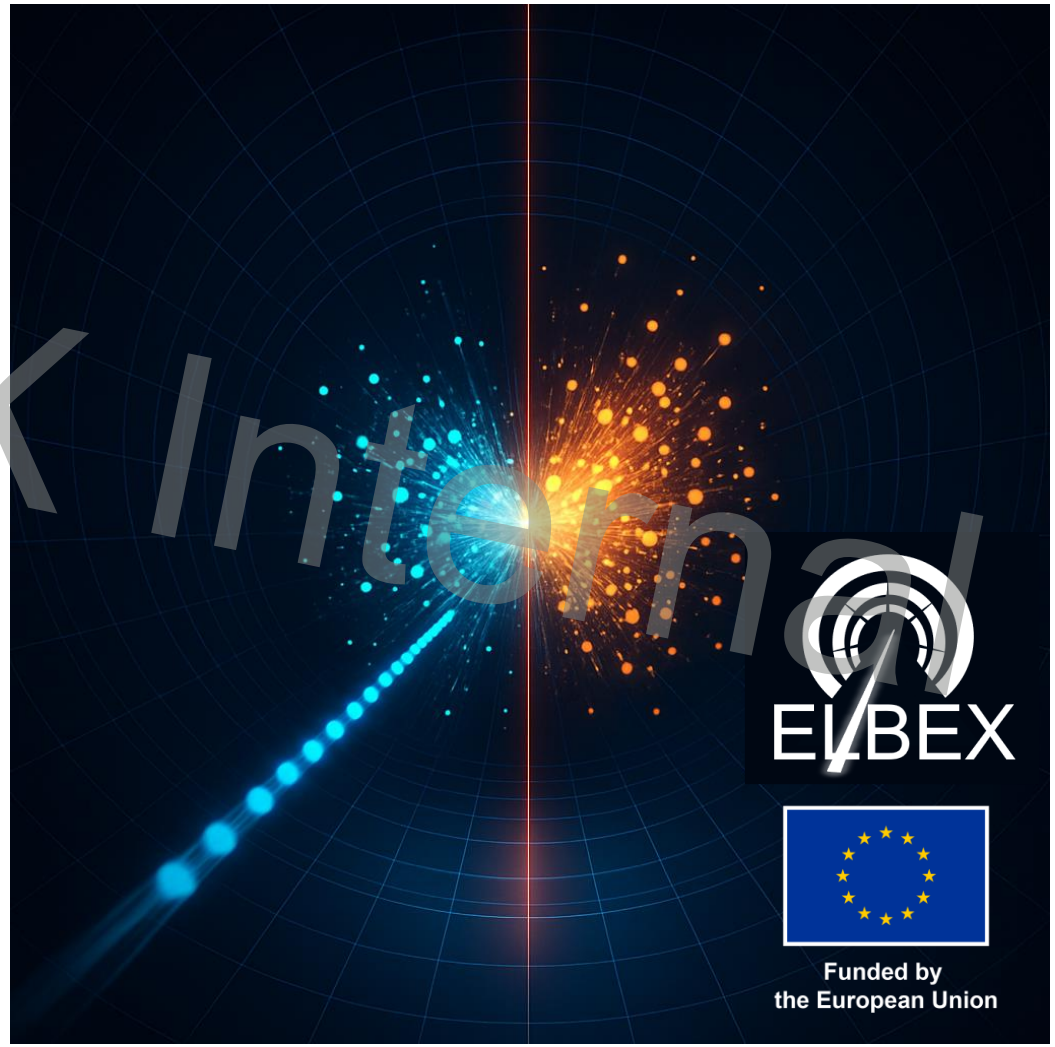
ELBEX

Marcel Stanitzki

PAB 27.11.2025



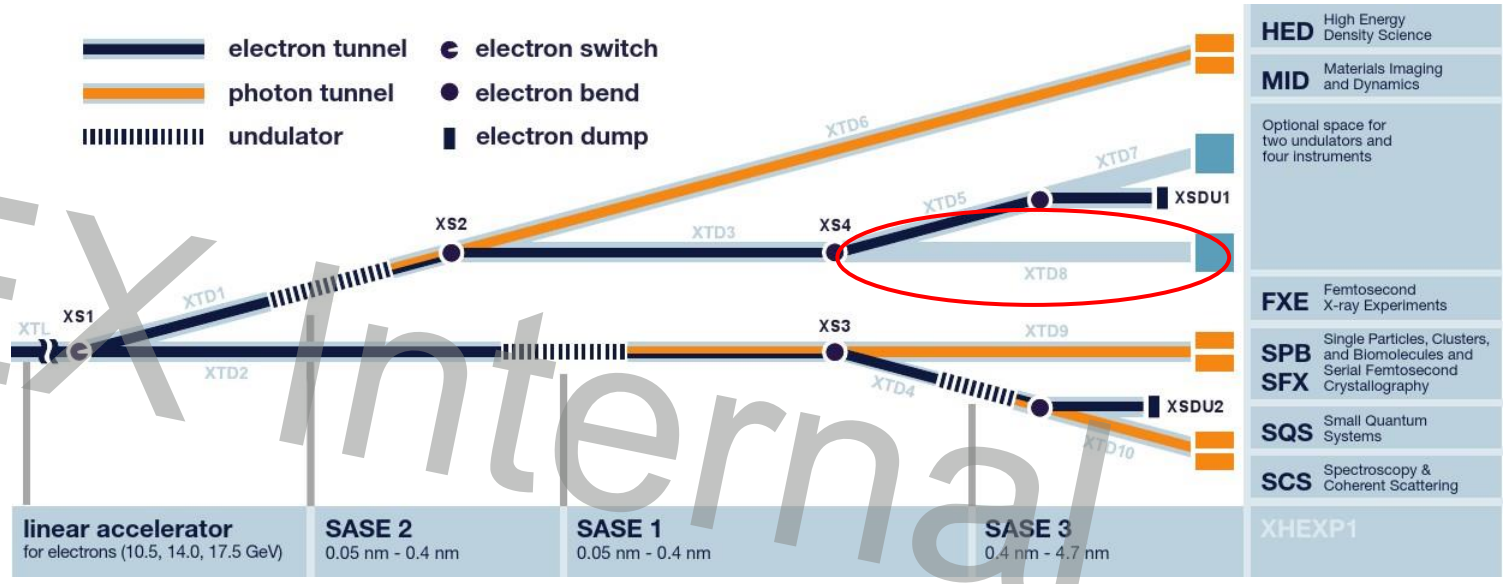
HELMHOLTZ

DESY.

ELBEX – in a nutshell

The executive summary

- ELBEX goal: beamline to extract 16.5 GeV EuXFEL electron beam (up to 50 bunches with 0.5 nC)
  - Unique, all other XFEL User beam lines only provide photons
  - XFEL e- beam very attractive: high energy, excellent beam quality and stability
  - This **infrastructure** can be used by different experiments
- Plan for several initial experiments
  - XFEL Forward: Flash-Forward at XFEL
  - LUXE: QED experiment
  - Additional Test Beam capabilities
- Successful ERC INFRA-DEV Grant
- European consortium: DESY, EuXFEL, IFIC Valencia, INFN Padova, University of Manchester



Funded by the European Union

Science using ELBEX

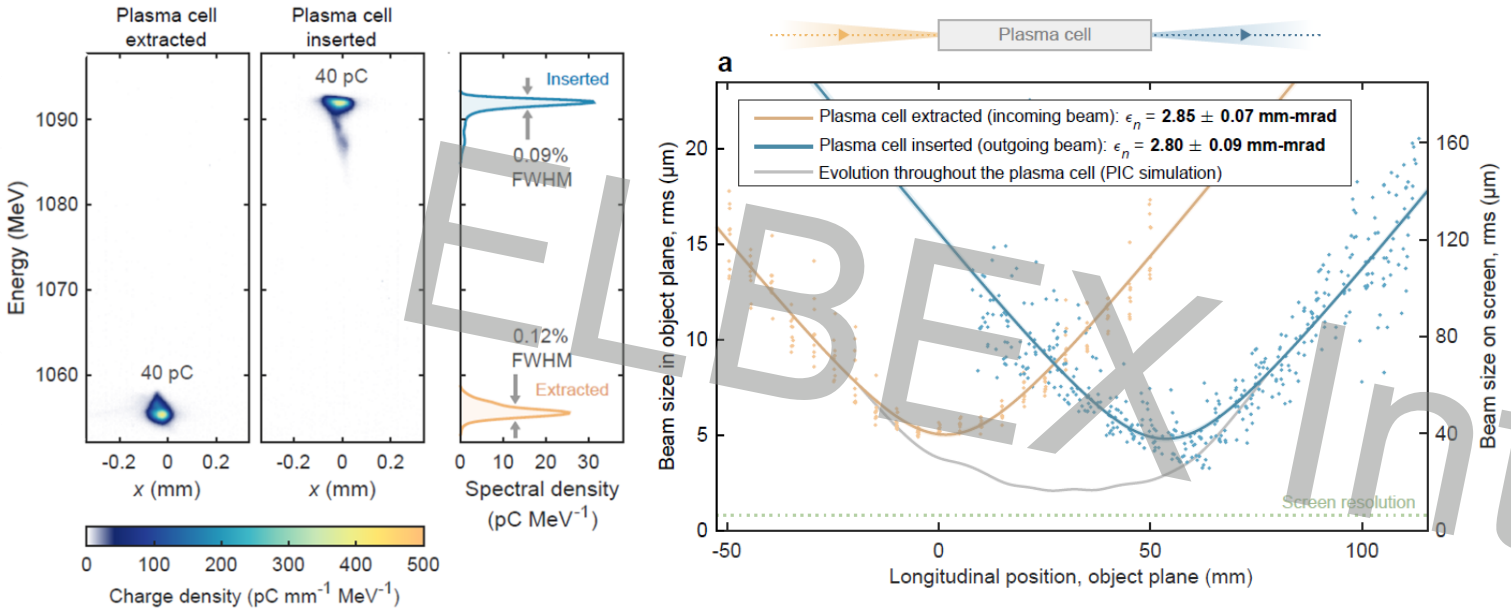
ELBEX – Science Case

Three pillars

- The ELBEX beamline has been designed with three user communities in mind
  - Basis for first experiment proposals
- Beam time can be either staged, split or shared
- As always „New Tools trigger new ideas…“
  - Room for new proposals

FlashForward at DESY

Advancing the quality of beam-driven plasma accelerators



- FLASHForward has made major progress in showing that plasma accelerators can boost the energy of high quality electron bunches.
- Showed that energy spread can be preserved at the 0.1% level while accelerating 10's pC at 1 GeV/m gradient.
- Preserved emittance during acceleration at 3 mm-mrad.
- Performing first studies of the acceleration of bunch trains.

