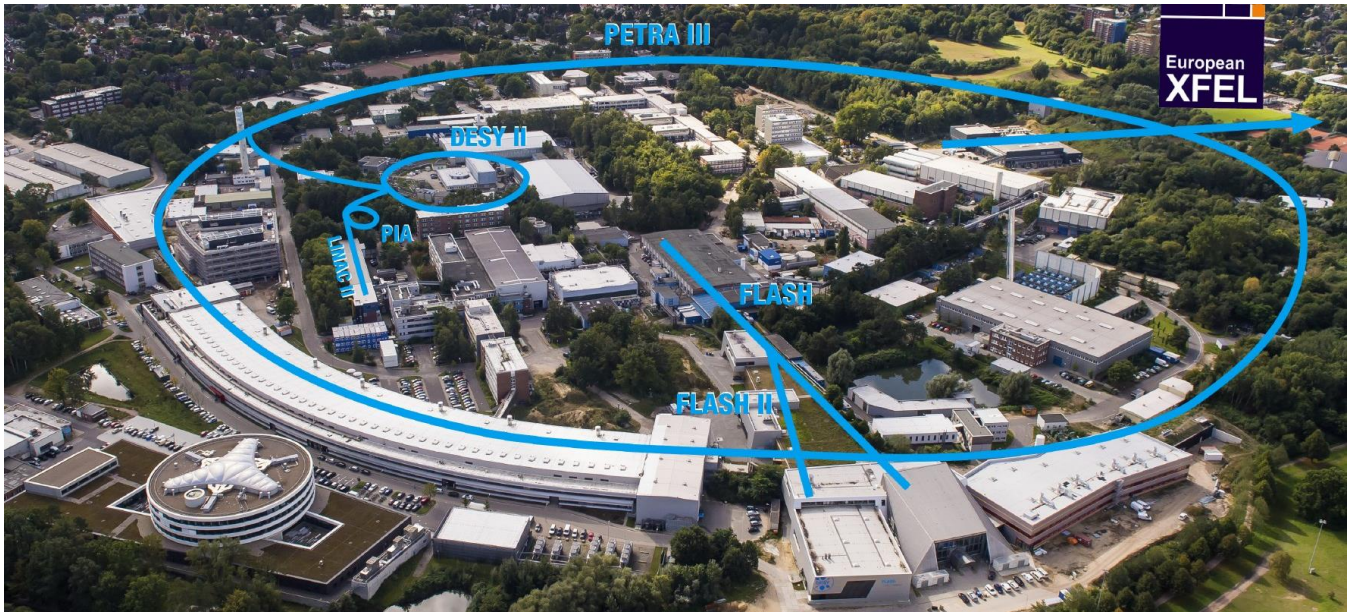
PETRA III, Status and Upgrade

M. Bieler,
for the PETRA III Team

ESLS XXVI, Krakow, 27.11.2018



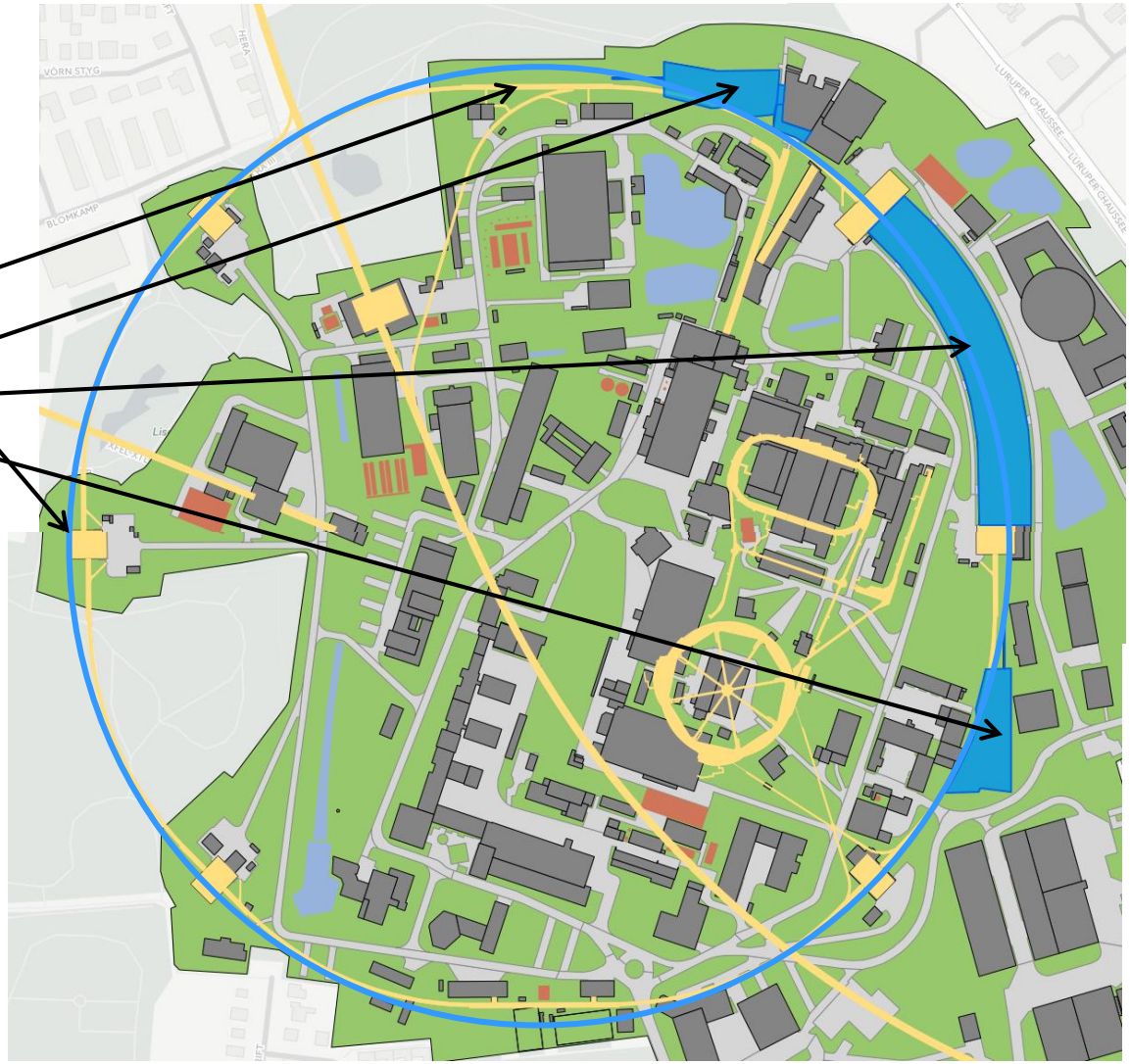
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Content

- PETRA III Overview
- PETRA User Operation 2018
- Plans for 2019
- PETRA IV

PETRA III Overview

- 2.3 km circumference
- 6 GeV electrons
- 20 damping wigglers
- 19 (+ 5) 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 2018

2018	Januar	Februar	März	April	Mai	Juni	2018	Juli	Aug.	Sep.	Okt.	Nov.	Dez.	2018
2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018
1		a c # BO61	IB	multi	40	multi	1	40	f61 cc # VN_N	40	multi	40	multi	1
2	#	a c # BO61	IB	multi	40 no MDT	multi	2	40	f61 cc # VN_N	40	multi	40	multi	2
3	#			multi	40	multi	3	40	f61 cc # VN_N	40 *MTRC*	multi no MDT	40	multi	3
4	#			MDT #	40	#	4	MDT #		40 *MTRC*	multi	40	multi	4
5	#	c #	IB	multi	40	#	5	multi		40 *MTRC no MI*	multi	40	MDT	5
6		c #	IB	multi	40	40	6	multi	f61 cc #	40 *MTRC*	multi	40	multi	6
7		c #	IB	multi	40	40	7	multi	f61 cc #	40 *MTRC*	multi	MDT #	multi	7
8	a b #	c #	IB	multi	40	40	8	multi	f61 cc #	40	#	40	multi	8
9	a b #	c #	IB	multi	MDT #	40	9	multi	f61 cc #	40	#	40	multi	9
10	a b #			multi	multi	40 *SRI18*	10	multi	f61 cc #	40	#	40	multi	10
11	a b #			MDT	multi	40 *SRI18*	11	MDT		40	#	40	multi	11
12	a b #	IMv	d IB	40	multi	40 *SRI18*	12	multi		MDT #		#	MDT #	12
13		IEv	d IB	40	multi	MDT *SRI18*	13	multi	f61 cc IP61 #	40	multi	#	multi	13
14		IEv	d IB	40	multi	40 *SRI18*	14	multi	f61 cc IP61 #	40	multi	#	multi	14
15	a c #	NG IEv	e so seM multi	40	multi	40 *SRI18*	15	multi	IB	40	multi	#	multi	15
16	a c #	NG IEv	e so seM multi	40	MDT	40	16	multi	IB	40	multi	#	multi	16
17	a c #		multi	40	multi	40	17	multi	IB	40	MDT	40	multi	17
18	a c #		multi	MDT # IP21v	multi	40	18	V61 K61 f61 cc #		40	multi	40	multi	18
19	a c #	NG IEv	e so seM multi	40	multi	40	19	V61 K61 f61 cc #		MDT	multi	40	multi no MI	19
20		NG IM	e so seM multi	40	multi	MDT #	20	V61 K61 f61 cc #	IB	40	multi	40	multi	20
21		NG IM	MDT #	40	multi	40	21		IB	40	multi	MDT	Shutdown	21
22	a c # VV61	NG IE	e so seM multi	40	multi	40	22		IB	40	multi	40	Shutdown	22
23	a c # VV61	NG IE	e so seM multi	IP21 #	MDT #	40	23	V61 K61 f61 cc #	IB	40	multi	40	Shutdown	23
24	a c # VV61		multi	IP21 #	multi	40	24	V61 K61 f61 cc #	IB	40	MDT #	40	Shutdown	24
25	a c # VV61		multi	IP21 #	multi	40	25	f61 cc # VN_N		40	40	40	Shutdown	25
26	a c # VV61	NG IE	seM multi	IP21 Prüfung	multi	40	26	f61 cc # VN_N		MDT #	40	40	Shutdown	26
27		NG IE	seM multi		multi	MDT	27	f61 cc # VN_N	IB	multi	40	40	Shutdown	27
28		NG	MDT	40	multi	40	28		IB	multi	40	MDT #	Shutdown	28
29	a c # BO61		seM multi	40	multi	40	29		dd e 40	multi	40	multi	Shutdown	29
30	a c # BO61		multi	40	MDT	40	30	f61 cc # VN_N	dd e 40	multi	40	multi	Shutdown	30
31	a c # BO61		multi		multi		31	f61 cc # VN_N	dd e 40		MDT		Shutdown	31

