UNIVERSITÀ DEGLI STUDI DI MILANO
CORSO DI DOTTORATO IN FISICA, ASTROFISICA E FISICA APPLICATA

1^{st} *year Ph. D. workshop*
XXXI Cycle

Generation of ultrashort high brightness beams and their longitudinal shaping

Marcello Rossetti Conti

TUTOR Prof. Vittoria Petrillo
CO-TUTOR Alberto Bacci

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1) **Context**
   - Me and my group, SPARC_LAB

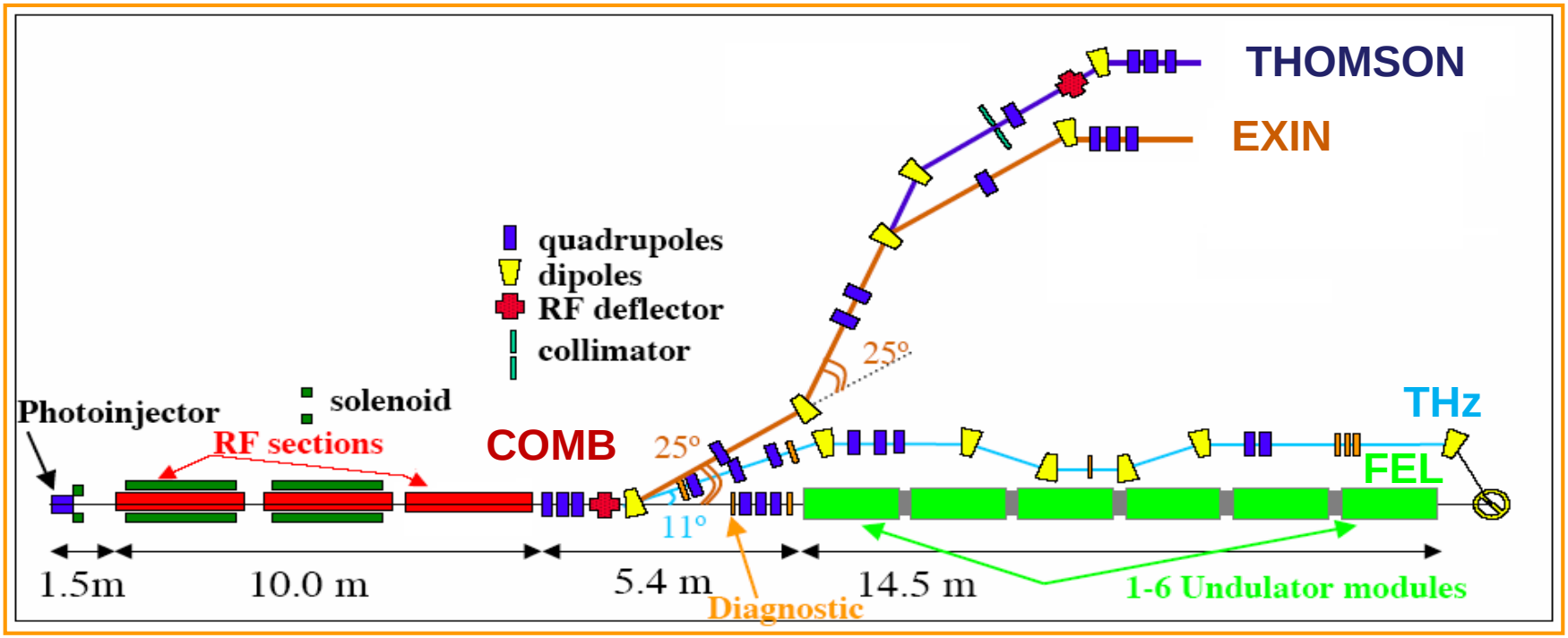
2) **Ultrashort bunches, an overview**
   - Definition
   - Most promising applications
   - Main techniques

3) **My activities**

1

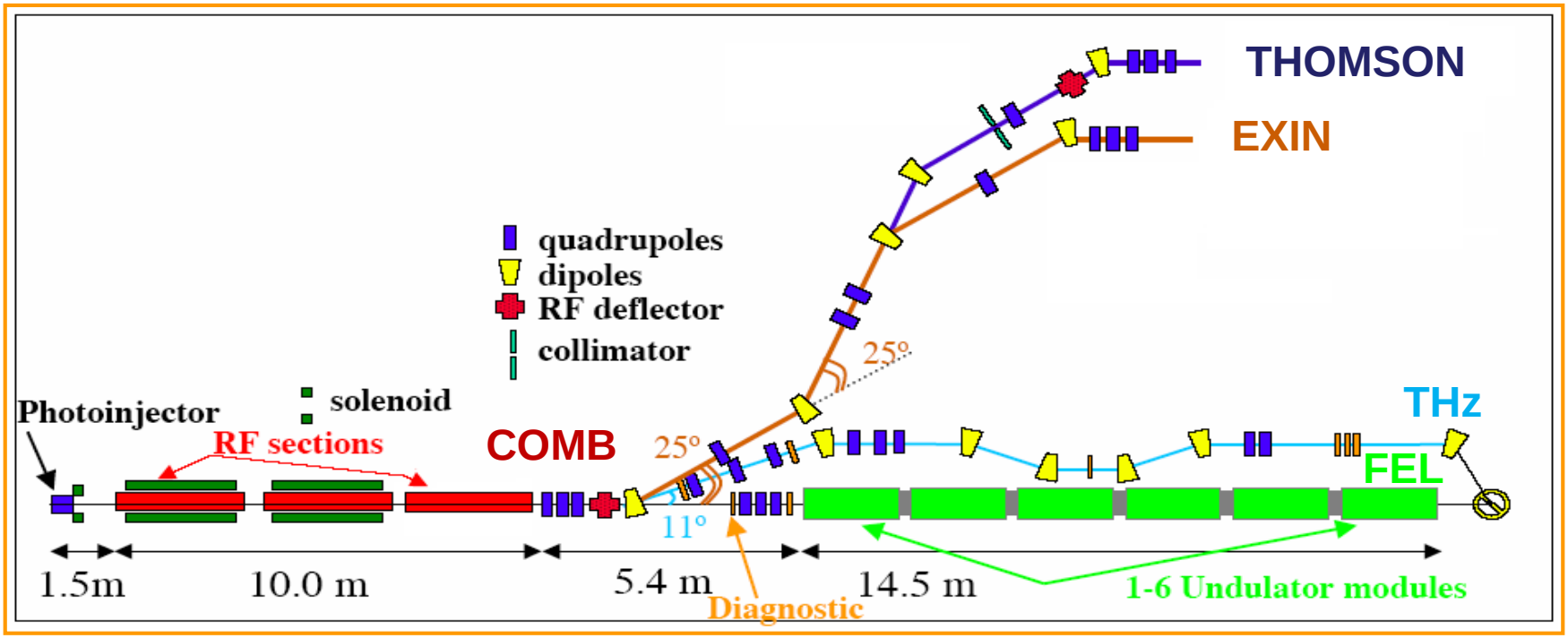
Where do I work?

Where do I work?



Test Facility composed by a **high brightness** electron linear accelerator and a high power laser (FLAME)

Where do I work?



Brightness:

$$B = \frac{2I}{\pi^2 \varepsilon_{n,x} \varepsilon_{n,y}}$$

Emittance:

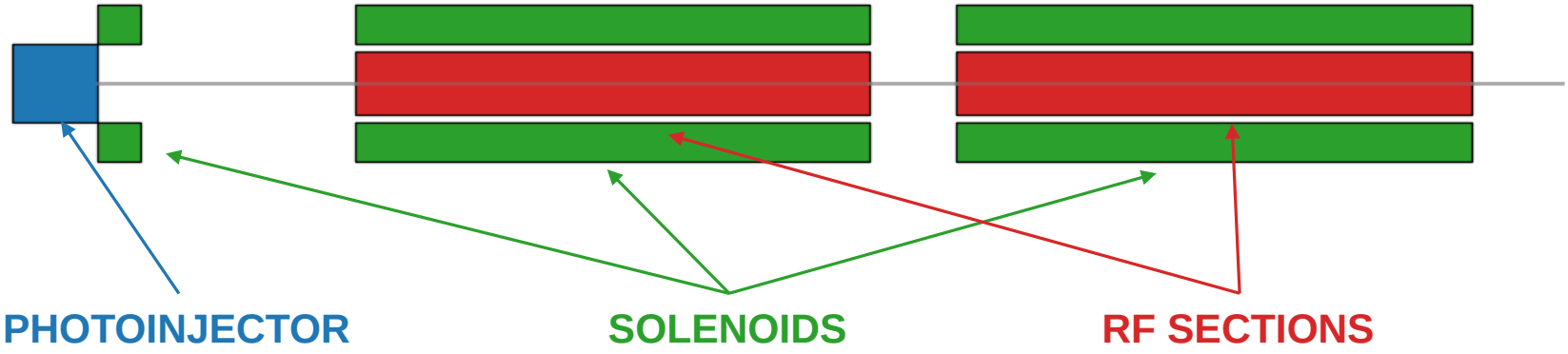
$$\varepsilon_{n,x} = \beta\gamma \sqrt{\langle x^2 \rangle \langle x'^2 \rangle - \langle x \cdot x' \rangle^2}$$