Major achievements

2024: Emittance preservation, acceleration of a bunch from 1.2 to 1.7 GeV

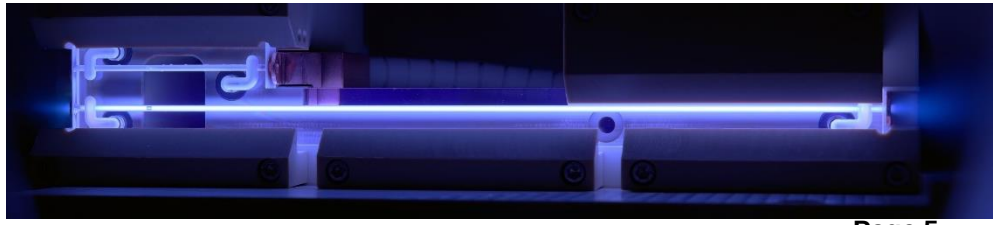
2023: Demonstration of MHz rep-rate plasma acceleration

2022: GHz plasma response

2021: Energy spread preservation

2020: Sampling of the accelerating field of the plasma wake

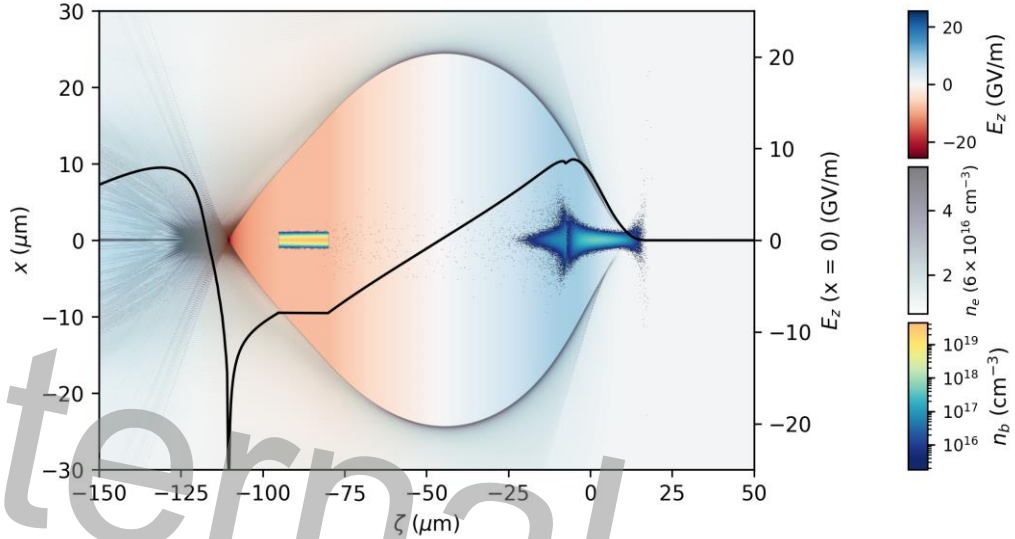
2019: Plasma dechirper, energy doubling of some electrons (1 → 2 GeV)

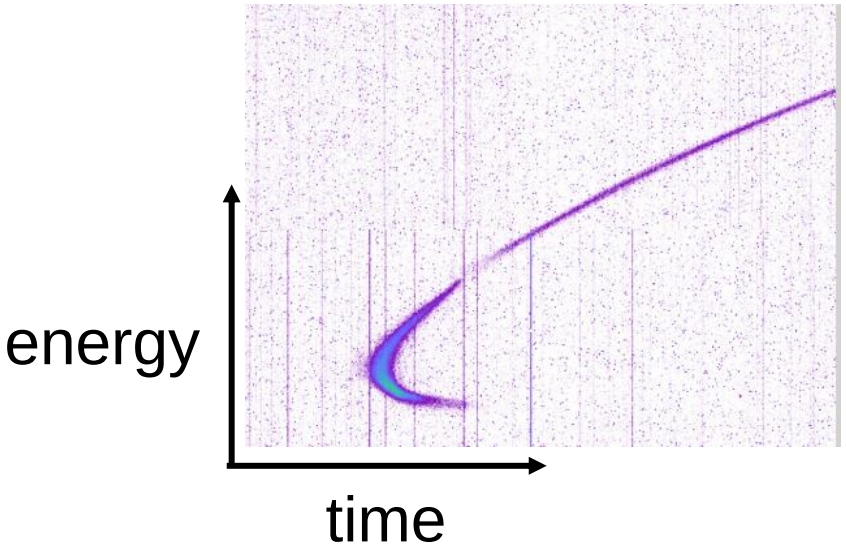


ELBEX – XFEL Forward

Initial studies towards an energy booster

- We have been performing a study of a plasma booster for EU-XFEL in the context of boosting the energies for SASE generation, particularly after the CW upgrade.
- Particle-in-cell simulations currently show acceleration from 17 to 31 GeV in 1.8 m of plasma.
- The energy spread remains low, while the emittance increases by ~ 30%. Mitigation strategies are being pursued.



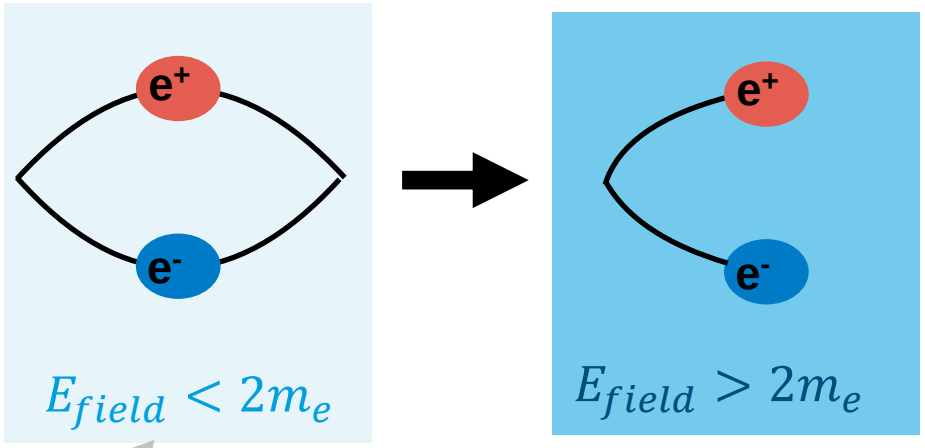


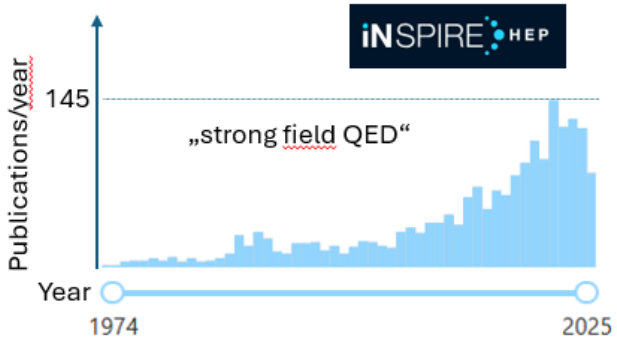
- Models have been developed to aid with the generation, shaping and control of suitable bunch pairs for plasma acceleration
- We performed beamtimes at XFEL showing that shaped bunch pairs can be generated at the photocathode, accelerated and transported to the TDS after the second bunch compressor.
- More work is needed to fully compress both bunches with the required temporal separation.

ELBEX – LUXE

Studying Strong-Field Quantum electrodynamics

- LUXE is an experiment to study Strong-Field Quantum electrodynamics (QED)
  - QED describes how light and matter and represents the quantum counterpart of classical electromagnetism
  - QED is one of the most well-tested theories in physics
  - Schwinger effect: creation of particles (e+e- pairs) from vacuum in constant field
    → unobservable: existing constant fields not strong enough
  - Use relativistic probe particles (e, γ) colliding with a laser beam→ fields $\mathcal{O}(\mathcal{E}\_cr$) in particle rest frame!



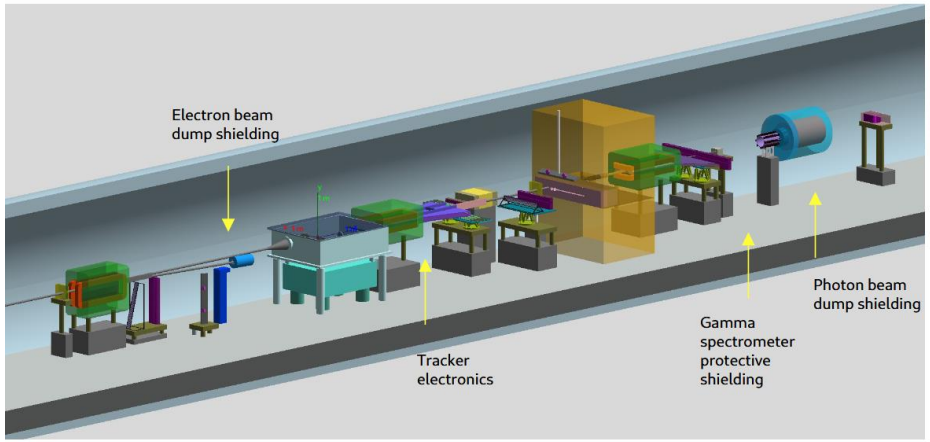


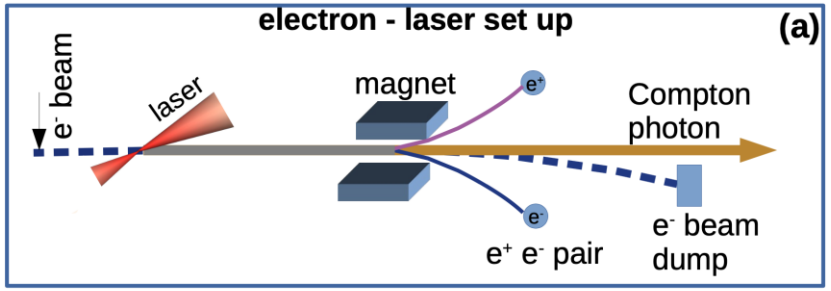
Strong field QED

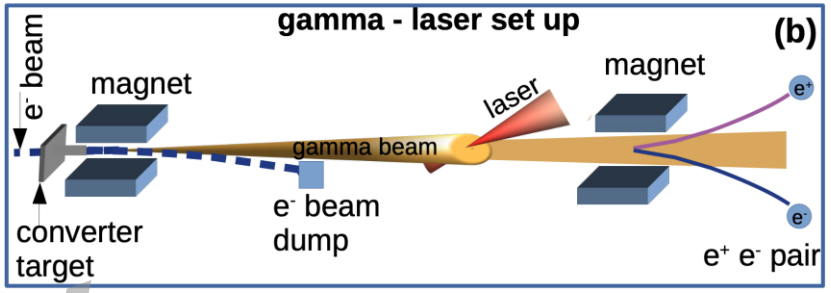
ELBEX – LUXE

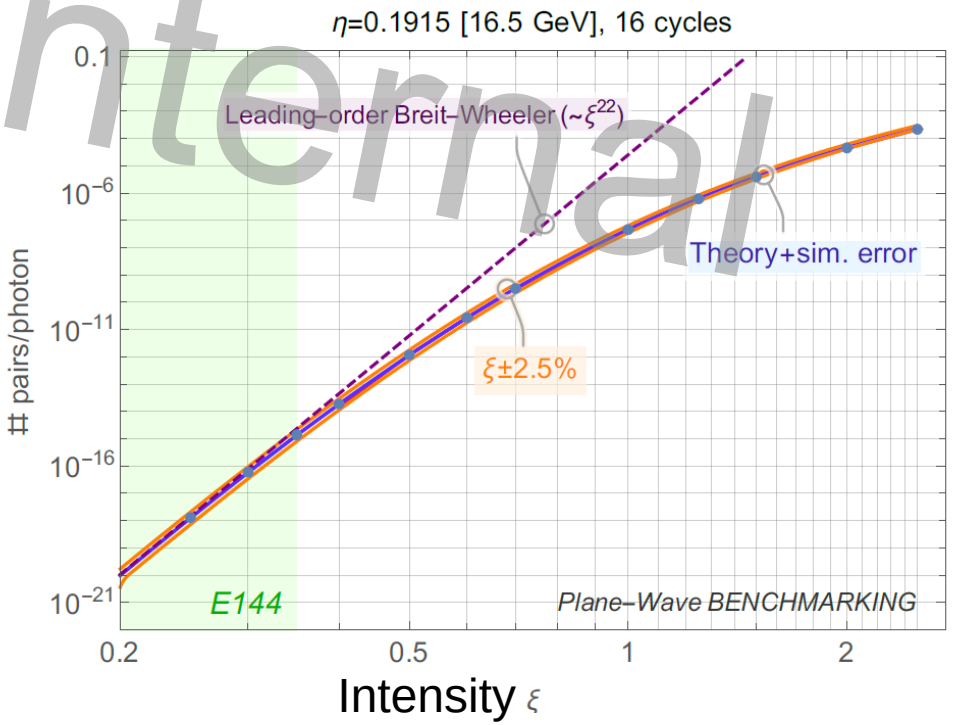
Studying Strong-Field Quantum electrodynamics

