Elettra 2.0: The Italian 4rd Generation Synchrotron Radiation Facility

Elettra Sincrotrone Trieste

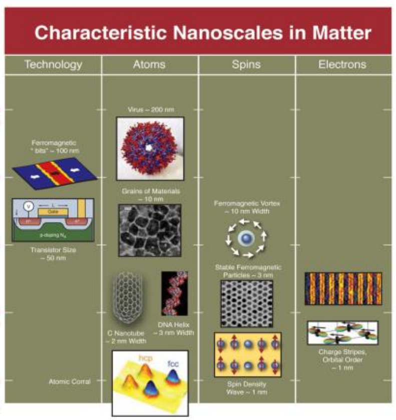
- ***Introduction***
- ***Elettra***
- ***Elettra 2.0***

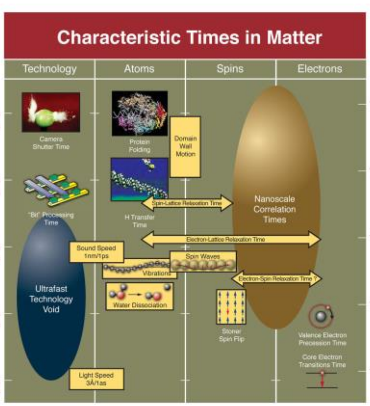
Emanuel Karantzoulis

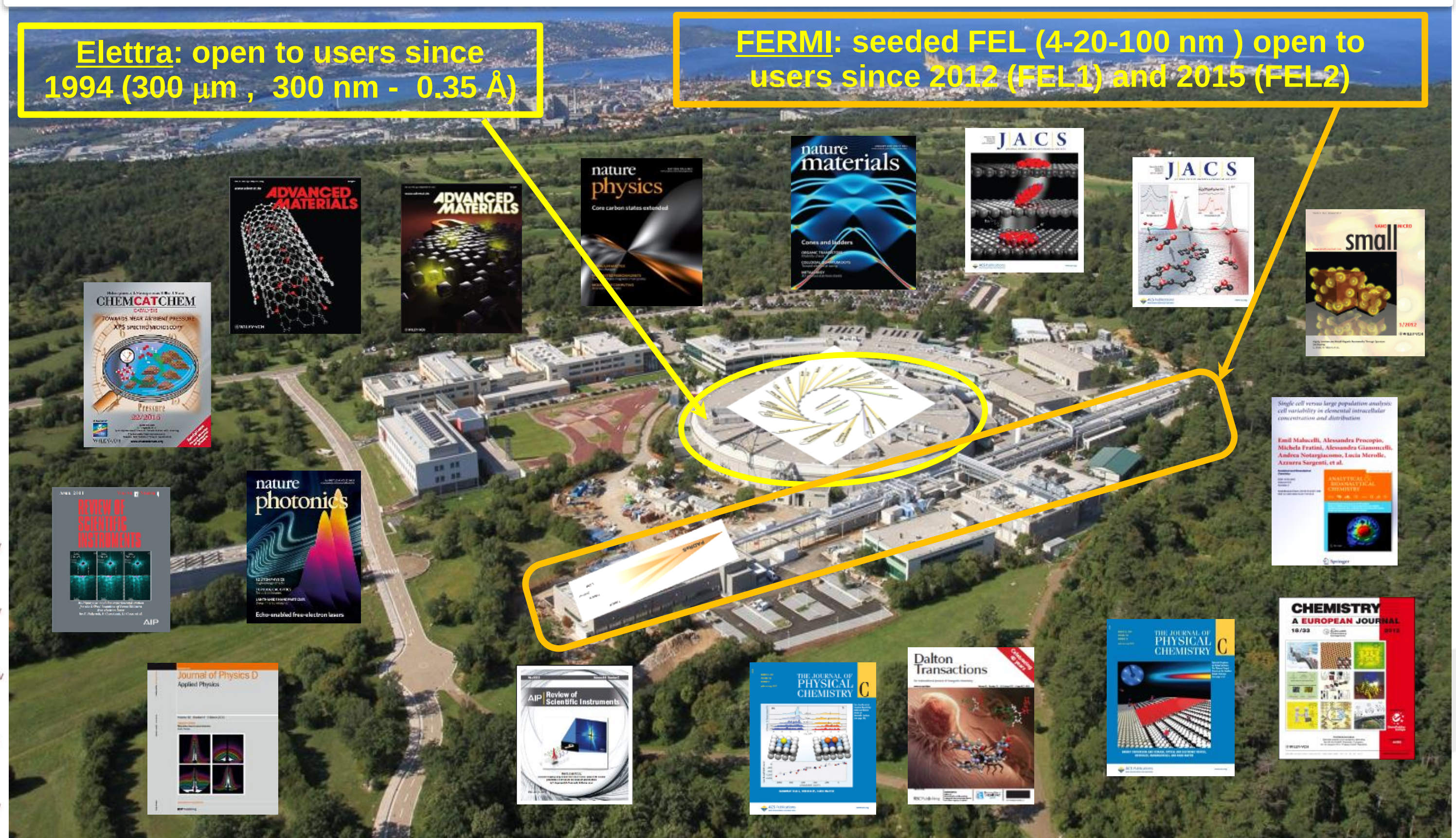
on behalf of the Elettra team

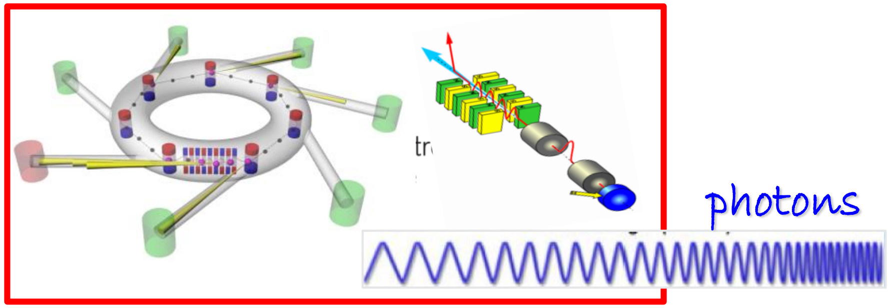
Elettra Laboratory :

Use Synchrotron and FEL radiation to conduct experiments in order to study the matter



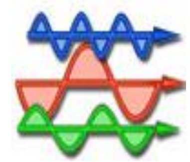




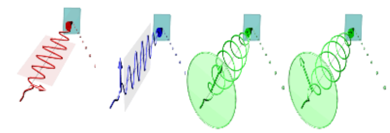


Bright

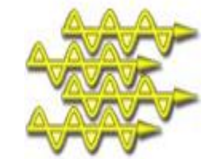
Tunable



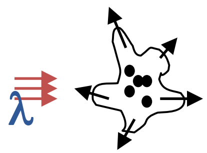
Polarized



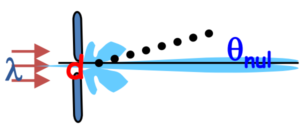
Coherent

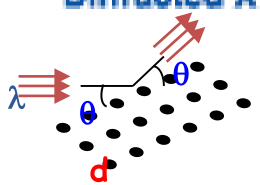


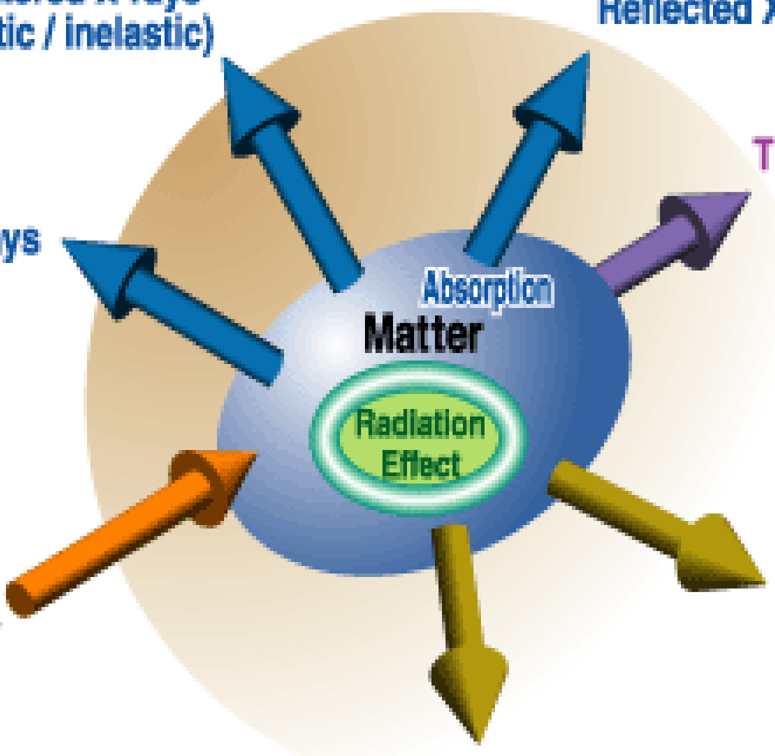
All methods are based on the interaction of photons with matter and find applications in all domains of science and technology



Resonant inelastic X-ray scattering (RIXS)







Coherent Diffraction Imaging (CDI)

X-ray Absorption Spectroscopy (XAS)

InfraRed Absorption Spectroscopy (IRAS)

Photoelectron Spectroscopy:

PES – ARUPS & XPS-AES and XAS

Fluorescence Spectroscopy (FS) and XAS

Courtesy M. Kiskinova

Elettra in brief

Elettra Sincrotrone Trieste

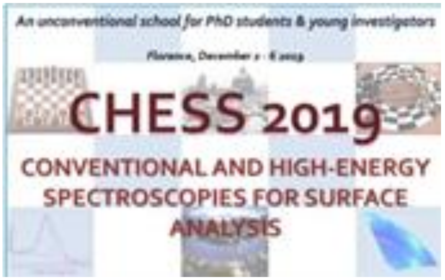
- Elettra – Sincrotrone Trieste
- Manages and operates two light sources
- Maintains backing laboratories for scientific and training activities
- Organizes schools for training on relevant subjects

XV School on Synchrotron Radiation:
Fundamentals, Methods and Applications
Muggia, Italy / 16-27 September 2019

SILS
Elettra Sincrotrone Trieste

HERCULES 2019
Local sessions and practicals @ Elettra / FERMI
Basovizza, Italy / 1-5 April 2019

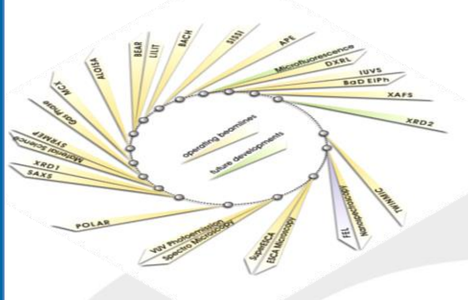
Elettra Sincrotrone Trieste



IAEA - Elettra training workshop on instrumentation for synchrotron radiation experiments (XRF, XAFS, MCX beamlines)

& MANY OTHER: **ICTP School "Biophysical approaches to macromolecules and cells: integrated tools for life sciences and medicine" , SESAME –** Environmental Science Thematic School ; **ICTP-IAEA Advanced Workshop on Portable X-Ray Spectrometry Techniques for Characterization of Archaeological/Art Objects, etc.…**

- Elettra – Light source
- First 3rd generation in Europe (DBA) for "soft" X-rays
- Operates for about 6400 hours per year (24h, 7/7), 5016 hours reserved for users in two energies all in top-up:
- 2.0 GeV, 75 % of users time, 7 nm-rad, 310 mA
- 2.4 GeV, 25 % of users time, 10 nm-rad, 160 mA
- 28 operating beam lines – over 1000 user and user proposals / year



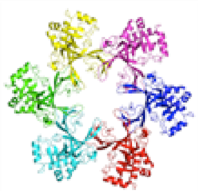
Laboratories backing the scientific and training activity of the Elettra and Fermi beamlines

Elettra
Sincrotrone
Trieste

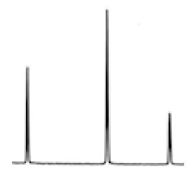
User support lab
Workshop and sample preparation tools incl. chemical laboratory.
MUST

SURFACE SCIENCE LABORATORY

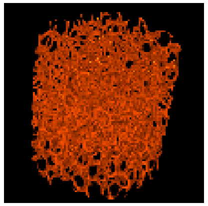
Collaboration with University Trieste for training students in Synchrotron environment.
Complementary research to PES and XAS beamlines (SuperESCA, NanoSpec, VUV etc)



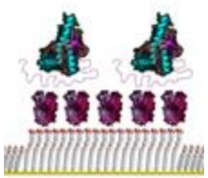
Structural Biology lab
Molecular and structural biology tools to complement research using SAXS and XRD beamlines.