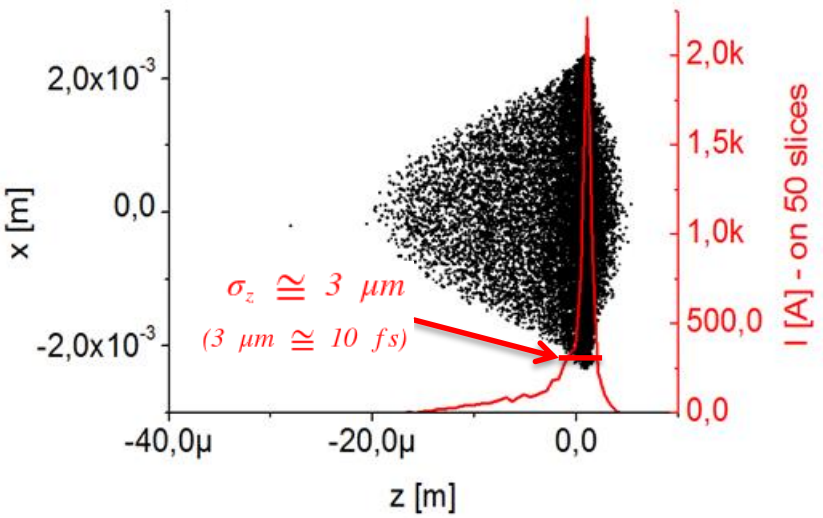
2

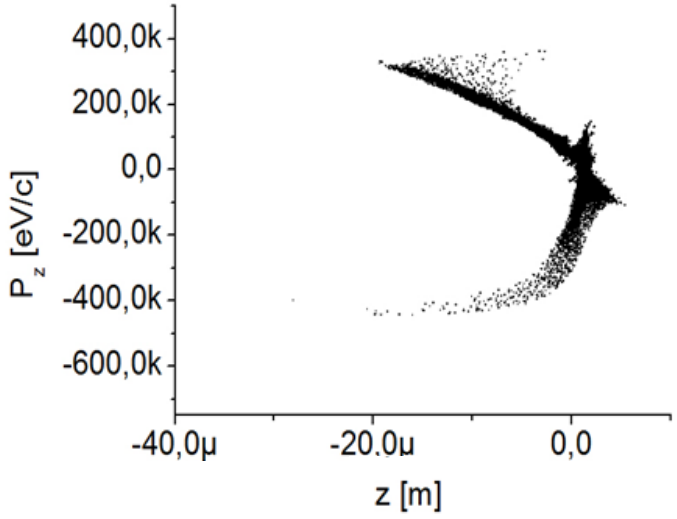
Ultrashort bunches

Ultrashort electron bunches

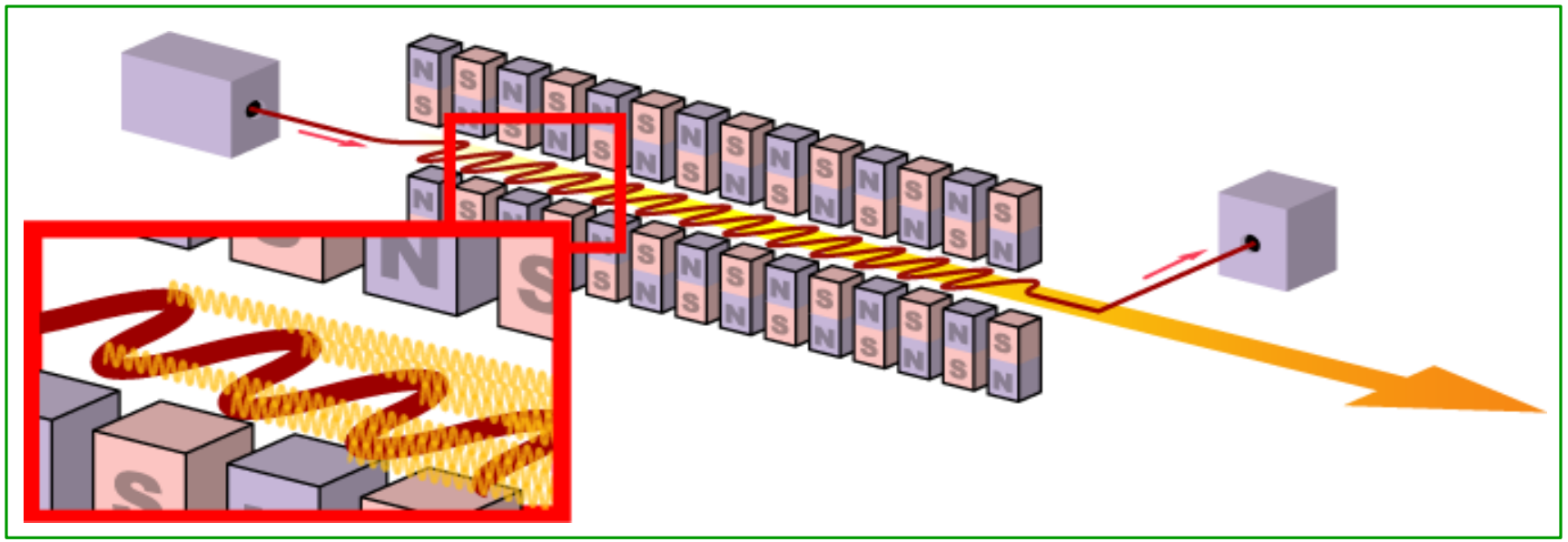
BASIC LINAC LAYOUT







Applications: Free Electron Lasers



Tunable laser with frequency ranging from microwaves to X-rays

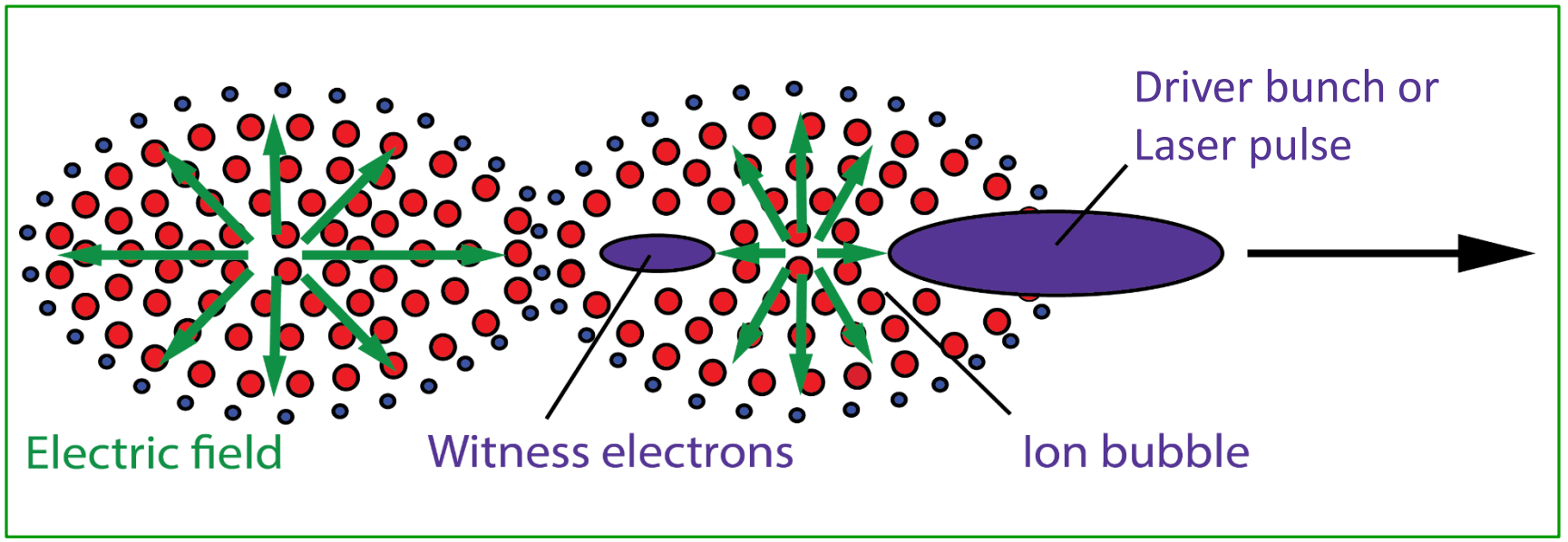
FEL : Single Spike Regime

$$\sigma_z < 2\pi L_{c,1D} \longrightarrow \cong 1\ \mu m$$

LCLS,Y.Ding, et al. PRL 102 (2009)

- **Ultrashort** radiation **pulses** for fast dynamic microscopy (protein motion, fast chemical reactions, …)

Applications: Laser / Plasma Wakefield Acceleration



For cheaper and compact accelerators. World record: 100 GeV / m

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PWFA : Driver

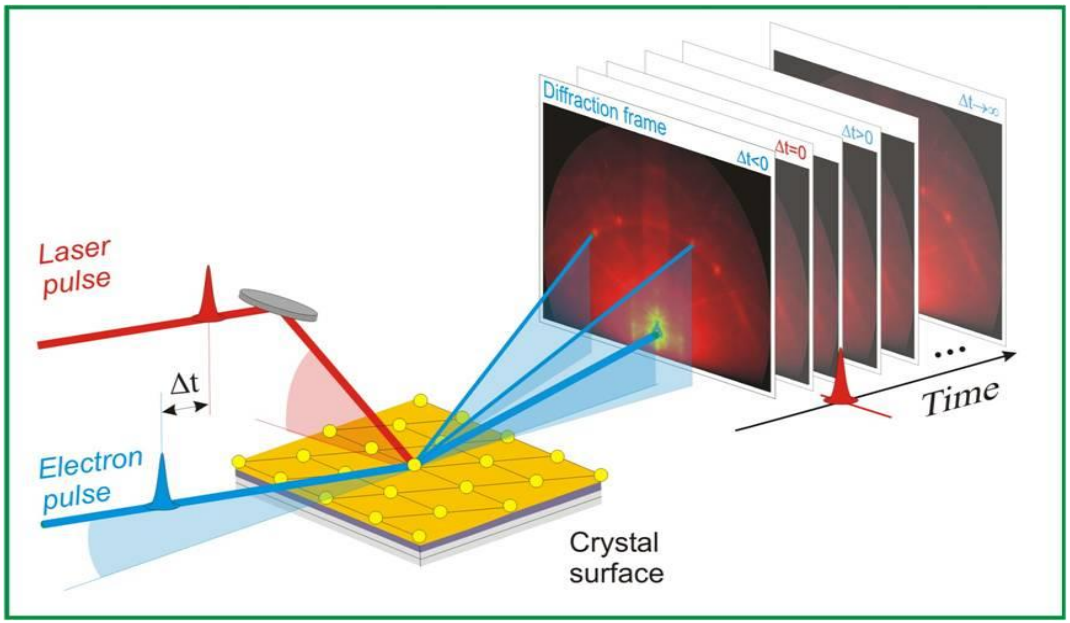
$$\Delta K \propto \frac{Q_b^2 \gamma}{\varepsilon_n \sigma_z}$$

PWFA e LWFA : Witness

$$\sigma_z \ll \lambda_p \rightarrow \leq 30 \mu m$$

E 164 SLAC-R-799 (2004)

Applications: Ultra-fast Electron Diffraction



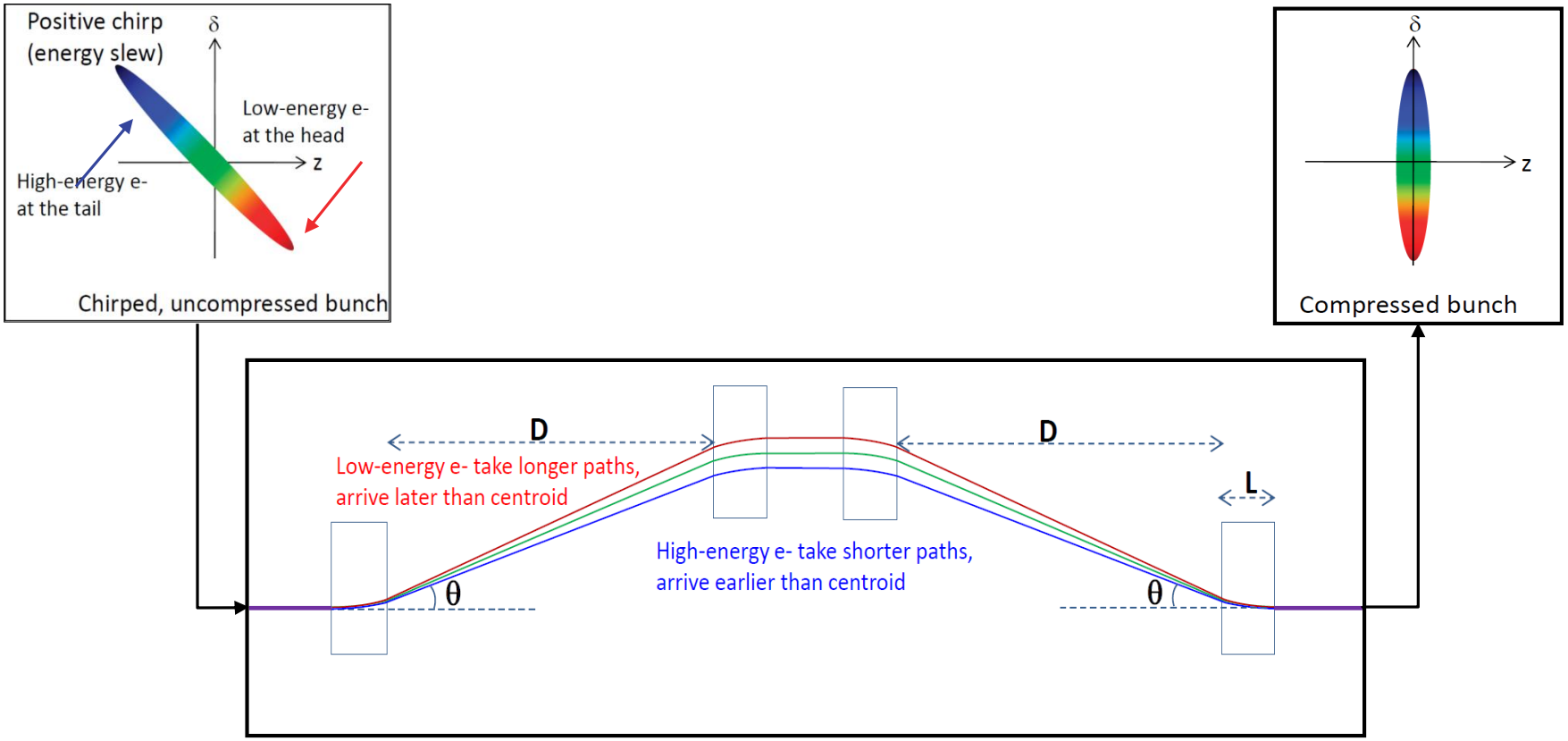
Atomic-level view of melting (2003). Femtosecond crystallography (2014).

Ultra-fast Electron Diffraction

$$\sigma_z \leq 30\,\mu m \cong 100\,fs$$

DESY, R. J. Dwaine Miller,
Science 343 (2014)

Compression Techniques: Chicane buncher (magnetic compressor)

