Searching for the Standard Model Higgs Boson in $H \to \tau\tau$ decays in proton-proton collisions with the ATLAS detector

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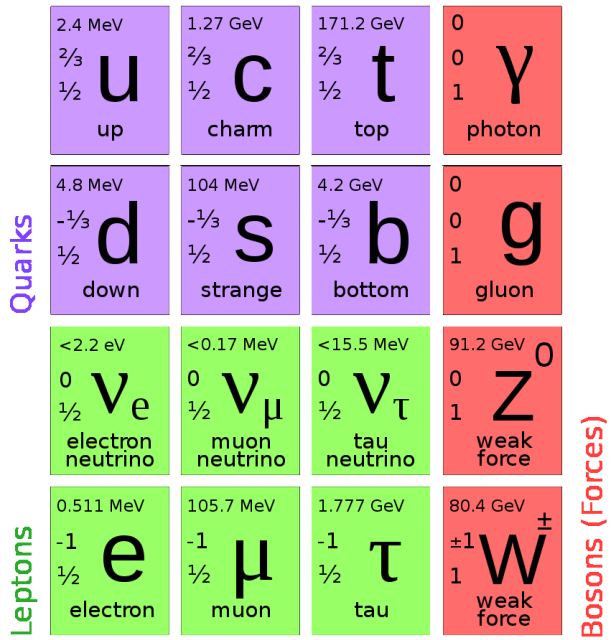
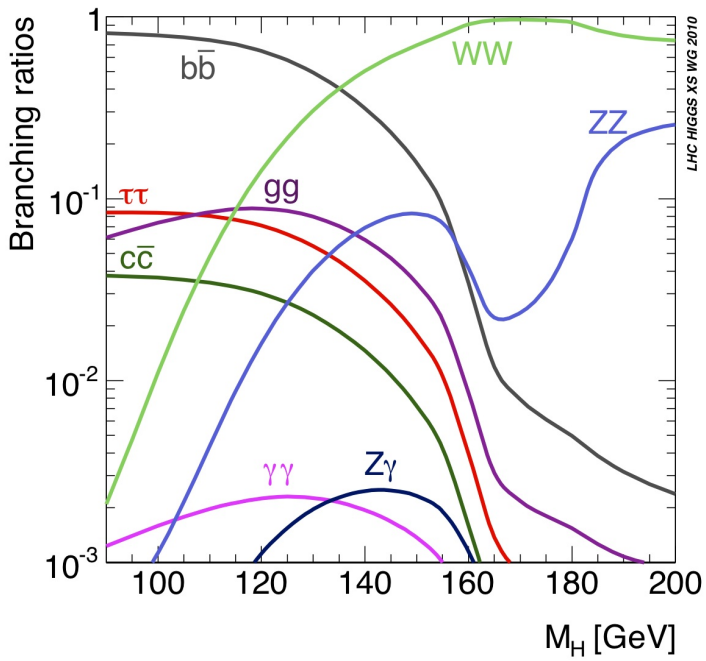
Introduction

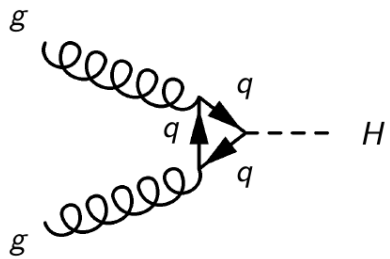
- Standard Model of Particle Physics' last missing piece
- Announcement of discovery of a compatible particle 4th July 2012
- $> 5\sigma$ C.L. in $H \to \gamma\gamma$, $H \to ZZ \to 4l$ and $H \to WW$
- Still no 5σ evidence in the direct fermionic coupling where $H \to \tau\tau$ is a key channel
  - CMS obtained a 3.2σ C.L. with full Run I data



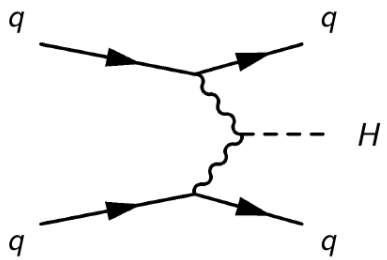
Topology of the process

- Branching ratio of $H \to \tau\tau \sim 6.7\%$
- Good Signal/Background ratio but fair Mass Resolution
- Less BR than $H \to bb$ but much easier detection
- Production modes:

