Search for a light Higgs boson in the di-photon final state at Tevatron

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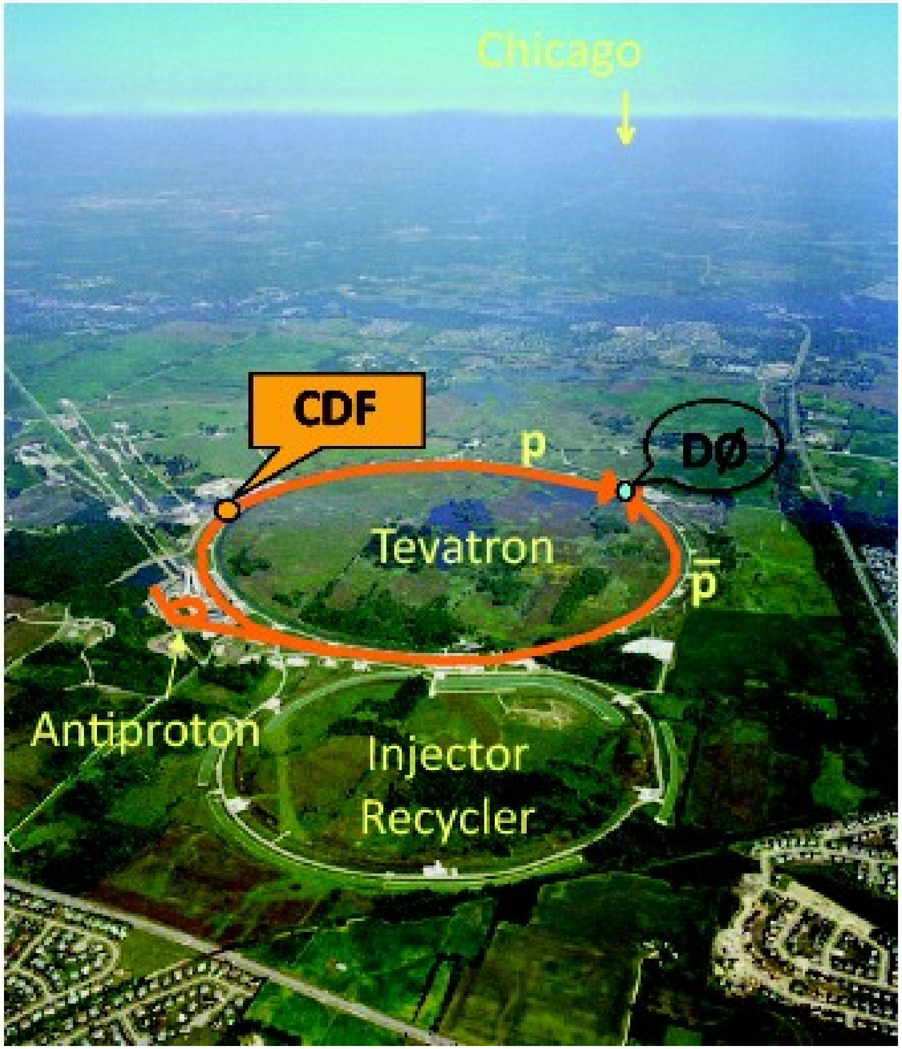
On behalf of the CDF&DØ collaborations

Outline

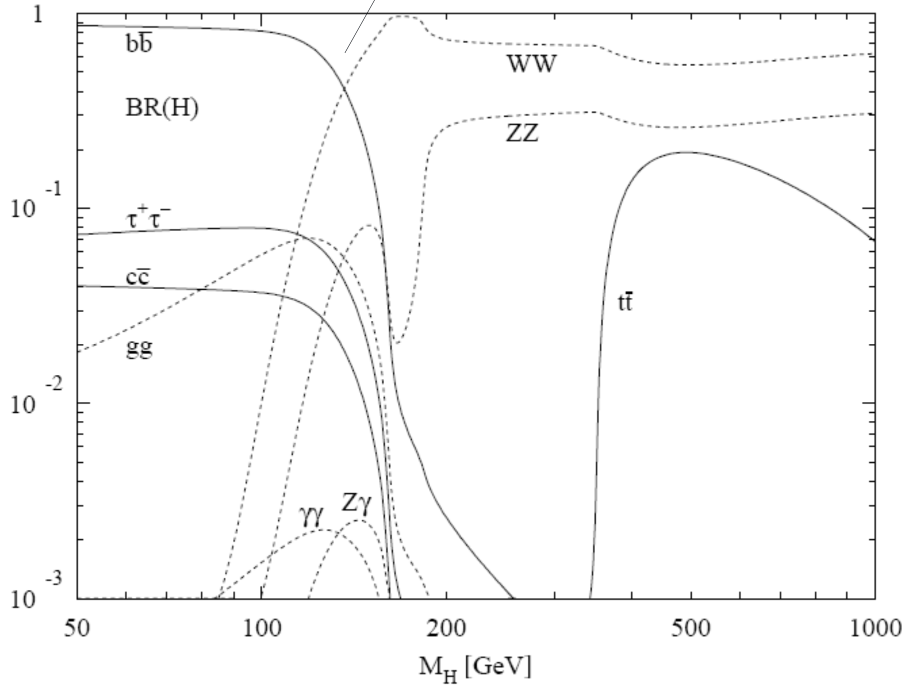
- Motivation
- SM H→γγ search at DØ
- Fermiophobic H→γγ search at CDF&DØ
- Conclusions



Motivation

- Di-photon production:
  - Search for new phenomena
  - Search for Higgs boson
    - M_H>114.4 GeV (LEP)
    - Exclusion M_H = 160-170GeV (Tevatron Moriond 09)
    - Contributes to the Tevatron combination in the intermediate mass region (110-140GeV)
    - Golden channel at LHC

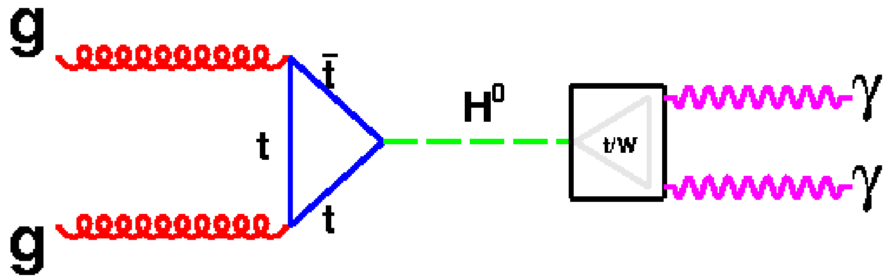
Filling the gap

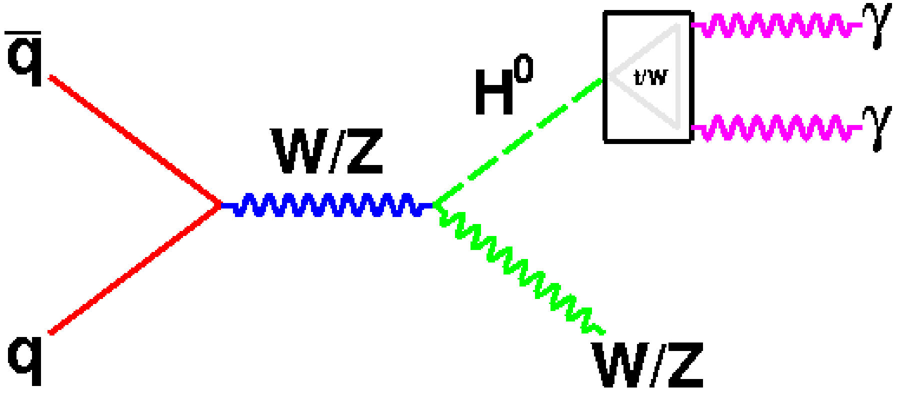


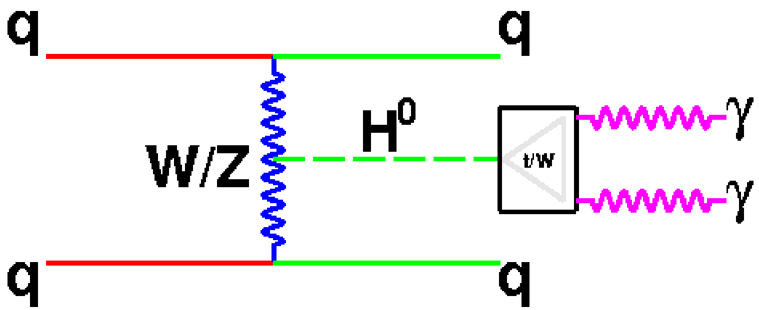
SM H→γγ search at DØ

Model-independent approach:

