Assemblée Générale du pôle Physique des Accélérateurs

Session Doctorants

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Début de 2ème année de thèse

Supervision de Christelle Bruni

Equipe BIMP

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General Scope

Study and mitigation of collective effects in the transport of relativistic electron beams with high peak current in single or multiple pass particle accelerators.

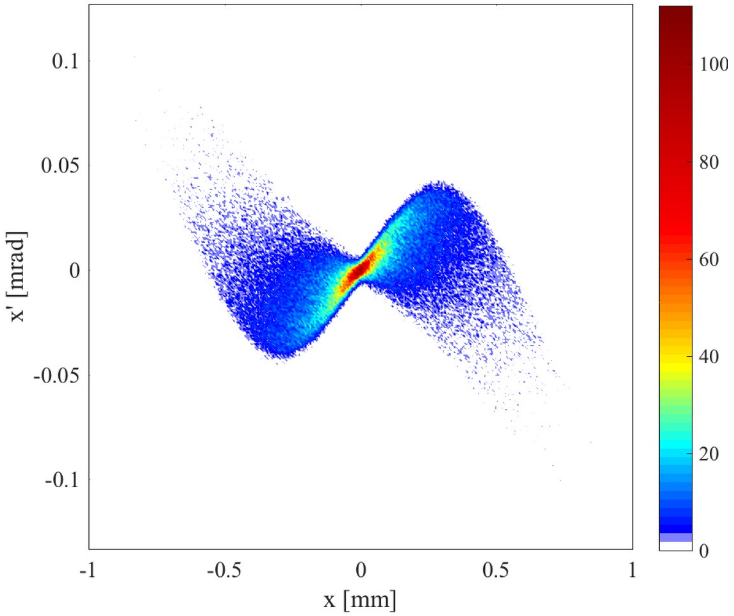
→ Beam Transport and Dynamics

→ Relativistic Electrons

→ High Peak Current

→ Collective effects

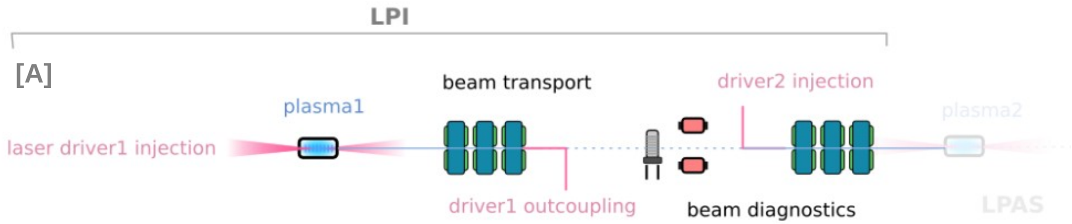
→ Simulations

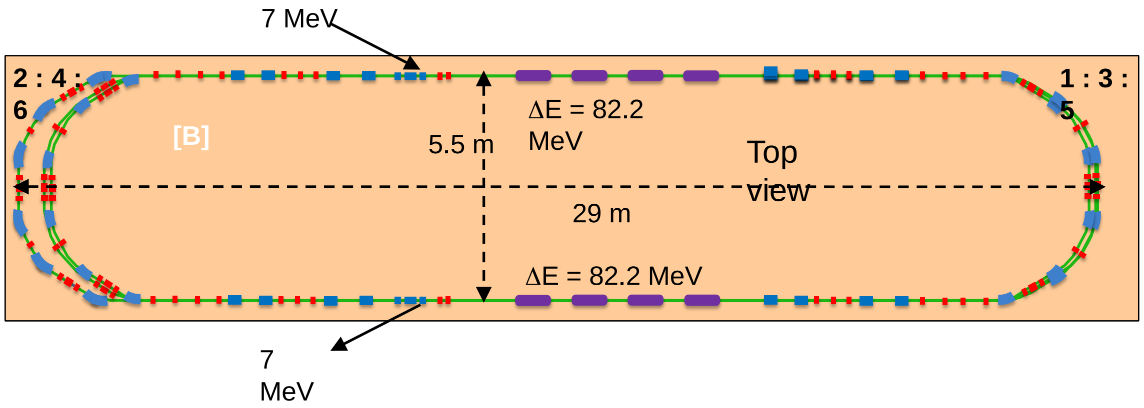


Application Cases : PALLAS & PERLE

→ two different **high peak current accelerator** projects :

