

Programmation et optimisation sur les architectures hétérogènes du mésocentre MUST

Pierre Aubert







Computing : ~7500 cores + 24 GPUs
Storage : 7 PB





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Storage : 7 PB

- 316 CPU computing units
- 158 blade servers
- 8000 computing tasks in parallel





Computing : ~7500 cores + 24 GPUs
Storage : 7 PB

- 316 CPU computing units
- 158 blade servers
- 8000 computing tasks in parallel
- 18 servers (cloud, container, virtualization)
- 2x20 Gb/s external connectivity



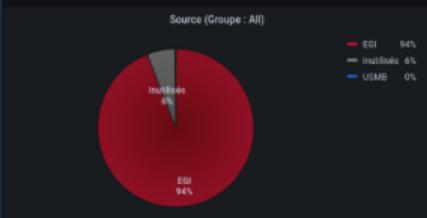


Average Usage :
92-96%

MUST : Production

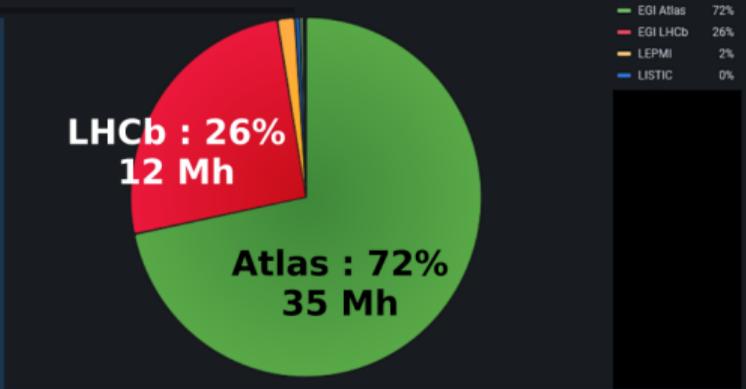


- Utilisation des JobSlots : Instantanée



Average Usage : 92-96%

Walltime en Heure



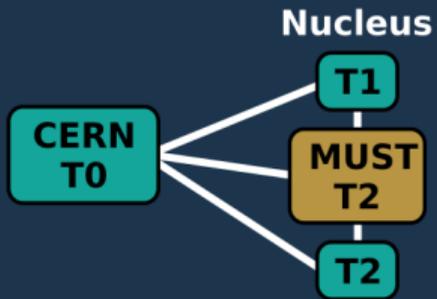
WLCG : Worldwide LHC Computing Grid



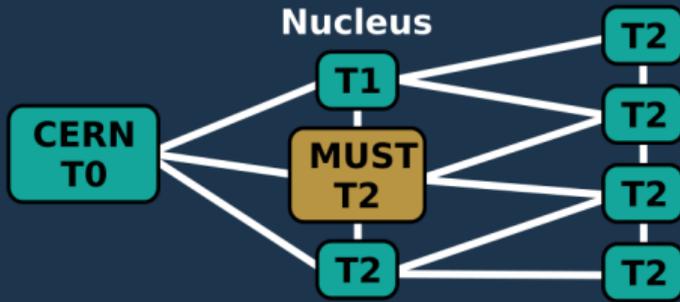


**CERN
TO**

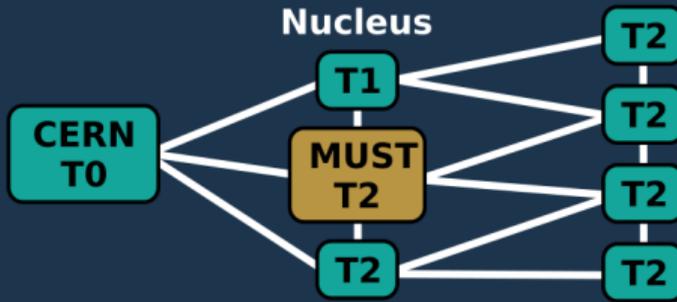




MUST : Data Challenge



MUST : Data Challenge



**Data Challenge 2024 : 40 Gb/s
between Nucleus -> Nucleus**



R&D with local companies -> digital transition



R&D with local companies -> digital transition

ADTP



Quality Check



R&D with local companies -> digital transition

ADTP



Quality Check

Heliocity



**Anomaly
Detection**



R&D with local companies -> digital transition

ADTP



Quality Check

Heliocity



**Anomaly
Detection**

Skiplay



**Predictive
Maintenance
(batteries)**



R&D with local companies -> digital transition

ADTP



Quality Check

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**Predictive
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32 prospects meet

R&D with local companies -> digital transition

ADTP



Quality Check

Heliocity



**Anomaly
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Skippy



**Predictive
Maintenance
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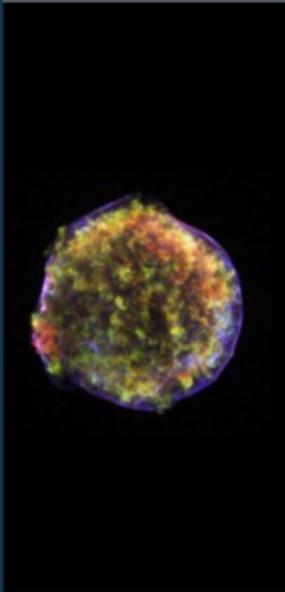


32 prospects meet

Various Project :

- **Work-study intern**
- **Willingness to respond to MINALOGIC calls for tenders**
- **CIFRE Thesis**

Galactic cosmic-ray sources



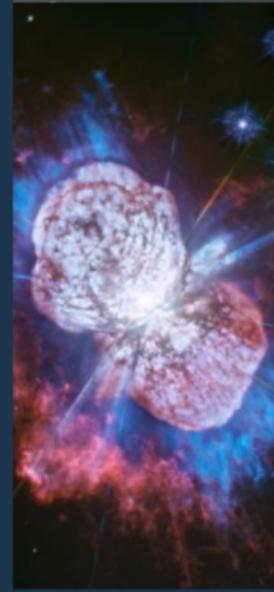
SNRs



Star Clusters



Pulsar Wind
Nebulae



Colliding Wind
Binaries



Photostellar Jets
Microquasars

and others !

Yoann Génolini

LAFTH



VILLUM FONDEN



Yoann Génolini

LAFTH



VILLUM FONDEN



Simulation in C++17 + nvc++



Yoann Génolini

LAFTH



VILLUM FONDEN



Simulation in C++17 + nvc++



Yoann's computer (with tbb, 8 threads 2.4 GHz)

49152 particules/140 secondes → 354 part/seconde → **gain = 1**

Yoann Génolini

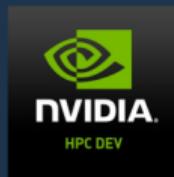
LAFTH



VILLUM FONDEN



Simulation in C++17 + nvc++



GPU P6000

3145728 particules/44 min → 1191 part/seconde → **gain = 3.4**

Yoann's computer (with tbb, 8 threads 2.4 GHz)

49152 particules/140 secondes → 354 part/seconde → **gain = 1**

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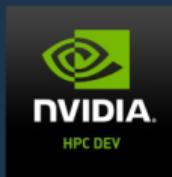
LAFTH



VILLUM FONDEN



Simulation in C++17 + nvc++



GPU V100

3145728 particules/14 min → 5242 part/seconde → **gain = 15**

GPU P6000

3145728 particules/44 min → 1191 part/seconde → **gain = 3.4**

Yoann's computer (with tbb, 8 threads 2.4 GHz)

