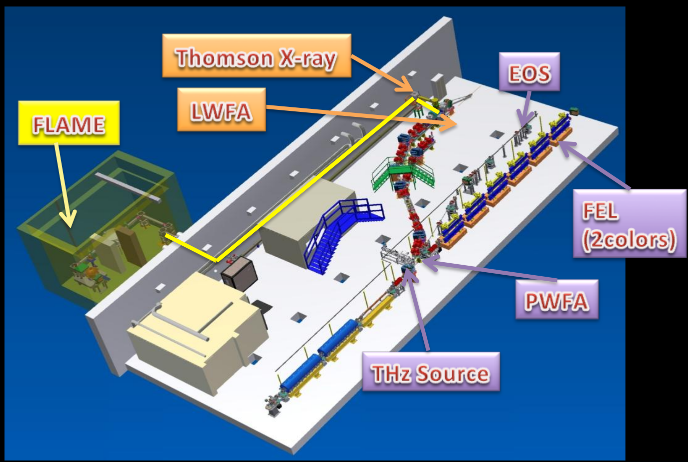
What Next with SPARC_LAB?

Massimo.Ferrario@LNF.INFN.IT
On behalf of the SPARC_LAB collaboration

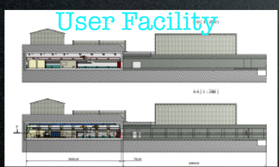


Perspective of fundamental physics at LNF, November 10, 2014

Future scenarios

Consolidation: on going, ~3 years,~ 4 M€ allocated

- FLAME maintenance
- Injector upgrade (C-band, X-band)
- THz user beam line upgrade
- Thomson and Plasma beam lines final commissioning
- FEL new undulator



Upgrade: proposed, ~5 years

- Infrastructure extension 4 M€
- Linac upgrade ~1 GeV (C-X-band, multibunch) 9 M€
- THz, X-ray Compton and FEL user facility) 11 M€
- Advanced FEL schemes (oscillator?) 7 M€
- FLAME upgrade towards 1 PW 10 M€
- Positron production and plasma acceleration 2 M€
- AND RELIABILITY !!!!

European Facility, ~10 years, ~200 M€

- Plasma based FEL Pilot User Facility
- Plasma based HEP beam line
- (Photon-Photon Collider?)

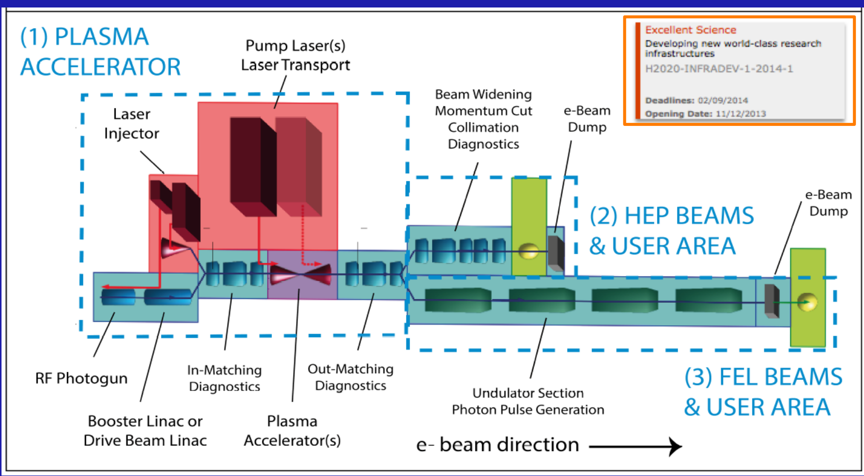
SPARC_EU_LAB?

- 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.

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

Submitted to HORIZON 2020 INFRADEV, 4 years, 3 M€



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 at 5 GeV

- 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.

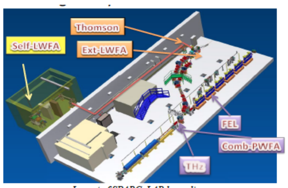
An upgraded (1 GeV, 1 PW) SPARC_LAB facility could be a strong candidate for the EuPRAXIA site

WHAT NEXT AT SPARC_LAB ?
M. Ferrario on behalf of the SPARC_LAB Collaboration

April 24, 2014

1- INTRODUCTION

SPARC_LAB [1] (Sources for Plasma Accelerators and Radiation Compton with Lasers And Beams) is an inter-disciplinary laboratory with unique features in the world. Born from the integration of a last generation photo-injector (SPARC)[2-7], able to produce electron beams up to 200 MeV energy with high peak current (> 1 kA) and low emittance (<2 mm-mrad), and of a high power laser (> 200 TW) (FLAME) [8,9], able to produce ultra-short pulses (<30 fs), SPARC_LAB has already enabled the development of innovative radiation sources and the test of new techniques for particle acceleration using lasers.



Layout of SPARC_LAB beam lines

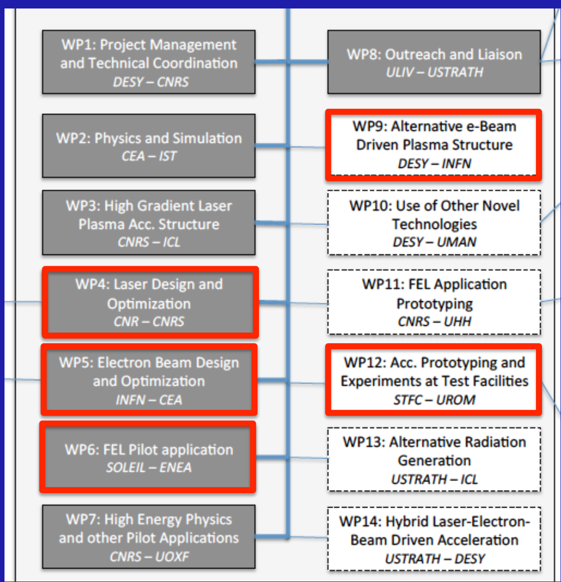
In particular the following highlight results have been achieved:

- a Free Electron Laser has been commissioned producing coherent radiation tunable from 500 nm down to 40 nm and new regimes of operation like Seeding, Single Spike, Harmonic Generation and Two Colors have been observed [10-14];
- a source of both broad band, narrow band (<30%) and high energy (> 10 μJ) THz radiation has been tested, first experiments with users are underway [15,16];
- electrons have been accelerated up to 100 MeV in 4 mm long plasma wave excited by the high power laser FLAME [9];

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
3	Consiglio Nazionale delle Ricerche	CNR	Italy
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
12	Commissariat à l'Énergie Atomique et aux énergies alternatives	CEA	France
13	Sapienza Universita di Roma	UROM	Italy
14	Universität Hansestadt Hamburg	UHH	Germany
15	Imperial College London	ICL	UK
16	University of Oxford	UOXF	UK

EuPRAXIA WPs and SPARC_LAB responsibilities (leaders or deputy leaders)



L. Gizzi
E. Chiadroni
G. Dattoli
M. Ferrario
A. Mostacci

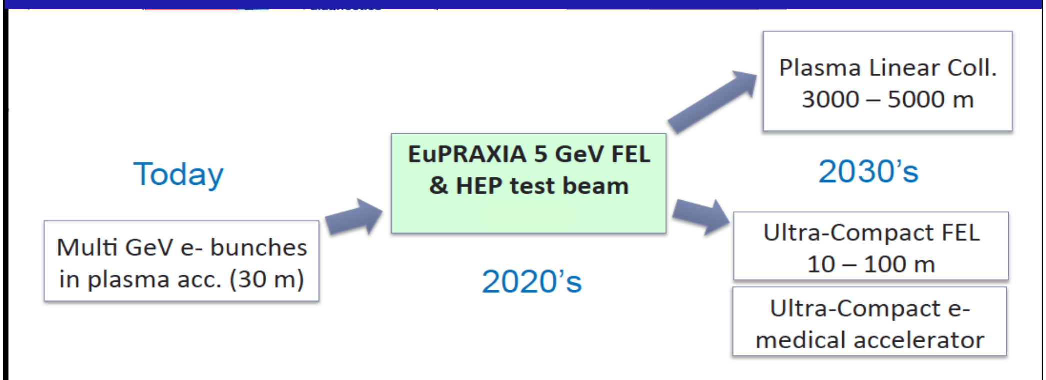
A commercially available 1 PW Ti: Sa laser laser driver or a high brightness 1 GeV electron beam linac could be adequate drivers for the EUPRAXIA plasma accelerator.

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

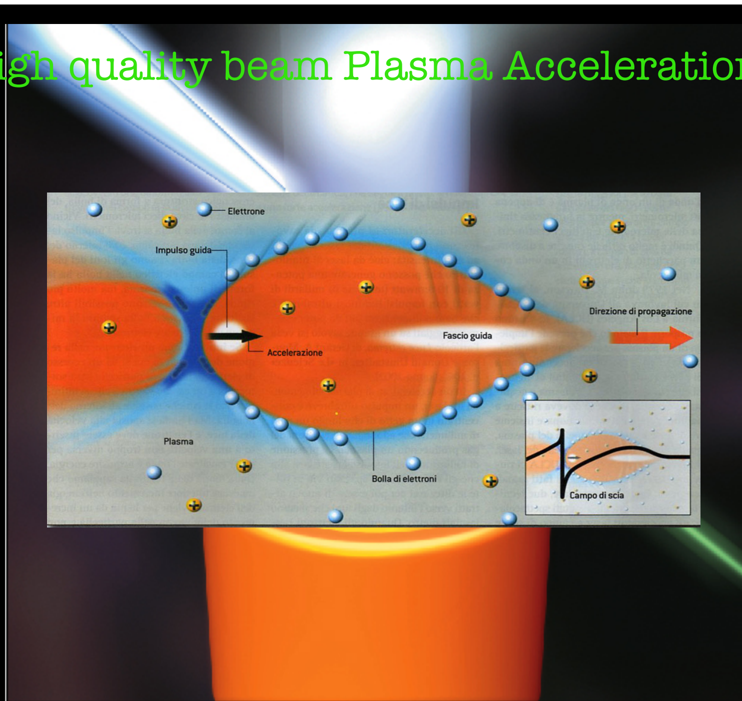
Positioning of the Project

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.



