LAL KEK Tsukuba HEP

Workshop on France-Japan and France-Korea Particle Physics Laboratories

<u>Continuation of the LHC-06 project:</u>

Improvement of the τ jet measurement applied to the low mass Higgs search in ττ

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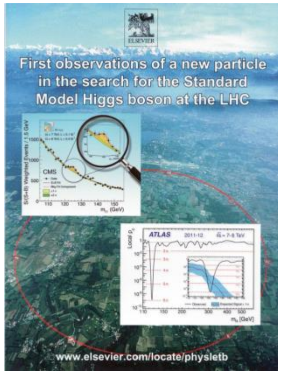
Introduction



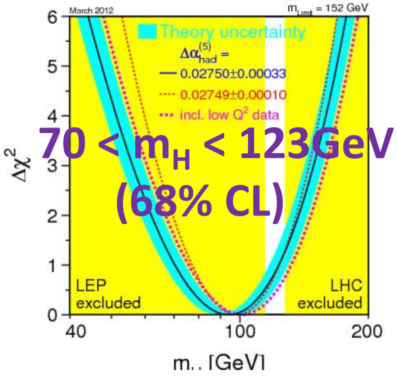
Phys.Lett. B716 (2012) 1-29

"These results provide **conclusive evidence for the discovery of a new particle** with mass 126.0±0.4 *(stat)*±0.4 *(sys)* GeV. "

What is "new particle"?

Mass :

125.5±0.2(stat)±0.6(sys)GeV



70 < m_H < 123GeV (68% CL)

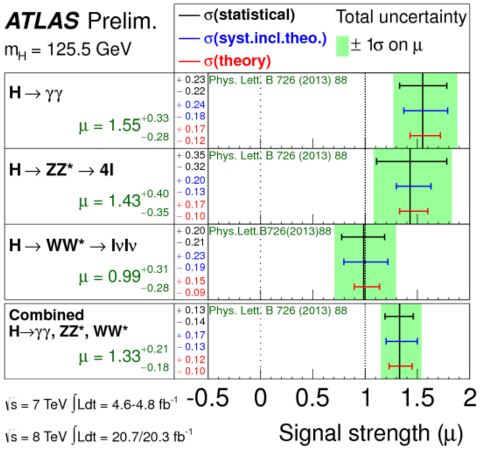
Spin Parity :

Consistent to scalar ($J^P=0^+$)

$J^P=0^-, 1^+, 1^-, 2^+$ were excluded.

Production and Decay (coupling)

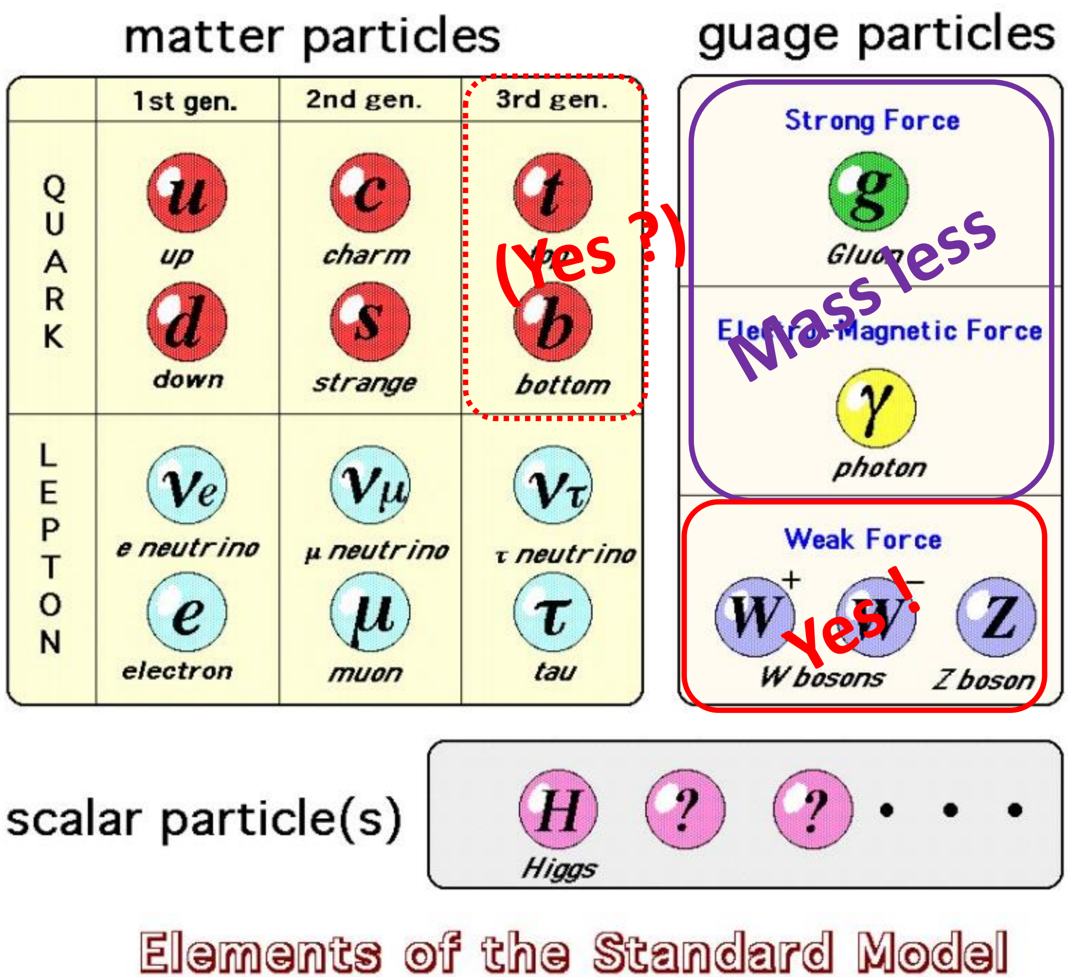
No significant deviation from SM



The particle should be a Higgs boson

Origin of mass

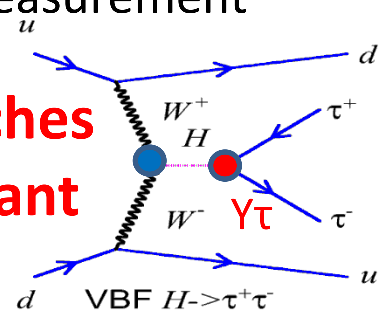
Particles are given the mass by H?



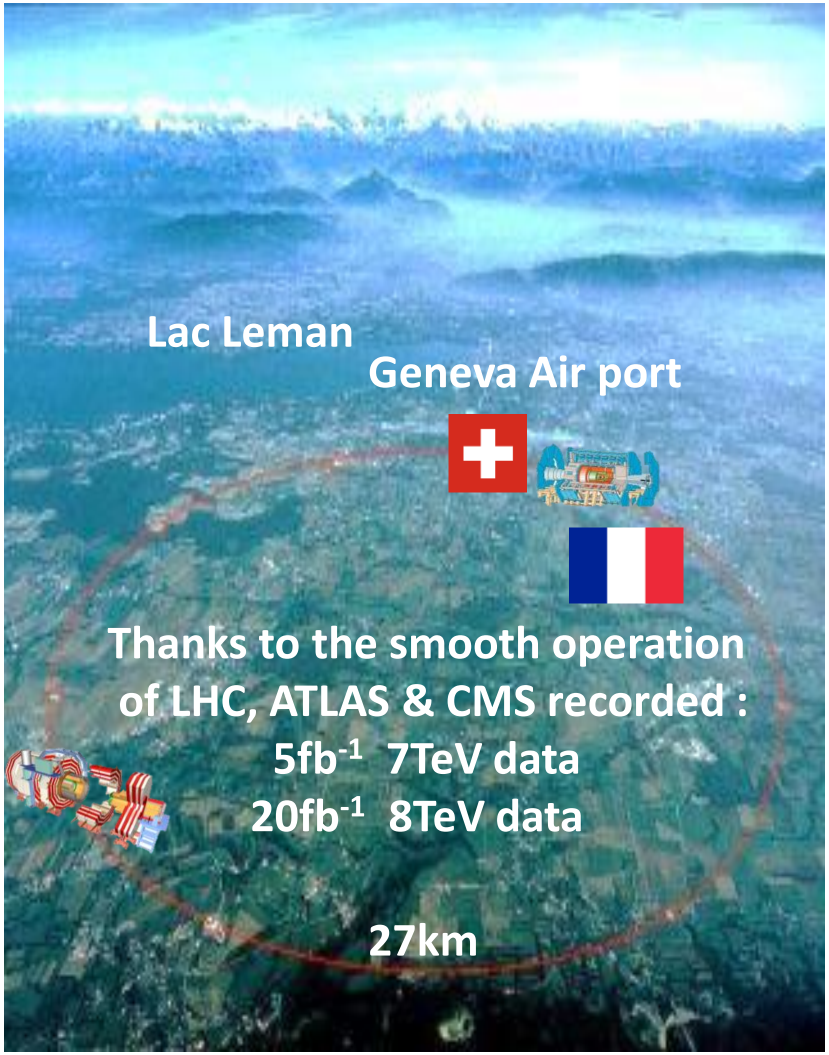
- Only W/Z boson For sure
  - Direct observation of H→WW/H→ZZ Decay
- Probably Quark
  - gg→H production would not exist w/o quark loop.
  - H→bb
    - Tevatron (2.8σ)
    - CMS (2.1σ)
    - ATLAS (0.4σ)

    3σ in combination??
- How about leptons?
  - No evidence including indirect measurement

H→ττ searches are important



LHC and ATLAS experiment

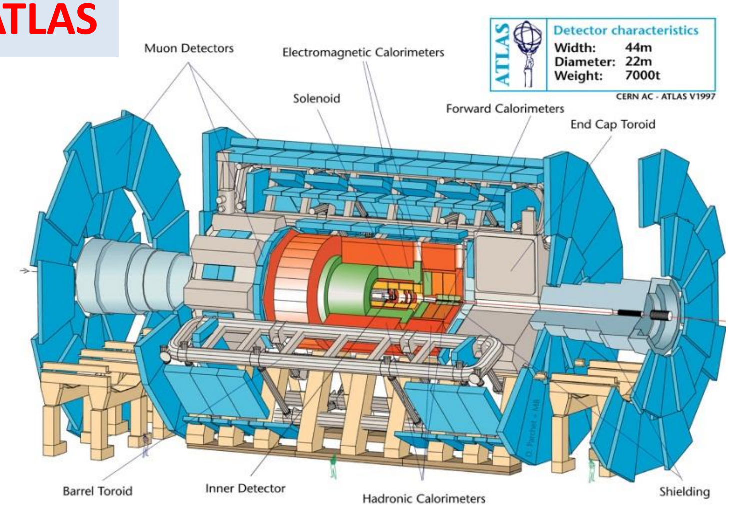


Thanks to the smooth operation of LHC, ATLAS & CMS recorded :

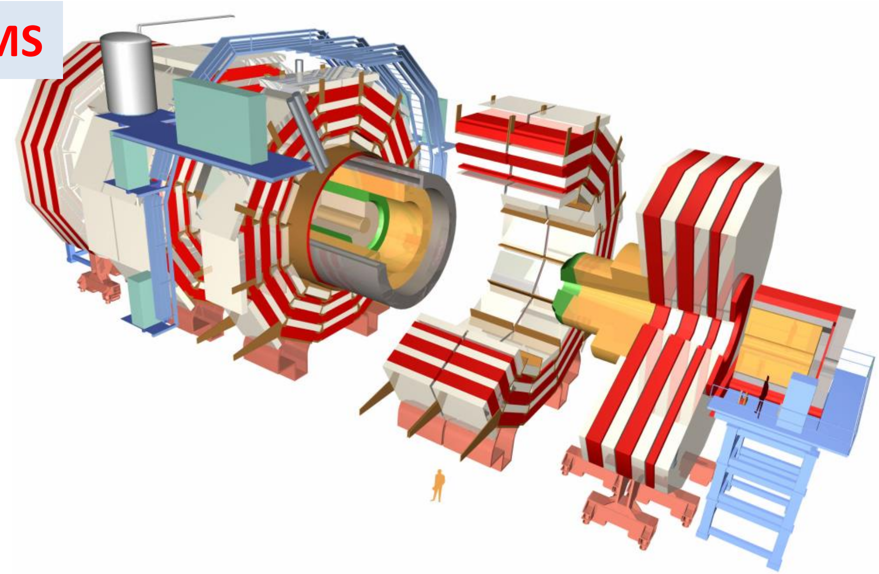
$5fb^{-1}$ 7TeV data

$20fb^{-1}$ 8TeV data

ATLAS

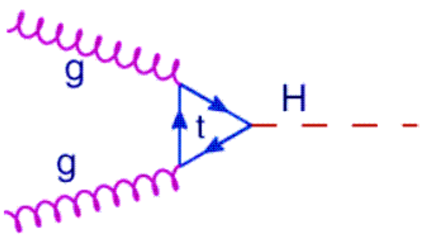


CMS

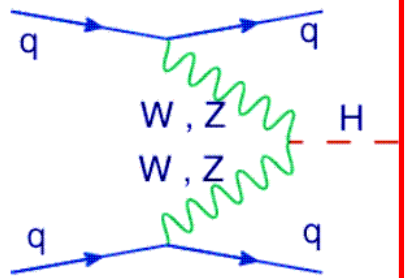


Higgs production and decay @ LHC

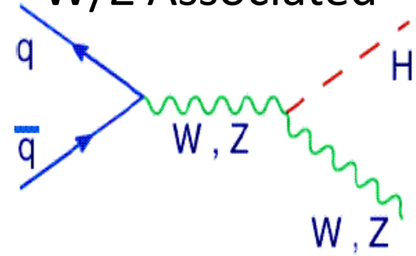
Gluon Fusion(ggF)



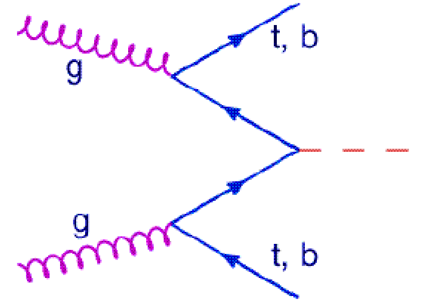
Vector Boson Fusion



W/Z Associated



tt/bb Associated

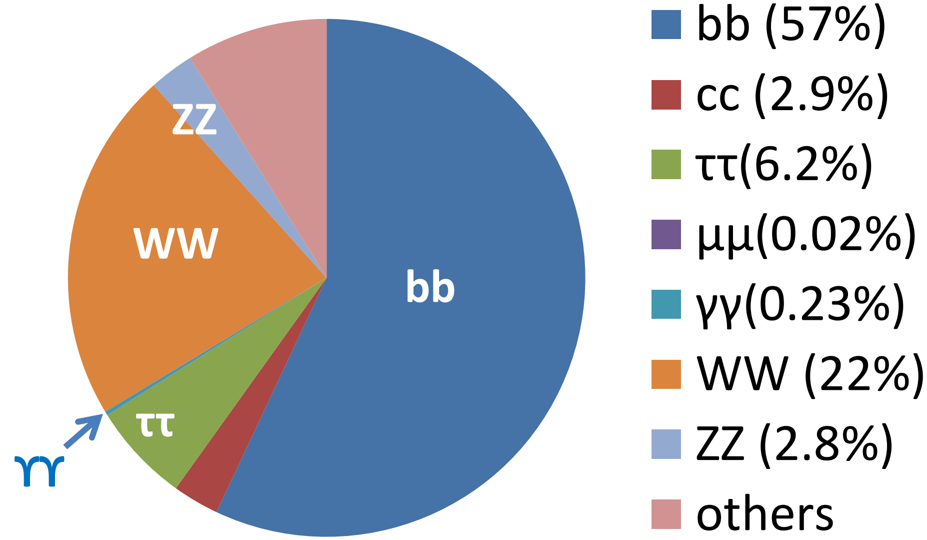


Now we know the cross section and Branching ratio!

Process	8TeV σ [pb]	14TeV σ [pb]
Gluon Fusion	**19.1**	**49.9**
Vector Boson Fusion	**1.57**	**4.18**
W/Z Associated	1.11	2.39
tt/bb Associated	0.128	0.611

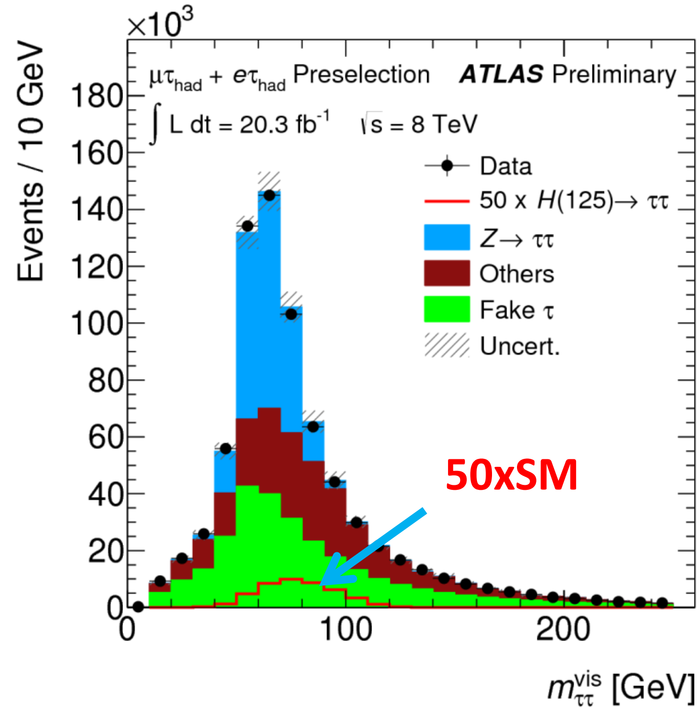
8TeV @125.5GeV
14TeV @125GeV

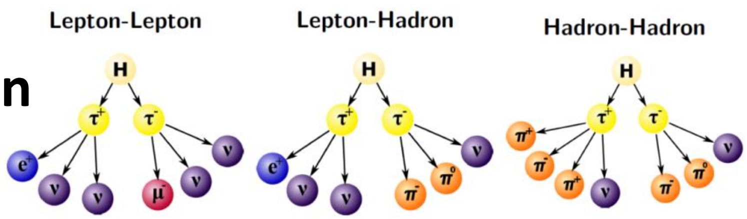
@125.5GeV



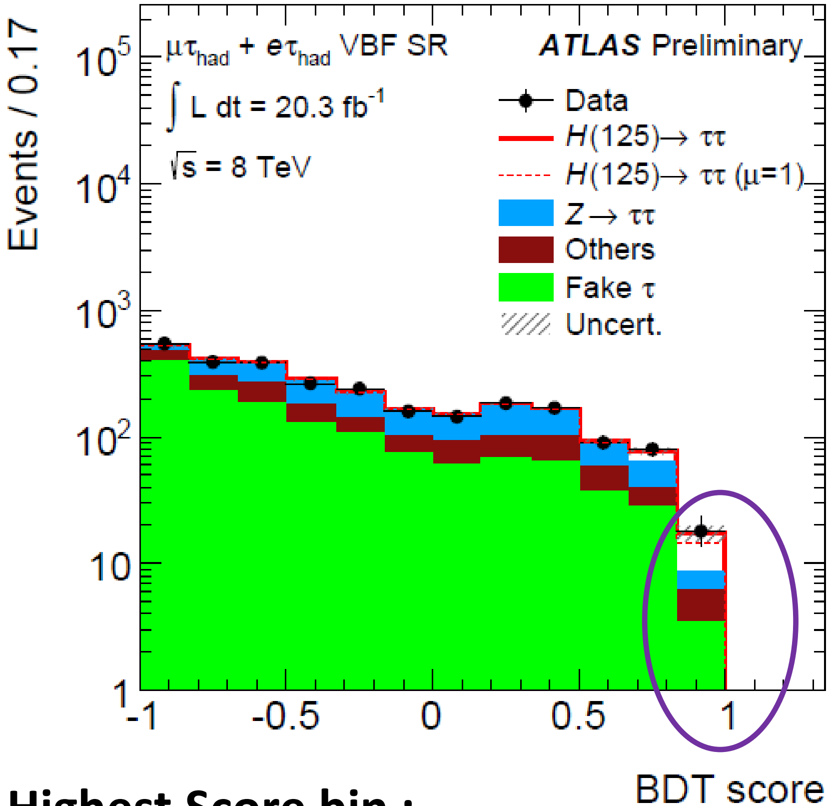
Analysis strategy

- **After di-tau candidate , S/B ratio is <0.001, while typical systeamtics of backgrounds are ~20%.**
- Categorize events to (leplep/lephad/hadhad)X(VBF/Boost)
- Used MVA technique to separate signal from background. (Used **MVA score as discriminant**.)
- Majority of Backgrounds are estimated by data-driven way.
  - **Z→ττ estimated by Z→μμ data replaced μ→τ**
  - **Z→ee/μμ + jets, Top, di-boson Estimated by MC with correction.**
  - **QCD and W+Jets – Data driven estimation for both shape and Normalization.**

