FLASH2020+

Progress Review Meeting

Status of Photon Diagnostics / FEL beamline F10

Sven Toleikis for the P team

Hamburg, 28.02.2025

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Overview I

- Recap of non-invasive measurement of

  Pulse energy
  Wavelength
  Beam position

  → copies of current FLASH2 instruments

- Beam alignment tools
- Pulse length → Statistical methods @ PG, LOLA (for SASE), seed laser diagnostic (for seeding)
- New gas absorber → improve attenuation capability (x100)
- Polarization → (eTOF-Polarimeter “Ball-chamber”), OPIS (maybe delayed ?)

Postponed additional photon diagnostics & new challenges:

- Spectral diagnostic for seeding
  Spectral information for users
  → New high-resolution VLS grating spectrometer
  geometrical/conceptional design finished
- Photon beam-based undulator alignment → K-Mono (XFEL design not 1:1 applicable)
- Atto-second pulse length diagnostics
  @FLASH2 only, not part of F2020+
  but high priority for PSC
  → angular streaking with advanced Cookie-box
  -> new photon diagnostic beamline FL28

Recap of the photon diagnostics concept

Basically a copy of the existing FLASH2 tools

- Intensity
- beam position
- spectral distribution
- polarization
- pulse length

Recap of the photon diagnostics concept

Basically a copy of the existing FLASH2 tools

- Intensity
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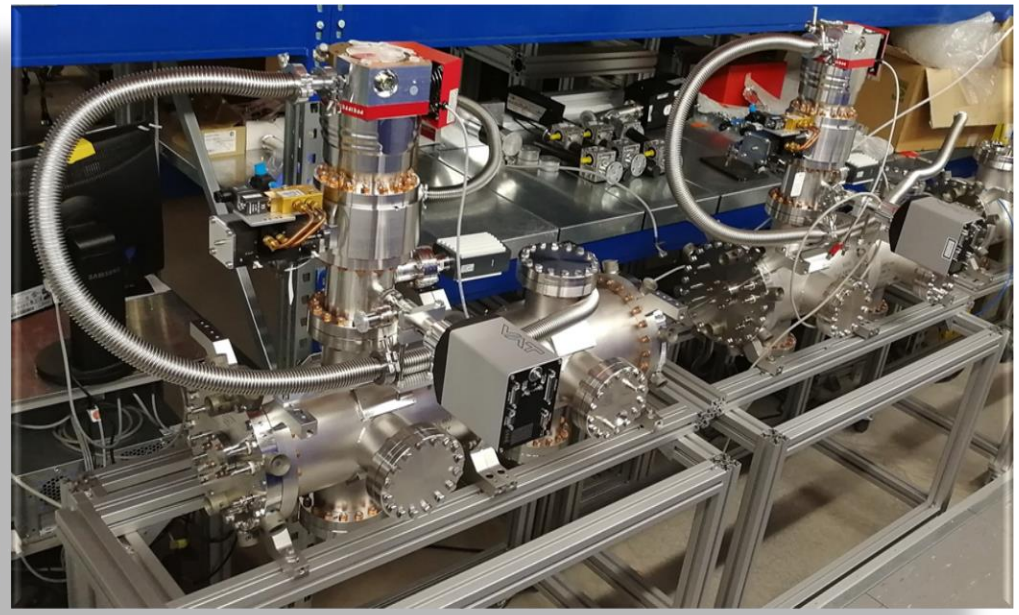
- polarization
- pulse length

XGMD:

- absolute intensity (within ~5%)
- pulsed resolved up to 4.5 MHz
- non-invasive
- Improved XGMD design (in use at XFEL, LCLS, and SwissFEL)

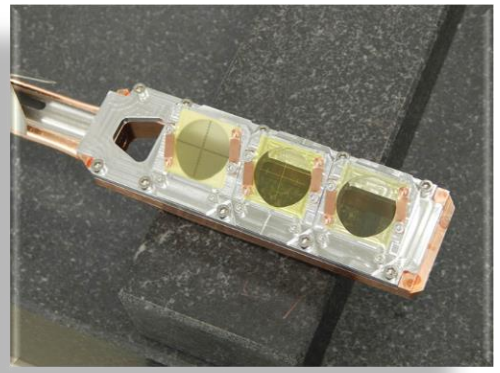


Recap of the photon diagnostics concept

Basically a copy of the existing FLASH2 tools

- Intensity
- beam position
- spectral distribution
- polarization
- pulse length

XGMD: precise beam position (within ~10µm)



Ce:YAG crystals

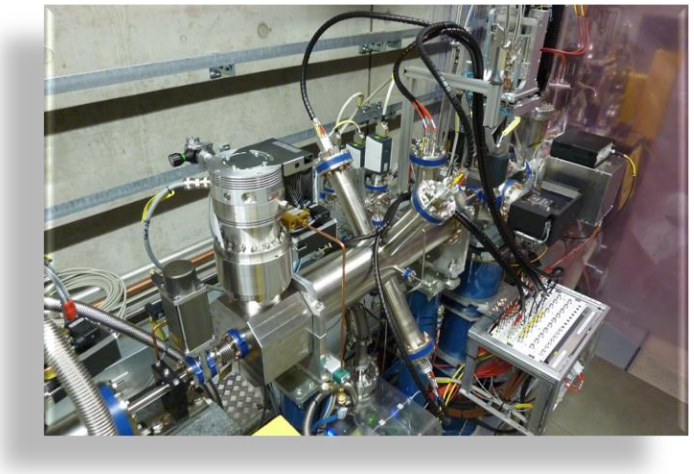
Recap of the photon diagnostics concept

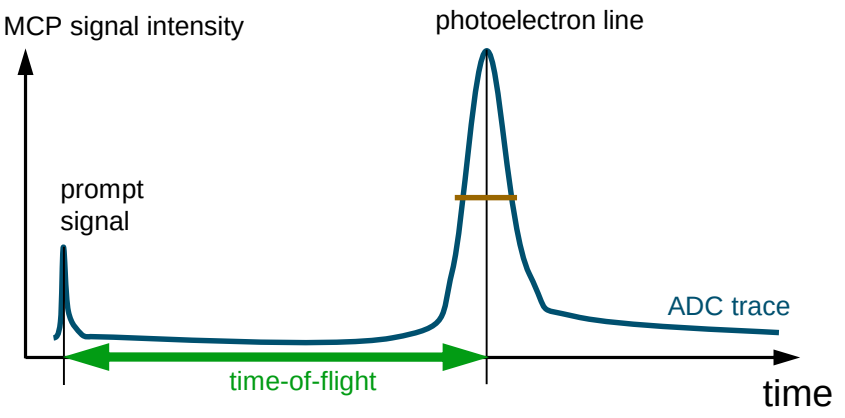
Basically a copy of the existing FLASH2 tools

- Intensity
- beam position
- spectral distribution
- polarization
- pulse length

OPIS:
Wavelength determination with photoelectron spectroscopy 4 eTOFs at “magic angles”

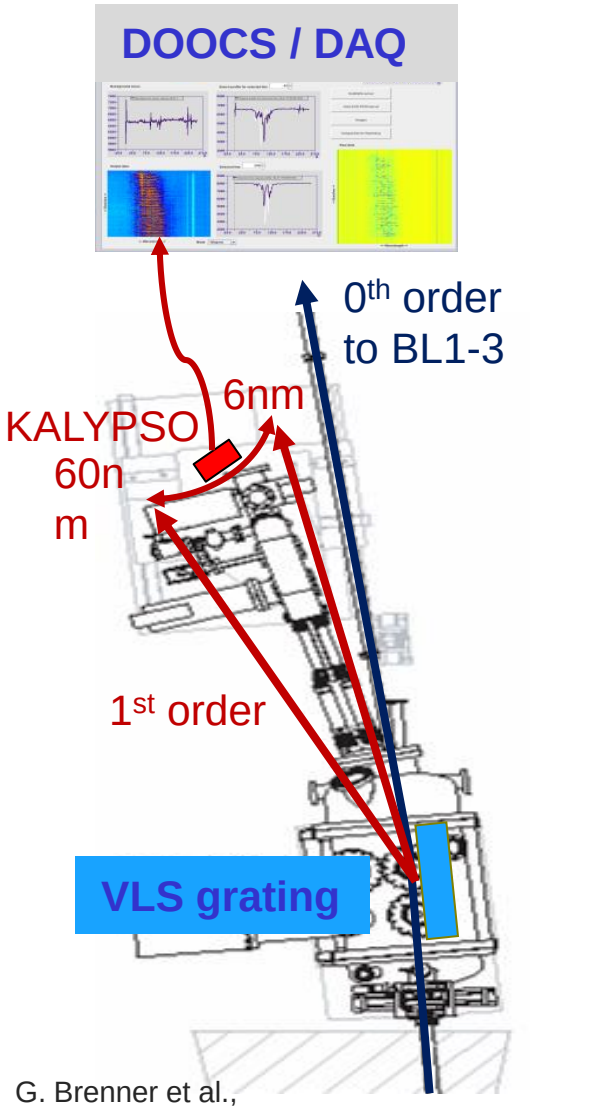
- Central wavelength monitoring (within ~0.1eV)
- Diagnostic tool for FEL bandwidth, beam position, two-color operation
- Non-invasive





Recap of the photon diagnostics concept

- Intensity
- beam position
- spectral distribution
- polarization
- pulse length



