



ARC-EN-CIEL
**Accelerator Radiation Complex for ENhanced
Coherent Intense Extended Light**

THE ARC-EN-CIEL PROPOSAL

**SOURCE OF COHERENT LIGHT TUNEABLE FROM UV TO
X RAYS, IMPLEMENTED ON A LINEAR ACCELERATOR**

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Acknowledgments to J. R. Marquès (LULI), L. Giannessi (ENEA)

MOTIVATION

- **FEL History in France**

ACO (1983), Super-ACO (1989), CLIO (1992),

First pump-probe two-color experiments using a UV FEL and synchrotron radiation (1994)

- **FEL source for 1 keV for user applications**

- **FEL physics : to exploit harmonic generation and seeding schemes**

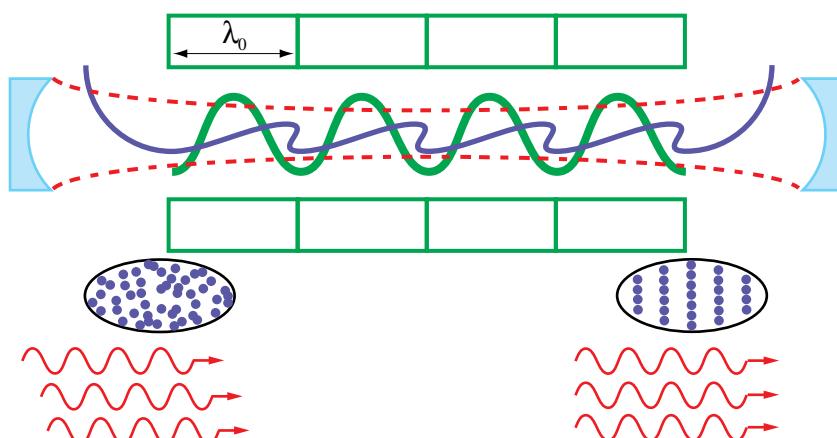
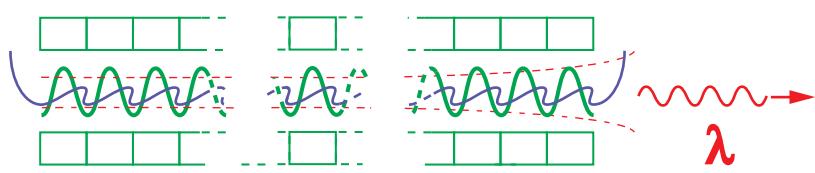
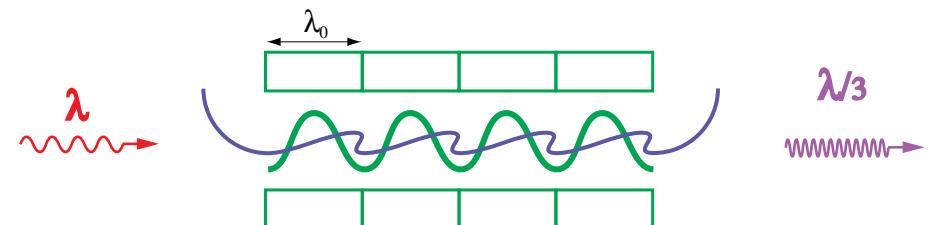
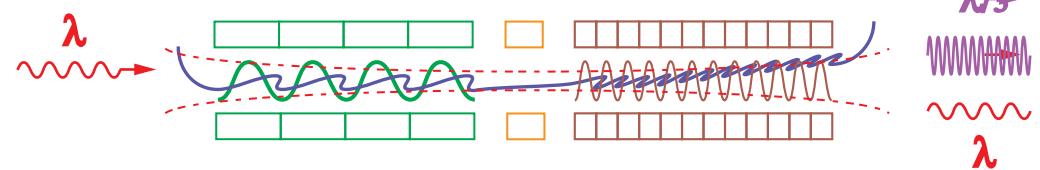
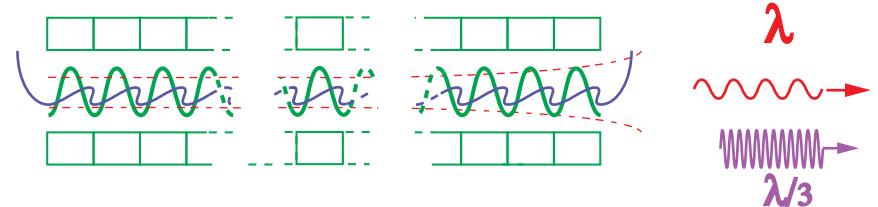
- **"CW" operation**

- **Expertise on accelerators (SC...)**

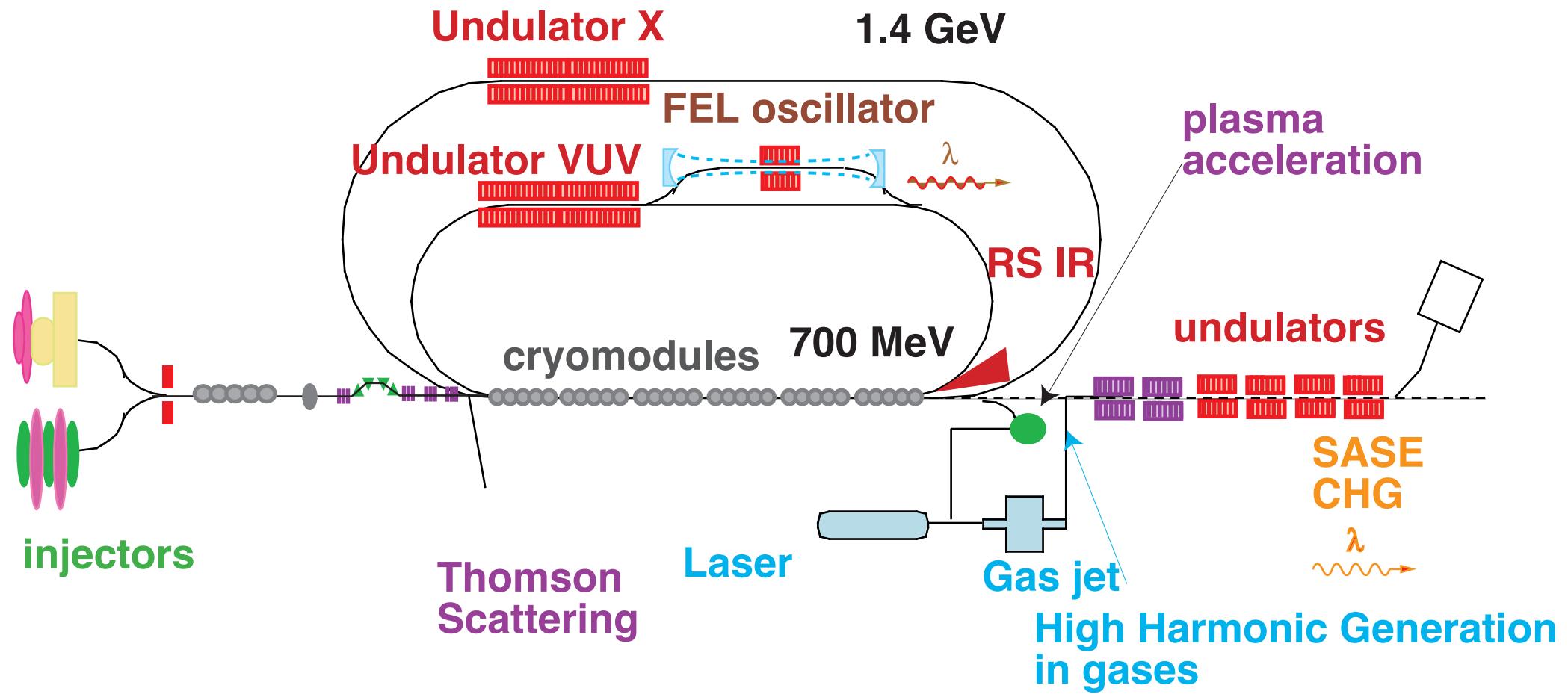
- **Close synergy between FEL and conventional laser sources communities in the same facility**

FEL CONFIGURATIONS

$$\lambda = \frac{\lambda_0}{2n\gamma^2} \left(1 + \frac{K^2}{2}\right) \quad K = 0.94 \lambda_0 \text{ (cm)} B_0 \text{ (T)}$$

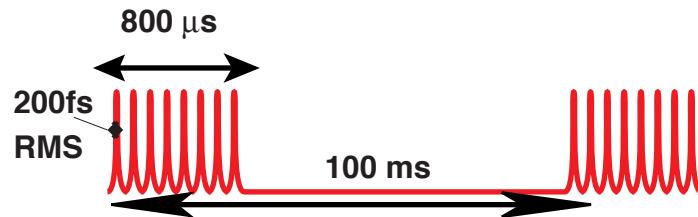
Oscillator**SASE****Harmonic Generation****HGHG****NHG**

