EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA

Hosting and outreach at INFN

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on behalf of the EuPRAXIA@SPRAC-LAB Collaboration

EuPRAXIA_PP Annual Meeting, September 22

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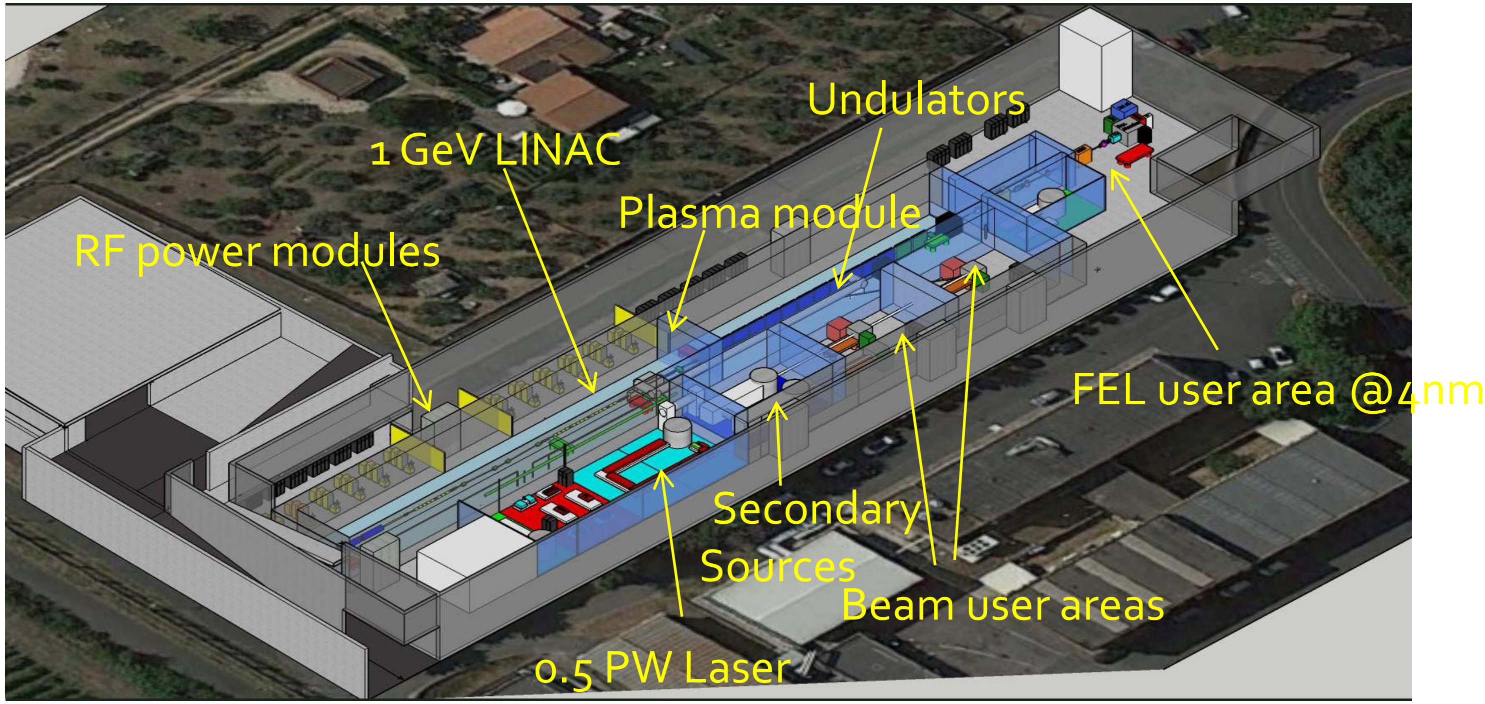
EuPRAXIA Mission

