HiggsTools Mid-Term Review.

Shruti Patel ESR 11 Deutsches Elektronen Synchrotron, Hamburg

Helmholtz Association, Brussels

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My Background



- ▶ ESR 11
- ▶ Shruti Patel
- 🕨 Mumbai, India

Masters in Science : 2012-14

- Indian Institute of Technology, Madras, India
- ▶ Masters Thesis: Study of the $B^{\pm} \rightarrow [\pi^+\pi^-\pi^0]_D K^{\pm}$ Mode and Sensitivity of CP Violation





PhD : September 2014 - Present

- DESY, Hamburg, Germany
- Supersymmetry, Higgs Physics, Collider Phenomenology





Objective: Work Package 1

▶ Interpretation of experimental results, compatibility with the SM, constraints on physics beyond the SM and the discrimination of different models

Tasks and Methodology

- ▶ Task 1.3: Phenomenology of possible new signatures of new physics and formulation of dedicated analysis strategies
- Task 3.2: Development and automatization of general next-to-leading order tools

Project milestones

- ▶ M 2.2.2: Precision calculations of non-standard Higgs Boson scenarios
- ▶ M 2.2.3: Standardized Description of non-standard Higgs Boson interactions
- ▶ M 2.2.4: Subsequent interpretation of experimental data
- ▶ M 3.2.1: Automation of NLO calculations
- ▶ M 1.4.1: Review of current state and future directions in Higgs Boson physics





Overview: Interplay of Higgs phenomenology and New Physics

Neutral Higgs production in the Minimal Supersymmetric Extension of the Standard Model (MSSM) with complex parameters

- \blacktriangleright Inconsistencies in the Standard Model \rightarrow Physics Beyond the SM
- Extended Higgs sectors of Supersymmetric models are a strong portal into new physics: at least 3 neutral Higgs Bosons $(H_{1,2,3})$
- ▶ Gluon Fusion Higgs production; $gg\Phi$ ($\Phi = H_{1,2,3}$): Dominant Higgs production channel @ LHC



- ➤ Signatures of new physics → Precise predictions of non-standard Higgs masses & cross-sections (XS)
- ▶ CP-symmetry is non-fundamental ⇒ study variation of Higgs couplings and XS accounting for complex parameters





Tools and Automation

- ▶ Step 1: Development of tools for precision calculations [M 2.2.2, M 3.2.1]
 - SUperSymmetric Hlggs (SusHi) calculates neutral Higgs Boson production XS through gluon fusion and bottom-quark annihilation (5FS) in the SM, the 2HDM, MSSM and the NMSSM.
 - \bullet FeynHiggs calculates the masses, couplings and Z factors of the Higgs sector of the $\rm MSSM$
- ▶ Step 2: Phenomenology of implemented model [M 2.2.3]
 - Implementation of MSSM with complex paratmers in SusHi→ Description of ggΦ for non-standard Higgs Bosons

Outcome

> Study of Higgs production XS in scenarios with H_1 consistent with experimental data of observed Higgs [M 2.2.4]





Main results: Research

▶ Phenomenology of $gg \rightarrow \Phi$ with SusHi linked to Feynhiggs



Results for Higgs cross-section predictions:





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Training Programs

- First HiggsTools Summer School (June '15, Palleusieux, Italy)
- ▶ Computer Algebra and Particle Physics (March '15, DESY Hamburg)
- WE-Heraeus-Seminar: Physics Landscape After the Higgs Discovery at the LHC (November '14, Bad Honnef, Germany)

Lecture Courses: SFB-676

- ▶ Introduction to Supersymmetry (Winter Sem '15/'16)
- Experiments in Physics Beyond the Standard Model (BSM)(Winter Sem '15/'16)
- Introduction to BSM Physics (Spring Sem '15)
- Higgs Physics (Winter Sem '14/'15)

Skills Training

- ▶ First Young Researcher's Meeting (June '15, Lumley Castle, UK)
- ▶ German Level A1 (Ongoing)





Conference Talks

- ▶ Neutral Higgs production in the MSSM with complex parameters @ DESY Theory Workshop 2015, Hamburg
- ▶ Higgs sector of the MSSM with complex parameters @ First Annual Meeting 2015, Freiburg

Conferences Attended

- ▶ DESY Theory Workshop 2015, Hamburg
- ▶ First Annual Meeting 2015, Hamburg
- ▶ Hamburg Workshop on Higgs Physics 2014, Hamburg
- ▶ DESY Theory Workshop 2014, Hamburg
- ▶ Second HiggsTools Young Researchers Meeting 2015, Brussels (upcoming)
- > Annual Meeting of the Helmholtz Alliance 2015, Hamburg (upcoming)





Implementing Next-to-Leading Order squark contributions to Higgs production XS

▶ Next-to-Leading Order contributions in the CP-violating MSSM:



- NLO contributions from quark loops known analytically
- ▶ Full NLO calculations require accounting for complex parameters occurring in squark loops





Implementing Next-to-Leading Order squark contributions to Higgs production XS

- Can be done by generalizing results obtained in the case for MSSM with real parameters [Degrassi, Di Vita, Slavich '12]
 - · Possible collaboration to carry out the calculations with Di Vita, Slavich
- ▶ Alternative strategies: NLO squark results known for phase $\phi_{A_t} = 0, \pi$.
- ▶ Results for full phase variation can be obtained by interpolation
 - FeynHiggs used the interpolation method to obtain Higgs mass predictions for NLO squark contributions
 - Similar interpolation routine can be adopted into SusHi





- ▶ Eventual release of SusHi with CP-violating MSSM (SusHi&Co.) in the public domain
- ▶ Study of interference effects including final states in Higgs production and decays
- ▶ Implementation of other CP-violating extended-sectors in SusHi
 - The 2-Higgs Doublet Model
 - The NMSSM with complex parameters
- ▶ BSM-EFT WG: HiggsTools collaboration with ESRs 5,9,12,14
 - Top-down approach to EFT; matching BSM scenarios to BSM-EFT
 - First calculations start tomorrow! \rightarrow Eventual joint HiggsTools paper





Private sector secondment at Wolfram Research from April-June 2016



- The opportunity to work at Wolfram Research will allow me to work on implementing state-of-the-art analytical computation techniques in Mathematica
- ▶ Mathematica is my primary tool for analytics, so the experience in working with Wolfram will lend me better abilities as a programmer in my PhD
- ▶ Valuable work experience in developing and applying my skills in the private sector





- Proposed secondment in Instituto de Fisica de Cantabria (IFCA) Spain, for investigation of interplay of new physics and EWSB phenomenology
- ▶ Application for post-doctoral positions in particular under the EU Marie Sklodowska-Curie actions fellowship
- ▶ Continued networking and collaborations with other theorists and experimentalists within HiggsTools
- Extended efforts towards science outreach to the public in the form of organized public lectures and social media

Thank You!