SCHEME

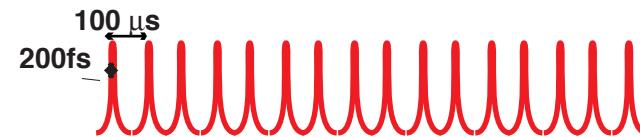


INJECTORS

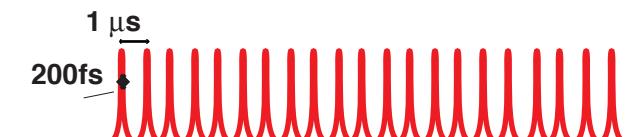
Injector 1



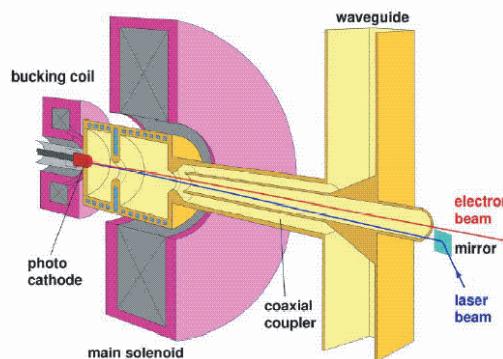
Injector 2



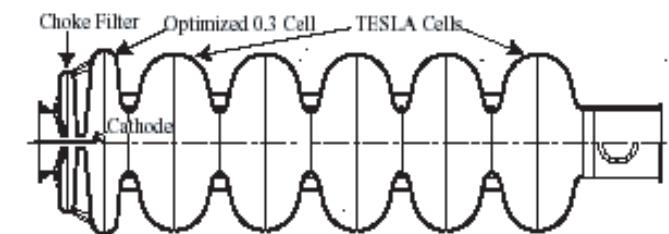
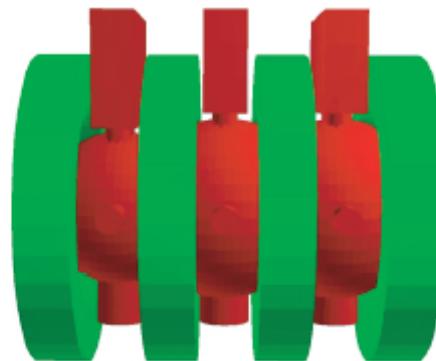
Injector 2 bis



emittance : 2π mm.mrad, charge : 1nC



RT pulsed RF gun (TTF 2)

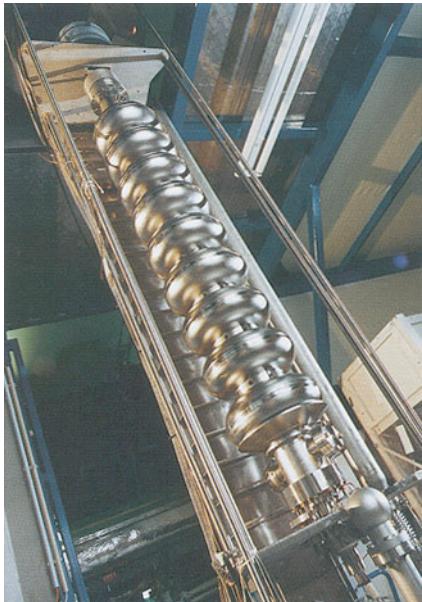


SC RF gun (Rossendorf)

R&D :

- Emittance compensation
- "cw" operation
- Reliability

THE LINAC CAVITIES



**TESLA type
superconducting
accelerator
6 cryomodules
(1.3 GHz)**

E=700 MeV

L=72 m

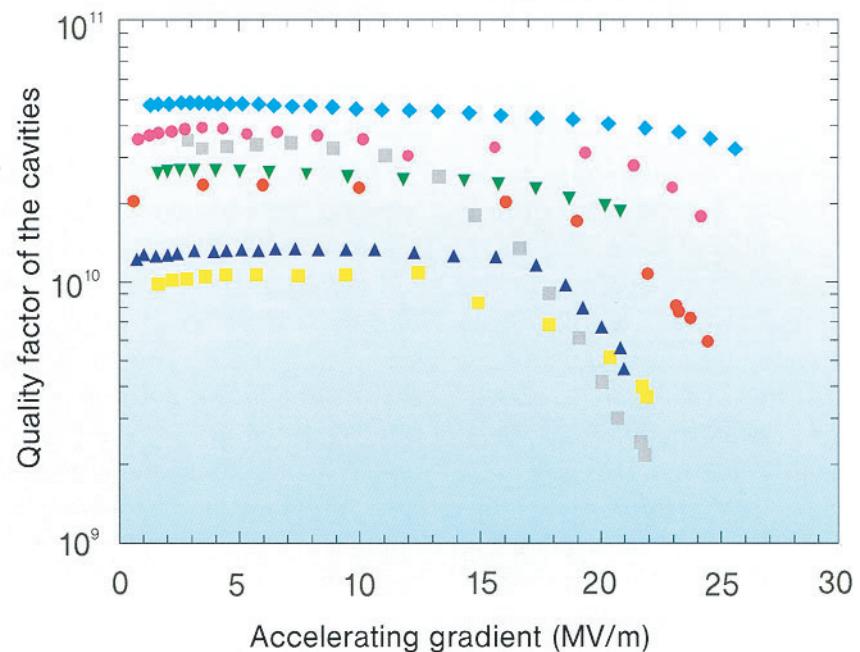
I=1mA/pass (ER : 5-10 mA)

emittance : 2π mm.mrad

charge : 1nC

energy spread : 0.1 %

$\hat{I}=3kA$, $\langle I \rangle = 0.1 mA$



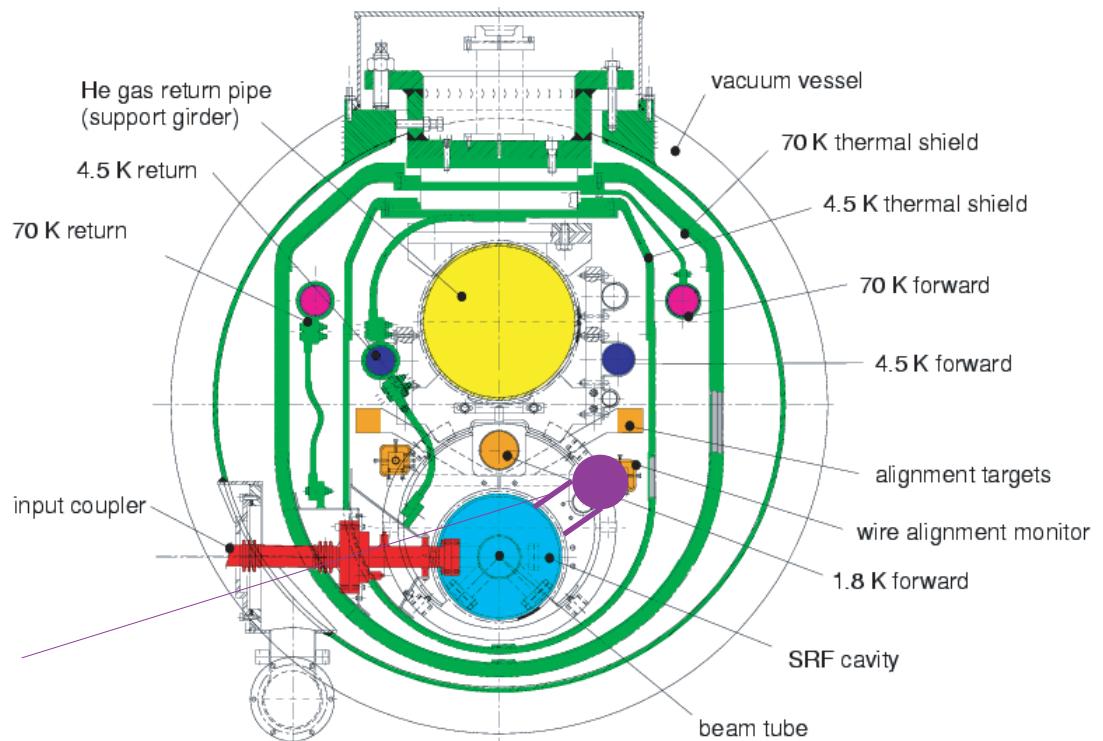
THE LINAC CAVITIES



R&D:

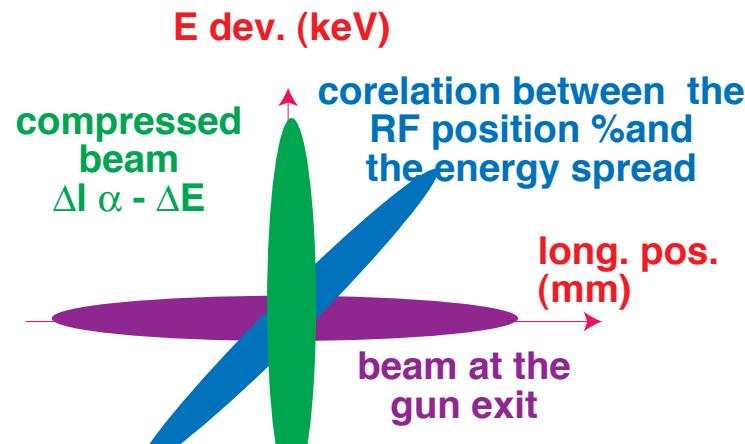
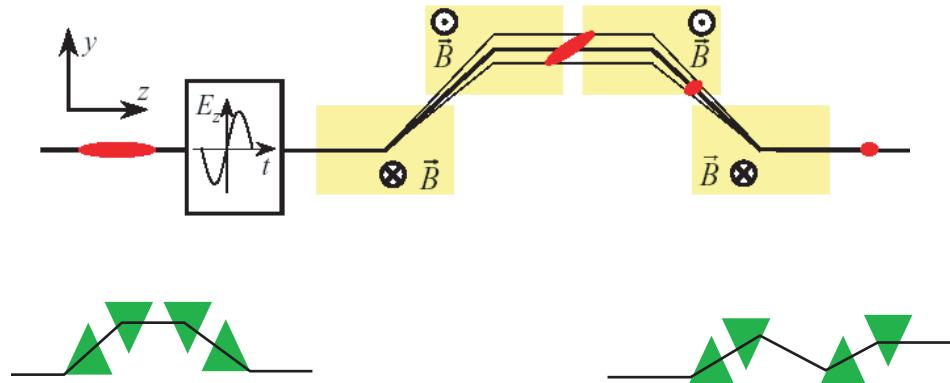
- Superconducting cavities in "cw" regime
 - power couplers
 - higher order modes couplers
 - frequency tuning

The cryogenic system

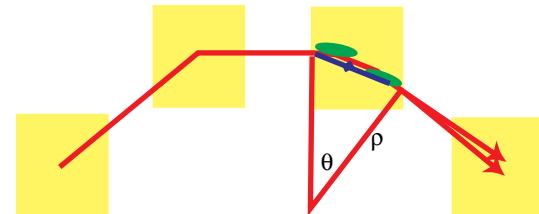


PULSE COMPRESSION

- Magnetic chicane



$$R_{56} = \frac{\Delta l}{\Delta E} \cdot \frac{E}{E}$$



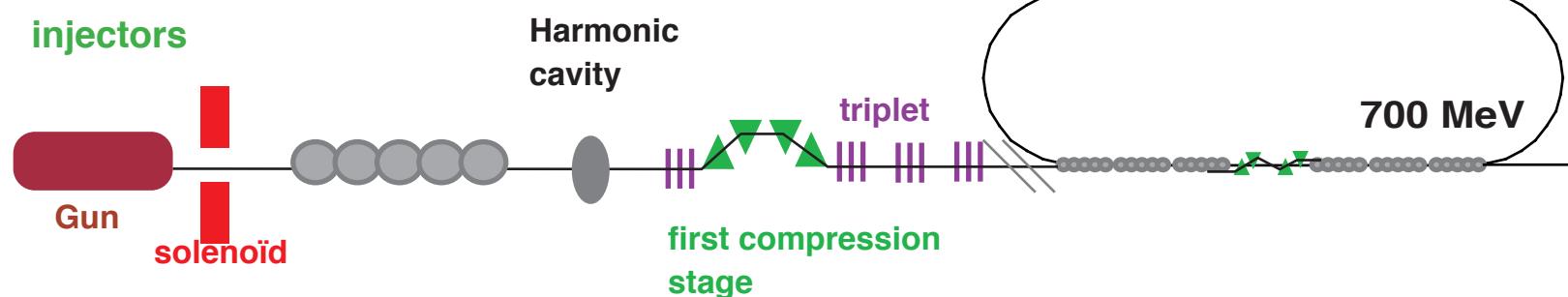
- Coherent Synchrotron Radiation
- Space Charge
- Wakefields
- Longitudinal jitter (synchronisation with an external laser)

the wave emitted by the tail coincides with the head of the bunch
 ⇒ non uniform energy loss
 ⇒ ϵ_t growth

- Harmonic cavity for a linear phase energy correlation in the bunch

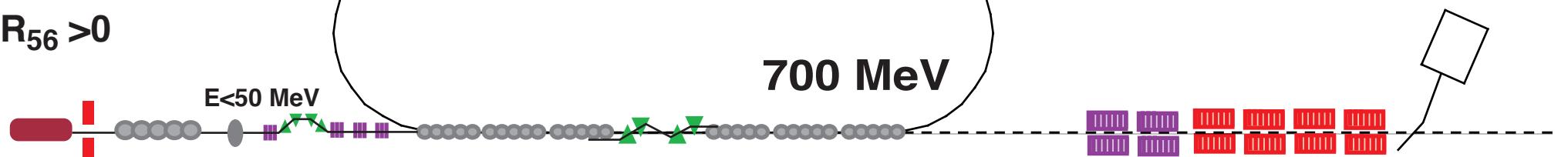
PRE-ACCELERATION - COMPRESSION

Pre-acceleration :

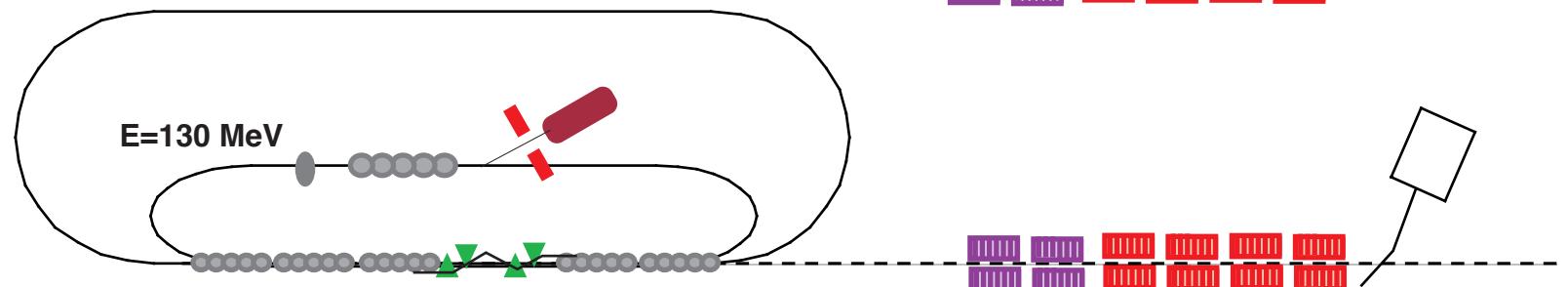


Bunch Compression :

Arc 1 :
bunch lengthening
 $R_{56} > 0$

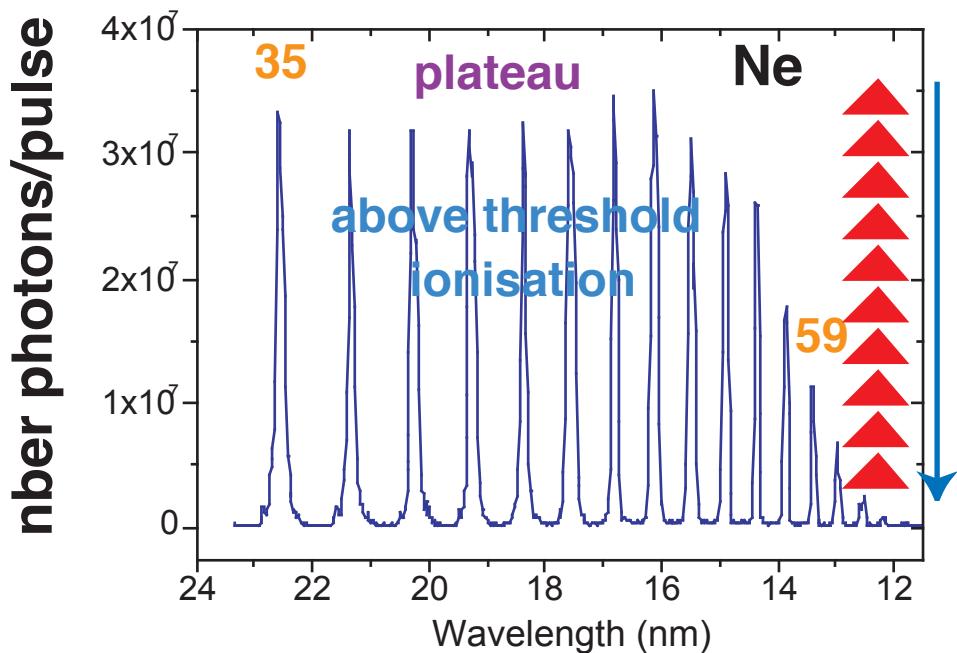
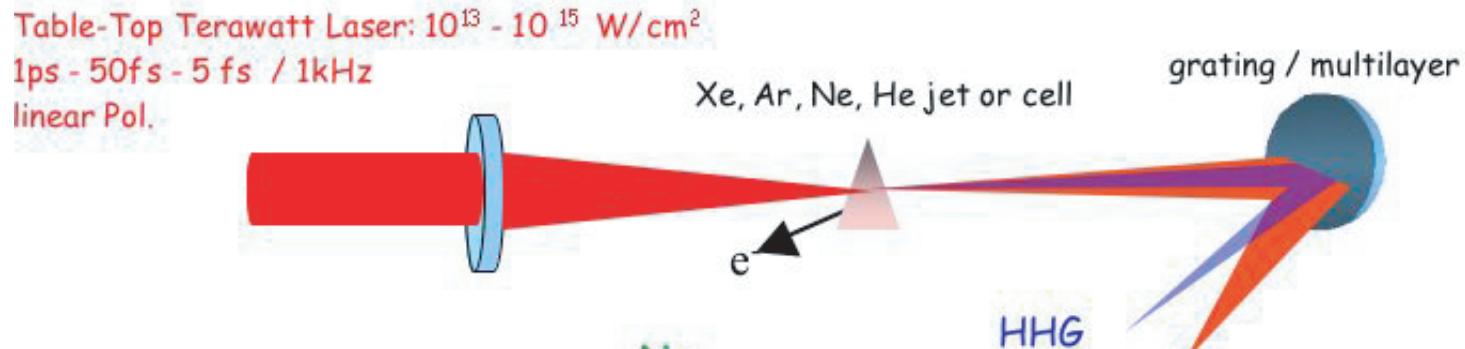


