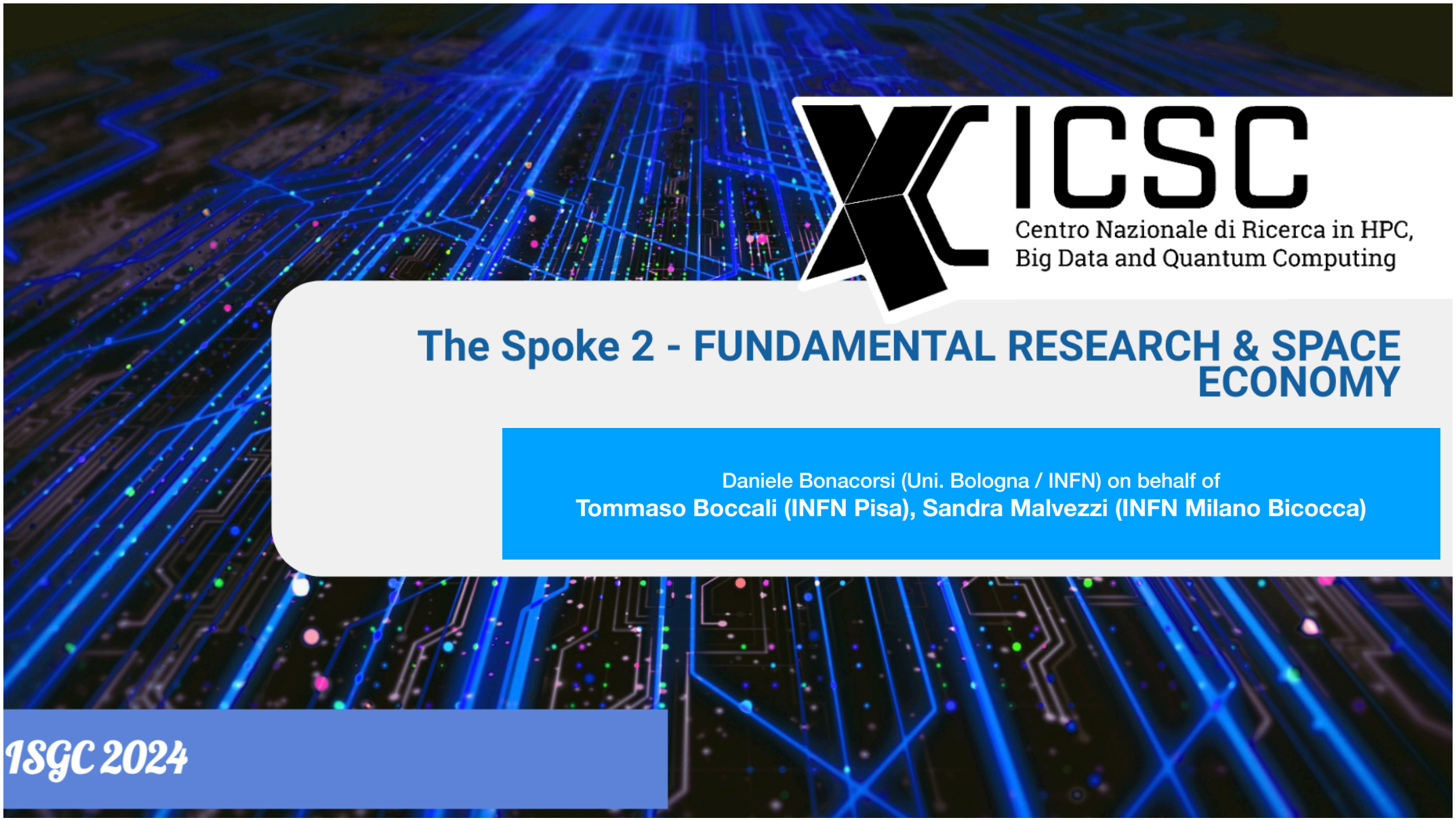


The Spoke 2 - FUNDAMENTAL RESEARCH & SPACE ECONOMY

Daniele Bonacorsi (Uni. Bologna / INFN) on behalf of
Tommaso Boccali (INFN Pisa), Sandra Malvezzi (INFN Milano Bicocca)