Funded by the European Union

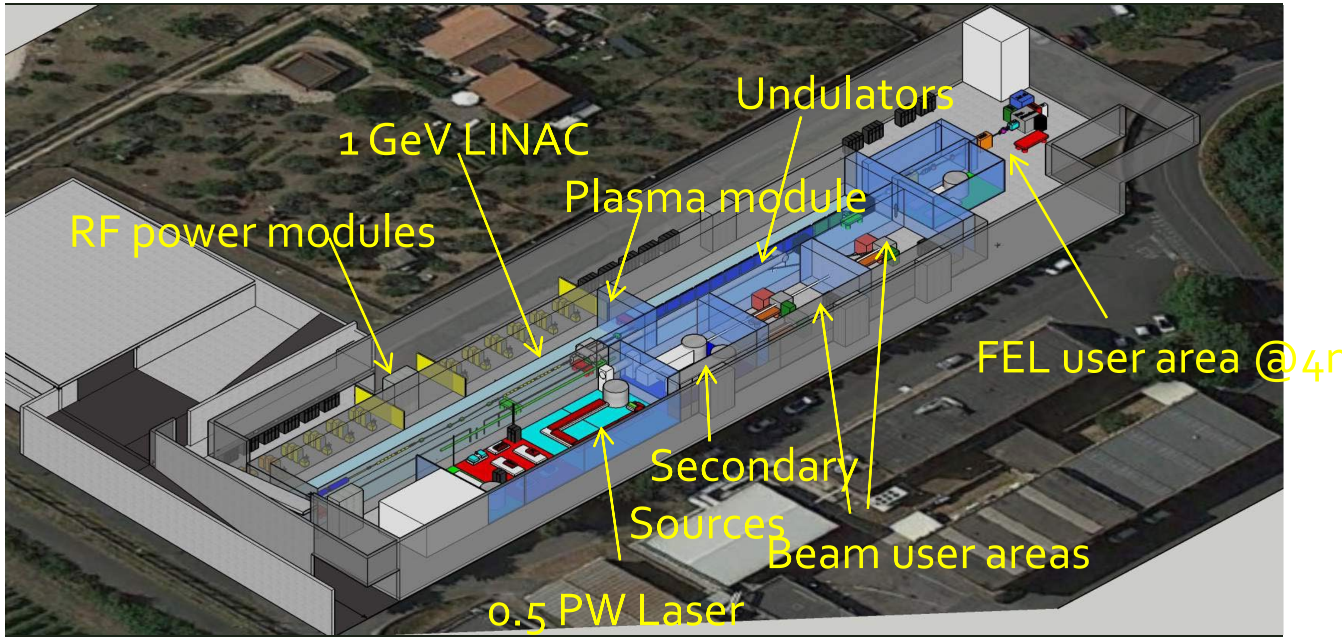
- EuPRAXIA is the first European project that develops a dedicated particle accelerator research infrastructure based on **novel plasma acceleration concepts** driven by innovative laser and linac technologies.



- High Acc. Tech. available => not limited to FEL applications on a longer term view

Possible Extensions

- High Brigthness X-band Linacs => CLIC Community, Coll. with CERN
- High Brightness Laser Systems => Inertial Fusion Community
- High rep rate modules => Plasma Collider => Alegro and Muon Collider
- Medical Applications =>VHEE, FLASH
- Positron Source
- Laboratory Astrophysics



- High Acc. Tech. available => not limited to Plasma Acceleration

EuCOLL: EuPRAXIA R&D for Plasma Collider

Funded by the European Union

EuPRAXIA, if properly supported, will be able to shading light among some still open issues relevant for a LC design:

WP1 Plasma accelerator theory and simulations (LNF, Mi, RM1,RM2, Pisa, ITS, QUB)

WP2 - High repetition rate plasma module (LNF, LNS)

WP3 High efficiency plasma acceleration, high transformer ratio mode (LNF, RM1, Mi)

WP4 Positron source and acceleration (QUB, LNF, RM2)

WP5 – Scalable laser driver technology (Pisa, LNF)

In addition it may provide fundamental information about long term machine operation and its reliability and, also very important, **training of the next generation Accelerator Scientist**.

WP2 - High repetition rate plasma module (LNF, LNS)

