SPARC_LAB

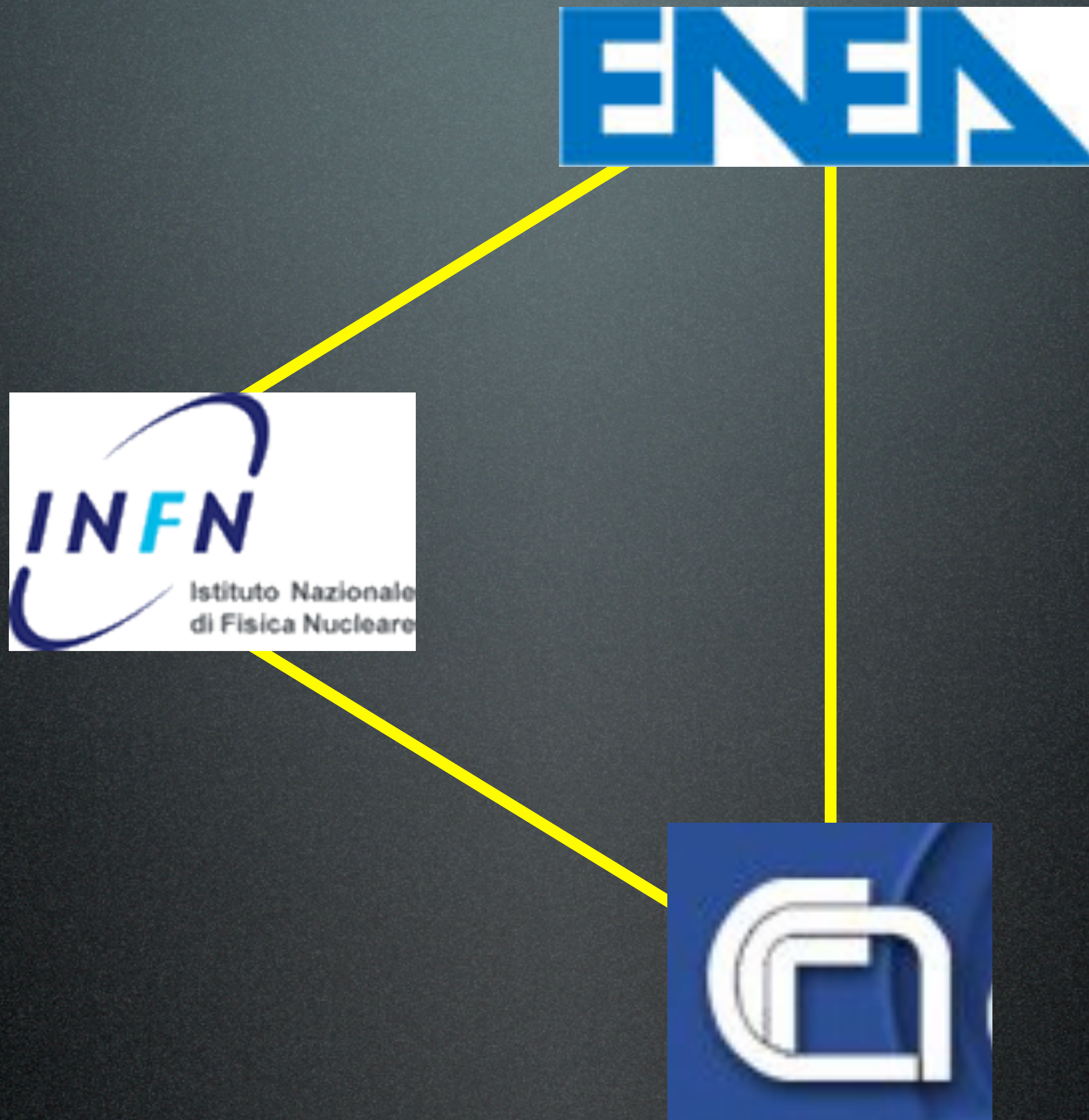
Sources for Plasma Accelerators and Radiation Compton with Lasers And Beams

Massimo Ferrario

INFN-LNF

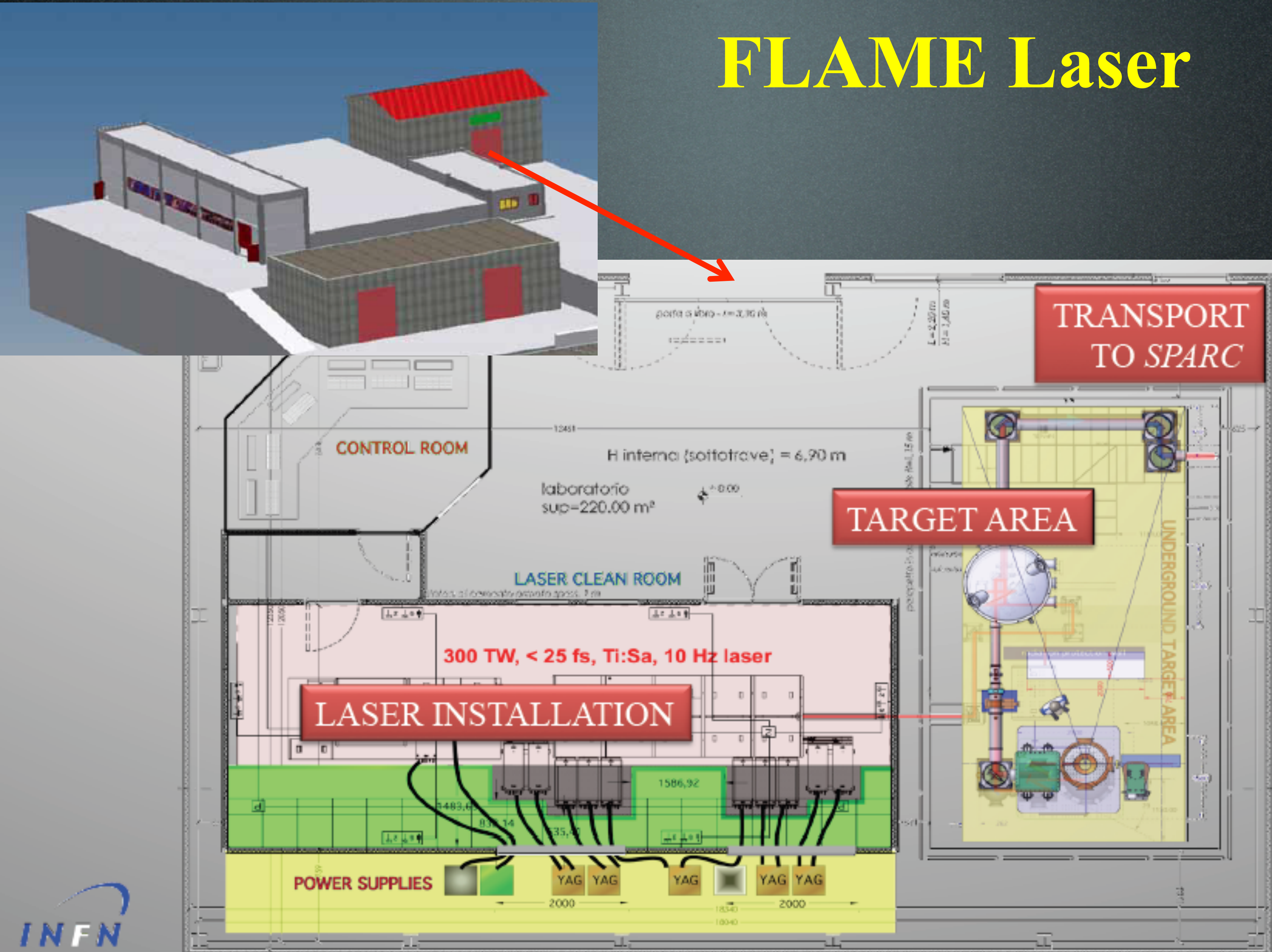
on behalf of the SPARC_LAB collaboration

Incontri di Fisica delle Alte Energie– Ferrara – 11 Aprile 2012

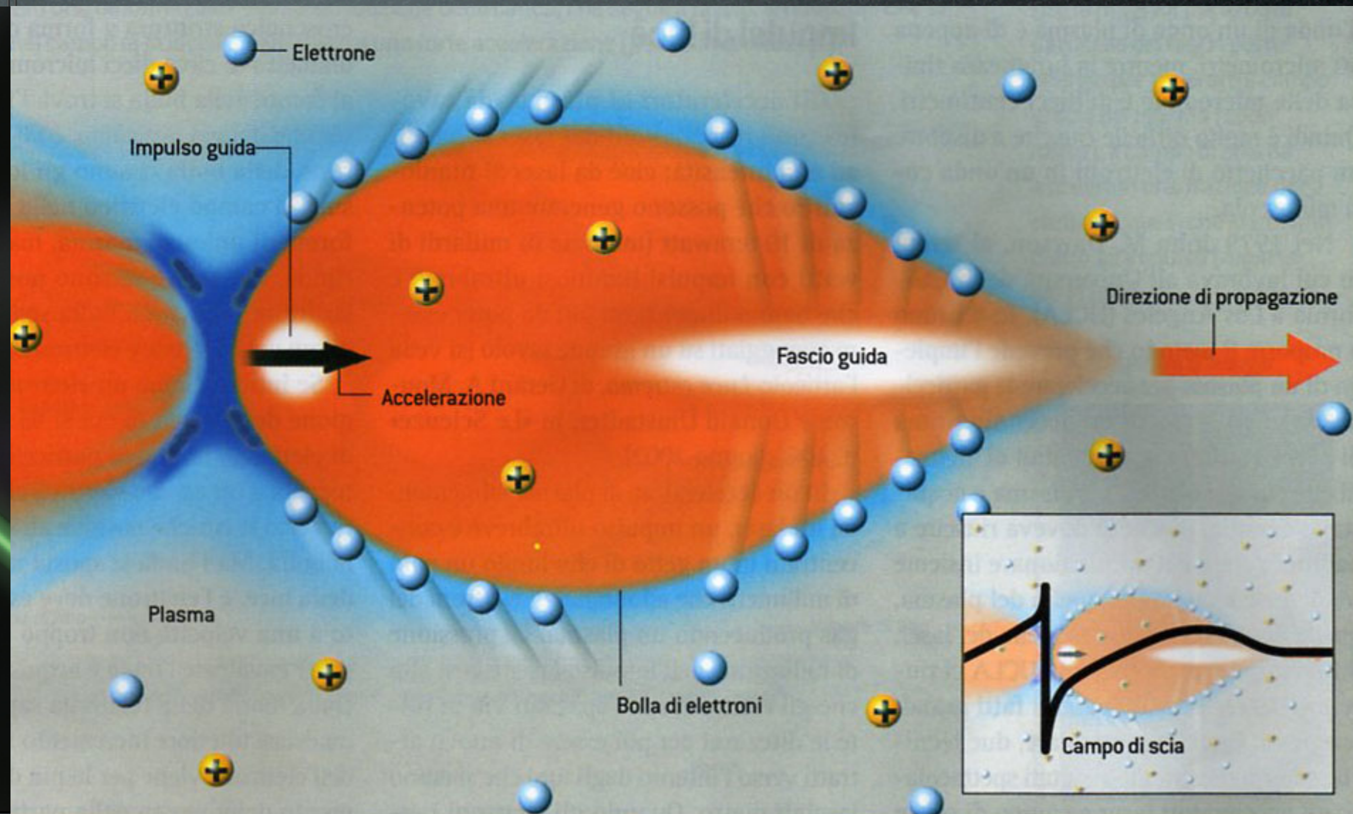

ENEA
INFN
Istituto Nazionale
di Fisica Nucleare

SPARC_LAB related INFN units

FLAME Laser


TRANSPORT TO SPARC
CONTROL ROOM
H interna (sottotrave) = 6,90 m
laboratorio sup=220.00 m²
TARGET AREA
LASER CLEAN ROOM
300 TW, < 25 fs, Ti:Sa, 10 Hz laser
LASER INSTALLATION
UNDERGROUND TARGET AREA
POWER SUPPLIES
YAG
YAG
YAG
YAG
YAG
2000
2000