G. Brenner et al.,
Nucl. Instr. and Meth A **635**, 99–103 (2011).

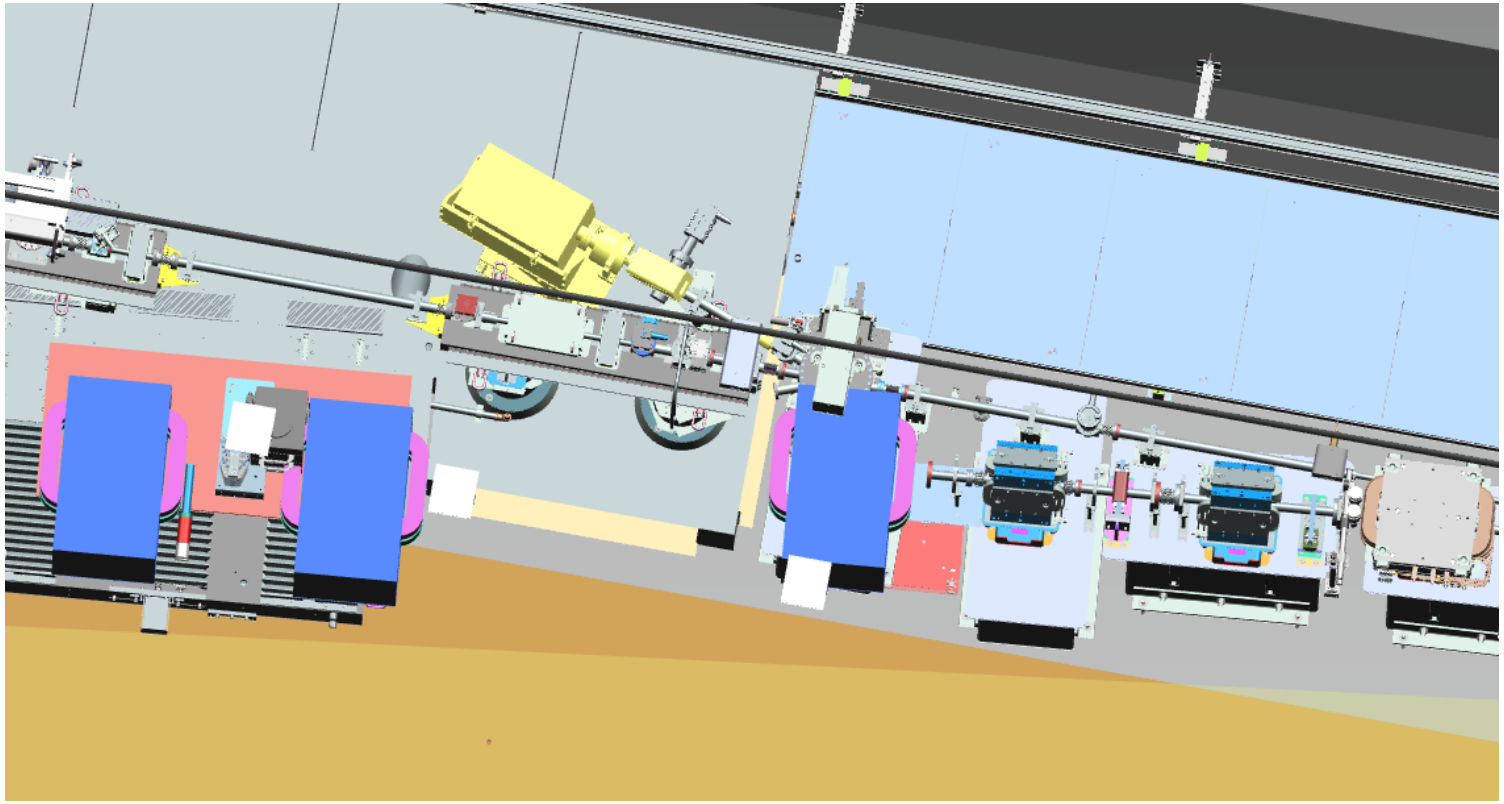
or PG beamline in case a higher resolution is required

Recap of the photon diagnostics concept

Re-usage of existing components

- Intensity
- beam position
- spectral distribution
- polarization
- pulse length

XSEED spectrometer in front of the absorber PS0 and V0 (J. Zemella)



Recap of the photon diagnostics concept

Basically a copy of the existing FLASH2 tools

- Intensity
- beam position
- spectral distribution
- polarization
- pulse length

We still need to gain experience with **OPIS** for online polarization measurements in the tunnel.
Only 4 e-TOFs might be insufficient…

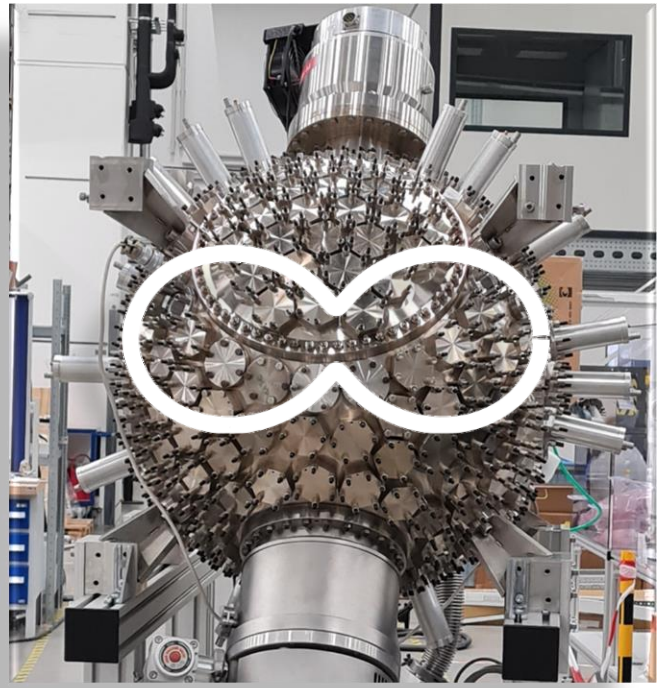
OPIS

Recap of the photon diagnostics concept

Using new cocepts

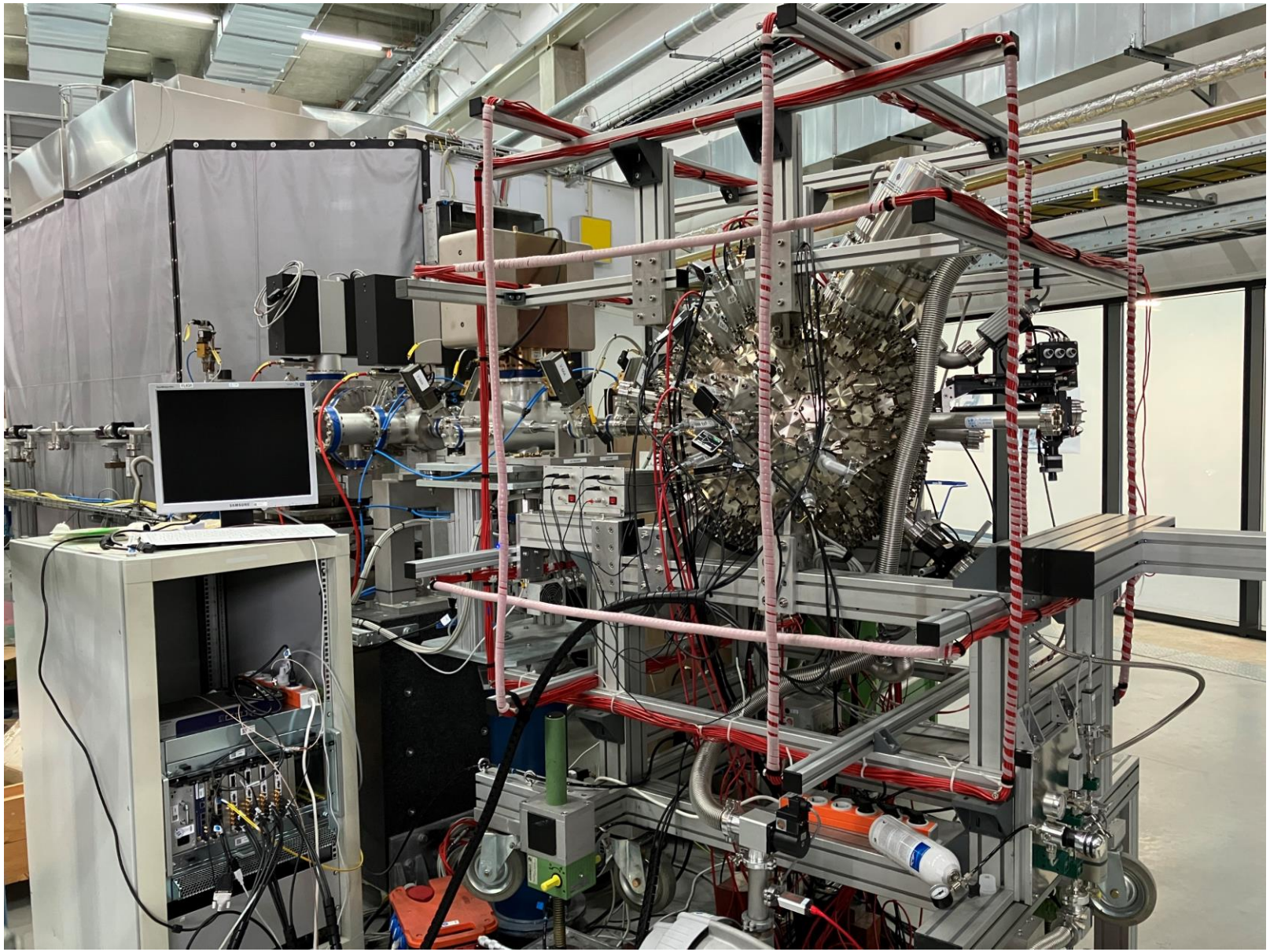
- Intensity
- beam position
- spectral distribution
- polarization
- pulse length

Angle resolving spectrometer setup **“ball chamber“.**
Idea is to check the reproducebility of the Apple-III undulator settings from time to time.