- LUXE is an experiment to study Strong-Field Quantum electrodynamics
  - Colliding a high-power laser TW/PW-class with an electron/photon beam
  - “Counting experiment“ – LUXE detector will measure rate of pair production – and more
- International Collaboration







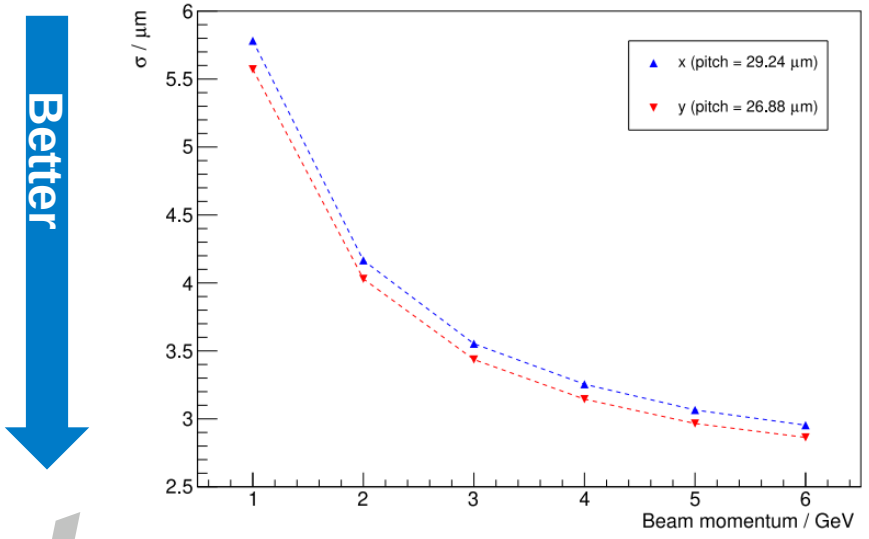


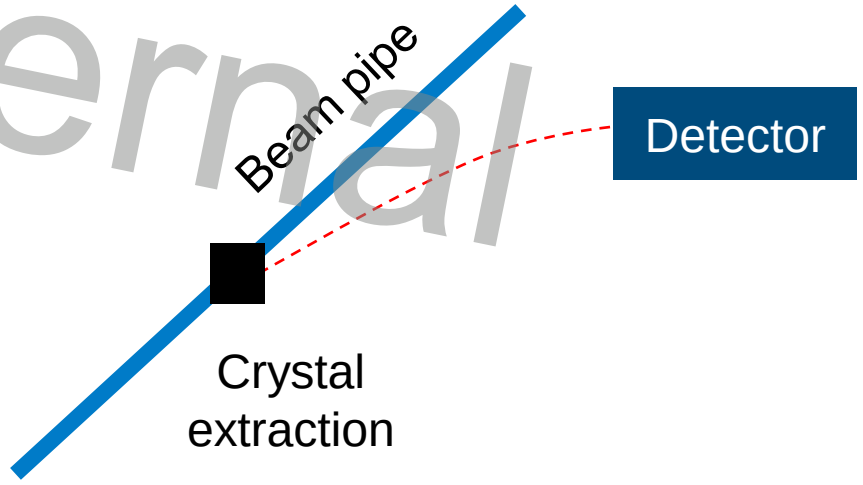
ELBEX – Test Beam

Unique additional test beam capabilities

- DESY has a very successful test beam program
  - 500 users/year +
  - Energy Range 1-6 GeV
- ELBEX would add additional capabilities by providing to low-rate but high-energy test beam
  - Complementary to the DESY II Test beam Facility
  - Test Bed for performing crystal extraction of particle beam
  - Future CW mode of XFEL would offer additional capabilities

Particle Track Resolution

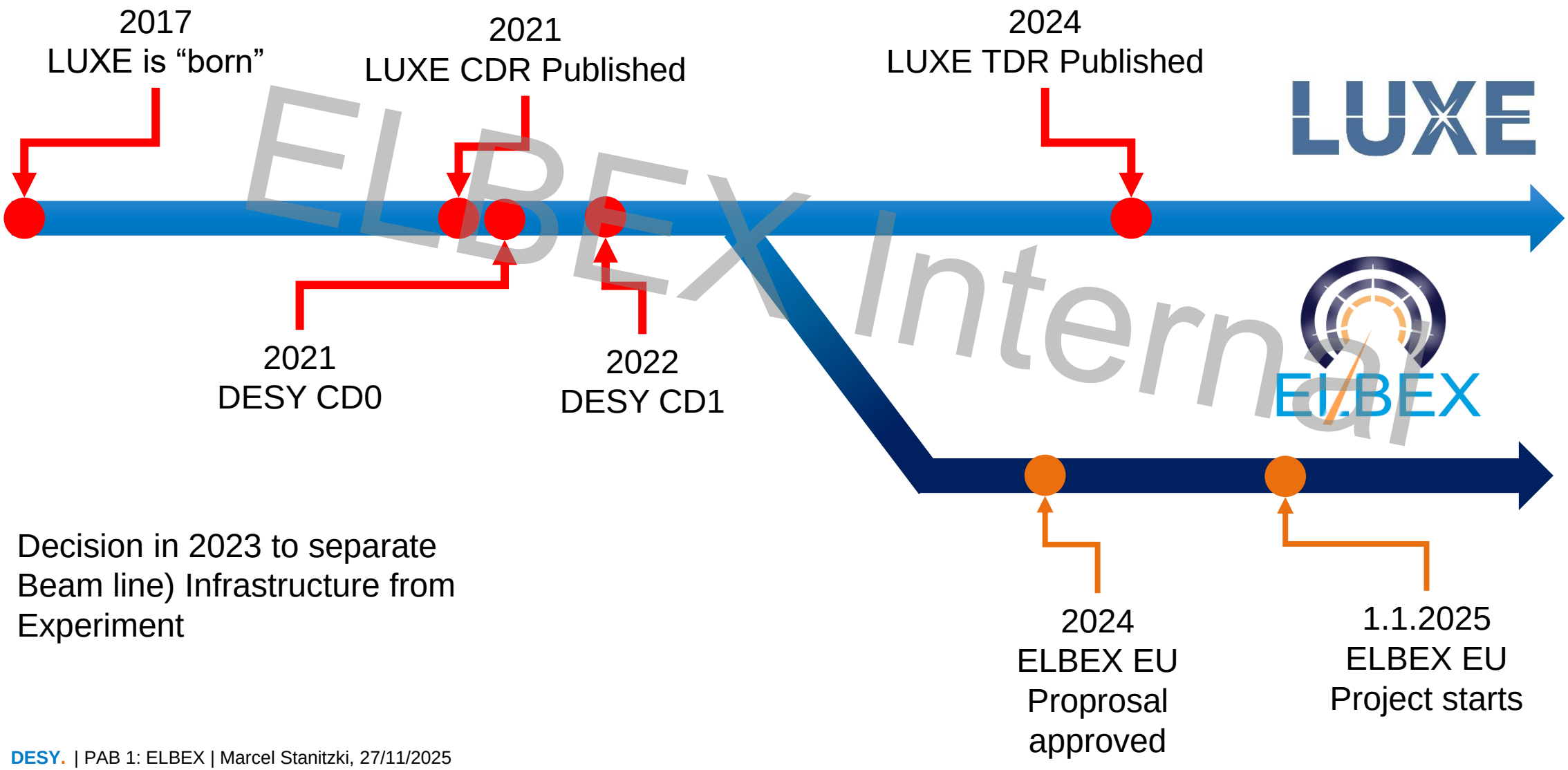




ELBEX Project history

ELBEX – LUXE relations

Starting from 2017



Decision in 2023 to separate Beam line) Infrastructure from Experiment

ELBEX – Consortium

Start point 1.1.2025

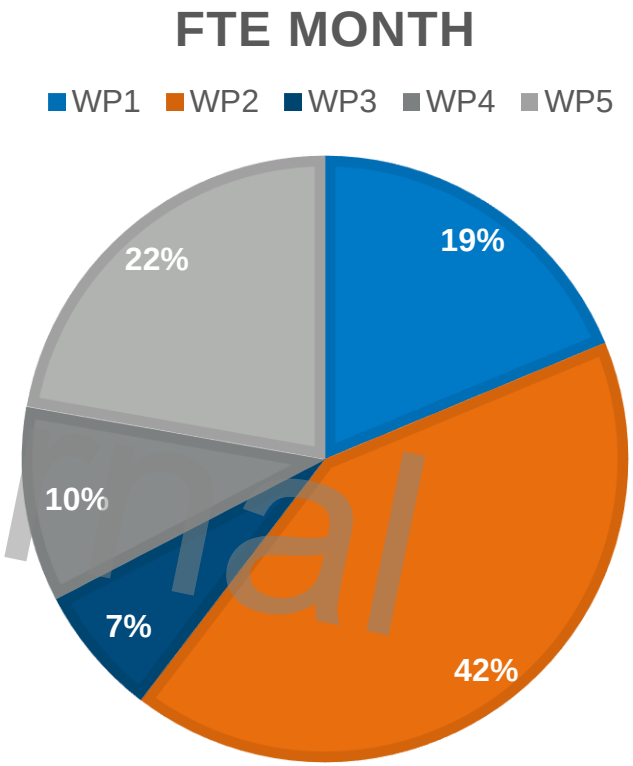
- Five Institutes
  - DESY Coordinating Institute
- Total EU-Grant
  - 4.2 Million
- Start of project : 1.1.2025
- Duration:4 years
- Scope :
  - Preparing the installation of the ELBEX beamline with LUXE as main users, maintain the possibility for plasma and test beam setup.
  - Develop the beamline design, prepare the installation (including sourcing the necessary hardware components) ..
    ;;;

ELBEX – EU Project

Work package Structure

ELBEX

WP1	WP2	WP3	WP4	WP5
Beam extraction line	Beam transfer line	Beam dumps	Service Infrastructure	Coordination
DESY	Manchester	INFN	EuXFEL	DESY

