7th RISE Collaboration workshop: NonMinimalHiggs

Monday, 27 May 2019 - Wednesday, 29 May 2019

Physicum

Book of Abstracts

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Supersymmetry versus Compositeness: 2HDMs tell the story

Supersymmetry and Compositeness are two prevalent paradigms providing both a solution to the hierarchy problem and a motivation for a light Higgs boson state. As the latter has now been found, its dynamics can hold the key to disentangle the two theories. An open door towards the solution is found in the context of 2-Higgs Doublet Models (2HDMs), which are necessary to Supersymmetry and natural within Compositeness in order to enable Electro-Weak Symmetry Breaking. We show how 2HDM spectra of masses and couplings accessible at the Large Hadron Collider may allow one to separate the two scenarios.

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Vacuum instabilities in the N2HDM

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Approximate alignment without decoupling in the 2HDM naturally

The 2HDM scalar potential governed by a generalized CP symmetry (called GCP3) is known to yield natural Higgs alignment independently of tan(beta). Nevertheless, such a model does not yield a realistic
extended Higgs sector for two reasons. First, the model possesses an axion associated with the electroweak
scale, which has long been ruled out by data. Second, the GCP3 symmetry cannot be extended to the Yukawa
sector in a way consistent with the flavor sector. Both problems can be alleviated by introducing vector
like quarks. Mass terms associated with the vector like quark sector provide soft-breaking of the GCP3
symmetry thereby avoiding the presence of the axion. Moreover, the GCP3 symmetry can be used to connect
the SM quarks to the vector like quarks, while preserving the SM flavor structure (up to small mixing between
the quarks and their vector-like partners). The naturalness of the Higgs alignment, which is now approximate
due to soft-breaking effects, is preserved as long as the UV cutoff of the theory is not too large.

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Electroweak multi-Higgs production in the 2HDM

Gluon-induced processes are often the most important production channels for double Higgs production in models with extended Higgs sectors, but we demonstrate that in some parts of the parameter space of the Type I 2HDM, electroweak pair production of neutral or charged Higgs states can dominate over QCD-initiated production. We study such regions of parameter space and highlight some specific double Higgs signatures that can be probed at the LHC and discuss which couplings that can potentially be accessed through these signatures.

Based on arXiv:1605.02498, arXiv:1706.01964 and arXiv:1812.01147

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LHC-friendly avenues for freeze-in Dark Matter

Freeze-in dark matter (DM) production constitutes an appealing
mechanism to generate the DM relic density for very weakly coupled DM particles which never achieve thermal equilibrium with the Standard Model (SM). We examine the collider probes of freeze-in DM through the decay of parent particles and highlight the complementarity of ATLAS/CMS and the planned MATHUSLA detector in probing such freeze-in DM scenarios at the LHC.

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Gravitational waves from phase transition in the early universe <https://bit.ly/2JG9hwr>

Gravitational waves are expected to be an important probe of physics beyond the Standard Model, through their production at first order phase transitions.
I will discuss simulations and models the generation of gravitational radiation, reporting on recent work on strong phase transitions. and outline possibilities for parameter estimation at the future space-based gravitational wave detector LISA.

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Bubble velocities: the (often) unknown parameter

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Higgs Sector in B–L supersymmetric Standard Model with inverse seesaw

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The Rise and Fall of the Cheng-Sher ansatz

The so-called "Cheng-Sher" ansatz has been the main benchmark for studies of tree-level flavor-changing neutral currents for decades. It was born in 1987, grew very slowly at first, was christened a few years later (by others) and had a pretty good run. It has now been afflicted with LHC data and, barring a surprise in the next year or so, will expire. The talk will briefly discuss the history, and primarily focus on the recent data that has placed the ansatz on life-support.

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Constraining extended scalar sectors at current and future colliders

After the discovery of the Higgs boson by the LHC experiments, particle physics has entered an exciting era. A crucial question that needs to be answered is whether the SM accurately describes the scalar sector realised in nature, or whether it is part of a more extended scalar sector. I will briefly discuss different extensions of the SM scalar sector, current constraints from theory and experimental searches, as well as discovery prospects at current and future colliders. For models containing a dark matter candidate, I will also make a connection to
dark matter experiments.

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Pseudo-Goldstone Dark Matter in the Z_3 Scalar Singlet Model

We consider pseudo-Goldstone dark matter in the Z_3 scalar singlet model with the imaginary part of the singlet as the dark matter candidate. For a large part of the parameter space, the direct detection cross section is highly suppressed. There is a region, however, where the model can produce a stochastic gravitational wave background that could be seen in future space based detectors.

