Indicate the state-of-the-art.

It is generally accepted that there are four fundamental forces that govern the evolution of the Universe. Three of these (strong, weak and electromagnetic) described in quantum field theory called the Standard Model (SM). It is believed that the successful resolution of the so called hierarchy problem of particle physics, namely, why the gravitational interaction is many orders of magnitude weaker than other forces, is an essential ingredient to the resolution of a wider problem, the construction of self-consistent description of quantum gravity and a unified theory of all interactions.

The SM describes strong, weak and electromagnetic interactions of elementary matter constituents. Since its inception in the 1960s, the SM was placed under high scrutiny in a vast range of experiments. The predictions of the SM were tested at the scales down to 10^{-19}m and no significant deviations were observed so far [1]. For example, the perturbative predictions of quantum chromodynamics (QCD), the theory of strong interaction of quarks and gluons, provide a very good agreement in the description of the **precise measurement of the inclusive-jet cross sections in ep collisions at HERA** (Hadron-Electron Ring Accelerator) [2], to which I made the main contribution.

The discovery in 2012 [3, 4] of the particle consistent with the Higgs particle, predicted by the BEH (Brout–Englert–Higgs) mechanism of electroweak symmetry breaking, marks a new era of experimental verification of the particle content of the SM. After all, the SM cannot be considered as ultimate theory because it has several limitations. In particular, the SM does not explain a priori why the scale of electroweak symmetry breaking is so much different from the Plank scale, at which all fundamental interactions are supposed to unify. In other words, the SM doesn't answer why gravitational force is much weaker than other interactions. Moreover, the huge difference of about seventeen orders of magnitude between the two scales is considered as very unnatural and suggests to look for mechanisms beyond the SM (BSM), capable to generate such a "hierarchy" of scales. In addition, there is neither explanation for observed matter-antimatter asymmetry of the Universe nor for the origin of dark matter and energy.

Various models extending the content of the SM were proposed over the past decades to provide a natural (without excessive fine-tuning of the model parameters) solution to the hierarchy problem. Suggested models can be approximately grouped into several classes including supersymmetric (SUSY) extensions of the SM, models with extra dimensions, composite Higgs and so-called little-Higgs models. **Most of the proposed solutions predict new particles with enhanced coupling to the heaviest SM particle — the top quark**[1]. Among those are models with vector-like quarks [5], models that predict additional massive color-singlet spin-1 Z' [6] or composite Higgs [7] boson, models with the so-called Kaluza-Klein (KK) states [8, 9], 2HDM model [10, 11, 12], as well as those with strongly interacting scalar fields — sgluons [13, 14]. Although a wealth of theoretically viable models have been proposed, only empirical evidence can establish their verity, therefore the **search for BSM processes is one of the main objectives of the experiments at the Large Hadron Collider (LHC)**, particularly in the so-called RUN 2 with increased collision energy and therefore larger cross section of hypothetical BSM processes. An observation of such processes will be a **major breakthrough in the field** after the Higgs boson discovery.

Four top quarks production is one promising channel to search for signals of new physics. For example, heavy resonances that couple strongly to top quarks, will result in four tops in the final state, if produced in pairs. Alternatively, if the scale of new physics is too high to be observed directly at the LHC, it can manifest itself as a deviation from the standard model predictions, e.g. an enhancement of $t\bar{t}t\bar{t}$ total cross section due to virtual contribution of BSM states. Being an example of a rare multiparticle process, the SM production of four top quarks is very interesting in its own right, since experimental data can challenge state-of-the art perturbative calculation techniques.

Two general-purpose experiments at the LHC, ATLAS and CMS, have extensive physics programs dedicated to BSM searches. The state-of-the-art analyses, focused on final states with a top quark signature, utilised $\sqrt{s} = 13$ TeV data to establish the upper limit on the SM four top quarks production cross section [15, 16, 17]. These new data can be re-interpreted within the BSM context as, for example, in [18], where the $\sqrt{s} = 8$ TeV results were used to derive the lower limit on the mass of scalar gluons up to 750 GeV assuming typical sgluon-top coupling values. Alternatively, in [19, 17], limits on four top quarks production were used to obtain the constrains of top-Higgs Yukawa coupling or masses of heavy higgs-like scalars, respectively.

BSM models with enhanced coupling to the top quark are constrained by SUSY searches looking for gluino[2]-mediated stop[3] production [20]. However, in contrast to the study to be pursued in this project, these searches impose very strict requirements on the missing momentum, $\vec{\not{p}}_T$, the assumption that undetected weakly interacting particles[4] are also produced.

[1] In what follows, (anti-)top quarks are generically called top and denoted by t, unless explicitly stated.
[2] Gluino is a fermionic SUSY partner of the gluon.
[3] Stop is a scalar SUSY partner of the top quark.
[4] Popular SUSY models, including the MSSM, endowed with the so-called R-symmetry, contain lightest neutral weakly-interacting SUSY

The analyses proposed here exploit properties of the top-quark decays to enrich data samples with hypothetical signal events. Top quarks decay almost exclusively via $t \to Wb$ channel, therefore initial t-selection is typically based on identifying secondary vertices from b-decays and leptons or jets from W-bosons. Additionally, if the W-boson decays via $W \to l\tilde{\nu}$, a small amount of $\vec{\not{p}}_T$ is also present in the event and attributed to neutrinos in the SM.

