PLASMON X

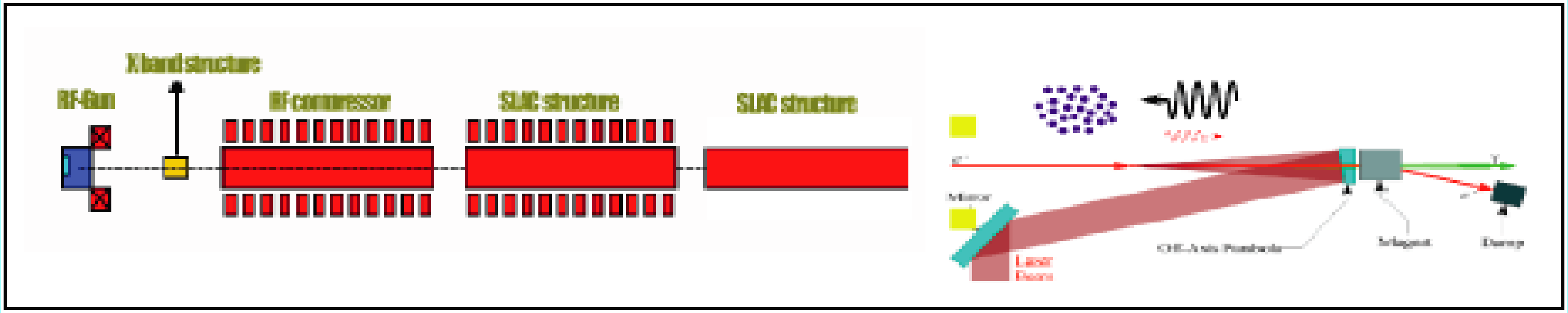
Design of the Thomson Source at SPARC/ PLASMONX for incoherent and coherent X-rays

Luca Serafini - INFN/MI - on behalf of SPARC & PLASMONX Team

- **The PLASMON-X Project: a marriage between the SPARC high brightness electron beam and a high intensity laser beam**

  Design and acquisition of a 200 TW Ti:Sa laser system for Plasma and IFEL acceleration exp. and a Thomson Source for monochromatic X-rays

PLASMON X



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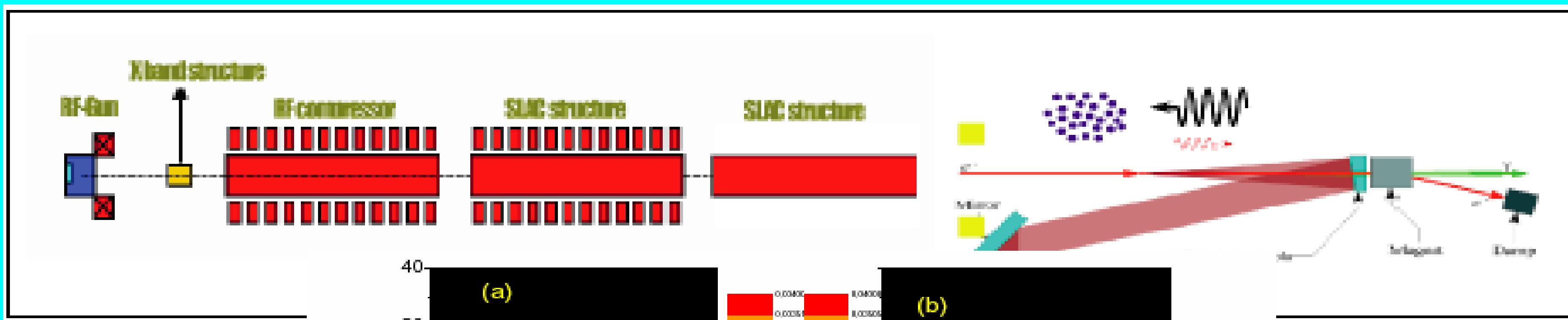
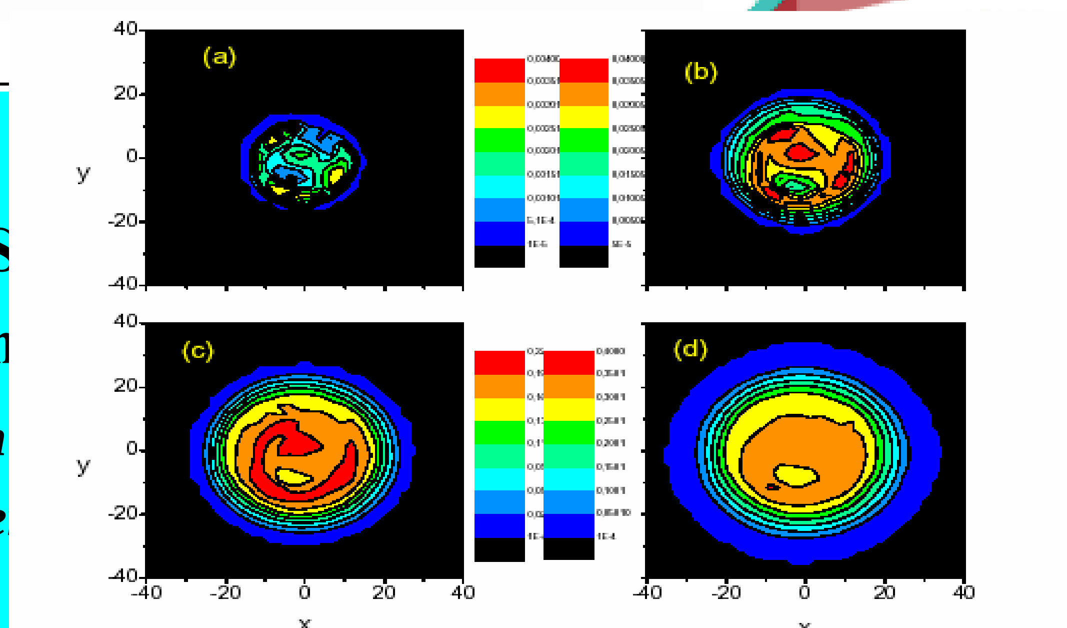
- **Coherent X-Rays at 1 Å from Thomson Sources as classical *SASE-FELs* or *Quantum FELs* (see also Maroli's and Piovella's talks in WG3)**

PLASMON X





- **The PLAS… he SPARC high brigh… y laser beam**

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PLASMON X

(*PLasma Acceleration at Sparc & MONochromatic X-rays*)

IS BASED ON THE MARRIAGE BETWEEN:

High Brightness Electron Beams (from 10's fs to a few ps bunch length)

$$B_n \equiv \frac{cQ_b}{\sigma_z \varepsilon_{nx} \varepsilon_{ny}} > 10^{15} \left[\frac{A}{m^2 rad^2}\right]$$

High Intensity Laser Beams (30-100 fs pulses)

$$I > 10^{19} \left[\frac{W}{cm^2}\right]$$

SPARC

IS THE FIRST INGREDIENT

Under INFN responsibility

(see also Daniele Filippetto's talk in WG4)

Under ENEA responsibility

Stanford Linear Accelerator Center

ENEA

elettra Synchrotron Light Laboratory

UCLA

ULTRAS INFM NATIONAL LABORATORY FOR ULTRAFAST AND ULTRAINTENSE OPTICAL SCIENCE

La Sapienza Università degli Studi di Roma

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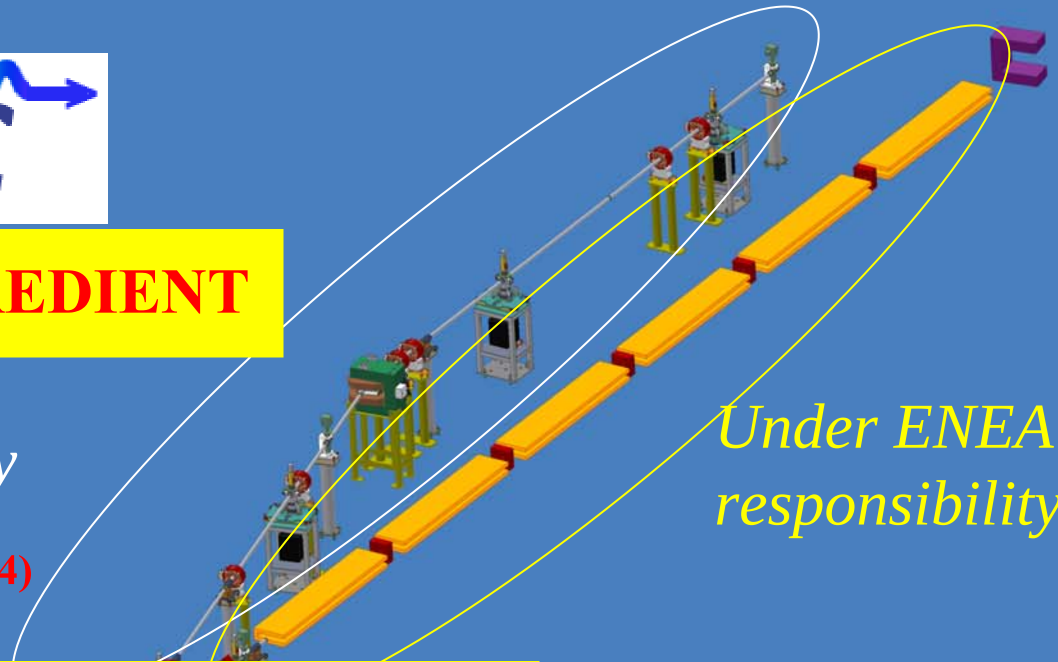

GOALS

Generation of 30-150 MeV e^- beams

(Q, σ_t, ε_n, $\Delta\gamma/\gamma$)

Phase 1) 1 nC, 3 ps, 1 μm, 10^{-3}

Phase 2) 1 nC, 300 fs, 2 μm, $2{\cdot}10^{-3}$

PLASMONX) 20 pC, 60 fs, 0.3 μm, $2{\cdot}10^{-3}$

ENEA

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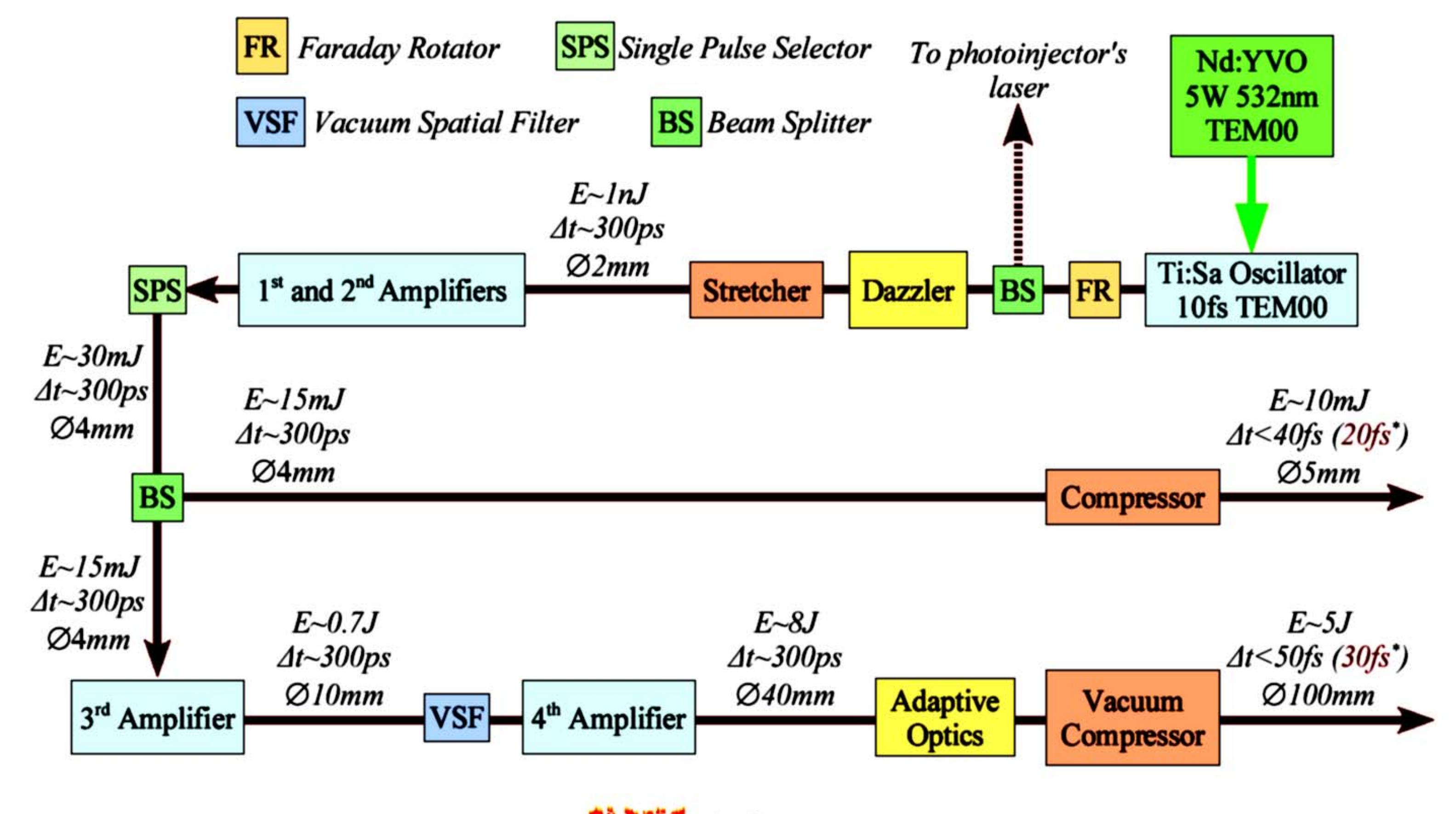
PLASMON X

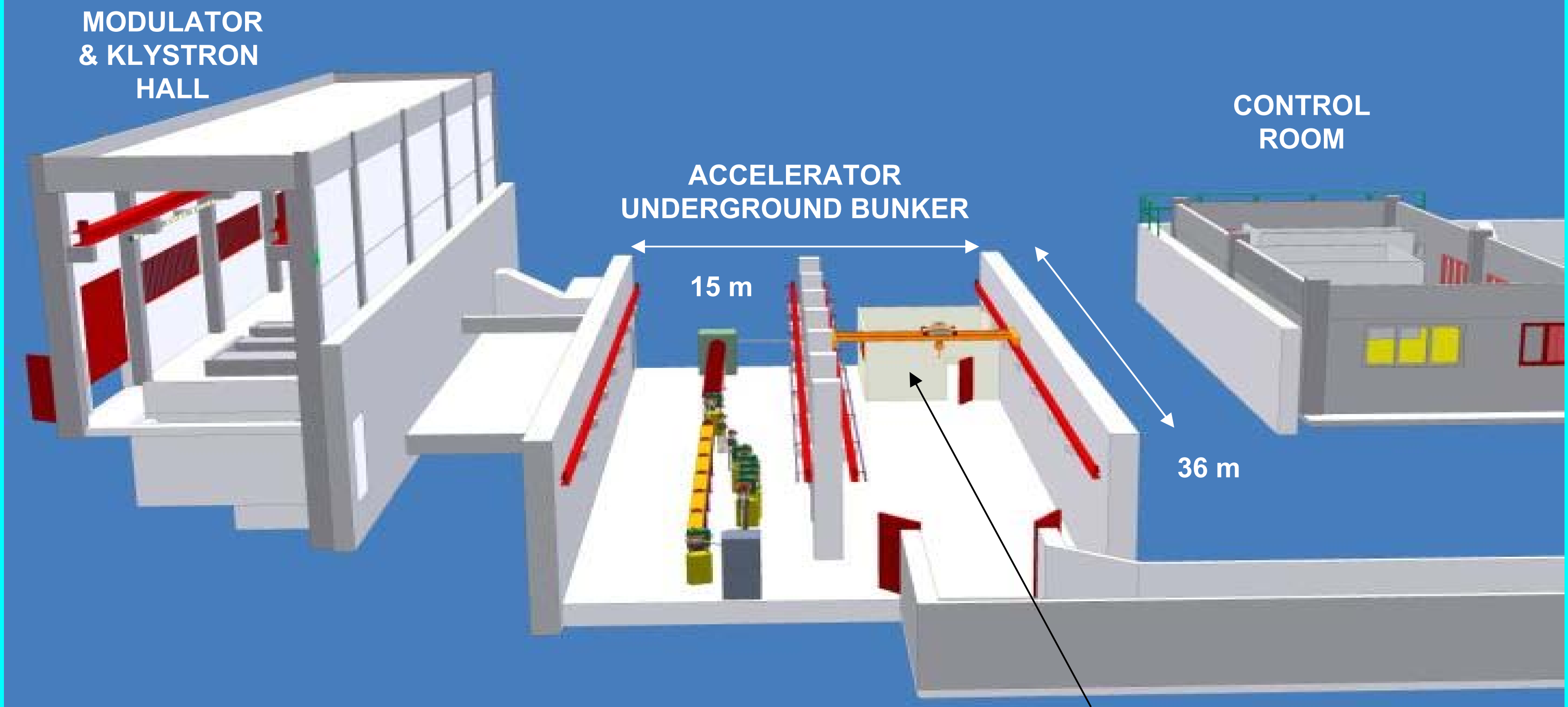
Frascati Laser for Acceleration and Multidisciplinary Experiments (FLAME)