Service Week
Sunday (User Run)
Userrun
MDT Machine Development

External users from March 26 to July 17 and from Sept. 3 to Dec. 20

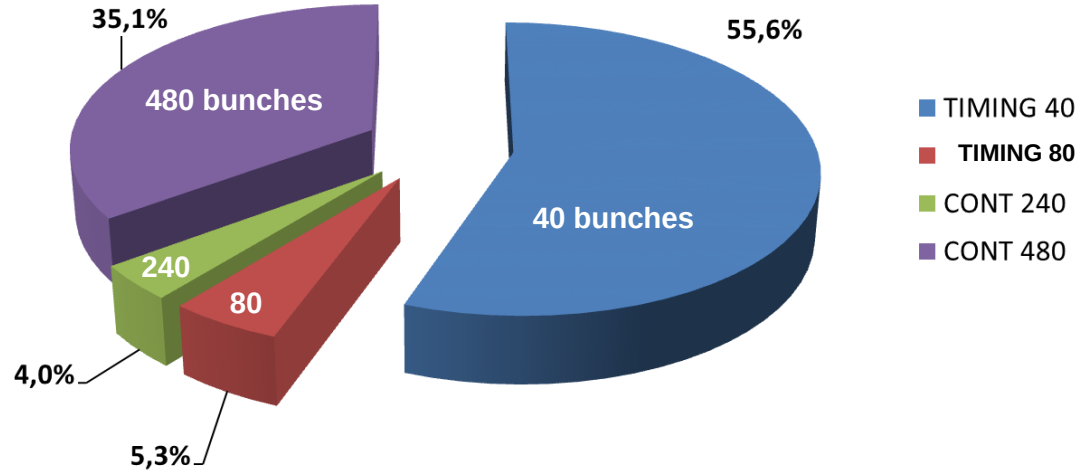
User Operation 2018

User Run 2018

Scheduled time: 3360 h

61 % Timing Mode (40/80 Bunches)

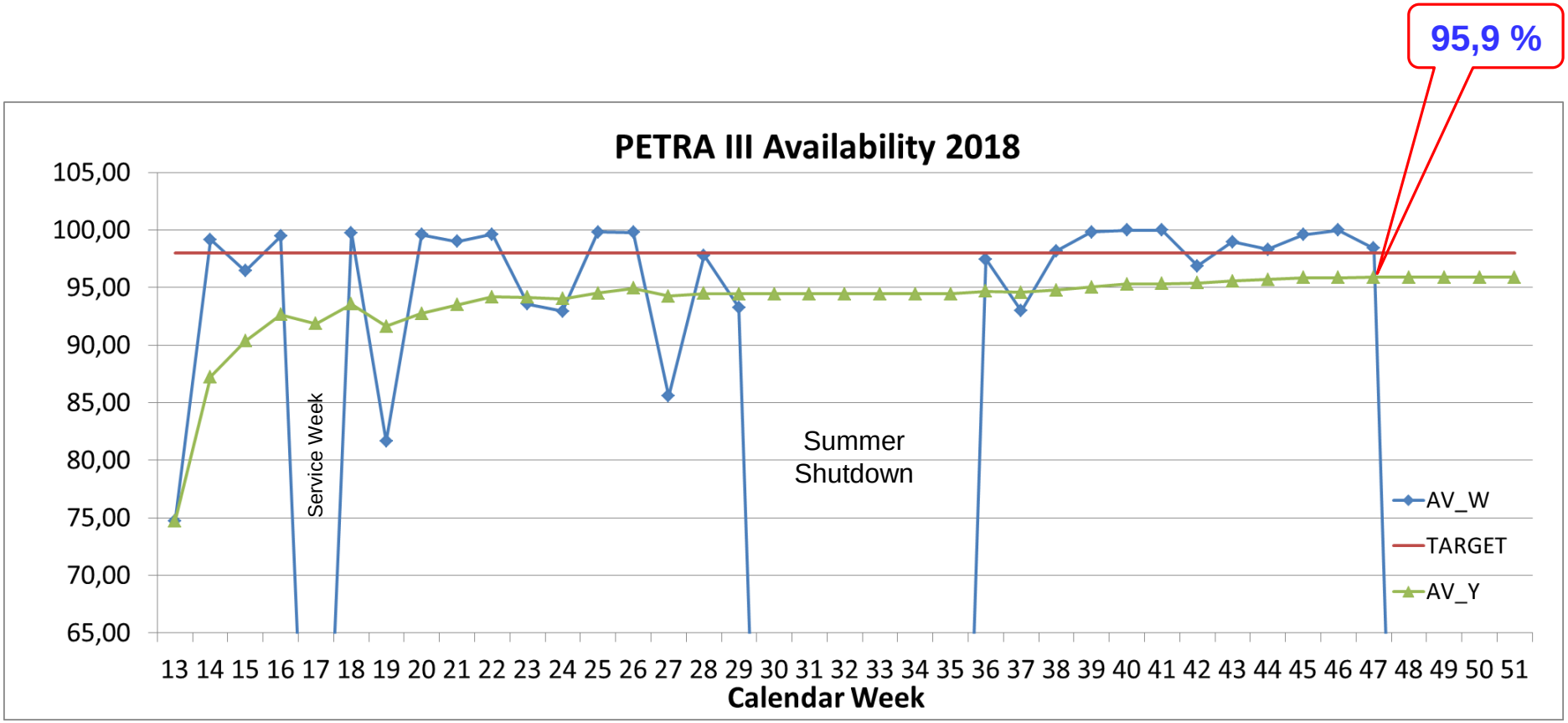
Availability 95.9 % (as of Nov. 22nd)



4 bunch patterns used:

- **Timing Mode**
  - **40 bunches, 192 ns**
  - **80 bunches, 96 ns**
- **Continuous Mode**
  - **240 bunches, 32 ns**
  - **480 bunches, 16 ns**

Availability 2018



Availability 2018

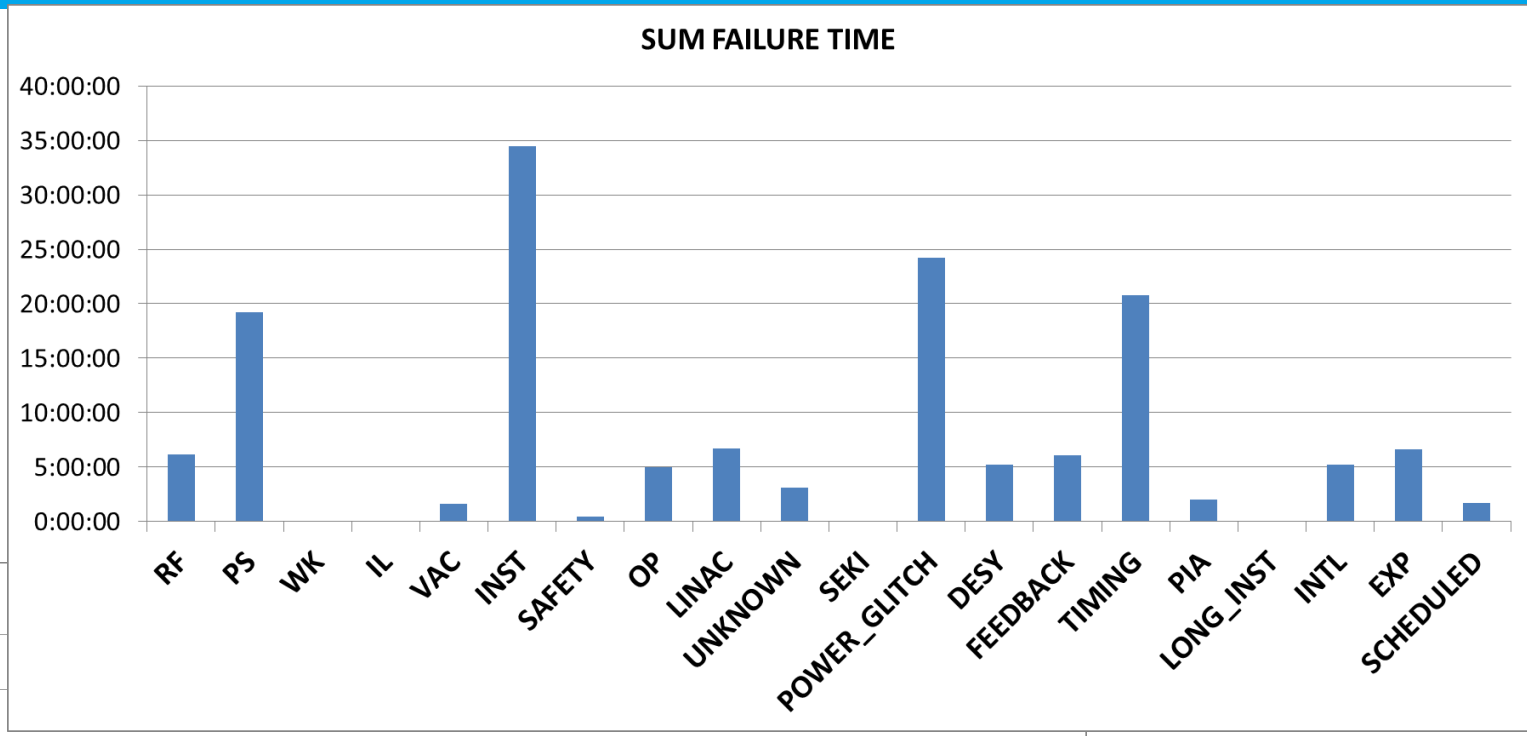
Definition:

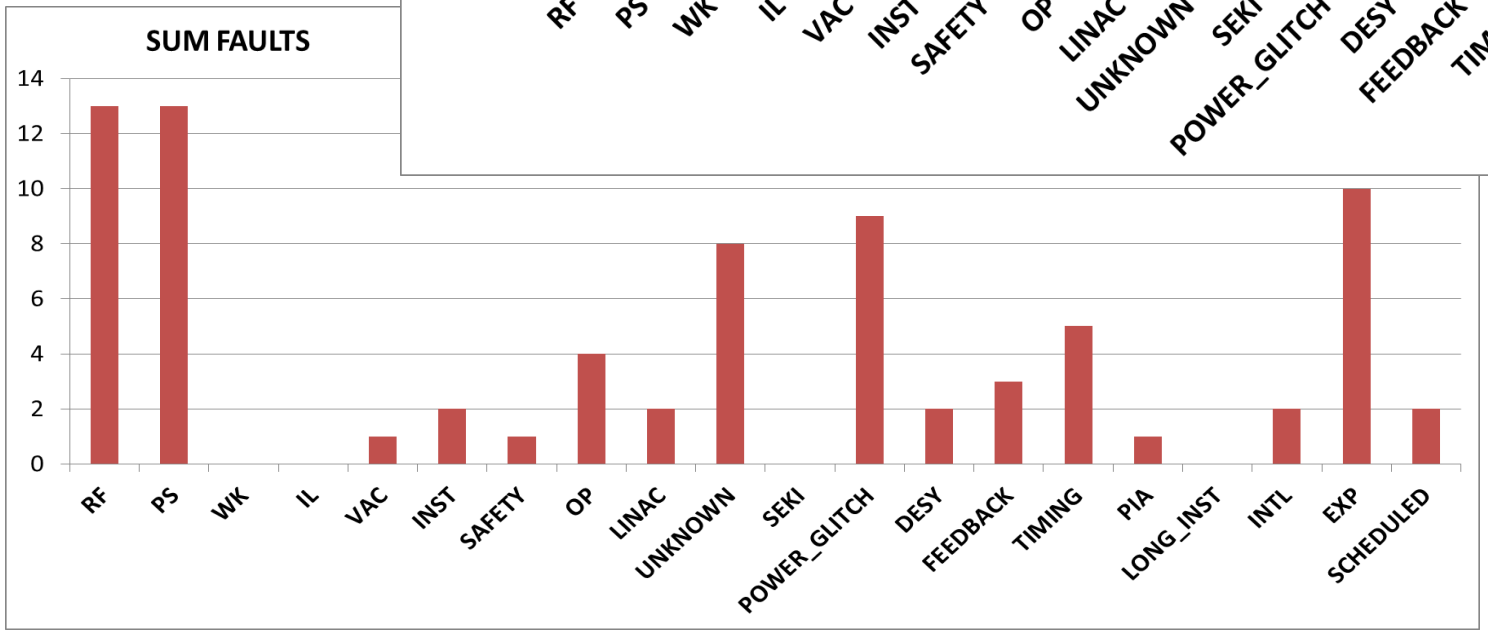
$$\text{Availability} = \frac{\text{delivered beam time}}{\text{scheduled beam time}}$$

Definition:

Fault: Every beam loss of more than 25%, ~~plus 1 hour (or 1 downtime)~~

Availability 2018

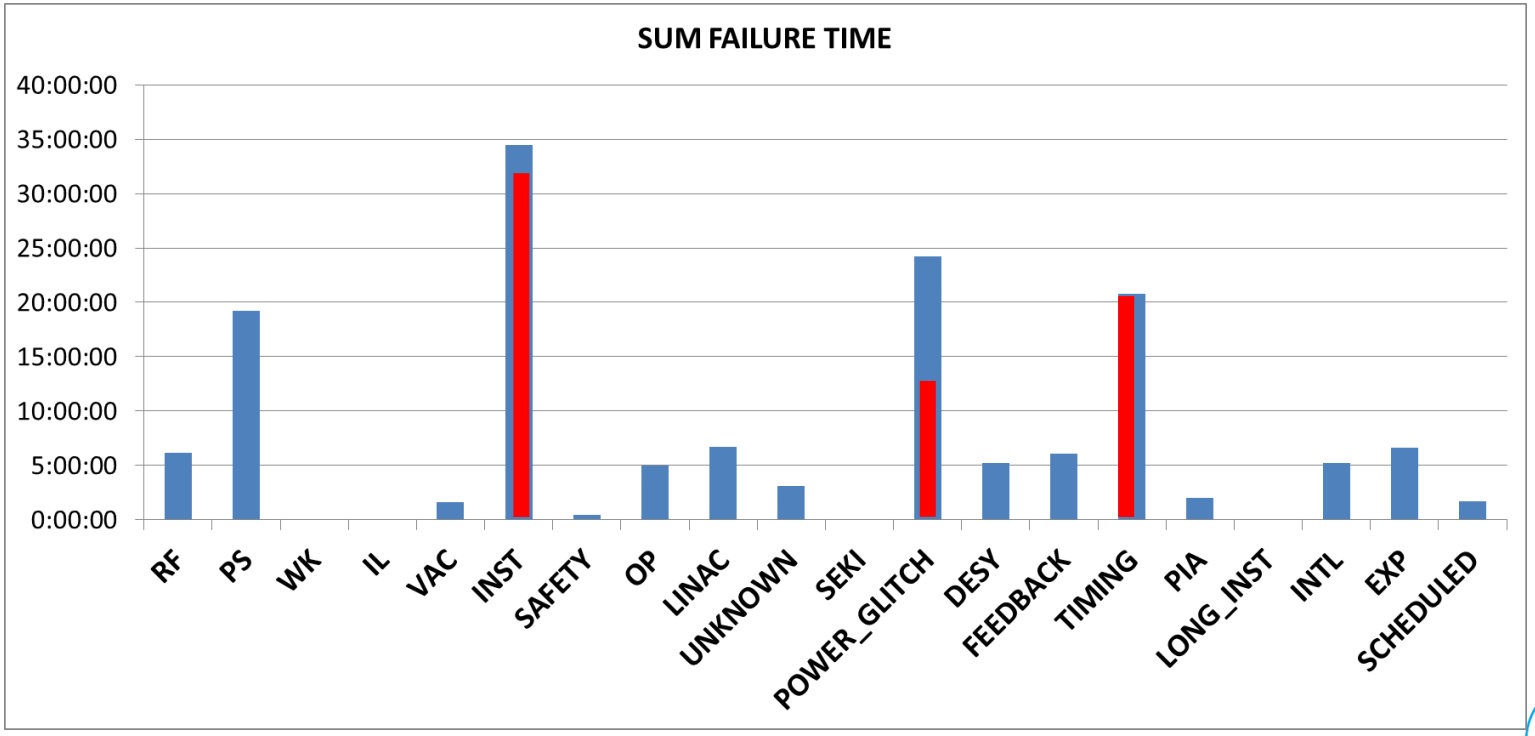




Availability 2018

Failure time:
Dominated by 3 disasters (red bars).
Together they represent

- **65 h failure time**
- **43 % of the total failure time**
- **1.8 % availability**



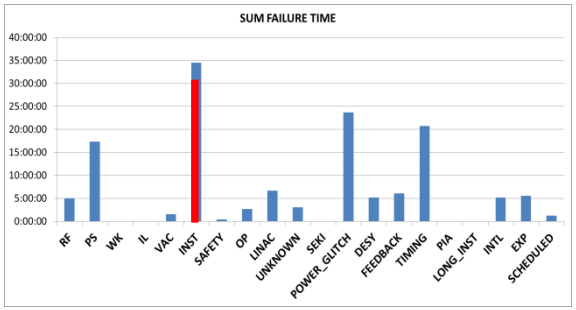
Availability 2018

Unused beam current monitor broken 30 minutes after a beam dump.
200 m storage ring and 4 frontends vented before the valves closed.