Powder Diffraction
Support laboratory for MCX, XRD and XAFS beamlines



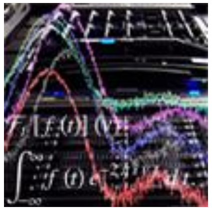
Tomolab
Complementary to the SYRMEP beamline setup for micro-CT with microfocus lab source



NanoInnovation Laboratory
Atomic Force Microscopy for complementary studies in support of all beamlines.

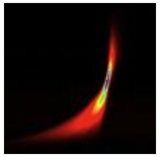
MNC Lab
micro-nano carbon laboratory

Micro and Nano Carbon Lab:
off-line laboratory for samples preparation and analysis focused on C materials and sensor related research,



Scientific Computing
Beamline Controls, Data acquisition, management and processing
MUST

CITIUS



CITIUS and T-ReX
Laser labs complementing Fermi and slicing source experiments.
CITIUS is located in the near-by University of Nova Goriza in Slovenija

Fields of research

Elettra Sincrotrone Trieste


Agro foodstuffs

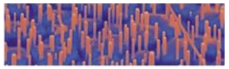

Chemistry and Catalysis


Conservation of Cultural heritage


Energy and Environment


High-Tech Materials

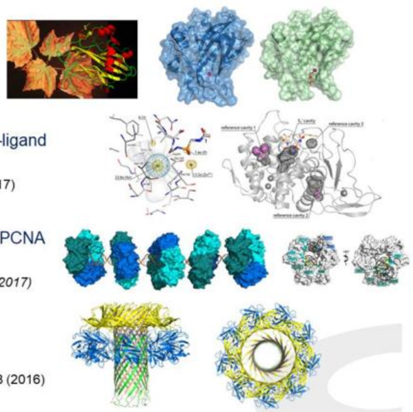

Medicine and Diagnostics


Micro and Nanotechnology


Optics, Electronics and ICT

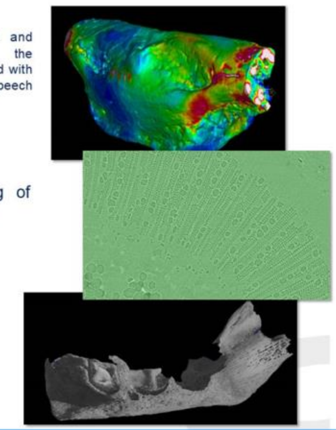
Macromolecular X-ray Crystallography

- How plants differ in toxin sensitivity
  Science, 358, 1431 (2017)
- Solvent effects in protein–ligand interactions
  J. Am. Chem. Soc., 139, 30, (2017)
- Structural basis of human PCNA sliding on DNA
  Nature Communication, 8:13935 (2017)
- Pore forming proteins
  Nature Communications, 7:11598 (2016)



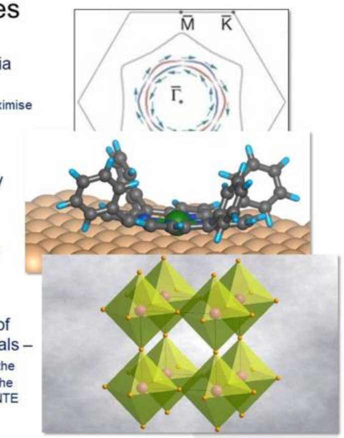
Hard X-ray imaging & tomography

- Anthropology - Internal architecture and micro-biomechanical behaviour of the Neanderthal Kebara 2 hyoid bone compared with modern human hyoids: implication for speech capacity
  PLoS ONE 8, e82261 (2013)
- The wounds of drought: imaging of embolized xylem conduits in plants
  The New Phytologist 213, 1068 (2017)
- Paleontology - The teeth of a prehistoric fetus give us information about the last months of a mother and child, who lived 27.000 years BC
  Scientific Reports, 7, 9427 (2017)



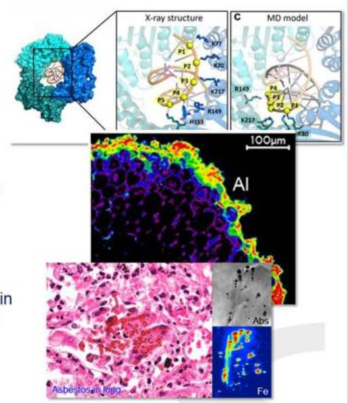
Spectroscopy & electronic band structures

- Maximal Rashba-like spin splitting via kinetic-energy-coupled inversion-symmetry breaking - a new route to maximise the spin-splitting of surface states
  Nature, 549, 492–496 (2017)
- Multi-orbital charge transfer at highly oriented organic/metal interfaces - theoretical and experimental evidence of a pronounced charge transfer involving nickel tetraphenyl porphyrin molecules adsorbed on Cu(100)
  Nature Communications, 8, 335 (2017)
- One major step towards the design of controlled thermal expansion materials – how redox intercalation of guest cations into the voids of a framework material can hindering the transverse atomic vibrations responsible for NTE
  Nature Communications, 8, 14441 (2017)



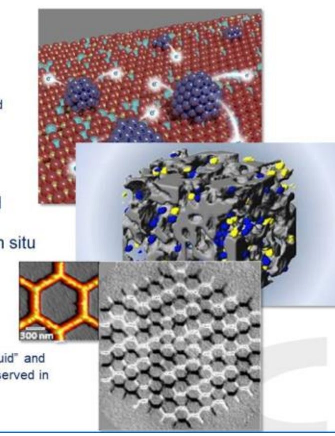
Life science & biotechnology

- Structural basis of human PCNA sliding on DNA - for the first time to visualize, at an atomic level, the interactions between the human sliding clamp PCNA and DNA, and to follow how they evolve in time.
  Nature Communications 7, 13935 (2016)
- Identification of the primary lesion of toxic aluminum (Al) in plant roots
  Plant Physiology 167, 1402 (2015)
- The interaction of asbestos and iron in lung tissue revealed by synchrotron-based scanning X-ray microscopy
  Scientific Reports 3, 1123, (2013)



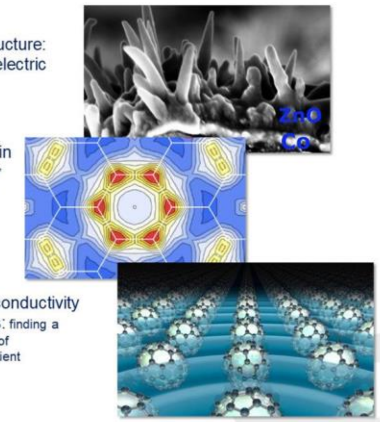
Materials research

- Counting electrons on supported nanoparticles – measuring the electrical charge exchanged between a nanoparticle and the support
  Nature Materials, 15, 284–288 (2016)
- Quantification of ion confinement and desolvation in nanoporous carbon supercapacitors with modelling and in situ X-ray scattering
  Nature Energy, 2, 16215 (2017)
- Fragmentation of magnetism in artificial dipolar spin ice – phases "liquid" and "solid" at the same time, has been recently observed in a magnetic metamaterial
  Nature Communications, 7, 11446 (2016)



Magnetism & Superconductivity

- Co/ZnO nanorod heterostructure: an innovative magneto-electric system
  Nanoscale, 10, 1326 (2018)
- Fragmentation of magnetism in artificial dipolar spin ice: "liquid" and "solid" phases at the same time, have been recently observed in a magnetic metamaterial
  Nat. Commun. 7, 11446 (2016)
- Possible light-induced superconductivity in K_3C_{60} at high temperatures: finding a way to raise the critical temperature of superconductive materials up to ambient conditions
  Nature 530, 461–464 (2016)

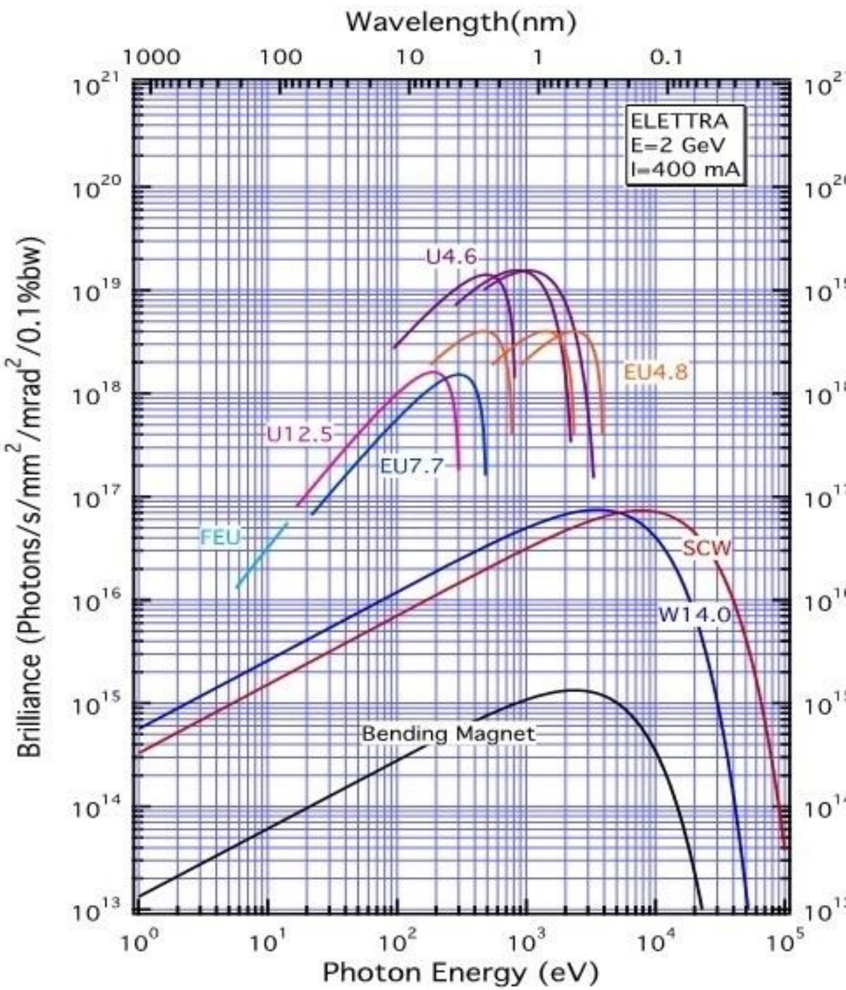


Insertion devices (IDs) and brilliance

ID	type	section	Period (mm)	Nper	gap (mm)	status
U5.6	PM/Linear	12 short	56	18	23	operating
EU10.0	PM/Elliptical	1	100	20+20	13.5	operating
U4.6	PM/Linear	2	46	2 x 49	13.5	operating
U12.5	PM/Linear	3	125	3 x 12	32.0	operating
EEW	EM/Elliptical	4	212	16	18.0	operating
W14.0	HYB/Linear	5	140	3 x 9.5	22.0	operating
U12.5	PM/Linear	6	125	3 x 12	29.0	operating
U8.0	PM/Linear	7	80	19	26.0	operating
EU4.8	PM/Elliptical	8	48	44	19.0	operating
EU7.7	PM/Elliptical	8	77	28	19.0	operating
EU6.0	PM/Elliptical	9	60	36	19.0	operating
EU12.5	PM/Elliptical/QP	9	125	17	18.6	operating
FEU	PM/Figure-8	10	140	16+16	19.0	operating
SCW	SC/Linear	11	64	24.5	10.7	operating

