Report from DESY

Joachim Mnich (DESY)
Plenary ECFA Meeting
20 November 2020
• DESY colleagues coping well with the Covid-19 crisis

• The laboratory is operational under strict safety measures and at somewhat reduced pace

• Accelerators run, work on detectors going on, workshops open, etc.

• A few examples below
European XFEL Status

In operation since 2017, service to experiments at all 6 photon beam lines since beginning of 2019

Superconducting linac operation matured, all design parameters achieved

- Maximum energy 17.5 GeV
- 27000 electron bunches/second in 10 Hz burst mode
- Very flexible beam distribution into 3 beamlines with up to 4.5 MHz switching frequency and arbitrary bunch patterns

Three FELs in parallel operation (6 experiments in 12 h shifts)

- Soft X-Ray (SASE 3): 0.6 – 2.8 keV, up to 10 mJ/photon pulse
- Hard X-Ray (SASE1/2): 6 – 14 keV, up to 4 mJ/photon pulse
- 30 keV demonstrated

About 6500 hours yearly linac operation, about 4000 (x3) hours of scheduled photon delivery for experiment commissioning, in-house research, and user service

COVID-19 caused ‘deep’ shut-down of about 8 weeks

Extended start-up afterwards, back to safe routine operation since summer shut-down 2020
**Future: PETRA IV TDR Underway**

Aiming at project completion beginning of 2027

- Synchrotron light source at the diffraction limit
- Upgrade and build new beamlines
- New experimental hall in the west
- CDR published in 2019, TDR underway

**New Injector chain**
- DESY IV as baseline
- Impact on DESY test beam facility
- Linear Plasma injector as second injector

**Current Timeline**
- TDR End 2022
- 2025 End Petra III /Start of Construction
- 2027 PETRA IV Startup
DESY Particle Physics Strategy

Very successful Helmholtz review in January 2020

In line with the updated European Strategy

Leading contributions to global collider projects (CERN, KEK)

LHC experiments @ CERN

Belle II @ KEK (Japan)

Axion experiments
Strong-field QED

Attractive on-site program

Broad theory portfolio

Collider Physics
Particle Cosmology
Lattice Gauge Theory
String Theory

Preparation of future facilities / experiments

International Linear Collider

DESY. Report from DESY | 20 Nov 2020 | Joachim Mnich
ATLAS High-Lumi Upgrade

Important steps towards final modules

Full petal side with strip modules built (partially with dummy sensors)
• Successful simultaneously communication with all modules
• Measured noise for all the modules within specifications
• First module with final chip-set built at DESY

Full petal with all module types (prototype readout chip)
Dee Prototype for Tracker Upgrade
Full activity in DAF in 2020, despite Covid-19 pandemic

Metrology of Dee: Inserts are mostly positioned within 200 μm tolerance (green arrows); only one outlier (red arrow)
SiPM-on-Tile technology where radiation levels permit
- common r/o ASIC for Si and SiPM: HGCROC
- spin-off from CALICE

Development of tile modules
- active elements with ASIC, DCDC, SiPMs, scintillator

Tile module prototype in the DESY Testbeam
- custom SiPMs from Hamamatsu in thermally conductive package
- injection-moulded tiles from Russia, automatically wrapped at DESY
- first particle signals with HGCROC

Development of production procedures
- reflector foil handling, tile wrapping, module assembly
- following successful applications for Russian funds, prepare for tile module assembly at DESY with Russian groups
- preparations at DESY on-going
Axion Experiments @ DESY
Purely with ALPS II, solar with BabyIAXO, or galactic with (i)MADMAX

ALPS II (shining light-through-a-wall)
24 modified superconducting dipoles from the former HERA proton accelerator installed in a straight section of the HERA tunnel.
Commissioning of high finesse long baseline optical cavities will start early 2021.
First data run in autumn 2021.

BabyIAXO (solar axions)
Ready to start construction, different options for sites at DESY.
Funding nearly secured, MoUs under preparation.
Expect to start data taking in 2025.