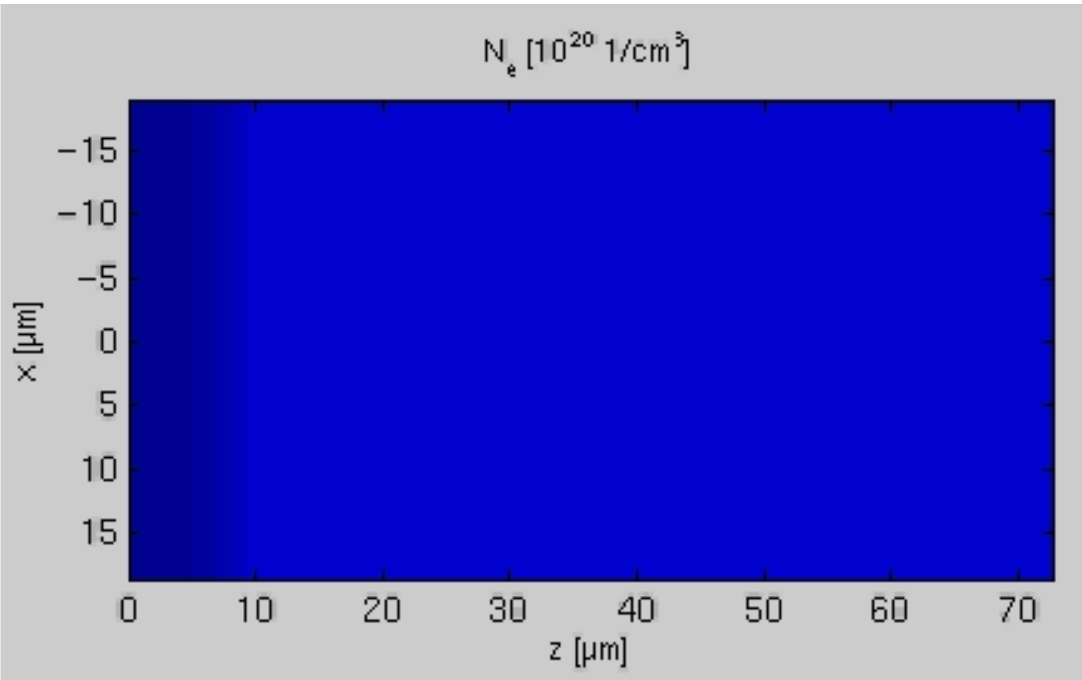
FLAME Target Area



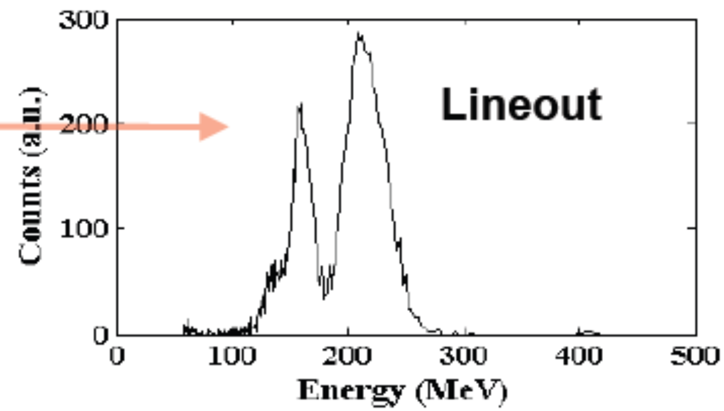
Self Injection:
spectrum of the accelerated electrons

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

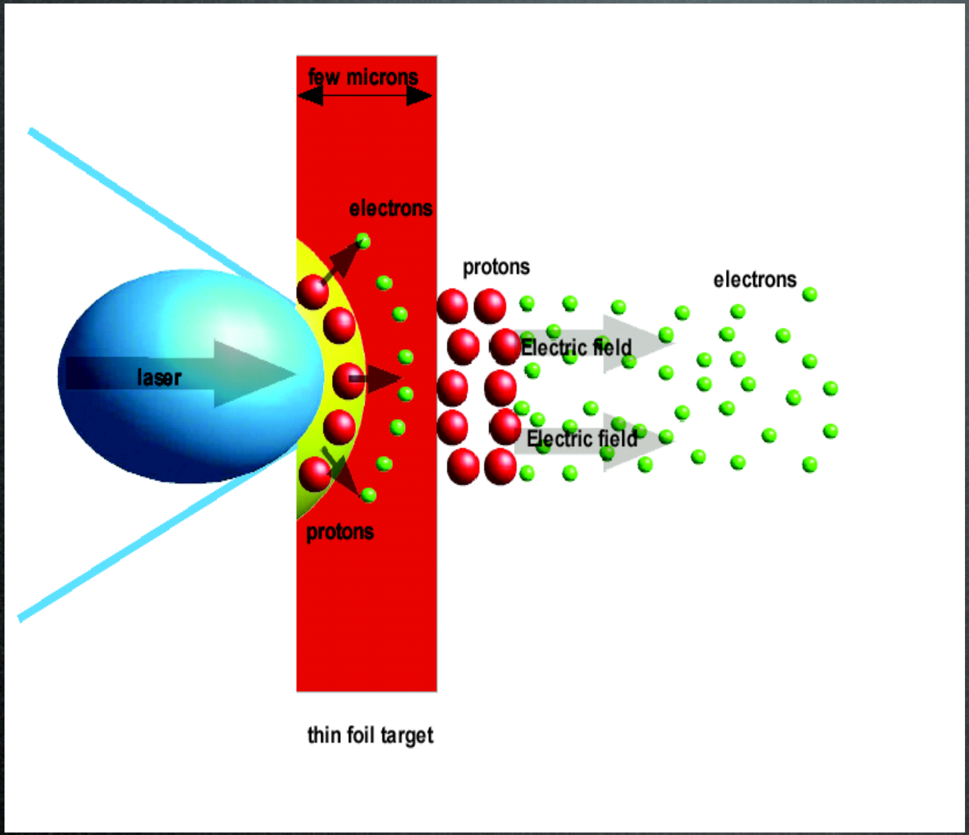


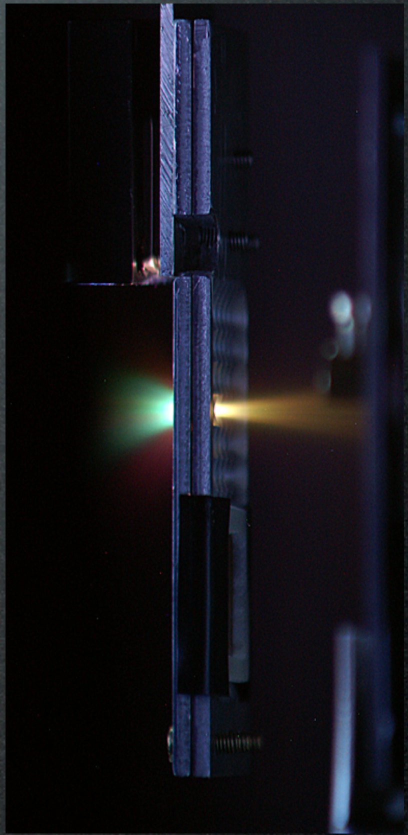
Energy of LPA electrons entering the multi 100 MeV range

