

The TeV-scale: a threshold to new physics?

MITP Scientific Program

(June 12 – July 7, 2017)

Organizers:

Csaba Csaki, Christophe Grojean, Pedro Schwaller and Andreas Weiler

Goals

After the discovery of the Higgs boson, the SM of particle physics is theoretically complete but phenomenologically limited and it also leaves many questions unanswered. Most important of those are the naturalness of the electroweak scale, the nature of dark matter, the origin of matter in the Universe and the structure of flavor. Eagerly awaited to comply with the naturalness arguments, the LHC has so far revealed no unambiguous signs of new physics. A situation that raises the question whether the TeV scale is indeed a threshold to new physics. This question has been debated and scrutinised in many different ways during the workshop. If no definitive conclusion could be reached, there is certainly no evidence yet that Hinchliffe's rule applies. The diversity of the models presented and discussed by the participants is a motivation to continue the exploration of the TeV threshold.

Format, style and participants of the Workshop

The format of the workshop has been chosen to maximally enhance interactions among participants, to foster discussion by raising topics during in-depth technical presentations followed by ample time public and private debates. We deliberately limited the numbers of talks to one per day. For these talks, we also gave priority to young scientists without permanent jobs and we encouraged black-board presentations. The format and the spirit of the workshop have been overwhelmingly appreciated by the participants. It resulted in in-depth discussions on a variety of active topics. Discussions over lunch at the Campus and dinner in town followed in smaller groups. The atmosphere has been very informal from the start (with a schedule organized on purpose at a late time, taking into account suggestions from the participants), something that has played a role in making the younger researchers immediately comfortable and triggered many informal discussions. The program (see Appendix I) has run over 4 weeks with a total of 20 talks.

The workshop was heavily oversubscribed with more than 130 applications, the vast majority of them being of very high level. Participants (see full list in Appendix II) have been chosen based on their proven expertise on the field, keeping an eye on assuring balance among various aspects. A total number of 57 physicists joined (including 6 locals and 2 Ph.D. students), of which 23/34 Europe/Out-of-Europe origin, 49/8 men/women.

Questions addressed and scientific output

A few models of TeV scale new physics were discussed, and several new developments were presented and elaborated. One main concern remained the hierarchy problem.

Variations of the well-established minimal models (supersymmetry and compositeness) were discussed, in particular some explicit UV realisations of composite Higgs models were presented relying on six dimensional constructions and establishing a connection to little Higgs and twin Higgs models. Fermion compositeness scenarios utilizing nonlinearly realized supersymmetry were introduced and it was shown that they can soften the usual constraints on contact interactions and predict specific patterns of interactions exhibiting a stiff growth with energy. It was also shown that non-minimal SUSY models can still be realized at or even below the TeV scale, showing that the strong constraints on superpartners which are often quoted do not always apply. Furthermore, it was pointed out that the LHC, while generally thought of as discovery machine, could also reveal new physics indirectly via precision measurements of standard model processes such as Drell-Yan. In the meantime, the exploration of the Higgs sector will remain a high priority on the experimental side and require a strong involvement of the theory community.

Recent alternative solutions to the hierarchy problem are the so called relaxion and clockwork models. There are no phenomenologically fully realistic models yet, and ongoing activities on the model building side were presented by the world experts on these topics.

Two of the strongest data driven motivations for new physics are dark matter and baryogenesis. Here some models were introduced that go beyond the usual paradigms, and new ways of probing dark matter and dark sectors experimentally were highlighted.

While solid quantum field theory arguments strongly motivate the TeV scale as new physics threshold, experimental data does not point to any definite scale as of today. Therefore, the search for new physics has to continue on all frontiers, including very weakly coupled states at lower scales like axions or dark photons. New methods for probing such light states were elaborated. In particular, the new method of using isotope shift spectroscopy to constrain new interactions benefitted from the presence of local experts in atomic physics, adding a refreshing and stimulating interdisciplinary aspect to the workshop.

