Recommendations of the 90th Physics Research Committee

November 2020

General remarks

The PRC congratulates Joachim Mnich on his appointment as CERN Research Director and notes that this is the second recent such appointment of a senior DESY scientist to that role, which is testimony to the calibre of the FH Division staff. The PRC reiterates the importance of the FH Division to the scientific mission of DESY and welcomes the timely appointment of a successor to J. Mnich as FH Director.

The PRC appreciates the visit by the Chair of the DESY Board of Directors, Helmut Dosch, and his outline of the plans for the appointment of a successor to J. Mnich. The PRC is happy to contribute to the selection process and provide suitable representation on the search committee. The PRC notes and welcomes the appointment of a respected senior FH scientist as Interim Director until a permanent appointment is made.

ATLAS

The DESY ATLAS group continues to make very strong contributions to the ATLAS experiment.

- The group holds many leadership positions across many areas of the ATLAS collaboration.
- The group covers a wide range of important physics analysis topics; many of them are coordinated by DESY scientists.
- The group plays a leading role for the upgrade of the ATLAS silicon strip tracker.
- Further strong commitments of the group include the development of physics object performance, software tools, and computing.
- Overall this effort resulted in eleven publications accepted in peer-reviewed journals since the last PRC meeting.

The group has mastered the COVID-19 pandemic very well so far, despite the mental stress it causes to its members: the group has kept its high spirit and the DESY management has governed the lab prudently through the crisis.

Concerning personnel and leadership, nine doctoral researchers have successfully defended their Ph.D. theses (some with rather long time to degree) since the last PRC, and some very high-level positions (physics coordinator, SUSY and Higgs conveners) have ended in September 2020.

PRC has started to review preparations of the DESY ATLAS Group for LHC Run 3:

- The group is already addressing many technical areas (e.g. new ATLAS software release, silicon strip tracker, triggers, flavor tagging, e/gamma).
- The group is planning a retreat to develop a clearer vision of its Run 3 physics goals and recruitment efforts (e.g. for new young investigator groups).

The upgrade of the silicon strip tracker is progressing well:

- The group has reviewed and successfully adapted the project schedule and funding profile according to the latest CERN schedule.
- The Detector Assembly Facility (DAF) is scheduled to be available until 2026 (one year after the SCT endcap has been shipped to CERN) in the current planning.
- The recent observations of a higher-than-expected noise level in certain module types and of early sensor breakdown in IV tests at high humidity require further investigation

Key comments and recommendations for ATLAS

- The PRC congratulates the DESY ATLAS group on its excellent physics results based on the full LHC Run 2 dataset.
- The PRC is looking forward to further high-quality Run 2 results and encourages the DESY ATLAS group to evolve their physics analysis planning for Run 3.
- The PRC notes that the DESY ATLAS group has stayed productive and in good spirits through the ongoing COVID-19 pandemic.

CMS

In 2019, the DESY CMS group saw 6 Ph.D. theses and 1 master thesis defended (1 summa cum laude) as well as 6 CMS papers and 1 phenomenology paper published. The group continues to offer excellent career opportunities to Ph.D. students and postdocs (high visibility / responsibility in their activities and in the experiment; very attractive for young researchers worldwide to get a position at DESY – good job offers afterwards). Highlights to be mentioned are the acquired Helmholtz.ai funding for deep generative models for simulations and the funding through the innovation pool for variational quantum computing.

The group has adapted well to the Covid-19 home-office conditions. However, with the pandemic there come visa delays and other issues, probably leading to an impact on the number of fellows. In addition, numerous fellows are leaving soon – the need for additional fellows thus continues.

The group keeps making strong, above average contributions to the experiment. Group members hold leadership positions and coordination roles across all aspects of the experiment, and there is strong cooperation/collaboration with other groups and large contributions to physics papers.

In physics analysis, there is a broad physics portfolio covering standard model, top physics, Higgs, SUSY and exotic searches. Data collection is well organized, and the computing resources are performing well.