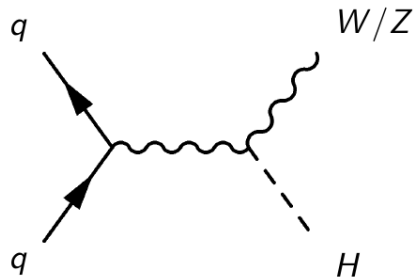




ggF $\sim 87\%$

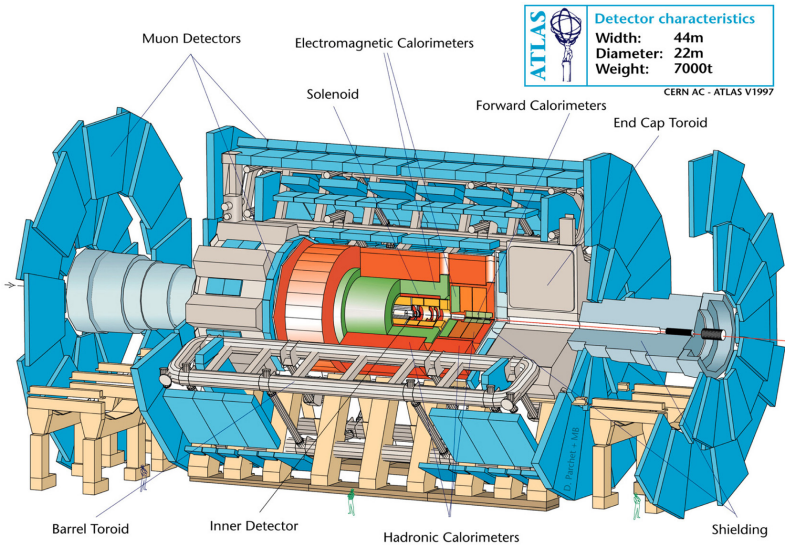


VBF $\sim 7\%$

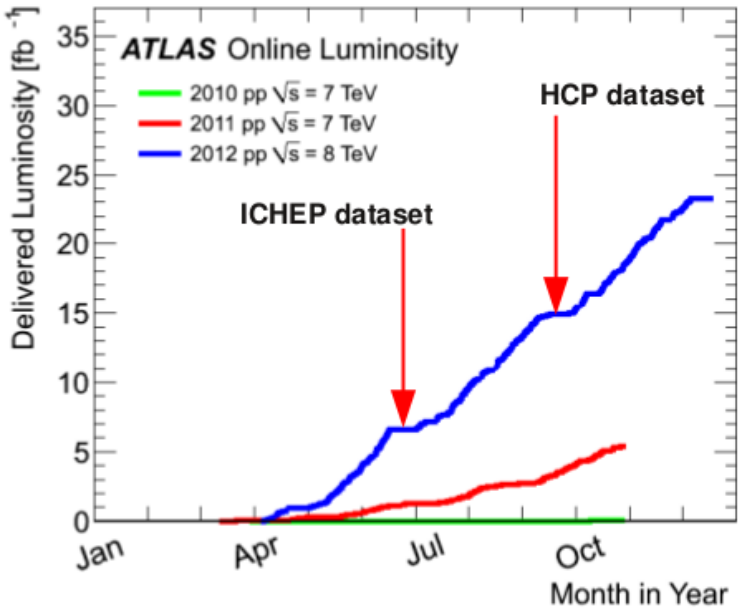


VH $\sim 5\%$

Experiment



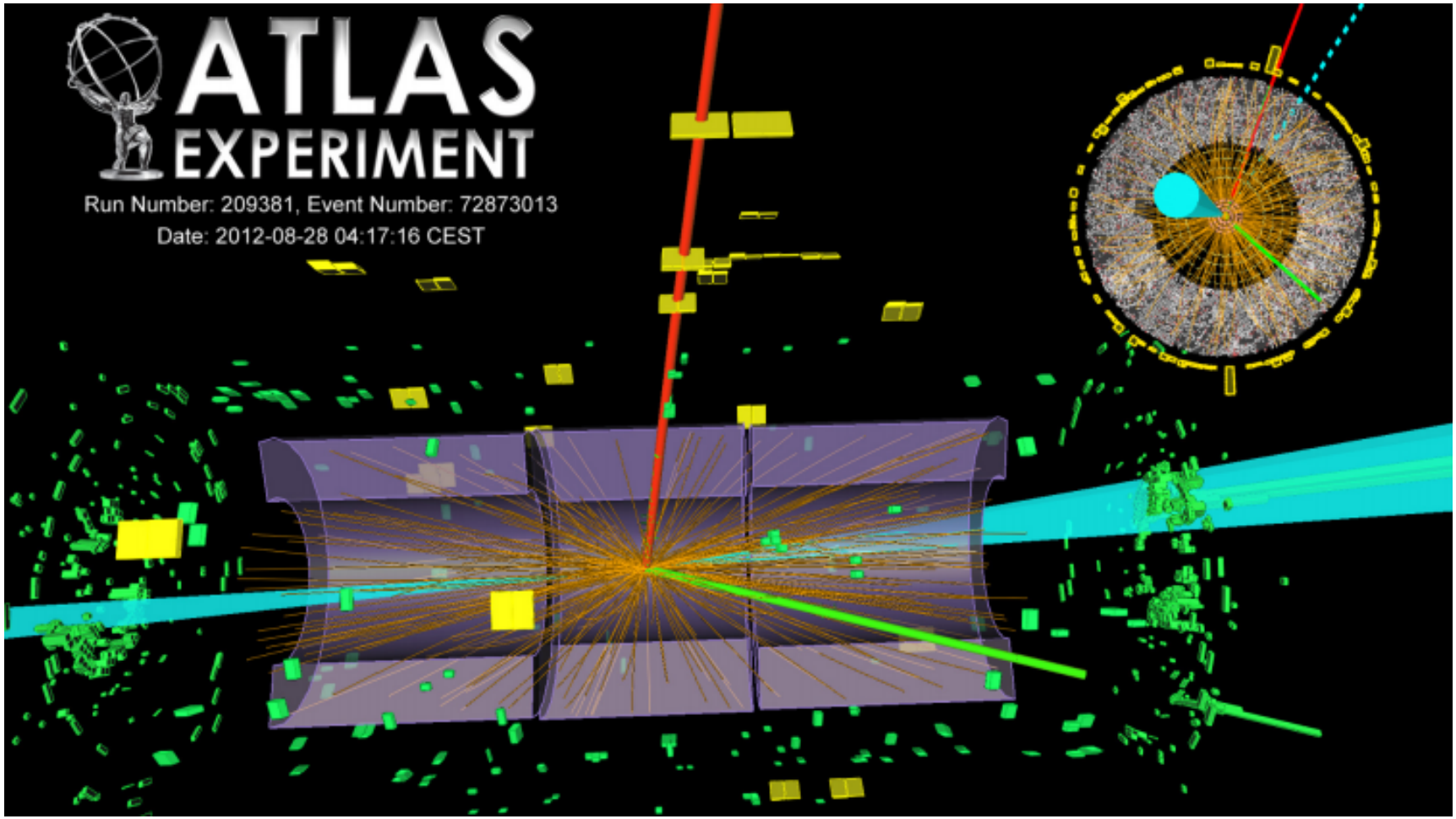
Structure of ATLAS detector at CERN



Data collected until LS1

- Total integral luminosity measured in 2012 $= 20.3 fb^{-1}$ ($+4.6 fb^{-1}$ in 2011)
- Data-taken efficiency for 2012 was 93.1%
- Data good quality for 2012 was 95.5%