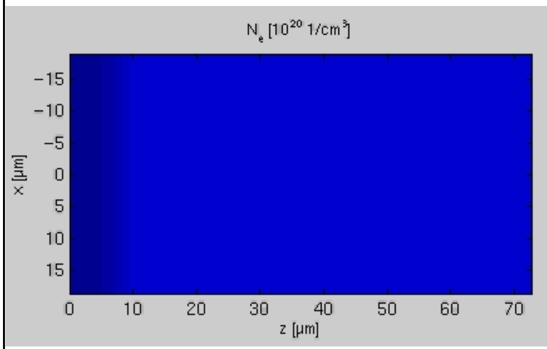
Current status of Plasma Accelerators

High quality beam Plasma Acceleration?



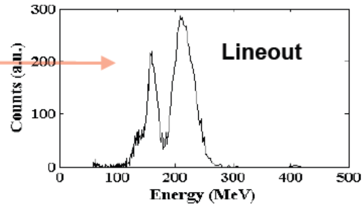
Self Injection:
spectrum of the accelerated electrons

Recent spectra acquired at 1 J laser energy on gas-jet target and 35 fs: expected intensity at focus: 7E18 W/cm2



Energy dispersion with a 0.9 T magnetic dipole

Electrons at lanex screen

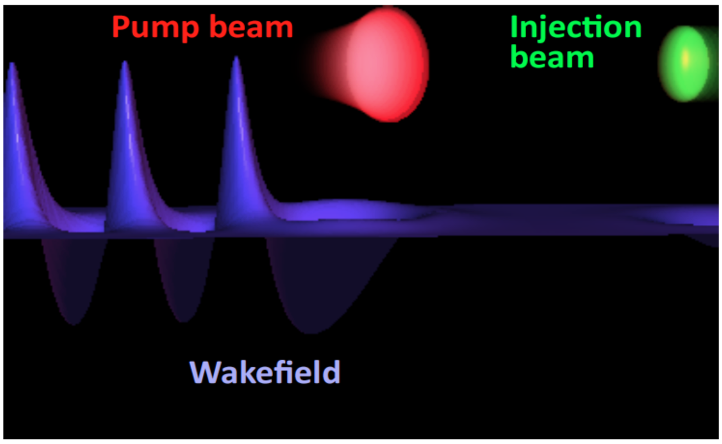


Energy of LPA electrons entering the multi 100 MeV range

T. Levato et al., EPS Conference in Plasma Physics, 2011

Colliding Laser Pulses Scheme

The first laser creates the accelerating structure, a second laser beam is used to heat electrons



Theory : E. Esarey *et al.*, PRL **79**, 2682 (1997), H. Kotaki *et al.*, PoP **11** (2004)
Experiments : J. Faure *et al.*, Nature **444**, 737 (2006)

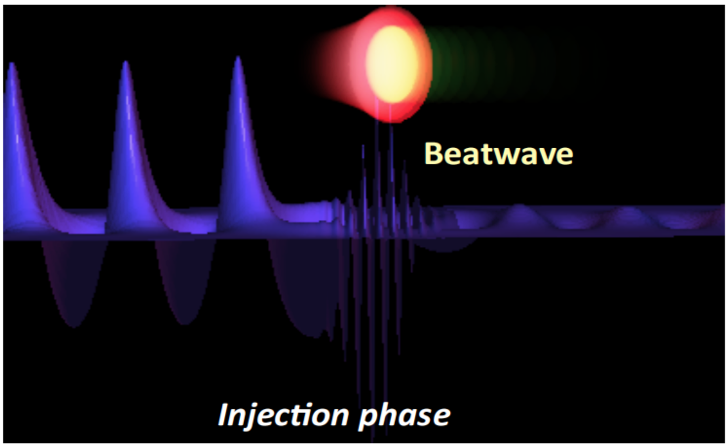
Ist European Advanced Accelerator Concepts Workshop, La Biodola, Isola d'Elba - Italy, June 2-7 (2013)

http://loa.ensta.fr/ UMR 7639

lundi 3 juin 13

Colliding Laser Pulses Scheme

The first laser creates the accelerating structure, a second laser beam is used to heat electrons



Theory : E. Esarey *et al.*, PRL **79**, 2682 (1997), H. Kotaki *et al.*, PoP **11** (2004)
Experiments : J. Faure *et al.*, Nature **444**, 737 (2006)

loa

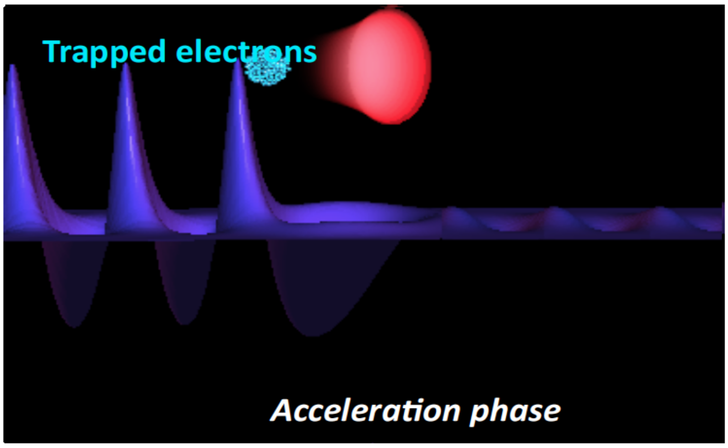
1st European Advanced Accelerator Concepts Workshop, La Biodola, Isola d'Elba - Italy, June 2-7 (2013)

http://loa.ensta.fr/ UMR 7639

lundi 3 juin 13

Colliding Laser Pulses Scheme

The first laser creates the accelerating structure, a second laser beam is used to heat electrons



Theory : E. Esarey *et al.*, PRL **79**, 2682 (1997), H. Kotaki *et al.*, PoP **11** (2004)
Experiments : J. Faure *et al.*, Nature **444**, 737 (2006)

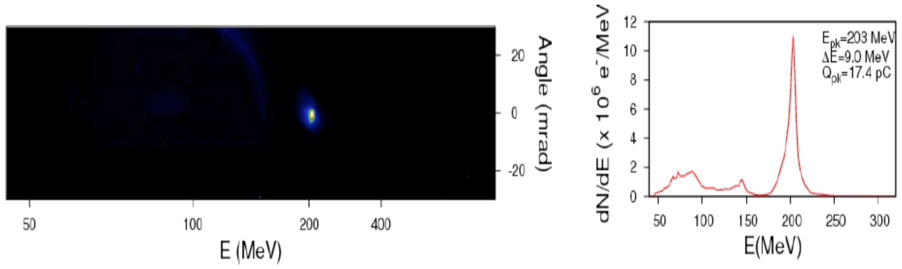
loa

1st European Advanced Accelerator Concepts Workshop, La Biodola, Isola d'Elba - Italy, June 2-7 (2013)

http://loa.ensta.fr/ UMR 7639

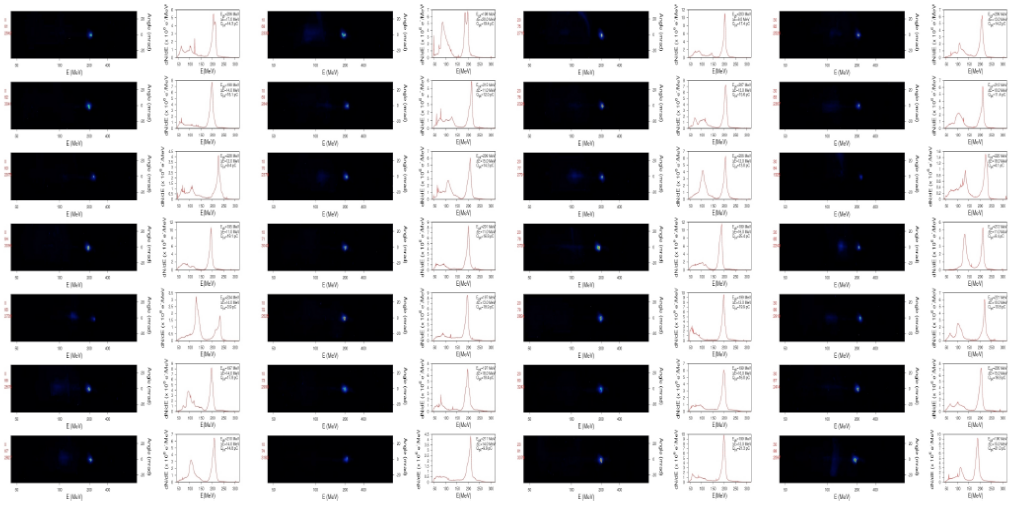
lundi 3 juin 13

Stable Laser Plasma Accelerators



Stable Laser Plasma Accelerators

Series of 28 consecutive shots with : $a_0=1.5$, $a_1=0.4$, $n_e=5.7\times10^{18}cm^{-3}$