In the field of detectors, the group is involved in the luminosity determination (BCM1F), the tracker alignment (where the Millepede II algorithm is carried to GPUs), the high-granularity calorimeter (HGCAL), in generic R&D (e.g. enhanced lateral-drift detectors), and in the phase-2 tracker upgrade.

For the HGCAL, the DESY SiPM-on-tile design has been chosen, The DESY FLC group contributes engineering to the effort, with an EDR to be delivered in 2021. Cooperation with Russian groups is foreseen. For the phase-2 upgrade, complications in the schedule are foreseen due to the pandemic.

Key comments and recommendations for CMS

- The PRC congratulates the DESY CMS team for its excellent performance, results and leadership, and it recognises the group for their continued significant accomplishments and publication record.
- Concerning the upgrade, there are some areas to be addressed regarding tests and scans of prototypes, but there are no showstoppers, and the PRC congratulates the team on the solid progress on the phase-2 tracker. The PRC also recognises that the HGCAL contribution is well appreciated by CMS management.

Belle II

DESY continues its leading role in the Belle II experiment. Group members hold many very visible convenorships in all areas from operations through software and calibration to physics analyses. The group continues to grow, with a new staff member, 2 new postdocs, and new master students who have recently joined.

The collaboration recently published its second physics paper with Belle II data on a search for axionlike particles which was performed by DESY physicists. The DESY group pursues a rich physics programme. Several analyses are close to being published on the Belle II data taken until now. New analysis methods and ideas are employed in all of them. The analysis effort is based on very solid contributions to detector related software developments and detector performance studies. This includes in particular leading contributions to tracking and to the reconstruction of neutral particles. The collaboration has recently published instrumentation papers in both these areas, with strong participation from DESY.

Since the last PRC the Super-KEKB accelerator delivered collisions until July, and has restarted operation in October. Belle II has collected data with a good efficiency of 84%. A total of 74/fb of data have been recorded in 2019 and 2020, and a new collider luminosity record of 2.4E34/cm2/s was reached on June 21. The necessary measures against the COVID-19 pandemic put a very high load on the local crew at KEK.

The maximum Super-KEKB beam currents are still limited by the tolerable beam backgrounds in the Belle II detector, namely in the central drift chamber (CDC) and in the particle ID detector (TOP). Further improvements require additional collimators and extra shielding but also an improved beampipe in the IP region (to be installed 2022) and a redesign of the final focus quadrupoles (to be installed 2026). The last measure will require a redesign of the remote vacuum connections delivered by DESY. Improvements in the accelerator (RF-System, around 2026) are planned as well. A “SuperKEKB Roadmap 2020”, submitted to MEXT, shows an integrated luminosity target of 50/ab by 2030/31, two years later than previously planned.

The PXD is running stably, with a hit efficiency beyond 99%, a signal-to-noise ratio of 40-50 and an impact parameter resolution of 14µm, which are all excellent results. The PXD has, however, suffered from uncontrolled beam losses which have permanently damaged 2.5% of the PXD (excluded from the above hit efficiency calculation). The collaboration is working on a faster emergency shutdown system to reduce such damage in the future. An unexpected increase of the leakage current in the PXD sensors has been observed, which is being investigated.

Preparation of the new PXD2 detector is progressing. All required ladders for layer 2 are in hands, ladder construction for layer 1 is ongoing. Transport of PXD2 to KEK is still planned

for October 2021, which would give several months of contingency at KEK. These plans are obviously contingent on the further development of the COVID-19 pandemic.

The Belle II collaboration considers upgrades to the detector during the extended shutdown planned for 2026. One idea is to replace the full vertex detector by a detector based on CMOS sensors. Expressions of interest are expected by the end of 2020. The DESY group is focussing on the operation of the current detector and is currently not engaged in these upgrade plans.