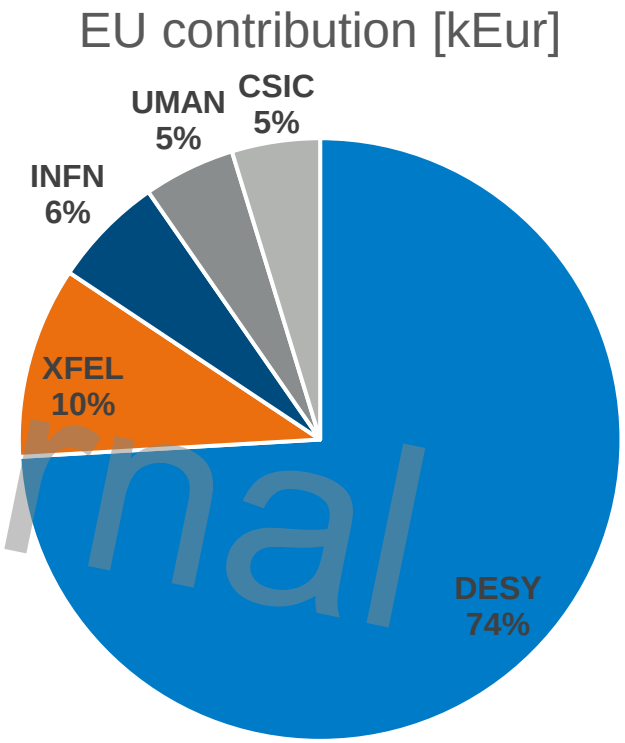


ELBEX – EU Project

Work package Structure

ELBEX

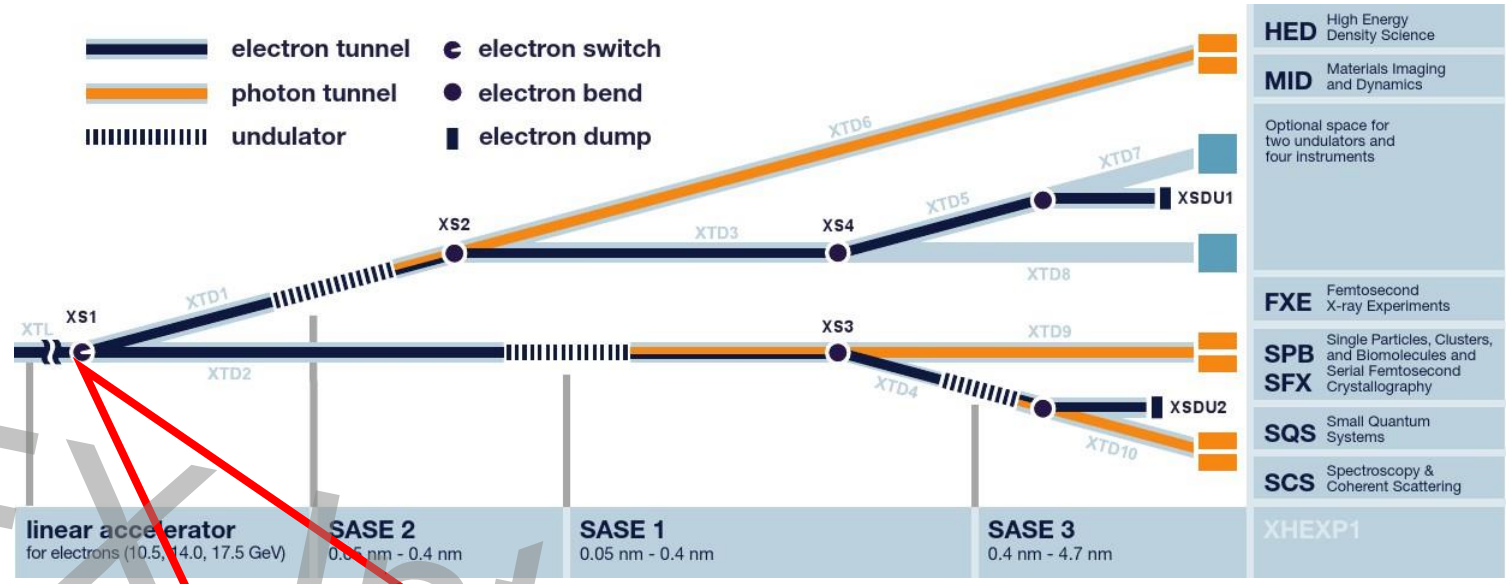
WP1	WP2	WP3	WP4	WP5
Beam extraction line DESY	Beam transfer line Manchester	Beam dumps INFN	Service Infrastructure EuXFEL	Coordination DESY

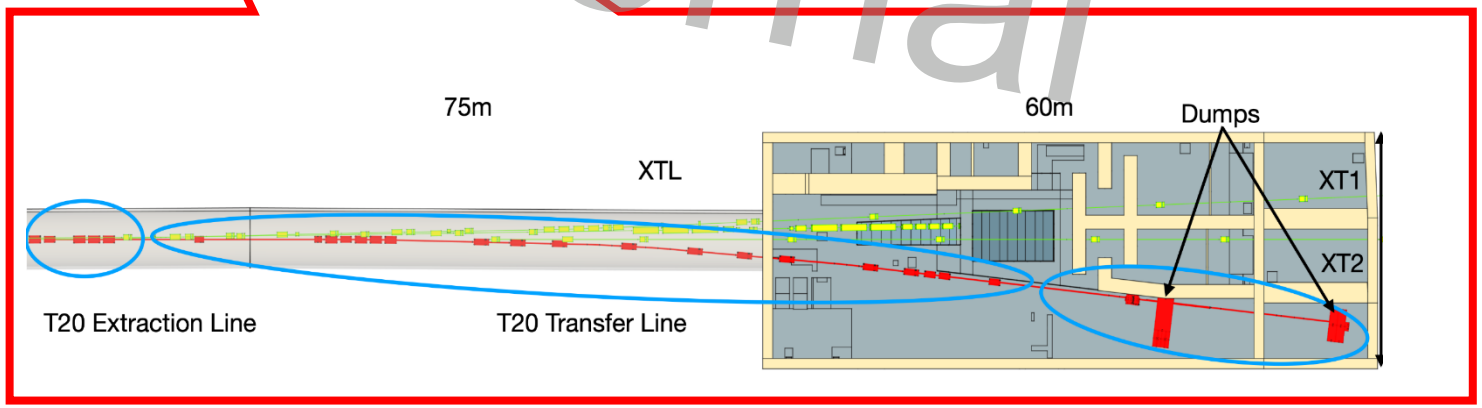


ELBEX - XS1 Location

Original location of ELBEX

- Since the LUXE CDR proposed location of LUXE
- Significant effort in preparing a design
  - Extraction
  - LUXE detector integration
  - Location of laser and services
- Full project schedule
- Vetted resource planning



