

Recommendations of the 89th Physics Research Committee

April 2020

General remarks

The PRC congratulates the DESY Particle Physics Division, its leadership and all its members, on their success in the PoF IV evaluation. The evaluation showed that particle physics continues to be a world-leading strength of DESY's research programme and that, within Helmholtz, it is considered to be "outstanding". PRC recognises the importance of the "outstanding" outcome for the continued support and funding of particle physics activities at DESY.

The PRC has heard of recent progress in the update process for the European strategy for particle physics. The committee appreciates DESY's constructive role in this process and is looking forward to its results and learning about the lab's prospects in future large endeavours.

ATLAS

The DESY group continues to make very strong contributions to the ATLAS experiment. The group has kept the high number of leadership positions across many areas of the ATLAS Collaboration. It also covers a wide range of important physics analysis topics; many of them are coordinated by DESY scientists. For the upgrade of the ATLAS silicon strip tracker, the DESY ATLAS group plays a leading role. Further strong commitments of the group include contributions to physics object performance, the development of software tools, and computing. Overall this effort resulted in six publications in peer-reviewed journals since the last PRC meeting. The PRC congratulates the DESY ATLAS group on their recent hires of two excellent young staff scientists in early 2020. The committee also notes that in view of the recent COVID-19 pandemic, the group has remained productive – and kept its high spirits. The PRC appreciates DESY's support in extending Ph.D. and postdoctoral contracts to compensate for delays caused by measures against COVID-19.

The PRC congratulates the DESY ATLAS group on its excellent progress towards analysing the full LHC Run 2 dataset. The group's physics analysis efforts cover standard model (SM) measurements as well as searches for physics beyond the standard model (BSM). The SM topics include precision measurements of Higgs-boson and top-quark properties, searches for rare production and decay modes of these particles, and single gauge boson and di-boson production. The group's BSM searches cover experimental signatures that are sensitive to many BSM scenarios.

The PRC is pleased to see further progress towards the ATLAS silicon strip tracker upgrade for the HL-LHC. A large number of setups and procedures for the automated assembly and testing of detector modules are already in place. Several reviews have been passed successfully, and the group is heading for the pre-production phase. In December 2019, CERN has announced a revised schedule for the HL-LHC that shifts the starting date of the HL-LHC by one year to 2027.

Key comments and recommendations for ATLAS

The PRC congratulates the DESY ATLAS group for its excellent performance, results and leadership, and for its adaption to the Covid-19 conditions.

The PRC recommends that DESY adjust the funding profile and the availability of laboratory space and technical personnel for the construction of the silicon strip tracker endcap according to the announced revised LHC schedule.

The PRC suggests a presentation, in the next open session, of ATLAS and CMS preparations for Run 3, including trigger, calibration, physics objects, reconstruction, physics analysis, and code development and algorithms.

CMS

In 2019, in the DESY CMS group 10 Ph.D. and 2 masters students defended their theses, 13 CMS physics analysis publications, 12 phenomenology papers, and one detector paper were published, and a Springer thesis award was received (Svenja Pflitsch).

Concerning the impact of Covid-19, the group has adapted well to the home office situation. Ph.D. defences happening during this period have been postponed by Hamburg University. The prospects for the career paths of DESY CMS Ph.D.s and postdocs continue to be excellent, as they have a high visibility and easily attain responsibility for their activities and in the experiment. It is therefore still very attractive for young researchers worldwide to get a position at DESY – they later have good changes on the job market.

The DESY CMS group keeps making strong contributions to the experiment. In particular, DESY scientists hold numerous leadership positions and coordination roles across all aspects of the experiment, and there is strong cooperation/collaboration with other groups and strong contribution to physics papers.

Concerning data collection and computing, the DESY grid resources are operating reliably. The CPU & disk resources are fully utilized. A deep-learning tool has been developed and installed to automatize the handling of processing workflows, and there are significant contributions to the ongoing CMS efforts on data preservation,

In the field of detector operations and development, several contributions are pursued: For the luminosity / BCM1F system, the Run 3 refurbishment using Si sensors, active cooling and AC-coupled R/O is progressing well, and the PC board prototype has been tested and is working. Two C-shapes have been produced, three more are under way, with the sensors arriving in April 2020 (with possible delays due to COVID-19).