SECOND INGREDIENT



FLAME Block Diagram

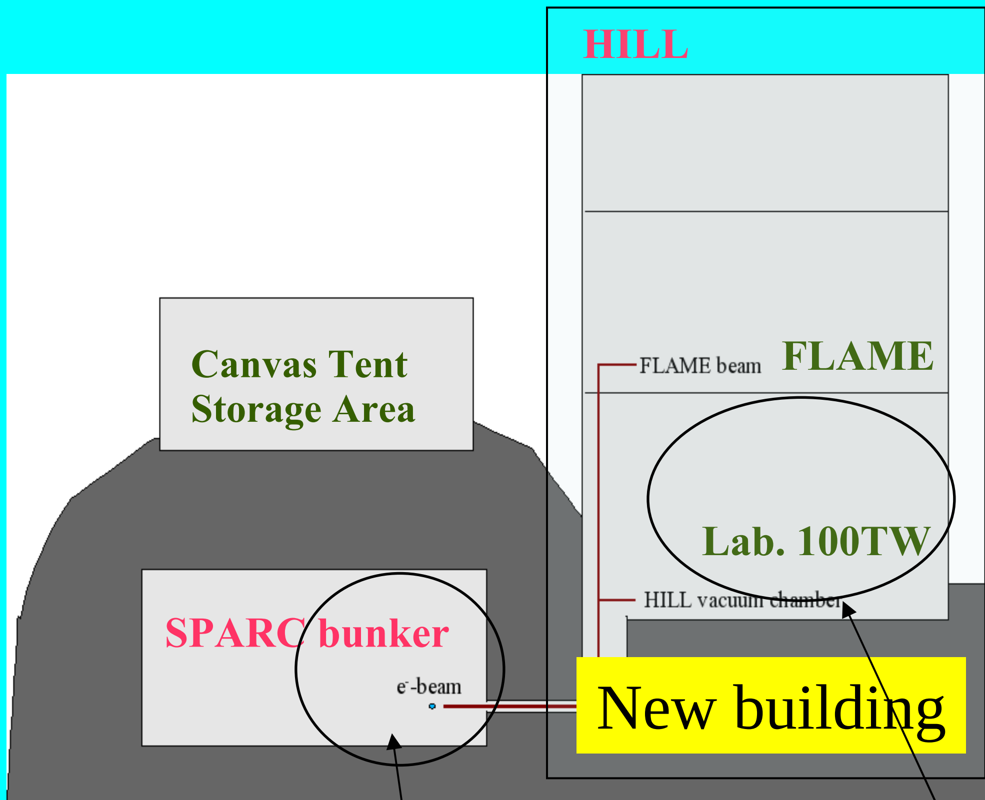
PLASMON X



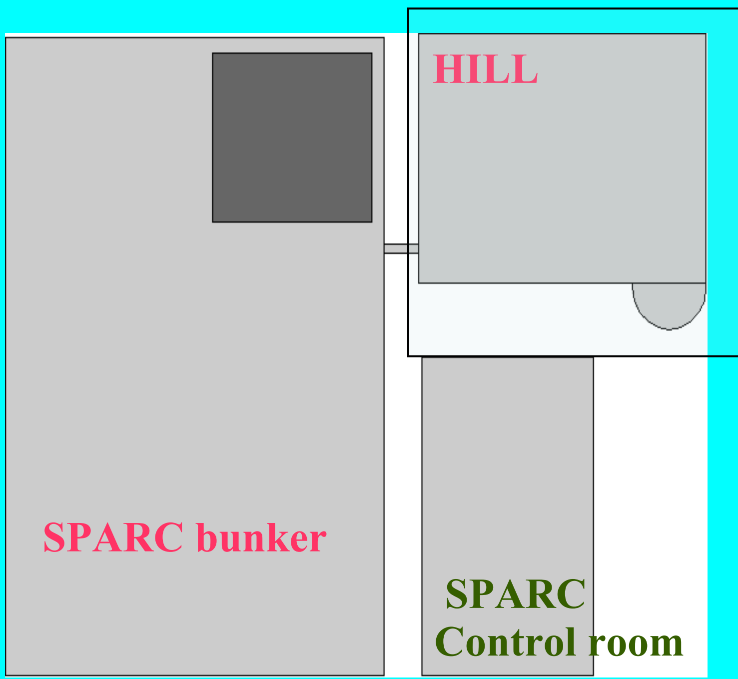
SPARC Building Complex

PLASMON X

Section view



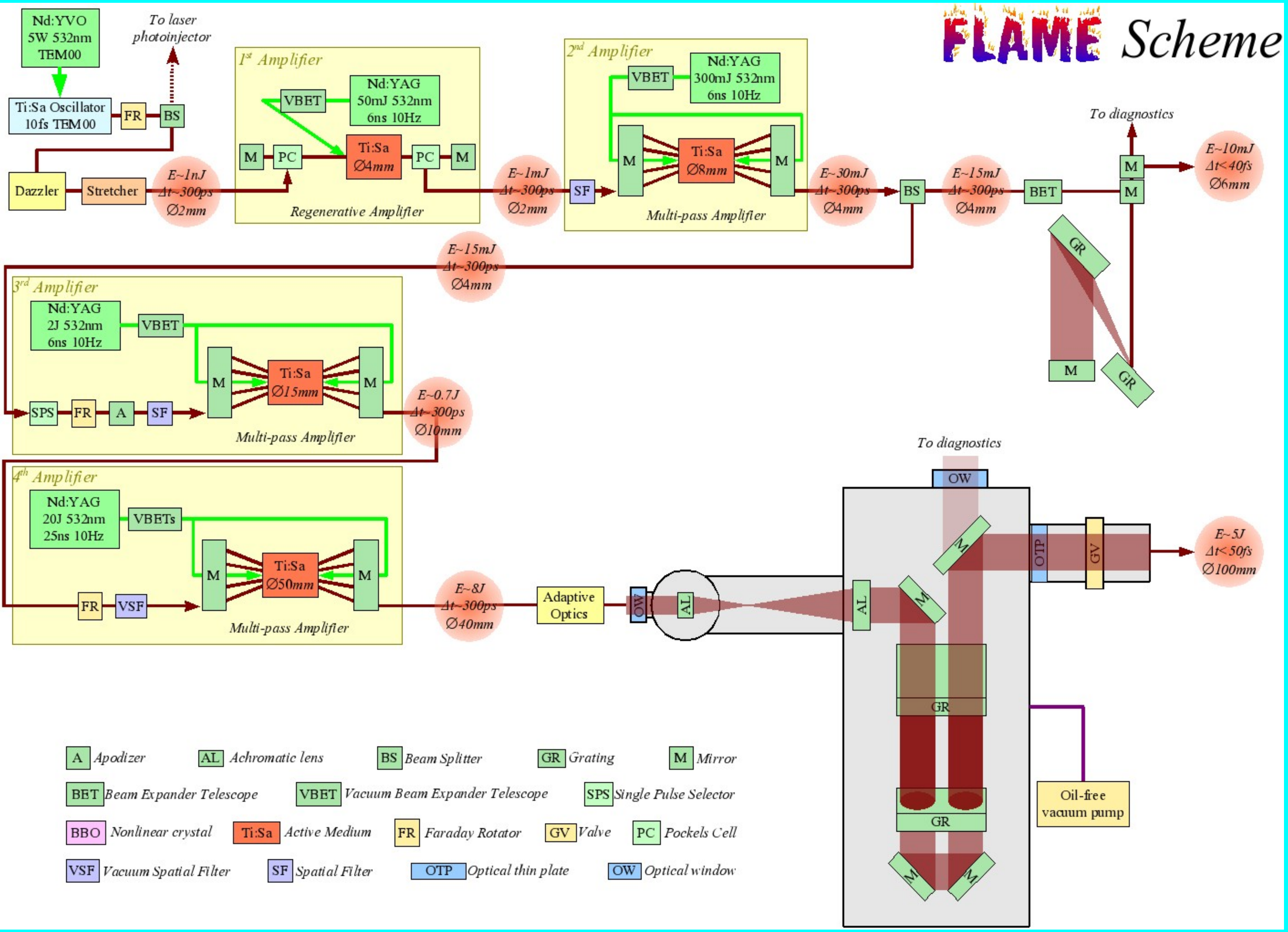
Top view



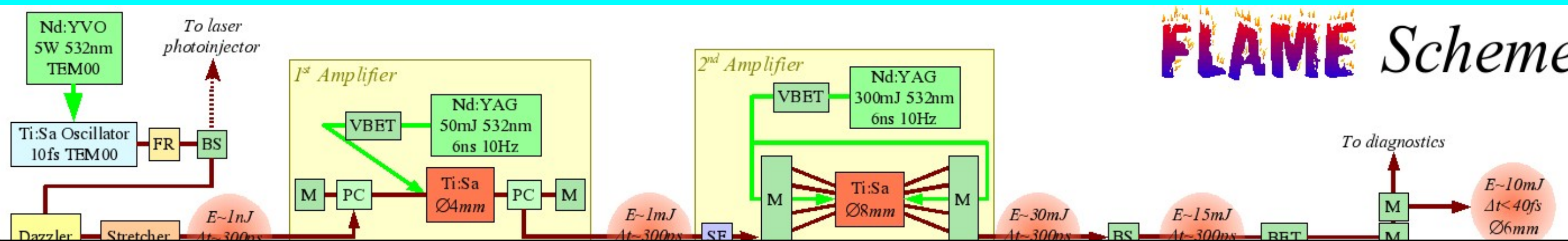
LWFA with **self-injection** + Thomson scattering

LWFA with **external injection** + Thomson scattering

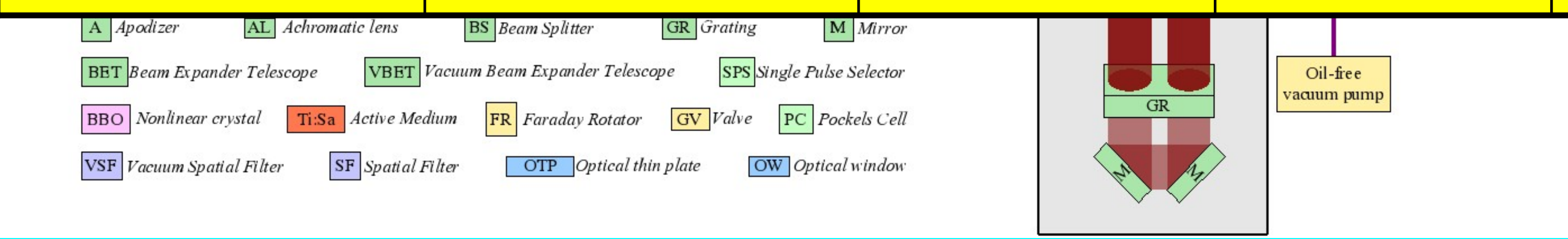
PLASMON X


FLAME Scheme
Nd:YVO 5W 532nm TEM00
To laser photoinjector
Ti:Sa Oscillator 10fs TEM00
FR
BS
Dazzler
Stretcher
E~1nJ Δt~300ps Ø2mm
1st Amplifier
VBET
Nd:YAG 50mJ 532nm 6ns 10Hz
M
PC
Ti:Sa Ø4mm
PC
M
Regenerative Amplifier
E~1mJ Δt~300ps Ø2mm
SF
2nd Amplifier
VBET
Nd:YAG 300mJ 532nm 6ns 10Hz
M
Ti:Sa Ø8mm
M
Multi-pass Amplifier
E~30mJ Δt~300ps Ø4mm
BS
E~15mJ Δt~300ps Ø4mm
BET
To diagnostics
M
M
E~10mJ Δt<40fs Ø6mm
GR
M
GR
E~15mJ Δt~300ps Ø4mm
3rd Amplifier
Nd:YAG 2J 532nm 6ns 10Hz
VBET
M
Ti:Sa Ø15mm
M
SPS
FR
A
SF
Multi-pass Amplifier
E~0.7J Δt~300ps Ø10mm
4th Amplifier
Nd:YAG 20J 532nm 25ns 10Hz
VBETs
M
Ti:Sa Ø50mm
M
FR
VSF
Multi-pass Amplifier
E~8J Δt~300ps Ø40mm
Adaptive Optics
OW
AL
AL
M
M
To diagnostics
OW
OTP
GV
E~5J Δt<50fs Ø100mm
GR
GR
M
M
Oil-free vacuum pump
A Apodizer
AL Achromatic lens
BS Beam Splitter
GR Grating
M Mirror
BET Beam Expander Telescope
VBET Vacuum Beam Expander Telescope
SPS Single Pulse Selector
BBO Nonlinear crystal
Ti:Sa Active Medium
FR Faraday Rotator
GV Valve
PC Pockels Cell
VSF Vacuum Spatial Filter
SF Spatial Filter
OTP Optical thin plate
OW Optical window

PLASMON X

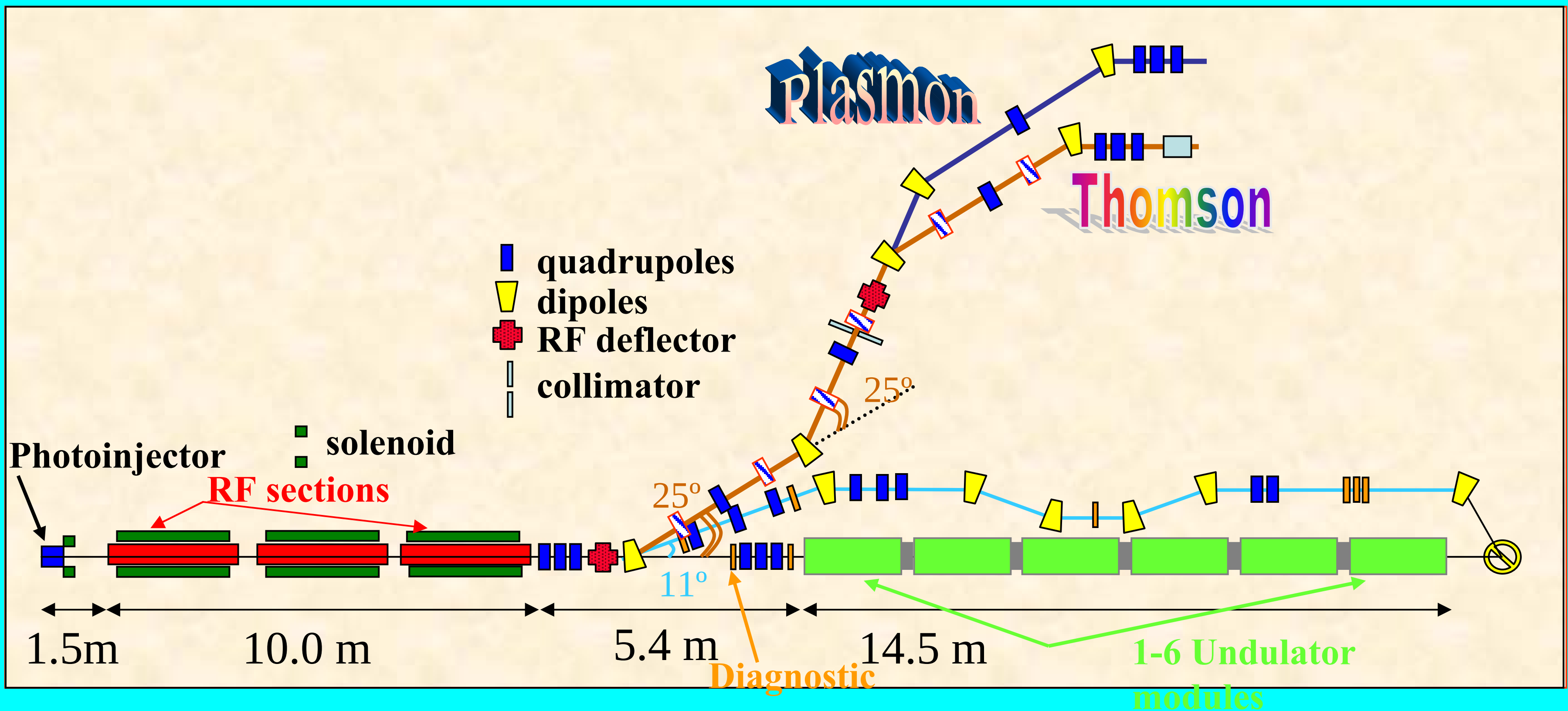


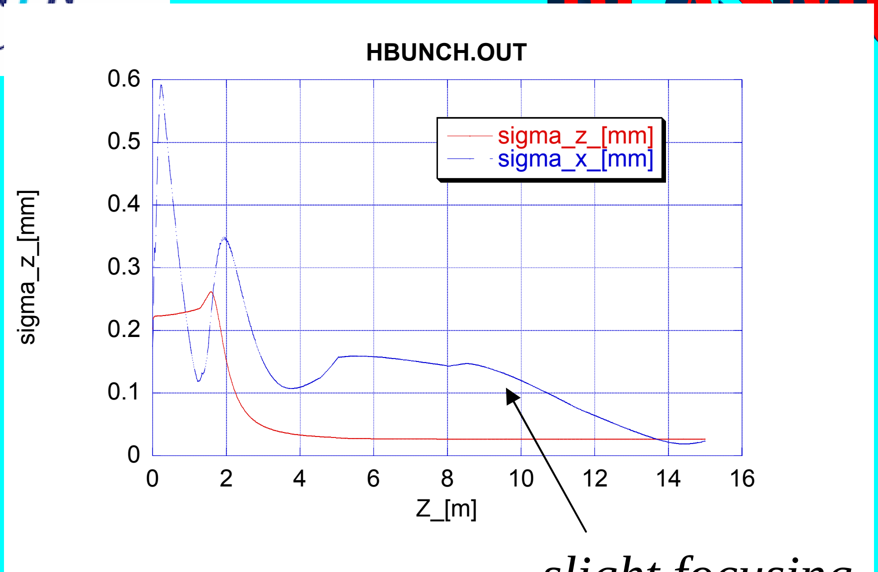
Type	Wavelength	Delivered energy	Duration	Contrast
Phase 1 CPA Ti:Sa	0.8 micron	5J	50fs	$>10^6$
Phase 2 CPA Ti:Sa with ***OPCPA***	0.8 micron	5J	30fs	$>10^8$

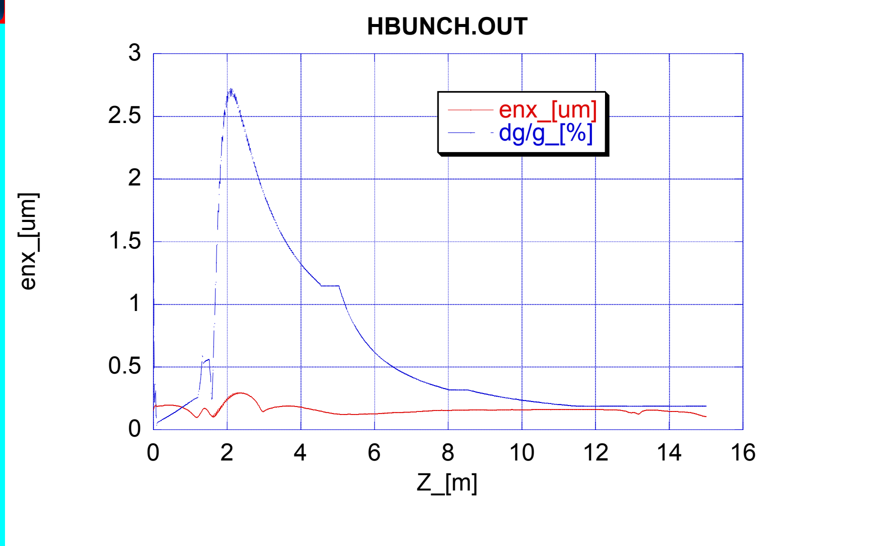


PLASMON X

Schematic layout



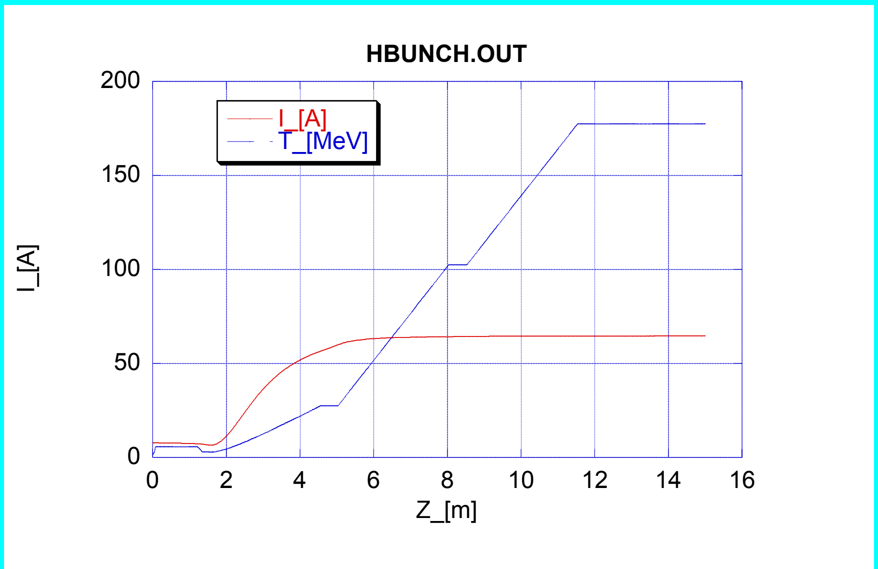


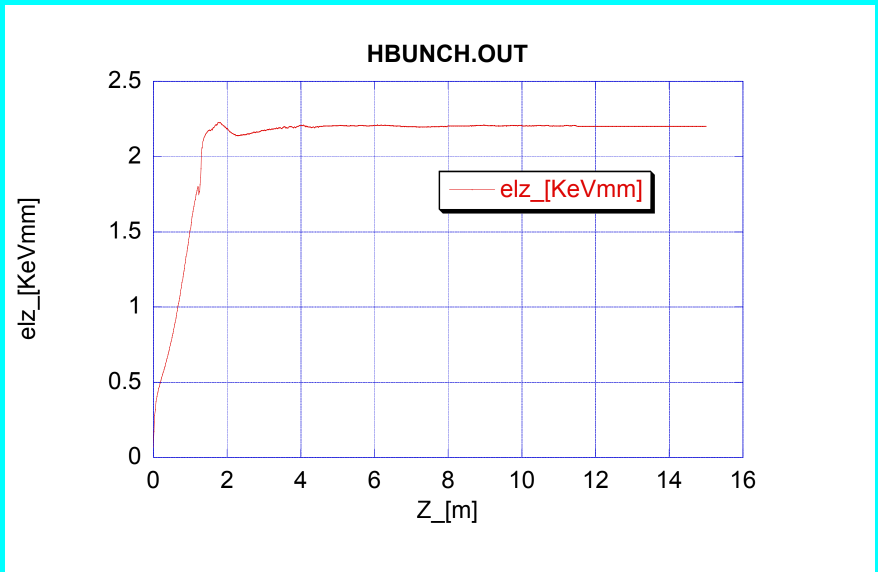


slight focusing after compression

Q = 20 pC

$\sigma_z = 25\ \mu m$, $\Delta\gamma/\gamma = 0.2\%$, $\varepsilon_{nx} < 0.3\ \mu m$

