LNF New Projects

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INFN
Istituto Nazionale di Fisica Nucleare

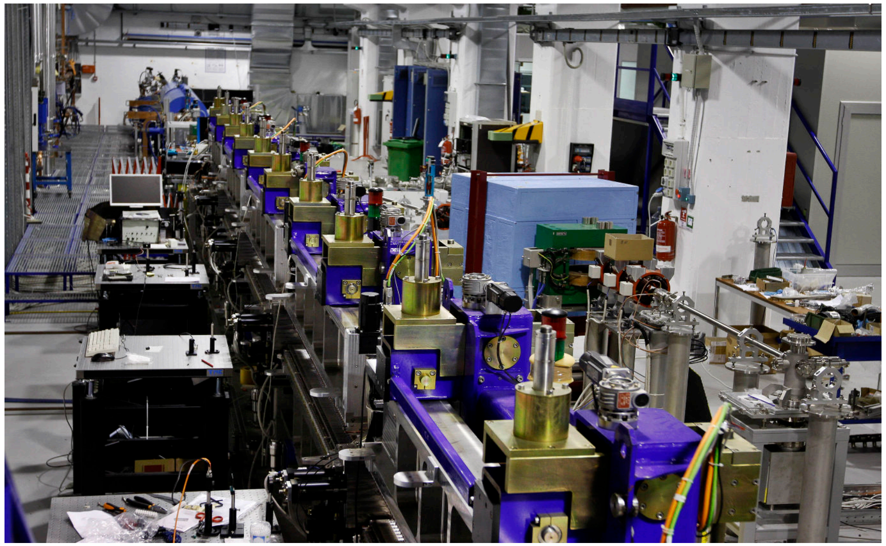
LNF is the largest and the oldest (since 1954) of INFN infrastructures: Personnel ~330 staff (1/3 scientists) + PhD & postdocs + 500 users (30% foreign)

Its main mission: accelerators for High Energy Physics (and not only) + fundamental physics: Main competences in electron/positron machines

Capabilities in designing, building and operate relatively large complex: Accelerator Division (~110 people) Technical Division (~30), Research Division (~150)

Current main activities in accelerator technologies:

- Operation 24/24 **of DAFNE collider** (**up to 2019**)
- Construction of Linac of **ELI-NP** facility (20 MeV Compton γ source in Romania)
- **R&D on plasma acceleration, 0.2 PW laser, FEL, THz sources (SPARC_LAB)**



Several other international collaborations:

- CERN, ESRF Grenoble, KEK (Japan)

Beam Test Facility also available (DAFNE Linac can be used parasitically)
Soft-X, UV, and infrared lines available around DAFNE ring (**DAFNE_Light**)

The Research Division is engaged in Experiments at DAFNE complex:

- KLOE2 (CPT and hadron physics, up to **30.3.18**)
- Siddharta2 (physics of strangeness),
- PADME (search for dark matter)

and at international labs, in particle, nuclear and astro-physics

CERN: LHC (ALICE, ATLAS, CMS, LHCb), NA62; FNAL, Jefferson Lab, China, etc …

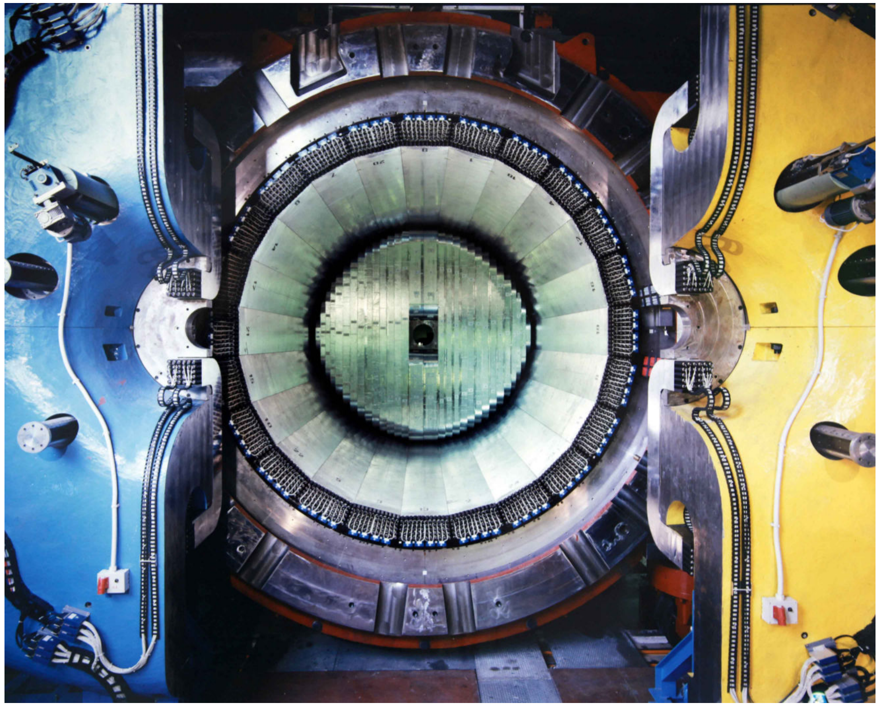
A large spectrum of technological R&D activities:

- Laboratory for space ranging characterization,
- New Materials Lab, X-rays, Neutron Lab,
- Cultural heritage, Radioprotection, etc…

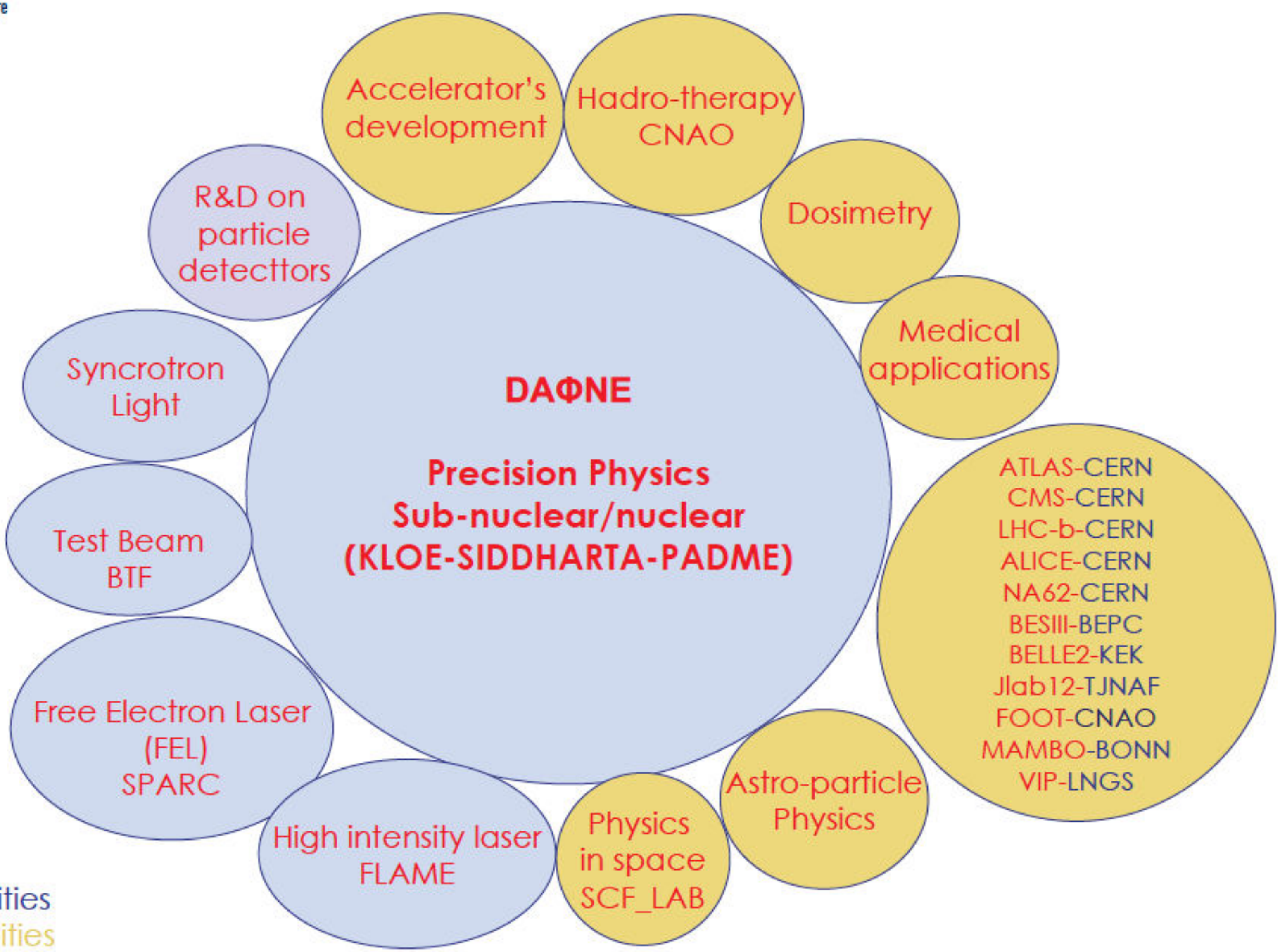
+ 400 m² clean rooms + mechanical/electronics workshops
+ irradiation facilities
+ computing (LHC Tier2 + KLOE data centre)

