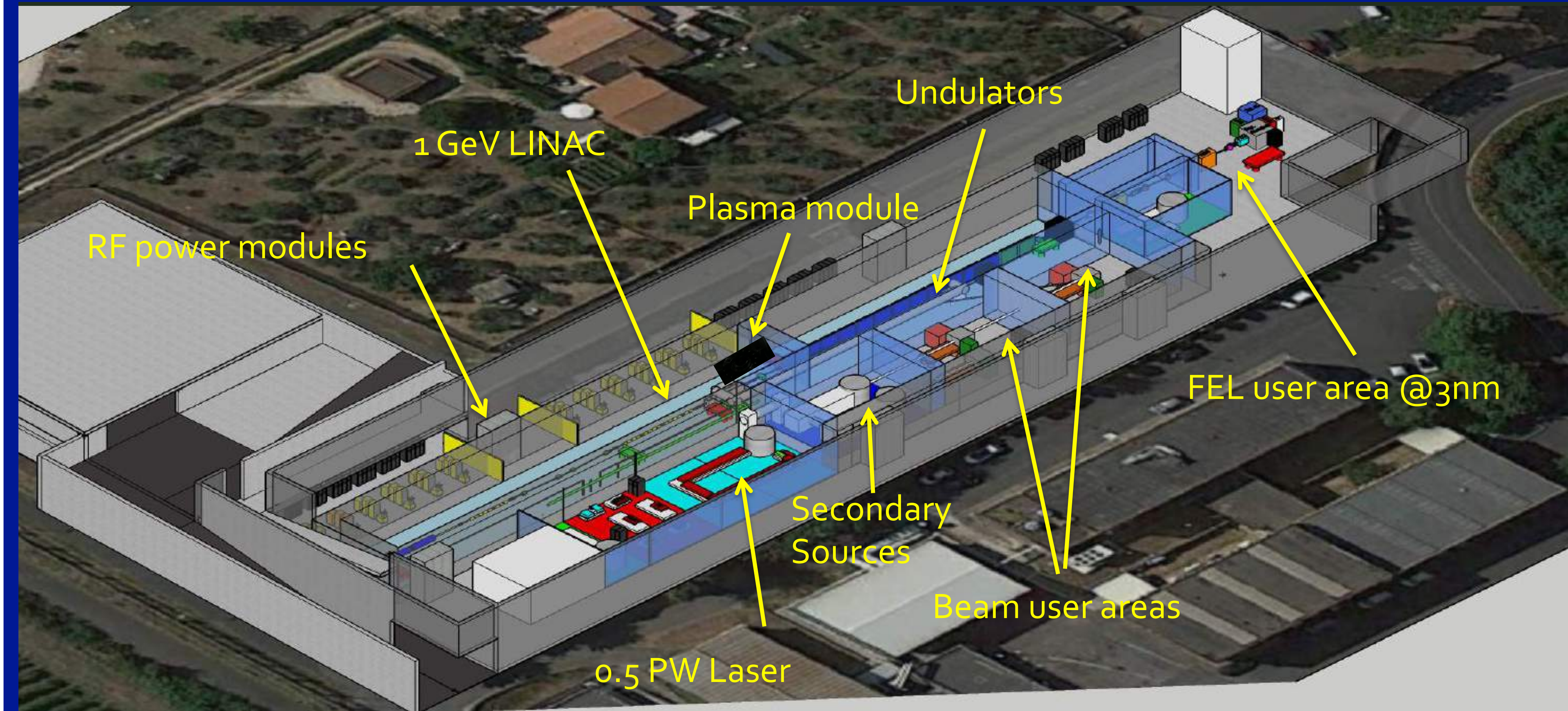
EuPRAXIA@SPARC_LAB

Massimo.Ferrario@lnf.infn.it
On behalf of the EuPRAXIA@SPARC_LAB team



LNF Scientific Committee – November 5, 2018

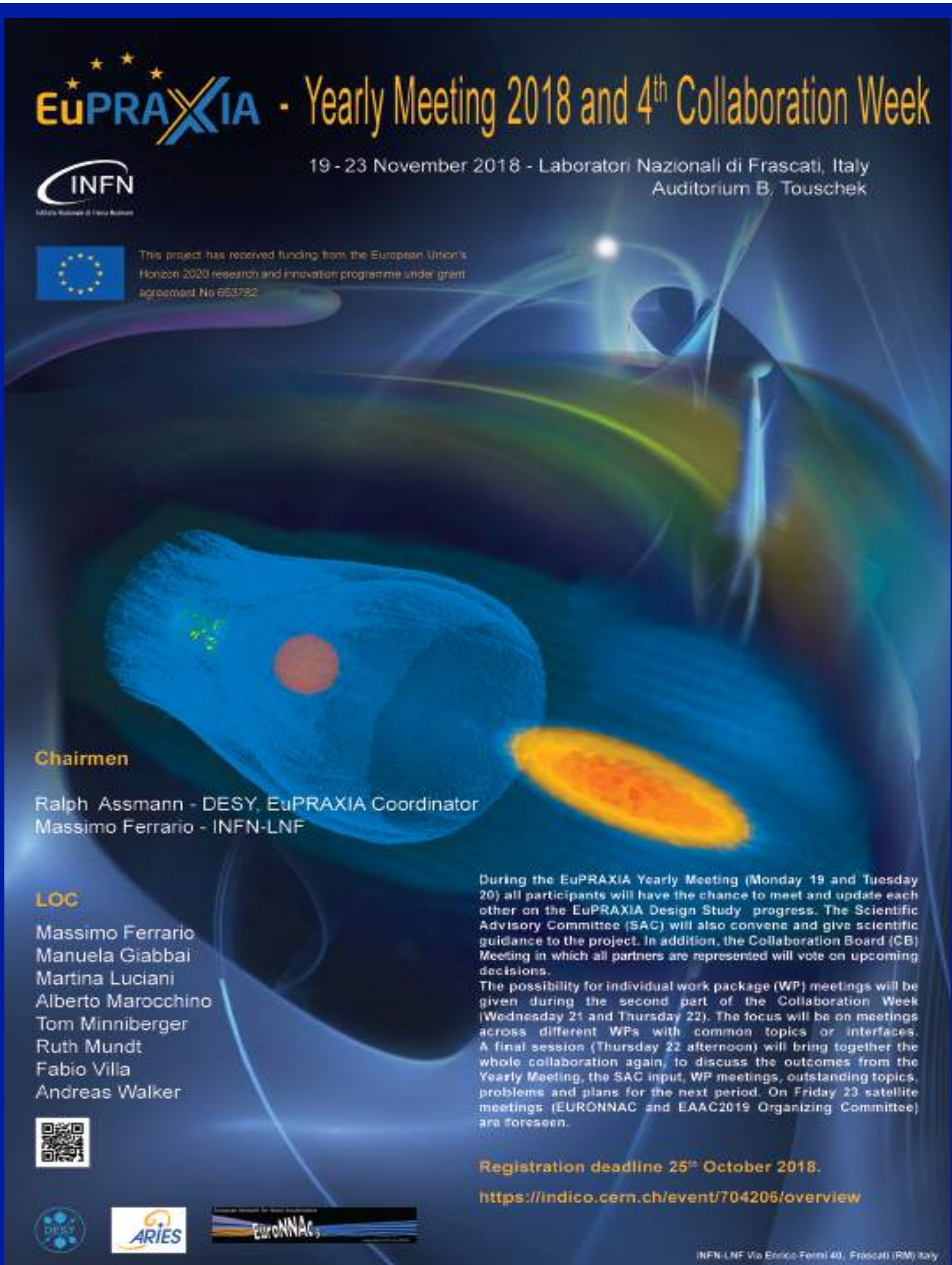
Last Sci-Com Recommendations

- The SC recommends that the EuPRAXIA@SPARC_LAB project be aligned as well as possible to the EuPRAXIA technical goals and time scales to maximize the chances to be selected as site for the EuPRAXIA research infrastructure.

- The SC recommends that the CDR review panel should include potential users of the facility to assess the interest of the photon science community in the EuPRAXIA@SPARC_LAB FEL.

- The SC suggests that work on the following topics should be continued:

  - Explaining the unique points of the EuPRAXIA@SPARC_LAB plasma FEL
  - Expanding the scientific case
  - Defining the EU context
  - Defining the operating costs (in progress)
  - Studying realistic performance

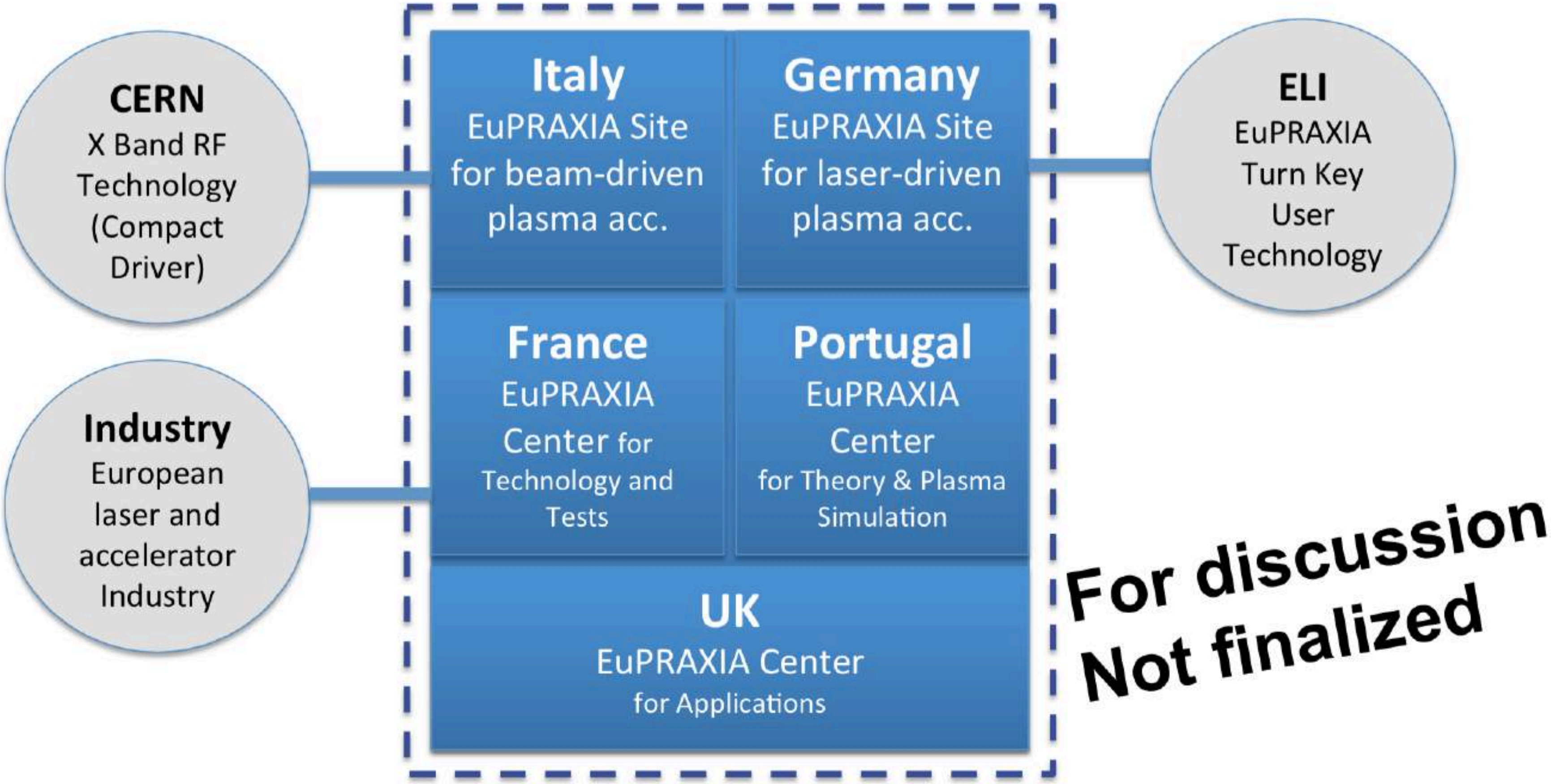


	Monday 19	Tuesday 20	Wednesday 21	Thursday 22	Friday 23
Morning I	Arrivals	Plenary (Auditorium)	Plenary (Auditorium) SAC (Salvini) WGs	Plenary (Auditorium) WGs	EuroNNAc (Auditorium)
Coffee Break					
Morning II	Registration	Plenary (Auditorium)	Plenary (Auditorium) SAC (Salvini)	WGs	EuroNNAc (Auditorium)
Lunch Break 13:30–14:30	LNF Cantine	LNF Cantine	LNF Cantine	LNF Cantine	LNF Cantine
Afternoon I	Plenary (Auditorium)	CB (Direzione) SAC (Salvini)	WGs	Plenary WGs	EAAC (Direzione)
Coffee Break					
Afternoon II	Plenary (Auditorium) SAC (Salvini)	Plenary (Auditorium) SAC (Salvini)	WGs	Plenary WGs	EAAC (Direzione)
Dinner	Free	SOCIAL DINNER CACCIANI	Free	Free	Free

https://indico.cern.ch/event/704206/timetable/#20181119

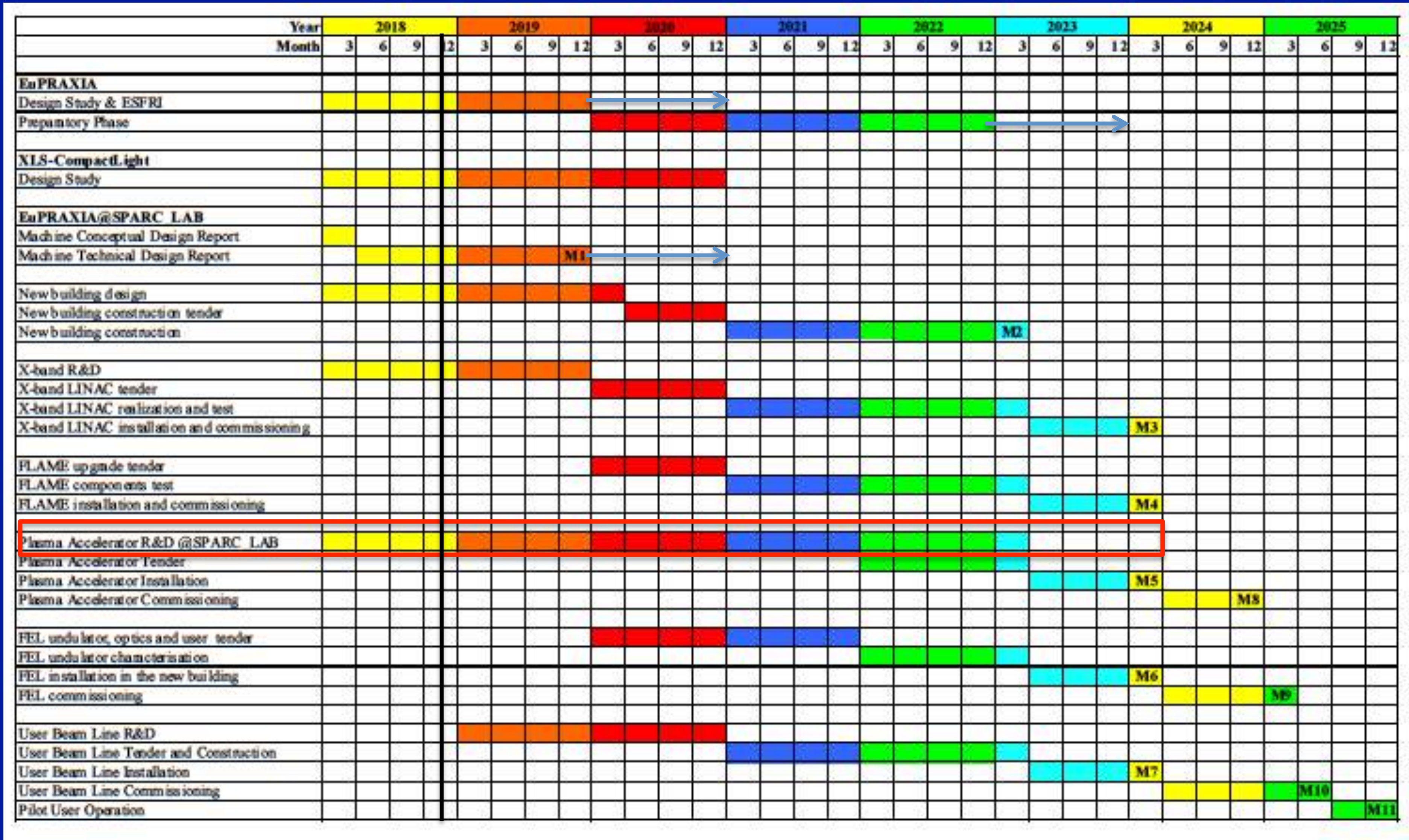
Matching Work, Expertise and Infrastructures

Sharing budget and responsibilities in countries involved, bringing in existing infrastructures



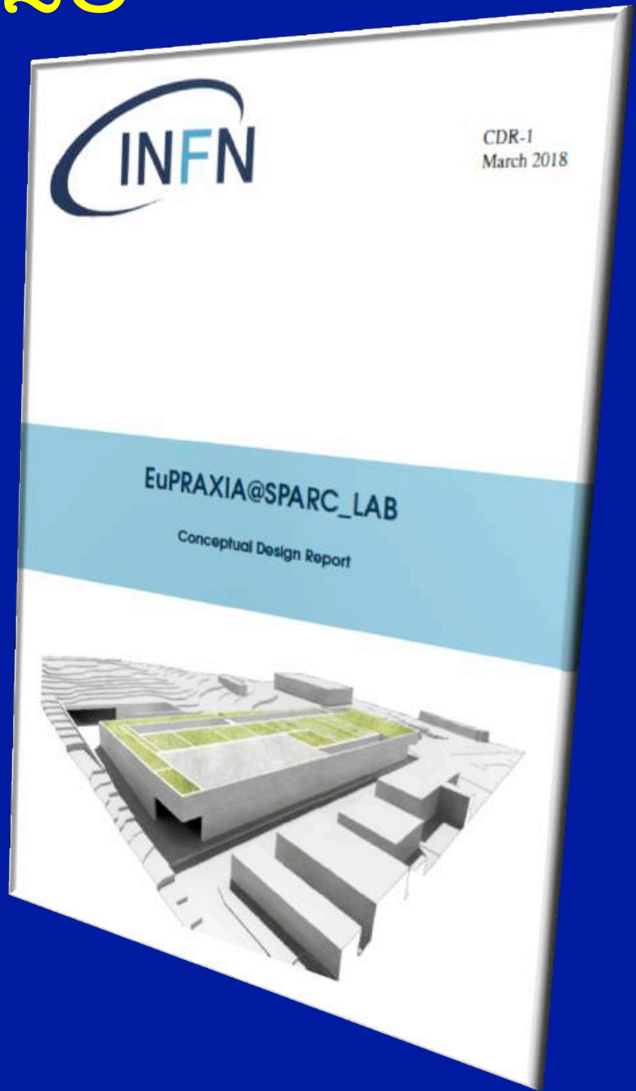
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653782.

