Recent results on H→ττ and improvements in this measurement

Workshop of France-Japan and France-Korea

Particle Physics Laboratories

Seoul

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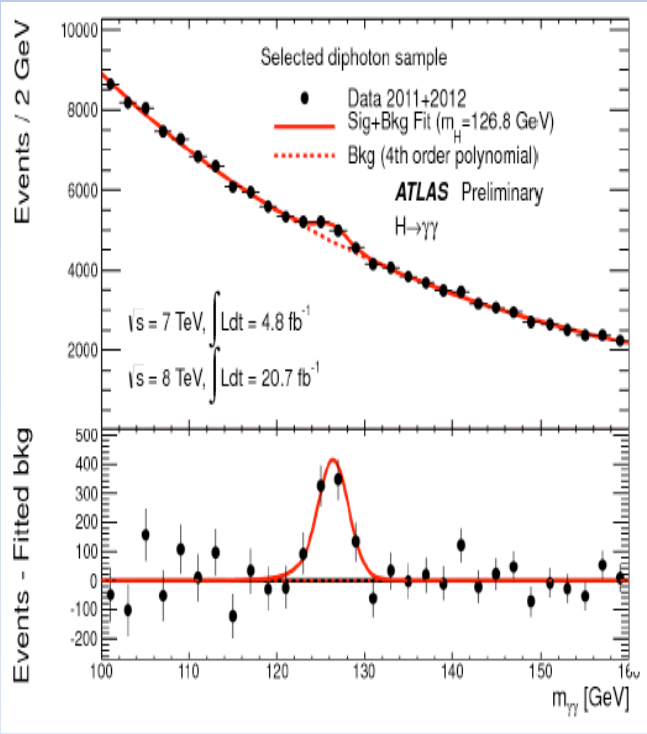
Today's contents

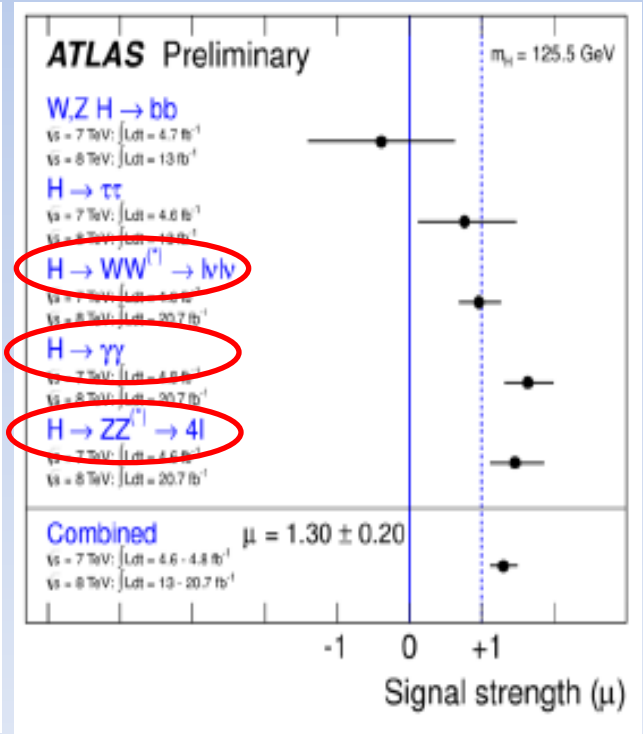
1. Introduction to Higgs to tau tau analysis.
2. Status of our effort and current analysis.
3. Plans for analysis improvement.
4. Summary

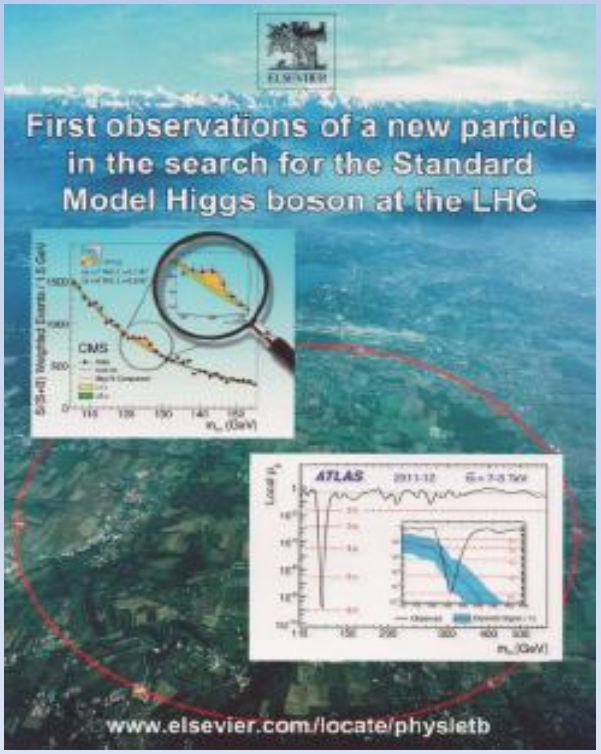
Part1:
Introduction to H→ττ analysis

Higgs boson

- Discovery of new boson, consistent with SM Higgs, on 4th July in 2012.
- Key to understand the origin of mass.
- What we know from current result:
  - ☑ H→WW,H→ZZ, H→γγ (>3σ)
  - ☑ ggF/VBF production (∼3σ)







To the era of measurement from the discovery

- We need to verify if the Higgs is of SM:

1. Mass

125.5±0.2(stat)±0.6(sys) GeV (ATLAS)

2. Spin/Parity

Excluded JP=0-,2+

3. Coupling

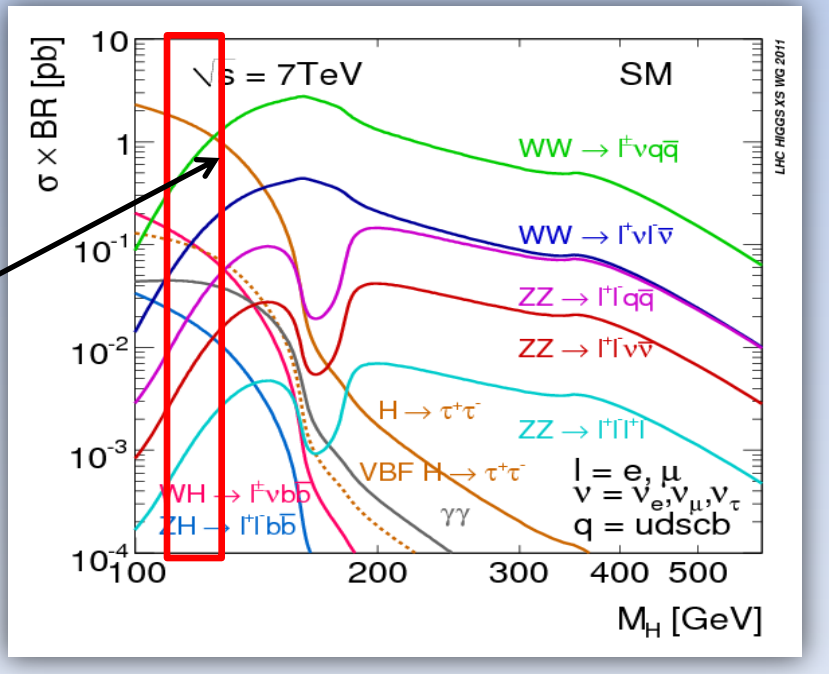
Quark : indirect from gluon fusion, but need direct measurement, H→bb.