ISGC 2024

Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

National Center for Big Data, HPC and Quantum Computing

- Italy has funded, with NRRP (pandemic recovery) funds, 5 large National Centers, for a total of 1.6 Beur over 3 years
- One of them, coordinated by INFN, focuses on modern IT technologies, with the final goal to deploy a long-term (>>3 years) distributed infrastructure available to the reseach and the industrial ecosystems in Italy

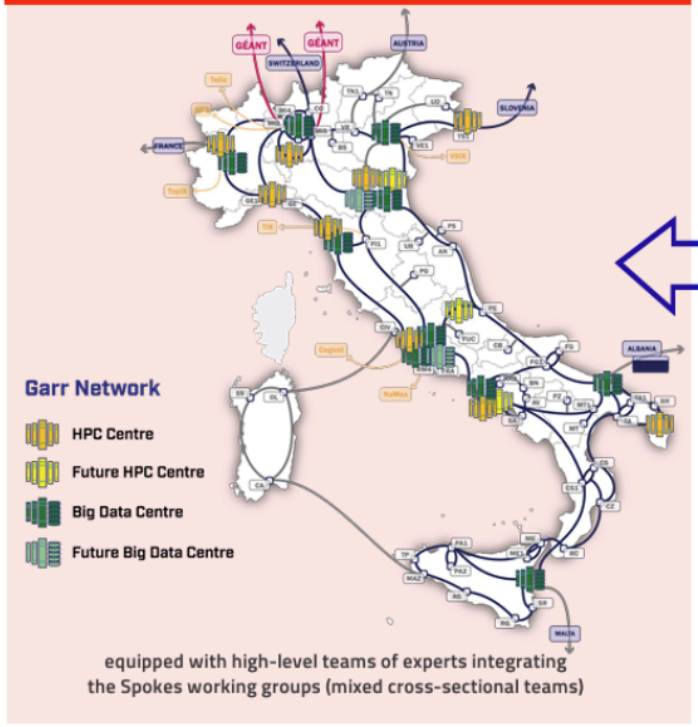
- Sept 2022 to Aug 2025

ICSC
Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

The ICSC will include

10 thematic Spokes and **1 Infrastructure spoke**

0 SUPERCOMPUTING CLOUD INFRASTRUCTURE



equipped with high-level teams of experts integrating the Spokes working groups (mixed cross-sectional teams)

EDUCATION & TRAINING, ENTREPRENEURSHIP, KNOWLEDGE TRANSFER, POLICY, OUTREACH

1 FUTURE HPC & BIG DATA

2 FUNDAMENTAL RESEARCH & SPACE ECONOMY

3 ASTROPHYSICS & COSMOS OBSERVATIONS

4 EARTH & CLIMATE

5 ENVIRONMENT & NATURAL DISASTERS

6 MULTISCALE MODELING & ENGINEERING APPLICATIONS

7 MATERIALS & MOLECULAR SCIENCES

8 IN-SILICO MEDICINE & OMICS DATA

9 DIGITAL SOCIETY & SMART CITIES

10 QUANTUM COMPUTING

- One “Spoke” dedicated to building the infrastructure (hw+middleware) (Spoke 0)
- Ten thematic Spokes, one dedicated to the High Energy Physics and Astroparticle research domains

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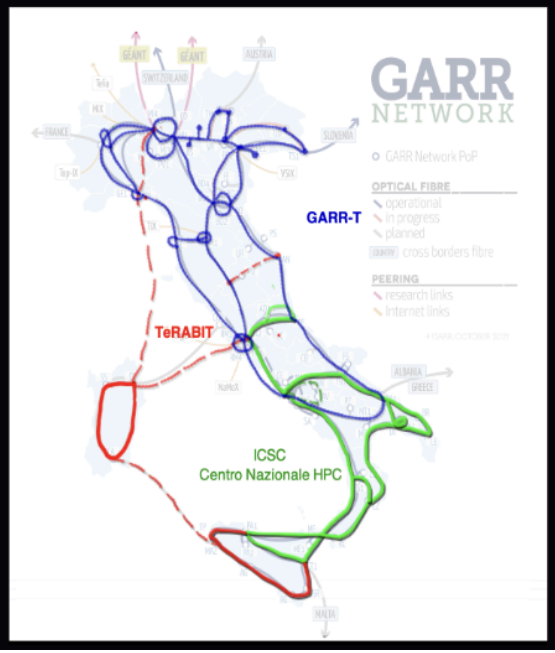
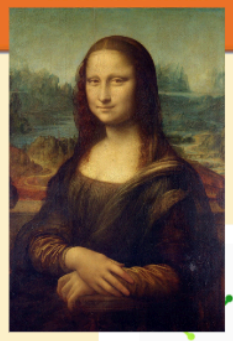
On the infrastructure: 3 major pillars

