CIEMAT-FP proposal for 2026 María de Maeztu call

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“María de Maeztu” Units of Excellence

- **Definition & Scope:**
  - **Recognition** awarded by the Ministry of Science, Innovation, and Universities to identify top-tier research units.
  - Targets **research units** within larger institutions (e.g., university departments or institutes)
- **Key Objectives:**
  - Strengthen **international scientific leadership** and global impact.
  - Attract and retain world-class **research talent**.
  - Enhance **knowledge transfer** to industry and society.
- **Duration & Accreditation:**
  - Accreditation is valid for **six years** (some earlier calls specified four).
  - Strategic plans are typically executed over a **four-year period**.
- **Funding & Support:**
  - Provides approximately **€500,000 per year** (€2M total over 4 years) to implement strategic research programs, with additional predoctoral training funds.

CFP MdM history

- The CIEMAT Particle Physics Unit (CIEMAT-FP) was awarded the "María de Maeztu" Unit of Excellence accreditation in the 2015 call for the 2016–2021 period
- This distinction placed CIEMAT-FP among Spain's most cutting-edge research institutions, highlighting its scientific impact and international leadership in the fields of experimental particle and astroparticle physics
  - Substantial growth in personnel, improved organization and synergies
- Subsequent proposals to renew the accreditation failed to be funded
  - Increased competition from other scientific fields
  - 2024 proposal based on two parallel strategic lines:
    - Scientific analysis at the physics frontier
    - Detector and instrumentation developments at the innovation frontier
  - Very good evaluation (85.6/100)
    - 3 referees “A: outstanding” and 2 “B: excellent”
    - Maybe too broad strategic program lacking some coherence/synergies

CFP MdM proposal for the 2026 call

- Next MdM call expected on May 27th 2026
- We have identified two transversal key elements for a MdM proposal:
  - Embedding **Artificial Intelligence** in all aspects of fundamental physics
  - Develop a **multi-messenger astrophysics** program
- **Opportunity** to secure funding to incorporate a necessary technology (AI) and develop a unique research line in which we are uniquely positioned (MM)
- The unit will leverage its expertise and unique data access from international collaborations, and its computing infrastructure
- The proposed research lines are aligned with national and international initiatives, and are **strategic for CFP growth**
- We would appreciate your advice on defining the scope of the proposal

The strategic plan: Pillar I

A transversal research program dedicated to applying **Artificial Intelligence and Data-Intensive Methods for Fundamental Physics**

Unprecedented Challenges:

The next generation of fundamental physics experiments (colliders, astroparticle, cosmology) face extreme data volumes, complex detectors, stringent real-time constraints, and long operational lifetime

The Need for AI:

Addressing these requires a paradigm shift: **embedding Artificial Intelligence across the entire experimental lifecycle**, from detector R&D to operations and physics exploitation

AI platform:

a common computational and methodological backbone, a scalable, distributed AI fabric implementing AI models, from the "classical" ML/DL to more complex emerging technologies like Foundation Models, Large Language Models, etc.

Applications

spanning collider physics, multimessenger astrophysics, real-time data processing, etc, encompassing all research lines

European Alignment:

ESPP

EUCAIF

The vision aligns strongly with the European Strategy for Particle Physics (ESPP) and the European Coalition for AI in Fundamental Physics (EUCAIF).

CIEMAT-FP's Position:

CIEMAT-FP is uniquely positioned to lead this transition, leveraging a decade of expertise in experimental physics, advanced computing, and instrumentation, supported by the PIC computing centre.

The strategic plan: Pillar II

Establish CIEMAT-FP as a national leader in **multimessenger astrophysics**

A New Frontier in Physics:

Multi-messenger astrophysics, combining data from neutrinos, gravitational waves, and electromagnetic and cosmic-ray observatories, is the key to exploring physics beyond the Standard Model of particle physics and cosmology.

Strategic Positioning & Infrastructure:

Aligns with major European roadmaps, leveraging CFP's expertise in international collaborations. Privileged access to leading facilities and the CosmoHub platform.