Lepton: no indication.

H→ττ measurement:

It should be the first evidence of Yukawa coupling(to lepton).

- Large branching ratio.
- Sophisticated τ ID.
- Mass peak reconstructable.



Introduction to H→ττ analysis

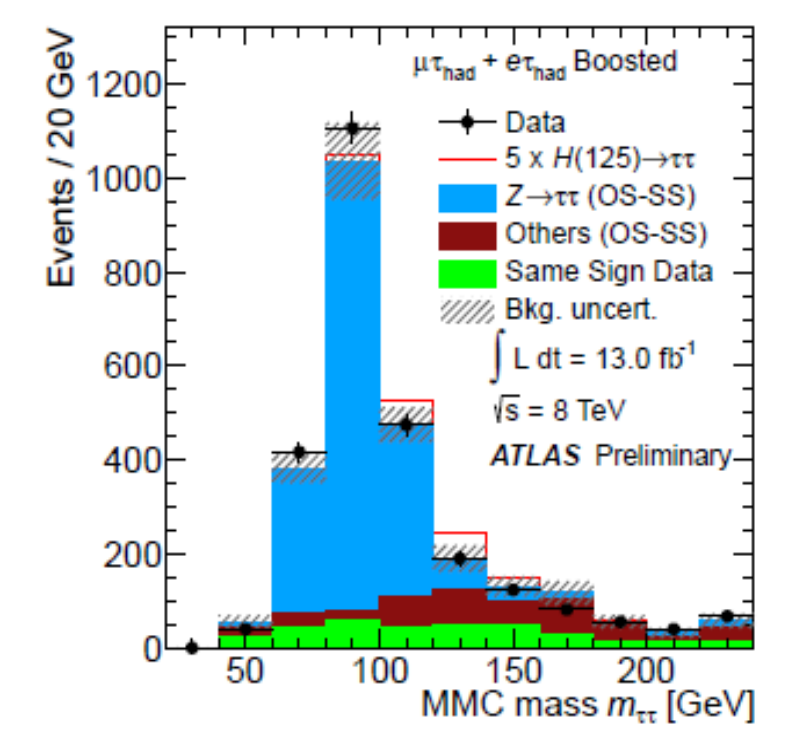
Analysis channel:

- 3 final states based on the decay of τ. (Missing et from neutrino.)

Channel	Br.	Characteristics
H→ττ→ll+4v	12.4%	Clean
H→ττ→hh+2v	42.0%	Large Br.
H→ττ→lh+3v	45.6%	Large Br. and clean

Selection:

1. Trigger:
   Depend on analysis channel.
   - lepton(e/mu) trigger
   - lepton + hadronic tau trigger
   - Di-hadronic tau trigger
2. Lepton or/and hadronic tau
3. Reconstract mass with Missing Mass Calculator(MMC).
   - Calculate ττ invariant mass, solving v statistically.
     (likelihood w/ angular p.d.f.)



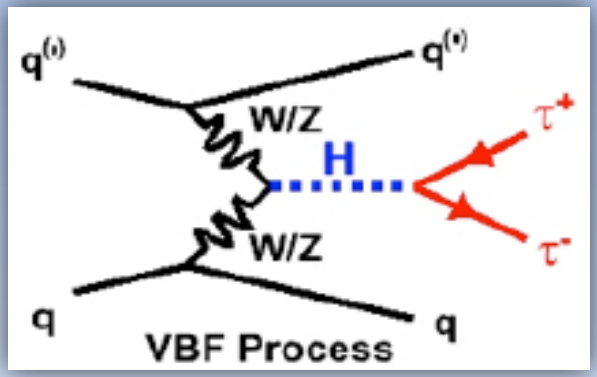
Contributing to ATLAS for this measurement.(effort and status in next page)

Contribution and Status of H→ττ measurement

- All channel contributing, especially H→ττ→lh/ H→ττ→hh.

H→ττ→lh

- Looking for Higgs with emphasis on Higgs production process, especially for VBF, forward high energy jets. (cut-base) →HCP results and thesis(K. Hanawa)
- Finalizing Multivariate analysis for summer.
- Plan is to implement particle flow.
- Trigger investigation started for 14 TeV run.