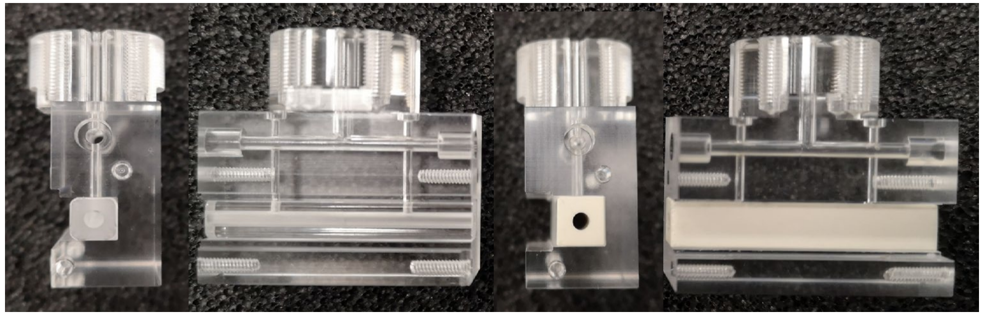
Task 2.1 - Study of a new generation of materials capable of withstanding the high temperatures produced during the plasma formation, which at the same time are machinable to produce long but very thin structures. This includes the use of 3D-printing techniques.

Task 2.2 - Study of plasma source segmentation techniques for making devices having lengths of several meters, where plasmas with controllable densities can be produced. A crucial part of this study is the development of high-voltage source systems for plasma formation.

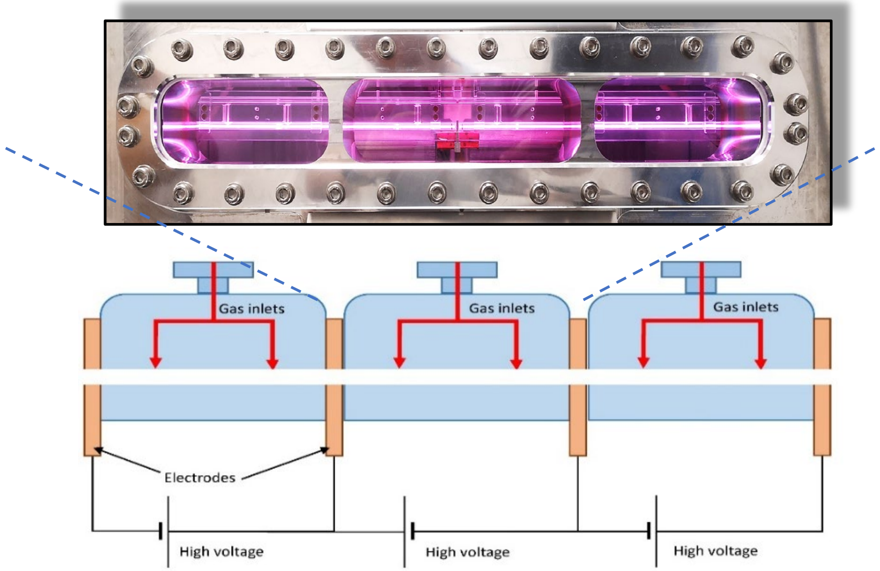
Task 2.3 - Optimization of the capillary discharge technique for high-power lasers, focusing on enhancing the density profile and mechanical resistance of the capillary. The objective is to increase the total electron charge and energy.

Task 2.4 - Investigate new approaches to capillary electron acceleration by incorporating oriented nanotube structures. This involves coupling capillary discharge with aligned capillary designs to improve beam emittance.

Sapphire | **Ceramics**



60 cm long Plasma module (1 GV/m), tested



Courtesy Biagioni and Crincoli

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WP4 Positron source and acceleration (QUB, LNF, RM2)

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Task 4.1 Positron beam production at EuAPS facility

Once the electron beam and x-ray characteristics have been optimised in terms of peak brightness and energy, the electron beam will also be used to generate high-energy positron beams during their interaction with mm-scale high-Z solid targets.

Task 4.2 Positron beam characterisation

The generated positron beams will be characterised by measuring, simultaneously, energy spectrum, total charge and energy-dependent divergence and source size, using a diagnostic method pioneered by the group of Prof. Sarri (see, e.g., Refs. [4]).

Task 4.3: selection and guiding of narrowband, low emittance positron beams.

Following the first proof-of-principle experimental demonstration [9] and numerical modelling [11], we aim to produce pC-scale positron beams with a 5% bandwidth at 1 GeV, micron-scale normalised emittance and femtosecond-scale duration. These are characteristics required for efficient injection in following plasma accelerator modules

Task 4.4: feasibility study of positron Wakefield acceleration .