A long standing tradition in the construction of large detectors

Strong engagements in GEM and micro-pattern detectors and in crystal calorimetry



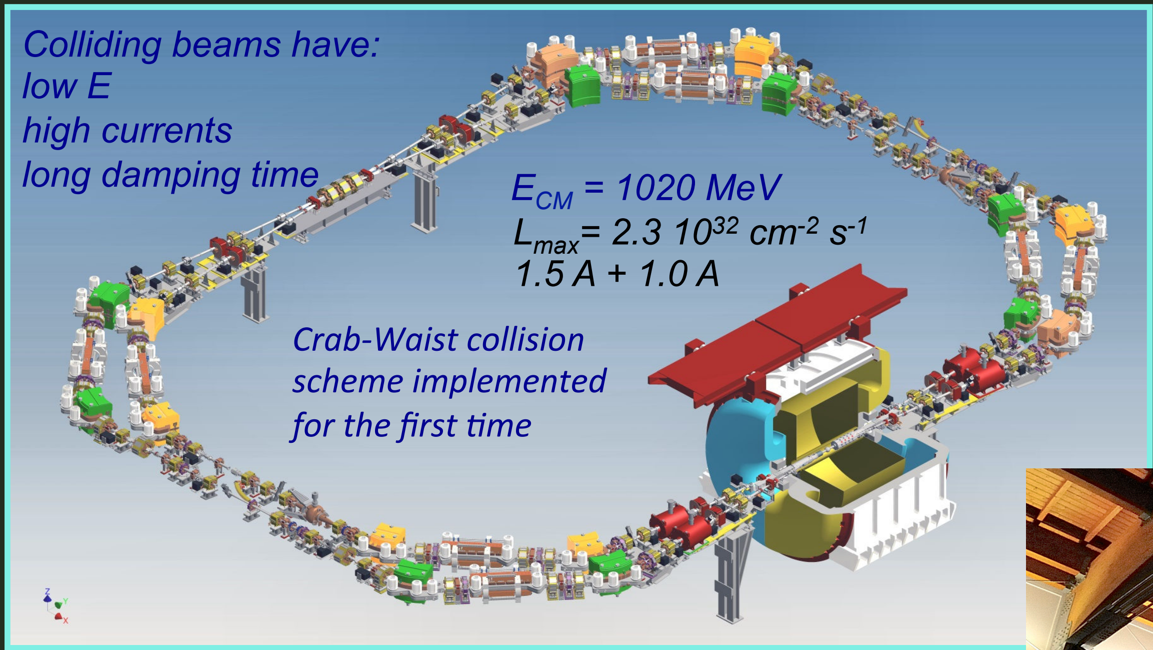
Research Activities at LNF

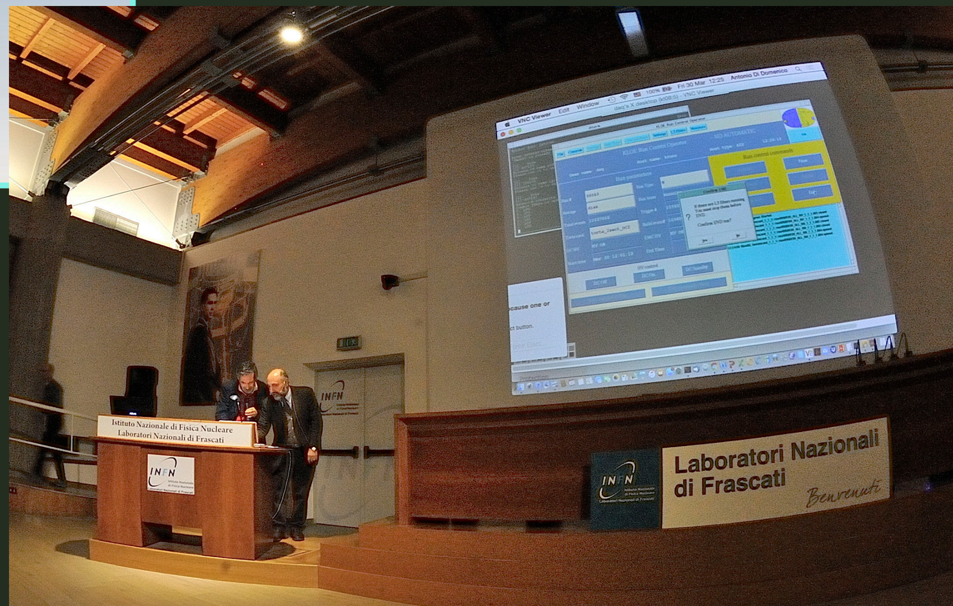


Internal Activities
External activities

KLOE-2 data-taking closing ceremony

March 30th 2018 at 11:00 in the Bruno Touschek Auditorium



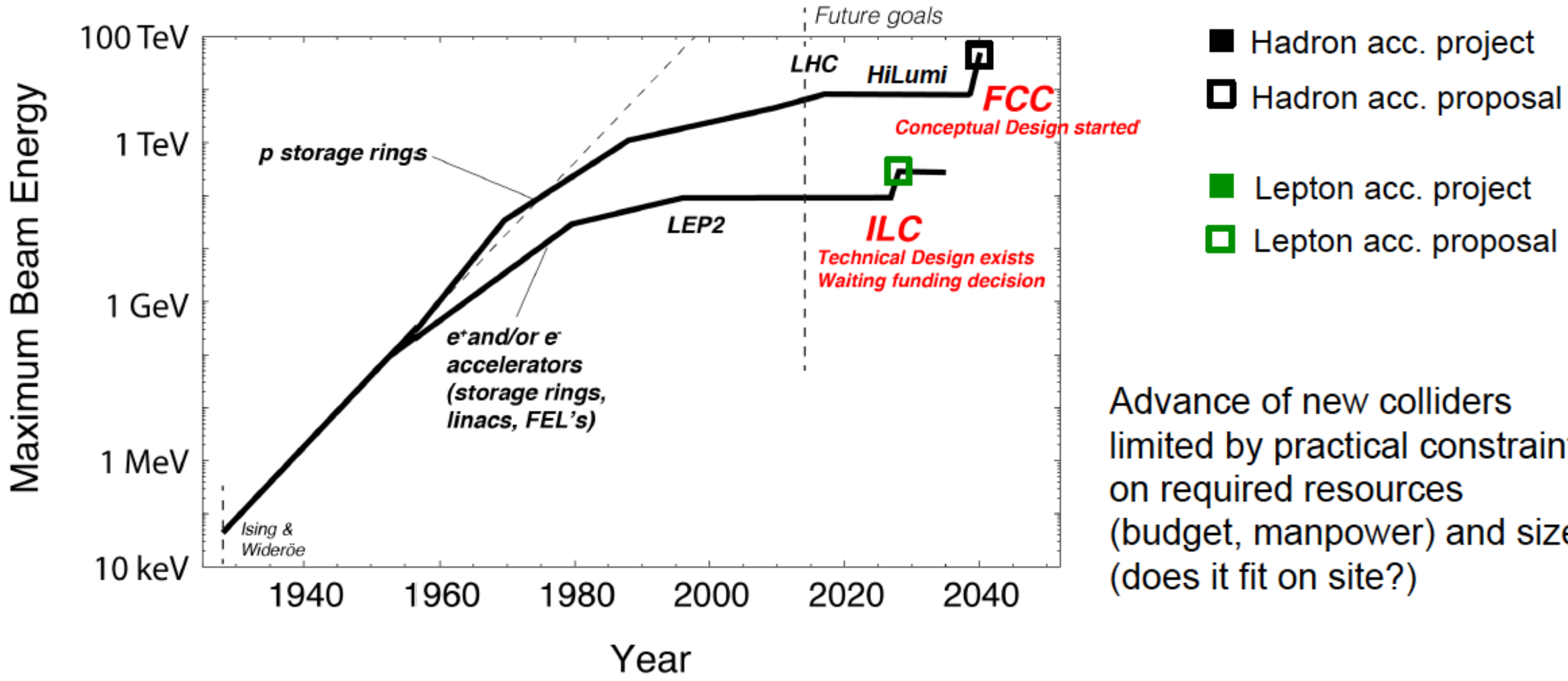


"What Next at LNF site?"

is an often addressed question in many other labs
See for ex. SLAC, DESY, CERN

Slow-down in Energy Increase of Frontier Accelerators

Livingston plot leveling off – here our version, giving beam energy versus time



Advance of new colliders limited by practical constraints on required resources (budget, manpower) and size (does it fit on site?)

Courtesy R. Assmann, DESY

“How to advance?”

Hadron (p) circular collider

$$p = e \cdot R \cdot B_y$$

Increase bending field
SC bend magnet work (FCC-hh)

Increase radius = size (FCC-hh)

Lepton (e-,e+) circular collider

$$p \propto E_0 \cdot \sqrt[4]{\rho \cdot U_0}$$

Increase supplied RF voltage (FCC-ee)

Increase mass of acc. particle (muon)

Increase radius = size (FCC-ee)

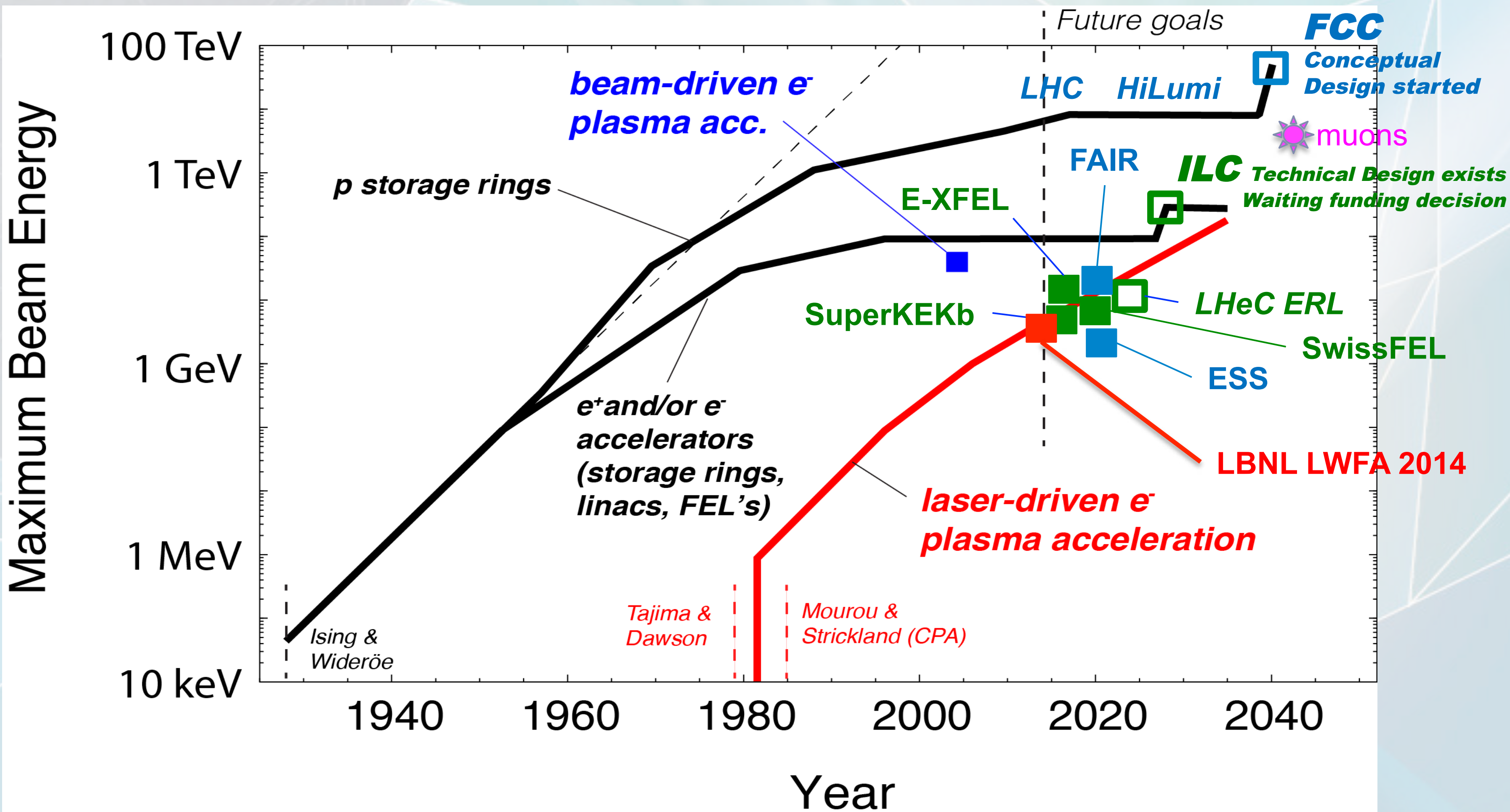
Lepton (e-,e+) linear collider

$$p = L \cdot G_{acc}$$

Increase accelerating gradient
(a) Pushing existing technology (ILC, CLIC)
(b) New regime of ultra-high gradients (plasma, dielectric accelerators)

Increase length (ILC, CLIC)

