Recommendations of the 97th Physics Research Committee

April 2024

General comments

The PRC recognises the major contributions made by the DESY groups at **ATLAS, Belle II, and CMS**. All three have large impact in their respective collaborations and shoulder many and diverse responsibilities that are vital for the experiments. This holds equally for construction and upgrades, operations, and physics analysis. The recent election of DESY scientists to the posts of ATLAS and CMS physics coordinators underlines the high appreciation and visibility of the DESY contributions to these global flagship projects.

The PRC equally appreciates the significant progress on all **axion experiments**. With the portfolio of ALPS II, (Baby)IAXO and MADMAX, DESY has the potential of becoming a world-leading hub for axion research. The further development of this research area at DESY will be an important strategic part of the PoF V preparation. There is an increasing number of collaborative studies between the experiments. These should be encouraged to maximise the use of magnets and infrastructure. The PRC recommends that the experimental programme continues to be accompanied by leading theory contributions to maintain the very visible position in the field.

The **beams at DESY** have performances and parameters that offer unique scientific opportunities for numerous important studies and world-leading on-site experiments. LUXE at the European XFEL and a potential HALHF demonstrator at FLASHForward are two obvious examples, and other possibilities should be considered. In fact, mirroring the successful example of the creation of a world-leading on-site axion programme, and in view of the ongoing PoF V planning, DESY should explore systematically the potential for beam-based experiments and studies that can be internationally leading. The recent success of acquiring EU funding for the ELBEX project – developing the prospects of realising a versatile extraction beamline at the European XFEL – is an excellent starting point for such deliberations.

The PRC appreciates how well the division management and the groups are handling the current difficult **budget situation**, trying to minimise the impact on junior positions and on the scientific output while at the same time very clearly pursuing the main obligations. In particular, the division is giving more and more **priority to its hardware and construction responsibilities**, most notably the HL-LHC tracker endcaps. It is noted that the division is extremely successful in attracting third-party funding – and that there is a broad understanding that third-party funding should ideally be used to amplify base funding and must not divert attention from core tasks. However, should the financial situation not improve the PRC is concerned that it could damage in particular the on-site programme.

The PRC has heard from the **two new platforms on scientific computing and on detector R&D** and discussed them. The PRC supports the general directions and intentions of the platforms as presented. For the next meeting in autumn 2024, the committee wishes to schedule an extended session with presentations from the platforms and their integration into the PoF V planning. In the farther future, the PRC will regularly monitor the platforms. It is noted that technology transfer, education, communication and the exchange of expertise are important topics that the platforms should address. The PRC notes with pleasure the arrival of a new head of the IT group and the efforts for developing a "scientific computing" vision for the division and the entire lab. Here, the scientific computing platform should play a visible role.

The PRC acknowledges the continuing success of the **theory group** to produce important papers and attract 3rd-party funding. PRC notes that 3rd-party funded projects are excellent opportunities for the career development of junior scientists as well as their supervisors.

The PRC expresses its concern about the technical personnel situation, and in particular about the capacity for wire-bonding as required for the ATLAS and CMS upgrade projects. In general, a very careful planning concerning personnel resources is required for a very hectic construction period towards on-time delivery and installation.

ATLAS

Findings

The **size of the DESY ATLAS group** has remained at about the same level compared to PRC96. The group attracted three new postdoctoral researchers and nine Master students or student assistants. An **ERC Starting Grant** was awarded to Young Investigator Group leader Pricilla Pani. The **broad involvement** of the group into detector operations, detector and physics object performance, and simulation continues. The long-standing efforts of the group to calibrate the ATLAS luminosity led to a convenership for K. Mönig.

The interests and contributions of the group in physics analysis cover a **wide range of topics**, with personnel split about equally between standard-model (SM) measurements and searches for physics beyond the standard model (BSM). Since PRC96, **17 articles** with substantial contributions of the group were published in scientific journals, six more papers as well as four conference notes and four papers on non-ATLAS topics were submitted. Recent highlight results include a review on the properties of the Higgs boson and a search for heavy (pseudo-)scalar particles into a top quark-antiquark pair. K. Tackmann was appointed **physics coordinator** of the ATLAS collaboration, starting in October 2024.

The current instrumentation focus of the group is the ATLAS upgrade towards a **new Inner Tracker** (ITk) for the high-luminosity LHC (HL-LHC), where one of the ITk endcaps is to be built at DESY. Since PRC96, a new problem was reported with modules cracking due to thermal stress. The plans for ITk production are evolving, with small changes in the module production steps done at DESY. The "end of structure" electronics cards moved from the pre-production phase to the in-house production of 1500 cards. The staff members of the group invest an increasing amount of time on ITk projects, but key technological support (specifically for wire bonding) is lacking because of insufficient technical staffing.

Comments

The PRC congratulates the DESY ATLAS group on their **excellent contributions to the ATLAS experiment**. The PRC extends its congratulations to the three newly appointed conveners, to Kerstin Tackmann for her appointment as the ATLAS physics coordinator, and to Priscilla Pani for her ERC Starting Grant. The additional funding through the ERC grant, and the high number of undergraduate students, will contribute to keeping the person power of the group at about the same level.

