

Recommendations of the 91st Physics Research Committee

May 2021

General remarks

In its 91st meeting, the PRC learned about the reduction of the FH research budget. Clearly the strategic considerations, especially on the strengthening of plasma wakefield acceleration studies, should be noted. Nevertheless, care has to be taken not to endanger the role of DESY as national lab and not to lose the momentum and spirit that characterises the division and its staff and that led to the highest marks in the PoF evaluation (that demanded to “retain [...] flexibility” and support “strong leadership in the field”).

The PRC welcomed Steinar Stapnes (CERN) and Jeff Templon (NIKHEF) as new members. The PRC also congratulates Ties Behnke on his appointment as interim director for particle physics at DESY.

ATLAS

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

Members of the group address a wide range of important physics analysis topics; many analyses are coordinated by DESY scientists. The group plays a leading role in the ATLAS silicon strip tracker upgrade. The group is continuously contributing to physics object performance, software tools, and computing. Overall, these efforts resulted in three articles with significant DESY contributions published or accepted in peer-reviewed journals since the last PRC meeting and twelve other articles submitted.

Personnel and positions: The group is keeping good spirits, despite the ongoing Covid-19 pandemic. Three doctoral researchers have finished their Ph.D. theses since the last PRC meeting. The group will gain a new important leadership position in ATLAS, the Data Preparation Coordinator. The group has also supported the preparation of an application for a new Young Investigator Group that would complement its portfolio if successful.

The DESY ATLAS group has presented a convincing plan for **future physics analysis**, well balanced between analyses based on the full LHC Run-2 dataset, early Run-3 data and the full Run-3 dataset.

The **upgrade of the silicon strip tracker** is progressing well, but is suffering delays. The group has made good progress in the investigation of silicon detector module noise. Delays are mainly due to the Covid-19 pandemic, but also some of the main ASICs are behind schedule. An update of the official CERN schedule may become available in spring 2022; changes may influence the group’s personnel planning. Delays of items on the critical path that are in DESY’s responsibility must be monitored closely.

Key comments and recommendations for ATLAS

The PRC commends the DESY ATLAS group on their broad range of achievements, from operating the experiment to software, object performance, and computing, and on their creative input to the experiment, for example improved luminosity determination, tracking in

dense environment, and novel background estimation techniques in measurements and searches.

The PRC takes notes that the ATLAS Inner Tracker Upgrade is delayed, with no contingency left with respect to the current HL-LHC schedule. A consolidation of the ITk schedule in view of the evolving HL-LHC schedule is necessary. Timely delivery of DESY's contributions is essential for the success of the upgrade and should be given the highest priority in schedule and resource planning for the group.

CMS

The DESY CMS group keeps making outstanding contributions to the experiment. Group members hold important leadership positions and coordination roles across all aspects of the experiment.

Concerning **physics analysis**, the group has a broad portfolio covering standard model, QCD, Top physics, Higgs, SUY and exotica searches. In the field of data collection and computing, all resources are performing well. There is a data preservation and open data effort ongoing, from which more than 20 papers have already been produced. Since the last PRC, one Ph.D. and one master thesis have been defended, and there were 2 CMS publications with substantial DESY contributions, 3 phenomenology papers and 3 computing papers.

Impact of Covid-19: The group adapted well to working at home and has maintained intense activities, the main negative effects being on the tracker upgrade activities.

For **Ph.D.s and postdocs** from the group, career paths continue to be excellent: They can gain high visibility/responsibility in their activities and in the experiment, and it is very attractive for young researchers worldwide to get a position at DESY – they will receive good job offers afterwards. Therefore, as always, many applications were received by the group.

On the **detector side**, for the BCM1F, the Run-3 refurbishment is on track for installation in CMS by June 2021. A precision measurement of the integrated luminosity (2015/2016) with 1.2% total uncertainty has been published. The Run-2 tracker alignment has been reprocessed – the result will be the standard reference for all analyses. A paper is close to completion. There is good progress on enhanced lateral drift (ELAD) detectors and on electron computed tomography efforts.

Upgrade work is continuing, despite Covid-19 delays: For the **phase-2 tracker** that task is to build 1250 4.0 mm PS modules and perform the end-cap integration. The DAF is now fully operational, and the module assembly procedure is fully established and operational. The main goal is to produce and test 1/2 PS module and test in it June at DESY. The Dee prototype has been a success, and the disk assembly has been system-tested. A general work plan and site organisation is established. Still some delays are reported.