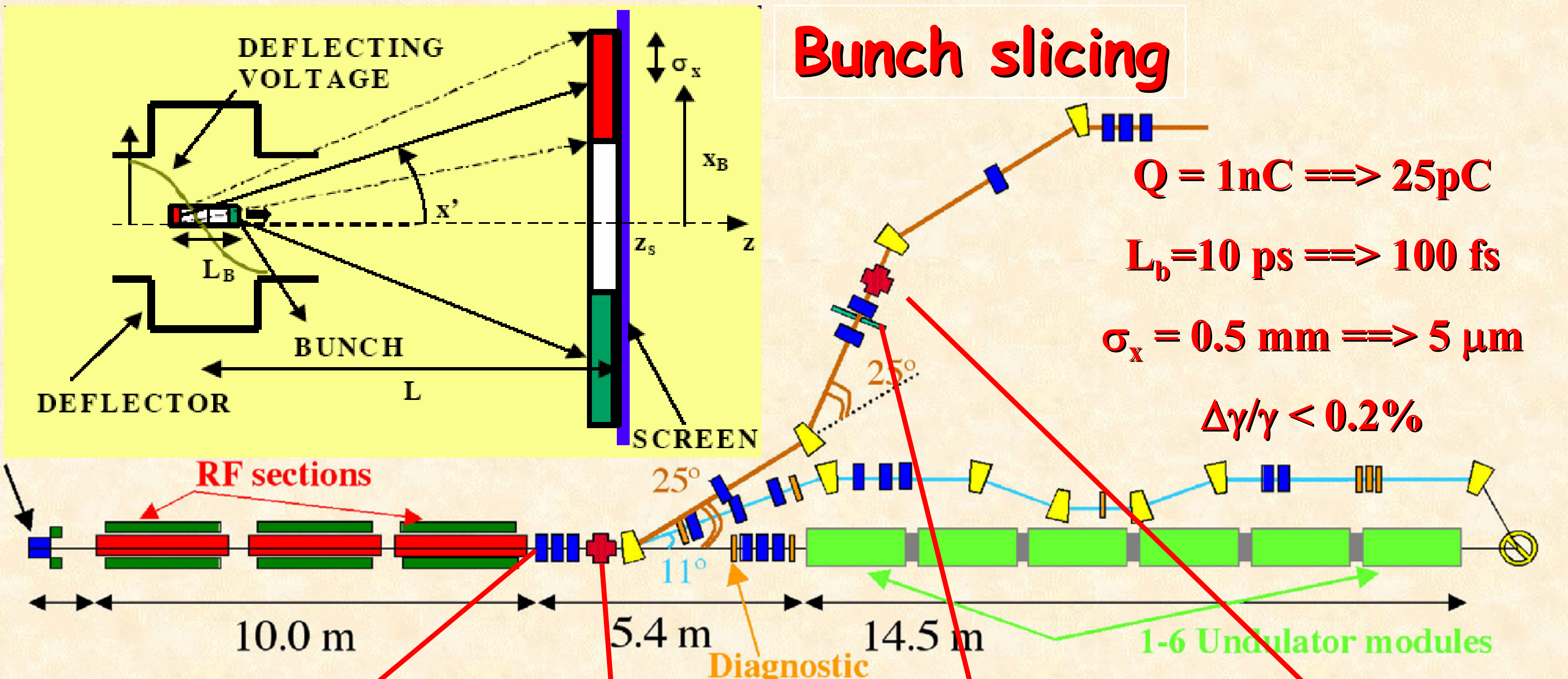




M. Ferrario, ICFA LBI-LPA 2005 Workshop, Taipei

PLASMON X

Bunch slicing

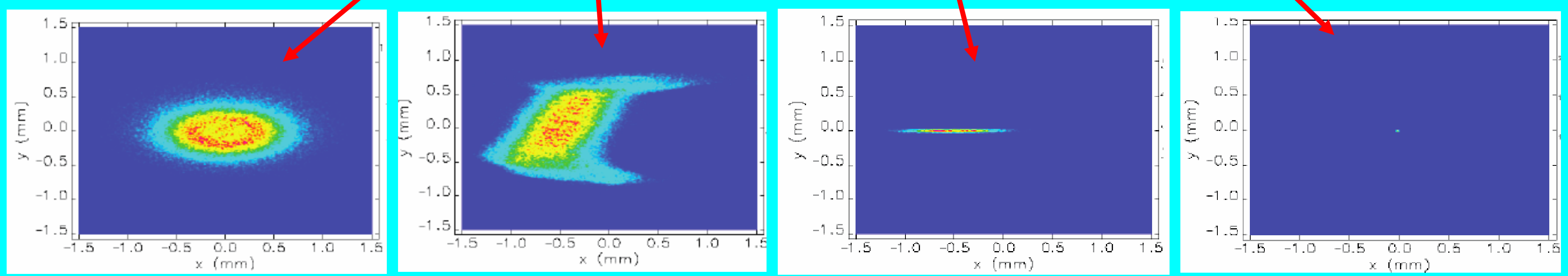


Q = 1nC ==> 25pC

L_b=10 ps ==> 100 fs

σ_x = 0.5 mm ==> 5 μm

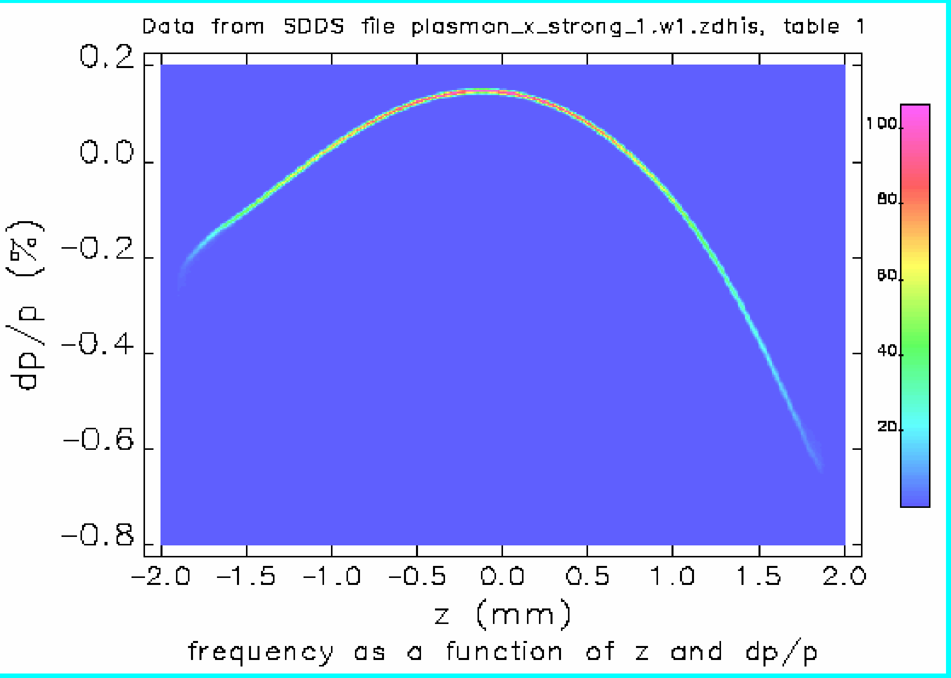
$\Delta\gamma/\gamma$ < 0.2%



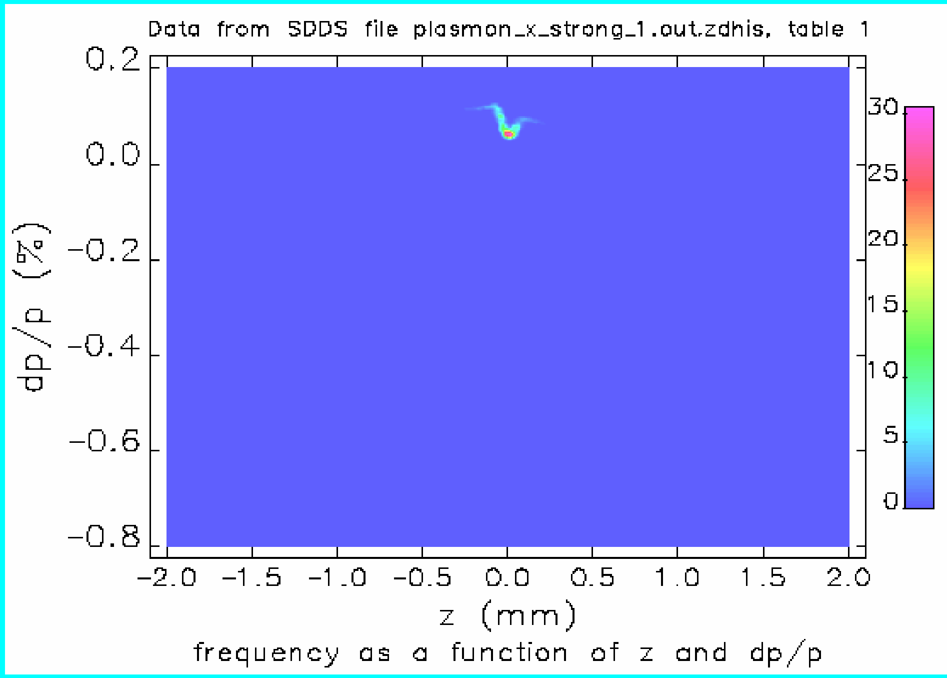
C. Vaccarezza et al., EPAC-04

PLASMON X

beam energy distribution at start/end of the beam line



start

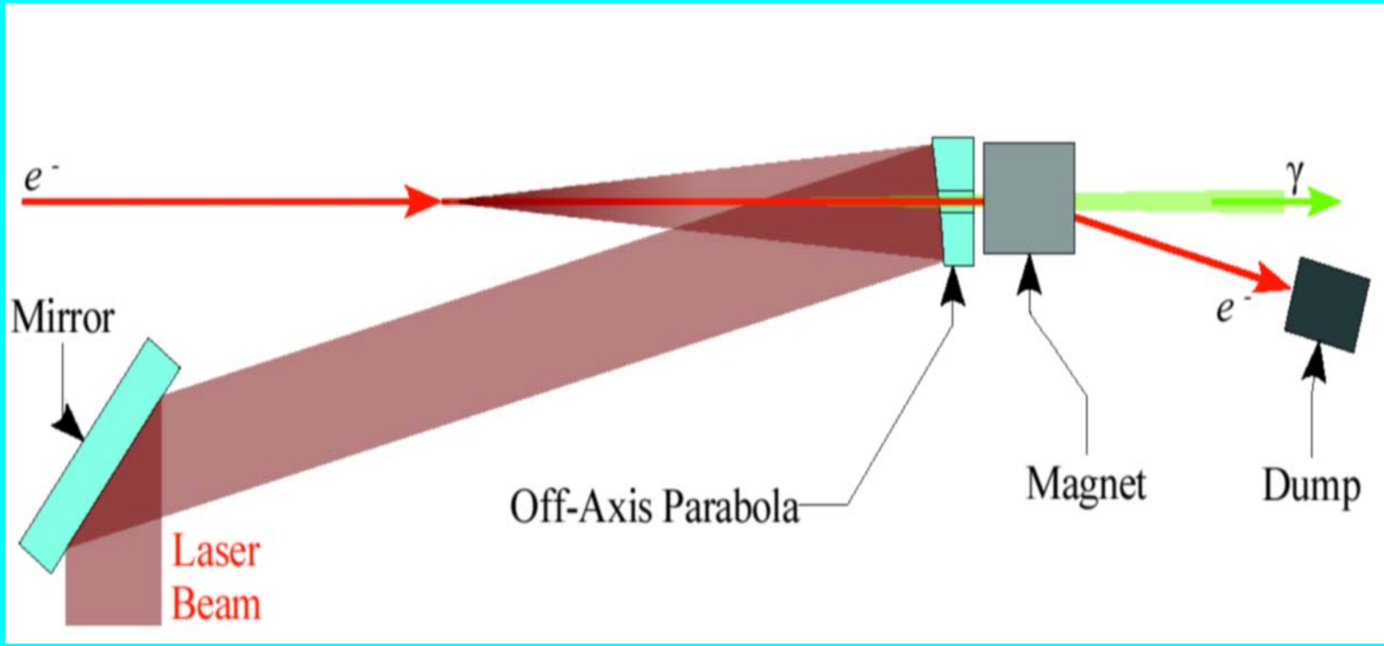


end

60 fs bunch (initially uncompressed)
-> 10 fs with RF compression, i.e. by
combining velocity bunching and bunch-slicing

PLASMON X

Experimental set-up for the generation of tunable X-ray radiation via Thomson scattering of optical photons by relativistic electron bunches



PLASMON X

THOMSON BACK-SCATTERING

$$\nu_T = \nu_0 \frac{1-\beta\cos\alpha_L}{1-\beta\cos\theta} \approx \nu_0 \frac{4\gamma^2}{1+\theta^2\gamma^2} \approx 4\gamma^2\nu_0$$

$$for \quad \alpha_L = \pi \quad and \qquad \theta << 1 \quad or \quad \theta = 0$$

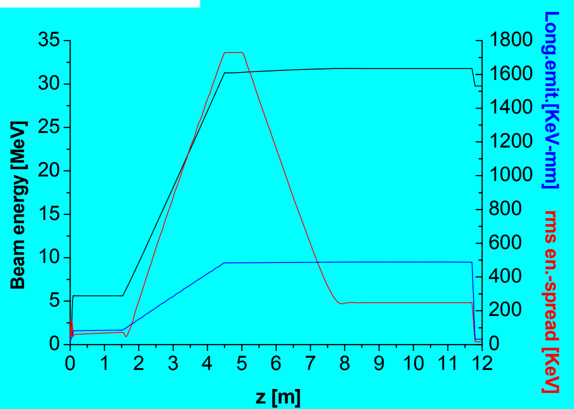
e^- (1 GeV); λ_0=1μm, E_0=1.24 eV → λ_T=6 x10^{-8}μm, E_T=20 MeV

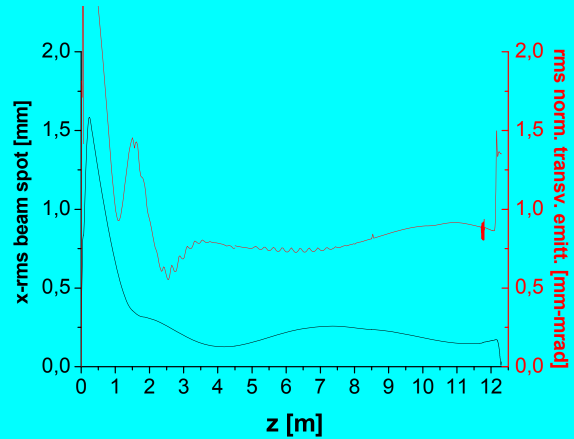
e^- (200 MeV); λ_0=1μm, E_0=1.24 eV → λ_T=1.56 x10^{-6}μm, E_T=800 KeV

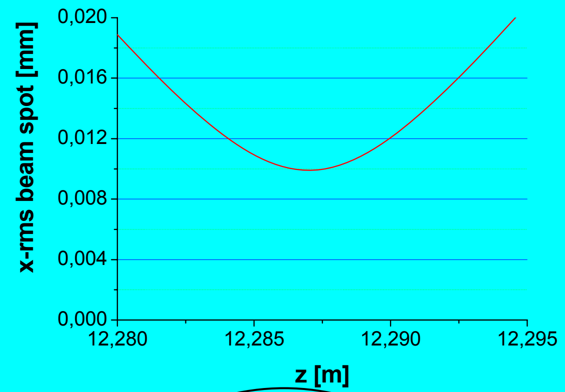
e^- (29 MeV); λ_0=0.8μm, E_0=1.5 eV → λ_T=0.5 x10^{-4}μm, E_T=20 KeV

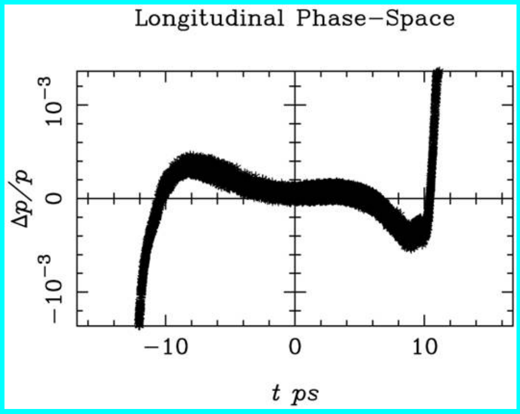
2005 best result (1nC Solenoid lens)

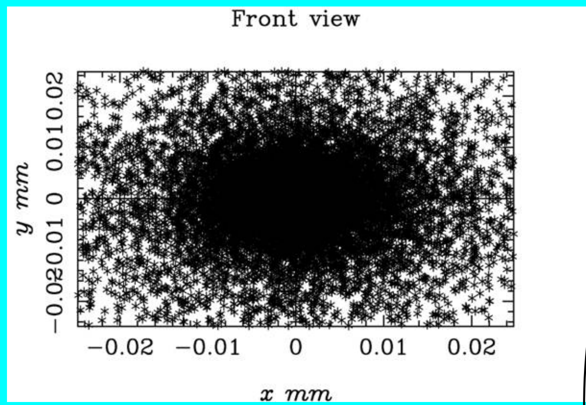
PLASMON X

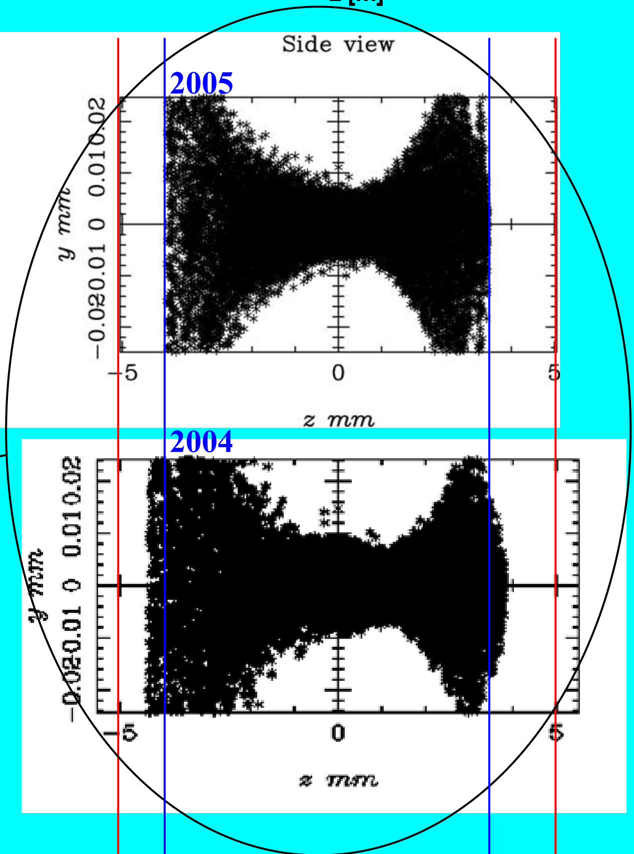








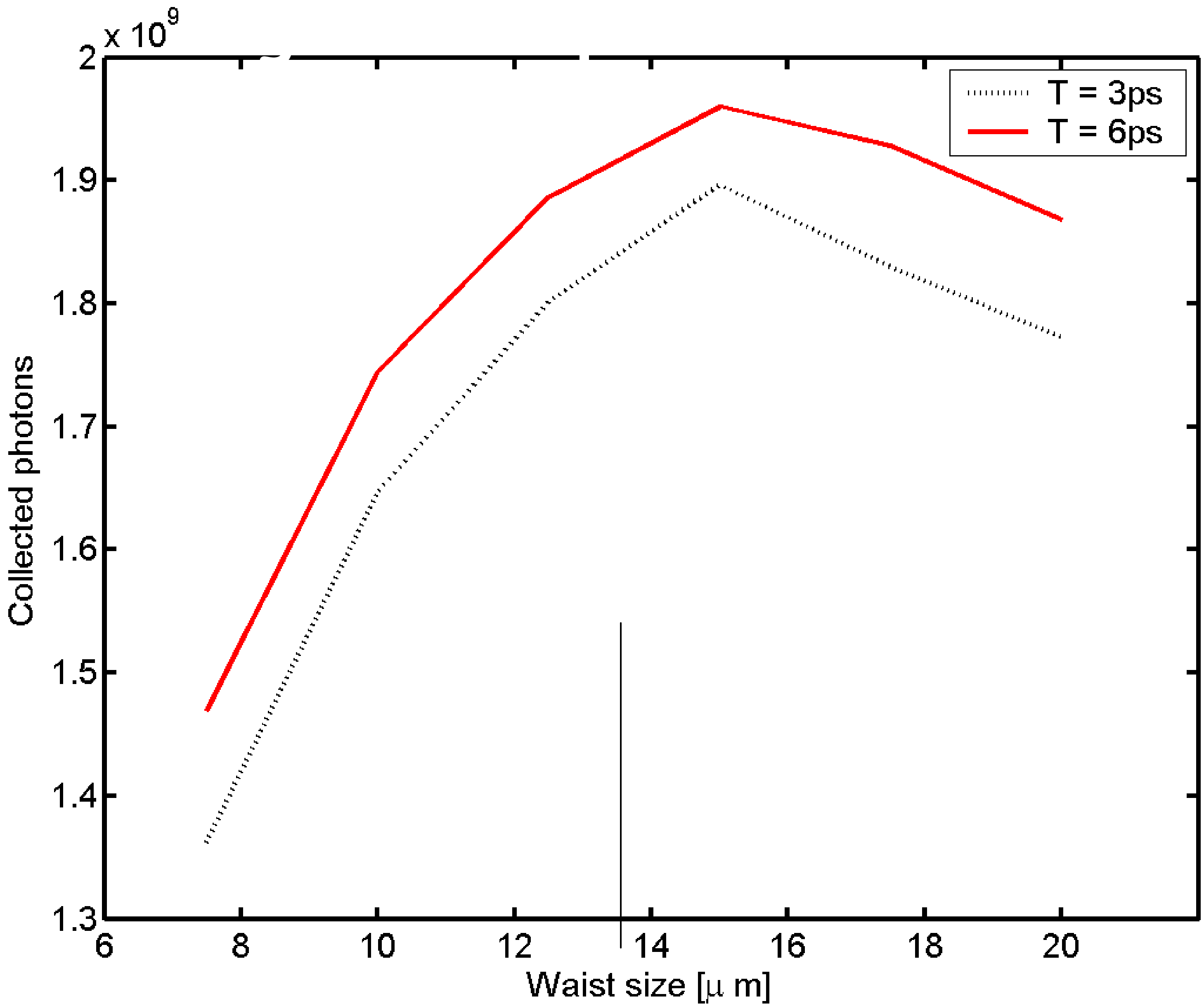




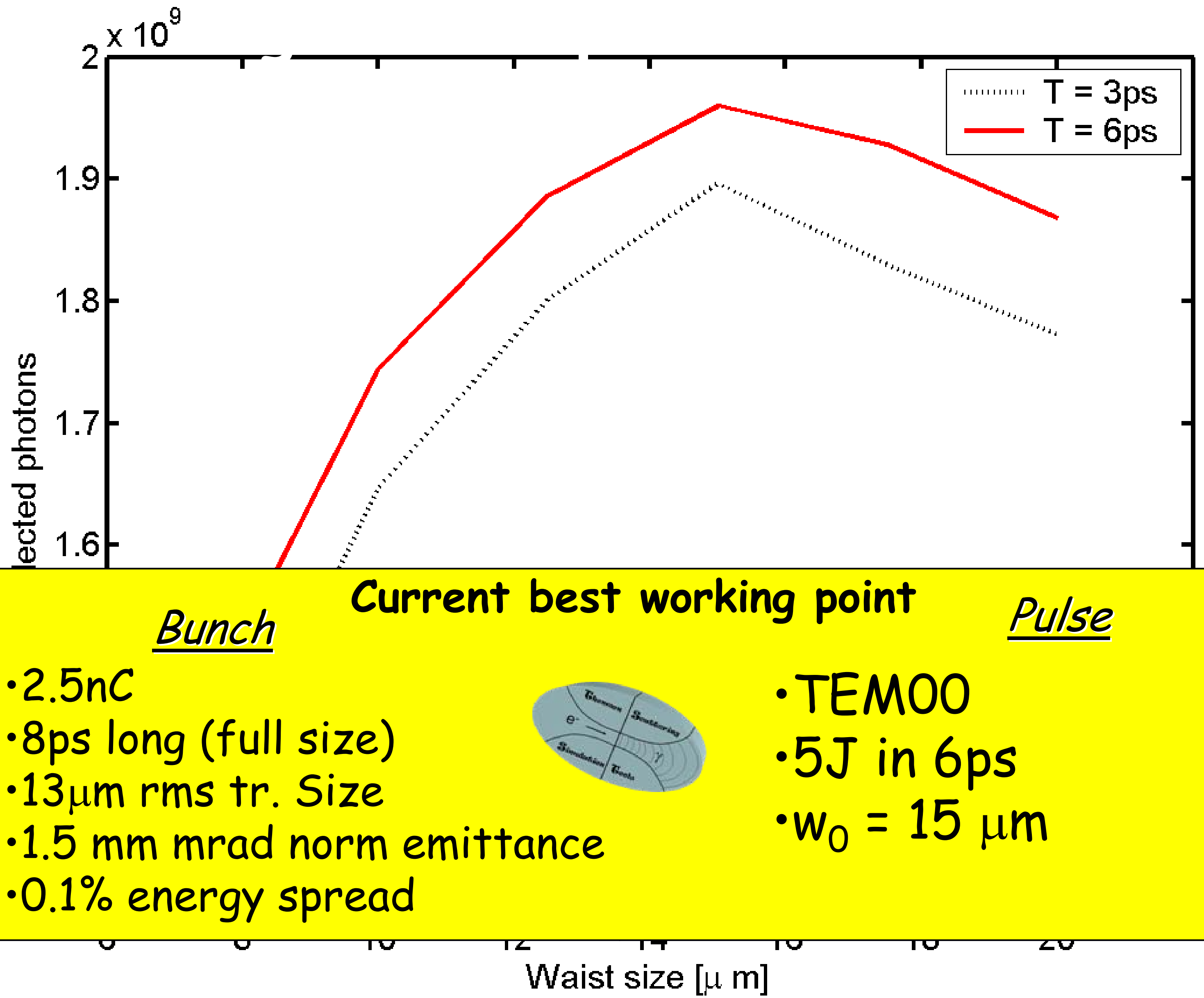
In the 2005 simulation (autumn), playing especially with the injection phase of the II TW structure (involved in the linear correlation correction) have been possible obtain a bunch of about 3ps (~1mm) shorter, with a denser core

