

Helmholtz Young Investigator Groups – Annual Report

Disclaimer: The questionnaire is provided in English and can also be filled out in

German. All form fields with a red frame are mandatory and need to be filled out.
(If you cannot make an entry, please enter “–” or “n/a”.)

Core data		
Funding program	Helmholtz Young Investigator Groups	
Project ID number	VH-NG-1302	
Project title	Ultimate precision measurements and search for new phenomena in processes with top quarks and a Z boson with the CMS experiment at the LHC	
Name of reporting person	Abideh Jafari	
Helmholtz Center	DESY Hamburg	
Partner university	Karlsruher Institut für Technologie	
Helmholtz research field	Matter	
Reporting period [dd.mm.yyyy – dd.mm.yyyy]	01/01/2019-30/12/2019	
Number and length of cost-neutral extensions of the project (if applicable)	---	
Annual installment (reporting year)	Reference value (in EUR)	Actual value (in EUR)
Share of the Initiative and Networking Fund	150.000	90.531,77
Share of the Helmholtz Center	49.500	43.061,40

1	How do you assess the utilization of the current allocated annual installment until the end of the year? (forecast)
Code	Item
V1.1	<p>I am planning to use 360.000 EUR of this year's allocated planned installment.</p> <p>(The planned annual installments are listed in the contract, which was concluded between the Helmholtz Association and the Helmholtz Center.)</p> <p>Please see V5.3 C for the team structure in 2020</p>

2	Please explain last year's expenses with regard to the following categories:
Code	Item
V2.1	<p>Investment costs: about 14.000,00 Eur, distributed over</p> <ul style="list-style-type: none"> • <i>Experimental fee (10.000,00 CHF):</i> to access the CMS data and large scale facilities for the team leader • <i>Travel expenses (the rest):</i> for the team members to travel to CERN and attending workshops and conferences.
V2.2	<p>Personnel costs: about 115.000.00 Eur, distributed over the salaries of</p> <ul style="list-style-type: none"> • <i>Team leader : as of Jan 2019</i> • <i>Postdoctoral researcher : as of mid-October 2019</i> <p>My PhD student was enrolled in DESY a bit before my account is created. For the first year he was paid by DESY. He has been moved under my account as of Jan 2020</p>
V2.3	<p>General expenses/material costs: about 4.000,00 Eur, spent on computing equipments for each of the three members of the group.</p>

3	How do you rate the following aspects?					
		I fully agree	I agree	I partially agree	I agree less	I do not agree
Code	Item					
V3.1	My research group has reached full development.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
V3.2	I am well connected with my university partner.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
V3.3	The status of my career development corresponds to my vision.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
V3.4	I am satisfied with my overall situation.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
V3.4C	Please list positive or critical aspects, if applicable: - <i>Development of the group:</i> the only reason I did not choose “fully agree” is because I think the first year of work is too early to reach the “full” development. The group is progressing extremely well to achieve that. - <i>University partner:</i> I have been appointed for a highly demanding research management role in the CMS experiment. KIT has agreed to delay my teaching contribution until after the current mandate. This is a clear sign of support from the university partner which particularly helps me to run my group successfully, without further pressure, while being heavily loaded with this management role. We have had discussions about common strategies and possible projects in the context of my YIG program. It will be pursued with hiring a common PhD student. The topic, electroweak production of the top quark, is of particular importance in the YIG project and fits well within the top quark physics program of KIT					
V3.5	The working progress of my research group is according to my schedule.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
V3.6	The promises of the Helmholtz Center, e. g. regarding access to technology and infrastructure, financial independence, personnel responsibility are being kept.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
V3.6C	Please list positive or critical aspects, if applicable: DESY offers the perfect infrastructure for international research and provides excellent support in continuation of the project as well as in promoting the young group leader within the large scale collaboration.					