Analysis of $H \rightarrow \tau\tau$



Analysis of $H \to \tau\tau$

Final states (tau decays)

- $H \to \tau(\to lep)\tau(\to lep)$
- $H \to \tau(\to lep)\tau(\to had)$
- $H \to \tau(\to had)\tau(\to had)$

Background models

- $Z \to \tau\tau$ (Irreducible)
- $Z \to ll$ ($l = \mu, e$)
- W+jets
- Top events
- Di-boson
- Fake leptons

Analysis categories

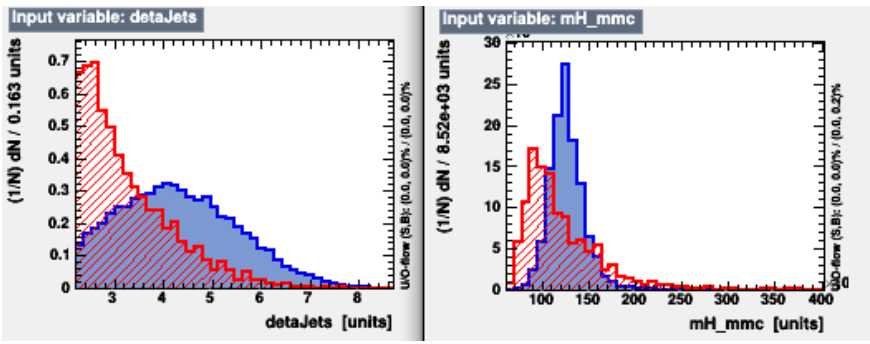
- VBF (at least two jets)
- Boosted (non VBF with high p^T)

