# Beyond EuPRAXIA_PP: the PACRI Project

## **P**lasma **A**ccelerator systems for **C**ompact **R**esearch **I**nfrastructures

*Gerardo D'Auria, Elettra – Sincrotrone Trieste*

*Massimo Ferrario, INFN Frascati*

*Leo Gizzi, CNR Pisa*

# Horizon Europe Call

**Horizon Europe Work Programme 2023-2024**
**INFRA-2024-TECH-01-01**
**Development of ground-breaking RI Technologies,…..**
**Including high tech developments for accelerators**

- Research and development of new scientific instrumentation, tools and methods for research infrastructures taking into due account **resource efficiency** (e.g. **energy consumption**) and **environmental impact.**
- Their **technology validation and prototyping.**
- **Training of RI staff** for the operation and use of these new solutions.
- The innovative potential for **industrial exploitation** of the solutions and/or for the benefits of the society.

**PACRI**
**Plasma Accelerator systems for Compact Research Infrastructures**

**EU contribution 10 M€**

# PACRI areas of interest

**1. Compact & efficient plasma accelerators (M. Ferrario - INFN)**

With focus on the high rep-rate plasma modules, as required for the EuPRAXIA project.

**2. Compact & efficient X-band technology for accelerators (G. D'Auria - Elettra)**

With focus on normal conducting RF technology for linear accelerators.

**3. Efficient & high repetition rate Lasers (L. Gizzi - CNR)**

With focus on high repetition rate laser technology, required to drive high-gradient and high-repetition-rate Laser Plasma Acceleration (LPA) related to the above-mentioned applications.

**The project was submitted beginning of March 2024**

Elettra Sincrotrone Trieste

# Evaluation Results

## Total score 14.50 (Threshold 10.0/15.0)

### Criterion 1 - Excellence

### Score: 5 (Threshold 3.0/5.0)

*The overall objective of PACRI is to promote the development of new acceleration schemes ad innovative breakthrough technologies for accelerators, Taking energy consuption, resource efficiency, costs and environmental impact into account.* ***The overall objective and the specific goals are very clear and pertinent and fully aligned with the overall aim of the INFRA-TECH call as well as with the scope of the TECH-01-01 topic……***

### Criterion 2 - Impact

### Score: 5 (Threshold 3.0/5.0)

***The proposal outlines its expected outputs in an excellent way, including prototypes of high repetition rate plasma modules, a high efficiency klystron and high rep-rate modulator, high power high rep –rate laser systems, and open-source codes for plasma module design……..***

### Criterion 3 – Quality and efficiency of the implementation

### Score: 4.5 (Threshold 3.0/5.0)

The work plan is sound and realistic, albeit ambitious. The breakdown into 14 WPs is logical ……Each WP involves multiple participants: mostly from rather different background which is beneficial for the synergy and coherence…..Milestones and deliverables are generally appropriate: **however, for several tasks there is a lack of intermediate control points, such as milestones or deliverables, which makes it difficult to track the progress of certain tasks throughout the project's lifetime. There is also an occasional lack of interconnection and collaboration between separate WPs, which are not always adequately eplained………**

# Project context

PACRI is a collaborative effort involving 19 International Research Laboratories and Universities, supported by 7 Industrial Partners. It is closely connected to two ESFRI Research Infrastructures:

**EuPRAXIA and the Extreme Light Infrastructure, ELI-ERIC**

**Project duration: 4 Years (2025-2028)**

**Overall project value 11 M€**

**10 M€ EU contribution + 1 M€ from PSI**

Elettra Sincrotrone Trieste

# PACRI objectives and ambitions

- Further developments on **high-repetition-rate plasma modules**, as the one foreseen by the **EuPRAXIA project**, extending its scientific domain to high average brightness radiation sources with possible future applications also to high energy physics.

- Improve the performance of normal conducting technology for linacs (**X-band**), aiming at extending their operating capabilities **up to the kHz regime** with the focus on **efficiency and energy consumption**, boosting the diffusion of extremely compact linacs and related X-ray facilities.

- Further developments on **high-power - high repetition rate laser technology,** to support the above-mentioned applications.

