Facility Report – DESY –

ARD-ST3 Annual Meeting 2020

Holger Schlarb, Group Leader MSK/DESY
KIT, Karlsruhe, 23. September 2020

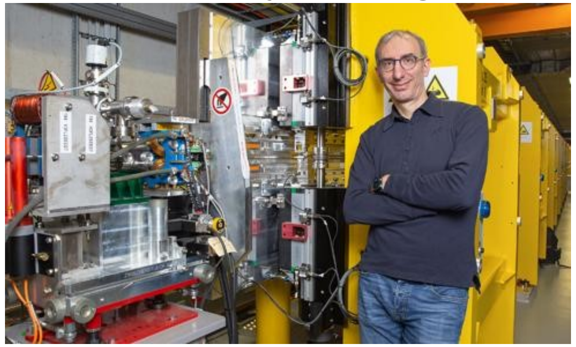
Report covers…

- **PETRA III / PETRA IV** new: Riccardo Bartolini

PIV Project Management

- **FLASH / FLASH2020+** new: Enrico Allaria

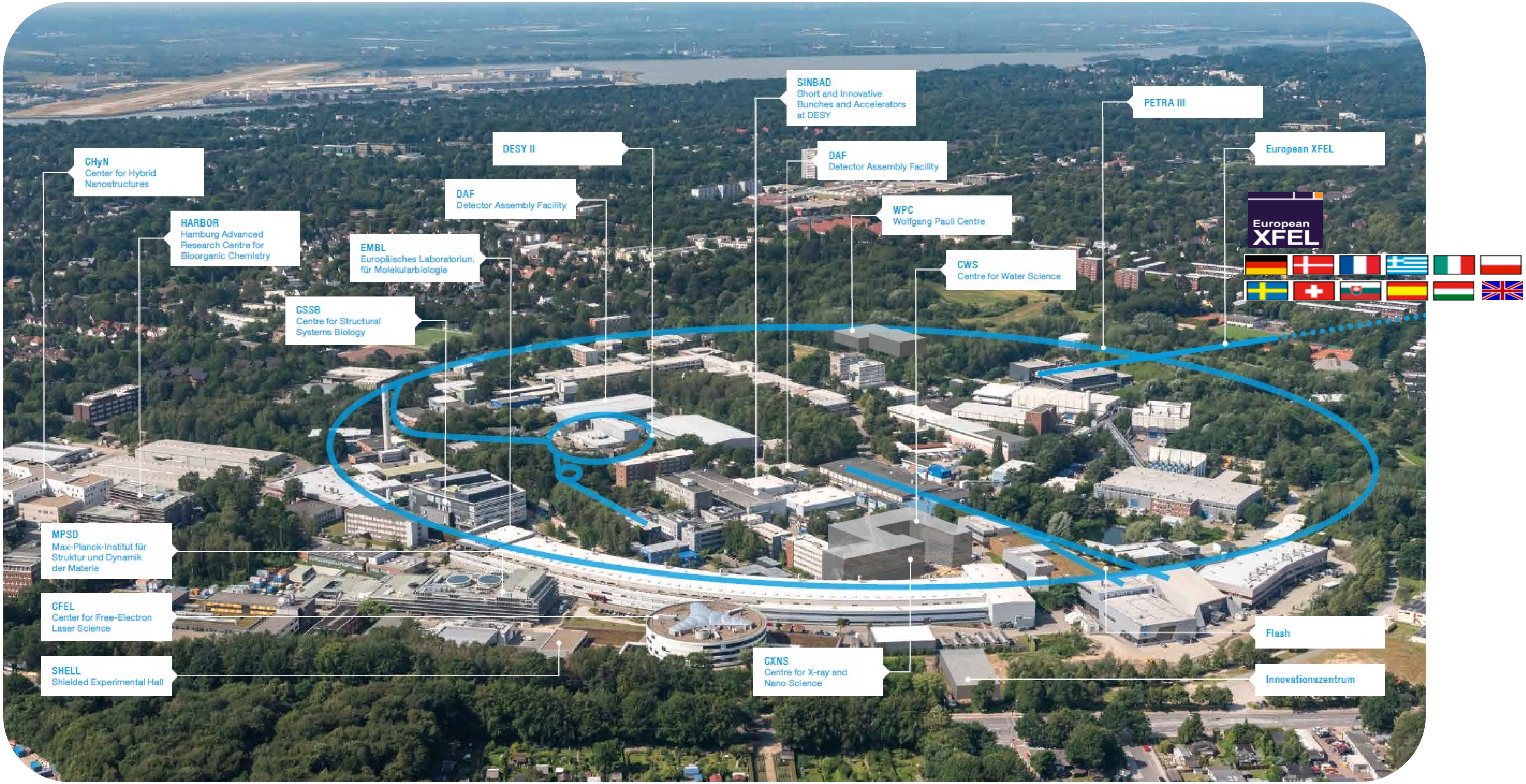
FLASH2020+ Project Management



- **European XFEL**

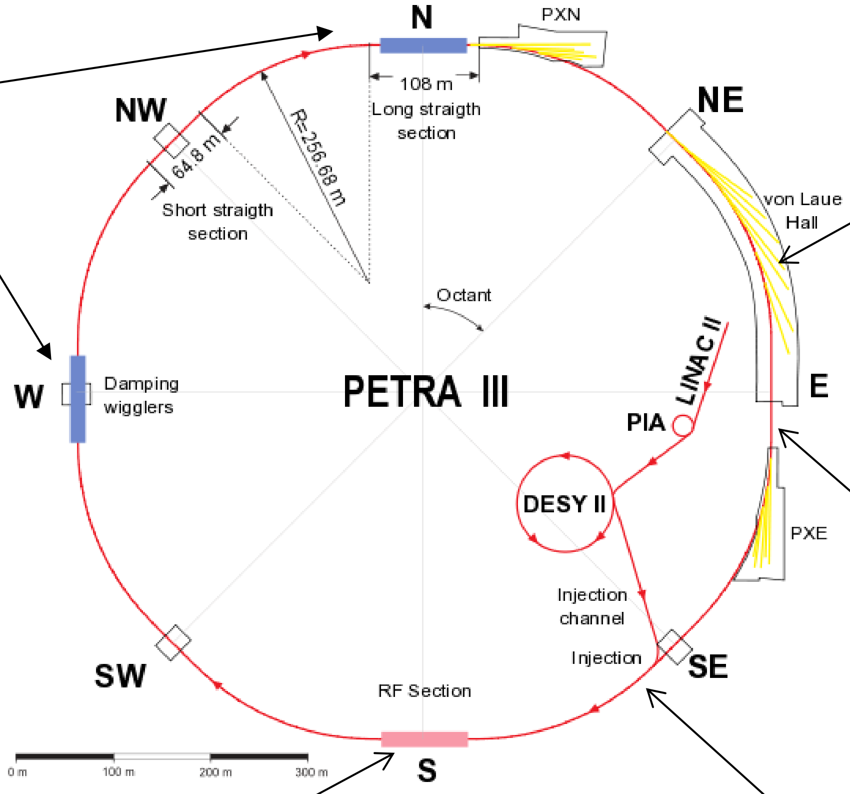
- **PITZ** → see **Mikheil Krasilnikov**
- **ARES/ATHENAe** → see **Florian Burkard**

