Progress in Experimental Aspect of Higgs and SUSY Physics with CMS at LHC

U. of Maryland

Shuichi Kunori

12-Apr-2001

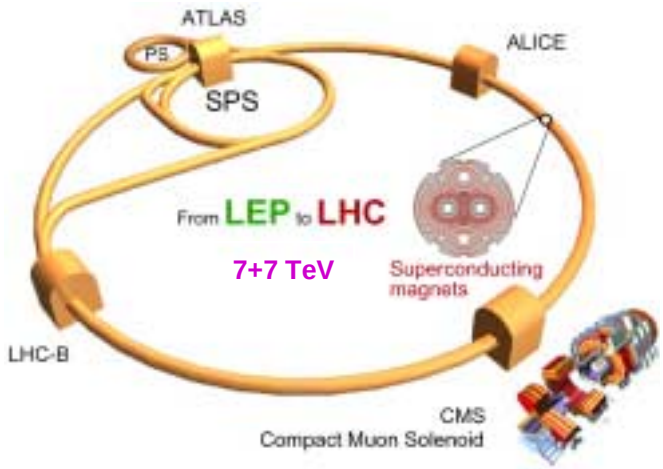
LHC and CMS

SM Higgs

MSSM Higgs

Conclusions

LHC Schedule



The magnet transport robot with
First preseries dipole (08-Feb-01)

31-Dec-05
Ring Closed and cold

01-Jan-06 to 31-Mar-06
Machine commissioning

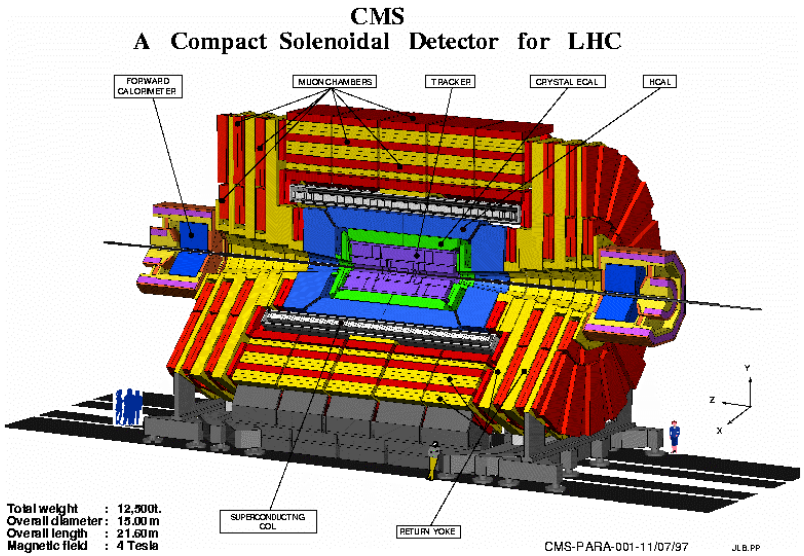
01-Apr-06 to 30-Apr-06
First collision, pilot run
$L=5\times10^{33}$ to 2×10^{33}, <1 fb^{-1}
Detector commissioning
~105 Z->ll, W->lν, tt events

1-May-06 to 31-Jul-06
Shut down:
Continue det. Installation

1-Aug-06 to 28-Feb-07
Physics run
$L=2\times10^{33}$, 10 fb^{-1}

Design luminosity :
$L=10^{34}\ cm^{-1}s^{-1}$, 100 fb^{-1} 2008 ?

CMS



Surface buildings and shaft at Point 5

1st iron yoke wheel extracted (Oct'00)

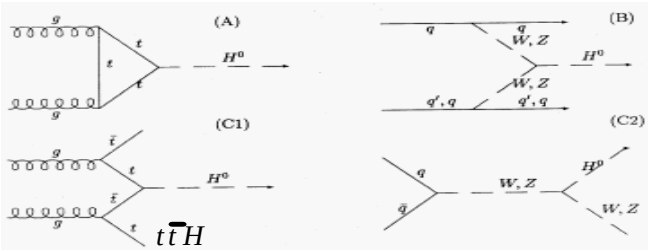
Reception of HB1 at Felguera, Spain (Oct'00)

