DØ results on Higgs Search

Yuji Enari
Brown University
On behalf of DØ Collaboration

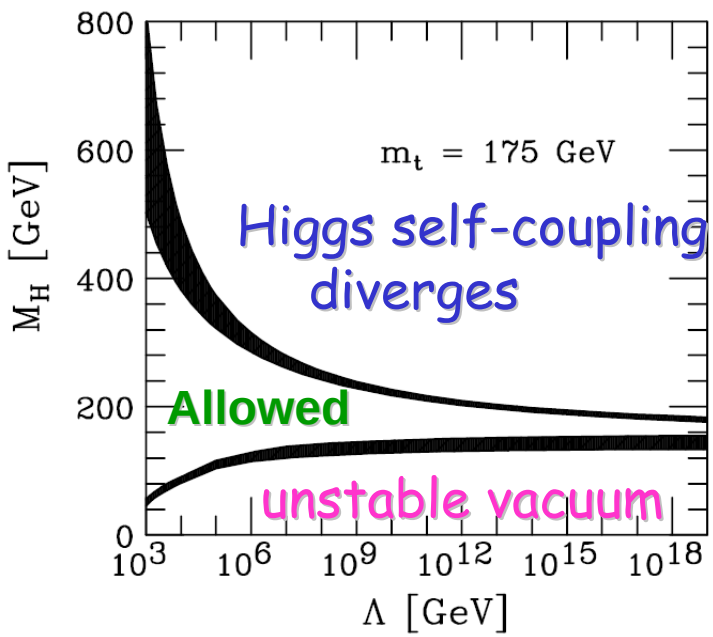
Lake Louise Winter Institute 2007

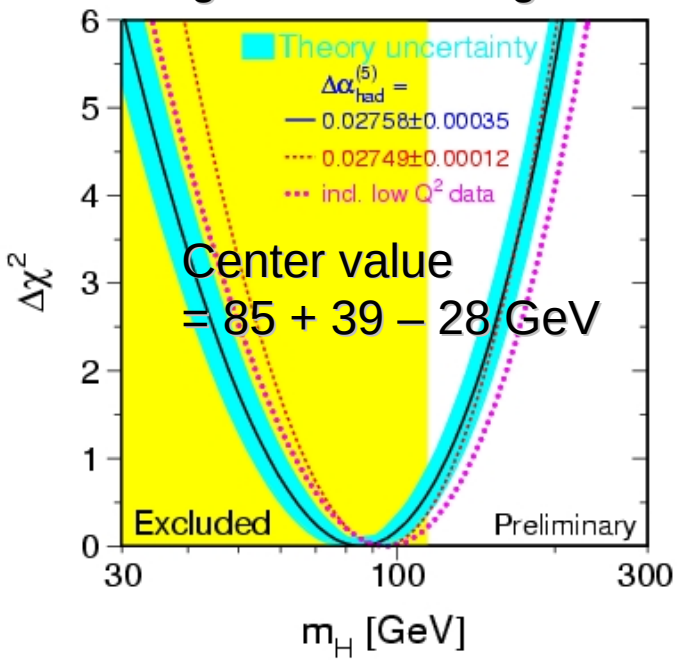
SM Higgs boson

- Gauge invariance: No mass term
- Mass of fundamental particles are given by Higgs boson

From theory
- Missing part of SM
- SM higgs mass is light

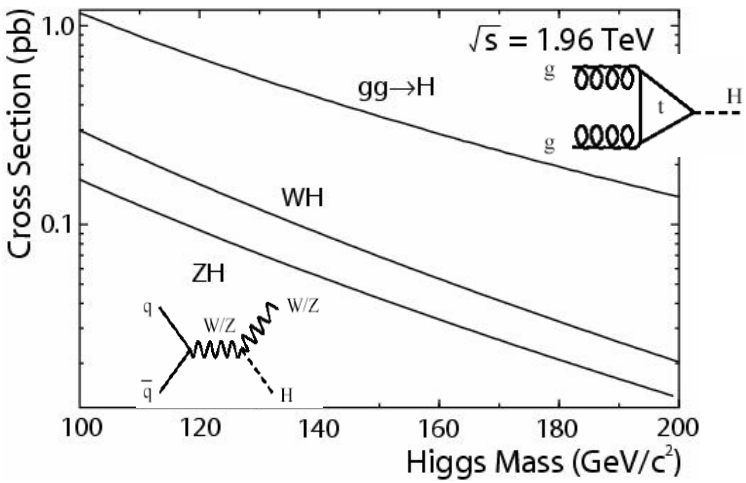
From experiment:
- M_H > 114.4 GeV @95% CL search by LEP2
- M_H < 166 (199) GeV @95% CL global EW fitting

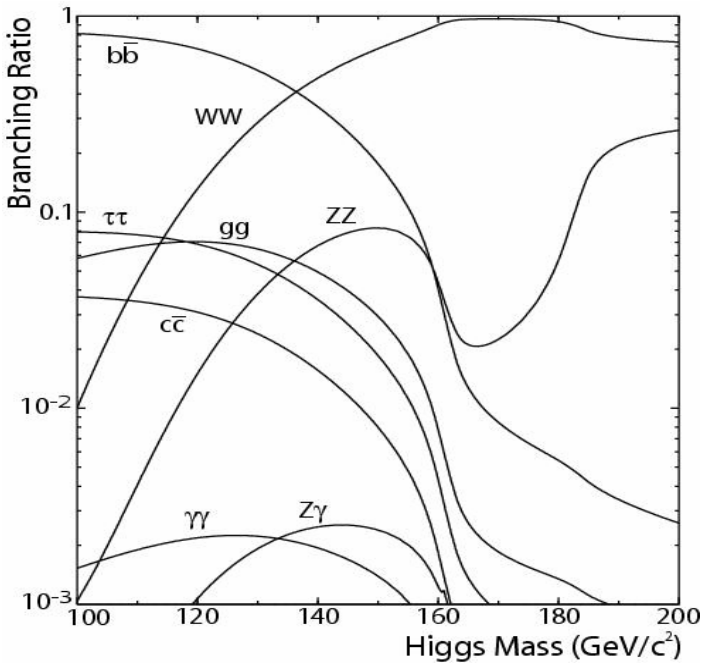




Tevatron can explore the mass range of 115 < M_H < 185 GeV

SM Higgs search at Tevatron





- **Production**
  1. **Gluon fusion** (0.8 ~ 0.2 pb)
  2. **WH associated production** (0.2~0.03pb)
  3. **ZH associated production** (0.1~0.01pb)
- **Decay**
  - **m_H < 135 GeV**
    H → bb is dominant
  - **m_H > 135 GeV**
    H→ WW

Analysis Strategy	**Background**
m_H < 135 GeV **WH/ZH + H→ bb**	**top, Wbb, Zbb**
m_H > 135 GeV **Gluon fusion + H→WW**	**WW, DY, WZ**

Current Status of Higgs search at DØ

SM

	mode	$\int$ Ldt (pb)
ZH	eebb	840
	$\mu\mu$bb	920
	$\nu\nu$bb	260
WH	eνbb	370
	$\mu\nu$bb	380
WH→ WWW	ee + qq	380
	eμ + qq	370
	$\mu\mu$+ qq	360
H→ WW	eνeν	950
	$\mu\nu\mu\nu$	930
	e$\nu\mu\nu$	950

MSSM

	mode	$\int$ Ldt (pb)
bh	bbb	880
	b$\tau\tau$	340
h→$\tau\tau$	$\mu\nu + \tau_h$	1000