For tracker alignment, the reprocessing of Run 2 data (2016-2017) has concluded, and Run 3 data taking is being prepared.

For the CMS HGCal (calorimeter end-caps), the DESY SiPM-on-tile design based on CALICE developments has been chosen. The DESY FLC group contributes engineering to this effort with an EDR to be delivered in 2021. The first tileboard prototype is under test; automated wrapping, gluing and assembly procedures are being optimised, with support by Russian groups. There is strong motivation to follow up on this cooperation in the construction phase. The CMS management highly welcomes this initiative.

In the PRC meeting, recent tracker phase II developments have been shown. The entire project comprises building of 1250 PS modules and one end-cap integration. The developments comprise the construction of the first silicon-based prototype and its alignment according to specifications, a 2S module testbeam in November/December 2019, completion

of DAF equipment, first Dee prototype including 2S and PS regions, and second prototype with full cooling sector, definition of arc frame Dee support structure, definition of concept for disk assembly and corresponding construction work (under way).

Key comments and recommendations for CMS

The PRC congratulates the DESY CMS group for its excellent performance, results and leadership, and for its adaption to the Covid-19 conditions. Members of the group hold many key coordination roles within the experiment, and they perform analyses in key areas.

We congratulate Katerina Lipka (joint professorship with Wuppertal U), Merjin van de Klundert (CMS Achievement Award) and Svenja Pflitsch (Springer Thesis Award) for their appointments and awards.

Concerning the upgrades, excellent progress has been made on the preparation of and planning for the construction of the phase II tracker. All developments are well on schedule, and no potential show stoppers have been identified.

PRC recognises the potential for successful application of technologies developed by the FLC group for the CMS HGCAL.

Belle II

DESY continues its leading role in the Belle II experiment. Group members hold a dozen very visible convenorships in all areas from operations through software and calibration to physics analyses.

The collaboration recently published the first physics paper with Belle II data, with strong participation from DESY, as was the case for a recent publication on track finding at Belle II. The physics programme of the DESY Belle II group contains topics such as tau physics and searches for dark matter (which allow to produce early physics results) as well topics that require more data and precision analyses like inclusive and exclusive rare B decays. The analysis effort is based on very solid contributions to detector-related software developments and detector performance studies. This includes in particular further improvements on the CDC data processing.

Since the last PRC the Super-KEKB accelerator delivered collisions from October until December 2019 and again since March 2020. In December 2019, the Phase 2 luminosity goal of 10^{34} /cm²s was passed. During the shutdown, a number of measures were taken in order to improve the instantaneous luminosity while at the same time improving on background conditions (new collimator, LINAC improvements, preparation of ‘crab waist’ scheme). DESY contributed a fast current monitor for the CDC that helps to optimise the beam parameters. Experience in the ongoing run shows that these measures are effective, but also that there is still a long way to go. For the immediate future one hopes to collect 100-150/fb until summer 2020 and 320-500/fb until spring 2021.

The current data taking is continuing despite the COVID-19 measures. Shift duties are shared among a remote and a local control room shifter. Due to travel restrictions it is increasingly difficult to cover local shifts at KEK.

A redesign of the final focus magnets is under study which might be required to remove hot spots around the interaction region and to reach the ultimate luminosity goal. Most likely this would also require a redesign of the remote vacuum connection (RVC).

The PXD is taking data with high efficiency both in terms of hits and in terms of running time. Background from synchrotron radiation is observed, related to changes in the beam optics. A modification of the central beam pipe design which would protect the PXD against this background source has been proposed by DESY and is being discussed with companies at KEK. The damage due to fast beam losses that had been observed last year could be reproduced in a beam test such that it is now possible to investigate the effectiveness of countermeasures like a fast power-down. Further studies have shown that already for the runs in the next two years the missing second layer of the PXD leads to a sizable performance degradation for time-dependent analyses due to random coincidences in the pattern recognition which affect reconstruction efficiency and flight length resolution.