The **High Granularity Calorimeter** (HGCAL) is entering the construction phase, with the engineering design finalised, and final choices and qualifications done. Construction procedures are being set up.

Key comments and recommendations for CMS

PRC congratulates the CMS DESY team for its excellent performance, results and leadership. The work has been well adapted to the new situation induced by the Covid-19

pandemic, the main concern being the work on the tracker and HGCal upgrades if the situation remains (working conditions, visas, travelling, ..).

Concerning the upgrades, PRC is very pleased to see the excellent progress of all the work accomplished and results obtained so far. No major concerns or show-stoppers have been identified. The High Granularity Calorimeter is a successful application of the FTX detector group and already constitutes a fully integrated effort to CMS.

Belle II

The Belle II experiment has collected by now about 130/fb of data at a luminosity of up to $2.6\text{E}34/\text{cm}^2/\text{s}$. Data taking was efficient (90%) and the recorded data are of high quality. The first four papers on Belle II data have been published. The recent publication of new evidence for lepton flavour violation by the LHCb experiment has highlighted the importance and the opportunities of the Belle II scientific programme.

DESY is one of the strongest groups in the Belle II collaboration, with leading contributions and responsibilities in many areas: detector operation (most notably the PXD), tracking and ECAL reconstruction, performance studies, computing, and data analysis. Two of the four first Belle II physics papers are fully DESY-based, one more with DESY participation. DESY is to be congratulated for its Belle II participation, which should be continued at full strength!

PXD operation is going well. The issue of an unexpected radiation induced increase of the HV current has been understood and dealt with such that it is no longer a worry. There were no further losses of modules despite the rough running conditions of the machine (likely thanks to the improved ramp-down mechanism). PXD performance is excellent. The proper time resolution is a factor of two better compared to Belle (I).

The **SuperKEKB accelerator** is struggling to reach its luminosity target. The current instantaneous luminosity is a factor of two lower than predicted last year. There are several limitations in the operational parameters that still need to be understood and removed. The updated planning foresees an extension of the current run until summer 2022, aiming to collect 0.5-1.0/ab (equiv. to Belle (I)), followed by the installation of the PXD 2 detector. A major upgrade of the interaction region (≥ 2026) will be necessary in order to reach the design luminosity. The goal of 50/ab is currently scheduled for 2031.

The **preparation of the PXD2 detector** has suffered some delays due to equipment failure at the sensor manufacturer. Ladder construction is going well. The 1st half-shell is expected at DESY in early summer 2021. Shipment of PXD2 to KEK is now planned for June 2022, following the extension of the current run. Access of the group to the HERA west hall until summer 2022 is required.

The Belle II collaboration considers **upgrades to the detector** during the extended shutdown planned for ≥ 2026 and has formed an Upgrade Advisory Committee, in which DESY is represented. Now a coherent plan has to be worked out. There are several very interesting options for DESY to contribute.

The **DESY Belle group** is in a transition phase with 11 out of 18 postdocs leaving in 2021 and only 5-6 new starting. Two of the main PXD experts need to be replaced. In addition, the YIG leader Torben Ferber accepted a call for a full professorship at KIT. The Belle group needs the full support of DESY to overcome this transition.

Key comments and recommendations for Belle II

PRC commends the DESY Belle group for their very visible contributions from operations through computing, software and calibration to physics analyses, and for playing a leading role in the resulting publications. DESY's participation in Belle II is a true highlight of its particle physics programme and will deliver new insights into lepton flavour violation and many other fundamental physics questions.

PRC takes note that the installation of the PXD2 detector was moved to summer 2022 and strongly recommends that the necessary support is given to the Belle group to successfully deliver the PXD2 detector on the new timescale.

PRC recommends that DESY develops a plan regarding its involvement in the currently considered Belle II upgrades.

