Preparatory Joint Sessions on ”Open questions and News Ideas”

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Book of Abstracts

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Aligned CP-Violating Higgs Model Canceling the Electric Dipole Moment

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

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Aligned CP-violating Higgs model canceling the electric dipole moment

Author: Mitsunori Kubota[1]

Co-authors: Kei Yagyu [1] ; Shinya Kanemura [1]

[1] *Osaka University*

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

The extended Higgs model with the CP-violation is a good candidate realizing baryogenesis. However, such extra CP violation is strongly constrained by the electric dipole moment (EDM) data. In this talk, we consider the general two Higgs doublet model in which the CP phases are originated by the Higgs potential and the Yukawa interaction, and we discuss the cancellation between the contributions of these CP phases to the EDM. As a result, we show that the individual CP-violating phases can get O(1) [rad] while the EDM constraints are satisfied. This talk is based on the paper S. Kanemura, M. Kubota, K. Yagyu, arXiv:2004.03943 [hep-ph].

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Anomalously charged and Long-lived avatars of BSM physics

Corresponding Author: jpinfold@ualberta.ca

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BFKL resummation effects

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Constraining heavy-flavor PDFs at hadron colliders

Author: Marco Guzzi[1]

[1] *Kennesaw State University*

Corresponding Author: mguzzi@kennesaw.edu

We discuss about the possibility of constraining heavy-flavor parton distribution functions (PDFs) in the proton, in particular the top and bottom PDFs. We discuss about heavy-flavor initiated processes and their potential impact in future global PDF analyses.

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Current bounds and future prospects of light neutralino dark matter in NMSSM

Authors: Rahool Kumar Barman[1] ; Dipan Sengupta[2] ; Rohini Godbole[3] ; Genevieve Belanger[4] ; Xerxes Tata[5] ; Biplob Bhattacherjee[6]

[1] *Indian Association for the Cultivation of Science*

[2] *University of California, San Diego*

[3] *Indian Institute of science (IN)*

[4] *LAPTh, Universit\'e Savoie Mont Blanc, CNRS, Annecy*

[5] *University of Hawaii*

[6] *Indian Institute of Science, Bangalore*

Corresponding Authors: rahoolkbarman@gmail.com, biplob@iisc.ac.in, tata@phys.hawaii.edu, belanger@lapth.cnrs.fr, rohini@iisc.ac.in, disengupta@physics.ucsd.edu

We examine the region of the parameter space of the Next to Minimal Supersymmetric Standard Model (NMSSM) with a light neutralino˜($M_{\tilde{\chi}_1^0} \le$ 62.5 GeV) where the SM-like Higgs boson can decay invisibly, the thermal neutralino relic density is smaller than the measured cold dark matter relic density, and where experimental constraints from LHC searches and flavor physics are satisfied. We observe allowed regions of parameter space where the lightest neutralino could have a mass as small as ≤ 10 GeV while still providing a significant component of relic dark matter (DM). We then examine the prospects for probing the NMSSM with a light neutralino via direct DM detection searches, via invisible Higgs boson width experiments at future e^+e^- colliders, via searches for a light singlet Higgs boson in $2b2\mu$, $2b2\tau$ and $2\mu2\tau$ channels and via pair production of winos or doublet higgsinos at the high luminosity LHC and its proposed energy upgrade. For this last-mentioned electroweakino search, we perform a detailed analysis to map out the projected reach in the $3l + \not{E}_{\rm T}$ channel, assuming that chargino decays to $W\tilde{\chi}_1^0$ and the neutralino(s) decay to Z or H_{125} + $\tilde{\chi}_1^0$. We find that the HL-LHC can discover SUSY in just part of the parameter space in each of these channels, which together can probe almost the entire parameter space. The HE-LHC probes essentially the entire region with higgsinos˜(winos) lighter than 1˜TeV˜(2˜TeV) independently of how the neutralinos decay, and leads to significantly larger signal rates that may allow further exploration of the underlying new physics.

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DM@Collider summary plots for snowmass - plans for DM simplified models

Authors: Antonio Boveia[1] ; Boyu Gao[1] ; Eric Edward Corrigan[2]

[1] *Ohio State University*

[2] *Lund University (SE)*

Corresponding Authors: eric.edward.corrigan@cern.ch, gao.1559@buckeyemail.osu.edu, antonio.boveia@cern.ch

Plots that compare results of dark matter searches at collider, direct and indirect detection have been prepared for the European Strategy.

Those plots use as comparison benchmarks the simplified models in the Dark Matter Forum whitepaper [arxiv: 1507.00966], but they are only made for coupling values of order unity [arxiv: 1703.05703].

For Snowmass, we propose to prepare a similar set of plots where the coupling is varied to reach lower values. This will allow us to have a more complete picture of the complementarity of collider DM searches with direct and indirect detection, as well as compare collider results with collaborations that are sensitive to much lower couplings, such as accelerator-based and fixed target experiments.

In this short contribution, I will talk about our plans and briefly introduce the methods that we intend to use, the inputs that would be required by the various future collider experiments, and the summary plots that can be made for dark matter at colliders.