Preparation of the new PXD detector is going well and is not yet too much affected by the COVID-19 measures. The Belle II collaboration has nevertheless de facto decided that a large dataset needs to be collected ($>1/\text{ab}$) before a long shutdown to insert the new PXD can take place. This shifts the PXD insertion by one year to spring/summer 2022. The modifications to the PXD insertion schedule pose three risks: i) by 2022 a large fraction of the experienced manpower will have left; ii) the cleanroom facilities need to be available for longer than anticipated; iii) a potential further delay by one year to synchronize the PXD installation with a possible replacement of the final focus magnets will make at least the first risk even much more severe.

Key comments and recommendations for Belle II

The PRC is pleased with the performance of the DESY group as a leading group in the Belle II experiment. Important and very visible contributions are made in many areas from operations through software and calibration to physics analyses.

The PRC takes note that the required increase of luminosity at the Super-KEKB accelerator is taking longer than expected and will likely require further modifications of the accelerator.

The PRC recommends that DESY take the necessary actions to support a delayed installation schedule of the new PXD detector.

International Linear Collider Activities and Preparations for Future Experiments

The DESY FLC group is recognized as one of the major players in the international effort to develop future projects of accelerator-based particle physics beyond the LHC programme. The activities of the group cover i) detector development (time projection chamber, vertex detector R&D, highly granular scintillator SiPM-on-tile calorimeter (AHCAL), forward calorimetry); ii) site studies, detector integration and machine-detector interface; iii) software developments; iv) physics studies (Higgs & BSM). The group showed a good publication record since the last PRC.

For the TPC and the Si detectors, the performance parameters were reached, and the dE/dx resolution was improved, as was the achieved particle identification performance (reducing pad size). A new readout was developed in collaboration with U. Bonn and Karlsruhe. Final results from testbeam campaign 2016/2017 is now close to be completed.

For the hadronic calorimeter (AHCAL), a prototype with 22.000 SiPMs was constructed and extensively tested by 2018. The group is also strongly involved in the calorimeter end-cap of the CMS upgrade, and it is contributing to the engineering of this effort; an EDR is expected

to be delivered in 2021. A first tileboard prototype is under test; automated wrapping and assembly procedures are being optimised.

There are on-going studies of the physics (Higgs + new physics) at future e^+e^- colliders, considering realistic detector and accelerator conditions. The group is also contributing to the optimisation and benchmarking effort of ILD with crucial inputs to the European strategy process and the ILD Interim Design Report. New analyses are going-on, and more publications will soon appear. There is collaboration with Hamburg University in comparison studies between different e^+e^- projects within the Platform of Future Facilities of the Quantum Universe Cluster of Excellence.

The group is performing software development on core software components, generic implementation of detector geometry (DD4hep), and event reconstruction. There are large productions of events for ILC and a strong motivation to extend software tools developed to other HEP projects like CLICdp, FCC and CEPC performance studies.

The group started an internal strategical process to broaden its scientific activities and to best adapt the knowledge of the group to the possible outcomes of the European strategy process. This includes a broader scope of applications on the basis of a strong R&D programme including detector development (tracking and calorimetry), software tools and physics studies (as was supported by PRC87). The strategy discussion is based on the FLC experience of i) TPC/ Si detectors (activities directed more strongly towards Si tracking R&D); ii) calorimetry on SiPM technology: develop present CMS cooperation and future applications to the DUNE detector; iii) software: apply to broader fields / machine learning techniques; iv) physics studies: create a platform for future facilities on the basis of a Higgs Factory.

FLC members also participate in the discussion of future on-site experiments such as IAXO and LUXE and the development of the DESY testbeam facility.