19 beam lines are served from 21 Insertion devices (IDs) (planar, elliptical, canted, electromagnetic) PM segments + 1 SCW + 1 EM

9 beam lines are served from 6 bending magnet source points



9 beam lines <1 keV (~1/3), 11 with their min energy <100 eV, some require as low as 4.6 eV. None in tender x-rays (7 keV)
The hard-x rays lines arrive up to 35 keV

Beam lines using IDs

		Energy eV	*ID beam lines*
1.1	**TwinMic**	**400 - 2200**	**Micoscopy, bio-technology, nanotechnology, environmental science and geo-chemistry, clinical and medical applications, novel energy sources, biomaterials, cultural heritage and archeometry.**
1.2L	**Nano-spectroscopy**	**50-1000**	**spectroscopic photoemission and low energy electron microscope (SPELEEM)-chemical state, electronic structure and magnetic order of surfaces, interfaces and thin films.**
1.2L	**NanoEsca**	**50-1000**	**nanometer lateral resolution with photoelectron microscope**
1.2R	**~~SR- FEL~~**	**12**	**Seeded, variable polarizzation**
2.2L	**ESCA Microscopy**	**400-800**	**SPEM (scanning photoelectron microscope), surface physics** and **chemistry**, **materials science**, and **nanotechnology**
2.2R	**SuperESCA**	**90-1500**	**High resolution core-level photoemission spectroscopy (HR-XPS) surface physics** and **chemistry** to **material science** and **nanotechnology**
3.2L	**Spectro microscopy**	**27-74**	**ARPES (angle resolved photo emission spectroscopy)-electronic structure phenomena such as electronic phase transitions and electronic structure of small – down to sub micrometre size – objects.**
3.2R	**VUV photoemission**	**20-750**	**band mapping, high resolution photoemission, photoelectron diffraction**
4.2	**CiPo**	**5 - 900**	**Fast circular polarization (dichroism, magnetization etc.)**
5.2L	**SAXS**	**5.4,8,16 keV**	**Small Angle X-ray Scattering, also production of nanoparticles or drug / DNA delivery systems for pharmaceutical applications, improvement of food standards etc.**
5.2R	**XRD1**	**4-21 keV**	**protein crystallography, powder diffraction, high pressure physics and solid-state experiments**
6.2R	**GasPhase**	**13-900**	**gaseous systems. electronic properties of free atoms, molecules and clusters**
7.2	**ALOISA**	**130-1500**	**chemistry and structure of surfaces. photoemission and absorption spectroscopy**
8.2	**BACH**	**35-1650**	**multi-spectroscopy investigation with photoemission UPS/XPS spectroscopy (including polarization x-ray magnetic circular dichroism in high magnetic fields ,time resolved**

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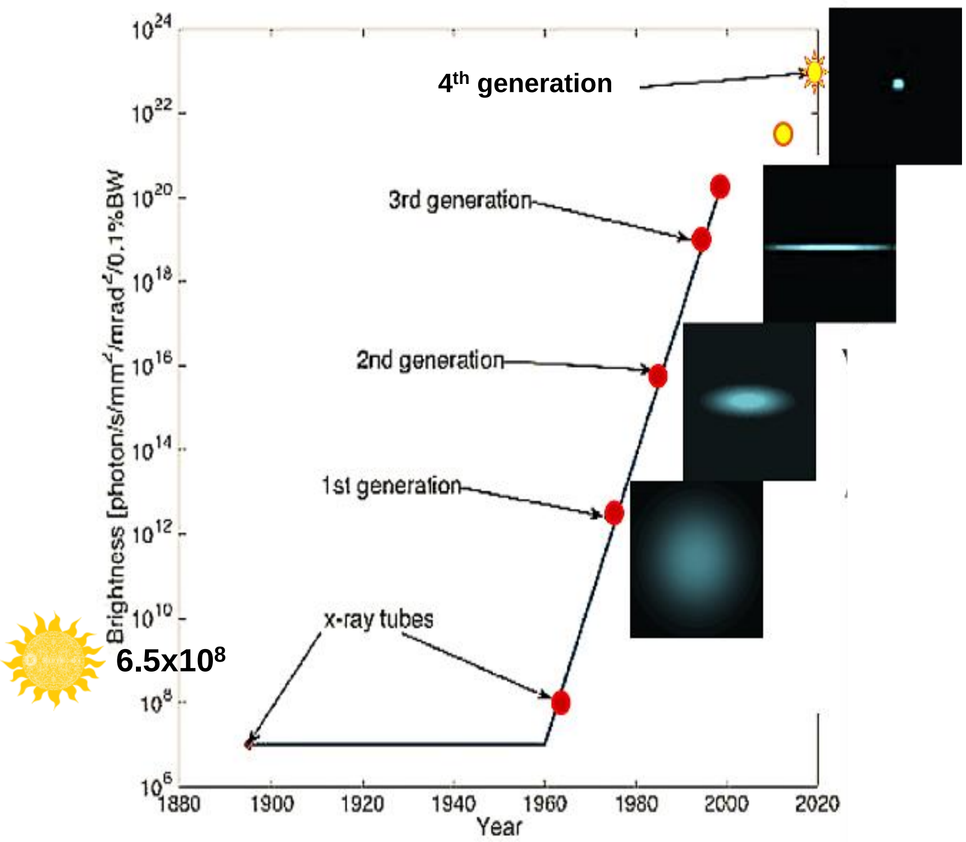
ID and Dipole beam lines

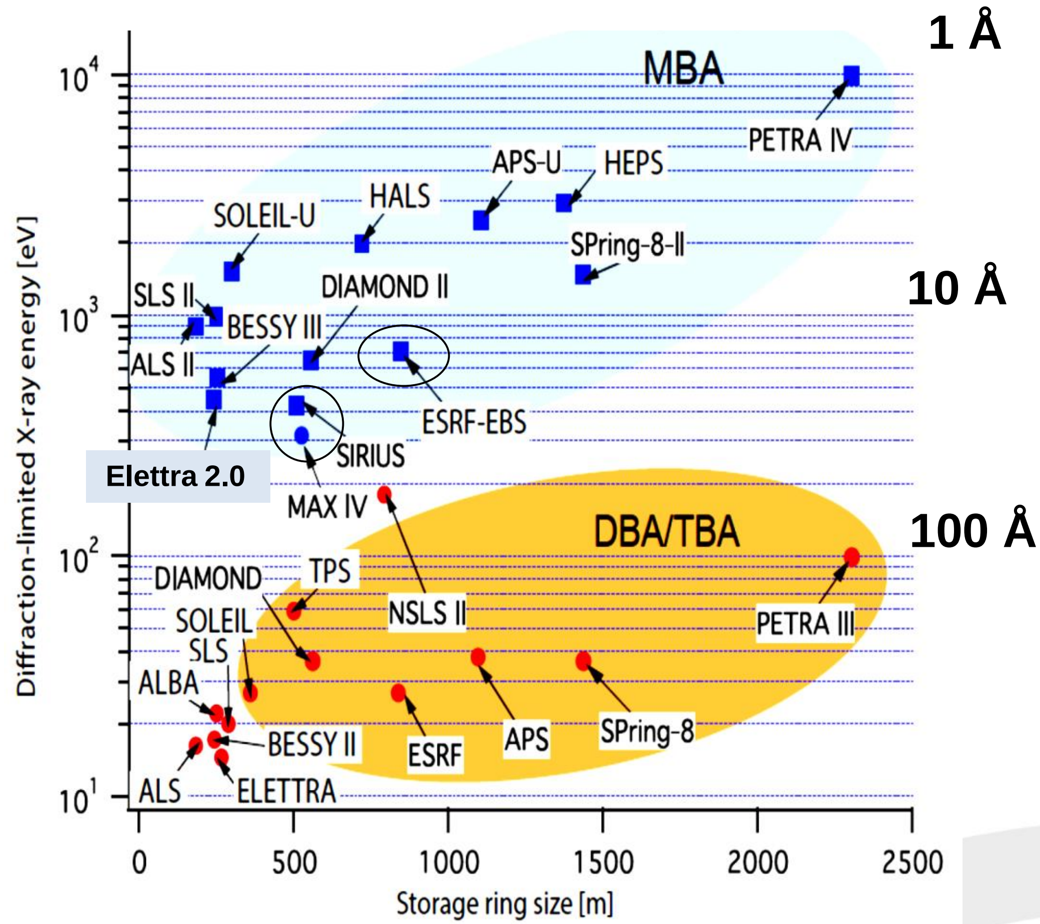
		Energy eV	ID beam lines
9.2	APE (canted)	8-120, 150-1600	spectroscopies ,Ar ion sputtering, annealing, controlled evaporation, LEED/Auger characterization atomic resolution scanning tunnelling microscope (STM)
10.2L	IUVS	5-11	Inelastic utraviolet scattering, UV Brillouin and UV Resonant Raman scattering instruments, in order to probe both the acoustic and optical phonons propagating in the system
10.2R	BaDELPh	4.6-40	The Band Dispersion and Electron-Phonon coupling . high-resolution angle-resolved photoemission spectroscopy (ARPES) experiments in the low photon energy regime
11.2L	XRD2	8-35 keV	SAD/MAD (single/two wavelength anomalous dispersion) experiments
11.2R	Xpress	25 keV	high pressure diffraction

		Energy eV	Dipole Beam lines
6.1L	Material sciences	22-1000	materials science, surface physics, catalysts and organic molecules on various surfaces, resonant photoemission (ResPES) and near edge X-ray absorption fine structure (NEXAFS) spectroscopies
6.1R	SYRMEP	8-35 keV	Synchrotron Radiation for MEdical Physics and Biology - mammography
7.1	MCX	6-20 keV	Materials Characterisation by X-ray diffraction non-single crystal diffraction experiments: grazing angle diffraction and reflectivity, residual stress and texture analysis, phase identification and structural studies and kinetic studies
8.1L	BEAR	2.8-1600	Reflectivity fluorescense Auger Luminescense absorption, NEXAFS, EXAFS,spectroscopy
8.1R	LILIT	1-12 keV	Laboratory for Interdisciplinary LIThography
9.1	SISSI	IR	infrared beamline at Elettra extracts the IR and visible components of synchrotron emission for performing spectroscopy, micro spectroscopy and imaging
10.1L	XRF	2-14 keV	X-Ray Fluorescence, Grazing Incidence XRF, Total-reflection XRF, 2D scanning XRF and XANES (X-ray absorption near edge structure), X-Ray Reflectometry etc.
10.1R	DXRL	2-20 keV	Deep X-ray lithography (LIGA), high aspect ratio three dimensional structures in polymer
11.1L	XAFS	2.4-27 keV	x-ray absorption spectroscopy, study of matter at extreme condition of pressure and temperature to the study of the relationship between local structure and properties of functional materials

Generations of Synchrotron light Sources
Brilliance and coherence

To increase brightness and coherence the beam dimensions (i.e. the emittance) must be reduced





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What is the benefit?

