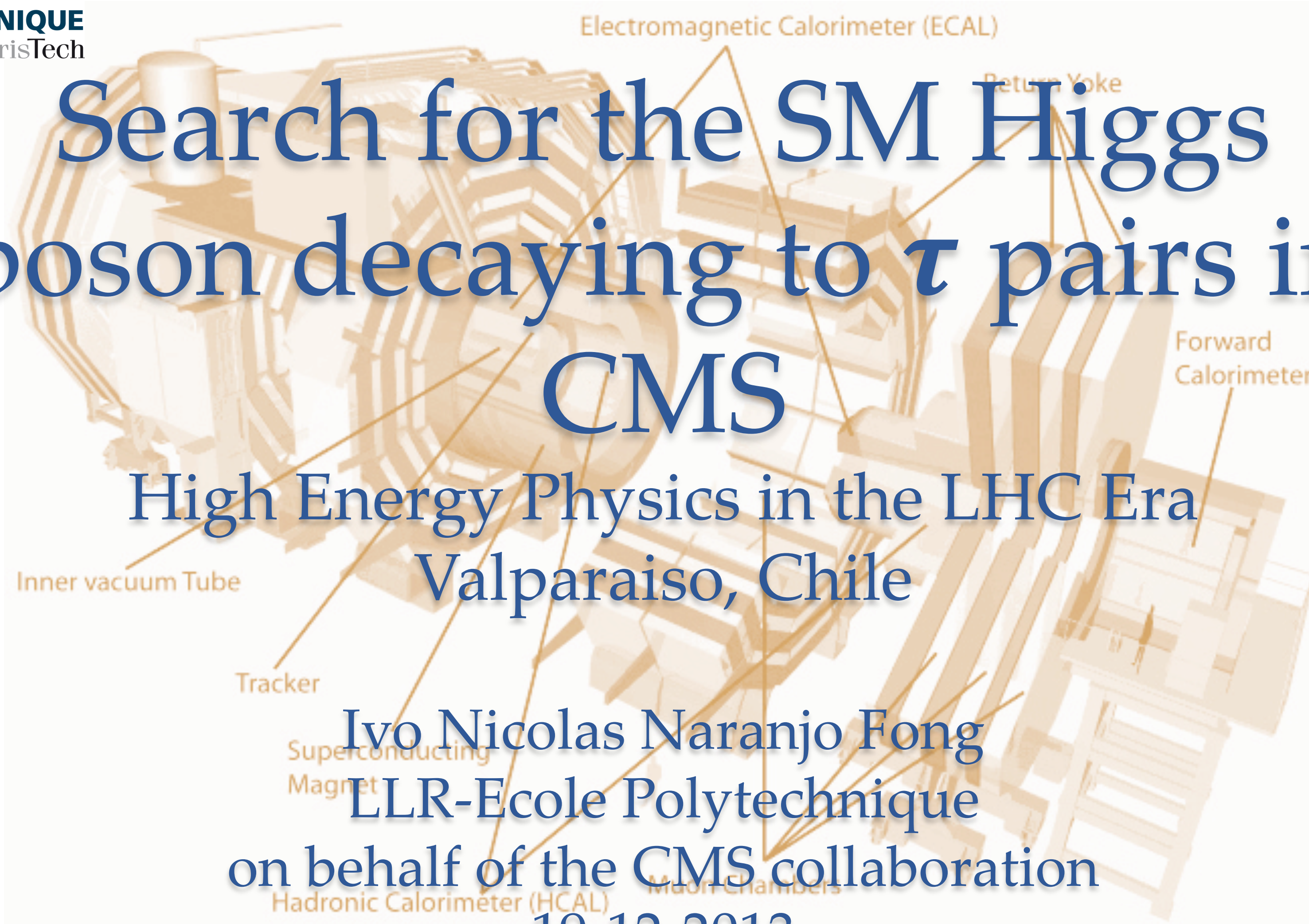
Search for the SM Higgs boson decaying to τ pairs in CMS



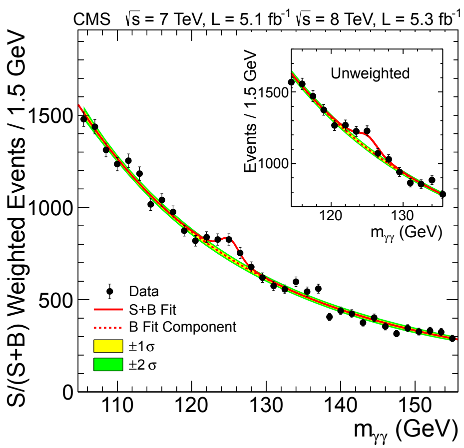
High Energy Physics in the LHC Era
Valparaiso, Chile

Ivo Nicolas Naranjo Fong
LLR-Ecole Polytechnique
on behalf of the CMS collaboration

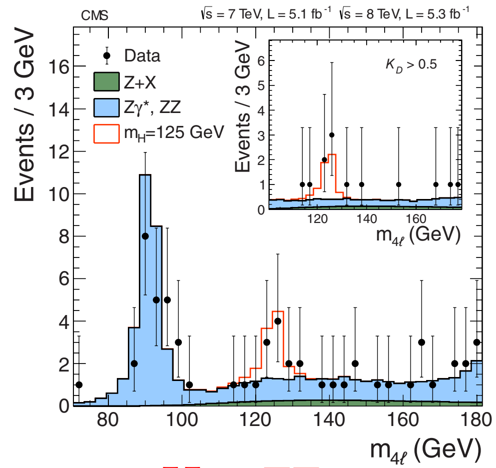
19-12-2013

Motivation

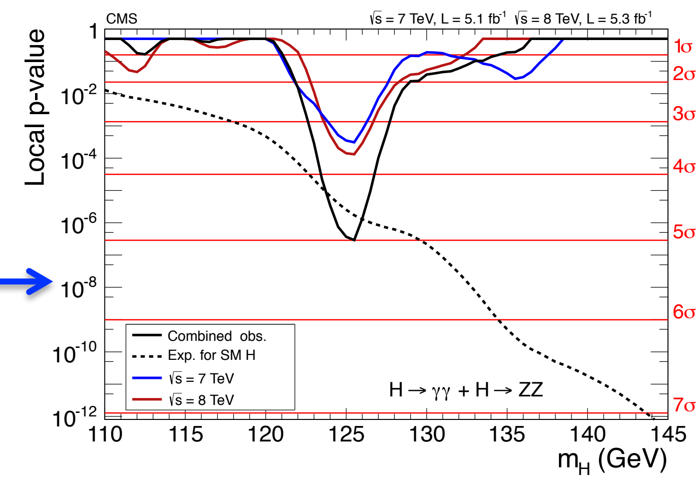
- New Higgs boson discovered at LHC with a mass around 125 GeV in 2012.



H→ γγ

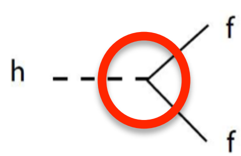


H→ ZZ



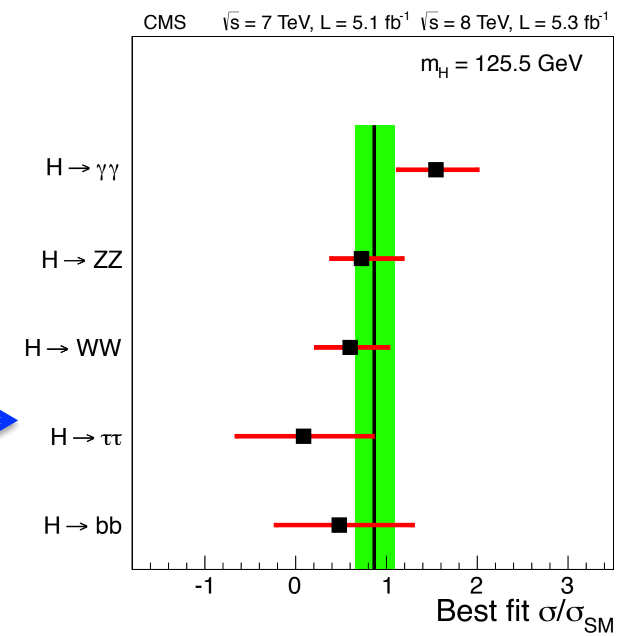
Physics Letters B Sep. 2012

- **Is it THE SM Higgs boson?**
- How does it couple to Fermions?



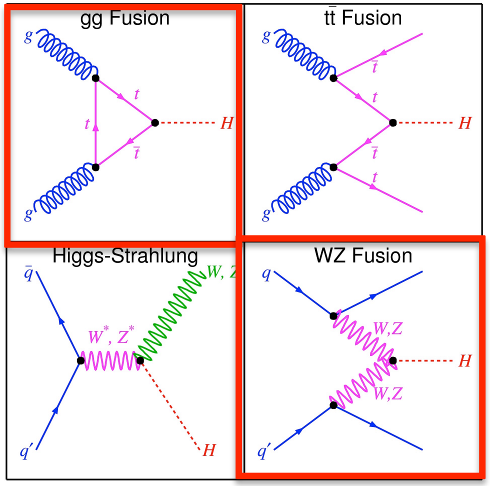
$= \frac{gM_f}{2M_W}$ **?**

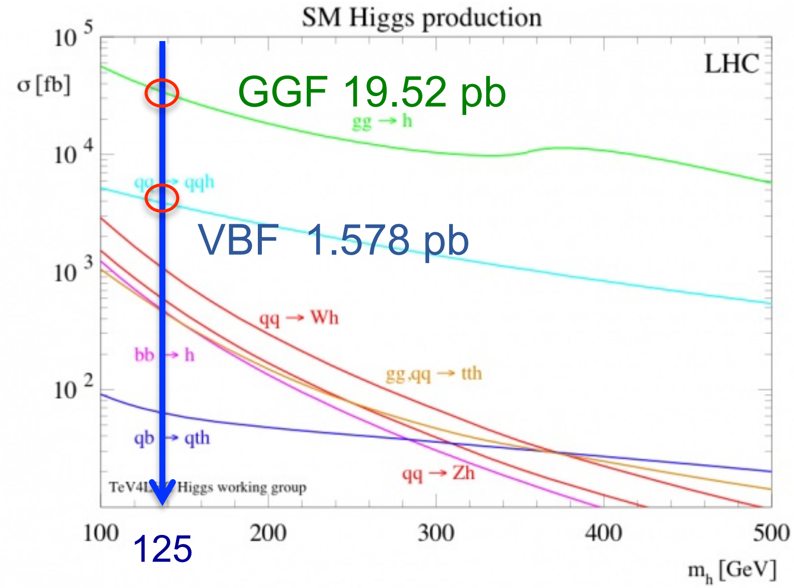
- **H→$\tau\tau$ is the best available channel that can probe coupling to Leptons.**



Higgs search at the LHC

- **Higgs production modes at LHC :**

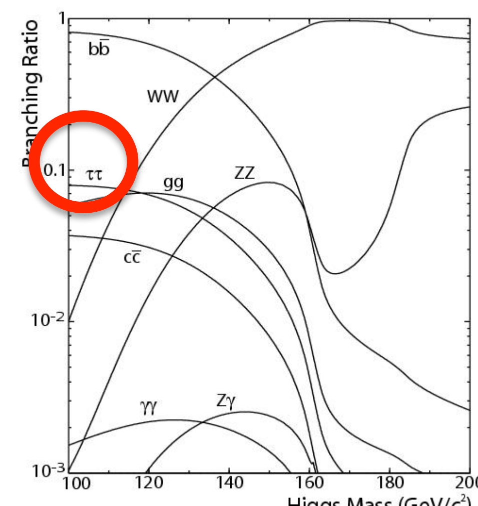




- **Different production modes lead to different topologies for the signal events.**

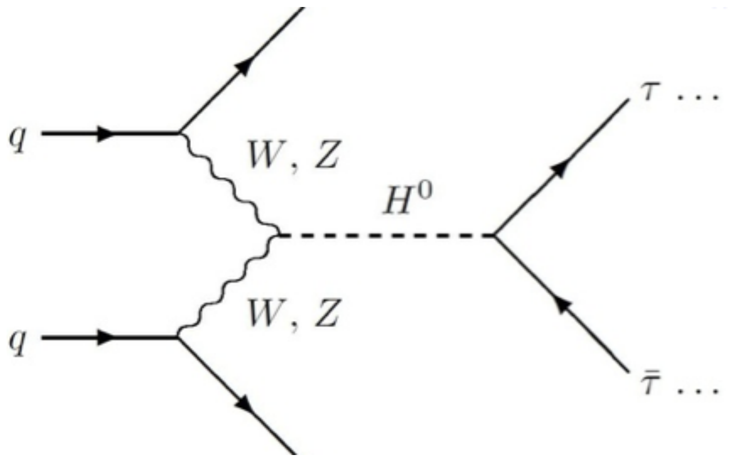
BR(SM $H_{125} \rightarrow \tau\tau$) ~ 6 %

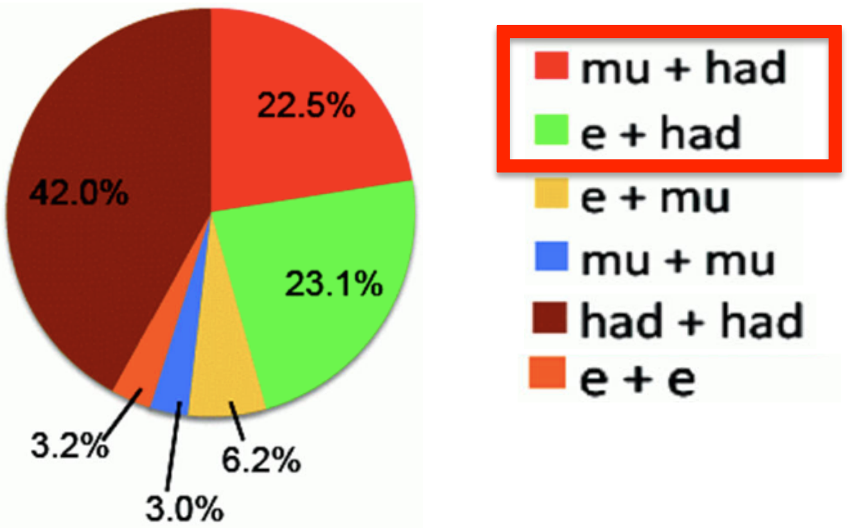
- **Favorable branching ratio at low mass**
- **The only channel available today able to probe the Higgs couplings to leptons**



H→ττ channel

Final states

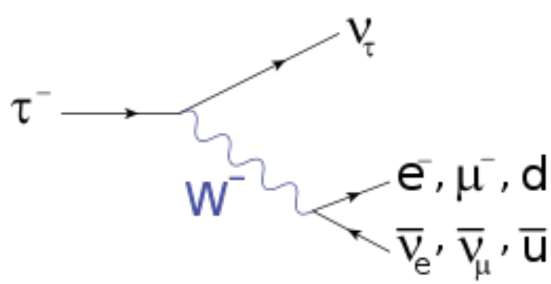




- **Analysis strategy** : Look for an excess in the reconstructed di-τ mass distribution.
- **Key ingredients :**
  - Hadronic τ reconstruction
  - Missing energy estimation (presence of neutrinos)
  - Di-τ mass reconstruction
  - Event categorization

τ lepton reconstruction in CMS

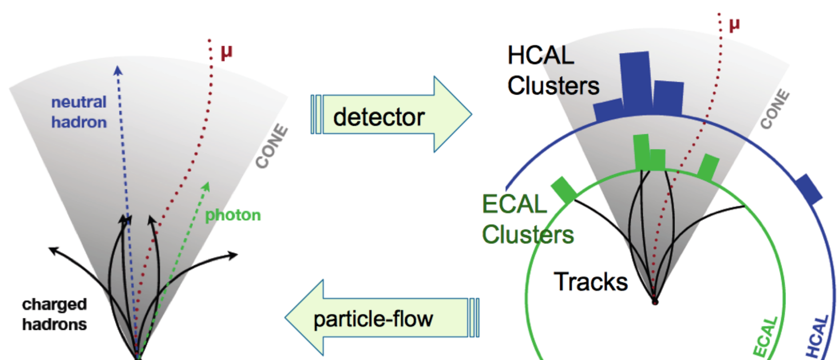
- τ lepton
  - Mass = 1.78 GeV
  - cτ = 87 μm
  - The only lepton that can decay hadronically :

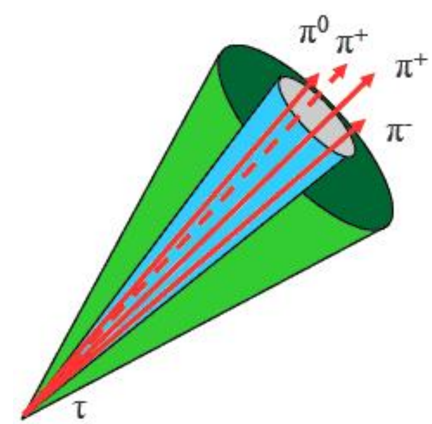


Decay channel	BR (%))
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$	17.36
$\tau^- \to e^- \bar{\nu}_e \nu_\tau$	17.85
$\tau^- \to h^- \nu_\tau$	11.6
$\tau^- \to h^- \pi^0 \nu_\tau$	26.0
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	9.5
$\tau^- \to h^- h^+ h^- \nu_\tau$	9.8
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$	4.8
others	3.1

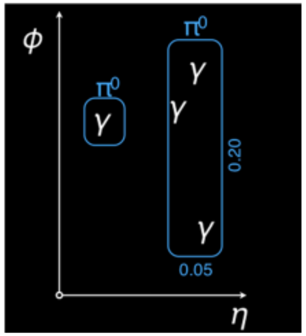
~2/3 of times (hadronic channels)

- Based in the Particle Flow algorithm

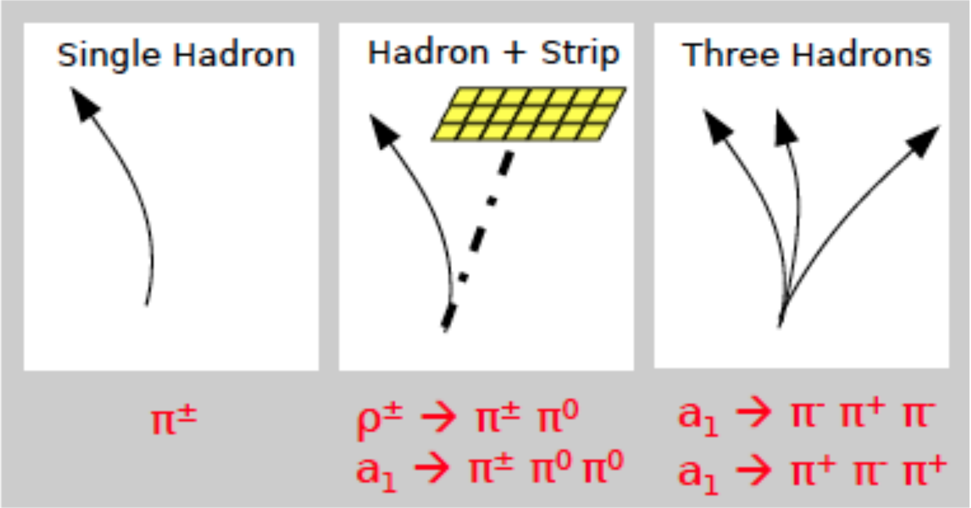


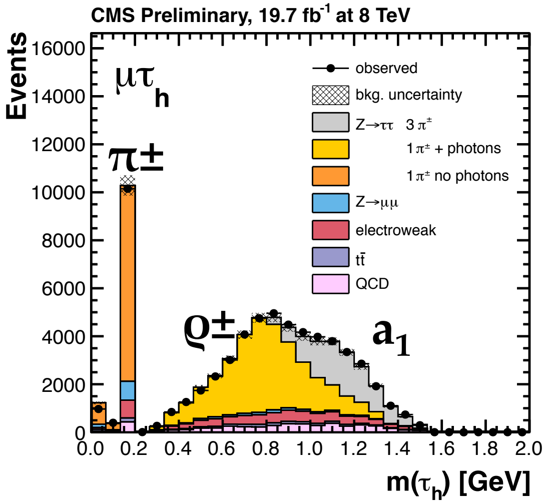


Hadron Plus Strips Algorithm



- $\pi°$s candidates form clusters in the ECAL ($\pi° \rightarrow \gamma\gamma$).
- $\pi\pm$ candidates : track + Energy deposit in the ECAL + HCAL.
- Combine Charged hadrons ($\pi\pm$s) and $\pi°$s for each decay mode.





- Jet $\rightarrow \tau$ fake rate in the order of ~3% for 70 % efficiency.
  - ➢ Dedicated cut based isolation.
- Lepton (e/μ) $\rightarrow \tau$ fake rate in the order of per mil level.
  - ➢ Dedicated anti-muon (cut based) and anti-electron (MVA based) discriminators.

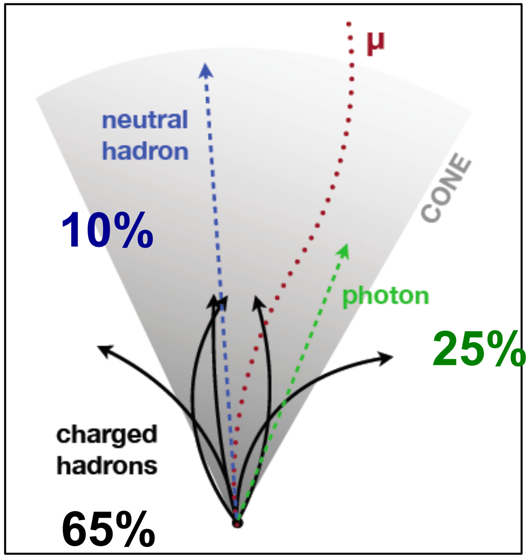
Missing transverse energy

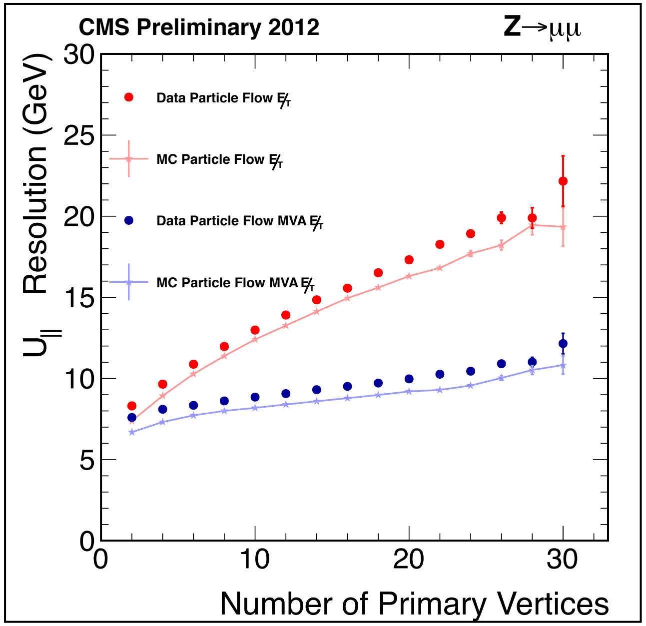
$$\vec{p}_T^{\,miss} = - \sum_{\text{all PF particles}} \vec{p}_T$$

- Uses Particle Flow to determine jet constituents contribution.
- ME_T resolution degrades with Pile-up
- MVA ME_T regression corrects for the pile-up contribution.

➢ Pile-up robust.

