

# PETRA III 2019

Operation and Upgrade

Michael Bieler  
ESLS XXVII, Barcelona, 28.11.2019

HELMHOLTZ RESEARCH FOR  
GRAND CHALLENGES

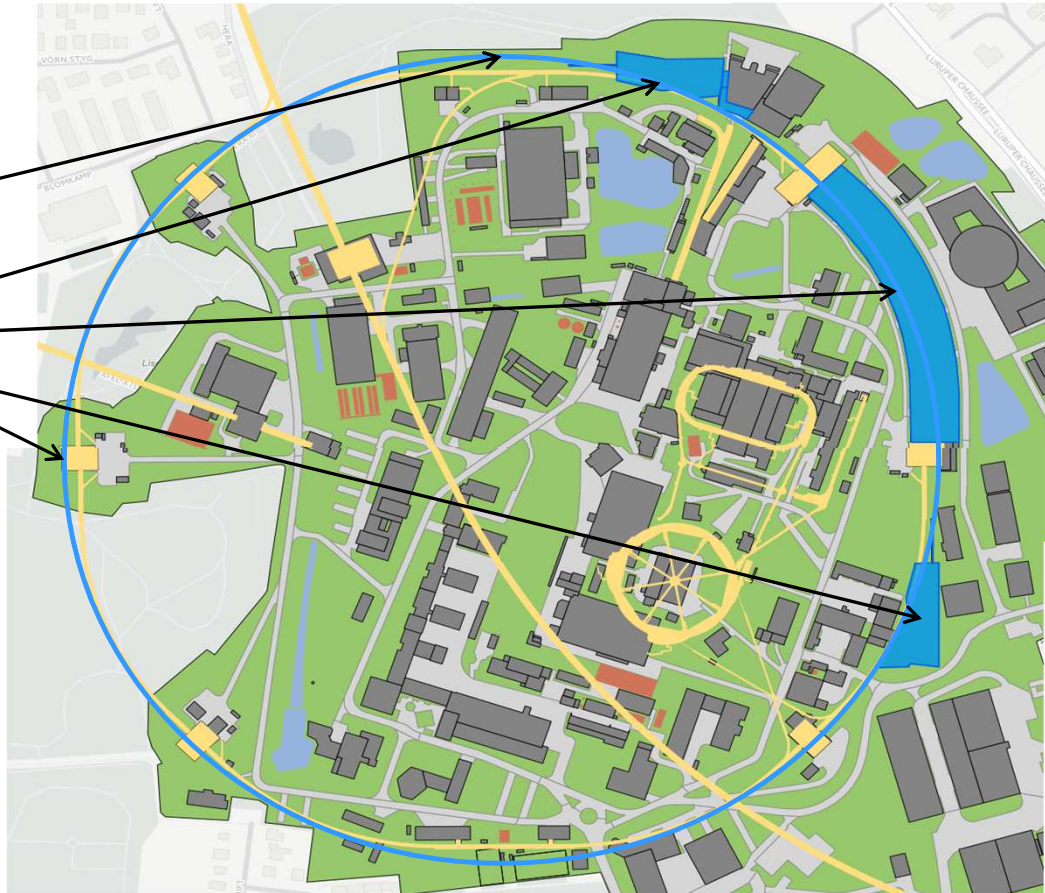


# Agenda

- 1 PETRA III Overview**
- 2 PETRA III Operation 2019**
- 3 PETRA IV**

# PETRA III Overview

- 2.3 km circumference
- 6 GeV electrons
- 20 damping wigglers
- 19 (+ 6) undulator beamlines
- 1 nm rad x 10 pm rad
- 100 mA
- TopUp operation, 1% beam current variation



# PETRA III Overview



- > Max von Laue Hall:
- > 1/8 of the circumference of PETRA III
- > 8 double bend acromat cells
- > 14 undulator beamlines:
  - 2 m Undulators: 11
  - 5 m Undulators: 3 (2+1)
  - 5 m Apple Undulator: 1

