



Helsinki BSM group - First RISE NonMinimal Higgs meeting



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Seniors:

Katri Huitu, prof, head of particle physics and astrophysics division

Oleg Lebedev, prof

Kimmo Tuominen, ass prof

Postdocs: Christian Gross

Matti Heikinheimo

Venus Keus

PhD students: Niko Koivunen, Timo Kärkkäinen, Sara Tähtinen, Paavo Tiitola,
Harri Waltari, Marco Zatta

Other particle physics theory professors and other seniors:

Kari Enqvist (cosmology), Kari Rummukainen (QCD, lattice), Esko Keski-Vakkuri,
Syksy Räsänen, Anca Tureanu, Aleksi Vuorinen

Experimental group in CMS (charged Higgs, heavy Higgses (H,A), B-physics)

Observational group in Planck, Euclid

Planned secondments:

To Helsinki

from Zewail (17)

from UAE (28,42)

From Helsinki

to Carleton (10, 8)

to UC (26,29)

to UT (30, 17)

to UAE (38,41)

So far agreed: Venus Keus to Santa Cruz 13.1.-13.2.2016 (8)

Higgs mixing with flavon

KH, N. Koivunen, V. Keus, O. Lebedev, to appear soon; Venus' talk
SM Higgs sector, one flavon to generate charged lepton masses by
Froggatt-Nielsen mechanism

-all precision constraints fulfilled

-flavon mixes with the Higgs boson

 possible to explain nonvanishing $H \rightarrow \tau\mu$ decay branching ratio


NMSSM with right-handed ν

KH, H. Waltari,

*Higgs sector in NMSSM with right-handed neutrinos and
spontaneous R-parity violation,*

