Tevatron searches for fermiophobic Higgs

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Outline

- Introduction
- Analysis strategy comparison
- CDF fermiophobic Higgs search
- DØ fermiophobic Higgs search
- Summary

Introduction

- Minimal standard model (SM) consists of one complex Higgs doublet, and produces one physical neutral scalar particle (SM Higgs boson)
- SM with extended Higgs sectors, *e.g.* two-doublet (2HDM), one-doublet-two-triplet, can affect tree-level couplings to fermions
- 2HDM type I predicts different couplings with type II (MSSM)

Fermion coupling of h in the 2HDM relative to SM

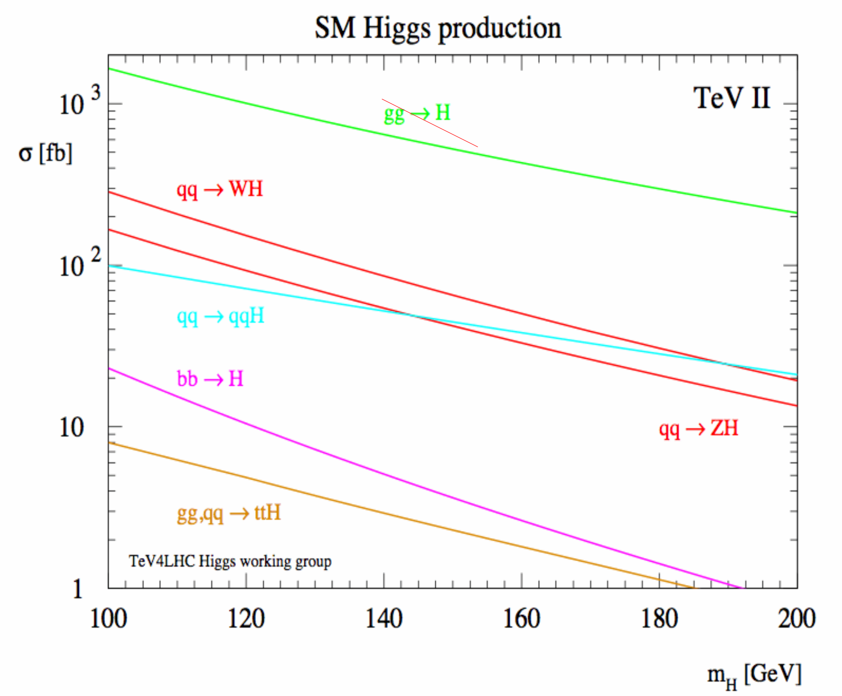
	Model I	Model I′	Model II	Model II′
$hu\bar{u}$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$
$hd\bar{d}$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$-\sin\alpha/\cos\beta$
$he\bar{e}$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$

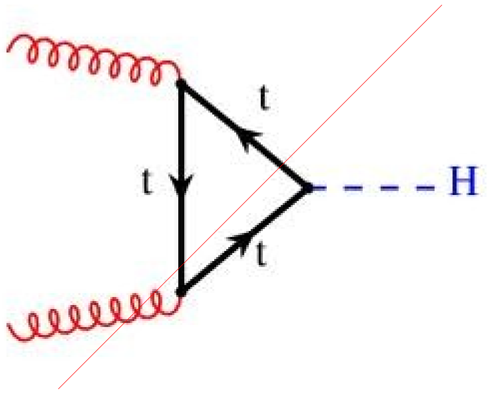
Fermiophobic $\alpha = \pi/2$ (Model I)

MSSM (Model II)

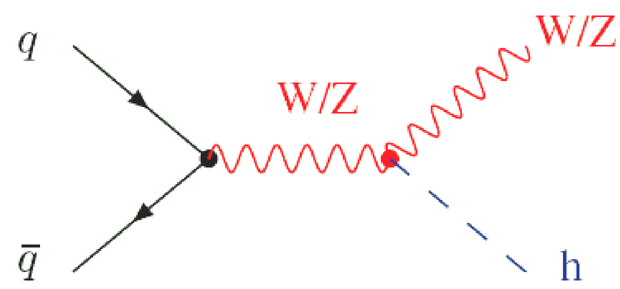
A. G. Akeroyd, Phys. Letter. B**368** (1996) 89

- "benchmark" fermiophobic model
  - 2HDM, type I, $\alpha = \pi/2$
  - tree-level coupling to fermions
  - SM coupling to bosons
- Impact on production
  - *gg*→ H is absent
  - VH, VBF cross sections remains SM value

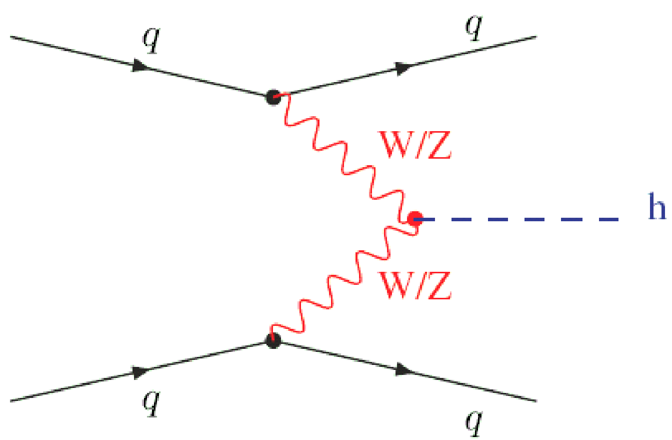




gluon-gluon fusion



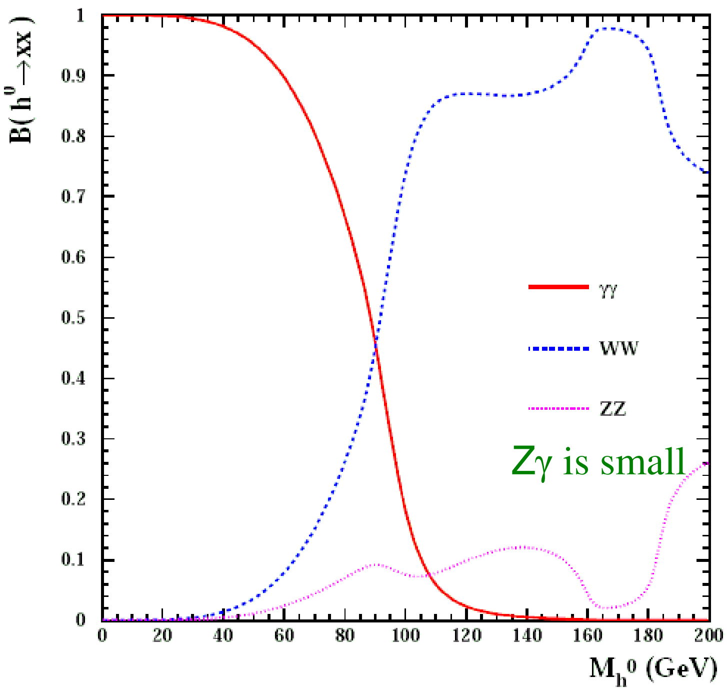
WZ associated production (VH)



