PETRA III OPERATION AND STUDIES IN 2022

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Abstract

The Synchrotron Light Source PETRA III is one of the core facilities at DESY offering each year more than 2000 users unique opportunities for experiments with hard X-rays of a very high brilliance. The light source is operated mainly in two operation modes with 480 and 40 bunches at a beam energy of 6 GeV. The availability and failure statistics is reviewed for the year 2022 in comparison with previous years. Studies at PETRA III are supporting the technical design phase for the planned upgrade PETRA IV. Several diagnostic devices have been tested and the installation of a cavity has been prepared. Furthermore, the operation of PETRA III at 5 GeV has been studied with the goal to reduce the electric power consumption of the accelerator. But a 5 GeV test run for all beam lines at PETRA III showed that this operation mode is impairing the experimental opportunities due to the lower brilliance and photon flux for hard X-rays.

INTRODUCTION

The Synchrotron Light Source PETRA III is one of the core facilities at DESY offering each year more than 2000 users unique opportunities for experiments with hard X-rays of a very high brilliance. The light source is operated mainly in two operation modes with 480 and 40 bunches at a beam energy of 6 GeV. The operational parameters are summarized in Table 1. The PETRA storage ring was originally built as an $e^- - e^+$ collider, later used as an pre-accelerator for the HERA lepton-hadron collider, and finally 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. In 2014, the PETRA III extension project started to accommodate additional beamlines in two new experimental halls in the North and the East of the PETRA ring. The PETRA III storage ring encircles the DESY site, see Fig. 1.

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}	1.2	12.0
Emittance (horz. /vert.) /nm	1.3 / 0.01	

In the framework of the PETRA IV project [4], it is foreseen to upgrade the existing synchrotron radiation source PETRA III to a synchrotron radiation source with an ultra-low emittance. 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. Several activities at PETRA III support the technical design of PETRA IV.

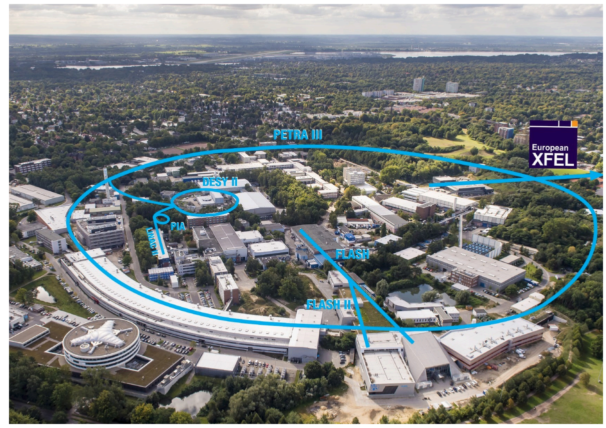

Figure 1: PETRA III at the DESY site.

OPERATION IN 2022

Regular user operation resumed on 18 February 2022 after a short commissioning period of about two weeks. In total, 4896 h of beam time were scheduled for the user run, which were complemented with 1040 h of test run time, which is used to set-up user experiments. Necessary maintenance was done in six dedicated service periods distributed over the year and additionally during the three and a half-week-long summer shutdown, which was also used to refurbish a cooling tower. On Wednesdays, user operation was interrupted by weekly regular maintenance or machine development activities as well as test runs for 24 h in total. The distribution of the different machine states in 2022 is shown in Fig. 2.

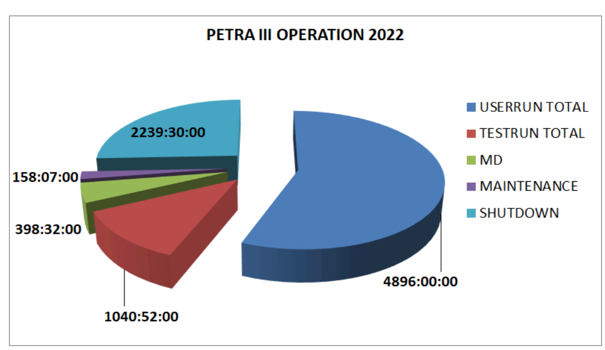

Figure 2: PETRA III operation.

