The path to an upgrade of the European XFEL

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The overall picture

- European XFEL lauched in 2024 its ***2030⁺ Strategy***.
- 2-level strategy: *Harvesting science and* ***developing opportunities***.
- New opportunities: mid-term improvements & **long-term facility upgrade**.

From May 2025; times to be adapted

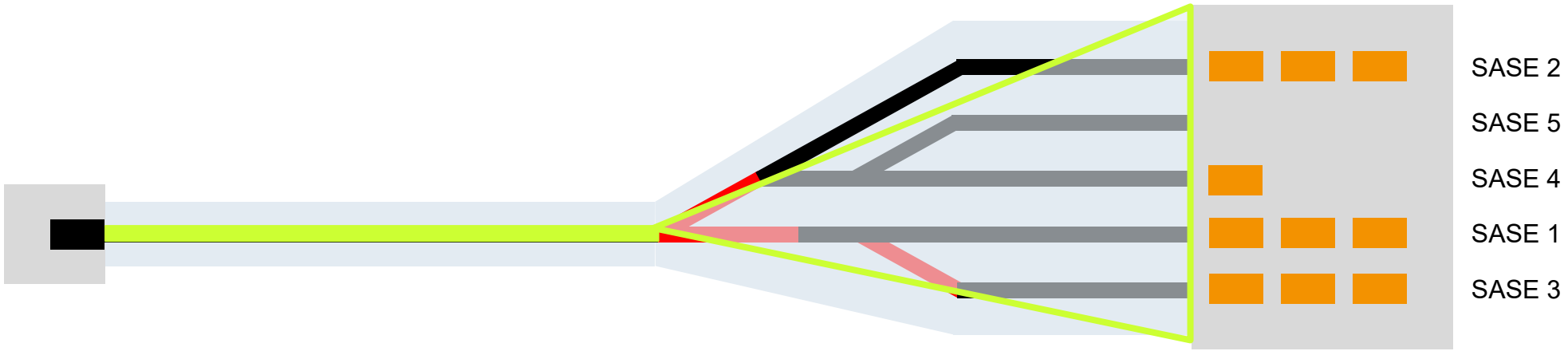
Preparation of a facility upgrade

- Science requirements
  - **Partly emerging from experiments done at European XFEL (or which cannot be done)**
  - **Partly from recent science cases formulated for other X-ray FELs (LCLS-II-HE, UK-XFEL)**
  - **Science workshops for an upgrade of European XFEL (to come …)**
  - **Provision of more experiment time to enable more experiments/reduce over-demand**
- Technological opportunities
  - **Accelerator developments,**
    - ► E.g. through the ability to provide high repetition rates continuously, or
    - ► Through the ability to provide smaller emittances, or similar.
  - **New FEL source developments**
    - ► Attosecond FEL schemes,
    - ► Delivery of high photon energy FEL radiation,
    - ► superconducting FELs, or
    - ► XFELO, or similar.
  - **New science instruments/experimental techniques**

Strengths & features of European XFEL

- Current situation → keep for future facility performance ?
- Accelerator features
  - **High electron energy**
  - **Delivery rates from < 1 Hz to 4.5 MHz**
  - **Medium high bunch charges**
  - **Stable delivery through feedback mechanisms**
  - **Multi-FEL facility operation**
  - **Flexible delivery schemes**
    - ► Between various instruments
    - ► Between various FEL modes
- FEL features
  - **Both small and very high photon energies**
  - **High pulse energies**
  - **Delivery of energetic attosecond* pulses**
  - **Long undulators**
  - **Self-seeding schemes (hard x-rays)**
  - **Variable polarization (soft x-rays)**
- Preliminary priorities
  - **High photon energies**
  - **Delivery of energetic attosecond* pulses**
  - **Multi-FEL facility operation**
  - **Delivery rates from < 1 Hz to MHz**

