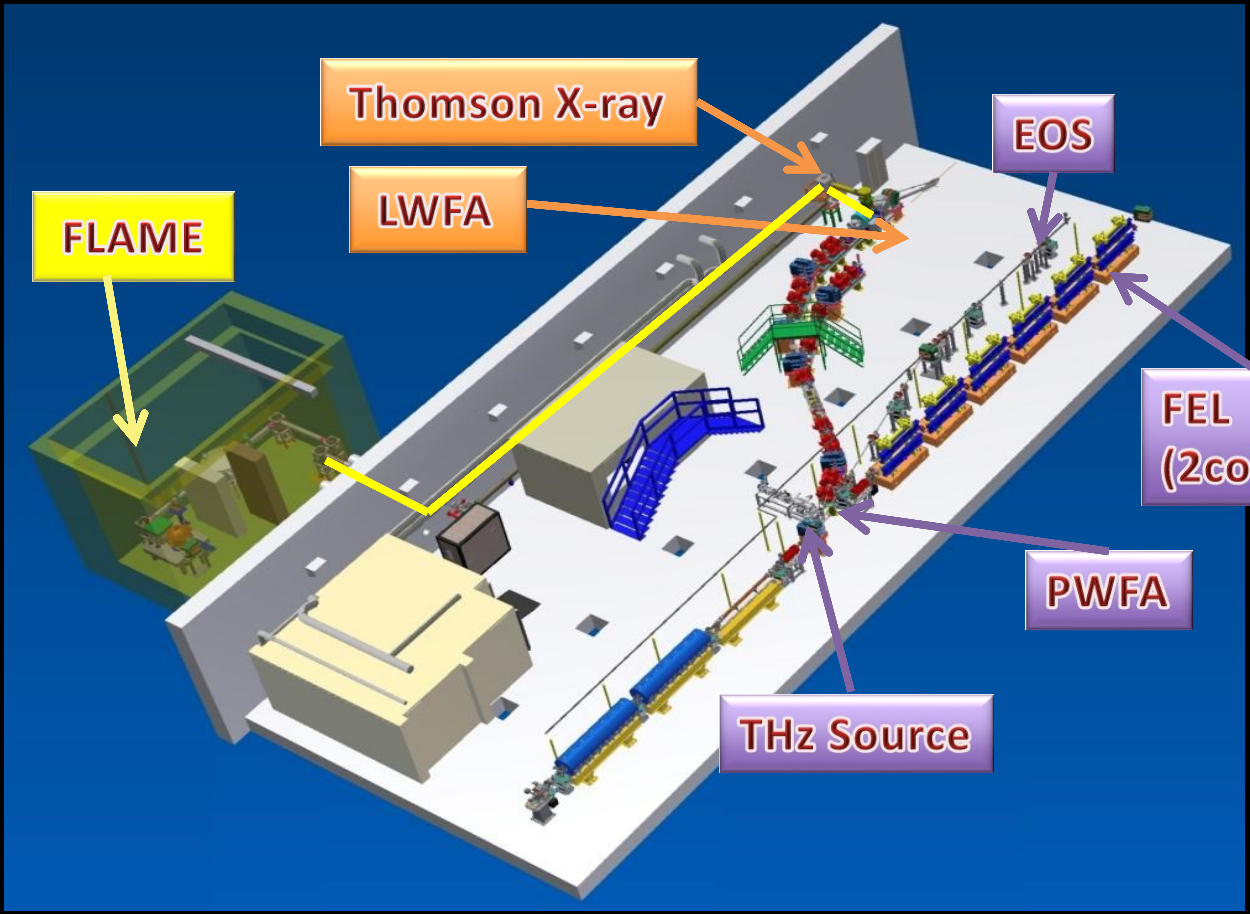
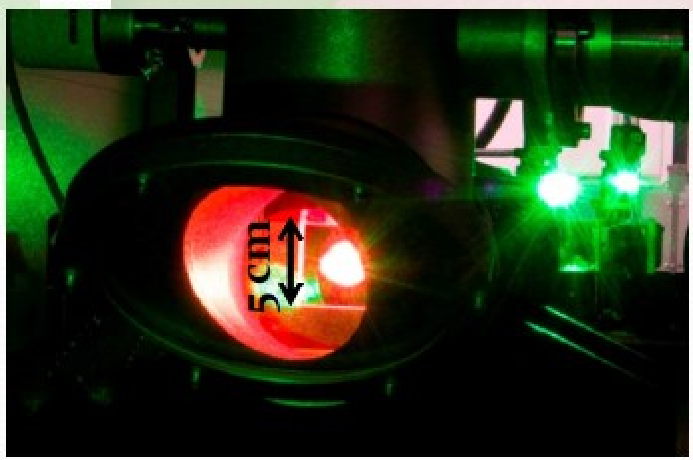
SPARC_LAB status