LUX type option

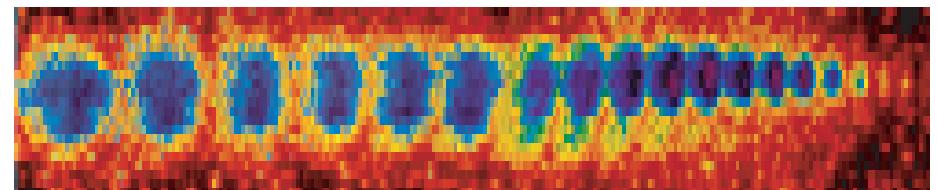


LASER SOURCES

Infra-red laser system Ti:Sa, mJ, 1-10 kHz, frequency conversion
High Gain Harmonic Generation in gas

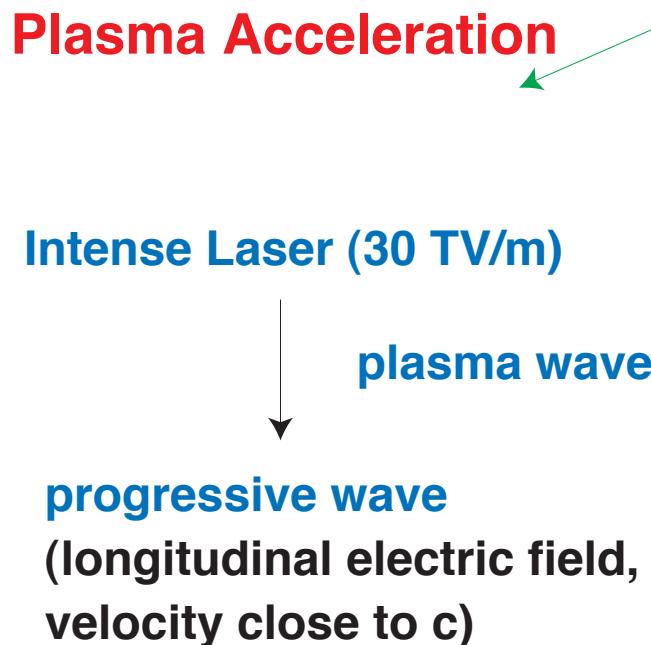


linear polarisation
tuneability
spatial and temporal coherence

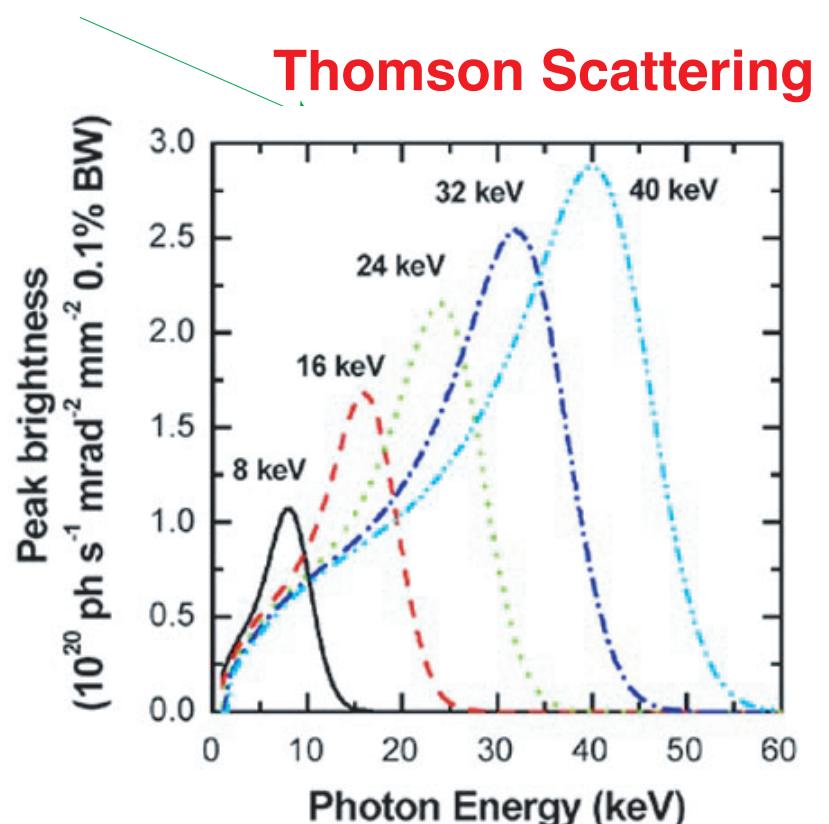


LASER SOURCE

Infra-red Ti:Sa laser system, mJ, 1-10 kHz, frequency conversion
amplification chain : few J, 10 Hz, 30 TW, 10^{20}W/cm^2



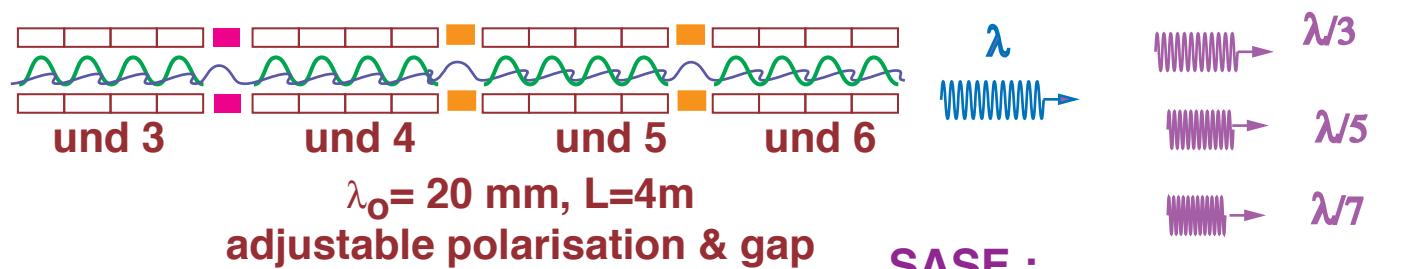
E_{in}	Δt	emitt	L_{acc}	E	spot	E_{fin}
MeV	fs	mm.mrad	cm	J	μm	GeV
10	200	1	0.5-3	1	20	1.6
700	200	1	8-32	100	100	1.6



8-40 keV, 100 fs FWHM
 $3 \times 10^7 \text{ ph/pulse/0.1\%BW}$
12 mrad, 50 μm

SINGLE PASS FEL SOURCES

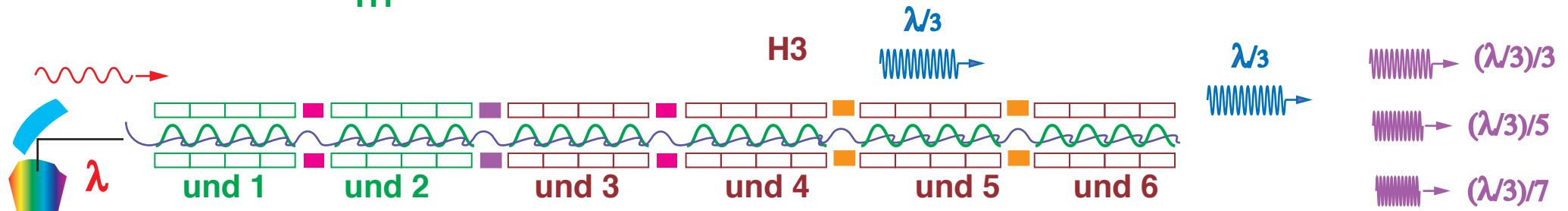
- SASE



- Harmonics generation

$\lambda_0 = 30 \text{ mm}$, $L = 4 \text{ m}$
adjustable polarisation & gap

H1



seeding : - Ti-Sa, 4ω

- high harmonics produced in gases
- 70-20 nm @ 700 MeV, 50 nJ@42 nm
- 10 nm@ 1.4 GeV