- Examine the inclusive di-photon dataset ($\gamma\gamma$+X) to search for high mass resonances
- The SM Higgs is used as a possible model
  - gluon fusion
  - associated production
  - vector boson fusion



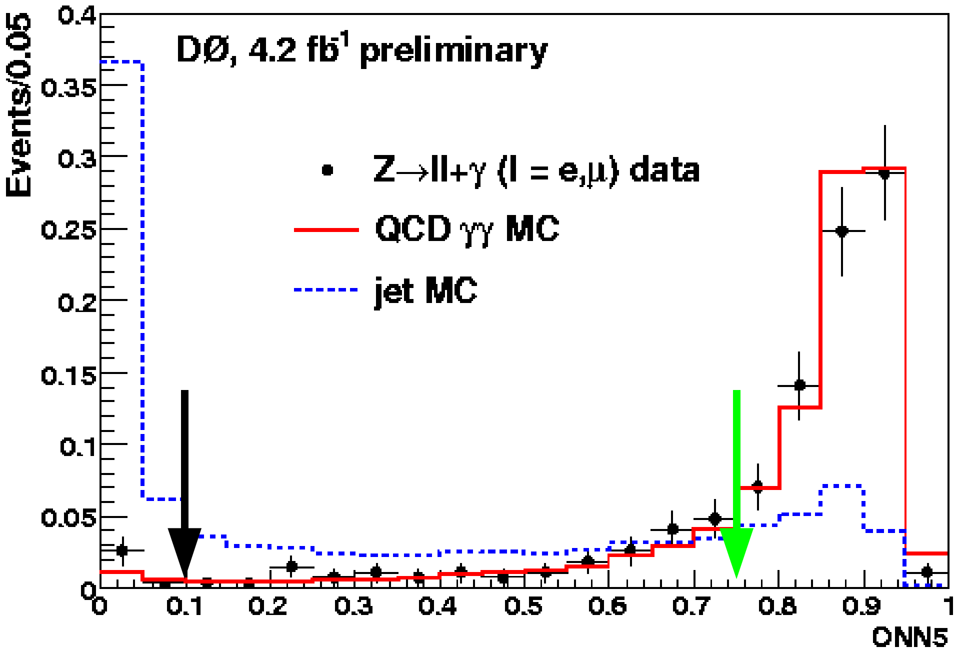




Event selection

- z primary vertex < 60 cm.
- At least two photons with:
  - $P_T > 25$ GeV;
  - $|\eta| < 1.1$;
  - EM shower;
  - Isolated in the calorimeter and tracker;
  - Track veto.

Artificial Neural Network



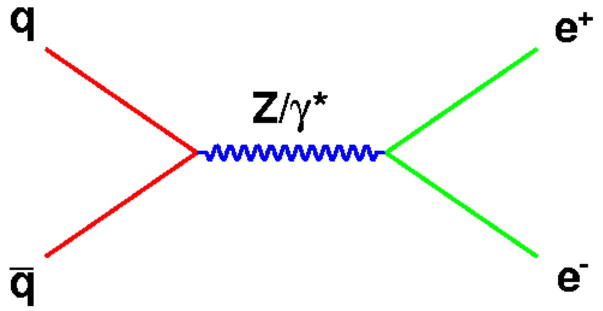
- To suppress the jets misidentified as photons;
- Photon candidates: ONN>0.1;
- Photon ONN efficiency is measured from data, jet ONN efficiency validated on data.

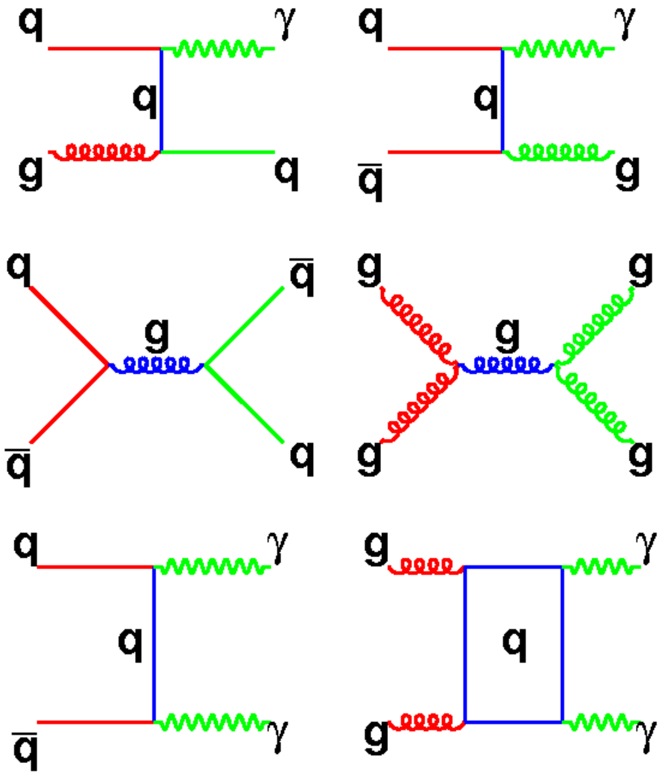
Major background

1. Z/γ*→ee, both electrons are misidentified as photons, estimated with Geant MC;

2. Non-γγ (γ+jet, jet+jet), when the jet(s) is(are) misidentified as the photon(s), estimated from data;

3. Direct γγ, the irreducible background, estimated from data, using side-band fitting method.





Event-by-event basis 4x4 Matrix Method

- used to estimate the non-γγ background

- Use ONN=0.75 as a boundary to separate the final candidates to four categories,
  - **Npp:** both pass the ONN>0.75 cut
  - **Npf:** first pass, second fail
  - **Nfp:** first fail, second pass
  - **Nff:** both fail

$$\begin{pmatrix} N_{ff} \\ N_{fp} \\ N_{pf} \\ N_{pp} \end{pmatrix} = E \times \begin{pmatrix} N_{jj} \\ N_{j\gamma} \\ N_{\gamma j} \\ N_{\gamma\gamma} \end{pmatrix}$$

$\epsilon_{\gamma 1}, \epsilon_{\gamma 2}$ are photon ONN>0.75 efficiency;
$\epsilon_{j1}, \epsilon_{j2}$ are jet ONN>0.75 efficiency.

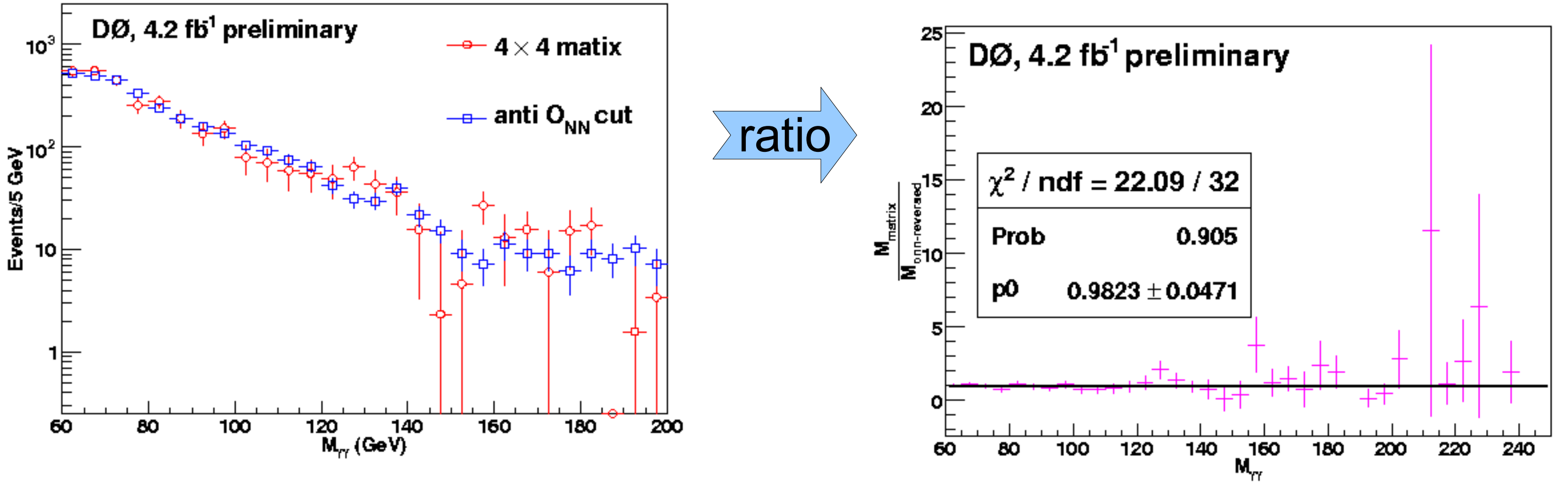
$$E = \begin{pmatrix} (1-\epsilon_{j1})(1-\epsilon_{j2}) & (1-\epsilon_{j1})(1-\epsilon_{\gamma 2}) & (1-\epsilon_{\gamma 1})(1-\epsilon_{j2}) & (1-\epsilon_{\gamma 1})(1-\epsilon_{\gamma 2}) \\ (1-\epsilon_{j1})\epsilon_{j2} & (1-\epsilon_{j1})\epsilon_{\gamma 2} & (1-\epsilon_{\gamma 1})\epsilon_{j2} & (1-\epsilon_{\gamma 1})\epsilon_{\gamma 2} \\ \epsilon_{j1}(1-\epsilon_{j2}) & \epsilon_{j1}(1-\epsilon_{\gamma 2}) & \epsilon_{\gamma 1}(1-\epsilon_{j2}) & \epsilon_{\gamma 1}(1-\epsilon_{\gamma 2}) \\ \epsilon_{j1}\epsilon_{j2} & \epsilon_{j1}\epsilon_{\gamma 2} & \epsilon_{\gamma 1}\epsilon_{j2} & \epsilon_{\gamma 1}\epsilon_{\gamma 2} \end{pmatrix}$$