SM Higgs

production **decay**

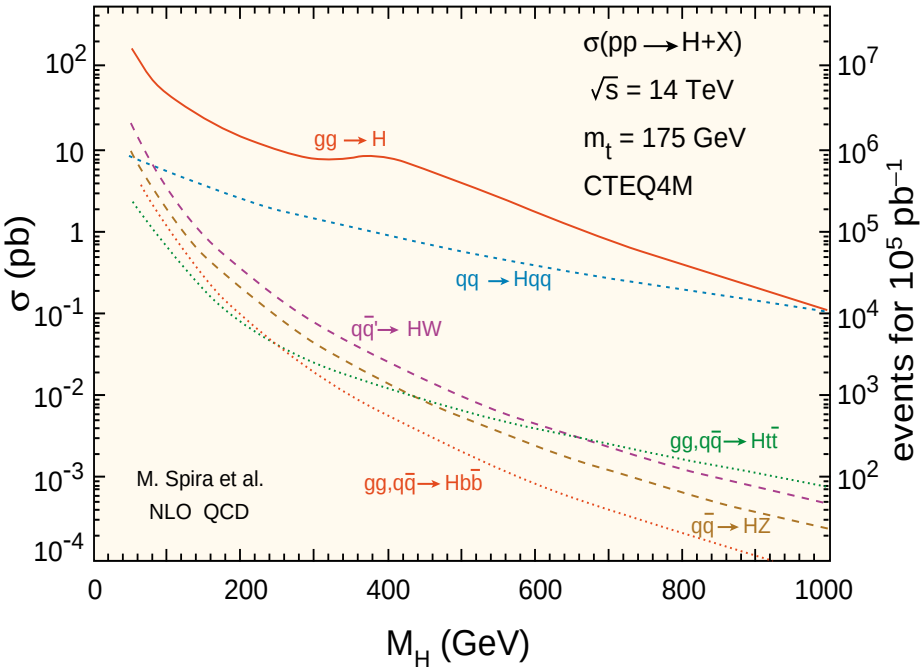
gg fusion

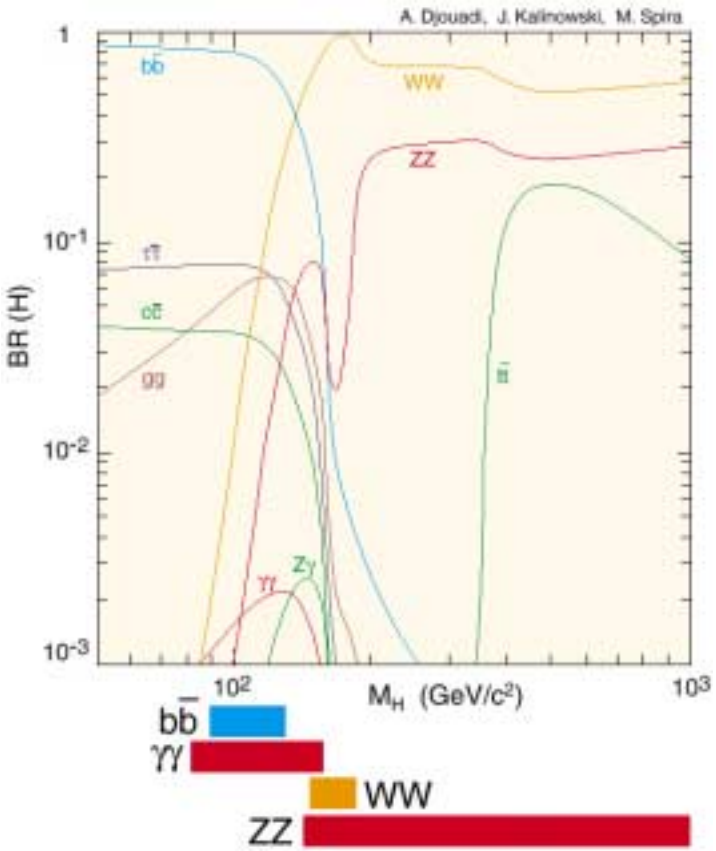
WW/ZZ fusion



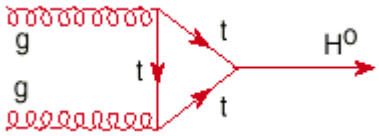
associated

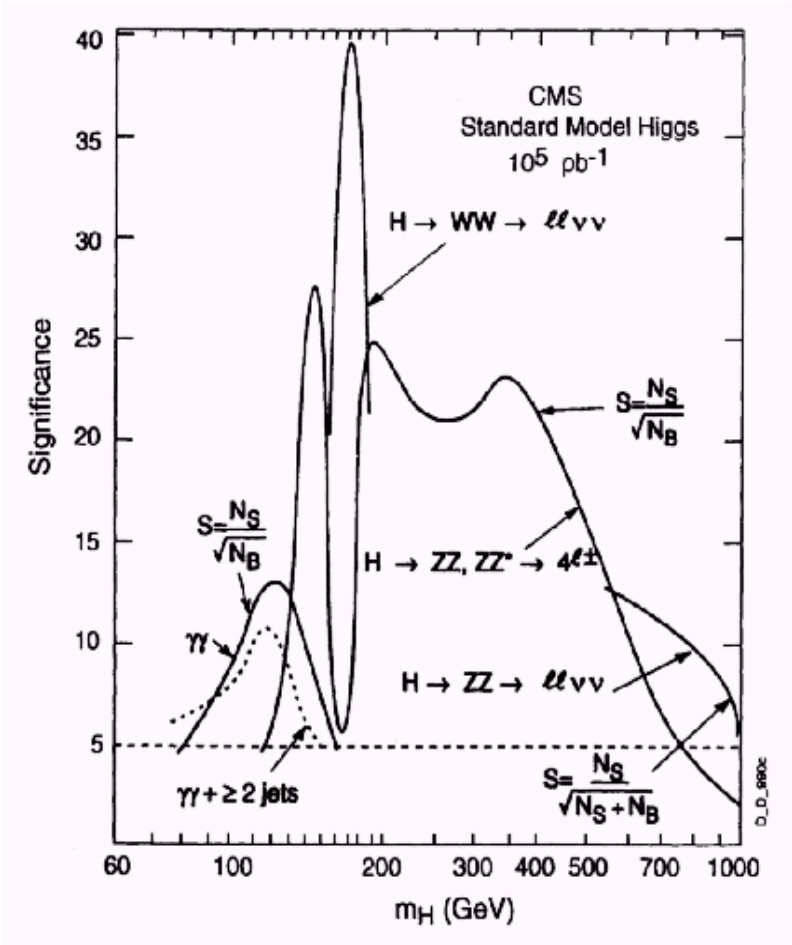
associated WH, ZH

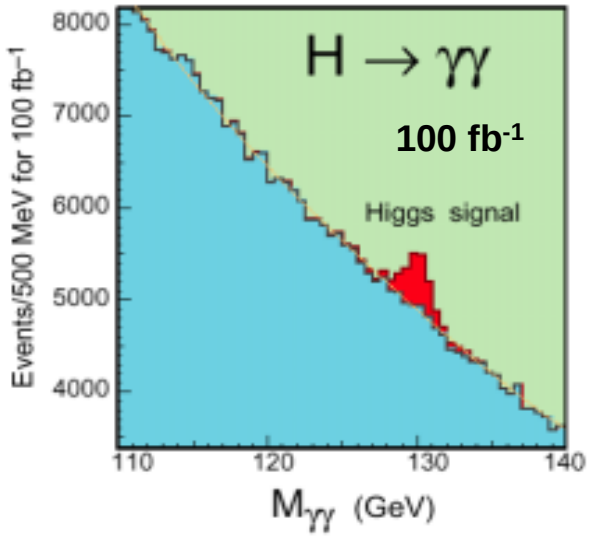


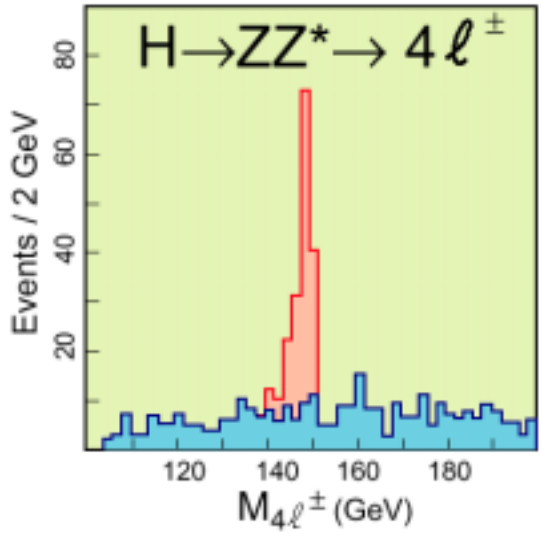


gg -> H_{SM}

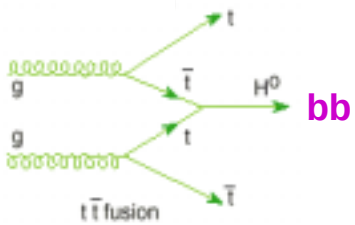

g
g
t
t
t
H0


CMS
Standard Model Higgs
10^5 pb^-1
H → WW → ℓℓνν
S = N_S / √N_B
H → ZZ, ZZ* → 4ℓ±
γγ
H → ZZ → ℓℓνν
γγ + ≥ 2 jets
S = N_S / √(N_S + N_B)
Significance
m_H (GeV)