Monitor build in 2008, no longer used, temperature no longer monitored.

Thorough investigation:
- **Vendor consulted**
- **Broken surface inspected in material science lab**
- **Temper colors normal**
- **RF field calculations: 46 W deposited (currently used design: 16 W)**

No reason found.



31 h lost.

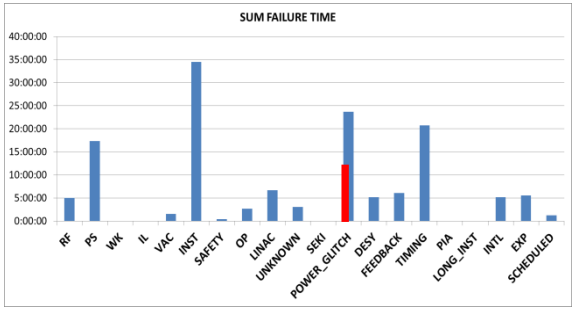
Lesson learned:
Remove all unnecessary components to reduce risks.

Availability 2018

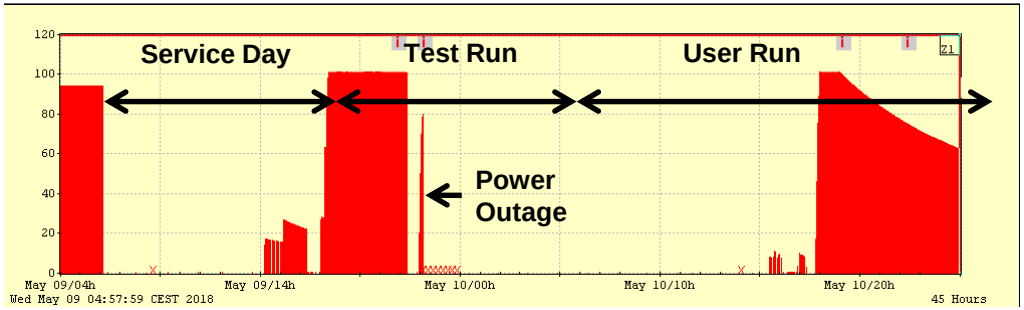
Power outage, 9.5.2018, 11 PM:
Flash in a 10 kV switch on site.
DESY lost 2 of 3 power feeds.
PETRA III and FLASH affected.
Buildings are dark, many broken components.
10 kV back after 2 hours.
On call services on site all night (after a full working day).
10.5.2018 is Ascension Day, national holiday, no fresh personal available. Several volunteers come in.
PETRA III user operation is supposed to start 10.5. 7 AM.
No beam before 10.5. 7 PM.

The 10 kV switch was investigated by
- **DESY personal**
- **experts from the local power provider**

The switch had been serviced regularly.
No reason for the fault found. The switch is back in operation.



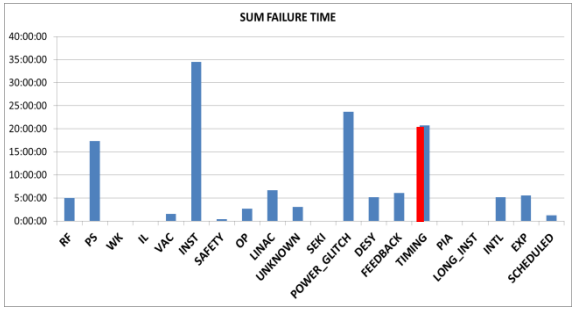
12 h lost.



Lesson learned:
A power outage on the night before a public holiday is hard to cover.

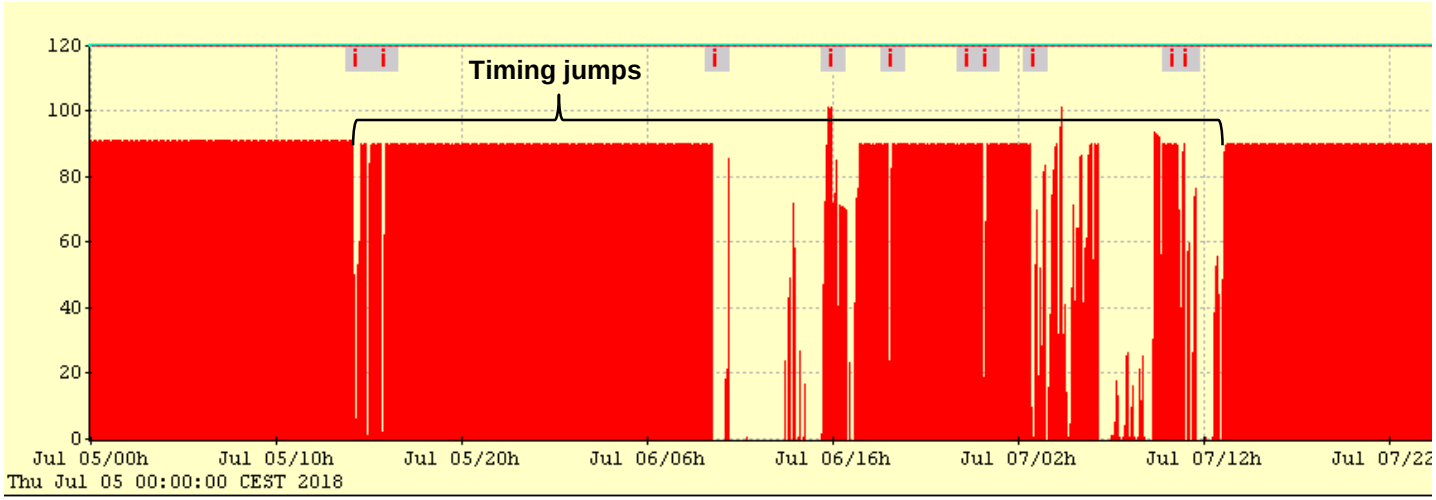
Availability 2018

Timing, 5.7.-7.7.2018:
Timing jumps lead to longitudinal instabilities and beam losses.
Reason unknown, components exchanged ‘randomly’. Very few experts working day and night.
Finally found: A faulty 500 MHz synthesizer in the timing system did phase jumps in the µs range.



20:45 h lost.

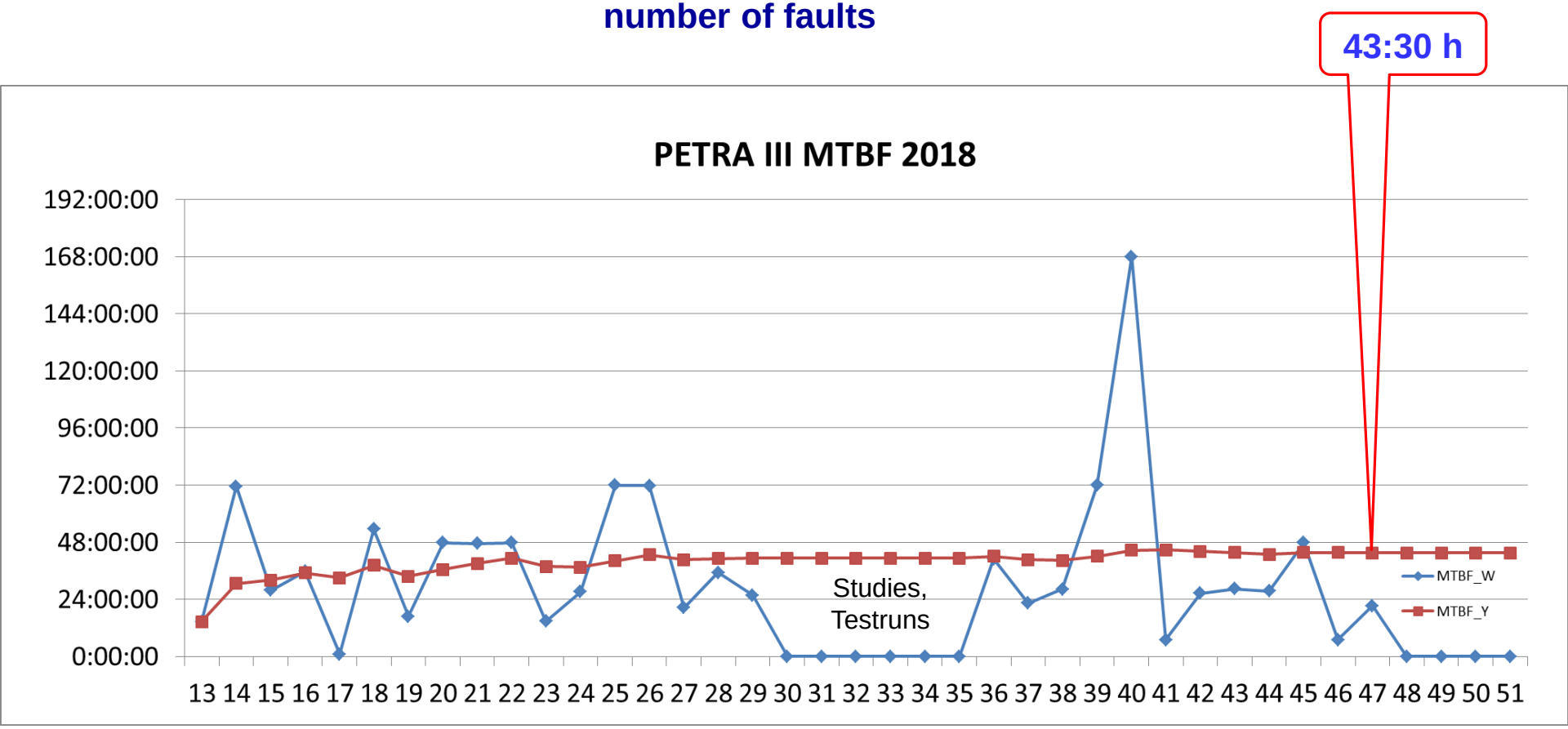
Lessons learned:
Timing had
- **not enough diagnostics (added here)**
- **not enough experts.**