The group's **expertise** on a broad range of operations, simulation, and detector and object performance topics continues to be **very valuable for the ATLAS collaboration**. The group's physics analysis activities show a very health 50:50 split between SM measurements and BSM searches. The overall topical breadth is adequate for the size of the group, and the choice of topics strikes a very good balance. The PRC congratulates the group on its **impressive scientific output** since PRC96, with more that 30 publications either published or submitted to journals.

The PRC notes that the group continues to make **very good progress on the ATLAS tracker upgrade** and moves deeper into the production phase. The quick turn-around in analyzing data from recent beam test illustrates the added value of the group's engagement in the DESY test beam facility. The PRC is concerned about the module cracking problem, which was only observed recently and may require changes to module design and assembly procedures rather late in the process. The lack of personnel for wire bonding at the Hamburg site, which is known for some time, may turn into a serious bottleneck for module production.

Identification of critical issues

The lack of personnel for wire bonding at the Hamburg site has the potential to turn into a critical issue for module production.

Specific recommendations for ATLAS

The timely delivery of the DESY contributions to the ATLAS upgrade should continue to have the highest priority. The PRC recommends that the group keeps its focus and staffing levels. The group shall pay close attention on any critical issues arising in the sub-projects and avoid loss of momentum on the many tasks to be accomplished.

CMS

Findings

A wide range of **physics results** have been published recently, or are being published, with DESY leadership or involvement, often with full Run-2 data. DESY physicists are also engaged in Run-2 review papers from CMS. **DESY scientists** hold the positions of Collaboration Board chair (Elisabetta Gallo), and incoming Physics Coordinator (Andreas Meyer). DESY physicists continue to hold a broad portfolio of responsibilities in the collaboration. DESY **institutional responsibilities** continue to face challenges, with the reduction in the number of non-permanent staff, staff retirements, or changed roles posing a challenge to preservation of expertise in both tracker alignment and BRIL/Luminosity. The overall size of the group continues to contract slowly, with a drop of 6% in the last year, providing a challenge to maintain operations activity while upgrade activity is increasing.
The team continues to contribute substantially to CMS **computing**, leveraging additional resource from external programmes. It was noted that the funding for the two Helmholtz.ai projects on shower and event generation will end in the next six months.
A two-day schedule **review of the outer tracker upgrade** took place in January. This event was arranged in the spirit of the Fraunhofer workshop for the CMS HGCAL that took place in summer 2023 and had the aim to understand better the overall schedule, critical paths and interdependencies, and to identify possibilities to accelerate production. It was the first time that scheduling had been scrutinised across all areas of the project, and many issues were identified, with some affecting DESY work. MaPSA testing, which had been dropped at DESY, has been reinstated, and the module production quota has also increased from 1120 to 1430. Delays to hybrid production and cost increase can only be avoided by accepting lower cleanliness devices, **adding schedule risk** to the speed of wire-bonding, and potentially also risk to the quality and durability of the bonds. Schedule analysis at DESY shows that more than two bonding technicians are essential during module production, especially over the year of full speed work, when 73 modules per week must be produced.
The first pre-production Dee was damaged during assembly at the company - lessons are being learnt for future iterations; there is no direct schedule or cost impact at this point. After two years of design work the concept and design of the Double-Disk alignment tool was successfully validated with a prototype. Work on the TEDD rotation tool continues well.
Wrapping of tiles for the **HGCal endcap calorimeter upgrade** is in production at DESY now, with the pre-series completed and being tested with a radioactive source and an LED. The production at DESY is of 150k tiles, and quality control (QC) will be done on a spot-sampled fraction of tiles. About 30 pre-series tile readout boards have been assembled, of all sizes, making use of DESY's SMD assembly capacity. Preparations for production QC are advanced including cold testing, although full QC of the assembled boards is delayed waiting for test equipment.

Comments

The PRC **congratulates** the CMS team on the continuing flow of physics results, and on the selection of A. Meyer as the next Physics Coordinator. The PRC notes that delivering the upgrades, and maintaining operational responsibilities, must be the highest priority of the group in the next three years.
The **outer tracker module production schedule** is now better understood - but nonetheless appears to be highly success-oriented, with no contingency. In the last months, DESY has been asked to increase its module production count by more than a quarter, and to take back significant MaPSA testing as well. It is to the credit of the DESY-CMS team that they have accepted this, but it is **high risk in terms of both schedule and cost**. This only exacerbates the situation with technical staffing on the outer tracker, which **remains critical,** in terms of numbers and the need for training new people.
While HGCal work is progressing well, the PRC would like routinely to see **high-level schedule** information, to be better able to assess progress. Risks related to the uncompleted system

mechanical engineering of the inner (Si) parts of the HGCal were reported - the HGCal project needs to ensure these are resolved rapidly, as there could be an impact on the tile sections.