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During user runs, the storage ring was operated in two distinct modes, characterised by their bunch spacing of either 16 ns (480 bunches) or 192 ns (40 bunches). In 2022, 51 % of the user time was allocated to the 480-bunch mode and 49 % to the 40-bunch mode.

Availability and MTBF

In 2022, the average availability was 98.3 %, which is a very good achievement, and an improvement compared to 2021. The long-time development of the availability of PETRA III during user runs is shown in Fig. 3. The average mean time between failures (MTBF) in 2022 was 58 h, and the mean time to recover (MTTR) was about 1 h. All faults were carefully analysed within an internal review process based on an essential effort from all the technical groups involved.

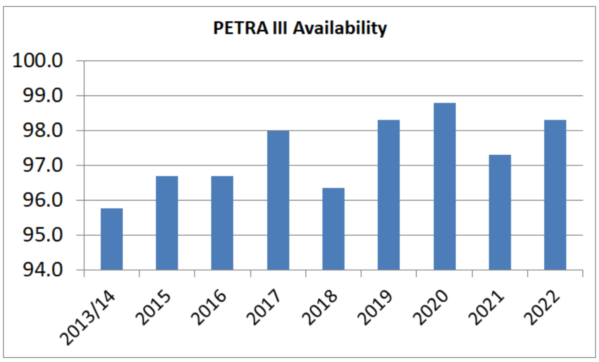

Figure 3: PETRA III availability

Operation at 5 GeV

Several measures have been studied to save electric energy to cope with the skyrocketing electric energy market in 2022. On 13 and 14 October 2022, 5 GeV operation of PETRA III was set-up for a test run to verify the energy saving of about 20 % compared to 6 GeV operation, and to investigate the conditions at the beamlines. Unfortunately, the 5 GeV operation mode is impairing the experimental opportunities due to the lower brilliance and photon flux for hard X-rays. Nevertheless, several energy saving measures could be implemented at the injector complex of PETRA III. Furthermore, it is planned to reduce the test run time to the absolutely necessary minimum in 2023.

STUDIES TO SUPPORT THE TECHNICAL DESIGN OF PETRA IV

In 2022, several activities at PETRA III were aiming to support the technical design of PETRA IV, which includes beam dynamics studies, test of new equipment and also improvements and tests of the stability of the existing PETRA III tunnel.

Tunnel Stability

The PETRA tunnel, constructed in 1976, is made of individual tunnel segments of mostly 24 m length. Nowadays, cracks in the walls and floor mark the connection points of the tunnel segments, which clearly indicates that the tunnel segments are moving against each other. At several places the movement is monitored by special movement sensors. During the winter shutdown 2021/22 the connection between tunnel segments in the South-West of the tunnel has been stabilised by reinforcement rods and the injection of a special resin through the tunnel ground plate into the soil under the tunnel. A view of the stabilised segment transition is shown in Fig. 4. Thirty sealed holes housing the reinforcement rods are still visible in the tunnel flour. First measurements with the movement sensors indicate that the movements of the tunnel segments could been significantly reduced (from 80 µm to 20 µm in the vertical plane).

Figure 4: Stabilisation of the transition between two PETRA III tunnel segments.

Test of New Diagnostics

In the summer shutdown 2022 a new vacuum chamber has been installed in the straight section in the South of the PETRA III ring to enable tests of prototype diagnostic equipment for PETRA IV. Two beam current monitors have been installed within this new section, see Fig. 5.

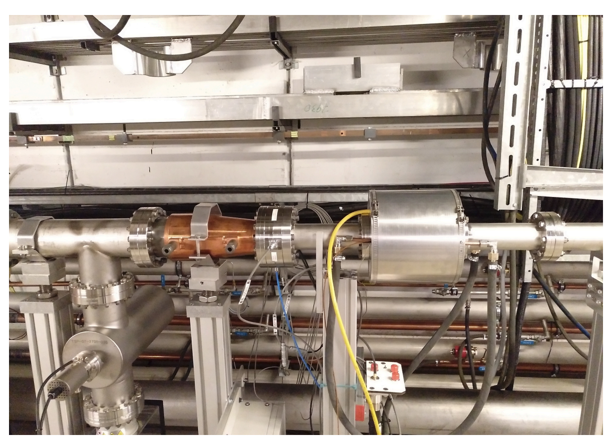

Figure 5: Test of new current monitors in PETRA III.