(i)MADMAX
Would be located in the iron yoke of the former HERA experiment H1.
Decided to go for an intermediate stage iMADMAX first.
ALPS II: Last Magnet (of 24) at HERA-North
ALPS II schedule:
March 2021: close vacuum system, start of optics commissioning
October 2021: dipoles ready for operation, start of axion search
BabyIAXO figure of merit:

(field-strength \cdot length)^2 \cdot \text{aperture} 
\approx 242 \cdot T^2 m^4 \approx 0.1 \cdot \text{IAXO} \approx 10 \cdot \text{CAST}

Status:

- R&D and design well advanced
- Ready to start purchase of long-lead items.
- DESY funding secured.
- Positive discussion with CERN on design & construction of the magnet (draft MoU).
- Site at DESY still unclear due to PETRA IV preparation planning.

BabyIAXO data taking could start 2024/25
MAGnetized Disk and Mirror Axion eXperiment MADMAX

The magnet challenge

Unique approach to look for dark matter in a theoretical favored region not accessible with other techniques:
- Place a “booster” of up to 80 dielectric disks of 1 m$^2$ in a 10 T magnetic dipole field.
- Main challenge: magnet design for figure of merit FoM $\approx 100$ T$^2$m$^2$.

Status:
- Design study for magnet successfully concluded.
- “Booster” and detector R&D ongoing.
- Test of booster in CERN's MOPURGO magnet (1.6 T) in 2022.
- MADMAX would be sited in the iron yoke of the H1 experiment in the HERA North hall.

Data taking could start 2026/27.
Colliding High-Energy Photons / Electrons With Intense Lasers

International Collaboration

Currently 38 people with 13 institutions – and growing:

- Tel Aviv University, Tel Aviv (Israel)
- Max Planck Institute for Structure and Dynamics of Matter, Hamburg
- Deutsches Elektronen-Synchrotron (DESY), Hamburg
- Institute for Nuclear Research NASU (KINR), Kiew (Ukraine)
- Weizmann Institute of Science, Rehovot (Israel)
- Helmholtz Institut Jena, Jena
- University College London, London (UK)
- Albert-Ludwigs-Universität Freiburg, Freiburg (Germany)
- University of Plymouth, Plymouth (UK)
- Universität Hamburg, Hamburg
- Queens University Belfast, Belfast (UK)
- Friedrich Schiller Universität Jena, Jena
- AGH, Cracow (Poland)

Discussions ongoing with Marseille, Orsay und Saclay (France), Gothenburg (Sweden), Skoltech (Russia), Padova (Italy)

Preparing CDR by the end of the year
- Will include initial (low-cost) and ultimate design
The Wolfgang Pauli Centre (WPC)

Progressing towards construction

WPC: bundle theory efforts in particle physics, cosmology, astroparticle physics, ultrafast, cold and condensed matter physics, mathematical physics,• comprising all DESY theory in Hamburg and Zeuthen + (inter)national partners.
• Mission: foster interdisciplinary research addressing fundamental challenges;
• Scientific evaluation of the WPC strategy completed – summary of reports compiled in agreement with the reviewers.

The WPC building:
• Approx. 170 persons from DESY theory and Hamburg University
• Open space / communication areas, seminar rooms, „Research hotel“
• MoU DESY and Hamburg University in preparation

Hamburg Prize for Theoretical Physics 2020 awarded to Prof. Valery Rubakov

• Due to the Covid-19 pandemic, the award ceremony (originally scheduled for 11 Nov 2020) and the WPC symposium (planned 11-13 Nov) postponed to November 2021 (dates to be fixed).
DESY II Testbeam Facility

Highlights and improvements

Improvements

- New target stations for even higher availability
- Primary Extraction beam line
  Preparations are on-going in the old extraction line to DORIS

Education and outreach

- Successfully hosted the EDIT 2020 detector school
- In collaboration with CERN hosted the 2020 BL4S edition
  - Again 197 team with 1400 high school students from 47 countries applied
  - Two winning teams from Berlin and Geneva
  - Remote participation by Geneva group
- Teacher Education programme in October 2020
  Enables high school teachers to conduct experiments at the test beam
DESY II has been again running again very smoothly: 99.5% availability

