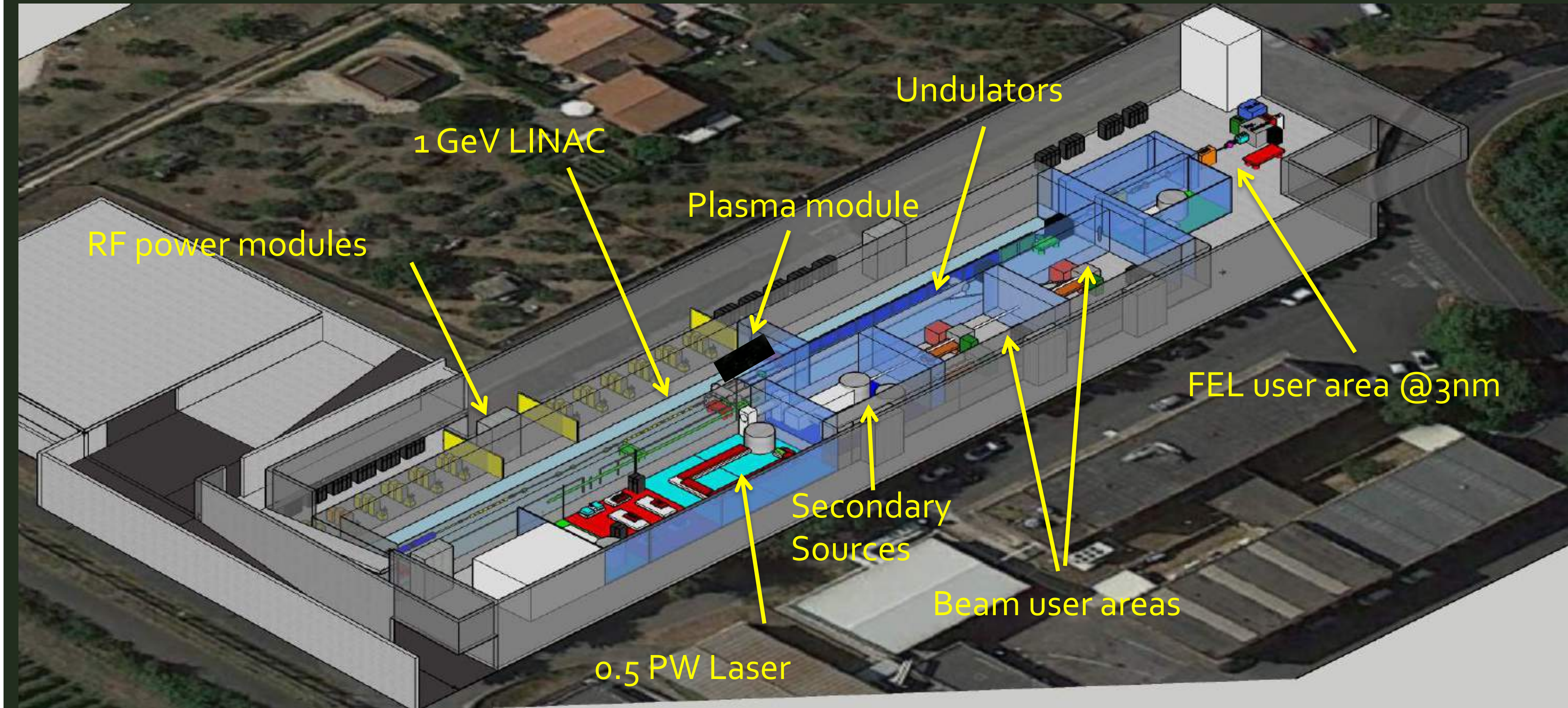
EuPRAXIA@SPARC_LAB

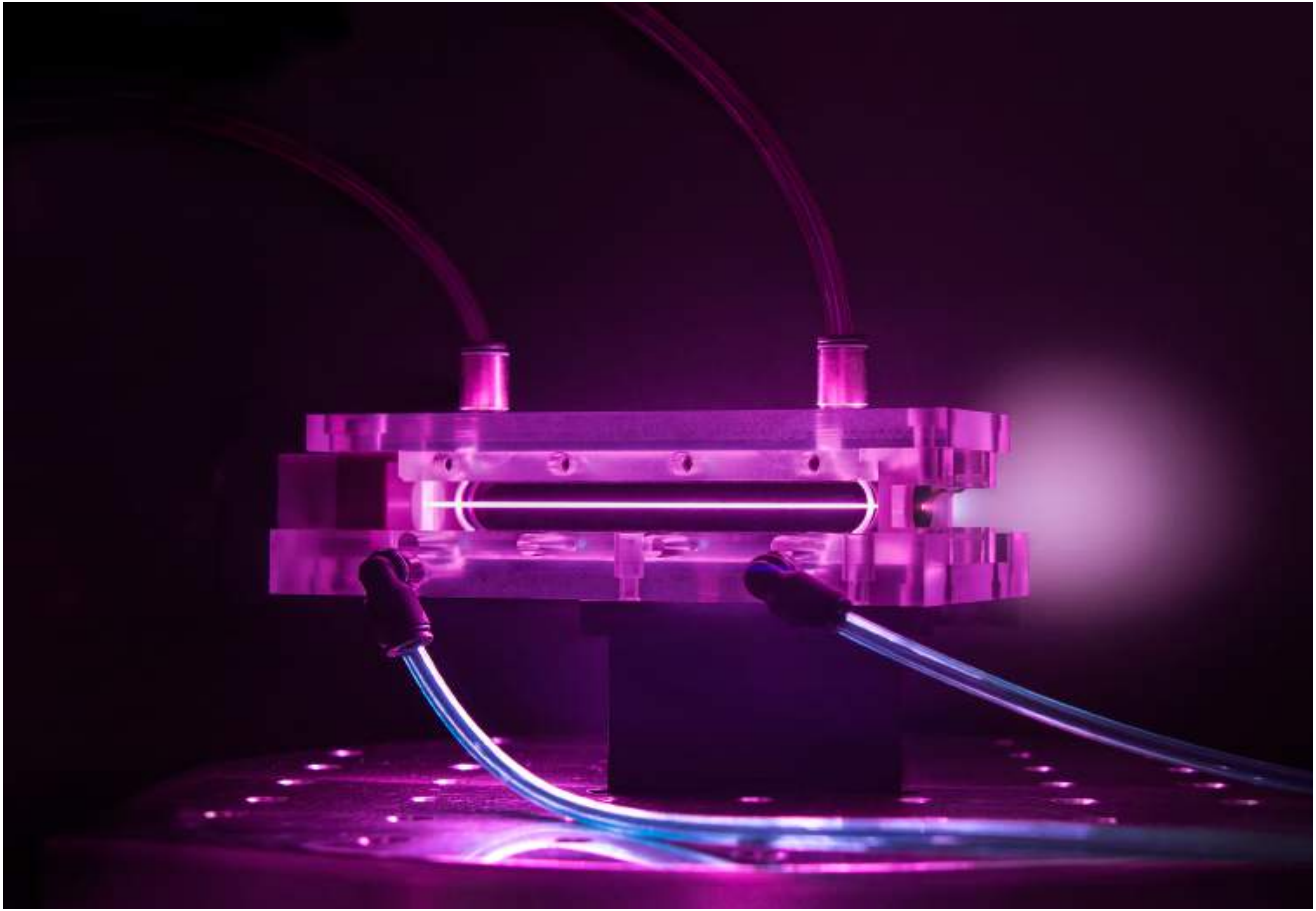
Massimo.Ferrario@lnf.infn.it

On behalf of the collaboration

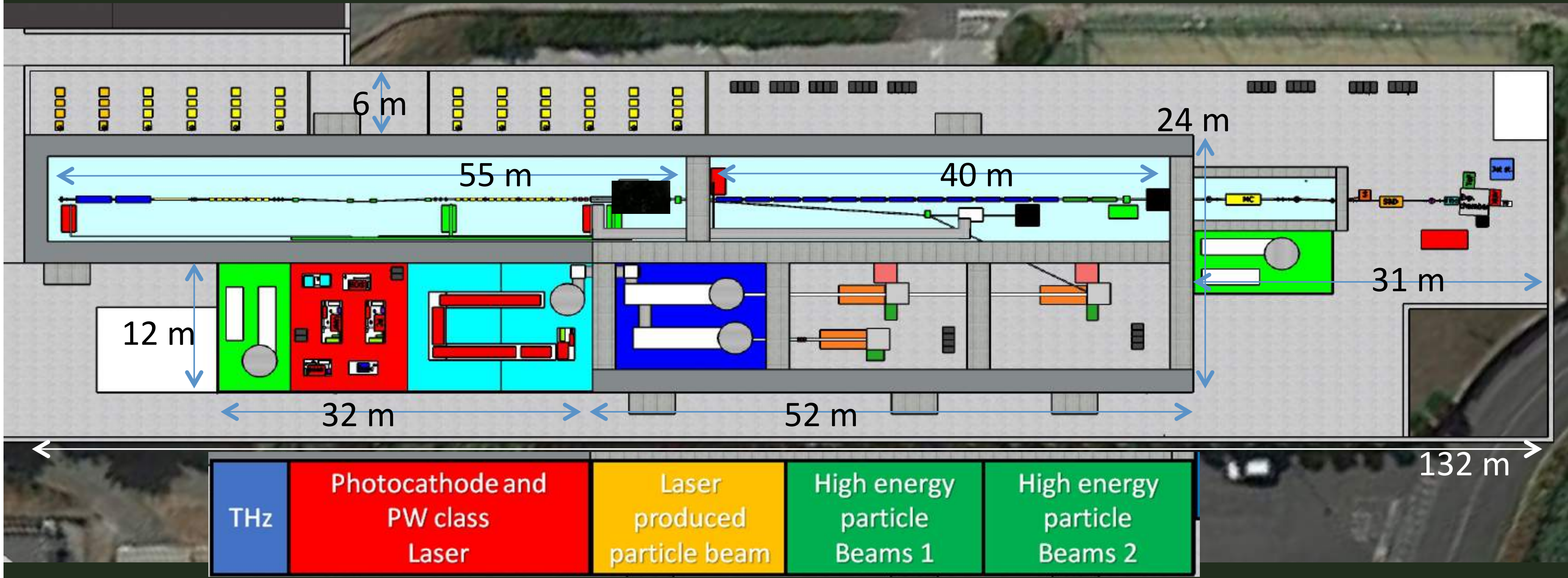
INFN
Istituto Nazionale di Fisica Nucleare