Total	7939
Total - N_{DY}	7722.7
$N_{\gamma\gamma}$	4538.8 ± 144.7
$N_{\gamma j} + N_{j\gamma}$	2189.0 ± 170.3
N_{jj}	994.9 ± 106.6
non-$\gamma\gamma$	3183.9 ± 200.9

The quoted uncertainties are statistical only.

Non-γγ (γ+jet, jet+jet) background

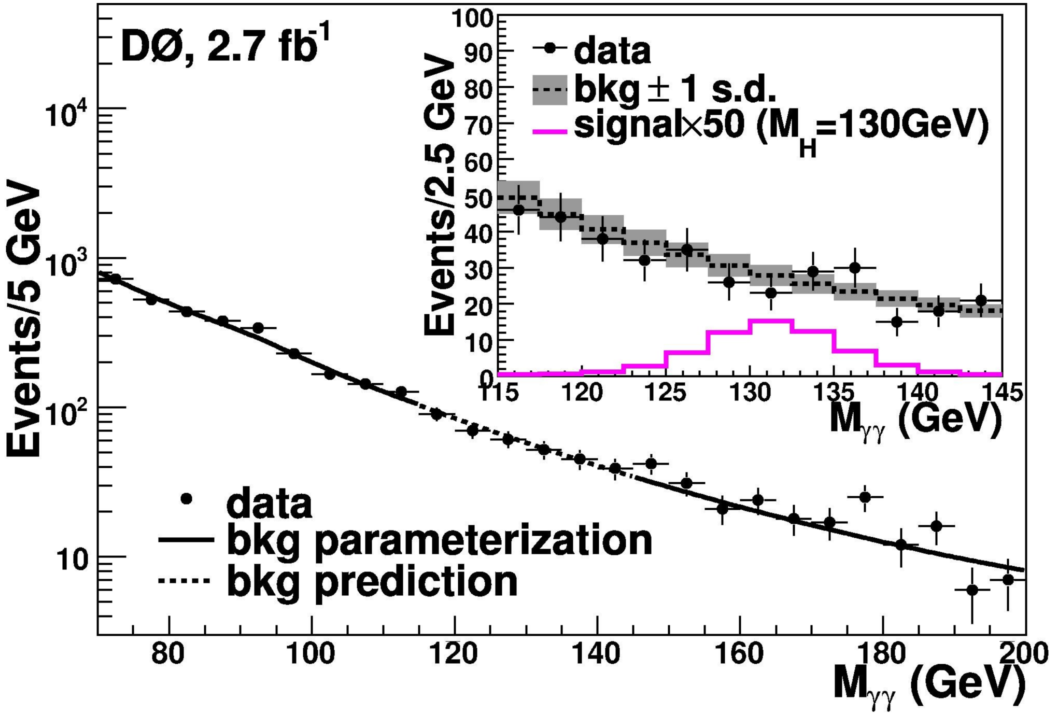
- first, estimate its contribution from data by using 4x4 matrix background subtraction method
- then compare the mass shape with the results by reversing the ONN cut (0.1) for one photon candidate
- as have good agreement between the two orthogonal samples, we choose to use the shape from "reversed-ONN" samples to predict its contribution



Shape from the anti ONN cut sample used as template, normalized to the number of events estimated from the 4X4 matrix method as the non-γγ contribution .

Direct γγ production (DDP) – irreducible background

- 15 GeV searching window (MH-15 GeV, MH+15 GeV);
- Subtract the non-γγ and Z/γ*→ee contributions, sideband fit to the Mγγ spectrum in mass region [70,200GeV] with an exponential function.



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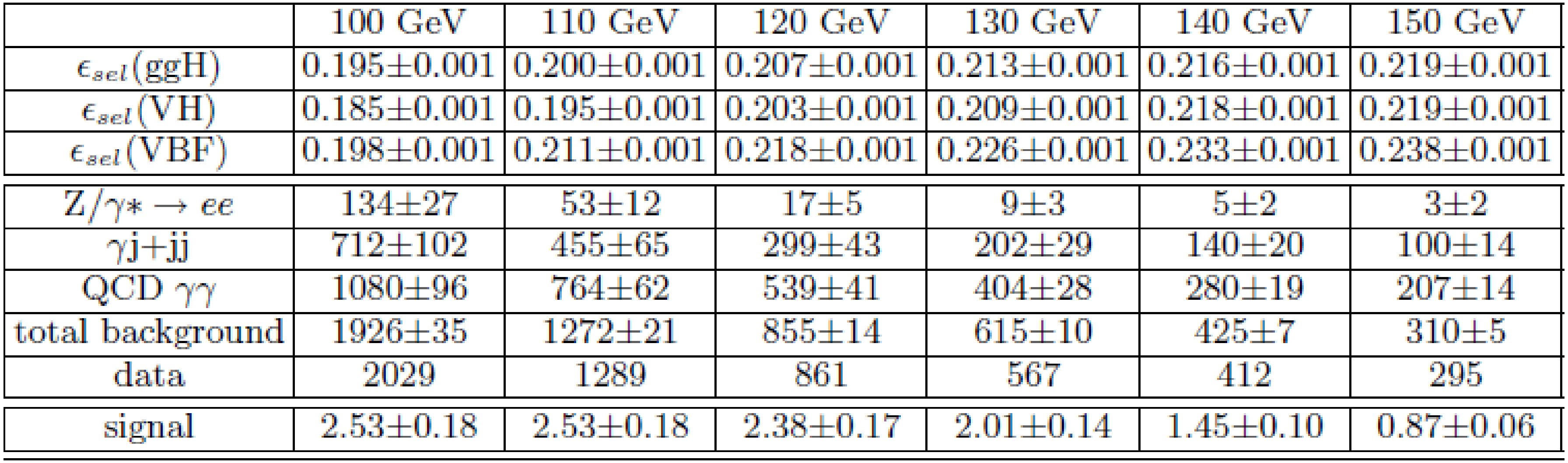
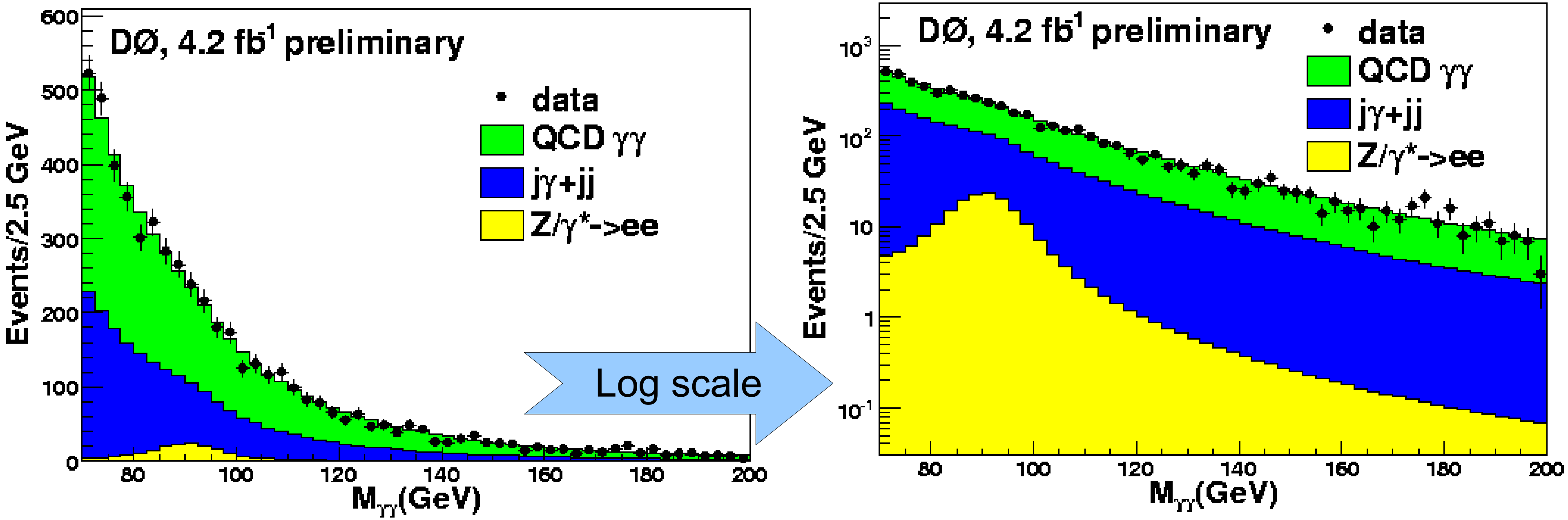
Number of events in data and background