- **Key ingredient for the di-τ mass reconstruction.**





Di-τ mass reconstruction

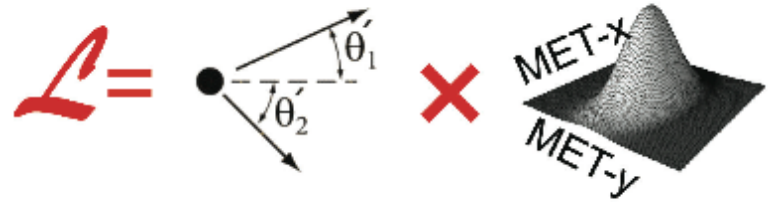
- Maximum Likelihood method
- Estimate the tau decay kinematics

using : $E_T^{miss}{}_{x,y}$, $P_t^{vis}(\tau_{1,2})$ **observables.**

➢ **Test hypothesis :** $M_{\tau\tau}$ from M_τ to 2 TeV

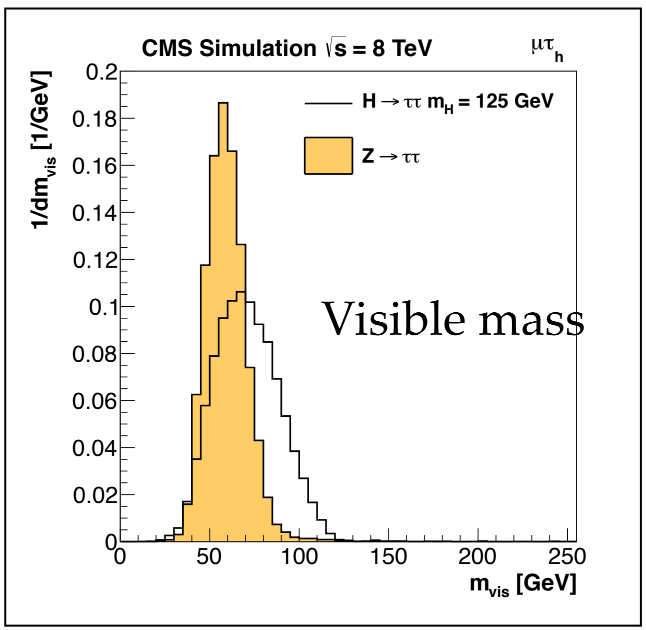
⇒ maximisation of **$L(M_{\tau\tau})$.**

- **15-20% resolution of the reconstructed mass.**

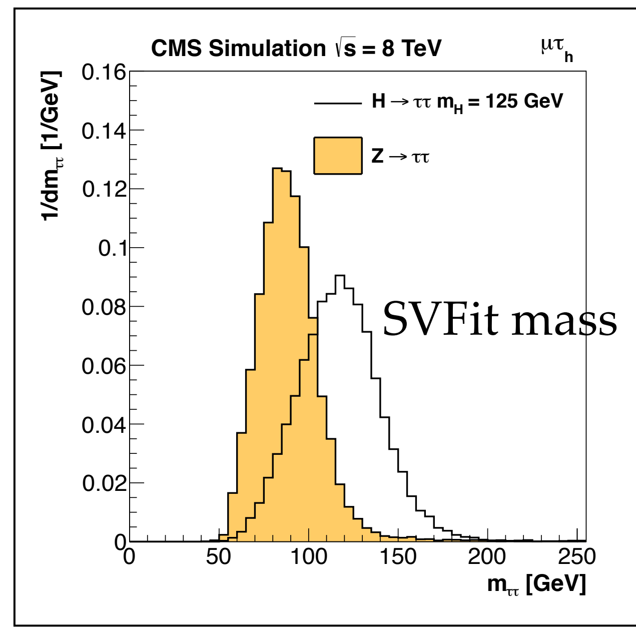


Tau decays phase-space

Expected ME_T resolution

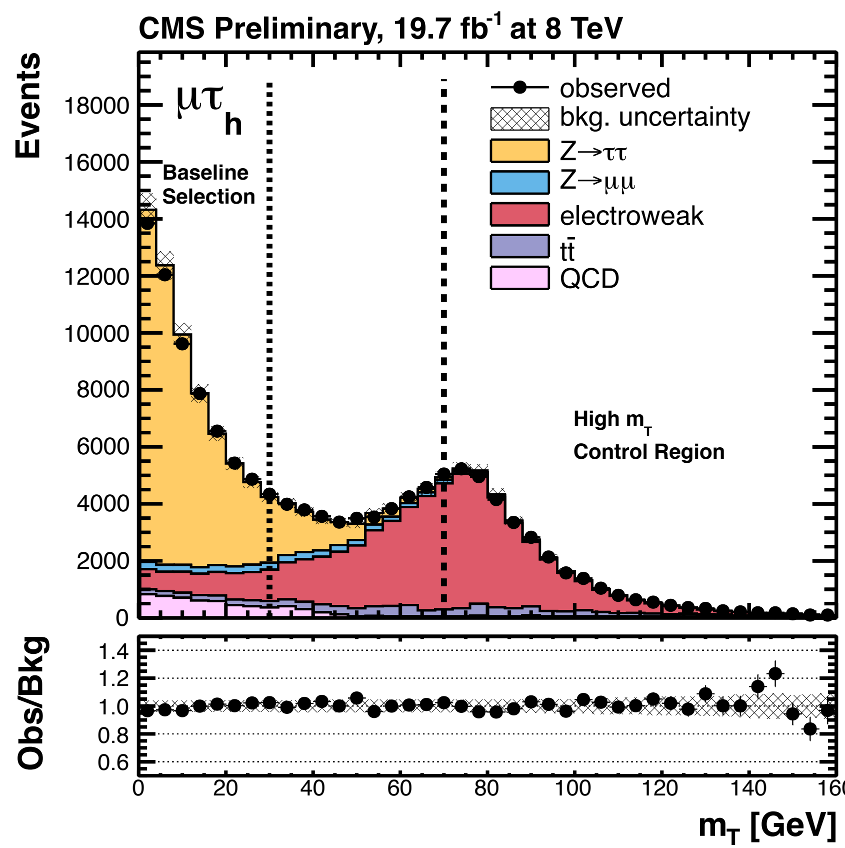


Better separation between H_{125} and Zττ dominant background



H→ττ candidate selections

- Here we focused in the semileptonic H→ττ →e/μ + τ channels.
- Lepton selection : electron (muon)
  - Pt > 24(20) GeV |η*|< 2.1
- Tau selection
  - Pt > 30 GeV, |η|< 2.3



- Event selection
  - Opposite sign between lepton and Tau
  - $M_T(\text{lep}+ME_T) < 30$ GeV (W+jets Bkg rejection)
  - Third lepton veto

$$^{*}\eta = -\ln[\tan(\frac{\theta}{2})]$$

Topologies/Categories

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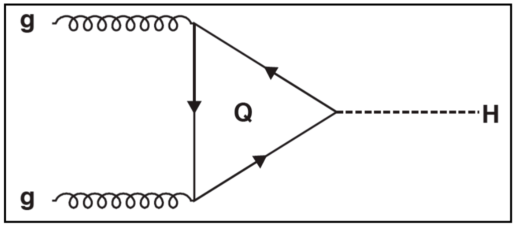
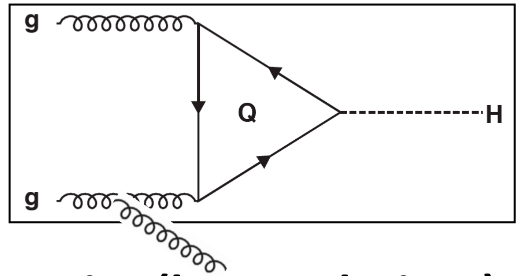
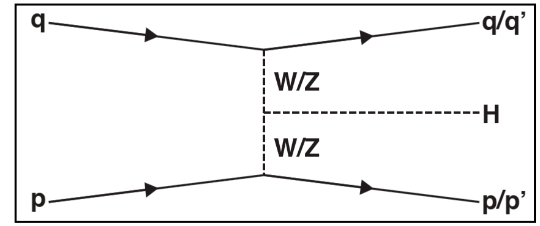
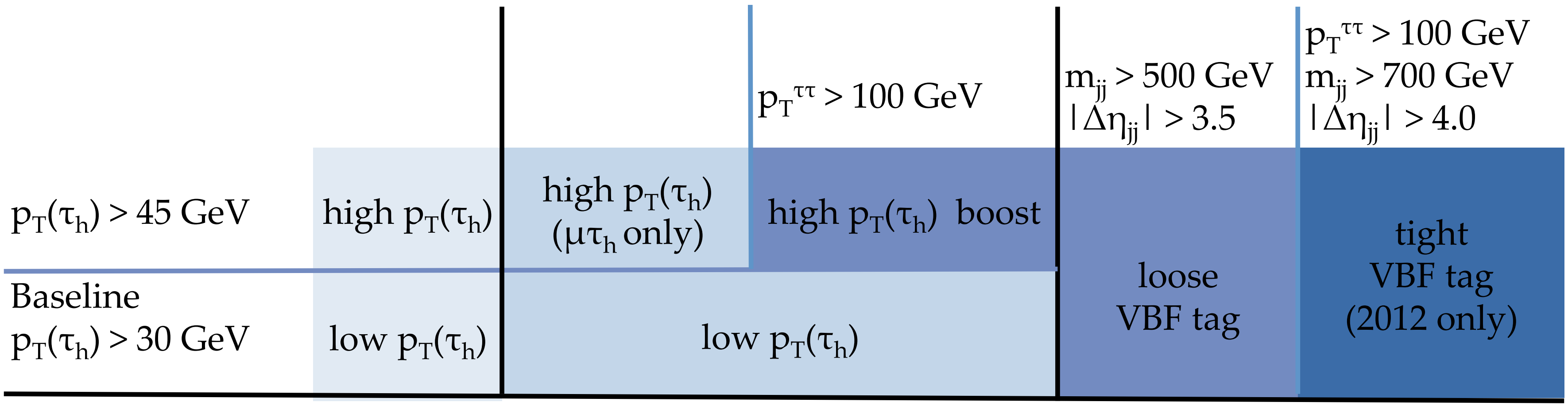






0-jet | **1-jet (boosted Higgs)** | **2-jet (VBF enhanced)**



- **Calibration of backgrounds.**

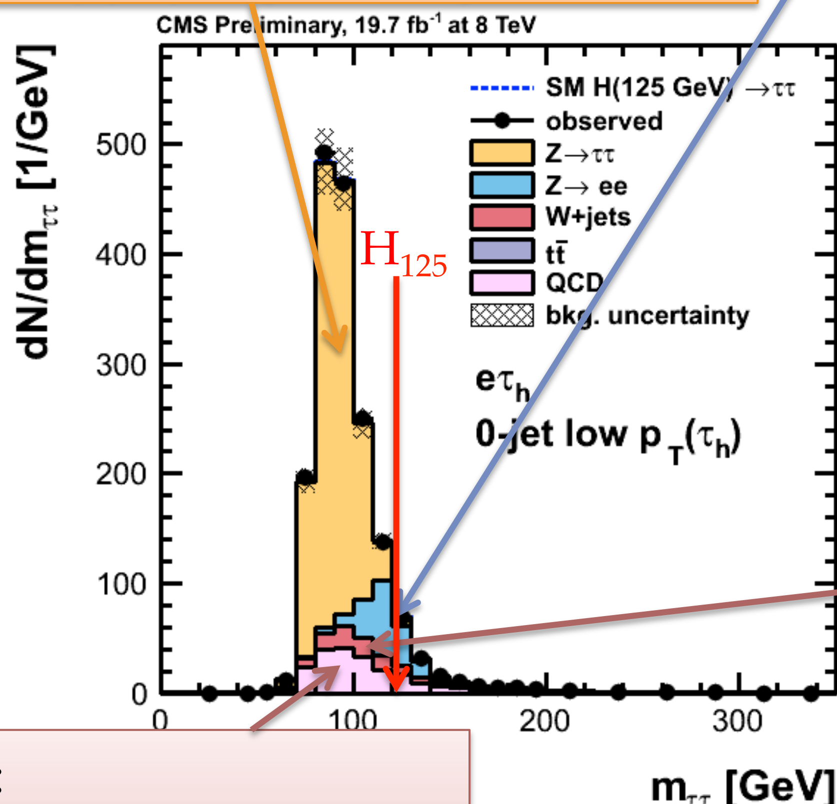
- Jet Pt > 30 GeV
- **Improved resolution of mass reconstruction.**

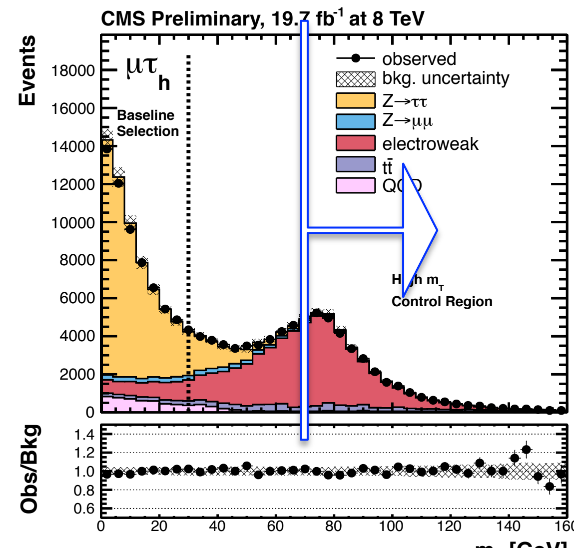
- 2 "tag" jets Pt > 30 GeV
- Central jet veto

Background estimation

$Z\to\tau\tau$:
Embedded technique.
Data $Z\to\mu\mu$, μ replaced by MC τ.

$Z\to ee$:
MC simulation.





ElectroWeak :
MC simulation, normalized from Data extrapolation from sideband.

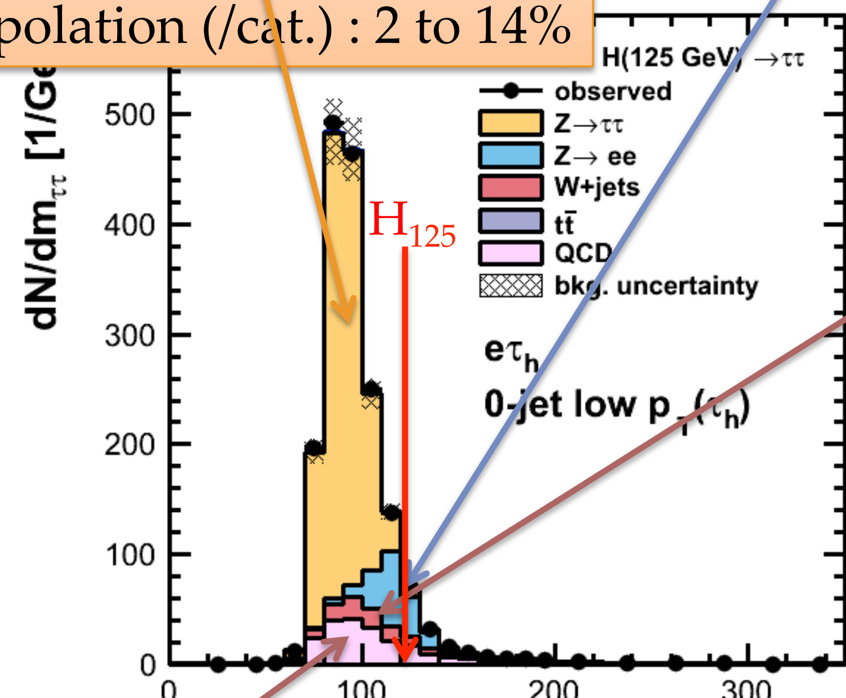
QCD :
Data driven.
SS not isolated events.

TTBar:
MC simulation
normalized from Data extrapolation.

Systematic uncertainties

$Z \rightarrow \tau\tau$:
τ Id efficiency : 8-19%
τ energy scale : 3% (shape)
Norm (σ) : 3%
Extrapolation (/cat.) : 2 to 14%

$Z \rightarrow l^+ l^-$:
$l \rightarrow$ Tau Fake-rate : 20 to 74%.



ElectroWeak :
Norm W : 10 to 100%
- extrapolation
- control region

Norm VV : 15 to 45%

Z+Jets→τ :
- j→τ fake-rate : 20 à 80 %
- shape : bin by bin

COMMON
- e/μ selection : 2 to 6%
- jet energy : 0 to 20%
- MET : 1 to 12%
- PDF : 4 to 10%
- H scale : 3 to 41%

QCD :
Norm QCD : 6 to 70%
Shape QCD : bin by bin

TTBar:
Norm ttbar
σ + stat : 8 to 35%.

Systematic uncertainties

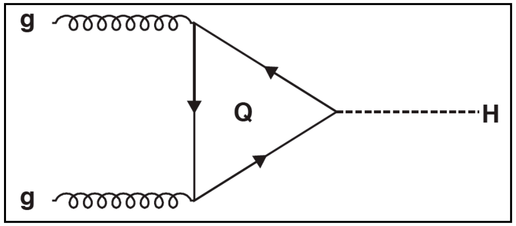
HIG-13-004

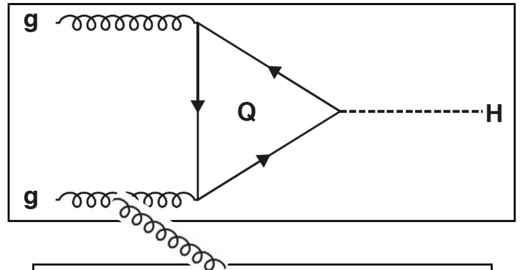
Group	Uncertainty	Affected samples	Change in acceptance
Experimental	Tau energy scale	signal & sim. backgrounds	shape
	Tau ID & trigger	signal & sim. backgrounds	8–19%
	e misidentified as τ_h	$Z \to ee$	20–74%
	μ misidentified as τ_h	$Z \to \mu\mu$	30%
	Jet misidentified as τ_h	Z boson plus jets	20–80%
	Electron ID & trigger	signal & sim. backgrounds	2–6%
	Muon ID & trigger	signal & sim. backgrounds	2–4%
	Electron energy scale	signal & sim. backgrounds	shape
	Jet energy scale	signal & sim. backgrounds	0–20%
	E_T^{miss} scale	signal & sim. backgrounds	1–12%
	$\varepsilon_{b\text{-tag}}$ b jets	signal & sim. backgrounds	0–8%
	$\varepsilon_{b\text{-tag}}$ light-flavoured jets	signal & sim. backgrounds	1–3%
Bkg estimation	Norm. Z production	Z	3%
	$Z \to \tau\tau$ category	$Z \to \tau\tau$	2–14%
	Norm. W+jets	W+jets	10–100%
	Norm. $t\bar{t}$	$t\bar{t}$	8–35%
	Norm. diboson	diboson	15–45%
	Norm. QCD multijet	QCD multijet	6–70%
	Shape QCD multijet	QCD multijet	shape
	Luminosity 7 TeV (8 TeV)	signal & sim. backgrounds	2.2% (2.6%)
Theory	PDF (qq)	signal & sim. backgrounds	4%
	PDF (gg)	signal & sim. backgrounds	10%
	Scale variation	signal	3–41%
	Underlying event & parton shower	signal	2–10%
	Limited number of events	all	bin-by-bin

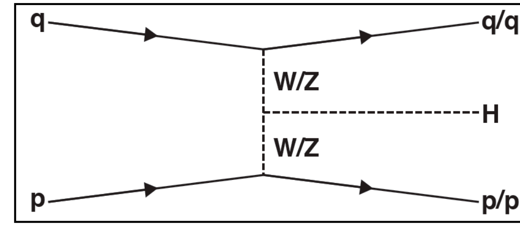
- Perform a simultaneous binned maximum likelihood fit in all channels /categories.
- Treat the uncertainties as nuisance parameters to the fit.

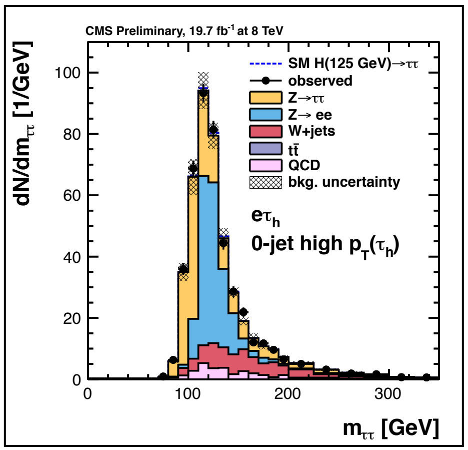
Mass plots $e\tau_h$

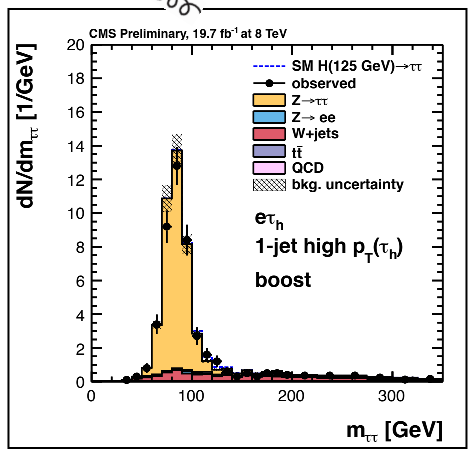
HIG-13-004

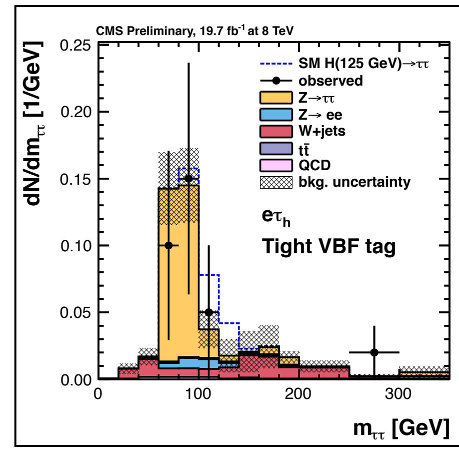


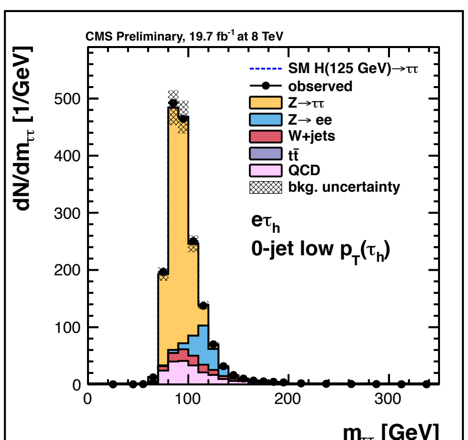


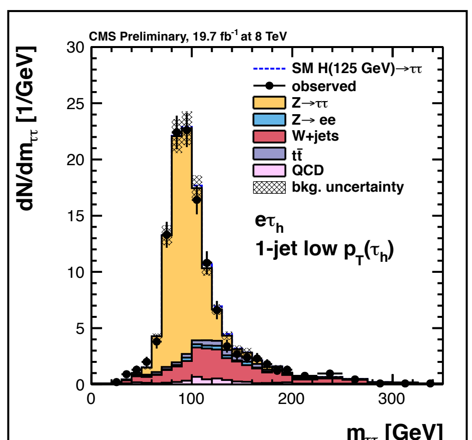


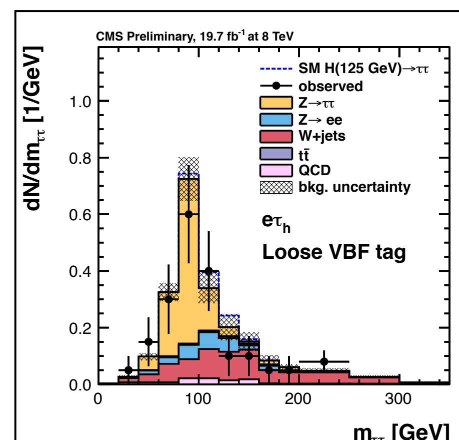












Mass plots $\mu\tau_h$

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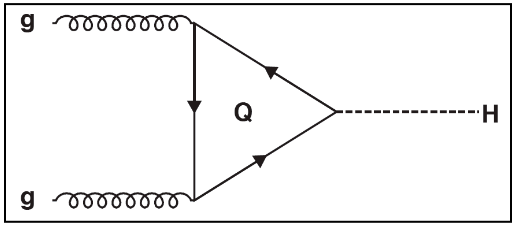

