Funded by the European Union

The CompactLight Project (XLS)

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on behalf of the CompactLight Collaboration

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Motivations

- Synchrotron Radiation has become a fundamental and indispensable tool for studying matter, as shown by the large number of Facilities in operation worldwide.
- The last generation of Synchrotron Light Sources is based on single-pass Free Electron Lasers (FELs), driven by linacs, and features unprecedented performance in terms of pulse duration, brightness and coherence.
- The demand for new FEL facilities is worldwide continuously increasing, spurring plans for new dedicated machines. This led to a general reconsideration of costs and spatial issues, particularly for the Hard X-ray Sources, driven by long and expensive multi-GeV NC linacs.
- For these machines the use of an optimum combination of emerging and innovative accelerator technologies can greatly reduce costs and capital investment, opening the way to the construction of a multitude of affordable *"Regional Facilities".*

X-ray FEL Facilities

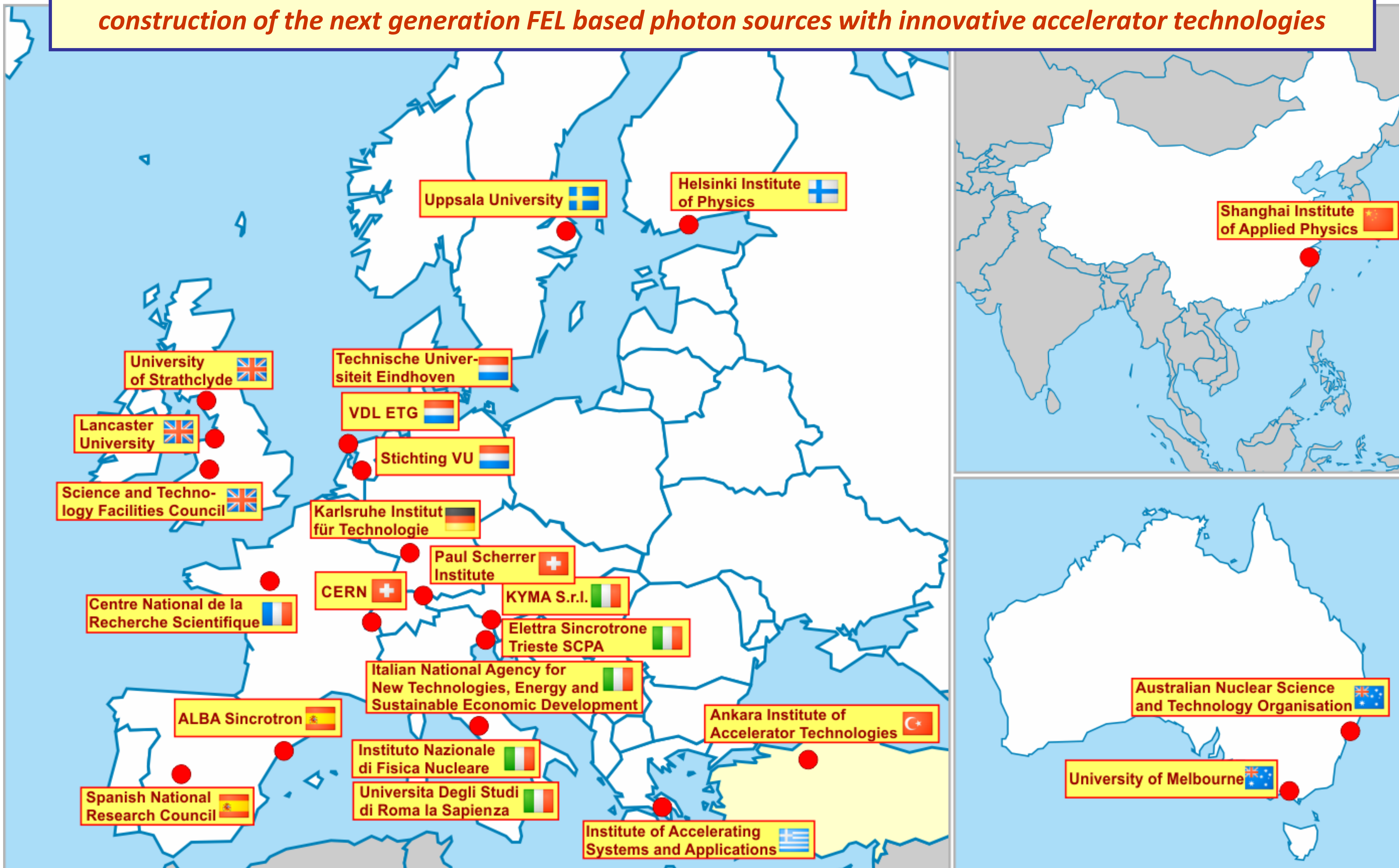
TABLE II. The characteristic parameters of the various x-ray FEL user facilities summarized across the globe. These include the location, name of the facility, linac type (NC: normal conducting, SC: superconducting), maximum electron energy (*E* energy), photon beam energy range, repetition rate (Rep. rate), and year of start or expected start of operation (Start ops.).