As mentioned, no deviations from predictions of SM were observed so far. Nevertheless, the 2017–2018 $\sqrt{s} = 13$ TeV and planned 14 TeV LHC runs have high discovery potential. As demonstrated in [17], the limit on the SM $t\bar{t}t\bar{t}$ can be significantly improved and possibly statistically significant observation of the SM signal can be made, provided the datasets that were accumulated in 2017 and will be collected in 2018. Given more than thirty-fold increase of the integrated luminosity of the $\sqrt{s} = 13$ dataset in 2016–2017, the LHC may provide a decisive answer to the naturalness problem during the time covered by this proposal. With increased amount of data and potentially pp collision energy, larger mass range and more complex event signatures become accessible at the LHC. To efficiently explore these new signatures, novel analyses strategies will be necessary. Such novel analysis is the subject of this proposal.

Decays of heavy objects, like aforementioned BSM states, result in large Lorentz-boost of daughter particles, therefore the decay products of the top quark, that originates from such a state, typically overlap in the detector. In order to overcome this problem and achieve high signal selection efficiency and purity[5], i.e. optimise statistical significance[6] of hypothetical signal, dedicated reconstruction procedures are necessary. Above-mentioned studies utilised multivariate analysis (MVA) methods and I propose to also use jet-substructure techniques to tackle this problem. Currently, development and optimisation of reconstruction and identification algorithms for boosted objects is an extremely active area of research in both experimental and theoretical communities.

The investigation of processes with multi-top-quark signature will be an important milestone in coming years and one of the main paths to indirect observation of new physics at the energy frontier. Such a discovery would likely be the start of a new revolution in fundamental physics.

Describe the objectives of the research.

With this project **I plan to perform direct search for BSM processes in events with $t\bar{t}t\bar{t}$ signature as well as measure four top quark production in pp collisions with the CMS detector at the LHC at centre-of-mass energy $\sqrt{s} = 13$ and 14 TeV.** The SM measurement aims at testing the state-of-the-art perturbative QFT predictions [21, 22] while direct searches seek for BSM signal. As described above, there is a certain class of models predicting significantly larger than SM cross section values and resonances [23, 24, 25], thus making direct test of such models at the LHC feasible in the RUN2 for which, in total, more than 150 fb^{-1} of the integrated luminosity are expected. The discovery of significant deviation from the SM predictions may have a major impact on the field, while the converse will help to restrict possible BSM scenarios. The recent constraints from $\sqrt{s} = 13$ TeV data for SM four top production at ATLAS [15] and CMS [17], to one of which I have made a leading contribution, resulted in 60 and 69 fb 95% CL upper limits on the production cross section, respectively. The study [16] reported the first observation of $t\bar{t}t\bar{t}$ production in multilepton channel. The observation is consistent with SM predictions, however it features about 80% uncertainty on the measured cross section that is still dominated by statistical component. The previous analysis at CMS in single-lepton and opposite sign dilepton channels made use of 2.3 fb^{-1} of integrated luminosity, that is about 20 signal events for the complete 2015 dataset. **I plan to analyse full data sample collected in 2016–2018 to increase statistical and systematic precision of the search** which will significantly improve the sensitivity to the processes with four top quarks.

Examples of leading order (LO) SM and corresponding BSM Feynman diagrams for $t\bar{t}t\bar{t}$ production are illustrated in Figure 1. The reconstruction of this process is especially challenging because such final state is characterised by large hadronic activity, H_T, and incorporates four b-quarks, jets or leptons from W-decays and additional jets from initial and/or final-state QCD radiation. In addition, such events have non-vanishing missing momentum in case of semileptonic W-decays, which is reasonably well under control in top physics. Bottom quarks are identified exploiting the properties of the weak decays of B-hadrons, which are typically formed from b's during the hadronisation stage. These hadrons have relatively long mean lifetime of the order of 10^{-12}s and travel several millimeters from the production point before they decay giving rise to displaced tracks. Depending on the decay channel of W-bosons, several possible combinations of jet and lepton multiplicities can be identified in $t\bar{t}t\bar{t}$ events e.g. final states

particle (LSP) in the mass spectrum. Thus, heavier SUSY partners decay to SM particles and the LSP resulting in significant missing momentum as an experimental signature.

[5]Efficiency determines the relative amount of signal evens surviving selection procedure, while purity is a measure of background contribution.

[6]For large number of event counts the statistical significance in counting experiments is approximately equal to the ratio $S = N_{\rm sig}/\sqrt{N_{\rm sig} + N_{\rm bg}}$, where $N_{\rm sig}$ $(N_{\rm bg})$, denotes an estimate of the number of signal (background) events.