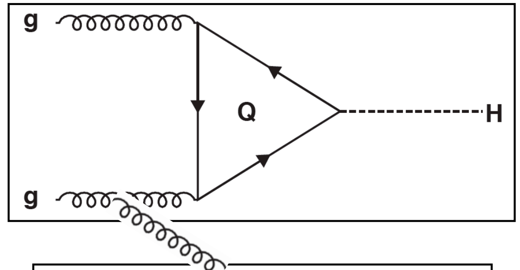

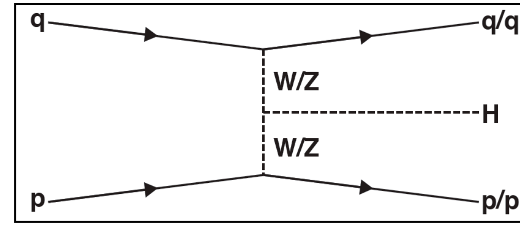

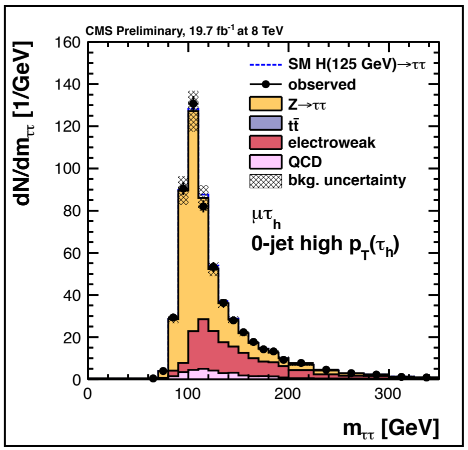

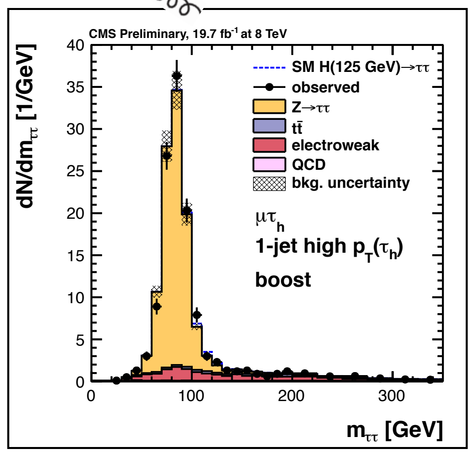

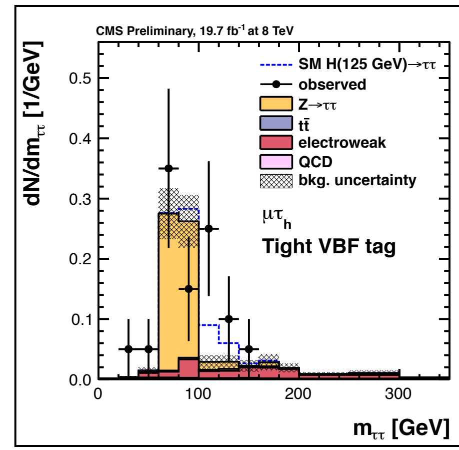

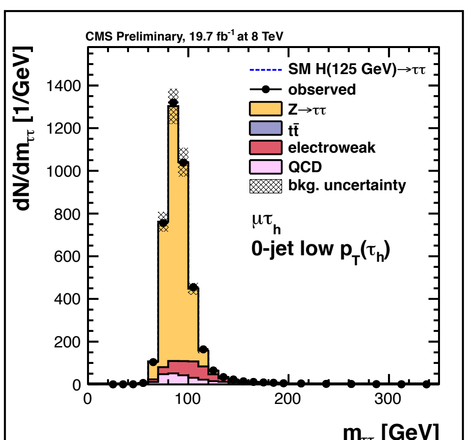

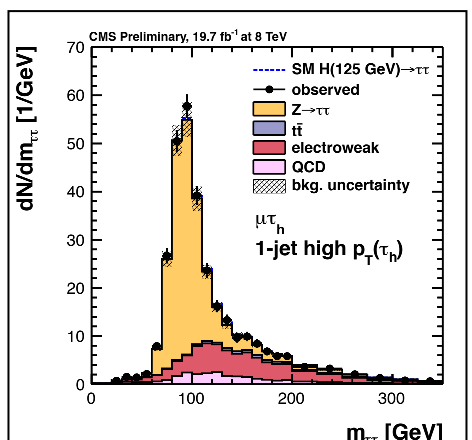

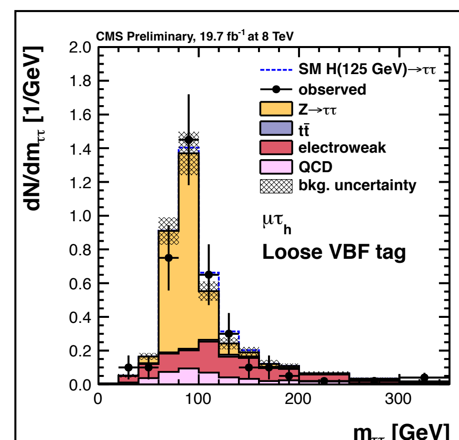

Weighted distributions

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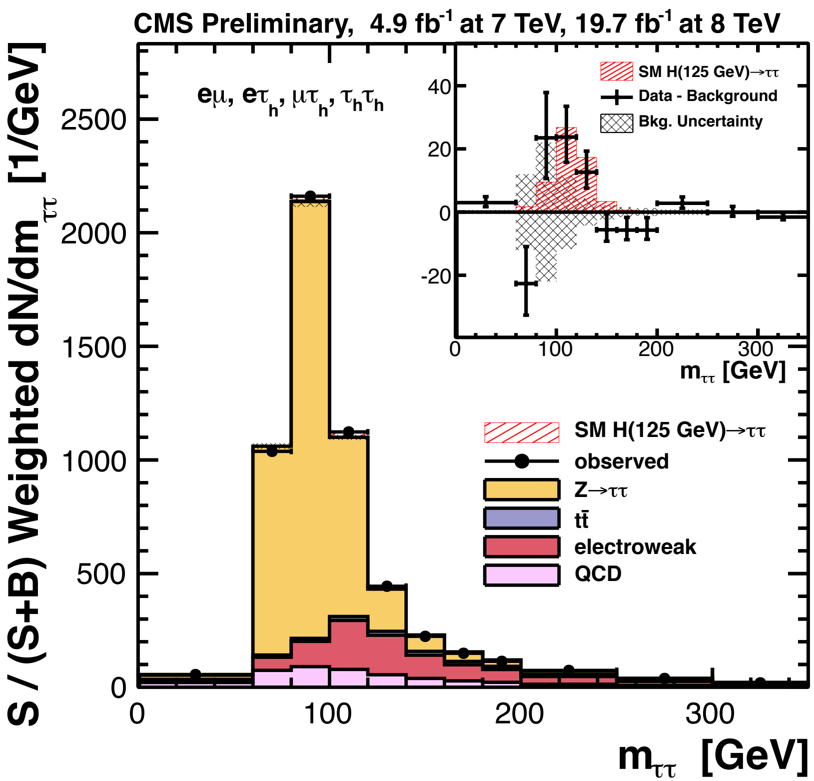
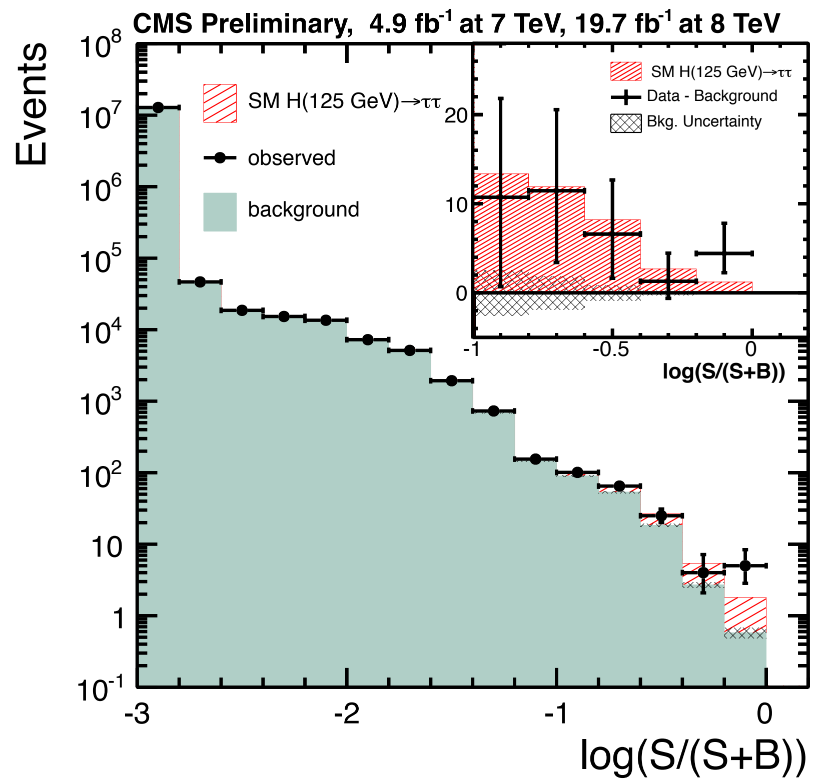
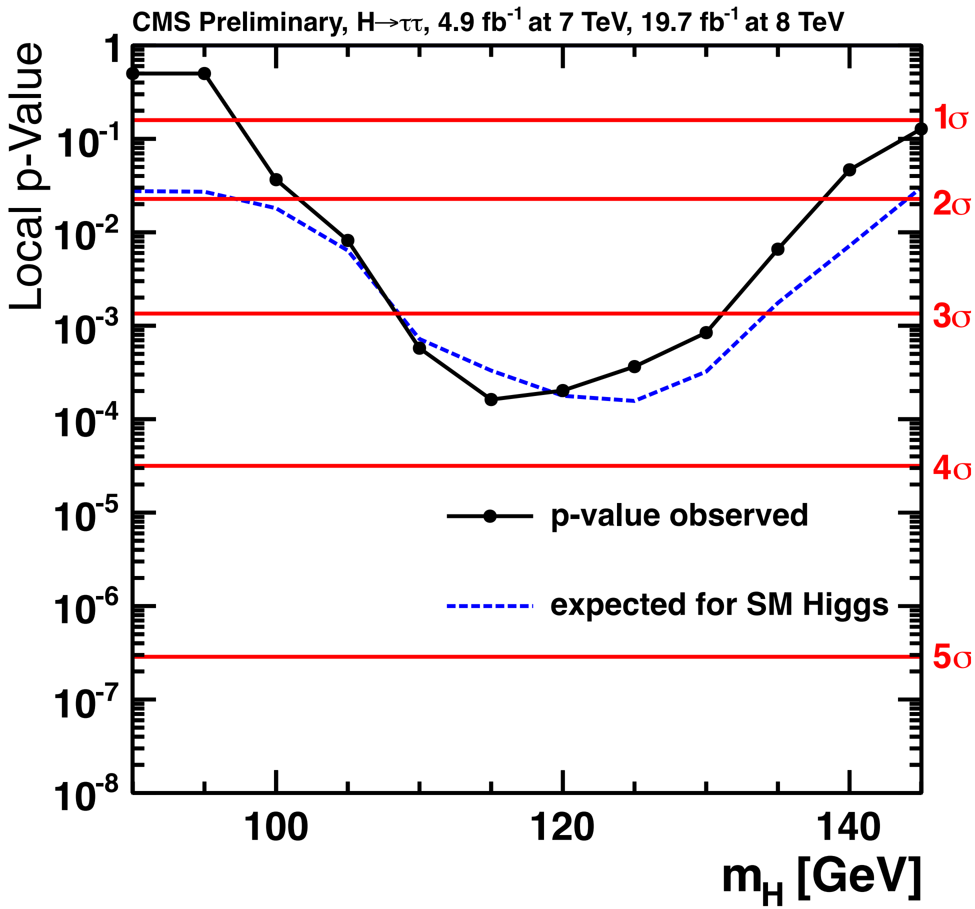




- Weighted S/S+B mass distribution.
- Combined distribution for all final states.
- Ordered in log(S/S+B) shows **clear excess** of events in the most sensitives bins.

Results : Evidence for a Higgs boson

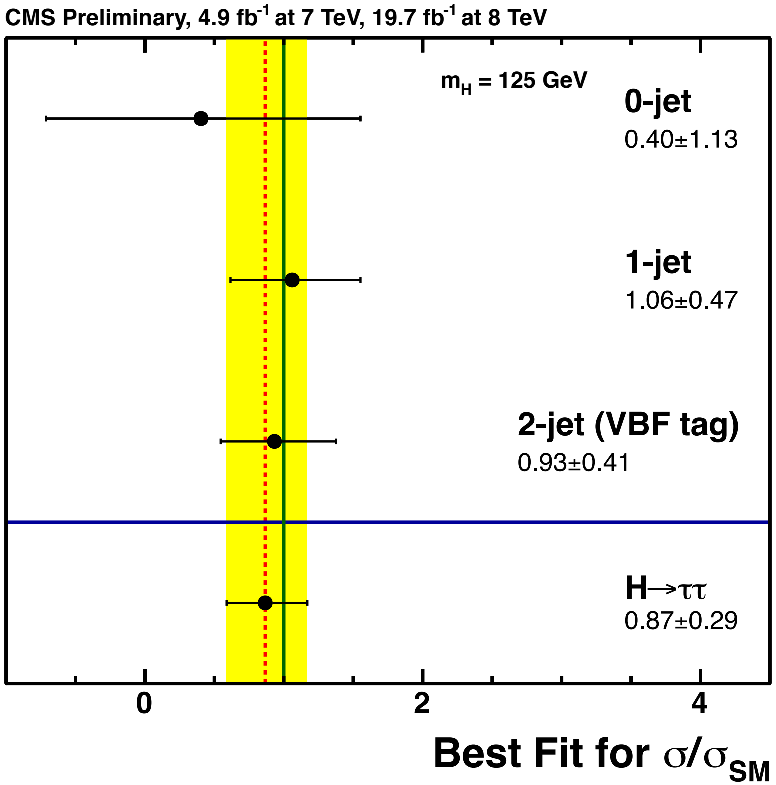
HIG-13-004

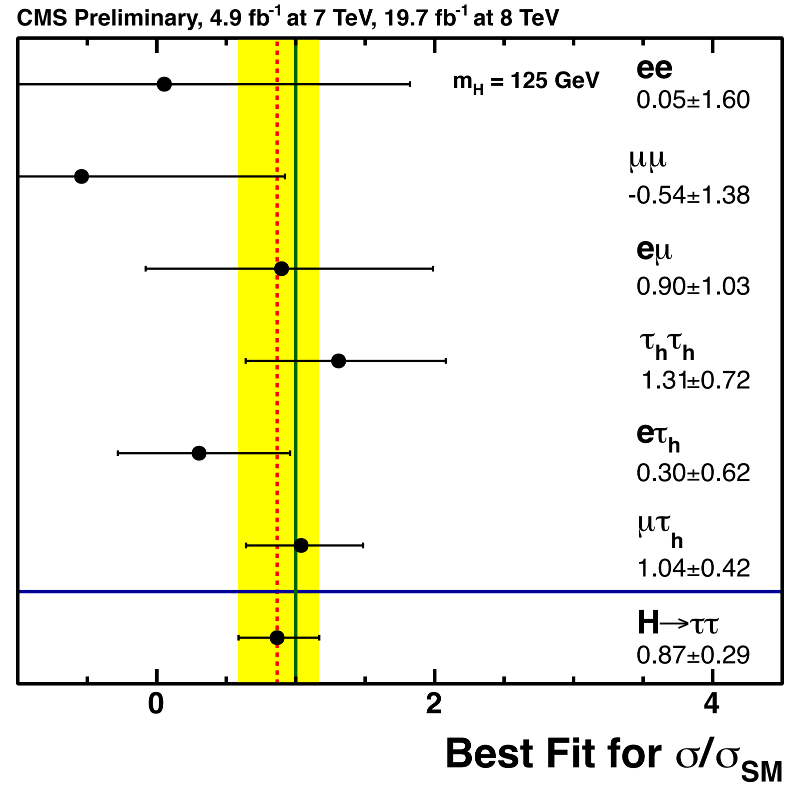


- Observed significance at 125 GeV = 3.38 σ
- Observed significance at 115 GeV = 3.59 σ
- **Excess > 3 σ for 110 < M_H < 130 GeV.**

Results : signal strength modifier

HIG-13-004

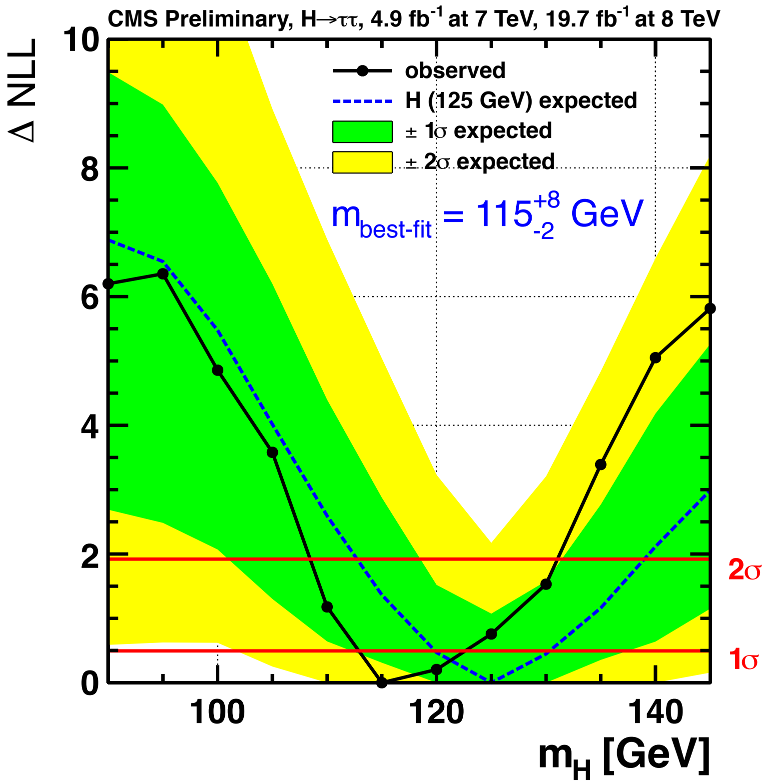


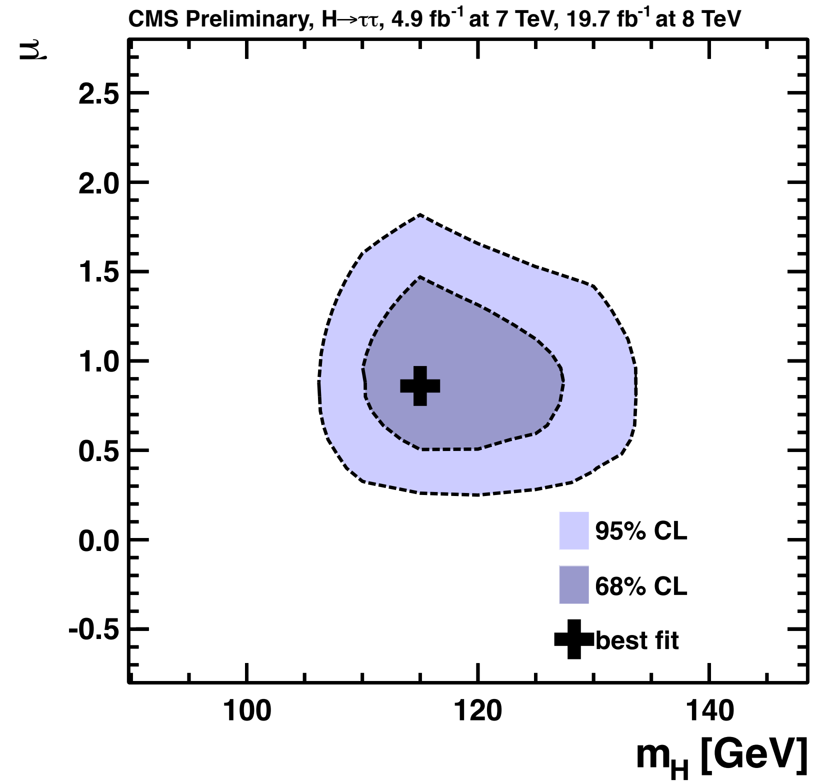


- Best fit $\mu = \sigma/\sigma_{SM} = 0.87 \pm 0.29$
- Compatible with the SM Higgs boson (125 GeV) prediction.

Results : mass measurement

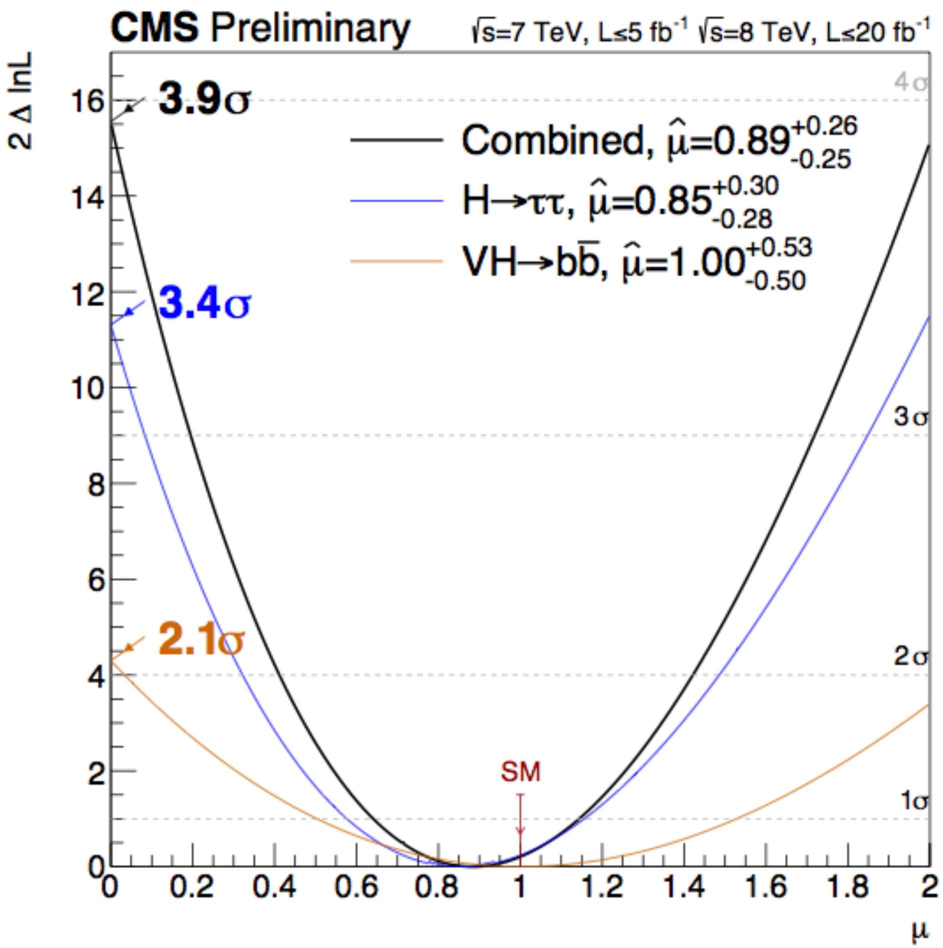
HIG-13-004





- Likelihood scan gives $m_H = 115_{-2}^{+8}$ GeV.
- Compatible with the measurements in high resolution channels (γγ, ZZ). m_H = 125.7±0.3(stat) ±0.3(syst) GeV
- Best fit of μ shows compatibility with H_{125}.

Combination with H→bb at m_H = 125 GeV

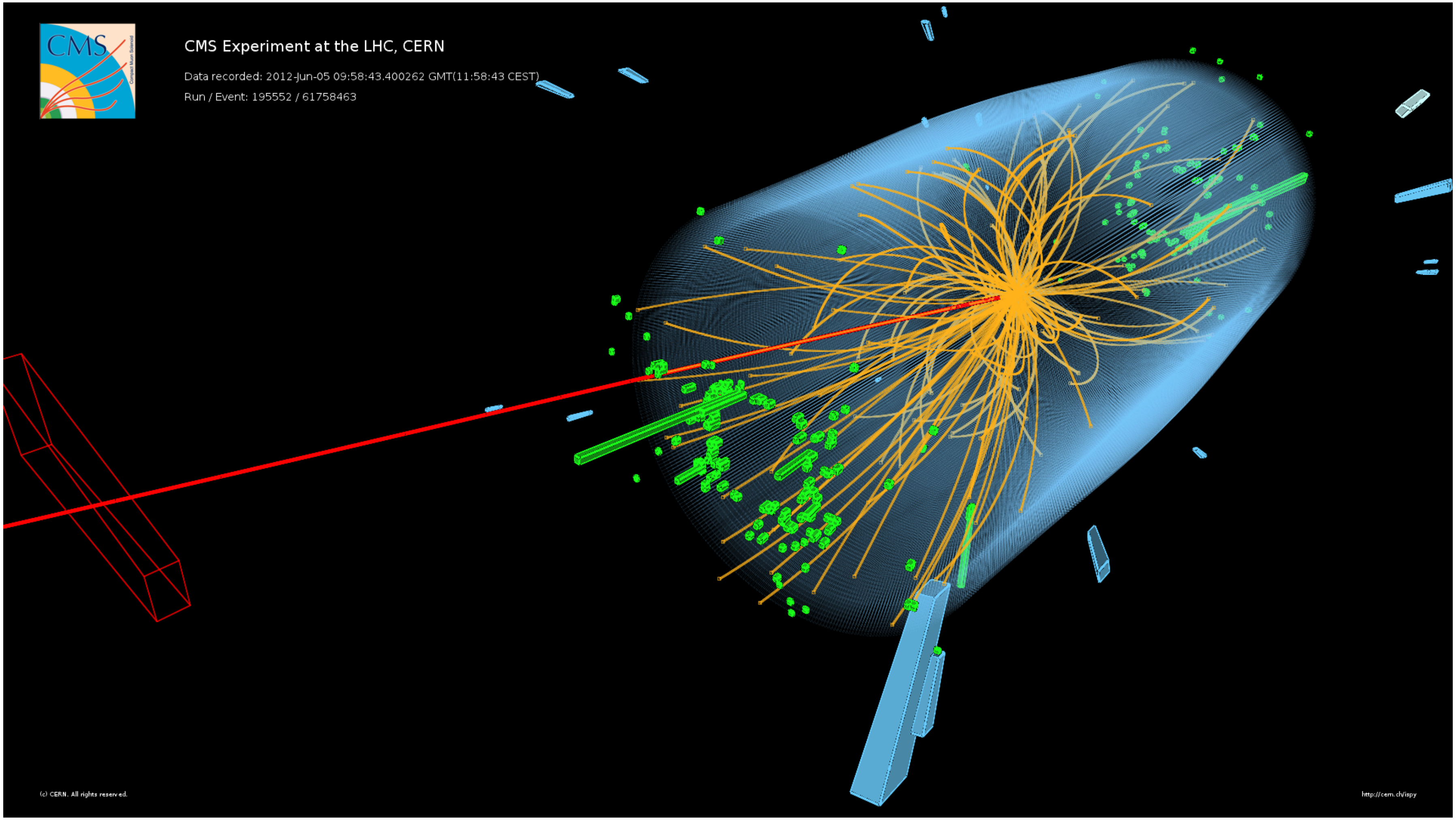


- H→bb observed (expected) significance at 125 GeV = 2.1 (2.3) **σ**
- H→**ττ** observed (expected) significance at 125 GeV = 3.4 (3.6) **σ**
- **Combination** observed (expected) significance at 125 GeV = **3.9** (4.3) **σ**

Summary

- $H \rightarrow \tau\tau$ analysis successful thanks to Particle Flow, τ lepton, ME_T and di-τ mass reconstruction.
- **Excess of more than 3 σ for 110 < M_H < 130 GeV.**
- Significance at 125 GeV = 3.38 σ
- Best fit $\mu = \sigma/\sigma_{SM} = 0.87 \pm 0.29$
- $H \rightarrow \tau\tau$ analysis shows compatibility with SM H(125). **Evidence** that the new boson discovered couples to τ leptons.
- Combination with $H \rightarrow bb$ leads to 3.9 σ evidence of fermionic Higgs decays.

Thank you. Questions?