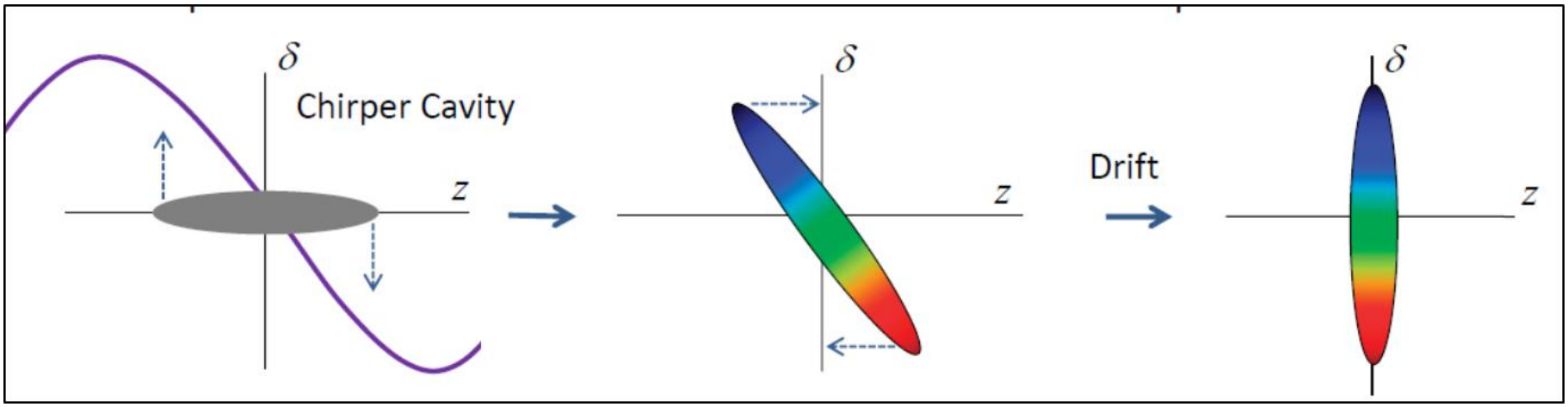


Pro: Compression at high energy

Cons: CSR emission → brightness loss

Used in : LCLS, XFEL, SACLA, FERMI@ELETTRA, PSI, …

Compression Techniques: Ballistic compressor

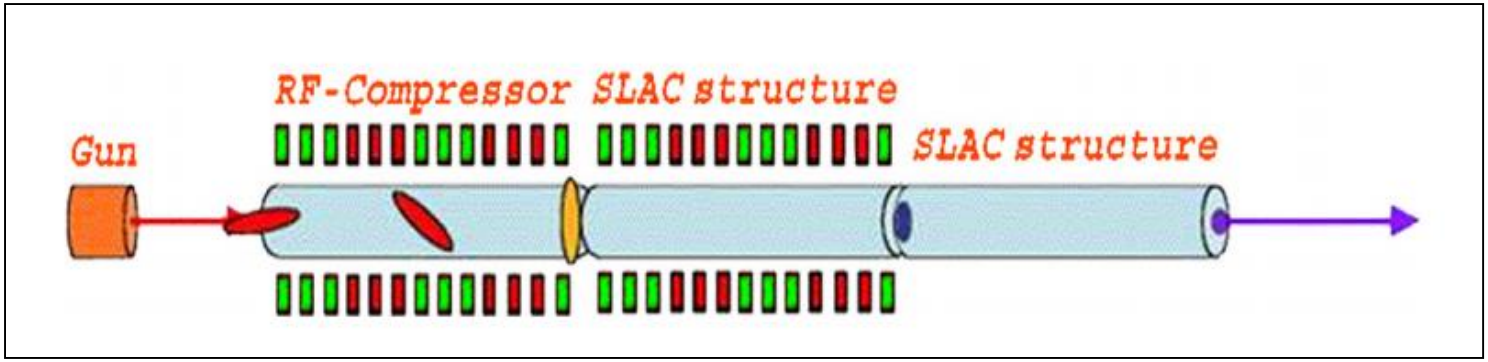


Used in : REAGE (DESY), Pegasus (UCLA), ...,

Pro: needs only a cavity

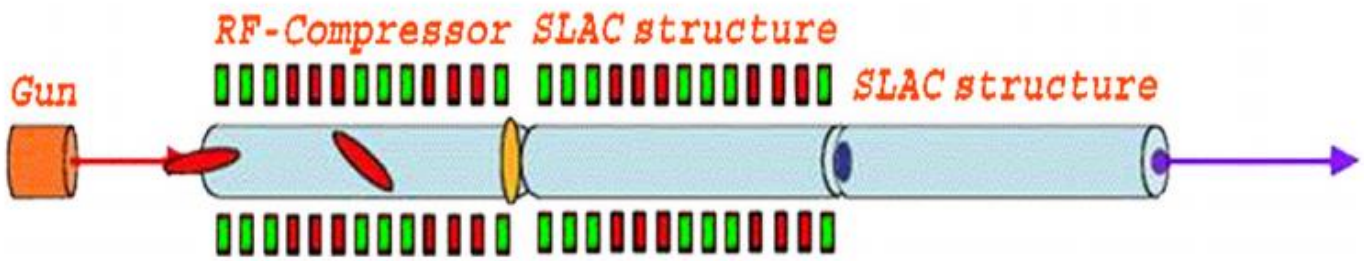
Cons: it works only at low energy

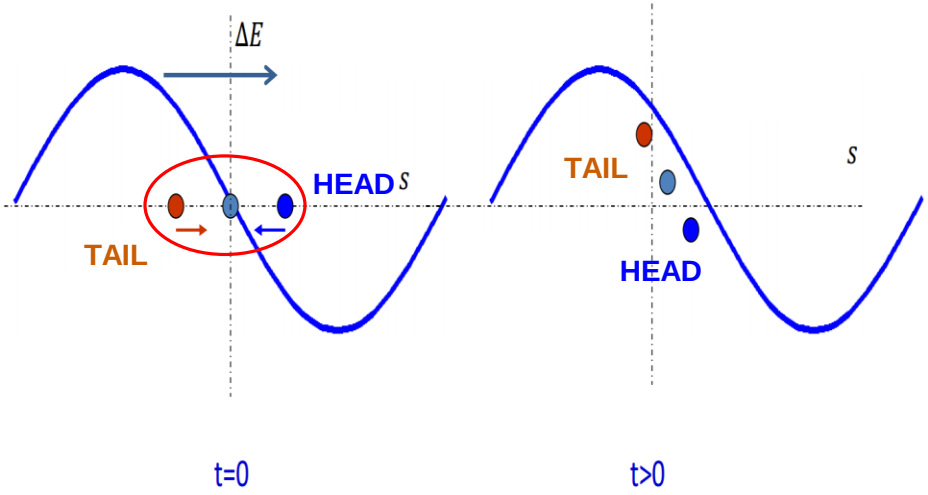
Compression Techniques: Velocity Bunching



Developed here in Milano
Studies or Test : PLEAIDES (LLNL), FLASH, XFEL (DESY), NERL (Tokyo Univ.), PSI
Operative: SPARC, Tsinghua University

Compression Techniques: Velocity Bunching





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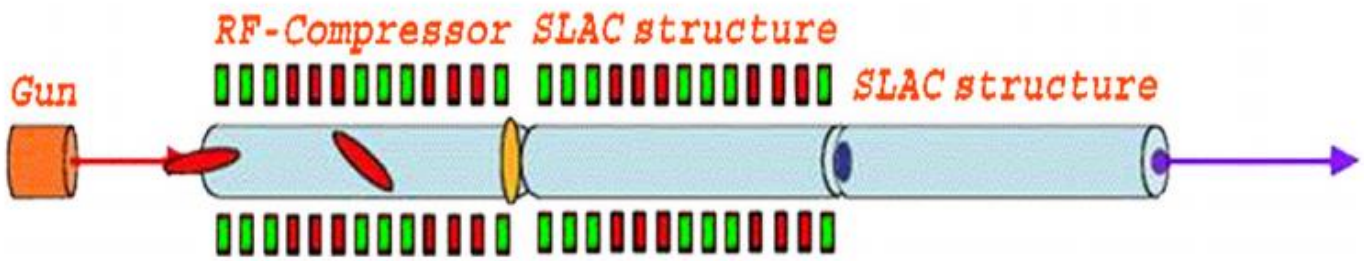

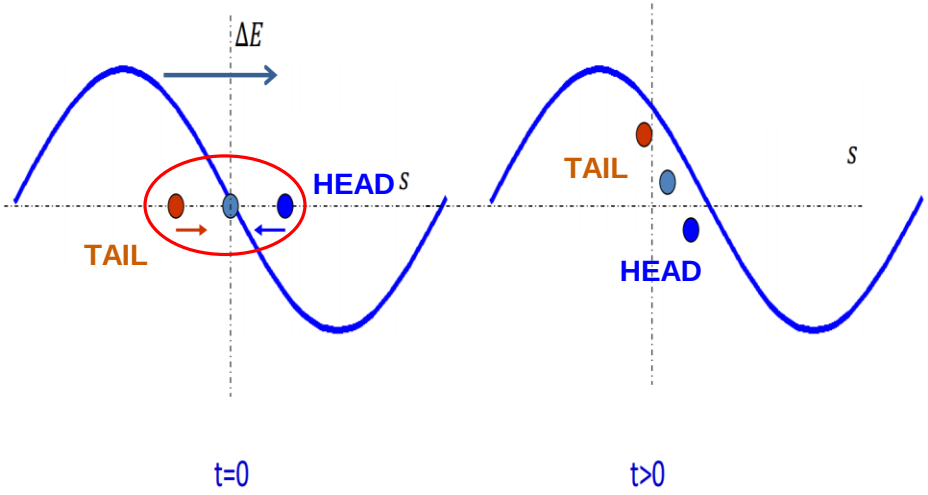

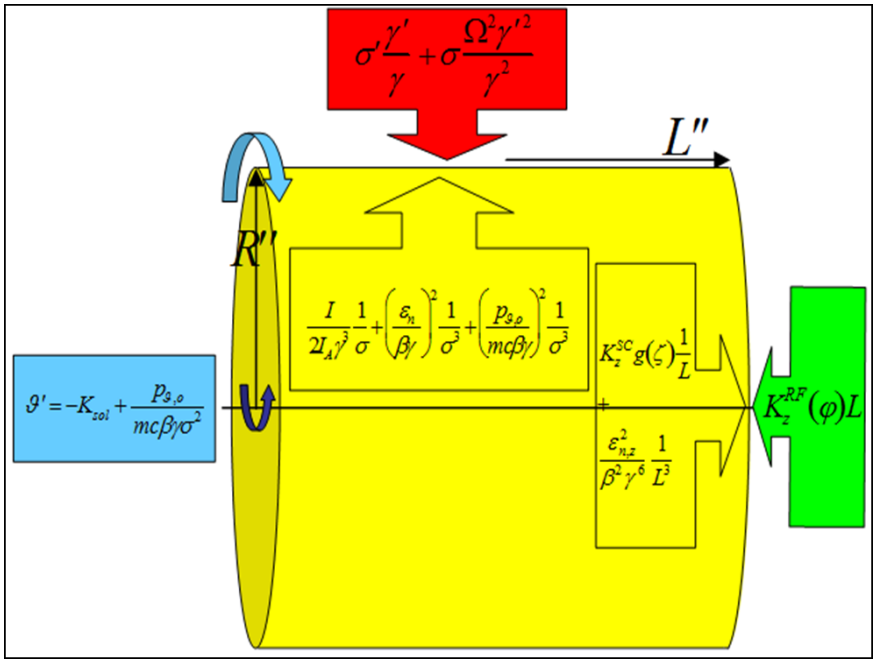

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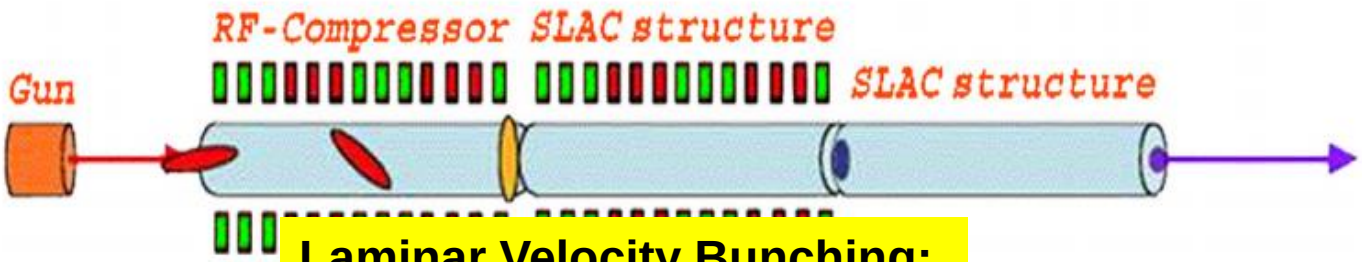
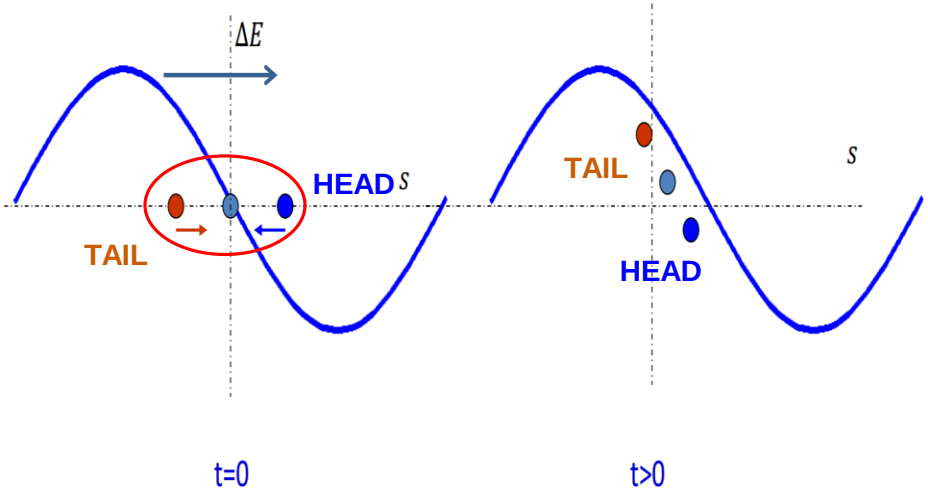
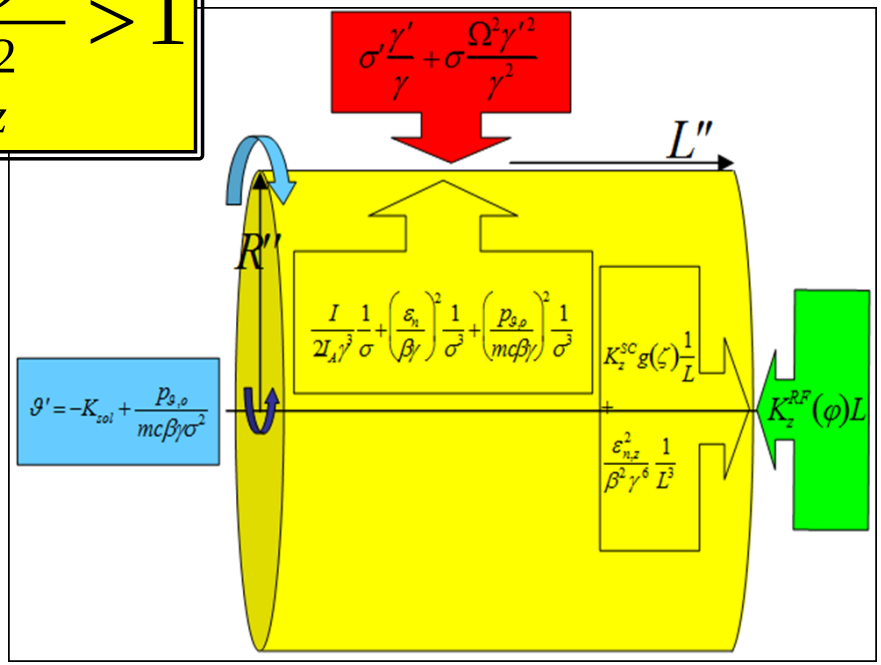


Laminar Velocity Bunching:

$$\rho_z = \frac{Qc(\gamma\sigma_z)^2}{I_0\,\sigma_x\varepsilon_z^2} > 1$$





Genetic Algorithms - Terminology

Genetic Algorithms are a family of stochastic optimization methods, their structure is inspired by the evolutionary theory of Darwin

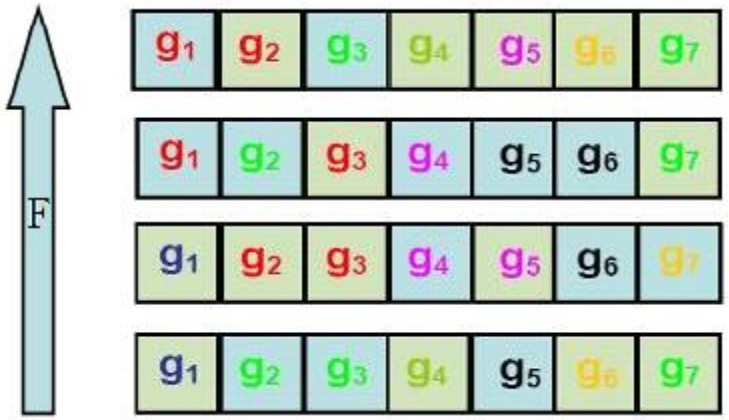
Gene	Machine parameter
Chromosome	Parameters set

Gene
ϕ_1
ϕ_2
ϕ_3
ϕ_4
$E_{max1,2}$
B_{max1}
B_{max2}
B_{max3}
σ_t
σ_L

Genetic Algorithms - Terminology

Genetic Algorithms are a family of stochastic optimization methods, their structure is inspired by the evolutionary theory of Darwin

