

Annual Report of MAX IV Laboratory

2019



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1 2019 in brief

MAX IV has 16 funded beamline projects. By the end of 2019, twelve of these were "taking light", four of which were in commissioning, and eight in general user operation. Procurement and construction of the remaining four beamlines are well underway, including for the ForMAX and MicroMAX beamline projects, the two most recently funded. At the close of 2019, MAX IV had more beamlines (twelve versus eleven) taking light than MAX-lab did at its peak in 2014. In particular, all five planned beamlines on the 1.5 GeV ring have been commissioned with three in general user operation, and the last two prepared to accept users in March 2020. Completing the planned beamline portfolio on the 1.5 GeV ring serves a long-standing Swedish soft X-ray spectroscopy and imaging community. MAX IV Biolab, a laboratory that supports Life Science experiments on various beamlines, opened during spring.

MAX IV users and staff together published almost 90 papers in 2019, rapidly adding to the science portfolio of the facility. The impact of MAX IV papers is growing as well, with notable publications in *Science Advances*, *Nature Communications*, and *Nature Chemical Biology*.

User proposal calls have been held twice per year since February 2019, in synchrony with a twice-yearly maintenance/installation shutdown schedule. The past two calls generated over 450 proposals. The quality of proposals received as rated by the Programme Advisory Committee (PAC) is also quite high, making the allocation of limited beamtime slots difficult on the most heavily subscribed beamlines. The number of users coming to MAX IV increased substantially from 2018. Between 1 March 2019 and 29 February 2020, MAX IV Laboratory had 662 users from 140 different institutions and 30 different countries.

As the MAX IV Laboratory user program is growing so is the amount of data produced. The Knut & Alice Wallenberg Foundation (KAW) has awarded MAX IV funds for the development of long-term data storage and services. The DataSTaMP-project started on 1 July 2019 and will run for five years.

MAX IV accelerators continued to perform superbly, and all three accelerator systems delivered X-ray light to beamlines 24/7 with very high reliability throughout 2019. The goals defined in late 2018 for the number of delivery hours as well as for accelerator performance and reliability have all been met or surpassed, except for the repetition rate during delivery of the beam to the short pulse facility (SPF), which remained at 2 Hz instead of the planned 10 Hz. The evolution of accelerator delivery and performance over the past three years shows a healthy improvement in all parameters, reaching world level for availability and coming close to the maximum (roughly 5 000) number of hours of yearly delivery to beamlines to be expected over the next years. Particularly noteworthy is the fact that downtime fraction (percentage of scheduled beam time during which the beam was not delivered) in the 3 GeV ring has been reduced by almost a factor three since the first year of general user operations. Accelerator performance and reliability goals for 2020 follow a similar trend with the major changes being 10 Hz delivery for the FemtoMAX beamline (attached to the SPF) and increase of the delivery current in the 1.5 GeV ring from the present 400 mA to 500 mA.

VR conducted reviews of MAX IV in July 2018, February 2019, and November 2019. The purpose of these reviews was to monitor how MAX IV is progressing toward operations and how the recommendations from previous reviews are being implemented and to give MAX IV principle advice on how to deal with any potential problems identified during the reviews. As with the July 2018 review, the focus of the February and November 2019 reviews was on project management; however, the November review also evaluated MAX VI's transition from projects

to the operational phase. The report written by the November review committee provided detailed findings and comments, a summary of MAX IV's progress on previous review recommendations, and a list of ten recommendations. The recommendations focused on communicating to stakeholders the expected consequences if current funding is not increased to meet budgetary needs, development of a science strategy to exploit the unique characteristics of MAX IV, and specifics concerning handling risks, scope, cost and schedule for effective project management. The November review committee further noted that *"We are delighted to learn that the committee concludes that significant progress can be identified regarding both the project management system, as well as in the development of the beamlines, since the last review held in February 2019. We are convinced that the project is now moving in the right direction."*

MAX IV began development in spring 2019 of a strategic plan with a decadal outlook to define the most compelling scientific priorities for the laboratory, using methodologies that best exploit MAX IV's unique characteristics. This effort began with a brief update to the 2016 MAX IV Strategy Report and several user-driven workshops at the annual MAX IV User Meeting held in September 2019. The plan was shared, and initial discussions were held with key advisory bodies and stakeholders starting in summer 2019. The next step is to engage leading scientists in Sweden to organise a series of workshops on focused science cases targeting grand challenges in the life, environmental, energy, materials, and physical sciences. The end-goal of this strategic planning effort is to develop compelling science cases and a roadmap for developing major new technical capabilities, including up to ten new beamlines, to build out the full capacity of MAX IV.

2 Organisation and staff

At the end of 2019, MAX IV Laboratory had 254 employees, see Figure 1. All parts of the organisation have been strengthened by new recruitments, although the vast majority have been of staff members for beamlines and to the Controls & IT group as more beamlines have

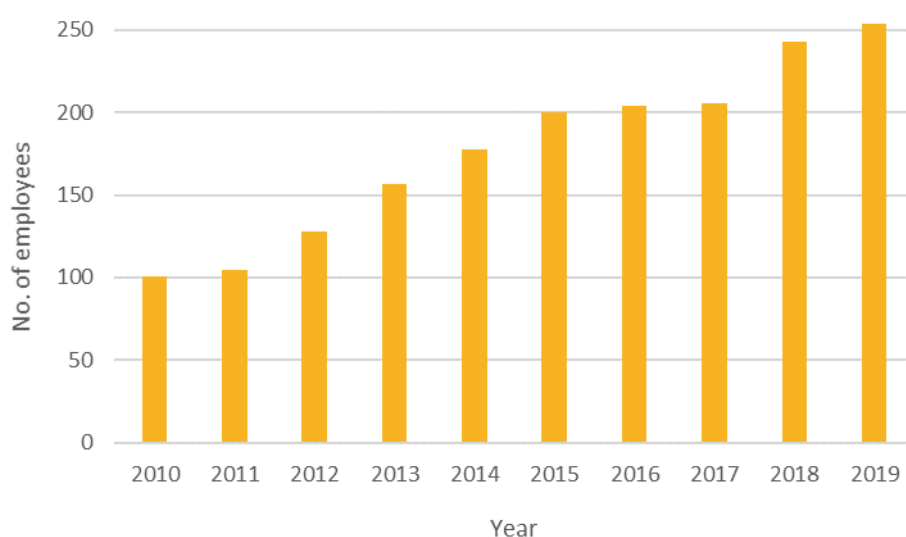


Figure 1. End of year numbers of MAX IV Laboratory employees for the years 2010-2019