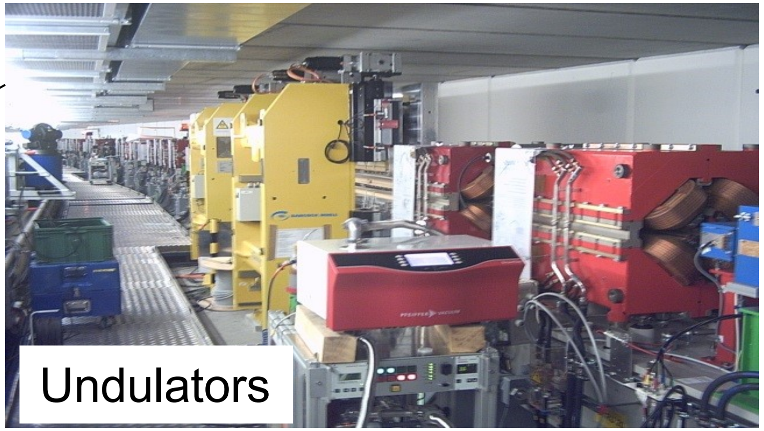
DESY activities : birds view …

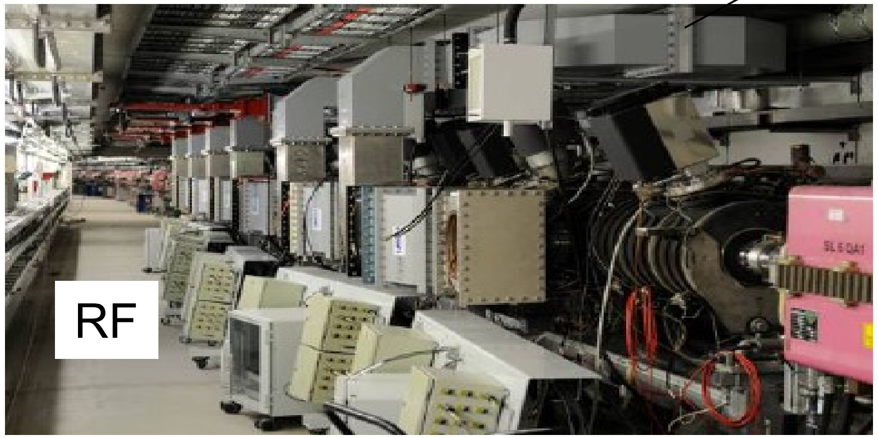


PETRA III / IV

PETRA III





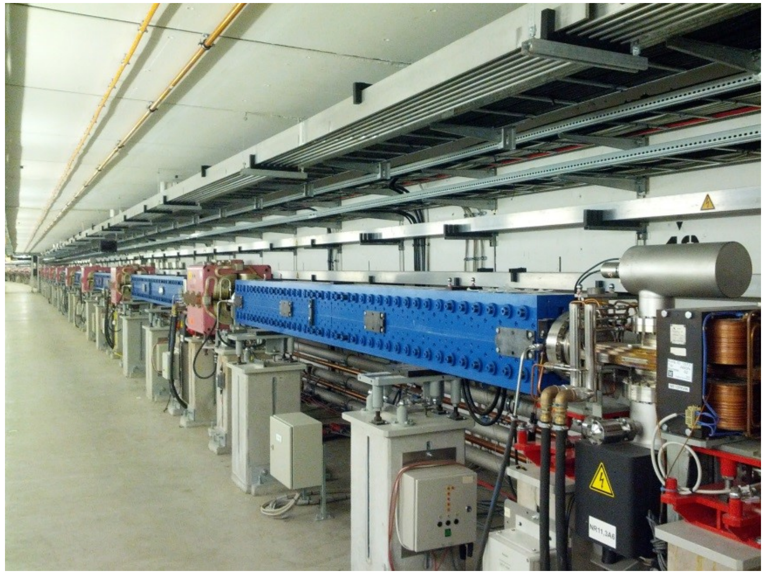


Courtesy: R. Wanzenberg

PETRA III

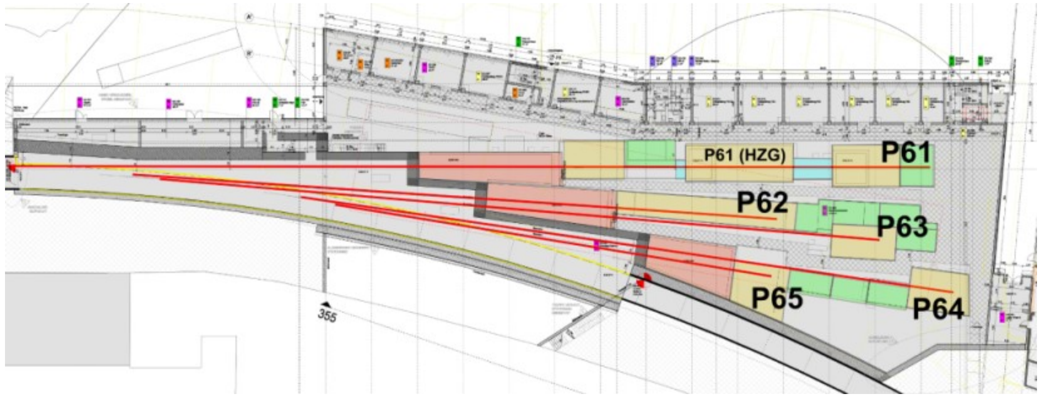
Parameter	PETRA III	
Energy / GeV	6	
Circumference /m	2304	
Emittance (horz. / vert.) /nm	1.2 / 0.012	
Total current / mA	100	
Number of bunches	960	40
Bunch population / 10^{10}	0.5	12
Bunch separation / ns	8	192

Damping Wigglers: B ~ 1.5 T, λ = 0.2 m
2 x 10 x 4 m = 80 m
ε_x: 5 nm → 1.2 nm

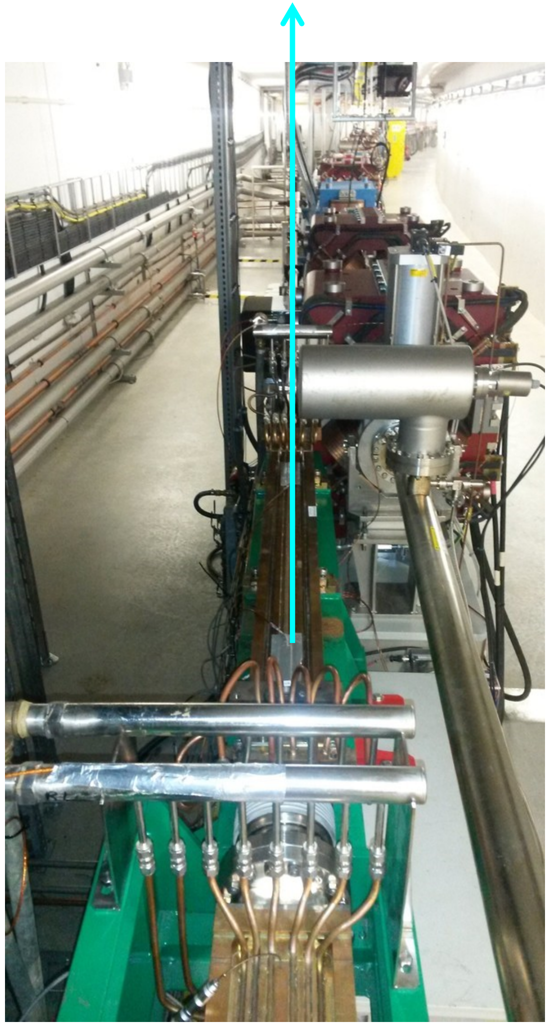


P21 b/a: In vaccum unudlator

Ext. North



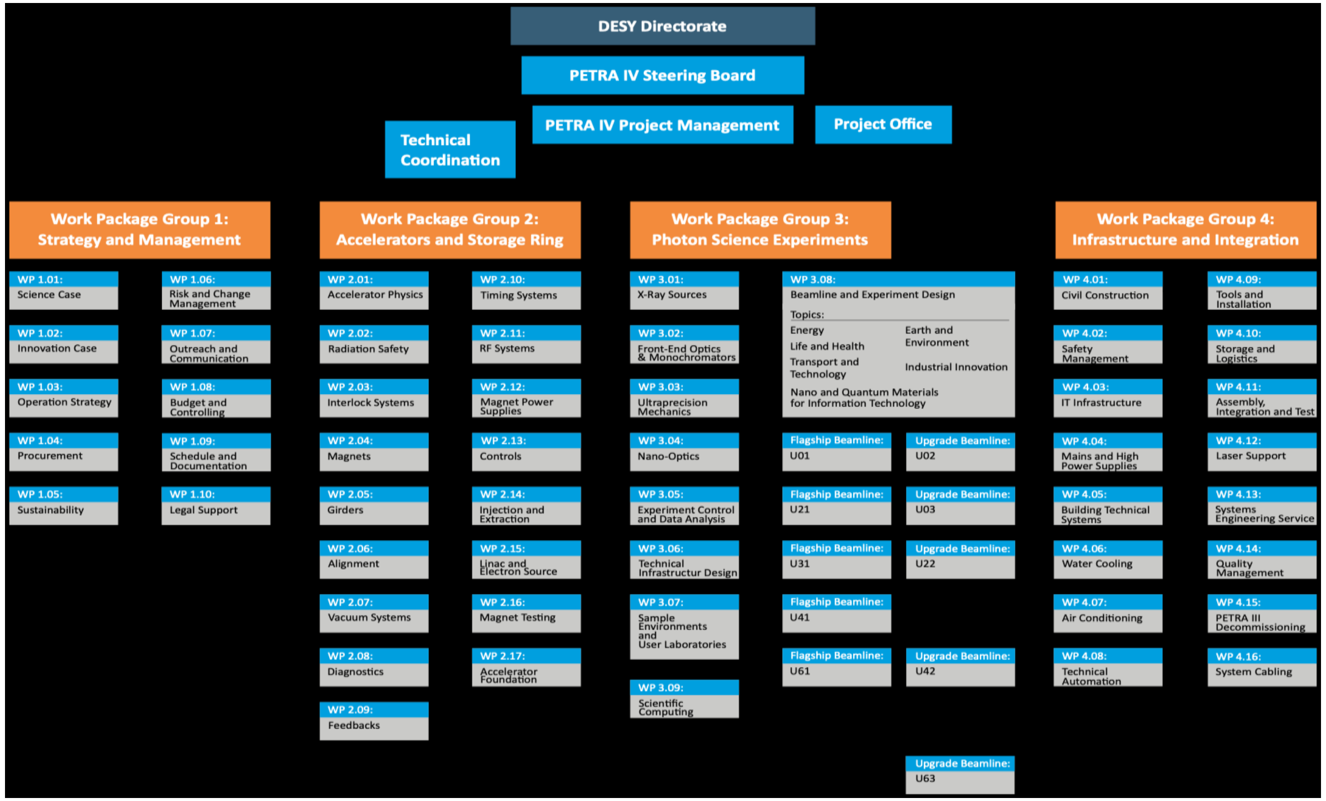
To beam line P61

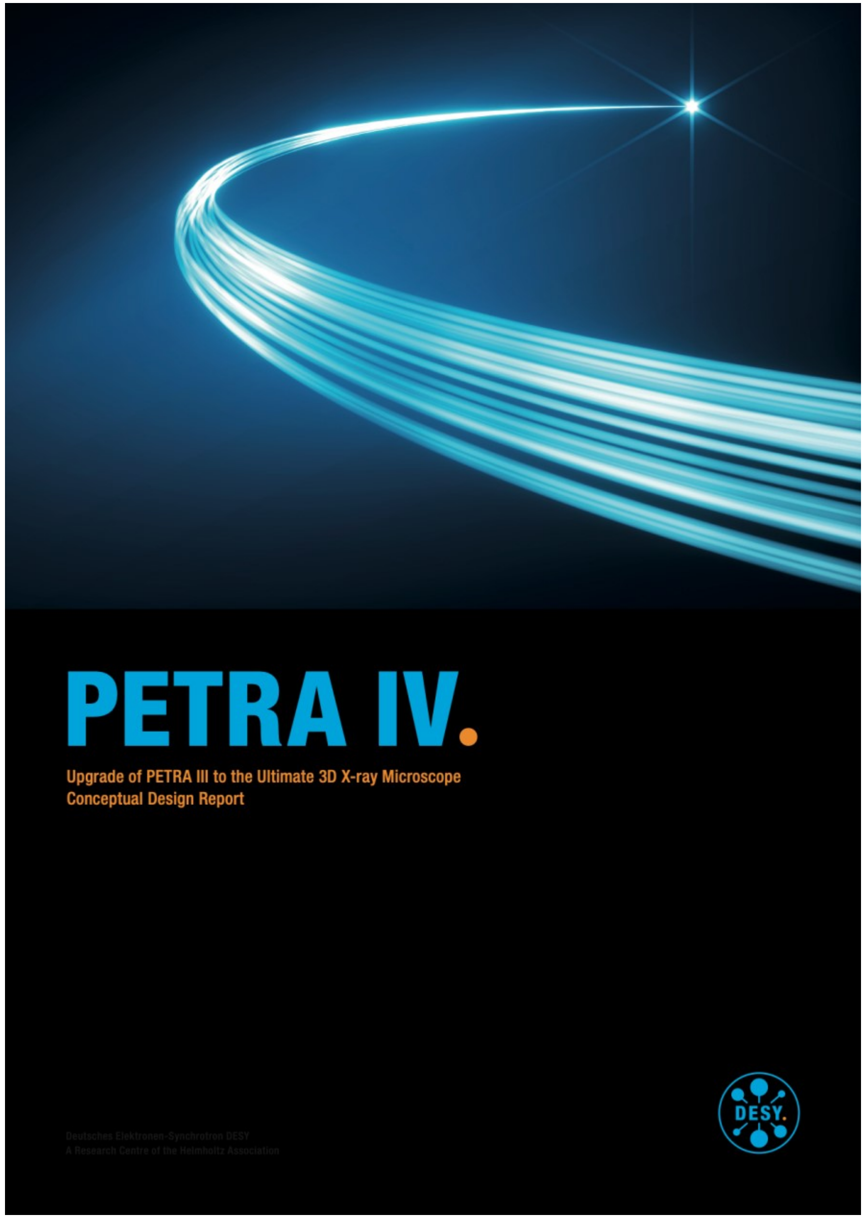


Courtesy: R. Wanzenberg

PETRA IV

- Conceptual Design Report Completed
    - Scientific case developed with the help of the user community (> 700 participants in 13 workshops, KFS support)
- Technical Design Report started 01/2020
    - Defined work packages & start hiring process