Location	Name	Linac type	*E* energy (GeV)	Photon energy (keV)	Rep. rate (Hz)	Start ops.
Germany	FLASH FLASH-II	SC SC	1.2	0.03–0.3	$(1-500)\times 10^{a}$	2005 2015
	XFEL	SC	17.5	3–25 0.2–3	$(1-2800)\times 10^{b}$	2017
Italy	FERMI-FEL1 FERMI-FEL2	NC	1.5	0.01–0.06 0.06–0.3	10–50	2012 2014
Japan	SACLA	NC	8	4–15	30–60	2011
Korea	PAL-XFEL	NC	10 3	1–20 0.3–1	60	2016
Switzerland	SwissFEL	NC	5.8 3	2–12 0.2–2	100	2017
USA	LCLS LCLS-II LCLS-II	NC NC SC	16 16 4	0.25–11 1–25 0.2–5	120 120 10^6	2009 2020 2020

[a]Pulsed mode operation at 10 Hz, with each macropulse providing up to 500 bunches.
[b]Pulsed mode operation at 10 Hz, with each macropulse providing up to 2800 bunches.

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



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.

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.
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

Compact?

http://compactlight.web.cern.ch

(work in progress)

is a Project submitted in March 2017, for EU funding to

Horizon2020 - Work Programme 2016 – 2017

Research & Innovation Action (RIA)

INFRADEV-1-2017 Design Studies

List of Participants

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

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

CompactLight Supports

FELs OF EUROPE

"………The aims of the CompactLight Design Study, 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 are strongly aligned to those of FELS OF EUROPE and so we are very supportive of this initiative. We agree that making use of the very latest concepts for bright electron photoinjectors, very high gradient accelerating structures, and novel short period undulators will result in a more compact facility with lower construction and operating costs and so increase the speed with which these unique facilities are implemented across Europe.

The CompactLight consortium brings together an impressive group of more than twenty leading accelerator and light source laboratories, universities, and industries. The inclusion of many of the leading European FEL laboratories, including Elettra – Sincrotrone Trieste, PSI, STFC, and INFN, gives confidence that the Hard X-ray Design Study will be completed successfully and will be the base for a fully fledged user facility with the needs of the FEL researchers driving the design solution proposed."

TIARA
ACCELERATING KNOWLEDGE AND INNOVATION

"……….TIARA welcomes and supports the CompactLight proposal given the potential it offers for increasing the availability and accessibility of FEL X-ray sources for the increasingly growing scientific community requiring access to such instruments."

XLS Approval

Europa / Participant Portal notification

23-08-2017

Dear Coordinator,

Congratulations. Your proposal has reached the stage of Grant Agreement preparation. To view the evaluation results and the instructions on how to provide additional information and data required for the preparation of your Grant Agreement, log on to the Participant Portal > My Area > My Project(s) (https://ec.europa.eu/research/participants/portal/desktop/en/projects/index.html) and click the Manage Project (MP) button. You will receive a separate notification when additional information for the Grant Agreement is required.