Future Linear Collider Activities and Preparations for Future Experiments (FTX)

The **DESY FTX group** is recognised as one of the key players in the common worldwide international activities to develop the future accelerator beyond the LHC programme and is well aligned with the results and priorities set by the updated European strategy for particle physics:

- Active and visible participation to the **European effort to develop the next Higgs factory** (ECFA Higgs factory committee (FCCee & ILC & CLIC), International Development Team working groups (WG1 & WG2 & WG3) of the ILC);
- **EU detector R&D efforts** (AIDAinnova with F. Sefkow as Project Leader (also F. Gaede and K. Krüger as WP coordinators), heavy involvement in the ECFA detector R&D roadmap coordination);
- **Software** – development of new tools common to ILC, CLIC, FCC and CEPC;
- **test beam / telescopes facilities** at DESY – successful operation and growing in use and running smoothly despite the Covid-19 pandemic;
- joining efforts with accelerator plasma wakefield development.

The process started at PRC87 and discussed in the following PRC meetings towards consolidating a new group structure has concluded, following the lines presented at PRC90 and approved by PRC. The final structure and responsibilities have been presented at this PRC meeting and approved by PRC.

The group has published 3 publications since the last PRC, and 2 are being submitted; there are also 3 preprints on physics & detector R&D. The group is involved in several projects with additional funding (Quantum Universe excellence cluster, CDCS, ...).

Key comments and recommendations for the FTX group

PRC continues expressing its strongest support to the FTX group and identifies the group as one of the key players in the common international effort to develop the future projects of new accelerators beyond the LHC, more specifically the future Higgs Factory. In this context and in view of reinforcing this role PRC recommends to support the initiative of the group to create the DESY Forum for Future Collider Activities (theory, experiment and accelerator).

PRC acknowledges the internal strategy process towards creating a team to develop generic R&D activities for future experiments in particle physics. The team will integrate physics

studies, particle physics detector R&D, scientific computing, test-beam facilities and will join efforts to the accelerator plasma wake-field group. In this respect PRC recognizes that this internal process has reached convergence and endorses the final structure and research objectives as presented at this meeting.

PRC recommends to continue the support of the lab to the group in terms of scientific and engineering resources.

Theory

The PRC appreciates the presentation on formal theory, highlighting recent developments in the mathematical structure of QFTs. The string theory group is to be congratulated on its excellent record of gaining third-party funding. There have been impressive and world-leading contributions to the study of scale-invariant quantum systems, particularly in developing new ideas and techniques in the testing ground of supersymmetric gauge theories, and the translation of new ideas such as cluster algebras to the study of Standard Model amplitudes. Many of the fundamental questions of QFT, like the vacuum structure, are still far from resolved and the exploration of new formal avenues for their answers is crucial to make any progress and should be pursued even independently of the direct applications.

The PRC is very pleased to hear that the new Wolfgang Pauli Centre is progressing well and has received an extremely positive evaluation. We endorse the view of the review panel that this initiative can raise the WPC to become Germany's leading institute for theoretical physics and a recognised leader on the world stage. The Wolfgang Pauli Centre is therefore a key long-term investment that has the potential to transform the way that theoretical physics at DESY operates. Creating the right environment for new ideas and synergies to emerge is critical, and the design of the building is fundamental to encouraging such creativity and exchange. We look forward to the partnership contract / cooperation agreement with UHH being signed and that construction can proceed on the agreed timescale culminating in a planned occupation in 2026.

The PRC is delighted to hear that two permanent scientist positions are being opened up in the Zeuthen Particle Physics Theory group to fill the vacancies created by the retirement of Johannes Blümlein and the anticipated retirement of Rainer Sommer.

It is recognised that the DESY Theory group has maintained an enviable stream of high-quality research outputs during the pandemic and the period of working from home. In many ways theoretical work in established collaborations and on well-defined projects are well suited to remote working. However, it is clear that new ideas, new projects and new collaborations are severely inhibited in on-line meetings. On-line conferences give access to new ideas when travel is curtailed, however they are not good at enabling small group conversations that become the new projects and collaborations of tomorrow. As we emerge from lockdown, it will be increasingly important to stimulate new ideas and collaboration by re-establishing both travel to conferences (travel budget) and a strong visitor program (space for visitors). This is particularly important for early-career researchers to give them the opportunity for training and to build the research network needed for their future career, as well as visibility in the community.

Key comments and recommendations for theory

We recommend that the momentum towards construction of the new building to host the Wolfgang Pauli Centre is maintained and that DESY participate in the project with full commitment and the necessary funding: since the WPC will form the theory landscape at DESY and UHH for the next 20/30 years or more it is not the time for half-measures.

We recommend that the high level of exchange in the theory is allowed to recover as soon as possible after the pandemic, allowing especially the younger scientists to be in part compensated for the missed opportunities of networking and training in the pandemics. In case of delays in projects caused by the Covid-19 pandemic, contracts should be extended accordingly.

