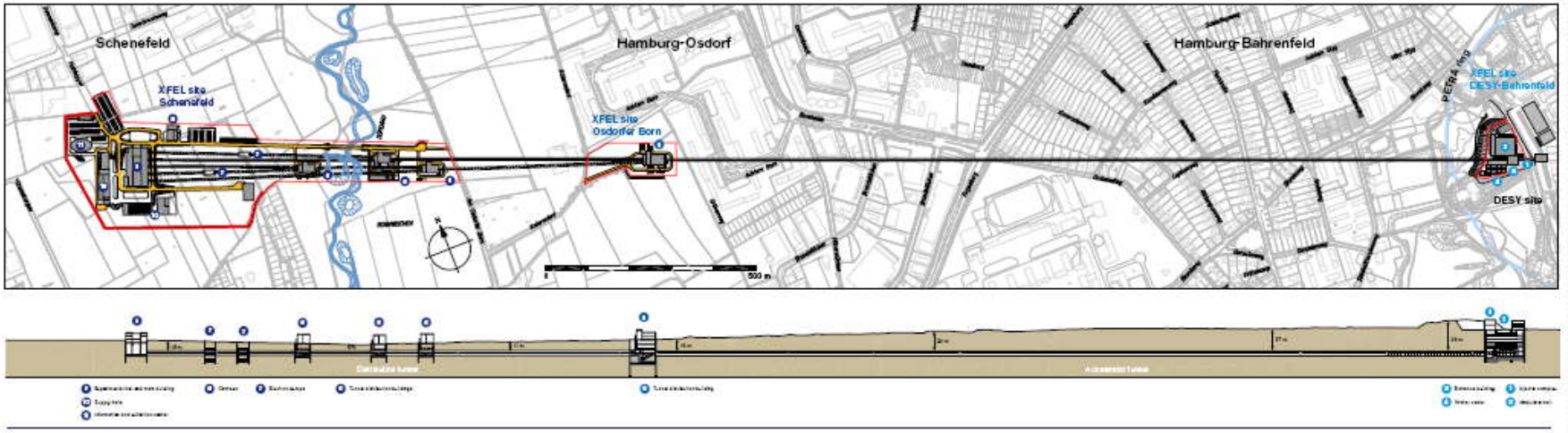
Photon Diagnostics and Photon Beamline Installations at the European XFEL



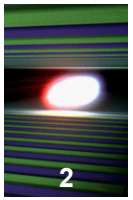
Dr. Jan Grünert

European XFEL GmbH, Hamburg, Germany

37th International Free Electron Laser Conference

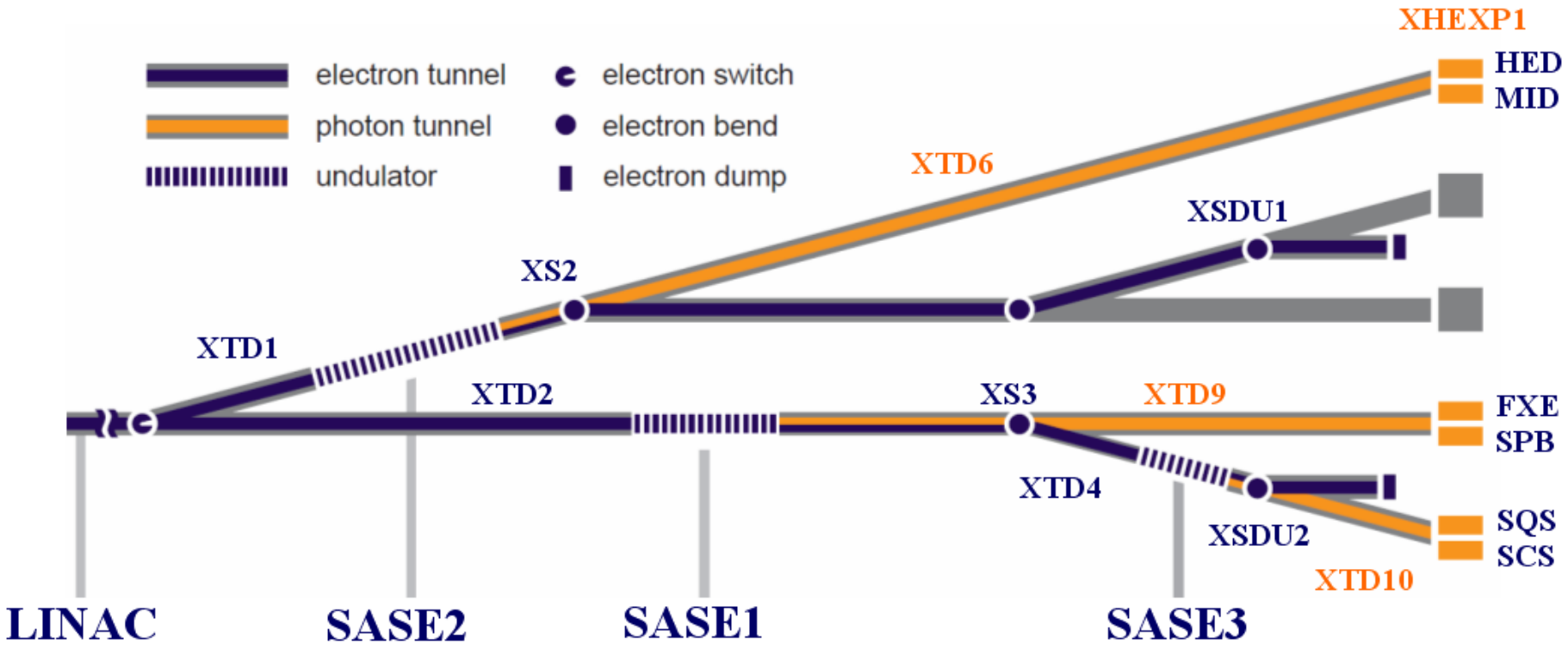
26 August 2015, Daejeon, Korea

Overview

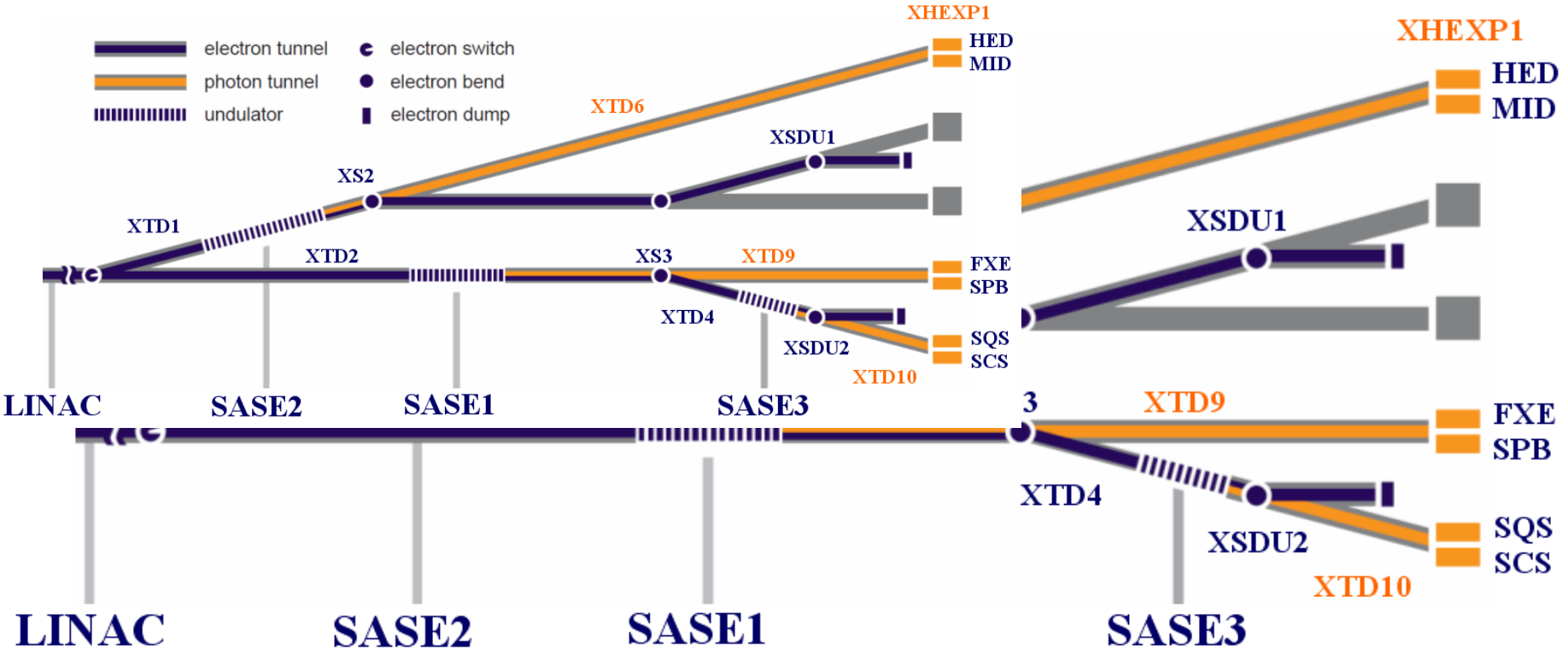


- European XFEL facility
- Photon diagnostics devices
- Status of assemblies
- Installations of diagnostics and beamlines
- Recent design developments for advanced diagnostics
- Schedule

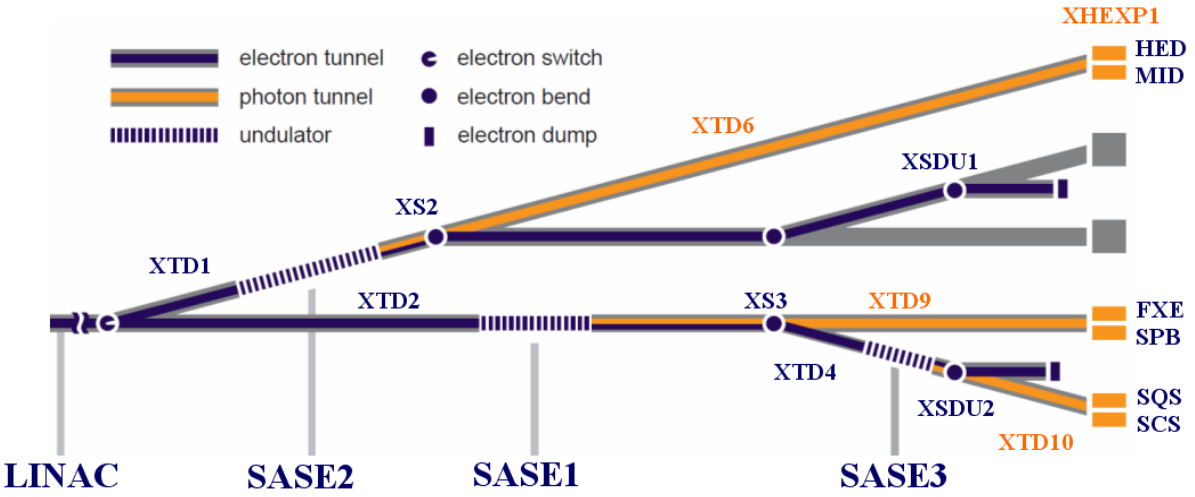
X-ray photon tunnels – beamlines & diagnostics

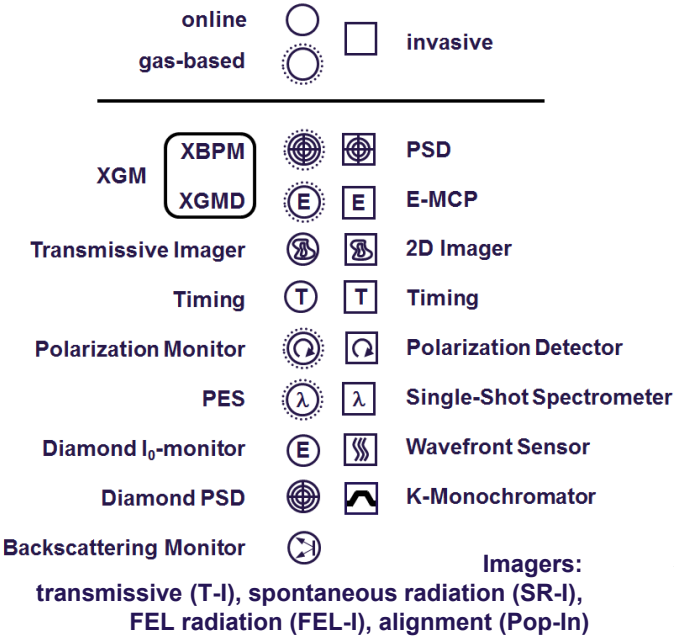


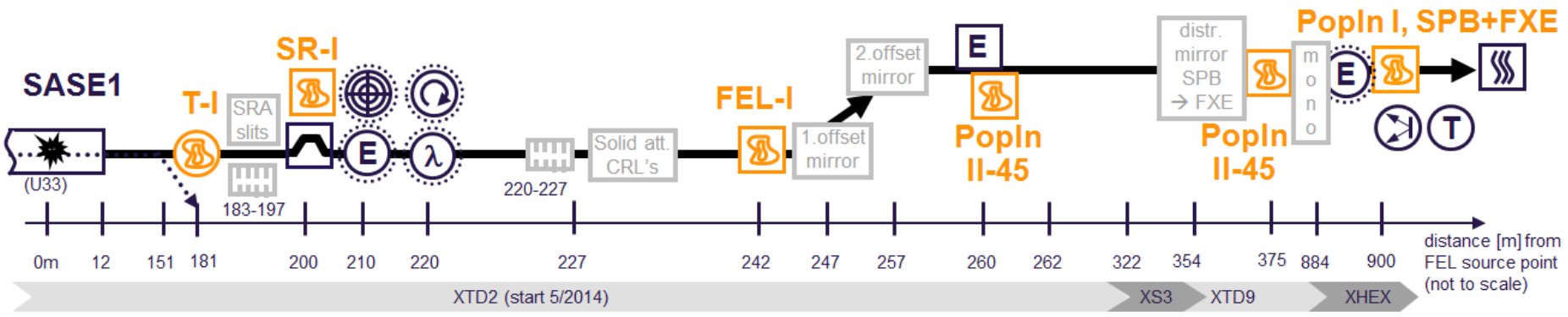
X-ray photon tunnels – beamlines & diagnostics