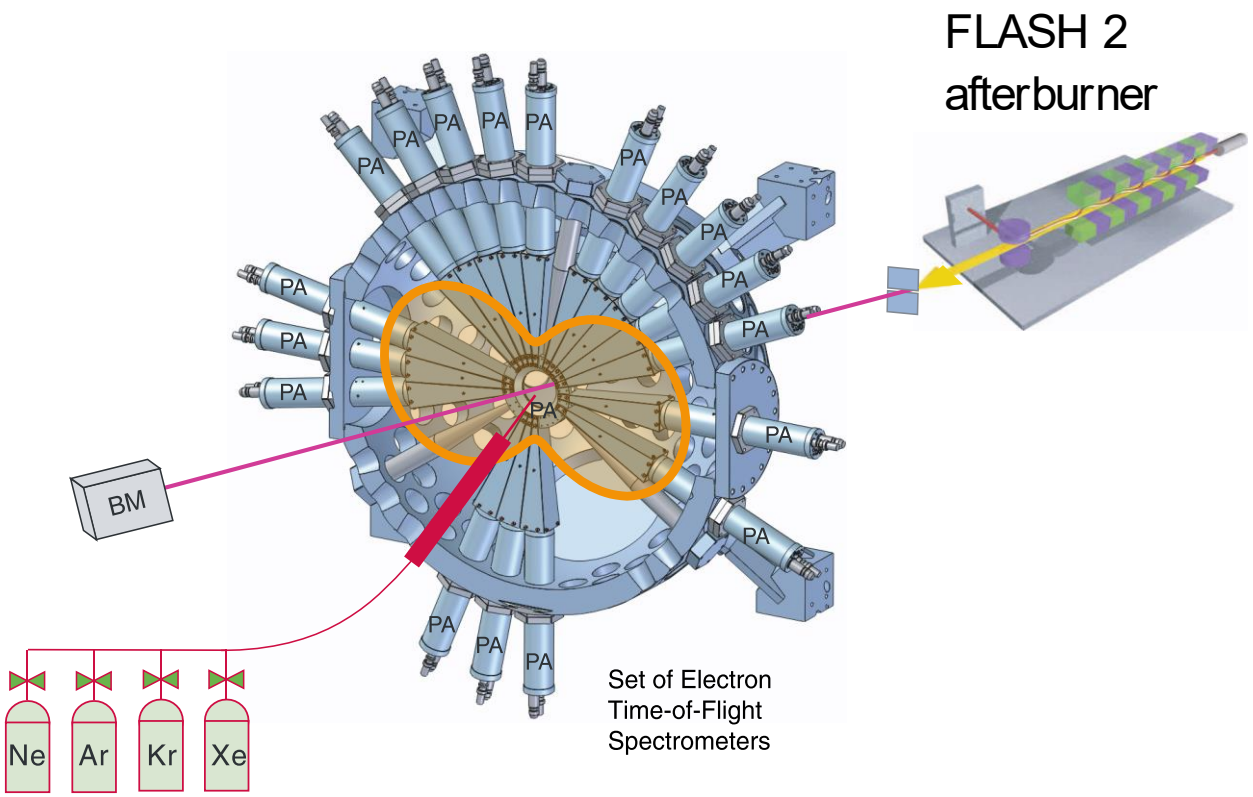
Polarization Diagnostics @ FLASH2

- Ball chamber instrument
  at FL21 diagnostics beamline



Polarization Diagnostics @ FLASH2

- Ball chamber instrument
  Measuring angular distribution of photoelectron emission
  of a certain photoelectron feature from 3rd harmonic



- Fit angular distribution formula

$$I(\theta) = \frac{\sigma}{4\pi}\left[1 + \frac{\beta}{4}\left[1 + 3 \cdot P_{\mathrm{lin}} \cdot \cos\left(2(\theta - \varphi)\right)\right]\right]$$

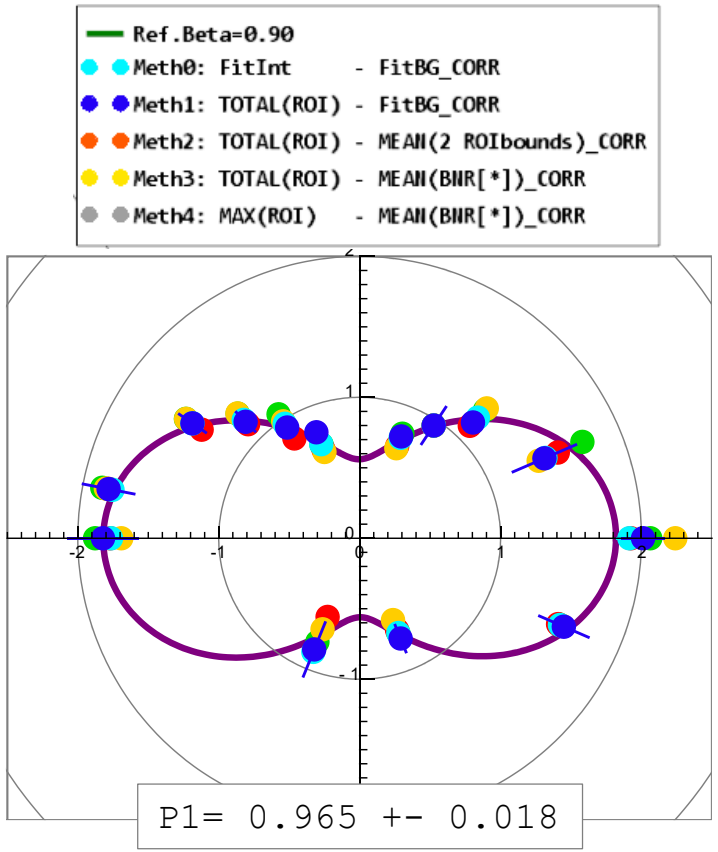
→ Stokes parameter P_{lin} of linear polarization
tilt angle φ versus horizontal axis

$\beta(3h\nu)$ anisotropy parameter
value needs to be known

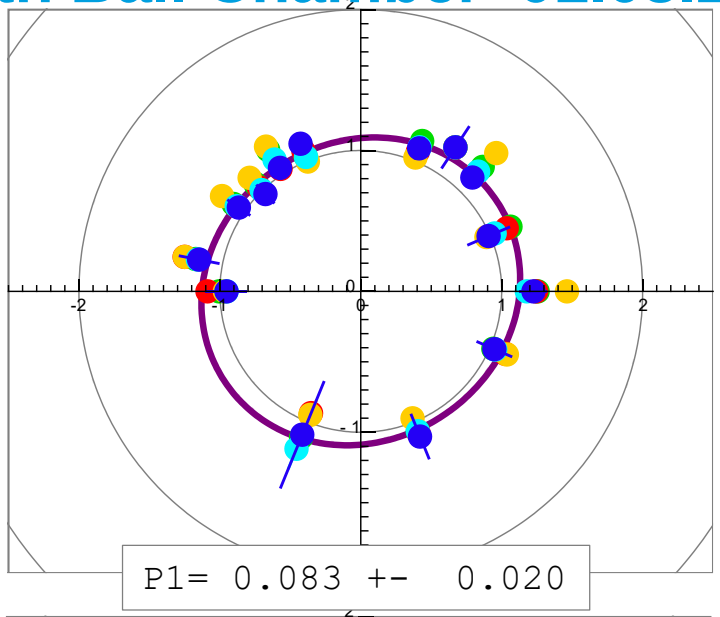
$\sigma(3h\nu)$ PE feature ionization cross section
value is relevant for choice of PE feature
and signal strength

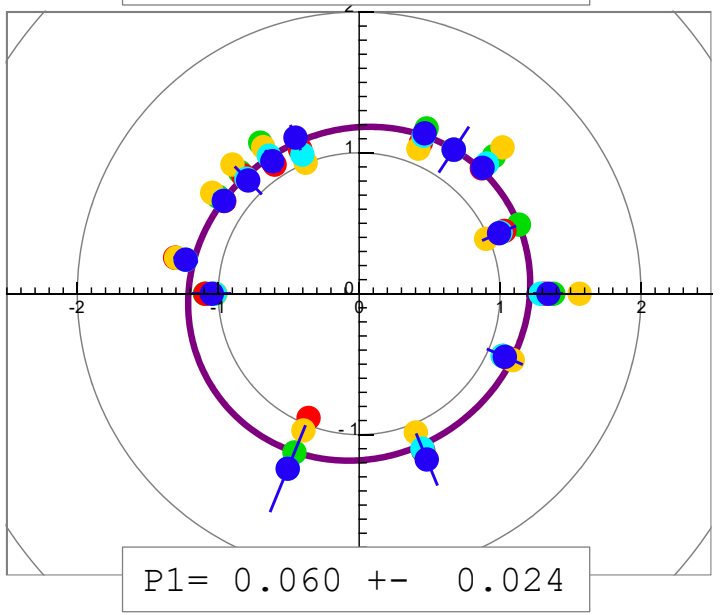
$I(\theta_{eTOF})$ Intensity measurement needs to be calibrated

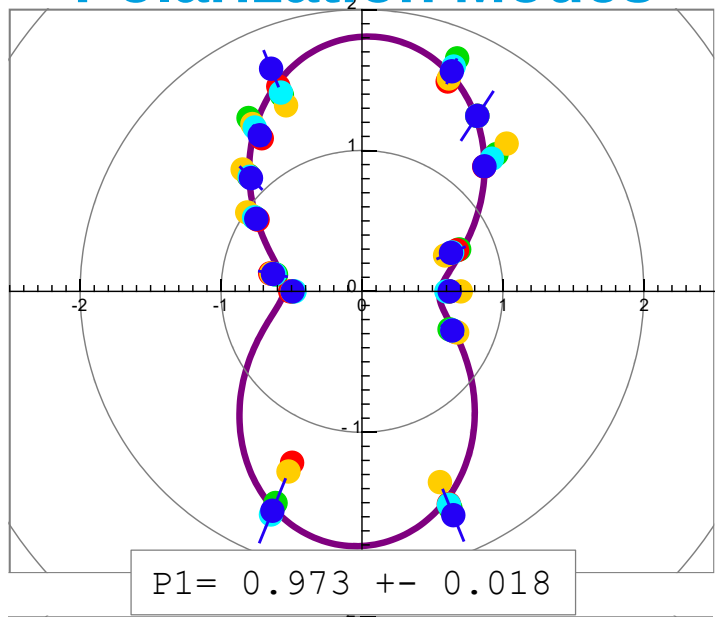
Polarization Diagnostics with Ball Chamber 01.03.2024 - Polarization Modes