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

LILIA

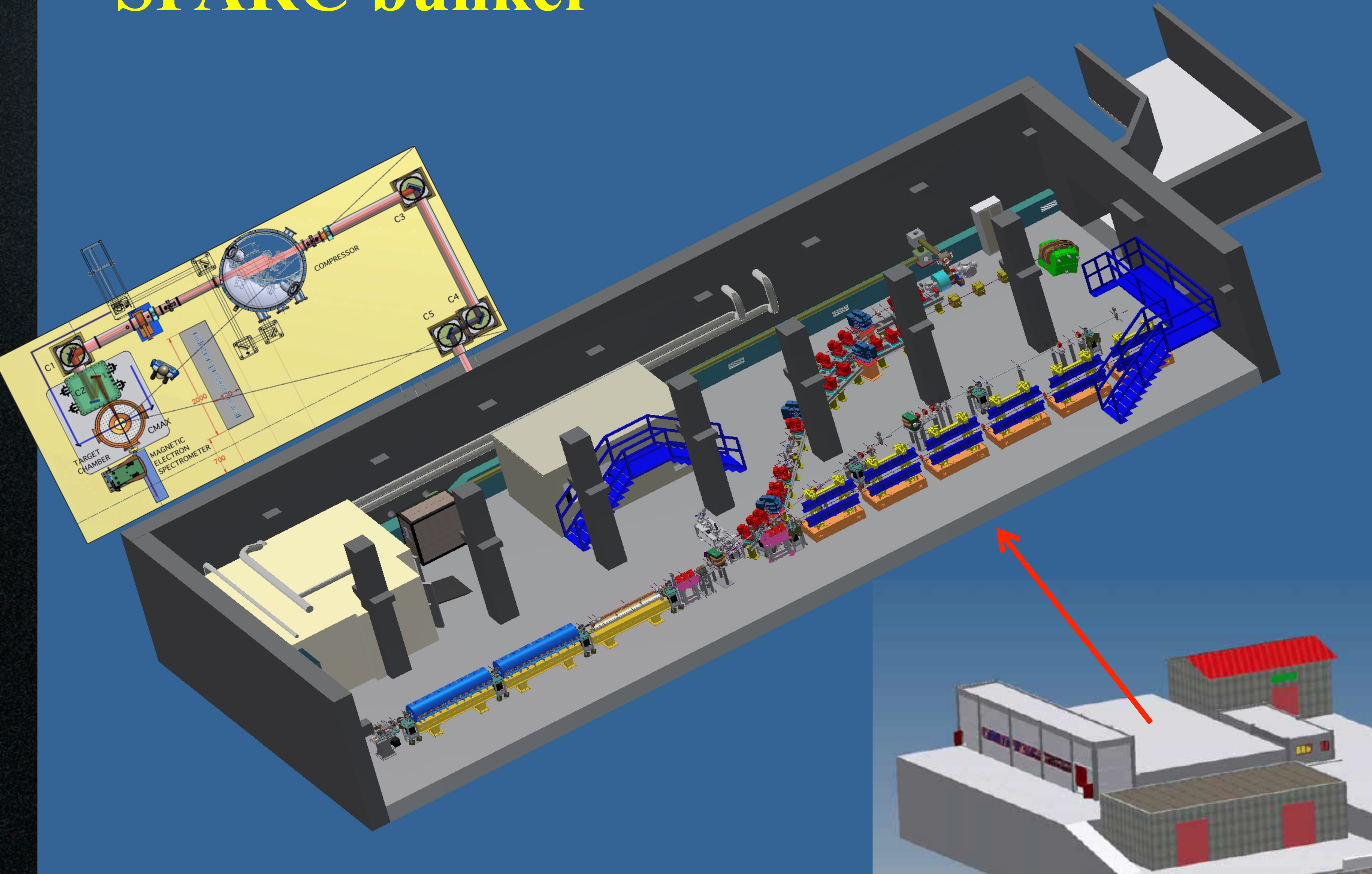
Laser Induced Light Ions Acceleration

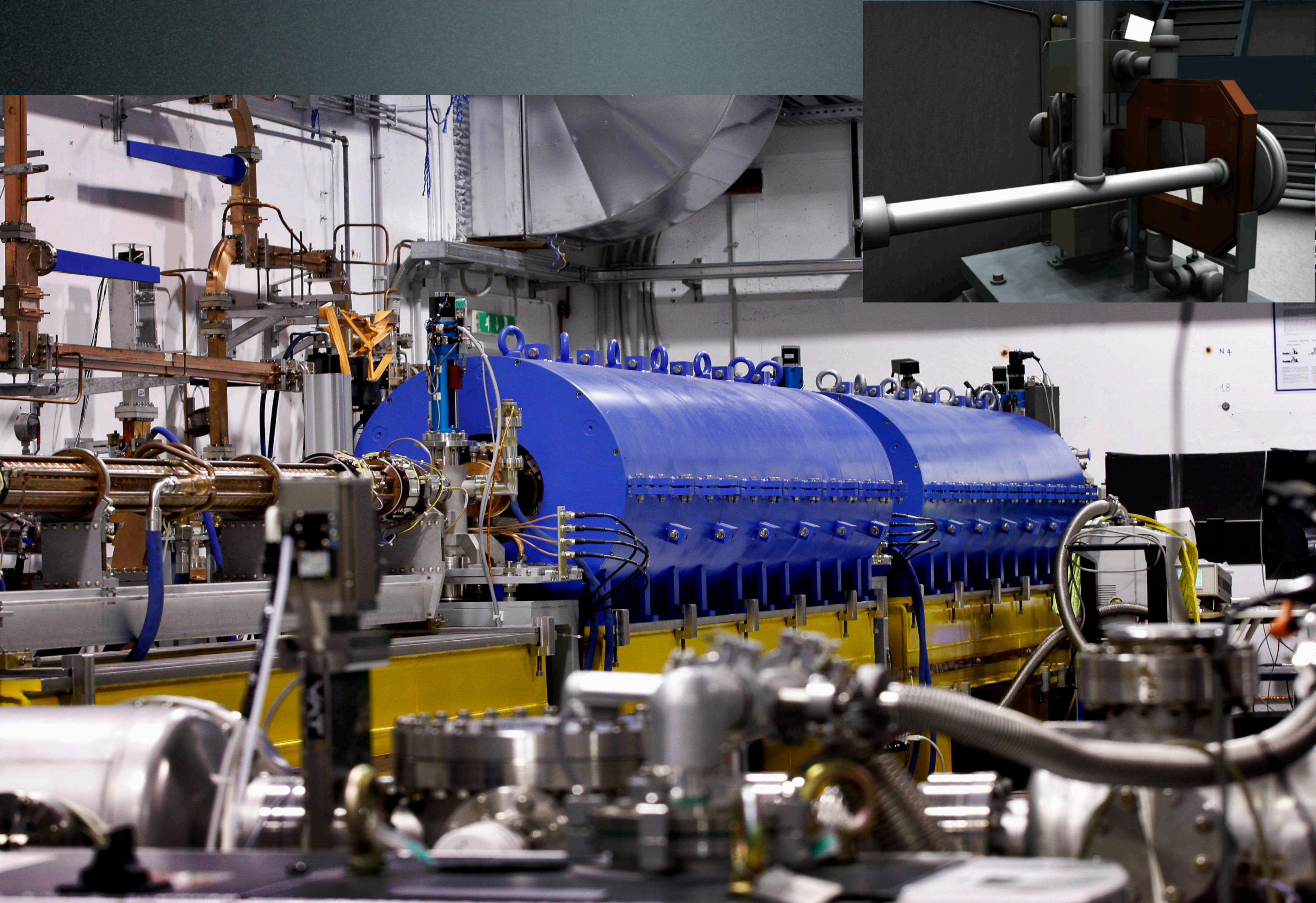


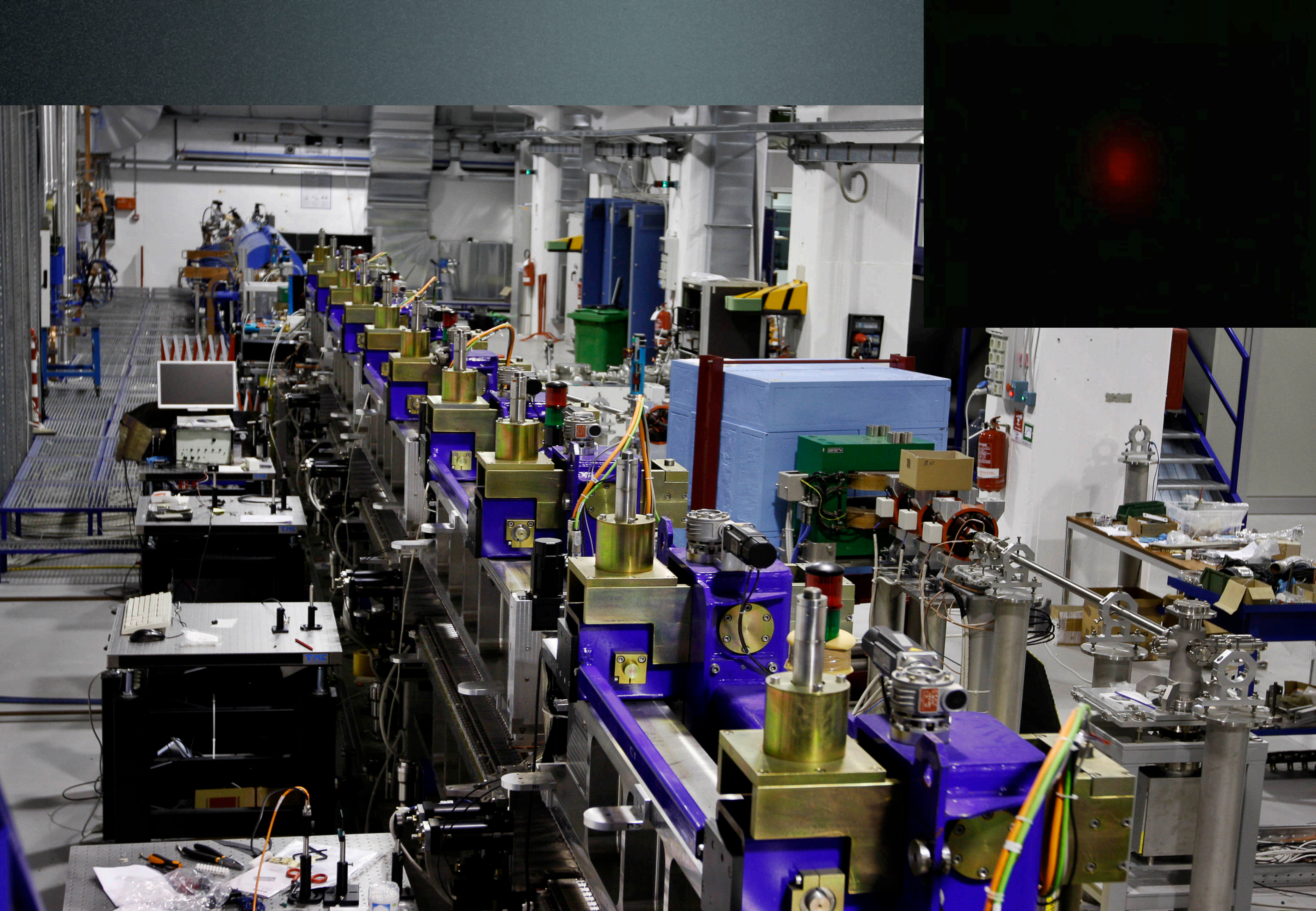


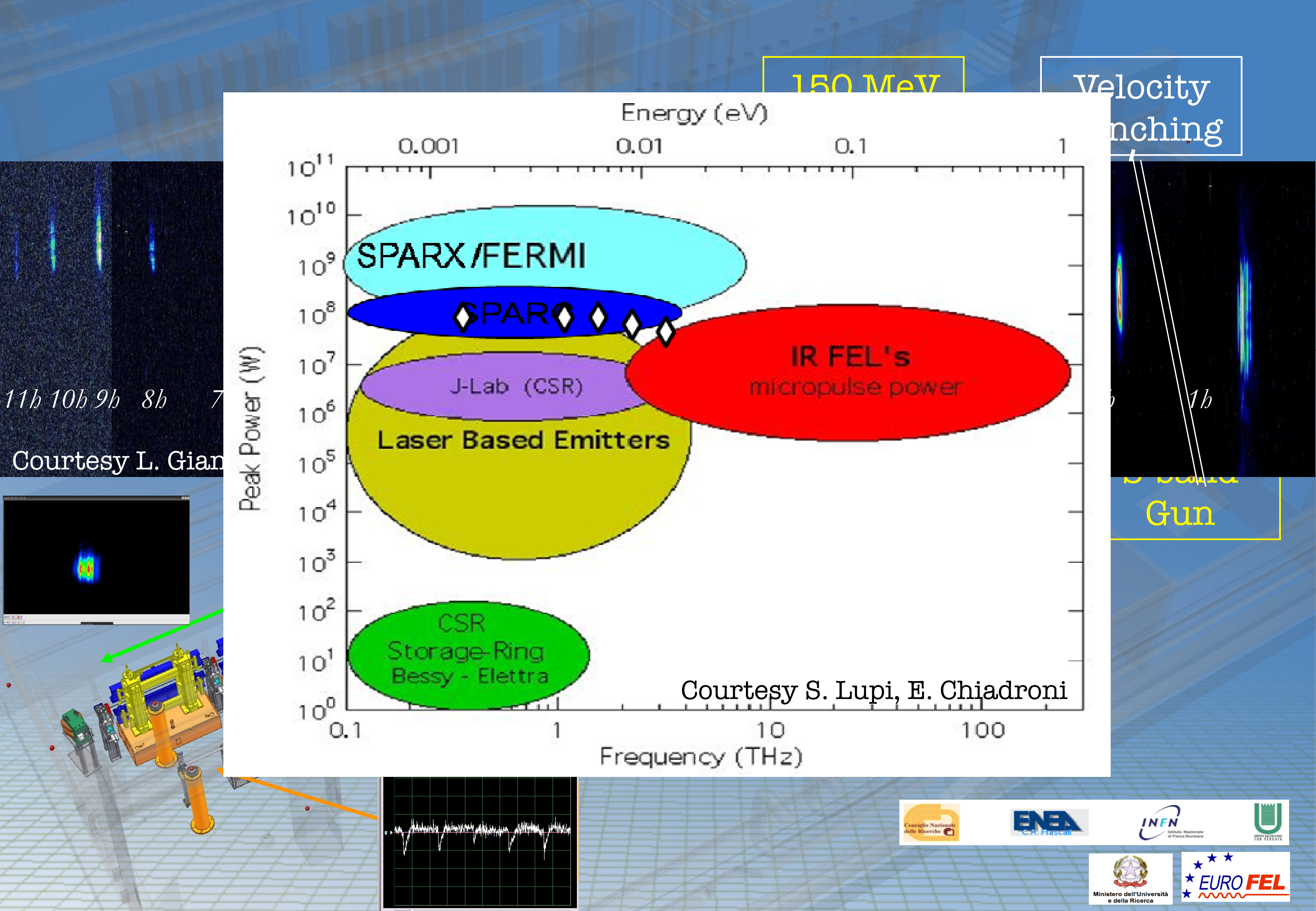
Courtesy C. De Martinis

SPARC bunker

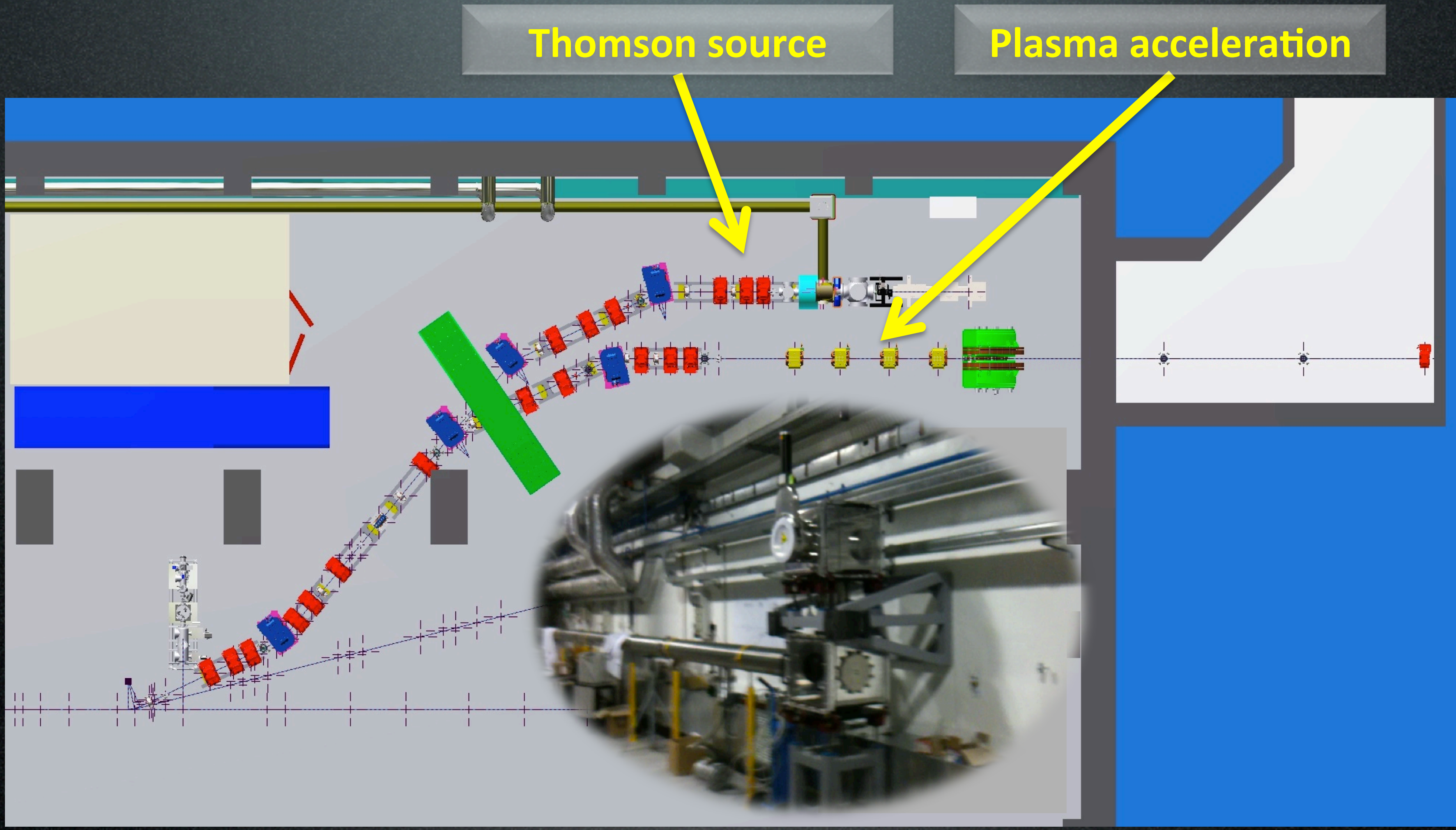



N4
18

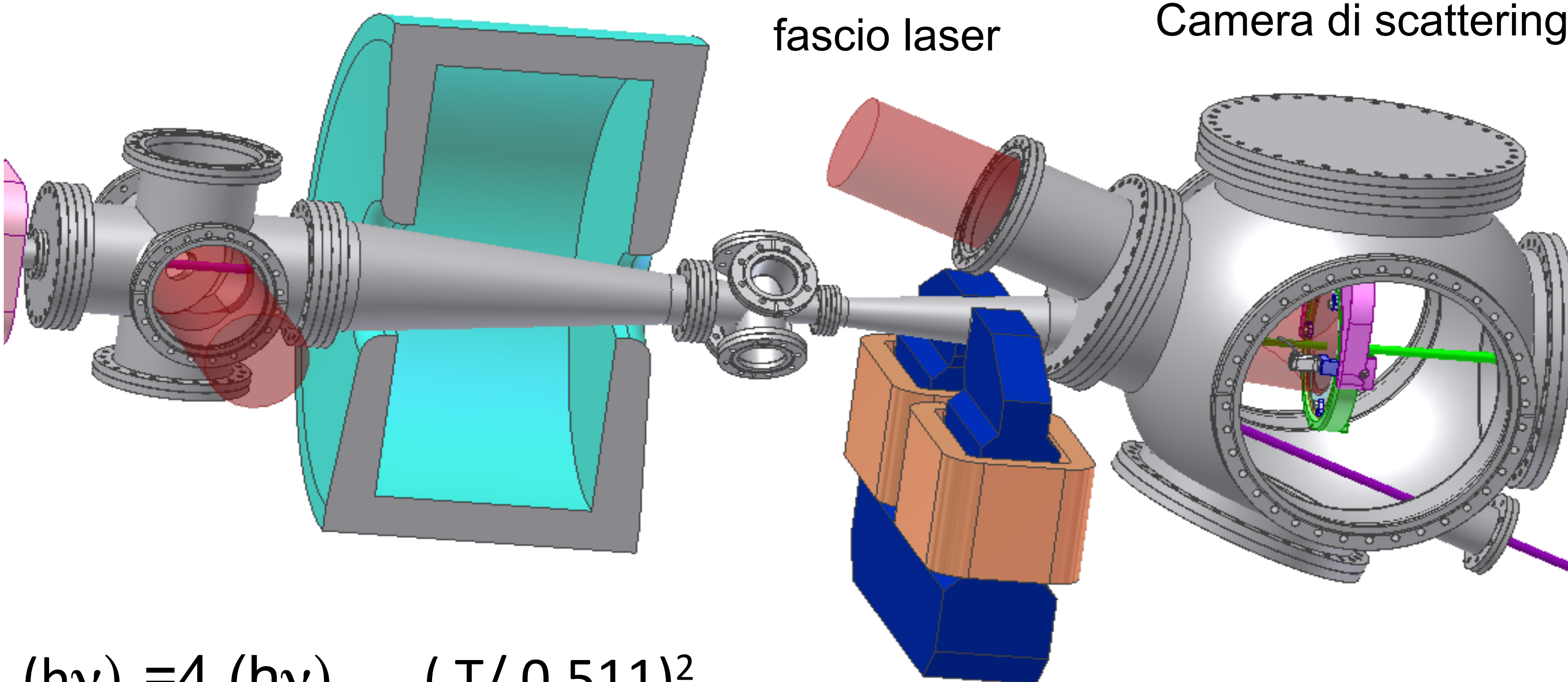



150 MeV
Velocity
nching
11b 10b 9b 8b 7
1b
Courtesy L. Gian
Gun
Energy (eV)
0.001
0.01
0.1
1
Peak Power (W)
SPARX/FERMI
SPARC
IR FEL's
micropulse power
J-Lab (CSR)
Laser Based Emitters
CSR
Storage-Ring
Bessy - Elettra
Courtesy S. Lupi, E. Chiadroni
0.1
1
10
100
Frequency (THz)
Consiglio Nazionale delle Ricerche
ENEA
C.R. Frascati
INFN
Istituto Nazionale di Fisica Nucleare
Ministero dell'Università e della Ricerca
EURO FEL

New installations



Thomson Interaction region (20-550 keV)

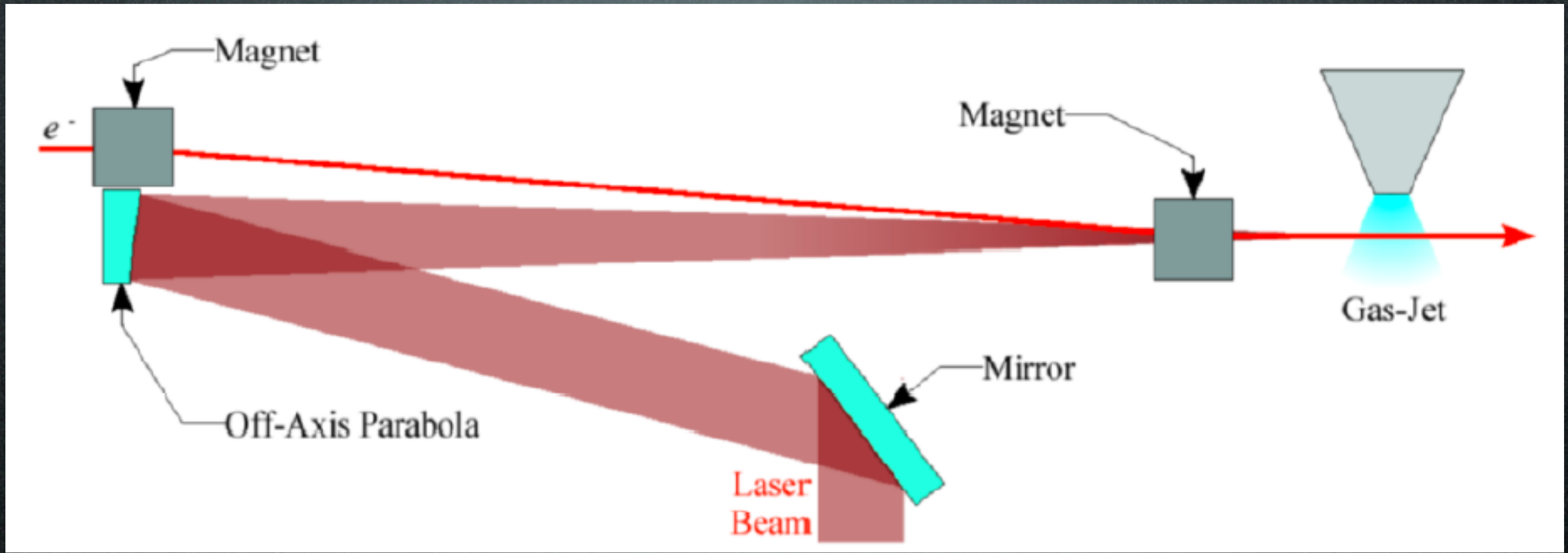


$$(h\nu)_X = 4\,(h\nu)_{laser}\,(T/0.511)^2$$

$(h\nu)_{laser}$ = 1.2 eV
T = 30.28 MeV
$(h\nu)_X$ = 20 keV mammografia

