Beam dynamics studies with comb electron beams for Particle driven WakeField Acceleration*

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*This poster presentation has received support from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004730.

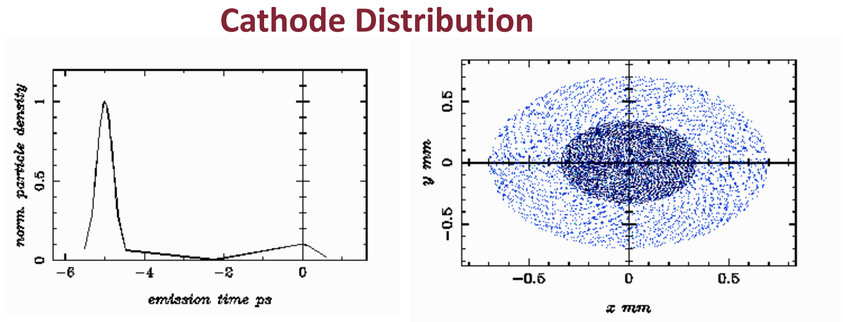
Abstract

A **comb-like electron beam** is composed by two or more high brightness electron bunches, of 10s of fs duration separated by ps scale time distance. Such a longitudinally modulated beam is used to drive plasma-based accelerating modules. In Particle-driven plasma Wakefield Acceleration (PWFA), the high-gradient WakeField is driven by an intense, high-energy charged particle beam (driver) as it passes through the plasma. A second, appropriately phased accelerating beam (witness), containing fewer particles than the drive beam, is then accelerated by the wake. The witness dynamics control is fundamental to achieve the optimum transverse and longitudinal matching needed at the plasma entrance to prevent emittance growth during the acceleration in the plasma module. Beam dynamics simulations were performed in **ASTRA** to study the witness bunch dynamics affected by the driver bunch in the velocity bunching regime. Starting from the **EUPRAXIA@SPARC_LAB** working point, i.e. a 30-pC witness and a 200 pC driver bunches, the 100 MeV injector has been studied to optimize the witness bunch emittance, spot size, energy spread and to adjust the longitudinal distance between driver and witness bunches.

1. Beam characteristics

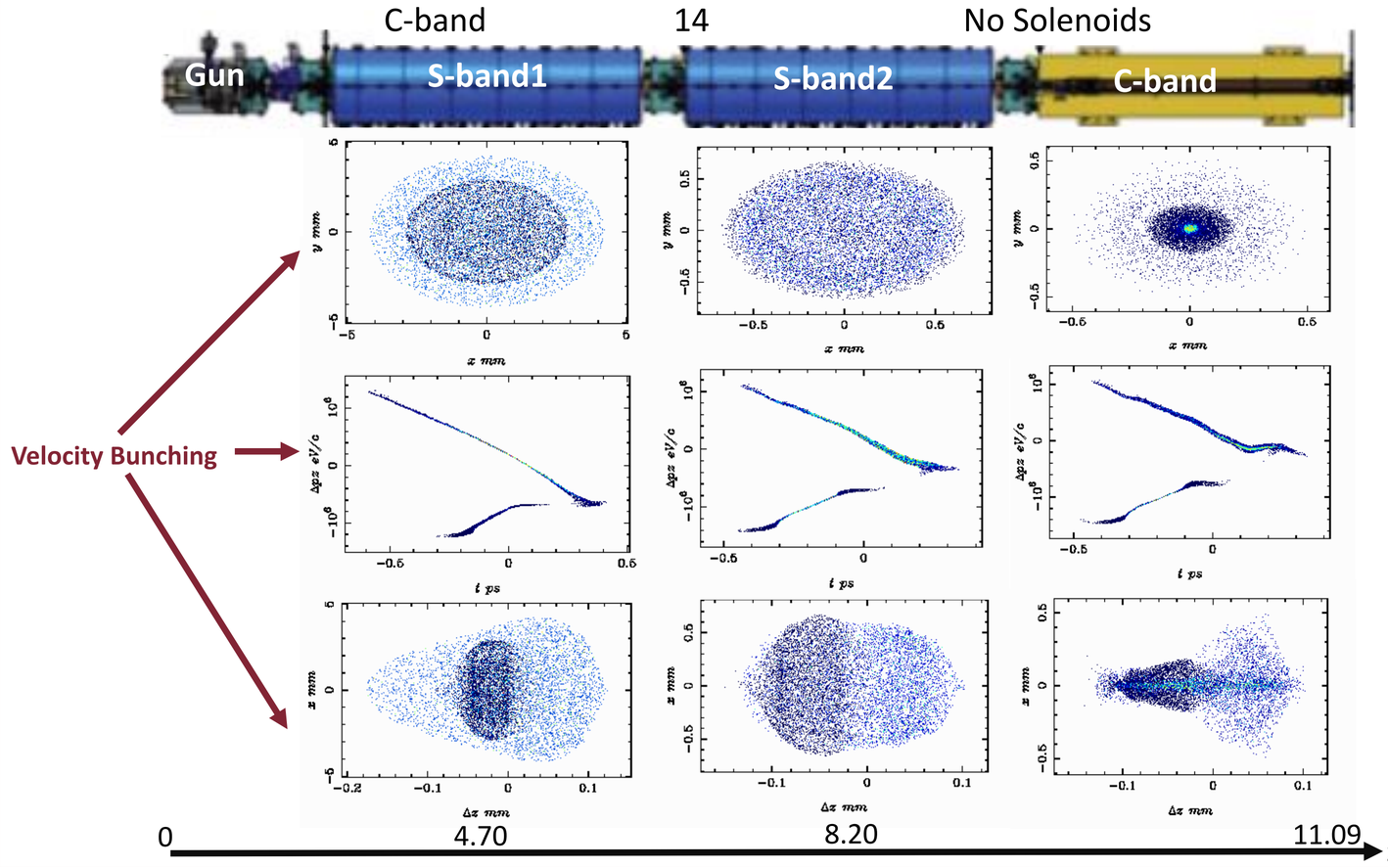
Witness	
charge	30 pC
Longitudinal distribution	gaussian
Transverse distribution	uniform
Bunch length (rms)	290 fs
Spot size (rms)	0.175 mm
n°particles	40000
Driver	
charge	200 pC
Longitudinal distribution	gaussian
Transverse distribution	uniform
Bunch length (rms)	210 fs
Spot size (rms)	0.35 mm
n°particles	40000