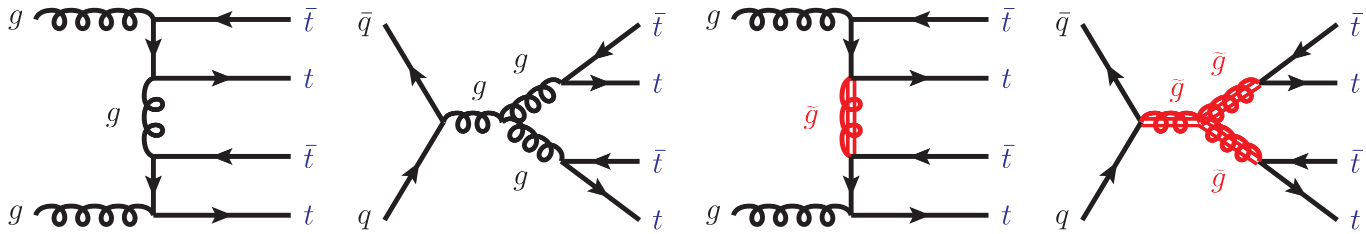

Figure 1: Examples of leading order SM and corresponding BSM Feynman diagrams for $t\bar{t}t\bar{t}$ production. The intermediate states, indicated by $\tilde{g}$, represent coloured scalar fields – sgluons.

with a single muon (μ)+jets or a single electron (e)+jets[7] arising promptly from W decays or in a cascade $W \to \tau\nu_\tau$, $\tau \to l\nu_l\nu_\tau$. This final state has the highest probability ($\approx 41\%$) of occurrence, while zero-leptons, two-leptons or three- and four-leptons have 30%, 22% and 6% odds, respectively [26]. Vanishing $\vec{\not{p}}_T$ in the all-hadronic channel as well as the capability to reconstruct the momentum of the neutrino[8] in the single-lepton channel, increases the sensitivity to BSM models without undetectable particles carrying significant momentum. This signature makes this proposal **unique as no similar analyses, besides ongoing effort of the applicant and the hosting group, are currently being performed by the CMS collaboration**.

Several principal challenges inherent to the explored final state can be identified early on. A difficulty persistent to the reconstruction of multiple top quarks is identification of a correct combination of final state objects arising from a common mother-particle decay. For example, in the single-lepton channel, $4! \cdot C_6^2 \cdot C_4^2 = 2160$, where C_n^k denotes binomial coefficient, possible assignments of four b-jets and six light-flavour jets to four top quarks exist. In order to suppress combinatorial background, decay products kinematic information can be used, e.g. combinations with invariant masses outside W-boson and top-quark mass windows can be rejected. Furthermore, MVA techniques can be applied to enhance classification power of assignment algorithm. The **improvement in the top-decay reconstruction** will have a significant impact on the signal sensitivity and background suppression.

The details of the suggested solutions to foreseen challenges as well as the generic strategy for reaching the objectives of this proposal are outlined below.

Describe the methodology of your research.

From experimental point of view, the process cross section can be determined applying generic formula:

$$\sigma = (N_{\rm sig} - N_{\rm bg}) \cdot \mathcal{A} \cdot \mathcal{L}^{-1}, \tag{1}$$

where $N_{\rm sig}$ $(N_{\rm bg})$, denotes an estimate of the number of signal (background) events, while $\mathcal{L}$ and $\mathcal{A}$ represent an integrated luminosity and a correction factor taking detector and possibly other effects into account, respectively.

As follows from the Eq. (1), to measure the process cross section, typically several steps have to be performed, i.e. the number of signal and background events as well as the integrated luminosity have to be determined for a given data sample; the detector effects attributed to e.g. inefficiencies, finite resolution, etc. also have to be taken into account. On the other hand, in the direct searchers for new phenomena, typically the regions of phase space are investigated in which the signal production cross section is enhanced and exceeds the background significantly. In general, in this procedure certain assumptions about e.g. modelling of the detector response or the shape of the background spectrum are typically made. The sensitivity of the result to variations of different assumptions is called systematic uncertainty and is one of the crucial components of the analysis that often requires elaborate studies. Besides that, the precision of the measurements with low event count rate as e.g. $t\bar{t}t\bar{t}$ production, is usually limited by stochastic effects[9], which also have to be properly taken into account. To achieve all mentioned tasks, various techniques, employing simulations of relevant processes, data-driven analysis methods and statistical means, exist. The proposed research follows closely well established paradigm in the field. The foreseen steps and intermediate goals of this study are detailed below.

Depending on the principal task, i.e. measurement of the SM cross section or direct search for BSM signal, two corresponding sub-projects can be identified in this proposal. In general, any experimental analysis aims at best measurement precision, however, in case of searches for new phenomena, the maximal statistical significance of the signal is required in addition. Two different strategies will be pursued in the respective sub-projects, however both can be performed using comparable tools. Furthermore, it is natural to split the sub-projects further according

[7]In the following, charged first and second generation leptons, i.e. e/μ are generically denoted by l.
[8]The SM decay hypothesis of the W boson has to be assumed
[9]Typically attributed to statistical uncertainty on the number of signal events.