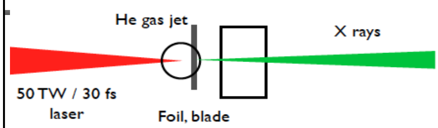
Accelerators point of view :

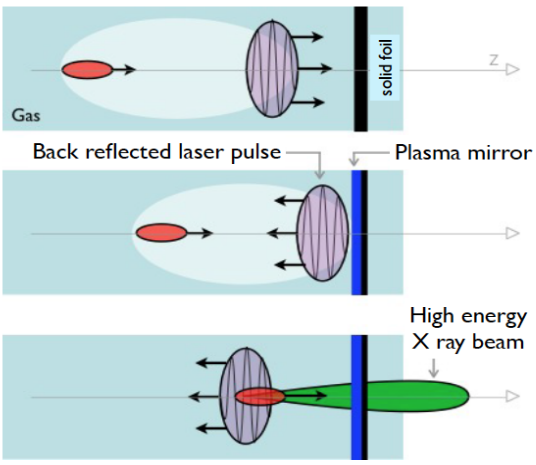
- Good beam quality & Monoenergetic dE/E down to 1 % √
- Beam is very stable √
- Energy is tunable: up to 400 MeV √
- Charge is tunable: 1 to tens of pC √
- Energy spread is tunable: 1 to 10 % √
- Ultra short e-bunch : 1,5 fs rms √
- Low divergence : 2 mrad √
- Low emittance[1-3] : < π.mm.mrad √

With PW class laser : peak energy at 3 GeV √

[1]S. Fritzler *et al.*, Phys. Rev. Lett. **92**, 165006 (2004), [2]C. M. S. Sears *et al.*, PRSTAB **13**, 092803 (2010)
[3]E. Brunetti *et al.*, Phys. Rev. Lett. **105**, 215007 (2010)

Inverse Compton Scattering : New scheme

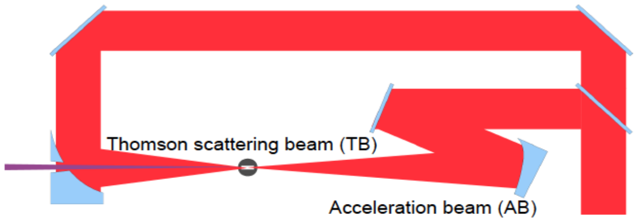




- A single laser pulse
- A plasma mirror reflects the laser beam
- The back reflected laser collides with the accelerated electrons
- No alignment : the laser and the electron beams naturally overlap
- Save the laser energy !

TWO BEAM CONFIGURATION AT FLAME 1/2

A possible simple setup for Thomson scattering experiments with self-injected electrons [1/2] (*~compatible with existing setup*)



Main params:

- **AB** OAP: f/10, a_0~4-5
- **TB** OAP: to be defined (see below), a_0~0.5, but size (→ energy) depending on the e- beam emittance

Submitted to HORIZON 2020 FET (AOX, F. Boscherini, G. Gatti, L. Gizzi)

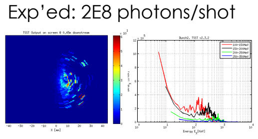
γ-RESIST

INFN

Inverse Compton scattering of of self-injected, LWFA sub-GeV electrons[1,2]

SIMULATIONS

Exp'ed: 2E8 photons/shot

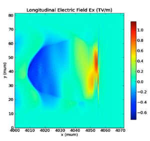


Montecarlo TSST: expected angular and spectral distribution

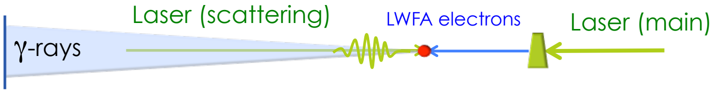
Photons at screen: image and spectrum

e- bunch

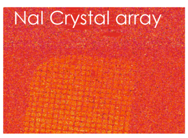
PIC (Jasmine) self-injection on a 4 mm gas–jet



γ-photons



EXPERIMENT

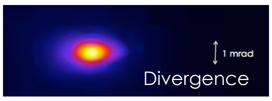


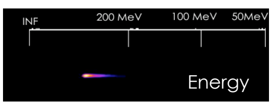
First measured (July 2013) γ-ray signal: low S/N ratio.
Higher shielding, collision stability and laser beam energy needed

γ-photons

e- bunch

Measured bunch fully established July 2013 run:
monoenergetic+ low emittance



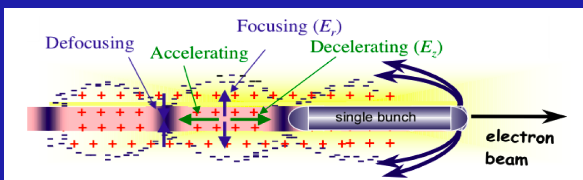


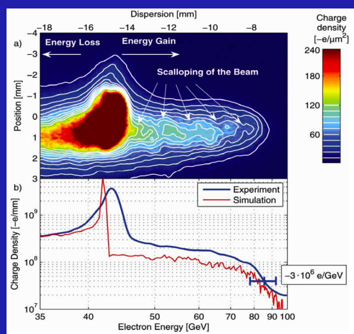
[1]L.A. Gizzi et al., NIM B 309, 202-209 (2013);[2]T. Levato et al., NIMA A720, 95-99 (2013) [3]P. Tomassini et al., Appl. Phys. B **80**, 419-436 (2005)

FACET Has a Multi-year Program to Study PWFA

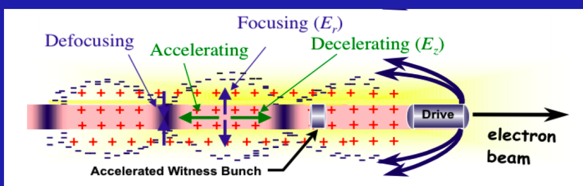
- Demonstrate a single-stage high-energy plasma accelerator for electrons
- Meter scale, high gradient, preserved emittance, low energy spread, and high efficiency
  - Commission beam, diagnostics and plasma source (2012)
  - Produce independent drive & witness bunch (2012-2013)
  - Pre-ionized plasmas and tailored profiles to maximize single stage performance: total energy gain, emittance, efficiency (2013-2015)
- First experiments with compressed positrons
  - Identify optimum technique/regime for positron PWFA (2014-2016)

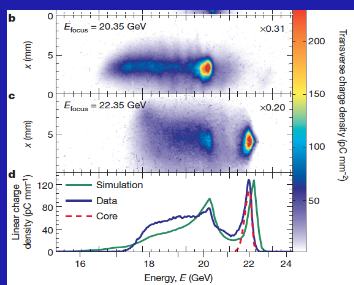
4





Blumenfeld, I. et al. *Energy doubling of 42 GeV electrons in a metre-scale plasma wakefield accelerator*. **Nature** 445, 741–744 (2007).



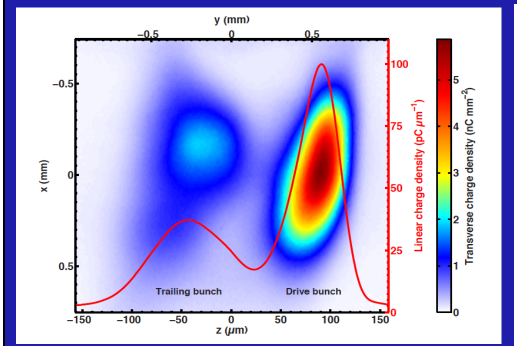


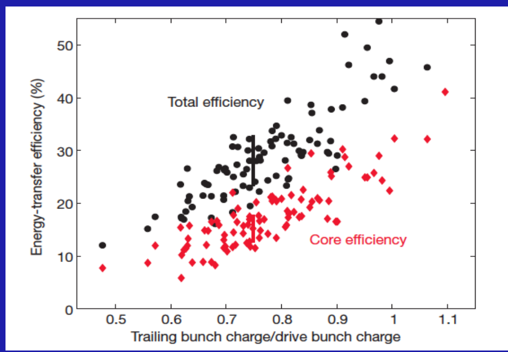
Litos, M. et al. *High-efficiency acceleration of an electron beamin a plasma wakefield accelerator*. **Nature** 515, 92–95 (2014).

doi:10.1038/nature13882

High-efficiency acceleration of an electron beam in a plasma wakefield accelerator

M. Litos[1], E. Adli[1,2], W. An[3], C. I. Clarke[1], C. E. Clayton[4], S. Corde[1], J. P. Delahaye[1], R. J. England[1], A. S. Fisher[1], J. Frederico[1], S. Gessner[1], S. Z. Green[1], M. J. Hogan[1], C. Joshi[4], W. Lu[5], K. A. Marsh[4], W. B. Mori[3], P. Muggli[6], N. Vafaei-Najafabadi[4], D. Walz[1], G. White[1], Z. Wu[1], V. Yakimenko[1] & G. Yocky[1]



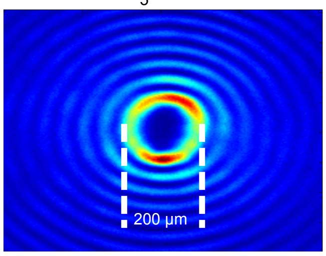


Positrons and Hollow Channel Plasma

SLAC

- The physics of accelerating positrons in a plasma is different than that of electrons!
- Hollow channel plasmas might be a viable method for accelerating positrons in a plasma.
- A special optic called a kinoform is used to create a hollow channel plasma.

