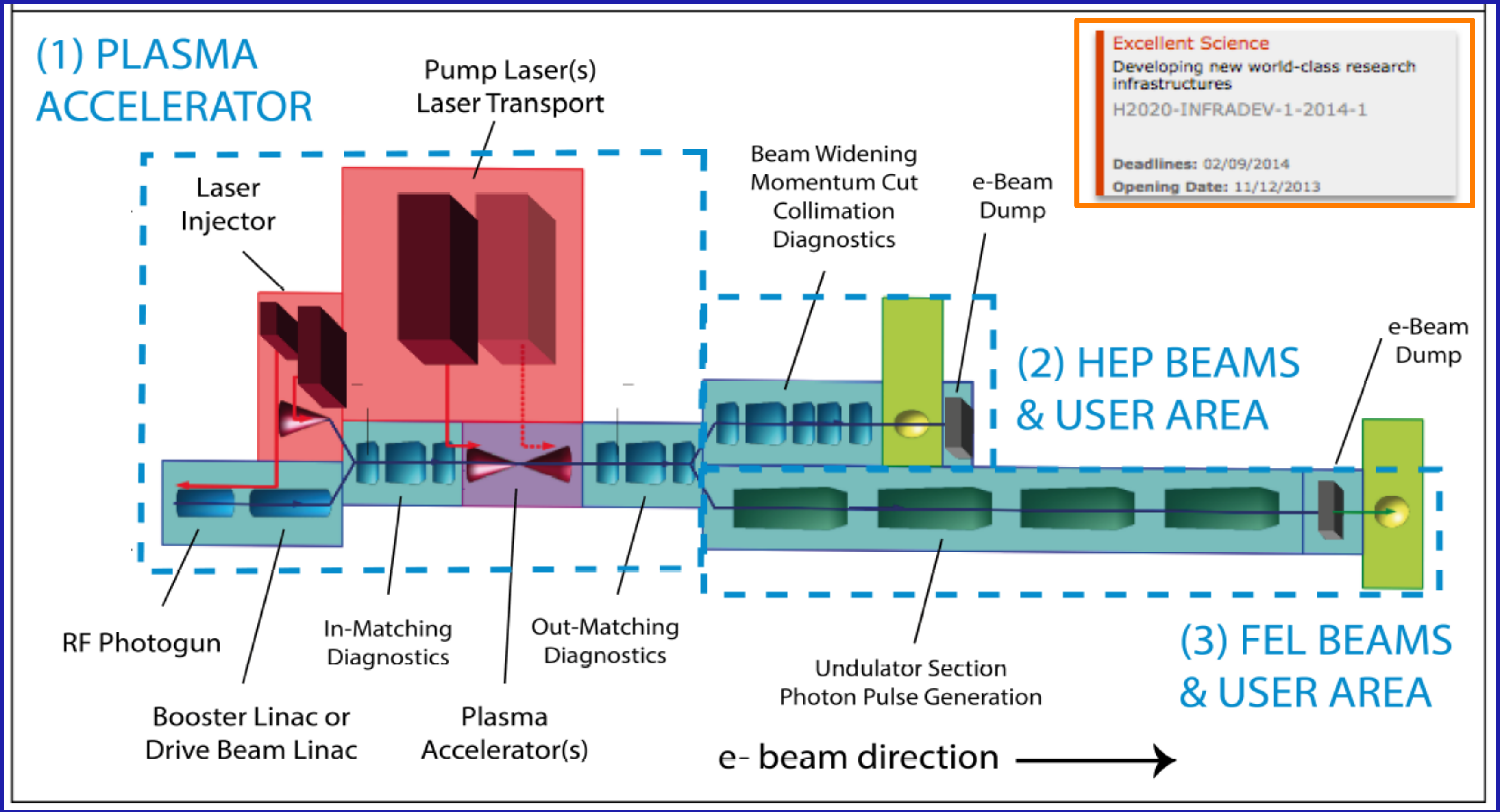
Design Study on the "European Plasma Research Accelerator with eXcellence In Applications" (EuPRAXIA)

Approved as HORIZON 2020 INFRADEV, 4 years, 3 M€



EuPRAXIA

Officially started on November 1, 2015

Excellent Science
Developing new world-class research infrastructures
H2020-INFRADEV-1-2014-1

Deadlines: 02/09/2014
Opening Date: 11/12/2013

ESFRI European Strategy Forum on Research Infrastructures

~200 M€

- Design Studies with at least 3 Countries,
- Cost. Schedule, Siting?
- What is the governance model?
- What is the intended user community?
- Will it be open access?
- Apply for H2020 preparatory phase (PP)?

- Support will be provided by Horizon2020 and MIUR for the implementation (PP) and operation of the research infrastructures listed on the ESFRI Roadmap and ERIC.

Plasma based electron accelerators have reached high gradient (~ 50 GV/m) with good electron beam quality → Is time to think about a Plasma based pilot user facility

EuPRAXIA goal is to produce a conceptual design report for the worldwide first plasma-based accelerator user facility

- The technical focus is on designing accelerator and laser systems for improving the quality of plasma-accelerated beams, similar to the methods used in conventional accelerators. These methods require significant space and investment.
- The scientific focus is on developing beam parameters, two user areas and the use cases for a femto-second Free Electron Laser (FEL) and High Energy Physics (HEP) detector science.
- The managerial focus is on developing an implementation model for a common European plasma accelerator. This includes a **comparative study of possible sites in Europe**, a cost estimate and a model for distributed construction in Europe and installation at one central site.

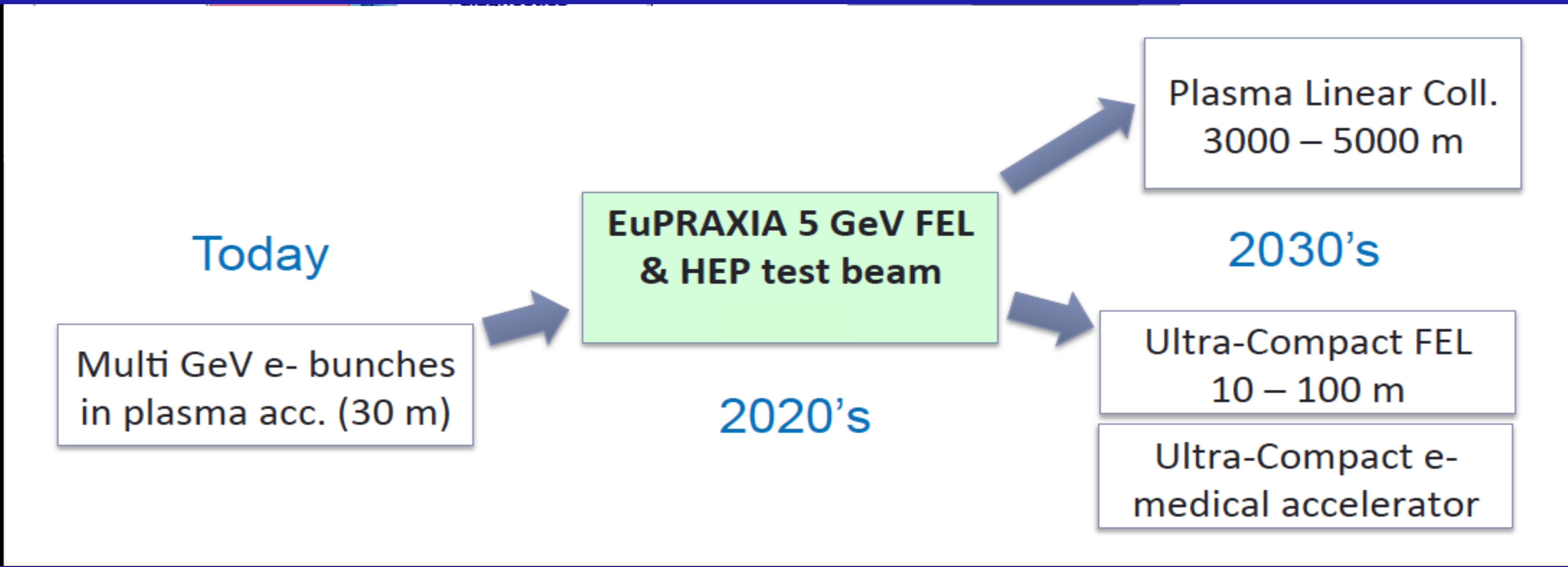
A commercially available 1 PW Ti: Sa laser laser driver or a high brightness 1 GeV electron beam linac could be adequate drivers for the EUPRAXIA plasma accelerator.

The foreseen parameters give access to:
(1) to an FEL in the EUV to X-ray regime (1 – 15 nm) and
(2) to short electron pulses with high brightness for HEP detector tests, material tests and other applications.