DOI: 10.3204/PUBDB-2019-03613

PETRA IV

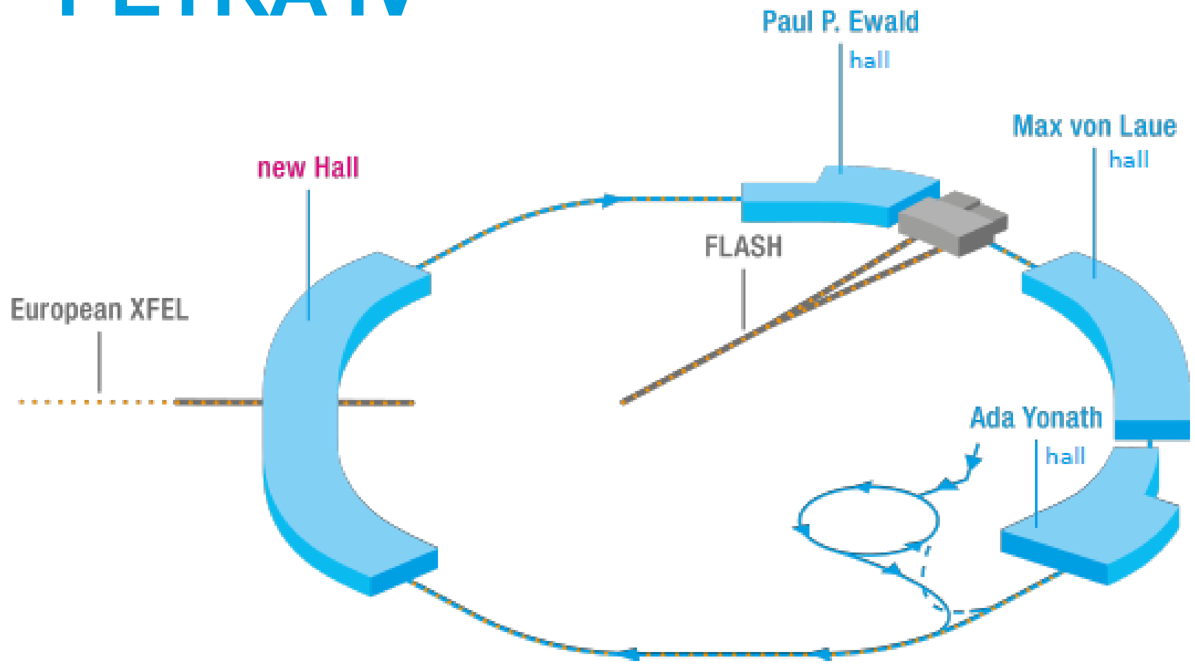
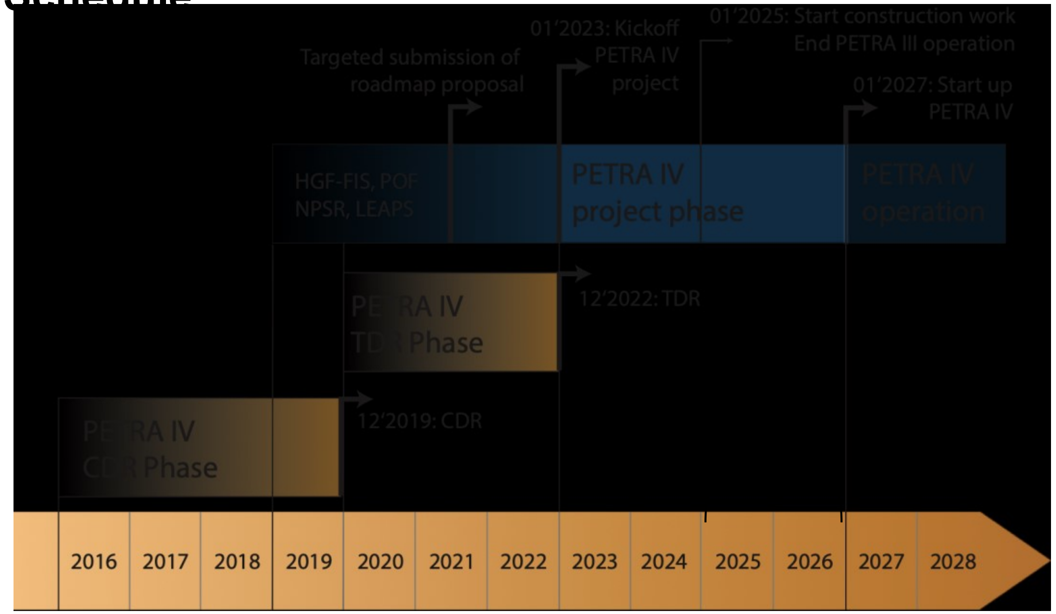


Figure 1.1.: *PETRA IV storage ring and accelerators. The new experimental hall in the west is located largely underground.*

Parameter	PETRA IV Brightness mode	PETRA IV Timing mode	PETRA III	
Energy / GeV	6	6	6	
Circumference / m	2304	2304	2304	
Total current / mA	200	80	100	
Number of bunches	1600	80	40 . . . 960	
Emittance				
Horiz. ϵ_x / pm rad	< 20	< 50	1300	**x 65**
Vert. ϵ_y / pm rad	< 4	< 10	10	**x 2.5**
Number of undulator beamlines	30		21(26)	

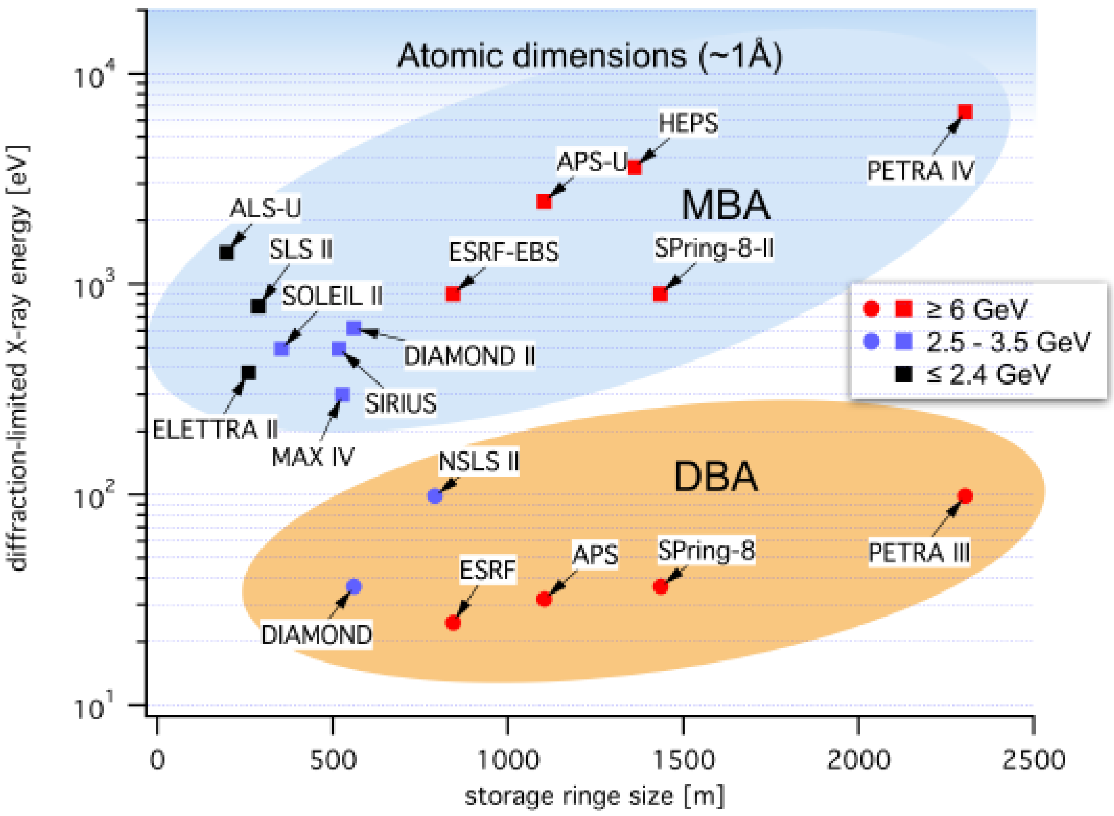
Schedule:



- > 150 improved emittance/ diff. limit at 1 Å
- Demanding schedule (~2 yr dark time)
- Public: www.desy.de/petra4

PETRA IV

- Diffraction-limited photon energy for syncr. rad. Sources and there upgrades



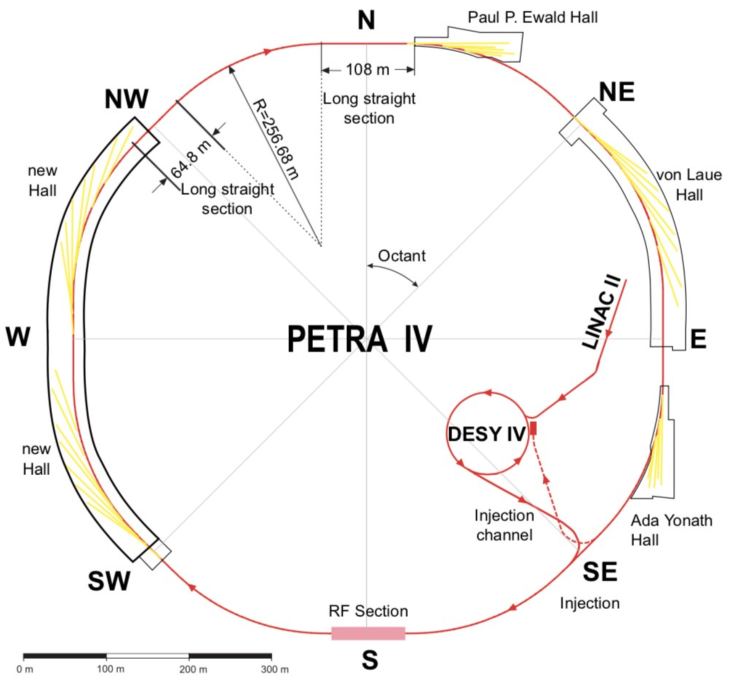
Science City Bahrenfeld

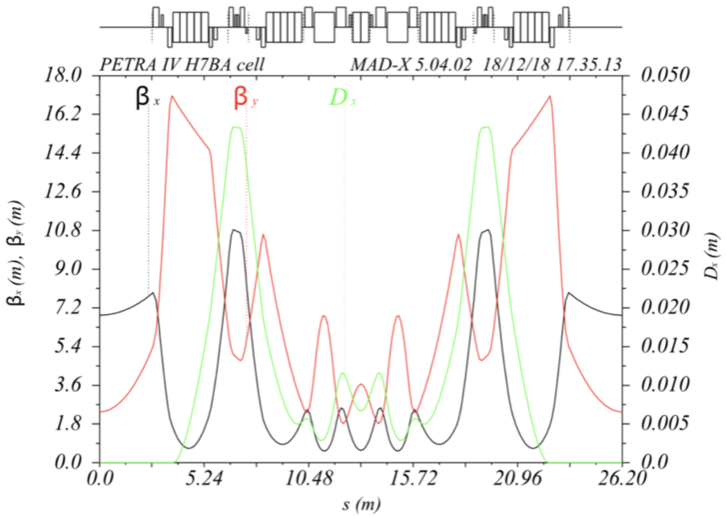
PETRA IV

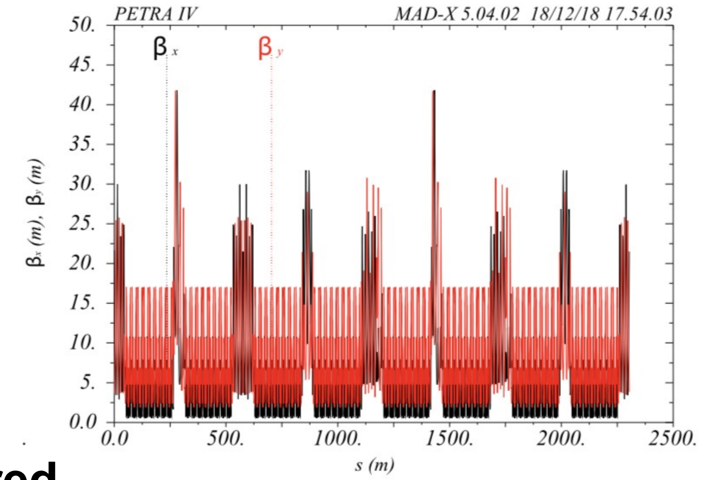
New hall (covered)