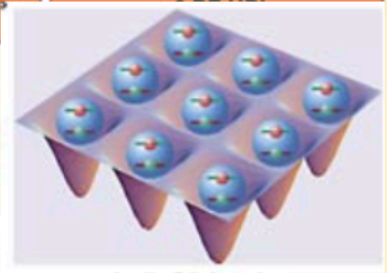
- **GARR**: Tbps-level connectivity between all public data centers



- **CINECA**: expansion of Leonardo (HPC#6 on top500.org) with Lisa, and deployment of a

GPU Module Lisa	CPU Module Lisa
500 compute nodes 4x GPUs / node	1000 compute nodes 2x CPUs + HBM / node

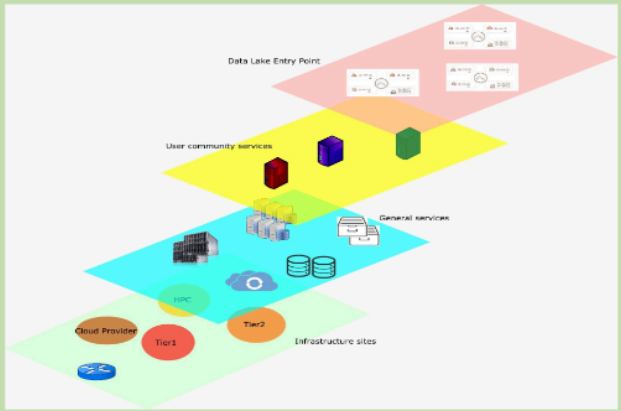




PASQAL

AQT

- **INFN**: strengthening of the WLCG infrastructure (1 Tier1 – 9 Tier-2s); acquisition of Cloud resources; implementation of the datalake middleware, based on INFN-Cloud



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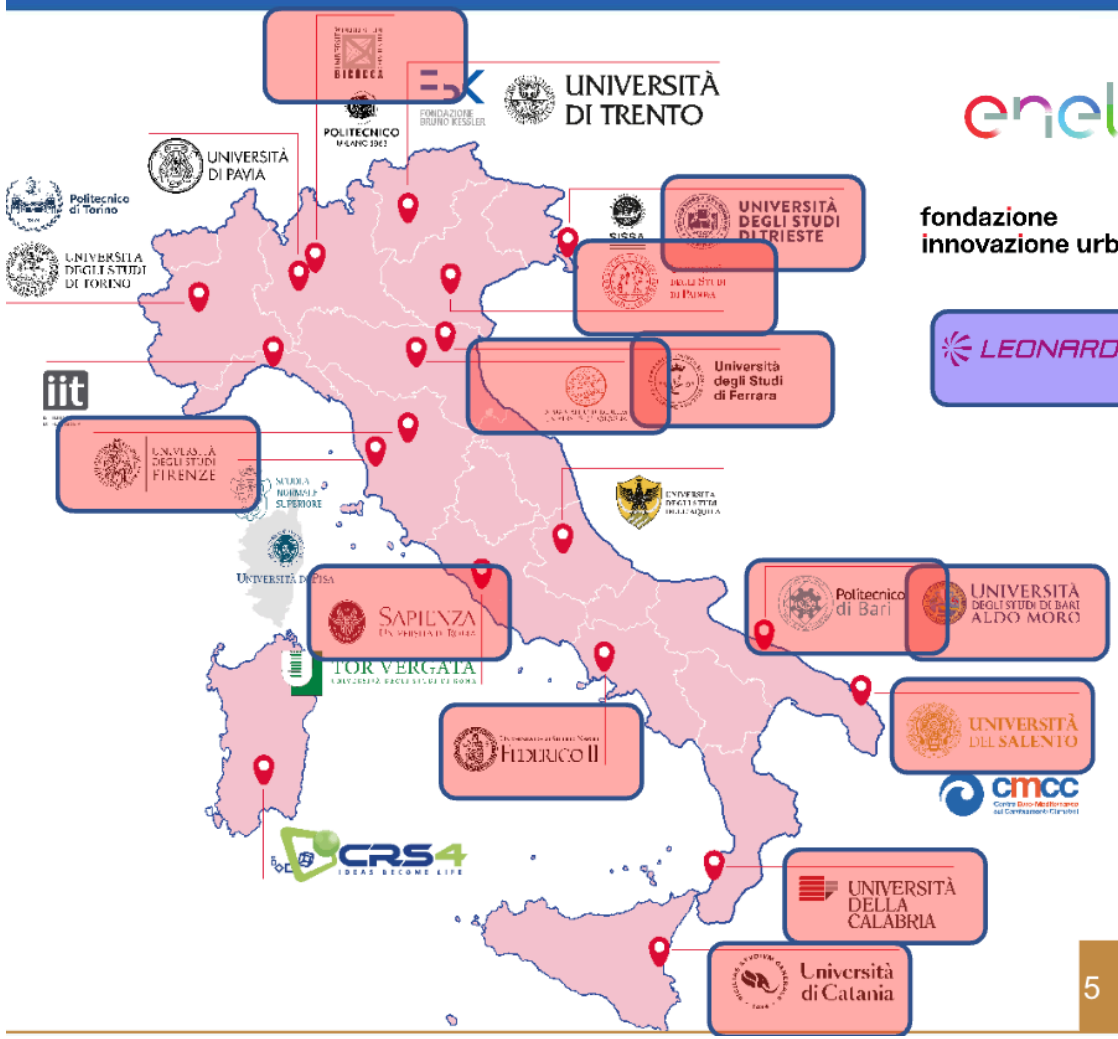