Project Timeline



CDR Review Committee Meeting
Nov. 27-28

- D. Angal-Kalinin (STFC)
- P. Muggli (MPI) – Chair
- M. Pedrozzi (PSI)
- L. Scibile (CERN)
- S. Schreiber (DESY)



http://www.lnf.infn.it/sis/preprint/pdf/getfile.php?filename=INFN-18-03-LNF.pdf

The Free Electron Laser EuPRAXIA@SPARC_LAB

Extended Scientific Case

F. Stellato (Uni-ToV)
C. Marcelli (LNF)

X-TRIM

An EUV/soft x-rays beamline @ SPARC_LAB

Istituto Nazionale di Fisica Nucleare

	Units	Full RF case	LWFA case	PWFA case
Electron Energy	GeV	1	1	1
RMS Energy Spread	%	0.05	2.3	1.1
Peak Current	kA	1.79	2.26	2.0
Bunch Charge	pC	200	30	30
RMS Bunch Length	μm (fs)	16.7 (55.6)	2.14 (7.1)	3.82 (12.7)
RMS normalized Emittance	mm mrad	0.5	0.47	1.1
Slice Length	μm	1.66	0.5	1.2
Slice Charge	pC	6.67	18.7	8
Slice Energy Spread	%	0.02	0.03	0.034
Slice normalized Emittance (x/y)	mm mrad	0.35/0.24	0.45/0.465	0.57/0.615
Undulator Period	mm	15	15	15
Undulator Strength $K(a_w)$		0.978 (0.7)	1.13 (0.8)	1.13 (0.8)
Undulator Length	m	30	30	30
Pierce parameter ρ **(1D/3D)**	$\times 10^{-3}$	1.55/1.38	2/1.68	2.5/1.8
Radiation Wavelength	nm (keV)	2.87 (0.43)	2.8 (0.44)	2.98 (0.42)
Photon Energy	μJ	177	40	6.5
Photon per pulse	$\times 10^{10}$	255	43	10
Photon Bandwidth	%	0.46	0.4	0.9
Photon RMS Transverse Size	μm	200	145	10
Photon Brilliance per shot	$(\text{s mm}^2 \text{ mrad}^2 \text{ bw}(0.1\%))^{-1}$	1.4×10^{27}	1.7×10^{27}	0.8×10^{27}

Table 4.1: Beam parameters from start-to-end simulations for full RF and for plasma wakefield acceleration cases with electron (PWFA) or laser (LWFA) driver beam

People & Institutions

A. Balerna
G. Batignani
E. Chiadroni
D. Cirrincione
F. Cometto
M. Coreno
A. Cricenti
S. Dabagov
E. De Santis
A. Di Cicco
C. Ferrante
G. Fumero
L. Giannessi
R. Gunnella
J.J. Leani
S. Lupi
C. Masciovecchio
A. Marcelli
A. Minicucci
S. Morante
E. Perfetto
S.J. Rezvani
A. Ricci
J. Robledo
M. Rubio
H.J. Sanchez
V. Sbarato
T. Scopigno
G. Stefanucci
F. Stellato
A. Trapananti
A. Vacchi
F. Villa

From
13 people
6 institutions
to
32 people
11 institutions

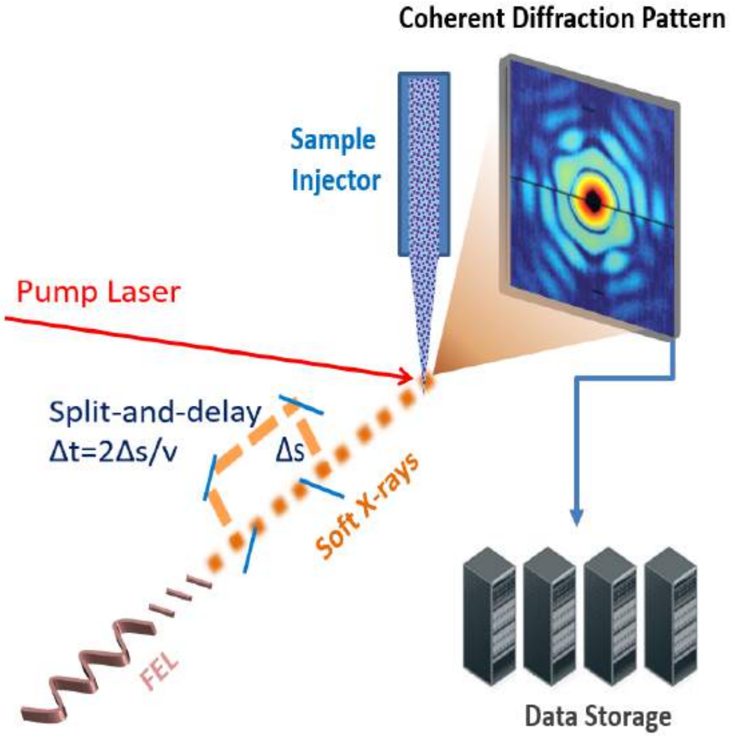
CNR - Istituto Struttura della Materia
Elettra-Sincrotrone Trieste
Istituto Nazionale di Fisica Nucleare
Istituto Italiano di Tecnologia
Argentinian Scientific and Technical Research Council
RICMASS - Rome
Roma La Sapienza University
Roma Tor Vergata University
Camerino University
Cordoba University
Udine University

Coherent Imaging at EuPRAXIA@SPARC_LAB

2 key issues: brilliance and coherence of the FEL radiation

1 experimental station performing coherent imaging experiments

Many applications, ranging from biological systems to condensed matter physics

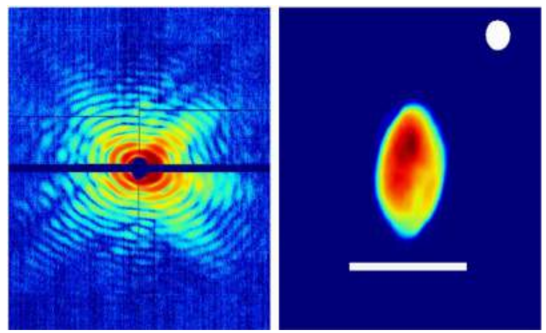


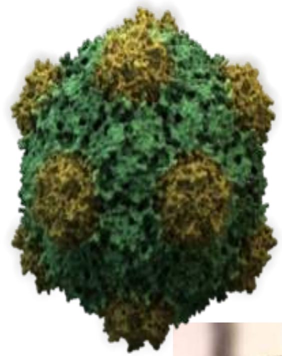
Water Window Coherent Imaging of biological systems

Energy region between oxygen and carbon K-edge

2D and 3D images of biological samples will be obtained

viruses, cells, organelles, protein fibrils…





Condensed-matter

High Temperature superconductors

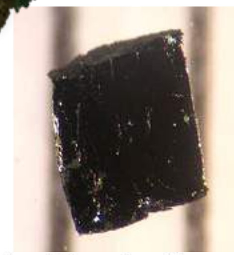
Metal-insulating transitions

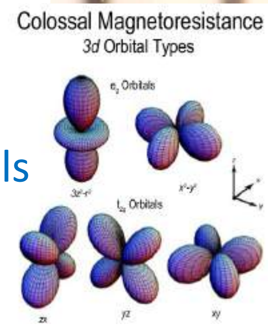
Colossal magnetoresistance phenomena

Ferroelectrics & multiferroics materials

Skyrmions, spintronics

Nanoparticles and plasma

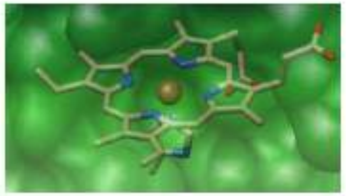




The (extended) Scientific Case
Soft- and hard-matter science with a soft X-ray/EUV FEL

Coherent Imaging Experiments
Biological samples (cells, viruses), nanomaterials

X-ray Absorption & Emission Experiments
Metal compounds, semiconductors, biomolecules



X-ray Raman experiments
Biological molecules

FEL induced photofragmentation experiments
Organic molecules

+ THz application (see Enrica Chiadroni's talk)

Several experimental techniques

A variety of samples

Coherent imaging

Nanoparticles, cells, viruses, soot

X-ray spectroscopies

Proteins, metals, semiconductors

X-ray Raman, RIXS

Proteins, liquids, magnetic materials

Photo-fragemntation

Organic molecules

I Science with Free Electron Laser

We will submit a paper on a special issue of «Condensed Matter» with a description of the scientific case

SPARC LAB

EuPRAXIA@SPARC_LAB Collaboration Meeting
October 24th, 2018
Aula Salvini, LNF

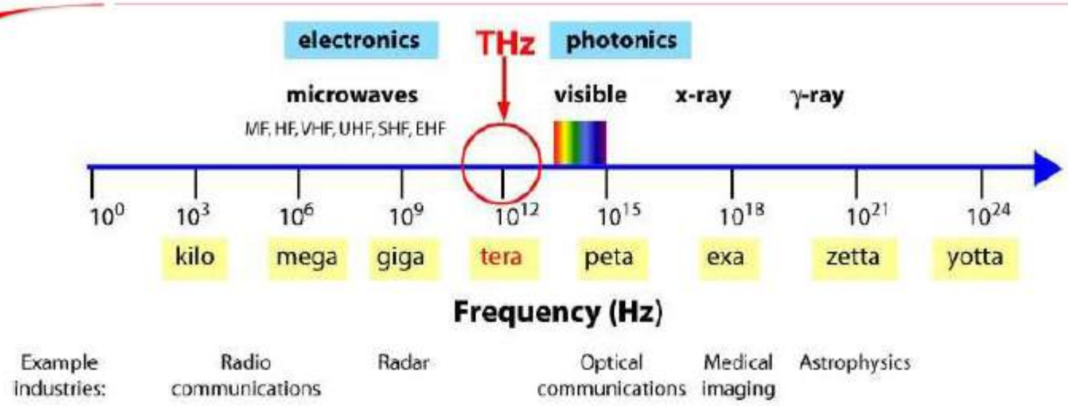
THz/MidIR Sources at the EuPRAXIA@SPARC_LAB Test User Facility

E. Chiadroni (INFN-LNF)
S. Lupi (Sapienza, Università di Roma and INFN)

Preliminary Studies

INFN Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DI FRASCATI

Scientific Motivation

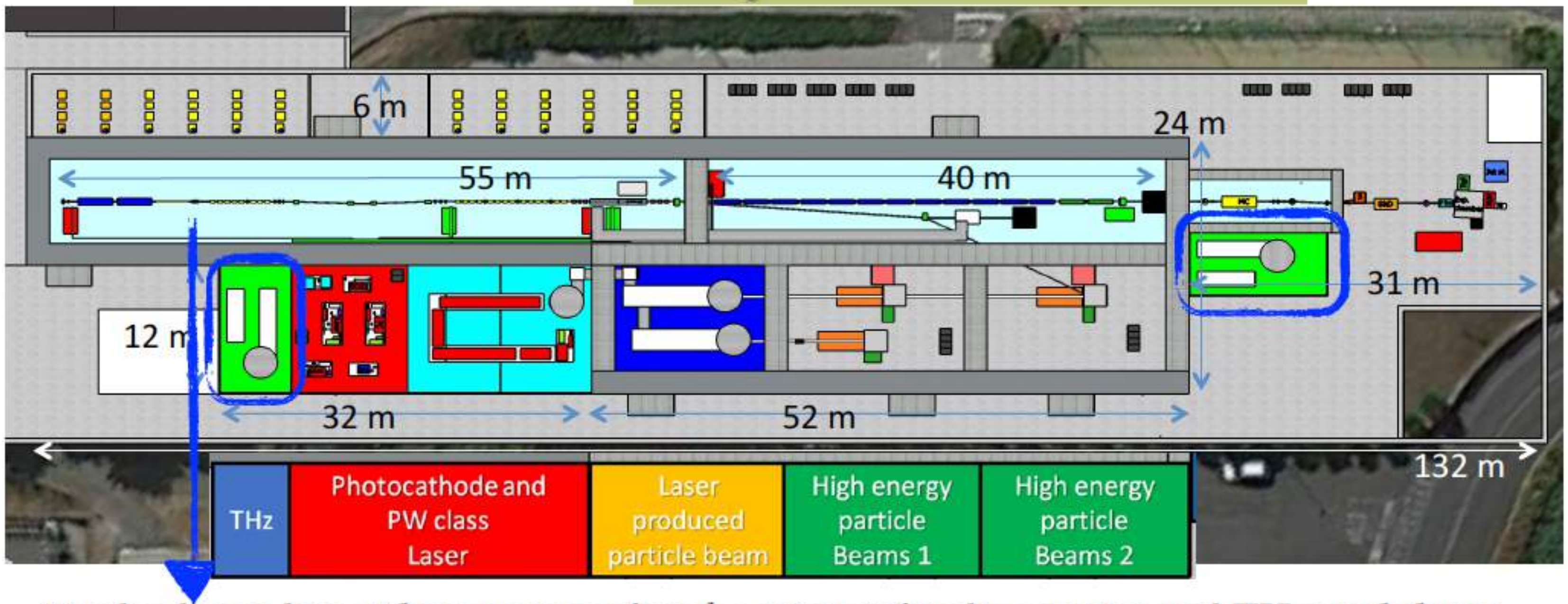


1 THz ~ 1 ps ~ 300μm ~ 33 cm^{-1} ~4.1 meV ~ 47.6°K

- Inducing an excitation in a system through a short (impulsive) light pulse and studying its temporal decay
- Controlling by light the quantum states in matter
- Strong interest in multicolor pump-probe spectroscopy combining pumping at low-energy and probing at high-energy
  - THz pump - X-ray probe
- Strong interest in one color pump-probe
  - THz pump - THz probe
- Strongly correlated-electron systems ($V_2 0_3$, VO_2)
  - THz pulses in the MV/cm range can drive lattice displacements in the pm range
    - Manipulation of the Mott-Hubbard Insulator to Transition
- Collective modes of macromolecules: study of the dynamical evolution from disordered conformational states to ordering
  - Large pump THz E field may coherent induce conformational ordering and THz probe may measure its temporal evolution
- Superconductors

EuPRAXIA@SPARC_LAB Layout

and possible THz beam lines

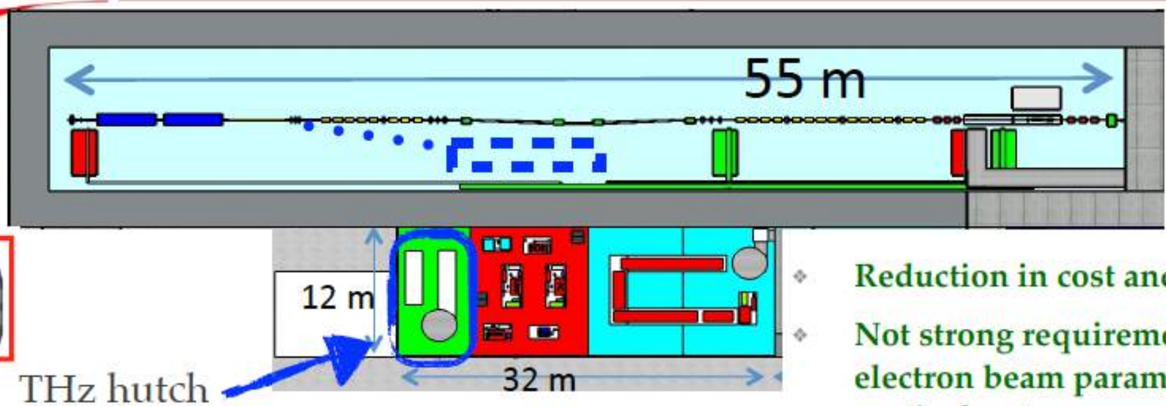


- Dogleg beam line at **low energy** after the injector for diagnostics and **THz undulator**
  - **IR/THz FEL**
    - Permanent magnets undulator
  - **Coherent Undulator Radiation**
    - Electro-magnets undulator
- Metallic targets at low and high energy for **Coherent Transition/Diffraction Radiation**

enrica.chiadroni@lnf.infn.it

IR/THz FEL

SPARC LAB



$$\lambda_{rn} = \frac{\lambda_u}{2\gamma^2}\left(1 + \frac{K^2}{2}\right)$$

- Reduction in cost and size
- Not strong requirements on the electron beam parameters (in particular, transverse emittance)

DESY-like undulator module

Undulator parameters	
Period length (mm)	27.3
Gap (mm)	12
Peak field (T)	0.468
K-parameter	1.17
Length (m)	4.492

Input from GPT simulations up to 12 m

Beam parameters	
Energy (MeV)	30 - 50
Charge (pC)	200
Bunch length (μm)	50
I_{peak} (A)	480
$\Delta E/E$ (%)	0.1 - 0.4%

Output from Ming Xie calculations

Radiation parameters	
lr (μm)	~ 6.5 - 2.3
L_{sat} (m)	3 - 4.4
P_{sat} (MW)	140 - 135
# of photons	~10^{15} - 6 10^{14}
Energy (μJ)	~60 - 56

enrica.chiadroni@lnf.infn.it

INFN LNF

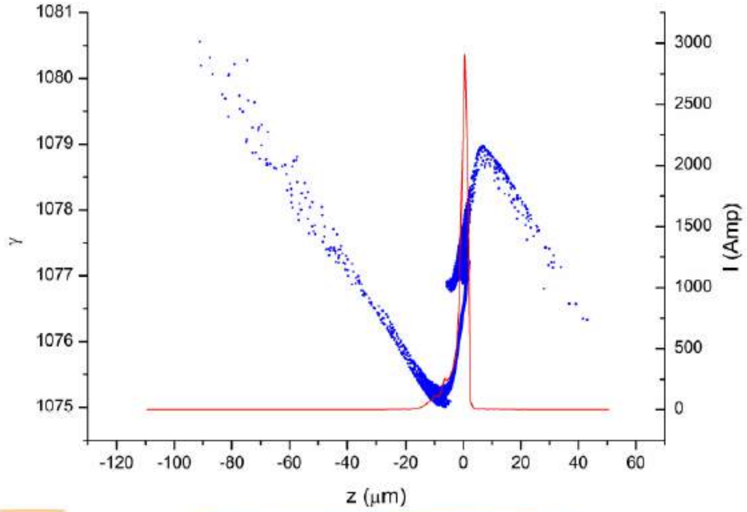
LWFA with External Injection EuPRAXIA@SPARC_LAB: simulations latest results