49152 particules/140 secondes → 354 part/seconde → **gain = 1**

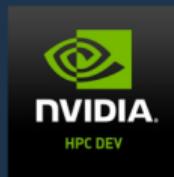
Yoann Génolini



VILLUM FONDEN



Simulation in C++17 + nvc++



GPU A100

40*3145728 particules/38 min → 55188 part/seconde → **gain = 155**

GPU V100

3145728 particules/14 min → 5242 part/seconde → **gain = 15**

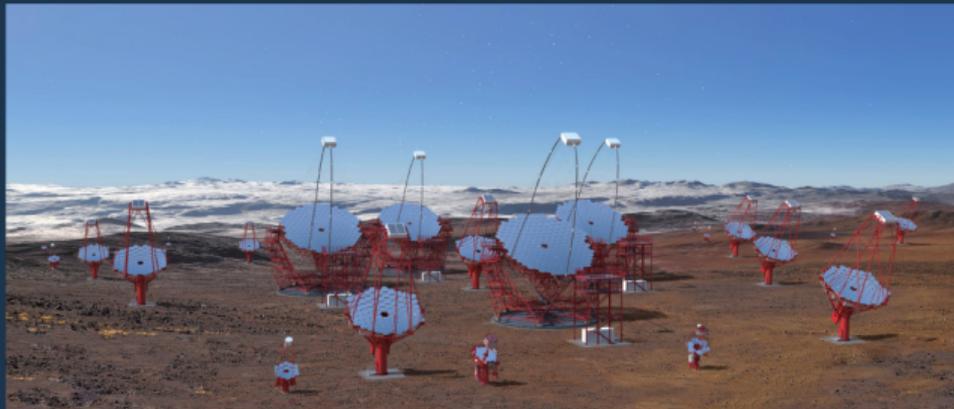
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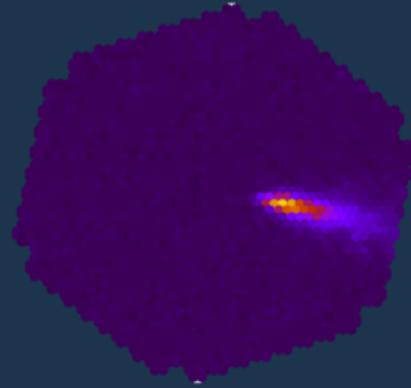
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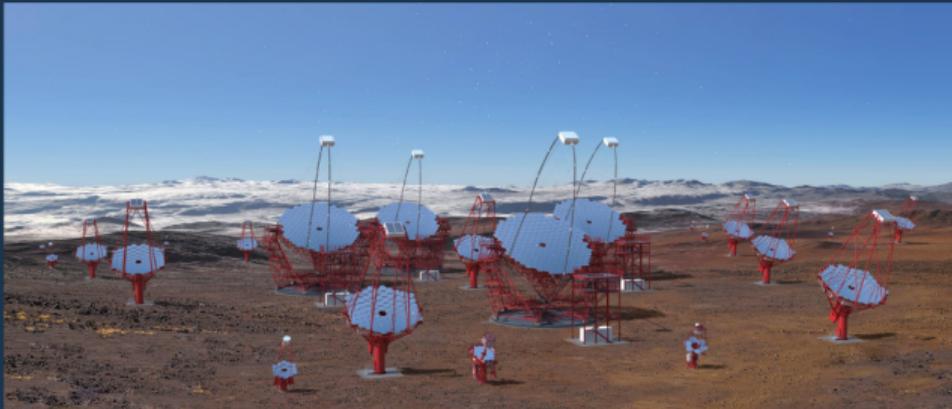




LST-1 prototype



- Particle :
- Type
 - Energy
 - Direction



LST-1 prototype

Server Options

Work environments
Dedicated work environment
Choose your environment

Training environments
Dedicated work environment
Choose your training

Gray Scott Reloaded
Dedicated work environment
Choose your training

Start



Kubernetes



Server Options

Work environments
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Training environments
Dedicated work environment
Choose your training:

Gray Scott Reloaded
Dedicated work environment
Choose your training:



Kubernetes



The screenshot shows a JupyterLab environment. On the left, a file browser displays a list of notebooks, including 'ATLAS Preliminary H→γγ channel'. The main area shows a document titled 'How to rediscover the Higgs boson yourself - with the coffea framework!'. The document text includes: 'This notebook uses ATLAS Open Data <https://openatlas.cern.com> to show you the steps to rediscover the Higgs boson yourself!', 'ATLAS Open Data provides open access to proton-proton collision data at the LHC for educational purposes. ATLAS Open Data resources are ideal for high school, undergraduate and postgraduate students.', and 'This notebook builds on [H2ANalysis.jupyter](#) in the same folder as this notebook.' Below the text, there are sections for '1. Set up', '2. Visualizations', and '3. Interactive test'. At the bottom, it mentions 'The coffea framework is a prototype currently in development in collaboration with RE-HEP. This notebook was created as part of an RE-HEP Fellowship project, and a repository containing all the code and notes created for this project can be found [here](#). You can find out more about coffea [here](#), and you can find out more about RE-HEP [here](#).' A footer note says 'Feynman diagram pictures are borrowed from our friends at <https://www.particleadventure.com>'.

Server Options



- Work environments

Dedicated work environment

Choose your environment

DataScience Environment

- Training environments

Dedicated work environment

Choose your training

Tensorflow How-to

- Gray Scott Reloaded**

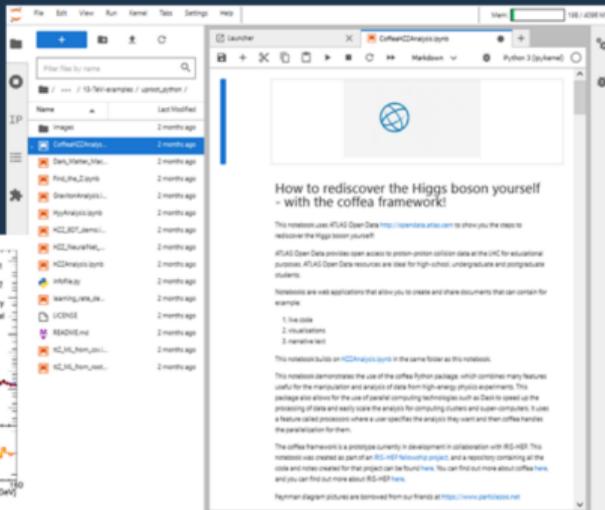
Dedicated work environment

Choose your training

How to develop and optimize your code by Pierre Aubert in 2024

Start

Kubernetes



Server Options



Work environments

Dedicated work environment

Choose your environment

DataScience Environment

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Tensorflow How-to

Gray Scott Reloaded

Dedicated work environment

Choose your training

How to develop and optimize your code by Pierre Aubert in 2024

How to develop and optimize your code by Pierre Aubert in 2024

How to debug your code by Pierre Aubert in 2024

How to find performance issues in your code by Pierre Aubert in 2024

How to use cpp premade algorithms by Pierre Aubert in 2024

How to use stencil for CPU computing by Pierre Aubert in 2024

How to use Sycl by David Chamont

Introduction to the MAQAO Code Quality Analyser (CQA) in 2024

How to optimize computation with HPC in 2024

Performance des calculs avec des NaN et autres valeurs exotiques in 2024

How to use stencil for CPU computing with Fortran by Vincent Lafage in 2024

How to use stencil for CPU computing with Rust by Hadrien Grasland in 2024

How to use stencil for CPU computing with Python by Alice Faure, Jean-Marc Colley & Nabil Garrum in 2024

How to optimize compilation by Pierre Aubert in 2024

IN2P3
transverse
project

~ 20 people

IN2P3
transverse
project

~ 20 people



IN2P3
transverse
project

~ 20 people



Fortran

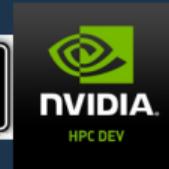


IN2P3
transverse
project

~ 20 people

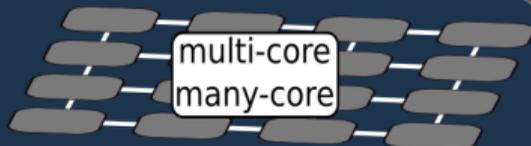
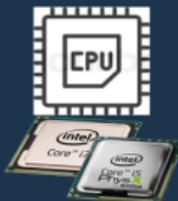
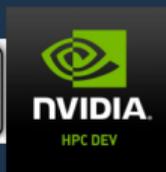


Fortran



IN2P3
transverse
project

~ 20 people



multi-core
many-core



- **Association**
- **Valorisation / Dissemination** of Knowledge :
Schools / Seminars / Interviews
- **Bridge** between **Academy** and **Industry**

France



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EuroCC (Catalog of HPC/HTC/HPDA formations)

France



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+33 Countries



EuroHPC

EuroCC (Catalog of HPC/HTC/HPDA formations)

France

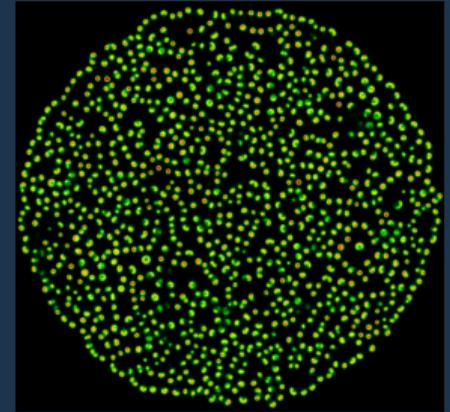


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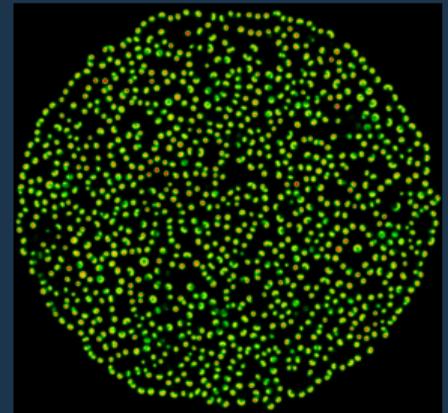
+33 Countries



Gray Scott reaction (a chemistry game of life)



Gray Scott reaction (a chemistry game of life)