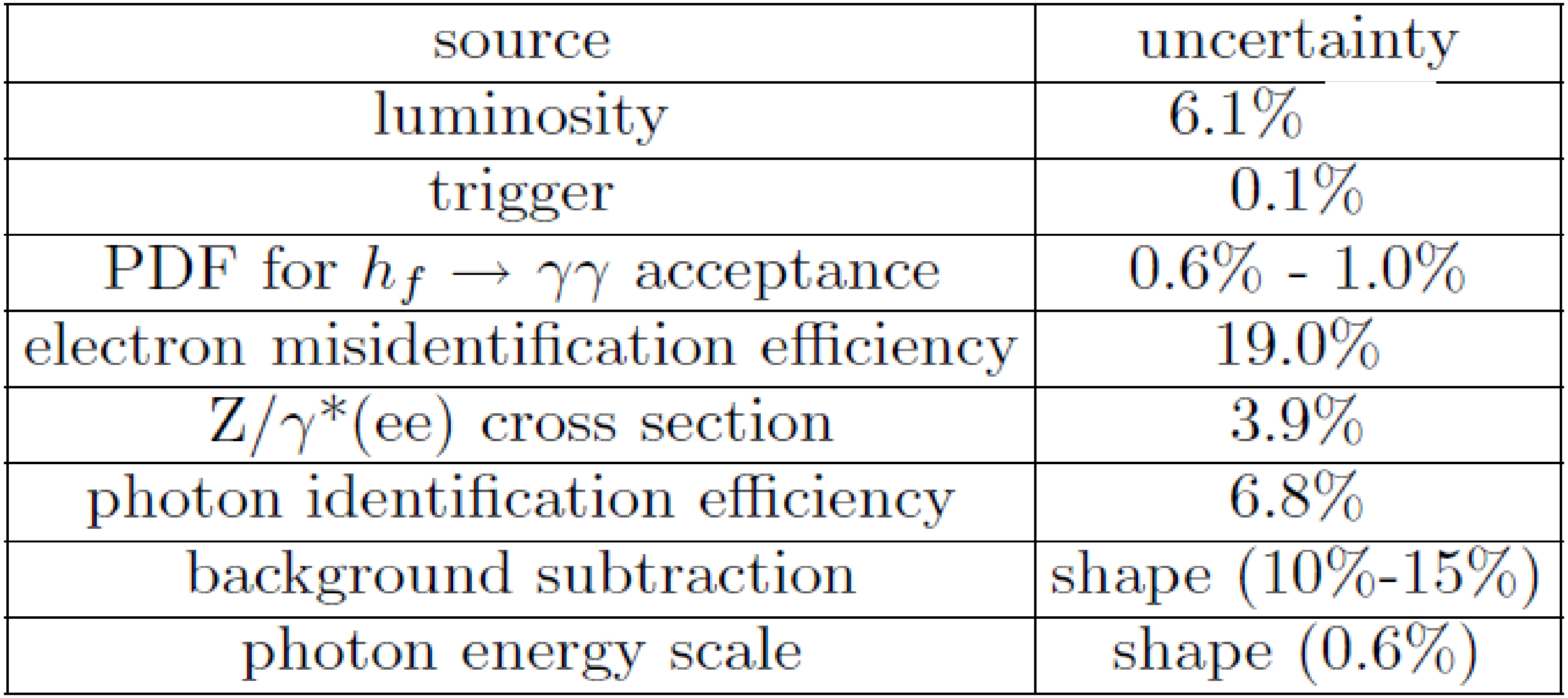
	100 GeV	110 GeV	120 GeV	130 GeV	140 GeV	150 GeV
ϵ_{sel}(ggH)	0.195±0.001	0.200±0.001	0.207±0.001	0.213±0.001	0.216±0.001	0.219±0.001
ϵ_{sel}(VH)	0.185±0.001	0.195±0.001	0.203±0.001	0.209±0.001	0.218±0.001	0.219±0.001
ϵ_{sel}(VBF)	0.198±0.001	0.211±0.001	0.218±0.001	0.226±0.001	0.233±0.001	0.238±0.001
$Z/\gamma* \rightarrow ee$	134±27	53±12	17±5	9±3	5±2	3±2
γj+jj	712±102	455±65	299±43	202±29	140±20	100±14
QCD $\gamma\gamma$	1080±96	764±62	539±41	404±28	280±19	207±14
total background	1926±35	1272±21	855±14	615±10	425±7	310±5
data	2029	1289	861	567	412	295
signal	2.53±0.18	2.53±0.18	2.38±0.17	2.01±0.14	1.45±0.10	0.87±0.06

