Search for the Standard Model Higgs in $\gamma\gamma$ and τ+lepton final states

Tevatron, $p\bar{p}$ $\sqrt{s}$ = 1.96 TeV

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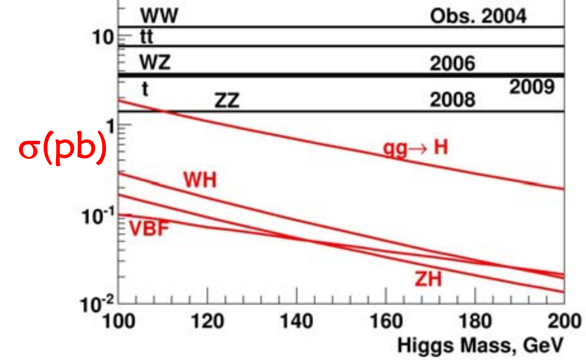
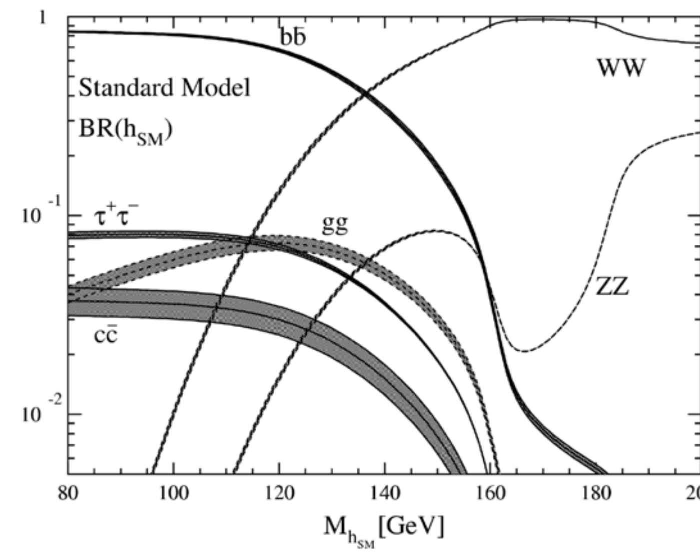
for the DØ Collaboration

At the Tevatron, SM Higgs is produced by gluon gluon fusion (GGF), associated VH (V=W/Z) production and vector boson fusion (VBF).



For M_H < 135 GeV, the dominant decay is H→bb, for which the GGF process is swamped by multijet QCD background.

For M_H > 135 GeV, H→WW/ZZ dominates, but gives diminishing sensitivity at lower M_H.



No single channel is capable of Higgs discovery, so subdominant channels are useful for improving the search.

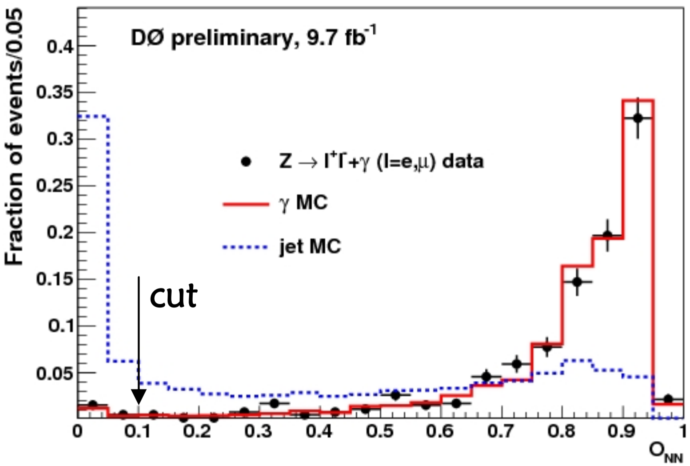
We report here on the H → γγ channel for which the good mass resolution partly overcomes the small BR (0.23% at M_H=125 GeV)

and the τ lepton+(e/μ) channel which is moderately low background and sensitive to a variety of production and decay processes, giving a relatively flat sensitivity for 100<M_H<200 GeV

$H \to \gamma\gamma$

9.7 fb^{-1} of data

D0 Notes xxxx-CONF 6297-CONF
GGF, VBF, VH production
Updated from Moriond 2012



<u>Select events</u>: 2 EM clusters in ϕ,η cone<0.2

- E_T>25 GeV and $|\eta|$<1.1
- Isolation from other calorimeter energy
- Shower shape consistent with e/γ
- No associated track or hits in road

