Higgs Bosons in the NMSSM

An additional gauge singlet S, whose vev $\langle S \rangle$ explains the supersymmetric Higgs mass parameter μ of the MSSM

$\rightarrow$ The simplest supersymmetric extension of the SM with a scale invariant superpotential

$\rightarrow$ 3 CP-even (h, S, H), 2 CP-odd neutral Higgs bosons (A_1, A)

Typically: heavy H, A as in the MSSM, but:

1) possibly strong mixings of the CP-even states h and $S \rightarrow H_1,\ H_2$

2) possibly a light singlet-like CP-odd state A_1

Consequences of 1): A mostly SM-like Higgs boson H_2 can have a mass well above 130 GeV (contrary to the MSSM)

BUT: Reduced production cross section of H_2 due to mixing with S

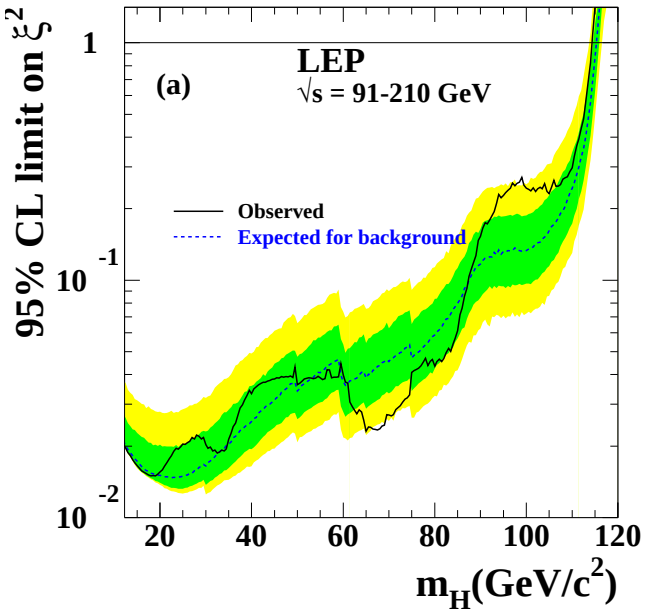
$\rightarrow$ reduced coupling to top-quarks/gluon-gluon
(possibly slightly enhanced BRs into WW/ZZ (by $\sim 10\%$)
and into $\gamma\,\gamma$(by $\sim 20\%$) due to a reduced width into $b\,\bar{b}$)

$\rightarrow$ Always accompanied by a lighter Higgs boson H_1 with reduced coupling $\xi_1 < 1$ to electroweak bauge bosons

Examples with max. prod. x-sect. ($\lambda \sim 0.7$, $\tan\beta \sim 2.7$):

M_{H_2}	140 GeV	145 GeV	150 GeV
Prod. x-sect/SM:	86%	77%	58%
M_{H_1}	91 GeV	97 GeV	115 GeV
ξ_1^2	0.16	0.25	0.46

Note:
M_{H_1} and ξ_1 are consistent with LEP constraints, which are particularly weak for $M_{H_1} \sim 90 - 100$ GeV



Lesson: A Higgs Boson in the $135 - 150$ GeV range, albiet with reduced production cross section, would not contradict supersymmetry (but can be a signal for the NMSSM); look for H_1 with $M_{H_1} > M_Z$ in the $\gamma\gamma$ mode!

Consequences of 2):
The mostly SM-like Higgs boson h would decay dominantly into $h \to A_1\, A_1 \to \ldots$ depending on M_{A_1}:

a) If $M_{A_1} \gtrsim 10.5$ GeV: $A_1 \to b\,\bar{b}$ ($\tau^+\,\tau^-$ subdominant)

b) If 9.2 $GeV \lesssim M_{A_1} \lesssim 10.5$ GeV: $A_1 \to gluon\ gluon$ (A_1 mixes with η_b)

c) If $M_{A_1} \lesssim 9.2$ GeV: $A_1 \to \tau^+\,\tau^-$ ($\mu^+\,\mu^-$ subdominant)

$\to$ $M_h < 114$ GeV can be consistent with constraints from LEP (Dermisek/Gunion), but all ranges for M_h and M_{A_1} are possible!

Have to look for

a) $h \to A_1\, A_1 \to 4\,b$ (or $b\,\bar{b} + \tau^+\,\tau^-$)
b) $h \to A_1\, A_1 \to 4\,gluons$
c) $h \to A_1\, A_1 \to 4\,\tau$ (or $\tau^+\,\tau^- + \mu^+\,\mu^-$?)

and/or single A_1 production!

Available studies of Higgs-to-Higgs decays and single A_1 production at the LHC (see the summary in 1108.0157), for different ranges of M_{A_1}

(CEP stands for central exclusive production.)

X* indicates that, apart from signal rates, signal and background processes have been simulated or estimated.

X** indicates that, in addition, the detector response has been included in the study.

M_{A_1}:	$\gtrsim 10.5$ GeV			$\lesssim 10.5$ GeV		$< 2\,m_\tau$
$h \to A_1\,A_1$						
Final state:	$4b$	$2b + 2\tau$	4γ	4τ	$2\tau + 2\mu$	4μ
	h production mode:					
VBF:		X*, X**		X*, X**		
$W/Z + h$:	X*, X*	X		X*, X*		
gg:			X*		X*	X*
CEP:				X**		
$b\bar{b}h$:	X	X	X	X		X*
Single A_1 production						
Final state:	$2b$	2τ	2μ	2γ	2τ	2μ	2μ
	A_1 production mode:						
gg:						X*	
$b\bar{b}A_1$:	X*	X*	X*	X*	X*	X*	X*
$H^\pm \to W^\pm A_1$	X				X		

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Note: Studies including detector responses are missing in most cases; "X" does not mean that discovery is guaranteed!

See also: NMSSM Higgs production in Susy cascade decays (Stal, Weiglein, . . .)

Note: The case $h \to A_1\, A_1 \to 4\, gluons$ requires the study of jet substructure from "boosted" Higgs decays from ass. $W + h$ production with high p_T-lepton from W; also useful for b/τ final states!

Lesson: The complete ranges for M_h and M_{A_1} should be covered by studies including detector responses (realistic b-tagging/ τ-tagging)!