enel
ENGINEERING
eni
FERROVIE DELLO STATO ITALIANE
FINCANTIERI
fondazione innovazione urbana
autostrade per l'italia
HUMANITAS
iFAB
INTESA SANPAOLO
LEONARDO
sogei
ThalesAlenia Space
Terna Driving Energy
UnipolSai ASSICURAZIONI

Staff Researchers	195
(kEur)	6333
Rectruited researchers	28
(kEur)	5067
Phd positions	25
(kEur)	1992
Budget Innovation Grants (kEur)	1800
Bugdet Cascade Calls (kEur)	3200
Total Budget (kEur)	**18391**
Total Positions	**248**

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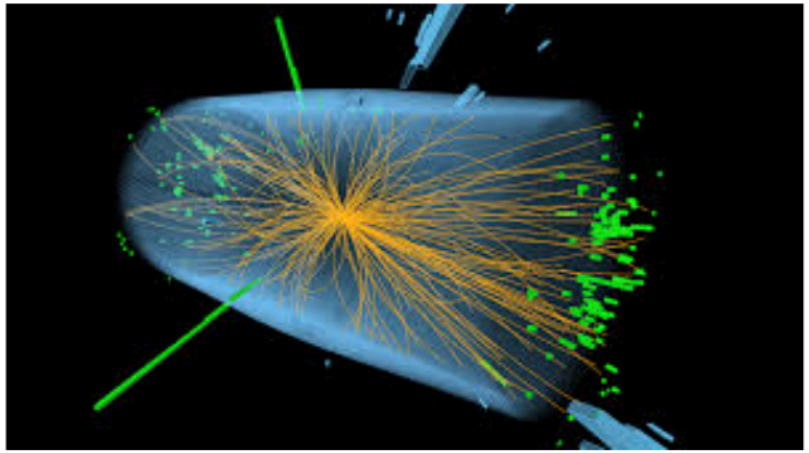
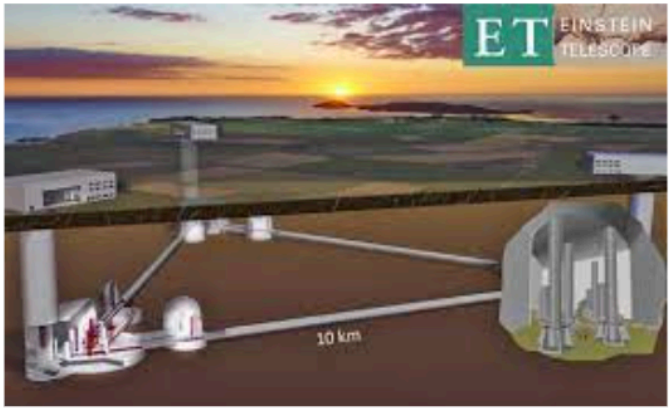
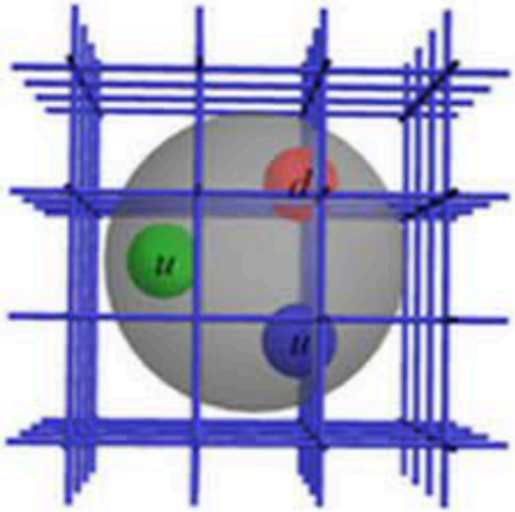
Who are "we"?



