

Section 1 - Overview of the spoke's stated goals and internal organization

The Spoke 2 “Fundamental Research & Space Economy” in the National Center for HPC, Big Data and Quantum Computing has the role to tackle the most urgent computing related problems in the basic research domain, with a clear focus on future experimental and theoretical activities. At the same time, the Spoke wants to perform technology transfer activities towards the Italian productive system, percolating the solutions and the tools used in the academia to real and relevant industrial problems.

The project goals are expected to have a huge scientific impact in the selected domains, where it has been recognized for a long time how a simple scaling of the current computing methodologies is expected to fail within a decade. In particular, the project aims to be a key player in developing and testing solutions which ensure the sustainability of computing for the next generation of scientific experiments. Sustainability needs to follow at least 3 distinct directions:

1. Economic sustainability, where the computing infrastructure (including resources, codes and algorithms) needed to extract physics knowledge from the collected / produced data can be procured within a reasonable cost envelope. According to the currently adopted standard criterion adopted for the computing of high-energy physics experiments, economic sustainability means that the yearly budget for computing must at most be constant at today's level. Solutions such as the use of heterogeneous computing with accelerators promise to decrease the cost per operation, while data-lake infrastructure designs point towards a reduction of the total storage deployment;
2. Environmental sustainability. This includes many aspects covered by the Spoke 2 activities:
 - a. the design of algorithms with a better cost per operation. This includes brand new solutions that may be designed, but also general strategies like a more pervasive utilization of Machine Learning technologies, which are known to lower the processing time in situations such as heavily combinatorial algorithms.
 - b. the use of heterogeneous technologies with a better operation/Joule cost. This includes the use of mobile-derived CPUs like ARM, known to perform at least 3x better energetically, and the use of GPGPU solutions, which scale similarly by using a more parallel architecture;
3. Scientific sustainability, in which the algorithms increase in complexity when analyzing data from more and more precise experiments. This is crucial to the advancement of the scientific domains and implies that the resource needed will increase faster than a naive extrapolation from data rates would suggest.

The work plan of Spoke 2 is organized in 6 work packages (WP1-WP6), whose goals and tasks are detailed below. Additionally, a WPO has been defined for management, and consists of the activities carried out in the Steering Board and the General Assembly. The WPs have different goals and nature: WP1-2-3 are “scientific”, and propose use cases of relevance in research, WP4-5 are technical and aim to provide solutions for the scientific needs; WP6, finally, wants to tackle generic problems like performance optimization of cross-domain tools and techniques.

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- **WP0 - [“Management”]**
 - The WP0 is the management WP in Spoke2, and its activities consist in the day-by-day review and organisation of the Spoke activities. It follows global activities and reports, like the organization of Innovation Grants and Cascade Calls.
- **WP1 – [“Design and development of science-driven tools and innovative algorithms for Theoretical Physics”]:**
 - The WP1 focuses on activities on advanced computing techniques for the domain of theoretical physics, via the development of algorithms, codes, and computational strategies for the simulation of physical theories and models, towards pre-Exascale and Exascale architectures.. The initial number of tasks proposed at the project presentation has been slightly revised, to merge the closest one in a more manageable set of tasks:
 - **Planned Tasks:**
 - T1.1 Development of algorithms and codes for Exascale architectures;
 - T1.2 Tools and Algorithms for Lattice Field Theory and Nuclear Physics;
 - T1.3; Tools and Algorithms for Collider Physics
 - T1.4 Tools and Algorithms for multi-messenger and Cosmology on Gravitational Waves;
 - T1.5 Tools and Algorithms for Complex Systems and Condensed Matter.
- **WP2 - [“Design and development of science-driven tools and innovative algorithms for Experimental High Energy Physics”]**
 - The WP2 focuses on the computing challenges in the domain of Experimental High Energy Physics, with a majority of the efforts in the sub-realms of Collider Physics. The plan of work includes the realization, using ICSC advanced infrastructures, of 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.
 - **Planned Tasks:**
 - T2.1 Innovative algorithms for Experimental High Energy Physics simulation, selection, data reduction, reconstruction and analysis;
 - T2.2 AI inspired techniques for Experimental High Energy Physics.
- **WP3 - [“Design and development of science-driven tools and innovative algorithms for Experimental Astroparticle Physics and Gravitational Waves”]**
 - The WP3 aims to develop 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.
 - **Planned Tasks:**
 - T3.1 Innovative algorithms for Experimental Astroparticle Physics a Gravitational Waves simulation, selection, data reduction, reconstruction and analysis;
 - T3.2 AI inspired techniques for Astroparticle Physics and Gravitational Waves.