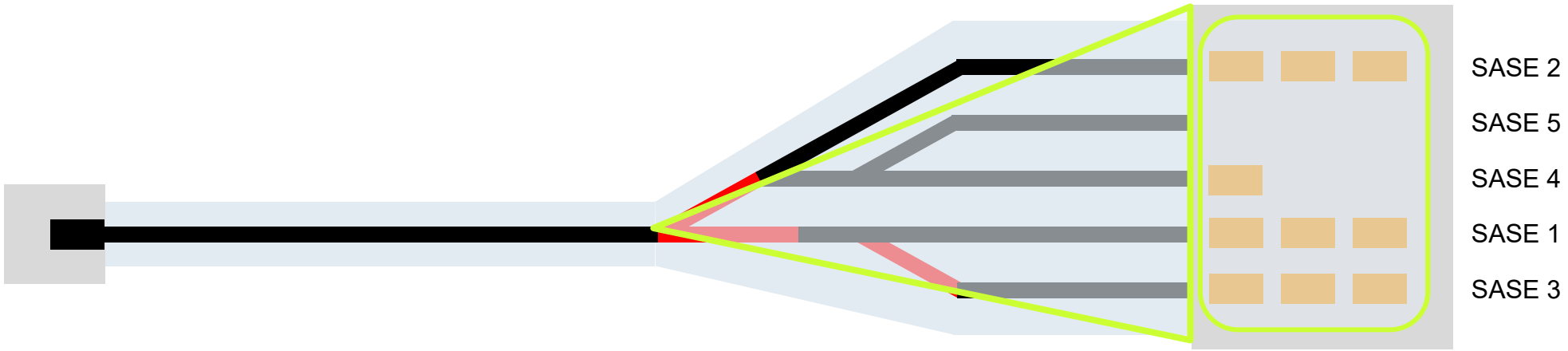
Options: Accelerator mode of operation



Major upgrade activity

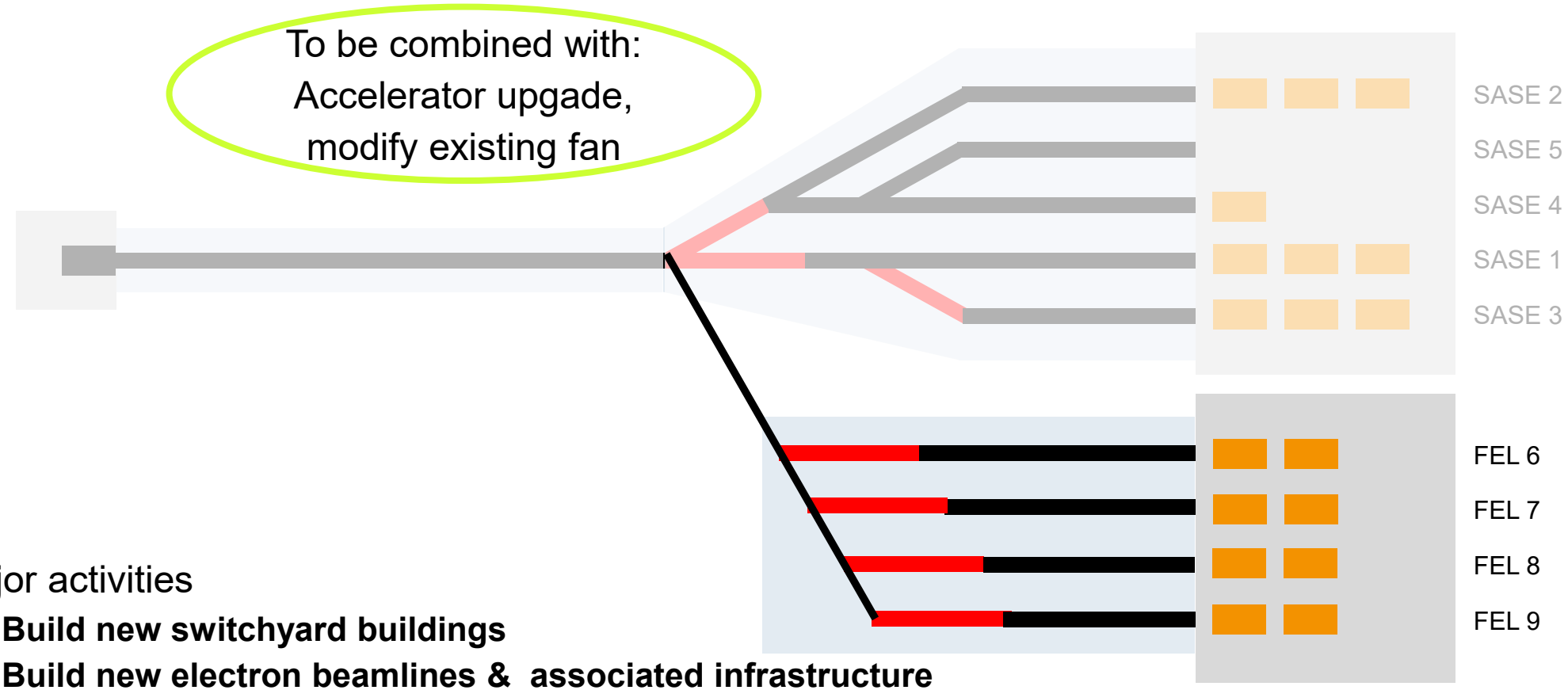
Modify/renew accelerator (& beam distribution)

Options: Renew scientific instrument suite



- Major upgrade activity
  - **Modify/renew FELs, beam transports and scientific instruments**
  - **Build out SASE 5 FEL, beam transport and scientific instruments**