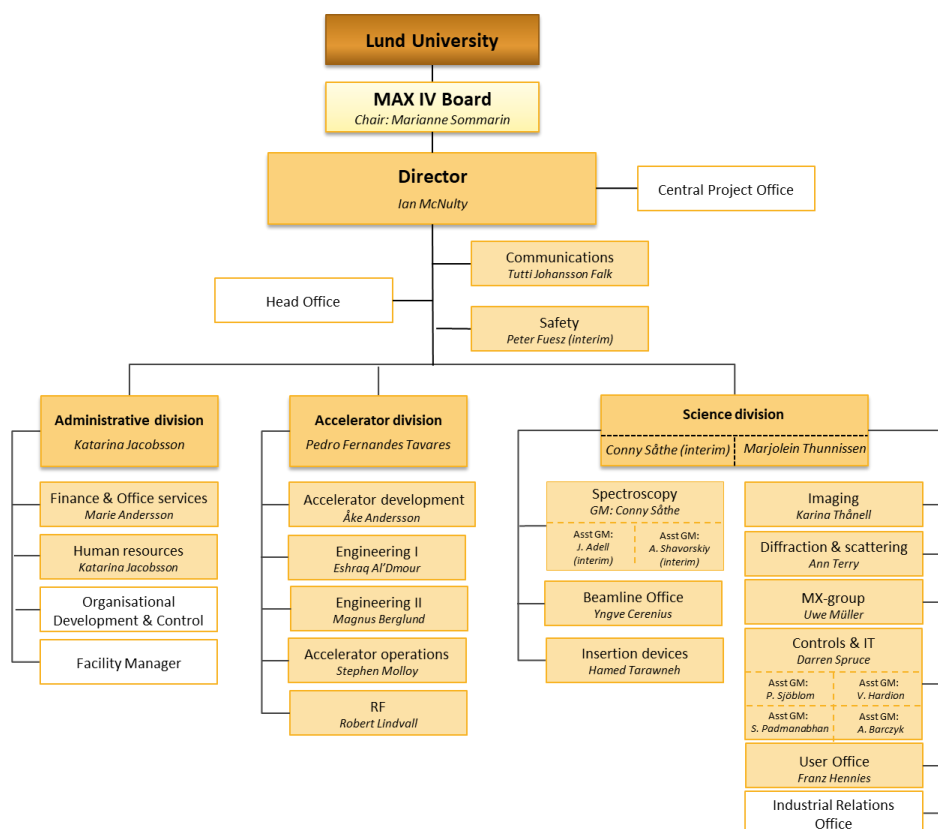


Figure 2. MAX IV organisation (31 December 2019)

become operational. About one-third of MAX IV employees are from countries other than Sweden. For MAX IV to be successful in its professional growth, we advertise most of the new recruitments internationally to reach adequate target groups. International recruitments place higher demands on the recruitment process and are often more time consuming and involving more stakeholders such as Swedish authorities and relocation services. In 2019, a working group was established and started the work to review processes, routines and templates to further improve our way of working with recruitment, to develop and improve the quality of the recruitment process.

Figure 2 shows the MAX IV Laboratory organisation as of 31 December 2019. In September 2019, Ian McNulty was appointed Director of MAX IV Laboratory. Conny Sâthe, group manager for the Spectroscopy group, was appointed interim Physical Science Director.

The term for the MAX IV Laboratory Board expired 31 December 2019. At its December meeting, the Lund University Board assigned new Board members nominated by a panel with representatives from Lund University, the Swedish Research Council (VR) and the Universities reference group for research infrastructure (URFI). The members of the MAX IV Board from 1 January 2020 are:

- Peter Honeth, former State Secretary, Chair
- Torbjörn Holmström, Senior Advisor to the CEO Volvo Group
- Professor Ingmar Persson, Swedish University of Agricultural Sciences
- Professor Massimo Altarelli, EuXFEL/Max Planck Institut
- Professor Paula Eerola, University of Helsinki, Finland
- Anna Sandström, Astra Zeneca
- Professor Stacey Sörensen, Lund University
- Professor Lise Arleth, University of Copenhagen
- Professor Aleksandar Matic, Chalmers University of Technology

3 Accelerator development

Following the development of a professional, dedicated accelerator operations group in 2018, the year 2019 was marked by an increase in the number of delivered beam hours in all three accelerators comprising the MAX IV facility. At the same time, a healthy decrease in downtime (or equivalently increase in availability) was also observed and is a result of the systematic work set in motion already the year before in order to identify, classify and subsequently address the root causes of downtime. This systematic work aims to both avoid new beam losses via preventive maintenance and to streamline our ability to recover from problems once they occur through increased availability of spare parts, improved documentation, and learning appropriate lessons from each downtime event. Therefore, this work will extend the mean time between failures and decrease the mean time to recover from them.

With the facility going into its third year of general user operations, it is now possible to identify longer-term trends as illustrated in the plots below (Figures 3, 4 and 5). Note, in particular, a nearly three-fold reduction in down time in the 3 GeV ring from 2017 to 2019 (Figure 3).

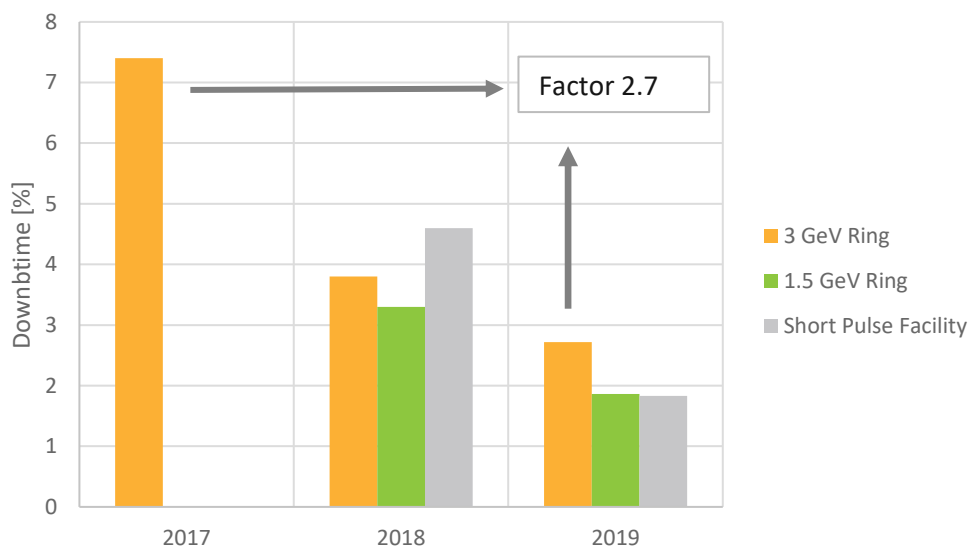


Figure 3. Evolution of accelerator downtime (ratio of downtime hours to planned delivery hours).