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- **WP4 - [“Boosting the computational performance of Theoretical and Experimental Physics algorithms”]**
 - The WP4 of Spoke 2 is (together with WP5) a technical WP, whose aim is to support the activities of the scientific / industrial use cases proposed, by setting a technical baseline / support / training system for the researchers who approach in large part for the first time advanced computing techniques, as those provided by the ICSC. Among the main expected activities, the porting of applications to GPUs and heterogeneous architectures. The solutions and tools implemented during the project are expected to be 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.
 - **Planned Tasks:**
 - T4.1 Tools and guidelines for developing and porting heterogeneous codes and algorithms on modern architectures;
 - T4.2 Training and support for heterogeneous computing.
- **WP5 - [“Architectural Support for Theoretical and Experimental Physics Data Management on the Distributed CN infrastructure”]**
 - The WP5 is (together with WP4) a technical WP, whose aim is to support the activities of the scientific / industrial use cases proposed. WP5 aims to give 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 extendable 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.
 - **Planned Tasks:**
 - T5.1 Support of the adaptation of existing applications on the data-lake distributed infrastructure, and via innovative computational models;
 - T5.2 training and support for computing model design and implementation and test
- **WP6 - [“Cross-domain Initiatives”]**
 - The WP6 aims to identify and improve the optimization and adaptation of widely used software packages on the national Centre infrastructure, like Geant4 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, the WP wants to try and build a bridge with activities and projects in the same domain, if the possibility is realized.
 - **Planned Tasks:**
 - T6.1 Optimization and adaptation of widely used cross-domain software packages;

- T6.2 Techniques and tools for high intensity analysis (techniques for fast data access, AI-based tools, data interpretation tools). The same tools are expected to be exploited for the analysis of the data streams from the Mirror Copernicus constellation of satellites. An effort at this scale needs a proper methodology to ensure a positive conclusion of the activities.

Section 2 - Research plan

Reporting period: [Sep 2023 - Feb 2024]

The reporting period coincides with the first part of the activities of the second year of ICSC/Spoke2. As explained in the submitted project, the second year is the “realization phase”, in which the activities defined in the first year (the “planning and identification phase”) are executed.

On top of this, due to a global decision from the HUB, the period includes also the definition of the Cascade Calls, which amount for Spoke 2 to 3.2 MEur; the projects, to be equally distributed between academic and industrial parties, will be defined during MS7, even if probably the formal part (open tender, evaluation, signature of the grants) will slip into MS8.

The projects defined during the first year include:

- 19 Flagship Projects. Shared among the 6 Work Packages. They are defined with codes like UC2.X.Y, where X is the Work Package handling executing the project (the main one, in case more WPs are involved), and Y is a sequential number. A complete list is:
 - UC2.1.1: “Multilevel Hybrid Monte Carlo for lattice QCD”
 - UC2.1.2: “QCD under extreme conditions”
 - UC2.1.3: “Advanced Calculus for Precision Physics (ACPP)”
 - UC2.1.4: “Large Scale Simulations of Complex Systems”
 - UC2.2.1: “Advanced Machine Learning - Flash Simulation and bleeding edge applications”
 - UC2.2.2: “Quasi interactive analysis of big data with high throughput”
 - UC2.2.3: “Ultra-fast algorithms running on FPGA”
 - UC2.2.4: “Porting code to GPU platforms”
 - UC2.2.5: “Validation of event reconstruction code on ARM”
 - UC2.3.1: “Frequency Hough (FH) Transform analysis on GW continuous sources”
 - UC2.3.2: “Efficient use of machine learning and GPUs in cosmological data analysis: from theory to likelihood to statistical inference”
 - UC2.3.3: “Inference of cosmological and astrophysical population properties from GW observations with and without electromagnetic counterparts”
 - UC2.3.4: “Development of innovative analysis techniques using realistic simulations of the upgraded Auger Observatory within the context of a machine learning environment”
 - UC2.3.5: “Detection and classification of SSO in Euclid Simulated data”
 - UC2.3.6: “Pipeline optimization for space and ground based experiments (PSGE)”
 - UC2.3.7: “Hydrodynamical simulations to test the nature of dark matter”

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- UC2.6.1: “Extended Computer Vision at high rate”
- UC2.6.2: “Enhancing Geant4 Monte Carlo Simulations through Machine Learning Integration”
- UC2.6.3: “AI algorithms for (satellite) imaging reconstruction”
- 7 Innovation Grants, with codes like IG2.X, where X is a sequential number:
 - IG2.1: “Blending Machine Learning with advanced numerical simulations: application to the sustainable exploitation of natural resources” (with Eni)
 - IG2.2: “Harnessing the power of Artificial Intelligence for predictive maintenance of industrial plants” (with Eni)
 - IG2.3: “Enabling scientific research and technology innovation on the Tier1 of the ENI green data center in Ferrera Erbognone” (with Eni and Spoke 0)
 - IG2.4: “Fraud Detection” (with Intesa Sanpaolo, Spoke 3 and Spoke 10)
 - IG2.5: “Agri@Intesa” (with Intesa Sanpaolo, Thales Alenia Spazio Italia and Spoke 5)
 - IG2.6: “HaMMon (Hazard Mapping and vulnerability Monitoring)” (with UnipolSAI, SOGEI, Spoke 0, Spoke 1, Spoke 3, Spoke 4, Spoke 5)
 - IG2.7: “Interoperable Data Lake (IDL)” (with Leonardo Company, Thales Alenia Spazio Italia and Spoke 3)

Not all the Flagship + Innovations grants have defined deliverables for all the future Milestones (MS7, MS8, MS9, MS10). In that case, an intermediate report will be provided.