Di-photon invariant mass distribution - whole spectrum



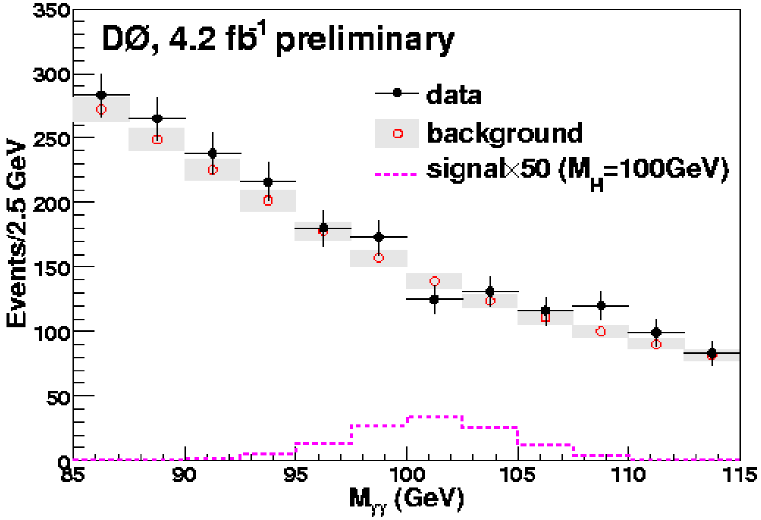
Log scale

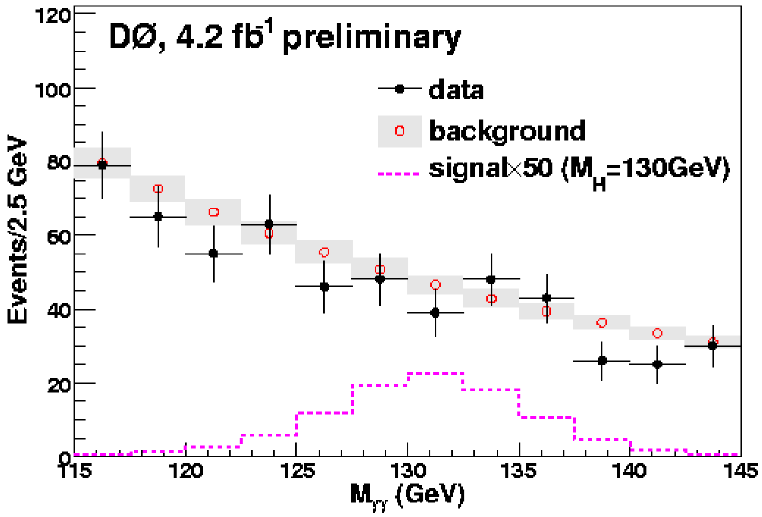
Systematic uncertainties

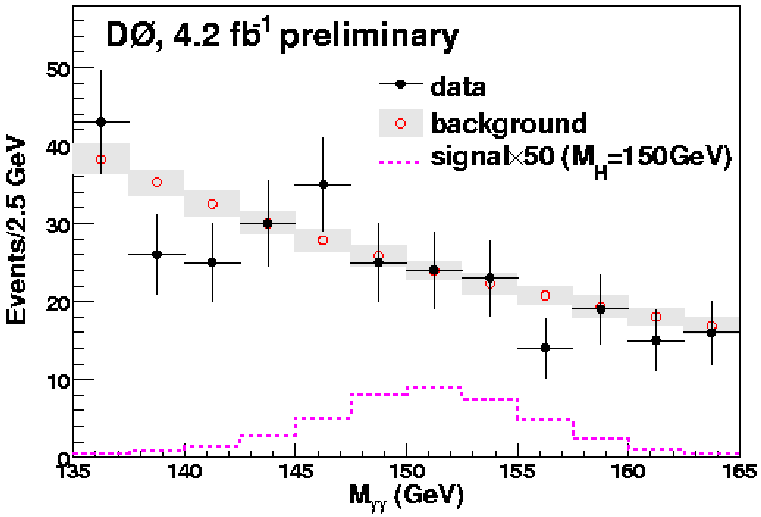


source	uncertainty
luminosity	6.1%
trigger	0.1%
PDF for $h_f \rightarrow \gamma\gamma$ acceptance	0.6% - 1.0%
electron misidentification efficiency	19.0%
$Z/\gamma^*(ee)$ cross section	3.9%
photon identification efficiency	6.8%
background subtraction	shape (10%-15%)
photon energy scale	shape (0.6%)

Di-photon invariant mass distribution - for some assumed M_H

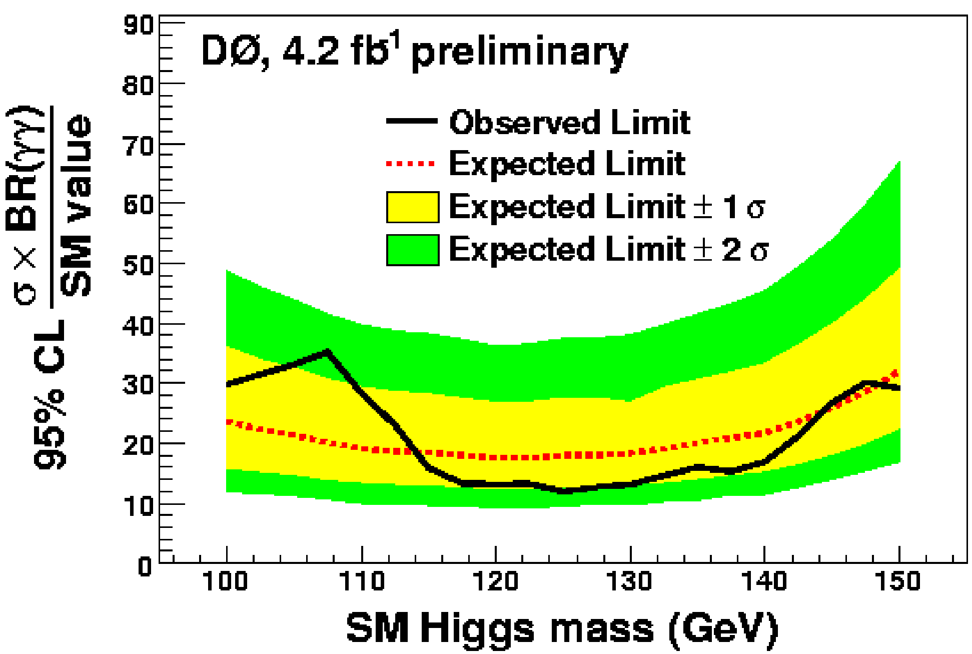


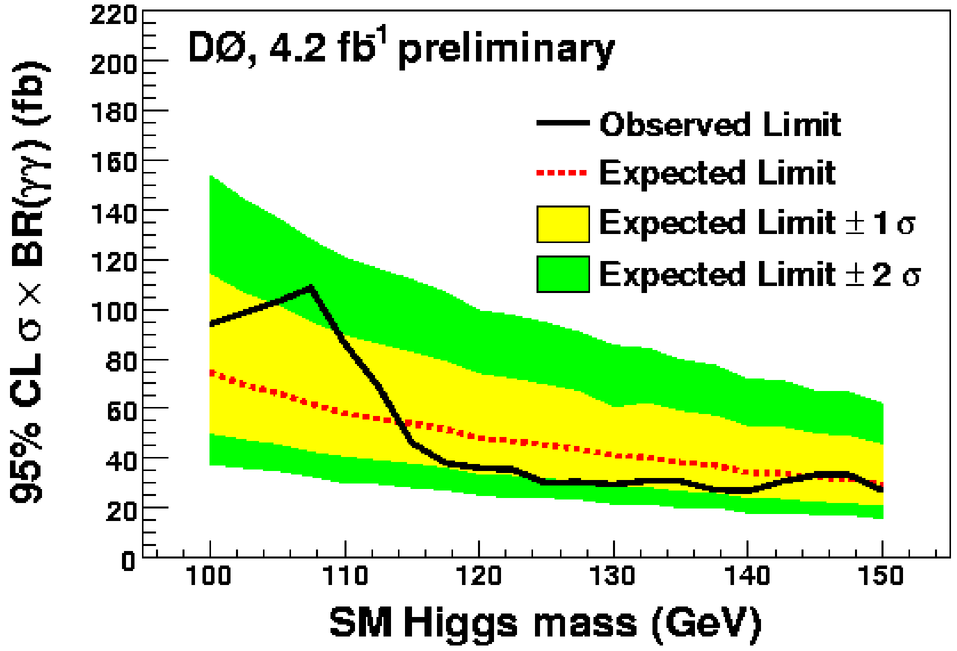




1. Good agreement between the data and background.
2. Use the mass shape to set limits.

95% C.L. limits



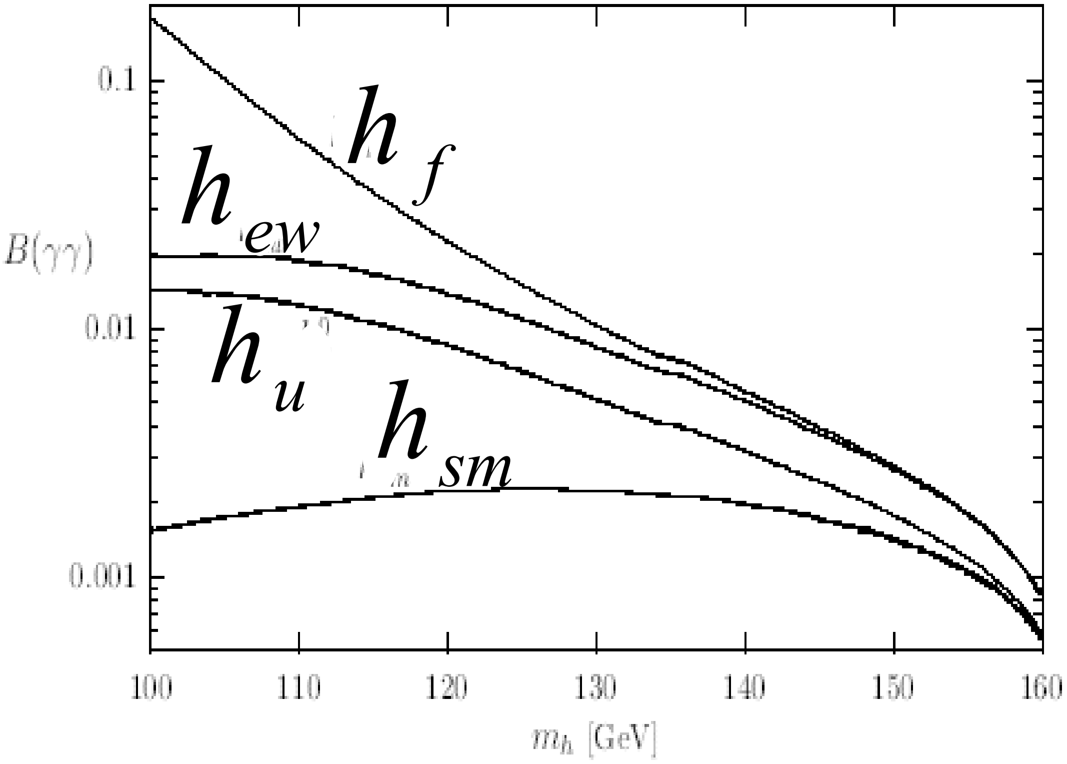


- Almost mass independent limits;
- Contribute ~5% for 115<M_H<130 GeV in the DØ SM Higgs combination.