The high brightness and strongly reduced horizontal beam size of the 4th generation light sources will be beneficial for:

- ✓ **All coherent hungry techniques – 3D CDI, Res-CDI, ptychography and *X-ray photon correlation spectroscopy (XPCS)*.**
- ✓ ***Spectroscopies do not need coherence – <u>they gain from brightness</u>, in particular photon hungry* RIXS and Spin-ARPES, *improved spectral resolution, reduced acquisition time & gain for weak signals.***
- ✓ ***Push the lateral resolution to the nanoscale range using diffraction focusing optics – spectroscopies with nano-sized photon beams.***

- ✓ shorter acquisition times favourable for operando characterizations
- ✓ push in spectra resolution for more precise speciation
- ✓ monitoring very weak signals beneficial for photon-hungry experiments, e.g. spin-resolved ARPES (angle resolved photoemission spectroscopy), RIXS (resonant inelastic x-ray scattering) , dilute or very small samples
- ✓ gain in spatial resolution using focusing optics offering nano-PES, nano-ARPES, nano-RIXS, nano-XAS (X-ray Absorption Spectroscopy), nano-XRF spectroscopy (X-ray fluorescence spectroscopy) and spectro-imaging options.

The enhanced coherence exerts the strongest impact on imaging in general, and in particular for coherent diffraction imaging (CDI), its scanning mode ptychography and closely related XPCS, where the coherent x-ray beam illuminating a heterogeneous sample creates a speckle diffraction pattern.

The high brightness will also be beneficial for hard X-ray beamlines getting more flux at higher photon energies with particular gain in high pressure XRD (X ray diffraction) , specular and grazing incidence XRD, X-ray reflectivity, scattering (SAXS and GISAXS - Grazing-Incidence Small-Angle X-ray Scattering) and tomography experiments.

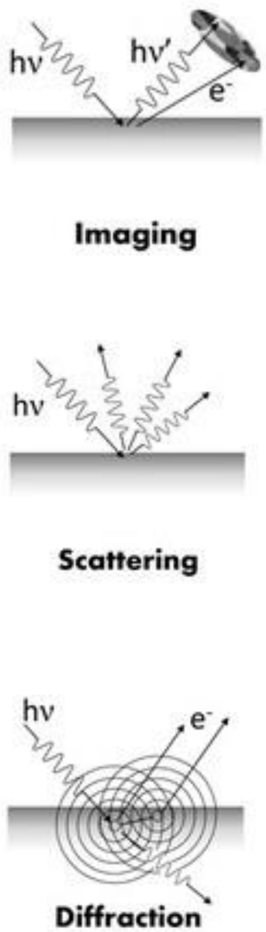
The significant coherence in the soft and medium-hard X-ray range will allow the approach to wavelength-limited spatial resolution with chemical specificity. The coherence will also be extremely beneficial for phase-contrast tomography, which enables low-dose studies of weakly absorbing bio-matter.

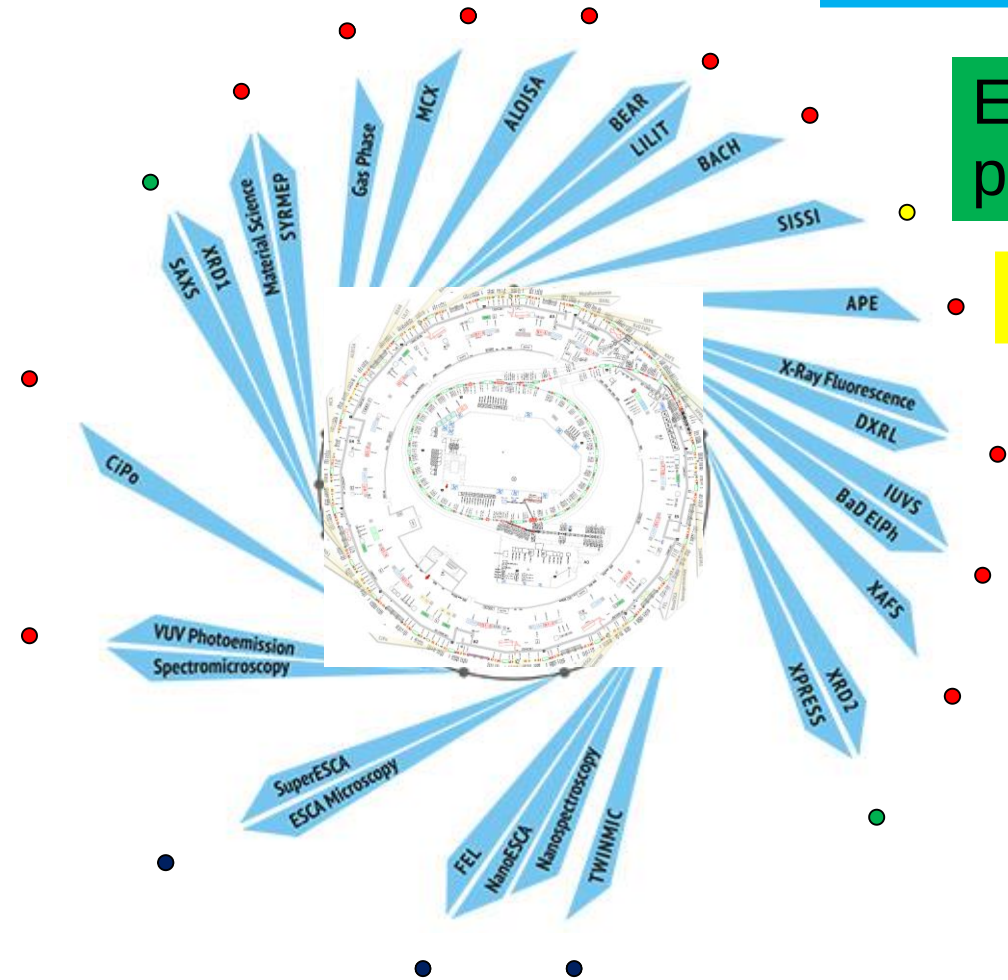
Caution due to different points of view

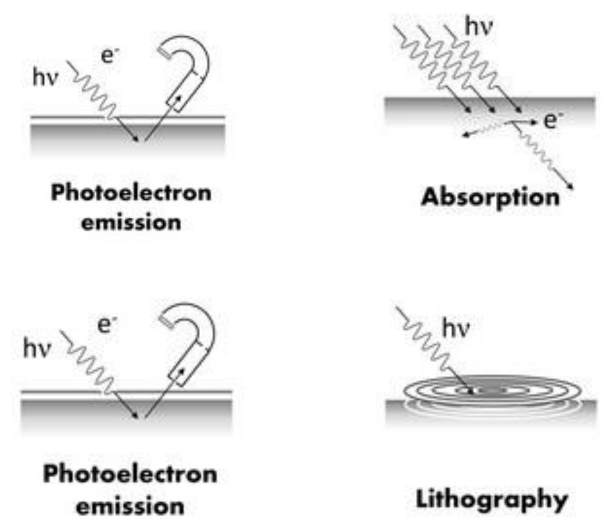
Elettra for Machine people

Elettra for Beam Lines people

Elettra for Users







Those different points of view require high collaboration of all involved scientists

Elettra 2.0 final requirements

✓ User demands

After many workshops (since 2014) and discussion with users and beam line scientists :

- ***Main operating energy 2.4 GeV (and for sometime at 2 GeV)***
- ***Reduce the horizontal equilibrium emittance at least one order of magnitude***
- ***Let open the possibility for installing bunch compression scheme***
- ***Include super-bends and in-vacuum undulators***

✓ Constraints

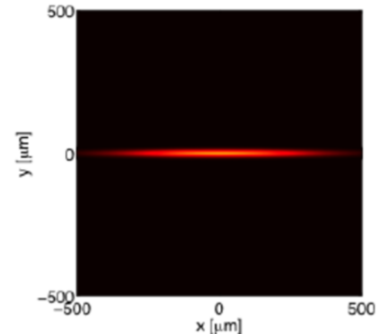
- Keep the same building and the same ring circumference (259.2 m)
- *Conserve the slots available for insertion devices* keeping the same source point.
- Preserve the present intensities and the time structure of the beam
- Keep the present injection scheme and injection complex
- Minimize the downtime for installation and commissioning to about 18 months maximum.

The emittance reduction is achieved by adding dipoles

Elettra has 2 dipoles / section i.e. 24 in total

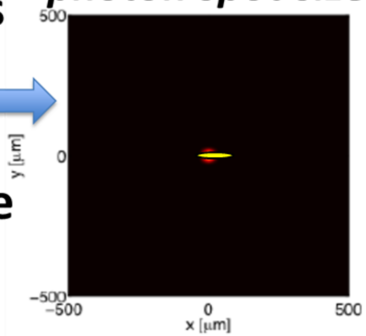
Elettra 2.0 will have 6 dipoles / section, i.e. 72 in total

Elettra ID photon spot size



Elettra 2.0 1000 times brighter and 50 times more coherent

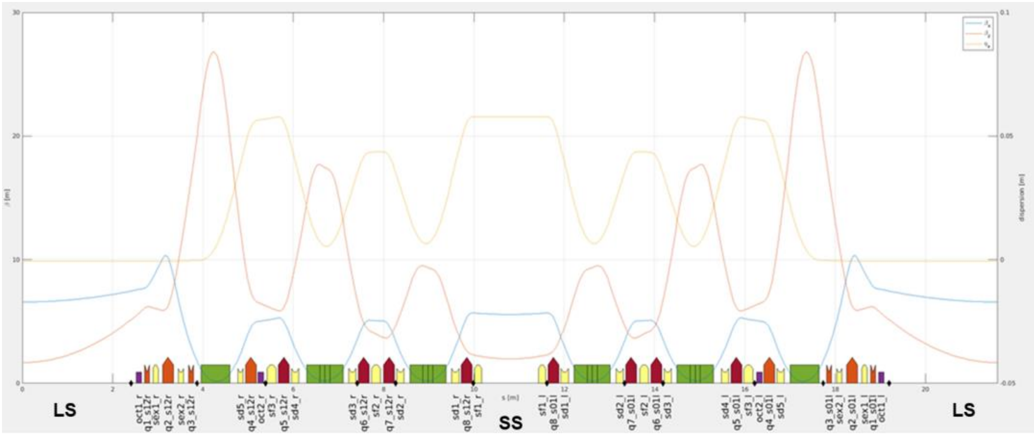
Elettra 2.0 ID photon spot size



Parameter	Units	Elettra	Elettra 2.0 S6BA-E
Circumference	m	259.2	259.2
Energy	GeV	2.4	2.4
Horizontal bare emittance	pm rad	10000	212
Vertical emittance @1% coupling	pm rad	100	2.1
Beam size @ ID (σx,σy)	um	286 , 16	36 ,1.5
Beam size at short ID	um	400 , 25	64, 2.2
Beam size @ Bend (at z=0)	um	272, 27	8 , 6
Bunch length (zero current, 2 MV,1σ)	ps	22	5.4
Energy spread	ΔE/E %	0.095	0.11
Bending angle half achromat	degree	15	3.6 and 2x6.5+LG + 4x -0.40