A first design of a plasma module for the post-acceleration of the positron beam will be prepared towards the first demonstration of an all-optical staged acceleration beamline

WP4: Laser-driven positron sources

- Plasma-based positron acceleration is **a challenging task!**
- Most research has been carried out numerically
- In preparation for the design of a plasma-based (or plasma-assisted…) positron arm for a collider, **it is necessary to experimentally test** these accelerators, in order to identify the best and most practical ways to accelerate positrons in a plasma.
- **A first step** would thus be to provide positron beam facilities to the community

For meaningful experimental studies, it is necessary to provide witness beams with remarkably demanding characteristics:

- short duration: $\sigma_z \sim 10\ \mu m$
- low normalized emittance: $\varepsilon_n \sim \mu m$
- "reasonable charge": $Q \sim 0.1 - 20$ pC
- "reasonable energy": E ~ 100s of MeV
- low energy spread: $\Delta E/E \sim$ few %
- fs-scale synchronization and μm-scale overlap with driver beams

A possible roadmap for the experimental development of high-quality positron beams could be:

1. **SHORT TERM** (5-10 years) — *Development of positron test beam facilities in Europe (e.g EuPRAXIA, EPAC…)*
2. **MEDIUM TERM** (10 – 20 years) — *- Converging onto specific acceleration schemes* *- Experimental demonstration of 10s of GeV high-quality beams*
3. **LONG TERM** (>20 years): — *- Demonstration of ~100 GeV high quality beams in a hybrid scheme (conventional injector + plasma accelerating modules)*

Gianluca Sarri

QUEEN'S UNIVERSITY BELFAST

EuPRAXIA sources

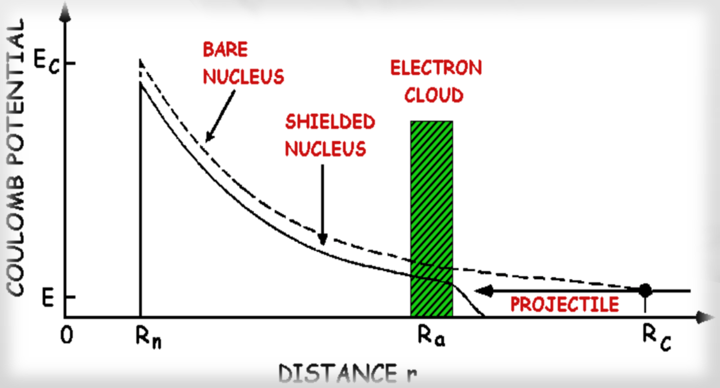
CSN3 Fisica Nucleare

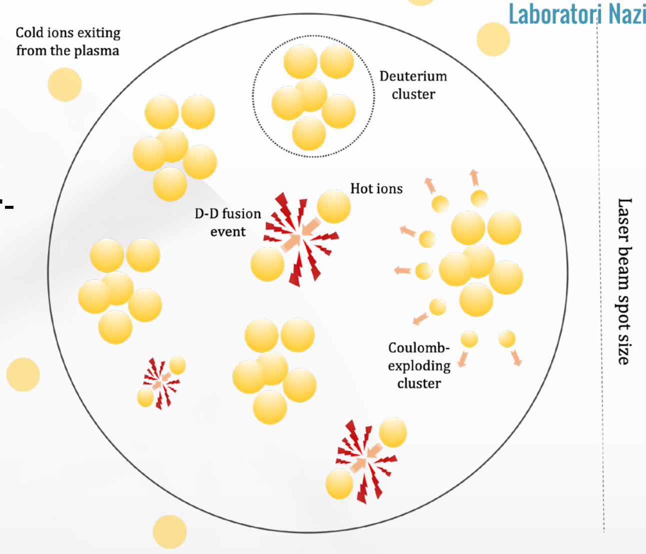
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

In the measurements of fusion processes, the understanding of the impact of the **electron screening** is crucial to properly extrapolate cross-sections in the kinematic region relevant for nuclear astrophysics. By performing these measurements in a laser-induced plasma one can estimate the electron screening contribution.

Example measurement: deuterium fusion

1. High-power laser is used to ionize deuterium
2. A Coulomb explosion takes places, due to the strong electric field produced by the ionized deuterium nuclei
3. Deuterium ions are accelerated, gaining enough kinetic energy to overcome the electrostatic barrier and undergo a fusion process





The laser can be used to produce plasma and will allow to perform measurements as

1. *Fusion processes of astrophysical interest in plasma*
2. *Nuclear decays in plasma*

Courtesy Silvia Pisano

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Thank for your attention