Jet/photon discrimination using neural network (O_{NN}) based on Σp_T^{trk}, calorimeter early shower deposits, preshower energy pattern before calorimeter. Train on MC and verify with $Z \to \ell\ell\gamma$ events

<u>**Backgrounds:**</u> a) Drell Yan: $Z/\gamma^* \to ee/\tau\tau$ from MC using NNLO cross section

b) γ+jet and dijet: flag leading and second γ as Photon or Fake by NN < or >0.75

$$\begin{pmatrix} N_{FF} \\ N_{FP} \\ N_{PF} \\ N_{PP} \end{pmatrix} = \mathcal{M} \begin{pmatrix} N_{JJ} \\ N_{J\gamma} \\ N_{\gamma J} \\ N_{\gamma\gamma} \end{pmatrix}$$

$\mathcal{M}_{ij}$ taken from efficiencies for jet/γ to pass NN cut, corrected using $Z \to \ell\ell\gamma$ data. Use $\mathcal{M}^{-1}$ to obtain JJ, Jγ, γJ, $\gamma\gamma$ contributions.

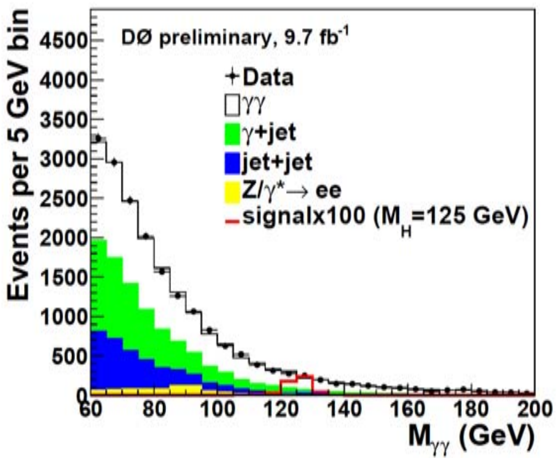
DY	858±14
Jet Jet	2864±189
Jet γ +γ jet	5837±349
$\gamma\gamma$	10621±231
Data	20180

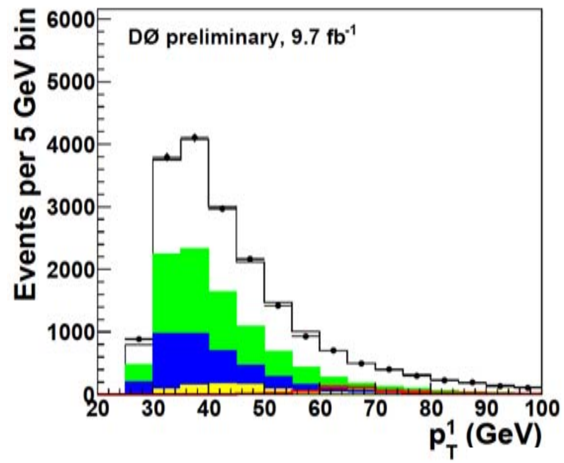
$\gamma\gamma$ background shape from SHERPA.

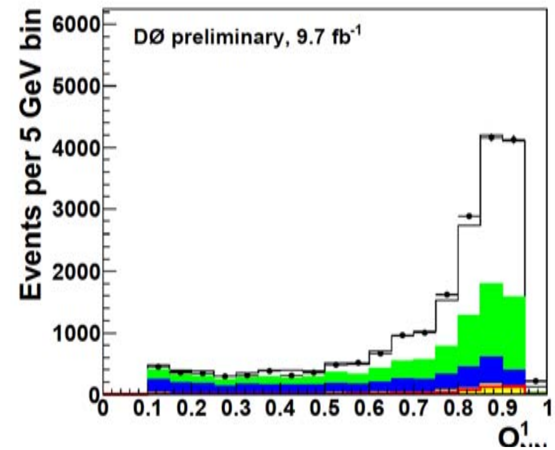
$H \rightarrow \gamma\gamma$ Multivariate analysis

Train boosted decision trees to discriminate signal and background

<u>Inputs</u>: p_T and NN output for both γs; $M_{\gamma\gamma}$, $p_T^{\gamma\gamma}$, $\Delta\phi^{\gamma\gamma}$, $\cos\theta^*$, ϕ^* (Collins Soper), $\not{E}_T$