Elettra
Sincrotrone
Trieste

Final optics (S6BA-E) and machine parameters



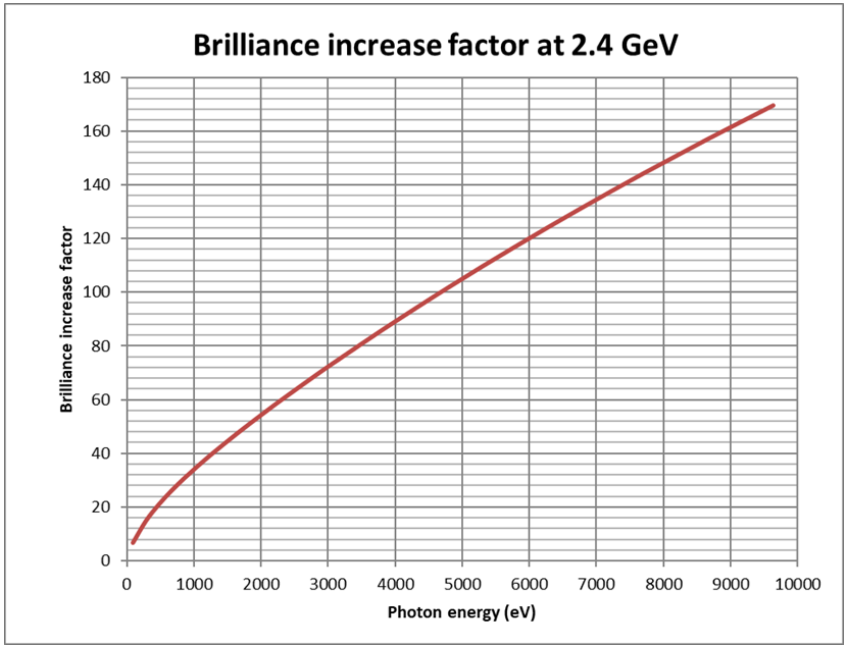
Circumference (m)	259.2	259.2
Energy (GeV)	2	2.4
Number of cells	12	12
Geometric emittance (pm-rad) 2% coupling	147	212
Horizontal tune	33.29	33.29
Vertical tune	9.18	9.18
Beta functions in the middle of straights (x, y) m	(5.7 , 1.6)	(5.7 , 1.6)
Horizontal natural chromaticity	-71	-71
Vertical natural chromaticity	-68	-68
Horizontal corrected chromaticity	+1	+1
Vertical corrected chromaticity	+1	+1
Momentum compaction	1.2e-004	1.2e-004
Energy loss per turn no IDs (keV)	220	457 (w SBs 486)
Energy spread	7.8e-004	9.3e-004
Jx	1.598	1.66
Jy	1.00	1.00
JE	1.402	1.34
Horizontal damping time (ms)	9.45	5.46
Vertical damping time (ms)	15.67	9.08
Longitudinal damping time (ms)	9.45	6.78
Dipole field (T)	<0.88 + 1.16T central	<1.03+1.46T central
Quadrupole gradient in dipole (T/m)	<19	<22
Quadrupole gradient (T/m)	<50	<60
Sextupole gradient (T/m^2)	<90000	<100000
RF frequency (MHz)	499.654	499.654
Beam revolution frequency (MHz)	1.1566	1.1566
Harmonic number	432	432
Orbital period (ns)	864.6	864.6
Bucket length (ns)	2	2
Natural bunch length (mm, ps)	1.3 , 4.3	1.7 , 5.7
Synchrotron frequency (kHz)	3.17 (@2MV)	2.86 (@2MV)

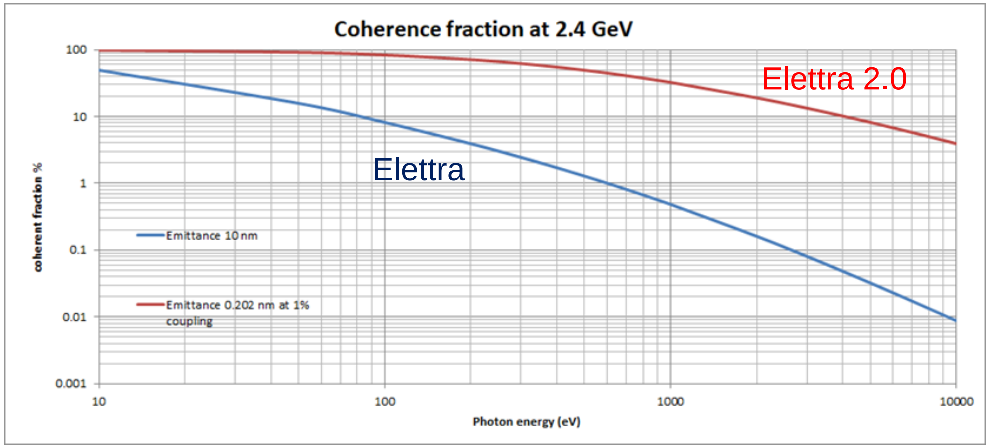
Emittance is **212 pm-rad at 2.4 GeV i.e. 47 times reduction in emittance or 7 times reduction in beam size compared with the actual Elettra**

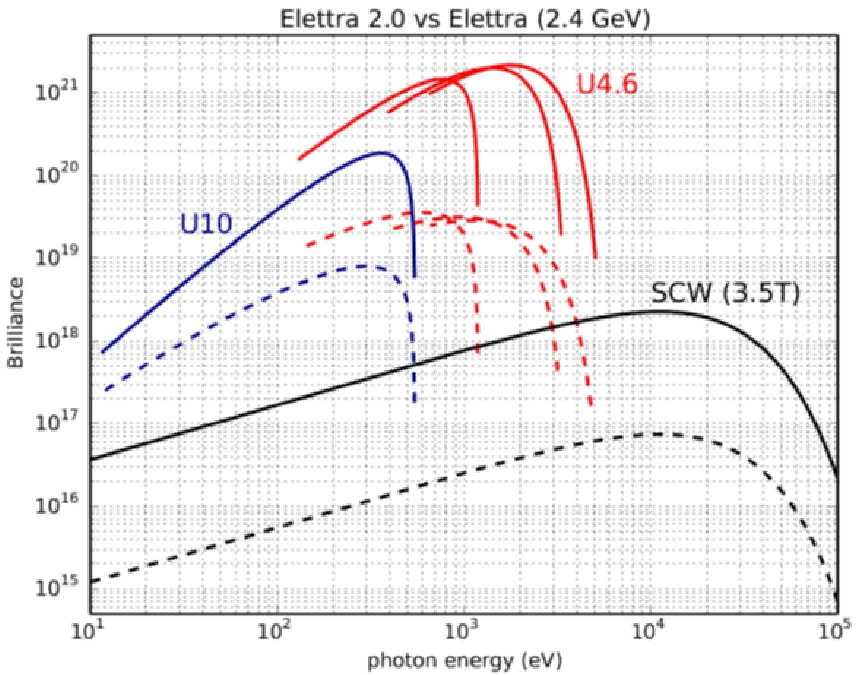
The ratio between C and free space for IDs is 30%. The available slots for IDs are 11 on LS and 5 on SS

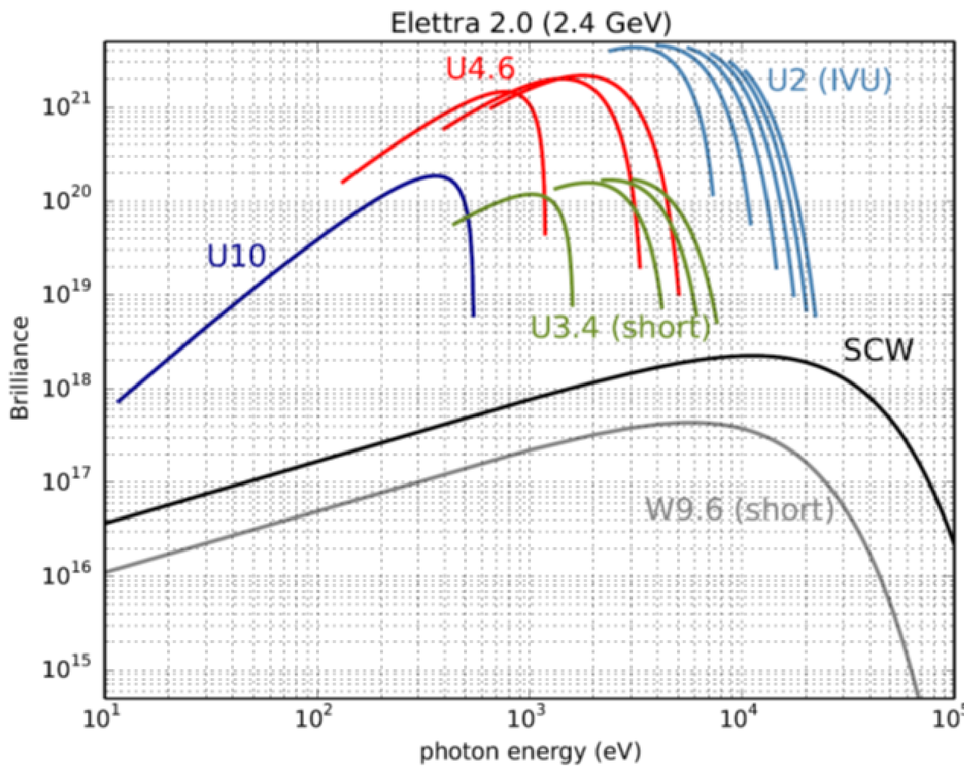
Beam size and divergence

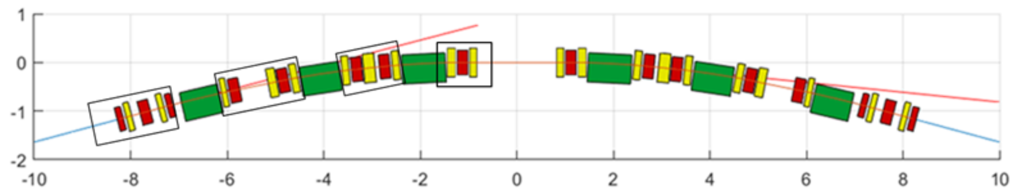
Energy 2.4 GeV	LS at 3% cpl	LS at 10% cpl	SS at 3% cpl	SS at 10% cpl
σx (um) /σ'x (urad)	36 /5.7	35/5.5	63/6	63/5.8
σy (um) /σ'y (urad)	3.2/1.9	5.7/3.4	3.5/1.8	6/3
Energy 2.0 GeV				
σx (um) /σ'x (urad)	30/4.8	29/4.6	53/5	52/4.8
σy (um) /σ'y (urad)	2.7/1.6	4.7/2.8	2.9/1.5	5.1/2.6

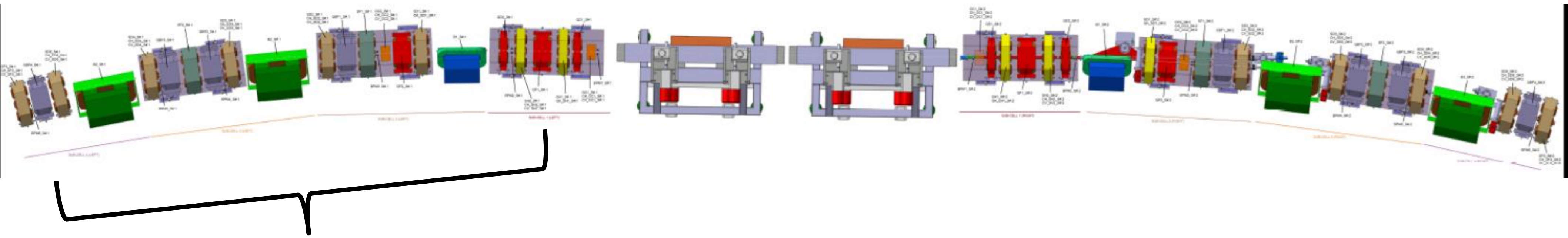

Brilliance increase factor at 2.4 GeV
Brilliance increase factor
Photon energy (eV)
0
20
40
60
80
100
120
140
160
180
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