The DESY II Test Beam facility
Fully booked until the Covid-19 shutdown on 18 March
Successful restart on June 1st in a Corona-safe mode
• Reduced team sizes, distancing measures, improved hygiene
• Rescheduling a lot of test beam slots to maximize beam for the community
• Employing remote-access tools
Travel restrictions lead to a lot of cancellations starting in September
• Use of facility down to 66%

2021: Again almost fully booked
• Early slots not as popular, lots of groups fear travel restrictions
• Telescopes remain popular, >80% of the request want to use a telescope
Towards a global strategy for particle physics

Every three years, the International Committee for Future Accelerators (ICFA) organises a seminar on “Future Perspectives in High Energy Physics”. This is a four-day international exchange of information concentrating on plans for future facilities in the field of particle physics. This by-invitation-only meeting has 250 participants, including directors of most of the world’s major laboratories in our field, senior particle and accelerator physicists, and government science officials from several countries.

ICFA has chosen to have the next seminar, to be held from 4-7 October 2021 in Berlin, Germany. The focus of the seminar will be on the global future of accelerator-based particle physics.

The 13th ICFA Seminar on Future Perspectives in High-Energy Physics is organised by the Deutsches Elektronen-Synchrotron DESY.
**Thank you!**

**Contact**

<table>
<thead>
<tr>
<th><strong>DESY. Deutsches Elektronen-Synchrotron</strong></th>
<th>Joachim Mnich</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.desy.de">www.desy.de</a></td>
<td>DESY Director for Particle Physics</td>
</tr>
<tr>
<td></td>
<td><a href="mailto:Joachim.Mnich@desy.de">Joachim.Mnich@desy.de</a></td>
</tr>
<tr>
<td></td>
<td>(+49) 040 8998 1921 / 3023</td>
</tr>
</tbody>
</table>
Backup
European XFEL

Status in a nutshell

Now in operation ~3 years (since 2017), parallel lasing in three FELs (SASE1, 2 & 3)

Maximum electron beam energy 17.6 GeV
- Re-established / checked Feb 2020, sufficient availability margin for 16.5 GeV user operations
- SASE bunch patterns / timing very flexible

LINAC specifics
- Max average operational gradient ~23.6 MV/m (spread 15 – 30 MV/m, 22 out of 776 installed SRF cavities detuned)
- Piezo active compensation of Lorentz force (detuning) now on all cavities
  → higher operational gradients, higher availability
  → Very stable system

2020 user run suspended, but restarting again

<table>
<thead>
<tr>
<th>Operation hours</th>
<th>7000 h/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-beam energy</td>
<td></td>
</tr>
<tr>
<td>Nominal</td>
<td>14.5 GeV</td>
</tr>
<tr>
<td>Other</td>
<td>11.5 GeV, 16.5 GeV</td>
</tr>
<tr>
<td>SASE energy</td>
<td></td>
</tr>
<tr>
<td>S1 &amp; S2</td>
<td>5.8—20 keV</td>
</tr>
<tr>
<td>S3</td>
<td>0.6—3 keV</td>
</tr>
<tr>
<td>Beam pulse</td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>600 μs</td>
</tr>
<tr>
<td>Machine rep rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10Hz</td>
</tr>
<tr>
<td>Beam rep. rates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.1 / 2.25 / 4.5 MHz</td>
</tr>
<tr>
<td>Bunch charge</td>
<td></td>
</tr>
<tr>
<td>typical</td>
<td>0.25 nC</td>
</tr>
<tr>
<td>E-beam stability</td>
<td></td>
</tr>
<tr>
<td>energy</td>
<td>&lt; 0.1%</td>
</tr>
<tr>
<td>transverse</td>
<td>0.1 σ_{beam}</td>
</tr>
<tr>
<td>timing</td>
<td>~25 fs</td>
</tr>
<tr>
<td>Availability (user runs)</td>
<td></td>
</tr>
<tr>
<td>LINAC</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>SASE</td>
<td>&gt;85%</td>
</tr>
</tbody>
</table>
KALDERA
DESY embarking on new class of drive laser

3kW average with >100 TW peak at 1 kHz
Why?
• Near term: PLASMED X, VUV FEL
• Longer term: injection into PETRA IV
What?
• GeV-level beams at 1 kHz from LP
• FEL-suitable current and energy
• Stability through active feedback
• Technology towards PETRA IV injection
How?
• KALDERA laser with kHz plasma sources
When?
• 2020-2025 phased construction

MAC October 23-24, 2019
"The MAC congratulates DESY for proposing KALDERA as the next crucial step to turn LPA from a concept to a technology. The MAC fully supports these efforts to take the world lead in this field."

