



Plasma acceleration with self-modulated long beams

from simulations to reality

10/9/2014

DESY Summer Student Session

Marcin Sliwa

Machine Physics Group (MPY)



Plasma acceleration with self-modulated long beams from simulations to reality

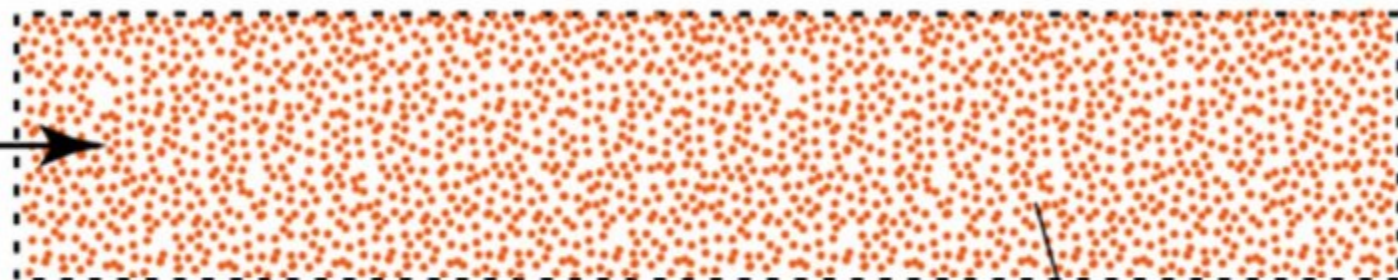
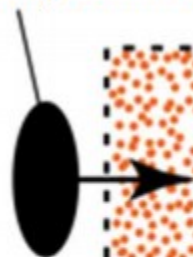
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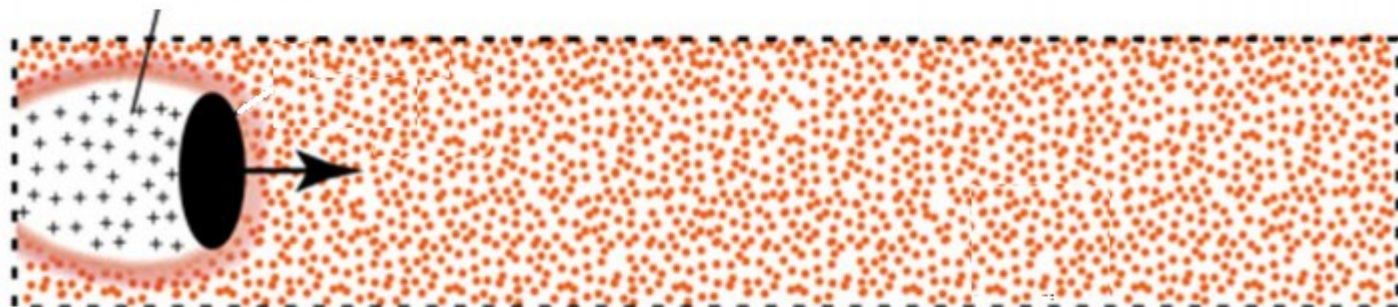
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Laser\Beam driver