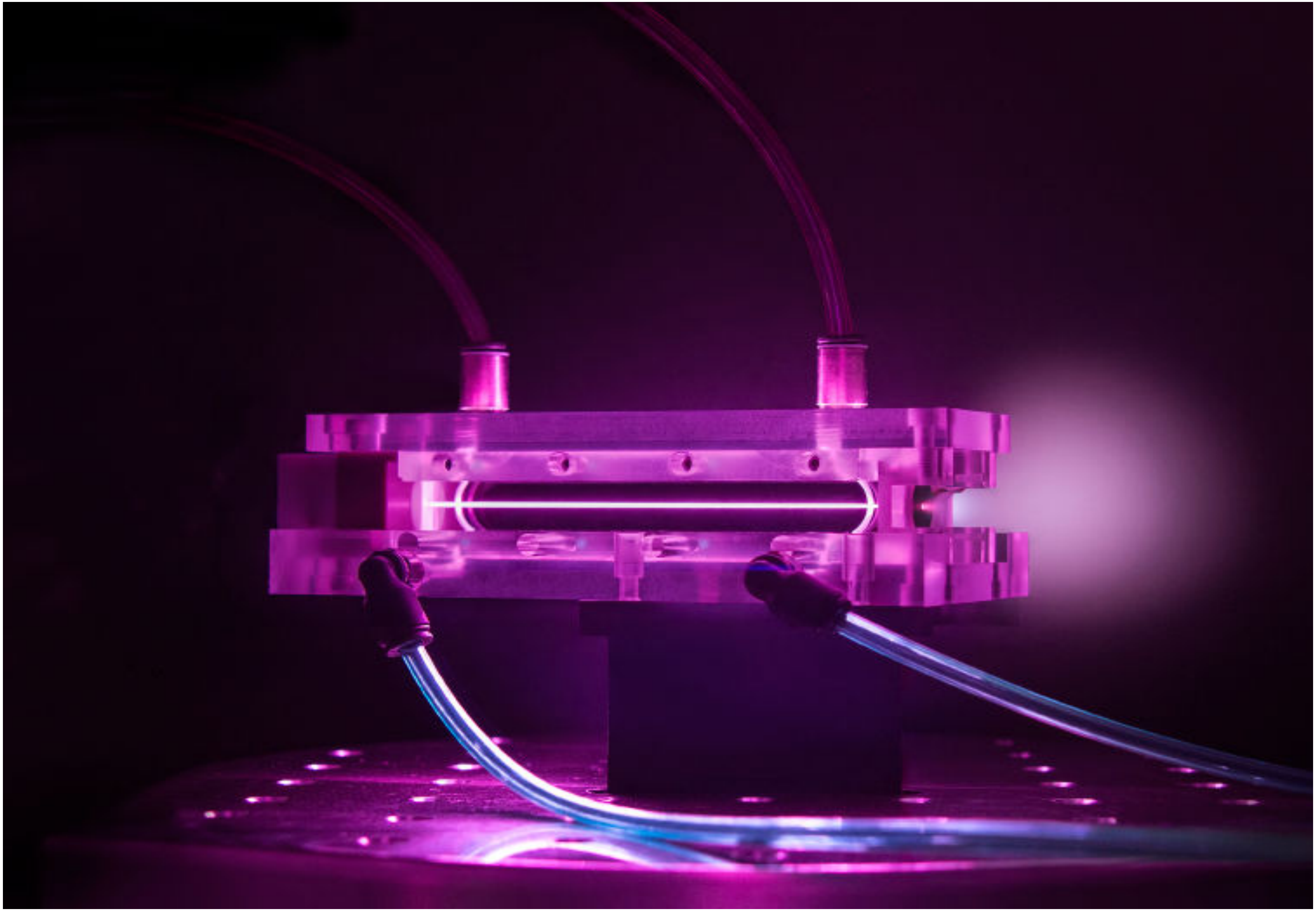
Future of Accelerators



■ Hadron acc. project ■ Lepton acc. project

□ Hadron acc. proposal □ Lepton acc. proposal

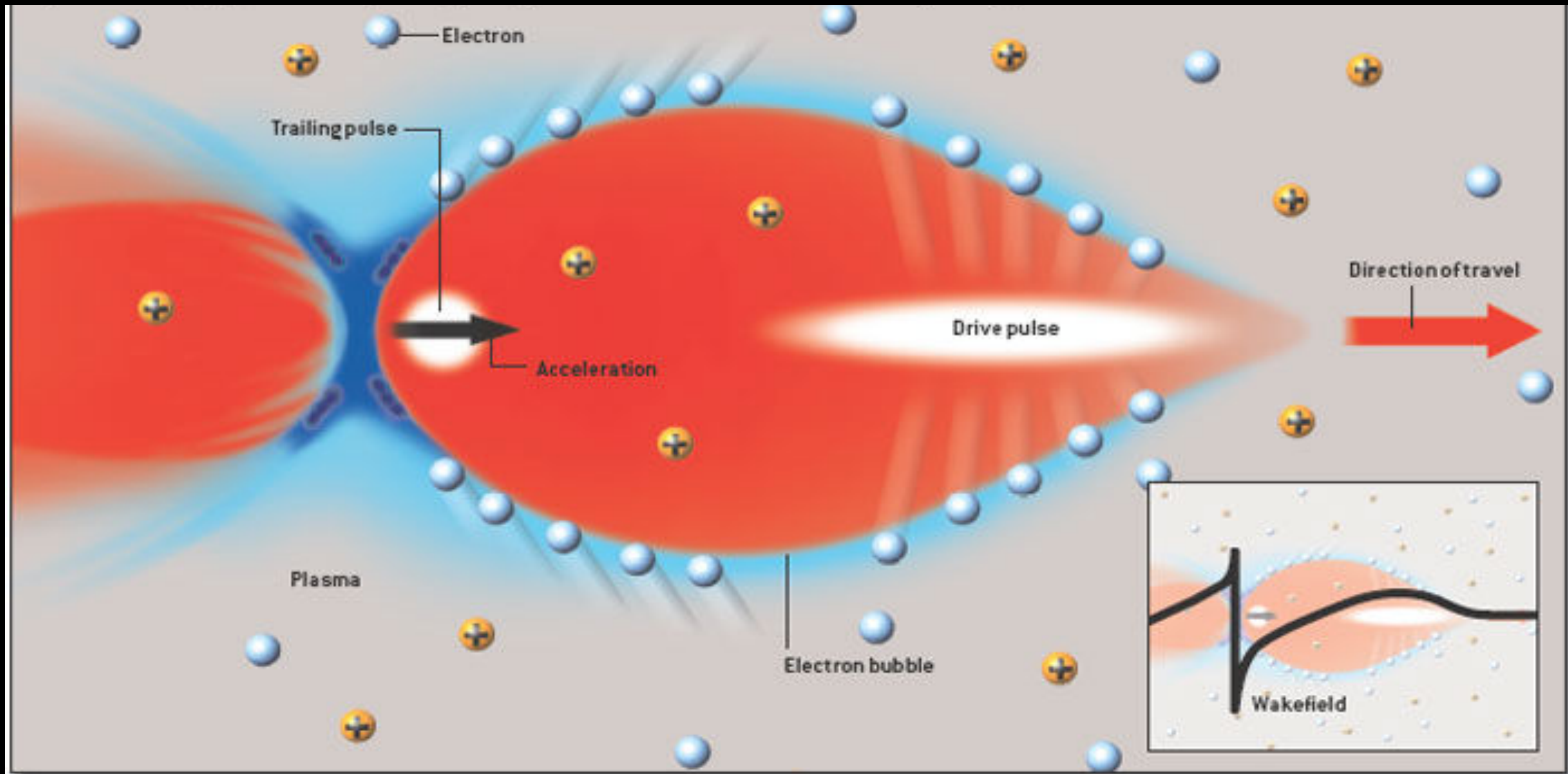
R. Assmann, EAAC 2015, 9/2015



VOLUME 43, NUMBER 4 PHYSICAL REVIEW LETTERS 23 JULY 1979

Laser Electron Accelerator

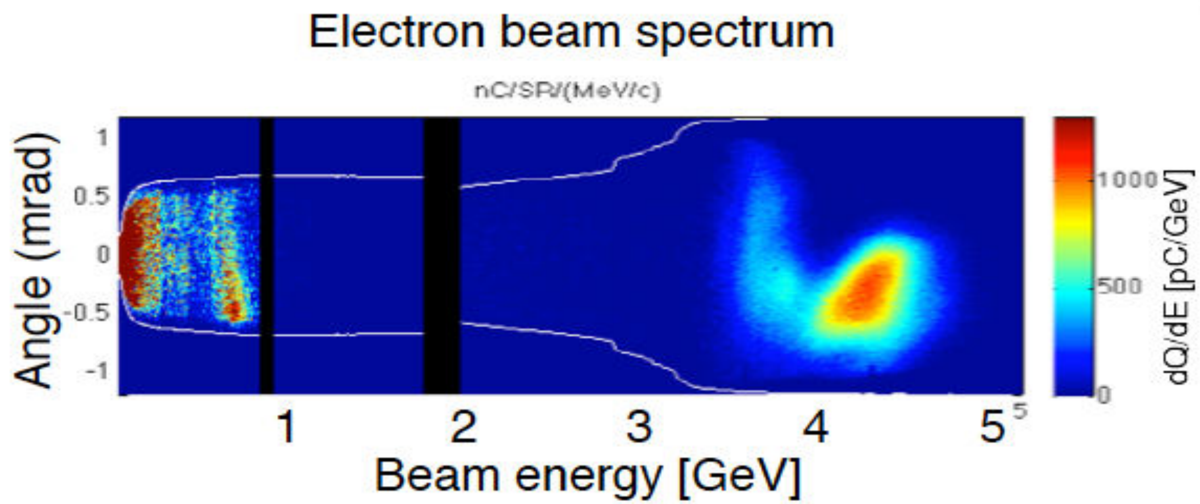
T. Tajima and J. M. Dawson
Department of Physics, University of California, Los Angeles, California 90024
(Received 9 March 1979)

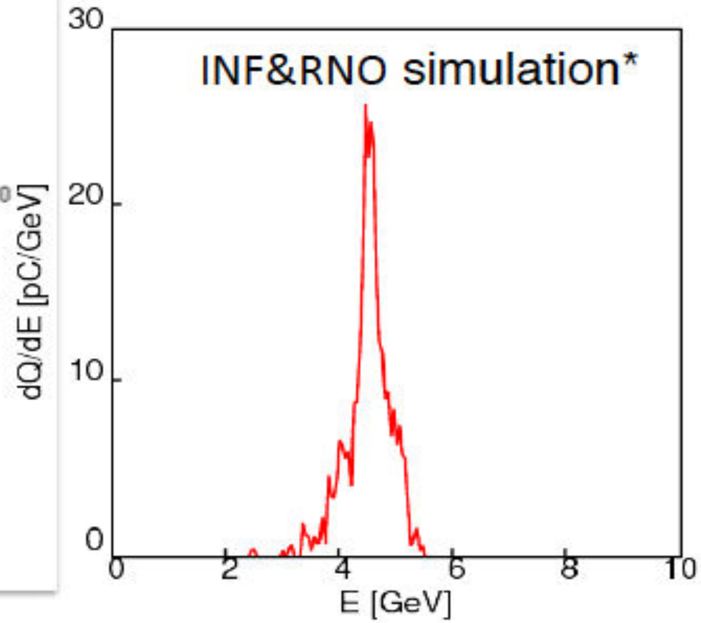


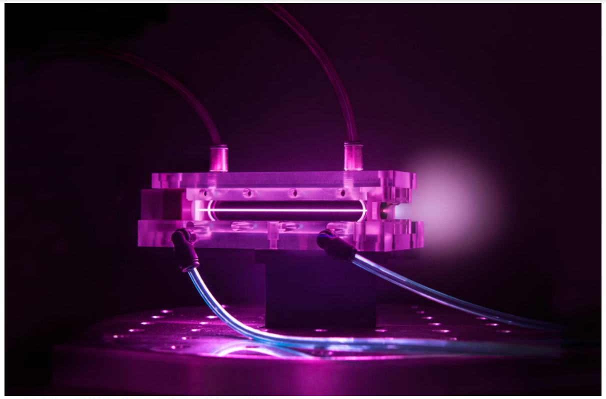
$$E_0 = \frac{m_e c \omega_p}{e} \approx 100[\frac{GeV}{m}] \cdot \sqrt{n_0[10^{18} cm^{-3}]}$$

4.25 GeV beams have been obtained from 9 cm plasma channel powered by 310 TW laser pulses (15 J)

*C. Benedetti et al., proceedings of AAC2010, proceedings of ICAP2012







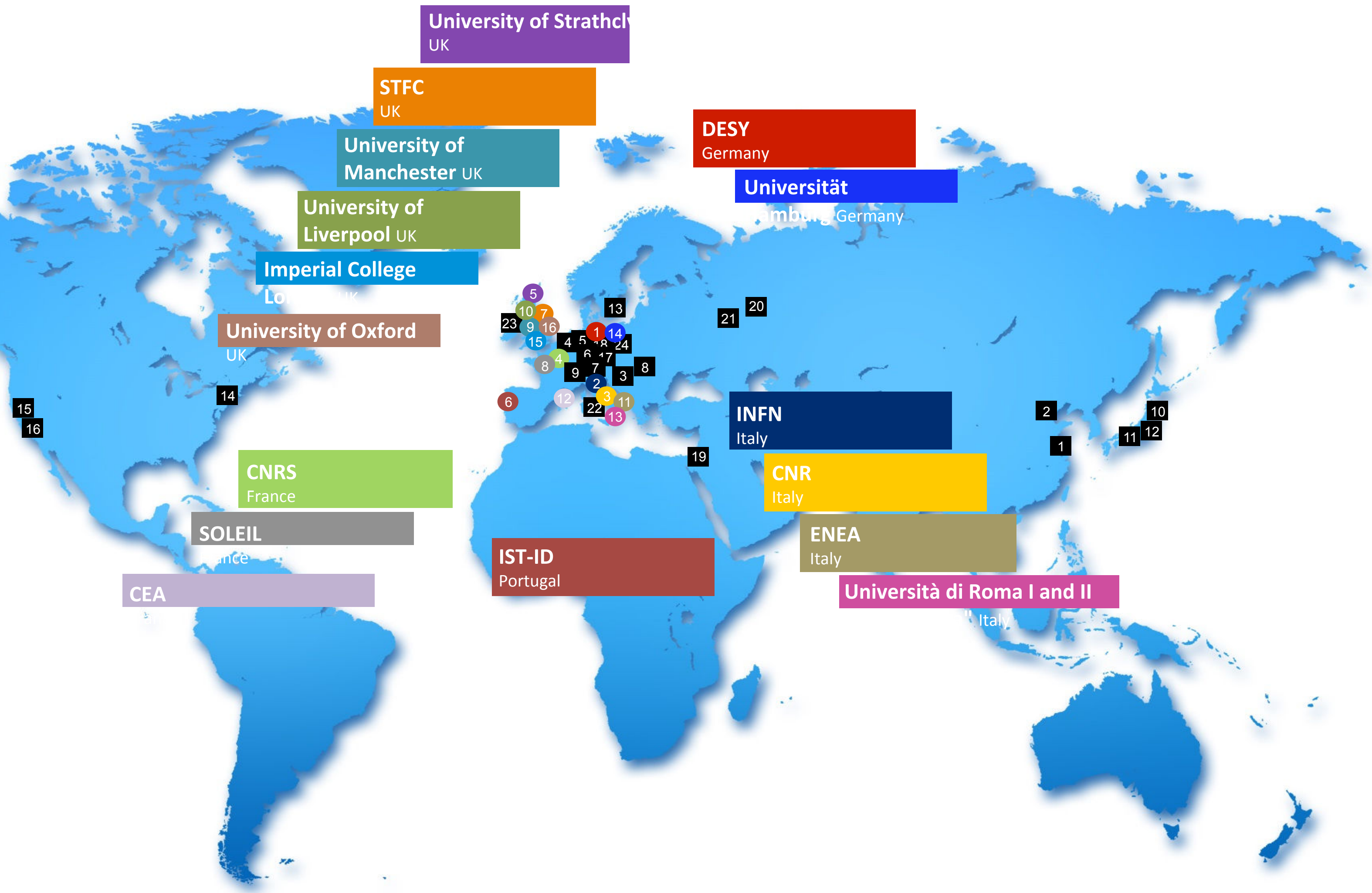
	Exp.	Sim.
Energy	4.25 GeV	4.5 GeV
ΔE/E	5%	3.2%
Charge	~20 pC	23 pC
Divergence	0.3 mrad	0.6 mrad

W.P. Leemans et al.,PRL 2014

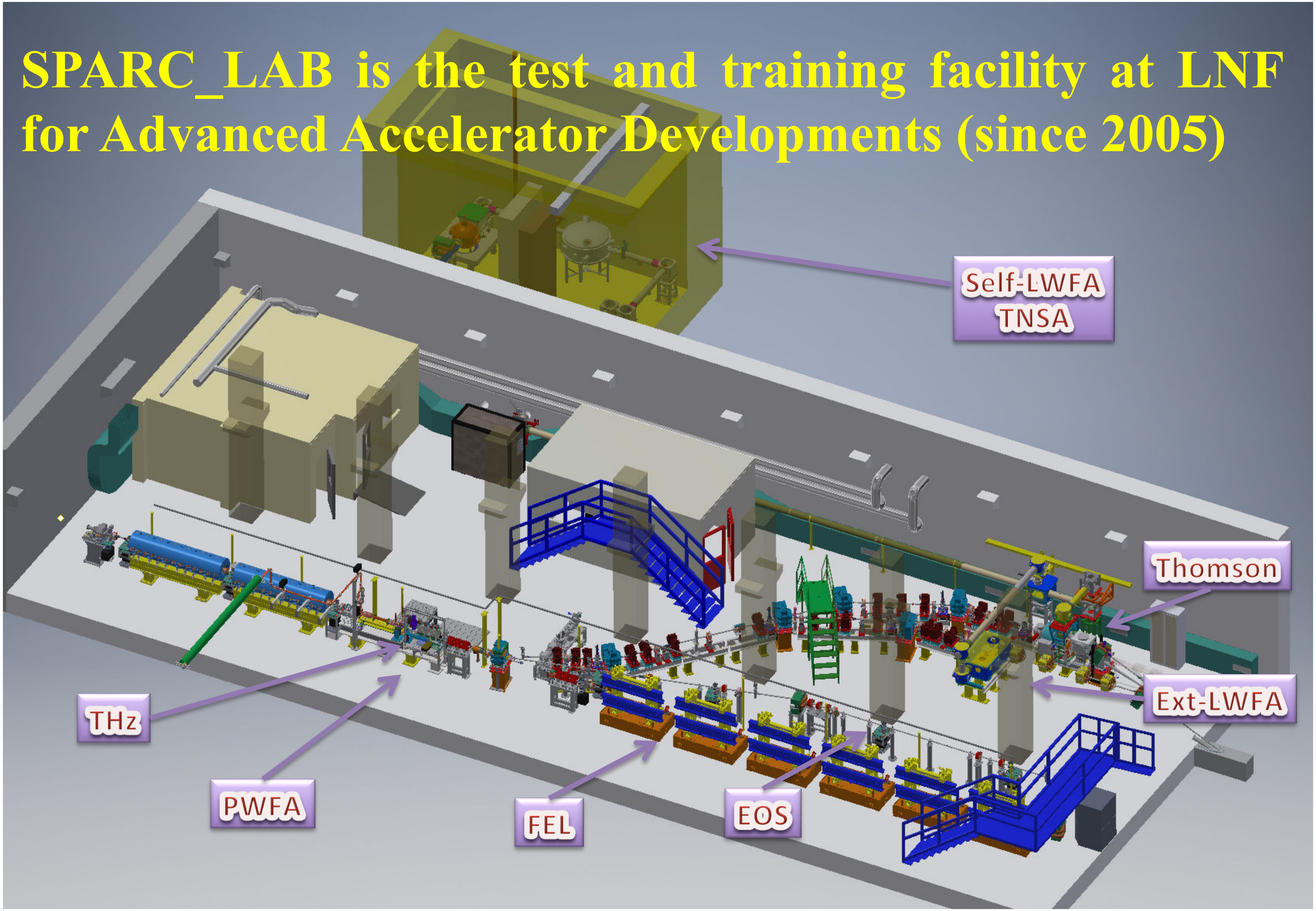
Worldwide effort towards high quality plasma beams