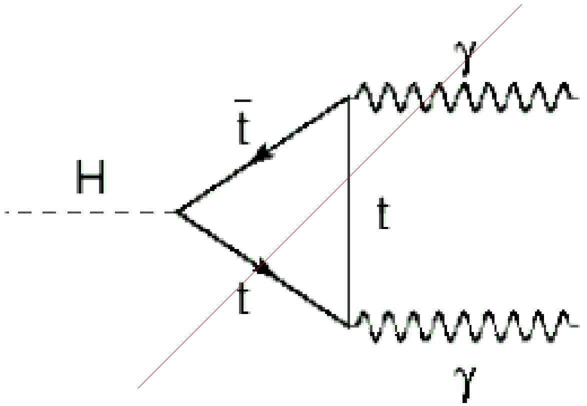
Vector boson fusion (VBF)

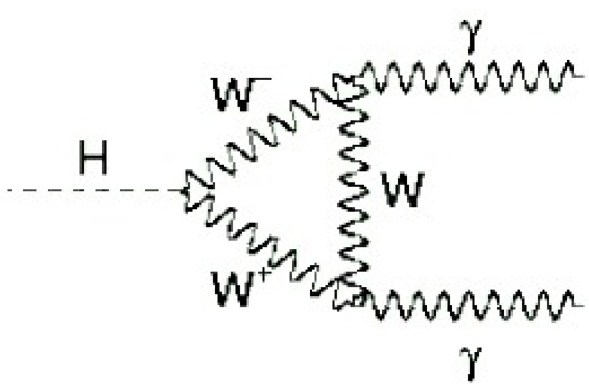
- # Impact on decays
  - $\gamma\gamma$, $Z\gamma$, ZZ, WW become dominant
  - *BR($h\to\gamma\gamma$)* is greatly enhanced, compensating *gg*→ H loss

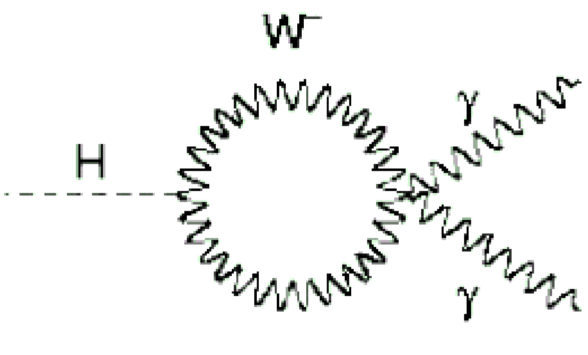
Fermiophobic Higgs BR



m_{h_f} (GeV)	100	110	120	130	140	150
$BR(H\to\gamma\gamma)$	0.0015	0.0019	0.0022	0.0022	0.0019	0.0014
$BR(h_f\to\gamma\gamma)$	0.18	0.062	0.028	0.019	0.0061	0.0020
$BR(h_f\to\gamma\gamma)/BR(H\to\gamma\gamma)$	120	33	13	9	3	1.4







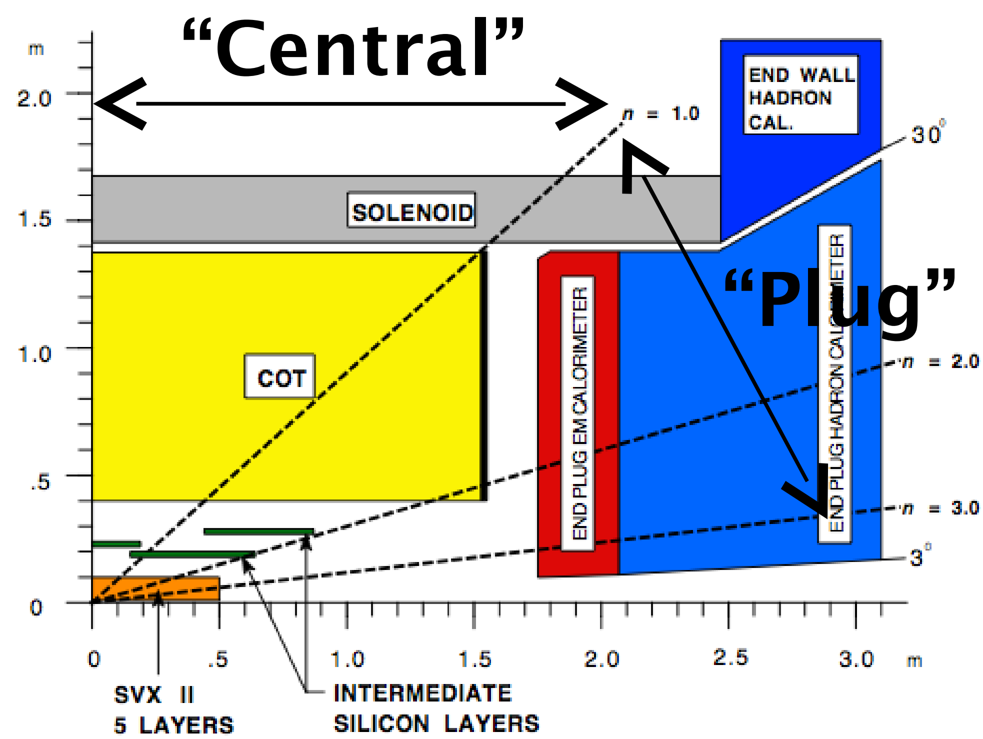
Analysis strategy comparison

	CDF	DØ
$h\rightarrow\gamma\gamma$	7.0 fb^{-1}	8.2 fb^{-1}
events:	CC, CP CC conversion CP conversion	CCCC
background	side-band fit	model individual process shape and normalization
s/b disc.	$m_{\gamma\gamma}$	Multivariate Analysis ($m_{\gamma\gamma}$, E_T^1, E_T^2, $p_T^{\gamma\gamma}$, $\Delta\phi^{\gamma\gamma}$)
limit setting	Bayesian	modified frequentist