Girder Movement Test

At the end of the beam operation period in 2022, three study days were dedicated to a girder movement test to support of the design of the PETRA IV girder alignment system. Owing to the lower emittance, PETRA IV [4] will have a factor of two to ten lower alignment and aperture tolerances with respect to PETRA III. The storage ring elements in the lattice of PETRA IV will be placed on girders that mechanically connect and carry a group of elements, such that those can be assembled, transported and aligned as a unit. In order to counteract the misalignment introduced by ground motion and temperature effects, the girders will feature a remote-controlled alignment system.

In PETRA III the Max von Laue Hall is equipped with girders that have a mover systems based on motor controlled eccentric shafts, see Fig. 6. This system has only been used during the initial installation of the storage ring elements in the tunnel in 2009. Movements can only be initiated when locally connecting to the motor controls in the tunnel. This implies that girders cannot be moved while beam is circulating. Nevertheless, an experiment procedure with alternating periods of tunnel access for girder movement and beam operation was implemented to observe the beam orbit response induced corrector settings. During three days five girder position shifts between ± 300 µm in the horizontal plane were evaluated.

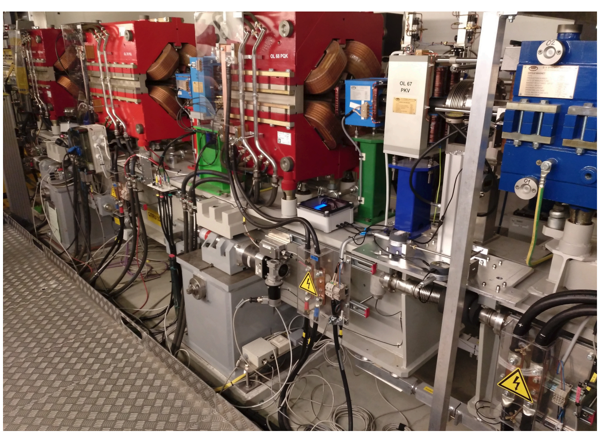

Figure 6: PETRA III Girder in the Max von Laue Hall.

The displacement was performed with the expected precision. However, about 40 % of the girder movement were observed also as shift of the undulator vacuum chamber upstream the girder and on the Beam Position Monitor (BPM) in the center of the girder. Taking this into account, the corrector currents are in good agreement with the expectation [5, 6].

PLANS FOR THE NEXT OPERATION PERIOD

During the winter shutdown 2022/23 a new undulator was installed for the beam line P25 in the Ada Yonath Hall. Furthermore, in the long straight section in the South of PETRA III a PETRA IV prototype single-cell cavity was installed, see Fig. 7. The cavity is based on the 500 MHz HOM damped cavity which was developed within the frame of an EC funded collaboration project by BESSY/ Germany, Daresbury Lab/England, DELTA/Germany, and Tsing Hua University/Taiwan [7].

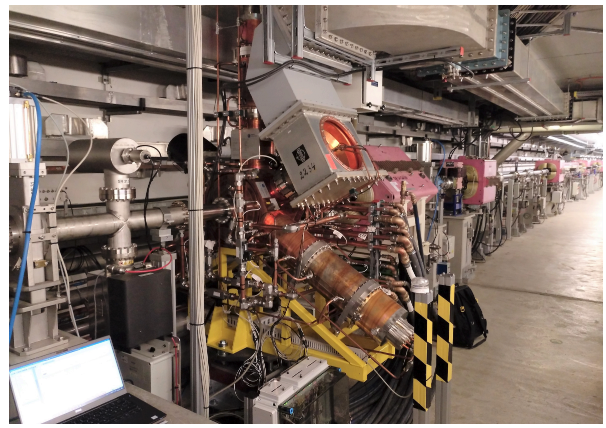

Figure 7: Single cell 500 MHz cavity.

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