CN HPC: Spoke2

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Spoke 2 - Fundamental research & Space economy: Goals and Objectives

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The activities in the “Fundamental Research & Space Economy” Spoke will be cast within the context of state- of-the-art research in basic science, and, in particular, of the domains of theoretical and experimental physics with accelerators and with space- and ground-based detectors for astroparticle physics and gravitational wave investigations. Within different time scales, all of these areas have or will have to face problems regarding the scaling and efficiency of computing infrastructures. These areas demand a scaling of the computing infrastructures and an improvement in efficiency.

The Spoke intends to address these needs designing, developing and testing solutions apt to the current and next-generation experiments, and fitting the contingent situation in Italy arising from the opportunities provided by the PNRR in general and the National Centre (CN) “Big Data, HPC and Quantum Computing”.

The crucial aspects of its mission concern the creation and/or optimization of algorithms and, in general, computing solutions capable of maximizing the potential physics output from experimental data and theoretical and phenomenological simulations, by using the tools made available by the Centre: e.g., heterogeneous and high-performance computing and the ability to process large quantities of data beyond the capabilities of traditional methods.

Spoke 2: Research Topics (WPs)

WP2.1 - Theoretical Physics (Giusti, Cosmai):

a) Development of algorithms, codes and computational strategies for the simulation of physical theories and models, towards pre-Exascale and Exascale architectures.

b) Theoretical research projects in domains already using HPC solutions, such as:

- lattice field theory (flavour physics, QCD phase diagrams, hadronic physics, interactions beyond the Standard Model, machine learning in quantum field theories, electromagnetic effects in hadronic processes);
- collider physics phenomenology;
- gravitational waves, cosmology and astroparticle physics (neutron-star physics, primordial universe, dark matter and energy, neutrino physics);
- nuclear physics;
- physics of complex systems (fluid dynamics, disordered systems, quantitative biology);
- condensed matter in low dimensional systems;
- quantum systems (entanglement, quantum simulations, quantum information).

WP2.2 - Experimental High Energy Physics (Lenzi, Vagnoni):

selection, data reduction, simulation and reconstruction algorithms (either via explicit programming or large-scale Machine Learning solutions) for HEP experiments (LHC, Future Colliders, KEK, IHEP, neutrino experiments...), with applications ranging from innovative triggers to distributed analysis techniques.

WP2.3 - Experimental Astro-Particle Physics (Natoli, Landoni)

data reduction, reconstruction and time cross-correlation algorithms, data selection and simulations of astroparticle and gravitational waves experiments, tools for cross-correlations and pattern recognition in multi-messenger physics, including novel implementations using techniques like Machine Learning.

Spoke 2: Research Topics (WPs)

WP2.4 - Boosting the computational performance of Theoretical and Experimental Physics algorithms (Pompili, Gennai): porting of applications to GPUs and heterogeneous architectures (e.g., scalability of scientific codes and applications on GPU/CPU many-cores clusters, local and remote offloading, mission-critical algorithms on FPGAs, ...). The solutions and tools implemented during the project will be easily extendable to other scientific domains of the Centre and to the industrial partners in the Spoke; moreover, the personnel trained within the Centre will help to spread and boost the application of HPC methodologies to Italian academic and industrial fields, for a comprehensive advancement of the Italian system.

WP2.5 - Architectural Support for Theoretical and Experimental Physics Data Management on the Distributed CN infrastructure (E. Rossi, Spiga): support for the adaptation of existing applications on the data-lake distributed infrastructure, and via innovative computational models (for example sharing of gauge configurations in lattice field theories, long-term data preservation, streaming access to data, tiered storage solutions, ...). The solutions implemented will be tailored to the needs of the scientific fields, easily extendible not only to the nearby scientific domains in the Centre, but also to all academic and industrial realities where needs to access distributed computing and large amounts of data exist. In particular, the industrial partners in the Spoke have expressed interest in using the same technologies for their specific use cases.

WP2.6 - Cross–domain Initiatives (Tricomi, Visconti): optimization and adaptation of widely used software packages on the national Centre infrastructure, like Geant4 or FLUKA or generic high-performance techniques for data access/analysis; statistical and AI-based tools; data-interpretations tools. In the context of the Space Economy Italian Strategy, develop and deploy techniques to access, analyze and process the data from the Mirror Copernicus program, creating the conditions to enable radically innovative services. In particular, enable thorough and continuous observation programs for global and local processes, allowing external partners to operate a large variety of services, including the planning for emergencies, risks and resources.

Spoke 2: Milestones

Time 0: 1/9/2022.

M1 (Mesi 1-8): Pubblicazione bando PhD
M2 (Mesi 9-16): Pubblicazione bando PhD posizioni rimanenti
M3 (Mesi 17-24): Pubblicazione bando PhD posizioni rimanenti

M4 (Mesi 1-8): Non prevista in spoke 2

M5 (Mesi 5-8): Pubblicazione bandi RTDA

M6 (Mesi 9-12): Pubblicazione bandi RTDA.
Landscape recognition on the state of the art algoritms and solutions in theoretical, particle, astroparticle, and gravitational-waves physics. Choice of use cases, solutions and tools to be developed.

M9 (Mesi 22-26): R&D activities performed on the selected use cases. Software packages at least at alpha level. Preparation of testbeds ; user-support activities at least at alpha level with the first training opportunities scheduled.

M10(Mesi 25-36): Test and validation phase of the project, on resources from the CN, in-kind from the partners, and from innovation Grants and Open Calls. Wrap -up milestone for the project, including activities and results from the test and benchmarking phases; (2) prepare best practices and solutions, also of industrial interest.