H → γγ
100 fb^-1
Higgs signal
Events/500 MeV for 100 fb^-1
M_γγ (GeV)

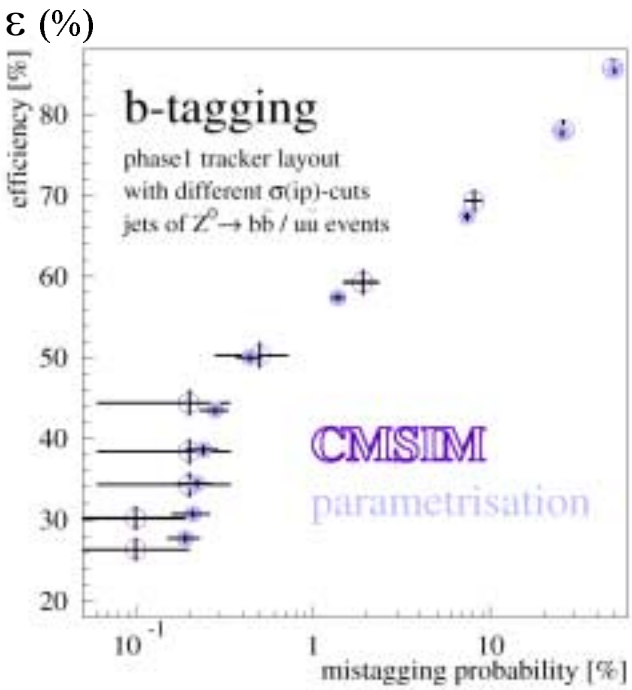

H→ZZ*→ 4ℓ±
Events / 2 GeV
M_4ℓ± (GeV)

$t\bar{t}H^0_{SM} \rightarrow l^{\pm}\nu q\bar{q}b\bar{b}b\bar{b}$



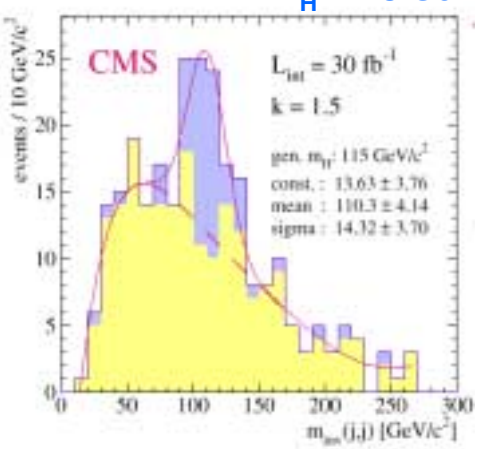
1 iso. lepton (PT>10GeV)
6 jets (*4 b tag*) (ET>20GeV)
-> max. likelihood
(b likeliness, W mass, top mass …)

Bg:
ttbb, ttjj, ttZ^0



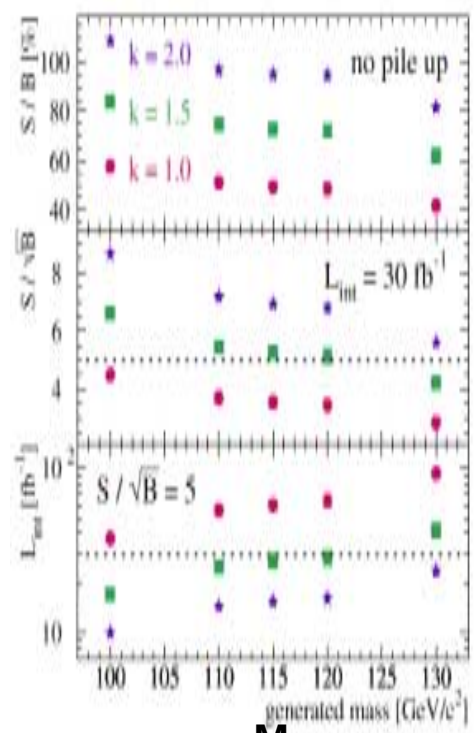
mistagging probability (%)

M_H=115 GeV



Mass(jj)

Δm/m=3.8% (stat)