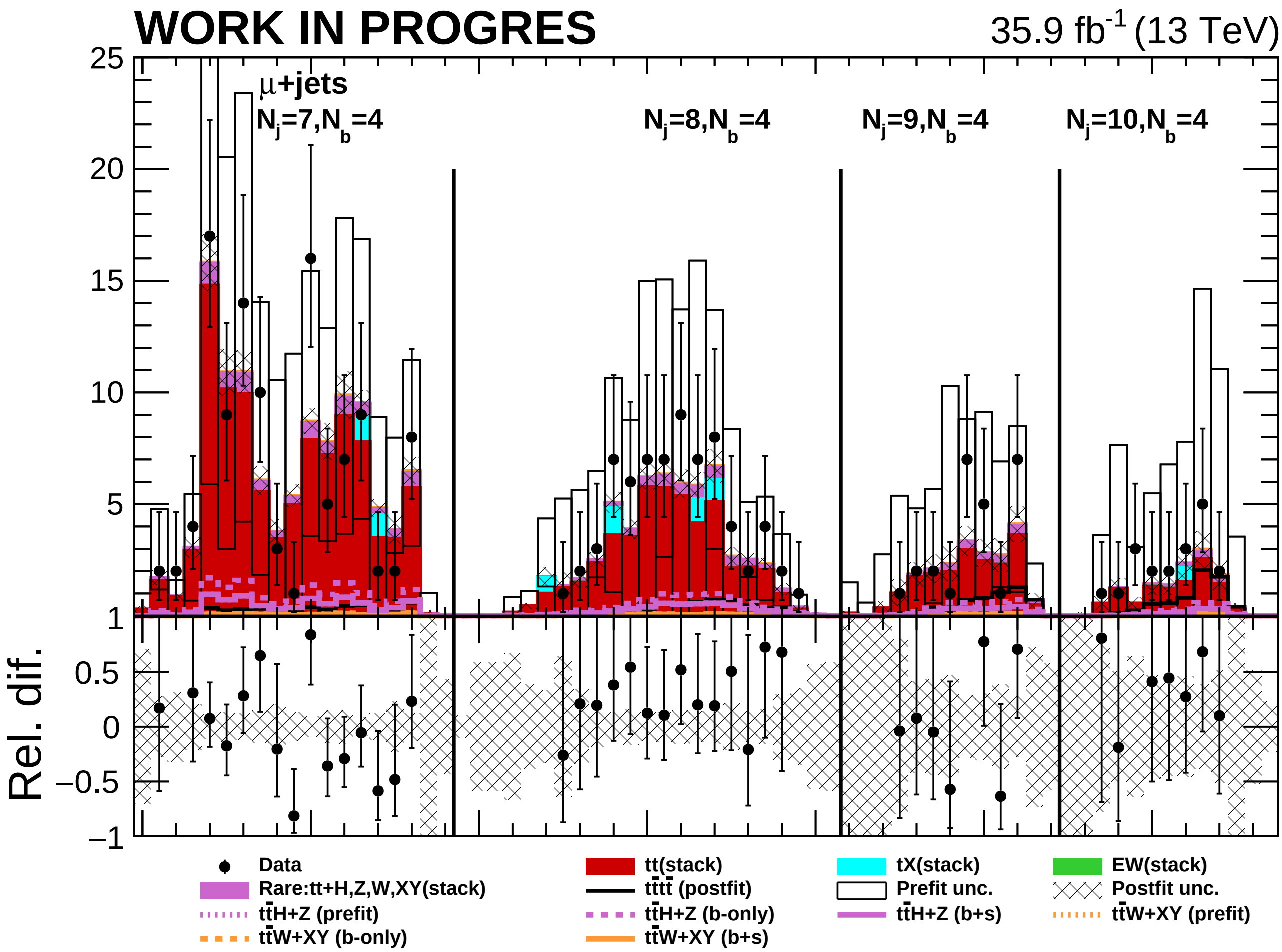

Figure 2: **Work in progress.** Distribution of MVA discriminant in the most sensitive search regions in μ+jets channel obtained using 35.9 fb^{-1} dataset collected during 2016 data tacking period. Observations are shown as black dots, while background predictions obtained from Monte Carlo simulations are shown as a stacked histogram. A prioty uncertainty on the MC predictions are shown as open squares and uncertainties obtained from the fit to the data in control regions are shown as hatched area. Bottom panel of the figure demonstrates relative difference of the data with respect to background predictions.

to the $t\bar{t}t\bar{t}$ decay channel to be considered, corresponding to zero-, single- and two-lepton final states, respectively. As all three have different experimental signatures, development and optimisation of individual reconstruction algorithms, selection of appropriate trigger chains, background studies as well as determination of statistical and systematic effects will be different in three sub-projects. However, they have a common core related to the reconstruction and identification of b-quark jets and reconstruction of hadronic top decays.

The single-lepton channel, previously studied in [27, 28] and [26] is considered the most straight-forward analysis in this project. It has the largest branching fraction and expected to have moderate background level. Moreover, constrained-kinematics reconstruction, extensively employed in CMS in top-pair production analyses, is directly applicable in this channel and will have significant effect on top quark identification efficiency. This sub-project will largely benefit from my extensive experience in this analysis and will use state-of-the-art dedicated tools developed at the host institution. Analysis framework for event selection and resolved hadronic top decays reconstruction is already developed and interfaced with statistical interpretation software. Preliminary results have been obtained using 35.9 fb^{-1} of integrated luminosity collected in 2016. Fig. 2 shows multivariate discriminant distributions in the most sensitive search regions. An **excess** of signal over SM predictions was observed, but further studies are necessary to understand the nature of the signal. The results obtained in same-sign dilepton and multilepton channels [16] also observe an excess, therefore further research in single-lepton channel is required to claim an observation. **It will be crucial to continue analysing 2016–2017 data in this channel to confirm or rule out the excess.** In general, the direct search in this channel represents the minimal goal of the proposal. The results of this study using 2016–2017 data are already novel enough to be published in a peer-reviewed journal.

