Funded by the European Union

The CompactLight Project (XLS)

Gerardo D'Auria (Elettra-ST)

on behalf of the CompactLight Collaboration

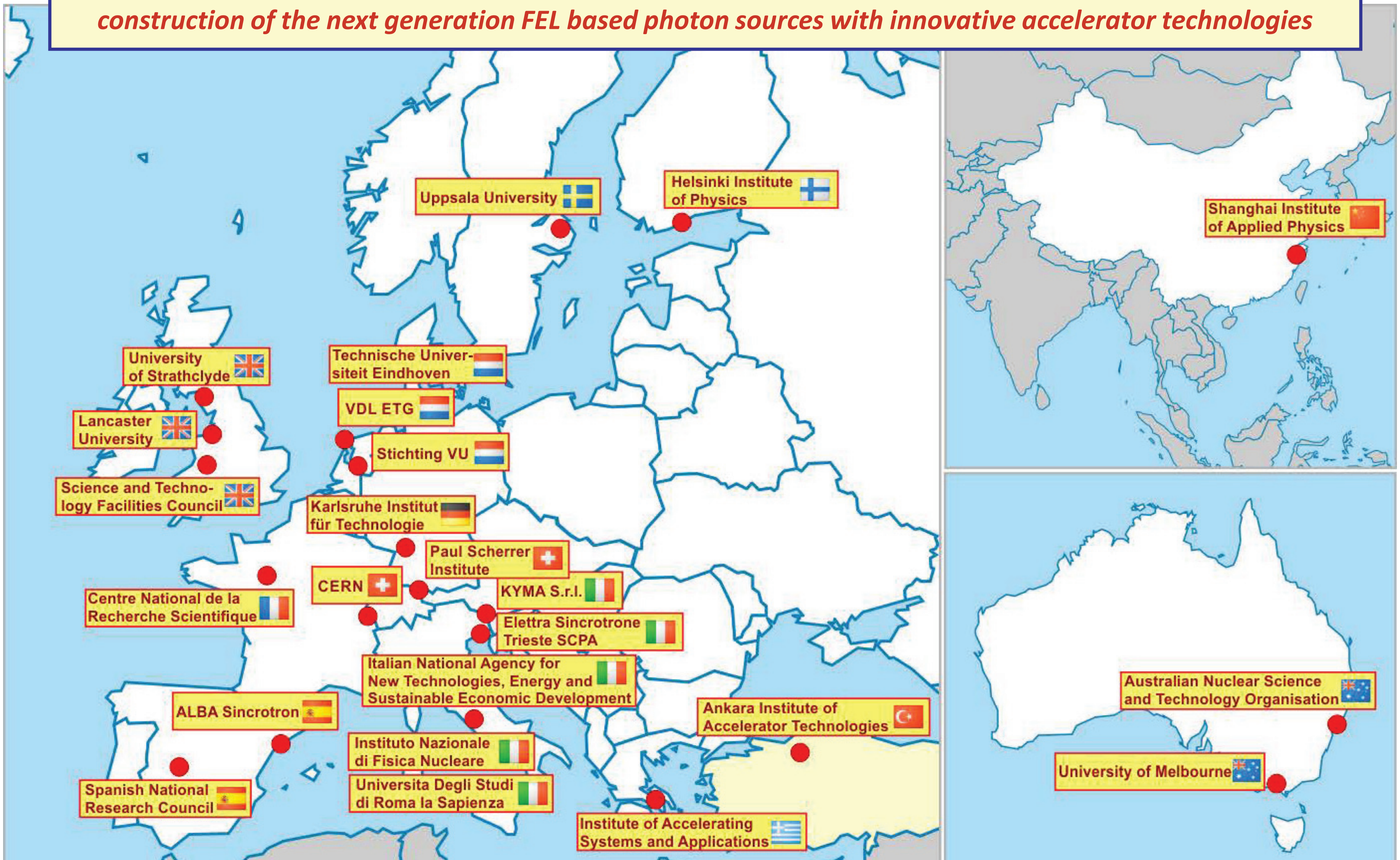
FLS 2018 March 7th 2018

Outline

- **Context**
  - X-ray FELs
  - The XLS Collaboration
- **Horizon 2020 call**
  - The CompactLight Project
  - Interests for X-ray FELs
  - XLS Aim
- **Work Packages Structure**
  - Top level summary
  - WP details
- **Timeline, Milestones and Deliverables**

XLS Collaboration

The XLS Collaboration is an initiative among several International Laboratories aimed at promoting the construction of the next generation FEL based photon sources with innovative accelerator technologies



