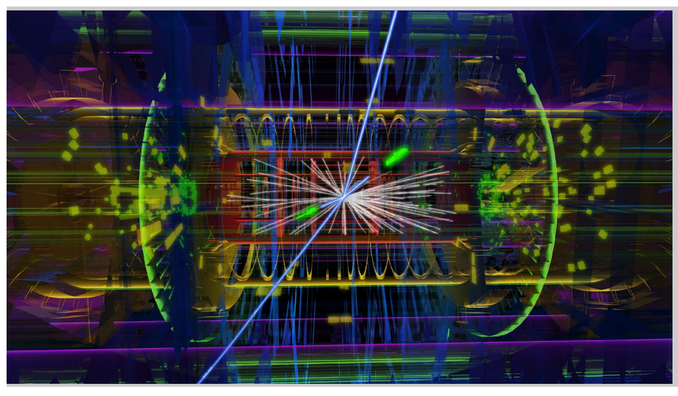

News

2/2017 (December)

Mass and Symmetries after the Discovery of the Higgs Particle at the LHC — GRK 2044

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Dear GRK fellows,
I am glad to present the last newsletter of the year. In this issue we continue the "Members of our GRK" series featuring the work by one of our students, show results of the survey, present a list of recent papers. I hope everyone can find something interesting here. Enjoy!

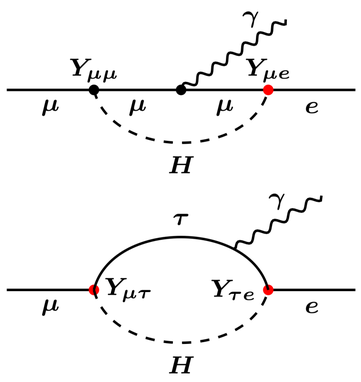
Your editor, *Vasily Sotnikov*

All dates, news, and updates can be found on the website of the GRK 2044: **www.grk2044.uni-freiburg.de**

SERIES: Members of our GRK: Search for lepton-flavour violating decays of the Higgs-boson

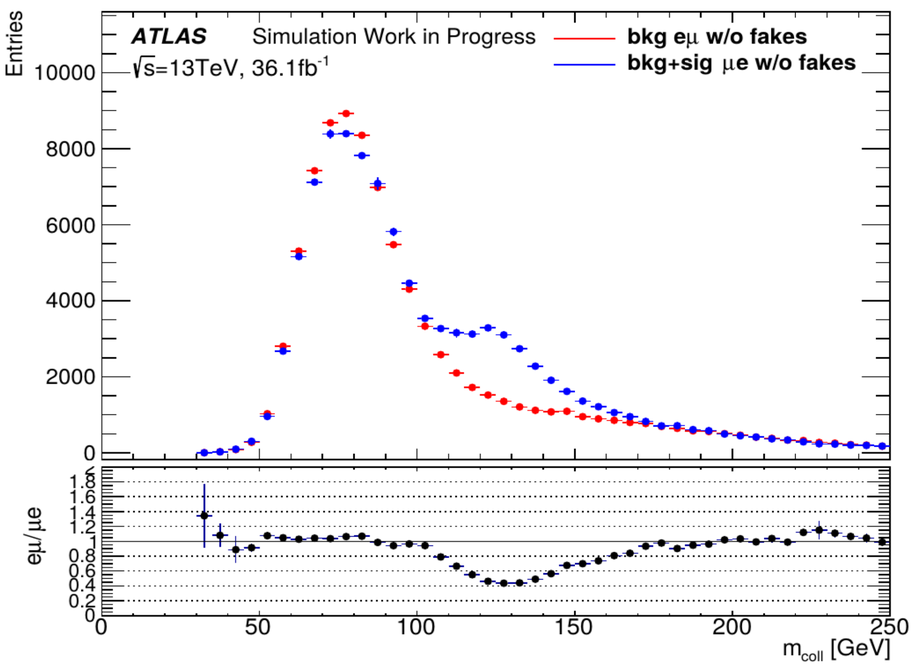
Katharina Schleicher

Motivation The coupling of the Higgs boson to fermions is investigated in detail since its discovery. Besides the Standard Model couplings, the search for lepton-flavour violating (LFV) couplings are of high interest. Lepton-flavor conservation is violated in many extensions of the Standard Model, e.g. in SUSY extensions, general two-Higgs doublet models and the Froggatt-Nielsen mechanism. In nature, LFV was already observed in the neutral lepton sector in form of neutrino oscillations.