- **PALLAS** : Laser Plasma Accelerator Prototype
- **PERLE** : Energy Recovery Linac





Tracking: 6D equation of motion resolution

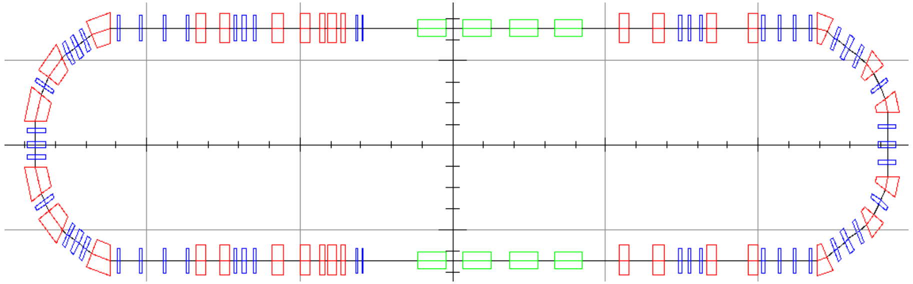
(x, p_x, y, p_x, s, p_s)

→ **Direct Numerical Integration**

$$\frac{d\mathbf{p}}{dt} = \mathbf{F} = q\left(\mathbf{E} + \mathbf{v} \times \mathbf{B}\right)$$

ASTRA

Map Fields and Runge-Kutta differential equation resolution



→ **Prior Integration**

'kick' method

transfer matrices

$$\begin{bmatrix} R_{1,1} & R_{1,2} & R_{1,3} & R_{1,4} & R_{1,5} & R_{1,6} \\ R_{2,1} & R_{2,2} & R_{2,3} & R_{2,4} & R_{2,5} & R_{2,6} \\ R_{3,1} & R_{3,2} & R_{3,3} & R_{3,4} & R_{3,5} & R_{3,6} \\ R_{4,1} & R_{4,2} & R_{4,3} & R_{4,4} & R_{4,5} & R_{4,6} \\ R_{5,1} & R_{5,2} & R_{5,3} & R_{5,4} & R_{5,5} & R_{5,6} \\ R_{6,1} & R_{6,2} & R_{6,3} & R_{6,4} & R_{6,5} & R_{6,6} \end{bmatrix}$$

CODAL

Homemade

Hamiltonian Mechanics & Lagrangian based on L.Nadoski's work [1]

[1] Laurent Nadolski. *Application de l'Analyse en Fréquence à l'Etude de la Dynamique des Sources de Lumière.* Thèses, Université Paris Sud - Paris XI, July 2001

RF transverse motion - CODAL upgrade

PHYSICAL REVIEW E VOLUME 49, NUMBER 2 FEBRUARY 1994

Transverse particle motion in radio-frequency linear accelerators

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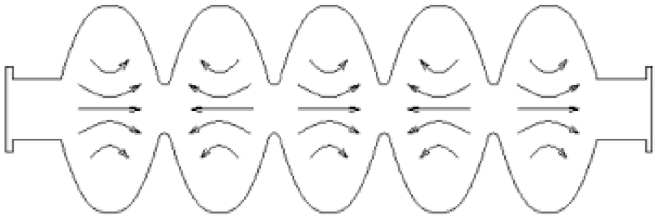
(Received 18 October 1993)