Elettra Sincrotrone Trieste

List of Participants

Compact

Participant		Organisation Name	Country
1	ST (Coord.)	Elettra – Sincrotrone Trieste S.C.p.A.	Italy
2	CERN	CERN - European Organization for Nuclear Research	International
3	STFC	Science and Technology Facilities Council – Daresbury Laboratory	United Kingdom
4	SINAP	Shanghai Inst. of Applied Physics, Chinese Academy of Sciences	China
5	IASA	Institute of Accelerating Systems and Applications	Greece
6	UU	Uppsala Universitet	Sweden
7	UoM	The University of Melbourne	Australia
8	ANSTO	Australian Nuclear Science and Tecnology Organisation	Australia
9	UA-IAT	Ankara University Institute of Accelerator Technologies	Turkey
10	ULANC	Lancaster University	United Kingdom
11	VDL ETG	VDL Enabling Technology Group Eindhoven BV	Netherlands
12	TU/e	Technische Universiteit Eindhoven	Netherlands
13	INFN	Istituto Nazionale di Fisica Nucleare	Italy
14	Kyma	Kyma S.r.l.	Italy
15	SAPIENZA	University of Rome "La Sapienza"	Italy
16	ENEA	Agenzia Naz. per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile	Italy
17	ALBA-CELLS	Consorcio para la Construccion Equipamiento y Explotacion del Lab. de Luz Sincrotron	Spain
18	CNRS	Centre National de la Recherche Scientifique CNRS	France
19	KIT	Karlsruher Institut für Technologie	Germany
20	PSI	Paul Scherrer Institut PSI	Switzerland
21	CSIC	Agencia Estatal Consejo Superior de Investigaciones Científicias	Spain
22	UH/HIP	University of Helsinki - Helsinki Institute of Physics	Finland
23	VU	VU University Amsterdam	Netherlands
24	USTR	University of Strathclyde	United Kingdom

Third Parties		Organisation Name	Country
AP1	OSLO	Universitetet i Oslo - University of Oslo	Norway
AP2	ARCNL	Advanced Research Center for Nanolithography	Netherlands
AP3	NTUA	National Technical University of Athens	Greece
AP4	AUEB	Athens University Economics & Business	Greece

Italy	5
Neth.	3+1
UK	2
Spain	2
Australia	2
China	1
Greece	1+2
Sweden	1
Turkey	1
France	1
Germany	1
Switz.	1
Finland	1
Norway	0+1
Internat.	1

Compact

http://compactlight.web.cern.ch

(work in progress)

Submitted in March 2017, for EU funding to

Horizon2020 - Work Programme 2016 – 2017

Research & Innovation Action (RIA)

INFRADEV-1-2017 Design Studies

CompactLight Approval

Europa / Participant Portal notification

23-08-2017

Dear Coordinator,

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2. **Starting date:** 01-01-2018
3. **Duration of the action:** 36 months
4. **Maximum grant amount:**
    a. Total cost of the project: >3.5 M€
    b. Requested EU contribution (according to proposal): 2,999,500 €
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EU Project Officer: Mina KOLEVA
EU Legal Officer: Spyridon POLITOPOULOS

CompactLight Aim

Our aim is to facilitate the widespread development of X-ray FEL facilities across Europe and beyond, by making them more affordable to construct and operate through an optimum combination of emerging and innovative accelerator technologies.

We plan to design a Hard X-ray Facility using the very latest concepts for:

a. ***High brightness electron photoinjectors.***
b. ***Very high gradient accelerating structures.***
c. ***Novel short period undulators.***

The resulting Facility will benefit from:

i. *A **lower electron beam energy** than current facilities, due to the enhanced undulator performance.*
ii. *Will be **significantly more compact** due to lower energy and high gradient structures.*
iii. *Will have a **much lower electrical power demand** than current facilities.*
iv. *Will have **much lower construction and running costs.***

Making X-ray FELs affordable

Interests for X-ray FELs

FEL Facilities	Institutes
Hard X-ray	STFC, PSI, UA-IAT, SINAP, UoM, ANSTO.
Soft X-ray	ELETTRA-ST, INFN.
Compton Sources	TU/e, ANSTO.
Upgrading of existing Facilities	ELETTRA-ST, INFN.

Sub-systems	Institutes
Accelerating Structures	CERN, SINAP, UU, VDL-ETG, PSI, CSIC, UH/HIP, USTR.
Undulators	ENEA, STFC, KIT, PSI, KYMA, ALBA-CELLS, UU, VU.
Beam diagnostics and manipulation	ST, CERN, STFC, SINAP, IASA, UU, UA-IAT, ULANC, INFN, SAPIENZA, INFN, PSI, ALBA-CELLS, CNRS

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CERN has no direct interest in Synchrotron Light Sources and FELs, but the activities on CompactLight will have strong return value for the CLIC project: i.e. accelerator and RF components optimization, technical developments with industry, costs reduction, etc.