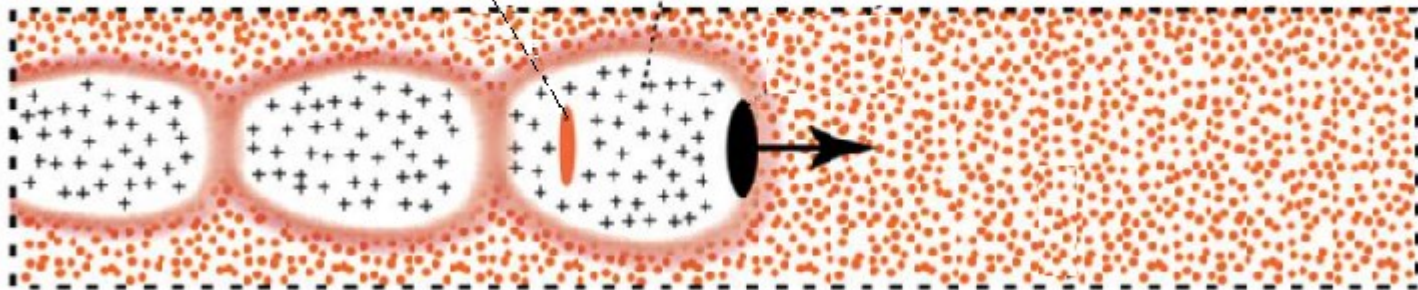
Plasma electrons

Wake



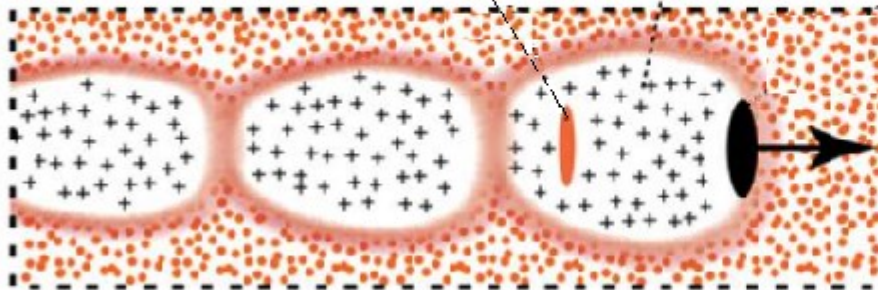
Trapped or externally
injected witness beam

Plasma cavity



Trapped or externally
injected witness beam

Plasma cavity



Electric field

RF cavities: $\sim 20 \text{ MV/m}$

Plasma: $\sim 100 \text{ GV/m}$

Experiment at Stanford Linear Accelerator Center (2006)

