Higgs Discovery Potential in Run 2 at the Tevatron

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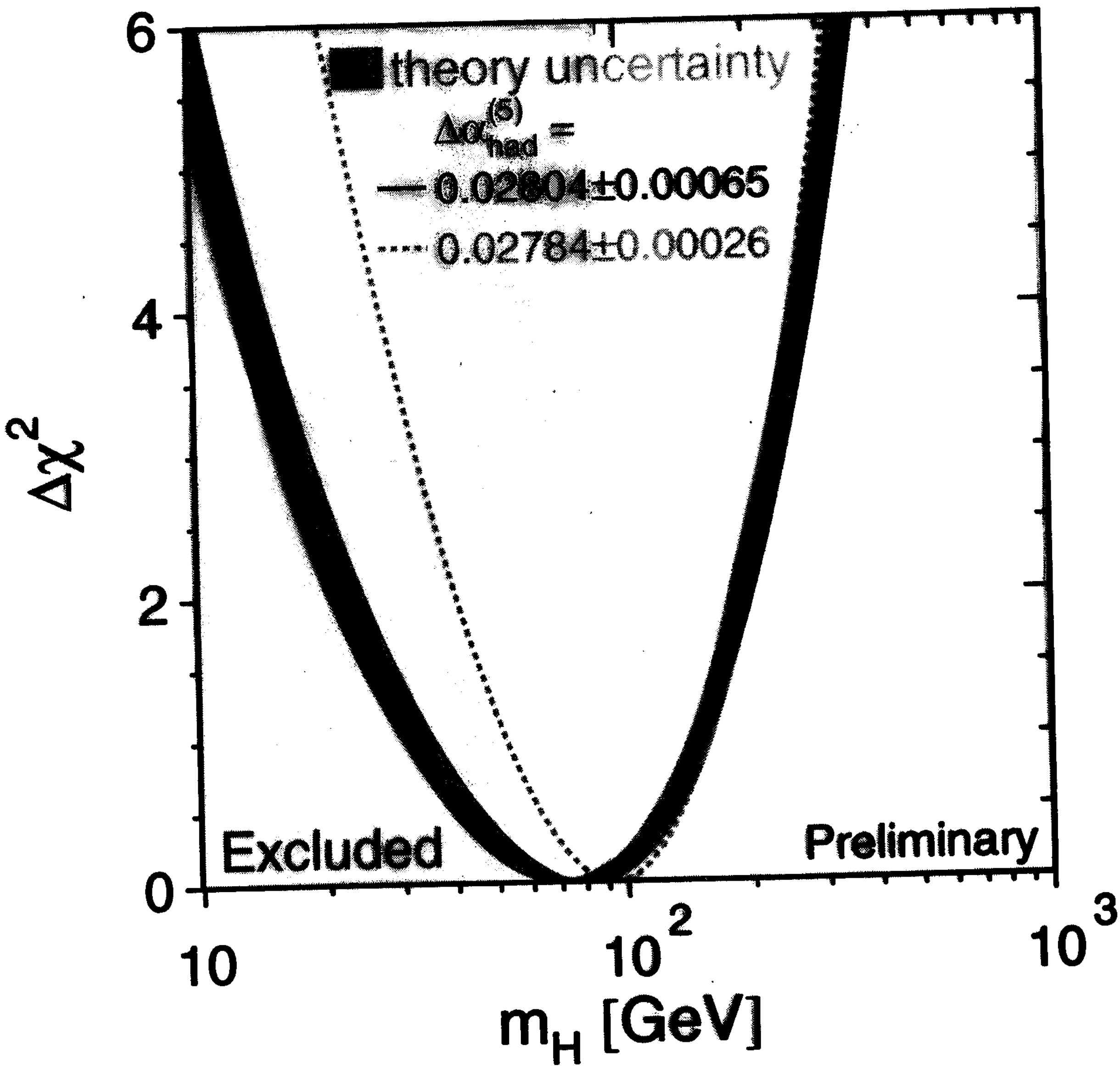
Linear Collider Workshop,

Sitges, Spain

30 April 1999

- Standard Model Higgs search
- SUSY Higgs projections from SM Higgs
- SUSY Higgs production at large $\tan\beta$

Motivation



SM-like Higgs could show up soon!

Tevatron Run 2 Workshop

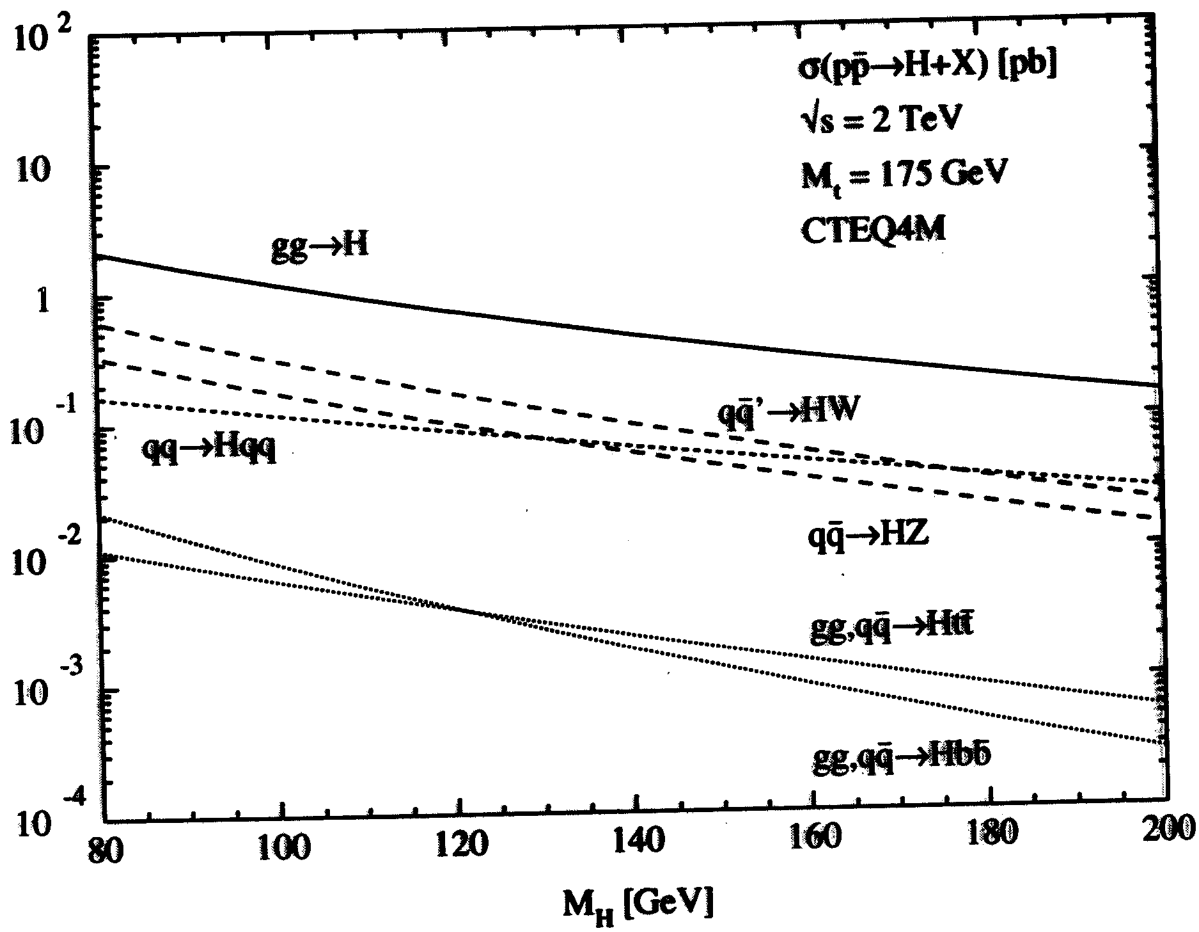
- repeat and extend the previous studies
- combine all possible channels
- simulate "average" of CDF and DØ
- establish SM Higgs discovery thresholds
- interpret SM Higgs results in MSSM
- explore new SUSY Higgs possibilities

SHW - simple CDF/DØ simulation

→ go beyond "parton-level" studies
→ simulate "average" CDF/DØ response

1. generate event (PYTHIA, ISAJET,...)
2. create list of tracks
3. create calorimeter tower energies
4. find calorimeter clusters
5. make list of trigger objects
6. make list of physics objects (γ, e, μ, τ, jets ...)

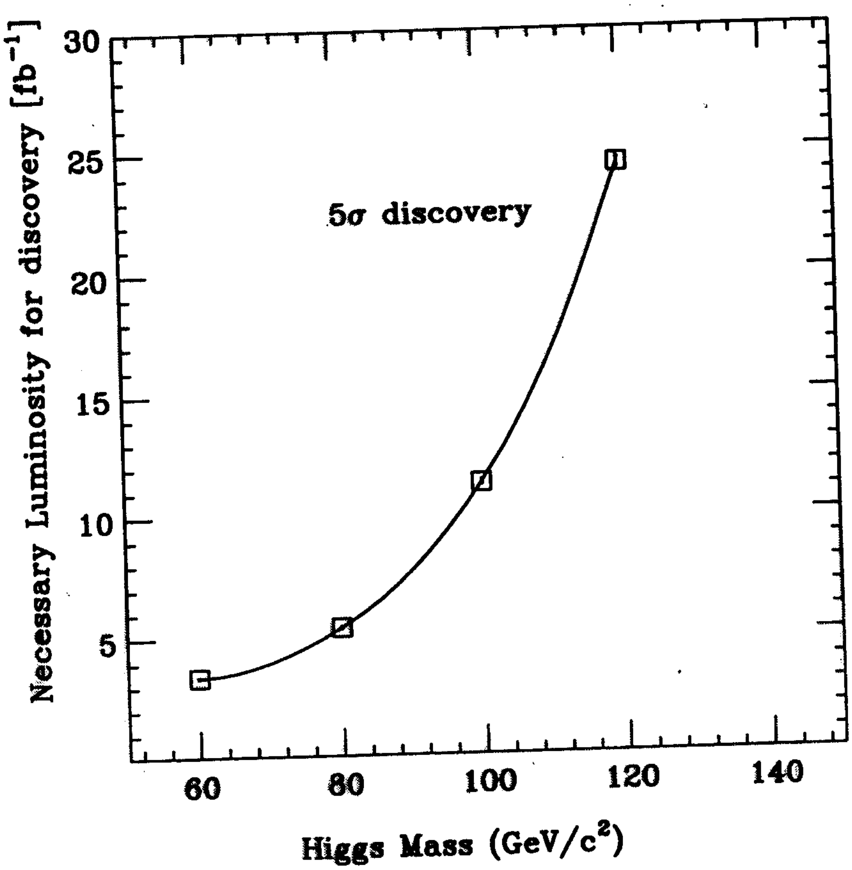
Standard Model Neutral Higgs searches



- gg→H dominates, but very difficult to see
- WH, ZH are most accessible
- SUSY enhances some cross sections!