In general, the IG projects are mildly associated with WPs, since they use techniques from the latter ones. In particular, we can consider:

- IG2.1 in line with the activities of WP2 and WP3;
- IG2.2 in line with the activities of WP2 and WP3;
- IG2.3 in line with the activities of WP1;
- IG2.4 in line with the activities of WP2 and WP3;
- IG2.5 in line with the activities of WP6;
- IG2.6 in line with the activities of WP6;
- IG2.7 in line with the activities of WP5 and WP6.

Still, for uniformity, we have decided to “assign” the IG projects to WP0, at the level of management and reporting.

Spoke Level Targets - WP0

Expected Targets

- TAR0.8: [Final list of Cascade Calls Objectives]. **KPI:** [Document with at least 4 Academic Objectives and 4 Industrial Objectives];
- TAR0.9: [Cascade Calls plan]. **KPI:** [Draft Plan provided, allocating at least 70% of the budget];
- TAR0.10: [General Meeting at the start of second year of Spoke 2]. **KPI:** [General Meeting executed, agenda and exec summary provided].
- TAR0.11: [MS activities for IG2.1, including first draft of literature studies, handshaking on use cases selection (UNITS, INFN, ENI)]. **KPI:** [Report on literary studies and on use case selection].

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- TAR0.12: [MS activities for IG2.2, including data collection and data exploration results]. **KPI:** [Report on literary studies and on use case selection]
- TAR0.13: [MS activities for IG2.3 initial studies, including a study of the state of the art]. **KPI:** [Report on the state of the art for executing Spoke2 solutions on Eni's Green Data Center]
- TAR0.14: [MS activities for IG2.4, including results on data exploration and how to format the dataset. Preprocessing the data (e.g. feature engineering, feature selection) executed]. **KPI:** [Report on preprocessing status and results]
- TAR0.15: [MS activities for IG2.5, including: final decision for the image dataset(s); at least a few example images to be used for initial code development; final decision for the financial dataset(s); at least a few example entries to be used for initial code development; technology tracking and description of strategies]. **KPI:** [Report selection of datasets for images and finance, example code repositories available; technology tracking report];
- TAR0.16 [MS activities for IG2.6]. **KPI:** [Intermediate report provided];
- TAR0.17 [MS activities for IG2.7, including the preparation of a Functional and Analysis document]. **KPI:** [Report available];
- TAR0.18 [Kick Off Meeting for IG2.1 by October 2023]. **KPI:** [Meeting executed, agenda provided]
- TAR0.19 [Kick Off Meeting for IG2.2 by October 2023]. **KPI:** [Meeting executed, agenda provided]
- TAR0.20 [Kick Off Meeting for IG2.3 by October 2023]. **KPI:** [Meeting executed, agenda provided]
- TAR0.21 [Kick Off Meeting for IG2.4 by October 2023]. **KPI:** [Meeting executed, agenda provided]
- TAR0.22 [Kick Off Meeting for IG2.5 by October 2023]. **KPI:** [Meeting executed, agenda provided]
- TAR0.23 [Kick Off Meeting for IG2.6 by October 2023]. **KPI:** [Meeting executed, agenda provided]
- TAR0.24 [Kick Off Meeting for IG2.7 by October 2023]. **KPI:** [Meeting executed, agenda provided]
- TAR0.25 [Repository for the Spoke 2 with initial project population, by October 2023]. **KPI:** [link to repository provided]

WP1 – [Design and development of science-driven tools and innovative algorithms for Theoretical Physics]

Expected Targets

- TAR1.5 [MS report for UC2.1.1]. **KPI:** [Intermediate report provided];
- TAR1.6 [MS report for UC2.1.2]. **KPI:** [Intermediate report provided];
- TAR1.7 [MS report for UC2.1.3]. **KPI:** [Intermediate report provided];
- TAR1.8 [MS report for UC2.1.4]. **KPI:** [Intermediate report provided];

WP2 – [Design and development of science-driven tools and innovative algorithms for Experimental High Energy Physics]

Expected Targets

- TAR2.5 [MS report for UC2.2.1]. **KPI:** [Intermediate report provided];