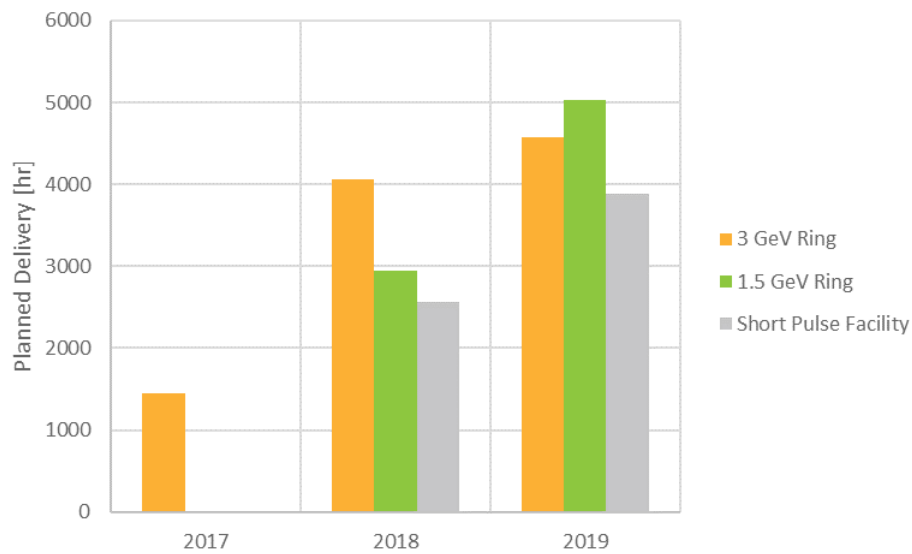


Figure 4. Evolution of yearly planned delivered hours to beamlines in the MAX IV Accelerators.

Work on a conceptual design report (CDR) for a future soft-X ray laser beamline (SXL) that can use the 3 GeV MAX IV linear accelerator as a driver, has continued. A meeting with the SXL CDR Scientific Advisory Committee was held in May. Two main modes of operation of the linear accelerator have been identified in the simulation and design work done so far. They both use the existing bunch compressors in the MAX IV linear accelerator (linac) to generate the required peak currents that allow lasing at the desired 1-5 nm wavelength: one aims at pulse durations of a few tens of femtoseconds whereas a second alternative aims at pulses as short as a few femtoseconds. Relevant progress in the CDR work includes the decision to change the undulator module length from three metres to two metres in order to open the door to a number of advanced schemes and an increased attention to the analysis of the sensitivity of beam parameters to various jitter sources.

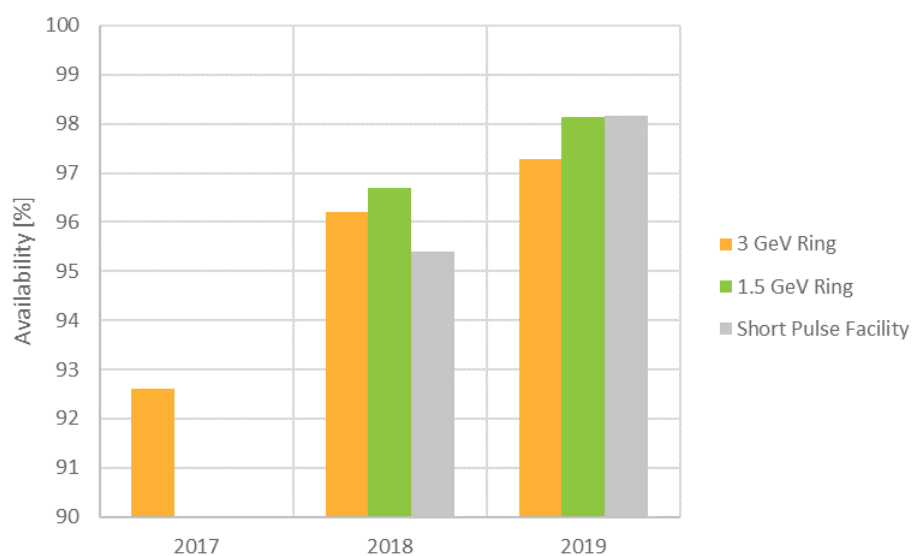


Figure 5. Evolution of yearly accelerator availability (ratio of actually delivered hours to planned delivered hours).

3.1 Technical highlights of the linear accelerator include:

- 1) Fabrication of a new radiofrequency (RF) photo-cathode low emittance gun designed for higher repetition rates (up to 100 Hz).
- 2) Start of commissioning of the Gun Test Facility (GTF), in which new guns can be conditioned and characterised. The GTF will allow further developments and research into high brightness electron sources and also serves as a hot spare to the pre-injector section of the MAX IV linac.
- 3) Demonstration of injection into the rings using the photo-cathode RF gun instead of the thermionic RF gun, providing redundancy of a critical system.
- 4) Improved beam trajectory stability enabled the operation of the insertion devices in the short pulse facility at minimum 2.6 mm gap.

3.2 Technical highlights of the 3 GeV storage ring include:

- 1) Installation and successful commissioning of a new multipole injection kicker (MIK) developed in collaboration with the French Synchrotron SOLEIL. The MIK allows achieving world-leading minimisation of perturbations to the stored beam during top-up.
- 2) Routine delivery of up to 250 mA to users in top-up mode.
- 3) Improved slow orbit feedback running at up to 10 Hz.
- 4) Implementation and first successful tests of a fast-orbit feedback system (with acquisition rates of 10 kHz) aimed at minimising perturbations generated by insertion device gap and phase motion.
- 5) Installation of the sixth main cavity in preparation for increase power needs as more insertion devices are installed.