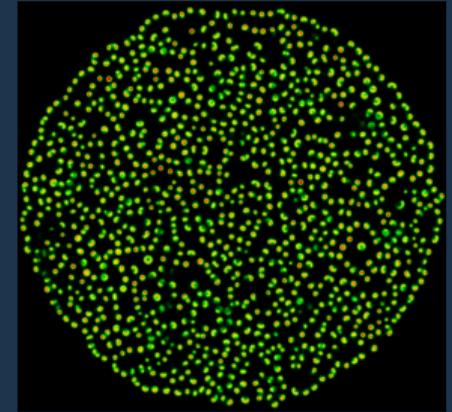
Gray Scott reaction (a chemistry game of life)



Computing :

$$\frac{\partial u}{\partial t} = r_u \nabla^2 u - uv^2 + f_r \times (1 - u)$$

$$\frac{\partial v}{\partial t} = r_v \nabla^2 v + uv^2 - (f_r + k_r) \times v$$



- ▶ u and v are concentration of product **U** and **V**
- ▶ r_u and r_v diffusion rate of **U** and **V**
- ▶ k_r (**Kill Rate**), conversion rate from **V** to **P**
- ▶ f_r (**Feed Rate**), speed of process which feed **U** and kills **V** and **P**
- ▶ $\nabla^2 u$ and $\nabla^2 v$ are différence of space concentration between current cell and its neighbours

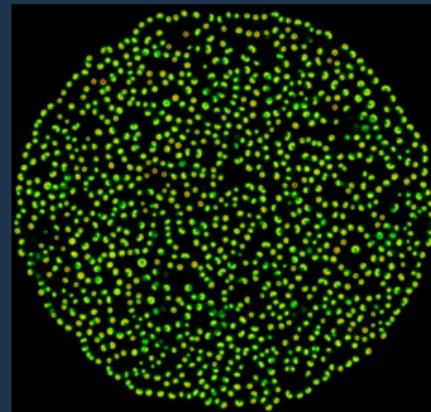
Gray Scott reaction (a chemistry game of life)



Computing :

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- ▶ u and v are concentration of product **U** and **V**
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- ▶ $\nabla^2 u$ and $\nabla^2 v$ are différence of space concentration between current cell and its neighbours
- ▶ Easy to understand
- ▶ Not so easy for the compiler
- ▶ Possibility of high speed up