MTBF 2018

Definition:

$$\text{Mean Time between Failures} = \frac{\text{delivered beam time}}{\text{number of faults}}$$

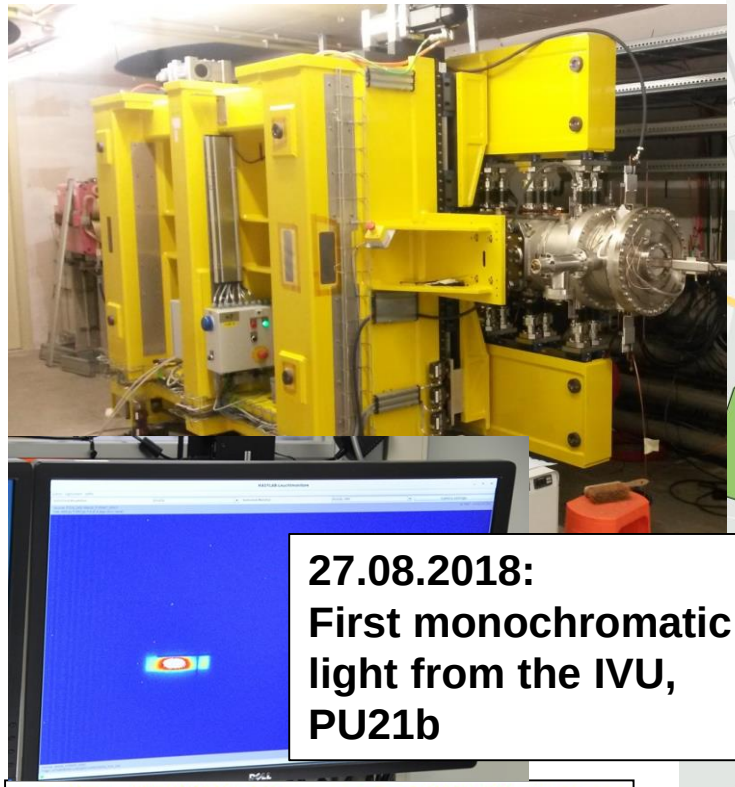


Status of Extension Beamlines

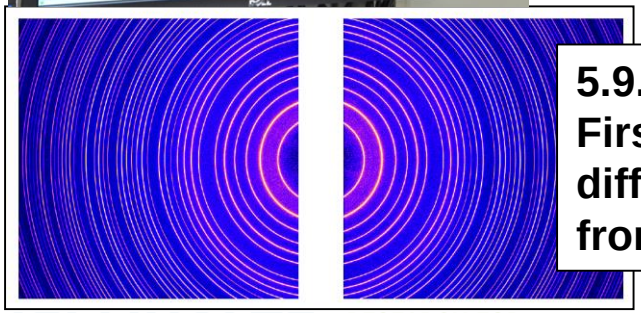
5 extension beamlines are fully operational: PU64, PU65 PU22, PU23, PU24

Status of Extension Beamlines

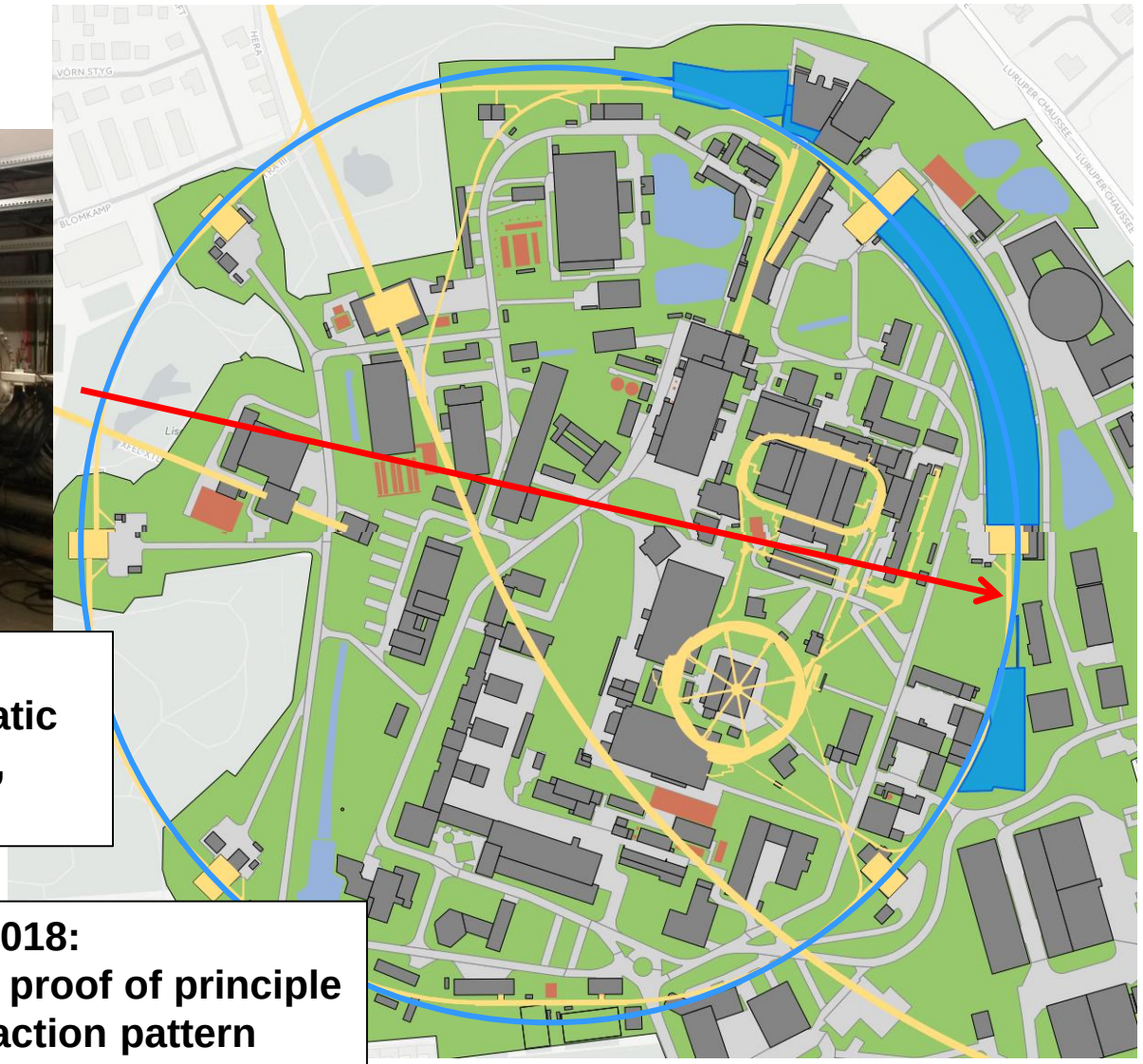
PU21b is the first in-vacuum-undulator in PETRA III



27.08.2018:
First monochromatic light from the IVU, PU21b

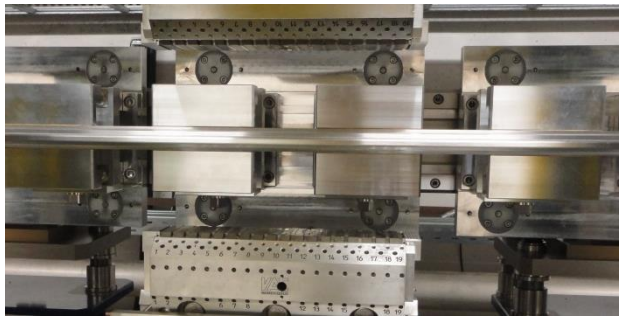


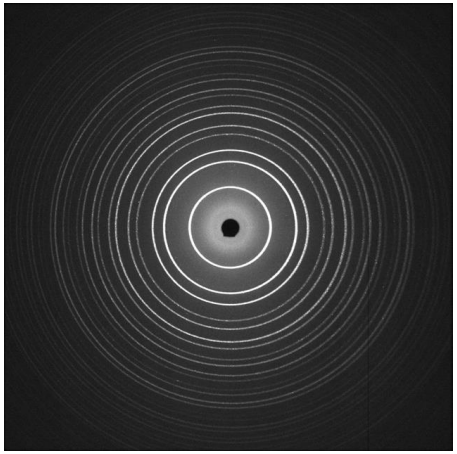
5.9.2018:
First proof of principle diffraction pattern from the IVU, PU21b