Signal models H125

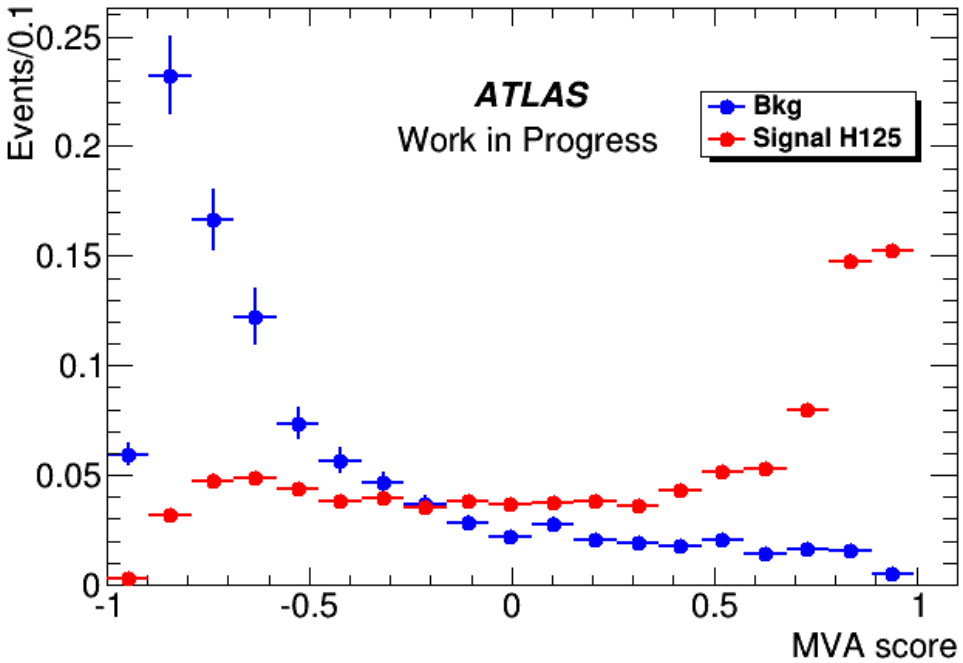
- VBF
- ggF
- VH

MVA Analysis

- MultiVariate Analysis
- Uses info from different dynamical variables to discriminate signal from background
- Trained on MC model and applied on data