PETRA IV: lattice design

- CDR baseline (optimized) lattice used in engineering integration
  - ➢ Hybrid 7BA cell (26.2m)
  - ➢ No reverse bends
  - ➢ 4 optimized “super-IDs” with 4m β







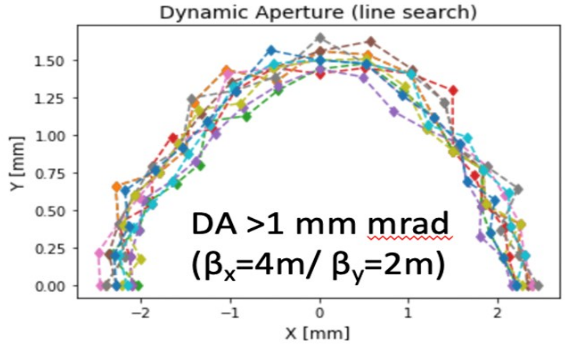
➔ On axis injection required

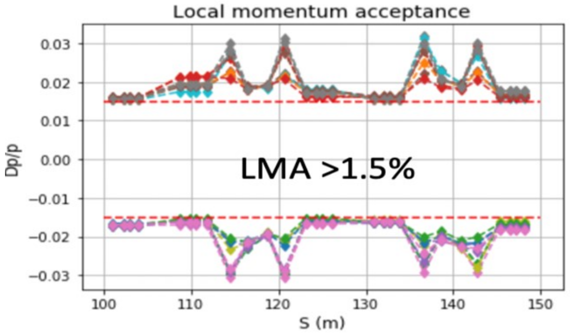
➔ Booster lattice currently finalized

Further optimizations ongoing:

- Improvement DA/MA
- Increase Touschek lifetime (timing mode)
- Photon extraction beamlines
- Reduce gradients Q,Sex,Oct

& Combi-lattice is investigated



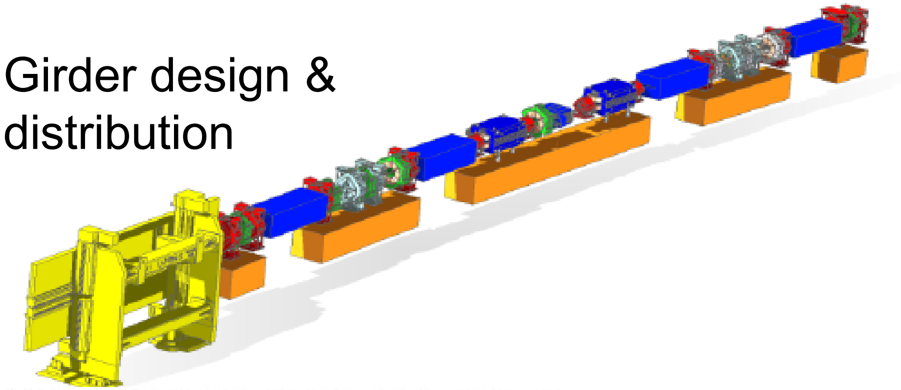


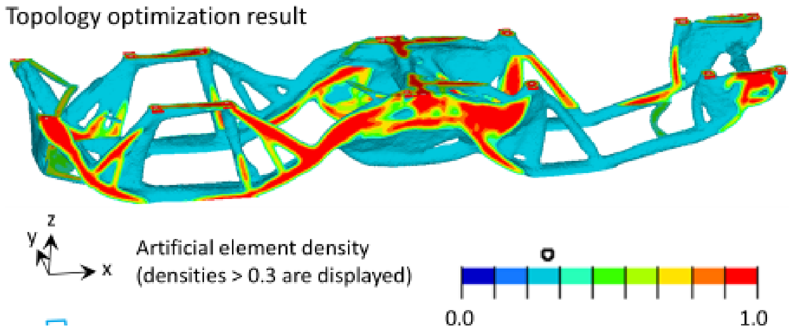
Courtesy: I. Agapov

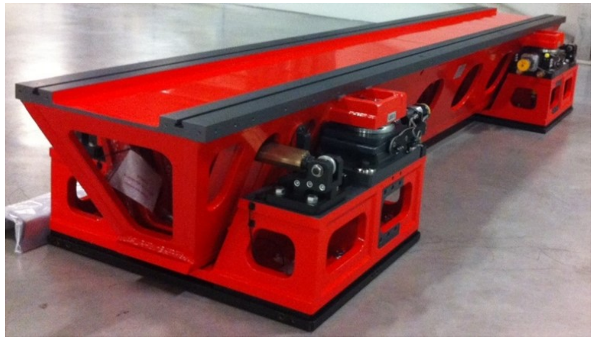
PETRA IV: challenges

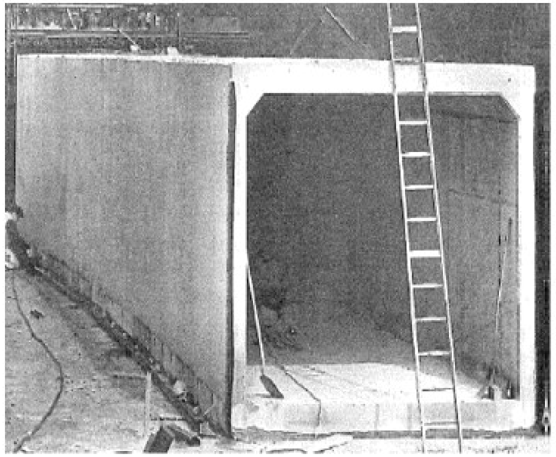
- Short & long term stability … ~ 10% of beam size

Girder design & distribution



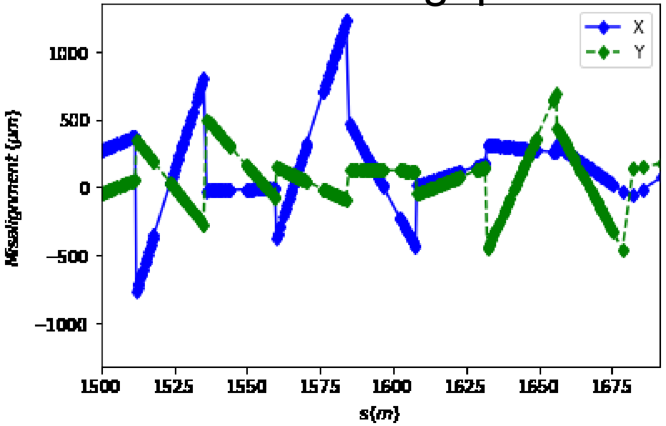


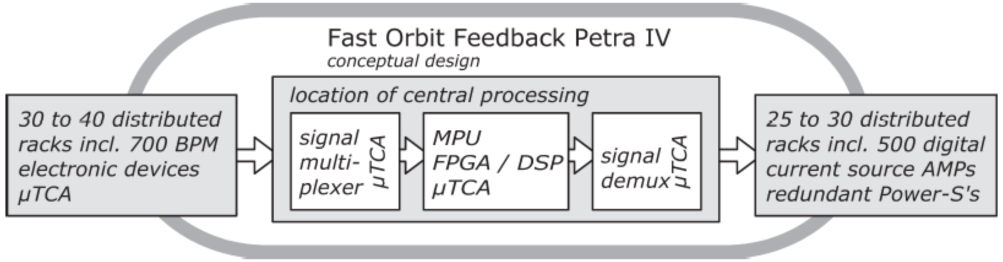




Old tunnel ~ 24m long segments

Simulation: I. Agapov





→ Integral approach (BPM+PhBPM) including Beamline & Experiment required

- … and many more e.g. 2000 magnets + PS, first turn, diagnostics, logistics, ….

