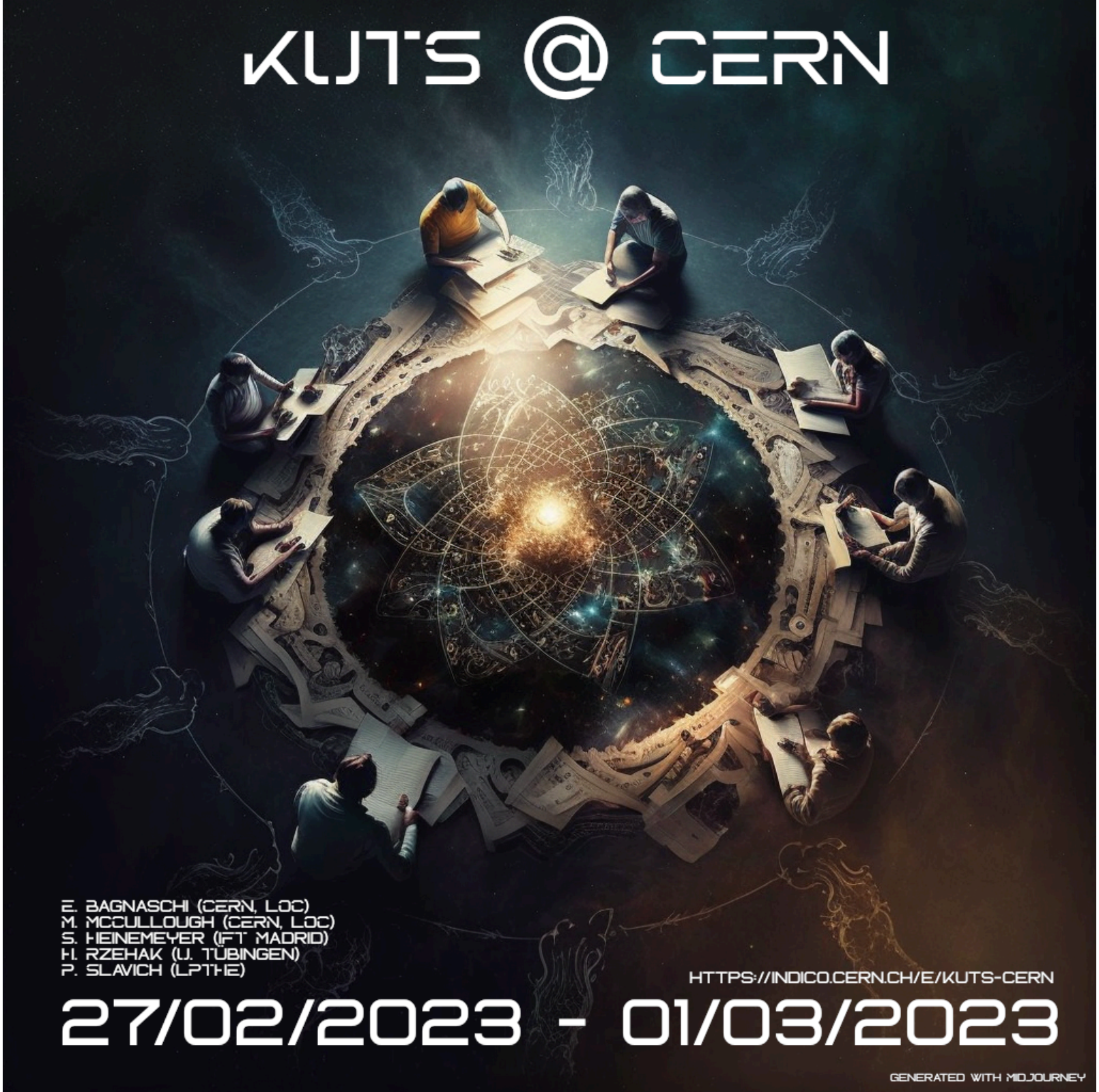
KUTS @ CERN



E. BAGNASCHI (CERN, LOC)
M. MCCULLOUGH (CERN, LOC)
S. HEINEMEYER (IFT MADRID)
H. RZEHAK (U. TÜBINGEN)
P. SLAVICH (LPTHE)

HTTPS://INDICO.CERN.CH/E/KUTS-CERN

27/02/2023 - 01/03/2023

GENERATED WITH MIDJOURNEY

It is with great pleasure that I announce the upcoming KUTS workshop at CERN, one of the most important events in the world of particle physics. This is going to be a tremendous gathering of the best and brightest minds in the field, and I have no doubt it will be a huge success.