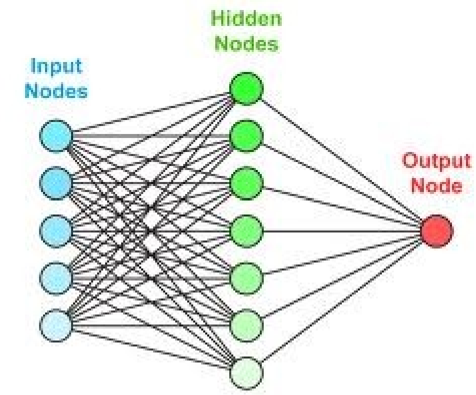
*CC: central central
CP: central plug
CCCC: two central calorimeter

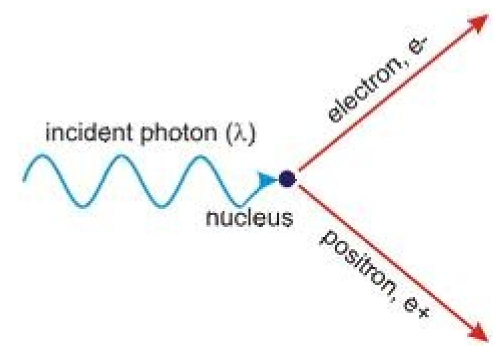
CDF fermiophobic Higgs search

- Based on 7 fb^{-1} in $\gamma\gamma$ and 8.2 fb^{-1} in WW channel
  - Consider low mass region, talk only on $h \rightarrow \gamma\gamma$
- 3 $p_T^{\gamma\gamma}$ bins:
  - <35 GeV
  - [35, 75] GeV
  - > 75 GeV
- 4 channels :
  - Central Central
  - Central Plug
  - Central Central conversion
  - Central Plug conversion
- High pT inclusive photon trigger



- Central photon ID
  - Neural Network technique
  - Signal efficiency 95.5%, background rejection 81.3%
- Plug photon ID
- Central conversion ID
- Overall signal acceptance

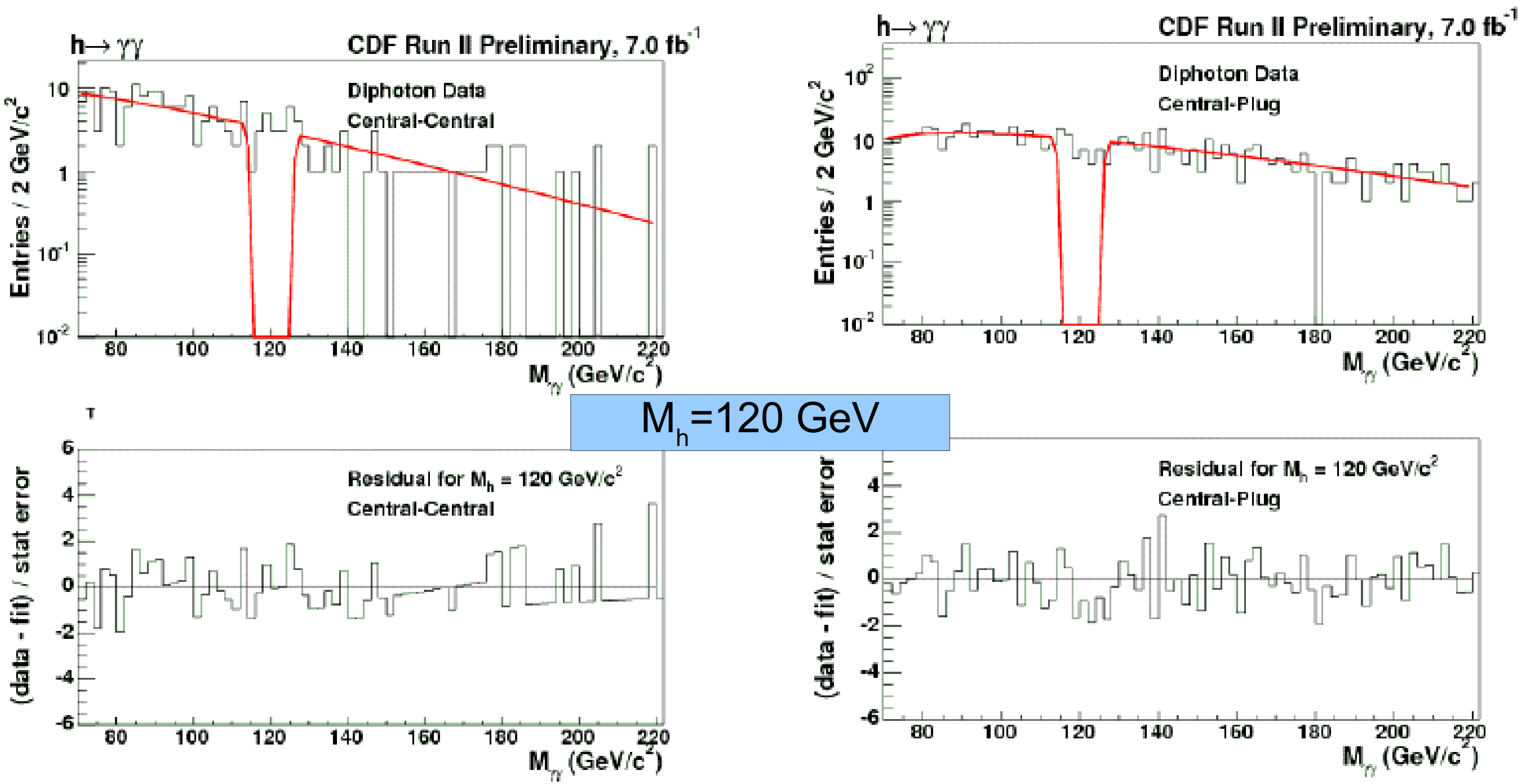




Production Process	M_H (GeV/c^2)	Signal Acceptances (%)			
		CC	CP	CC Conv	CP Conv
VH	125	6.24	5.73	1.29	.57
VBF	125	5.23	4.71	1.10	.46