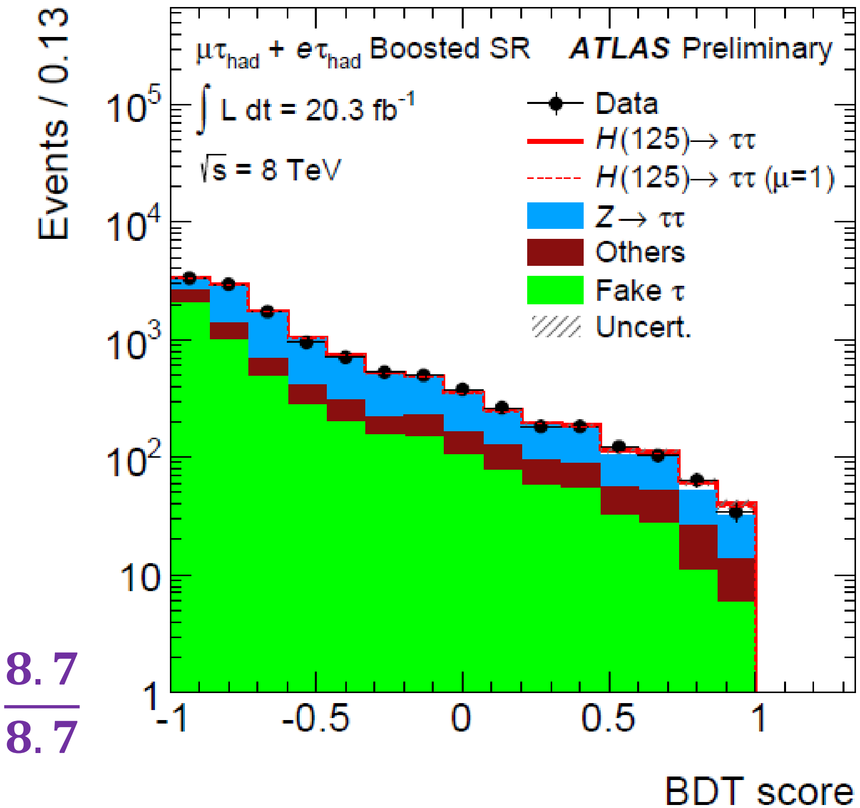




Result :BDT distribution in lephad SR



$$\frac{S}{B}=\frac{8.7}{8.7}$$

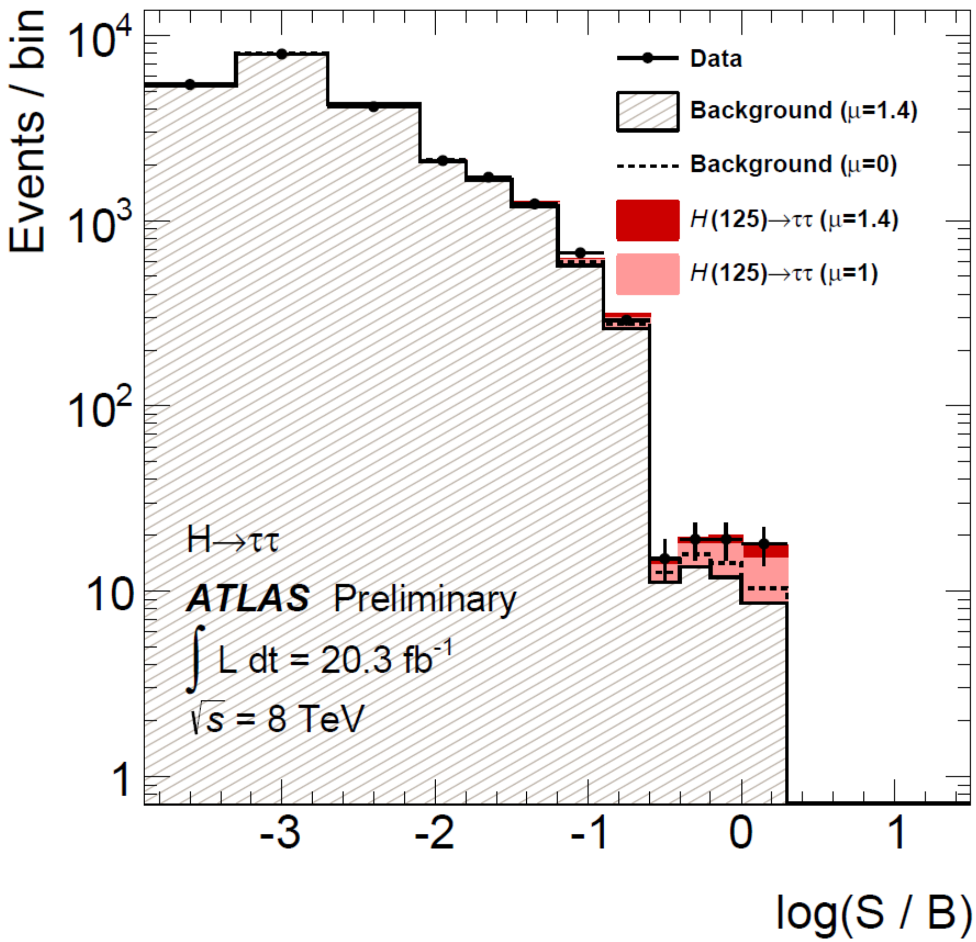


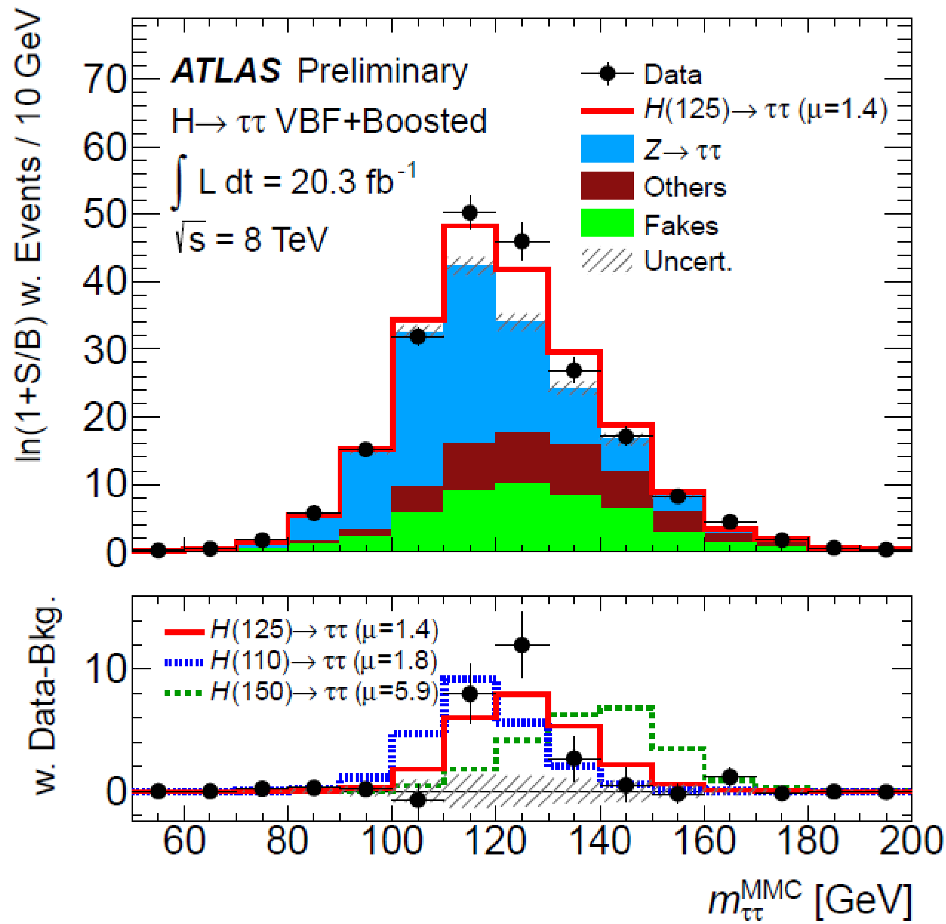
Highest Score bin :

	ggF	VBF	VH	$Z\to\tau\tau$	Fake	Top	Others	S/B
VBF	1.2±0.6	7.5±2.2	--	2.4±0.4	3.5±0.5	1.5±0.4	1.3±0.7	**1.0**
boosted	5.5±2.1	1.3±0.4	1.2±0.3	18±2	5.8±1.4	2.2±0.3	5.5±1.2	**0.25**

Summary plots

- Event yield as a function of log(S/B) for all signal region BDTscore-bins.
- MMC distribution where events are weighted by ln(1+S/B).



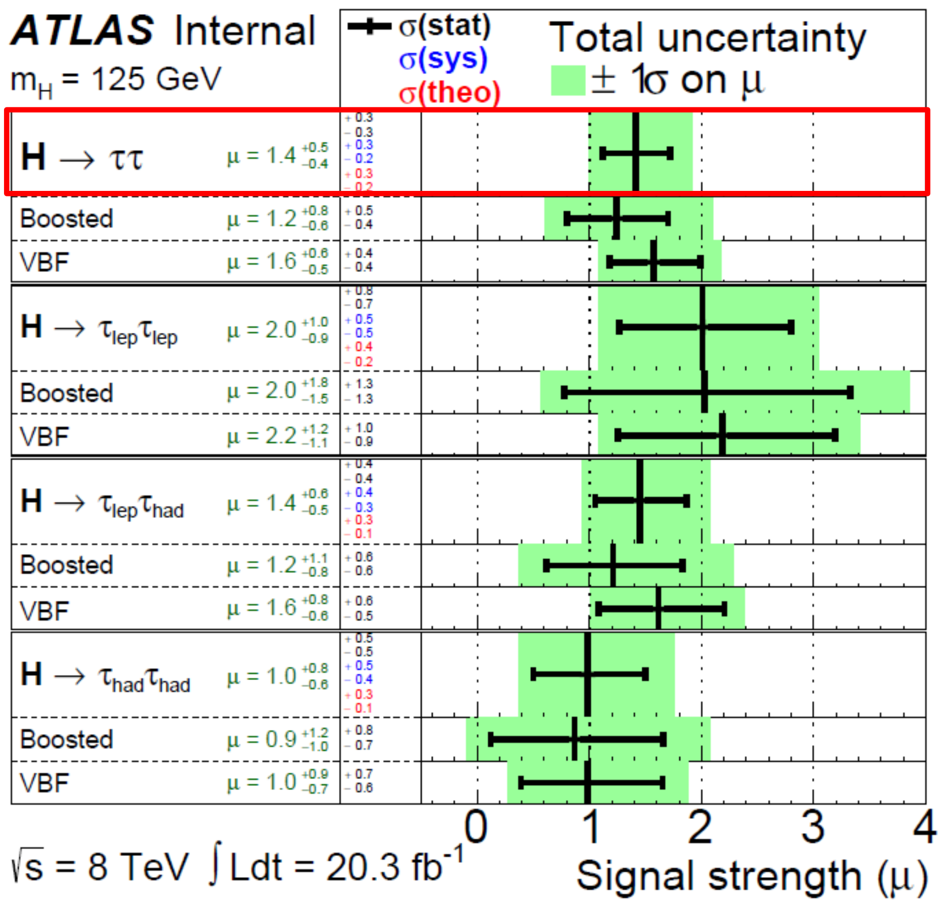


Conclusion : Significance and Signal strength

For mH=125GeV,

Evidence of H→ττ decay!

p_0^{exp} = 6.2 x 10^{-4} (3.2σ), **p_0^{obs} = 1.9 x 10^{-5} (4.1σ)**



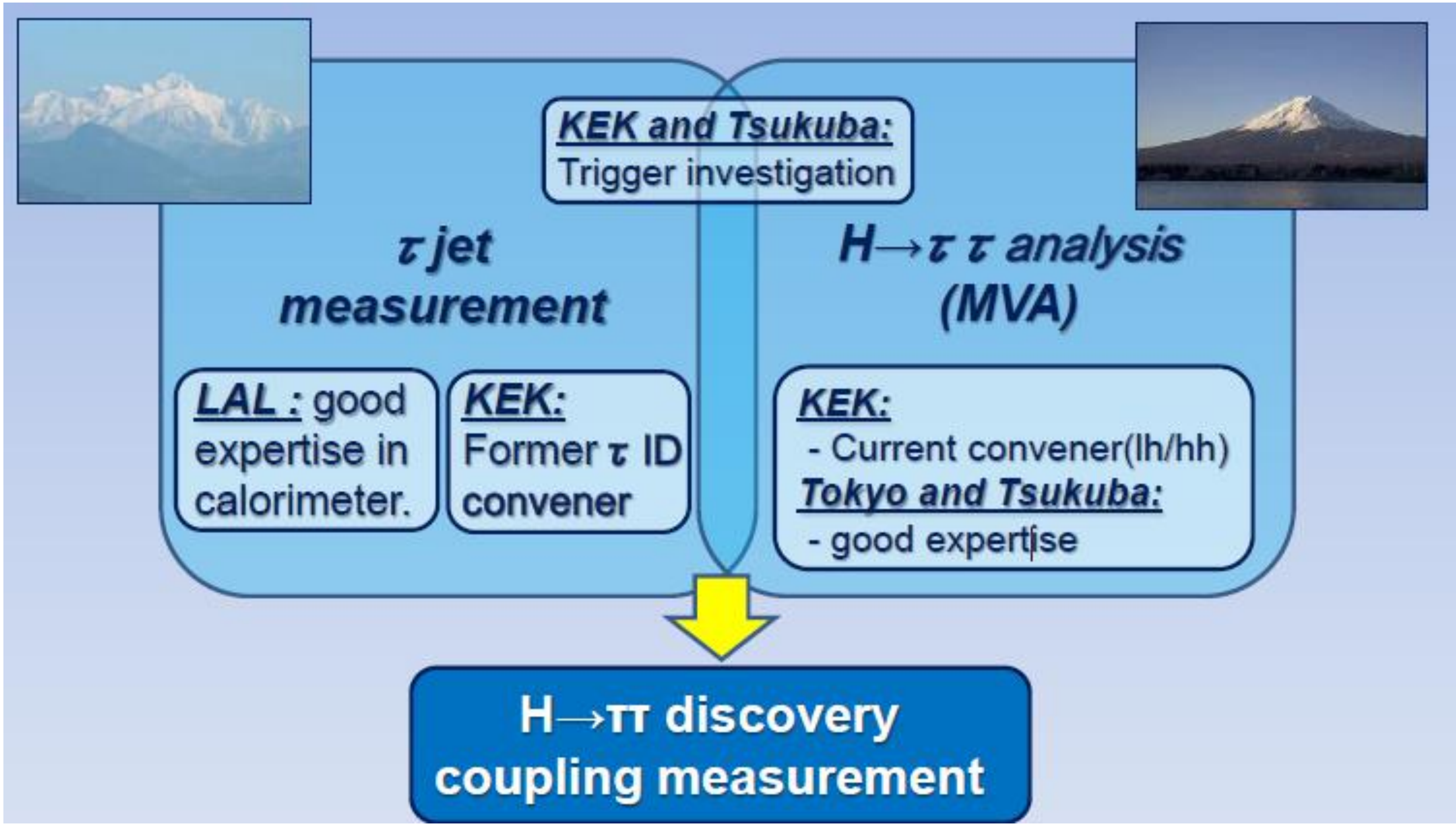
Assuming mH=125GeV :

μ_{best}=1.4+0.5-0.4

Impact of uncertainty sources

Source of Uncertainty	Uncertainty on μ
Signal region statistics (data)	0.30
$Z \to \ell\ell$ normalization ($\tau_{lep}\tau_{had}$ boosted)	0.13
ggF $d\sigma/dp_T^H$	0.12
JES η calibration	0.12
Top normalization ($\tau_{lep}\tau_{had}$ VBF)	0.12
Top normalization ($\tau_{lep}\tau_{had}$ boosted)	0.12
$Z \to \ell\ell$ normalization ($\tau_{lep}\tau_{had}$ VBF)	0.12
QCD scale	0.07
di-τ_{had} trigger efficiency	0.07
Fake backgrounds ($\tau_{lep}\tau_{lep}$)	0.07
τ_{had} identification efficiency	0.06
$Z \to \tau^+\tau^-$ normalization ($\tau_{lep}\tau_{had}$)	0.06
τ_{had} energy scale	0.06

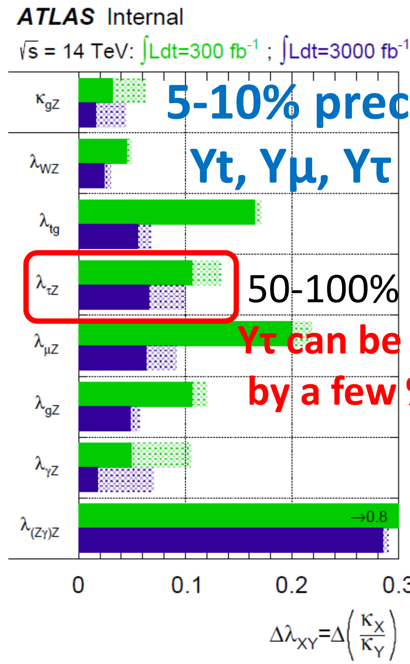
Sharing the work



PhD: F. Hariri (LAL), M. Ayoub (LAL), R. Fuchi (Tsukuba)

Next Step in tautau analysis

- Writing paper for "this result + 7TeV analysis".
- Improve measurement of Y_τ in 13/14TeV data (with better VBF-ggF separation)
- Measure mass by ττ to confirm if ττ is from the same Higgs boson as the other cannels. → **Need better tau-energy measurement.**
- CP mixing angle (CP even/odd) can be proved by ττ spin correlations. → **Need better id (π^0 counting)**



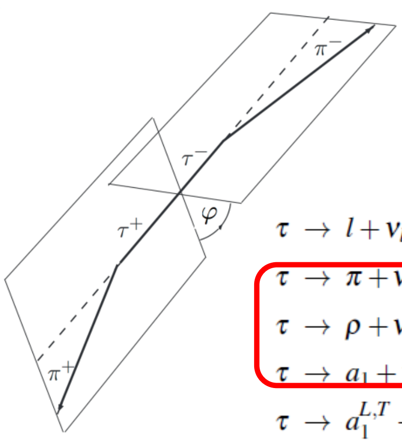
5-10% precision for Yt, Yμ, Yτ

50-100% improve !

Yτ can be measured by a few % precision!

$$\mathcal{L}_Y = -N(\cos(\phi)\bar{\tau}\tau + \sin(\phi)\bar{\tau}i\gamma_5\tau)h$$

CP-Mixing Angle



$$\tau \to l + \nu_l + \nu_\tau\,, \qquad l = e, \mu\,,$$
$$\tau \to \pi + \nu_\tau\,,$$
$$\tau \to \rho + \nu_\tau \to \pi + \pi^0 + \nu_\tau\,,$$
$$\tau \to a_1 + \nu_\tau \to \pi + 2\pi^0 + \nu_\tau\,,$$
$$\tau \to a_1^{L,T} + \nu_\tau \to 2\pi^\pm + \pi^\mp + \nu_\tau$$

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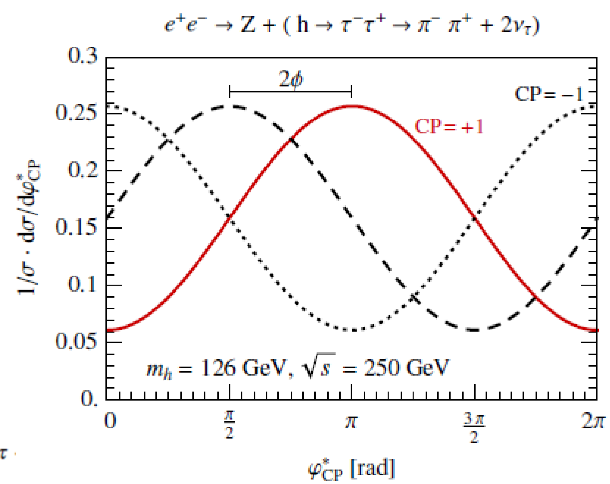
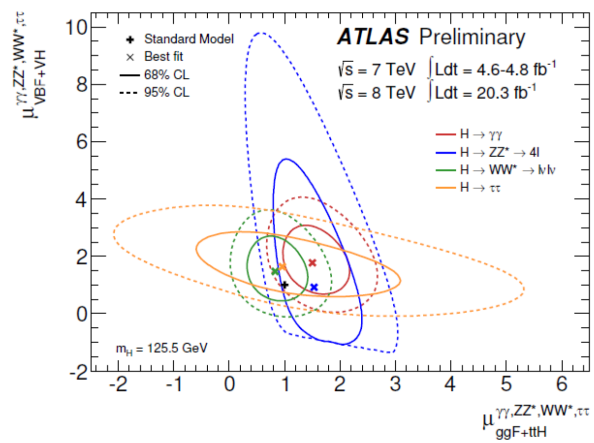




τ jet measurement is still quite important task :

"LHC_6: Improvement of the τ jet measurement applied to the low mass H Higgs search in ττ channel"

Summary of the 2014-2015 Project

1- The selection of hadronic τ decays proceeded by requiring one or three prongs in the τ while two prongs decays are rejected. This results in a lack of efficiency if a photon in the π^0 decay is converted to an electron-positron pair with one of the two tracks measured by the tracker and inside the τ cluster cone. A first very promising study indicates that a non negligible τ decays could be recovered by selecting two prongs and identifying one of the prongs as coming from a photon conversion.

2- The group continues working on the improvement of the τ-id as well as tau energy scale by using the energy flow techniques. This technique will become more and more challenging with the increase of luminosity.

3- The group continues investigating the τ trigger optimum for the coming 13-14 TeV run at higher luminosities.

