



Scalars 2017

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Book of abstracts

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parallel session 1 / 0

Strongly Self-Interacting Vector Dark Matter via Freeze-InAuthor: HUANG, Da ¹Co-Authors: GRZADKOWSKI, Bohdan ¹; DUCH, Mateusz ¹¹ *University of Warsaw***Corresponding Author:** dahuang@fuw.edu.pl

We study a vector dark matter (VDM) model in which the VDM couples to the Standard Model sector via the Higgs portal. As a result, the VDM can be produced via the freeze-in mechanism. In particular, we find that the electroweak phase transition have a great impact on the prediction of the VDM relic density. We further assume that the dark Higgs which gives the VDM mass is so light that it can induce strong VDM self-interactions and solve the small-scale structure problems in the Universe. Due to the extreme smallness of the Higgs portal coupling derived by the freeze-in mechanism, the dark matter direct detection bounds do not limit our model at all, which is illustrated with the latest LUX data. However, the model is well constrained by the indirect detections of VDM from BBN, CMB, AMS-02, and diffuse γ /X-rays. Consequently, only when the dark Higgs mass is at most of $\mathcal{O}(\text{keV})$ can we find some parameter region that leads to a right amount of VDM relic abundance and an appropriate VDM self-scatterings while satisfying all other constraints simultaneously.

parallel session 5 / 1

Cascade Decay of a Heavy HiggsProf. POULOSE, Poulouse ¹; SAHOO, SHIBANANDA ²; Dr. COLEPPA, Baradhwaj ³; Prof. FUKS, Benjamin ⁴¹ *IIT Guwahati*² *INDIAN INSTITUTE OF TECHNOLOGY, GUWAHATI, ASSAM*³ *IIT Gandhinagar*⁴ *LPTHE, Paris***Corresponding Author:** shibasipu@gmail.com

We study the discovery prospects of heavy neutral higgs bosons in Beyond the Standard Model scenarios where it cascade decays to a lighter scalar eigenstate which subsequently decays to the Standard Model Higgs. We consider either of 4 leptons and 2 b-jets or of 2 leptons + 4 b-jets final states. We find that these two signatures allows us to both optimally reduce the Standard Model backgrounds and reconstruct the mass of the parent Higgs boson. We first present a model independent analysis at the 14 TeV LHC for various benchmark points, and deduce the signal cross-sections necessary to report a 5σ discovery. We then translate our result in the context of the Type-II Two-Higgs-Doublet Model and identify regions of parameter space in the $\tan\beta$ - $\sin(\beta-\alpha)$ plane that permits discovery.

parallel session 4 / 2

The scalar field on Einstein-Maxwell background with cosmological constant

GHEZELBASH, Masoud¹¹ *University of Saskatchewan***Corresponding Author:** amg142@campus.usask.ca

We find exact solutions to the wave equation of scalar field in the background of five-dimensional Einstein-Maxwell theory with cosmological constant where the scalar field couples to the electromagnetic field as well as to the cosmological term with two different coupling constants. We find that the five-dimensional spacetime is non-stationary and is a conformally regular spacetime, everywhere. Both the scalar and the electromagnetic field depends on time and two spatial directions. The cosmological constant takes positive, negative or zero value, depending on the value of coupling constant. We study the physical properties of the spacetime and show that the solutions are unique in five dimensions and can't be uplifted to higher-dimensional Einstein-Maxwell theory or Einstein gravity in presence of cosmological constant. Moreover, we construct new solutions to the theory where both coupling constants are equal.

parallel session 1 / 7

Heavy Quarks Flavored Real Scalar Dark Matter

Author: WU, Peiwen¹Co-Authors: Prof. KO, Pyungwon²; Prof. BAEK, Seungwon³¹ *Korea Institute for Advanced Study (KIAS)*² *KIAS*³ *Korea Institute for Advanced Study***Corresponding Author:** peiwen.wu123@gmail.com

The absence of confirmed signal in dark matter (DM) direct detection (DD) may suggest a weak coupling between DM and the first generation quarks. In this work we consider a real scalar dark matter ϕ which has new Yukawa interactions with charm c and top quark t via a vector-like fermion mediator ψ . By setting the Higgs portal to be negligible, we focus on the new Yukawa interactions. Since there is no valence c, t quark in nucleons, DM-gluon scattering at loop level becomes important. We found that renormalization group equation (RGE) effects are crucial in calculating the DM-nucleon scattering rate at $\mu_{\text{had}} \sim 1, \text{ GeV}$ if one constructs the effective theory at $\mu_{\text{EFT}} \sim m_Z$. For the perturbative benchmark couplings we choose, combined results from relic abundance requirement $\Omega h^2 = 0.12$, direct/indirect detection constraints, 13 TeV LHC data have excluded a thermal relic DM with $m_S < m_t/2$ in this model. FCNC processes of top quark can be generated at both tree level $t \rightarrow \psi^{(*)} S \rightarrow c S$ and loop level $t \rightarrow c + \gamma/g/Z$, of which the branching fractions are usually below 10^{-9} after passing the other constraints, which are still safe from the current top quark width measurements.

parallel session 3 / 8

Off-shell renormalization of dimension 6 operators in Higgs effective field theoriesAuthor: QUADRI, Andrea ¹Co-Author: Dr. BINOSI, Daniele ²¹ INFN, Sez. di Milano² ECT* - Trento, Italy

Corresponding Author: andrea.quadri@mi.infn.it

The off-shell one-loop renormalization of a Higgs effective field theory with a sextic scalar potential is presented. This is achieved by renormalizing the theory once reformulated in terms of two auxiliary fields, allowing to diagrammatically separate the SM and BSM contributions to 1-PI amplitudes. Invariance under an extended Becchi-Rouet-Stora-Tyutin symmetry guarantees the physical equivalence with the standard formalism as well as the existence of some functional identities, constraining the dependence on the additional auxiliary fields. The latter allow in turn the explicit derivation of the mapping onto the original theory. We elaborate on some phenomenological consequences of our results, as well as provide the generalization of the method to potentials involving operators of arbitrary higher powers in the scalar field.