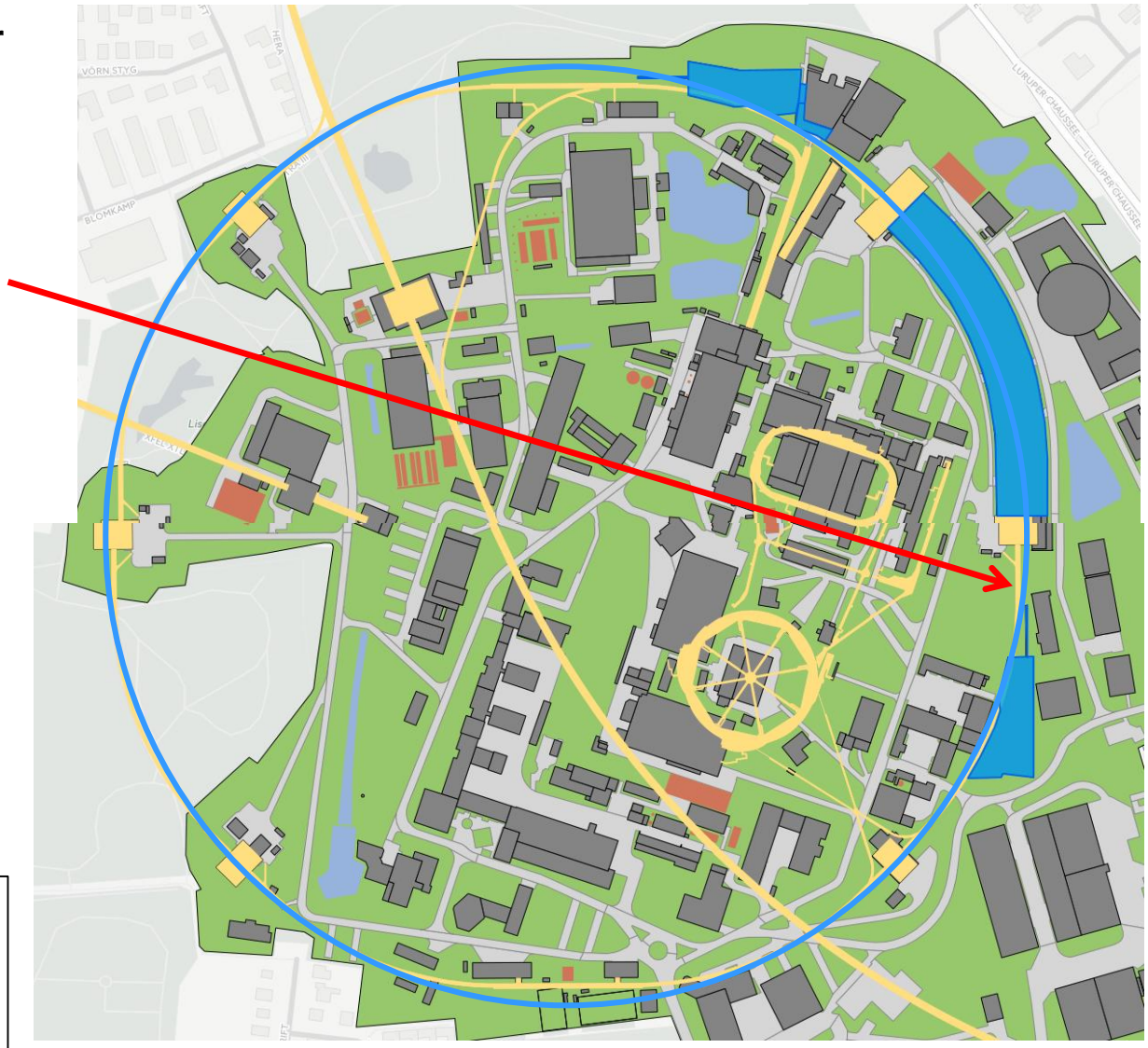


Status of Extension Beamlines

PU21a is a very short undulator (30 cm)





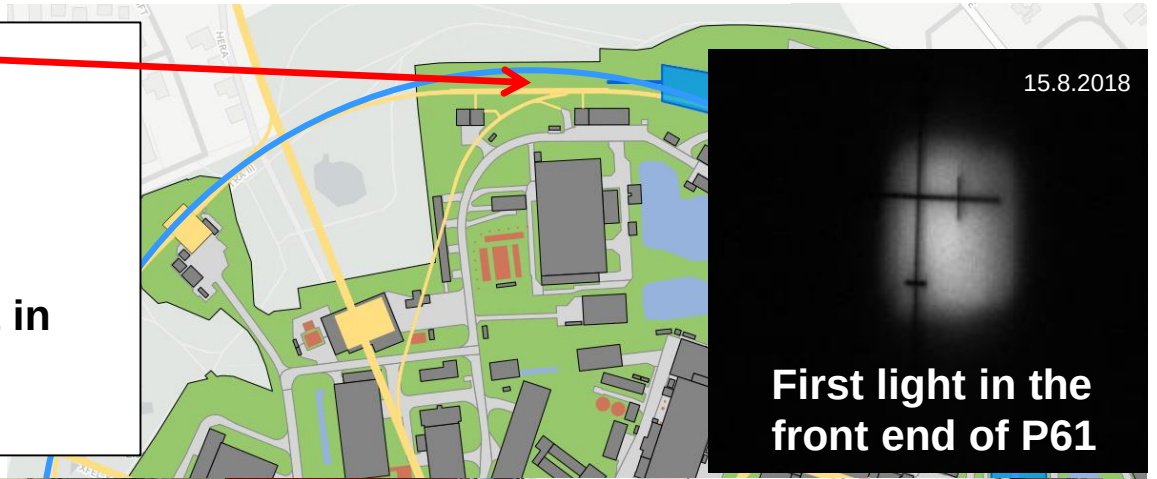


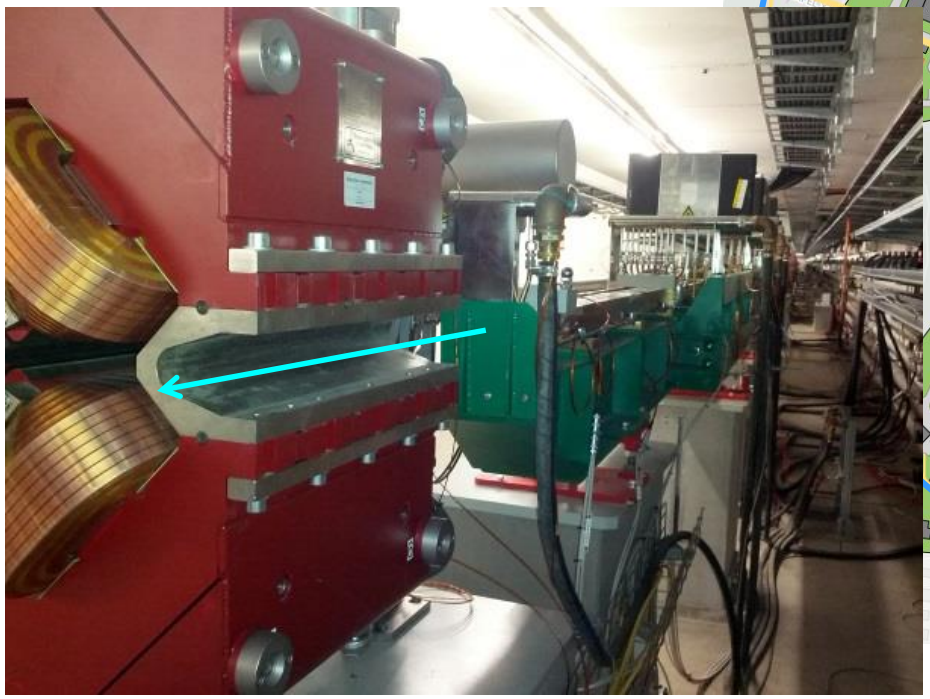
17.9.2018:
First proof of principle diffraction pattern from the ‘baby undulator’ PU21a

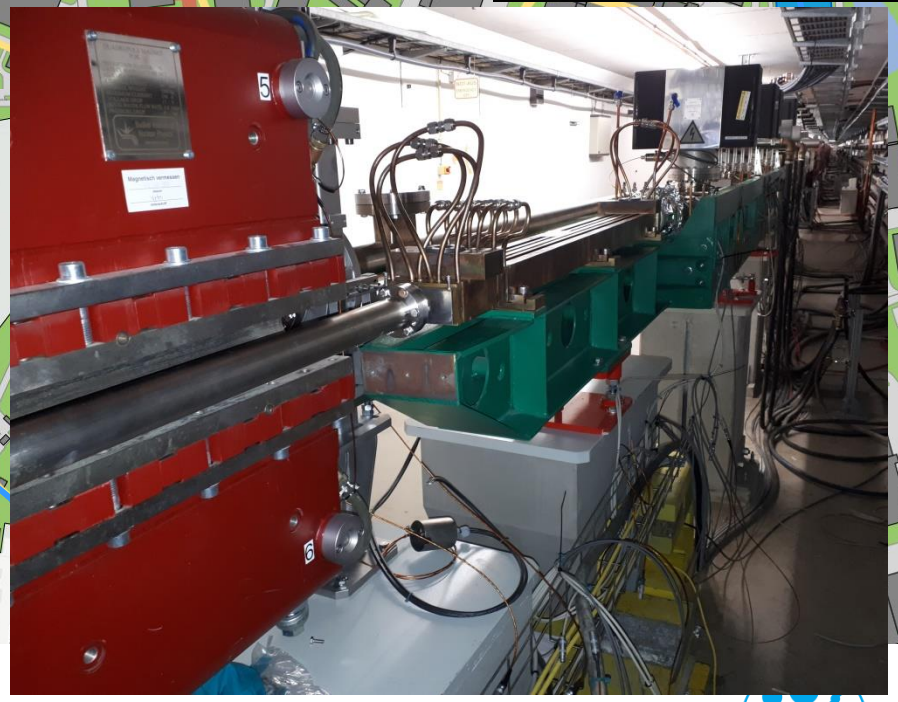
Status of Extension Beamlines

Straight section north, damping wigglers:

- **Hole in the wall for P61**
- **Exchange of last absorber in damping wiggler section**
- **Installation of front end for P61 in the tunnel, including a power absorber**







Plans for 2019

Dez. 2018		Januar 2019	Februar 2019	März 2019	April 2019	Mai 2019	Juni 2019	2019	Juli 2019	Aug. 2019	Sep. 2019	Okt. 2019	Nov. 2019	Dez. 2019
. multi	1		f6263	IB	. 40	. multi low b	. 40	1	. multi	IB tr	. 40	#	. 40	. multi low b
. multi	2			tr	. 40		. 40	2	. multi	IB tr	#	. multi	. 40	. multi low b
. multi	3			tr		. multi low b	# 2m21a	3	#	tr	#	. multi	. 40	. multi low b
. multi	4		IMV	IB tr so	. multi	. multi low b	# 2m21a	4	. multi	tr	#	. multi	. 40	#
MDT	5		IEV NG	IB tr so	. multi	. multi low b	# 2m21a	5	. multi	. 40	#	. multi	. 40	. multi
. multi	6		IEV NG	#	. multi	. multi low b	# 2m21a	6	. multi	. 40	IB	. multi	#	. multi
. multi	7	2m07A f6263 #	IEV NG	tr so	. multi	. multi low b	# 2m21a	7	. multi	. 40		#	. 40	. multi
. multi	8	2m07A f6263 #	IEV NG	tr so	. multi HERC	#		8	. multi	. 40		#	. 40	. multi
. multi	9	ivu07 f6263 p61 #		tr	. multi HERC	. 40		9	. multi	. 40	. multi	#	. 40	. multi
. multi	10	ivu07 f6263 p61 #		tr	HERCULES #	. 40		10		. 40	. multi	#	. 40	. multi
. multi	11	ivu07 f6263 p61 #	IEV NG	. 40	. multi HERC	. 40	IB	11	. multi	. 40	. multi	IB	. 40	#
MDT #	12		IM	. 40	. multi HERC	. 40	IB tr	12	. multi	. 40	. multi		. 40	. multi
. multi	13		IM	. 40	. multi	. 40	. multi	13	. multi	. 40	. multi			. multi
. multi	14	ivu07 f6263 p61 #	IE NG	. 40	. multi	. 40	. multi	14	. multi		. multi	. 40	. 40	. multi
. multi	15	ivu07 f6263 p61 #	IE NG	. 40	. multi		. multi	15	bloptics 3GEV	. 40	. multi	. 40	. 40	. multi
. multi	16	ivu07 f6263 p61 #		. 40	. multi	. 40	. multi	16	bloptics 3GEV	. 40	. multi	. 40	. 40	. multi
. multi	17	ivu07 f6263 p61 #		. 40	#	. 40	. multi	17	bloptics 3GEV	. 40	. multi	. 40	. 40	. multi
. multi	18	ivu07 f6263 p61 #	IE NG	. 40	#	. 40	. multi	18	bloptics 3GEV	. 40	#	. 40	#	. multi
. multi no	19		IE NG	. 40		. 40	Reserve 2m2	19	bloptics 3GEV	. 40	. multi	. 40	#	. multi
. multi	20		NG			. 40	. multi	20		. 40	. multi	. 40	#	
Shutdown	21	ivu07 f6263 p61 #	IB	. 40		. 40	. multi	21			. multi	. 40	#	
Shutdown	22	ivu07 f6263 p61 #	IB	. 40		#	. multi	22	bloptics 3GEV	. 40	. multi	. 40	IB	
Shutdown	23	ivu07 f6263 p61 #		. 40	#	. 40	. multi	23	bloptics 3GEV	. 40	. multi	#		
Shutdown	24	ivu07 f6263 p61 #		. 40	#	. 40	. multi	24	bloptics 3GEV	. 40	. multi	. 40		
Shutdown	25	ivu07 f6263 p61 #	IB	. 40	IB tr	. 40	. multi	25	bloptics 3GEV	. 40		. 40	. multi low b	
Shutdown	26		IB	. 40	. multi low b	. 40		26	bloptics 3GEV	. 40	. multi	. 40	. multi low b	
Shutdown	27		IB	#	. multi low b	. 40	. multi	27		. 40	. multi	. 40	. multi low b	
Shutdown	28	ivu07 f6263 p61 #	IB	. 40	. multi low b		. multi	28			. multi	. 40	. multi low b	
Shutdown	29	ivu07 f6263 p61 #		. 40	. multi low b	. 40	. multi	29	bloptics #	. 40	. multi		. multi low b	
Shutdown	30	ivu07 f6263 p61 #		. 40	. multi low b	. 40	. multi	30	bloptics #	. 40	. multi	. 40	. multi low b	
Shutdown	31	f6263 #		. 40		. 40		31	bloptics #	. 40		. 40		

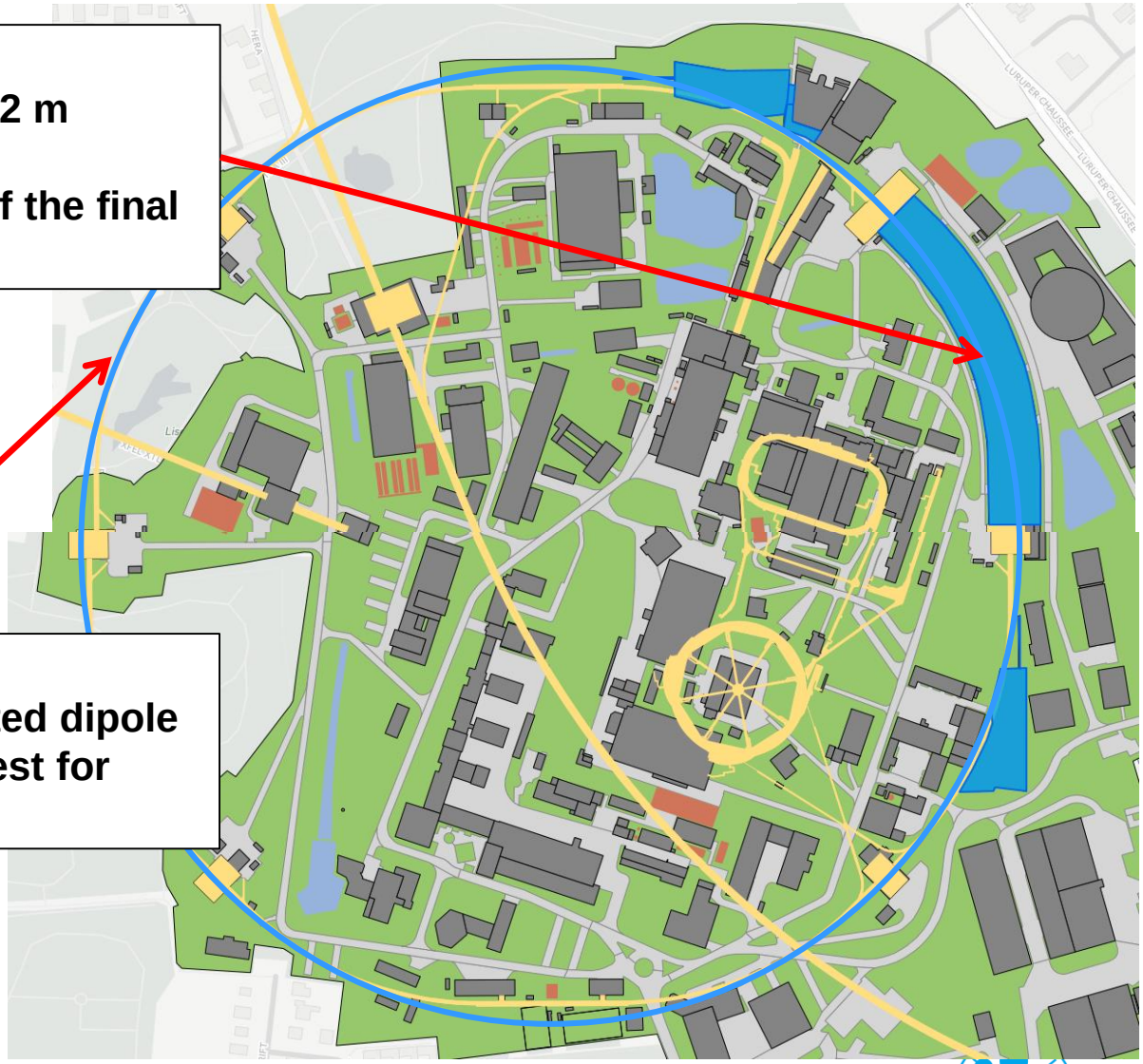
set-up
service week
user time
MDT machine time
Sunday/holiday