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Dark matter and tau g–2 using the LHC as a photon collider

Author: Jesse Liu[1]

Co-author: Lydia Beresford [2]

[1] *University of Chicago*

[2] *University of Oxford*

Corresponding Authors: lydia.beresford@cern.ch, jesse.liu@cern.ch

Electromagnetic fields surrounding LHC beams source high energy photons that can collide to produce new particles. We highlight important and interesting BSM physics targets for QED production from two recent proposals: 1) slepton and dark matter production with proton-tagging using pp beams, 2) new physics modifications to tau g-2 using PbPb beams. These open new cross-cutting opportunities at the energy frontier.

Based on PRL 123 (2019) 14 141801 and 1908.05180

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Discussion

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Early kinetic decoupling of dark matter and the Higgs invisible decay in collider experiments

Authors: Tomohiro Abe[1] ; Tobias Binder[2] ; Mihoko Nojiri[3] ; Shigeki Matsumoto[2]

[1] *Nagoya University*

[2] *Kavli IPMU*

[3] *KEK*

Corresponding Authors: abetomo@kmi.nagoya-u.ac.jp, nojiri@post.kek.jp

We revisit the Higgs-to-invisible decay ratio in Higgs-portal dark matter models. The Higgs-to-invisible decay searches are powerful probes of the models with increasing sensitivity in upcoming colliders. Close to the mass threshold of a Higgs decay into a pair of DM particles, the coupling value is expected to be very small in order to be compatible with the observed value of the thermal relic abundance. This small coupling perfectly fits with the current status of Higgs-to-invisible constraints and direct detection experiments, such as the XENON1T experiment. At the same time, the small coupling implies a lower DM scattering rate with particles in the early Universe plasma. The suppression of the scattering rate makes the kinetic decoupling happens earlier. Thus, the standard assumption in many relic abundance computations, namely the local thermal equilibrium, is not justified during the freeze-out process. We reanalyze Higgs-portal DM models, such as the Scalar-Singlet and a fermion DM model, taking the new effect of early kinetic decoupling in the relic abundance computation into account. Our results show that a larger value of the DM coupling to the Higgs is allowed. Therefore, current and future Higgs-to-invisible decay searches can generically probe more of the parameter space than previously expected.

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Easy e+e- event analysis with LCIO & miniDST

Authors: Jenny List[1] ; Frank Gaede[1] ; Shin-ichi Kawada[1] ; Mikael Berggren[1]

[1] *DESY*

Corresponding Authors: jenny.list@desy.de, shin-ichi.kawada@desy.de, mikael.berggren@desy.de, frank.gaede@desy.de

We introduce a new data format tailored to provide an easy and efficient entry into projections for e+e- colliders, called miniDST. The miniDST comprises isolated electron, muon, tau and photon candidates, jets with b- and c-tagging information, particle flow objects and MC truth information as well as event shape variables.
It is based on LCIO and is directly readable in root.
The miniDST can be filled from full detector simulation, SGV fast simulation and from Delphes.
The ILC community is planning to provide substantial data sets at various center-of-mass energies in this format, along with examples and documentation.

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Exclusive electroweak processes

Corresponding Author: c.baldenegro@cern.ch

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Forward Physics Facility

Author: Jonathan Feng[1]

[1] *UC Irvine*

Corresponding Author: jlf@uci.edu

There is growing interest in the far forward region at the LHC. Detectors placed hundreds of meters downstream from existing interaction points along the beam collision axis may search for LLPs,

detect thousands of TeV neutrinos, and make measurements of relevance for a broad range of topics, from hadronic physics to cosmic ray experiments. These efforts are currently limited to fit within existing tunnels, but one could imagine enlarging this space to create a Forward Physics Facility, which would allow more and larger experiments to be placed there, with a huge gain in sensitivity to new physics and standard model studies. In this talk, I would like to propose such a Facility, present some nascent ideas of what it could be good for, and stimulate physicists with a broad range of interests to come together to study the feasibility of creating such a Facility and explore the ways it could expand the existing LHC physics program.

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Future physics opportunities with W and Z bosons and top quarks for high-density QCD at LHC

Author: Georgios Konstantinos Krintiras[1]

[1] *The University of Kansas (US)*

Corresponding Author: gkrintir@cern.ch

Droplets of quark-gluon plasma (QGP), a state of strongly interacting quantum chromodynamics matter, are produced in high-energy collisions between heavy nuclei. Recent theoretical studies suggest using the top quark, the heaviest elementary particle known to date, as a novel time-delayed probe of the QGP. The top quark is a colored particle that decays almost always into a W boson plus a bottom quark, hence by "triggering" on the top quark transverse momentum we can select W bosons produced at different QGP timescales. At variance with most of the experimental signatures considered in the literature so far, where a limiting factor is that they are the integrated result of a fast-evolving and extended medium, top quark thus offers the opportunity to perform a full tomographic analysis of the QGP time evolution.

Using the largest data sample of lead-lead collisions recorded by the Compact Muon Solenoid (CMS) experiment at the unprecedented nucleon-nucleon center-of-mass energy of 5.02 TeV achieved at the Large Hadron Collider (LHC), evidence of top quark pair production is reported. Therefore, for the first time, the feasibility of reconstructing top quark decay products is demonstrated, irrespective of whether interacting with the medium (bottom quarks) or not (leptonically decaying W bosons). This measurement paves the way for more detailed investigations of top quark production in nuclear interactions with increased colliding energies and/or luminosities at current or future higher-energy colliders. In particular, it establishes a new tool for probing nuclear parton distribution functions as well as the properties of the produced QGP.