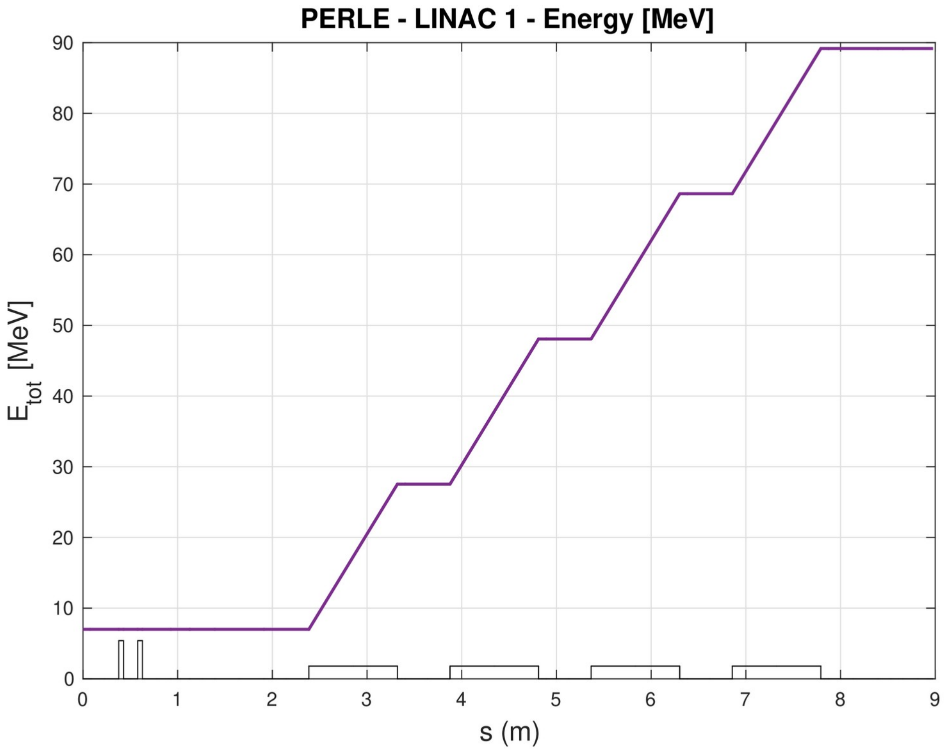


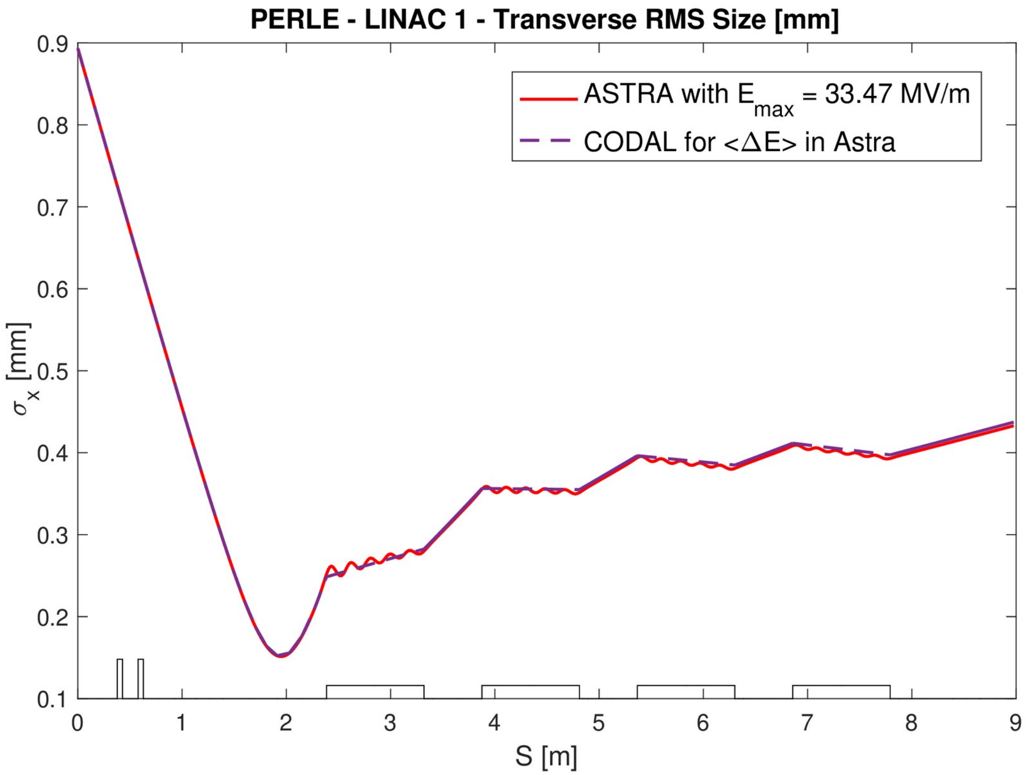
$$M_{cell} = \begin{bmatrix} \cos(\alpha) & \sqrt{\frac{8}{\eta(\phi)}}\frac{\gamma_i}{\gamma'}\cos(\phi)\sin(\alpha) \\ -\sqrt{\frac{\eta(\phi)}{8}}\frac{\gamma'}{\gamma_f\cos(\phi)}\sin(\alpha) & \frac{\gamma_i}{\gamma_f}\cos(\alpha) \end{bmatrix}$$

