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NMSSM Benchmarks for Charged Higgses

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From MSSM to the NMSSM

The Higgs sector of the MSSM contains a soft SUSY breaking term $\sim \mu H_u H_d$ - μ exists in the Superpotential before EWSB so natural value would be either 0 or M_P - both phenomenologically unfeasible

This 'μ-problem' is elegantly addressed in the Next-to-Minimal Supersymmetric Standard Model (NMSSM), described by

$$W = \hat{Q}\hat{H}_u \mathbf{h_u} \hat{U}^C + \hat{H}_d \hat{Q} \mathbf{h_d} \hat{D}^C + \hat{H}_d \hat{L} \mathbf{h_e} \hat{E}^C + \lambda \hat{S}(\hat{H}_u \hat{H}_d) + \frac{1}{3}\kappa \hat{S}^3$$

(Do not consider here nMSSM, MNSSM – $\kappa = 0$ and linear terms are present instead.)

A new singlet Higgs field S is introduced and $B\mu H_u H_d$ gets replaced by an interaction term $\lambda A_\lambda S(H_u H_d)$, so that EWSB yields a VEV to S naturally of the order of M_{SUSY} or M_W along with the other two Higgs fields; generating an 'effective μ-parameter':

$$\boxed{\mu_{\mathrm{eff}} = \lambda < S >}$$

$$-\mathcal{L}_{\rm soft} \supset m_{H_u}^2|H_u|^2 + m_{H_d}^2|H_d|^2 + m_S^2|S|^2 + \left(\lambda A_\lambda S H_u H_d + \frac{1}{3}\kappa A_\kappa S^3 + \text{h.c.}\right) ,$$

where, like A_λ, A_κ is a dimensionful coefficient of order $\sim M_{\rm SUSY}$.

After employing the minimization conditions for the Higgs potential and demanding the known value of the Z mass, the parameters specifying the Higgs sectors in the NMSSM are as follows.

$$\boxed{\lambda, \quad \kappa, \quad A_\lambda, \quad A_\kappa, \quad \mu = \mu_{\rm eff}, \quad \tan\beta\ .}$$

The upper limit on the lightest Higgs mass is now:

$$M_{H_1}^2 \leq M_Z^2 \cos^2(2\beta) + \frac{2\lambda^2 M_W^2}{g^2}\sin^2(2\beta) + \epsilon,$$

The NMSSM relaxes the LEP bound on M_{H_1}. Due to the second term in red above.

Effect pronounced at moderate $\tan\beta$

$$M^2_{H^+} = M^2_A + M^2_W\left(1 - \frac{2\lambda^2}{g^2}\right)$$

A limit on $M_{H^\pm}$ is possible **only** a limit on λ is possible.

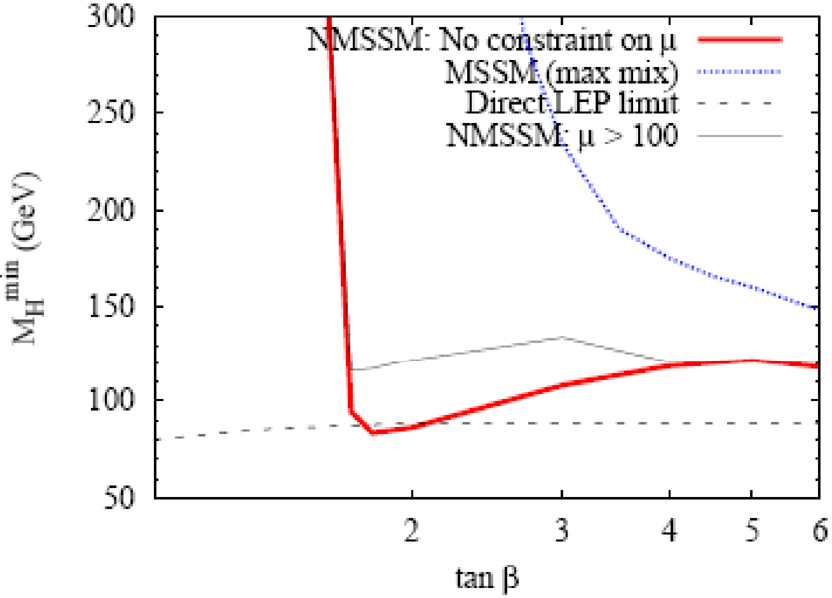
Such a limit obtained by demanding that all couplings remain perturbative upto some high scale.