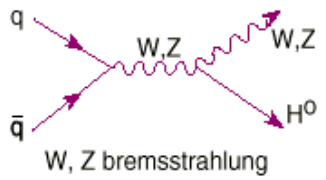


M_H

5

30fb^{-1}

$W^{\pm} H^{0}_{SM} \rightarrow l^{\pm} \nu b\bar{b}$

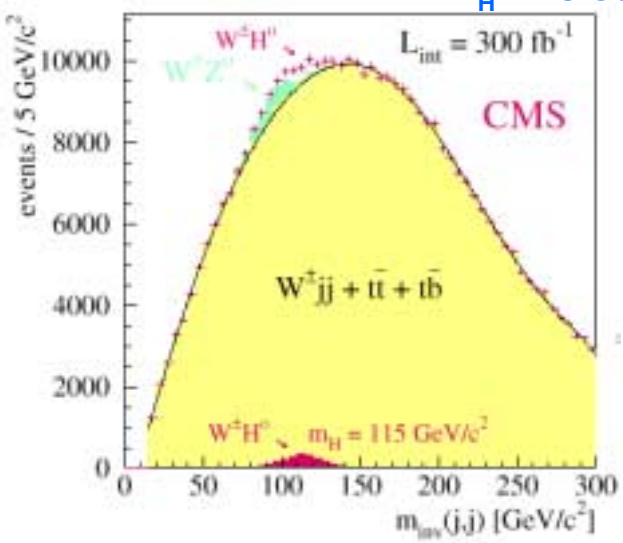


bb

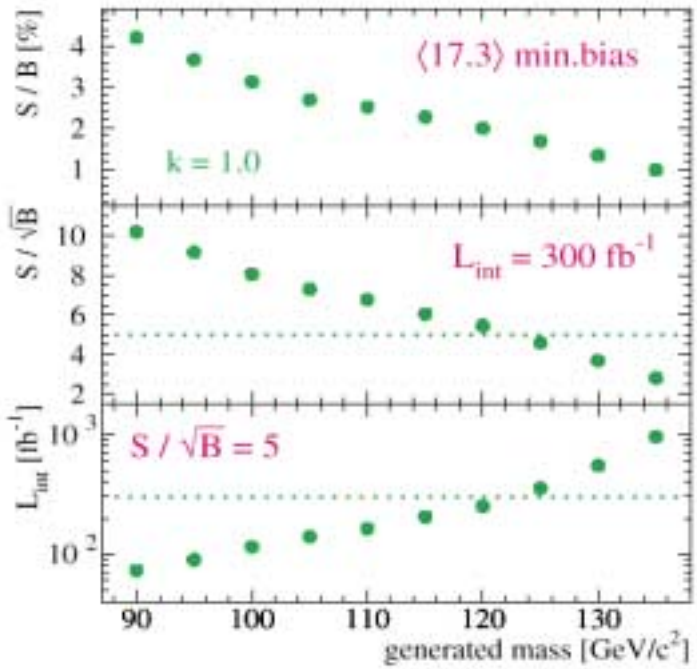
1 iso. lepton (e,μ) (P_T>20GeV)
only 2 jets (b-tag) (E_T>30GeV)
M_T(W)
-> events in higgs mass window

Bg:
Wjj, tt, tb

M_H=115 GeV



$\sigma_{W^{\pm}H^0} \times BR_{H^0 \rightarrow b\bar{b}}$	=	1.28 - 0.54 pb
m_{H^0}	=	110 - 130 GeV/c^2
$\sigma_{W^{\pm}Z^0}$	=	18.2 pb
$\sigma_{W^{\pm}jj}$	=	27.1 nb
$\sigma_{t\bar{t}}$	=	569 pb
$\sigma_{t\bar{b}}$	=	318 pb

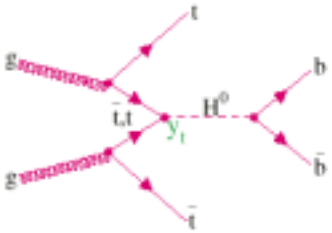


5

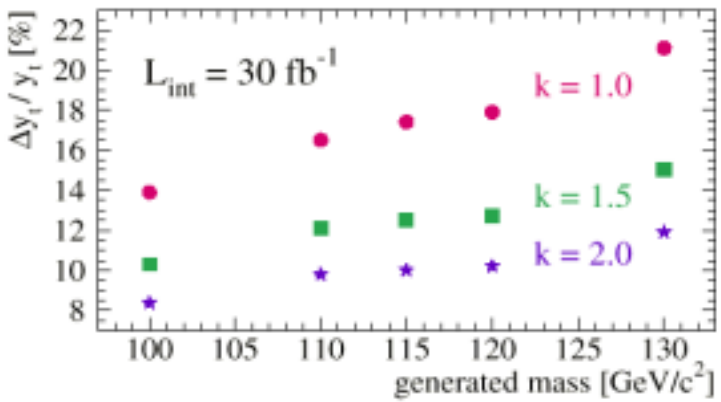
300fb^{-1}

Couplings

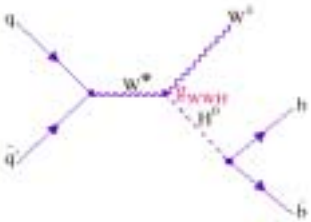
Top Higgs Yukawa Coupling



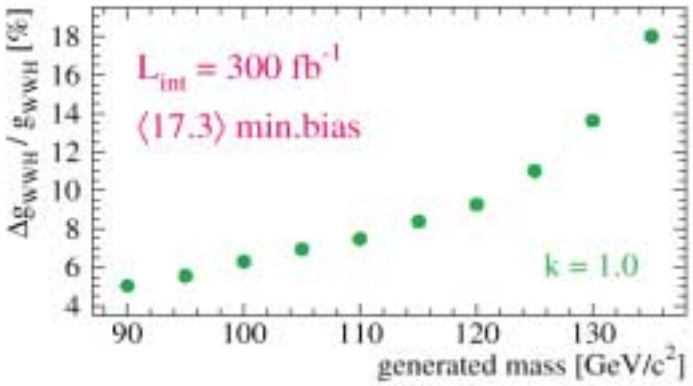
- $y_t \sim \sqrt{\sigma} \sim \sqrt{N}$
- assume known coupling to $b\bar{b}$



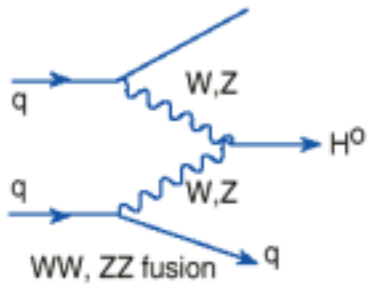
WWH Coupling



- $g_{WWH} \sim \sqrt{\sigma} \sim \sqrt{N}$
- assume known coupling to $b\bar{b}$



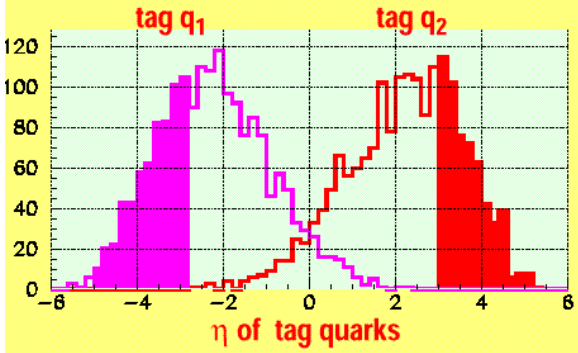
VB Fusion / Forward Jet Tag



σ ~ 10% of gg-fusion
at smaller M_H

qqH → ZZ → ll$\nu\nu$	400-1000GeV
qqH → WW → lνjj	400-1000GeV
qqH → $\tau\tau$ → (l$\nu\nu$)(jν)	100-150GeV
qqH → WW → (lν)(lν)	115-190GeV [1]
qqH_{SUSY} → invisible	110-400GeV [2]

HF acceptance for tagging quarks of E_t^q > 30 GeV		
no q	1 q	2 q's
0.47	0.46	0.07