TeV33

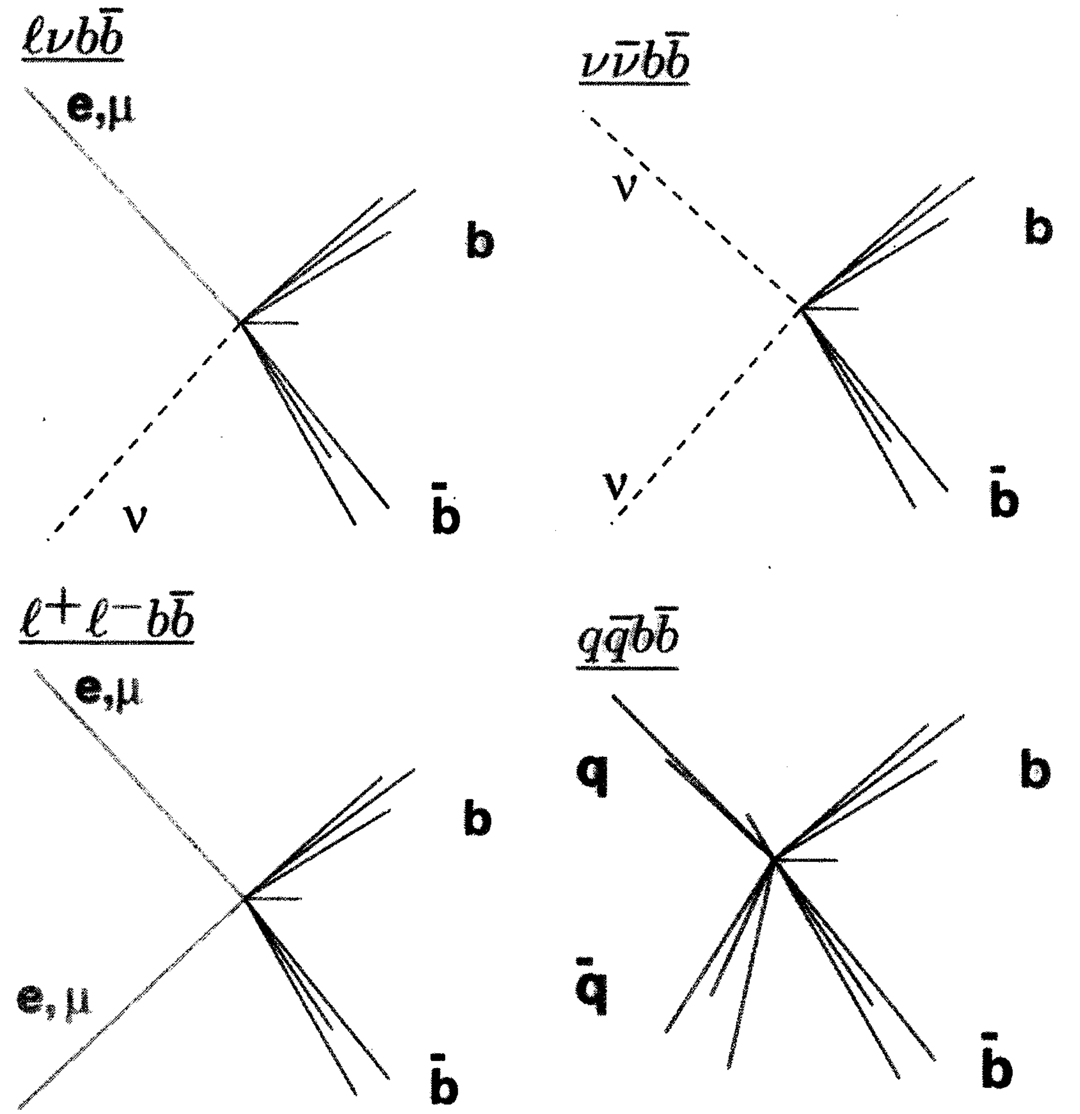
study result



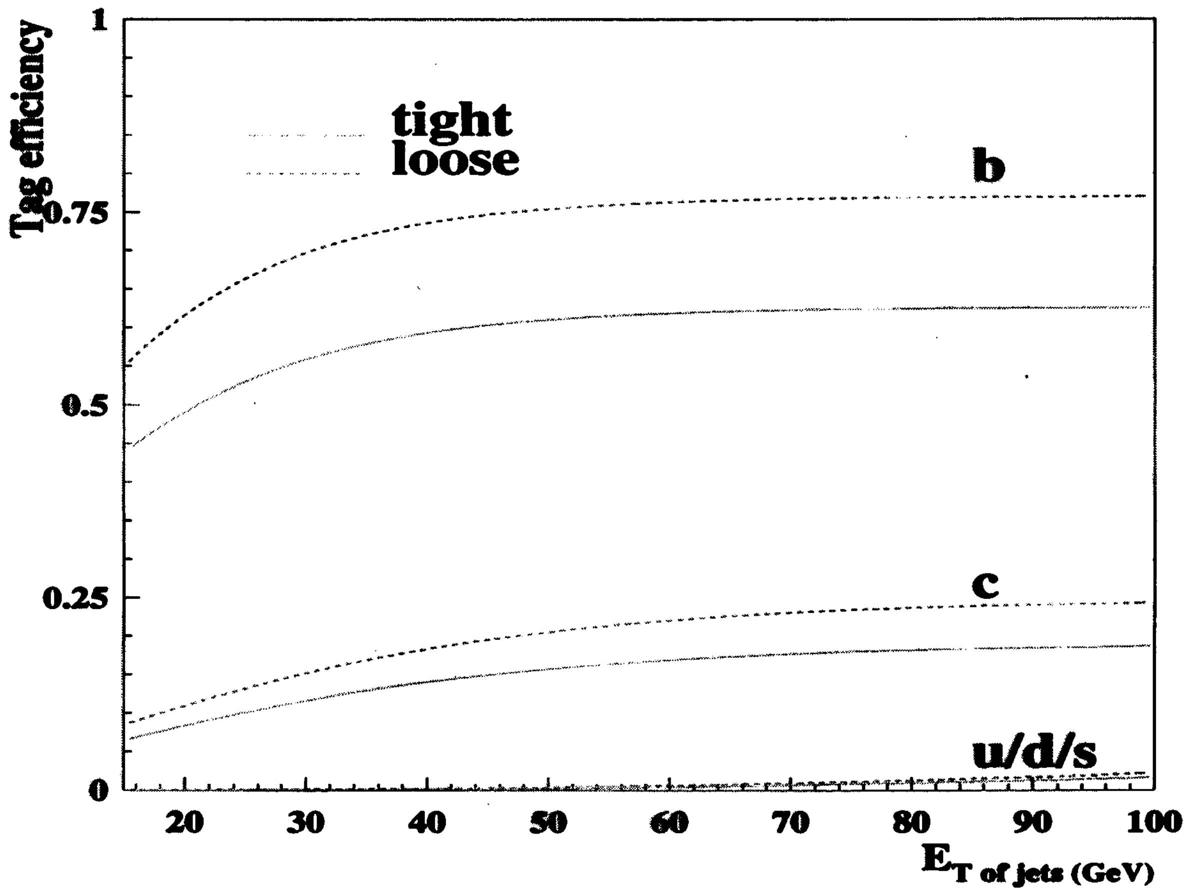
How do we improve upon previous studies?

- better $b\bar{b}$ mass resolution
- new triggers
- better selection
- add new channels
- combine all channels

Low mass SM Higgs channels

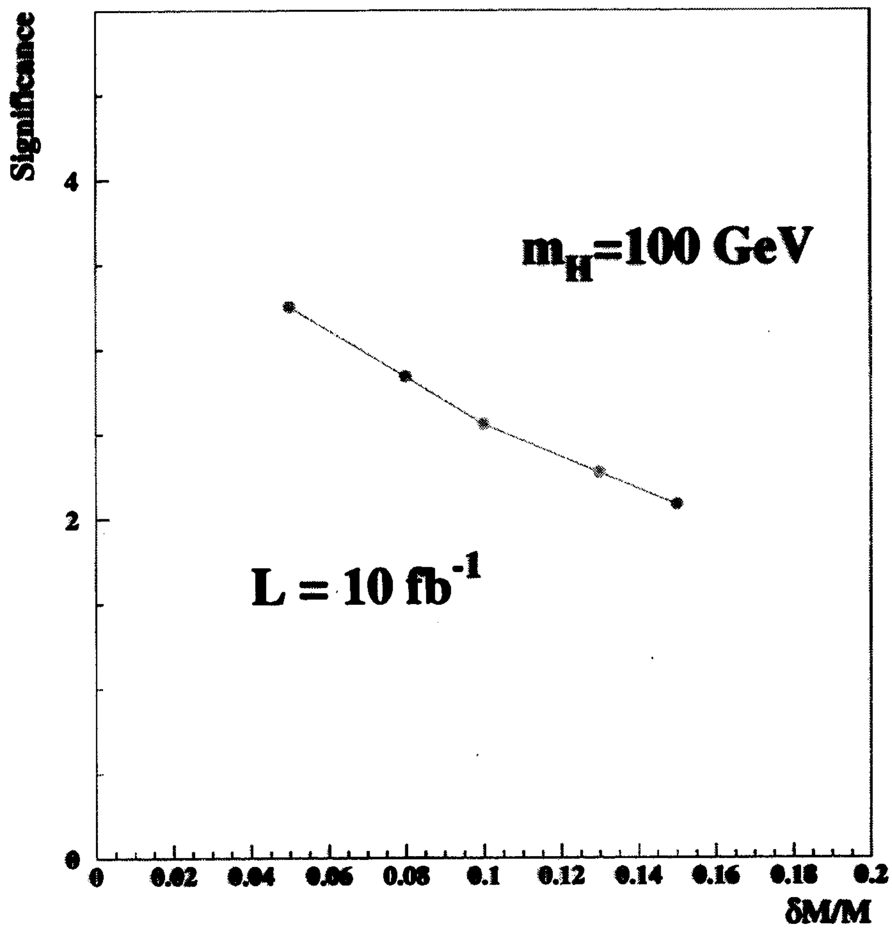


main backgrounds: $Wb\bar{b}$, $Zb\bar{b}$, $t\bar{t}$, WZ, single top, QCD tight/loose b tagging efficiency:



→ can perhaps do even better...