→ CODAL upgrade with transfer matrices for standing wave RF cavities

[2] J.Rosenzweig and L.Serafini. *Transverse Particle Motion in Radio-Frequency Linear Accelerator. Phys. Rev. E*, 49:1599-1602, Feb 1994.

→ validation of the upgrade (benchmark with Astra)





$$M_{cell} = \begin{bmatrix} cos(\alpha) & \sqrt{\frac{8}{\eta(\phi)}}\frac{\gamma_i}{\gamma'}cos(\phi)sin(\alpha) \\ -\sqrt{\frac{\eta(\phi)}{8}}\frac{\gamma'}{\gamma_f cos(\phi)}sin(\alpha) & \frac{\gamma_i}{\gamma_f}cos(\alpha) \end{bmatrix}$$

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

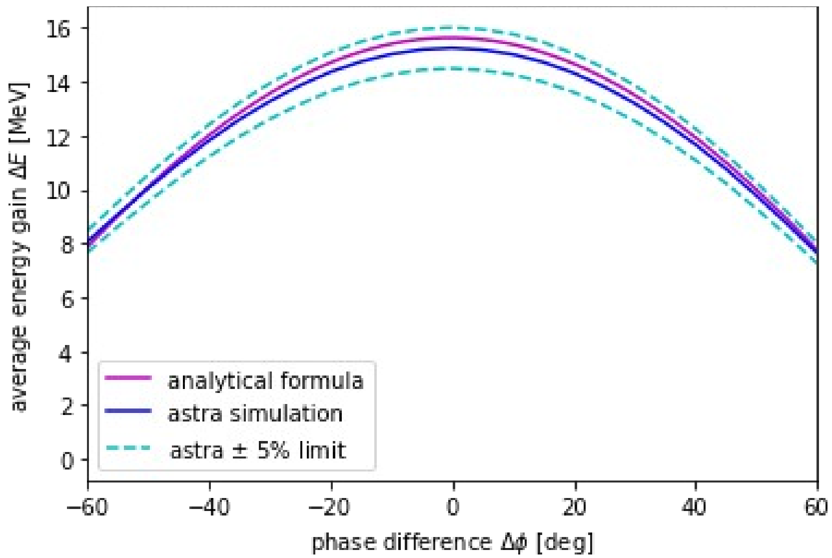
journal homepage: www.elsevier.com/locate/nima

Analytical modeling of longitudinal beam dynamics in an RF-gun: From almost zero to relativistic velocities