Cathode Distribution



2. SPARC_LAB LAYOUT

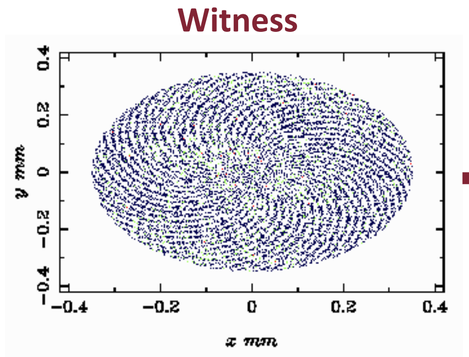
Simulation layout	E acc (MV/m)	Solenoid field (T)
Gun	114	0.2522
S-band1	28.35	0.0650
S-band2	28.35	off
C-band	14	No Solenoids



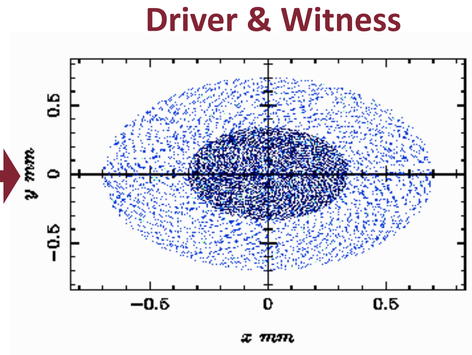
3. Simulation set up

The study starts from Witness dynamics optimization, then ASTRA simulations were tuned with comb–like distribution.

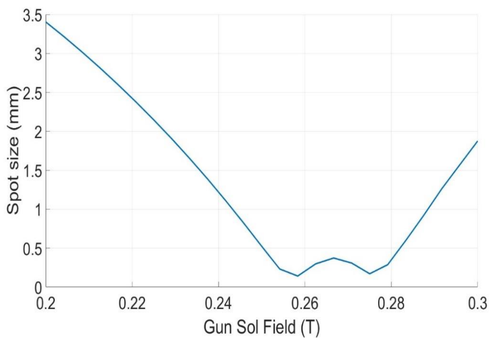
Witness

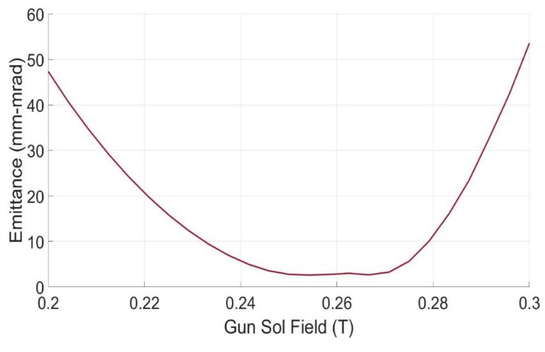


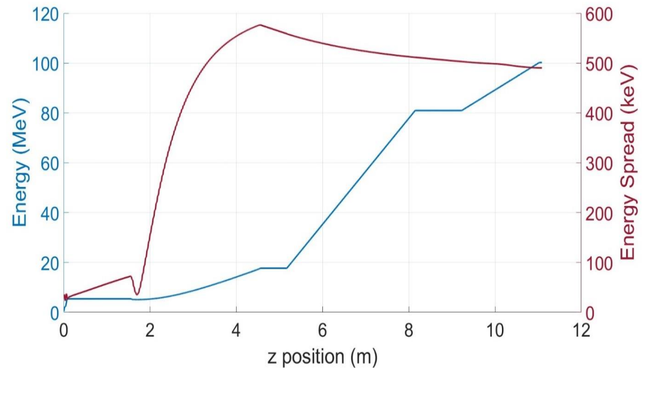
Driver & Witness



Both Gun and S-band solenoids are set to optimize emittance, spot size and bunch length of comb-like distribution at the end of 100 MeV injector.