The KEK, Tsukuba HEP and LAL Orsay groups are very complementary to fulfill successfully the working program described above

Budget

IN2P3 (euros): 8000 (800K yen) :

3 month stay of a student at LAL, meeting + travel

KEK (yen) : 300K (3000 euros) :

meeting + travel

Tsukuba HEP (yen) : 1140 K (11,400 euros) :

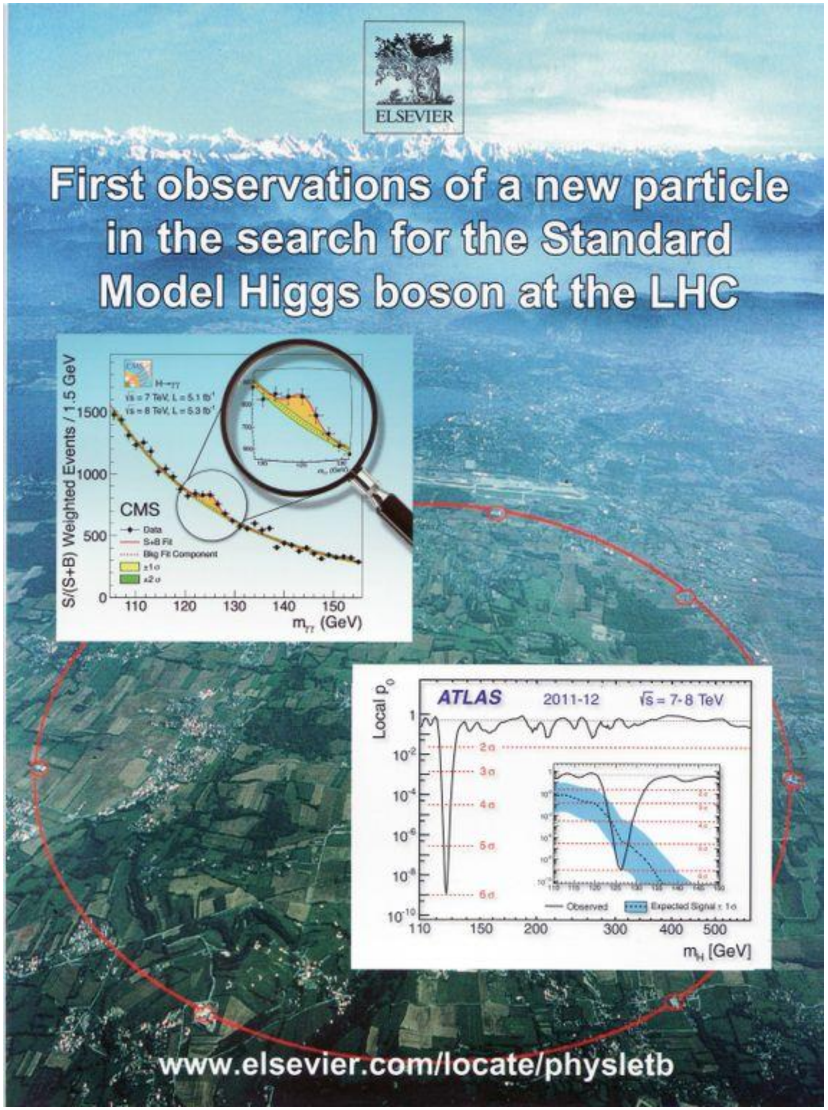
Travel to attend this workshop

Short stays in France + travel

For more details, report to the LH06 written proposal

Thank you!

Observation of a new Boson



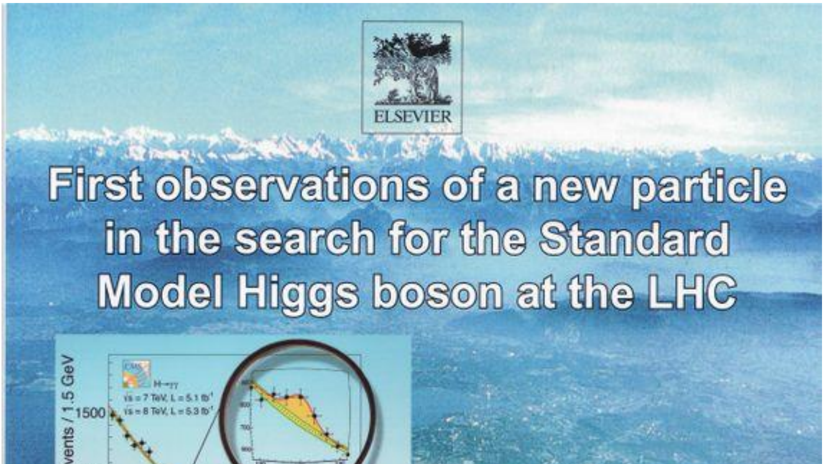
Phys.Lett. B716 (2012) 1-29

"These results provide conclusive evidence for the discovery of a new particle with mass 126.0±0.4 *(stat)*±0.4 *(sys)* GeV. "

What is "new particle"?

July 4th 2012 : ATLAS Higgs WG

Observation of a new Boson



Phys.Lett. B716 (2012) 1-29

"These results provide **conclusive evidence for the discovery of a new particle** with mass 126.0±0.4 *(stat)*±0.4 *(sys)* GeV. "

What is "new particle"?

The Nobel Prize in Physics 2013

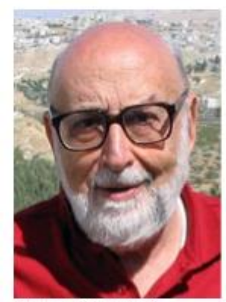


Photo: Pnicolet via Wikimedia Commons

François Englert

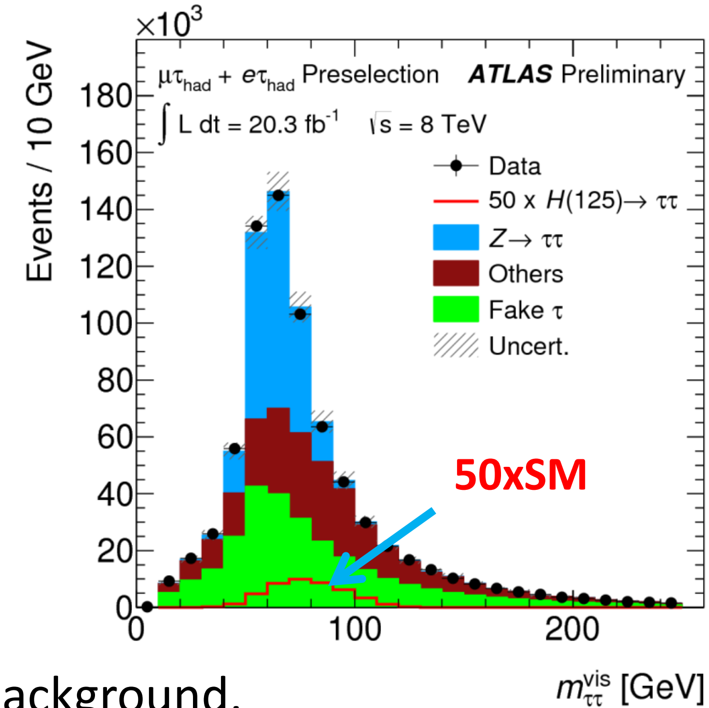
Photo: G-M Greuel via Wikimedia Commons

Peter W. Higgs

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"*

Why is H→ττ difficult? How to improve?

After di-tau candidate , S/B ratio is <0.001, while typical systeamtics of backgrounds are ~20%.

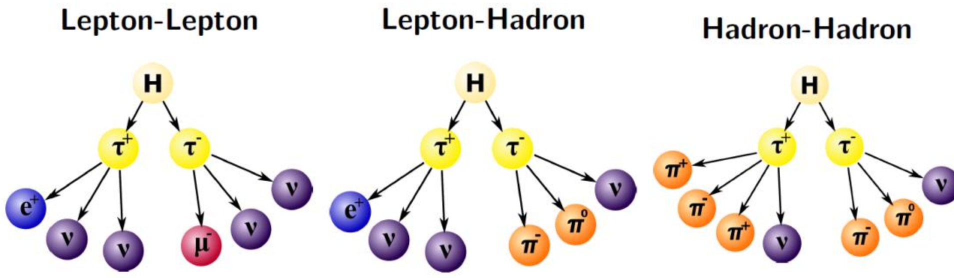


Quite different approaches were taken by ATLAS and CMS

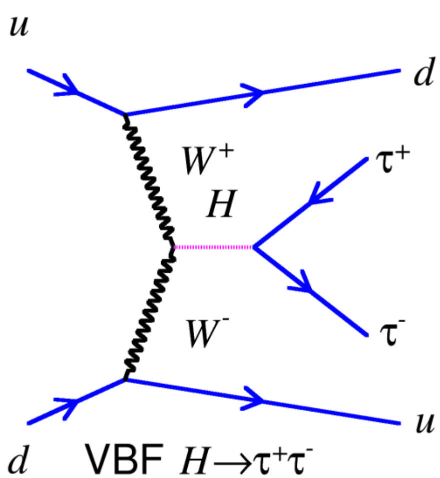
- ATLAS (8TeV)
  - Used very simple categorization (**6 categories**)
  - Used MVA technique to separate signal from background. (Used **MVA score as discriminant**.)
- CMS (7+8TeV)
  - Split data to many categories(**>50 categories**) based on S/B ratio.
  - Used Cut based analysis. (Used **Mass as discriminant**.) except ee and μμ channel (MVA analysis).

Analysis channels

- Analysis was optimized for each di-tau decay mode.
  - Different trigger, object selection and backgrounds.
- Categorize events to 2 category.

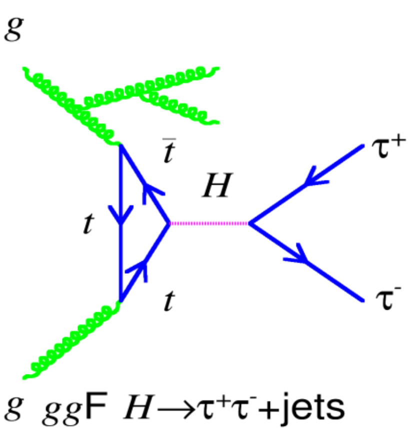


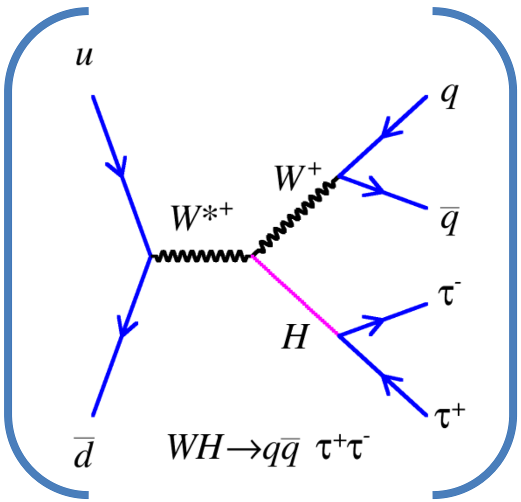
VBF category



- Find VBF jets with loose selection.
- Train BDT for VBF signal.

Boosted category





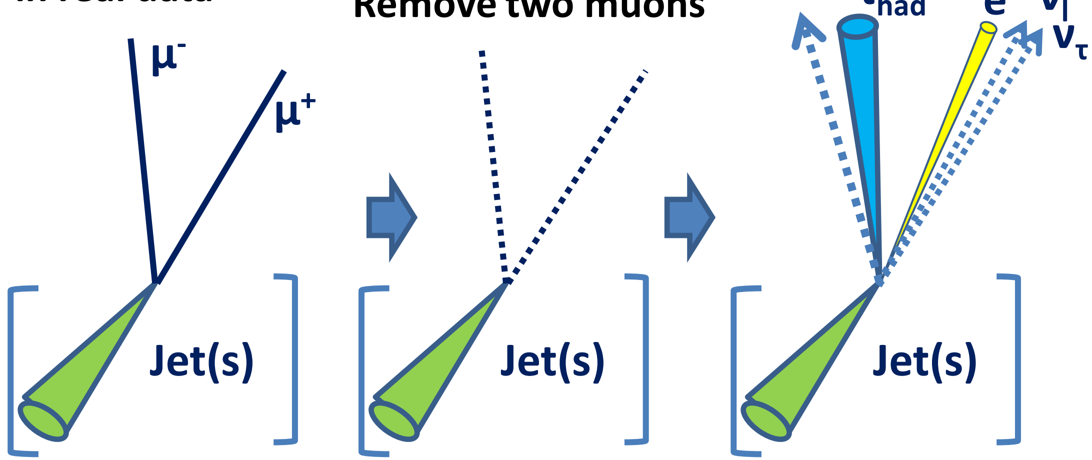
- Select events with high vector sum pT of tautau decay products.
- Not included non-boosted events.

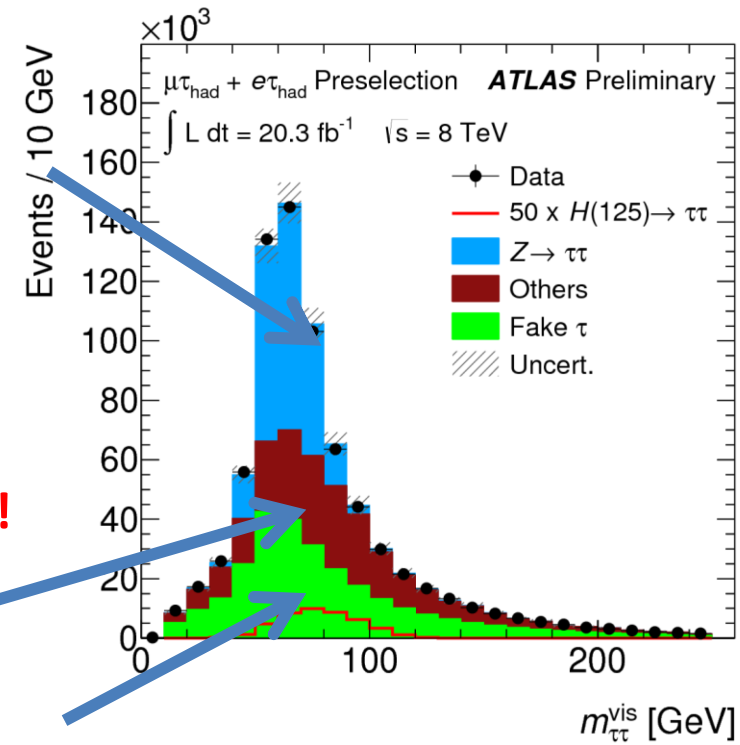
Background estimation overview

- Most important background is Z→ττ (irreducible).

Z→ττ estimated by embedding method

Select Z(+Jets) events in real data **Remove two muons** **Add simulated tau decay product**





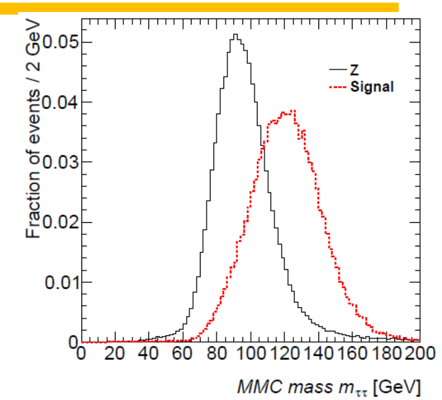
→ All jet kinematics and p_T^Z are from real data!

Z→ee/μμ + jets, Top, di-boson Estimated by MC with correction.

QCD and W+Jets – Data driven estimation for both shape and Normalization.

BDT input variables

- Trained BDT separately for 3 channels and VBF/Boosted. (total 6 categories)
  - **125GeV signal MC for the signal template.**
- MMC($m_{\tau\tau}$) is also included as one of the most powerful variable for the training.



VBF category

Variable	$\tau_{\rm lep}\tau_{\rm lep}$	$\tau_{\rm lep}\tau_{\rm had}$	$\tau_{\rm had}\tau_{\rm had}$
$M_{\tau\tau}^{MMC}$	●	●	●
$\Delta R_{\tau\tau}$	●	●	●
$\lvert\eta_{j2}-\eta_{j1}\rvert$	●	●	●
$m_{j1,j2}$	●	●	●
$\eta_{j1}\times\eta_{j2}$		●	●
$p_T^{\rm Total}$		●	●
$E_T^{miss}\phi$ centrality		●	●
$min(\Delta\eta_{\ell1\ell2,jets})$	●		
$\ell1\times\ell2\ \eta$ centrality	●		
$\Delta\eta_{j3,j1j2}$	●		
m_T		●	
$\ell\ \eta$ centrality		●	
$\tau_1\ \eta$ centrality			●
$\tau_2\ \eta$ centrality			●

Boosted category

Variable	$\tau_{\rm lep}\tau_{\rm lep}$	$\tau_{\rm lep}\tau_{\rm had}$	$\tau_{\rm had}\tau_{\rm had}$
$M_{\tau\tau}^{MMC}$	●	●	●
$E_T^{miss}\phi$ centrality	●	●	●
$\Delta R_{\tau\tau}$		●	●
sum P_T		●	●
$P_T(\tau_1)/p_T(\tau_2)$		●	●
$m_{\tau\tau,j1}$	●		
$m_{\ell1,\ell2}$	●		
$\Delta\phi_{\ell1,\ell2}$	●		
sphericity	●		
$p_T^{\ell1}$	●		
p_T^{j1}	●		
$E_T^{miss}/p_T^{\ell2}$	●		
m_T		●	
τ_{1x}			●
τ_{2x}			●

Di-tau Mass reconstruction

Di-tau invariant mass should be an important discriminating variable from backgrounds. But having 2-4ν in a event.

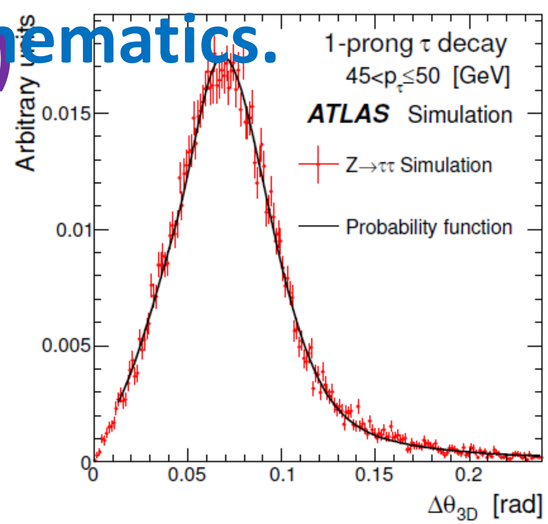
Need…

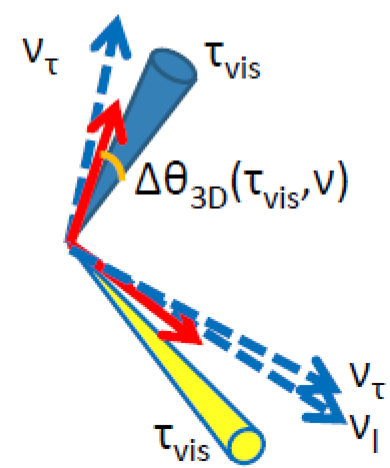
Event by Event estimator of true di-τ mass likelihood.

Full reconstruction of event kinematics.

Missing Mass Calculator (MMC)

- Solve τ, E_T^{miss} in $\Delta\phi(\tau_{vis},\nu)$ parameter space using $\Delta\theta_{3D}(\tau_{vis},\nu)$ template from simulation as PDF.





CMS uses the similar method with Matrix element

Background estimation and validation

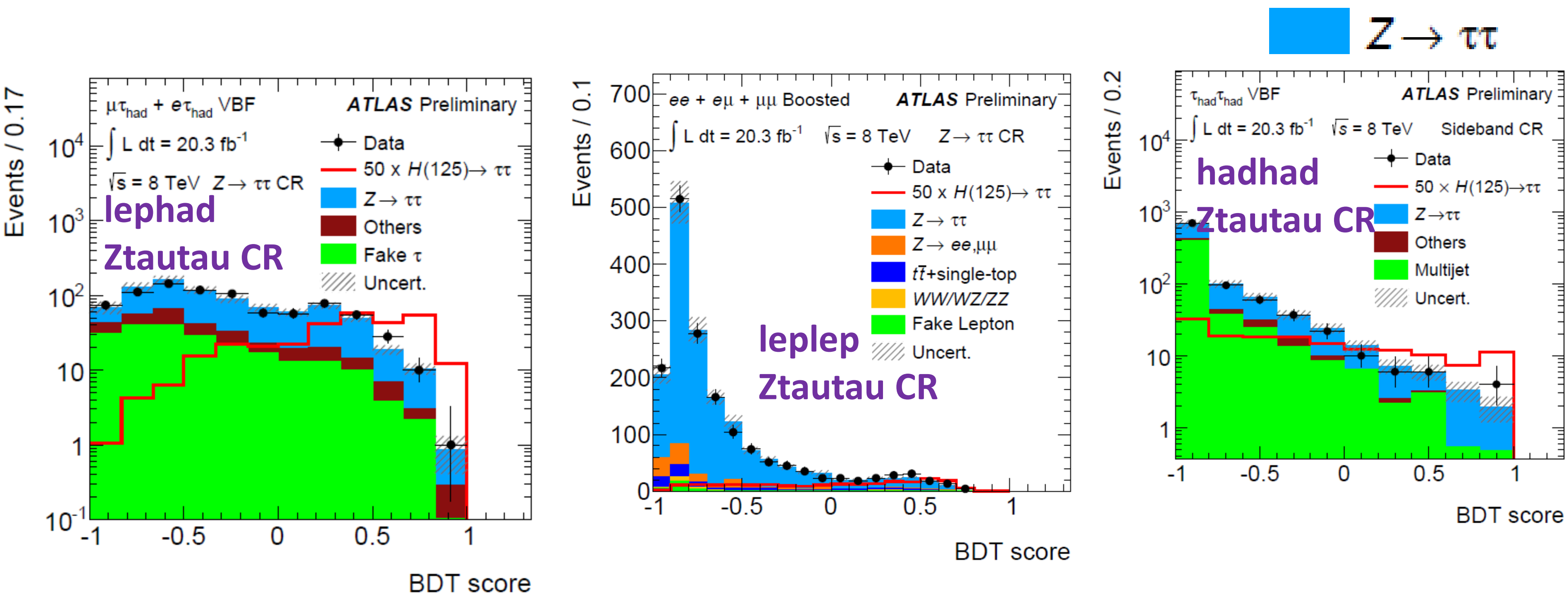
NOTE: MVA(BDT) analysis has to be validated carefully :

if all training variables are modeled well. → **checked OK for each.**

if all variable correlations are also modeled.