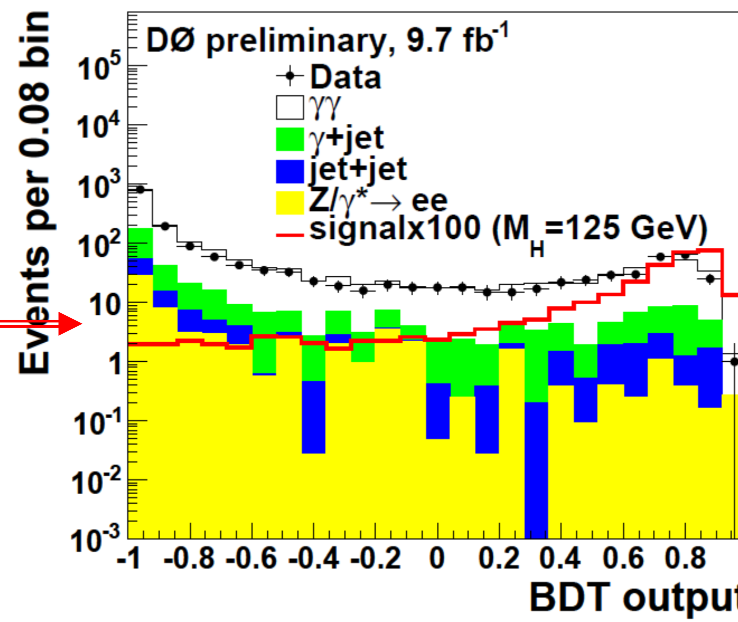






At each M_H hypothesis, train BDTs for both γs good (O_{NN} >0.75) as well as one γ good and one bad to obtain information on backgrounds.

BDT for two good γs

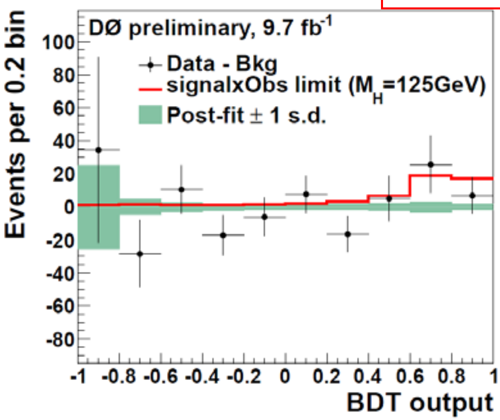


<u>Systematic uncertainties</u>: Lumi, photon ID, signal acceptance (PDFs), GGF p_T, track veto, NN efficiencies, higher order K factors