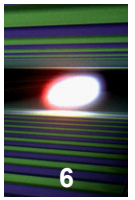
X-ray photon tunnels – beamlines & diagnostics







Timeline Diagnostics



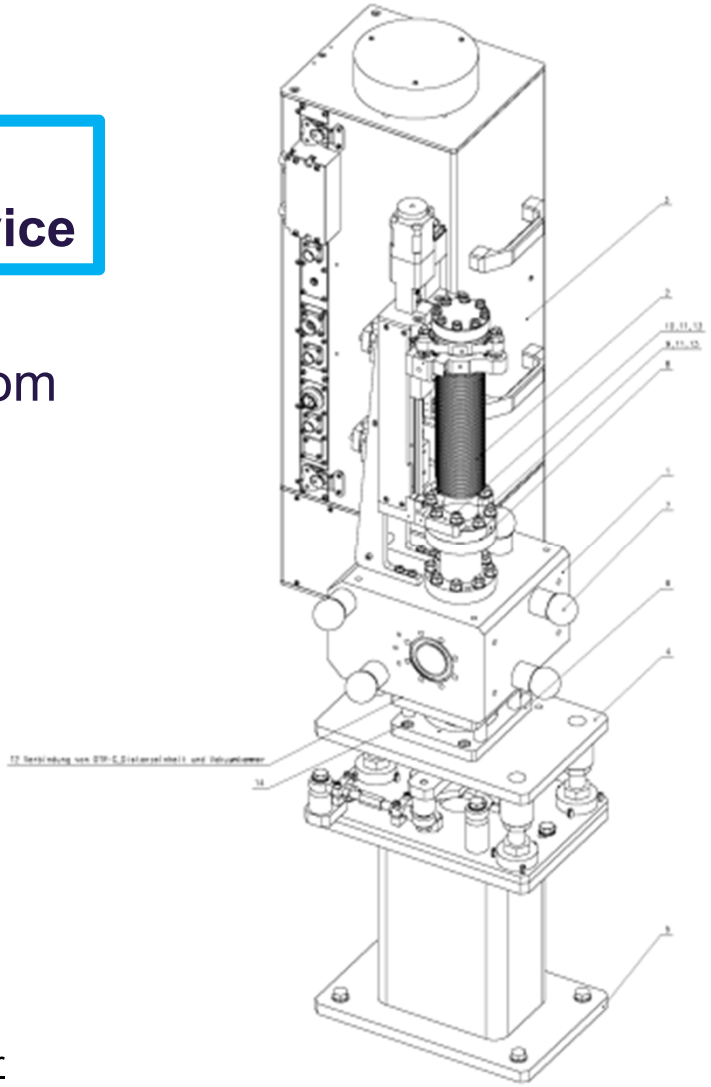
- 2014
  - **Final assembly** of first UHV-chambers
    - → Imagers, K-mono, XGM (SASE1), PES (SASE3)
  - Tunnel installation of first **support structures** (XTD2)
    - → Concrete pedestals and grouted steel pillars
- 2015
  - Final assembly + tunnel installation of systems for **SASE1+3**
  - Detailed **design and production** of several devices
    - → HiReX spectrometer, PES for hard X-rays, Exit Slit Imager, SR-imager-2D
  - **DAQ&Control** System preparation, cabling, technical commissioning
- 2016
  - Installation of remaining systems in **SASE3**
  - Production/assembly/installation of **SASE2** systems

SASE1 tunnel XTD2 in 2014

Transmissive Imager

Most upstream photon diagnostics device

- standard „OTR-C“ imager from e-beam diagnostics (DESY)
- Modified scintillator holder for photon detection



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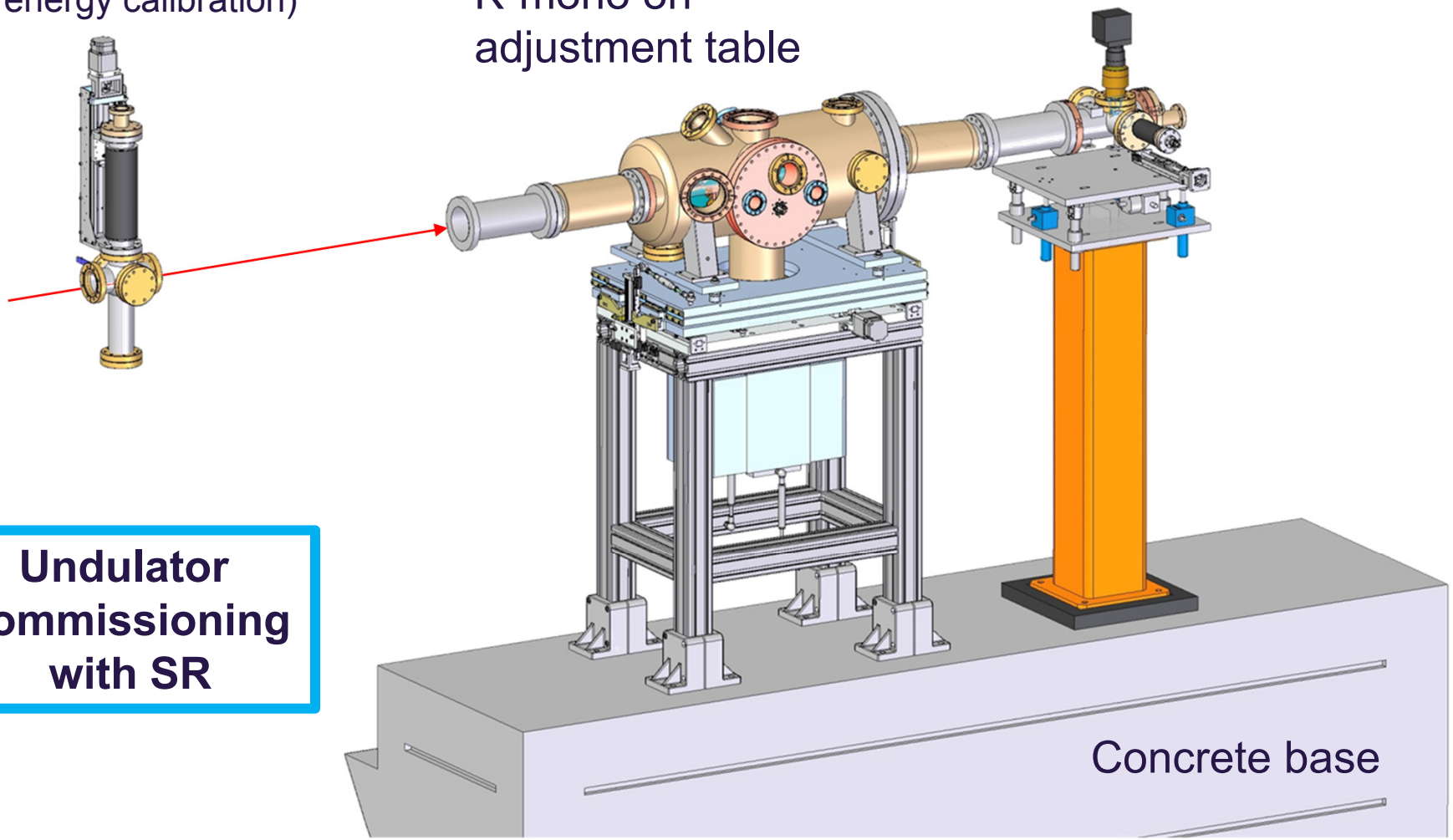
K-monochromator system (SASE1)

Filter chamber
(for energy calibration)

K-mono on
adjustment table

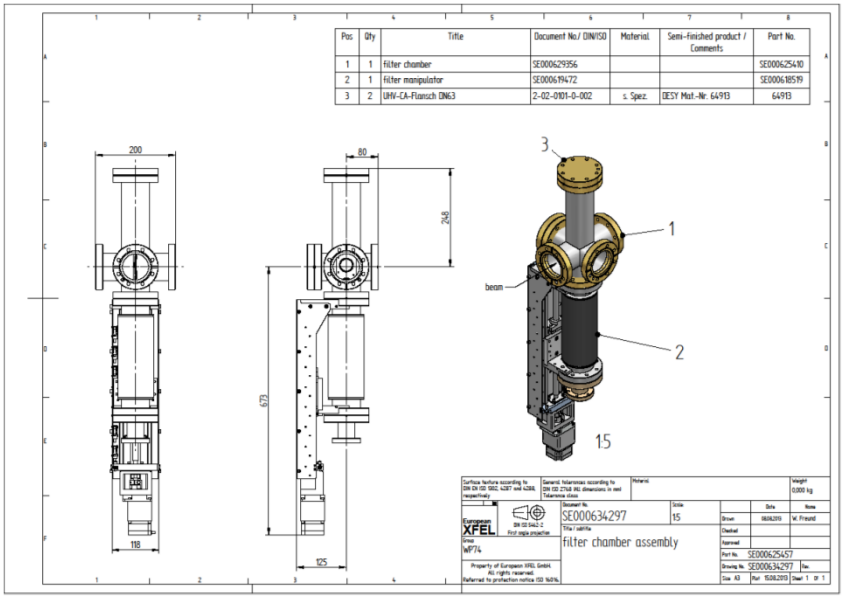
2d SR imager

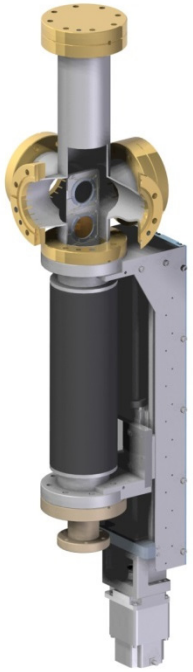


Undulator Commissioning with SR

Filter chamber

- Alignment base plates produced
- Assembly & tests done → RFI
- Holds up to 5 filter foils





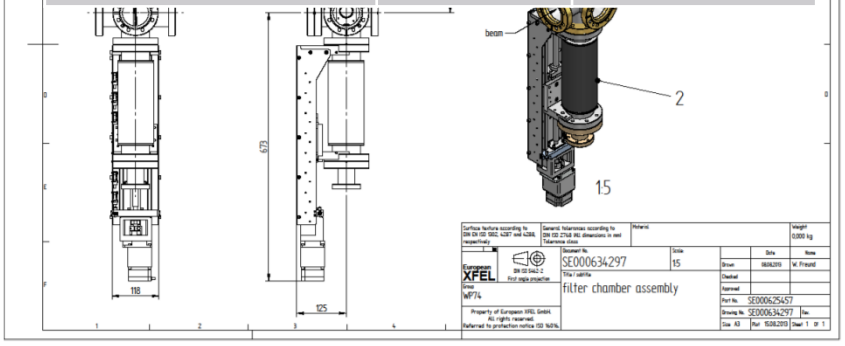
N:\4all\intern\User data\wp74\Devices\31-2_K-Mono\production drawings\filter chamber

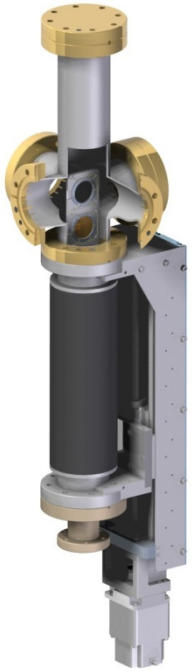
Design: Wolfgang Freund, WP74

Filter chamber

- Alignment base plates produced
- Assembly & tests done → RFI
- Holds up to 5 filter foils

Material	Thickness	K-edge
Aluminum (light blocker)	2.5 µm	(1559.6eV)
Chromium	5 µm	5989 eV
Copper	10 µm	7709 eV
Nickel	5 µm	8333 eV
Molybdenum	20 µm	20 keV