Back up Material

Yields $\mu\tau_h$

Event category	ggH	VBF	VH	tot Signal	tot. Background	Data	S/(S+B)	H125 width [GeV]
0-jet low p_T^τ 7 TeV	21.9	0.2	0.1	22.3 ± 3.3	11969 ± 716	11959	0.002	17.4
0-jet low p_T^τ 8 TeV	82.9	0.8	0.4	84.1 ± 11.6	40839 ± 2316	40353	0.003	16.2
0-jet high p_T^τ 7 TeV	16.6	0.2	0.2	17.0 ± 2.5	1595 ± 95	1594	0.021	15.1
0-jet high p_T^τ 8 TeV	65.4	0.7	0.7	66.8 ± 9.3	6000 ± 302	5789	0.020	15.2
1-jet low p_T^τ 7 TeV	8.7	1.6	0.8	11.0 ± 1.6	2021 ± 133	2047	0.012	18.8
1-jet low p_T^τ 8 TeV	36.0	6.2	3.1	45.3 ± 6.0	9035 ± 430	9010	0.010	18.6
1-jet high p_T^τ 7 TeV	7.3	1.1	0.6	9.0 ± 1.2	796 ± 45	817	0.032	19.1
1-jet high p_T^τ 8 TeV	29.6	4.4	2.5	36.5 ± 4.7	3182 ± 153	3160	0.029	19.7
1-jet high p_T^τ, higgs boosted 7 TeV	2.4	0.7	0.5	3.6 ± 0.6	282 ± 19	269	0.052	17.7
1-jet high p_T^τ, higgs boosted 8 TeV	11.3	3.0	2.1	16.5 ± 2.6	1264 ± 73	1253	0.071	17.2
VBF tag 7 TeV	0.2	1.3	-	1.5 ± 0.2	22 ± 2	23	0.14	19.6
loose VBF tag 8 TeV	1.2	3.5	-	4.7 ± 0.4	80 ± 7	76	0.18	17.0
tight VBF tag 8 TeV	0.4	2.1	-	2.5 ± 0.2	15 ± 2	20	0.51	18.1

Yields $e\tau_h$

Event category	ggH	VBF	VH	tot Signal	tot. Background	Data	S/(S+B)	H125 width [GeV]
0-jet low p_T^τ 7 TeV	11.7	0.1	0.1	11.9 ± 1.8	6153 ± 368	6238	0.002	16.4
0-jet low p_T^τ 8 TeV	35.0	0.4	0.2	35.6 ± 4.9	16825 ± 879	17109	0.003	15.8
0-jet high p_T^τ 7 TeV	11.0	0.1	0.1	11.2 ± 1.7	1169 ± 69	1191	0.015	14.3
0-jet high p_T^τ 8 TeV	32.7	0.3	0.3	33.4 ± 4.7	4393 ± 194	4536	0.010	15.4
1-jet low p_T^τ 7 TeV	3.1	0.6	0.3	4.0 ± 0.6	368 ± 27	385	0.028	19.6
1-jet low p_T^τ 8 TeV	9.6	1.9	1.1	12.6 ± 1.7	1208 ± 64	1214	0.026	16.5
1-jet high p_T^τ, higgs boosted 7 TeV	1.2	0.3	0.2	1.8 ± 0.3	151 ± 10	167	0.088	15.4
1-jet high p_T^τ, higgs boosted 8 TeV	5.4	1.5	1.0	7.9 ± 1.2	500 ± 30	476	0.11	15.5
VBF tag 7 TeV	0.2	0.7	-	0.9 ± 0.1	14 ± 2	13	0.23	15.9
loose VBF tag 8 TeV	0.6	1.8	-	2.5 ± 0.2	45 ± 4	40	0.15	16.8
tight VBF tag 8 TeV	0.3	1.3	-	1.6 ± 0.1	9 ± 1	7	0.52	16.1

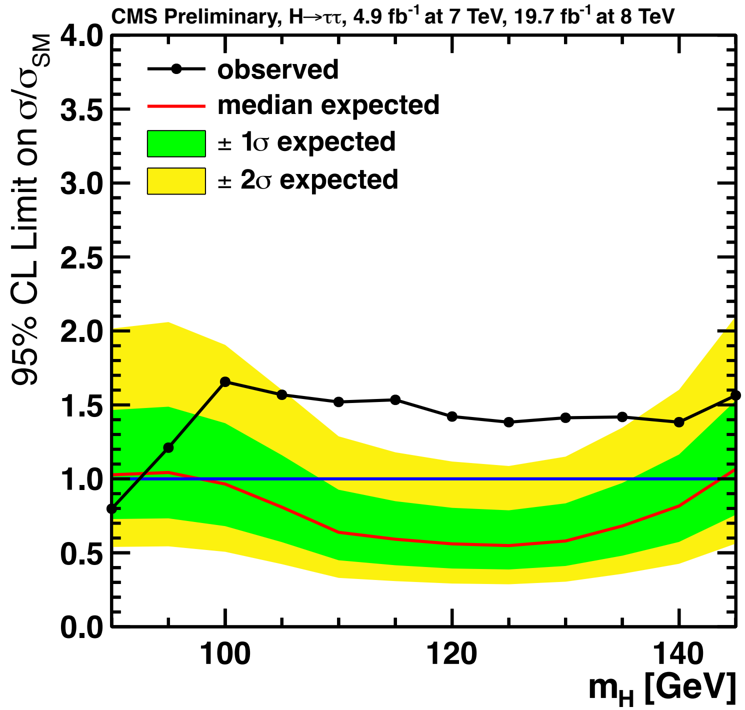
Yields $\tau_h\tau_h$ and eμ

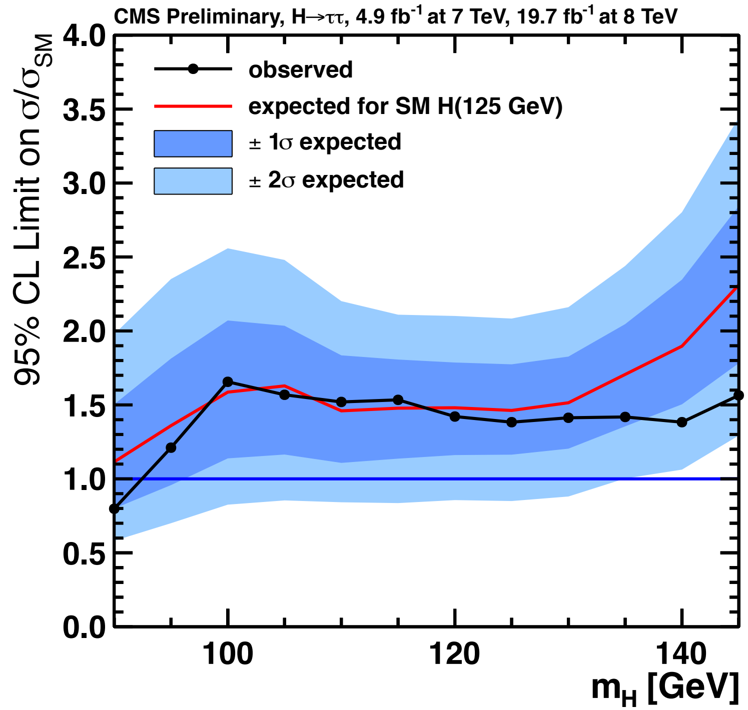
Event category	ggH	VBF	VH	tot Signal	tot. Background	Data	S/(S+B)	H125 width [GeV]
1-jet boost 8 TeV	7.3	2.1	1.0	10.4 ± 1.7	1130 ± 56	1120	0.055	15.2
1-jet large-boost 8 TeV	5.6	1.6	1.2	8.4 ± 1.2	375 ± 26	366	0.14	13.1
VBF tag 8 TeV	0.5	2.5	-	3.1 ± 0.3	29 ± 4	34	0.33	14.3

Event category	ggH	VBF	VH	tot Signal	tot. Background	Data	S/(S+B)	H125 width [GeV]
0-jet low p_T^μ 7 TeV	21.4	0.2	0.2	21.8 ± 3.1	11320 ± 324	11283	0.002	24.4
0-jet low p_T^μ 8 TeV	72.3	0.7	0.7	73.7 ± 9.9	40496 ± 1085	40381	0.002	23.6
0-jet high p_T^μ 7 TeV	7.8	0.1	0.1	8.0 ± 1.1	1638 ± 60	1676	0.007	22.7
0-jet high p_T^μ 8 TeV	24.6	0.2	0.5	25.4 ± 3.4	6005 ± 178	6095	0.006	20.7
1-jet low p_T^μ 7 TeV	8.6	1.6	1.0	11.2 ± 1.4	2470 ± 83	2482	0.007	23.7
1-jet low p_T^μ 8 TeV	40.4	6.5	3.7	50.6 ± 6.1	10910 ± 299	10926	0.006	23.8
1-jet high p_T^μ 7 TeV	4.4	1.0	0.6	6.0 ± 0.8	918 ± 39	901	0.012	23.4
1-jet high p_T^μ 8 TeV	18.1	3.4	2.6	24.0 ± 3.0	4039 ± 120	4050	0.011	23.1
VBF tag 7 TeV	0.2	0.9	-	1.1 ± 0.1	18 ± 1	12	0.10	22.8
loose VBF tag 8 TeV	0.6	2.6	-	3.2 ± 0.3	97 ± 6	112	0.050	23.5
tight VBF tag 8 TeV	0.2	1.4	-	1.6 ± 0.1	14 ± 1	17	0.18	17.9

Results : 95% CL_s upper limits on σ

HIG-13-004





- After a binned maximum likelihood fit in all channels / categories
- Excess of events over a broad range vs mH hypothesis.
- Excess compatible with the SM Higgs boson (125 GeV) prediction.

Fermion/Vector couplings

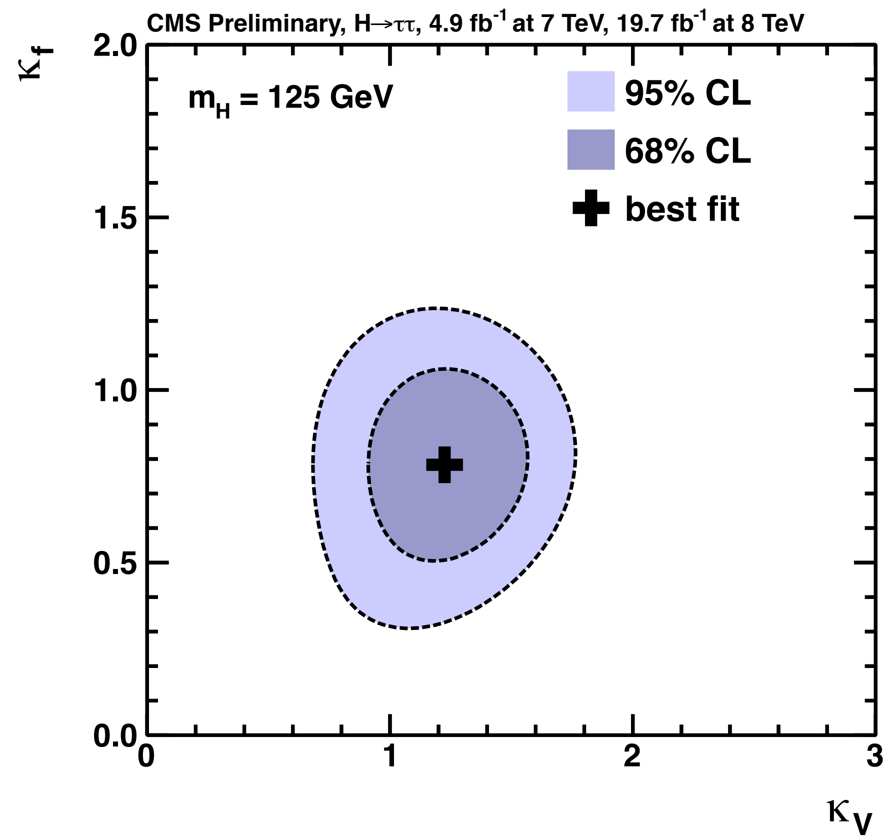
HIG-13-004

Vector and fermion couplings grouped

κ_V: $\kappa_W = \kappa_Z$

κ_F: $\kappa_t = \kappa_b = \kappa_\tau = \kappa_g$

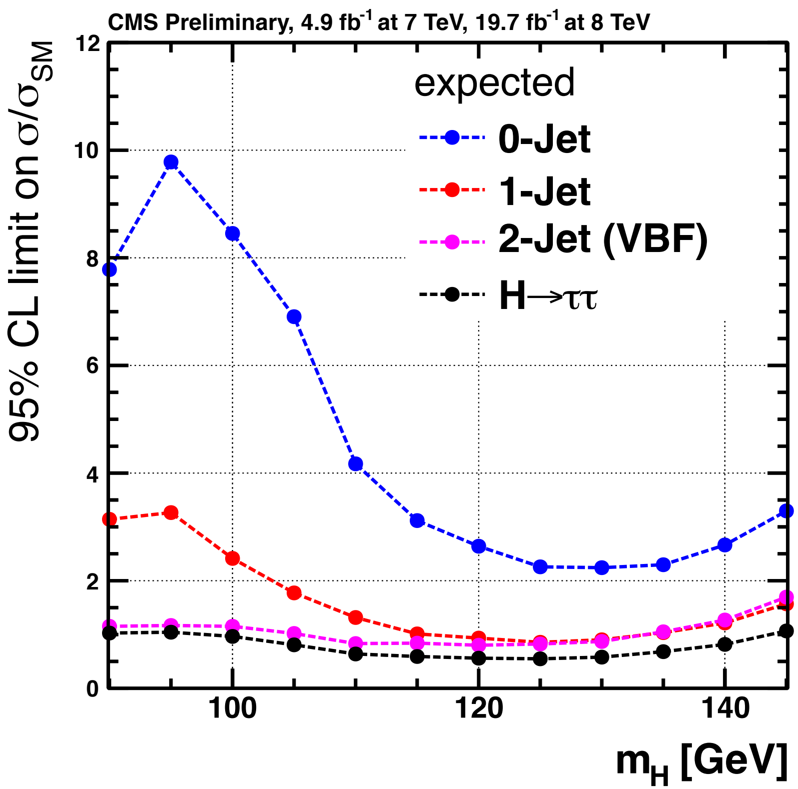
Only SM particles in the loop for κ_g & κ_γ

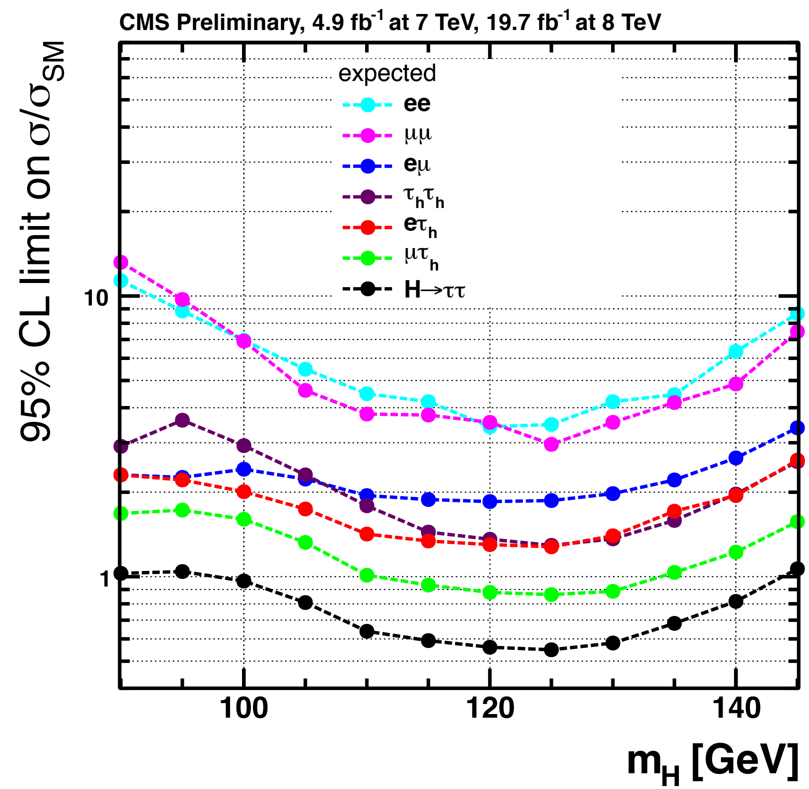


- Likelihood scans as a function of κ_V and κ_F.
- $H \rightarrow WW$ contribution is considered as part of the signal.
- Compatible with the SM ($\kappa_V = \kappa_F = 1$)

Channels/categories sensitivity

HIG-13-004

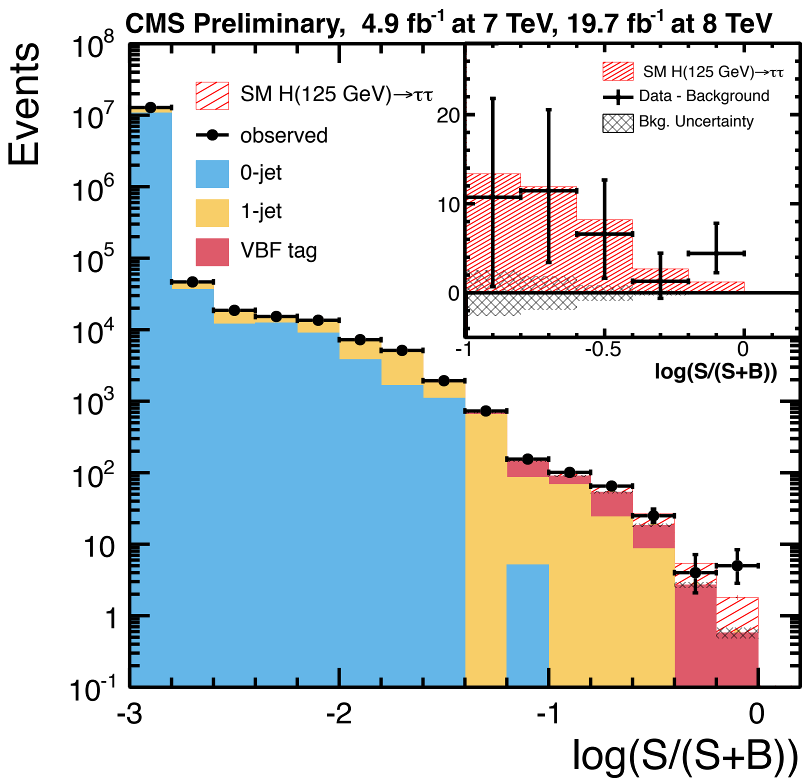


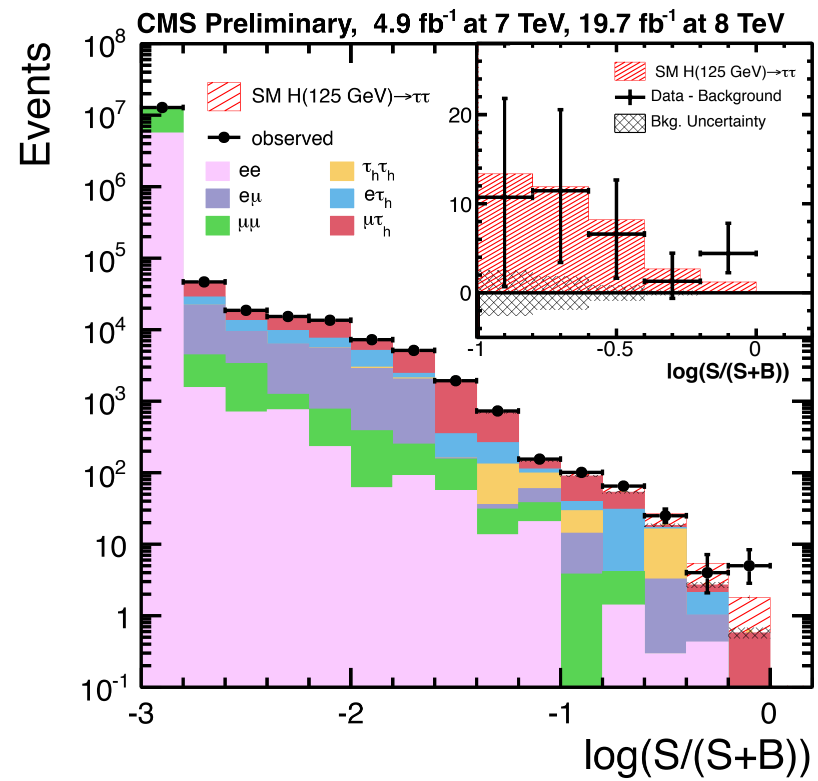


- VBF tag most sensitive category followed by 1jet.
- $\mu\tau_h$ most sensitive channel followed by $e\tau_h$ and $\tau_h\tau_h$.

Combined distributions

HIG-13-004

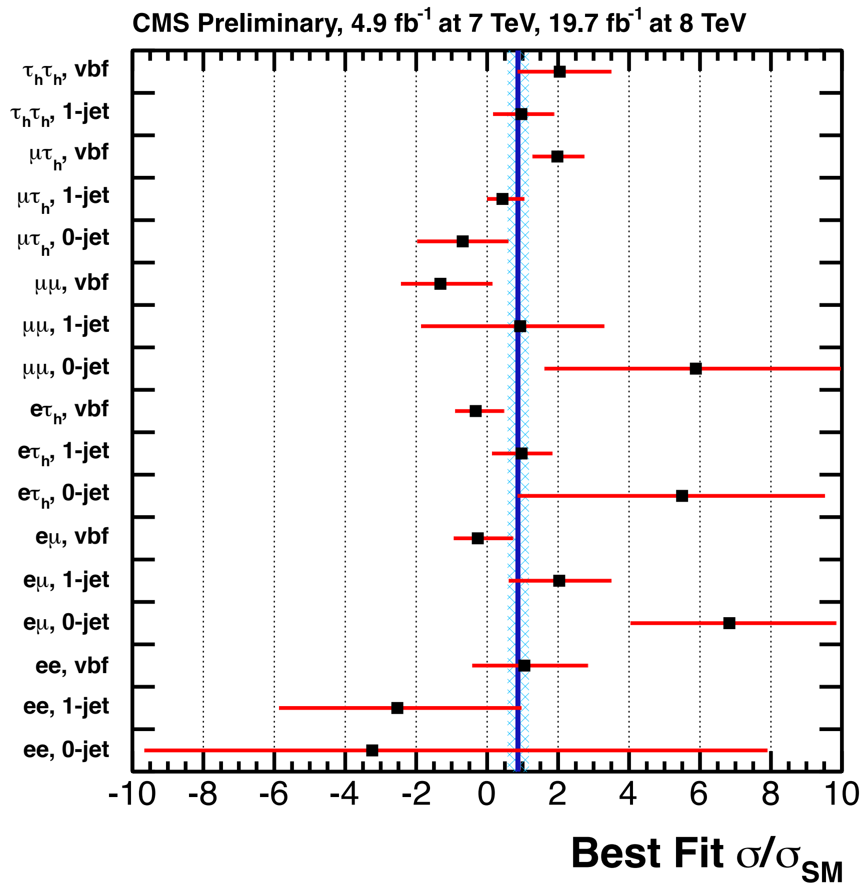




- Combined distribution ordered in log(S/S+B) shows clear excess of events in the most sensitives bins.
- Separately for category (left) and channel (right).

Channel compatibility

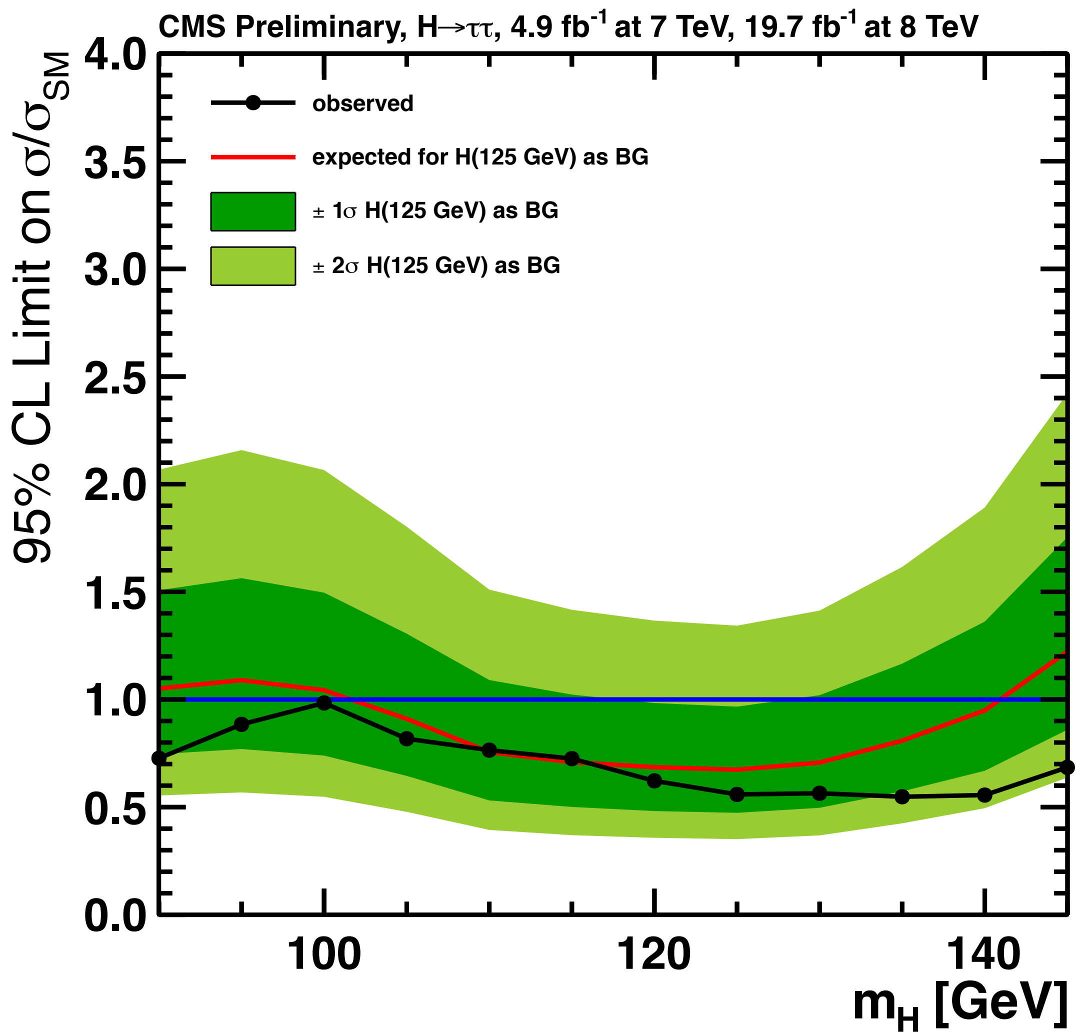
HIG-13-004



- All channels are fairly compatible.