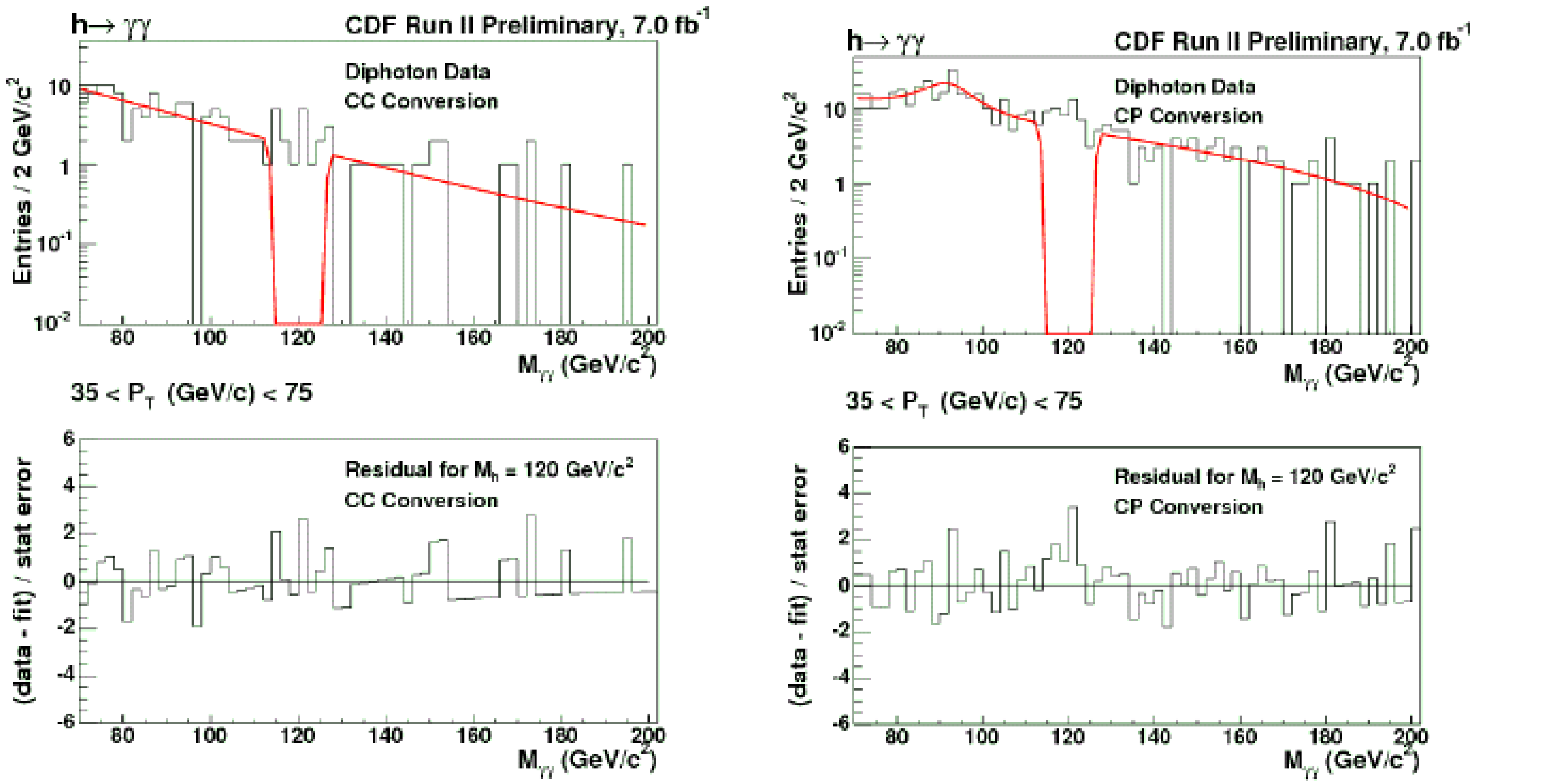
High $p_T^{\gamma\gamma}$ for example

- Background is modeled by side-band fit
  - Narrow mass peak, mass resolution ~ 3 GeV
- Search region is 100-150 GeV
  - $M_h \pm 6$ GeV, 5 GeV interval