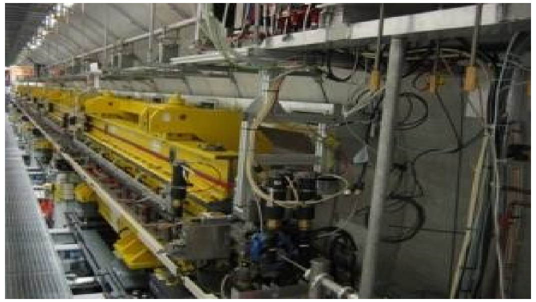
FLASH

FLASH Layout

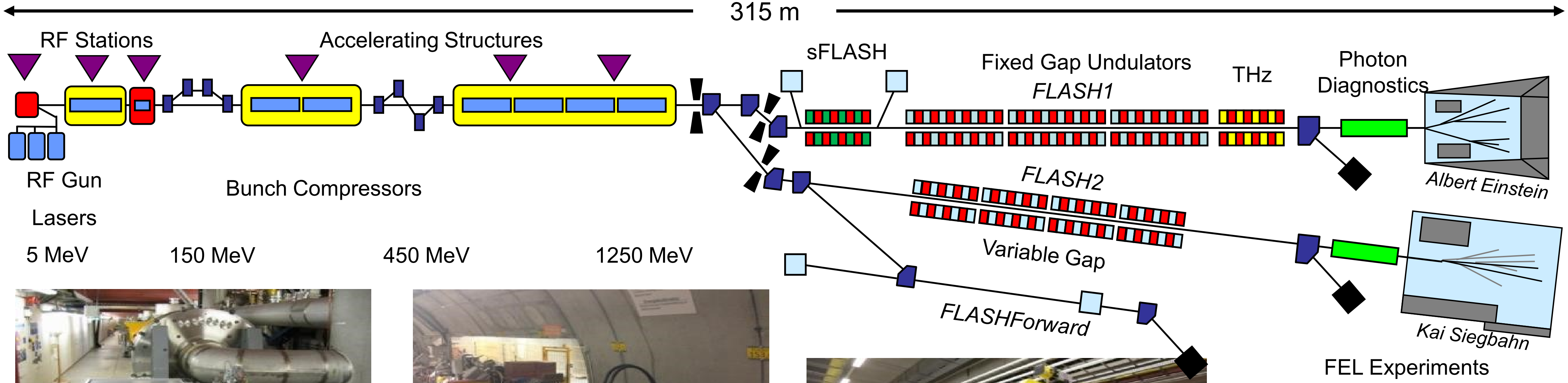
3rd harmonic sc module 3.9 GHz

TESLA type superconducting accelerating modules 1.3 GHz

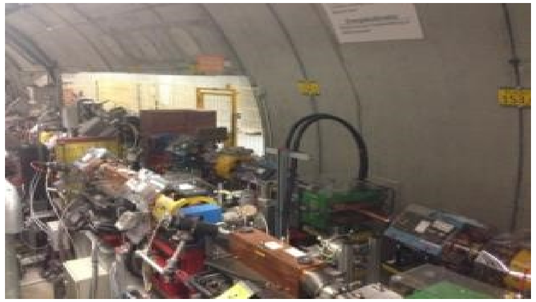
FLASH1 fixed gap undulators



FLASH1 Albert Einstein Hall



Normal conducting 1.3 GHz RF gun
Ce_2Te cathode / 3 injector lasers



Extraction to FLASH2

FLASH2 variable gap undulators

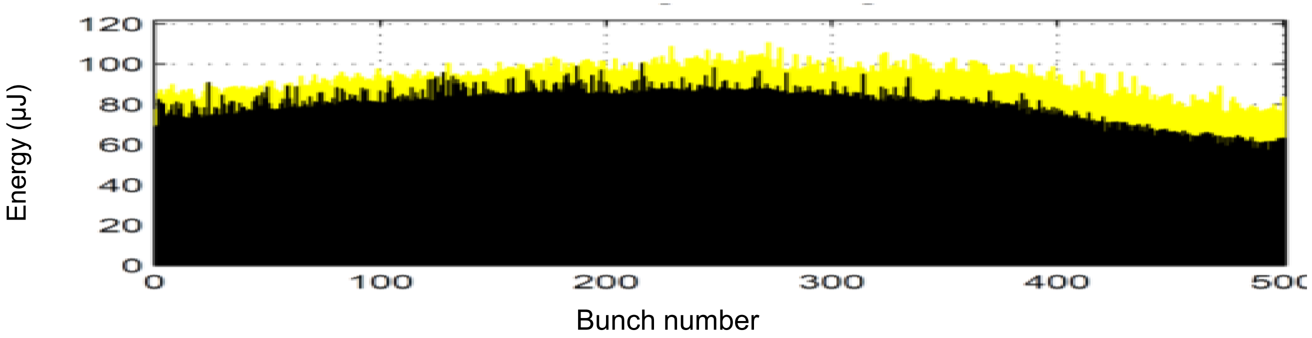
FLASH2 Kai Siegbahn Hall

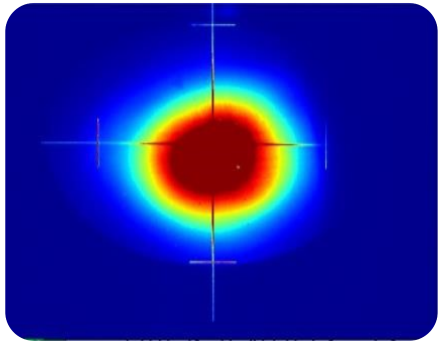
FLASH Parameters

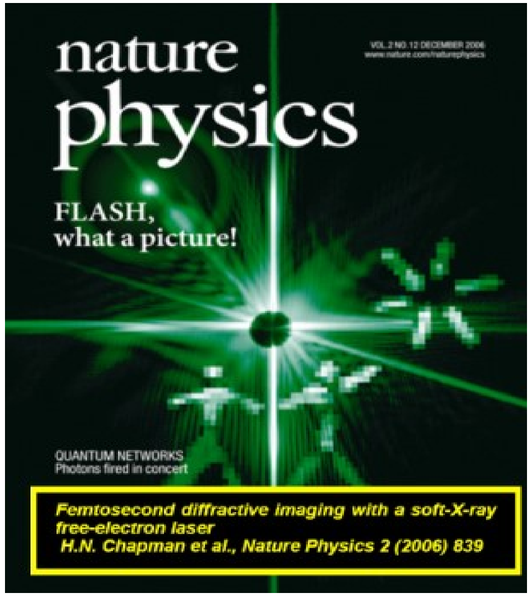
No changes in parameters

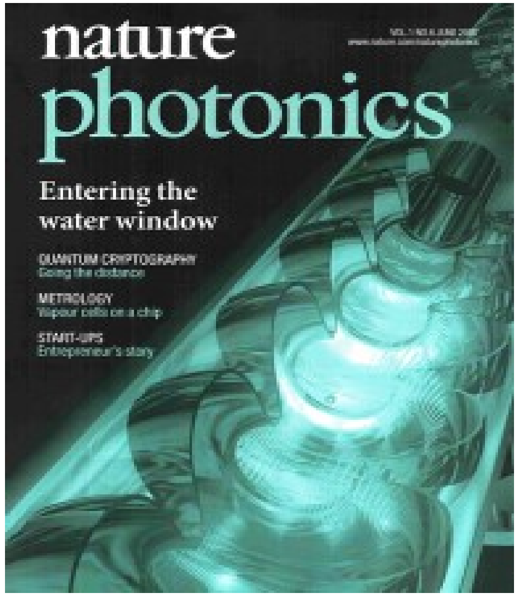
FEL Radiation Parameter FL1 / FL2	
Wavelength range (fundamental)	4.2 – 51 nm / 4 – 90 nm
Average single pulse energy	1 – 500 µJ / 1 – 1000 µJ
Pulse duration (FWHM)	< 30 – 200 fs
Peak power (from av.)	1 – 5 GW
Pulses per second	10 – 5000
Spectral width (FWHM)	0.7 – 2 % / 0.5 – 2 %
Photons per pulse	$10^{11} – 10^{14}$
Average Brilliance	$10^{17} – 10^{21}$ B*
Peak Brilliance	$10^{28} – 10^{31}$ B*

* photons/ s/ mrad^2/ mm^2/ 0.1%bw









http://photon-science.desy.de/facilities/flash/publications/scientific_publications

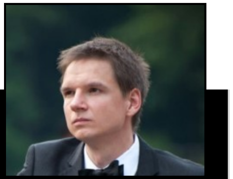
FLASH 2020+ Conceptual Design Report

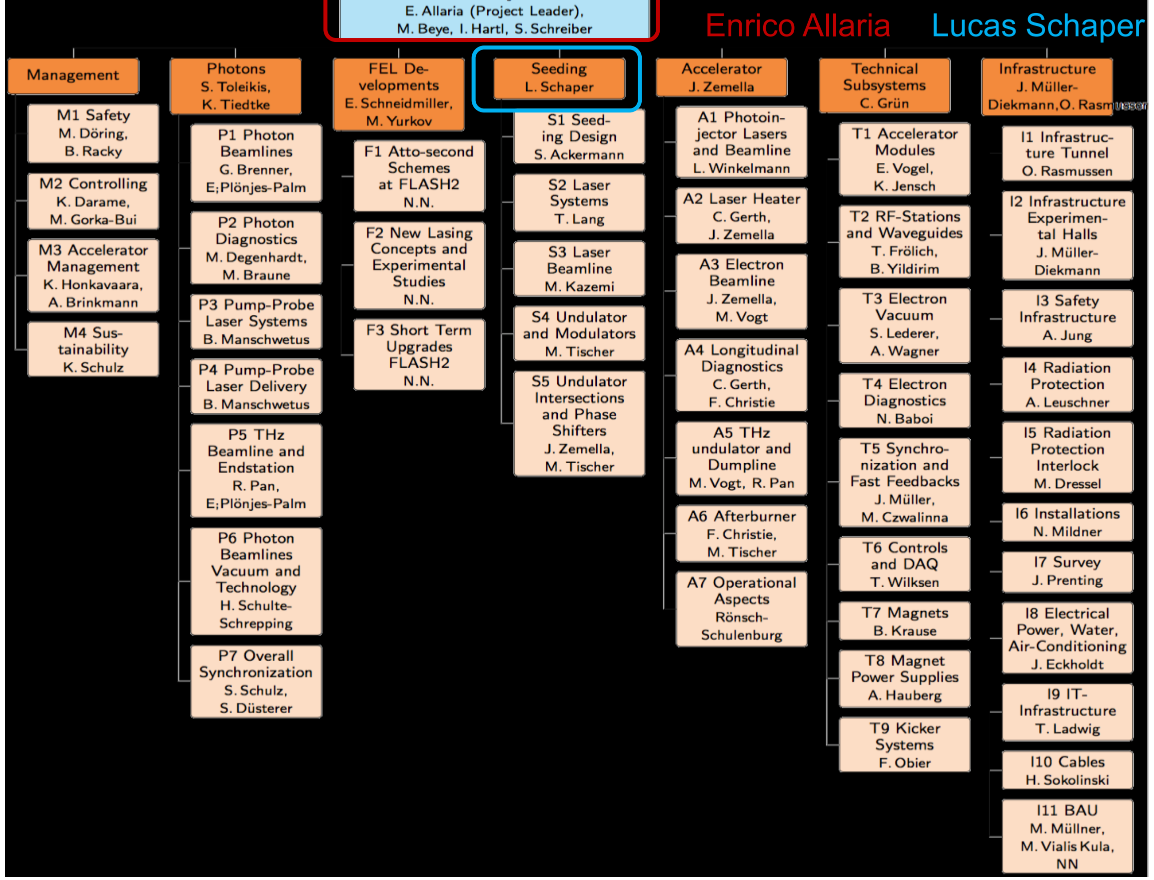
A concept to secure a bright future for the next decade

- FLASH2020+ Conceptual Design Report
  ➔ Science case & facility upgrade

- Project Structure established


Enrico Allaria


Lucas Schaper



User Requirements vs. upgrade plans

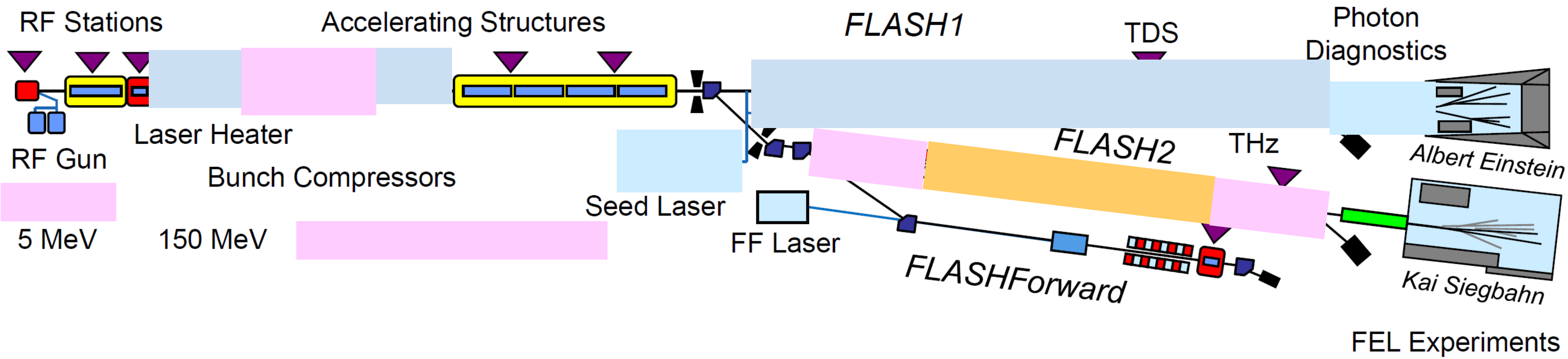
Dream facility expressed within the "Future of Science at FLASH" Workshop Sept. 25-27, 2017