3.3 Technical Highlights of the 1.5 GeV ring include

- 1) Routine delivery of 400 mA to users in multi-bunch top-up mode.
- 2) Demonstration of > 90 mA stored current in single-bunch mode.
- 3) Delivery of > 20 mA in single-bunch mode for pilot tests at the beamlines.
- 4) Hardware implementation of an insertion device compensation scheme for correction of linear optics perturbations caused by insertion devices. Commissioning with beam is planned for 2020.
- 5) Improvements of radiation shielding to prevent dose budget issues upon beam losses at high current.
- 6) Successful tests of implementation of transverse resonance island buckets, a potential mechanism for providing pseudo single-bunch mode capability.

4 Beamline development

The first seven beamlines (Balder, BioMAX, Bloch, FemtoMAX, HIPPIE, NanoMAX and Veritas) were funded by the Knut and Alice Wallenberg Foundation (KAW) together with twelve Swedish Universities¹ in 2011. In 2012 Estonia and Finland financed the construction of the eighth

¹ Chalmers University of Technology, Gothenburg University, Karlstad University, Karolinska Institutet, KTH Royal Institute of Technology in Stockholm, Linköping University, Luleå University of Technology, Lund University, Stockholm University, Swedish University of Agricultural Sciences (SLU), Umeå University and Uppsala University

beamline, FinEstBeAMS. These first eight beamlines constitute the Phase I beamlines. In 2013, KAW and VR funded the Transfer Package, three beamlines (SPECIES, FlexPES and MAXPEEM) consisting of moved and upgraded instruments from MAX-lab. In addition, VR funded two new beamlines, CoSAXS and SoftiMAX. These five beamlines represent the Phase II beamlines. The Danish Agency for Science and Higher Education, the Capital Region of Denmark and the Central Denmark Region fund together with the Technical University of Denmark, Aarhus University and the University of Copenhagen, the DanMAX beamline. In 2017 KAW granted funding for the construction of the ForMAX beamline, and the Novo Nordisk Foundation (NNF) awarded funding for the MicroMAX beamline. At the end of 2019, MAX IV had sixteen funded beamlines.

Eight beamlines (Table 1) were in general user operation by autumn 2019. FemtoMAX, FlexPES and SPECIES have had expert users to contribute to the commissioning of these beamlines. The installation of ForMAX infrastructure started in October. The MicroMAX optics detailed design report (DDR) was successfully reviewed by external evaluators in March 2019.

The first remote-controlled experiments, in which the user submitted their samples to MAX IV and then controlled the data collection remotely, were performed at the BioMAX beamline in October by one of our industrial user groups.

Table 1. Number of user visits to beamlines and instruments at MAX IV Laboratory 1 March 2019 to 29 February 2020.

Beamline	User visits
Balder	154
BioMAX	308
Bloch	49
FemtoMAX*	11
FinEstBeAMS	109
FlexPES*	32
HIPPIE	89
MAXPEEM	29
NanoMAX	135
SPECIES-APXPS*	12
Veritas	17
Total	945

** Beamlines in commission*

5 User operations

User statistics in this report covers the period 1 March 2019 to 29 February 2020. By the end of this period, eight beamlines were in operation and received general users (Table 1). In addition, the FemtoMAX, FlexPES and SPECIES-APXPS beamlines have been open to expert users. In total, MAX IV Laboratory had 945 user visits by 662 individual users between 1 March 2019 to 29 February 2020. The user gender distribution was 33% women and 67% men.

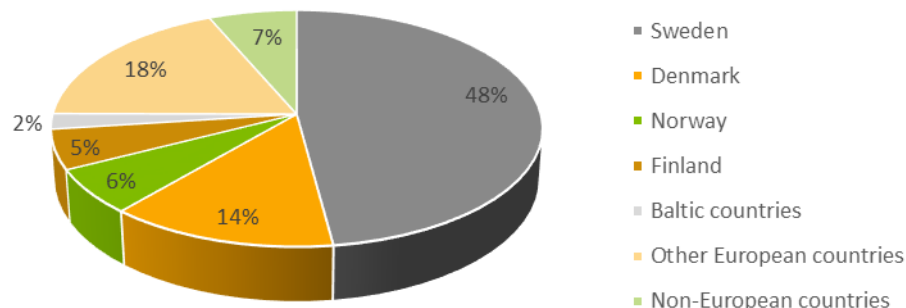


Figure 6. Distribution of users' home institution, 1 March 2019 to 29 February 2020

The vast majority of users between 1 March 2019 to 29 February 2020 came from the Nordic countries, Figure 6. In total, MAX IV had users from 30 different countries and 140 various institutions in this period.

There were two general user calls in 2019. The spring call (closed 19 March) for beamtime at Balder, BioMAX, Bloch, HIPPIE, FinEstBeAMS, NanoMAX, MAXPEEM and Veritas from September 2019 to February 2020 and the autumn call which closed the 17 September was for beamtime at Balder, BioMAX, Bloch, HIPPIE, FinEstBeAMS, FlexPES, NanoMAX., SPECIES-APXPS and Veritas from March to August 2020. Submitted proposals are sent to one of the Programme Allocation Committees (PAC) for scientific review. In parallel, the proposals are reviewed by

Table 2. Number of proposals per beamline and call in 2019

PAC Research Area	Beamline	Number of proposals spring call*	Number of proposals autumn call^
Structural Biology	BioMAX [#]	28 (11 BAG)	12 (3 BAG)
Chemistry	Balder	45	36
Nano sciences	MAXPEEM	13	N/A
	NanoMAX	47	44
	Bloch	17	21
Spectroscopy	FinEstBeAMS	24	17
	FlexPES	Not open	25
	HIPPIE	51	31
	MAXPEEM	N/A	12
	SPECIES-APXPS*	Not open	16
	Veritas	3	4
	Total	228	218

* spring call (closed 19 March)

^ autumn call (closed 17 September)