To complete the analysis and draw the conclusions about the impact of new searches, the data can be interpreted within the so-called effective-field theory (EFT) approach in which the impact of BSM physics is parametrised by higher-dimensional operators constructed from the products of SM fields. In my opinion, this is the optimal ap-

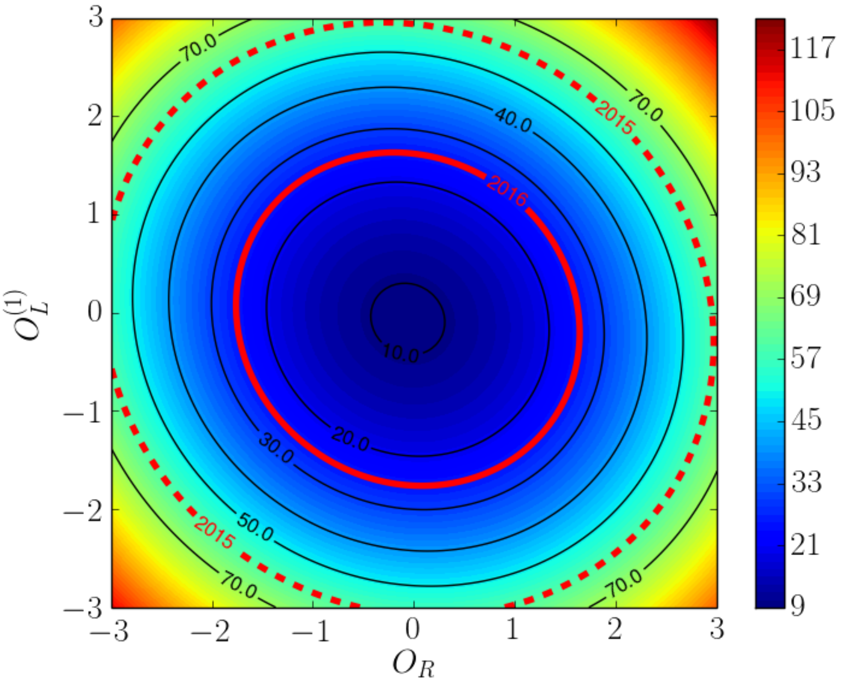

Figure 3: **Work in progress.** Independent limits on four fermion dimension 6 operators $O_L^{(1)}$ and O_R, defined in [29], that can be obtained using 2015 (dashed line) or 2016 (solid line) datasets. The region outside red dashed or solid ellipses are excluded by observations. Color axis represents predictions for four top total cross section, $\sigma_{t\bar{t}t\bar{t}}$, for given values of effective coupling parameters (Wilson coefficients) of $O_L^{(1)}$ and O_R operators.

proach, because these results, in contrast to a particular ultraviolet-complete model, have much broader scope and, at least in principle, can be reinterpreted within any BSM model. The EFT-analysis of the measurements is a novel approach to the interpretation of the $t\bar{t}t\bar{t}$ data and may attract larger attention to the obtained results. The outcome of this analysis can be presented as a **separate publication** or together with the results of the searches.

Preliminary research on EFT interpretation has been already carried out in parallel to the 2016 data analysis. Fig. 3 demonstrates the marginalised constrains on dimension-6 four-fermion operators contributing to four top quarks production at the LHC [29, 30]. As can be seen, significant improvement can be achieved with larger Run 2 data sample. Even stronger constraints, potentially ruling out some theoretical models, can be obtained with the full Run 2 dataset.

Determination of the $t\bar{t}t\bar{t}$ production cross section in other channels and corresponding searches are a logical extension of the described analysis. The two-lepton channel can provide a valuable contribution with a moderate effort, while the analysis in the zero-lepton channel may present significant challenge due to major difference in the final-state. In order to reach the ultimate sensitivity in the BSM searches, the next logical step, contingent with these sub-tasks, is a combination and interpretation of the results obtained in various channels. They will perfectly fit together with the analysis of the single-lepton channel, but can be issued together with the combination in a **separate publication**. **My experience in four top searches makes me perfect candidate for these tasks.**

To fulfill the ambitious plans outlined above, the research will be delivered in three work-packages which are elucidated in the following.

Provide a work plan, i.e. the different work packages (WPs) and a detailed timetable.