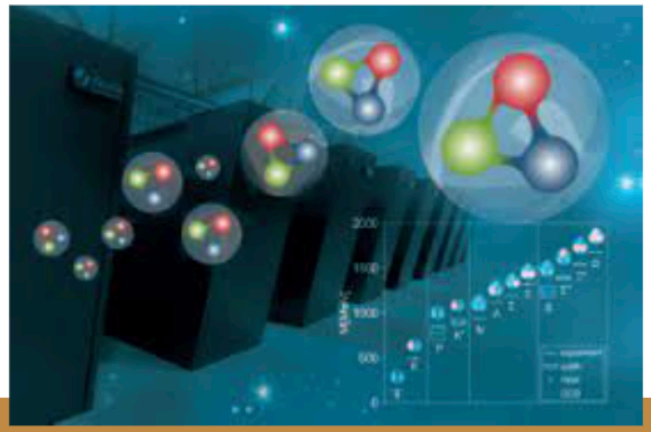




Why our communities need an ICSC

- Since at least 2 decades, research at the fundamental frontier is heavily "computing bound"
  - Latest (and next) generation experiments collect data at the Exabyte and beyond
  - Simulation efforts in theoretical and experimental physics are at the Exascale
  - We have been forced to develop in-house solutions when nothing was available, with a good success. But it is now due time to evolve to a shared infrastructure model
    - The Web, the GRID, …
- Examples:
  - LHC has has already surpassed the global scale of several Exabytes of Data, and more than 1 Million CPU cores
  - Lattice QCD simulations are, with Meteo, the main driver and benchmark for HPC systems

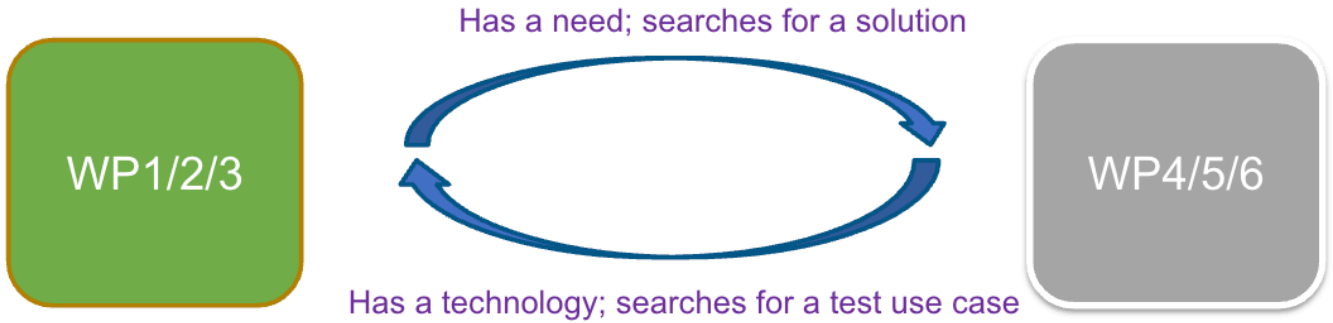
The Worldwide LHC Computing GRID



Lattice QCD on HPC

Work Packages – the structure

- We defined 2 types of Work Packages:
  - **"scientific" WPs**: they analyze the needs of the (sub-)domain, and pose open problems for which advanced computing solutions are needed
  - **"technological" WPs**: they harvest / investigate technical solutions in computing, on the infrastructure of the ICSC and beyond, and provide support / training for these; at the same time propose these to a larger audience, including industries