Laser Profile for J_5 Bessel Focus



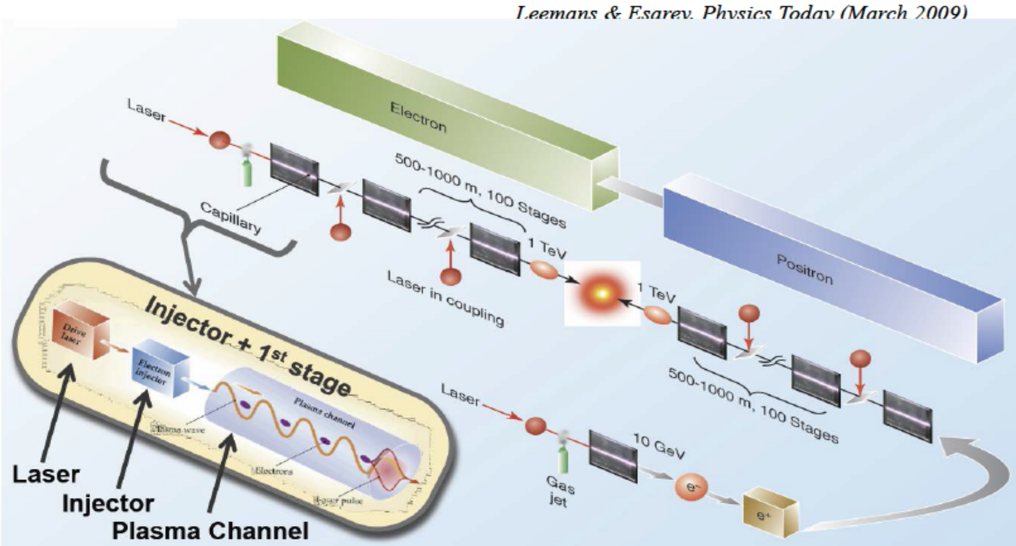
Positrons plasma acceleration is a crucial step towards a plasma based linear collider. FACET hosts the only active research on positron PWFA.

27

The Path towards a Plasma based Linear Collider

Laser-Plasma-Accelerator LC

Leemans & Esarey, Physics Today (March 2009)



Vladimir Shiltsev - Colliders - DESY, Jan 15, 2014 45

Parameter Set for LPWA LC

Case: CoM Energy (Plasma density)	1 TeV (10^{17} cm^{-3})	1 TeV (2×10^{15} cm^{-3})	10 TeV (10^{17} cm^{-3})	10 TeV (2×10^{15} cm^{-3})
Energy per beam (TeV)	0.5	0.5	5	5
Luminosity (10^{34} cm^{-2}s^{-1})	2	2	200	200
Electrons per bunch ($\times10^{10}$)	0.4	2.8	0.4	2.8
Bunch repetition rate (kHz)	15	0.3	15	0.3
Horizontal emittance $\gamma\varepsilon_x$ (nm-rad)	100	100	50	50
Vertical emittance $\gamma\varepsilon_y$ (nm-rad)	100	100	50	50
β^* (mm)	1	1	0.2	0.2
Horizontal beam size at IP σ^*_x (nm)	10	10	1	1
Vertical beam size at IP σ^*_y (nm)	10	10	1	1
Disruption parameter	0.12	5.6	1.2	56
Bunch length σ_z (μm)	1	7	1	7
Beamstrahlung parameter Υ	180	180	18,000	18,000
Beamstrahlung photons per e, n_γ	1.4	10	3.2	22
Beamstrahlung energy loss δ_E (%)	42	100	95	100
Accelerating gradient (GV/m)	10	1.4	10	1.4
Average beam power (MW)	5	0.7	50	7
Wall plug to beam efficiency (%)	6	6	10	10
One linac length (km)	0.1	0.5	1.0	5

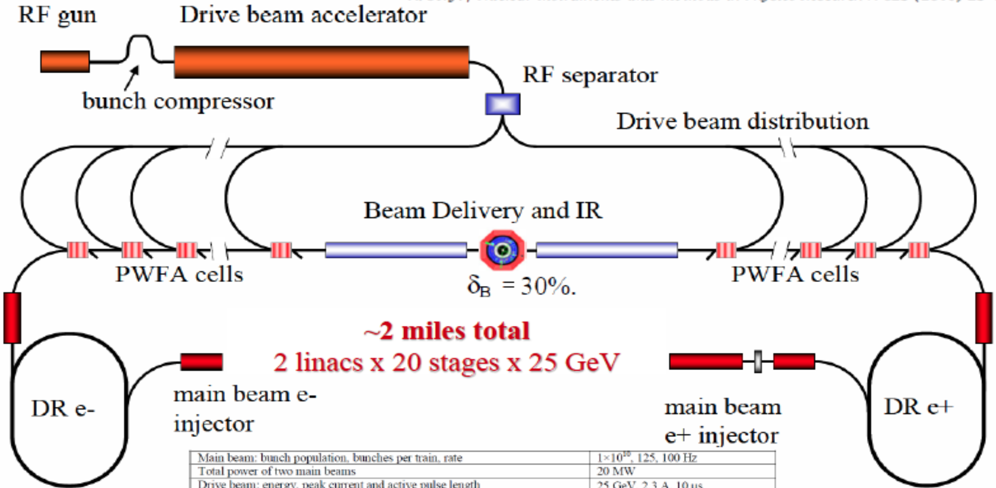
×2+FF

W.Leemans, ICFA BD Newsletter, No.56 (2011)

Vladimir Shiltsev - Colliders - DESY, Jan 15, 2014 46

Plasma Wake Field *e+e-* 1 TeV

A. Seryi / Nuclear Instruments and Methods in Physics Research A 623 (2010) 23–28



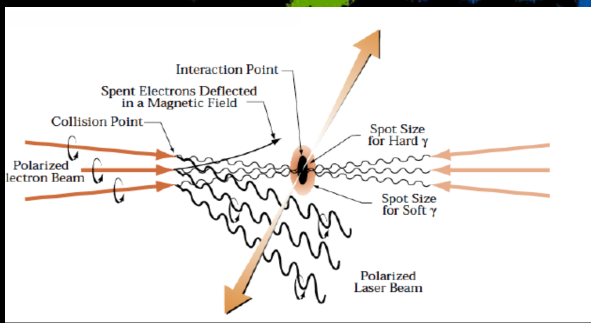
Main beam: bunch population, bunches per train, rate	1×10^{10}, 125, 100 Hz
Total power of two main beams	20 MW
Drive beam: energy, peak current and active pulse length	25 GeV, 2.3 A, 10 μs
Average power of the drive beam	58 MW
Plasma density, accelerating gradient and plasma cell length	1×10^{17}cm^{-3}, 25 GV/m, 1 m
Power transfer efficiency drive beam=>plasma =>main beam	35%
Efficiency: Wall plug=>RF=>drive beam	50% × 90% = 45%
Overall efficiency and wall plug power for acceleration	15.7%, 127 MW
Site power estimate (with 40MW for other subsystems)	170 MW
Main beam emittances, x, y	2, 0.05 mm-mrad
Main beam sizes at Interaction Point, x, y, z	0.14, 0.0032, 10 μm
Luminosity	3.5×10^{34} cm^{-2}s^{-1}
Luminosity in 1% of energy	1.3×10^{34} cm^{-2}s^{-1}

SLAC

43

Plasma Based Photon-Photon Linear Collider demonstration?

The vacuum of QED poses some still unsolved challenges which are central not only in the context of field theory, but also of super-symmetry and string theory as well. The elastic photon-photon scattering offers unique opportunities to probe the nature of QED vacuum. We propose an experiment to observe photon-photon scattering in the range 1 MeV – 2 MeV CM energy, i.e., near the peak of the QED cross-section. In addition a low-energy photon-photon collider investigation could lead to the necessary technology developments and prepare the ground for a higher energy complex, while still providing a rich testing ground for QED, and, more generally, QFT.



The most striking failing of QFT is the huge mismatch between the measured energy density of vacuum and the energy density of the ground level of the fundamental fields which is wrong by something like 120 orders of magnitude.