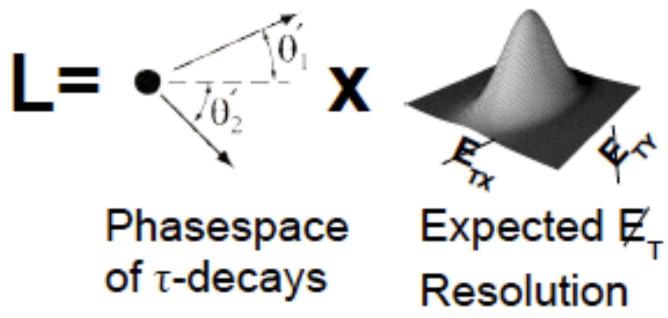
H_{125} as background

HIG-13-004

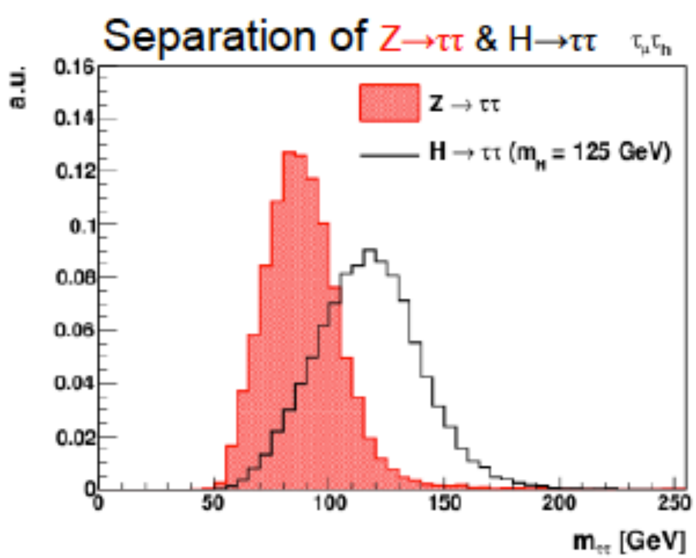


DiTau mass reconstruction

- Determine invariant mass of di-τ system with maximum likelihood method.

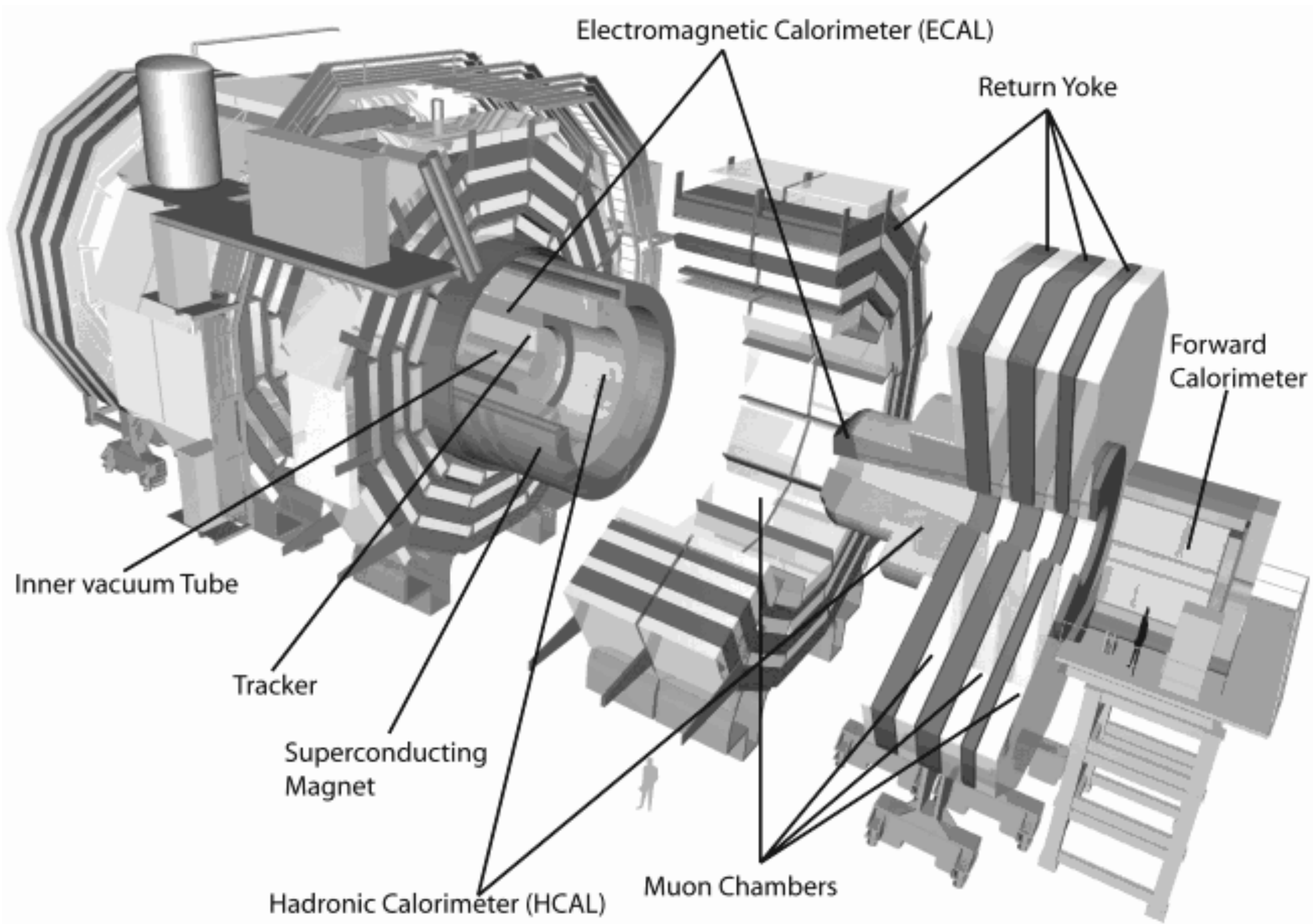


- Estimate for di-τ system, to be real for given value of $m_{\tau\tau}$.
- Inputs: four-vector information of visible leptons, x- and y- component of $\not{E}_T$ on event by event basis.
- Free parameters: φ, θ*, ($m_{\upsilon\upsilon}$) per τ-lepton (4-6 parameters).
- Full integration of kernel. Scan of $m_{\tau\tau}$ from m_{τ} up to 2TeV.
- 15-20% resolution of the reconstructed $m_{\tau\tau}$ mass.



6

CMS detector



Limits

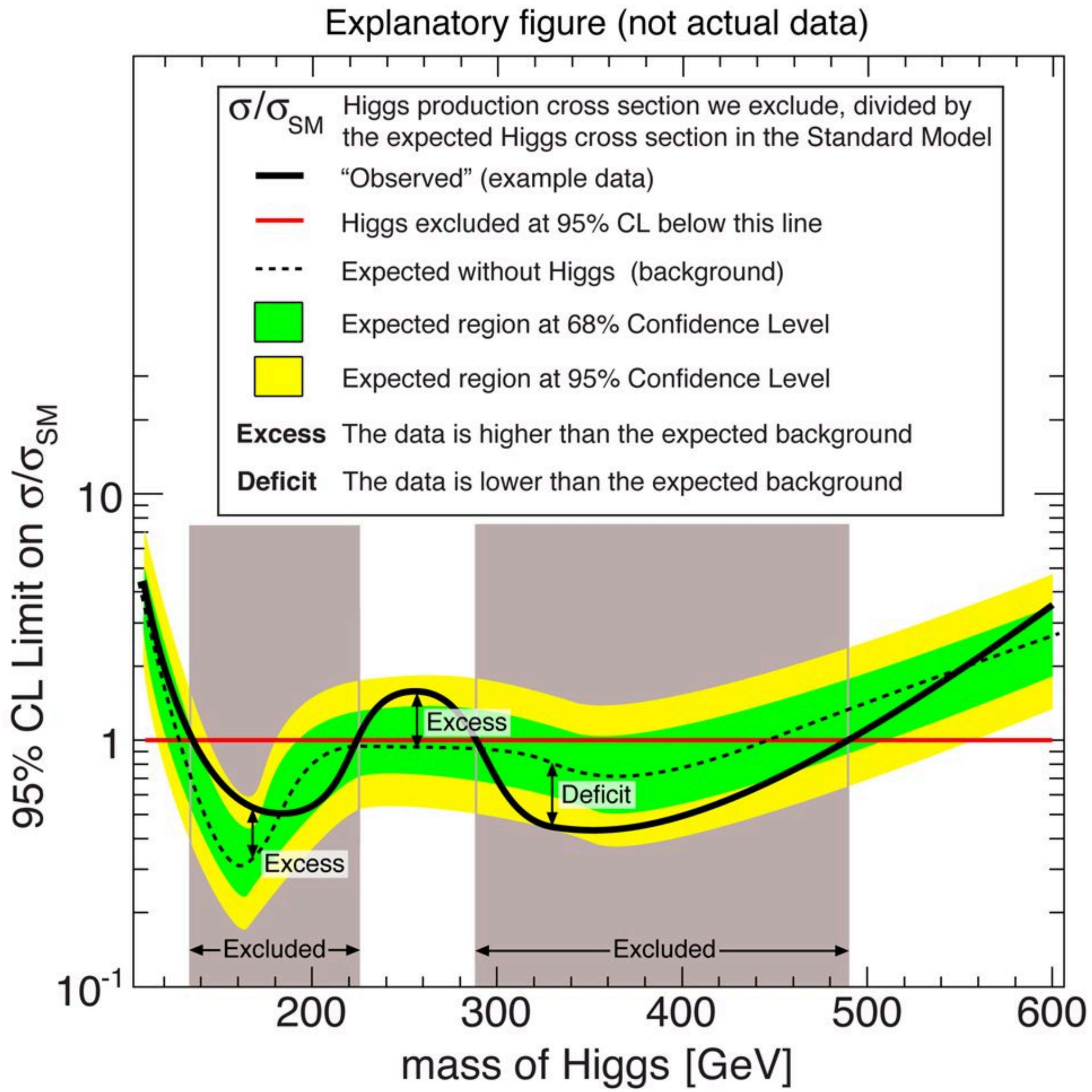
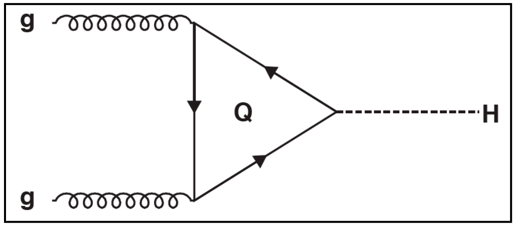