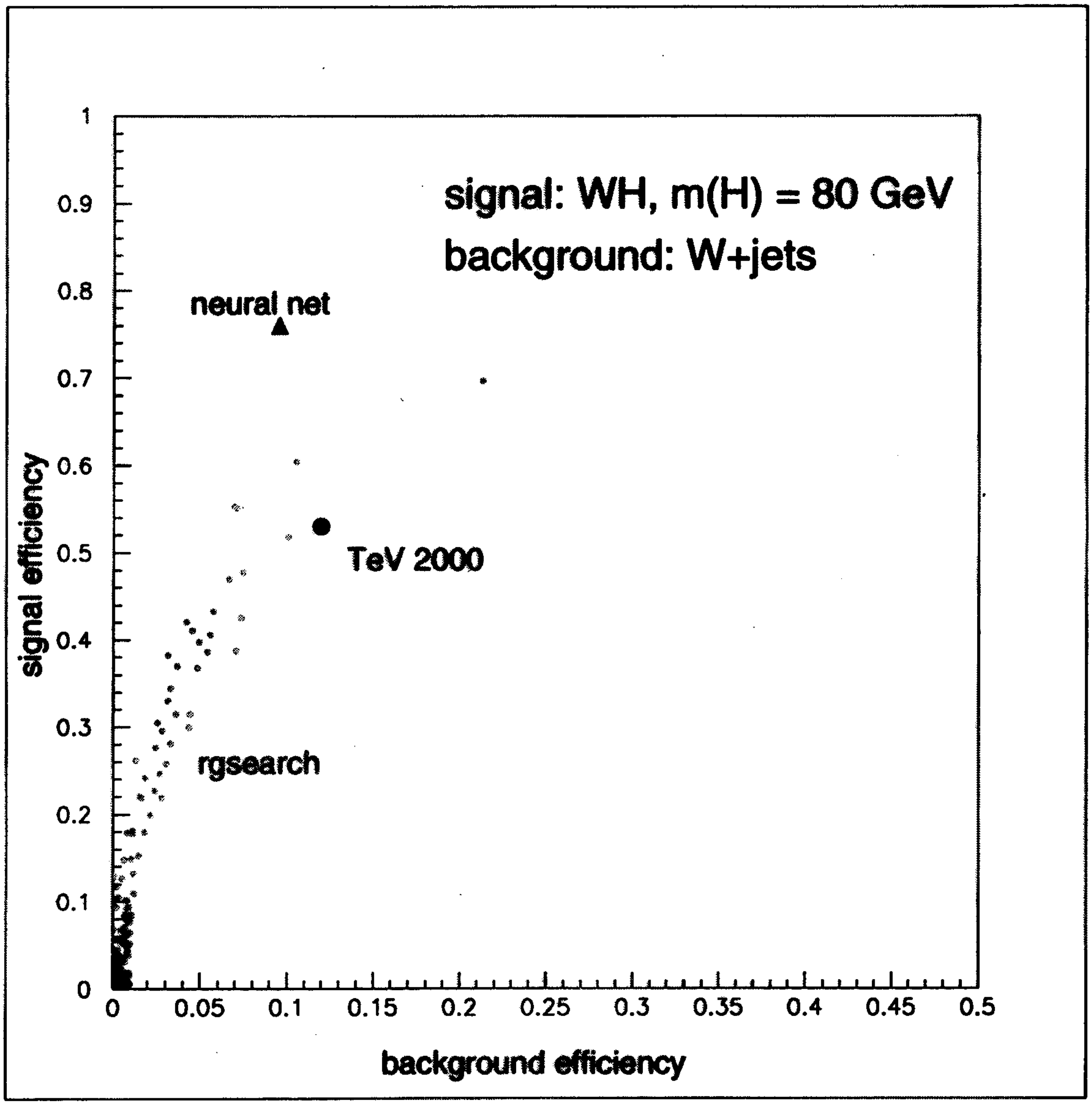
$\ell\nu b\bar{b}$ channel dependence on mass resolution



→ can reasonably hope for 10% mass resolution:

- use <u>all</u> jet energy information
- correct for $\not{E}_T$ in jet
- use $Z \to b\bar{b}$ as calibration

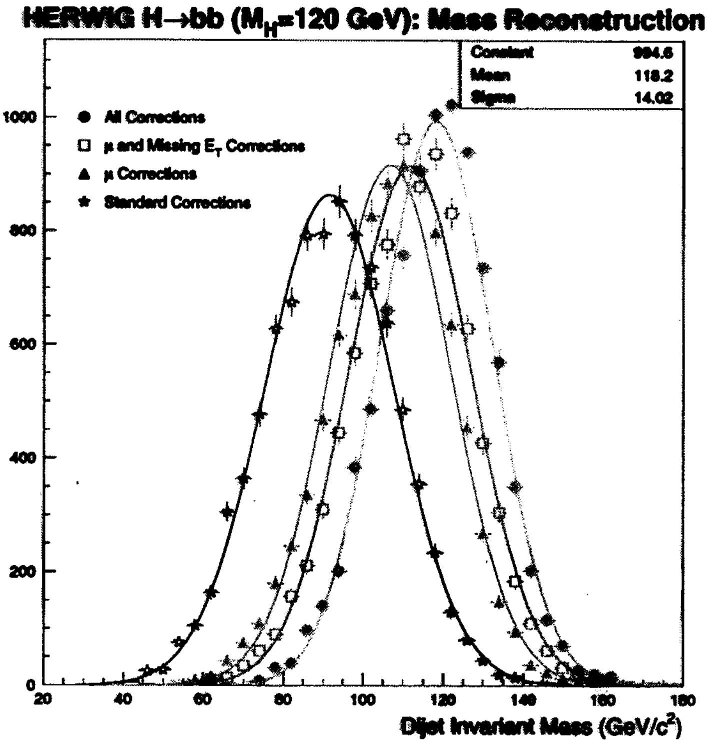
Pushpa Bhat: studies of selection optimization



→ improvement possible with these techniques

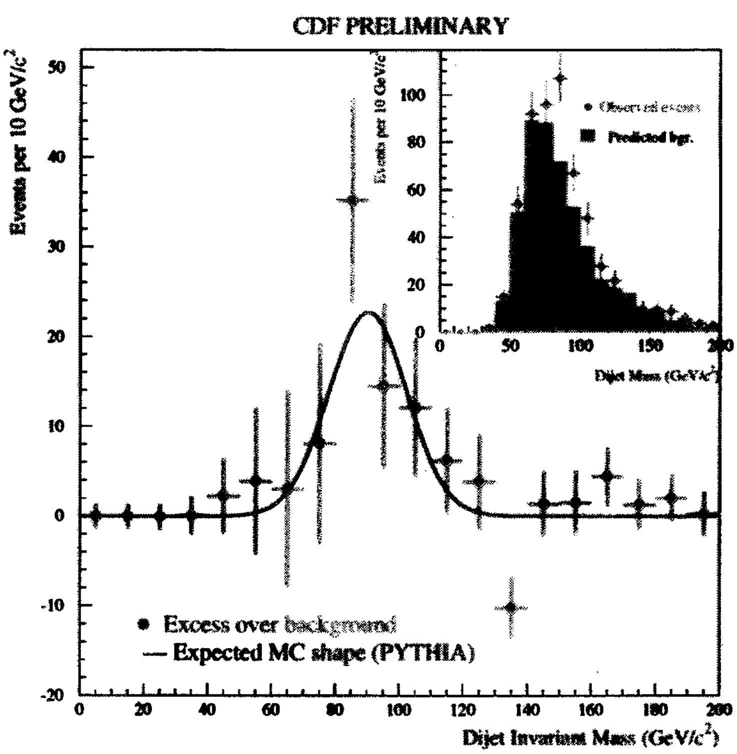
Studies of $b\bar{b}$ mass resolution

Steve Kuhlmann, Stefano Lami, Rob Snihur, Tommaso Dorigo, Alberto Ribon, ...



make various corrections...

...can see $Z \to b\bar{b}$

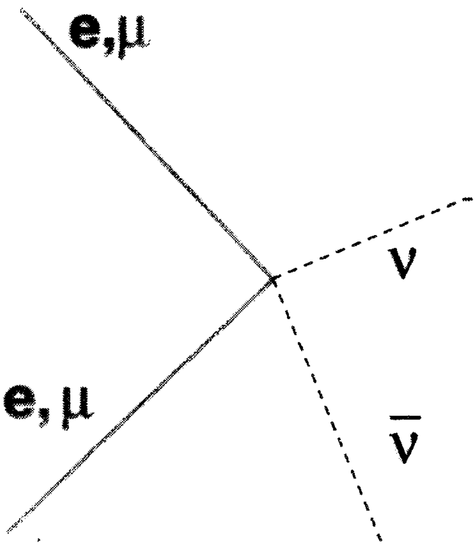


Low-mass SM Higgs Channel Sensitivities

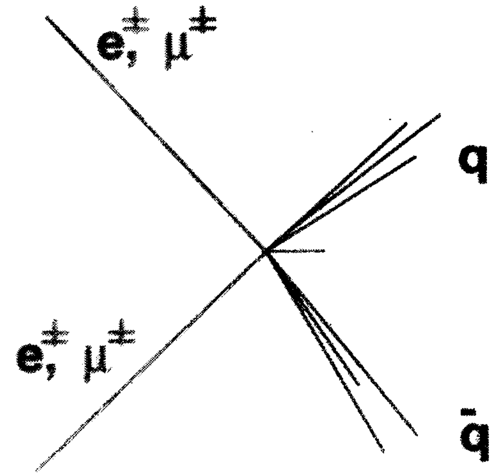
channel	rate	Higgs mass (GeV/c^2) 90	100	110	120	130
$\ell\nu b\bar{b}$ (CDF)	S	8.4	6.6	5.0	3.7	2.2
	B	48	52	48	49	42
	$S/\sqrt{B}$	1.2	0.9	0.7	0.5	0.3
$\ell\nu b\bar{b}$ (SHW)	S	10	8	5	4	3
	B	75	68	57	58	52
	$S/\sqrt{B}$	1.1	1.0	0.7	0.5	0.4
$\ell\nu b\bar{b}$ (NN)	S	8.8	6.5	3.8	3.1	2.2
	B	30.6	24.0	18.0	22.0	27.8
	$S/\sqrt{B}$	1.6	1.3	0.9	0.7	0.4
$\nu\bar{\nu}b\bar{b}$ (CDF)	S	2.5	2.2	1.9	1.2	0.6
	B	10.0	9.3	8.0	6.5	4.8
	$S/\sqrt{B}$	0.8	0.7	0.7	0.5	0.3
$\nu\bar{\nu}b\bar{b}$ (SHW)	S	8.9	6.7	4.6	3.2	2.1
	B	36	32	25	17.2	13.2
	$S/\sqrt{B}$	1.5	1.2	0.9	0.8	0.6
$\nu\bar{\nu}b\bar{b}$ (NN)	S	3.5	2.5	0.8	1.0	0.6
	B	11.5	10.4	1.0	3.4	4.2
	$S/\sqrt{B}$	1.0	0.8	0.8	0.5	0.3
$\ell^+\ell^-b\bar{b}$ (CDF)	S	1.0	0.9	0.8	0.5	0.3
	B	3.6	3.1	2.5	1.8	1.1
	$S/\sqrt{B}$	0.5	0.5	0.5	0.4	0.3
$\ell^+\ell^-b\bar{b}$ (SHW)	S	1.5	1.2	0.9	0.6	0.4
	B	4.9	4.3	3.2	2.3	1.9
	$S/\sqrt{B}$	0.7	0.6	0.5	0.4	0.3
$\ell^+\ell^-b\bar{b}$ (NN)	S	0.9	1.1	0.6	0.5	0.2
	B	2.4	8.4	3.9	4.2	2.0
	$S/\sqrt{B}$	0.6	0.4	0.3	0.24	0.14
$q\bar{q}b\bar{b}$ (SHW)	S	8.1	5.6	3.5	2.5	1.3
	B	6800	3600	2800	2300	2000
	$S/\sqrt{B}$	0.10	0.09	0.07	0.05	0.03