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- TAR2.6 [MS report for UC2.2.2, on approaching new interactive analysis frameworks for big data with a high throughput. This activity will be performed in synergy with WP5, regarding the infrastructural support and future upscaling with CN resources]. **KPI:** [Intermediate report provided];
- TAR2.7 [MS report for UC2.2.3, including identifying most suitable ML models and finalising the code development targeting the FPGA hardware in use at the moment.]. **KPI:** [Intermediate report provided];
- TAR2.8 [MS report for UC2.2.4]. **KPI:** [Intermediate report provided];
- TAR2.9 [MS report for UC2.2.5]. **KPI:** [Intermediate report provided];

WP3 – [Design and development of science-driven tools and innovative algorithms for Experimental Astroparticle Physics and Gravitational Waves]

Expected Targets

- TAR3.5 [MS report for UC2.3.1, including a test of an alternative CPU implementation in MATLAB; Deliverable: 1- A report on the code with the description of the performances obtained through the tests done; 2- Code released on an private repository (cannot be public)]. **KPI:** [Intermediate report and code repository shown (no public access)];
- TAR3.6 [MS report for UC2.3.2]. **KPI:** [Intermediate report provided];
- TAR3.7 [MS report for UC2.3.3, including analysis of the performances of the codes and identification of pipeline bottlenecks to identify the parts that could be improved and release of the new CHIMERA code with improved GPU performances]. **KPI:** [Report provided];
- TAR3.8 [MS report for UC2.3.4, including setting up the simulation and reconstruction chain for the hybrid detector of the Pierre Auger Observatory adopting the “Real Monte Carlo” scheme in the INFN-cloud resources]. **KPI:** [Report provided];
- TAR3.9 [MS report for UC2.3.5, including development of the first fully working code]. **KPI:** [Report and code repositories provided];
- TAR3.10 [MS report for UC2.3.6, including the design of two or more pipeline prototypes, which include the definition of the software architecture, functions and I/O interfaces, the technological solutions for the containerization, the requirements (e.g. speed, data transfer, memory load, scalability), the software repository and the selection of the target infrastructures (e.g. the INFN Cloud infrastructure)]. **KPI:** [Report and code repositories provided];
- TAR3.11 [MS report for UC2.3.7, including production of the large scale (lower resolution) boxes as a pathfinder sample]. **KPI:** [Report provided];

WP4 – [Boosting the computational performance of Theoretical and Experimental Physics algorithms]

Expected Targets

- TAR4.6 [Participation to Scientific WP targets]. **KPI:** [Reports on WP4 activities in UC2.2.4, UC2.2.3, UC2.3.3, UC2.3.4, UC2.3.6];
- TAR4.7 [Training on FPGA]. **KPI:** [Training on FPGA executed; agenda and exec summary provided];

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- TAR4.8 [ML training opportunity on GPU, with WP2 and WP5]. **KPI:** [Training on ML executed; agenda and exec summary provided];

WP5 – [Architectural Support for Theoretical and Experimental Physics Data Management on the Distributed CN infrastructure]

Expected Targets

- TAR5.6 [Participation to Scientific WP targets]. **KPI:** [Reports on WP5 activities in UC2.1.1, UC2.1.2, UN2.2.1, UC2.2.3, UC2.2.5, UC 2.2.2, UN2.3.6, UC2.6.1, UN2.6.2, UN2.6.3];
- TAR5.7 [Training on Distributed Computing Models]. **KPI:** [Training on Distributed Computing Models executed; agenda and exec summary provided];
- TAR5.8 [ML training opportunity on the Cloud, with WP2 and WP4]. **KPI:** [Training on ML executed; agenda and exec summary provided];

WP6 – [Cross-domain Initiatives]

Expected Targets

- TAR6.6 [MS report for UC2.6.1]. **KPI:** [Intermediate report provided];
- TAR6.7 [MS report for UC2.6.2, including a thorough examination of modern technologies and methodologies. Keep up with the latest advancements in hardware and software that are relevant to the project. Define a first simple test case on the utilization of ML to speed up a typical Monte Carlo Simulation, with the definition of Geant4 part to be modified.]. **KPI:** [Report on use cases provided];
- TAR6.8 [MS report for UC2.6.3]. **KPI:** [Intermediate report provided].

Section 3 - Research report

Intermediate Reporting period: [Sep 2023 - Oct 2023]

The reporting period coincides with the first 2 months of the MS7 reporting period, out of a total length of 6 months. Hence, most of the targets will not be completed in this period, and a status report is given (either inlined, or as an attached document).