Apart from λ, κ and x, one also has the soft SUSY breaking parameters: A_λ, A_κ.

We obtain a limit by varying all these parameters of the NMSSM potential, imposing LEP constraints.

Direct LEP bound is also shown.

For $\tan\beta \leq 6(4)$ $M_{H^+} > 150(175)$ GeV for MSSM. In NMSSM a $H^\pm$ with mass less than 120 GeV allowed over this range.



Godbole/Roy, 2005

Conventions: $\mu = \lambda x$ $x = \langle S \rangle$

NMSSM Benchmarks for H+ searches

1. If ($M_{H^+} \sim 120$ GeV) one has a dominantly singlet H_1 with ($M_{H_1} \sim 50$ GeV). Thus this H_1 will evade LEP searches and will be difficult to produce at LHC as well. There is a light (50 GeV) pseudoscalar A_0 with significant doublet component. Such $H^\pm$ can be searched through $H^+ \to \tau^+\nu$.

2. ($M_{H^\pm} > 130$ GeV), (in this $\tan\beta$ range), decays dominantly via the $H^+ \to W^+ A_1^0$. This is a good channel for the $H^\pm$ as well as A_1^0 search.

$\tan\beta$	M_{H^+} (GeV)	M_{A_1} (GeV)	B_{A_1} (%)	λ, κ	$x = v_s/\sqrt{2}, A_\lambda, A_\kappa$ (GeV)
2	147	38	94	.45,-.69	224,-8,2
3	159	65	83	.33,-.70	305,40,38
4	145	48	89	.28,-.70	563,170,85
5	150	10	91	.26,-.54	503,109,38

Interesting new phenomenology for a light charged Higgs boson at the LHC

Benchmark scenarios for the NMSSM

A. Djouadi[1,2,3], M. Drees[3], U. Ellwanger[1], R.Godbole[4], C. Hugonie[5], S.F. King[2], S. Lehti[6], S. Moretti[1,2], A. Nikitenko[7], I. Rottländer[3], M. Schumacher[8], A. M. Teixeira[1]

P5 cannot be a benchmark for
BR(H+ -> W+A1)~1x10^3 &
BR(H+ -> W+H1)~1x10^2

NMSSMTools from Ellwanger et al. include constrained/universal NMSSM version with RGE evolution, in addition to test all exp. bounds and generating all EW level spectra of couplings and masses as well as all decay rates

