- new ZZ signal strength and mass values
- can now rule out pseudoscalar in favor of scalar
- will take a lot more data to to rule out spin 2 with Z alone; $\gamma\gamma$?
- did not cover new WW, bb, combination results

Vanilla, anyone?

SM H→ZZ→4ℓ

- data strongly favor the 0^+ over the 0^- spin/parity hypothesis:



p-value for 0^- 0.00648

p-value for 0^+ 0.28

CLs = 2.4%

We exclude the pseudoscalar hypothesis in favor of the scalar at 95% CL