We have the best physicist and the best ideas, no one can match us in precision calculations, these are the kind of smart people we need in our country. We are going to make particle physics great again.

Gian Giudice, head of the theoretical physics division at CERN, he's a good man, a great guy, he said he has very high expectations for the workshop. I have to tell you, I have even higher expectations, we are going to make breakthroughs nobody thought possible.

This is all about making America, and the world, great again. The KUTS workshop is going to be huge, the best ever, and everyone is going to be talking about it. Trust me, it's going to be YUGE.

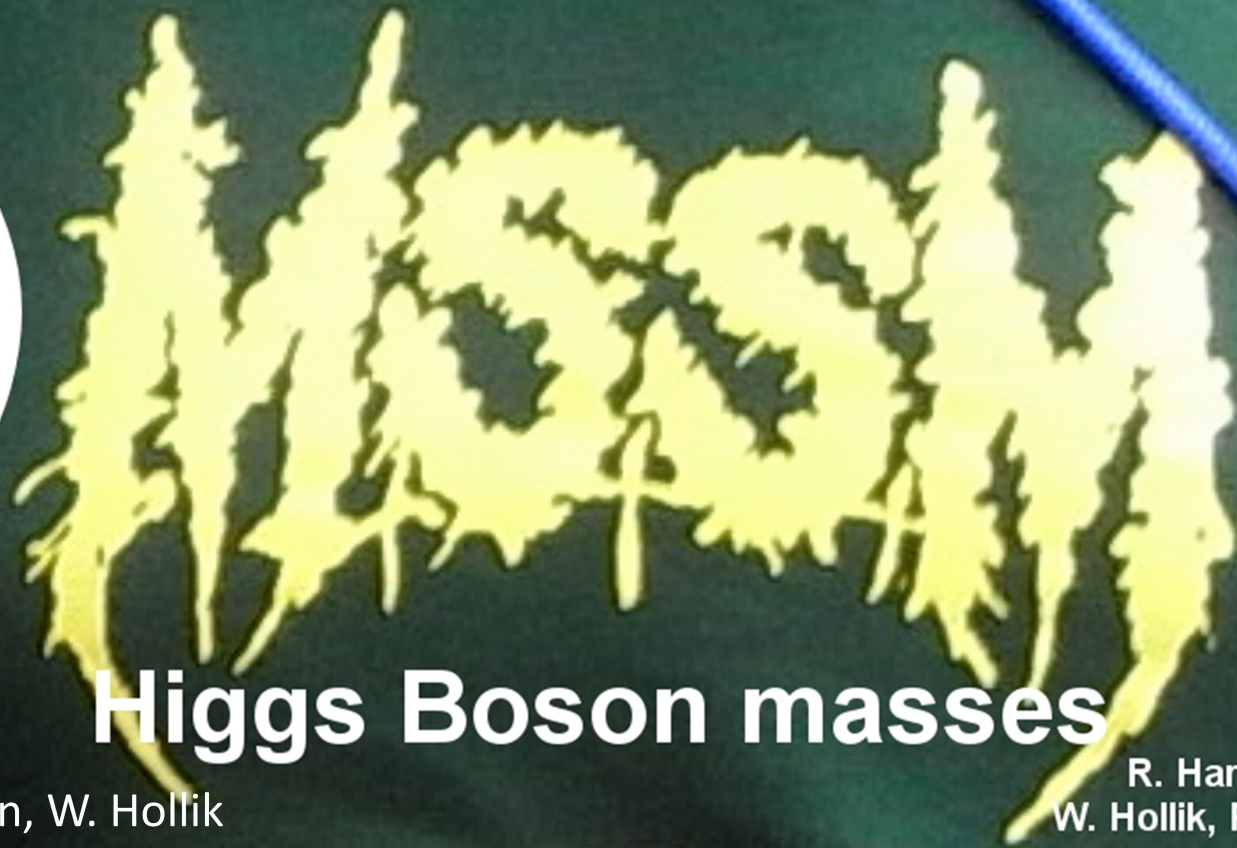
Feels like a lifetime ago...