# User Operation 2019

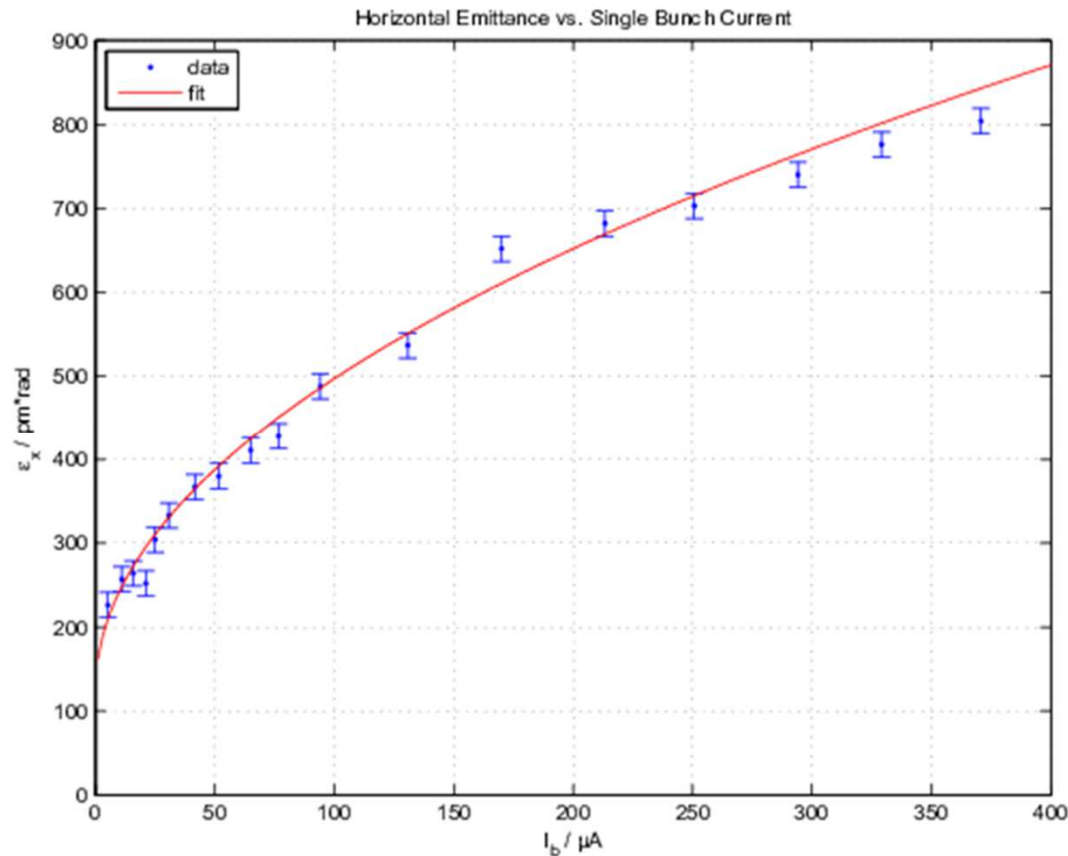
|    | Januar<br>2019    | Februar<br>2019 | März<br>2019 | April<br>2019 | Mai<br>2019   | Juni<br>2019 | 2019<br>2019 | Juli<br>2019  | Aug.<br>2019 | Sep.<br>2019 | Okt.<br>2019 | Nov.<br>2019  | Dez.<br>2019  | 2019<br>2019 |
|----|-------------------|-----------------|--------------|---------------|---------------|--------------|--------------|---------------|--------------|--------------|--------------|---------------|---------------|--------------|
| 1  |                   | f6263           | IB           | . 40          | . multi low b | . 40         | 1            | . multi       | IB tr        | . 40         | #            | . 40          | . multi low b | 1            |
| 2  |                   |                 | tr           | . 40          |               | . 40         | 2            | . multi       | IB tr        | #            | . multi      | . 40          | . multi low b | 2            |
| 3  |                   |                 | tr           |               | . multi low b | # 2m21a      | 3            | #             | tr           | #            | . multi      | . 40          | . multi low b | 3            |
| 4  |                   | IMV             | IB tr so     | . multi       | . multi low b | # 2m21a      | 4            | . multi       | tr           | #            | . multi      | . 40          | #             | 4            |
| 5  |                   | IEV NG          | IB tr so     | . multi       | . multi low b | # 2m21a      | 5            | . multi       | . 40         | #            | . multi      | . 40          | . multi       | 5            |
| 6  |                   | IEV NG          | #            | . multi       | . multi low b | # 2m21a      | 6            | . multi       | . 40         | IB           | . multi      | #             | . multi       | 6            |
| 7  | 2m07A f6263 #     | IEV NG          | tr so        | . multi       | . multi low b | # 2m21a      | 7            | . multi       | . 40         |              | #            | . 40          | . multi       | 7            |
| 8  | 2m07A f6263 #     | IEV NG          | tr so        | . multi HERC  | #             |              | 8            | . multi       | . 40         |              | #            | . 40          | . multi       | 8            |
| 9  | ivu07 f6263 p61 # |                 | tr           | . multi HERC  | . 40          |              | 9            | . multi       | . 40         | . multi      | #            | . 40          | . multi       | 9            |
| 10 | ivu07 f6263 p61 # |                 | tr           | HERCULES      | . 40          |              | 10           | . multi       | . 40         | . multi      | #            | . 40          | . multi       | 10           |
| 11 | ivu07 f6263 p61 # | IEV NG          | . 40         | . multi HERC  | . 40          | IB           | 11           | . multi       | . 40         | . multi      | IB           | . 40          | #             | 11           |
| 12 |                   | IM              | . 40         | . multi HERC  | . 40          | IB tr        | 12           | . multi       | . 40         | . multi      |              | . 40          | . multi       | 12           |
| 13 |                   | IM              | . 40         | . multi       | . 40          | . multi      | 13           | . multi       | . 40         | . multi      |              | . 40          | . multi       | 13           |
| 14 | ivu07 f6263 p61 # | IE NG           | . 40         | . multi       | . 40          | . multi      | 14           | . multi       | . 40         | . multi      | . 40         | . 40          | . multi       | 14           |
| 15 | ivu07 f6263 p61 # | IE NG           | . 40         | . multi       |               | . multi      | 15           | bloptics-3GEV | . 40         | . multi      | . 40         | . 40          | . multi       | 15           |
| 16 | ivu07 f6263 p61 # |                 | . 40         | . multi       | . 40          | . multi      | 16           | bloptics-3GEV | . 40         | . multi      | . 40         | . 40          | . multi       | 16           |
| 17 | ivu07 f6263 p61 # |                 | . 40         | #             | . 40          | . multi      | 17           | bloptics-3GEV | . 40         | . multi      | . 40         | . 40          | . multi       | 17           |
| 18 | ivu07 f6263 p61 # | IE NG           | . 40         | #             | . 40          | . multi      | 18           | bloptics-3GEV | . 40         | #            | . 40         | #             | . multi       | 18           |
| 19 |                   | IE NG           | . 40         |               | . 40          | Reserve 2m2  | 19           | bloptics-3GEV | . 40         | . multi      | . 40         | #             | . multi       | 19           |
| 20 |                   | NG              |              |               | . 40          | . multi      | 20           |               | . 40         | . multi      | . 40         | #             |               | 20           |
| 21 | ivu07 f6263 p61 # | IB              | . 40         |               | . 40          | . multi      | 21           |               | . 40         | . multi      | . 40         | #             |               | 21           |
| 22 | ivu07 f6263 p61 # | IB              | . 40         |               | #             | . multi      | 22           | bloptics-3GEV | . 40         | . multi      | . 40         | IB            |               | 22           |
| 23 | ivu07 f6263 p61 # |                 | . 40         | #             | . 40          | . multi      | 23           | bloptics-3GEV | . 40         | . multi      | #            |               |               | 23           |
| 24 | ivu07 f6263 p61 # |                 | . 40         | #             | . 40          | . multi      | 24           | bloptics-3GEV | . 40         | . multi      | . 40         |               |               | 24           |
| 25 | ivu07 f6263 p61 # | IB              | . 40         | IB tr         | . 40          | . multi      | 25           | bloptics-3GEV | . 40         |              | . 40         | . multi low b |               | 25           |
| 26 |                   | IB              | . 40         | . multi low b | . 40          |              | 26           | bloptics-3GEV | . 40         | . multi      | . 40         | . multi low b |               | 26           |
| 27 |                   | IB              | #            | . multi low b | . 40          | . multi      | 27           |               | . 40         | . multi      | . 40         | . multi low b |               | 27           |
| 28 | ivu07 f6263 p61 # | IB              | . 40         | . multi low b |               | . multi      | 28           |               | . 40         | . multi      | . 40         | . multi low b |               | 28           |
| 29 | ivu07 f6263 p61 # |                 | . 40         | . multi low b | . 40          | . multi      | 29           | bloptics      | #            | . 40         | . multi      | . multi low b |               | 29           |
| 30 | ivu07 f6263 p61 # |                 | . 40         | . multi low b | . 40          | . multi      | 30           | bloptics      | #            | . 40         | . multi      | . multi low b |               | 30           |
| 31 | f6263             | #               | . 40         |               | . 40          |              | 31           | bloptics      | #            | . 40         | . 40         |               |               | 31           |