4	How do you assess the independence of your research group?		
		Yes	No
Code	Item		
V4.1	I can freely decide on the budget allocated to me as per the application.	<input checked="" type="checkbox"/>	<input type="checkbox"/>
V4.2	I continue to develop my research agenda autonomously. – <i>Personally I always ask for feedback and get advise. But the decisions, I make it!</i>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
V4.3	I make my own personnel decisions.	<input checked="" type="checkbox"/>	<input type="checkbox"/>

5 How do you assess the progress of the project?			
		Yes	No
Code	Item		
V5.1	Compliance with the timeline as described in the proposal	<input checked="" type="checkbox"/>	<input type="checkbox"/>
V5.1C	<p>In case you deviated from the timeline, please give a brief explanation:</p> <p>Please note that, being on maternity leave, I started my YIG project 1.5 year after the budget was granted. Hence the project was adjusted with the developments that had happened in the field in the meantime. The current timeline is therefore different from the one in the proposal. The project is well on track with the adjusted timeline.</p>		
V5.2	Achievement of important milestones in line with the proposal	<input checked="" type="checkbox"/>	<input type="checkbox"/>
V5.2C	<p>In case milestones have not been reached, please give a brief explanation:</p>		
V5.3	Compliance with the financial plan as described in the proposal	<input checked="" type="checkbox"/>	<input type="checkbox"/>
V5.3C	<p>If changes to the financial plan have occurred, please give a brief explanation:</p> <p>The group, started at 01.2019, consists of the group leader and the following members:</p> <ul style="list-style-type: none"> • David Walter – PhD student – since January 2019. • Nicolas Tonon – Postdoc – since mid-October 2019 <p>As planned a new PhD has joined since Jan. 2020.</p> <p>Mr Walter was enrolled in DESY a bit before my budget code is defined. Therefore, his salary in 2019 was not paid from my YIG account while I paid for his investment and material costs. As a result, the 2019 budget has a bit of left over. He has been moved under my budget since 1 Jan 2020.</p>		

6	Please describe the scientific progress of the project in the reporting year along the individual work packages.
Code	Item
V6.1	<p>The goal of the project is to achieve an ultimate precision in the measurement of top quark interactions and, to set stringent bounds on new phenomena hypothesized for these couplings. It is pursued via a set of coherent measurements of the standard model (SM) processes involving top quarks and other bosons, particularly the Z boson. The search for new interactions are performed in the context of Effective Field Theory (EFT). In all cases, advanced analysis techniques and state-of-the-art methods are being exploited.</p> <p>Being on maternity leave, the project has started 15 months after the fund was granted. The YIG leader has been able to adjust the work-packages and the priorities in such a way to have a significant impact in the field despite the progresses happened in the meantime. At this point of time the project is well on track and evolves as expected. Some details are provided below:</p> <p>Precision measurements of top quark couplings</p> <p>The group plays a key role in the measurement of top quark interactions with other heavy particles of the SM, namely the Z and W bosons in CMS. Currently, the focus of the team is the electroweak production of the top quark, single-top production, which is complementary to the ongoing efforts in the DESY top group. The team is expected to continue with a significant impact in this area particularly given the in-depth knowledge and the longstanding experience of the YIG leader. The contribution of the team goes beyond the CMS experiment and involves combination of the measurements with ATLAS. In addition, the YIG has been the only contributor to a recently initiated effort in the precise measurement of the LHC luminosity in CMS, using Z boson decays to muons. This measurement has a major contribution in all physics analyses in CMS as the precision of every measurement relies on the accuracy of luminosity.</p> <ul style="list-style-type: none"> • The YIG has accomplished the combination of several single-top production measurements performed by the ATLAS and CMS experiments during LHC Run-I. The electroweak production of the top quark processes in three modes, depending on the virtuality of the W boson: t- and s-channel and in association with an on-shell W boson. It provides a direct access to the top quark interaction with the W boson and is very sensitive to the V_{tb} element of the Cabibbo–Kobayashi–Maskawa matrix. In this work, the measured cross sections from each channel are combined separately and lead to improved precisions. The combination requires a great insight into the systematic uncertainties of the measurements and their correlations inside and across the two experiments. Additionally, results from all production modes across the experiments are combined to directly extract the most precise V_{tb} estimate to date without SM assumptions. • The measurement of differential distributions in single-top production in association with a Z boson (tZq) has started at the start of the YIG project and is now in advanced stages. Using the entire data from Run-II LHC, it is possible to measure the distributions in this process differentially for the first time. A set of observables with high sensitivity to top-Z couplings are identified for the measurement. Advanced Machine Learning (ML) techniques are being employed to separate tZq from other processes. The deep neural network is designed such as to have the Z-associated $t\bar{t}$ production, $t\bar{t}Z$, as a distinct node. This is inline with the ultimate goal of the project to use both $t\bar{t}Z$ and tZq processes in constraining new phenomena in top-Z couplings. Techniques to unfolding data to parton level in each distribution are also in place. The measurement is now being document and is expected to soon become ready for the CMS internal review. • Aiming at the best possible precision in the SM measurements, the YIG has a significant contribution to reducing the uncertainty on the luminosity of the LHC machine. The uncertainty on the luminosity is the main source of uncertainty in almost all of the currently precise measurements in CMS. The YIG works on a self-calibrating method to measure the luminosity which is based on the Z boson production cross section in the dimuon final state. The main uncertainty in this measurement arises from muons. This is already small and can even be further improved with ongoing developments on muon identification. This work is quiet advanced and is expected to be part of the future luminosity publication(s) of CMS. <p>Search for new phenomena in top quark interactions and heavy particles</p> <p>Despite starting recently, the group has taken the lead in employing ML-based techniques to probe new phenomena in top quark interactions within the EFT framework, using events with top quark(s) and a Z boson. Furthermore, the YIG has the most stringent limits on the anomalous top quark interaction with the Higgs boson, where the electroweak production of the top quark is accompanied by a Higgs boson decaying into photons. Looking for new phenomena in the heavy sector of the SM, the group has also accomplished a search for non-standard decays of the Higgs boson, introducing new light particles that interact with SM fermions (quarks and leptons) via mixing with Higgs.</p> <ul style="list-style-type: none"> • The YIG pioneers a novel approach, designing a Deep-Neural-Network-based search for new top quark electroweak interactions with EFT. The search exploits simultaneously, multiple processes involving top quarks and the Z boson, namely, $t\bar{t}Z$, tWZ and tZq. It is based on the recent developments in Monte Carlo (MC) simulation to reweight events based on the EFT hypothesis. Currently, the MC implementation is being finalized and the work is focused on the <i>parametrized</i> DNN architecture. It allows for the in-situ EFT parameter scan in the training of the network. • The YIG has crucially contributed to the results of a search for new top quark interactions with the Higgs boson in Higgs-associated single-top events, tHq. The production rate of tHq increases significantly if the relative sign of the Higgs boson interaction with the top quark and W boson, y_t, is negative. The focus of the YIG was on the Higgs to di-photon decay which, because of the high mass resolution, is the most sensitive in a wide range of the parameter space. For a standard model-like value Higgs interaction with the W boson, the data favor positive values of y_t and exclude values of y_t below about $-0.9 y_t^{SM}$. • The uncertainty on the current Higgs boson measurements allows for beyond SM decays to new particles which means new interactions in the heavy sector of the SM. In extended scenarios for Two-Higgs-Doublet models and supersymmetry, the Higgs boson decays to light pseudo-scalars, decaying consequently to quarks and leptons. Any hint to these scenarios will have an impact on top quark interactions since they predict new top quark interactions via, e.g., top quark decay to a light charged Higgs boson. A search in the final state of two muons and two b-jets, $\mu\mu b\bar{b}$, is performed, placing an stringent upper limit of $(1-7) \times 10^{-4}$ on the Higgs branching fraction to $\mu\mu b\bar{b}$ via pseudo-scalars in the mass range of $[20 - 62.5]$ GeV.