SASE :

200-7 nm@700 MeV
 $10^{17}-10^{16} \text{ ph/s/0.1\%BW}$
 $10^{15}-10^{13} \text{ ph/pulse}$

CHG :

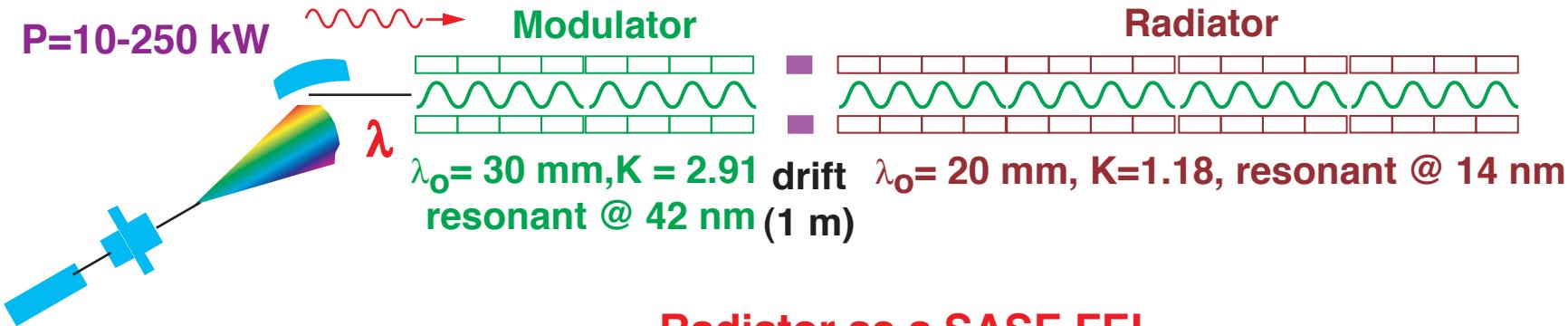
100-0.8 nm @ 700 MeV,
 $10^{17}-10^{12} \text{ ph/s/0.1\%BW}$
 $10^{14}-10^9 \text{ ph/pulse}$
0.4 nm@ 1.4 GeV



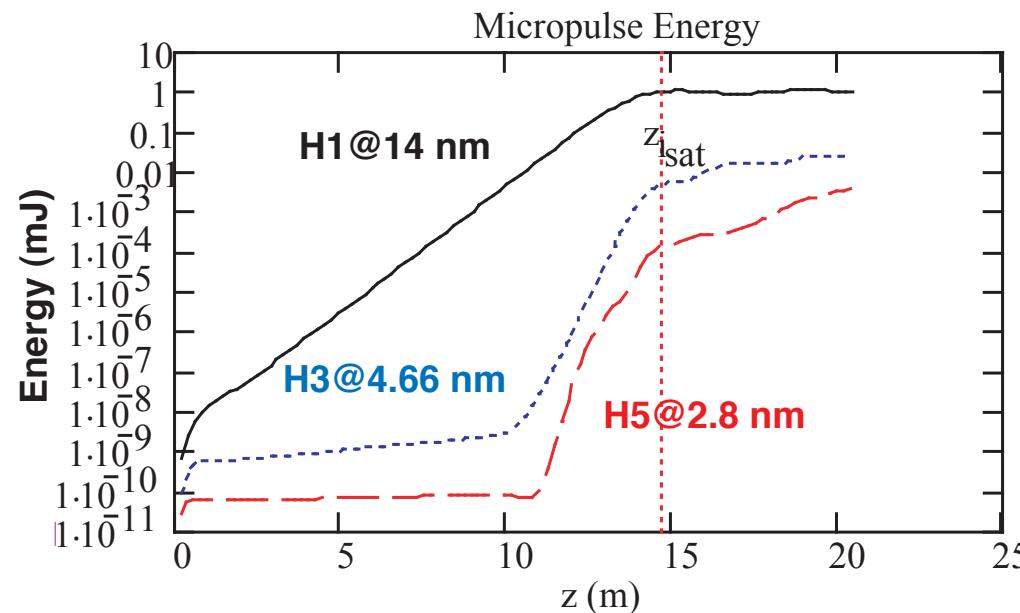
PERSEO CALCULATIONS

1D steady state (L. Giannessi)

* Perseo Mathcad library, available @ <http://www.perseo.enea.it>



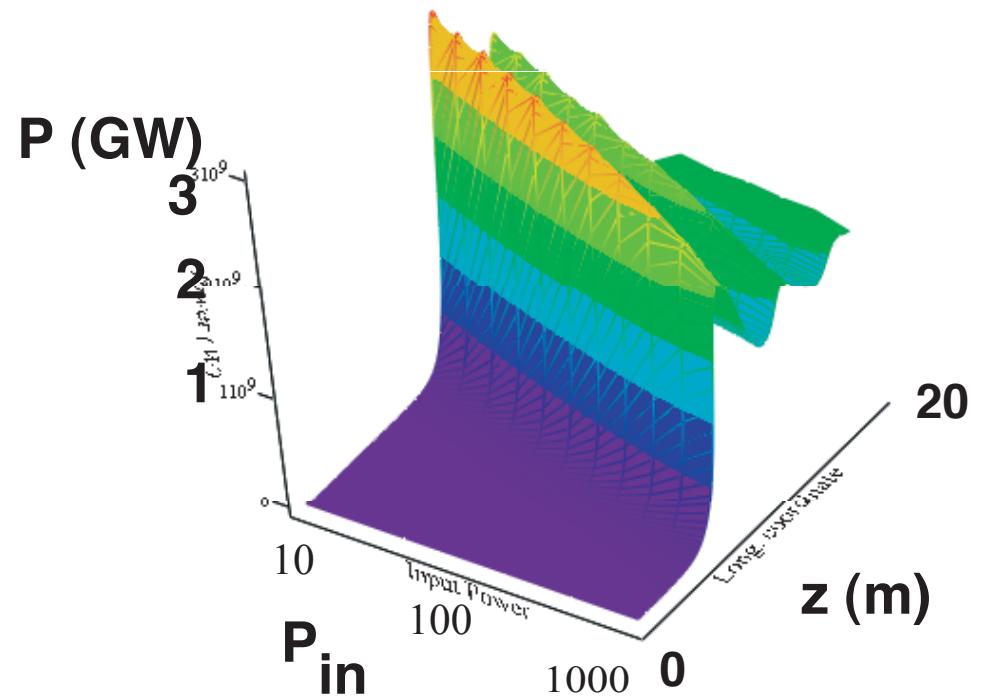
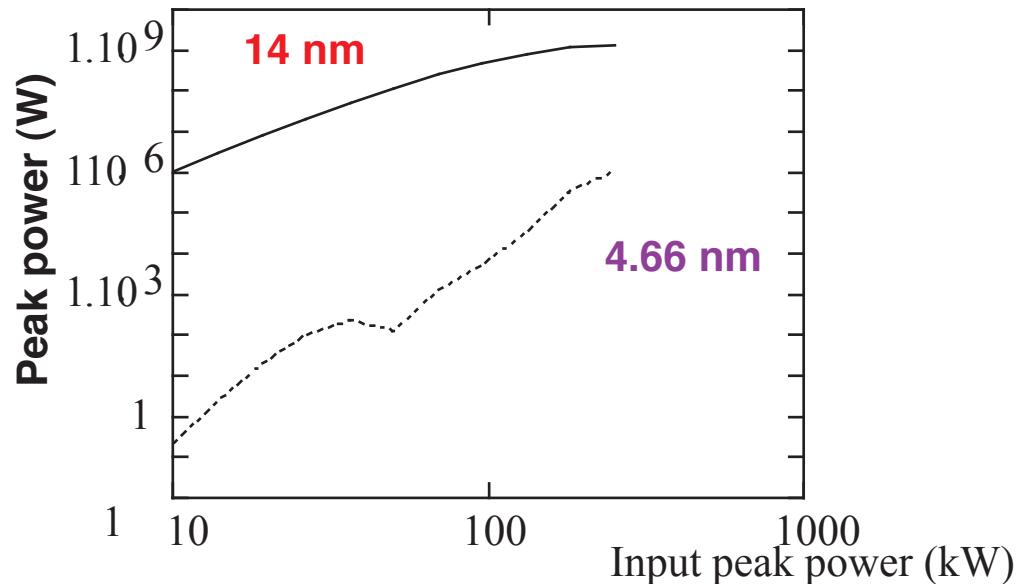
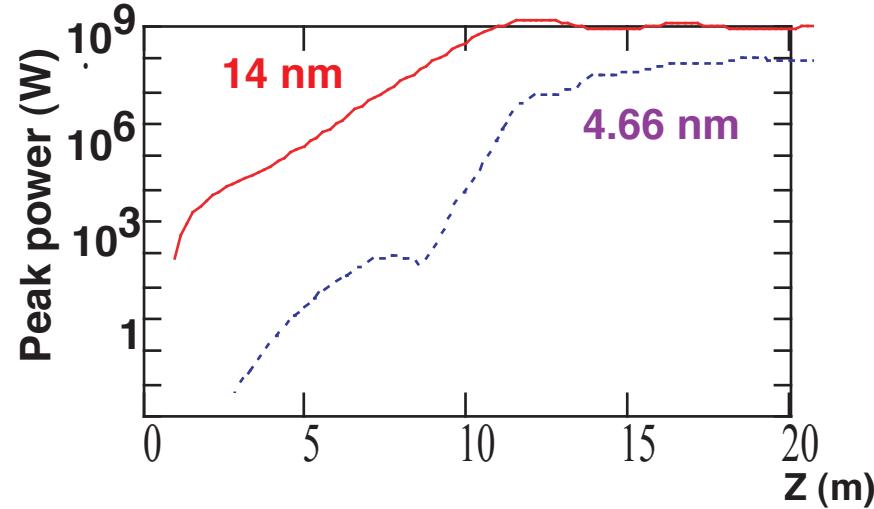
Radiator as a SASE FEL