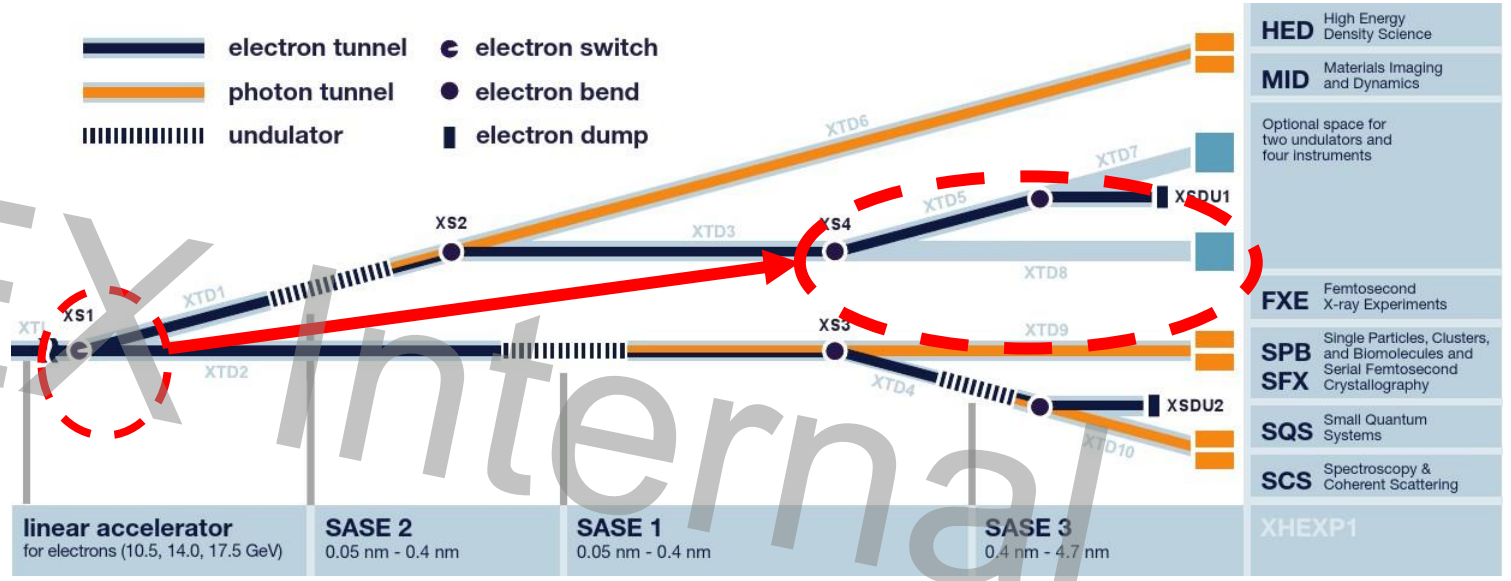


ELBEX Current status

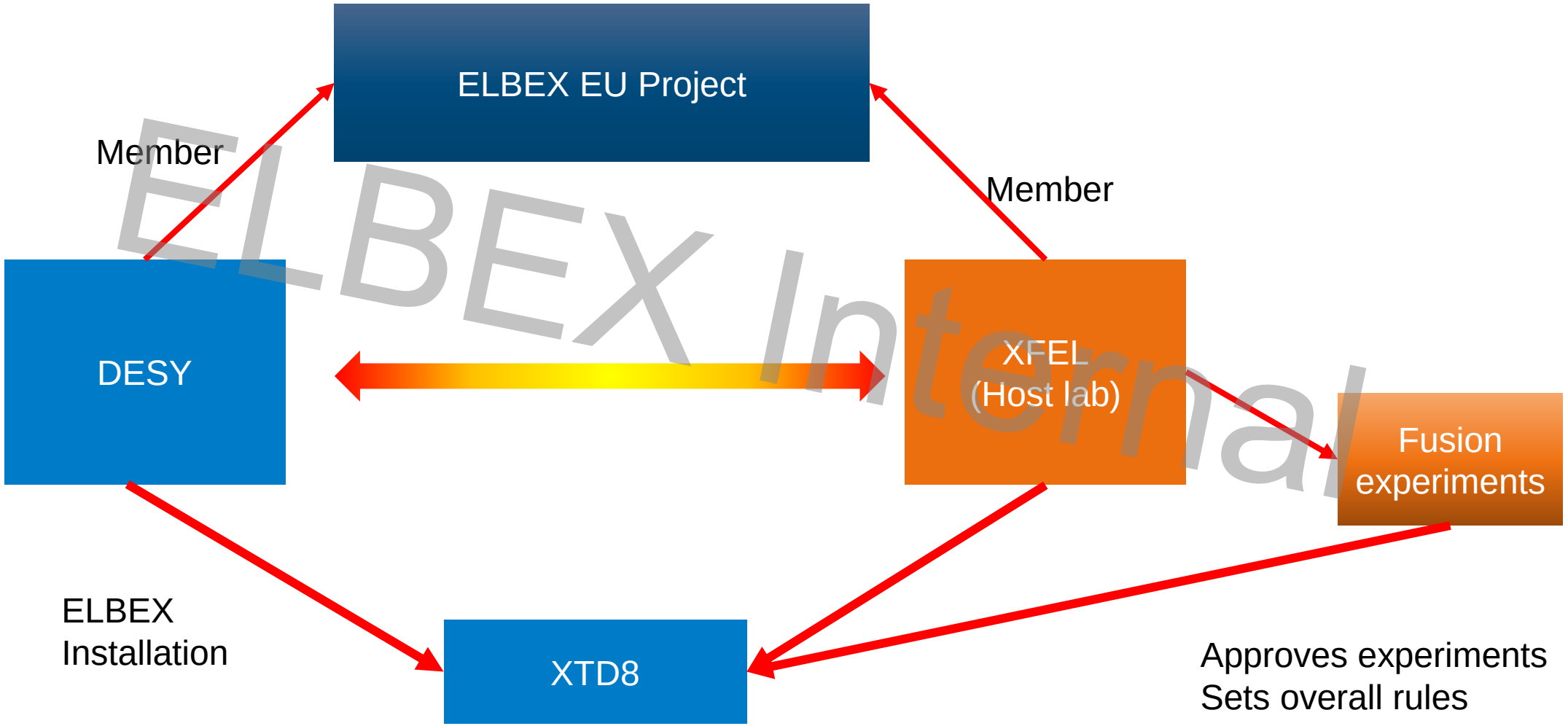
ELBEX – Recent developments

Since the start of the EU-ELBEX project

- **1.1.2025:** Project starts
  - Location of ELBEX is XS1
- **February/March 2025:** Discussions with XFEL to move ELBEX to a different location in the fan.
- **April 2025:** Decision to do a feasibility study for ELBEX location from XS1 to XTD8
  - Co-sharing of XTD8 with new Fusion program at XFEL
- Complete Reset of ELBEX Project
  - New Location, new beam line …



ELBEX – DESY – XFEL relations



ELBEX XTD8 overview

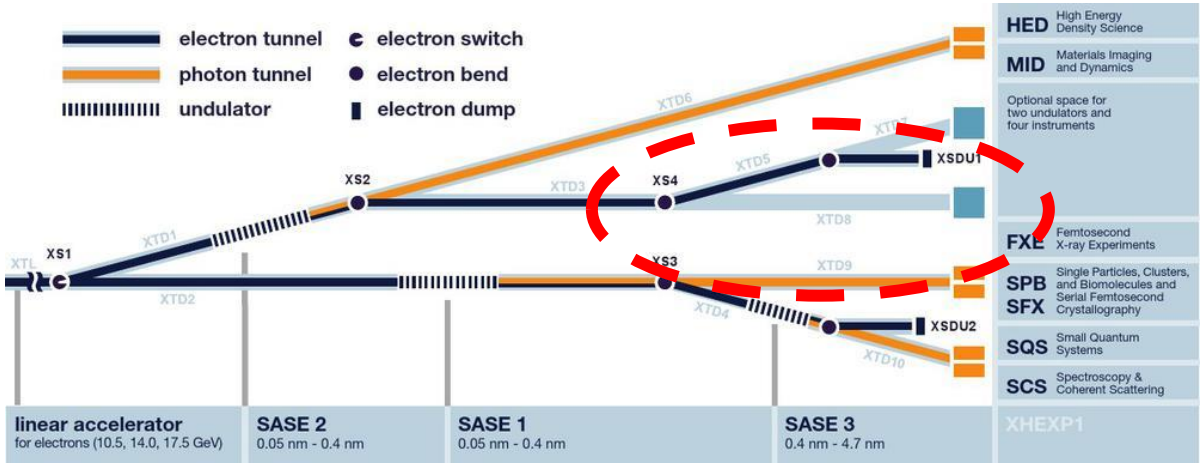
New site for ELBEX:

- Opportunity: ELBEX in XTD8 tunnel, co-use with planned EuXFEL fusion facility
  - Plans for fusion project still developing

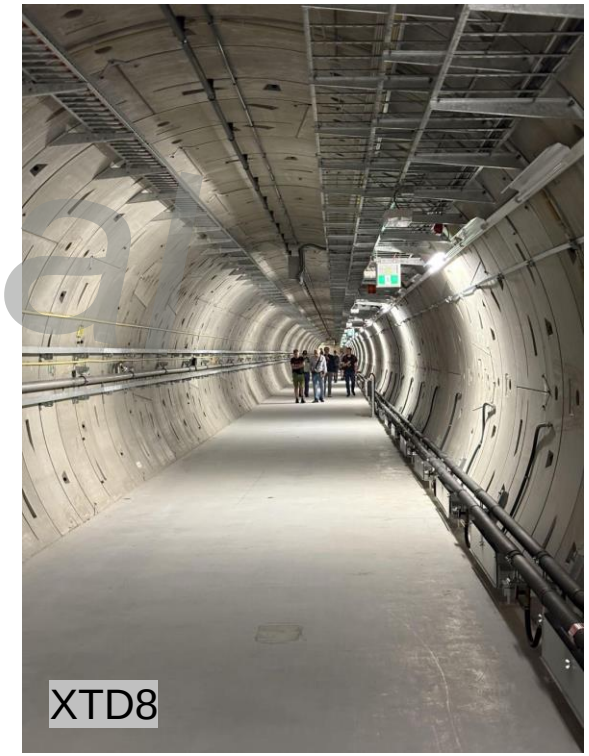
    → closely coordinating with EuXFEL
  - So far XTD8 has been unused
  - XTD8 comes with many advantages

ELBEX beam parameters

- 50 bunches , max 40 GeV beam energy

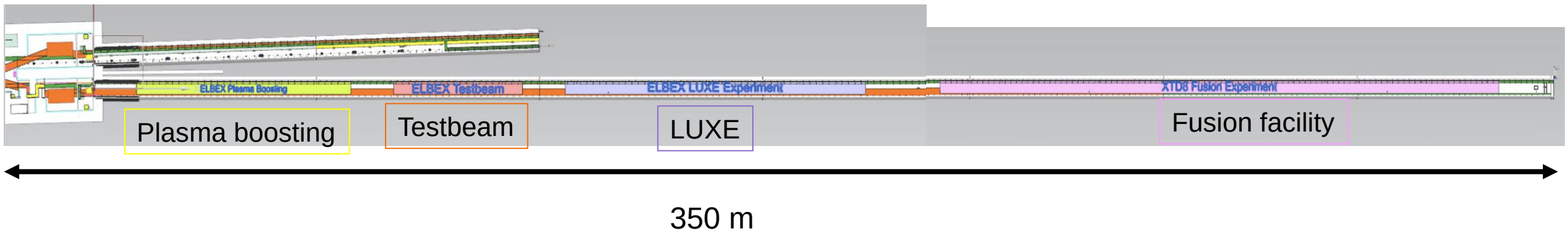



XTD3 near ELBEX branch-off

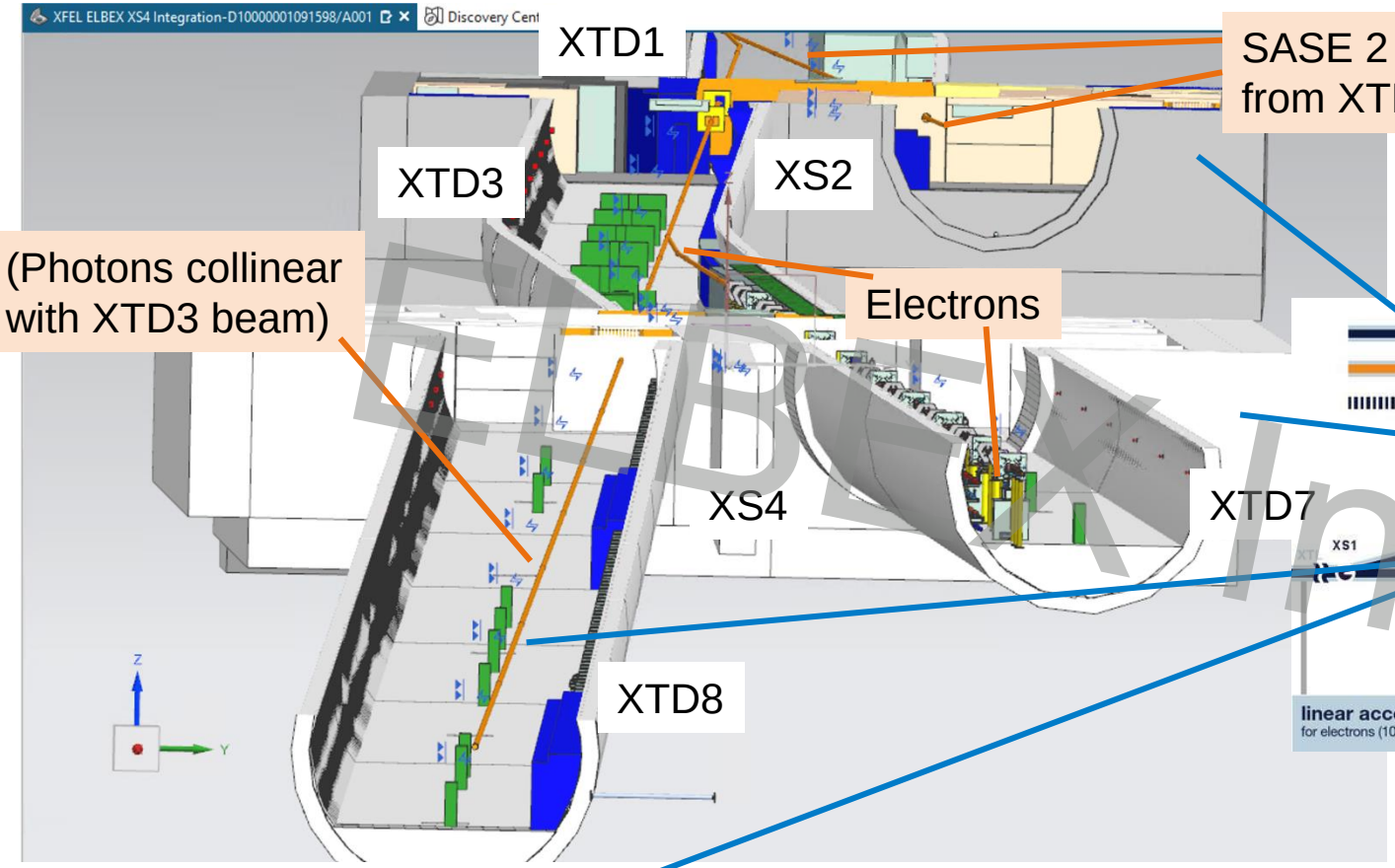

XTD8

ELBEX XTD8 Advantages

- A lot more longitudinal space is available – 350 m in total, 4.5 m Tunnel diameter
- No extended shutdown required for installation like in XS1, a normal winter shutdown should be sufficient
- Installation of ELBEX decoupled for normal XFEL operation
- Access to XTD8 doesn't require shutdown of the entire XFEL, essential for commissioning experiments