Gene	Machine parameter
Chromosome	Parameters set
Population	Proposed solutions
Idoneity function	Tracking with Astra



Gene
ϕ_1
ϕ_2
ϕ_3
ϕ_4
$E_{max1,2}$
B_{max1}
B_{max2}
B_{max3}
σ_t
σ_L

3

What I’m doing

Personal activities

Proceedings of IPAC2016, Busan, Korea THPMB011

BEAM BASED ALIGNMENT METHODS FOR CAVITIES AND SOLENOIDS IN PHOTO-INJECTORS

M. Rossetti Conti[1], A. Bacci[†], Istituto Nazionale di Fisica Nucleare, Milano, Italy
[1]also at Università degli Studi, Milano, Italy

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Proceedings of IPAC2016, Busan, Korea WEPOY039

GIOTTO: A GENETIC CODE FOR DEMANDING BEAM-DYNAMICS OPTIMIZATIONS

A. Bacci, INFN/Milan, Italy
V. Petrillo, M. Rossetti Conti, Univ. of Milan, Milano, Italy

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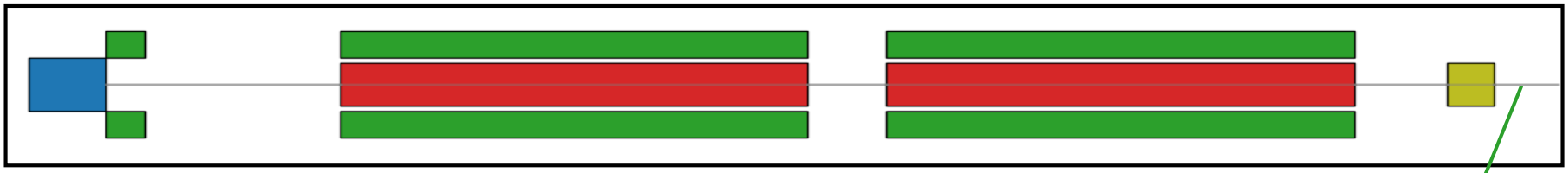
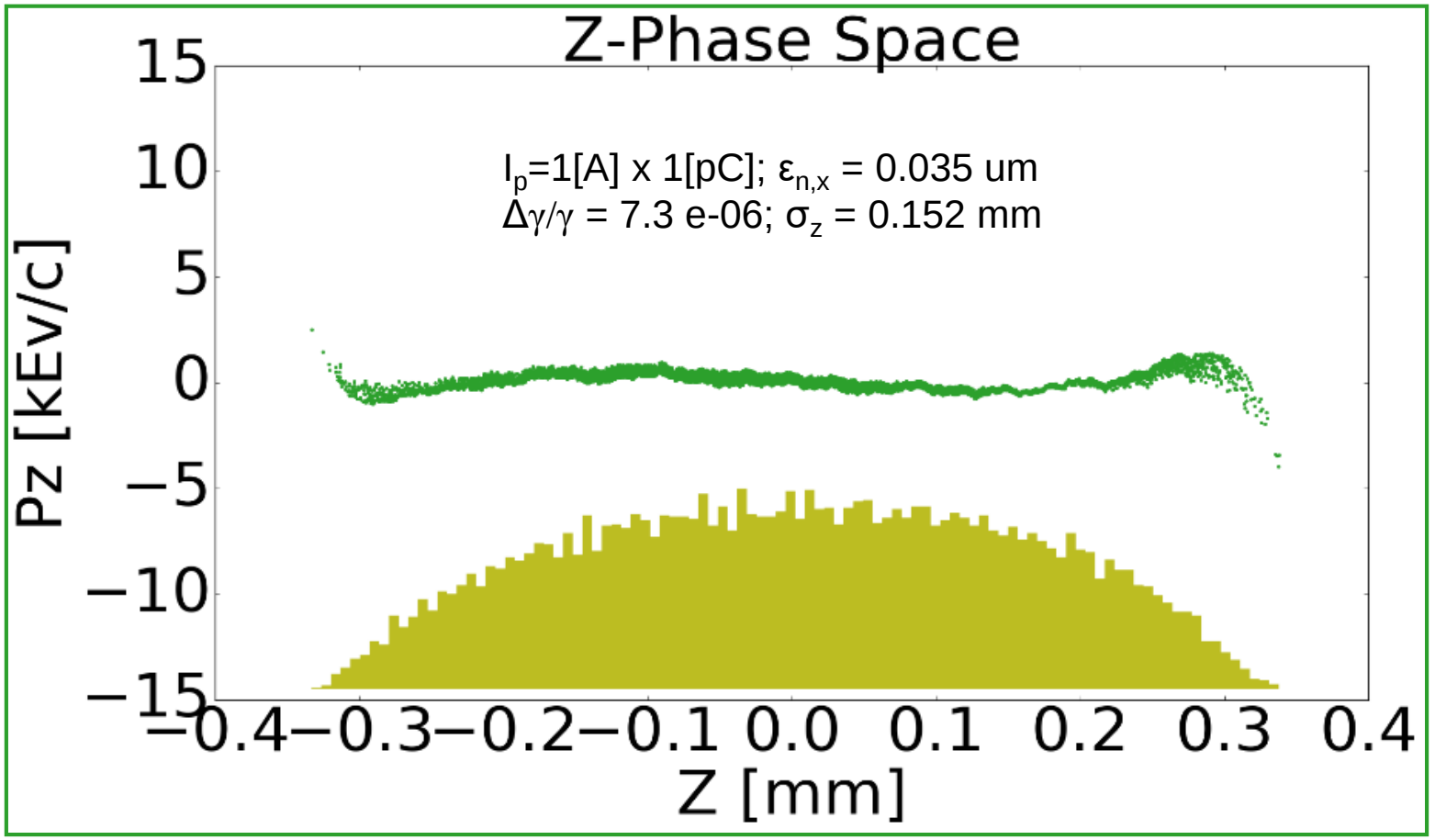
Proceedings of IPAC2016, Busan, Korea TUPOW004

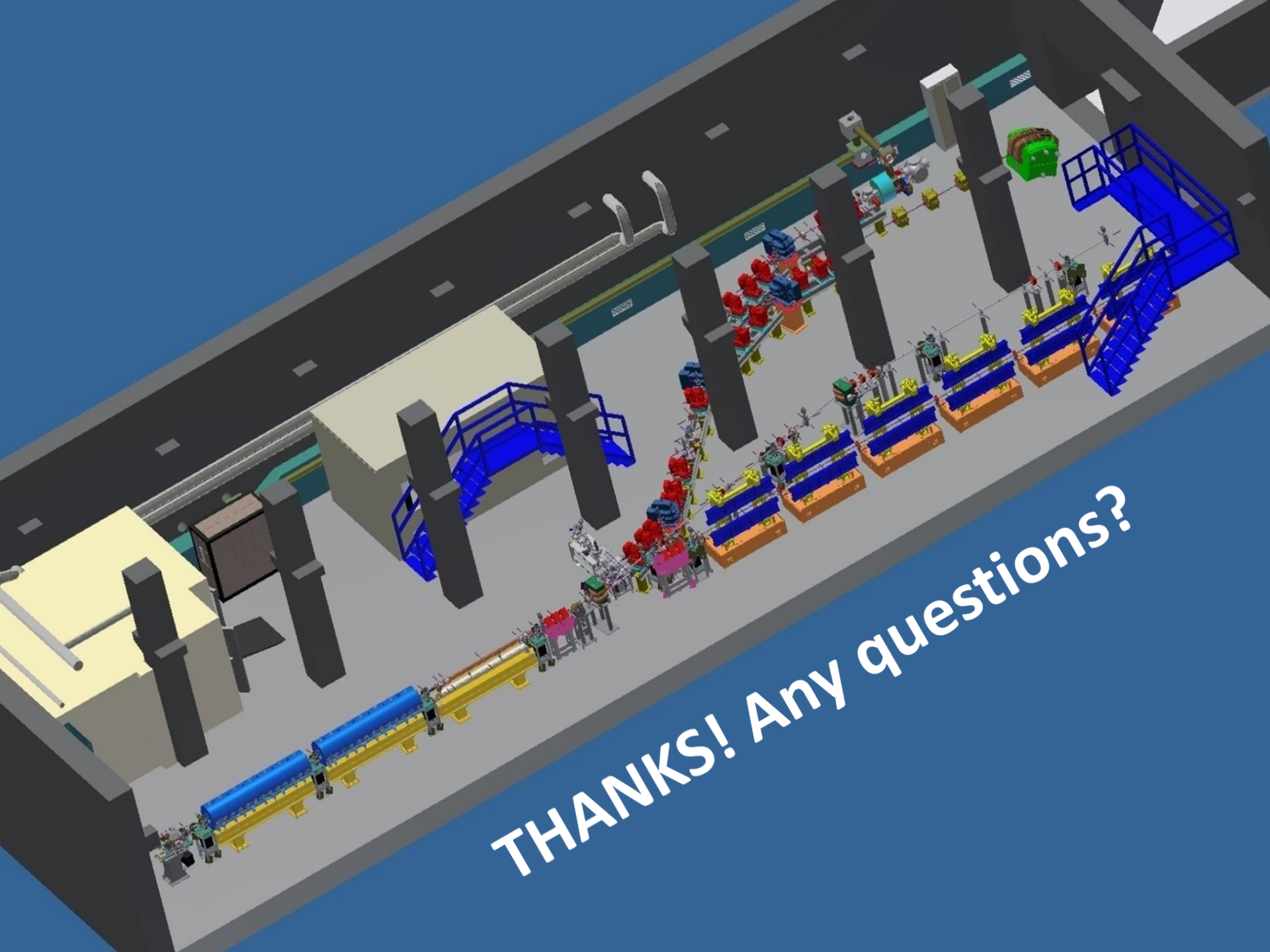
STATUS OF THE STAR PROJECT

A. Bacci†, I. Drebot, L. Serafini, V. Torri, INFN/Milan, Italy;
V. Petrillo, M. Rossetti Conti, Univ. of Milan, Milano, Italy;
Ezio Puppin, CNISM and Politecnico of Milan, Milano, Italy;
D. Alesini, M. Bellaveglia, F. Bisesto, B. Buonomo, G. Di Pirro, A. Esposito, F. Iungo, J. J. Beltrano, G. Borgese, G. Di Raddo, A.Gallo, A. Ghigo, L. Pellegrino, A. Stella, C. Vaccarezza, INFN/LNF,Roma, Italy;
A. Cianchi, Univ. Tor Vergata, Roma, Italy;
R. G. Agostino, R. Barberi, M. Ghedini, F. Martire, and C. Pace,
UNICAL, Arcavacata di Rende, Cosenza, Italy;
G. Dauria, A. Fabris, and M. Marazzi, Elettra/Sinc. Trieste, Trieste, Italy

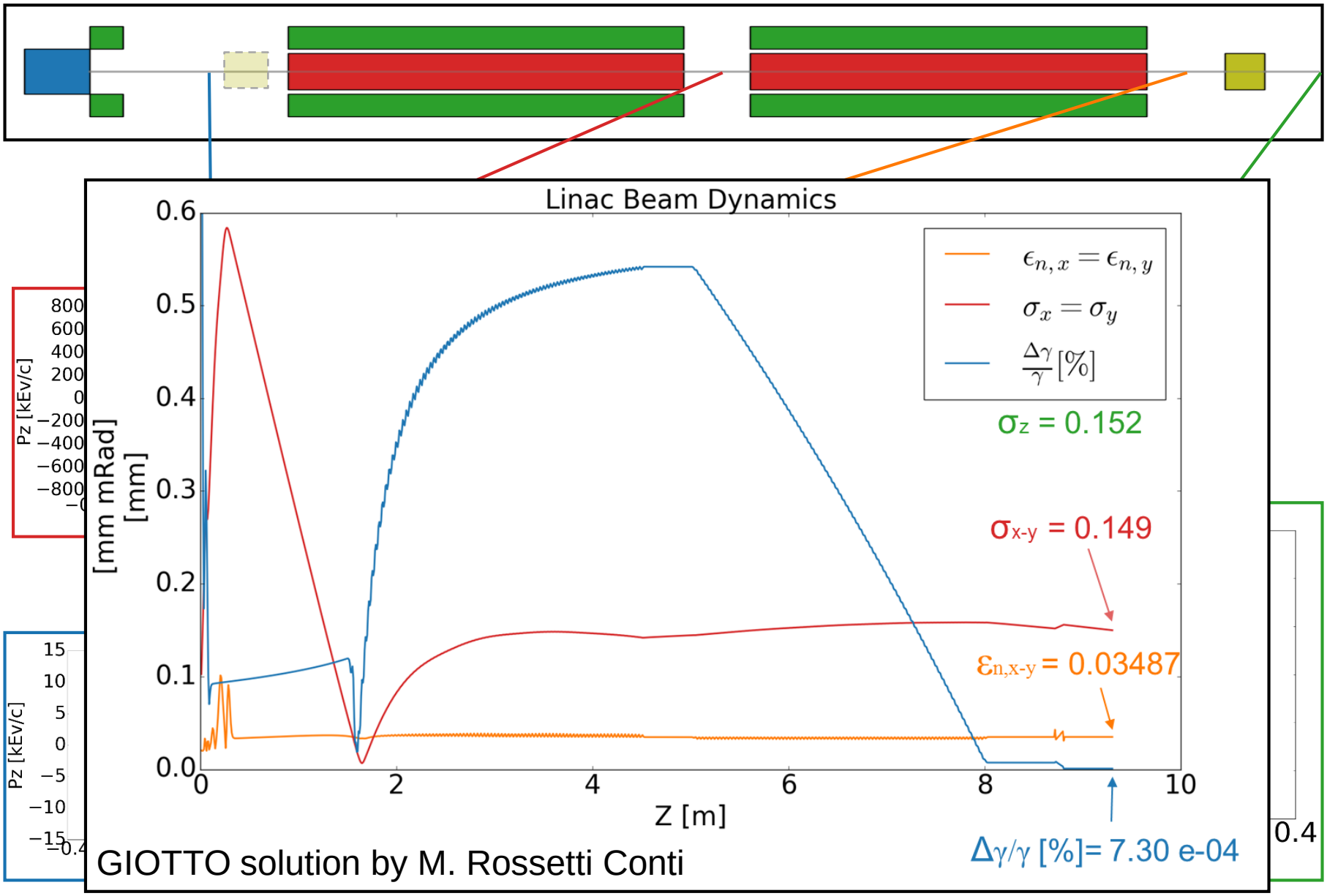
Ultracold beam (preliminary) – quantum FEL






THANKS! Any questions?