7 How do you assess your career development and networking with the university?			
		Yes	No
Code	Item		
V7.1	I work closely together with the university and its structures (e.g. integration into the faculty council, doctoral procedures).	<input type="checkbox"/>	<input checked="" type="checkbox"/>
V7.2	I am gaining teaching experience.	<input type="checkbox"/>	<input checked="" type="checkbox"/>
V7.2C	If yes, please indicate the number of semester hours per week:		
V7.3	I am appointed to a joint junior professorship.	<input type="checkbox"/>	<input checked="" type="checkbox"/>
V7.4	I am appointed to a joint W2/W3 professorship.	<input type="checkbox"/>	<input checked="" type="checkbox"/>
V7.5	I have an option for permanent employment ("tenure").	<input checked="" type="checkbox"/>	<input type="checkbox"/>
V7.6	<p>Please describe your foreseeable or planned future career prospects:</p> <p>At the moment my main focus is to pursue my YIG program successfully. This means that I consider applying for academic positions seriously once I am positive that the project has achieved its goals or it is close enough to that point. The answer to V7.5 corresponds to an offer that I got at the same time of getting the YIG position. It is from a university in my home country and the option is still available.</p>		
V7.7	I have taken advantage of the employer's support for family phases.	<input type="checkbox"/>	<input checked="" type="checkbox"/>
V7.8	<p>Please describe your current function within the Helmholtz Center (position description):</p> <p>I am a YIG leader with my autonomy about my team. I am always invited to the staff meetings of the CMS group and my opinion is asked in different matters regarding the scientific strategy of the group, hiring new postdocs and PhDs, etc.</p> <p>I am being particularly consulted about the physics program of the top quark subgroup in DESY. My scientific management role in the CMS experiment (convener of the Top Quark Physics Analysis Group), has made me a point of consultation on what concerns the continuity of excellent contribution of the DESY top group to CMS.</p>		
V7.9	<p>Please describe your current function within the university (e. g. also as a committee member):</p> <p>I don't have any official function at the university yet. As mentioned earlier, my connection with university partner will get stronger once I can start teaching after my current management mandate. We have discussions about common strategies and possible projects in the context of my YIG program. It will be pursued with hiring a common PhD student. Meanwhile, I am following the activities of the top quark physics group in KIT, also because of my role as the TOP convener in CMS.</p>		
V7.10	<p>Please indicate the current status of networking with other actors (multiple answers possible)</p> <p><input checked="" type="checkbox"/> Cooperations at the partner university</p> <p><input checked="" type="checkbox"/> Cooperations with other universities in Germany ^[1]</p> <p><input checked="" type="checkbox"/> Cooperations with universities abroad ^[1]</p> <p><input type="checkbox"/> Cooperations with other non-academic research institutions in Germany</p> <p><input checked="" type="checkbox"/> Cooperations with non-academic research institutions abroad ^[1]</p> <p><input type="checkbox"/> Cooperations with companies</p> <p><input type="checkbox"/> Cooperations with other organisations, namely</p> <p>^[1] Within the CMS collaboration, the YIG cooperates with multiple universities and research institutes worldwide. The cooperation ranges from exchanging ideas to developing new research topics and analysis methods in order to exploit the LHC data the best. We are in particular collaborating with the University of Ghent in Belgium on improving the definition of leptons which play a key role in our analysis of multilepton final state.</p>		