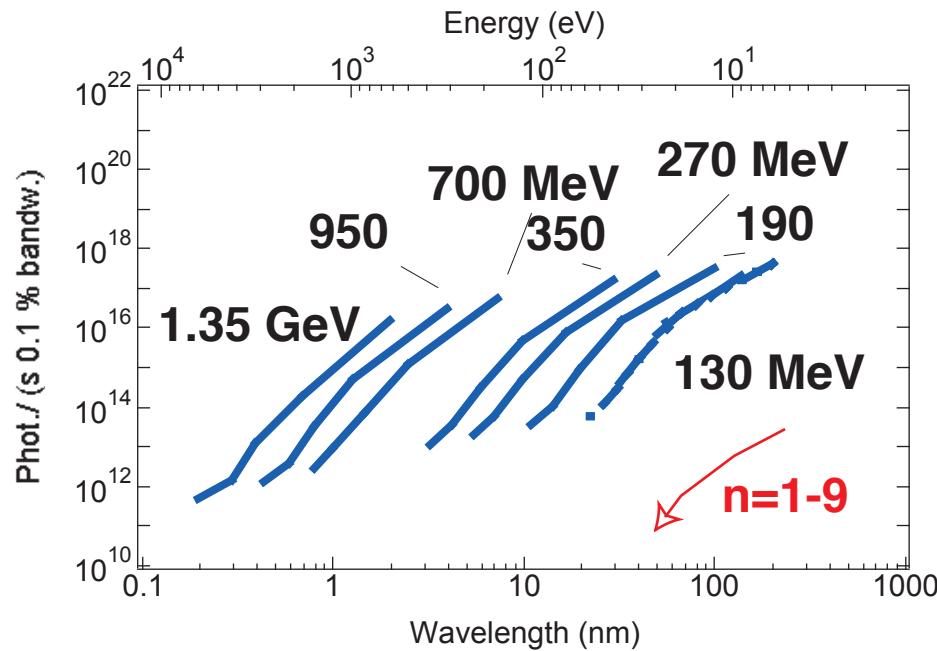
PERSEO CALCULATIONS

1D steady state (L. Giannessi), HGHG from HH in gases at 42 nm (50 kW)

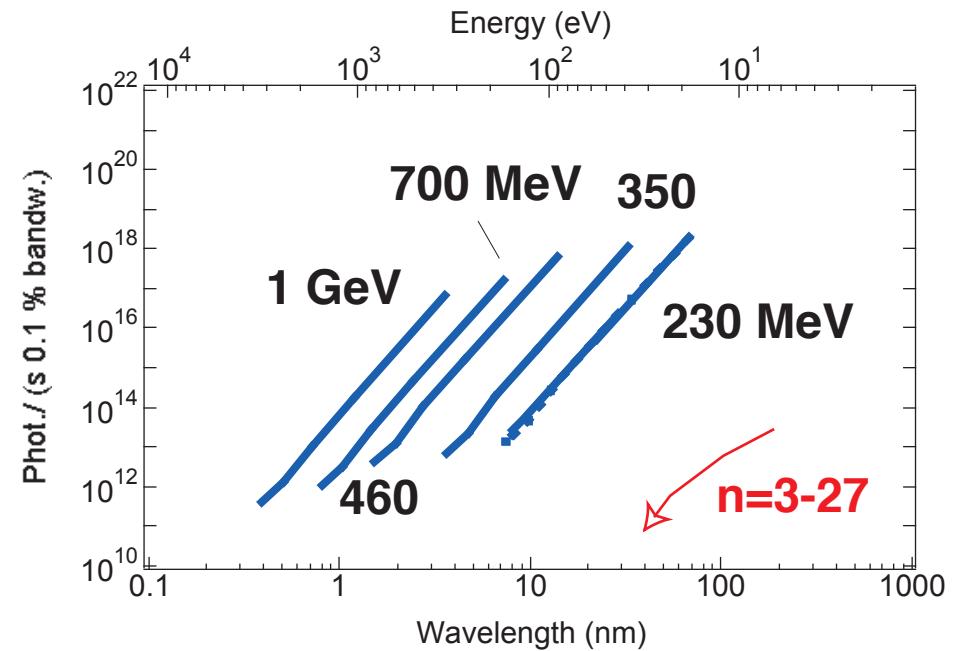


NON LINEAR HARMONICS

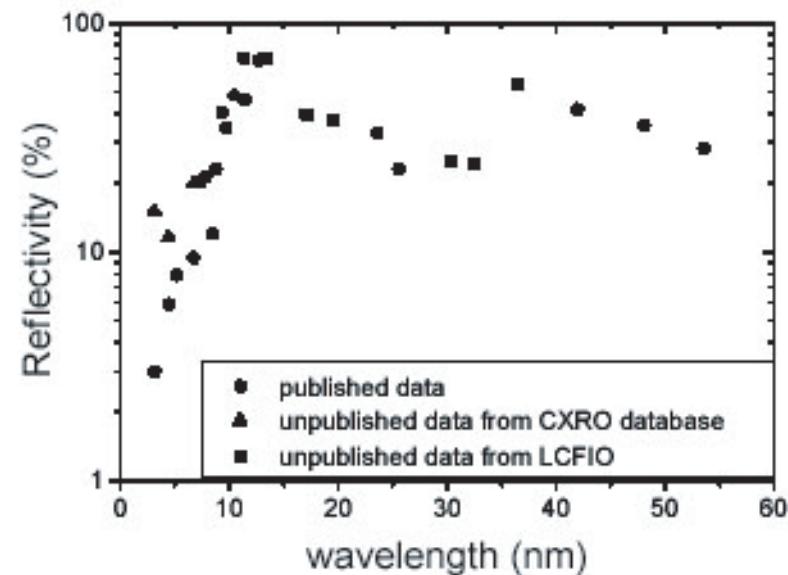
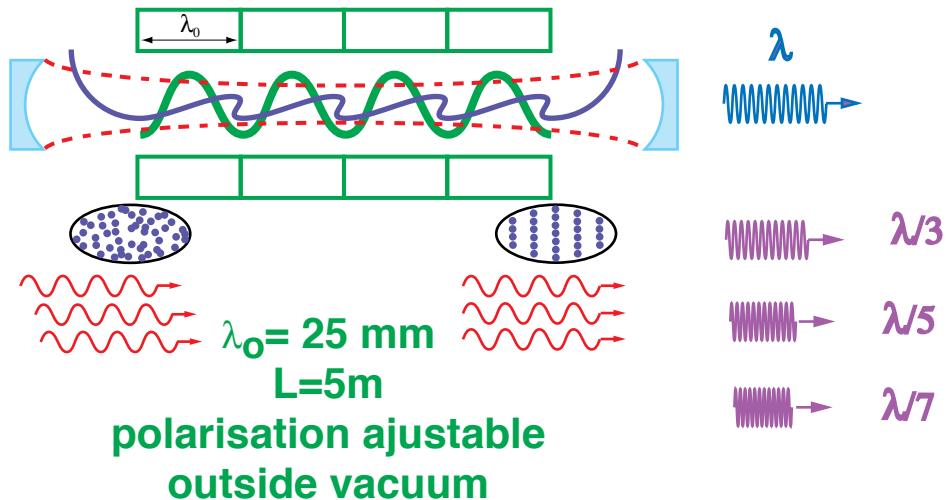
SASE