High harm. cav. for very cold beams (preliminary) – quantum FEL



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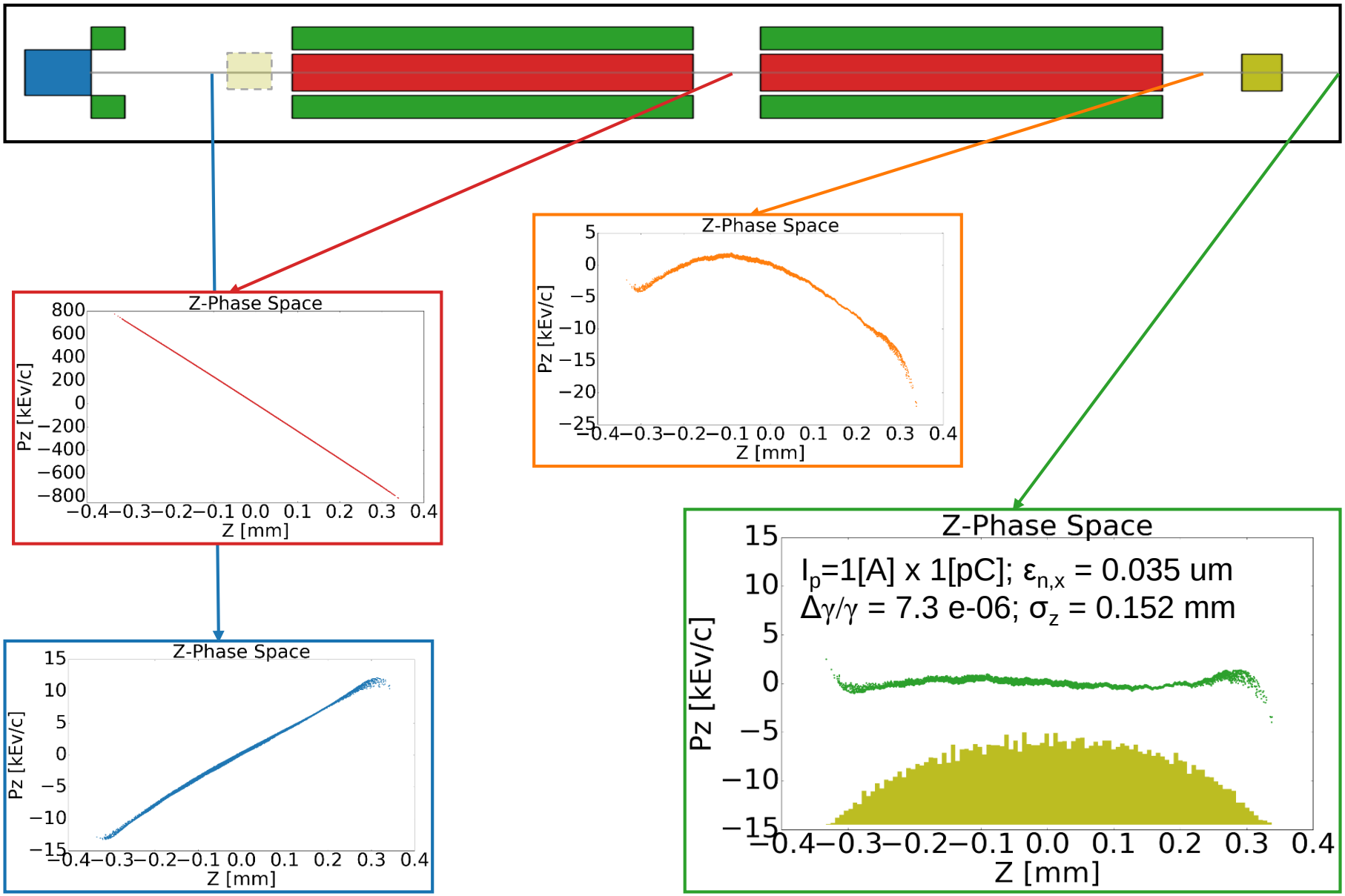
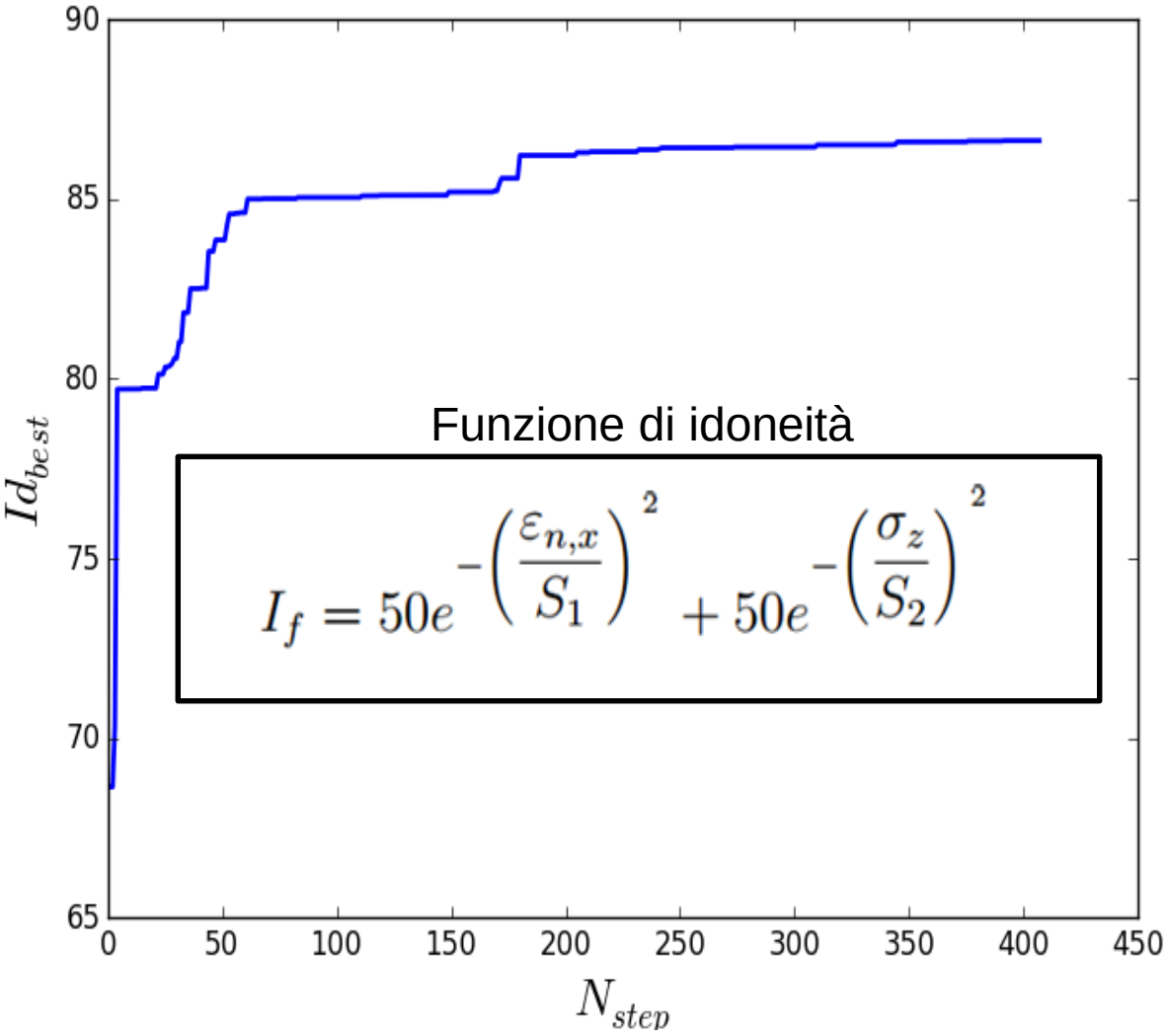


3) LINAC: GIOTTO + Astra, Risultati

Andamento dell'idoneità



Funzione di idoneità

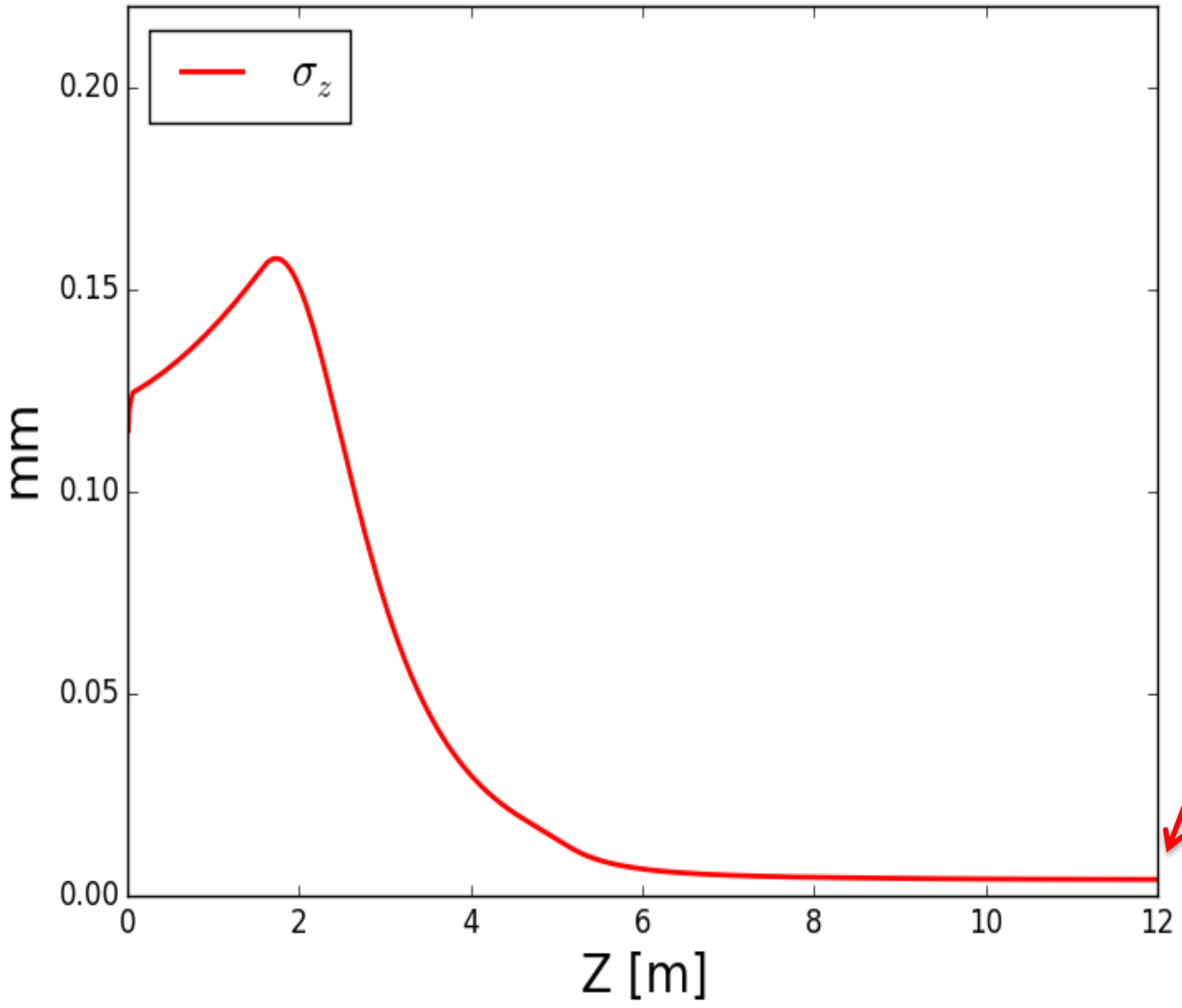
$$I_f = 50e^{-\left(\frac{\varepsilon_{n,x}}{S_1}\right)^2} + 50e^{-\left(\frac{\sigma_z}{S_2}\right)^2}$$