In general, personal contacts and some amount of travel for conferences in person or long-term visits remain vital for the development of new ideas and exchange of knowledge and methods, so the Theory group should be provided the needed travel funding.

ALPS-II

The construction of the ALPS-II Experiment in the HERA tunnel is proceeding according to the schedule, the installation of the optics has started in March and recently for the first time light shone through the whole experiment successfully, showing the good alignment of all the components. Installation and commissioning of the optics should be completed soon, and the collaboration is preparing for the first run of data taking in autumn 2021. The collaboration has been able to attract a new member, Dr. Manuel Meyer, supported by a prestigious ERC starter grant for axion research and detector development. He will join ALPS-II and work on the TES detector, which will be used in the second run of the experiment. We congratulate the collaboration on the steady progress and soon-to-start data taking!

There are a few open issues: Refurbishing the general infrastructure of the HERA North area has become necessary and may not be finished for the start of data taking. Furthermore, the delayed schedule could lead to loss of the optics expertise at the time of long-term data taking

Key comments and recommendations for ALPS

We congratulate the collaborations for keeping the schedule Corona notwithstanding and be ready for data-taking in 2021. We strongly encourage the collaboration and DESY to continue their efforts to have a physics run at the end of 2021.

We recommend that every possibility is explored to keep or substitute the optical expertise for the experiment, which is crucial during data-taking until 2024 and maybe beyond.

BabylAXO

The BabylAXO collaboration has progressed on different fronts since the last PRC:

- The MoU DESY-CERN about the magnet design has been signed at the end of the last year and now discussions about further collaborations are taking place.
- Testing of the old cable for the magnets is progressing according to schedule.

- Prototypes of the detector are being constructed and the improved prototype will be tested at the Canfranc Underground Laboratory to measure the background.

We congratulate the collaboration for reaching these milestones and for the steady progress.

There are two of open or critical issues: The INR cable presents a substantial sample-to-sample variability calling for a more extensive qualification. And the location of Baby IAXO on the DESY site appears not to be settled yet, contrary to previous discussions on the HERA south hall. Now an external location is under discussion, with consequent longer preparatory phase.

Key comments and recommendations for BabyIAXO

We congratulate the collaboration on the agreement between CERN and DESY for the magnet design and we recommend to continue to support the experiment in the further negotiations with CERN.

We recommend that a decision on the location of BabyIAXO on the DESY site is reached shortly, as the external location calls for additional construction work and preparations. It should be avoided that this issue becomes a bottleneck for the realization of the experiment.

MADMAX

The interest in MADMAX physics is very strong, and the approach is certainly one of the best ways to reach the high-frequency axion dark matter range.

The collaboration has made progress assuring the MORPURGO magnet at CERN and has put together a technical plan of achieving their goals. It's also making critical technical tests and studies to clarify the physics with RF at 20 GHz and above.

Collaborations like ADMX are considering joining MADMAX, a testament to the physics reach of MADMAX.

Key comments and recommendations for MADMAX

We are very happy with the collaboration's emphasis on securing some short-term victories, with the CERN magnet, technical accomplishments, and being open to strong collaborations joining the experiment.

We strongly encourage the collaboration in putting effort also in the optimization of the booster design early on, and in possibly duplicating and cross-checking the difficult studies related to the attainable boost factor before fixing the final design.

We encourage the collaboration to focus on a simple booster prototype that is easy to understand, build and test in a magnet like the MORPURGO magnet. Its physics reach needs to be better than the astrophysical limits, demonstrate scalability and resources needed to materialize the next target.

LUXE

PRC has conducted a review of the LUXE CDR. The full results of the report can be found in a separate document. Here, we only cite the main findings of the review.

From the executive summary:

“LUXE is a well thought out and unique opportunity to combine the state of the art EU-XFEL accelerator parameters and performance, with access to world class lasers and associated expertise, and deliver high quality measurements in a new exciting, unexplored and experimentally-driven physics regime. Over the next decade the experiment has the potential to be world-leading in experimentally exploring Strong Field QED (SFQED) in both electron-photon and photon-photon interactions, and to also perform Beyond the Standard Model (BSM) physics searches for axion-like particles.