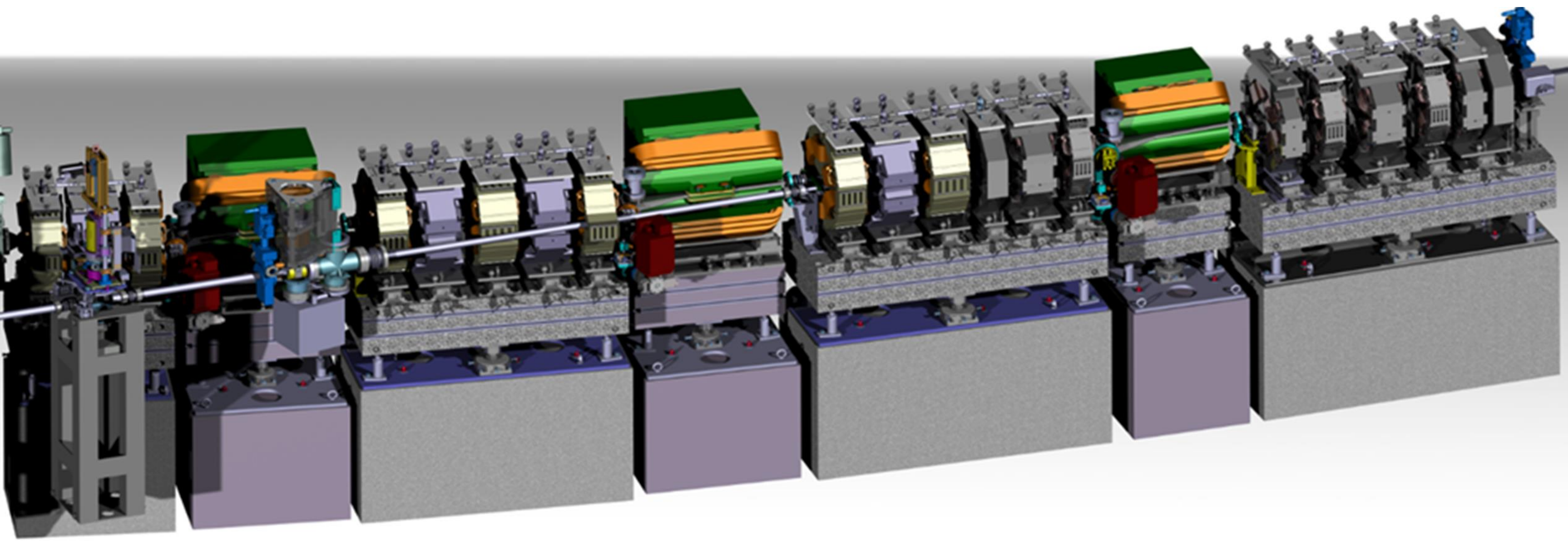

Coherence fraction at 2.4 GeV
coherent fraction %
Photon energy (eV)
Elettra 2.0
Elettra
Emittance 10 nm
Emittance 0.202 nm at 1% coupling
100
10
1
0.1
0.01
0.001
10
100
1000
10000

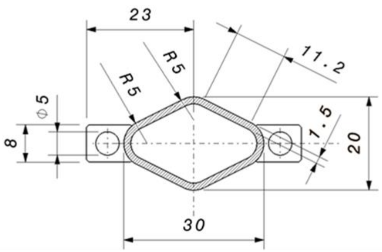

Elettra 2.0 vs Elettra (2.4 GeV)
Brilliance
photon energy (eV)
U4.6
U10
SCW (3.5T)
10^{21}
10^{20}
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}

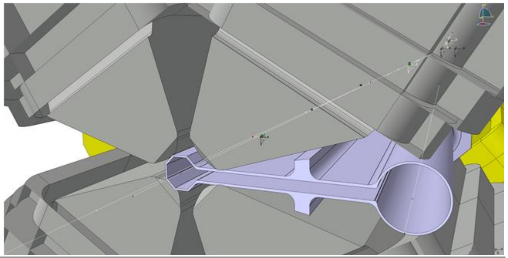

Elettra 2.0 (2.4 GeV)
Brilliance
photon energy (eV)
U4.6
U2 (IVU)
U10
U3.4 (short)
SCW
W9.6 (short)
10^{21}
10^{20}
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}

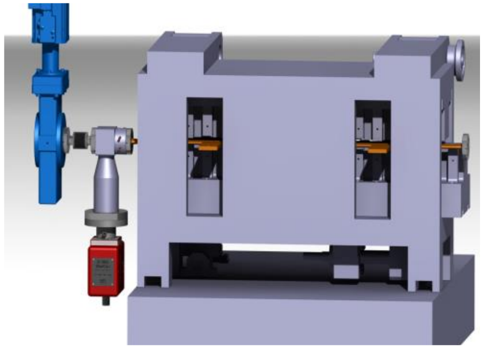

1
0
-1
-2
-10
-8
-6
-4
-2
0
2
4
6
8
10

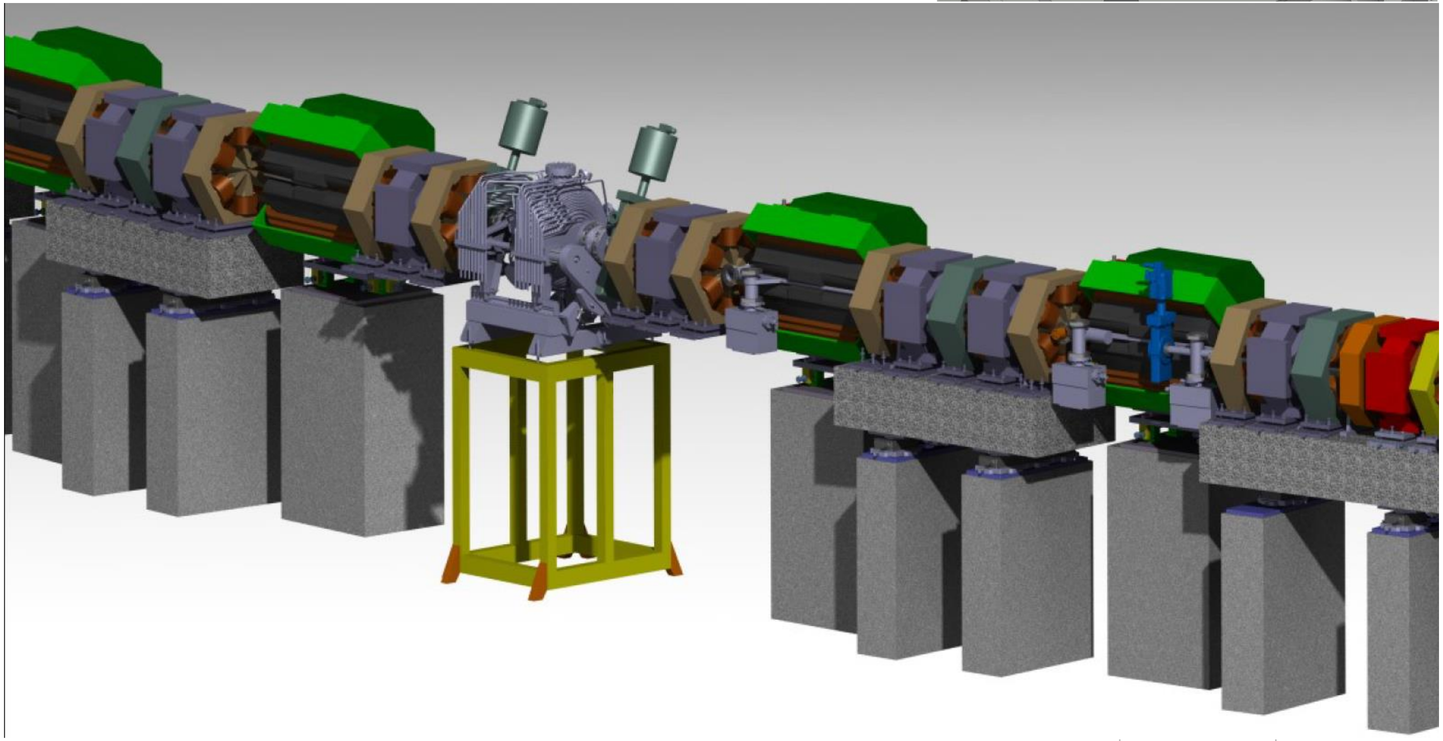


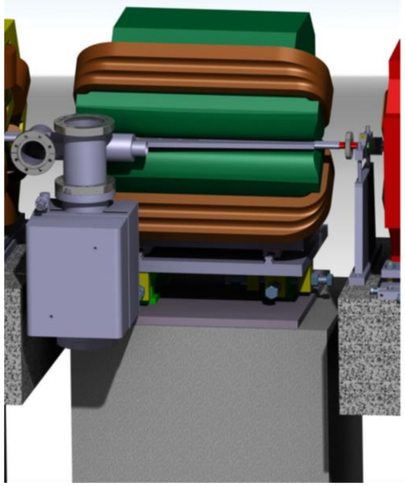


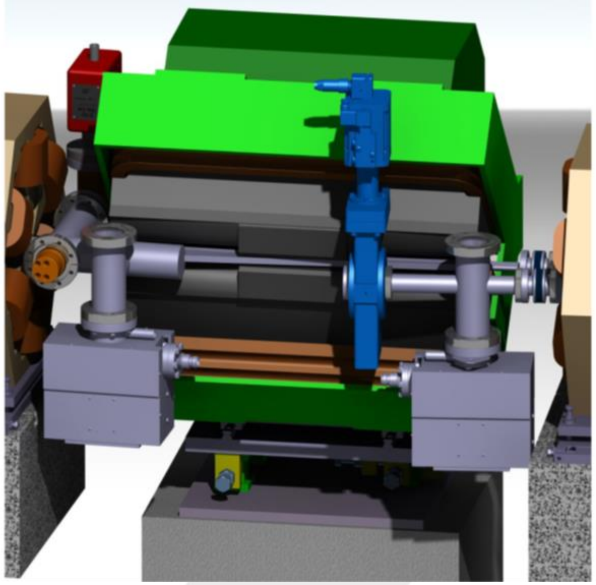




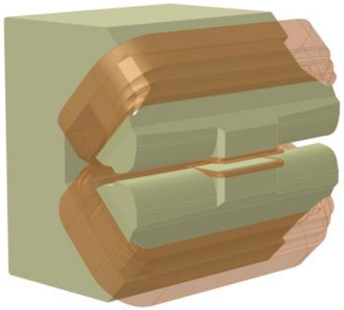


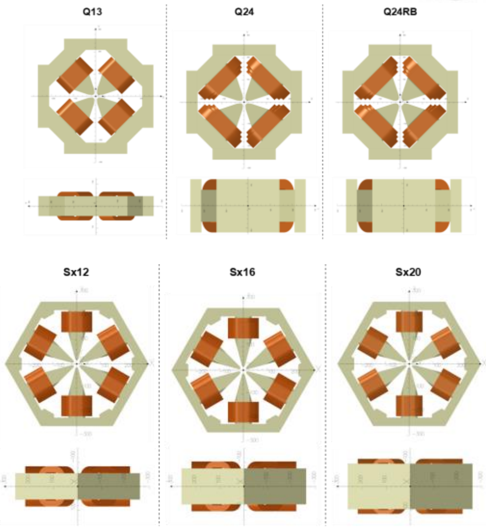






Total 552 magnets
+ 480 coils including
48 fast correctors
(292 Elettra 1.0)