Fermiophobic

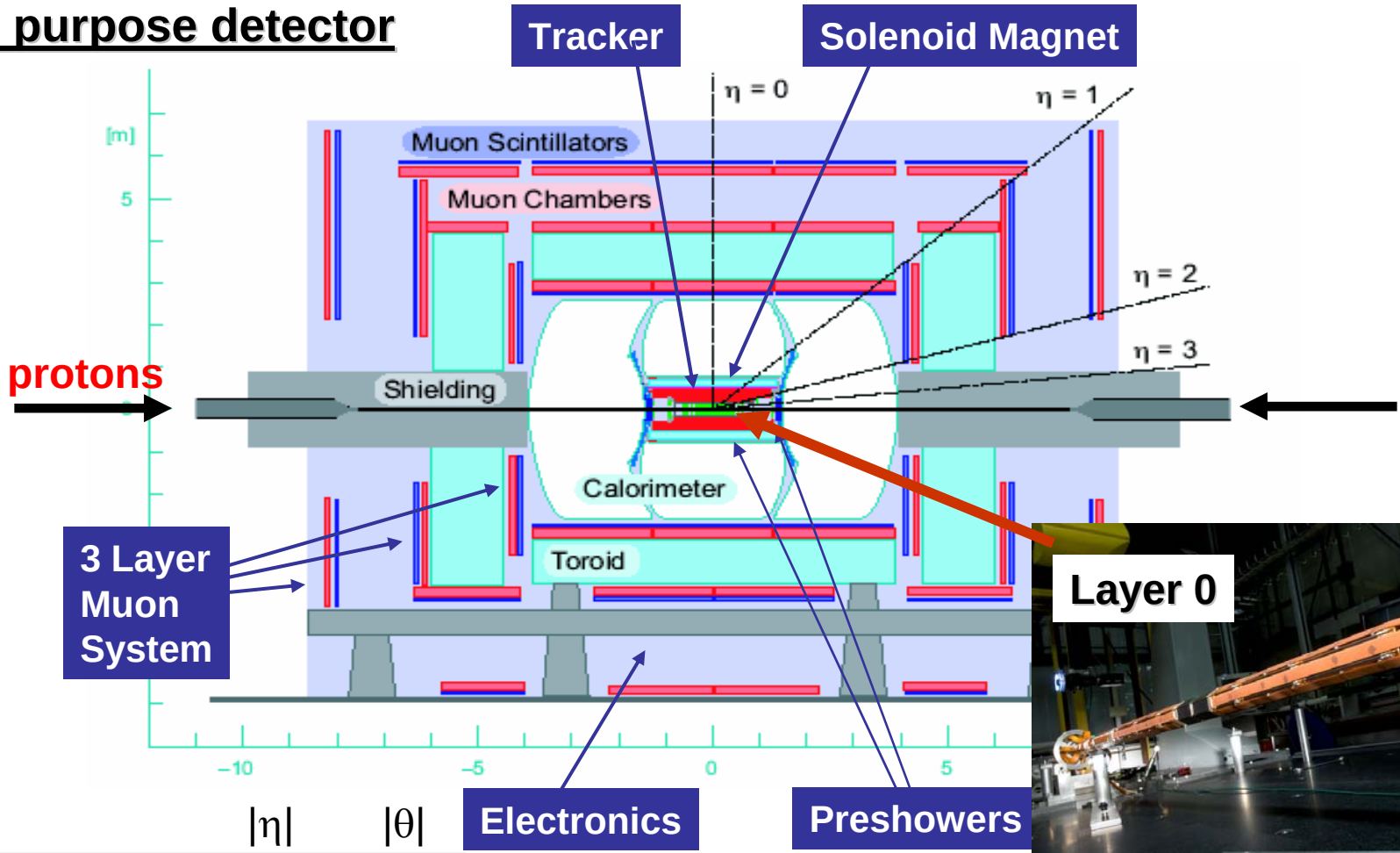
	mode	$\int$ Ldt (pb)
V→h_fH	$\gamma\gamma\gamma(\gamma)$X	1000
V+h_fV	$\gamma\gamma$	190

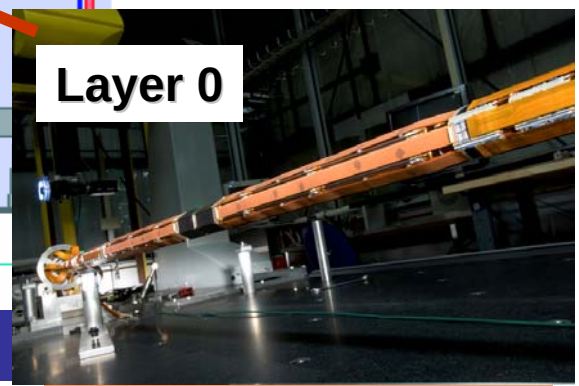
Others

h++ → tt, Htb,
tt(t→ H^+b, H+→cs)
H++ → $\mu\mu$, ee

DØ detector

Multi purpose detector



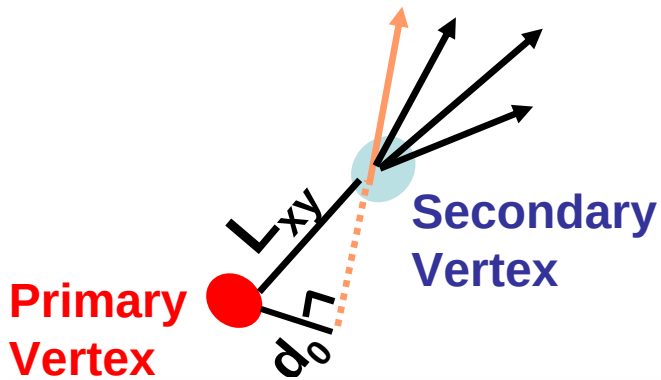


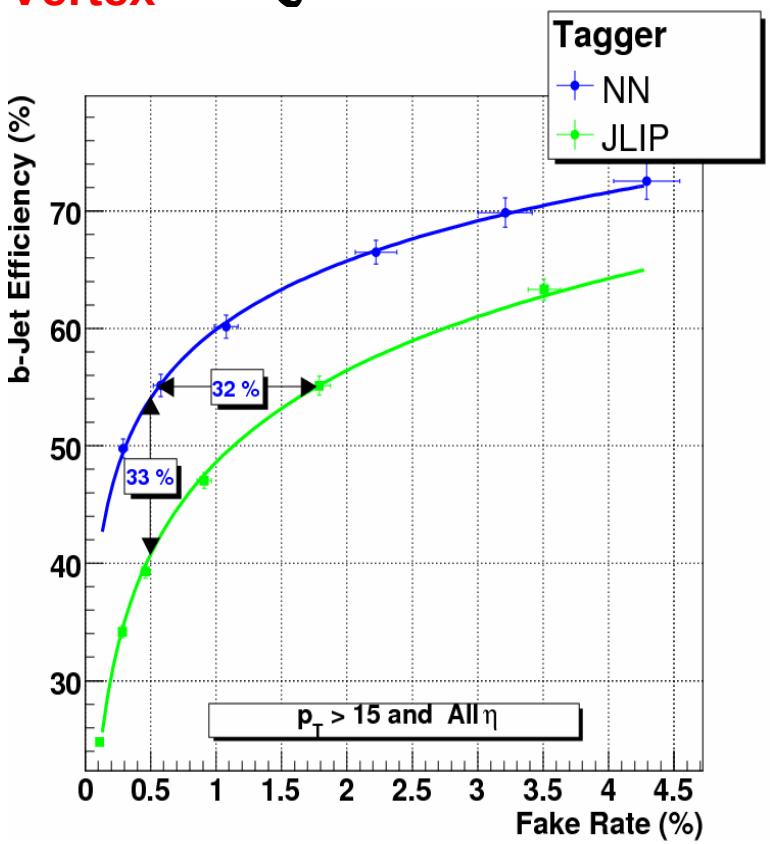
	$\lvert\eta\rvert$	$\lvert\theta\rvert$
Muon ID	~2	~15°
Tracking	~2.5	~5°
EM / Had CAL	~4	~2°

New silicon detector for improvement of b-jet ID
Installed last spring

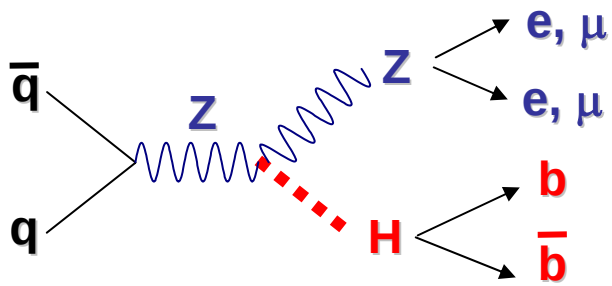
Improvement on b-tagging

- Characteristic of b-quark
  - Lepton from semileptonic B decay (Br~10%)
  - Longer lifetime, τ~1.6ps
    → Travel distance from PV ~ 1mm
- Tagging Algorithms
  - Secondary vertex reconstruction
  - Impact Parameter based
- NN tagger
  - Use these information as input of NN
    → 33% gain with same fake rate of 0.5%





Low mass SM Higgs: ZH → llbb



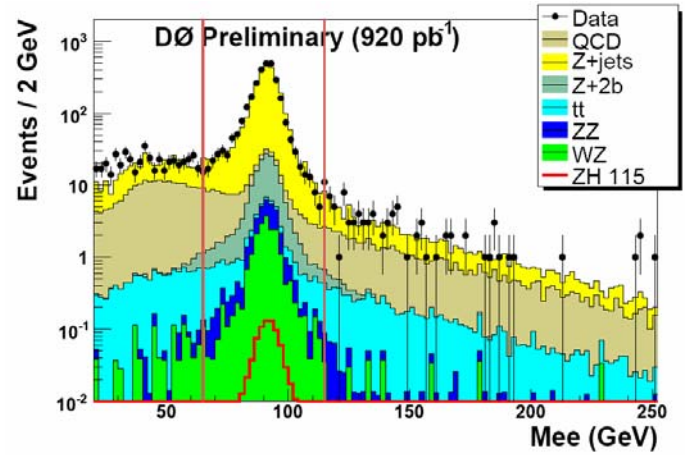
$\int Ldt = 920 / 840 pb^{-1}$

New result!

