High Energy Physics Model Database – HEPMDB. Towards decoding of the underlying theory at the LHC.

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Abstract

We present here the first stage of development of the High Energy Physics Model Data-Base (HEPMDB) which is already a convenient centralized storage environment for HEP models, and can accommodate, via web interface to the HPC cluster, the validation of models, evaluation of LHC predictions and event generation-simulation chain. The ultimate goal of HEPMDB is perform an effective LHC data interpretation isolating the most successful theory for explaining the LHC observations.

1. The idea behind HEPMDB

The year 2010 has marked the start of real data taking at the Large Hadron Collider (LHC). The central task of the LHC is to find signals from new physics and to reveal the underlying dynamics of Nature responsible for such signals. This is a highly non-trivial problem since many promising models could and do lead to similar signatures. For the next decades research in High Energy Physics (HEP) will be concentrated on interpreting the data from the LHC. We propose to create a High Energy Physics Model Data-Base (HEPMDB) which will be an unparallelled tool to isolate the most successful theory for explaining the LHC observations. This project is aimed at boosting the activity of HEP groups around the world and will play an important role for the LHC data interpretation.

The first phase of the HEPMDB prototype is accessible at `https://hepmdb.soton.ac.uk`. The HEPMDB was created as a result of ideas discussed in the context of the "Dictionary of LHC signatures" activity [1], at the FeynRules workshop [2] and at the "Mini-Workshop on Dynamical Symmetry Breaking models and tools" [3]. Following the "Dictionary of LHC signatures" activities it was agreed that the identification of the underlying theory from LHC signals can only be sensibly realised via a flexible database which collects models and their specific signatures.

The HEPMDB is aimed to:

1. collect HEP models for various multipurpose Matrix Element (ME) generators like CalcHEP [4], CompHEP [5, 6], FeynArts [7, 8], MadGraph/MadEvent [9, 10, 11, 12], AMEGIC ++/COMIX within SHERPA [14, 15]. and WHIZARD [13]. Under "HEP models" we denote the set of particles, Feynman rules and parameters written in the format specific for a given package;

2. collect models' sources which can be used on the HEPMDB to generate HEP models for various ME generators using FeynRules [17] or LanHEP [16] which automate the process of generating Feynman Rules, particle spectra, etc.. Under the "model source" we denote the model (lagrangian etc.) written in the form of input for FeynRules or LanHEP. For the moment, FeynRules interfaces to CompHEP, CalcHEP, FeynArts, GoSam [18], MadGraph/MadEvent, SHERPA and WHIZARD [19] are available. Currently LanHEP works with CalcHEP, CompHEP, FeynArts and GoSam. Also, the latest LanHEP version 3.15 has an option under testing of outputting the model in UFO format [12] which provides a way to interface it with MadGraph/MadEvent;
3. allow users to upload their models onto a server in order to perform evaluation of HEP processes and event generation for their own models using the full power of the High Performance Computing (HPC) cluster standing behind the HEPMDB itself. HPC cluster at Southampton University, IRIDIS3 is the state-of-the-art fastest university owned HPC resource in the UK which has 1008 8-core compute nodes (Intel Nehalem 2.26 GHz), at least 24GB of memory per node connected with fast infiniband network for parallel communication. This is one of the very powerful features of the HEPMDB: it provides a web interface to various ME generators which can then also be run directly on the HPC cluster. This way, users can preform calculations for any model from HEPMDB (including their own models which they can upload) avoiding problems related to installing the actual software, which can sometimes be quite cumbersome;
4. cross check and validate models for different ME generators. We should note that similar functionality is also provided by the FeynRules web validation framework which is also presented in these proceedings. However, the FeynRules web validation is mainly geared towards comparing FeynRules models and can use its knowledge of the model format to provide a throughout and highly automatized test procedure for those, while HEPMDB works in a more generic way and will provide access to more model formats at the price of slightly less automatization. Also, one should stress that uploads and evaluations at HEPMDB are available to *all users*. This is an important new feature of HEPMDB as compared to FeynRules website.
5. collect predictions and specific features of various models in the form of (sub)database of signatures and perform comparison of various model predictions with experimental data. There are a lot of different aspects related to this problem details of which are outside the scope of the current short contribution. We would like to mention though, that this task includes a comprehensive development of a database of signatures as well as development of the format of presentation of these signatures. This format will be consistent with the format which will be used by the experimentalists for the presentation of the LHC data, discussed at the workshop in the context of the "Les Houches Recommendations for the Presentation of LHC Results" activity.
6. trace the history of the model modifications (in case modifications take place), and makes available all the versions of the model. Through this application, we stress the importance of reproducibility of the results coming from HEPMDB or from a particular model downloaded from HEPMDB.