Identification of critical issues

The increased work required by the tracker upgrade project and the limited amount of trained staff for the relevant tasks remains a concern.

Specific recommendations for CMS

In order to achieve the ambitious tracker endcap construction goals, the CMS group is recommended to prepare additional trained technical staff. As for ATLAS bonding capacity is expected to become a critical issue.

Belle II

Findings

Belle II data-taking has resumed in the new Run-2 configuration from the end of January, in line with the schedule reported at PRC96. The SuperKEKB luminosity is ramping up gradually, reaching around 5 fb^{-1} per week so far, about half of the sustained maximum in Run-1. Sudden Beam Losses, observed in Run-1, are still present. Very recently they have led to the loss of about 1% of the "switcher gates" of the pixel detector (see below). The path to higher luminosities in Run-2 is being sought at SuperKEKB.

The **pixel detector (PXD2)** is operating successfully. At present five of the 40 modules are not being read out, all in the outer layer-2 of PXD2. Two ladders (4 modules) are those previously noted not to be sliding properly. Alignment, calibration and performance studies are in hand. Time-dependent alignment is being commissioned, with ~1 min time granularity, to cope with slow thermal movements seen at the start of fills. These arise because of high thermal heating of the beam-pipe in the forward region – this may result in large thermal stresses in future if it cannot be mitigated. The central tracker (CDC) current is also being watched carefully as it evolves with beam current. A full-scale PXD test rig is operating at DESY, the only one with a full-scale DAQ outside KEK. Leadership of the PXD2 project has passed to the University of Bonn.

The DESY team is engaged in a wide range of performance work with the new data. Operation with beam has revealed CDC readout errors caused by radiation. A new software recovery allows many of these to be recovered without significant inefficiencies.

Two **new physics results with DESY leadership** have been released, both in the τ physics area: a lepton-flavour universality test of $\tau \to \mu$ vs $\tau \to e$, and a search for $\tau \to 3\mu$ decays. Both results are world leading in terms of precision. Many other analyses are in progress, and will be released with more Run-2 data.

Belle II submitted a CDR for future detector upgrades to the Belle Programme Advisory Committee (BPAC). DESY is not directly involved in the upgrade proposals submitted. A new vertex detector (VTX) proposed has involvement from other German Belle II institutes, as noted at PRC96. Feedback from the BPAC on the CDR has been received by Belle II.

The DESY role in **Belle II computing** continues to be very substantial. The National Analysis Facility (NAF) operated by DESY continues to be the only general analysis facility of the collaboration outside KEK. DESY continues to be a raw data centre, and provides 11% of the Grid CPU resources, for the experiment. Crucial collaborative services for Belle II are also hosted at DESY.

Comments

The DESY Belle II team is **congratulated** on the **successful commissioning and operation of PXD2**, and its **leading roles in four physics working groups**.

The PRC notes that feedback from the BPAC to the **Belle II detector upgrade CDR** was rather critical, having noted that the overall plans presented were not coherent, and also not integrated with the anticipated accelerator upgrades. The BPAC stressed that the LS2 timing

is likely to change, as experience is gained in Run-2. The collaboration has been asked to go back and define the overall scope of upgrades based on physics performance, and then to write a new document providing a coherent and integrated description of the accelerator and detector upgrade plans. The timescale for this, and the role that the German groups, including DESY, will play, needs to be clarified.
The PRC notes that there is a milestone in summer 2026 when the timescale and plans need to be defined, as this is a critical decision point for MEXT funding.
Substantial IR upgrades at SuperKEKB in LS2 remain fundamental in order to achieve the target luminosity.
The PRC notes that this is the last PRC meeting at which Carsten Niebuhr will lead the DESY Belle II team, he is handing over to Ami Rostomyan. Carsten Niebuhr is warmly thanked for his outstanding dedication, technical expertise, and leadership of the team over many years.

Identification of critical issues

No critical issues identified.

Specific recommendations for Belle II

DESY should establish its interest in the Belle II upgrade and play a more active role in shaping the SuperKEKB plans for LS2 and beyond, both the upgrade of the IR and upgrades to the Belle II detector. If DESY chooses to play a significant role in the Belle II upgrades, the Belle II group will need additional detector expertise.

ALPS II

Findings

Since the last PRC meeting, **ALPS II continued data taking**, collecting more than 700,000 seconds of good data with magnetic field switched on in a light polarization allowing to search for new scalar particles. The collaboration makes efficient use of the operation, understanding and improving the experimental set-up as well as the data analyses methods. The optics system works stably, reaching duty cycles of 80% with long uninterrupted locking times of up to 32 hours.
The experiment is currently running, looking for **pseudo-scalars like the QCD axion**.
Minor technical issues on the magnet string infrastructure - person interlock system, the cryo facility, the power supply and the quench protection system - interrupted the run, triggering (false) quench alarms. The causes of these issues are investigated to understand if an upgrade of the quench protection system in 2024/2025 could further improve the situation.
For scalar searches, ALPS II has now reached a scalar-photon coupling constant $g_{\phi\gamma\gamma}$ sensitivity about a factor 30 beyond earlier similar experiments.
This **sensitivity** is a little less than expected for an ideal experiment limited by shot-noise, and the following reasons were identified:

- Evidence for stray-light levels on the order of 10 −22 W with surprisingly long coherence times of more than 10,000 seconds.
- Limitation of the heterodyne sensing scheme by technical noise at a level roughly a factor of 10 above shotnoise.