Possible LFV decays in the Higgs sector are H → eμ, H → τ e, and H → τ μ. Indirect limits on the branching ratios of these decays can be derived from measurements of the decays μ → eγ, τ → eγ, and τ → μγ. An upper limit of $O(10^{-9})$ on the branching ratio of H → eμ is obtained which is too small to be accessible at the LHC. In contrast, the decays H → τ e and H → τ μ could have a branching ratio of O(10%). However, they are not expected to coexist with similar sizes.
The tightest limits on the branching ratios of the latter two decays are at the moment set by the CMS collaboration. By analyzing data from 2015 and 2016 at √s= 13 TeV they obtained the following upper limits [CMS-PAS-HIG-17-001]: BR(H → μτ) < 0.25% and BR(H → eτ) < 0.61% at 95% CL.

Background Estimation Method We search for LFV Higgs-decays with a leptonically decaying lepton and a different flavor final state, i.e. H → τ e →μ e 2ν and H → τ μ→e μ 2ν. For background estimation the data-driven asymmetry method [Bressler et al., 2014] is used. It is based on two assumptions. First, Standard Model backgrounds are symmetric with respect to a replacement of electrons with muons and vice versa. Second, the two considered LFV decays break this symmetry. The latter assumption is true when their branching ratios are not of the same order of magnitude, which is well motivated as stated above. Data are split into two samples depending on the transverse momentum of the leptons. When the electron has a larger momentum than the muon the event is part of the eμ-sample, when it is the other way round the event is part of the μe-sample. Following assumption one, both samples are expected to be in agreement in terms of size and properties for standard model processes and when neglecting detector effects. That means that one sample can be an estimate of the other. When assuming that the lepton with the higher transverse momentum stems from the Higgs-boson and the lepton with the lower transverse momentum from the τ-lepton and provided that BR(H →τ e) = 0 and BR(H → τ μ) ≠ 0 only the μe-sample is enriched with LFV signal. Hence, the eμ-sample can serve as its background estimate.



It shows the distribution of the collinear mass, in red for the eμ-sample, in blue for the μe-sample. For illustration purposes a branching ratio of 20% was chosen for H → τ μ. The peak at the Higgs-boson mass is nicely visible as well as the agreement of the two datasets in the sideband regions.
In a more general case for which BR(H → τ e) and BR(H → τ μ) are both not zero this method is only sensitive to the difference between the branching ratios.

Analysis Strategy Detector effects, which break the symmetry for Standard Model background processes, cannot be neglected but need to be taken into account. The trigger and reconstruction efficiencies for leptons as well as the rate for jets to be misidentified as an electron or muon are different for electrons and muons. They are, amongst others, dependent on the transverse momentum and on the pseudorapidity. These differences introduce an asymmetry between the two samples (eμ and μe) which would bias the result.
The trigger and reconstruction efficiencies can be determined and a backfolding performed to restore the symmetry. In addition, the contribution from jets misidentified as electrons or muons needs to be estimated separately.
A further important step is to enhance the sensitivity by separating signal and background. Therefore, boosted decision trees are trained. One has to ensure that the symmetry in the distribution of the boosted decision tree's output is still conserved. A great advantage of this method is its data-driven approach. The more data the LHC records the smaller the uncertainties get.

The analyis is performed in close cooperation with Dr. Shikma Bressler and Mattias Birmann from the Weizmann Institute of Science in Israel.

Welcome to the New GRK PhDs of 2017!

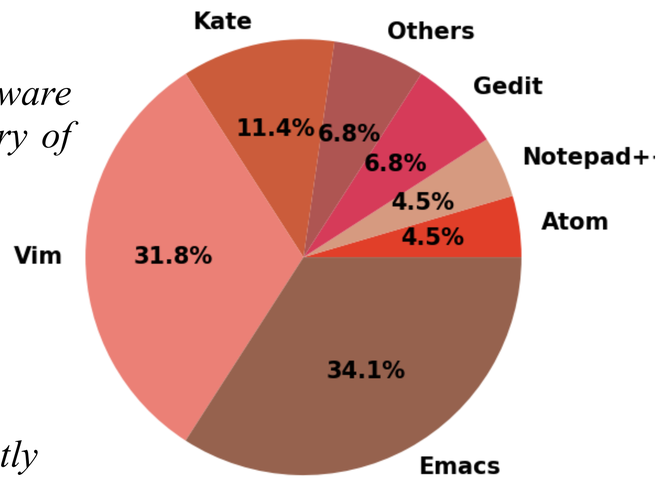
As usual, we give the new members of the RTG a warm welcome!
Jerry Dormans (Febres Cordero), Fabian Becherer (Schumacher), Justin Baier (Fischer)