Associated Partners
(as of December 2017)

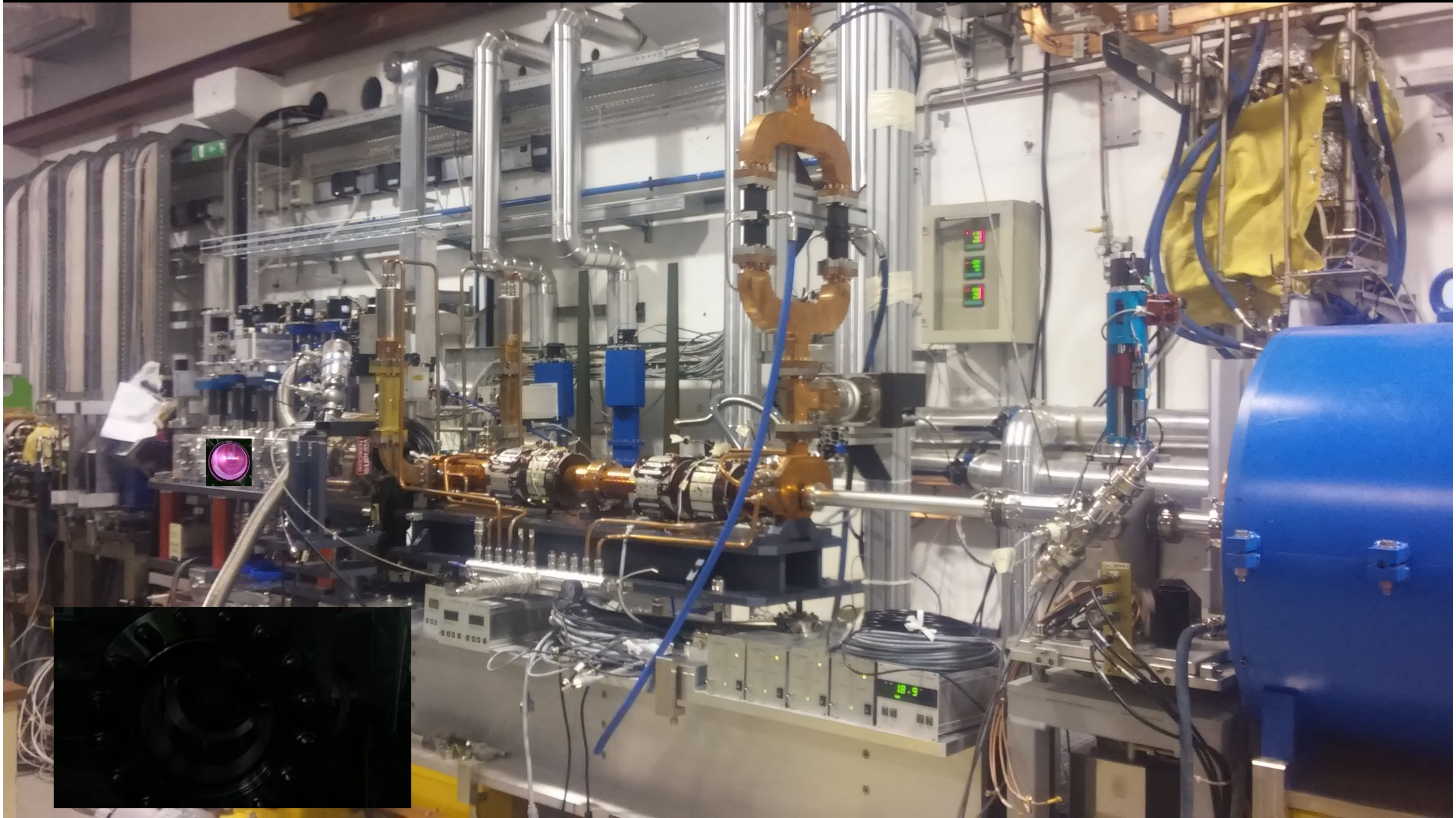
1 **Shanghai Jiao Tong-University**, China
2 **Tsinghua University Beijing**, China
3 **ELI Beamlines**, International
4 **PHLAM, Université de Lille**, France
5 **Helmholtz-Institut Jena**, Germany
6 **HZDR (Helmholtz)**, Germany
7 **LMU München**, Germany
8 **Wigner Fizikai Kutatóközpont**, Hungary
9 **CERN**, International
10 **Kansai Photon Science Institute**, Japan
11 **Osaka University**, Japan
12 **RIKEN SPring-8**, Japan
13 **Lunds Universitet**, Sweden
14 **Stony Brook University & Brookhaven NL**, USA
15 **LBNL**, USA
16 **UCLA**, USA
17 **Karlsruher Institut für Technologie**, Germany
18 **Forschungszentrum Jülich**, Germany
19 **Hebrew University of Jerusalem**, Israel
20 **Institute of Applied Physics**, Russia
21 **Joint Institute for High Temperatures**, Russia
22 **Università di Roma 'Tor Vergata'**, Italy
23 **Queen's University Belfast**, UK
24 **Ferdinand-Braun-Institut**, Germany



SPARC_LAB is the test and training facility at LNF for Advanced Accelerator Developments (since 2005)



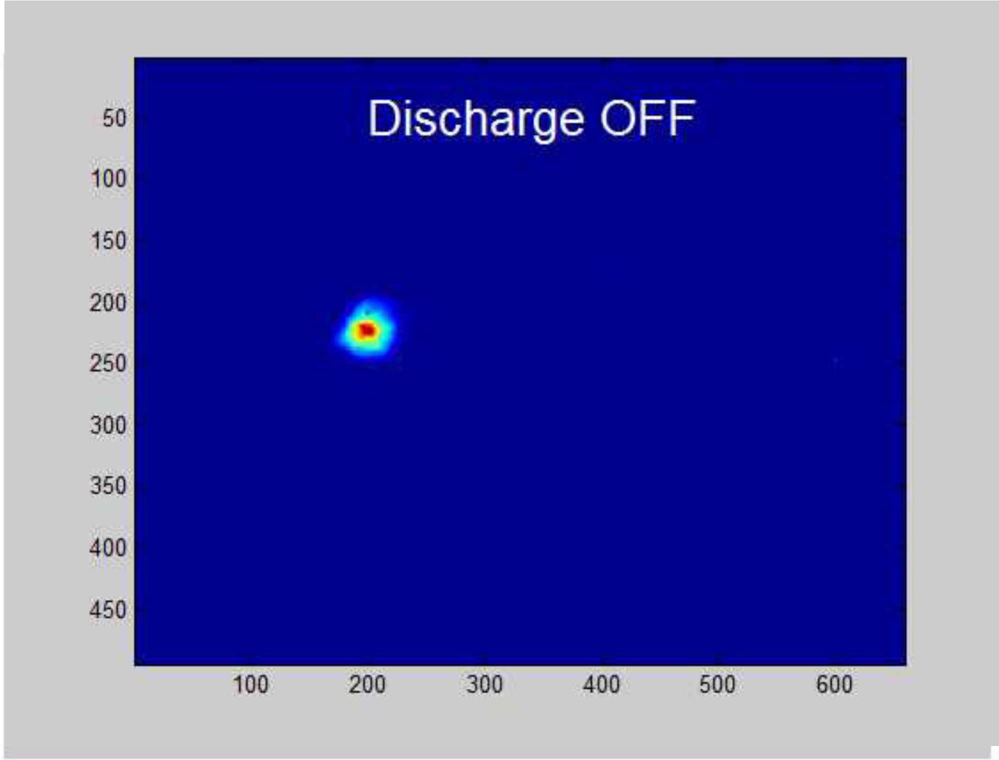
PWFA vacuum chamber at SPARC_LAB

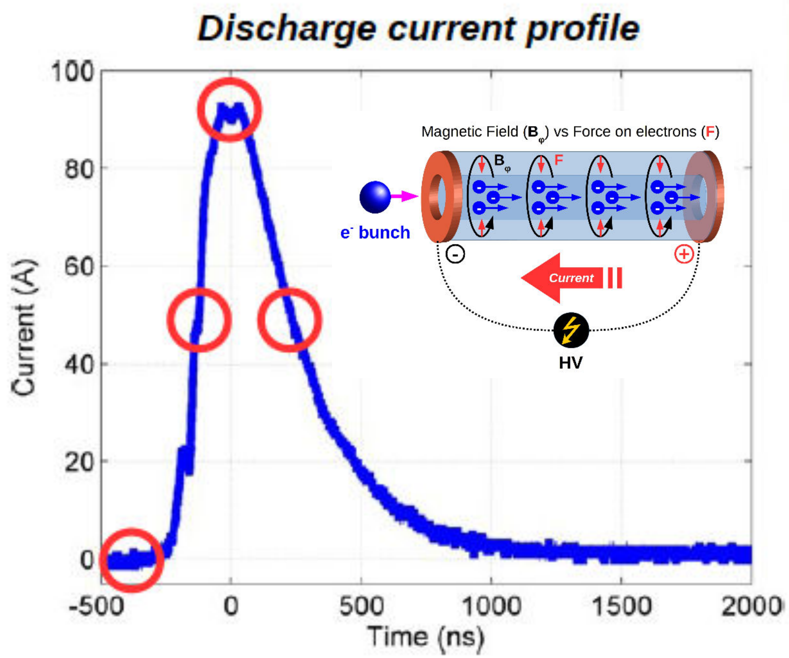


APPLIED PHYSICS LETTERS **110**, 104101 (2017)

Experimental characterization of active plasma lensing for electron beams

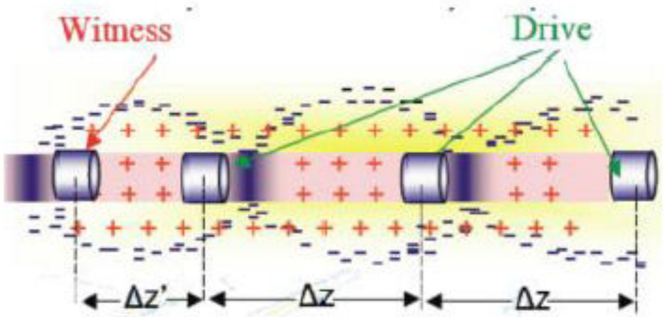
R. Pompili,[1,a)] M. P. Anania,[1] M. Bellaveglia,[1] A. Biagioni,[1] S. Bini,[1] F. Bisesto,[1]
E. Brentegani,[1] G. Castorina,[1,2] E. Chiadroni,[1] A. Cianchi,[3] M. Croia,[1] D. Di Giovenale,[1]
M. Ferrario,[1] F. Filippi,[1] A. Giribono,[4] V. Lollo,[1] A. Marocchino,[1] M. Marongiu,[4] A. Mostacci,[4]
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

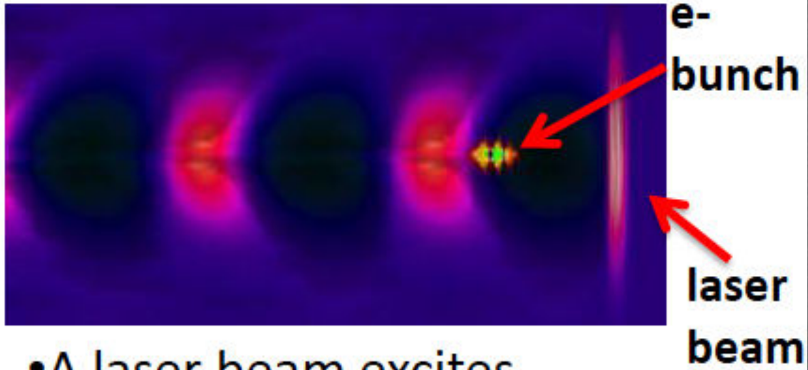
resonant-PWFA



•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}
λ_p = 300µm
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}
λ_p = 100µm
Capillary 100 µm
Hydrogen

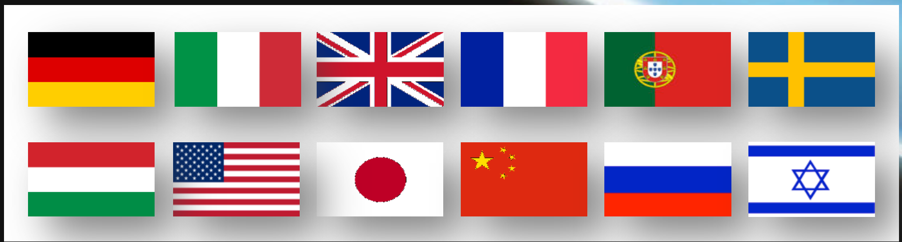
EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA

EuPRAXIA Design Study started on Novemebr 2015

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

Coordinator: Ralph Assmann (DESY)



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

http://eupraxia-project.eu

Motivations

Horizon2020

PRESENT EXPERIMENTS

Demonstrating **100 GV/m** routinely

Demonstrating **GeV** electron beams

Demonstrating basic **quality**

EuPRAXIA INFRASTRUCTURE

Engineering a high quality, compact plasma accelerator

5 GeV electron beam for the 2020's

Demonstrating user readiness

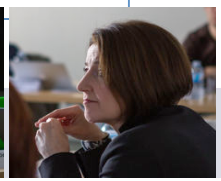
Pilot users from FEL, HEP, medicine, ...