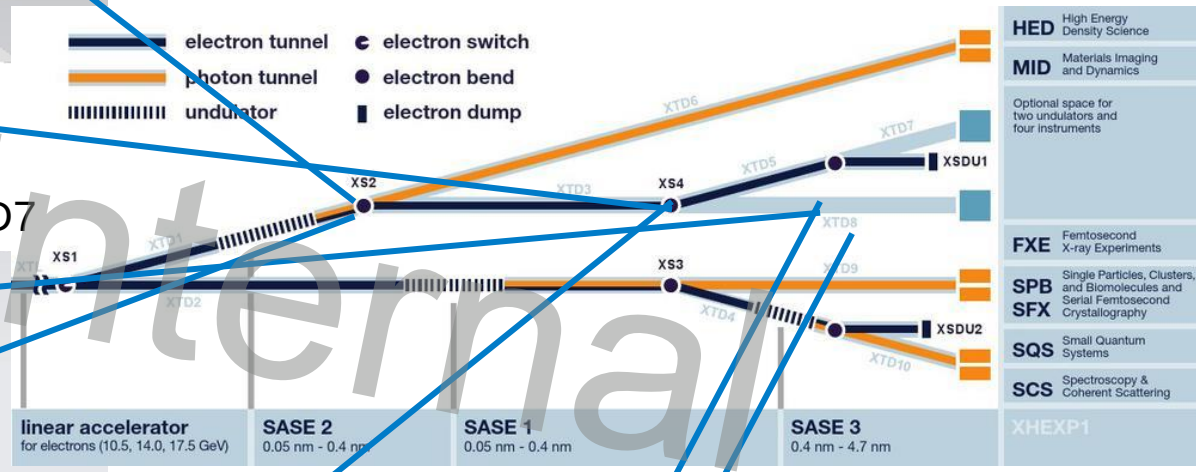
ELBEX - Overview

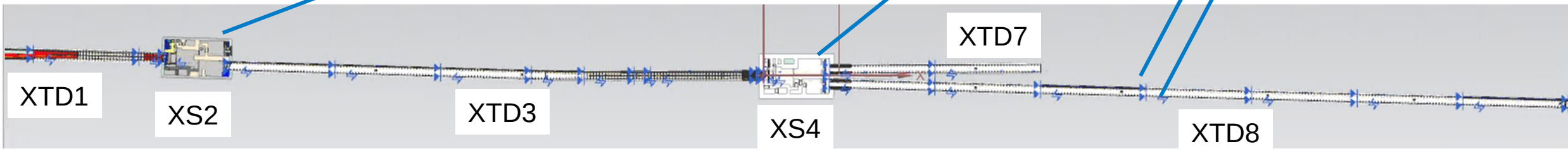


SASE 2 photons from XTD1

(Photons collinear with XTD3 beam)

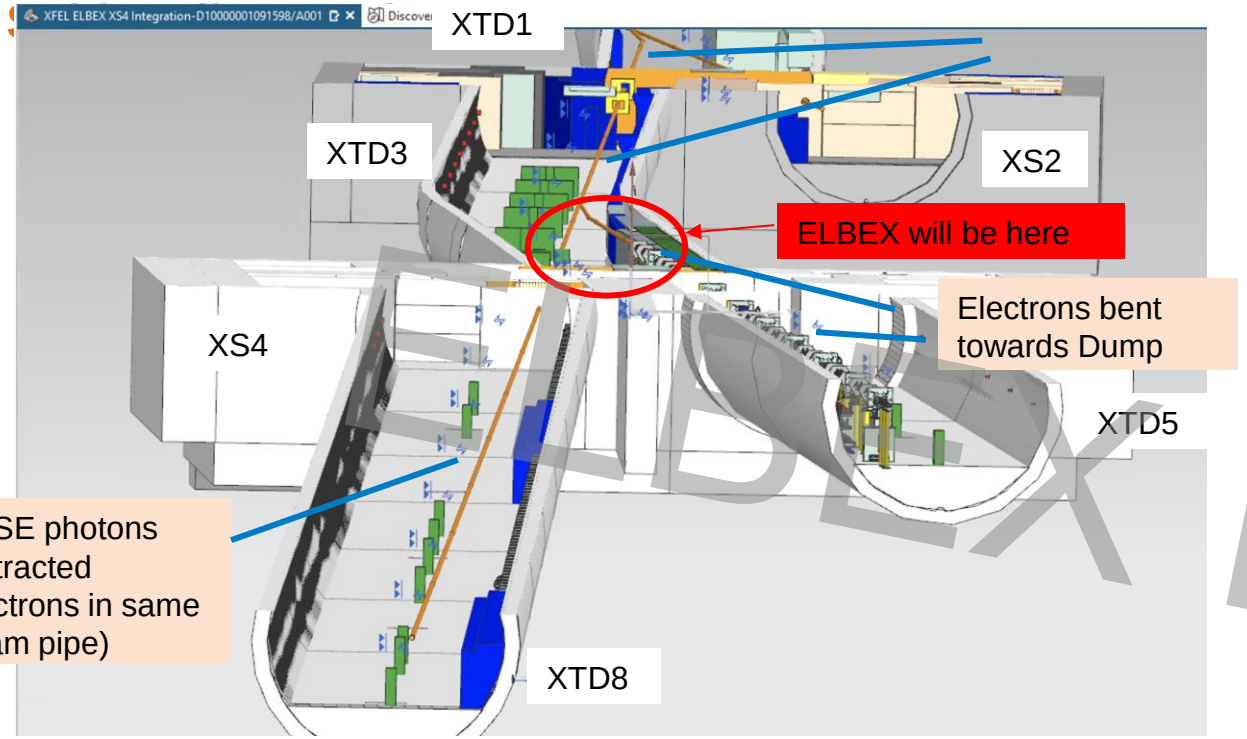
Electrons

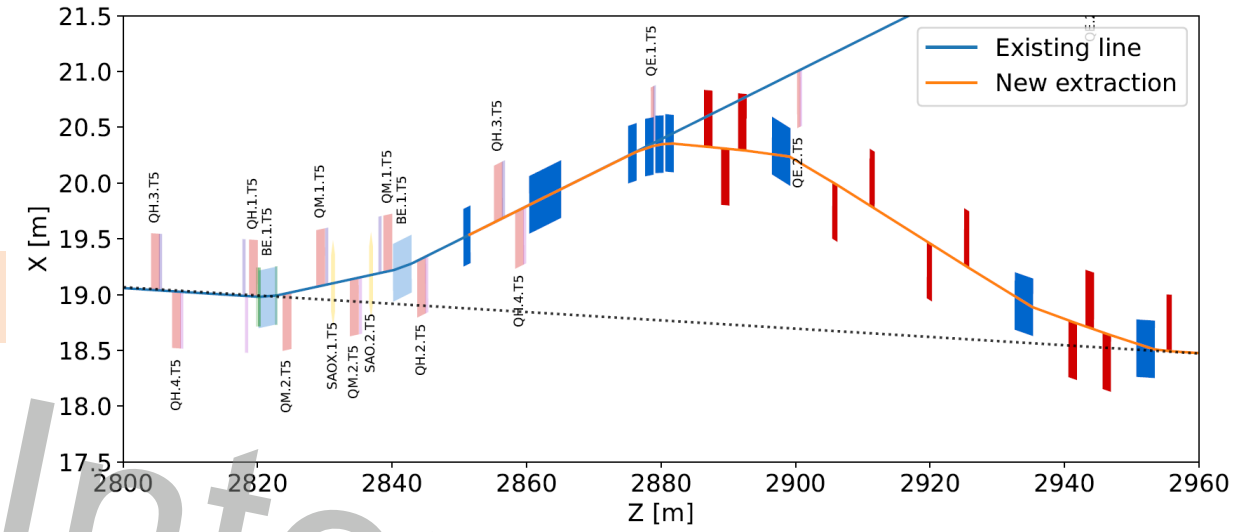




ELBEX extraction beamline design

Stewart Boogert, Marin Deniaud
(University of Manchester)

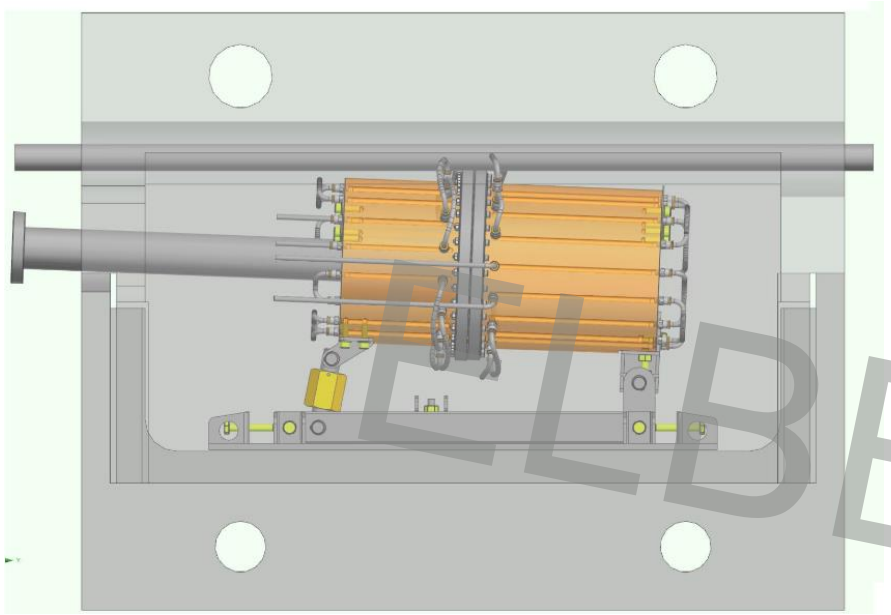


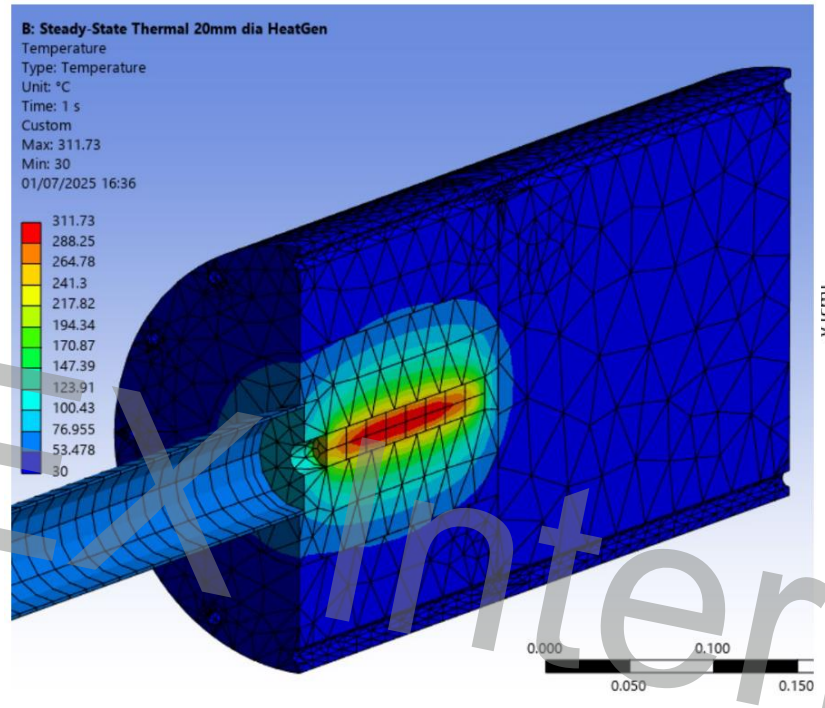


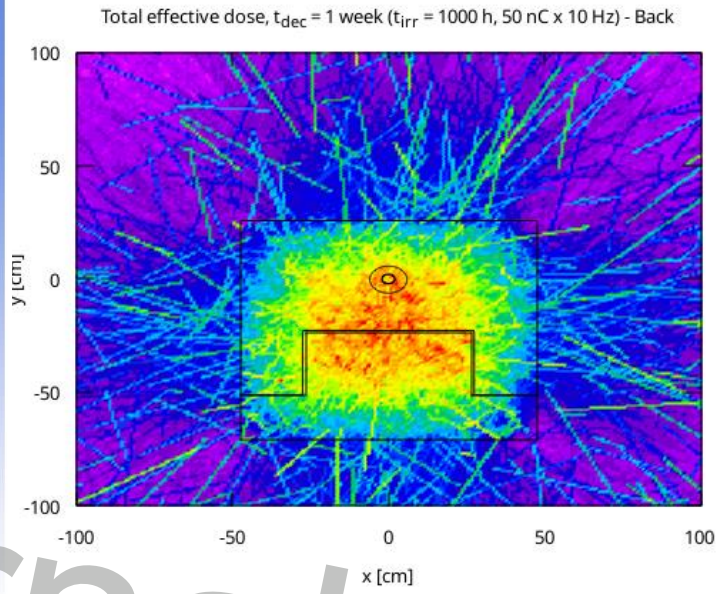
- Challenge: ELBEX electrons share beam pipe with SASE2 x-rays from mirror at XTD1 to fusion area
  → ELBEX extraction beamline: dogleg double bend from XTD3 into XTD8
- Matched lattice design achieved, optimization ongoing
  → goal: 10 µm spot size at IP