H→ττ→hh

- Looking for Higgs with emphasis on Higgs production process(cut-base) →HCP results.
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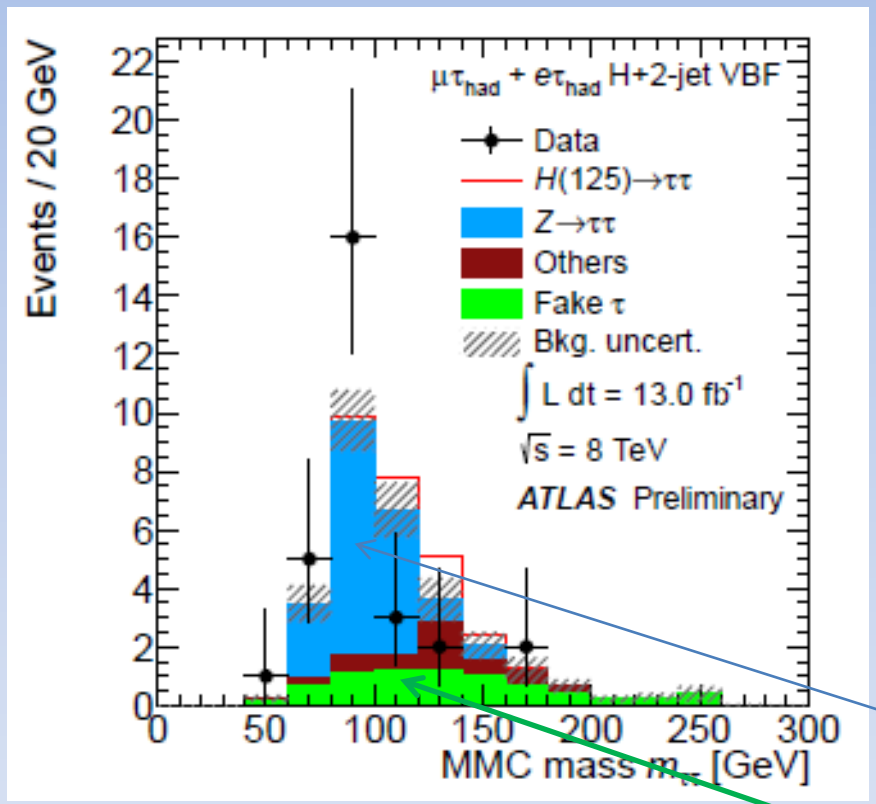
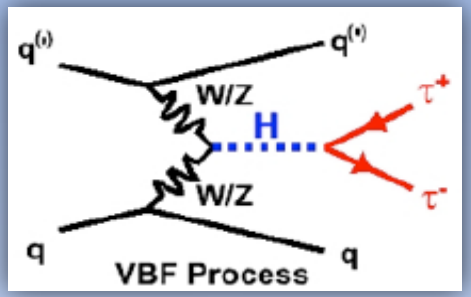
Part2:
(Traditional)
Cut-based analysis

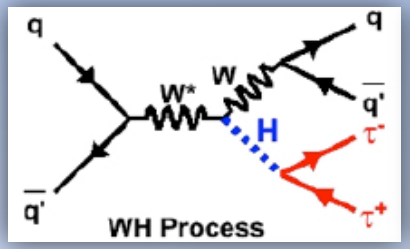
Cut!

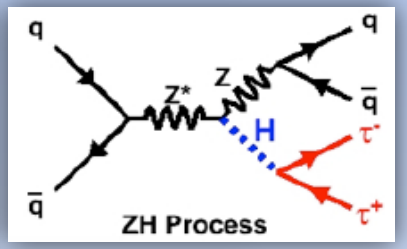
Cut-based analysis in lh channel

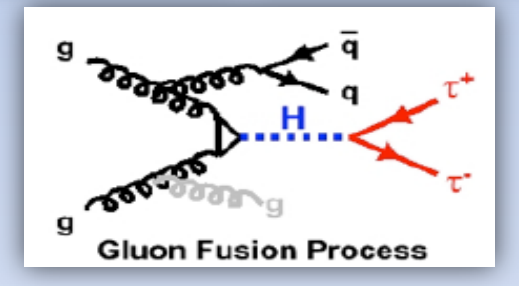
1. Selection optimization for each production process:
   - VBF : two forward jets.
   - ggF/VH: High resonance pt





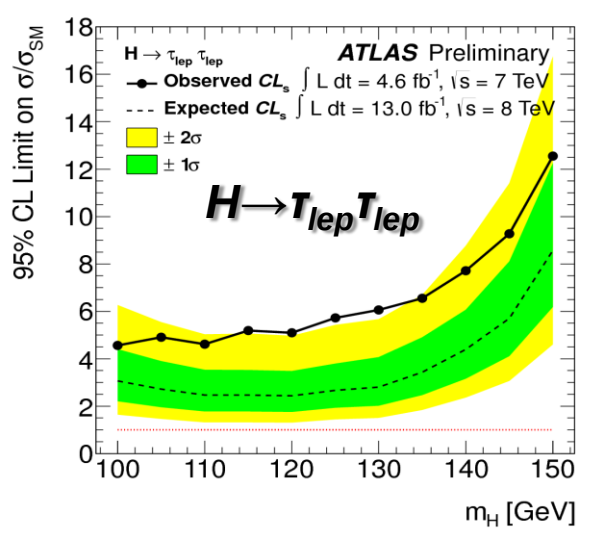


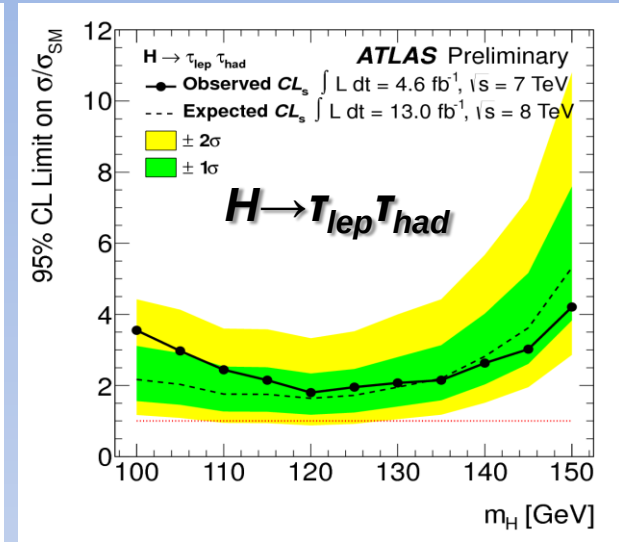


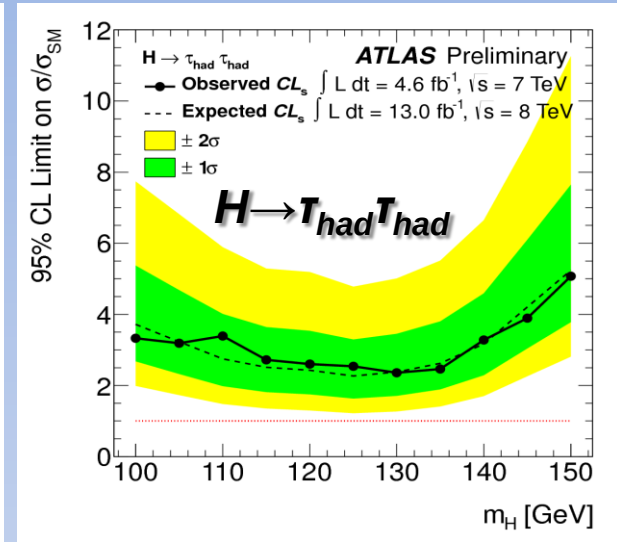


2. Background estimation:
   - Z+jets: Develop/validate technique of high MC stat. technique.
   - fake τ: Reliable estimate from high stat CR for fake taus.