→ **checked BDT score for each background CR.**

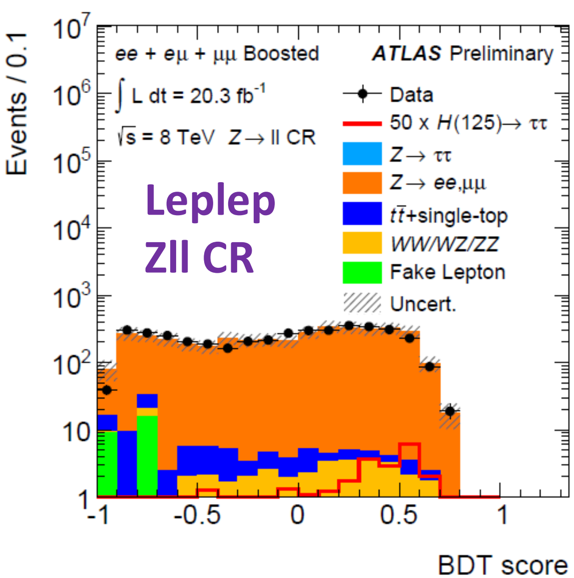
- E.g. $m_{\tau\tau}$ sideband CR as Z→tautau validation region



Background estimation and validation

- Z→ll CR (mll~mZ) for leplep channel

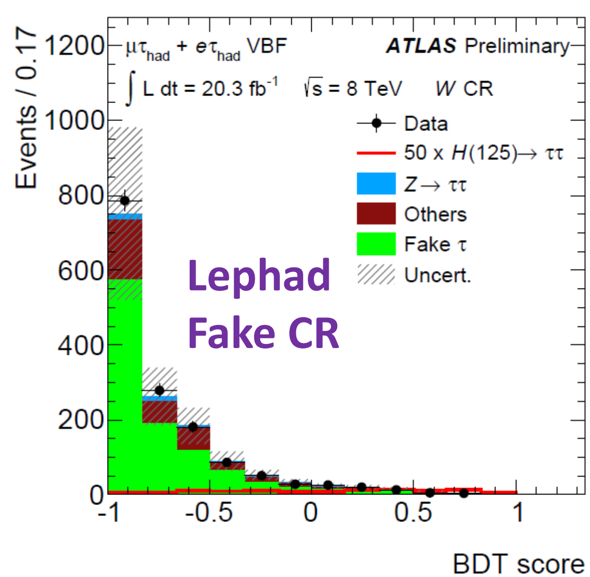
Z→ ee,μμ

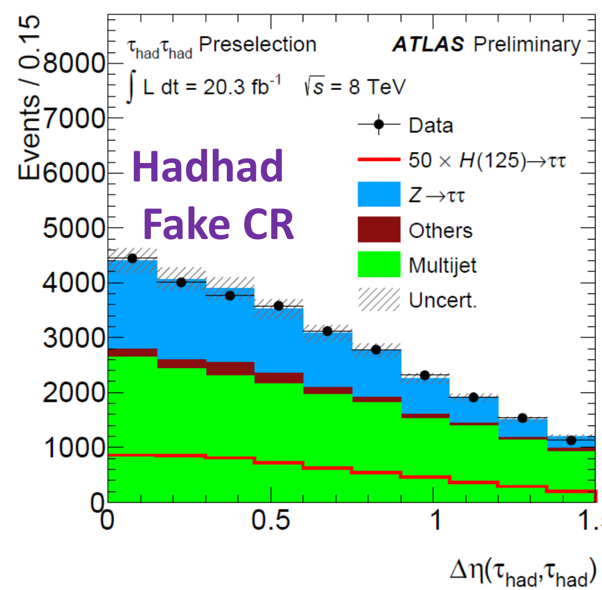


- W+jets & QCD CR

Fake τ

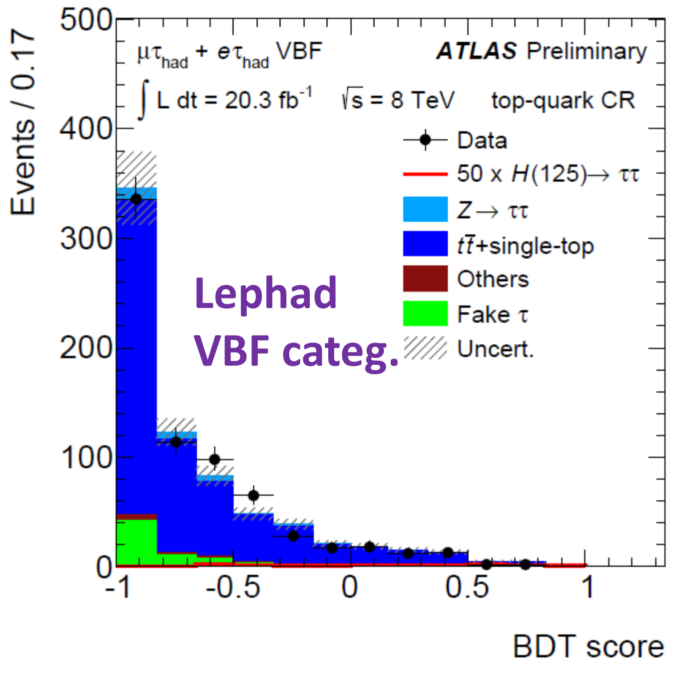
lephad (high mT) hadhad(pre-selection)

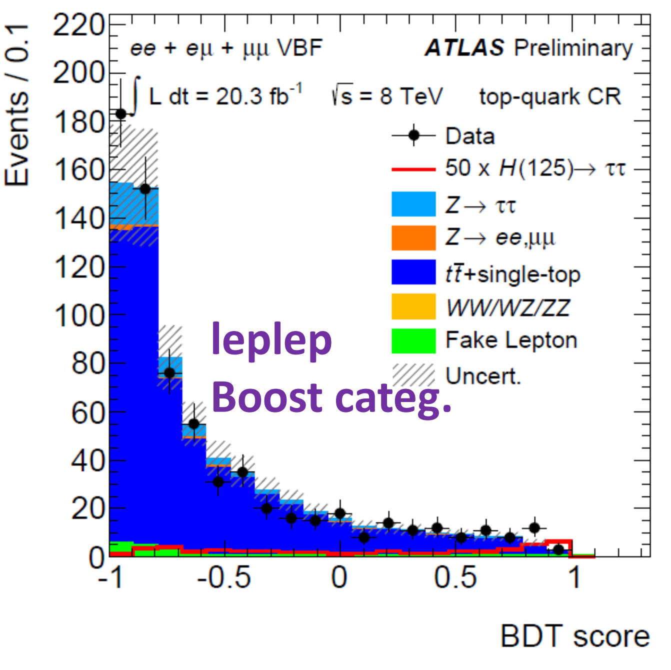




Background estimation and validation

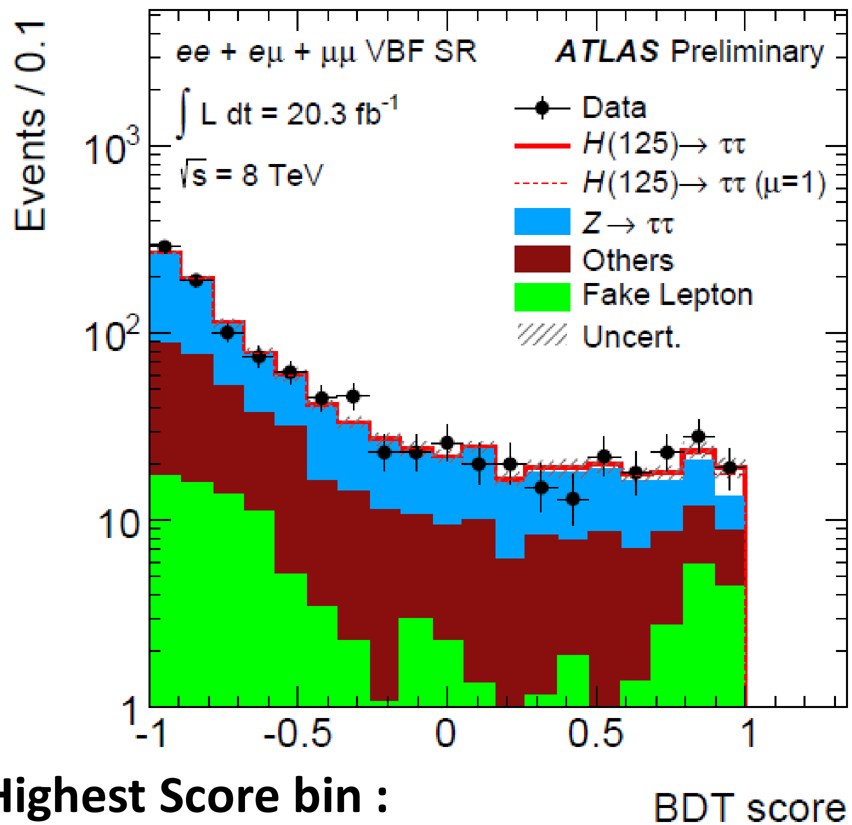
- Top CR by requiring at least one b-tagged jets.

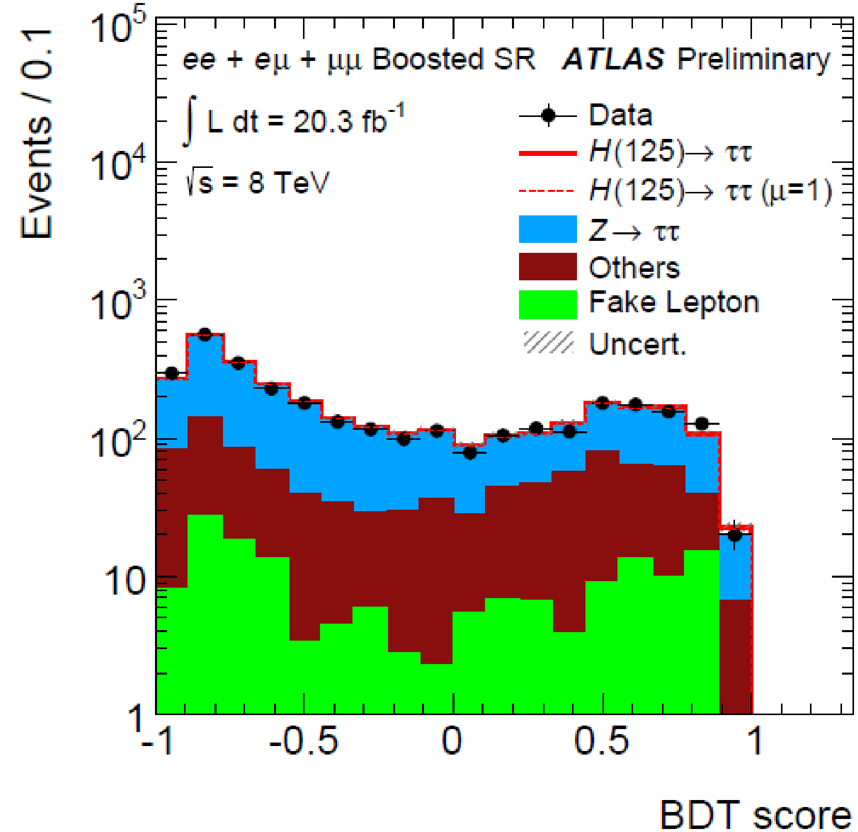




→ All training variables and BDT score distributions in each CRs are modeled by estimation.

BDT distribution in leplep SR

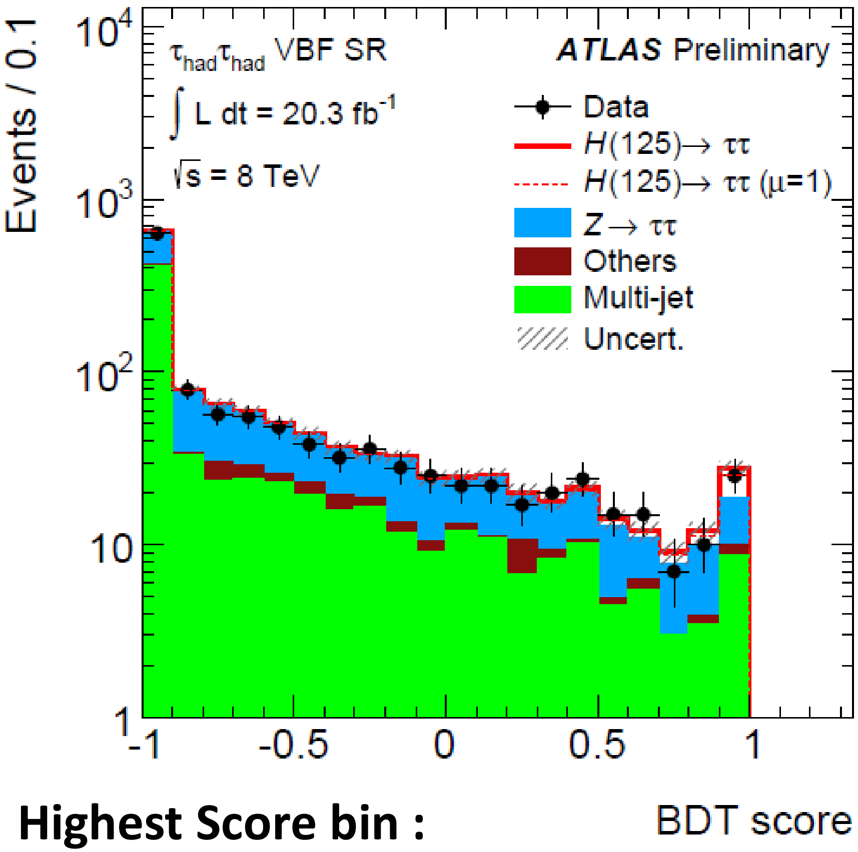


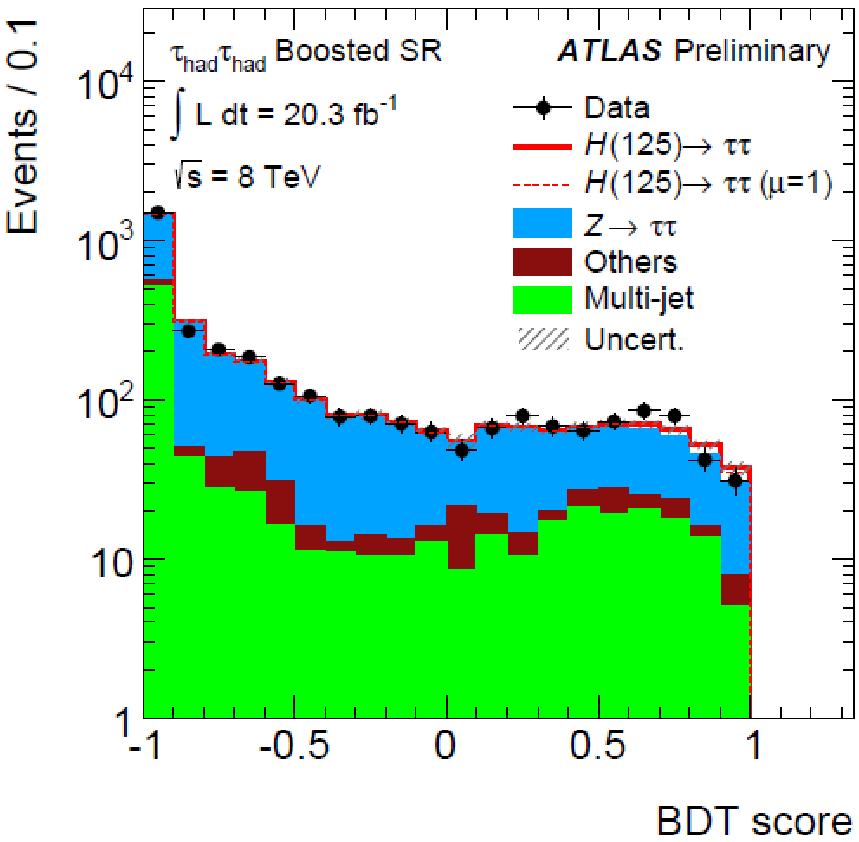


Highest Score bin :

	ggF	VBF	VH	Z→ττ	Fake	Top	Others	S/B
VBF	0.7±0.4	5.0±1.5	--	4.6±0.6	4.5±1.7	1.8±0.4	2.7±0.4	**0.42**
boosted	1.7±0.7	0.7±0.2	0.2±0.1	13±1	0.8±0.3	3.5±0.9	2.3±0.2	**0.13**

BDT distribution in hadhad SR





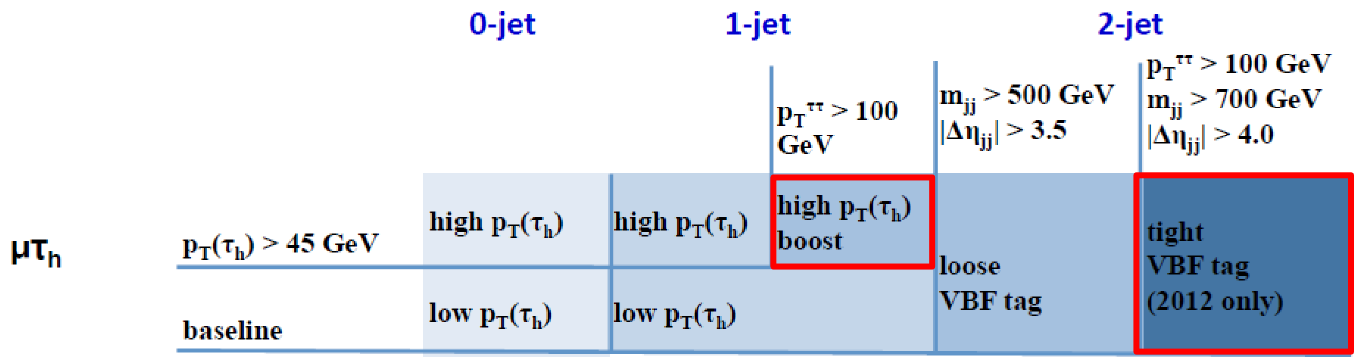
Highest Score bin :

	ggF	VBF	VH	Z→ττ	Fake	Others	S/B
VBF	2.0±0.9	5.9±1.8	--	5.3±1.0	5.9±0.9	0.6±0.1	**0.67**
boosted	2.3±0.9	0.6±0.2	0.7±0.2	9.7±1.6	1.4±0.2	0.07±0.02	**0.32**

CMS Analysis

Categorization

- Categorize events based on different S/B ratio.
  - Introduced new high sensitivity categories.



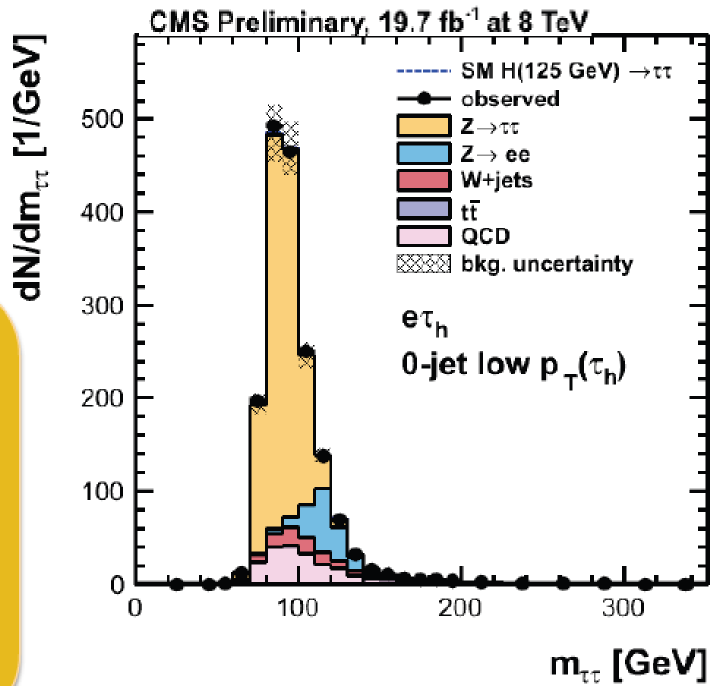
- Each di-tau decay channels have at most 7 categ.
  - 27 categories for 8TeV
  - 24 categories for 7TeV
  - Total : 51 categories

had + had	3(3) categ.	Used mass discriminant
mu + had	7(6) categ.	Used mass discriminant
e + had	6(5) categ.	Used mass discriminant
e + mu	6(5) categ.	Used mass discriminant
mu + mu	6(5) categ.	MVA score discriminant
e + e	5(5) categ.	MVA score discriminant

- Used MVA for ee/μμ channels

Background estimation

All normalizations are data-driven



W+jets:
- Normalization from high m_T control region
- Shape from MC

Different from ATLAS

$Z\rightarrow\tau\tau$:
embedded samples
No MET/JES scale uncertainties
Shape estimation and correction for selection efficiencies

ttbar:
- Normalization from eμ b-tag control region
- Shape from MC

$Z\rightarrow ee/\mu\mu$
- Normalization scale factor from tag-and-probe in data
- Shape from MC

QCD:
- Normalization from ratio of same-sign(SS) to opposite-sign (OS) data events
- Shape from SS data events

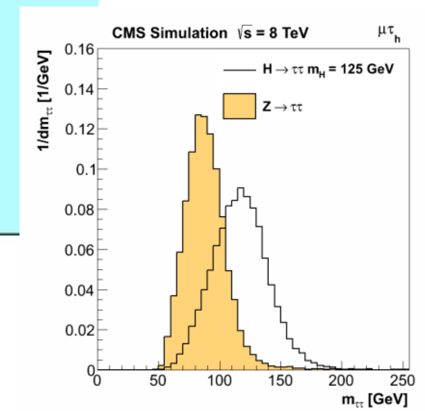
Different from ATLAS

Systematic uncertainties

Experimental uncertainties / **Background estimation**

Uncertainty	Affected samples	Change in acceptance
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%
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%)

Rows from "Tau energy scale" to "$\varepsilon_{b\text{-tag}}$ light-flavoured jets": Experimental uncertainties. Rows from "Norm. Z production" to "Luminosity 7 TeV (8 TeV)": Background estimation.