parallel session 6 / 9

Extra Higgs bosons and spin-1 heavy vector bosonsNAGAI, Ryo ¹¹ Tohoku University

Corresponding Author: nagai@tuhep.phys.tohoku.ac.jp

We investigate decay modes of spin-1 heavy vector bosons (V') from the viewpoint of perturbative unitarity in a model-independent manner. Our findings are: [1] $\text{Br}(W' \rightarrow WZ)$ is less than 2% in the system that contains V' and CP-even scalars as well as the SM particles. [2] Contributions of CP-odd scalars help to make $\text{Br}(W' \rightarrow WZ)$ larger than $\text{Br}(W' \rightarrow ff)$ as long as the CP-odd scalars couple to both the SM fermions and the SM gauge bosons. The existence of the CP-odd scalar couplings is a useful guideline to construct models that predict $\text{Br}(W' \rightarrow WZ) > 2\%$. Our analysis relies only on the perturbative unitarity of $ff \rightarrow WW'$. Therefore our result can be applied to various models. This talk is based on Phys.Rev. D95 (2017) no.7, 075022 [arXiv:1607.03706].

parallel session 4 / 10

Gravitational wave, collider and dark matter signals from a scalar singlet electroweak baryogenesisLEWICKI, Marek ¹¹ University of Warsaw

Corresponding Author: marek.lewicki@fuw.edu.pl

I will discuss a simple extension of the SM with just an additional scalar singlet coupling to the Higgs. My main focus will be the possible probes of electroweak baryogenesis in this model including collider searches, gravitational wave detection and direct dark matter detection experiments. I will show there are regions in the parameter space where observation of gravitational waves is the most promising way of finding evidence for this model.

arXiv:

1702.06124

parallel session 2 / 12

Exotic Higgs decay into displaced heavy neutrinos

DELLE ROSE, Luigi ¹; Dr. ACCOMANDO, Elena ²; Prof. MORETTI, Stefano ³; Dr. OLAIYA, Emmanuel ¹; Dr.

SHEPHERD-THEMISTOCLEOUS, Claire ¹

¹ *Rutherford Appleton Laboratory*

² *Southampton*

³ *NExT Institute (Southampton & RAL, UK)*

Corresponding Author: l.delle-rose@soton.ac.uk

We examine the observability of heavy neutrino (ν_h) signatures of a U(1)' enlarged Standard Model (SM) encompassing three heavy Majorana neutrinos alongside the known light neutrino states at the the Large Hadron Collider (LHC). We show that heavy neutrinos can be rather long-lived particles producing distinctive displaced vertices that can be accessed in the CERN LHC detectors. We concentrate here on the gluon fusion production mechanism $gg \rightarrow H_{\{1,2\}} \rightarrow \nu_h \nu_h$, where H_1 is the discovered SM-like Higgs and H_2 is a heavier state, yielding displaced leptons following ν_h decays into weak gauge bosons. Using data collected by the end of the LHC Run 2, these signatures would prove to be accessible with negligibly small background.

parallel session 3 / 13

Unified model of fermion masses with a Universal Texture Zero

DE MEDEIROS VARZIELAS, Ivo ¹

¹ *Instituto Superior Tecnico*

Corresponding Author: ivo.de@udo.edu

We show that a universal texture zero in the (1,1) position of all fermionic mass matrices, including heavy right-handed Majorana neutrinos driving a type-I see-saw mechanism, can lead to a viable spectrum of mass, mixing and CP violation for both quarks and leptons, including (but not limited to) three important predictions: the Cabibbo angle, the charged lepton masses, and the leptonic 'reactor' angle. We model this texture zero with a non-Abelian discrete family symmetry that can easily be embedded in a grand unified framework, and discuss the details of the phenomenology after electroweak and family symmetry breaking. We provide an explicit numerical fit to the available data and obtain excellent agreement with the 18 observables in the charged fermion and neutrino sectors with just 9 free parameters. We further show that the vacua of our new scalar familon fields are readily aligned along desired directions in family space, and also demonstrate discrete gauge anomaly freedom at the relevant scale of our effective theory.

parallel session 3 / 14

Generating hierarchies on the fermion masses in a 3HDM limit of the pSHUT model

Author: MORAIS, Antonio ¹

Co-Author: Prof. PASECHNIK, Roman ²

¹ Aveiro University

² Lund University

Corresponding Author: aapmorais@ua.pt

The fermion spectrum observed in nature exhibits a wide range of hierarchies that go from the sub-eV regime up to hundreds of GeV. In this talk I will introduce a multi-Higgs extension of the Standard Model whose origin is inspired in a recently proposed Grand Unified Theory denoted as Supersymmetric Higgs Unified Trinification (or SHUT model for short). The presence of an SU(3) family symmetry at the high scale forbids any tree-level lepton masses and only one generation of quarks can get its mass by leading order Yukawa interactions. I will discuss how quantum effects and the choice of the scalar sector are crucial for the generation of a realistic fermion spectrum as well as discussing the prominent phenomenological potential of this model in predicting e.g., the CKM mixing in the quark sector.

session 11 / 15

Radiative alignment in 2HDM

FERREIRA, Pedro ¹

¹ ISEL and CFTC, UL

Corresponding Author: pmmferreira@fc.ul.pt

The possibility that alignment arises in 2HDM as a consequence of the high-scale behaviour of the theory is discussed here. Requiring the 2HDM to be bounded from below and perturbative up to scales as low as a few TeV forces the lightest CP-even scalar to have SM-like properties for model Type II. Analogous conclusions are found for model I, if the charged higgs mass is larger than about 400 GeV. We therefore argue that alignment may arise "naturally" in the 2HDM, as a consequence from radiative corrections to the model.

parallel session 4 / 16

Higgs domain walls beyond the Standard Model

Author: KRAJEWSKI, Tomasz ¹

Co-Authors: Prof. LALAK, Zygmunt ²; Mr. LEWICKI, Marek ¹; OLSZEWSKI, Pawel ¹

¹ *University of Warsaw*

² *IITP UW*

Corresponding Author: tkrajewski@fuw.edu.pl

The study of the renormalization group improved effective potential of the Standard Model has revealed existence of a local maximum at field strengths of the order of 10^{10} GeV. If the Standard Model is valid for very high energy scales, then the possibility of the production of cosmological domain walls in the early Universe occurs.