Sub-systems	Institutes
Accelerating Structures	CERN, SINAP, UU, VDL-ETG, PSI, CSIC, UH/HIP, USTR.
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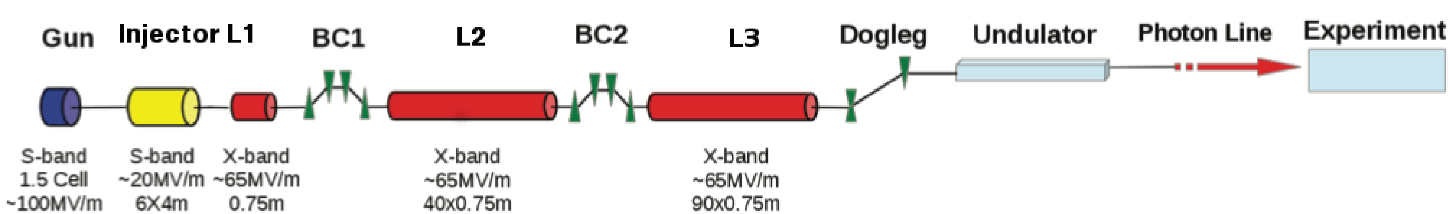
XLS Specific Goals

- Based on user-driven scientific requirements, determine the overall design and parameters for an ideal X-band driven FEL for Hard X-rays, with options for Soft X-ray FEL and Compton Source (WP2).
- Design the main machine sub-assemblies required, including e-Gun, RF power units and power distribution systems, accelerating structures and undulators (WPs 3 to 5).
- Specify the key parameters of the machine including beam structure, lattice, geometric layout, mechanical tolerances, magnetic transverse focusing, required diagnostics, while identifying a solution as common as possible (WP6).
- Gathering the user demands on FELs and accelerator upgrades, in the near and mid-term future, emphasizing the needs from European laboratories and global partners, to develop plans for an harmonious integration within new Research Infrastructures (WP7).

XLS Performance

Parameter	Value	Unit
Minimum Wavelength	0.1	nm
Photons per pulse	>10^{12}	
Pulse bandwidth	<<0.1	%
Repetition rate	100 to 1000	Hz
Pulse duration	<1 to 50	fs
Undulator Period	10	mm
K value	1.13	
Electron Energy	4.6	GeV
Bunch Charge	<250	pC
Normalised Emittance	<0.5	mrad



XLS Preliminary Parameters and Layout

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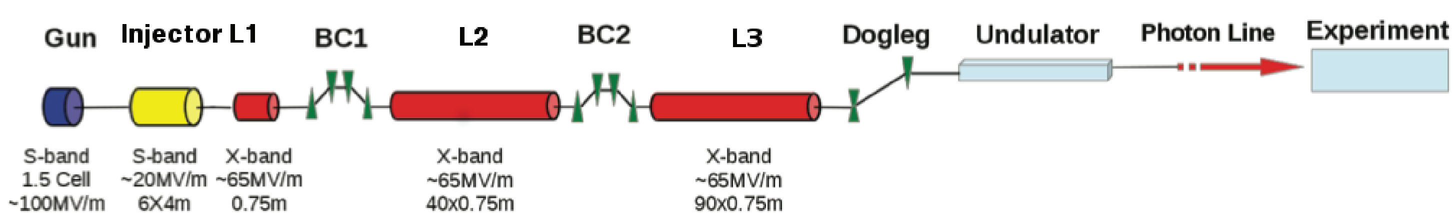

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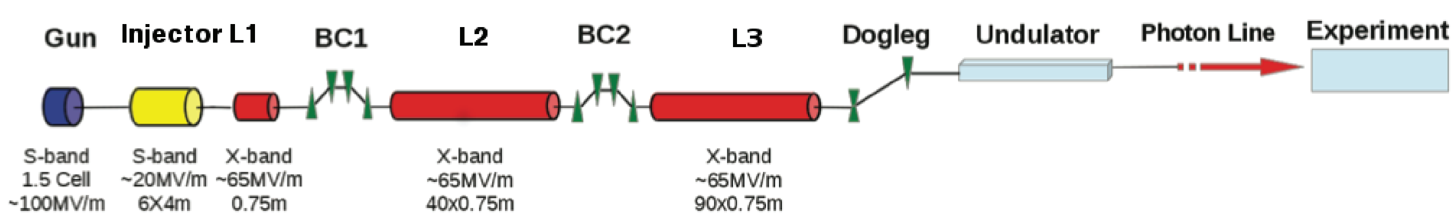

