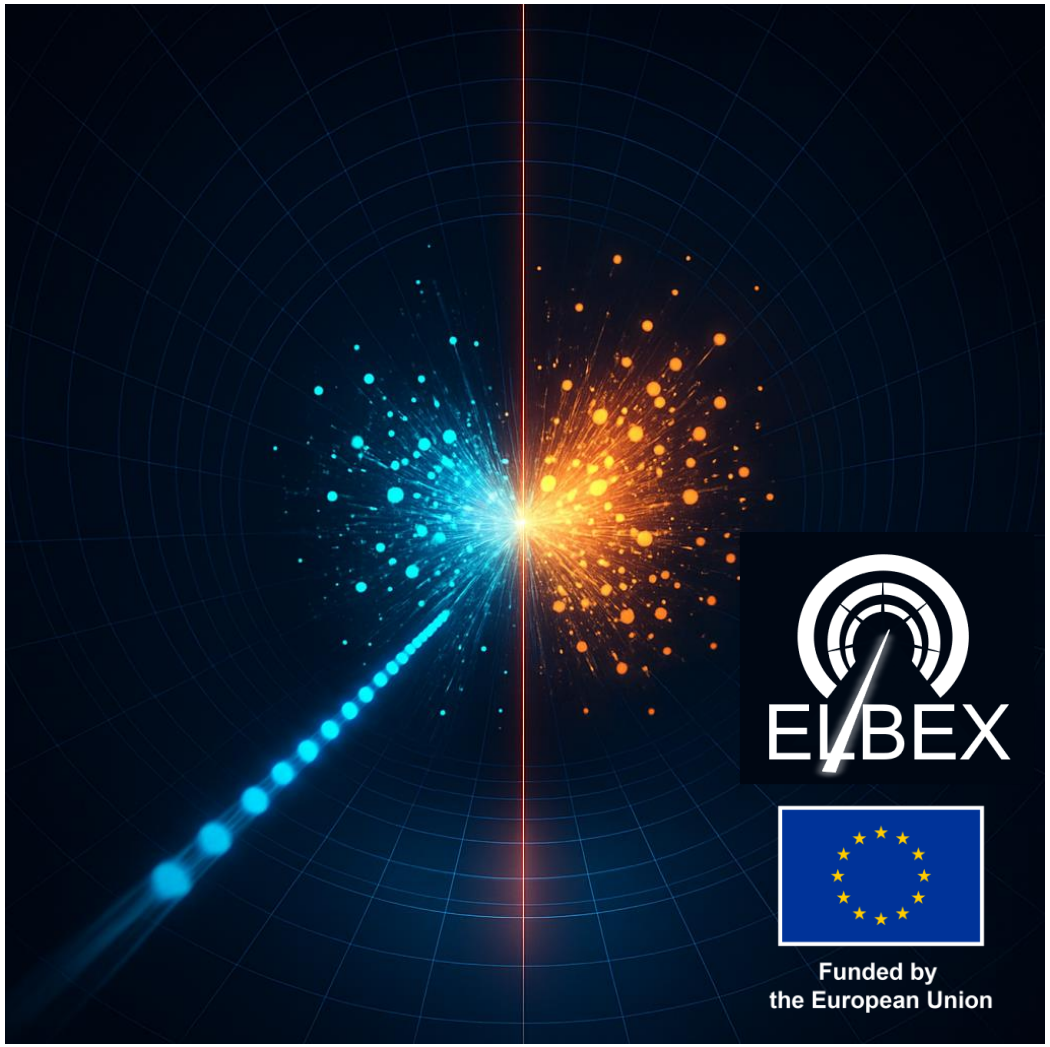
ELBEX

Marcel Stanitzki

PAB 27.11.2025



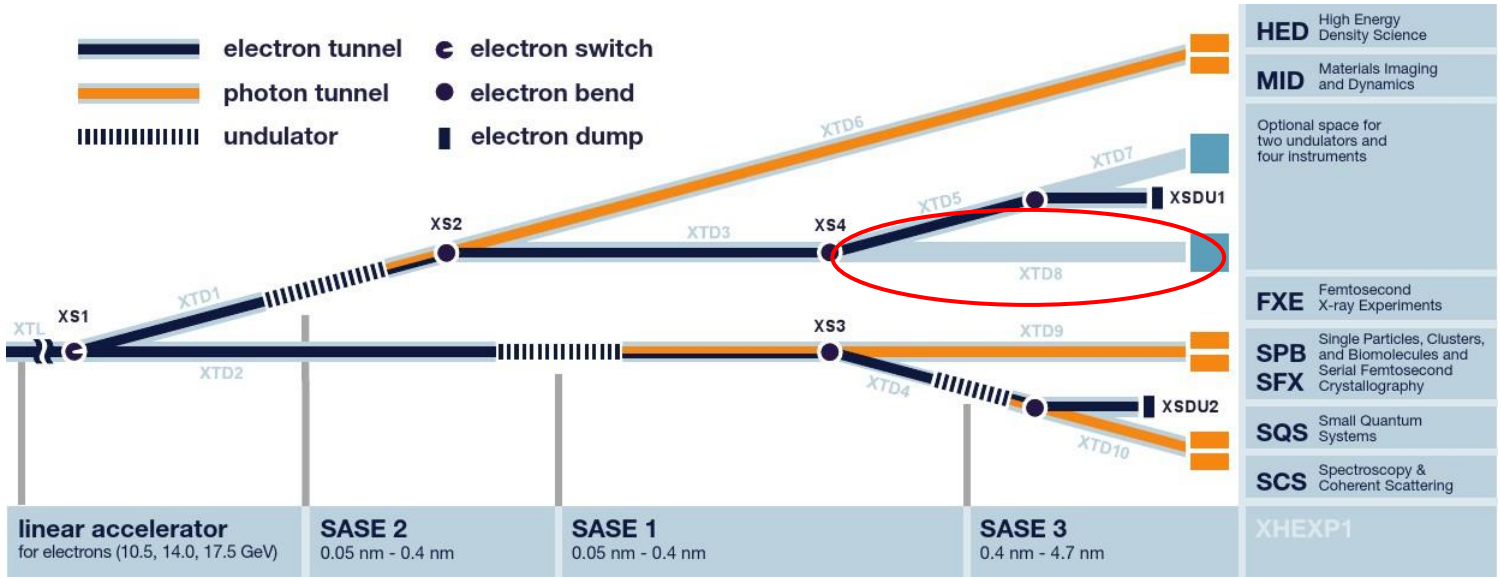
HELMHOLTZ

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

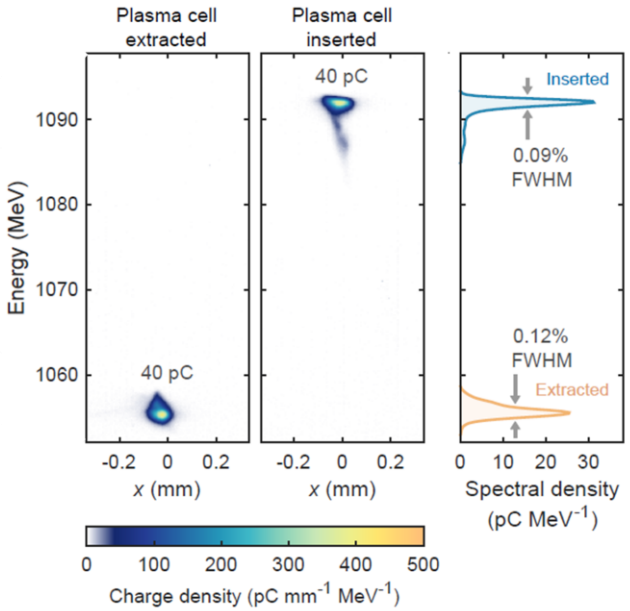
ELBEX – Science Case

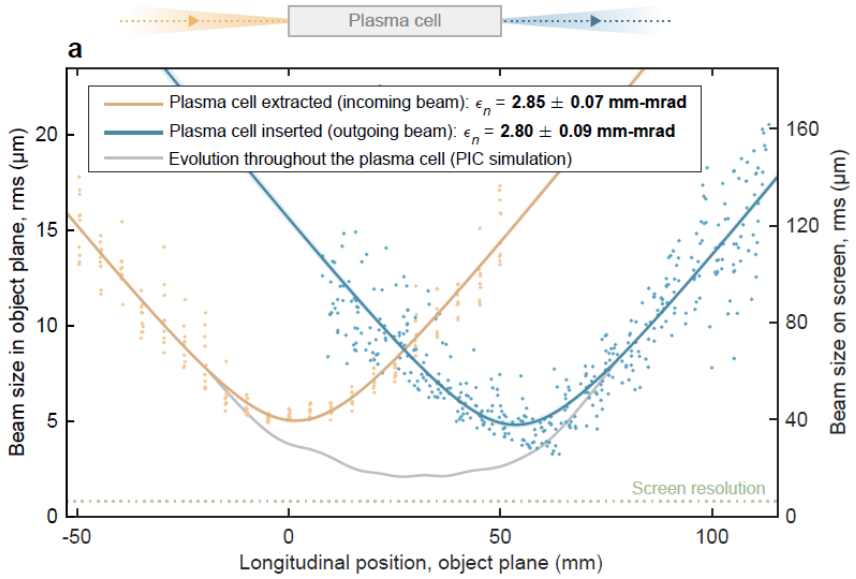
Three pillars

- 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

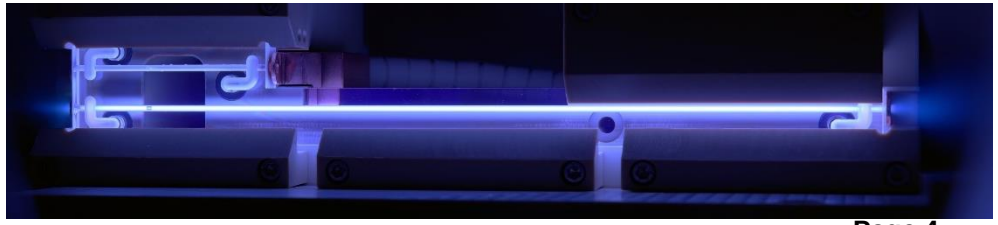