We investigated dynamics of networks of domain walls using lattice simulations. In our previous research we assumed that the Standard Model is valid up to the Planck scale. Recently we studied scenario in which the Standard Model breaks down at much lower scales using the formalism of the Effective Field Theory. A nonrenormalizable operator was included in the Lagrangian density and its impact on the evolution of networks of domain walls was investigated. We studied the possibility of a formation of metastable networks for the case of nearly degenerate minima of the potential. The energy spectrum of gravitational waves emitted from Higgs domain walls was determined.

parallel session 6 / 17

Constraints on running vacuum model with $H(z)$ and $f\sigma_8$

YIN, Lu ¹

¹ *Department of Physics, National Tsing Hua University*

Corresponding Author: yinlumail1010@gmail.com

We set the cosmological constant Λ is not constant but a function of Hubble parameter, and Λ can decay with matter and radiation in the expansion universe. We examine the running vacuum model with $\Lambda(H) = 3\nu H^2 + \Lambda_0$, where ν is the model parameter and Λ_0 is the cosmological constant. From the data of the cosmic microwave background radiation, weak lensing and baryon acoustic oscillation along with the time dependent Hubble parameter $H(z)$ and weighted linear growth $f(z)\sigma_8(z)$ measurements, we find that $\nu = 1.37 \times 10^{-4}$ with the best fitted χ^2 value slightly smaller than that in the Λ CDM model.

session 7 / 18

The Higgs portal update

LEBEDEV, Oleg ¹

¹ *Helsinki U.*

Corresponding Author: oleg.lebedev@helsinki.fi

I'll discuss recent progress in the Higgs portal framework in relation to dark matter and inflation.

session 4 / 19

Scalars for flavor physics and dark matter

CLINE, James ¹

¹ *McGill University and NBI*

Corresponding Author: jcline@physics.mcgill.ca

Tentative evidence for lepton flavor nonuniversality in semileptonic B meson decays from LHCb suggests new physics beyond the standard model.

I present some representative models for explaining this observation, simultaneously with other puzzles such as the origin of flavor or dark matter, emphasizing the essential role played by new scalar particles.

session 5 / 20

Distinguishing scalar DM from fermion DM in dilepton events

DELGADO, Antonio ¹

¹ *University of Notre Dame*

Corresponding Author: antonio.delgado@nd.edu

Discovering DM can be challenging in situation when the spectrum of new physics is compressed. I will show how to distinguish between scalar and fermion DM using dileptons produce through loops of new physics states.

session 11 / 21

Gauge-Higgs unification : distinct signals at LHC and ILC

HOSOTANI, Yutaka ¹

¹ *Osaka University*

Corresponding Author: hosotani@het.phys.sci.osaka-u.ac.jp

SO(5) \times U(1) gauge-Higgs EW unification gives almost the same phenomenology as the standard model and is consistent with the data at low energies and at 8 TeV LHC. It gives many predictions to be explored and verified at 14 TeV LHC and 250-500 GeV ILC. In addition to the production of Z' bosons around 7 - 9 TeV with broad widths at 14 TeV LHC, distinct signals are predicted in future e^+e^- collider experiments with polarized beams.

Significant deviations in the energy and polarization dependence in $\sigma(\mu^+\mu^-)$, the lepton forward-backward asymmetry, $R_b(\mu) \equiv \sigma(\bar{b}b)/\sigma(\mu^+\mu^-)$ and the left-right asymmetry from the standard model are predicted.

(arXiv:1705.05282)

session 8 / 22

On the Cosmological Quantum Frame Problem in Multifield Inflation

PILAFTSIS, Apostolos ¹

¹ *University of Manchester*

Corresponding Author: apostolos.pilaftsis@manchester.ac.uk

Predictions for cosmological observables, such as the scalar and tensor power spectra, their spectral indices and their higher order runnings, suffer from the so-called frame problem. They depend on whether the computation has been performed in the Jordan or Einstein frame. In this talk, I will present a frame-covariant formalism which enables one to address the frame problem in the context of general scalar-curvature multifield theories. The formalism makes use of notions and techniques known from differential geometry, and can be extended beyond the tree approximation in the Vilkovisky-De Witt framework which needs to be generalized appropriately. I will show how frame-invariant predictions for cosmological observables can be obtained in simple two-field models, motivated by Higgs inflation.

session 13 / 23

Dynamical scale symmetry breaking and scale phase transition

Author: KUBO, Jisuke ¹

Co-Authors: Mr. SOESANTO, Qidir Maulana Binu ¹; Dr. YAMADA, Masatoshi ²

¹ *Kanazawa University*

² *University of Heidelberg*

Corresponding Author: jik@hep.s.kanazawa-u.ac.jp

We assume that the origin of the electroweak (EW) scale is a gauge-invariant scalar-bilinear condensation in a strongly interacting non-abelian gauge sector.

The dynamical scale genesis appears as a phase transition at finite temperature, and it can produce a gravitational wave (GW) background in the early Universe.

session 13 / 24

CP4 miracle: Yukawa sector from CP symmetry of order 4

Author: IVANOV, Igor ¹

Co-Authors: Dr. FERREIRA, Pedro ²; Dr. PASECHNIK, Roman ³; Dr. SERODIO, Hugo ³; Dr. JIMENEZ, Enrique ⁴

¹ CFTP, IST, Lisbon

² ISEL and CFTC, UL

³ Lund University

⁴ Universidad de Colima, Mexico

Corresponding Author: igor.ivanov@tecnico.ulisboa.pt

We explore the phenomenology of a unique three-Higgs-doublet model based on the single CP symmetry of order 4 (CP4) without any accidental symmetries. The CP4 symmetry is imposed on the scalar potential and Yukawa interactions, strongly shaping both sectors of the model and leading to a very characteristic phenomenology.

Although the model is very constrained by CP4, we find points in the parameter space which comply with the electroweak precision data and the SM-like 125 GeV Higgs boson properties, and reproduce all fermion masses, mixing, CP violation, and K and B meson oscillation parameters.

session 5 / 25

Dark pion DM : WIMP or SIMP ?