Energy doubling of 42 GeV electrons



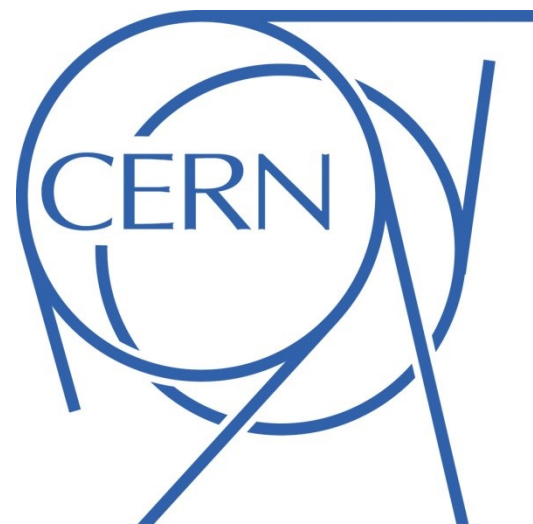
proton beams



proton beams



plasma wakefield



proton beams



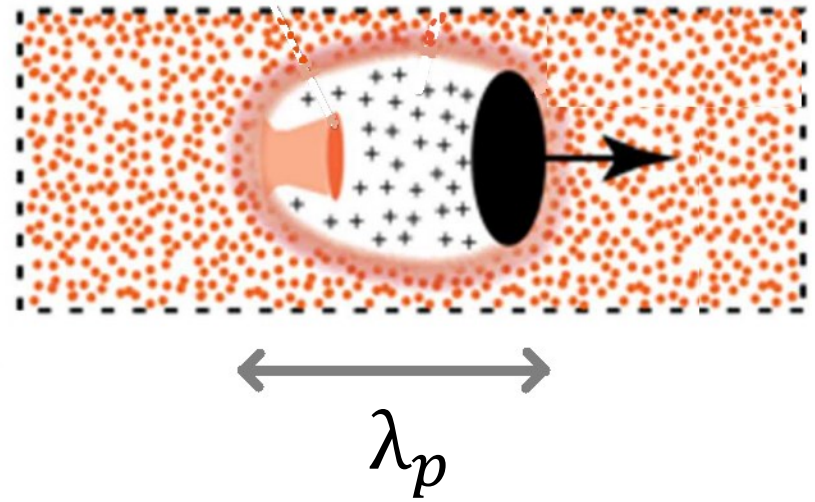
plasma wakefield



electrons

**Energy:
~TeV**

Plasma oscillation



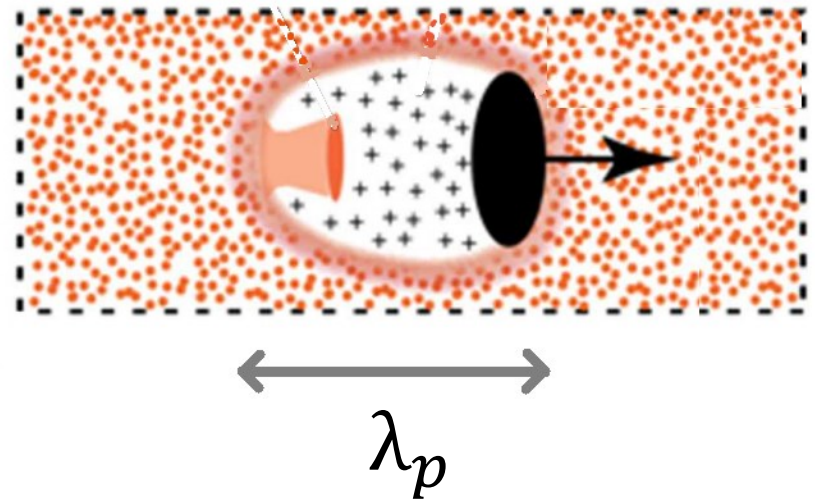
Plasma wavelength: $3.3 \times 10^4 / \sqrt{n[\text{cm}^{-3}]}$