Key comments and recommendations for Belle II

- PRC commends the DESY Belle II group for the excellent results achieved in many areas from operations through software and calibration to physics analyses, and for the resulting publications.
- PRC commends the DESY Belle II group for remaining productive despite the difficulties caused by the ongoing COVID-19 pandemic.
- 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.
- PRC recommends that the DESY Belle II group closely follows the discussions on a possible detector upgrade around 2026 and makes good use of the opportunities that arise.

Future Linear Collider Activities and Preparations for Future Experiments

The DESY FLC group continues being one of the major players to the common worldwide international effort to develop the future projects of accelerator-based particle physics beyond the LHC programme:

- Major directions of the group are well aligned with the highest priority of the updated European strategy, namely an electron-positron collider Higgs Factory.
- There is very active participation in the Snowmass process in the USA (physics studies, software, etc.).
- There are large EU-funded and other detector R&D efforts. AIDAinnova was recently approved), and F. Sefkow is PI of the AIDA project and has led the new proposal.
- There is participation in the structure of the new organization of the ILC effort (International Development Team – IDT).

The activities of the group cover detector development (TPC, Lycoris beam telescope, vertex detector R&D, high-granularity scintillator SiPM-on-tile calorimetry (AHCAL), CMS HGCAL, forward calorimetry), site studies including detector integration and machine-detector interface issues, software developments) ILCsoft, machine learning, future colliders packages); physics studies (detector optimization & EW, Higgs and BSM). The publication records since the last PRC comprises 2 Ph.D. theses, 2 publications and 5 preprints on physics & detector R&D.

Future plans and strategic considerations: The group continues the internal-strategical process to broaden its scientific activities and to best adapt the knowledge of the group to the

outcomes of EPPSU and long-term strategy of the group (as supported by PRC87). The FLC strategy considerations are reaching convergence and main lines of research have been defined at this PRC90: i) Science at future particle physics facilities and experiments; ii) scientific computing for particle physics experiments; iii) detector development iv) accelerator development. This covers the following activities: Higgs factory development (ILC and others); discussion participation / cooperation in future on-site experiments such as LUXE/BabyIAXO; organization and development of the DESY testbeam facility; cooperation with accelerator development in the area of plasma wake-field; CMS HGCAL.

Key comments and recommendations for the FLC group

- The PRC continues to express 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 involving new accelerators beyond the LHC.
- PRC recognizes that the group is extremely well placed to play major roles in the implementation of the EPPSU and well aligned with its priorities for future colliders, i.e. *development of a Higgs Factory as the next collider after LHC/HL-LHC.* Important and visible participation in the Snowmass process (physics studies, software developments / preparations, discussions) and in the new structure of ILC process (IDT organization).
- PRC congratulates the group for the recently approved EU project AIDAinnova for detector R&D development in which the group has leading contributions. In particular to Felix Sefkow, PI of AIDA and of the new EU proposal AIDAinnova.
- PRC acknowledges the progress on the internal strategy process towards forming a team at DESY to develop generic detector R&D and joining efforts with the accelerator plasma wake-field group. In this sense test-beam development is considered an essential piece (optimisation and coordination with detector R&D). PRC supports the present plan and on-going discussions.
- PRC recognizes the collaboration with the CMS-HGCAL as successful and consolidated. PRC looks forward to see the evolution of future cooperation with the proposed on-site future experiments.

Theory

The PRC appreciated the presentation on the strategy and plans for theory at DESY. Theory plays a key role in a number of areas, for example, supporting the experimental activities at DESY, making the case for future experiments, probing the frontiers of idea-space, reacting rapidly to new ideas, and developing new talent. The strength of a theory group rests on the critical mass of individually strong researchers, coupled with the right environment to stimulate cross fertilisation of ideas and transfer of methodology. The Wolfgang Pauli Centre has the potential to make a step change in the way that theoretical physics at DESY operates, by forming a fluid structure in which different ideas and research groupings can form and align with short to medium term goals and funding opportunities.