Beam Parameter	**Unit**	**Value**
Particle type	-	Electrons
Energy	GeV	1 – 5
Charge per bunch	pC	1 – 50
Repetition rate	Hz	10
Bunch duration	fs	0.01 - 10
Peak current	kA	1 – 100
Energy spread	%	0.1 – 5
Norm. emittance	mm	0.01 – 1
FEL wavelength	nm	1 - 15

Positioning of the Project

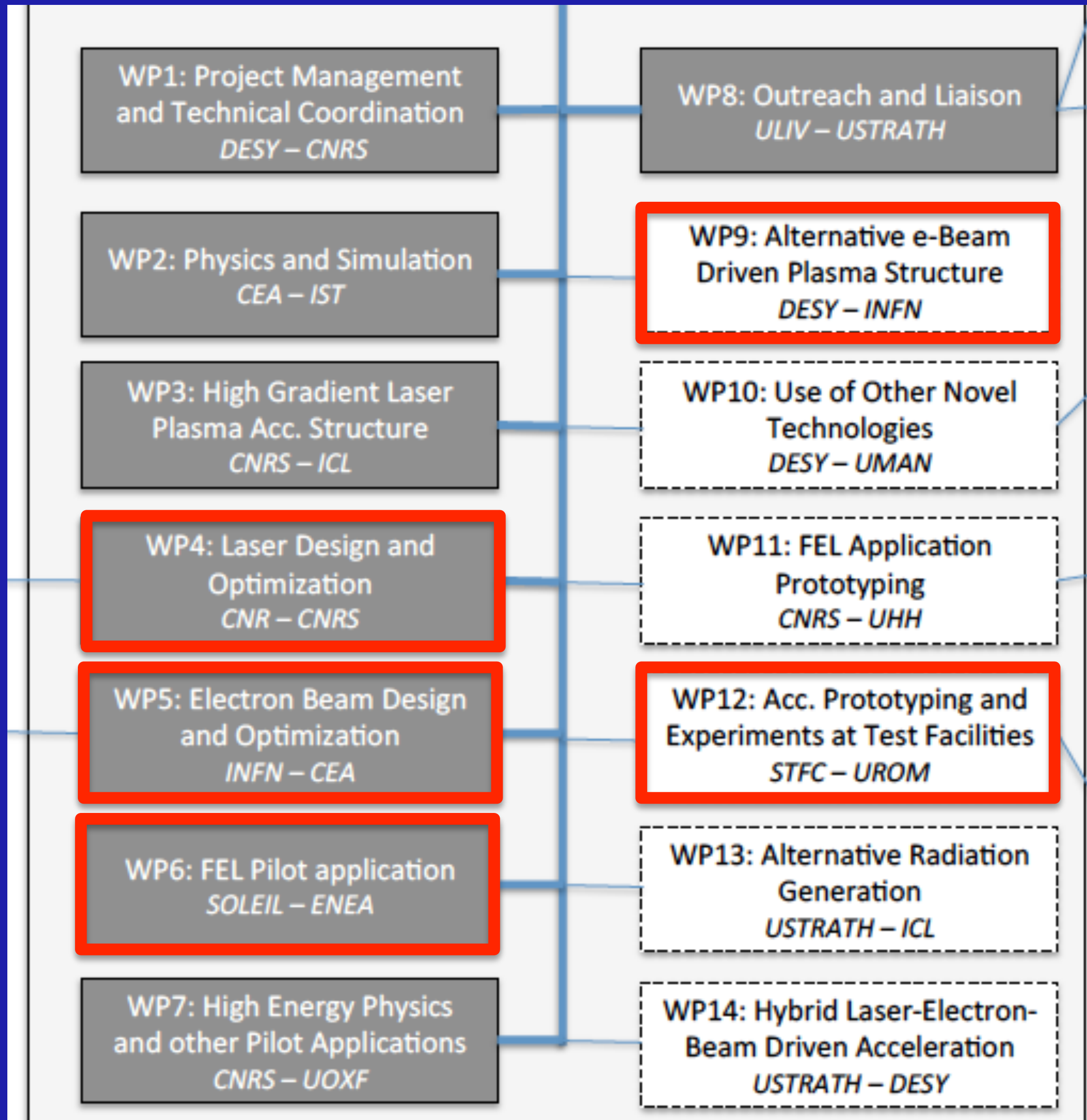
The **EuPRAXIA project will bridge the gap between successful proof-of-principle experiments (today) and a reliable technology with many applications (end of the 2020's)**. It should be considered as a ground-breaking, full-scale demonstration facility with pilot users and unique ultra-fast science features. EuPRAXIA would solve several technical shortcomings with known solutions and prove the potential of plasma accelerators for users. It would establish the basis for applications in industry, medicine, photon science and HEP.



EuPRAXIA Participants

Participant no.	Participant organisation name	Short name	Country	
1 (Coordinator)	Stiftung Deutsches Elektronen Synchrotron	DESY	Germany	
2	Istituto Nazionale di Fisica Nucleare	INFN	Italy	SPARC_LAB
3	Consiglio Nazionale delle Ricerche	CNR	Italy	SPARC_LAB
4	Centre National de la Recherche Scientifique	CNRS	France	
5	University of Strathclyde	USTRATH	UK	
6	Instituto Superior Técnico	IST	Portugal	
7	Science & Technology Facilities Council	STFC	UK	
8	Synchrotron SOLEIL – French National Synchrotron	SOLEIL	France	
9	University of Manchester	UMAN	UK	
10	University of Liverpool	ULIV	UK	
11	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenible	ENEA	Italy	SPARC_LAB
12	Commissariat à l'Énergie Atomique et aux énergies alternatives	CEA	France	
13	Sapienza Universita di Roma	UROM	Italy	SPARC_LAB
14	Universität Hansestadt Hamburg	UHH	Germany	
15	Imperial College London	ICL	UK	
16	University of Oxford	UOXF	UK	

EuPRAXIA WPs and SPARC_LAB responsibilities (SPARC_LAB WG leaders or deputy leaders)



M. Ferrario

L. Gizzi

E. Chiadroni

A. Mostacci

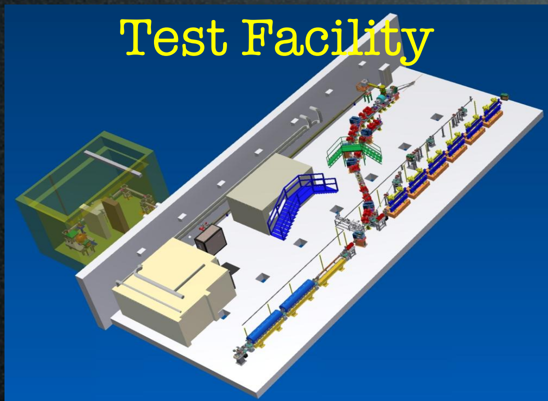
G. Dattoli

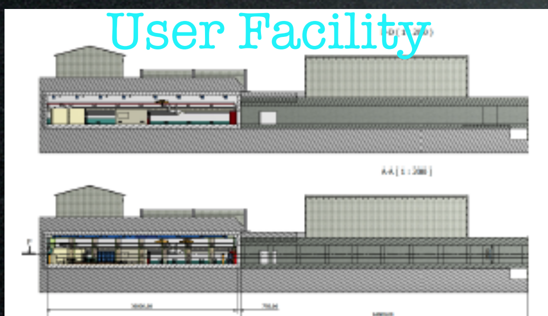
From SPARC_LAB to EUPRAXIA

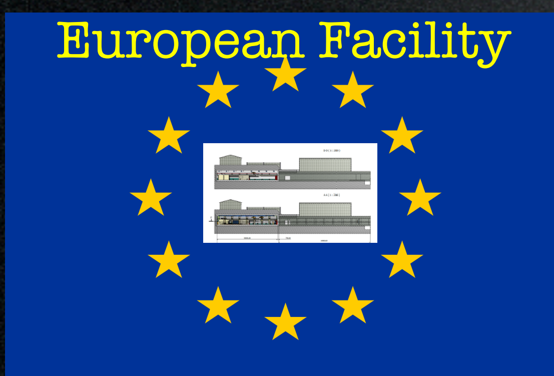
SPARC LAB

EuSPARC

Future SPARC_LAB scenarios







Consolidation: on going, ~3 years

- FLAME maintenance and consolidation
- Injector upgrade (Cryogenic?)
- THz user beam line upgrade
- Thomson and Plasma beam lines final commissioning
- FEL new short period undulator (RF, optical?)

Upgrade: proposed, ~5 years

- Infrastructure extension
- Linac upgrade <1 GeV (L-S-C-X-band, multi-bunches)
- FLAME upgrade towards 1 PW
- Plasma, dielectric and high frequency acceleration
- Positron production and acceleration with plasma
- Advanced FEL schemes (oscillator, optical,QFEL?)
- THz, Compton and FEL user beam lines
- AND RELIABILITY !!!!

European Facility, ~10 years

- Plasma based FEL Pilot User Facility
- Plasma based HEP beam line

European Commission

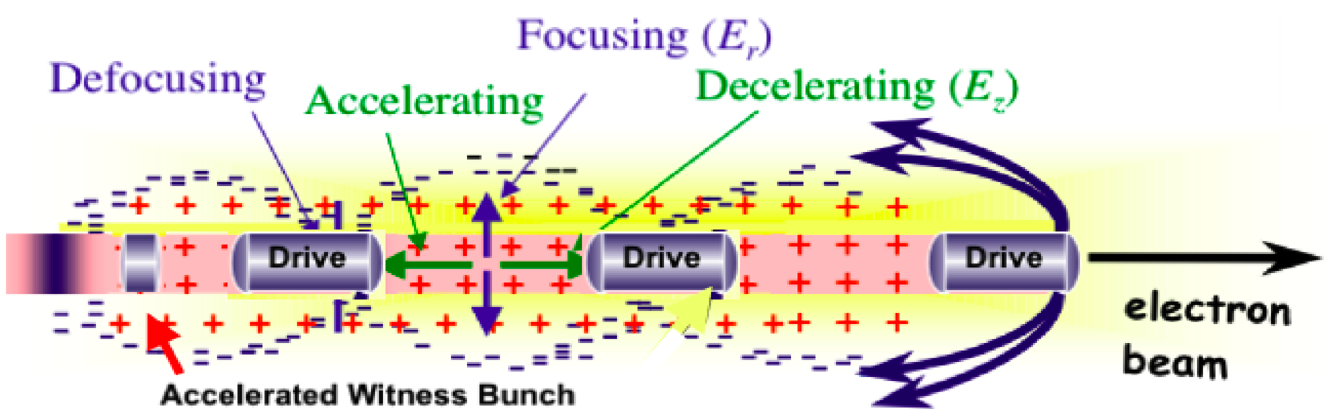
Research and Innovation actions
Future and Emerging Technologies:
FETOPEN 1

Title of Proposal: **Electron Linear Beam-driven Accelerator**

Acronym: **ELBA**

Project duration: **4 years**

Funding requested: **3.9 M€**



ESGARD Recommendations for H2020 call for FET projects

The role of ESGARD is to optimize and enhance the outcome of the Research and Technical Development in the field of Accelerator Science and Technology in Europe by:

- promoting mutual coordination and facilitating the pooling of European resources,
- promoting a coherent and coordinated utilization and development of infrastructures,
- promoting inter-disciplinary collaboration including industry.