Fermiophobic H→$\gamma\gamma$ search at CDF&DØ

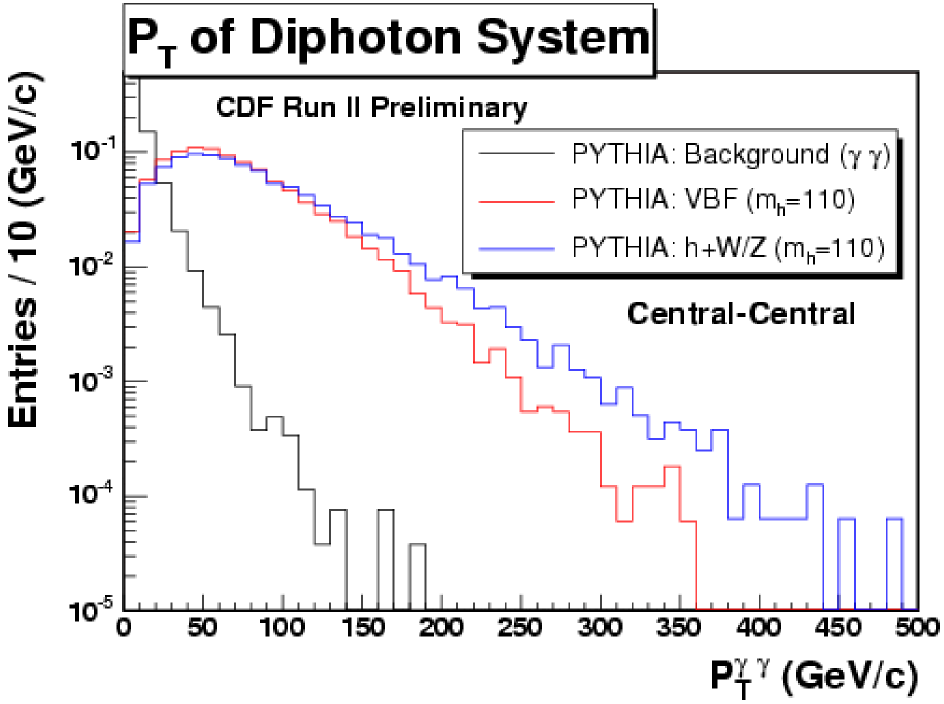
BSM

- In some models beyond the SM, the branching ratio (H→γγ) could be significantly large, for instance:
  - ➔ h_u
  - ➔ h_{ew}
  - ➔ h_f