e.g. $n \sim 10^{17} \text{cm}^{-3}$ $\lambda_p \sim 100 \mu\text{m}$

Need short beams ($< \lambda_p$) to drive beams resonantly

Proton beam: $\sim 10 \text{cm}$

Plasma oscillation



Plasma wavelength: $3.3 \times 10^4 / \sqrt{n[\text{cm}^{-3}]}$

e.g. $n \sim 10^{17} \text{cm}^{-3}$

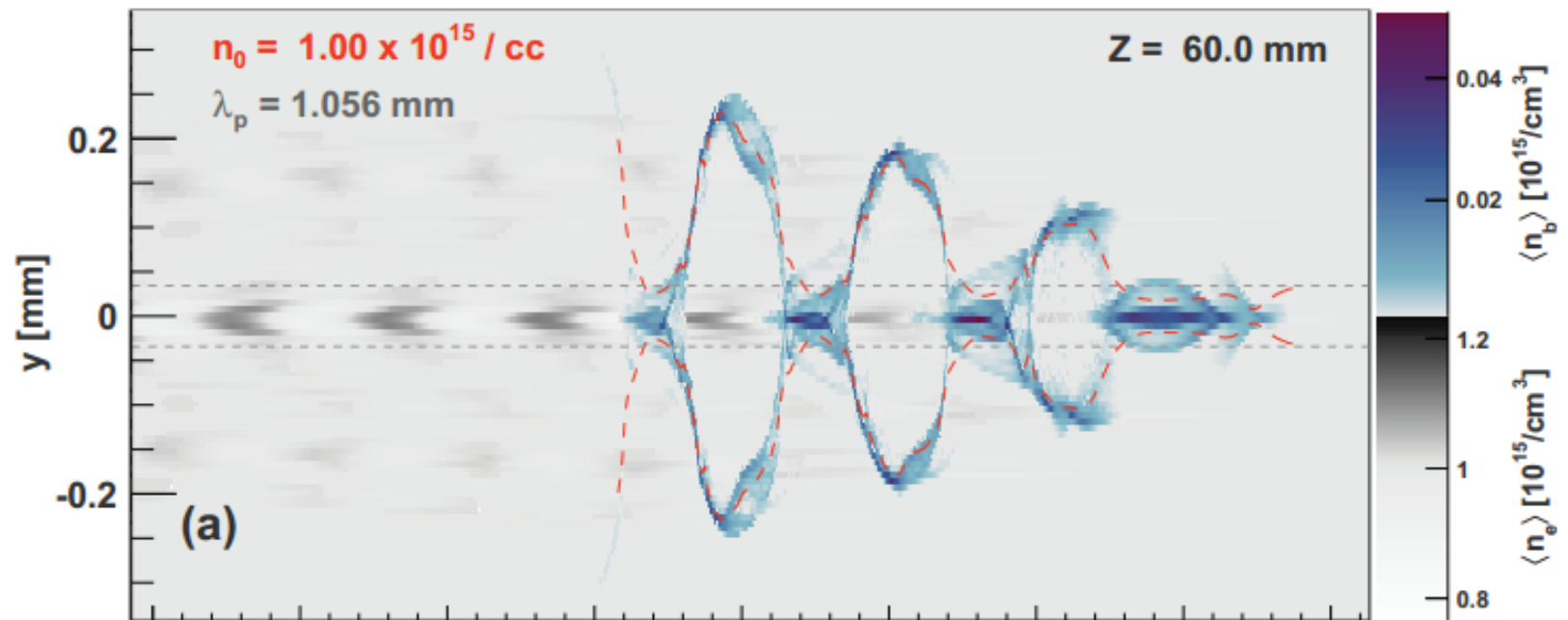
$\lambda_p \sim \mathbf{100 \mu m}$

Need short beams ($< \lambda_p$) to drive beams resonantly

Proton beam:

$\sim \mathbf{10 cm}$

Plasma acceleration
with **self-modulated long beams**
from simulations to reality



Plasma acceleration with self-modulated long beams **from simulations to reality**

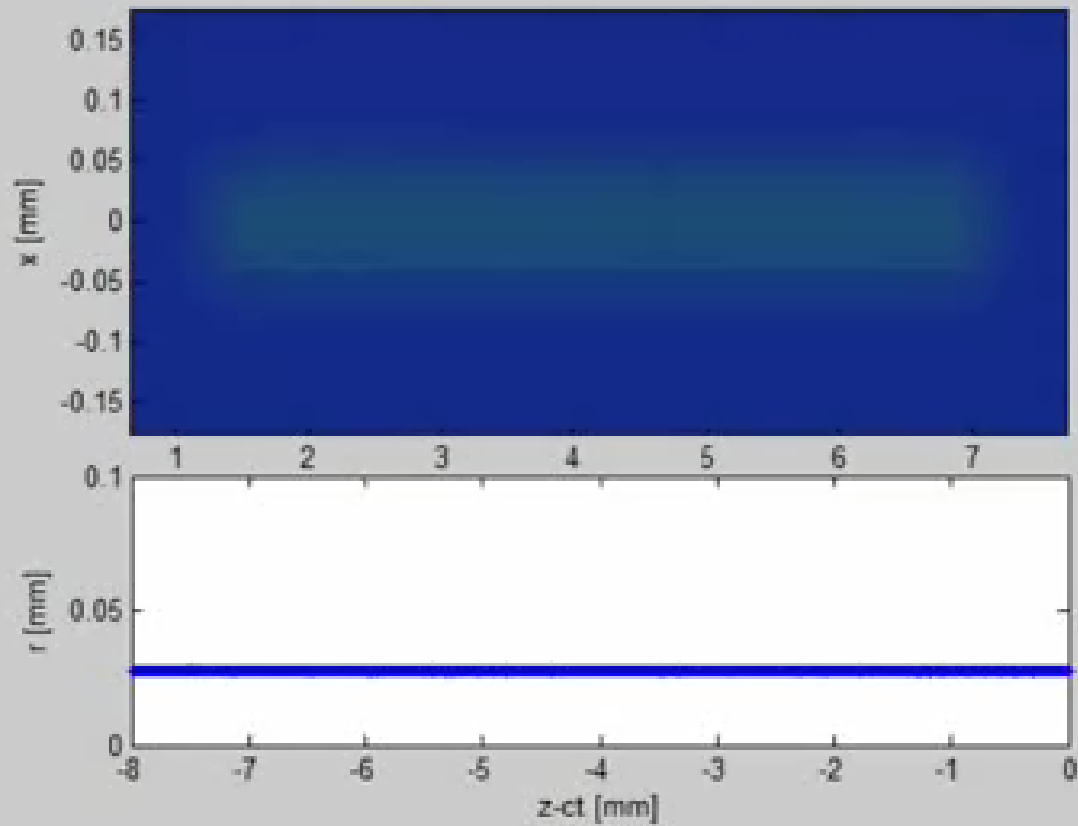
Very few experimental evidence!

