Impact of the COVID-19 Pandemic on Fundamental Physics Research

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Abstract
The outbreak and pandemic of the COVID-19 has dramatically changed the world in almost every aspect. Its impact on the community of high energy physics is also apparent. In this analysis we show that social distancing has greatly changed the working style of the physics community. In the field of high energy physics the online communications and video conferences are becoming daily routine arrangements. However, such a change of working styles may need some time to get used to. The influence can be seen by scientific outcomes harvested from arXiv, INSPIRE databases and JHEP, PRD official websites.

Keywords: COVID-19; High-energy Physics; Impact; Fundamental Physics Research

1. Introduction

As sudden, rapid and large-scale effects of the COVID-19 continue to grow globally since early 2020 [1,2], its impact has been on all aspects of our society. How this has affected the high energy physics (HEP) community in their academic activities is the question of interest in this study. We may see that the pandemic has deeply changed the working style of HEP researchers, and some of these changes may continuously be part of their daily life.

To learn how exactly the HEP community is affected we combine the preprint data from arXiv[3], and the relevant data from INSPIRE [4], including Literature, Jobs, and Conferences of each month between January and May from 2016-2020 for an analysis. In addition, we take samples of published papers from two HEP journals, Physical Review D (PRD) [5] and Journal of High Energy Physics (JHEP) [6], which are widely recognized top peer-review journals within the community, to show the influence of the virus. arXiv, run by Cornell university and supported by Simons Foundations, is the global leading preprints repository with a coverage of most of the natural science subjects including physics, mathematics, computer science, biology, chemistry and so on. It provides an ideal and laudable dissemination platform for the timely scientific information and developments, and attracts global researchers to post their first-hand drafts of the to-be-published papers on it. INSPIRE, run by a collaboration of several world-leading HEP laboratories, i.e. CERN, DESY, Fermi Lab, IHEP, IN2P3, and SLAC, is a HEP-devoted indexed repository with high-quality curations, and interacts closely with HEP publishers,
such as arXiv, NASA-ADS, PDG, HEPDATA and other information resources. The arXiv submission data of the HEP related categories can reflect the trustworthy statistics for the productivities of HEP researchers dynamically. All the preprints submitted to arXiv will be finally published or perished. In contrast, the INSPIRE keeps the footages of all published or unpublished papers as long as they are available online. By examining the HEP data collected by arXiv and INSPIRE we anticipate an indication of the pandemic influence on the activities of the HEP community.

INSPIRE also provide services on job advertisement and conference information. It has been a major communication platform for efficiently circulating the HEP posts and major international conferences and workshops. Comparing the variates of these activities with those in the same period of time of the previous years should also shed some light on the influence of the pandemic. These statistics could also be useful indices for demonstrating the impact of the pandemic on the HEP community during the past five months.

In brief, we will focus on the patterns of performances and activities of the HEP community illustrated by the monthly HEP data between January and May from 2016-2020 to understand how the HEP researchers cope with the pandemic globally.

2. Status of scientific outputs of the HEP community

2.1 Preprints submitted to arXiv

We select four categories under the HEP or HEP-related subjects on arXiv for the analysis, i.e. hep-ex, hep-th, hep-ph and gr-qc. The time range covers between January and May from 2016 to 2020 and we compare the numbers of preprints submitted to these sessions month by month with the other four previous years. As shown in Figure 1, except for hep-ex, where the submission numbers keep stable all the time, the preprints submitted to the other three sessions have an obvious increase in 2020. It is even more interesting to notice that the submission numbers in hep-th, hep-ph and gr-qc were actually going up steadily by month. In hep-th, the growth rate within the last 5 months is more than 20% in average, and sharp increases can be seen clearly. In comparison with the average of the previous 4 years, the growth rate is about 40% which is indeed a significant change. Similar phenomenon happens in hep-ph and gr-qc but with even larger growth rates of about 50% and 60%, respectively, in comparison with the averages of the previous four years.