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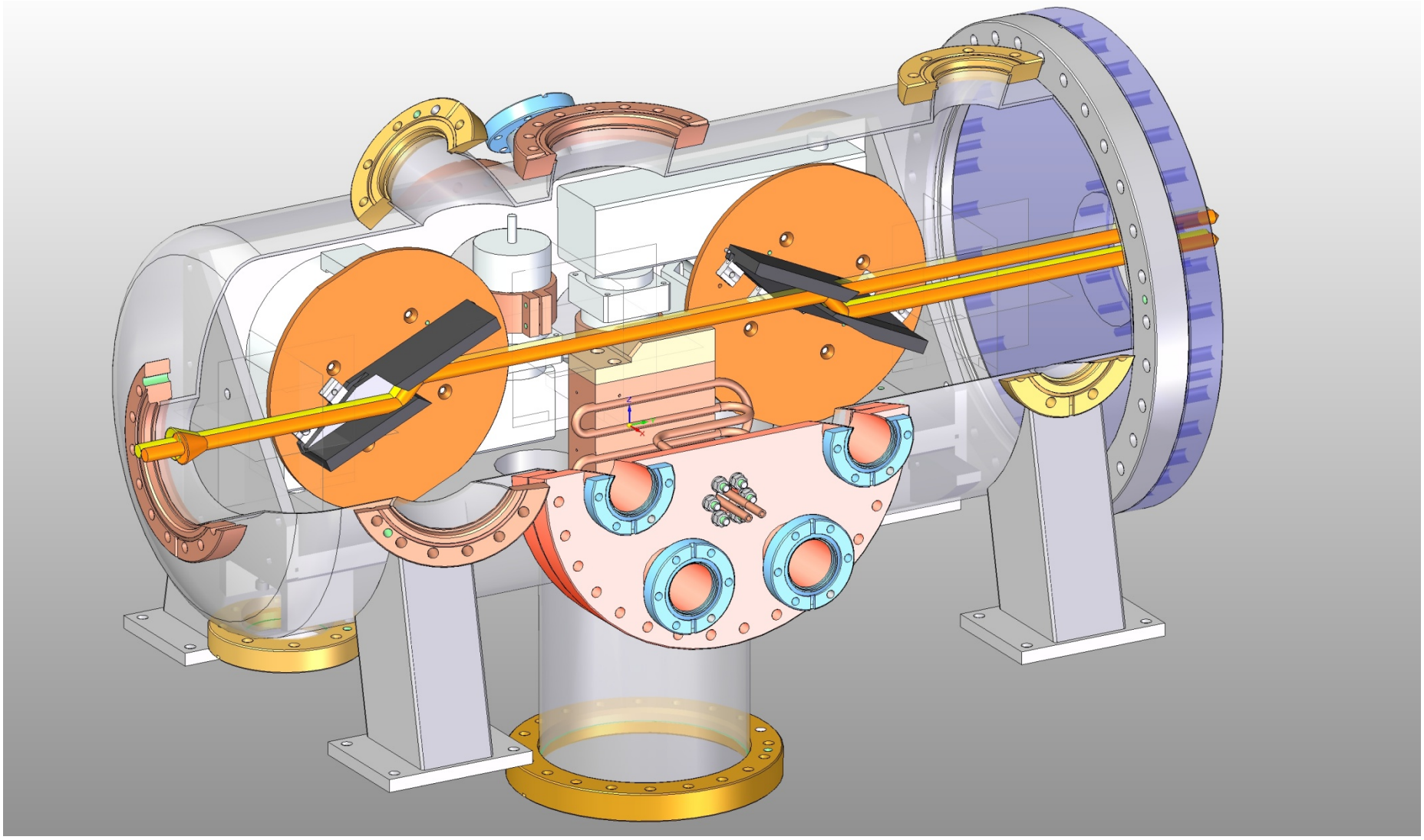
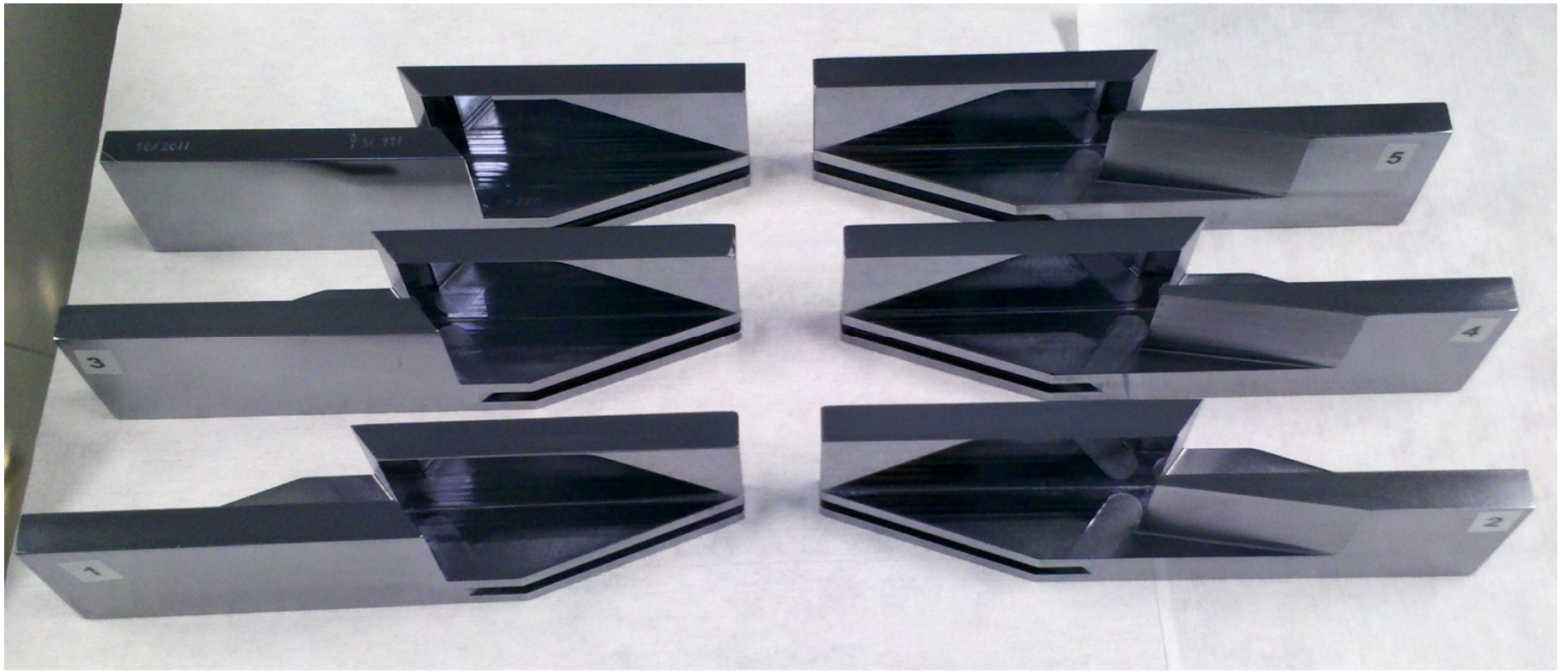
K-Monochromator