PRODUCTION FACILITIES

Plasma-based **linear collider** in 2040's

Plasma-based **FEL** in 2030's

Medical, industrial applications soon



Courtesy R. Assmann

Consortium

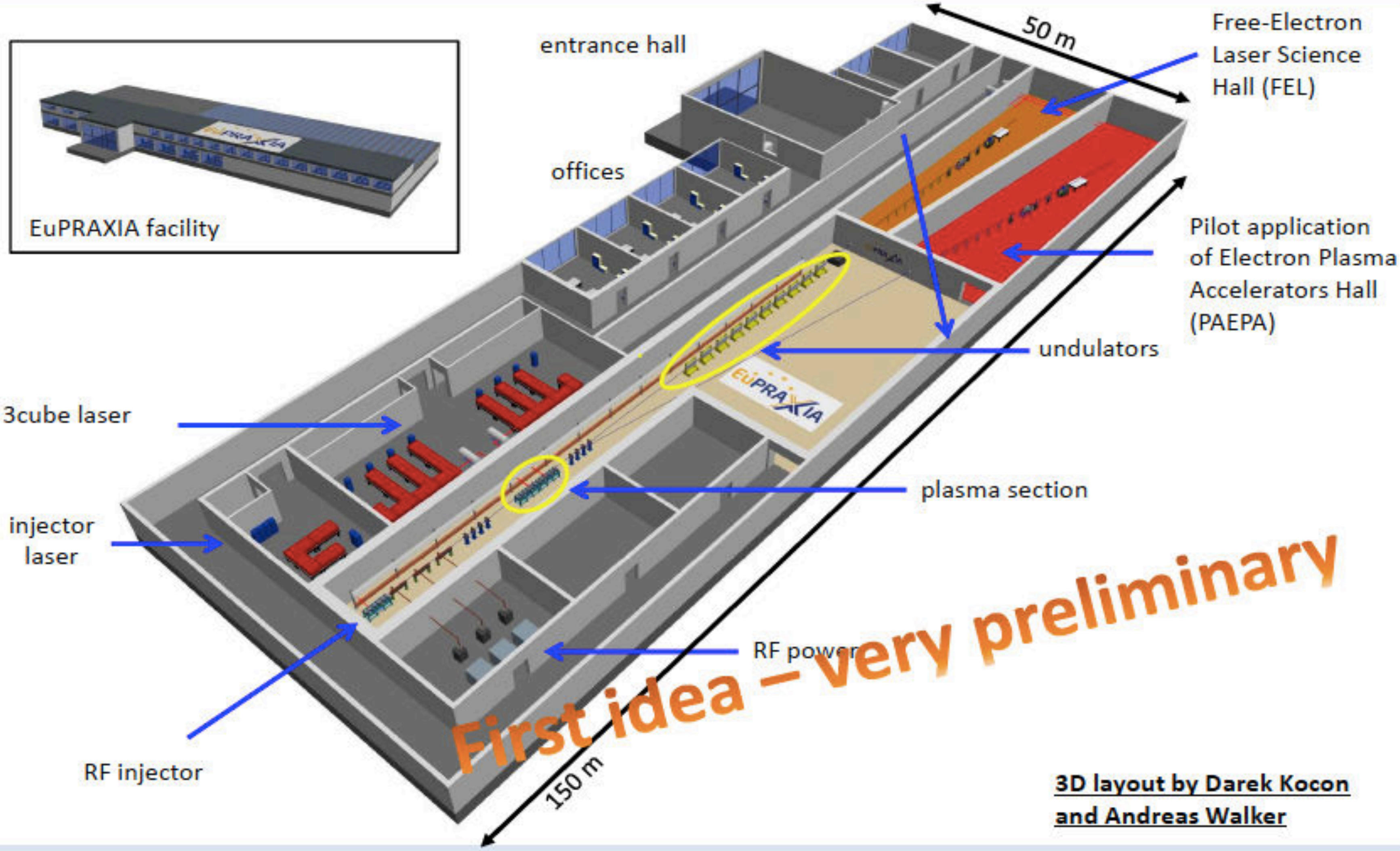
Horizon 2020

16 Participants

24 Associated Partners

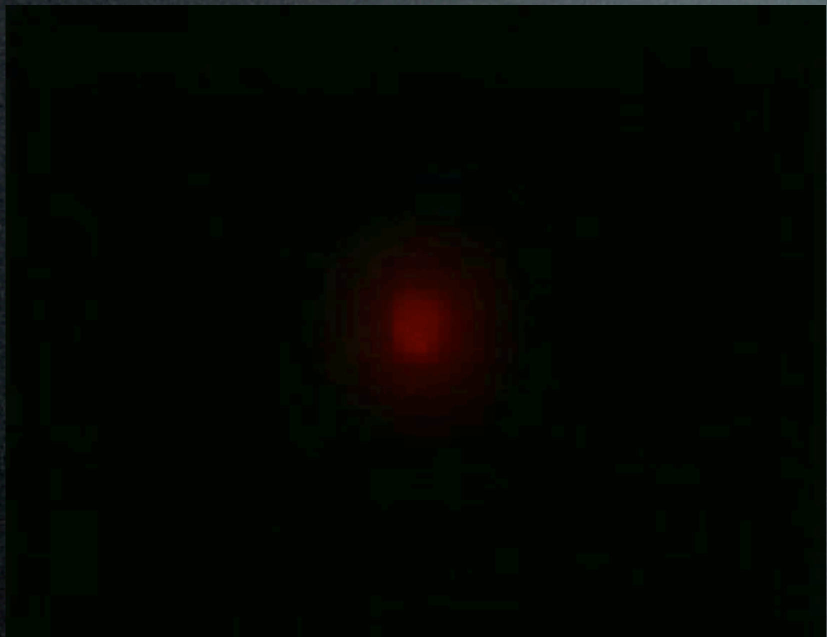
(as of December 2017)

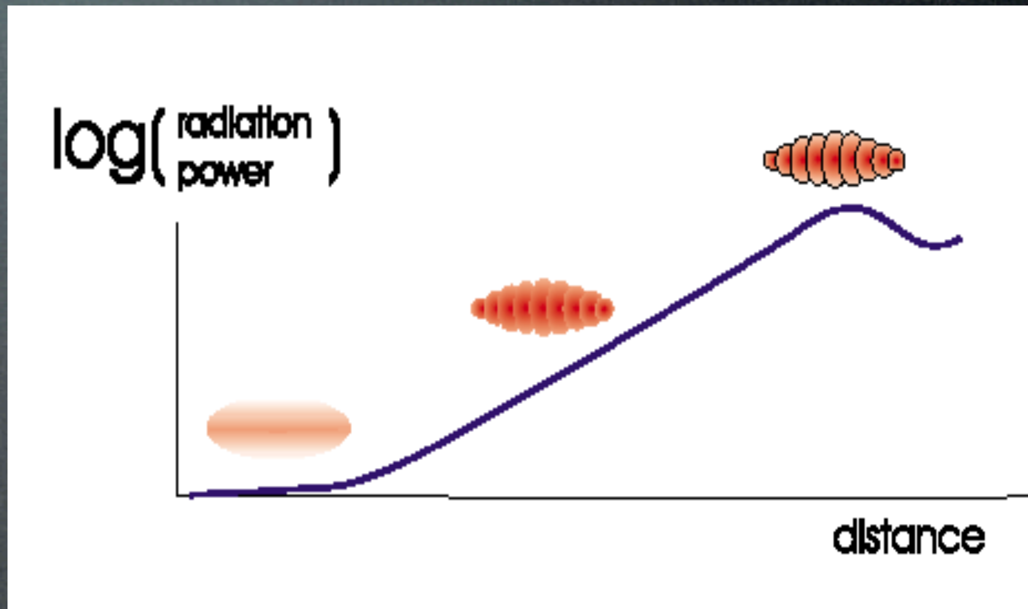
draft of facility layout



3D layout by Darek Kocon and Andreas Walker

A Free Electron Laser is a device that converts a fraction of the electron kinetic energy into coherent radiation via a collective instability in a long undulator





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

(Tunability - Harmonics)

Location of possible sites within EU

Horizon 2020

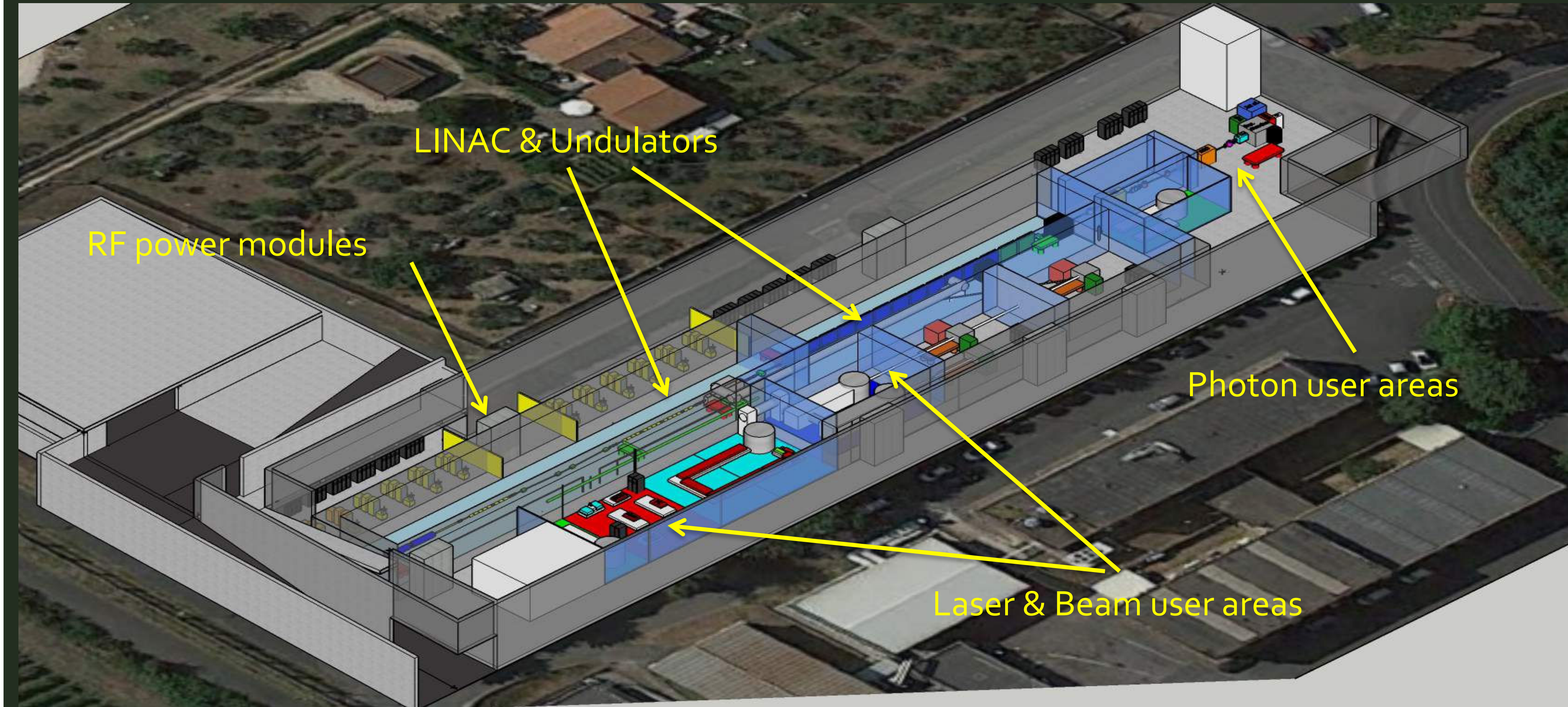
EuPRAXIA site studies:

- 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

EuPRAXIA@SPARC_LAB



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

D. Alesini[a], M. P. Anania[a], M. Artioli[b], A. Bacci[c], S. Bartocci[d], R. Bedogni[a], M. Bellaveglia[a], A. Biagioni[a], F. Bisesto[a], F. Brandi[e], E. Brentegani[a], F. Broggi[c], B. Buonomo[a], P. Campana[a], G. Campogiani[a], C. Cannaos[d], S. Cantarella[a], F. Cardelli[a], M. Carpanese[f], M. Castellano[a], G. Castorina[g], N. Catalan Lasheras[h], E. Chiadroni[a], A. Cianchi[i], R. Cimino[a], F. Ciocci[f], D. Cirrincione[j], G. A. P. Cirrone[k], R. Clementi[a], M. Coreno[l], R. Corsini[h], M. Croia[a], A. Curcio[a], G. Costa[a], C. Curatolo[c], G. Cuttone[k], S. Dabagov[a], G. Dattoli[f], G. D'Auria[l], I. Debrot[c], M. Diomede[a,g], A. Drago[a], D. Di Giovenale[a], S. Di Mitri[l], G. Di Pirro[a], A. Esposito[a], M. Faiferri[d], M. Ferrario[a], L. Ficcadenti[g], F. Filippi[a], O. Frasciello[a], A. Gallo[a], A. Ghigo[a], L. Giannessi[f,l], A. Giribono[a], L. A. Gizzi[e], A. Grudiev[h], S. Guiducci[a], P. Koester[e], S. Incremona[a], F. Iungo[a], L. Labate[e], A. Latina[h], S. Licciardi[f], V. Lollo[a], S. Lupi[g], R. Manca[d], A. Marcelli[a,m,n], M. Marini[d], A. Marocchino[a], M. Marongiu[g], V. Martinelli[a], C. Masciovecchio[l], C. Mastino[d], A. Michelotti[a], C. Milardi[a], M. Migliorati[g], V. Minicozzi[i], F. Mira[g], S. Morante[i], A. Mostacci[g], F. Nguyen[f], S. Pagnutti[f], L. Palumbo[g], L. Pellegrino[a], A. Petralia[f], V. Petrillo[o], L. Piersanti[a], S. Pioli[a], D. Polese[d], R. Pompili[a], F. Pusceddu[d], A. Ricci[m], R. Ricci[a], R. Rochow[l], S. Romeo[a], J. B. Rosenzweig[p], M. Rossetti Conti[o], A. R. Rossi[c], U. Rotundo[a], L. Sabbatini[a], E. Sabia[f], O. Sans Plannell[a], D. Schulte[h], J. Scifo[a], V. Scuderi[k], L. Serafini[c], B. Spataro[a], A. Stecchi[a], A. Stella[a], V. Shpakov[a], F. Stellato[i], P. Tomassini[e], E. Turco[d], C. Vaccarezza[a], A. Vacchi[j], A. Vannozzi[a], G. Vantaggiato[e], A. Variola[a], S. Vescovi[a], F. Villa[a], W. Wuensch[h], A. Zigler[q], M. Zobov[a]

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[d] *Universitá degli Studi di Sassari, Dip. di Architettura, Design e Urbanistica ad Alghero, Palazzo del Pou Salit - Piazza Duomo 6, 07041 Alghero, Italy*
[e] *Intense Laser Irradiation Laboratory (ILIL), Istituto Nazionale di Ottica (INO), Consiglio Nazionale delle Ricerche (CNR), Via G. Moruzzi 1, 56124 Pisa, Italy and INFN Pisa section, Pisa, Largo Pontecorvo 3, 56127 Pisa, Italy*
[f] *ENEA - Centro Ricerche Frascati, Via E. Fermi 45, 00044 Frascati, Italy*
[g] *Sapienza University of Roma and INFN, P.le Aldo Moro 2, 00185 Rome, Italy*
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[l] *Elettra-Sincrotrone Trieste, Area Science Park, 34149 Trieste, Italy*
[m] *RICMASS, Rome International Center for Materials Science Superstripes, 00185 Rome, Italy*
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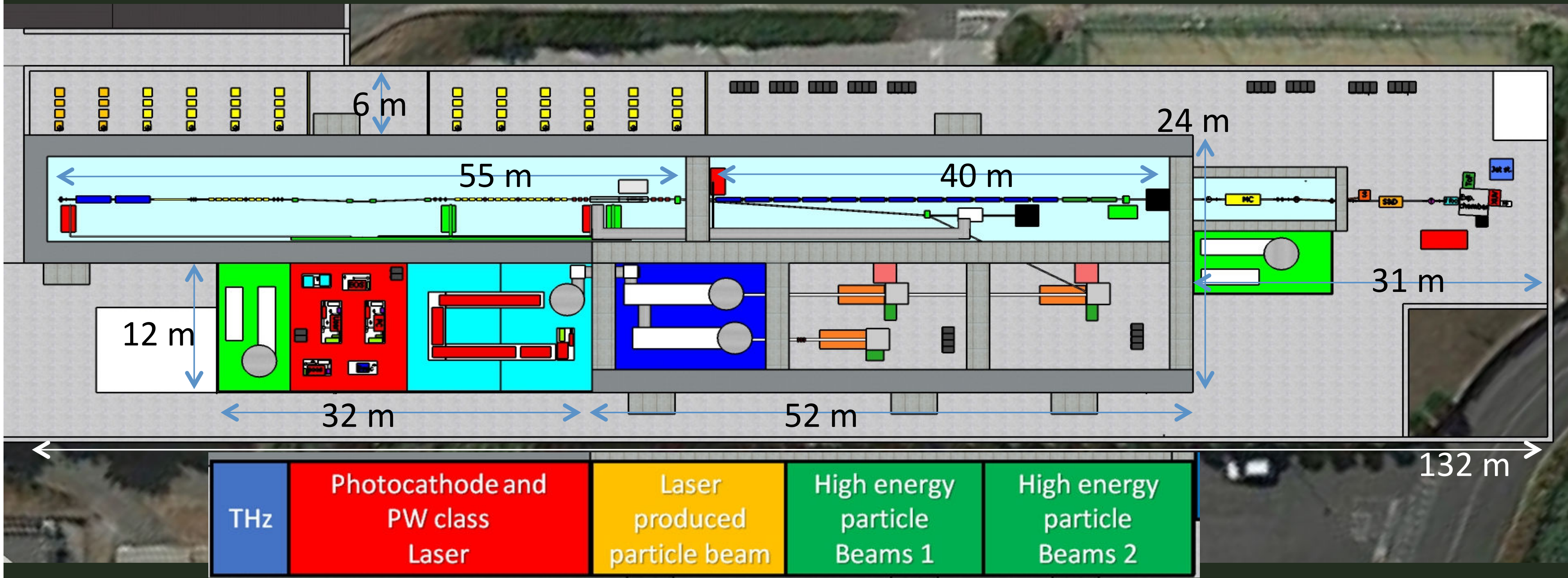
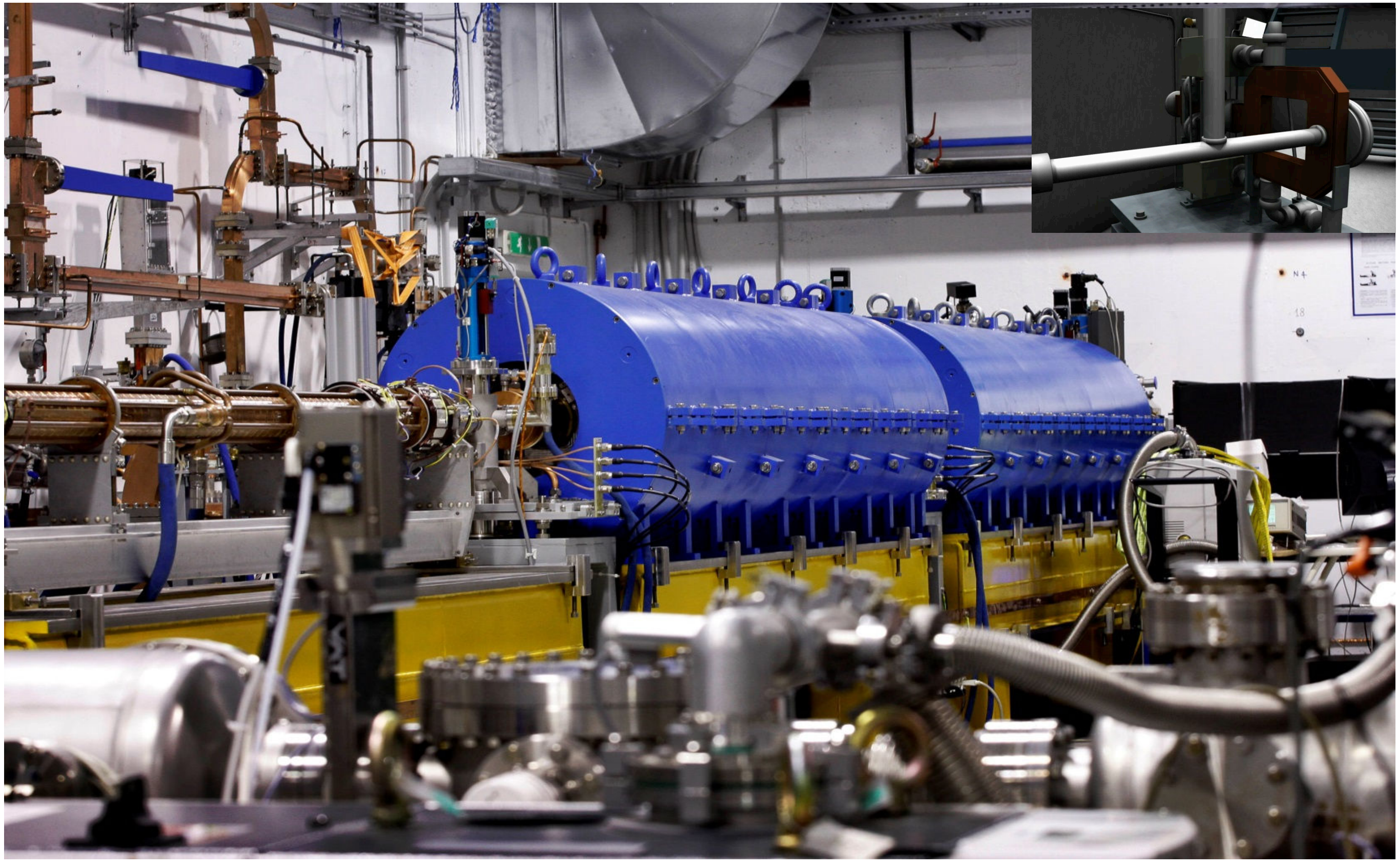
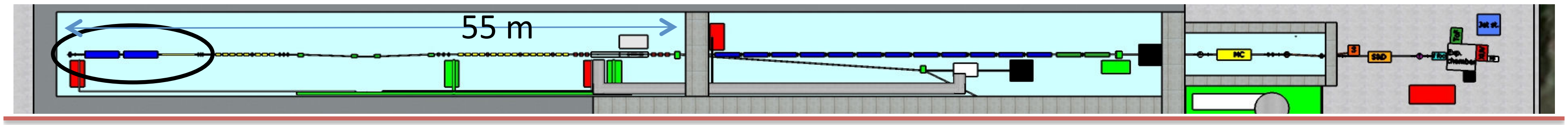
- Candidate LNF to host EuPRAXIA (1-5 GeV)
- FEL user facility (1 GeV – 3nm)
- Advanced Accelerator Test facility (LC) + CERN



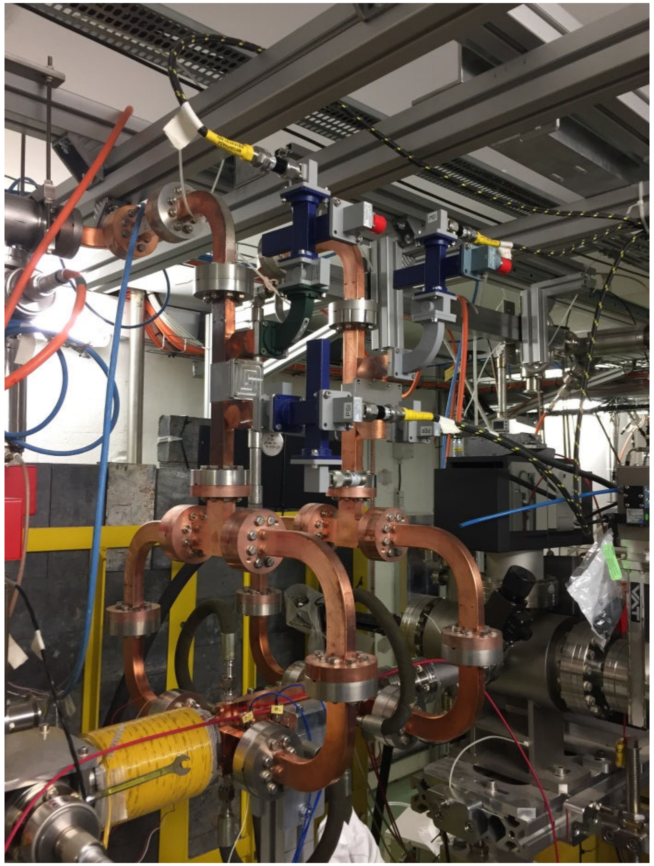
- 500 MeV by RF Linac + 500 MeV by Plasma (LWFA or PWFA)
- 1 GeV by X-band RF Linac only
- Final goal compact 5 GeV accelerator