2023: Demonstration of MHz rep-rate plasma acceleration

2022: GHz plasma response

2021: Energy spread preservation

2020: Sampling of the accelerating field of the plasma wake

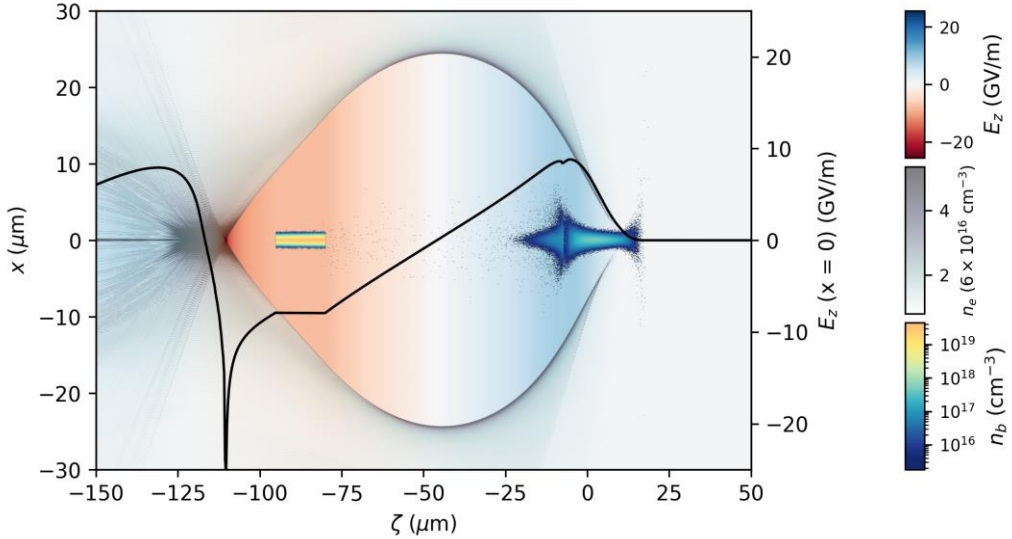
2019: Plasma dechirper, energy doubling of some electrons (1 → 2 GeV)

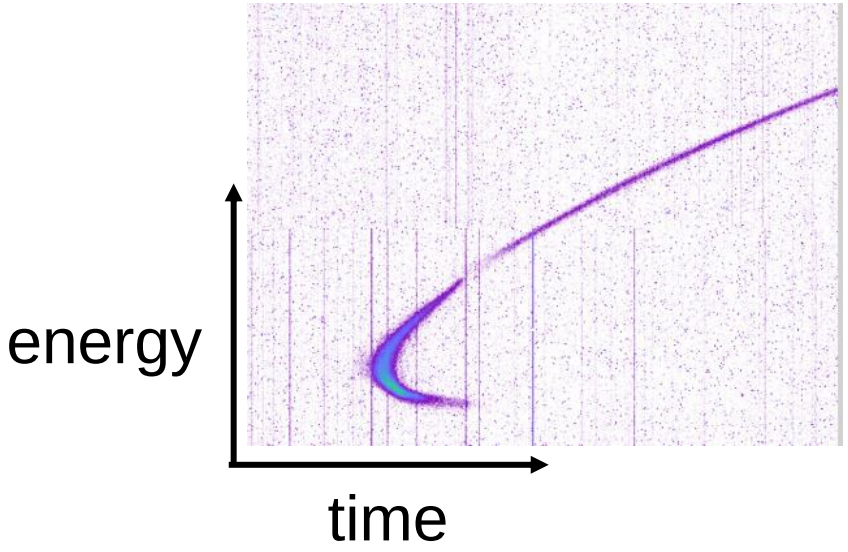


ELBEX – XFEL Forward

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.