High-mass SM Higgs channels

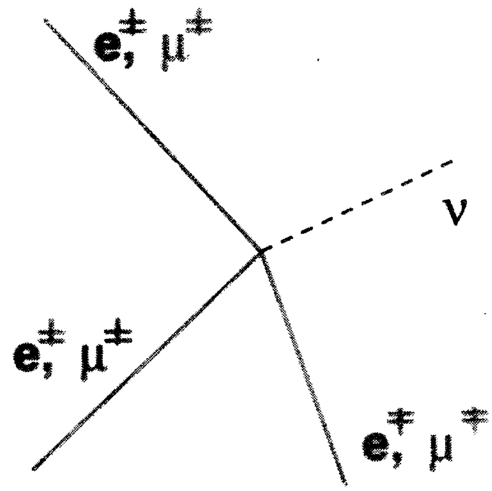
$\ell^+\ell^-\nu\bar{\nu}$



$\ell^\pm\ell^\pm jj$



$\ell^\pm\ell'^\pm\ell^\mp$



main backgrounds: $WW!$, WZ, ZZ, $t\bar{t}$

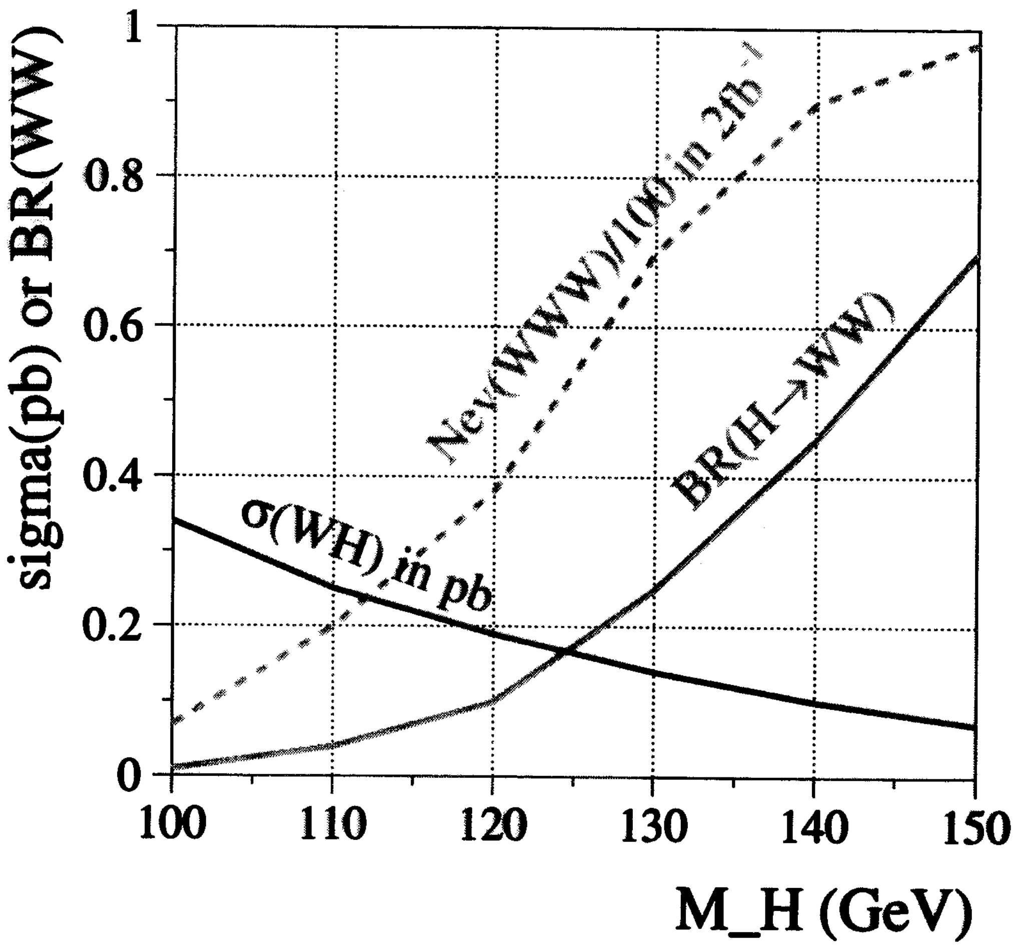
→ most powerful channel at high masses: $\ell^\pm\ell^\pm jj$

→ published in hep-ph/9812275 (Han, Turcot, Zhang)

SM Higgs in WW^*, WWW^*, ZWW^* modes

idea: exploit $H \to WW^*$ decays at higher masses

- $gg \to H \to WW^*$
- $ZH \to ZWW^*$
- $WH \to WWW^*$

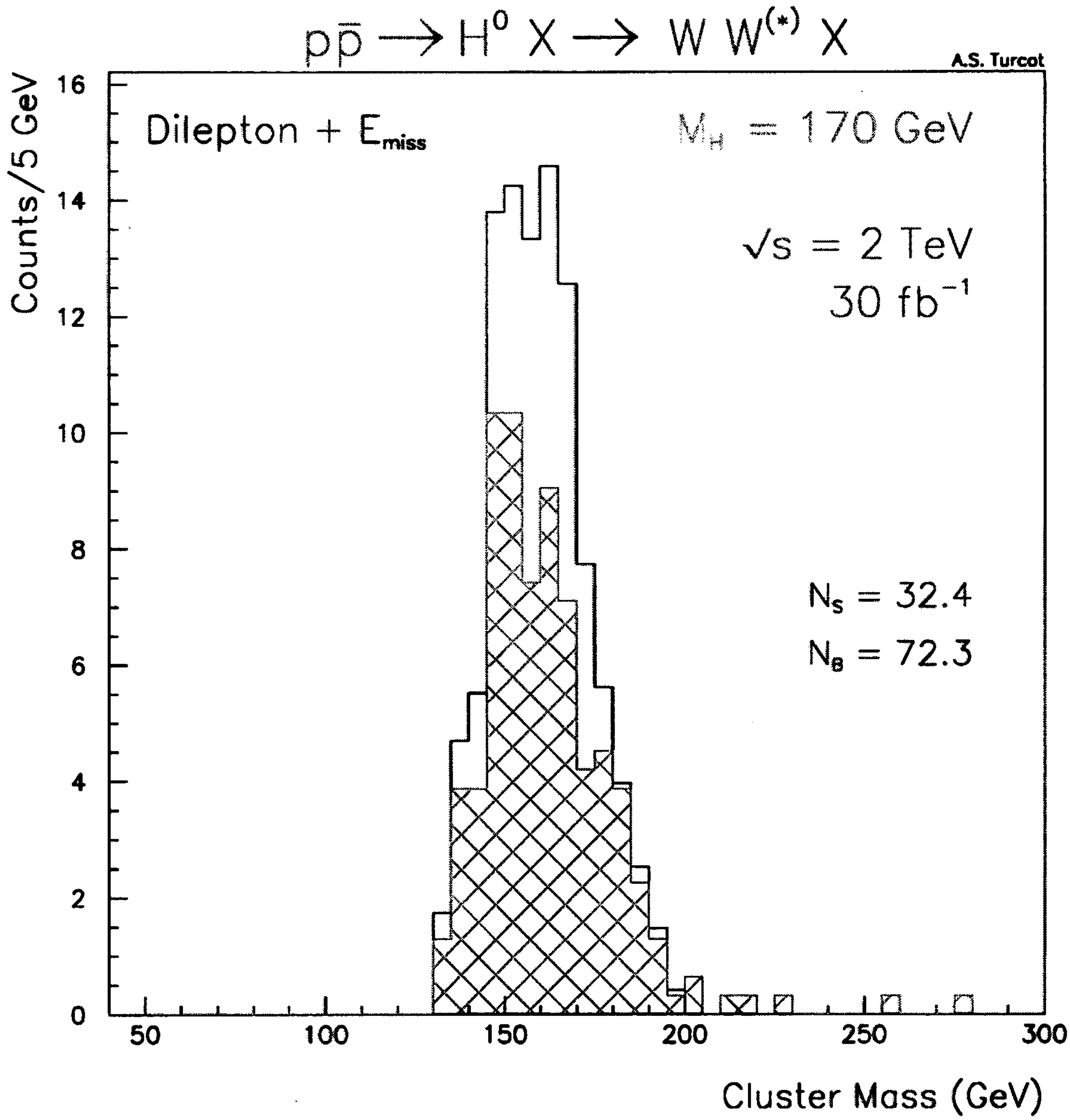


→ dilepton, trilepton, like-sign dilepton plus jets

$\ell^+\ell^-\nu\bar{\nu}$ channel

→ lots of finely tuned cuts

→ use "cluster transverse mass" to sharpen mass



$$M_C \equiv \sqrt{p_T^2(\ell\ell) + m^2(\ell\ell)} + \not{E}_T$$

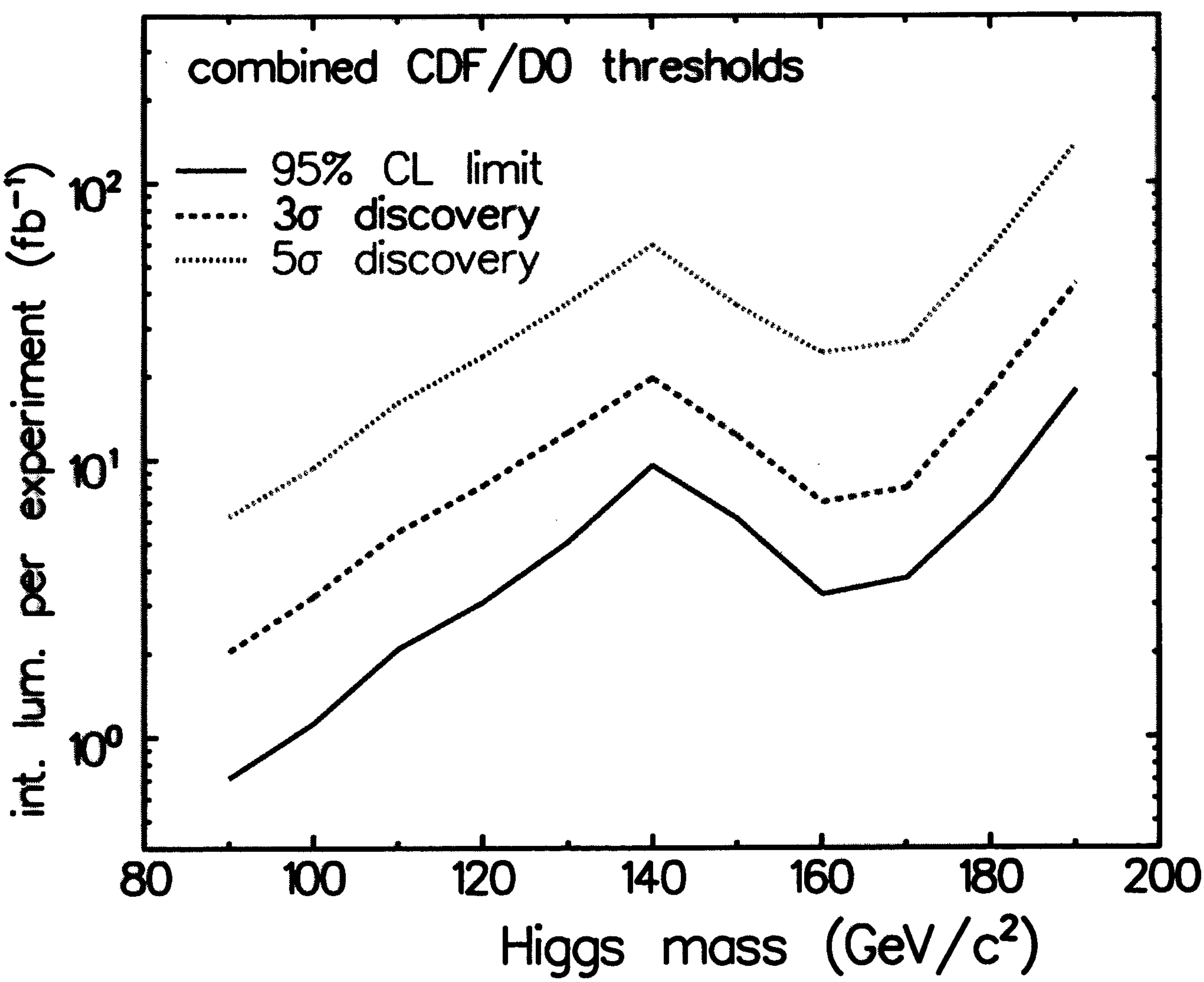
High-mass SM Higgs Channel Sensitivities

expected events and sensitivity in 1 fb^{-1}

channel	rate	Higgs mass (GeV/c^2) 130	140	150	160	170	180
$\ell^\pm\ell'^\pm\ell^\mp$	S	0.025	0.039	0.050	0.057	0.033	0.033
	B	0.025	0.025	0.025	0.025	0.025	0.025
	$S/\sqrt{B}$	0.16	0.25	0.32	0.36	0.21	0.21
$\ell^+\ell^-\nu\bar{\nu}$	S	-	2.6	2.8	1.5	1.1	1.0
	B	-	44	30	4.4	2.4	3.8
	$S/\sqrt{B}$	-	0.39	0.51	0.71	0.71	0.51
$\ell^\pm\ell^\pm jj$	S	0.15	0.29	0.36	0.41	0.38	0.26
	B	0.58	0.58	0.58	0.58	0.58	0.58
	$S/\sqrt{B}$	0.20	0.38	0.47	0.54	0.50	0.34