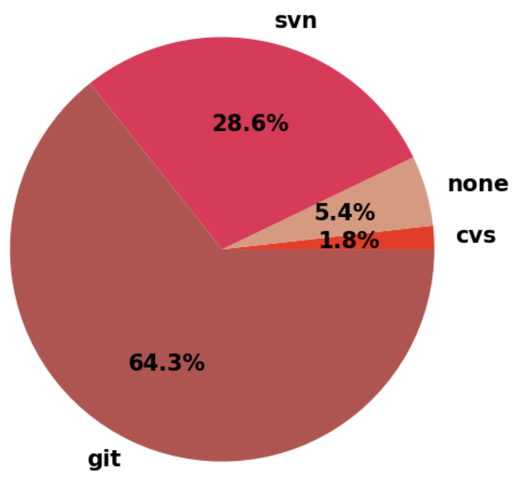

3rd Annual Meeting of the GRK 2044

This year's annual GRK meeting took place in the city of Breisach from the 4th to the 6th of October. Regarding the number of participants, it has been the largest meeting so far with a total number of 55 participants, including 3 guest speakers, 19 PI's, 27 PhD students, 5 Master students and last but not least Christina Skorek who was responsible for the perfect organization.
During the meeting the students presented their work in a total of 8 talks and in a poster session with 14 contributions. Furthermore, three lectures were offered covering a broad range of topics from both theoretical and experimental points of view. The start was made by Laura Covi, talking about *Baryogenesis* while Rüdiger Schmidt gave an *Introduction to accelerator physics and technology* and Joachim Kopp presented various aspects of *Neutrino Physics*. Apart from physics, this year's social event, consisted of a visit to the caves of a sparkling wine company *Geldermann*.

Software Preferences of GRK Members

All members of GRK were asked to participate in the survey exploring software preferences. In total 44 people participated. Here I present you a brief summary of the results.

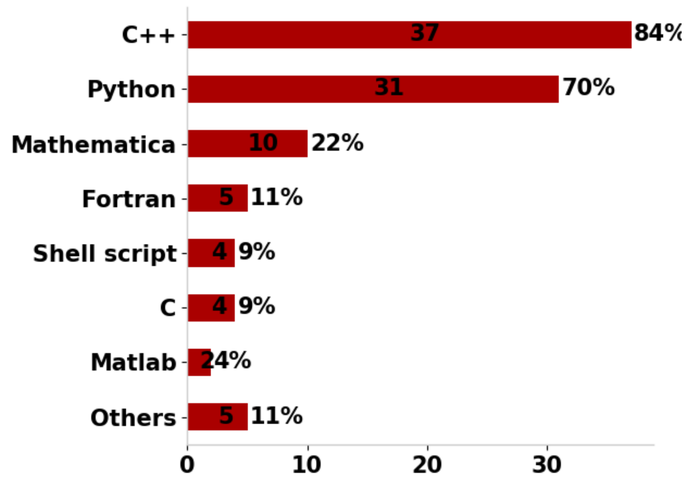




Text Editors: *Which one is your favorite?*
As expected and not without a reason Emacs and Vim are the most popular text editors. The third place goes to Kate. A bit of a surprise is that a simple Gedit takes a noticeable share of 7%

Programming Languages: *Which programming languages do you use frequently for your work?*
The majority of GRK members chose C++ as one of their most frequently used language with the runner up, Python, being not far from the top. Fortran apparently is still alive and is used by 11%. Bizarrely 9% of respondents indicated that they use shell script to write complicated programs. We can express our condolences. Amongst other languages notable mentions are Lua, Cython, and VHDL.

Version Control Systems: *Which version control system(s) do you use most often?*
No big surprises here. Git is the most popular one, followed by svn. Only 5% do not use any version control systems.