Main BG:
Z+jj, Z+bb

- e : pt>15GeV, 2 loose electron
- μ : pt>15GeV, 2 loose muon

Mass window
e: $-1.5\sigma \sim 1.5\sigma$
μ: $-1\sigma \sim 2\sigma$

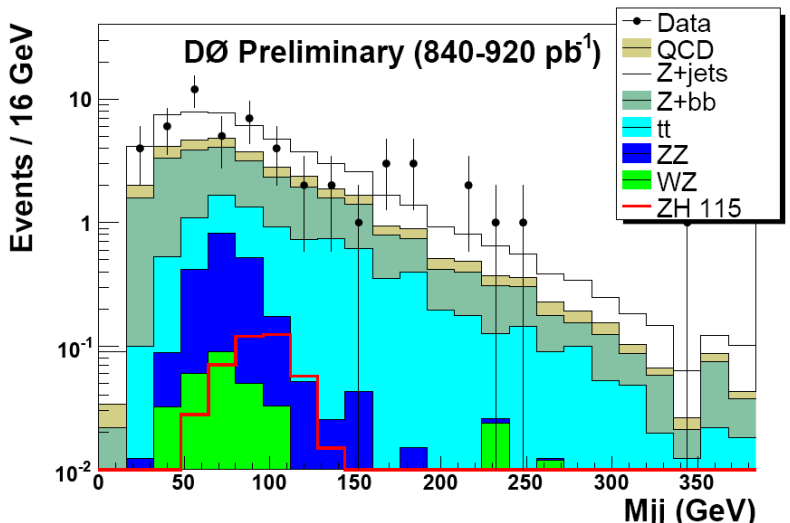


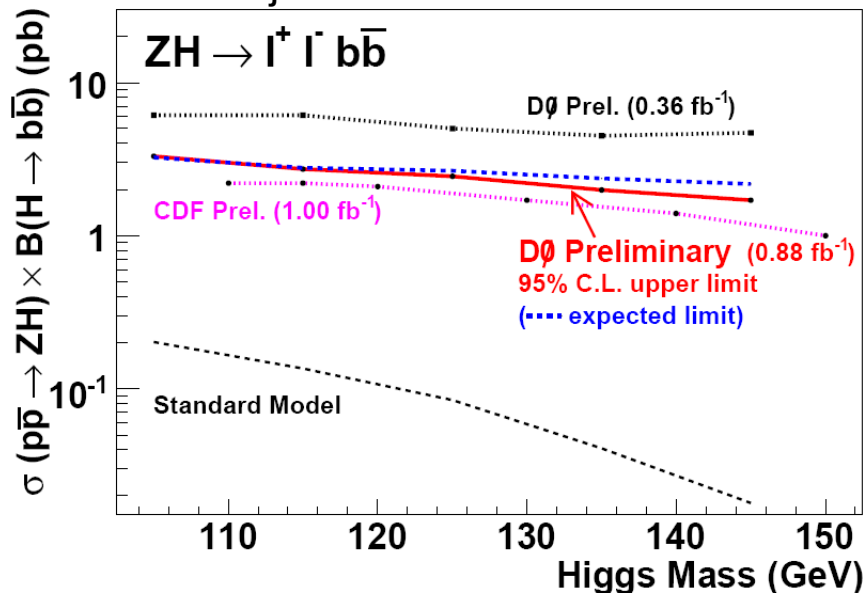
After double NN b-tag

	data	BG exp.	m_H=115
e	7	10.7 ± 3.7	0.20
μ	11	9.8 ± 3.4	0.17

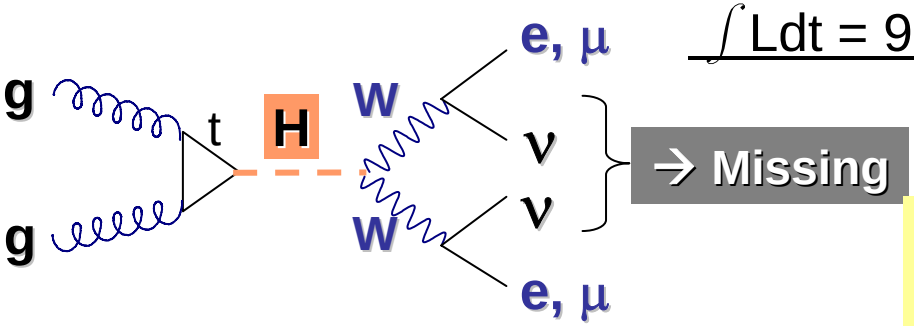
Combine e and μ, 1 tag + 2 tag

Modified frequentist approach (CLs) from dijet mass distribution



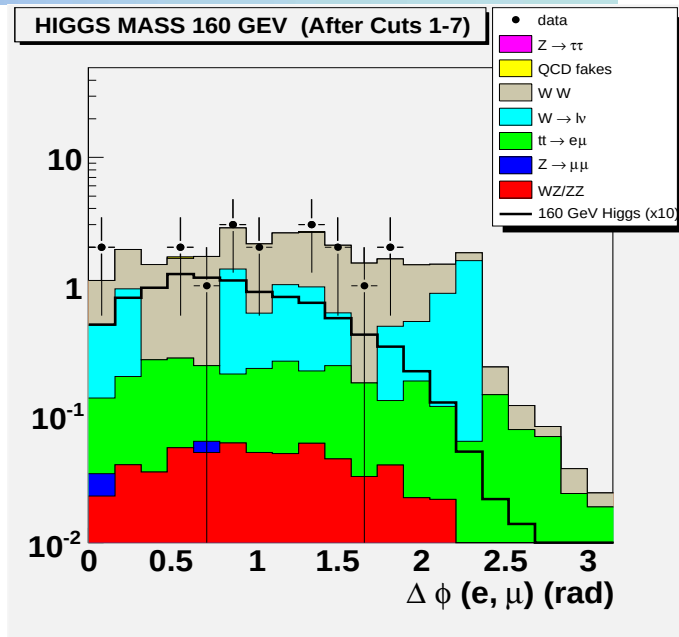


High mass SM Higgs: H→WW



$\int Ldt$ = 930-950 pb^{-1}

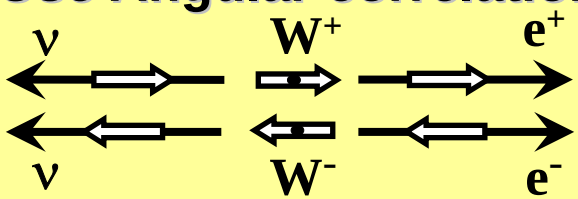
Main BG: gg→WW



- Two isolated high p_T leptons + missing E_T
  - ee, μμ, eμ channel are considered.