Options: Build a 2nd fan for new FELs and scientific instruments



- Major activities
  - **Build new switchyard buildings**
  - **Build new electron beamlines & associated infrastructure**
  - **Build new science instruments**

The ‚big' questions

- To be clarified in order to make an attractive upgrade proposal
- How would an accelerator upgrade look and which performance parameters could one expect ?
  - **Consider context of SHINE, and LCLS-II-HE (and LCLS-X ?)**
  - **Flexibility in parameter/mode selection**

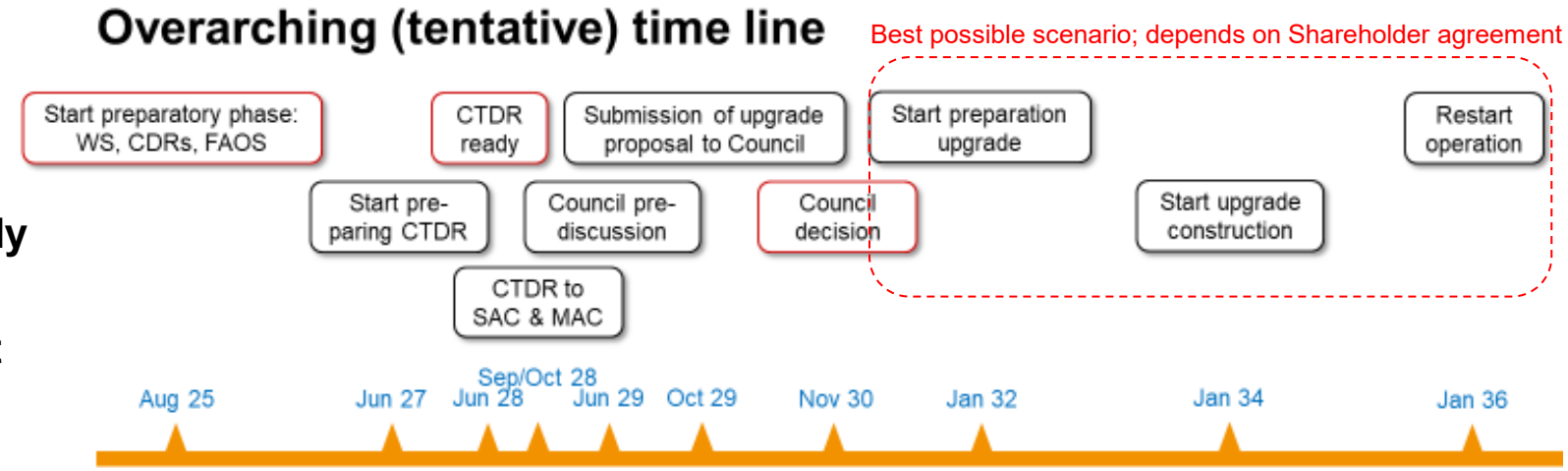
  → Accelerator R&D projects (initiated 2022, ongoing)
- How would a 2nd fan look like and which performance could one expect ?
  - **Issues related to geometrical bend / emittance growth**

  → Accelerator R&D (starting)
- How do science requirements match with accelerator operation modes ?
  - **cw operation vs. highest performance**

  → Workshops and down-selection of options (starting)

Time line & CTDR

- Timeline for CDTR preparation
  - **summer 2028: DRAFT CTDR ready**
  - **fall 2028: to MAC/SAC**
  - **Summer 2029: CTDR supplement**
  - **Oct 2029: CTDR to Council**
  - **Nov 2030: Council decision**



- CTDR describes
  - **the upgrade proposal, ideally one option,**
  - **the suporting science case, and the technical elements of the upgrade itself.**
- CTDR supplement for estimate of costs, effort and timeline approx. 1 yr later.
- The upgrade proposal will be based on various activities addressing parts of a potential upgrade (e.g. HDC FOS, science workshop reports, detector & DAQ assessments) and will require a balancing of the advantages & disadvantages of the various options.

This colloquium

- Presentation of results of a first R&D phase addressing the technological opportunities for an upgrade of the electron accelerator, in particular of the so-called **High Duty Cycle (HDC) mode of operation**.
- Understand the concept of modifying the EuXFEL accelerator to this mode of operation.
- Start to address the impact – what will work in future, what will no longer work, where do we need to invest into further R&D to figure out consequences.
- Identify opportunities, but as well limitations for the x-ray delivery to be considered in expert meetings and science workshops.

- **There should be enough time for questions & discussion. Please make use of it !**

- **Last not least: a big thanks to Nick, Julien, Riko and Winni to pushing this R&D phase and for everybody from DESY having brought these R&D activities to their current status.**