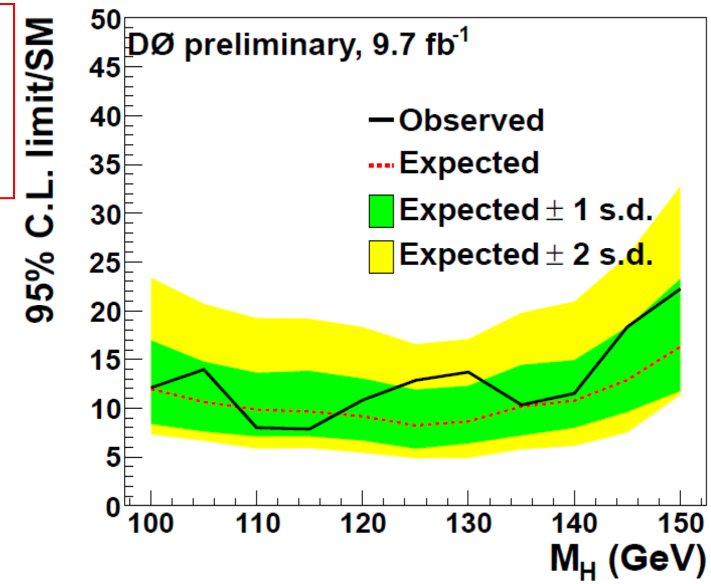
$H \to \gamma\gamma$ Limits

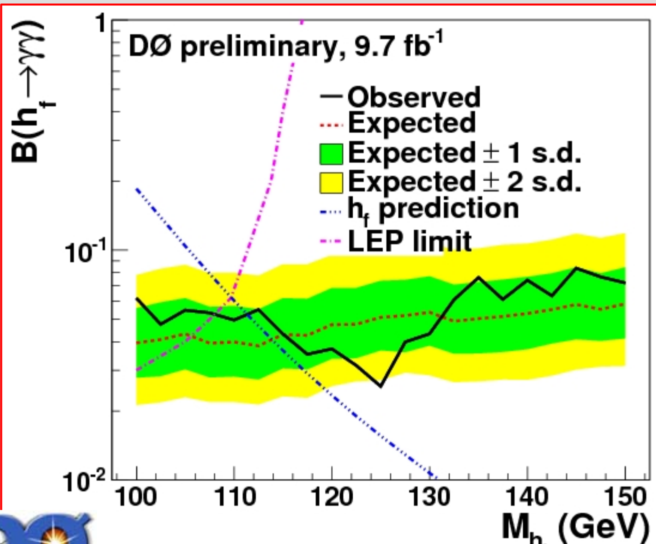
Modified frequentist (CL_s) using ensembles of simulated experiments to obtain –LLR distributions for S+B and B only. Best fits of systematic uncertainties with Gaussian priors, maintaining correlations.

Ratio of 95% C.L. exclusion XS to SM Higgs XS. Observed (expected) ratio is 12.9 (8.2) at M_H=125 GeV.



Best fit background subtracted data, showing background uncertainty and 125 GeV signal at the observed limit





The analysis can be recast as a search for Fermiophobic Higgs, for which the $\gamma\gamma$ BR is enhanced by ~x10. There is now no GGF production, which is dominantly through top loops. The observed (expected) 95% C.L. limits are 111.4 (114) GeV, above the LEP limits.

(not updated from MoriondEW 2012)

$\tau\ \ell$ +X search

arXiv:(hepex) 1203.4443

τ leptons decay hadronically, principally by $\tau \rightarrow \pi\nu$, $\tau \rightarrow \rho\nu$, and $\tau \rightarrow a_1\nu$.

Hadronic taus (τ_H) can be distinguished from jets by the track multiplicity, the presence of EM activity in close proximity to tracks, and isolation from other energy deposits. However, the multijet (MJ) background for Higgs decay to 2 hadronic taus is large, so we restrict ourselves to final states with one τ_H and a lepton (**e** or μ).

For low mass Higgs, we consider five channels: (1) WH, (2) ZH, (3) GGF, and (4) VBF where $H \rightarrow \tau_H\tau_\ell$ as well as (5) HZ with $H \rightarrow qq$ and $Z \rightarrow \tau_H\tau_\ell$.

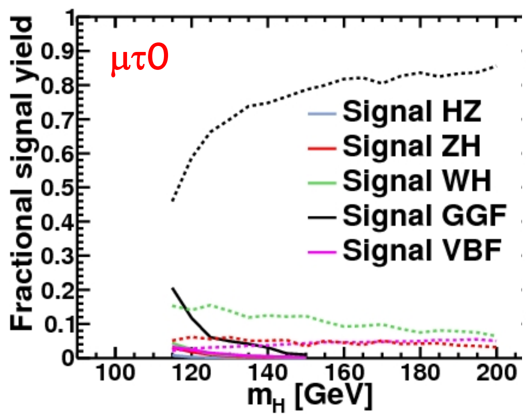
For higher mass Higgs, the $H \rightarrow VV$ becomes dominant, and the $\ell\tau X$ final state in reactions (1 – 4) can occur through a mixture of W/Z decays directly to τ or ℓ, or through $V \rightarrow \tau \rightarrow \ell$.

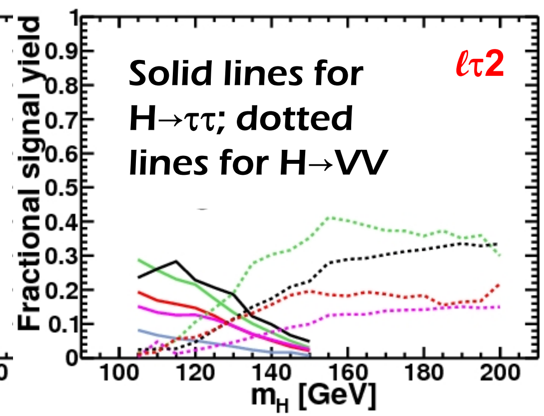
We analyze:

$\mu\tau_H$+0 or 1 jet (7.3 fb^{-1}) – **$\mu\tau0$**

$\mu\tau_H$ +2 jets (6.2 fb^{-1}) – **$\mu\tau2$**

$e\tau_H$ +2 jets (4.3 fb^{-1}) – **$e\tau2$**





The resulting yields for each of the production/decay/N_{jet} channels vary with M_H but the sum of yields is relatively constant as M_H varies.