While new funding opportunities often require that groups of researchers coalesce to form new short- to medium-term structures, in general, these structures should not inhibit collaboration, nor take away too much time from research; the fewer barriers there are to collaboration and the fewer constraints the better. We would not like to see the success of the DESY Theory group and the consequent increase in structures becoming a hindrance

rather than an advantage and we encourage the group and DESY to simplify/reduce any additional or unnecessary structure within the WPC.
The PRC strongly endorses the new strategy being developed for the Zeuthen Particle Physics Theory (ZPPT) group, which is focussed on maintaining the core strengths in perturbative and non-perturbative quantum field theory and its application to experimental particle physics experiments and building synergies with other activities at DESY. We appreciate the funding provided by the DESY Zeuthen ATLAS group to sustain the activities of the phenomenology sub-group.
The PRC is convinced that the change of personnel is an opportunity to refresh the core strengths of the ZPPT, while at the same time developing very fruitful synergies with the astroparticle group in DESY Zeuthen, the Humboldt University and the other theory teams in DESY Hamburg. We are pleased to hear that the ZPPT will be part of the WPC and expect that this will magnify the potential synergies.
Covid: While a lot of theoretical work does not require access to substantial facilities and can plausibly take place off site, the enforced restrictions on office occupancy do inhibit research. Many institutions and funding agencies are extending Ph.D. and PDRA contracts by a few months in order to enable research projects to be completed. At the moment, there is a second wave of infections and once again there is a lockdown. The pandemic has not landed on everyone equally, so flexibility in allowing home-office is recommended. In the longer term, more flexibility in home-working is almost certain to be more common place, and we are excited by the 'Digital DESY' initiative which could enable that.
We recognise that on-line seminar series are not quite the same. However, this does give an opportunity for the theory group to play a wider coordinating role nationally (and even internationally).
We were pleased to hear that about 40% of the theoretical particle physics professors in Germany had worked at DESY at some stage of their careers. There are certainly many permanent academic staff now based outside Germany who have also benefitted from the training opportunities at DESY, and it would be interesting to evaluate the wider impact of the DESY theory group. The importance of nurturing young talent is particularly important for theoretical physics. Often the career path involves several two- to three-year postdocs, followed by a longer but still limited term position to establish an independent research profile before gaining a permanent academic post. Moving from place to place is an opportunity to learn new techniques and gain new collaborators. The importance of being able to develop and support early career researchers at each stage of this path is self-evident. Sometimes modern recruitment rules are at odds with this process, by restricting opportunities because of time after PhD, or by insisting that permanent positions are committed after, for example, an ERC or Young Investigator grant.

Key comments and recommendations for theory

- The PRC strongly encourages DESY and the theory group to develop the WPC as a vehicle for supporting the full diversity of theoretical activities, both for adding coherence and opening doors to collaborations across all groups, but also developing new directions and synergies between and beyond the core strengths, reacting to the evolving scientific landscape.
- The PRC strongly endorses the new strategy being developed for the ZPPT which is focussed on maintaining the core strengths and building synergies with other activities at DESY.

- The PRC acknowledges the difficulties presented by the pandemic and encourages the theory group to seize opportunities to show leadership to the community.
- The PRC encourages the Theory group and DESY to identify ways of supporting excellent young researchers with long term fellowships to develop an independent research profile which will make them competitive for permanent positions elsewhere.

ALPS-II

The construction of the ALPS-II Experiment in the HERA tunnel is proceeding very well, Corona notwithstanding. All the dipoles have been moved to the tunnel, the installation of the cryogenics is nearly finished, and the construction of the central optic table and clean room is proceeding. Small delays were unavoidable, but luckily all in all an end of construction, and commissioning, in 2021 still looks possible. PRC congratulates the collaboration on the very good progress.

An important future milestone is the optics commissioning planned to start in March 2021. Open issues are the delayed schedule that could clash with other DESY projects and lead to loss of optics expertise at the time of running the experiment

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 at the end of 2021, at the least in the magnets-off mode.
- It is critical to ensure this first physics stage, so that the essential international collaborators can also report some physics results to help the case for their continuing funding.
- We note that 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.