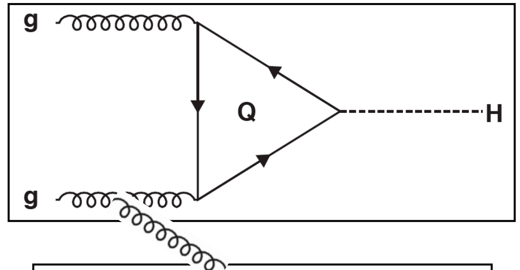
Figure A

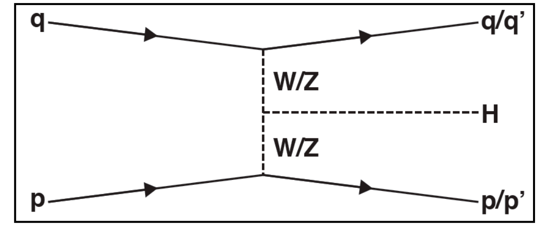
Mass plots 8 TeV

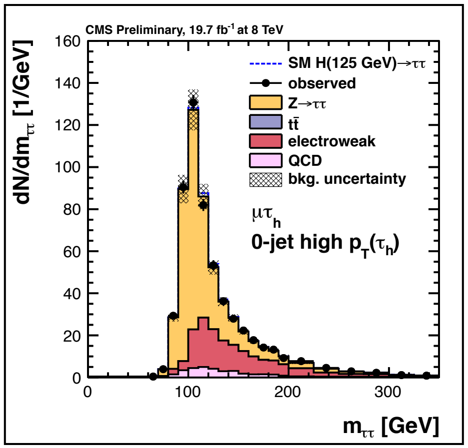
Mass plots $\mu\tau_h$

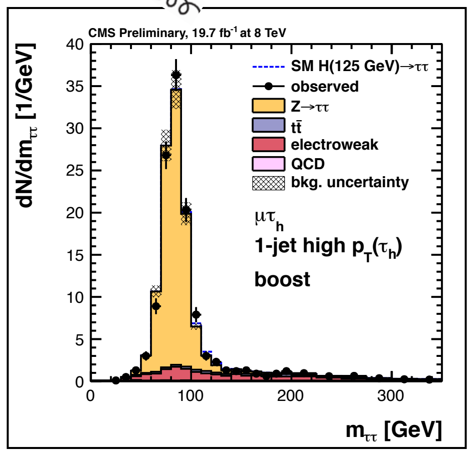
HIG-13-004

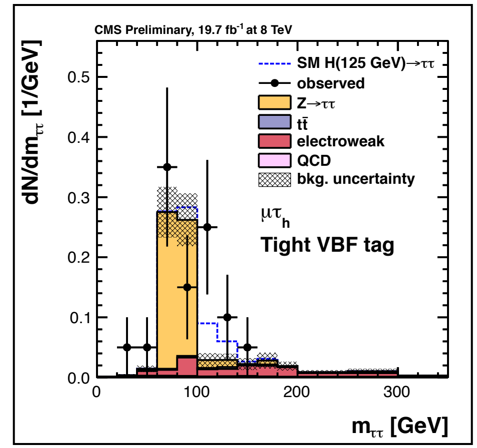


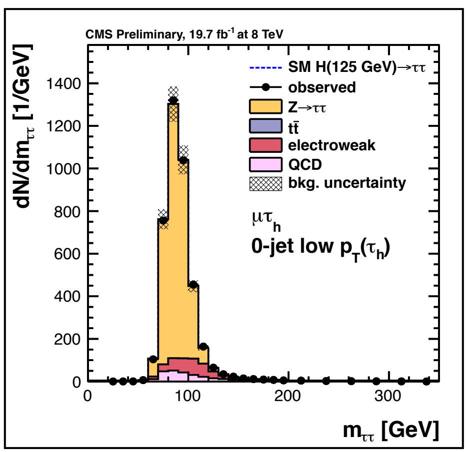


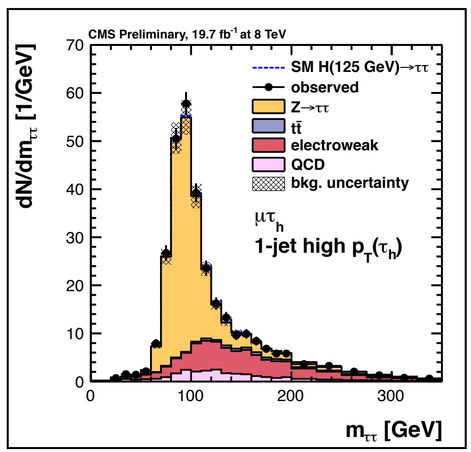


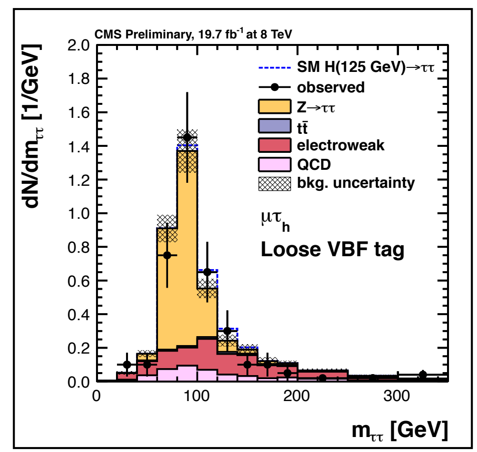






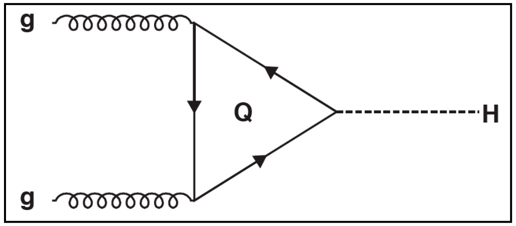


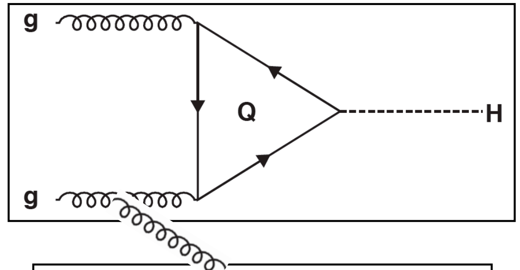


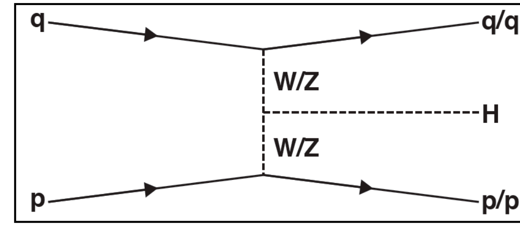


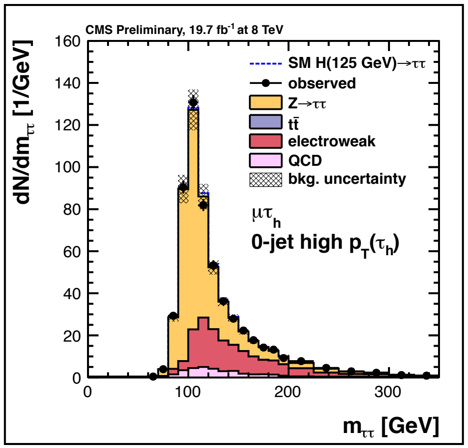
Mass plots $\mu\tau_h$

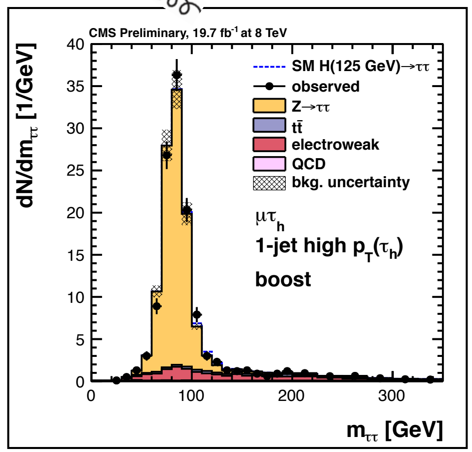
HIG-13-004

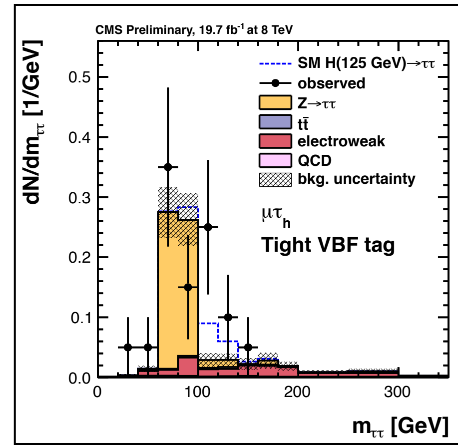


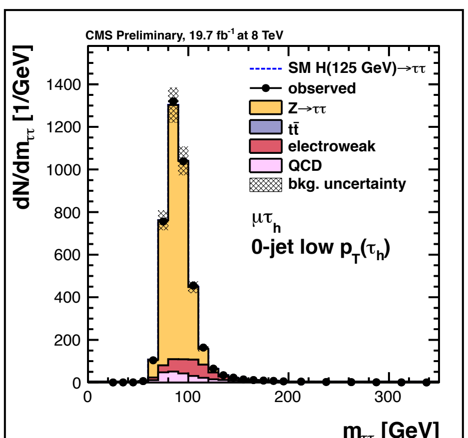


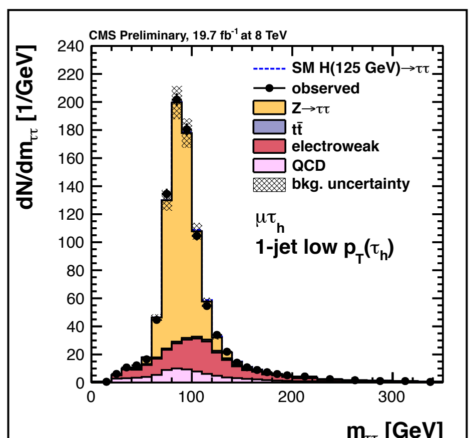


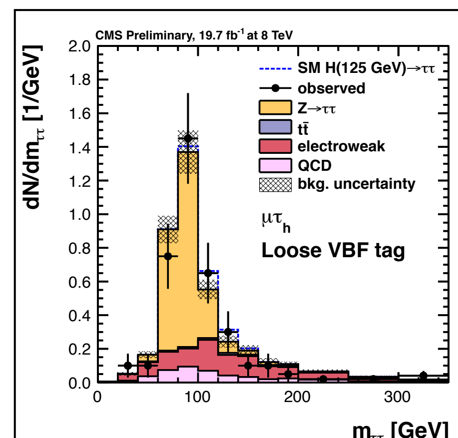






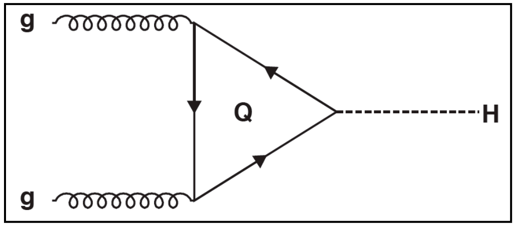


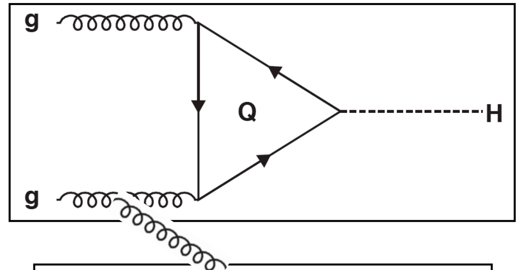


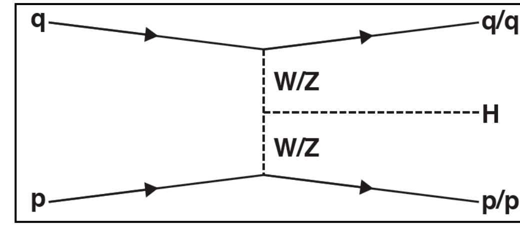


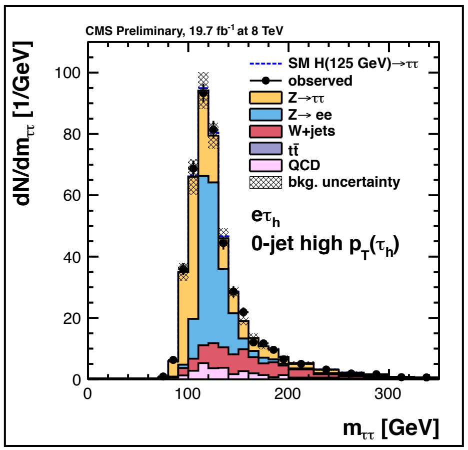
Mass plots $e\tau_h$

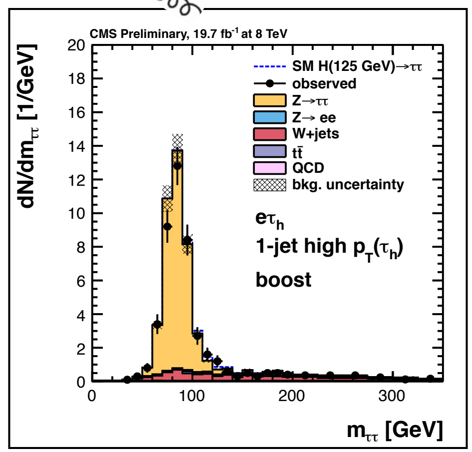
HIG-13-004

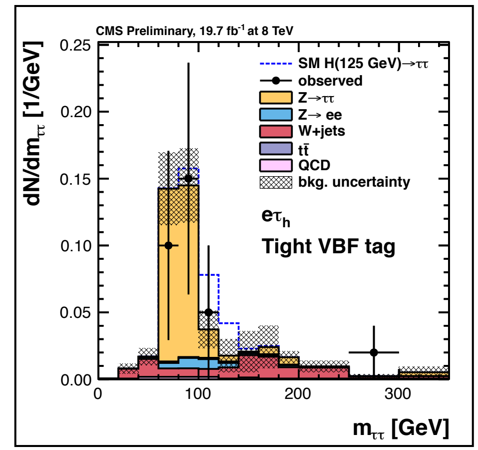


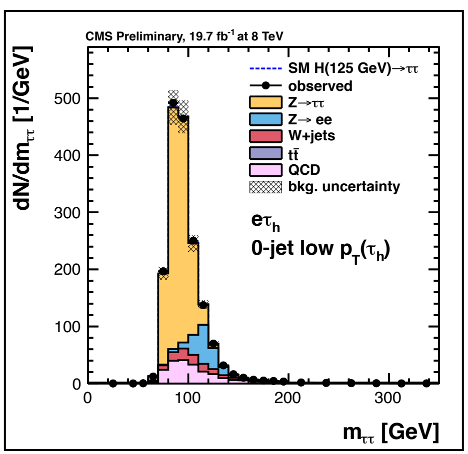


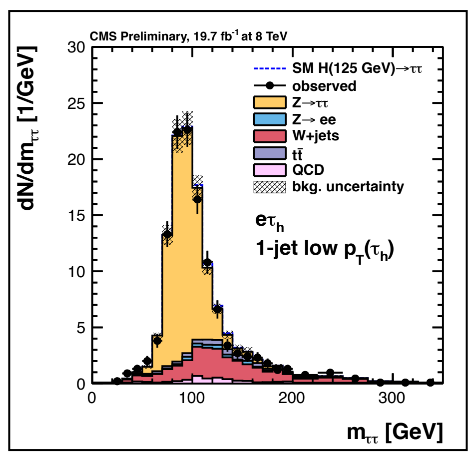


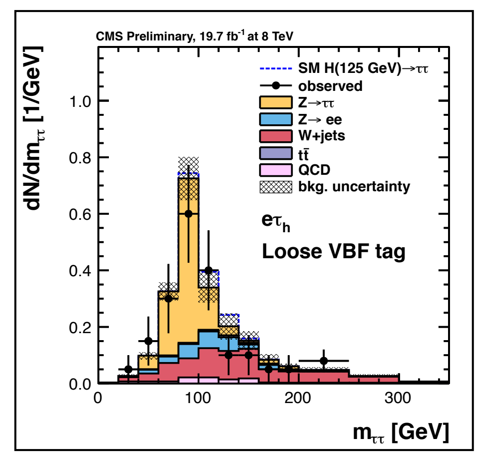






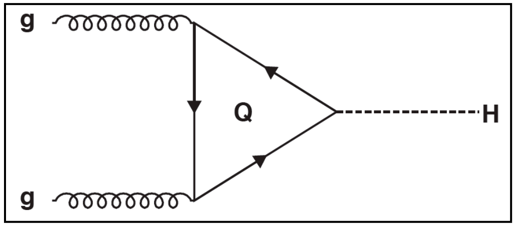


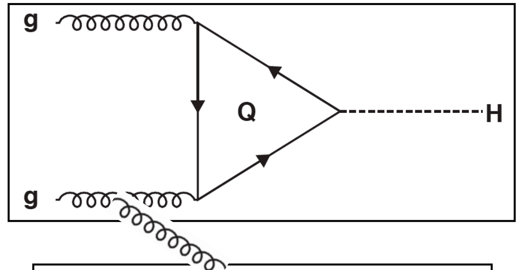


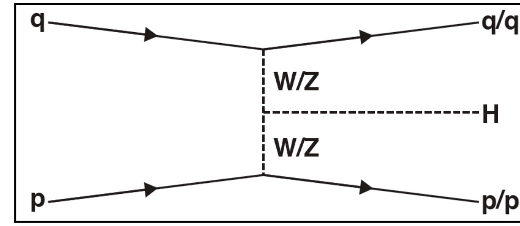


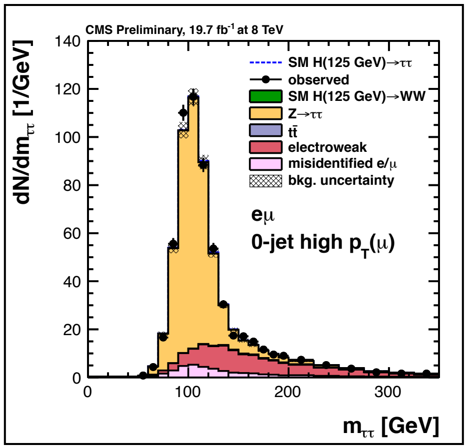
Mass plots eμ

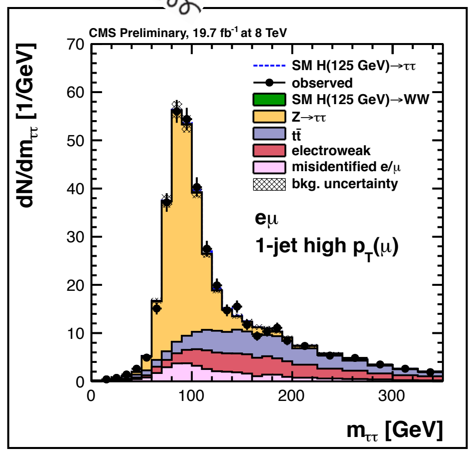
HIG-13-004

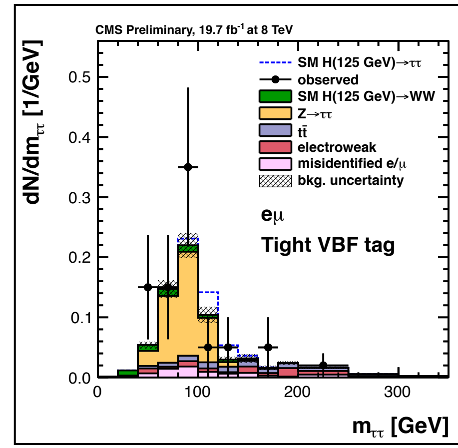


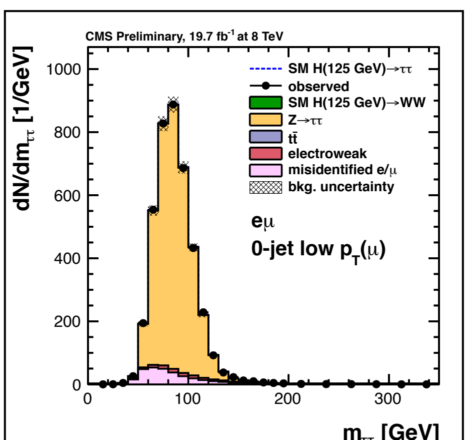


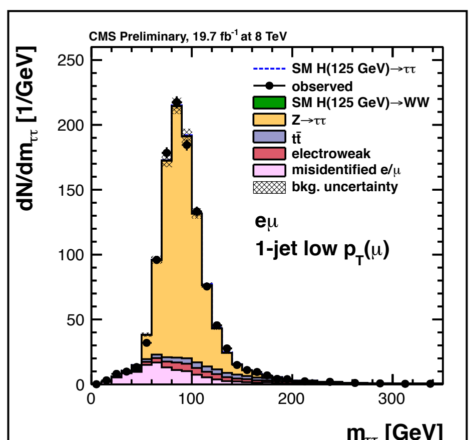


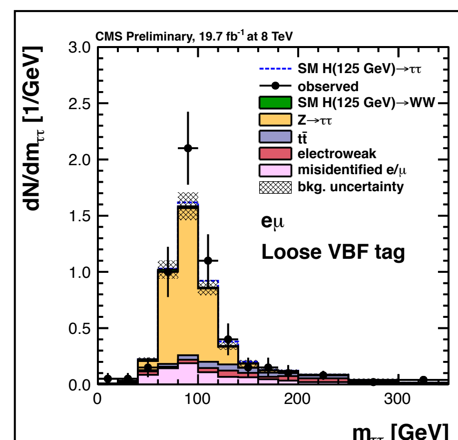






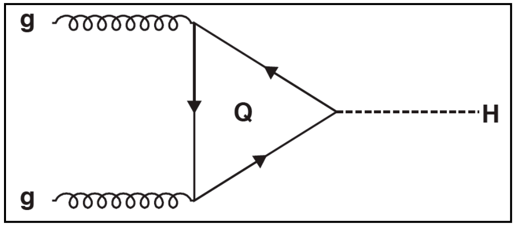


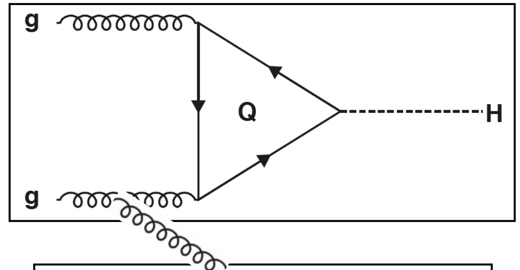


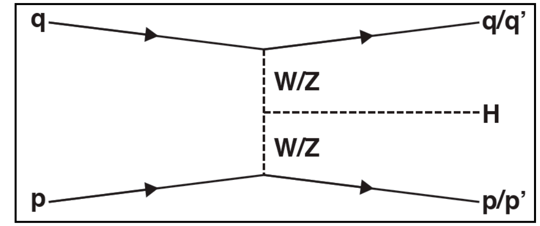


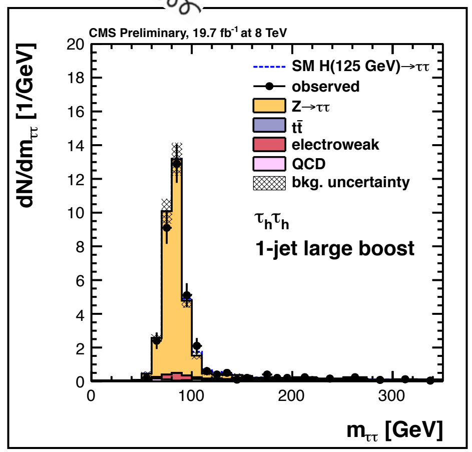
Mass plots $\tau_h\tau_h$

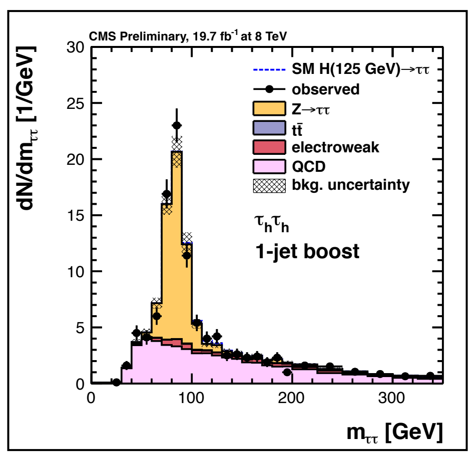
HIG-13-004

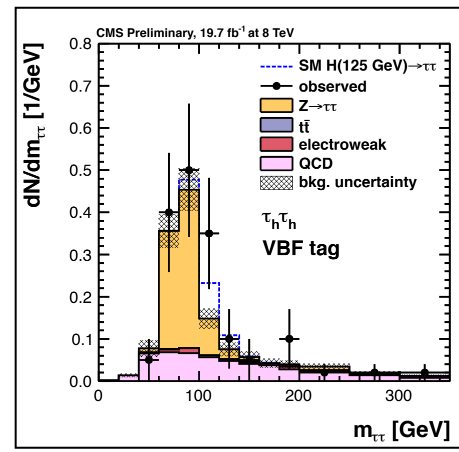






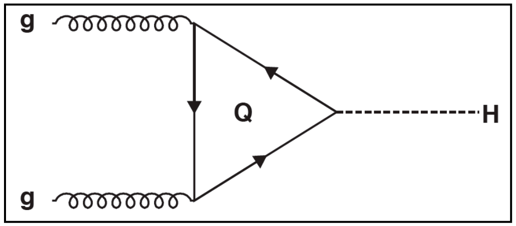


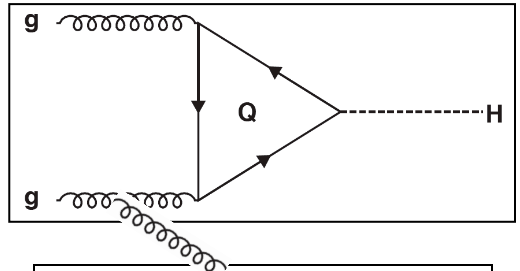


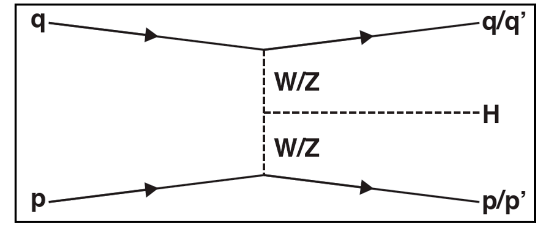


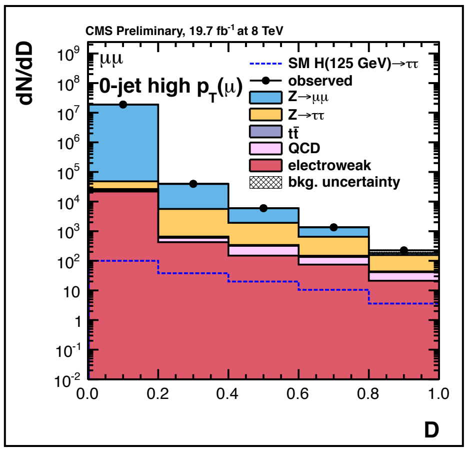
Mass plots μμ

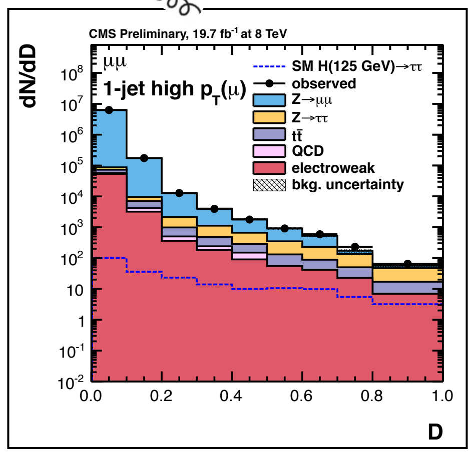
HIG-13-004

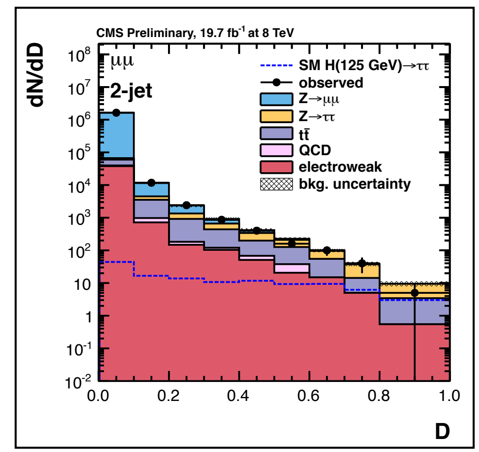


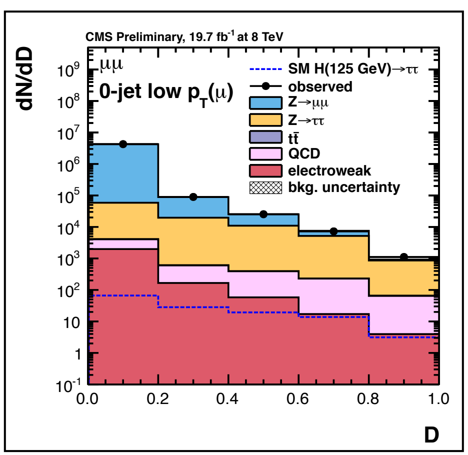


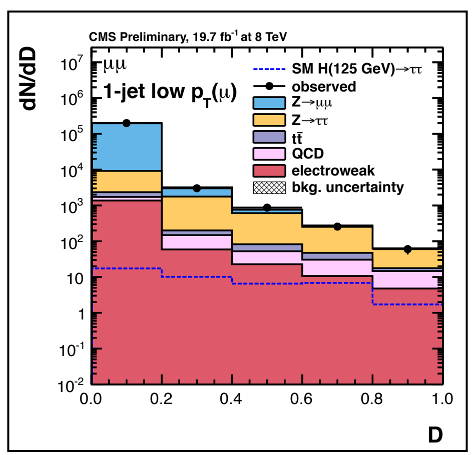






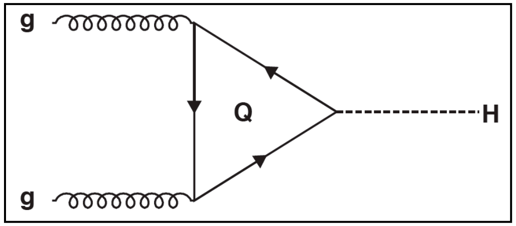


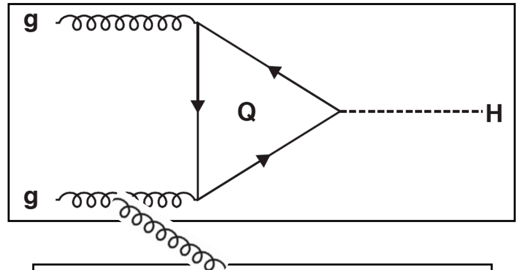


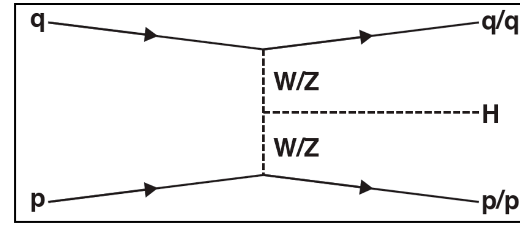


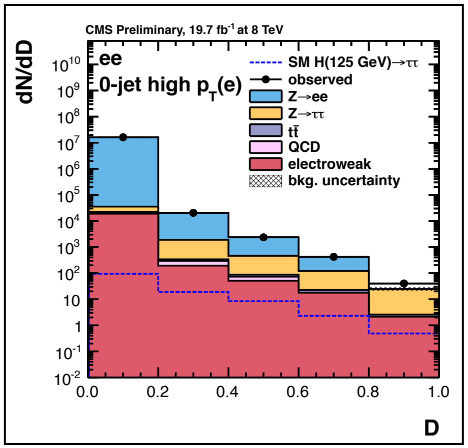
Mass plots ee

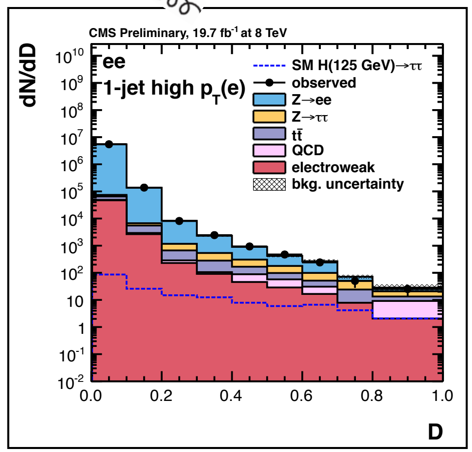
HIG-13-004

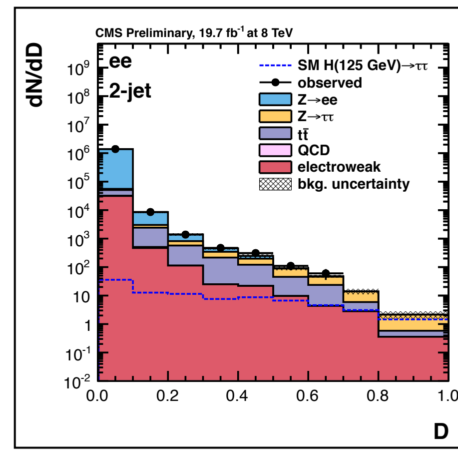


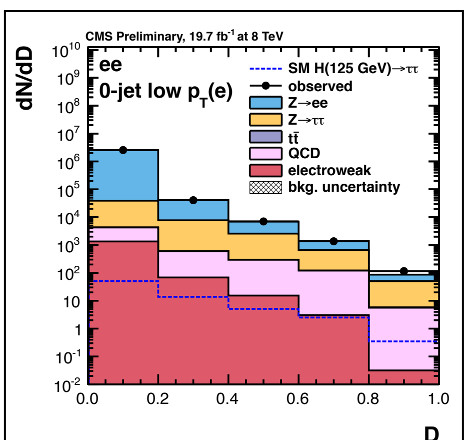


