Facilities WG Report

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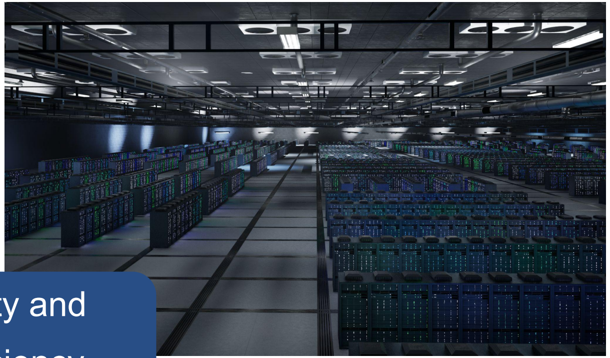
European Strategy Update

Introduction

European Strategy for Particle Physics



There are about 40 submissions to the Computing Track

- Approximately 25% are primarily facilities related

Common Themes in Facilities

Evolution of Processor Architectures	HPC Integration in HEP	Sustainability and Energy Efficiency
AI Facilities	Specialized Analysis Infrastructures	Interdisciplinary and Industry Collaborations

Disclaimer: We have attempted to make a comprehensive overview, but in 10 minutes we will not be able to cover everything

Evolution of Processor Architectures

See Estela Suarez's talk

Theme: Processor Architectures and Industry Trends

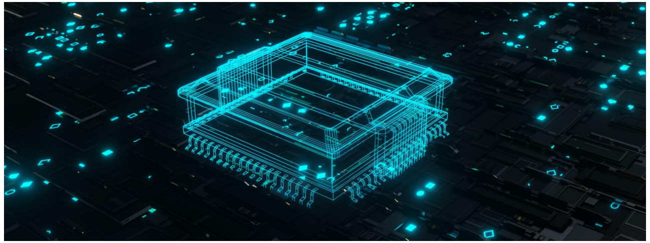
The **computing landscape** is shifting rapidly as **industry** increasingly **prioritizes AI-focused technologies** and specialized architectures over general-purpose **CPUs**. Substantial **efforts** are required to **optimize** scientific codes for new architectures.

Observations:

- HEP computing is progressively integrating **GPU-based** systems. GPU is ubiquitous in **online** systems and growing in offline workflows.
- **Software** must be **robust, portable**, and designed for long-term adaptability **across architectures. Co-design** with **industry** and **HPC centers** is key.
- AI applications do not require **high precision** while HEP do— a key area for collaboration with industry to maintain this capability.

Related Activities and Initiatives:

- **GPU-enabled** workflows, including **AI**, benchmarking and integration of **HPC/cloud resources** (WLCG/HEP evolution)
- Interoperability and **portability** across diverse hardware platforms
- Strategic **industry** collaborations (e.g. CERN openlab) and EC-funded projects (e.g. **SPECTRUM**, **ODISSEE**) and community-organized activities (**JENA**)
- Heterogeneous Architecture Testbed (e.g. CERN openlab) for evaluating new technologies



9 The Worldwide LHC Computing Grid input to the ESPP24-269; 12 Strategy for HPC Integration in WLCG/HEP; 124 JENA White Paper on European Federated Computing; 18 CERN openlab: A Flagship Model for Industry-Science Computing R&D; 80 SPECTRUM Project: Input to the European Particle Physics Strategy Update 2026; 73 INFN Input on the update of the European Strategy for Particle Physics: Computing;152 United States Muon Collider Community White Paper for the European Strategy for Particle Physics Update

HPC Integration in HEP

See Andrej Filipcic's talk

European Strategy for Particle Physics

Theme: Evolution towards a Federated Infrastructure Including HPC/Cloud Environments

There is a strategic movement towards leveraging heterogeneous, **distributed computing** models that integrate **HPC, Cloud,** and **HTC r**esources. This includes and expands beyond traditional LQCD applications to support AI and high-throughput workloads across HEP.