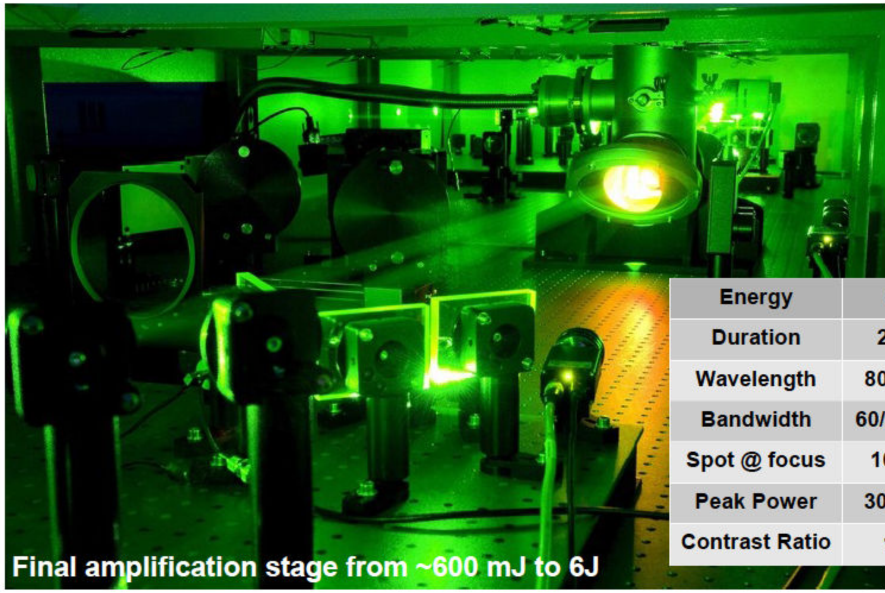
SPARC_LAB HB photo- injector





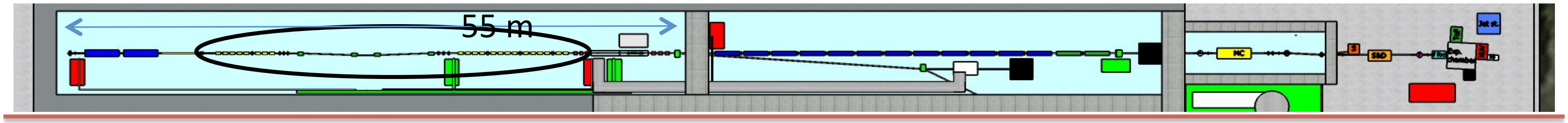
X-band Linac and High Power Laser



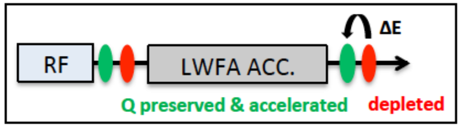


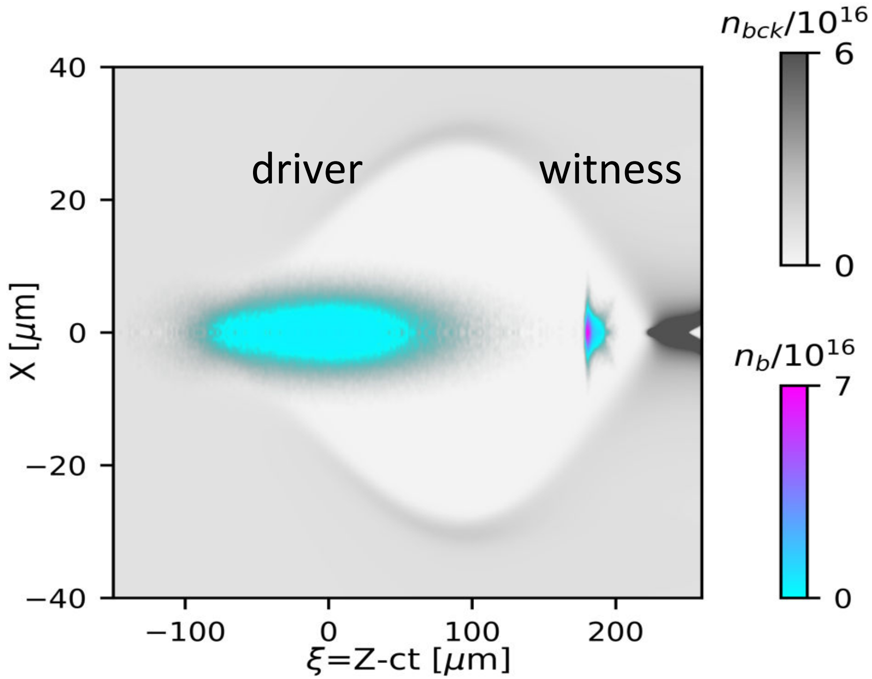
Final amplification stage from ~600 mJ to 6J

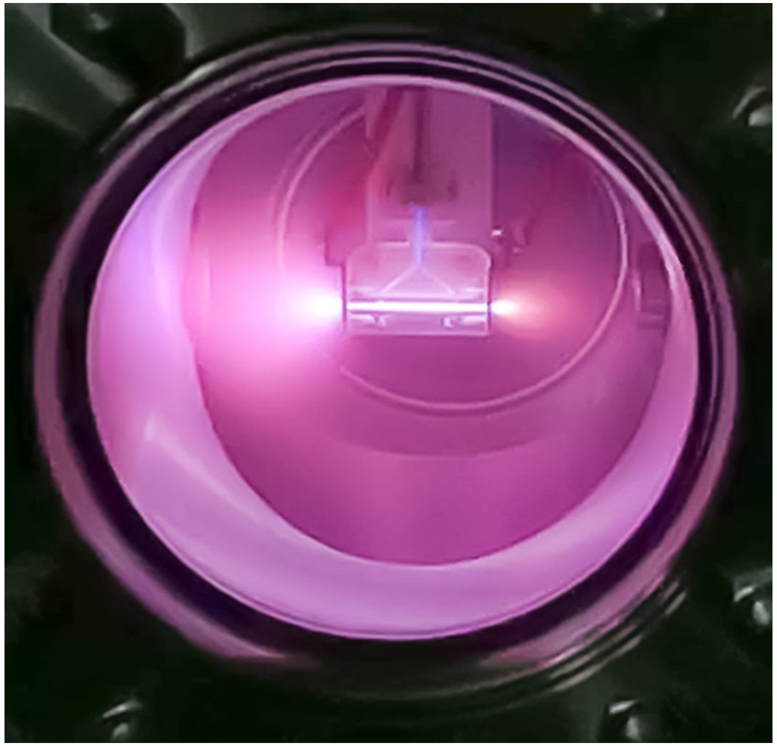
Energy	6 J
Duration	23 fs
Wavelength	800 nm
Bandwidth	60/80 nm
Spot @ focus	10 μm
Peak Power	300 TW
Contrast Ratio	10^{10}



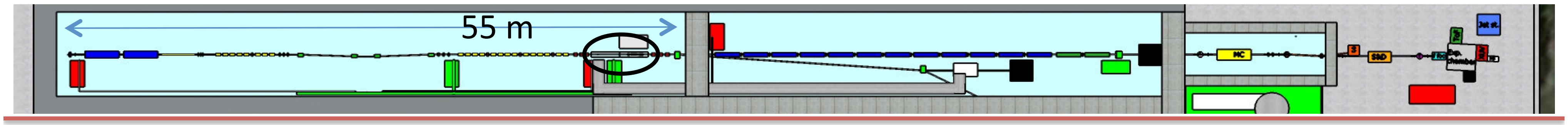
Plasma WakeField Acceleration – External Injection



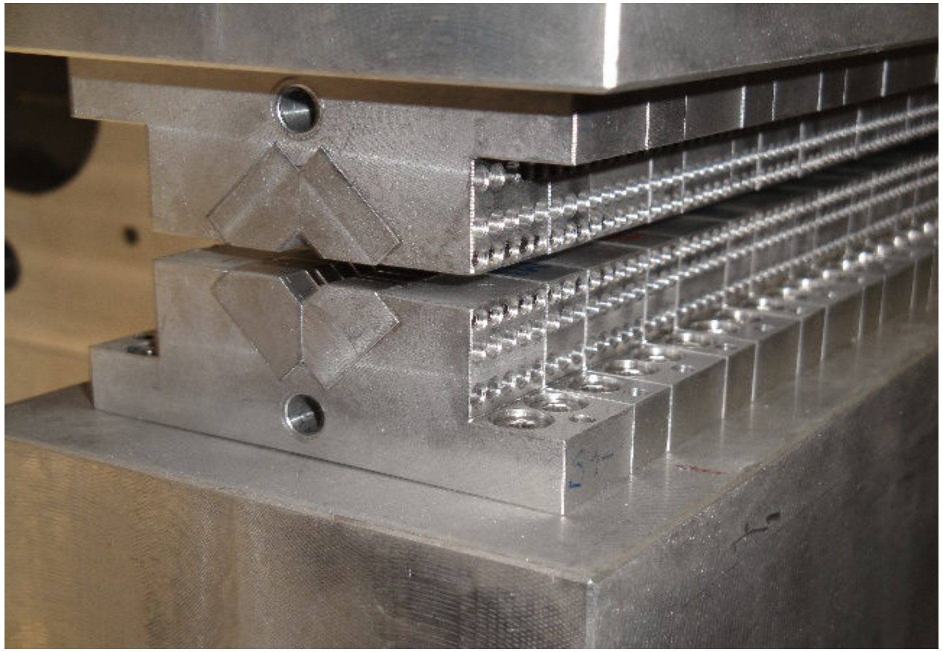


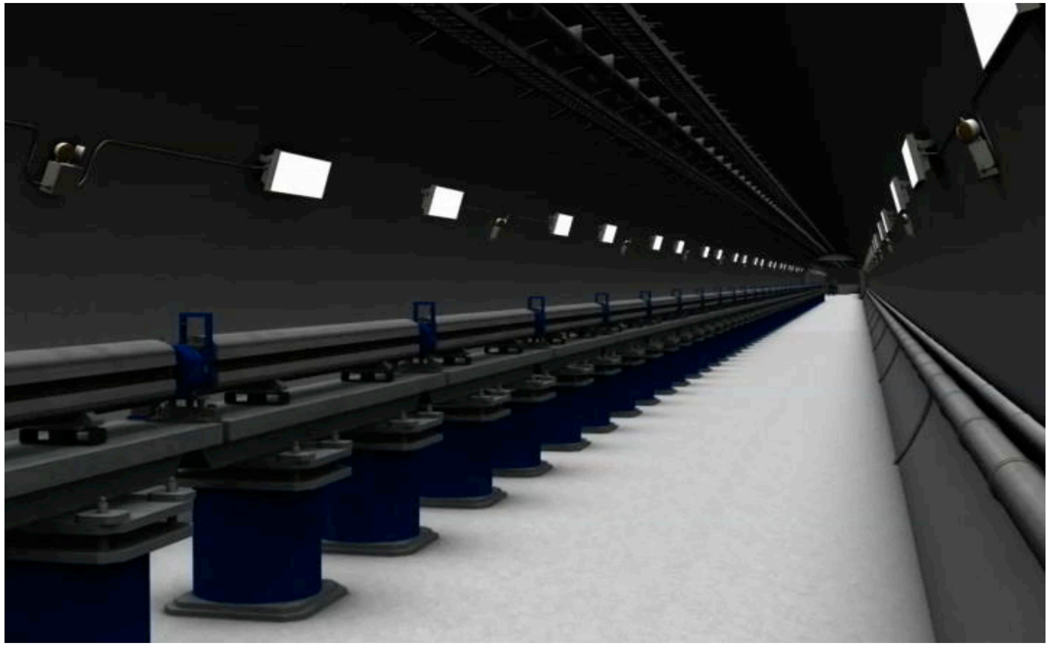


Capillary discharge at SPARC_LAB

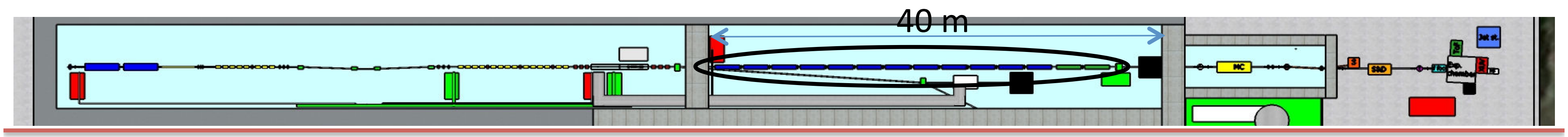


Undulators

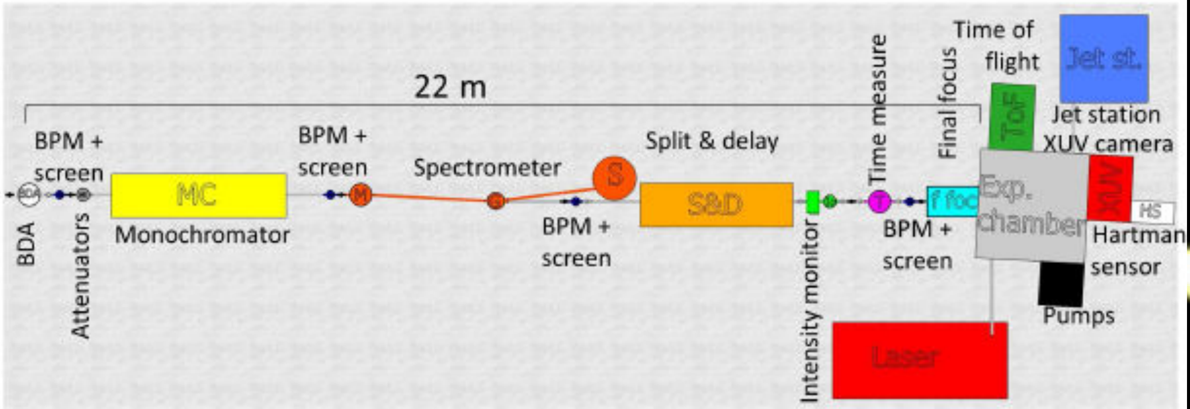


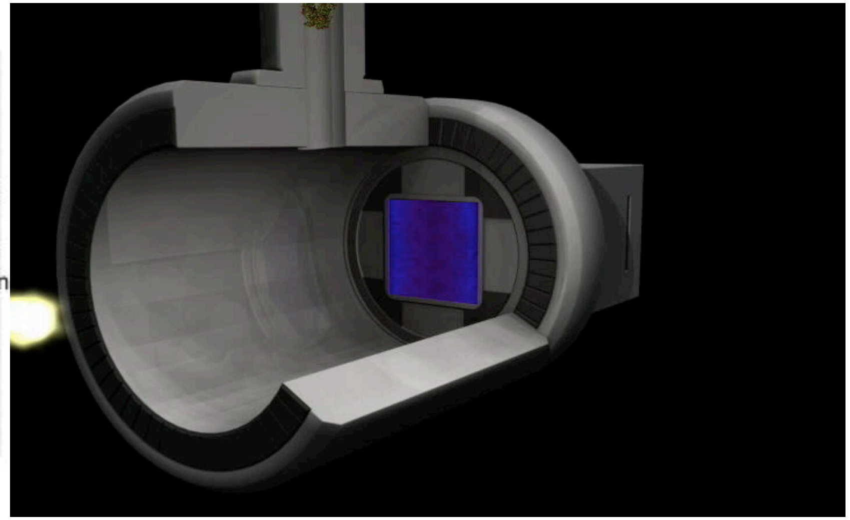


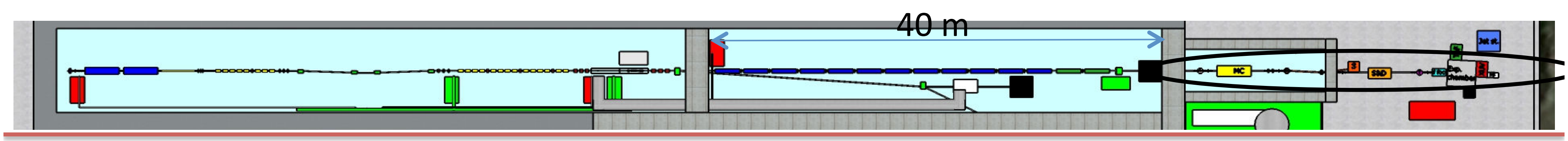
KYMA Δ udulator at SPARC_LAB: λ=1.4 cm, K1



