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PETRA III OPERATIONAL PERFORMANCE AND AVAILABILITY

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Abstract

At DESY the Synchrotron Light Source PETRA III offers scientists outstanding opportunities for experiments with hard X-rays of exceptionally high brilliance since 2009. The light source is operated mainly in two operation modes with 480 and 40 bunches at a beam energy of 6 GeV. With the completion of the last milestone of the extension project in summer 2021, which brought the new dipole beamline P66 into operation, 2022 is the first year where almost 5000 hours of user run time could be scheduled. This paper will review the statistics of availability and failures over the years and provides a detailed description of the operation in 2021. Additionally, an outlook for the next runs is given.

INTRODUCTION

The Synchrotron Light Source PETRA III is one of the core facilities at DESY offering each year more than 2000 users outstanding opportunities for experiments with hard X-rays of exceptionally high brilliance. In the seventies PETRA was originally built as an $e^- - e^+$ collider, which was later used as a pre-accelerator for the HERA lepton-hadron collider. After the end of the HERA collider physics program in 2007 the PETRA ring was converted into a dedicated 3rd generation synchrotron radiation facility, called PETRA III [1].

Beam operation started in 2009 [2] and 14 beamlines in the Max von Laue hall are operational since 2011. Because of the high demand for additional beamlines, the lattice of the ring was redesigned to accommodate additional beamlines in the framework of the PETRA III extension project. In 2014 two tunnel sections of about 80 m each in the North and the East of the PETRA ring were completely reconstructed and new experimental halls were build. The storage ring was recommissioned in 2015 [3]. The present layout of PETRA III is shown in Fig. 1, including the experimental halls of the extension project: Paul P. Ewald in the North and Ada Yonath in the East. Presently, 25 beamlines are operational. The operational parameters are summarized in Table 1. In total 80 m of wigglers are installed in the straight sections in the West and the North to achieve the horizontal emittance of 1.3 nm.

In the framework of the PETRA IV project, it is foreseen to upgrade the existing synchrotron radiation source PETRA III to a synchrotron radiation source with an ultra-low emittance, based on a multi-bend achromat, which was pioneered at MAX IV [4] and ESRF-EBS [5, 6]. Unique new experiments and scientific opportunities will be made possible. The project includes the construction of a new experimental building in the West of the PETRA ring. The conceptual design report was published in 2019 [7]. Presently, the project team is preparing a technical design report [8].

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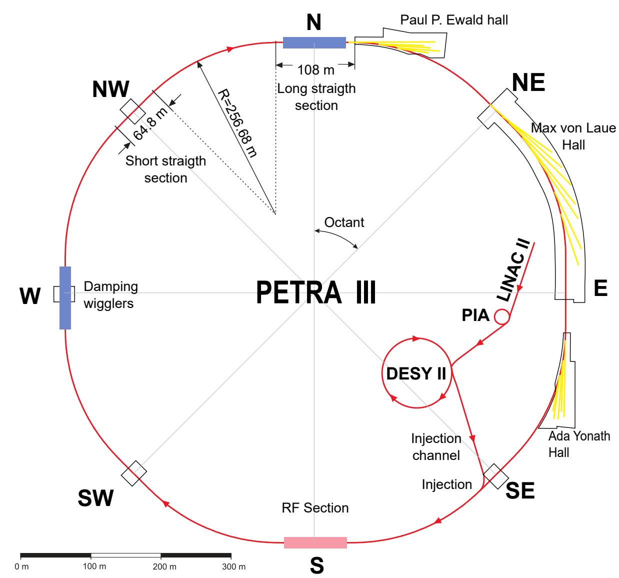

Figure 1: Layout of PETRA III.