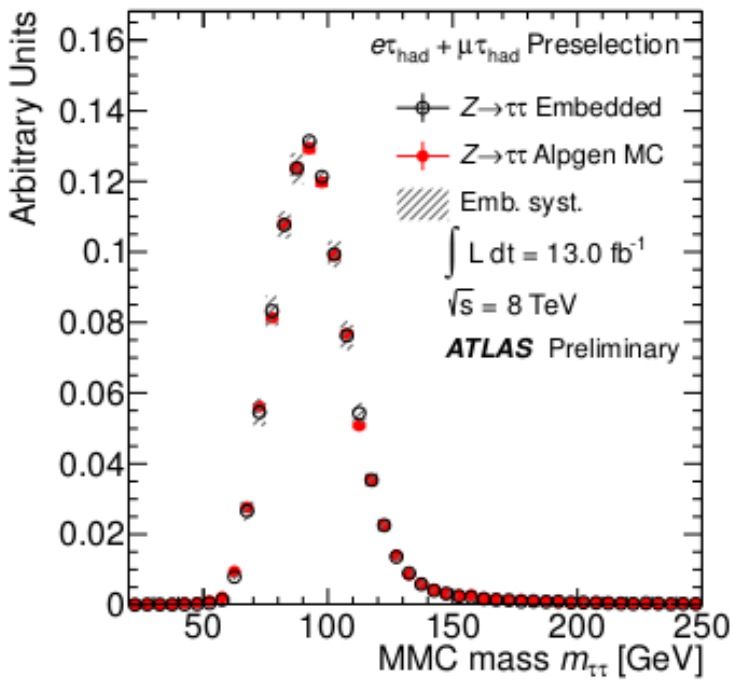


Discrimination power of two input variables



Normalized shape of BDT output for MC

Background modelling: $Z \to \tau\tau$



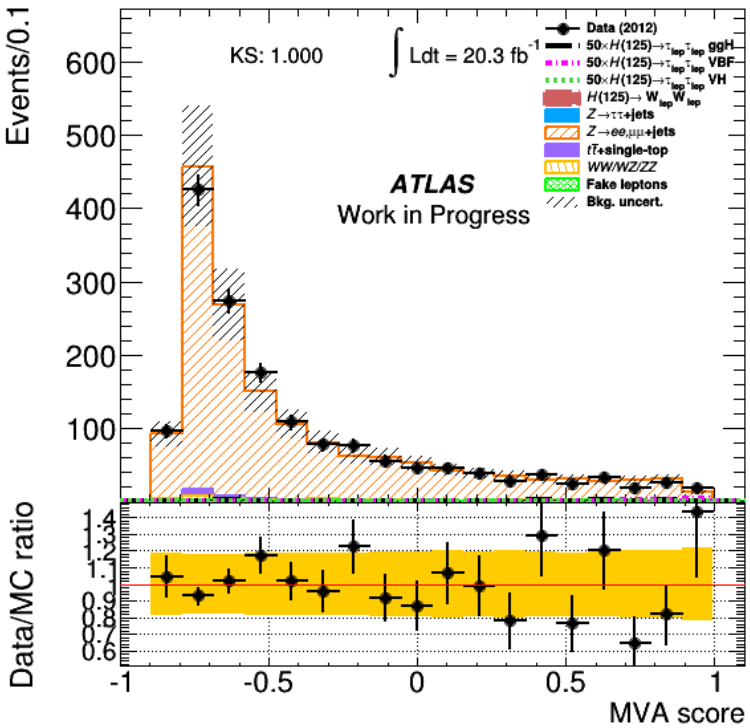
Invariant mass $m_{\tau\tau}$ in $\tau_{lep}\tau_{had}$ channel

$Z \to \tau\tau$

- Main irreducible background in analysis
- Obtained from data $Z/\gamma^\star \to \mu\mu$, where the muon tracks and associated calorimeter cells are replaced by MC simulated taus.
- Advantages of embedding are a much better modelling of hadronic decays, MET, and pileup; since they are obtained directly from data

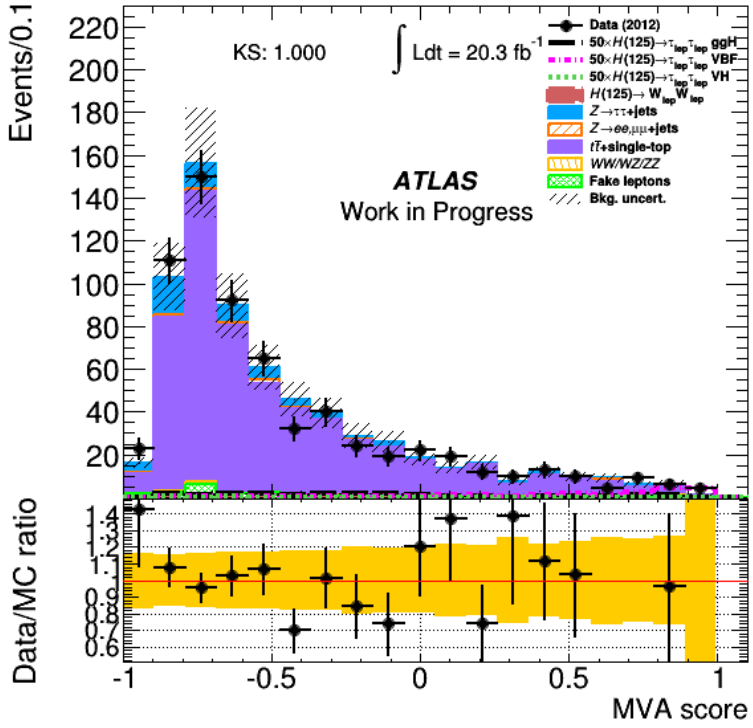
Background modelling: $Z \to ll(e, \mu)$ and $t\bar{t}$