CHG

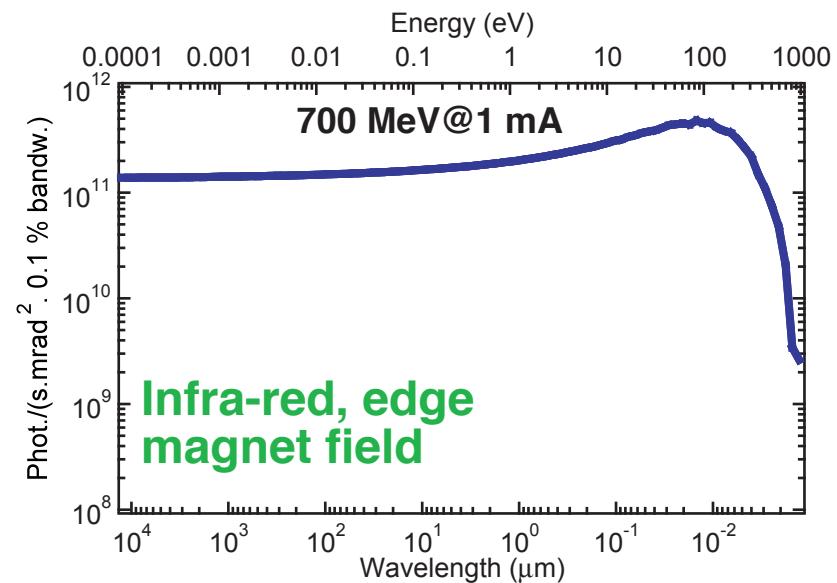
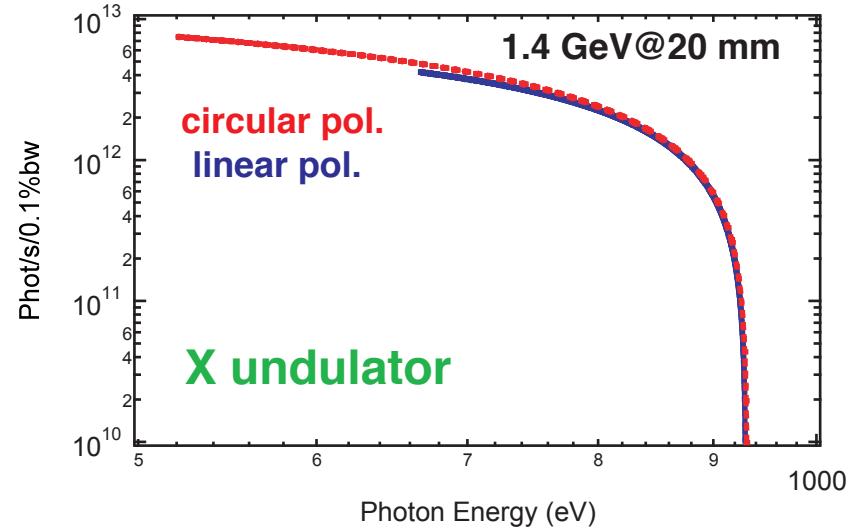
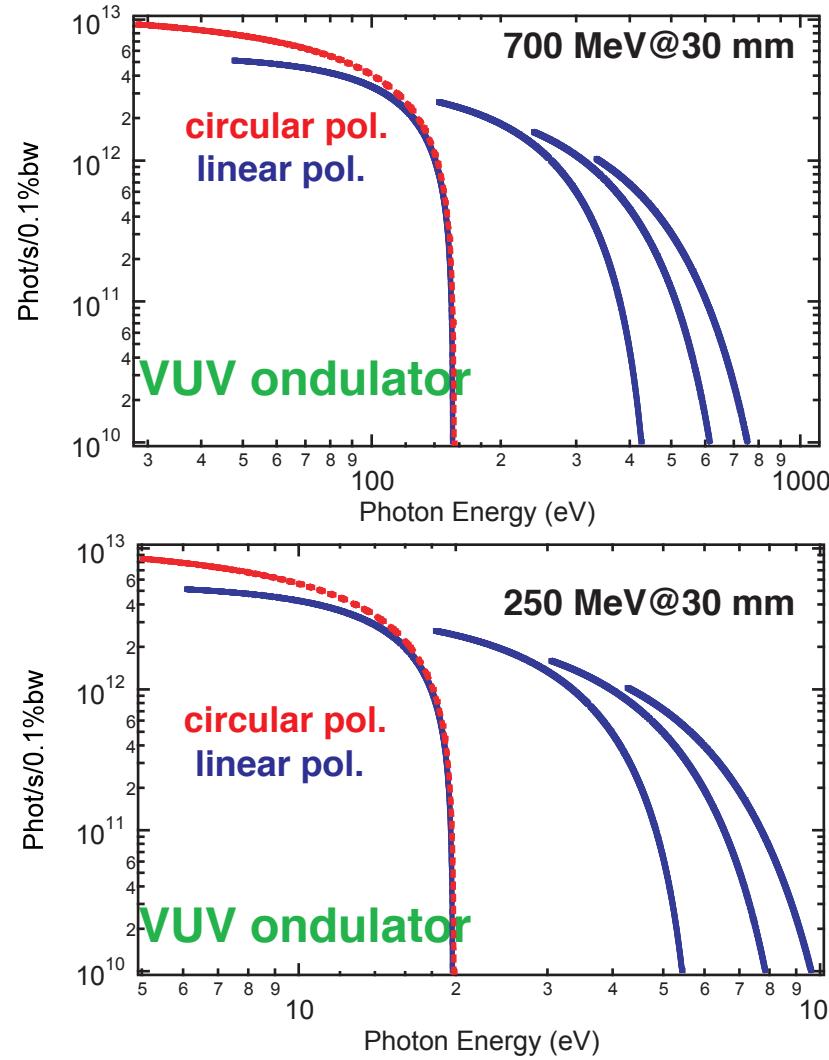


THE FEL OSCILLATOR



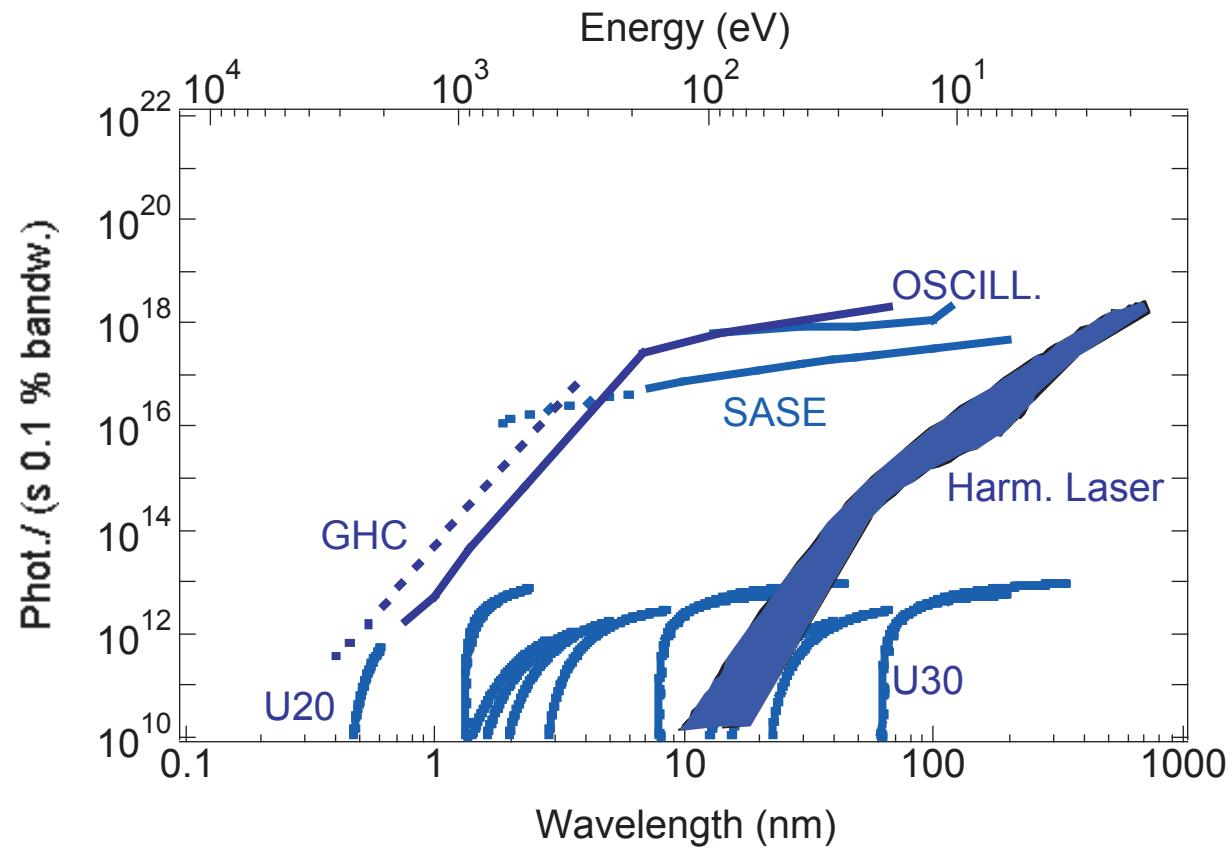
130-13 nm
 $\langle P \rangle = 100\text{W}-1\text{kW}$
adjustable polarisation