Dream Facility	FLASH2020+ Goals	FEL Line
Fundamental up to O-K-edge	Extend wavelength range of the fundamental → novel undulator schemes, **increase beam energy**	FLASH2
Variable polarization	**Variable polarization** (FL2 with afterburner)	FLASH1 and 2
Flexible pump-probe schemes (THz → XUV)	Provide flexible laser- and FEL based schemes for **multi-color pump-probe experiments**	FLASH1 and 2
Fourier-limited pulses (transverse and longitudinal)	Laser manipulate electron bunches in burst mode with up to 1 MHz rate → **external seeding** with high rep. rate	FLASH1
Few fs- and sub-femtosecond pulses	Enable dynamic studies with **sub-femtosecond** to attosecond precision	FLASH2
100 kHz cw		FLASH@XFEL

Courtesy: S. Schreiber

FLASH2020+ will be executed in four phases

Initial upgrades were started 3 years ago and funding for full project secured in 2019/2020



Phase 0
Energy upgrade
3^{rd} BC (FLASH2)
TDS (FLASH2)
Injector Laser
Afterburner FLASH2

Phase 1
Variable gap undulators (FLASH1)
Pump-probe laser (FLASH1)

Laser heater in 1st BC
New 2nd bunch compressor (BC)

Phase 1+
High rep.rate seeding (FLASH1)
Photon diagnostics (FLASH1)

Phase 2
New variable gap undulators + chicanes
for new lasing concepts (FLASH2)

2017 2018 2019 2020 2021 2022 2023 2024 2025 2026

Phase 0 | **Phase 1** | **Phase 1+** | **Phase 2**

Courtesy: Schreiber

Parameter Space FLASH2020+

The first seeded high repetition rate XUV and soft X-ray FEL

	FLASH1 (Seeded)	FLASH1 (SASE)	FLASH2	
Wavelength range	4 – 60	4 – 60	1.3 – 60*	nm
Pulse energy	<100	<1000	<1000	µJ
Pulse duration (FWHM)	30***	5 – 200	0.1 – 200	fs
Spectral width	Fourier limited	0.5 – 2	0.5 – 2	%
Pulses per second**	10 – 5000	10 – 5000	10 – 5000	

* including third harmonic

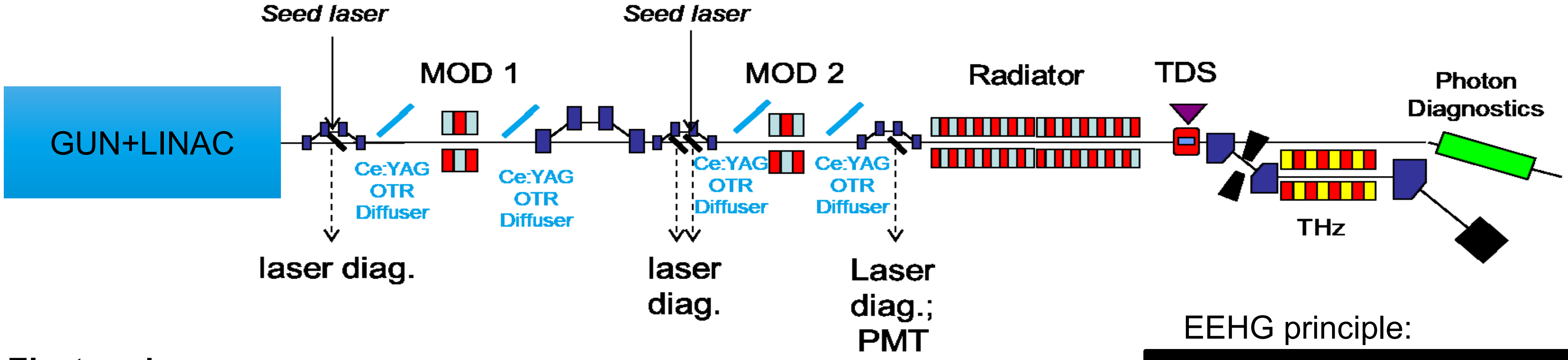
** to be shared between FLASH1 and FLASH2 (goal: 1 ms RF pulse length)

*** from 23 fs @ 4nm → 45 fs @ 60 nm

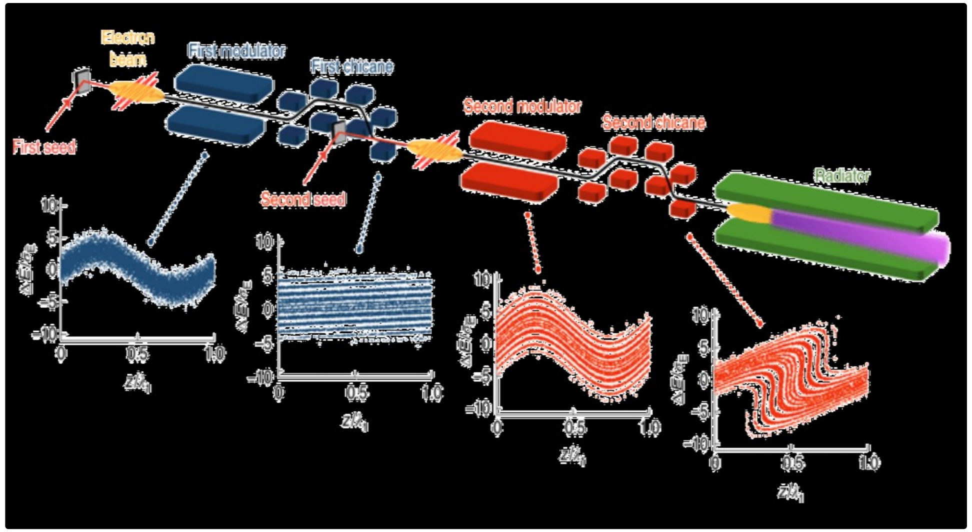
Courtesy: S. Schreiber

FLASH2020+ Seeding is a central component for the project

Basic layout of the FLASH1 seeding section is being designed



EEHG principle:



Electron beam

Parameter	Value
Charge	0.17 nC
Peak current	500 A
Energy	EEHG 1.35 GeV HGHG 750 MeV
Emittance $\epsilon_{x,y}$	0.6 mm mrad
Energy spread σ_E	150 keV
β_x/β_y	~40 – 5 m

Seed laser

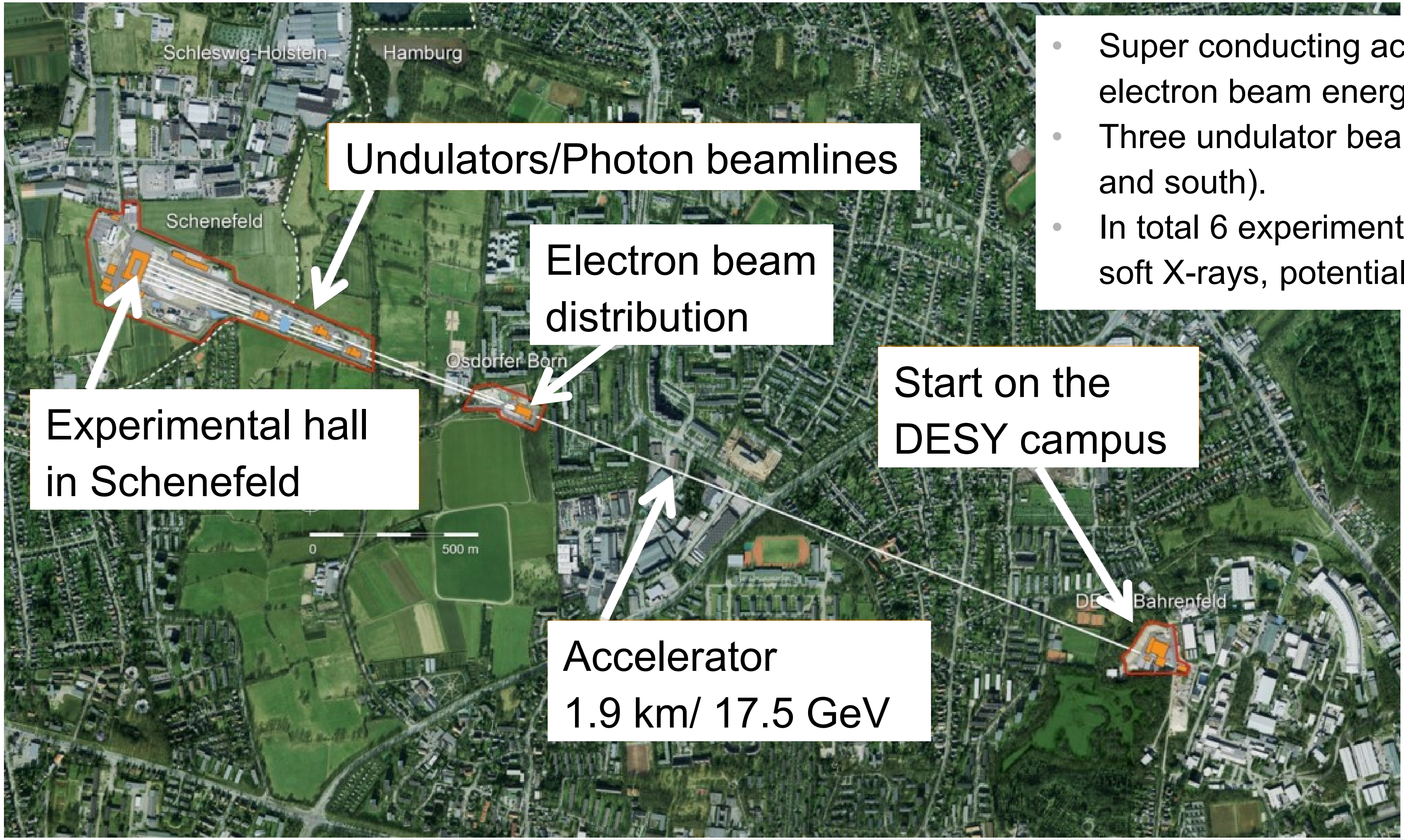
Parameter	Value
Repetition rate	1 MHz
Energy	100 µJ
Duration FWHM	50 fs
Waist w_0	760 µm
Wavelength	Green or UV

Courtesy: S. Schreiber, E. Allaria

European XFEL

The European XFEL between Hamburg Bahrenfeld and Schenefeld

- Super conducting accelerator with up to 17.5 GeV electron beam energy.
- Three undulator beamlines in two branches (north and south).
- In total 6 experiments, 4 for hard X-rays and 2 for soft X-rays, potential for 2 more FELs



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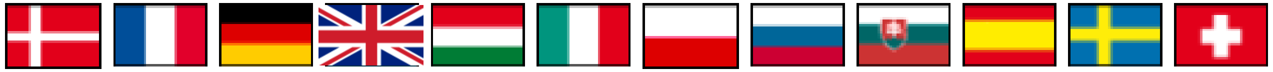


The longest superconducting linac in the world is in operation

- 96 superconducting modules in a single cryostat in the main tunnel
- plus 2 injector modules
- RF components and electronics rack are located below the accelerator.