Tau Energy Scale(TES) uncertainty is one of the dominant uncertainty unlike ATLAS.

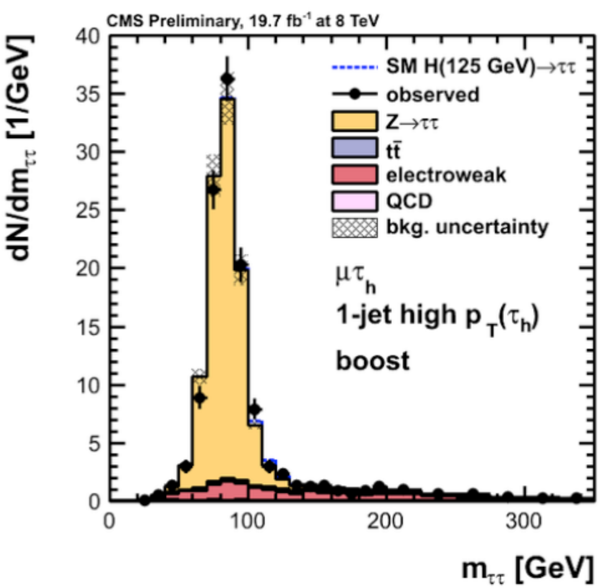
This is simply because CMS uses the mass discriminant which is quite sensitive to the TES.

CMS Results

Mass distribution in the signal region

- $\mu\tau_h$ channel is the most sensitive channel

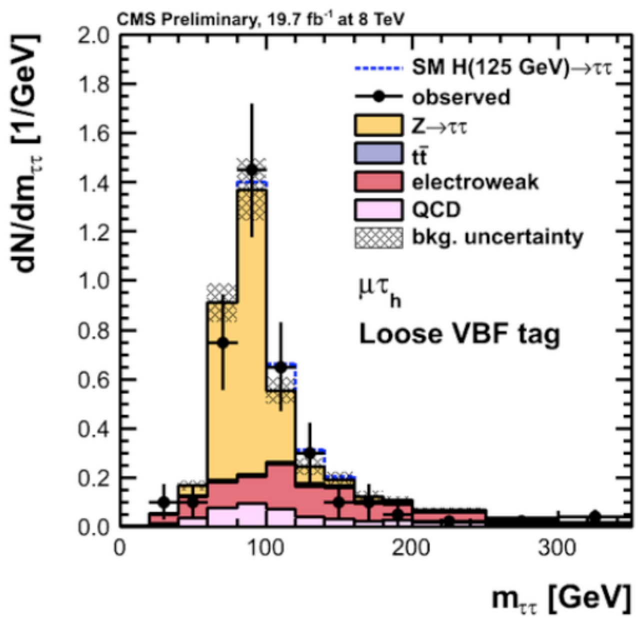
1-jet high $p_t(\tau_h)$ boost



$p_t(\tau_h) > 45$ GeV

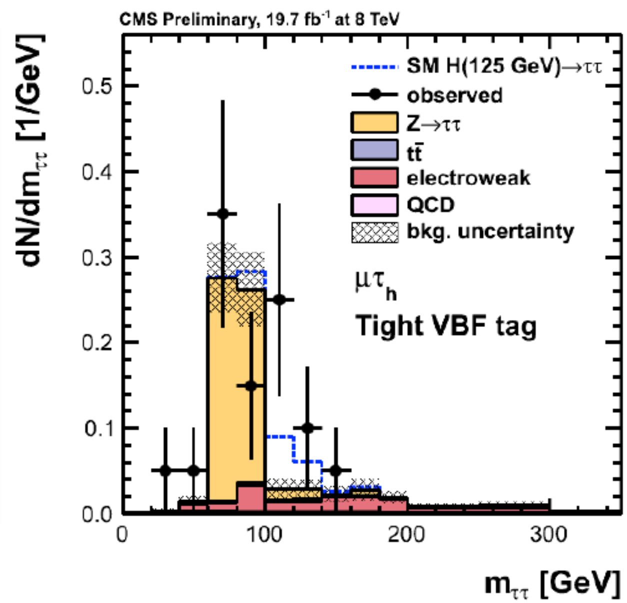
$p_t^{\tau\tau} > 100$ GeV

2-jet: loose VBF tag



$M_{jj} > 500$ GeV $|\Delta\eta_{jj}| > 3.5$

2-jet tight VBF tag



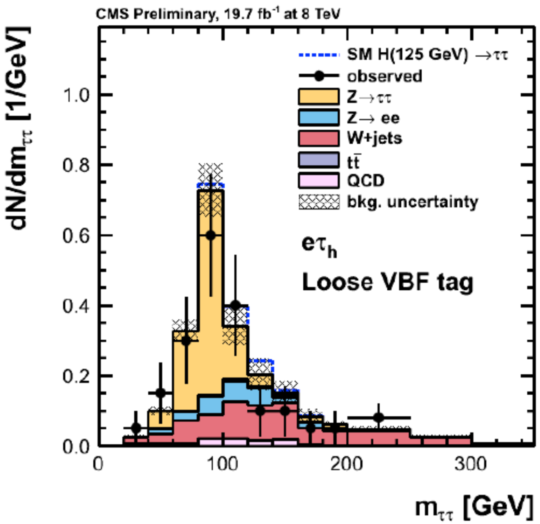
$M_{jj} > 700$ GeV, $|\Delta\eta_{jj}| > 4$

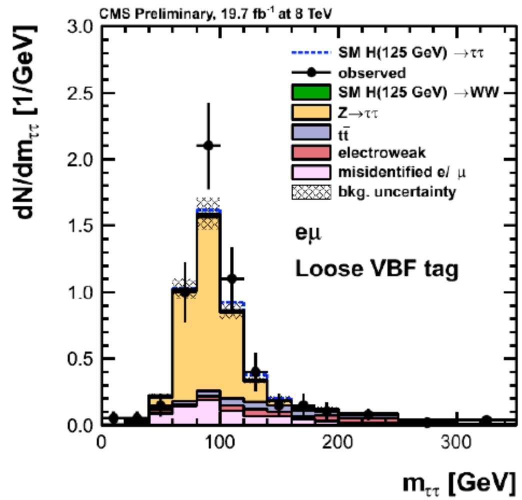
$p_t^{\tau\tau} > 100$ GeV

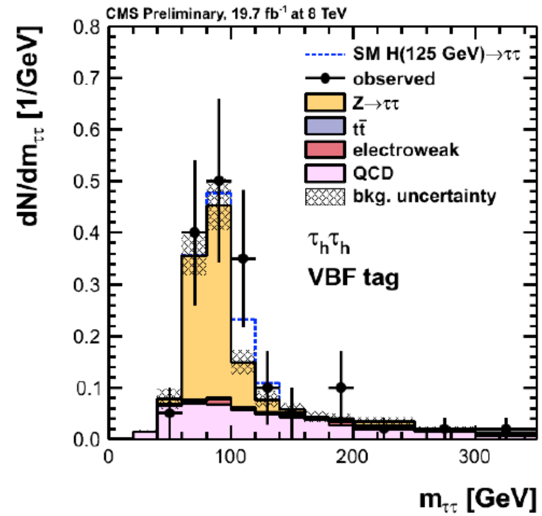
Mass distribution in the signal region

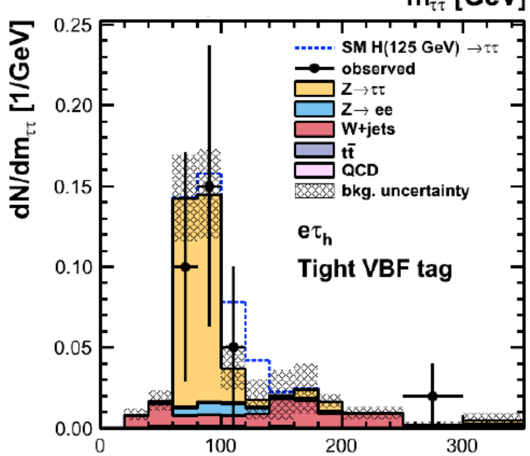
- Other VBF channels

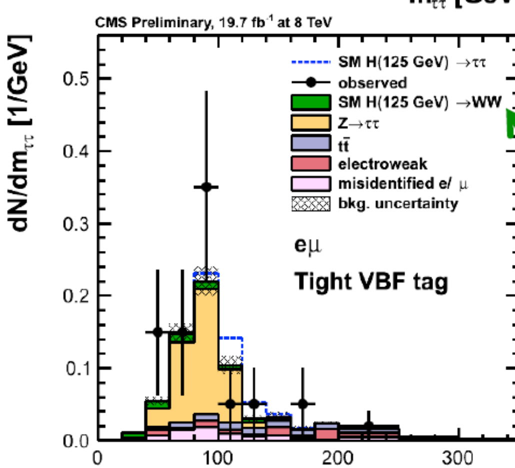
eτ **eμ** **$\tau_h\tau_h$**











$\tau_h\tau_h$: no tight-VBF

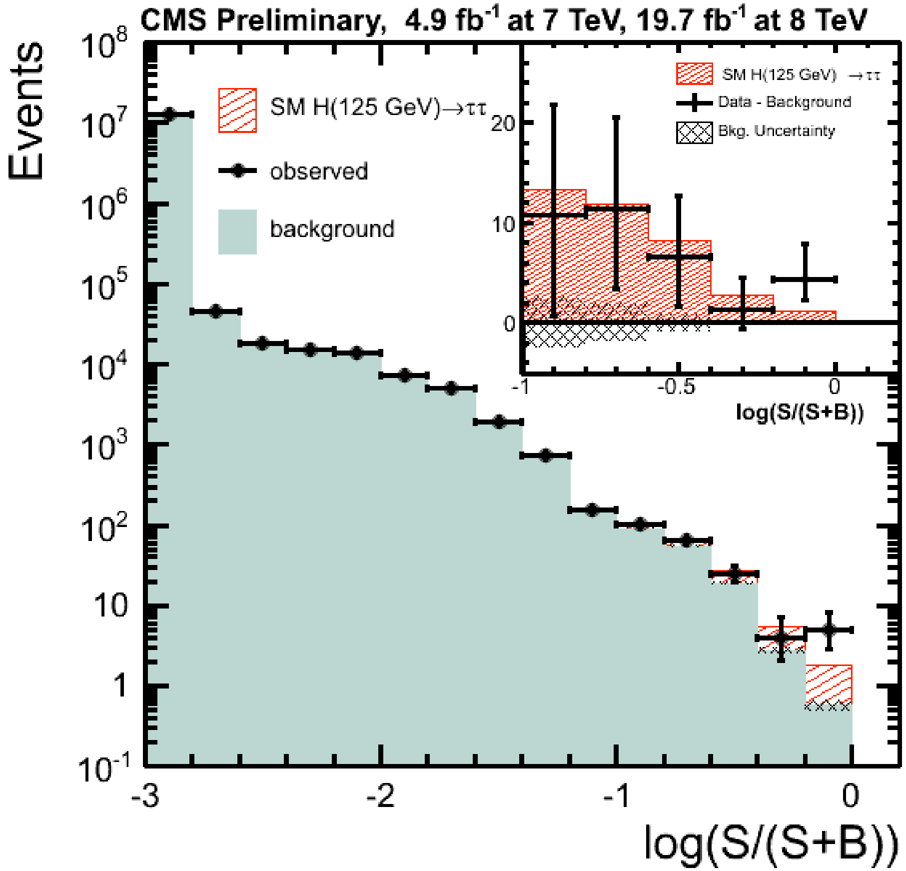
eμ:
H→WW contribution!

H→WW is treated as background to probe fermionic decay contribution

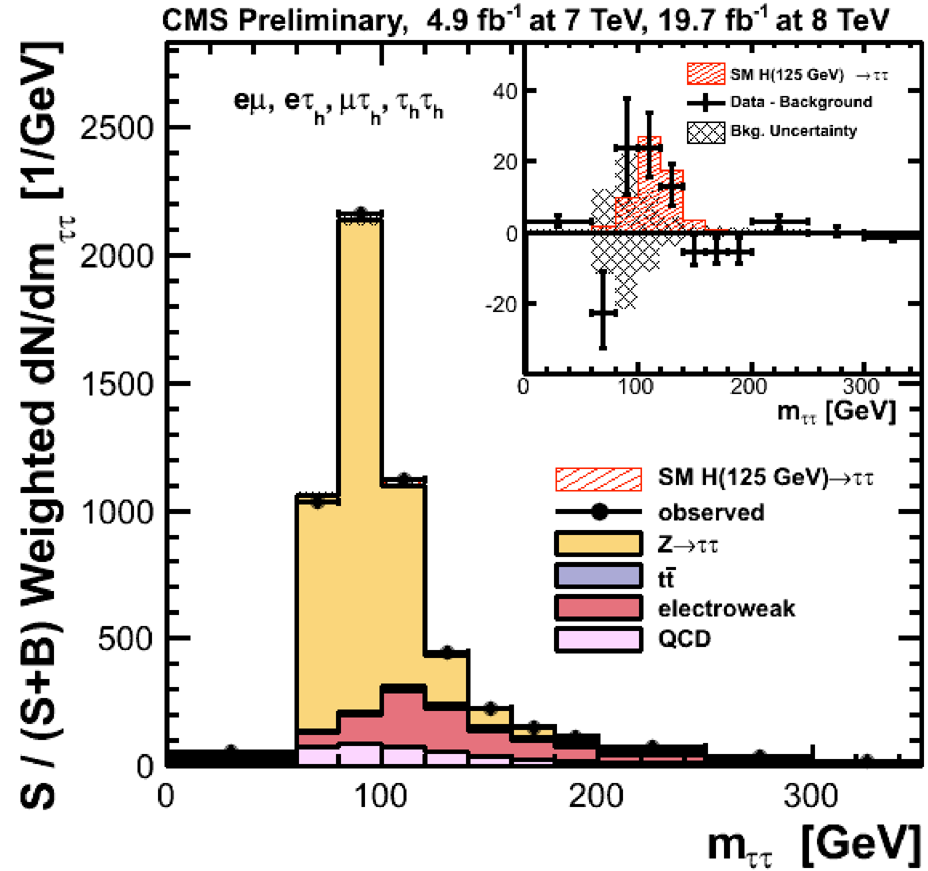
Summary plots

- Calculate S/(S+B) in every bin of the mass distributions of every event category and channels.
- Weighted by S/(S+B) using 68% region around the $m_{\tau\tau}$ peak.

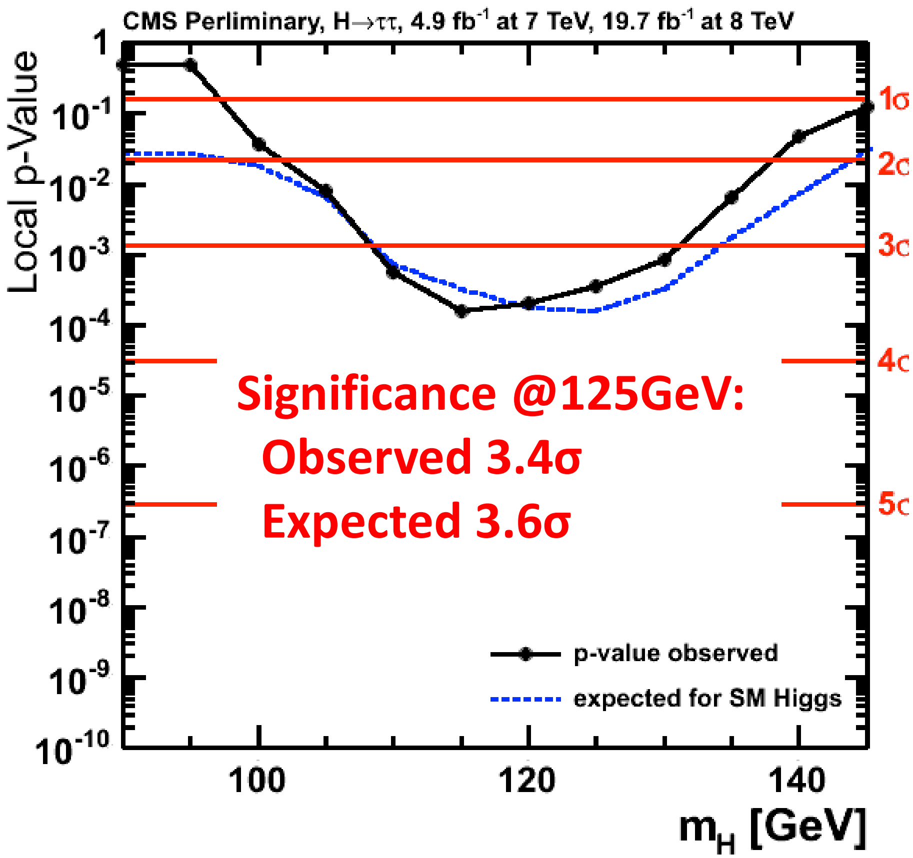
All channels : $e\mu$, $e\tau_h$, $\mu\tau_h$, $\tau_h\tau_h$, ee, $\mu\mu$

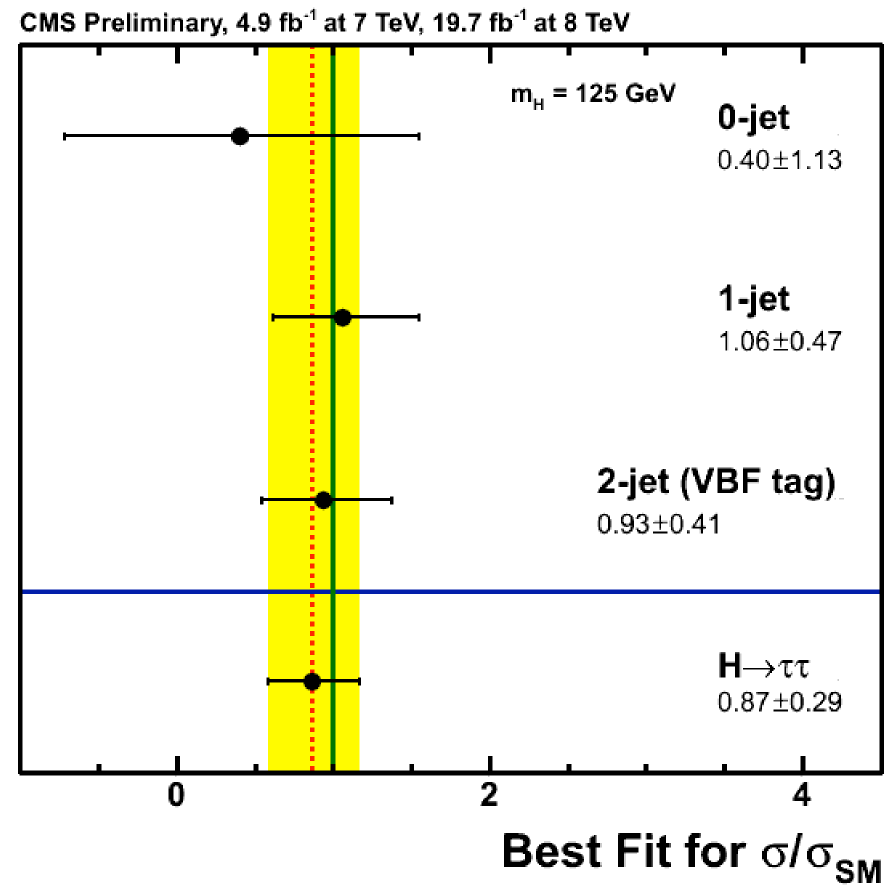


$e\mu$, $e\tau_h$, $\mu\tau_h$, $\tau_h\tau_h$ Only



Significance and Signal strength





Assuming mH=125GeV :

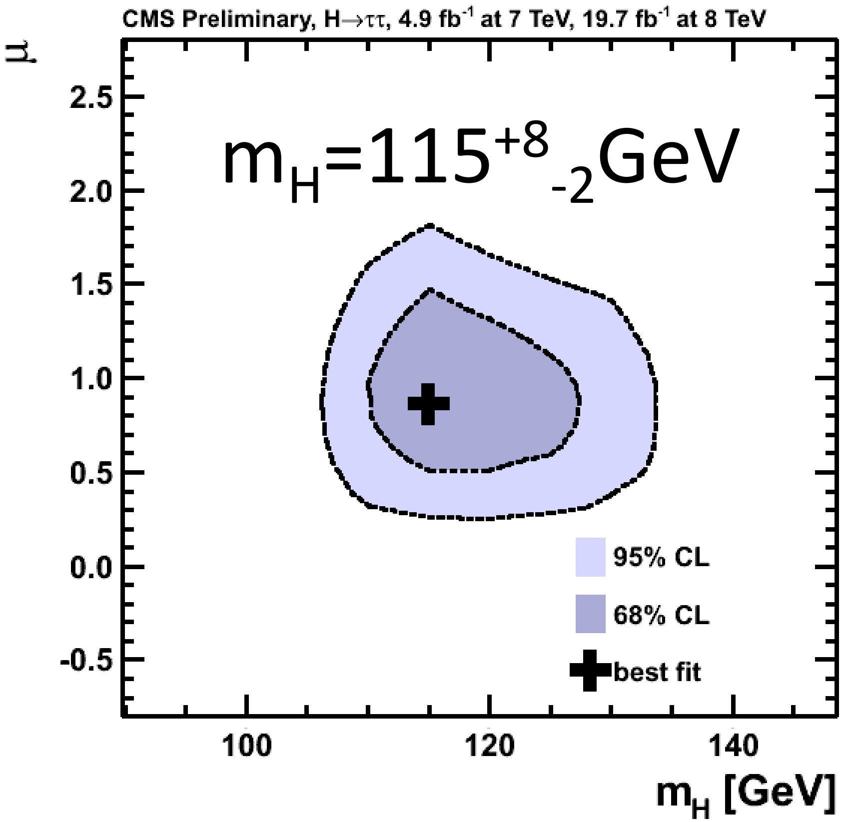
Evidence of H→ττ decay!