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Generic ILC detector model for Delphes

Author: Aleksander Filip Zarnecki[1]

[1] *University of Warsaw*

Corresponding Author: zarnecki@fuw.edu.pl

Delphes is a framework for fast simulation of a generic collider experiment. It allows to take into account basic experimental effects as acceptance, efficiency and detector resolution, and provides also expected results of event reconstruction (as lepton identification, flavour taging and jet clustering). We would like to present a new model for fast ILC detector simulation in Delphes. While it has been mainly based on the ILD detector concept, it can be considered a generic ILC detector model, as expected performances of both ILD and SiD are very similar and details of the detector design are not taken into account in Delphes.

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HL-LHC and ILC sensitivities in the hunt for heavy Higgs bosons

Author: Sven Heinemeyer[1]

[1] *IFT (CSIC, Madrid)*

Corresponding Author: sven.heinemeyer@cern.ch

We assess the sensitivity of the Large Hadron
Collider (LHC) in the high luminosity (HL) run alone and in combination
with a possible future International Linear Collider (ILC) to probe
heavy neutral Higgs bosons. We employ the Minimal Supersymmetric
Standard Model (MSSM) as a framework and assume the light \cp-even
MSSM Higgs boson to be the Higgs boson observed at $125\tilde{}$GeV.
We discuss the constraints on the MSSM parameter space arising from
the precision measurements of the rates of the detected signal at $125\tilde{}$GeV and fromdirect searches for new heavy Higgs bosons in the $\tau^+\tau^-$, $b\bar{b}$ and di-Higgs (hh) final states. For the future Higgs rate measurements at the HL-LHC and ILC two different
scenarios are investigated, namely the case where the future rate
measurements agree with the SM prediction and the case where the rates agree
with the predictions of possible realizations of
the MSSM Higgs sector in nature.

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Hadron spectroscopy at future facilities

Corresponding Author: bryan.fulsom@pnnl.gov

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Higgs Boson Self-Coupling vs. CM Energy at the ILC

Author: Chris Potter[1]

[1] *University of Oregon*

Corresponding Author: ctp@uoregon.edu

The Higgs boson self-coupling is accessible in the double Higgstrahlung process $e^+e^- \to ZHH$ and the double WW fusion process $e^+e^- \to \nu\bar{\nu}HH$. Present ILC studies typically evaluate sensitivity to this coupling at center-of-mass energies of $\sqrt{s} = 500$ GeV and $\sqrt{s} = 1000$ GeV, two well-established ILC operating points. In this study we investigate the ILC sensitivity to the self-coupling at $\sqrt{s}$ from turnon threshold to above 1000 GeV.

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Higgs Bosons With Large Couplings to Light Quarks

Corresponding Author: danielegana@gmail.com

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Higgs branching ratios with radiative corrections in various extended Higgs models

Authors: Shinya Kanemura[1] ; Mariko Kikuchi[2] ; Kentarou Mawatari[3] ; Kodai Sakurai[None] ; Kei Yagyu[1]

[1] *Osaka University*

[2] *Kitakyushu College*

[3] *Iwate University*

Corresponding Authors: kodai.sakurai@kit.edu, yagyu@het.phys.sci.osaka-u.ac.jp, kikuchi@kct.ac.jp

We have studied on radiative corrections to observables for the discovered Higgs boson and published the computation program, H-COUP. Current version of H-COUP evaluates the branching ratios with NLO EW corrections and NNLO QCD corrections in various extended Higgs models, i.e., the Higgs singlet model, 4 types of two Higgs doublet models and the inert doublet model. Using the program, we analyzed deviations for the branching ratios from the SM in each extended Higgs model. I will discuss how above models can be separated wth the precise measurement of the branching ratios in the ILC. This talk is based on [S. Kanemura, M. Kikuchi, K. Sakurai, K. Yagyu; Nucl Phys, Nucl. Phys. B949 (2019) 114791; arXiv:1910.12769].

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Higgs couplings and VBF at Muon Colliders

Corresponding Author: luca.mantani@uclouvain.be

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Higgs measurements and perspectives at the FCC-hh

Corresponding Author: michele.selvaggi@cern.ch

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Higgs-gamma production in extended Higgs models at future electron-positron colliders

Authors: Shinya Kanemura[1] ; Kentarou Mawatari[2] ; Kodai Sakurai[None]

[1] *Osaka university*

[2] *Iwate U.*

Corresponding Authors: kodai.sakurai@kit.edu, kanemu@het.phys.sci.osaka-u.ac.jp, mawatari@iwate-u.ac.jp

We study associated production of the Higgs boson with a photon in various extended Higgs models at future electron-positron colliders. The process is loop-induced, and hence the cross sections are sensitive to additional scalars and model parameters. We discuss how much new physics contributions can enhance the signal rate.

The talk is based on [S.Kanemura, K.Mawatari, K.Sakurai, Phys. Rev. D99 (2019) 035023 (arXiv:1808.10268)].