|     |                     |
|-----|---------------------|
|     | Service Week        |
|     | Sunday (User Run)   |
|     | Usserrun            |
| MDT | Machine Development |

External users from March 11 to July 14  
and from Aug. 5 to Dec. 19.  
4752 hours for users in 2019, 4944 in 2020.

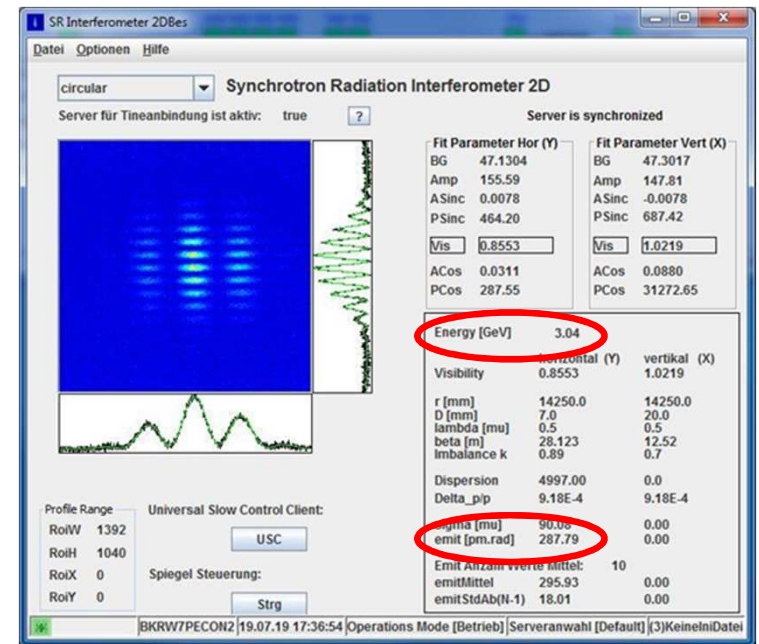
# User Operation 2019

## Summer Break 2019: 3 GeV



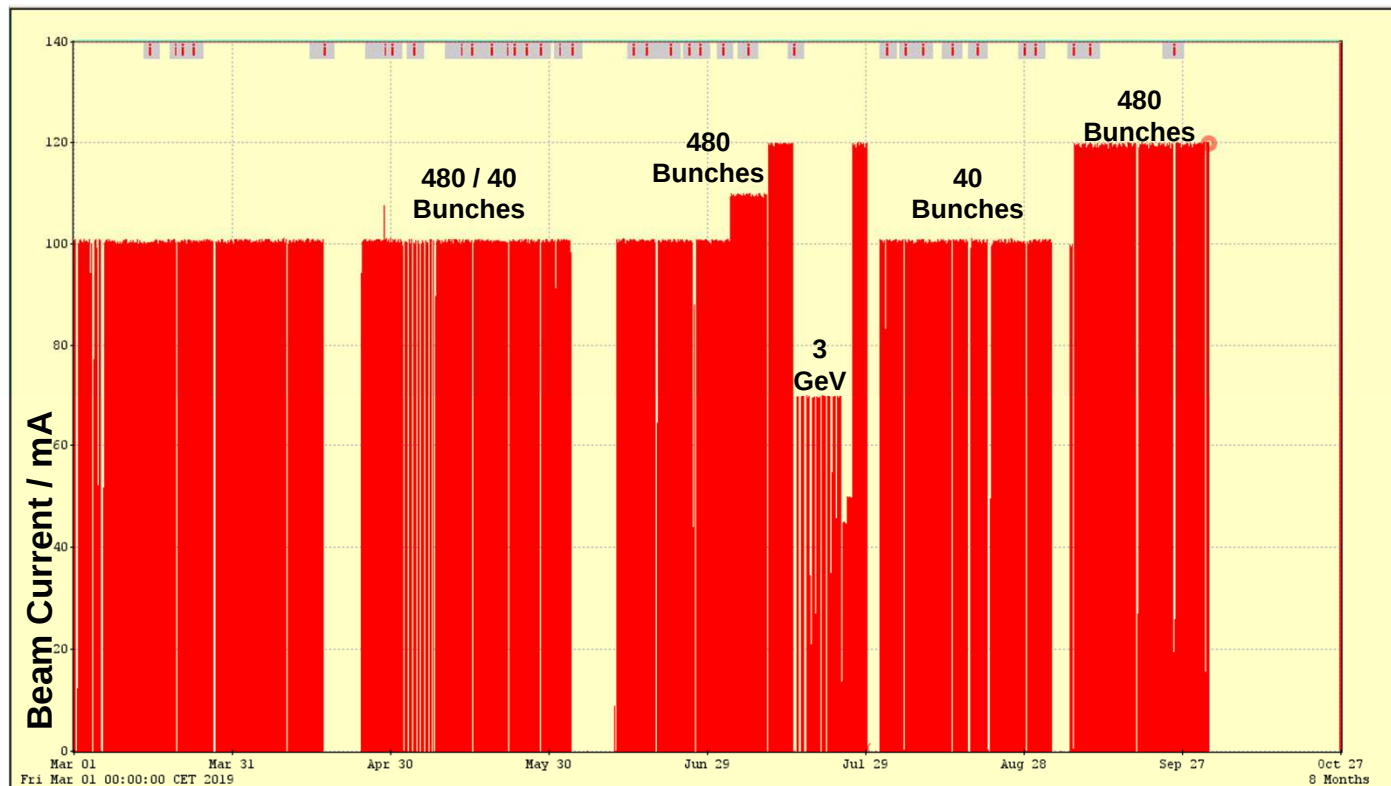
2 weeks at 3 GeV:

- smaller emittance
- tests for PETRA IV (instrumentation, users)



# User Operation 2019

July: Beam Current increased  
(480 bunch mode only)



Exploring higher power levels at the user side

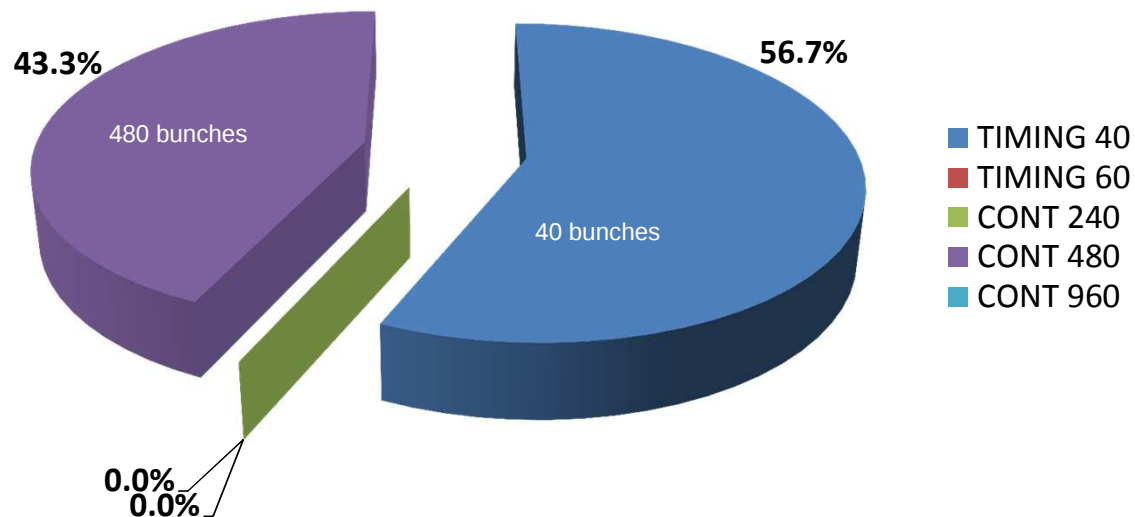
# User Operation 2019

User Run 2019

Scheduled time: 4752 h

57 % Timing Mode (40 Bunches)

Availability 98.5 % (as of Nov. 25<sup>nd</sup>)



2 bunch patterns used:

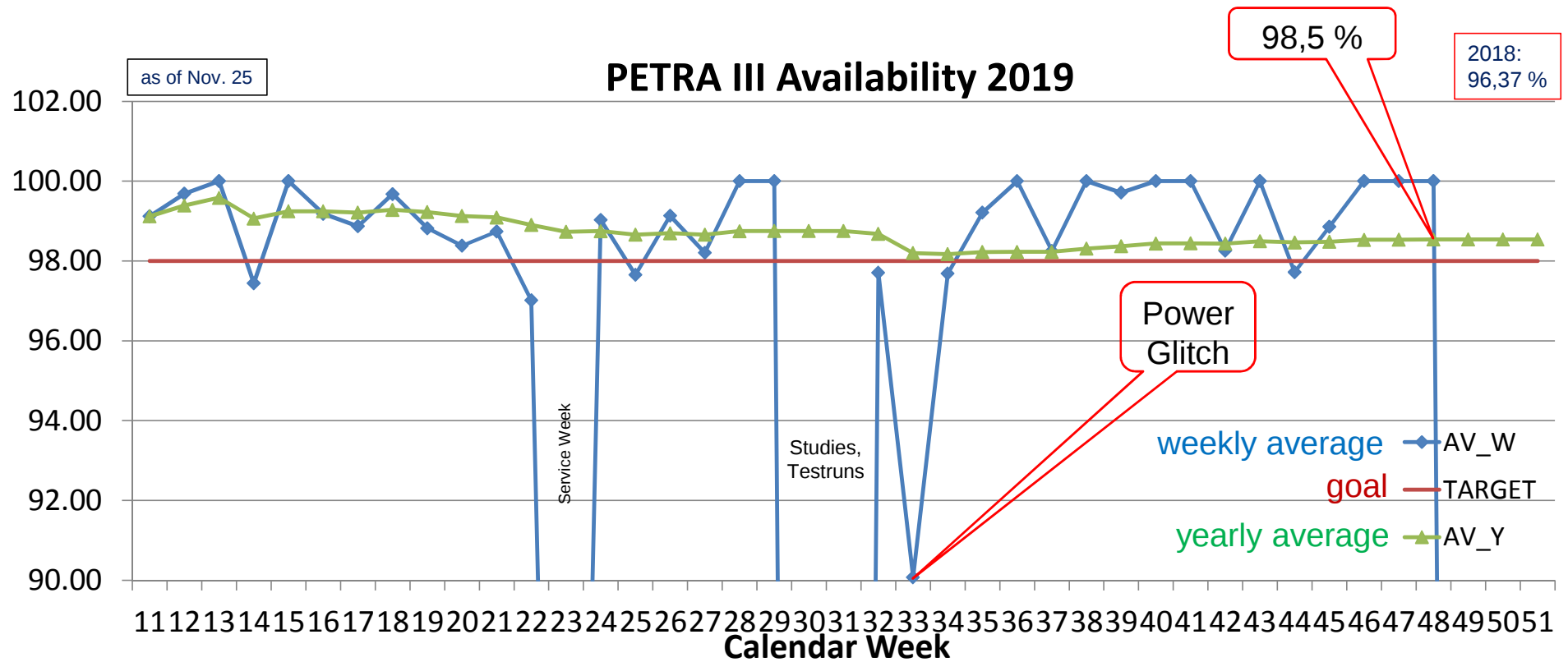
> Timing Mode

- 40 bunches, 192 ns

> Continuous Mode

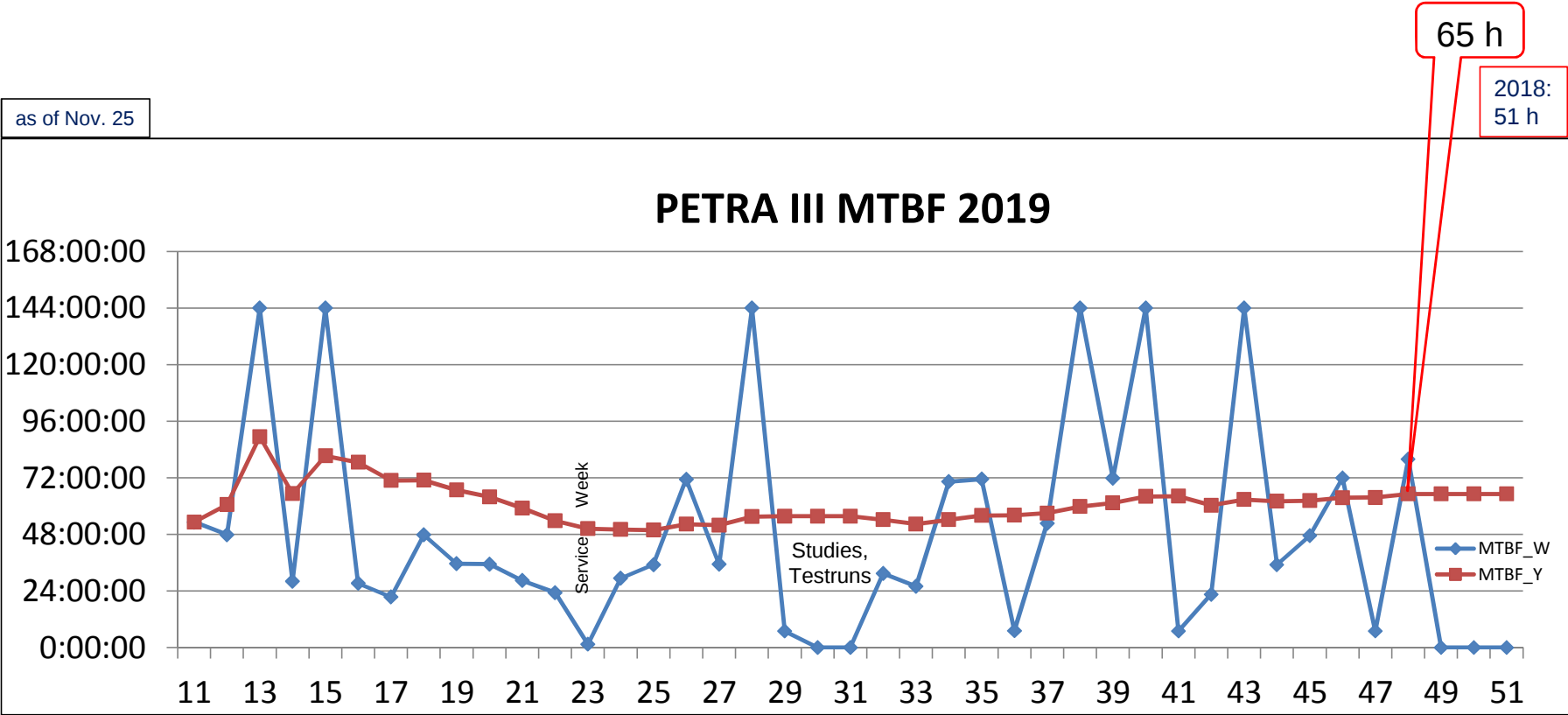
- 480 bunches, 16 ns

# Availability 2019



# Availability 2019

as of Nov. 25

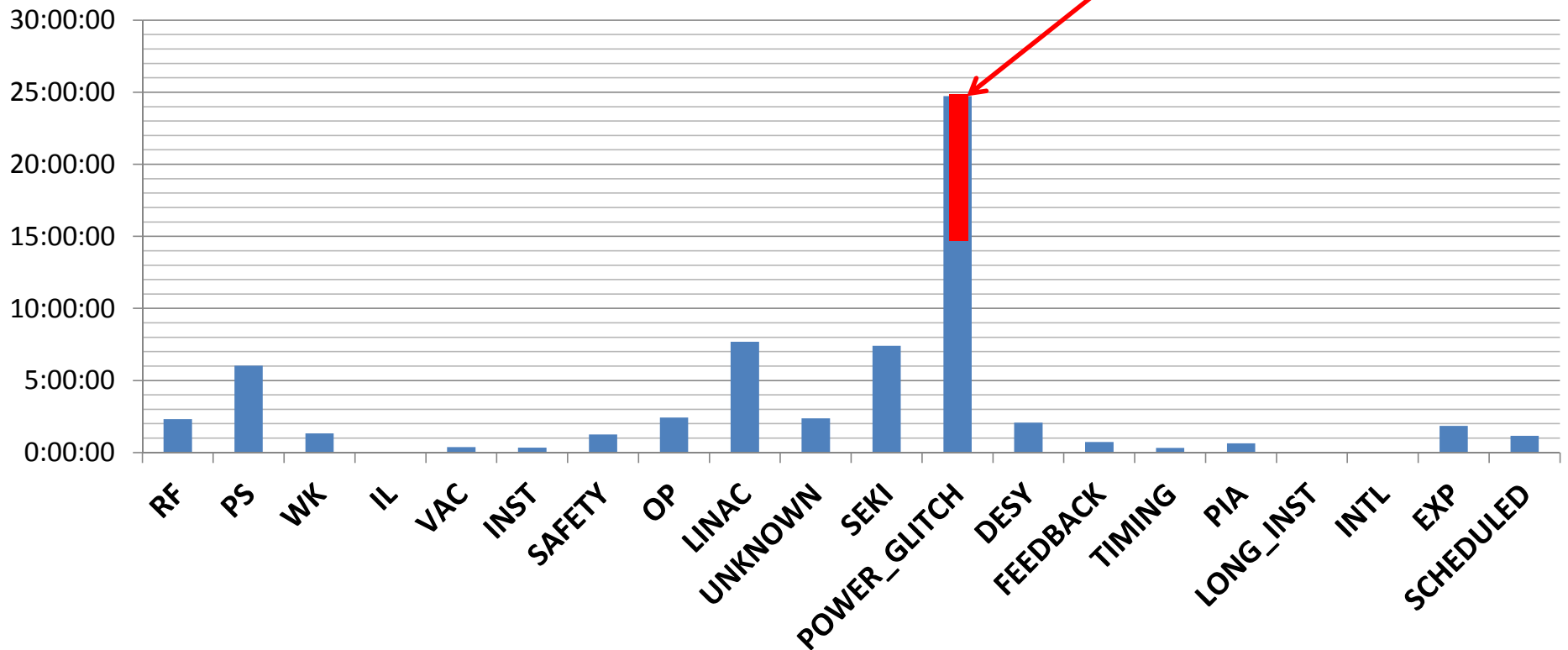


# Availability 2019

as of Nov. 25

10 h lost by 1 incident

SUM FAILURE TIME

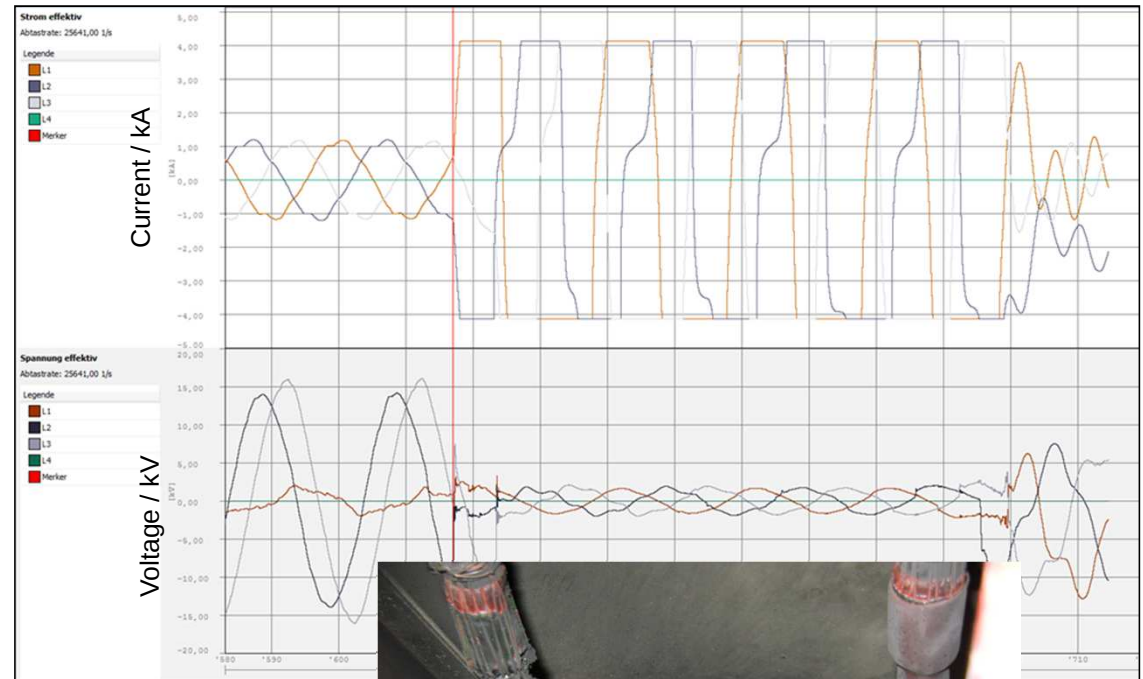