Massimo Ferrario
On behalf of the SPARC_LAB collaboration



Virtual Institute meeting – Elba - September 13, 2015

Il laser FLAME



Energia massima: 7J

Energia massima sul target: ~5J

Durata minima: 23 fs

Lunghezza d'onda: 800 nm

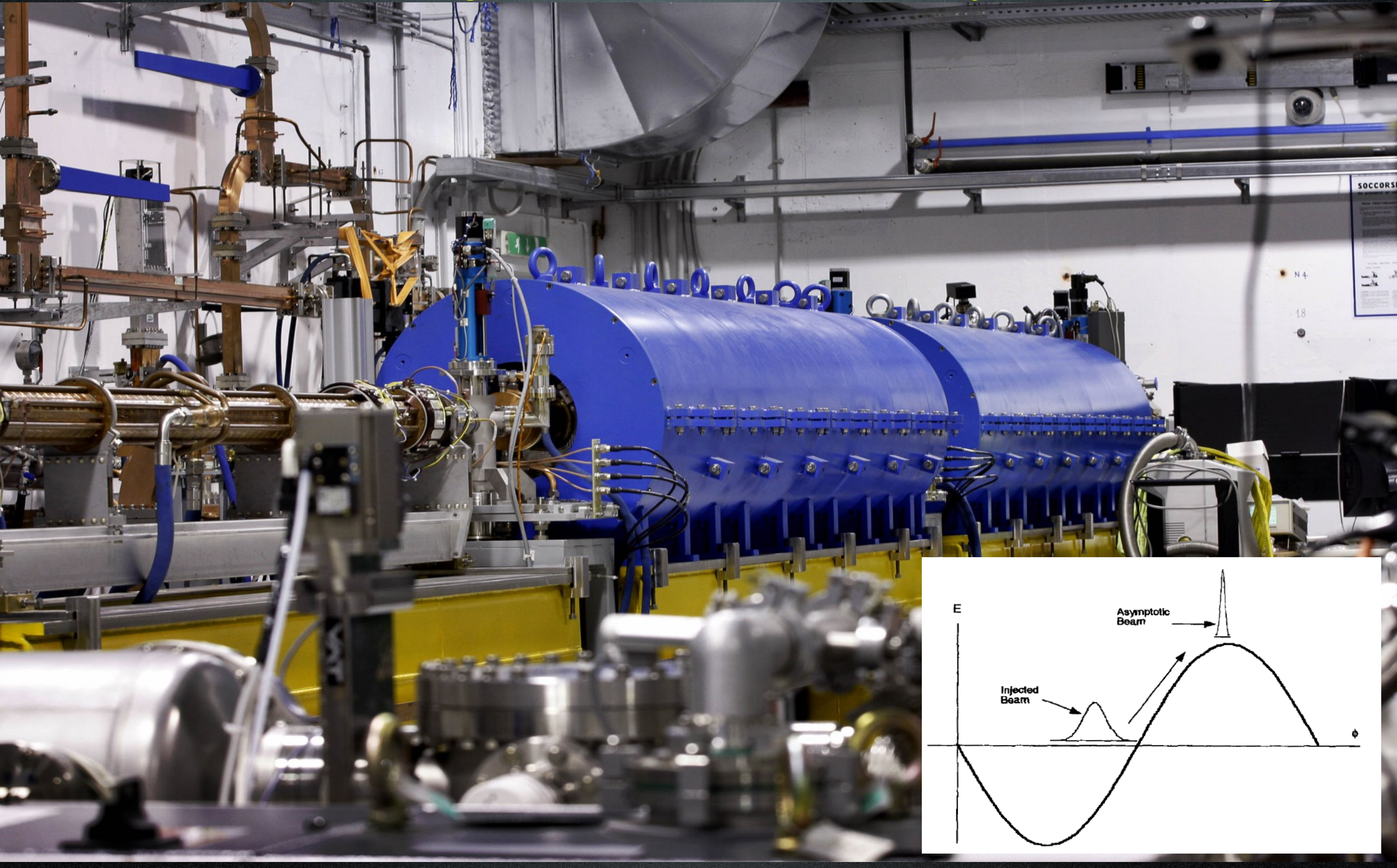
Larghezza di banda: 60/80 nm

Spot-size @ focus: 10 μm

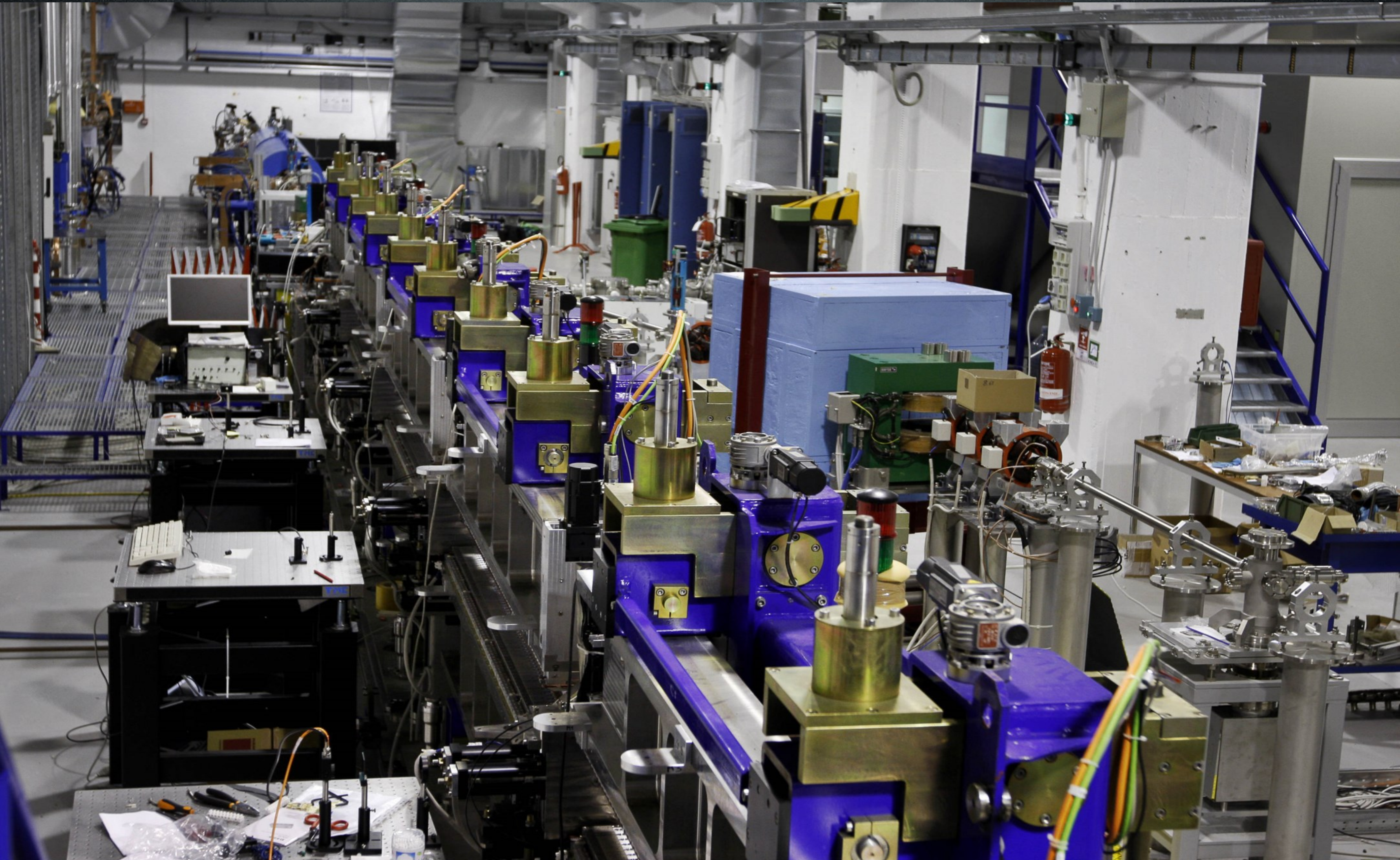
Potenza massima: ~300 TW

Contrasto: 10^{10}

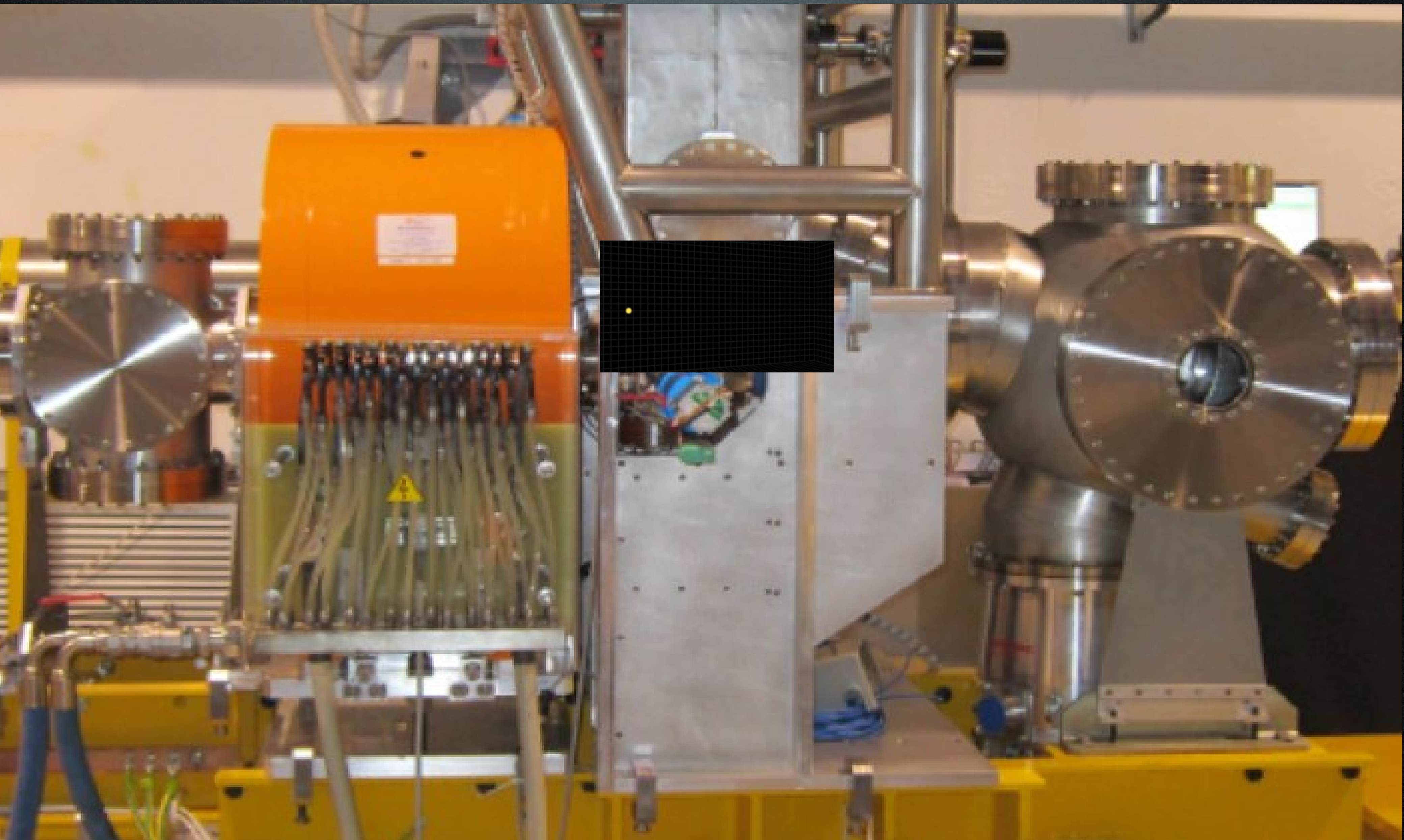
HB photo- injector with Velocity Bunching