Beam lines

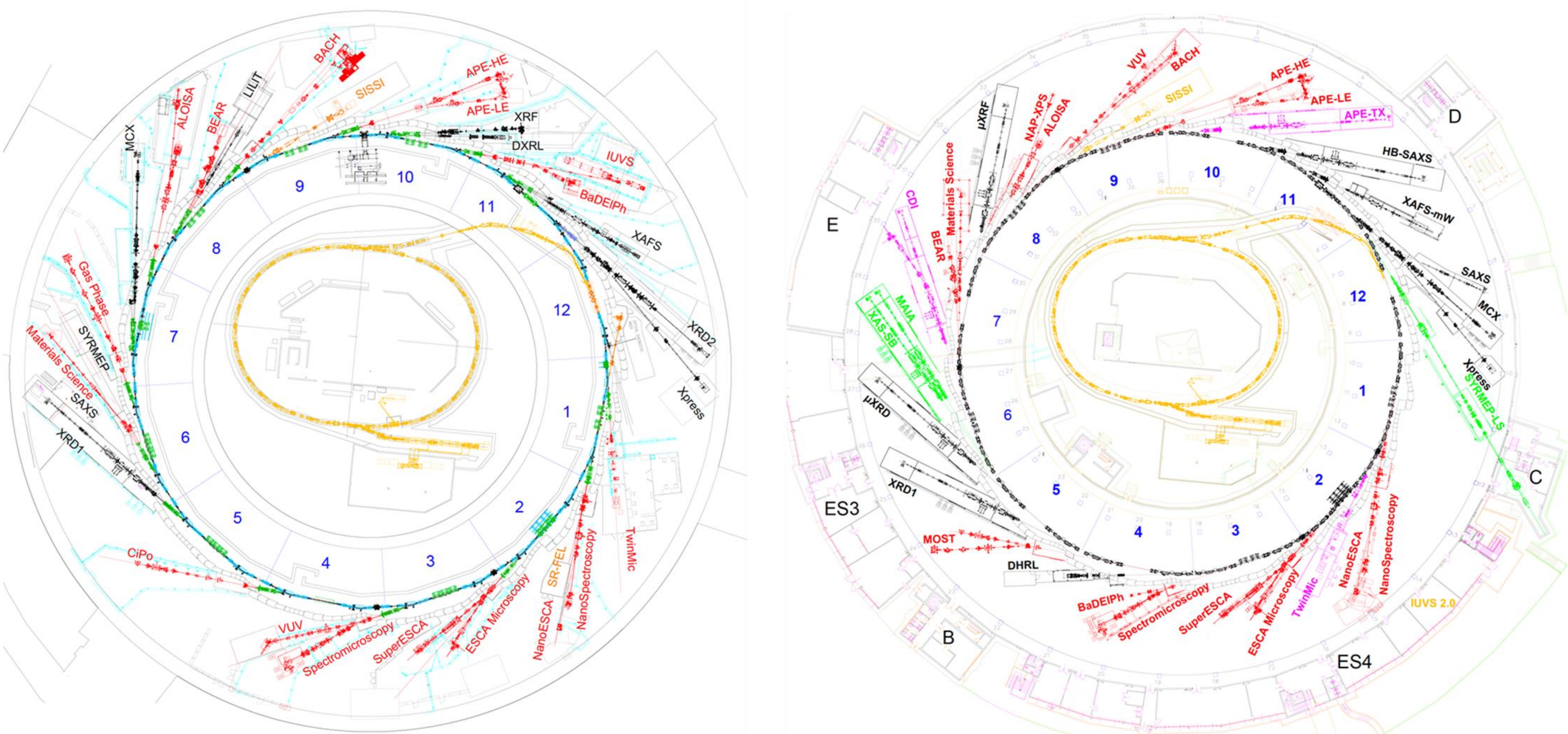
31 beam lines (Elettra actual has 28 beam lines) of which: 2 from super-bends (6T), 2 mini-wigglers, 3 IVU (new micro-spot beam lines) and 1 CDI. **The micro-spot and CDI beam lines cannot be supported by the present machine and will be the "flagship"** beam lines**.**

The micro-spot beam lines require a flux of 10^{14}ph/s at the source and are: the µXRD at 14 keV with a 10×10 µm spot size at the end station, the µSAX at 13 keV with a spot size of 10×10µm and the µXRF at 15 keV that requires a spot of 1×1µm to be served by in-vacuum undulators. Also, a coherent diffraction imaging beam line using a short undulator will be installed. Additionally, 2 super-bends at 6 T will serve the hard X-ray imaging beamlines cluster (evolution of the Syrmep BL) requiring a flux at the source of at least 10^{13}ph/sec at 50 keV

BL long sect.	Machine long sect.	BL short sect.	Short sect. free for BL	Machine short sect.	BL on BM	BM free for BL	BL: beamlines	hv-range	source	Insertion devices length (m)	period (cm) ; field (T)
				1.1							
1.2							Nanospectr/NanoESCA	25-1700 eV	Ellipt. Und.	2x2	10 ; 1
		2.1					TwinMic/free	130-4000 eV	AdjustPhase Und. (linear h)	0.80	5.6 ; 0.5
2.2	2.2 (Crab Cavities)						SuperESCA ESCA Microscopy	130-1800 eV	Lin. Pol. Und. (linear h)	2x2.0	4.6;0.9
				3.1 (RF)		3.1 (BM)					;1.4
3.2							Spectroµ/BaDElPh	10-200 eV	Figure8 Und. (linear h/v)	2x2.2	14 ; 0.75/0.14
				4.1 (RF)	4.1 (BM)		DXRL	5-10 keV	Bending Magnet		;1.4
4.2							MOST	10-1500 eV	Ellipt. Und.	HE 1.5 LE 1.5	HE 5;0.85 LE 1.32;0.64
		5.1					XRD1	4-21 keV	miniWiggler	0.80	10 ; 1.8
5.2	Machine***						µXRD	4-15 keV	InVacuum Und.	3.00	2 ; 1
				6.1	6.1 (SB)		XAFS1/MAIA	4-60 keV	SuperBend (6T)		; 6
6.2							CDI/free	330-4000 eV	Ellipt. Und.	2x2	4.4 ; 0.6
				7.1 (RF)	7.1 (BM)		BEAR/MatSci	10*-1500 eV	Bending Magnet		; 1.4
7.2	Machine***						µXRF	2-15 keV	InVacuum Und.	3.00	2 ; 1
		8.1					ALOISA/NAP-XPS	150-2500 eV	AdjustPhase Und. (linear h)	0.80	8 ; 0.5
8.2							BACH/VUV	30-1500 eV	Ellipt. Und.	HE 2,LE 2	HE 4.8;0.6 LE 7.7;0.9
				9.1 (RF)	9.1 (BM)		SISSI	IR/THz	Bending Magnet		;1.4
9.2							APE LE/HE	13-1500 eV	Ellipt. Und.	HE 2.16, LE 2.1	HE 6;0.78 LE 12.5;0.77
		10.1					APE-TX	550-7000 eV	Ellipt. Und.	0.80	3.4 ; 0.7
10.2	Machine***						HB-SAXS	5-15 keV	InVacuum Und.	3.00	2 ; 1
		11.1					XAFS-mW	3-15 keV	miniWiggler	0.80	10 ; 1.8
11.2	3HC						SAXS/MCX/Xpress	9-35 keV	SCW	1.57	6.4 ; 3.5
				12.1	12.1 (SB)		SYRMEP-LS	4-60 keV	SuperBend (6T)		;6
	12.2 (Injection)										

*** space available for Machine before and after the IVU in the center of LS depending on the overall length of the IVU.

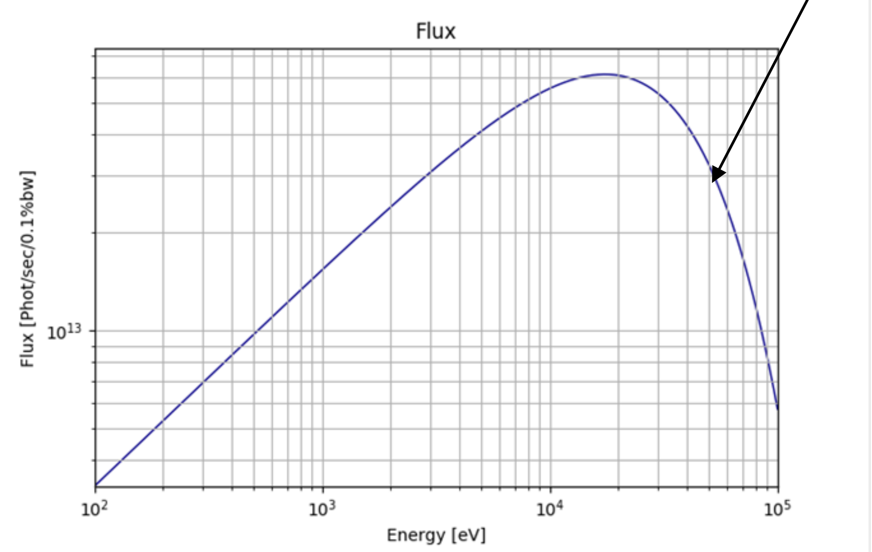
Beam Line redistribution

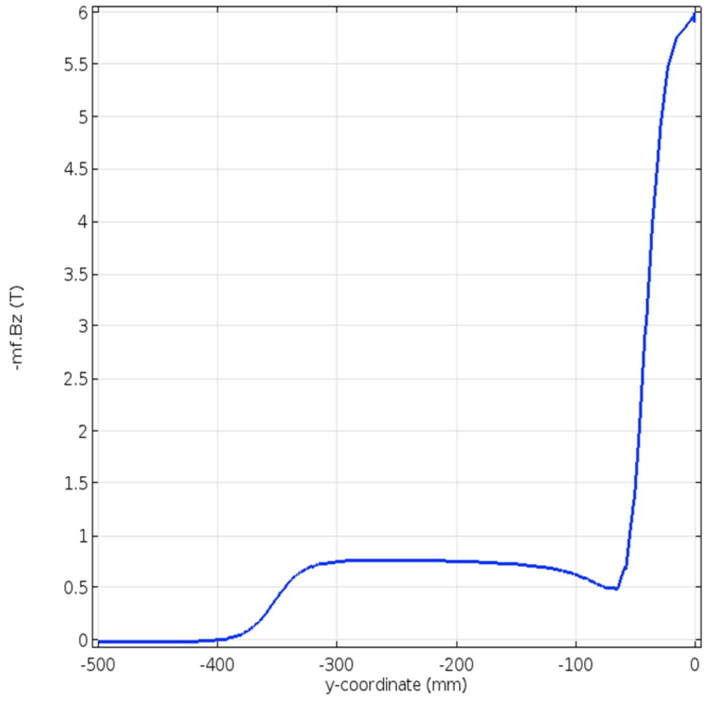


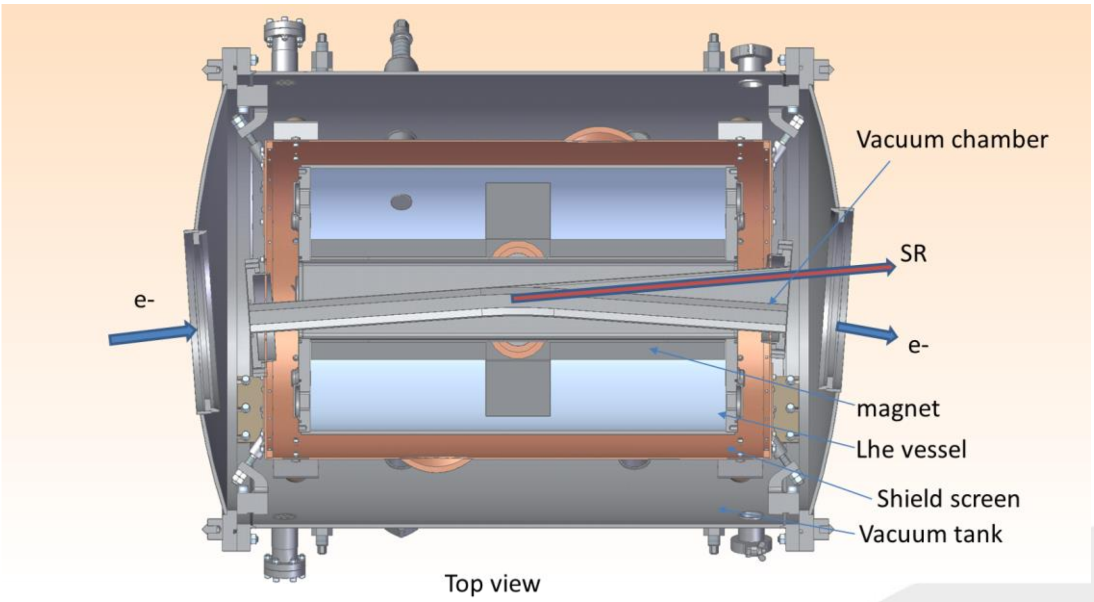
Layout of Elettra (left) and Elettra 2.0 (right). In black the hard X-ray beamlines, in red the beamlines operating in the UV to soft X-ray range and in orange the IR/THz beamline. The storage ring, frontends and the insertion devices are also displayed in the figure. The numbers indicate the different sectors.