ELBEX final dump design and simulation

S. Vasiukov (INFN Padova)
M. Benettoni (INFN Padova)



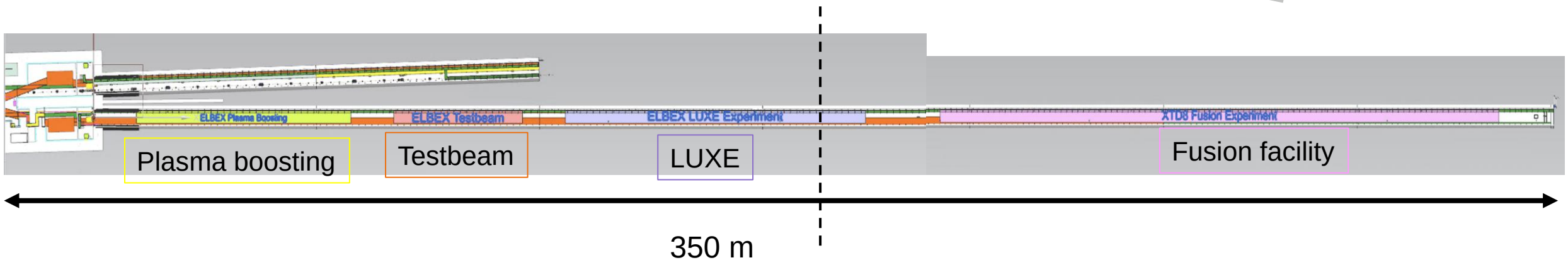




- Mechanical design of ELBEX final dump, based on LUXE electron dump design, consulted with MIN
- Compared to LUXE dump: higher energies (<40 GeV) and larger number of bunches (O(50)) (Plasma boosting)
- FLUKA simulation in place at INFN and FLUKA setup validated with DESY D3

ELBEX – Interplay with Fusion experiments

- Sharing of longitudinal space still needs to be agreed 50:50 is mere working hypothesis
- Transport paths in XTD8: Access to the tunnel for larger components is possible only through XS4
- Vacuum system modifications to existing electron beamline in XTD3: The modifications to the existing accelerator vacuum system in XTD3 (initial branch-out of x-ray beam tube and ELBEX extraction line) should be done at the same time.
- Common beam pipe for electrons and photons has consequences for the ELBEX design.
- Operation concept and radiation protection: The ELBEX operation and radiation/general safety concept is connected with the operation mode of the Fusion facility.
- Many of these issues need the host lab – EuXFEL – to define the rules of engagement



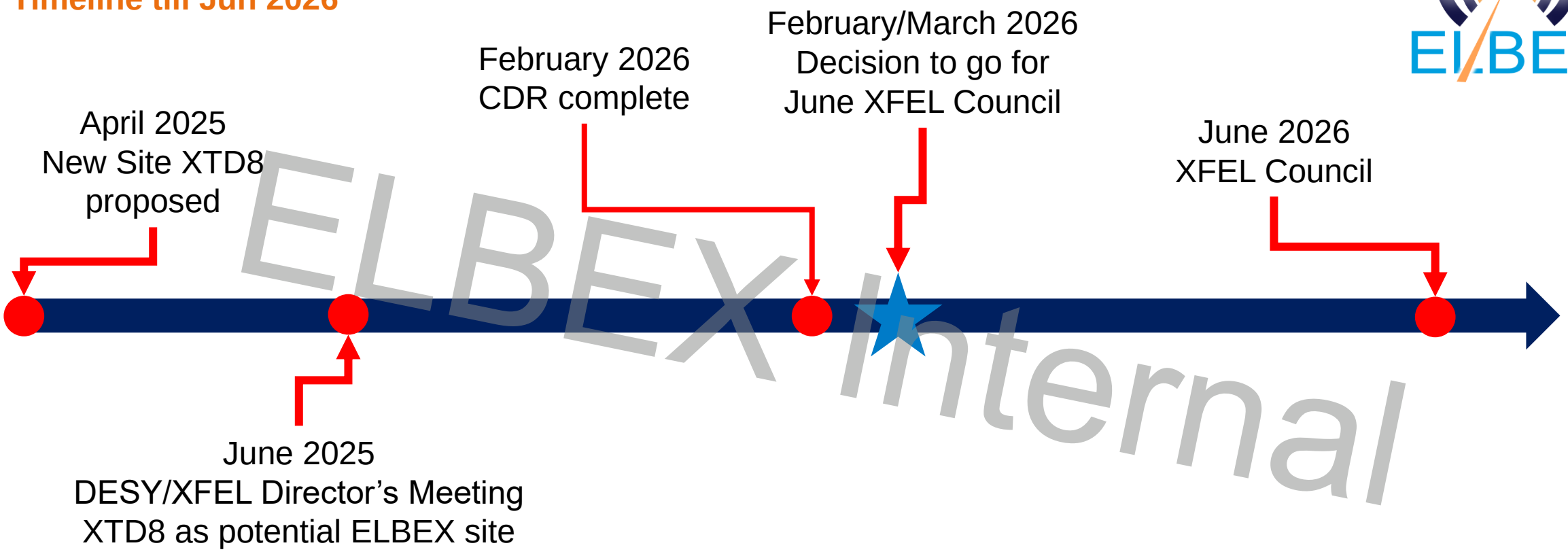
ELBEX – General Safety Concept

Incorporate Safety already in the CDR phase

- General XFEL Tunnel Safety – Proven concept
- Interlocks – Proven concept
- Radiation Safety - Primary beam user area – New for XFEL
  - Person safety – controlled areas, access schemes
  - Activation issues (Air, Ground water, soil)
  - Depends on external constraints
  - Needs work, but simulation machinery is in place
- ELBEX experiment specific risks
  - Currently nothing worrisome (magnets, HV) – need to get more input from potential user experiments

ELBEX – Next Steps

Timeline till Jun 2026



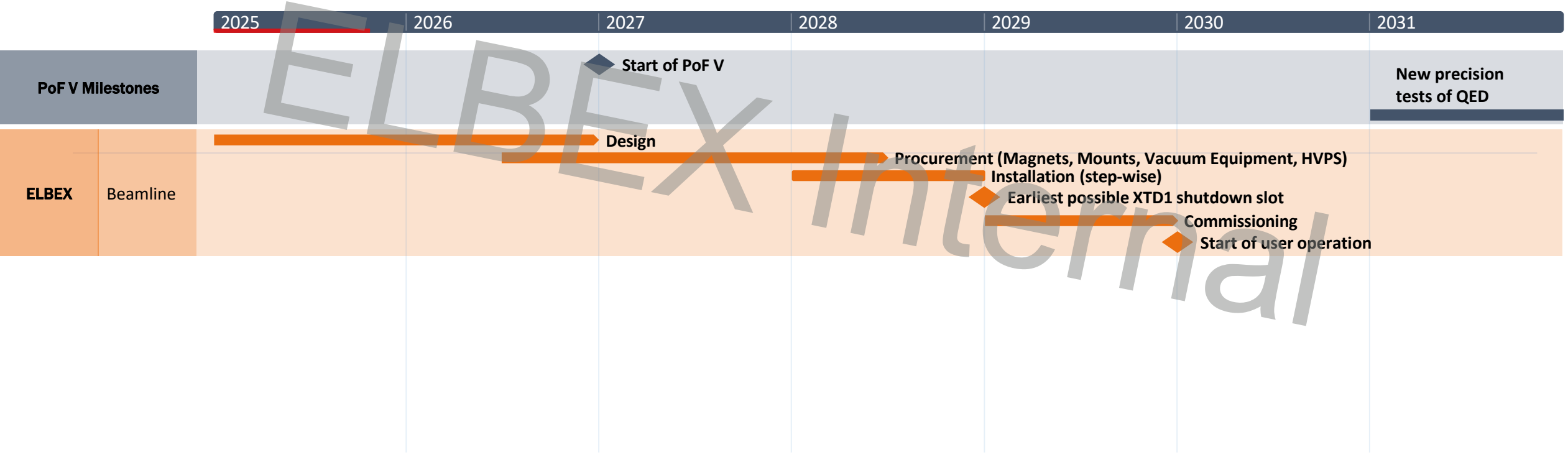
ELBEX – The February 2026 Milestone

Crucial moment for ELBEX

- We need approval in Jun 2026 to really move ahead
- Any further delay would impact ELBEX significantly
  - Starting to interfere with PETRA IV preparation & construction
  - Re-scoping of EU project
- Hence February/March an agreement with XFEL management is required
  - This will then trigger a few more preparatory actions, so we could place orders quickly after the approval