EuPRAXIA@SPARC_LAB





- Candidate LNF to host EuPRAXIA (1-5 GeV)
- FEL user facility (1 GeV – 3nm)
- Advanced Accelerator Test facility (LC) + CERN

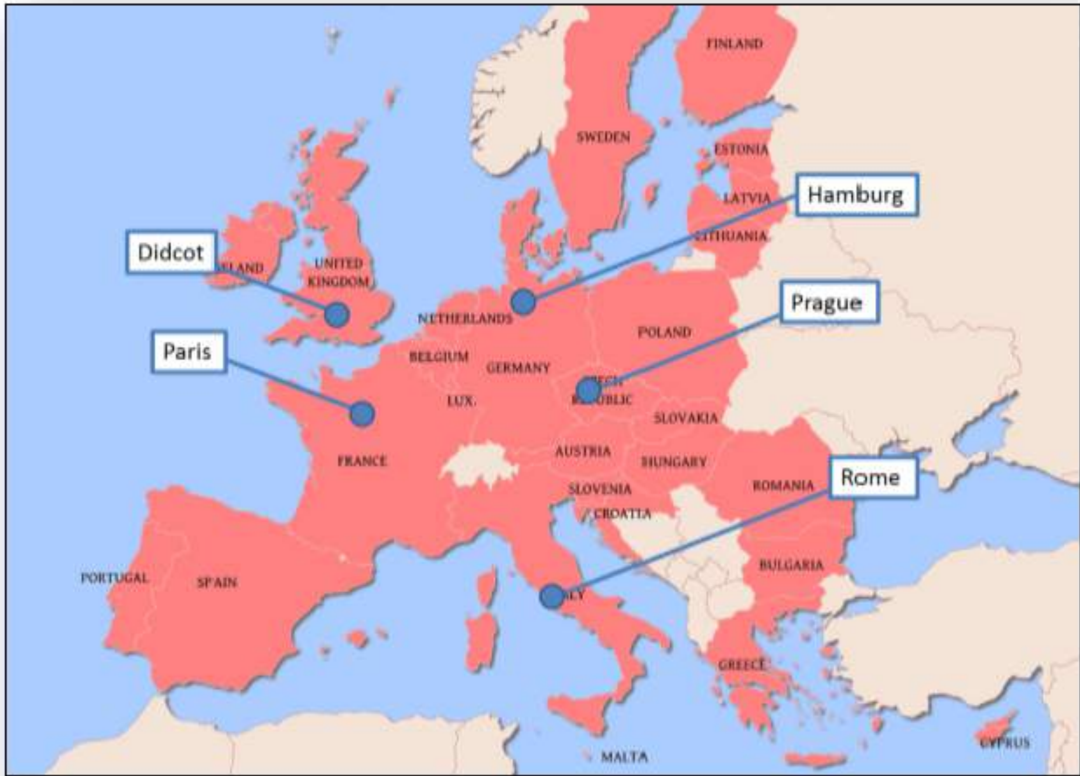


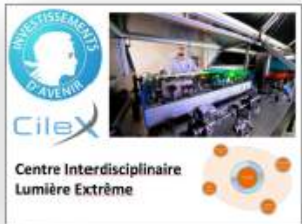
- 500 MeV by RF Linac + 500 MeV by Plasma (LWFA or PWFA)
- 1 GeV by X-band RF Linac only
- Final goal compact 5 GeV accelerator

Location of possible sites within EU

Horizon 2020

EuPRAXIA site studies:
- Design study is site independent
- Five possible sites have been discussed so far
- We invite the suggestions of additional sites