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High scale twisted custodial symmetry in two Higgs doublet models

Author: Masashi Aiko[1]

Co-author: Shinya Kanemura [2]

[1] *Osaka University*

[2] *Osaka university*

Corresponding Authors: kanemu@het.phys.sci.osaka-u.ac.jp, m-aikou@het.phys.sci.osaka-u.ac.jp

We study the high scale twisted custodial symmetry in two Higgs doublet models and its phenomenology. We show that this scenario can be valid up to Planck scale, and both discovered Higgs boson couplings and electroweak precision observable can be explained without decoupling of additional Higgs bosons. We find that the characteristic mass spectrum is predicted and this scenario can be studied at future HL-LHC and ILC experiments. This talk is based on M. Aiko, S. Kanemura, K. Mawatari, Phys. Lett. B797 (2019) 134854 (arXiv: 1906.09101) and on the ongoing project with S. Kanemura.

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High-energy phenomenology implications of the Electron-Ion Collider

Author: Timothy Hobbs[1]

[1] *CTEQ at SMU*

Corresponding Author: timojhobbs@gmail.com

With the recent approval of CD-0 for the Electron-Ion Collider and its siting at Brookhaven National Lab, the EIC program enjoys strong forward momentum. As a community, we are now tasked with understanding the phenomenological implications of the future EIC program, which will extend to many corners of particle physics, and planning accordingly to enhance the scientific impact. In this talk, I concentrate on the role the EIC will play in growing the sensitivity of hadron collider-based searches for beyond Standard Model (BSM) physics, as well as other activities at the Energy and Intensity Frontiers. I will highlight recent progress toward the realization of a working community dedicated to maximizing the EIC benefits to efforts at hadron colliders and vice versa.

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Improved (g-2)_mu Measurements and Supersymmetry

Authors: Sven Heinemeyer[1] ; Manimala Chakraborti[2] ; Ipsita Saha[3]

[1] *IFT (CSIC, Madrid)*

[2] *IFT (UAM/CSIC)*

[3] *IPMU (Tokyo)*

Corresponding Authors: ipsita.saha@ipmu.jp, sven.heinemeyer@cern.ch, mani.chakraborti@gmail.com

The electroweak (EW) sector of the Minimal Supersymmetric Standard Model (MSSM) can account for variety of experimental data. The lighest supersymmetric particle (LSP), which we take as the lightest neutralino, $\tilde{\chi}_1^0$, can account for the observed Dark Matter (DM) content of the universe via coannihilation with the next-to-LSP (NLSP), while being in agreement with negative results from Direct Detection (DD) experiments. Owing to relatively small production cross-sections a comparably light EW sector of the MSSM is also in agreement with the unsuccessful searches at the LHC. Most importantly, the EW sector of the MSSM can account for the persistent $3-4\,\sigma$ discrepancy between the experimental result for the anomalous magnetic moment of the muon, $(g-2)_\mu$, and its Standard Model (SM) prediction. Under the assumption that the $\tilde{\chi}_0^1$ provides the full DM relic abundance we first analyze which mass ranges of neutralinos, charginos and scalar leptons are in agreement with all experimental data, including relevant LHC searches. We find an upper limit of ~ 600˜GeV for the LSP and NLSP masses. In a second step we assume that the new result of the Run˜1 of the "MUON G-2" collaboration at Fermilab yields a precision comparable to the existing experimental result with the same central value. We analyze the potential impact of the combination of the Run˜1 data with the existing \gmin2\ data on the allowed MSSM parameter space. We find that in this case the upper limits on the LSP and NLSP masses are substantially reduced by roughly 100˜GeV. This would yield improved upper limits on these masses of ~ 500˜GeV. In this way, a clear target could be set for future LHC EW searches, as well as for future high-energy e^+e^-˜colliders, such as the ILC or CLIC.

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Jet Physics in Relativistic Heavy Ion Collisions and EIC

Corresponding Author: fmringer@lbl.gov

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LHC/ILC Synergy for Exploration of Extended Higgs Sectors

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LHC/ILC synergy for exploration of extended Higgs sectors

Authors: Kei Yagyu[1] ; Kentarou Mawatari[2] ; Masashi Aiko[1] ; Shinya Kanemura[1]

[1] *Osaka University*

[2] *Iwate University*

We discuss the possibility that the parameter space of extended Higgs sectors
is significantly narrowed down by considering synergy between the direct search for additional Higgs bosons at the LHC and the precise measurement of the Higgs boson properties at the ILC 250 GeV. This talk is based on the collaboration with M. Aiko, S. Kanemura and K. Mawatari.

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Leading two-loop corrections to the Higgs trilinear coupling in models with extended scalar sectors

Authors: Johannes Braathen[None] ; Shinya Kanemura[1]

[1] *Osaka University*

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

The Higgs trilinear coupling provides a unique opportunity to study the structure of the Higgs sector and search for BSM Physics. In models with extended Higgs sectors, large deviations in this coupling can appear at one loop because of non-decoupling effects in the radiative corrections from extra scalars.
It is then natural to ask how this result can be modified at two loops. I will present new results for the dominant two-loop corrections to the Higgs trilinear coupling in models with extended scalar sectors. I will show that, while the two-loop corrections do not modify significantly the one-loop non-decoupling effects, their computation will be necessary in the perspective of future precise measurements of the Higgs trilinear coupling, for instance at high-energy stages of the ILC.
This talk is based on J. Braathen and S. Kanemura, PLB 796 (2019) 38-46 [arXiv:1903.05417] and EPJC 3 (2020) 80:227 [arXiv:1911.11507].