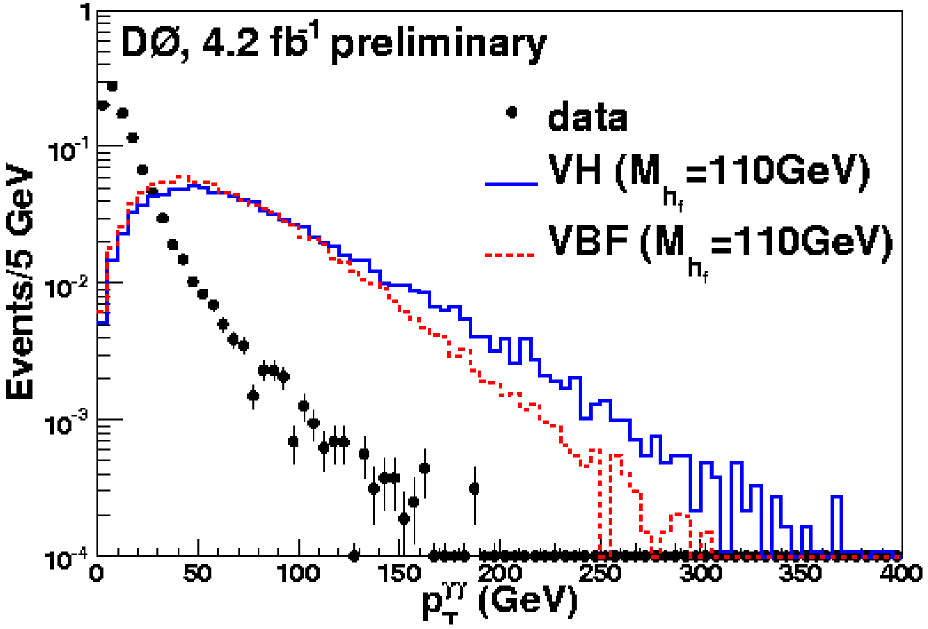


P_T of the di-photon system

$$p_T^{\gamma\gamma} > 75 \;\; GeV$$

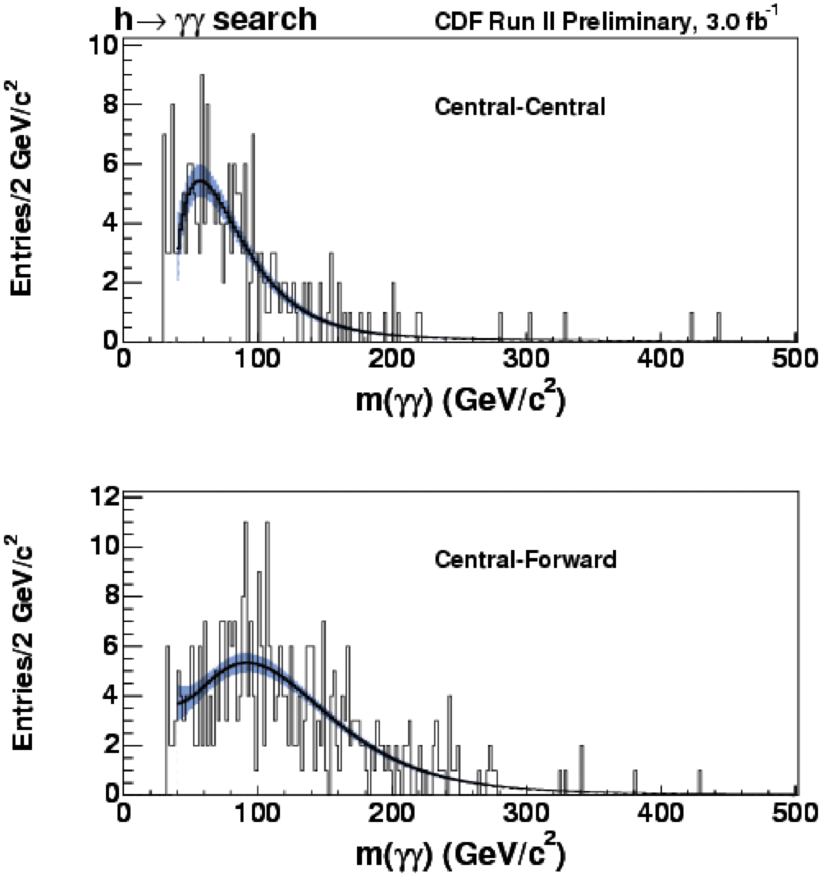


$$p_T^{\gamma\gamma} > 35 \;\; GeV$$



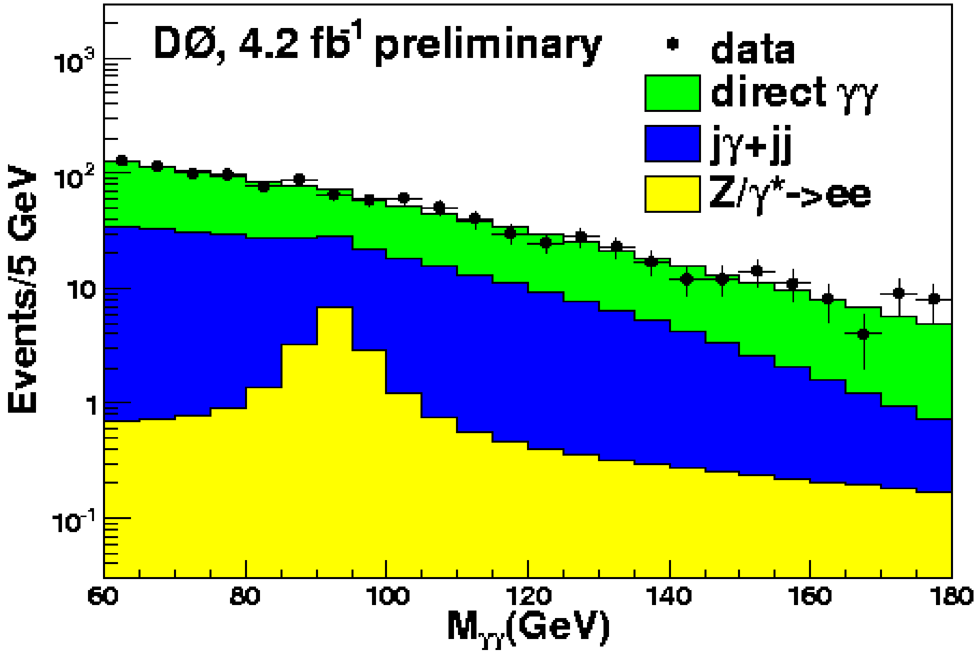
Di-photon invariant mass distribution - CDF

- P_T>15 GeV;
- | η |<1.05 (CC),|1.2<| η |<2.8 (CP) ;
- EM shower;
- Isolated in both calorimeter and tracker;
- Track veto.
- $p_T^{\gamma\gamma} > 75\ GeV$

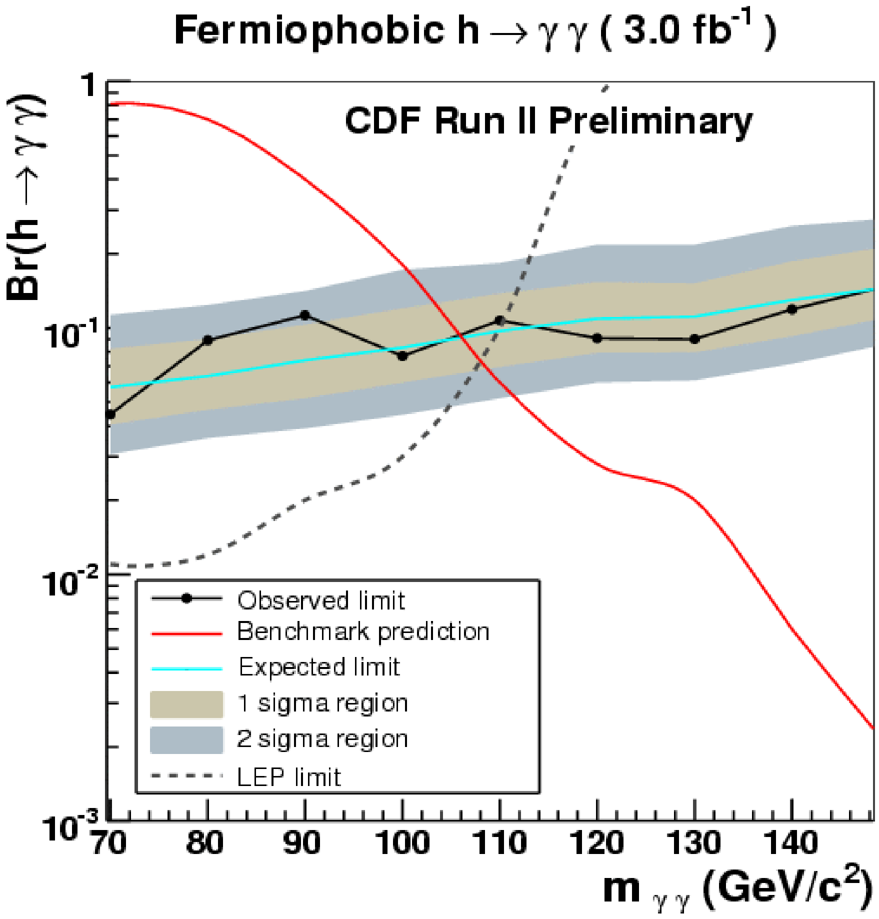


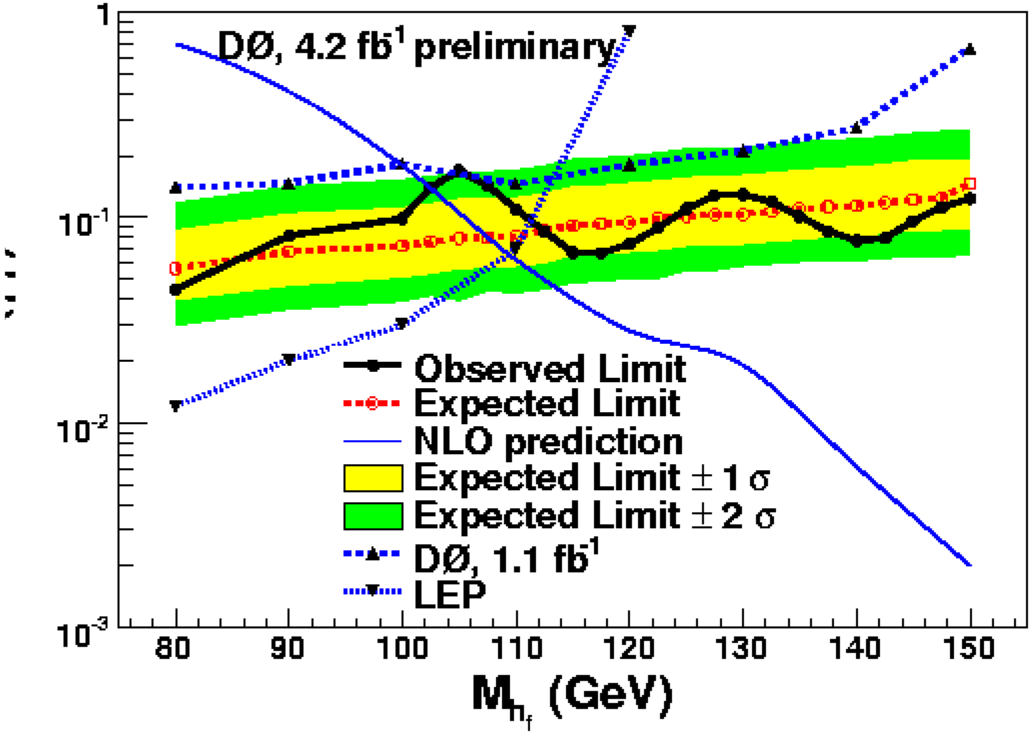
Di-photon invariant mass distribution - DØ

- Using the same technique as the SM search, except
  - P_T>20GeV
  - $p_T^{\gamma\gamma} > 35 \ GeV$



95% C.L. limits


Fermiophobic h → γ γ (3.0 fb^{-1})
CDF Run II Preliminary
Br(h → γ γ)
1
10^{-1}
10^{-2}
10^{-3}
70
80
90
100
110
120
130
140
m$_{\gamma\gamma}$ (GeV/c^2)
Observed limit
Benchmark prediction
Expected limit
1 sigma region
2 sigma region
LEP limit


DØ, 4.2 fb^{-1} preliminary
1
10^{-1}
10^{-2}
10^{-3}
80
90
100
110
120
130
140
150
M$_{h_f}$ (GeV)
Observed Limit
Expected Limit
NLO prediction
Expected Limit ± 1 σ
Expected Limit ± 2 σ
DØ, 1.1 fb^{-1}
LEP

Compare with LEP results

LEP exp.

ALEPH	104.6 GeV
DELPHI	105.1 GeV
OPAL	104.9 GeV
L3	105.2 GeV
combined	109.0 GeV

Tevatron exp.