Katharsis of Ultimate Theory Standards

11th meeting: 20-22 November 2019 (MPI Munich)

Precise Calculation of

(N)



Higgs Boson masses

Organized by:
M. Carena, H. Haber
R. Harlander, S. Heinemeyer
W. Hollik, P. Slavich, G. Weiglein

Local organizers: T. Hahn, W. Hollik

Not yet time to surrender…

Hirō "Hiroo" Onoda (小野田 寛郎

Onoda Hirō, 19 March 1922 – 16 January 2014) was an Imperial Japanese Army intelligence officer who fought in World War II and was a Japanese holdout who did not surrender at war's end in August 1945. After the war ended Onoda spent 29 years hiding out in the Philippines until his former commander traveled from Japan to formally relieve him from duty by order of Emperor Shōwa in 1974.[1][2] He held the rank of second lieutenant in the Imperial Japanese Army. He was the penultimate Japanese soldier to surrender, with Teruo Nakamura surrendering later in 1974.

Workshop-2020-06

12th KUTS workshop, Paul Scherrer Institut (Switzerland), 24-26 June 2020

Contacts:

- Local organizer: Emanuele Bagnaschi (emanuele.bagnaschi _at_ psi.ch)
- Secretariat: Anita Van Loon (anita.vanloon _at_ psi.ch)

If you have difficulties in the organization of your trip, or in finding an accommodation, please do not hesitate to contact Anita, the secretary of the laboratory, who has very kindly given her availability in supporting the workshop.

Getting there:

You can find a general overview of how to reach PSI at this address: https://www.psi.ch/en/visit/how-to-find-us .

Please consult https://www.sbb.ch/ for the train and bus timetables. Google map link to the location of PSI: https://goo.gl/maps/mkJEzbSZrsiH5nFZ7 .

In addition to what you can find using the links above, I will add a couple of more information based on my personal experience:

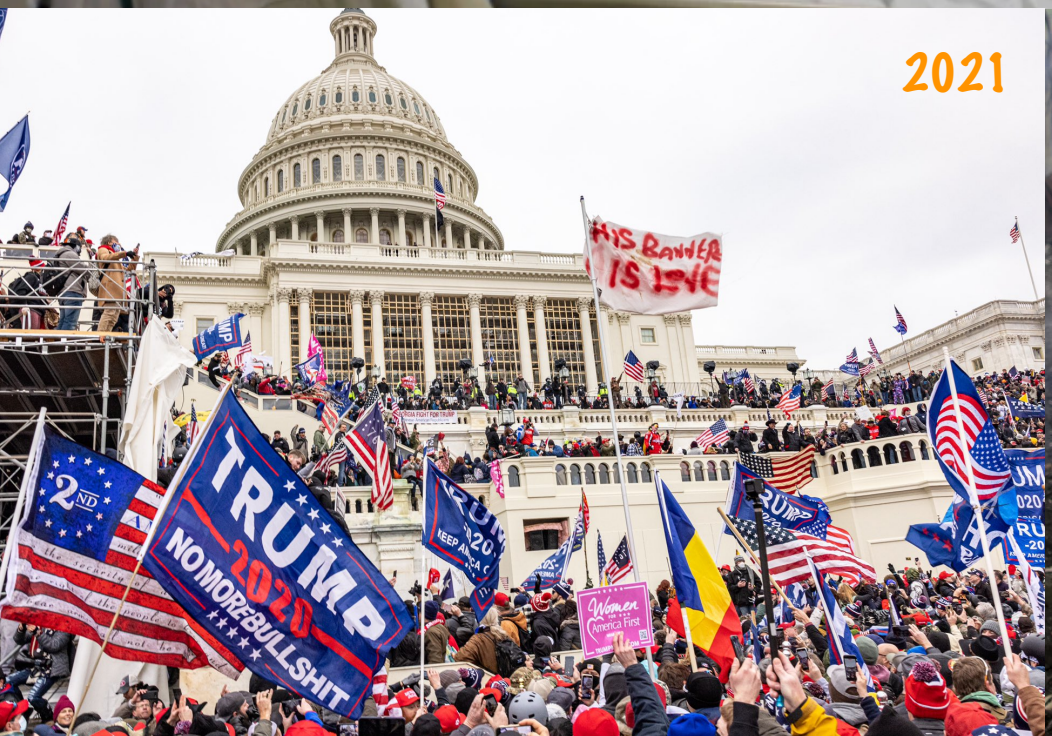
- if you are coming from France, you should take a look at the the TGV Paris-Basel. It is relatively fast and quite cheap, if booked in advanced;
- if you coming from the Münich area, you might take into consideration the possibility of taking a bus from Münich to Zürich (check the SBB website linked above).