Can't reconstruct H invariant mass

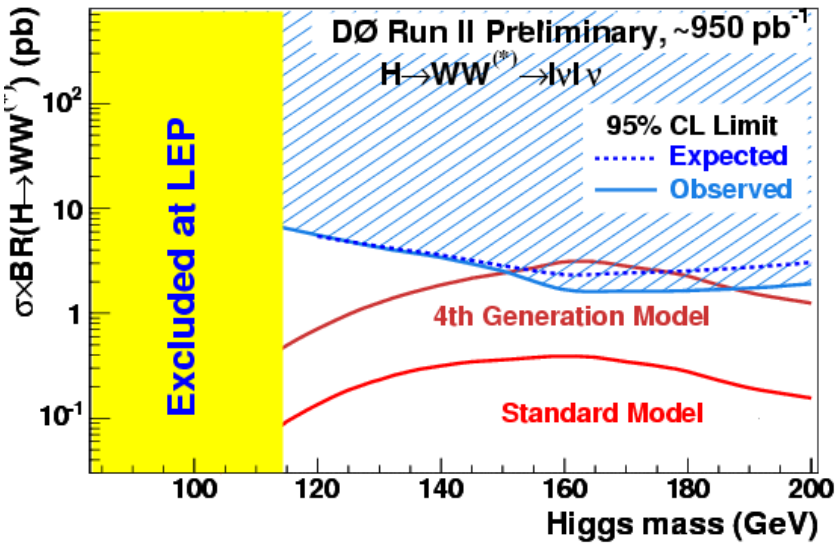
→ Use Angular correlation



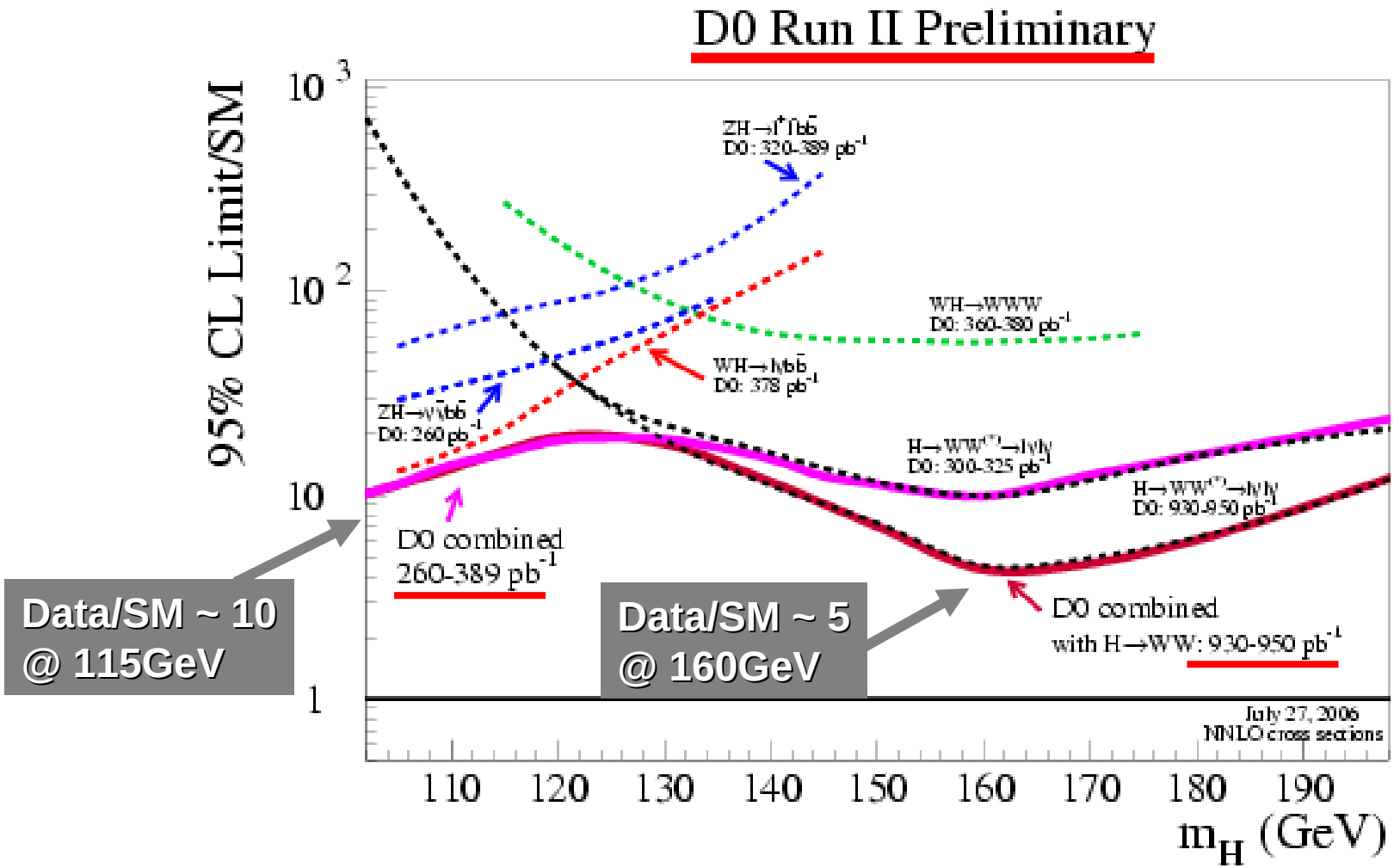
WW is daughter of scalar H. Leptons from W tend to have same direction

	Data	BG exp.	m_H=160
ee	10	10.3 ± 1.5	0.42
μμ	9	9.8 ± 1.6	0.35
eμ	18	24.4 ± 3.7	0.97

No excess from BG exp in Δφ dist.



Limits on SM Higgs production



Data/SM ~ 10 @ 115GeV

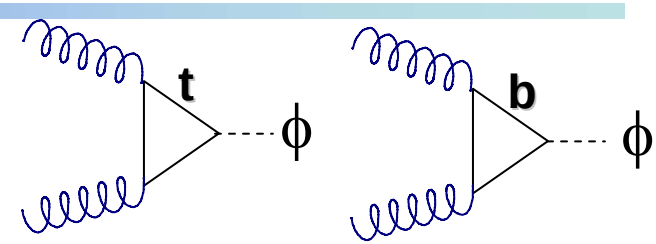
Data/SM ~ 5 @ 160GeV

- Latest ZH→llbb is not included in these limits.
- New result of WH→lνbb and ZH→ννbb will be coming soon.

MSSM Higgs

- MSSM
  - Two Higgs doublets to avoid anomaly
  - 8 degrees of freedom – 3 (longitudinal pol. of $W^{\pm}$,Z)
    → 5 physical scalars (h, H, A, $H^{\pm}$)

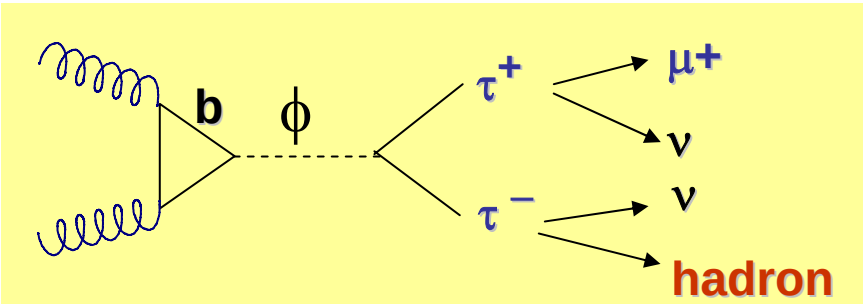
ϕ



$\sigma \sim 1/\tan\beta$ $\sigma \sim \tan\beta$

At high $\tan\beta(=H_u/H_d)$, σ(h or H, A) is enhanced

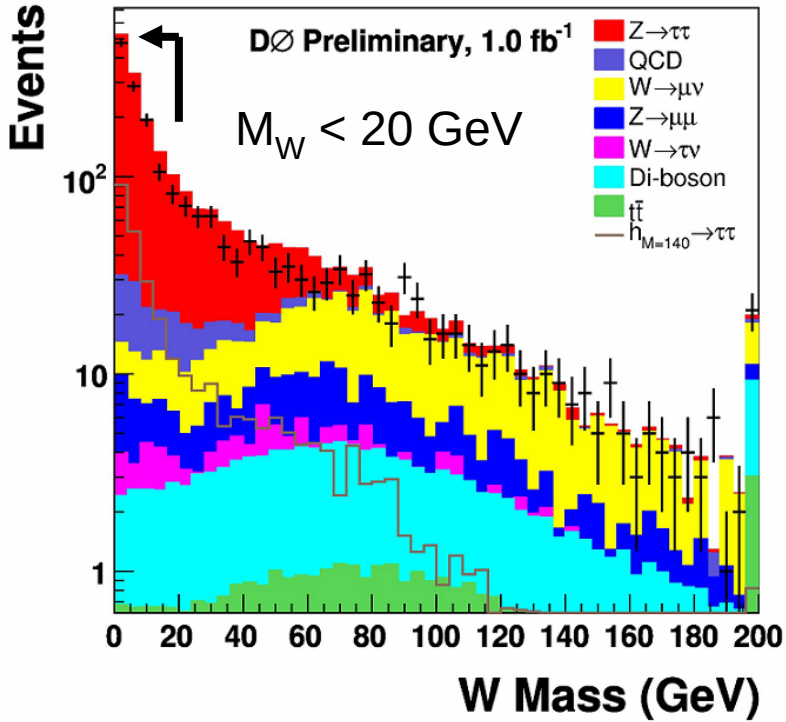
- Search for $\phi \rightarrow \tau\tau$
  - $Br(\phi \rightarrow bb) \sim 90\%$, $Br(\phi \rightarrow \tau\tau) \sim 10\%$
    → High QCD BG → l+had (17%x62%)