Key comments and recommendations for the FLC group

The PRC reinforces its strongest support to the FLC group and identifies the group as one of the key players in the common international effort to develop future projects of new accelerators beyond the LHC. The PRC in particular notes the group's outstanding contribution to the document preparation of the ILC case and participation/discussion in working groups of the European strategy update.

The PRC follows with great interest the progress of the internal discussion to form a generic detector R&D DESY team with a broad scope covering future HEP experiments. The PRC suggests a presentation on this in the open session in a future PRC.

The PRC recognises the collaboration with the CMS end-cap high-granularity calorimeter (HGAL) as a successful application of the FLC detector group and congratulates the group for the excellent results achieved. This activity follows past recommendations of the committee. The PRC considers scientifically well justified the proposal to continue the activity during the construction phase. Hence the PRC recommends that the FLC and CMS groups, together with the DESY management, follow up on this proposal and pursue an appropriate contribution to the CMS upgrade subject to availability of resources

Theory

We congratulate the phenomenology group in Zeuthen for their continued efforts in making highly sophisticated and highly relevant computations in quantum field theory, including the most precise evaluation of initial state radiation corrections at an electron-positron collider, inclusion of heavy quark mass effects in Higgs-boson production at the LHC and their work on the three-loop massive form factors.

Most impressive is the new application of their extensive expertise in quantum field theory methods to the calculation of the inspiral phase of black hole mergers. This is a very topical field, and the speed at which they have adapted to solve a completely different type of problem is impressive. Even more impressive is the fact that their calculations have helped to resolve a disagreement in the field. They continue to make an internationally leading impact well beyond that expected for their size.

The PRC strongly endorses the merger of the phenomenology and lattice groups at Zeuthen to form the Zeuthen Particle Physics Theory (ZPPT). The PRC looks forward to receiving the strategy paper currently being prepared to flesh out a plan for maintaining a long-term sustainable activity in lattice and phenomenology at Zeuthen. As seen from the PRC presentation and from the lattice talk at the last PRC, the theory group in Zeuthen is unique worldwide in their expertise in perturbative and non-perturbative computations, and their scientific output and impact are on a par with much larger groups.

The PRC congratulates the DESY Theory group on developing a strategy for the Wolfgang Pauli Centre to concentrate theoretical physics activities on the DESY Hamburg site. We strongly believe that the planned new building that is supposed to host all the Theory group members will strengthen the research activities of the Theory group and will boost the interdisciplinary collaboration and communication within the Hamburg theory community. We note with pleasure that excellent progress has been made in obtaining financial commitments towards the estimated construction costs of 20M EUR. It is important that the momentum in this project is maintained in order to meet the target construction date of 2025/2026. Indeed it is highly desirable that the new facilities are fully operational by the end of the PoF IV period and can be a positive factor when it comes to applying for an extension for the Quantum Universe Cluster of Excellence.

The success of the DESY Theory group depends crucially on the level of support at the postdoctoral and Ph.D. level. The DESY Theory group runs a very competitive high-impact fellowship programme with about 500 applications every year. These postdocs make key contributions to the research output of the group. An adequate level of core-funded positions is indispensable in order to leverage third-party funding. Cutting into those resources would severely compromise the success of the DESY theory group, which is demonstrated by the fact that it was rated at the top level, both in absolute terms and in comparison to the other DESY groups, in all the evaluations that were conducted during the last couple of years.

The PRC would like to thank the members of the theory group for arranging the pre-meeting, and in particular thanks the speakers who presented results spanning the excellent activities in formal theory, cosmology and phenomenology. The interviews with the postgraduate students, postdocs and staff confirmed our impression of the group as a very dynamic and active group, which is well knitted together scientifically and socially. However, a number of themes emerged mainly to do with administrative procedures – around hiring, contracts (of differing length and value), charging for conference dinners, purchase of laptops. It was

recognised that there may well be fewer administrative obstacles than in many places, but that a lack of consultation before implementation was frustrating. A number of understandable frustrations were expressed with bureaucratic procedures that now seem common in most laboratories and universities worldwide.