T. Vinatier *, C. Bruni, P. Puzo

Laboratoire de l'accélérateur linéaire, 91898, Orsay, France

Average energy gain according to the phase difference for an initial gamma = 8.8



→ adaptation for standing wave RF cavities

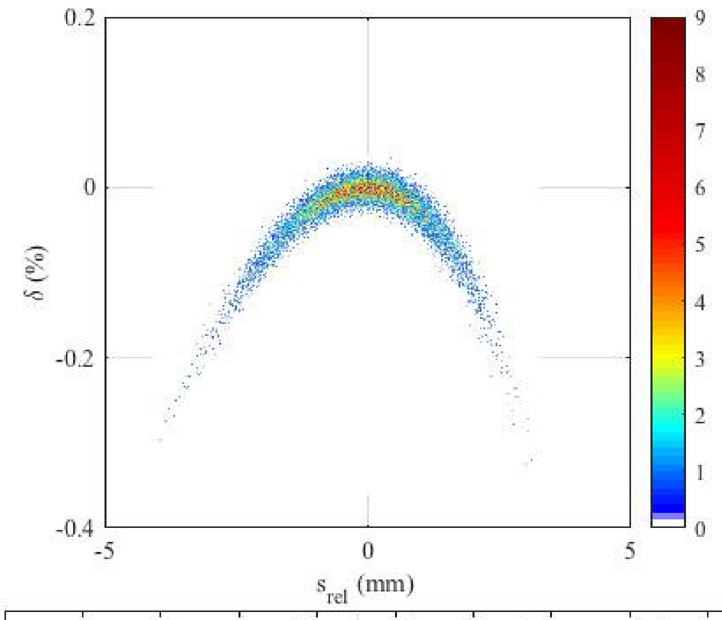
→ validation of the upgrade (benchmark with Astra)

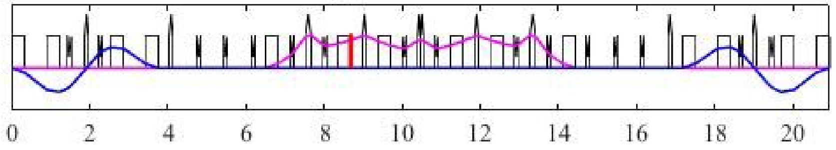
[3] T.Vinatier, C.Bruni, P.Puzo. *Analytical modeling of longitudinal beam dynamics in an rf-gun : from almost zero to relativistiv veolcities.* Nuclear Instruments and Methods in Physics Reasearch. Section A : Accelerators, Spectrometers, Detectors and Associated Equipement, 953:162914, 2020.