Regards,
Participant Portal Grant Management Service

1. **Proposal:** 777431 — XLS
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 €
   c. Maximum grant amount (proposed amount, after evaluation): 2,999,500 €

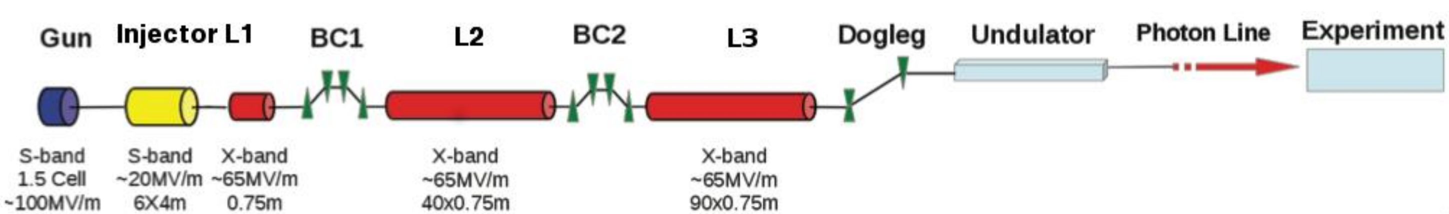
EU Project Officer: Mina KOLEVA
EU Legal Officer: Spyridon POLITOPOULOS

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



Preliminary Parameters and Layout of XLS hard X-ray FEL facility

Beyond the state-of-the-art

European XFEL (Germany)	24 MV/m	Superconducting L-band
Swiss FEL (Switzerland)	28 MV/m	Normal-conducting C-band
SACLA (Japan)	35 MV/m	Normal-conducting C-band

Examles of Linac gradients of current X-ray free electron

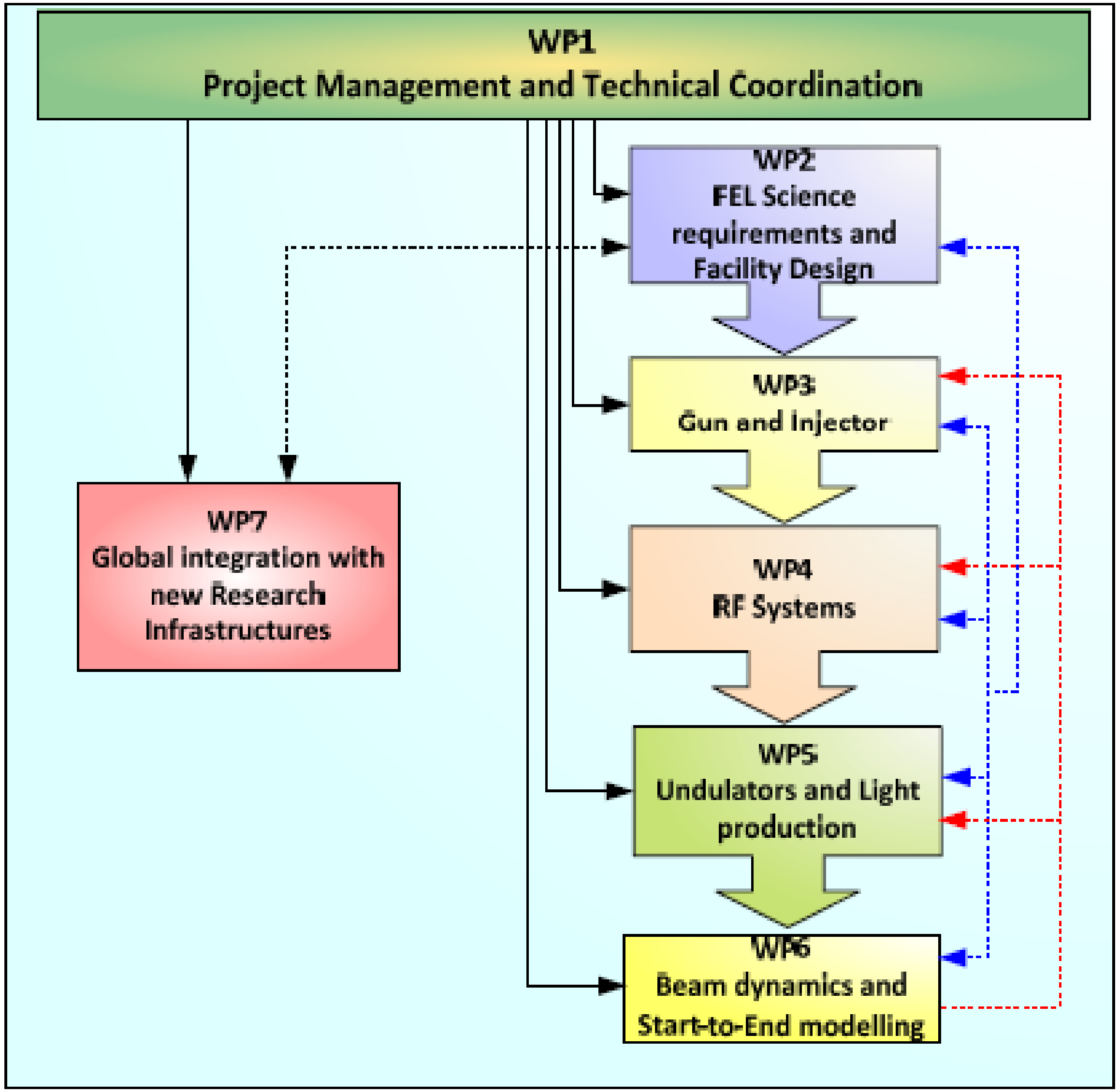
Parameter	Value
Length L	0.75m
Phase advance per cell φ	120°
First iris aperture a1/λ	0.15
Last iris aperture a2/λ	0.1
First iris thickness d1	0.9mm
Last iris thickness d2	1.7mm
Fill time τ	150ns
Operational gradient G	65MV/m
Input power Pin	41.8MW