A. R. Rossi (INFN-Mi)

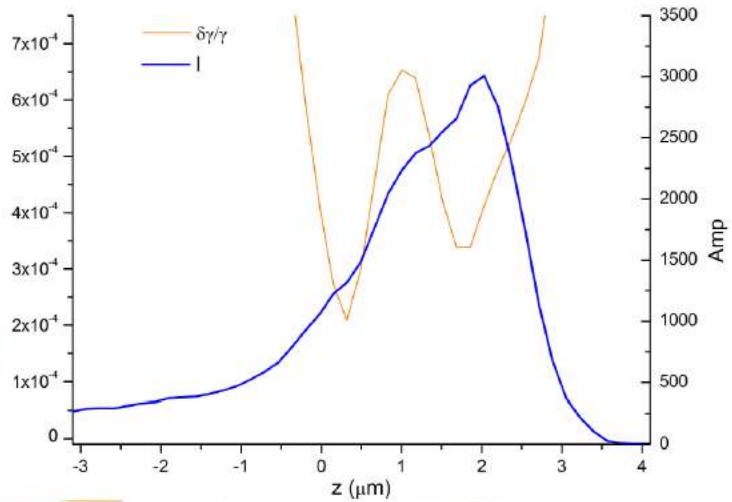
Input beam by A. Giribono and C. Vaccarezza

σ_{tr} = 3 μm σ_z = 16.7 fs E = 538,3 MeV

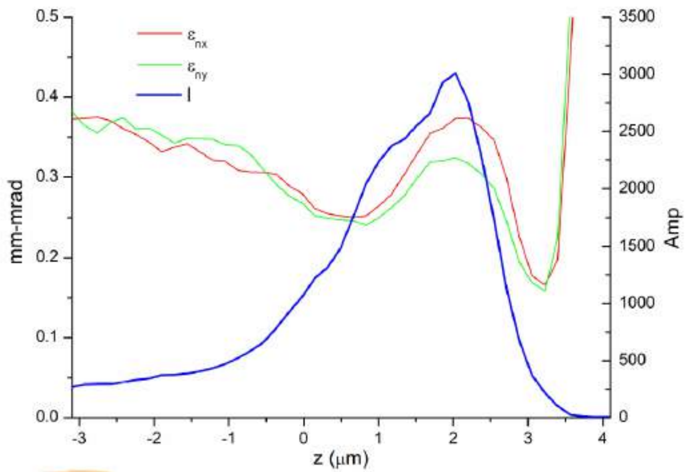
dE/E = 7 10^{-4} L_{FWHM} = 3.9 fs q = 30 pC ε_n = 0.45 μm



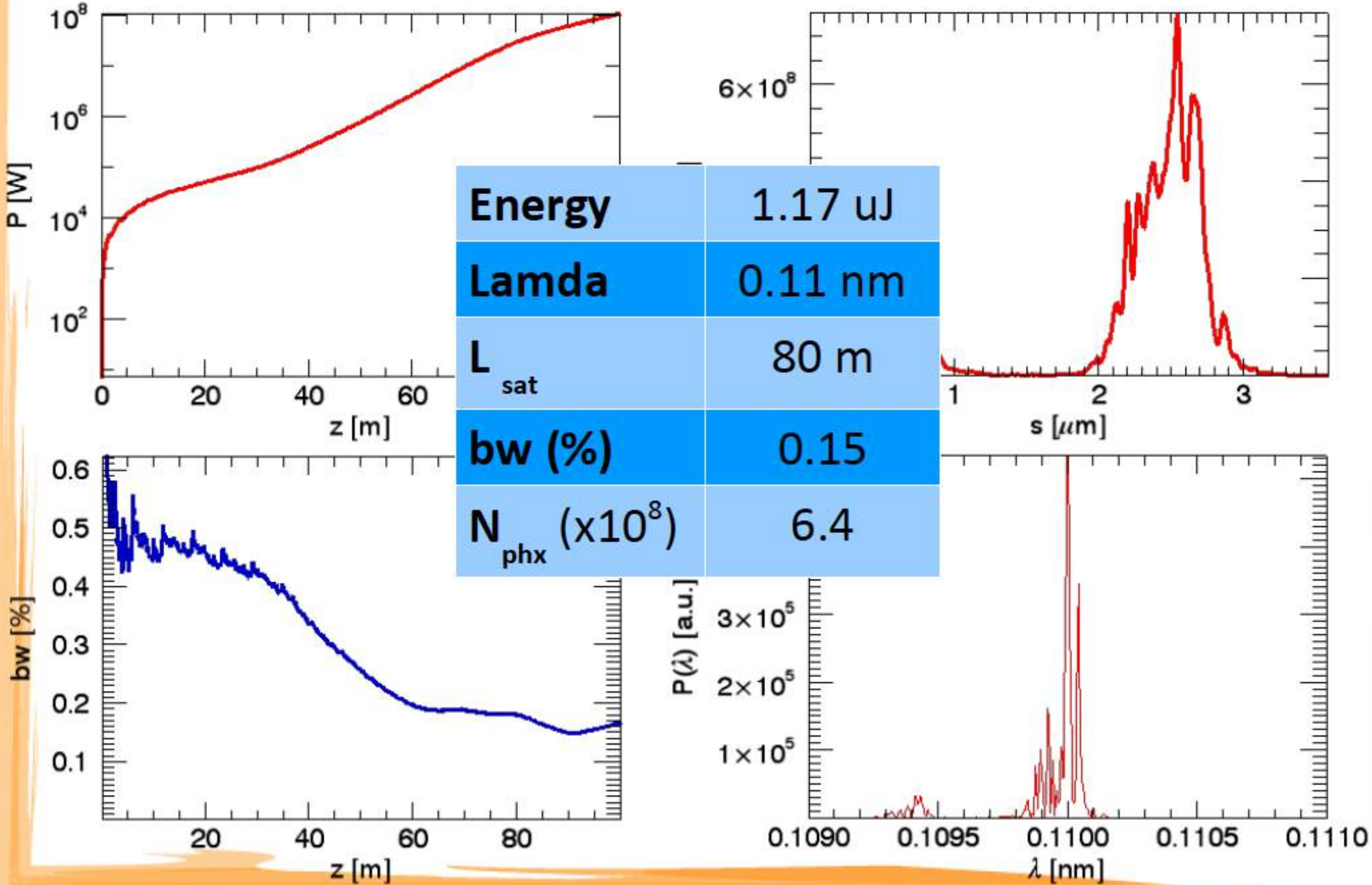
Slice analysis: energy spread



Slice analysis: emittance



FEL performances @ 0.11 nm



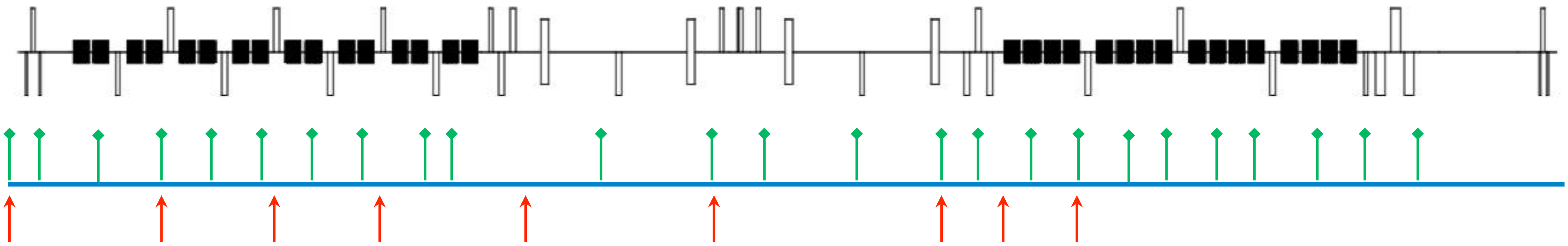
Energy	1.17 uJ
Lamda	0.11 nm
L_{sat}	80 m
bw (%)	0.15
N_{phx} ($x10^8$)	6.4

Beam Dynamics studies for the X-band Linac of the EuPRAXIA @ SPARC_LAB Project

Cristina Vaccarezza

On behalf of SPARC_LAB collaboration

Static and dynamic errors simulation:



Steerer + BPM

Beam error kick (girder to girder)

- ✓ Static errors:
  - 100 (20) μm (x ,y) random misalignment on RF's structures and magnetic elements
  - 0.05 (0.01) μrad tilt on magnetic elemts
  - 100 μm misalignment kick to the beam, ex. girder to girder
  - 100 random simulated machines
- ✓ Dynamic errors:
  - Quad strength errors 0.1% rms
  - Sterer kick errors 0.01% rms (0.4 μrad rms)
  - RF Acc Grad 0.1% rms
  - RF phase 0.5°
  - 100 random machine for each static arrangement

Static plus dynamic errors summary table

	WP1 (@capillary in) witness	WP1(@capillary in) driver	Previous WP3(@undulator in) with no RF jit
Q (pC)	30	30	200
E (GeV)	0.5	0.5	1.0
σ_{Cx} (μm)	6	5	10
σ_{Cy} (μm)	2	5	30
σ_x (μm)	2.1	7	30
StDevσ_x (μm)	0.04	0.1	10
σ_y (μm)	1.6	8	40
StDevσ_y (μm)	0.02	0.2	5
σ_{δ} (%)	0.07	0.2	.14

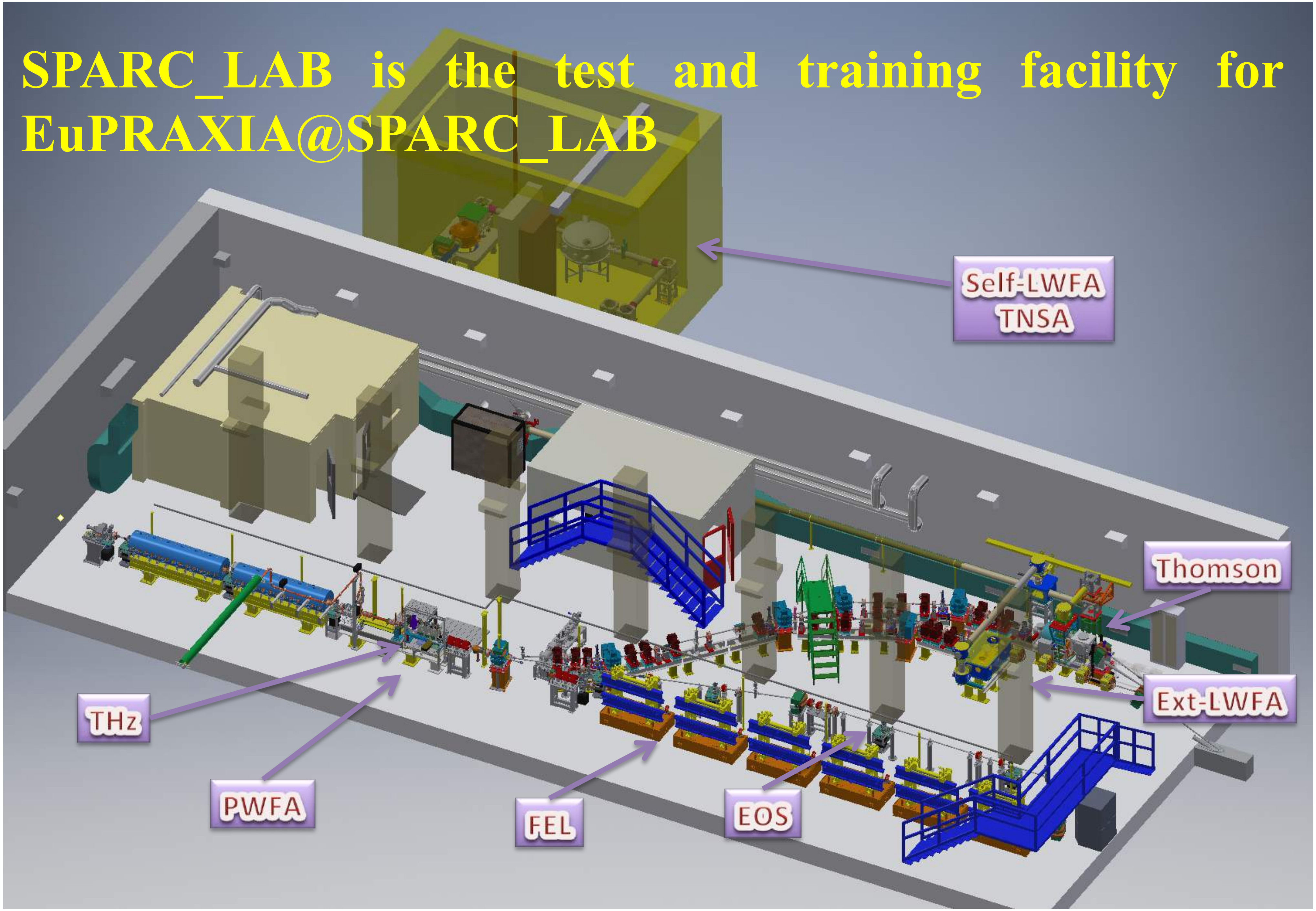
* No dispersion free steering

work in progress

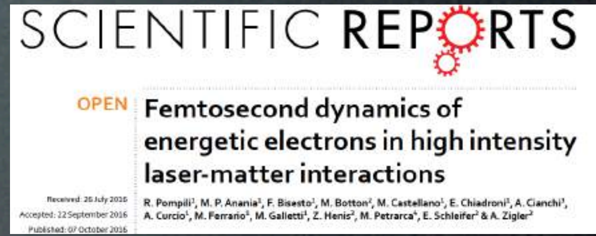
- Detailed tolerance studies by S2E
- Driver / Witness separation at the plasma exit
- Options for 5 GeV electron beams
- Multi-bunch RF linac operation => excluded
- Plasma Target
- Current losses and beam dump due by April 2019

- Secondary particle Sources
- Compton Source
- Update cost analysis
- Managerial structure

SPARC_LAB is the test and training facility for EuPRAXIA@SPARC_LAB



Scientific Highlights


SCIENTIFIC REPORTS

OPEN

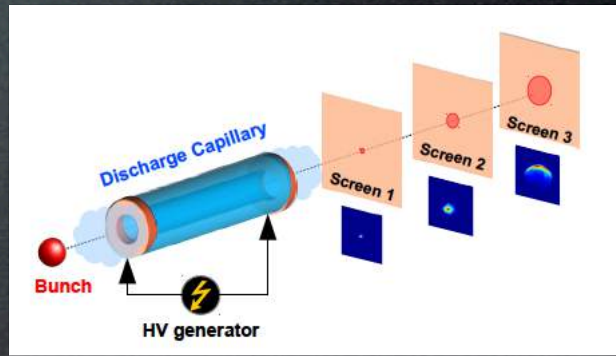
Femtosecond dynamics of energetic electrons in high intensity laser-matter interactions

Received: 26 July 2016
Accepted: 22 September 2016
Published: 07 October 2016

R. Pompili[1], M. P. Anania[1], F. Bisesto[1], M. Botton[2], M. Castellano[1], E. Chiadroni[1], A. Cianchi[3], A. Curcio[1], M. Ferrario[1], M. Galletti[1], Z. Henis[2], M. Petrarca[4], E. Schleifer[2] & A. Zigler[2]

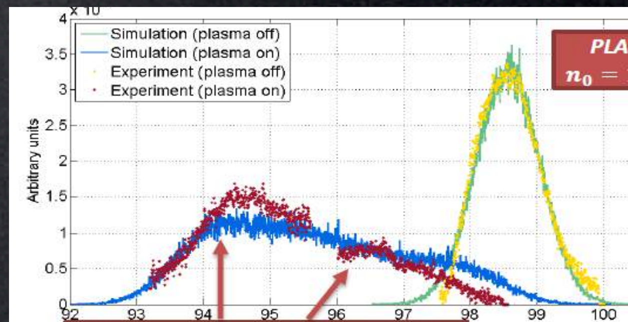
- TNSA: results in progress

- Plasma Lab: discharge capillaries characterization



- PWFA: active plasma lens, deceleration test, de-chirper results

- LWFA: plasma target studies



Last Sci-Com Recommendations

- While support from the management has increased over the last few years, the source of major delays in repair and absence of problem prevention may be the lack of perception, particularly among the scientific staff, that SPARC_LAB is a major project of the laboratory.

- Involvement of beam operators to operate SPARC_LAB on a 24h-basis (experiments during the day, training and reliability tests at night) would help for increasing the importance of SPARC_LAB uptime and operation and determining weaknesses of the systems in preparation for transition towards a user facility status.

- The SC strongly recommends an internal review to be conducted, in order to analyze the problems that have occurred at SPARC_LAB, the state of the infrastructure and the effectiveness of the work organization. The review should also investigate if more frequent meetings between the laboratory service, operational teams, maintenance groups and experimental groups would be useful.

- The SC recommends to implement with priority measures to increase the uptime of the experiments.