Zll background, controlled in Z peak region



BDT Score in ZllCR

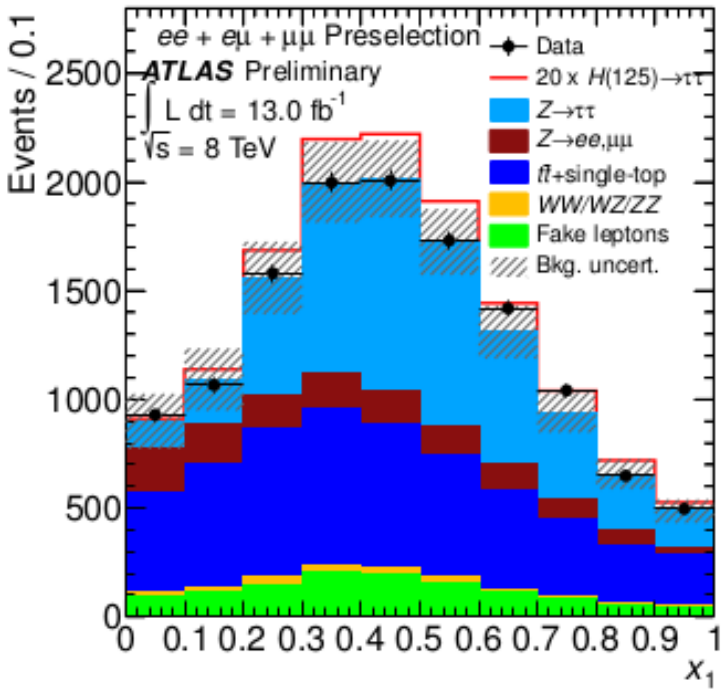
Top Background, controlled in b-tagged region



BDT Score in Top CR

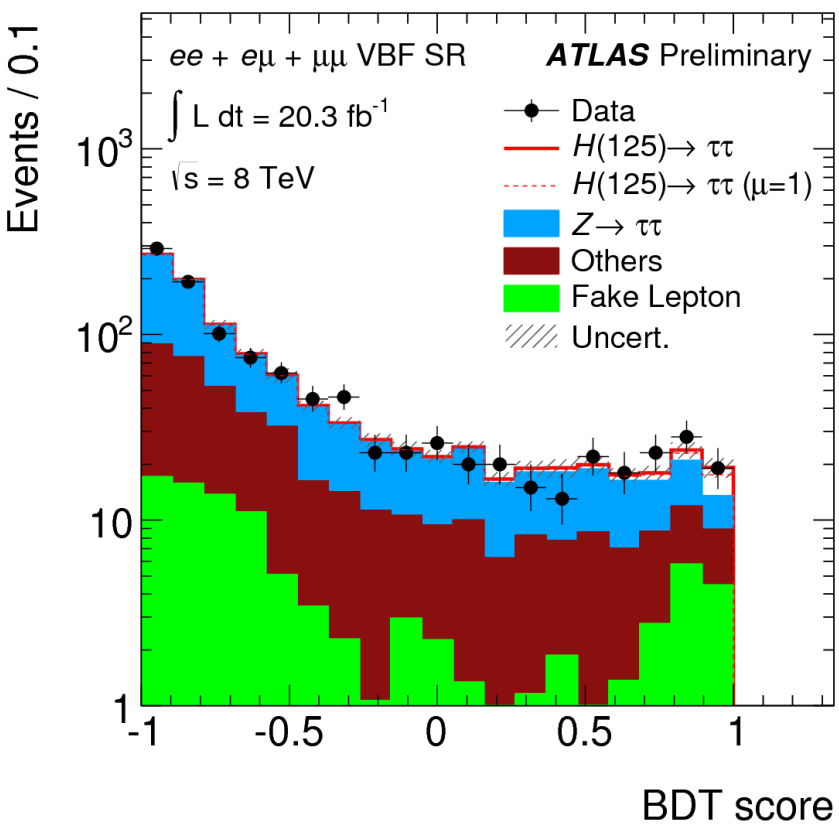
Background modelling: Other backgrounds

- Top events: t, tt (leplep, lephad)
- Di-boson: WW, WZ, ZZ (leplep, lephad)
- W+jets (lephad)
- Fakes: QCD events misreconstructed as leptons (hadhad)