To re-gain sensitivity, new baffles and absorbers to lower the stray-light intensity for the ongoing pseudo-scalar run have been implemented. As well, heterodyne sensing will be improved in the long shutdown period, when the ALPS II production cavity will be installed and commissioned.
First science results of ALPS II are expected to get published by late summer 2024.
The **ALPS II near-term plans** to reach the design sensitivity remain essentially unchanged. As a next step the Production Cavity (PC) in front of the wall will be implemented and commissioned, with full system engineering runs to proof the system from June 2025 to August 2025, followed by full system science runs from September 2025 to November 2025.

Work on the Transition Edge Sensor (TES) detection system is progressing nicely. New sensors from the National Institute of Standards and Technology (NIST), are now in hand, outperforming the old modules.
The successful operation of ALPS II continues to trigger **attention**. The success and first results were celebrated at an "axion symposium" at DESY in January 2024.

Comments

The PRC congratulates the ALPS II collaboration and DESY for **successfully operating** the experiment and achieving the goals of the initial ALPS II science run during 2023. The committee notes with satisfaction the excellent performance of the experiment and of the infrastructure. The PRC notes with pleasure that the media response to the ALPS II continues to be huge, and that there is a wide range of interest in our science and DESY as laboratory. This success continues to underline the ambition at DESY to exploit on-site axion experiments as goldmines for fundamental research in particle physics.
The committee notes with satisfaction that **the ALPS II optical system operates works stably**, reaching high duty cycles and allowing for long uninterrupted locking times. The committee encourages the collaboration to profit from the experience gained on the magnet string infrastructure and - if possible - to further improve it to gain operation time.
The committee is looking forward to the publication of first science results using the data of the runs taken in 2023 and 2024.
The referees note/ emphasize that the program of ALPs to probe scalar couplings has a value as an independent test, even if the sensitivity at reach a priori falls short of existing limits.

Identification of critical issues

The committee underlines that one of the main challenges for the future progress of the experiment arises from a potential shortage of person power. Many experts are on short term postdoctoral contracts. The difficulty and challenge to identify suitable candidates and to continuously training new experts will hamper the efficiency of the experiment.

Specific recommendations for ALPS II

None.

BabyIAXO

Contrary to the usual practice, we report here only on the BabyIAXO magnet review that took place two days prior to the PRC meeting with a handful of leading magnet experts from around the world. Their report provides guidelines for future work and reviews.

One additional remark is that it has been discussed to turn the BabyIAXO magnet into a general magnet infrastructure that could serve and accommodate several experimental enterprises, including MADMAX (see below).

Findings

The proposed BabyIAXO superconducting dipole is a challenging magnet: Out of the different superconducting magnet types, dipoles are considered to be the most challenging choice. A superconducting dipole of this size (bore volume), has not been built before. In addition, the magnet is to be placed on a rotating platform, giving complications for providing services as well as needs to ensure stable operation during rotation. It is also the first superconducting magnet of this size to be cooled by cryo-coolers, (no cryo-plant available, environmentally friendly).
In general, the reviewers consider the project to be an interesting and very challenging one. New technical solutions with an indirectly cooled design will pioneer technology for many future projects.
The choice of aluminum-stabilised conductor gives rise to concerns: There is currently no company world-wide to produce the required cable (SC Rutherford cable surrounded by

"block" of aluminum). Contacts have been made to a Chinese company that already provided a first non-conforming sample of a potential cable, to be tested. On this issue, the reviewers have a number of recommendations (see below).
Concerning the presented budget, the reviewers note that a first estimation was presented, with no contingency, and not sufficient funding for now. This gives rise to concerns and recommendations, see below.

Comments

The reviewers and PRC stress that the BabyIAXO magnet is the key instrument for axion searches and a future DESY axion infrastructure. The current design is judged to be robust.
The reviewers **congratulate the proponents** for the detailed report and the documentation shown at the review. The reviewers appreciate contact by collaboration to the Chinese cable-manufacturing company.
The reviewers further commented on the **innovative cold mass design** w.r.t. the 2020 conceptual design. There are, however, questions concerning the bonding between the cold mass and the winding packs, which require discussion and further studies. Confirmation of the mechanical and cryogenic designs should be part of the follow-up review.
The reviewers note that the **presented schedule is success-oriented.** They suggest to consider at least one year for the aluminum conductor choice and procurement. The schedule needs to be further discussed and analyzed once more information on the progress on the conductor and the funding availability is in hand.

Identification of critical issues

The availability of aluminum-stabilised conductor gives rise to concerns: There is currently no company world-wide to produce the required cable. This item must be resolved quickly.
A main concern is about the presented magnet cost, as only one supplier (Elytt) up to now has been consulted.