Tau ID (hadronic τ decay)
- NN: 8 variables related to jet shape
- Train NN each topology separately

Performance: @ τ's pt=15GeV
$\tau \rightarrow h\nu$: 60% with 2% fake,
$\tau \rightarrow h\pi^0\nu$: 60% with 4% fake,
$\tau \rightarrow 3h\nu$: 40% with 3% fake

$$M_W = \sqrt{2E^{\nu}E^{\mu}(1-\cos\Delta\phi)}$$



MSSM Higgs $\phi \rightarrow \tau\tau$

- $\phi \rightarrow \tau\tau \rightarrow \mu\upsilon + \tau_h$
  - NN>0.9
  - $\Delta R\mu\tau > 0.5$
  - $M_W < 20$ GeV
- Main BG
  - $Z \rightarrow \tau\tau$
  - QCD is well suppressed

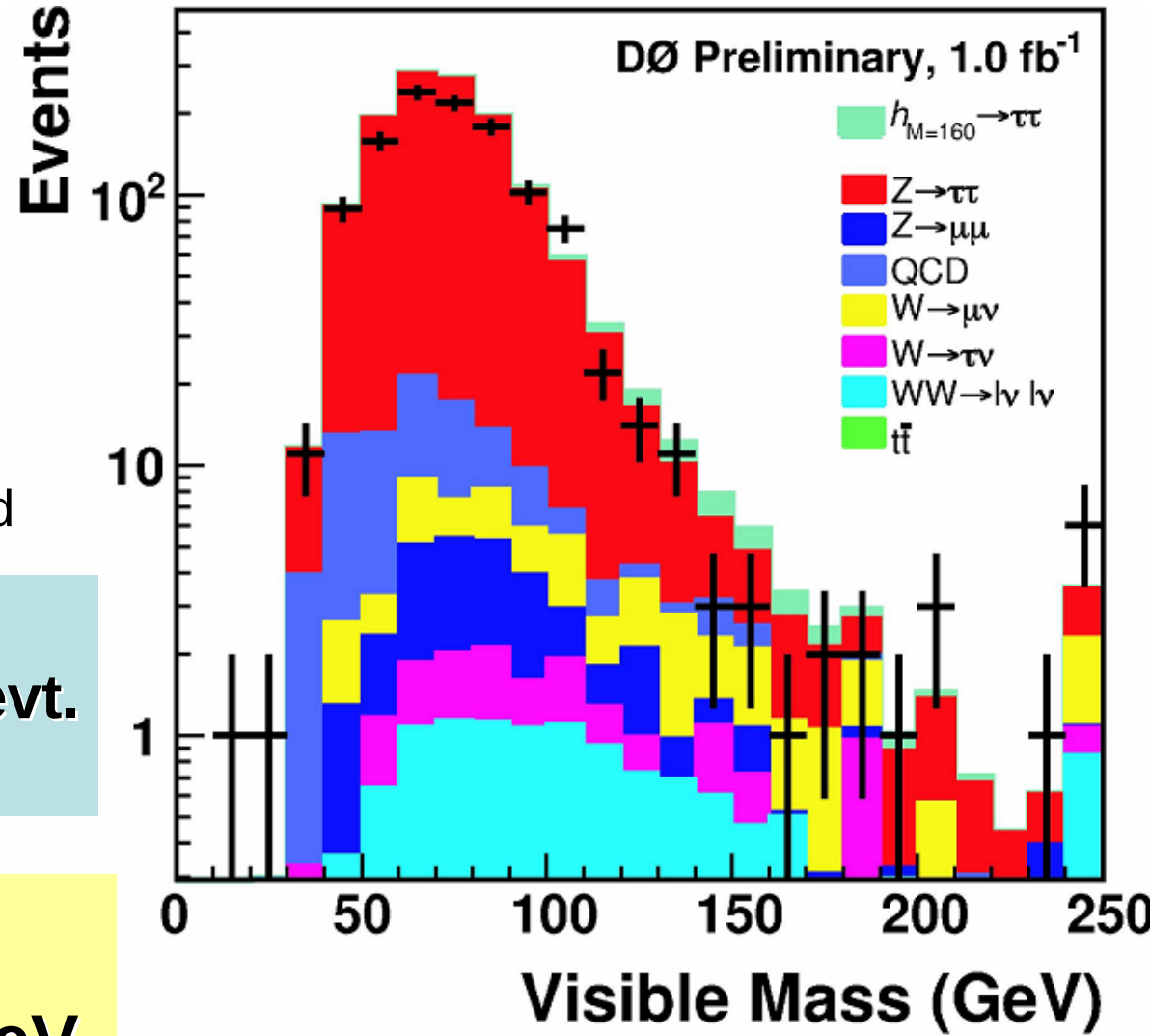
DATA: 1141 evt.
MC : 1287 ± 130 evt.
Eff($\phi \rightarrow \tau\tau$) : 1.4%

Observed events are fully consistent with expectation

No excess ~ 140 GeV

$\int Ldt = 1000\ pb^{-1}$

New result!



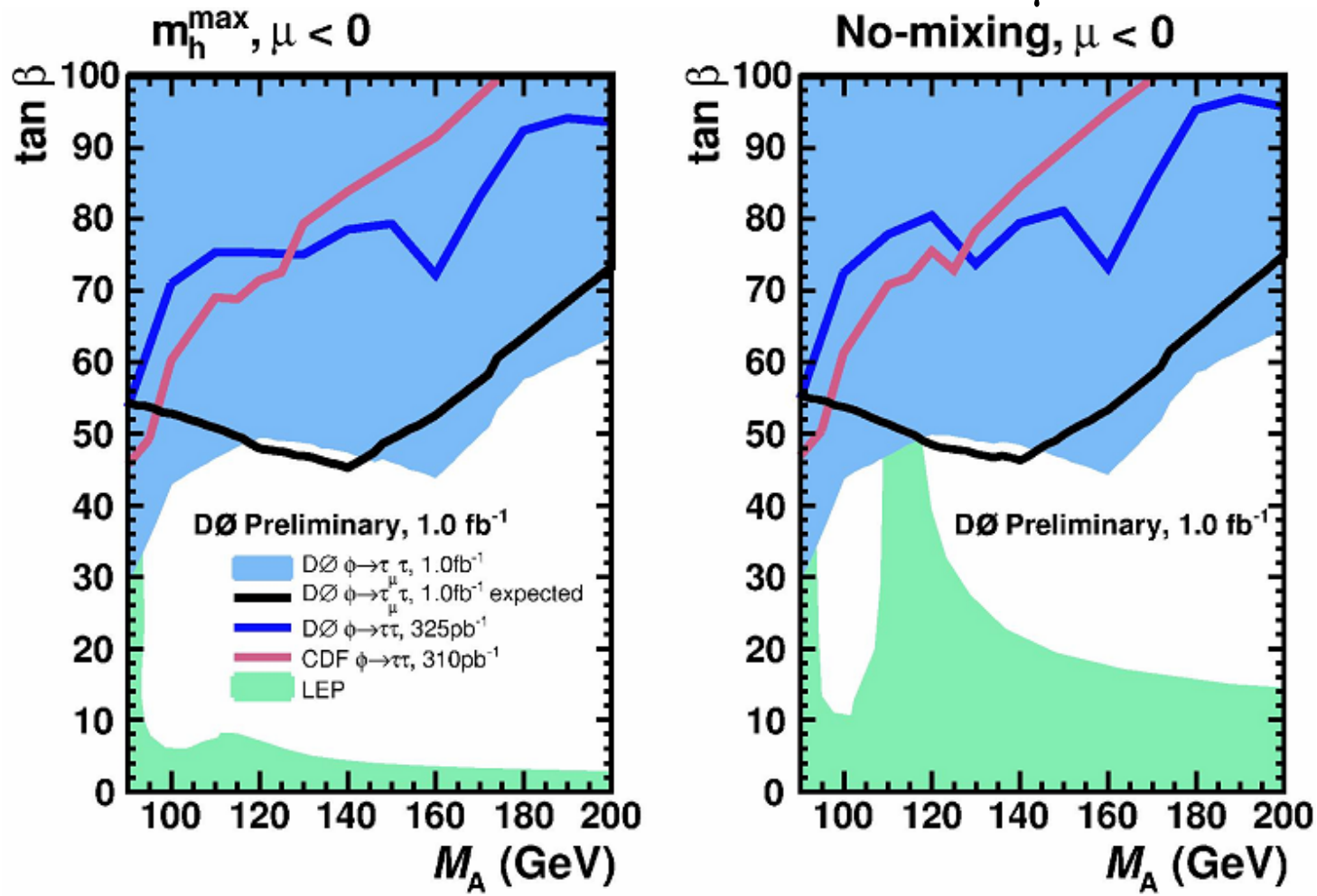
$$M_{\rm vis} = \sqrt{(P^{\mu} + P^{\tau} + \not{P}_{\rm T})^2}$$