BabyIAXO

The BabyIAXO collaboration has performed a very detailed study of the possibilities for magnet design and has now reached an optimized design, exploiting existing resources like the old superconducting cable from INR of 50km of MELC conductor. The new magnet design has been presented to the review committee last Friday and all the expert questions were answered successfully. The full expert review report is attached to these recommendations.

Preparation of a DESY-CERN MoU about the magnet design has progressed and the agreement should be signed soon. Moreover, the support and positioner from CTA has been now moved to Hamburg to the HERA south hall as planned.

We congratulate the collaboration for reaching these milestones so quickly and for the very clever use of available resources and for reducing the costs.

Open or critical issues are the following:

- Before constructing the magnet, the old cable has to be thoroughly tested to ensure that it satisfies the specifications.

- The location of Baby IAXO at DESY appears not to be settled yet, contrary to previous discussions on the HERA south hall.

Key comments and recommendations for BabyIAXO

- Obviously the collaboration is mature and took to heart the recommendation to concentrate on the magnet as the key building block for the experiment.
- We congratulate the collaboration on the newly developed magnet design that was very positively evaluated by the expert's panel, and strongly encourage the collaboration to keep momentum to realise BabyIAXO 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 realize and finance a significant part of the magnet construction. Indeed, the magnet is the key element of the experiment, and the expertise and support of the magnet detector group at CERN is essential for its construction as recognised and stated by the magnet review panel.
- Moreover, a decision on the location of BabyIAXO on the DESY site should be reached as soon as possible, to allow for refurbishment/construction and for the collaboration to prepare for the site.

MADMAX

The MADMAX collaboration is very strong technically and in developing innovative solutions to problems as they appear.

The figure of merit of the MADMAX setup (B^2V) is (much) more than an order of magnitude larger than present systems dedicated to axion dark matter search. Their smart application of dielectrics can reach the difficult high axion frequency range.

The prototype setup is progressing very fast. For the year 2022, a test of the booster in the CERN MOPURGO magnet is foreseen.

Early funding hopes from MADMAX have not materialized (MPI). Prototype magnet application and support is critical to keep momentum.

Key comments and recommendations for MADMAX

We strongly encourage the collaboration and DESY to come up with a viable plan to keep MADMAX with a strong physics programme even with the prototype magnet.

MADMAX will dominate the axion dark matter field for more than a decade, but it needs support to keep post-docs and graduate students interested now.

The prototype MADMAX setup coupled with the prototype magnet can make all the difference, and DESY should provide a strong support to keep the momentum and the interest of the community. There is a need for a small investment for the long term, which it's critical to its final success. The investment should be geared towards materializing the prototype magnet for a reasonable physics program in the interim.

LUXE

LUXE aims to probe QED in the strong- field regime beyond the Schwinger critical field where spontaneous production of electron-positron pairs is expected to take place - the so-

called boiling of the QED vacuum. There is a unique but time limited opportunity to use a stub beamline in the European XFEL complex that is not planned to be used for XFEL operations until approximately 2028. The experiment would shine a high-power multi TW laser on either the 16.5 GeV electron beam extracted from the XFEL or a converted photon beam and search for Compton scattering or pair production events. Previous experiments at SLAC have probed the perturbative region. LUXE would be the first experiment to probe the non-perturbative region of QED. There are also possibilities for using the high photon flux from strong-field Compton process for beam dump type experiments to searching for neutral BSM particles.
The PRC was pleased to receive the open-session presentation for the LUXE experiment which reaffirmed the physics case and outlined the substantial progress that has been made since PRC89, although the CDR is not yet complete.
In particular, the PRC was pleased to see the progress in identifying the 40 TW laser to be used in the first stage, the CAD design of the experimental area, optimisation of the detector, improved background estimates and strong field simulations and the increasing size of the collaboration (now up to 57) as well as internationalization.