Free Electron Laser

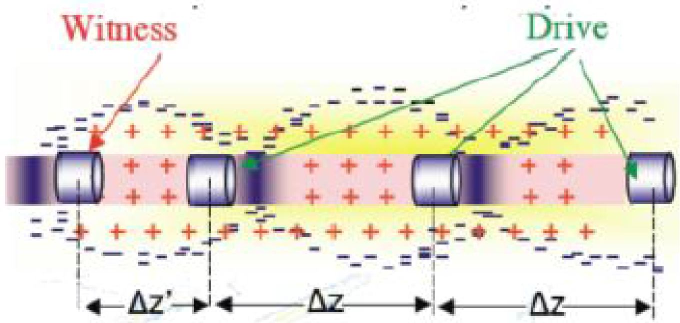


Thomson backscattering



Plasma-based acceleration techniques

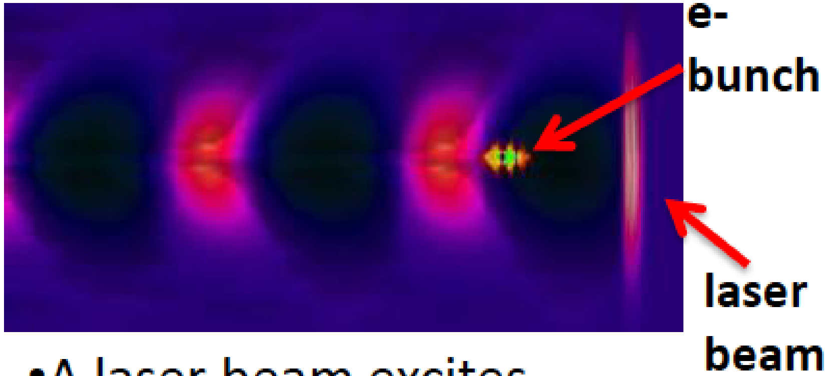
resonant-PWFA



•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

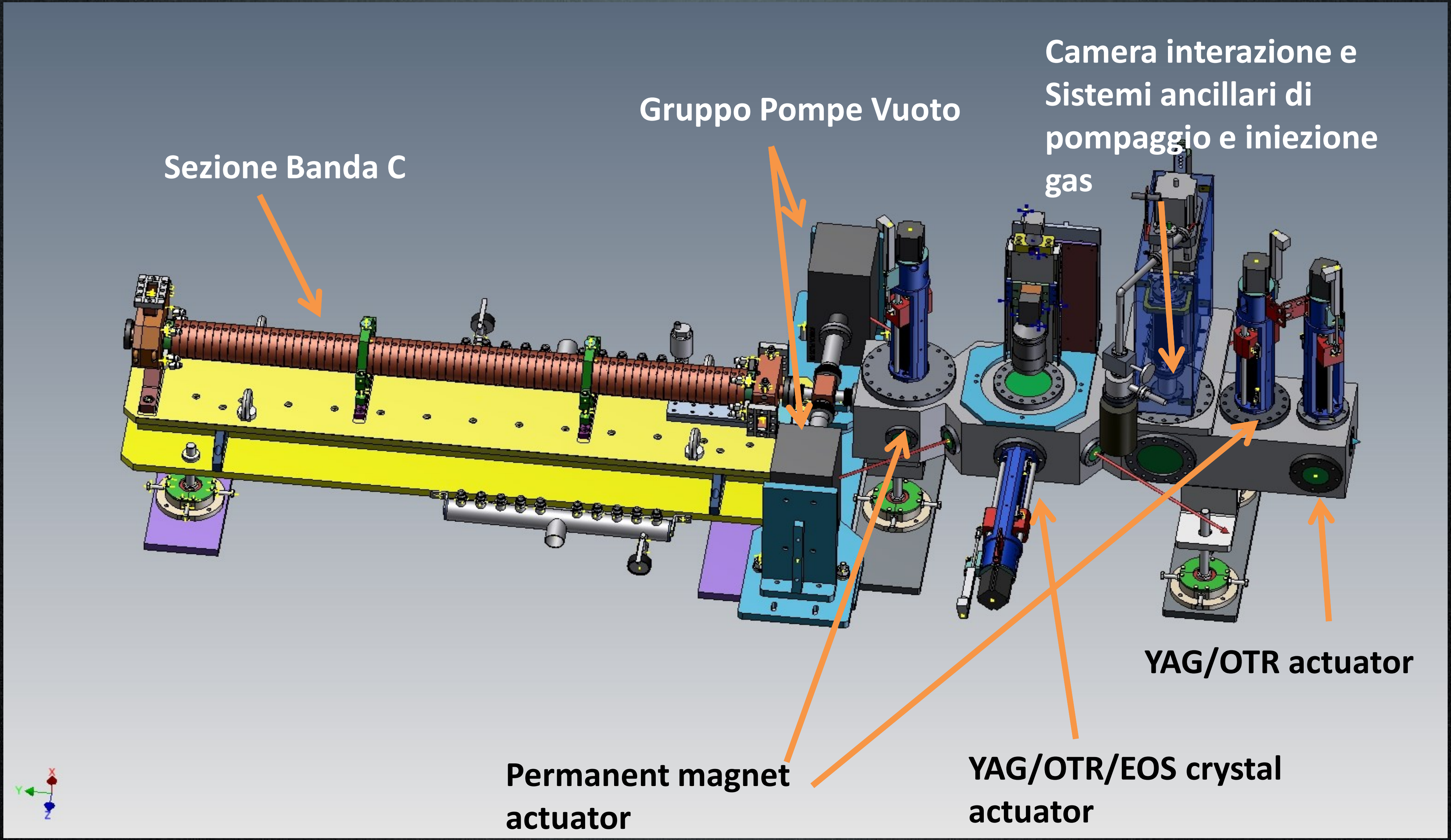
external injection LWFA

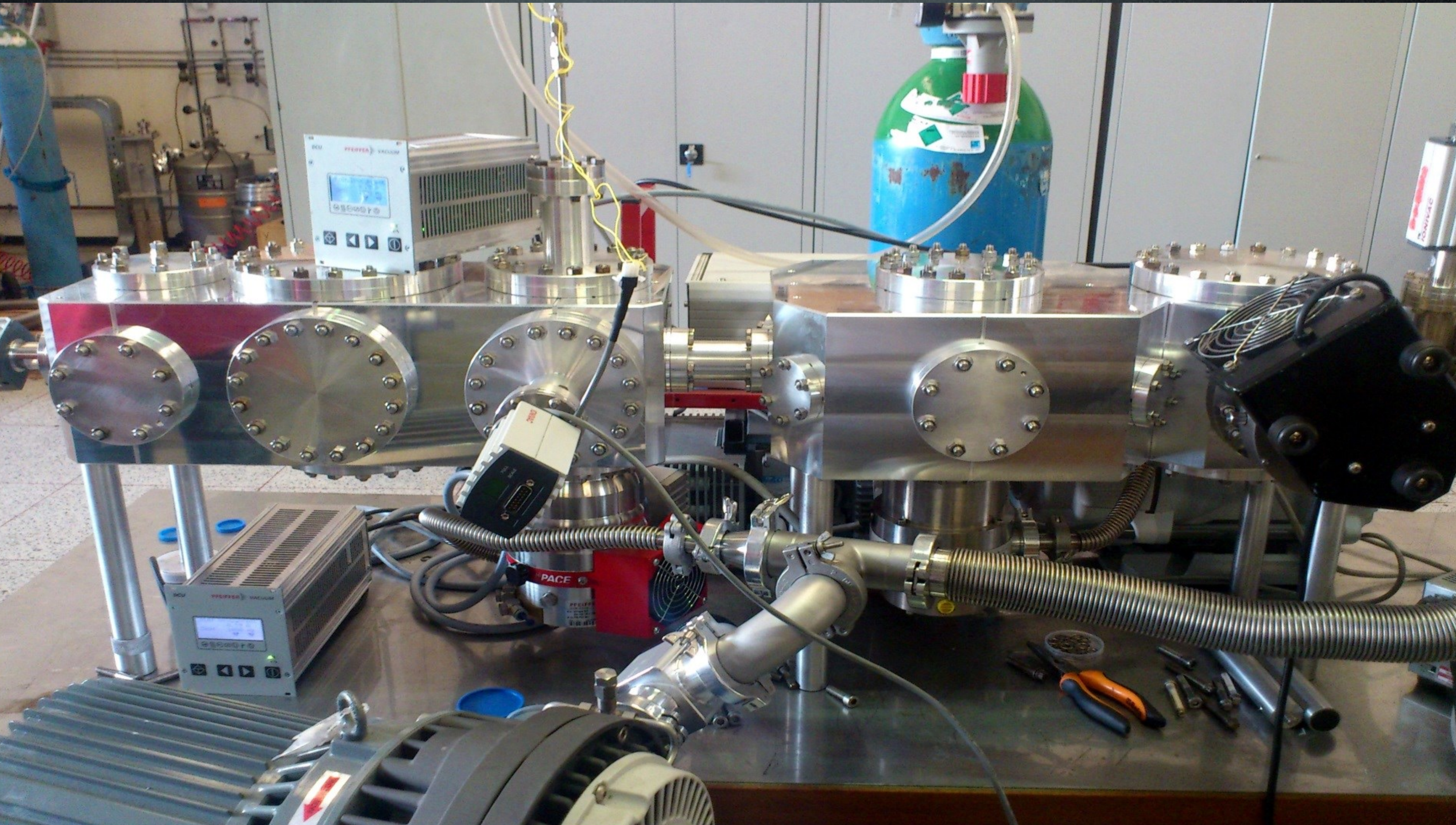


•A laser beam excites plasma waves in a capillary filled with gas
•A high brightness electron beam uses this wave to be accelerated

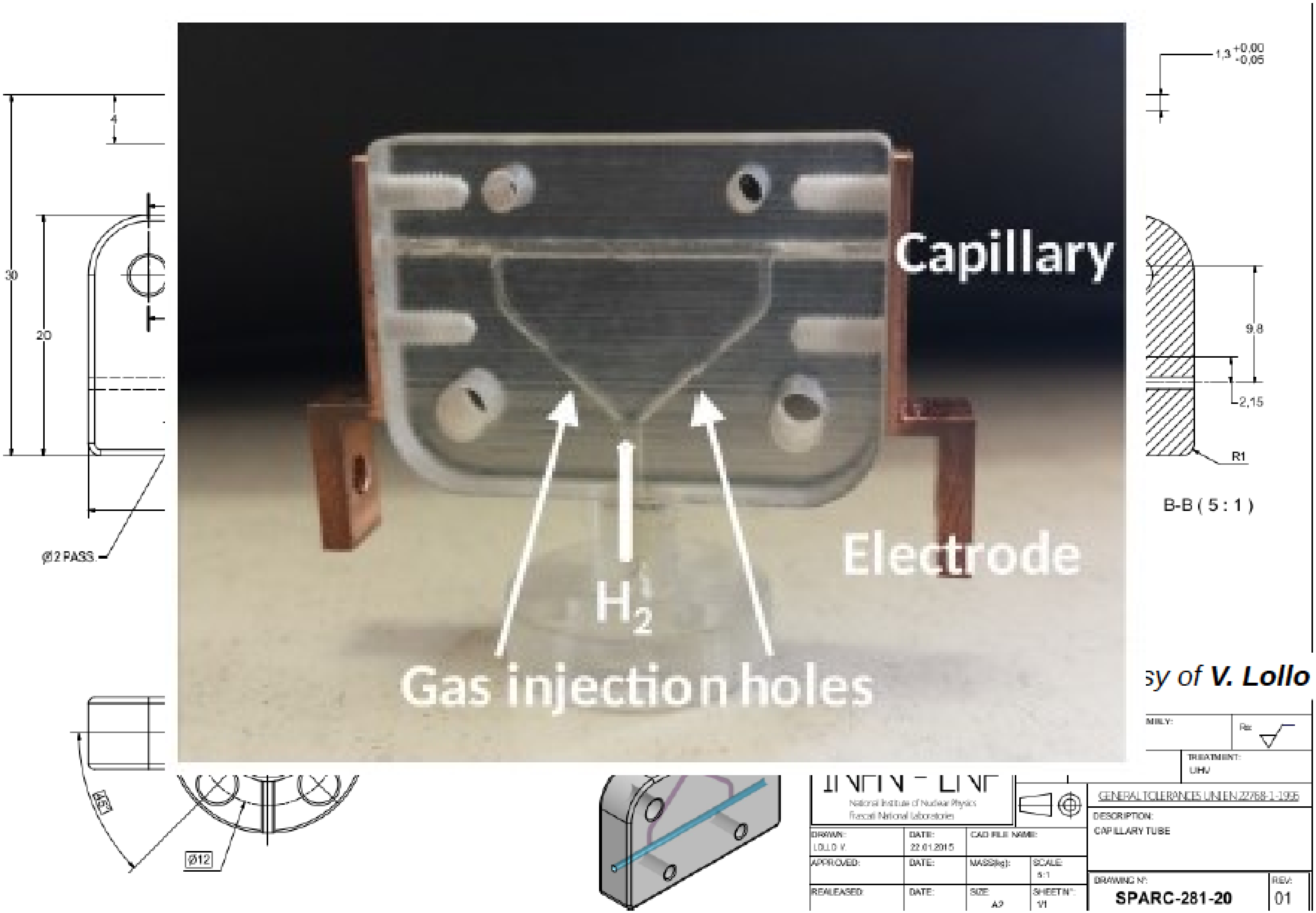
$n_e = 1x10^{17}$ cm^{-3}
λ_p = 100µm
Capillary 100 µm
Hydrogen