New limit on M_A vs tanβ

New result with 1fb^{-1}

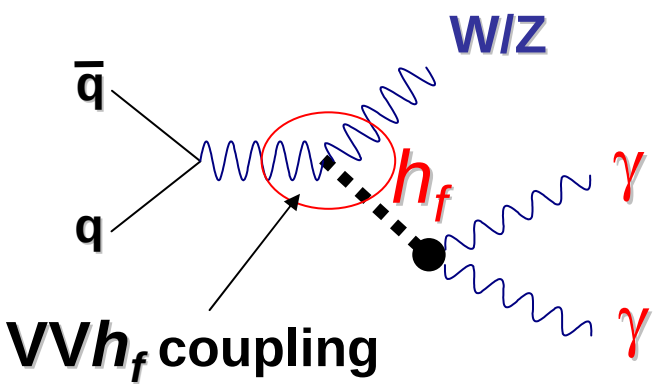
- To maximize sensitivity NN output is used in the limit calculation

NN input: Visible Mass, p_T^{μ}, p_T^{τ} (cal), p_T^{τ} (trk), η_μ, η_τ

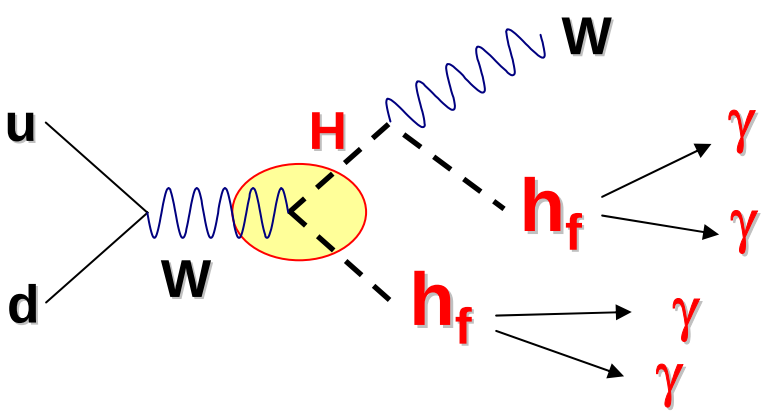


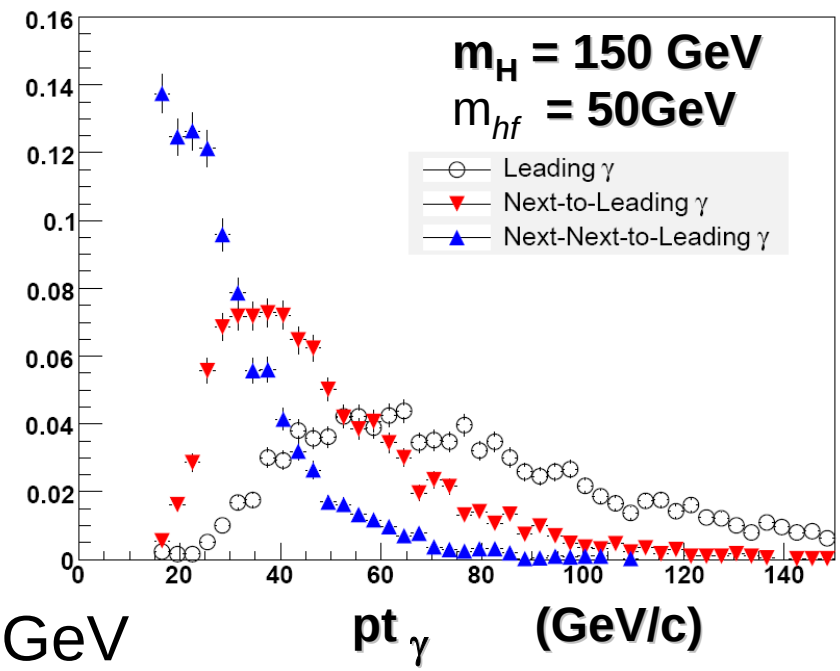
New search: Fermiophobic Higgs
$h_f h_f W \rightarrow \gamma\gamma\gamma(\gamma)$ X

- Fermiophobic Higgs search with **SM** VVh_f coupling:
  - LEP: e+e- → Zh_f m_{hf} > 105 GeV
    e+e- → Ah_f $m_{hf}+m_A$ > 160 GeV
  - TeV: qq → V → V+h_f m_{hf} > 82 GeV



- There is still possibility in **2HDM**
  tanβ>1, m_{hf} < 90 GeV, m_H < 200GeV





- Signature
  pp → $h_f H^{\pm}$ → $h_f h_f W^{\pm}$ → $\gamma\gamma\gamma(\gamma)$ X
  pt_1 >30 GeV, pt_2 >20 GeV, pt_3 >15 GeV

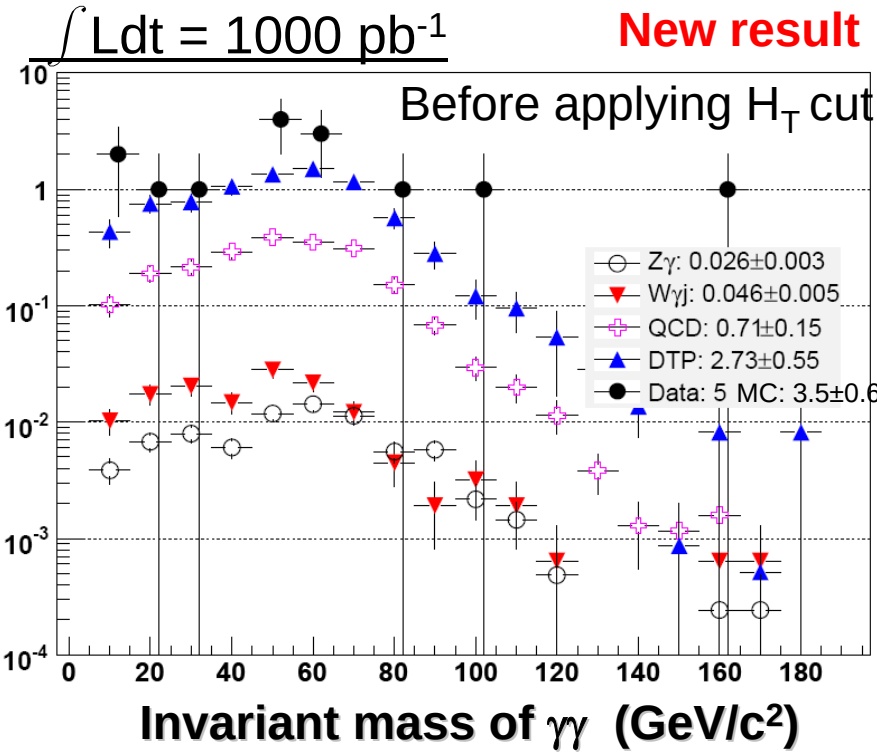
$h_f h_f W \rightarrow \gamma\gamma\gamma(\gamma)\ X$