Central Laser Facility
Didcot, United Kingdom

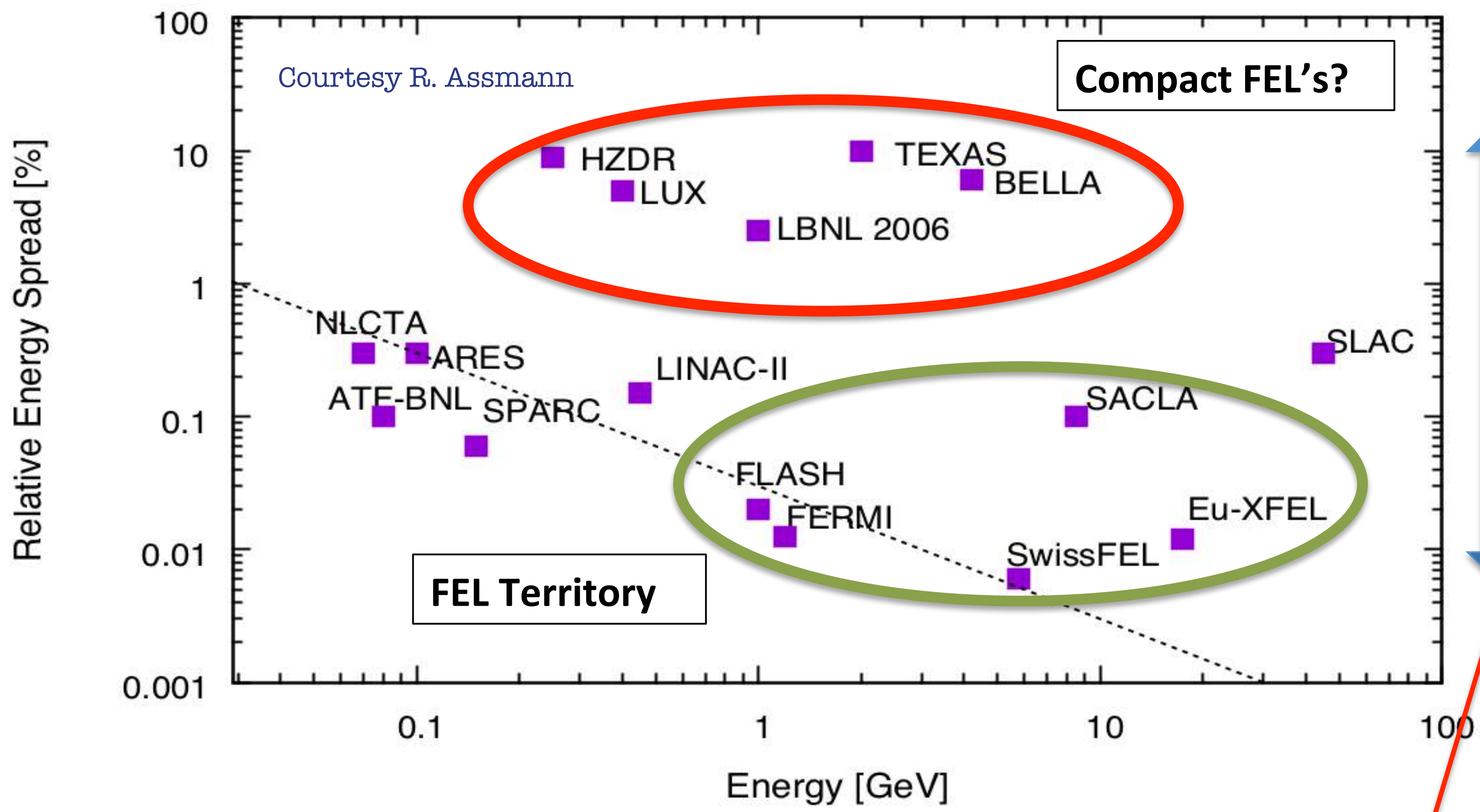
Eli Beamlines
Prague, Czech Republic

Conceptual Design Report Ready for the LNF site

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

- D. Alesini, M. P. Anania, R. Bedogni, M. Bellaveglia, A. Biagioni, F. Bisesto, E. Brentegani, B. Buonomo, P.L. Campana, G. Campogiani, S. Cantarella, F. Cardelli, M. Castellano, E. Chiadroni, R. Cimino, R. Clementi, M. Croia, A. Curcio, G. Costa, S. Dabagov, M. Diomede, A. Drago, D. Di Giovenale, G. Di Pirro, A. Esposito, M. Ferrario, F. Filippi, O. Frasciello, A. Gallo, A. Ghigo, A. Giribono, S. Guiducci, S. Incremona, F. Iungo, V. Lollo, A. Marcelli, A. Marocchino, V. Martinelli, A. Michelotti, C. Milardi, L. Pellegrino, L. Piersanti, S. Pioli, R. Pompili, R. Ricci, S. Romeo, U. Rotundo, L. Sabbatini, O. Sans Plannell, J. Scifo, B. Spataro, A. Stecchi, A. Stella, V. Shpakov, C. Vaccarezza, A. Vannozzi, A. Variola, F. Villa, M. Zobov.
- **INFN - Laboratori Nazionali di Frascati**
- A. Bacci, F. Broggi, C. Curatolo, I. Debrot, A. R. Rossi, L. Serafini. **INFN - Sezione di Milano**
- D. Cirrincione, A.Vacchi. **INFN - Sezione di Trieste**
- G. A. P. Cirrone, G. Cuttone, V. Scudieri. **INFN - Laboratori Nazionali del Sud**
- M. Artioli, M.Carpanese, F.Ciocci, D.Dattoli, S.Licciardi, F.Nguyen, S. Pagnutti, A.Petralia, E. Sabia. **ENEA – Frascati and Bologna**
- L. Gizzi, L. Labate. **CNR - INO, Pisa**
- R. Corsini, A. Grudiev, N. Catalan Lasheras, A. Latina, D. Schulte, W. Wuensch. **CERN, Geneva**
- C. Andreani, A. Cianchi, G. Festa,V. Minicozzi, S. Morante, R. Senesi, F. Stellato. **Universita' degli Studi di Roma Tor Vergata and Sezione INFN**
- V. Petrillo, M. Rossetti. **Universita' degli Studi di Milano and Sezione INFN**
- G. Castorina, L. Ficcadenti, S. Lupi, M. Marongiu, F. Mira, A. Mostacci. **Universita' degli Studi di Roma Sapienza and Sezione INFN**
- S. Bartocci, C. Cannaos, M. Faiferri, R. Manca, M. Marini, C. Mastino, D. Polese, F. Pusceddu, E. Turco. **Università degli Studi di Sassari, Dip. di Architettura, Design e Urbanistica ad Alghero**
- M. Coreno, G. D'Auria, S. Di Mitri, L. Giannessi, C. Masciovecchio. **ELETTRA Sincrotrone Trieste**
- A. Ricci. **RICMASS, Rome International Center for Materials Science Superstripes**
- A. Zigler. **Hebrew University of Jerusalem** J. B. Rosenzweig. **University of California Los Aangeles**

Quality: Example Energy Spread



Lower quality

Higher quality

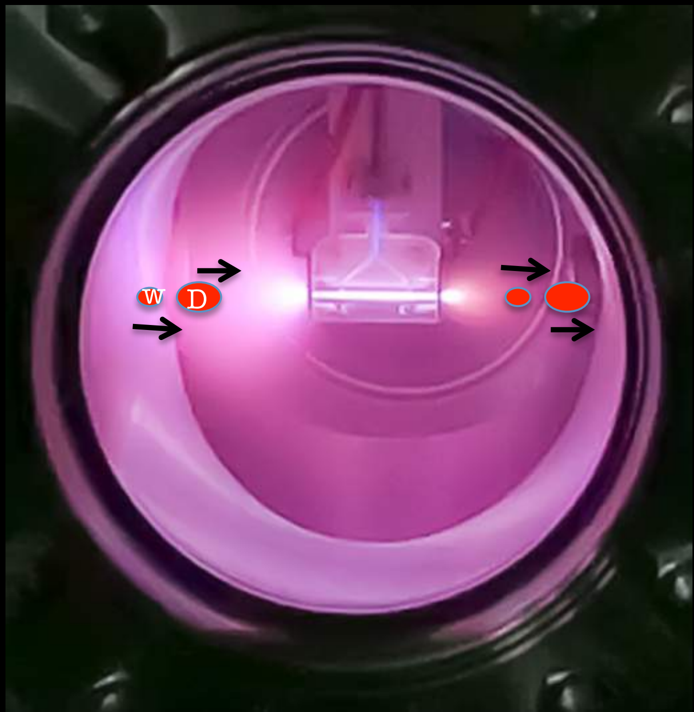
$$\sigma_\gamma = \frac{\sqrt{3}}{2} k_p^2 \sigma_z^2$$

$$\sin\varphi_w \propto \frac{q_w}{Q_d}$$

$$\varepsilon_{n,rms} = \sqrt{\left\langle \gamma^2 \right\rangle \left(\sigma_\gamma^2 \sigma_x^2 \sigma_{x'}^2 + \varepsilon_{rms}^2 \right)}$$

M. Migliorati et al, Physical Review Special Topics,Accelerators and Beams 16, 011302 (2013)
K. Floettmann, PRSTAB,6, 034202 (2003)

External Injection



$$\Delta T_w = \left(R - \frac{q}{Q}\right)\left|\Delta T_D\right|$$

$$R \cong 2$$

First evidences of plasma wakefield deceleration

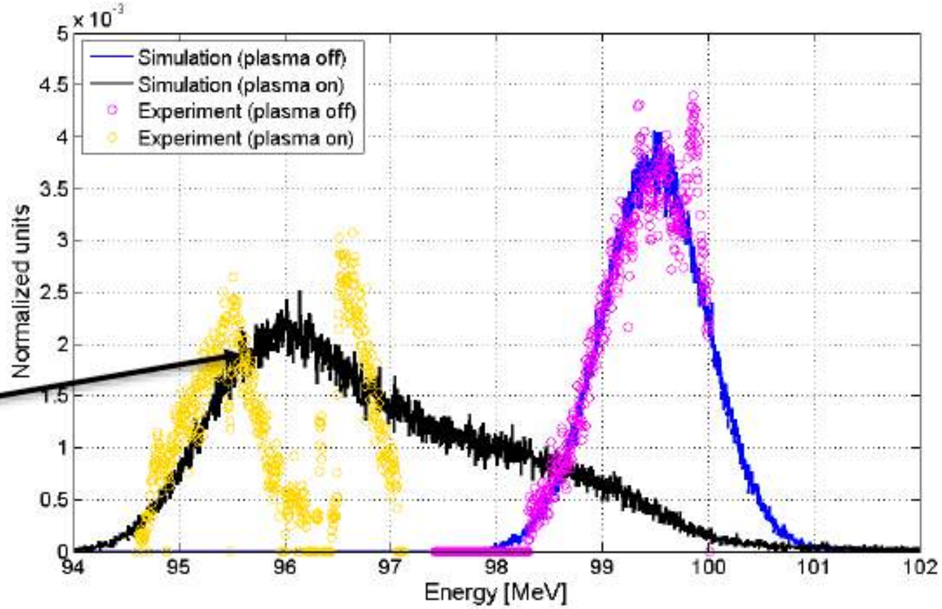
Experimental data at injection

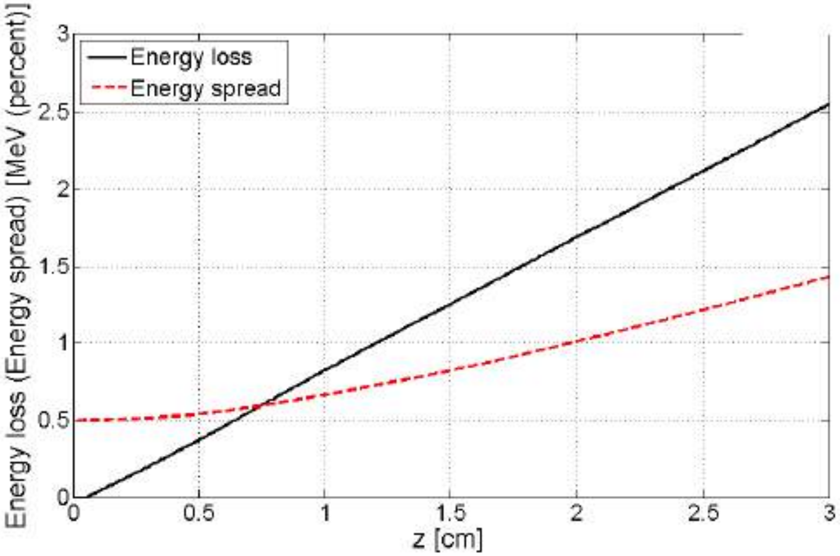
$\sigma_{x,(y)} = 23.9(22.5)\mu m$
$\sigma_z = 87\mu m$
$\varepsilon_{x,(y)} = 1.8(1.4) mm\ mrad$
$\sigma_E = 0.4\%$