Possible high-impact Science WPs (Overview):

Possible high-impact Science Work Packages:

WP1: Dark Sirens

Use gravitational-wave and LSST data to independently measure the Hubble constant and address the current major discrepancy in cosmology.

WP2: Galactic Supernovae

Establish CIEMAT-FP as the leading Spanish institution for the multi-messenger detection and study of the next galactic supernova, leveraging the unique capabilities of the DUNE experiment.

WP3: Fundamental Physics through Multi-wavelength Monitoring

Test physics beyond the SM (e.g., Lorentz invariance, EBL) by developing multi-wavelength monitoring and automated trigger pipelines for the CTAO.

WP4: Multimessenger Static Searches

Systematically search for new spatial and temporal correlations in archival, long-term datasets using the CosmoHub platform's unified access to diverse catalogs.

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European Strategy for Particle Physics: 2026 update

The European Strategy for Particle Physics:
2026 Update

Recommendations
by the European Strategy Group

[Link to the document]

European Strategy
for Particle Physics

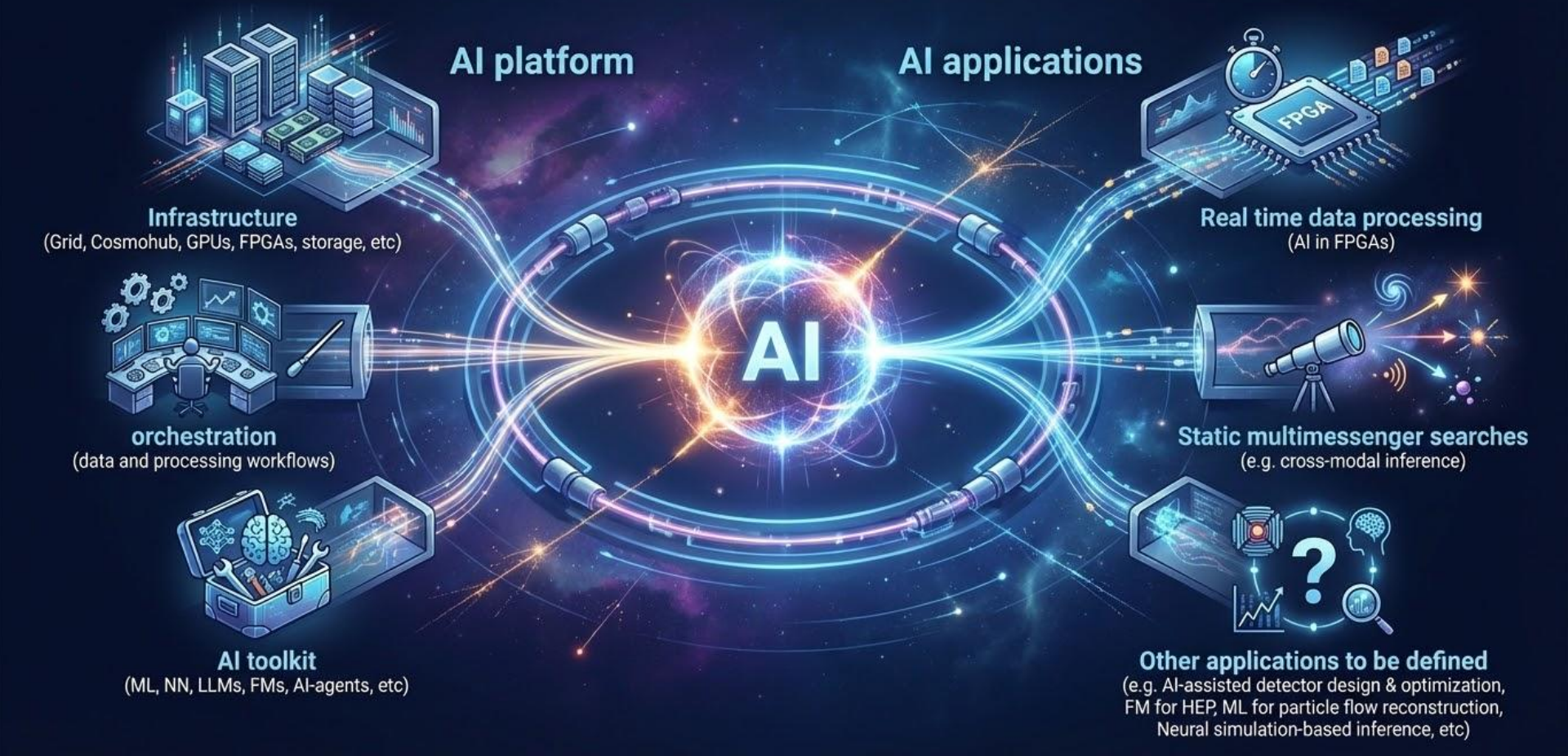
AI is a transformative technology that already plays a crucial role in particle physics, which in turn is contributing to the evolution of AI with its specific competencies.