Fortran



Fortran





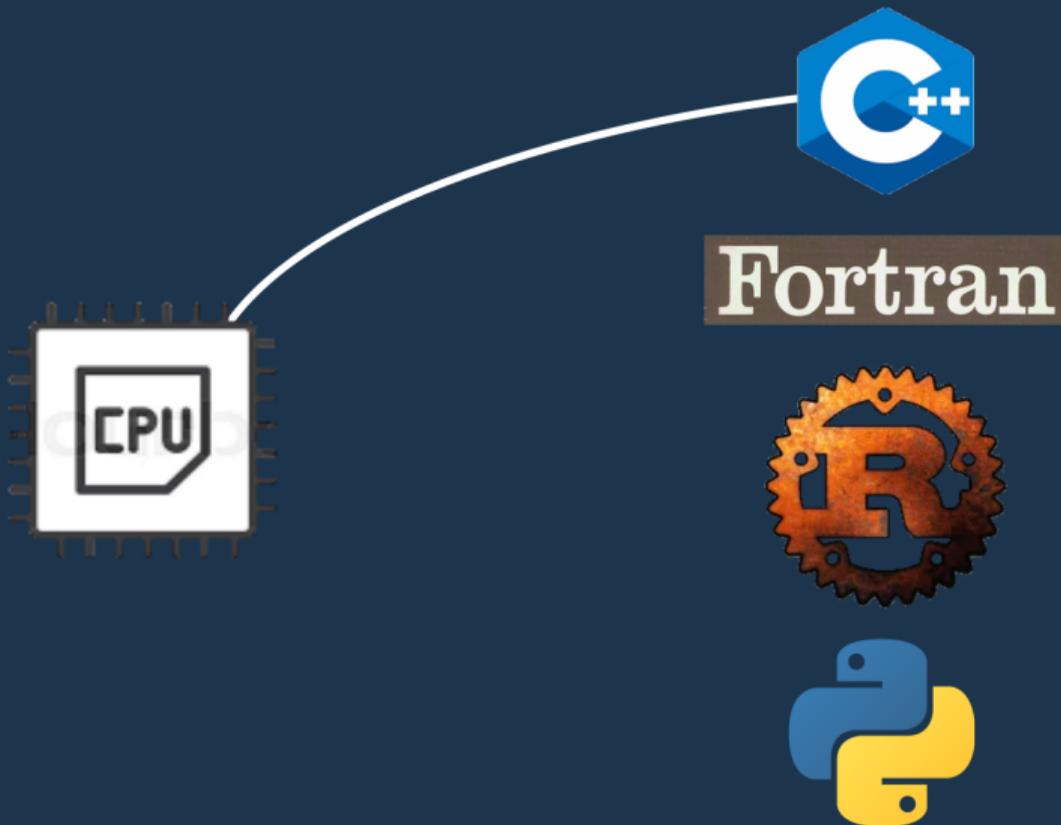
Fortran

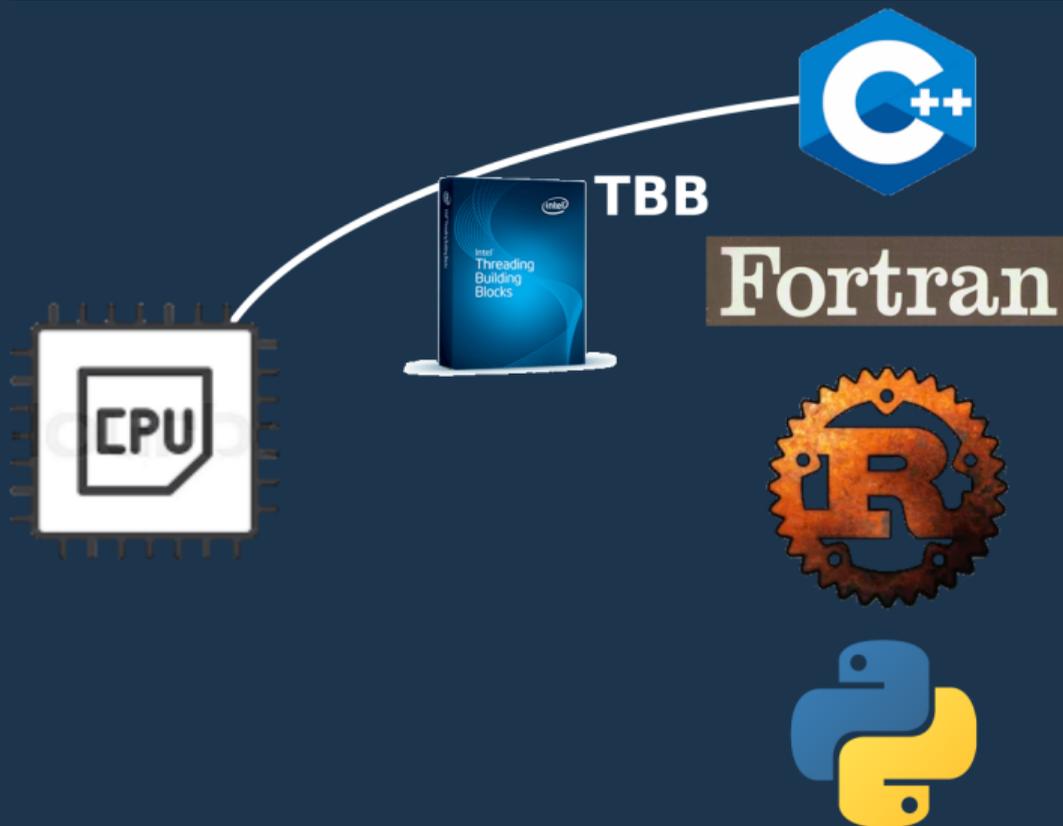


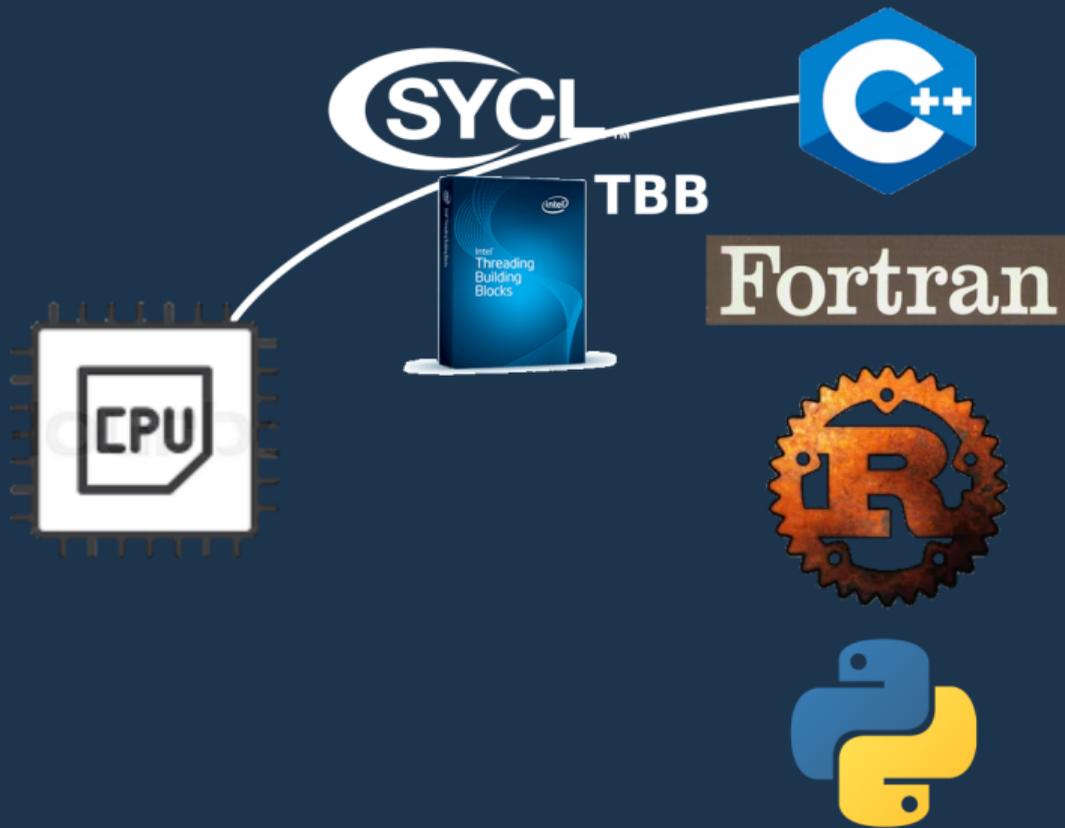


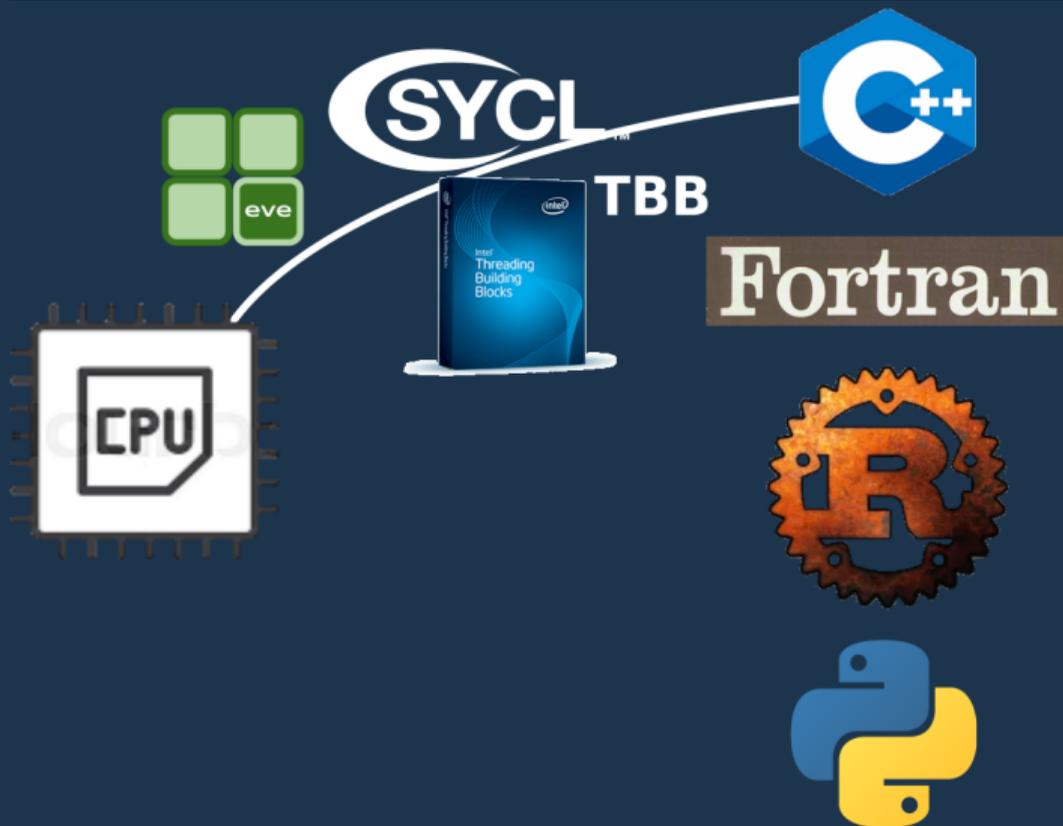
Fortran

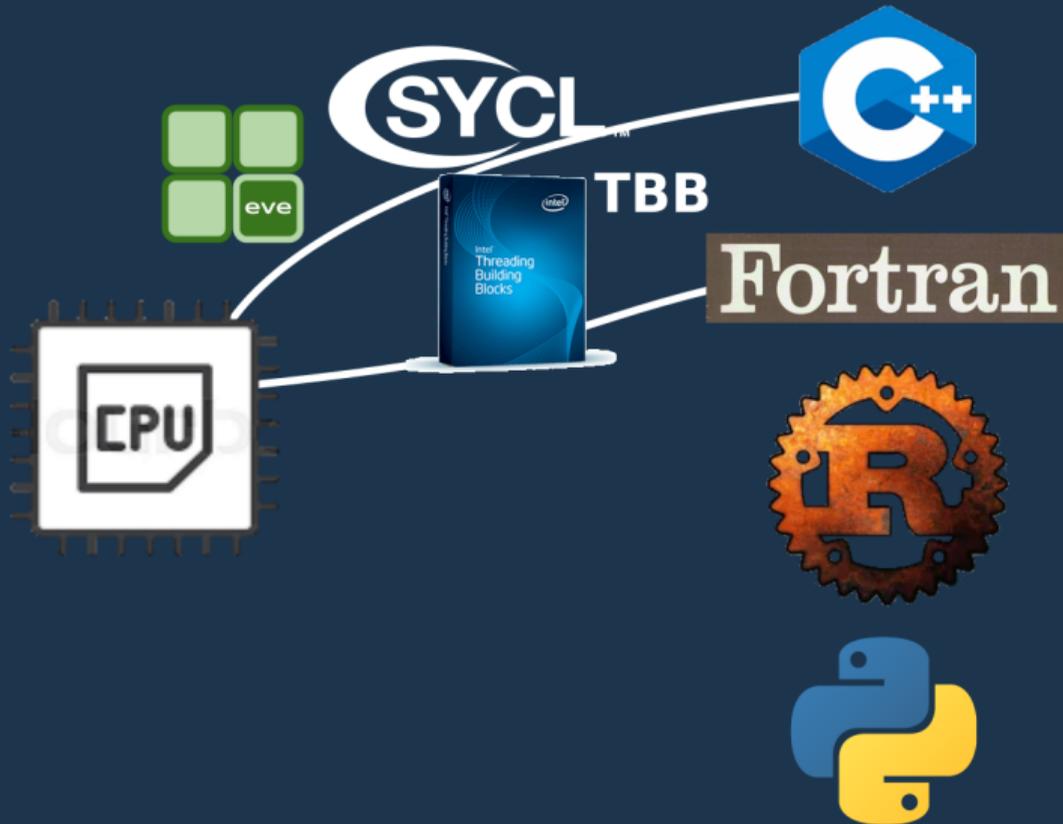