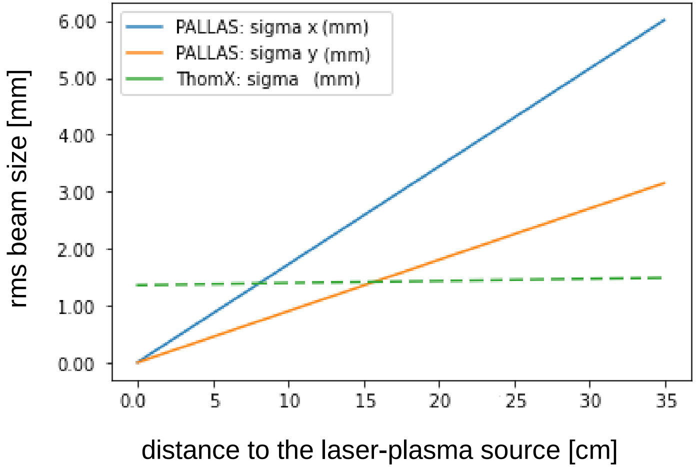
→ 1st full pass

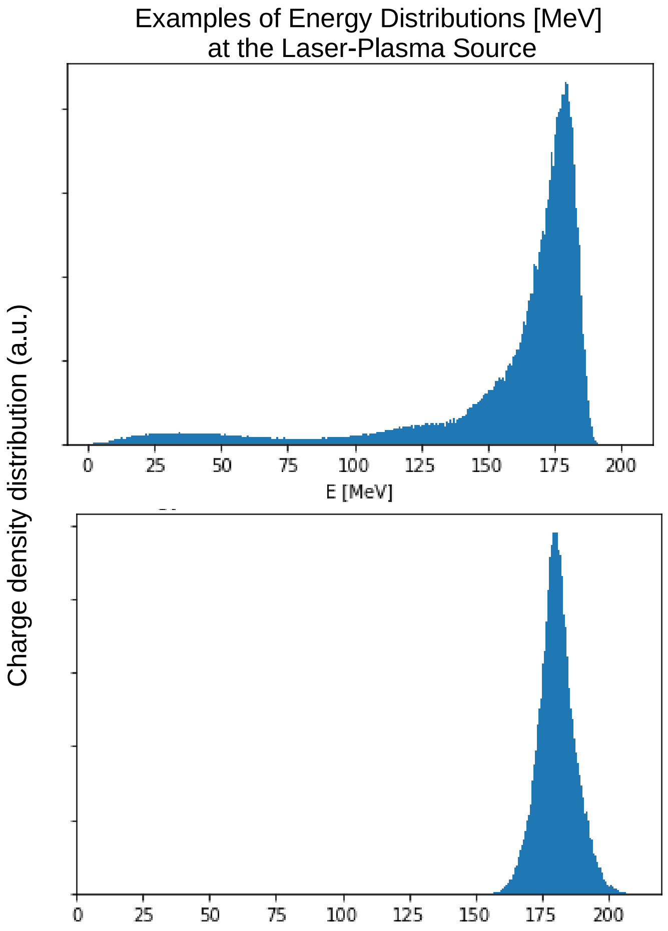
→ start to end

→ collective effects (CSR, ...)









High energy spread and divergence :

→ Emittance blow-up during the 1st focusing

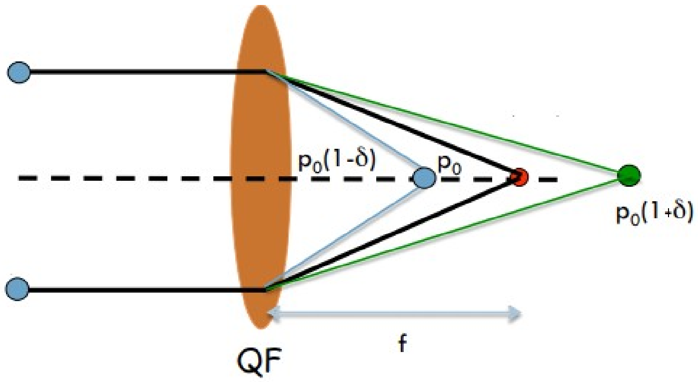
→ Transverse position discrimination according to the energy possible