The present membership of the committee is:

R. Aleksan (Chairperson; CEA-Saclay, France)
M. Vretenar (Secretary; CERN)
M. Cerrada (CIEMAT, Spain)
R. Edgecock (STFC, UK)
E. Elsen (DESY, Germany)
S. Guiducci (INFN, Italy)
O. Kester (GSI, Germany)
M. Jezabek (IFJ-PAN, Poland and Polish consortium[1])
B. Launé (CNRS/IN2P3)
K. Osterberg (HIP, Finland and Nordic Consortium[2])
L. Rivkin (PSI, Switzerland)

- ***ELBA***

Plasma Wakefied Acceleration has been demonstrated since many years either by driving the plasma with lasers or particle beams. The latter method of acceleration offers efficient and compact means for increasing substantially the energy of the beam at existing accelerator facilities. A very large number of low energy electron accelerators are available at in research laboratories and universities and could therefore benefit from such a potential upgrade. However, for many applications the accelerated beam characteristics obtained so far are not satisfactory.

The ELBA proposal objective is to investigate the feasibility to produce high quality electron beams with excellent brightness. To this end, it is proposed to investigate new interesting, innovative and promising approaches and schemes.

ESGARD finds that the ELBA proposal is well structured and organized appropriately for exploring the feasibility of new methods of beam-driven Plasma WakeField Accelerations, which are investigated in a coherent and collaborative manner. The proposal federates major European competences and institutes required to accomplish the needed tasks. It includes also important laboratories in which electron beams are available for carrying out tests. This proposal fits nicely the FETOPEN call objectives as it explores novel concepts of foundational nature.

ESGARD welcomes and strongly support the ELBA initiative, which is the first collaborative effort in the kind in Europe. If successful, this project will enable means to upgrade in a very effective manner existing accelerators and to develop a long-term vision for the realization of affordable accelerators with a large number of applications for basic research as well as interdisciplinary, medical and commercial applications.

Scope: Proposals are sought for collaborative research with all of the following characteristics:

- **Long-term vision**: the research proposed must address a new, original or radical long-term vision of technology-enabled possibilities that are far beyond the state of the art and currently not anticipated by technology roadmaps.

- **Breakthrough S&T target**: research must target scientifically ambitious and technologically concrete breakthroughs that are arguably crucial steps towards achieving the long-term vision and that are plausibly attainable within the life-time of the proposed project.

- **Foundational**: the breakthroughs that are envisaged must be foundational in the sense that they can establish a basis for a new line of technology not currently anticipated.

- **Novelty**: the research proposed must find its plausibility in new ideas and concepts, rather than in the application or incremental refinement of existing ones.

- **High-risk**: the potential of a new technological direction depends on a whole range of factors that cannot be apprehended from a single disciplinary viewpoint. This inherent high-risk has to be countered by a strongly interdisciplinary research approach, where needed expanding well beyond the strictly technological realm.

- **Interdisciplinary**: the proposed collaborations must be interdisciplinary in the sense that they go beyond current mainstream collaboration configurations in joint science- and technology research, and that they aim to advance different scientific and technological disciplines together and in synergy towards a breakthrough.

This call is open to early-stage research on any new technological possibility.

The Commission considers that proposals requesting a contribution from the EU of between EUR 2 and 4 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Section 1: S&T Excellence

1.1 Targeted breakthrough, Long term vision and Objectives

Plasma-based accelerators hold the great promise to accelerate charged particles to high energies over short distances and with high quality. They are one of the possible technologies that could revolutionize directly or indirectly many fields of science (Free Electron Lasers (FEL) and Linear Colliders (LC) in particular), medicine and industry. Despite the recent impressive progresses in achieved accelerating gradient performances, Plasma-based accelerators have not yet produced a beam quality really competitive with the existing RF particle accelerators in terms of beam emittance, energy spread, repetition rate, stability and staging capability. Thus ingenious but rather complicated countermeasures have to be undertaken in order to try to capture, transport and match the plasma accelerated beams to the final users devices (undulators or other radiators). Based on our expertise and experience, combined with a review of the current scientific literature on the subject [1], we estimate the Technological Readiness Level ('TRL') of Plasma-based technology to be 3-4 (Experimental proof of concept - Technology validated in lab). With the ambition of overcoming these limitations a collaboration of nine research institutes from four European countries has been established, promoted by an enthusiastic effort of young scientists with outstanding curricula and specific leadership responsibilities within the project.

The goal of this proposal is to demonstrate the possibility of producing high quality electron beams with normalized brightness exceeding 10^{15} A /m^2 as the one required for Advanced Radiation Sources applications, by means of new concepts for a compact high gradient (> 1 GV/m) and high efficiency (~20%) *electron beam driven* plasma wake field accelerator module (PWFA).

We consider the *electron beam driven* PWFA approach the most promising way to achieve our goals for the following reasons:

- there are already many working conventional electron linacs in research laboratories and universities that can provide the required driving and witness electron bunches and that could greatly benefit from a compact energy upgrade with minor hardware modifications,
- timing and synchronization are rather simpler issues compared to Laser Wake Field Accelerator (LWFA) schemes since both drive and witness bunches are generated by the same source,
- existing RF electron linacs can achieve repetition rates as high as GHz in pulsed mode in normal conducting linacs or MHz in CW operation in superconducting linacs, for comparison high-power lasers are at present limited to a 10 Hz repetition rate,
- two limiting factors for energy gain and efficiency in LWFA schemes such as laser diffraction and electron beam-plasma wave dephasing are absent in PWFA schemes. With state of the art drive bunch emittance and energy, the only common unavoidable limitation is the driver pulse energy depletion.

We are convinced that high gradient acceleration and efficiency (~20%) can be obtained in a plasma channel driven by a *resonant bunch train*, see Figure 1. It will be investigated by means of a low emittance witness beam produced by a high brightness photoinjector [2] and *externally injected* in a preformed plasma channel excited by a train of short bunches with constant and/or *ramped charge distribution*, [3,4] (WP4). For example a train of three bunches with 50 pC/bunch and σ_z = 65 µm (σ_r = 5 µm) separated by one plasma wavelength (300 µm), can generate an accelerating field in excess of 1 GV/m. In this configuration we expect to accelerate a 10 pC witness bunch with a final emittance ~0.1 µm and energy spread < 1 %. With a peak current of 100 A the expected normalized beam brightness is ~ 10^{16} A/m^2 as the one required to drive a short wavelength FEL. This technique being an excellent solution to be used by itself as *afterburner for conventional linacs* [5] is also propedeutical to any other PWFA scheme for high energy applications where *staging* (i.e. external injection in a subsequent module) is required [6,7].

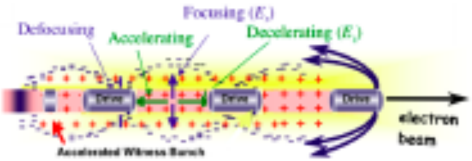


Figure 1 – Principle of resonant bunch train excitation of a plasma wave.

The beam quality of the accelerated witness bunch with this technique depends on the conventional injector performance and on the capability to mitigate beam degradation in the plasma with a proper beam to plasma matching. The generation and acceleration of ultralow emittance ultrahigh brightness beams can be even more effective if the witness bunch is generated in a controlled way directly inside the plasma (*Plasma Injector*). This

Proposal Evaluation Form

EUROPEAN COMMISSION

Horizon 2020 - Research and Innovation Framework Programme

Evaluation Summary Report - Research and Innovation actions/Innovation actions

Call:	H2020-FETOPEN-2014-2015-RIA
Funding scheme:	Research and Innovation action
Proposal number:	665099
Proposal acronym:	ELBA
Duration (months):	48
Proposal title:	Electron Linear Beam-driven Accelerator
Activity:	All

N.	Proposer name	Country	Total Cost	%	Grant Requested	%
1	ISTITUTO NAZIONALE DI FISICA NUCLEARE	IT	993,750	24.95%	993,750	24.95%
2	STIFTUNG DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY	DE	718,750	18.05%	718,750	18.05%
3	SCIENCE AND TECHNOLOGY FACILITIES COUNCIL	UK	625,000	15.69%	625,000	15.69%
4	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA	IT	300,000	7.53%	300,000	7.53%
5	UNIVERSITA DEGLI STUDI DI ROMA TORVERGATA	IT	256,250	6.43%	256,250	6.43%
6	ASSOCIACAO DO INSTITUTO SUPERIOR TECNICO PARA A INVESTIGACAO E DESENVOLVIMENTO	PT	268,750	6.75%	268,750	6.75%
7	THE UNIVERSITY OF MANCHESTER	UK	287,500	7.22%	287,500	7.22%
8	UNIVERSITY OF STRATHCLYDE	UK	273,750	6.87%	273,750	6.87%
9	MAX PLANCK GESELLSCHAFT ZUR FOERDERUNG DER WISSENSCHAFTEN E.V.	DE	258,750	6.50%	258,750	6.50%
	Total:		3,982,500		3,982,500	

Abstract:

Particle accelerators drive a wide range of applications from the cancer therapy in modern hospitals to the giant colliders used to unlock the secrets of our universe. A widespread use of particle accelerators is severely hampered by the tremendous cost and size of current particle accelerators, based on long and expensive radio-frequency structures.It would be highly desirable if the size of these research infrastructures could be reduced significantly to lower their costs and reduce their complexity. Plasma based acceleration techniques have demonstrated accelerating gradients orders of magnitude beyond presently used technologies and could be a solution to this problem. The goal of this project is to demonstrate the possibility of producing high quality electron beams by means of new concepts for high gradient and high efficiency beam-driven plasma wake field accelerator (PWFA) module. We foresee a strong impact towards new compact advanced radiation sources (THz, FEL, Compton) with the additional possibility to upgrade the final electron beam energy (by a factor ~2 in less than 1 m) of existing or proposed FEL user facilities thus enabling the user capabilities to shorter wavelength. The new approaches we propose are aiming at going well beyond the state-of-the-art: we foresee a final Technological Readiness Level of 7. This specific research program is completely absent in Europe and represents a foundational attempt to develop an extremely promising technology that will bring Europe in a leading position in compact accelerator development and applications for a better society. A wide interdisciplinary effort is necessary merging the capability of accelerator, plasma and lasers scientists in strong contact with potential users from industries interested in taking advantage of new market opportunities. A statement of strong support has been received by the European Steering Group for Accelerator Research and Development (ESGARD).