Machine Advisory Committee - 2018 October meeting

chaired by Alessandro Variola

from Monday, 22 October 2018 at **14:00** to Tuesday, 23 October 2018 at **14:05** (Europe/Rome)
at **LNF (Aula Direzione)**
Laboratori Nazionali di Frascati - Via Enrivco Fermi 40, Frascati

Description **Componenti del Comitato:** Alessandro Variola (Chair), Roberto Losito (CERN), Maurizio Vretenar (CERN), Riccardo Bartolini (Diamond - UK), Gerardo D'Auria (ELETTRA), Roberto Cimino (LNF), Augusto Lombardi (LNL), Luigi Celona (LNS)

Componenti ex Officio: Eugenio Nappi (Giunta INFN), Roberto Saban (Coordinamento Tecnico LABs), Nadia Pastrone (Presidente CSN1), Mauro Taiuti (Presidente CSN3), Valter Bonvicini (Presidente CSN5)

Go to day

Monday, 22 October 2018

14:00 - 16:00 Relazione sulle attività di SPARC LAb e il suo stato *2h0'*

14:00 M. Ferrario – From SPARC_LAB to EuPRAXIA

14:40 R. Pompili – SPARC results and status

15:10 M. P. Anania – FLAME results and status

15:40 G. Di Pirro – Technical overview and issues

SPARC operation procedures

Every week a new Run Coordinator is designed

He/She coordinates the experimental activities and manage machine operations with SPARC operators

Starting from June, DAFNE operators are also involved in SPARC activities

2 shifts (8-16 and 15-23). Total of 4 SPARC people involved. Daily report (by mail) at shift end

Total of 2 DAFNE operators (per shift) involved for 24h operation. Possibility to keep the machine turned on during night (22-6) from DAFNE control room

Systems maintenance (laser, installations, etc.) is planned each Monday

Usually half day (entire day if needed)

Experimental and technical operations (requiring machine shutdown) must be announced during the SPARC_LAB meetings

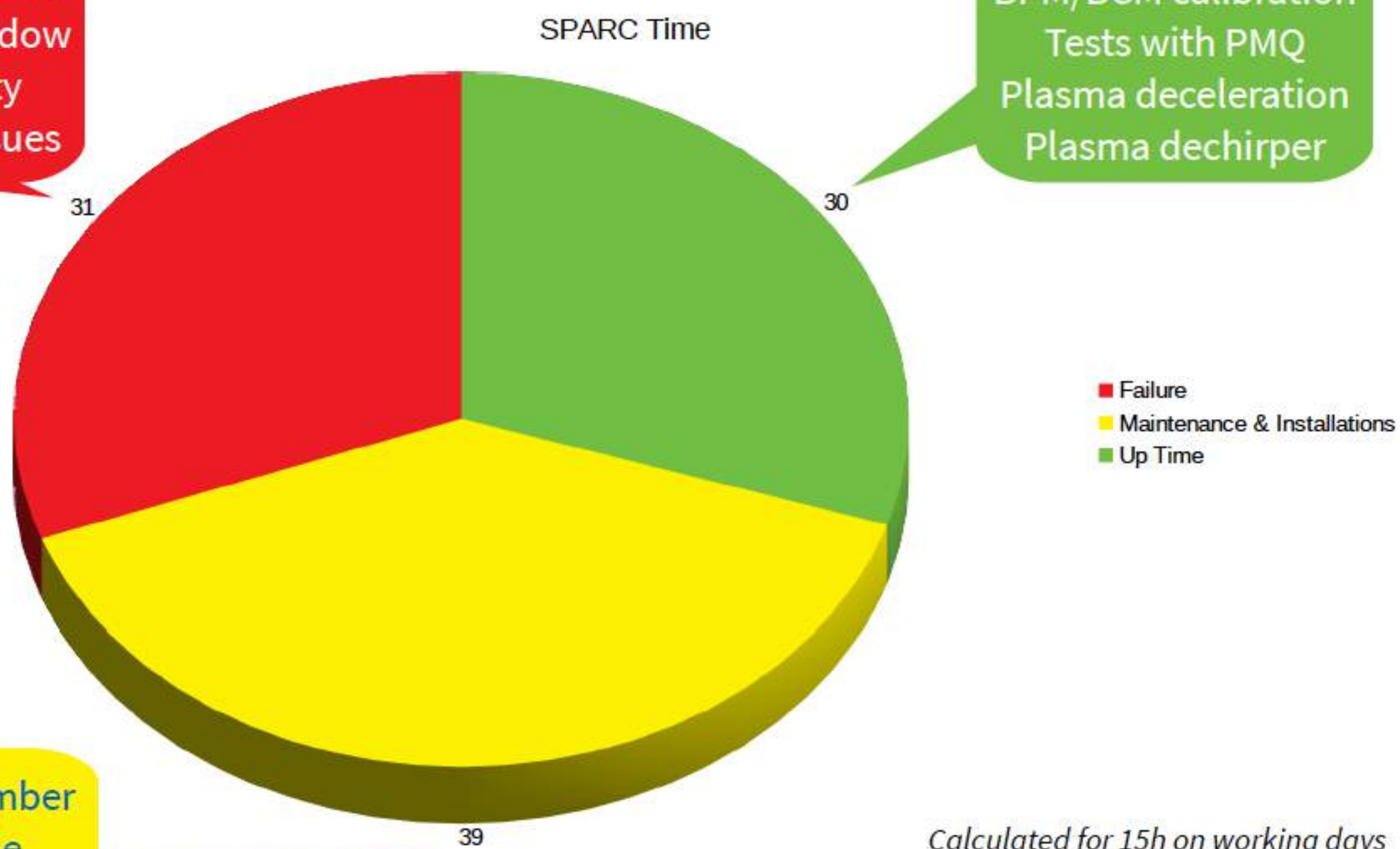
Scientific SPARC_LAB meeting is planned on Tuesday

Technical SPARC_LAB meeting with AD technical services is planned on Thursday

SPARC time (YTD)

KLY1 ceramic window
KLY2 ceramic window
Laser instability
Water/chillers issues

BPM/BCM calibration
Tests with PMQ
Plasma deceleration
Plasma dechirper



New COMB chamber
Laser upgrade
PMQ/capillary

Calculated for 15h on working days
Shifts planned from 8.00 to 23.00

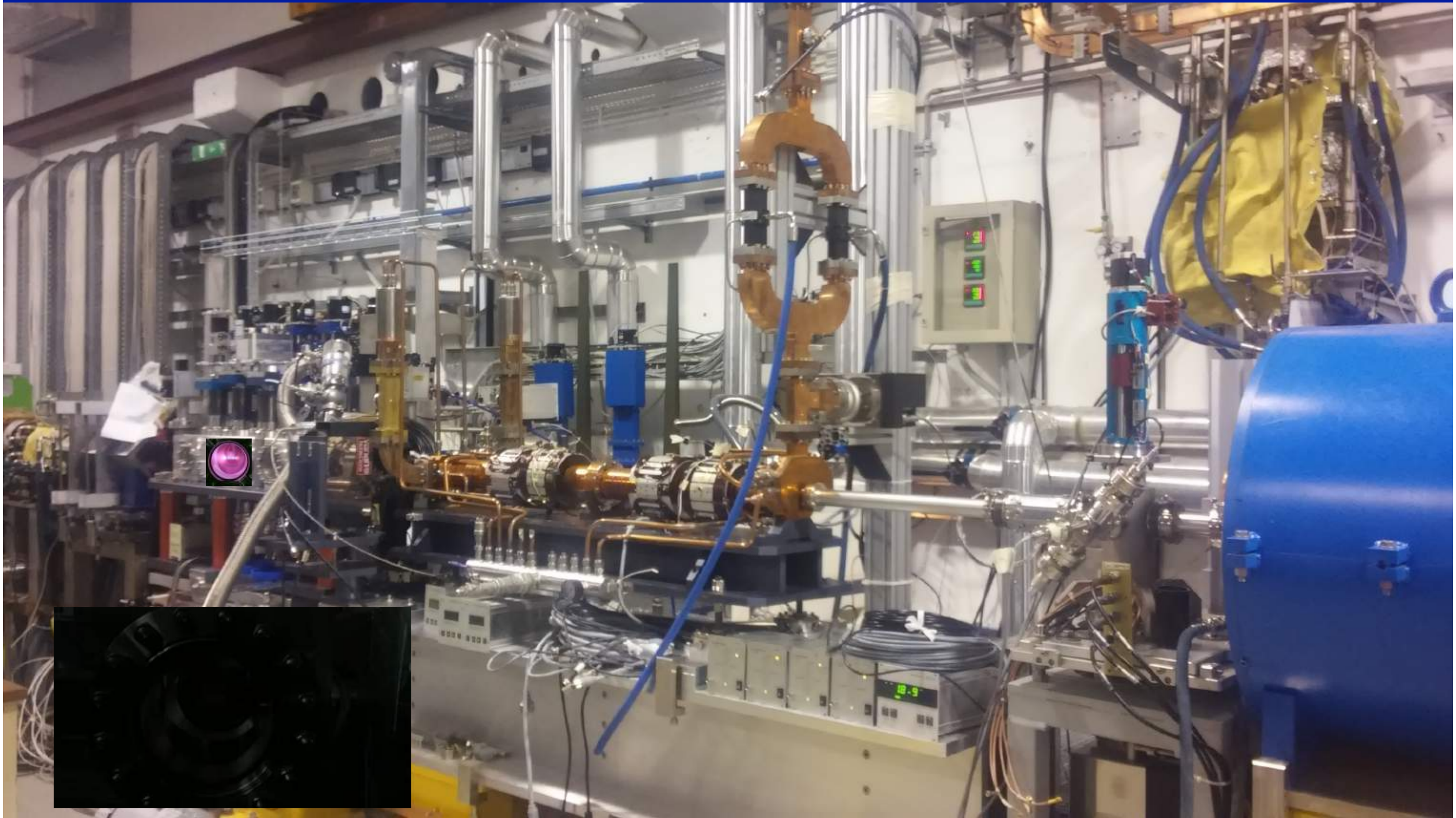
2018 - Planned experimental activities

- ✓ May => PM Quads matching studies
- ✓ June => Driver interaction with the Plasma
- June => Witness interaction with the Plasma
- July => Driver +Witness interaction with the Plasma
- August => Shut down, maintenance, start up
- September => Calipso$^+$ Smith Purcell experiment
- October-December => PWFA experimets

- **May**
  - Cannot achieve laser stability with uniform profile.
  - Amplitude visit and system upgrade to CFR (gaussian mode). Now instability below 1%
  - Characterization of the SPARC beam. Tests with PMQs
  - Plasma density measurement tests in vacuum chamber @ Plasma LAB
- **June**
  - Beam trajectory instabilities due to PEEK (plastic) vacuum impedences in new COMB chamber. Replaced with aluminum ones
  - Definition of the compressed beam working point (driver-like). Tests with PMQs
- **July**
  - Deceleration tests with driver-like bunch
  - Measurements with plasma dechirper
  - Plasma density measurement tests in vacuum chamber @ Plasma LAB
- **August**
  - Measurements with plasma dechirper
  - Plasma density measurement tests in vacuum chamber @ Plasma LAB
  - End of activities for summer closure
  - Removal of the PMQs and capillary for offline alignment

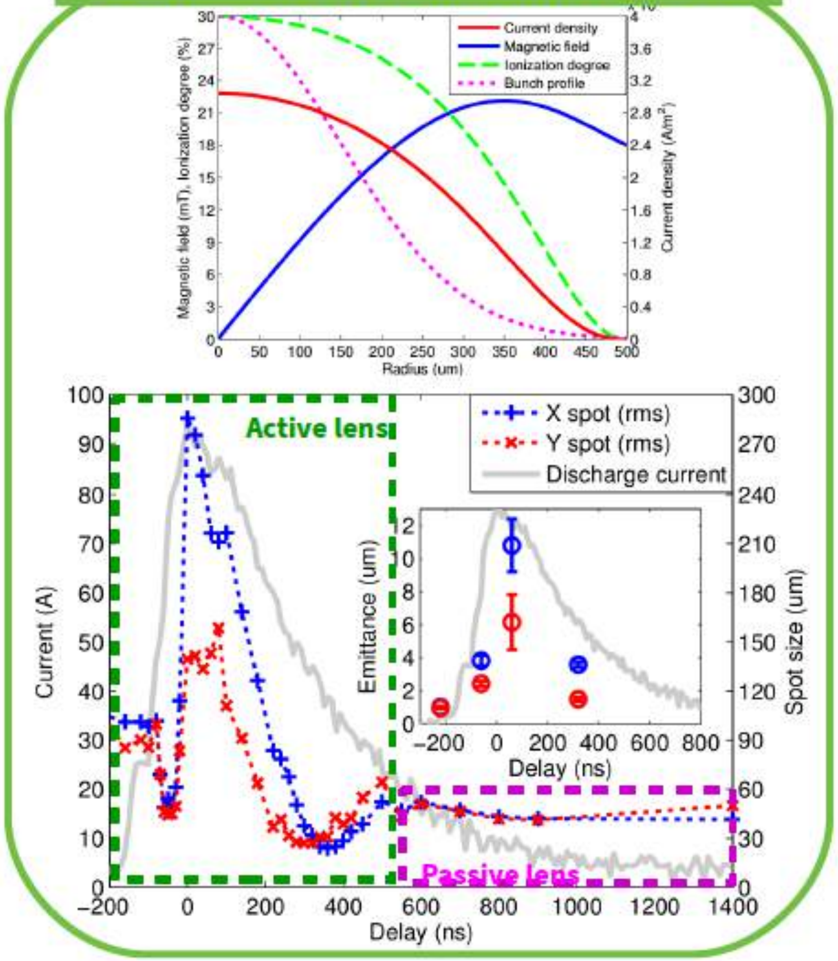
- **September**
  - Magnetic alignment of PMQs with vibrating current-wire
  - Definition of the beam working point for the SMITH-PURCELL experiment (Calipso+)
  - Failure of KLY2 ceramic window. Water leak into the waveguide 2
  - Conditioning of waveguide 2
  - Cancelation of SMITH-PURCELL experiment
- **October**
  - Conditioning of waveguide 2
  - Cancelation of ELI experiment
  - Setup of the system for PMQs characterization (field measurements)

PWFA vacuum chamber at SPARC_LAB



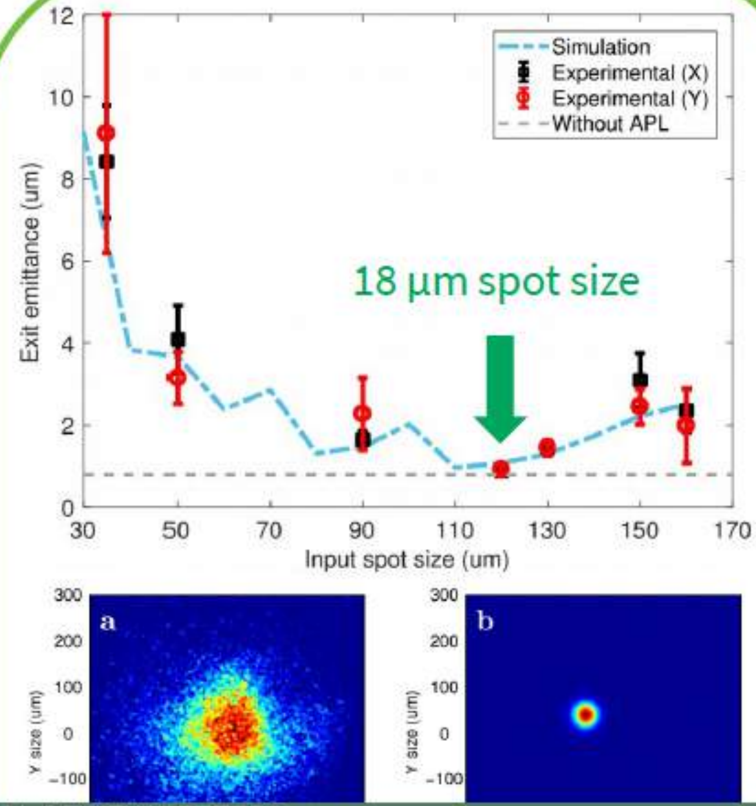
Experimental results

Demonstration of emittance growth



Pompili, R., et al. Applied Physics Letters 110.10 (2017): 104101.
Marocchino, A., et al. Applied Physics Letters 111.18 (2017): 184101.

Demonstration of emittance preservation



PHYSICAL REVIEW LETTERS

Accepted Paper

Focusing of high-brightness electron beams with active-plasma lenses

Phys. Rev. Lett.

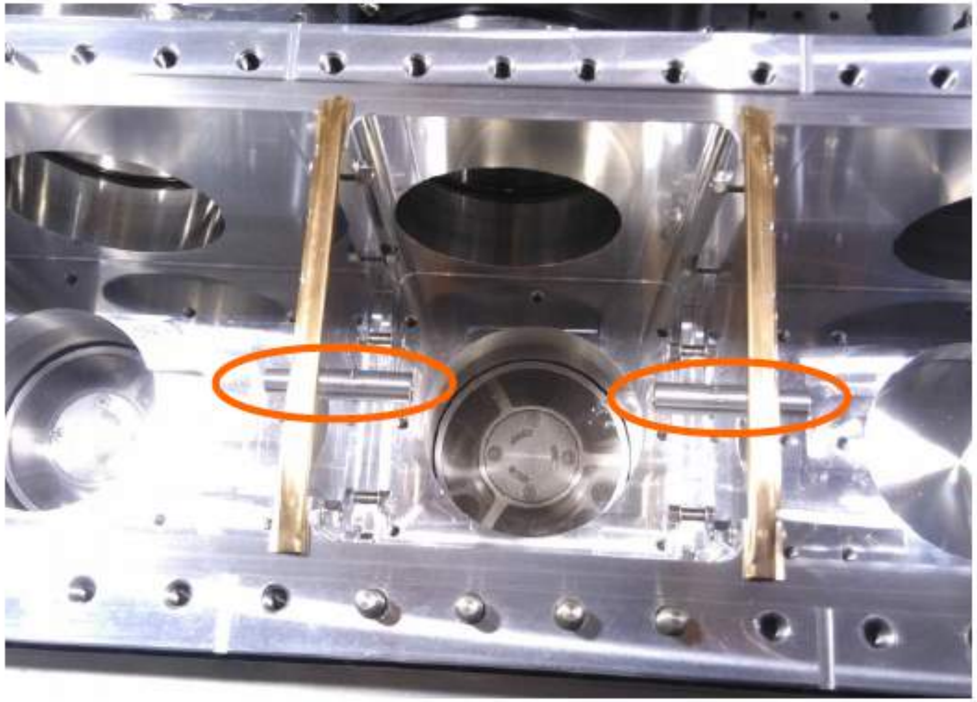
R. Pompili et al.