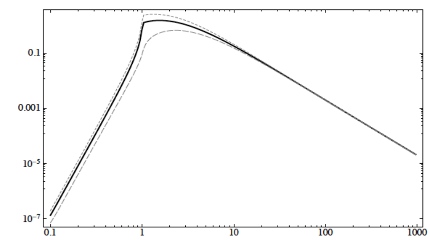
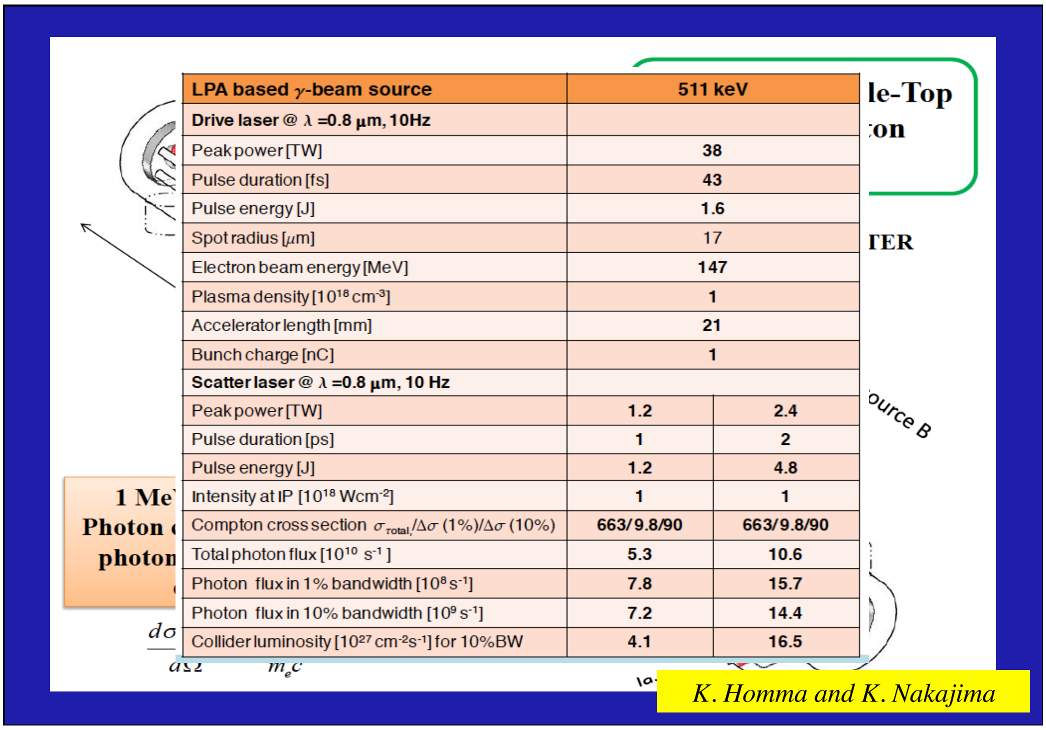


Figure 18: total cross-section (μbar) vs. CM energy (MeV). Solid line: cross-section averaged over initial photon polarizations. Dotted line: incoming photons have the same circular polarization. Dashed line: incoming photons have opposite circular polarization.

a photon-photon scattering experiment with photon energies in the 0.5-0.8 MeV range – where the cross-section is reasonably large, would be an important test of our understanding of the QED vacuum.

This experiment needs a low-energy photon-photon collider, and a photon detection apparatus which is very similar to that current PET scanners



LPA based γ-beam source	511 keV	
Drive laser @ λ =0.8 μm, 10Hz		
Peak power [TW]	38	
Pulse duration [fs]	43	
Pulse energy [J]	1.6	
Spot radius [μm]	17	
Electron beam energy [MeV]	147	
Plasma density [10^{18} cm^{-3}]	1	
Accelerator length [mm]	21	
Bunch charge [nC]	1	
Scatter laser @ λ =0.8 μm, 10 Hz		
Peak power [TW]	1.2	2.4
Pulse duration [ps]	1	2
Pulse energy [J]	1.2	4.8
Intensity at IP [10^{18} Wcm^{-2}]	1	1
Compton cross section $\sigma_{Total}/\Delta\sigma$ (1%)/$\Delta\sigma$ (10%)	663/9.8/90	663/9.8/90
Total photon flux [10^{10} s^{-1}]	5.3	10.6
Photon flux in 1% bandwidth [10^{8} s^{-1}]	7.8	15.7
Photon flux in 10% bandwidth [10^{9} s^{-1}]	7.2	14.4
Collider luminosity [10^{27} cm^{-2}s^{-1}] for 10%BW	4.1	16.5

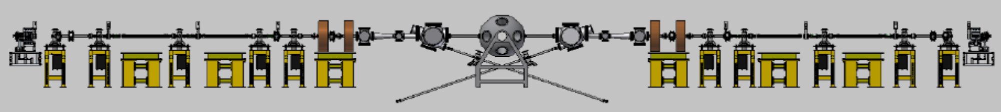
Photon – Photon Collider
A Possible New Configuration at SPARC_LAB?
200 MeV, 800 nm => ~1 MeV

Colliding 2 gamma-ray 0.5 - 1 MeV beams, carrying 10^9 photons per pulse at 10 Hz rep rate, with focal spot size at the collision point of about 2 μm, we achieve: $L_{SC}=2.10^{25}$, cross section = 1 μbarn, events/s=2.10^{-5}, events/day=1.8, 0.1 nanobarn^{-1} accumulated after 3.2 months of 5/24 machine running.

INFN SPARC_LAB

a) 200 MeV/m peak cathode field of X-Band SLAC RF Photo-Injector (recently proven)

b) 100 MeV/m SLAC (Tantawi/Spataro) new X-band RF cavities (recently demonstrated)



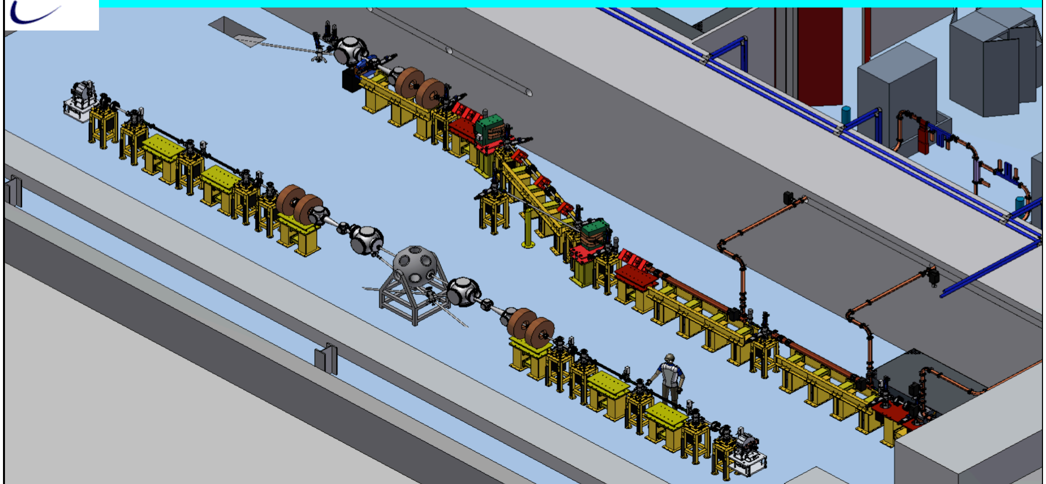
1) Electron beam operation in single bunch – focusability to 3 micron spot size at Compton Interaction Point

2) Pointing stability at 2 Compton Sources

3) Deflection of counter-propagating electron bunches to avoid e-/e- interactions

Fundam. and Quantum Physics with Lasers, LNF, Oct. 23rd 2014

INFN SPARC_LAB



Colliding 2 gamma-ray 0.5 MeV beams, carrying 10^9 photons per pulse at 100 Hz rep rate, with focal spot size at the collision point of about 2 μm, we achieve: $L_{SC}=2.10^{26}$, cross section = 1 μbarn, events/s=2.10^{-4}, events/day=18, 1 nanobarn^{-1} accumulated after 3.2 months of 5/24 machine running.

Fundam. and Quantum Physics with Lasers, LNF, Oct. 23rd 2014

D. Palmer, G. Diraddo

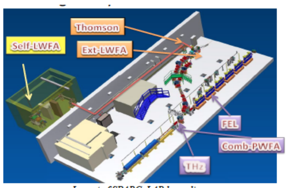
An upgraded (1 GeV, 1 PW) SPARC_LAB facility could be a strong candidate for the EuPRAXIA site

WHAT NEXT AT SPARC_LAB ?
M. Ferrario on behalf of the SPARC_LAB Collaboration

April 24, 2014

1- INTRODUCTION

SPARC_LAB [1] (Sources for Plasma Accelerators and Radiation Compton with Lasers And Beams) is an inter-disciplinary laboratory with unique features in the world. Born from the integration of a last generation photo-injector (SPARC)[2-7], able to produce electron beams up to 200 MeV energy with high peak current (> 1 kA) and low emittance (<2 mm-mrad), and of a high power laser (> 200 TW) (FLAME) [8,9], able to produce ultra-short pulses (<30 fs), SPARC_LAB has already enabled the development of innovative radiation sources and the test of new techniques for particle acceleration using lasers.