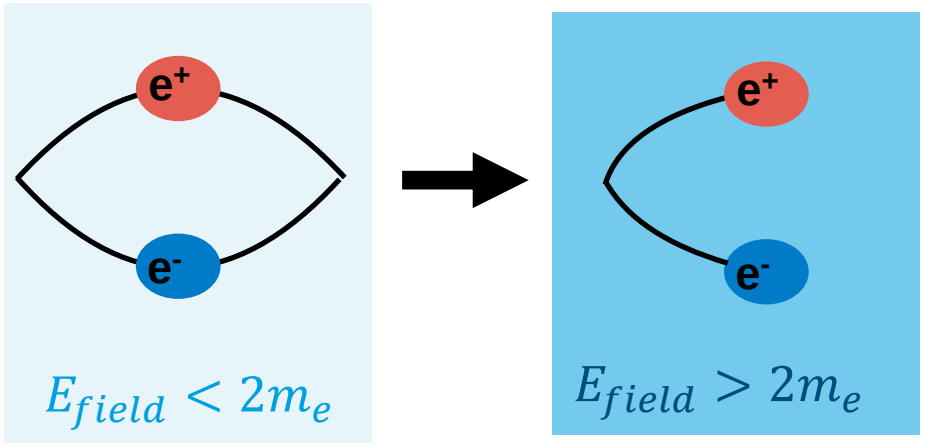


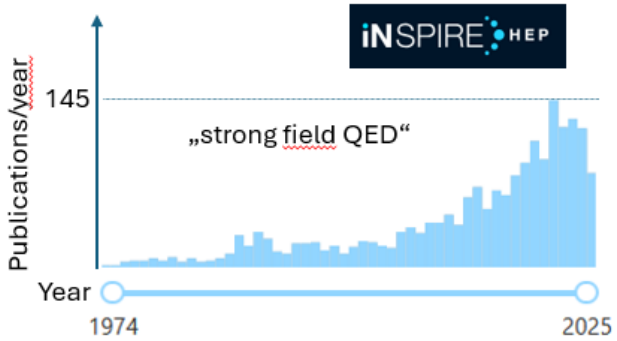
- Models have been developed to aid with the generation, shaping and control of suitable bunch pairs for plasma acceleration
- We performed beamtimes at XFEL showing that shaped bunch pairs can be generated at the photocathode, accelerated and transported to the TDS after the second bunch compressor.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

ELBEX – LUXE

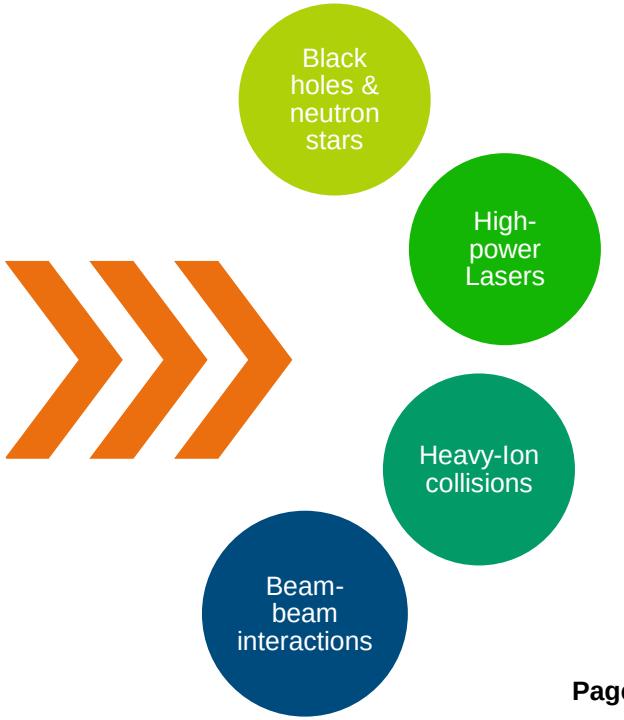
Studying Strong-Field Quantum electrodynamics

- 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!