Table 1: PETRA III Parameters

Parameter	PETRA III	
Energy /GeV	6	
Circumference /m	2304.0	
Total current /mA	120	100
Number of bunches	480	40
Bunch Population /10^{10}	0.5	12.0
Emittance (horz. /vert.) /nm	1.3 / 0.01	

INSTALLATION OF A NEW DIPOLE BEAMLINE

During the winter shut-down 2020–2021 and in the summer shut-down 2021, a new beamline P66 was successfully installed close to the Paul P. Ewald hall in the North East of the PETRA ring, see Fig. 2. The beamline P66 is the first dipole beamline of the PETRA III facility, dedicated to VUV luminescence and reflection spectroscopy experiments. Thanks to essential efforts of all technical groups, all shut-down activities could be finished within the schedule. First synchrotron light from the dipole was guided to the absorber of the beamline on 30 July 2021. A mirror reflects the light then from the accelerator level upwards to the experimental hutch, which is located in building 47k on top

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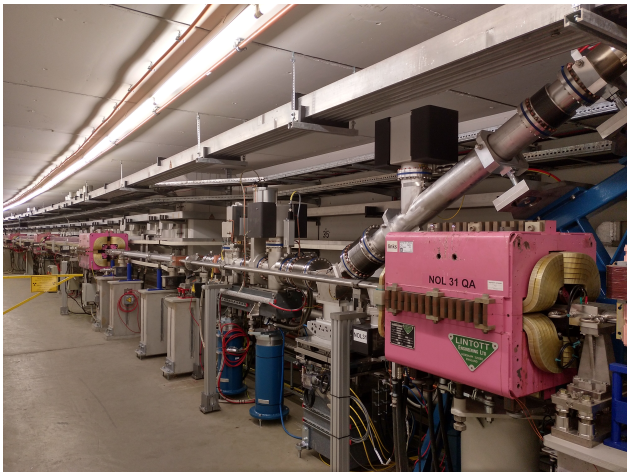

Figure 2: Dipole magnet and front-end components of the dipole beam P66 in the PETRA III tunnel.

of the PETRA III tunnel between the FLASH experimental hall 'Kai Siegbahn' and PETRA III experimental hall 'Max von Laue'.

USER OPERATION IN 2021

After the 2020/21 winter shut-down regular user operation was resumed on 15 March 2021, after a short commissioning period of about two weeks. Originally, 4824 h of beam time were planned for the user run. Nevertheless, due to the COVID19 pandemic the schedule had to be revised to accommodate a home office period at the beginning of January, resulting in a delayed start of the activities in the winter shut-down. Fortunately, any further impact of the pandemic on the installation work and the user operation could be mitigated with additional safety measures. Considering the challenging condition of a pandemic in 2021, a good resilience of the user operation of PETRA III was achieved and finally 4632 h of beam time could be scheduled for the user run. In addition to the regular user run, 1003 h of test run time could be planned for the users.

The necessary maintenance was done in five dedicated service periods distributed over the year and additionally during the three-week long summer shut-down period. On Wednesdays, user operation was interrupted by weekly regular maintenance or machine development activities, which is usually followed by a test run until the next morning.

Operation Modes

During user runs, the storage ring was operated in two distinct modes characterized by their bunch spacing. In the "continuous mode" 120 mA were filled in 480 evenly distributed bunches, corresponding to a bunch spacing of 16 ns. The "timing mode" allows users to perform time-resolved experiments and is thus characterized by a considerably larger bunch spacing of 192 ns, corresponding to 40 evenly distributed bunches with a total current of 100 mA.

Apart from the different filling patterns, two optics configurations are provided. While the so-called 'high-beta optics'

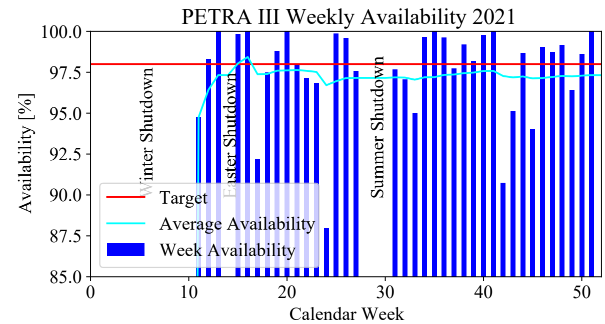

Figure 3: PETRA III availability per calendar week in 2021.

