SL_COMB2FEL

(Resp. Naz.: E. Chiadroni, LNF)

Sezioni proponenti=

LNF (Resp. Loc.: E. Chiadroni),

Roma (Resp. Loc.: A. Mostacci),

Roma Tor Vergata (Resp. Loc.: A. Cianchi)

Lecce (Resp. Loc.: A. Lorusso),

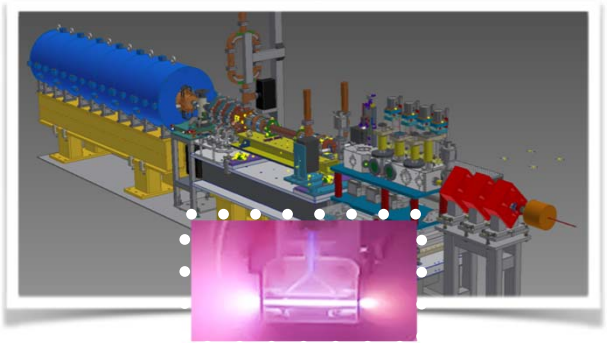
Napoli (Resp. Loc.: R. Fedele)

Situation

- Sparc_Lab is testing new technologies towards plasma acceleration
- The accelerating structures are not the only thing that must be reduced in order to have a compact machine.
- Magnets, diagnostics, dumps, everything must be reconsidered for two main reasons:
  - Compactness
  - New very challenging beam parameters
- Acceleration without control is nothing. Only high quality beam can produce FEL radiation.

From SL_COMB to SL_COMB2FEL

- **SL_COMB is a CSN5-funded experiment (ending2018)**
  - **Beam dynamics studies with start-to-end simulations**
    - Experimental beam dynamics studies with multi-bunch trains
    - Side effect: **EuPRAXIA@SPARC_LAB Conceptual Design Report**
  - Experimental and theoretical **studies** of final focus and extraction with both **active plasma lenses**
  - Experimental and theoretical studies on the **impact of plasma jets**, **gas partial ionization and passive plasma lens on** the preservation of the **emittance**
  - **Code benchmark with measurements**
  - Development of **new capillary design** for the optimization of plasma ramps
  - New cathodes (Yttrium films) fabrication and tests



EuPRAXIA@SPARC_LAB Conceptual Design Report is publicly available and can be downloaded from http://www.lnf.infn.it/sis/preprint/pdf/getfile.php?filename=INFN-18-03-LNF.pdf

Why SL_COMB2FEL

SL_COMB2FEL is a five-years experiment proposal (2019-2023), aiming at

- Demonstration of high quality of PWFA-electron beam through the final measurement of the FEL gain curve
- Great effort on the transport and matching from plasma to the undulator
- **Miniaturization** of ancillary components to move towards a **compact facility (**accelerating modules, diagnostics, measurement stations, beam position monitors)
- **R&D on diagnostics**
- **Path towards EuPRAXIA@SPARC_LAB test user facility:**

EuPRAXIA Framework

- EuPRAXIA ("European Plasma Research Accelerator with eXcellence In Applications") Horizon 2020 Design Study

- A new WP has been recently created in the project: Electron diagnostics
- A. Cianchi has been nominated WP leader

Description of the activities TOV

- Demonstration (with measurements) of the high quality of the accelerated beams => LNF, **Tor Vergata**
- **Single shot diagnostics** for bunch length and transverse emittance, **Tor Vergata**

Financial request all (Keuro/year)

	Missioni	Consumo	Attrezzature scientifiche	Costruzione apparati	TOTAL
Workshop/Conference/Collaborations	10				
Capillaries (Sapphire, plastic, tapered)		15			
Cathode deposition		5			
Discharge circuit development			12		
Advanced diagnostics				12	
Bunch length spectrometer				10	
X-band integrated BPM				10	
Compact Cavity BPM				8	
FEL transfer line and diagnostics			5	5	
TOTAL					92

TOV Request 2019

- 12 kEuro (costruzione apparati) for advanced compact diagnostics view screens
- 3 kEuro missioni
- 1 keuro consumo

Extended abstract I

- SL_COMB2FEL is a five-years experiment proposal (2019-2023), aiming at the demonstration of the high quality of PWFA-electron beams through the final measurement of the FEL gain curve.
- This research proposal is integrated in the framework of Horizon 2020 to prepare a Design Study called EuPRAXIA ("European Plasma Research Accelerator with eXcellence In Applications") for the feasibility of a plasma-based user facility and is of utmost interest for the future EuPRAXIA@SPARC_LAB test user facility.
- Based on the experience gained in SL_COMB, we foresee to study with simulations and experimental solutions the impact of plasma in- and out-ramps, plasma jets and non-uniform plasma density profiles on the acceleration efficiency and on the quality of accelerated electron beams, to drive a Free-Electron Laser. Simulation studies will thus include FEL codes.
- The path towards this challenging result requires the proper design of the transfer line downstream from the plasma accelerating module to allow the transport and matching to the given application. Indeed when exiting the plasma region, electrons move from an extremely intense focusing field to a free space where the focusing effect suddenly vanishes. These fields can be two or three order of magnitude larger than in conventional accelerators; therefore, because of mrad-scale angular divergence, the beam experiences a huge transverse size variation when propagating from the plasma outer surface to the following beam line element, a quadrupole magnet for instance. Under these conditions, the particle transverse motion becomes extremely sensitive to the energy spread, resulting in a dramatic increase of the transverse emittance, with a degradation of the overall beam quality, preventing any FEL generation. We plan to integrate at SPARC_LAB active plasma lenses in the conventional transfer line to proper design the matching to the undulator.
- Active plasma lenses will be also used as driver removal devices to help the optimization and transport only of the witness beam, which gains energy in the plasma accelerating module.

Extended abstract II

- The demonstration of the high quality beam accelerated and transported by means of plasma-based devices to the user application is performed by the diagnostics, which should accomplish the single shot and compactness requirements.
- In this regard we foresee to take profit of the knowledge acquired during SL_COMB experience on active plasma lenses to demonstrate the possibility of using them also to measure the transverse beam emittance. Indeed, combining active plasma lenses and Cherenkov radiators, placed close to the beam trajectory, a non-perturbing multi-"screen" technique can be used more efficiently than a quadrupole scan method, for a compact, non-intercepting, single shot emittance measurement.
- Plasma-based accelerators are characterized by ultra-short, in the femtosecond scale, bunch duration; the proper measurement of the longitudinal profile is of paramount importance to optimize FEL lasing conditions. We propose an experimental setup to measure very short (< 10 fs) electron bunch profiles, based on direct measurement of the coherent transition radiation spectrum in the far-infrared region. The spectrum will be obtained using dispersive prism and recorded by the detector array which allows single shot operation.
- Acceleration, characterization and transport of plasma-accelerated electron beams require extremely precise alignment tools and position monitors, which cannot be accomplished with conventional devices. To meet these requirements, ~μm level of resolution, an X-band integrated beam position monitor is planned too be design and a prototype built and tested at SPARC_LAB.