Accommodation:

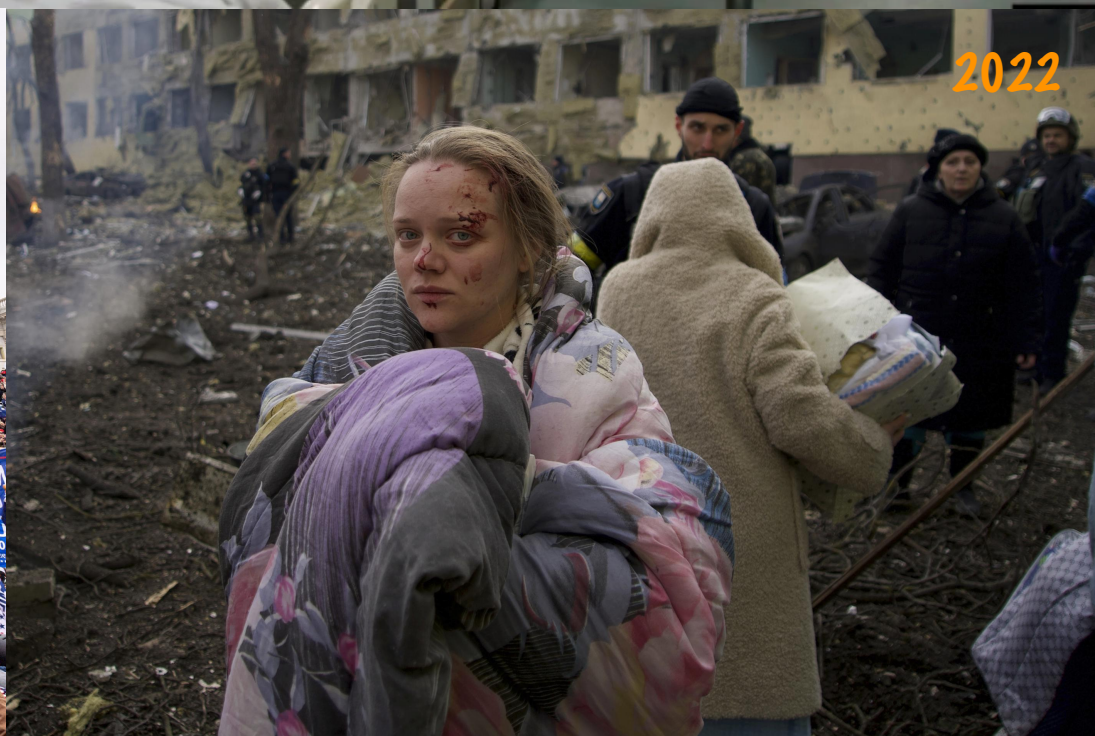
Then the world went crazy