8	Please describe the current output of your group.		
Code	Item	Amount / total sum	N/a
V8.1	Peer-reviewed publications in the reporting year	3 + 6 (see V8.5)	<input type="checkbox"/>
V8.2	Registered patents in the reporting year		<input checked="" type="checkbox"/>
V8.3	Spin-offs in the reporting year		<input checked="" type="checkbox"/>
V8.4	Acquisition of third-party funding in the reporting year (please mention the type and amount of funding as well as the involved persons):		<input checked="" type="checkbox"/>
V8.5	Awards and recognitions (please include the names of the respective persons): In recognition of my scientific impact and contribution, the I have been elected as the convener of the Top quark Physics Analysis Group in the CMS collaboration since Sep 2019. This is a level-2 management role in CMS where the responsibility is to make the strategy for the precision measurements in the field of top quark physics and to ensure the scrutiny of the data analyses from the beginning to the final publication in journals – <i>so far, I have contributed to 6 journal publications</i>	1	<input type="checkbox"/>
V8.6	Please describe which activities you have carried out in the area of knowledge and technology transfer: My YIG project is integrated in the High Energy Physics department of DESY, in the CMS group, and contributes significantly to the research program of the Centre. As planned, a close cooperation has been formed between YIG and the corresponding working groups (WG) in the field of top quark physics. I have initiated and established the measurements of electroweak top quark production in the WG which, before, was exclusively working on QCD-induced productions. My YIG project has remarkably strengthened top-EFT program of the WG. It has also activated the use of Z bosons in the luminosity measurement, which is one of the main occupations of the CMS group in DESY. Furthermore, with my role as the CMS TOP convener (see V8.5), I am in day-to-day interaction with O(200) researchers worldwide, including scientific staff members, postdoctoral researchers and PhD students. This has a substantial impact in the worldwide knowledge transfer to the center and eventually makes the contribution of DESY to the physics program of the CMS collaboration even stronger.		<input type="checkbox"/>

9	How do you assess the personnel development measures and qualification? (Helmholtz Academy)			
		Yes	No	N/a
Code	Item			
V9.1	Have you fully attended the course “Leading Your Group”?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
V9.2	Have you implemented the acquired personnel development measures and the qualification plan?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
V9.3	Have you been assigned a permanent contact person? – <i>not for post-leadership-academy development, but for general matters related to Helmholtz (Mrs. B. Wittmann)</i>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
V9.4	Did you have opportunities for discussions with the institute management to reflect on your own development and career planning?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

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