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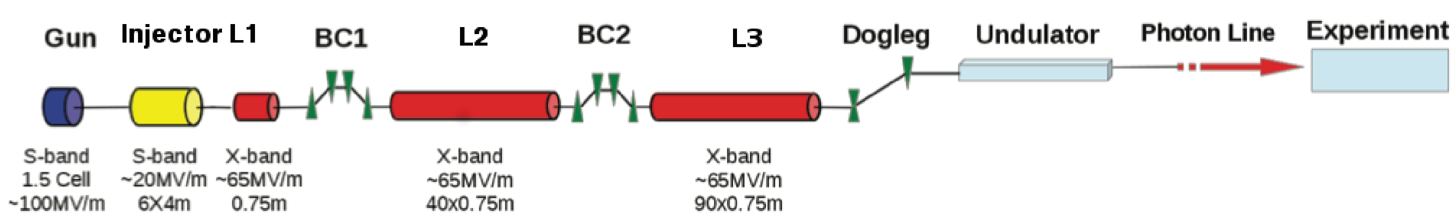

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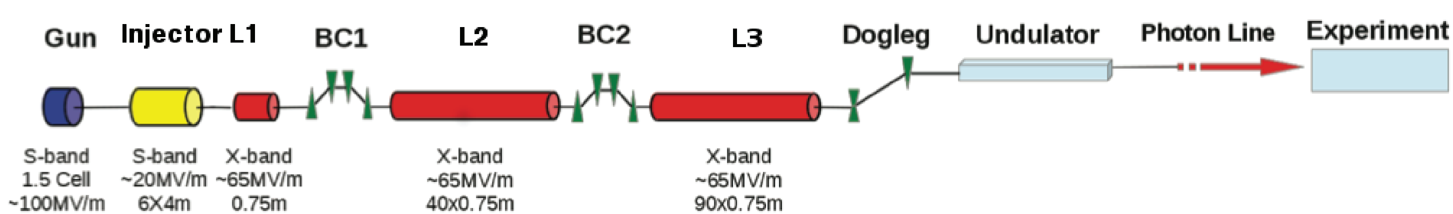

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Beyond the state-of-the-art

European XFEL (Germany)	24 MV/m	Superconducting L-band
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Examples of Linac gradients for most recent X-ray FELs

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Parameter	Value
Length L	0.75m
Phase advance per cell φ	120°
First iris aperture a1/λ	0.15
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First iris thickness d1	0.9mm
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Fill time τ	150ns
Operational gradient G	65MV/m
Input power Pin	41.8MW

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Preliminary parameters of the X-band RF unit, compared with the C-band SwissFEL technology.

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Preliminary parameters of the X-band RF unit, compared with the C-band SwissFEL technology.

	unit	XLS X-band	SwissFEL C-band
Structures per RF unit		10	4
Klystrons per RF unit		2	1
Structure length	m	0.75	1.98
Allowed gradient	MV/m	80+	
Operating gradient	MV/m	65	27.5
Energy gain per RF unit	MV	488	203
Klystron nominal power	MW	50	50
Power in operation	MW	45	40
Klystron pulse length	µs	1.5	3
RF energy/pulse/GeV	J	277	591