Key comments and recommendations for theory

- We recommend that DESY continues to support the world-leading activities of the lattice and phenomenology groups in Zeuthen that are vital for future precision programmes. We continue to be concerned about the long-term viability of these activities and we endorse the merger of the phenomenology and lattice groups to form the Zeuthen Particle Physics Theory (ZPPT) as a route to developing a robust strategy for maintaining the very high impact of both the groups.
- We recommend that the momentum towards construction of the new building to host the Wolfgang Pauli Centre is maintained by assigning this project a high priority.
- We recommend that all efforts are taken to preserve the number of postdoc and Ph.D. positions in the theory group, in view of the outstanding performance of the theory group in recent evaluations.

ALPS-II

The construction of the ALPS-II Experiment is now in the hot phase. All the dipoles are ready to be moved to the tunnel, the installation of the cryogenics is supposed to start soon (depending on Corona), coating for the cavity mirror's substrate is under way. We congratulate the collaboration on the very good progress.

An important future milestone is the closure of the experimental vacuum planned for September 2020, necessary for the start of optics commissioning. It is currently unclear how the ALPS II schedule will be affected by the present crisis and if the clash with other DESY activity like the FLASH upgrade can be avoided.

Key comments and recommendations for ALPS

We strongly encourage the collaboration and DESY to continue their efforts and to preserve the plans to be ready for data taking in 2021. Connecting all the magnets and closing the vacuum tubes (magnet bores) should be the minimum target in order to allow the collaboration to take physics data even with the magnets off. It is critical to ensure this minimum physics stage, so that the essential international collaborators can also report some physics results for their funding to continue.

If a substantial delay due to the Corona outbreak is unavoidable, we recommend that DESY tries to mitigate possible delays and help the collaboration to keep the needed expertise for the experimental data taking.

As already mentioned the success of ALPS-II is vital also for the future axion activities at DESY and should not be neglected compared to the other projects.

BabylAXO

The BabylAXO collaboration has already started the first stage of the installation on the DESY site: a new technical coordinator (Uwe Schneekloth) has been appointed at DESY. Obviously, the collaboration is mature and experienced, gearing up at a rapid pace.

Transport of the support and positioner (the former CTA MST support) to Hamburg are supposed to take place in April and the conceptual design for the alignment system has been worked out. R&D for the magnet at CERN and the optics is steadily continuing.

We congratulate the collaboration on the very quick and efficient start! We also thank the collaboration for the detailed report and pre-meeting. Among the critical and open issues we see the following: i) the revised magnet design. The magnet is the most important element of BabylAXO, and it is critical to cross-check the design for a final decision is taken. The PRC requests the collaboration to present a detailed plan; ii) the new setup for the cryo-coolers and increased cooling power; iii) a possible collaboration with NASA on the optics for the photon detection system.

Key comments and recommendations for BabylAXO

We congratulate the collaboration on the good start and strongly encourage the collaboration to keep momentum to realise BabylAXO as planned.

We recommend to DESY to support the experiment as much as possible, especially (critically so) with regards to the collaboration with CERN to realise and finance a significant part of the magnet construction. Indeed, the magnet is the key element of the experiment and it is absolutely necessary to construct it according to specifications.

The PRCs requests a detailed plan for the magnet design to be presented at the next PRC meeting.

MADMAX

The MADMAX collaboration is moving very rapidly, implementing a solid collaboration management, and addressing all the PRC's recommendations. The new technical coordinator Pierre Karst from CPPM Marseille is appointed, while magnet experts are overseeing the magnet procurement procedure. The collaboration is proceeding very fast on the magnet studies, and it is also making impressive progress on a possible use of CERN's Morpurgo to start a physics programme much earlier than the long timeline of the main magnet would allow. Impressive results on the prototype booster are also shown, testing all critical components.

We congratulate the collaboration on the very fast and impressive progress, but want to mention one open or critical issue concerning the magnet prototype and design: This is the most important element for MADMAX. It is therefore critical to cross-check it before a final decision. The PRCs requests that a magnet plan be presented at the next PRC meeting.