KO, Pyungwon ¹

¹ KIAS

Corresponding Author: pko@kias.re.kr

Dark pion in the strongly interacting dark sector could be a good DM candidate with some assumptions. One can realize either WIMP or SIMP scenario within this setup. I discuss each scenario including the dark resonances.

session 6 / 26

A Clockwork WIMP

TYTGAT, Michel ¹

¹ Université Libre de Bruxelles

Corresponding Author: mtytgat@ulb.ac.be

We embed a thermal dark matter (DM) candidate within the clockwork framework. This mechanism allows to stabilize the DM particle over cosmological time because it suppresses its decay into Standard Model (SM) particles. At the same time, pair annihilations are unsuppressed, so that the relic density is set by the usual freeze-out of the DM particle from the thermal bath. The slow decay of the DM candidate is induced by "clockwork" particles that can be quite light (rather than at some GUT or Planck scale) and could be searched for at current or future colliders. According to the scenario considered, the very same particles also mediate the annihilation process, thus providing a connection between DM annihilation and DM decay, and fixing the mass scale of the clockwork states, otherwise unconstrained, to be in the TeV range or lighter. We then show how this setup can minimally emerge from the deconstruction of an extra dimension in flat spacetime. Finally, we argue that the clockwork mechanism that we consider could induce Majorana neutrino masses, with a seesaw scale of order TeV or less and Yukawa couplings of order unity.

parallel session 4 / 27

Gravitational waves, inflation and gravitational reheating

ARTYMOWSKI, Michal¹¹ Jagiellonian University**Corresponding Author:** michal.artymowski@uj.edu.pl

I will present the Idea of an inflaton without direct couplings to any additional fields. I will show a possible mechanisms of reheating via gravity together with implications of such an approach to inflation on predictions of inflation, dark energy, dark matter, thermal history of the Universe, electro-weak phase transition and especially gravitational waves production.

session 7 / 28

Cosmological relaxation of the EW scale after inflation

MORGANTE, Enrico¹¹ DESY**Corresponding Author:** enrico.morgante@desy.de

Cosmological relaxation is a mechanism that can explain the smallness of the EW scale without the need of new dynamics at the TeV scale. We discuss how to realize this mechanism during the radiation dominated era, where the role of Hubble friction is played by the production of SM gauge bosons.

parallel session 1 / 29

Sneutrino Dark Matter in the BLSSM

KING, Simon¹; Mr. DELLE ROSE, Luigi²; Prof. MORETTI, Stefano³; KULKARNI, Suchita⁴; Dr. UN, Cem Salih⁵; Prof. KHALIL, Shaaban⁶; Dr. MARZO, Carlo⁷¹ University of Southampton² Rutherford Appleton Laboratory³ NExT Institute (Southampton & RAL, UK)⁴ LPSC⁵ Center of Fundamental Physics, Zewail City Science and Technology⁶ Center for Fundamental Physics, Zewail City of Science and Technology⁷ National Institute of Chemical Physics and Biophysics**Corresponding Author:** sjd.king@soton.ac.uk

In the framework of the $B-L$ Supersymmetric Standard Model (BLSSM), we assess the ability of ground and space based experiments to establish the nature of its prevalent Dark Matter (DM) candidate, the sneutrino, which could either be CP-even or -odd. Firstly, by benchmarking this theory construct against the results obtained by the Planck spacecraft, we extract the portions of the BLSSM parameter space compliant with relic density data. Secondly, we show that, based on current sensitivities of the Fermi Large Area Telescope (FermiLAT) and their future projections, the study of high-energy gamma-ray spectra will eventually enable us to extract evidence of this DM candidate through its annihilations into W^+W^- pairs (in turn emitting photons), in the form of both an integrated flux and a differential energy spectrum which cannot be reconciled with the assumption of DM being fermionic (like, e.g., a neutralino), although it should not be possible to distinguish between the scalar and pseudoscalar hypotheses. Thirdly, we show that, while underground direct detection experiments will have little scope in testing sneutrino DM, the Large Hadron Collider (LHC) may be able to do so in

the well-studied tri-lepton (plus missing transverse energy) signal following data collection during Run 2 and 3.

parallel session 6 / 30

Unstable particles in physical processes. Solved and unsolved problems

GINZBURG, Ilya ¹

¹ *Sobolev Institute of Mathematics SB RAS Novosibirsk Russia*

Corresponding Author: ginzburg@math.nsc.ru

We consider three different series of problems

1. The t-channel singularity in small angle scattering (almost solved).
In the processes like $\mu^+\mu^-\rightarrow W e\nu$ with effective mass $e\nu$ lower than m_μ transferred momentum of ν can be both space-like and time-like. In the naive approach it gives divergent cross section. This difficulty is eliminated when treat initial states as wave packets, no plane wave. We discuss experiment in which such phenomenon can result sizable effect.
2. The s-channel singularity near threshold (a way for solution is seen). If the decay $A\rightarrow BC$ is possible, cross section of process $\gamma a\rightarrow BC$ grows at lower energy of photon ω as $1/\omega^2$. The solution of this problem is in the fact that the number of photons per volume at finite field energy decreases as $1/\omega^3$. We discuss possible using of approach to the description of processes in strong non-monochromatic field.
3. The perturbative QFT with unstable particles for the observable processes (unsolved). The space of states in the loop calculation on EW theory contains heavy W, Z, etc.. They should be removed from the loop, since these particles have no asymptotic states. How to formulate accurate theory?

parallel session 5 / 31

Two Higgs doublets as pseudo Nambu-Goldstone bosons

Author: YAGYU, Kei ¹

Co-Authors: Prof. MORETTI, Stefano ²; Dr. DELLE ROSE, Luigi ²; Prof. DE CURTIS, Stefania ¹

¹ *INFN, University of Florence*

² *Rutherford Appleton Laboratory*

Corresponding Author: m0741111@googlemail.com

We discuss composite two Higgs doublet models based on the global symmetry breaking $SO(6)$ to $SO(4)*SO(2)$. We construct two Higgs doublets emerging from 8 pseudo Nambu-Goldstone bosons, and then show how the scalar potential is generated through the Coleman-Weinberg mechanism at one-loop level. We also show several phenomenologically viable scenarios, a mass spectrum of Higgs bosons, their couplings to SM fields and branching ratios, which are predicted by fundamental parameters in a composite sector.

parallel session 5 / 32

Two Higgs Doublet Models with controlled Flavour Changing Neutral Couplings

NEBOT GÓMEZ, Miguel ¹

¹ *CFTP - Lisbon*

Corresponding Author: negomi@uv.es

A general Two Higgs Doublet Model includes uncontrolled sources of tree level flavour violation in neutral couplings. In popular cases like type I or II, the imposition of a symmetry forbids them. We explore scenarios where a symmetry requirement, rather than removing them, allows for their presence in a controlled manner. Phenomenological consequences of those controlled tree level FCNC are explored.