Typical selection for forward jets

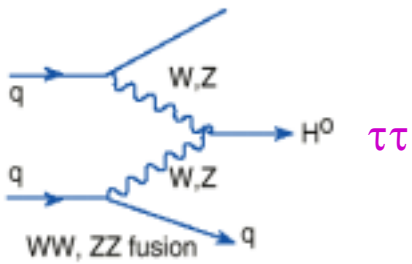
$E_t(q)$ > 40GeV, $|\eta(q)|$<5.0

$|\Delta\eta(q1q2)|$>4.4, M(q1q2) >1TeV

$\eta(q1)*\eta(q2)$<0

1) N.Kauer, T.Plehn, D.Rainwater, D.Zeppenfeld hep-ph 0012351
5σ signal with 35fb-1 for M_H~115 GeV
2) O.J.Eboil and D.Zeppenfeld, hep-ph 009158
limit: BR(invisible) 13%
Mass 480GeV (for BR~100%) with 10fb^{-1}
→ forward jet trigger

qqH, H -> 2τ -> (lνν)(jν)



Trigger:
- 1 lepton
- 1 tau-jet

Event selection:

$E_t(e,\mu) > 15GeV$, $|\eta(e,\mu)|<2.4$

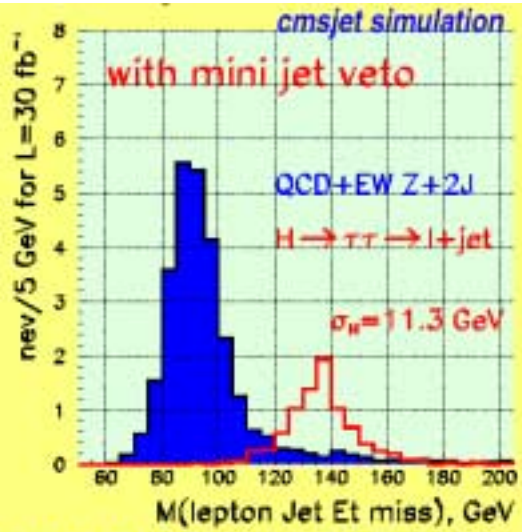
$E_t(\tau) > 30GeV$, $|\eta(\tau)|<2.4$

$E_t(q) > 40GeV$, $|\eta(q)|<5.0$

$|\Delta\eta(q1q2)|>4.4$, $M(q1q2) >1TeV$

mini-jet veto

Bg:
Zjj, Wjj, bbjj



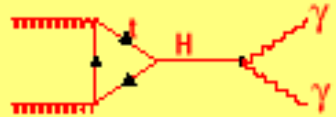
Data for 30 fb^{-1} at low luminosity running

Mass, GeV	115	125	135	145
σ, pb	4.49	4.15	3.81	3.57
Br, %	7.2	6.1	4.5	2.6
S	12.6	9.9	6.7(6.2)	3.6
B	5.5	2.3	1.5(1.1)	1.1

Higgs Couplings

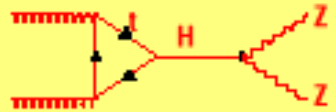
D.Zeppenfeld, R.Kinnunen, A.Nikitenko, E.Richter-Was, Phys.Rev.,D62(2000) pp13009

gg->H->γγ — M_H < 150 GeV



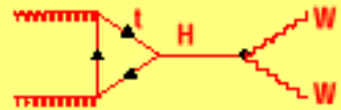
$\sim \Gamma_g(\Gamma_\gamma/\Gamma) = Y_\gamma$

gg->H->ZZ->4lept — M_H > 120 GeV



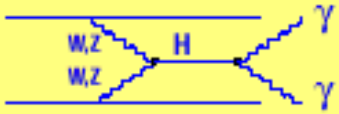
$\sim \Gamma_g(\Gamma_Z/\Gamma) = Y_Z$

gg->H->WW->2lept — M_H > 120 GeV



$\sim \Gamma_g(\Gamma_W/\Gamma) = Y_W$

qq->qqH, H->γγ — M_H < 150 GeV



$\sim \Gamma_W(\Gamma_\gamma/\Gamma) = X_\gamma$

qq->qqH, H->ττ — 100 < M_H < 150 GeV

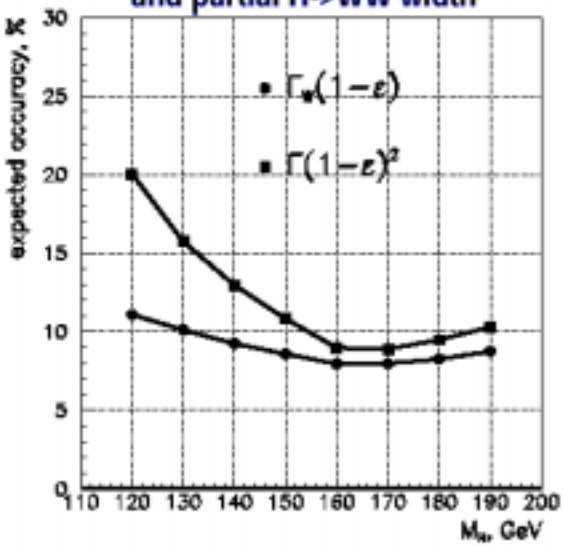
$\sim \Gamma_W(\Gamma_\tau/\Gamma) = X_\tau$

qq->qqH, H->WW->2lept — M_H > 120 GeV

$\sim \Gamma_W(\Gamma_W/\Gamma) = X_W$

Accuracy expected with 200 fb^{-1} of data with ATLAS+CMS detectors at LHC

accuracy of Higgs boson width and partial H->WW width

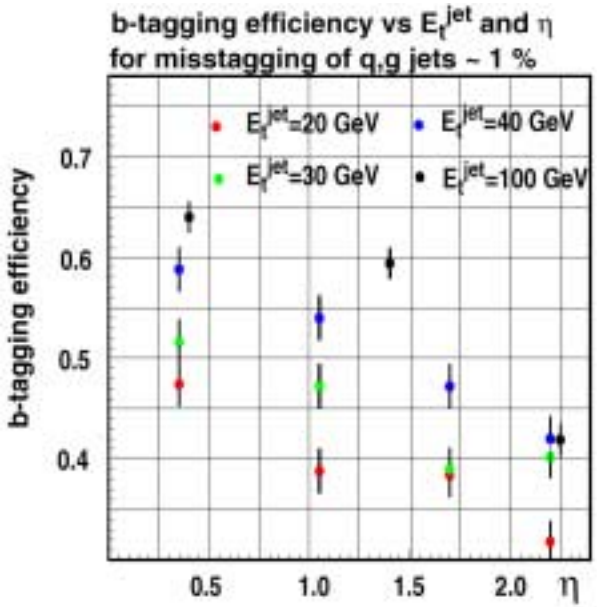


- measure Hγγ, Hττ, Hgg couplings at 10 % level
- hWW coupling can be measured at 5% level