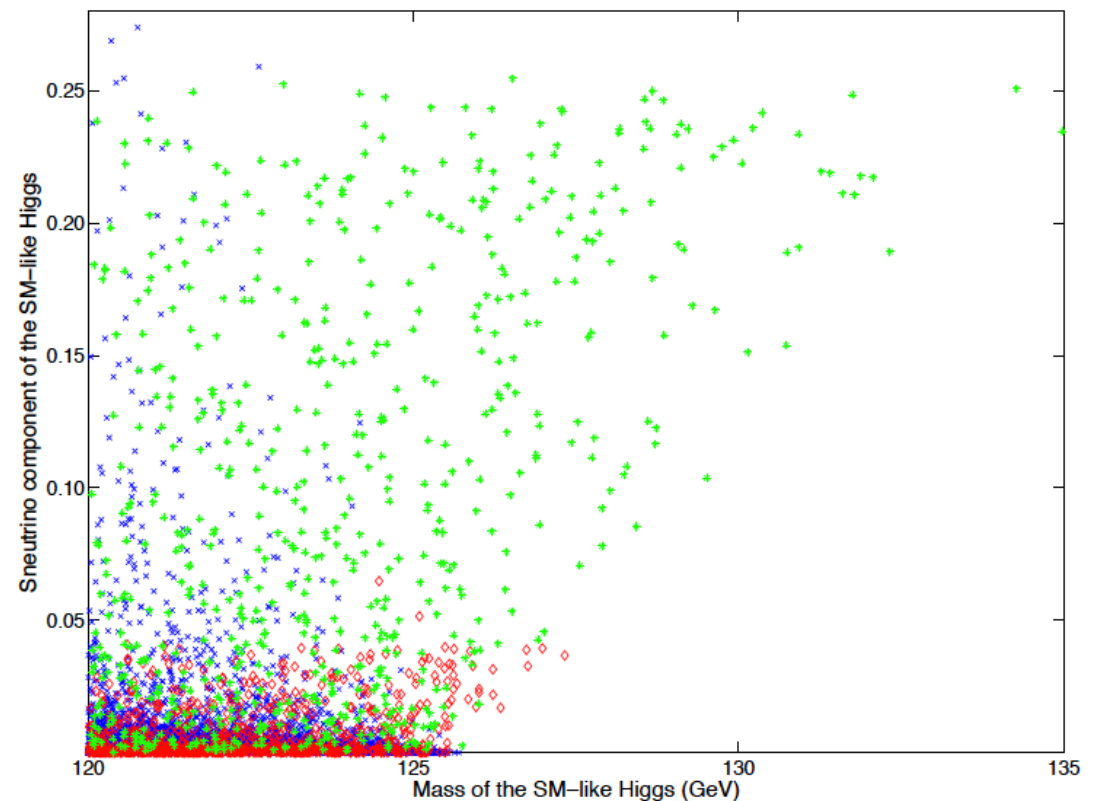
JHEP 1411 (2014) 053

From the tree level mass matrix ($\langle \tilde{N} \rangle = v_N \neq 0, (H_1, H_2, \tilde{L}, \tilde{N}, S)$):
 $Det(M^2), Det(M^2 - m_Z^2)$ cannot both be positive.

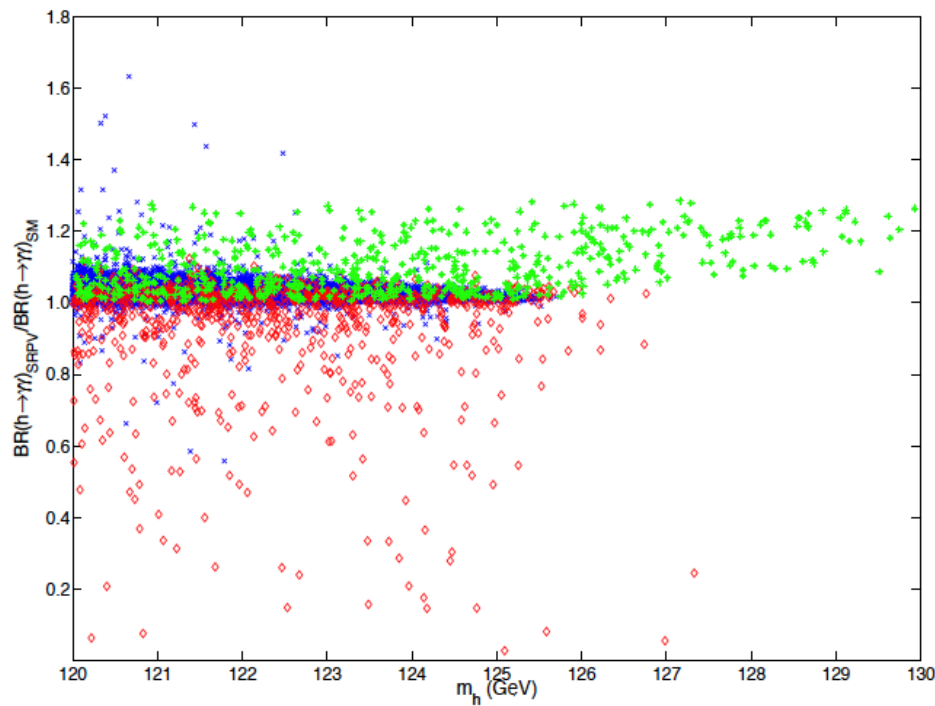

 $\left\{ \begin{array}{l} m_{h_1} = m_Z \text{ can be achieved with large } \tan\beta; \\ m_{h_1} > m_Z \text{ leads to R-parity conserving vacuum} \end{array} \right.$

With large sneutrino-doublet mixing easy to achieve 125 GeV.