Angular and spectral distribution of the TS radiation in the case of an unguided 3 ps laser pulse (12.5 μm beam waist)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.


x 10^9
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
6
8
10
12
14
16
18
20
Collected photons
Waist size [μ m]
T = 3ps
T = 6ps

PLASMON X



Current best working point

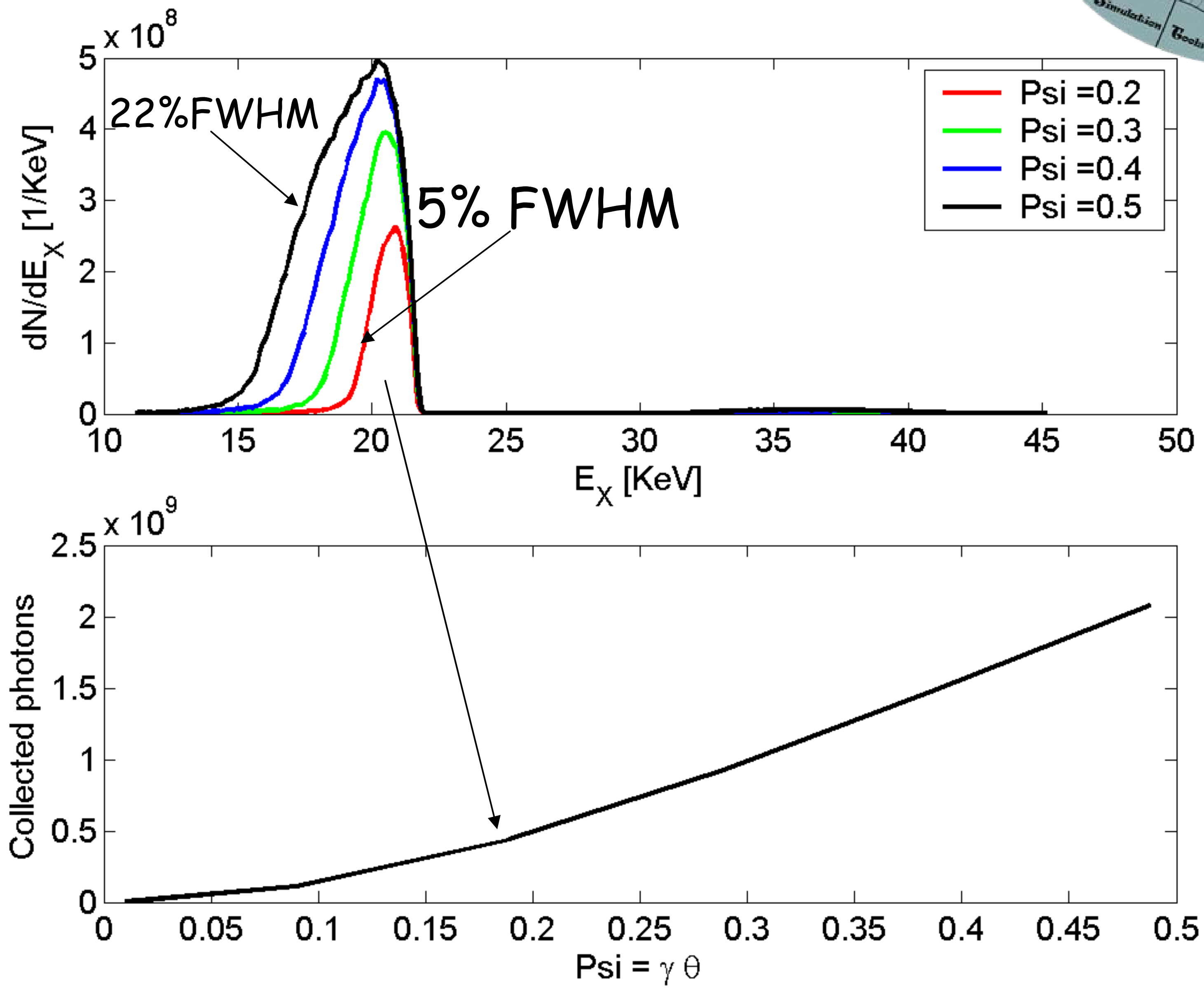
Bunch

- 2.5nC
- 8ps long (full size)
- 13μm rms tr. Size
- 1.5 mm mrad norm emittance
- 0.1% energy spread

Pulse

- TEM00
- 5J in 6ps
- w_0 = 15 μm

PLASMON X


x 10^8
5
4
3
2
1
0
dN/dE_X [1/KeV]
22%FWHM
5% FWHM
Psi =0.2
Psi =0.3
Psi =0.4
Psi =0.5
10
15
20
25
30
35
40
45
50
E_X [KeV]
x 10^9
2.5
2
1.5
1
0.5
0
Collected photons
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Psi = γ θ

PLASMON X

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

PLASMON X

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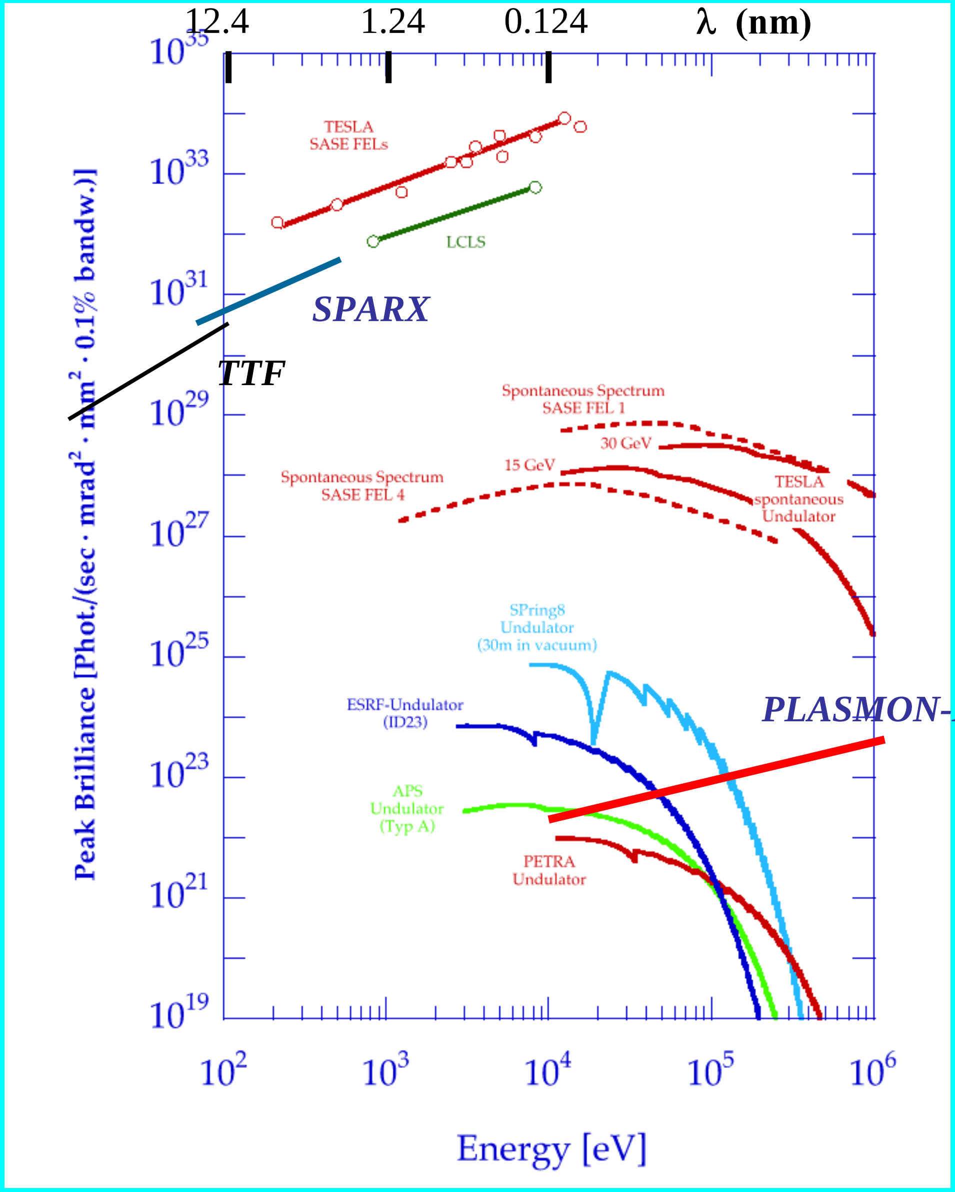
Brilliance of X-ray radiation sources

SASE-FELs will allow an unprecedented upgrade in Source Brilliance

Covering from the VUV to the 1 Å X-ray spectral range: **new Research Frontiers**

Compact Thomson Sources extend SR to hard X-ray range allowing Advanced Radiological Imaging **inside** Hospitals



FEL resonance condition

$$\lambda = \lambda_w \frac{\left(1 + a_w{}^2\right)}{2\gamma^2}$$ (magnetostatic wiggler)

Example : for *λ=1A, λ_w=1cm, E=3.5GeV*

$$\lambda = \lambda_{pump} \frac{\left(1 + a_w{}^2\right)}{4\gamma^2}$$ (electromagnetic wiggler)

Example : for *λ=1A, λ_{pump}=1μm, E=25MeV*

PLASMON X

SPARC

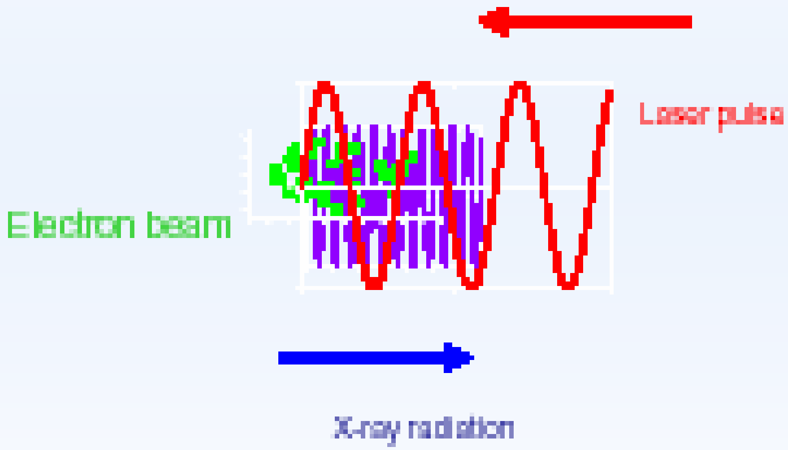
Toward Coherent X-rays: exploring coherent emission mechanisms (FEL-like) in Thomson Sources

COLLECTIVE EFFECTS IN THE THOMSON BACK-SCATTERING BETWEEN A LASER PULSE AND A RELATIVISTIC ELECTRON BEAM

A. Bacci ,L. Serafini *INFN*-Sezione di Milano, Via Celoria,16, 20133 Milano (Italy) C. Maroli, V. Petrillo Dipartimento di Fisica dell'Università di Milano e INFN-Sezione di Milano, Via Celoria,16, 20133 Milano (Italy) M. Ferrario INFN-LNF, Via Fermi 40, 00044 Frascati (RM), Italy

FEL-Conf. 2005

The physical system



Laser pulse characteristics:

wavelength λ=0,8 μm, power 1TW, time duration T=5 ps
Circular polarization, focal spot diameter w_0 >50 micron

Electron beam characteristics:

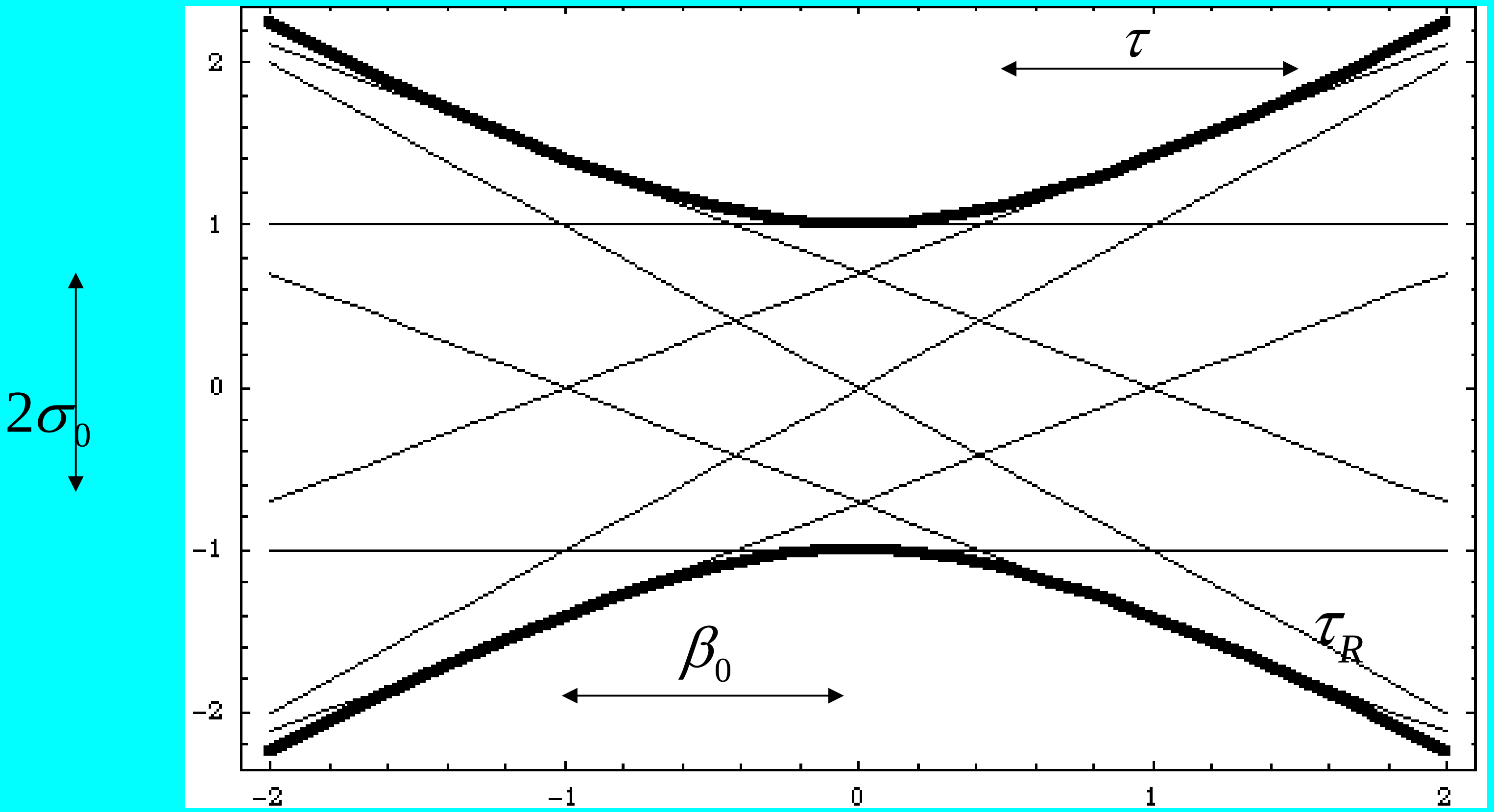
Conterpropagating respect the lasr pulse
Energy 15 MeV (γ=30), spot size σ_0=10 μm, length L_b=100-200μm, charge Q=1 nC

Radiation characteristics:

Wavelength λ=2.2 Ang

Conditions to operate a Thomson Source in FEL mode

$$\lambda_R = \lambda \frac{\left(1 + a_0^{\;2}\right)}{4\gamma^2}$$



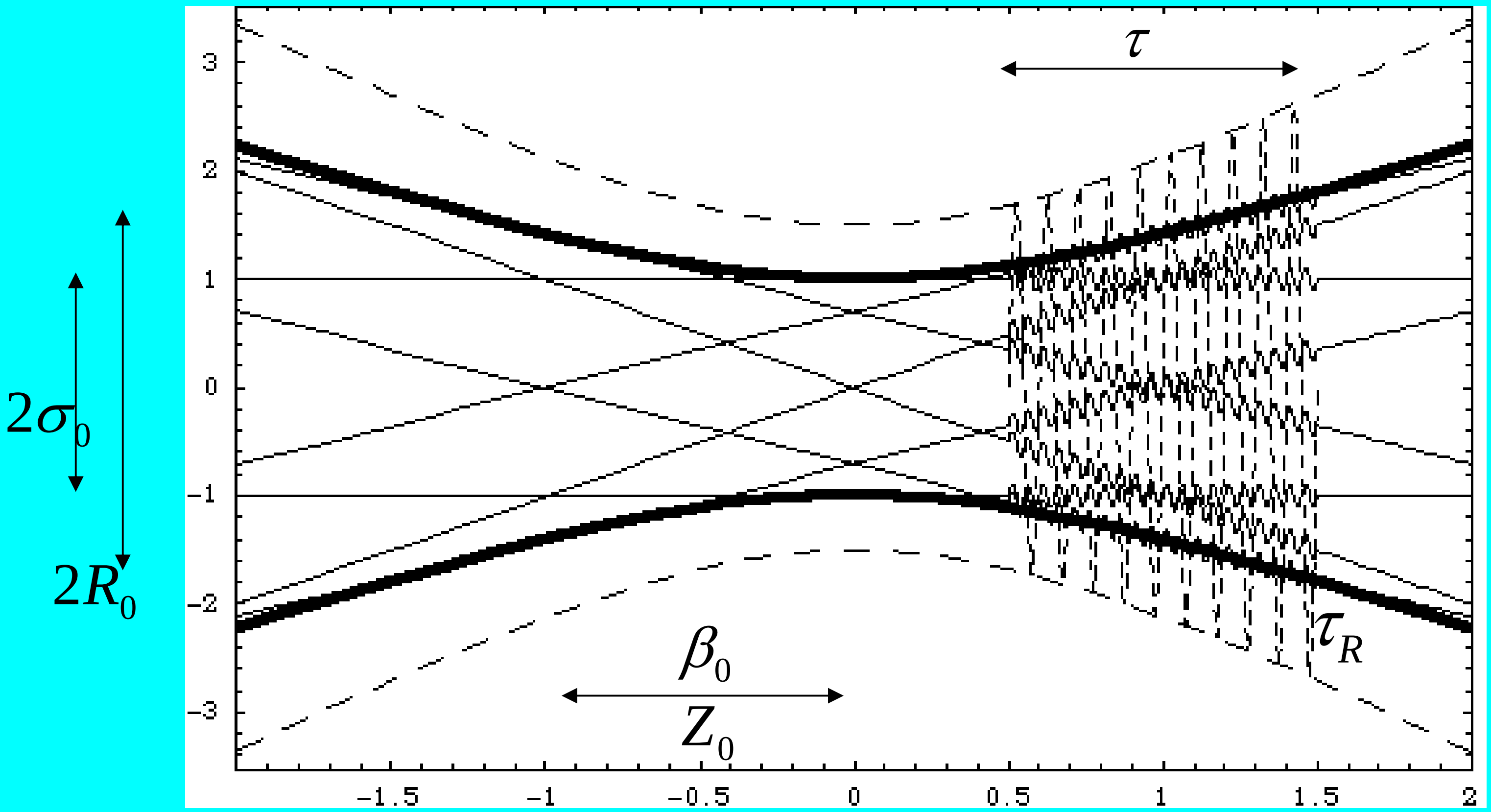
INFN Istituto Nazionale di Fisica Nucleare