Accepted 11 October 2018

New vacuum impedances

We replaced the plastic (PEEK) vacuum impedences with new ones made by aluminum

- This is to avoid charging of the impedance walls that caused kicks on the beam trajectory



Permanent Magnet Quadrupoles

PMQs are used to inject the beam into the plasma and extract from it after acceleration

- First 6 prototypes were manufactured by KYMA and consist of 12 sectors with field gradient ~520 T/m
- Based on first results and more theoretical investigation we ordered more samples with 16 magnetized sectors (more uniform quadrupolar field
- Now we have 520, 580, 710, 460, 500 T/m PMQs both for SPARC and FLAME activities

Adjustable PMQ triplet

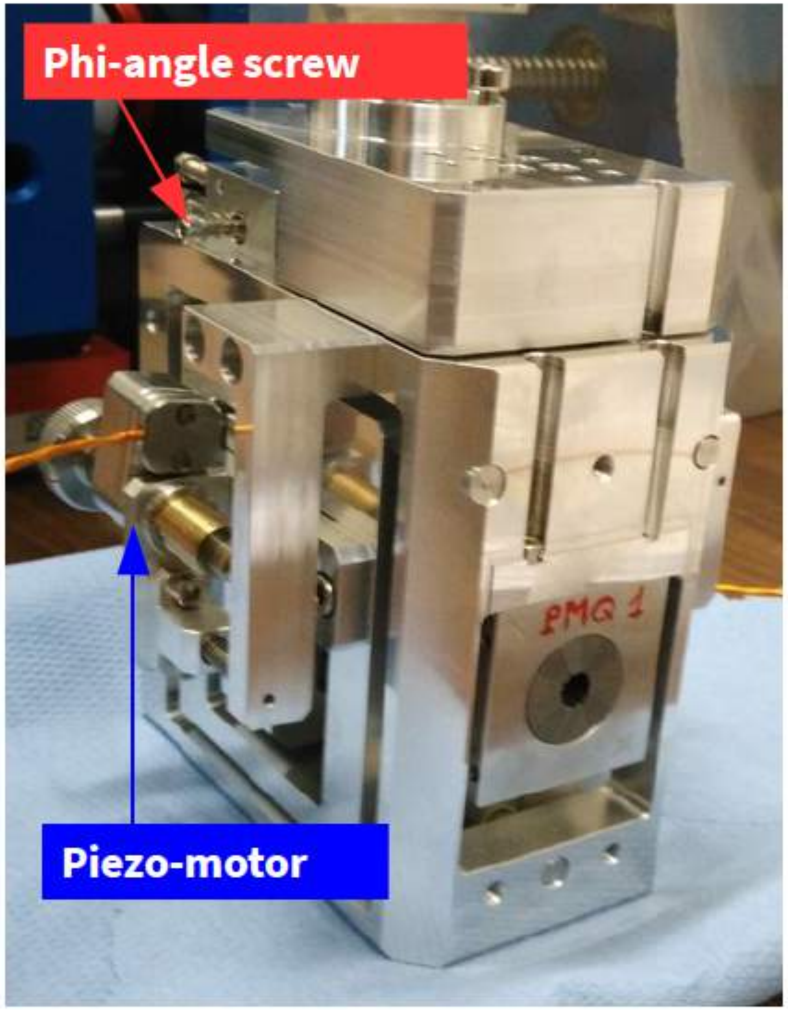
Three PMQs installed, z-movable

Two PMQs movable, 1 fixed

- Minimum distance ~ 2-3 mm
- Maximum distance ~ 8-10 mm

Piezo-actuators N-474K by PI

- 20 nm resolution
- Feed force > 40 N
- Holding force > 100 N
- UHV (10^{-9} mbar)
- Non-magnetic



Long driver bunch results

The PMQs have been tested with the following beam configuration

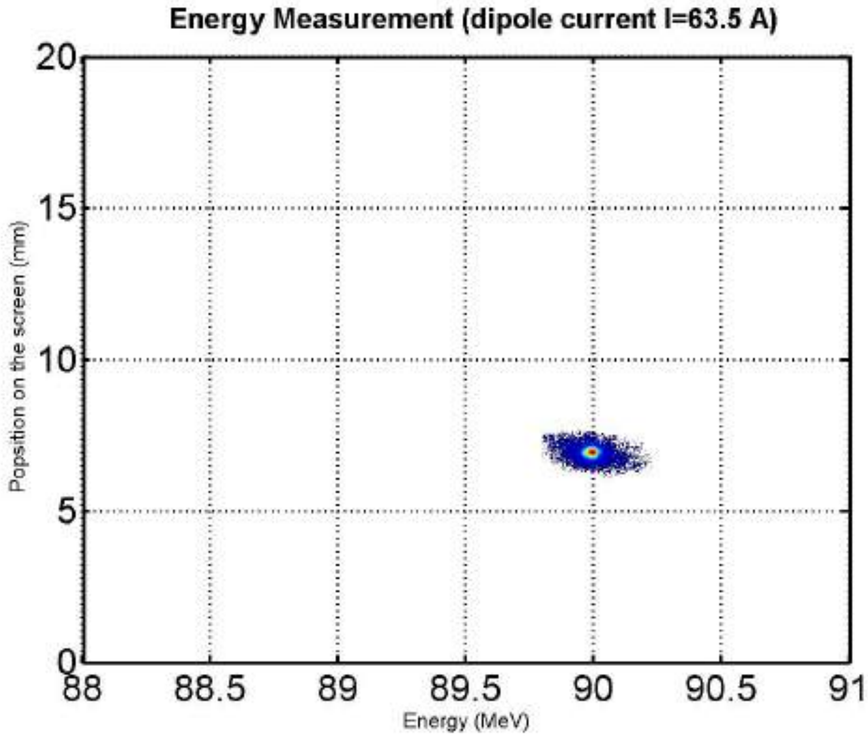
Charge: 150 pC

Duration: 1.5 ps (rms)

Energy: 90 MeV

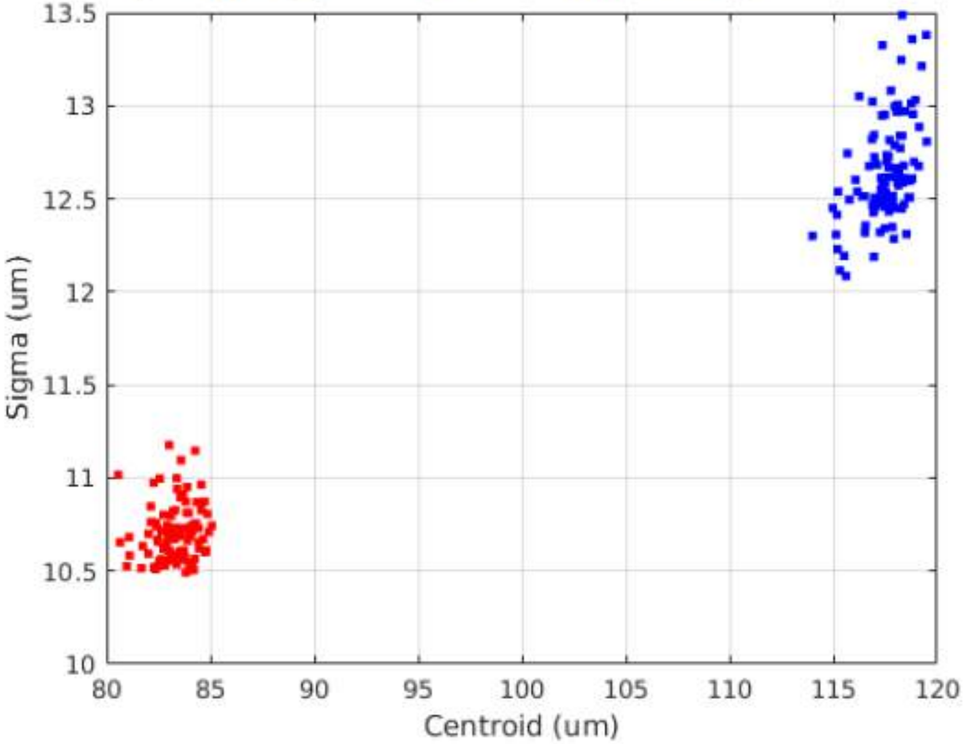
Emittance: 0.8 um (rms)

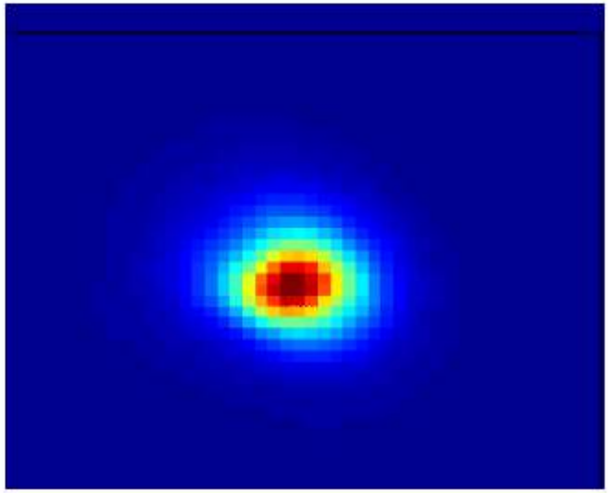
Spot @ PMQ entrance: 100 um (rms)

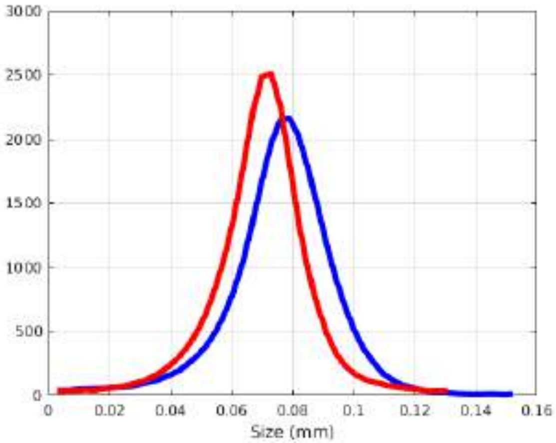


PMQ focusing

X spot size → 12.6 um
Y spot size → 10.7 um
(7 um expected from simulations)



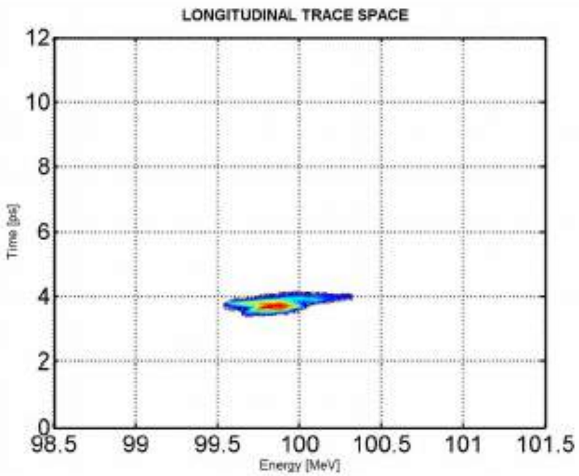


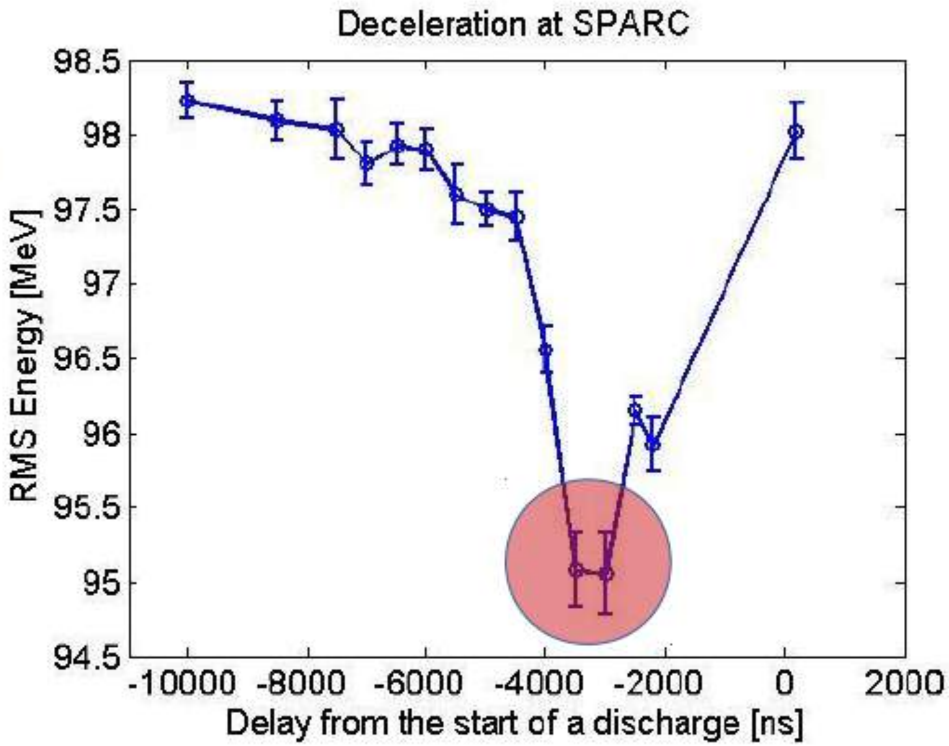


Plasma deceleration

Beam parameters

- 200 pC, 97 MeV, 180 fs (rms), 0.34 MeV spread
- Emittance: 1.8 um (X), 1.4 um (Y)
- Spot size: 24 um (X), 22 um (Y)

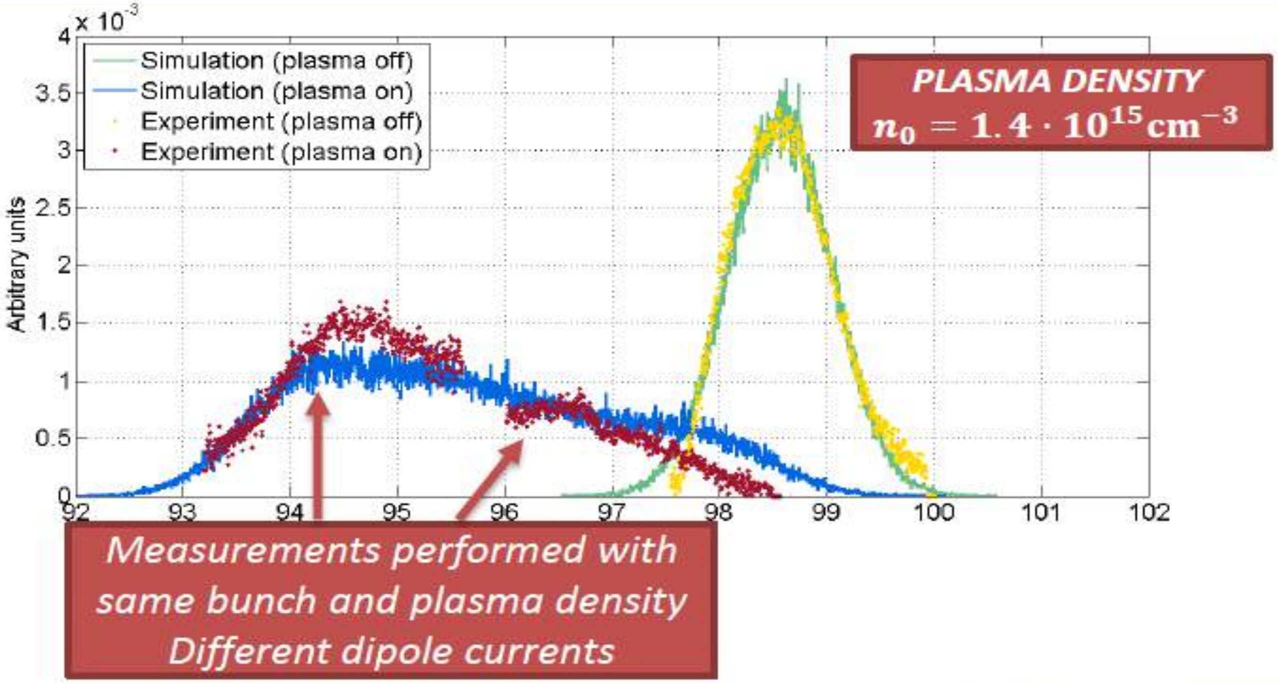




140 MV/m deceleration

Maximum deceleration corresponds to plasma density ~10^{14} cm^{-3}

Deceleration test - July 2018



Experimental data at injection

$\sigma_{x,(y)} = 24(33)\mu\text{m}$

$\sigma_z = 50\mu\text{m}$

$\varepsilon_{x,(y)} = 1.7(1.8)\text{mm mrad}$

$\sigma_E = 0.5\%$

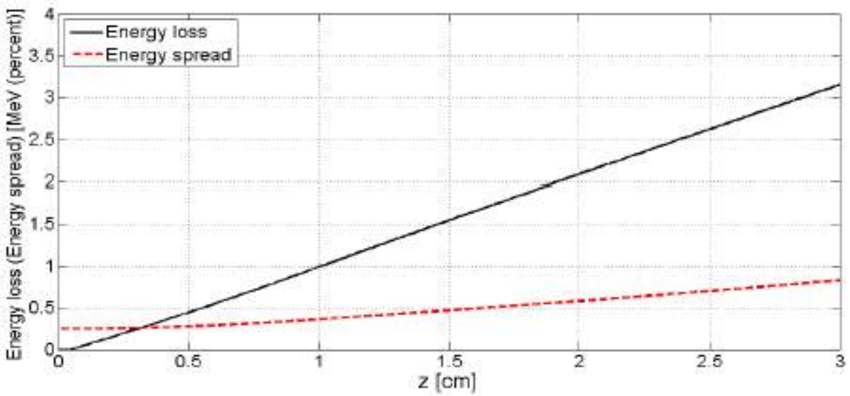
Simulation parameters

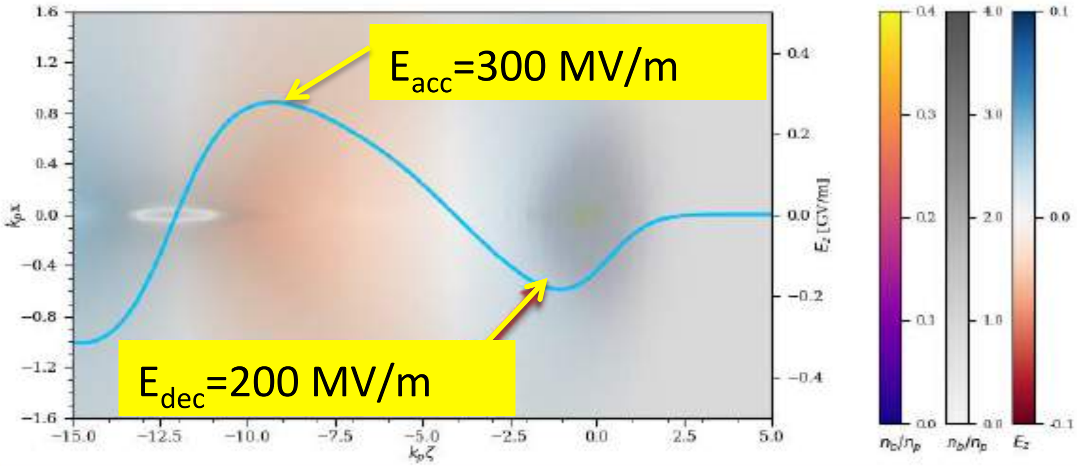
$\sigma_{x,y} = 28.3\mu\text{m}$

$\sigma_z = 50\mu\text{m}$

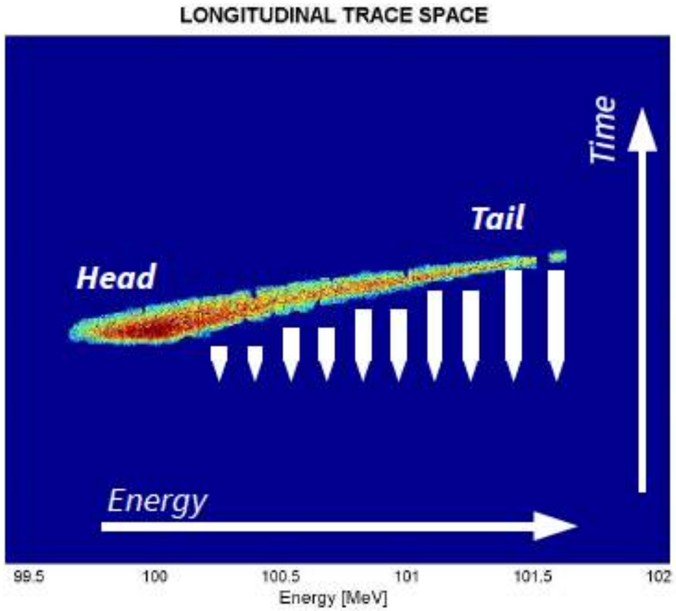
$\varepsilon_{x,y} = 1.75\text{mm mrad}$