Specific recommendations for BabyIAXO

Concerning the SC magnet cable, it is recommended to produce a first length of the aluminum-stabilised conductor offered by the Chinese company (> 100 m) to be engaged as soon as possible. (in line with BabyIAXO planning). It is also recommended to have a follow-up review once the results of tests with first cables is in hand. In case of lack of progress, a plan B will have to be considered, despite the delay it will imply (SC cable soldered into a copper channel for instance).
The PRC follows the reviewers in their recommendation to **clarify the magnet project organisation and collaboration model**, i.e. responsibilities of collaboration, DESY, CERN, company… The referees express their wish and preference to have CERN involved in the manufacturing and to have the integration at CERN, i.e. that the magnet manufacturer will probably not be ready to accept the full responsibility on the magnet performances at an affordable price.
The reviewers and PRC recommend to include the CDR review of the remaining items (manufacturing process, magnet and project FMEA, rotating platform and on-site integration, first commissioning plan …) into the **next review**, once information on the cables are available.
Reviewers strongly recommend that a **first budget** should be secured for the aluminum-stabilized conductor procurement as well as for prototypes already started at CERN. In addition, it is also recommended that other manufacturers (Tesla, Ansaldo, Bilfinger, Sigma-phi…) should be contacted.

MADMAX

Findings and comments

MADMAX continued to run successfully at CERN using the 1.6T MORPURGO magnet in 2022, 2023 and continues in 2024. The collaboration developed the booster mechanism, a critical component of the experimental setup. In addition, they have learned how to identify and

calibrate the booster mode they are using, a critical cornerstone achievement. The collaboration had runs with the CB200 booster (200 mm dielectric diameter disks) at room temperature and with the CB100 at both room temperature and at 10 K. The number of disks used is still 1 or 3 but it is a start to learn to tune them, done so far at room temperature. The collaboration discovered how to correctly identify the correct TE mode pointing out that all detectors based on mode identification need to identify all present modes in their system.
They started taking data at around 19 GHz, with a **significantly improved sensitivity** over present limits with a clear path towards hadronic axion sensitivity using the final magnet and improved booster system. For the near future they plan to make steady improvements in the boost technology and in their ability to tune the system at cryogenic temperatures. The target for FY2028 is to achieve sensitivity less than an order of magnitude away from KSVZ sensitivity for 1 MHz axion frequency range at around 19 GHz. That would be already an amazing accomplishment. The number of discs in their plans is increasing from the current maximum of 3 to 20 and in the disc diameter from 200 mm to 300 mm, planning to run in both 10 K and then 7 K.
Eventually, **the booster surface area** will increase to ~1 m^2 with an expected sensitivity level well down to hadronic axions for high-frequency when using 10 T magnetic field with large volume. The collaboration was approached by Fermilab for a collaboration opportunity using the large aperture 9 T MRI magnet to be installed at Fermilab within 2024 and could become available for physics runs with the MADMAX method.
The committee congratulates the collaboration for keeping the momentum and for making impressive progress in the understanding of a critical part of the detector.

Identification of critical issues

No critical issues are identified.

Specific recommendations for MADMAX

- The collaboration should continue working at CERN using the MORPURGO magnet and continue making physics progress. In that regard, new physics opportunities should also be used to further enrich the physics outcome before its own magnet is developed.
- Several ongoing developments are encouraged, e.g. mode identification with beads, larger diameter boosters, demonstration of system tunability in a cryogenic environment.
- The committee would like to see an update on the status of the magnet and a realistic plan as soon as possible. It has been suggested that the BabyIAXO Magnet could be seen as a "generic infrastructure" with several purposes and as such provides a unique opportunity. If the magnet could be materialized before the PETRA IV construction start (2030-2031) it would allow for a world-class axion-physics program at DESY in less than a decade and every effort should be made to achieve this.

LUXE

Findings

The **LUXE collaboration remains attractive** for institutes from all over the world, with currently more than 100 collaboration members from 20 institutes. Beate Heinemann announced to step down as spokesperson, the search for new spokesperson is currently ongoing.
The **overall collaboration situation is difficult**, due to uncertainty of the realisation of LUXE at DESY and the European XFEL. With the decision of the DESY directorate not to install the extraction line in long shutdown 2025, any possible schedule will not allow the LUXE experiment to start before 2030. **Still, LUXE remains a strategic goal of DESY FH** and will be part of the new application round to Helmholtz (PoF V). DESY provides continued support to LUXE through base funding, covering aspects of project management, software and detector R&D. Members of the DESY LUXE team partially moved to other projects.