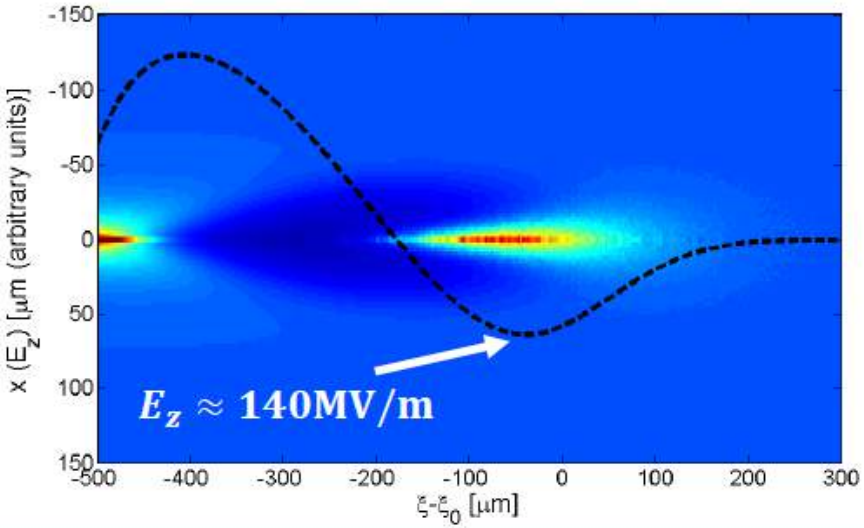
Simulation parameters

$\sigma_{x,y} = 20\mu m$
$\sigma_z = 87\mu m$
$\varepsilon_{x,y} = 1.5 mm\ mrad$
$\sigma_E = 0.4\%$

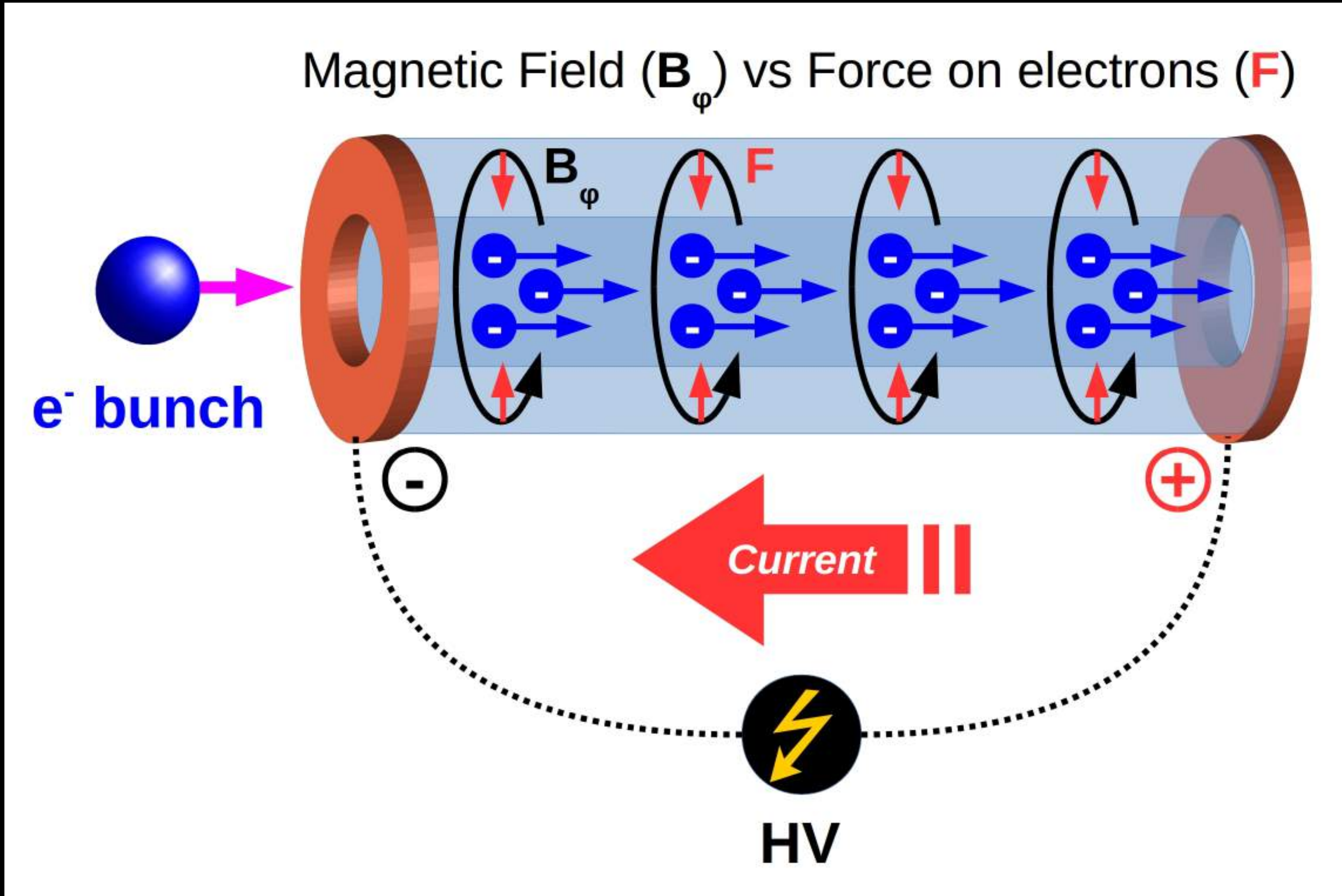
Discrepancy probably due to beam longitudinal profile not bigaussian







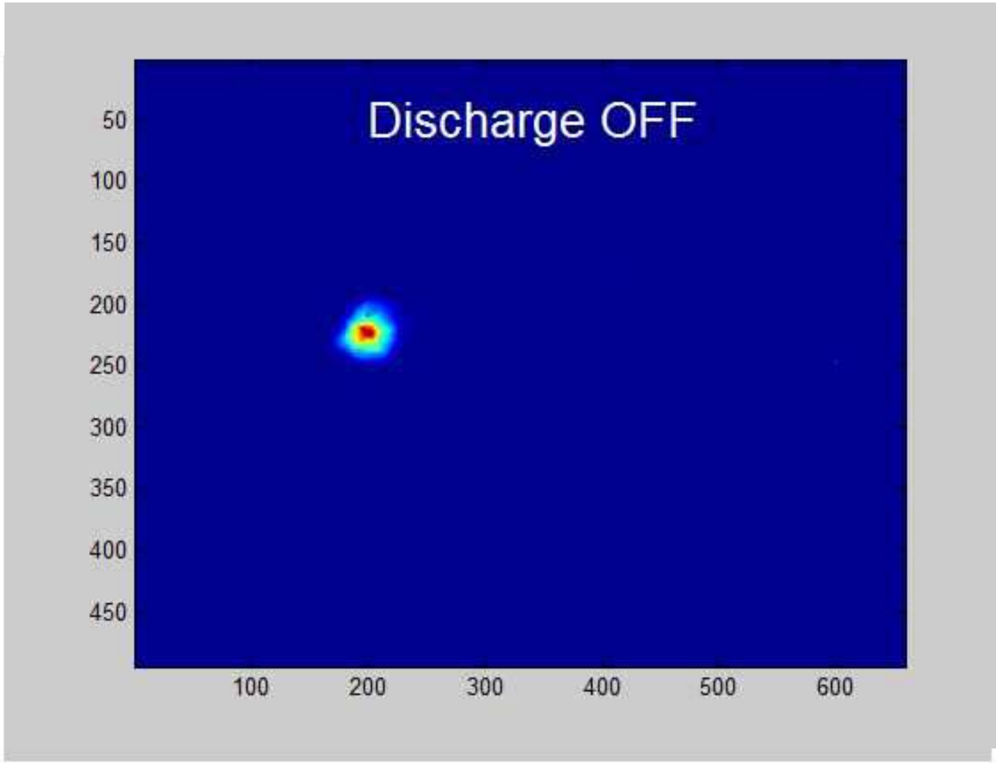
Active Plasma Lens

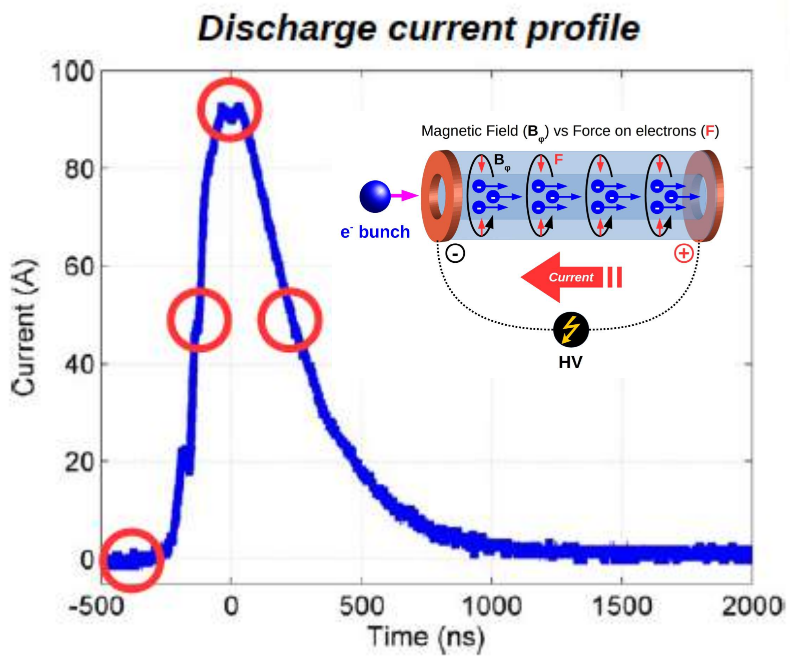


APPLIED PHYSICS LETTERS **110**, 104101 (2017)