$\sigma_E = 0.5\%$





Plasma dechirper



Beam-driven plasma wakefields can be used to tune/reduce the beam energy-chirp

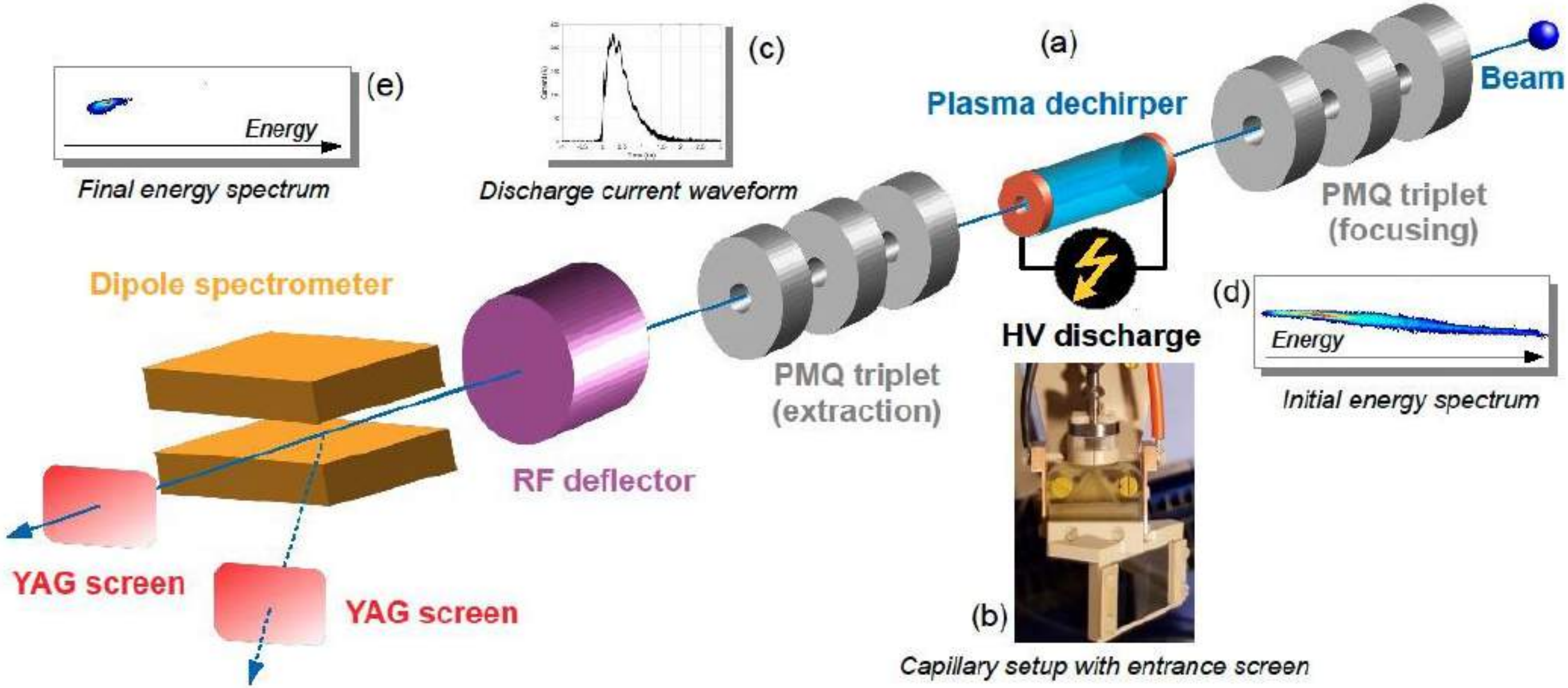
The tail of the beam is decelerated with respect to the head

Several knobs allow to adjust the energy-time correlation

Plasma density, bunch charge/density, bunch length, capillary length

It allows to remove such correlation and reduce the overall energy spread to its *uncorrelated* term

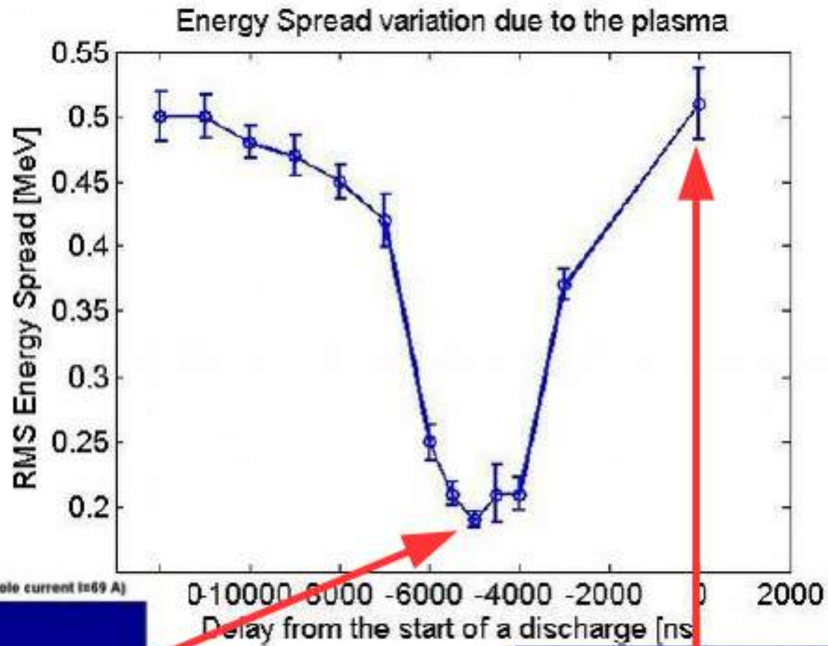
Experimental setup

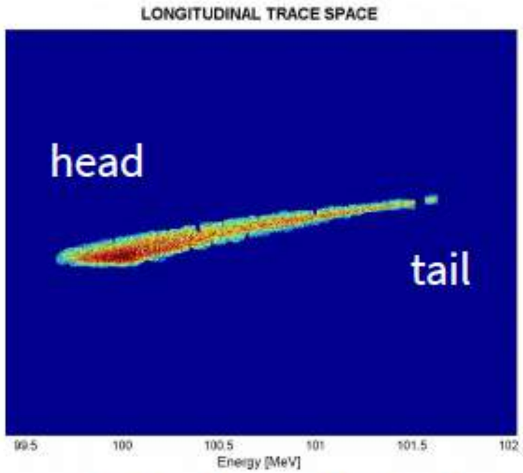


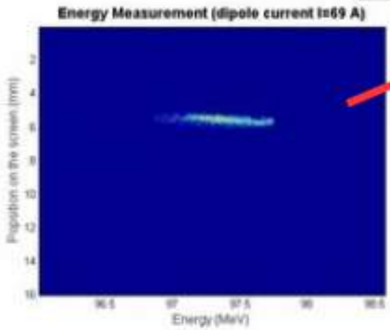
Preliminary results

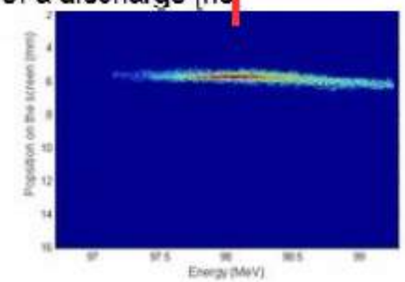
Beam parameters

- 200 pC, 98 MeV, 355 fs (rms)
- Emittance: 1.72 um (X), 1.80 um (Y)
- Spot size: 24.79 um (X), 32.92 um (X)





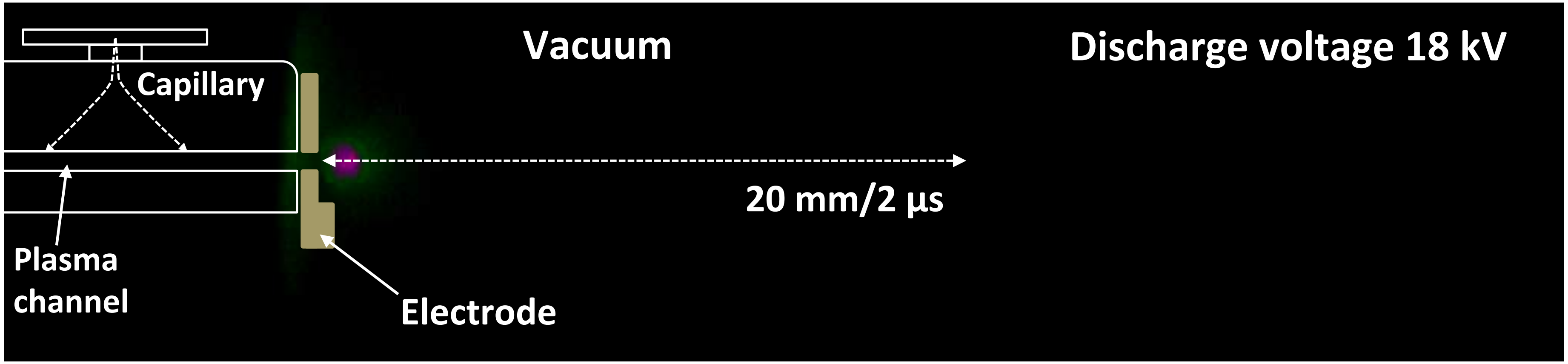




Under condition, that the beam has a positive chirp at the injection, the energy spread was reduced in more than ×2.5, from 0.51 to 0.19 MeV

Plasma plumes

- **20 images separated by 100 ns, so 2 μs of total observation time of the plasma plumes**
- **The ICCD camera area is 1024 x 256 pixel**



- Both plama plumes can reach a total expansion length around 40 mm (20 mm each one) that is comparable with the channel length of 30 mm, so they can strongly affect the beam properties that passes through the capillary

- Temperature, pressure and plasma density, inside and outside the gas-filled capillary plasma source, represent essential parameters that have to be investigated to understand the plasma evolution and how it can affect the electron beam.

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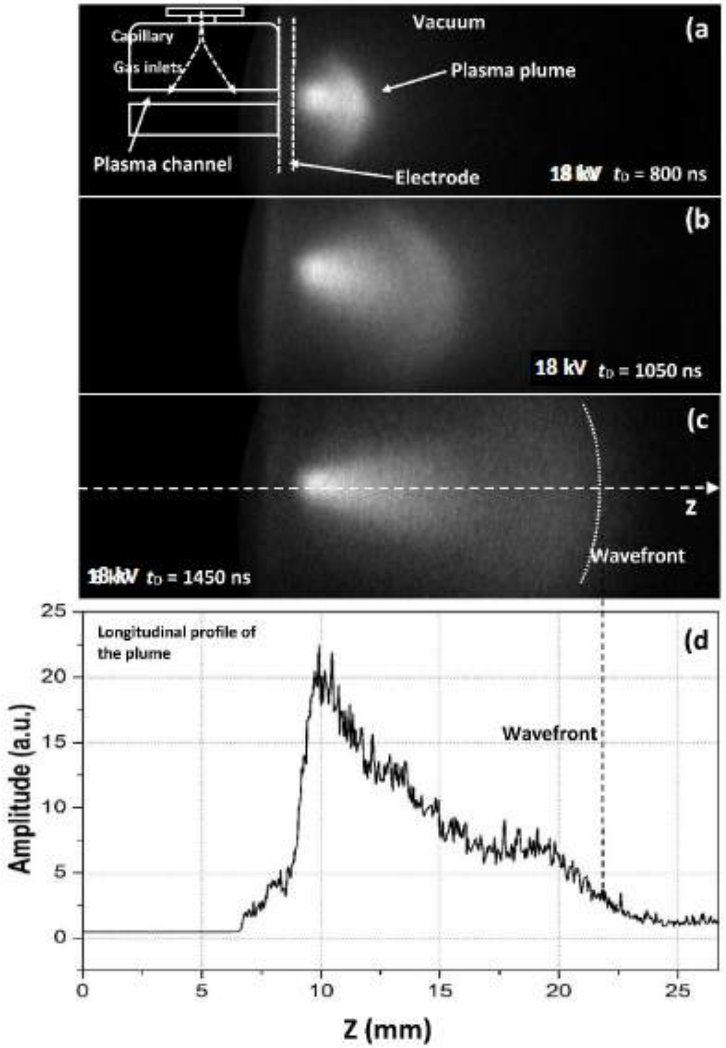
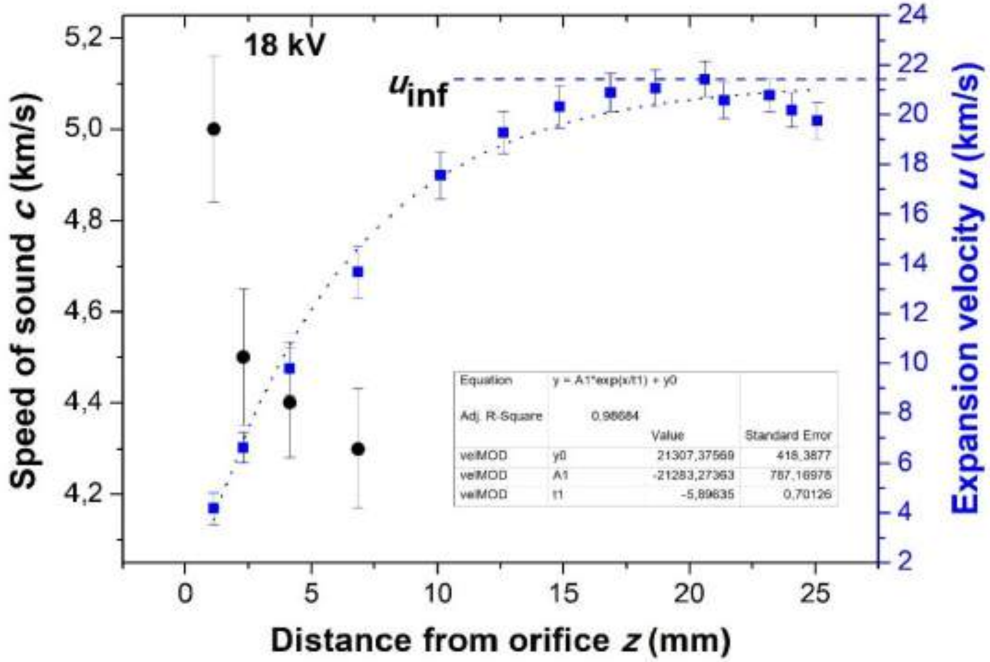
Plasma shock regime diagnostics





New plasma diagnostics based on Shock regime analysis is currently under study

Outflow velocity increases due to adiabatic expansion into vacuum

Gas temperature decreases → sound speed decreases too.

It represents a complementary measurement to Stark-based diagnostics allowing to fully characterize the plasma (density + temperature)

2018

1. **Pompili, R., et al. "Focusing of high-brightness electron beams with active-plasma lenses", accepted on Physical Review Letters**
2. **Filippi, F., et al. "3D-printed capillary for hydrogen filled discharge for plasma based experiments in RF-based electron linac accelerator." Review of Scientific Instruments 89.8 (2018): 083502.**
3. Filippi, F., et al. "Tapering of plasma density ramp profiles for adiabatic lens experiments." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
4. **Cianchi, Alessandro, et al. "Frontiers of beam diagnostics in plasma accelerators: Measuring the ultra-fast and ultra-cold." Physics of Plasmas 25.5 (2018): 056704.**
5. Fares, H., et al. "Quantum-mechanical analysis of low-gain free-electron laser oscillators." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 889 (2018): 47-56.
6. Bisesto, F. G., et al. "Evolution of the electric fields induced in high intensity laser–matter interactions." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
7. Giribono, A., et al. "EuPRAXIA@ SPARC_LAB: the high-brightness RF photo-injector layout proposal." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
8. Filippi, F., et al. "Plasma ramps caused by outflow in gas-filled capillaries." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
9. Brentegani, E., et al. "Numerical studies on capillary discharges as focusing elements for electron beams." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
10. Rossi, A. R., et al. "Plasma boosted electron beams for driving Free Electron Lasers." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
11. Cianchi, A., et al. "Conceptual design of electron beam diagnostics for high brightness plasma accelerator." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
12. Vaccarezza, C., et al. "EUPRAXIA@ SPARC_LAB: Beam Dynamics studies for the X-band Linac." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
13. Pompili, R., et al. "Compact and tunable focusing device for plasma wakefield acceleration." Review of Scientific Instruments 89.3 (2018): 033302.
14. Ferrario, M., et al. "EuPRAXIA@ SPARC_LAB Design study towards a compact FEL facility at LNF." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
15. Romeo, Stefano, et al. "Simulation design for forthcoming high quality plasma wakefield acceleration experiment in linear regime at SPARC_LAB." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).