Preliminary parameters of an optimized RF structure (x-band)

Preliminary parameters for 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

WPs Structure



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	ST	27	6 (2)	36
		Total Person Months	**440**		

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. It will be lead by the Project Coordinator and be focused on the effective management and coordination of all the WPs and deliverables, the budget and the project implementation plans.

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.***

WP2-WP3-WP4 Objectives

WP2: FEL science requirements and facility design

The objective of WP2 is to provide the overall design of the FEL. It will determine performance specification for the Facility based on user-driven scientific requirements. It will identify and choose the most appropriate technical solutions considering cost, technical risk and performance.

WP3: Gun and injector

The objective of WP3 is the comparative assessment of advanced guns and injector design. Options considered:

- A full-X-band solution, inclusive of higher-harmonic linearization in K band. This aims to utilize the recent achievements in the design of X-band guns and reduce limitations of machine repletion rate currently given by the injector.
- High-gradient injectors at existing frequencies, S-C bands (towards lower emittance guns).

WP4: RF systems

The primary objective of WP4 is to define the RF system for the linac in the main and sub-design variants (specialized hardware for an eventual 36 GHz lineariser system, deflectors for profile measurement systems,…).

A key goal will be to define a standardized RF unit:

- Simplify the preparation of future construction projects.
- Cost savings (industrialization of linac hardware).

WP5: Undulators and light production

The primary objective of WP5 is to determine the undulator design for XLS. It will start by investigating 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 undulator.
- RF-microwave undulators.