# PACRI Collaboration

25 Partners
+
1 Associated Partner

19 Universities and Scientific Labs.
+
7 Industries

| # | Partner | Acronym |
|---|---|---|
| 1 | Elettra - Sincrotrone Trieste SCpA (Coordinator) | ST |
| 2 | European Organization for Nuclear Research | CERN |
| 3 | Istituto Nazionale Fisica Nucleare | INFN |
| 4 | University of Liverpool | ULIV |
| 5 | Thales-MIS | Th-MIS |
| 6 | Scandinova Systems AB | SCND |
| 7 | VDL ETG Technology & Development BV | VDL |
| 8 | COMEB | COMEB |
| 9 | United Kingdom Research and Innovation | UKRI |
| 10 | Consiglio Nazionale delle Ricerche | CNR |
| 11 | Extreme Light Infrastructure ERIC | ELI-ERIC |
| 12 | Centre National de la Recherche Scientifique CNRS | CNRS |
| 13 | Thales LAS France SAS | Th-LAS |
| 14 | Amplitude | Amplitude |
| 15 | Centro de LÁSERES Pulsados | CLPU |
| 16 | Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Hoechstfrequenztechnik | FBH |
| 17 | Associacao do instituto superior Tecnico para a Investigacao e Desenvolvimento | IST |
| 18 | Università degli Studi di Roma La Sapienza | USAP |
| 19 | Heinrich-Heine-Universitaet Duesseldorf | UDUS |
| 20 | Deutsches Elektronen-Synchrotron DESY | DESY |
| 21 | The Chancellor, Masters and Scholars of the Univ. of Oxford | UOX |
| 22 | Ludwig-Maximilians-Universitaet Muenchen | LMU |
| 23 | GSI Helmholtz Centre for Heavy Ion Research | GSI |
| 24 | Università degli Studi di Roma Tor Vergata | UTOR |
| 25 | SourceLAB | SourceLAB |
| 26 | Paul Scherrer Institut (Associated partner) | PSI |

Elettra Sincrotrone Trieste

# PACRI work packages

| WP No. | Work Package | Lead Partic. Short Name | Person Months | Start Month | End month |
|---|---|---|---|---|---|
| 1 | Coordination and project management | ELETTRA | 68 | 1 | 48 |
| 2 | Scientific and industrial exploitation | ULIV | 49 | 1 | 48 |
| 3 | Plasma accelerator theory and simulations | IST | 126 | 1 | 48 |
| 4 | High repetition rate plasma structures | INFN | 156 | 1 | 48 |
| 5 | Plasma acceleration diagnostics and instrumentation | CNRS | 206 | 1 | 48 |
| 6 | High efficiency RF generator | Thales-MIS | 26 | 1 | 48 |
| 7 | High repetition rate modulator | Scandinova | 25 | 1 | 48 |
| 8 | X-band RF Pulse Compressor (BOC) | INFN | 31 | 1 | 48 |
| 9 | RF tests and validation | CERN | 29 | 1 | 48 |
| 10 | High repetition rate high power Ti:Sa amplifier module | UKRI | 55 | 1 | 48 |
| 11 | Efficient kHz laser driver modules for plasma acceleration | CNR | 70 | 1 | 48 |
| 12 | High-rep rate pump sources for laser drivers | ELI-ERIC | 51 | 1 | 48 |
| 13 | Prototype of high average power optical compressor | Thales-LAS | 40 | 1 | 48 |
| 14 | Laser Driver System Architecture,transport and engineering | CNRS | 68 | 1 | 48 |

Plasma (WP 3–5)

X-band (WP 6–9)

Lasers (WP 10–14)