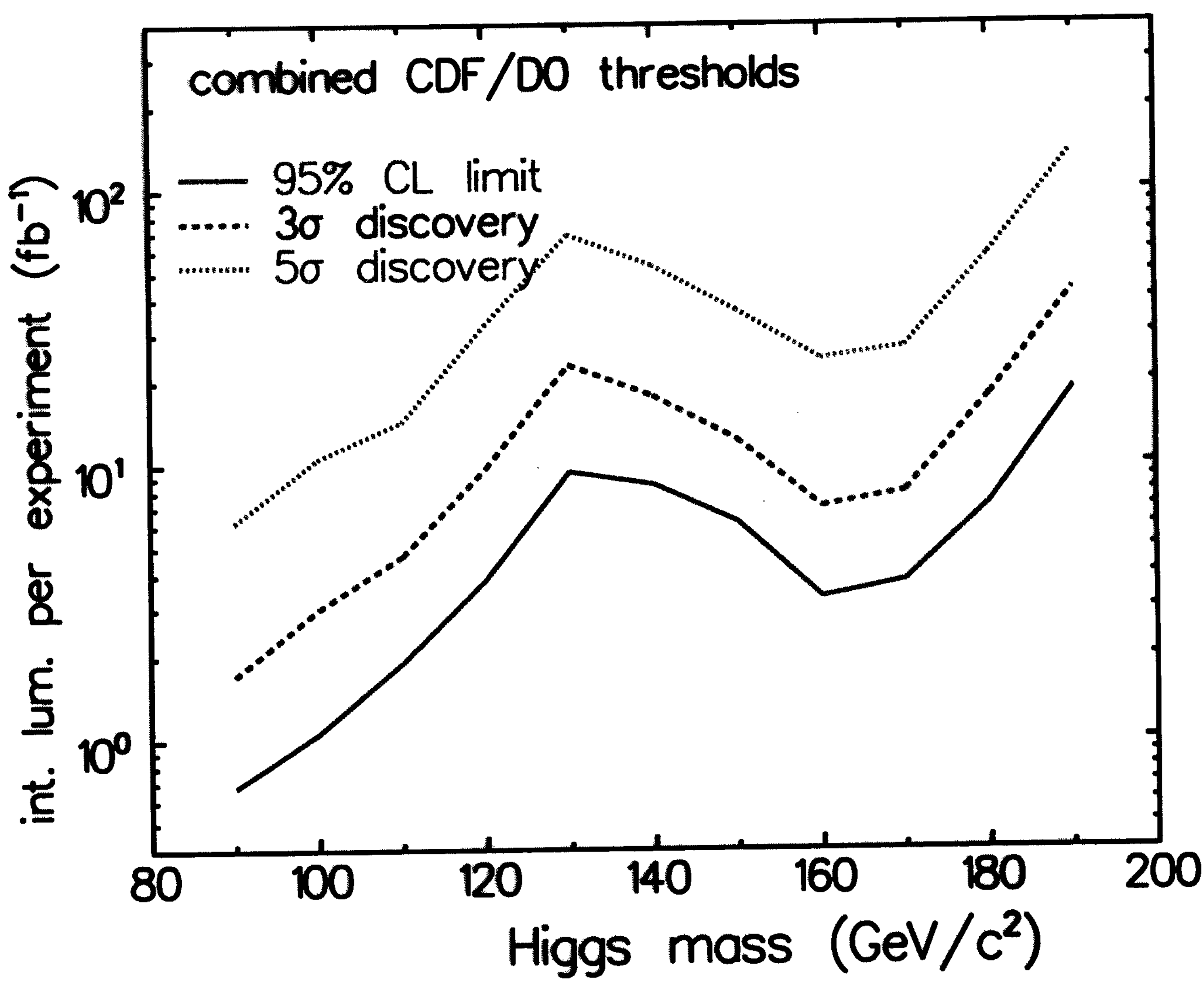
SM Higgs combined channel thresholds

→ Bayesian combination method - two experiments
→ 30% better $m_{b\bar{b}}$ resolution than Run 1
→ SHW acceptance
→ nominal systematic errors: 10% or $1/\sqrt{LB}$



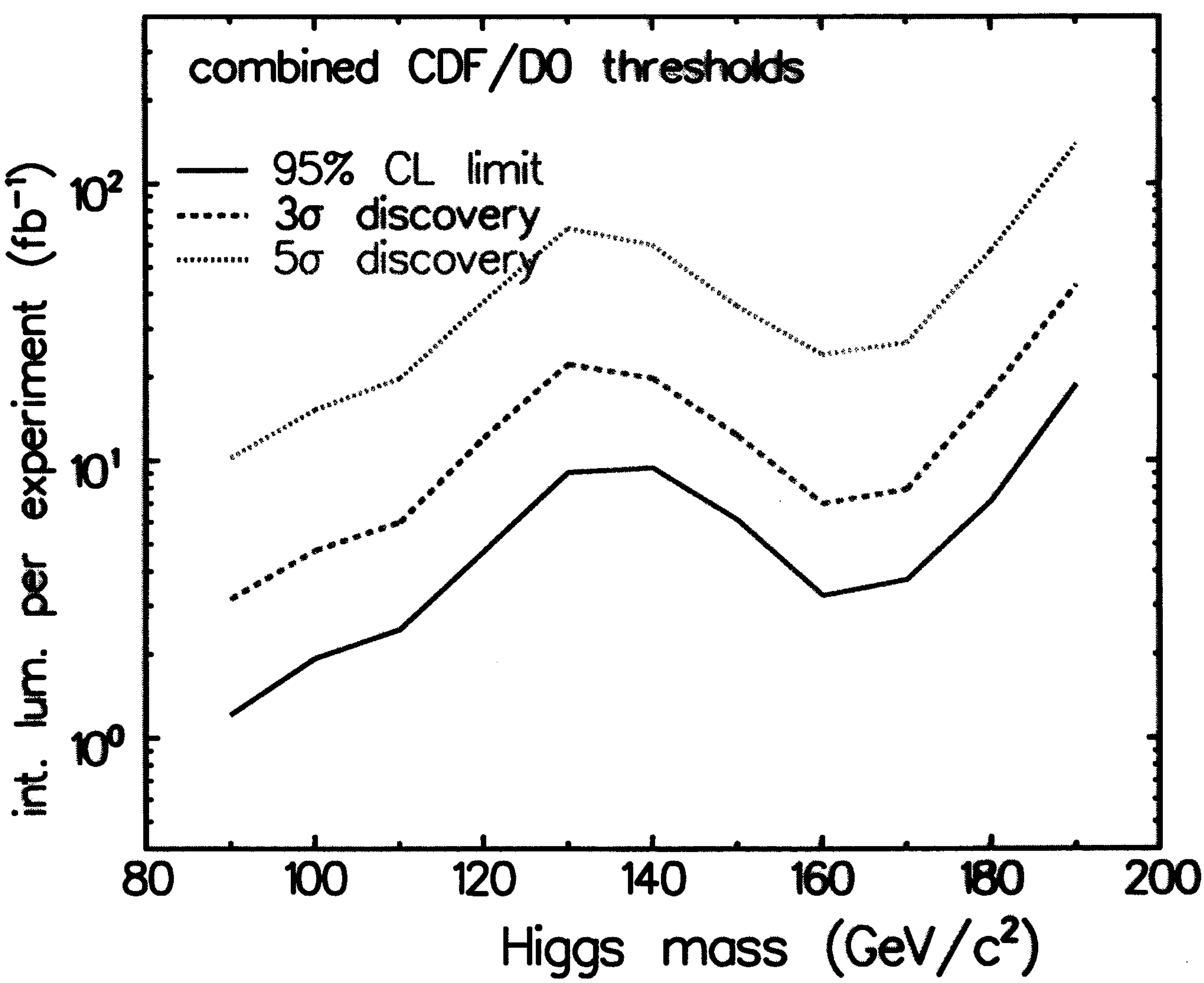
SM Higgs combined channel thresholds

→ Bayesian combination method - two experiments
→ 30% better $m_{b\bar{b}}$ resolution than Run 1
→ SHW acceptance, neural network selection
→ nominal systematic errors: 10% or $1/\sqrt{LB}$