Evaluation Summary Report

Evaluation Result

Total score: 2.95 (Threshold: 0.00)

Section 1: S&T Excellence

1.1 Targeted breakthrough, Long term vision and Objectives

Plasma-based accelerators hold the great promise to accelerate charged particles to high energies over short distances and with high quality. Despite the recent impressive progresses in achieved accelerating gradient performances, Plasma-based accelerators have not yet produced a beam quality really competitive with the existing RF particle accelerators in terms of beam brightness, energy spread and repetition rate, limited also by a lack of fast running simulations codes and adequate beam and plasma diagnostics tools able to achieve a reliable characterization of the specific plasma accelerated beam features. Thus ingenious but rather complicated countermeasures have to be undertaken in order to try to capture, transport and match the plasma accelerated beams to the final users devices (undulators or other radiators). We estimate the Technological Readiness Level ("TRL") of Plasma-based technology to be 3-4 (Experimental proof of concept -Technology validated in lab). With the ambition of overcoming these limitations a collaboration of 8 research institutes from 4 European countries and one industrial partner from Israel has been established, promoted by an enthusiastic effort of young scientists with outstanding curricula and specific leadership responsibilities within the project.

The goal of this proposal is to demonstrate the possibility of producing high quality electron beams with normalized brightness exceeding 10^{16} A /m^2 as the one required for Advanced Radiation Sources applications, by means of new concepts for a compact high gradient (> 1 GV/m) and high efficiency (> 20%) ***electron beam driven*** **plasma wake field accelerator module (PWFA).** The expected electron beam quality performances are hereafter compared with the state of the art FACET [2] (PWFA) and LCLS [3] (Conventional RF, low charge operation) recent results:

Quantity	ELBA	FACET [2]	LCLS [3]
Electron beam Brightness A/m^2	> 10^{16}	< 3 x 10^{12}	2.4 x 10^{16}
Gradient GV/m	> 1	4.4	0.02
Rms norm. emittance um	0.1 - 1	> 36	0.3-1
Energy spread %	< 1	> 2	0.1

We consider the *electron beam driven* PWFA approach the most promising way to achieve our goals for the following reasons:

1) there are already many working conventional electron linacs in research laboratories and universities that can provide the required driving and witness electron bunches and that could greatly benefit from a compact energy upgrade with minor hardware modifications; 2) timing and synchronization are rather simpler issues compared to Laser Wake Field Accelerator (LWFA) schemes since both drive and witness bunches are generated by the same source; 3) existing RF electron linacs can achieve repetition rates as high as GHz in pulsed mode in normal conducting linacs or MHz in CW operation in superconducting linacs, for comparison high-power lasers are at present limited to a 10 Hz repetition rate; 4) two limiting factors for energy gain and efficiency in LWFA schemes such as laser diffraction and electron beam-plasma wave dephasing are absent in PWFA schemes. The only common unavoidable limitation is the driver pulse energy depletion.

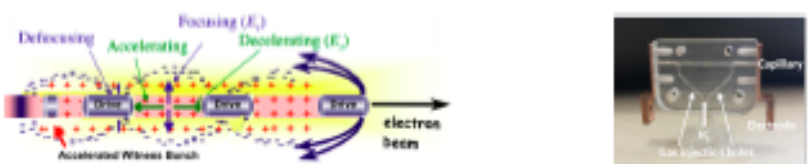


Figure 1 – Left: Principle of resonant bunch train excitation of a plasma wave. Right: 3 cm long, 1 mm diameter plastic capillary prototype with external electrodes mounted (HIL Applied Medical) produced by a 3D printer.

We are convinced that high gradient acceleration and efficiency (> 20%) can be obtained in a plasma channel created by a high voltage discharge in a capillary driven by a *resonant bunch train*, see Figure 1. It will be investigated by means of a low emittance witness beam produced by a high brightness photoinjector [4] and *externally injected* in a preformed plasma channel excited by a train of short bunches with constant and/or *ramped charge distribution*, [5,6] (WP4). For example a train of three bunches with 50 pC/bunch and s_z = 65 mm (s_r = 5 mm) separated by one plasma wavelength (300 mm), can generate an accelerating field in excess of 1 GV/m. In this configuration we expect to accelerate a 10 pC witness bunch with a final emittance ~0.1 mm and energy spread < 1 %. With a peak current of 100 A the expected normalized beam brightness is ~ 10^{16} A/m^2 as the one required to drive a short wavelength FEL. This technique being an excellent solution to be used by itself as *afterburner for*

Proposal Evaluation Form

EUROPEAN COMMISSION

Horizon 2020 - Research and Innovation Framework Programme

Evaluation Summary Report - Research and Innovation actions

Call: H2020-FETOPEN-2014-2015-RIA
Funding scheme: RIA
Proposal number: 713018
Proposal acronym: ELBA
Duration (months): 48
Proposal title: Electron Linear Beam-driven Accelerator
Activity: FETOPEN-RIA-2015-2

N.	Proposer name	Country	Total Cost	%	Grant Requested	%
1	ISTITUTO NAZIONALE DI FISICA NUCLEARE	IT	823,125	21.80%	823,125	21.80%
2	STIFTUNG DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY	DE	718,750	19.03%	718,750	19.03%
3	SCIENCE AND TECHNOLOGY FACILITIES COUNCIL	UK	618,750	16.39%	618,750	16.39%
4	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA	IT	293,750	7.78%	293,750	7.78%
5	UNIVERSITA DEGLI STUDI DI ROMA TORVERGATA	IT	254,750	6.75%	254,750	6.75%
6	ASSOCIACAO DO INSTITUTO SUPERIOR TECNICO PARA A INVESTIGACAO E DESENVOLVIMENTO	PT	262,500	6.95%	262,500	6.95%
7	THE UNIVERSITY OF MANCHESTER	UK	258,750	6.85%	258,750	6.85%
8	UNIVERSITY OF STRATHCLYDE	UK	273,125	7.23%	273,125	7.23%
9	HIL Applied Medical, LTD	IL	272,500	7.22%	272,500	7.22%
	Total:		3,776,000		3,776,000	

Abstract:

Particle accelerators drive a wide range of applications from the cancer therapy in modern hospitals to the giant colliders used to unlock the secrets of our universe. A widespread use of particle accelerators is severely hampered by the tremendous cost and size of current particle accelerators, based on long and expensive radio-frequency structures. It would be highly desirable if the size of these research infrastructures could be reduced significantly to lower their costs and reduce their complexity. Plasma based acceleration techniques have demonstrated accelerating gradients orders of magnitude beyond presently used technologies and could be a solution to this problem. The goal of this project is to demonstrate the possibility of producing high quality electron beams by means of new concepts for high gradient and high efficiency beam-driven plasma wake field accelerator (PWFA) module. We foresee a strong impact towards new compact advanced radiation sources (THz, FEL, Compton). ELBA will be also synergic with the recently funded H2020 project EuPRAXIA, (INFRADEV-1-2014), a design study of the first 5 GeV plasma-based FEL user facility with industrial beam quality and user areas. In addition the industrial partner of the ELBA project, HIL Applied Medical, LTD, will have an important role in outlining the exploitation plan of a robust and reliable PWFA module with particular reference to medical applications and to keep cost-saving the final design. This specific research program is completely absent in Europe and represents a foundational attempt to develop an extremely promising technology that will bring Europe in a leading position in compact accelerator development and applications for a better society. A wide interdisciplinary effort is necessary merging the capability of accelerator, plasma and lasers scientists in strong contact with potential users from industries interested in taking advantage of new market opportunities.

Evaluation Summary Report

Evaluation Result

Total score: 4.15 (Threshold: 0)

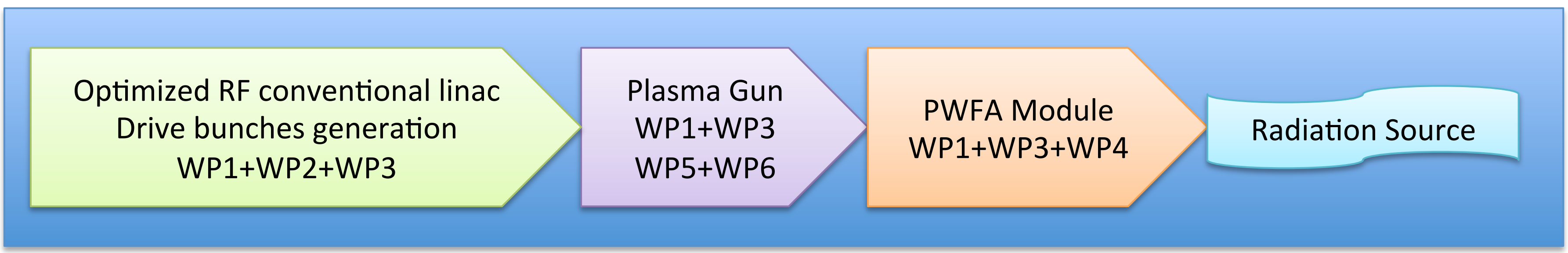
	ELBA 1	ELBA 2
Excellence	2.75	4.00
Impact	3.00	4.25
Implementation	3.50	4.50
Total	**2.95**	**4.15**

Electron Linear Beam-driven Accelerator

Participan Institutes	Country	Collaborators
INFN	Italy	Massimo Ferrario Enrica Chiadroni
DESY	Germany	Jens Osterhoff Lucas Schaper Alberto Martinez de la Ossa Barbara Marchetti
STFC	UK	Steven Jamison Deepa Angal-Kalinin
University of Roma “La Sapienza”	Italy	Mauro Migliorati
University of Roma “Tor Vergata”	Italy	Alessandro Cianchi
IST	Portugal	Jorge Vieira
University of Manchester	UK	Guoxing Xia
University of Strathclyde	UK	Bernhard Hidding Grace Manahan
Max Planck Institute	Germany	Patric Muggli

Targeted breakthrough, Long term vision and Objectives

The goal: demonstrate the possibility to produce high quality electron beams with normalized brightness as the one required for Advanced Radiation Sources applications, by means of new concepts for a compact high gradient (> 1 GV/m) and high efficiency (~20%) *electron beam driven* plasma wake field accelerator module (PWFA).



