LHC phenomenology of light pseudoscalars in the NMSSM, 1409.8393, 1503.04228

N.-E. Bomark[1]
S. Moretti[2], S. Munir[3], L. Roszkowski[1]

[1]NCBJ, Warsaw
[2]University of Southampton
[3]APCTP, Pohang

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Outline

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Why the NMSSM?

- The NMSSM relates the only dimensionful supersymmetric parameter, μ, to the soft SUSY breaking scale.
- Additional contributions to the Higgs mass makes it easier to accomodate the measure 125 GeV, as compared to the MSSM.
- The potential presence of light singlet-like scalars and/or pseudoscalars (as well as singlino) may significanty alter the phenomenology.

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Light pseudoscalar

NMSSM has 3 neutral scalars and 2 neutral pseudoscalars.
The H_{SM} is the non-singlet-like of H_1 and H_2.
The singlet-like scalar and pseudoscalar might be very light without conflict with data.
m_{A_1} is essentially a free parameter in the theory.
m_{A_2}, m_{H_3} and $m_{H^\pm}$ are all similar and typically $\gtrsim$ 400 GeV.

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Detecting a light pseudoscalar

- Indirect effects in B-physics may be seen for $m_{A_1} < 10$ GeV.
- Direct production through associated production, $b\bar{b}A_1$. But looks unlikely, maybe feasible for $m_{A_1} < 10$ GeV.
- Indirect production; e.g. $H \to A_1 A_1$ and $H \to A_1 Z$.

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The scan

Bayesian scan using MultiNest, see 1409.8393 for details.

- $122 < m_{H_{\rm SM}} < 129$ GeV,
- $m_{A_1} \lesssim 150$ GeV,
- $\Omega_\chi h^2 < 0.131$,
- $\mathrm{BR}(\mathrm{B_s} \to \mu^+\mu^-) = (3.2 \pm 1.35 \pm 0.32) \times 10^{-9}$,
- $\mathrm{BR}(\mathrm{B_u} \to \tau\nu) = (1.66 \pm 0.66 \pm 0.38) \times 10^{-4}$,
- $\mathrm{BR}(b \to s\gamma) = (3.43 \pm 0.22 \pm 0.21) \times 10^{-4}$.

ATLAS: $\mu^{\gamma\gamma} = 1.57^{+0.33}_{-0.28}\,,\, \mu^{ZZ} = 1.44^{+0.40}_{-0.35}$.
CMS: $\mu^{\gamma\gamma} = 1.13 \pm 0.24\,,\, \mu^{ZZ} = 1.0 \pm 0.29$.

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Analyses

Analyses done using MadGraph (for backgrounds), pythia and fastjet.
All events must satisfy:

- $|\eta| < 2.5$ for all final state objects,
- $p_T > 15$ GeV for all final state objects,
- $\Delta R \equiv \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} > 0.2$ for all b-quark pairs,
- $\Delta R > 0.4$ for all other pairs of final state objects.

In addition kinematic constraints on invariant masses are used, as well as jet substructure methods (0802.2470) to find “fat b-jets”.

Available channels

$H_{1,2} \to A_1 Z$ and $H_3 \to A_1 A_1$ hopeless due to small rates.
$H_{1,2} \to A_1 A_1$ and $H_3 \to A_1 Z$ interesting for further study.

$H_{1,2,3}$ can be produced through gluon fusion (GF), vector boson fusion (VBF) or Higgsstrahlung (ZH and WH). But H_3 only doable through GF.
GF and VBF gives higher rates but larger backgrounds, GF most promising. $bb\tau\tau$ or $bb\mu\mu$ most promising final state.

ZH (with $Z \to ee, \mu\mu$) has almost no background but small signal.
WH ($W \to e\nu, \mu\nu$) has bigger backgrounds (from $t\bar{t}$ and $b\bar{b}t\bar{t}$) but shows some promise for low masses.