PWFA interaction chamber




PFEIFFER VACUUM

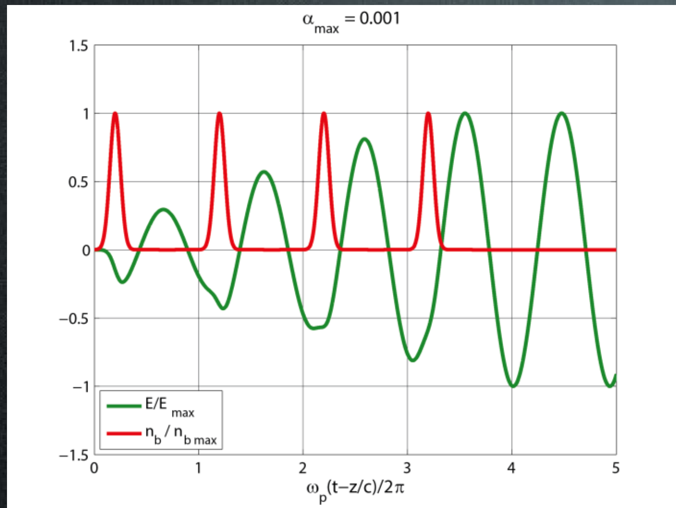
Plasma capillary

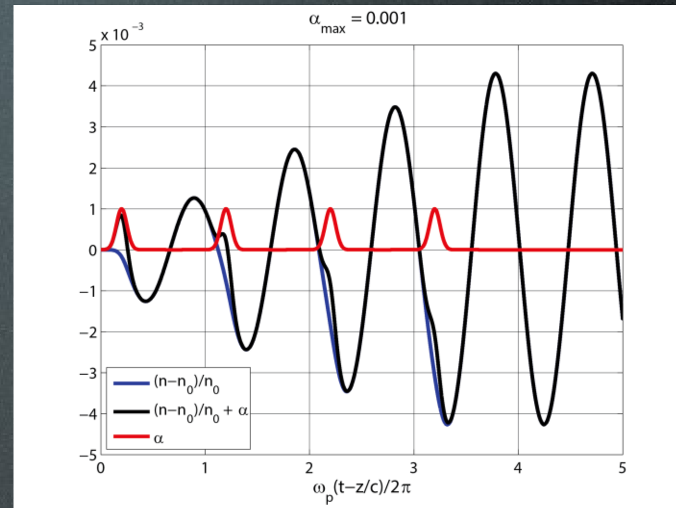


sy of *V. Lollo*

Quasi-Non Linear regime

Linear

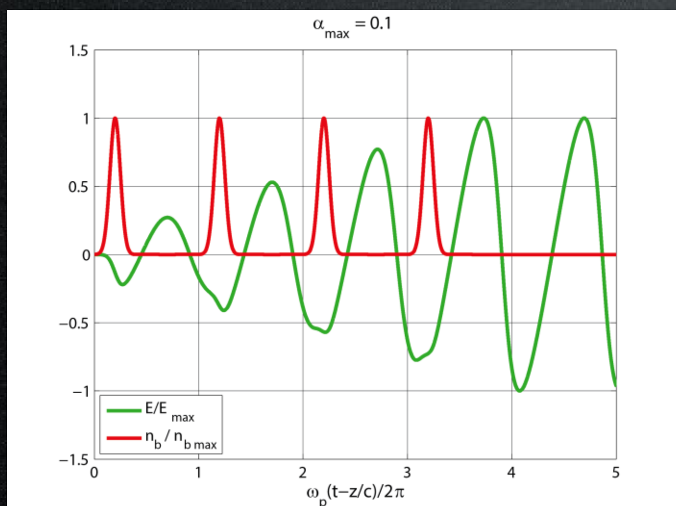


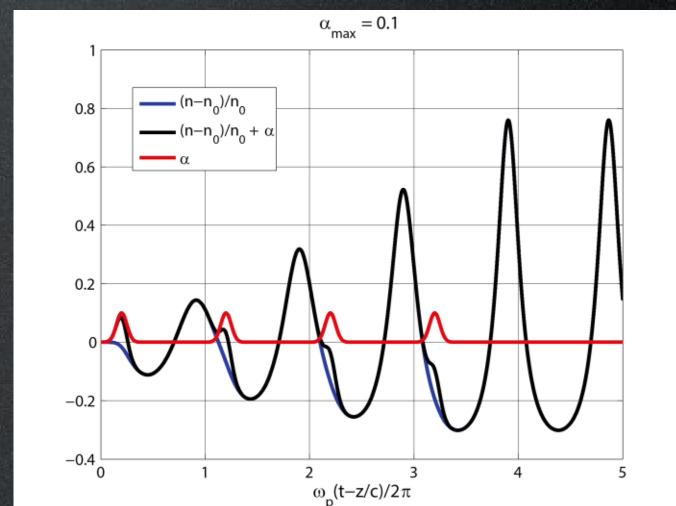


Accelerating field

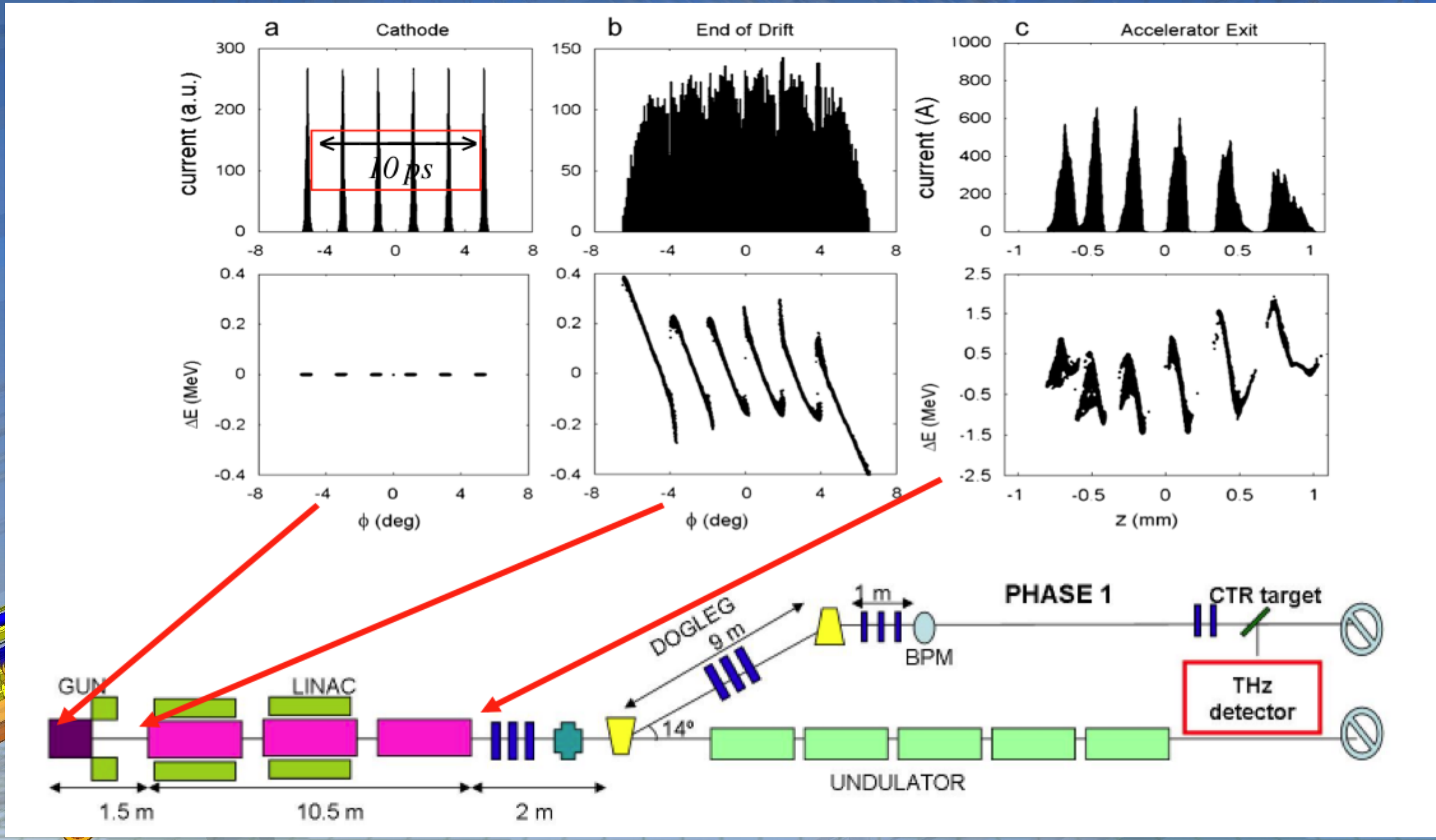
Plasma density

Quasi-Non Linear





Laser Comb technique: generation of a train of short bunches



- P.O.Shea et al., Proc. of 2001 IEEE PAC, Chicago, USA (2001) p.704. (Low charge regime only)
- M. Ferrario, et al., Int. J. of Mod. Phys. B, 2006 (High charge, Beam Echo)