The final deliverable at the end of the 4th year will consist in a prototype of a PWFA described in a TDR.

Why beam driven?

- many working conventional electron linacs in research laboratories and universities can provide the required driving and witness electron bunches,

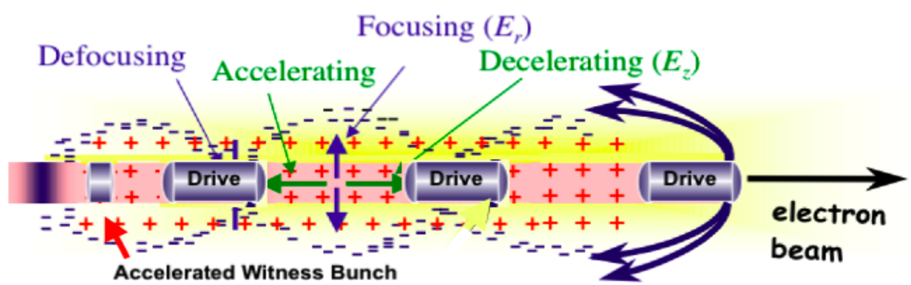
- timing and synchronization are rather simpler issues compared to Laser Wake Field Accelerator (LWFA) schemes,

- existing RF electron linacs can achieve repetition rates as high as GHz in pulsed mode in normal conducting linacs or MHz even in CW operation in superconducting linacs,

- two limiting factors for energy gain and efficiency in LWFA schemes such as laser diffraction and electron beam-plasma wave dephasing are absent in PWFA schemes with state of the art drive bunch emittance and energy, the only common unavoidable limitation being driver pulse energy depletion.

Beyond the state-of-the-art

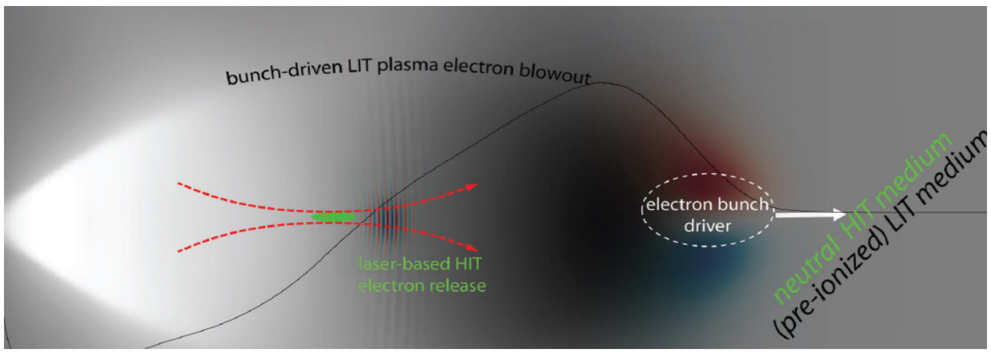
RESONANT BUNCH TRAIN - a new regime called *weak blow out* [4] has been recently investigated. It requires operation in the quasi-nonlinear regime, where one uses beam with relatively low charge and longitudinal and transverse beam size smaller than a plasma wavelength, . In this case, the beam density may exceed that of the plasma, producing blowout (strongly non linear regime) [5], but due to the small total charge, producing a disturbance that behaves in many ways as linear, having frequency essentially that of linear plasma oscillations.

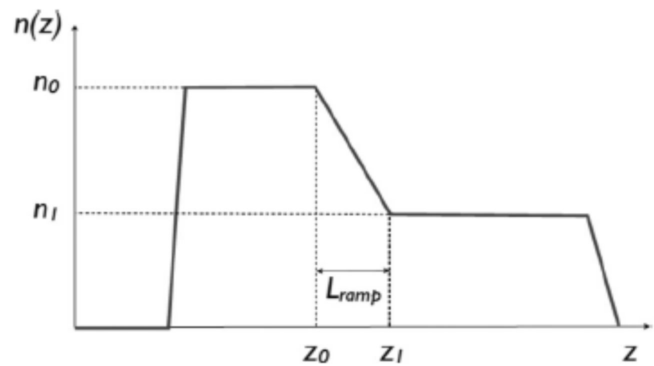


RAMPED BUNCH TRAIN - In a PWFA driven by a single gaussian electron bunch, the peak accelerating field is, in principle, limited to twice the value of the peak decelerating field within the bunch (transformer ratio R=2). Therefore the maximum possible energy gain for a trailing bunch is less than twice the incoming energy. Several methods has been proposed to increase the accelerating field. A very promising method is the so called *ramped bunch train* [3 wherein the charge increases along the train produce a transformer ratio proportional to the number of driving bunches

PLASMA GUNs

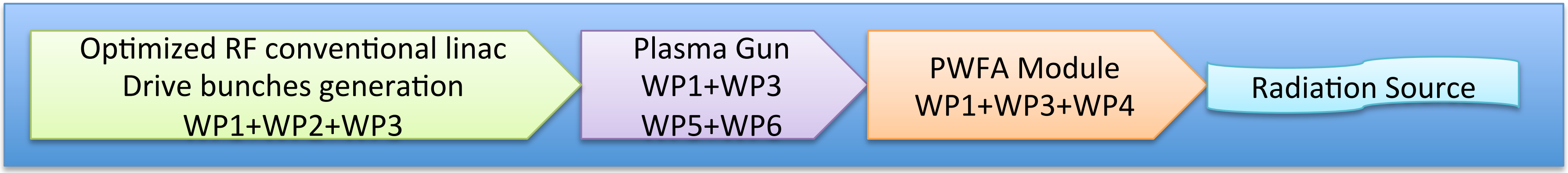
- The concept is based on laser-controlled or beam-controled release of electrons directly into a particle-beam-driven plasma blowout, paving the way for controlled, shapeable electron bunches with ultralow emittance and ultrahigh brightness. The electron beam driver will set up the plasma wave in a low-ionization-threshold (LIT) gas, and a low energy laser pulse will ionize an additional plasma component with high-ionization-threshold (HIT) locally within this plasma wave. It is applicable as a beam brightness transformer for electron bunches from LWFA and PWFA systems alike.



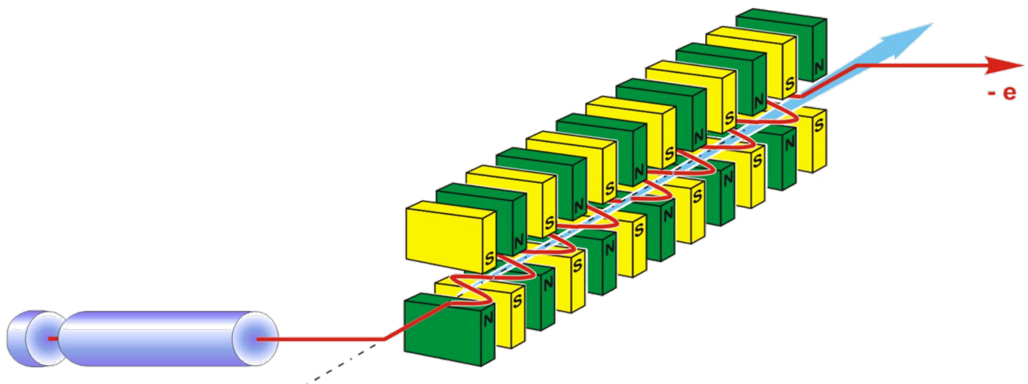


- Density down-ramps in the propagation direction of a plasma wake (longitudinal direction) facilitate electron trapping from the background plasma into the accelerating and focusing phase of the wakefield. The mechanism allows for control over the injection process and the bunch parameters by controlling the plasma-density profile. This enables tailoring of beam parameters, i.e. the energy spread, charge, current, and emittance.

Short term impacts



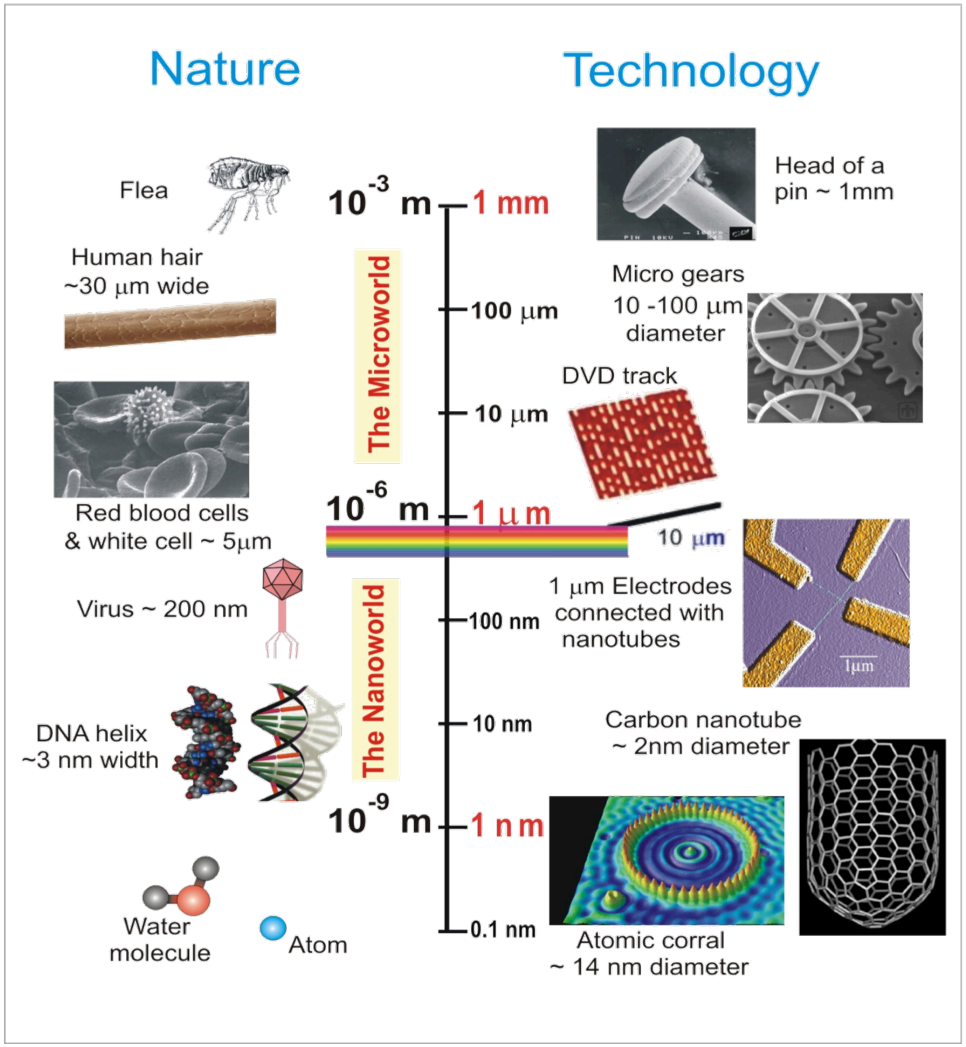
- **Impact** towards new compact **Advanced Radiation Sources** (THz, FEL, Compton) for Medical, Industrial, University applications.