Impulso laser: 6 ps, 5 J
pacchetto e^- : 1 nC , l: 2 mm (rms)
Impulso X: 10 ps, 10^9 fotoni per interazione
α emissione: 12 mrad

EXIN (EXternal INjection)

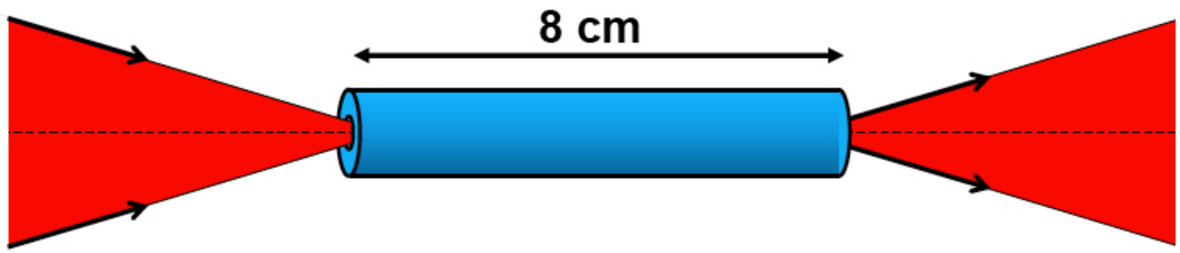


n_e [cm^{-3}]	E_{max} [GV/m]	λ_p [μm]	Ldeph [m]	Energy gain over L = 2cm [MeV]	Energy gain over L = 10cm [MeV]
1e16	0.2	330	400	<4	<20
5e16	1	150	5	<20	<100
2.5e17	3.8	66	0.45	<76	<380
7.5e17	7.5	39	0.1	<150	<750
2.5e18	8.5	30	0.04	<190	-

Courtesy L. Serafini

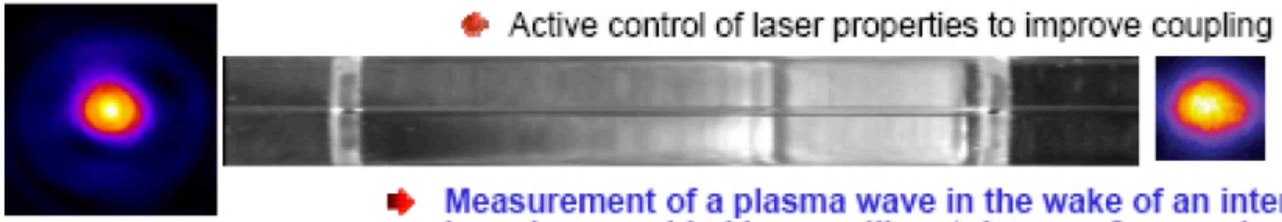
Hollow Dielectric Waveguide Capillaries

With LPGP Orsay, Brigitte Cros *et al.*



Recent achievements

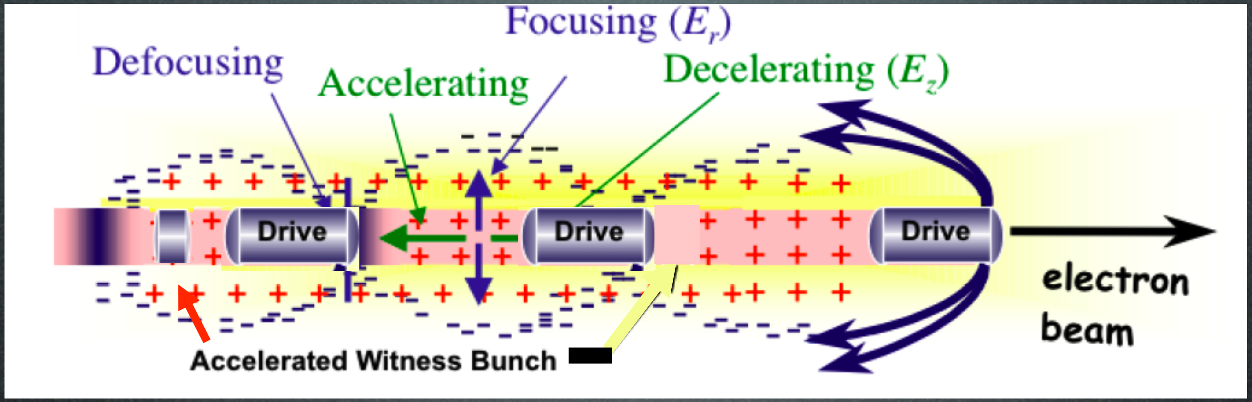
- Optimisation of laser guiding using capillary tubes (10cm):
  - vacuum or under-dense plasmas
  - Relevant for moderate intensities in laser wakefield schemes
  - Active control of laser properties to improve coupling



- Measurement of a plasma wave in the wake of an intense laser beam guided in a capillary tube over 8 cm, using optical diagnostics. Measured field up to 7GV/m over 8 cm.