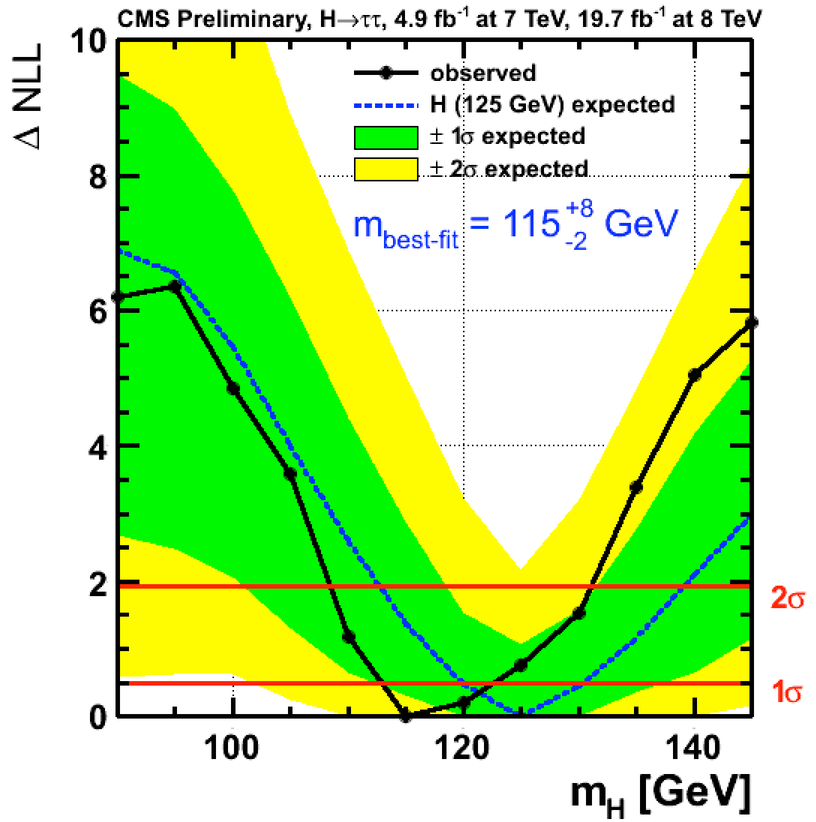
μ_{best}=0.87±0.29

Mass measurement of the resonance?

Mass sensitivity in CMS

- Since CMS uses the mass distribution as discriminant, it is possible to measure the mass.





Previous result

Last tautau public results are :

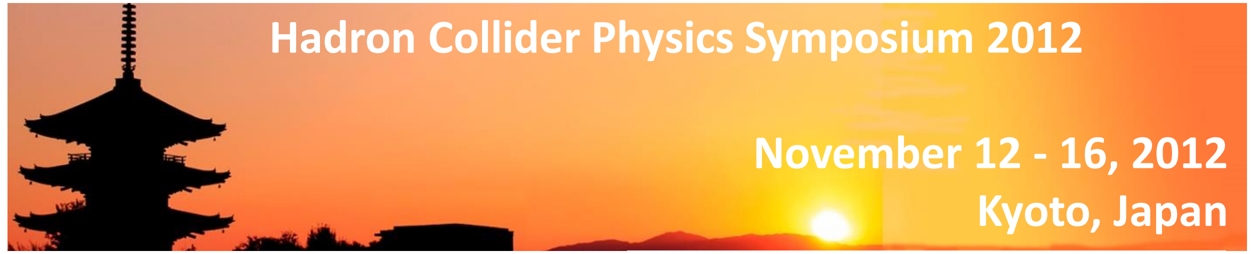
ATLAS-CONF-2012-160

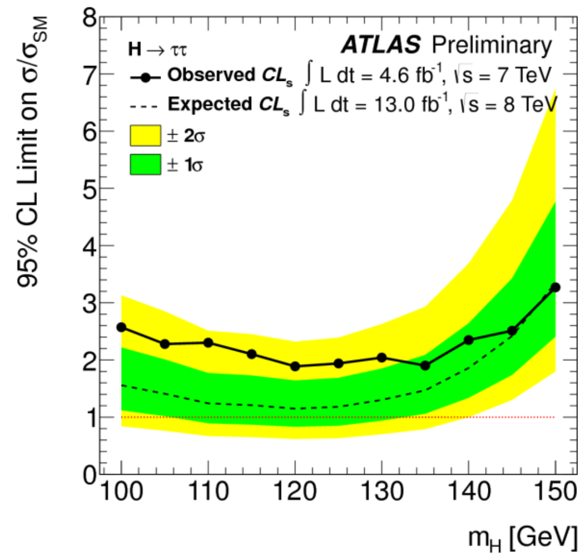
One year ago…

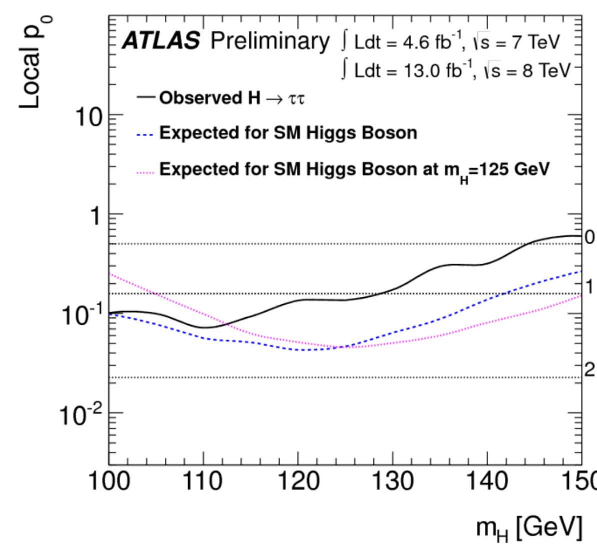
Limit (exp):1.9(1.2)xSM

p0(exp): 1.1(1.7)σ

μ= 0.7 ±0.7







- **Repeated analyses by using full data ($13 \rightarrow 20 fb^{-1}$) didn't expect reaching evidence.**

Backgrounds in highest score bins (leplep)

Process/Category	VBF			Boosted		
BDT score bin edges	0.684-0.789	0.789-0.895	0.895-1.0	0.667-0.778	0.778-0.889	0.889-1.0
ggF	0.53 ± 0.26	0.8 ± 0.4	0.7 ± 0.4	5.3 ± 2.1	5.2 ± 2.0	1.7 ± 0.7
VBF	1.15 ± 0.35	2.0 ± 0.6	5.0 ± 1.5	1.01 ± 0.33	1.5 ± 0.5	0.67 ± 0.22
WH	< 0.05	< 0.05	< 0.05	0.71 ± 0.22	0.64 ± 0.20	0.16 ± 0.05
ZH	< 0.05	< 0.05	< 0.05	0.36 ± 0.11	0.32 ± 0.10	0.06 ± 0.02
$Z \to \tau^+\tau^-$	7.6 ± 0.8	9.0 ± 0.9	4.6 ± 0.6	97 ± 7	61.5 ± 3.2	13.6 ± 1.3
Fake	2.8 ± 0.7	5.8 ± 2.0	4.5 ± 1.7	10.1 ± 3.1	15 ± 5	0.79 ± 0.29
Top	4.0 ± 0.9	2.9 ± 0.7	1.8 ± 0.4	28 ± 7	15 ± 4	3.5 ± 0.9
Others	1.97 ± 0.26	3.3 ± 0.4	2.7 ± 0.4	24.7 ± 1.9	8.8 ± 0.6	2.34 ± 0.24
Total Background	16.3 ± 1.5	20.9 ± 2.4	13.5 ± 2.4	160 ± 7	101 ± 4	20.2 ± 1.8
Total Signal	1.7 ± 0.5	2.9 ± 0.9	5.7 ± 1.7	7.4 ± 2.4	7.7 ± 2.5	2.6 ± 0.8
S/B	0.10	0.14	0.42	0.05	0.08	0.13
Data	23	28	19	156	128	20

	ggF	VBF	VH	$Z \to \tau\tau$	Fake	Top	Others	S/B
VBF	0.7±0.4	5.0±1.5	--	4.6±0.6	4.5±1.7	1.8±0.4	2.7±0.4	0.42
boosted	1.7±0.7	0.7±0.2	0.2±0.1	13±1	0.8±0.3	3.5±0.9	2.3±0.2	0.13

Backgrounds in highest score bins (lephad)

Process/Category	VBF			Boosted		
BDT score bin edges	0.5-0.667	0.667-0.833	0.833-1.0	0.6-0.733	0.733-0.867	0.867-1.0
ggF	2.2 ± 0.9	3.5 ± 1.5	1.2 ± 0.6	7.7 ± 2.9	6.3 ± 2.3	5.5 ± 2.1
VBF	4.1 ± 1.2	9.2 ± 2.7	7.5 ± 2.2	1.7 ± 0.5	1.5 ± 0.5	1.3 ± 0.4
WH	< 0.05	< 0.05	< 0.05	0.95 ± 0.29	0.85 ± 0.26	0.81 ± 0.25
ZH	< 0.05	< 0.05	< 0.05	0.42 ± 0.13	0.47 ± 0.14	0.41 ± 0.12
$Z \to \tau^+\tau^-$	28.6 ± 1.4	25.0 ± 1.6	2.41 ± 0.35	48.3 ± 3.4	26.1 ± 2.7	18.4 ± 2.0
Fake	37.7 ± 1.8	27.9 ± 2.1	3.5 ± 0.5	27 ± 4	10.8 ± 1.8	5.8 ± 1.4
Top	6.5 ± 0.7	4.1 ± 0.8	1.5 ± 0.4	7.0 ± 0.9	5.7 ± 0.8	2.23 ± 0.33
Diboson	2.9 ± 0.4	3.0 ± 0.5	0.23 ± 0.04	4.8 ± 0.5	4.0 ± 0.5	1.69 ± 0.23
$Z \to \ell\ell(j \to \tau_{\text{had}})$	8.7 ± 1.7	3.3 ± 0.5	0.40 ± 0.10	3.8 ± 0.5	0.71 ± 0.07	< 0.05
$Z \to \ell\ell(\ell \to \tau_{\text{had}})$	2.8 ± 1.2	1.9 ± 1.2	0.7 ± 0.6	9.4 ± 1.9	4.9 ± 1.1	3.8 ± 1.2
Total Background	87.2 ± 2.7	65 ± 5	8.7 ± 2.5	101 ± 6	52 ± 4	32 ± 4
Total Signal	6.3 ± 1.8	12.7 ± 3.5	8.7 ± 2.4	10.7 ± 3.3	9.2 ± 2.8	8.0 ± 2.5
S/B	0.07	0.20	1.0	0.11	0.18	0.25
Data	90	80	18	103	64	34

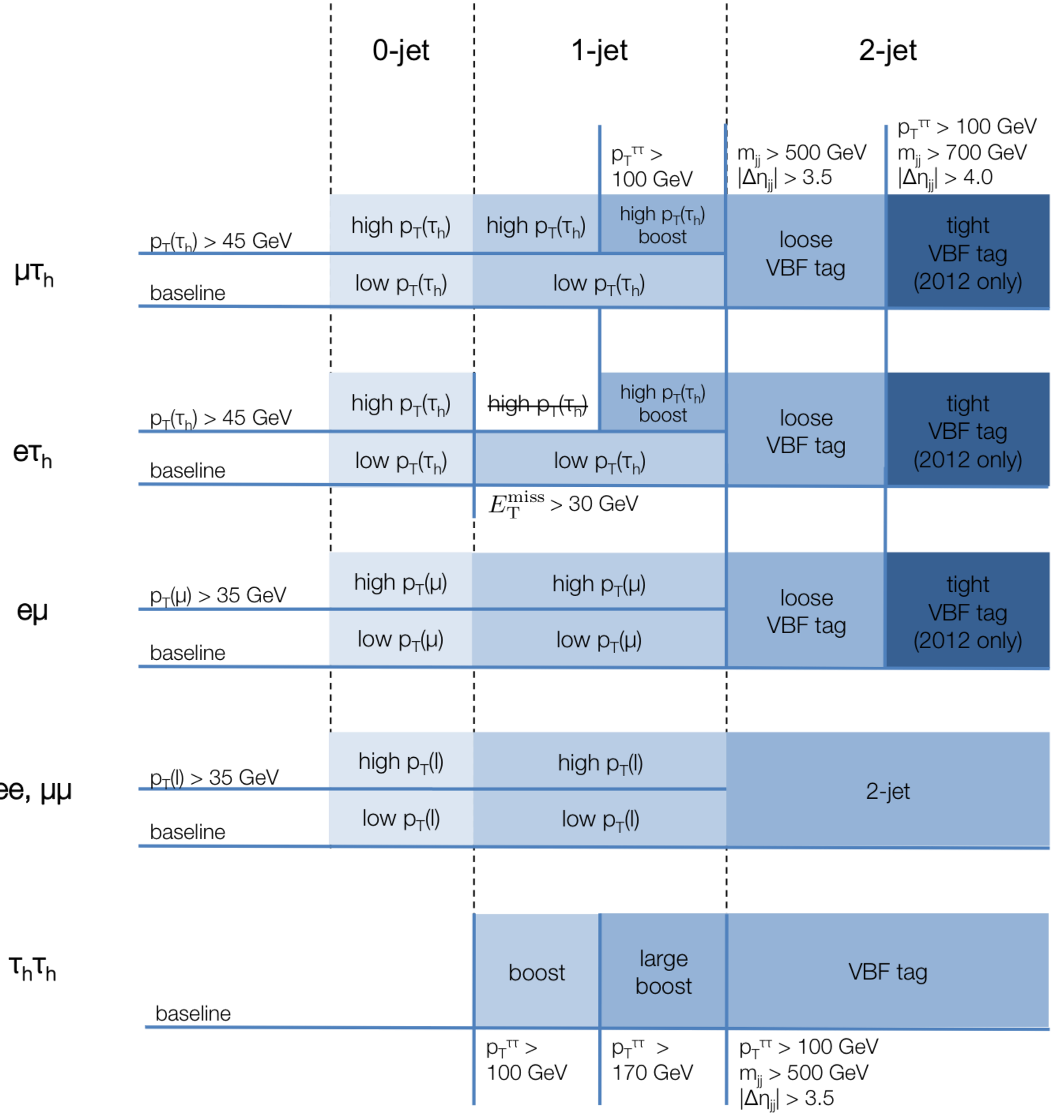
	ggF	VBF	VH	$Z \to \tau\tau$	Fake	Top	Others	S/B
VBF	1.2±0.6	7.5±2.2	--	2.4±0.4	3.5±0.5	1.5±0.4	1.3±0.7	1.0
boosted	5.5±2.1	1.3±0.4	1.2±0.3	18±2	5.8±1.4	2.2±0.3	5.5±1.2	0.25

Backgrounds in highest score bins (hadhad)

Process/Category	VBF			Boosted		
BDT score bin edges	0.85-0.9	0.9-0.95	0.95-1.0	0.85-0.9	0.9-0.95	0.95-1.0
ggF	0.39 ± 0.17	0.35 ± 0.16	2.0 ± 0.9	2.2 ± 0.8	2.5 ± 1.0	2.3 ± 0.9
VBF	0.57 ± 0.18	0.72 ± 0.22	5.9 ± 1.8	0.55 ± 0.17	0.61 ± 0.19	0.57 ± 0.17
WH	< 0.05	< 0.05	< 0.05	0.34 ± 0.11	0.40 ± 0.12	0.44 ± 0.14
ZH	< 0.05	< 0.05	< 0.05	0.22 ± 0.07	0.22 ± 0.07	0.22 ± 0.07
$Z \rightarrow \tau^+\tau^-$	3.2 ± 0.6	3.4 ± 0.7	5.3 ± 1.0	15.7 ± 1.7	12.3 ± 1.8	9.7 ± 1.6
Multijet	3.3 ± 0.6	2.9 ± 0.6	5.9 ± 0.9	5.2 ± 0.6	3.7 ± 0.5	1.40 ± 0.22
Others	0.38 ± 0.09	0.49 ± 0.12	0.64 ± 0.13	1.49 ± 0.27	2.8 ± 0.5	0.07 ± 0.02
Total Background	6.9 ± 1.3	6.8 ± 1.3	11.8 ± 2.6	22.4 ± 2.5	18.8 ± 2.8	11.2 ± 1.9
Total Signal	0.97 ± 0.29	1.09 ± 0.31	8.0 ± 2.2	3.3 ± 1.0	3.8 ± 1.2	3.6 ± 1.1
S/B	0.14	0.16	0.67	0.15	0.2	0.32
Data	6	6	19	20	16	15

	ggF	VBF	VH	$Z \rightarrow \tau\tau$	Fake	Others	S/B
VBF	2.0±0.9	5.9±1.8	--	5.3±1.0	5.9±0.9	0.6±0.1	0.67
boosted	2.3±0.9	0.6±0.2	0.7±0.2	9.7±1.6	1.4±0.2	0.07±0.02	0.32

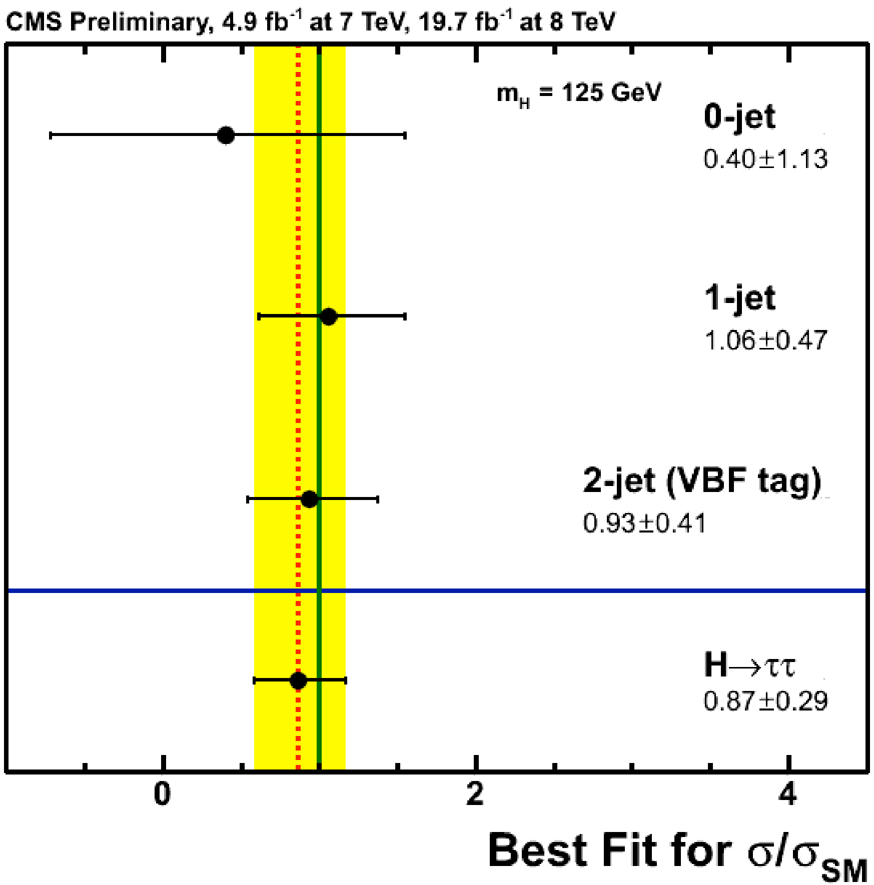
Full categorization chart



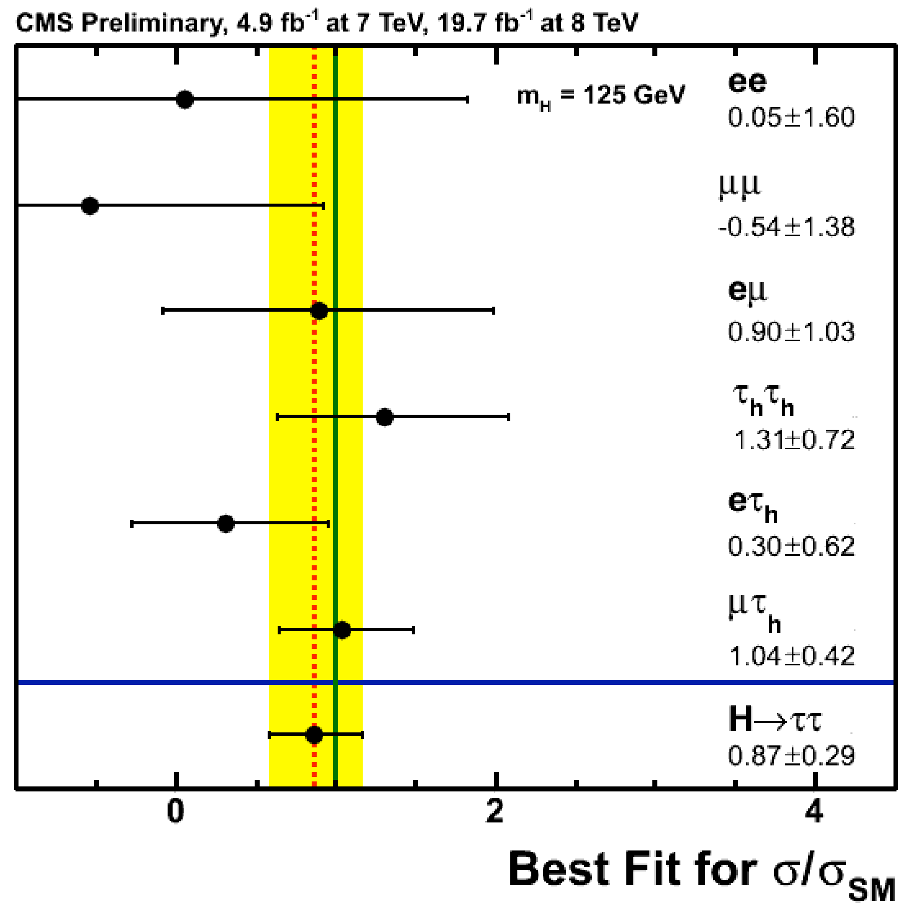
- For 7TeV analysis, loose and tight VBF categories are merged.
- 1jet e-had cahnnels used MET>30GeV cut.