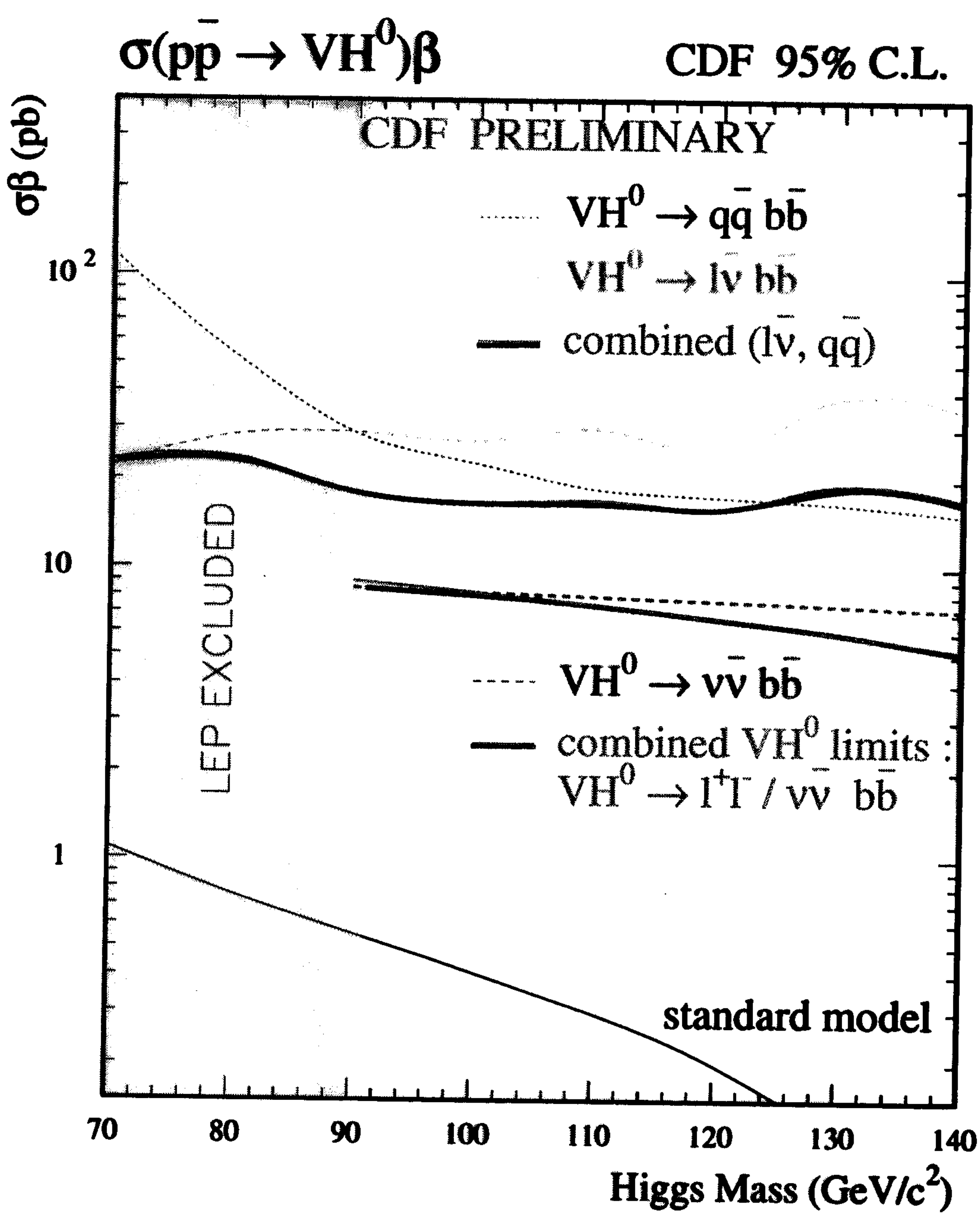


SM Higgs combined channel thresholds

→ Bayesian combination method - two experiments
→ 30% better $m_{b\bar{b}}$ resolution than Run 1
→ CDF extrapolated acceptance
→ nominal systematic errors: 10% or $1/\sqrt{LB}$



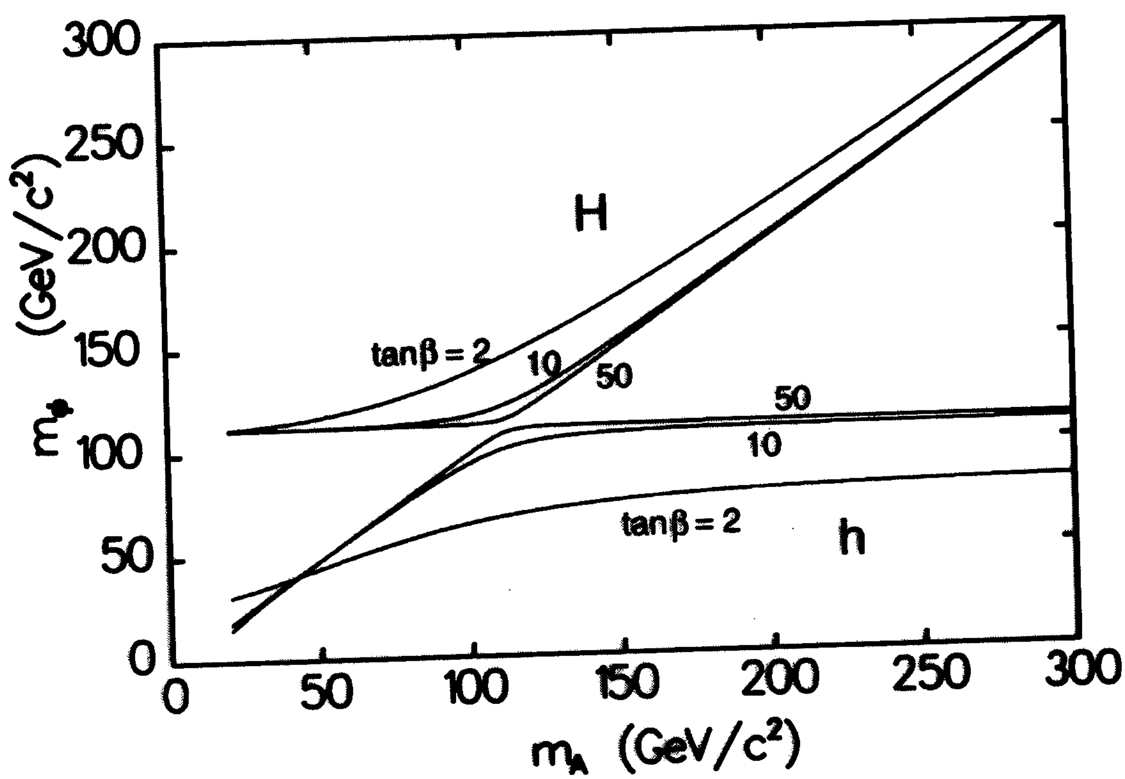
CDF Run 1 Higgs limits



SUSY Higgs (MSSM)

Have five Higgs bosons: h,A,H,$H^{\pm}$

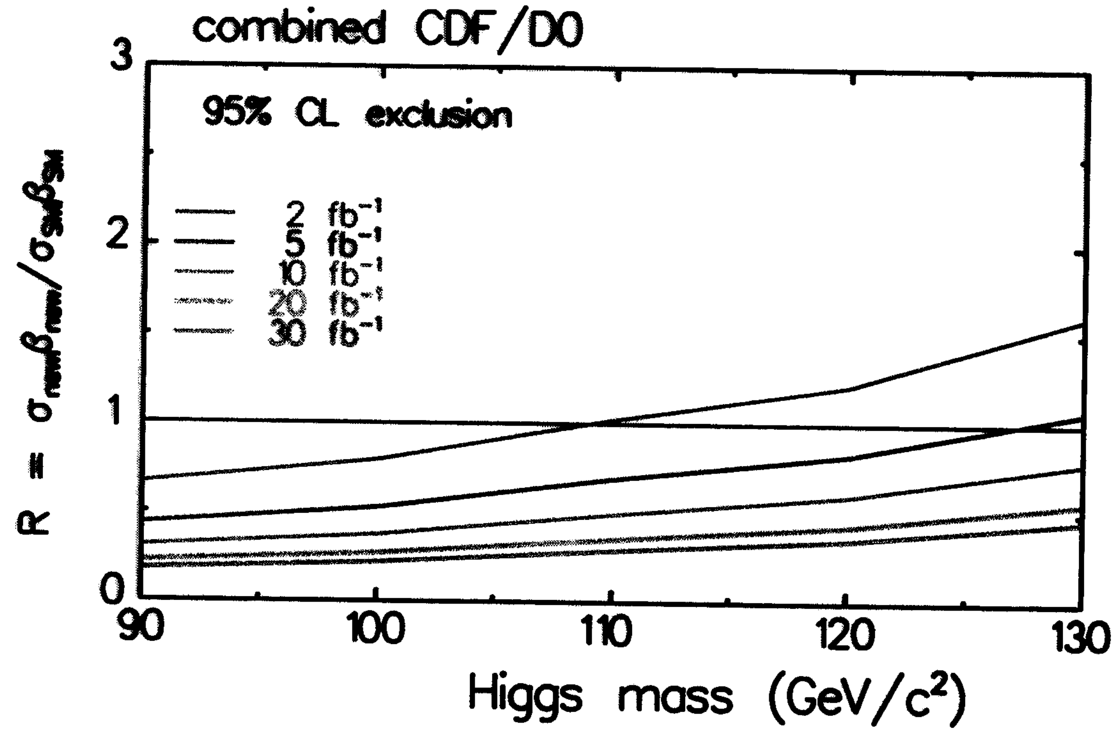
Masses governed by two parameters: m_A, $\tan\beta$

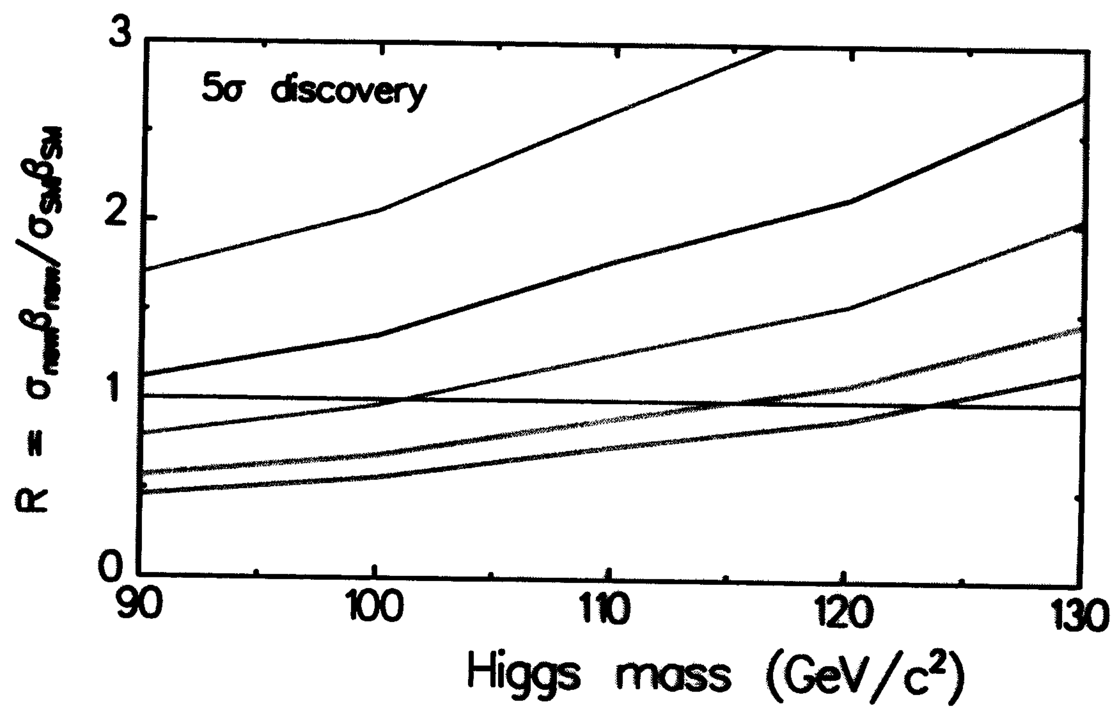


→ Vh, VH can be Standard Model-like

→ apply SM Higgs search to MSSM parameter space

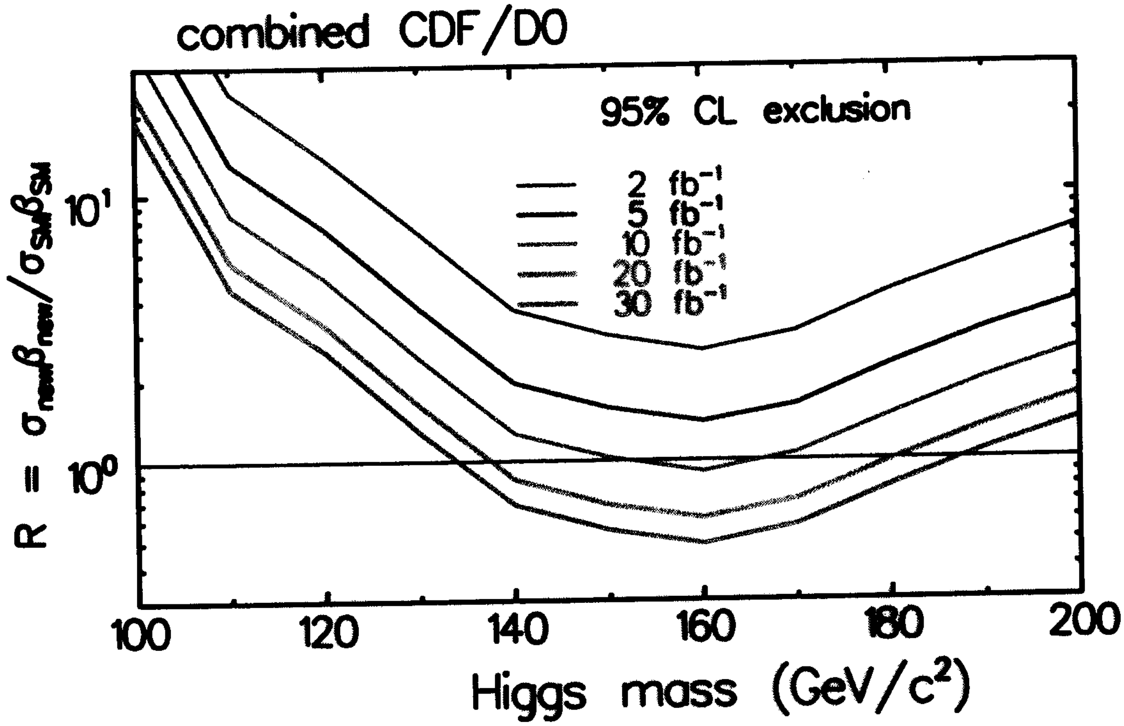
Express SM contours in terms of ratio of new physics to Standard Model for low-mass channels:

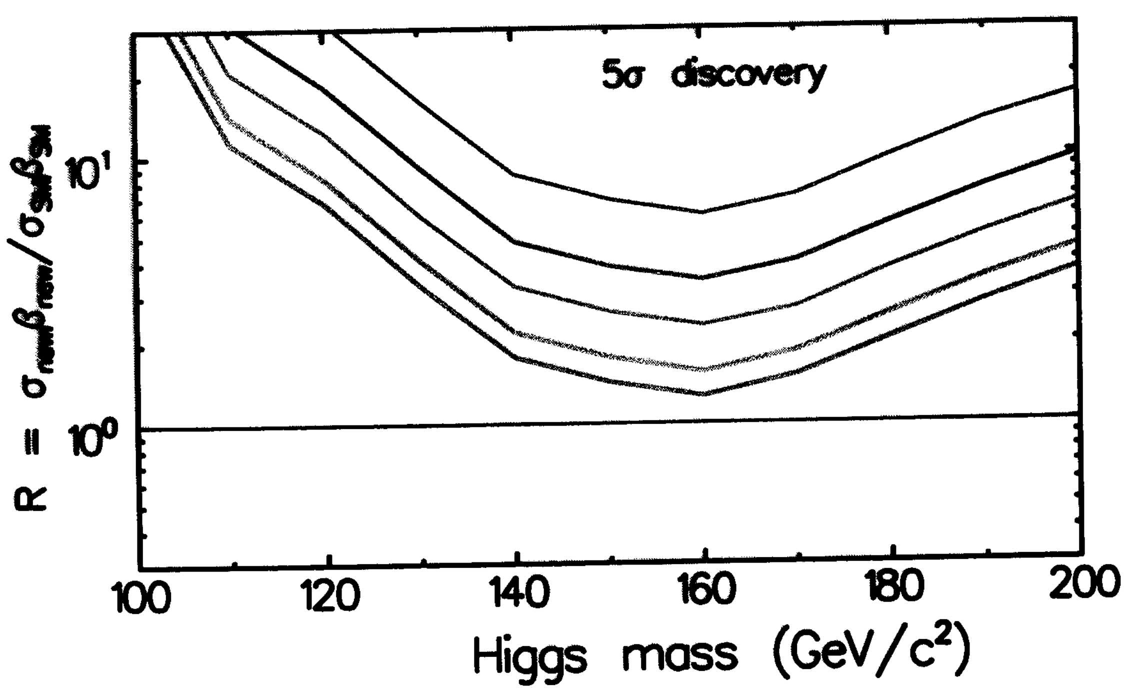




(Here assume improved $m_{b\bar{b}}$ resolution, SHW analyses)

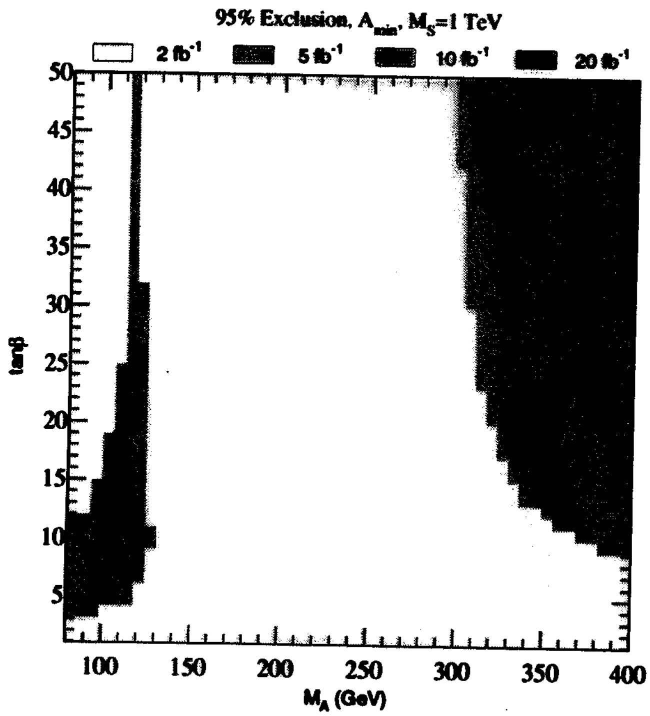
Express SM contours in terms of ratio of new physics to Standard Model for high-mass channels:

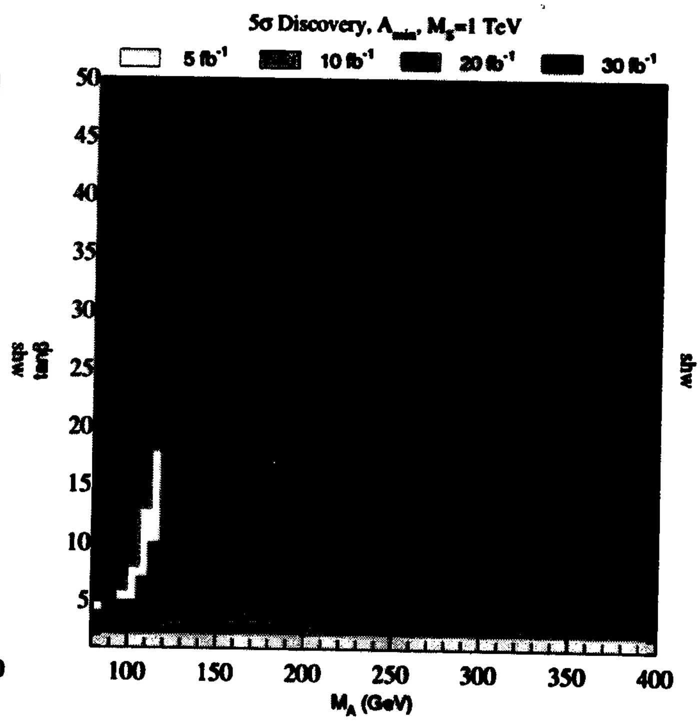




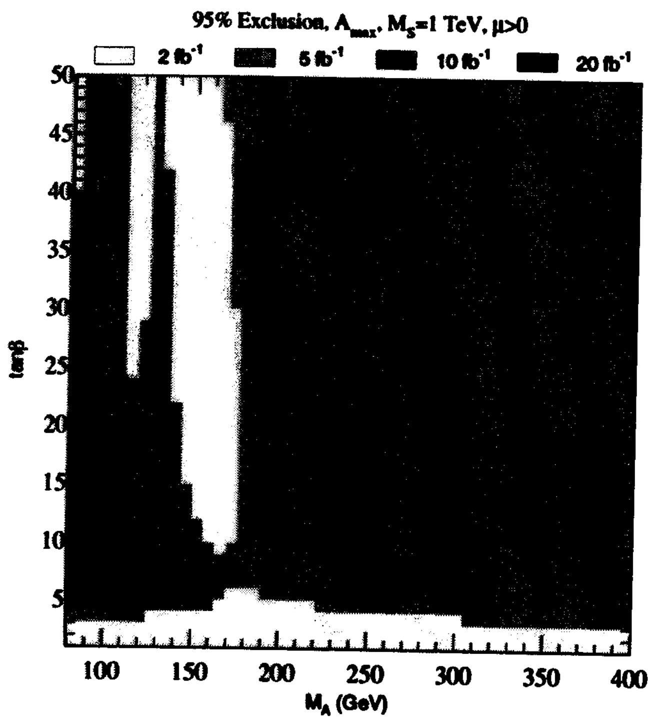
MSSM discovery/exclusion from SM Higgs channels