(Accelerator) Parameter Space (as of Today)

Quantity	Unit	Project Goal	Achieved	Routine
electron energy	GeV	8 – 17.5	6 – 17.5	14
bunch repetition within pulse	MHz	Up to 4.5	Up to 4.5	1.13 - 4.5, plus subharmonics
bunch charge	pC	20 – 1000	100 – 500	250
max. beam power	kW	500 kW	80 kW	40 kW
undulators in operation (lasing)		SASE1-3	SASE1-3	SASE1-3
photon pulses / s / undulator		27000	5000	<3000
photon energy	keV	0.25-25	0.4-4.5; 5.8-20	0.6-2.2; 6 – 14
photon pulse intensity (SASE1) @ 14 GeV, 250 pC, 9.3 keV	mJ		4	2
photon pulse intensity (SASE3) @ 14 GeV, 250 pC, 600 – 900 eV	mJ		10	>5
photon pulse intensity SASE2 (@ 14 GeV, 250 pC, 9 keV	mJ		3	2

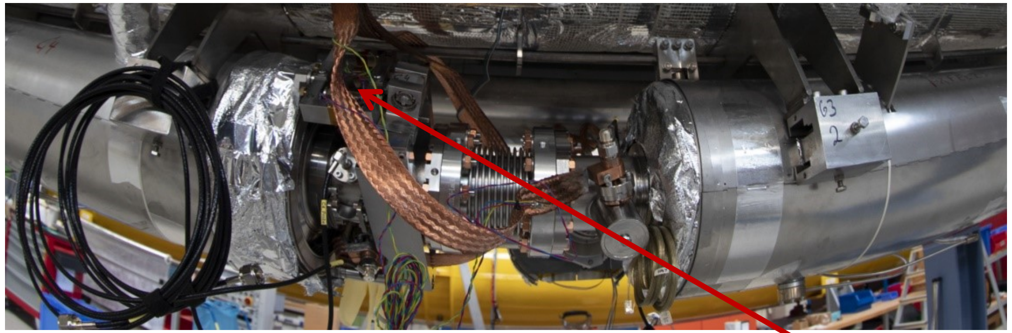
Limited by protection reasons

Stand: 17.09.2020

- **Equal intensity** on SA1/SA2
- **Remaining challenge** (for both hard X-ray undulators):
  - Photon energy scaling
  - keV steps still require re-tuning air coils and phase shifters
- Pre-prepared files, but this reduces flexibility
- Trade off between peak power and tunability

- … it is difficult to keep this performance level in delivery mode, with frequently changing settings

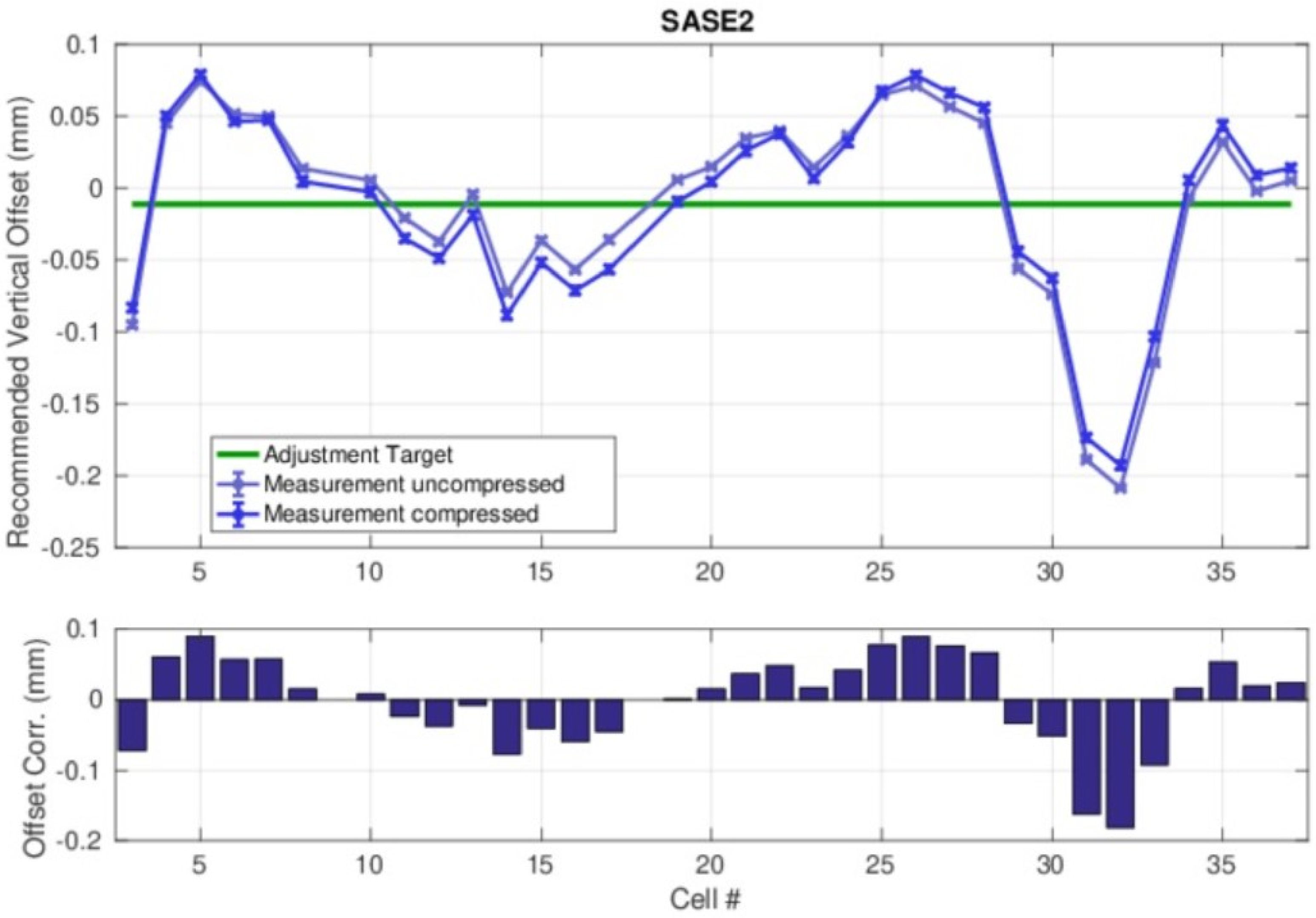
LINAC Improvement: Piezo Operation



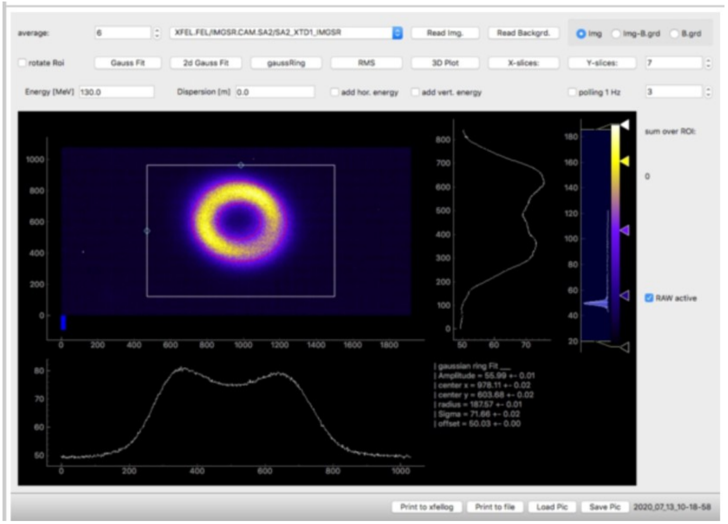
- **Piezo operation commissioning**
  - Technical commissioning
  - Software commissioning
  - Integration with cavity tuning
- **Benefits of piezo operation**
  - More **efficient** use of available klystron power
  - More **stable** operation **close(r)** to quench limit
  - Piezo tuning range allows for 100-200 MeV gradient change **without** having to retune cavities with slow tuners

➔ operation more robust reliable operation at high gradients AND …

K-Mono: Middle plain corrections -> Applied for SASE1/2



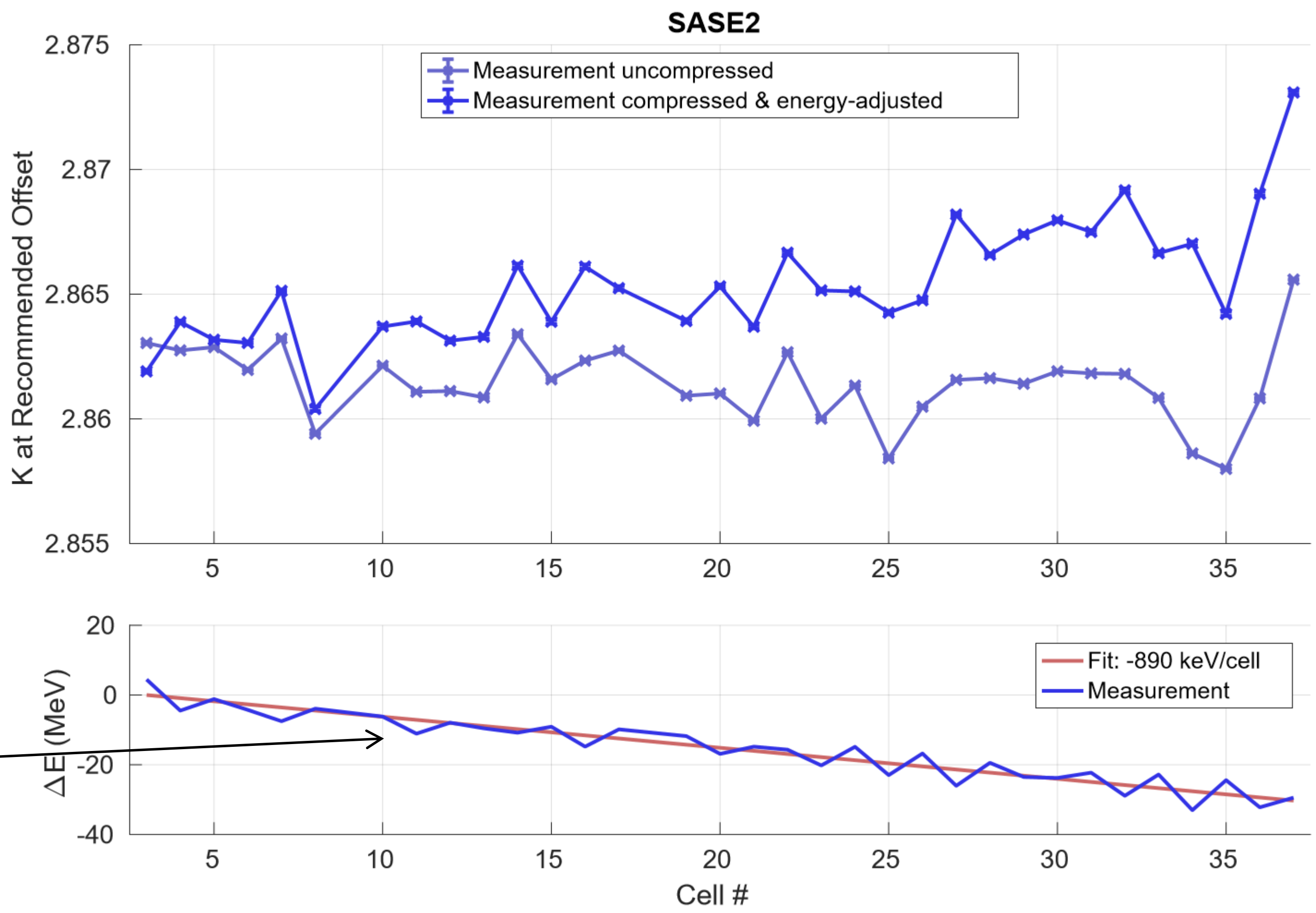
- Enable K-Mono Device
- Scan for Minimum K for Each Undulator on BBA Orbit
- Involves:
  - K-Mono Operation
  - Undulator Controls
  - Different Bridges between DOOCS & Karabo
  - Still Expert Work