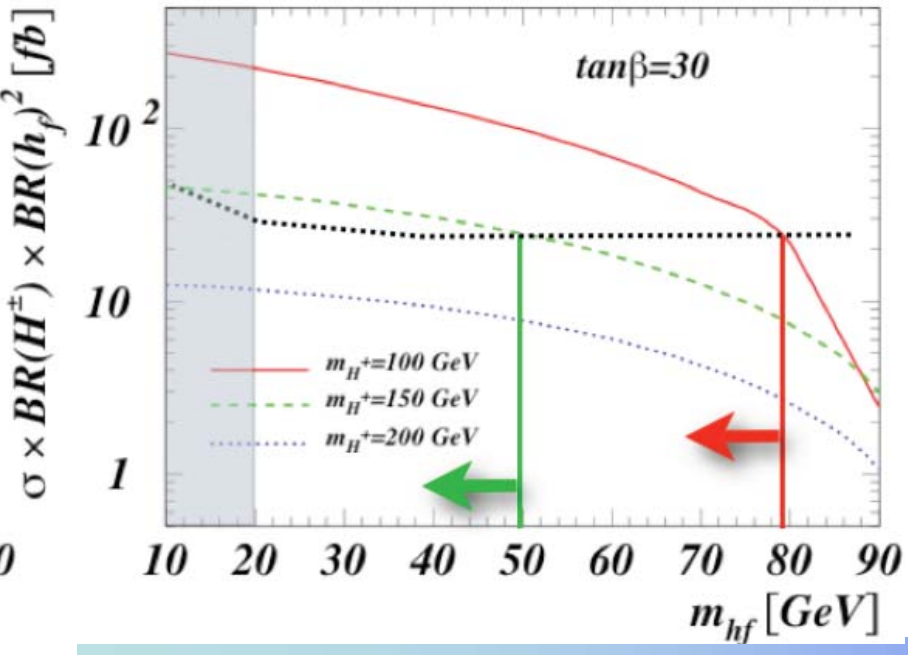
- Additional selection

  $H_T > 25$ GeV

$$H_T \equiv \sqrt{\left(\sum_{i=1}^{3} p_x^i\right)^2 + \left(\sum_{i=1}^{3} p_y^i\right)^2}$$

Observed Event : 0 ev
Expected # of BG: 1.1 ± 0.2 ev
Acceptance : 0.16 ± 0.03





Limit: σ = 25.3 fb @95%CL

M_{hf} = 66GeV for m_H < 100 GeV @ tanβ =3
M_{hf} = 44GeV for m_H < 150 GeV @ tanβ =3
M_{hf} = 80GeV for m_H < 100 GeV @ tanβ =30
M_{hf} = 50GeV for m_H < 150 GeV @ tanβ =30

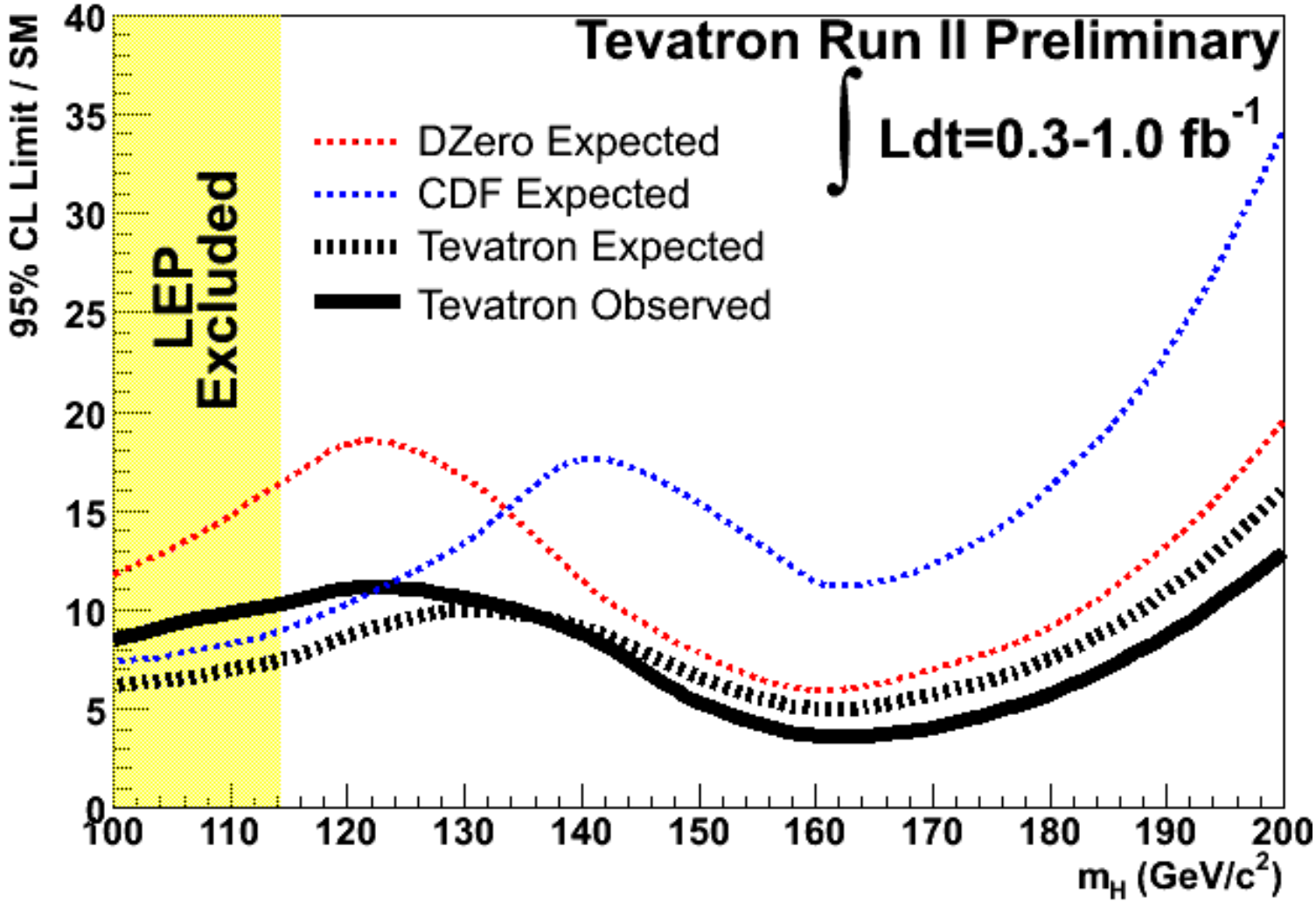
preliminary result

Summary and Prospect

- No excess yet observed in data from BG expectation.
- Observed limit is getting close to SM expectation.
- We are currently improving our analysis
  - bID performance much improved by using Neural Net
  - Optimization of selection
  - Use Event shape: NN, Matrix Element, etc…
  - Increased acceptance
  - Jet energy resolution
  - Reduce systematic uncertainty
  - Adding new channels
  - Combine with CDF
- Increase statistics: 2fb^{-1} of data on tape,