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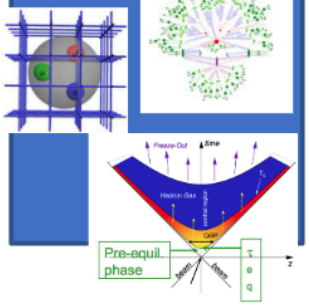
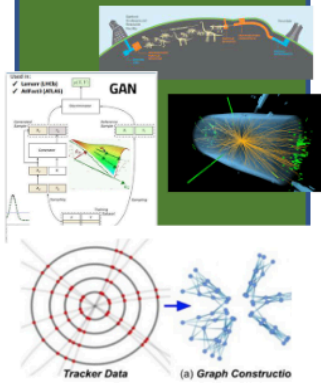
Work Package Structure

WP1: tools and algorithms for Theoretical Physics



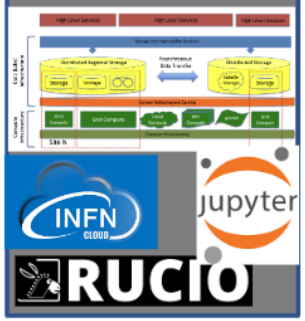
WP2: tools and algorithms for Experimental Collider Physics



WP3: tools and algorithms for Experimental Astroparticle Physics and Gravitational waves

WP4: tools for porting / optimization on new architectures (low power, GPU, FPGA, …)

WP5: data management on the distributed CN infrastructure

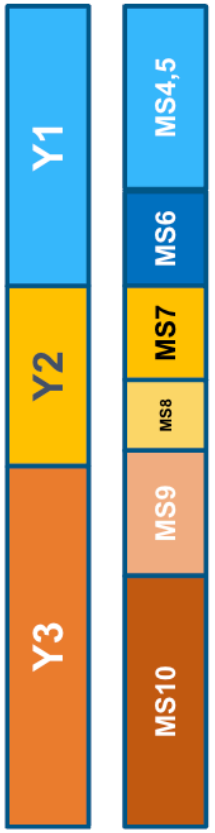


WP6: cross domain initiatives, + space economy

Plan of Work

- All the activities designed in the submitted project with a standard 4-phase plan over the three years
- We are now in the crucial year: the realization phase

1. **planning and identification**: the first year of the project is dedicated to a landscape recognition for interesting state-of-the-art use case; its outcome is a work plan identifying the activities on which the core part of the project will be focusing - in particular, algorithms and services to be accomplished;
2. **a realization phase**, in which the actual development is performed via the staff/ hired personnel; the outcome is usable algorithms / services, documented (alpha/beta level) and ready to be tested on a larger scale;
3. **a validation phase**, in which the outcomes of the realization phase are verified in testbeds and proofs of concept, and benchmarked in order to assess their adherence to the specifications;
4. **a wrap-up phase**, in which results are analysed and consolidated in reports and white papers to be used as guidelines for similar use cases.



The technologies in place ...

- **Software:**
  - Machine Learning as a substitute for hand-written algorithms
  - Porting of codes to
    - GPU systems, with heterogeneous frameworks
    - FPGA systems, with HLS or direct programming
    - Low power Architectures (ARM today, possibly RISC-V)
  - Adapting codes to
    - Distributed computing ("datalake compatible")
    - Generic dat management, data access
    - Conteinerization, ...
    - Single node to Multinode (MPI, ...)

- **Hardware**
  - deploy generally accessible pilots with FPGA
  - Deploy generally accessible pilots with ARM and RISC-V
  - Deploys clusters accessible via cloud technologies, and managed via central data management systems

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How do we operate?