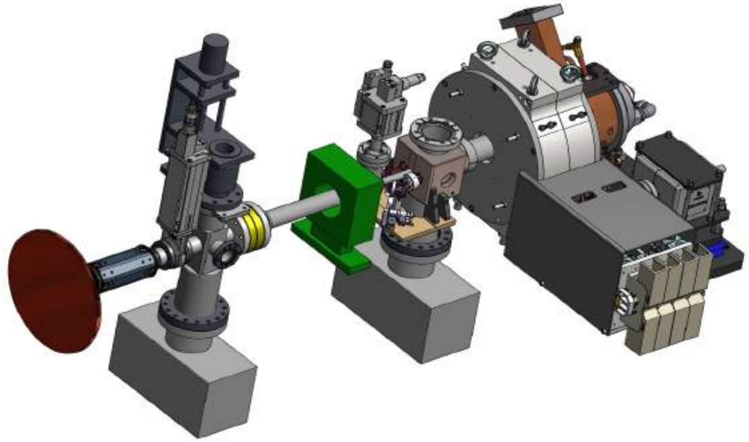
16. Marocchino, Alberto, et al. "Design of high brightness Plasma Wakefield Acceleration experiment at SPARC_LAB test facility with particle-in-cell simulations." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
17. Shpakov, V., et al. "Plasma acceleration limitations due to betatron radiation." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
18. Rosenzweig, J. B., et al. "Ultra-high brightness electron beams from very-high field cryogenic radiofrequency photocathode sources." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
19. **Pompili, R., et al. "Ultrafast evolution of electric fields from high-intensity laser-matter interactions." Scientific reports 8.1 (2018): 3243.**
20. Petrillo, V., et al. "Free Electron Laser in the water window with plasma driven electron beams." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
21. Rosenzweig, J. B., et al. "Adiabatic plasma lens experiments at SPARC." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
22. Bisesto, F. G., et al. "Recent studies on single-shot diagnostics for plasma accelerators at SPARC_LAB." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
23. Bisesto, F. G., et al. "The FLAME laser at SPARC_LAB." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
24. Chiadroni, E., et al. "Overview of plasma lens experiments and recent results at SPARC_LAB." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
25. **Curcio, A., et al. "Electro-Optical Detection of Coherent Radiation Induced by Relativistic Electron Bunches in the Near and Far Fields." Physical Review Applied 9.2 (2018): 024004.**
26. Costa, G., et al. "Characterization of self-injected electron beams from LWFA experiments at SPARC_LAB." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
27. Pompili, R., et al. "Recent results at SPARC_LAB." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
28. Biagioni, A., et al. "Wake fields effects in dielectric capillary." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
29. Scifo, J., et al. "Nano-machining, surface analysis and emittance measurements of a copper photocathode at SPARC_LAB." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
30. Giribono, A., et al. "RF injector design studies for the trailing witness bunch for a plasma-based user facility." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
31. Diomede, M., et al. "Preliminary RF design of an X-band linac for the EuPRAXIA@ SPARC_LAB project." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
32. Mira, Francesco, et al. "Characterisation of beam driven ionisation injection in the blowout regime of Plasma Acceleration." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018).
33. **Pompili, Riccardo, et al. "Guiding of charged particle beams in curved capillary-discharge waveguides." AIP Advances 8.1 (2018): 015326.**

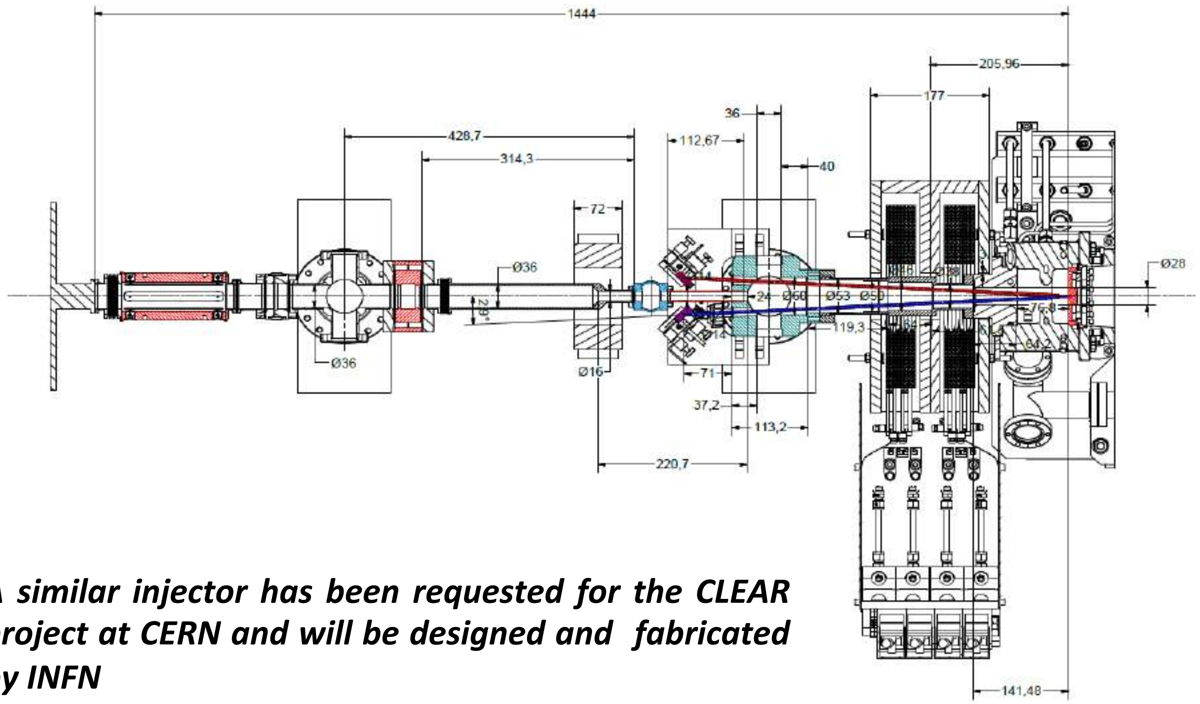
2019 Work Plan

NEW SPARC_LAB INJECTOR

With respect to the present injector the new one:

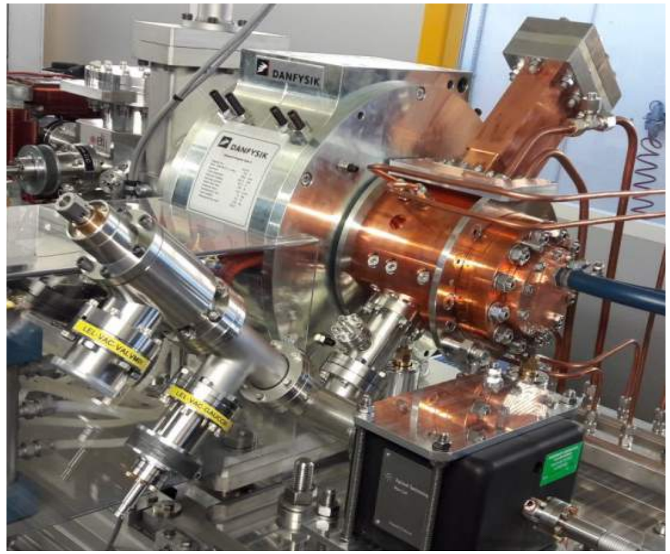
1) Will integrate an RF gun fabricated with the **new technology without brazing** (like the ELI-NP one);
2) Will integrate a **new solenoid** with two coils (like the ELI-NP one) and a **remote control of the transverse position;**
3) Will integrate an **on axis laser external injection system** with the last mirror in air and not into the beam pipe;
4) Will have **an available space for the future integration of an X/C band cavity linearizer;**
5) Will integrate a **variable skew quadrupole** after the gun for the compensation of the quadrupole components induced by the input coupler and non idealities of the solenoid (similar to the PSI one).





A similar injector has been requested for the CLEAR project at CERN and will be designed and fabricated by INFN

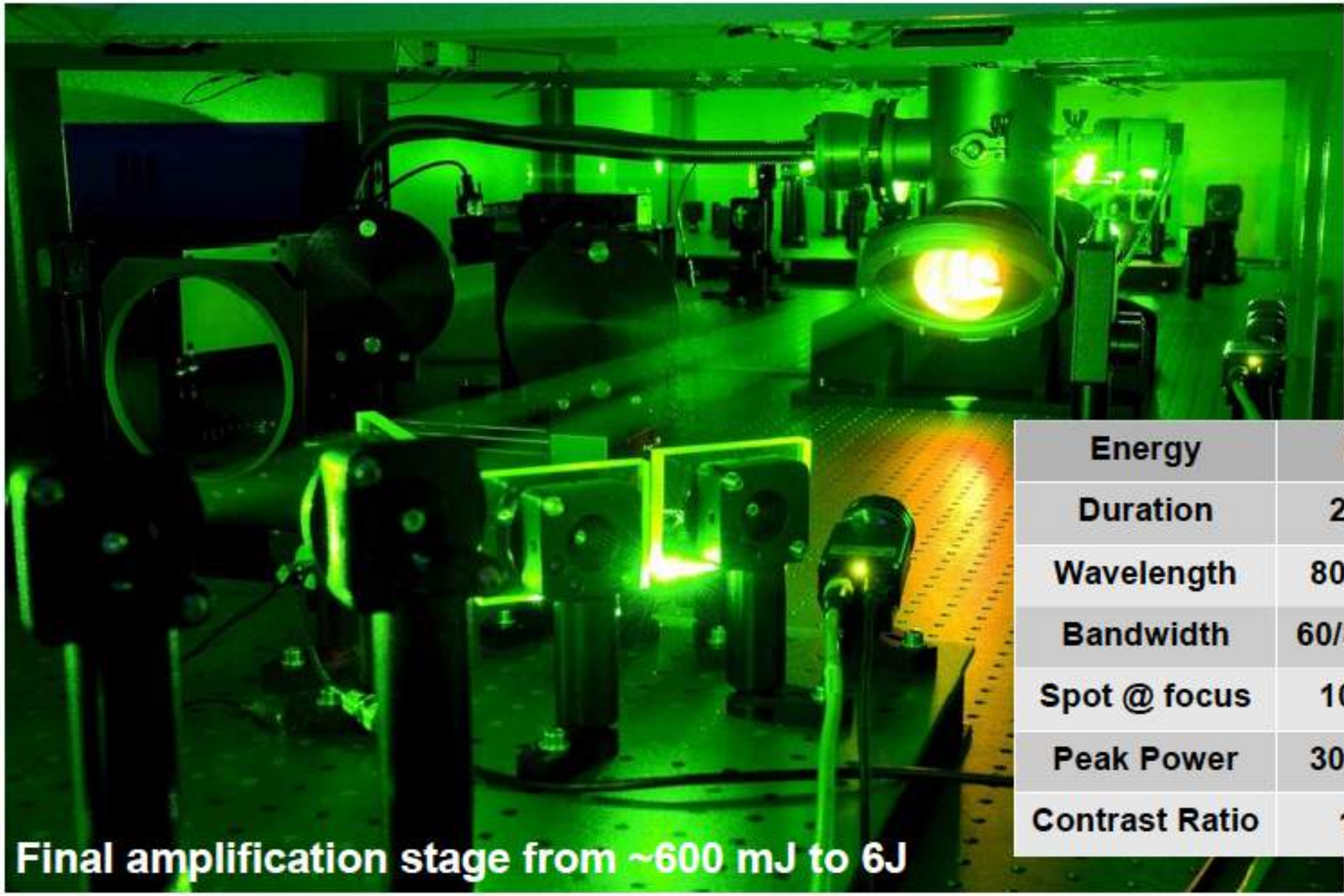
ELI-NP RF injector



NEW SPARC_LAB INJECTOR: POSSIBLE TIMELINE

	2018		2019											
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Conclusion of design of the quadrupole with variable polarity														
Conclusion of design of solenoid with remote control of its transverse position														
Preparation of final mechanical drawings														
Offer requests and orders														
Realization of components														
Installation of the new injector off-axis														
Final installation														

FLAME activity

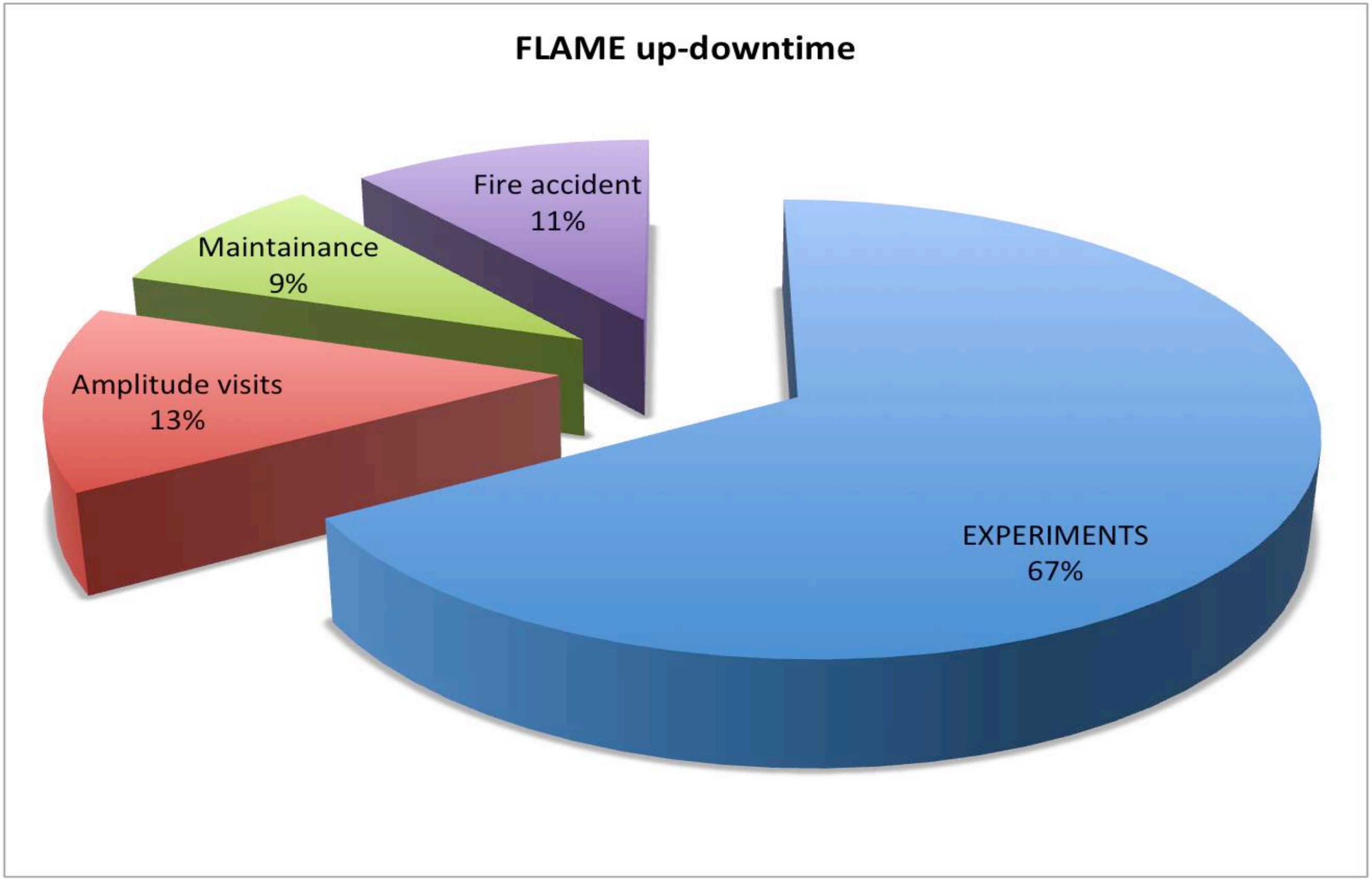


Final amplification stage from ~600 mJ to 6J

Energy	6 J
Duration	23 fs
Wavelength	800 nm
Bandwidth	60/80 nm
Spot @ focus	10 μm
Peak Power	300 TW
Contrast Ratio	10^{10}

Technical Issues

From NOV2017 to OCT2018



Technical Issues

1. Synch issue for EXIN in Jul 2018 (while trying to synchronize FLAME with SPARC synch group has observed a change in oscillator cavity which we have find to be addressed to piezo that moves the cavity. We are still trying to understand how to solve this issue without having to dismount the whole oscillator cavity).
2. MP3 crystal damage in Jul2018 due to a creation of an hot spot in the laser beam (crystal has been sent out for recoating and it takes 4 months to have it back).
3. Oscillator pump degradation in Sept2018 (the diode pump of the oscillator is not anymore delivering the right power. Here as well problem is due to ageing of the pump…)

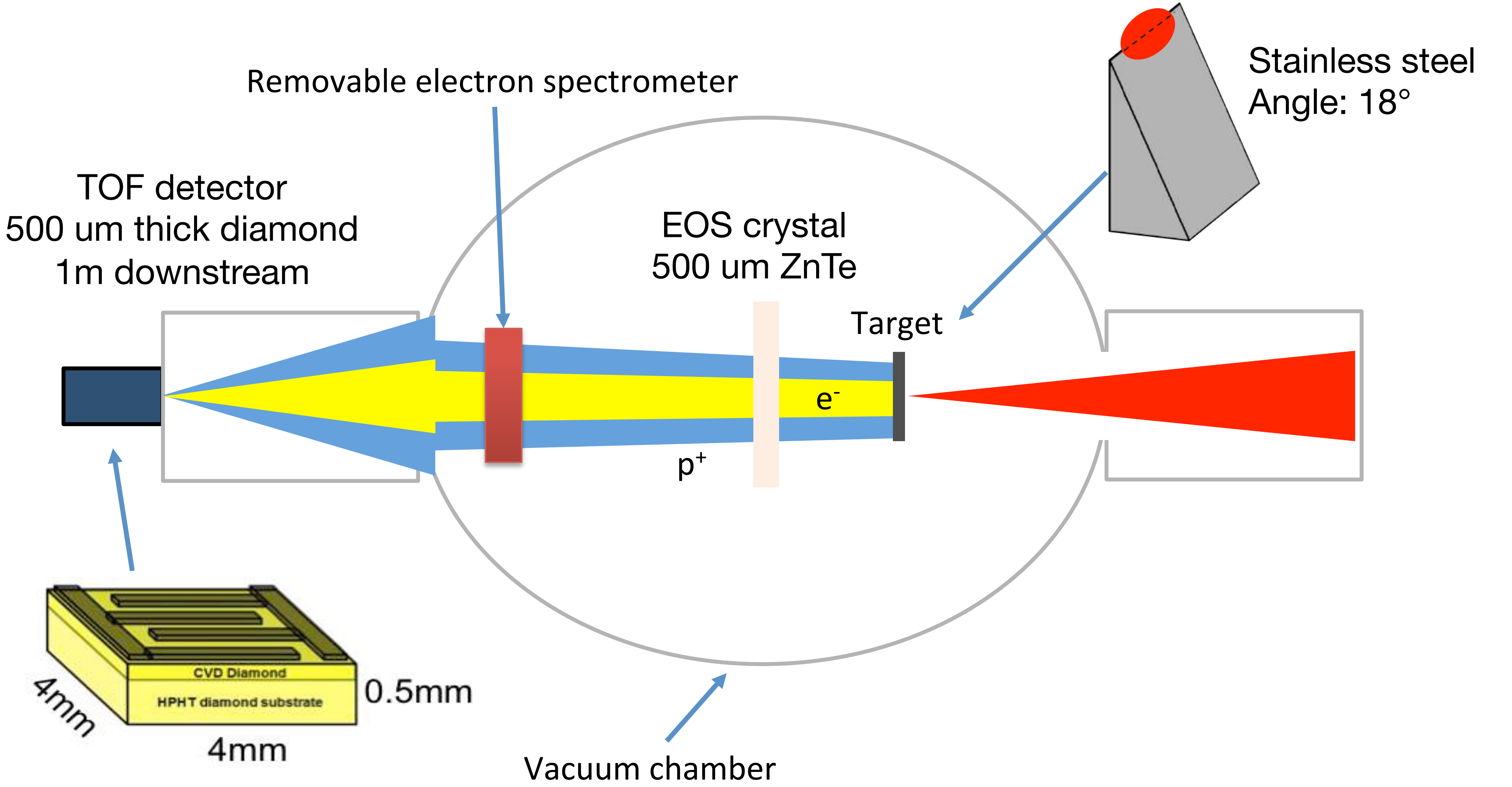
Technical Issues

Open issues:

Air difference from clean room to the rest of the building. We have partially resolved by tubing the laser but this is still giving too many instabilities on the beam (expecially on focal spot quality and pointing instabilities); A new and dedicated air condition system is required.