1. The SM $t\bar{t}t\bar{t}$ production measurement. (low-risk)

Given the excess observed in 2016 dataset, the immediate target of the first WP is to establish or exclude signal. Before claiming an observation, careful scrutiny of background contribution is needed. The ongoing effort is focused on validation of Monte Carlo modelling of $t\bar{t}+X$ backgrounds and checking potential contributions from sources with fake leptons, such as events with hadronic jets misidentified as muons or electrons. Decay of four top quarks in the single-lepton mode results in ten jets in the final state. Matrix-element predictions of such high jet multiplicity $t\bar{t}$ events are not possible with existing event generators, therefore the background modelling in this corner of phase space relies on parton shower models that typically have several free parameters fitted to the data. Comparison of

$t\bar{t}+X$ predictions based on different parton shower models is one the steps towards understanding of the observed excess.

In case no deviations from the SM will be found and given that the systematic and statistical uncertainties analysis framework will be established, the search results can be reinterpreted using EFT models. **The ongoing analysis is an extension of the previous results obtained using 2015 dataset [17]. My experience in both projects makes me an ideal candidate to carry out this project.** The dataset collected in 2017 will be sufficient to make statistically significant observation of $t\bar{t}t\bar{t}$ SM production. Taking these conditions into account, this WP is considered as low-risk.

2. Top-tagging performance optimisation. (medium-risk)
As described above, the reconstruction of $t\bar{t}t\bar{t}$ final-state suffers from combinatorial ambiguity in assigning the decay products to theirs parent t-quarks. At $\sqrt{s}$=13(14) TeV, however, a significant fraction of top quarks is expected to be produced with large Lorentz-boost, leading to strongly collimated decay products which end-up in a single jet. This feature helps to mitigate combinatorial problem, because it suggests natural candidates for decay products originating from the same parton. Moreover, as was mentioned, many BSM models predict heavy states, resulting in a large boost of the decay products, thus making the reconstruction of boosted top decays crucial for direct searches. The top-tagging is currently an active area of research and many novel techniques were proposed over the recent years. In particular, the HepTopTagger algorithm [31] demonstrated very good performance in the recent search for pair production of vector-like T quarks in events with similar event signature in CMS [32]. Besides that, the CMSTopTagger [33] employs a different jet deconstruction approach which is more suitable for highly boosted top decays. More algorithms exist including shower-deconstruction tagger and N-subjettiness algorithm, the applicability of which [34] still has to be explored. Therefore, in order to enhance sensitivity to SM and BSM $t\bar{t}t\bar{t}$ signal, especially in the zero-leptons decay channel, the investigation of different techniques is foreseen in this project. To my knowledge, besides the discontinued attempt of W-tagging at UGent, this will be the **first significant effort on jet substructure in Belgium**. As previously mentioned, the development of substructure algorithms is of great interest in the field. Therefore, it is expected that new developments will be included in a **performance paper** by the CMS collaboration. My experience in various jet-analyses makes me a perfect candidate for this pioneering effort.

This task goes hand-in-hand with optimisation of the b-tagging in sub-jet environment. A better performance of the b-tagging can give a significant gain in terms of light-flavour background rejection, therefore I plan to investigate novel tools designed in CMS [35] and explore new promising jet-charge identification technique developed recently in ATLAS [36, 37]. This effort is very timely with the LHC instantaneous luminosity increase foreseen for the year 2017 and may have a positive impact for other studies in the collaboration, for example, for 'high-profile' $ttH \to ttb\bar{b}$ search planned to be performed by the hosting group. **I am ideally placed for this task because I have a wide knowledge acquired during my doctoral studies in the area of track reconstruction**.

In the single-lepton channel one can benefit from the constrained kinematics of the event. If the lepton is well isolated and its momentum is reliably measured, the four-momentum of the neutrino from the W decay can be reconstructed as well. Considering a single $t\bar{t}$ pair, four equations: momentum conservation, two constraints due to the $W^{\pm}$ mass and equality of t and $\bar{t}$ masses, can be used to determine four unknown components of the neutrino momentum vector. This information will help to improve the resolution of the various quantities derived from the momenta of final-state objects. In principle, same technique can be applied in the zero-lepton channel as well, although due to much worse precision of the jet measurement and even larger combinatorial ambiguity, the solution of the constrain equations can be less robust.

Overall, this task is assessed as a **medium-risk**, because t- and b-tagging is a very diverse area and requires a significant effort and collaboration with many people.

3. Direct searches for beyond Standard Model processes. (high-risk)
Whenever the data sample is fixed, the search for new signal is a well-established process. A fit to the multivariate discriminator distribution will be performed in order to estimate the amount of $t\bar{t}t\bar{t}$ events in selected samples. In this analysis a significant fraction of the background contamination is expected in the final datasets, therefore its shape and normalisation have to be determined preferably using data-driven approaches or employing theoretical predictions. A simultaneous fit to different background- (signal-) enhanced event categories can be performed to constrain the background and determine the number of signal events. I have a good knowledge of various fitting approaches, including multidimensional likelihood fits to the distributions with low counting statistics to effectively work on this task.

In both BSM searches and SM measurement (see below) the experimental and theoretical sources of systematic uncertainty have to be taken into account as both can affect the shape and normalisation of the measured distributions. Examples of theoretical uncertainty include the ones due to the variation of renormalisation and factorisation scales in perturbative calculations or the variation of the matching scale in the parton-shower-matching procedure. The experimental uncertainties arise, for example, due to finite jet and lepton energy resolutions, b- and top-identification procedures, luminosity etc. These uncertainties can be included as a nuisance parameters into the above-mentioned likelihood fits.