2020

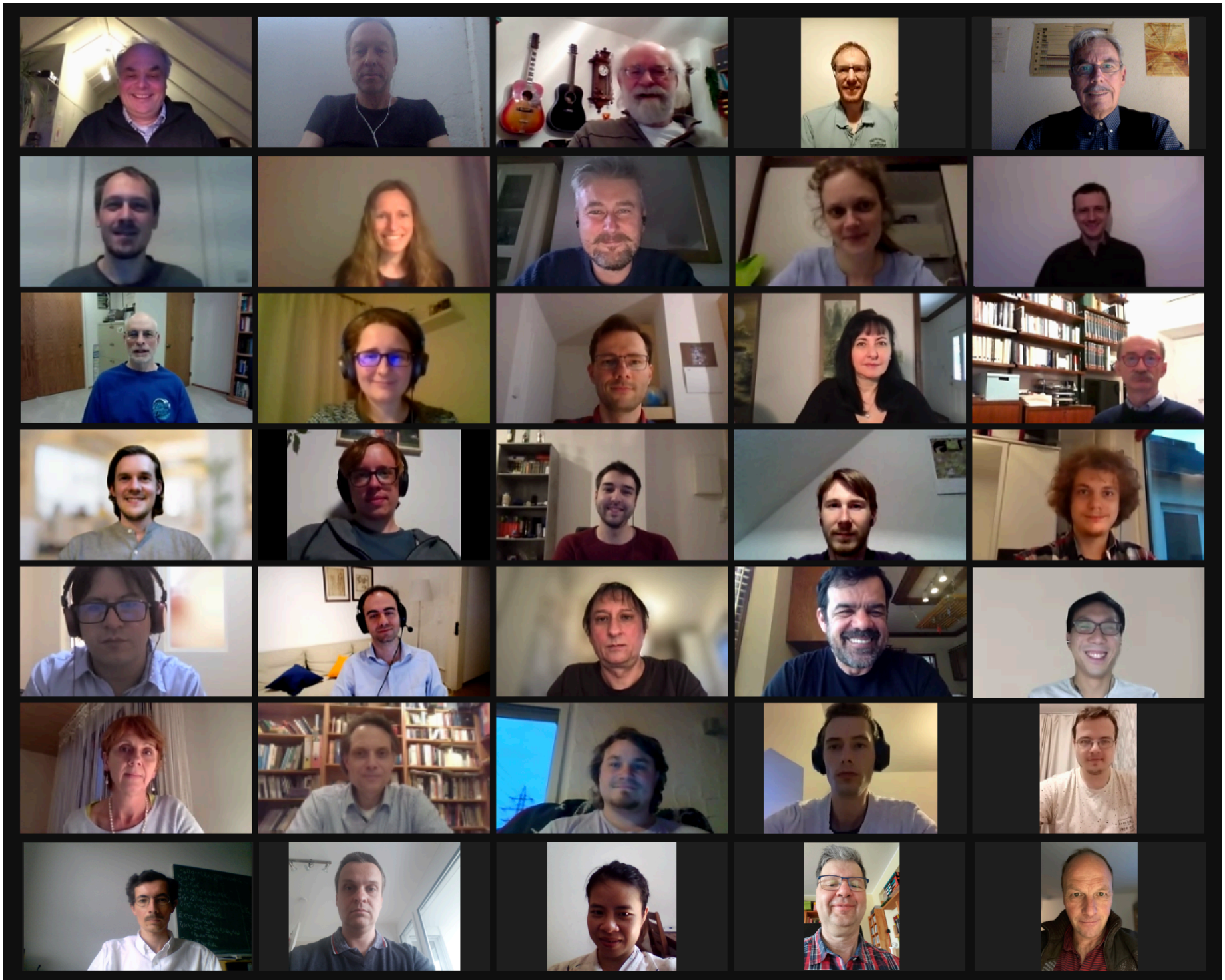
2021



2022



We all tried to cope...