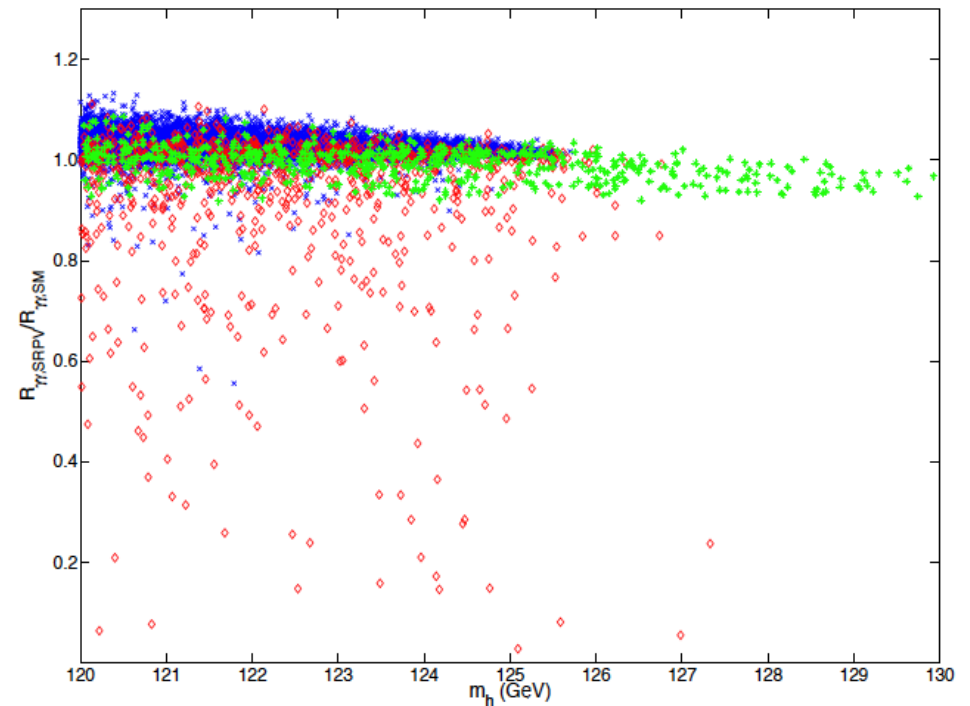
Blue: lightest scalar SM-like Higgs,
 Red: lightest scalar lighter than 80 GeV,
 Green: lightest scalar between 80-120 GeV



$BR(h \rightarrow \gamma\gamma)$



Cross section $\times BR(h \rightarrow \gamma\gamma)$



NMSSM ongoing:

- Bandyopadhyay, KH, Niyogi on charged Higgs at LHC
- Higgs phenomenology with right-handed ν , following earlier paper (KH, Laamanen, Leinonen, Rai and Ruppel, JHEP 1211 (2012) 129)

SUSY models with $Y=0$ triplets: TESSM

P. Bandyopadhyay, KH and A.S.Keceli, *Status of $Y=0$ Triplet Higgs with supersymmetry in the light of 125 GeV Higgs discovery*, JHEP 1310 (2013) 091