$bbH_{SUSY} \rightarrow \tau\tau$

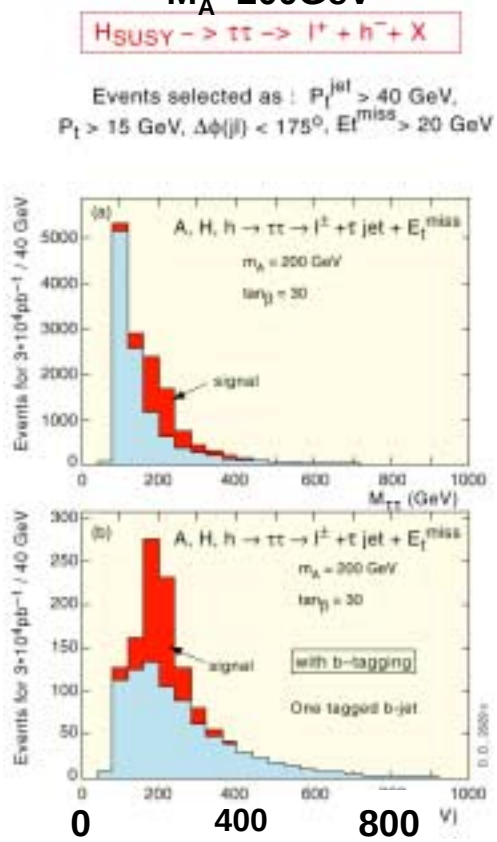
- τ-jet trigger at Level 1- 3
  calo: narrow jet, pixel: 1 charged track
  See A.Nikitenko's talk at Higgs & SUSY at Orsey
  http://www.lal.in2p3.fr/actualite/conferences/higgs2001/index.html

- b tagging

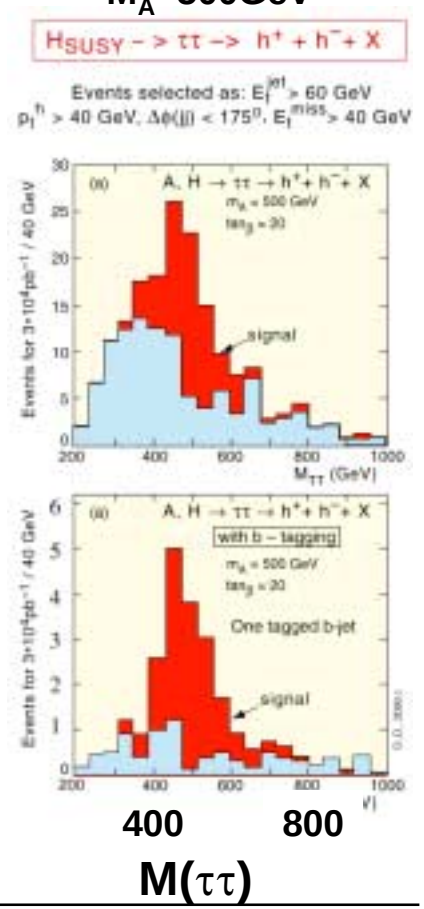


b-tag

M_A=200GeV



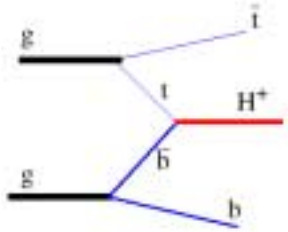
M_A=500GeV



$M(\tau\tau)$

$M(\tau\tau)$

$H^+ \to \tau\nu \to \tau$-jet in tbH



t→Wb - W, top mass window

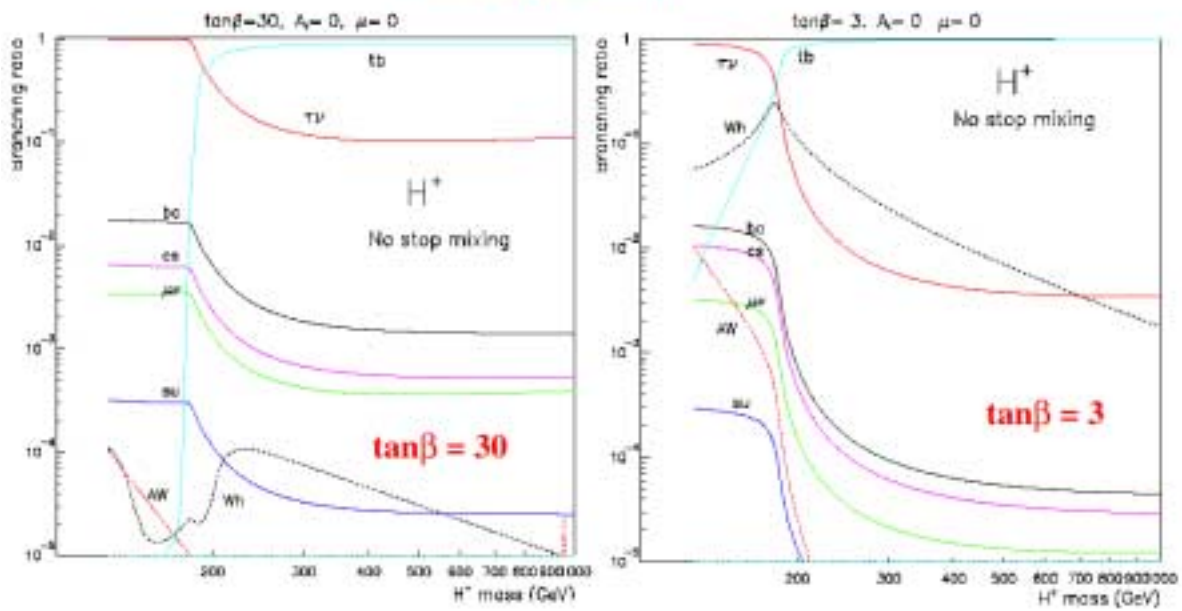
τ - tau-jet

ν - missingET

b - b tagging

bg:
tt, Wtb, Wjj

no stop mixing



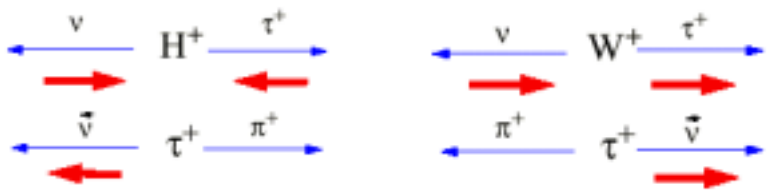
$\tau\nu$ mode is cleaner than tb mode!