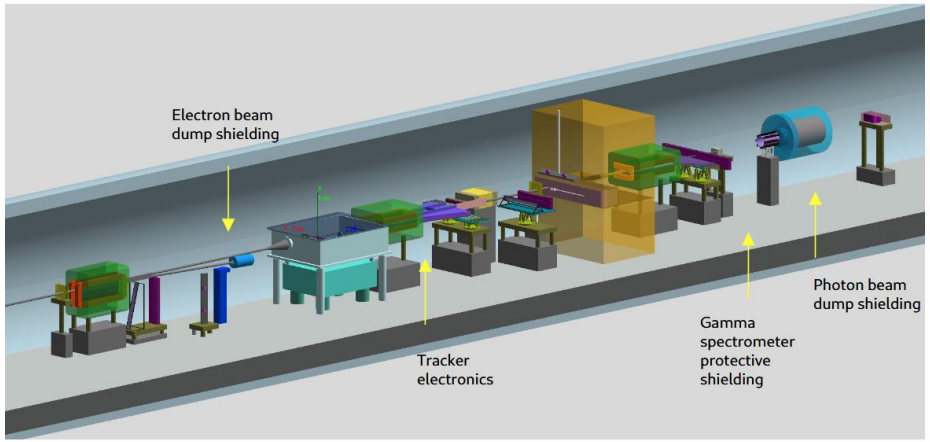
Strong field QED

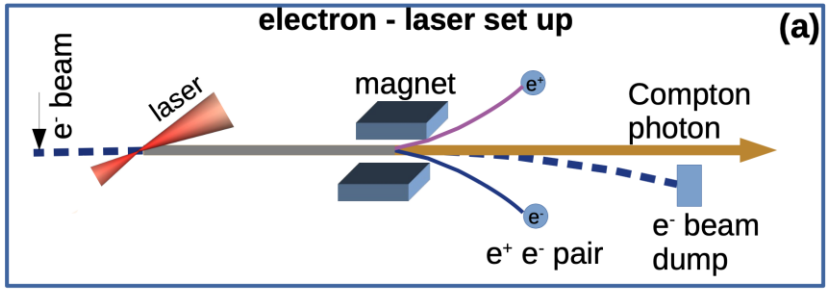


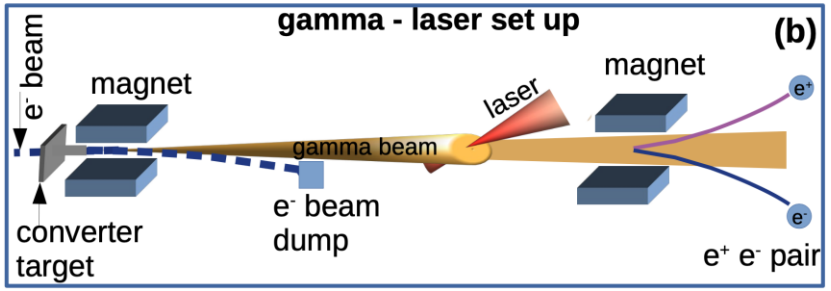
ELBEX – LUXE

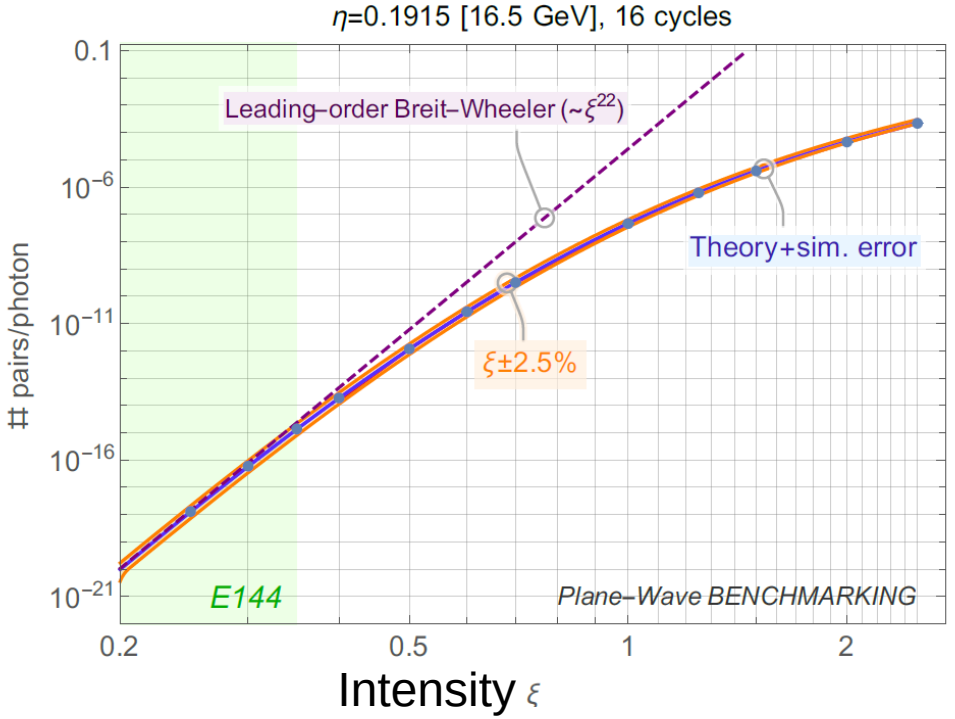
Studying Strong-Field Quantum electrodynamics

- 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







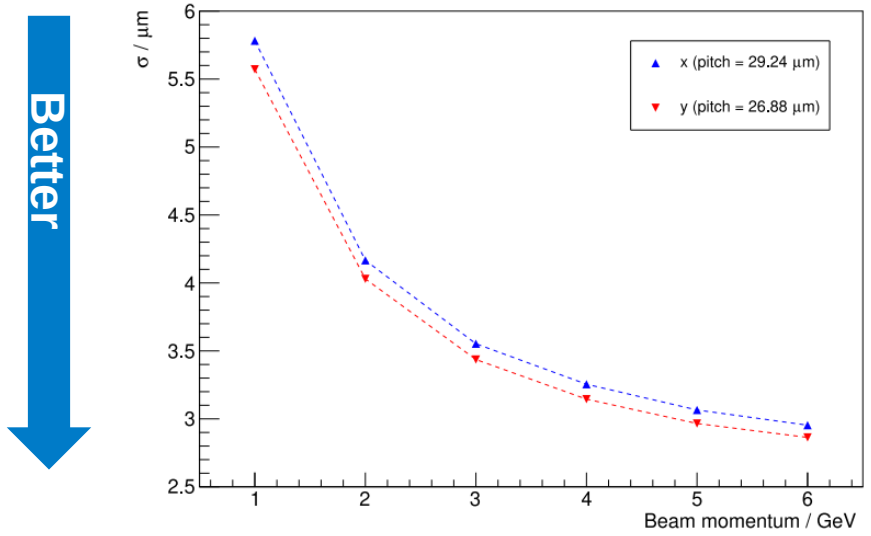


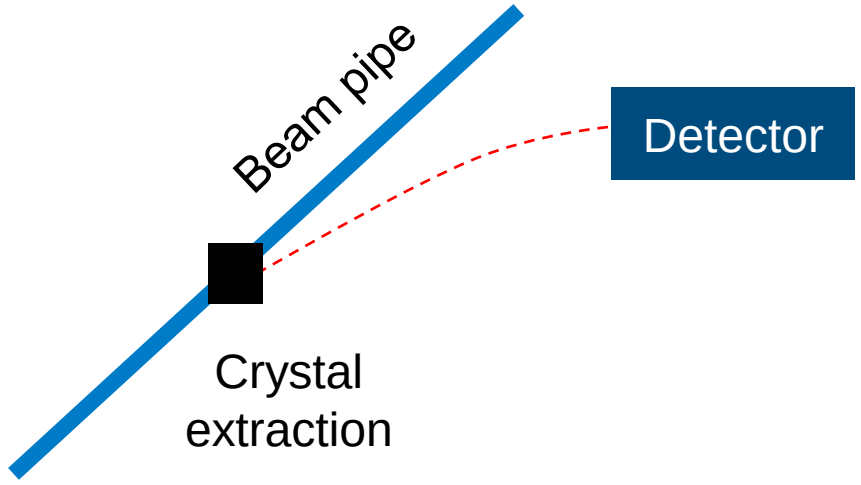
ELBEX – Test Beam

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 – 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 XTD8 overview