Key for intermediate reporting period:

-  : failed target (for example a target to be executed by October 2023, and missed) – failed
-  : a target not yet realized but due in a later moment (for example by MS7 - Feb 2024) – in progress
-  : a target positively concluded within its natural deadline – done

Spoke-Level Targets - WP0

Expected Targets

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-  TAR0.8: [Final list of Cascade Calls Objectives]: not yet finalized at the end of October. Tentative list provided, subject to a merging of the objective if requested for administrative purposes.
 - KPI0.8: **Spoke2_WP0_TAR0.8**
-  TAR0.9: [Cascade Calls plan]: The included plan allocates much more than the available 3.2 MEur, since it provides space for recovering the budget from objectives with no applications.
 - KPI0.9: **Spoke2_WP0_TAR0.9**
-  TAR0.10: [General Meeting for the start of second year of Spoke 2]: the current best options seem to be the dates December 18-20 2023, in Bologna. The draft agenda is provided
 - KPI0.10: <https://agenda.infn.it/event/37915/>
-  TAR0.11: [MS activities for IG2.1, including first draft of literature studies, handshaking on use cases selection (UNITS, INFN, ENI)]: An initial status report on the studies is provided.
 - KPI0.11: **Spoke2_WP0_TAR0.11**
-  TAR0.12: [MS activities for IG2.2, including data collection and data exploration results]: An initial status report on the studies is provided.
 - KPI0.12: **Spoke2_WP0_TAR0.12**
-  TAR0.13: [MS activities for IG2.3, including a study of the state of the art]: An initial status report on the studies is provided.
 - KPI0.13: **Spoke2_WP0_TAR0.13**
-  TAR0.14: [MS activities for IG2.4, including results on data exploration and how to format the dataset. Preprocessing the data (e.g. feature engineering, feature selection) executed]: An initial status report on the studies is provided.
 - KPI0.14: **Spoke2_WP0_TAR0.14**
-  TAR0.15: [MS activities for IG2.5, including: final decision for the image dataset(s); at least a few example images to be used for initial code development; final decision for the financial dataset(s); at least a few example entries to be used for initial code development; technology tracking and description of strategies]: An initial status report on the studies is provided.
 - KPI0.15: **Spoke2_WP0_TAR0.15**
-  TAR0.16 [MS activities for IG2.6]: An initial status report on the studies is provided.
 - KPI0.16: **Spoke2_WP0_TAR0.16**
-  TAR0.17 [MS activities for IG2.7, including the preparation of a Functional and Analysis document]. An initial status report on the studies is provided.
 - KPI0.17: **Spoke2_WP0_TAR0.17**
-  TAR0.18 [Kick Off Meeting for IG2.1 by October 2023]: kick-off meeting executed.
 - KPI0.18: <https://agenda.infn.it/event/37885/>
-  TAR0.19 [Kick Off Meeting for IG2.2 by October 2023]. kick-off meeting executed.
 - KPI0.19: <https://agenda.infn.it/event/37945/>

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-  TAR0.20 [Kick Off Meeting for IG2.3 by October 2023]: meeting executed.
 - KPI0.20: <https://agenda.infn.it/event/38209/>
-  TAR0.21 [Kick Off Meeting for IG2.4 by October 2023]. (pre) kick-off meeting executed.
 - KPI0.21: <https://agenda.infn.it/event/37983/>
-  TAR0.22 [Kick Off Meeting for IG2.5 by October 2023]: Meeting did not take place yet.
-  TAR0.23 [Kick Off Meeting for IG2.6 by October 2023]: kick-off meeting executed.
 - KPI0.23: <https://agenda.infn.it/event/38069/>
-  TAR0.24 [Kick Off Meeting for IG2.7 by October 2023]: kick -off meeting executed.
 - KPI0.24: <https://agenda.infn.it/event/37886/>
-  TAR0.25 [Repository for the Spoke 2 with initial project population, by October 2023]: GitHub repository (all public) created and populated with a few projects. In many cases, the researchers prefer to use owned repositories, so the fork on our repository will be done later in the project (probably, when a code reaches at least beta test)
 - KPI0.25: <https://github.com/ICSC-Spoke2-repo>

WP1 – [Design and development of science-driven tools and innovative algorithms for Theoretical Physics]

Expected Targets

-  TAR1.5 [MS report for UC2.1.1]: see report
 - KPI1.5: **Spoke2_WP1_TAR1.5**
-  TAR1.6 [MS report for UC2.1.2]: see report
 - KPI1.6: **Spoke2_WP1_TAR1.6**
-  TAR1.7 [MS report for UC2.1.3]: see report
 - KPI1.7: **Spoke2_WP1_TAR1.7**
-  TAR1.8 [MS report for UC2.1.4]: see report
 - KPI1.8: **Spoke2_WP1_TAR1.8**

WP2 – [Design and development of science-driven tools and innovative algorithms for Experimental High Energy Physics]

Expected Targets

-  TAR2.5 [MS report for UC2.2.1]: report included
 - KPI2.5: **Spoke2_WP2_TAR2.5**
-  TAR2.6 [MS report for UC2.2.2, on approaching new interactive analysis frameworks for big data with a high throughput. This activity will be performed in synergy with WP5, regarding the infrastructural support and future upscaling with CN resources.]: report included
 - KPI2.6: **Spoke2_WP2_TAR2.6**

