Detailed closing report

In our research plan we intended to create event simulation codes for proton-proton collisions and provide generated events for the following processes:

1. pp → t + anti-t + b anti-b
2. pp → t + anti-t + H
3. pp → t + anti-t + Z
4. pp → t + anti-t + photon
5. pp → t + anti-t + two jets
6. pp → t + anti-t + two photons
7. processes that cannot be described within the SM (beyond SM processes), as hinted by the early LHC data about the possible BSM physics where more precise theoretical predictions may be important for further progress.

In addition to these processes, we also planned

8. the inclusion of a systematic treatment of the t-quark decays taking into account spin correlations correctly.

Our goal was to provide event samples that can be used to prepare kinematical distributions that take into account the next-to-leading order (NLO) radiative corrections correctly and any usual experimental event selection cut can be implemented easily (NLO matched to parton shower Monte Carlo programs).

We have implemented the simulation of all but one of the listed final states, which were published in eight research papers [1-8] and in invited conference presentations (eight contributions in proceedings have been published [9-16]). The simulation of process (5), planned for the third year of the project, had been published by another group, therefore, we have given up that plan and instead we have published the simulation of the

5'. pp -> W+W- + b anti-b process in a research paper [17].

In addition we have performed and published the simulation of the

9. pp -> t anti-t + W process too.

As a result of our achievements we have been invited to participate in the studies of the Higgs Cross Section Working Group of CERN, where we have contributed to four large reviews published by CERN [18-21], which are used by the experimental groups at the LHC regularly. In the research papers and in the CERN reports we have also performed extensive phenomenological studies, such as investigation of the dependence on the unphysical renormalization and factorization scales, methods of measurements of t-quark properties.

Related to the simulated processes we were in continuous contact with the experimental groups at the LHC and generated many million events using the physical parameter values preferred by them. These generated events have been used by the experiments regularly in the data analyses of the experimentalists, which resulted in more than 500 hundred independent citations during the project. These achievements have also been recognized at home: Dr. Kardos, the participant in this project was awarded the Junior Prima prize in 2016.

We have also implemented the decay of the t-quarks (item 8 in our list above) in the hard-scattering processes. The detailed description of this method has been published in ref. [17] and was used in the studies of the Higgs Cross Section Working Group [21].

In our view we have completed the research plan successfully even if we have not simulated any BSM process planned in item (7) in the list above because there is no hint of new physics at the LHC up to now. Instead, following the change in focus of international research trends, we have started to invest more efforts in the computation of the second (next-to-next-to-leading order, NNLO) radiative

corrections to jet cross sections (project started before the research pursued during the reported period). In this topic we have published the first physical predictions for the following processes in five research papers [22-25] and in conference talks (four contributions in conference proceedings have appeared [26-29]):

(i) decay of a Higgs-boson into a b anti-b quark pair

(ii) electron-positron annihilation into two and three jets

We have computed kinematical and event shape distributions at the highest accuracy available in the literature. In these investigations three other researchers have taken place who joined the researchers of the project during the last year of the funding period.

We had requested and were granted the extension of the funding period until 30 September, 2016 because as a result of our contributions to the theory of computing NNLO corrections, we had been invited to participate in the activities of the international working group LHC Run II and the Precision Frontier in May-June, 2016. Here we have started new international relations to cooperate in the development of computing higher-order corrections to jet cross sections.

We have fulfilled our plans of investments, with some modifications though. Due to the stop in purchasing computer infrastructure at institutions of higher education, we had to delay the development of our computing center. After the cancellation of the stop, we have purchased CPU servers instead of GPU ones because during our collaboration with the experimental groups we had realized that the data analyses performed by the LHC experiments the GPU based codes are less preferred. Thus our codes use traditional CPU-based programming. Also, due to the delay in the investments, in order not to delay our research plans, we had to recourse to external computing resources, which we could secure only in CPU-based computing centers.

During the funding period, we have also presented many public lectures related to our investigations (see our website for a detailed list [30]), as well the PI was invited to present eight lectures at the prestigious European School of High Energy Physics in 2013 [31].

In summary, we believe that this research was highly successful and we are grateful to the fund provided by the National Research, Development and Innovation Office.

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