
WIR SCHAFFEN WISSEN – HEUTE FÜR MORGEN

Thomas Schietinger :: Paul Scherrer Institut

SwissFEL Porthos Machine Working Group

Kickoff Meeting, 18 August 2020

Porthos

> *"Porthos, honest and slightly gullible, is the extrovert of the group, enjoying wine, women and song."*

Wikipedia, "Porthos"

Content

- Objectives and deliverables: the SERI roadmap process
- Internal timetable
- Organization of the working group(s)
- Porthos options
- Decision process
- Where to go from here…

Objective and deliverable

- Goal: positioning of “SwissFEL Porthos” on the *“Swiss Roadmap for Research Infrastructures in view of the ERI Dispatch 2025–2028 (Roadmap for Research Infrastructures 2023)”* issued by the SERI (Swiss State Secretary for Education, Research and Innovation, German abbreviation SBFI).
- To end up on this roadmap, projects are subject to a lengthy multi-level selection procedure, for which a **sound and well motivated concept including a credible cost estimate** needs to be worked out.
- The immediate deliverable is a **two-page document summarizing the project (“fact sheet”)**, which will first be evaluated by the ETH council.
- This does not a priori mean that PSI wants to build Porthos in the period 2025–28! It may just as well be realized in 2029–32 only (with proton upgrades in 2025–28), or in stages between 2025 and 2032... *in any case* we will need a concept and a cost estimate!

Previous PSI projects on the roadmap

- **2015 Roadmap:**
  - **SwissFEL Athos: 46M (2017–20)** + 16M (2021–24)
  - SLS 2.0: 2M (2017–20) + 83M (2021–24)

    both under "planned research infrastructures of great scientific relevance"
- **2019 Roadmap:**
  - SwissFEL Athos:

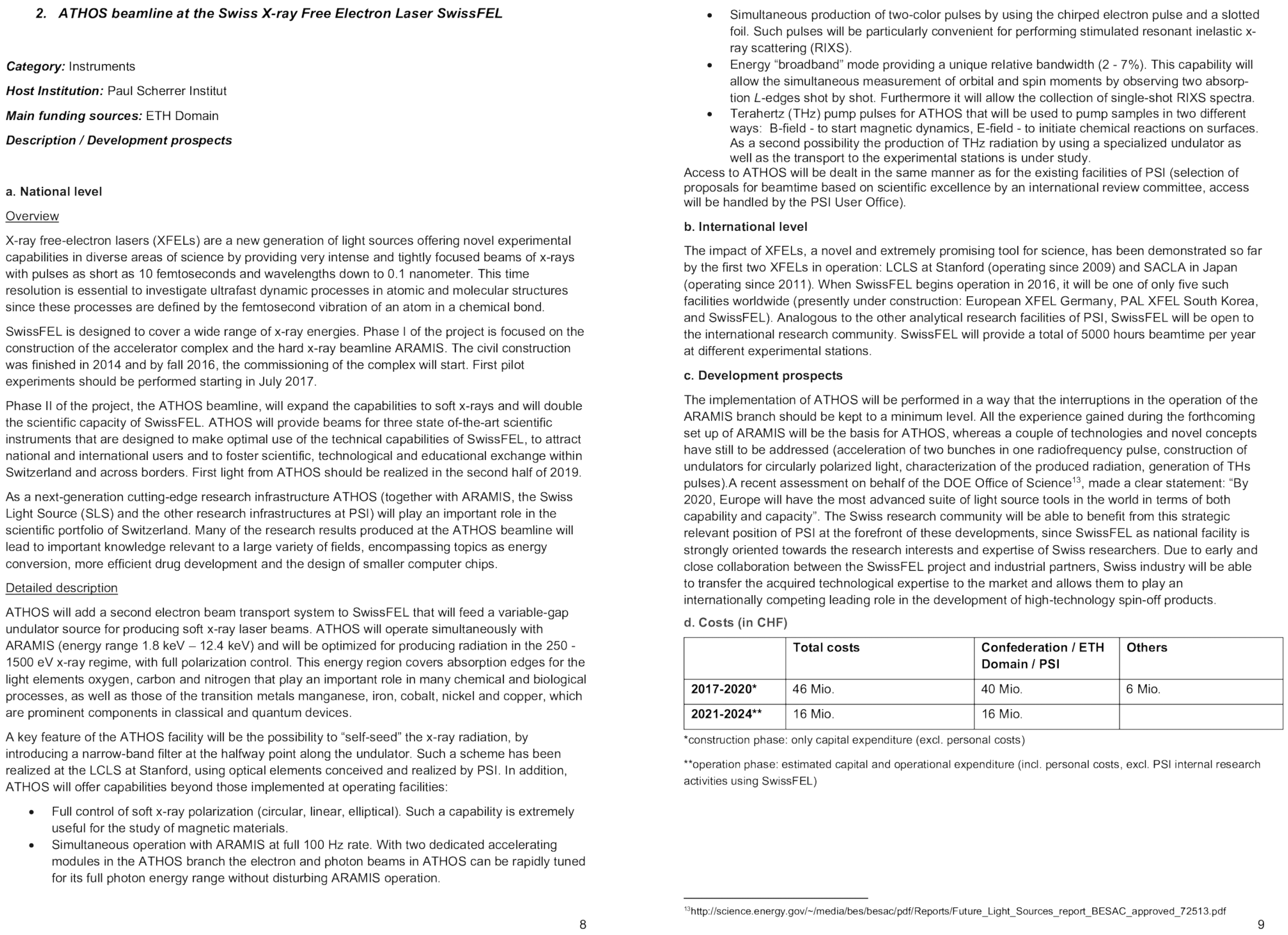
    under "update of national infrastructures on the 2015 roadmap"

    46M (2017–20) + 16M (2021–24) + 12M (2025–28)
  - **SLS 2.0:**

    under "new [or substantially upgraded] national infrastructure projects in the 2019 roadmap "

    2M (2017–20) + **167M (2021–24)** + 29M (2025–28)

SwissFEL Athos on the 2015 roadmap



2. ATHOS beamline at the Swiss X-ray Free Electron Laser SwissFEL

Category: Instruments

Host Institution: Paul Scherrer Institut

Main funding sources: ETH Domain

Description / Development prospects

a. National level

Overview

X-ray free-electron lasers (XFELs) are a new generation of light sources offering novel experimental capabilities in diverse areas of science by providing very intense and tightly focused beams of x-rays with pulses as short as 10 femtoseconds and wavelengths down to 0.1 nanometer. This time resolution is essential to investigate ultrafast dynamic processes in atomic and molecular structures since these processes are defined by the femtosecond vibration of an atom in a chemical bond.

SwissFEL is designed to cover a wide range of x-ray energies. Phase I of the project is focused on the construction of the accelerator complex and the hard x-ray beamline ARAMIS. The civil construction was finished in 2014 and by fall 2016, the commissioning of the complex will start. First pilot experiments should be performed starting in July 2017.

Phase II of the project, the ATHOS beamline, will expand the capabilities to soft x-rays and will double the scientific capacity of SwissFEL. ATHOS will provide beams for three state of-the-art scientific instruments that are designed to make optimal use of the technical capabilities of SwissFEL, to attract national and international users and to foster scientific, technological and educational exchange within Switzerland and across borders. First light from ATHOS should be realized in the second half of 2019.

As a next-generation cutting-edge research infrastructure ATHOS (together with ARAMIS, the Swiss Light Source (SLS) and the other research infrastructures at PSI) will play an important role in the scientific portfolio of Switzerland. Many of the research results produced at the ATHOS beamline will lead to important knowledge relevant to a large variety of fields, encompassing topics as energy conversion, more efficient drug development and the design of smaller computer chips.

Detailed description

ATHOS will add a second electron beam transport system to SwissFEL that will feed a variable-gap undulator source for producing soft x-ray laser beams. ATHOS will operate simultaneously with ARAMIS (energy range 1.8 keV – 12.4 keV) and will be optimized for producing radiation in the 250 - 1500 eV x-ray regime, with full polarization control. This energy region covers absorption edges for the light elements oxygen, carbon and nitrogen that play an important role in many chemical and biological processes, as well as those of the transition metals manganese, iron, cobalt, nickel and copper, which are prominent components in classical and quantum devices.

A key feature of the ATHOS facility will be the possibility to "self-seed" the x-ray radiation, by introducing a narrow-band filter at the halfway point along the undulator. Such a scheme has been realized at the LCLS at Stanford, using optical elements conceived and realized by PSI. In addition, ATHOS will offer capabilities beyond those implemented at operating facilities:

- Full control of soft x-ray polarization (circular, linear, elliptical). Such a capability is extremely useful for the study of magnetic materials.
- Simultaneous operation with ARAMIS at full 100 Hz rate. With two dedicated accelerating modules in the ATHOS branch the electron and photon beams in ATHOS can be rapidly tuned for its full photon energy range without disturbing ARAMIS operation.

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- Simultaneous production of two-color pulses by using the chirped electron pulse and a slotted foil. Such pulses will be particularly convenient for performing stimulated resonant inelastic x-ray scattering (RIXS).
- Energy "broadband" mode providing a unique relative bandwidth (2 - 7%). This capability will allow the simultaneous measurement of orbital and spin moments by observing two absorption *L*-edges shot by shot. Furthermore it will allow the collection of single-shot RIXS spectra.
- Terahertz (THz) pump pulses for ATHOS that will be used to pump samples in two different ways: B-field - to start magnetic dynamics, E-field - to initiate chemical reactions on surfaces. As a second possibility the production of THz radiation by using a specialized undulator as well as the transport to the experimental stations is under study.

Access to ATHOS will be dealt in the same manner as for the existing facilities of PSI (selection of proposals for beamtime based on scientific excellence by an international review committee, access will be handled by the PSI User Office).

b. International level

The impact of XFELs, a novel and extremely promising tool for science, has been demonstrated so far by the first two XFELs in operation: LCLS at Stanford (operating since 2009) and SACLA in Japan (operating since 2011). When SwissFEL begins operation in 2016, it will be one of only five such facilities worldwide (presently under construction: European XFEL Germany, PAL XFEL South Korea, and SwissFEL). Analogous to the other analytical research facilities of PSI, SwissFEL will be open to the international research community. SwissFEL will provide a total of 5000 hours beamtime per year at different experimental stations.

c. Development prospects

The implementation of ATHOS will be performed in a way that the interruptions in the operation of the ARAMIS branch should be kept to a minimum level. All the experience gained during the forthcoming set up of ARAMIS will be the basis for ATHOS, whereas a couple of technologies and novel concepts have still to be addressed (acceleration of two bunches in one radiofrequency pulse, construction of undulators for circularly polarized light, characterization of the produced radiation, generation of THs pulses).A recent assessment on behalf of the DOE Office of Science[13], made a clear statement: "By 2020, Europe will have the most advanced suite of light source tools in the world in terms of both capability and capacity". The Swiss research community will be able to benefit from this strategic relevant position of PSI at the forefront of these developments, since SwissFEL as national facility is strongly oriented towards the research interests and expertise of Swiss researchers. Due to early and close collaboration between the SwissFEL project and industrial partners, Swiss industry will be able to transfer the acquired technological expertise to the market and allows them to play an internationally competing leading role in the development of high-technology spin-off products.

d. Costs (in CHF)

	Total costs	**Confederation / ETH Domain / PSI**	**Others**
2017-2020*	46 Mio.	40 Mio.	6 Mio.
2021-2024**	16 Mio.	16 Mio.	