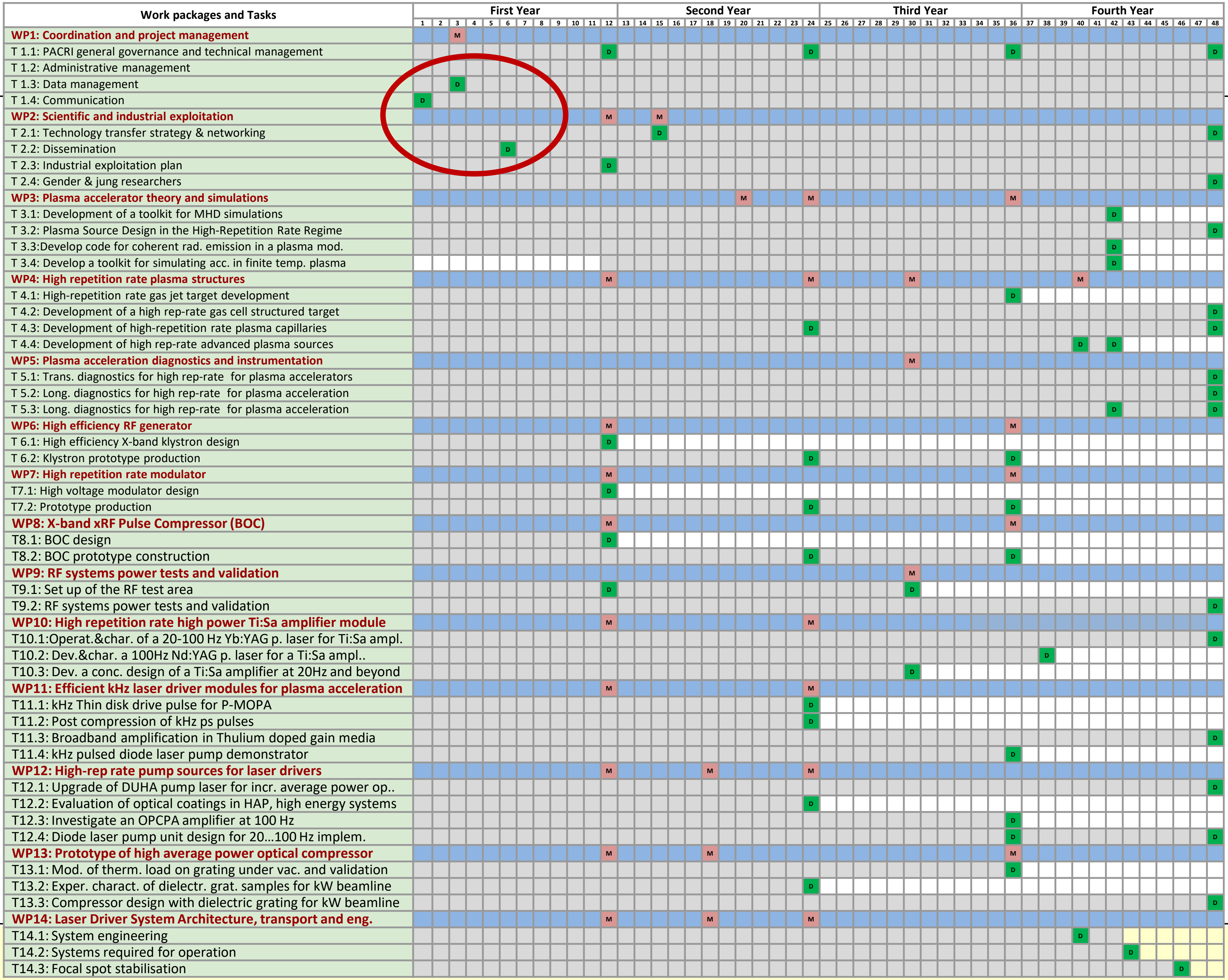
**Total 1000 person months**

Elettra Sincrotrone Trieste

# PACRI Gantt chart

D 54 Deliverables

M 40 Milestones



# WPs and Tasks

## WP1: Coordination and project management (Elettra):

To ensure, through suitable actions and measures, a timely and complete achievement of the objectives of all project WPs, an efficient exploitation of the results, maximal benefits for science and society, and the fulfilment of all obligations towards the European Commission and other stakeholders.

- Task 1.1: General governance and technical management
- Task 1.2: Administrative management
- Task 1.3: Data management
- Task 1.4: Communication

## WP2: Scientific and industrial exploitation (ULIV):

To follow, steer and promote the scientific development of PACRI for existing and future Research Infrastructures. It will also monitor, steer and promote the industrial exploitation of PACRI technologies in European industry.

- Task 2.1: Technology transfer strategy & networking
- Task 2.2: Dissemination
- Task 2.3: Industrial exploitation
- Task 2.4: Gender & joung researchers

# WPs and Tasks_Plasma

## WP3: Plasma accelerator theory and simulations (IST):

To develop, in the EuPRAXIA context, software tools to perform long-time scale (ps-ms) simulations to model the temporal evolution of discharge-based plasma sources in 3D geometries

- Task 3.1: Development of a toolkit for hydrodynamic simulations
- Task 3.2: Design in the High-Repetition Rate Regime
- Task 3.3: Development of codes for radiation emission in a plasma module
- Task 3.4 Development of a toolkit for simulating acceleration in finite temperature plasma

## WP4: High repetition rate plasma structures (INFN):

To design and test high repetition rate plasma components for the EuPRAXIA project

- Task 4.1: high-repetition rate Gas jet target development
- Task 4.2: Development of a high-repetition rate gas cell structured target
- Task 4.3: Development of high-repetition rate plasma capillaries
- Task 4.4: Development of high-repetition rate advanced plasma sources

## WP5: Plasma Accelerator diagnostics and instrumentation (CNRS):

To design and test high repetition rate plasma components for the EuPRAXIA project

- Task 5.1: Transverse diagnostics for high repetition rate for plasma accelerators
- Task 5.2: Longitudinal diagnostics for high repetition rate for plasma acceleration
- Task 5.3: Development of virtual instrumentation and AI driven control systems

# WPs and Tasks_RF I

## WP6: High efficiency RF generator (Thales-MIS):

With the specific goal of designing a high-efficiency, high-repetition-rate X-band klystron, making a prototype and testing it at full power.

