DeepDose: Real-Time AI for Safer Proton Therapy

International PhD Position (Rome & Grenoble)

Particle therapy can theoretically confine dose with millimetric precision, yet in daily practice small anatomical shifts—or even the gradual shrinkage of the tumour itself—leave clinicians uncertain about where protons actually stop. The Grenoble–Marseille–Nice consortium has already built TIARA, a Cherenkov-based detector array that times prompt-gamma photons and, together with an upstream beam monitor, delivers eight time-of-flight histograms for every pencil beam spot. Solving the inverse problem that links those histograms to a full three-dimensional dose map is the remaining bottleneck: analytical iterative solvers respect the physics but need minutes and lose spatial resolution in heterogeneous tissue.

The proposed PhD project substitutes those solvers with deep learning. A first "global" path feeds the eight histograms—and ancillary beam metadata—into a volumetric U-Net or Swin-Transformer that learns the nonlinear mapping to a 128×128×128 voxel dose cube. Training pairs will be generated by Monte-Carlo digitisations of about one hundred head-and-neck patient CTs, enriched through rotation, field splitting and rigorous noise models so that the network encounters the full spectrum of clinical variability. A second, hybrid path keeps the proven analytical forward model but replaces its regularisation term with a neural prior in a plug-and-play framework; this combination promises reconstruction times below 250 ms while retaining interpretability and hard physical constraints. Both strategies will embed physics-informed losses derived from Bethe–Bloch energy deposition, enforce non-negativity and mass conservation, and output per-voxel uncertainty so that any deviation beyond two percent automatically flags the parallel analytic pipeline.

Feasibility is underpinned by an ERC-funded detector, an existing Monte-Carlo chain, a secured agreement to access retrospective and prospective clinical data, and the complementary expertise of medical physicists, inverse-problem mathematicians and AI specialists. Risks linked to data scarcity will be mitigated through transfer learning from large vision transformers, while domain randomisation and Bayesian dropout will harden generalisation to detector mis-calibration and patient variability.

The project will deliver the first AI-powered, physics-guided modality capable of streaming true 3-D dose information back to the beam line during treatment. Such real-time feedback would unlock per-fraction adaptive radiotherapy, substantially reduce toxicity and establish a transferable blueprint for hybrid physics/deep-learning reconstruction in nuclear medicine and industrial non-destructive testing.

What makes DeepDose unique?

- **Big Science Meets Big Data:** Work with terabytes of prompt-gamma detector signals, high-fidelity Monte Carlo simulations, and patient CT scans to train and validate your models.
- **Physics-Guided Machine Learning:** Develop AI that not only predicts, but truly understands particle interactions—respecting physical laws, energy deposition, and conservation principles.
- **Sub-Second, Real-Time Results:** Engineer algorithms capable of reconstructing detailed dose distributions in milliseconds, fast enough for real-time adaptive therapy.
- **Immediate Clinical Impact:** See your work tested on actual patients in European proton-therapy centers, with a clear route to implementation.
- **Interdisciplinary Collaboration:** Learn and grow in an environment that brings together physicists, clinicians, mathematicians, and computer scientists from multiple countries.
- **National and International Training:** Benefit from Italy's flagship PhD-AI program, international workshops, and a strong mentoring network.
- **State-of-the-Art Resources:** Access ERC-funded detector technology, a robust Monte Carlo data chain, and extensive clinical data partnerships.

Who should apply?

- Physicists (medical, nuclear, particle) or exceptional computational scientists/engineers with a strong foundation in physics.
- Candidates with experience in scientific programming (Python preferred) and/or Monte Carlo simulation (Geant4, GATE, FLUKA, etc.).
- Motivated individuals eager to learn advanced AI methods, collaborate across disciplines, and work in English-speaking, multicultural teams.

Details:

- Fully funded 3-year PhD position
- Based in Rome and Grenoble, with additional visits to partner centers
- Flexible start date (late 2025 preferred)
- Application deadline: 15 July 2025
- Mobility funding for research abroad already granted

To apply, please send a CV, an application letter and at least one reference to:
Nicola Toschi, University of Rome Tor Vergata: nicola.toschi@uniroma2.eu
Sara Marcatili, CNRS, LPSC: sara.marcatili@lpsc.in2p3.fr
Subject: **"PhD DeepDose Application – YOUR NAME"**
We value diversity and welcome applicants of all backgrounds and nationalities. Be part of something transformative—help us bring true intelligence and precision to the frontlines of cancer therapy.