*construction phase: only capital expenditure (excl. personal costs)

**operation phase: estimated capital and operational expenditure (incl. personal costs, excl. PSI internal research activities using SwissFEL)

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[13] http://science.energy.gov/~/media/bes/besac/pdf/Reports/Future_Light_Sources_report_BESAC_approved_72513.pdf

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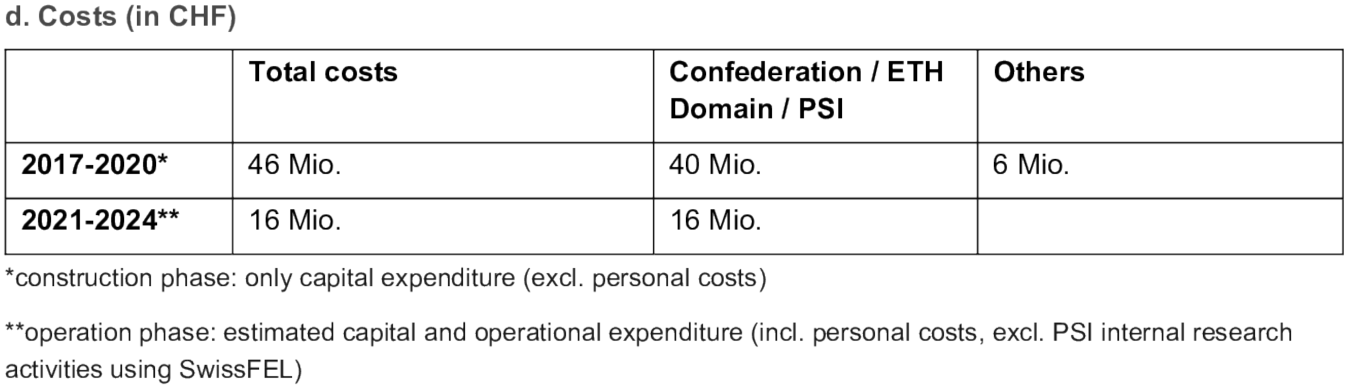
SwissFEL Athos on the 2015 roadmap



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2017-2020*	46 Mio.	40 Mio.	6 Mio.
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**operation phase: estimated capital and operational expenditure (incl. personal costs, excl. PSI internal research activities using SwissFEL)

SwissFEL Athos on the 2019 roadmap

ATHOS beamline at the Swiss X-ray Free Electron Laser SwissFEL

Category: Instruments
Host institution(s): Paul Scherrer Institute (PSI)
Main funding sources: ETH Domain
Description / Development prospects

a. National level

Overview

X-ray free-electron lasers (XFELs) are a new generation of light sources offering novel experimental capabilities in diverse areas of science by providing very intense and tightly focused beams of x-rays with pulses ranging from 50 femtosecond to sub-femtosecond and wavelengths down to 0.1 nanometre. This time resolution is essential to investigate ultrafast dynamic processes in atomic and molecular structures since these processes are defined by the femtosecond vibration of an atom in a chemical bond. SwissFEL is designed to cover a wide range of x-ray energies. Phase I of the project was focused on the construction of the accelerator complex and the hard x-ray beamline ARAMIS. The civil construction was finished in 2014 and first pilot user experiments were performed in 2017. The pilot user operation and consolidation phase will continue until the end of 2018 followed by normal user operation starting in 2019. Phase II of the project, the ATHOS beamline, will expand the capabilities to soft x-rays (250 to 1900 eV) and will double the scientific capacity of SwissFEL. ATHOS will provide beams to two state-of-the-art experimental stations that are designed to make optimal use of the technical capabilities of SwissFEL, to attract national and international users and to foster scientific, technological and educational exchange within Switzerland and across borders. The ATHOS layout allows an extension to a third scientific instrument to be built after 2020. First light from ATHOS should be realised by the end of 2019 with first pilot user experiments expected for 2021. As a next-generation cutting-edge research infrastructure, ATHOS (together with ARAMIS, the Swiss Light Source (SLS) and its upgrade (SLS 2.0), as well as the Swiss Neutron Source (SINQ) and the Swiss Muon Source (SμS)) will play an important role in the scientific portfolio of Switzerland. Many of the research results produced at the ATHOS beamline will lead to important knowledge relevant to a large variety of fields, encompassing topics such as energy conversion, more efficient drug development and the design of smaller computer chips.
SwissFEL with its two beamlines ATHOS and ARAMIS will complement Swiss users' access to European XFEL, an international research organisation based in Hamburg of which Switzerland is a member.

Detailed description

ATHOS will add a second electron beam transport system to SwissFEL that will feed a variable-gap undulator line for producing soft x-ray laser beams. ATHOS will operate simultaneously with ARAMIS (energy range 1.8 keV – 12.4 keV) and will be optimised for producing radiation in the 250 - 1900 eV x-ray regime, with full polarisation control. This energy region covers absorption edges for the light elements oxygen, carbon and nitrogen, which play an important role in many chemical and biological processes, as well as those of the transition metals manganese, iron, cobalt, nickel, and copper, which are prominent components in classical and quantum devices. Also the absorption edge of silicon can be reached with ATHOS to cover the science related to semiconductor research.
A key feature of the ATHOS facility is the use of small magnetic chicanes between each undulator in order to manipulate the electron bunch during the lasing process, thus offering new capabilities beyond those implemented at operating facilities:
- Full control of soft x-ray polarisation (circular, linear, elliptical). Such a capability is extremely useful for the study of magnetic materials.
- Sub-femtosecond pulses with enough energy (above 100 μJ), which are very important for atomic, molecular and optical physics, as well as for non-linear x-ray optics.
- Parallel operation with ARAMIS at full 100 Hz rate. With a dedicated accelerating module in the ATHOS branch the electron bunch and photon beams in ATHOS can be rapidly tuned for its full photon energy range without disturbing ARAMIS operation.
- Simultaneous production of two-colour pulses with adjustable delay by splitting the 16 undulators in two sections separated by a delay chicane. Such pulses will be particularly convenient for performing stimulated resonant inelastic x-ray scattering (RIXS).
- Energy "broadband" mode providing a bandwidth up to 10% and the ultra-narrow bandwidth of the "high brightness" mode are unique operation schemes of ATHOS. Those capabilities will allow either the simultaneous measurement of orbital and spin moments by observing two absorption L-edges shot by shot, or high resolution RIXS with high transmission. Furthermore, it will allow the collection of single-shot RIXS spectra.
- Terahertz (THz) pump pulses for ATHOS that will be used to pump samples in two different ways: "B-field" to start magnetic dynamics, "E-field" to initiate chemical reactions on surfaces.

Access to ATHOS will be handled in the same manner as for the PSI existing facilities (selection of proposals for beamtime based on scientific excellence by an international review committee, access will be handled by the PSI User Office).

b. International level

The impact of XFELs, the new generation of x-ray radiation source, has been demonstrated so far by the first two XFELs in operation: LCLS at Stanford (operating since 2009), SACLA in Japan (operating since 2011) and European XFEL in Hamburg (operating since 2017). In 2017, first successful experiments were performed with SwissFEL, contributing to science development. Analogous to the other analytical research facilities of PSI, SwissFEL is open to the international research community. SwissFEL will provide a total of 5,000 hours' beamtime per year and per FEL beamline (ATHOS and ARAMIS) at different experimental stations.

c. Development prospects

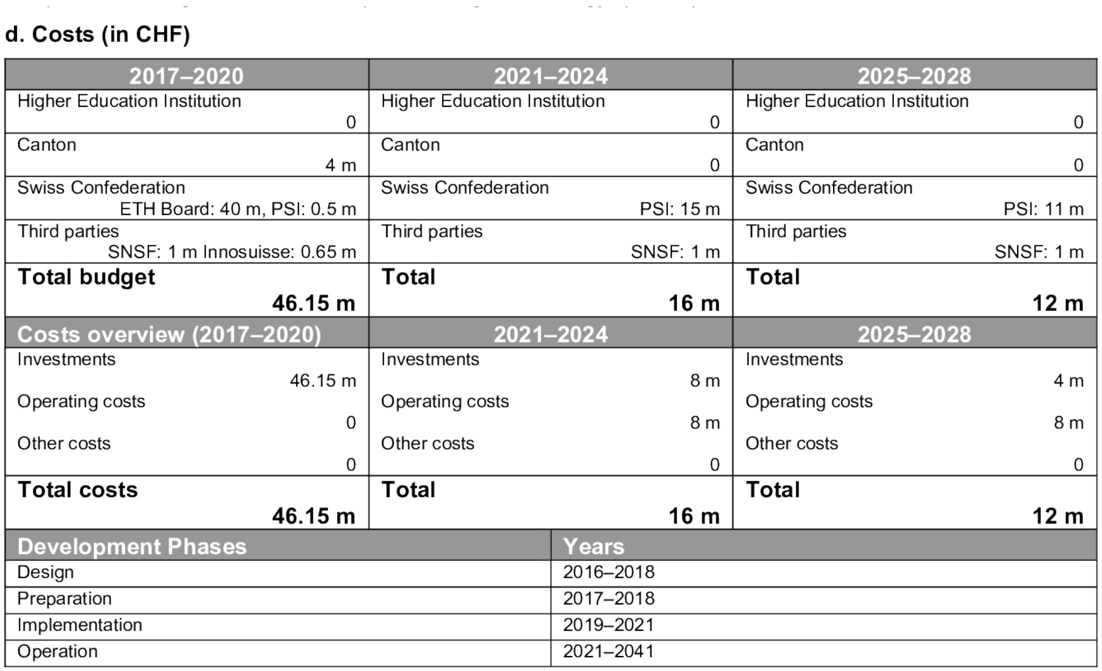
The implementation of ATHOS is done in a way that the interruptions in the operation of the ARAMIS branch is kept to a minimum level mainly combined with the necessary maintenance shutdowns of SwissFEL (3 times 3 weeks per year). Electron beam transmission through the first 110 m of ATHOS line has been recently demonstrated, as has the transport of two bunches in one radiofrequency pulse. The undulator prototype providing circularly polarised light is currently under assembly and will be tested by the end of 2018. The design of the light transport layout is close to completion and experimental stations are being designed in order to best fit the particularities of the ATHOS light. The Swiss research community will be able to benefit from this strategically relevant position of PSI at the forefront of these developments, since SwissFEL as the national facility is strongly oriented towards the research interests and expertise of Swiss researchers. Due to early and close collaboration between the SwissFEL project and industrial partners, Swiss industry will be able to transfer the acquired technological expertise to the market and allows them to play an internationally competitive leading role in the development of high-technology spin-off products.

d. Costs (in CHF)