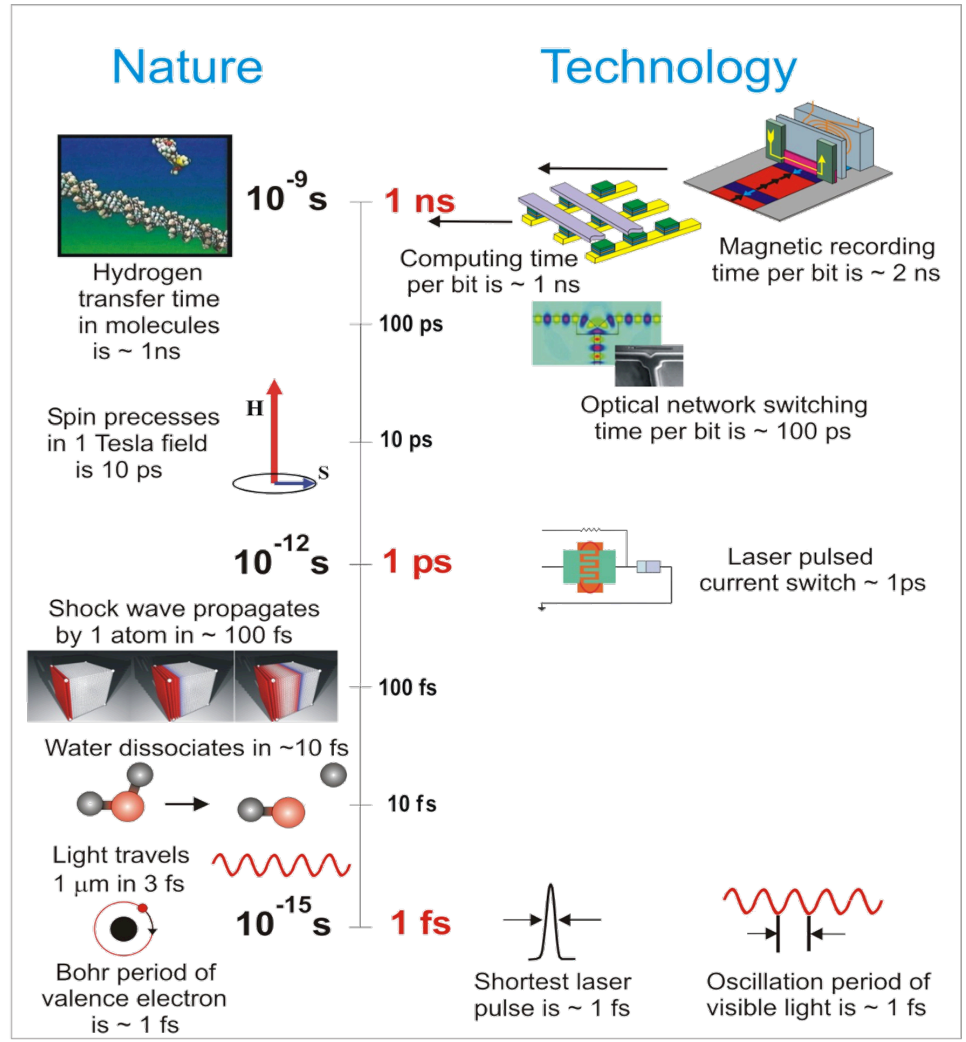
- **Impact** on existing or proposed FEL user facilities (SPARC, CLARA, FERMI, FLASH, SwissFEL, XFEL) as **afterburner => shorter wavelength**

$$\lambda_{rad} \approx \frac{\lambda_u}{2\gamma^2}\left(1 + \frac{K^2}{2} + \gamma^2\vartheta^2\right)$$

Ultra-Small



Ultra-Fast



Long term impact

- **Impact** on CLIC-like **Linear Collider** schemes from the Higgs energy up to TeV range

- **Impact** on collision energy upgrade of the future **International Linear Colliders** (ILC) to several tens of TeV.

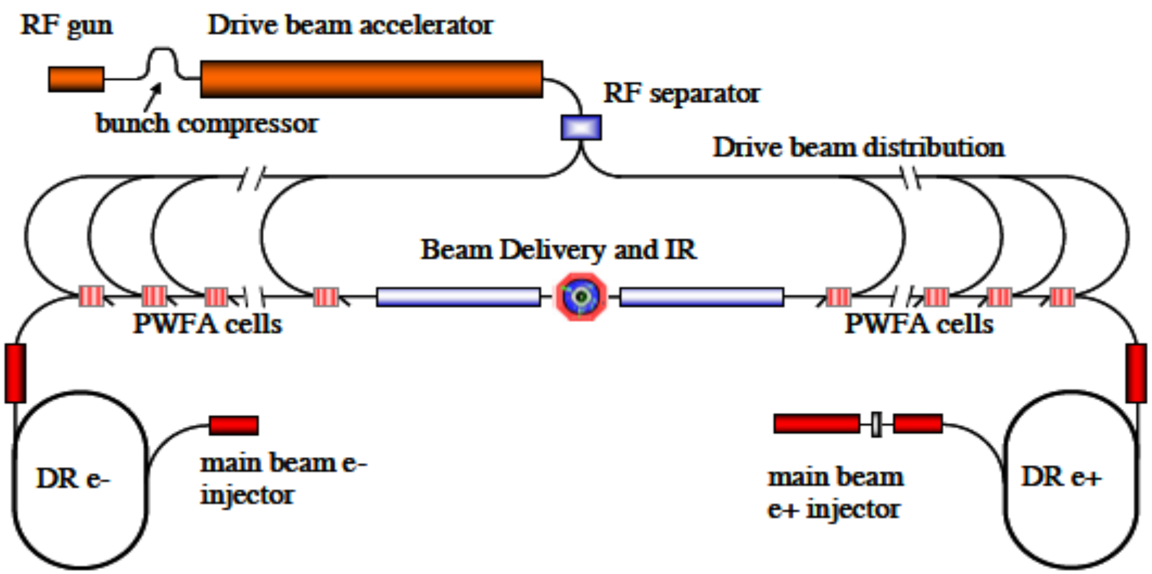
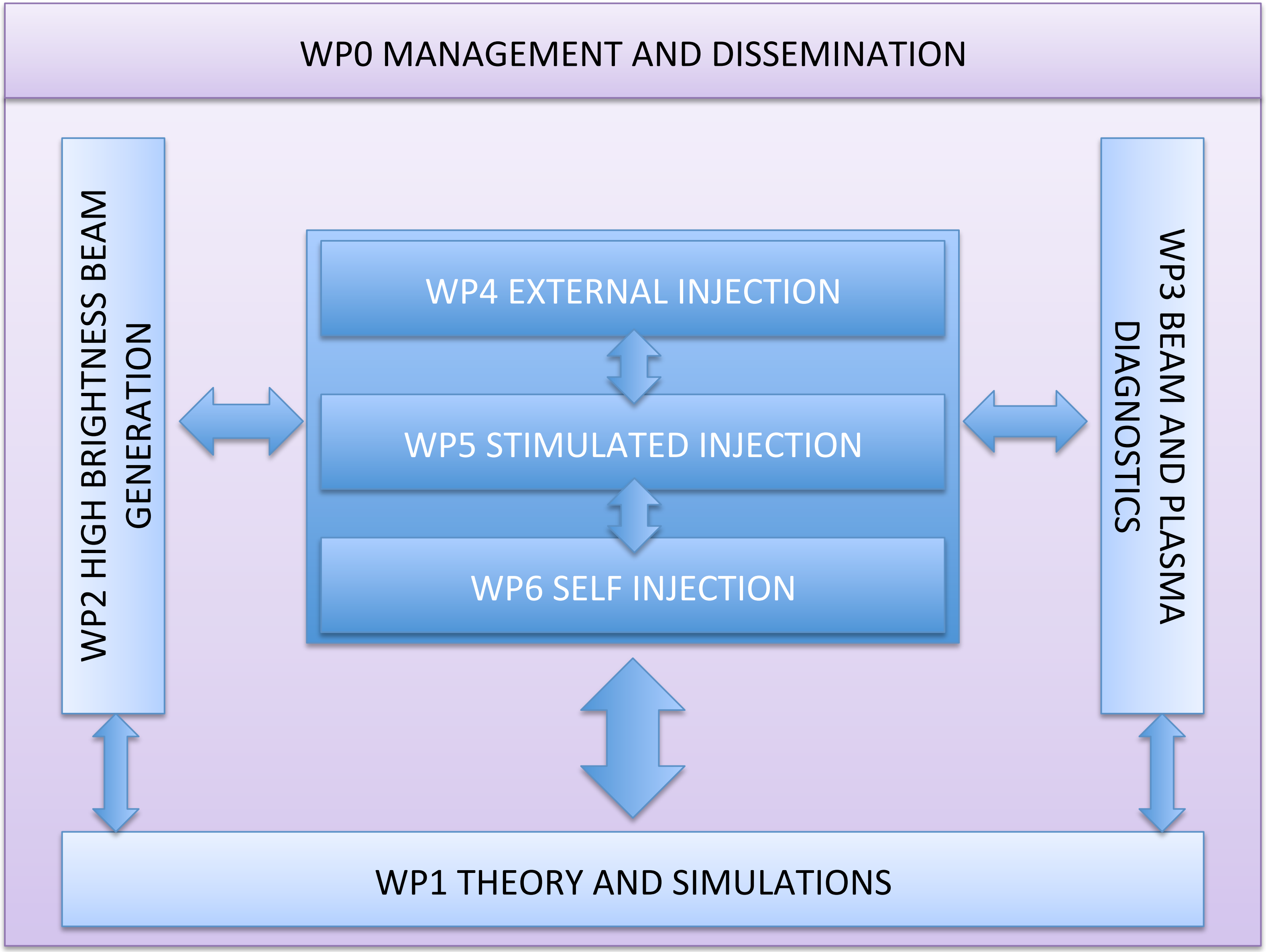


Fig. 1: Concept for a multi-stage PWFA Linear Collider.