Mh=120 GeV

M_h=120 GeV

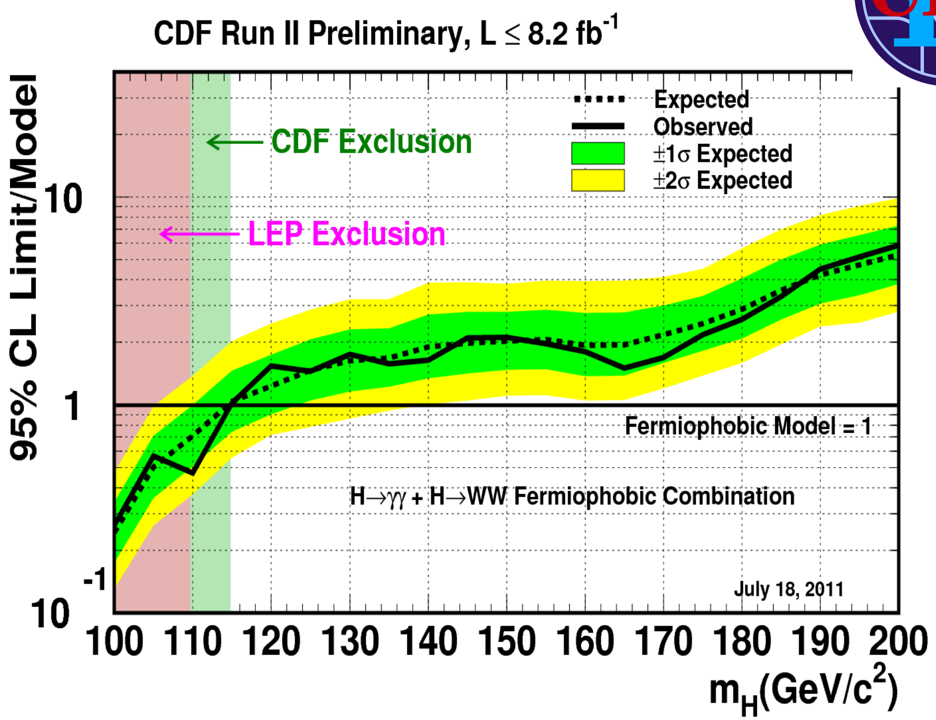


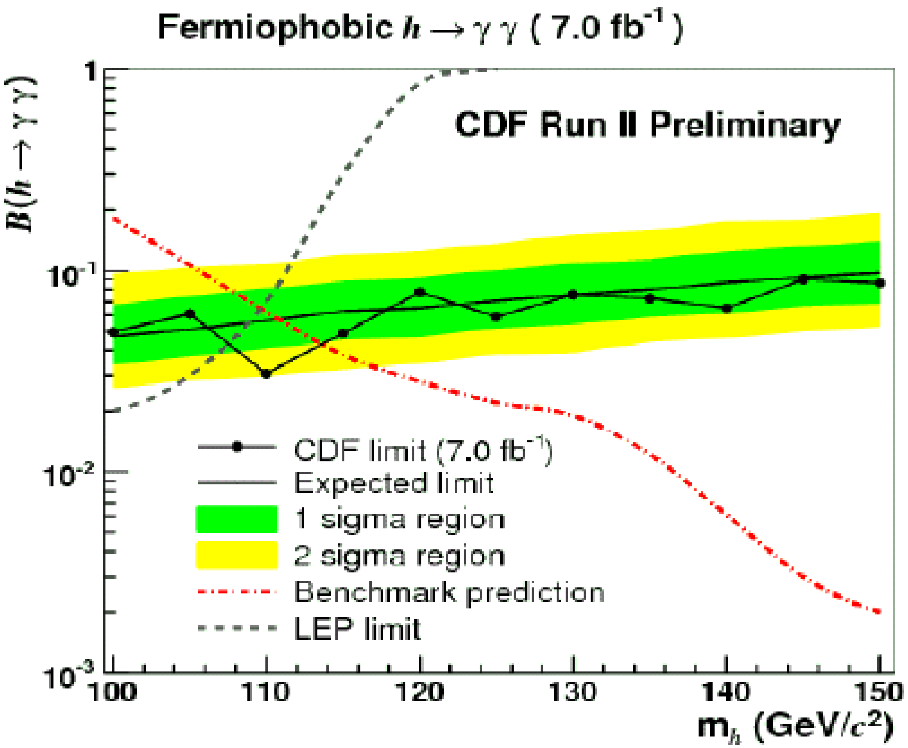
- Systematic uncertainties
  - Luminosity
  - Signal cross section
  - PDF, *etc*

CDF Run II Preliminary $\int \mathcal{L} = 7.0$ fb^{-1}

	Systematic Errors on Signal (%)			
	CC	CP	CC Conv	CP Conv
Luminosity	6	6	6	6
σ_{VH}	7	7	7	7
σ_{VBF}	5	5	5	5
PDF	2	2	2	2

- No excess is observed
- Bayesian C.L. limit
- Exp: M_h > 111 GeV
- Obs: M_h > 114 GeV



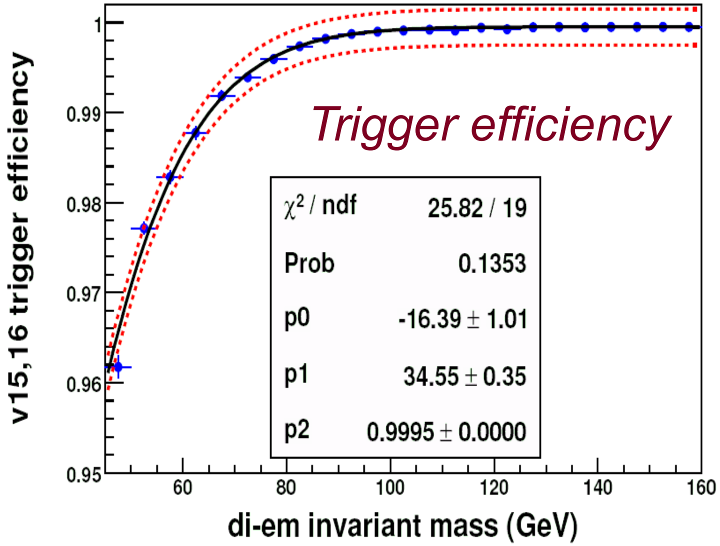


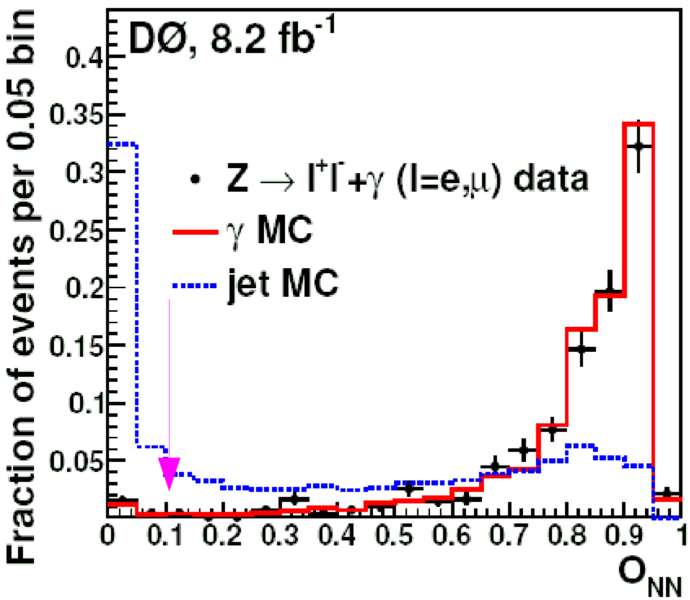
Combined with $h \rightarrow WW$

$M_h >$ 115 GeV

DØ fermiophobic Higgs search

- Only based on $h \to \gamma\gamma$ channel with 8.2 fb^{-1}
- Two central photons,
  - $|\eta_{det}| < 1.1$, $E_T > 25$ GeV
  - Di-EM trigger
- Photon ID
  - Basic shower shape cut
  - Neural Network technique $O_{NN} > 0.1$, rejecting ~40% jet, keeping almost all real photons
  - Track veto, ~2% electron fake rate
- $\Delta\phi^{\gamma\gamma} > 0.5$
- Overall efficiency for signal,~20%