We would like to stress that HEPMDB is an important project which has no analogy at the moment. It is different from projects which sound quite similar but in fact serve a different purpose. For example, "Database of Numerical HEP scattering cross sections" (`http://durpdg.dur.ac.uk/HEPDATA/REAC`) collects various particle scattering process which are connected to experimental searches of different reactions. On the other hand "Signatures of New Physics at the LHC" web-site (`http://www.lhcnewphysics.org/`) collects various BSM signatures, their classification and related papers. The part of HEPMDB related to signatures has definitely a lot of in common with "Signatures of New Physics at the LHC" but the global aim of HEPMDB is generically different. HEPMDB is aimed to provide an important connection between theory (in the form of theoretical models which user can upload), phenomenology (in the form of cross sections and distributions which user can evaluate at HEPMDB) and experiment (in the form of collections of model-specific signatures and simulated events which can be used by experimental collaborations).

2. The current status of HEPMDB

The HEPMDB project main page is presented in Fig. 1(a). At the moment the HEPMDB allows the user to perform the following operations.

1. To find and download an existing HEP model from the database. The search engine checks patterns in the following fields: Model, Authors, References, Abstract, Signatures and Information (see Fig. 1(b)).
2. To upload a new model (upon user registration). The model can be uploaded in the format of any ME generator. Also, a user can upload the model *source* in FeynRules or LanHEP formats. An example of the model entries as well as the model history is given in Fig. 1(c).
3. To perform the evaluation of cross sections for user-defined processes for the chosen model from the HEPMDB and to produce a respective LHE file with generated parton-level events. This file becomes available for download once the process is finished. Currently, the HEPMDB allows the user to perform these calculations (using the aforementioned HPC) for CalcHEP and WHIZARD models only. An example of such evaluation is given in Fig. 1(d).
4. To update/add features and respective signatures specific to each model. These features and signatures can be used in the future to distinguish the model from others and connect it to the LHC signatures.
5. To keep track of the model changes, providing reproducibility for the results obtained with previous versions of the models uploaded to HEPMDB.

3. HEPMDB: conclusions and future prospects

The present stage of HEPMDB is a first step towards realizing a systematic comparison of various model predictions with experimental data and decrypting of the underlying theory.

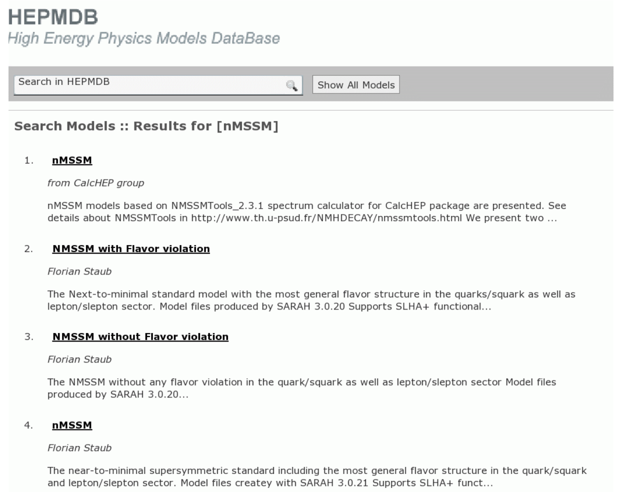
The following improvements/additions will take place in the HEPMDB in the coming months.