2017–2020	2021–2024	2025–2028
Higher Education Institution 0	Higher Education Institution 0	Higher Education Institution 0
Canton 4 m	Canton 0	Canton 0
Swiss Confederation ETH Board: 40 m, PSI: 0.5 m	Swiss Confederation PSI: 15 m	Swiss Confederation PSI: 11 m
Third parties SNSF: 1 m Innosuisse: 0.65 m	Third parties SNSF: 1 m	Third parties SNSF: 1 m
Total budget **46.15 m**	**Total** **16 m**	**Total** **12 m**
Costs overview (2017–2020)	**2021–2024**	**2025–2028**
Investments 46.15 m Operating costs 0 Other costs 0	Investments 8 m Operating costs 8 m Other costs 0	Investments 4 m Operating costs 8 m Other costs 0
Total costs **46.15 m**	**Total** **16 m**	**Total** **12 m**

Development Phases	Years
Design	2016–2018
Preparation	2017–2018
Implementation	2019–2021
Operation	2021–2041

SwissFEL Athos on the 2019 roadmap

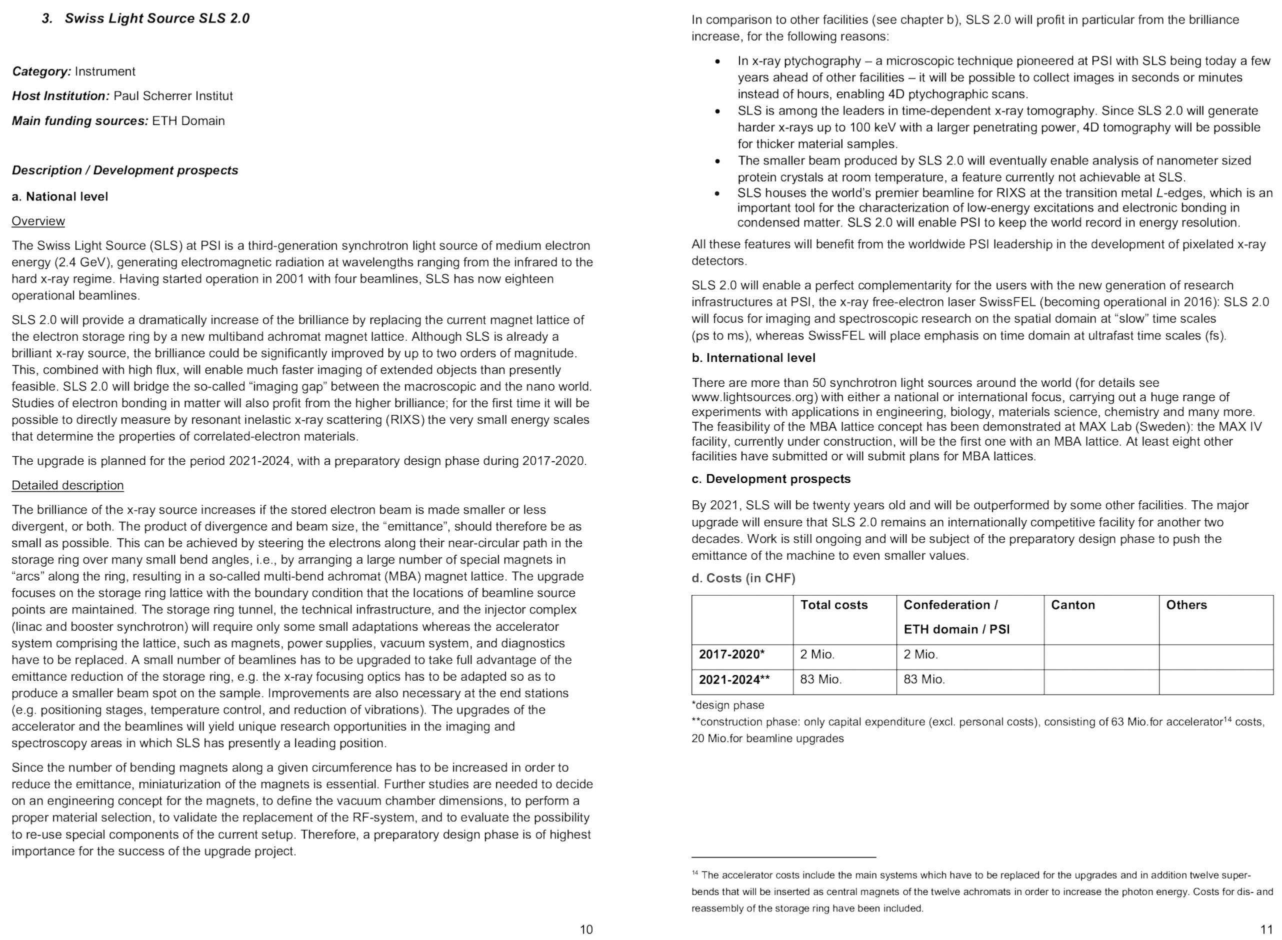


d. Costs (in CHF)

2017–2020	2021–2024	2025–2028
Higher Education Institution 0	Higher Education Institution 0	Higher Education Institution 0
Canton 4 m	Canton 0	Canton 0
Swiss Confederation ETH Board: 40 m, PSI: 0.5 m	Swiss Confederation PSI: 15 m	Swiss Confederation PSI: 11 m
Third parties SNSF: 1 m Innosuisse: 0.65 m	Third parties SNSF: 1 m	Third parties SNSF: 1 m
Total budget **46.15 m**	**Total** **16 m**	**Total** **12 m**
Costs overview (2017–2020)	**2021–2024**	**2025–2028**
Investments 46.15 m	Investments 8 m	Investments 4 m
Operating costs 0	Operating costs 8 m	Operating costs 8 m
Other costs 0	Other costs 0	Other costs 0
Total costs **46.15 m**	**Total** **16 m**	**Total** **12 m**

Development Phases	Years
Design	2016–2018
Preparation	2017–2018
Implementation	2019–2021
Operation	2021–2041

SLS 2.0 on the 2015 roadmap



3. *Swiss Light Source SLS 2.0*

Category: Instrument

Host Institution: Paul Scherrer Institut

Main funding sources: ETH Domain

Description / Development prospects

a. National level

Overview

The Swiss Light Source (SLS) at PSI is a third-generation synchrotron light source of medium electron energy (2.4 GeV), generating electromagnetic radiation at wavelengths ranging from the infrared to the hard x-ray regime. Having started operation in 2001 with four beamlines, SLS has now eighteen operational beamlines.

SLS 2.0 will provide a dramatically increase of the brilliance by replacing the current magnet lattice of the electron storage ring by a new multiband achromat magnet lattice. Although SLS is already a brilliant x-ray source, the brilliance could be significantly improved by up to two orders of magnitude. This, combined with high flux, will enable much faster imaging of extended objects than presently feasible. SLS 2.0 will bridge the so-called “imaging gap” between the macroscopic and the nano world. Studies of electron bonding in matter will also profit from the higher brilliance; for the first time it will be possible to directly measure by resonant inelastic x-ray scattering (RIXS) the very small energy scales that determine the properties of correlated-electron materials.

The upgrade is planned for the period 2021-2024, with a preparatory design phase during 2017-2020.

Detailed description

The brilliance of the x-ray source increases if the stored electron beam is made smaller or less divergent, or both. The product of divergence and beam size, the “emittance”, should therefore be as small as possible. This can be achieved by steering the electrons along their near-circular path in the storage ring over many small bend angles, i.e., by arranging a large number of special magnets in “arcs” along the ring, resulting in a so-called multi-bend achromat (MBA) magnet lattice. The upgrade focuses on the storage ring lattice with the boundary condition that the locations of beamline source points are maintained. The storage ring tunnel, the technical infrastructure, and the injector complex (linac and booster synchrotron) will require only some small adaptations whereas the accelerator system comprising the lattice, such as magnets, power supplies, vacuum system, and diagnostics have to be replaced. A small number of beamlines has to be upgraded to take full advantage of the emittance reduction of the storage ring, e.g. the x-ray focusing optics has to be adapted so as to produce a smaller beam spot on the sample. Improvements are also necessary at the end stations (e.g. positioning stages, temperature control, and reduction of vibrations). The upgrades of the accelerator and the beamlines will yield unique research opportunities in the imaging and spectroscopy areas in which SLS has presently a leading position.

Since the number of bending magnets along a given circumference has to be increased in order to reduce the emittance, miniaturization of the magnets is essential. Further studies are needed to decide on an engineering concept for the magnets, to define the vacuum chamber dimensions, to perform a proper material selection, to validate the replacement of the RF-system, and to evaluate the possibility to re-use special components of the current setup. Therefore, a preparatory design phase is of highest importance for the success of the upgrade project.

In comparison to other facilities (see chapter b), SLS 2.0 will profit in particular from the brilliance increase, for the following reasons:

- In x-ray ptychography – a microscopic technique pioneered at PSI with SLS being today a few years ahead of other facilities – it will be possible to collect images in seconds or minutes instead of hours, enabling 4D ptychographic scans.
- SLS is among the leaders in time-dependent x-ray tomography. Since SLS 2.0 will generate harder x-rays up to 100 keV with a larger penetrating power, 4D tomography will be possible for thicker material samples.
- The smaller beam produced by SLS 2.0 will eventually enable analysis of nanometer sized protein crystals at room temperature, a feature currently not achievable at SLS.
- SLS houses the world’s premier beamline for RIXS at the transition metal *L*-edges, which is an important tool for the characterization of low-energy excitations and electronic bonding in condensed matter. SLS 2.0 will enable PSI to keep the world record in energy resolution.

All these features will benefit from the worldwide PSI leadership in the development of pixelated x-ray detectors.

SLS 2.0 will enable a perfect complementarity for the users with the new generation of research infrastructures at PSI, the x-ray free-electron laser SwissFEL (becoming operational in 2016): SLS 2.0 will focus for imaging and spectroscopic research on the spatial domain at “slow” time scales (ps to ms), whereas SwissFEL will place emphasis on time domain at ultrafast time scales (fs).

b. International level

There are more than 50 synchrotron light sources around the world (for details see www.lightsources.org) with either a national or international focus, carrying out a huge range of experiments with applications in engineering, biology, materials science, chemistry and many more. The feasibility of the MBA lattice concept has been demonstrated at MAX Lab (Sweden): the MAX IV facility, currently under construction, will be the first one with an MBA lattice. At least eight other facilities have submitted or will submit plans for MBA lattices.

c. Development prospects

By 2021, SLS will be twenty years old and will be outperformed by some other facilities. The major upgrade will ensure that SLS 2.0 remains an internationally competitive facility for another two decades. Work is still ongoing and will be subject of the preparatory design phase to push the emittance of the machine to even smaller values.

d. Costs (in CHF)

	Total costs	**Confederation / ETH domain / PSI**	**Canton**	**Others**
2017-2020*	2 Mio.	2 Mio.		
2021-2024**	83 Mio.	83 Mio.		

