Welcome to CERN openlab
The HL-LHC brings unprecedented computing challenges: the total computing capacity required by the experiments is expected to be 10 times greater than today.

Large investments in R&D are needed to improve software and workflows, reduce storage needs, integrate new resources and solutions from technology providers.

HL-LHC computing needs
Upgraded program = new challenges

Upgraded Accelerator
• Higher Luminosity

Upgraded Detectors
• Higher Granularity
• Higher Occupancy

Changing Filtering Paradigms
• Higher Data Rates
• Higher Sensitivity

New Computing Challenges

R&D Investments
• Code modernization, HPC and hardware accelerators
• Reducing storage needs
• New techniques, from AI to QC
CERN OPENLAB’S MISSION

Our recipe for success

Evaluate and test state-of-the-art technologies in a challenging environment and improve them in collaboration with industry.

Communicate results, demonstrate impact, and reach new audiences.

Collaborate and exchange ideas with other communities to create knowledge and innovation.

Train the next generation of engineers/researchers, promote education and cultural exchanges.
DRIVING INNOVATION FOR 20 YEARS

- I 2003
- II 2006
- III 2009
- IV 2012
- V 2015
- VI 2018

SET UP 2001

Seventh Phase VII

2021
Collaboration Model

1. **Pick a challenging problem**
2. **Check how this problem impacts or is impacted by industry**
3. **If a good match is found, define a joint project with a company**
4. **Company invests because can get a return from the investment**
5. **Requirements**
6. **Assessment Due Diligence**
7. **Technical Negotiation**
8. **Legal/Financial Negotiation**

CERN openlab - Challenges in Computing
Collaboration members

<table>
<thead>
<tr>
<th>PARTNERS</th>
<th>CONTRIBUTORS</th>
<th>RESEARCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>intel</td>
<td>IBM</td>
<td>INFN</td>
</tr>
<tr>
<td>ORACLE</td>
<td>E4</td>
<td>Fermilab</td>
</tr>
<tr>
<td>SIEMENS</td>
<td>Comtrade Three-Sixty</td>
<td></td>
</tr>
<tr>
<td>Micron</td>
<td>Google</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roche</td>
<td></td>
</tr>
</tbody>
</table>

CERN openlab
# Strategic Innovation Areas

<table>
<thead>
<tr>
<th>XT</th>
<th>eXascale Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>A comprehensive investigation of HPC and Cloud infrastructures, frameworks, tools to support key scientific workloads and applications, including AI, HPC, Digital Twins</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AI-S</th>
<th>Artificial Intelligence for Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis and development of algorithms, optimisation for new architectures, interpretability, synergies between Physics and other sciences</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QTI-C</th>
<th>Quantum Technology Initiative - Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assess the potential impact of quantum computing in HEP and other sciences, investigate quantum machine learning algorithms and areas of potential quantum advantage, set up a collaborative quantum computing (simulation) platform</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MSC</th>
<th>Multi-Science Collaborations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share the expertise and knowledge generated across all activities with other sciences, work with CERN KT to explore novel applications of CERN computing systems and ideas, create collaborations and contribute to common solutions</td>
<td></td>
</tr>
</tbody>
</table>
Exascale technologies: Heterogeneous Architectures Adoption

We collaborate with Intel, E4/NVIDIA, and Micron

CPU Delivered: HS06 hours per month

Robust resource growth of resources:

- Average +20% CPU and disk yearly growth.
- Consistent with a ‘flat budget’ funding for computing centres, the de-facto adopted model across all Funding Agencies for the past 10 years

Run 3 – more than 40% online reconstruction offloaded to GPU. Image courtesy of Andrea Bocci et al.
Exascale technologies: Heterogeneous Architectures Adoption

We collaborate with Intel, E4/NVIDIA, and Micron

HEPScore 2023 CPU Benchmarks

- INTEL XEON 8480+ (224) SNC4*
- INTEL XEON 8480+ (224)*
- INTEL XEON MAX 9462 (128)*
- INTEL XEON 8360Y (144)
- INTEL XEON 8362 (64)†
- INTEL XEON 8260 (96)
- INTEL XEON 8160 (96)

*pre-production sample, † SMT disabled

GPU Benchmarking. Image courtesy of Andrea Valassi et al.

CUDACPP vs SYCL on NVidia/AMD/Intel GPUs

- Nvidia GPUs: the performances of the SYCL implementation seems ~comparable to direct CUDA for gg→ffgg
  - More fine-grained analysis on the next slide, for different physics processes
- Intel and AMD GPUs: the SYCL implementation runs out of the box

CPU Benchmarking. Image courtesy of David Southwick et al.