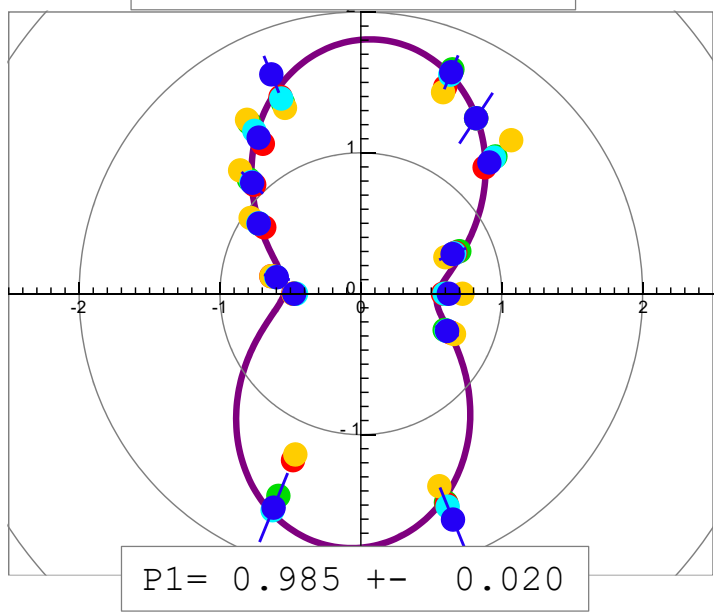


E_{ACC} = 880 MeV
hv = 104.6 eV / 313.8 eV







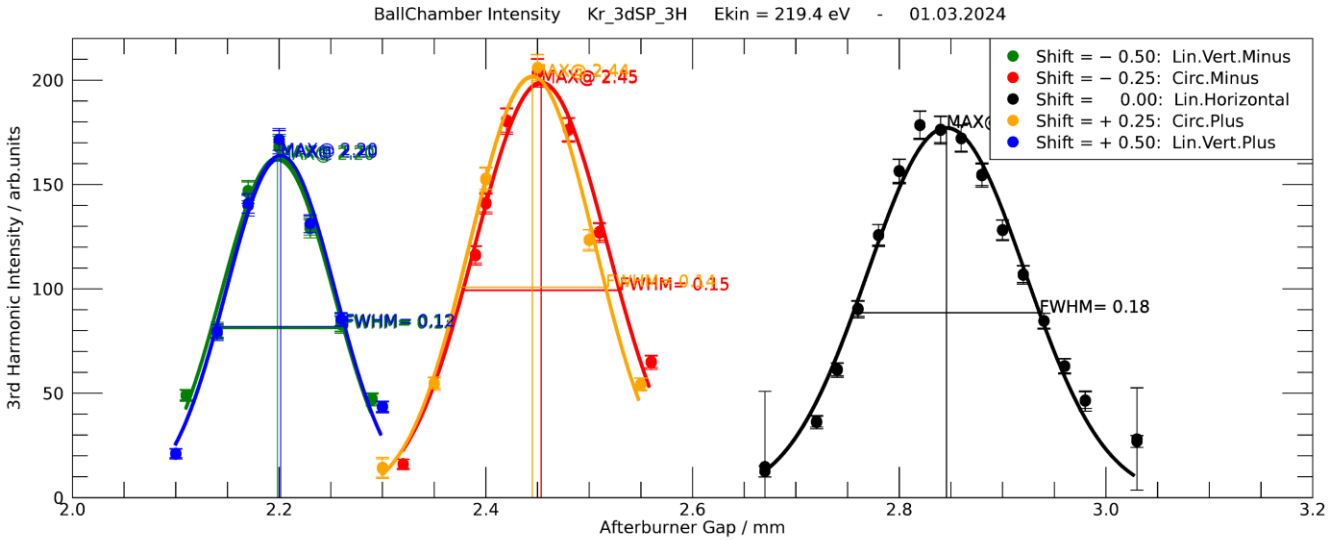


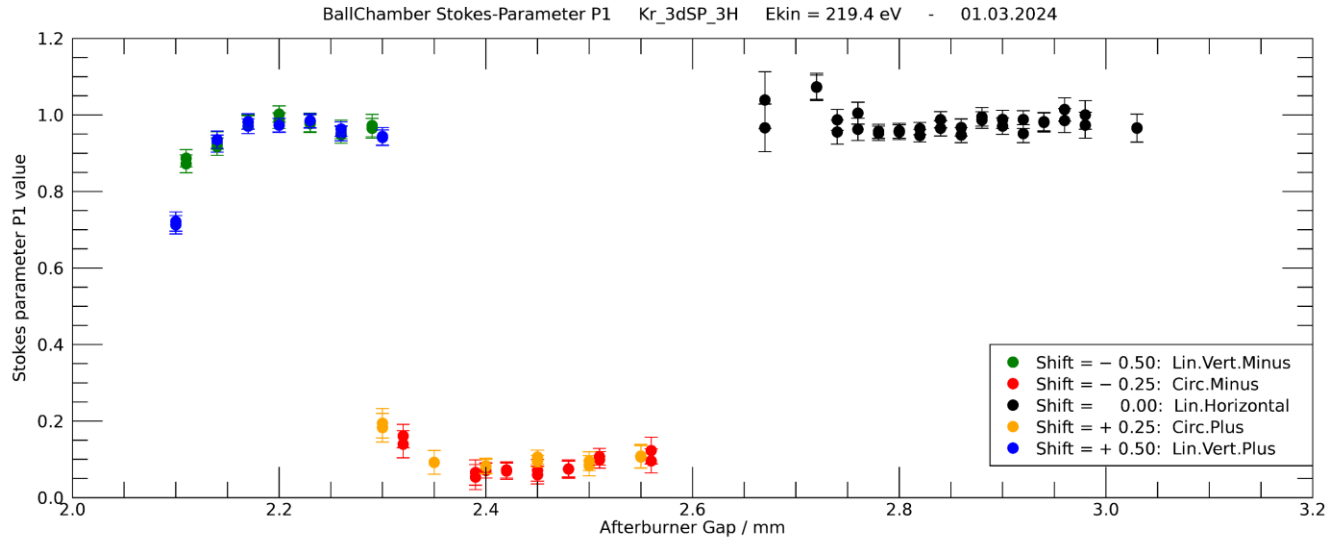
ABU shift = 0.0

ABU shift = +/- 0.25

ABU shift = +/- 0.5

Polarization Diagnostics with Ball Chamber 01.03.2024 - ABU gap scans





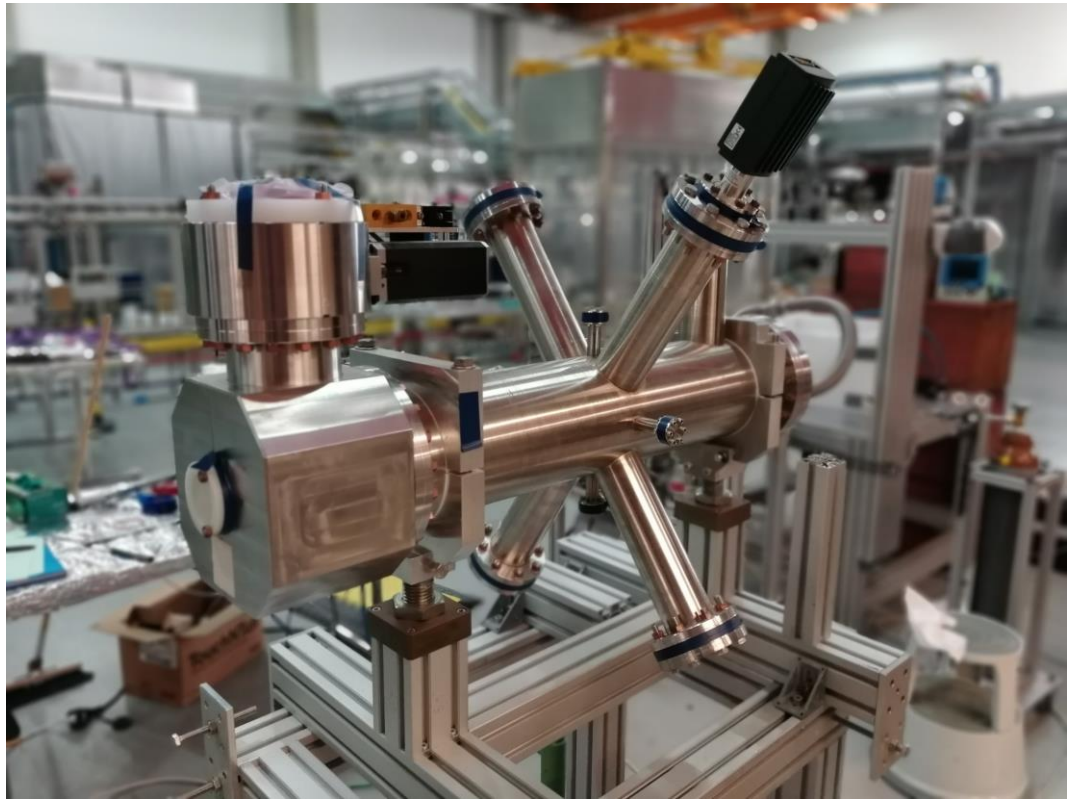
- 3rd harmonic signal intensity change along afterburner gap variation
- Determine/confirm the optimal gap value