-  TAR2.7 [MS report for UC2.2.3, including identifying most suitable ML models and finalising the code development targeting the FPGA hardware in use at the moment.]: Intermediate report provided
 - KPI2.7: **Spoke2_WP2_TAR2.7**
-  TAR2.8 [MS report for UC2.2.4]: report included
 - KPI2.8: **Spoke2_WP2_TAR2.8**
-  TAR2.9 [MS report for UC2.2.5]: report included
 - KPI2.9: **Spoke2_WP2_TAR2.9**

WP3 – [Design and development of science-driven tools and innovative algorithms for Experimental Astroparticle Physics and Gravitational Waves]

Expected Targets

-  TAR3.5 [MS report for UC2.3.1, including a test of an alternative CPU implementation in MATLAB; Deliverable: 1- A report on the code with the description of the performances obtained through the tests done; 2- Code released on an private repository (cannot be public)]: see report
 - KPI3.5: **Spoke2_WP3_TAR3.5**
-  TAR3.6 [MS report for UC2.3.2]: see report
 - KPI3.6: **Spoke2_WP3_TAR3.6**
-  TAR3.7 [MS report for UC2.3.3, including analysis of the performances of the codes and identification of pipeline bottlenecks to identify the parts that could be improved and release of the new CHIMERA code with improved GPU performances]: see report
 - KPI3.7: **Spoke2_WP3_TAR3.7**
-  TAR3.8 [MS report for UC2.3.4, including setting up the simulation and reconstruction chain for the hybrid detector of the Pierre Auger Observatory adopting the “Real Monte Carlo” scheme in the INFN-cloud resources.]: see report
 - KPI3.8: **Spoke2_WP3_TAR3.8**
-  TAR3.9 [MS report for UC2.3.5, including development of the first fully working code]: see report
 - KPI3.9: **Spoke2_WP3_TAR3.9**
-  TAR3.10 [MS report for UC2.3.6, including the design of two or more pipeline prototypes, which include the definition of the software architecture, functions and I/O interfaces, the technological solutions for the containerization, the requirements (e.g. speed, data transfer, memory load, scalability), the software repository and the selection of the target infrastructures (e.g. the INFN Cloud infrastructure). This activity will be performed in collaboration with WP 4 and 5]: see report
 - KPI3.10: **Spoke2_WP3_TAR3.10**

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-  TAR3.11 [MS report for UC2.3.7, including production of the large scale (lower resolution) boxes as a pathfinder sample]: see report
 - KPI3.11: **Spoke2_WP3_TAR3.11**

WP4 – [Boosting the computational performance of Theoretical and Experimental Physics algorithms]

Expected Targets

-  TAR4.6 [Participation to Scientific WP targets]: WP4 is actively participating in the Flagship projects driven by “scientific WPs” 1-2-3-6. A small report for the first two months of MS7 is included
 - KPI4.6: **Spoke2_WP4_TAR4.6**
-  TAR4.7 [Training on FPGA]: Spoke 2 members are organising for November 27th-30th an “Introductory course to HLS FPGA programming”; preliminary agenda included
 - KPI4.7: **Spoke2_WP4_TAR4.7**, <https://agenda.infn.it/event/38191/>
-  TAR4.8 [ML training opportunity on GPU, with WP2 and WP5]: The “Fifth ML-INFN Hackathon: Advanced Level” is scheduled for Nov 13th-16th, in Pisa. Its scientific and local organisation teams include as a majority Spoke 2 members.
 - KPI4.8: **Spoke2_WP4_TAR4.8**, <https://agenda.infn.it/event/37650/>

WP5 – [Architectural Support for Theoretical and Experimental Physics Data Management on the Distributed CN infrastructure]

Expected Targets

-  TAR5.6 [Participation to Scientific WP targets]: a status report from the first 2 months is present at
 - KPI5.6: **Spoke2_WP5_TAR5.6**
-  TAR5.7 [Training on Distributed Computing Models]: School SOSC (organized by Spoke 2 members, and sponsored by ICSC) executed
 - KPI5.7: <https://agenda.infn.it/event/36074/>
-  TAR5.8 [ML training opportunity on the Cloud, with WP2 and WP4]: The “Fifth ML-INFN Hackathon: Advanced Level” is scheduled for Nov 13th-16th, in Pisa. Its scientific and local organisation teams include as a majority Spoke 2 members; it is also sponsored
 - KPI5.8: <https://agenda.infn.it/event/37650/>

WP6 – [Cross-domain Initiatives]