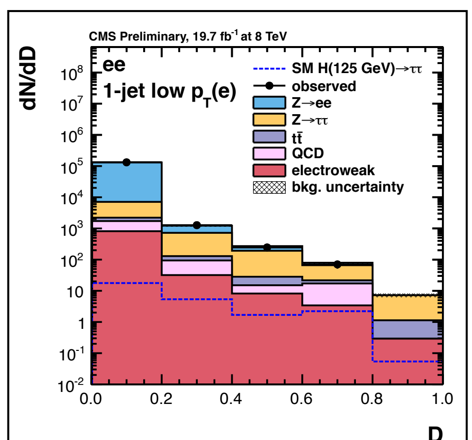








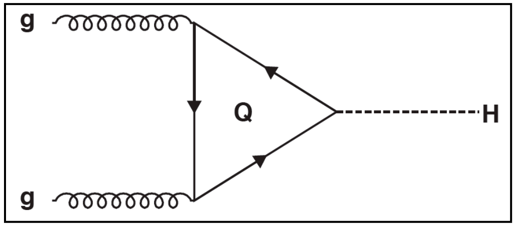


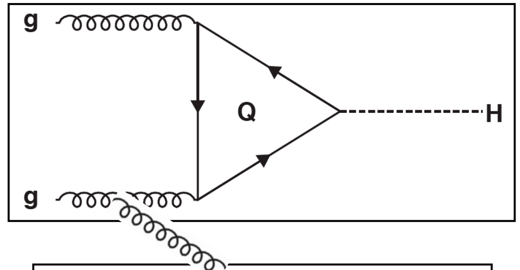


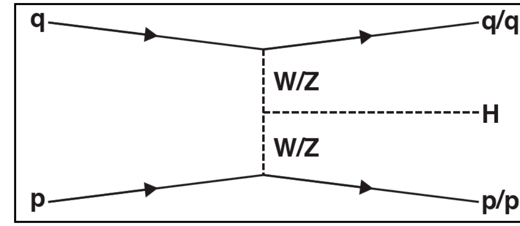
Mass plots 7 TeV

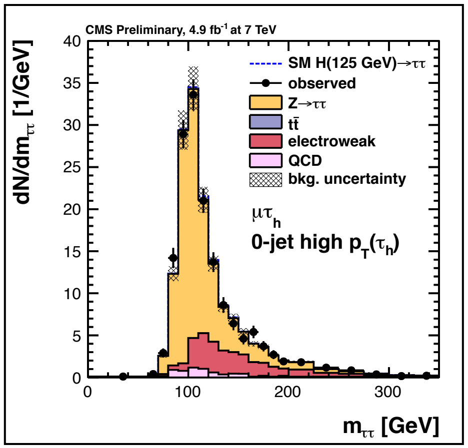
Mass plots $\mu\tau_h$

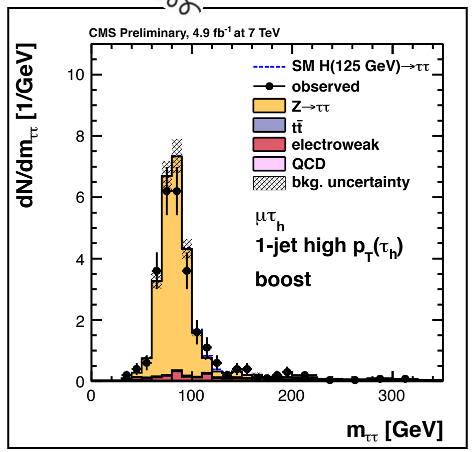
HIG-13-004

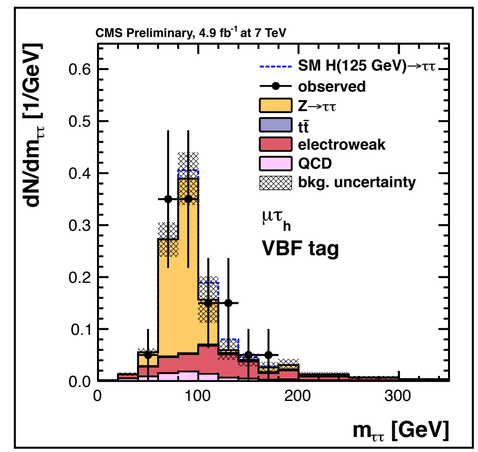


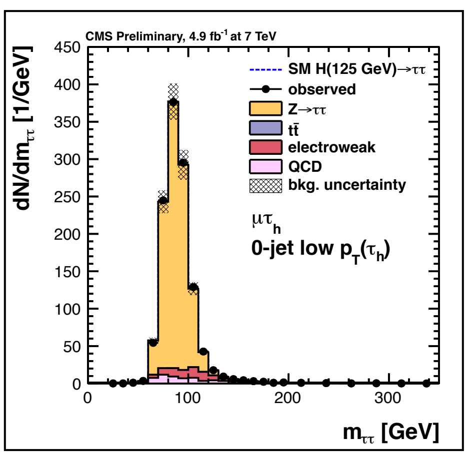


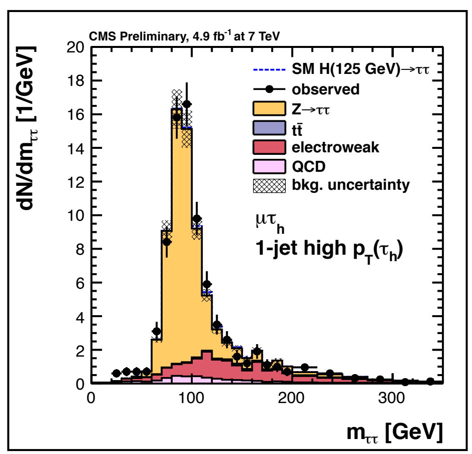






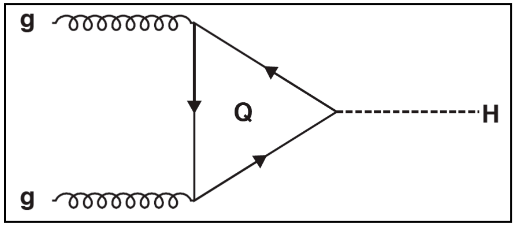


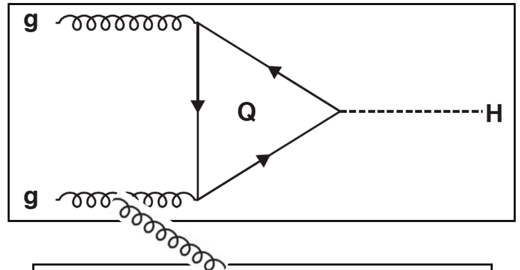


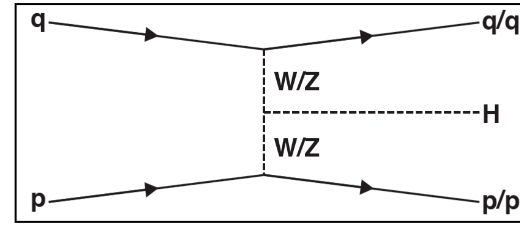


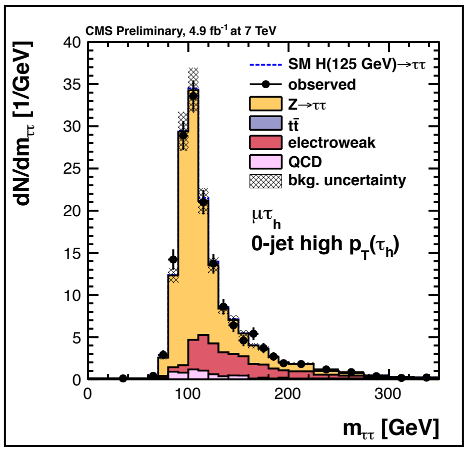
Mass plots $\mu\tau_h$

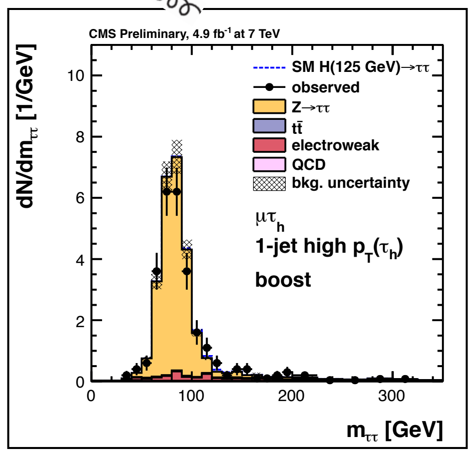
HIG-13-004

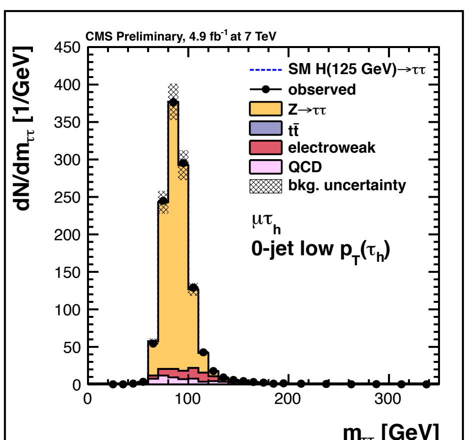


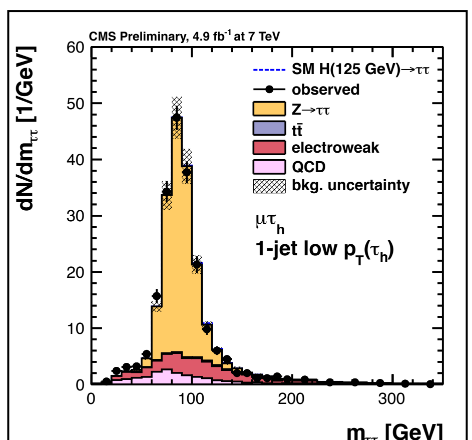


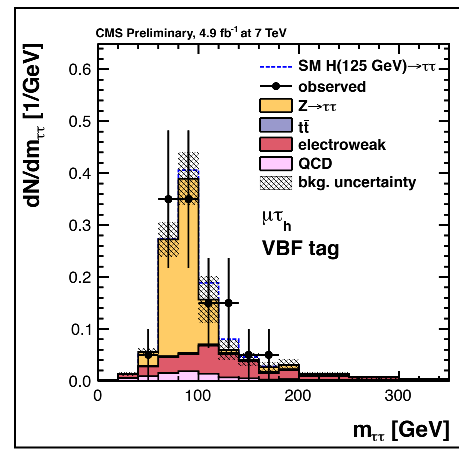






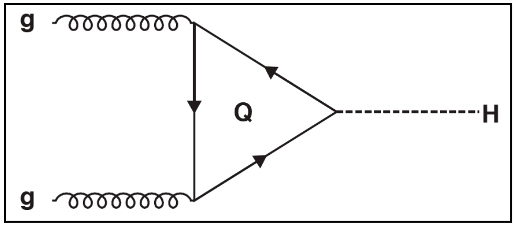


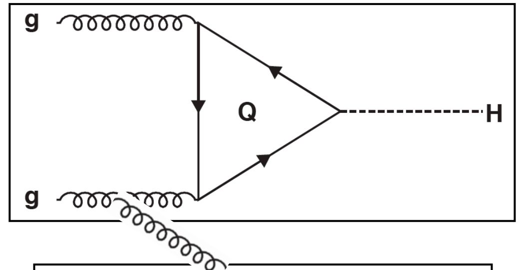


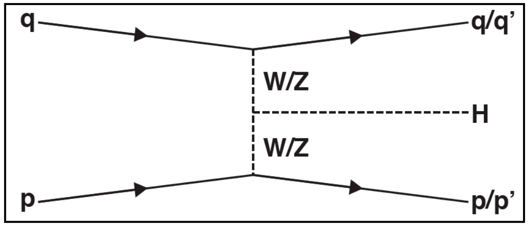


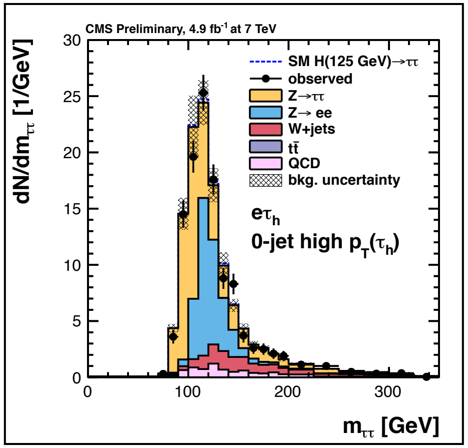
Mass plots $e\tau_h$

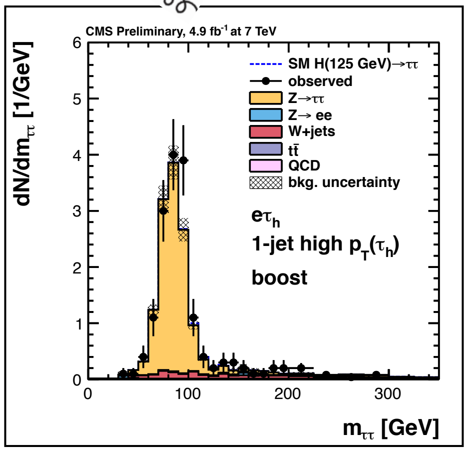
HIG-13-004

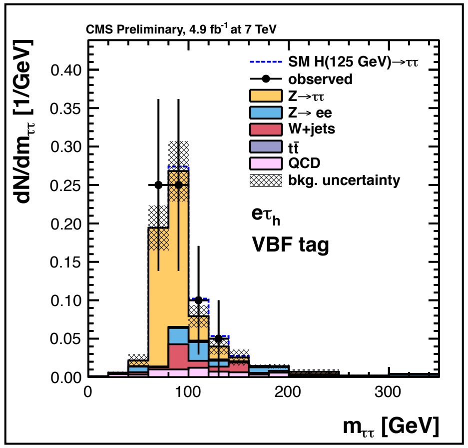


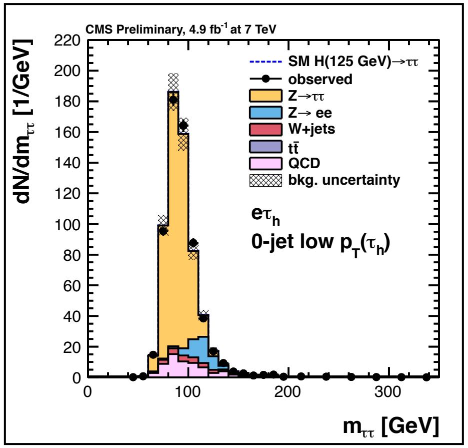


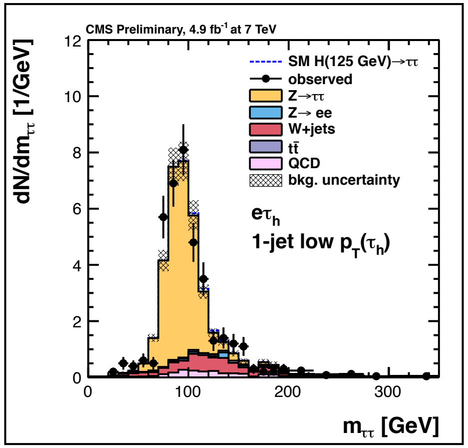






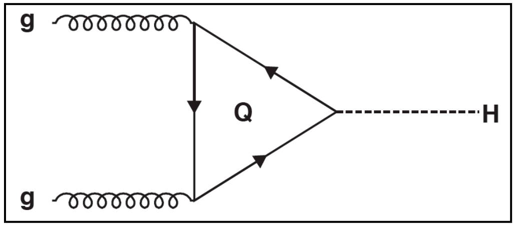


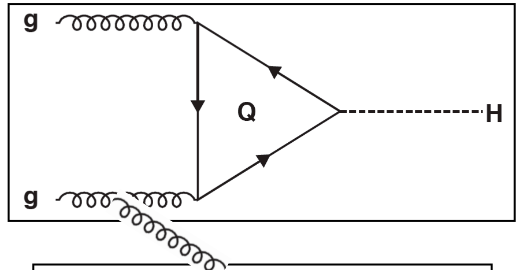


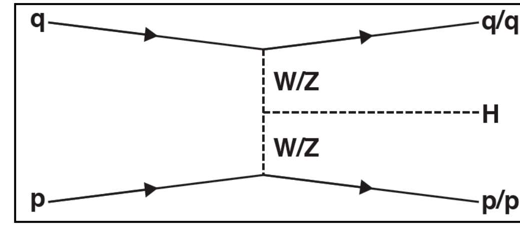


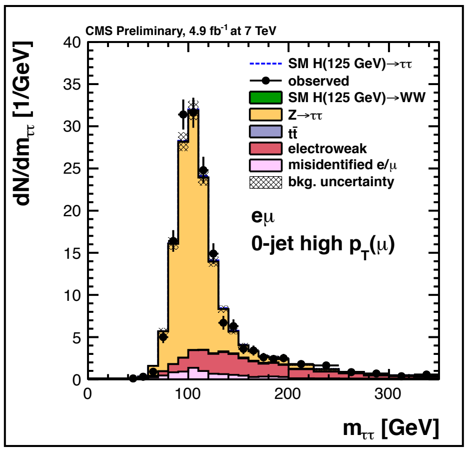
Mass plots eμ

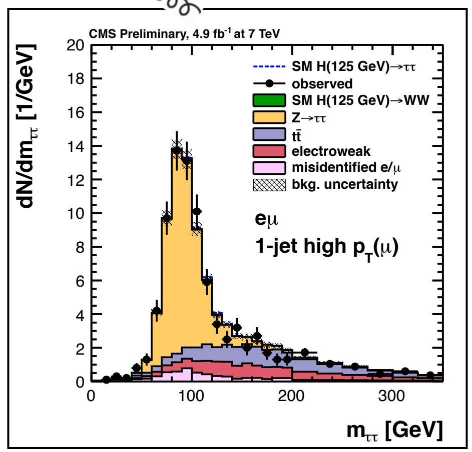
HIG-13-004

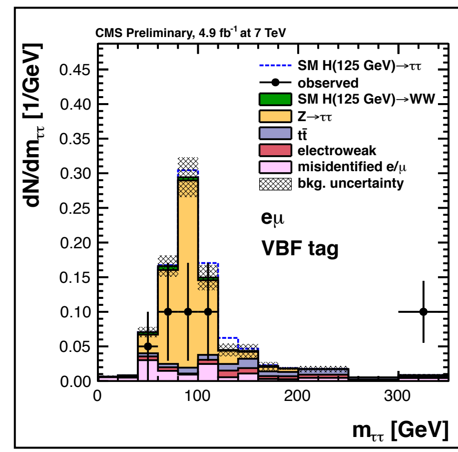


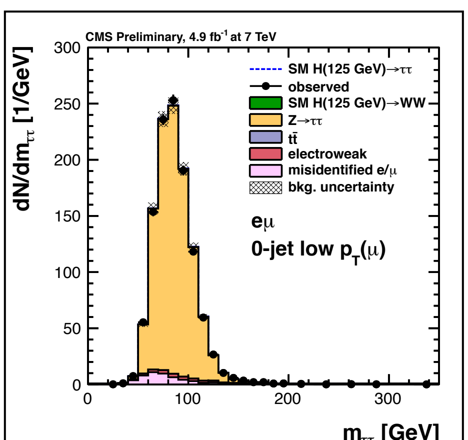


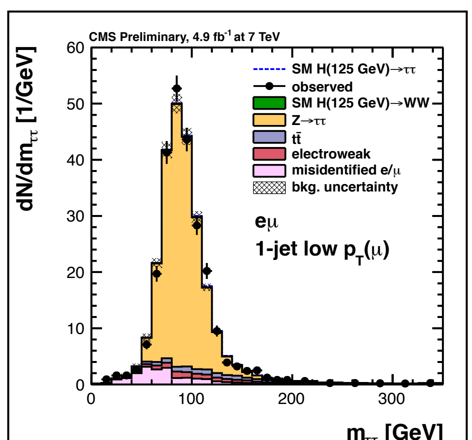






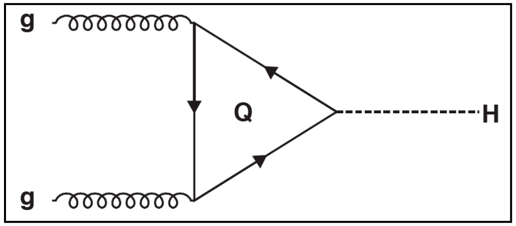


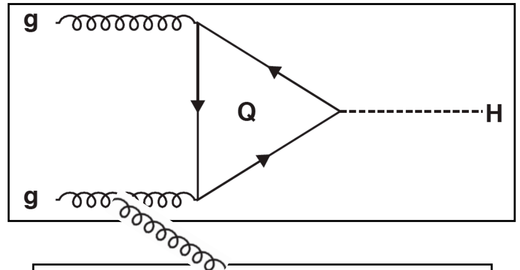


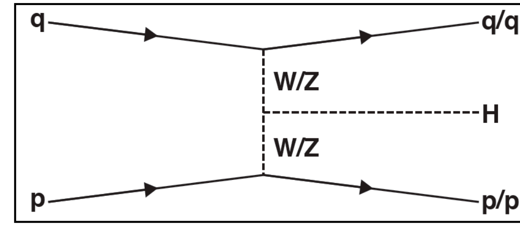


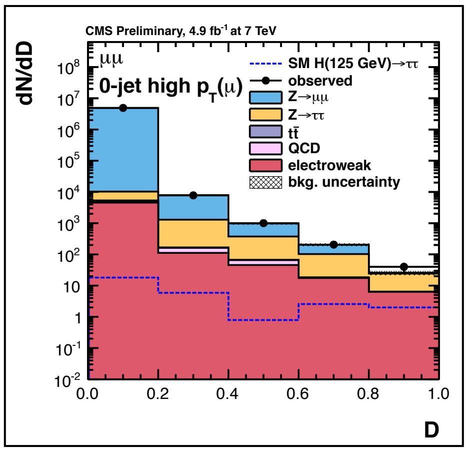
Mass plots μμ

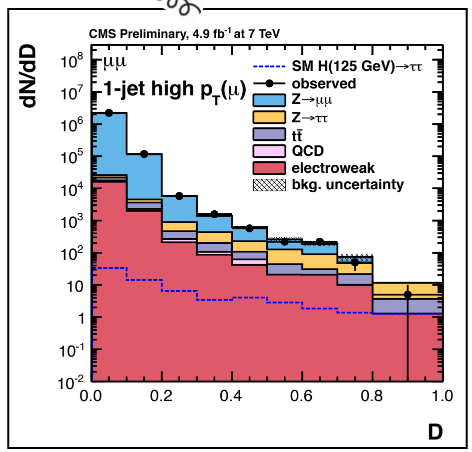
HIG-13-004

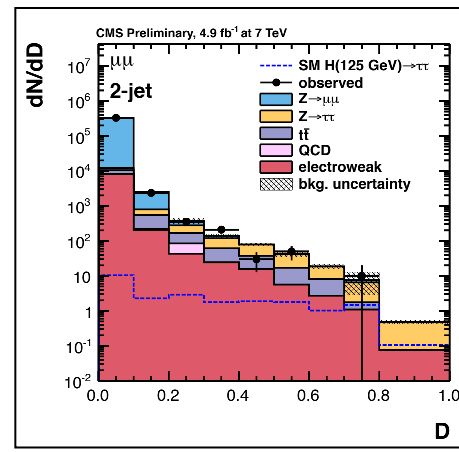


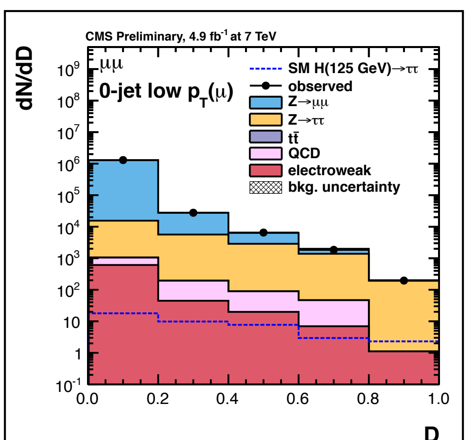


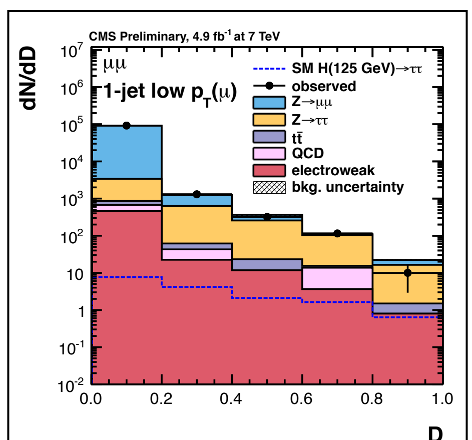






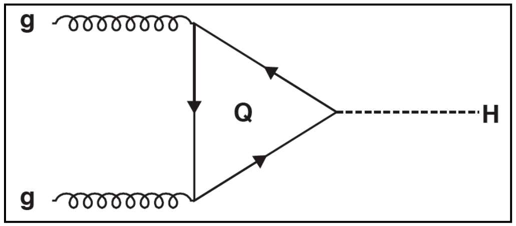


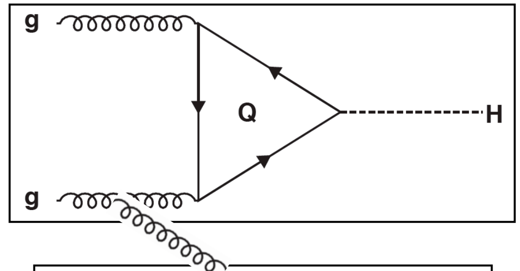


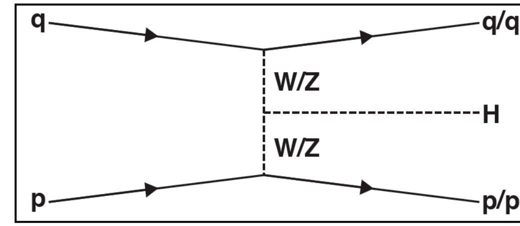


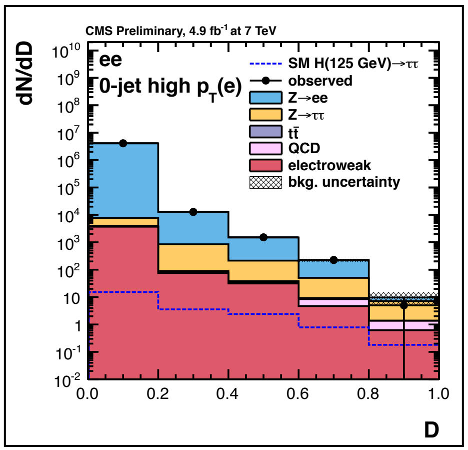
Mass plots ee

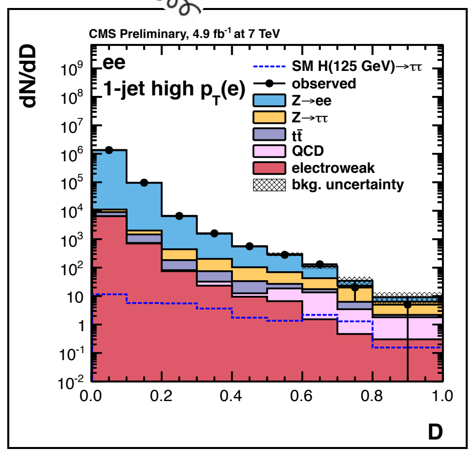
HIG-13-004

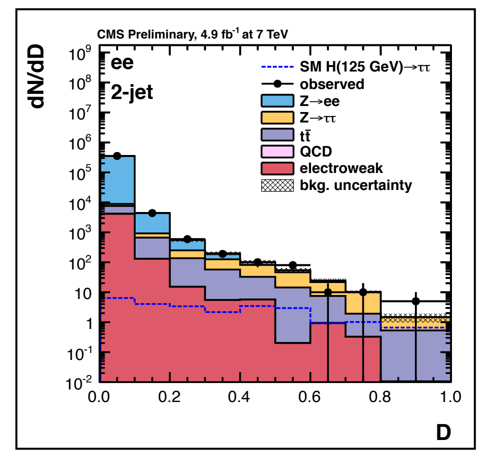


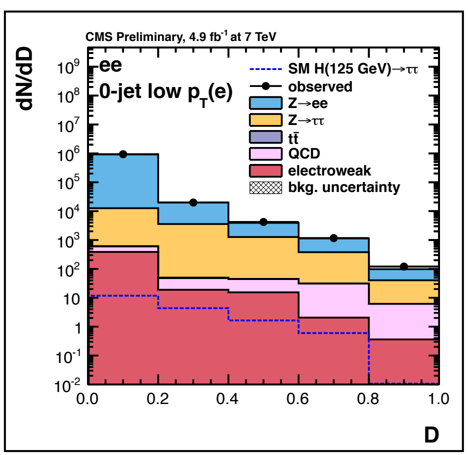


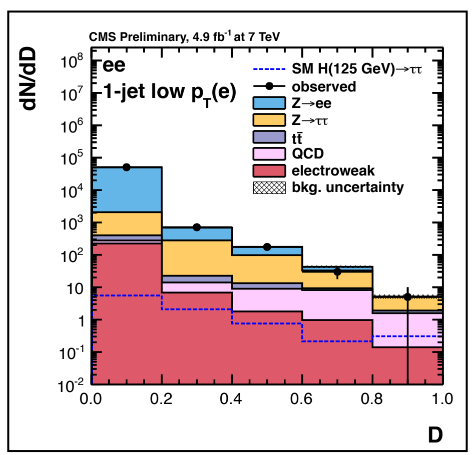






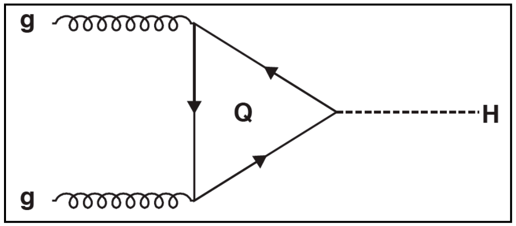


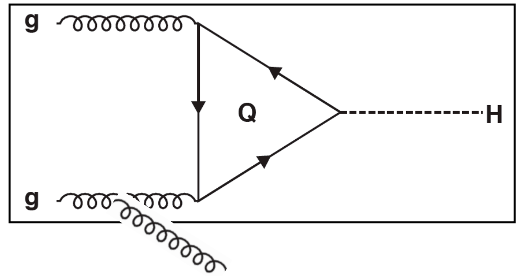


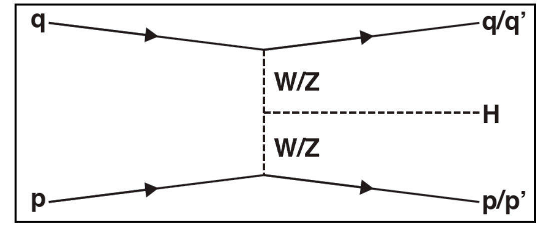


Moriond'13

Topologies/Categories Moriond'13







	0-jet	1-jet	2-jet
			$m_{jj} > 500$ GeV $\lvert\Delta\eta_{jj}\rvert > 3.5$
$p_T(\tau_h) > 45$ GeV	high $p_T(\tau_h)$	high $p_T(\tau_h)$	VBF tag
baseline	low $p_T(\tau_h)$	low $p_T(\tau_h)$	