Vincolo di laminarità

$$\rho_z = \frac{Qc(\gamma\sigma_z)^2}{I_0\,\sigma_x\varepsilon_z^2} > 1$$

3) LINAC: GIOTTO + Astra, Risultati

Compressione

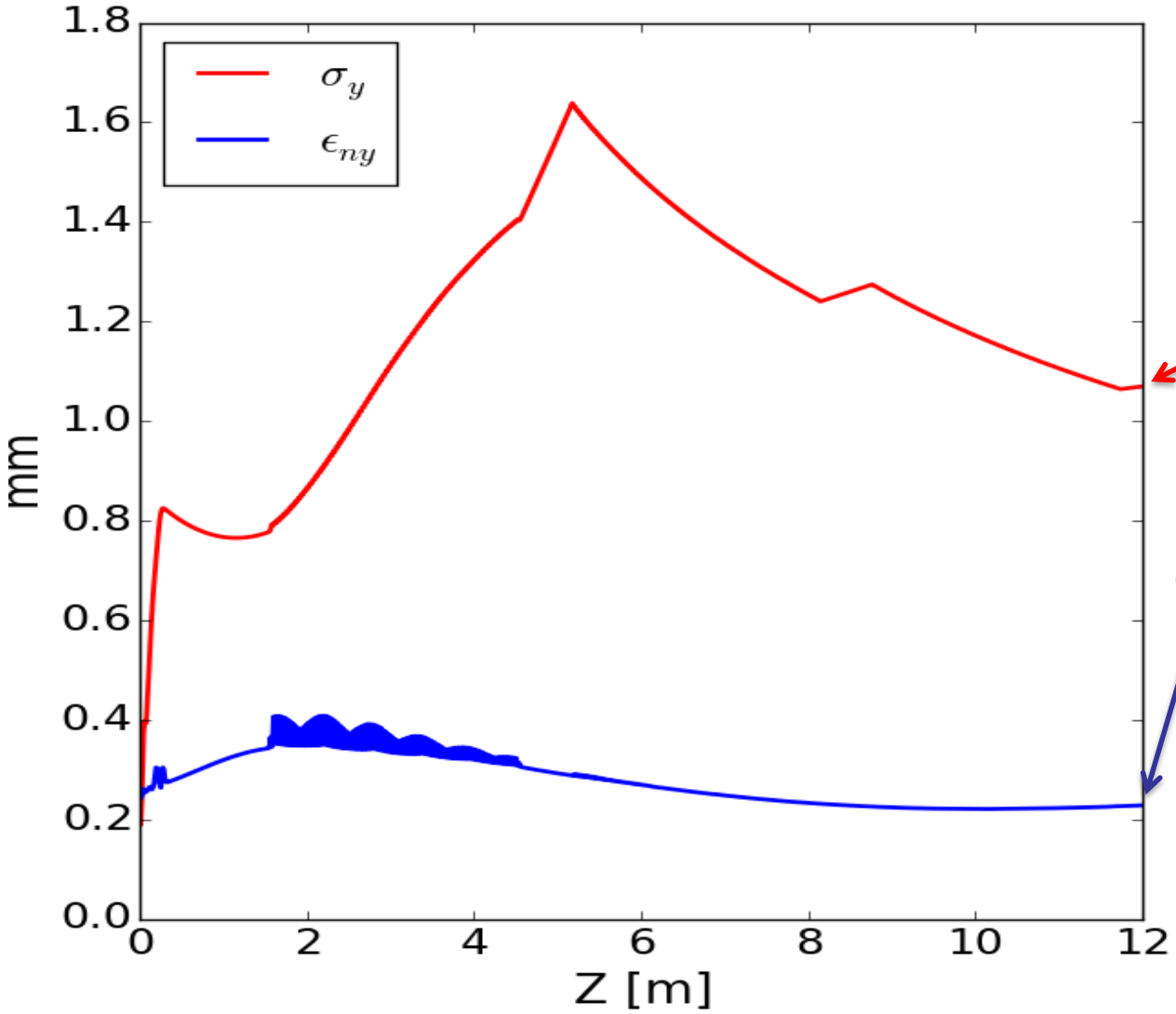


$\sigma_z \cong 4\ \mu m$

$C \cong 37$

3) LINAC: GIOTTO + Astra, Risultati

Emittanze ed inviluppi traversi

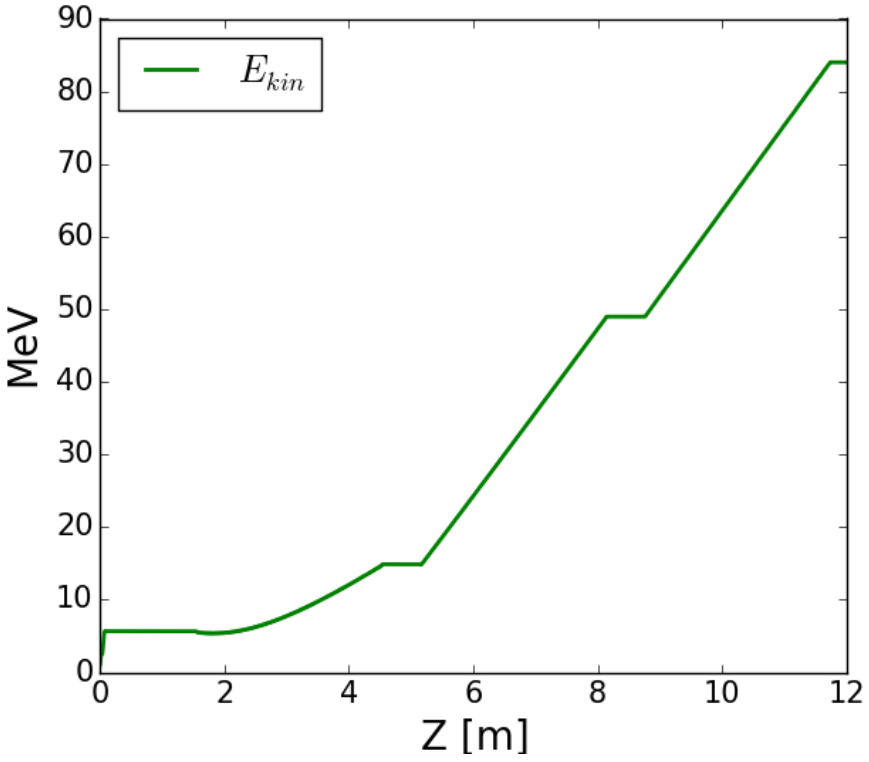


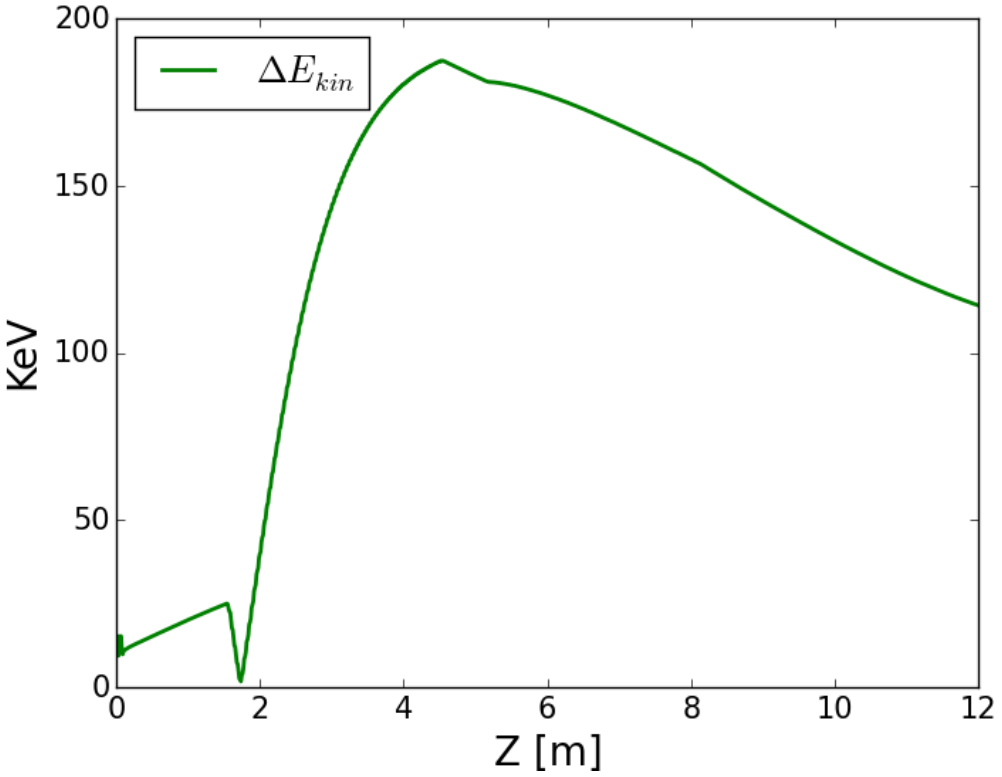
$$\sigma_x = \sigma_y \cong 1.1 \ mm$$

$$\varepsilon_{n,x} = \varepsilon_{n,y} \cong 0.2 \ mm{\cdot}mRad$$

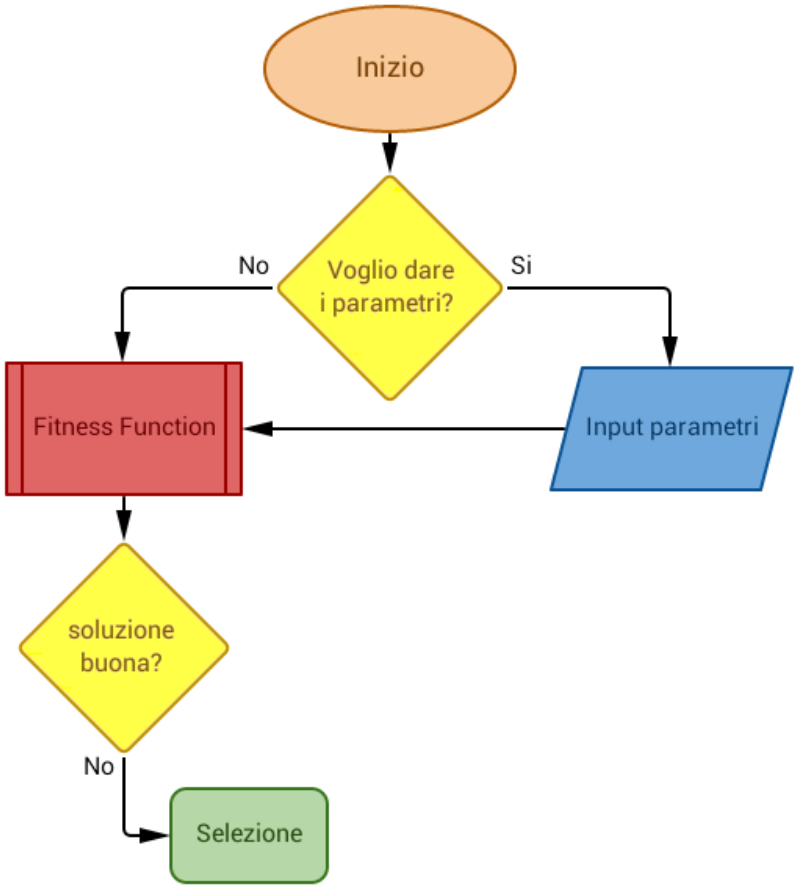
3) LINAC: GIOTTO + Astra, Risultati

Energia cinetica ed energy spread





Algoritmi Genetici - Funzionamento



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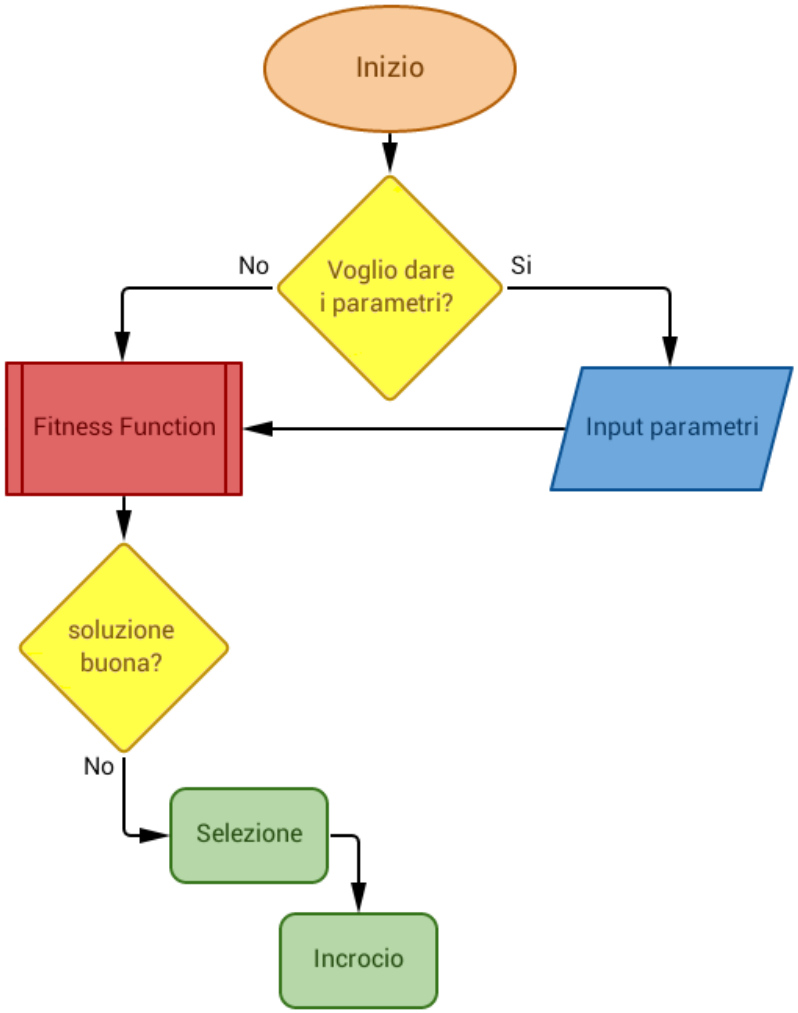

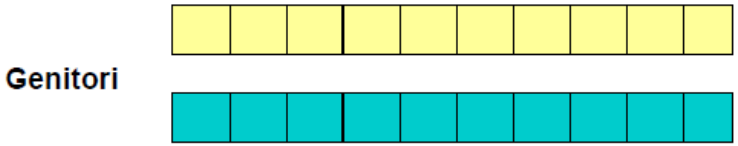

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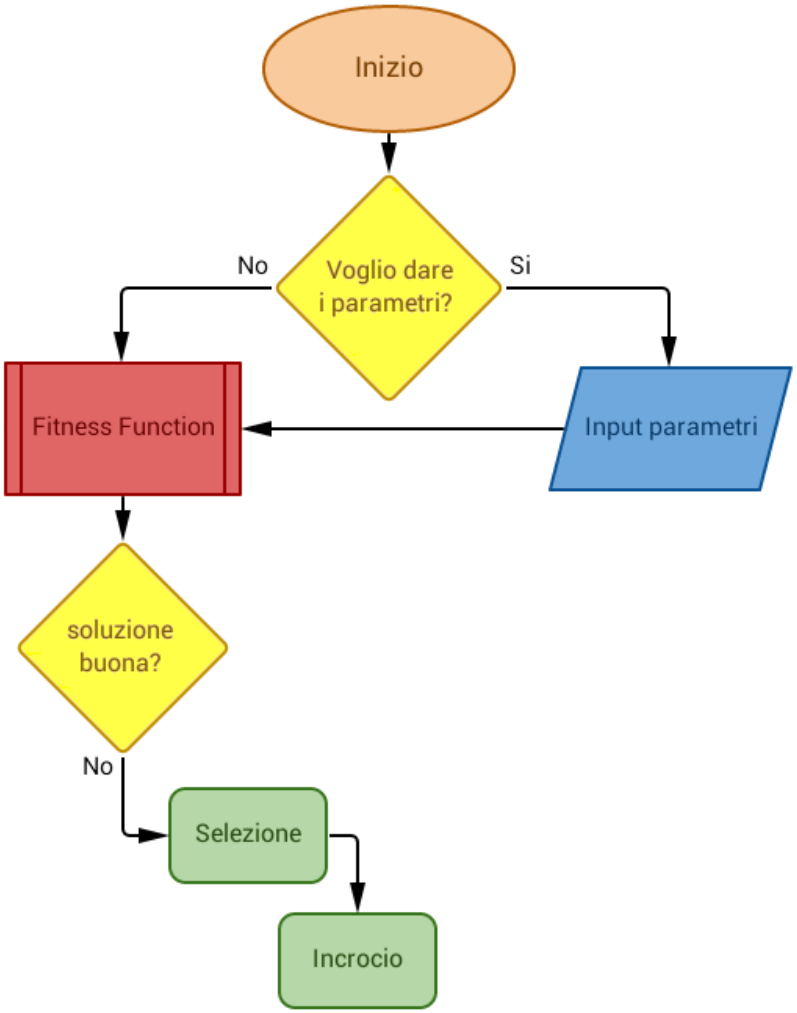