GPU Benchmarking. Image courtesy of Andrea Valassi et al.
Exascale technologies: Heterogeneous Architectures Adoption (2)

Fortran version

Cuda accelerated version

85% of CPU time spent in so called “matrix element calculations”

Madgraph5_aMC@NLO speedup on NVidia GPUs for fast MCMC simulations.

Relevant lectures:

GPU programming
Stephan Hageboeck
IT Amphitheatre (31/3-004)
14:00-16:00, 1 August

Best practices: the theoretical and practical underpinnings of writing code that is less bad
Axel Naumann
IT Amphitheatre (31/3-004)
14:00-15:30, 3 August
Exascale Technologies: Advanced Data and Storage Solutions

We collaborate with Intel, HPE, SIEMENS, Comtrade, and ORACLE.

Exascale Technologies: Advanced Data and Storage Solutions (2)

We collaborate with Siemens, Comtrade, and Oracle.

Relevant lectures:

Highly durable and dense data storage through synthetic DNA
**Raja Appuswamy**
IT Amphitheatre (31/3-004)
14:00-16:00, 8 August

Physics data recording with EOS. Image courtesy of [Luca Mascetti et al.](#)
Exascale technologies: AI and HPC

We collaborate with Micron, E4/NVIDIA, and ORACLE.

Micron SB-852 for optical input -> DMA to PC
Perform NN inference with Micron DLA after firmware data reduction / zero suppression
MDLA is embedded within the infrastructure & L1 scouting firmware

Deep learning-based trigger embedded on Micron’s board. Image courtesy of Thomas James et al.
Exascale technologies: AI and HPC (2)

We take part to EC-funded CoE RAISE project

AI-based particle flow reconstruction workflow. Image courtesy of Eric Wulff et al.
We take part to EC-funded CoE RAISE project

- 96 GPUs in parallel
- Using ASHA + Bayesian Optimization
- Scalable up to hundreds of GPUs
- Mean validation loss decreased by ~44% giving a significant performance improvement

Large-scale distributed hyperparameter optimization (HPO). Image courtesy of Eric Wulff et al.
Exascale technologies: AI and HPC (3)

Proposed lectures

Introduction to Machine Learning and Deep Learning
*Michael Kagan*
IT Amphitheatre (31/3-004)
14:00-16:30, 13 July

Graph Neural Networks: From fundamentals to Physics application
*Ilias Tsaklidis*
IT Amphitheatre (31/3-004)
14:00-16:00, 17 July

Hyperparameter Optimization for Deep Learning Models Using High Performance Computing
*Eric Wulff*
IT Amphitheatre (31/3-004)
14:00-16:00, 18 July

Reinforcement learning and its applications at CERN
*Matteo Bunino*
IT Amphitheatre (31/3-004)
14:00-15:30, 21 July
Digital Twins

We participate to EC project **interTwin**, and ECMWF’s EMPP.
Digital Twins (2)

We participate to EC project interTwin, and ECMWF’s EMPP.

First proof-of-concept of a machine-learning based global environmental model trained on terabytes of observational data

Image courtesy of Ilaria Luise et al.
Digital Twins (3)

Proposed lectures

Digital twins and their application at CERN
Ilaria Luise, Alexander Zoehlbauer, Kalliopi Tsolaki
IT Amphitheatre (31/3-004)
14:00-16:00, 7 August

Agent-Based Modeling: A Paradigm for Simulating Complex Systems
Lukas Breitwieser, Tobias Duswald
IT Amphitheatre (31/3-004)
14:00-16:00, 19 July
Quantum computing

Proposed lectures

**Basics of quantum computing (theory)**
*Alice Barthe*
BE Auditorium Meyrin (6/2-024)
14:00-15:30, 27 July

**Basics of quantum computing (practice)**
*Su Yeon Chang*
BE Auditorium Meyrin (6/2-024)
15:30-17:00, 27 July

**Applications of Quantum Computing: CERN use case, Quantum Machine Learning and optimization**
*Carla Sophie Rieger*
IT Amphitheatre (31/3-004)
14:00-15:30, 31 July

**Quantum Kernel Methods (hands-on on Quask)**
*Francesco Di Marcantonio, Roman Wixinger*
IT Amphitheatre (31/3-004)
15:30-16:00, 31 July
Evening lectures

Introduction to quantum computing (1/2)
Ahmed Abdelmotteleb
IT Amphitheatre (31/3-004)
17:00-18:30, 25 July

Introduction to quantum computing (2/2)
Ahmed Abdelmotteleb
IT Amphitheatre (31/3-004)
17:00-18:30, 26 July

Movie night: “Particle Fever”
Mark Levinson
Main Auditorium (500/1-001)
19:30-22:00, 25 July
Thanks!