Observations:

- Current reliance on x86 limits compatibility with diverse HPC platforms; improved **software** and workflow **portability** is essential for broader integration.
- **Investment in training** and support for **domain-specific software development** tailored to HPC environments.
- Funding agencies are increasingly encouraging greater use of national **HPC infrastructures**.
- **HEP** must position itself as a **strategic** science to influence **HPC/AI/QC co-design** of future facilities and secure multi-year resource allocations.

Related Activities and Initiatives:

- HEP-HPC Strategy Meetings and White paper
- JENA Working Group 1 (HPC and HTC)
- EU, US-funded and international projects: SPECTRUM, InPEx, IRI, EFP
- EuroHPC-JU provides access to HPC, AI, and Quantum Infrastructures

9 The Worldwide LHC Computing Grid input to the ESPP24-269; 12 Strategy for HPC Integration in WLCG/HEP; 29 Strategy for the Future of Lattice QCD; 124 JENA White Paper on European Federated Computing; 187 ATLAS Software and Computing for the Future; 205 The Belle II Experiment at SuperKEKB; 127 Computing and software for LHCb Upgrade II; 121 DUNE Software and Computing Research and Development

Sustainability and Energy Efficiency

E. Suarez's and C. Doglioni's talk

Theme: Sustainability in Scientific Computing: Reducing Cost, Energy Consumption, and Carbon Footprint

As computing demands rise, **minimizing environmental** and financial **impact** has become a central concern. **Sustainable** infrastructure **design**, **energy-efficient operations**, and **optimized** software are essential to balancing performance with energy and cost efficiency.

Observations:

- There is growing recognition in the HEP community of the **environmental** and financial impact of large-scale computing.
- **Efficient software** plays a **critical** role in achieving **sustainable** computing.
- Sustainability MUST be treated as a **core design** constraint—shaping software design, future architectures, facility planning, and the full lifecycle of HEP computing.

Related Activities and Initiatives:

- Energy-aware job scheduling and intelligent workload placement
- Carbon tracking and reporting metrics
- Optimization of Power Usage Effectiveness (PUE) in data centers
- Increased reliance on **energy-efficient storage** (e.g., tape systems)
- Investigation of **low-power** hardware (e.g. ARM, RISC-V)
- EU-funded project **ODISSEE**

107 CMS Offline Software and Computing input to the European Strategy for Particle Physics - 2026 update; 124 JENA White Paper on European Federated Computing; 214 A roadmap for astroparticle theory in Europe; 18 CERN openlab: A Flagship Model for Industry-Science Computing R&D; 9 The Worldwide LHC Computing Grid input to the ESPP24-26

AI Facilities

Theme: Enabling Scalable AI Research and Production Through Specialized and Shared Facilities

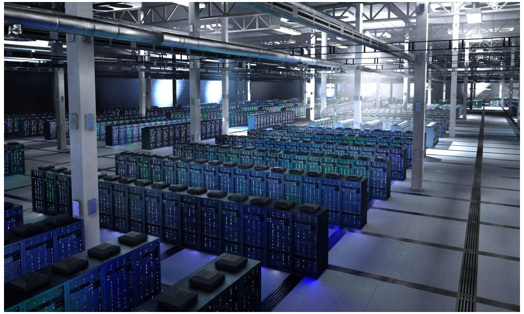
As AI gains relevance in scientific discovery, facilities should evolve to **support large-scale training, inference, and workflow integration.** This includes shared **AI platforms**, access to **AI accelerators,** and **MLOps** infrastructures designed for collaborative and scalable AI development.

Observations:

- Large investments in **data-intensive AI facilities** at scale, presenting a strategic opportunity for HEP to benefit from this evolving ecosystem.
- Demand for **AI in science is rising rapidly**; on-prem facilities often lack the scale and specialization required.
- **Purpose-built, shared** infrastructure is needed for supporting AI workflows from development to production.