[#] includes block allocation group (BAG) proposals

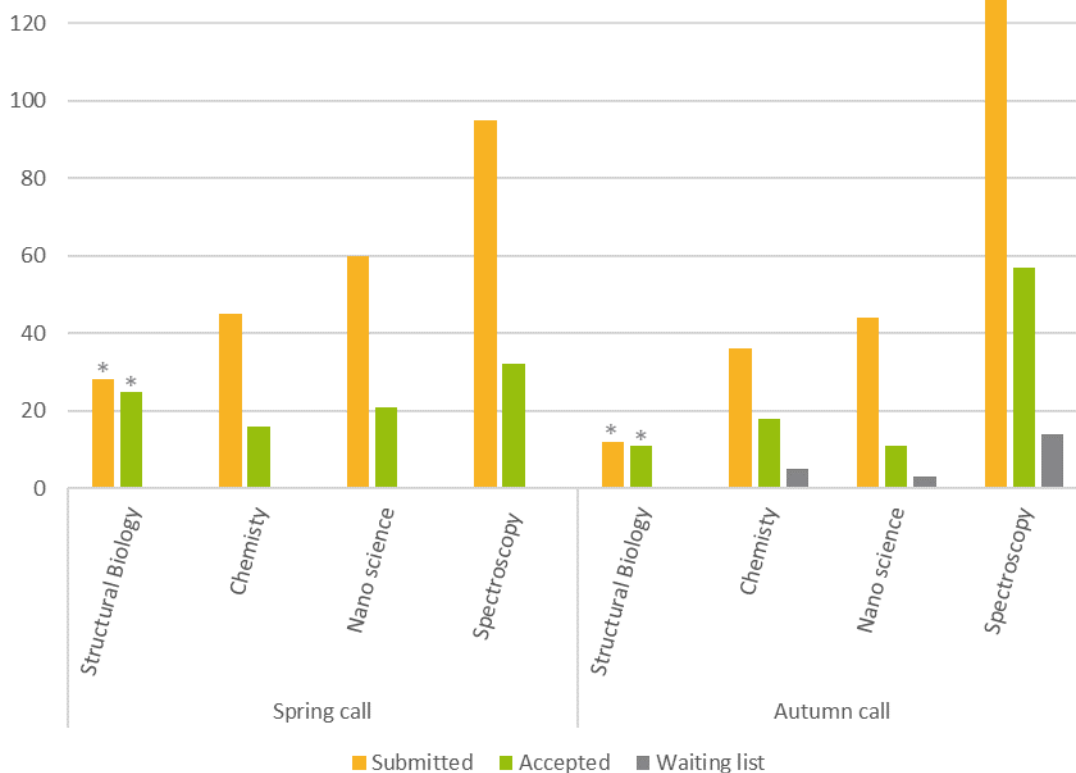


Figure 7. The number of proposals for beamtime per scientific areas to MAX IV Laboratory in the call for proposals 2019. There is no waiting list for the Spring call as the waiting list is cleared after a cycle ends * Proposals for BioMAX include BAG-proposals.

beamline staff for feasibility and our Safety teams performs safety review. Based on the result from these reviews, MAX IV Management takes the final decision on beamtime allocation. The PACs are structured into groups with different fields of expertise, and the proposals are distributed to the relevant PAC group. For the calls in 2019, a new PAC group for chemistry was installed. Table 2 shows the research areas of the different PACs at MAX IV with the including beamlines. As shown in Figures 7 and 8, there were far more requests for beamtime than most of the beamlines can provide for. The highest-ranked proposals were allocated beamtime, and some proposals were put on a waiting list in case more beamtime will become available. Only BioMAX can meet the demand due to the short turn-over time for typical protein crystallography experiments. In 2019, BioMAX commissioned remote access mode, which will increase efficiency and decrease costs for the beamline and its users.

BioMAX is currently the only beamline at MAX IV, which is open for block allocation group (BAG) proposals. In these types of proposals, researchers in large well-established groups can combine their beamtime requests into a single, common proposal to permit greater flexibility in beamtime allocation and scheduling. Accepted BAG proposals are valid for four beamtime cycles (two years). Out of the 40 submitted proposals to BioMAX in the 2019 call, fourteen were BAG-proposals. Taken together, this explains why the number of both submitted and allocated proposals at BioMAX are seemingly smaller than at the other beamlines.

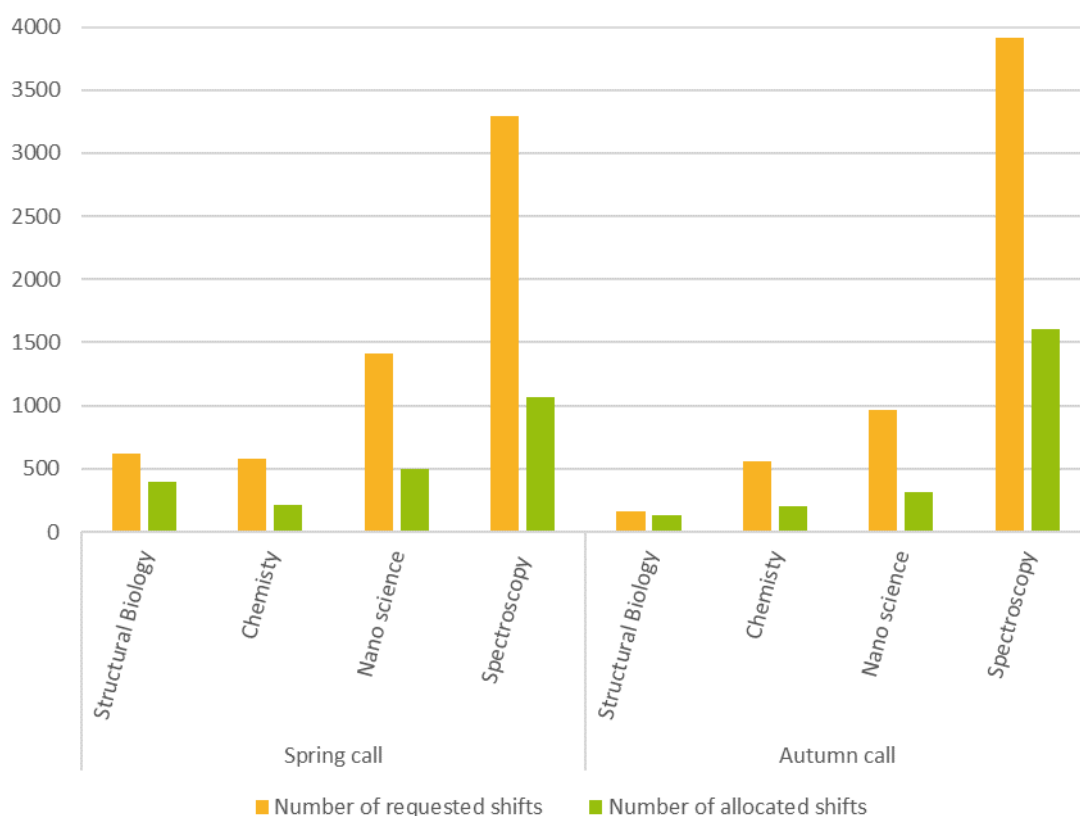


Figure 8. The number of requested and allocated shifts (four hours each) for beamtime at MAX IV Laboratory in the calls for proposals 2019.