# Availability 2019

**Saturday, 17.8.2019,**  
**10 kV supply for RF transmitter:**  
**10:05 AM: 1 phase shorted to ground,**  
**transmitter runs on 2 phases for 1.5**  
**hours.**  
**11:33 AM: 3 phases shorted to ground**  
**for 80 ms, DESY wide power glitch.**



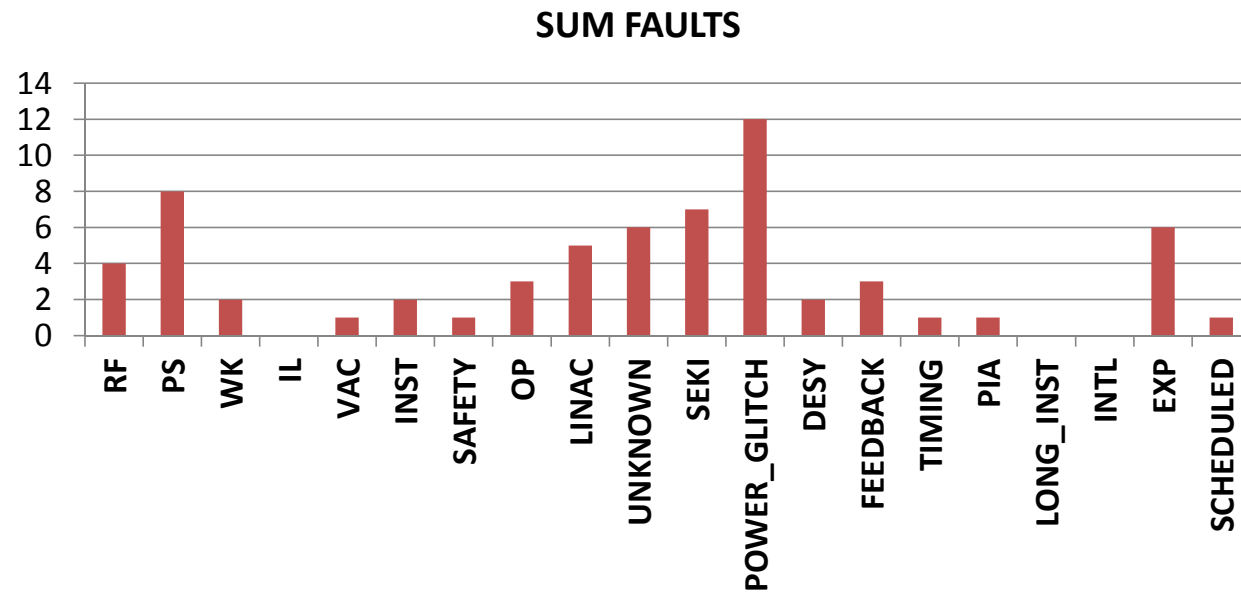
10 kV cabinet



Root cause: Loose cables



# Availability 2019



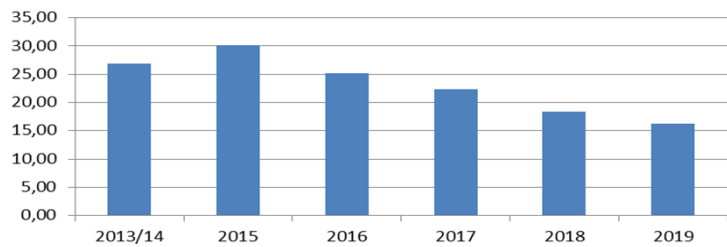
Power Glitches  
Magnet Power Supplies  
Kickers  
Users / Beam lines  
Unknown  
....