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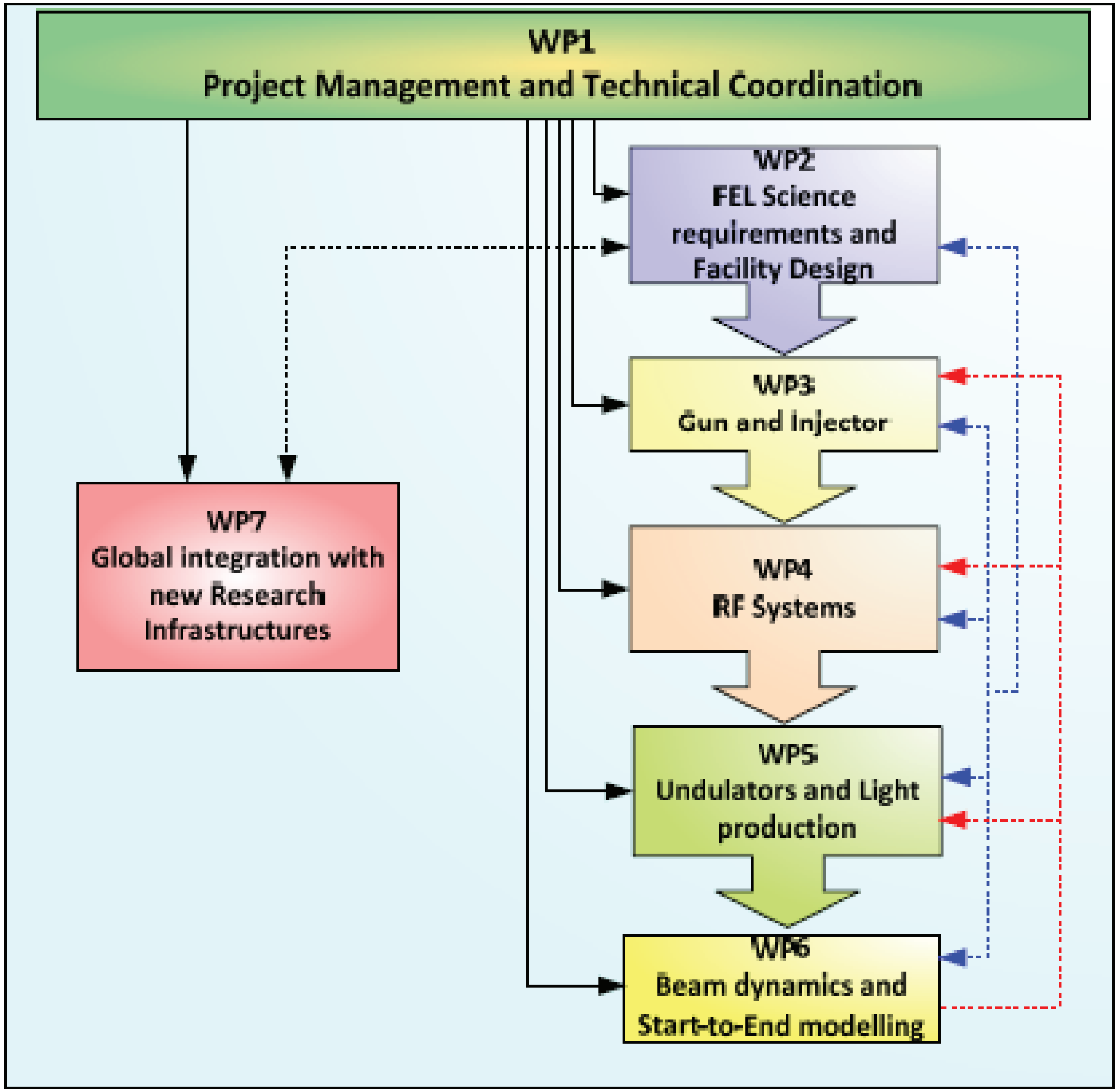
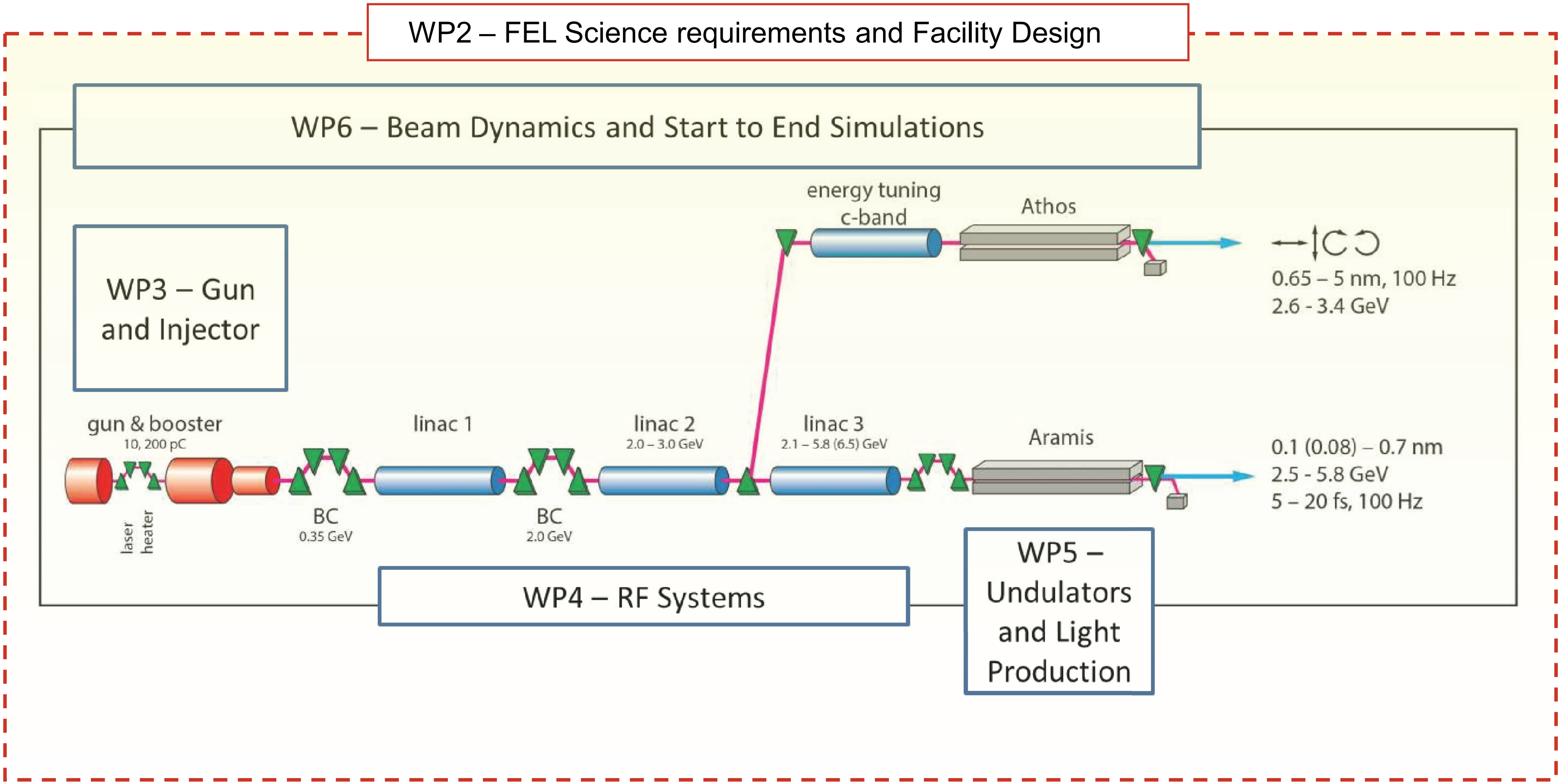
Work Packages