Experimental characterization of active plasma lensing for electron beams

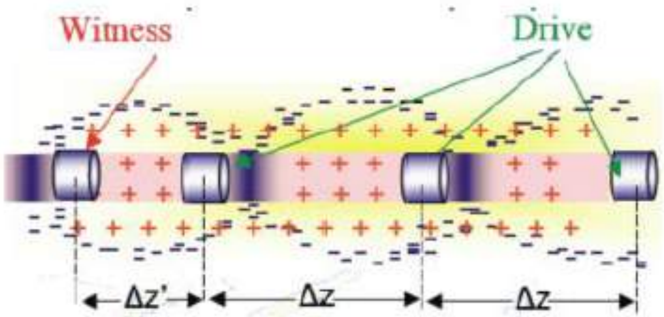
R. Pompili,[1,a)] M. P. Anania,[1] M. Bellaveglia,[1] A. Biagioni,[1] S. Bini,[1] F. Bisesto,[1] E. Brentegani,[1] G. Castorina,[1,2] E. Chiadroni,[1] A. Cianchi,[3] M. Croia,[1] D. Di Giovenale,[1] M. Ferrario,[1] F. Filippi,[1] A. Giribono,[4] V. Lollo,[1] A. Marocchino,[1] M. Marongiu,[4] A. Mostacci,[4] G. Di Pirro,[1] S. Romeo,[1] A. R. Rossi,[5] J. Scifo,[1] V. Shpakov,[1] C. Vaccarezza,[1] F. Villa,[1] and A. Zigler[6]





Plasma-based acceleration techniques

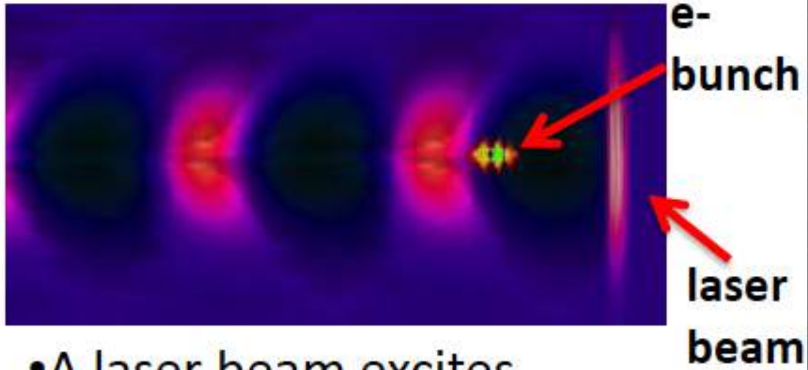
resonant-PWFA



•A train of three electron bunches (driver bunches) is sent through a capillary discharge
•A resonant plasma wave is then excited in plasma
•A fourth electron beam (witness beam) uses this wave to be accelerated

$n_e = 2x10^{16}\ cm^{-3}$
$\lambda_p = 300\mu m$
Capillary 1mm
Hydrogen

external injection LWFA



•A laser beam excites plasma waves in a capillary filled with gas
•A high brightness electron beam uses this wave to be accelerated

$n_e = 1x10^{17}\ cm^{-3}$
$\lambda_p = 100\mu m$
Capillary 100 µm
Hydrogen

Consiglio di Laboratorio - Preventivi 2019
LNF - 2 July 2018

SL_COMB2FEL

Resp. Naz.:
E. Chiadroni (LNF)

Sezioni proponenti:
LNF (Resp. Loc.: E. Chiadroni),
Roma1 (Resp. Loc.: A. Mostacci),
Roma2 (Resp. Loc.: A. Cianchi)
Lecce (Resp. Loc.: A. Lorusso),
Napoli (Resp. Loc.: R. Fedele)

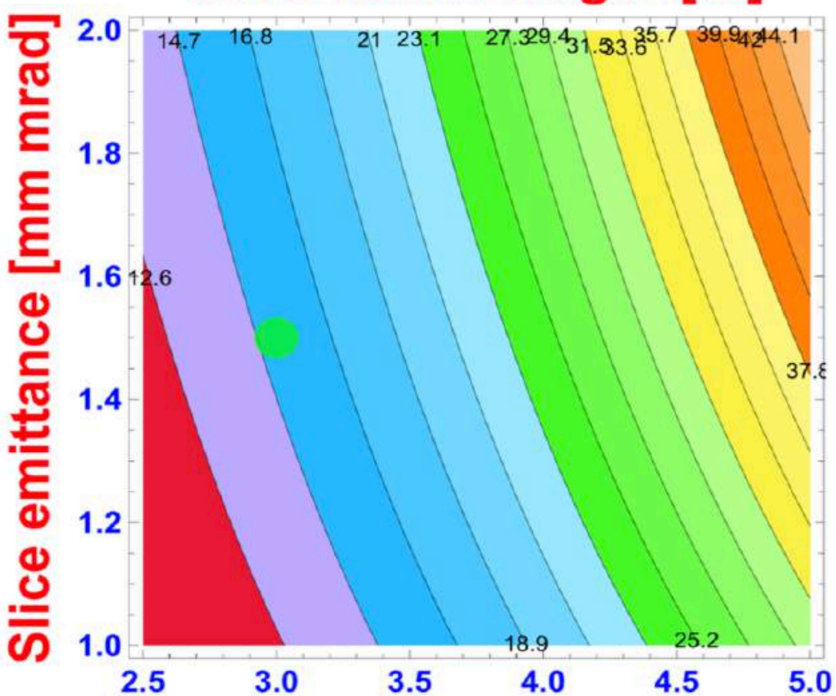
Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DI FRASCATI

Optimized FEL Results

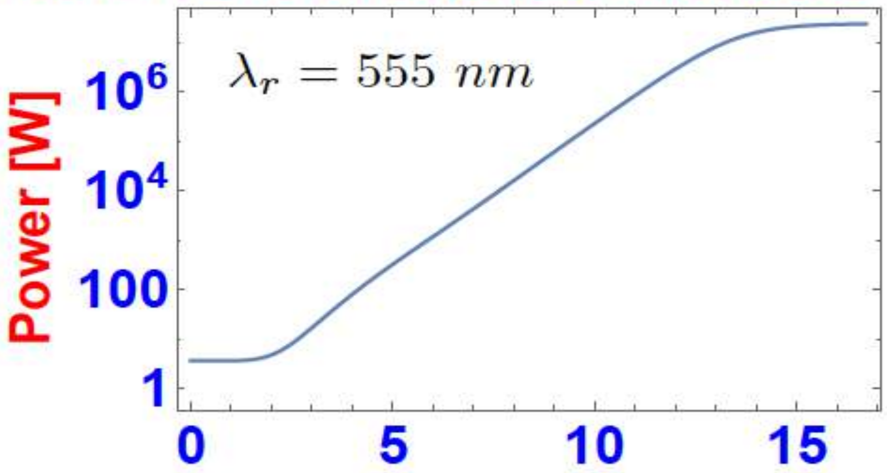
$\Delta E/E = 0.3\%$
emit = 1.5 mm mrad
Ipeak = 200 A

140 MeV
30 pC
K=2

Saturation Length [m]