parallel session 1 / 33

Light dark Higgs boson in minimal sub-GeV dark matter scenarios

DARME, Luc ¹; RAO, Soumya ¹; ROSZKOWSKI, Leszek ¹

¹ *National Centre for Nuclear Research (NCBJ)*

Corresponding Author: soumya.rao@ncbj.gov.pl

Minimal scenarios with light (sub-GeV) dark matter whose relic density is obtained from thermal freeze-out must include new light mediators. In particular, a very well-motivated case is that of a new "dark" massive vector gauge boson mediator. The mass term for such mediator is most naturally obtained by a "dark Higgs mechanism" which leads to the presence of an often long-lived dark Higgs boson whose mass scale is the same as that of the mediator. We study the phenomenology and experimental constraints on two minimal, self-consistent dark sectors that include such a light dark Higgs boson. In one the dark matter is a pseudo-Dirac fermion, in the other a complex scalar. We find that the constraints from BBN and CMB are considerably relaxed in the framework of such minimal dark sectors. We present detection prospects for the dark Higgs boson in existing and projected proton beam-dump experiments. We show that future searches at experiments like Xenon1T or LDMX can probe all the relevant parameter space, complementing the various upcoming indirect constraints from astrophysical observations.

parallel session 5 / 34

How to study models with an arbitrary number of Higgs-boson doublets

MANIATIS, Markos ¹; Prof. NACHTMANN, Otto ²

¹ *Departamento de Ciencias Basicas, UBB Concepcion, Chile*

² *Heidelberg University*

Corresponding Author: maniat8@gmail.com

We would like to show how stability, electroweak symmetry breaking and symmetries may be studied in models with various Higgs-boson doublets.

parallel session 6 / 35

Phenomenology of the model based on classically scale invariance for electroweak symmetry breaking

Author: HASHINO, Katsuya ¹

Co-Author: Prof. KANEMURA, Shinya ²

¹ *Osaka University / University of Toyama*

² *Osaka University*

Corresponding Author: hashino@het.phys.sci.osaka-u.ac.jp

In the standard model, the negative mass parameter is introduced in the Higgs potential to occur electroweak symmetry breaking. In a class of models based on classically scale invariance, parameters with mass dimensions in the Lagrangian are prohibited by classically scale invariance and electroweak symmetry breaking dynamically occurs by Coleman and Weinberg mechanism.

In this talk, I focus on the extended Higgs model with classically scale invariance for electroweak symmetry breaking and we discuss the phenomenology in the model.

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From parameters to observables in the 2HDM

Author: OGREID, Odd Magne ¹

Co-Authors: Prof. OSLAND, Per ²; GRZADKOWSKI, Bohdan ³

¹ *Western Norway University of Applied Sciences*

² *University of Bergen*

³ *University of Warsaw*

Corresponding Author: omo@hvl.no

A straightforward method to translate the potential parameters of the 2HDM into physical masses and couplings is presented. The method is applied to CP-odd and CP-even weak-basis invariants of the model in order to express them exclusively in terms of the physical observable masses and couplings.

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Gravitational waves from the first order electroweak phase transition in the Z_3 symmetric singlet scalar model

Dr. KANG, Zhaofeng ¹; Prof. KO, Pyungwon ²; MATSUI, Toshnori ²

¹ *Huazhong University of Science and Technology*

² *KIAS*

Corresponding Author: matsui@kias.re.kr

Among various scenarios of baryon asymmetry of the Universe, electroweak baryogenesis is directly connected with physics of the Higgs sector. We discuss spectra of gravitational waves which are originated by the strongly first order phase transition at the electroweak symmetry breaking, which is required for a successful scenario of electroweak baryogenesis. In the Z_3 symmetric singlet scalar model, the significant gravitational waves are caused by the multi-step phase transition. We show that the model can be tested by measuring the characteristic spectra of the gravitational waves at future interferometers such as LISA and DECIGO. This talk is based on arXiv:1706.09721 in collaborated with Zhaofeng Kang and Pyungwon Ko.

parallel session 1 / 38

Boltzmann equation for relativistic species and Hot Dark Matter

SZCZERBIAK, Paweł¹

¹ *Warsaw University, Faculty of Physics*

Corresponding Author: pawel.szczerebiak@fuw.edu.pl

The latest Planck CMB data seem to strongly constrain the Hot Dark Matter scenarios, although they stay in tension with direct Hubble constant measurements. However, one can believe that in near future the experimental uncertainty for the effective number of neutrino species N_{eff} will shrink vastly. Therefore, in order to estimate the allowed parameter space of models predicting a Hot Dark Matter component, it is crucial to calculate its relic density with high accuracy. In my talk I will exploit the Boltzmann equation in the form suitable for relativistic species in Weinberg's Higgs portal model. I will also discuss how in similar scenarios different statistics of incoming/outgoing particles influence the results.

parallel session 2 / 39

Twin Photon and Twin Higgs Phenomenology

Author: NAJJARI, Saereh¹

Co-Authors: Prof. CHACKO, Zackaria²; Prof. KILIC, Can³; Dr. VERHAAREN, Christopher⁴

¹ *University of Warsaw*

² *University of Maryland, College Park*

³ *University of Texas*

⁴ *University of California, Davis*

Corresponding Author: saereh.najjari@fuw.edu.pl

I will present the phenomenology of twin photon and twin sector Higgs in the Mirror Twin Higgs framework. I will show the experimental constraints on the parameters of the model and discuss how that will allow us to confirm the Twin Higgs mechanism at colliders.

parallel session 5 / 41

$(g-2)_{\mu}$ in the presence of CP-violation

KEUS, Venus¹

¹ *University of Helsinki*

Corresponding Author: venus.keus@helsinki.fi

It is known that the CP-even and CP-odd scalars contribute with an opposite sign to the anomalous magnetic moment of the muon.

We study popular scalar extensions of the Standard Model, namely the singlet extension, the 2-Higgs doublet model (2HDM) and the doublet plus singlet extension.

We show that these models are incapable of explaining the observed discrepancy in $(g-2)_{\mu}$, with the exception of 2HDM Type-II which contributes too strongly to $(g-2)_{\mu}$.