Courtesy B. Cros

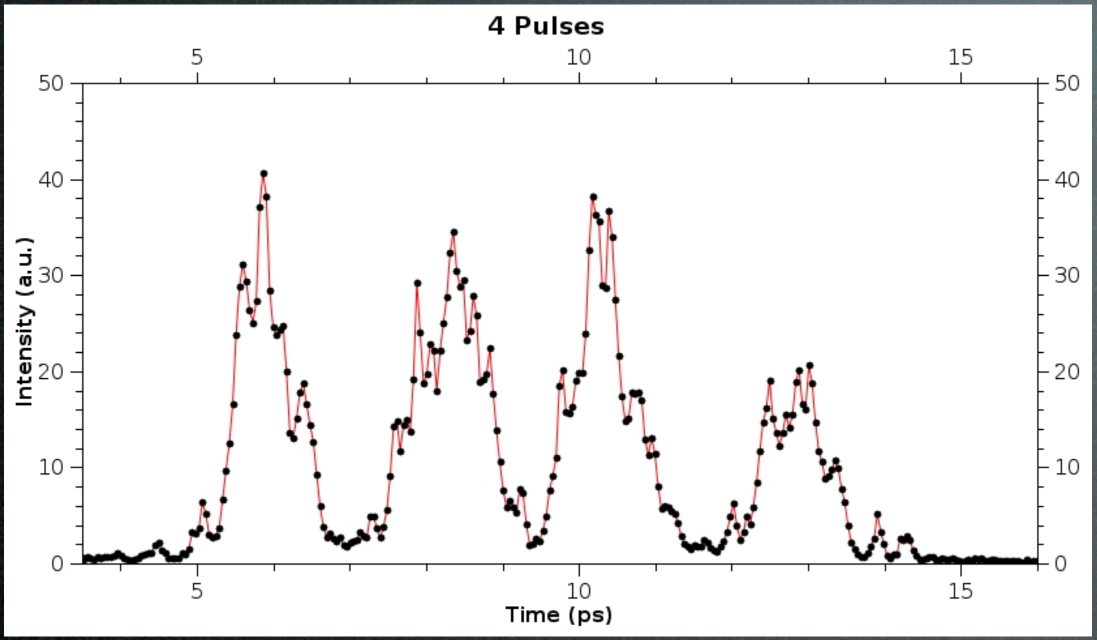
Resonant plasma Oscillations by Multiple electron Bunches

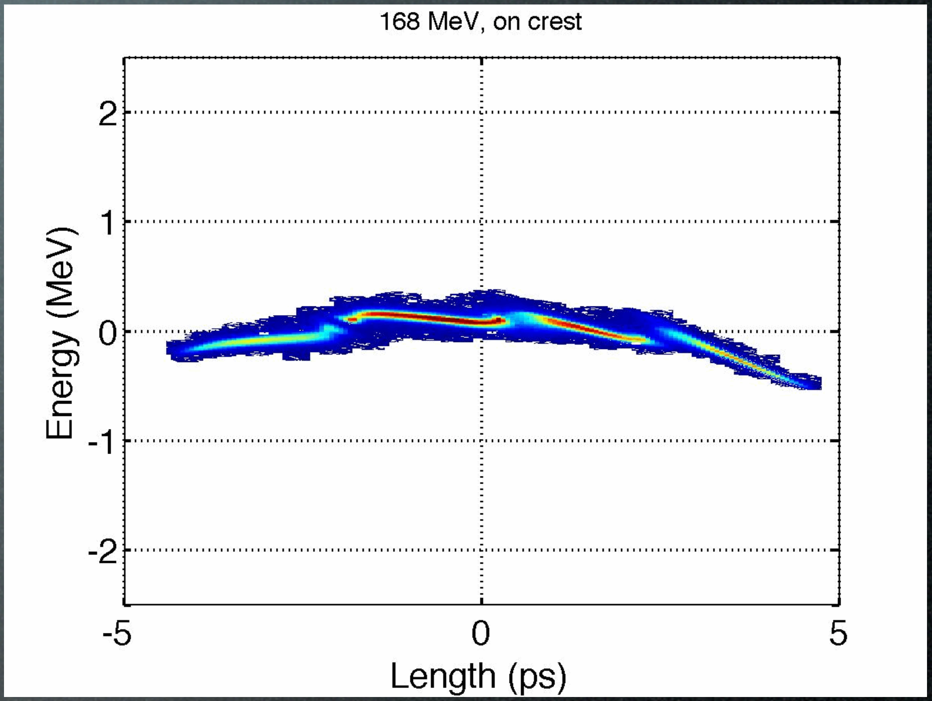


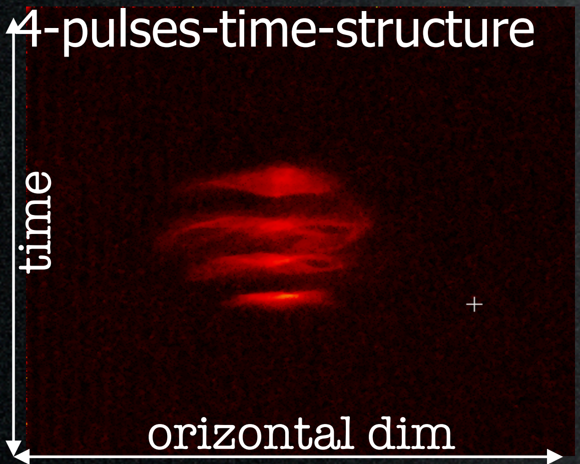
- **Weak blowout regime** with resonant amplification of plasma wave by a train of high Brightness electron bunches produced by **Laser Comb** technique ==> **5 GV/m** with a train of 3 bunches, 100 pC/bunch, 50 μm long, 20 μm spot size, in a plasma of density 10^{22} e^-/m^3 at λ_p=300 μm ?
- **Ramped bunch train configuration** to enhance tranformer ratio?
- **High quality bunch** preservation during acceleration and transport?
- **Strong blowout regime** with pC/fs bunches ==> **TV/m** regime ?