- We identified "Flagship Projects", 19 of them, which will demonstrate a technology / a new approach in a scientific domain

WP1 (4): «Multilevel Hybrid Monte Carlo for lattice QCD», «QCD under extreme conditions», «Advanced Calculus for Precision Physics (ACPP)», «Large Scale Simulations of Complex Systems»

WP2 (5): «Advanced Machine Learning - Flash Simulation and bleeding edge applications», «Porting Algorithms on GPU», «Ultra-fast algorithms running on FPGA», «Validation of HEP reconstruction code on ARM», «Quasi interactive analysis of big data with high throughput»

WP3 (7): «Frequency Hough (FH) Transform analysis on GW continuous sources», «Efficient use of machine learning and GPUs in cosmological data analysis: from theory to likelihood to statistical inference», «Inference of cosmological and astrophysical population properties from GW observations with and without electromagnetic counterparts», «Development of innovative analysis techniques using realistic simulations of the upgraded Auger Observatory within the context of a machine learning environment», «Detection and classification of SSO in Euclid Simulated data», «Pipeline optimization for space and ground based experiments (PSGE)», «Hydrodynamical simulations to test the nature of dark matter»

WP4 and WP5 do not have specific Flagship, but participate to most of the other flagships, with themes like GPU / FPGA utilization; Low power computing with ARM; High rate analysis solutions on the Data Lake; Machine learning at large scale; Fast simulations via generative networks, ; …

WP6 (3): «Enhancing Geant4 Monte Carlo Simulations through Machine Learning Integration», «Fast Extended Computer Vision», «AI algorithms for (satellite) imaging reconstruction»

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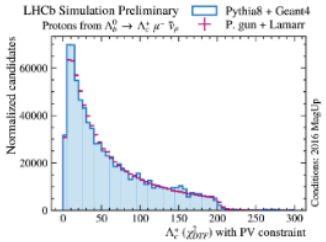
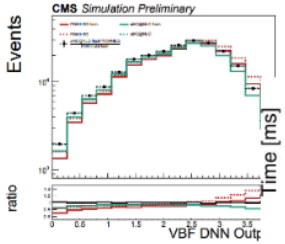
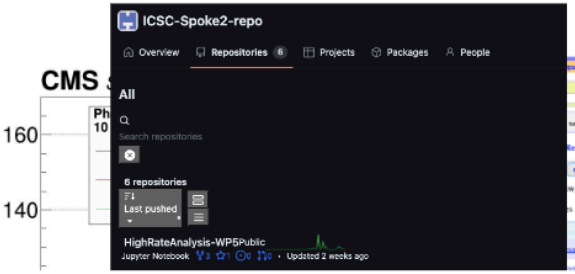
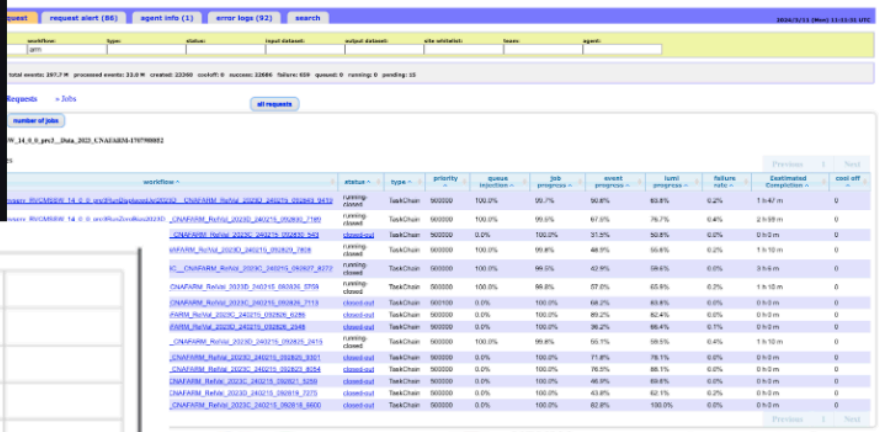
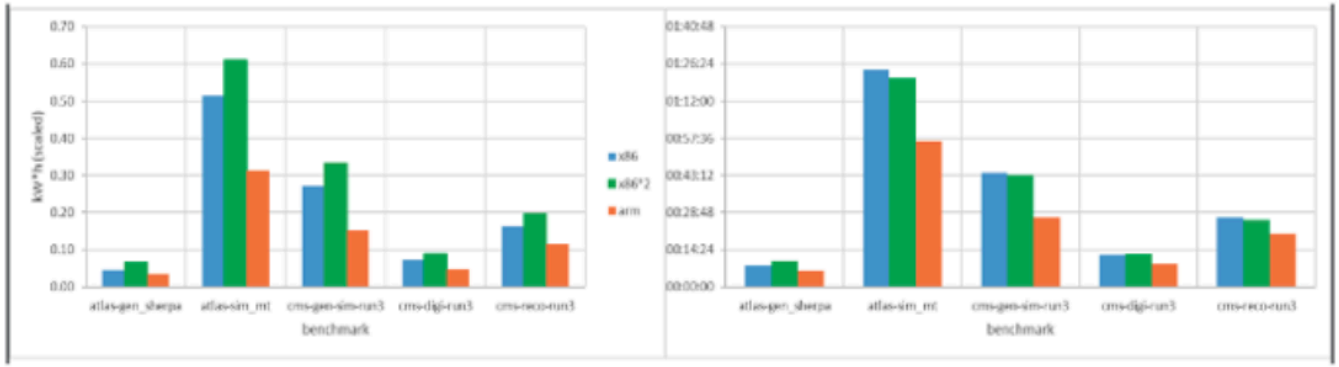
Results are already flowing