Four bunches: long. phase space rotation

Measurements with 200pC

Gun energy 5.1MeV

Charge
40pC/80pC/50pC/30pC

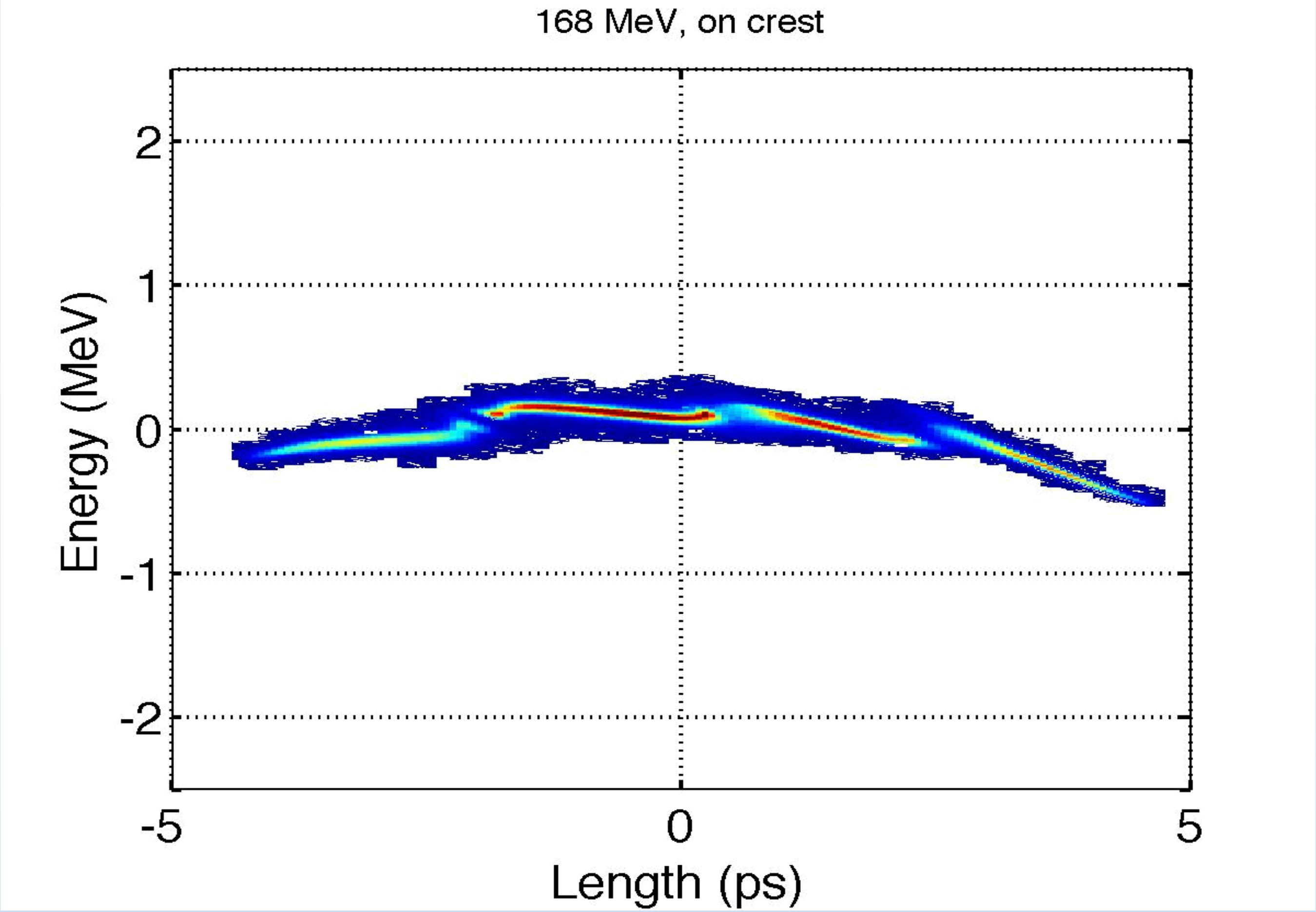
Energy 168-109 MeV

Energy Spread <0.8%

Bunch length on crest 2126.3 (8.7) fs

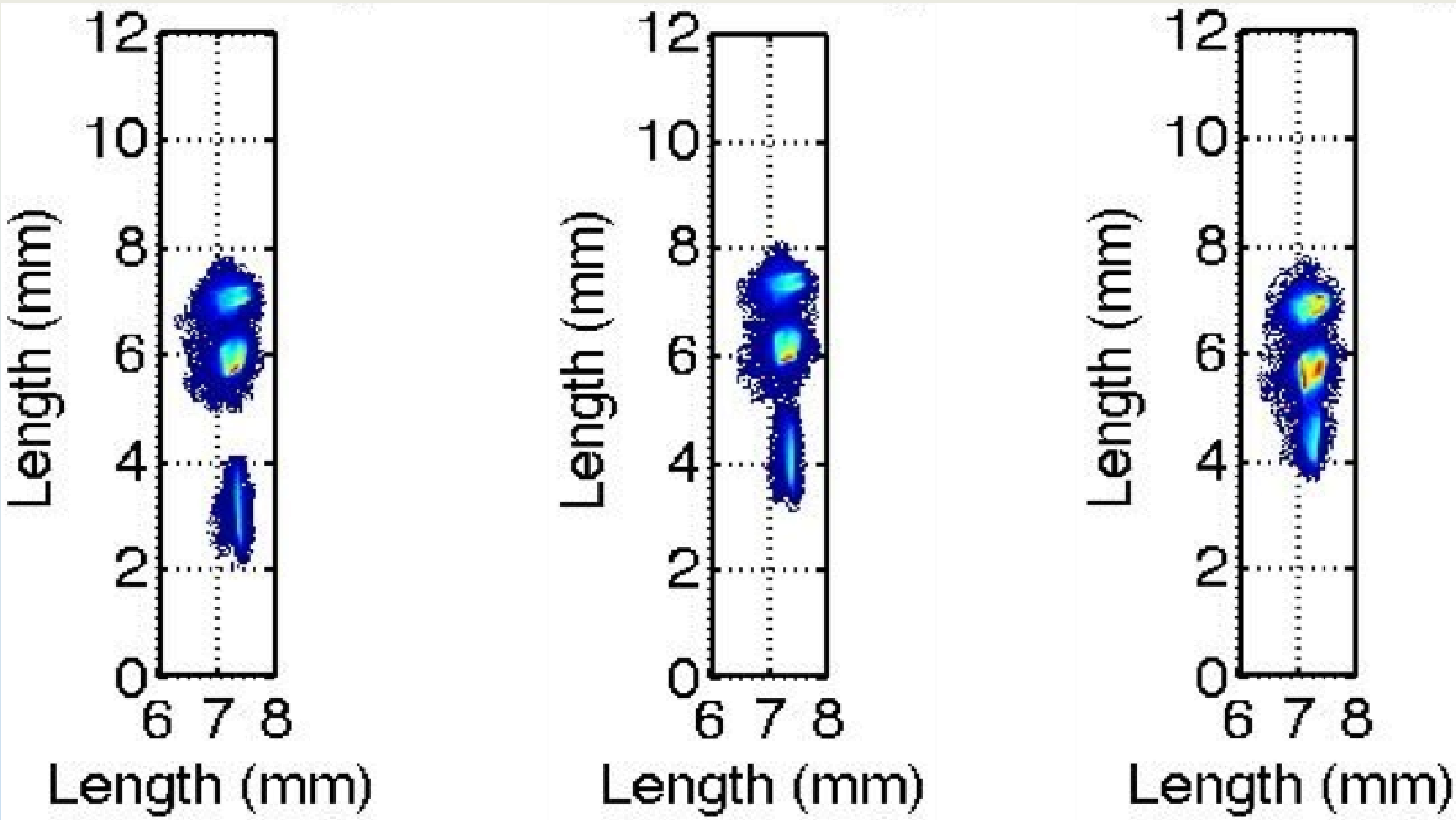
Min. bunch length
168.2 (8.7) fs

Gun ext. phase
35 deg

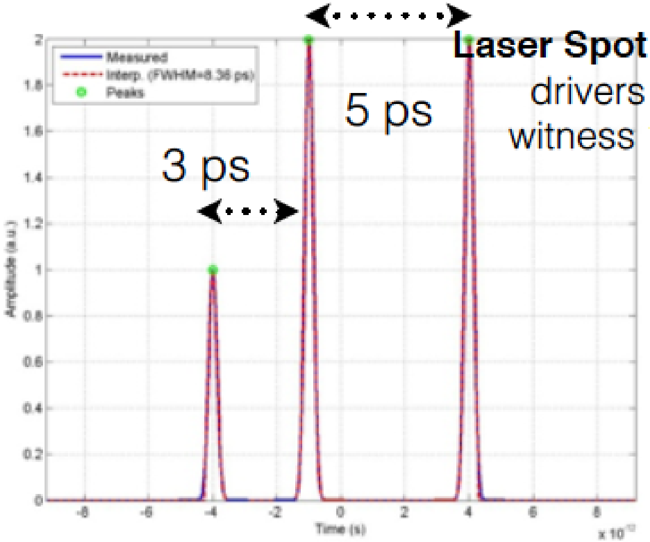


Three bunches: witness position tuning

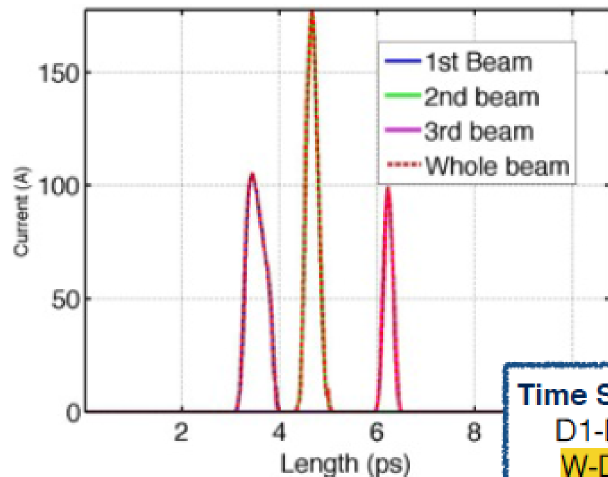
+ 1.67 ps | Reference | - 1.67 ps

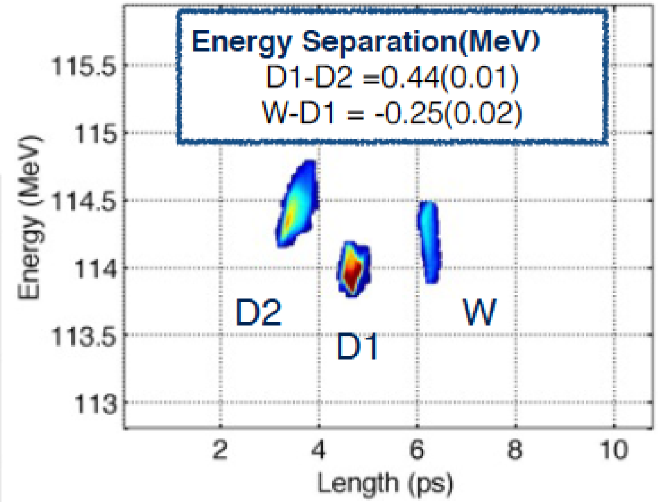


Three Bunches Train



Laser Spot diameter:
drivers 2 mm
witness 1.3 mm



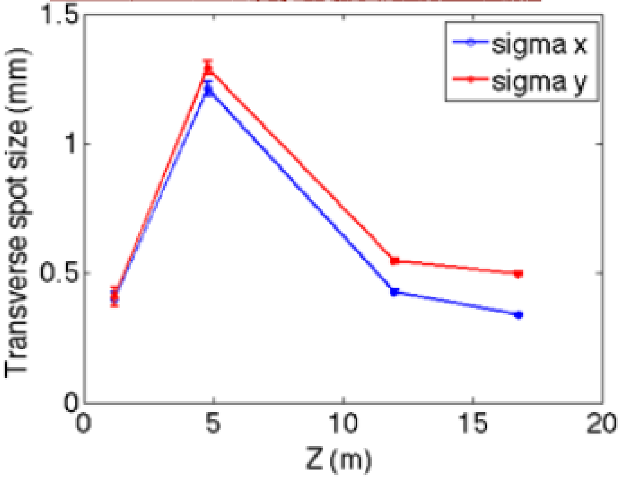