At least, something good came out of it

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https://doi.org/10.1140/epjc/s10052-021-09198-2

THE EUROPEAN PHYSICAL JOURNAL C

Review

Higgs-mass predictions in the MSSM and beyond

P. Slavich[1,a], S. Heinemeyer[2,3,4], E. Bagnaschi[5], H. Bahl[6], M. Goodsell[1], H. E. Haber[7], T. Hahn[8], R. Harlander[9], W. Hollik[8], G. Lee[10,11,12], M. Mühlleitner[13], S. Paßehr[9], H. Rzehak[14], D. Stöckinger[15], A. Voigt[16], C. E. M. Wagner[17,18,19], G. Weiglein[6], B. C. Allanach[20], T. Biekötter[6], S. Borowka[21], J. Braathen[6], M. Carena[18,19,22], T. N. Dao[23], G. Degrassi[24], F. Domingo[25], P. Drechsel[6], U. Ellwanger[26], M. Gabelmann[13], R. Gröber[27], J. Klappert[9], T. Kwasnitza[15], D. Meuser[6], L. Mihaila[28], N. Murphy[29], K. Nickel[25], W. Porod[30], E. A. Reyes Rojas[31], I. Sobolev[6], F. Staub[13]

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Received: 15 March 2021 / Accepted: 27 April 2021

Abstract Predictions for the Higgs masses are a distinctive feature of supersymmetric extensions of the Standard Model, where they play a crucial role in constraining the parameter space. The discovery of a Higgs boson and the remarkably precise measurement of its mass at the LHC have spurred new efforts aimed at improving the accuracy of the theoretical predictions for the Higgs masses in supersymmetric models. The "*Precision SUSY Higgs Mass Calculation Initiative*" (KUTS) was launched in 2014 to provide a forum for discussions between the different groups involved in these efforts. This report aims to present a comprehensive overview of the current status of Higgs-mass calculations in supersymmetric models, to document the many advances that were achieved in recent years and were discussed during the KUTS meet-

Editors: P. Slavich and S. Heinemeyer.

S. Borowka, P. Drechsel, L. Mihaila, N. Murphy, K. Nickel, F. Staub: Former academic affiliation.

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Published online: 25 May 2021

KUTS 8 2018/01

Friday 26 January, Morning session:

10:00: Write-up discussion

10:45: Coffee Break

11:15: Write-up discussion

12:00: Endgame discussion

KUTS 9 2018/07

Wednesday 18 July Morning session: (write-up discussion and more) 9.30am

- Robert, Pietro, Sven: general status, timeline

- Sebastian, Heidi, Luminita, Maggie: fixed order

- Gabe, Emanuel: EFT

- Henning, Alex: Hybrid

- Pietro(?): theory uncertainties

- Mark, Thomas: codes

- all: how to go ahead / next workshop

KUTS 10 2019/04

Wednesday 10 April Morning session: (write-up discussion and more) 9.30am

- Robert, Pietro, Sven: general status, timeline

- Sebastian, Heidi, Luminita, Maggie: fixed order

- Gabe, Emanuel: EFT

- Henning, Alex: Hybrid

- Pietro: theory uncertainties

- Mark, Thomas: codes

- all: how to go ahead / next workshop

KUTS 11 2019/11

Friday 22 November, Morning session: Write-up and more (10am)

- Write-up convenors: Status of the KUTS write up

- All: How to go ahead / next workshop

ings, and to outline the prospects for future improvements in these calculations.

Contents

1 Introduction

The spectacular discovery of a scalar particle with mass around 125 GeV by the ATLAS and CMS collaborations [1–3] at CERN constitutes a milestone in the quest for understanding the physics of electroweak symmetry breaking (EWSB). While the properties of the observed particle are compatible with those predicted for the Higgs boson of the Standard Model (SM) within the present experimental and theoretical uncertainties [4], they are also in agreement with the predictions of many models of physics beyond the SM (BSM). For the latter, the requirement that the model under consideration include a state that can be identified with the observed particle can translate into important constraints on the model's parameter space.