PLASMON X

SPARC

Conditions to operate a Thomson Source in FEL mode

$$\lambda_R = \lambda \frac{\left(1 + a_0^{\ 2}\right)}{4\gamma^2}$$



Conditions to operate a Thomson Source in FEL mode

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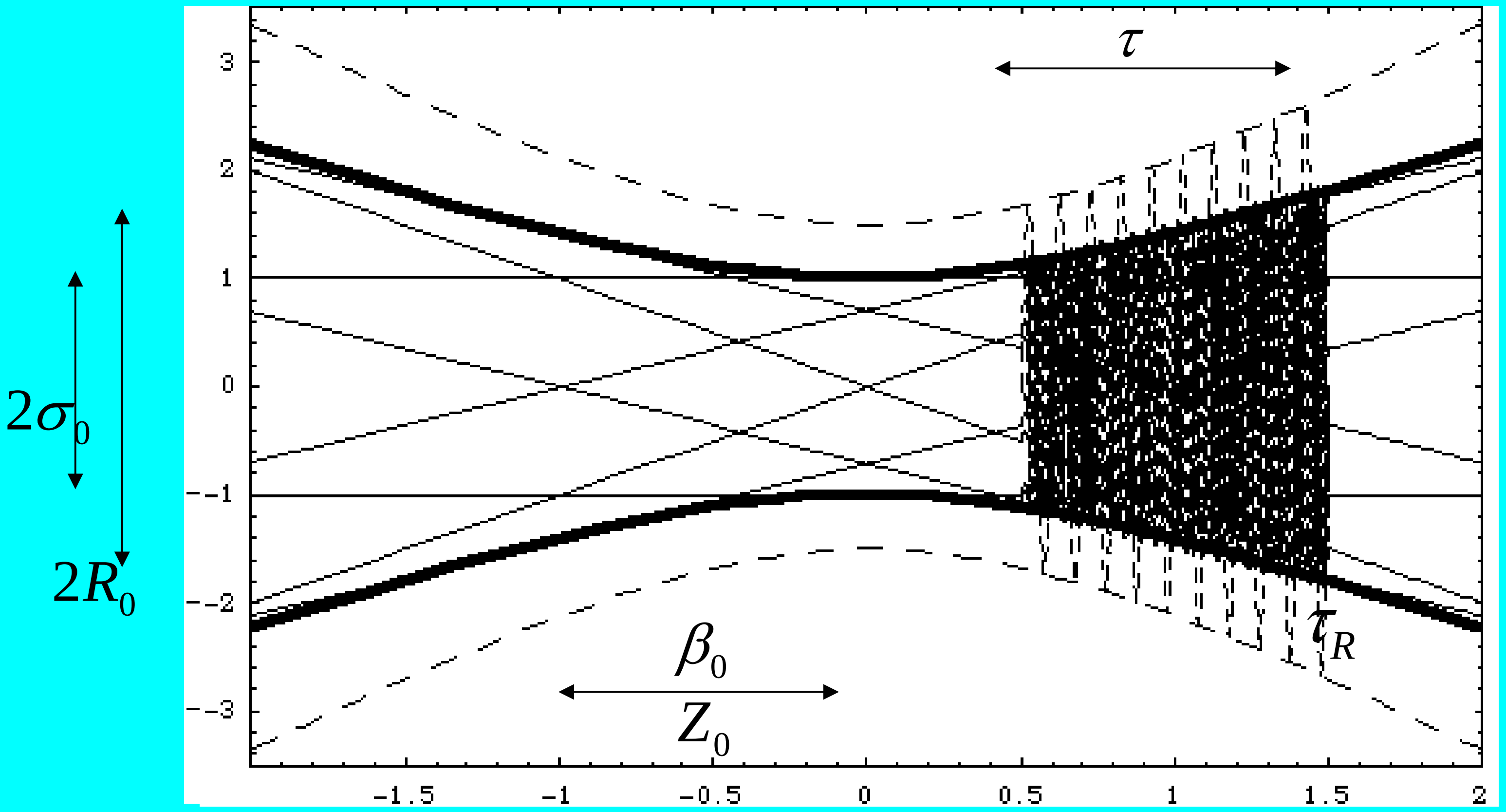
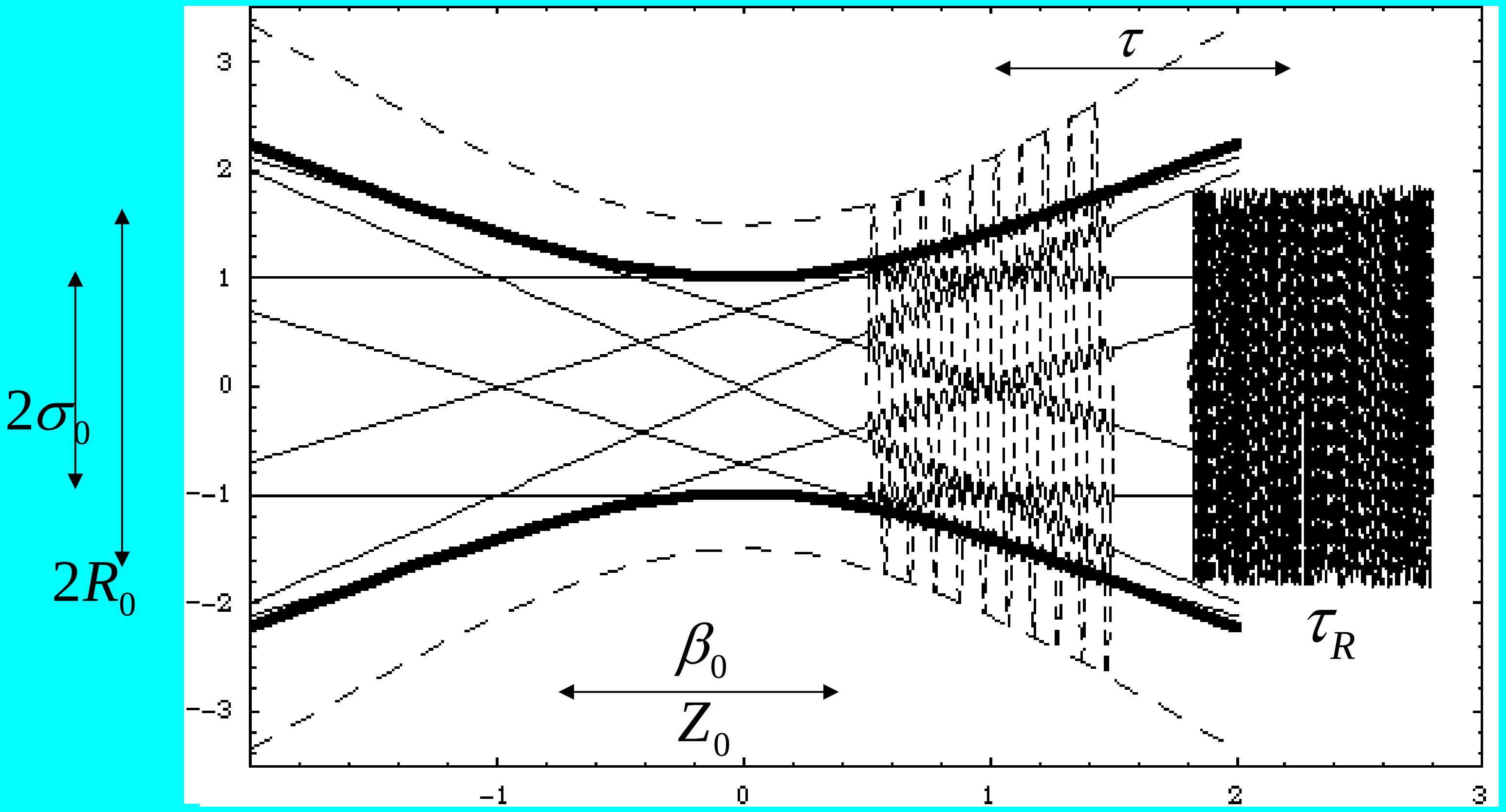


Conditions to operate a Thomson Source in FEL mode

$$\lambda_R = \lambda \frac{(1 + a_0^{\ 2})}{4\gamma^2}$$



PLASMON X

Laser $a_0 = 8.5 \cdot 10^{-6} \dfrac{\lambda\sqrt{P}}{R_0}$ $Z_0 = \dfrac{4\pi R_0^{\,2}}{\lambda}$

e-beam $\sigma_0 = \sqrt{\dfrac{\varepsilon_n \beta_0}{\gamma}}$; I ; $\Delta\gamma/\gamma$

FEL $\lambda_R = \lambda \dfrac{\left(1 + a_0^{\,2}\right)}{4\gamma^2}$ $\rho = \dfrac{10^{-2}}{\gamma}\sqrt[3]{I\lambda^4 P/\sigma_0^4}$ $L_g = \dfrac{\lambda}{4\pi\rho}$ $\dfrac{\Delta\lambda_R}{\lambda_R} = \rho$

Conditions to operate a Thomson Source in FEL mode

Laser length $c\tau = 10 L_g$

Beam-laser overlap (laser uniform in x,y,z) $R_0 = 2\sigma_0$ $c\tau \le 2Z_0$

Laser ripples $\Delta \equiv \dfrac{\Delta a_0}{a_0}$ $\dfrac{\Delta\lambda_R}{\lambda_R} = \dfrac{2a_0^2}{1 + a_0^2}\Delta$ ➡ $\Delta \le \rho \dfrac{1 + a_0^2}{2a_0^2}$

Laser bandwidth $\dfrac{\Delta\lambda_R}{\lambda_R} = \dfrac{\Delta\lambda}{\lambda} = \dfrac{c\tau}{\lambda}$ ➡ $c\tau \ge \dfrac{\lambda}{\rho}$

PLASMON X

Conditions to operate a Thomson Source in FEL mode

FEL bandwidth broadening due to beam emittance

$$\lambda_R = \lambda \frac{\left(1 + a_0{}^2 + \gamma^2\theta^2\right)}{4\gamma^2}$$

$$\frac{\Delta\lambda_R}{\lambda_R} \approx \frac{\gamma^2\theta^2}{1 + a_0^2} \approx \frac{4\varepsilon_n^2}{\sigma_0{}^2} \quad \begin{cases} \dfrac{\Delta\lambda_R}{\lambda_R} \leq \alpha\rho \\ \alpha \geq 1 \end{cases} \Rightarrow \quad \varepsilon_n \leq \frac{1}{2}\sqrt{\alpha\rho}\,\sigma_0$$

$$L_g = \frac{\lambda}{4\pi\rho} \qquad Z_R = \frac{4\pi\sigma_0{}^2}{\lambda_R} \quad \Rightarrow \quad \rho = \frac{Z_R}{L_G}\frac{\lambda_R\lambda}{8\pi^2\sigma_0^2}$$

Generalized Pellegrini criterion

$$\varepsilon_n \leq \sqrt{\alpha}\sqrt{\frac{Z_R}{L_G}\frac{\lambda_R\gamma}{2\sqrt{2}\pi}}$$

PLASMON X

Generalized Pellegrini criterion

$$\varepsilon_n \le \sqrt{\alpha}\sqrt{\frac{Z_R}{L_G}\frac{\lambda_R \gamma}{2\sqrt{2}\pi}}$$

$$\lambda_R \cong 1 \ \ Angstrom$$

LCLS

$$\gamma = 3 \cdot 10^4$$

$$\lambda_w = 2.5 \ \ cm$$

$$L_g \cong Z_R \cong 10 \ \ m$$

$$\varepsilon_n < \frac{3 \cdot 10^4 10^{-10}}{4\pi} \cong 0.25 \ \ \mu m$$

FEL-Thomson

$$\gamma = 30$$

$$\lambda = 1 \ \ \mu m$$

$$L_g \cong 100 \ \ \mu m \ ; \ Z_R \cong 10 \ \ m$$

$$\varepsilon_n < \sqrt{10^5}\frac{30 \cdot 10^{-10}}{2\sqrt{2}\pi} \cong 0.11 \ \ \mu m$$

PLASMON X

Satisfying all conditions above implies:

$$\varepsilon_n = \frac{\lambda}{5.62}$$

$$\gamma = 0.068\sqrt[3]{\frac{I}{\Delta^2}}$$

$$L_G = 0.44\lambda/\Delta$$

$$\lambda_R = 120\lambda\sqrt[3]{\frac{\Delta^4}{I^2}}$$

$$U = 47\lambda/\Delta^2$$

$$\bar{\rho} = 6\cdot 10^{11}\lambda\sqrt[3]{\frac{\Delta^5}{I}}$$

$$P = 3.1\cdot 10^9/\Delta$$

$$\tau = 1.5\cdot 10^{-8}\lambda/\Delta$$

$$Z_0 = 2.2\lambda/\Delta$$

$$a_0 = 1.12$$

$$\rho = 0.18\Delta$$

$$\beta_0 = 0.018\lambda\sqrt[3]{\frac{I}{\Delta^5}}$$

$$\sigma_0 = 0.21\lambda/\sqrt{\Delta}$$

For the case of a Ti:Sa laser we derive:

$$\varepsilon_n = 0.14\ \mu m$$

$$\gamma = 1.47\ \sqrt[3]{\frac{I}{\Delta^2}}$$

$$L_G = 35/\Delta\ [\mu m]$$

$$U = 0.37/\Delta^2\ [J]$$

$$\lambda_R = 2063\Delta\sqrt[3]{\frac{\Delta}{I^2}}\ [Angstrom]$$

$$\bar{\rho} = 222\Delta\sqrt[3]{\frac{\Delta^2}{I}}$$

$$P = 0.31/\Delta\ [TW]$$

$$\tau = 1.2/\Delta\ [ps]$$

$$Z_0 = 0.18/\Delta\ [mm]$$

$$a_0 = 1.12$$

$$\rho = 1.8 \cdot 10^{-3}\Delta$$

$$\beta_0 = \frac{0.03}{\Delta}\sqrt[3]{\frac{I}{\Delta^2}}\ [mm]$$

$$\sigma_0 = 1.7/\sqrt{\Delta}\ [\mu m]$$

$$\Delta\ [\%]\ ;\ I\ [A]$$

Setting *Δ = 0.5 %* and *I = 1700 A*

Classical SASE

$\varepsilon_n = 0.14\ \mu m$

$\gamma = 28$

$L_G = 70\ \mu m$

$U = 1.5\ J$

$\lambda_R = 5.7\ Angstrom$

$\bar{\rho} = 6$

$P = 3.1\ TW$

$\tau = 2.4\ ps$

$Z_0 = 0.36\ mm$

$a_0 = 1.12$

$\rho = 9 \cdot 10^{-4}$

$\beta_0 = 1.14\ mm$

$\sigma_0 = 2.4\ \mu m$

PLASMON X

Setting *Δ = 0.1 %* and *I = 2500 A*

Quantum FEL

$\varepsilon_n = 0.14 \;\; \mu m$

$\gamma = 93$

$L_G = \;\; 350 \;\; \mu m$

$U = 37 \;\; J$

$\lambda_R = 0.52 \;\; Angstrom$

$\bar{\rho} = 0.35$

$P = 0.6 \;\; TW$

$\tau = 12 \;\; ps$

$Z_0 = 1.8 \;\; mm$

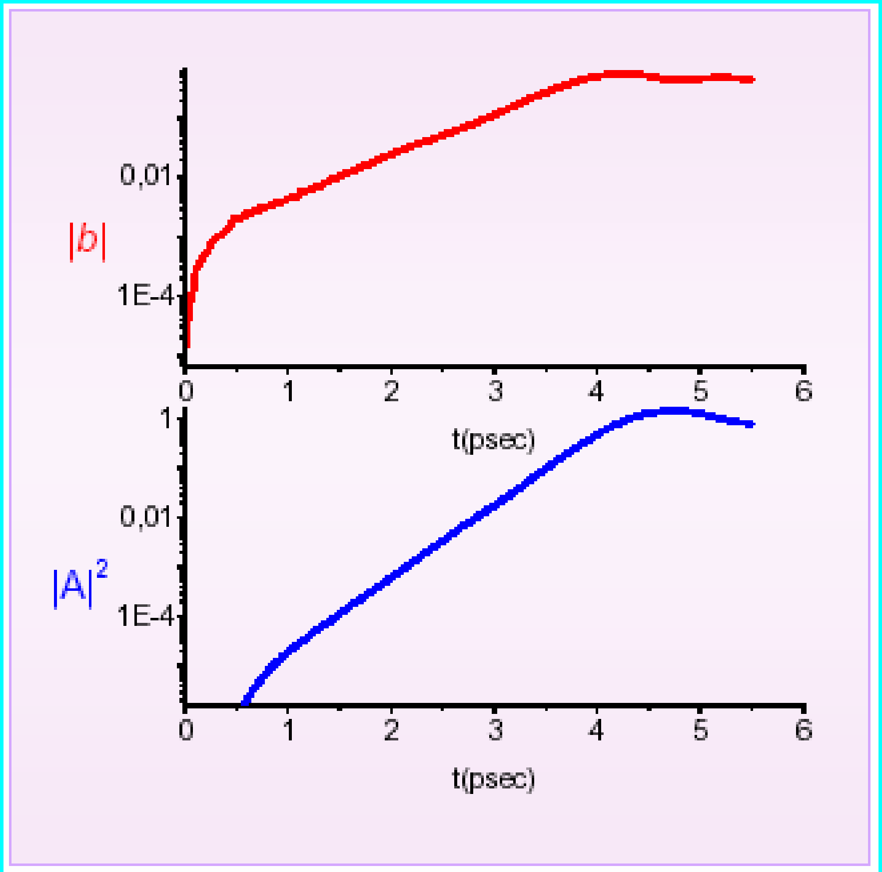
$a_0 = 1.12$

$\rho = 1.8 \cdot 10^{-4}$

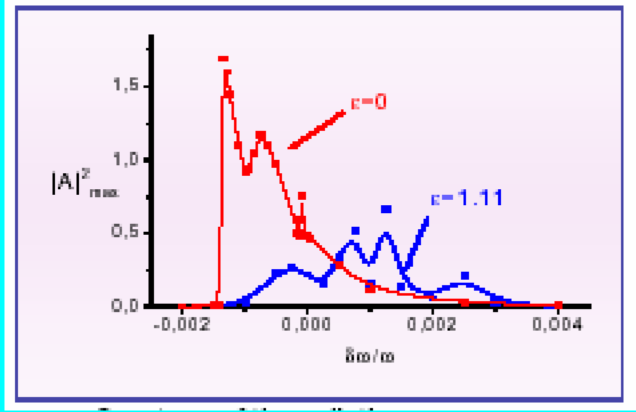
$\beta_0 = 18.8 \;\; mm$

$\sigma_0 = 5.4 \;\; \mu m$

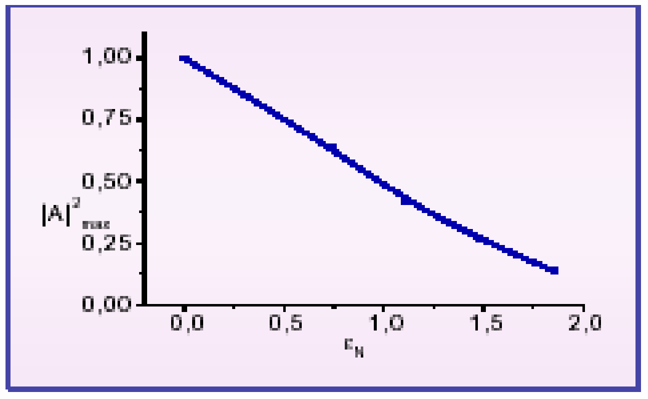
PLASMON X



0,01
|b|
1E-4
0 1 2 3 4 5 6
t(psec)
1
0,01
|A|²
1E-4
0 1 2 3 4 5 6
t(psec)