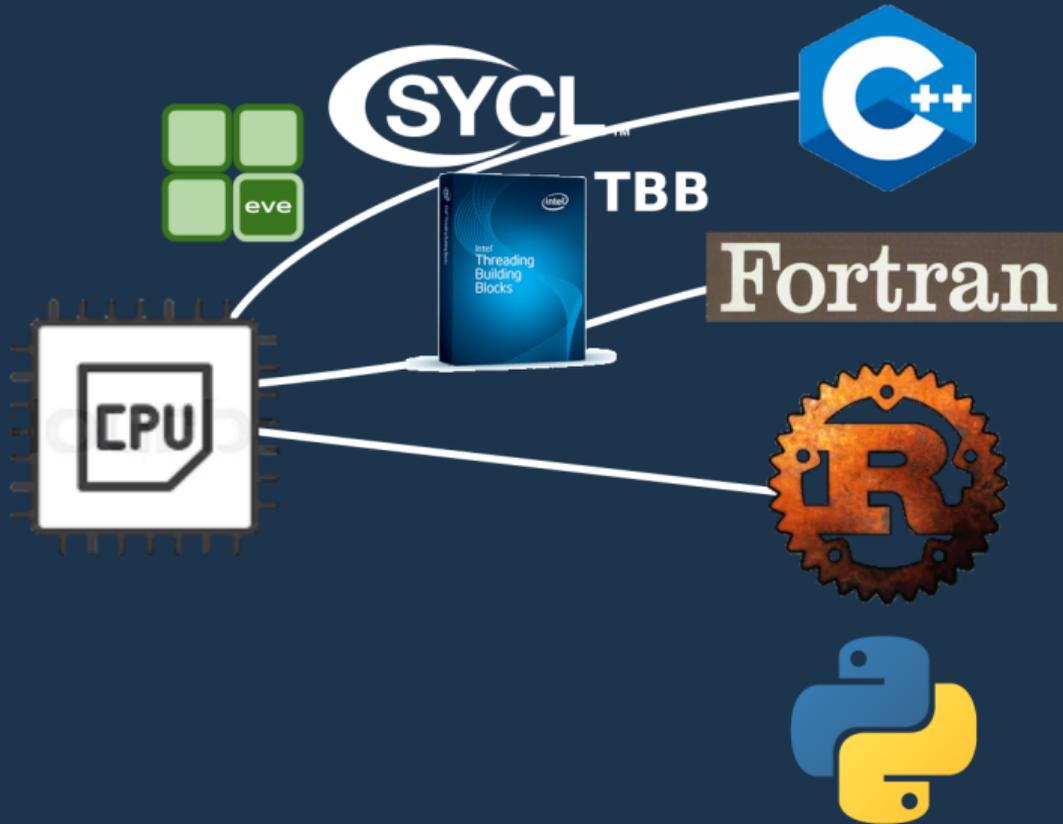


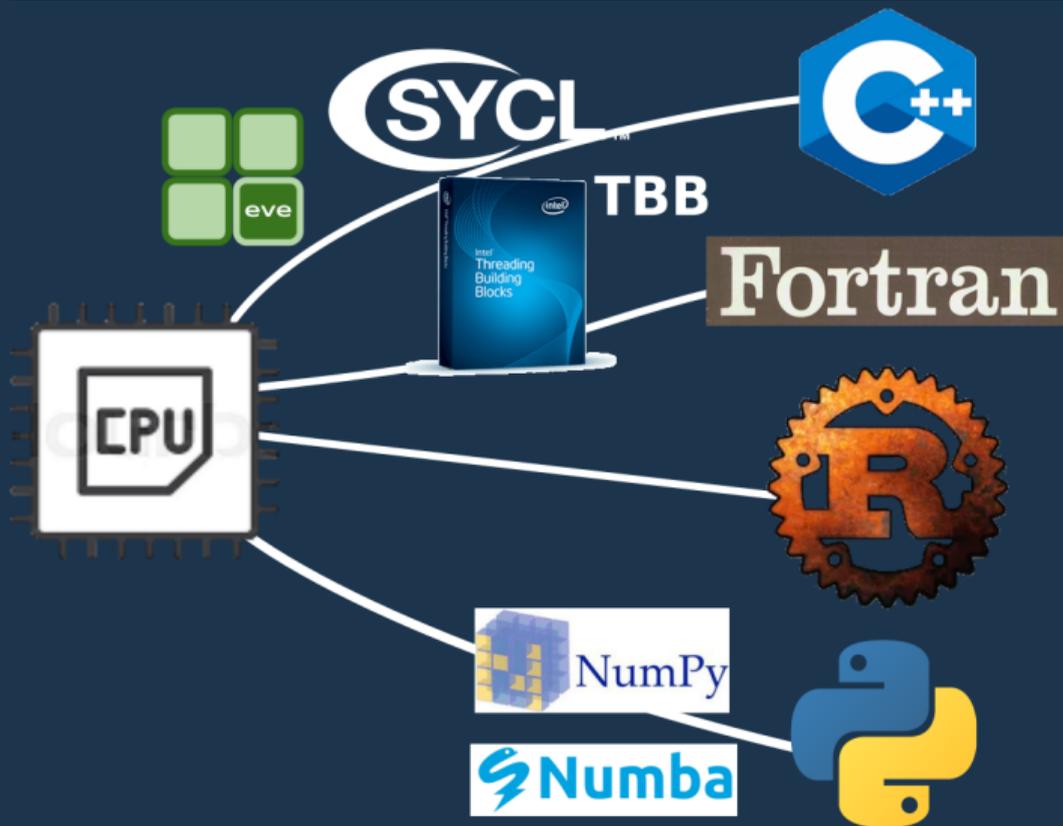


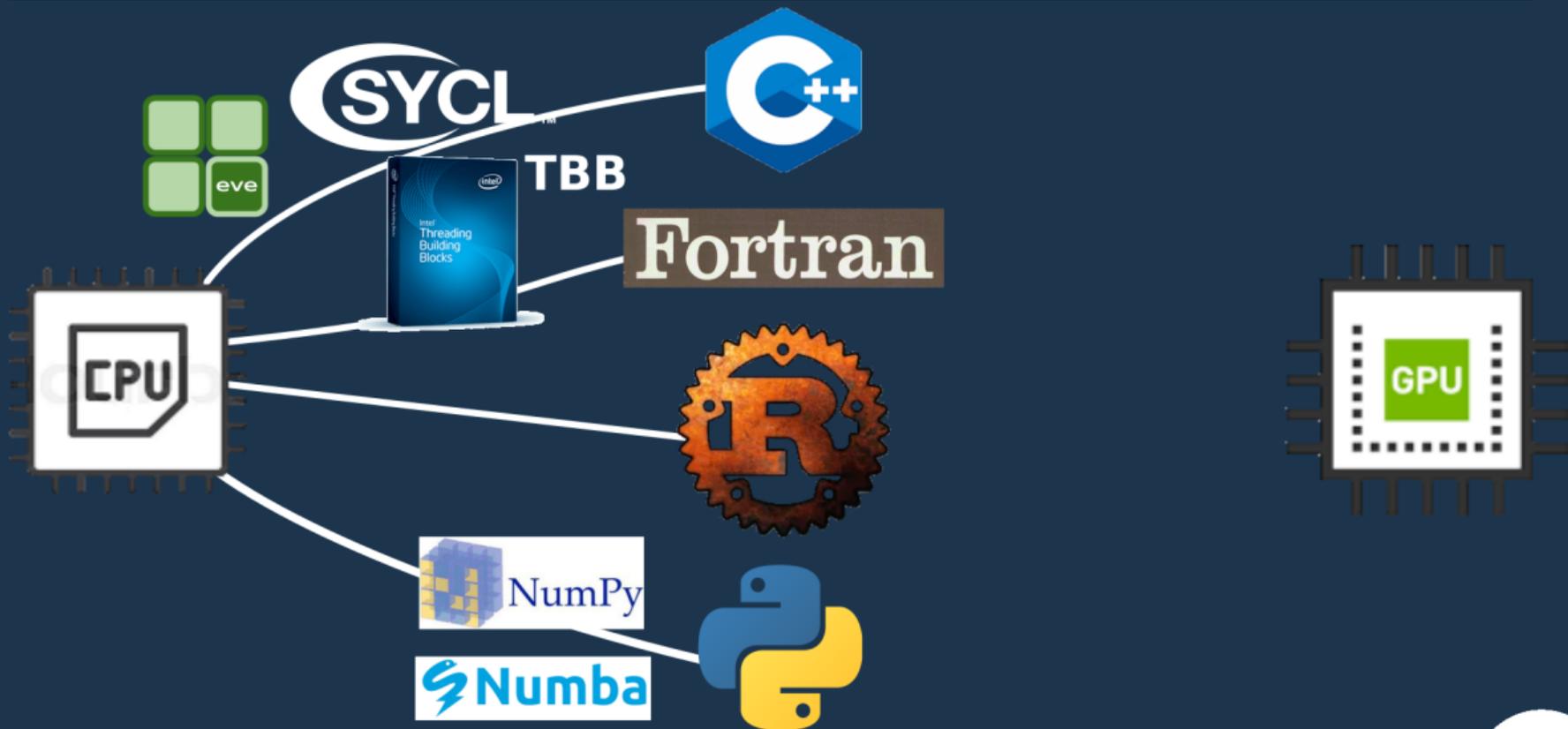


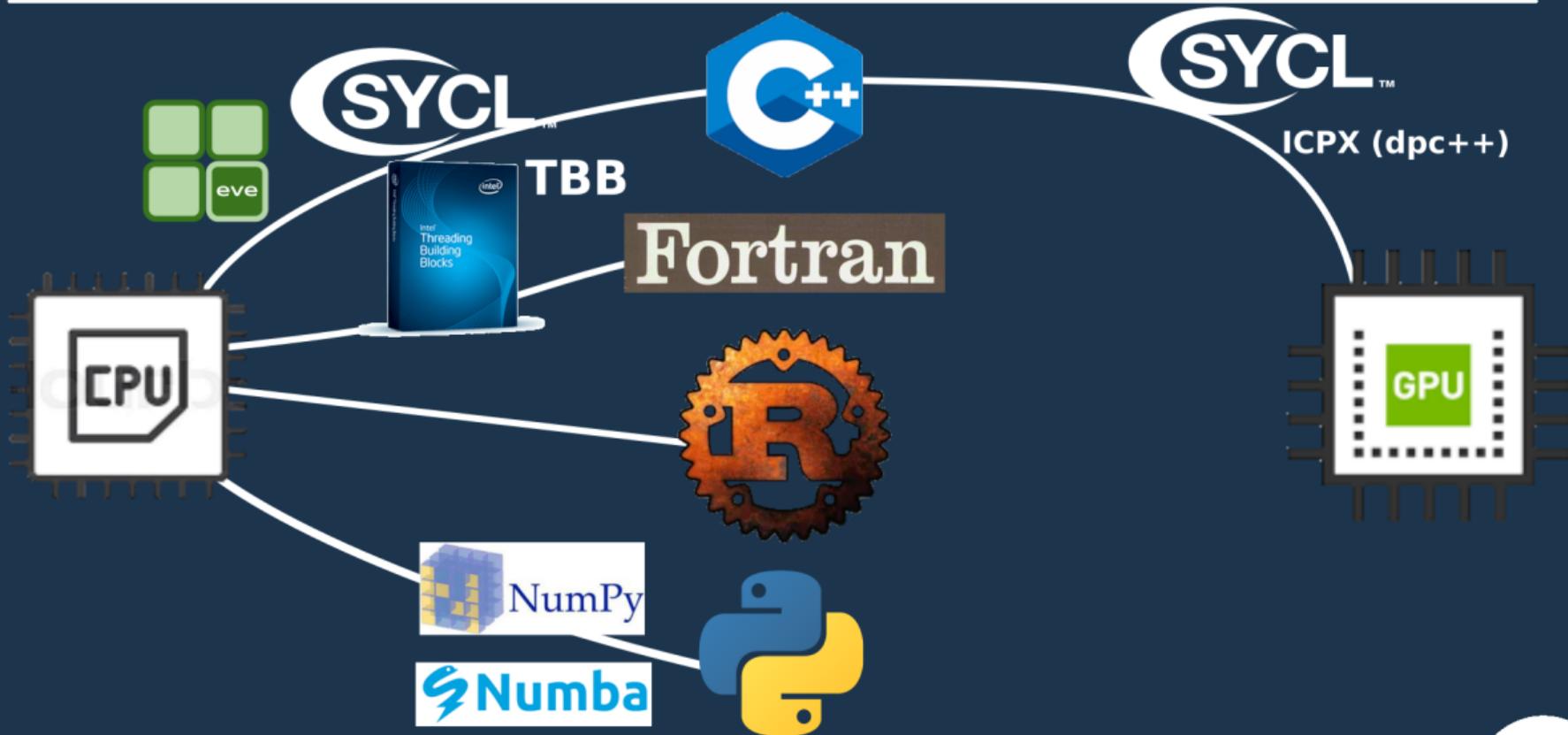


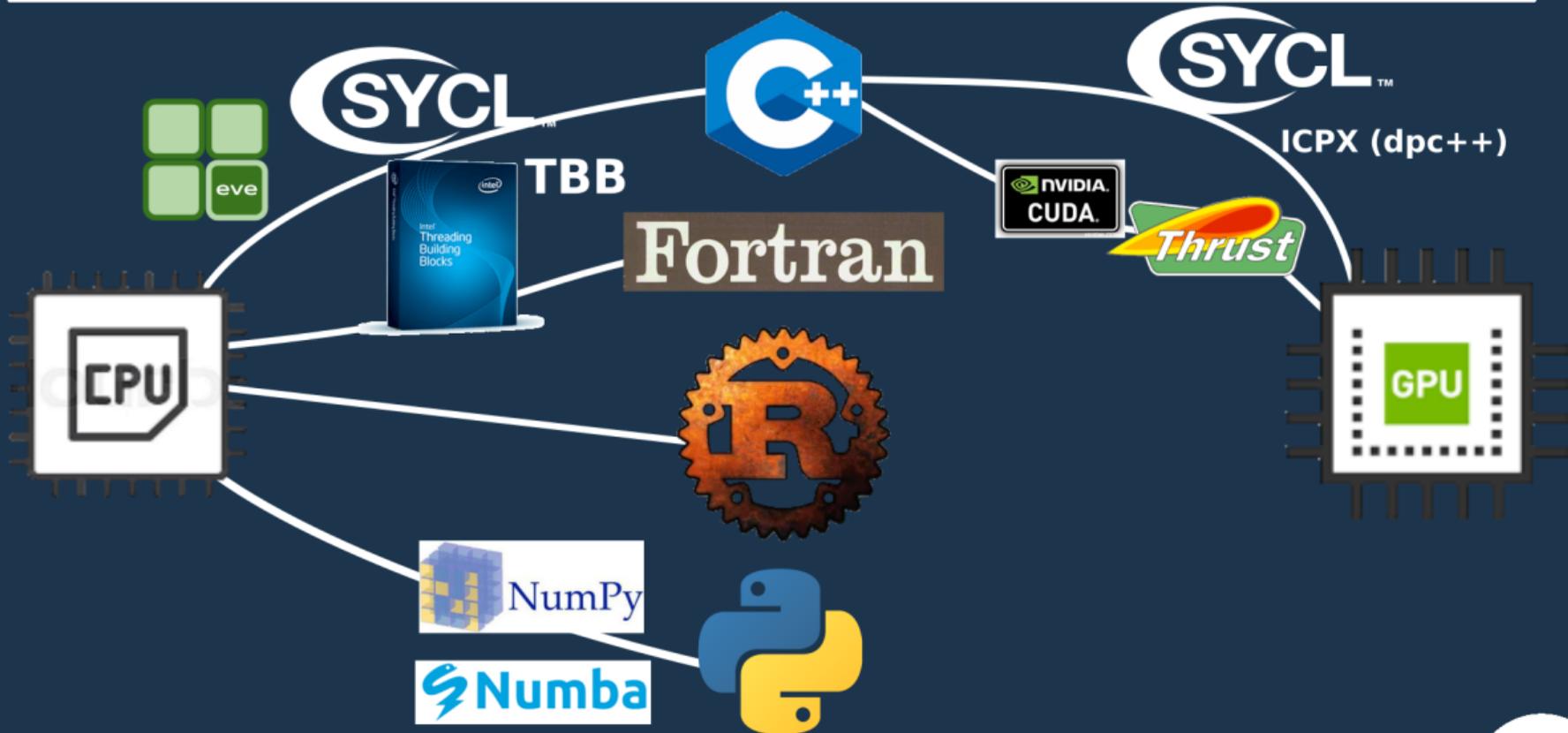