On the resources side, an ERC synergy grant for funding of significant parts of laser and detectors failed, however an EU-INFRA grant ("ELBEX" consortium DESY, European XFEL, U Manchester, INFN, IFIC Valencia) of 5M Euro total (3.3M Euro for DESY, mostly technical person power), has been granted.
Detector R&D, e.g. on the Backscattering Calorimeter and beam tests of the LUXE electron detection system at E320 at SLAC have been performed successfully, and **software development** (e.g. the integration of LUXE event reconstruction into HEP software) progresses well. All these activities produce results also beneficial for other experiments.
The LUXE collaboration is **exploring synergies with the LUPE collaboration**, which is proposing to perform high-density QED experiments using a "low energy" plasma generated with an electron beam and plasma mirrors. The goal is to explore the opportunities that European XFEL and DESY offer and to study if synergies in instrumentation can be identified, also in view of joined funding applications.

Comments

The committee congratulates the collaboration for publishing the TDR.
The overall collaboration situation difficult, due to uncertainty of LUXE realisation at DESY and XFEL. With the decision of the DESY directorate not to install the extraction line in long shutdown 2025, any possible schedule will not allow the LUXE experiment to start before 2030.
The PRC continues to consider LUXE as an exciting opportunity to probe an unexplored domain of physics using the unique facilities available at DESY.
The PRC notes the continuous progress achieved by the collaboration on the design, prototyping and test of detectors and appreciates that the collaboration continues making use of opportunities for beam tests e.g. at SLAC. The committee notes with pleasure that the collaboration continues to explore synergies with other experiments and collaborations (LUPE, E320).

Identification of critical issues

The PRC remains concerned on the **funding situation** of the experiment. However, the committee is pleased to hear about the successful application for an EU-Infrastructure grant "ELBEX", which opens the opportunity to prepare the installation of the extraction line, including purchasing & testing all components until a possible start in 2030. This gives a significant timeframe to acquire funding for the laser (ca 5M Euro) and the rest of the experiment, which then in turn convince European XFEL to schedule a shutdown of sufficient length for installation.
The committee is concerned on the **shift of the earliest possible date for LUXE operation** to 2030. The impact on the motivation of the collaboration as well as on the process to find funding for the rest of experiment needs to be understood.
The committee notes that a **strong and unambiguous support for LUXE** from the full DESY directorate would further foster the perception of LUXE as a credible project inside and outside DESY. As well it will increase chances for success of further 3rd party funding applications.

Specific recommendations for LUXE

The committee recommends that the fact of receiving an EU infrastructure grant should trigger further studies and strategies for opportunities to use the beamline for other experiments and tests. In general, the PRC emphasizes the strategic opportunity to have a beam-based particle physics experiment at DESY.

Theory

Findings

We congratulate the DESY Theory Group on its successful work on and its important contributions to the development of **particle physics phenomenology**. On this occasion, an extended report on QCD-related theoretical developments was provided.

In **lattice simulations**, the critical slowing down of the Hybrid Monte Carlo algorithm has been addressed with innovative Machine Learning techniques. The goal is to surpass the benchmark set by the MIT/Google collaboration since 2021. A key physics objective is to calculate NN and NNN interactions directly from QCD theory, without relying on models. A highlight are the NN calculations performed at DESY, which explore varying lattice spacing and demonstrate its strong impact. This is currently unattainable by other groups, who typically employ a single lattice spacing. Additionally, we emphasise the support of lattice collaborations across Europe and globally provided by the DESY lattice group.

In the domain of **QCD phenomenology and tools**, the research group is advancing the scope and the precision of QCD predictions using various approaches. These include radiative corrections up to three-loop accuracy, effective field theory resummations, Monte Carlo event generators, and corrections in both QCD and electroweak sectors for the Standard Model and Beyond Standard Model theories. Support from the "Colorfree" ERC grant significantly enhances these activities. There is a particular emphasis on the analysis of double-parton scattering, generally a secondary effect but potentially significant at low transverse momentum or in key event channels like same-sign W production. Dedicated next-to-leading order computations for double-parton scattering are under development, crucial for addressing the growing dataset of effects sensitive to double-parton interactions at the LHC. This theoretical endeavour is gradually achieving the capability to predict such cross-sections directly from the full QCD framework, thus necessitating the adoption of novel computational techniques.

Theory at DESY has grown due to the arrival of **several junior research groups**: The Emmy Noether groups of Johannes Braathen ("Cornering New Physics with Generic Precision Calculations") and Mathias Pierre ("Identifying the dark sector of the Universe: imprints from early dynamics to late time signatures") as well as the HFG W2 professorship of Elina Fuchs (joint with the University of Hannover, Topic: "Particle Physics Beyond the Standard Model"). This is only one of the many manifestations of the Theory Group's continued success in attracting third party funding. Additionally, one should emphasize the ERC Consolidator Grants of Frank Tackmann and Elli Pomoni, the Emmy Noether group of Till Bargheer, as well as, very importantly, the positive funding decision on SFB 1624 String Theory/Mathematics. It is extremely impressive that, in total, more than half of the PhD and postdoc positions in DESY Theory are due to third party funding. This is even more remarkable given that permanent DESY staff may not apply for standard DFG grants.