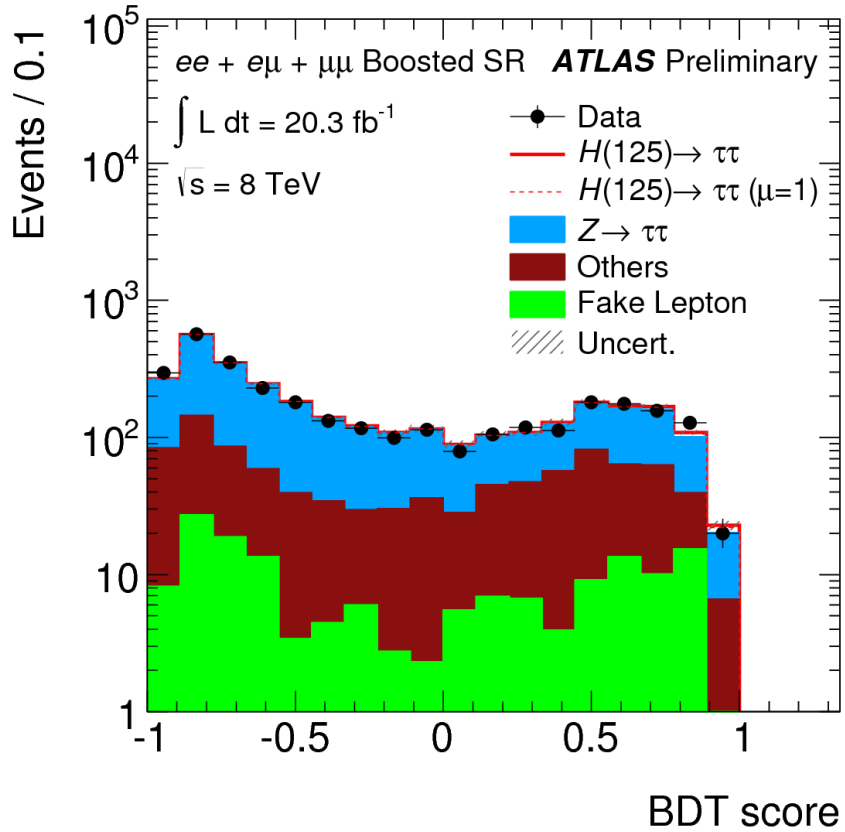


Visible fraction of tau decay after cut in E_T^{miss} in $H \to \tau_{lep}\tau_{lep}$

Results Lep Lep

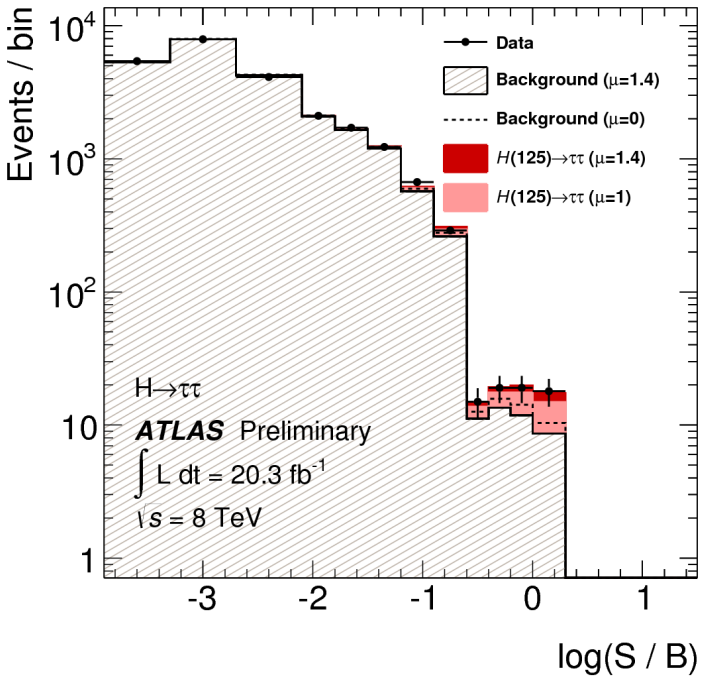


BDT Score after the complete cutflow for VBF category in $H \rightarrow \tau_{lep}\tau_{lep}$