Final conclusions and the successes of the program

The timing of the workshop, after the consolidated results of the LHC at 13 TeV with more than 30/fb, has been extremely appropriate. The flavor anomalies reported by LHCb were of course extensively discussed. But the absence so far of clear evidence of new physics at the TeV raised many questions and a workshop like this one with ample time for informal discussions is the perfect avenue to ponder on the current situation and foster new unconventional and creative ideas. The program was extremely successful in triggering people with very different strengths and expertise to discuss and collaborate on the challenges posed by the LHC results. Many of the most pressing and sometimes controversial questions were addressed, giving the possibility of debating freely from the usual (negative) constraints (time, closed experimental collaborations, presence of non-specialized audience). A very positive and constructive atmosphere has characterized all the meetings, as confirmed also by the very positive feedbacks that we have received from the participants afterwards.

Let us conclude by expressing our gratitude to the MITP (starting from an amazingly

kind, warm and helpful staff to the board and director) for making our life extremely easy and for having allowed us to organize and run this program. We feel that our program has been successful and that we will collect the fruits of our work in the coming months/years. We have already seen a few papers on the arXiv acknowledging the MITP hospitality during the workshop. More will follow for sure.

Appendix I: Talk schedule

The talks have been video-recorded and are available on YouTube:

<https://www.youtube.com/playlist?list=PLEjkXpUan6WGw8lHM55BPhJg7dNyLH3jv>

12/06: S. Jeager – flavour anomalies

13/06: F. Sala – R-axion at collider

14/06: S. Wetshoff - Indirect constraints on dark sectors

15/06: J. Serra – The other fermion compositeness

16/06: G. Marques-Tavares – Relaxion

--

19/06: W. Xue – Split susy

20/06: R. Harnik – Twin Higgs and neutral naturalness

21/06: T. Lin – ALPs in heavy ion collisions

22/06: D. Sutherland – Disassembling the clockwork mechanism

23/06: A. Tesi – Baryogenesis at a Lepton number breaking phase transition

--

26/06: E. Salvioni: Composite DM

27/06: E. Fuchs: Isotope shift spectroscopy

28/06: M. Geller: Warped little Higgs from 6D

29/06: G. Panico: Electroweak precision at the LHC

30/06: J. Shu: Maximally symmetric composite Higgs

--

03/07: Y. Soreq: B-anomalies and dark photon at LHCb

04/07: Y. Hochberg: Dark spectroscopy

05/07: R. Gupta: Hierarchion

06/07: E. Hardy: Stellar cooling bounds on new light particles

07/07: M. Chala: Sneutrinos saving stops

Appendix II: List of participants

Altmannshofer, Wolfgang

Azatov, Alex

Baker, Michael

Balkin, Reuven

Bellazzini, Brando

Carena, Marcela

Chala, Mikael

Csaki, Csaba

Collins, Jack

Cui, Yanou

D'Eramo, Francesco

Delgado, Antonio

Dreiner, Herbi

Durieux, Gauthier

Elias-Miro, Joan

Falkowski, Adam

Fonseca, Nayara
Fuchs, Elina
Geller, Michael
Gherghetta, Tony
Gori, Stefania
Grojean, Christophe
Gupta, Rick S
Han, Tao
Hardy, Edward
Harnik, Roni
Hochberg, Yonit
Jaeger, Sebastian
Kaminska, Anna
Kats, Yevgeny
Katz, Andrey
Kribs, Graham
Kuflik, Eric
Lee, Seung
Lin, Tongyan
Low, Matthew
Marques-Tavares, Gustavo
Martin, Adam
Matsedonskyi, Aleksey
Montull, Marc
Panico, Giuliano
Perez, Gilad
Pomarol, Alex
Ruderman, Josh
Sala, Filippo
Salvioni, Ennio
Santiago, Jose
Schlaffer, Matthias
Schwaller, Pedro
Serra, Javi
Shadmi, Yael
Shirman, Yuri
Shu, Jing
Soreq, Yotam
Sutherland, Dave
Telem, Ofri
Terning, John
Tesi, Andrea
Thamm, Andrea
Vega-Morales, Roberto
Wagner, Carlos
Weiler, Andi
Westhoff, Susanne
Xue, Wei
Yu, Felix
Zurita, Jose