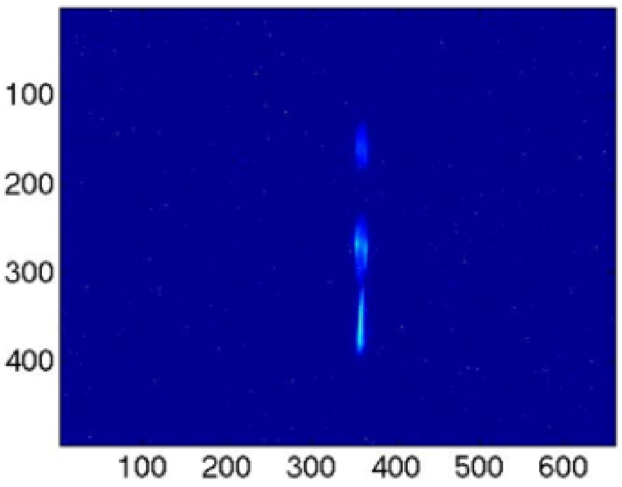
Time Separation(ps)
D1-D2 = -1.16(0.03)
W-D1 = -1.56(0.04)

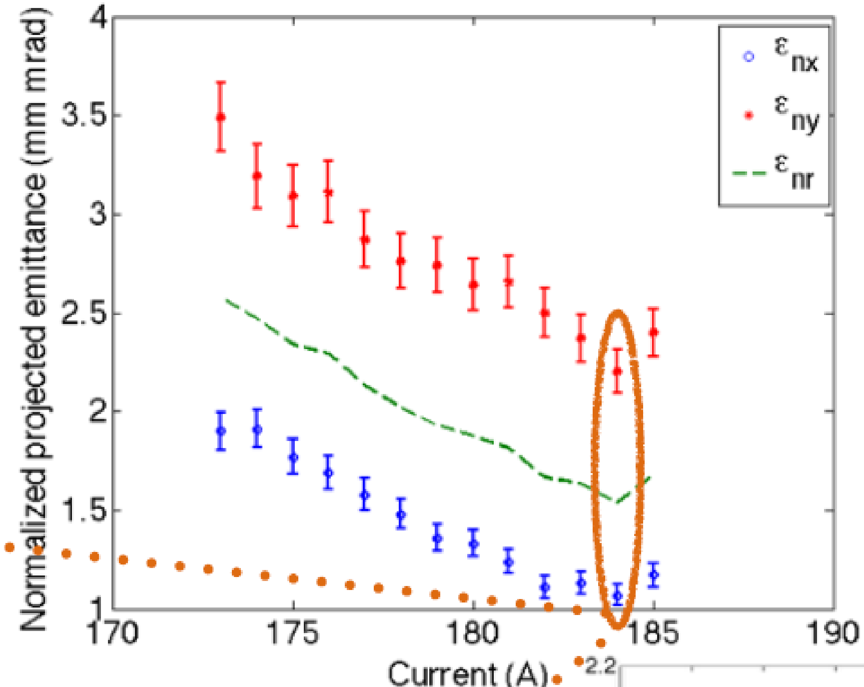
	Energy spread (%)	Position (ps)	Bunch duration* (ps)	Charge (%)	Charge (pC)
Drive Beam 2	0.114(0.001)	3.57(0.02)	0.141(0.001)	39.7(0.3)	51.7(0.4)
Drive Beam 1	0.074(0.001)	4.72(0.03)	0.057(0.001)	41.7(0.3)	54.1(0.4)
Witness Beam	0.135(0.001)	6.28(0.03)	<<0.089(0.000)	18.6(0.1)	24.2(0.2)
Whole Beam	0.203(0.001)	4.55(0.02)	0.987(0.003)	100.0(0.7)	130.0(0.9)

Transverse Characterization

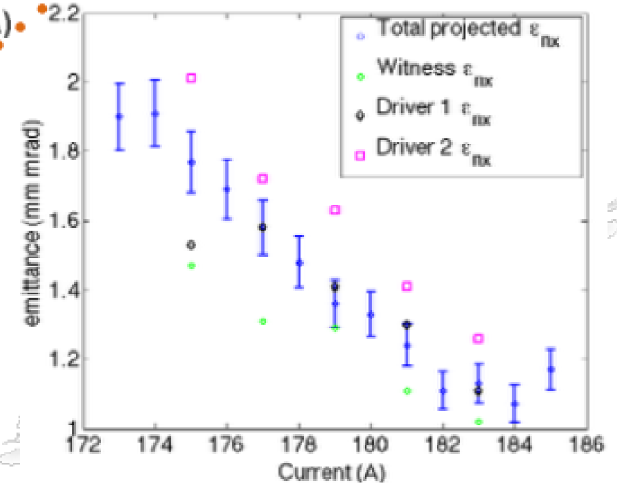
Gun solenoid 184 A
S1 solenoid 70/60/60/60 A