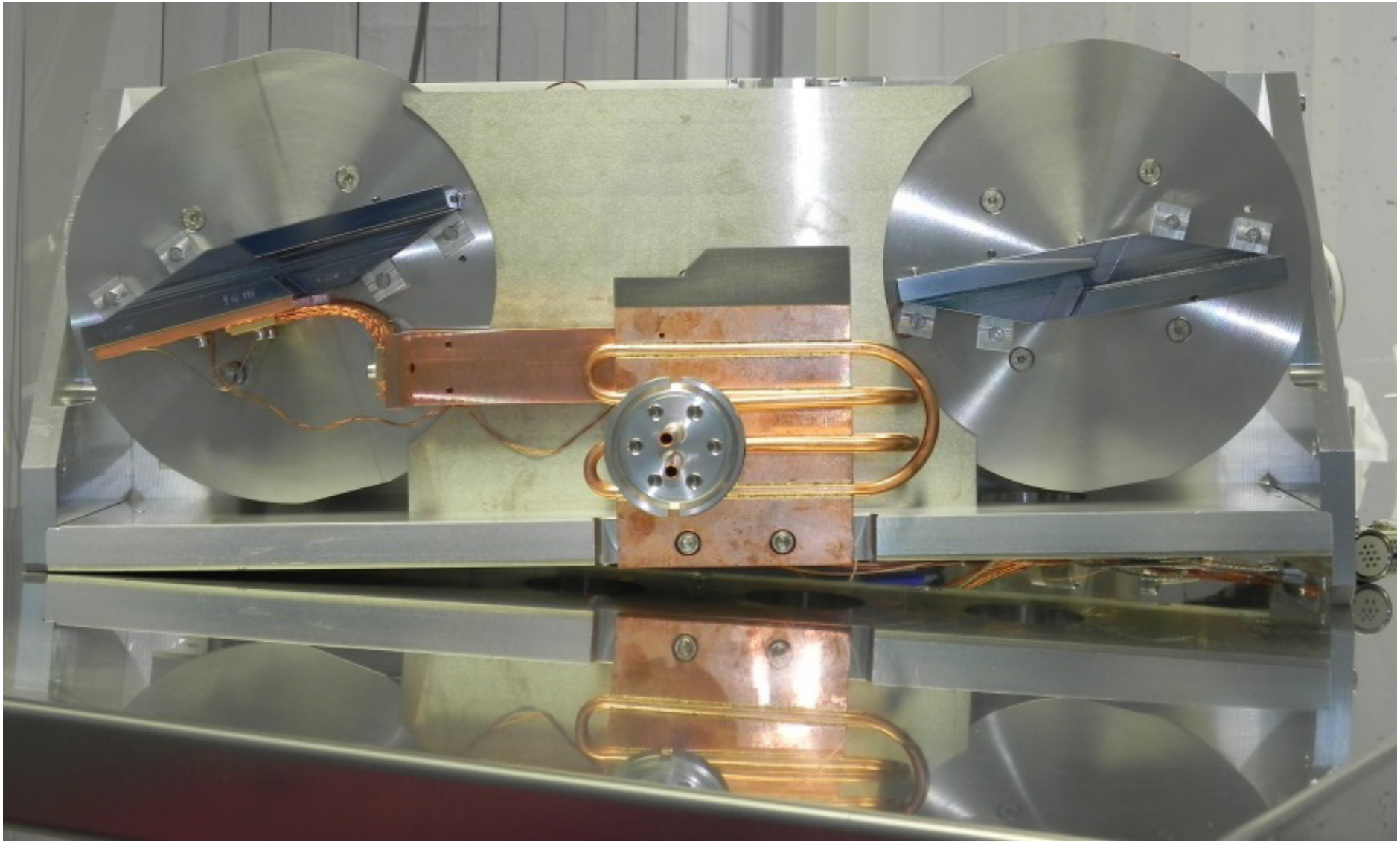


Design: Wolfgang Freund, WP74

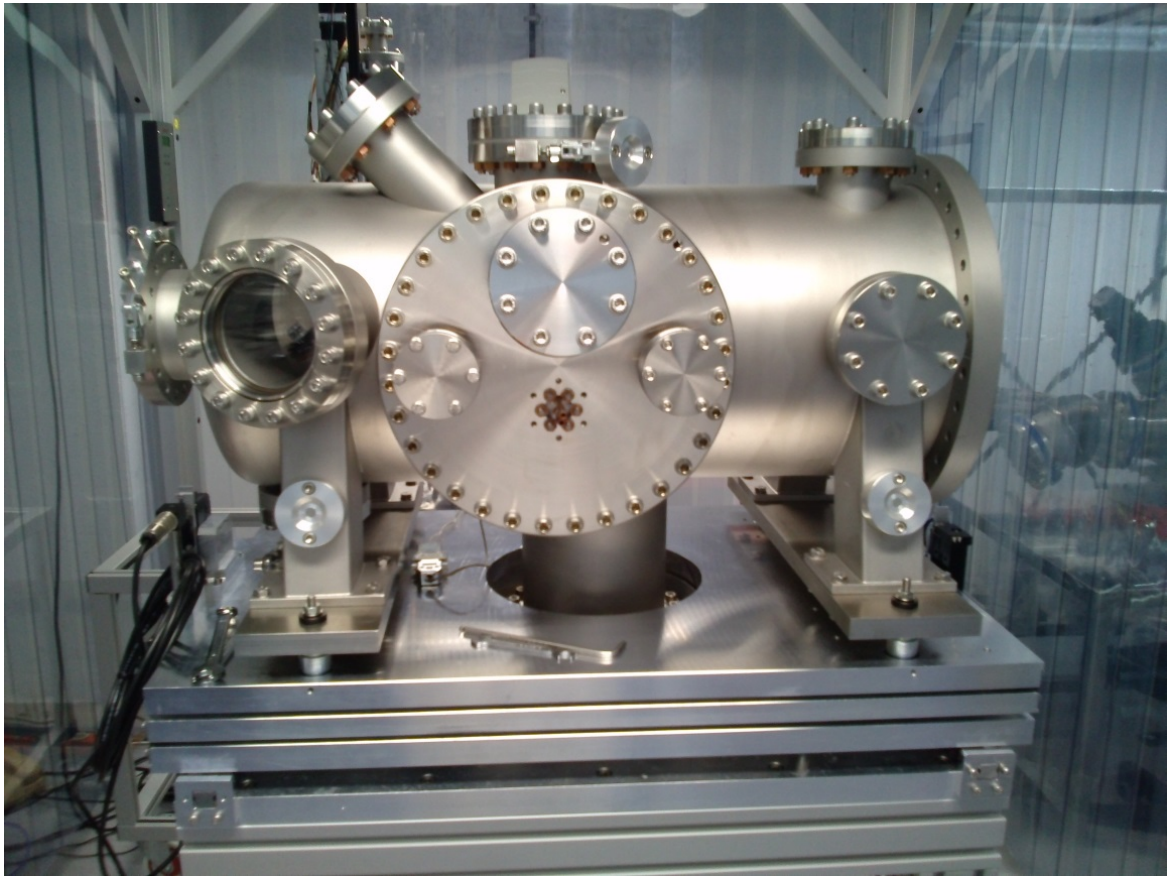
K-Monochromator crystals



K-Monochromator



K-Monochromator



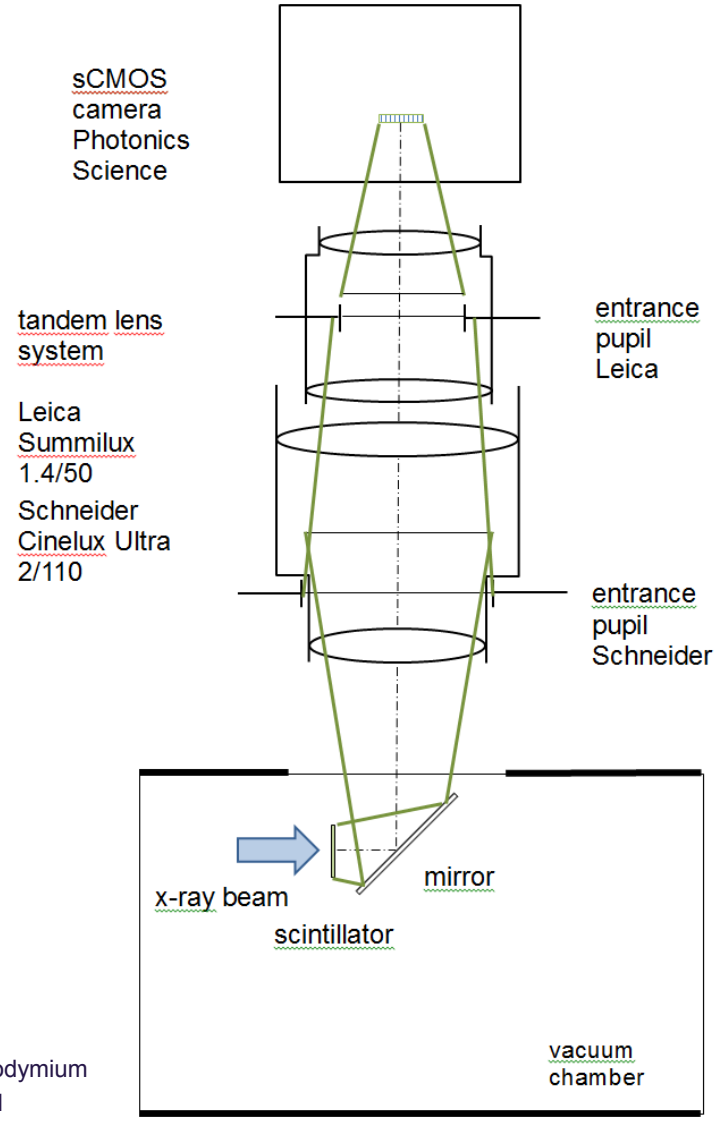
- SASE1 device produced, assembled, tested, and installed in XTD2
- Next: assembly of 2 more units

Spontaneous radiation imager

- visualize spontaneous radiation behind K-mono for undulator commissioning

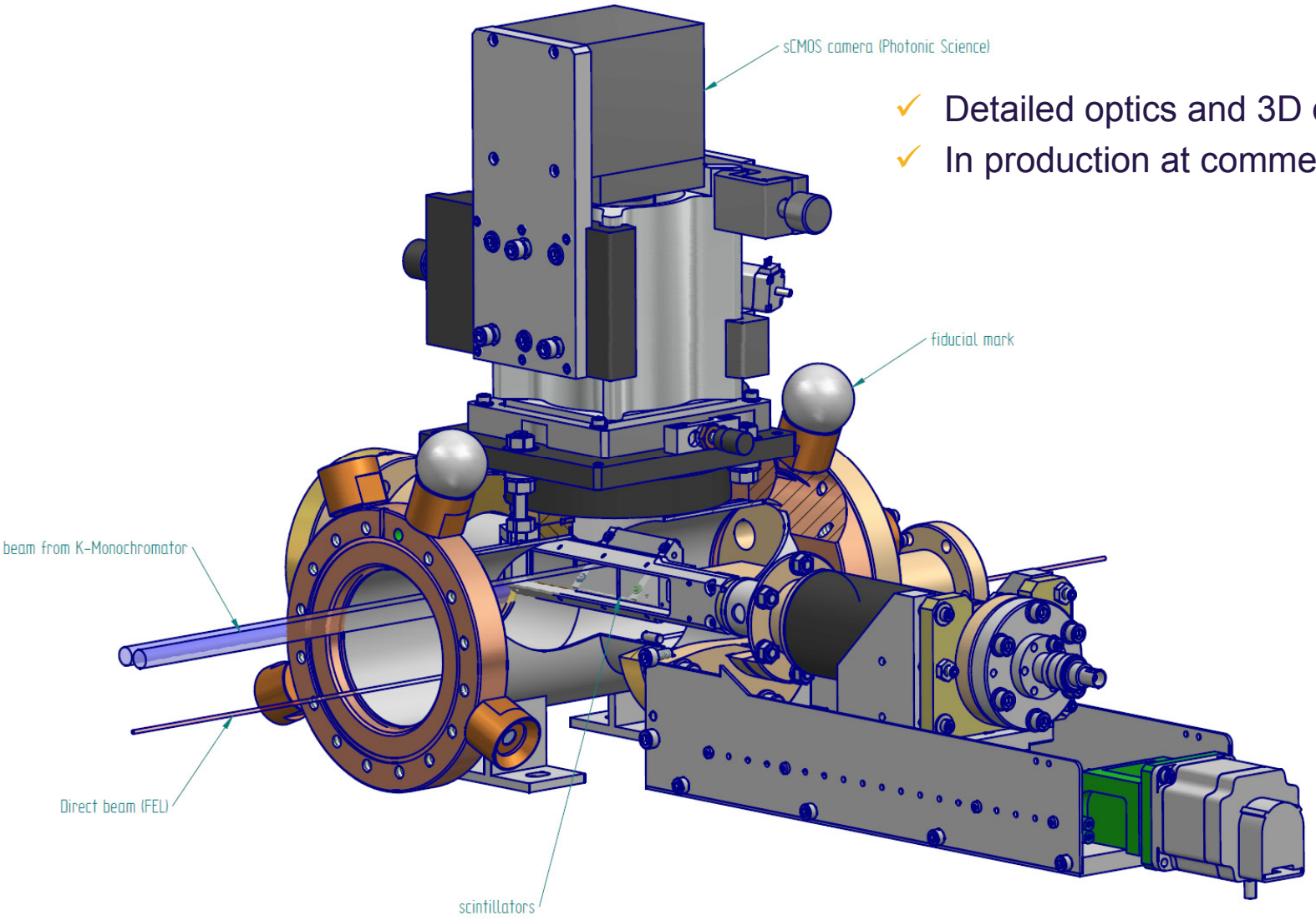
- Design:
  scintillators (YAG:Ce, $Gd_2O_2S:Pr^*$), mirror, tandem optics (Leica – Schneider, f/0.95), motorized iris, **low noise camera (Photonic Science sCMOS** 16 bit, noise 0.92 e^- rms).

- Specifications:
  - SNR = 90 for 10 pulses av., 2x2 binning
  - 30 µm spatial resolution, demagn. 2.2:1
  - Field of view 27x15 mm^2
  - NES = 20 keV ph rms, dynamic range 10^6
  - 10 Hz operation



* Gadolinium oxysulfide, doped with praesodymium
** NES = input exposure density for SNR=1

SR imager



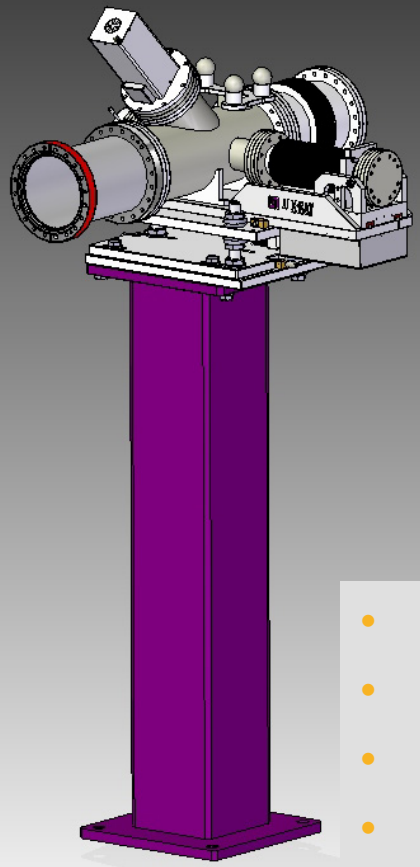
- ✓ Detailed optics and 3D design done
- ✓ In production at commercial workshop

Design: Wolfgang Freund, WP74

Pop-in Monitor

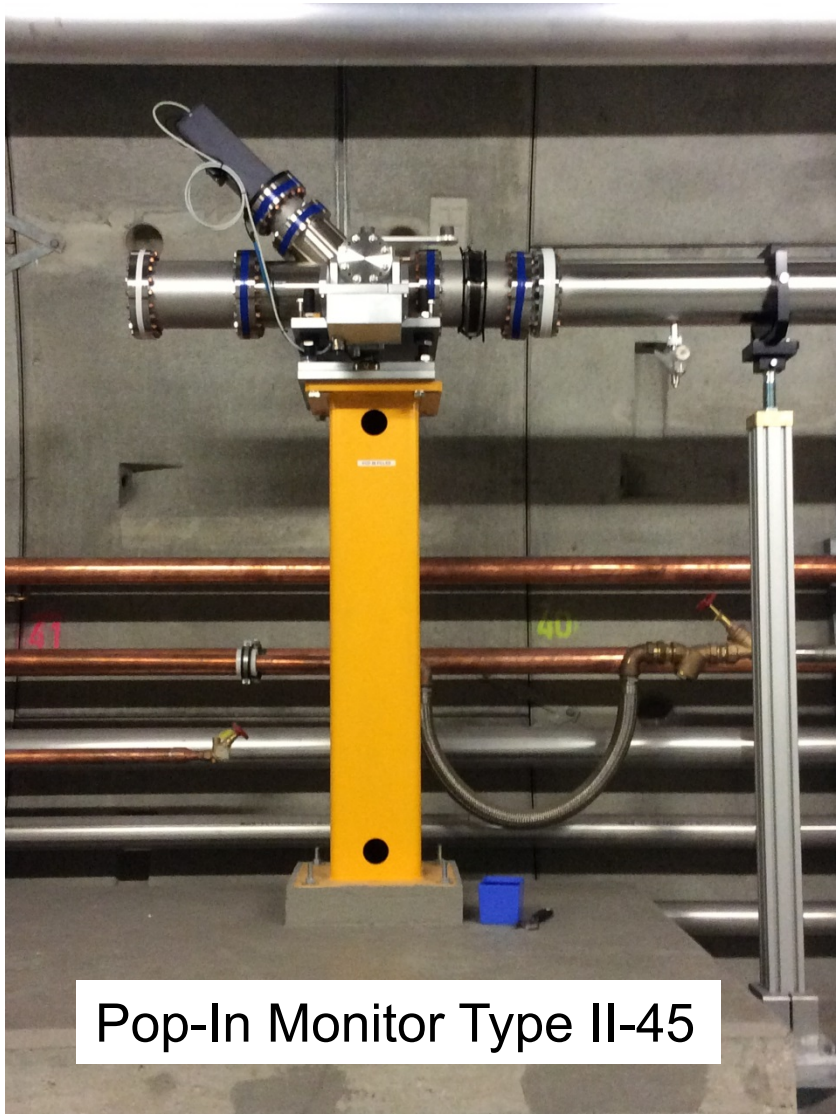
SASE beam alignment

Type II-45°



- FDR/PPR/production/SAT done
- Detailed optics implementation approved 03/2015
- Final assembly (scintillators) + vacuum tests: 03/2015
- **First device installed in XTD2 in 04/2015**
- Continuous finalization of devices (~15 in total)