*design phase

**construction phase: only capital expenditure (excl. personal costs), consisting of 63 Mio.for accelerator[14] costs, 20 Mio.for beamline upgrades

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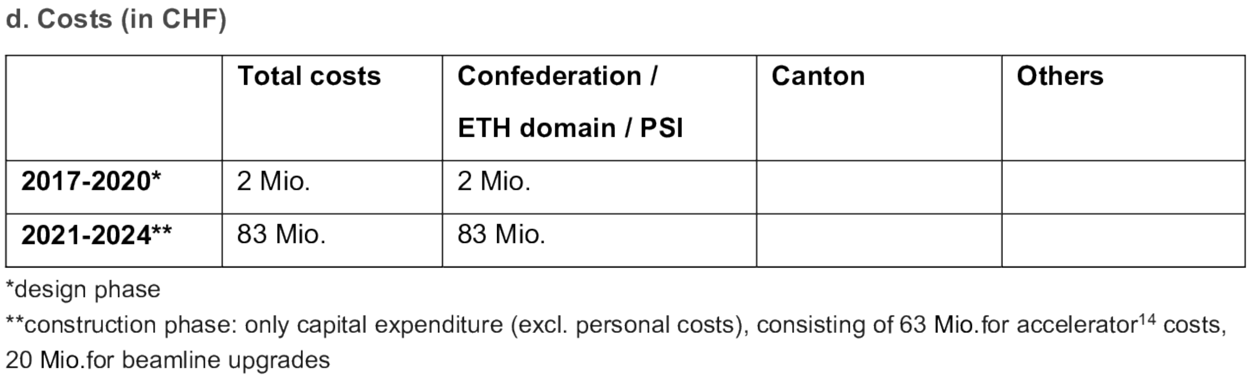
[14] The accelerator costs include the main systems which have to be replaced for the upgrades and in addition twelve super-bends that will be inserted as central magnets of the twelve achromats in order to increase the photon energy. Costs for dis- and reassembly of the storage ring have been included.

SLS 2.0 on the 2015 roadmap



d. Costs (in CHF)

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2017-2020*	2 Mio.	2 Mio.		
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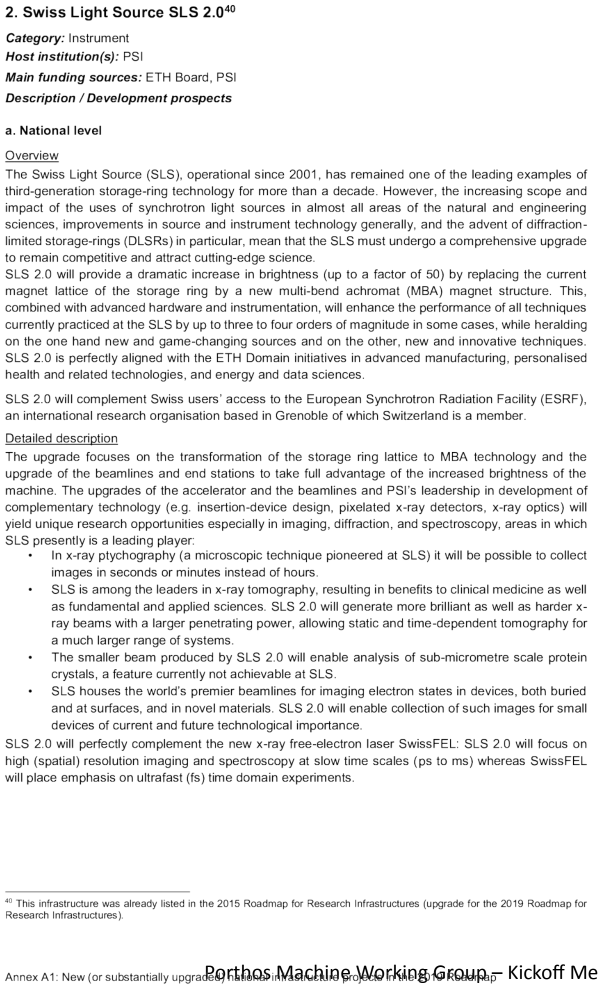
SLS 2.0 on the 2019 roadmap



2. Swiss Light Source SLS 2.0[40]

Category: Instrument
Host institution(s): PSI
Main funding sources: ETH Board, PSI
Description / Development prospects

a. National level

Overview

The Swiss Light Source (SLS), operational since 2001, has remained one of the leading examples of third-generation storage-ring technology for more than a decade. However, the increasing scope and impact of the uses of synchrotron light sources in almost all areas of the natural and engineering sciences, improvements in source and instrument technology generally, and the advent of diffraction-limited storage-rings (DLSRs) in particular, mean that the SLS must undergo a comprehensive upgrade to remain competitive and attract cutting-edge science.
SLS 2.0 will provide a dramatic increase in brightness (up to a factor of 50) by replacing the current magnet lattice of the storage ring by a new multi-bend achromat (MBA) magnet structure. This, combined with advanced hardware and instrumentation, will enhance the performance of all techniques currently practiced at the SLS by up to three to four orders of magnitude in some cases, while heralding on the one hand new and game-changing sources and on the other, new and innovative techniques. SLS 2.0 is perfectly aligned with the ETH Domain initiatives in advanced manufacturing, personalised health and related technologies, and energy and data sciences.

SLS 2.0 will complement Swiss users' access to the European Synchrotron Radiation Facility (ESRF), an international research organisation based in Grenoble of which Switzerland is a member.

Detailed description

The upgrade focuses on the transformation of the storage ring lattice to MBA technology and the upgrade of the beamlines and end stations to take full advantage of the increased brightness of the machine. The upgrades of the accelerator and the beamlines and PSI's leadership in development of complementary technology (e.g. insertion-device design, pixelated x-ray detectors, x-ray optics) will yield unique research opportunities especially in imaging, diffraction, and spectroscopy, areas in which SLS presently is a leading player:

- In x-ray ptychography (a microscopic technique pioneered at SLS) it will be possible to collect images in seconds or minutes instead of hours.
- SLS is among the leaders in x-ray tomography, resulting in benefits to clinical medicine as well as fundamental and applied sciences. SLS 2.0 will generate more brilliant as well as harder x-ray beams with a larger penetrating power, allowing static and time-dependent tomography for a much larger range of systems.
- The smaller beam produced by SLS 2.0 will enable analysis of sub-micrometre scale protein crystals, a feature currently not achievable at SLS.
- SLS houses the world's premier beamlines for imaging electron states in devices, both buried and at surfaces, and in novel materials. SLS 2.0 will enable collection of such images for small devices of current and future technological importance.

SLS 2.0 will perfectly complement the new x-ray free-electron laser SwissFEL: SLS 2.0 will focus on high (spatial) resolution imaging and spectroscopy at slow time scales (ps to ms) whereas SwissFEL will place emphasis on ultrafast (fs) time domain experiments.

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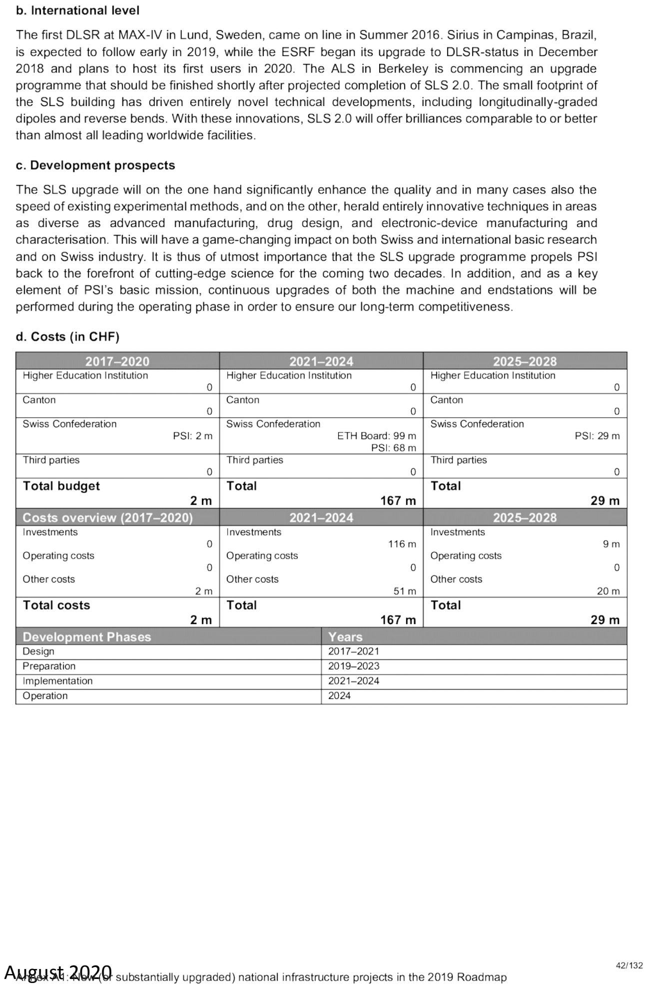
[40] This infrastructure was already listed in the 2015 Roadmap for Research Infrastructures (upgrade for the 2019 Roadmap for Research Infrastructures).



b. International level

The first DLSR at MAX-IV in Lund, Sweden, came on line in Summer 2016. Sirius in Campinas, Brazil, is expected to follow early in 2019, while the ESRF began its upgrade to DLSR-status in December 2018 and plans to host its first users in 2020. The ALS in Berkeley is commencing an upgrade programme that should be finished shortly after projected completion of SLS 2.0. The small footprint of the SLS building has driven entirely novel technical developments, including longitudinally-graded dipoles and reverse bends. With these innovations, SLS 2.0 will offer brilliances comparable to or better than almost all leading worldwide facilities.

c. Development prospects

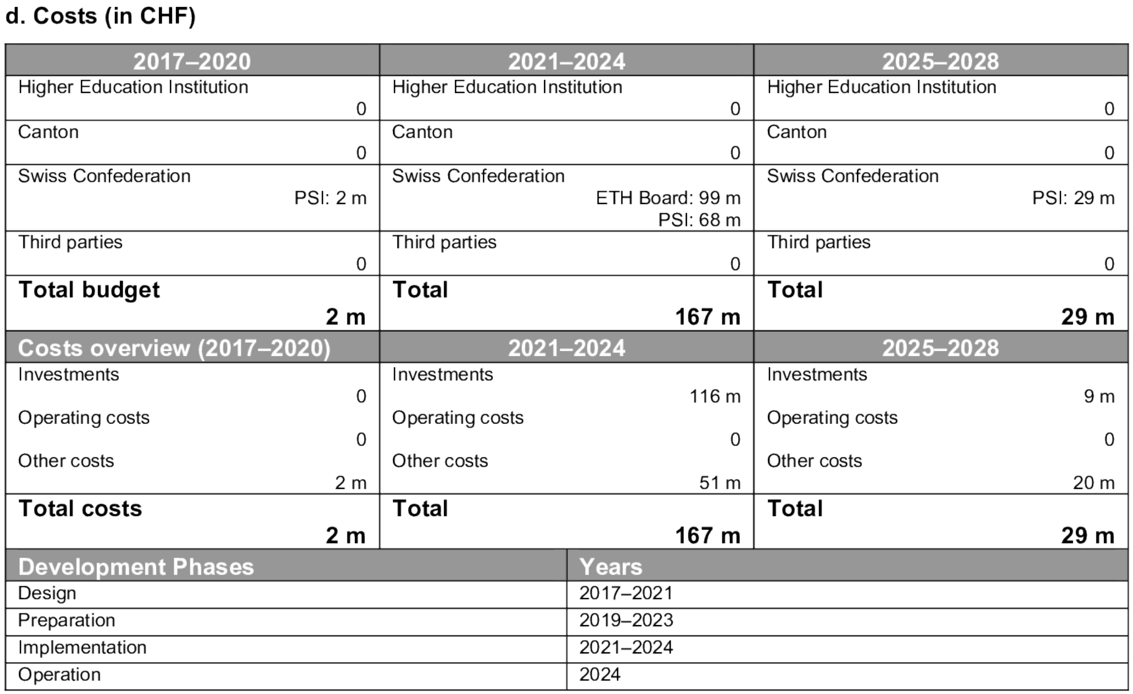
The SLS upgrade will on the one hand significantly enhance the quality and in many cases also the speed of existing experimental methods, and on the other, herald entirely innovative techniques in areas as diverse as advanced manufacturing, drug design, and electronic-device manufacturing and characterisation. This will have a game-changing impact on both Swiss and international basic research and on Swiss industry. It is thus of utmost importance that the SLS upgrade programme propels PSI back to the forefront of cutting-edge science for the coming two decades. In addition, and as a key element of PSI's basic mission, continuous upgrades of both the machine and endstations will be performed during the operating phase in order to ensure our long-term competitiveness.