$\tau\,\ell$ +X selection

- p_T^{τ} > (12.5, 12.5, 15) GeV for τ_H types (1,2,3); $|\eta_\tau|<2$
- p_T of e or μ > 15 GeV; $|\eta_\mu|<1.6$; $|\eta_e|<1.1$ or $1.5<|\eta_e|<2.5$
- Neural net τ vs. jet discriminant based on calorimeter and tracking variables required to be >(0.9, 0.9, 0.95) for τ_H types (1,2,3)
- For $\ell\tau$**2**, p_T^j > 20 (15) GeV for jet 1(2) and $|\eta^{jet}|<3.4$. These cuts reversed for $\mu\tau$**0**
- For eτ**2**, additional τ_H cuts to reduce Z→**ee** and MET significantly non-zero
- $\mu\tau$**0** requires M_T>25 GeV
- Require opposite sign τ_H and ℓ. Require τ, ℓ, jets well separated in ϕ and η

Backgrounds

Simulated by MC:

tt and single top

W+jets (for $\ell\tau$**2**)

Z+jets

WW/WZ/ZZ

Measured in data:

MJ (use orthogonal MJ enriched samples to get shapes and normalize to signal sample)

W+jets (for $\mu\tau$**0**)

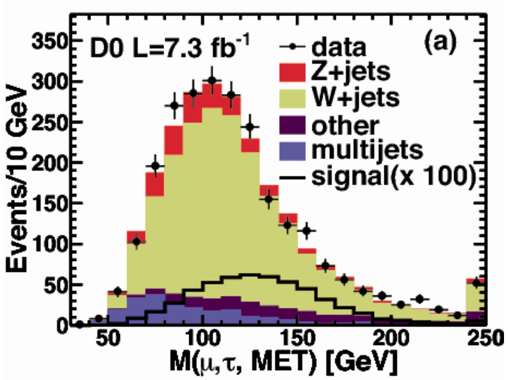
Event yields

	top	Wjet	$Z_{\ell\ell}$jet	$Z_{\tau\tau}$jet	VV	MJ	ΣBkd	Data
$\mu\tau$0	27	1764	172	86	162	223	2433	2473
$\mu\tau$2	112	100	31	231	16	99	589	608
eτ2	24	40	16	46	4	47	176	167

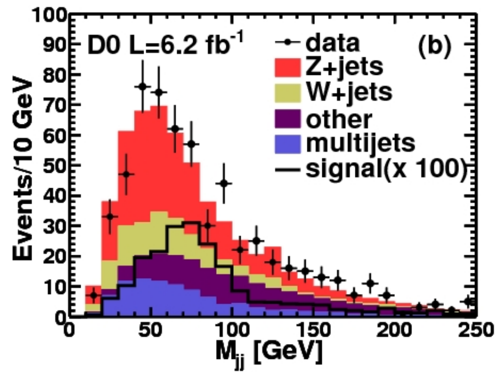
$\tau\,\ell$ +X Multivariate analysis

Each analysis uses 17 well modeled variables (object p_T, E_T^{miss}, mass combinations, separations in η,ϕ, NN_τ etc.) as inputs to Multivariate classifier.

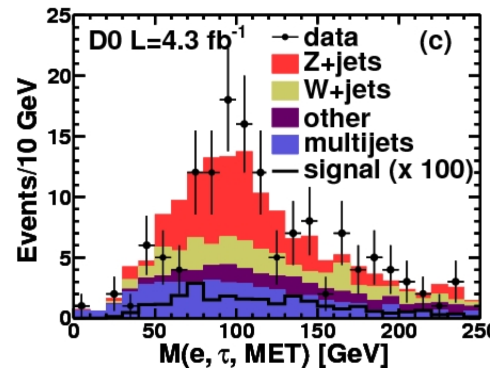
Variable examples:



μτ0: Inv. mass(μτMET)