LUXE is parasitic on the XFEL and therefore will require close cooperation with the accelerator division and the support of the Directorate if it is to go ahead. Completing the TDR will also place demands on technical and engineering manpower in the accelerator and particle physics division.

Key comments and recommendations for LUXE

- The PRC reaffirms its enthusiasm for the physics motivation for the experiment and encourages the collaboration to complete the CDR and to 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 (PRC91 in April 2021). Moreover, PRC, together with M division and European XFEL, will contribute to an in-depth review of LUXE in spring 2021.

Computing / IT

We commend the continuing success of the DESY Computing Large Scale Facility. The T2 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, although a short-term transfer from BNL for ATLAS encountered the limits of the border firewall.
We commend the strategic presentation for IT made in the open session. The strategy leverages existing horizontal infrastructure projects (such as ESCAPE) which fed into R&D project targeted towards ‘data lakes’, part of the HL-LHC strategy that could broadly beneficial as a reference for balancing network, storage and compute for multiple sciences. DESY is a full participant and well-integrated in these projects. The DESY strategy begins with a vision of the challenges across multiple disciplines—ever growing data rates, a need for support for real time activities, and a growing need for access to High Performance Computing (HPC) resources. Elements of this strategy received a positive review in for the POF-IV,with new area ‘Data Management and Analysis’ was added to *Matter and Technology.* As part of this area, the Tier-2 centre will transition to an interdisciplinary Analysis Facility (IDAF).

The work in utilizing the MAXWELL cluster for new use cases/users that require HPC resources, such as Machine Learning/AI applications and other computing activities that require parallel processing makes an excellent step in realizing the strategy.
Articulating and executing this strategy is important for flexibility as there may be changes to the WLGC Tier Model going into HL-LHC which could lead to a change in the role that DESY plays in WLGC.

Recommendations for computing / IT

- The PRC commends IT on developing a strategy roadmap that leverages existing systems, the horizonal infrastructure processes and HL-LHC R&D projects that is forward looking towards future scientific needs.
- The PRC commends IT on contributing to the COVID19 research through Folding@Home.

The TPEX proposal

TPEX aims to make a new precision measurement of the positron-proton to electron-proton elastic cross section ratio, R2gamma, which is a direct measure of the contribution of hard two-photon exchange to the elastic cross section. Hard two- photon exchange is believed to be the cause of the discrepancy between the Rosenbluth and polarization transfer methods of measuring the proton electromagnetic form factors.

Three experiments - CLAS at JLAB, VEPP-3 at Novosibirsk and OLYMPUS at DESY - have previously measured R2gamma, at low Q^2 and moderate to large virtual photon polarization where the hard two-photon exchange contribution is relatively small. The results of these experiments are by no means definitive. The majority of the data are well below where the proton electromagnetic form factor discrepancy is significant (Q^2 > 2 GeV^2), so questions regarding the source of this discrepancy remain largely unanswered.

TPEX aims to make a more precise measurement over a wider range of virtual photon polarization and over a wider range of Q^2 (up to 4.5 GeV^2), thereby enabling this question to be resolved.

Performing the experiment at DESY would require significant effort and coordination. In particular, the experiment would require extracting the full DESY II beam into a new and fully equipped test beam area in Hall 2. A positron production target is also needed. The DESY synchrotron is used to fill the PETRA III ring. Depending on the fill rate PETRA and TPEX could run in parallel with electrons but positron running would likely only be possible during shutdown or maintenance periods of PETRA. The experiment is envisaged to take place in a series of several-week-long runs in 2024 and 2025.

Recommendations and specific comments for TPEX

The PRC endorses the physics motivation for the experiment and, while recognising the technical infrastructure challenges in the test-beam area, encourages the collaboration and DESY management to explore further the potential for realising TPEX at DESY.
If implementation looks feasible, PRC encourages the collaboration to prepare a more detailed technical proposal and suggests to hold a review of the status of plans for TPEX in spring 2021.