d. Costs (in CHF)

2017–2020	2021–2024	2025–2028
Higher Education Institution 0	Higher Education Institution 0	Higher Education Institution 0
Canton 0	Canton 0	Canton 0
Swiss Confederation PSI: 2 m	Swiss Confederation ETH Board: 99 m PSI: 68 m	Swiss Confederation PSI: 29 m
Third parties 0	Third parties 0	Third parties 0
Total budget **2 m**	**Total** **167 m**	**Total** **29 m**
Costs overview (2017–2020)	**2021–2024**	**2025–2028**
Investments 0 Operating costs 0 Other costs 2 m	Investments 116 m Operating costs 0 Other costs 51 m	Investments 9 m Operating costs 0 Other costs 20 m
Total costs **2 m**	**Total** **167 m**	**Total** **29 m**

Development Phases	Years
Design	2017–2021
Preparation	2019–2023
Implementation	2021–2024
Operation	2024

SLS 2.0 on the 2019 roadmap



d. Costs (in CHF)

2017–2020	2021–2024	2025–2028
Higher Education Institution 0	Higher Education Institution 0	Higher Education Institution 0
Canton 0	Canton 0	Canton 0
Swiss Confederation PSI: 2 m	Swiss Confederation ETH Board: 99 m PSI: 68 m	Swiss Confederation PSI: 29 m
Third parties 0	Third parties 0	Third parties 0
Total budget **2 m**	**Total** **167 m**	**Total** **29 m**
Costs overview (2017–2020)	**2021–2024**	**2025–2028**
Investments 0 Operating costs 0 Other costs 2 m	Investments 116 m Operating costs 0 Other costs 51 m	Investments 9 m Operating costs 0 Other costs 20 m
Total costs **2 m**	**Total** **167 m**	**Total** **29 m**

Development Phases	Years
Design	2017–2021
Preparation	2019–2023
Implementation	2021–2024
Operation	2024

Other PSI projects on the 2023 roadmap

- **High-Intensity Muon Beamline (HIMB):**
  - New target M at HIPA, collecting muons with large acceptance.
  - Concept study coordinated by Andreas Knecht (NUM) and Daniela Kiselev (GFA).
- **Terbium-149 isotope production at HIPA (TATTOOS):**
  - Produce clinically relevant amounts of Tb-149 isotopes by sending 100 µA of the HIPA 590 MeV proton beam (peeled off) to a spallation target. Bake out online, surface or laser resonance ionization and mass separation.
  - TATTOOS stands for *“Targeted Alpha Therapy using Terbium and Other Oncological Solutions”*
  - Concept study coordinated by Robert Eichler and Nick van der Meulen (NES) and Daniela Kiselev (GFA).
- **Or other projects (suggestions welcome, but time is running out)**
  - Electron diffraction station?
  - Dedicated small storage for UV radiation? Not needed anymore after latest SLS-2.0 changes!(?)

Porthos: 2025–28 or later?

- Several options are considered for the timing of Porthos:
  - **Full realization in ERI period 2025–28.** May be challenging after SLS-2.0!
  - **Partial realization in ERI period 2025–28** (e.g. switchyard with undulator prototypes), with the rest being realized in the period 2029–32 (staging the project).
  - **Postpone to ERI period 2029–32.** After three periods of electron facilities, give the proton facility a chance for a significant upgrade.
  - Regardless of the chosen option, we must deliver a cost estimate for the full project!
- Note: Gabriel Aeppli wants Porthos to be realized in 2025–28 for three reasons:
  1) We must prevent PSI from taking a "wrong turn" in 2025 by focusing on proton upgrades!
  2) By 2030, the high-rep.-rate machines in Stanford and Shanghai will dominate the scene and pressure will be high for PSI to follow suit with SwissFEL 2.0… We must make sure that all four beamlines of SwissFEL 1.0 are well underway by then!
  3) SwissFEL must become more economical by providing more beamlines (more like a synchrotron).

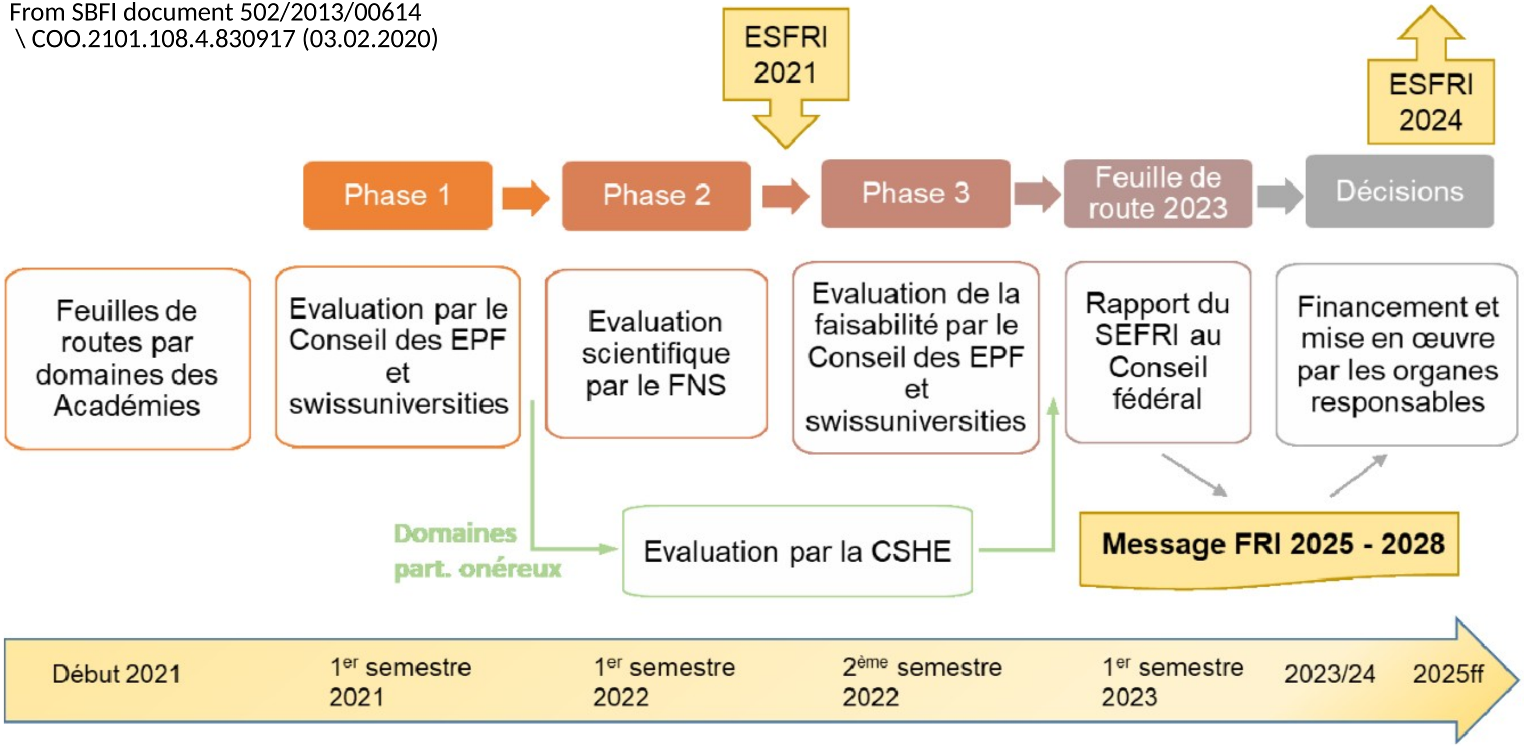
Roadmap process

- The process towards the roadmap 2023 is expected to be very similar to the process that led to the last roadmap (2019).
- From the “Leitfaden” to the roadmap 2019, as well as an SBFI communication from 3 Feb. 2020, we may infer the following timeline (translated to the 2025–28 ERI period):

Phase	Date	Procedural steps
Preparatory phase	during 2020	SCNAT prepares discipline specific roadmaps
	Dec. 2020–Feb. 2021	SERI prepares the roadmap process.
Phase I	March–Dec. 2021	First assessment by ETH board and swissuniversities for facilities in their respective areas – requires a **two-page fact sheet**
Phase II	Jan.–Aug. 2022	Scientific evaluation by SNF – requires a **conceptual design report!** Only the highest ranked facilities proceed to the next level
Phase III	Jan.–Dec. 2022	In-depth assessment of technical and financial feasibility, again by ETH board and swissuniversities for their respective facilities
Phase IV	Jan.–Aug. 2023	SERI finalizes the roadmap report and presents it to the federal council.
Decisions	Dec. 2024	Federal council presents ERI dispatch with recommended support for facilities to parliament, which votes on the dispatch. (The decision to actually build or upgrade a facility still rests with the ETH board or swissuniversities.)
Implementation	2025–2028	Realization by ETH institutions / universities

Roadmap process 2023

From SBFI document 502/2013/00614
\ COO.2101.108.4.830917 (03.02.2020)