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Long-lived particle signatures and connections with SUSY and Dark Matter

Corresponding Author: desai@theory.tifr.res.in

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Muonic Decays of Charged Higgs Bosons

Author: Marc Sher[1]

[1] *William & Mary*

Corresponding Author: mtsher@wm.edu

If the charged Higgs mass is below the top mass, then the usual decay modes are into $\tau\nu$ or $\bar{c}s$. Here, it is pointed out that in some models, the decay into $\mu\nu$ can be substantial, in many cases 50% and in some as high as 100%. Searches for this decay mode are encouraged.

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N3LO QCD theory for future experiments

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New approach to DM searches with mono-photon signature

Authors: Aleksander Filip Zarnecki[1] ; Jan Kalinowski[1] ; Wojciech Kotlarski[2] ; Krzysztof Mekala[1] ; Pawel Sopicki[1]

[1] *University of Warsaw*

[2] *Institut für Kern- und Teilchenphysik, TU Dresden*

Corresponding Authors: zarnecki@fuw.edu.pl, k.mekala@student.uw.edu.pl, pawel.sopicki@fuw.edu.pl, jan.kalinowski@fuw.edu.pl, wojciech.kotlarski@tu-dresden.de

One of the important goals of the proposed future e^+e^- collider experiments is the search for dark matter particles using different experimental approaches. The most general one is based on the mono-photon signature, which is expected when production of the invisible final state is accompanied by a hard photon from initial state radiation. We propose the procedure of merging the matrix element calculations with the lepton ISR structure function implemented in WHIZARD, which allows for consistent, reliably simulation of mono-photon events for both signal and SM background processes. We demonstrate that cross sections and kinematic distributions of mono-photon in neutrino pair-production events agree very well with corresponding predictions of the KKMC, a Monte Carlo generator providing perturbative predictions for SM and QED processes, which has been widely used in the analysis of LEP data. We plan to exploit the proposed procedure in estimating the sensitivity of future e^+e^- colliders to different DM scenarios. Here we would also like to propose a novel approach, where the experimental sensitivity is defined in terms of both the mediator mass and mediator width. This approach is more model independent than the approaches presented so far, assuming given mediator coupling values to SM and DM particles.

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New frontiers in PDF analyses in the HL-LHC era

Author: Maria Ubiali[1]

[1] *University of Cambridge*

Corresponding Author: m.ubiali@damtp.cam.ac.uk

A robust knowledge of the proton subnuclear structure is a crucial input at the LHC. The uncertainty on the Parton Distribution Functions (PDFs) often represents a limiting factor in the accuracy of theoretical predictions at hadron colliders and this will be even more crucial in the High Luminosity run. I will give an overview of the new exciting challenges that the precision frontier is presenting, such as the simultaneous determination of the parameters entering QCD fits, theoretical uncertainties affecting the predictions entering such fits and the interplay between the proton structure and the hunt for new physics beyond the Standard Model.

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Optimising top-quark pair-production threshold scan at future e+e- colliders

Authors: Kacper Nowak[1] ; Aleksander Filip Zarnecki[1]

[1] *University of Warsaw*

Corresponding Authors: zarnecki@fuw.edu.pl, k.nowak27@student.uw.edu.pl

One of the main goals of the future e^+e^- colliders is to measure the top-quark mass and width in a scan of the pair production threshold. Yet, the shape of the threshold cross section depends also on other model parameters as the top Yukawa coupling and the strong coupling constant. We study the expected precision of the top-quark mass determination from the threshold scan at CLIC, ILC and FCC-ee. We use the most general fit approach with all relevant model parameters and expected constraints from earlier measurements taken into account. We demonstrate that even in the most general approach the top-quark mass can be extracted with statistical precision of the order of 20 to 30 MeV. Additional improvement is possible if the running scenario is optimized. We propose the optimisation procedure based on the genetic algorithm. When optimising the mass measurement the statistical uncertainty can be reduced by up to 30%, corresponding to factor of 2 increase in the integrated luminosity. We plan to improve and extend our study by taking into account effects of beam polarisation, including additional observables in the fit (eg. angular distributions) and by more detailed analysis of backgrounds and systematic uncertainties.

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Phenomenology of Theories with Enhanced Higgs Yukawas

Authors: Samuel Homiller[1] ; Daniel Egana-Ugrinovic[2] ; Patrick Meade[3]

[1] *YITP, Stony Brook*

[2] *Perimeter Institute*

[3] *Stony Brook University*

Corresponding Authors: patrick.meade@stonybrook.edu, shomiller@insti.physics.sunysb.edu, danielegana@gmail.com

We present a phenomenological program to look for extended Higgs sectors with large couplings to light quarks. These theories come with complementary features in flavor physics, precision Higgs studies, and searches for new resonances. The most striking signals of these theories resonant production of Higgs pairs via quark fusion, with larger rates than models usually studied at the LHC, but they also lead to large deviations in predictions for the SM Higgs signal strengths, and new signals in dijet channels. In addition to laying out this phenomenology, we'll propose several directions for further scrutiny of these theories at both the LHC and future lepton and hadron colliders.