The pattern shown by the arXiv preprints in hep-ex, hep-th, hep-ph and gr-qc turns out to be informative and slightly surprising. In particular, the increase of submissions in hep-th, hep-ph and gr-qc seems to be counterintuitive. However, regarding the features of researches in these fields one may easily understand the reason behind. Most physicists
working in hep-th, hep-ph and gr-qc are theoreticians. The outbreak of the COVID-19 has reduced many social events, such as face-to-face meetings and conferences. As a consequence, theoreticians seem to have more time indoors to work on their papers. Meanwhile, with email exchanges, online meetings and discussions, and even Twitter and WeChat kinds of social intercourses becoming convenient solutions for communications and even daily routines the research activities of theoreticians seem to be continuing and even accelerated to some extent. In contrast, the impact of the pandemic on experimentalists seems to have slowed down their paces. The social-distancing means that experimental operations, data-taking, machine maintenances, and other cooperative activities will be strongly affected.
Figure 1. Preprints submitted to arXiv in the first five months in hep-ex, hep-th, hep-ph, gr-qc from 2016-2020

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2.2 Published articles/Journals

There always exists a time gap between preprints and published papers, which is the duration of the journal’s publication process. Because of this, the published papers between January and May in 2020 cannot reflect the researchers’ productivities. Instead, it may demonstrate how the pandemic affects the publishers directly. Thus, the statistics for monthly published articles shown in Figure 2 may serve as the barometer indicating the efficiency of the publishers on how the scientific drafts are handled during the COVID-19 pandemic. It shows that the number of published papers in the HEP field keeps a flat behavior during the past 4 years in the same period of time. However, it suffered a cliff fall in the last few months by about 30-50%. The trend is rather clear that with the spread of the pandemic the HEP publishers get more and more severely affected.
Figure 2: Monthly publications between January and May from 2016 to 2020 in the HEP field.
To see more clearly such a dramatic change, we plot in Figure 3 the publications in 4 HEP fields, i.e. hep-ex, hep-th, hep-lat and hep-ph, plus 3 HEP-related fields, i.e. nucl-ex, nucl-th and gr-qc. Again, an overall decrease of publications over the past five months can be seen explicitly. It suggests a broad influence of the pandemic on the publishers in fundamental sciences.

It is interesting to compare the performances of some single leading journals to the overall statistics shown in Figure 2. We sample PRD and JHEP for a demonstration.

PRD, as a leading journal in elementary particle physics, field theory, gravitation, and cosmology, appears monthly in two sections, D1 and D15: D1 covers experimental and theoretical particle physics as well as phenomenological aspects of quantum field theory. D15 covers gravitation, cosmology, astroparticle physics, formal aspects of the theory of particles and fields, and related areas [5]. Figure 4 is a comparison of the PRD papers published between January and May for the past five years. It shows that the monthly publications in February and April of 2020 even reach a peak compared with those in the previous four years. Statistically, the journal seems not to suffer from the pandemic apparently and still keeps a steady momentum forward. However, if we compare the PRD publications to the whole HEP publications in Figure 2, the going-down trend with other less influential journals is implied. By looking into the publishing procedure of PRD one may realize that sufficient and high-quality submissions to those leading journals have been the crucial factor for their survivals in such a severe situation.

One possible barricade that slows down the journal publications is the prolongation of the publishing procedure caused by the COVID-19 pandemic. It means that those journals which only publish online papers may not be affected seriously. JHEP [6] is the first online HEP journal which is run by physicists themselves and has a similar impact factor as PRD. Figure 5 is a comparison of the JHEP papers published between January and May for the past five years. Interestingly, the monthly published papers between January and May of 2020 exhibits a gradual drop in comparison with the previous years, although the fluctuations seem to be significant over the past 4 years. In comparison with the overall HEP statistics presented in Figure 2, the impact from the pandemic seems not to be as strong as that experienced by other HEP journals. The surveys of PRD and JHEP should have suggested that the leading journals are less affected by the COVID-19 pandemic. But its influences on other journals may be severe. Furthermore, JHEP may set up an inspiring mode here for the HEP journals, and raises a generally interesting question on the form of publications. Namely, would the electronic form of publication be more preferable in the future?

It is also interesting to look at the papers published in February and April in 2020 even reached to the top comparing with papers published in the same month in other four years. Although papers published in January in 2020 are the lowest comparing with other four months in 2020. However, it reached to the average of the average of published papers amount in January during the five years. Even many traditional journals are
affected by the COVID-19 pandemic, but the leading journals can retain to attract high quality papers and get published process done to resist the disturbance of the outside factors.