ESFRI 2021

ESFRI 2024

Phase 1 → Phase 2 → Phase 3 → Feuille de route 2023 → Décisions

Feuilles de routes par domaines des Académies

Evaluation par le Conseil des EPF et swissuniversities

Evaluation scientifique par le FNS

Evaluation de la faisabilité par le Conseil des EPF et swissuniversities

Rapport du SEFRI au Conseil fédéral

Financement et mise en œuvre par les organes responsables

Domaines part. onéreux

Evaluation par la CSHE

Message FRI 2025 - 2028

Début 2021

1er semestre 2021

1er semestre 2022

2ème semestre 2022

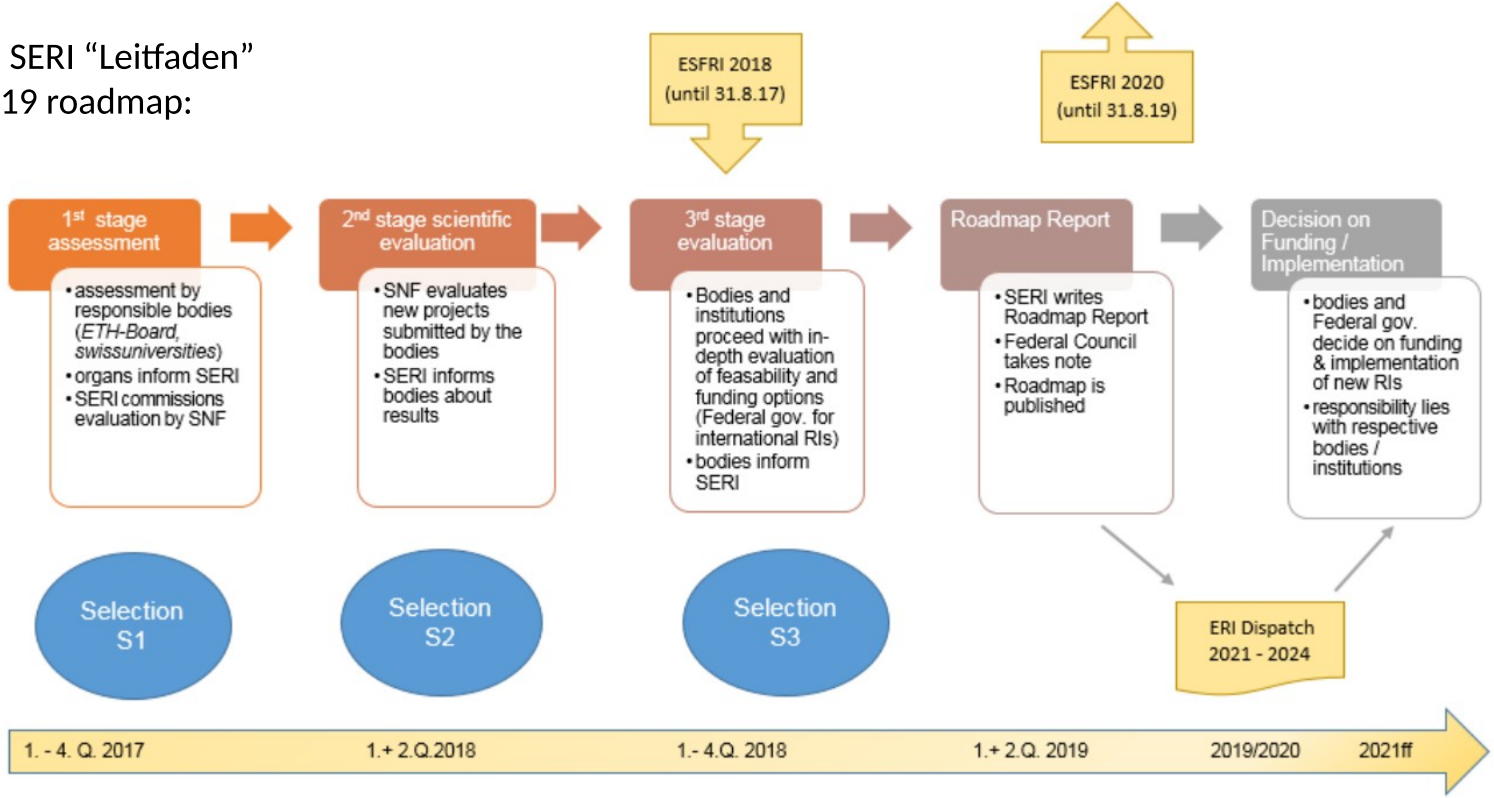
1er semestre 2023

2023/24

2025ff

Roadmap process 2019

From the SERI “Leitfaden”
to the 2019 roadmap:



ESFRI 2018
(until 31.8.17)

ESFRI 2020
(until 31.8.19)

1st stage assessment
- assessment by responsible bodies (*ETH-Board, swissuniversities*)
- organs inform SERI
- SERI commissions evaluation by SNF

2nd stage scientific evaluation
- SNF evaluates new projects submitted by the bodies
- SERI informs bodies about results

3rd stage evaluation
- Bodies and institutions proceed with in-depth evaluation of feasability and funding options (Federal gov. for international RIs)
- bodies inform SERI

Roadmap Report
- SERI writes Roadmap Report
- Federal Council takes note
- Roadmap is published

Decision on Funding / Implementation
- bodies and Federal gov. decide on funding & implementation of new RIs
- responsibility lies with respective bodies / institutions

Selection S1

Selection S2

Selection S3

ERI Dispatch
2021 - 2024

1. - 4. Q. 2017

1.+ 2.Q.2018

1.- 4.Q. 2018

1.+ 2.Q. 2019

2019/2020

2021ff

Source: https://www.sbfi.admin.ch/dam/sbfi/en/dokumente/2017/03/ch-roadmap-2019.pdf.download.pdf/170308_Leitfaden_Roadmap_2019_SBFI_DE.pdf

Preparatory phase: discipline specific roadmaps

- In preparation of the actual roadmap, the SERI asks the SCNAT for roadmaps of individual communities, e.g., photon science.
- These discipline specific roadmaps then form the basis for the actual SERI roadmap:

- The specific roadmap for photon science is prepared by the **Swiss Society for Photon Science** (SSPh). The FEL part in that roadmap is prepared by **Rafael Abela.**

Swiss Society for Photon Science

https://naturalsciences.ch/organisations/scnat/for_a_solid_science/networks_and_infrastructures/research_infrastructures

PSI/ETH internal timeline

Phase I	March–Dec. 2021	First assessment by ETH board and swissuniversities for facilities in their respective areas

ETH timetable (info from I. Günther-Leopold):

21 April 2021	**ETH council meeting:** first discussion of project ideas. **⇒ for this a two-page fact sheet is needed! (close to what actually goes into the roadmap)**
early July 2021	**ETH closed session** (“Klausur”): in-depth discussion of projects
September 2021	**Notification of SNF** on ETH projects planned for the '23 roadmap
January 2022	**Submission of final requests to SNF for evaluation**

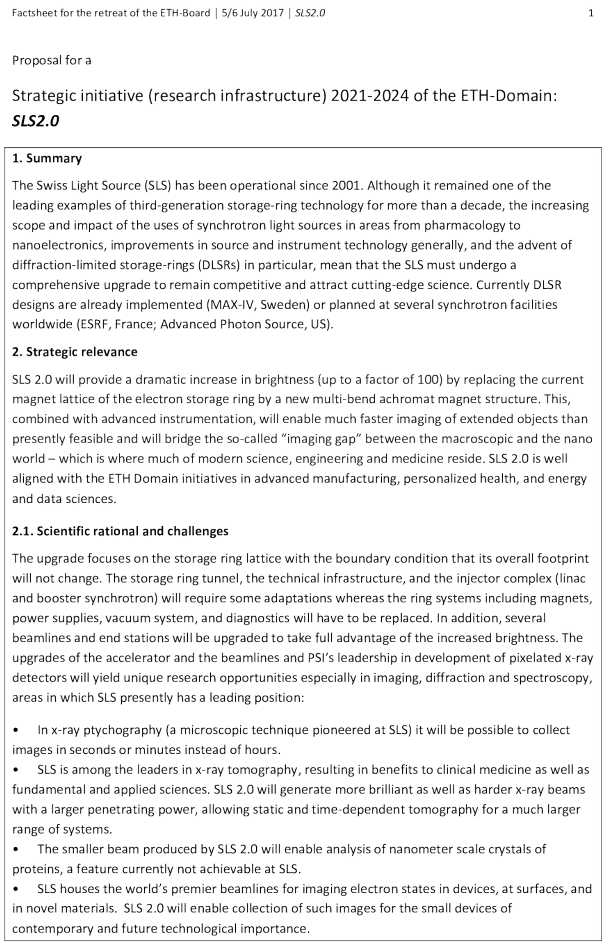
From this we can infer a rough **PSI timetable** (to be updated as more information becomes available):

early March 2021	**Internal deadline for PSI evaluation** (two-page fact sheet with supporting material)

Earlier meetings for intermediate discussions:

14/15 Dec. 2020	**Photon Science Advisory Committee (PSAC)**
13 October 2020	**SwissFEL Strategy Board (SSB)**

Fact sheet: example SLS 2.0



Proposal for a

Strategic initiative (research infrastructure) 2021-2024 of the ETH-Domain: *SLS2.0*

1. Summary

The Swiss Light Source (SLS) has been operational since 2001. Although it remained one of the leading examples of third-generation storage-ring technology for more than a decade, the increasing scope and impact of the uses of synchrotron light sources in areas from pharmacology to nanoelectronics, improvements in source and instrument technology generally, and the advent of diffraction-limited storage-rings (DLSRs) in particular, mean that the SLS must undergo a comprehensive upgrade to remain competitive and attract cutting-edge science. Currently DLSR designs are already implemented (MAX-IV, Sweden) or planned at several synchrotron facilities worldwide (ESRF, France; Advanced Photon Source, US).

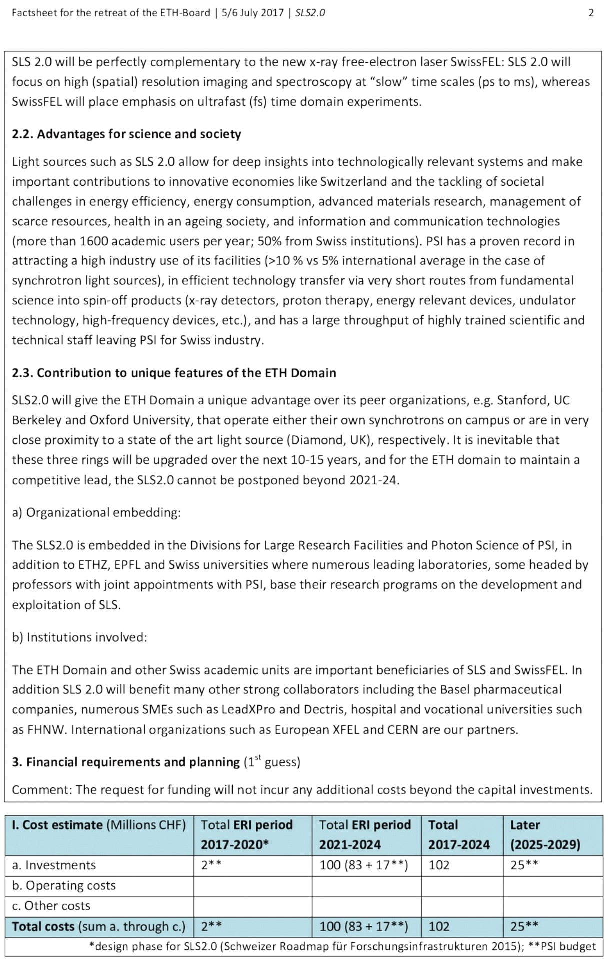
2. Strategic relevance

SLS 2.0 will provide a dramatic increase in brightness (up to a factor of 100) by replacing the current magnet lattice of the electron storage ring by a new multi-bend achromat magnet structure. This, combined with advanced instrumentation, will enable much faster imaging of extended objects than presently feasible and will bridge the so-called "imaging gap" between the macroscopic and the nano world – which is where much of modern science, engineering and medicine reside. SLS 2.0 is well aligned with the ETH Domain initiatives in advanced manufacturing, personalized health, and energy and data sciences.