Photo Injector Test facility (PITZ)

DESY, Zeuthen

$$n \sim 10^{15} \text{cm}^{-3} \quad \lambda_p \sim 1 \text{mm}$$

$$\text{Beam length} \quad \sim 6 \text{mm}$$

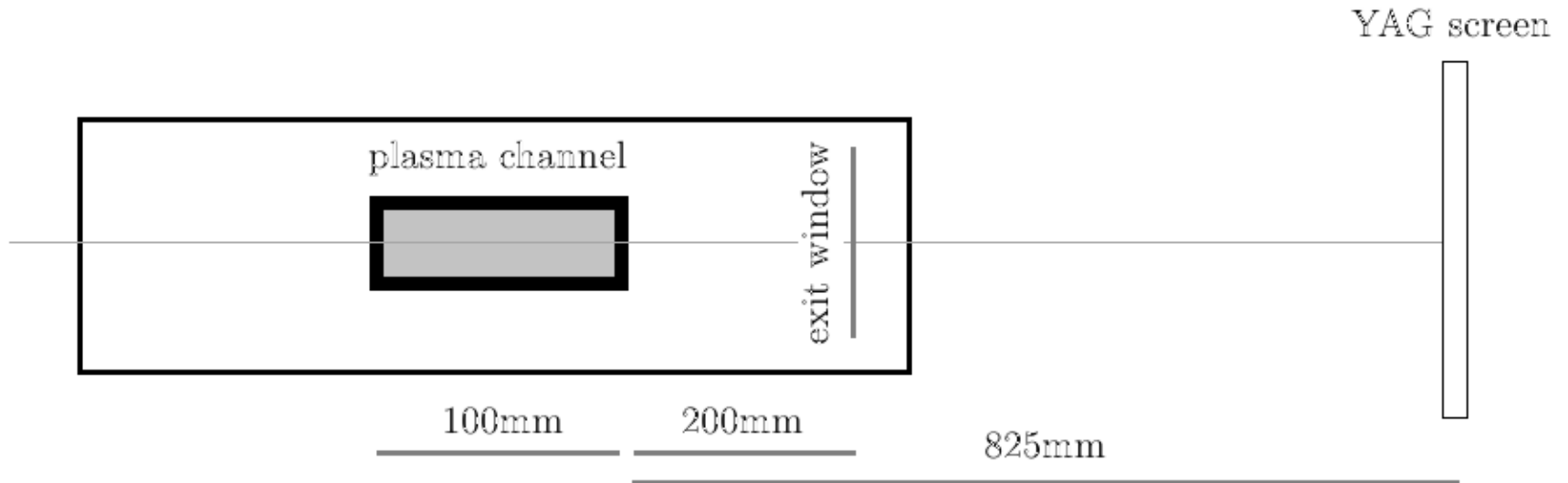


osiris
v2.0