We then identify by introducing CP-violation which of these models can explain the anomalous magnetic moment of the muon in a region of the parameter space which is allowed by the eEDM constraints.

parallel session 3 / 42

Froggatt-Nielsen mechanism in a model with 331-gauge groupAuthor: KOIVUNEN, Niko ¹Co-Author: Prof. HUITU, Katri ¹¹ *University of Helsinki***Corresponding Author:** niko.koivunen@helsinki.fi

The models with the gauge group $SU(3)_c \times SU(3)_L \times U(1)_X$ (331-models) have been advocated to explain why there are three fermion generations in Nature. As such they provide partial understanding of the flavour sector. The hierarchy of fermion masses in the Standard Model is another puzzle which remains without compelling explanation. In this talk I present a model that incorporates Froggatt-Nielsen mechanism into a 331-model in order to explain both fundamental problems. It turns out that no new additional scalar representations are needed to take care of this. The 331-models thus naturally include explanations to both the number of fermion generations and their mass hierarchy. This talk is based on arXiv:1706.09463[hep-ph].

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Correlation between the decays of h^0 to photon and gluon pairs in the MSSM with quark flavour violationEBERL, Helmut ¹¹ *Hephy Vienna***Corresponding Author:** helmut.eberl@oeaw.ac.at

We study the correlation between the loop-induced decays h^0 to photon photon and h^0 to gluon gluon in the Minimal Supersymmetric Standard Model (MSSM) with non-minimal quark flavour violation assuming that h^0 has a mass of the Higgs boson measured at LHC.

We perform a MSSM parameter scan respecting theoretical and experimental constraints. The deviations of these two decay widths from the Standard Model values can be large, in the order of $\pm 10\%$, simultaneously and they are correlated.

Such large deviations can be observed at a future $e^+ e^-$ collider.

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Production of squarks at the LHC in R-symmetric SUSY: NLO resultsDIESSNER, Philip ¹¹ *DESY Hamburg***Corresponding Author:** philip.diessner@desy.de

Experimental limits on the masses of SUSY states from searches at the LHC are becoming quite stringent, especially for the gluino of the MSSM.

The MRSSM is an alternative supersymmetric model which features an continuous R-symmetry and it leads to a Dirac-type gluino.

Compellingly, it is natural for a Dirac gluino to have a large mass outside the current bounds.

For an accurate prediction of the production strongly interacting SUSY states at the LHC next-to leading order corrections are relevant and need to be considered.

This has not yet been done for the case of Dirac gluinos and it is our goal to remedy this for the MRSSM.

In this talk I will present details of the NLO SUSY-QCD calculation in the MRSSM for the squark production at the LHC.

Special emphasis will be put on the differences between the MSSM and the MRSSM.

parallel session 2 / 45

Exploring the Scalar Sector of the Twin Higgs Models

AHMED, Aqeel ¹

¹ *University of Warsaw*

Corresponding Author: aqeel.ahmed@fuw.edu.pl

Twin Higgs models are the prime illustration of neutral naturalness, where the new particles of the twin sector, gauge singlets of the Standard Model, ameliorate the little hierarchy problem. I will discuss the phenomenological implications of the heavy Higgs of the Mirror Twin Higgs and Fraternal Twin Higgs models at the LHC. In particular, I will show how the scalar sector of the Twin Higgs models could lead to their potential discovery at the LHC.

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A systematic mass insertion expansion for lepton violating decays in the MSSM

FABISIEWICZ, Zofia ¹

¹ *University of Warsaw*

Corresponding Author: zofia.fabisiewicz@fuw.edu.pl

In this talk we analyze the sources of lepton flavor violation in the Minimal Supersymmetric Standard Model (MSSM) in the processes $l \rightarrow l' \gamma$ and $h \rightarrow ll'$. Using the Flavor Expansion Theorem, a recently developed technique of a purely algebraic mass-insertion expansion of the amplitudes, we recover the direct analytic dependence of the results on the MSSM Lagrangian parameters. Both flavor-violating off-diagonal terms and flavor-conserving mass-insertions are considered. We also study the decoupling features of the amplitudes in the limit of heavy SUSY spectrum. The results are compared with calculations in the mass eigenstates basis (i.e. using the exact diagonalization of the mass matrices).

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Scalar Physics at CMS

Corresponding Author: landsberg@hep.brown.edu

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Scientific highlights from ATLAS - LHC Run 2

Corresponding Author: alan.barr@physics.ox.ac.uk

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Naturalness: Standard searches and the alternative relaxing way

Corresponding Author: christophe.grojean@cern.ch

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The 0^{++} scalar of QCD: A Beacon for new physics

Corresponding Author: adleroni@gmail.com

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Higgs (and flavour) constraints in 2HDM

Corresponding Author: mahmoudi@in2p3.fr

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Unified Scenario for Composite Right-handed Neutrinos and Dark Matter

Corresponding Author: hooman@bnl.gov

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Testing the Scalar Sector of the Mirror Twin Higgs at Colliders

Corresponding Author: zchacko@umd.edu

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The hierarchion, a unified explanation of all SM hierarchies and neutrino masses

Corresponding Author: sandeepan.gupta@durham.ac.uk

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Baryogenesis from L-violating Higgs doublet decay

Corresponding Author: thambye@ulb.ac.be

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Non-Local Field Theory: From Gravity to Higgs

Corresponding Author: anupam.mazumdar@rug.nl

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Gravity and the EW vacuum Stability

Corresponding Author: branchina@ct.infn.it

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Replicating the Higgs doublet

Corresponding Author: haber@scipp.ucsc.edu

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The golden age, 2030s

Corresponding Author: kanemu@phys.sci.osaka-u.ac.jp

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Looking for scalar resonances at the LHC

Corresponding Author: per.osland@uib.no

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Controlled Flavour Changing Neutral Currents in the Higgs Sector

Corresponding Author: gbranco@tecnico.ulisboa.pt

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A simple method to detect spontaneous CP Violation in multi-Higgs Models

Corresponding Author: rebelo@tecnico.ulisboa.pt

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Cosmological constraints on Higgs portal coupled scalars

Corresponding Author: pospelov@uvic.ca

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Natural Lepton Flavor Universality Violation

Corresponding Author: quiros@ifae.es

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The Hunt for Extra Higgs Bosons in the NMSSM

Corresponding Author: ellwanger@th.u-psud.fr

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The C2HDM revisited

Corresponding Author: rasantos@fc.ul.pt

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Muon $g-2$ from light A_0 in the 2HDM

Corresponding Author: dominik.stoeckinger@tu-dresden.de

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Bounds on $M_{H^{\pm}}$ from B to $X_{\{s,d\}}$ gamma decays

Corresponding Author: misiak@fuw.edu.pl

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Low-energy probes of heavy particles

Corresponding Author: afalkows017@gmail.com

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Renormalisation-group improvement of multi-field effective potentials

Author: SWIEZEWSKA, Bogumila ¹

Co-Authors: Dr. PROKOPEC, Tomislav ¹; CHATAIGNIER, Leonardo ²; Prof. SCHMIDT, Michael G. ³

¹ *Utrecht University*

² *University of Cologne*

³ *Universität Heidelberg*

Corresponding Author: b.swiezewska@uu.nl

In this talk we present a new method of renormalisation-group (RG) improvement of effective potentials in models with extended scalar sectors. The method amounts to running with the renormalisation scale to a surface in the parameter space where quantum corrections to the effective potential vanish. This can be equivalently understood as fixing the renormalisation scale to a suitably chosen field-dependent value, in analogy to the well-known approach in the one-field case. It allows to evaluate the effective potential using the tree-level form for any values of fields. In the talk we discuss limitations of the method as well as several applications. One of these is the study of stability of the potential beyond tree-level for which the RG improvement is indispensable and which can be simplified with the use of our method.