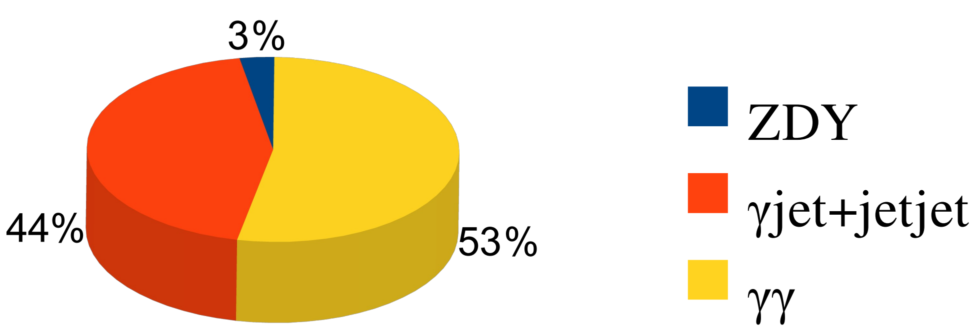


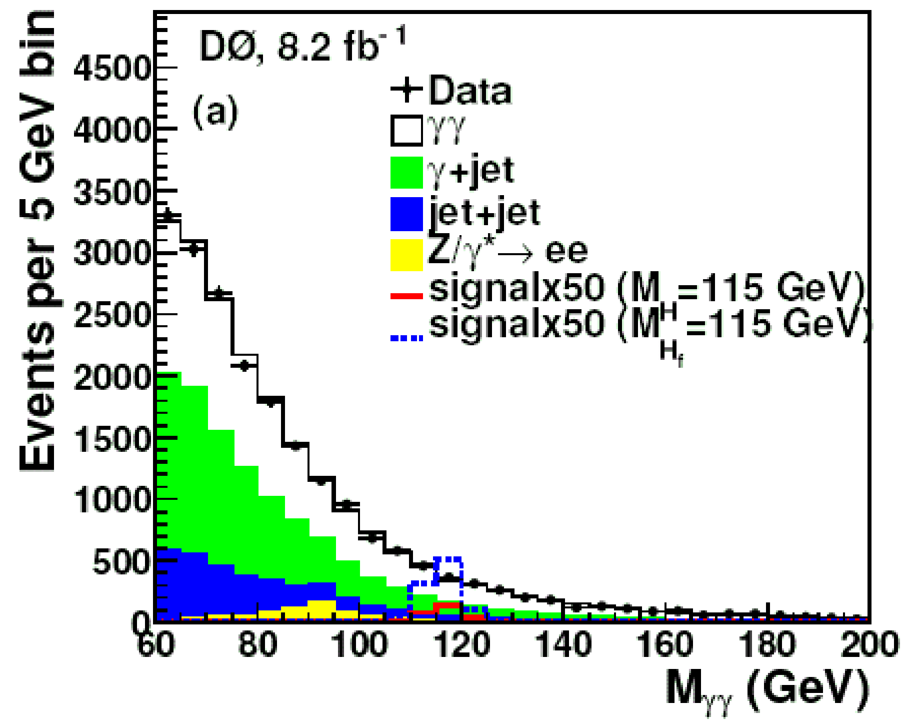
- # Background modeling and composition

	shape	normalization
$Z/\gamma^{*}\rightarrow ee$ (ZDY)	PYTHIA	NNLO
γ+jet, jet+jet	control data sample	4x4 matrix method
Direct $\gamma\gamma$	SHERPA	fit

- # Search region is 100-150 GeV
  - $M_h \pm 30$ GeV
  - 2.5 GeV interval, ~ mass resolution

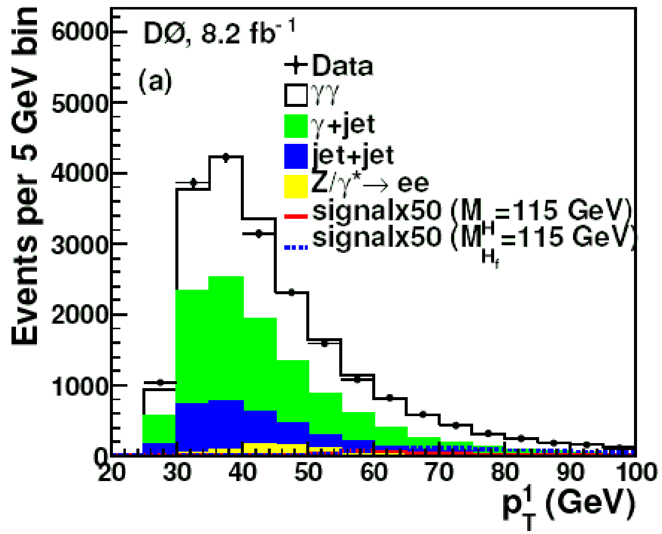
Bkg composition at M_h= 120 GeV

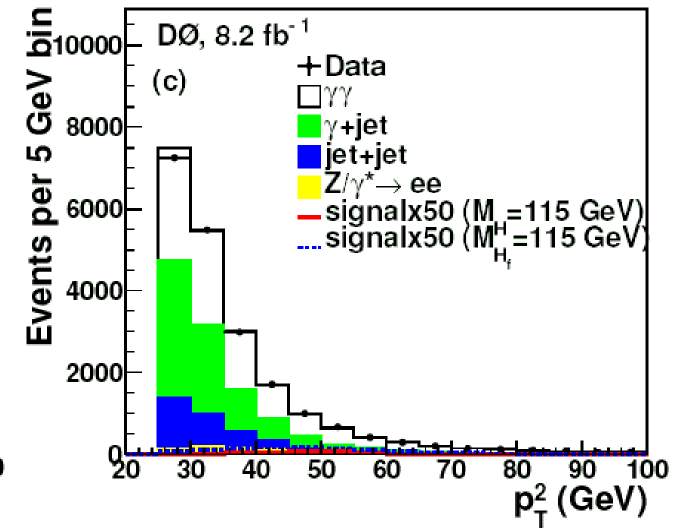


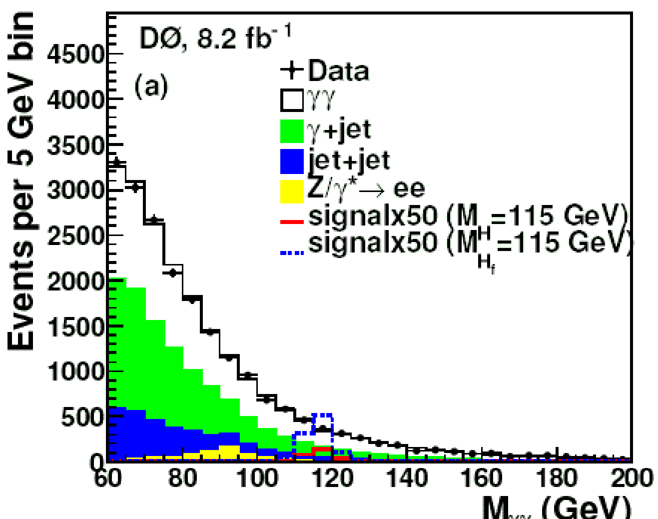


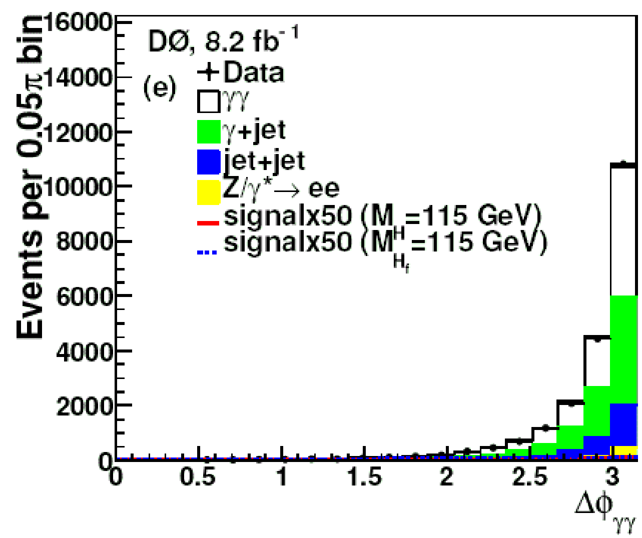
- Multivariate analysis
  - Gradient boosted decision tree
  - 5 variables are used for training: $m_{\gamma\gamma}$, E_T^1, E_T^2, $p_T^{\gamma\gamma}$, $\Delta\phi^{\gamma\gamma}$