One of the prime candidates for BSM physics is supersymmetry (SUSY), which predicts scalar partners for all SM fermions, as well as fermionic partners for all bosons. A remarkable feature of SUSY extensions of the SM is the requirement of an extended Higgs sector, with additional neutral and charged bosons. In such models the couplings of the Higgs bosons to matter fermions and to gauge bosons can differ significantly from those of the SM Higgs. Moreover, in contrast to the case of the SM, the masses of the Higgs bosons are not free parameters, as SUSY requires all quartic scalar couplings to be related to the gauge and Yukawa couplings. For example, in the minimal SUSY extension of the SM, the MSSM, the tree-level mass of the lighter neutral CP-even scalar in the Higgs sector is bounded from above by the mass of the Z boson. However, radiative corrections

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“Prospects” shopping list: FO calculations

- Complete the calculation of the 2-loop corrections to the Higgs-boson masses (beyond the “gaugeless limit”) in the MSSM and the NMSSM

- Full 2-loop calculation of scalar self-energies in a general renormalizable theory completed in 2019; now adapt the results to specific SUSY models

- Additional 2-loop results (gauge-boson self-energies, muon-decay amplitude) necessary to connect $\overline{\text{DR}}$ parameters to physical observables

- Complete the calculation of the 3-loop corrections to the Higgs-boson masses in the “gaugeless limit” (large cancellations among $\alpha_s^2\alpha_t\,,\ \alpha_s\alpha_t^2\,,\ \alpha_t^3$)

“Prospects” shopping list: EFT calculations

- NLL result (1-loop matching, 2-loop RGE) already available for a general theory, can be adapted to any SUSY model without heavy gauge bosons

- EFT = SM : full 2-loop SUSY-scale matching condition for $\lambda_{\rm SM}$ needed for NNLL (possibly in a general theory); renormalization-scheme subtleties (e.g. heavy $\tilde{g}$)

- EFT ≠ SM : 3-loop RGEs of the EFT also needed for a full NNLL result;
  also 2-loop matching conditions for trilinear couplings with singlets and triplets

- N^{3}LL calculation: complete at least the $\mathcal{O}(y_t^4\, g_s^4)$ correction to $\lambda_{\rm SM}$ in the MSSM, beyond the X_t/M_S expansion;

- Include dimension-6 operators to account for $\mathcal{O}(v^2/M_S^2)$ contributions?

“Prospects” shopping list: Hybrid calculations

- Incorporate any advance in FO and EFT calculations

- Find an “OS” definition of X_t that avoids the occurrence of $\ln \frac{M_S^2}{M_t^2}$ terms

“Prospects” shopping list: Uncertainty estimates

- Compute extra corrections to reduce the uncertainties… ;-)
  Then adapt the uncertainty estimates to the improved calculations

- Extend uncertainty estimates to non-minimal EFT scenarios (e.g, THDM-EFT)

- “Automated” uncertainty estimates for a general renormalizable theory?

- Use uncertainty estimates to identify best EFT setup for a given SUSY scenario

What have we been up to since last KUTS?

Relevant papers since KUTS-11: 2019/12

- 1912.04199 Bahl, Heinemeyer, Hollik, Weiglein
  Theoretical uncertainties in the MSSM Higgs boson mass calculation

- 1912.06168 Liu
  Leading Two-loop corrections to the mass of Higgs boson
  in the High scale Dirac gaugino supersymmetry

- 1912.10002 Bahl, Sobolev, Weiglein
  Precise prediction for the mass of the light MSSM Higgs boson
  for the case of a heavy gluino