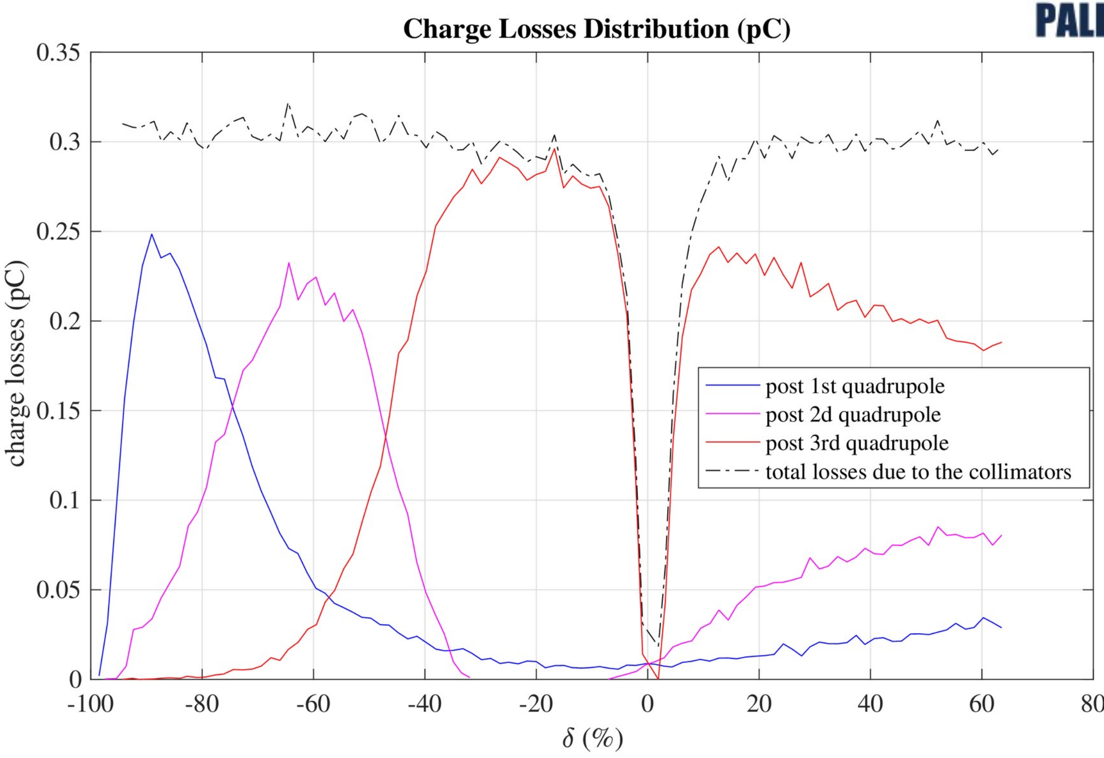
Energy Spread – LWFA beams

High energy spread and divergence :

→ Emittance blow up during the 1st focusing = challenging beam quality preservation

→ Transverse postion discrimination according to the energy possible = possibility of **cleaning some energies from the electron bunch**