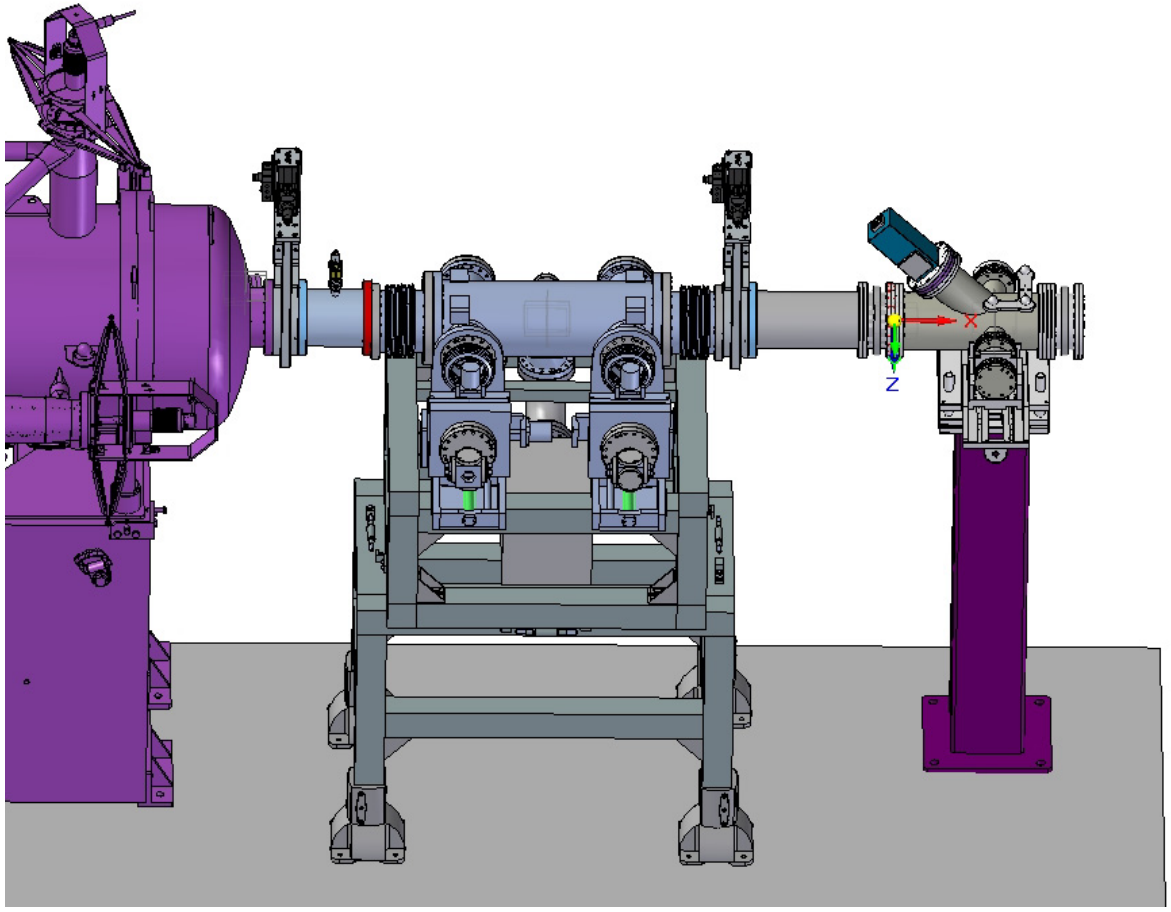
Installation of the first Imager (XTD2)



MCP-based detector (E.Syresin, JINR/Dubna, Russia)

SASE search and optimization

- ✓ Final devices (S1,S2,S3) are RFI at HERA-S
- ✓ Camera section now also operational



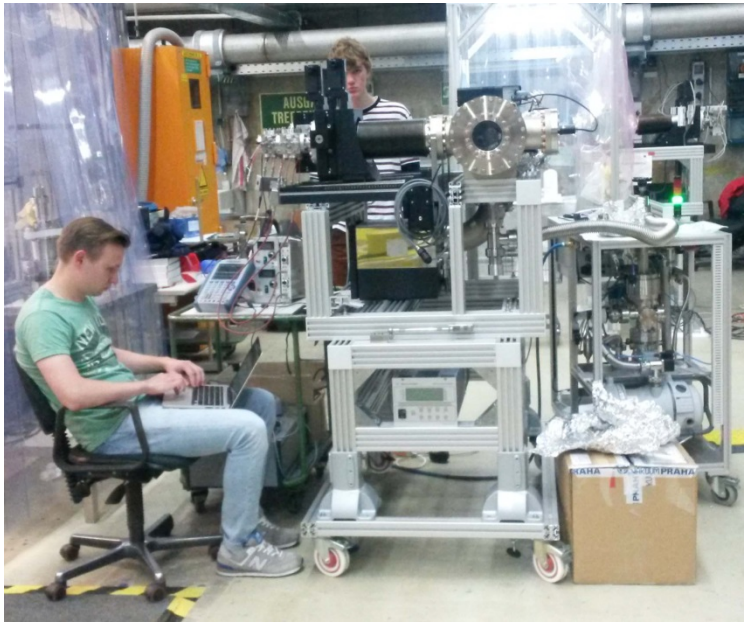
SASE2 MCP-detector at HERA-S, 03/2015

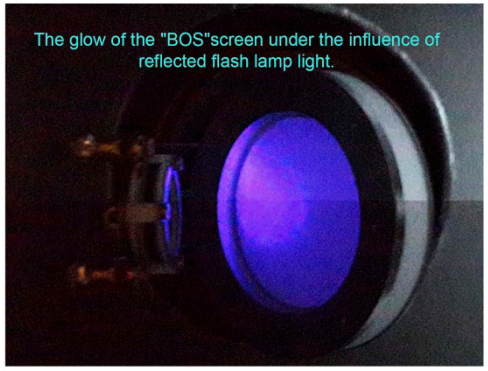
Design: JINR/Dubna, Russia

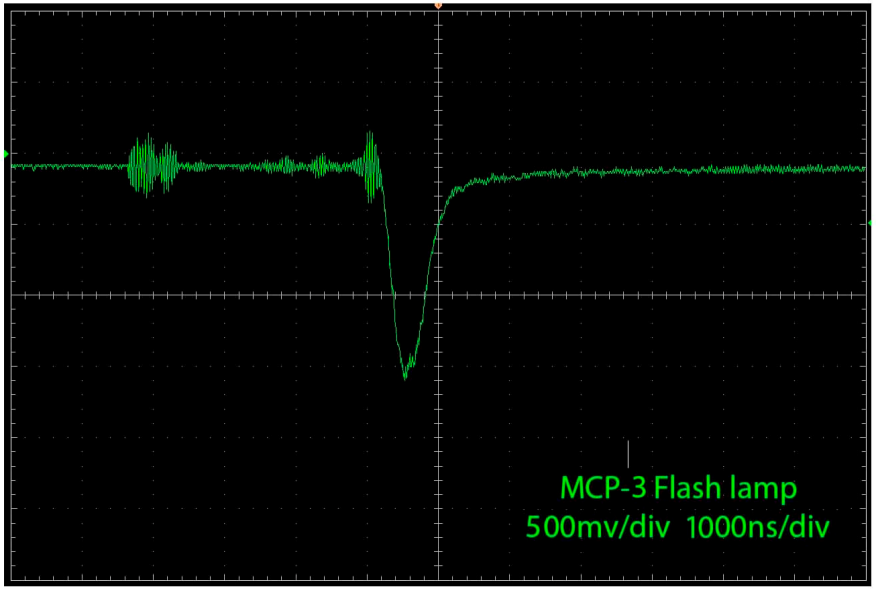
N:\4all\intern\User data\wp74\Devices\31-1_MCP-Detector\3D-sketches

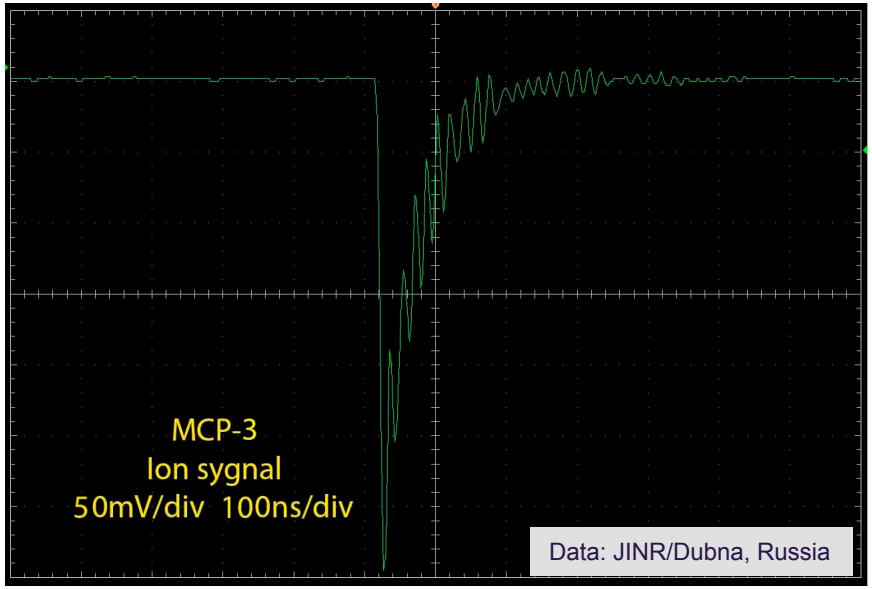
MCP-detector tests

JINR team with SASE3 MCP-detector









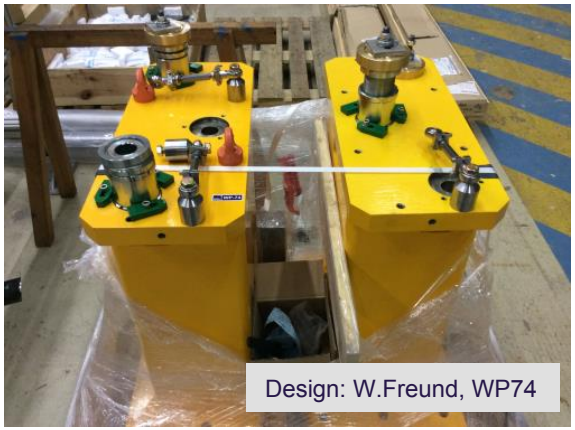
X-ray Gas Monitor (XGM)

Contributed by Tiedtke group @ FLASH/DESY

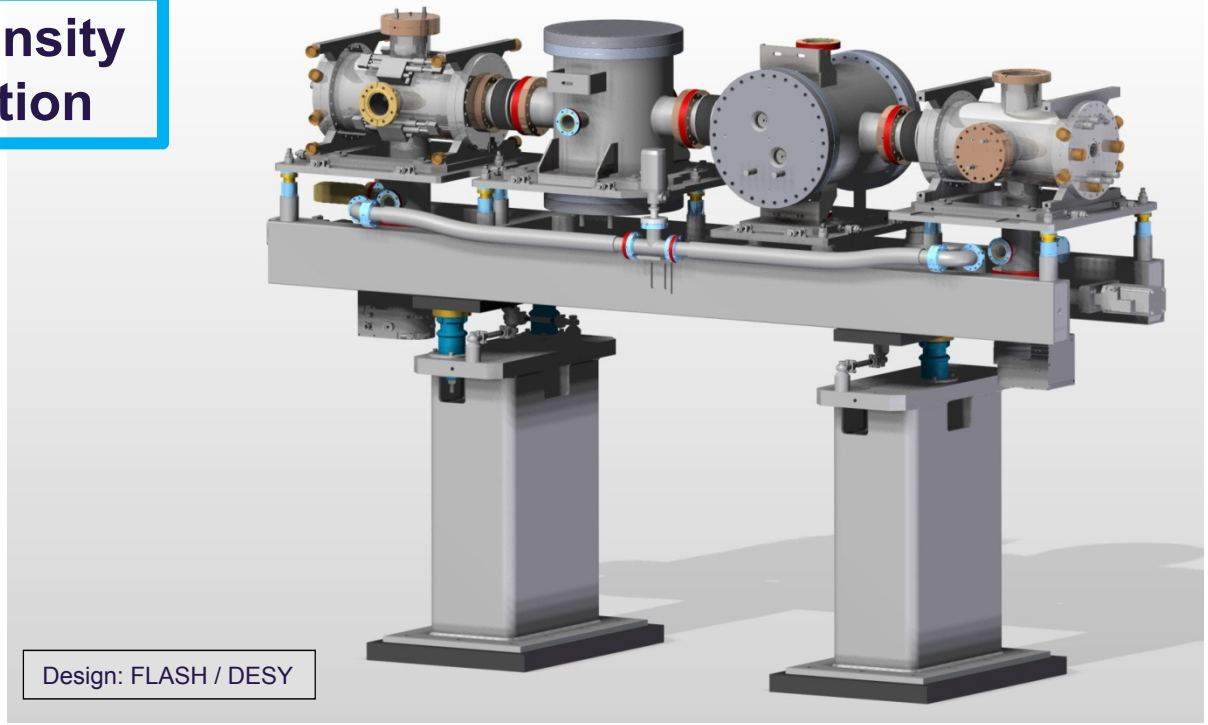
Status 08/2015 :