Key comments and recommendations for MADMAX

The collaboration is very enthusiastic and competent, moving at all all fronts rapidly. We congratulate the collaboration for showing such an impressive progress and we encourage them to keep the momentum with the critical components and trying to improve the equivalent noise temperature of the system.

The good news regarding the magnet cable needs to be looked at critically and approved by an internal review committee with the help of an outside expert familiar with the original design. The “Magnet Czar” appointment proceeded, and we expect this person to inform the collaboration of all the critical changes and how they are reviewed properly.

We recommend to DESY to support the experiment as much as possible, as this experiment needs to come up fast and properly. The magnet is still (and will be for a long time) the critical path, and should be followed very closely. We endorse the plan for an intermediate step magnet in order to reduce risks, and the overall new magnet strategy. The PRC recognises the need to install a common fund for the MADMAX collaboration – a step that requires setting up a memorandum of understanding between the different collaborating institutions. The PRC also strongly encourages the procurement of a prototype cryostat.

The PRC requests that a detailed magnet plan be presented at the next PRC meeting.

LUXE

The PRC was glad to receive the short document and open-session presentation outlining the motivation and plans for the LUXE experiment. LUXE aims to probe QED in the strong-field regime beyond the Schwinger critical field. The experiment would capitalise on a stub beamline in the European XFEL complex that is not planned to be used for XFEL operations until approximately 2028. High-energy electron, and photon, interactions with a powerful laser would be studied with the aim of observing ‘boiling’ of the QED vacuum via the production of e^+e^- pairs. Such pair production, in the perturbative regime, was observed by the E144 experiment at SLAC in the 1990s; LUXE would push the exploration of QED into the non-perturbative regime. A collaboration comprising roughly 40 people from 12 institutes has prepared a letter of intent and is currently working on preparing a CDR, aiming for completion in autumn 2020.

Recommendations for LUXE

The PRC endorsed enthusiastically the physics motivation for the experiment and encouraged the collaboration to prepare a timely CDR and explore further the potential for realising LUXE at DESY. The PRC would welcome the opportunity to provide feedback on the CDR at its next meeting (PRC90 in November 2020).

Computing / IT

We commend the continuing success of the DESY computing large-scale facility. The Tier 2 compute and disks systems and the NAF are performing very well with good strong utilization and good uptime. All pledges are met and operations are routine. The increased wide-area network capacity has relieved the bottleneck for the moment. This area will need continued attention as the networking demands are likely to grow with changes to the CMS and ATLAS Data Organization, Management, and Access (DOMA) models and as the data traffic for Belle 2 grows.

There are strong activities in machine learning / AI and other data science topics, and in quantum computing. IT is playing a role internally with other groups across DESY and externally with university groups in Germany.

For the PoF IV period, a new area topic ‘Data Management and Analysis’ was added to the research program *Matter and Technologies*. To foster an interdisciplinary approach, the Tier

2 centre will transition to the Interdisciplinary Analysis Facility (IDAF). The proposal received a favorable review.

Recommendations for computing / IT

The PRC commends IT on the positive outcome of the PoF IV process.

PRC90 will present a good opportunity for a strategic presentation concerning IT, in light of the success of the PoF IV evaluation.

The DESY-II Testbeam Facility

The PRC congratulates the testbeam crew for the facility's excellent performance. In particular, we commend the team for their service attitude and for the "plug&play" working of the testbeam environment. Especially during the CERN shutdown, user numbers have reached a new all-time high, and numbers are expected to stay high, putting significant strain on the team.

As an upgrade of the DESY-II testbeam facility, the large-area Si strip telescope LYCORIS is being constructed. In the coming year, the development will continue to transform the setup into a user infrastructure at the DESY-II testbeam facility.

The "Beamline 4 Schools" event was an additional highlight during late 2019.

Recommendations and specific comments for the DESY-II testbeam facility

The PRC recognises the need for a thorough planning of the future development of the facility, also in view of the preparations for PETRA IV facility. Administration support, e.g. in the form of a user office, should be considered.