Related Activities and Initiatives:

- Development of “**AI factories”** for large-scale model training and serving
- **MLOps infrastructure** to support end-to-end lifecycle of AI models
- Exploration of **foundation models** tailored for physics and scientific domains
- Benchmarking tools and practices for scientific **AI workloads**
- Initiatives like EuCAIF and EU-funded **SPECTRUM**



167 AI-RDs: A EuCAIF proposal to structure AI research in Particle Physics; 185 EuCAIF Recommendations for Scaling AI Capabilities in Particle Physics; 180 SPECTRUM Project: Input to the European Particle Physics Strategy Update 2026; 18 CERN openlab: A Flagship Model for Industry-Science Computing R&D; 215 A roadmap for astroparticle theory in Europe

Specialized Analysis Infrastructures

Theme: Specialized Analysis Infrastructures to Support Next-Generation Data Volumes and User Needs

The **scale** and complexity of data expected from upcoming scientific projects necessitates new types of f**acilities optimized for analysis.** These must offer a different capabilities than the past including **interactive+scaleout,** and **user-friendly environments** that streamline access to data and support diverse workflows across experiments.

Observations:

- Traditional computing environments are often not optimized for interactive analysis at scale.
- There is **growing demand for dedicated platforms** that reduce barriers to analysis and enhance scientific productivity
- Tailored user interfaces to **co-located compute and storage**, and shared infrastructure can improve efficiency and accessibility.

Related Activities and Initiatives:

- **Elastic Analysis Facilities (EAF)** for scalable, on-demand compute
- Dedicated high-performance execution environments with integrated resources
- **High-performance, low-latency storage systems for rapid analysis**
- **Multi-experiment platforms** supporting shared infrastructure
- Emphasis on user-centric design and seamless interfaces for analysis workflows

237 The Elastic Analysis Facility's (EAF's) Contribution to the Future of Analysis at Multi-Experiment Institutions and Future Colliders; 11 Fermilab Interest in a Higgs Factory at CERN; 138 Data Preservation in HIgh Energy Physics; 150 Reinterpretation and preservation of data and analyses in HEP

See Estela Suarez's talk

Interdisciplinary and Industry Collaborations

Theme: Federated and Interdisciplinary Collaboration Through Shared Infrastructure

To maximize the return on investment in scientific computing, facility strategies must embrace **federated infrastructure models** that span disciplines and national boundaries. **Interoperable systems** and **collaboration with industry** are essential for enabling cross-domain research, optimizing resource use, and accelerating discovery.

Observations:

- Increasing data and compute demands across disciplines highlight the need for **coordinated infrastructure planning**.
- Shared platforms and **federated systems** reduce duplication, foster innovation, and improve scientific return.
- Pursue EuroHPC **Centres of Excellence** (CoE) for HEP (including LQCD) to share technical advancements and promote collaboration.

Related Activities and Initiatives:

- **Foster synergies** between Lattice QCD, astroparticle physics, and radio astronomy on the use of infrastructures, shared data services, and sharing expertise towards performant codes for heterogeneous architectures.
- Data federation initiatives such as **SPECTRUM** for cross-site data access
- Promotion of **FAIR** **(**Findable, Accessible, Interoperable, Reusable) data principles
- EU-funded project **EVERSE** in pursuit of building a European network of Research Software Quality

124 JENA White Paper on European Federated Computing; 52 The Astro-particle Physics Commission 2; 185 EuCAIF Recommendations for Scaling AI Capabilities in Particle Physics; 73 INFN Input on the update of the European Strategy for Particle Physics: Computing; 168 Addressing Scientific Computing for HEP needs beyond Experimental Particle Physics

Conclusions

There is broad and active interest across the community in advancing the scale, efficiency, and capabilities of computing facilities, as reflected in the diverse submissions to the computing track.

- Focus on AI is growing, with rising demand for facilities that support development and production of ML workflows.
- Sustainability is a major concern, driving efforts to reduce the carbon footprint of future facilities.
- Effective HPC integration into HEP computing remains a key priority for the LHC and the large future projects, with efforts focused on technical and organizational challenges. Support from HPC experts and user friendliness is critical.
- Robust, efficient, and portable software is necessary to meet the future HEP computing needs, and support for career development and training of software and computing professionals is crucial for this.
- Cross-disciplinary and industry collaboration is seen as vital for maximizing impact and accelerating progress at the interface of HPC, AI and Quantum Infrastructures.

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THANK YOU!
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