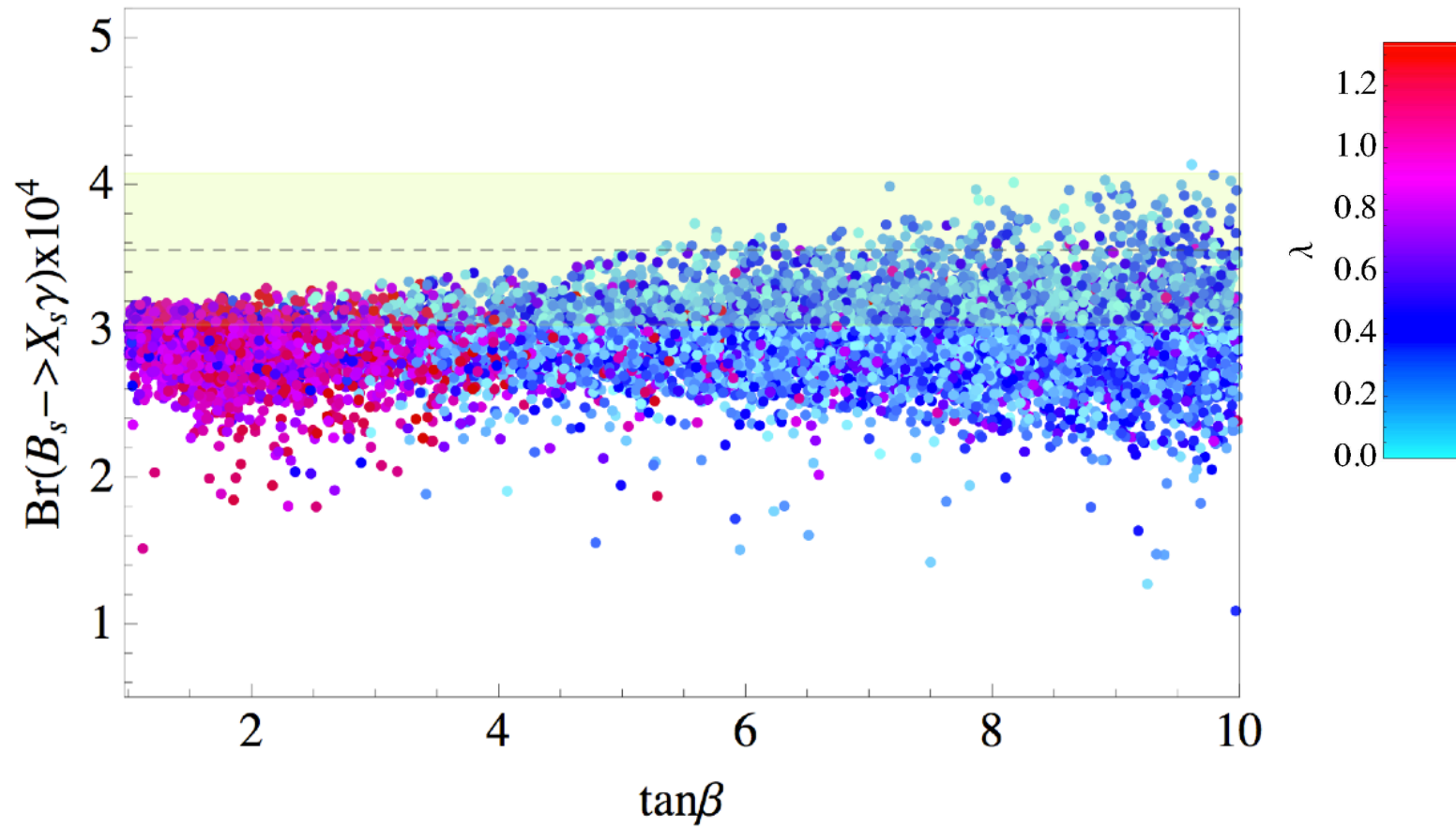
P. Bandyopadhyay, S. Di Chiara, KH, A.S. Keceli, *Naturalness vs perturbativity, B physics, and LHC data in triplet extension of MSSM*, JHEP11 (2014) 053

P. Bandyopadhyay, KH and A.S.Keceli, *Multi-Lepton Signatures of the Triplet Like Charged Higgs at the LHC*, JHEP 1505 (2015) 026

Triplet couplings μ_T and λ added to the superpotential:

$$W_{\text{TESSM}} = \mu_T \text{Tr}(\hat{T}\hat{T}) + \mu_D \hat{H}_d \cdot \hat{H}_u + \lambda \hat{H}_d \cdot \hat{T} \hat{H}_u + y_t \hat{U} \hat{H}_u \cdot \hat{Q} - y_b \hat{D} \hat{H}_d \cdot \hat{Q} - y_\tau \hat{E} \hat{H}_d \cdot \hat{L}$$

$\text{BR}(b \rightarrow s\gamma)$ allowed at one σ in the yellow band.