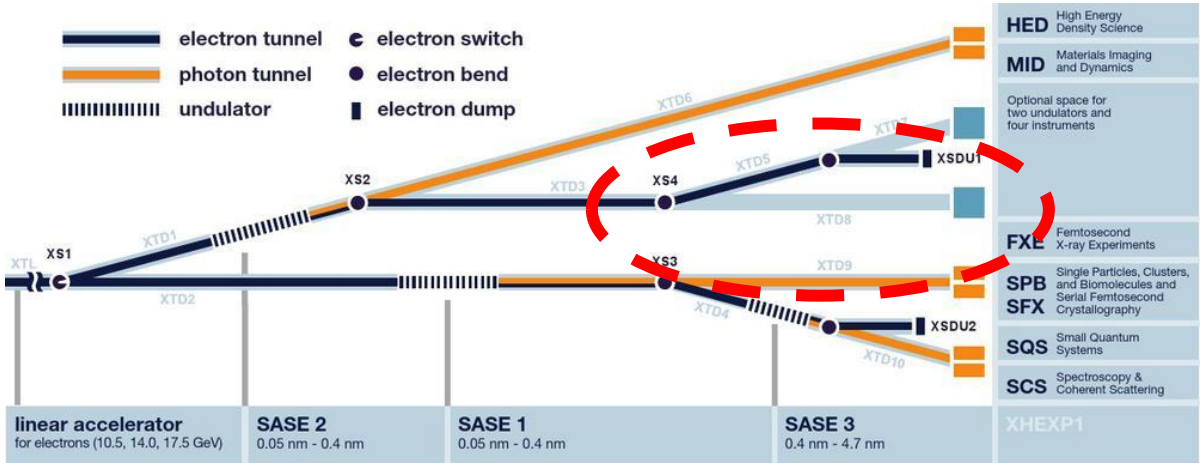
New site for ELBEX:

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

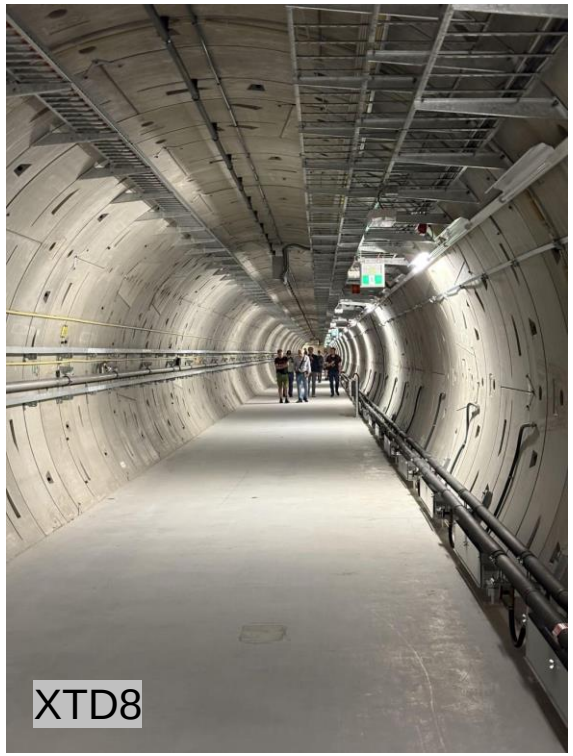
    → closely coordinating with EuXFEL
  - So far XTD8 has been unused
  - XTD8 comes with many advantages