Shutdowns in Jan/Febr and July/Aug

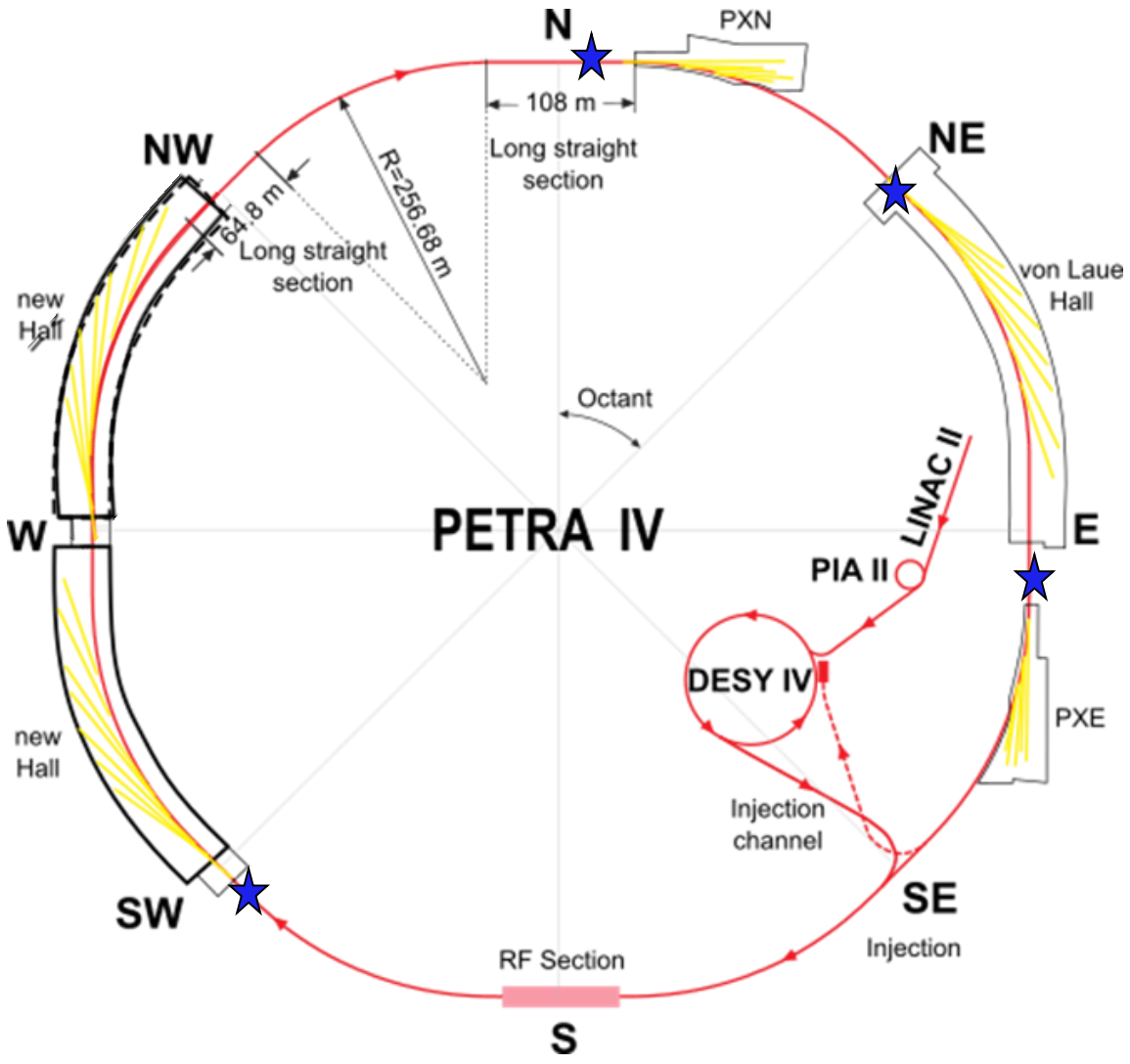
Plans for Winter 2018/2019

Max von Laue Hall:
- **Removal of the temporary 2 m undulator PU7**
- **Installation and bake out of the final In-Vacuum-Undulator PU7**

In the arc West Right:
- **Installation of 10 NEG coated dipole chambers, NO bake out (Test for PETRA IV)**



PETRA IV



PETRA IV:

- 2 new experimental halls
- 4 undulator cells in the long straight sections ★
- H7BA – ESRF 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 ξ_x/ξ_y	-230 / -185
Damping part. number J_x	1.24
Nat. emittance ε_x	6.7 pm*rad
MCF α_c	1.48e-5
Energy spread σ_e	0.92e-3
Bunch Length σ_t	6.4 ps
Hor. damping time τ_x	18 ms
Ver. damping time τ_y	23 ms
Long. damping time τ_e	13 ms
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**

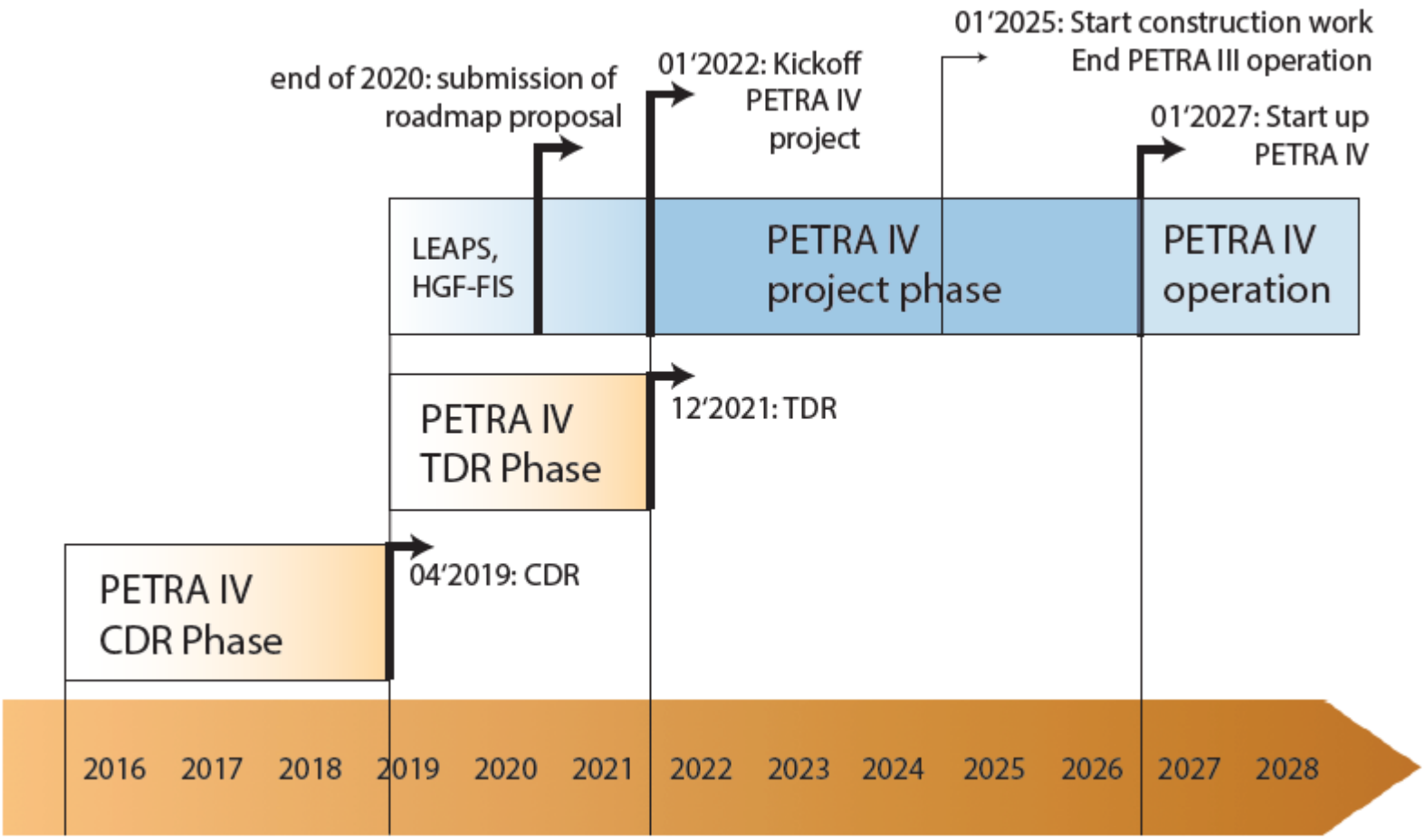
on axis injection, 96 ns timing structure
- **20 bunches (76 ns + 20 ns gap)**
- **1 bunch**

Work in Progress

PETRA IV

Presently: CDR preparation phase
Goal: CDR 04' 2019

TDR Phase defined from the project phase
Goal: 1) bring PETRA IV onto the national roadmap of large-scale research facilities
2) TDR 12'2021



Thank you for your attention!