Explicit CP Violation in the MSSM Through $H \longrightarrow \gamma\gamma$

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based on

S. Moretti, S. Munir, P. Poulose, PLB 649 (2007) 206 [hep-ph/0702242]

SH, S. Moretti, S. Munir, P. Poulose, arXiv:0706.4269

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Introduction MSSM with complex parameters

- General MSSM:

  Many parameters can be complex

- Explicit CP violation
  - May help to explain baryon asymmetry of universe
  - Constraints from electric dipole moments (EDMs) of e, n, Hg, Tl

    [Ibrahim, Nath, '99; Barger, Falk, Han, Jiang, Li, Plehn, '01; Abel, Khalil, Lebedev, '01]
    [Oshima, Nihei, Fujita, '05; Pospelov, Ritz, '05; Olive, Pospelov, Ritz, Santoso, '05]
    [Abel, Lebedev, '05; Yaser Ayazi, Farzan, '06, '07]

- Global U(1) symmetries: some phases eliminated

  $\longrightarrow$ e.g. phase of one gaugino mass parameter M_i

- Physical phases in Higgs sector

  μ : Higgs-higgsino mass parameter

  A_f : trilinear couplings of sfermions

Introduction — Higgs sector in complex MSSM

- MSSM: 2 Higgs doublets

  $\longrightarrow$ 5 physical Higgs particles at tree-level ($h, H, A, H^{\pm}$)

- $\tilde{t}$ and $\tilde{b}$ loops $\Rightarrow$ explicit CP violation in Higgs sector [Pilaftsis, '98]
  [Pilaftsis, Wagner, '99; Demir, '99, Carena, Ellis, Pilaftsis, Wagner, '00, '01; Choi, Drees, Lee, '00]

  - CP-even (h, H) and CP-odd (A) neutral Higgs mix

    $\longrightarrow$ 3 neutral mass eigenstates (H_1, H_2, H_3), mixing matrix O

  - Leading contributions to (h, H)-A mixing $\propto$ Im(μA_f) $\longrightarrow$ $\varphi_{\text{eff}} = \varphi_\mu + \varphi_{A_f}$

    $\longrightarrow$ Choosing A_f real, analyzing $\varphi_{\text{eff}} = \varphi_\mu$ effects in the following

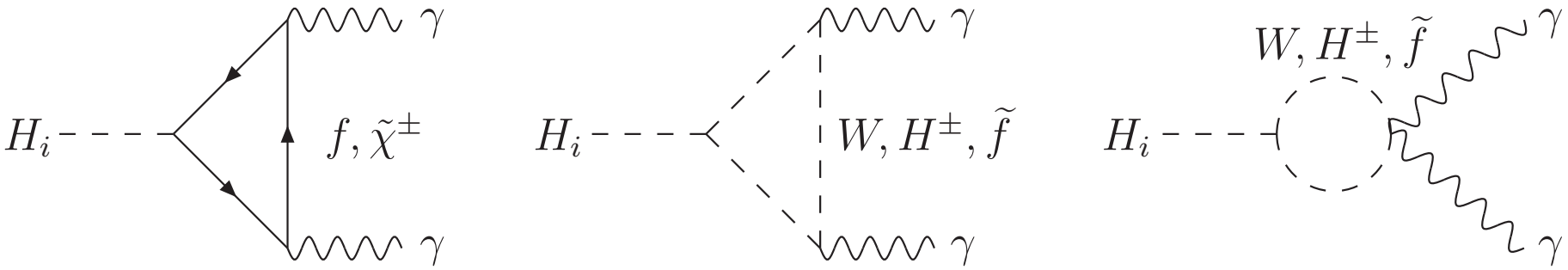
- Spectrum calculation (masses m_{H_i} and mixing matrix O)

  - CPSUPERH [Carena, Ellis, Pilaftsis, Wagner '00]
    [Lee, Pilaftsis, Carena, Choi, Drees, Ellis, Wagner '03; Ellis, Lee, Pilaftsis, '06]

  - FEYNHIGGS [Heinemeyer '01; Frank, Heinemeyer, Hollik, Weiglein '02]
    [Frank, Hahn, Heinemeyer, Hollik, Rzehak, Weiglein, '06]