- one XGM (RFI) at XFEL-lab since 05‘2015 (install, when tunnel XTD9 is ready)
- one XGM (RFI) will be installed in XTD2 in August
- two more XGM at DESY, produced&calibrated, two final ones in Q1/2016

Shot-to-shot intensity and beam position



Supports, now installed in XTD2 and XTD9



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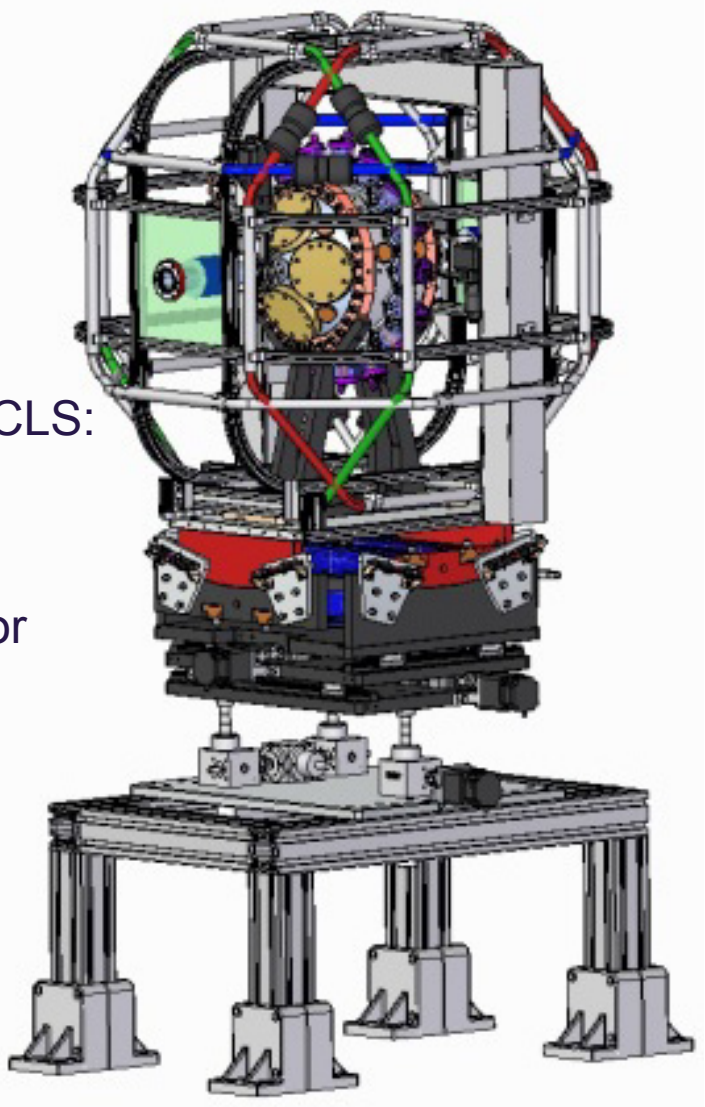
XGM girder, RFI at FLASH2 hall

Ref: Tiedtke group @ FLASH/DESY

Photoelectron spectrometer (PES)

Shot-to-shot spectrum and polarization

- Detailed design completed for SASE3 device and the fully motorized support
- SASE3 device fully assembled and very successfully tested with X-ray FEL beam at AMO/LCLS:
  - Scientific beamtime L52 (PI Helml)
  - Scientific IH-beamtime (PI Coffee)
  - Commissioning beamtimes for DELTA undulator
- SASE1 device requires development of modifications for hard X-ray application



Design: Buck/Planas, WP74

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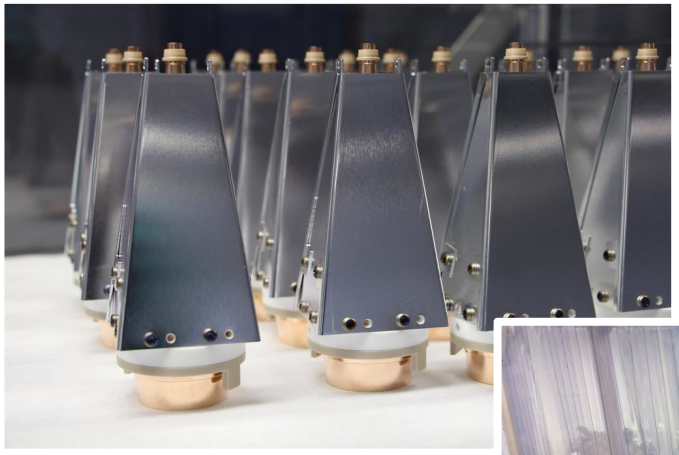
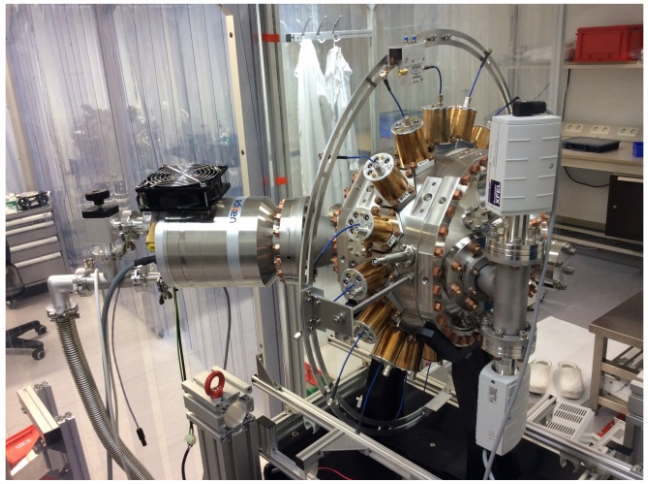
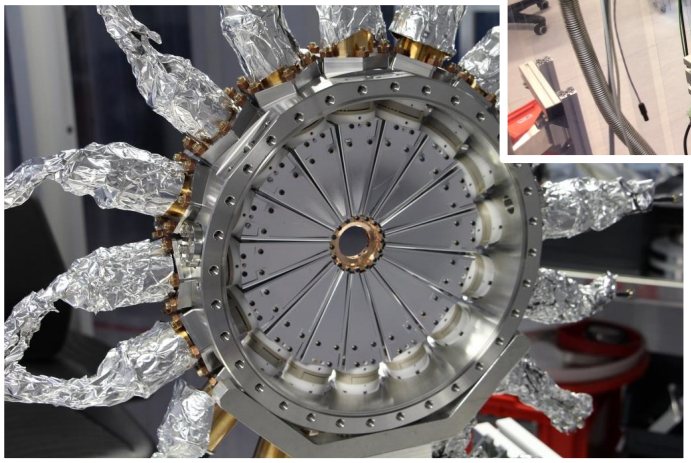
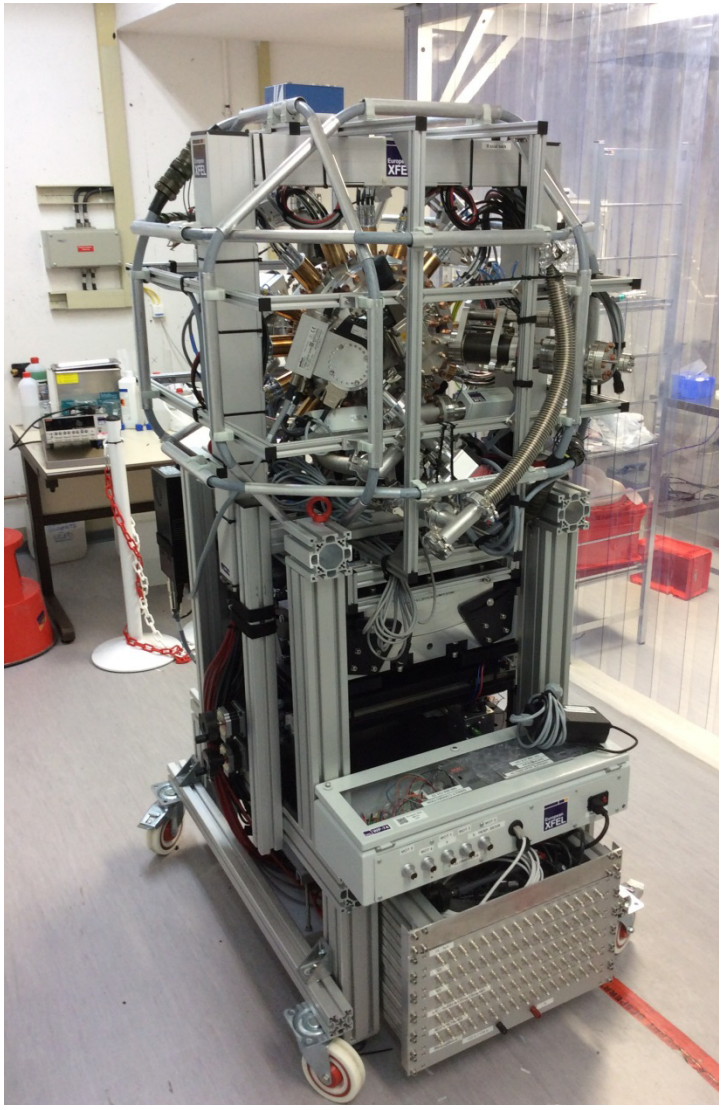
PES assembly