Work Package		Lead Participant	Person Months	Start Month	End month
WP1	Project management and Technical Coordination	Elettra - ST	32	1	36
WP2	FEL Science Requirements and Facility Design	STFC	68	2	36
WP3	Gun and Injector	INFN	76	2	36
WP4	RF systems	CERN	78	2	36
WP5	Undulators and Light production	ENEA	81	2	36
WP6	Beam dynamics and Start to End Modelling	UA-IAT	78	2	36
WP7	Global Integration with New Research Infrastructures	Elettra - ST	27	6 (2)	36
		Total Person Months	440		

XLS WPs Structure



WPs Relationship



Using SwissFEL as an example https://www.psi.ch/swissfel/

Courtesy J. Clarke

WP1: Project management and coordination

WP1 carries the overall management of the XLS Design Study to ensure timely achievement of project results through technical and administrative management (Elettra – ST).

WP1 duties:

- ***Coordination of all the Partners and conflict resolution.***
- ***Manage internal communication.***
- ***Monitor project activities.***
- ***Coordinate WPs Activities.***
- ***Organise periodic Meetings and Events.***
- ***Keep contacts with the Advisory and Executive boards.***
- ***Keep contacts with EC and report to EC.***
- ***Coordinate administration.***
- ***Manage public communication***
- ***Identify risks and propose corrective actions.***

The objective of WP2 is to provide the overall design of the Hard X-ray FEL facility (STFC- Daresbury).

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Description of work:

- *Starting from the performance specification of the FEL, based on user-driven scientific requirements, the aim of WP2 is to identify and chose the most appropriate technical solutions for the FEL considering cost, technical risk and performance.*

Deliverables:

- *A report summarising the requests from the users and defining the final performance specifications for the FEL (31/12/18).*
- *A report summarising the FEL design, with the accelerator and undulator requirements to achieve the specification, i.e. electron energy, bunch charge, peak current, emittance, energy spread, undulator parameters, etc. (31/12/19).*
- *The conceptual design report for a fully fledged Hard X-ray FEL facility, including cost estimates, with options for Soft X-ray FEL and Compton Source, (31/12/20).*

WP3: Gun and Injector

The objective of WP3 is to provide the technical specification and the optimum design of the Linac e-gun and injector (INFN-Frascati).