ERL SOURCES



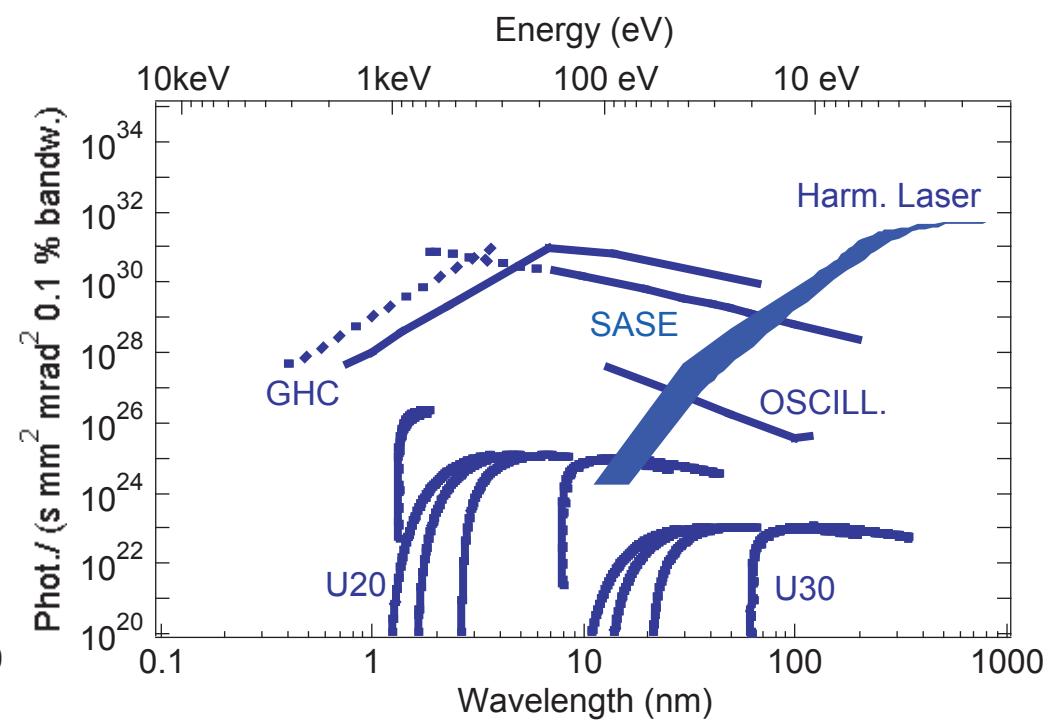
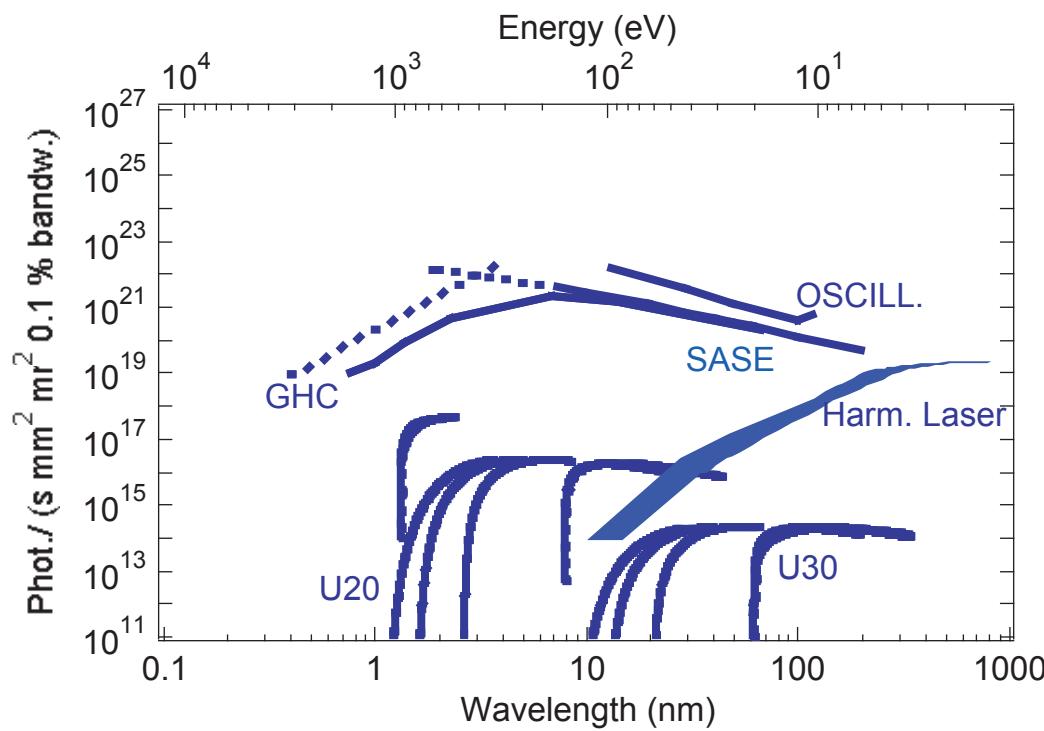
ARC-EN-CIEL PERFORMANCES

Flux

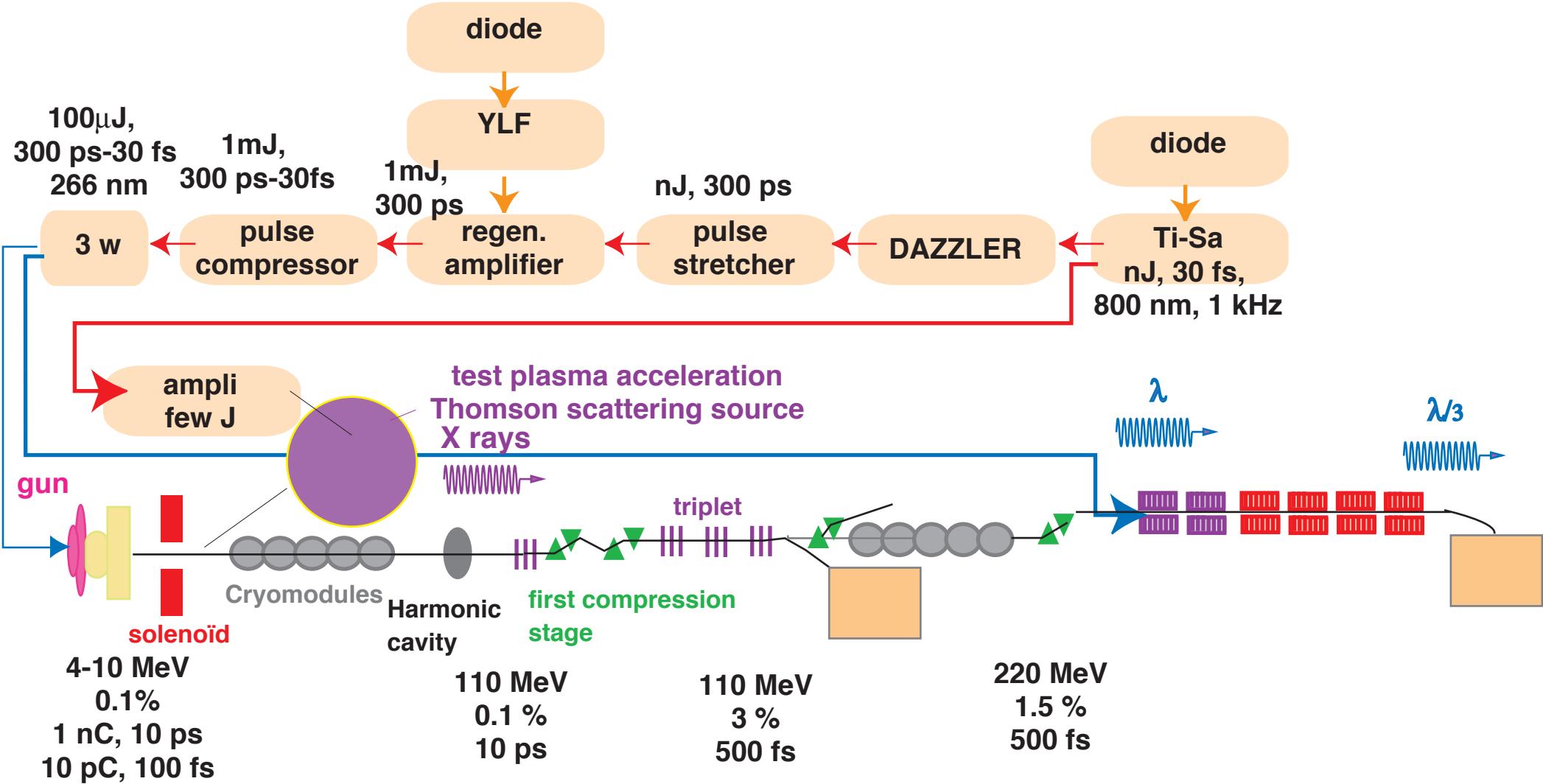


ARC-EN-CIEL PERFORMANCES

Brilliance



PHASE 1



APPLICATIONS DES SOURCES ACCORDABLES VUV-X FS COMBINANT ACCÉLÉRATEURS ET LASERS: "SLICING" À SOLEIL ET LE PROJET ARC-EN-CIEL



3-4 février 2004, à l'amphithéâtre Lehmann à Orsay
Site web: <http://www.lure.u-psud.fr/congres/femto/>

Chairs :

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A. Rousse (LOA)

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M. Jablonka (CEA/SACM)
C. Jucha (LURE)
P. Morin (SOLEIL)
P. O'Keeffe (LURE)

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