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Positivity Bounds on aQGC

Corresponding Authors: cenzhang@bnl.gov, cenzhang@ihep.ac.cn

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Positivity bounds on aQGC

Author: Cen Zhang[1]

[1] *Institute of High Energy Physics, Chinese Academy Sciences*

Corresponding Author: cenzhang@ihep.ac.cn

Searching for anomalous quartic gauge boson couplings (aQGCs) is one of the main tasks in multi-boson final state measurements. The current interpretation of these couplings are based on a dim-8 SMEFT operators, which are subject to the so called positivity bounds, i.e. certain linear combinations of these coefficients need to be positive, for the SMEFT to admit a UV completion that satisfies the fundamental principles of quantum field theory. Since the ultimate goal of SMEFT is to bridge between measurements and concrete UV models, these bounds need to be understood to allow a meaningful SMEFT interpretation for future aQGC results. In a previous work, we have derived a set of bounds by using elastic scattering of vector bosons in the mass eigenstates, which already restricts the aQGC parameter space to 2.1% of the total. Recently we have developed a new approach that allows for even stronger bounds to be derived. I will briefly introduce this approach and show some preliminary results for the transversal QGC couplings.

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Precision QCD at future DIS facilities

Corresponding Author: olness@smu.edu

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Probing charged lepton number violation via ℓ±ℓ'±W∓W∓

Authors: Mayumi Aoki[1] ; Kazuki Enomoto[2] ; Shinya Kanemura[2]

[1] *Kanazawa university*

[2] *Osaka university*

Corresponding Authors: kanemu@het.phys.sci.osaka-u.ac.jp, kenomoto@het.phys.sci.osaka-u.ac.jp

Observed tiny neutrino masses may indicate the existence of new physics including a source of Lepton Number Violation (LNV) at high energies. The effect of such a high-scale physics may be well described by higher dimensional LNV operators. We investigated the dimension-five lepton number violating operator, ℓ±ℓ'±W∓W∓, containing important information on the origin of tiny neutrino masses, which is independent of that from Weinberg operator, and we found that this operator can be probed by current and future experiments, such as neutrinoless double beta decay and high-energy collider experiments. In this talk, I'll show our result and discuss the constraint on the scale of new physics from these experiments. This talk is based on the paper, M. Aoki, K. Enomoto, S. Kanemura, Phys. Rev. D101, 115019 (arXiv:2002.12265[hep-ph]).

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Quantifying the Effects of Beam Polarization on Charged Triple Gauge Couplings

Corresponding Author: jakob.beyer@desy.de

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Quantifying the effects of beam polarisation on charged triple gauge couplings

Author: Jakob Beyer[1]

Co-author: Jenny List [1]

[1] *DESY*

Corresponding Authors: jakob.beyer@desy.de, jenny.list@desy.de

Charged triple gauge couplings (cTGCs) describe potential deviations from the Standard Model in the coupling of two W bosons to a Z boson or a photon. These couplings may interfere with the extraction of Higgs properties. Future e^+e^- colliders need to measure these cTGCs with high precision to fully exploit the potential of their Higgs program.

Current proposals for e^+e^- colliders vary in many aspects, most notably in their energy, luminosities and beam polarisations. Of those, the energy determines the relevant physics and the luminosity trivially scales the statistical precision.

Beam polarisation refers to the preferred direction of the spin in the beam particles. A dedicated magnet setup can flip the direction of a spin with non-zero polarisation.

Electroweak physics depends on the chirality and therefore the spin of the colliding particles. This flipping of the spin changes the allowed interactions. Both reducible and irreducible backgrounds can be suppressed by choosing the appropriate polarisation combination. The cTGC measurement is performed in the production of W bosons and highly sensitive to this effect.

While the physics changes when flipping the polarisations, the systematic effects remain the same. Beam polarisation may therefore provide a direct handle on systematic uncertainties in any measurement.

This study aims to quantify these effects of that a polarised beam may offer.

An extraction of cTGCs is performed together with a measurement of beam polarisations and 2-fermion parameters on generator level differential distributions. The fit is planned to be extended to include systematic effects that are correlated between the different processes.

A collider with polarised beams may achieve a qualitatively different measurement of cTGCs and other electroweak parameters. The extent to which polarisation may reduce systematics and provide access to electroweak physics needs to be clarified.

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SMEFT Fits and the Higgs Inverse Problem

Corresponding Author: shomiller@insti.physics.sunysb.edu

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SMEFT Fits and the Higgs Inverse Problem

Authors: Samuel Homiller[1] ; Sally Dawson[2] ; Samuel Lane[3]

[1] *YITP, Stony Brook*

[2] *BNL*

[3] *University of Kansas*

Corresponding Authors: sallydawsonbnl@gmail.com, shomiller@insti.physics.sunysb.edu, samuel.lane@ku.edu

The Standard Model Effective Field Theory (SMEFT) provides a consistent framework for comparing precision measurements at the LHC to the Standard Model (SM). The observation of statistically significant non-zero SMEFT coefficients would correspond to physics beyond the SM (BSM) of some sort. A more difficult question to answer is what, if any, detailed information about the nature of the underlying high scale model can be obtained from these measurements (the "Higgs Inverse Problem"). In this work, we consider the patterns of SMEFT coefficients in five example models and discuss the assumptions inherent in using global fits to make BSM conclusions. As a by-product of our study, we present an up-dated global fit to SMEFT coefficients including some NLO corrections in the SMEFT theory.