Signal strength

Events split by categories



Events split by channels



Background estimation and validation

<table>
<tr><th></th><th>Lep-had</th><th>Leplep</th><th>hadhad</th></tr>
<tr><td>Z→ττ</td><td colspan="3">Shape : Embedding
Norm : Fit in SR (+ Δη CR for hadhad)</td></tr>
<tr><td>Fake (QCD)</td><td rowspan="2">Fake factor Estimation
(used Anti-tau CR)
Shape&Norm : data</td><td rowspan="2">Template fit method
(used non-isol CR)
Shape&Norm : data</td><td>Shape : not OS data
Norm : Fit in Δη CR</td></tr>
<tr><td>Fake (W+jets)</td><td>MC</td></tr>
<tr><td>Z→ll (l→τ)</td><td>Shape & Norm : MC
(with SF)</td><td rowspan="2">Shape : MC
Norm : Fit in ZCR
(80<mll<100)</td><td rowspan="2">MC(very small)</td></tr>
<tr><td>Z→ll(Jet→τ)</td><td>Shape : MC
Norm : Fit in Zll CR</td></tr>
<tr><td>Top</td><td colspan="2">Shape : MC
Norm : Fit in b-tag CR</td><td>MC(very small)</td></tr>
<tr><td>Diboson</td><td colspan="3">Shape & Norm : MC (very small)</td></tr>
</table>

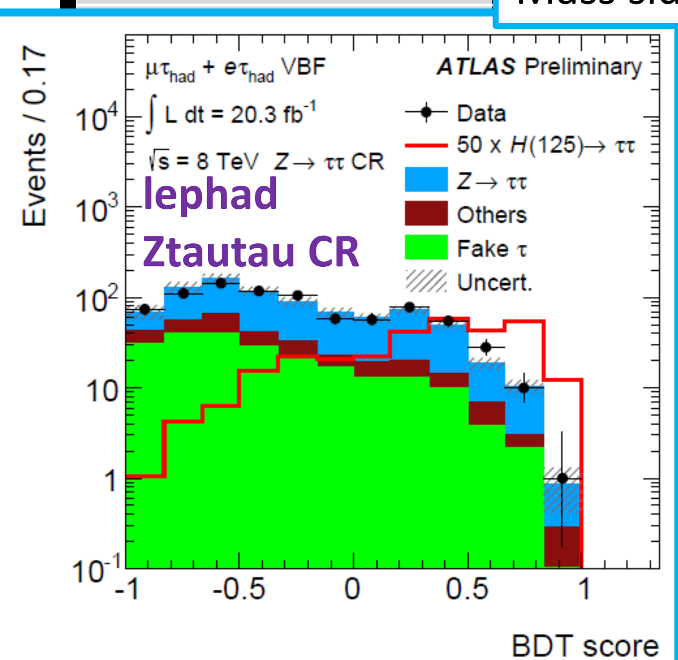
(orange-shaded cell) : Background estimated by (at least partially) data-driven way.

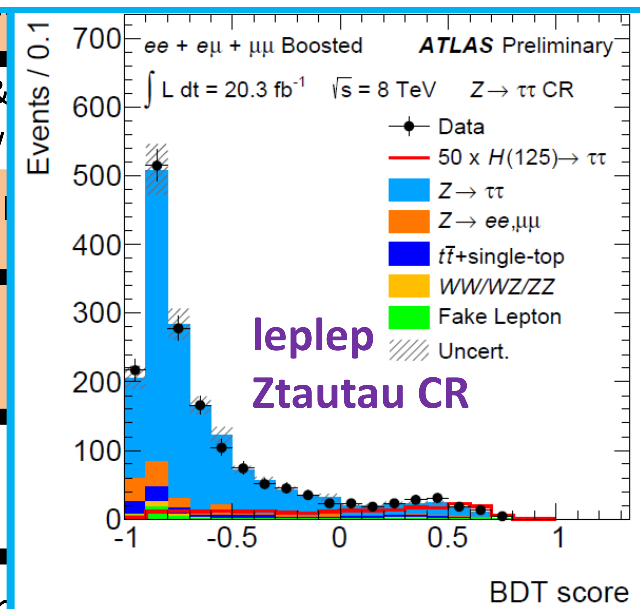
Fit in XX : The CRs are included in the Profile Likelihood Fit (Fit model.)

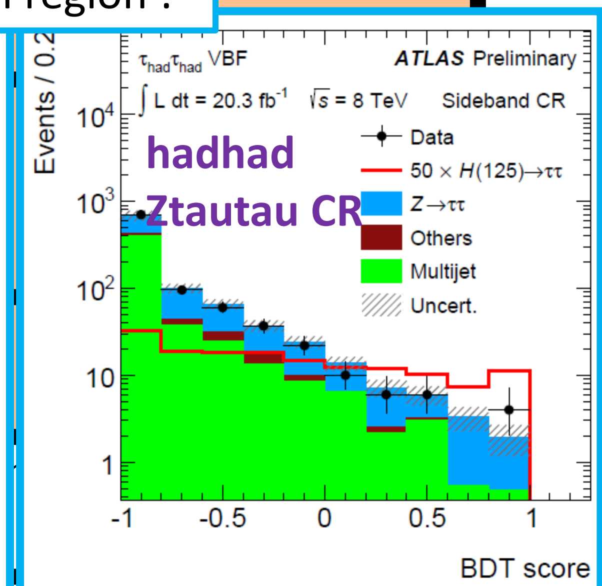
Background estimation and validation

	Lep-had	Leplep	hadhad
$Z \rightarrow \tau\tau$	Shape : Embedding Norm : **Fit in SR** (+ Δη CR for hadhad)		
Fake (QCD)	Fake factor Estimation	Template fit method	Shape : not OS data … **Fit in Δη CR**

Mass sideband CR as Z→tautau validation region :



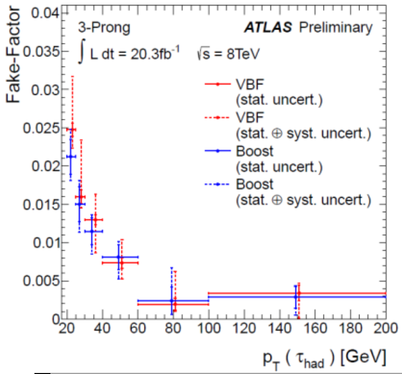




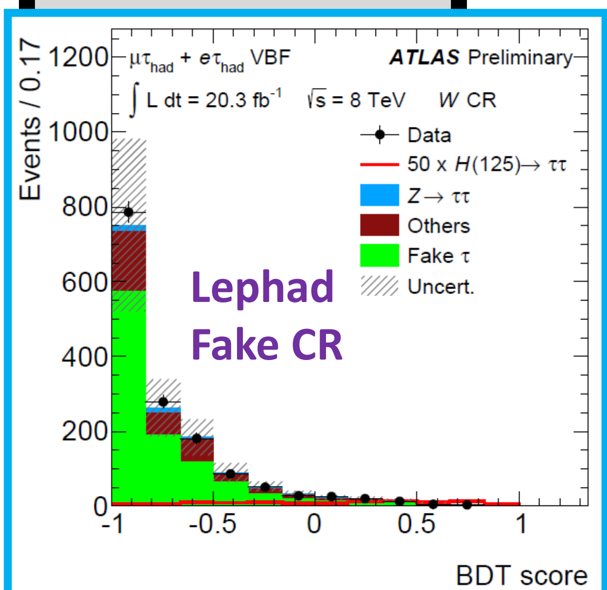
… driven way.

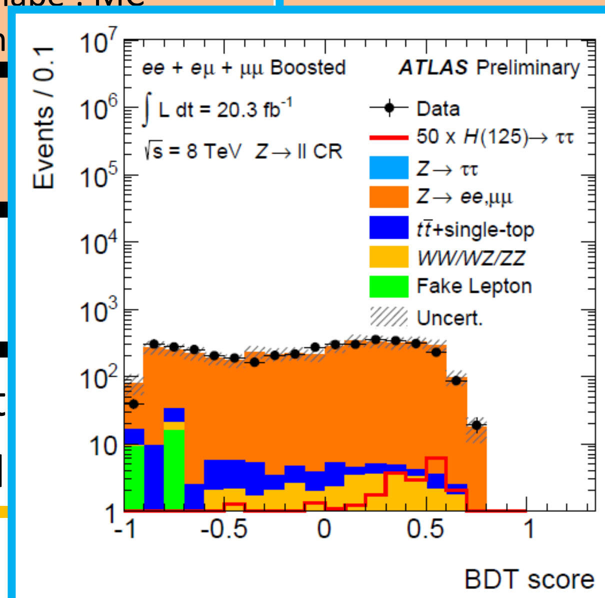
Fit in XX : The CRs are included in the Profile Likelihood Fit (Fit model.)

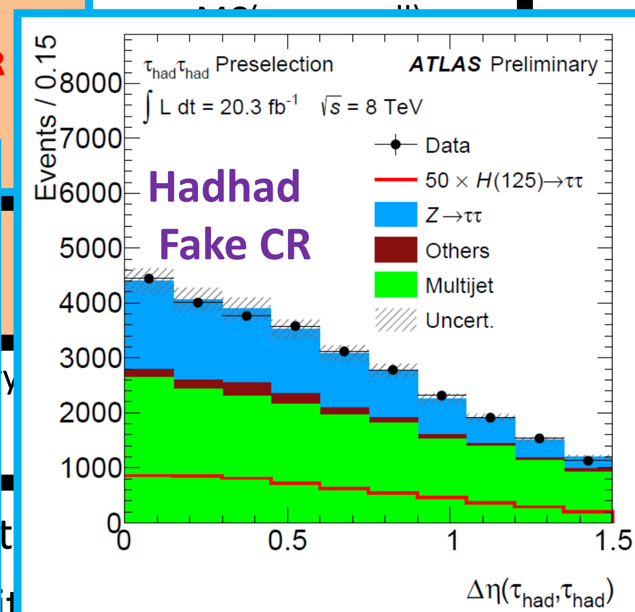
Background estimation and validation



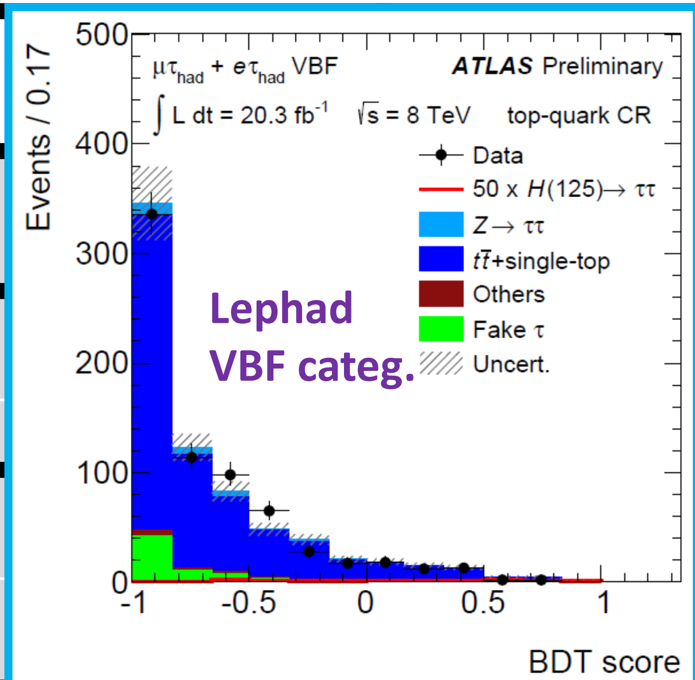
	Lep-had	Leplep	hadhad
	Shape : Embedding Norm : **Fit in SR** (+ Δη CR for hadhad)		
Fake (QCD)	Fake factor Estimation (used Anti-tau CR) Shape&Norm : data	Template fit method (used non-isol CR) Shape&Norm : data	Shape : not OS data Norm : **Fit in Δη CR**
Fake (W+jets)			MC
Z→ll (l→τ)	Shape & Norm : MC (with SF)	Shape : MC Norm : **Fit in ZCR** (80<mll<100)	
	hape : MC		

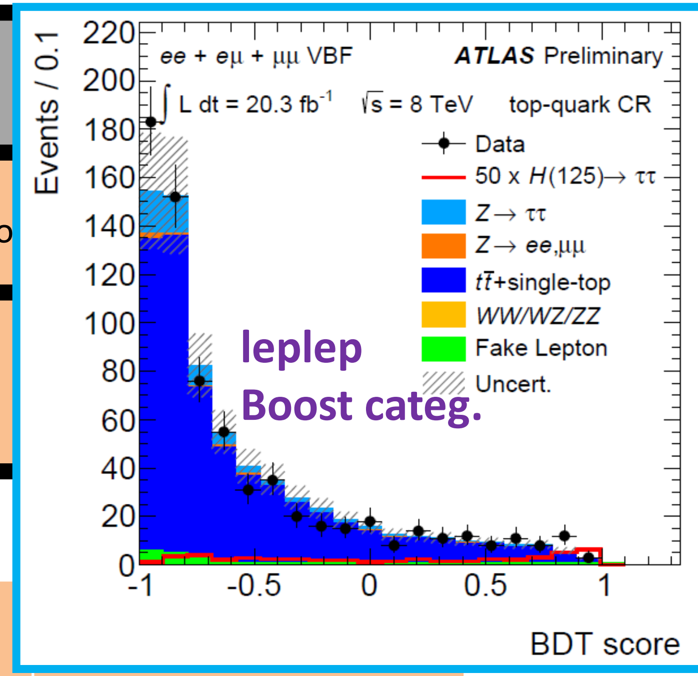






Background estimation and validation





ad

No

ation | OS data

R) | n Δη CR

ata

MC | small)

CR

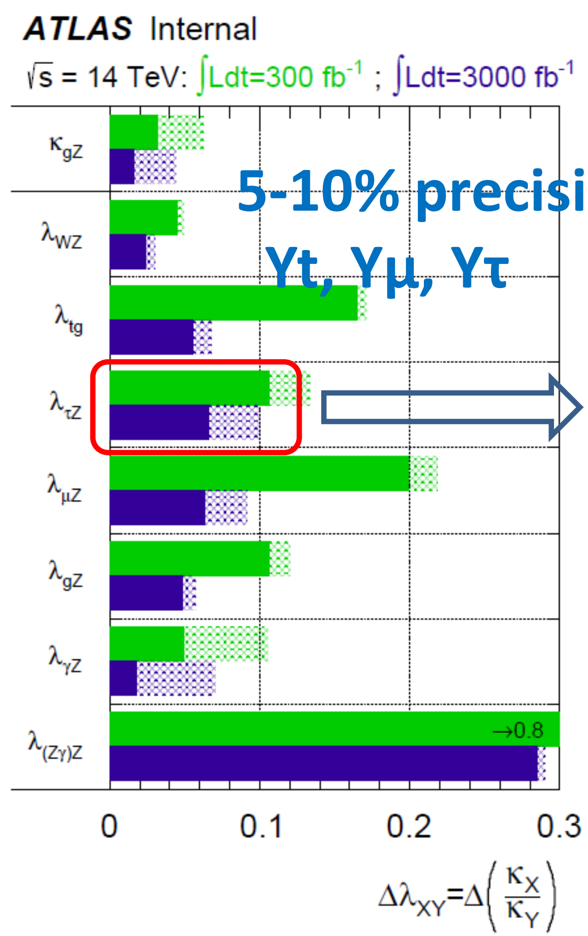
Top	Shape : MC Norm : **Fit in b-tag CR**	MC(very small)
Diboson	Shape & Norm : MC (very small)	

: Background estimated by (at least partially) data-driven way.

Fit in XX : The CRs are included in the Profile Likelihood Fit (Fit model.)

Future prospect

Updated coupling measurement results are presented.



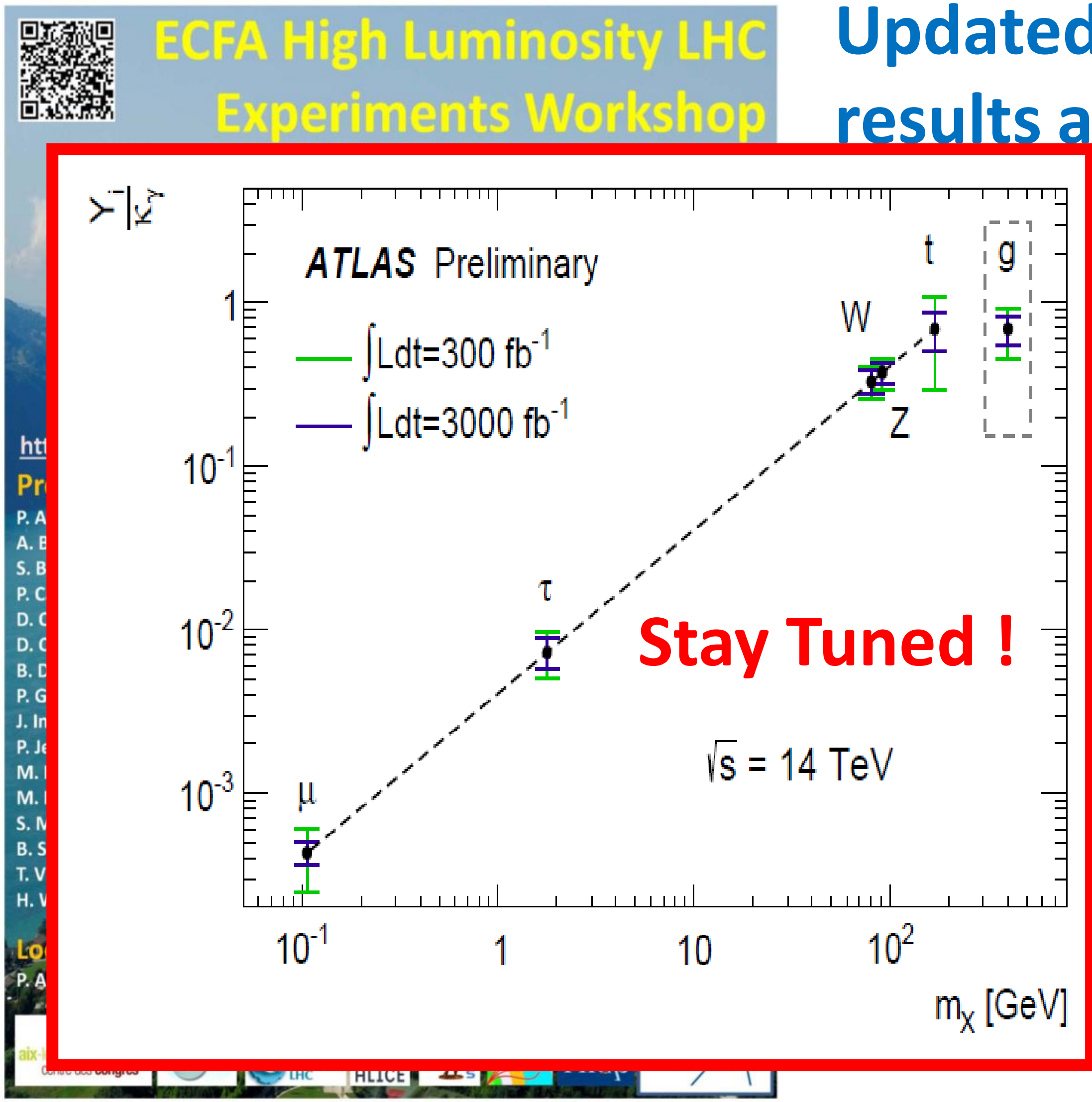
5-10% precision for Yt, Yμ, Yτ

50-100% improve !