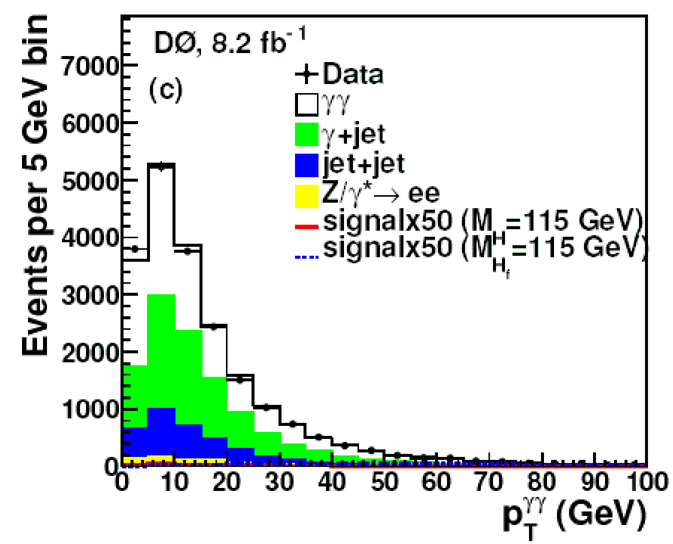
All in linear scale
Log scale next slide