Recent results in ATLAS







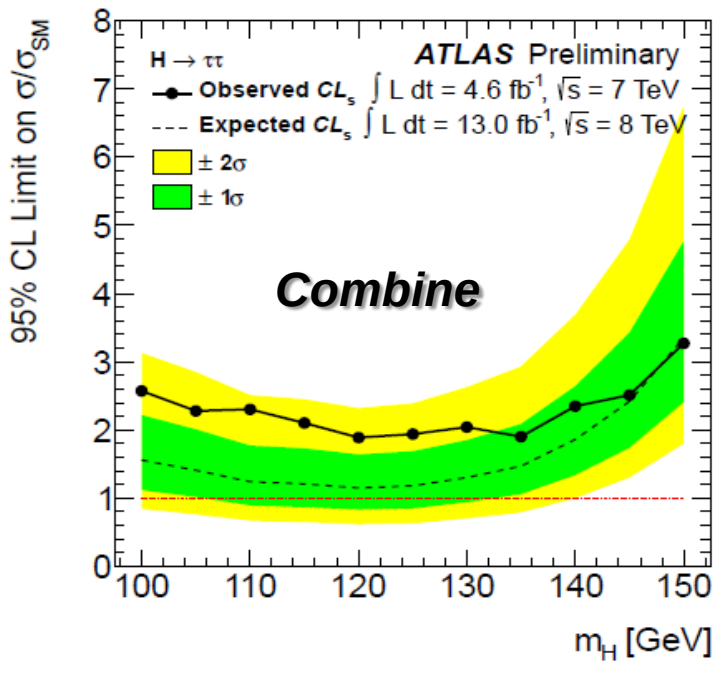
Combined 95% CL limit 125GeV (4.6fb^{-1}in 7TeV +13.0 fb^{-1} in 8TeV):

Expected : 1.2 × SM

Observed: 1.9 × SM (p0=1.1σ)

<u>Our goal/target</u>

- 3σ evidence(7/8 TeV run)
- 5σ discovery(14 TeV run)

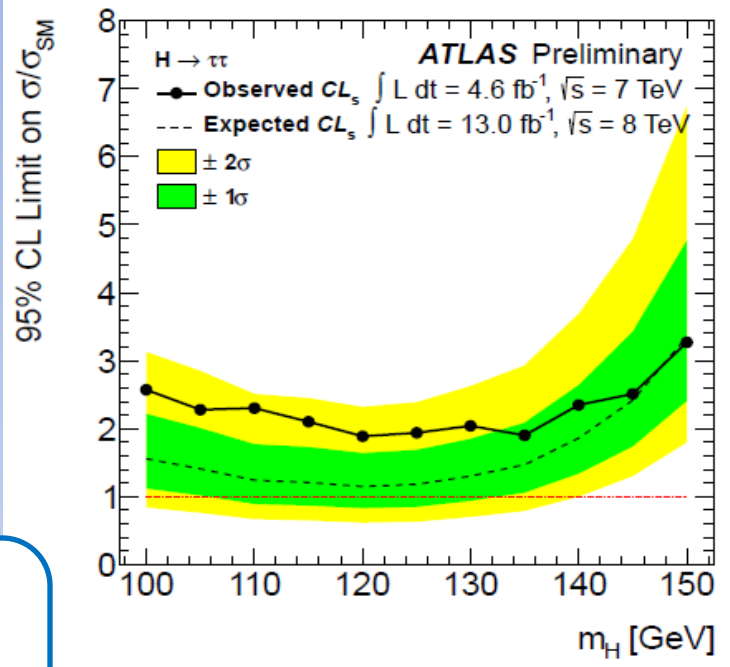


Improvements

Current ATLAS@mH=125GeV
Upper limit (95% C.L.): Expected 1.2 × SM
Observed 1.9 × SM
Local p0: Expected 1.7σ
Observed 1.1σ

Extrapolate to full stat.
($13.0fb^{-1} \rightarrow 20.7fb^{-1}$)

@mH=125GeV
Upper limit 1.0 × SM (expected)
Local p0 2.0σ (expected)
→Need $55fb^{-1}$ to achieve 3σ ⇒*Need improvement!*



1. Multivariate analysis:

- Good separation sig. vs bkg. keep high signal efficienecy.

2. τ energy measurement with particle flow:

- τ energy scale is a dominant uncertainty in current analysis.

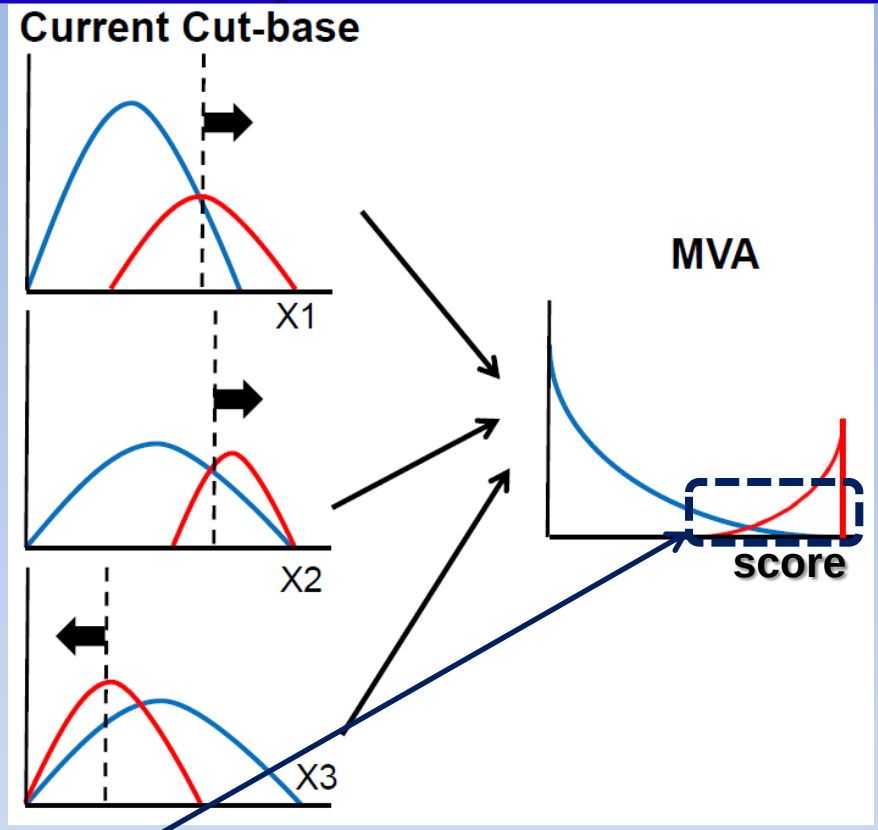
Part3: Improvement plan and collaboration detail

Multivariate Analysis

Current Cut-Based Analysis:
- Good sensitivity by tight cut.(VBF/Boost)
- But low signal acceptance

⇒Multivariate Analysis:
- Gain signal acceptance.
- better separation signal vs bkg.