$\Gamma(H^+ \to tb) / \Gamma(H^+ \to \tau\nu)$ could provide a measurement of $\tan\beta$

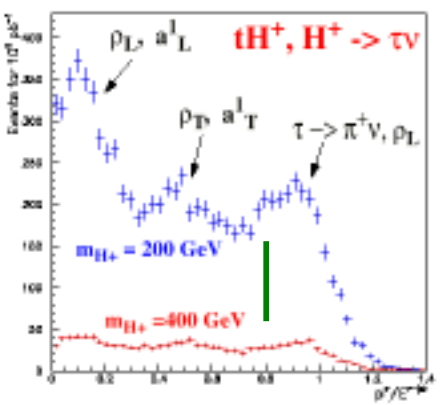
τ polarization & Δϕ cut

Tau polarization in H^+ decay

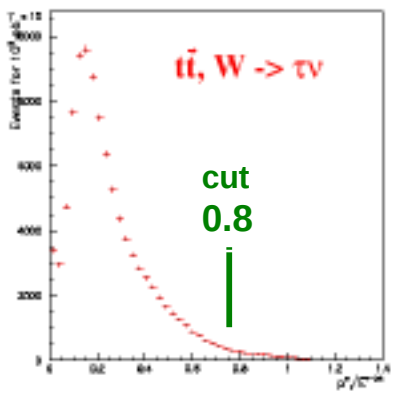
(pointed out by D.P.Roy)



Reconstructed τ-jets, $E_t^{\tau\text{-jet}} > 100$ GeV



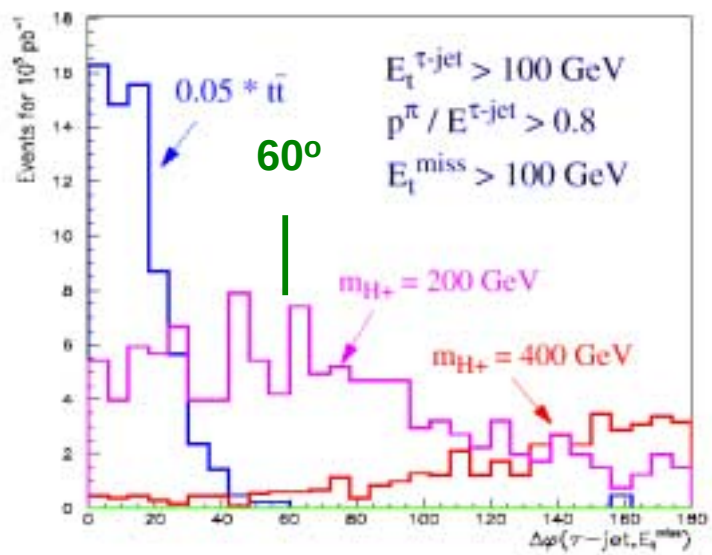
$p^\pi/E^{\tau\text{-jet}}$



$p^\pi/E^{\tau\text{-jet}}$

$\tau^+ \to \pi^+\nu$	12.5%
$\tau^+ \to \rho^+\nu \to \pi^+\pi^0\nu$	26%
$\tau^+ \to a_1\nu \to \pi^+\pi^0\pi^0\nu$	7.5%