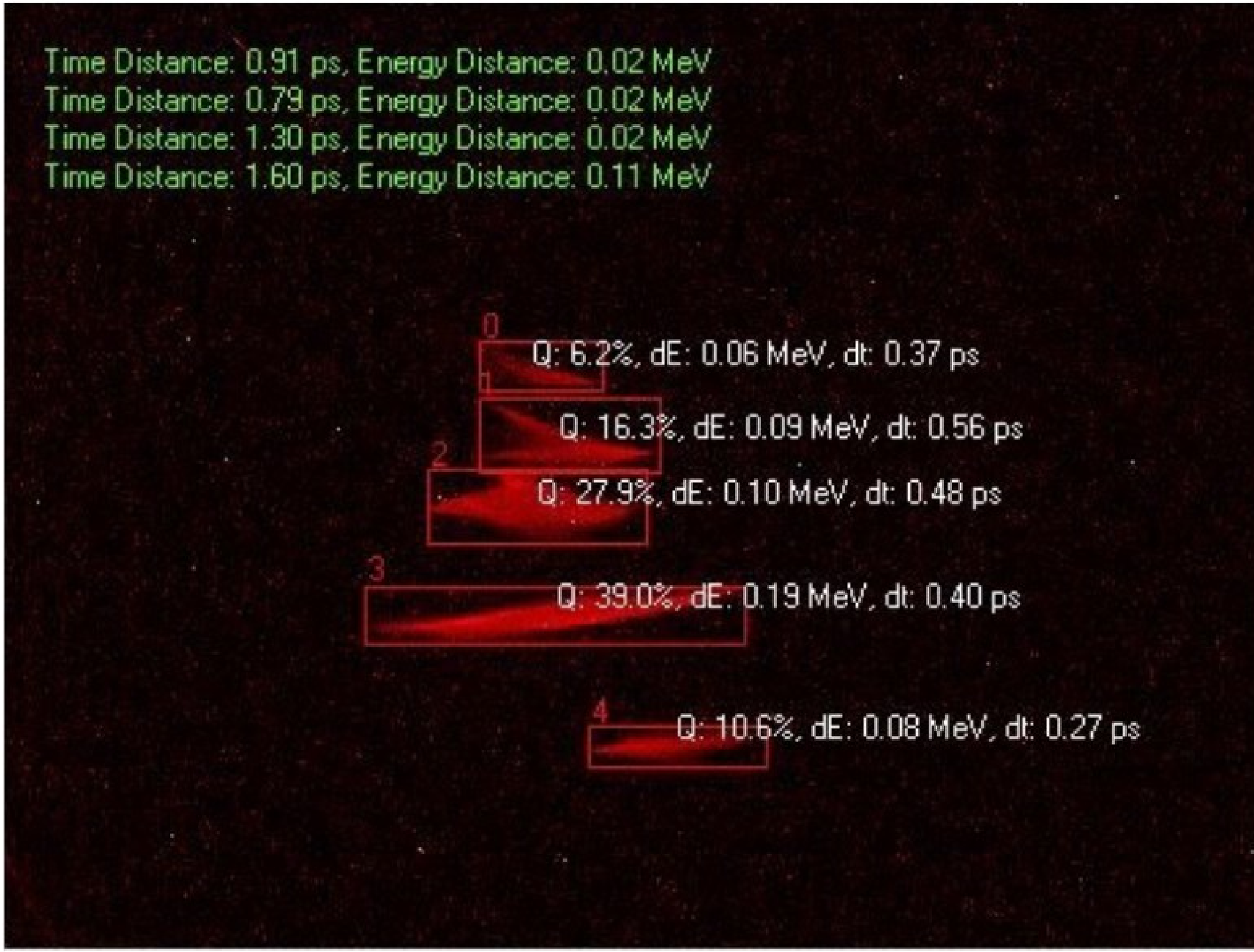




Total Projected Emittance
e_{nx} = 1.07 (0.05) mm mrad

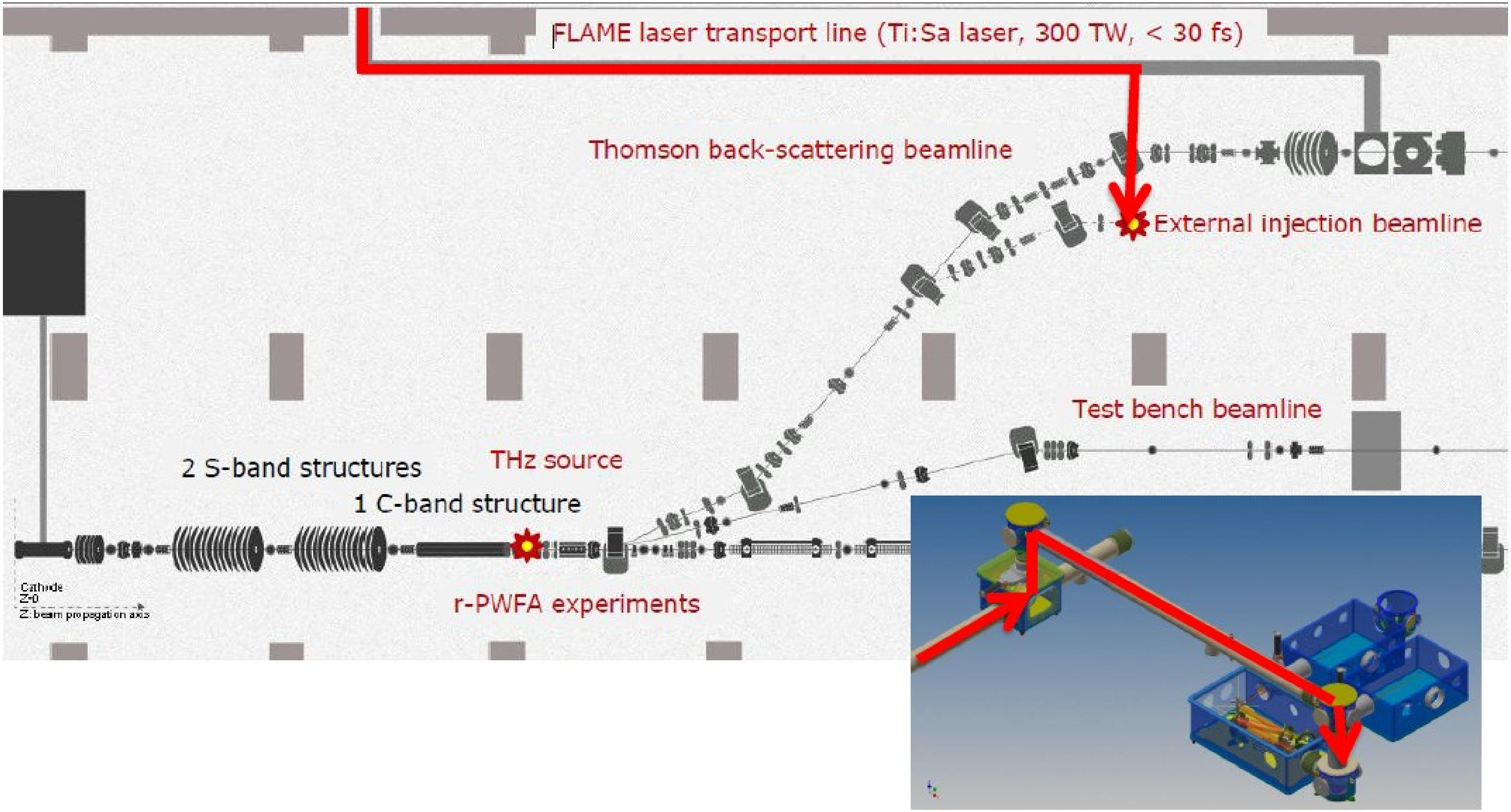


Five Bunches Train: Ramped Charge

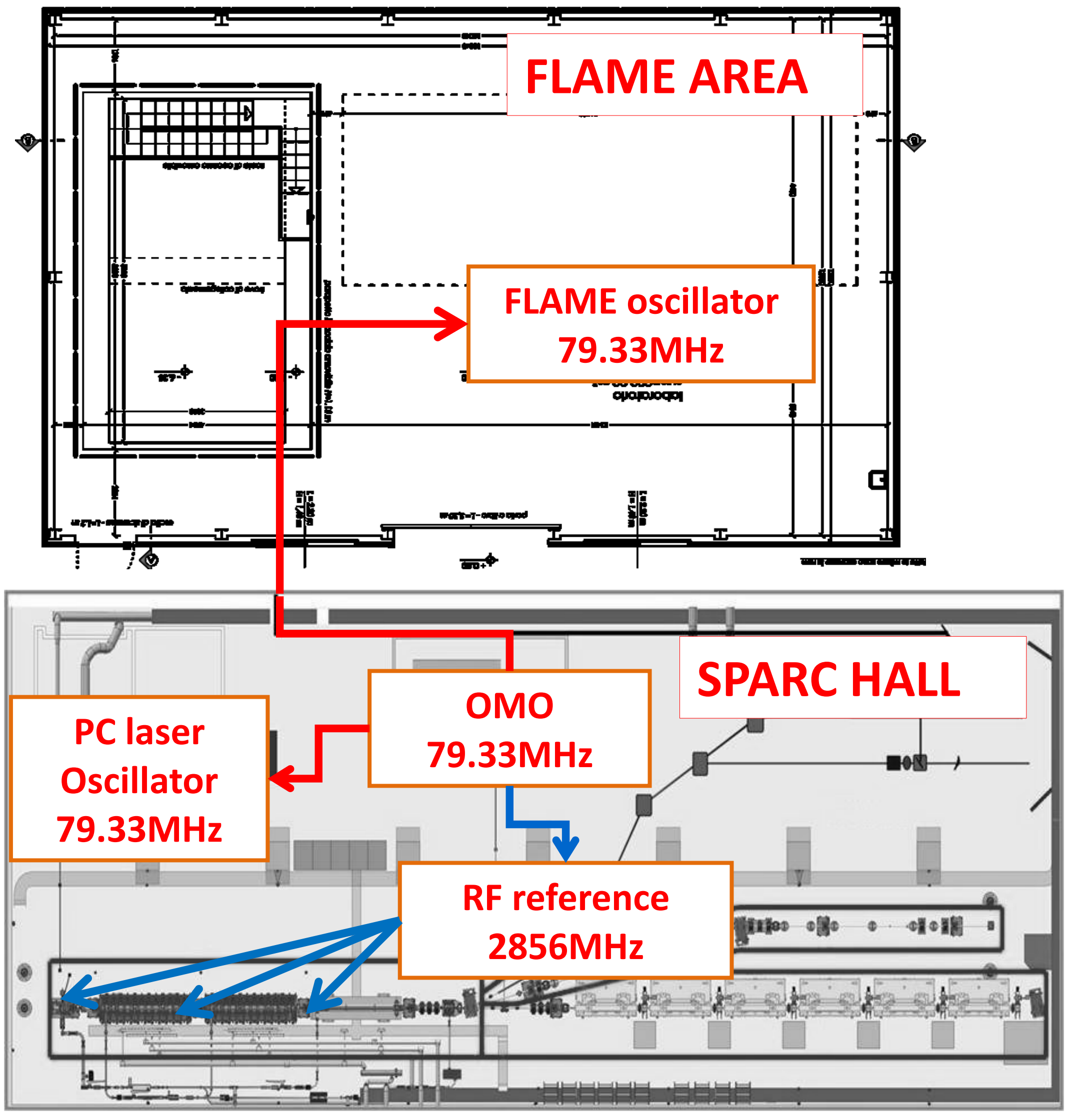


Laser Driven Plasma Wake Field Acceleration
(EXIN exp.)

Experimental setup



Synchronization System upgrade

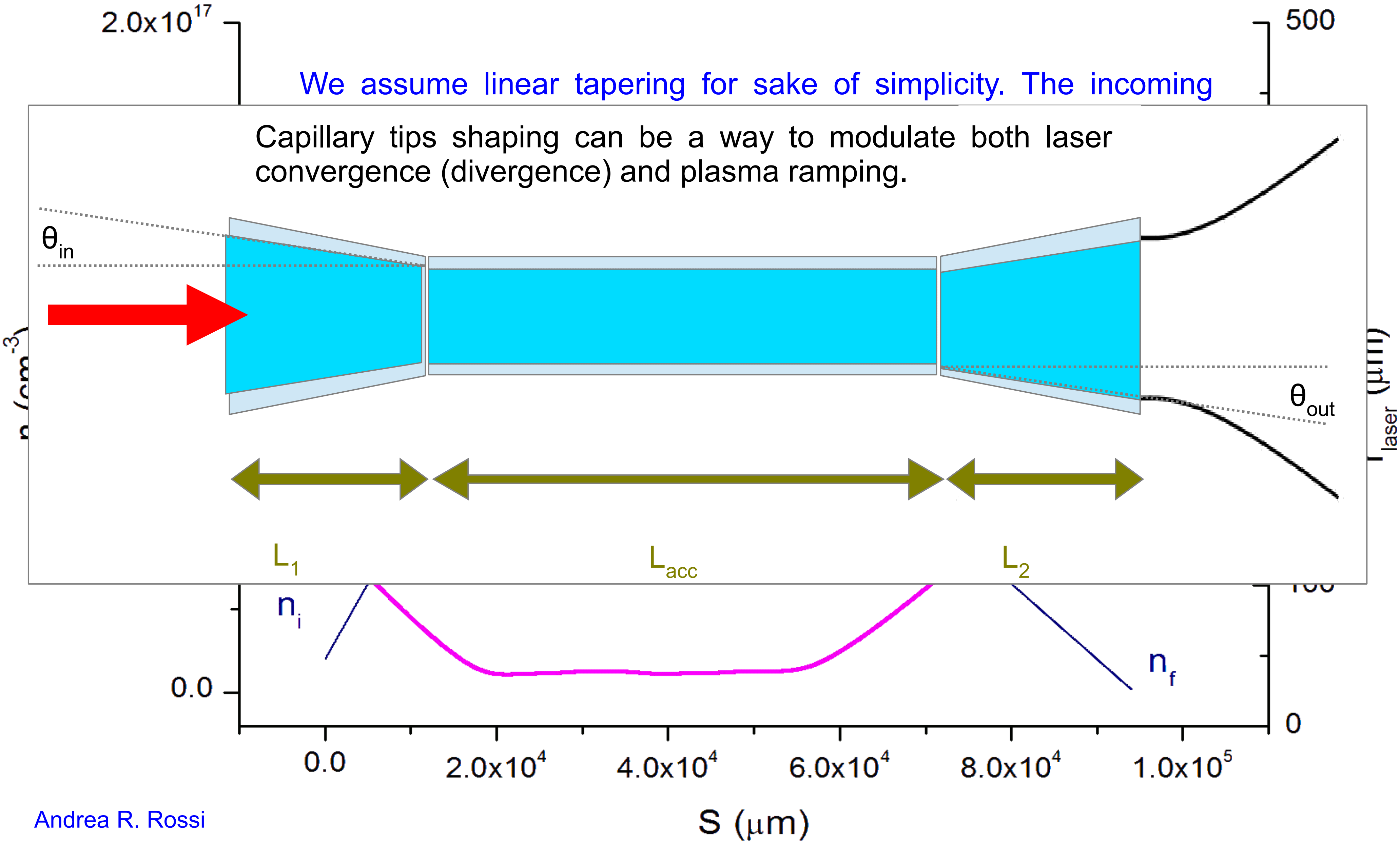


- <u>Optical reference</u>
  - RF reference will be substituted by fiber optical oscillator
  - Fiber laser OMO (Optical Master Oscillator) installed and tested
  - Systems locked through high resolution optical phase monitors (cross-correlators in house and ready to be tested)
  - Fiber link stabilization is ongoing (order placed) to distribute the reference signal
  - **FLAME laser VS electrons estimated time jitter <50fs$_{RMS}$**