Relevant papers since KUTS-11: 2020

- 2003.04639 Kwasnitza, Stöckinger, Voigt
  Improved MSSM Higgs mass calculation using the 3-loop FlexibleEFTHiggs approach including x_t -resummation
- 2007.11010 Domingo, Paßehr
  Towards Higgs masses and decay widths satisfying the symmetries in the (N)MSSM
- 2009.07572 Bahl, Sobolev, Weiglein
  The light MSSM Higgs boson mass for large tanβ and complex input parameters
- 2009.12887 Biekötter
  munuSSM: A python package for the μ-from-ν Supersymmetric Standard Model
- 2010.01989 Bahl, Sobolev
  Two-loop matching of renormalizable operators: general considerations and applications
- 2010.04711 Bahl, Murphy, Rzehak
  Hybrid calculation of the MSSM Higgs boson masses using the complex THDM as EFT

Relevant papers since KUTS-11: 2021

- 2103.06773 Braathen, Goodsell, Paßehr, Pinsard
  Expectation management
- 2103.08616 Kwasnitza, Stöckinger
  Resummation of terms enhanced by trilinear squark-Higgs couplings in the MSSM
- 2105.01139 Domingo, Paßehr
  Fighting off field dependence in MSSM Higgs-mass corrections of order αtαs and αt^2
- 2106.06990 Dao, Gabelmann, Mühlleitner, Rzehak
  Two-loop O((αt+ αλ + ακ)^2) corrections to the Higgs boson masses in the CP-violating NMSSM
- 2109.00585 Domingo, Paßehr
  Curing tachyonic tree-level syndrome in NMSSM light-singlet scenarios
- 2109.15277 Ke, Slavich
  Higgs-mass constraints on a supersymmetric solution of the muon g–2 anomaly
- 2112.11419 Bahl, Braathen, Weiglein
  External leg corrections as an origin of large logarithms
- 2112.15295 Reyes, Fazio
  High-Precision Calculations of the Higgs Boson Mass

Relevant papers since KUTS-11: 2022-2023

- 2206.04618 Bagnaschi, Goodsell, Slavich
  Higgs-mass prediction in the NMSSM with heavy BSM particles

Relevant papers since KUTS-11: 2022-2023

- 2206.04618 Bagnaschi, Goodsell, Slavich
  Higgs-mass prediction in the NMSSM with heavy BSM particles

- 2212.11213 Bahl, Braathen, Weiglein
  Theoretical concepts and measurement prospects for BSM trilinear couplings: case study for scalar top quarks

- 2212.13757 Rehman, Heinemeyer
  Non-Holomorphic Soft-Term Contributions to the Higgs-Boson Masses in the Feynman Diagrammatic Approach

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- Higgs properties (not just mass) still one of the best portals to BSM physics

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Time to widen the focus of KUTS?

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- Higgs properties (not just mass) still one of the best portals to BSM physics

Time to widen the focus of KUTS?

- From *"Higgs-mass calculations in SUSY"* to *"Precision calculations in BSM"* ? (including non-SUSY models, other Higgs properties, non-Higgs observables…)
- IMO no phenomenology, lest we become "Higgs Days without experimentalists"
- Identifying future directions for KUTS is one of the purposes of this workshop, do not hesitate to contribute to the discussion!

The Program

Monday Afternoon:
Old-style KUTS:
The NMSSM

- Martin Gabelmann: *Recent developments in NMSSMCALC*
- Pietro Slavich: *Higgs mass in the NMSSM with heavy BSM particles*

Tuesday Morning:
New observables:
M_W prediction

- Wojciech Kotlarski: *M_W in FlexibleSUSY*
- Mark Goodsell: *M_W in SARAH*

Tuesday Afternoon I:
New observables:
Trilinear Higgs couplings

- Martin Gabelmann: *Automated Higgs trilinear calculation*
- Johannes Braathen: *Higgs trilinear calculations @ 2-loop*

Tuesday Afternoon II:
General issues

- Johannes Braathen: *External-leg corrections as origin of large logs*
- Sven Heinemeyer: *Automated renormalization-scheme choice*

Friday Morning:
Wrap-up

- All participants: *Discussion on the future of KUTS*

Let the KUTS-12 begin!!!

Let the ~~KUTS-12~~ begin!!!

KUTS2 -1 ???