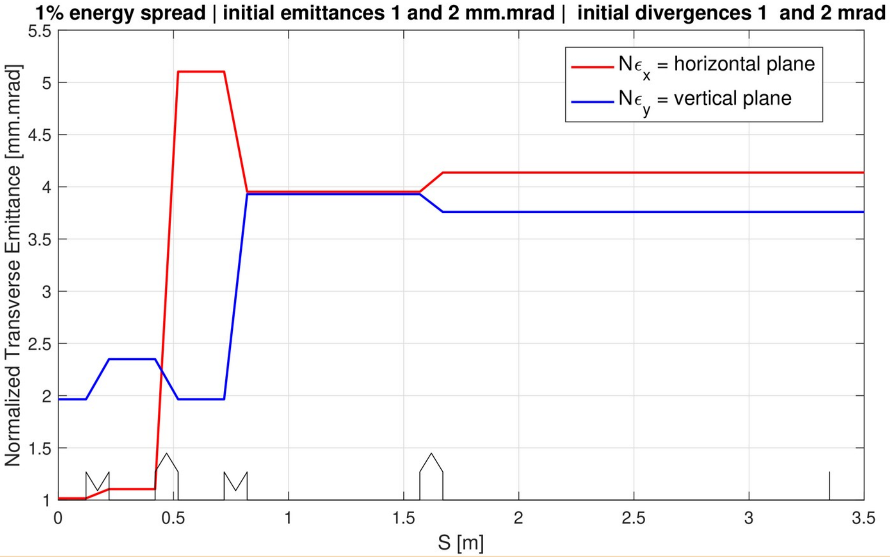


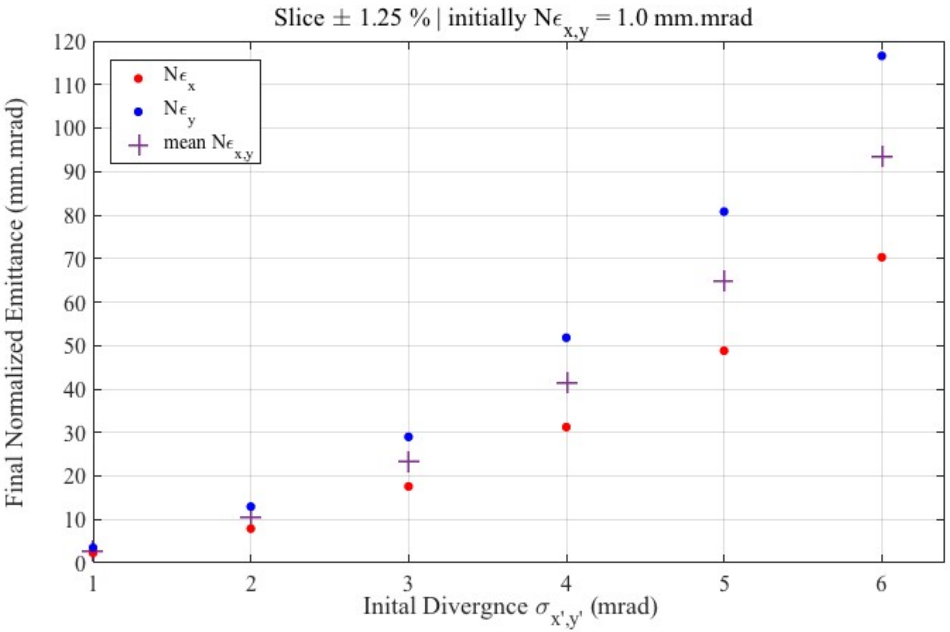
Beam Quality – **LWFA beams**

High energy spread and divergence :

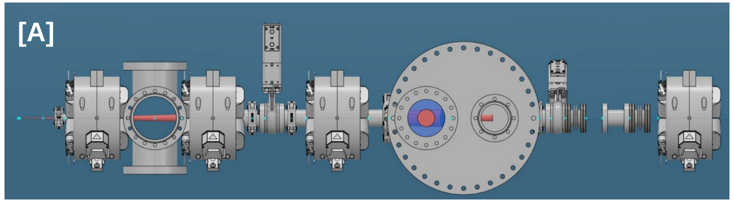
→ Emittance blow up during the 1st focusing = **challenging beam quality preservation**

→ Transverse postion discrimination according to the energy possible = possibility of cleaning some energies from the electron bunch





→ quasi quadradic emittance growth with the inital divergence



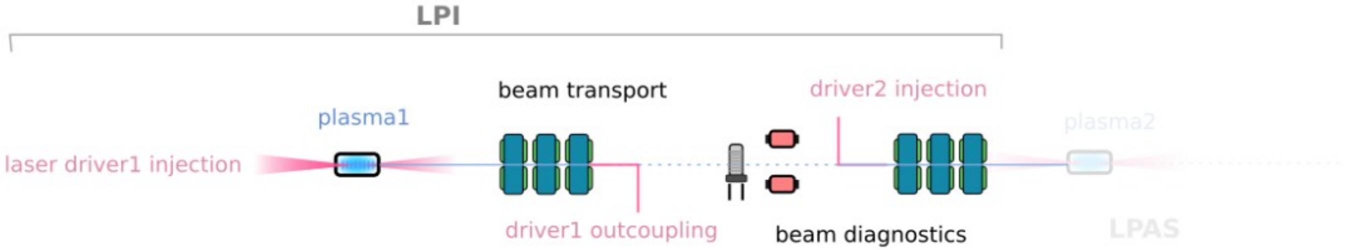
Thank you for your attention

Different application – PALLAS

PALLAS

Build a laser-plasma **accelerator test facility** aiming to achieve **reliability** and **control** comparable to conventional **RF accelerator** standards.

Push LPA technological development starting with a 10 Hz 150-200 MeV **laser-plasma injector** (**LPI**) prototype



Research and development lines :

1. advanced **laser control**
2. development of **plasma targetry** => plasma cell
3. electron **beam control and transport**

Achieved fully optimized and controlled LPI

First brick of a more ambitious beamline with second plasma stage (LPAS) or applications