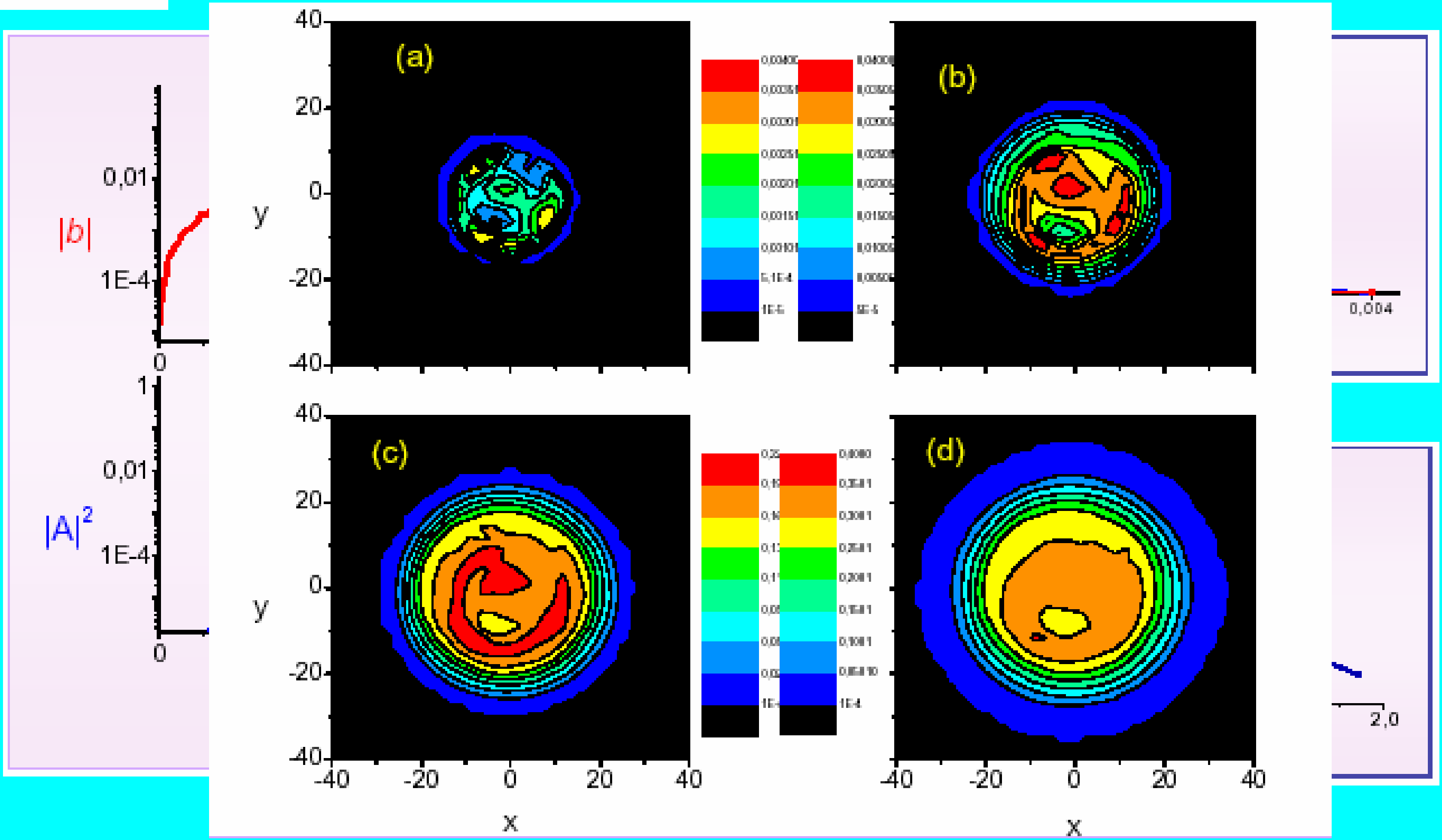


1,5
1,0
0,5
0,0
|A|²max
ε=0
ε=1.11
-0,002
0,000
0,002
0,004
δω/ω



1,00
0,75
0,50
0,25
0,00
|A|²max
0,0
0,5
1,0
1,5
2,0
εN

PLASMON X

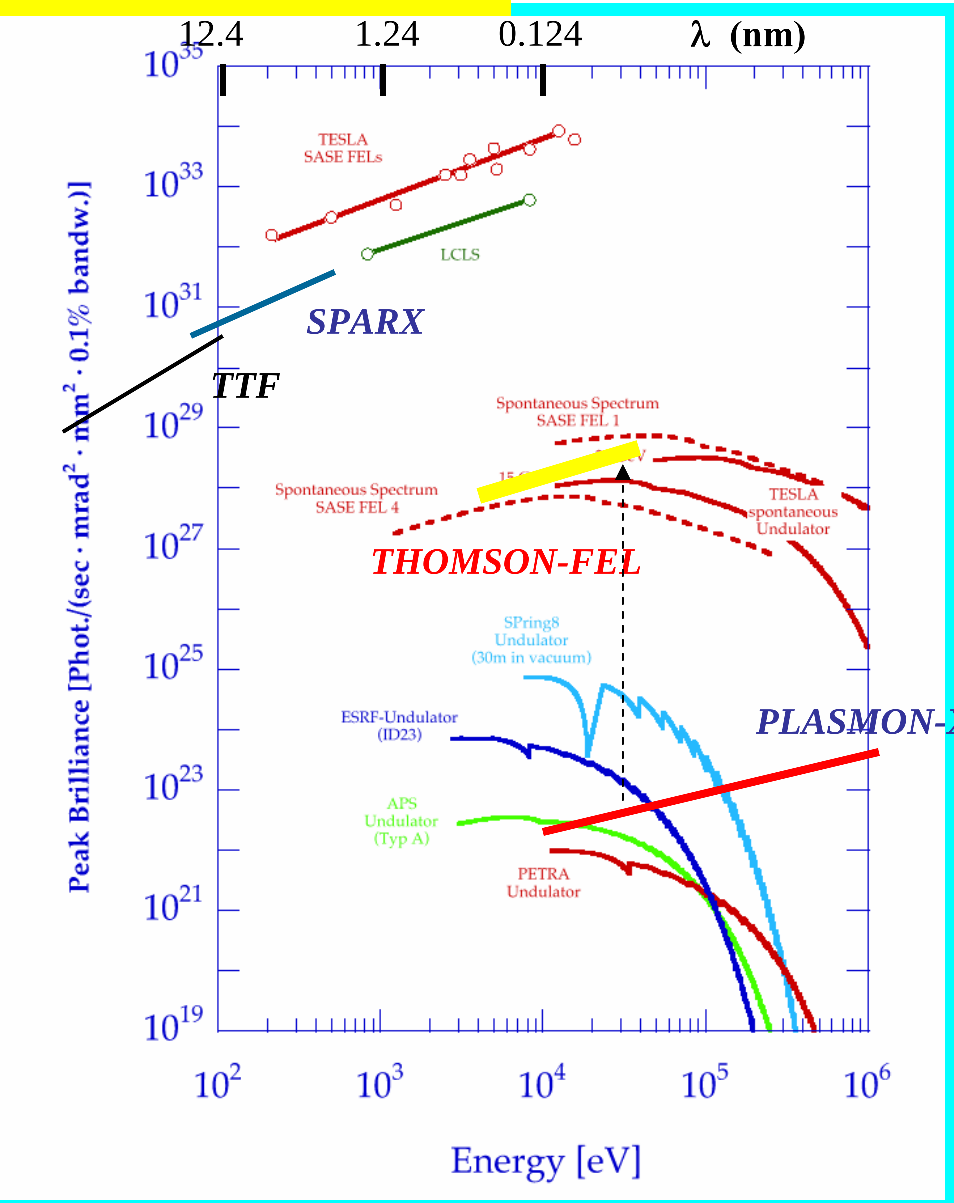


up to 2·10^{10} photons per pulse @ 6 keV,
emitted in a coherent diffraction limited radiation beam, Δθ=3 μrad
(cmp. 10^{9} ph/pulse in Δθ=3 mrad of incoherent Thomson radiation)

Brilliance of X-ray radiation sources

Compact Thomson Sources extend SR to hard X-ray range allowing Advanced Radiological Imaging **inside** Hospitals

Coherent Thomson Sources will push the achievable brilliance if laser pulses with *$\Delta I/I < \Delta\omega/\omega = 2\cdot10^{-3}$* will be made available

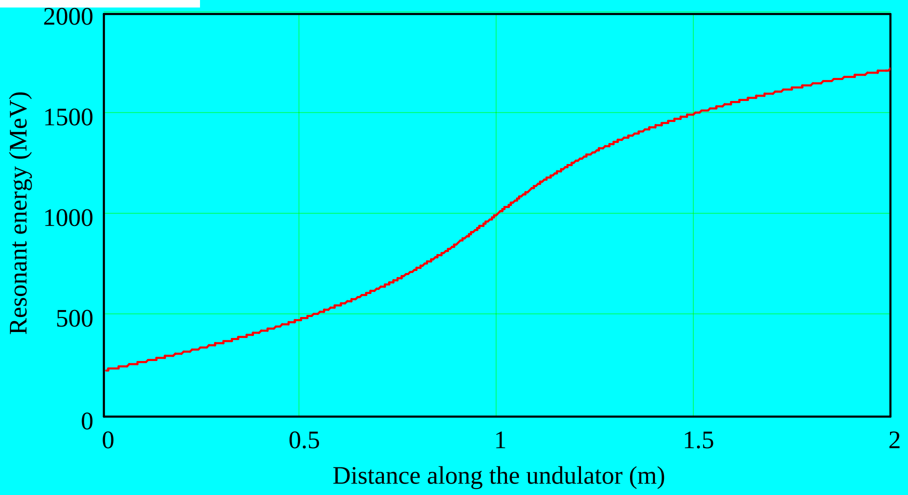


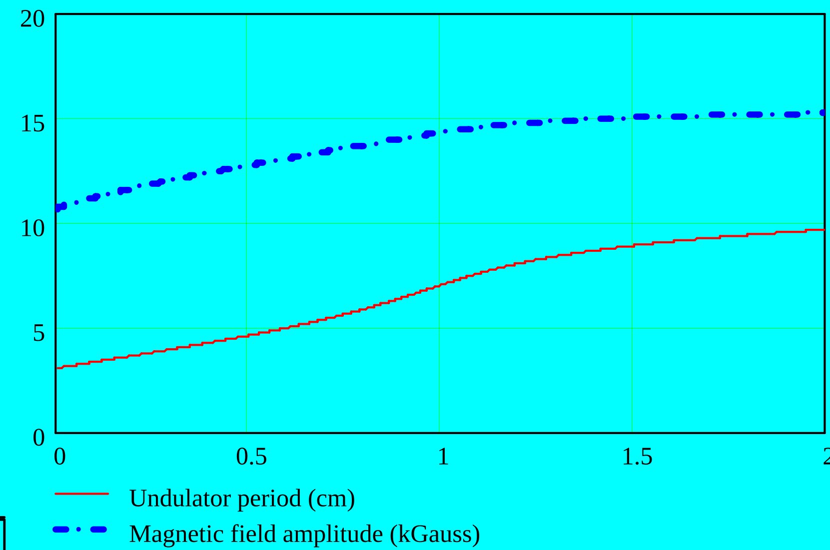
GeV-class IFEL design:

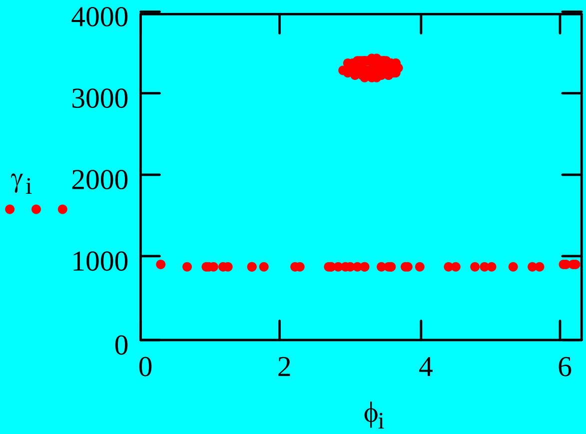
- Application of IFEL scheme as 4th generation light source driver
- Compact-size accelerator
- ESASE benefits intrinsic
  - Exponential gain length reduction
  - Absolute timing synchronization with external laser
  - Control of x-ray radiation pulse envelope
- Advanced Accelerator driven light source
- Design exercise aimed to extend the energy and wavelength reach of planned SPARC linac

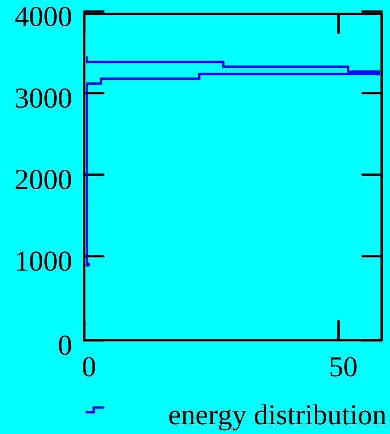
Initial *e*-beam energy (γ value)	210 MeV
Initial *e*-beam intrinsic energy spread	0.1% (1σ)
Initial *e*-beam current	1 kA
Laser wavelength	800 nm
Laser peak power	20 TW
Nominal length of wiggler, L_w	200 cm

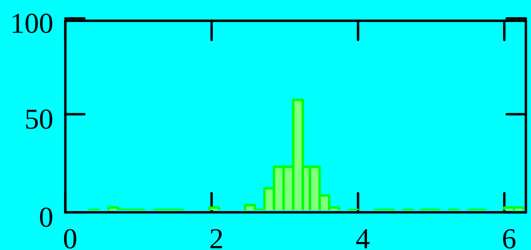
IFEL design











Longitudinal phasespace

zpos = 1.996m

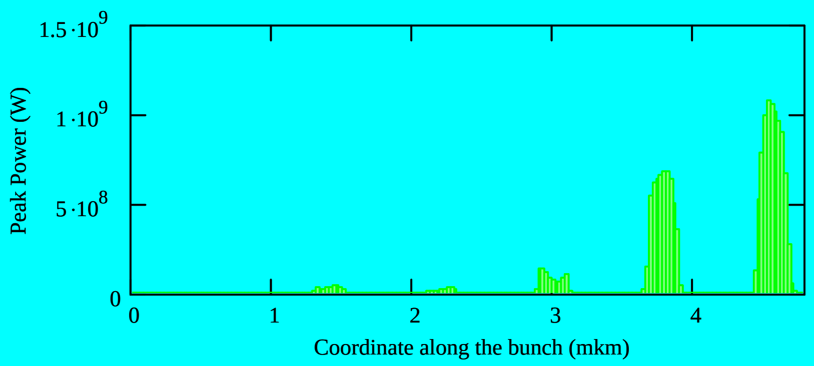
Final output parameters

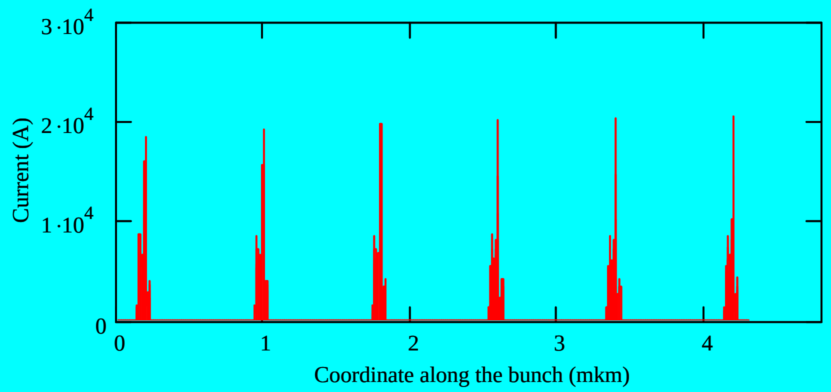
Energy	**1.7 GeV**
Energy spread	<0.8 %
Microbunch length	**250 as**
Peak current	**> 6 kAmp**
Avg. gradient	**750 MeV/m**

Conclusions

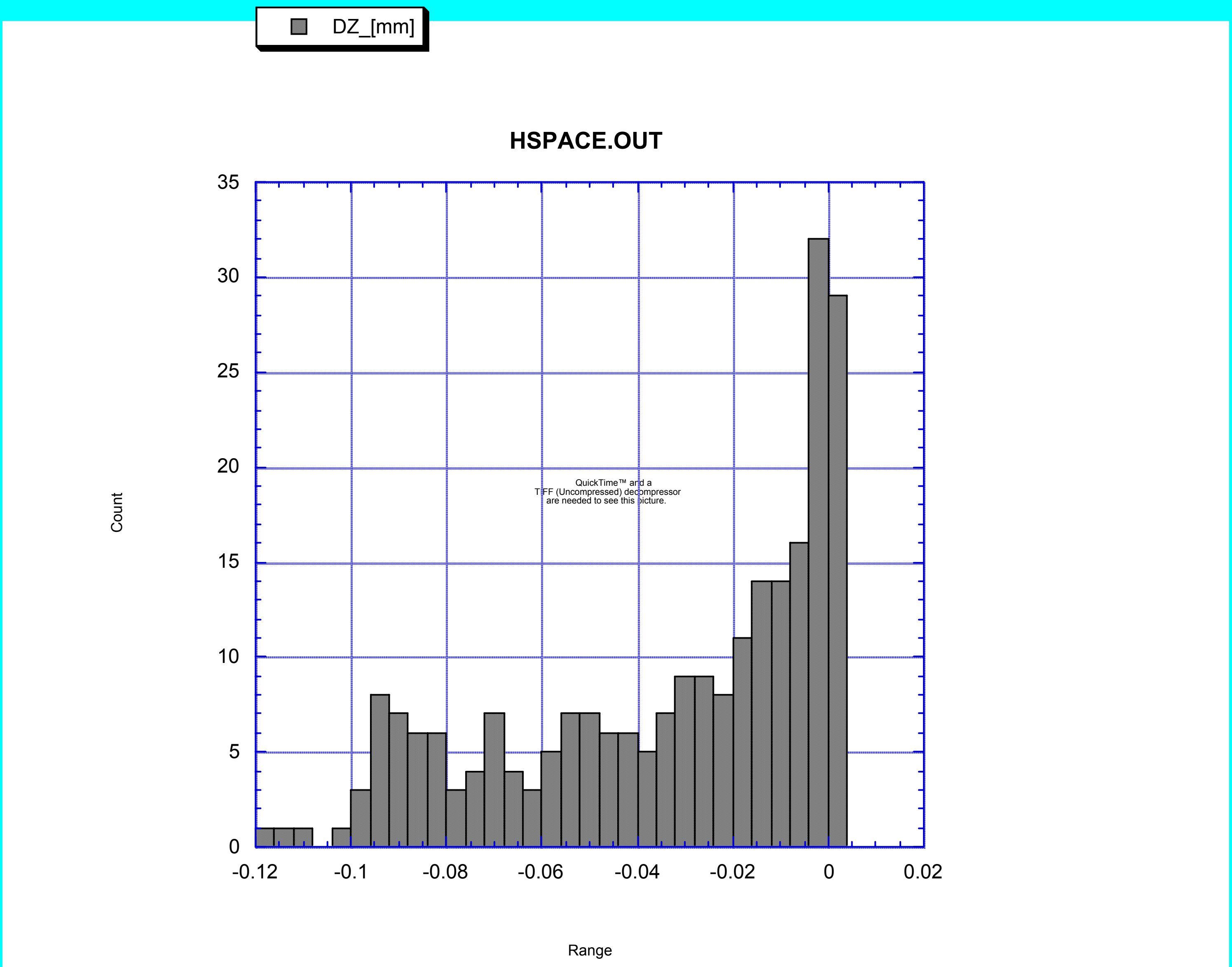
- Sending such a beam into an undulator
  - FEL radiation @ λ = 3 nm (water window). Peak power 1 GW in 300 attoseconds

- Among laser accelerators, the IFEL offers best control of the longitudinal phase space.
- Preserving ultrashort pulse structure in the radiation output requires some precautions in the design of the FEL amplifier (slippage problems) but can be done.
- Path towards ultrashort probe beams pass through fa synergy between laser and accelerator worlds.





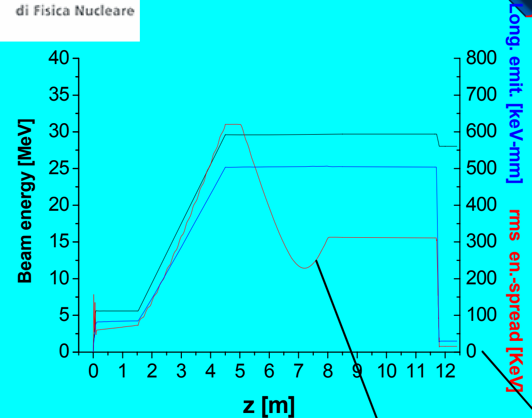
PLASMON X

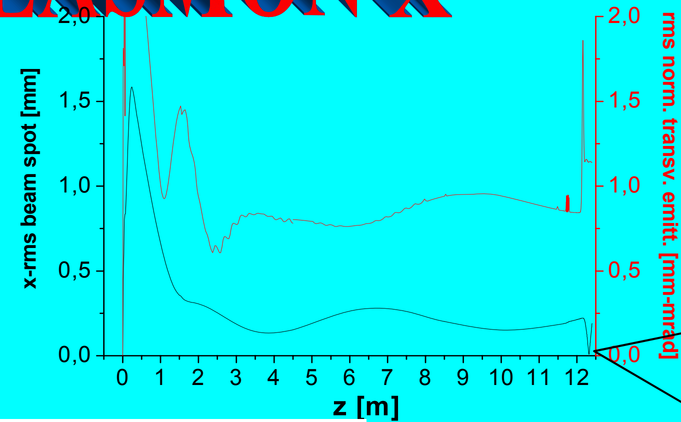


DZ_[mm]
HSPACE.OUT
35
30
25
20
15
10
5
0
Count
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.
-0.12
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
Range

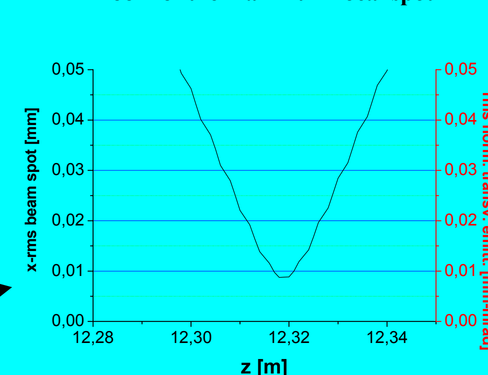
Best result in 2004 σ = 8.7μm (1nC Solenoid lens)

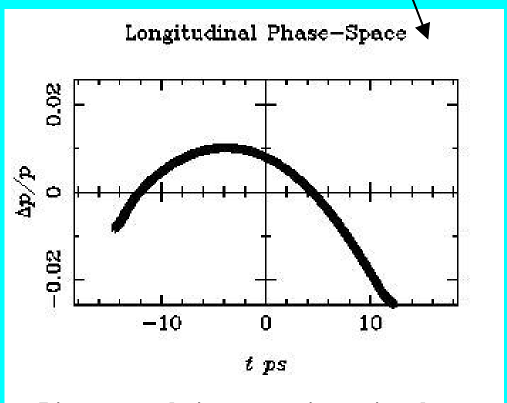
PLASMON X



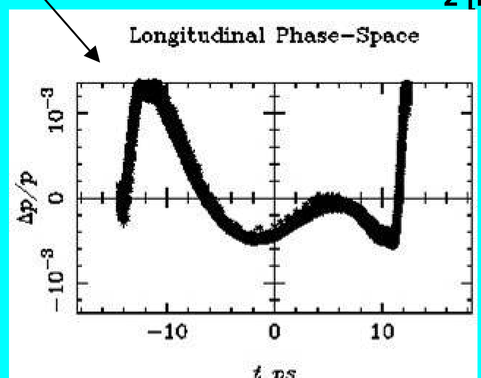


Zoom of the maximum focal spot

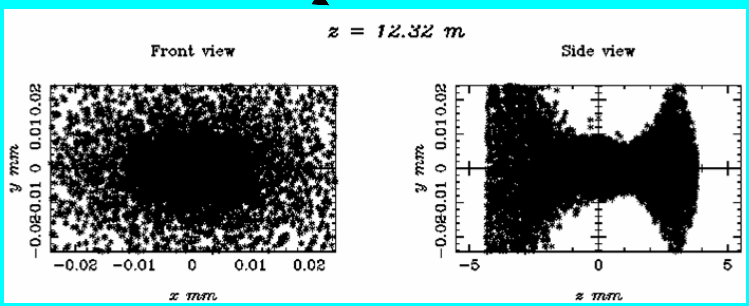




Linear correlation correction, using the second TW acceleration structure: Ez=2.70 MV/m, Φi=85°