ELBEX beam parameters

- 50 bunches , max 40 GeV beam energy

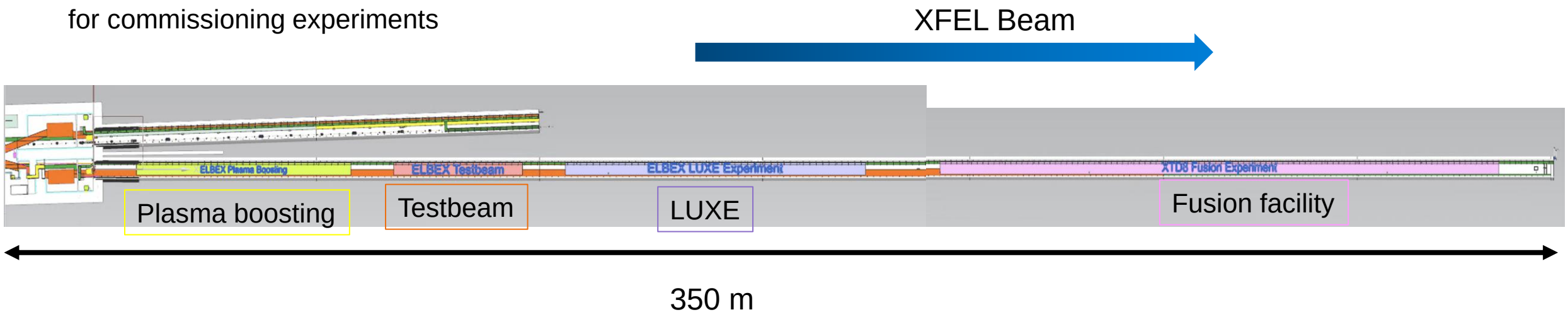



XTD3 near ELBEX branch-off

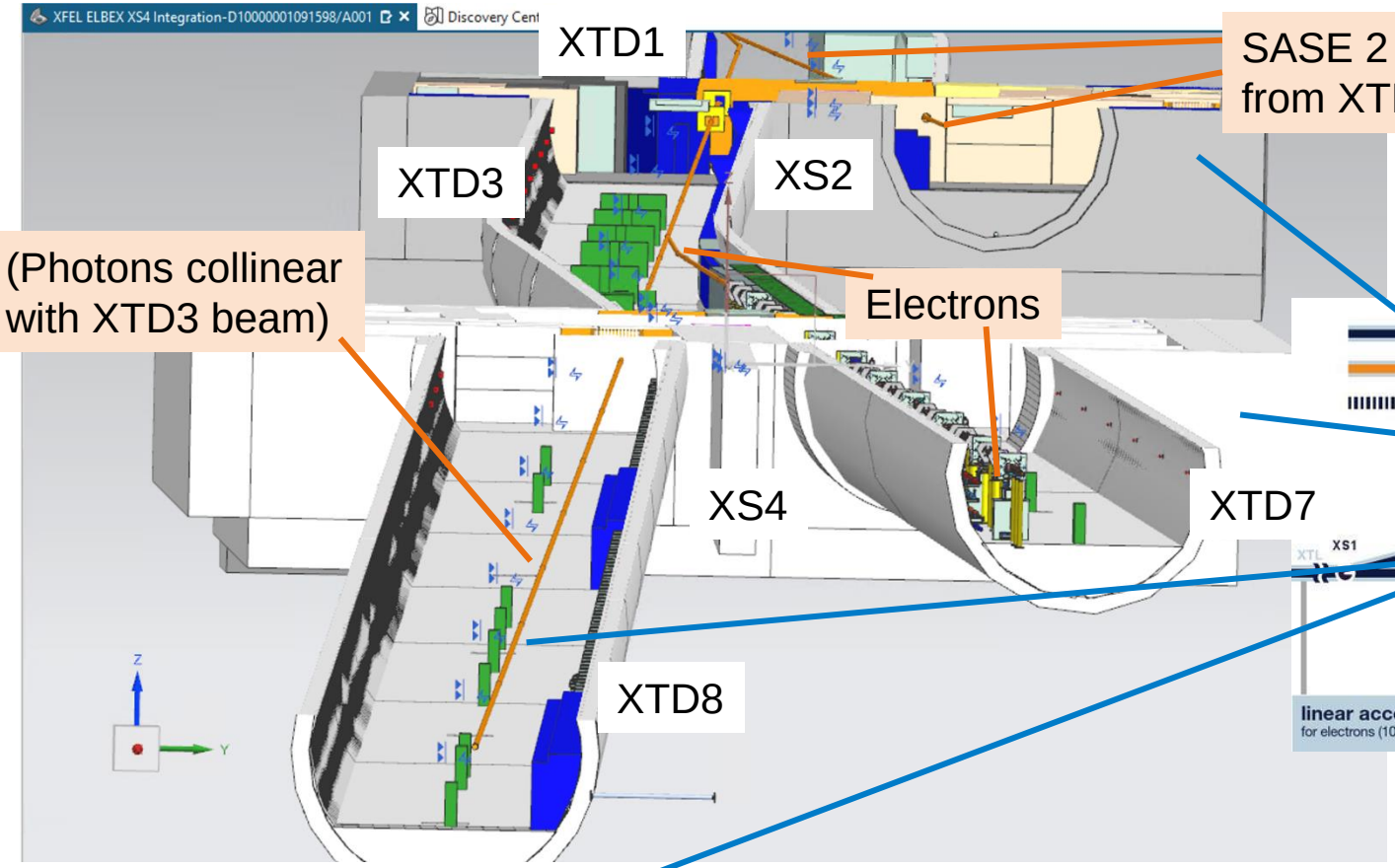

XTD8

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



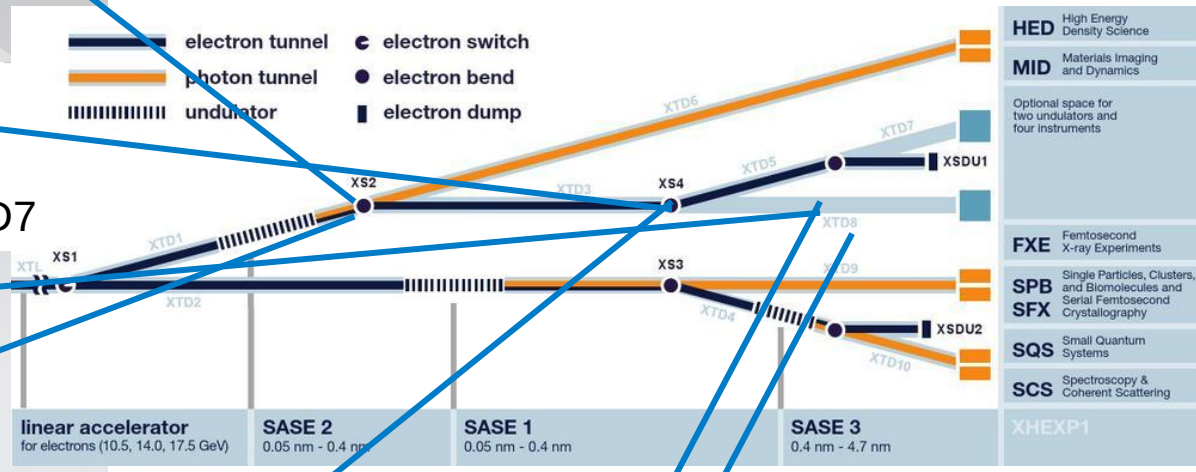
ELBEX - Overview

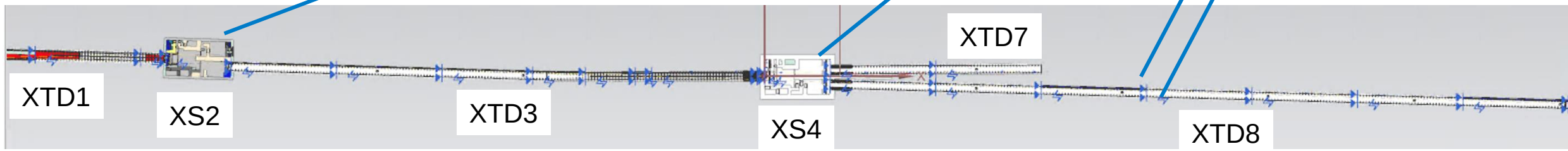


SASE 2 photons from XTD1

(Photons collinear with XTD3 beam)