- Task 6.1: High efficiency X-band klystron design
- Task 6.2: Klystron prototype production

## Klystron main operating parameters

| | |
|---|---|
| RF peak power: | 25 MW |
| Pulse length: | from 2.5 μs to 3.5 μs |
| RF efficiency: | > 50% |
| Pulse rep. rate: | 400 Hz* |

*With the possibility of extending it up to 1 kHz

## WP7: High repetition rate modulator (Scandinova):

With the specific goal of designing and building a high repetition rate Solid State Modulator (SSM) capable of driving the high efficiency X-band klystron prototype.

- Task 7.1: Modulator design
- Task 7.2: Prototype production

## Modulator main operating parameters

| | |
|---|---|
| Pulse peak power: | ≥ 50 MW |
| H.V. pulse length: | from 2.5 μs to 3.5 μs |
| Pulse rep. rate: | 400 Hz (up to 1 kHz) |

# WPs and Tasks_RF II

## WP8: RF pulse compressor (BOC) (INFN):

With the specific goal of designing and building an innovative high repetition rate RF pulse compressor (BOC), clumped (not brazed),

- Task 8.1: BOC design
- Task 8.2: BOC prototype construction
- Task 8.3: BOC low power RF characterization.

## WP9: High power RF tests and validation (CERN):

With the specific goal of testing and validating, at CERN, in operational environment, the whole RF power plant, the high efficiency klystron, the SSM and the BOC.

- Task 9.1: Set up of the RF testing area
- Task 9.2: RF systems power tests

**In addition, where possible, training of technical staff in the use of the new systems will be organised during the installation and power tests of prototypes.**

# WPs and tasks_Laser I

**WP10: High repetition rate high power Ti:Sa amplifier module (UKRI):**

The goal of this work package is to develop a scalable testbed for a Ti:Sapphire (Ti:Sa) amplifier operating from 20 to 100 Hz and assess its operational performance.

- Task 10.1: Operation and characterization of a 20-100 Hz Yb:YAG pump laser for a Ti:Sa amplifier.
- Task 10.2: Development and characterization of a 100 Hz Nd:YAG pump laser for a Ti:Sa Amplifier.
- Task 10.3: Developing a conceptual design of a Ti:Sa amplifier at 20 Hz and beyond.

**WP11: Efficient kHz laser driver modules for plasma acceleration (CNR):**

The goal of this WP is to develop components for kHz ultrashort pulse laser drivers for plasma accelerators.

- Task 11.1: kHz thin disk drive pulse for P-MOPA.
- Task 11.2: Post compression of kHz ps pulses.
- Task 11.3: Broadband amplification in Thulium doped gain media.
- Task 11.4: kHz pulsed diode laser pump demonstrator.

**WP12: High-rep rate pump sources for laser drivers (ELI-ERIC):**

The goal of this work package is to address challenges shared by Ti:Sapphire and OPCPA pump lasers, specifically pump lasers based on Yb:YAG.

- Task 12.1: Upgrade DUHA pump laser for increased average power operation.
- Task 12.2: Evaluation of optical coatings in high average power, high energy systems.
- Task 12.3: Investigate an OPCPA amplifier at 100 Hz.
- Task 12.4: Diode laser pump unit design for 20…100 Hz implementation.

# WPs and tasks_Laser II

**WP13: Prototype of high average power optical compressor (Thales-LAS):**

To develop technology for high repetition rate, high average power optical compression for Chirped Pulse Amplification lasers using advanced grating technology.

- Task 13.1: Modelling of thermal load impact on grating under vacuum and validation with existing systems.
- Task 13.2: Experimental characterization of dielectric grating samples with density power compatible with kW beamline.
- Task 13.3: Compressor design based on dielectric grating technology for kW beamline.

**WP14: Laser driver system architecture, transport and engineering (CNRS):**

This WP provides a complete path to the overall architecture of a laser driver that incorporates the components developed in WP10 to WP13 , to deliver a high quality laser pulse to the focal point (plasma).

- Task 14.1: System engineering.
- Task 14.2: Systems required for operation.
- Task 14.3: Focal spot stabilisation.

Elettra Sincrotrone Trieste

# PACRI ongoing activities

- Grant Agreement Preparation Phase
  - Grant Signature expected by the end of October 2024
- Consortium Agreement in Preparation

For more info:
Cecilia Blasetti (Project Management Office)
cecilia.blasetti@elettra.eu

We are also working on:

- The project Web page and logo

**Project starting date: 01-03-2025**

# Acknowledgements

Thanks to all the persons who worked for the preparation and submission of the project.

Special thanks go to Massimo, Leo and Cecilia for their commitment and fundamental support, and to Regina Rochow who worked with us on a earlier version of the PACRI project (CREATE).

There is a lot of work ahead of us, but I hope that PACRI can make a significant contribution to the development of new accelerators.

# *Thanks for your attention*

# PACRI

# PACRI