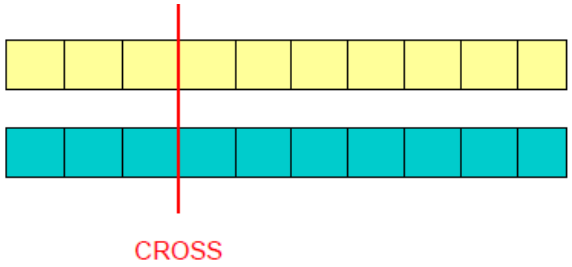

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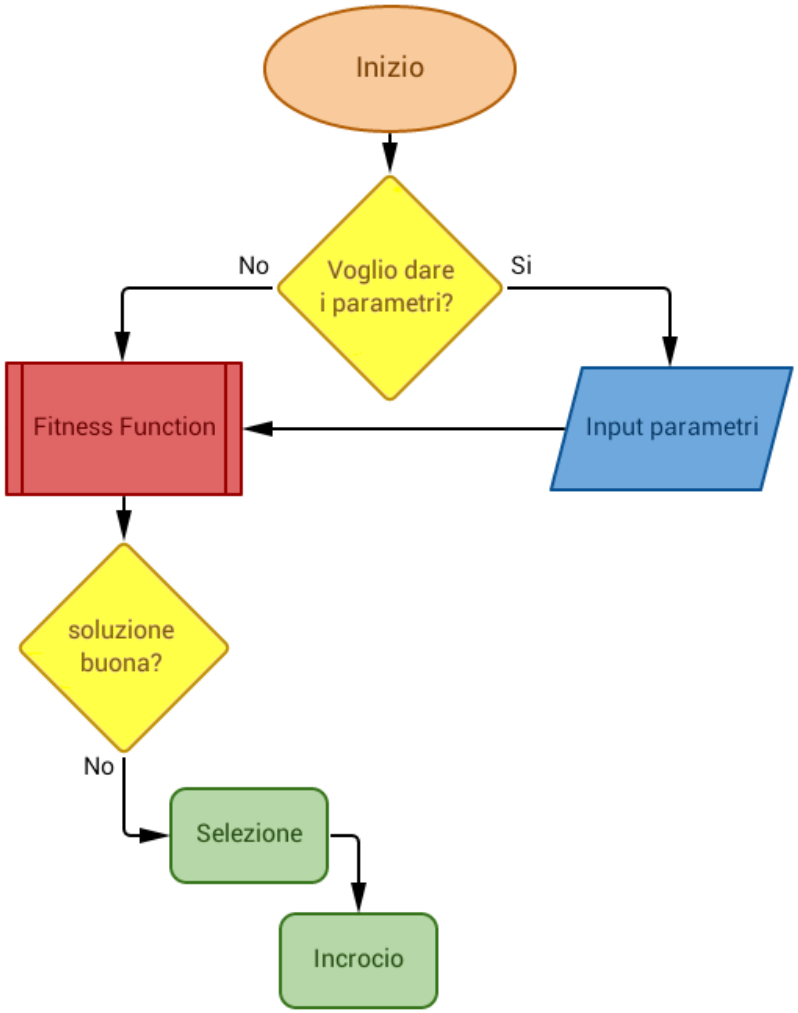

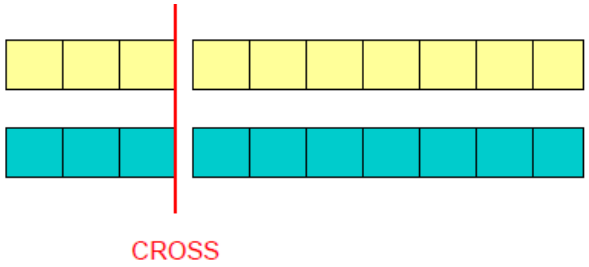

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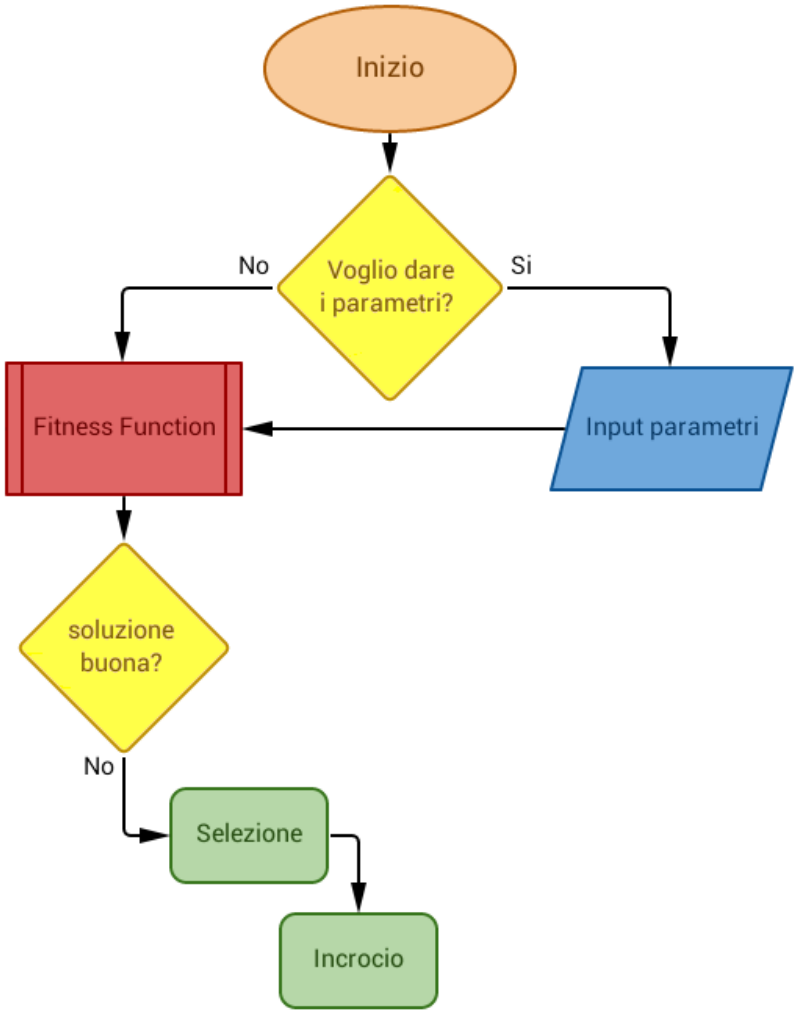

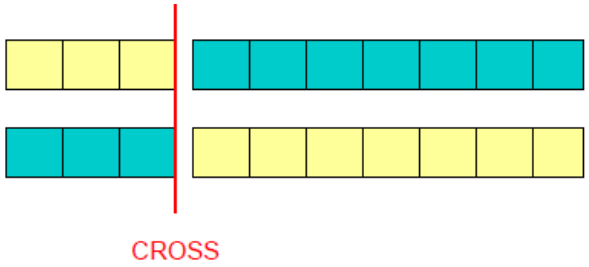

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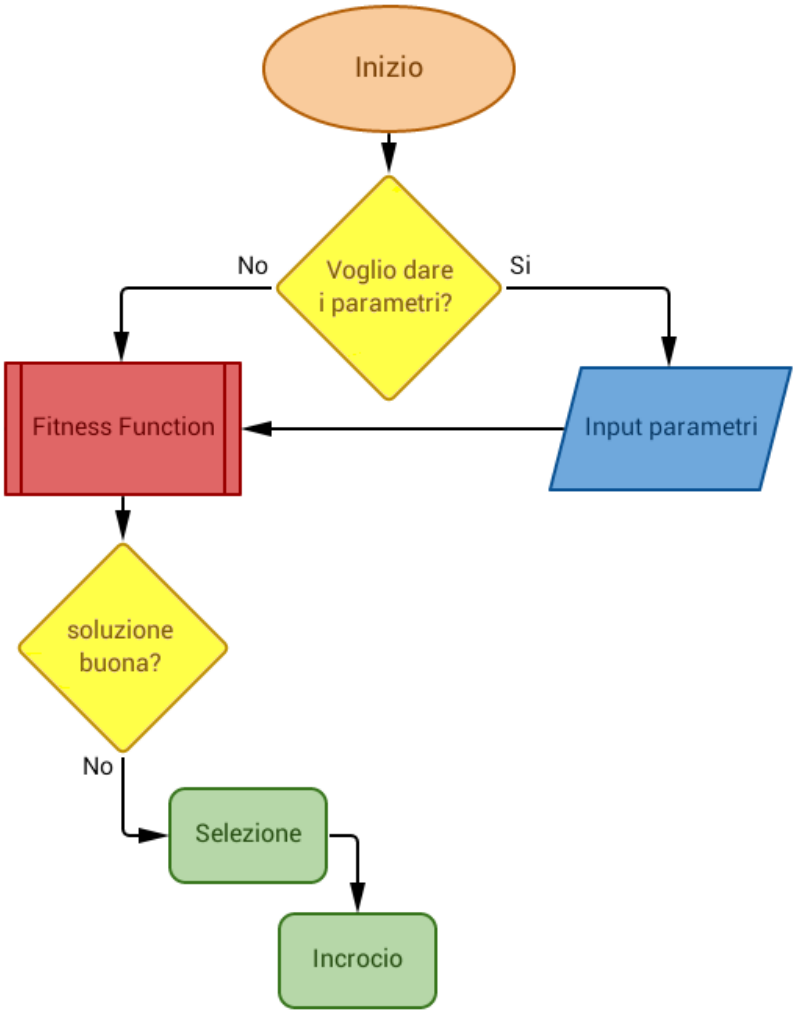

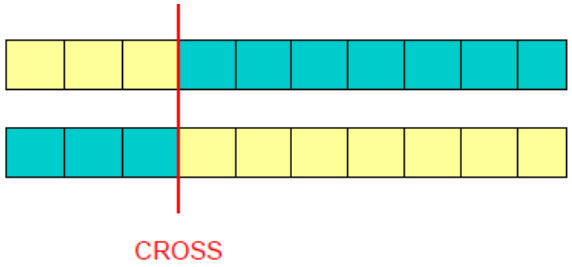

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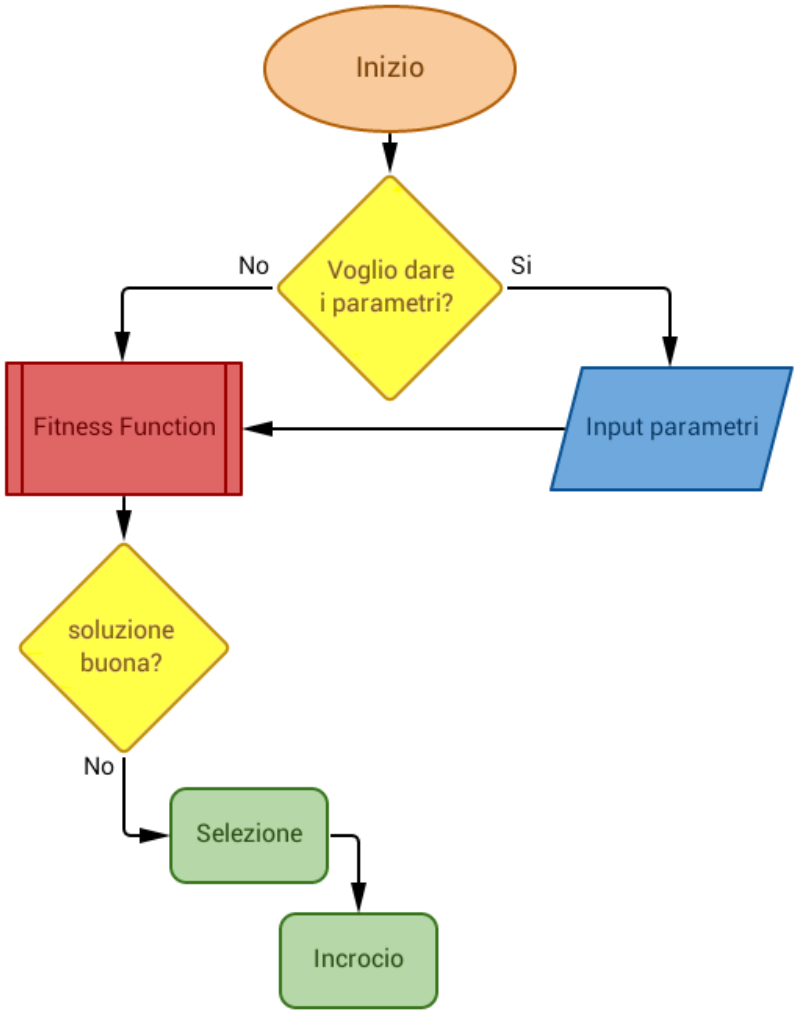