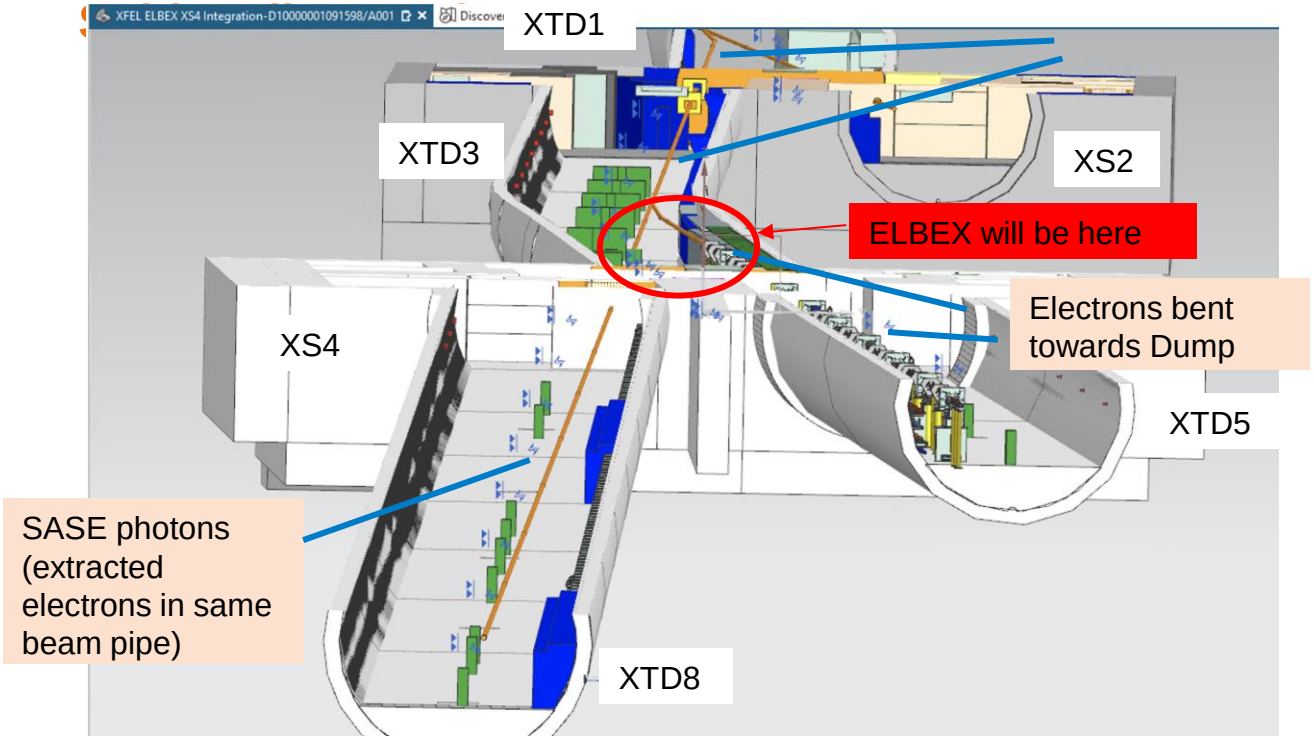
Electrons

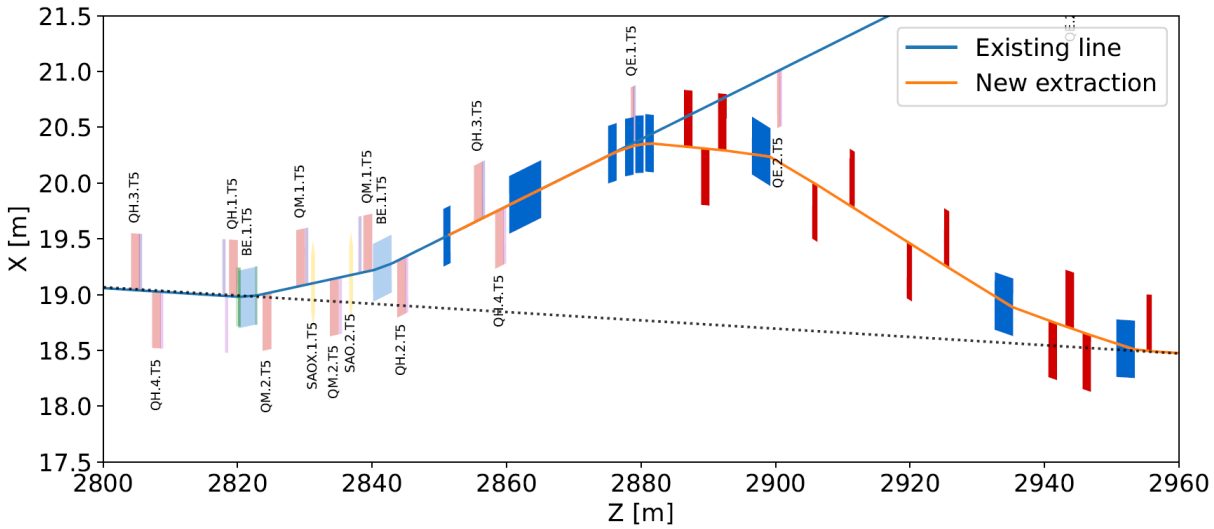




ELBEX extraction beamline design

Stewart Boogert, Marin Deniaud
(University of Manchester)