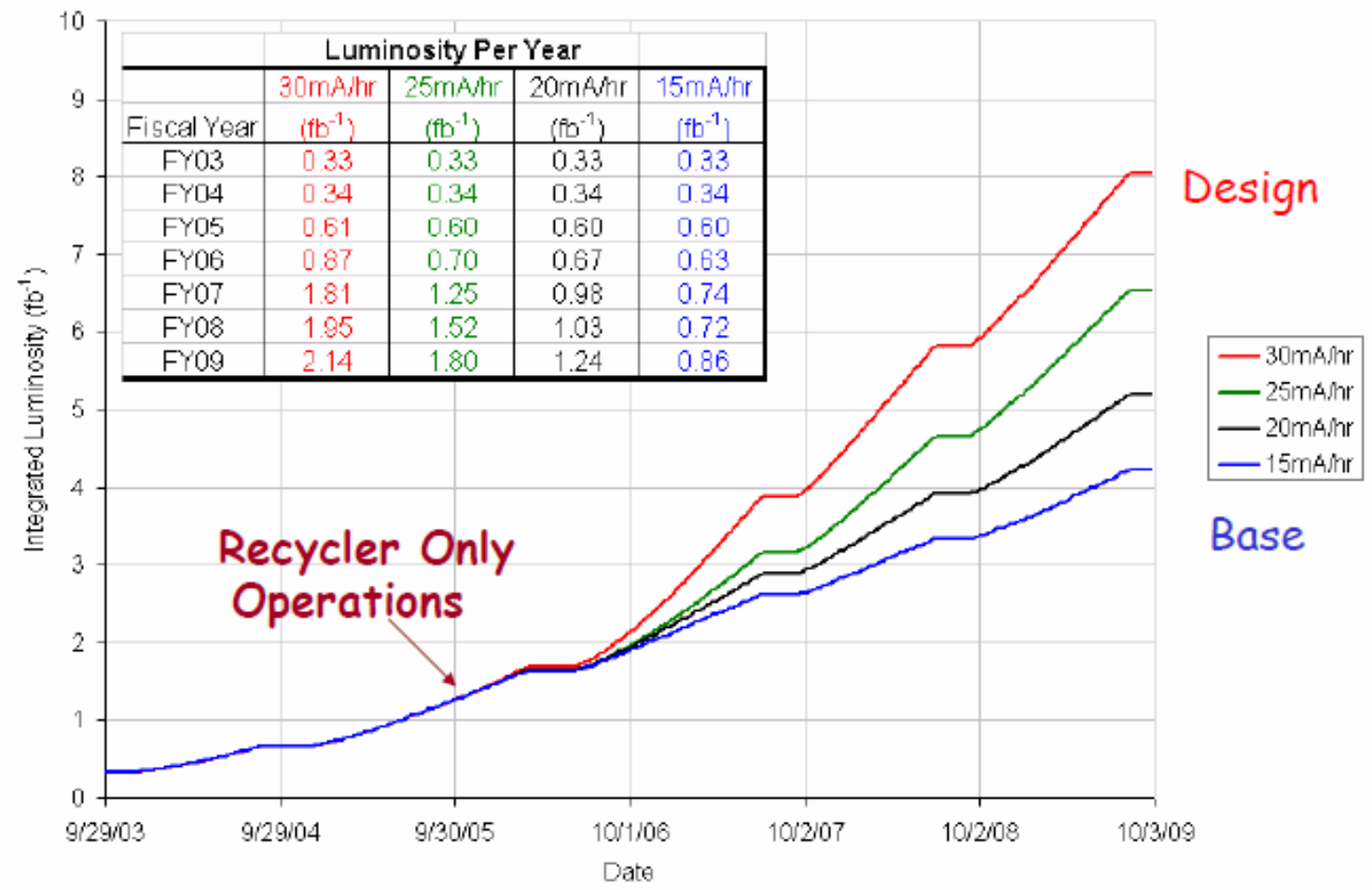
  expect 4-8fb^{-1} by 2009.

NOW is time for Higgs search at Tevatron! Stay tuned!

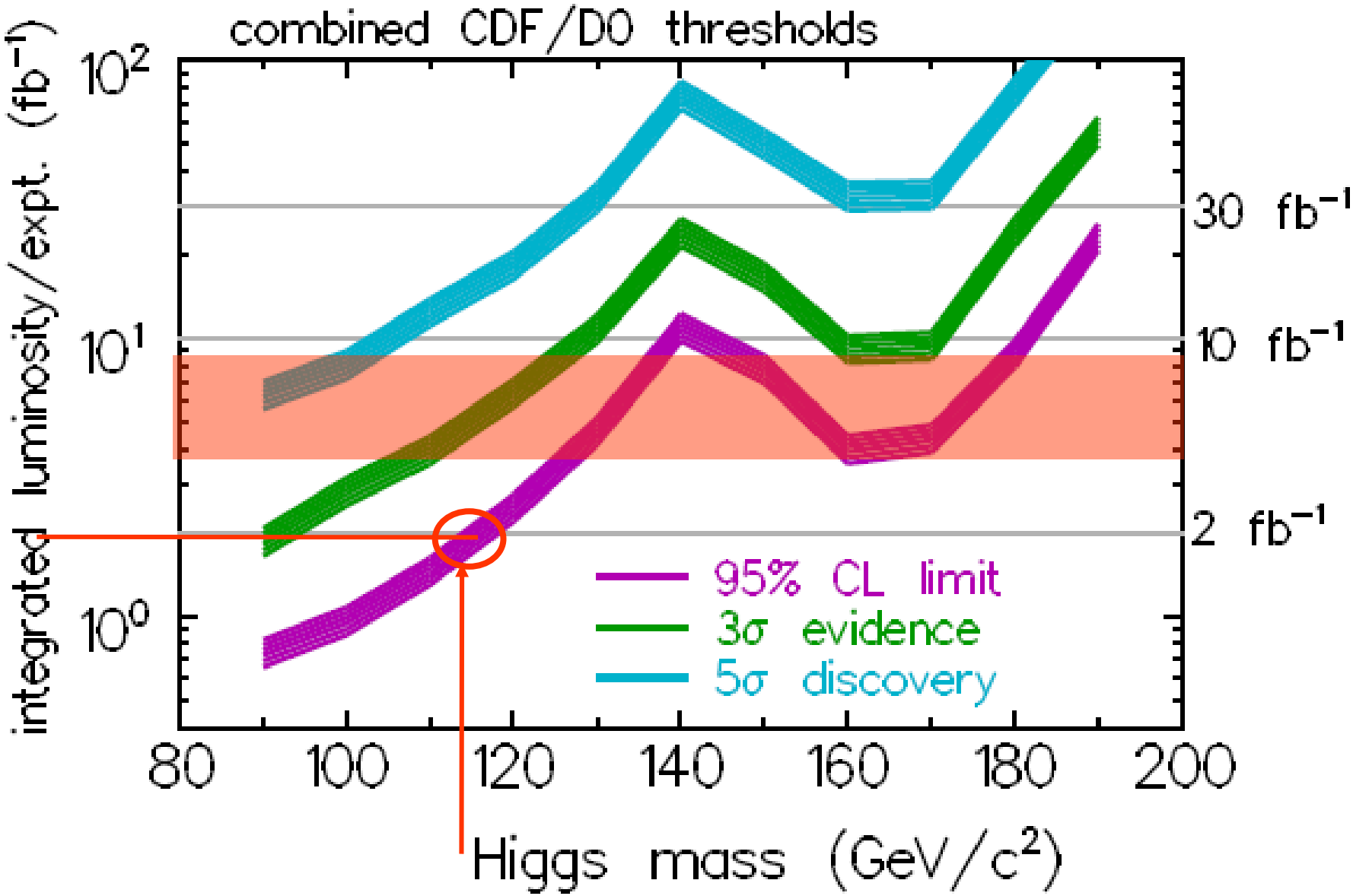

Tevatron Run II Preliminary
∫ Ldt=0.3-1.0 fb-1
DZero Expected
CDF Expected
Tevatron Expected
Tevatron Observed
LEP Excluded
95% CL Limit / SM
0
5
10
15
20
25
30
35
40
100
110
120
130
140
150
160
170
180
190
200
mH (GeV/c2)

Prospect

- 4~8fb-1 will be available by 2009



Luminosity Per Year				
	30mA/hr	25mA/hr	20mA/hr	15mA/hr
Fiscal Year	(fb^{-1})	(fb^{-1})	(fb^{-1})	(fb^{-1})
FY03	0.33	0.33	0.33	0.33
FY04	0.34	0.34	0.34	0.34
FY05	0.61	0.60	0.60	0.60
FY06	0.87	0.70	0.67	0.63
FY07	1.81	1.25	0.98	0.74
FY08	1.95	1.52	1.03	0.72
FY09	2.14	1.80	1.24	0.86


combined CDF/D0 thresholds
integrated luminosity/expt. (fb^{-1})
10^2
10^1
10^0
30 fb^{-1}
10 fb^{-1}
2 fb^{-1}
95% CL limit
3σ evidence
5σ discovery
80
100
120
140
160
180
200
Higgs mass (GeV/c^2)

MSSM parameter for $\phi \rightarrow \tau\tau$

The parameters:	m_h^{max}	no-mixing
– Mixing parameter, X_t	2 TeV	0 TeV
– Mass parameter, μ	$\pm$0.2 TeV	$\pm$0.2 TeV
– Gaugino mass term, M_2	0.2 TeV	0.2 TeV
– Gluino mass, $m_{\tilde{g}}$	0.8 TeV	1.6 TeV
– Common scalar mass, M_{SUSY}	1 TeV	2 TeV