Expected Targets

-  TAR6.6 [MS report for UC2.6.1]: report included

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- KPI6.6: **Spoke2_WP6_TAR6.6**
-  TAR6.7 [MS report for UC2.6.2, including a thorough examination of modern technologies and methodologies. Keep up with the latest advancements in hardware and software that are relevant to the project. Define a first simple test case on the utilization of ML to speed up a typical Monte Carlo Simulation, with the definition of Geant4 part to be modified.]: see report
 - KPI6.7: **Spoke2_WP6_TAR6.7**
-  TAR6.8 [MS report for UC2.6.3]: see report
 - KPI6.8: **Spoke2_WP6_TAR6.8**

Final Reporting period: [Sep 2023 - Feb 2024]

The reporting period coincides with the first 2 months of the MS7 reporting period, out of a total length of 6 months. Hence, most of the targets will not be completed in this period, and a status report is given (either inlined, or as an attached document).

Key for intermediate reporting period:

-  : failed target (for example a target to be executed by October 2023, and missed) – failed
-  : a target not yet realized but due in a later moment (for example by MS7 - Feb 2024) – in progress
-  : a target positively concluded within its natural deadline – done

As per a global decision by the HUB, targets involving Innovation Grants will no longer be inserted in this report, but will be documented in a specific report.

Spoke-Level Targets - WPO

Expected Targets

-  TAR0.8: [Final list of Cascade Calls Objectives]: Open Calls have been published on Monday Feb 19th. The call with the objectives is at the moment open on the INFN and ICSC home pages
 - KPI0.8:
<https://home.infn.it/it/pnrr-2/bandi-a-cascata/6409-pnrr-m4c2-bandi-cascata-icsc>,
<https://www.supercomputing-icsc.it/en/2024/02/19/cascade-grants-spoke-2/>
-  TAR0.9: [Cascade Calls plan]: The draft plan is included in the Call. Each of the 14 Objectives have been allocated up to 400kEur, so the total is much more than the total of 3.2 Million Euros.
 - KPI0.9:
<https://home.infn.it/it/pnrr-2/bandi-a-cascata/6409-pnrr-m4c2-bandi-cascata-icsc> (see “Allegato2” for the themes)

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-  TAR0.10: [General Meeting for the start of second year of Spoke 2]: the General meeting happened on December 18th-20th 2023, in Bologna. More than 50 contributions were presented, with a particular attention from short presentations from the young collaborators hired for the project
 - KPI0.10: <https://agenda.infn.it/event/38374/>
-  TAR0.25 [Repository for the Spoke 2 with initial project population, by October 2023]: GitHub repository (all public) created and populated with a few projects. In many cases, the researchers prefer to use owned repositories, so the fork on our repository will be done later in the project (probably, when a code reaches at least beta test)
 - KPI0.25: <https://github.com/ICSC-Spoke2-repo>

WP1 – [Design and development of science-driven tools and innovative algorithms for Theoretical Physics]

Expected Targets

-  TAR1.5 [MS report for UC2.1.1]: see report at the end of the updated Flagship document
 - KPI1.5: **Spoke2_WP1_TAR1.5_final**
-  TAR1.6 [MS report for UC2.1.2]: see report at the end of the updated Flagship document
 - KPI1.6: **Spoke2_WP1_TAR1.6_final**
-  TAR1.7 [MS report for UC2.1.3]: see report at the end of the updated Flagship document
 - KPI1.7: **Spoke2_WP1_TAR1.7_final**
-  TAR1.8 [MS report for UC2.1.4]: see report at the end of the updated Flagship document
 - KPI1.8: **Spoke2_WP1_TAR1.8_final**

WP2 – [Design and development of science-driven tools and innovative algorithms for Experimental High Energy Physics]

Expected Targets

-  TAR2.5 [MS report for UC2.2.1]: report included
 - KPI2.5: **Spoke2_WP2_TAR2.5_final**
-  TAR2.6 [MS report for UC2.2.2, on approaching new interactive analysis frameworks for big data with a high throughput. This activity will be performed in synergy with WP5, regarding the infrastructural support and future upscaling with CN resources.]: report included at the end of the Flagship document
 - KPI2.6: **Spoke2_WP2_TAR2.6_final**
-  TAR2.7 [MS report for UC2.2.3, including identifying most suitable ML models and finalising the code development targeting the FPGA hardware in use at the moment.]: Intermediate report provided at the end of the Flagship document

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- KPI2.7: **Spoke2_WP2_TAR2.7_final**
-  TAR2.8 [MS report for UC2.2.4]: report included
 - KPI2.8: **Spoke2_WP2_TAR2.8_final**
-  TAR2.14 [MS report for UC2.2.5]: report included
 - KPI2.9: **Spoke2_WP2_TAR2.9_final**

WP3 – [Design and development of science-driven tools and innovative algorithms for Experimental Astroparticle Physics and Gravitational Waves]