2.1. Scientific rational and challenges

The upgrade focuses on the storage ring lattice with the boundary condition that its overall footprint will not change. The storage ring tunnel, the technical infrastructure, and the injector complex (linac and booster synchrotron) will require some adaptations whereas the ring systems including magnets, power supplies, vacuum system, and diagnostics will have to be replaced. In addition, several beamlines and end stations will be upgraded to take full advantage of the increased brightness. The upgrades of the accelerator and the beamlines and PSI's leadership in development of pixelated x-ray detectors will yield unique research opportunities especially in imaging, diffraction and spectroscopy, areas in which SLS presently has a leading position:

- In x-ray ptychography (a microscopic technique pioneered at SLS) it will be possible to collect images in seconds or minutes instead of hours.
- SLS is among the leaders in x-ray tomography, resulting in benefits to clinical medicine as well as fundamental and applied sciences. SLS 2.0 will generate more brilliant as well as harder x-ray beams with a larger penetrating power, allowing static and time-dependent tomography for a much larger range of systems.
- The smaller beam produced by SLS 2.0 will enable analysis of nanometer scale crystals of proteins, a feature currently not achievable at SLS.
- SLS houses the world's premier beamlines for imaging electron states in devices, at surfaces, and in novel materials. SLS 2.0 will enable collection of such images for the small devices of contemporary and future technological importance.



SLS 2.0 will be perfectly complementary to the new x-ray free-electron laser SwissFEL: SLS 2.0 will focus on high (spatial) resolution imaging and spectroscopy at "slow" time scales (ps to ms), whereas SwissFEL will place emphasis on ultrafast (fs) time domain experiments.

2.2. Advantages for science and society

Light sources such as SLS 2.0 allow for deep insights into technologically relevant systems and make important contributions to innovative economies like Switzerland and the tackling of societal challenges in energy efficiency, energy consumption, advanced materials research, management of scarce resources, health in an ageing society, and information and communication technologies (more than 1600 academic users per year; 50% from Swiss institutions). PSI has a proven record in attracting a high industry use of its facilities (>10 % vs 5% international average in the case of synchrotron light sources), in efficient technology transfer via very short routes from fundamental science into spin-off products (x-ray detectors, proton therapy, energy relevant devices, undulator technology, high-frequency devices, etc.), and has a large throughput of highly trained scientific and technical staff leaving PSI for Swiss industry.

2.3. Contribution to unique features of the ETH Domain

SLS2.0 will give the ETH Domain a unique advantage over its peer organizations, e.g. Stanford, UC Berkeley and Oxford University, that operate either their own synchrotrons on campus or are in very close proximity to a state of the art light source (Diamond, UK), respectively. It is inevitable that these three rings will be upgraded over the next 10-15 years, and for the ETH domain to maintain a competitive lead, the SLS2.0 cannot be postponed beyond 2021-24.

a) Organizational embedding:

The SLS2.0 is embedded in the Divisions for Large Research Facilities and Photon Science of PSI, in addition to ETHZ, EPFL and Swiss universities where numerous leading laboratories, some headed by professors with joint appointments with PSI, base their research programs on the development and exploitation of SLS.

b) Institutions involved:

The ETH Domain and other Swiss academic units are important beneficiaries of SLS and SwissFEL. In addition SLS 2.0 will benefit many other strong collaborators including the Basel pharmaceutical companies, numerous SMEs such as LeadXPro and Dectris, hospital and vocational universities such as FHNW. International organizations such as European XFEL and CERN are our partners.

3. Financial requirements and planning (1st guess)

Comment: The request for funding will not incur any additional costs beyond the capital investments.

I. Cost estimate (Millions CHF)	Total **ERI period 2017-2020***	Total **ERI period 2021-2024**	**Total 2017-2024**	**Later (2025-2029)**
a. Investments	2**	100 (83 + 17**)	102	25**
b. Operating costs				
c. Other costs				
Total costs (sum a. through c.)	2**	100 (83 + 17**)	102	25**

*design phase for SLS2.0 (Schweizer Roadmap für Forschungsinfrastrukturen 2015); **PSI budget

Working group (machine)

Topics and associated people (machine):

Beam dynamics:	Sven Reiche, Eduard Prat, Eugenio Ferrari
Undulators:	Marco Calvi
LLRF:	Zheqiao Geng
Kicker:	Martin Paraliev
Timing & Synch., SwissFEL int.:	Florian Löhl
Diagnostics:	Rasmus Ischebeck
Laser systems:	Alexandre Trisorio
Building/infrastructure:	Ivo Widmer
Cryogenics: (und., quads, chicanes)	Carolin Zoller
RF and FCC-ee integration:	Paolo Craievich

Invited for information: Mike Seidel, Hans Braun, Daniela Kiselev, Marco Stampanoni (coordinator of photon science working group)

Organization of the working group(s)

- Machine and photon science working groups work independently (first)
  - avoid a crowd of 20 people for working group meetings;
  - the two groups require very different organization (tiny beam dynamics group, huge scientific crowd!)
  - no time to lose if a concept has to be circulated in early March!!

- Marco and Thomas meet every two weeks for status updates

- Machine working group will meet **once per month** for exchanges and updates (but experts are encouraged to interact more frequently if needed!)
  - Suggested dates until the end of the year: 22 Sept., 27 Oct., 24 Nov.
(SSB on 1 Dec., PSAC on 14–15 Dec.)
  - Hybrid meetings until further notice.
  - Let me know when you are ready to give an updated (I will let you know when you have to give an update…)

How many options to consider?

- **Management opinions:**
  - G. Aeppli: “You should come up with a technical menu of options, from which the science guys can choose.”
  - M. Seidel: “In the end there should be two options for discussion.”

- My take: the machine group should initially come up with **3–4 feasible options** covering a varying range of user demands and cost.
  - e.g. tender versus hard X-rays, NC (affordable) versus SC (expensive) undulators…

- These options should then be compared to the user evaluation (running in parallel) to **converge on two options to be followed up in detail.**

- **Joint meeting of the two working groups** towards the end of the year to decide on options?

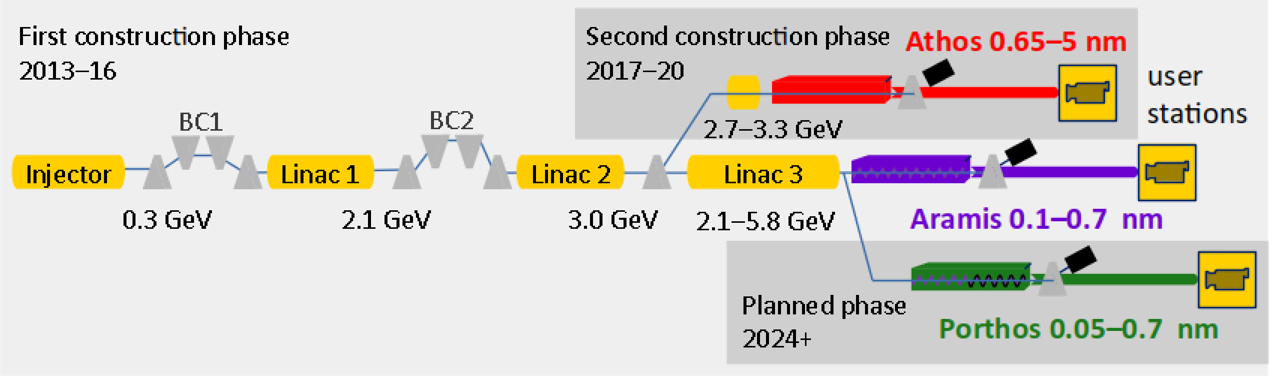
Porthos within SwissFEL

Athos:

Soft X-ray FEL, λ=0.65–5.0 nm

Variable polarization, Apple-X undulators

First users 2021



Linac:

Pulse duration : 1–20 fs

Electron energy : up to 5.8 GeV

Electron bunch charge : 10–200 pC

Repetition rate: 100 Hz (2-bunches)

Aramis:

Hard X-ray FEL, λ=0.1–0.7 nm

Linear polarization, variable gap,
in-vacuum undulators

First users 2018

Porthos:

Hard X-ray FEL, λ=0.05–0.7 nm

Linear polarization, fix gap,
super conducting undulators

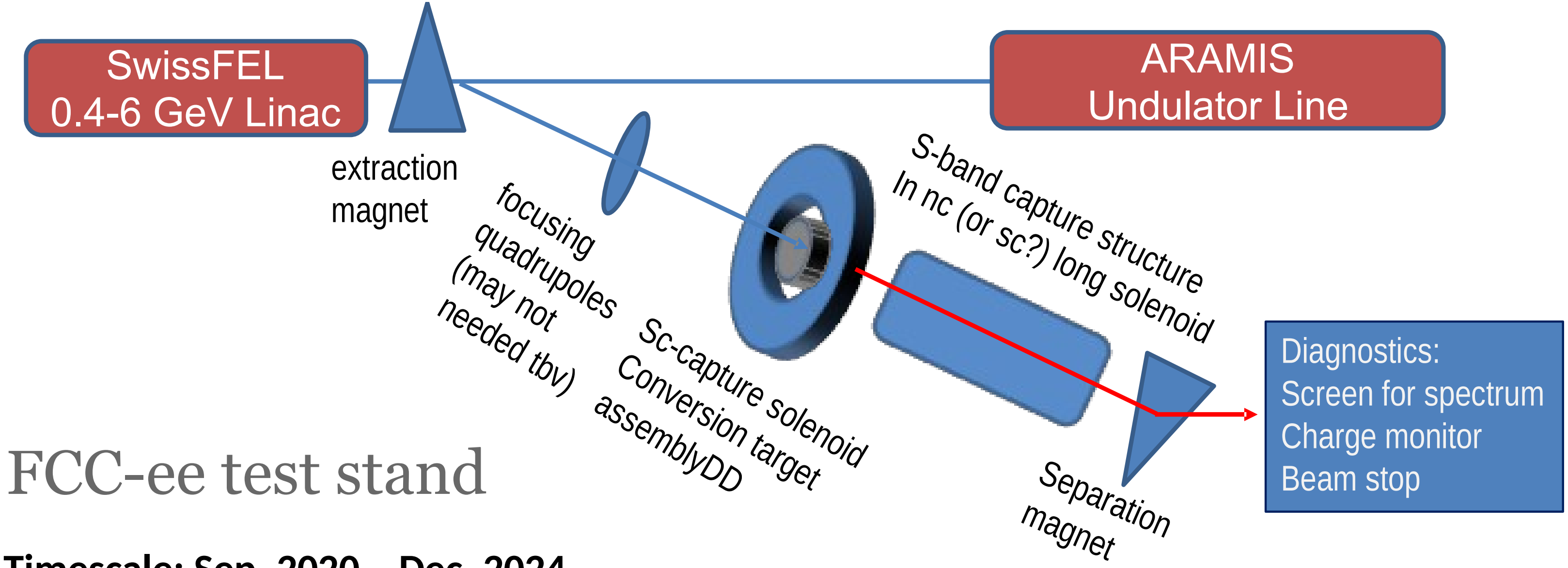
Start of construction: 2025+

S. Reiche

Porthos boundary conditions

- **Existing infrastructure**
  - 100 Hz repetition rate (unless we go for SwissFEL 2.0)
  - 3–6 GeV electron energy
  - about 100 m undulator length (building space)
- **Technological feasibility**
  - E.g. undulator $0 < K < 2.5$
- **Financial envelope**
  - 50–100 MCHF (G. Aeppli, 14 August 2020)
- **Parallel operation with Aramis**
  - Cannot easily use e-beam energy to tune photon wavelength
- **D'Artagnan to come after Porthos**
  - The Porthos evaluation should be done in the context of a fourth beamline, which will complete the “SwissFEL portfolio”

Another boundary condition(?)