CONCEPTUAL DESIGN OF THE DRIVE BEAM FOR A PWFA-LC*

S. Pei#, M. J. Hogan, T. O. Raubenheimer, A. Seryi, SLAC, CA 94025, U.S.A.
H. H. Braun, R. Corsini, J. P. Delahaye, CERN, Geneva

Work Packages structure and Interrelations



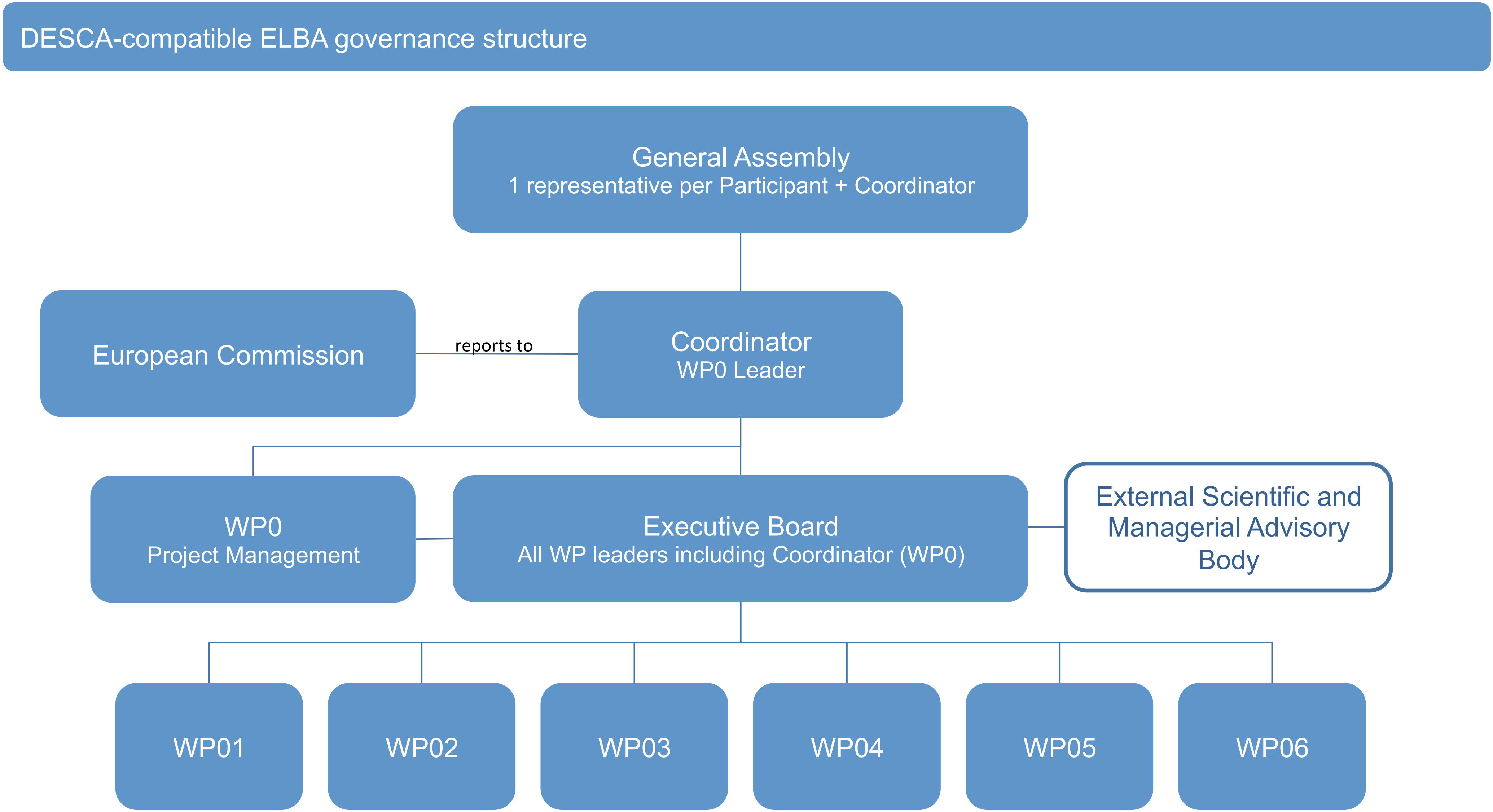
	Year 1				Year 2				Year 3				Year 4			
Month	**3**	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**
WP0																
0.1 Administrative and financial coordination																
0.2 Technical Coordination																**D0.7**
0.3 Collaboration meeting organisation	**D0.1**			**D0.4**				**D0.5**				**D0.6**				**D0.8**
0.4 Reporting and interaction with the Commission				M0.1				M0.2				M0.3				M0.4
0.5 Data Management Planning and Dissemination		**D0.2**	**D0.3**													**D0.9**
0.6 Synergies and networking																
WP1																
1.1 Codes upgrade, comparison and experimental validation				M1.1		M1.3		**D1.1**								**D1.4**
1.2 Theoretical modelling of plasma wake generation and beamtransport				M1.2								**D1.2**				
1.3 Beam Plasma Instabilities Studies												M1.5				**D1.5**
1.4 New beam transport components design								M1.4				**D1.3**				
WP2																
2.1. Driver Bunch Generation (Shaped, High charge)		M2.1				**D2.1**										
2.2. Generation of ultra-short Witness pulses				M2.2				**D2.2**								
2.3. Generation of a train of ultra-short shaped drivers/witness bunches						M2.3						**D2.3**				
2.4. Experimental beam dynamics and matching with plasma																**D2.4**
WP3																
3.1: Longitudinal beam diagnostics of the Accelerated beam				M3.1				M3.2				**D3.1**				
3.2: Transverse beam diagnostics of the accelerated beam						M3.3						**D3.2**				
3.3: High resolution plasma density mapping,									M3.4			**D3.3**				
3.4: Spatial imaging of plasma Wakefields and injected beams																**D3.4**
WP4																
4.1. Start to End simulations of optimized beam line				M4.1		**D4.1**										
4.2. Plasma pre-ionization techniques				M4.2			**D4.2**									
4.3. Characterization of the accelerated witness bunch				M4.3		M4.4	M4.6	**D4.3**	**D4.4**	**D4.5**	M4.7	**D4.6**				
4.4 Tolerances and instability measurements							M4.5							**D4.7**		**D4.8**
WP5																
5.1: Start to End simulations of optimised beam line						**D5.1**										
5.2: Multi-component plasma target								**D5.2**								
5.3: Timing and synchronisation										**D5.3**						
5.4: Characterisation of the accelerated witness bunch														**D5.4**		
5.5: Tolerances and Instabilities Study																**D5.5**
5.6: Final design of an optomized PWFA beam line based on stimulated injection																**D5.6**
WP6																
6.1 Start-to-end (S2E) simulations of optimized beam line		M6.1						M6.5		**D6.3**						
6.2 Self-injention techniques: Density down-ramp and Ionization injection.		M6.1		M6.2		**D6.1**		M6.4		**D6.4**				**D6.6**		**D6.8**
6.3 Plasma target development for self-injection techniques				M6.3		**D6.2**						M6.6		**D6.5**		
6.4 Tolerance and instability study												M6.7				**D6.7**

Summary of staff effort

	WP0	WP1	WP2	WP3	WP4	WP5	WP6	Total PM
INFN	30	5	40	5	38	0	0	118
University Roma 1	0	23	8	4	10	0	3	48
University Roma 2	0	0	10	0	38	0	0	48
DESY	7,2	0	36	24	0	0	36	103,2
MPP	0	0	0	0	0	0	0	0
STFC	0	5	12	20	0	36		73
University Strathclyde	0	0	0	5	0	36	36	77
University Manchester	0	36	0	20	0	0	0	56
IST	0	37,4	0	0	3	3	3	46,4
Total	37,2	106,4	106	78	89	75	78	569,6