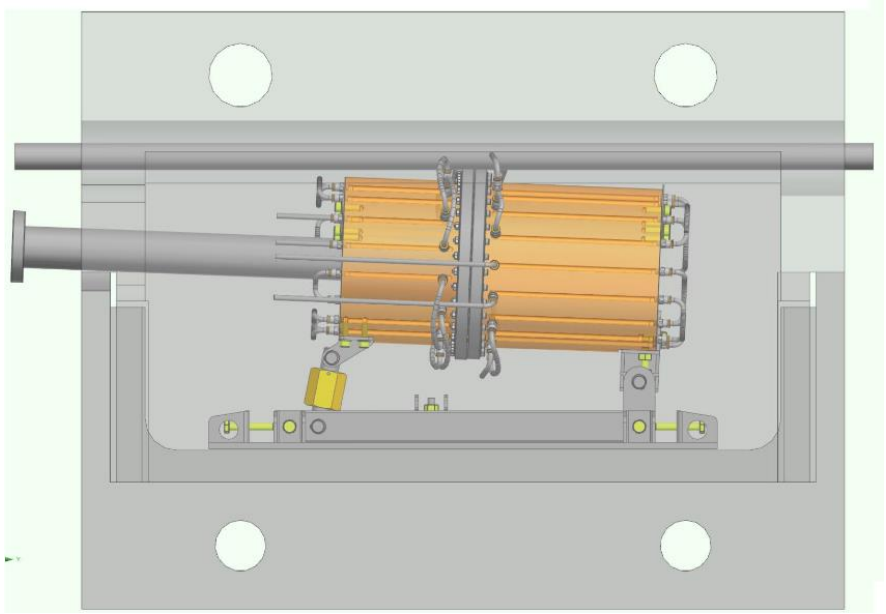


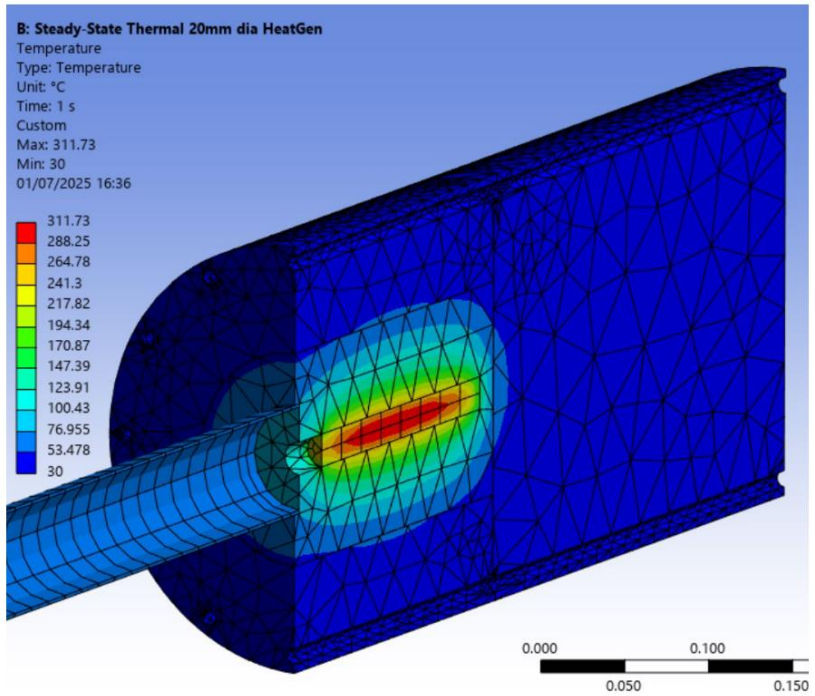


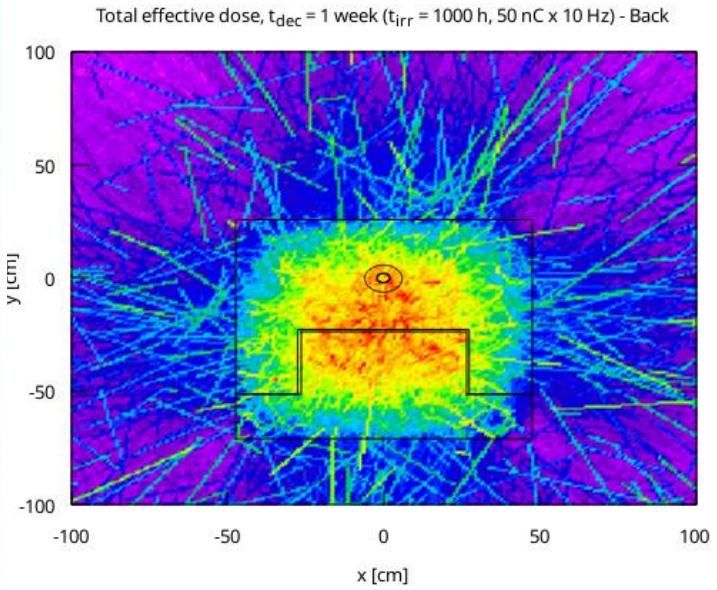
- Challenge: ELBEX electrons share beam pipe with SASE2 x-rays from mirror at XTD1 to fusion area
  → ELBEX extraction beamline: dogleg double bend from XTD3 into XTD8
- Matched lattice design achieved, optimization ongoing
  → goal: 10 µm spot size at IP

ELBEX final dump design and simulation

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



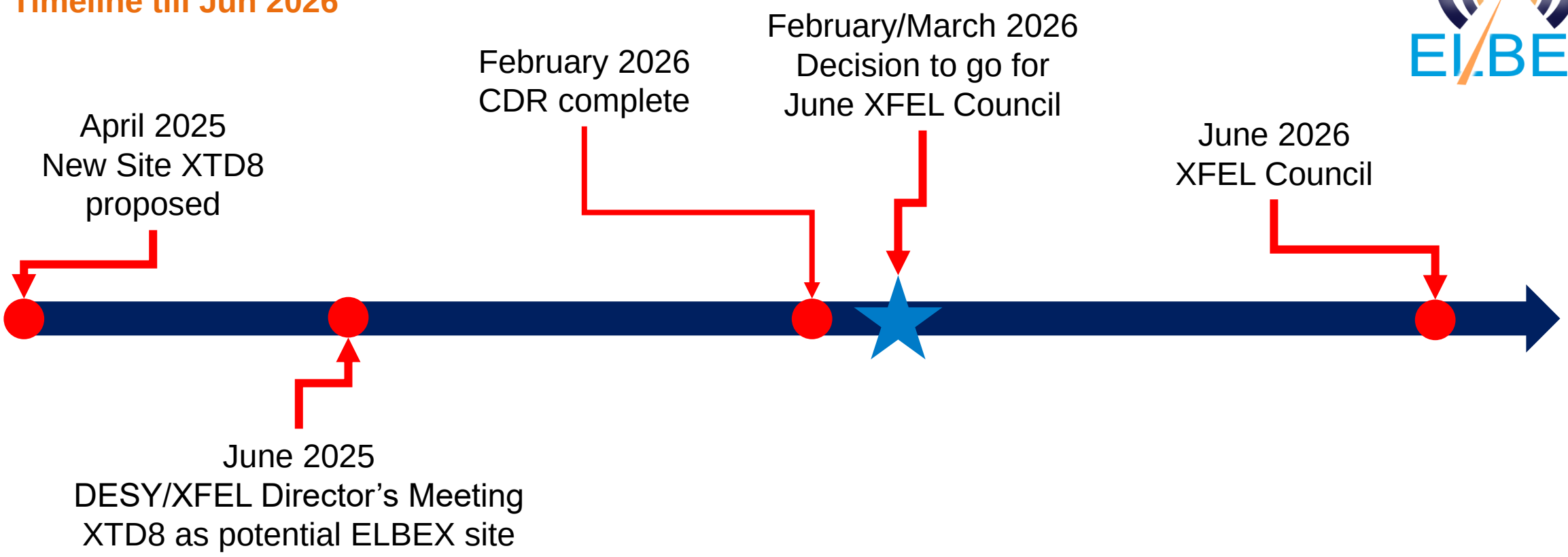




- Mechanical design of ELBEX final dump, based on LUXE electron dump design, consulted with MIN
- Compared to LUXE dump: higher energies (<40 GeV) and larger number of bunches (O(50)) (Plasma boosting)
- FLUKA simulation in place at INFN and FLUKA setup validated with DESY D3

ELBEX – Next Steps

Timeline till Jun 2026



Detailed Technically Driven Schedule

As presented to the EU and during PoF