Photon beam line





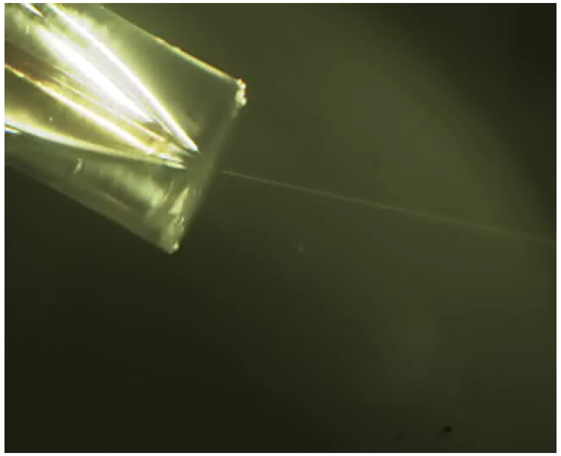


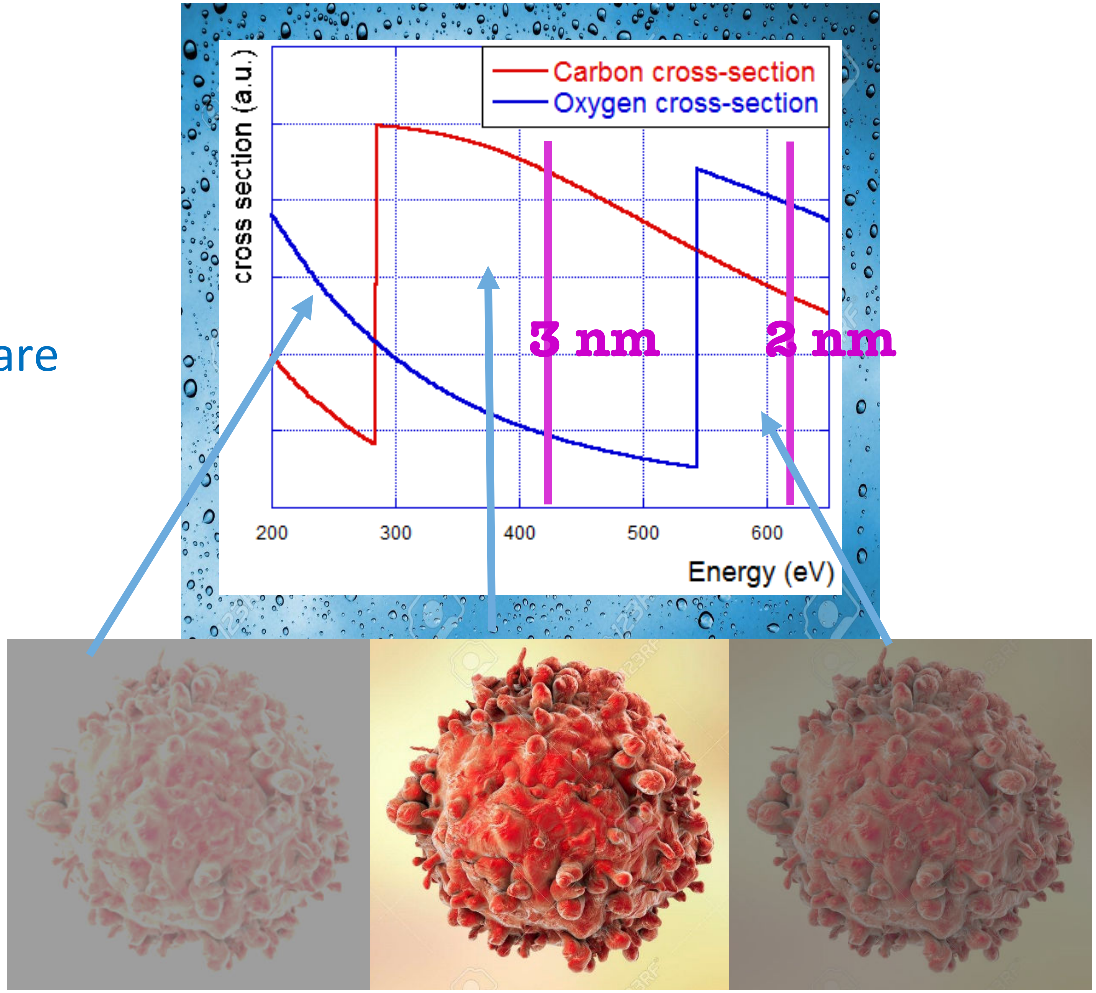
Water Window Coherent Imaging

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

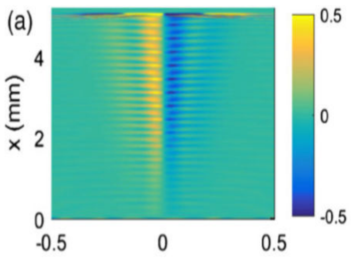


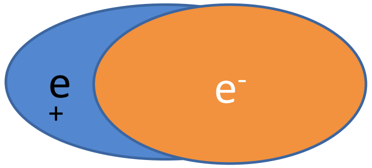


Courtesy F. Stellato, UniToV

Laboratory Astrophysics with high charge beams

your help is welcome

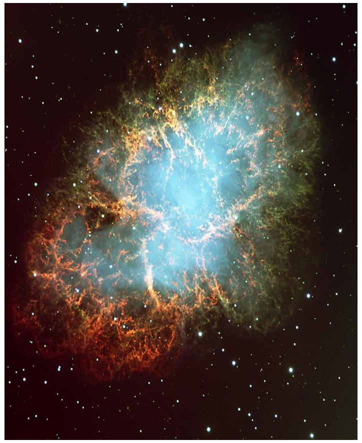




Ultra relativistic **Quasi Neutral beams**, positron bunch embedded into an electron bunch

- high-energy astrophysical phenomena
- ultra relativistic out- flows from active galactic nuclei and pulsars
- emission of gamma-ray bursts

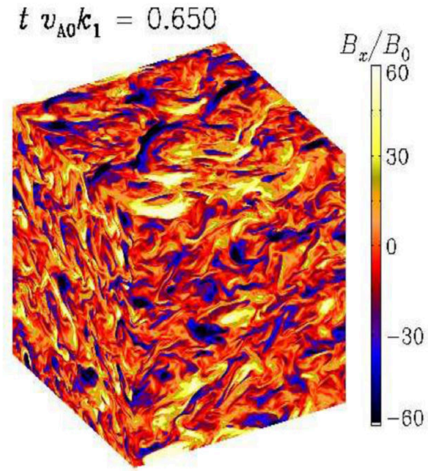
Experimental Observation of a Current-Driven Instability in a Neutral Electron-Positron Beam PRL 2017 J. Warwick et al.



Ultra relativistic charged beams into a quasi neutral low density plasma:

- bunch produced by supernova explosions
- generation of magnetic fields
- magnetic field dynamo processes

Magnetic field generation and diffusion by a laser-produced blast wave propagating in non-homogenous plasma, A Marocchino et al 2015 New J. Phys. 17 043052



Energetic particles (cosmic rays) are accelerated in supernova remnants or relativistic jets

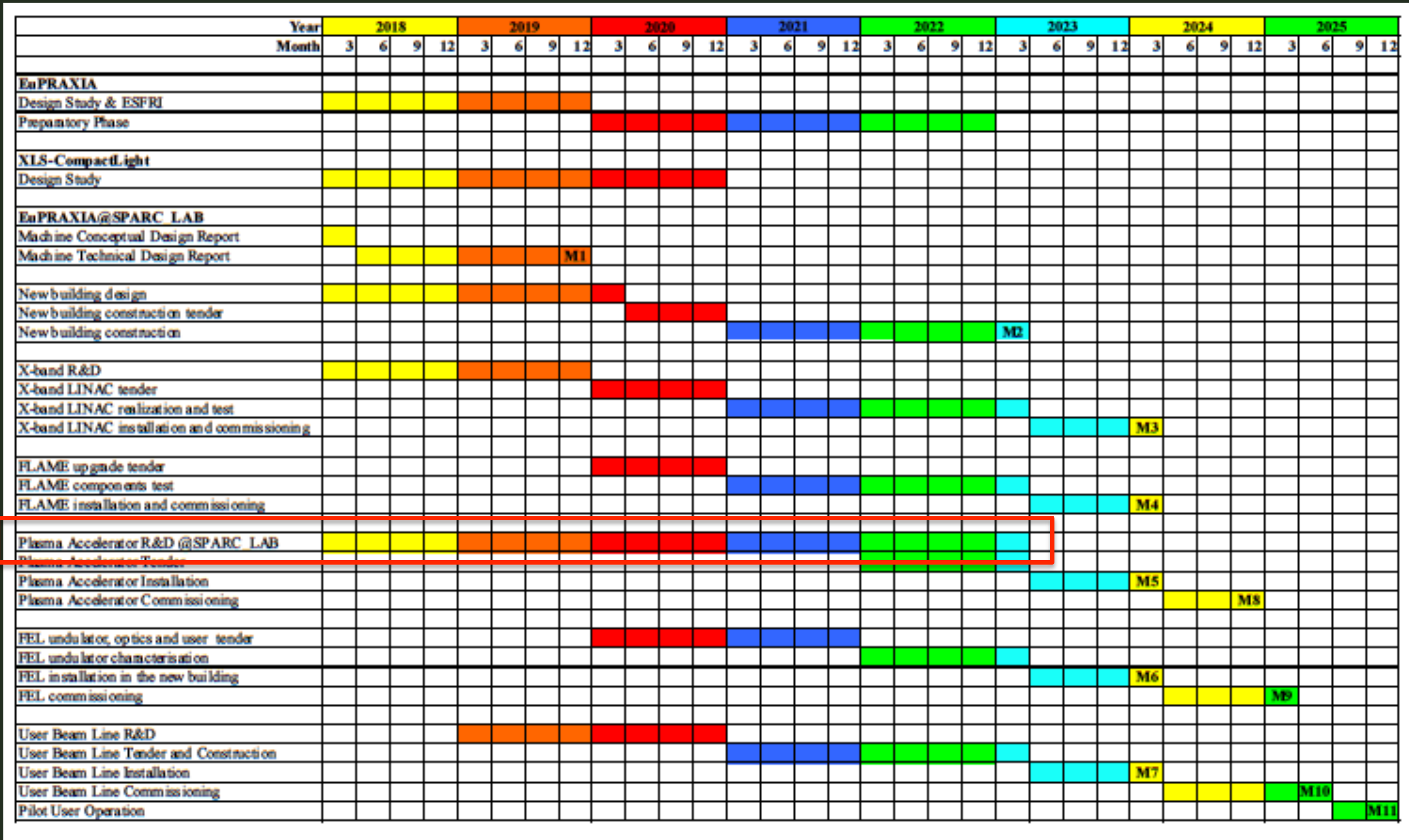
- mechanisms of magnetic field amplification
- Instabilities due to charged particle break of neutrality
- These processes are strictly related to the previous Supernova Remnant case study

Microphysics of Cosmic Ray Driven Plasma Instabilities, Space Science Reviews, October 2013, A. M. Bykov et al.

R&D perspectives

- X-band RF technology implementation,➔ CompactLight => CERN collaboration
- Science with short wavelength Free Electron Laser (FEL)
- Physics with high power lasers and secondary particle source
- Compact Neutron Source
- R&D on compact radiation sources for medical applications
- Detector development and test for X-ray FEL and HEP
- Science with THz radiation sources
- Nuclear photonics with γ-rays Compton sources
- R&D on polarized positron sources
- R&D in accelerator physics and industrial spin – off

Project Timeline



The future EUPRAXIA@SPARC_LAB Facility

- Procedure for purchasing neighboring land started.
- Announcement of tender for the building design (1.2 Meuro).

INFN
Istituto Nazionale di Fisica Nucleare


Waiting for the Green Light
Thank for your attention