$H_1 \to \gamma\gamma$

- $pp \to H \to \gamma\gamma$: important search channel at LHC for $m_H \lesssim 150$ GeV
- Decay at 1-loop via f, W, $H^\pm$, $\tilde{f}$, $\tilde{\chi}^\pm$ loops in MSSM



- CP violation (CPV) enters via phase dependence of
  - Masses $m_{H_1} \to$ small
  - Mixing matrix $O \leftrightarrow H_i$ couplings (also to SM particles)
  - $\tilde{f}$, $\tilde{\chi}^\pm$ sector (masses, couplings to H_i)

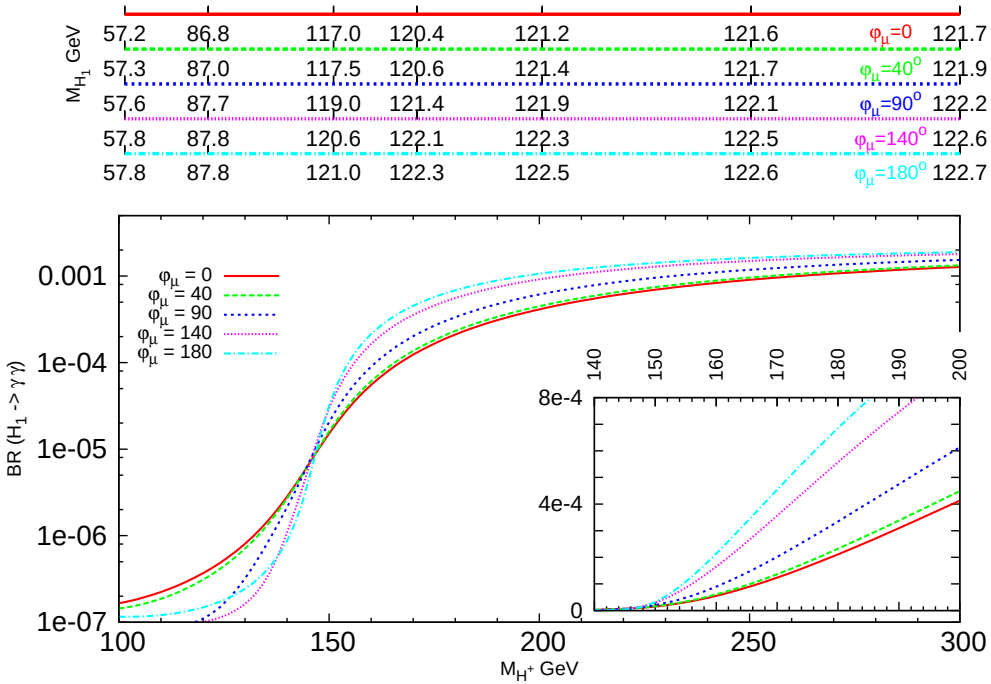
$H_1 \to \gamma\gamma$

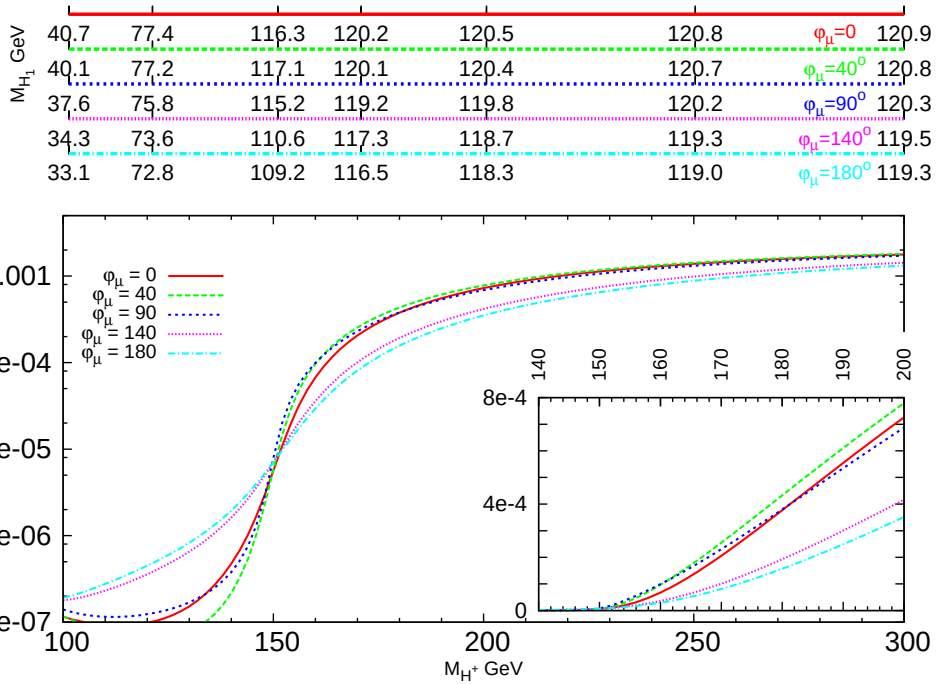
- $gg \to H_i \to \gamma\gamma$ at LHC in CPV MSSM [Choi, Hagiwara, Lee, '01]
  - Scenarios with heavy sparticles ($\tilde{f}$, $\tilde{\chi}^{\pm}$) $\leftrightarrow$ CPV in H_i couplings
  - $\mathcal{O}(10^2$–$10^3)$ suppression of BR($H_1 \to \gamma\gamma$) possible
    $\Rightarrow$ suppression of $\sigma \times$ BR