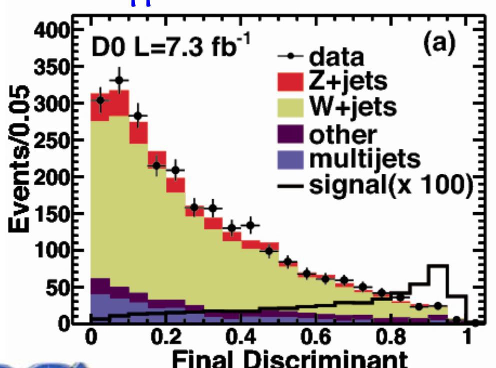
μτ2: Dijet Inv. mass



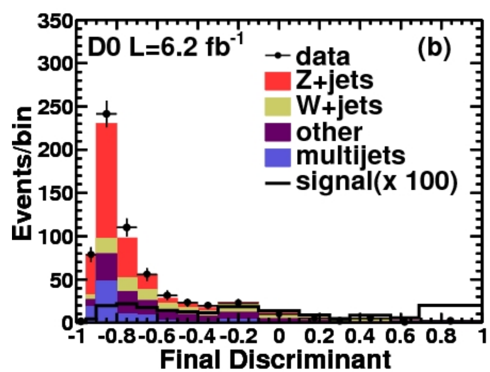
eτ2: Di-tau Inv.mass

Multivariate output

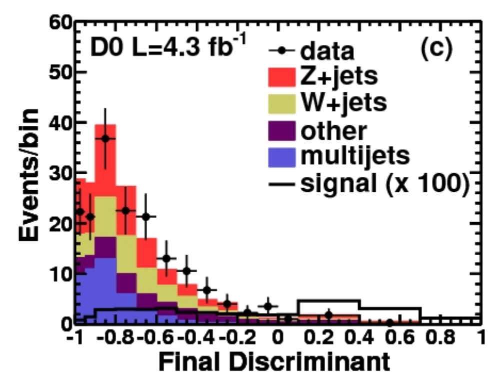
NN output for μτ0, M_H=165 GeV



BDT output for μτ2, M_H=150 GeV



BDT output for eτ2, M_H=150 GeV

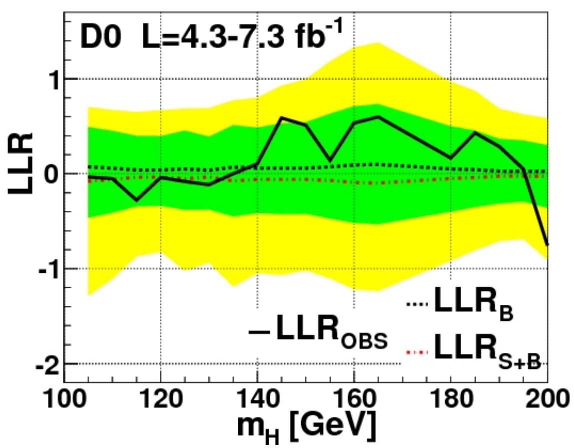


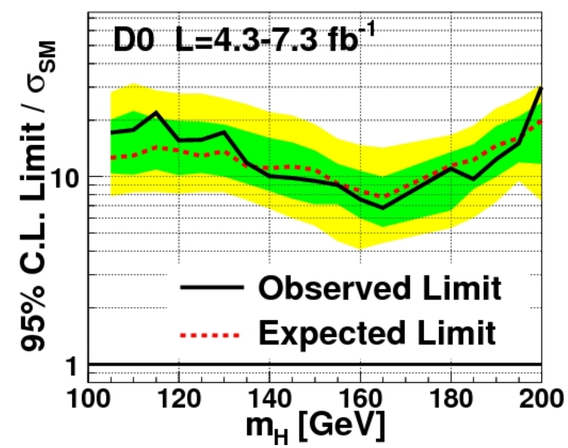
$\tau\,\ell$ +X Limits

Systematic uncertainties determined for luminosity; background and signal cross sections; MJ background determination; lepton and tau energy and ID; jet energy/resolution/ID.

Modified frequentist (CL_S) using ensembles of simulated experiments to obtain –LLR distributions for S+B and B only. Best fits of systematic uncertainties with Gaussian priors, maintaining correlations.

Combine limits for **$\mu\tau$0, $\mu\tau$2** and **eτ2**, together with previous independent 1 fb^{-1} **$\mu\tau$2** analysis. Systematic uncertainties are correlated across channels as appropriate.





Combined 95% C.L. limit ratio to SM XS observed (expected):

125 GeV: 15.7 (12.8) 150 GeV: 9.5 (10.8) 175 GeV: 8.0 (9.6)

Summary

Higgs searches in both the $\gamma\gamma$ and $\ell\tau$+X channels have reached sensitivity levels of about 10 times the SM cross section in the most interesting region between 115 and 140 GeV.

Both analyses continue with more data, improved triggering and particle ID, and improved multivariate analyses.

The addition of subdominant channels aids the overall Tevatron Higgs search sensitivity.