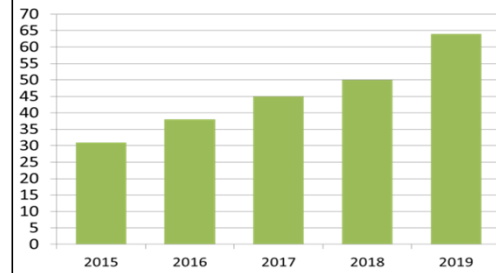
# Availability 2019

## Improvements over the years

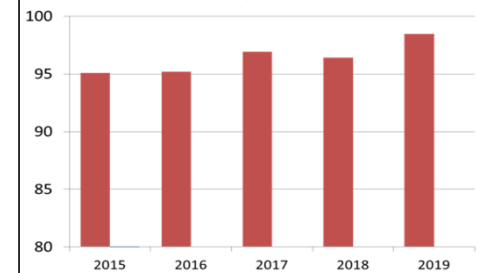
Faults / 1000 h



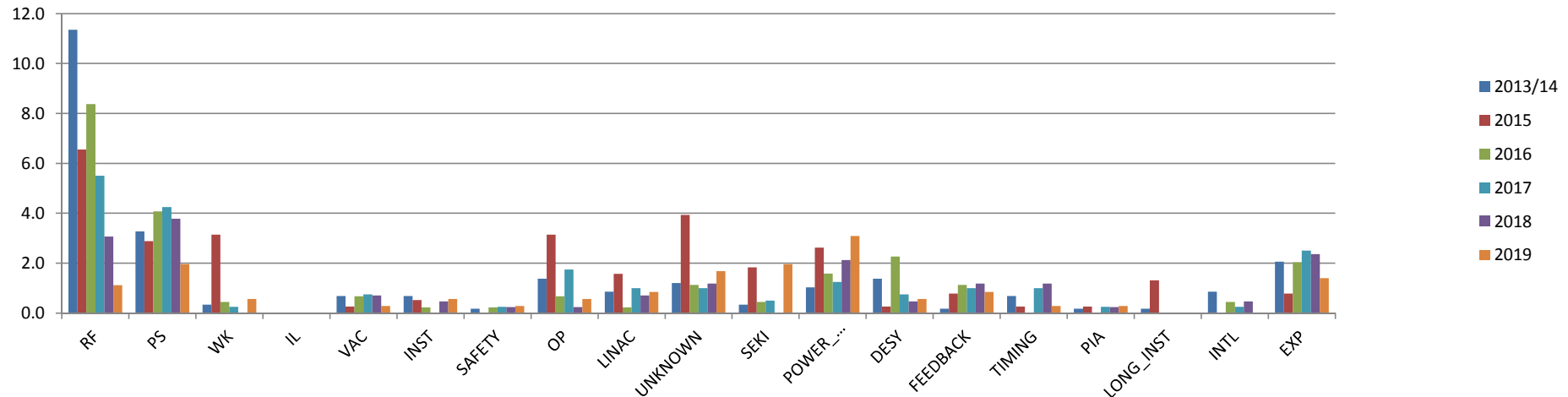
MTBF 2015 - 2019



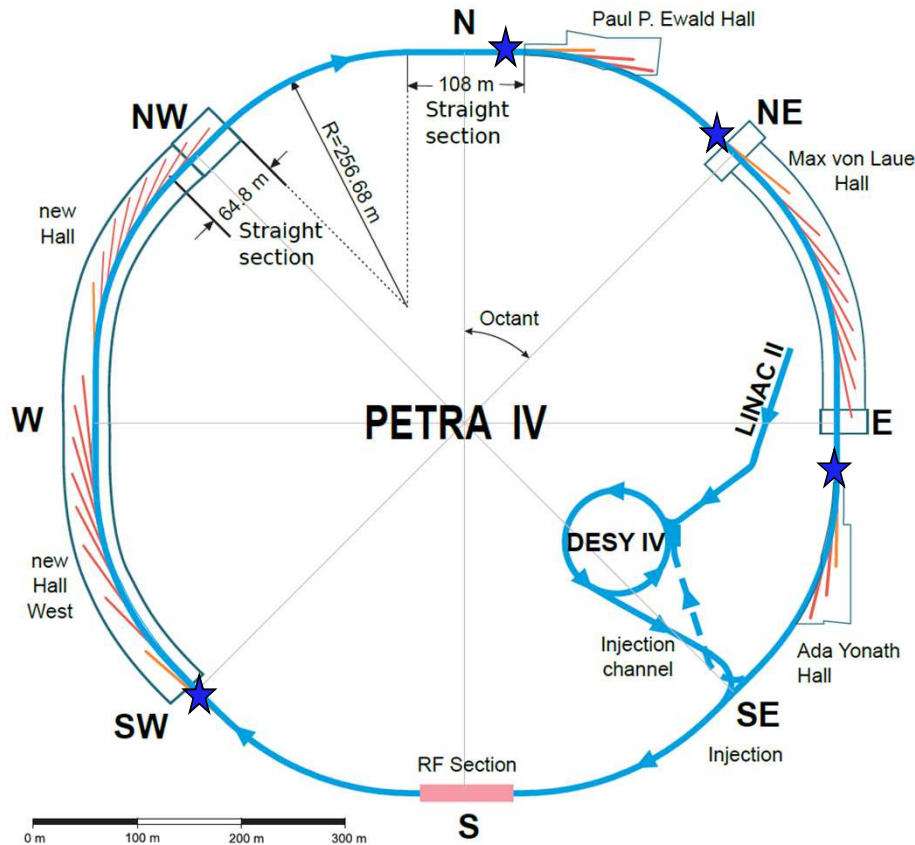
Availability 2015 - 2019



Faults per 1000 h user run: 2013 ... 2019



# PETRA IV



## PETRA IV:

- 2 new experimental halls
- 4 undulator cells in the long straight sections ★
- H7BA – ESRF-EBS style lattice
- 8 cell / arc
- ⇒ 26.2 m cell length. Beamlines have to be moved/adapted to the new lattice layout
- option: canted beamlines
- on-axis injection with fast kickers
- 500 MHz RF + higher harmonic cavity
- vacuum system, 20 mm inner diameter
- magnets, bore radius 13 mm