BALL: Kr 3d photoelectrons

- Value of linear Stokes parameter P1 along afterburner gap variation

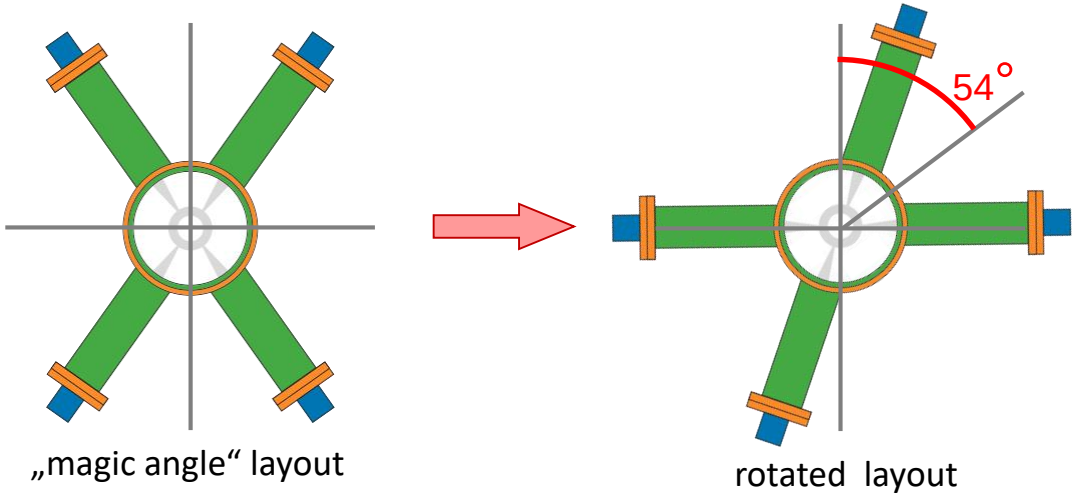
OPIS

- Wavelength determination with photoelectron spectroscopy
  4 eTOFs at “magic angles”
  - Central wavelength monitoring (within ~0.1eV)
  - Diagnostic tool for FEL bandwidth, beam position, two-color operation
  - Non-invasive



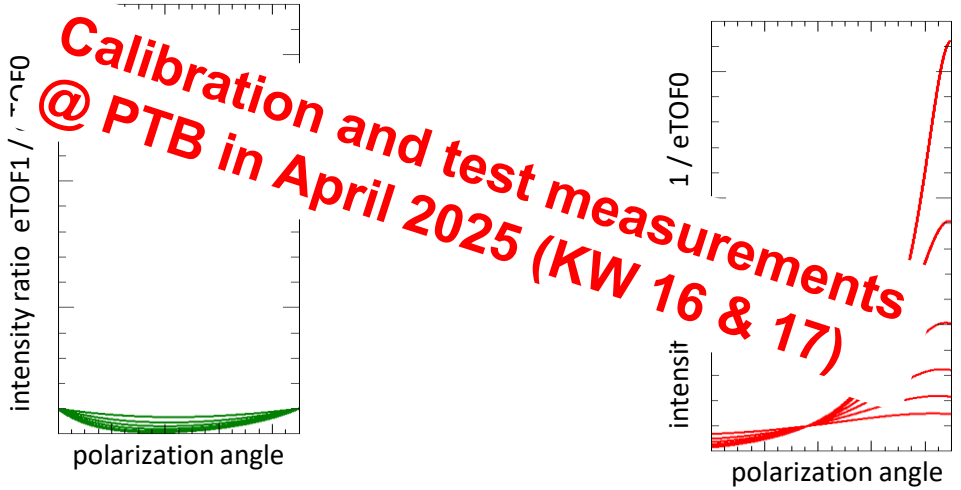
Simulation study on polarization measurement

- Mounting OPIS chamber with a different angular alignment for improved (linear) polarization diagnostics via photoemission anisotropy
- Optimal rotation angle: 45° (with CF160 adapting flanges)
  Acceptable rot. Angles: 36°/54° (use bore circle position)



„magic angle“ layout

rotated layout



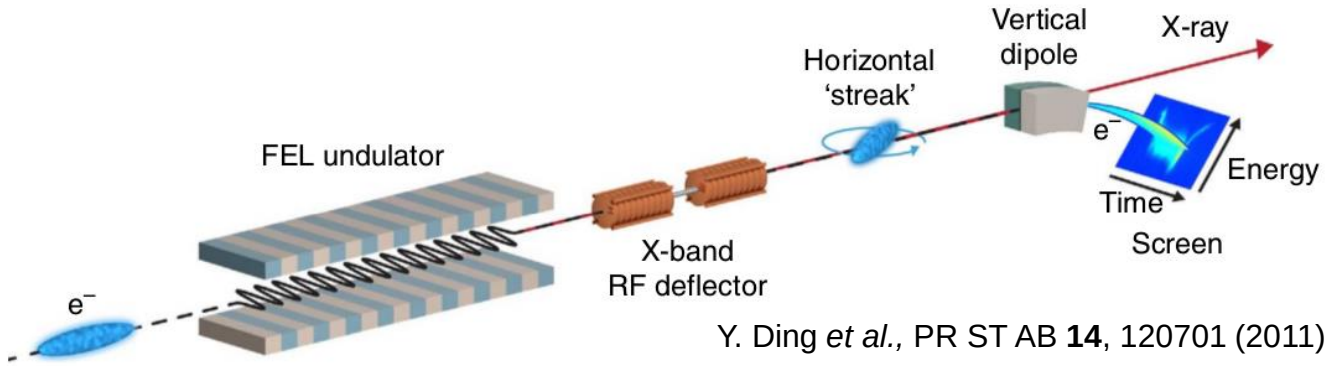
Calibration and test measurements @ PTB in April 2025 (KW 16 & 17)

Recap of the photon diagnostics concept

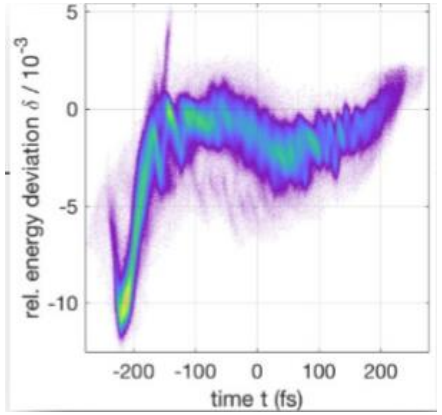
Basically a copy of the existing FLASH2 tools

- Intensity
- beam position
- spectral distribution
- polarization
- pulse length (indirect)
- beam attenuation / filtering

Here, we have to rely on indirect measurements
using a TDS like PolariX or LOLA then at FLASH1