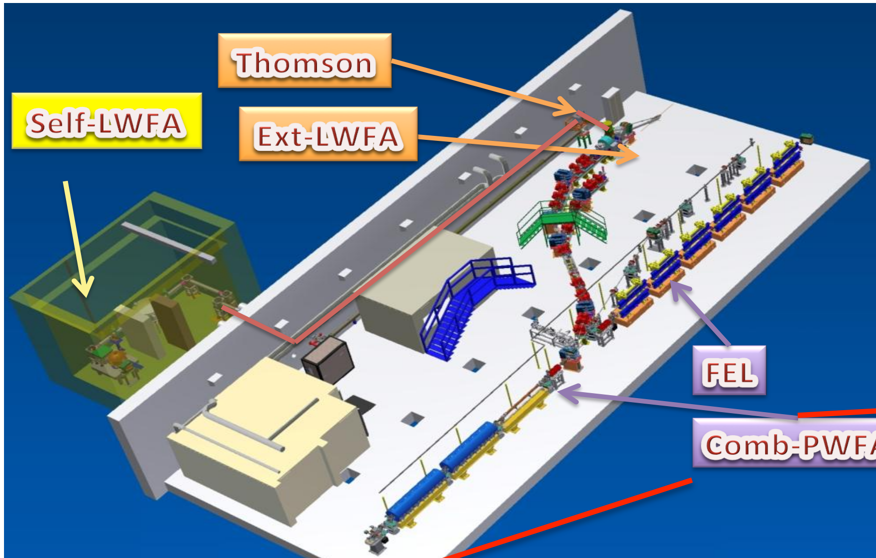
Budget status

Participant	Country	(A) Direct personnel costs	(B) Other direct costs	(C) Direct cost of Subcontracting	(D) Direct cost Financial support to third parties	(E) Cost of In kind contributions not used on the beneficiary's premises	(F) Indirect costs (=0,25*(A+B-E))	(G) Special unit costs covering direct & indirect costs	(H) Total estimated eligible costs (A+B+C+D+F+G)	(I) Reimbursement rate	(G) Maximum grant (=H*I)	(K) Requested grant
INFN+WP0	IT	463.500,00	299.000,00	-			190.625,00		953.125,00	100%	953.125,00	953.125,00
DESY	DE	515.000,00	120.000,00	-			158.750,00		793.750,00	100%	793.750,00	793.750,00
STFC	UK	321.200,00	124.000,00	-			111.300,00		556.500,00	100%	556.500,00	556.500,00
UNIRM1	IT	180.000,00	104.000,00	-			71.000,00		355.000,00	100%	355.000,00	355.000,00
UNITOV	IT	180.000,00	59.400,00	-			59.850,00		299.250,00	100%	299.250,00	299.250,00
IST	PT	192.000,00	44.000,00	-			59.000,00		295.000,00	100%	295.000,00	295.000,00
MANCHU	UK	192.000,00	59.000,00	-			62.750,00		313.750,00	100%	313.750,00	313.750,00
STRTHU	UK	192.000,00	48.000,00	-			60.000,00		300.000,00	100%	300.000,00	300.000,00
MPG	DE	192.000,00	124.000,00	-			79.000,00		395.000,00	100%	395.000,00	395.000,00
TOTAL		2.427.700,00	981.400,00	-	-	-	852.275,00	-	4.261.375,00	100%	4.261.375,00	4.261.375,00

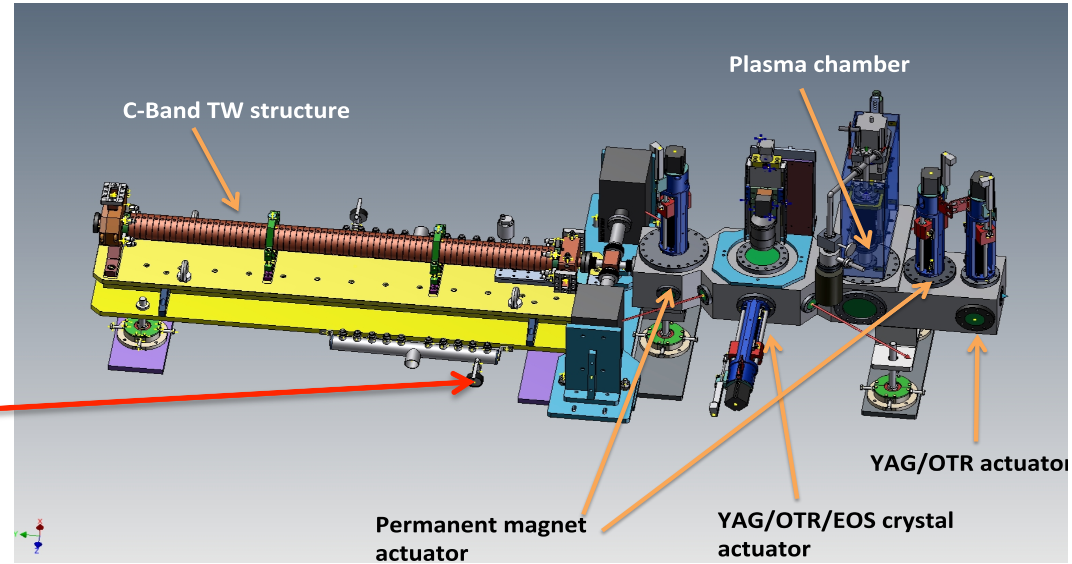

DESCA-compatible ELBA governance structure
General Assembly
1 representative per Participant + Coordinator
European Commission
reports to
Coordinator
WP0 Leader
WP0
Project Management
Executive Board
All WP leaders including Coordinator (WP0)
External Scientific and Managerial Advisory Body
WP01
WP02
WP03
WP04
WP05
WP06

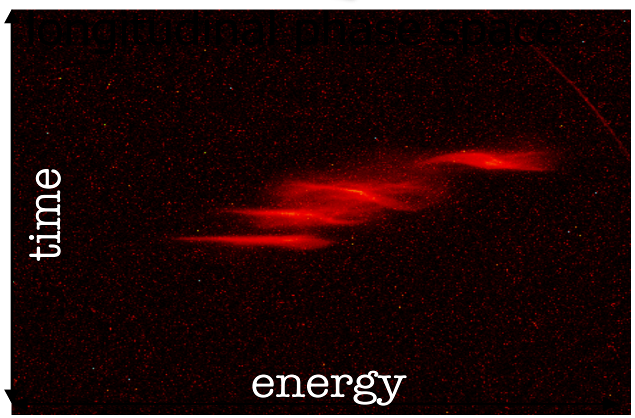
SPARC_LAB

Existing facility



PWFA vacuum chamber to be installed in 2015





- Bunch trains generation with the COMB technique based on RF Velocity Bunching
- Resonant plasma wave excitation in a capillary discharge
- Advanced electron beam and plasma diagnostics test
- Beam dynamics studies
- Possibility to inject the plasma accelerated beam in the downstream undulator chain

Preliminary COMB exp. results: 4 pulses 200 fs long separated by 1 ps

(number)		package number	participant		level	y date
D0.1	Kick-off meeting organisation and minutes	0	INFN	R	CO	1
D0.2	Data Management Plan	0	INFN	R	CO	6
D0.3	Web site on line	0	INFN	DEC	PU	9
D0.4	Project annual meeting organisation and minutes (M12)	0	INFN	R	CO	12
D0.5	Project annual meeting organisation and minutes (M24)	0	INFN	R	CO	24
D0.6	Project annual meeting organisation and minutes (M36)	0	INFN	R	CO	36
D0.7	Technical Design Reports compiled, adopted and released	0	INFN	R	CO	48
D0.8	Final meeting organisation and minutes (M48)	0	INFN	R	CO	48
D0.9	International Workshop	0	INFN		PU	48
D1.1	Codes Upgraded (D24)	1	IST	R	PU	24
D1.2	Design of injection and extraction matching new optics (D36)	1	ROMA1	R	PU	36
D1.3	Codes Experimental validation (D48)	1	IST	R	PU	48
D2.1	Generation and characterization of shaped drive bunch (before injection)	2	DESY	R	PU	18
D2.2	Generation and characterization of ultra-short witness bunch (before injection)	2	INFN	R	PU	24
D2.3	Generation and characterization of bunch train for resonant excitation (before injection)	2	INFN	R	PU	36
D2.4	Optimized injectors design for PWFA	2	INFN	R	PU	48
D3.1	Design sub-100fs temporal-structure	3	STFC	R	PU	12

	diagnostics					
D3.2	Demonstrate sub-100fs temporal characterisation	3	STFC	DEM	PU	36
D3.3	design of emittance diagnostic	3	MANCHU	R	PU	18
D3.4	prototype plasma diagnostic system		DESY ???	R	PU	21
D3.5	Characterisation of the Multi-component plasma targets	3	STRATH ???	R	PU	36
D3.6	Demonstration of Wakefield imaging diagnostic	3	INFN	R	PU	42
D4.1	Working point (S2E simulation)	4.1	MPG	R	PU	18
D4.2	Pre-ionization studies	4.2	??	R	PU	21
D4.3	Energy and energy spread	4.3	UNITOV	R	PU	24
D4.4	Plasma Characterization	4.3	INFN	R	PU	27
D4.5	Longitudinal phase space	4.3	UNITOV	R	PU	30
D4.6	Emittance	4.3	UNITOV	R	PU	36
D4.7	Tolerances and instability measurements	4.4	INFN	R	PU	42
D4.8	Final design of an optimized PWFA beam line based on external injection	4.4	INFN	DEM	PU	48
D5.1	S2E simulations for optimized beam lines	5	STFC	R	PU	M18
D5.2	Plasma characterisation in a multi-component plasma target	5	STRATH	R	PU	M24
D5.3	Timing and Synchronisation measurements	5	STRATH	R	PU	M30
D5.7	Quality characterisation of the accelerated bunch	5	STFC	R	PU	M40
D5.8	Tolerances and instability measurements	5	STRATH	R	PU	M48

D5.9	Final design of an optimized PWFA beam line based on stimulated injection	5	STFC	DEM	PU	M48
D6.1	Appropriate driver-beam parameters for DDR and ionization-induced (II) injection strategies in PWFA	6	DESY	R	PU	12
D6.2	Plasma target specifications for PWFA with DDR and II	6	DESY	R	PU	12
D6.3	Expected witness-beam parameters from DDR and II techniques in PWFA	6	DESY	R	PU	18
D6.4	Start-to-end simulations for optimized beam lines	6	DESY	R	PU	18
D6.5	Plasma characterization in multi-component and ramped plasma targets	6	DESY	R	PU	24
D6.6	Quality characterization of the accelerated bunch	6	DESY	R	PU	40
D6.7	Tolerances and instability measurements	6	DESY	R	PU	48
D6.8	Final design of an optimized PWFA beam line based on DDR and II	6	DESY	DEM	PU	48