J. *The European particle physics community must further intensify its activities in AI and sustain them with adequate resources. A roadmap, coordinated among CERN and national laboratories, institutes and universities, should be developed to prioritise AI activities, taking into account synergies with international partners and other communities.*

AI initiatives all around our field

- US genesis mission (AI-enabled science to accelerate scientific advancement; 320 M€ initiallly)
  - White paper AI for HEP: Building an AI-native Research Ecosystem for Experimental Particle Physics
- eucaif.org initiative from Joint ECFA-NuPECC-APECC (JENA)
  - Advancing AI and fundamental physics research and training network
  - Strategic White Paper on AI Infrastructure for Particle, Nuclear, and Astroparticle Physics: Insights from JENA and EuCAIF
- MODE collaboration (Machine-learning Optimized Design of Experiments)
- CoE RAISE (Center of Excellence on AI and Simulation-Based Engineering at Exascale)
  - Development of innovative AI methods on heterogeneous HPC architectures scaling towards Exascale
  - CERN, academic institutions, industry
- White paper LSST Dark Energy Science Collaboration
  - Opportunities in AI/ML for the Rubin LSST Dark Energy Science Collaboration

AI-enabled Fundamental Physics proposal



Exploring applications of AI to Fundamental Physics

- Embedding Artificial Intelligence across the entire experimental lifecycle, from detector R&D to physics exploitation
- **The proposal must be physics-driven**; we are doing fundamental physics
- There is some apprehension about inexperience with AI within the physics groups and the challenge of pinpointing where to effectively apply it
- From the “classical” ML/DL to more complex emerging AI technologies like Foundation Models (FM), Large Language Models (LLM), AI assistants for detector co-design and optimization, etc
    - Foundation models—large, multimodal systems trained on diverse datasets—offer a scalable alternative by learning shared representations that can be adapted efficiently to new tasks and domains
    - FMs jointly encode detector-level data, reconstructed events, time-series signals, images, waveforms, catalogs, and metadata, bridging simulation and real data through self-supervised and weakly supervised learning.

Exploring applications of AI to Fundamental Physics

Evolving Neural Networks for Real-Time Inference

- CIEMAT-FP has extensive experience in FPGA/GPU co-development and online systems
- Real-time selection systems require hardware-aware, energy-efficient neural architectures
- Evolving neural networks (neuro-evolution) are capable of optimizing network structure, weights, and latency under FPGA/GPU constraints. These models will target HL-LHC triggers and FCC TDAQ challenges

Cosmology

- Improving cosmological simulations using AI
- Photometric redshifts and galaxy classification using AI
- Simulation-based inference for cosmology
- Improving observatory diagnostics and efficiency with Foundation Models

Exploring applications of AI to Fundamental Physics

Collider physics

- AI-assisted detector co-design and optimization
- Foundation Models for HEP
- ML for particle flow reconstruction
- Neural simulation-based inference

Multi-messenger astronomy

- Develop an AI-enabled Multi-Messenger Framework that encodes heterogeneous data—skymaps, alerts, light curves, catalogs—into shared latent spaces, enabling cross-modal inference beyond ad hoc correlations