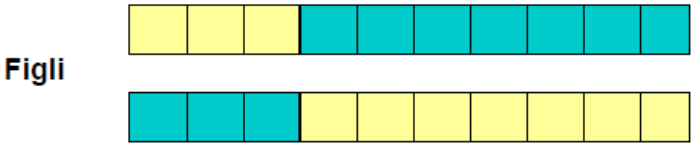

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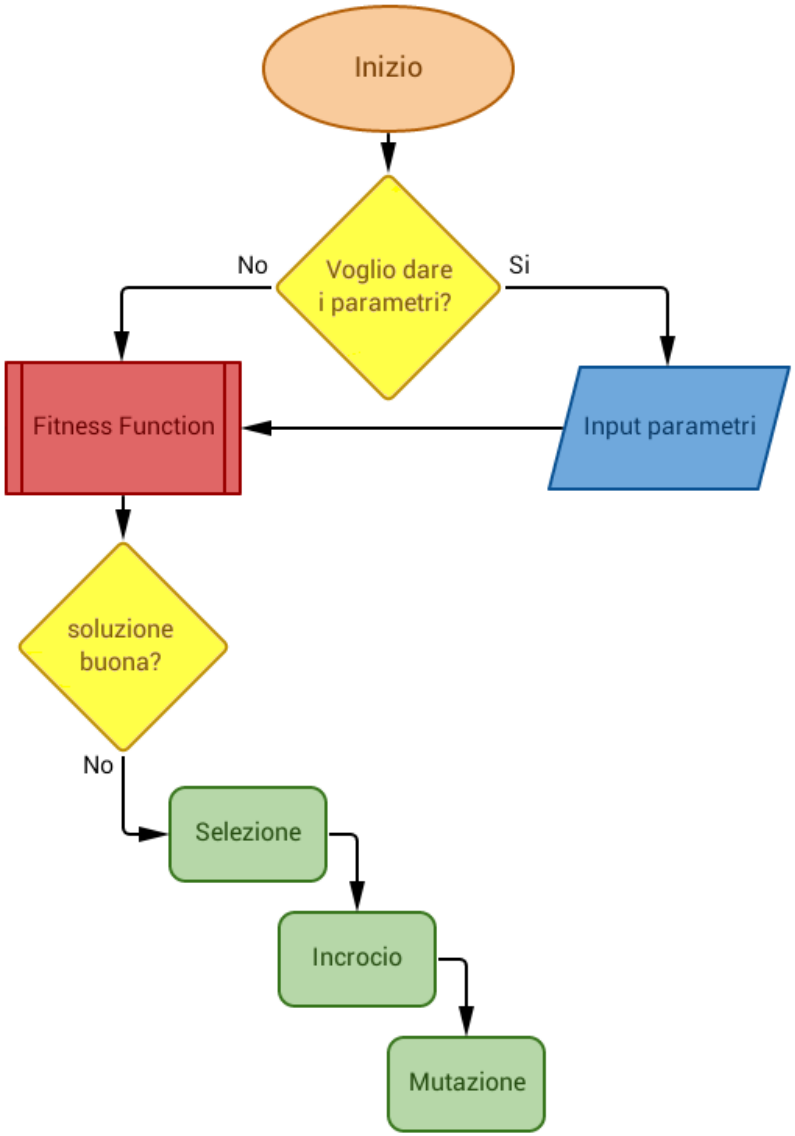
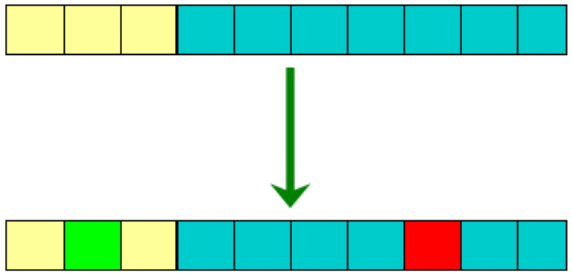
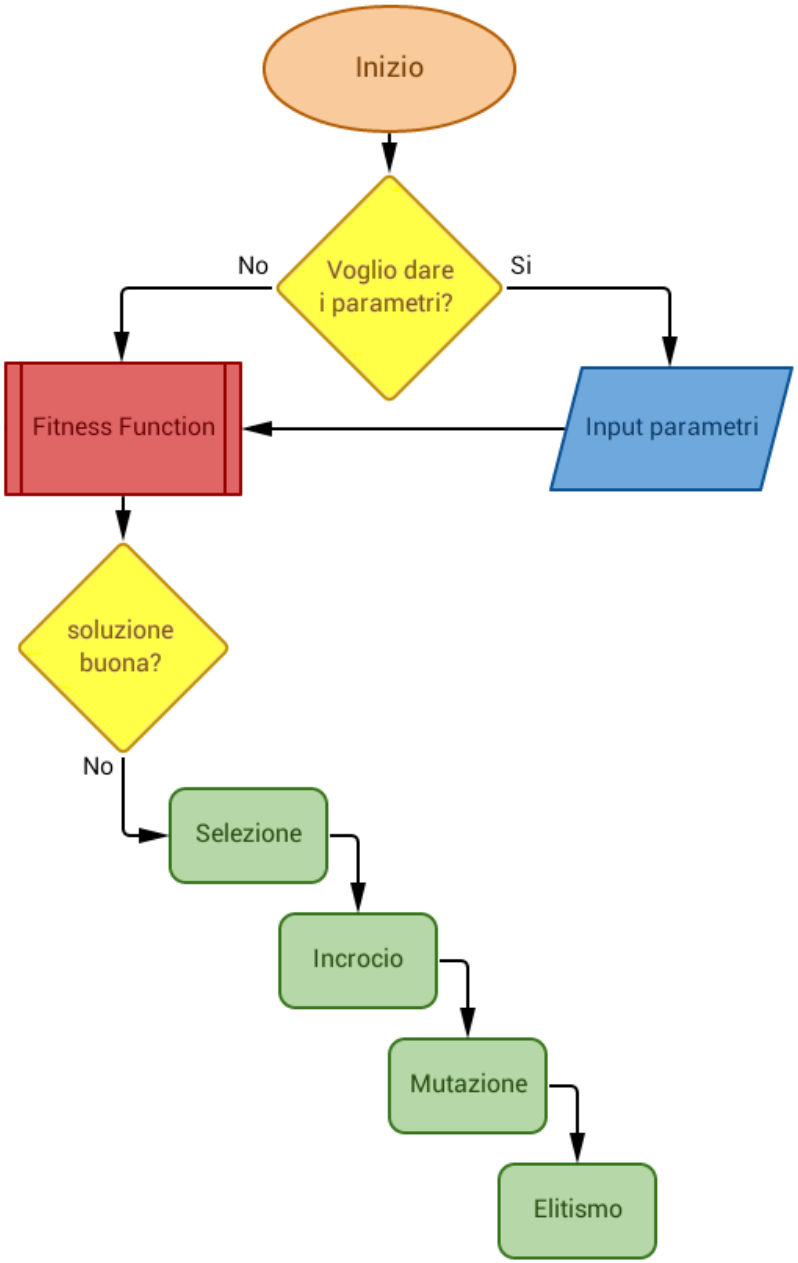
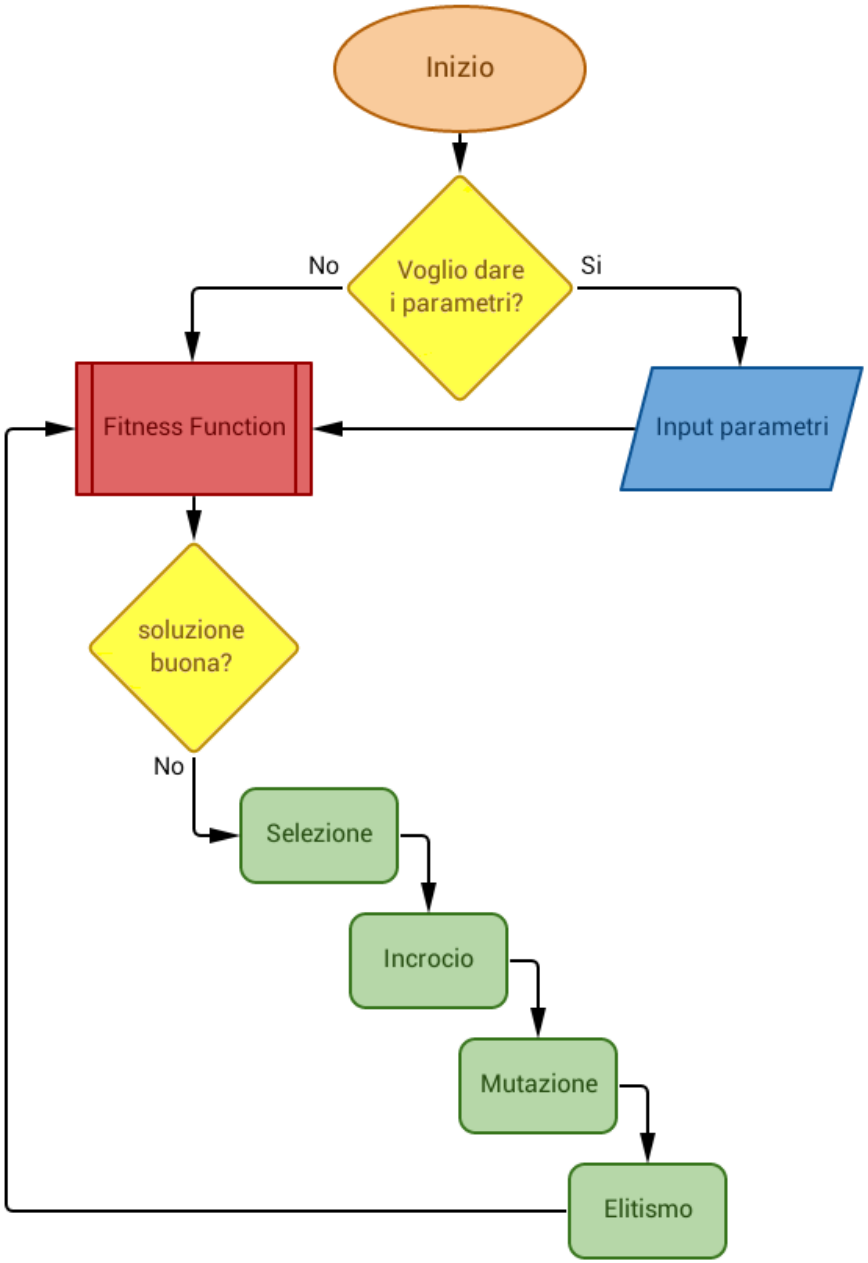




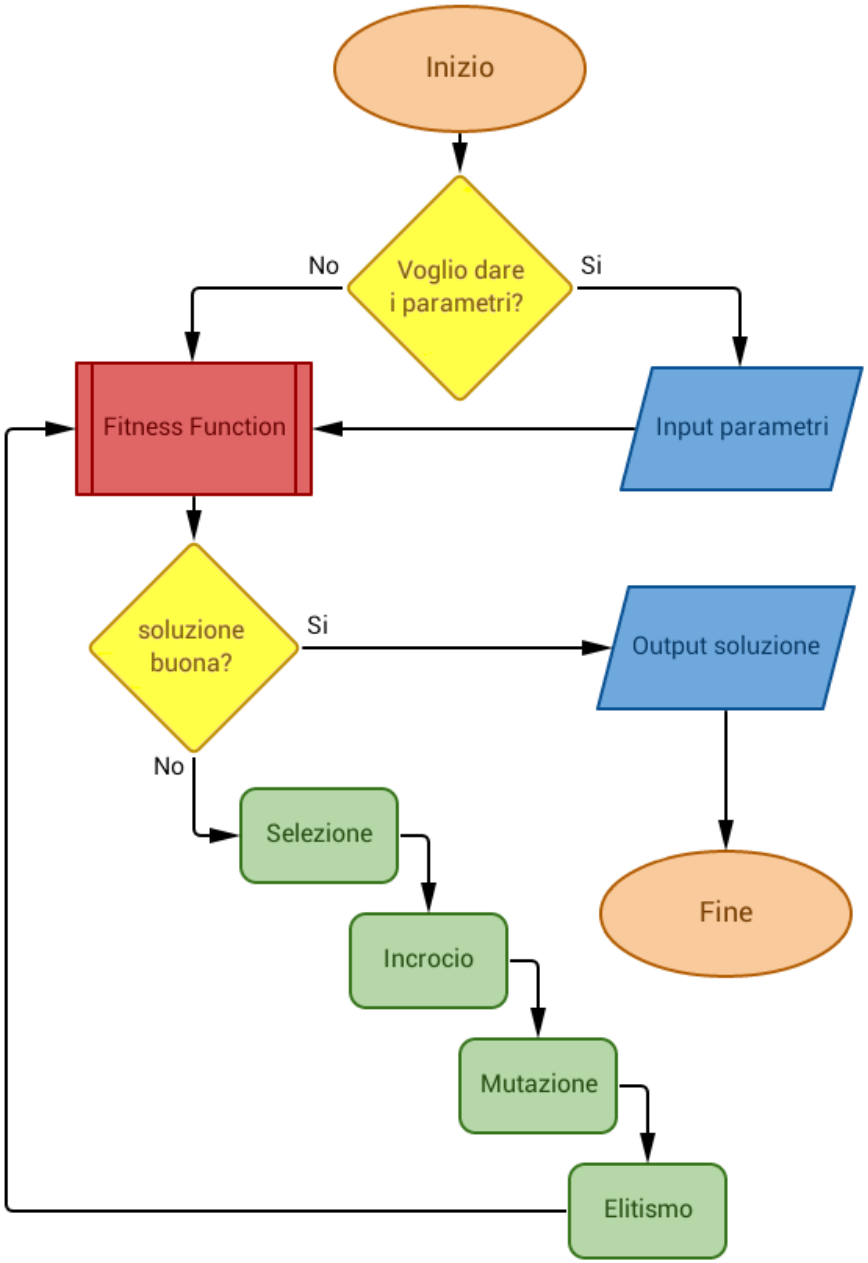
Algoritmi Genetici - Funzionamento



Algoritmi Genetici - Funzionamento



Algoritmi Genetici - Funzionamento



Template