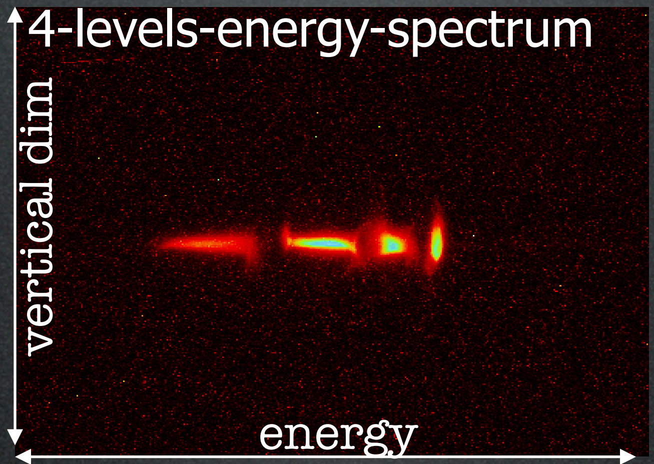
c o w b

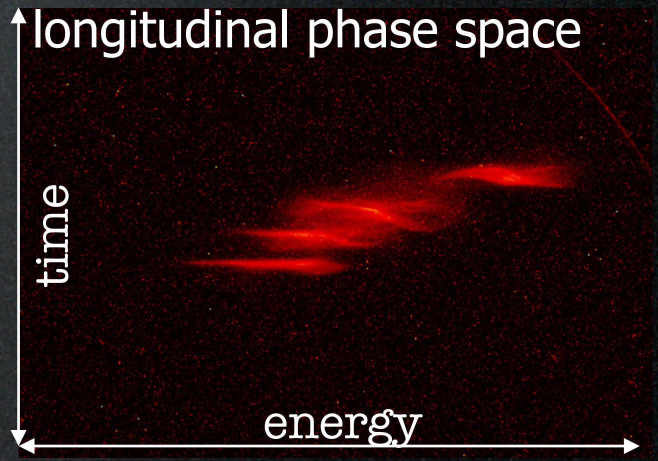
Laser COMB technique







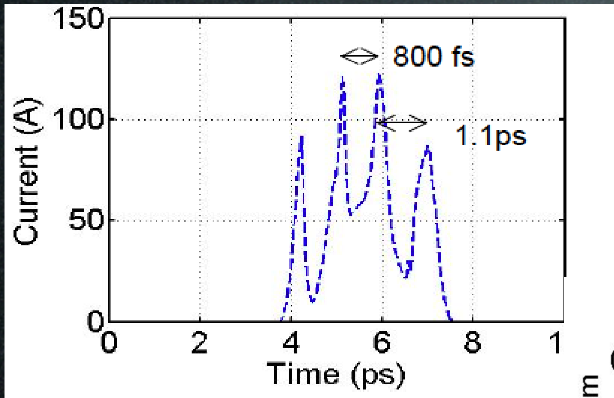




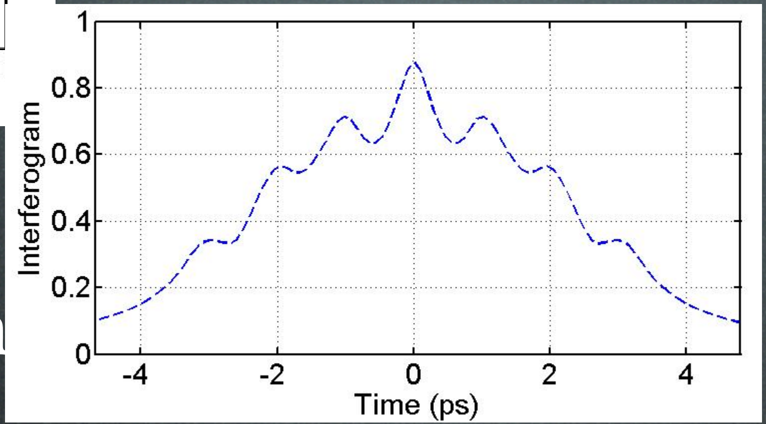
THz source

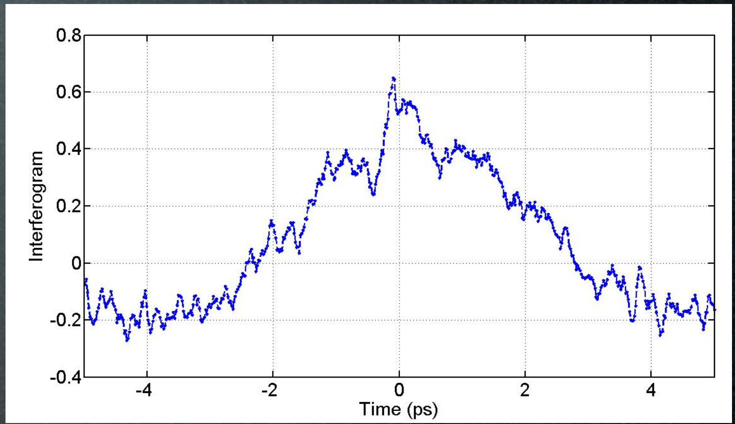
Expected

Measured

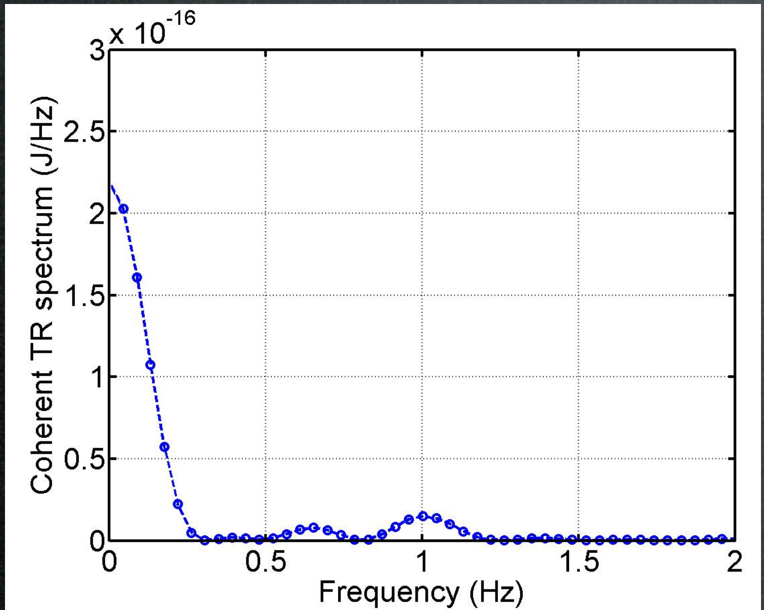


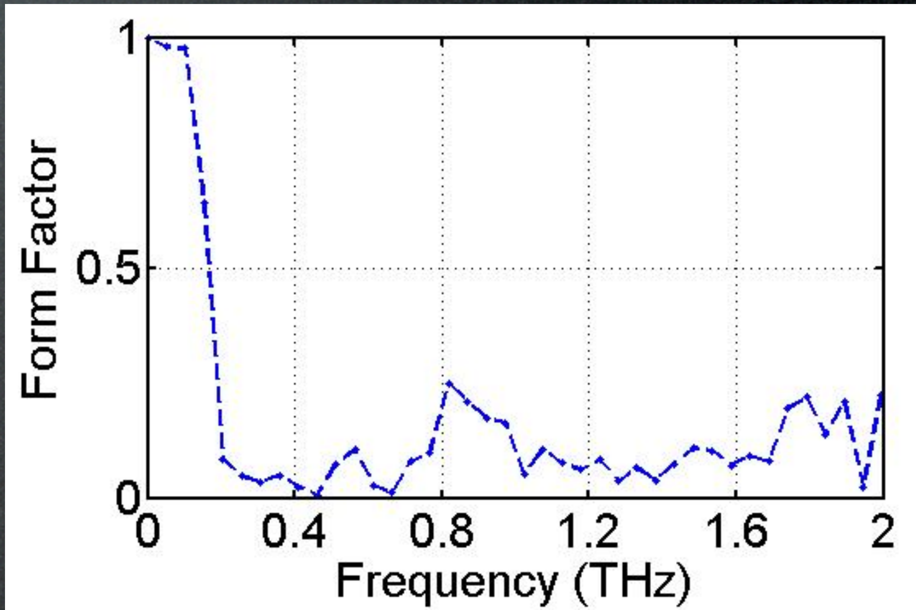
Interferogram





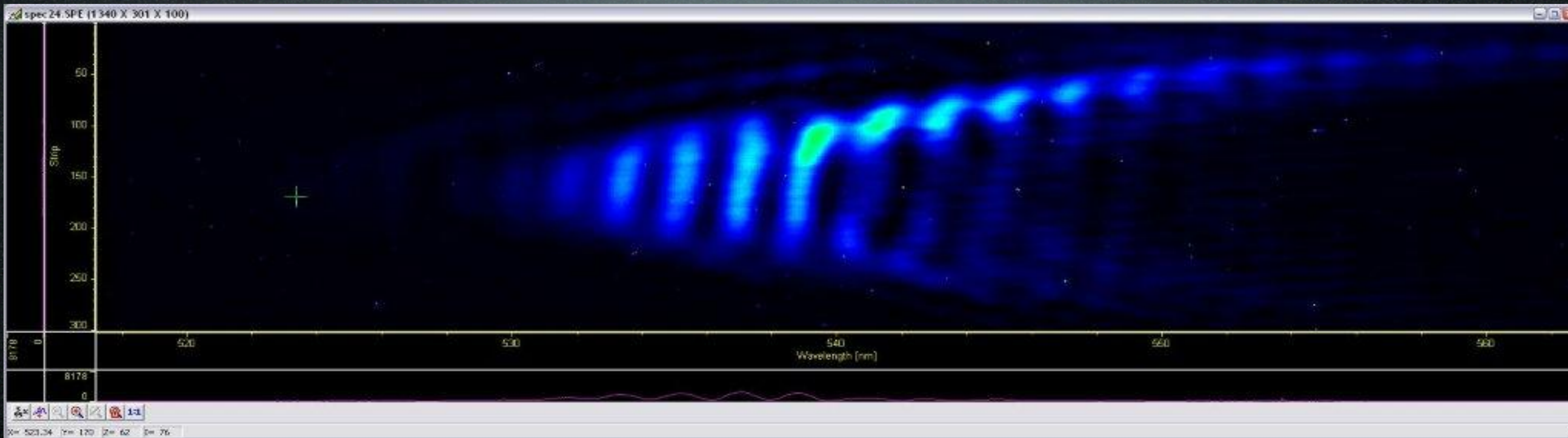
Spectrum



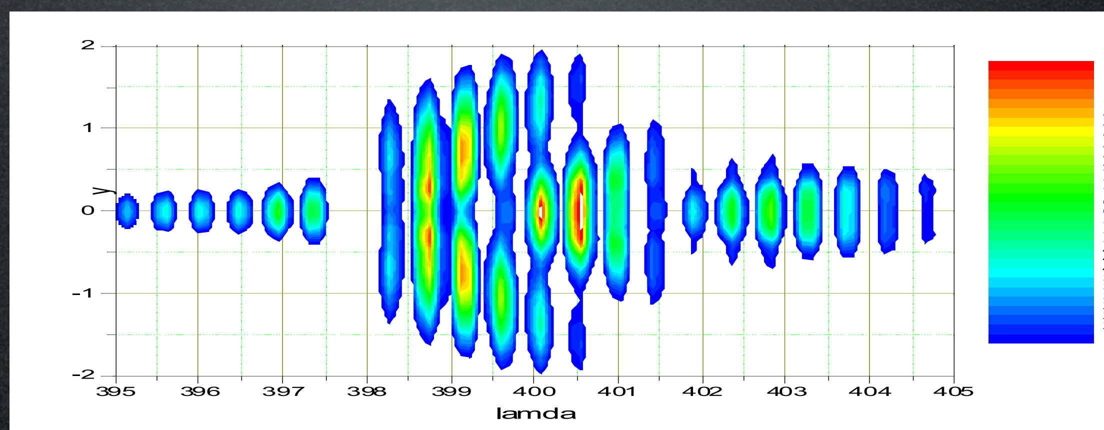


Courtesy E. Chiadroni

Double FEL pulse

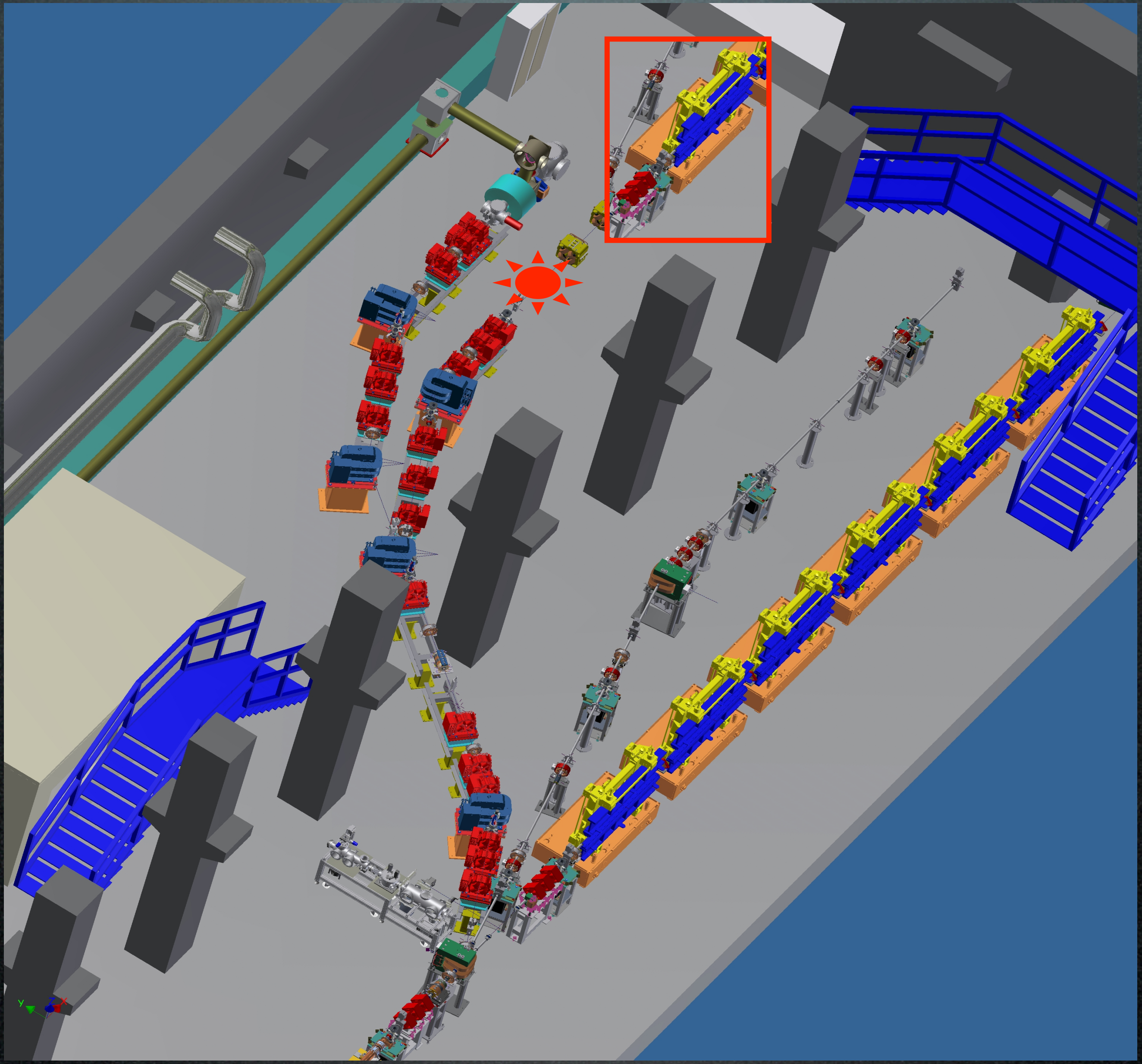


$$\Delta x = \frac{\lambda^2}{\Delta \lambda}$$



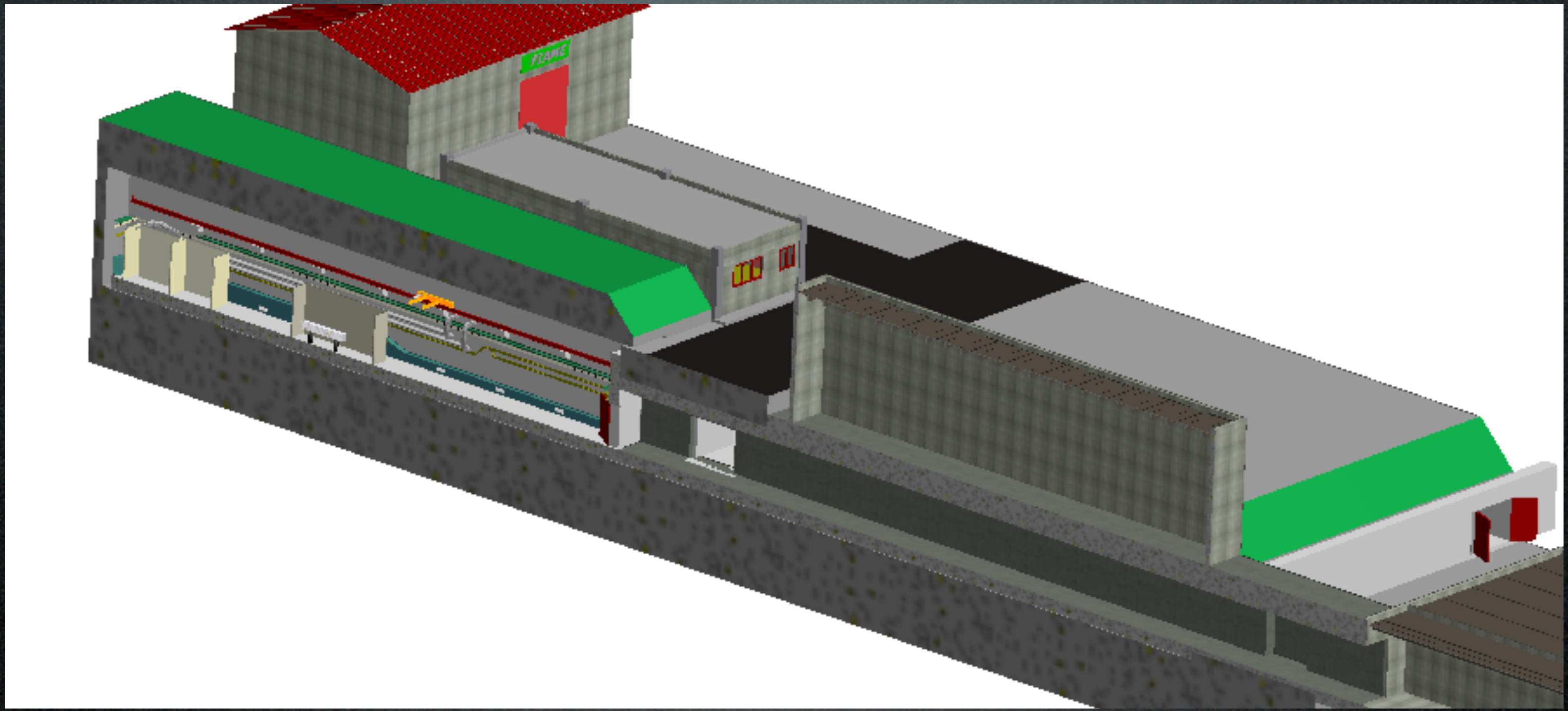
Courtesy L. Giannessi, V. Petrillo