Layout of SPARC_LAB beam lines

In particular the following highlight results have been achieved:

- a Free Electron Laser has been commissioned producing coherent radiation tunable from 500 nm down to 40 nm and new regimes of operation like Seeding, Single Spike, Harmonic Generation and Two Colors have been observed [10-14];
- a source of both broad band, narrow band (<30%) and high energy (> 10 μJ) THz radiation has been tested, first experiments with users are underway [15,16];
- electrons have been accelerated up to 100 MeV in 4 mm long plasma wave excited by the high power laser FLAME [9];

INFRASTRUCTURE EXTENSION AND LINAC ENERGY UPGRADE TOWARDS 1 GeV
- Multi bunch operation

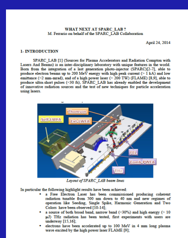
ADVANCED ACCELERAROR CONCEPTS
- High quality electron beam from plasma to drive a compact FEL source
- Test of palsma accelerator staging
- Positron acceleration in a plasma: a demonstrative experiment
- Low emittance Positron Source (Channelling – Compton)

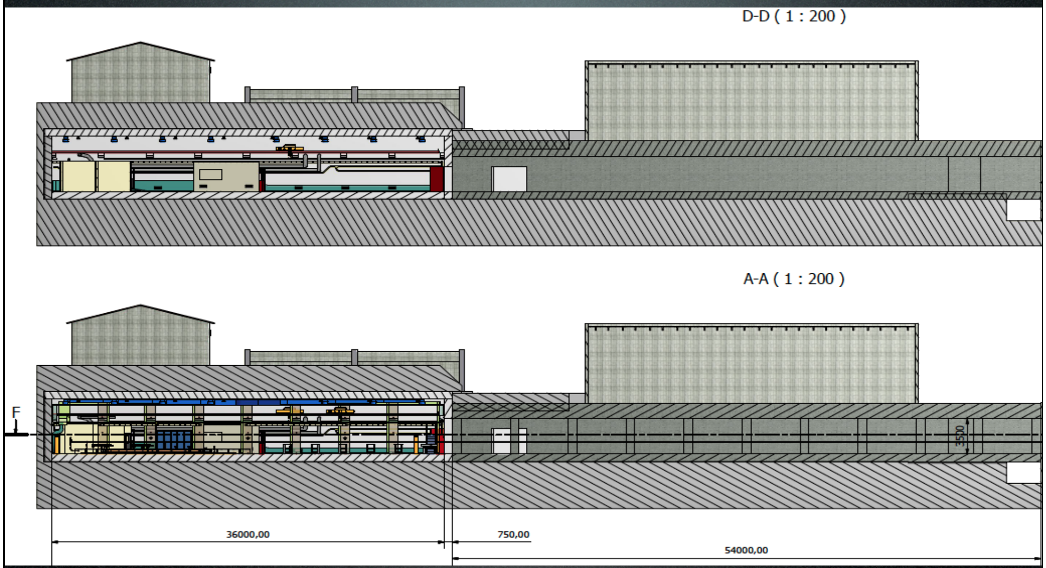
X-RAYS THOMSON SOURCE BEAM LINE UPGRADE
- Low-medium energy, ultra fast X-ray microscope (>10keV)
- Optimizing chemotherapy through quasi-monochromatic radiation (30-100keV)
- Breast CT with quasi-monochromatic and spatially coherent source (30-100 keV)
- High energy applications (>500 keV)

FEL BEAM LINE UPGRADE
- FEL oscillator, intra-cavity Compton, short Period Undulators
- Low energy beam lines 5–35 eV (250 - 35 nm)
- High energy beamline ~10 keV

THz RADIATION SOURCE UPGRADE
- Dedicated undulator

FLAME LASER UPGRADE TOWARDS 1 PW
- Electron acceleration with self-injection beyond the GeV;
- QED and generation of high energy radiation;
- Proton and ion acceleration beyond the TNSA regime.



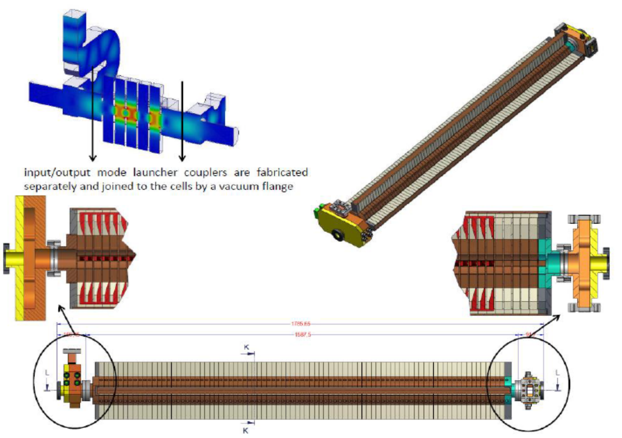


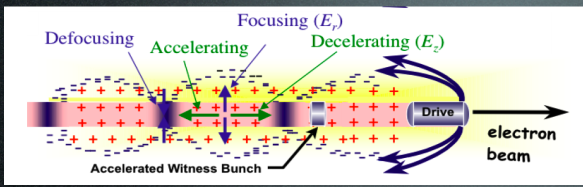
C-band structures

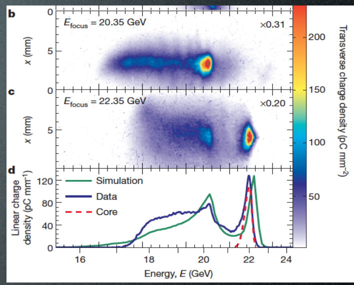
D. Alesini

The beam loading effect and the Beam break UP (BBU) instability have been extensively studied to guarantee the multibunch operation feasibility.

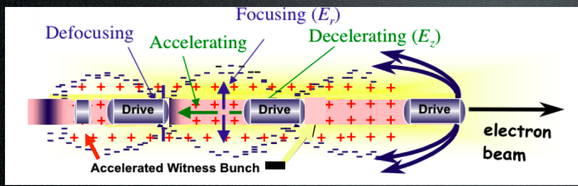
In particular the beam loading in the structures will be compensated with a modulation of the input power to maintain the required energy spread along the bunch train.

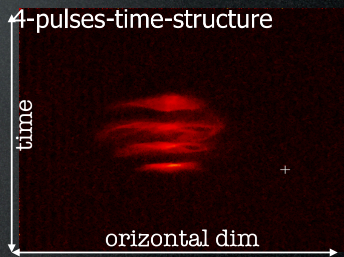






Litos, M. et al. *High-efficiency acceleration of an electron beamin a plasma wakefield accelerator.* **Nature** 515, 92–95 (2014).





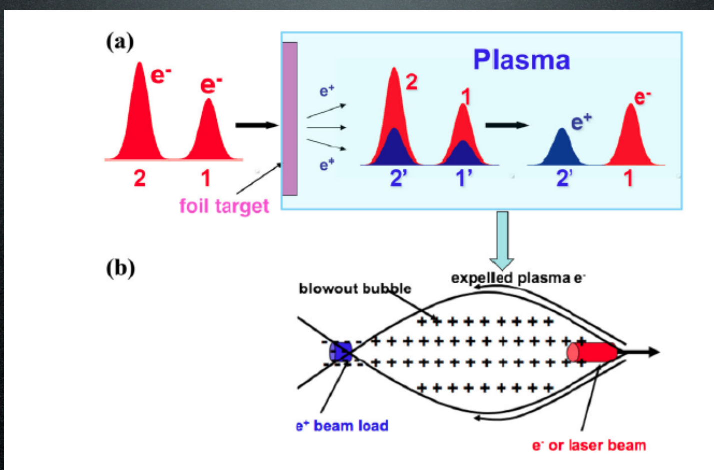
In progress also at SPARC_LAB

Submitted to HORIZON 2020 FET, (ELBA, M. Ferrario, E. Chiadroni, A. Cianchi)

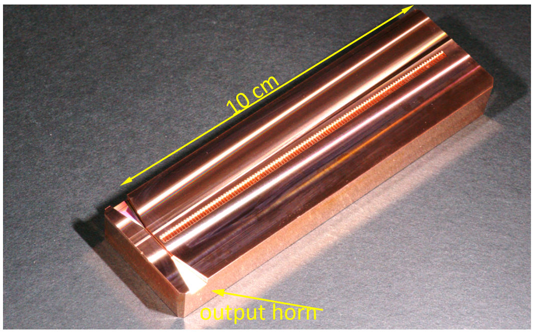
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 12, 051303 (2009)

Optimization of positron trapping and acceleration in an electron-beam-driven plasma wakefield accelerator

X. Wang,[1] P. Muggli,[1] T. Katsouleas,[1] C. Joshi,[2] W. B. Mori,[2] R. Ischebeck,[3] and M. J. Hogan[3]



100 GHz Accelerating structure (schematic half cross section)



High power tests will be carried out at SLAC within two or three months

The goal is to get some GV/m

In addition the fabrication of a couple of 235 GHz structures is in progress, too

NORCIA

Courtesy B. Spataro

FLAME at present

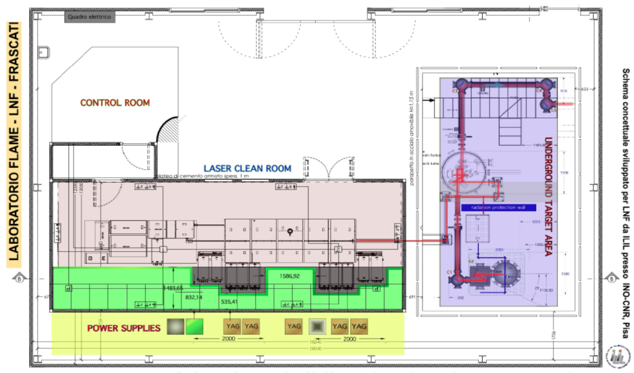


Figure 1: Current Layout of the Flame building showing the Laser, underground target area and the transport line to the Sparc bunker.