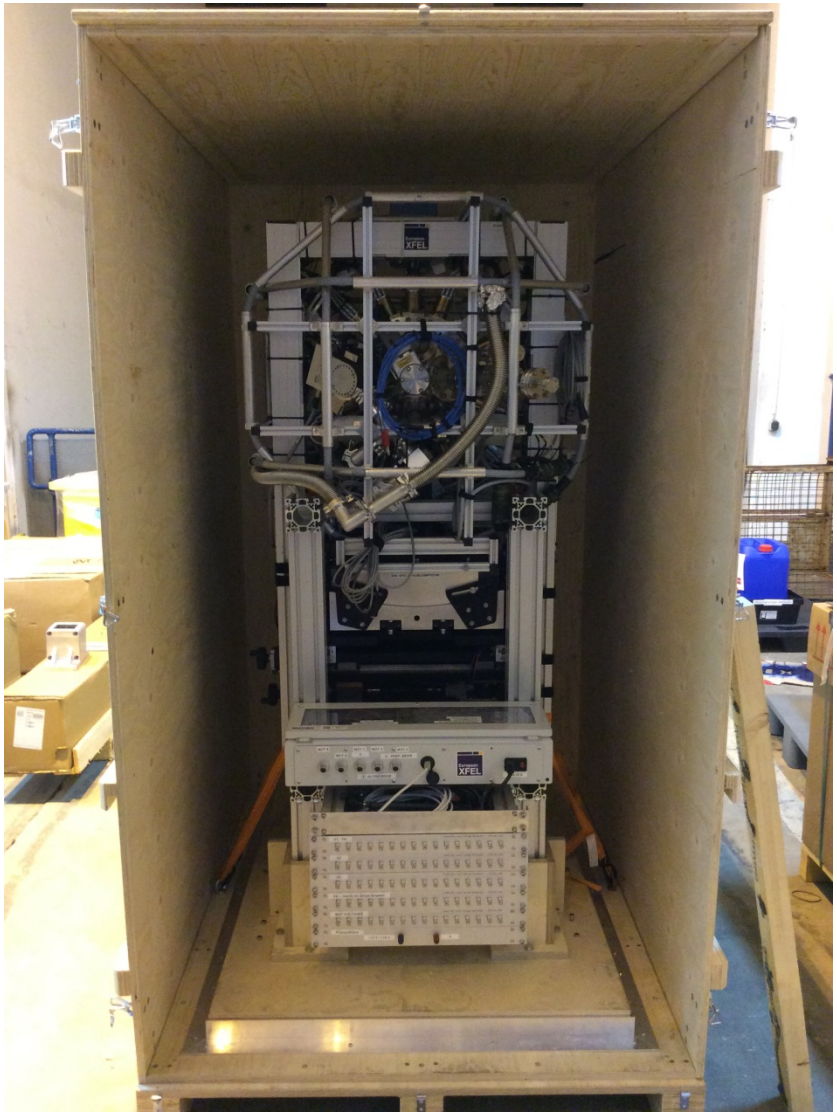


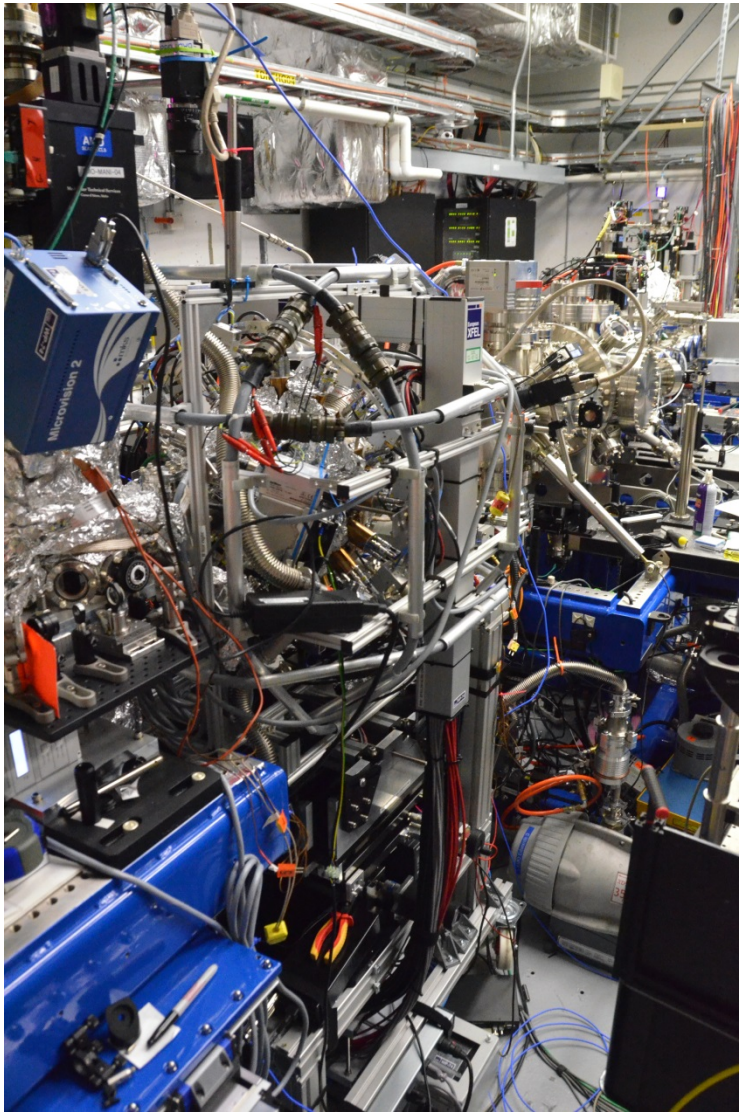






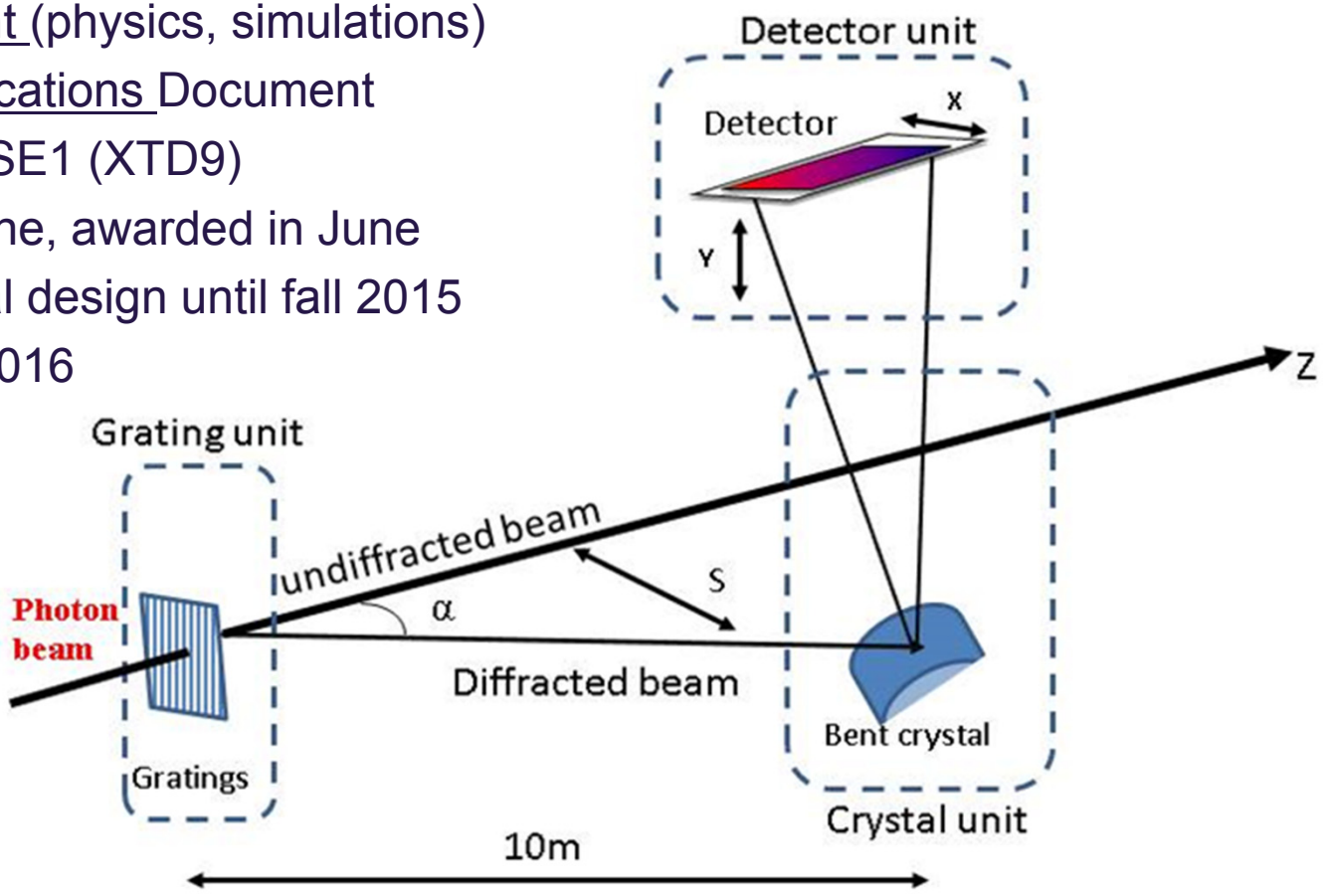
Transport to SLAC and use at AMO / LCLS





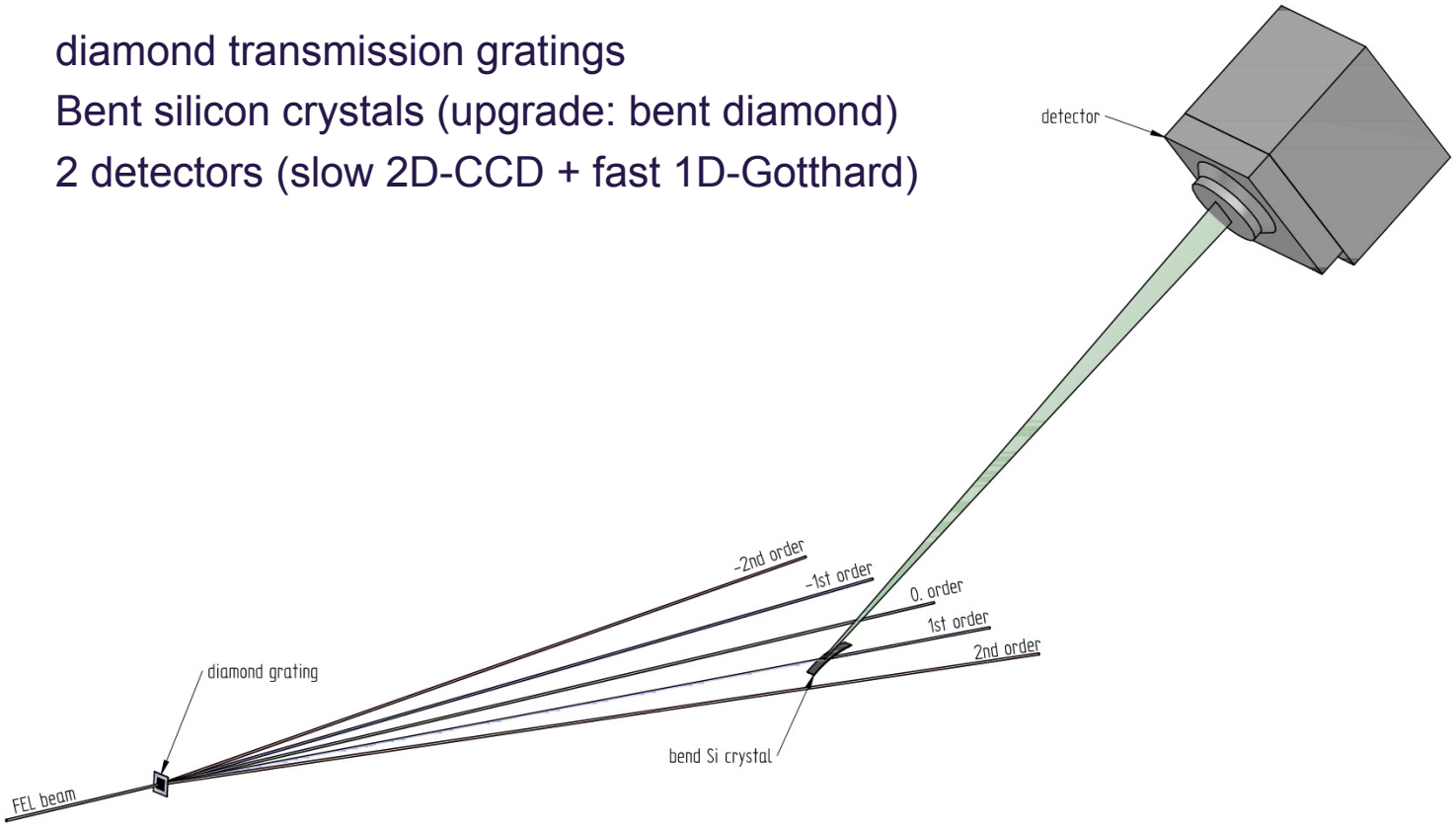
HiREX spectrometer

- Hard X-ray High Resolution Single Shot Spectrometer (**HiREX**) new
  - Design Document (physics, simulations)
  - Technical Specifications Document
  - Designed for SASE1 (XTD9)
  - Public Tender done, awarded in June
  - Detailed technical design until fall 2015
  - Installation in 7/2016



HiREX spectrometer

- diamond transmission gratings
- Bent silicon crystals (upgrade: bent diamond)
- 2 detectors (slow 2D-CCD + fast 1D-Gotthard)



1:2

Projekt / PROJECT	Arbeitspaket / WORKPACKAGE		Gruppe / GROUP WP74	Ers.für / REPLACES	Ers.durch / REPLACED BY
Gewicht / WEIGHT 0,000 kg	Halbzeug / SEMIFINISHED PRODUCT			Werkstoff / MATERIAL	Format/SIZE A3
Allg. Toleranzen / GENERAL TOLERANCES ISO 2768, ISO 13920		Maßstab / SCALE MAßSTAB		Titel / TITLE HRHXSSS-geometry	
Tolerierungsgrundsatz / FUNDAMENTAL TOLERANCING PRINCIPLE ISO 8015	Toleranzklasse / TOLERANCE CLASS	Teile-ID / PART-ID SE000820221			
Oberflächenkenngrößen / SURFACE TEXTURE ISO 1302, 4287, 4288			Datum / DATE, Name / NAME		
		Gez. / CRE.	16.02.2015 W. Freund		
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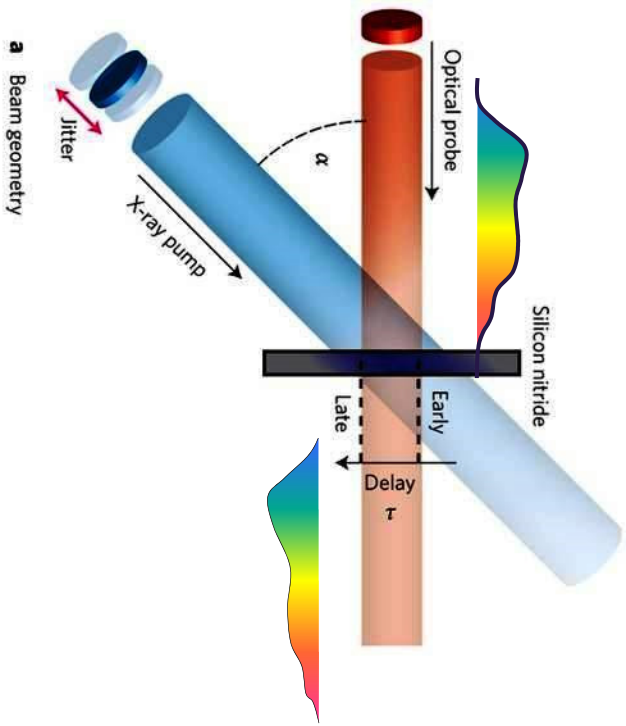
		Freig. / REL.			
		Gen. / APR.		Zchng.-ID / DRAW-ID SE000820791	Rev. / REV. Ver. / VER. Status / STATUS 0-Verfügbar
				PLOT 16.02.2015	