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Description of work:

- *Perform comparative assessment of advanced guns and injector designs. Options considered:*
  - *High-gradient injectors at existing gun frequencies, S and C bands (towards lower emittance guns).*
  - *A full-X-band solution, inclusive of higher-harmonic linearization in K band.*
  - *Injector diagnostics & beam manipulations based on X-band technology. Bunch compression techniques (compact magnetic chicanes, velocity bunching).*

Deliverables:

- *Preliminary assessments and evaluations of the optimum e-gun and injector solution for the CompactLight design, (30/06/19).*
- *A review report on the bunch compression techniques and phase space linearization, (30/06/19).*
- *Design of the injector diagnostics/beam manipulations based on a X-band cavities, (31/12/20).*
- *Design of the CompactLight e-gun and injector, with phase space linearizer (31/12/20).*

WP3 Tasks

Task 3.1 – *Gun design* *(RF, Solenoid, Cathode, Laser, Diagnostics) => D3.1 M18 => D3.3 M36*

- *S-Band Gun RF Design*
- *C-Band Gun RF Design*
- *X-Band Gun RF Design*
- *DC Gun Design*
- *Laser/Photocathode*

WP3 Tasks

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- *X-Band Gun RF Design*
- *DC Gun Design*
- *Laser/Photocathode*

Task 3.2 – *Compressor Design* *(Velocity Bunching, Magnetic Chicane) => D3.2 M18 => D3.3 M36*

- *S-Band Velocity Bunching*
- *C-Band Velocity Bunching*
- *X-Band Velocity Bunching*
- *Magnetic Compressor*

WP3 Tasks

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- *X-Band Velocity Bunching*
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Task 3.3 – *X-Band Diagnostics* *(Transverse RF Deflector) => D3.3 M36*

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Task 3.2 – *Compressor Design* *(Velocity Bunching, Magnetic Chicane) => D3.2 M18 => D3.3 M36*

- *S-Band Velocity Bunching*
- *C-Band Velocity Bunching*
- *X-Band Velocity Bunching*
- *Magnetic Compressor*

Task 3.3 – *X-Band Diagnostics* *(Transverse RF Deflector) => D3.3 M36*

Task 3.4 – Linearizer Design *(RF and passive linearizers) => D3.2 M18 => D3.3 M36*

- *X-Band RF Linearizer*
- *K-Band RF Linearizer*
- *Passive linearizers*

WP4: RF systems

The primary objective of WP4 is to define the RF system for the linac of the CompactLight design (CERN).

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Description of work:

- *Define a standardized RF unit which can be used in all main and sub-design variants. Making a standardized design available can simplify the preparation of future construction projects, stimulate the industrialization process and cost savings by future facilities.*

Deliverables:

- *A parametrized performance and cost model of the RF unit to be used by WP2 for the facility optimization. The model will be established in computer code and described in a report, (30/06/19).*
- *A design report of the optimized RF unit. Based on the parameters emerging from the facility optimization, the design of the RF unit will be established at the component level and described in a report, (31/12/20).*
- *A report on the design and fabrication procedure, optimized for series industrial production, of the accelerating structure which is an important cost driver for the facility, (31/12/20).*

WP5: Undulators and Light production

The objective of WP5 is to provide the design of the CompactLight undulator (ENEA-Roma).

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Description of work:

- *Investigate the state of art undulators and then consider on-going developments. "Ambitious undulators" will be compared with the boundary conditions of technologies available on 4-5 years time scale. These will include:*
  - *novel short period undulators*
  - *superconducting undulators*
  - *RF-microwave undulators*
  - *laser electromagnetic wave undulators*

Deliverables:

- *Technologies for the CompactLight undulator: a report comparing near and medium-term undulator technologies for CompactLight (30/06/19).*
- *Conceptual Design Report of the CompactLight undulator to be included in the main deliverable of the Design Study. (31/12/20).*

WP6: Beam dynamics and start to end modelling

The objective of WP6 is to design the accelerator lattice and to provide the key parameters and performance estimates of the overall facility, from the electron source up to undulator exit (UA-IAT).

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Description of work:

- *WP6 will carry out integrated performance studies of the facility. These include start to end simulations, covering the beam transport from the cathode to the undulator exit, including space charge effects, coherent synchrotron radiation in magnetic compressors, wake field effects in the X-band linac, tolerance studies and FEL performances. Beam-based alignment and tuning methods that can relax the tolerances will also be addressed.*

Deliverables:

- *A report providing a global analysis of the most advanced computer codes available for the facility design and performance evaluations (30/06/19).*
- *Final report of the accelerator lattice and FEL design and performance (31/12/20).*

WP7: Global integration with new Research Infrastructures

The WP7 objectives will be the global integration of XLS for new Research Infrastructures at European level and Worldwide (Elettra - ST).