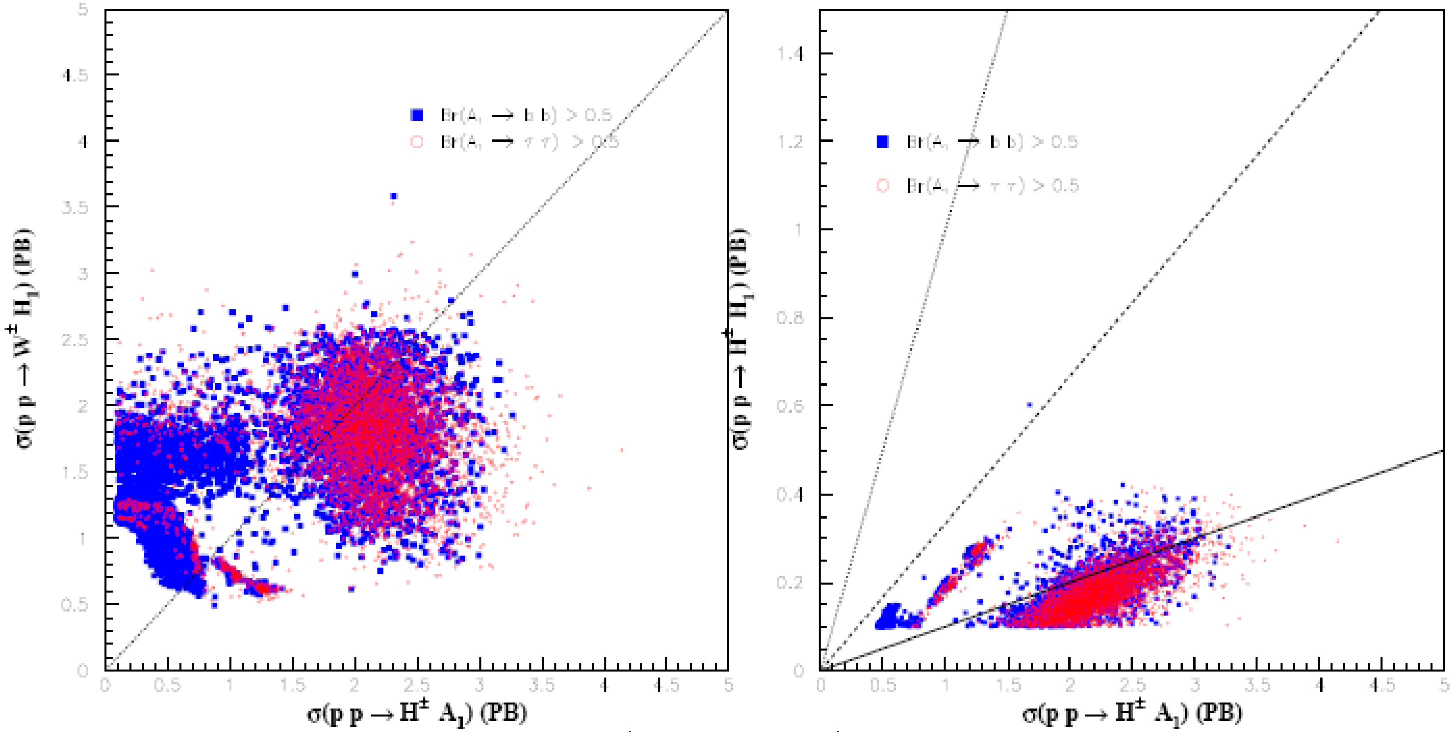
Output can be fed into a public NMSSM CalcHEP/Pythia event generator via SLHA2

Proper simulations could be done right now !