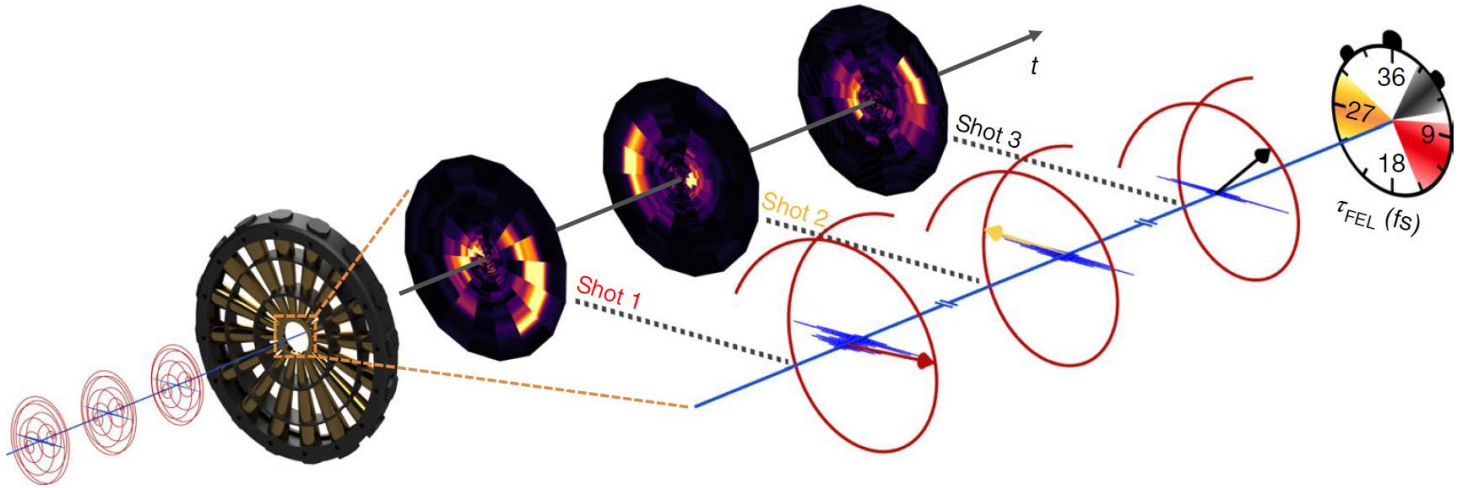


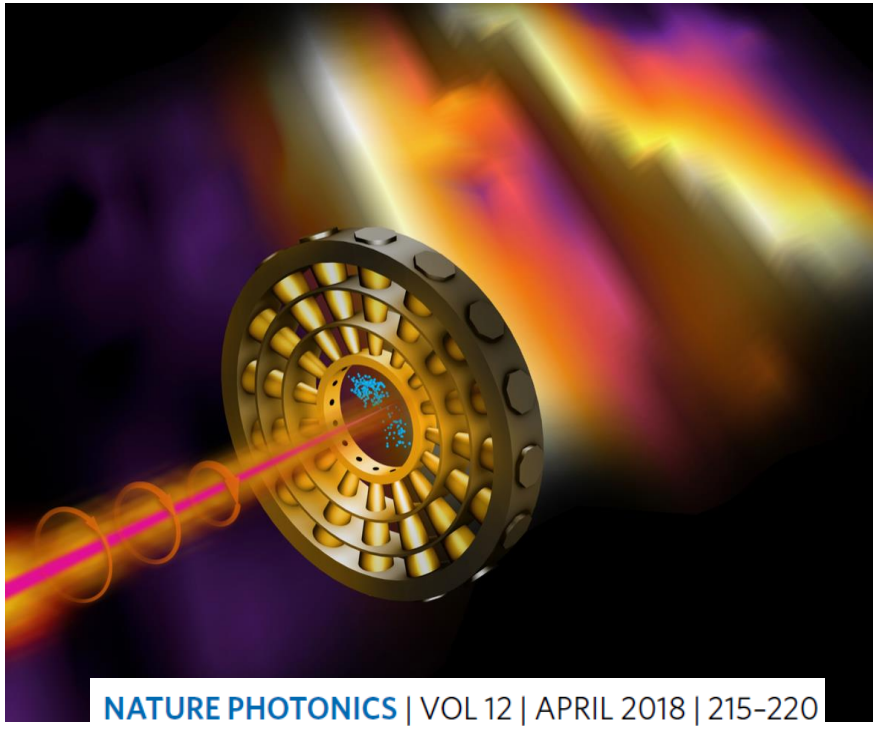
Y. Ding *et al.*, PR ST AB **14**, 120701 (2011)



Attosecond- and Polarization Diagnostics FLASH 2020+

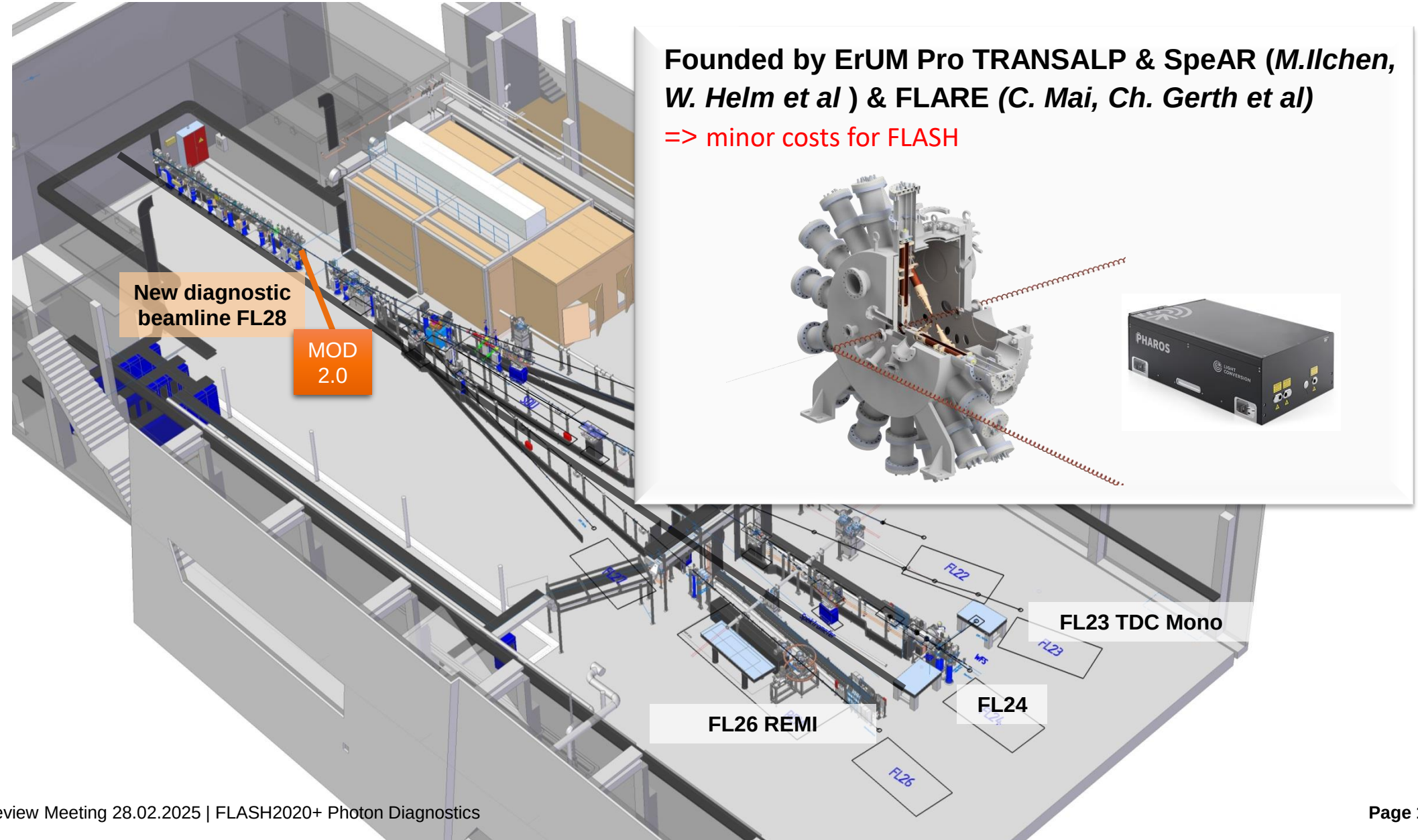
First steps towards angular streaking





- Single-shot, non-invasive online diagnostics for time-energy structure and polarization.
- Mapping FEL pulse time structure on the angular coordinate of photoemission („hand of a clock“)
- Advanced setup (SpeAR – BMBF funded) in 2023 and adaptation for FLASH following at FL28
- ErUM-Pro TRANSALP project dedicated to a laser system (incl. postdoc) and instrumentational advances for angular streaking @ FLASH

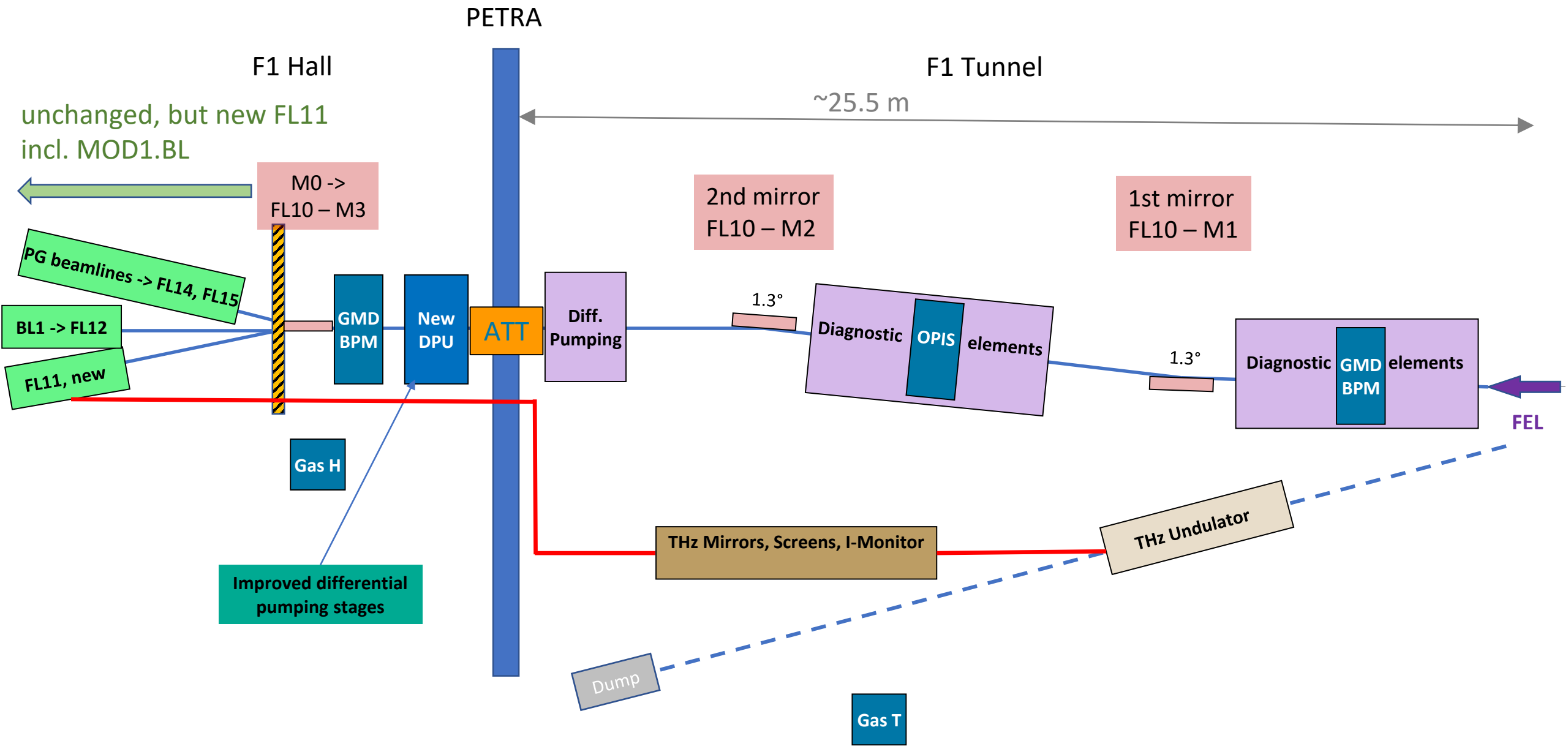
New angular streaking pulse length diagnostic at FLASH 2.