MAX IV has dedicated 2 % of the beamtime for education and training initiatives. Eight courses with a total of around 100 participants have had beamtime for educational purposes between 1 March 2019 to 29 February 2020. Together these eight courses were allocated 144 hours of beamtime. Beamlines Balder, NanoMAX, MAXPEEM, BioMAX, Bloch and FlexPES all hosted Education and Training activities.

To our knowledge, MAX IV users and staff together published at least 89 papers in 2019 on beamline and accelerator accomplishments. Thirty-six of these publications arose from work carried out at MAX IV, whereas the remainder derives from prior work carried out at MAX-lab before its shutdown in 2015. As the figures depend on self-reporting by users, usually done in connection with submissions of applications for beamtime, they are underestimated and often lag behind by two to three years. Besides, since the proposal calls in the past three years have addressed a rather limited user community at the operational beamlines at MAX IV Laboratory, there are more unreported publications than usual.

6 Communication and outreach

MAX IV Laboratory operates an extensive outreach program through scientific workshops, conferences and the web site, study visits and social media platforms. During 2019 publications with results from MAX IV have started to come out, hence the Communications group has

Table 3. Visits to www.maxiv.se (thousands)

Visits				Unique visitors				Pageviews			
2019	2018	2017	2016*	2019	2018	2017	2016*	2019	2018	2017	2016*
156	136	100	56	69	55	41	28	541	482	422	203

*The web page was launched May 2016 so numbers should be read with that in mind.

focused on writing news based on those and down-prioritised study visits targeting the general public.

Priority concerning study visits has been given to secondary schools as well as to groups that represent existing or potential users. A group of approximately twelve students (MSc & PhD) from the natural science programs at Lund University are hired on an hourly basis to work as tour guides. 2019 is the fourth year with student employees. Helping with guided tours is a great workplace experience and an introduction to working at MAX IV and could be seen as part of the recruiting efforts. Using university students as guides also give secondary school students that are visiting an opportunity to explore how to pursue a career in STEM (Science, Technology, Engineering and Mathematics).

During 2019, the visitors' centre MAXESS welcomed around 500 visitors from schools, different associations and organisations who were given presentations of MAX IV (and ESS). At the facility itself, approximately 3 000 visitors were received during 2019. Most of these had links to either funding or use of the facility, but visits from the general public are also included.

MAX IV did not arrange any Open Day during 2019 because the so-called *Kulturnatten* coincided with user operations (accelerator running, i.e. safety restrictions). Going forward, Open Days will be planned during summer shutdowns.

The MAX IV web site www.maxiv.se is the primary channel for information and news about the MAX IV Laboratory, its development, technical details on beamlines and examples of the research conducted. To complement, and to lead visitors to the web site, a newsletter is sent out to users and stakeholders on a periodic basis. Table 3 shows the number of visits to the website the past three and a half years.

The social media channels are targeting different groups and interests, and the content posted and language used reflects this – Twitter (English) for the scientific community, Facebook (mainly Swedish) for the geographically close community, LinkedIn (English) for job postings and science and finally Instagram (English) for photos and weekly scientific and technical updates. Table 4 gives an overview of MAX IV Laboratory's activities on different social media channels from 2016 to 2019.

Table 4. MAX IV Laboratory on social media channels

	Followers				Impressions (thousands)		
	2019	2018	2017	2016	2019	2018	2017
Twitter	3 400	2 870	2 400	1 850	341	473	321
Facebook	2 770	2 574	2 400	2 200	100	188	
LinkedIn	4 400	3 441	2 700	2 350	159	164	229
Instagram	1 040	839	625	50			

Development over time. Empty cells indicate that statistics are not available or applicable.

7 Engaging industry

Proprietary beamtime allocated at MAX IV increased in 2019, both in terms of hours and in terms of the number of organisations and beamlines used. In total, 216 hours of proprietary beamtime was sold to eight different organisations at 22 scheduled occasions during 2019. BioMAX is the dominant beamline accepting proprietary users with several pharmaceutical companies and mediator companies buying beamtime; however, HIPPIE, Balder and NanoMAX also served proprietary users. The introduction of remote operation at BioMAX during the autumn was a welcome addition for MAX IV industrial users, and there is an increasing request for remote operation and mail-in services also at other beamlines. Thanks to the introduction of remote operation at BioMAX, beamtime sales were higher than expected. Three new user organisations came to MAX IV through Vinnova funded projects within the program for industrial pilot projects for utilisation of large-scale infrastructures for neutron and photon-based techniques.

The proprietary access of beamlines is an important access mode for companies that do not want to publish their results. However, the most substantial industrial impact of MAX IV comes from academic-industrial collaborations. About a quarter of the proposals that were scheduled for general user beamtime in 2019 declared to have an industrial relation within the project. This result motivates us to continue strengthening industry-academic collaborations to create societal impact from MAX IV.

During 2019 the MAX IV industry relations office (IRO) has significantly strengthened its outreach and engagement towards the soft matter and life science communities. MAX IV IRO continuous the successful work with thematic initiatives and has in 2019 expanded the portfolio with the Food and Packaging sector, Life Science and Textile while continuing the successful work with the Metal industries. With the aim of closer collaboration and finding synergies between the national research infrastructures and a joined activation strategy for the Life Science sector, the relationship with key actors such as the Strategic Innovation Program SweLife and the national infrastructure SciLifeLab have been strengthened. By additional support to HALOS industrial activities and collaboration with the DESY Business Development Office, MAX IV IRO has expanded its Life Science strategy beyond Sweden.

Within the metal science sector, MAX IV IRO has worked with industrial partners within the BIR2Gain project and MetalBeams network for more than three years. The first proprietary experiment outside the field of protein crystallography at MAX IV was from one such company within the metal community.

Table 5 shows industrial outreach activities in 2019 within the different sectors.

In 2019 the MAXESS Industry Arena was formed after an initiative from MAX IV IRO. This working group consisting of members from MAX IV, ESS, Science Village Scandinavia (SVS), RISE and Big Science Sweden aim to enable industrial access to the large scale research infrastructures ESS and MAX IV by developing the facilities and the associated ecosystem of research partners and service providers to match the needs of the industry.

By the end of the year, MAXESS Industry Arena formed a project with seed funding of 0.5 MSEK from the Skåne Region to establish a web platform where mediators, research groups, institutes and facilities with knowledge within the synchrotron and neutron field are made visible for the industry. The project will run throughout 2020.