DØ 101.2 pb^{-1}	78.5 GeV
CDF 100 pb^{-1}	82.0 GeV
DØ 1.1 fb^{-1}	100.0 GeV
CDF 3.0 fb^{-1} pre.	106.0 GeV
DØ 4.2 fb^{-1} pre.	107.5 GeV

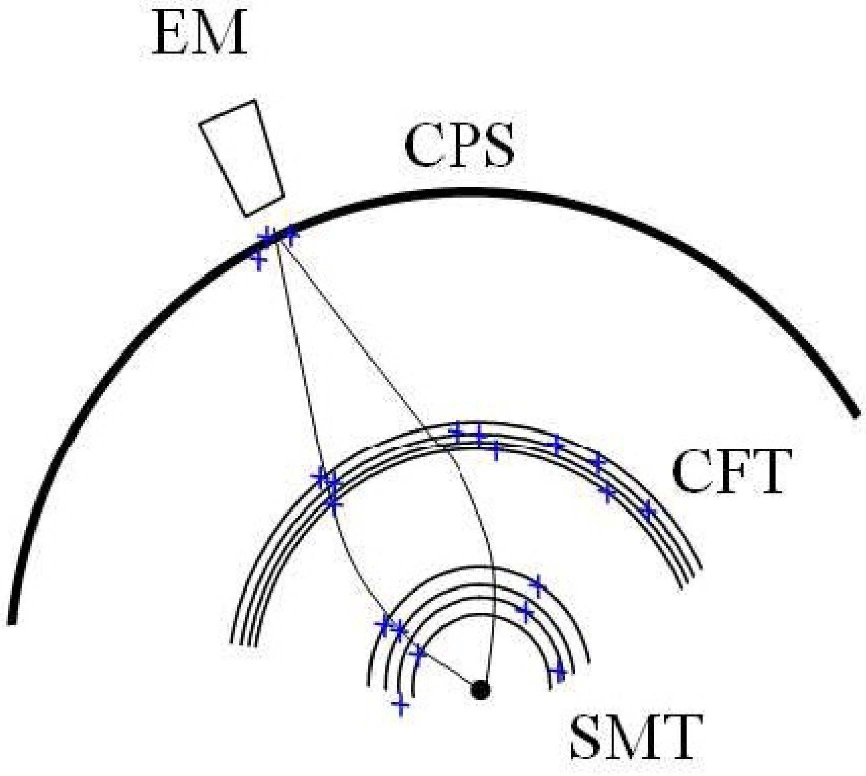
1. Both Tevatron experiments have better sensitivity than any single LEP experiments;
2. Also provide the access to the M_H>125GeV region, which is inaccessible by LEP;
3. The combination results of CDF&DØ would potentially exceed the LEP.

Conclusions

- **Presented a search for a light Higgs boson in the di-photon final state at Tevatron.**
- **Set 95% C.L. limits on the production cross section times branching ratio (H→γγ) on the SM Higgs.**
- **Set world's most stringent limits on the branching ratio (H→γγ) of a fermiphobic Higgs.**
- **The combination of CDF&DØ results would potentially exceed the LEP results.**

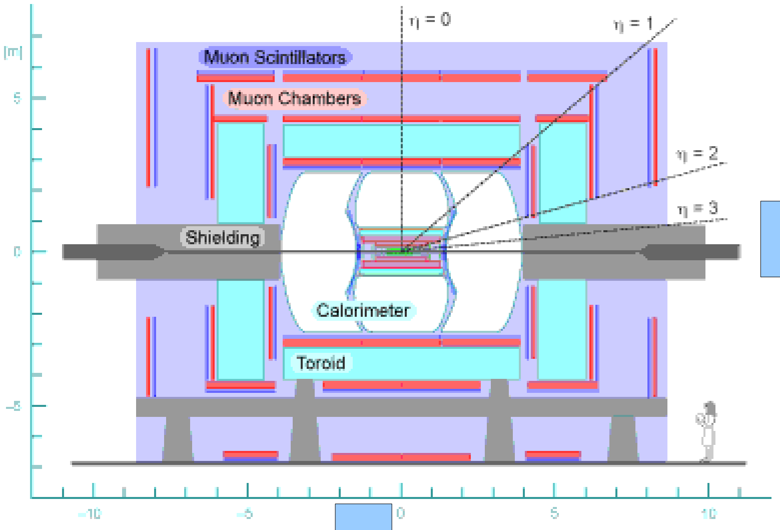
back-up

Hits on the road

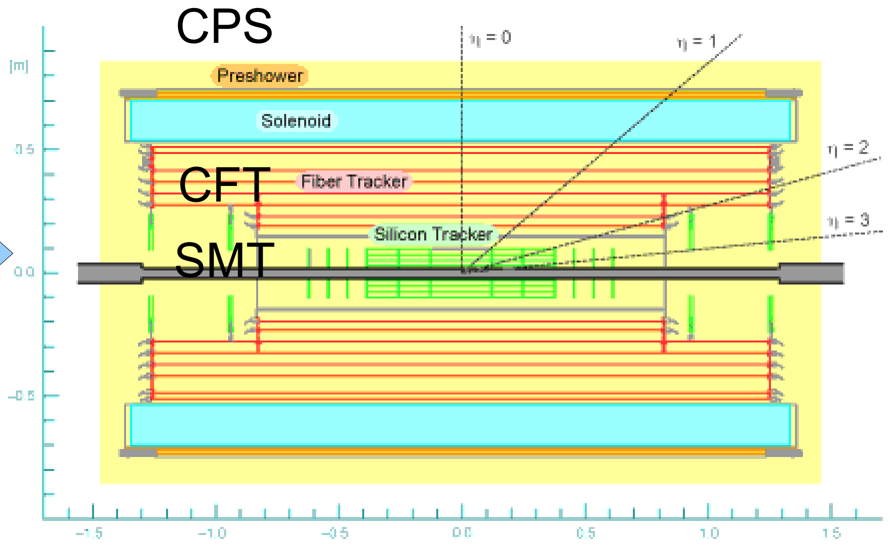


- To suppress the Drell-Yan background;
- Use the primary vertex and CPS or EM calorimeter to define two 3D roads;
- Count the hits deposited in the SMT and CFT along the roads.

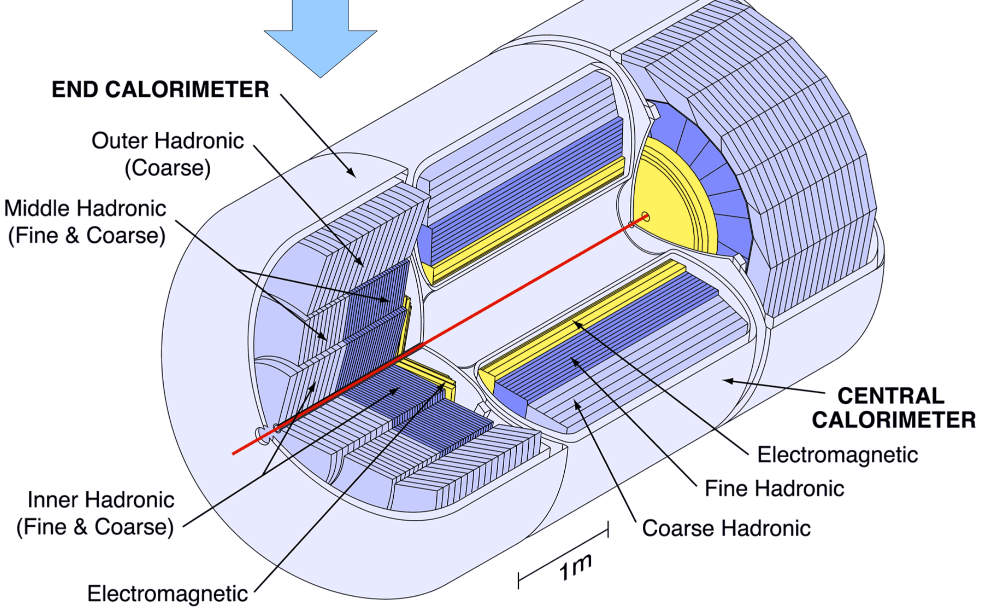
DØ detector



tracking



calorimeter



- Electrons: |η|<3.0
- Muons: |η|<2.0
- Silicon tracking: |η|<3.0
- Calorimetry: |η|<4.2
- High data taking efficiency ~ 90%
- Well-understood detectors and mature analysis tools