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Searches for milli/fractional/multiple charged particles

Corresponding Author: matthew.citron@cern.ch

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Signatures of new scalar particles at future e+e- colliders

Authors: Jan Kalinowski[1] ; Wojciech Kotlarski[2] ; Jan Klamka[1] ; Tania Robens[3] ; Dorota Sokolowska[4] ; Aleksander Filip Zarnecki[1]

[1] *University of Warsaw*

[2] *Institut für Kern- und Teilchenphysik, TU Dresden*

[3] *Rudjer Boskovic Institute*

[4] *International Institute of Physics, Universidade Federal do Rio Grande do Norte, Brasil*

Corresponding Authors: jan.kalinowski@fuw.edu.pl, trobens@irb.hr, zarnecki@fuw.edu.pl, wojciech.kotlarski@tu-dresden.de, dsokolowska@iip.ufrn.br, j.klamka@student.uw.edu.pl

A number of astrophysical observations based on gravitational interactions point to the existence of dark matter (DM) in the Universe, which can not be described with the Standard Model (SM). Many of the proposed extensions of the SM, which can provide a dark matter candidate, involve extended scalar sector and new scalar particles which could be produced at future e^+e^- colliders. We studied the case of the Inert Doublet Model (IDM) in detail, where pair-production of new neutral or charged scalars is possible already at 250 GeV collision energy, and the expected signature is mono-Z or W-pair production (where Z or W can be on- or off-shell, depending on the model parameters) and a large missing energy. For low mass benchmark scenarios, high statistical significance of signal observation is expected for the leptonic signature, while for high scalar masses semi-leptonic final state should be considered, as it provides much higher statistics of signal events. We plan to extend our studies to other models with extended scalar sector, as eg. 2HDM+a model, where new interesting signatures are expected.

EF08+09+10+02+07 / 21

Signatures of new scalar particles at hadron colliders

Author: Tania Robens[1]

[1] *Rudjer Boskovic Institute*

Corresponding Author: trobens@irb.hr

EF05+06+07 / 53

Small x physics at the LHC, EIC, and FCC

Corresponding Author: kovchegov.1@osu.edu

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Testing neutrino mass generation mechanism at the electron positron collider

Author: Arindam Das[1]

[1] *Osaka University*

Corresponding Authors: dasarindamphysics@gmail.com, arindam.das@hetmail.phys.sci.osaka-u.ac.jp

The neutrino oscillation experiment has clearly pointed out that the Standard Model neutrinos have tiny masses and their flavors are mixed. There are a plenty of models which explain the mechanism of the generation of the neutrino mass. In this talk we will discuss about the simple neutrino mass generation process at the TeV scale which is often called the seesaw mechanism and its testability at the high energy colliders.

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The Future of Heavy Flavor and Exotic Meson Production in RHIC and LHC

EF01+03+04+05+06 / 34

The third-generation quarks - from the LHC to the e+e- collider and beyond

Author: Marcel Vos[1]

[1] *IFIC (UVEG/CSIC) Valencia*

Corresponding Author: marcel.vos@cern.ch

I will present a brief review of the role of the top and bottom quarks in an exhaustive characterization of the Standard Model and its possible extensions. The talk will explore the many connections between the top and Higgs/EW sectors and will highlight the qualitatively new information that can be obtained with new installations. I discuss existing work and indicate a few areas where further studies are required.

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The ultimate measurements of the Higgs boson mass and width in Run 3, the HL-LHC and beyond

Authors: Rajdeep Chatterjee[1] ; Roger Rusack[2] ; Zhen Liu[3]

[1] *University of Minnesota*

[2] *The University of Minnesota*

[3] *University of Maryland*

Corresponding Authors: rusack@umn.edu, rmchatterjeejr@gmail.com, zliuphys@umd.edu