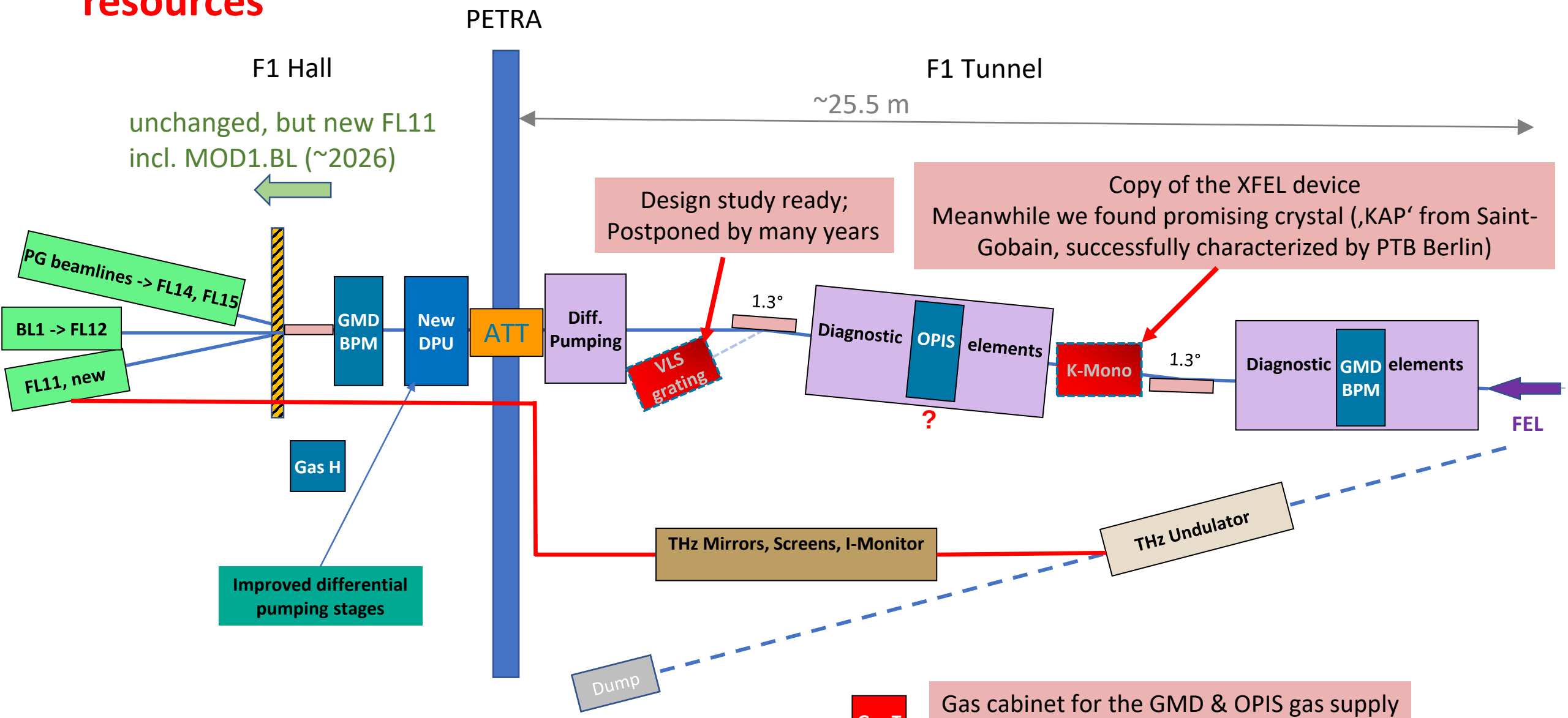
Founded by ErUM Pro TRANSALP & SpeAR (*M.Ilchen, W. Helm et al*) & FLARE *(C. Mai, Ch. Gerth et al)*

=> minor costs for FLASH

Diagnostics and beam transport concept for FLASH1

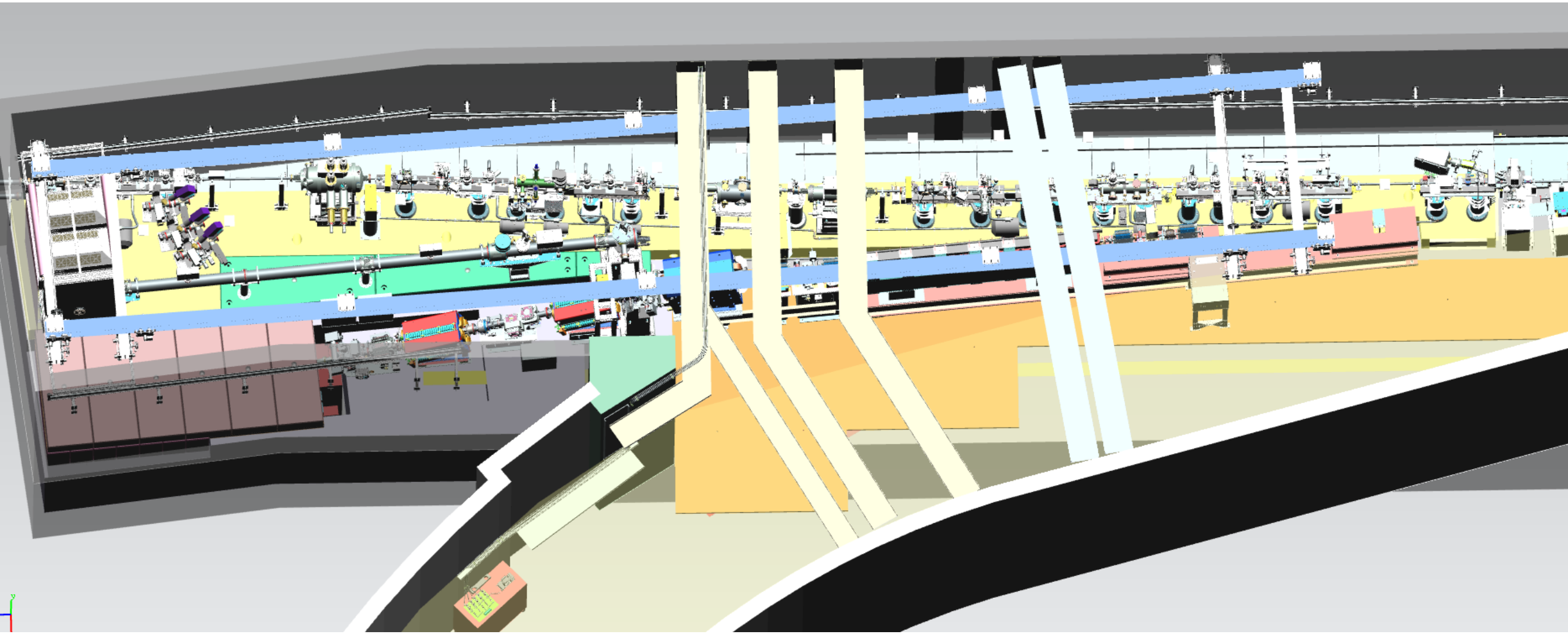


Things we could not implement due to the reduced budget and limited resources



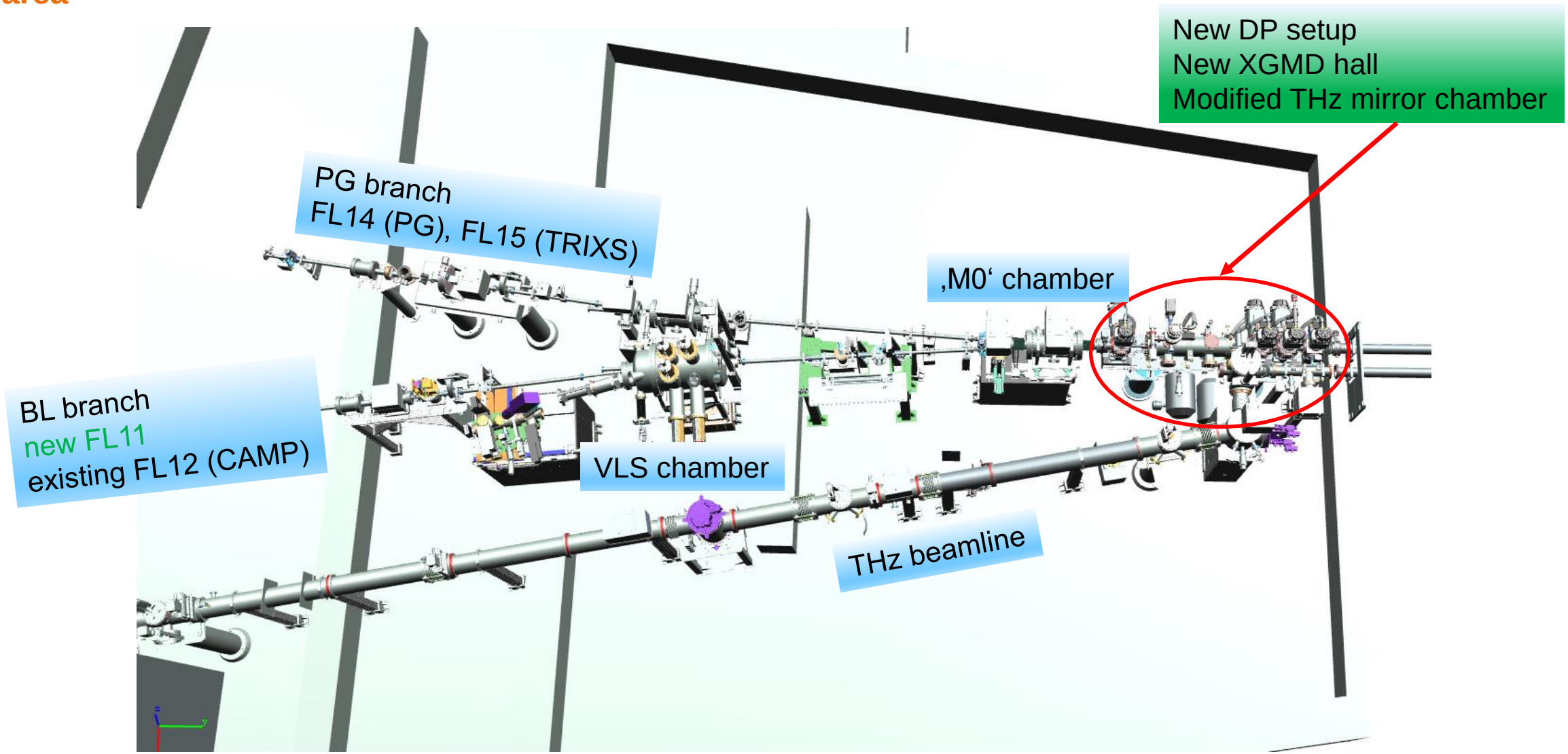
Diagnostics and beam transport concept for FLASH1 (tunnel) - FL10