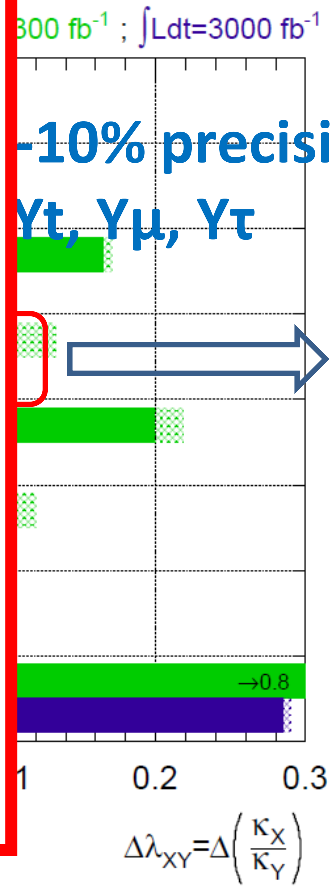
Yτ can be measured by a few % precision!

Future prospect

Updated coupling measurement results are presented.



Stay Tuned !

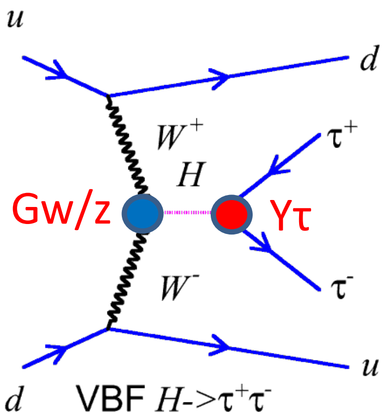


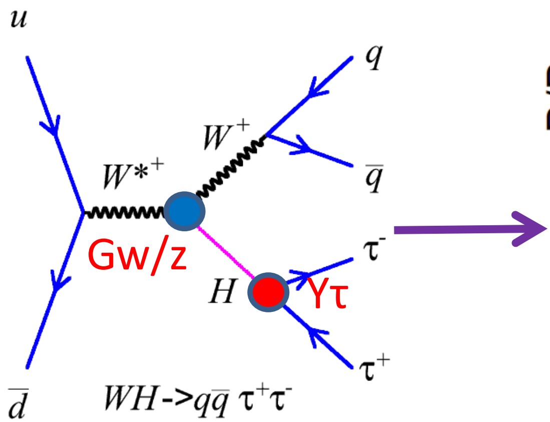
~10% precision for Yt, Yμ, Yτ

50-100% improve !

Yτ can be measured by a few % precision!

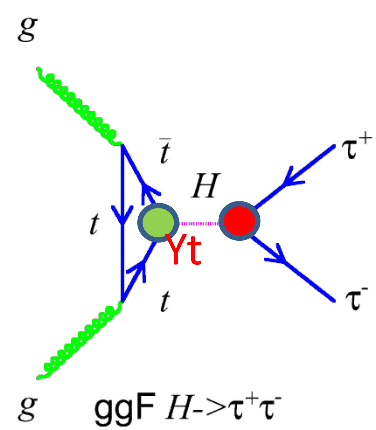
Production dependence



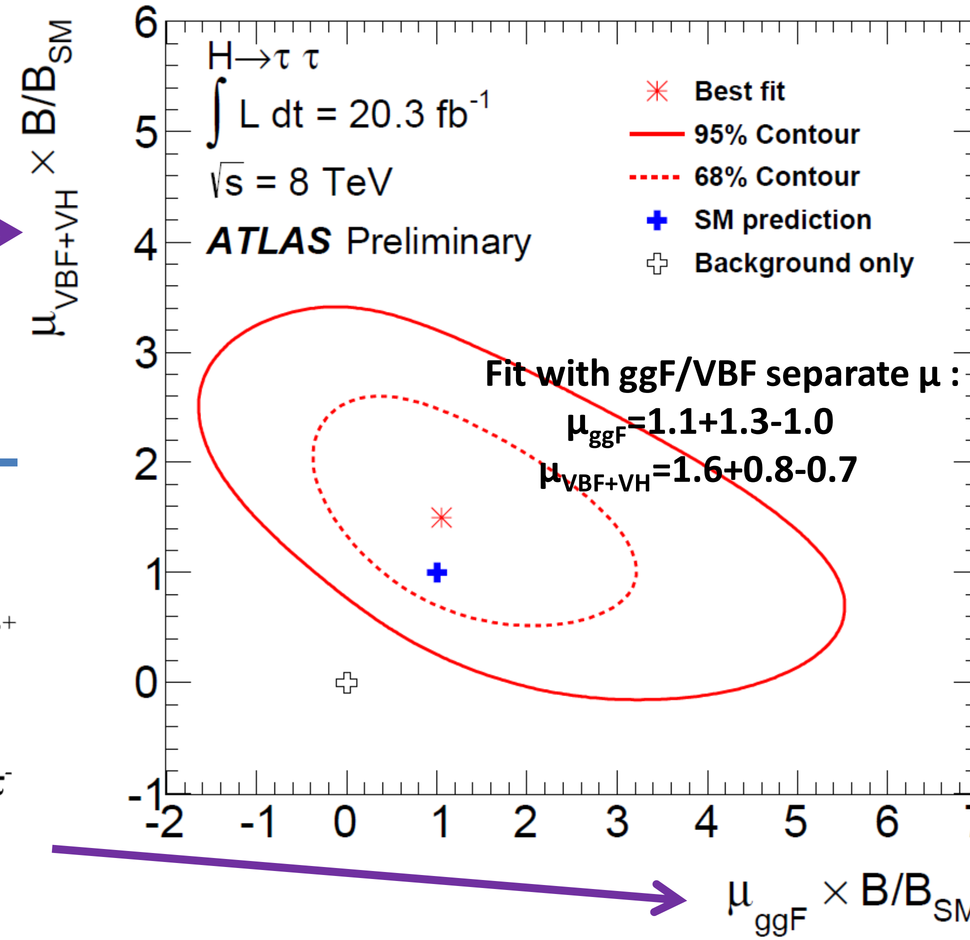


$$\frac{\sigma_{VBF}}{\sigma^{SM}_{VBF}} = \frac{\sigma_{WH}}{\sigma^{SM}_{WH}} = \frac{\sigma_{ZH}}{\sigma^{SM}_{ZH}}$$

$= \mu_{VBF+VH}$



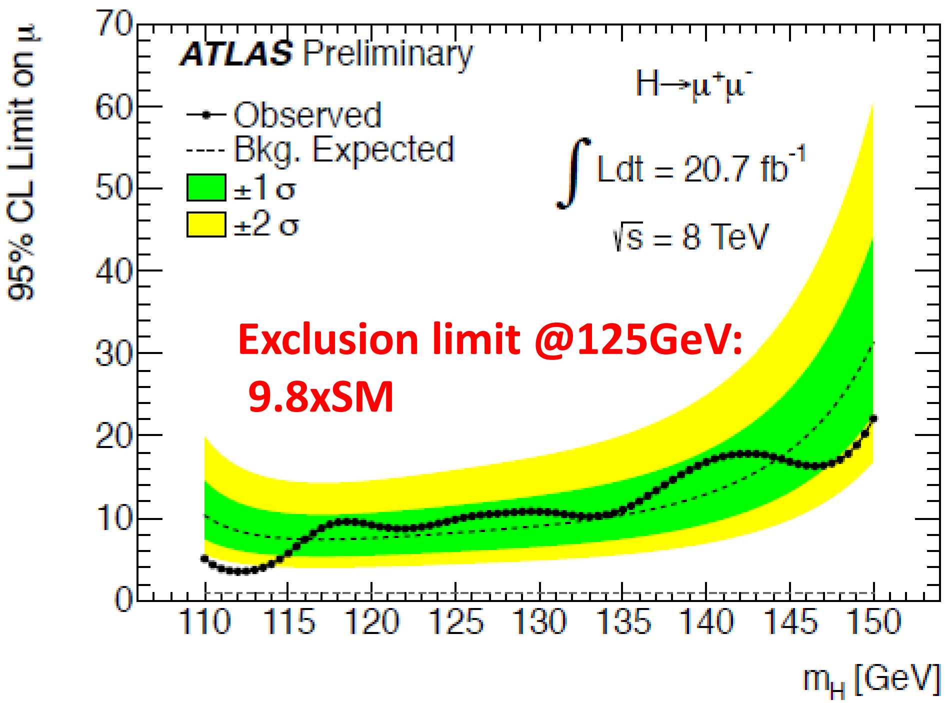
$$\frac{\sigma_{ggH}}{\sigma^{SM}_{ggH}} = \mu_{ggF}$$

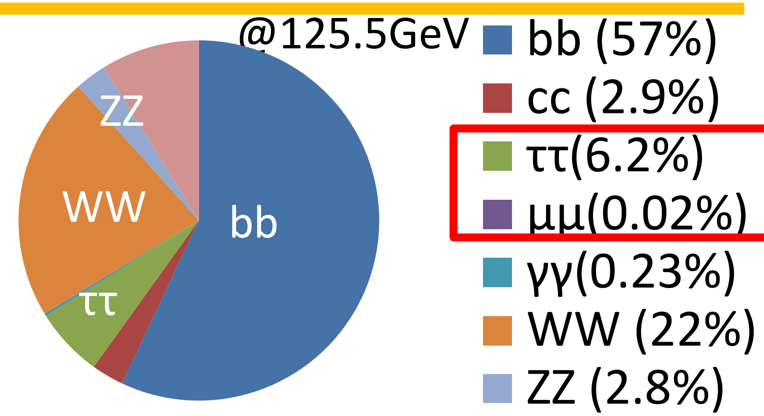


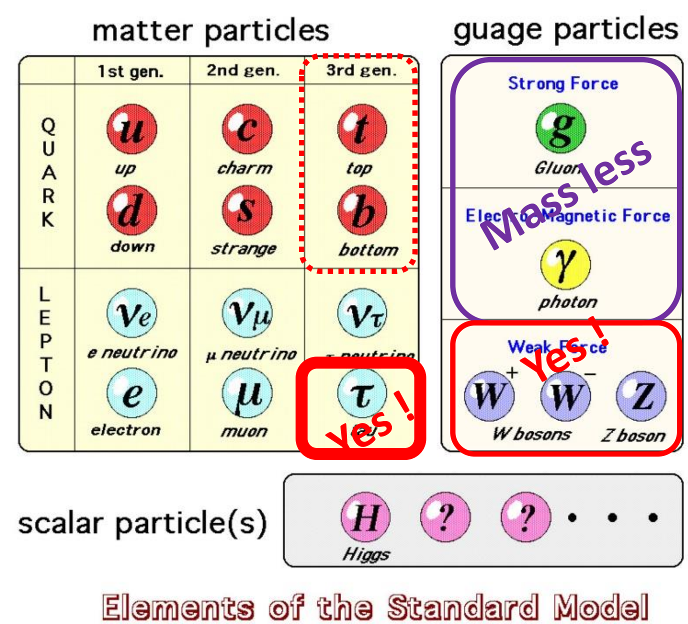
Both ggF and VBF production process are consistent to the SM!

Lepton universality ?

- H→μμ decay is also searched.





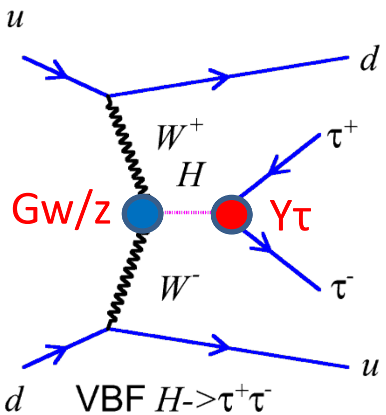


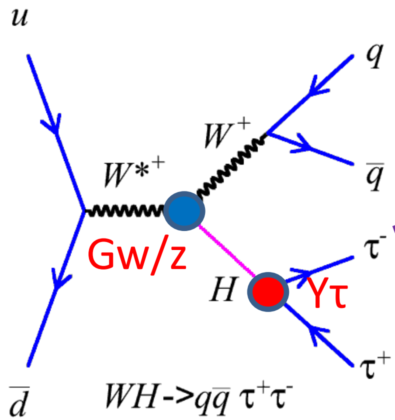
This correspond to the BR(H→μμ)<0.2%

So, BR(H→ττ) >> BR(H→μμ)

Higgs boson does not universally couple to fermions (leptons)

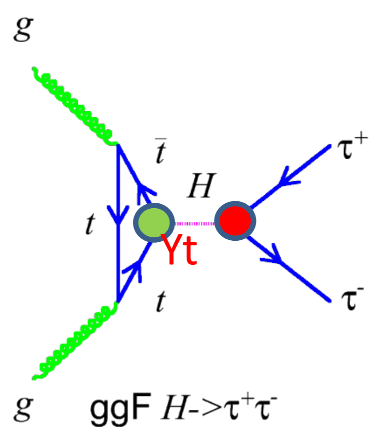
VBF v.s. ggF production



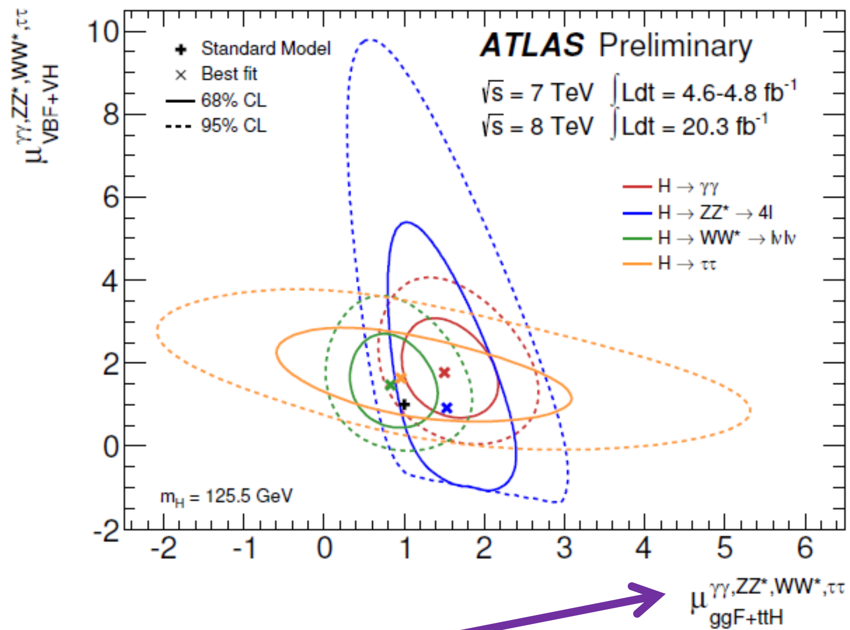


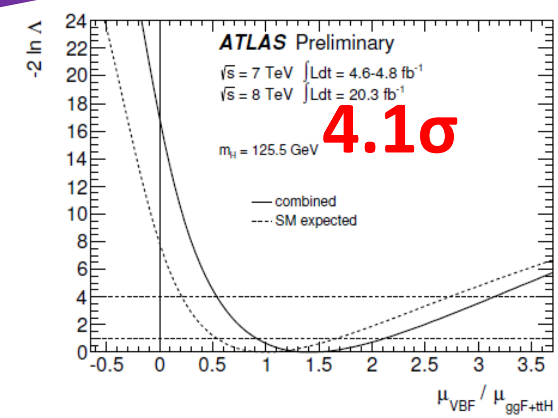
$$\frac{\sigma_{VBF}}{\sigma_{VBF}^{SM}} = \frac{\sigma_{WH}}{\sigma_{WH}^{SM}} = \frac{\sigma_{ZH}}{\sigma_{ZH}^{SM}}$$

$= \mu_{VBF+VH}$



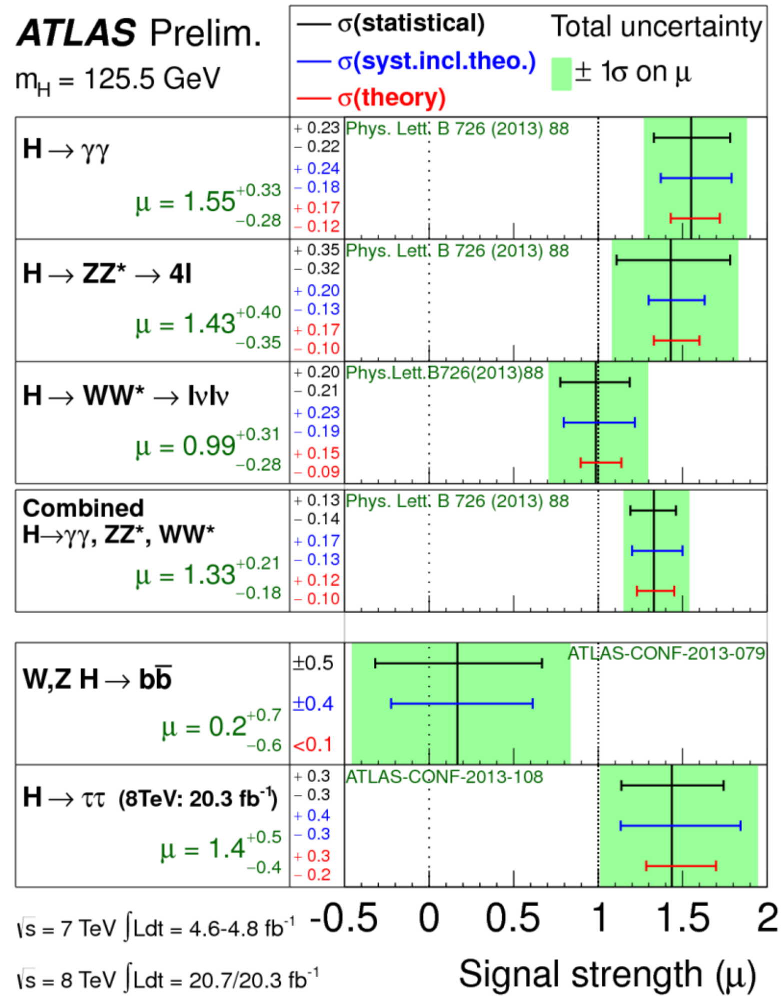
$$\frac{\sigma_{ggH}}{\sigma_{ggH}^{SM}} = \mu_{ggF}$$





Conclusion

- Both ATLAS and CMS observed significant excess in tautau searches.
  - Result @125GeV:
    - ATLAS: 4.1σ (expected 3.2σ)
      - μ_{best}=1.4+0.5-0.4
    - CMS: 3.4 σ (expected 3.6σ)
      - μ_{best}=0.87±0.29
  - **This is 4th channel which observed significant excess.**
  - **First strong evidence of fermion decay of the Higgs Boson!**



Decay channel	Expected sensitivity	Observed Sensitivity
H(124.3)→ZZ	4.4σ	6.6σ
H(126.8)→γγ	4.1σ	7.4σ
H(125)→WW	3.7σ	3.8σ
H(125)→ττ	3.2σ	4.1σ
H(125)→bb	1.6σ	0.4σ

FJPPL (TYL) application 2014-2015

Fiscal year April 1st 2014 – March 31st 2015

Please replace the red examples by the appropriate data in black

ID[1]:LHC-06	Title:Improvement of the τ jet measurement applied to the low mass H Higgs search in ττ channel					
	French Group			Japanese Group		
	Name	Title	Lab./Organis.[2]	Name	Title	Lab/Organis.[3]
Leader	P. Pétroff	DR	LAL/IN2P3	K. Hara	AP	Tsukuba HEP
Members	M. Jaffré	DR	LAL/IN2P3	S. Kim	P	Tsukuba HEP
	L. Poggioli	DR	LAL/IN2P3	R. Fuchi	PhD	Tsukuba/HEP
	D. Rousseau	DR	LAL/IN2P3	K. Tokushuku	P	KEK
	R.Tanaka	CR	LAL/IN2P3	S. Tsuno	AP	KEK
	F. Hariri	PhD	LAL/IN2P3	K. Nakamura	AP	KEK
	M. Ayoub	PhD	LAL/IN2P3			

Allocated Funding (U Tsukuba)

Additional Funding from Japan		
Provided by/Requested to[6]	Type	k¥
Tsukuba HEP		
Round travel France-Japan per diem	2 travel 50/day	500 500
Round travel CERN-Paris	70x2	140
Total		1140

Funding Requested

Funding Request from France				
Description	€/unit	Nb of units	Total (€)	Requested to[4]:
Student stay in anceF	1000/month	3 months	3000	IN2P3
Visit to KEK/Tsukuba (2 persons)	150/day	10 days	3000	IN2P3
Travels	1000	2 travels	2000	IN2P3
Total			8000	

Funding Request from KEK				
Description	k¥/Unit	Nb of units	Total (k¥)	Requested to:
Round travel France-Japan	230	1 travel	200	KEK
Visit to France per diem	10/day	7 days	70	KEK
Total			300	