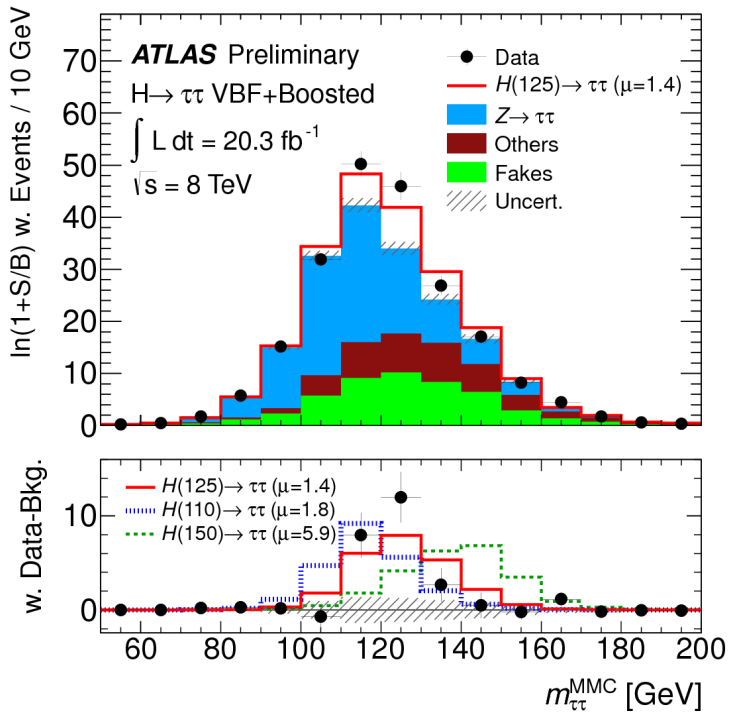


BDT Score after the complete cutflow for Boosted category in $H \rightarrow \tau_{lep}\tau_{lep}$

Results: Combined $H \to \tau\tau$



Event yields as a function of log(S/B) for the combined $H \to \tau\tau$



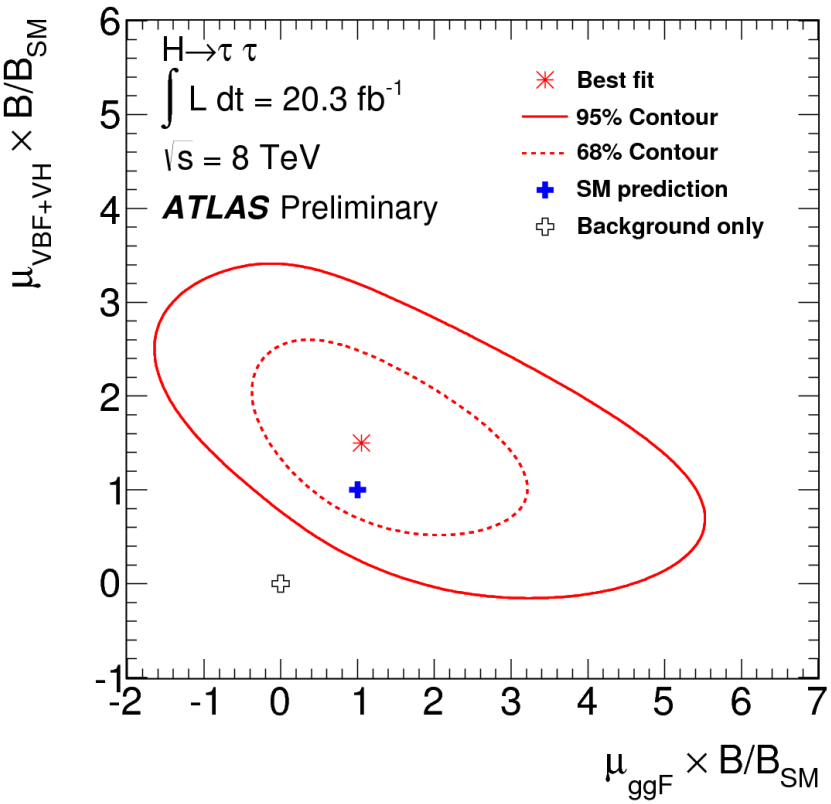
Reweighted MMC plot for the combined $H \to \tau\tau$

Excess at 4.1σ of significance

Expected for H125: 3.2σ

Results: Significance

$$\mu = 1.4^{+0.6}_{-0.4} \text{ at } 4.1\sigma \text{ of significance}$$



Likelihood contours showing compatibility with SM

Summary and Future Prospects

- ATLAS Results: $\mu = 1.4^{+0.6}_{-0.4}$ at 4.1σ (3.2σ expected)
- CMS Results: $\mu = 0.78 \pm 0.27$ at 3.2σ (3.7σ expected)

- First solid evidences of the coupling of Higgs boson to fermions
- Results compatible with SM

- Paper with revisited analysis of Full 7+8TeV Data will be published soon
- For Run II, a better S/B ratio are expected, Higgs XS will be 3 times higher than Run I
- Next aim is to reach 5σ and start the studies on CP/Spin