- Here:
  - Investigate possible effects of light sparticles
  - Calculation of m_{H_i}, O, BR($H \to \gamma\gamma$) with CPSUPERH
  - Detailed discussion of A_f, μ, $\tan\beta$ dependence
- Scan over MSSM parameters [Moretti, Munir, Poulose, '07]
  $\to$ in average $\sim$ 50% deviation between CPV and CPC case possible
  for parameter points with m_{H_1} in bins of size 4 GeV

$H_1 \to \gamma\gamma$ Numerical results

BR($H_1 \to \gamma\gamma$) as function of $m_{H^\pm}$

for $M_{(\tilde{Q}_3, \tilde{D}_3, \tilde{L}_3, \tilde{E}_3)}$ = 1 TeV, $|\mu|$ = 1 TeV, A_f = 1.5 TeV, tan β = 20





→ $M_{\tilde{U}_3}$ = 1 TeV (no light sparticles)

→ CP effects from H_1 couplings to W, t, b in loops

→ $M_{\tilde{U}_3}$ = 250 GeV ($m_{\tilde{t}_1} \sim$ 200 GeV)

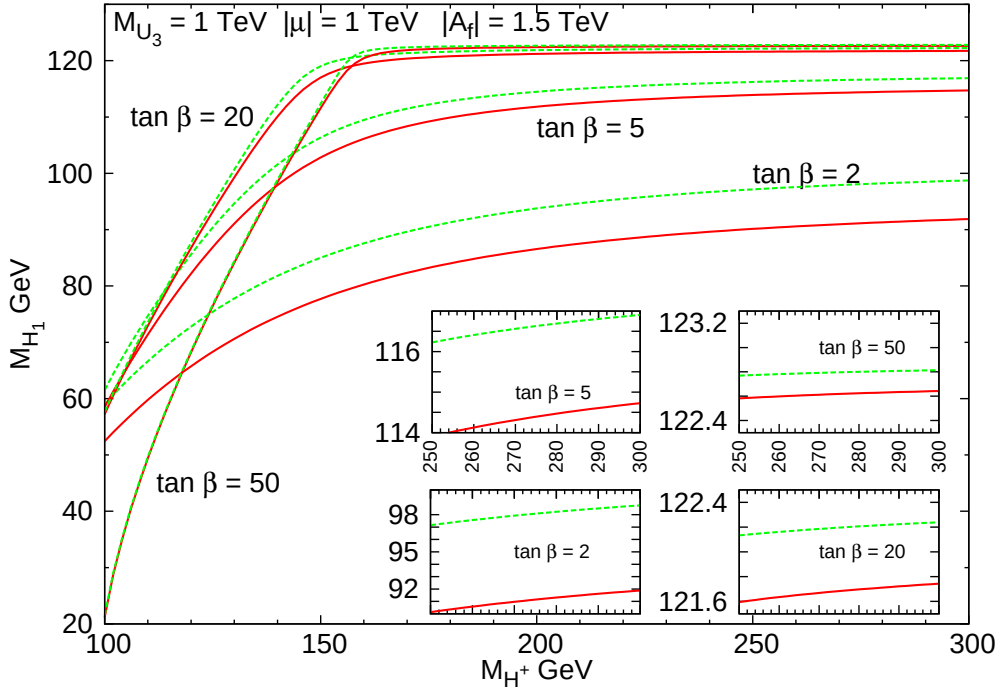
→ additional effects from light $\tilde{t}_1$