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Stability of the electroweak vacuum in the early universe

Non-equilibrium processes during inflation and reheating could have triggered a fatal transition away from the metastable electroweak vacuum. The fact that this did not happen is a non-trivial consistency test of the Standard Model of particle physics and its extensions. I review the vacuum stability analysis and discuss how the survival of the electroweak vacuum constrains the non-minimal curvature coupling of the Higgs field, the last unknown parameter of the Standard Model.

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Higgs sector of the pMSSM

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Indications for a Higgs Boson below 125 GeV

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Electroweak Phase Transition & Extended Scalar Sectors

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A Fresh Look at the Calculation of Tunneling Actions (blackboard talk)

The calculation of tunneling actions, that control the exponential suppression of the decay of metastable phases (like the unstable electroweak vacuum), can be reformulated as an elementary variational problem in field space. This alternative approach circumvents the use of bounces in Euclidean space by introducing an auxiliary function, a tunneling potential Vt that connects smoothly the metastable and stable phases of the field potential V. The tunneling action is obtained as the integral in field space of an action density that is a simple function of Vt and V and can be considered as a generalization of the thin-wall action to arbitrary potentials. This formalism provides new handles for the theoretical understanding of different features of vacuum decay, can be easily extended to include gravitational effects in an elegant way and has a number of useful applications that I will discuss.

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Primordial black holes from Higgs inflation?

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Primordial black holes are a possible form of dark matter. In principle, they can be formed from strong perturbations seeded by cosmic inflation. Such strong perturbations can be produced in Higgs inflation, where the Standard Model Higgs field coupled non-minimally to gravity is the inflaton, if quantum corrections produce a critical point into the Higgs effective potential. In this talk I explore

this possibility and contrast it to observational bounds on cosmic microwave background radiation and black hole abundance.

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Spectator Dark Matter <https://bit.ly/2Ezq4Nw>

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The observed dark matter abundance in the Universe can be fully accounted for by a scalar field that was light during cosmic inflation and has sufficiently strong self-coupling. In this scenario, dark matter was produced in a somewhat non-standard way: by amplification of quantum fluctuations of the scalar field during inflation. The self-interaction of the field suppresses its fluctuations on large scales, and therefore avoids cosmological isocurvature constraints. The scenario does not require any fine-tuning of parameters. I will also discuss ways to test the scenario.

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Multi-Higgs solution to flavour anomalies and implication for neutrino physics

I review the status of current flavour anomalies that indicate for lepton flavour violation, and show that those can be explained in the context of three Higgs doublet model with GeV scale right-handed neutrinos. Thus the flavour anomalies may indicate for the low scale leptogenesis and neutrino mass mechanism rather than for new exotic physics.

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Dark Electroweak Baryogenesis

Current phenormenological constraints, in particular on the CP-violating parameters from ACME, are rapidlly hunting the viable visible sector EWBG models to extinction. The same fate is falling upon most WIMP dark matter models as a result of the campaign provisoned by DM direct detection experiments. And yet, here we are, and so apparently is the dark matter. DM might escape the hunting parties turning FIMP or outright Despicable. For EWBG a low energy solution would be desirable - to avoid the hierarchy problem, if SM, as Data seem to suggest, remains valid up to ultra high energies. An elegant solution to the quandary would be to combine the two and have a baryogenesis powered by the Dark Sector, perhaps by the DM itself.

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Revisiting jet vetos as handles on new physics

The production of high-mass color-singlet systems in hadron collisions is universally accompanied by initial state QCD radiation that is predominantly soft with respect to the hard process scale and/or collinear with respect to the beam axis. At TeV-scale colliders, this contrasts with most backgrounds. Consequently, vetoing events with jets possessing large transverse momenta in searches for new color-singlet states can efficiently reduce non-singlet backgrounds, thereby increasing experimental sensitivity. To quantify this generic observation, we investigate the production and leptonic decay of extra gauge bosons at next-to-leading order (NLO) in QCD with parton shower (PS) matching. We demonstrate that jet vetoes applied to color-singlet processes can be reliably modeled at the NLO+PS level. We show how jet vetoes can increase the signal-to-noise ratios by roughly 10%-250% for W' boson searches (depending on the W' mass), and how dynamic jet vetoes can improve the sensitivity to sleptons independently of the integrated luminosity.

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Dark matter through the Higgs at the LHC

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Dynamical electroweak symmetry breaking and exotic scalars

We explore the possibility of implementing the Bardeen-Hill-Lindner mechanism of electroweak symmetry breaking in presence of interactions giving rise to new exotic scalars.

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Gravitational waves from hot and cold hidden sectors

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Gravity track of Higgs inflation

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Using the Standard Model Higgs as the inflation is attractively economical. However, there are complications both on the side of quantum corrections and gravity. I will discuss possibilities and problems due to such complications. In particular I will cover how Higgs inflation can be used to distinguish between different gravitational degrees of freedom to find what spacetime is made of.