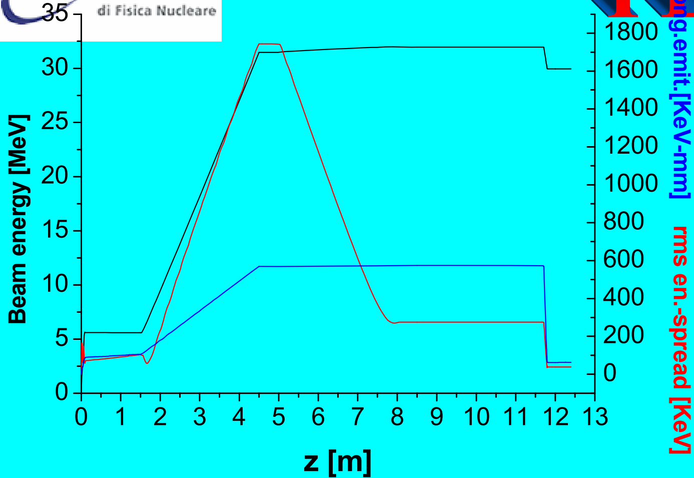


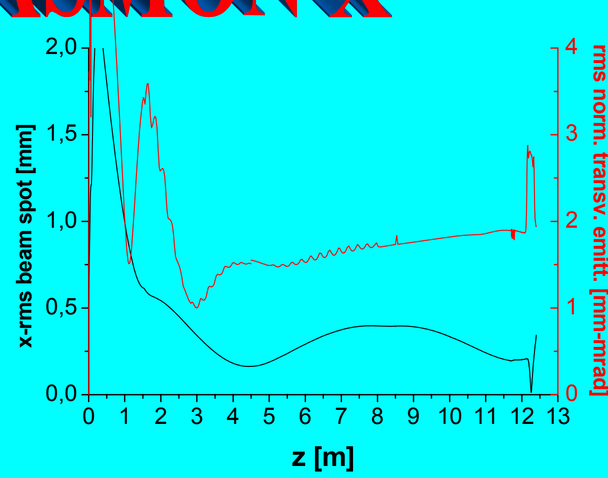
Quadratic correlation correction, using a dedicated x-band structure : Ez=30 MV/m Φi=275°

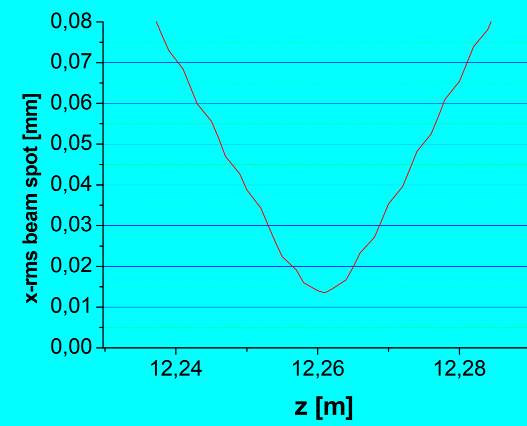


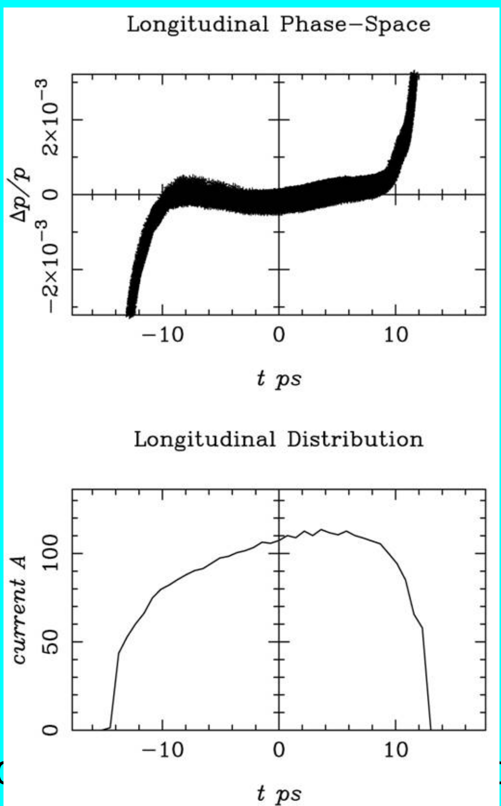
The results seem to be good especially for the very low longitudinal energy spread. Keeping in consideration that the beta in the focal spot is about 5 mm, the principal limitation is due to bunch length.

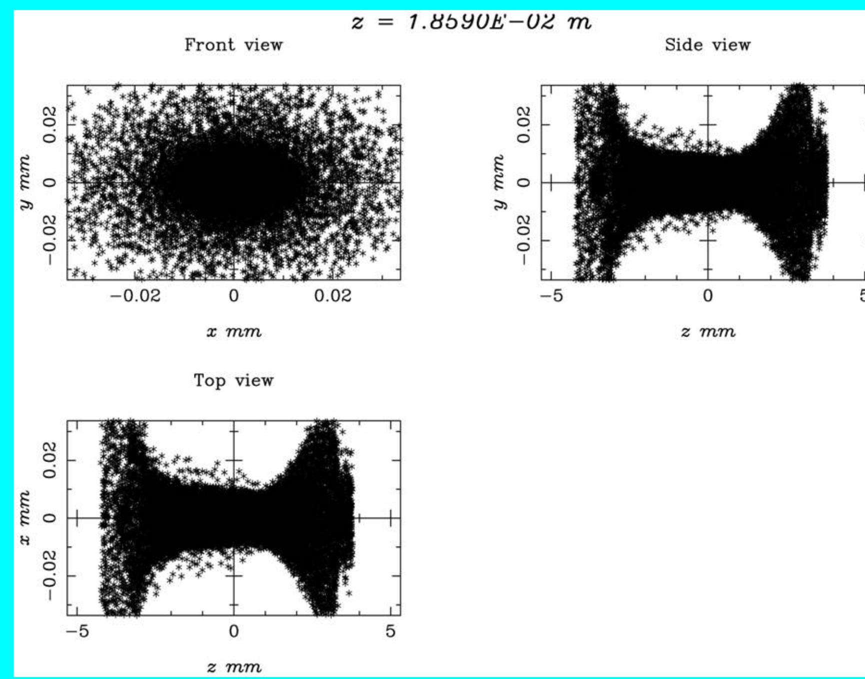
2005 best result (2.5nC Solenoid lens)





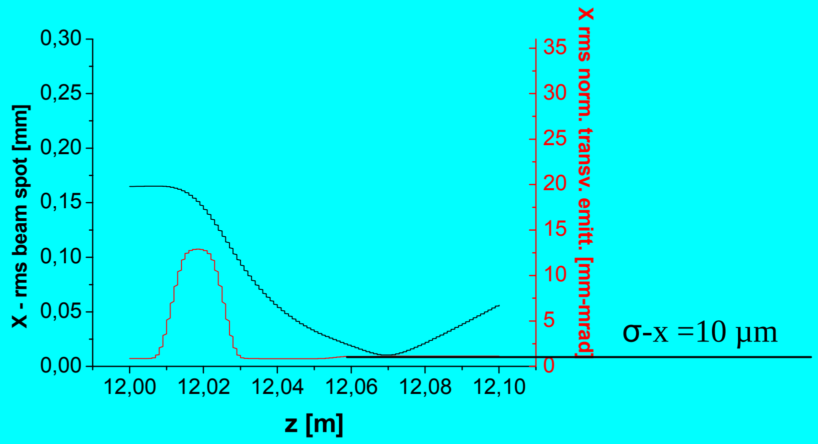


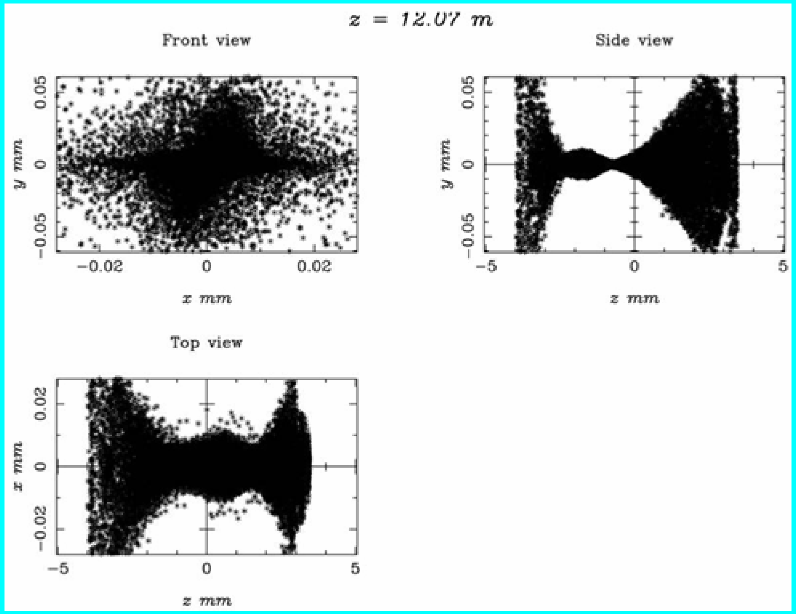


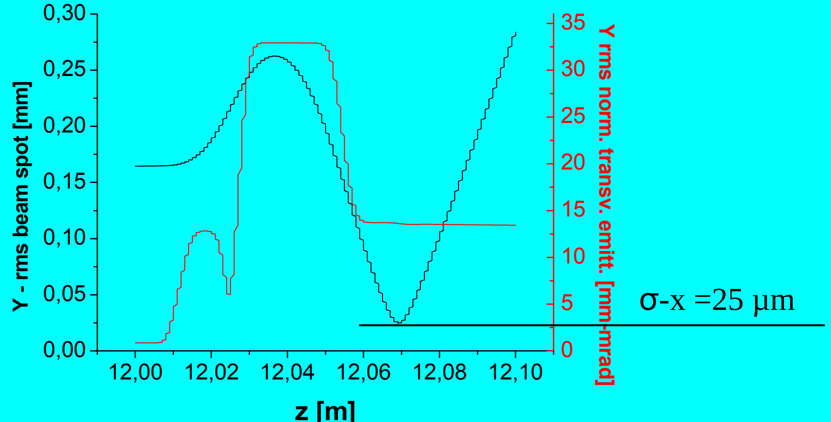


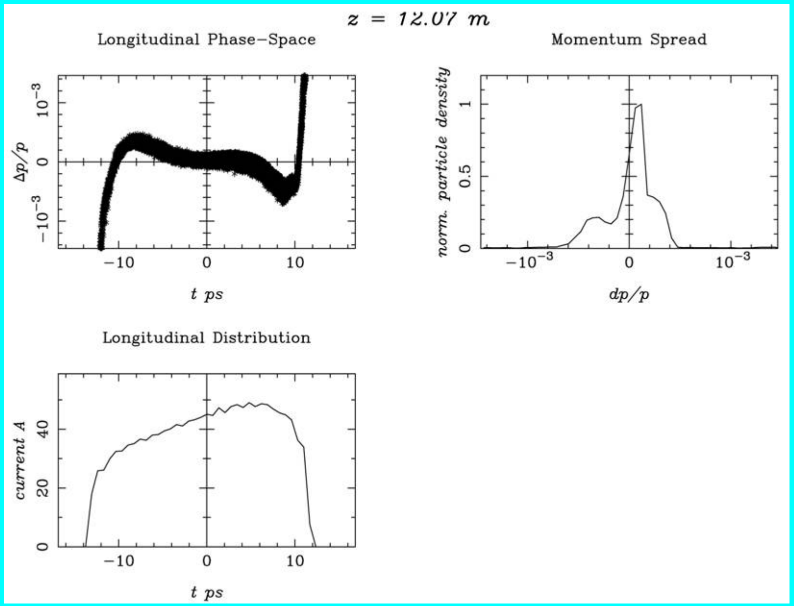
PLASMON X

Triplet configuration:
Ideal +1 -2 +1
Q-length = 1.46 cm
Q-Gradient = 300 T/m



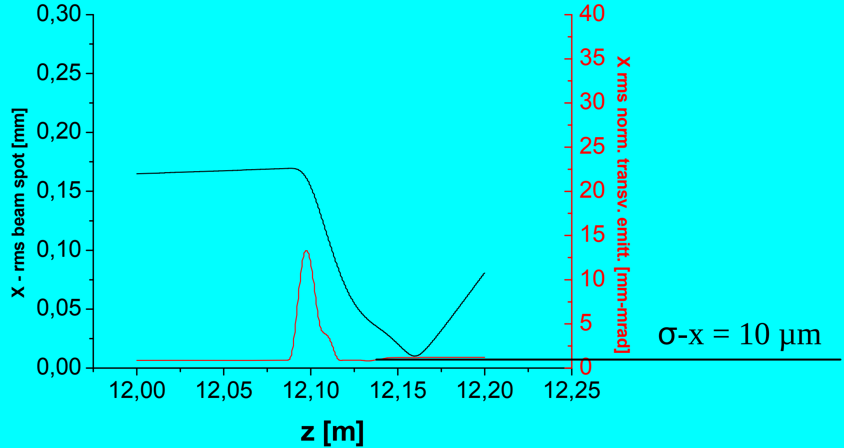


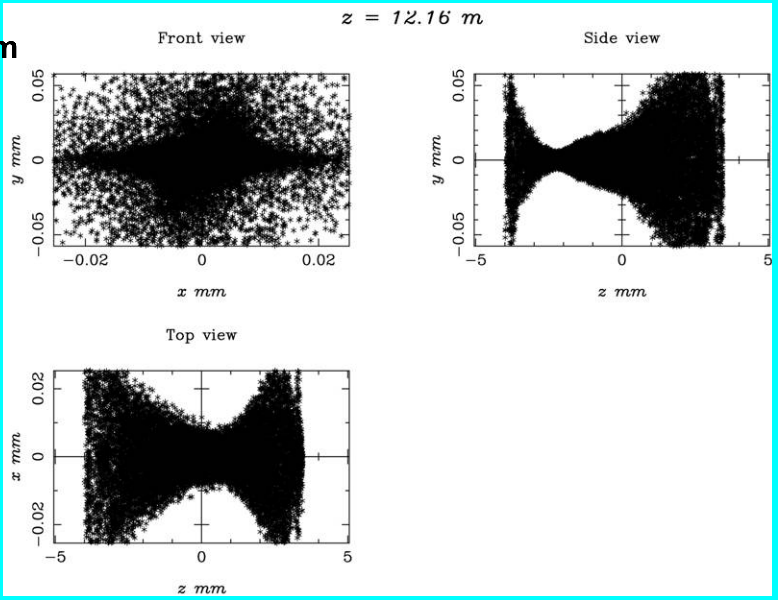


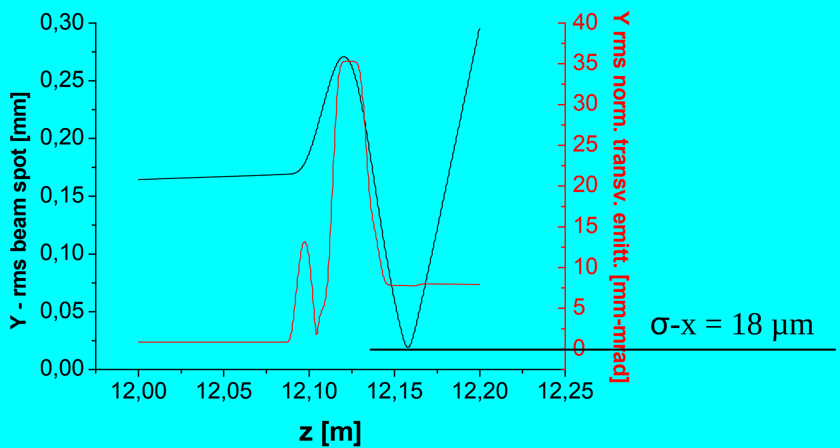


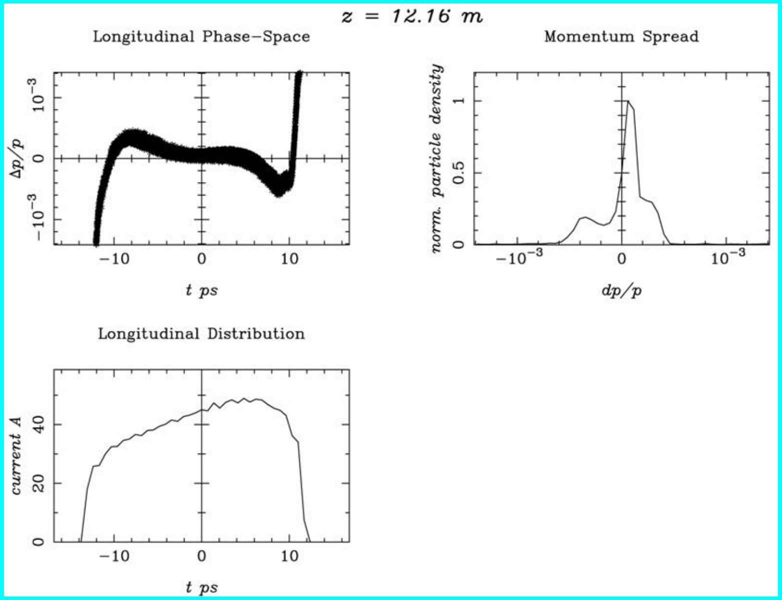
PLASMON X

Triplet configuration:
Q1-length = 1.00 cm ; Q2-length = 2.00 cm ; Q3-length = 2.00 cm
Gradient = +300 ; -300; +300 (T/m)
Position, Q1 = 12.0968 m; Q2 = 12.12305 m; Q3 = 12.1511 m



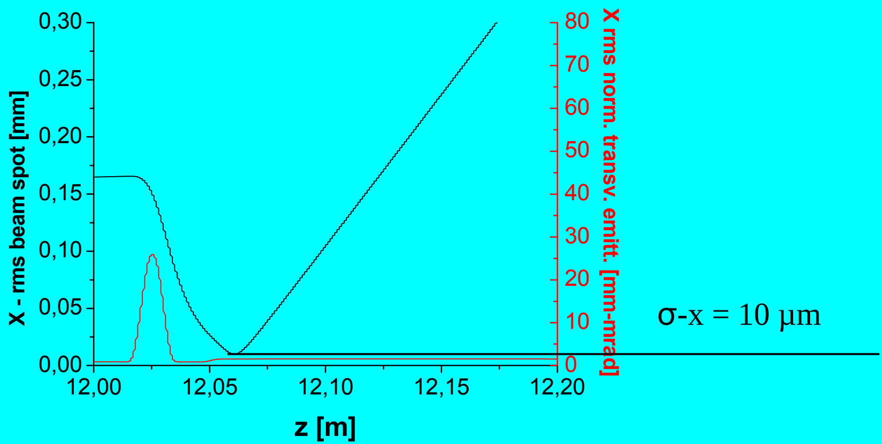


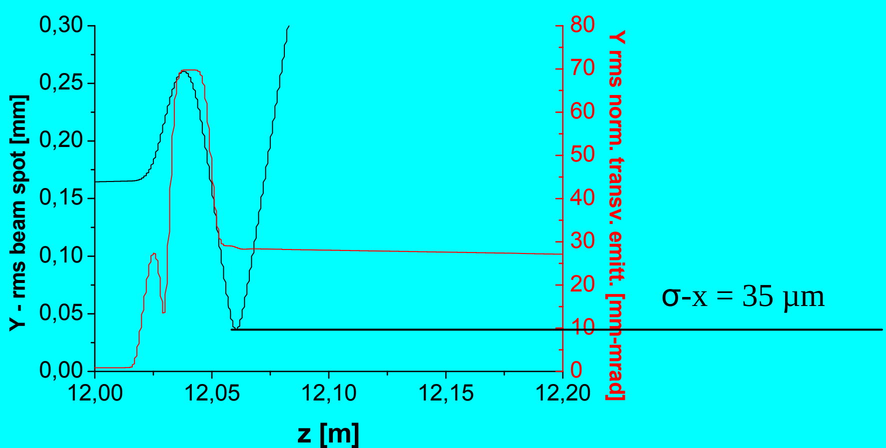


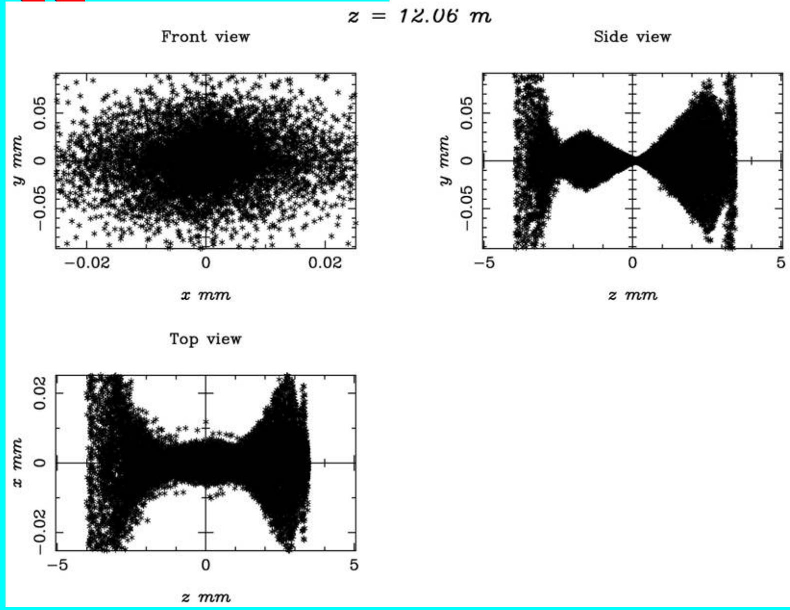


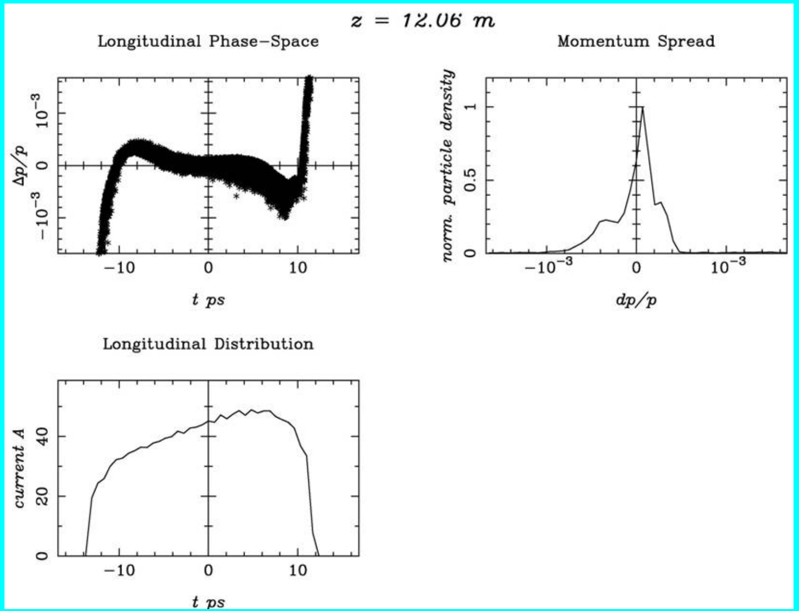
PLASMON X

Triplet configuration- thin lens:
Ideal +1 -2 +1
Q-length = 1.00 cm
Q-Gradient = 645 T/m





