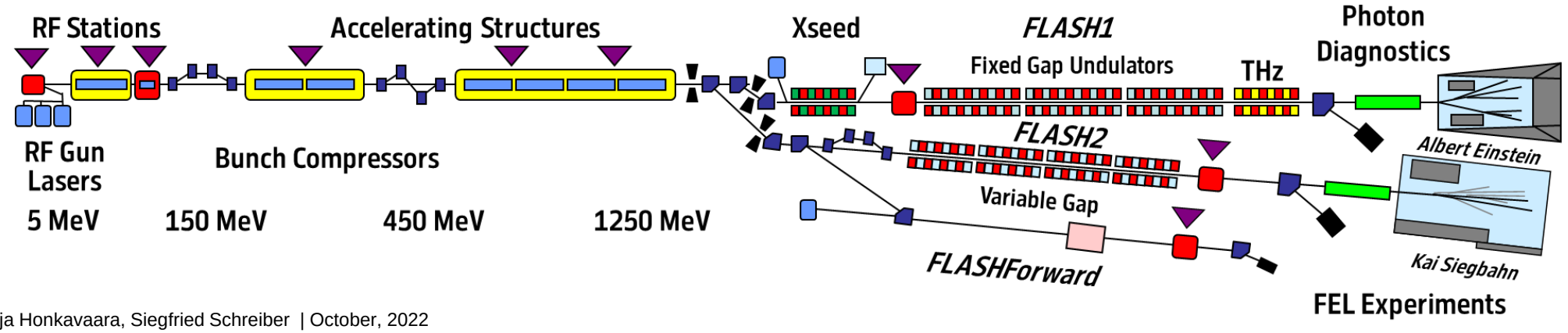
FLASH: the first FEL user facility driven by a superconducting linac

- Single-pass high-gain SASE FEL (300 m long)
- Superconducting linear accelerator
  - Seven TESLA type 1.3 GHz modules (DESY) + one 3.9 GHz module (4 cavites, Fermilab)
  - Pioneer of TESLA technology: based on the TESLA Test Facility (TTF) Linac (1996 – 2002)
- FLASH FEL user facility constructed in 2003 - 2004, in user operation since 2005
  - 2nd undulator beamline (FLASH2) in operation since 2014
- Several energy upgrades (next slide)
- FLASH2020+ upgrade project: modification of FLASH1 beamline to seeded operation in 2024/25

FLASH Layout 2021



FLASH accelerator: several energy upgrades over the last 20 years

- FLASH 2004-2006: five TESLA type modules with electron beam energy up to 700 MeV
- 2007 energy upgrade to 1 GeV: 6th module (ACC6) installed, ACC3 exchanged
- 2009/10 energy upgrade to 1.25 GeV: 7th module (ACC7) installed, ACC1 exchanged, ACC39 (3.9 GHz module) installed
- 2022 energy upgrade to ~1.35 GeV
  - Modules ACC2 and ACC3 exchanged to high performance refurbished XFEL prototype modules
  - Waveguide system of ACC4 and ACC5 refurbished to optimize energy gain
  - Nine months shutdown finished in August 2022, accelerator cool-down in September 2022, commissioning on-going

Year	ACC1	ACC39	ACC2	ACC3	ACC4	ACC5	ACC6	ACC7	Max e-beam energy
2004-2006	M2* type 2	-	M1* type 1	M3* type 2	M4 type 3	M5 type 3	-	-	700 MeV
2007-2009	M2* type 2	-	M1* type 1	M7 type 2	M4 type 3	M5 type 3	M6 type 3	-	1000 MeV
2010-2021	M3*** type 2	Fermilab	M1* type 1	M7 type 2	M4 type 3	M5 type 3	M6 type 3	PXFEL1	1250 MeV
2022 -	M3*** type 2	Fermilab	PXM2.1	PXM3.1	M4 type 3	M5 type 3	M6 type 3	PXFEL1	~1350 MeV (not confirmed yet)

FLASH operation: facility up-time ~97%

- Availability = Facility up-time
  - Availability is defined from the facility operation point of view:
    up-time of Linac* + FLASH1 / FLASH2 undulator lines
    - up-time = (beam operation time) - (downtime due to technical or other failures)
  - Goal: better than 98%
- No downtime due to accelerator modules
  - Pie-charts show downtime due to accelerator related subsystems (RF-stations, LLRF, Cryogenics) in 2019 and 2021, as examples
- No degradation of cavity performance over the years
- Loaded Q tests in 2015 accidently produced permanent field emission of the last cavity of ACC7
  - Cavity ACC7.C8 is operated with a reduced gradient since the incident
- Some issues with ACC39 HOM coupler temperatures

Remarks
** Linac = injector + accelerator (beamline from RF-gun to end of ACC7 module)*
*** RF-stations: five 1.3 GHz RF-stations (4 for modules, 1 for RF-gun), one 3.9 GHz station, LLRF includes also RF-gun (RF-gun: normal conducting 1.3 GHz 1.5 cell cavity)*
**** Others: controls, infrastructure, operating, RF-gun, magnets, and other beamline components*