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Higgs pair production in the SM and BSM

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Vector-like quarks decaying to new scalars

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Light (pseudo)scalars lurking undetected? Some suggestions on mass reconstruction

There are non-minimal Higgs scenarios where one may still have light spin-zero particles consistently with the present data. An example is a Type-X two-Higgs doublet scenario, where one can have a neutral pseudoscalar as light as 50 GeV or less, and a neutral scalar as well as a charged scalar in the range of 200 GeV. Some suggestions for their reconstruction are discussed.

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New Fundamental Interactions

I will report on the state-of-the-art of new theories of fundamental interactions of both safe and free nature. These theories are prime candidates for consistent extensions of the standard model.

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What future colliders will know about the Higgs?

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I will review the Higgs physics programme at the various future colliders.
A special attention will be devoted to the Higgs self-coupling determination.

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Same-sign pair production of singly charged Higgs boson at hadron colliders

We propose a new process of charged Higgs boson production in two Higgs doublet models, which is the weak boson scattering process where singly charged Higgs bosons are produced in a same-sign pair at current and future hadron colliders. The amplitude is proportional to the mass difference between additional CP-even and CP-odd neutral Higgs bosons in the alignment limit, which directly relates to the global symmetry structure of the Higgs potential. The produced charged Higgs bosons predominantly decay into a pair of the tau lepton and the neutrino or into a pair of top and bottom quarks, depending on the type of Yukawa interactions. We evaluate the signal and the background in the both cases at the high-luminosity LHC with the integrated luminosity of 3000 fb^{-1} and also at the high-energy LHC with the energy of 27~TeV. We find that this same-sign production can be feasible at the high-luminosity LHC when the charged Higgs boson decays into either the lepton pair or the top-bottom pair.

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On axions and ALPs

New recent developments on axions and axion-like particles (ALPs) will be presented. On the theoretical side, novel heavy axions constructions that solve the Standard Model (SM) strong CP problem with axion masses in the GeV-teV range and low scales will be presented. Small size instantons provide an extra source of axion mass. As a result, no very light axions are present in the low-energy spectrum while massless sterile fermions are a trademark. The axion scale may be not far from the TeV region which translates in observable signals at colliders. This type of models naturally enlarges the parameter space for axions which solve the strong CP problem, well beyond that of invisible axion models. On the phenomenological consequences, new signals at colliders associated to heavy axions and also to generic ALPs will be discussed.

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Zee Model with Minimal Flavour Violation

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We discuss a simple model for tiny neutrino masses which are generated at one-loop level without right-handed neutrinos.
The scalar sector is extended to have 2 Higgs doublets and a charged singlet filed.
This model has been known as the Zee model, where its original version
was already excluded as it cannot reproduce current neutrino mixing data.
We thus extend the Zee model by introducing a global U(1) symmetry which
plays a role not only to forbid dangerous FCNCs in the quark sector, but also
provides sufficient degrees of freedom to reproduce the current neutrino mixing data.
We show that there are regions of parameter space to explain neutrino data,
lepton flavour violation data and LHC data. We then discuss expected collider signatures.

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Global fits in the Aligned Two-Higgs Doublet model

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We perform a global fit to the most general Aligned Two-Higgs Doublet Model using the open source HEPfit package. The constraints considered include theoretical ones (positivity and perturbativity of the potential), electroweak and Higgs constraints (signal strengths and direct searches) and several flavour observables. The combination of these constraints is used to restrict the value of the scalar masses, the parameters of the potential and the Yukawa couplings.

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Global fits in the coloured scalar model

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In this work we study the phenomenological constraints to the parameter space of scalars carring color quantum numbers. Specifically we constrain the Manohar-Wise model based on the addition of a SU(2) doblet and SU(3) octet to the minimal Higgs model. The fits are performed using the open source HEPfit package. We include both theoretical constraints, such us unitarity and pertubativity, and experimental constraints, like the ones coming from flavour and electroweak observables. For the fist time we combine all these results and we are able to contrain the parameters of the potential, the Yukawa couplings and the masses of the scalars.

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Low-scale leptogenesis via extended scalar sectors

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Probing conformal symmetry through gravitational waves

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In this talk the electroweak and conformal symmetry-breaking phase transition is analysed within the SU(2)cSM model. It consists of the conformal standard model extended by a new gauge SU(2) group and a scalar field that is a doublet under this new symmetry. The two sectors communicate through a Higgs portal coupling. The phase transition proceeds after a large super-cooling and is thus very strong. I will present estimates of the gravitational-wave signal and show that it generically falls into the LISA sensitivity region.

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The TBA model*

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Consistent use of Effective potentials

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Welcome words