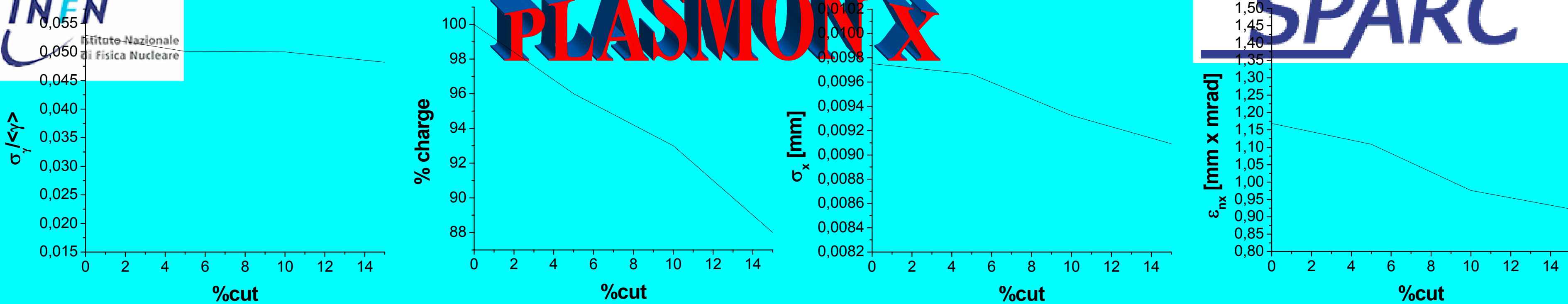




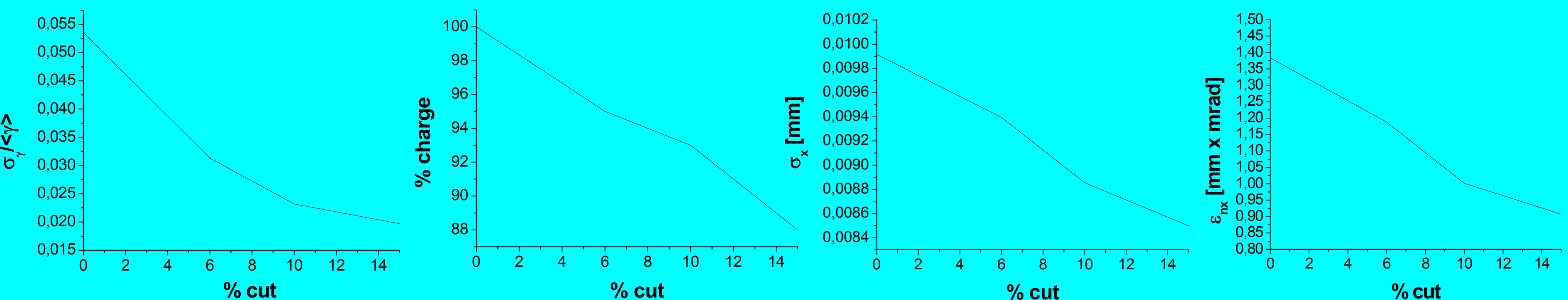
PLASMON X

SPARC

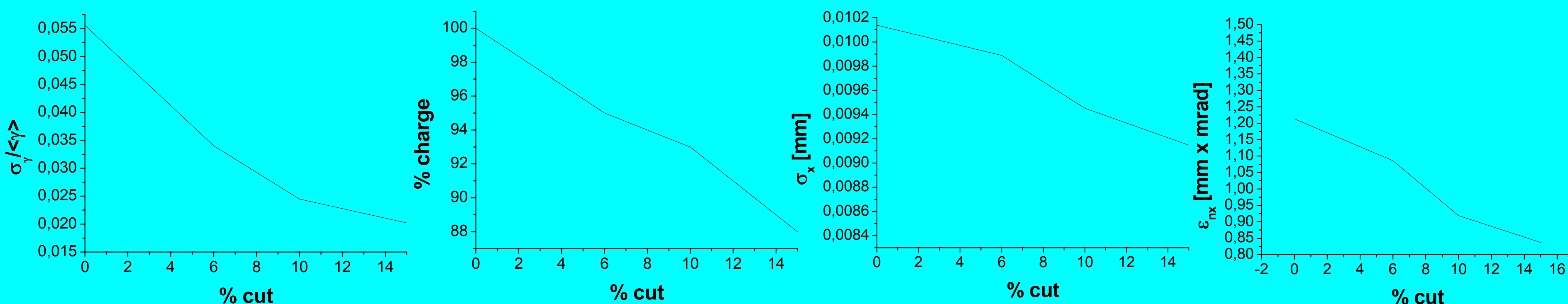
Best result in 2004   σx = 8.7µm (1nC Solenoid lens)



2005 best results (1nC Solenoid lens)



best results with triplet (1nC Solenoid lens) – ONLY X PROIECTION



PLASMON X

30-50 fs synchr. Ti:Sa 200-TW Laser System

ε_n=2 μm, σ =5 μm, $\Delta\gamma/\gamma=4\cdot10^{-4}$

2 nC, 10 ps

1 J, 10 ps gaussian

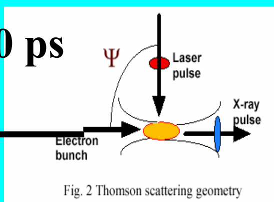
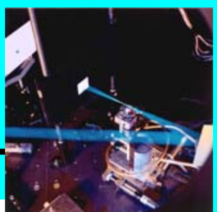


Fig. 2 Thomson scattering geometry

Compr.

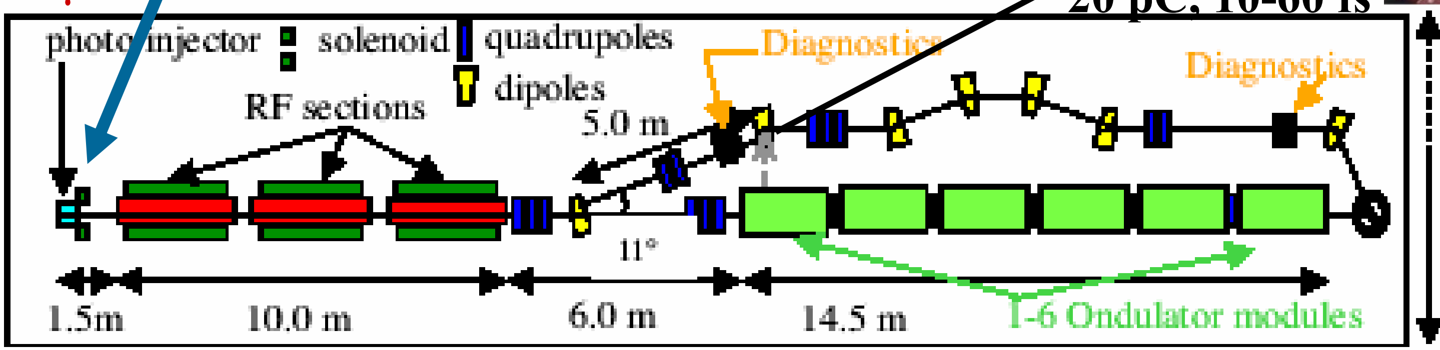
J, 100 fs gaussian



20 mJ, 10 ps flat top

500 μJ

20 pC, 10-60 fs



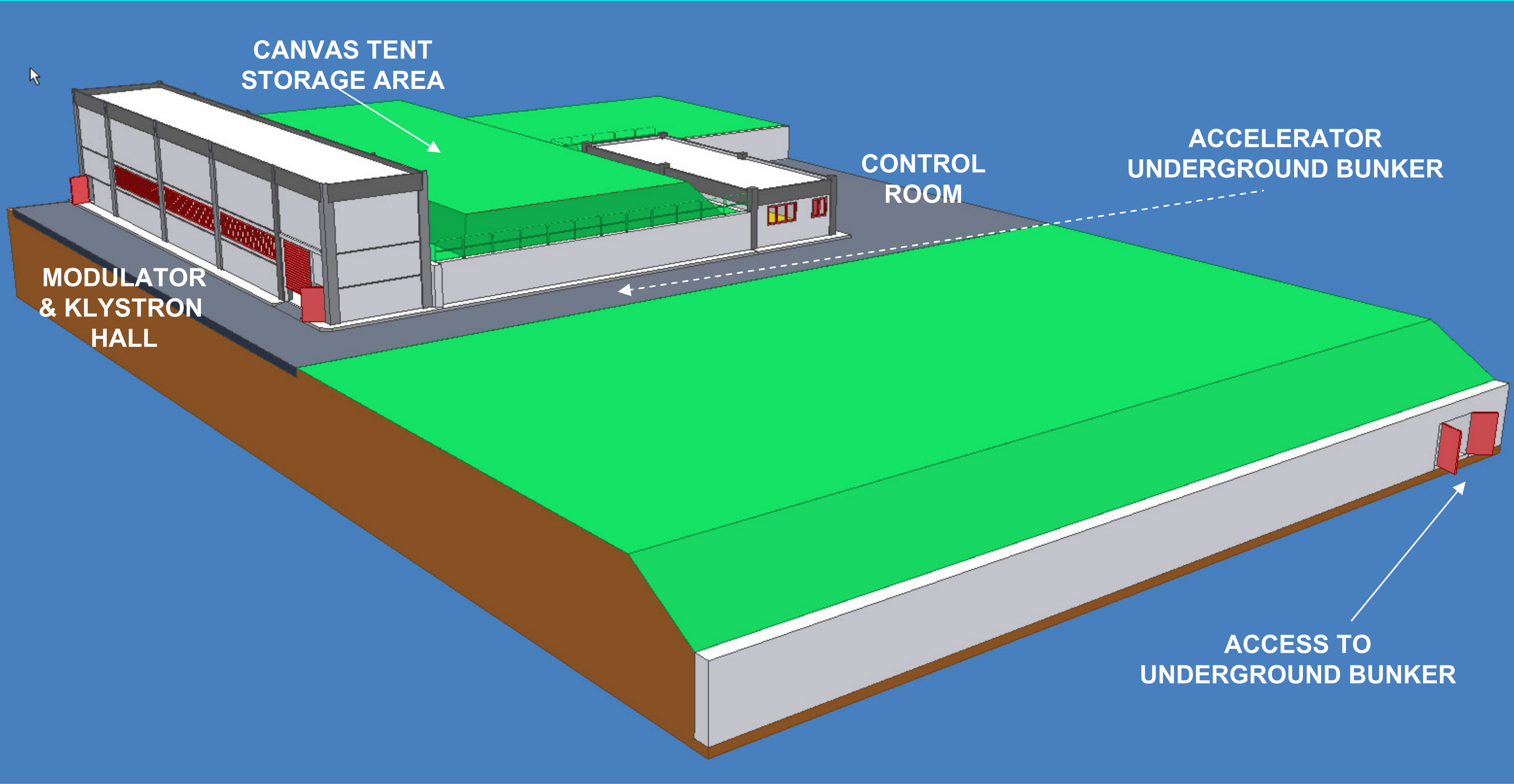
ε_n=0.2 μm, σ =10 μm

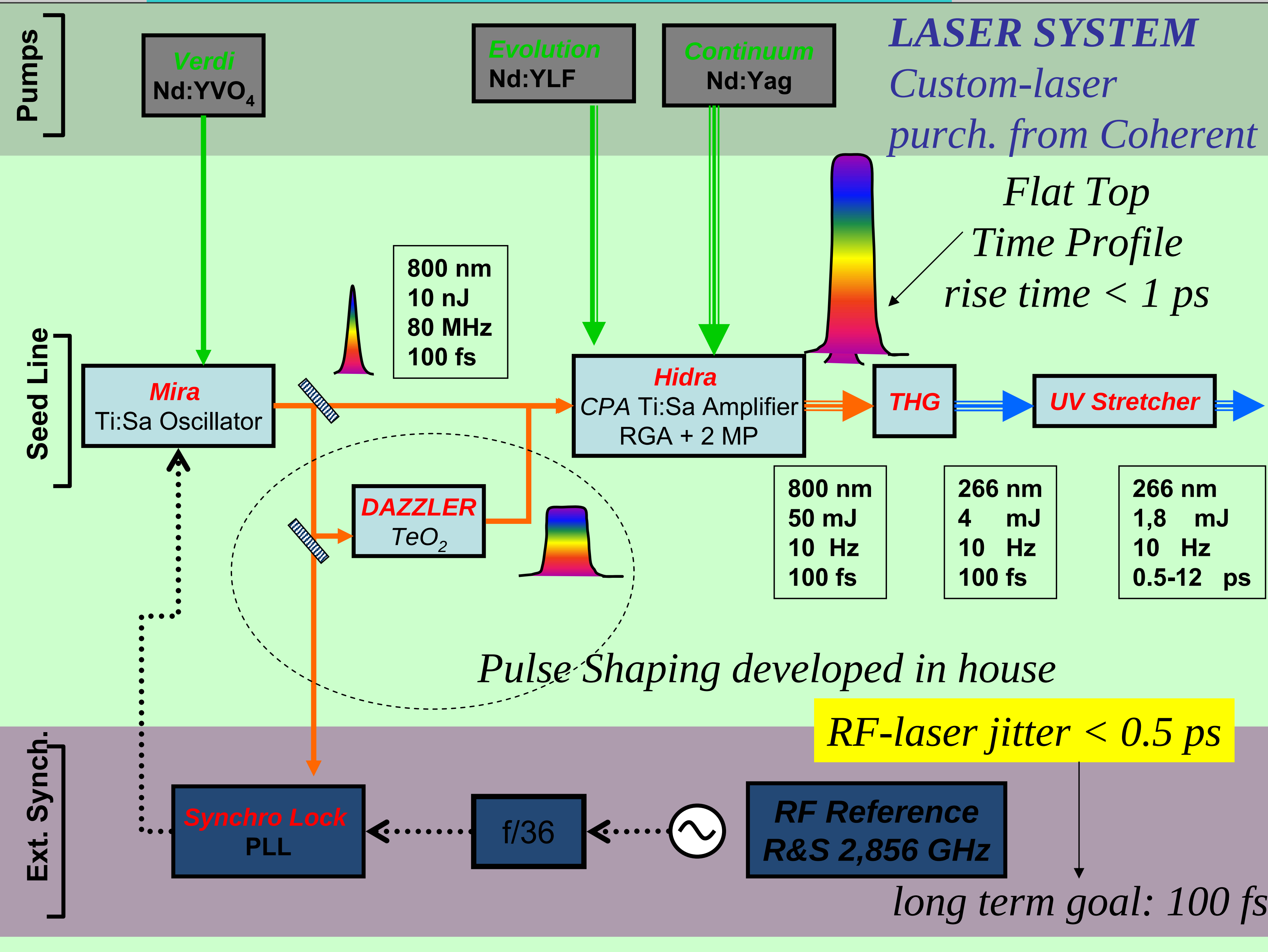
1 nC, 10 ps, ε_n=1 μm

Two additional beam lines at SPARC for plasma acceleration and monochromatic X-ray beams

PLASMON X

A 3D Model View of the buildings from outside





LASER SYSTEM
Custom-laser
purch. from Coherent
Pumps
Verdi
Nd:YVO4
Evolution
Nd:YLF
Continuum
Nd:Yag
Flat Top
Time Profile
rise time < 1 ps
Seed Line
Mira
Ti:Sa Oscillator
800 nm
10 nJ
80 MHz
100 fs
Hidra
CPA Ti:Sa Amplifier
RGA + 2 MP
THG
UV Stretcher
DAZZLER
TeO2
800 nm
50 mJ
10 Hz
100 fs
266 nm
4 mJ
10 Hz
100 fs
266 nm
1,8 mJ
10 Hz
0.5-12 ps
Pulse Shaping developed in house
RF-laser jitter < 0.5 ps
Ext. Synch.
Synchro Lock
PLL
f/36
RF Reference
R&S 2,856 GHz
long term goal: 100 fs

Schedule of the planned PLASMONX activity

Activity/Year	2004	2005	2006	2007	2008	2009
Set up cluster for parallel computing						
Test experiments @ CEA -Saclay						
Development of m.w. PIC codes						
Modelling of acceleration schemes						
Modelling of T.S.						
Design of Laser System						
Set up LASER LABORATORY at LNF						
Set up Phase 1: 30fs, 0.1TW			M			
Set up I II amplification stage						
Development of the OPCPA amplifiers						
Installation of laser diagnostics						
Phase 2: 1TW compression test				M		
IV amplification stage						
Phase 3: 100 TW compression test					M	
Self injection LWFA experiments						
External injection LWFA test						M
Set up additional beam-line at LNF						
Set up laser beam transport to LINAC						
Set up laser beam–electron bunch interaction						
Synchronization R&D and setup						
Thomson source test						M
TS beam users (MAMBO, etc)						

2.5 Meuro bid is ongoing for the FLAME laser

QFEL experim. under study with PLASMONX facility

PLASMON X

With these parameters, $\rho = \frac{1}{\gamma_0}\left(\frac{\omega_b^2 a_{L0}^2}{16\omega_L^2}\right)^{\frac{1}{3}}$ =7 10-4.

The gain lenth L_g=110 micron, and the system is classic

$$\mathbf{A}_L(\underline{r},t) = \frac{a_{L0}}{\sqrt{2}}(g(\underline{r},t)e^{-i(k_L z+\omega_L t)}\hat{\mathbf{e}} + cc) + O(\frac{\lambda_L}{w_0})$$

with

$$\hat{\mathbf{e}} = (\mathbf{e}_x + i\mathbf{e}_y)/\sqrt{2}$$

And with envelope

$$g(\underline{r},t) = \Phi(z+ct)\frac{1+i\frac{z}{z_0}}{1+\frac{z^2}{z_0^2}}\exp\left[-4\frac{x^2+y^2}{w_0^2(1+\frac{z^2}{z_0^2})} - 4i\frac{x^2+y^2}{w_0^2(\frac{z}{z_0}+\frac{z_0}{z})}\right]$$

PLASMON X

The 3 dimensional collective equations that describes the collective effects are similar to the FEL equation with the SVEA approximation

$$\frac{d}{d\bar{t}}\bar{\mathbf{r}}_j(\bar{t}) = \rho\,\frac{\mathbf{P}_j(\bar{t})}{\bar{\gamma}_j(\bar{t})}$$

$$\frac{d}{d\bar{t}}P_{jz}(\bar{t}) = -\frac{\bar{a}_{L0}^2}{2\rho\gamma_0^2}\frac{1}{\bar{\gamma}_j}\left[\frac{\partial}{\partial\bar{z}}|g|^2\right]_{\bar{\mathbf{x}}=\bar{\mathbf{r}}_j} -$$

$$\frac{2}{\bar{\gamma}_j}\mathrm{Re}\;al\left[(g^*\bar{A})_{\bar{\mathbf{x}}=\bar{\mathbf{r}}_j}e^{i\theta_j(\bar{t})}\right]+ \ldots.$$

$$\frac{d}{d\bar{t}}\mathbf{P}_{j\perp}(\bar{t}) = -\frac{\bar{a}_{L0}^2}{2\rho\gamma_0^2}\frac{1}{\bar{\gamma}_j}\left[\bar{\nabla}_\perp|g|^2\right]_{\bar{\mathbf{x}}=\bar{\mathbf{r}}_j}$$

$$-\frac{4\frac{k_L}{k}\rho}{1+\frac{k_L}{k}}\frac{1}{\bar{\gamma}_j}\mathrm{Im}\left[(\nabla_\perp(g^*\bar{A}))_{\bar{\mathbf{x}}=\bar{\mathbf{r}}_j}e^{i\theta_j(\bar{t})}\right]+ ..$$

$$\left(\frac{\partial}{\partial\bar{t}}+\frac{\partial}{\partial\bar{z}}\right)\bar{A}(\bar{\mathbf{x}},\bar{t}) - i\frac{k_L}{k}\rho\bar{\nabla}_\perp^2\bar{A} = b$$