FLAME Upgrade

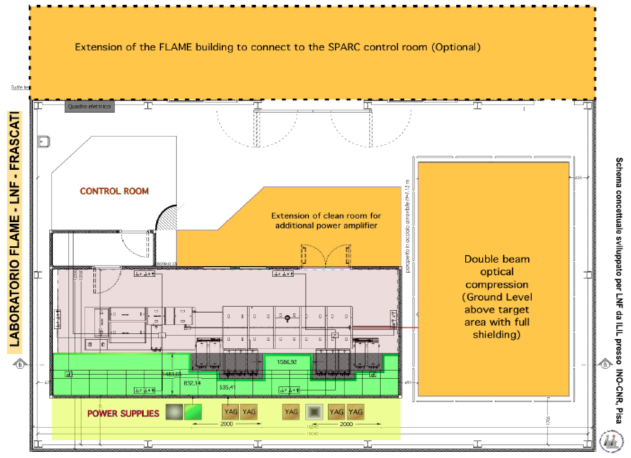


Figure 2: Layout of the upgraded Flame building, with the ground floor layout including the extension of the clean room and the dual compressor room. An optional extension of the Flame building is also planned to allow a better connection with the present Sparc control room building.

FLAME Upgrade

Basic parameters of the two beams of the Flame upgrade.

Beam n.	Pulse Duration	Pulse Energy	Contrast (ps)	Rep Rate
Beam 1 (0.2PW)	17 fs	3.5J	1E12	10Hz
Beam 2 (PW)	20 fs	20J	1E13	1Hz

The following steps can be identified in the overall Flame upgrade.:

1) upgrade of the front-end (currently 0.5J) to higher energy (>1J) and short <15 fs pulse duration;
2) Upgrade of the existing main amplifier for beam 1 at ≈1 PW;
3) Installation of a new amplifier for beam 2 at 0.2 PW;
4) Upgrade (and relocation) of the new compressor for beam 1;
5) Installation of a new compressor set-up for beam 2;
6) New layout of the target area, including fully shielded ceiling and dual beam target chamber as shown in the Figure 3 below.

FLAME Upgrade

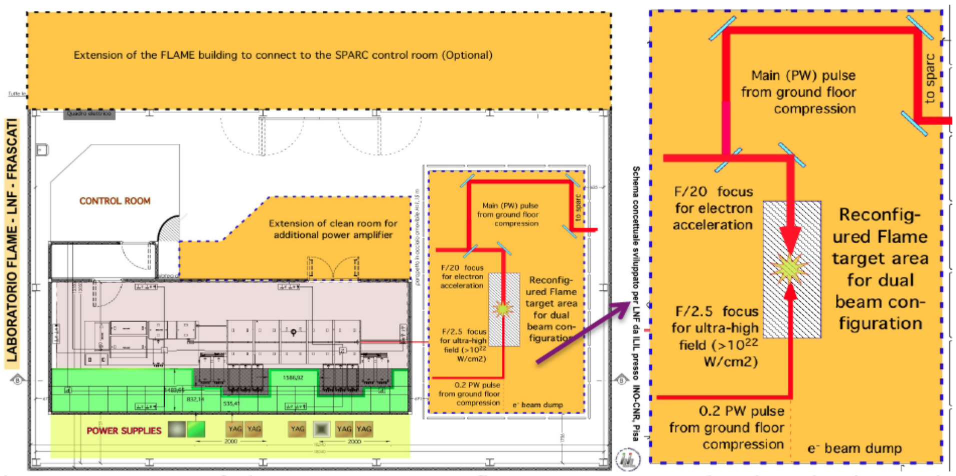
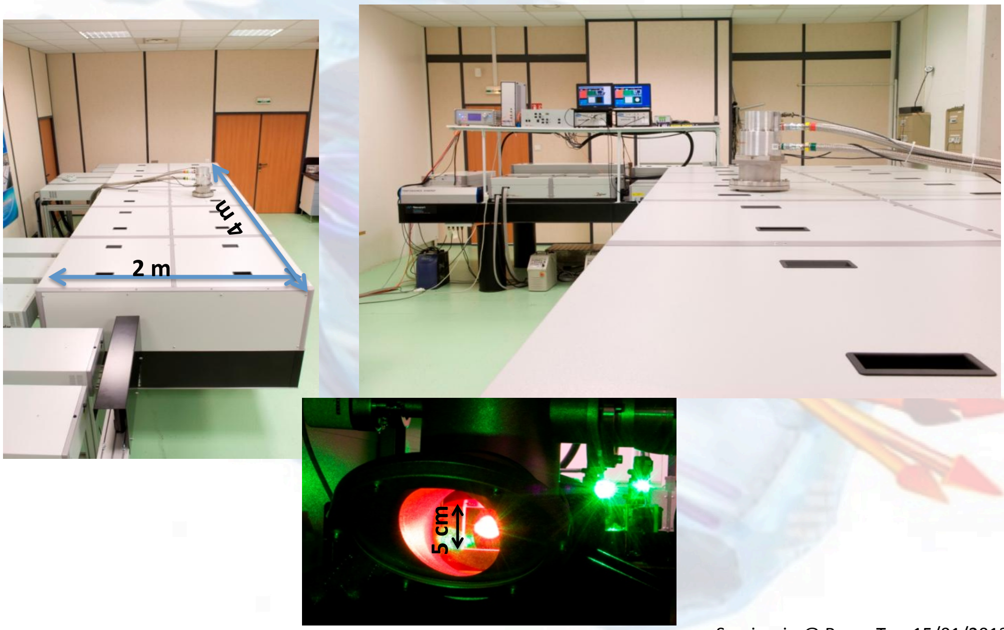


Figure 3. Layout of the **undergoround** flame target area, showing the interaction chamber after reconfiguration with the new dual-beam configuration.