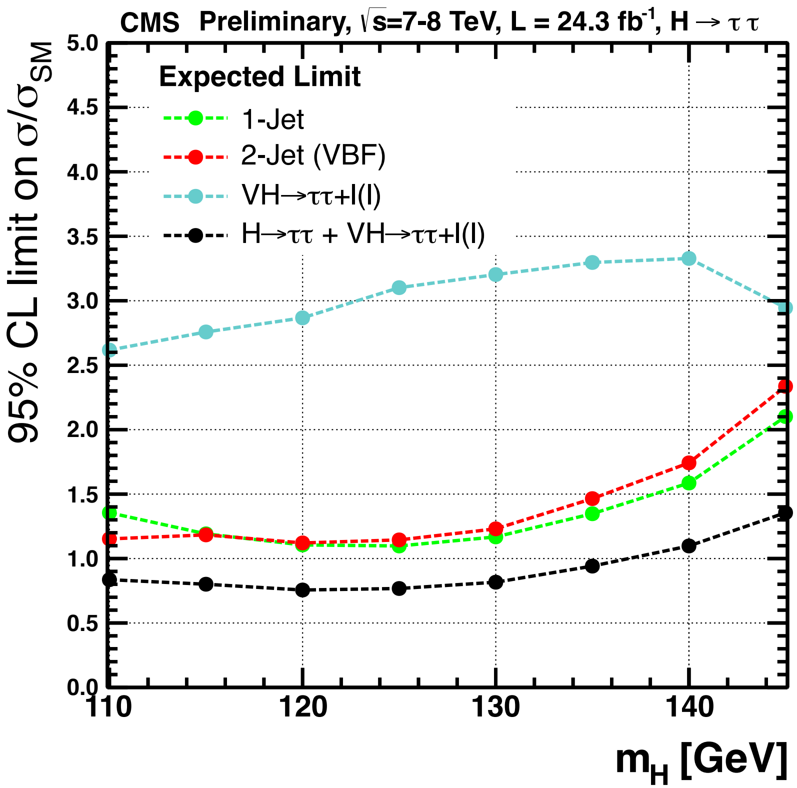
- **Calibration of backgrounds.**

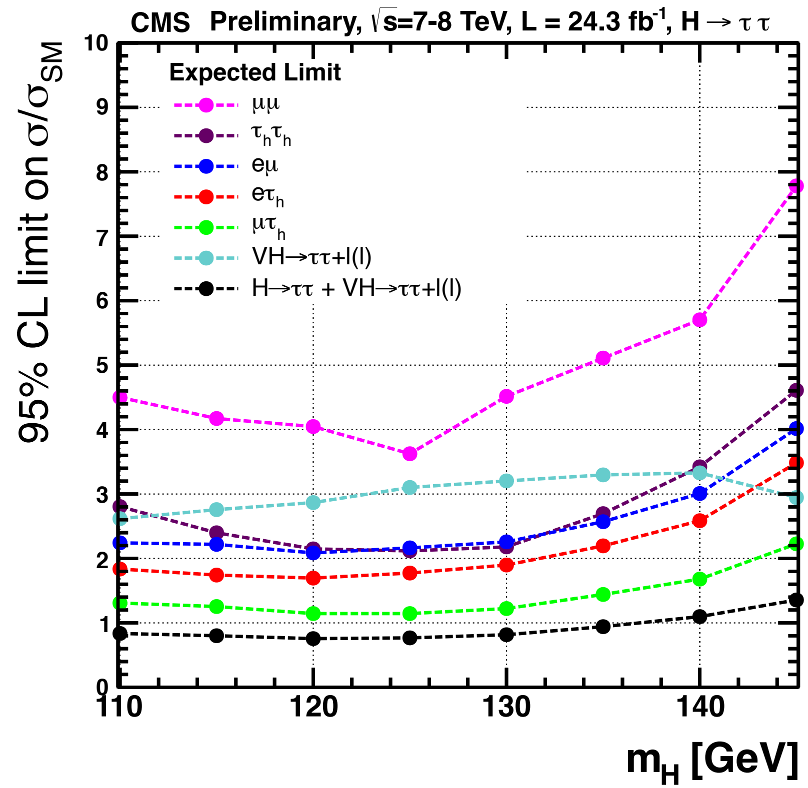
- Jet Pt > 30 GeV
- **Improved resolution of mass reconstruction.**

- 2 "tag" jets Pt > 30 GeV
- Central jet veto

Results

Moriond'13

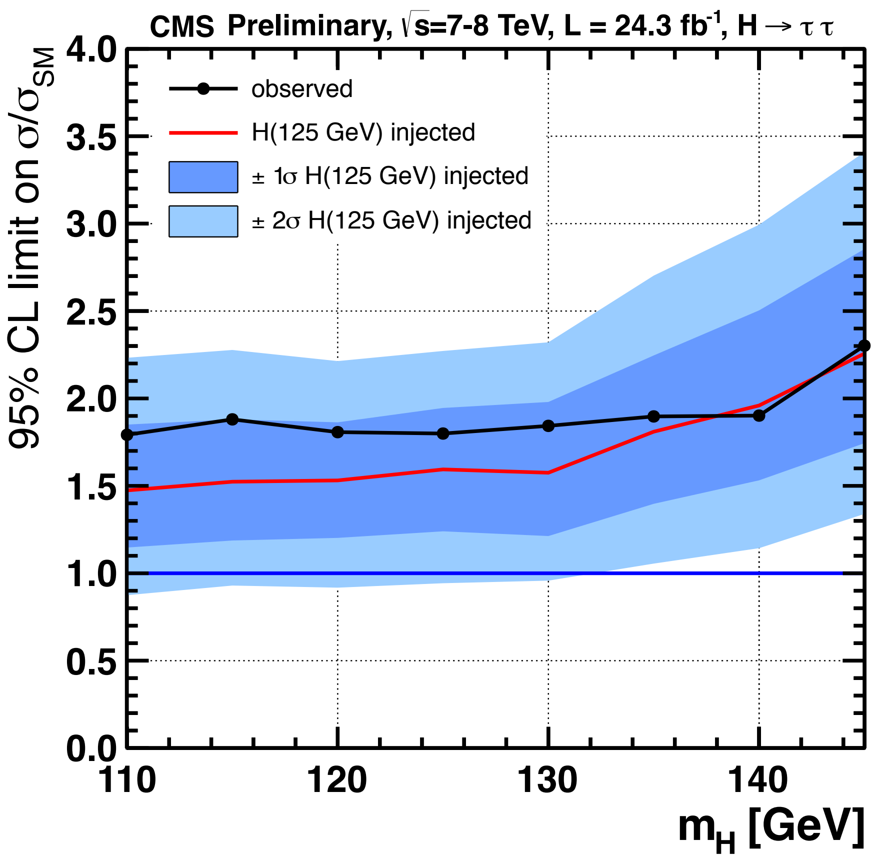


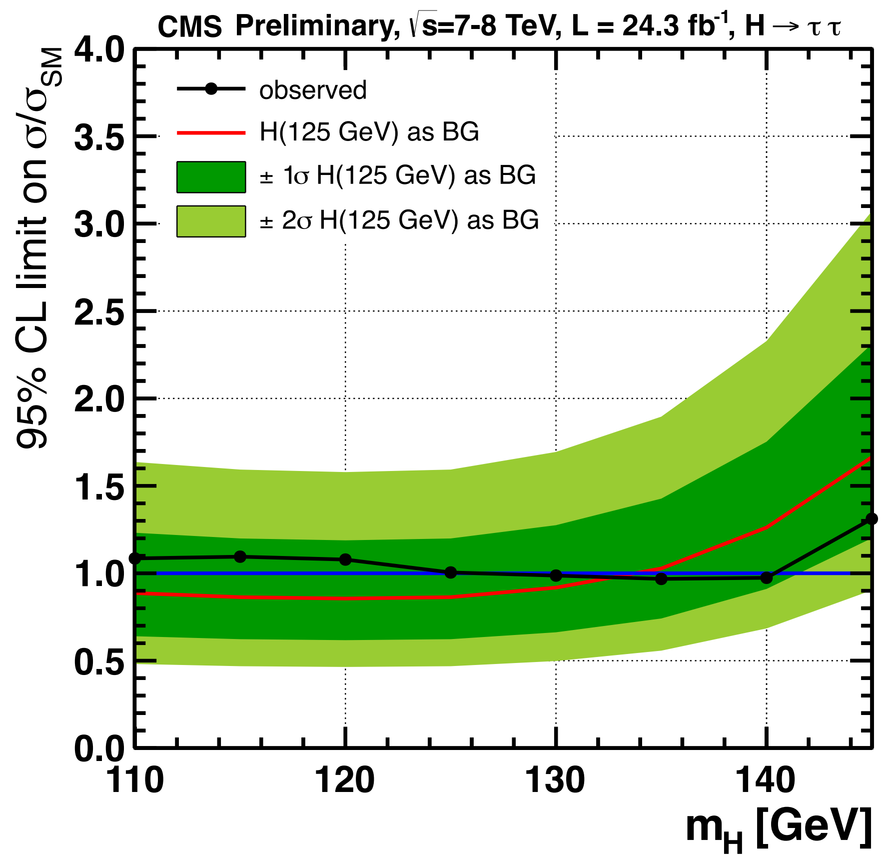


- 1 jet and VBF categories of similar power.
- Driving channel $H\rightarrow\tau\tau\rightarrow\mu+\tau$. Then semileptonic : $e+\tau$.

Expected Limits injecting Higgs signal with mH=125 GeV

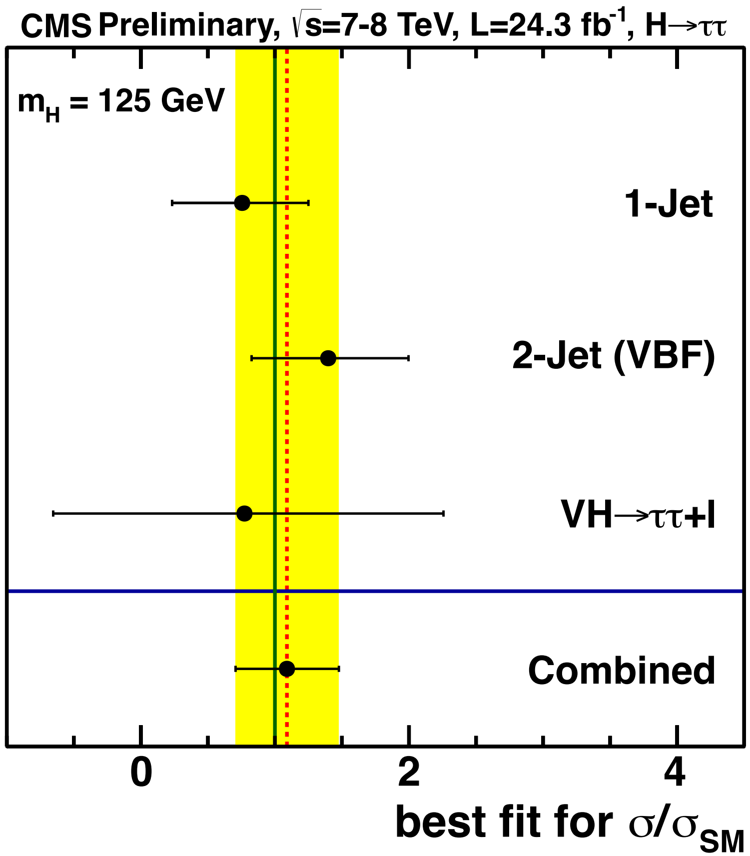
Moriond'13

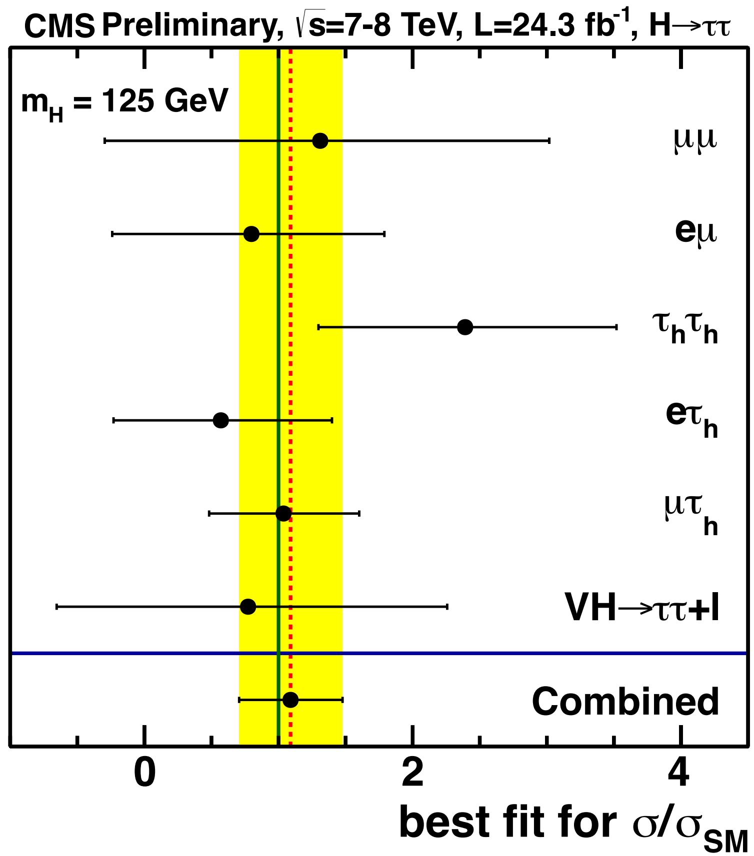




Best fit for signal strength

Moriond'13

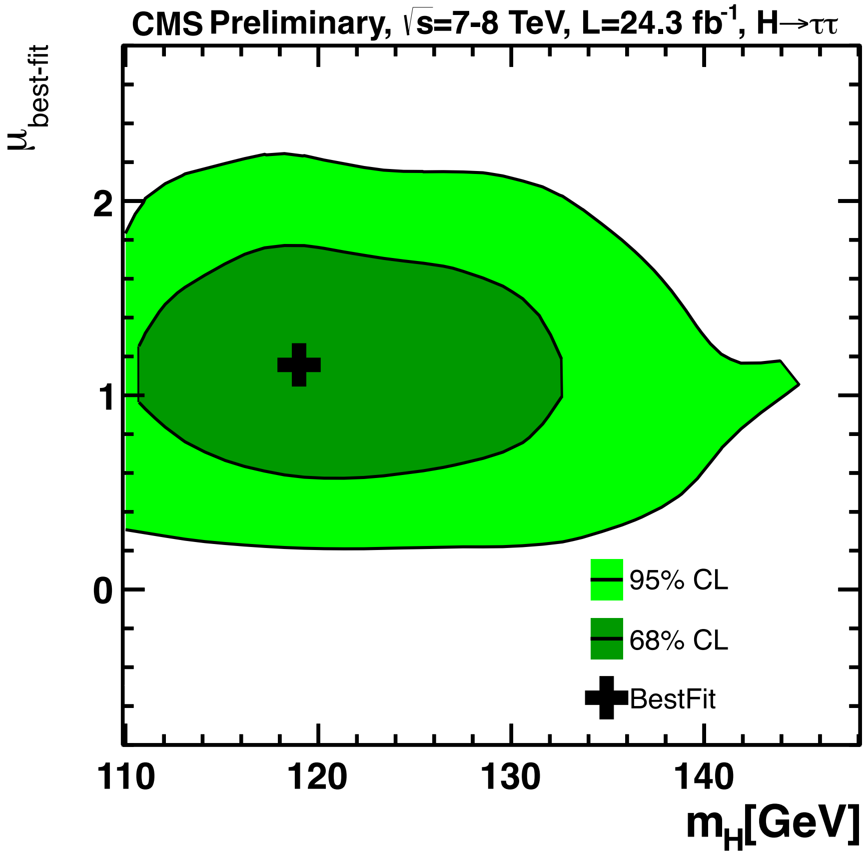


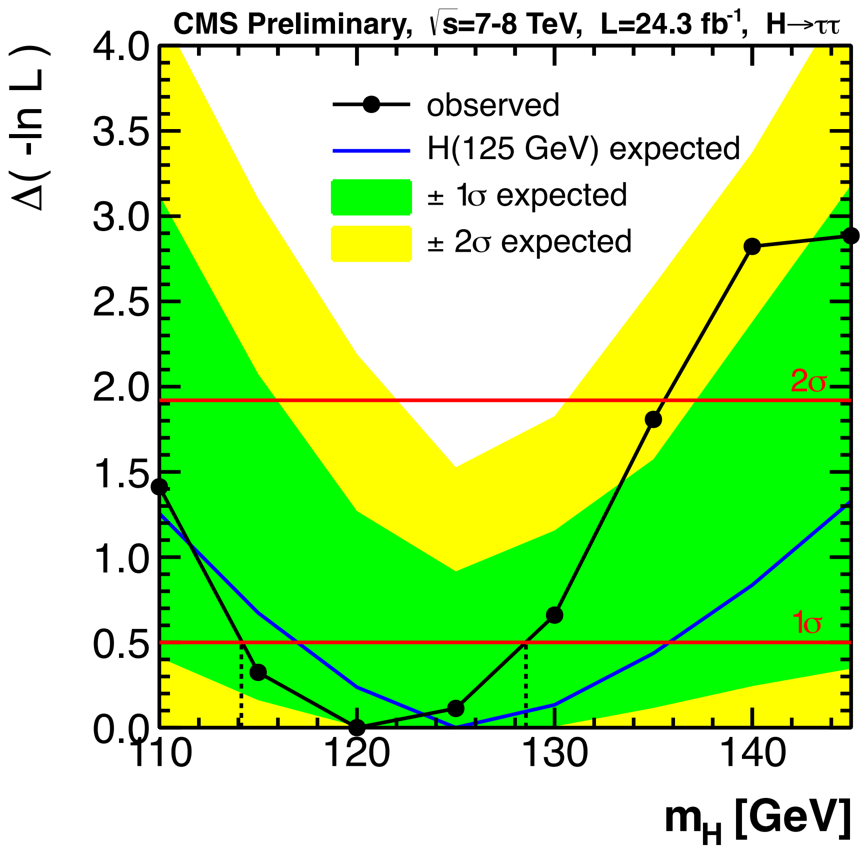


- Signal strength **μ =1.1+-0.4**, obtained in the global fit combining all channel

Best fit for signal strength

Moriond'13





- Signal strength **μ =1.1+-0.4**
- Log likelihood versus SM Higgs boson fit mass, combining all search channels. **mH = 120^{+9}_{-7}(stat+syst) GeV**

Yields

Moriond'13

Table 3: Observed and expected event yields, and expected signal efficiency in the $\mu\tau_h$ channel.

Process	*0-Jet*	*1-Jet high p_T*	*VBF*
$Z \rightarrow \tau\tau$	84833 ± 1927	4686 ± 232	109 ± 11
QCD	18313 ± 478	481 ± 38	48 ± 7
EWK	8841 ± 653	1585 ± 153	63 ± 9
$t\bar{t}$	11 ± 1	155 ± 11	5 ± 1
Total Background	111998 ± 2090	6908 ± 281	225 ± 16
$H \rightarrow \tau\tau$	- ± -	73 ± 13	11 ± 2
Observed	112279	7011	240

Signal Eff.			
$gg \rightarrow H$	-	$1.99 \cdot 10^{-3}$	$8.51 \cdot 10^{-5}$
$qq \rightarrow H$	-	$4.09 \cdot 10^{-3}$	$3.46 \cdot 10^{-3}$
$qq \rightarrow Ht\bar{t}$ or VH	-	$3.00 \cdot 10^{-3}$	$1.60 \cdot 10^{-5}$

Table 4: Observed and expected event yields, and expected signal efficiency in the $e\tau_h$ channel.

Process	*0-Jet*	*1-Jet high p_T*	*VBF*
$Z \rightarrow \tau\tau$	25161 ± 708	792 ± 62	47 ± 6
QCD	7706 ± 307	3 ± 0.3	17 ± 4
EWK	9571 ± 510	365 ± 53	44 ± 6
$t\bar{t}$	4 ± 0.5	47 ± 4	4 ± 1
Total Background	42443 ± 924	1207 ± 82	113 ± 9
$H \rightarrow \tau\tau$	- ± -	15 ± 3	5 ± 1
Observed	42481	1217	117

Signal Eff.			
$gg \rightarrow H$	-	$3.94 \cdot 10^{-4}$	$3.33 \cdot 10^{-5}$
$qq \rightarrow H$	-	$1.10 \cdot 10^{-3}$	$1.78 \cdot 10^{-3}$
$qq \rightarrow Ht\bar{t}$ or VH	-	$8.30 \cdot 10^{-4}$	$1.46 \cdot 10^{-6}$

MSSM

Standard Model and Supersymmetry

- SM describe physics at weak scale, but Hierarchy problem in Higgs sector.
  - There are no high-mass particles which couple to the Higgs field (even indirectly)
  - Striking cancellation are needed in high-order loop corrections to m_H

➢ SUSY solution to hierarchy problem at TeV scale
  - Introduces super-partners of SM particles and cancels problematic loop corrections

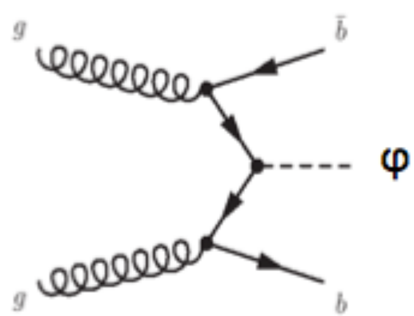
- MSSM
  - 2 Higgs doublets →5 physical Higgs states: **$H^{\pm}$, h, A, H.**
  - Result interpretation in the m_h^{max} scenario where : m_h~130 GeV and m_H~m_A.
  - 2 free parameters m_A and $\tan\beta = v_2/v_1$.

MSSM Neutral Higgs→ττ search

- 2 main production modes

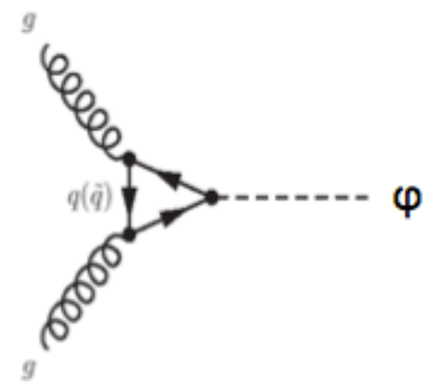
➤ Specific analysis categories :

b-tag category
≥ 1 b-tag jet with
p_T > 20 GeV



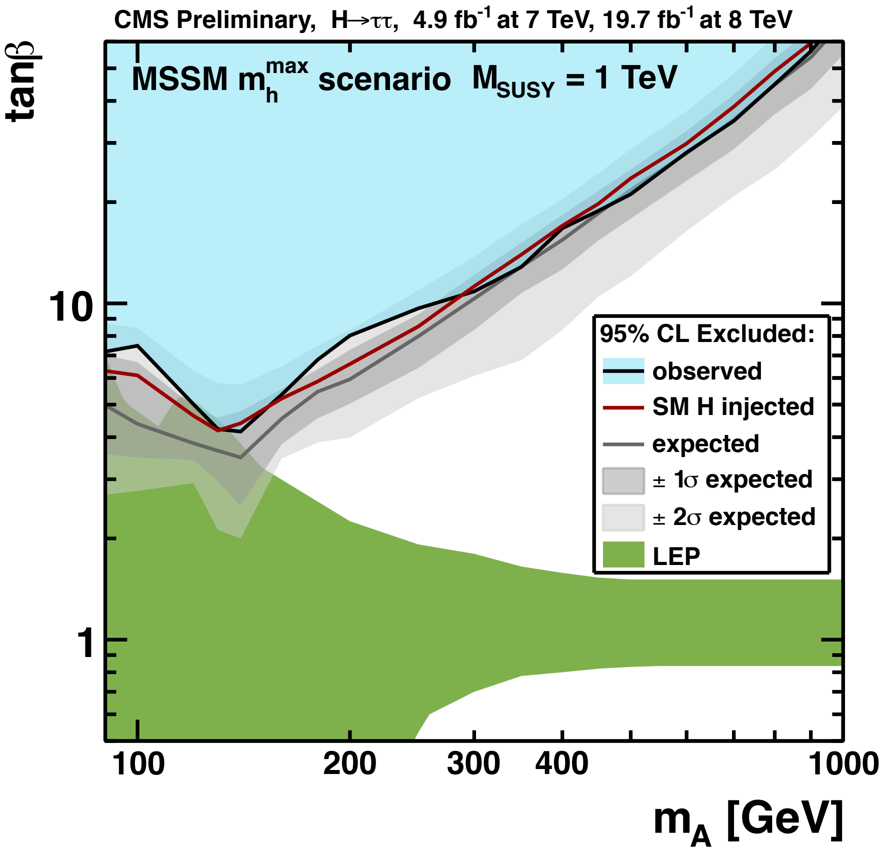
gg→bbφ

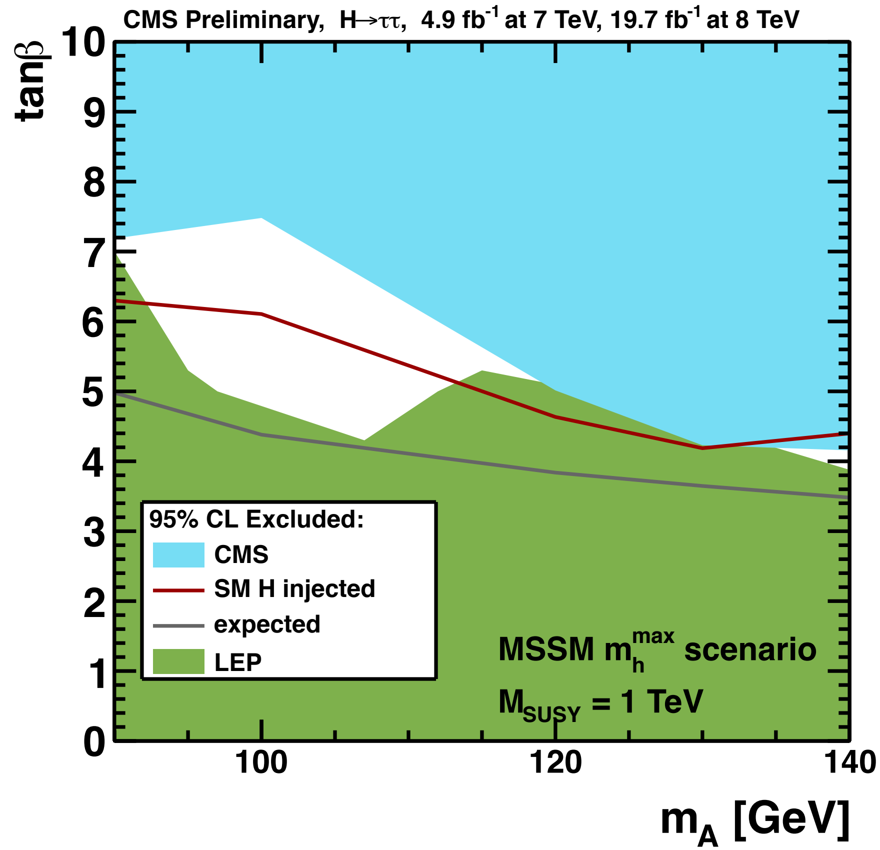
No b-tag category
No b-tag jets with
p_T > 20 GeV



gg→φ

MSSM Neutral Higgs→ττ search results





- No excess observed.
- Large m_A-tanβ plane excluded.