Photon Arrival time Monitor (PAM)

Spectral encoding



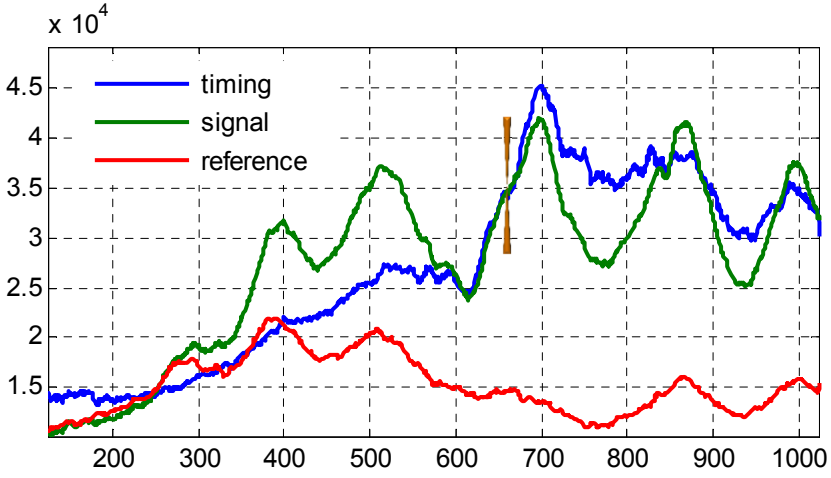
Chirped white light generation

- White light detection & characterization
- Resolution: (~ 10 fs rms)
  - Spectrometer resolution
  - white light chirp

Courtesy: *Nat. Photonics* **8**, 706 (2014)

X-ray & white light

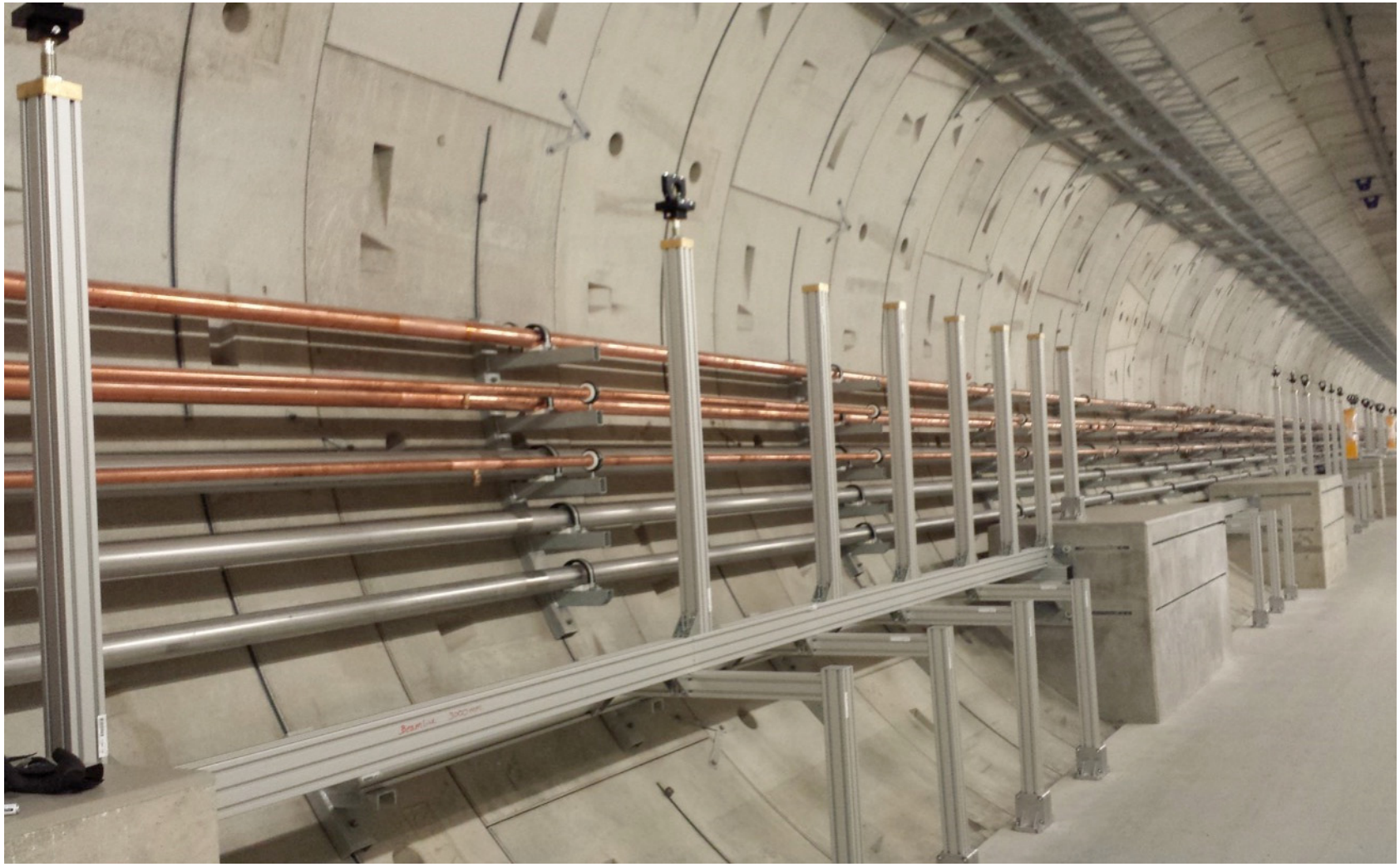
- Coarse timing overlap (~10-30 ps)
  - high bandwidth oscilloscope
  - fast diode
- Binary search for etalon effect in spectral transmission (~ 500 fs)
- Find spectrum change (~10 fs rms)
- Measure the spectral chirp and fitting



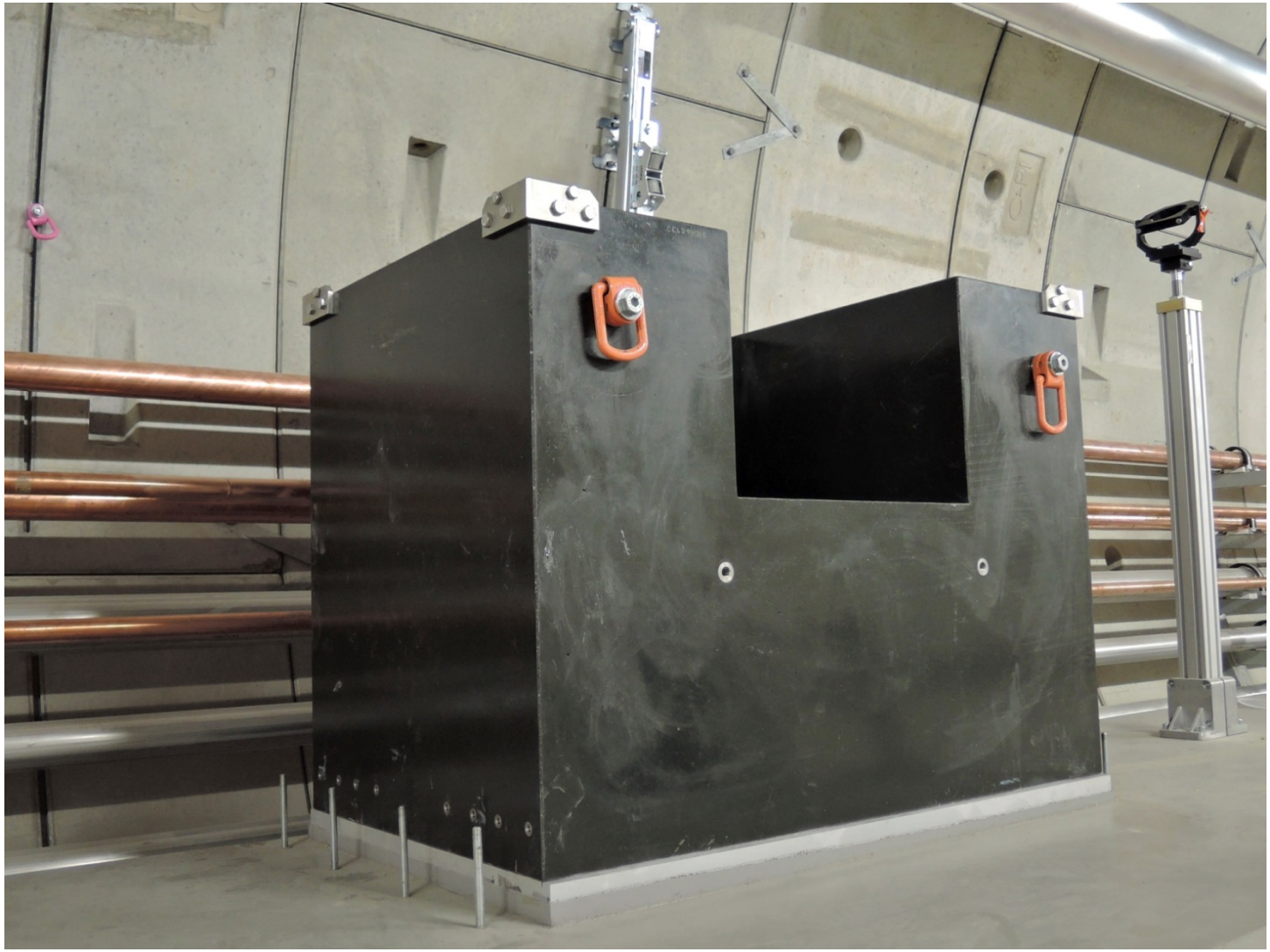
- **Challenges: High photon energy & MHz repetition?**
  - Fast target cascading & relaxation
  - High target damage threshold
  - High speed signal detection

Provided by J.Liu, WP74

All supports in XTD2 installed



Installation of mirror granites



SRA (Spontaneous Radiation Aperture) in XTD2

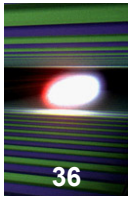
Photon beam transport in XTD2

Photon beam transport in XTD9

Electronic racks

- All SASE1 photon racks are on their positions
- Now: electrical power, IT network, cooling water, fire extinguishing units

Outlook – long term



- 2015:
  - Finish SASE1 vacuum and electrical installations
  - Start SASE3 installation
    - ➔ Detailed beam transport designed
    - ➔ Mirror chamber, Soft X-ray monochromator, PES, DP
  - Commissioning control system in SASE1
- 2016:
  - More SASE1 Installations:
    - ➔ Hard X-ray monochromators, HiReX spectrometer, PES
  - SASE2 installations
  - SASE1 beam commissioning and First Lasing
- 2017: Transition to User Operation

Acknowledgements

X-ray photon diagnostics team (WP74)

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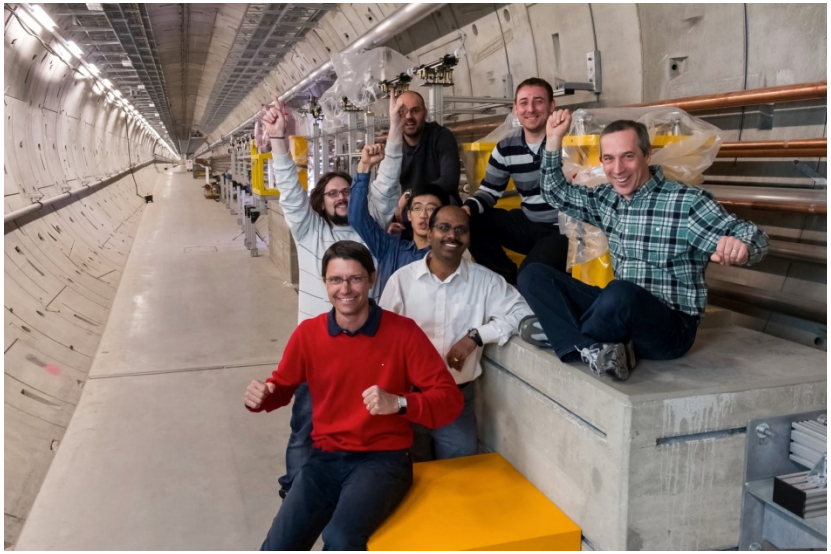
- Jens Buck — *Photoemission*
- Marc Planas — *Engineer*
- Andreas Koch — *Imaging Stations*
- Jia Liu — *Temp. Diagnostics*
- Florian Dietrich — *Engineer*
- Naresh Kujala — *HiREX*
- Sascha Lübbe — *Student*
- → **Serguei Molodtsov** — ***Scientific Director***



X-ray optics and beam transport team (WP73, H.Sinn & M.Dommach)

Other groups at European XFEL like CAS, AE, ITDM, …

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Thank you for your attention !

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