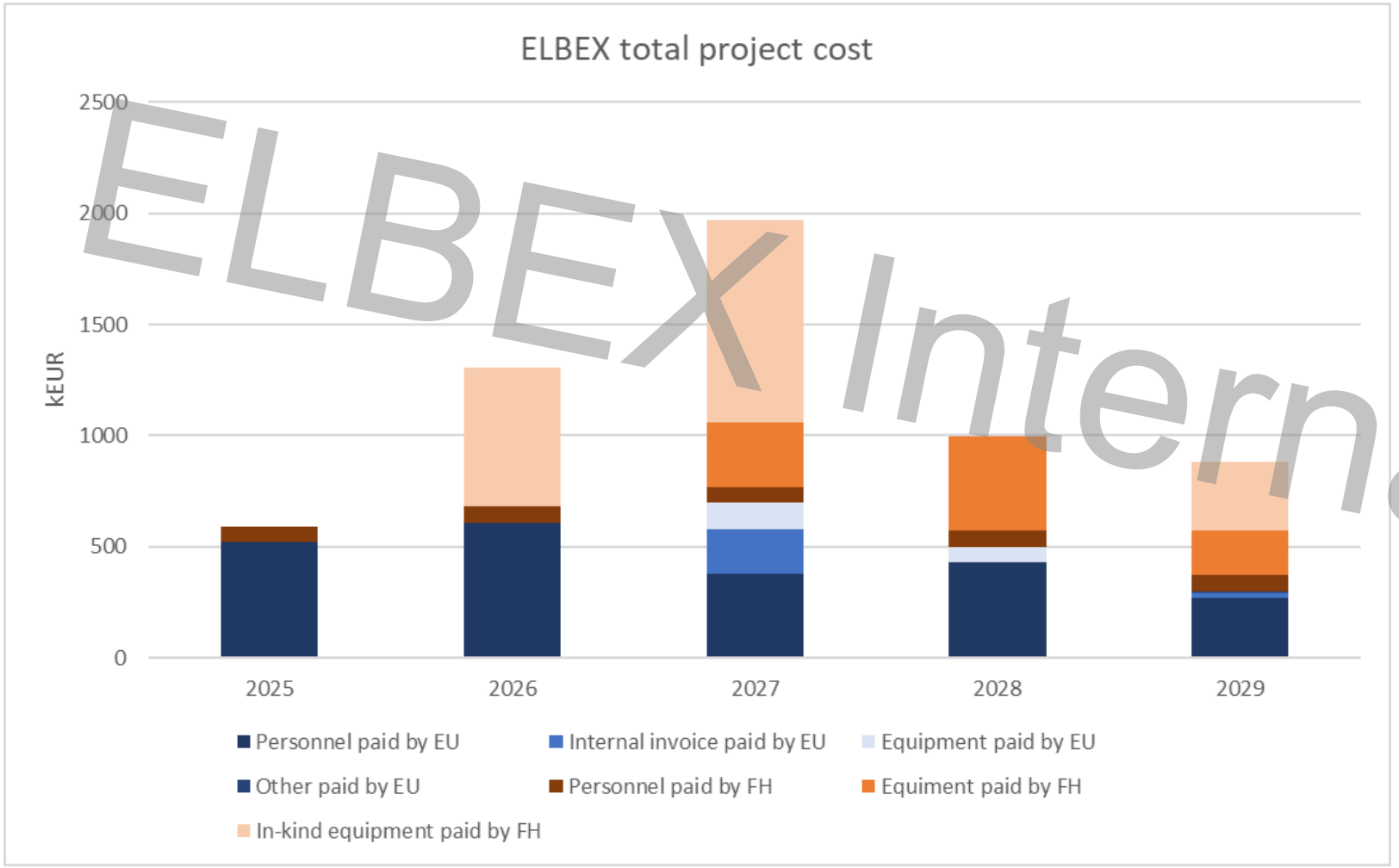
Detailed Technically Driven Schedule

As presented to the EU and during PoF



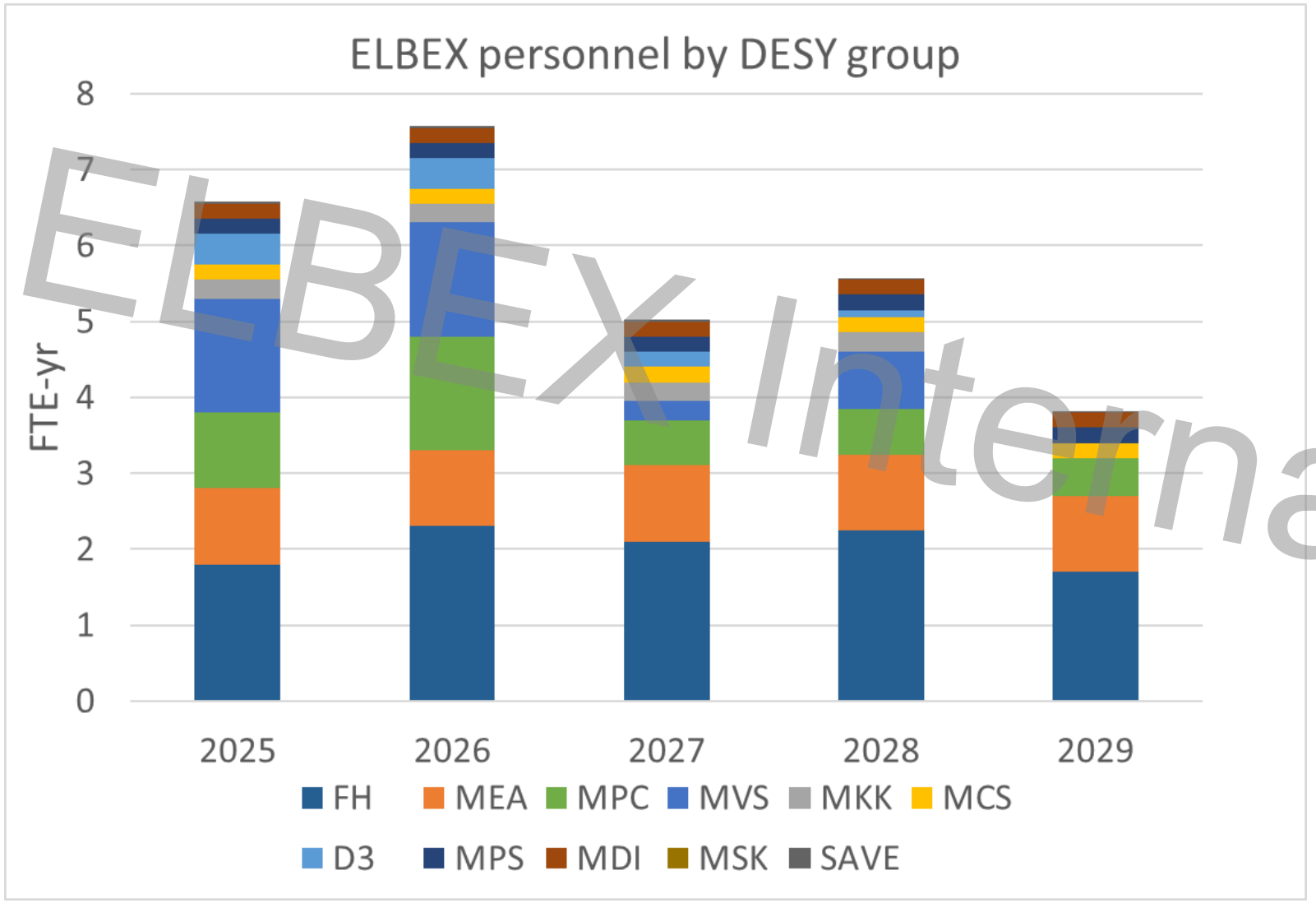
ELBEX – Total Budget

For the XS1 location - to be updated for XTD8



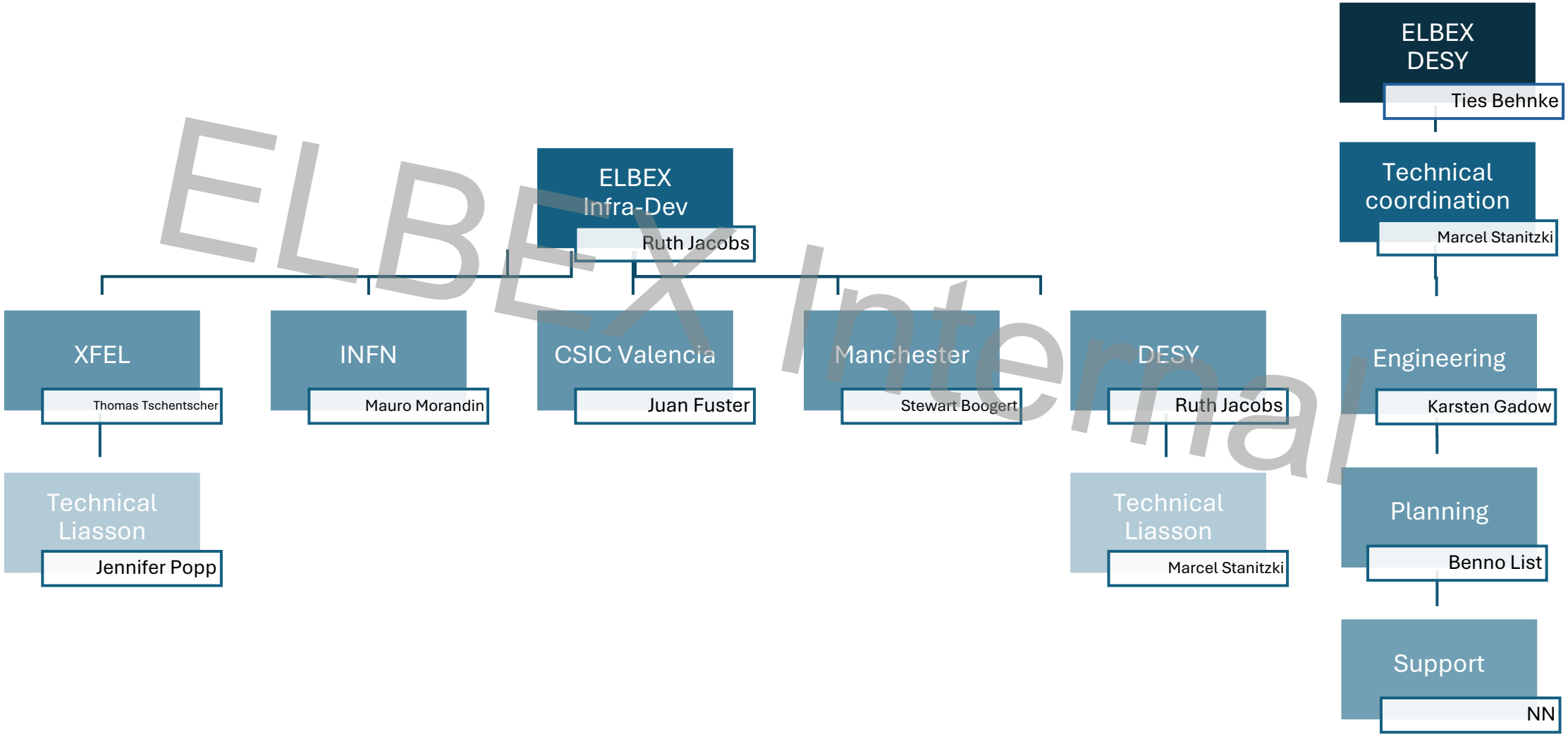
ELBEX – EU-Funded Resources

For the XS1 location - to be updated for XTD8



ELBEX – Organigram

CRD-Phase - Status November 2025



ELBEX – Risk register

Both internal and external high-impact risks

Risk	Probability	Impact	Risk type	Mitigation	Comment
Interference with PETRA IV Schedule	Low	medium	External	None	Biggest impact would be if PETRA IV schedule would move ahead in time
Delay of other projects, that could impact ELBEX schedule	medium	high	External	None	If EuXFEL Fusion project gets further delayed, it will have impact on ELBEX
Delays in the approval of ELBEX by DESY & EuXFEL	high	high	External	None	This is our biggest worry at the moment
Delays due to the DESY Base Budget Situation	high	medium	External	Stretching expenditure	The XTD8 location simplifies a longer installation time
Radiation Safety – Doses too high	Low	high	internal	Reducing number of bunches	Simulation effort ongoing

We have not yet identified any technical risk in XTD8, that is a real show-stopper, but a complete risk register will be part of the CDR

ELBEX –Points for the PAB

Given the February 2026 Milestone

- Without an final agreement between DESY and EuXFEL directorates ELBEX cannot proceed
- EuXFEL needs to set overall rules of engagement in XTD8
  - Without this we can advance ELBEX only to a certain extent
- Access to M resources
  - Until a green light from XFEL Council we‘d request – besides advice – modest support from MEA to prepare the Magnet order from February 2026 onwards

Backup