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The Energy and Accuracy Frontier

Corresponding Author: a.wulzer@gmail.com

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Axion-like particles at the LHC and future colliders

Corresponding Author: neubertm@uni-mainz.de

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The Hunt for the Axion

Corresponding Author: andreas.ringwald@desy.de

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New symmetries and electro-weak symmetry breaking

Corresponding Author: lindner@mpi-hd.mpg.de

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Electroweak production of multiple scalars in the two-Higgs doublet model

ENBERG, Rikard ¹¹ *Uppsala University***Corresponding Author:** rikard.enberg@physics.uu.se

We consider the electroweak production of multiple Higgs bosons at the LHC in the two-Higgs doublet model (2HDM). We show that in realistic models the electroweak cross sections for production of 2 or 3 Higgs bosons can dominate over QCD production. This is because in a gg-initiated process, production via a resonant Z in the s-channel is prohibited according to the Landau-Yang theorem, which is not the case for a qq-initiated process.

We discuss the issue of accessing the 3-particle couplings with combinations of Higgs bosons and vector bosons, as well as Higgs-fermion couplings, using electroweak production modes in final states with multiple Higgs bosons and/or vector bosons.

We therefore explore regions of parameter space of the Type-I and Type-II models that are consistent with constraints from collider searches, b-physics and EW precision data and the data on the Higgs boson at LHC. We compute cross sections for Higgs pair production $qq \rightarrow h_i h_j$ and associated production with a gauge boson, $qq \rightarrow h_i V_j$, where h_i is any of the 2HDM scalars. We also consider production of 3 and 4 Higgs bosons, and we compute the corresponding gg initiated cross sections. In some interesting cases the qq initiated cross sections can be as large as hundreds of femtobarns.

We also consider the special case when the Higgs boson discovered at the LHC is the heavier CP-even Higgs boson of the 2HDM, and when the sum of the masses of the lighter CP-even scalar and the CP-odd scalar is smaller than the Z boson mass. We find that there is a region of parameter space in the Type-I model where this is possible, and study the phenomenology of such parameter points.

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Dark Matter Signals at the LHC from a 3HDM

Author: SOKOLOWSKA, Dorota ¹Co-Authors: Prof. MORETTI, Stefano ²; Dr. KEUS, Venus ³¹ *University of Warsaw*² *Rutherford Appleton Laboratory*³ *University of Helsinki***Corresponding Author:** dsok@fuw.edu.pl

We analyse new signals of Dark Matter (DM) at the LHC, in a 3-Higgs Doublet Model (3HDM) in which only one doublet acquires a Vacuum Expectation Value (VEV), preserving a Higgs parity Z_2 . The other two doublets are inert and do not develop a VEV, leading to a dark scalar sector controlled by the Higgs parity and a Dark Matter (DM) candidate provided by the lightest CP-even dark scalar H_1 . This leads to a loop induced decay of the next-to-lightest scalar, $H_2 \rightarrow H_1 \gamma^* \rightarrow H_1 l+l$ mediated by loops involving both the dark CP-odd and charged scalars. This smoking gun decay, not permitted in the 2HDM with one inert doublet, is expected to be important when H_2 and H_1 are close in mass. We examine the significance of this channel in the light of the LHC Run 2.

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Pair production of doubly charged scalar particles in future colliders

KORDIACZYNSKA, Magdalena¹

¹ *University of Silesia*

Corresponding Author: mkordiaczynska@us.edu.pl

In this presentation we consider doubly charged scalars pair production and decays within the Higgs Triplet Model (HTM) in lepton and hadron colliders. The HTM is an extension of the Standard Model realising the type II seesaw mechanism [1]. The additional scalar triplet contains the doubly charged particle H^{++} , which contributes to lepton flavour violating (LFV) processes. We discuss relation between the vacuum expectation value (VEV) of the triplet, H^{++} mass, and H^{++} pair production at colliders, taking into account constraints on VEV coming from low energy effects connected with rho-parameter, muon $g-2$, LFV processes and neutrino oscillations (normal and inverted mass scenarios). Branching ratios for H^{++} decays are also discussed. A difference between HTM model and H^{++} pair production predictions when additional right-handed currents are present is discussed.

In analysis the newest neutrino oscillation data are taken into account [2]. We apply those data to calculate the $e^+ e^- \rightarrow H^{++} H^{--}$ cross section for both S and T channel and predict cross sections. Then we present the pair production at hadron collider and compare the four lepton signals with results obtained within the Minimal Left Right Symmetric Model [3] where doubly charged scalars are also present.

[1] M.Magg, C. Wetterich, Phys. Lett. B94, 61 (1980)

[2] I. Esteban, M. C. Gonzalez-Garcia, M. Maltoni, I. Martinez-Soler and T. Schwetz, JHEP 01 (2017) 087

[3] G. Bambhaniya, J. Chakraborty, J. Gluza, M. Kordiaczynska and R. Szafron, JHEP 05 (2014) 033

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Methods for computing the critical temperature of the electroweak phase transition

Author: LÖFGREN, Johan ¹

Co-Author: ENBERG, Rikard ¹

¹ *Uppsala University*

Corresponding Author: johan.lofgren@physics.uu.se

In theories with spontaneous symmetry breaking it is possible to calculate the critical temperature of the phase transition between the symmetric and broken phases of the theory. In the Standard Model and its extensions, the temperature of the electroweak phase transition is interesting for a number of physical questions – for example when considering the observed matter/antimatter asymmetry, or when calculating the spectrum of gravitational waves generated by the phase transition.