Table 5. Major outreach activities towards industry in 2019.

Sector/thematic initiative	Activity	Collaborators	Funding
Food and Packaging sector	Workshop Northern Lights on Food, March	RISE, LINXS, LU physical chemistry and Livsmedelskollegiet	Formas
	Working group on Food Science and Technology	LINXS, LU, RISE, Chalmers, SLU, Aarhus University and VTT-Finland	
	Nothorn Lights on Food (NLF) Network	RISE, Chalmers, SLU and Sweden Food Arena/Livsmedelsföretagen	
Life Science	MAXAMedtech workshop, March	Medtech4health SIP	Vinnova
	Nordic Life Science Days		
Metallic materials	MetalBeams seminar, March	Jernkontoret	Vinnova
	Workshop on Metal processing at MAX IV User Meeting, September	Lund University, AlfaLaval	
Energy materials	Energy materials workshop, March	Uppsala University	VR
Wood materials	ForMAX portal workshop, March	Chalmers	VR
Textile	Networking meetings	IKEA, University of Borås, Future by Lund	
Mechanical systems production, Scientific equipment production	Ultra-high vacuum training for companies	Big Science Sweden, RISE, ESS	

8 Collaborations and partnerships

MAX IV Laboratory is actively working to take advantage of the ever-increasing interest from other research facilities, research organisations, companies and scientists worldwide. MAX IV Laboratory participates actively in several projects, for example, LEAPS – League of European Accelerator-based Photon Sources, lightsources.org, PARI – workshop on Public Awareness of Research Infrastructures, EuroScience Open Forum (ESOF), Big Science Business Forum and Big Science Sweden. These projects all aim to raise awareness of synchrotron and/or neutron techniques through targeted outreach both to users, funders and the general public.

The MAX IV KITS (Controls and IT) group are part of the Horizon 2020 funded project, ExPaNDS (EOSC Photon and Neutron Data Services) that started in September and runs to 2022 together with ten other research infrastructures. ExPaNDS's ambition is to enrich the European open science cloud with data management services, to coordinate activities to facilitate national

photon and neutron research infrastructures to make the majority of their data ‘open’ following FAIR principles and to enable sharing of data in a uniform way.

BioMAX and the FragMAX platform are partners in the Horizon 2020 funded project iNEXT-Discovery, which brings together facilities for X-rays, NMR, cryo-EM and macromolecular biophysics. The aims are to make the facilities accessible to new user communities, develop the methods further through joined research efforts, and offer better integration between scientific fields and within the field of structural biology, through scientific meetings, practical courses, and training workshops. This project started on the 1 February 2020 and will run to 2023.

A collaboration with Vilnius University, Lithuania, was initiated during the year in which joint education and research projects in spectroscopy will be implemented.

At the end of 2019, the Swedish Institute granted funding for the continuation of a scholarship program where researchers from the Middle East, in connection to SESAME synchrotron in Jordan, receive training in Sweden. The program aims to let younger researchers and doctoral students get experience in synchrotron science, build networks and then bring their new knowledge home to continue their research at SESAME and contribute to the development of science in the region. The first round of fellows in 2019 came from Iran, Pakistan and Egypt.

An important event to bring users and MAX IV Laboratory staff together is the annual User Meeting. The 2019 meeting, held during 23–25 September in Lund, combined sessions discussing the status and prospects of different aspects of MAX IV Laboratory with parallel sessions covering the science that will be supported at MAX IV Laboratory and a poster session. The meeting attracted more than 300 users and other stakeholders from Sweden and abroad, and from academia as well as industry. Several satellite meetings were held in connection to the user meeting.

9 Financial report with comments

With 2019, a new five-year funding period of the operation of MAX IV Laboratory started. In 2019 MAX IV operation was supported by the Swedish Research Council (VR) under contract 2018-07152, Lund University, Swedish universities², the Swedish Governmental Agency for Innovation Systems (Vinnova) under contract 2018-04969, and Formas under contract 2019-02496. The Academy of Finland also contributed to the operations funding.

The 2019 funding, costs, and result (finding-cost) figures for operations at MAX IV Laboratory are found in Table 6.

² Chalmers University of Technology, Gothenburg University, Karlstad University, Karolinska Institutet, KTH Royal Institute of Technology in Stockholm, Linköping University, Linnæus University, Luleå University of Technology, Lund University, Malmö University, Stockholm University, Swedish University of Agricultural Sciences (SLU), Umeå University and Uppsala University

Table 6. Funding, costs, and result for 2019 (MSEK)

(MSEK)

FUNDING	Result 2019	Budget 2019	Diff
Research council	310	310	
Lund University	53	54	-1,0
Swe universities cash contribution	42,1	43,2	-1,1
Vinnova	15	15	
Energimyndigheten	0	5	-5,0
Formas	5	5	
Essence IT	,5	,5	
LP3	-,5	-,5	
Operations contribution Finland	4,0	,0	4,0
Industrial beamtime and services	1,3	,3	1,0
Other income	4,9	3,4	1,5
TOTAL FUNDING	435	436	-1

COST	Result 2019	Budget 2019	Diff
Staff	-168,0	-170,7	2,7
Central Project Office	-4,0	-3,3	-,7
Accelerators (AFSG, RF, AccDev, Op)	-19,0	-28,4	9,5
Life science beamlines	-5,9	-7,6	1,8
Physical science beamlines	-5,4	-5,8	,4
Beamline office & Insertion Device	-3,6	-4,2	,6
IT & Controls	-14,1	-14,5	,4
Engineering	-5,3	-7,6	2,3
Safety	-5,7	-7,4	1,7
Admin support (FIOS, HR, Procur, Legal)	-7,2	-9,0	1,7
User Office, IRO, COM, Head office	-2,8	-3,9	1,1
DanMAX	-6,6	-9,4	2,8
Rent	-66,4	-61,6	-4,8
Electricity	-21,3	-14,0	-7,3
Facility cost	-18,5	-18,5	
Logistics & Technical Service	-5,9	-7,9	2,1
Pavilions	-,2	-5,0	4,8
Ph 1 project (NLF funding gap)	-3,4	-3,4	
DM Ex contingency	-7,0	-7,2	,2
Decommissioning MAX IV	-1,0	-1,0	
Lund University overhead	-21,8	-21,8	
TOTAL COST	-393,1	-412,2	19,0

RESULT (FUNDING-COST)	42,2	23,7	18,4
MAX IV co-funding external projects	-4,7	-1,7	
Indirect cost external projects	4,7	4,7	
RESULT INCL EXTERNAL PROJECTS	42,2	26,7	15,5
Upkeep - planned allocation of VR grant	-15,2	-15,4	
Change in undepreciated funds	-41,4	-25,7	
TOTAL RESULT	-14,4	-14,4	

9.1 Comments to the outcome in MAX IV operations

MAX IV delivered the budgeted result of -14.4M and hence a corresponding decrease in agency capital. The outgoing agency capital in 2019 is 31.8M.