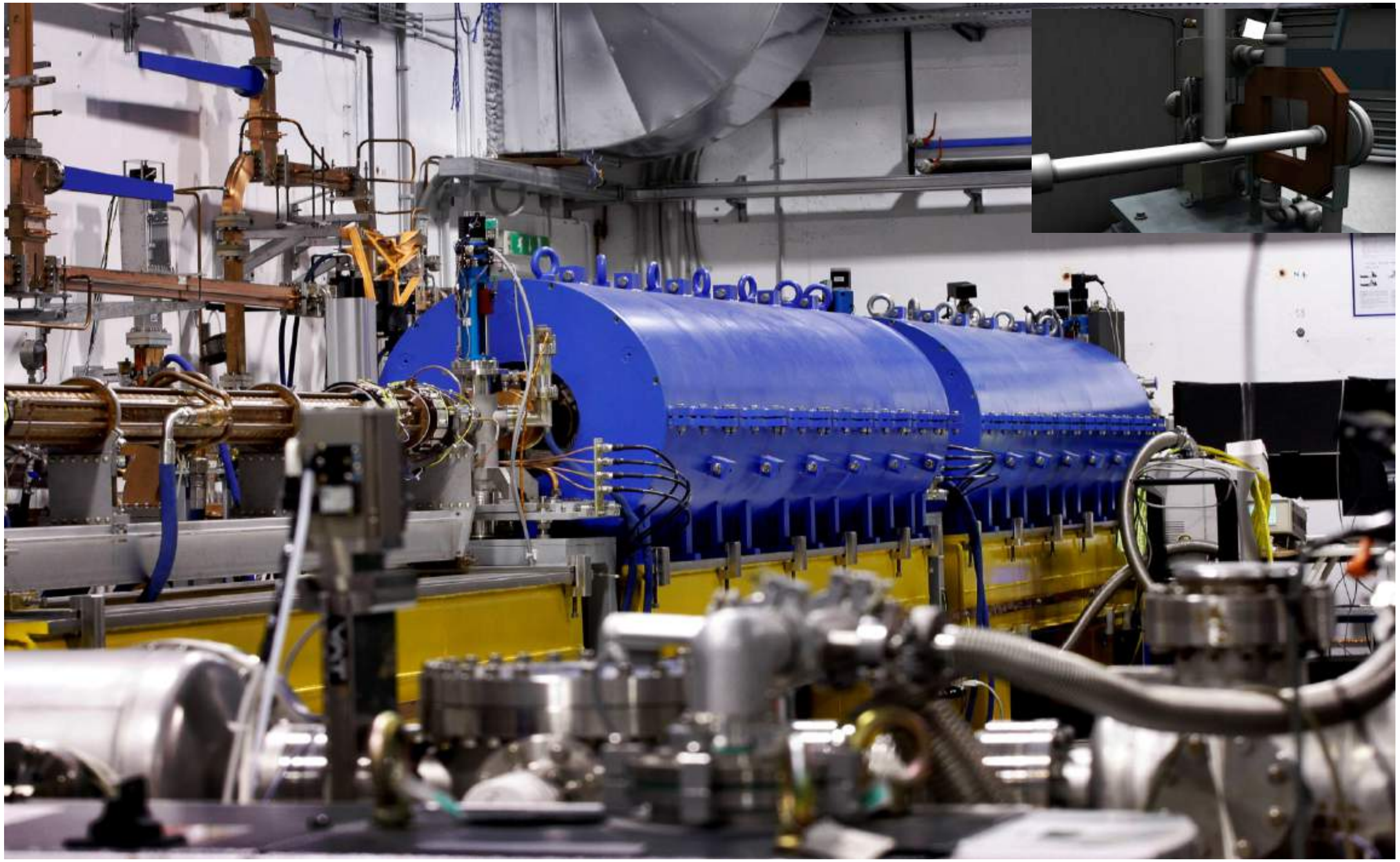
Power as a function of undulator length

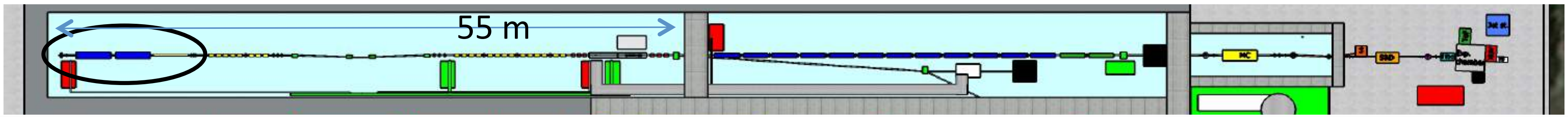


Compatible with SPARC undulator!

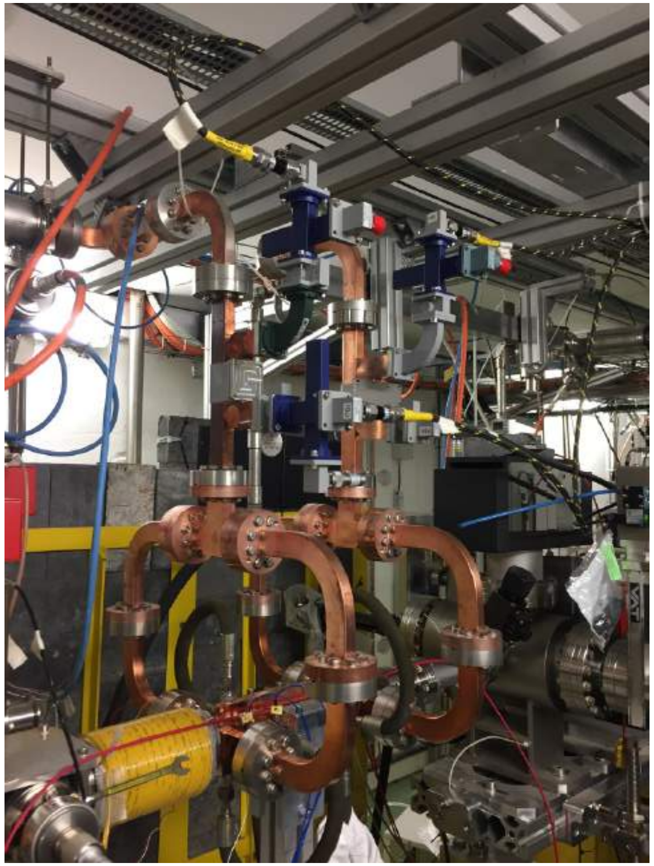
enrica.chiadroni@lnf.infn.it

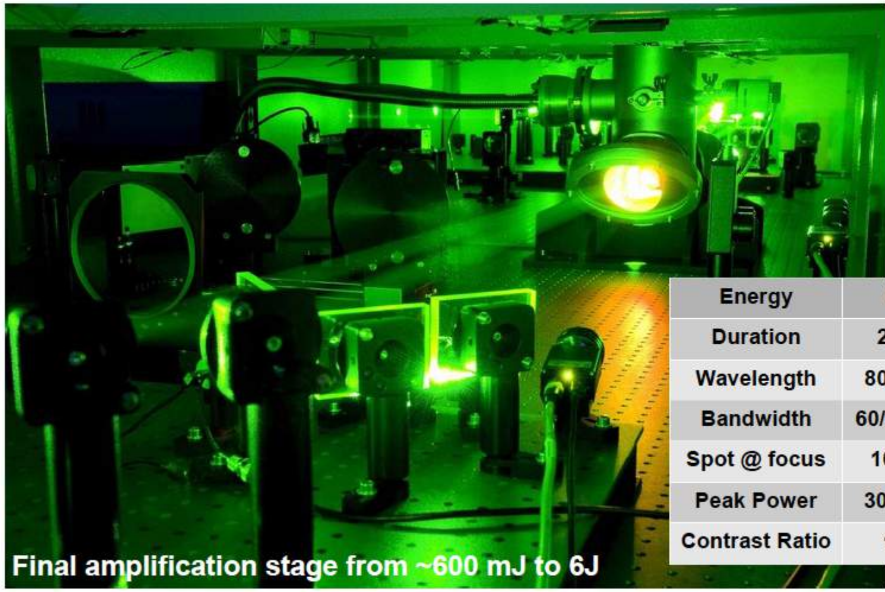
SPARC_LAB HB photo- injector



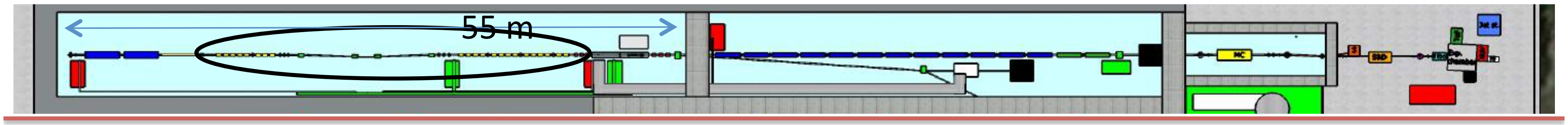


X-band Linac and High Power Laser

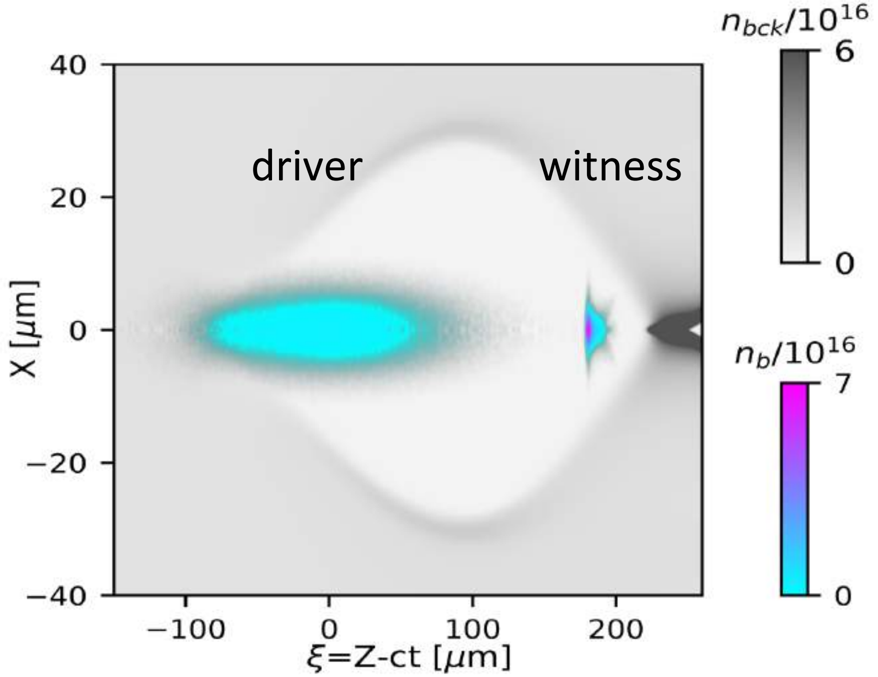


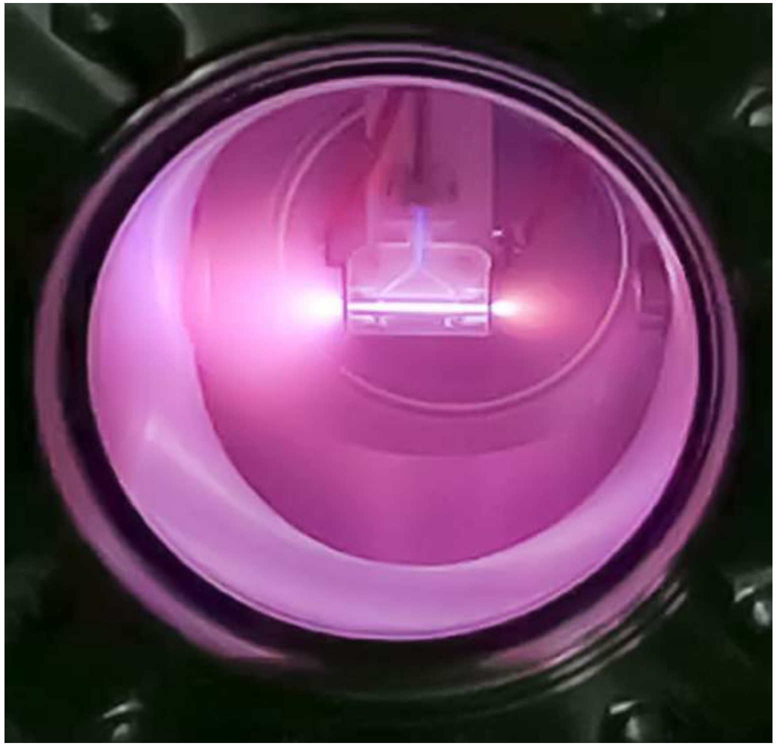


Energy	6 J
Duration	23 fs
Wavelength	800 nm
Bandwidth	60/80 nm
Spot @ focus	10 µm
Peak Power	300 TW
Contrast Ratio	10^{10}