1. The LanHEP and FeynRules packages will be added to provide event generation from model sources.
2. The MadGraph/MadEvent and CompHEP packages will be added.
3. A systematic model validation process will be started and the respective pages will be added.
4. The possibility to study events beyond the parton level will be carefully considered, up to detector simulation. One concrete possibility would be the chain `LHE events -> HEPMC events -> FASTSIM events (ROOT format)`. For the latter, Delphes [21] seems a promising candidate.
5. The structure of the database of signatures will be extended to deal with correlated signatures (i.e., whereby multiple signatures, or lacks thereof, must be accounted for simultaneously).
6. The possibility to produce plots for various kinematical distributions will be added.

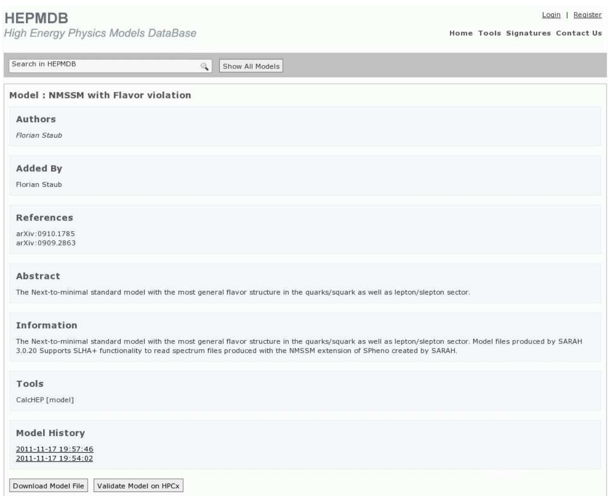
On the longer time scale (of the order of one year) we plan to install the MicrOMEGAs package for evaluation of the dark matter relic density as well as to provide a possibility for scans of various model parameter spaces. During this stage, a development of the format for model predictions consistent with the format for presentation of the LHC data by experimentalists is planned. The question about including automatic tools for NLO evaluations is under discussion and will be developed further at the later stages of HEPMDB development.

To conclude, we hope that starting from the present stage, HEPMDB development will be boosted further via involvement of the HEP community. HEPMDB is already a convenient centralized storage environment for HEP models, and can accommodate, via web interface to the HPC cluster, the validation of models, evaluation of LHC predictions and event generation-simulation chain. We think that in the near future the HEPMDB will also become a powerful tool for isolation of the most successful theory for explaining the LHC data.

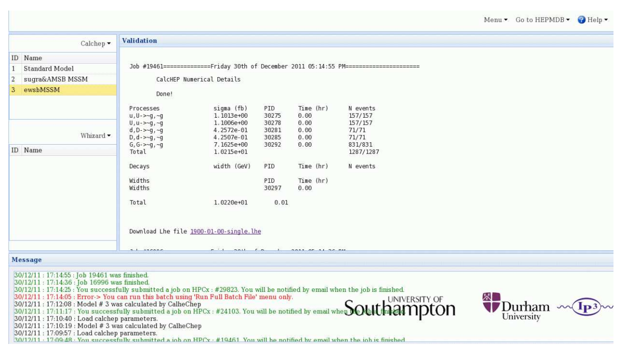
(a)



(b)



(c)



(d)

Fig. 1: HEPMDB - (a): main page, (b): example of the search pattern and results, (c): model details, (d): ME evaluation.

ACKNOWLEDGEMENTS

AB and MB acknowledge financial support of HEPMDB at its initial stage by University of Southampton and IPPP Institute. AB, LB and SM thank the NExT Institute and SEPnet for partial financial support. AB also does so with the Royal Society. CS and (partially) LB have been supported by the Deutsche Forschungsgemeinschaft through the Research Training Group GRK 1102 *Physics of Hadron Accelerators*. NC was partially supported by the United States National Science Foundation under grant NSF-PHY-0705682 and partially by the PITTsburgh Particle Physics, Astrophysics and Cosmology Center (PITT PACC).

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