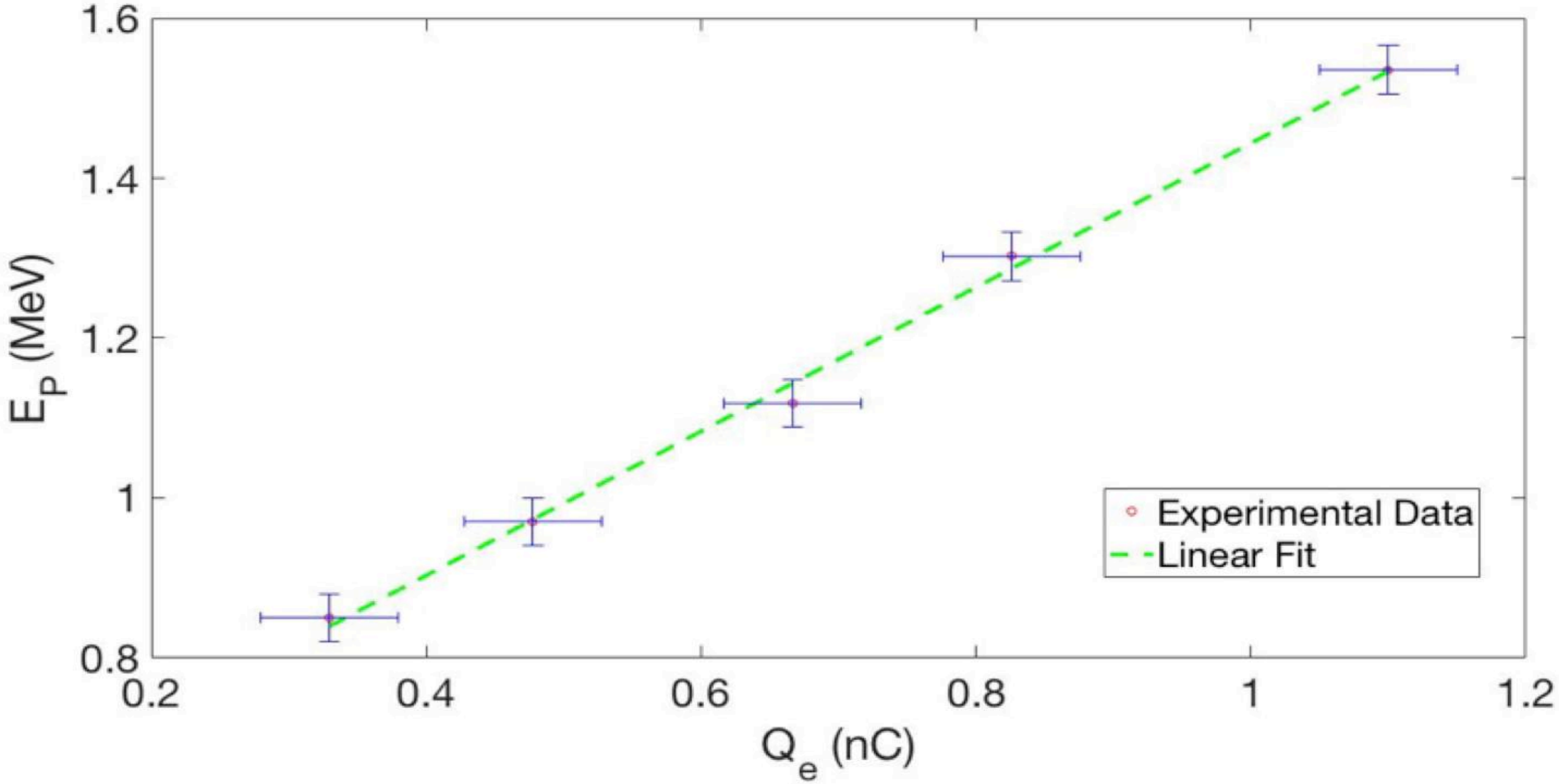
Water plant for laser cooling which is switching off lasers; this has been partially solved cleaning filters every 3 months; However, a new water plant dedicated to FLAME and which doesn't use tap water is under design.

Results achieved in the last year

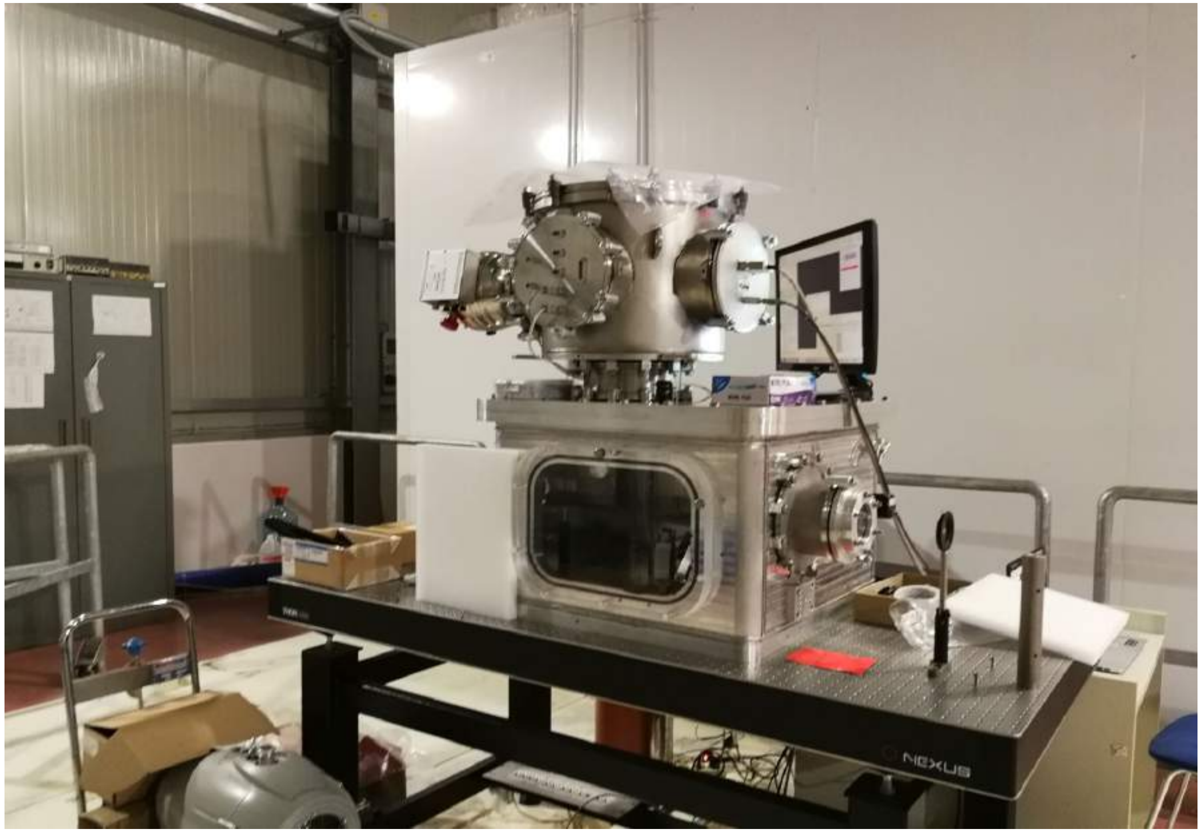


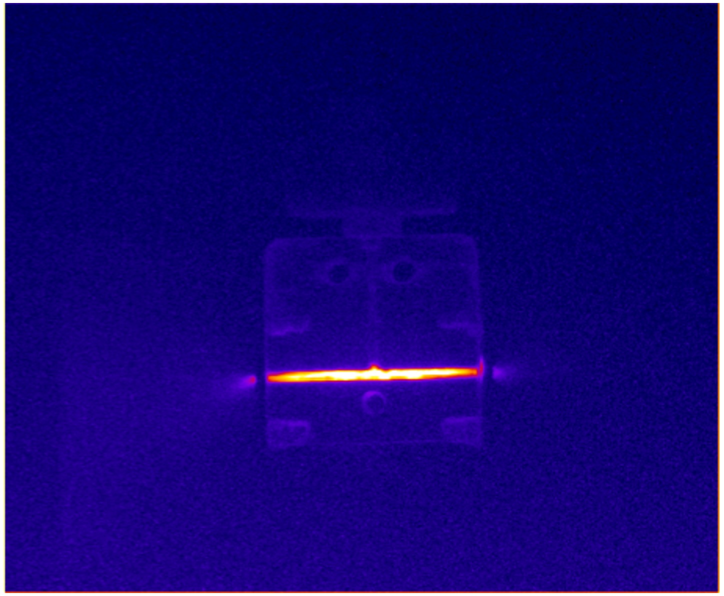
Results achieved in the last year

Data analysis has eventually confirmed our first hypothesis that higher charge electrons means higher energy protons!



Work in progress for SL_EXIN





Results achieved in the last year

A series of diagnostics have been mounted in order to be able to have as much information as possible:

Before laser injection:

- Focal spot size;
- Focal position;
- Laser time arrival;
- Laser duration;

During injection:

- Discharge current;
- Plasma profile (transverse and longitudinal);

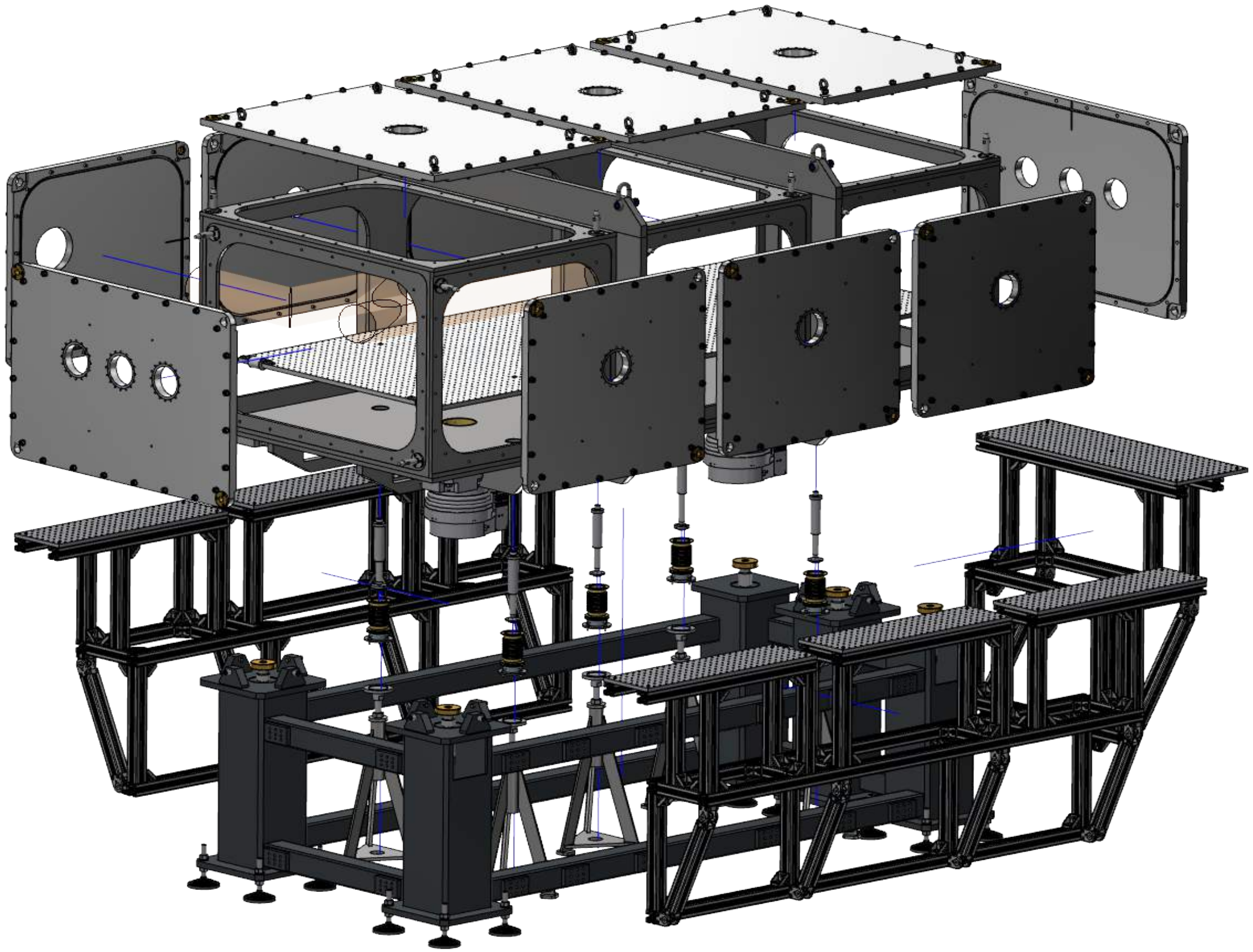
After injection:

- Laser duration;
- Laser spectral profile;
- Laser spot size;
- Laser time arrival;

2018 Pubblication List

1. F. Filippi, et al.: *Tapering of plasma density ramp profiles for adiabatic lens experiments*. DOI:10.1016/j.nima.2018.04.037
2. A. Cianchi, et al.: *Frontiers of beam diagnostics in plasma accelerators: Measuring the ultra-fast and ultra-cold*. Physics of Plasmas 05/2018; 25(5):056704., DOI:10.1063/1.5017847
3. R. Pompili, et al.: *Compact and tunable focusing device for plasma wakefield acceleration*. Review of Scientific Instruments 03/2018; 89(3):033302., DOI:10.1063/1.5006134
4. F.G. Bisesto, et al.: *Evolution of the electric fields induced in high intensity laser-matter interactions*. DOI:10.1016/j.nima.2018.03.040
5. E. Brentegani, et al.: *Numerical studies on capillary discharges as focusing elements for electron beams*. Nuclear Instruments and Methods in Physics Research Section A Accelerators Spectrometers Detectors and Associated Equipment 03/2018;, DOI:10.1016/j.nima.2018.03.012
6. F. Filippi, et al.: *Plasma ramps caused by outflow in gas-filled capillaries*. DOI:10.1016/j.nima.2018.02.102
7. A. Cianchi, et al.: *Conceptual design of electron beam diagnostics for high brightness plasma accelerator*. DOI:10.1016/j.nima.2018.02.095
8. F. G. Bisesto, et al.: *Recent studies on single-shot diagnostics for plasma accelerators at SPARC_LAB*. DOI:10.1016/j.nima.2018.02.059
9. A. Curcio, et al.: *Electro-Optical Detection of Coherent Radiation Induced by Relativistic Electron Bunches in the Near and Far Fields*. Physical Review Applied 02/2018; 9(2)., DOI:10.1103/PhysRevApplied.9.024004
10. G. Costa, et al.: *Characterization of self-injected electron beams from LWFA experiments at SPARC_LAB*. DOI:10.1016/j.nima.2018.02.008
11. F. G. Bisesto, et al.: *The FLAME laser at SPARC_LAB*. DOI:10.1016/j.nima.2018.02.027
12. R. Pompili, et al.: *Ultrafast evolution of electric fields from high-intensity laser-matter interactions*. Scientific Reports 01/2018; 8(1)., DOI:10.1038/s41598-018-21711-4
13. Alessandro Curcio, et al.: *Ray optics hamiltonian approach to relativistic self focusing of ultraintense lasers in underdense plasmas*. The European Physical Journal Conferences 01/2018; 167(5):01003., DOI:10.1051/epjconf/201816701003

What next?



The new interaction chamber has been designed with the intend to be flexible to accommodate different experimental set-up.

Also, the internal breadboard is decoupled from the structure so that vacuum pump vibrations cannot affect the laser transport and the target.

It's also higher to accommodate the hexapod.

It's supposed to be installed in JAN2019.

SPARC LAB

What next?

Ministero degli Affari Esteri e della Cooperazione Internazionale

MINISTRY OF FOREIGN AFFAIRS AND INTERNATIONAL COOPERATION
DIRECTORATE GENERAL FOR CULTURAL AND ECONOMIC PROMOTION AND INNOVATION
ITALIAN REPUBLIC

MINISTRY OF SCIENCE AND TECHNOLOGY
STATE OF ISRAEL

APPLICATION Form

Area of Cooperation	Acronym	Italian Organisation Name	Italian Principal Investigator	Contact data of Italian/Israeli Principal Investigator (email, direct telephone, mobile phone)	Israeli Organisation Name	Israeli Principal Investigator
2. Applicazioni della fisica dei sistemi complessi	CAMEL	Istituto Nazionale di Fisica Nucleare	Dr. Maria Pia Anania	In Italy: Maria.pia.anania@lnf.infn.it +390694038022 In Israel: zigler@vms.huji.ac.il +97226585157	Hebrew University of Jerusalem	Prof. Arie Zigler

We have won a Scienti-fic Research collabora-tion project founded by MAECI and MOST with Hebrew University based on the study of curved capillaries which could open the possibili-ty to accelerate elec-trons to high energy with high quality by controlling critical limi-ting parameters.

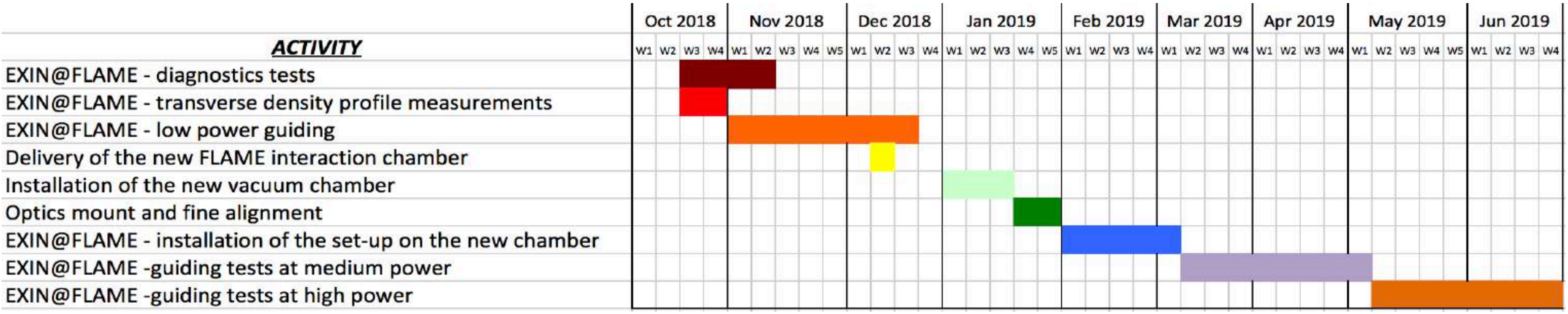
What next?

Project aim → control critical parameters encountered with LWFA:

1. Pump depletion → preformed plasma and multi-laser inputs;
2. Dephasing → tapered plasma channel;
3. Diffraction → optical guiding with plasma.

In-line with EXIN, also because it can be used to remove laser from the electron transport line!

What next?



We will work mainly on EXIN project with the aim not only to grow knowledge on the capillary alignment, but also to understand how to grow capillaries lifetime, to adjust and understand the right diagnostics to be placed before, during and after the interaction.

Next SPARC_LAB Milestones

1. 2019 - PWFA – Beam/Plasma matching studies (=> June)
2. 2020 - PWFA – Acceleration and transport (=>June)
3. 2021 – LWFA - Beam/Plasma matching studies
4. 2022 – LWFA – Acceleration and Diagnostics
5. 2023 –COMB2FEL - PWFA SASE demonstration

https://agenda.infn.it/conferenceDisplay.py?confId=16759

La lunga marcia
(verso un Ente migliore)

Fernando Ferroni

LNF

- un nodo centrale per il futuro dell'Ente
- Il laboratorio ha elaborato un piano realistico
- che e' stato approvato dal CD
- EUPRAXIA@SPARC_LAB verra' fatta
- il progetto finale dipende dalle decisioni sul grado di internalizzazione (aspettate a breve)


Thank for your attention