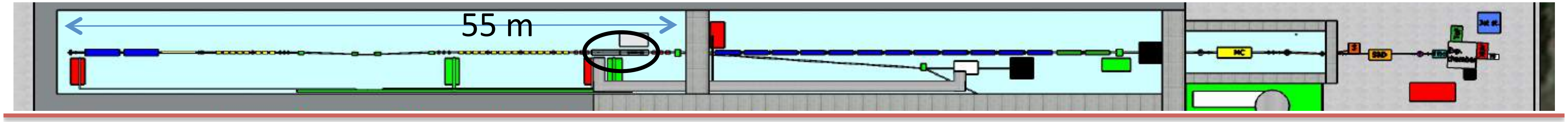


Plasma WakeField Acceleration – External Injection

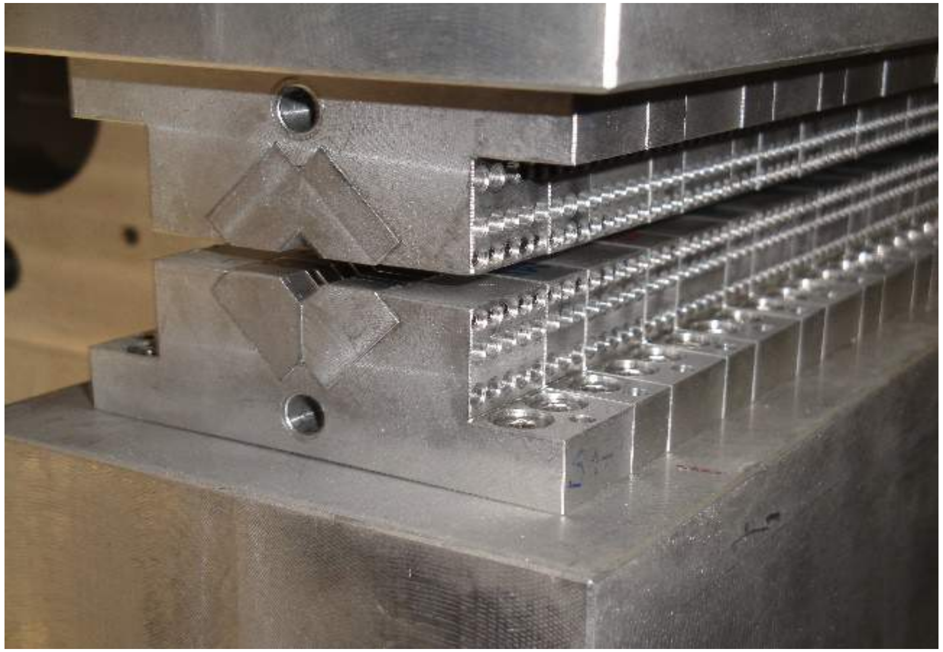




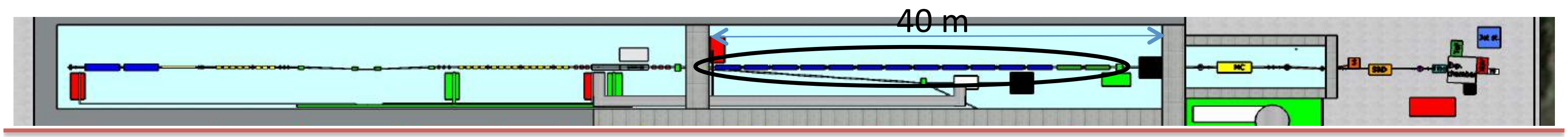
Capillary discharge at SPARC_LAB



Undulators



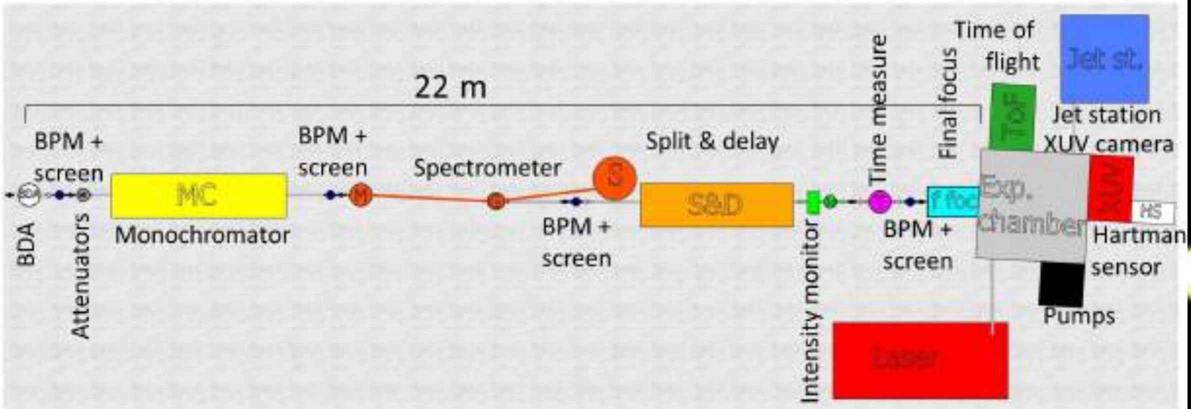
KYMA Δ udulator at SPARC_LAB: λ=1.4 cm, K1

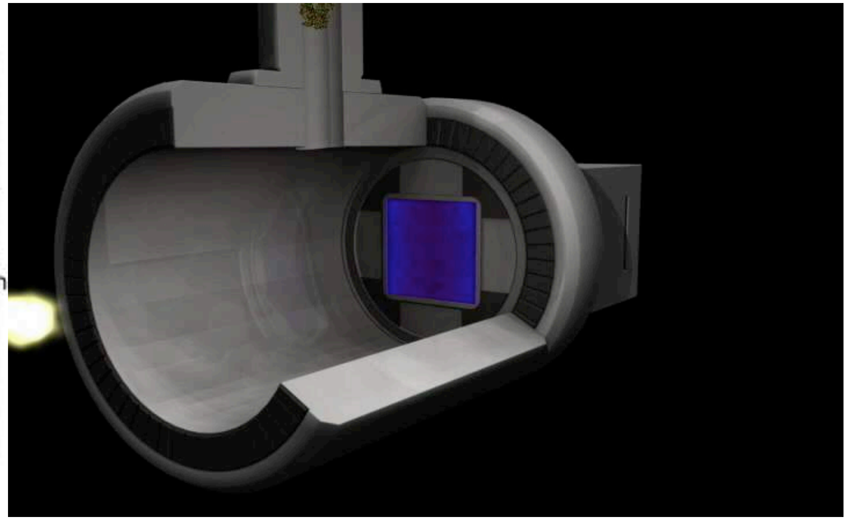


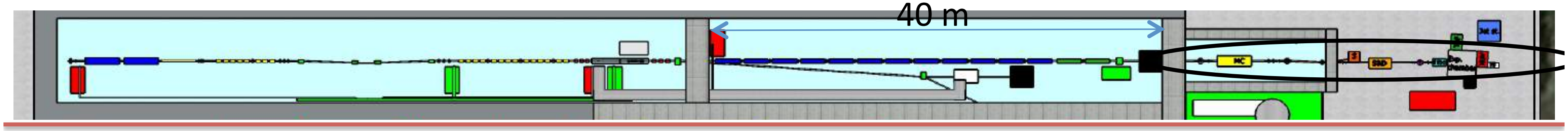
	Units	Full RF case	Plasma case
Electron Energy	GeV	1	1
Bunch Charge	pC	200	30
Peak Current	kA	2	3
RMS Energy Spread	%	0.1	1
RMS Bunch Length	fs	40	4
RMS matched Bunch Spot	μm	34	34
RMS norm. Emittance	μm	1	1
Slice length	μm	0.5	0.45
Slice Energy Spread	%	0.01	0.1
Slice norm. Emittance	μm	0.5	0.5
Undulator Period	mm	15	15
Undulator Strength K		1.03	1.03
Undulator Length	m	12	14
Gain Length	m	0.46	0.5
Pierce Parameter ρ	x 10^{-3}	1.5	1.4
Radiation Wavelength	nm	3	3
Undulator matching β_u	m	4.5	4.5
Saturation Active Length	m	10	11
Saturation Power	GW	4	5.89
Energy per pulse	μJ	83.8	11.7
Photons per pulse	x 10^{11}	11	1.5