[Images and diagrams related to KALDERA and PETRA IV]
Timeline of Planning

<table>
<thead>
<tr>
<th>Year</th>
<th>Project/Programme</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>LHC operation &amp; analysis</td>
<td>analysis</td>
</tr>
<tr>
<td>2021</td>
<td>HL-LHC detector construction</td>
<td>HL-LHC operation &amp; analysis</td>
</tr>
<tr>
<td>2022</td>
<td>ALPS II</td>
<td>setup</td>
</tr>
<tr>
<td>2023</td>
<td>WPC</td>
<td>planning &amp; construction</td>
</tr>
<tr>
<td>2024</td>
<td>BabyIAXO</td>
<td>R&amp;D &amp; setup</td>
</tr>
<tr>
<td>2025</td>
<td>IAXO</td>
<td>R&amp;D &amp; setup</td>
</tr>
<tr>
<td>2026</td>
<td>MADMAX</td>
<td>R&amp;D &amp; setup</td>
</tr>
<tr>
<td>2027</td>
<td>LUXE</td>
<td>R&amp;D &amp; setup</td>
</tr>
<tr>
<td>2028</td>
<td>Next collider experiment</td>
<td>R&amp;D &amp; setup</td>
</tr>
<tr>
<td>2029</td>
<td>ALPS II (2022)</td>
<td>On-site programme</td>
</tr>
<tr>
<td>2030</td>
<td>LUXE (2023?)</td>
<td>BabyIAXO (2024?)</td>
</tr>
</tbody>
</table>
HGCAL Tilemodule Centre

Preparations in progress

Collaborators from Russia
• to start with 3 people in November
• work on SiPM characterisation
  and preparation of QC

Foil cutting
• use ATLAS machine

Tile wrapping
• sound-proof room in DAF

Module assembly
• room with separate entrance
  in DAF
• Pick & Place machine delivered

Cosmic tests
• HERA Hall West
DESY Participation in Belle II

Key roles in all aspects of the experiment

SuperKEKB + Belle II offer high potential for breakthrough results
• So far accumulated 74 fb\(^{-1}\) of data for physics analysis
• Recent update of SuperKEKB roadmap: upgrade of final focus system in 2026 ➔ reach 50 ab\(^{-1}\) by 2031
DESY fully committed to make this project a success by providing unique expertise

Detector construction & operation: PXD operation & understanding of installed pixel detector, and preparing tests and installation of full detector in 2022
• Strong engagement in machine-detector interface task force to understand and mitigate background issues in sub-detectors and improve lumi performance

Software and computing: leading roles in reco&calibration algorithms for tracking+calorimetry, and providing essential tools and services for vital collaborative activities
• Key grid resource contributions for MC, from 2021 onwards Belle II raw data centre, ...

Physics performance and analysis:
• leading efforts in monitoring and improving detector performance for analysis
• DESY convenors for 4 out of 10 physics WGs, leading contributions to first physics papers.
Axion Physics at DESY
Developing a new focal activity

Huge phase space for axions / ALPs with different motivations

Three detection approaches:

- Lab: L-S-W ALPS-II
- Helioscope (baby)IAXO
- Haloscope MADMAX

DESY involved in all three.
LUXE („Laser und XFEL“ Experiment)

Colliding high-energy photons/electrons with lasers

Scientific goal: Probe quantum physics in novel regime
- Observe transition from perturbative to non-pert. Regime; reach Schwinger critical field value for the first time!

\[ \varepsilon_{\text{crit}} = \frac{m_e^2 c^3}{\hbar e} \simeq 1.3 \cdot 10^{18} \text{ V/m} \]

- Now possible thanks to new laser developments!

Collaboration of particle, accelerator and laser physicists
- Recommended by EPPSU; 14 institutions (and growing)

European XFEL and DESY unique place!
Conceptual design report (CDR) by end of 2020!