Superbends

- ✓ The Hard X-ray Imaging beamlines cluster require a flux at the source of at least **10^{13} ph/sec at 50 keV**.
- ✓ To satisfy such flux requirements, two super-bend magnets of 6 T at 2.4 GeV are to be used.



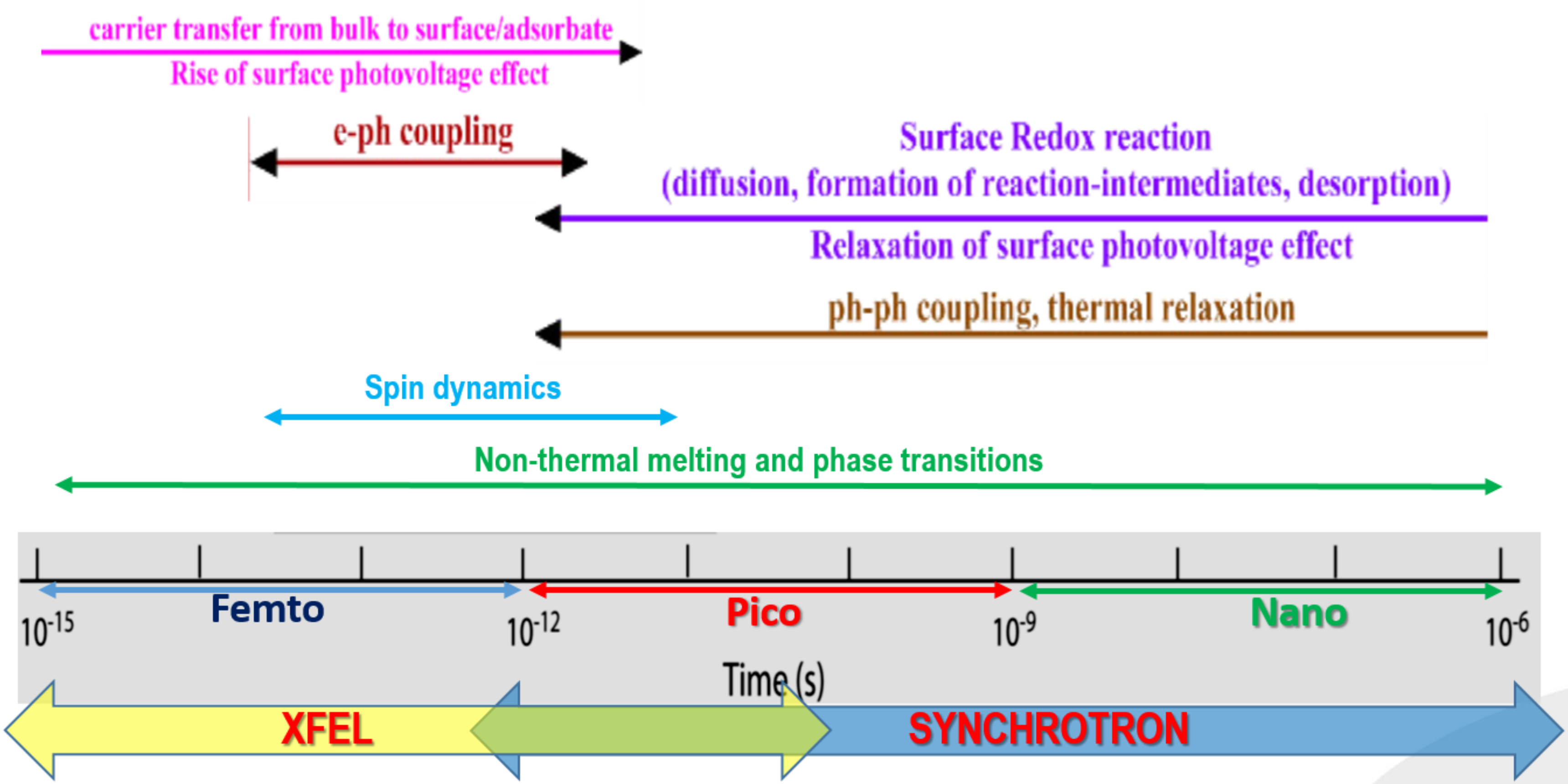




Courtesy N. Mezentsev

Short pulses, why in SR?

There is a range of time resolved experiments that require high repetition rate without damaging the sample



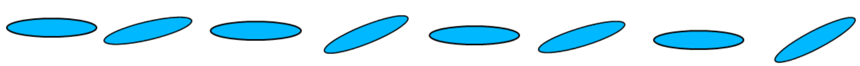
Short pulses: Elettra 2.0

Elettra 2.0 will naturally provide e-pulses of 6 ps rms (fwhm of ~14 ps) at low intensities due to its low momentum compaction ~ 10^{-4}

In multi-bunch with the third harmonic cavity up to 100 mA the fwhm is 20 ps while at 400 mA becomes 70 ps. However there is an interest for 1-3 ps pulse and this is not naturally possible.

Very short photon pulses via deflecting (crab) cavities

ANL-SLAC - Elettra collaboration



200 buckets straight and 200 tilted. Four (4) oblique can be filled with 2 mA each. The pulse length depends on the beam line slit opening, whether there is drift or imaging optics and differs at each beam line position.

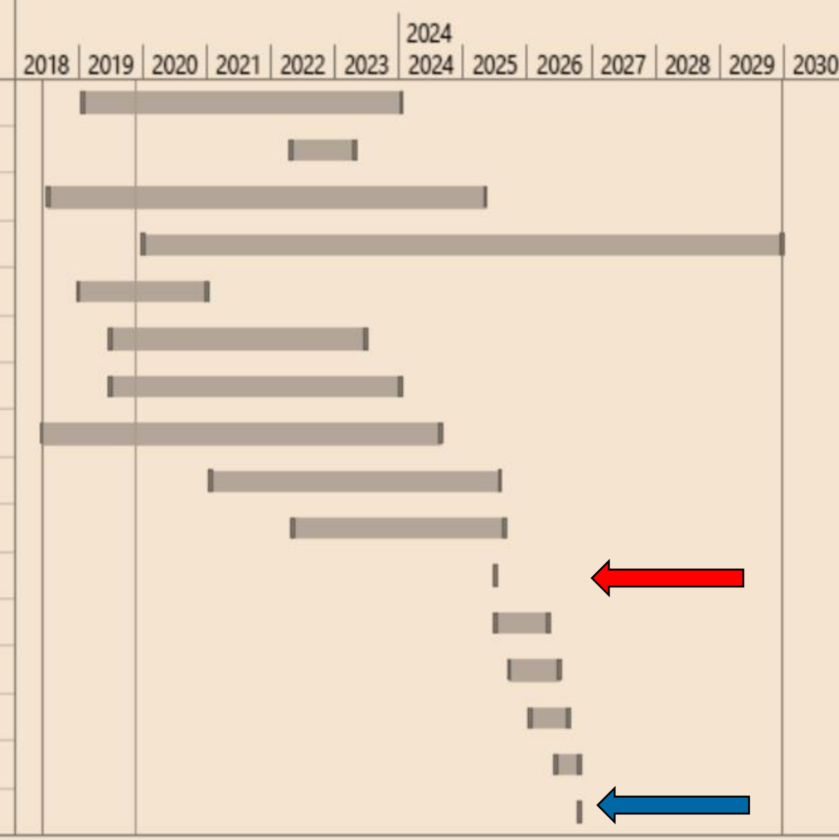
Photon pulse length (ps, fwhm) corresponding at each beamline if using deflecting cavities.

Section	Beamline	Lowest photon energy				Highest photon energy			
		Δt_{FWHM} (ps)		ΔF/F (%)		Δt_{FWHM} (ps)		ΔF/F (%)	
		DR	*IM*	*DR*	*IM*	*DR*	*IM*	*DR*	*IM*
1.2	Nanospectroscopy	16.5	10	1	3	2	1.8	0.2	3
2.1	TwinMic	48	1.2	1	1.6	45	0.8	0.5	1.7
3.2	Spectroμ	47	10	1	1.6	45	2.9	1	2
4.2	MOST	14	18	0.5	8	2.8	4.5	0.1	10
5.1	XRD1	1.8	1.4	0.2	3	1.3	1.4	0.2	3
5.2	μXRD	9	0.9	1	2	5.8	0.8	1	2
6.2	CDI	3.5	5.3	0.5	5	1	2.4	0.1	5
7.2	μXRF	5.5	1	0.4	2	2.4	0.9	0.4	2
8.1	Aloisa	27	1.1	1	1.6	9.4	0.8	0.3	2
8.2	BACH	15	6	0.5	3	2.5	1.8	1	4
9.2	APE LE	38	7	0.2	2	13	1.9	1.5	2
9.2	APE HE	15	2.2	1.5	2	5	1.2	1	2
10.1	APE TX	17	0.8	0.5	1.6	7	0.7	0.5	1.6
10.2	HB-SAXS	1.2	1.3	0.1	3	0.9	1.2	0.1	3
11.1	XAS-mW	1.4	23	0.1	50	1	22	0.1	50
11.2	Xpress (SCW)	30	1.1	0.5	2	17	1.1	1	2.5

Schedule

The project is financed (does not include the deflection cavity part for short pulses) and running

ID	Ta Mo	Task Name	Duration	Start	Finish
1		Infrastructures upgrade	1300 days?	Wed 23/01/19	Tue 16/01/24
2		New building costruction	260 days?	Sun 01/05/22	Thu 27/04/23
3		Some Accelerator systems upgrade	1780.5 days?	Fri 13/07/18	Fri 09/05/25
4		Beam lines upgrade	2600.5 days?	Mon 06/01/20	Mon 24/12/29
5		Technical Design study	524 days?	Tue 01/01/19	Fri 01/01/21
6		Engineering Design	1040.5 days?	Mon 01/07/19	Mon 26/06/23
7		Prototyping	1184 days?	Mon 01/07/19	Thu 11/01/24
8		Calls for tender	1621 days?	Thu 07/06/18	Thu 22/08/24
9		Manufactoring construction and testing	1176 days?	Wed 27/01/21	Wed 30/07/25
10		Preparations and assembly	864 days?	Mon 09/05/22	Thu 28/08/25
11		End of user mode	1 day?	Wed 02/07/25	Wed 02/07/25
12		Ring decomissioning	215 days?	Thu 03/07/25	Wed 29/04/26
13		Installations	203 days?	Sun 21/09/25	Tue 30/06/26
14		Accelerator system tests /commissioning	153 days?	Fri 23/01/26	Tue 25/08/26
15		Ring commissioning with beam lines	97 days?	Mon 15/06/26	Tue 27/10/26
16		Elettra 2.0 user mode	1 day?	Fri 30/10/26	Fri 30/10/26



Summary

- The final lattice is called S6BA-E with 12 equal sections and will operate mainly at 2.4 GeV (and for some time also at 2 GeV) since a notable shift to tender, high and very high photon energies has been decided.
- Four new beam lines will be added that the present machine cannot support while the existing ones are being upgraded / redistributed or cancelled
- The crab cavity option may give an up to 60 times reduction of the short pulse for some beam lines compared to the standard hybrid mode being valid for all beam lines. It does not deteriorate the machine emittance or has any other serious implications.
- The TDR (V1) is available since July 2021 however the upgrade of the experimental instrumentation and the construction of a new auxiliary building has already started.
- New personnel employment started (https://www.elettra.eu/about/careers.html)

Thank you for your attention