Do you care about quality of the code you publish or share with other people?
Surprisingly the majority of respondents (89%) considers code quality to be important, with staggering 23% of them claiming to *always* spend as much time as necessary to polish their code! Only 9% indicated that cleaning up the code to be a low priority task, and *nobody* stated to explicitly disregard the problem.

Would you consider your current programming skills to be competitive on the industry job market?
A good share of GK members (39%) are confident in their programming skills and answered "yes" to this question, while 27% think they could not be competitive at the moment. 34% are not sure.

Maybe the time of crappy academic software is going to end with the new generation of young scientists, understanding the increasingly important role of the software development in science? Let's wait and see...

Recent Papers by GRK Students

- *Gernot Knippen* contributed to
  "Next-to-leading-order QCD and electroweak corrections to WWW production at proton-proton colliders", 10.1007/JHEP09(2017)034
- *Michele Boggia*, *Giulia Gonella*, and *Théo Megy* contributed to
  "The HiggsTools Handbook: Concepts and observables for deciphering the Nature of the Higgs Sector", [1711.09875]
- *Veronika Magerl* and *Simone Curcio* contributed to
  "Search for squarks and gluinos in final states with jets and missing transverse momentum using 36 fb-1 of √s=13 TeV pp collision data with the ATLAS detector", [1712.02332]
- *Katharina Schleicher* contributed to
  "The ATLAS Tau Trigger in Run 2", ATLAS-CONF-2017-061
- *Peter Tornambé* and *Fabio Cardillo* contributed to
  "Search for supersymmetry in final states with two same-sign or three leptons and jets using 36 fb-1 of √s=13 TeV pp collision data with the ATLAS detector", 10.1007/JHEP09(2017)084
- *Felix Anger* and *Vasily Sotnikov* contributed to
  "NLO QCD Predictions for W $b\bar{b}$ Production in Association with up to Three Light Jets at the LHC", [1712.05721]

From the GRK PhD Student Speakers:

Dear PhD students,

Unfortunately Alena stepped down from being a student speaker. We warmly thank her for her year of committed work and wish her a very nice time at CERN. Sven took over her part and is completing the speaker team with Gernot. We, the student speakers, represent your interests concerning the graduate school. You can always contact us with new ideas, suggestions and further issues.

Looking back, we had a very successful year, and lots of events took place since the last newsletter. Beside the informative and very interesting annual meeting in Breisach, we had an extensive statistics lecture by Prof. Dr. Schumacher with an accompanied dinner. Furthermore the PhD students conducted some research into the local wine scene at the "Weinfest" of Freiburg. The graduate college was also present at the "Wissenschaftmarkt" of Freiburg, where our PhD students, their supervisors and other faculty members presented the different research fields they are involved in.

We hope to see you all bright-eyed and bushy-tailed back after the Christmas break and wish you all merry Christmas and a happy new year!

Sven & Gernot

Ideas for Christmas Presents

by Dirk Sammel

Who doesn't love to buy Christmas presents on the 23rd (or even the 24th), together with hundreds of stressed out people in packed stores, fighting over the last pair of socks?
And it will be a pair of socks, because you didn't think about it earlier and now you have to improvise! But don't despair, I prepared a (non-exhaustive) list of presents for your loved ones.

Alcohol: The range here is large: wine, whisky, gin with a matching tonic water, a compilation of different craft beers, etc. Some might see this as a last resort present (and it certainly can be), but you can actually spend quite some time for finding a good bottle.
Suggestions: Whisky Gin Beer

Books: There's nothing better than enjoying a nice book in the warmth of your apartment while it's freezing outside.
Suggestions: Haruki Murakami - Norwegian Wood
Gabriel García Márquez - One Hundred Years of Solitude
Matthew D. Schwartz - Quantum Field Theory and the Standard Model

A pair of socks: Because let's be honest: everyone needs them! But don't buy boring black socks, there are a lot more options, for instance a nice unicorn motif. Or just knit them yourself!
Suggestions: Unicorn Einstein The Knitter's Book of Socks

Maybe this list gave you some ideas. There are of course countless other possibilities, but I have to stop now to meet the newsletter deadline ;-)

Merry Christmas!

Thank you for the contributions to: Gernot Knippen, Sven Mägdefessel, Katharina Schleicher, Philipp Mogg, Dirk Sammel, and Jerry Dormans. Icons made by Alfredo Hernandez from www.flaticon.com is licensed by CC 3.0 BY.