Point	P1	P2	P3	P4	P5
GUT/input parameters					
sign($\mu_{\rm eff}$)	+	+	+	−	+
$\tan\beta$	10	10	10	2.6	6
m_0 (GeV)	174	174	174	775	1500
$M_{1/2}$ (GeV)	500	500	500	760	175
A_0	-1500	-1500	-1500	-2300	-2468
A_λ	-1500	-1500	-1500	-2300	-800
A_κ	-33.9	-33.4	-628.56	-1170	60
NUHM: M_{H_d} (GeV)	-	-	-	880	-311
NUHM: M_{H_u} (GeV)	-	-	-	2195	1910
Parameters at the SUSY scale					
λ (input parameter)	0.1	0.1	0.4	0.53	0.016
κ	0.11	0.11	0.31	0.12	-0.0029
A_λ (GeV)	-982	-982	-629	-510	45.8
A_κ (GeV)	-1.63	-1.14	-11.4	220	60.2
M_2 (GeV)	392	392	393	603	140
$\mu_{\rm eff}$ (GeV)	968	968	936	-193	303
CP even Higgs bosons					
$m_{h_1^0}$ (GeV)	120.2	120.2	89.9	32.3	90.7
R_1	1.00	1.00	0.998	0.034	-0.314
t_1	1.00	1.00	0.999	0.082	-0.305
b_1	1.018	1.018	0.975	-0.291	-0.644
BR($h_1^0 \to b\bar{b}$)	0.072	0.056	7×10^{-4}	0.918	0.895
BR($h_1^0 \to \tau^+\tau^-$)	0.008	0.006	7×10^{-5}	0.073	0.088
BR($h_1^0 \to a_1^0 a_1^0$)	0.897	0.921	0.999	0.0	0.0
$m_{h_2^0}$ (GeV)	998	998	964	123	118
R_2	-0.0018	-0.0018	0.005	0.999	0.927
t_2	-0.102	-0.102	-0.095	0.994	0.894
b_2	10.00	10.00	9.99	1.038	2.111
BR($h_2^0 \to b\bar{b}$)	0.31	0.31	0.14	0.081	0.87
BR($h_2^0 \to t\bar{t}$)	0.11	0.11	0.046	0.0	0.0
BR($h_2^0 \to a_1^0 Z^0$)	0.23	0.23	0.72	0.0	0.0
$m_{h_3^0}$ (GeV)	2142	2142	1434	547	174
CP odd Higgs bosons					
$m_{a_1^0}$ (GeV)	40.5	9.1	9.1	185	99.6
t_1'	0.0053	0.0053	0.0142	0.0513	-0.00438
b_1'	0.529	0.528	1.425	0.347	-0.158
BR($a_1^0 \to b\bar{b}$)	0.91	0.	0.	0.62	0.91
BR($a_1^0 \to \tau^+\tau^-$)	0.085	0.88	0.88	0.070	0.090
$m_{a_2^0}$ (GeV)	1003	1003	996	546	170
Charged Higgs boson					
$m_{h^\pm}$ (GeV)	1005	1005	987	541	188

Establish a benchmark from Abdesslam's scans ?

$\mathrm{Br}(H^{\pm} \to W^{\pm} A_1)$ and $\mathrm{Br}(h_1 \to A_1 A_1) \gtrsim 50\%$



It is possible to have $pp \to H^{\pm}A_1 \to W^{\pm}A_1A_1 \to \{W4b, W4\tau\}$ and $pp \to W^{\pm}h_1 \to W^{\pm}A_1A_1 \to \{W4b, W4\tau\}$ with sizeable cross sections.

WG Members

- Stefano Moretti (CMS)
- Martin Flechl (ATLAS)
- Nazila Mahmoudi (Theory)
- Arhrib Abdesslam (Theory)

Others welcome to join, contact myself or Martin.

Backup Slides

Some interesting NMSSM scenarios for the Charged Higgs sector
(to be discussed in Benchmark Break-out Session)

Must be different from MSSM:

1) H+ -> W+A1 (a la Godbole/Roy) but also WH1 & WH2

2a) H3/A2 -> W-H+

2b) H3 -> H+H- (by CPC, A cannot decay to 2 charged Higgses!)

3) m+ ≠ mA (mH+ just above mH2 and mA1, H3, A2 heavy and singlet)

4) m+ << mt-mb (a la Godbole/Roy)

5) m+ > mt-mb, all other Higgses < mt

	no constraints			SUSY, Higgs + theory			all constraints		
	# points	$\tan(\beta)$	m_{H+}	# points	$\tan(\beta)$	m_{H+}	# points	$\tan(\beta)$	m_{H+}
BMP1	100k	1	90	30k	1.4	170	15k	15	250
BMP2a	380k	1	70	170k	1.4	160	80k	15	210
BMP2b	90k	1	70	24k	1.6	170	7k	16	210
BMP3	44k	1	70	6k	3	160	2k	18	215
BMP4	13k	1	70	3	18	160	-	-	-
BMP5	3	10	180	-	-	-	-	-	-

NMSSM (weak scale). Soft masses for sleptons at 1 TeV, 2.5 TeV for trilinears and 150 GeV, 300 GeV, 1TeV for M1, M2, M3 risp. I then randomly scanned on lambda, kappa, Alambda, Akappa, mu and tan(beta), taking 10^9 points. Positive mass squared for all scalars, all exp. constraints (LEP/Tevatron limits, b->sγ, g–2, etc.)