# PETRA IV

| Parameter                       | Value (with 29 IDs) |
|---------------------------------|---------------------|
| Energy E                        | 6 GeV               |
| Length L                        | 2304 m              |
| Tune $Q_x/Q_y$                  | 164.18 / 68.27      |
| Nat. chromaticity $\xi_x/\xi_y$ | -230 / -185         |
| Damping part. number $J_x$      | 1.24                |
| Nat. emittance $\epsilon_x$     | 7 pm*rad            |
| MCF $\alpha_c$                  | 1.48e-5             |
| Energy spread $\sigma_e$        | 0.92e-3             |
| Energy loss per turn $U_0$      | 4.0 MeV             |

## Notes: (lattice version 15.7)

- Zero-current values – without IBS!
- 3 halls, no canting!

| Design Parameter              | PETRA IV |          |
|-------------------------------|----------|----------|
| Energy / GeV                  | 6        |          |
| Circumference /m              | 2304     |          |
| Emittance (horz. / vert.) /pm | < 20 / 4 | <50 / 10 |
| Total current / mA            | 200      | 80       |
| Number of bunches             | 1600     | 80       |
| Bunch population / $10^{10}$  | 0.8      | 6        |
| Bunch separation / ns         | 4 + gaps | 96       |

## Brightness Mode Timing Mode

on axis injection, 96 ns timing structure

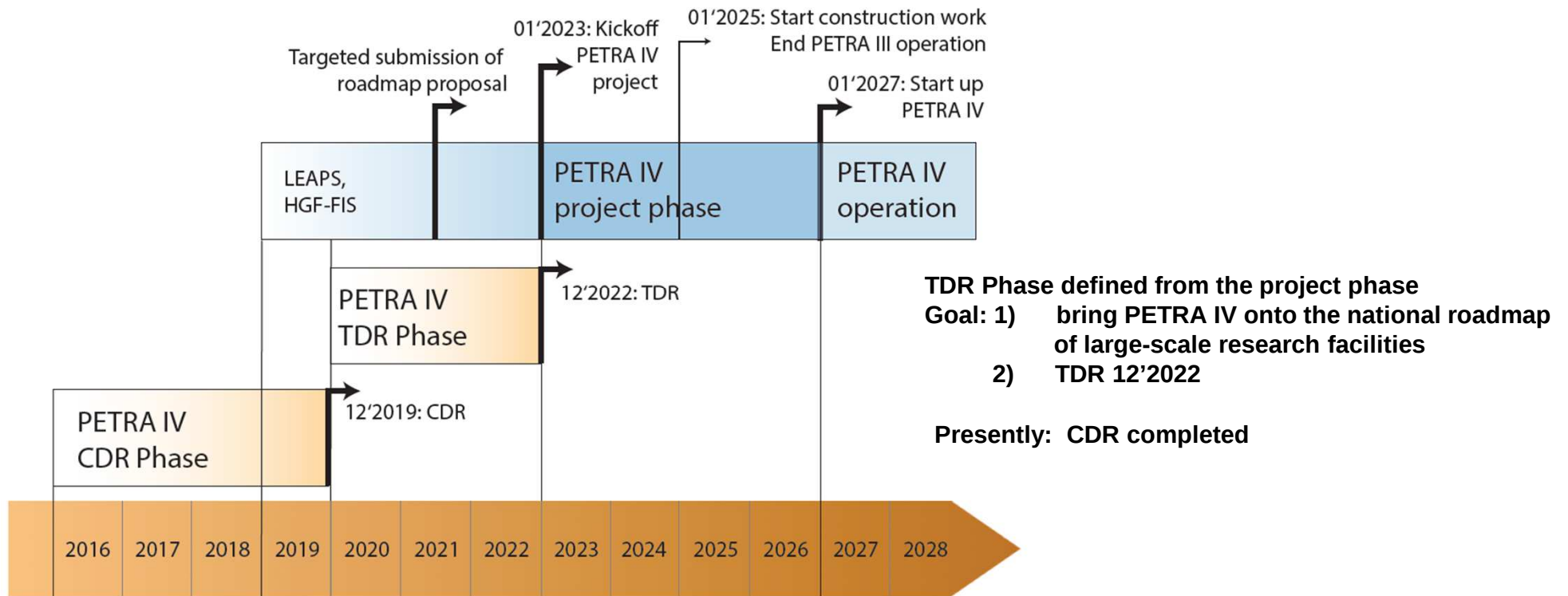
- 20 bunches (76 ns + 20 ns gap)
- 1 bunch

## Design goals achieved !

(with IBS + collective effects, Harmonic cavity)

| Parameter              | Reference | Brightness mode | Timing mode |
|------------------------|-----------|-----------------|-------------|
| Bunch current /mA      | 0.01      | 0.125           | 1           |
| Hor. emittance /pm rad | 7.37      | 11.6            | 19.21       |
| Ver. emittance /pm rad | 1.47      | 2.32            | 3.84        |
| Bunch length /mm       | 11.7      | 13.7            | 19.3        |
| Bunch length /psec     | 39.1      | 45.7            | 64.3        |
| Energy spread / 10-3   | 0.914     | 0.963           | 1.562       |
| Touschek lifetime / h  | 49.4      | 4.7             | 1.2         |

# PETRA IV



**Thank you**

## Contact

**DESY.** Deutsches  
Elektronen-Synchrotron

[www.desy.de](http://www.desy.de)

Michael Bieler  
MBB  
[Bieler@desy.de](mailto:Bieler@desy.de)  
+494089983805