The experimental collaboration is strong on both the physics and detector sides and has the potential to grow further as the physics goals and detector technologies are of widespread interest. The experiment has a clear upgrade path with a higher intensity laser, and can potentially be an exemplar for a longer term exploration of this field of physics at other accelerators.

While the LUXE experimental layout is well adapted to and optimised for the physics goals of the experiment, and both feasibility and implementation studies were convincingly presented in the CDR and review session, the most significant challenge is the installation milestone during the EU-XFEL shutdown in early 2024. To respect this schedule three urgent actions are recommended by the Committee,

- 1. to perform detailed technical designs of the extraction beamline and the experimental area to ensure that the most critical parts of the installation can take place during this shutdown,*
- 2. to swiftly move towards a TDR for LUXE such that detailed resources loaded schedules and plans are available and the deliverables for the collaboration partners are defined, and*
- 3. to define and agree on fallback strategies between DESY and the EU-FEL consortium that allow completion of the installation of the experiment in the shorter winter/summer shutdowns in 2025 and/or 2026, if needed.*

These actions will require a significant and immediate ramp up of the technical resources at DESY for LUXE preparation, building on the studies already started addressing these points.

The LUXE collaboration should be congratulated for their work to prepare a comprehensive and high quality CDR, including also more recent studies, going well beyond the conceptual level. Their detailed answers to questions and excellent presentations of the main studies and issues, including additional information provided about the planned next steps, have allowed.”

Overall conclusion and recommendations:

“LUXE is potentially a world leading experiment for probing Strong Field QED in a hitherto unexplored domain, and has additional BSM capabilities for axion-like particle searches. The main elements for a successful project, namely the accelerator, the laser, the detector-systems, and a strong collaboration including theory partners are already or can soon be available. The collaboration has successfully secured funding for important parts of the current work on LUXE, among others for laser diagnostics development, and other funding applications are pending.

The possibility of building, installing and operating LUXE at DESY during the next decade represents a unique and important opportunity for the laboratory. The high quality CDR of LUXE, in some cases complemented by more recent studies, and informative and in depth answers to questions, have been very appreciated by the committee. The committee finds that the physics case is compelling and the overall experimental approach and the main components of LUXE are very feasible. The readiness for the main installation period in 2024 is challenging.

We recommend that the project is moved to the next stage, aiming for TDR level project planning and documentation, by releasing resources to address:

- A detailed design of the beam extraction and experimental area layouts and elements.*
- Detailed work-breakdowns, costs and schedules for the implementation phase of the extraction and experimental area.*
- Updated reports on the experiment, the technical progress and preparation for it, including definition of deliverables, and the physics potential. In parallel LUXE should aim to strengthen the experimental and possibly theory collaborations further.*

- *Work on fallback scenarios that allow installation of components in later shutdowns, in discussions with the EU-XFEL.*
- *Aim for construction and installation scenario decisions - based on the above and an overall cost, resource and risk analysis - by the end of 2021."*

Computing / IT

The DESY computing infrastructure continues to excel in providing high-quality computing resources to the DESY science community, including also agreed resource contributions to the international collaborations of the LHC and Belle II experiments. For the latter, DESY is one of the largest "Tier-2" computing centers worldwide, and for the former, DESY's National Analysis Facility (NAF) is the primary computing resource for German high-energy physicists (not only internal to DESY). It is vital that funding for these resources can be secured for the coming years.

DESY IT works on a broad range of projects within the context of the Helmholtz Association, with a focus on Federated services and Data services, capitalising on the expertise built up in these areas over the past decade. There is also work being done to increase integration of the various resource segments (Grid, NAF, Maxwell HPC, Openstack Cloud) into the Interdisciplinary Data and Analysis Facility.

"Digital DESY" is a challenge facing the IT Department. The department will need to continue doing the things it already does well, like providing the large-scale computing and data infrastructure, whilst moving into other areas like autonomous systems, quantum computing, and administrative computing.

Recommendations for computing / IT

- We recommend that IT develop an activity map, grouping the wide variety of activities and services around a handful (five or less) main themes. This facilitates the process of organising and communicating the strategic choices being made, especially in view of the additional demands made by Digital DESY.
- The NAF facility is utilised at a level (sometimes at 85%) that precludes its use as a semi-interactive analysis facility. This introduces delays for scientists, particular during the crucial times preceding collaboration deadlines typical in high-energy physics. An expansion of the facility would be very desirable for all German users.