Multivariate analysis(MVA):
- Powerful statistical techniques to analyze data with many variables simultaneously.



Current status

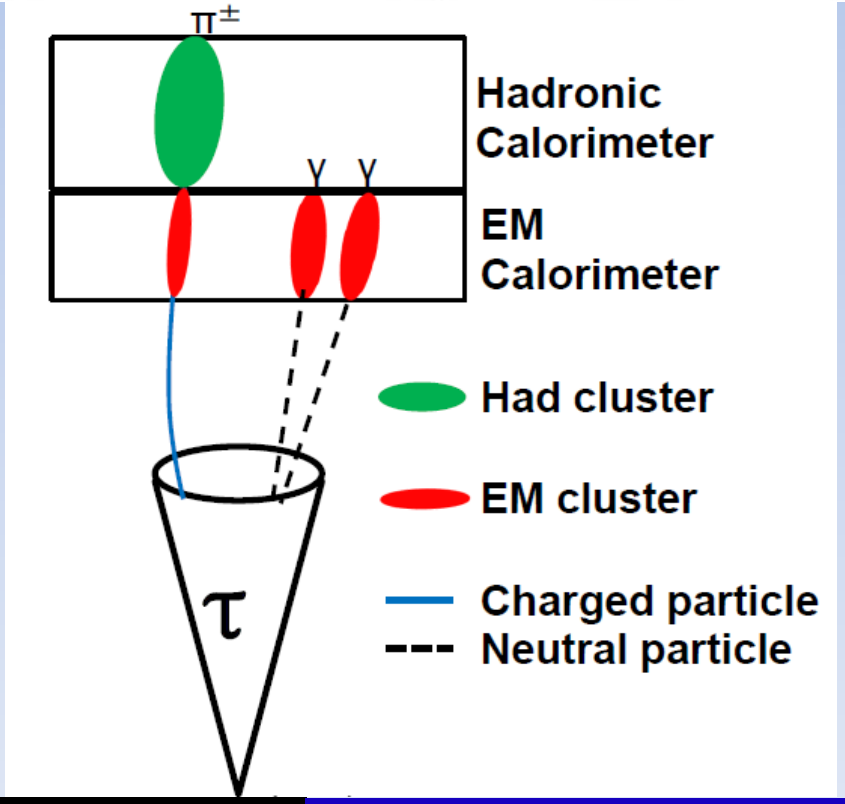
1. Develop background estimation technique:
   - It's for background estimation in high score region.
     i.e) Fake τ est.(QCD, W+jets), MC high stat. technique(Z+jets) and ttbar.
2. Optimize the training:
   - select input variable
   - training against (vs W+jets)

Particle Energy Flow

- τ energy scale is the most dominant systematic source.
- Largest contribution is a hadronic shower measurement. (used only calorimeter Information)
- τ decay into 1-3 prongs + nπ0.

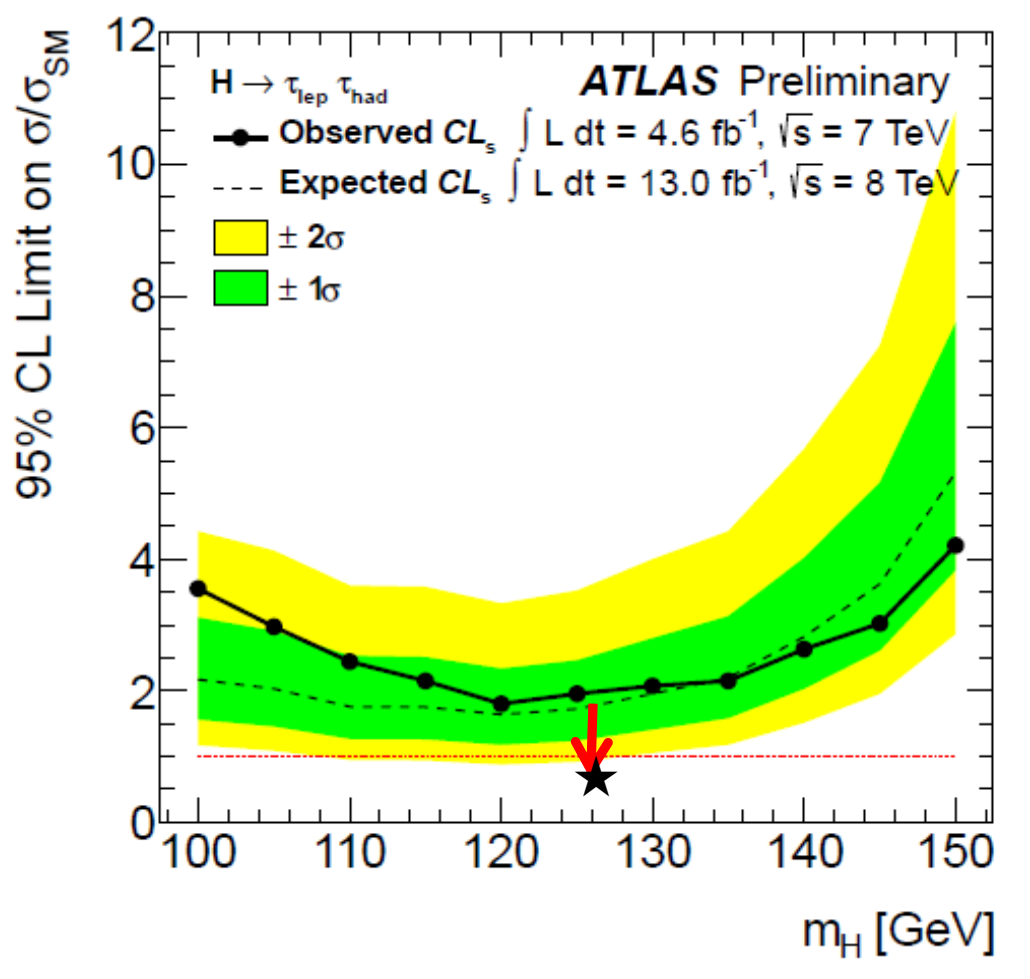
decay mode	branching fraction
main hadronic modes	
$\tau^{\pm} \to \pi^{\pm}\nu_{\tau}$	10.9%
$\tau^{\pm} \to \pi^{\pm}\pi^{0}\nu_{\tau}$	25.5%
$\tau^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}\nu_{\tau}$	9.3%
$\tau^{\pm} \to \pi^{\pm}\pi^{\pm}\pi^{\mp}\nu_{\tau}$	9.3%
$\tau^{\pm} \to \pi^{\pm}\pi^{\pm}\pi^{\mp}\pi^{0}\nu_{\tau}$	4.6%

- τ energy can be decomposed into the energy of its constituent particles.
- Each particle can be measured with the most appropriate detector:
  - Tracker for π± 's (more accurate than calorimeter)
  - Calorimeter for π0 's



Improvement in lepton-hadron channel

- Summarize possible improvement in H→ττ→lh.