Diagnostics:
Screen for spectrum
Charge monitor
Beam stop

FCC-ee test stand

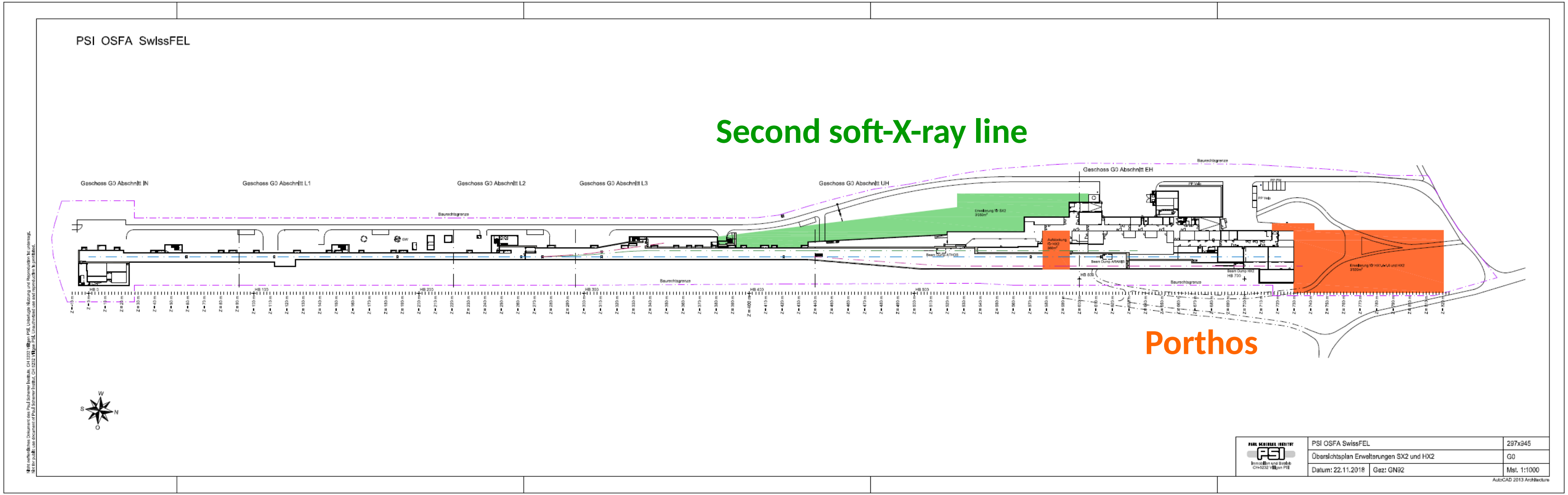
Timescale: Sep. 2020 – Dec. 2024

Synergies? Conflicts? Radiation?
To be evaluated!...

From: P. Craievich, A. Grudiev, CHART proposal "FCC-ee Injector Design and Test Stand at PSI" (March 2020)

SwissFEL space reservations

In the original construction zoning provisions for both additional soft- and hard-X-ray line


Second soft-X-ray line

Porthos

SwissFEL building extensions

For Porthos:

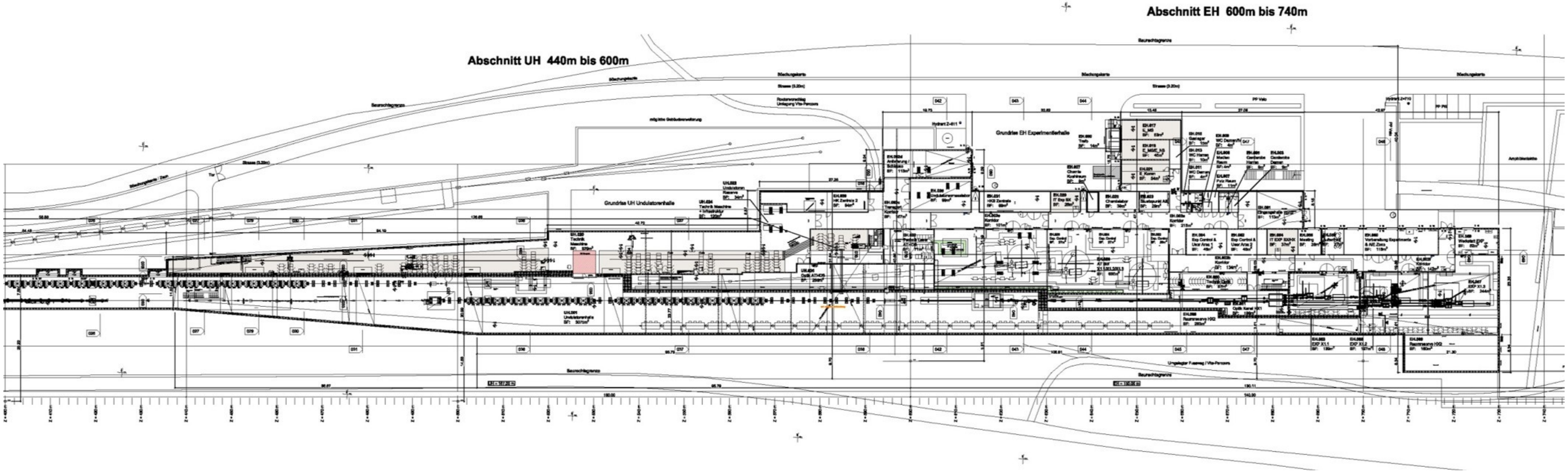
- Space for undulator line and optical hutch available in existing building
- Space reservation for experimental hall (today's “entrance triangle”)

Second soft-X-ray line

additional storey
for Porthos

Porthos

Detailed layout of Porthos line



A wide spectrum of options…

Upgrade existing Aramis with CHIC	**“No Porthos”**
Build a copy of the Aramis line (double the capacity)	**“Aramis clone”**
Build a copy of the Aramis line but with CHIC	**“Aramis + CHIC”**
Undulators optimized for CHIC (shorter)	**“CHIC Porthos”**
Longer-period undulators for tender X-rays	**“Tender Porthos”**
Superconducting undulators (for higher photon *or* more flexibility)	**“SC Porthos”**
Build a separate FEL to seed Porthos (FEL^2)	**“Seeded Porthos”**
High rep.-rate superconducting machine	**“SwissFEL 2.0”**

A wide spectrum of options…

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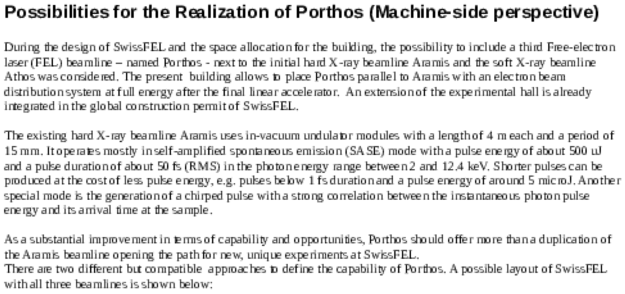
Build a separate FEL to seed Porthos (FEL²)	**“Seeded Porthos”**
High rep.-rate superconducting machine	**“SwissFEL 2.0”**

too boring!

too expensive!

Summary of options for SSPh roadmap

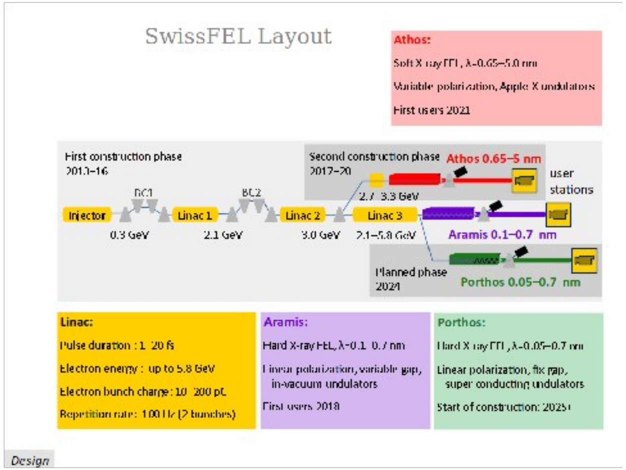


Possibilities for the Realization of Porthos (Machine-side perspective)

During the design of SwissFEL and the space allocation for the building, the possibility to include a third Free-electron laser (FEL) beamline – named Porthos - next to the initial hard X-ray beamline Aramis and the soft X-ray beamline Athos was considered. The present building allows to place Porthos parallel to Aramis with an electron beam distribution system at full energy after the final linear accelerator. An extension of the experimental hall is already integrated in the global construction permit of SwissFEL.

The existing hard X-ray beamline Aramis uses in-vacuum undulator modules with a length of 4 m each and a period of 15 mm. It operates mostly in self-amplified spontaneous emission (SASE) mode with a pulse energy of about 500 uJ and a pulse duration of about 50 fs (RMS) in the photon energy range between 2 and 12.4 keV. Shorter pulses can be produced at the cost of less pulse energy, e.g. pulses below 1 fs duration and a pulse energy of around 5 microJ. Another special mode is the generation of a chirped pulse with a strong correlation between the instantaneous photon pulse energy and its arrival time at the sample.

As a substantial improvement in terms of capability and opportunities, Porthos should offer more than a duplication of the Aramis beamline opening the path for new, unique experiments at SwissFEL.
There are two different but compatible approaches to define the capability of Porthos. A possible layout of SwissFEL with all three beamlines is shown below:



Athos:
Soft X-ray FEL, λ=0.65–5.0 nm
Variable polarization, Apple X undulators
First users 2021

Linac:
Pulse duration: 1–20 fs
Electron energy: up to 5.8 GeV
Electron bunch charge: 10–200 pC
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Linear polarization, variable gap, in-vacuum undulators
First users 2018

Porthos:
Hard X-ray FEL, λ=0.05–0.7 nm
Linear polarization, fix gap, super conducting undulators
Start of construction: 2025+

⇒ see Sven's presentation!

Homework assignment for the next meeting

- Think about Porthos… what would it mean for your area of expertise?
  - For many areas, the details of the chosen option are irrelevant: gun laser, LLRF (three-bunch operation), resonant kicker, building extension, diagnostics (PM or SC options), FCC-ee integration,…
  - In these areas we can go ahead full steam with the conceptual work and cost estimates!
- Beam dynamics, undulators: explore the extremes within (and slightly beyond) the given boundary conditions
  - *Show* what is possible at what cost.
  - *Explain* what is not possible or sensible (but might be asked by users), e.g.,
    - Circular polarization?
    - EEHG?

Objective: management table of options

Option (examples)	"SC Porthos A"	"SC Porthos B"	"Tender Porthos"	Porthos XY
science capabilities *(uniqueness?)*				
main risks				
estimated cost				

Thank you for your participation!