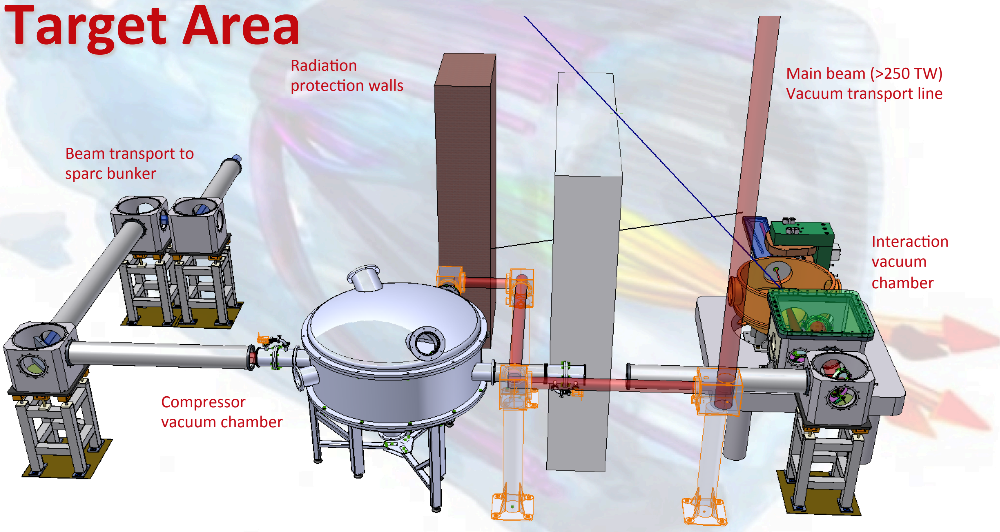
Current SPARC_LAB Plasma activities

Il laser FLAME

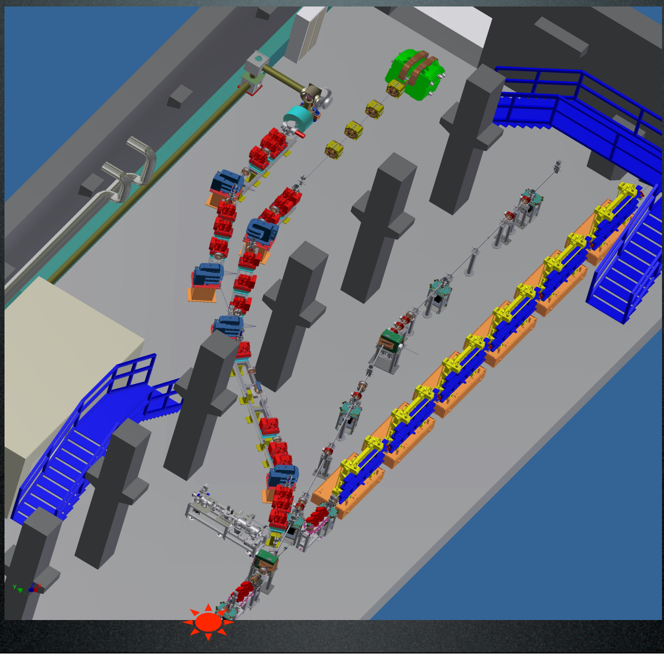


Esperimenti di auto-iniezione

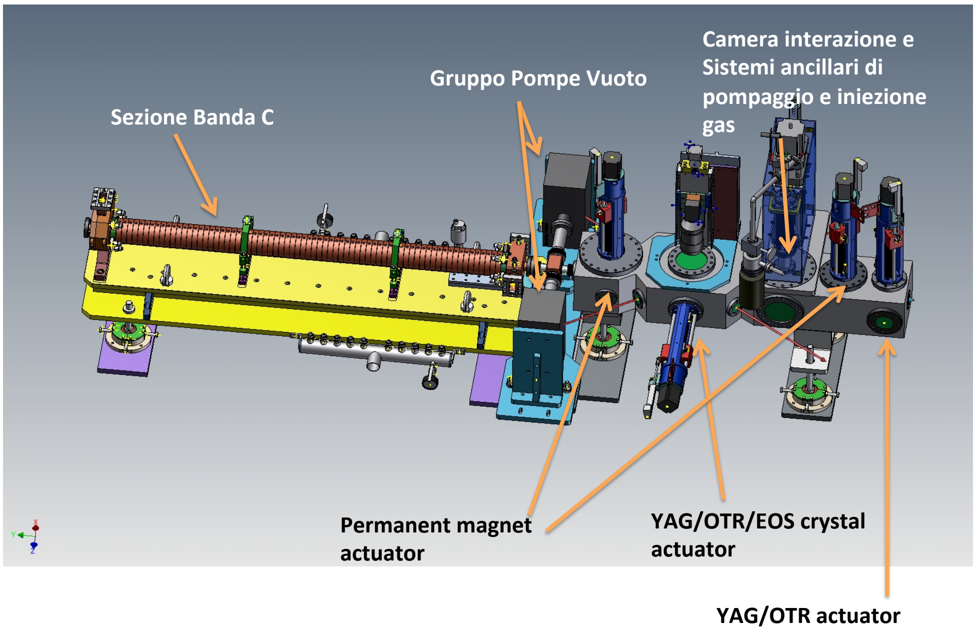
Target Area



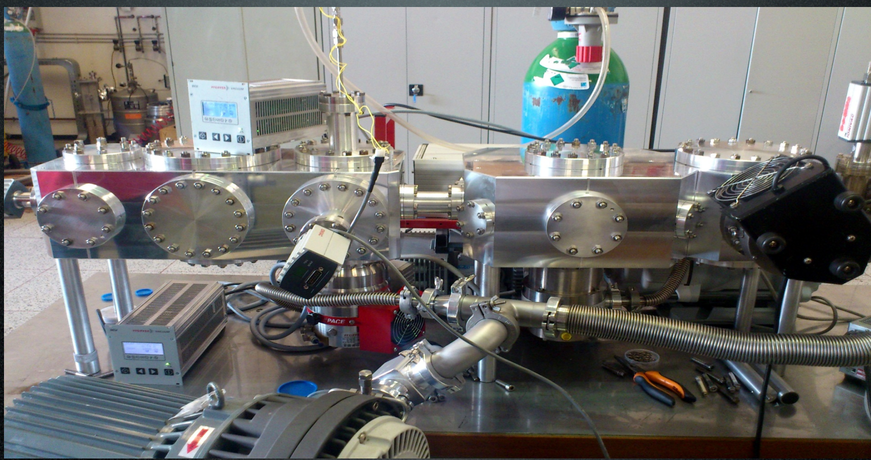
A FEL driven by Plasma Accelerator at SPARC_LAB?

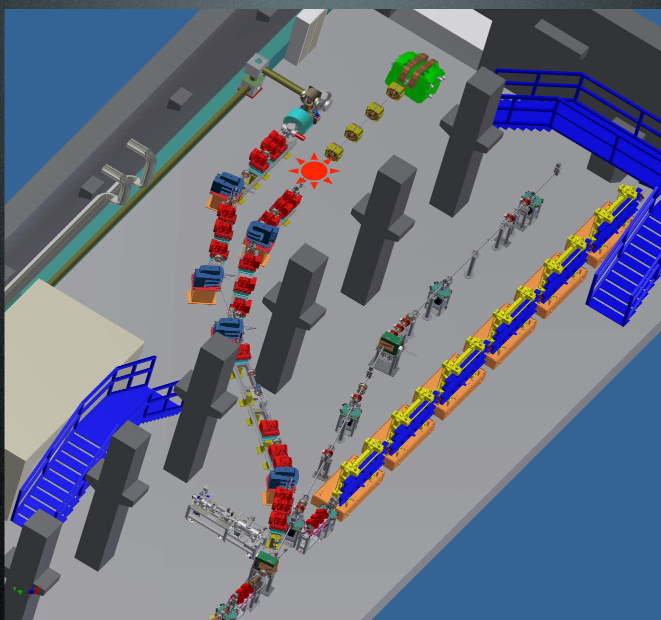


COMB plasma interaction chamber

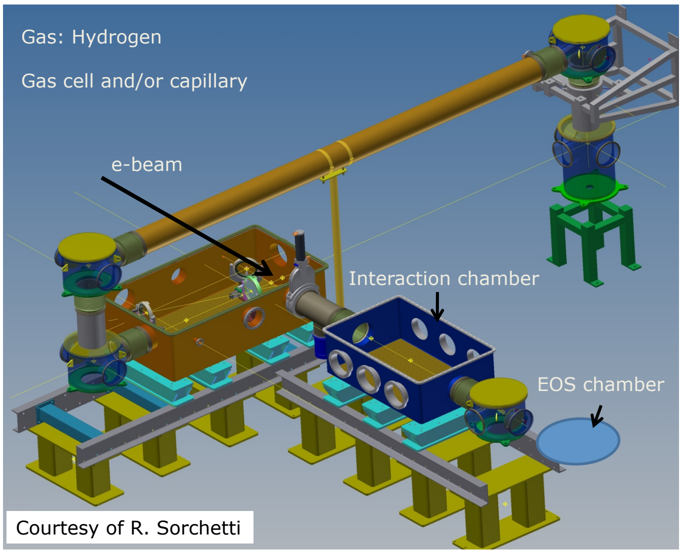


COMB interaction chamber





Interaction Layout



56

Considerations

- A facility based on the unique combination of high brightness electron beams with high intensity ultra-short laser pulses will be soon available for the entire accelerator community, such to allow the investigation of all the different configurations of plasma accelerator and the development of a wide spectrum inter-disciplinary leading-edge research activity
- The ongoing SPARC_LAB activities are being studied in several other laboratories, including SLAC, DESY, CERN and KEK with equally or even more ambitious research programs.
- Therefore the time factor becomes very important to remain at the research frontier and to produce results with high-impact on the international scientific community.

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.

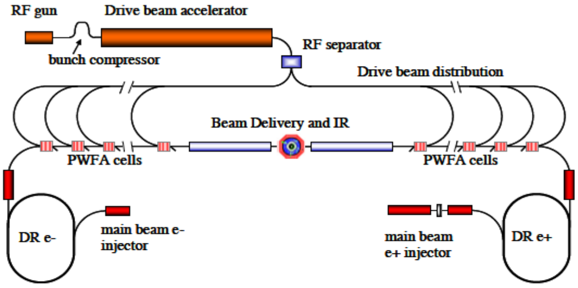


Fig. 1: Concept for a multi-stage PWFA Linear Collider.

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

Table 2: ILC energy upgrade by PWFA after-burner

Parameter	Unit	ILC	ILC	ILC + PWFA
Energy (cm)	GeV	500	1000	PFWA = 500 to 1000
Luminosity (per IP)	$10^{34}cm^{-2}s^{-1}$	1.5	4.9	2.6
Peak (1%)Lum(/IP)	$10^{34}cm^{-2}s^{-1}$	0.88	2.2	1.3
# IP	-	1	1	1
Length	km	30	52	30
Power (wall plug)	MW	128	300	175
Lin. Acc. grad.(p/eff)	MV/m	31.5/25	36/30	7600/1000
# particles/bunch	10^{10}	2	1.74	0.66
# bunches/pulse	-	1312	2450	2450
Bunch interval	ns	554	366	366
Pulse repetition rate	Hz	5	4	15
Beam power/beam	MW	5.2	13.8	13.8
Norm Emitt (X/Y)	$10^{-6}/10^{-9}$radm	10/35	10/30	10/30
Sx, Sy, Sz at IP	nm,nm,µm	474/5.9/300	335/2.7/225	286/2.7/20
Crossing angle	mrad	14	14	14
Av # photons	-	1.70	2.0	0.7
δb beam-beam	%	3.89	9.1	9.3
Upsilon	-	0.03	0.09	0.52

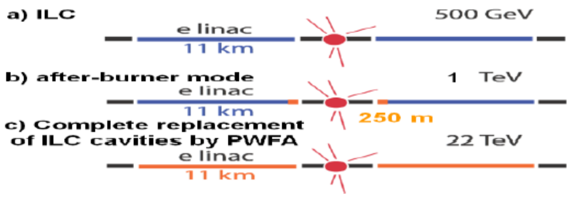


Figure 3: ILC energy upgrade by PWFA technology in the 500 GeV ILC tunnel (a), in after-burner mode (b), in the extreme case of PWFA technology use only (c).

A BEAM DRIVEN PLASMA-WAKEFIELD LINEAR COLLIDER FROM HIGGS FACTORY TO MULTI-TEV*

J.P. Delahaye, E. Adli, S.J. Gessner, M.J. Hogan, T.O. Raubenheimer (SLAC),
W. An, C. Joshi, W. Mori (UCLA)

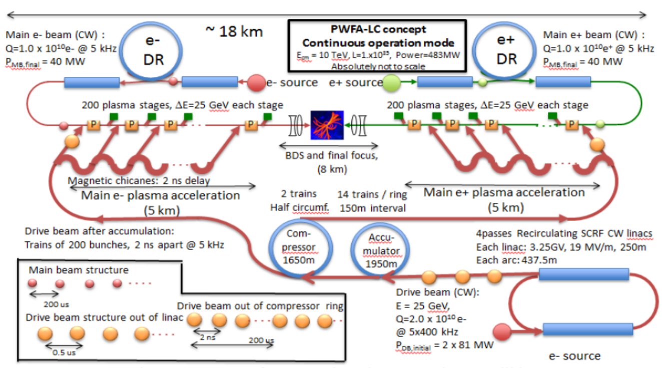


Figure 1: Layout of a PWFA-based 10 TeV Linear Collider