LRSUSY models with Y=2 triplets (B-L gauged)


M. Frank, D.K. Ghosh, KH, S.K. Rai, I. Saha, H. Waltari, *Left-right supersymmetry after the Higgs boson discovery*, PRD90 (2014) 115021;

Two step breaking $SU(2)_R \times U(1)_{B-L} \rightarrow U(1)_Y$, $SU(2)_L \times U(1)_Y \rightarrow U(1)_{em}$

$$\langle S \rangle = \frac{v_s}{\sqrt{2}} e^{i\alpha_s}, \quad \langle \Phi_1 \rangle = \begin{pmatrix} \frac{v_1}{\sqrt{2}} & 0 \\ 0 & \frac{v'_1}{\sqrt{2}} e^{i\alpha_1} \end{pmatrix}, \quad \langle \Phi_2 \rangle = \begin{pmatrix} \frac{v'_2}{\sqrt{2}} e^{i\alpha_2} & 0 \\ 0 & \frac{v_2}{\sqrt{2}} \end{pmatrix}$$

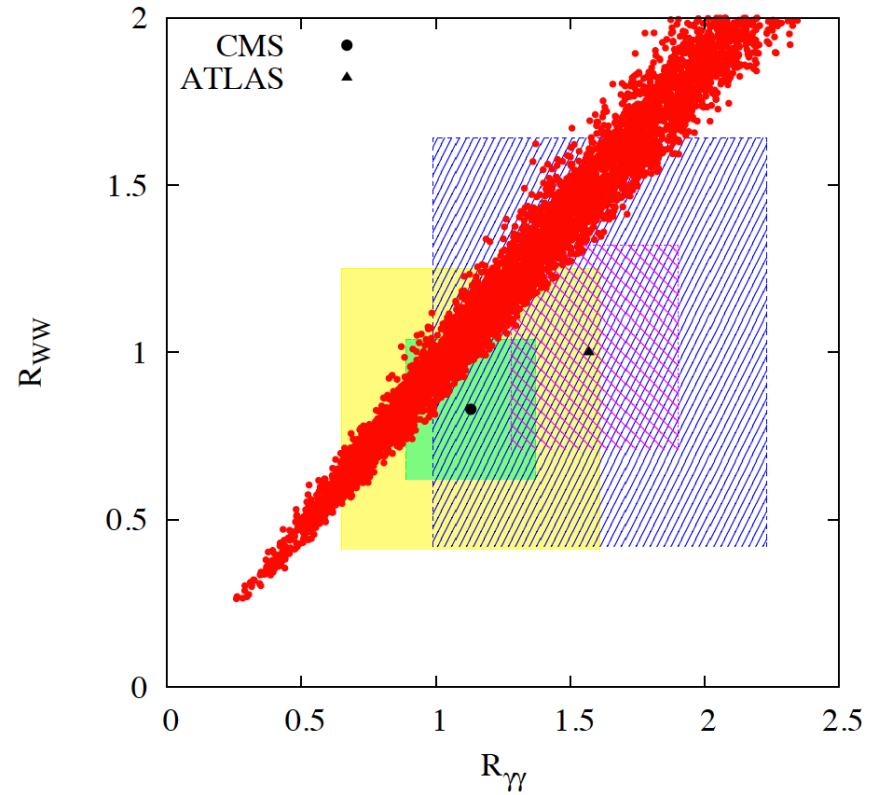
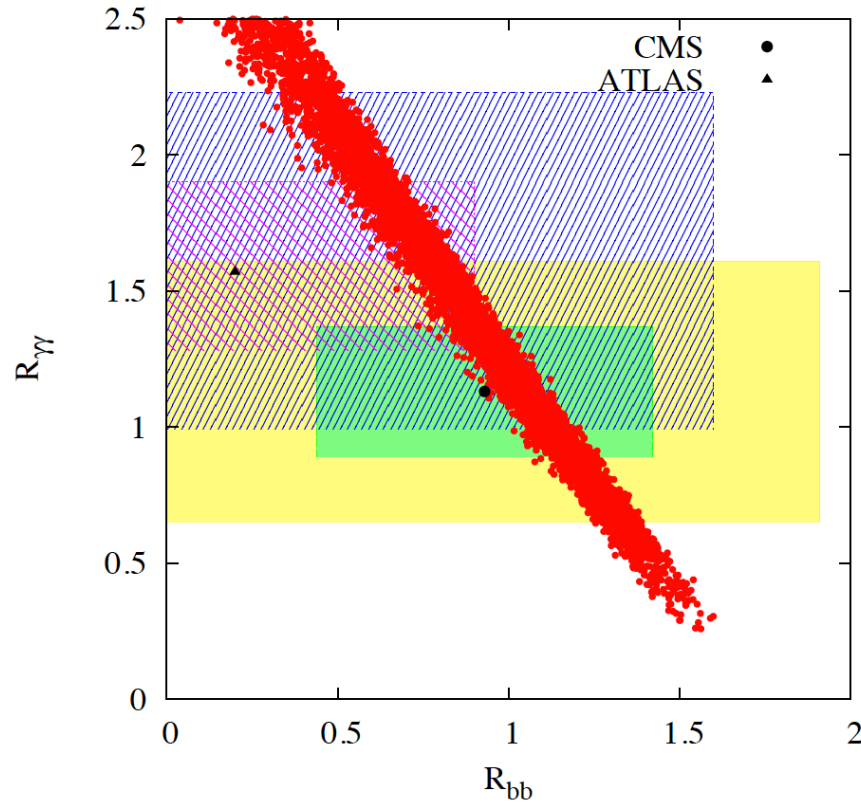
$$\langle \Delta^c \rangle = \begin{pmatrix} 0 & \frac{v_R}{\sqrt{2}} \\ 0 & 0 \end{pmatrix}, \quad \langle \bar{\Delta}^c \rangle = \begin{pmatrix} 0 & 0 \\ \frac{\bar{v}_R}{\sqrt{2}} & 0 \end{pmatrix}.$$