We note that **Andreas Ringwald**, who has contributed very essentially to DESY's excellent reputation in axion physics and related areas, will retire very soon – in January 2025. To fill this key position as soon as possible, the Theory Group is trying to attract someone who would bring in associated third party funding for the first years.

The building for the **Wolfgang Pauli Center** will be rented, an architect has been hired, and a first proposal is expected in May 2024.

Comments

DESY Theory continues to be of **central importance for the world-wide visibility** and the connectedness of particle theory in Germany, given that most German universities cannot afford a particle theory group of this size and breadth. The Theory group also enhances the international reputation of the whole Laboratory and strengthens its ties with Hamburg University, being in total relatively inexpensive compared to most experimental efforts aiming at a comparable world-wide impact. DESY Theory plays a central role in the **Quantum Universe excellence cluster**.

In spite of **last year's severe cuts**, the Theory Group has continued to do very well both in terms of its spirit, its science output and, as emphasized above, in attracting third-part funding. This is impressive but it is also clear that everything possible should be done to avoid

any further cuts since the ability to function (and to attract external funding) will otherwise be compromised. In other words, the increasing dependence on external funding for PhDs and postdocs is creating a dangerous vulnerability on the essential scientific activities of the group. The committee supports the plan to **replace Andreas Ringwald** – a world leading figure in axion physics (the latter being as central research theme of the DESY laboratory)–with a young researcher or a young or established female researcher bringing in associated funding for the first years. Excellent possibilities for attracting third party funding in such cases exist. However, focusing exclusively on this option has risks. The alternative option of hiring –if possible-- an already established more senior person or a top junior –male or female-- who at this moment does not have their own grant should not be dismissed prematurely. DESY is now a world flagship in axion and ALP physics and this success calls for extraordinary efforts to ensure an appropriate leadership position also in the corresponding theoretical arena.
The vision originally associated with the **Wolfgang Pauli Center deserves high priority**. The risk that --due to the significant delays and the financial problems – the strategic importance of the center is forgotten and it turns merely into office space for the theorists should be avoided.

Identification of critical issues

No critical issues identified.

Specific recommendations for Theory

DESY Theory is doing excellent work and it deserves a central place within and the continued support by the Laboratory.
Hiring an excellent theorist as a successor of Andrea Ringwald is a high-priority task for the Theory Group and for the Laboratory as a whole. It would be very desirable if the options of hiring an established senior or a young rising star without a personal grant could also be considered and vigorously explored.
The grand vision originally associated with the Wolfgang Pauli Center should be upheld. It can and should be much more than merely office space for the particle theorists working at DESY. We emphasize the key role of additional facilities (high seminar room for 100+ people, "research hostel" and "visitor centre", see pervious PRC report). This is, among many other reasons, important for attracting top junior talent and research groups with third party funding, and for the interaction with Hamburg University, including for the successful application for an extension of the Quantum Universe excellence cluster. Moreover, it would be ideal if the building could accommodate both theorists and experimentalists, so as to create an environment where unprepared and informal encounters can happen and seed truly new ideas and breakthrough discoveries.

FTX

Findings

The **FTX group serves an important purpose at DESY** and in the (inter)national community, as it provides interdisciplinary technology and services, and seeds future experiments and instrumentation. The group also serves in several key leadership positions for future development for the HEP community at large. Previous R&D investments continue to bear fruit for a number of projects (e.g. LUXE, CMS upgrade - HGCAL). FTX staff provide and maintain research infrastructure such as the test beams and computing frameworks, and work on facilities design and operations, e.g. FLASHForward. Finally, the FTX group also drives a number of high-impact science education and outreach activities, such as the DESY Heidelberg Testbeam School.
The PRC observed **good progress on all fronts**. For example, the Science with Lepton Beams group continues its leading role in the ECFA study on Higgs/top/EW factories and has been driving the submission of the LUXE TDR. LEAP, the Polarised Electrons from Laser Plasma Acceleration Project (with MPA), with relevance for HALHF, has been pushed forward. The

Advanced Software group leads the Key4HEP and ILCSoft efforts and does fast simulation in highly granular calorimeters using ML algorithms. This work is supported by a number of third-party funding sources. The Test Beam group has integrated new telescopes, and user demand and performance remain very high. The DTA group works on a range of important calorimetry hardware, simulation, and software issues and acts as a central partner in German (BMBF funded High-D) as well as French-German (ANR-DFG funded Calo5D, CNRS-Helmholtz funded DMLab) consortia.
The **plasma wakefield R&D group** is making good progress and has been instrumental in developing a new Higgs factory machine concept (HALHF) using plasma acceleration to accelerate electrons to 500 GeV. The HALHF concept is being followed up also on the physics and detector side. A new and promising study along with the M division considers use of the European XFEL for plasma wakefield experiments.
Staffing levels are critically low across the board, for students, engineering, and scientists. The effects will be seen soon, for example in the SLB group, as students who have worked on future Higgs studies, detector optimization and high-level reconstruction, are graduating and will not be replaced. It is also rather urgent for the software frameworks effort. DESY has an important mandate to provide support to German Universities working in this field. In the present situation departures not replaced will hurt some parts of the activities more than others, and with limiting hiring possibilities imbalances are developing.
Group members have key roles in the recently established Scientific Computing and Detector R&D platforms. These platforms are strategically important for lab wide coordination and knowledge exchange, and also for addressing exploiting scientific and funding opportunities.