Source	Gain
Full data	~15%
Improvement of performance (MET etc…)	~25%
MVA	~40%
Improvement of τ ID/ES	~15%

- We are finalizing MVA for summer conference!
- Check analysis improvement when ID/TES are improved.
- If we achieve all improvement, we can excluded or touch 3σ evidence.

Toward to 14TeV run

In High energy run at LHC, trigger for this analysis is crucial.
Threshold of lepton and hadronic tau should be raised
- Electron :25GeV(8TeV)→33GeV
- Hadronic tau:40GeV(8TeV)→80GeV

→can't get Higgs signal!

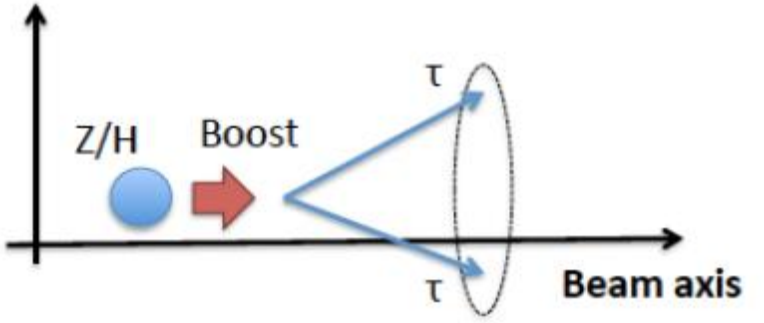
Main issue in L1 trigger(first in three step trigger scheme).
- important to reduce the trigger rate from QCD jets.

→Use L1 Calo, Muon and Missing Et information.

e.g.) $\Delta\eta(\tau,\tau)$ cut:

ττs go into similar direction in sensitive category(Boost/VBF).

Preliminary investigation in hh tells us we can reduce three times the rate.
→ Plan to check any other kinematics and effect in lh channel.



Sharing work!

KEK and Tsukuba:
Trigger investigation

τ jet measurement

LAL : good expertise in calorimeter.

KEK:
Former **τ ID convener**

H→τ τ analysis (MVA)

KEK:
- Current convener(lh/hh)

Tokyo and Tsukuba:
- good expertise

H→ττ discovery coupling measurement

☑ Ryosuke Fuchi(Tsukuba): Higgs to tautau →D thesis.
☑ Faten Hariri(LAL): Higgs to tautau →D thesis.

Budget

IN2P3 euros: 8000 (800K yen) :
3 month stay of a student at LAL, meeting + travel

KEK yen : 340K (3400 euros) :
meeting + travel

Tsukuba yen : 1300 K (10,000 euros) :
Travel to attend this workshop
To Japan for the collaboration.
Short stays in France + travel

For more details, report to the LH06 written proposal

Summary

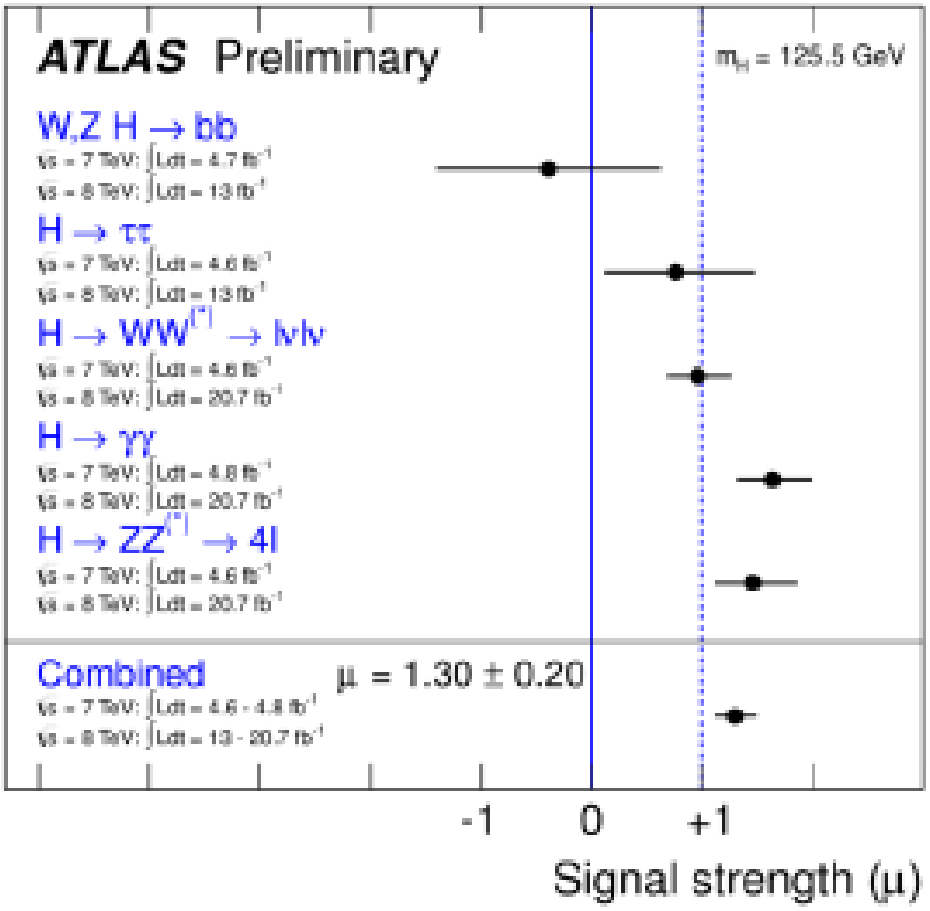
- KEK, LAL, Tsukuba and Tokyo groups have been working on Higgs search in di-tau pair mode and have accumulated expertise in analysis. (Large contribution current ATLAS result.)