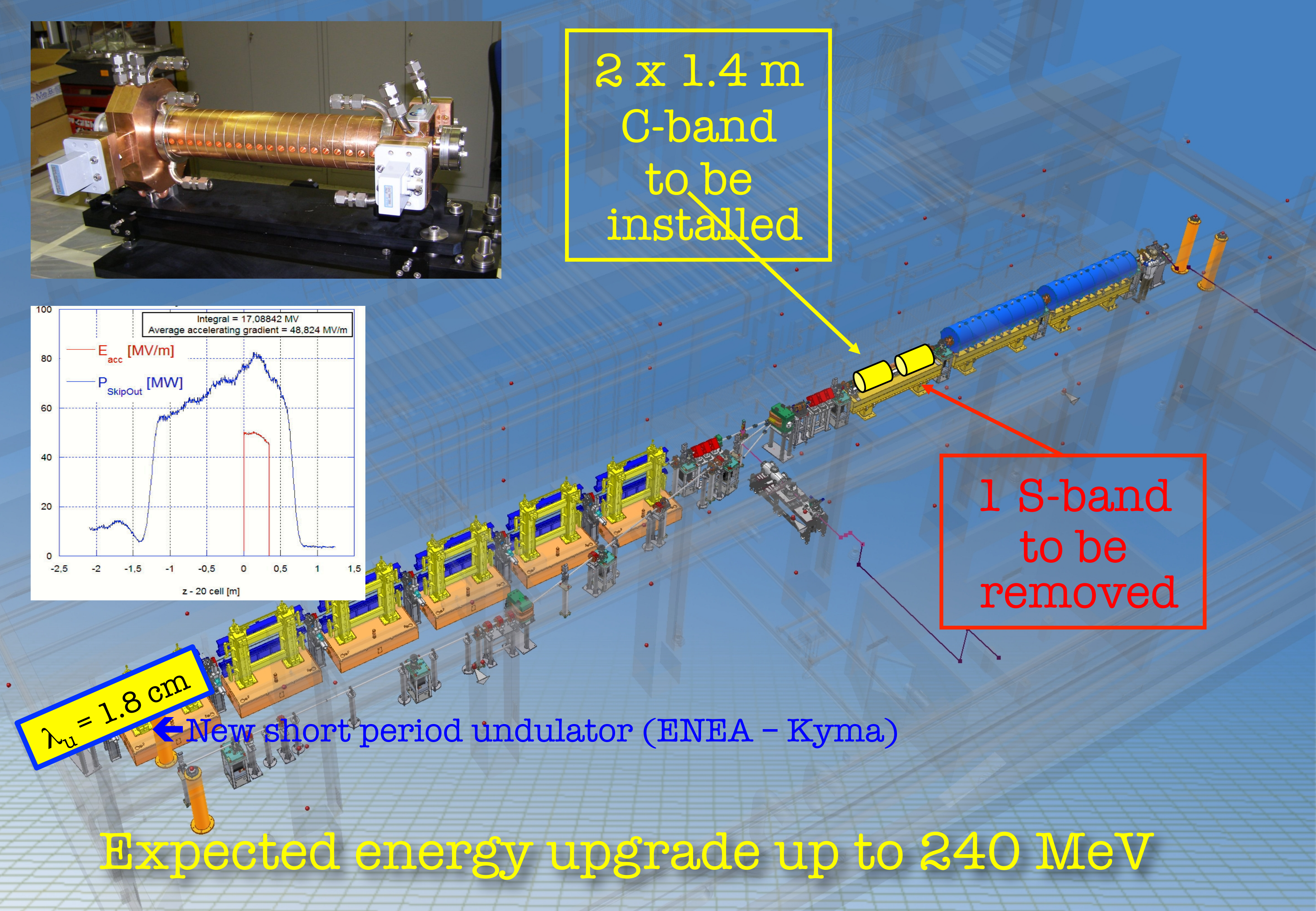
A FEL driven by Plasma Accelerator at LNF?



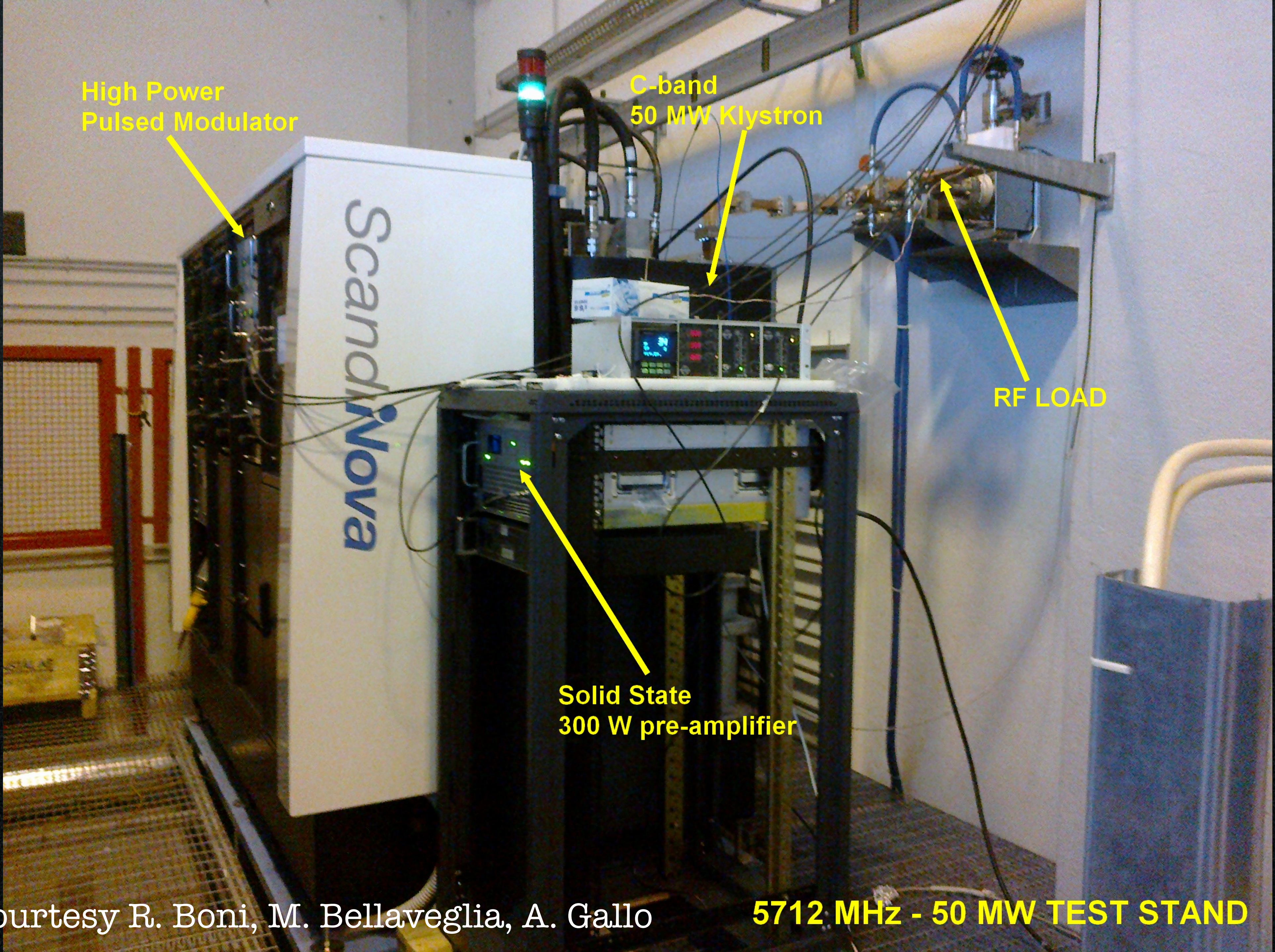
SPARC_LAB User Facility?

SPARC_LAB User Facility?





2 x 1.4 m C-band to be installed
1 S-band to be removed
Integral = 17,08842 MV
Average accelerating gradient = 48,824 MV/m
E_acc [MV/m]
P_SkipOut [MW]
z - 20 cell [m]
λ_u = 1.8 cm
New short period undulator (ENEA – Kyma)
Expected energy upgrade up to 240 MeV



Courtesy R. Boni, M. Bellaveglia, A. Gallo

5712 MHz - 50 MW TEST STAND

ELI_NP Layout

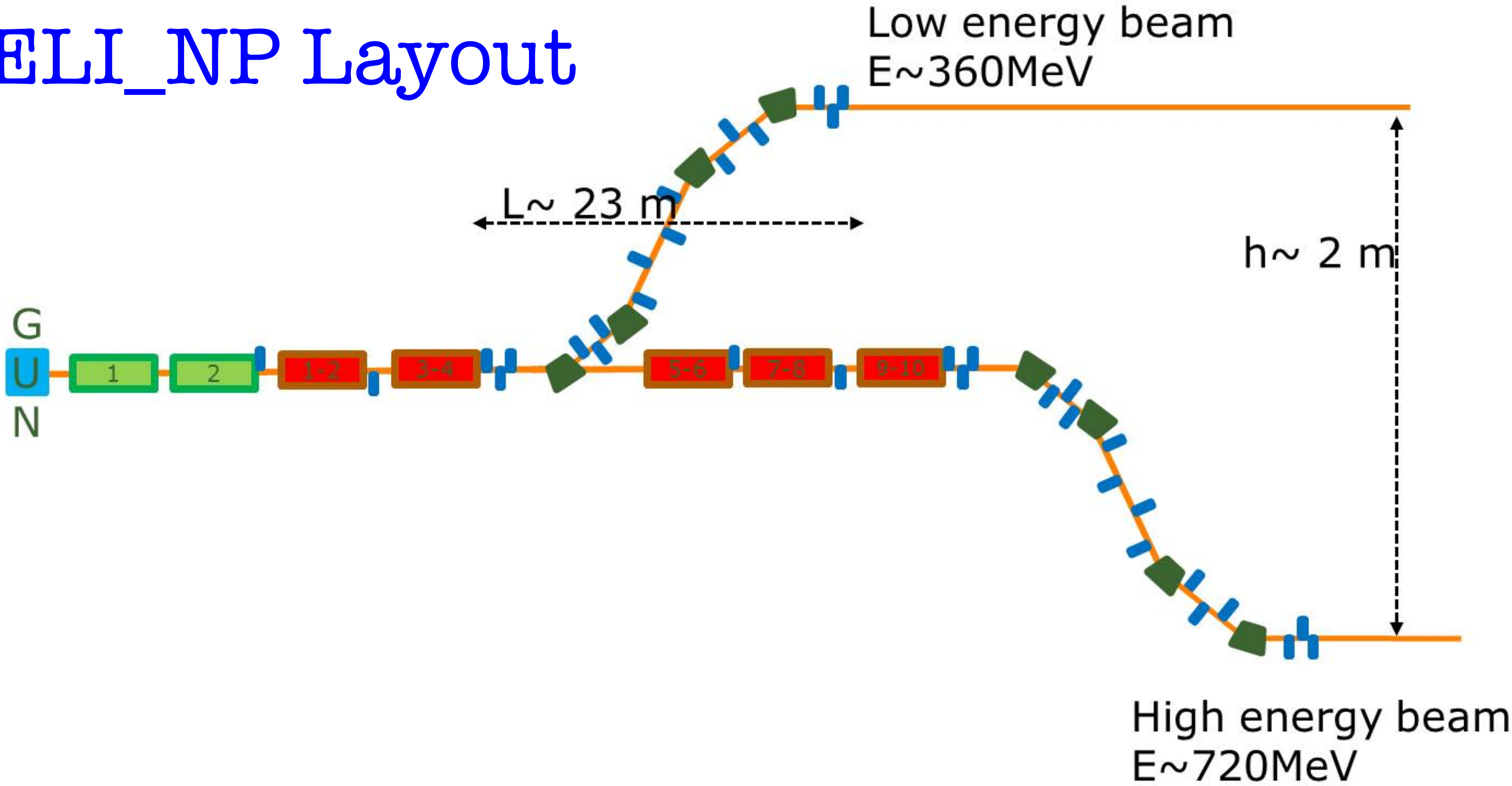


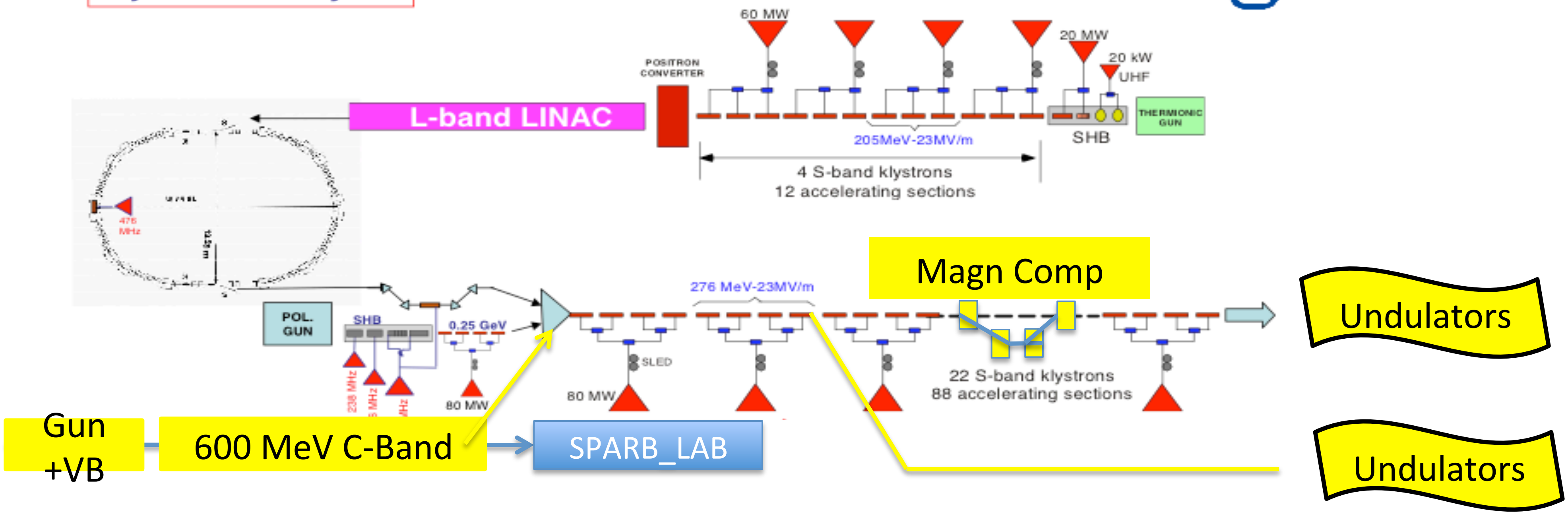
Table 13: expected source performances based on preliminary evaluations