Comments

The **FTX group's wide expertise** and the forward-looking R&D are very important for **strategic planning and new initiatives** in upcoming experiments, especially now as planning for future collider experiments is becoming even more concrete than before. Key4HEP is used actively in the international community, and **current staffing levels** will not be sufficient to maintain the service at the current level.
The **test beam facility** continues to be a critical community and outreach service and is aligned with the core mission of DESY. It is a major asset for detector R&D and serves many groups at DESY and internationally. It is important to maintain such a facility also in the future. This will requiring a coordinated approach with the PETRA IV implementation and schedule and will be challenging in certain scenarios of the yet to be defined PETRA IV injector chain.
Finally, two more general comments:

- The beams at DESY have performances and parameters that offer unique scientific opportunities for on-site world-leading experiments and studies in HEP. LUXE using an extracted beam for the European XFEL and the demonstrations in FLASHForward of beam-quality and gradients for plasma acceleration, needed for staging plasma acceleration elements to reach high energies, as e.g. in HALHF, are good examples, and other possibilities could be considered.
- In addition to FLASHForward activities, the FTX group, building on their expertise in physics studies, detector and software developments for future colliders, is very well situated to analyze these opportunities, and possibly initiate activities to exploit them.

Identification of critical issues and key recommendation

Staffing levels are critically low for future Higgs studies, detector optimization and high-level reconstruction. With the ESPP update coming up this is an area where DESY's strong role should not be lost. With future collider-oriented detector R&D activities gradually ramping up at German universities and in the newly created DRD collaboration context, central support for the physics case and detector optimisation studies based on a well-maintained software framework is an increasingly important complement. It is indispensable to ensure low enough entry thresholds for young researchers and to prepare for a balanced participation and impact of the German HEP community in a Higgs factory project after the LHC. It is recommended to consolidate and strengthen the support for central software frameworks, to maintain a healthy in-house activity

of Higgs factory physics studies and to support DESY's main thrusts of detector development in highly granular calorimetry and silicon-based tracking.

Specific recommendations for FTX

Maintain, even if at reduced level compared to before, the world leading expertise on future colliders, from physics to software.

IT

Findings

The PRC recognizes the work done by IT in the past period, pragmatically addressing a number of pressing challenges without the support of **an IT group leader**. This last point (a director) has been addressed as well, with **P. Neumann starting** the week after the PRC meeting. The PRC looks forward to the fresh perspective he brings to IT.
The PRC commends DESY IT for delivering computing resources and starting new initiatives during these challenging times, the challenges being both financial (budgets) and organisational (changes in the German HEP community with respect to the upcoming HL-LHC, and computing structures such as involvement of NHR centers). Financially, IT has taken creative measures to achieve pledged resource levels despite the funding gap.
Discussions with other German labs, with the universities and NHR have led to **a multi-year plan for the transition to the new scheme** for academic / scientific computing for HEP in Germany. The universities have indicated their wish for DESY involvement. The PRC applauds this move. DESY IT has the expertise, and their up-front involvement with the deployment has the potential to minimise the future manpower requirements on both DESY IT and NHR staff, a risk identified in earlier PRC meetings.
Regarding the person power, which will receive additional pressure from the transition just described, the PRC applauds the efforts to consolidate the computing discussions within DESY.
The PRC looks forward to results from the new **FH scientific computing platform**.

Comments

The PRC is pleased to hear that **funding for pledge provision and extending the network capacities** for 2025 and 2026 is secured. This will ensure smooth continuation of pledge provisions in 2025 and 2026, and to expand network capacities in preparation for HL-LHC, supported by the data challenges.
Work (prototyping, testing, design) related to the collaboration with **NHR centers** should be started this year already, as such transitions always take longer than expected. The tests should exercise the full chain (not just simulation) as the interplay between computing and data generally generate the most difficult challenges.
Given current developments such as the transition of **AAI infrastructure** to tokens, we urge close collaboration between the smaller (in-house) experiments and IT, to find pragmatic, yet integrated solutions and avoid ad hoc improvisations to maintain the continuity of experiment computing infrastructures.
We encourage to develop an **integral view of DESY computing**, taking into account the HEP international, national, and local computing, Helmholtz contributions, and the in-house experiments - of both smaller resource envelopes (e.g. ALPS II, BabyIAXO and MADMAX) and larger (Photon Science) as well as key collaborative partners such as the European XFEL. The FH Scientific Computing Platform should substantially contribute to this integral view.

Identification of critical issues

None.

Specific recommendations for IT

- PRC recommends a prompt start in DESY IT for the work on incorporating the NHR centers into the German HEP computing landscape.
- PRC also recommends timely contacts between IT and in-house experiments regarding time-critical computing-infrastructure transitions.