The impact of the pandemic on the HEP community in different countries can be reflected by the HEP publications categorized by countries. In Figure 6 the regional distribution of the HEP publications is sampled for 8 countries, i.e. China, USA, Japan, UK, Italy, France, Switzerland, and Germany. We select these countries considering that these countries have major HEP researches in both experiment and theory. The data are categorized by the first affiliation in the author list. One can see that the number of publications keeps to be stable between January and May from 2016 to 2019 for all these sampled countries. But it drops significantly in 2020 indicating the influence of the COVID-19.
Figure 3: Comparison of publications of 7 HEP and HEP-related subfields between January and May from 2016 to 2020.
Figure 4: Publications of PRD between January and May from 2016 to 2020.
Figure 5: Publications of JHEP between January and May from 2016 to 2020.
Figure 6: Regional publications between January and May from 2016 to 2020 in the HEP field.
2.3 Jobs and conferences

As mentioned earlier, being the leading information platform for HEP literature INSPIRE also provides the global and timely information of jobs and conferences in the HEP community. The collection “Jobs” is one of the most visited and active sites on INSPIRE. The number of jobs that were posted on INSPIRE has increased year by year before the pandemic. Figures 7 and 8 collect the information about the global and regional HEP job postings, respectively. When looking into the comparison of the global HEP job postings between January and May from 2016–2020 (Figure 7), the posting amount experiences an overall dropping trend in early 2020, although it is noticeable that the posting amount in March of 2020 is not obviously smaller than those in the previous years. One also sees from Figure 8 that the regional job postings have decreased this year in North America. However, it seems that such a decrease has started since 2018 and the COVID-19 should not be the only reason for it. In contrast, the decrease in Europe is not drastic, and the position number is slightly increased in Asia. Since the vacancy information is generally scheduled one year or at least few months earlier, the position information in early 2020 may be unable to reflect the situation. But the hit of the impact wave may be just on the way and a follow-up analysis of the job postings should be crucial for understanding the status of the HEP community.

The collection “Conferences” on INSPIRE collects information of conferences and workshops either regional or international ones. Generally, these activities will be scheduled in advance. In Figure 9 the scheduled conferences and workshops in early 2020 exhibit a decrease since February although the number in March seems to be comparable with the other years. This is similar to what happens in Jobs. Namely, the impact wave of the pandemic on the conferences actually will hit later. Looking at the conference and workshop schedules in the near future this year, one sees either cancellations, postponements, or virtual meetings via internet. Remote participation of conferences or meetings becomes the most preferable and convenient solution. And it has been adopted by several scheduled large-scale conferences such as the eighth Large Hadron Collider Physics (LHCP) Conference [7] just held in Paris on May 25–30, and the 40th International Conference on High Energy Physics (ICHEP-2020) [8] to be held in Prague in July. Apart from the international conferences or workshops, video conferences and remote participations are broadly used in collaboration meetings, or small-scale meetings and discussions almost every day. There is no doubt that virtual meeting has become a routine work in the HEP community. The COVID-19, in fact, has forced the change of communication forms of the HEP community and is redefining the working style of the HEP researches.
Figure 7: Global job vacancies posted between January and May from 2016 to 2020. The data are from INSPIRE database.
Figure 8: Global HEP postings between January and May from 2016-2020.
Figure 9: Global conference announcement between January and May from 2016-2020.
3. Brief summary

In this analysis we document the papers submitted to arXiv in the HEP and HEP-related fields, such as hep-ex, hep-th, hep-ph, and gr-qc, of each month between January and May from 2016-2020. We find that the distribution of the preprints of the first five months in hep-th, hep-ph, and gr-qc globally displays an obvious increase of submissions in 2020, while the submission number to hep-ex is lower than the same time range of the previous years. We also compare the publications of 7 HEP and HEP-related subfields within the same time intervals to examine the impact of the pandemic, which has indicated a drop of the publications because of the influence on the publishers. To see more clearly such an impact, we sample publications from eight countries which are the main contributors of the HEP researches in both experiment and theory, and the decrease of the published HEP articles is apparent. With the help of INSPIRE Jobs we show that the impact wave is just on the way to hit the community. A drop of the HEP vacancies may be inevitable in the near future and could globally affect the HEP researches around the world. The most immediate and significant changes caused by the pandemic are possibly the way of communications within the community. With the cancellations and postponements of many scheduled conferences and workshops, it also comes the preferable and convenient solution of adopting video conferences instead of face-to-face meetings. This seems to be deeply changing the working style of the HEP researchers around the world. Attention to the prospects of such a change for broader fields in science should be given as it could be a novel feature with an academic life, and a lot of potentials of such a working style should be explored.

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