K-Mono: After Middle Plain Correction, measure K-Offsets along the Undulator

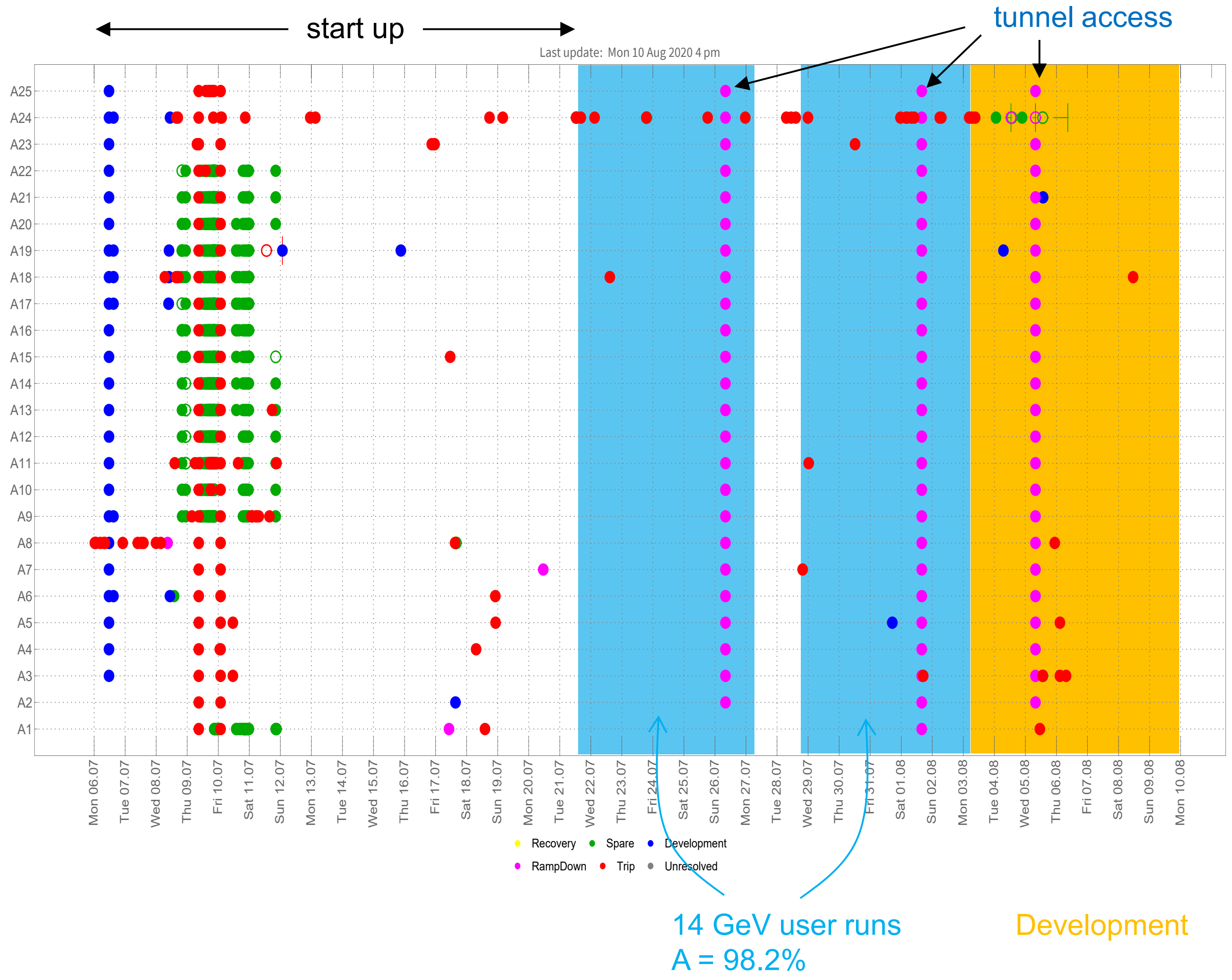
Two Measurements:

- Uncompressed
  - K-Offsets along Undulator
  - Weak wakefield effects (energy loss)
- Compressed
  - K-Offsets along the Undulator
  - K- Slope due to strong wakefield effects
  - Indication for Linear Taper

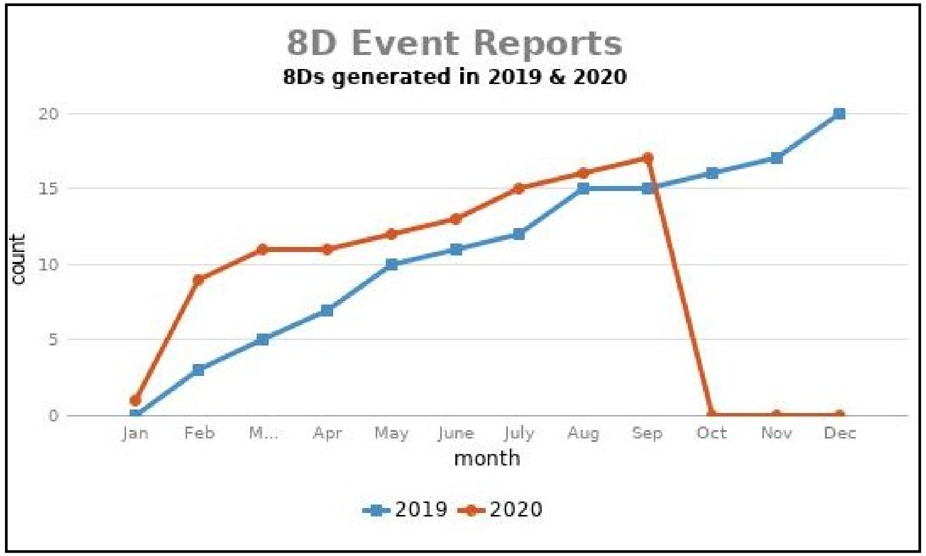


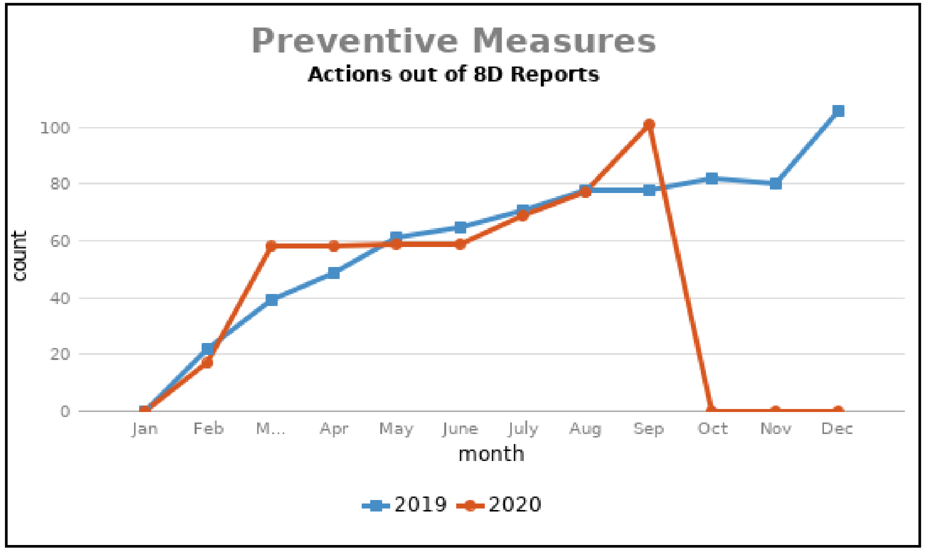
LINAC Availability (Summer start-up and study time)

- LINAC **RF availability** generally very good
  - Generally > 98%
- Most trips < 2’ and automatically recovered
  - LLRF triggered (e.g. Q-detect)
  - Klystron gun arcs
- Automated tools for availability analysis
  - Database driven
- Weekly meetings to discuss trips



Quality Assurance – 8 D Processes





- Criteria: Duration, Severity, Occurrence

Status of reports

	2019 open	2019 closed	2019 canceled		2020 open	2020 closed int.	2020 closed ext.	2020 canceled
8D-Reports	1	14	1		10	4	0	0
4D-Repots	0	2	0		2	1	0	0
Σ	1	16	1	Σ	12	5	0	0

Tabelle 2.1: Bearbeitungsstand sämtlicher 8D- und 4D-Reports für 2019 und 2020 im Bereich MXL + XFEL

Status of actions

Datum: 10.09.20

2019	tbd	open	overdue	on hold	canceled	done	Total
8D-Reports	1	2	0	0	2	82	87
4D-Repots	0	0	0	0	0	6	6
Σ	1	2	0	0	2	88	93

2020	tbd	open	overdue	on hold	canceled	done	Total
8D-Reports	9	32	0	1	5	51	98
4D-Repots	0	2	0	0	2	10	14
Σ	9	34	0	1	7	61	112

Tabelle 2.2: Bearbeitungsstand sämtlicher 8D- und 4D-Reports für 2019 und 2020 im Bereich MXL + XFEL

2019:

- 18 reports triggered , 16 closed
- 93 preventive measures defined, 88 executed

2020:

- 17 Reports triggered, 5 closed
- 122 preventive measures defined, 61 executed

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