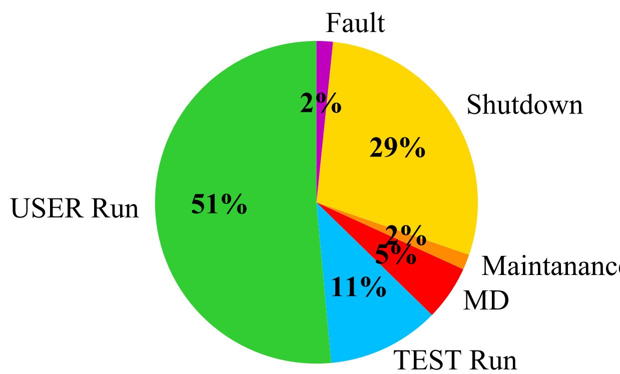

Figure 4: The distribution of the machine time during the year 2021.

is the standard configuration and used for the main part of the user run, the 'low-beta optics' is setup to deliver a more narrow photon beam to the beamline P07, which enables this beamline to perform different kinds of user experiments, usually only for a few weeks per year. In both optics configurations either filling pattern is used. The beta functions at the other beamlines remain unchanged.

Availability

High reliability is one of the key requirements for a synchrotron radiation facility. The key performance indicators are availability and mean time between failures (MTBF). In 2020, the average availability was 98.8%, which was a new record for PETRA III. Unfortunately, this high level of availability could not be maintained in 2021, where the scheduled 4632 h of beam time were delivered to the users with a good but not excellent availability of 97.3%.

The evolution of the achieved availability during user run is presented in Fig. 3 as a function of the calendar week. The light blue line shows the average availability until the current week. During 22 out of 37 operational weeks the target of 98% (red horizontal line) was reached or exceeded. During six weeks even 100% could be achieved. Only a few, but major faults significantly affected the average availability in 2021: a water leak in the injectors in week 17, a complicated problem with the multibunch-feedback electronics in

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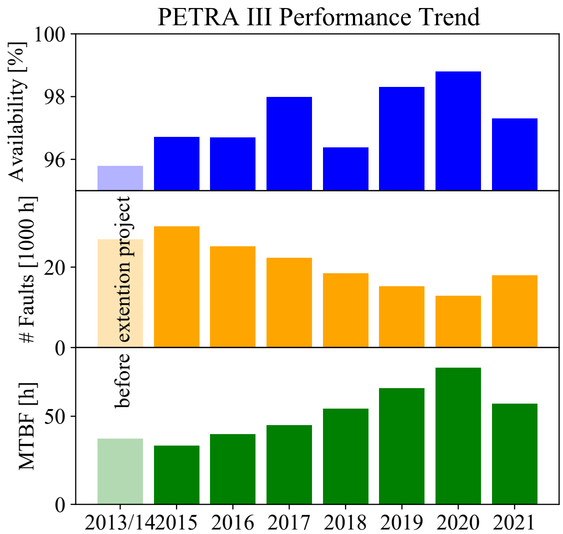

Figure 5: PETRA III performance trend. Top: availability, middle: number of faults per 1000 h, bottom: MTBF. All quantities are given during user run time only.

week 24, a series of power glitches in weeks 31-33, a fault of the remote emergency system in week 42 and a reoccurring problem with the switches of the injection kicker causing several beam dumps between weeks 43-49. The final distribution of the achieved time for the different machine states is shown in Fig. 4. In total 62% of the year beam was delivered to the experiments, out of which more than 50% of was spent in user run.

In Fig. 5 the evolution of the yearly availability, number of faults per 1000 h and the MTBF during user run time is shown since the last year before the extension project was implemented in 2015. A clear trend of continuous performance improvement from one year to the next could be achieved. This availability statistics are based on a metric that is in agreement with internationally recognised performance characteristics, and does not include 'warm-up' time after each fault.

STUDIES AND PLANS

Currently several studies are performed at PETRA III that support the technical design for the planned upgrade to PETRA IV. The areas of particular interest include beam stability concepts [9], accelerator physics and beam dynamics [10], but also prototyping for technical subsystems [11]. In particular, in the summer shut-down 2022, it is planned to prepare the installation of a new single cell cavity and new beam current monitors to test prototype components with beam for the upgrade project PETRA IV.

CONCLUSION

The Synchrotron Light Source PETRA III, one of the core facilities at DESY, is operated with a high availability in two operation modes with 480 and 40 bunches at a beam energy of 6 GeV. The technical design of the upgrade project PETRA IV is strongly supported with a study program.

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