$H_1 \to \gamma\gamma$ Numerical results

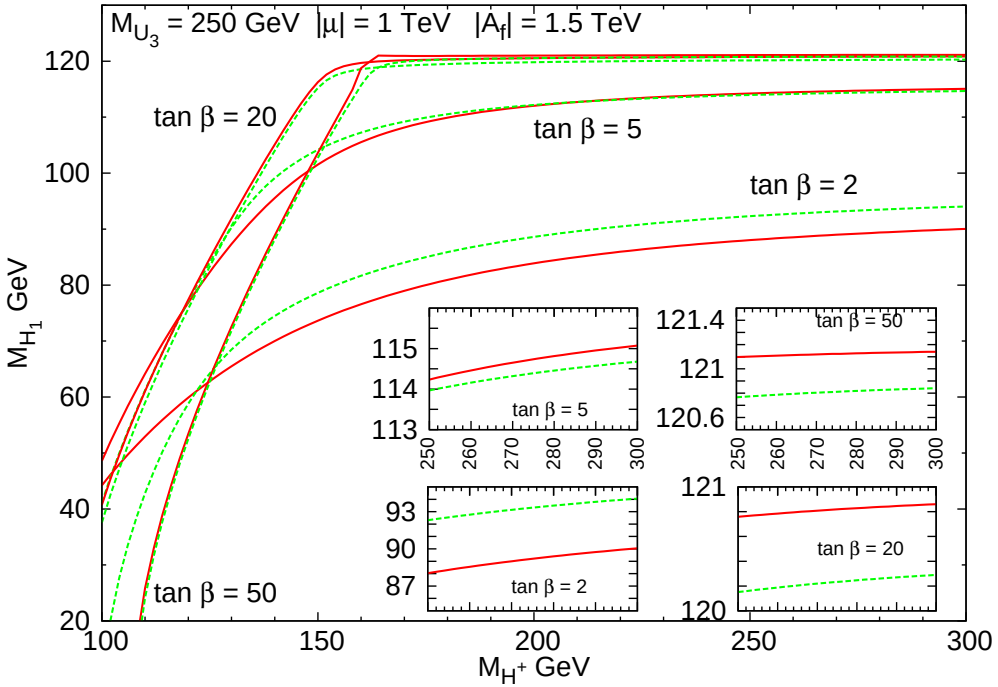
m_{H_1} as function of $m_{H^\pm}$

for $M_{(\tilde{Q}_3,\tilde{D}_3,\tilde{L}_3,\tilde{E}_3)}$ = 1 TeV, $|\mu|$ = 1 TeV, A_f = 1.5 TeV, φ_μ = 0, φ_μ = 90°

$M_{\tilde{U}_3}$ = 1 TeV



$M_{\tilde{U}_3}$ = 250 GeV ($m_{\tilde{t}_1} \sim$ 200 GeV)



→ deviations $\Delta m_{H_1}(\varphi_\mu)$ within experimental uncertainty

Summary

- BR($H_1 \to \gamma\gamma$) in CP-violating MSSM
- Analyzed φ_μ dependence for φ_{A_f} = 0
  (parameterization of arg(μA_f) dependence)
- Impact of light sparticles
  $\to$ light stops ($\tilde{t}_1$): possibly large effect
  $\to$ other light sparticles ($\tilde{b}_1$, $\tilde{\tau}_1$, $\tilde{\chi}_1^\pm$): little effect
- BR increased or decreased for $\varphi_\mu \neq 0$
  $\to$ depends on SUSY scenario

Outlook

Projects within

New connections between Experiment and Theory

(NExT) Institute

(Southampton University $\leftrightarrow$ PPD, RAL)

`http://www.hep.phys.soton.ac.uk/next/NEXT_web/NEXT_web.htm`

- Analysis of full production + decay process $gg \to H_i \to \gamma\gamma$
  - Enhancement or cancellation between production + decay?
  - Impact of Higgs mixing in propagator [Ellis, Lee, Pilaftsis, '04]

  $\to$ Net effect for Higgs search at LHC

- Explicit CP violation in NMSSM Higgs sector