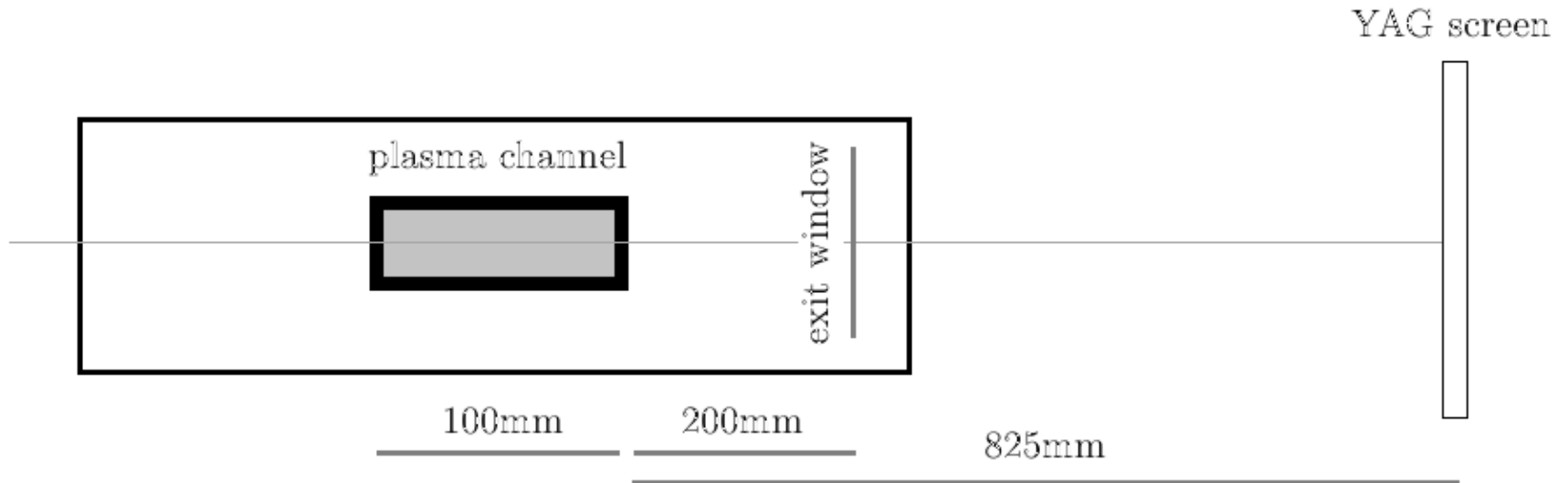


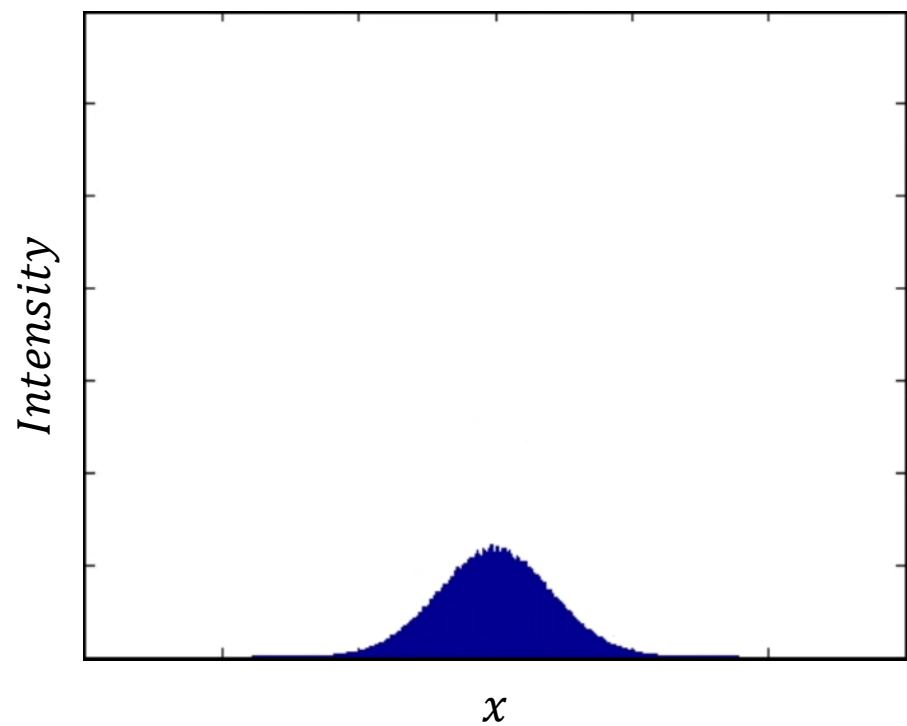
UCLA

- Energy spectrum
- Transverse profile

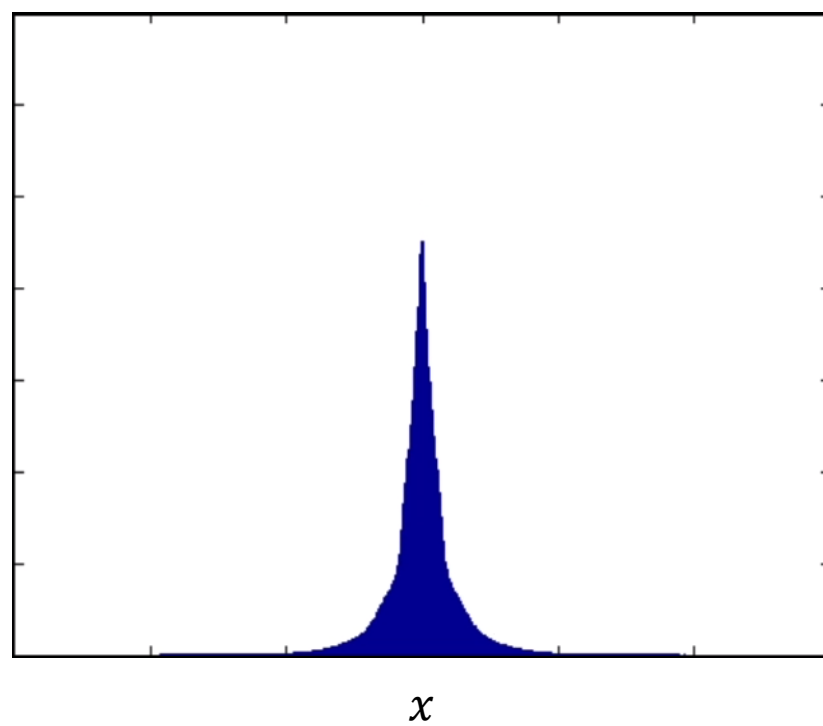


- Energy spectrum
- Transverse profile





without plasma



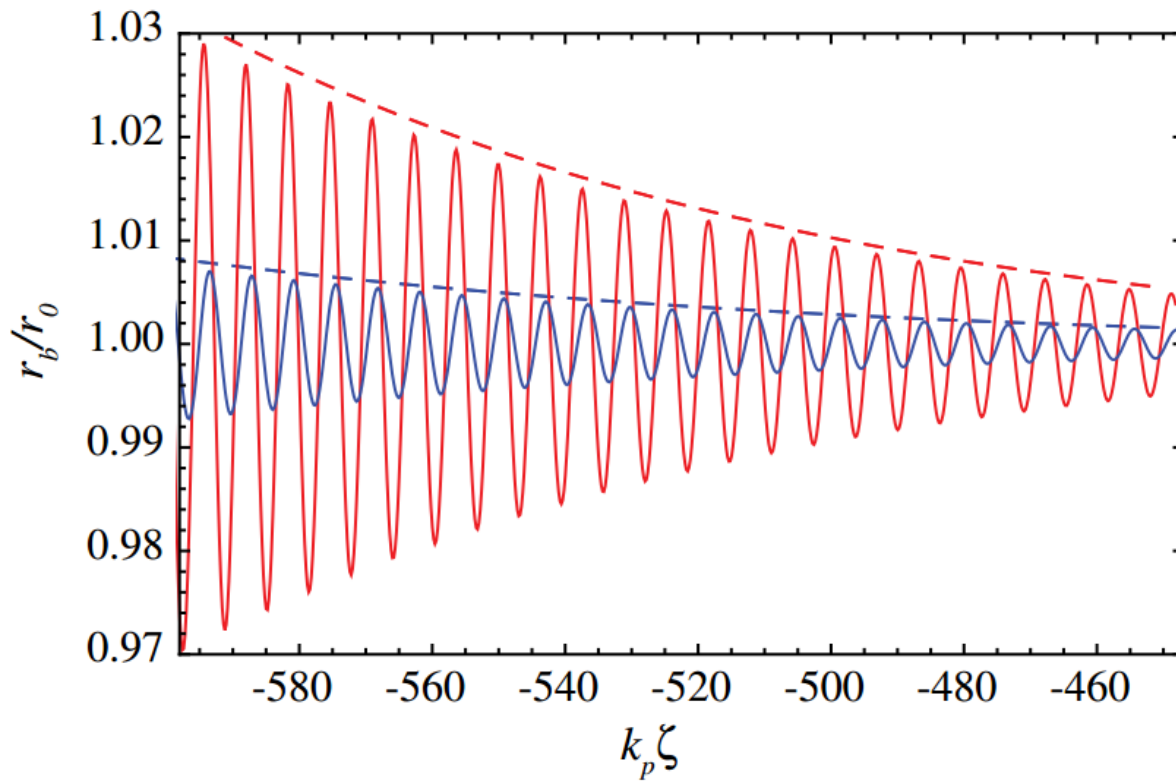
with 25mm long plasma

Conclusions

- Transverse profile analysis can be used to detect self-modulation in plasma
- Analysis may give us qualitative and quantitative understanding
- Non-linear: difficult to describe analytically