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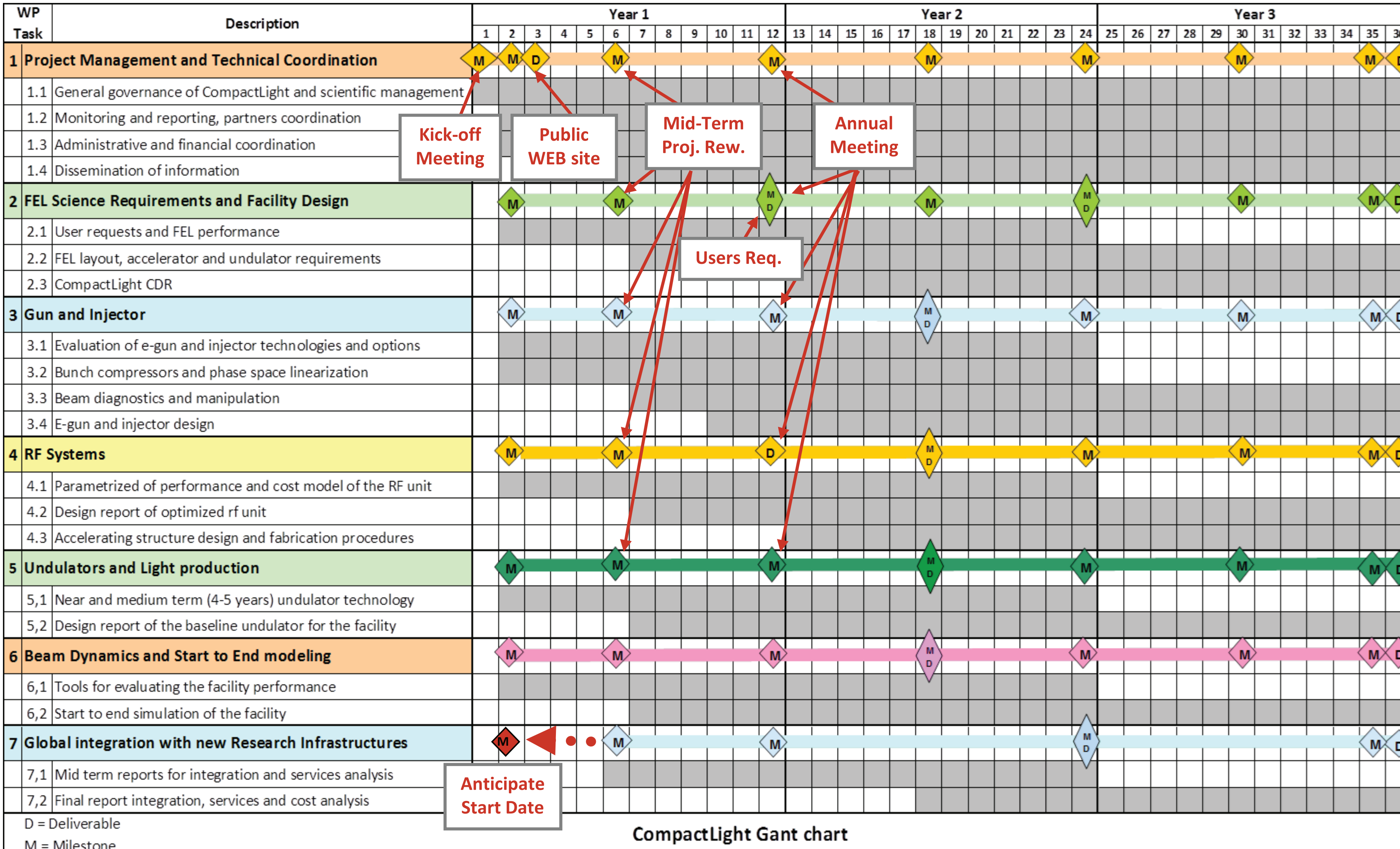
Description of work:

- *WP7 will address strategic issues related to the XLS impact and benefits for the user community, in both the public and private sectors, at the scientific and technical level. The results of this work package will be a series of reports which target funding agencies and policy makers in the decision making process for the approval of new research infrastructures or the upgrade of existing Facilities.*

Deliverables:

- *Mid-term report providing a global integration analysis and services to be provided, (31/12/19).*
- *Final report giving an overview of the integration process, services and a preliminary cost estimate, (31/12/20).*

Time plan, Milestones and Deliverables



CompactLight Gant chart

Acknowledgements

- All the Members of the XLS Collaboration for contributing to make CompactLight a successful Project!
- In particular:
  - R. Rochow (Elettra)
  - A. Latina, S. Stapnes, W. Wuensch, D. Schulte (CERN)
  - J. Clarke (STFC)

  for their hard work and continuous support.
- CERN for the INDICO Platform and the WEB Page.

Thanks for your attention!