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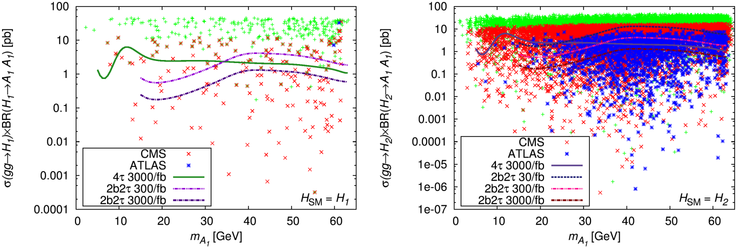
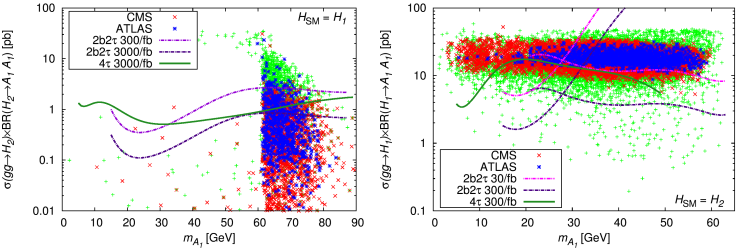
Sensitivity in the $H_{\rm SM} \to A_1 A_1$ channel



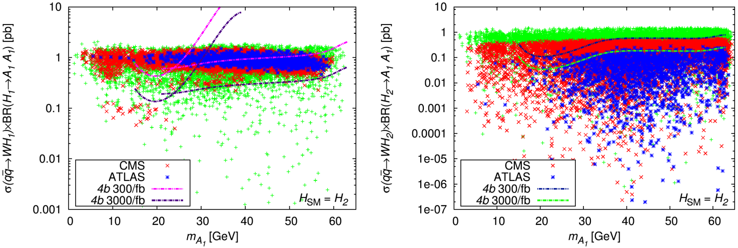
Some reach but few points due to conflict with signal rates.

Sensitivity in the $H_{\mathrm{non-SM}} \to A_1 A_1$ channel



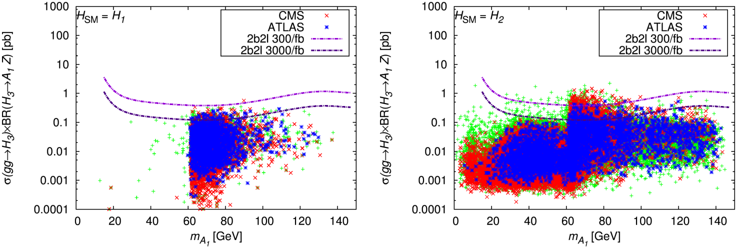
For $H_2 = H_{\mathrm{SM}}$, $m_{A_1} \lesssim 60$ GeV can be almost excluded.

Sensitivity in $WH_{1,2} \to WA_1A_1$, $H_2 = H_{\rm SM}$



Complementary at least for smaller masses.

Sensitivity in $H_3 \to A_1 Z$ channel



Interesting channel for further study.

Outline

Detectability ranges

Production mode	Channels	Accessibility	Range (GeV)
$b\bar{b}A_1$	—	x	
$H_1 \to A_1A_1$ (H_1)	gg, VBF, VH	✓ 300/fb	$m_{A_1} < 63$
$H_1 \to A_1A_1$ (H_2)	gg, VBF, VH	✓ 30/fb	$m_{A_1} < 60$
$H_1 \to A_1Z$	—	x	
$H_2 \to A_1A_1$ (H_1)	gg, VBF	✓ 300/fb	$60 < m_{A_1} < 80$
$H_2 \to A_1A_1$ (H_2)	gg, VBF, VH	✓ 30/fb	$m_{A_1} < 63$
$H_2 \to A_1Z$	—	x	
$H_3 \to A_1A_1$	—	x	
$H_3 \to A_1Z$	gg	✓ 300/fb	$60 < m_{A_1} < 120$

Conclusions

- Due to the extra singlet, the NMSSM may feature a very light pseudoscalar.
- In the most natural region (large λ, small $\tan\beta$) the LHC will practically exclude $m_{A_1} < 60$ GeV.
- For somewhat heavier pseudoscalars, $H_3 \to A_1 Z$ is a very interesting channel.
- For the non-SM-like of $H_{1,2}$ these channels might be the only way for discovery.

For an experimental perspective on the 4τ final state in similar models, see poster by Robin Aggleton, CMS