Modell



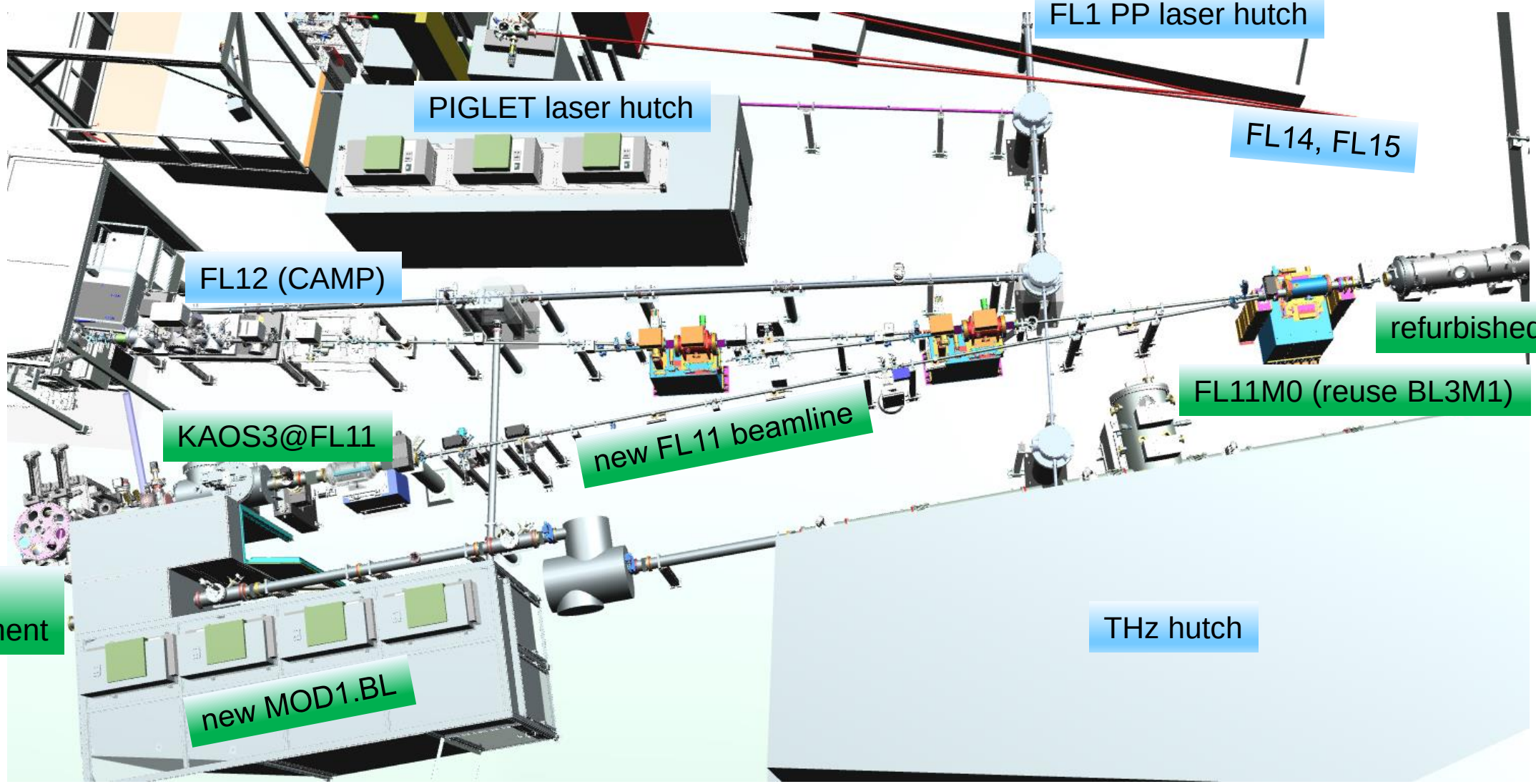
FLASH1 Experimental Hall (‚Albert-Einstein-Hall‘)

BDA area



FLASH1 Experimental Hall (‚Albert-Einstein-Hall‘)

new FL11 beamline incl. OL beamlines and MOD hutch – currently in design phase!



Installation schedule

Pretty tight schedule

Beginning of Jan.:

Orignally planned start of installing components but components are late as well:
still missing: two beamshutter chambers for FL10
four THz chambers (manufactured outside): out of specs!!!

9	24.Feb - 2.Mar			
10	3.Mar - 9.Mar			
11	10.Mar - 16.Mar			
12	17.Mar - 23.Mar			
13	24.Mar - 30.Mar			
14	31.Mar - 6.Apr			
15	7.Apr - 13.Apr			
16	14.Apr - 20.Apr			
17	21.Apr - 27.Apr			
18	28.Apr - 4.May	personal interlock test	intern personal interlock test	tunnel partially closed
19	5.May - 11.May	cool down		
20	12.May - 18.May	cool down		
21	19.May - 25.May	cool down		
22	26.May - 1.Jun			
23	2.Jun - 8.Jun	personal interlock test	Generalprobe - IL-Test	tunnel partially closed
24	9.Jun - 15.Jun			
25	16.Jun - 22.Jun			
26	23.Jun - 29.Jun			
27	30.Jun - 6.Jul			
28	7.Jul - 13.Jul	personal interlock test (TUV)	personnel interlock test (TUV)	tunnel partially closed
29	14.Jul - 20.Jul		RF-gun conditioning (Fr - Su)	Fr,12:00-Mo,7:00: tunnel closed
30	21.Jul - 27.Jul		RF-gun conditioning (Fr - Su)	Fr,12:00-Mo,7:00: tunnel closed
31	28.Jul - 3.Aug		RF-gun conditioning (Fr - Su)	Fr,12:00-Mo,7:00: tunnel closed
32	4.Aug - 10.Aug	Commissioning		
33	11.Aug - 17.Aug	Commissioning with beam		

Dump installation
Clean room installation – dump section
Drilling holes for the FL10 and THz beamline
Crane installation
Crane installation
First pillars and granites installed in the tunnel / Water / air pressure pipes installation?
Installation of the cable trays beside the concrete pedestral?
Installation of covers for the pedestral bay? Test of OPIS @ PTB
Installation of covers for the pedestral bay? Test of OPIS @ PTB

Further installation and cabling and commissioning

Alignment of BDA and tunnel lance – Differential pumping gas attenuator
Close photon vacuum systems in the tunnel

Commissioning of all components

Further things which needs to be done at FLASH2 before the start of beam operation:

- **Replacement of several ion gauges in the FL20 beamline (tunnel and exp. hall)**
- **Back-intallation of the FL2 SDU into the FL23/24 beamline**
- **Finalizing FL23M0 mirror chamber**

Installation schedule 2

Still on the agenda – 2026…

- Tunnel: missing components of FL10: e.g. OPIS?, THz: PARC, missing FEL undulators, …
- Building FL11 beamline, MOD1.BL, OL beamlines and FL11 exp. laser hutch
- Building FL28: Angular streaking setup for attosecond- and polarization diagnostics
- Further improvement of the optical pump-probe lasers: FLASH1 and FLASH2
- …

<u>Reminder for the commissioning with FL1 seeded photons:</u>

w/o FL11 + MOD1.BL

only	**FL12 (CAMP)**	but w/o pump-probe laser, but SDU at 13.5 nm
	FL14 (PG2)	only open port beamline, with PIGLET PP laser
	FL15 (TRIXS)	fixed endstation with PIGLET PP laser

are available!

Summary

- Non-invasive measurement of

  Pulse energy
  Wavelength
  Beam position

  → copies of current FLASH2 instruments

- Beam alignment tools
- Pulse length → Statistical methods @ PG, LOLA (for SASE), seed laser diagnostic (for seeding)
- New gas absorber → improve attenuation capability (x100)
- Polarization → eTOF-Polarimeter variant of the “Ball chamber” or OPIS

Postponed additional photon diagnostics & new challenges:

- **Spectral diagnostic for seeding**
  Spectral information for users
  → **New high-resolution VLS grating spectrometer geometrical/conceptional design finished**
  → **lead time from decision to installation ~3 years**

- Photon beam-based undulator alignment
  → K-Mono (XFEL design not 1:1 applicable)
  → **new R&D development necessary**

Acknowledgements

FLASH2020+ is team work - WPs P1, P2, P3, P4, P5, P6, P7, S1, S4, A6 …
FS-BT, ZM, XFEL, TU Dortmund, HZB

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Sören Grunewald
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Sven Toleikis
Rolf Treusch
Nicole von Bargen
Mikhail Yurkov
Michael Walter
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Thank you !

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