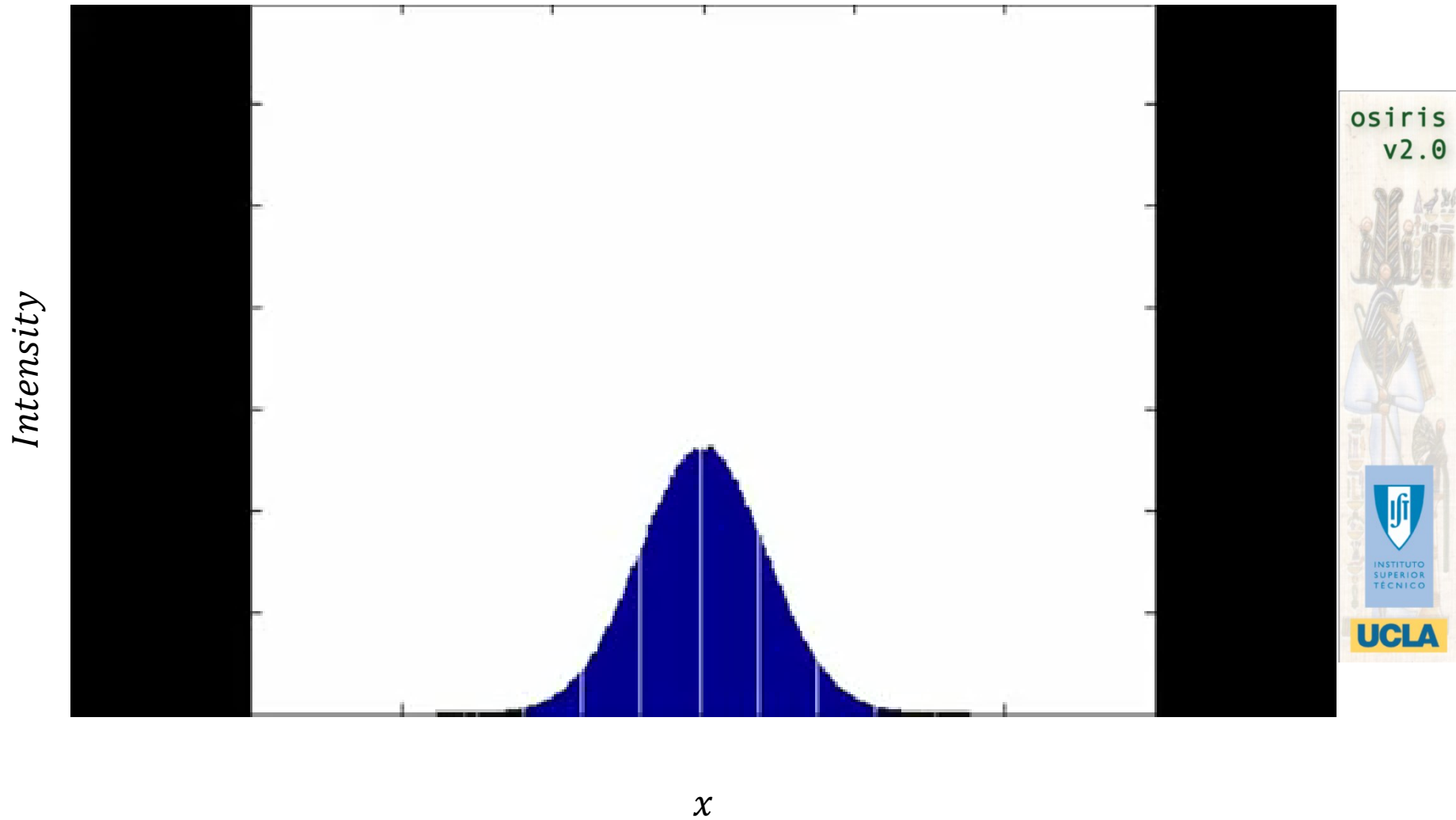
Full understanding requires further analysis

Thank you



$\sim e^N$ where

$$N = \frac{3^{3/2}}{4} \left(\nu \frac{n_{b0} m_e}{n_0 M_b \gamma} k_p^3 |\zeta| z^2 \right)^{1/3}$$



Simulation by Alberto Martinez de la Ossa

Transverse profile evolution