Table 2.1: Beam parameters for the EuPRAXIA@SPARC_LAB FEL driven by X-band linac or Plasma acceleration

Photon beam line





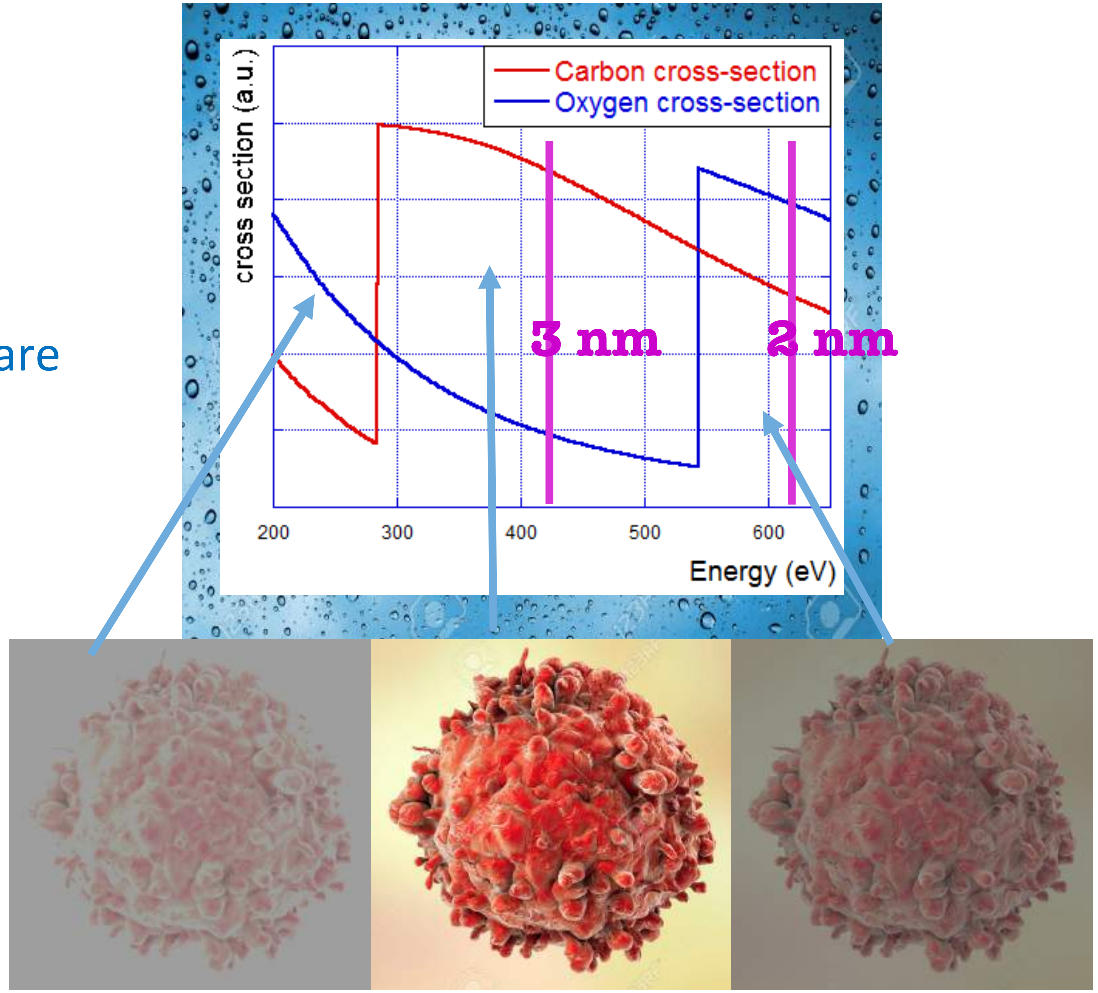


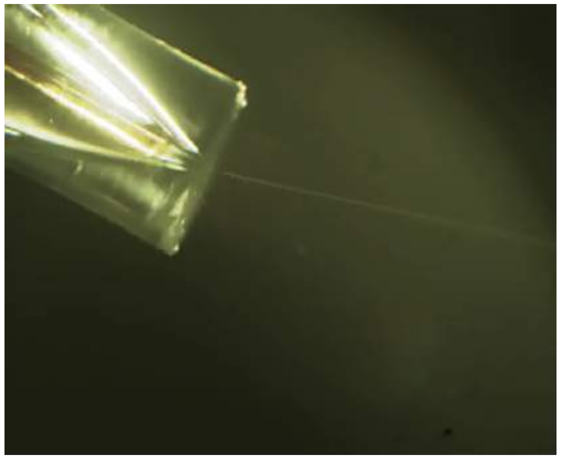
Water Window Coherent Imaging

Energy region between Oxygen and
Carbon K-edge 2.34 nm – 4.4 nm
(530 eV -280 eV)

Water is almost transparent to radiation in this range while nitrogen and carbon are absorbing (and scattering)

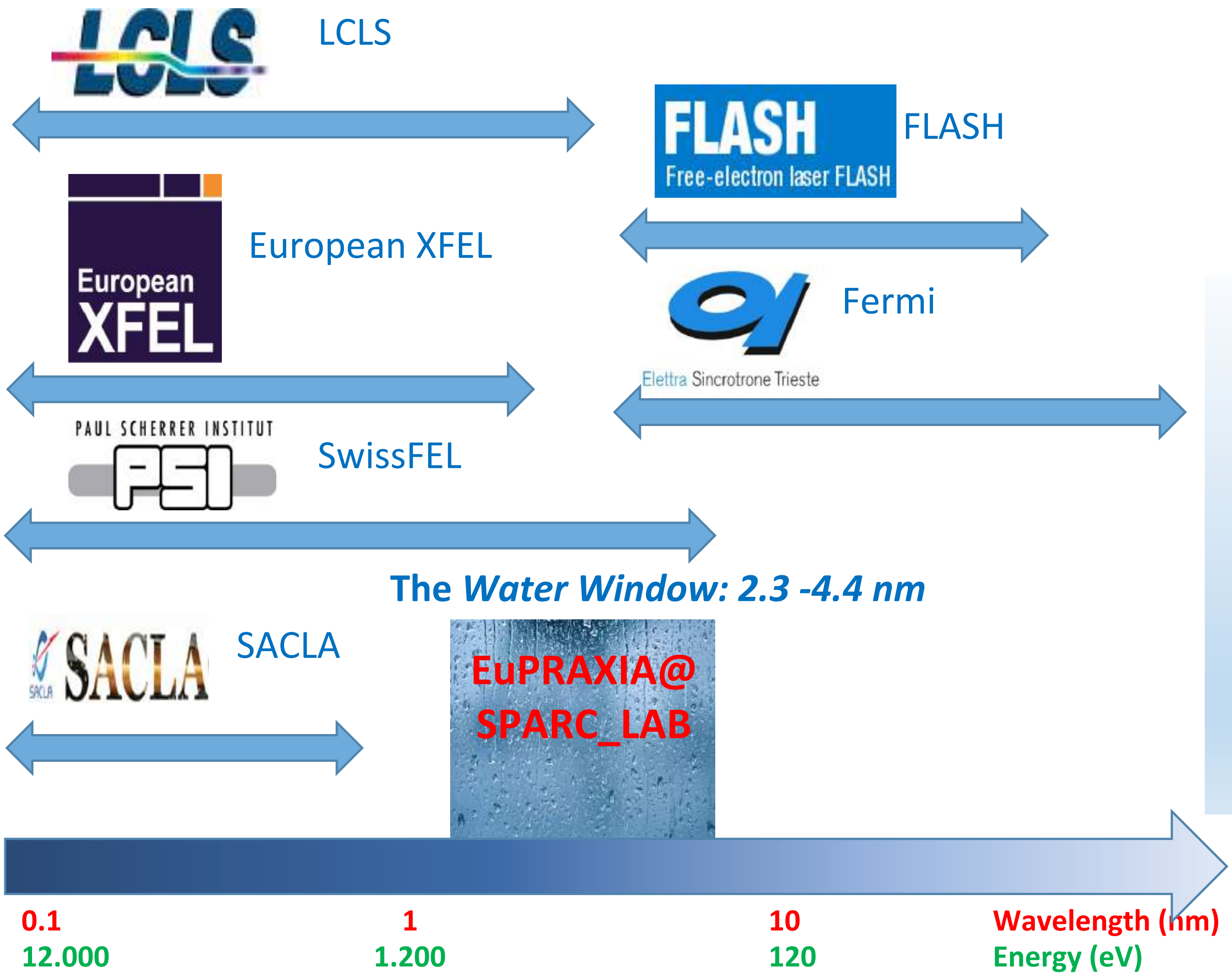
Coherent Imaging of biological samples living in their native state
Possibility to study dynamics





Courtesy F. Stellato, UniToV

Coherent EUV-soft x-ray FELs



Few machines are nowadays operational in the «water window»

Some others will in the mid-term future

Project Timeline