WP6: Beam dynamics and start-to-end modelling

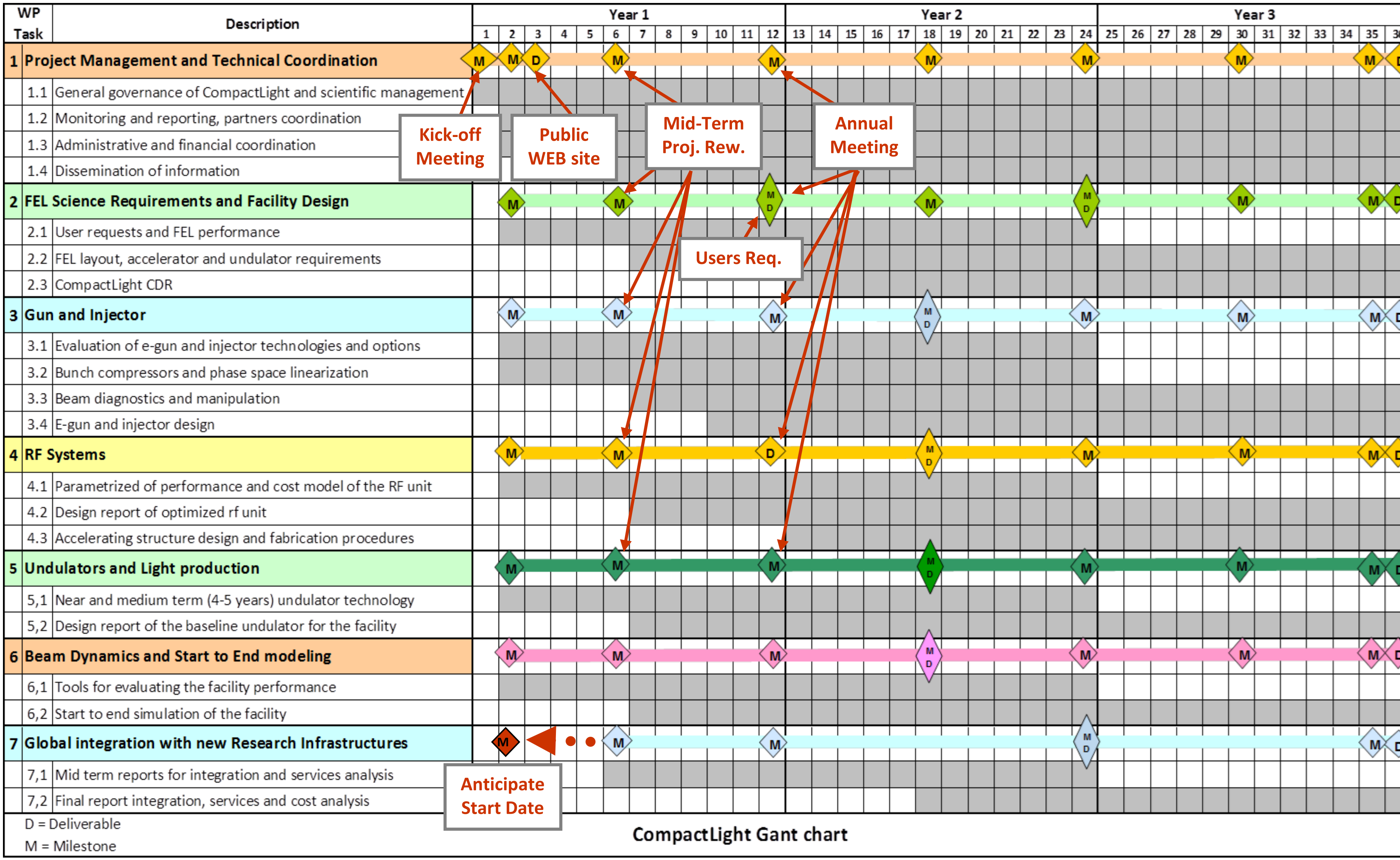
The main objective of WP6 is to provide key parameters and performance estimates of the Facility. Consistent tools for modelling the machine, as the basis for the integrated performance studies, will be developed.

- S2E simulations from the cathode to the undulator exit.
- Tolerance studies will be also performed.
- Beam-based alignment and tuning methods that can relax the tolerances.

WP7: Global integration with new Research Infrastructures

WP7 will address strategic issues related to the objectives of XLS, namely the 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.

Time plan, Milestones and Deliverables



CompactLight Gant chart

Acknowledgements

- **CERN Support**
  - **Proposal Preparation**
  - **INDICO Platform and WEB Page**
  - **Hosting our Kich-off Meeting**
- **S. Stapnes for launching the idea, stimulating discussions and continuous trusting the initiative.**
- **R. Rochow, A. Latina, W. Wuensch, D. Schulte and J. Clarke for their strong work and support in the proposal preparation.**
- **All the Consortium Members for contributing to make this proposal a successful Project!**

Thanks for your attention

and

See you in Trieste for next meeting!