Individual channels will differ in the details of systematic studies, mainly because of the variations in the background strength and sources composition. The studies for single- and two-leptons channels will largely benefit from the experience developed by the host institute, while in the zero-leptons channel my expertise in QCD jet analysis will be a valuable complement.

Overall, the described work package is assessed as high risk because it is contingent upon the progress in the previous WP. Moreover, the all-hadronic channel may require more significant effort investment, because of severe QCD background that is not completely understood. Without doubt, the discovery of a new state will have major impact on the field, but negative result is also worth an effort since very little is known about this extreme corner of phase space. The obtained results will be **published in a refereed journal**.

4. Results combination and interpretation. (low/medium-risk)

The modified frequentist $\mathrm{CL_s}$ approach [38, 39] can be used to assess the statistical significance of the signal in case of observation or to establish the limits on the mass and production cross section, as well as to combine results obtained in different channels. **This WP will build on the expertise of other researchers in the institution and strong collaboration with the authors of respective theoretical predictions and thus has potential risks.** The minimal goal of this WP is a top-down interpretation of the results of the searches within the framework of existing models, similarly to what has already been performed by the hosting group or within the framework of simplified models. A bottom-up approach would be the interpretation of the data using the EFT calculations. My experience with the MC generation together with cooperation with the phenomenology groups in Brussels is the perfect fit to complete this task in an effective manner.

The outcome of these findings will be **together with the experimental results** outlined above or in a **separate publication**.

The Gantt chart (allocated time interval and estimated risk) for the envisaged WPs and corresponding subtasks is illustrated in Figure 4. The publication procedures are not included into the chart because of the specific nature of the publication policy in the CMS collaboration. In general, the foreseen journal articles will be prepared in parallel to the outlined active stages of research.

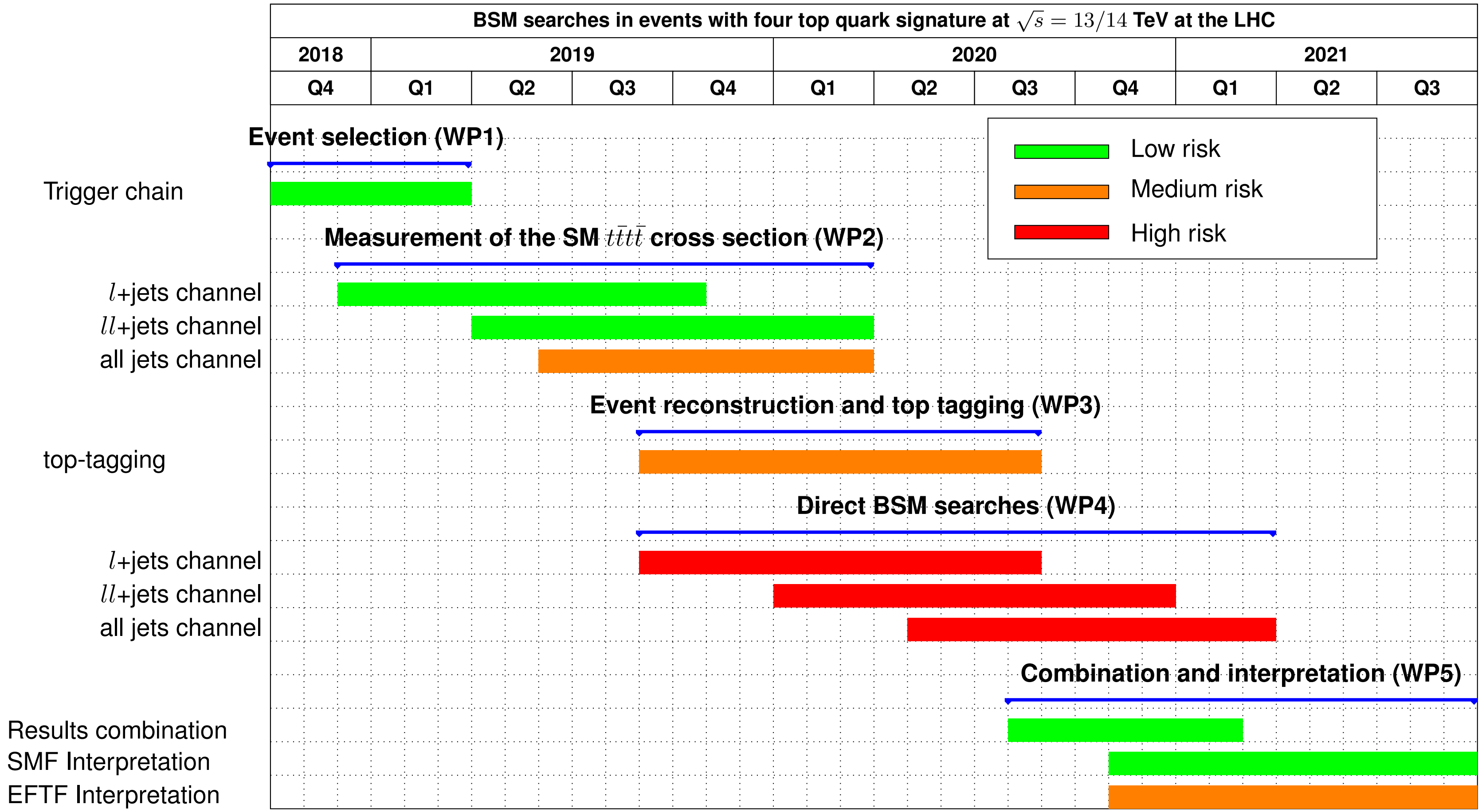

Figure 4: Time-line of the proposed project. Each year of the fellowship mandate is divided into intervals of three months (Q1-4). The extend of the color bands indicates the start and the end of corresponding task, while their color encodes the risk estimate. In this figure, SMF — simplified model framework; EFTF — effective field theory framework.