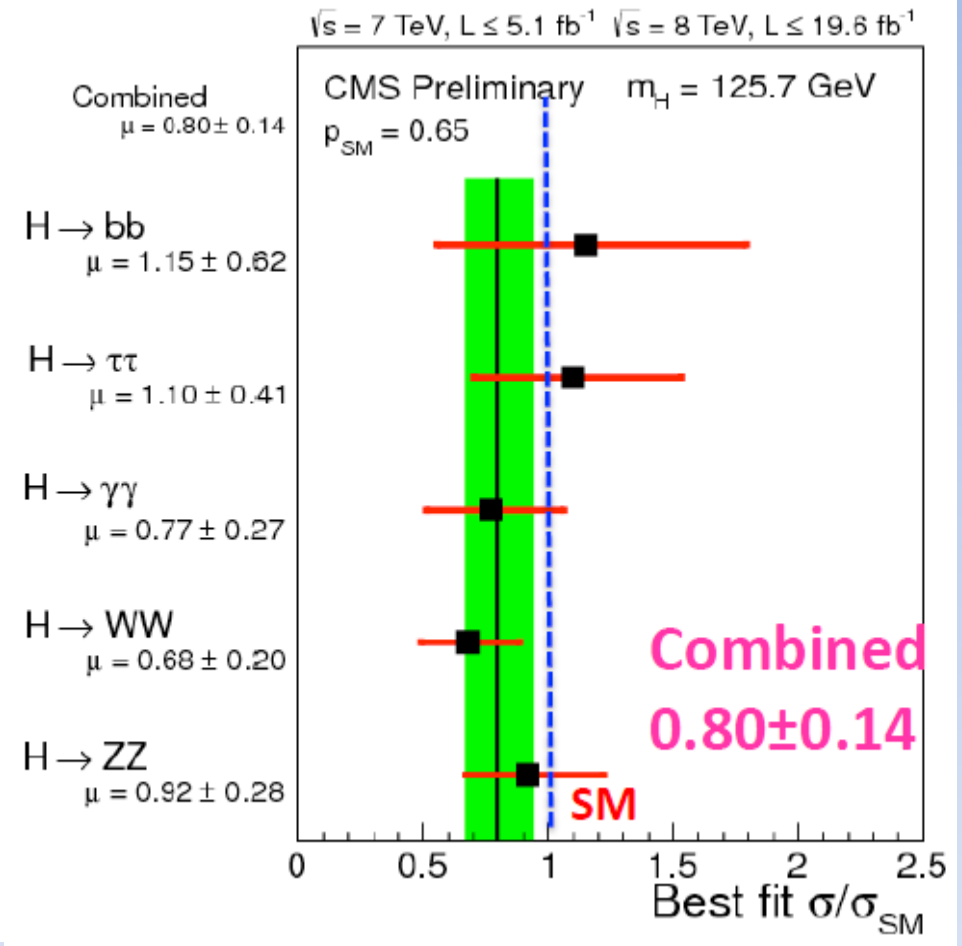
- To enhance the sensitivity of this decay mode, which is required for Yukawa coupling measurement, improvement in tau energy measurement and adoption of MVA are crucial.

- This can be achieved by a close collaboration of LAL (for calorimetry expertise) and KEK/Tsukuba/Tokyo (for analysis expertise), who are very complementary to fulfill the searching program presented here.

Back up

Higgs result in ATLAS and CMS





Signal strength in CMS is smaller than that in ATLAS.

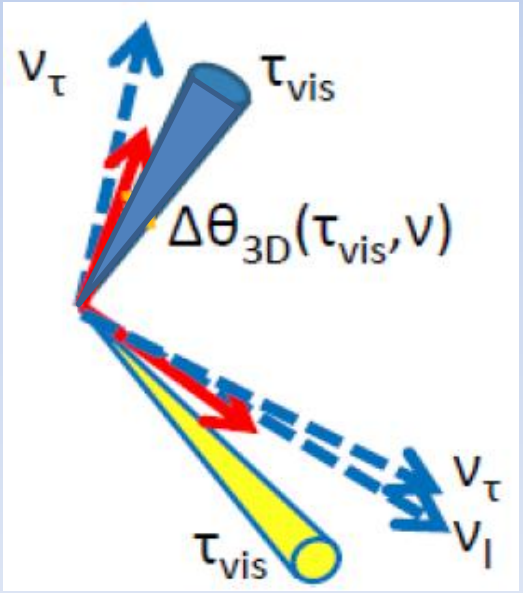
Tau Pair Invariant Mass Reconstruction

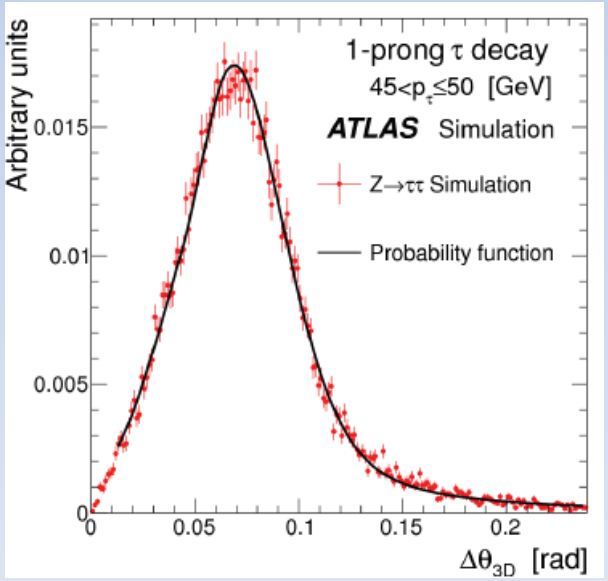
Tau pair invariant mass should be a important discriminating variable from backgrounds, but events have 3 neutrinos.

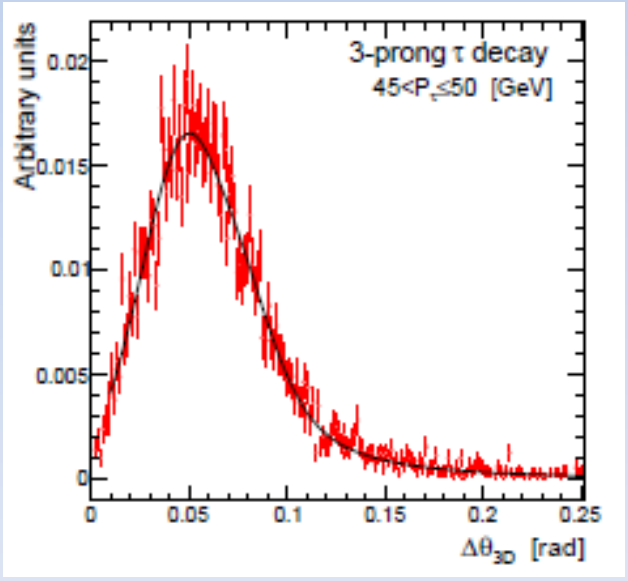
- Event by Event estimator of true di-τ mass likelihood.
- Full reconstruction of event kinematics.