γ (MeV)	Nγ/sec	w_0 (μm)	σ_E (%)	σ_E (keV)	f (f_{RF} x n_{RF})	Nγ/sec.eV
11.1	$2.1 \cdot 10^9$	15	0.25	27.7	100x100	$7.6 \cdot 10^4$

SPARC_LAB contribution to:

SuperB

Injector RF Layout



SASE FEL scaling laws

$$\lambda_r^{MIN} \propto \sigma_\delta \sqrt{\frac{\left(1+K^2/2\right)}{\gamma B_n K^2}}$$

minimum radiation wavelength

energy spread

undulator parameter

$$B_n = \frac{2I}{\varepsilon_n^2}$$

$$L_g \propto \frac{\gamma^{3/2}}{K\sqrt{B_n\left(1+K^2/2\right)}}$$

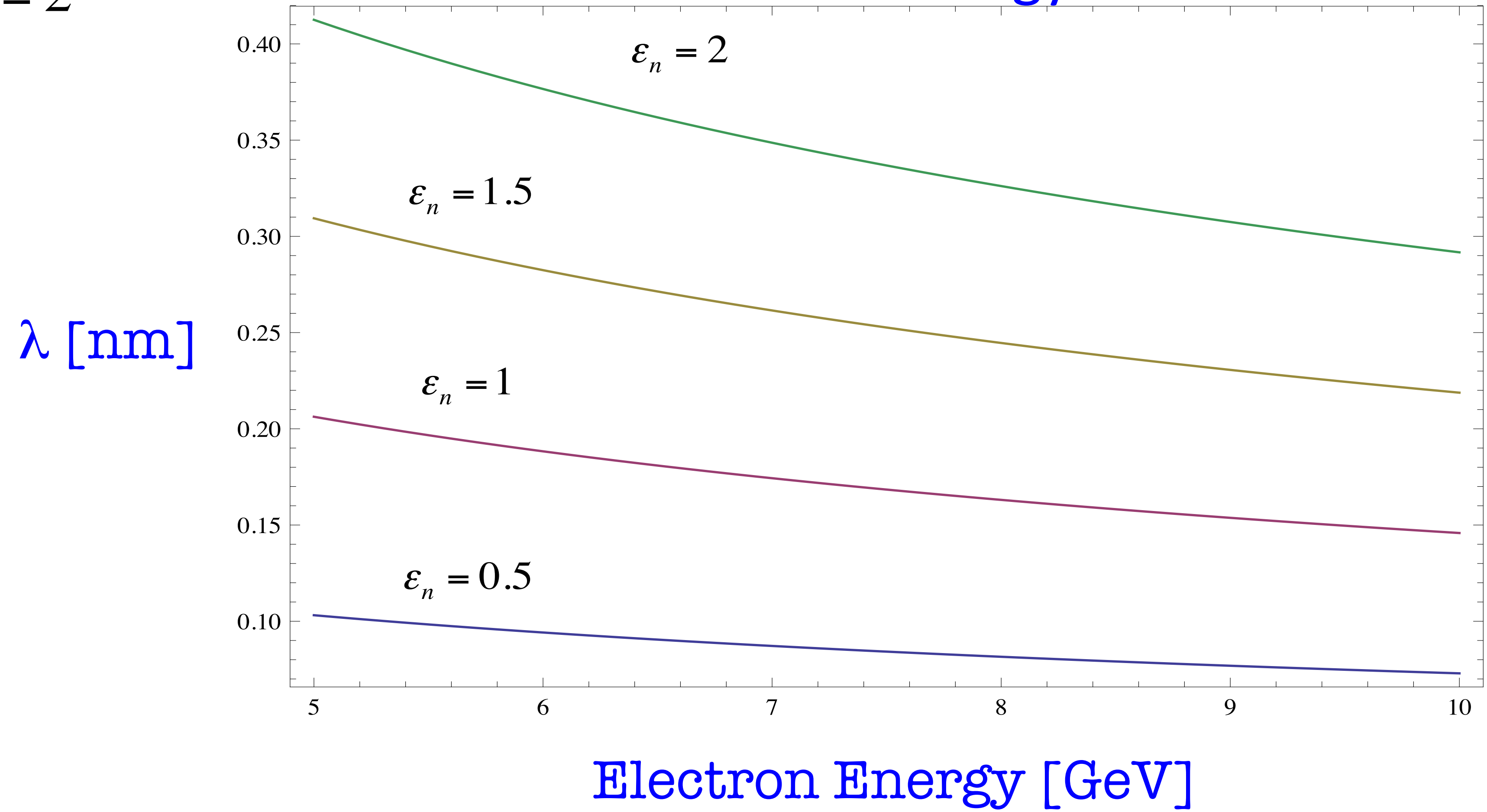
gain length

$I = 3\ kA$

$\sigma_\gamma = 0.01\ \%$

$K = 2$

Minimum achievable radiation wavelength versus electron beam energy and emittance

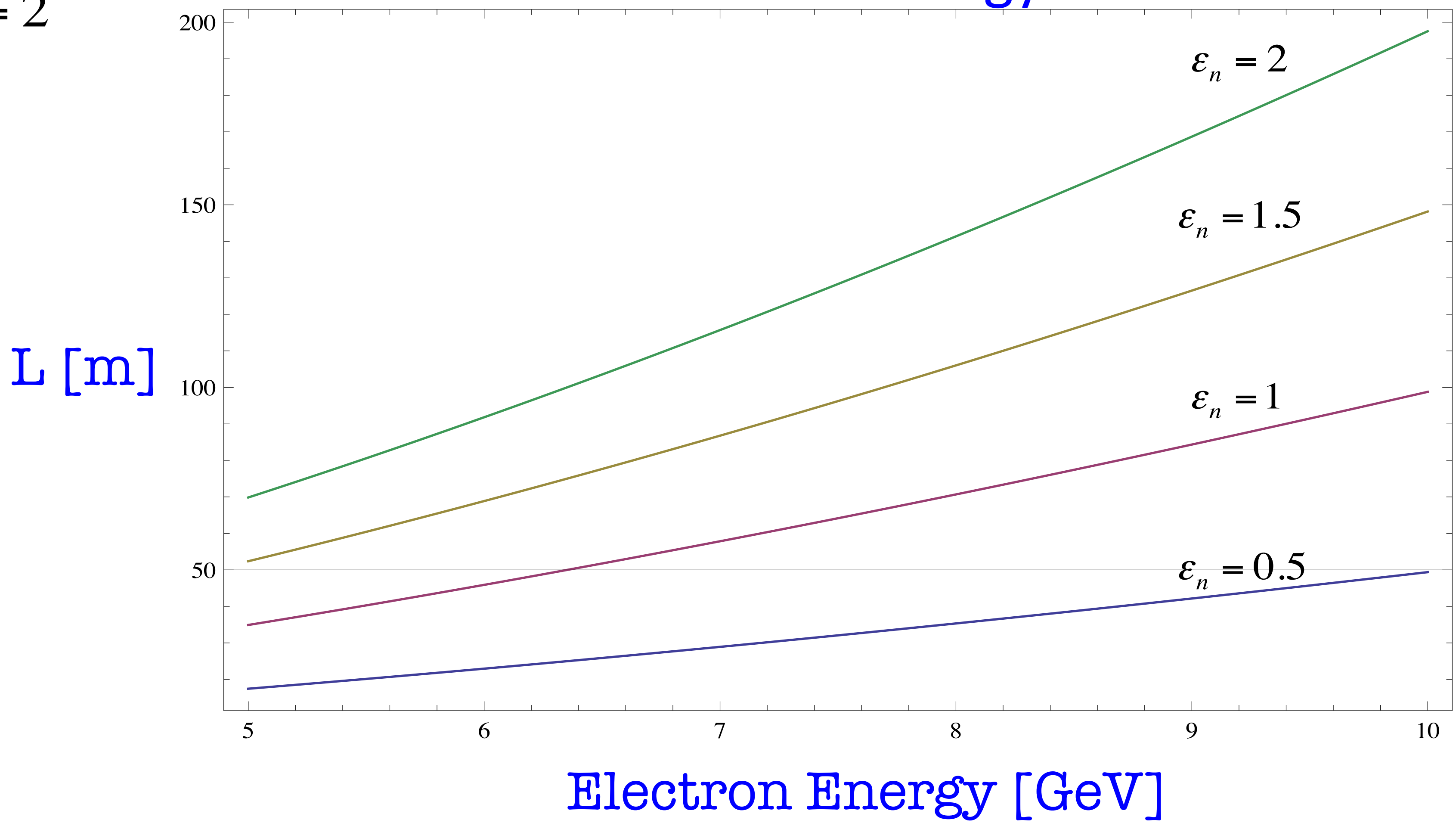


$$I = 3\ kA$$

$$\sigma_\gamma = 0.01\ \%$$

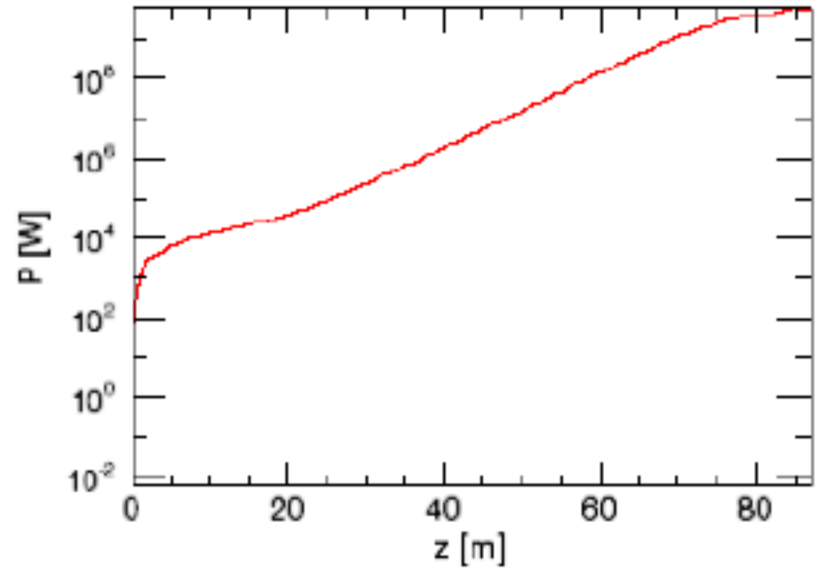
$$K = 2$$

Undulators active length versus electron beam energy and emittance

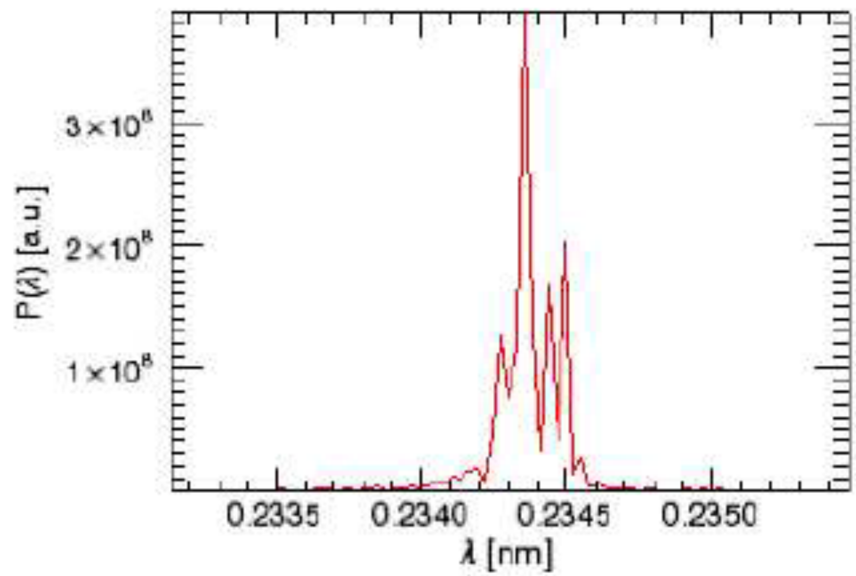


Preliminary GENESIS simulations

Energy	GeV	7
Energy spread	slice(%)	0.003
Vertical emittance	mm mrad	0.5
Horizontal emittance	mm mrad	0.5
Peak Current	kA	3



	SPARClike	LCLSlike	Short period
$\lambda_r(\mathring{A})$	2.34	3.92	1.12
$L_s(\mathrm{m})$	90	70	90
$E_S(\mu J)$	40	40	20
bw(%)	0.05	0.05	0.025
$L_g(\mathrm{m})$	~ 4.8	~ 3	~ 5



CONCLUSIONS

SPARC_LAB is 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 scientific 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 with advanced radiation sources