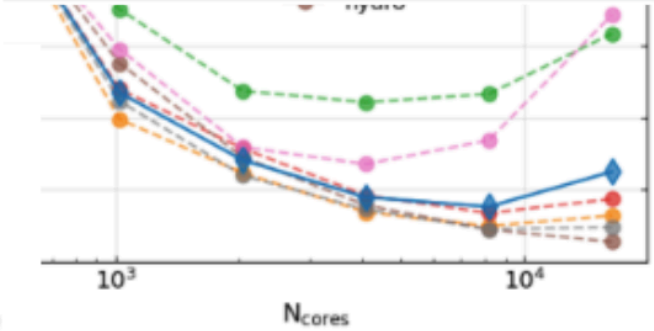


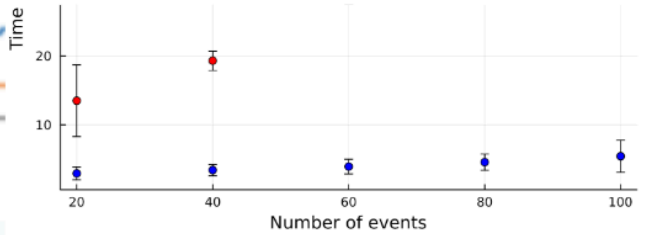


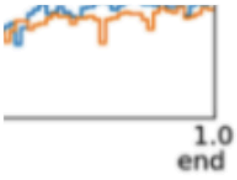












A further step: "From Research to Industry"

- Why should industry be interested in what we do ("finding the Higgs boson?")
- Clearly they don't, but on the technological side we can share the platforms, the solutions, the expertise

- Spoke 2 has funded
  - 2+ Meur on "Innovation Funds": projects between Spoke 2 and Large Enterprises
  - 3.2 Meur on "Cascade Calls": projects between research groups and SME

An example of collaborations – Innovation Funds

- **ENI:**
  - Testing HEP workflows on a industrial data center
  - Predictive maintenance on ENI's industrial plants
  - Physics Inspired ML for the exploitation of natural resources
- **Leonardo + TASI:**
  - Interoperable Datalake: Data management + Block Chain pilot per dati da space economy
- **Unipol:**
  - Merging data and AI for improving Seismic Risk assessment and Management in populated areas
- **UnipolSAI + SOGEI:**
  - Monitoring of alert and vulnerability hurban for fast response and assurance evaluation
- **Intesa Sanpaolo:**
  - Correlations between satellite images and budget in agricoltural enterprises
  - Fraud detection as anomaly search on financial streams
- **IFAB, SECO, Coldiretti, …**
  - Digital Twins for Precision Agricolture
- **IFAB, Bonfiglioli, Tampieri, SECO, …**
  - Edge AI Anomaly Detection System for Critical Environments

Conclusions

- The National Center for HPC, Big Data and Quantum Computing is a unique opportunity for research in Italy: build a modern infrastructure for research initially, and industry later, and make sustainable beyond the initial fundings

- Spoke 2 Activities are aligned with the needs from High Energy and Astroparticle Physics
- We are trying to form the next generatoin of scientists, versed in modern technologies
- While doing that, we want to strenghten the links with italian industries