However, the traditional way of calculating the critical temperature has long been known to give a gauge dependent result. In 2011, Patel and Ramsey-Musolf have shown how to calculate this temperature in a gauge-invariant way by consistently truncating the perturbation expansion.

In this talk we will compare these two methods of finding the critical temperature, exploring the differences between the results they yield, based on a code which we have developed. Using this code it is straight-forward to implement an arbitrary model – in this talk we will consider simple Standard Model extensions, in particular standard model effective field theory up to dimension 6 operators. We will also discuss possible future uses for the code, such as studying the critical temperature of the Two Higgs Doublet Model.

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Relaxion in symmetric 2HDM

MARKIEWICZ, Adam ¹; Prof. LALAK, Zygmunt ²

¹ *University of Warsaw*

² *ITP UW*

Corresponding Author: adam.markiewicz@fuw.edu.pl

Dynamical relaxation provides an interesting solution to the hierarchy problem, which allows to produce a large hierarchy of scales without abandoning the naturalness principle. The observed value of the electroweak scale is then a consequence of an interaction between the Higgs boson and a new axion-like field, a relaxion. Attempts at extending this mechanism to a two-doublet scenario (arXiv:1612.09128) show that without an additional symmetries of the potential the second doublet does not affect the relaxation process and generally remains vevless. However, non-trivial contributions are possible when some classes of accidental (possibly weakly-broken) symmetries are considered. This talk will present an attempt at introducing the relaxation in the maximally-symmetric 2HDM (MS-2HDM), where the doublets are connected by an approximate SO(5) symmetry.

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Multilepton signals of heavier electroweakinos at the LHCAuthor: CHAKRABORTI, Manimala ¹Co-Authors: Prof. DATTA, Amitava ²; Ms. GANGULY, Nabanita ³; Dr. PODDAR, Sujoy ⁴¹ *University of Bonn*² *Fellow of Indian National Science Academy*³ *University of Calcutta*⁴ *Diamond Harbour Women's University***Corresponding Author:** mani.chakraborti@gmail.com

We examine the phenomenology of the full electroweakino sector of the pMSSM without invoking the ad hoc but often employed assumption that the heavier ones are decoupled. We identify several generic models which illustrate the importance of the heavier electroweakinos and constrain them with the LHC 3l + missing E_T data. The constraints are usually stronger than that for decoupled heavier electroweakinos indicating that the LHC data is already sensitive to their presence. We also take into account the constraints from the observed dark matter relic density of the universe and precisely measured anomalous magnetic moment of the muon. Using the allowed parameter space thus obtained, we show that in addition to the conventional 3l + missing E_T signatures novel multilepton (ml) + missing E_T final states with $m > 3$, which are not viable in models with lighter electroweakinos only, can be observed before the next long shut down of the LHC.

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On reheating in alpha attractor models of inflationWIECZOREK, Michal ¹¹ *University of Warsaw***Corresponding Author:** krolb@fuw.edu.pl

With increasing accuracy of CMB data, a thorough, quantitative understanding of the post-inflationary reheating era becomes more and more important for constraining different models of inflation. In particular, a precise computation of the non-homogeneous field evolution during preheating is desirable. In this talk I will present results of such computation for alpha-attractors models of inflation. I will show the Floquet analysis of field perturbations evolution, as well as results of full non-linear simulations of the field evolution. I will discuss the importance of studying the dynamics of both scalar fields present in the model.

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The Supersymmetric Georgi-Machacek modelVEGA, Roberto ¹¹ *Southern Methodist University***Corresponding Author:** krolb@fuw.edu.pl

We show that the well known Georgi-Machacek (GM) model can be realized as a limit of the recently constructed Supersymmetric Custodial Higgs Triplet Model (SCTM) which in general contains a significantly more complex scalar spectrum. We dub this limit of the SCTM the Supersymmetric GM (SGM) model. We derive a mapping between the SGM and GM models using it to show supersymmetry implies constraints on the Higgs potential in the conventional GM model. We then perform a simplified phenomenological study of diphoton and ZZZ signals for a pair of benchmark scenarios to illustrate under what circumstances the GM model can mimic the SGM model and when they should be easily distinguishable.

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Multi-component vector-fermion dark matter with scalar mediator

DUCH, Mateusz¹

¹ *University of Warsaw*

Corresponding Author: mateusz.duch@fuw.edu.pl

It is possible that dark matter consists of two or more particle species with non-negligible contribution to the relic abundance. This scenario leads to a complicated dynamic in the hidden sector where various processes are responsible for the thermal production of dark matter. We discuss the model with fermionic and vector dark matter candidates that interact with the Standard Model through the Higgs portal. Their masses are generated due to the spontaneous breaking of gauge symmetry in the hidden sector whose remnants stabilize two or three DM components. We indicate the regions in the parameter space, where bounds from direct detection are satisfied and all dark matter components have substantial contributions to the relic abundance.

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A neutrino option for the Higgs potential

Corresponding Author: michael.trott@cern.ch

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Overview

Corresponding Author: zchacko@umd.edu

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TBA

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DM in 3HDMs

Corresponding Author: stefano.moretti@stfc.ac.uk

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Extension of the Standard Model with a Doublet and a Complex Singlet and Heavy Vector Quarks

Corresponding Author: neda.darvishi@fuw.edu.pl

I will discuss the extension of the Standard Model by a doublet and a complex scalar singlet and a pair of heavy vector quarks. This model provides an extra source of spontaneous CP violation and a strong enough first-order electroweak phase transition to suppress the baryon-violating sphaleron process. This model contains a proper description for baryogenesis and provides a correct relic density of dark matter (DM) while fulfilling direct and indirect DM detection limits and simultaneously agreeing with the LHC results.

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Test

Corresponding Author: krolb@fuw.edu.pl

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Fine-tuning in Multifield Inflation

Corresponding Author: sotirios.karamitsos@manchester.ac.uk

The choice of initial conditions in multifield inflation has a direct effect on observable quantities. Even after the attractor solution has been reached, the existence of multiple scalar degrees of freedom requires us to exclude certain inflationary trajectories when comparing their predictions to actual values. In the presence of observational uncertainties, this translates to fine-tuning for the initial values of the inflaton fields. In this talk, I will present a method that may be used to quantitatively distinguish between stable and unstable trajectories in general scalar-curvature models of inflation, and I will show how to quantify the degree of fine-tuning required for inflationary trajectories living in a curved field space.