Expected Targets

-  TAR3.5 [MS report for UC2.3.1, including a test of an alternative CPU implementation in MATLAB; Deliverable: 1- A report on the code with the description of the performances obtained through the tests done; 2- Code released on an private repository (cannot be public)]: see report at the end of flagship description document and attachments within.
 - KPI3.5: **Spoke2_WP3_TAR3.5_final**
-  TAR3.6 [MS report for UC2.3.2]: see report at the end of flagship description document and attachments within.
 - KPI3.6: **Spoke2_WP3_TAR3.6_final**
-  TAR3.7 [MS report for UC2.3.3, including analysis of the performances of the codes and identification of pipeline bottlenecks to identify the parts that could be improved and release of the new CHIMERA code with improved GPU performances]: see report at the end of flagship description document and attachments within.
 - KPI3.7: **Spoke2_WP3_TAR3.7_final**
-  TAR3.8 [MS report for UC2.3.4, including setting up the simulation and reconstruction chain for the hybrid detector of the Pierre Auger Observatory adopting the “Real Monte Carlo” scheme in the INFN-cloud resources.]: see report at the end of flagship description document and attachments within.
 - KPI3.8: **Spoke2_WP3_TAR3.8_final**
-  TAR3.9 [MS report for UC2.3.5, including development of the first fully working code]: see report at the end of flagship description document and attachments within
 - KPI3.9: **Spoke2_WP3_TAR3.9_final**
-  TAR3.10 [MS report for UC2.3.6, including the design of two or more pipeline prototypes, which include the definition of the software architecture, functions and I/O interfaces, the technological solutions for the containerization, the requirements (e.g. speed, data transfer, memory load, scalability), the software repository and the selection of the target infrastructures (e.g. the INFN Cloud infrastructure). This activity will be performed in collaboration with WP 4 and 5]: see report at the end of flagship description document and attachments within
 - KPI3.10: **Spoke2_WP3_TAR3.10_final**
-  TAR3.11 [MS report for UC2.3.7, including production of the large scale (lower resolution) boxes as a pathfinder sample]: see report at the end of flagship description document and attachments within
 - KPI3.11: **Spoke2_WP3_TAR3.11_final**

WP4 – [Boosting the computational performance of Theoretical and Experimental Physics algorithms]

Expected Targets

- :TAR4.6 [Participation to Scientific WP targets]: WP4 is actively participating in the Flagship projects driven by “scientific WPs” 1-2-3-6. A small report for the first two months of MS7 is included
 - KPI4.6: see WP1-2-3-6 targets
- :TAR4.7 [Training on FPGA]: Spoke 2 members organized for November 27th-30th an “Introductory course to HLS FPGA programming”; agenda
 - KPI4.7: <https://agenda.infn.it/event/38191/>
- :TAR4.8 [ML training opportunity on GPU, with WP2 and WP5]: The “Fifth ML-INFN Hackathon: Advanced Level” is scheduled for Nov 13th-16th, in Pisa. Its scientific and local organisation teams include as a majority Spoke 2 members. On top of this, a workshop on ML explainability in medical physics was organized by WP4.
 - KPI4.8: <https://agenda.infn.it/event/37650/>,
<https://indico.cern.ch/event/1312529/>

WP5 – [Architectural Support for Theoretical and Experimental Physics Data Management on the Distributed CN infrastructure]

Expected Targets

- :TAR5.6 [Participation to Scientific WP targets]: WP5 is actively participating in the Flagship projects driven by “scientific WPs” 1-2-3-6. A report for the first two months of MS7 is included directly in these reports
 - KPI5.6: **see WP1-2-3-6 targets**
- :TAR5.7 [Training on Distributed Computing Models]: School SOSC (organized by Spoke 2 members, and sponsored by ICSC) executed
 - KPI5.7: <https://agenda.infn.it/event/36074/>
- :TAR5.8 [ML training opportunity on the Cloud, with WP2 and WP4]: The “Fifth ML-INFN Hackathon: Advanced Level” took place in Nov 13th-16th, in Pisa. On top of this, a workshop on ML explainability in medical physics was organized by WP4.
 - KPI5.8: <https://agenda.infn.it/event/37650/>,
<https://indico.cern.ch/event/1312529/>

WP6 – [Cross-domain Initiatives]

Expected Targets

- :TAR6.6 [MS report for UC2.6.1]: report included
 - KPI6.6: **Spoke2_WP6_TAR6.6_final**
- :TAR6.7 [MS report for UC2.6.2, including a thorough examination of modern technologies and methodologies. Keep up with the latest advancements in

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hardware and software that are relevant to the project. Define a first simple test case on the utilization of ML to speed up a typical Monte Carlo Simulation, with the definition of Geant4 part to be modified.]: see report

- KPI6.7: **Spoke2_WP6_TAR6.7_final**
-  TAR6.8 [MS report for UC2.6.3]: see report
 - KPI6.8: **Spoke2_WP6_TAR6.8_final**