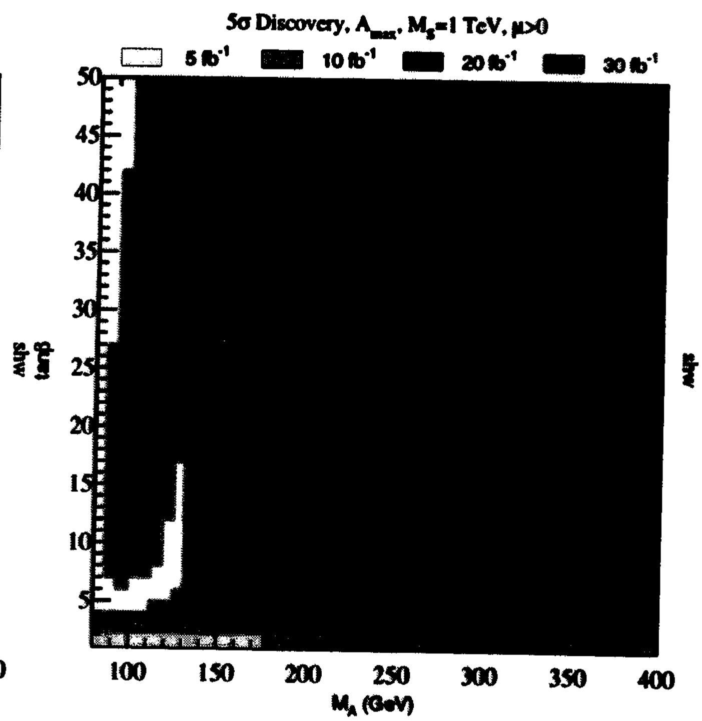
A_{min}, $M_S = 1$ TeV



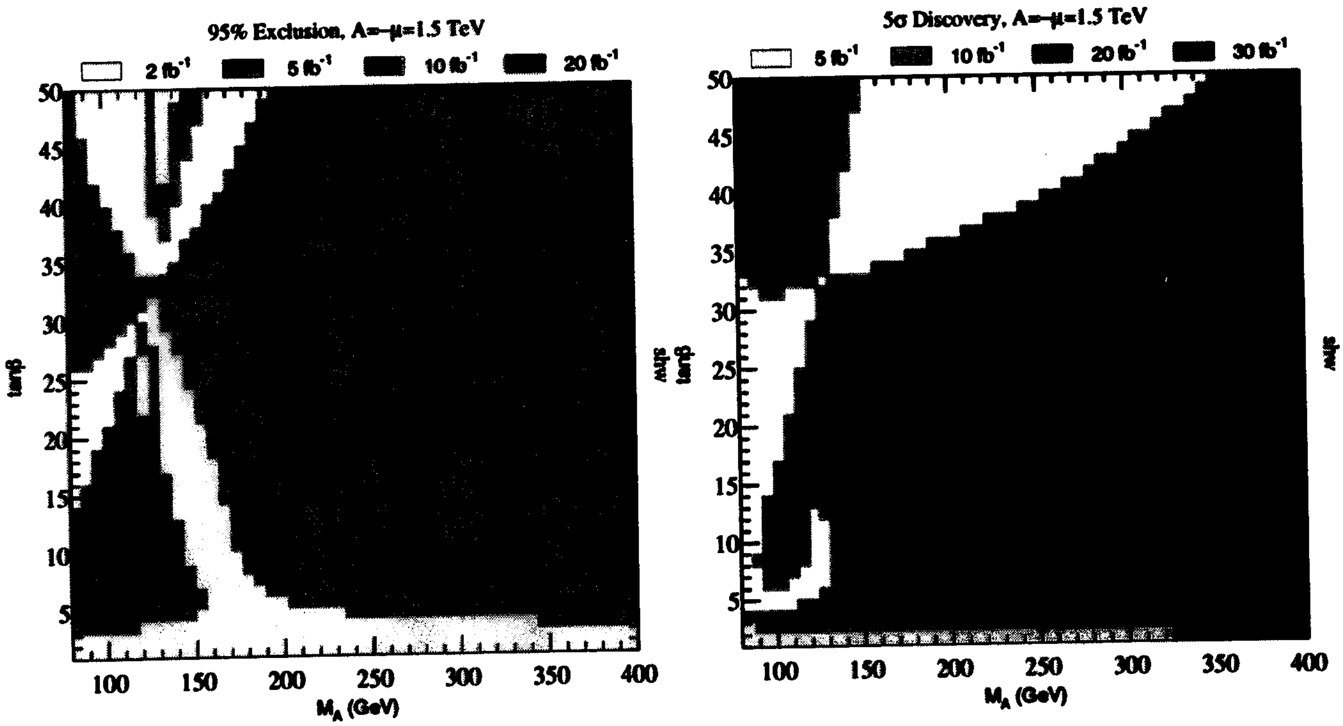


A_{max}, $M_S = 1$ TeV





$A = -\mu = 1.5$ TeV



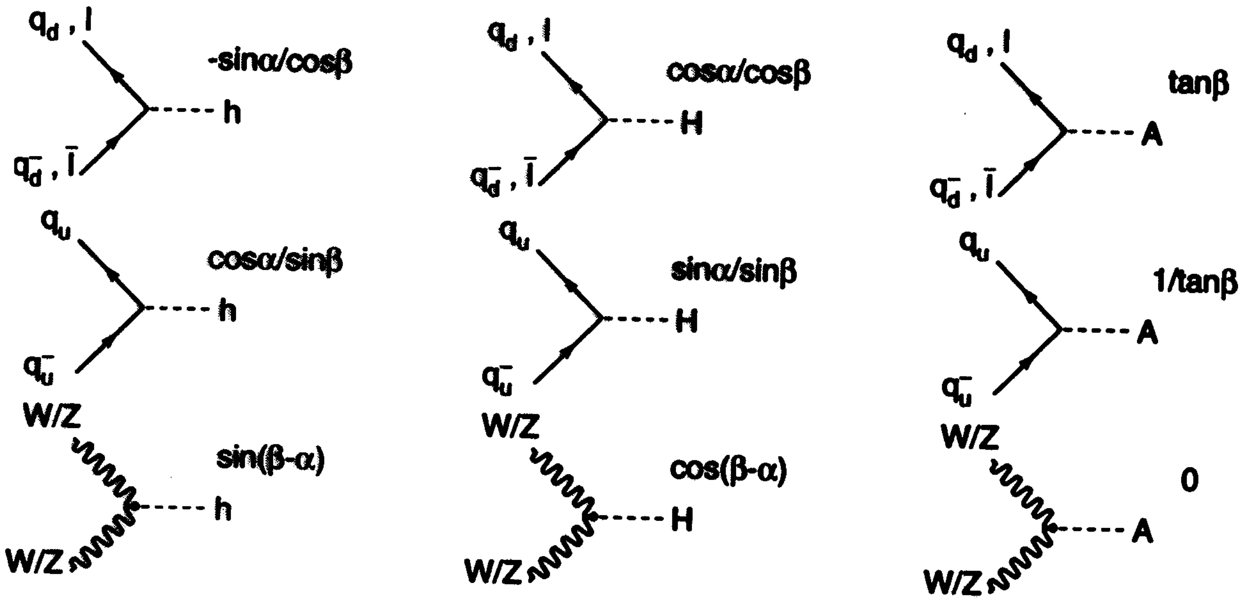
→ difficult region at large tan β

→ Higgs coupling to $b\bar{b}$ becomes small

→ $WH, H \to WW^*$ could work...studies underway

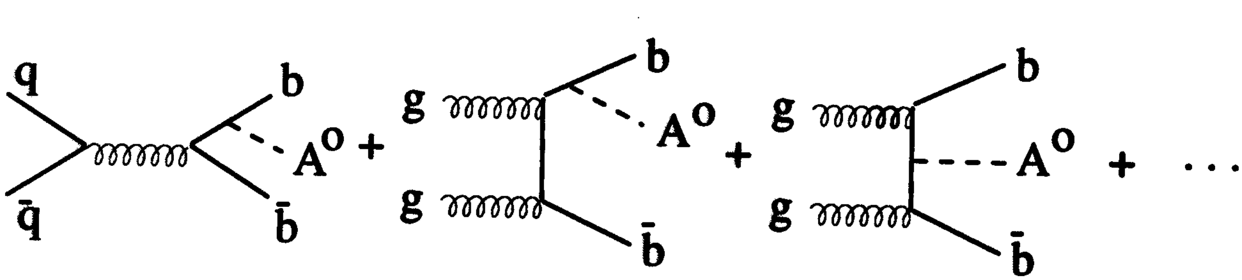
SUSY Higgs Production at large tanβ

Maria Roco, A. Belyaev, Juan Valls, John Conway, Leslie Groer



→ $b\bar{b}A/b\bar{b}h/b\bar{b}H$ enhanced at large tanβ

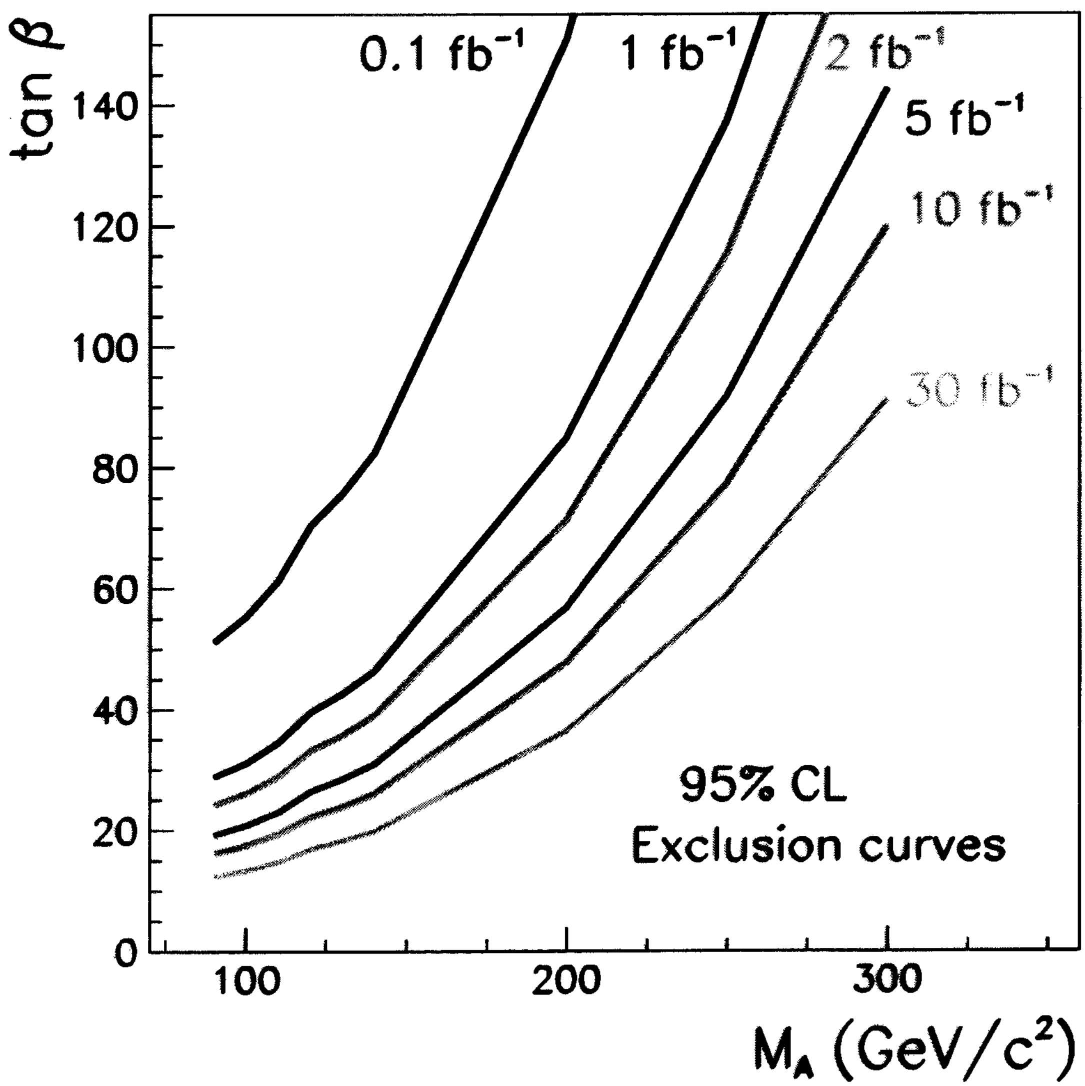
→ cross sections $\propto \tan^2\beta$



search modes:

- $b\bar{b}b\bar{b}$
- $\tau\tau j \not{E}_T$
- $\tau b j \not{E}_T$

$b\bar{b}b\bar{b}$ mode: limits in $\tan\beta$ versus m_A plane



Summary - SM Higgs

- We have greatly extended the depth and breadth of previous studies of Higgs reach at Run 2 and beyond.

- There is no single, golden discovery channel: combining all channels, and both experiments, is crucial!

- If there is no SM Higgs, we can exclude it at 95% CL up to 120 GeV mass in Run 2, and with 10 fb^{-1} can extend the exclusion up to 190 GeV mass.

- If there is a Higgs, we can discover it at the 3-5σ level with 10-30 fb^{-1} per experiment, up to 190 GeV mass.

Summary - SUSY Higgs

- Can exclude at 95% CL the entire MSSM Higgs parameter space with 10 fb^{-1}
- With 20 fb^{-1} can discover MSSM Higgs over nearly the entire space at the 5σ level

The bottom line

To do all this we need:

- better b tagging efficiency/purity
- improved $m_{b\bar{b}}$ resolution, $\sim$ 10% or better
- solid control of $Wb\bar{b}$, $Zb\bar{b}$, diboson backgrounds
- lots of data!