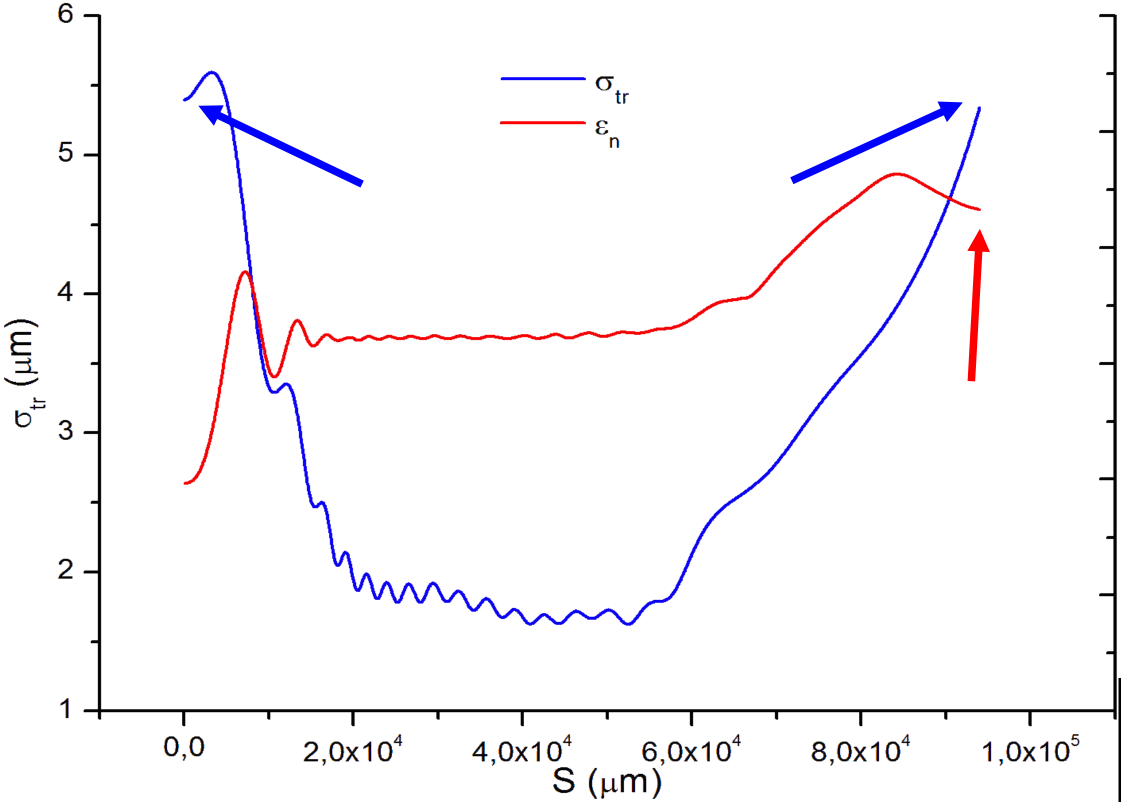
Simulation settings

We assume linear tapering for sake of simplicity. The incoming

Capillary tips shaping can be a way to modulate both laser convergence (divergence) and plasma ramping.



Simulation results: matching and focusing/defocusing

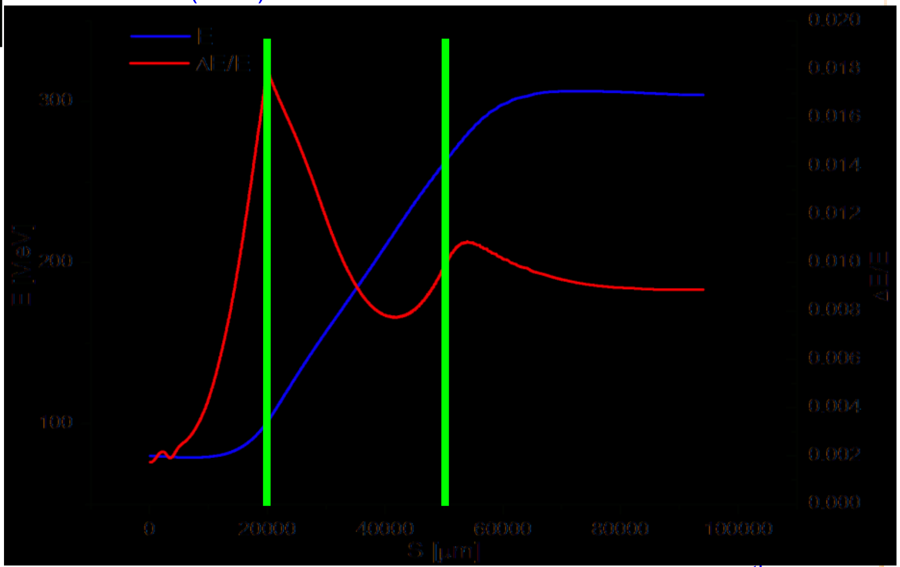


Energy gain is in excess of 200 MeV in a 3 cm acceleration length, which means an average electric field in excess of

7 GV/m

Energy spread is within 1% (a safe threshold for subsequent transport*) and REDUCED IN THE FINAL RAMP due to beam loading and plasma wavelength increase.

* P. Antici et al., J. App. Phys. 112, 044902 (2012).

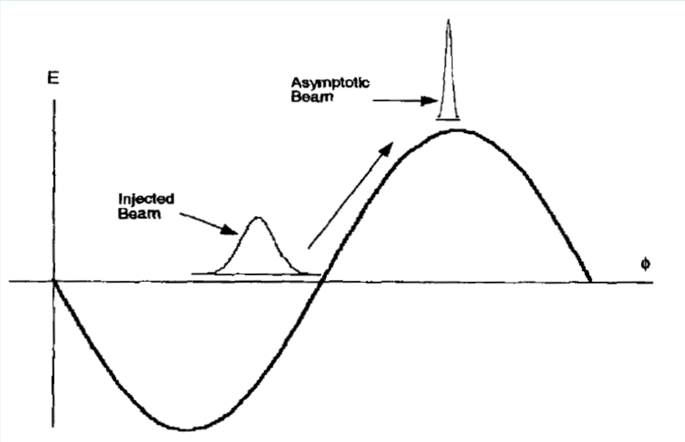


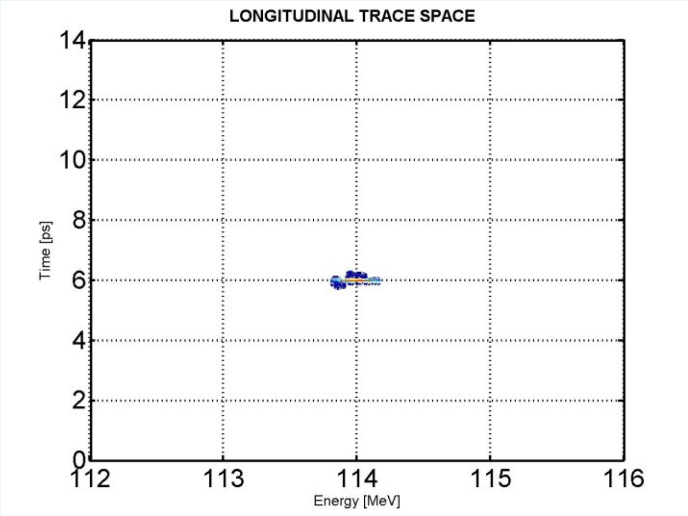
A very nice matching is obtained by laser focusing method.

Beam size is reduced to matched size and then increased back to initial value in a quasi-adiabatic transformation.

Both initial and final sizes seems to be within manageability of permanent magnet quads.

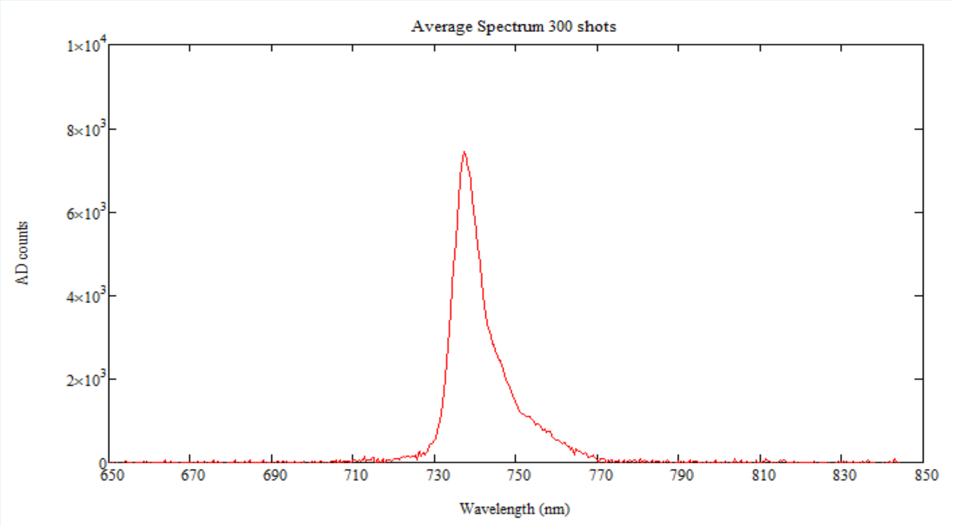
Single Bunch - 20 pC





$$\sigma_t = 26\,fs$$
$$\varepsilon_{nx} = 1.2\,um$$
$$\sigma_E = 0.1\%$$
$$I = 400\,A$$

Single Spike FEL ~ 100 fs , 40 μJ




Thank
you