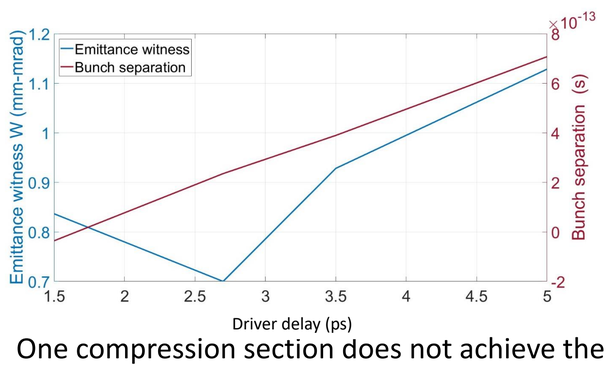


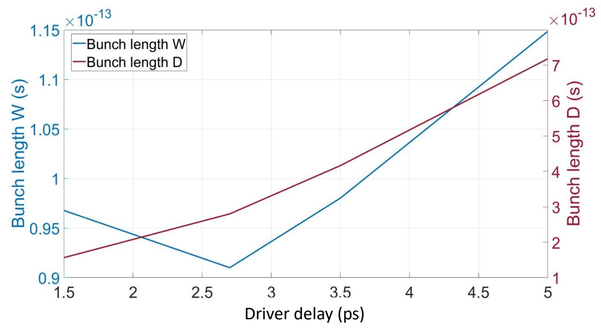




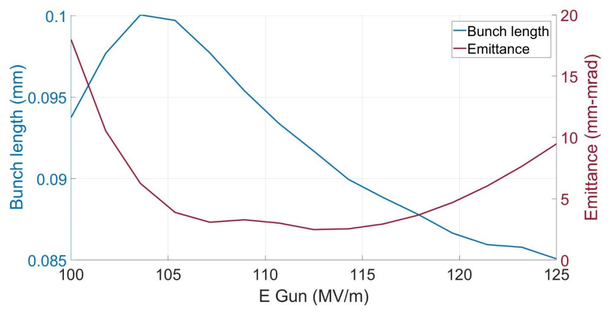
4. Simulation results

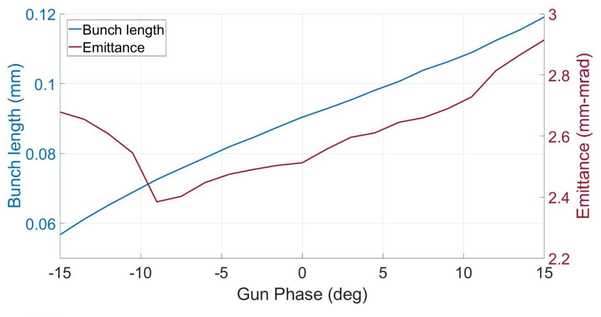
Parametric Scan with comb beam in VB regime @ injector end

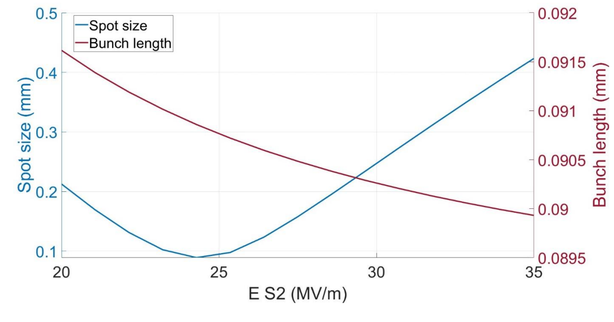


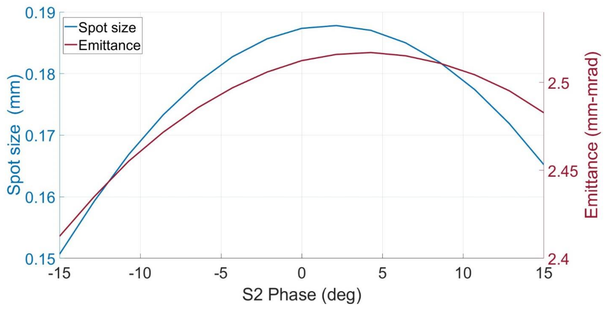


- One compression section does not achieve the beam quality needed for plasma acceleration.
- Another velocity bunching stage allows to achieve proper bunch lengths and separation at the plasma entrance.









A parametric scan of all beamline components was performed to understand how machine parameters influence comb dynamics.

References

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