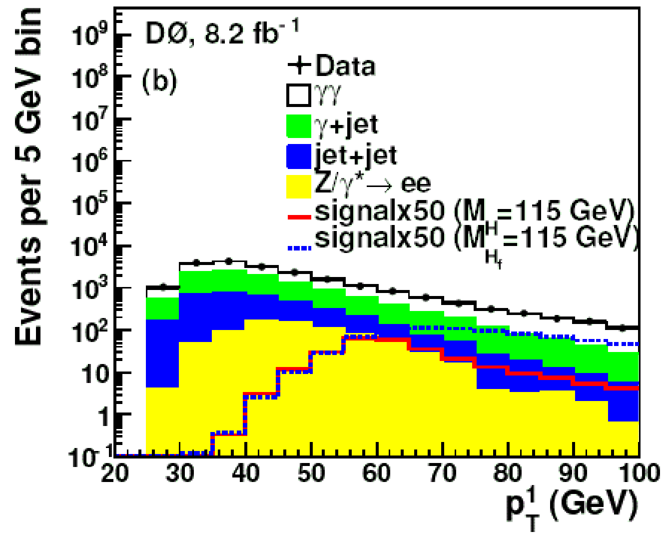


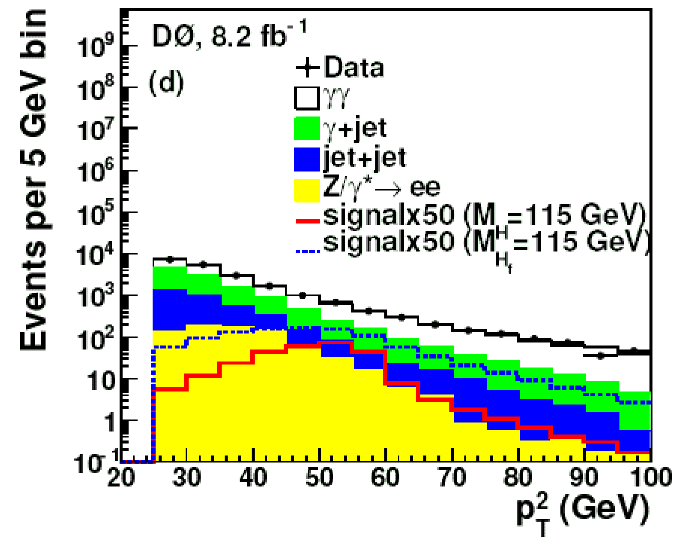


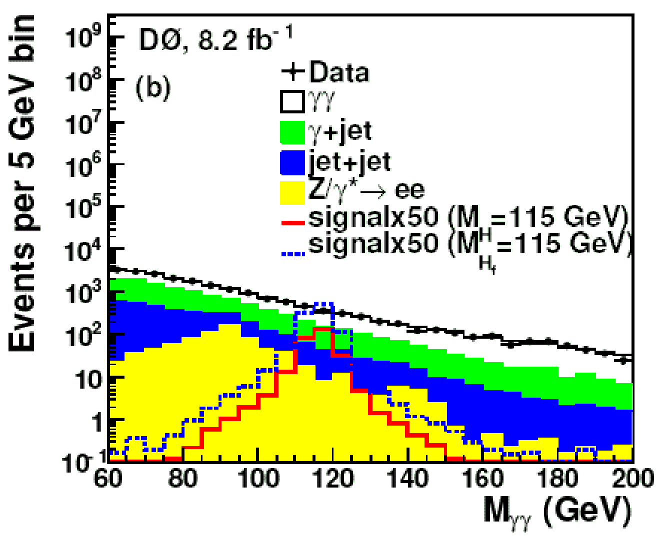


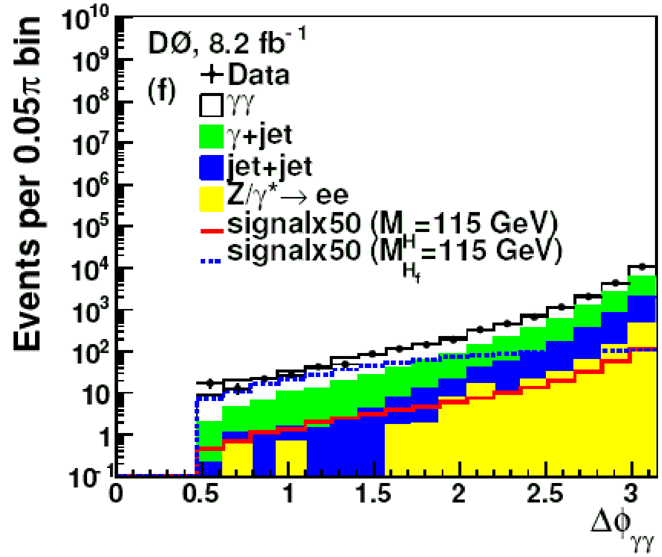


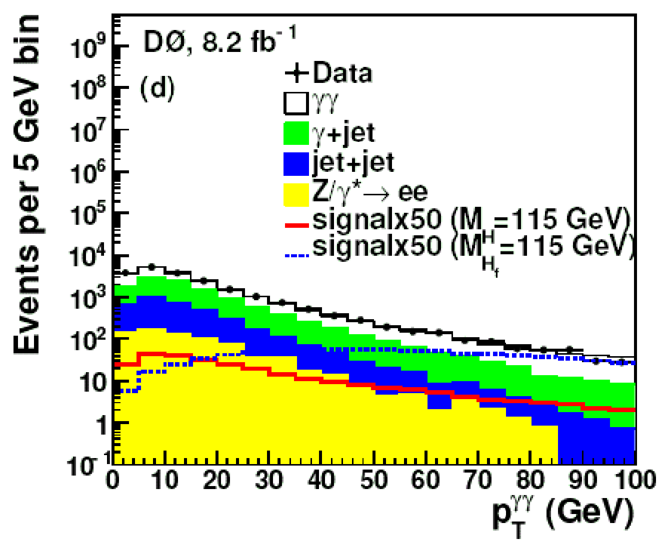
All in log scale



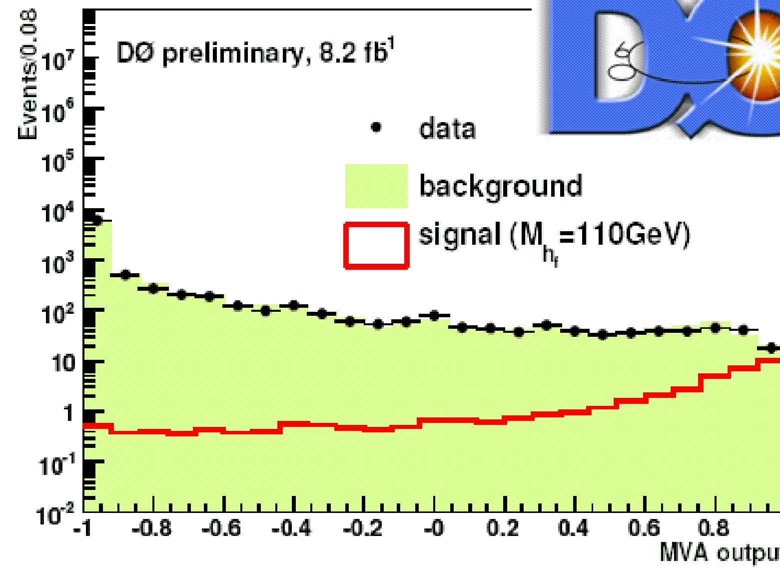


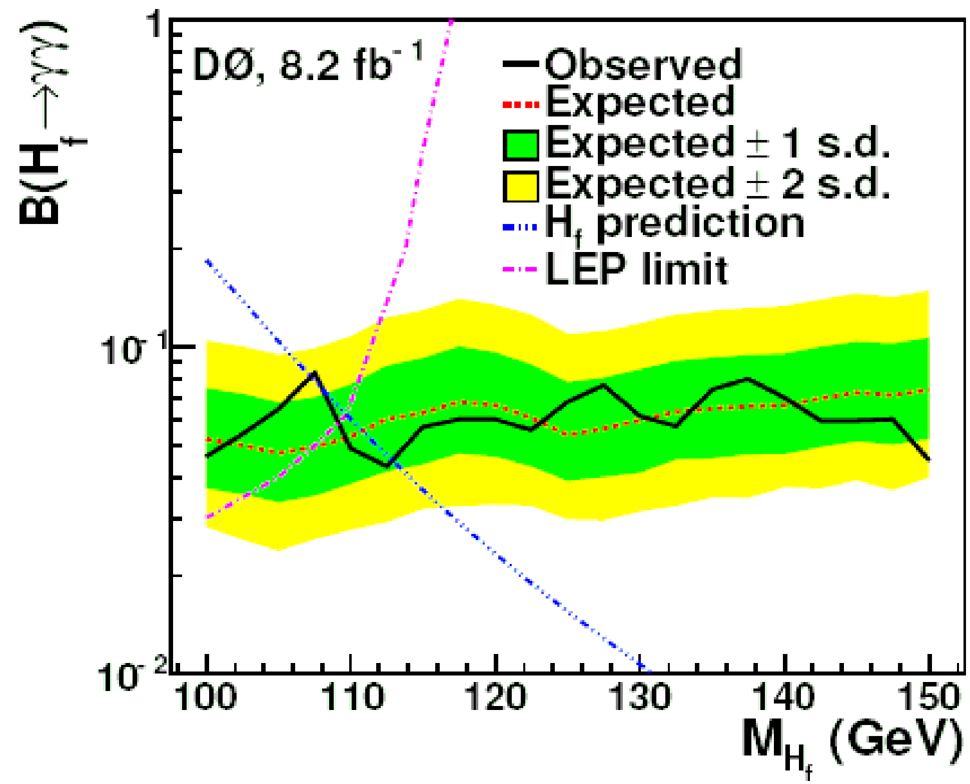






- Systematic uncertainties
  - Consider both normalization and shape
  - Signal cross section, VH ~6%, VBF ~5%
  - Luminosity ~6%
  - 4x4 matrix method ~8.4%, *etc*
- No excess is observed
- Modified Frequentist (CL_S) used to set upper limits
  - Use BDT output
  - Fit systematics in S+B & B only hypotheses
- Exp: $M_h >$ 111 GeV
- Obs: $M_h >$ 112.9 GeV





Summary

- Searches for fermiophobic Higgs are performed at Tevatron, both extend the exclusion region by LEP (M_h > 109.7 GeV)
  - CDF $h \rightarrow \gamma\gamma$: M_h > 114 GeV
    $h \rightarrow \gamma\gamma + h \rightarrow WW$: M_h > 115 GeV
  - DØ $h \rightarrow \gamma\gamma$: M_h > 112.9 GeV
- Tevatron combination is in review and expected to be shown later this week