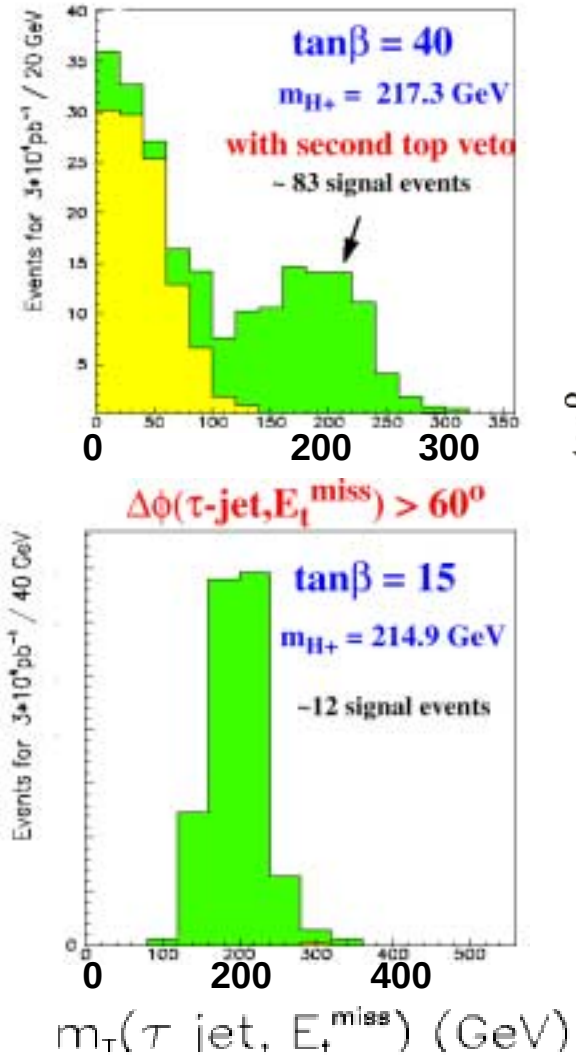
$\Delta\phi > 60^o$ cut



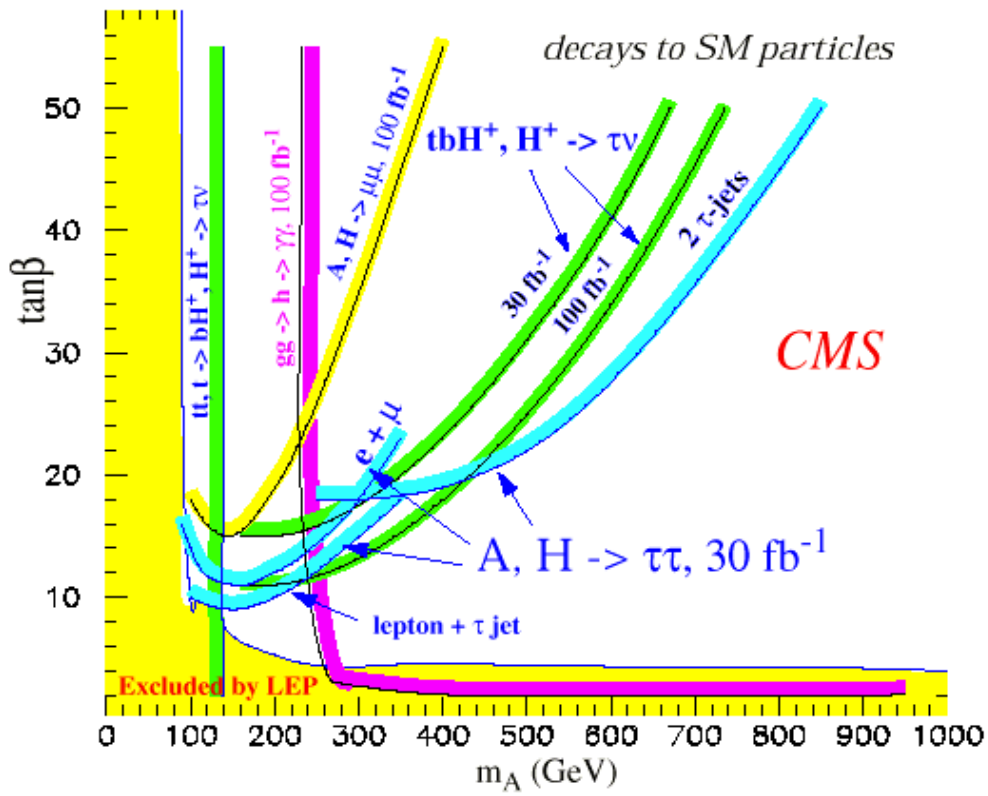
$\Delta\phi(\tau\text{-jet}, E_t^{miss})$

Mass and Discovery potential

M_A=200GeV, 30fb^{-1}



5s significance countours



$H^0, A^0 \rightarrow \chi_2^0 \chi_2^0 \rightarrow 4\,l$

MSSM parameters: $M2 = 120$ GeV, $M1 = 60$ GeV,
$\mu = -500$ GeV, $M_{\tilde{l}} = 250$ GeV, $M_{\tilde{q},\tilde{g}} = 1000$ GeV

4 iso. Lept (Pt<80GeV)
20 < MissEt < 130GeV
ET jet <100 GeV

bg

SM : ZZ, $Zb\bar{b}$, $Zc\bar{c}$, $t\bar{t}$, Wtb
SUSY : $\tilde{q}/\tilde{g}$, $\tilde{l}\tilde{l}$, $\tilde{\nu}\tilde{\nu}$, $\tilde{q}\tilde{\chi}$, $\tilde{\chi}\tilde{\chi}$

Low $\tan\beta$:

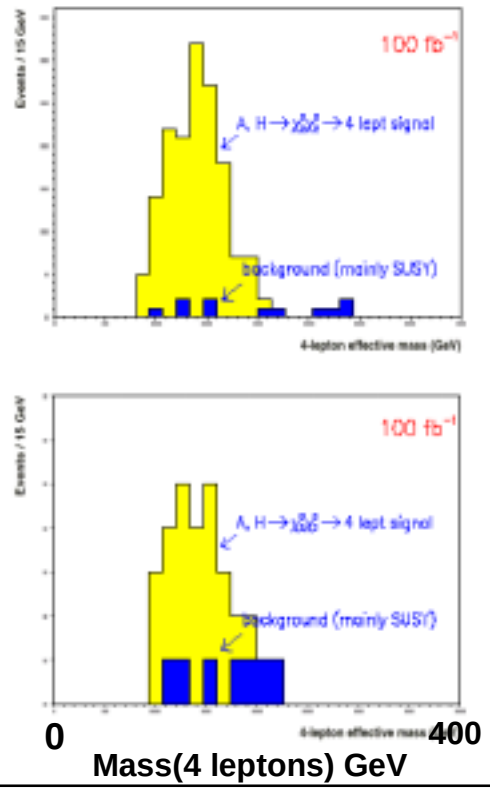
$M_A = 350$ GeV

$\tan\beta = 5$

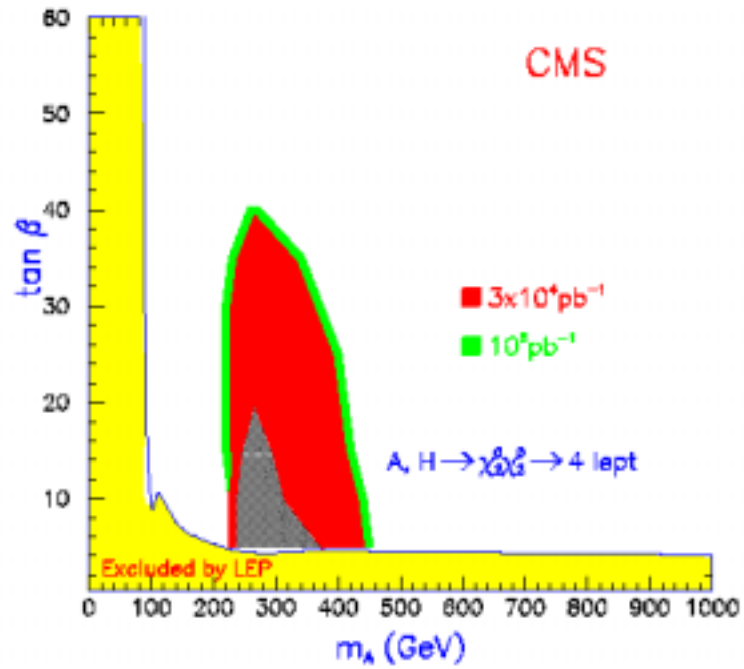
High $\tan\beta$:

$M_A = 350$ GeV

$\tan\beta = 35$



5s significance contours



Conclusions

LHC and CMS

- Many components have been already built and assembled.
- First physics run: Aug.2006 –Feb.2007 for $10fb^{-1}$.

SM Higgs

- Full mass range is covered for 5σ discovery.

MSSM Higgs

- Whole parameter space will be covered with 30fb-1, except 'void' around M_A~200, tanβ~8 (which requires higher luminosity or improved acceptance or new channels.)

On going/future studies

- Focus has been shifted from 'discovery' to 'measurement of Higgs/SUSY parameters'.

  Adding new channels: e.g.

  WBF (qqH) channels: $H \rightarrow \tau\tau$, WW($l\nu l\nu$), invisible…. more

  Improving/developing new algorithms (low → high luminosity)

  trigger and identification – tau, forward-jet, b-jet

  resolution and energy scale - jets and missingEt