Since the discovery of the Higgs boson, the focus in Run 2 (2015–2018) of the LHC has shifted from observation to precision measurements of its properties. The couplings of the Higgs boson to other elementary particles can be predicted by the standard model of particle physics only when its mass is known. This motivates precise measurements of the mass of the Higgs boson. These measurements are carried out in the two high resolution channels, which are the H⟶γγ and the H⟶ZZ⟶ 4l channels respectively.
The most precise measurement of the Higgs boson mass till date was published recently by the CMS collaboration with mH=125.38 ± 0.24 (0.12(stat.) ± 0.08 (syst.)) GeV, a precision of nearly 0.1%. This was obtained by combining the measurements in the high resolution channels performed with the 2016 dataset and in Run 1. The precision obtained was made possible by a dedicated effort to mitigate the systematic uncertainties associated with such a measurement. In the immediate future both the ATLAS and CMS collaborations are updating the mH measurements with the full Run 2 dataset. Once these results are combined together the measurement will tend to get limited by the systematic uncertainty of the measurement.
The width of the Higgs boson of the Standard model is 4.1 MeV. The typical experimental resolution of mH is ˜1.5 − 3 GeV. Hence direct measurements of the width of the Higgs boson are limited severely by the experimental resolution in both H⟶γγ and H⟶ZZ⟶ 4l channels. In the H⟶ZZ⟶ 4l channel indirect measurements utilizing off-shell Higgs boson production in combination with the on-shell signal strength measurements have constrained the width to 0.08 < ΓH< 9.16 MeV. In the H⟶γγ channel, the interference between Higgs boson production via gluon fusion and the continuum QCD diphoton production leads to a mass shift compared to what is measured in the H⟶ZZ⟶ 4l where this interference effect is absent. A measurement of this mass shift can be translated to a constraint of the Higgs boson width.
By the end of the HL-LHC, with a dataset nearly 10 times of the current one the statistical precision of the mH measurement will improve to ˜20 MeV (0.01%). However if we continue with the current strategy it is unlikely that we can achieve a systematic precision of better than ˜ 0.07%, which is based on the precision with which we can measure the lepton and photon energy scales. A new strategy needs to be developed to benefit from the large HL-LHC dataset and measure the mass of the Higgs boson to a precision of better than 0.05%. With such precision, effects such as the mass shift in the diphoton decay channel due to interference can be measured and tested against the standard model prediction. The width of the Higgs boson is expected to measured in the H⟶ZZ⟶ 4l channel with a precision of ˜25 % using the off-shell technique.
In this oral presentation the authors will summarize the currently available measurements of the Higgs boson mass and width. An estimate of the ultimate precision possible for these measurements in the future will also be presented with a focus on the key challenges that need to be met to achieve the same. In future we shall explore the feasibility of these measurements in FCC(hh) machines.

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Theory of Higgs bosons with large couplings to light quarks

Authors: Daniel Egana-Ugrinovic[1] ; Patrick Meade[2] ; Samuel Homiller[3]

[1] *Perimeter Institute*

[2] *Stony Brook University*

[3] *YITP, Stony Brook*

Corresponding Authors: shomiller@insti.physics.sunysb.edu, patrick.meade@stonybrook.edu, danielegana@gmail.com

A common lore has arisen that extended Higgs sectors should couple preferentially to third-generation fermions.
In this talk we present natural and motivated theories where extra Higgs bosons couple preferentially to the light quarks instead.
This possibility opens up the avenue for a broader exploration of the Higgs sector,
which requires new theoretical and experimental efforts targeting BSM physics with large couplings to first- and second-generation quarks.
Such theories point to striking new phenomenological signatures,
that provide interesting connections between searches at colliders and flavor experiments.

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Triple Higgs Couplings in the 2HDM

Corresponding Author: francisco.arco@uam.es

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Triple Higgs couplings in the 2HDM

Authors: Sven Heinemeyer[1] ; Fran Arco[2]

[1] *IFT (CSIC, Madrid)*

[2] *IFT (UAM/CSIC)*

Corresponding Authors: francisco.arco@uam.es, sven.heinemeyer@cern.ch

Within the framework of Two Higgs Doublet Models (2HDM) type˜I and˜II we
investigate the allowed ranges for all triple Higgs couplings involving at
least one light, SM-like Higgs boson. We take into account theoretical
constraints (unitarity, stability), experimental constraints from
direct Higgs-boson searches, measurements of the SM-like Higgs-boson
properties, flavor observables and electroweak precision data. We find
that the SM-type triple Higgs coupling w.r.t.\ its SM value,
$\lambda_{hhh}/\lambda_{hhh}^{\rm SM}$, can range between ~ -0.5 and ~ 1.5. Depending on
which value is realized, the HL-LHC can compete with, or is clearly inferior
to the ILC. We also derive limits on the triple Higgs couplings involving heavy Higgs bosons.

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Two-real-scalar-singlet extension of the SM: LHC phenomenology and benchmark scenarios

Author: Tania Robens[1]

[1] *Rudjer Boskovic Institute*

Corresponding Author: trobens@irb.hr

I discuss a model that contains in total 3 neutral scalars in the electroweak sector. This model allows for interesting multi-step cascade decays, including hhh and hhhh final states. I present benchmark scenarios for the LHC. Studies might be extended to discuss future collider options.

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Unitarity Bounds on New Physics From Higgs Coupling Measurements

Corresponding Authors: markus.luty@gmail.com, spchang123@gmail.com

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Unitarity bounds on new physics from Higgs coupling measurements

Authors: Spencer Chang[1] ; Markus Luty[2]

[1] *University of Oregon*

[2] *UC Davis*

Corresponding Authors: markusluty@gmail.com, spchang123@gmail.com

With the discovery of the Higgs and precise measurement of its mass, all the parameters of the Standard Model (SM) are determined at the percent level. Measurements of the Higgs couplings are therefore searches for physics beyond the SM. Given a deviation from the SM, a model-independent bound on the scale of new physics can be obtained without theoretical assumptions using the fact that the theory violates tree-level unitarity in the absence of additional states. In this way, any measured deviation from the SM points to a new scale that can be a target for future experiments. This talk will present results for the scale of new physics and other model-independent implications of measurements of hhh, hVV, and htt couplings. For example, HL-LHC measurements consistent with current experimental limits may point to a scale of new physics below several TeV.

EF05+06+07 / 55

Very forward detector: QCD opportunities

Corresponding Author: mxs43@psu.edu

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Welcome

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e+e- Event Analysis with LCIO & miniDST

Corresponding Author: jenny.list@desy.de