Small $W_L - W_R$ mixing proportional to $v_i v'_i e^{i\alpha}$

 $v_R, \bar{v}_R \gg v_2, v_1 \gg v'_1 = v'_2 \approx 0$ and $\alpha_1 = \alpha_2 = \alpha_s \approx 0$

One doubly charged scalar is light, since its mass comes from the radiative corrections (tau-stau loops are essential!)

Signal strengths $h \rightarrow \gamma\gamma$ and $h \rightarrow b\bar{b}$ are anticorrelated, all other signal strengths are correlated



SUSYLR ongoing:

-M. Frank, B.Fuks, KH, S.K. Rai, H. Waltari, on SUSYLR Higgses at LHC

Recent work by Oleg Lebedev:

C. Gross, O. Lebedev, M. Zatta, *Higgs-inflaton coupling from reheating and the metastable Universe*, arXiv:1506.05106 [hep-ph]

A. Falkowski, C. Gross, O. Lebedev, *A second Higgs from the Higgs portal*, JHEP 1505 (2015) 057

S. Di Chiara, V. Keus and O. Lebedev, *Stabilizing the Higgs potential with a Z'* , Phys.Lett.B 744 (2015) 59

Recent work by Kimmo Tuominen:

S. Di Chiara, R. Foadi, [K. Tuominen](#), [S. Tähtinen](#), *Dynamical Origin of the Electroweak Scale and the 125 GeV Scalar*, Nucl.Phys.B 900 (2015) 295

T. Alanne, H. Gertov, F. Sannino, [K. Tuominen](#), *Elementary Goldstone Higgs boson and dark matter*, Phys.Rev.D 91 (2015) 9, 095021

C. Kouvaris, I.M. Shoemaker, [K. Tuominen](#), *Self-Interacting Dark Matter through the Higgs Portal*, Phys.Rev.D 91 (2015) 4, 043519

S. Di Chiara, R. Foadi, [K. Tuominen](#), *125 GeV Higgs from a chiral techniquark model*, Phys.Rev.D 90 (2014) 11, 115016

H.S. Fukano, [K. Tuominen](#), *126 GeV Higgs boson in the top-seesaw model*, JHEP 1309 (2013) 021