Missing Mass Calculator (MMC)

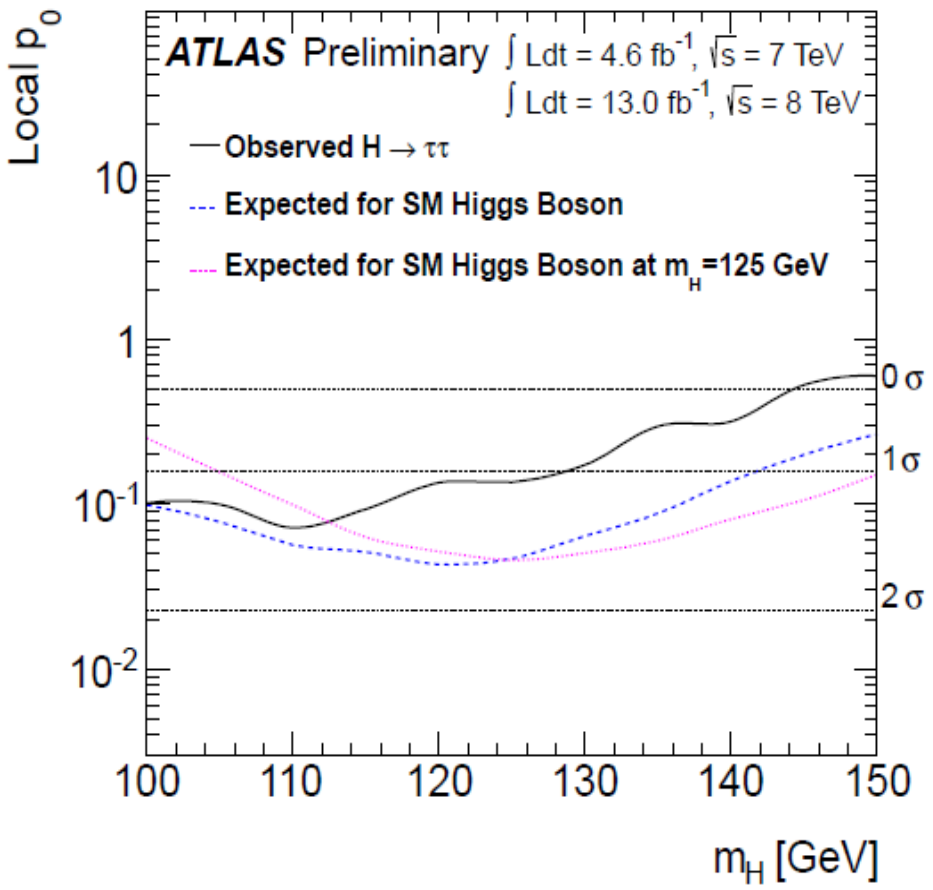
- Solve τ, E_T^{miss} in $\Delta\Phi(\tau_{vis}, \nu)$ parameter space using $\Delta\theta_{3D}(\tau_{vis},\nu)$ template from simulation as PDF.

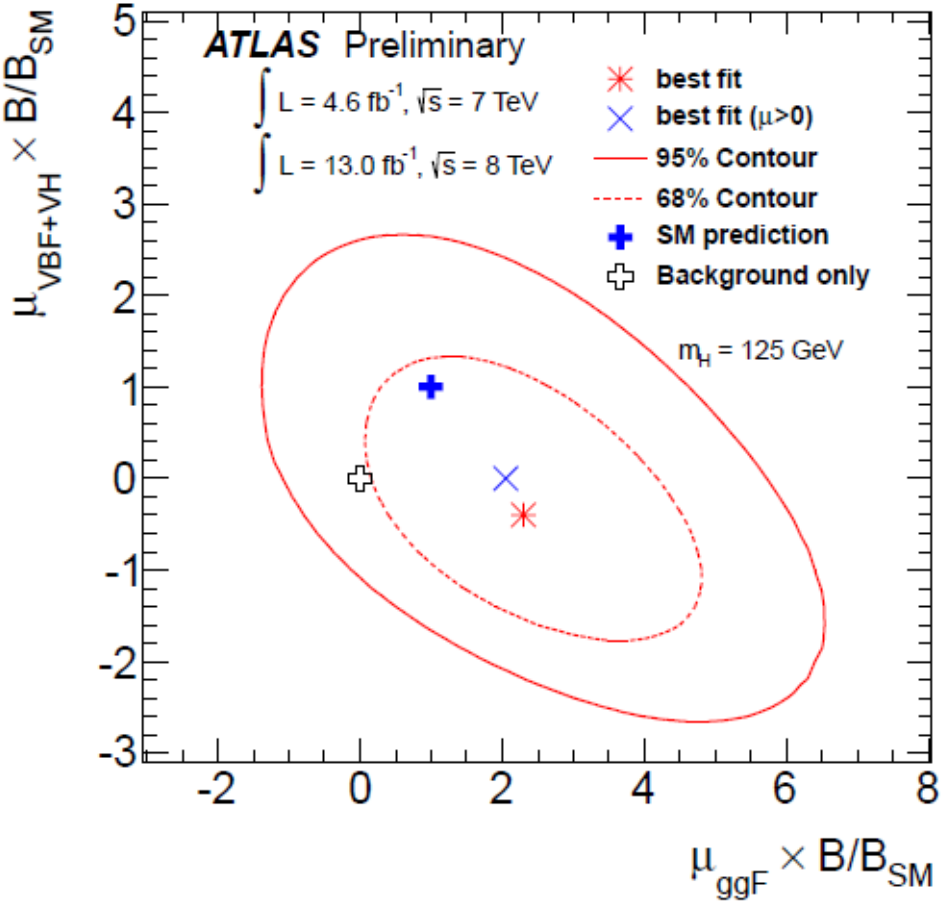






Result Combined with All Three Channels





1.7σ (maximum point)
Best fit μ= 0.7+-0.7

Consistent with SM