Indicate below whether you think the results of the proposed research will be suitable to be communicated to a non-expert audience and how you would undertake such communication.

The Large Hadron Collider is one of the largest scientific instruments that was ever built. Its research program is mainly focused on the searches for new phenomena and achievements of the LHC are widely known. Besides providing unique information to the scientific community, I believe that LHC became a cultural symbol for scientific curiosity and dedication. I am very enthusiastic about the opportunity to communicate scientific results to general audience and, especially, as a professional researcher, to encourage young individuals to study science. In this respect, several activities targeted at high-school and university students are planned. The VUB regularly organises infodays delivered in English for international Master students, in order to get acquainted with professors, visit laboratories and get to know to students life, therefore the participation in such or similar events is planned during the mandate.

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I am a co-author of more than 153 publications as a member of the CMS, ZEUS and CDF collaborations. These publications have on average 36 citations (per paper) and overall h-index $h_{\mathrm{HEP}} = 27$. Moreover, for the contribution to the maintenance of the CMS Monte Carlo simulations production system I am be included in the CMS author list starting from 8 February 2016.

By convention, articles published by particle physics experiments list all collaboration members as authors in strict alphabetical order. This policy reflects the substantial efforts in detector construction and maintenance, data acquisition, data reconstruction and calibration that all collaborators contribute to and which is a prerequisite to any data analysis. This is particularly relevant for those who have committed a substantial fraction of their time to construction, installation and commissioning of detectors. As such, scientific leadership, which is awarded after selection on merits and excellence within the collaboration, as are conference presentations, and seminar invitations add a reliable additional measure of scientific productivity in the hep-ex field than merely citations alone. The complete list of my publications is available from `http://inspirehep.net/search?ln=en&ln=en&p=find+a+lontkovskyi&of=hb&action_search=Search&sf=earliestdate&so=d&rm=&rg=25&sc=0`

In 2016 I was invited as a referee for journal Phys.Lett.B (Impact factor 4.787).

List of the publications in peer-reviewed journals to which I made the main contribution:

1. * “Search for standard model production of four top quarks in proton-proton collisions at 13 TeV”
   By CMS Collaboration (V. Khachatryan et al.).
   to be submitted to Phys.Lett.B
   also in CMS public document TOP-16-016
   cited 4 times as of 26 January 2017.
   I studied systematic effects attributed to the b-jet tagging, performed statistical combination of different searches and paper writing. As an exception, I will be added to the CMS authors list for this publication, for my essential contribution.

2. * “Measurement of central exclusive $\pi^+\pi^-$ production in $p\bar{p}$ collisions at $\sqrt{s} = 0.9$ and 1.96 TeV at CDF”
   By CDF Collaboration (Timo Antero Aaltonen et al.).
   Physical Review **D 91** (2015) 9, 091101.
   journal impact factor: 4.506.
   cited 22 times as of 26 January 2017.
   I was one of the main analysers that developed and optimised the trigger chain for selection of exclusive central production events.

3. * “Inclusive-jet photoproduction at HERA and determination of alphas”
   By ZEUS Collaboration (H. Abramowicz et al.).
   10.1016/j.nuclphysb.2012.06.006.
   Nuclear Physics **B 864** (2012) 1-37.
   journal impact factor: 3.735.
   cited 32 times as of 26 January 2017.
   I was one of the main analysers that contributed to all stages of the analysis, including, MC studies, measurement unfolding, analysis of systematic uncetrainties, etc.

4. * “The Pomeron and Odderon in elastic, inelastic and total cross sections at the LHC”
   By L.L. Jenkovszky, A.I. Lengyel and D.I. Lontkovskyi.
   International Journal of Modern Physics **A 26** (2011) 4755.
   journal impact factor: 1.699
   cited 23 times as of 26 January 2017.
   I was the main author of the model fits presented in the publication.

List of contributions to the conference proceedings

1. “Proton structure measurements at HERA”
   By D. Lontkovskyi (for the H1 and ZEUS Collaboration).
   in Proceedings of 46th Rencontres de Moriond. QCD and High Energy Interactions: La Tuile, Italy (2012).
   I presented combined HERA summary results on behalf of the two collaborations.

2. “Jet cross sections in photoproduction at ZEUS”
   By D. Lontkovskyi (for the ZEUS Collaboration).

in Proceedings of science, XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects: Firenze, Italy (2010) 120.
I presented preliminary results that were later published in [1].