Overall the spending was somewhat lower than planned, which added to operations funding being transferred into 2020 (41M instead of budgeted 26M). A transfer was planned in budget 2019 in order to balance increasing costs in the coming years to flat funding (see budget item change in undepreciated funds in Table 6).

Funding

All operations funding for 2019 was secured except for the payment of 5M from Energimyndigheten that they transferred to 2020.

The agreement between 14 Swedish universities to contribute to the funding of MAX IV operations resulted in a cash contribution of 42 M and in-kind contributions equivalent to 6 M in 2019.

A renewed agreement with the Academy of Finland was put in place during the year covering 2019-2021 with an amount of 350 KEUR per year.

Beamtime sales substantially exceeded the budget, see section *Engaging Industry* for details.

As other income, we account for revenue from recycled heat, various re-invoicing, hosted conferences and guesthouse revenue, some of which was not in the budget or underestimated.

Cost

Staff cost is approximately 2 % below budget as a result of prolonged recruitment processes, unforeseen leave of absences and staff turnover.

The accelerator group reports lower spending, due to delays in ordering parts, although not affecting the accelerators current performance.

The rent differs because the STIBOR interest was raised earlier (Dec-18) than what was assumed in the budget (Feb-18). The current interest rate projection from Sweden's National Bank indicates continued low-interest rates, which is favourable for MAX IV.

Engineering has a centralised budget for cooling and vacuum components, and this was, to a large extent, not utilised in 2019.

Budget costs for office densification were taken already in 2018 and in addition, the need for consultancy support within areas concerning the facility, legal and HR did not materialise as planned, hence the deviation in Admin support.

Co-funding of DanMAX construction project continues into 2020.

Electricity prices soared last winter, resulting in a major budget deviation. The projected consumption was, however, on point.

A mid-term solution for extended office space (pavilions) was investigated and budgeted presuming MAX IV would receive additional operations funding to hire more staff. The MAX IV Board did not approve this project to go ahead.

10 Financial outlook

Until the end of 2019, we assumed that an additional 50 MSEK/year for 2021-2023, requested per the original application to VR to meet the planned growth in operational costs of the MAX IV beamline portfolio, would be granted. This additional funding has not yet been secured. The long-term financial plan (LTP) for MAX IV was based on operations cost increases expected to meet the planned growth, but with the funding secured to date, it showed an increasing gap totalling approximately 150 MSEK by 2023. The MAX IV Board requested at its meeting on 28 November 2019 that the 2020 and future budgets are to be balanced.

We aligned the LTP to the secured funding by applying these cost-reduction measures:

- Discontinuing the MAX IV in-house postdoctoral program. Operations funding will no longer be allocated for unfilled postdoc positions, and expiring positions will not be refilled. Postdocs funded by external grants are not affected.
- Reducing accelerator upkeep portfolio, beamline upkeep, and other investment allocations principally supporting MAX IV infrastructure.
- Releasing agency capital.

It is likely that further budgetary adjustments will be necessary beyond 2020 to balance the budget through 2023 in light of increasing operational costs, as the construction of the full planned suite of 16 beamlines is completed and transitions into operations. These adjustments include reducing the number of staff supporting development activities to enable hiring more staff for beamline and safety user support. In addition to operations funding uncertainties after 2023, the current commitment by fourteen Swedish universities to contribute approximately 50 MSEK per year of co-funding of MAX IV operations will end.

The direct effects of flat operations funding at the current level are:

- Hiring slowdown: It will be difficult to make up for personnel losses (disaffection, job mismatch, attrition) during the near term. Limited staff would need to share more tasks and be less specialised. There will be fewer possibilities for in-house research. Delivery of planned beamline capabilities to users will slow down. Beamline user support will decrease.
- Reducing upkeep: Implementation of beamline sample environments beyond baseline will be limited. Opportunities to replace detectors and other instruments with the latest technology to keep beamlines at the forefront will decrease. Full implementation of fast orbit feedback (3 GeV ring and 1.5 GeV ring) and Phase 2 of the RF power plants in the 3 GeV ring will be delayed.

Due to the long time scales associated with hiring personnel, the current funding environment has already impacted beamline user support and thus full utilisation of MAX IV. Without additional operations funding, the expected long-term consequences include less productivity, more rapid ageing, increased exposure to the risk of component failure, and decreased ability to maintain the facility at the state of the art. Ultimately, these consequences will make MAX IV less attractive to the user community for the most compelling and challenging experiments. Overall, the impact to the research community will be slower delivery of planned and future capabilities and reduced user operations.

Appendix 1. List of Abbreviations

BAG	Block Allocation Group
CDR	Conceptual Design Report
DataSTaMP	Data Storage and Management Project
DDR	Detailed Design Report
ESS	European Spallation Source
EUXFEL	European XFEL
eV	Electron Volt
FEL	Free Electron Laser
GTF	Gun Test Facility
IRO	Industrial Relations Office
KAW	Knut and Alice Wallenberg Foundation
KITS	Controls and IT-group
KTH	KTH Royal Institute of Technology, Stockholm
LEAPS	League of European Accelerator-based Photon Sources
Linac	Linear Accelerator
LINXS	Lund Institute Of Advanced Neutron And X-Ray Science
LTP	Long-term financial plan
LU	Lund University
MAX IV	MAX IV Laboratory
MIK	Multipole Injection Kicker
NLF	Nothern Lights on Food
PAC	Programme Allocation Committee
RF	Radio Frequency
RISE	Research Institutes of Sweden
SIP	Strategic Innovation Programmes
SLU	Swedish University of Agricultural Sciences
SPF	Short Puls Facility
STEM	Science, Technology, Engineering and Mathematics)
SVS	Science Village Scandinavia
SXL	Soft X-ray Laser
URFI	Universities reference group for research infrastructure
Vinnova	Swedish Governmental Agency for Innovation Systems
VR	The Swedish Research Council/