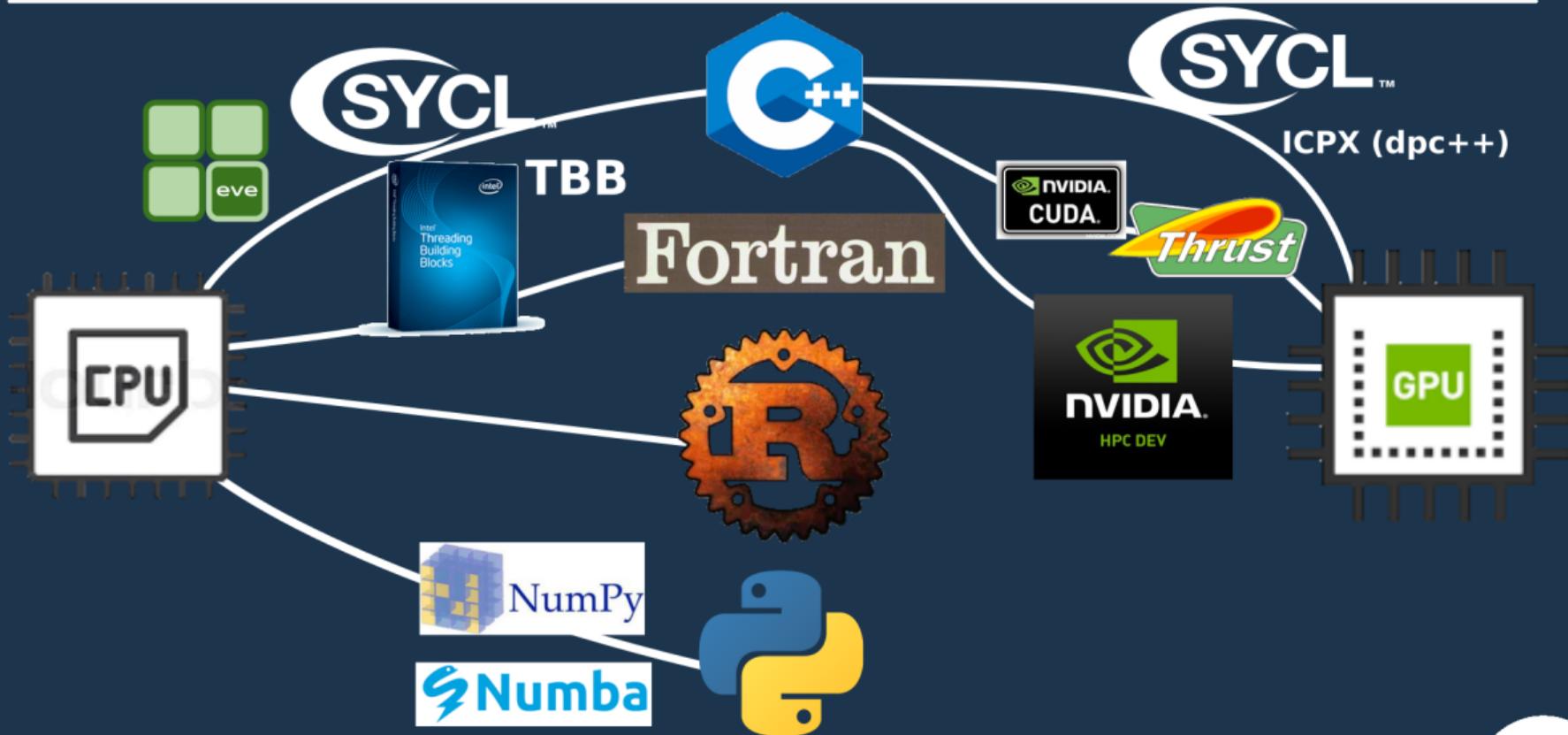


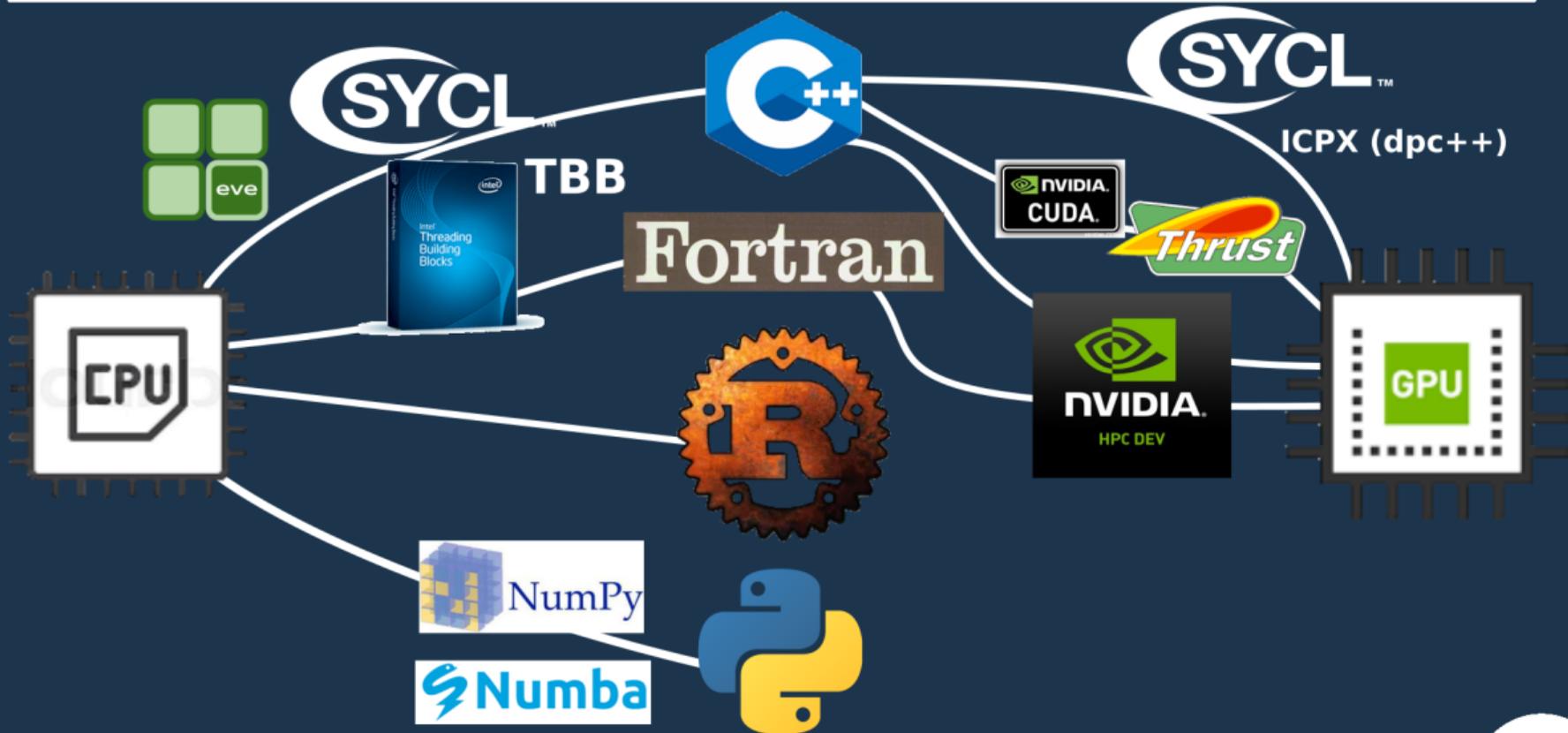


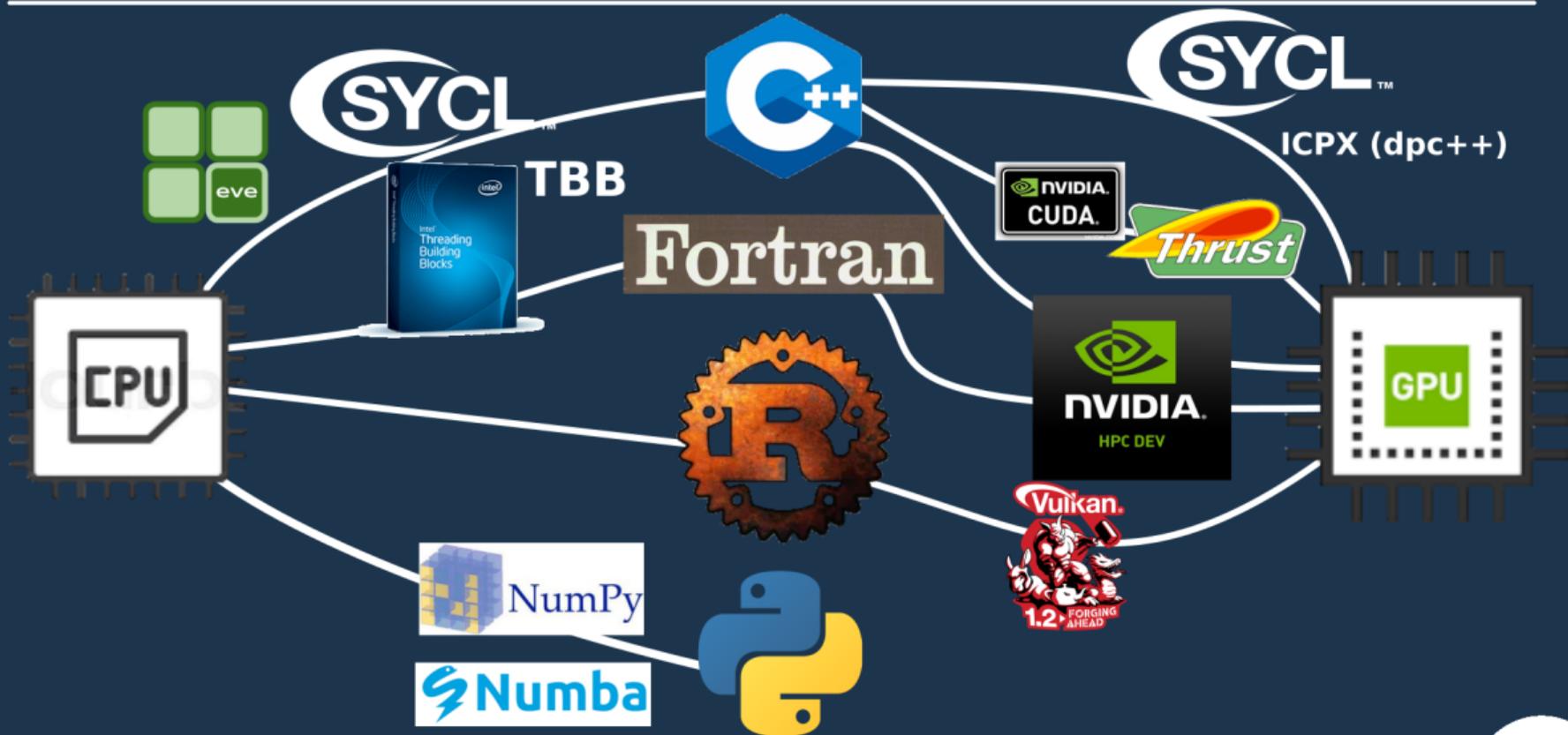


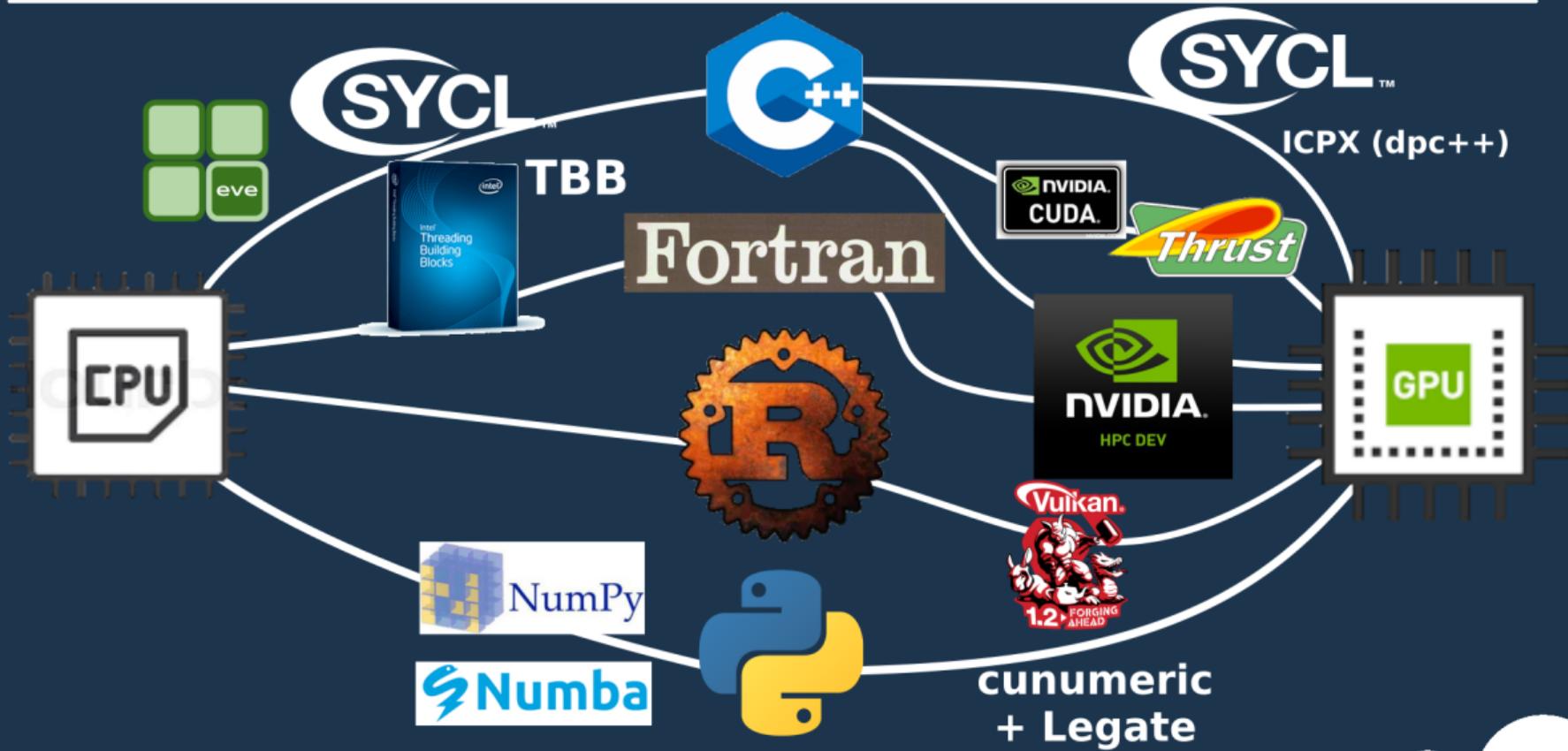


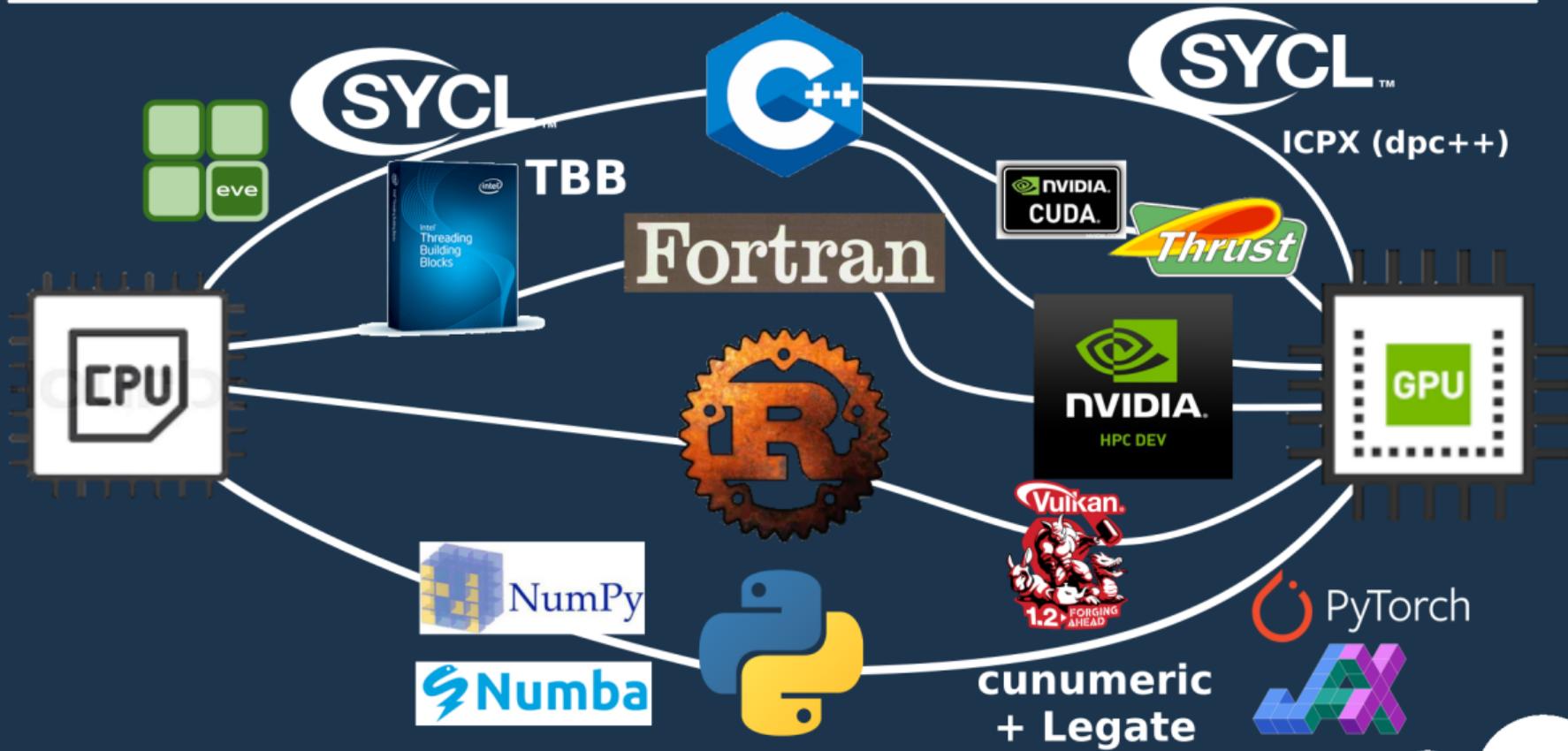




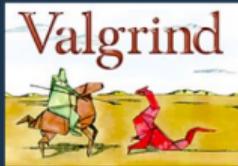




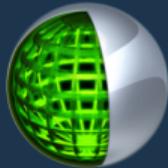




Performance tests

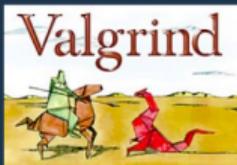


Perf

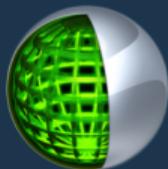


NSight

Performance tests



Perf



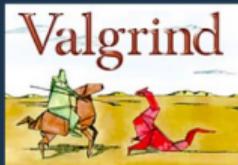
NSight

Memory Profiler

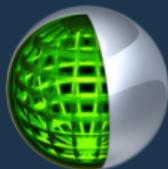
MATL

NUMA Prof

Performance tests



Perf



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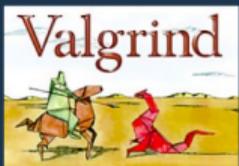
Compilers

Memory Profiler

MATL

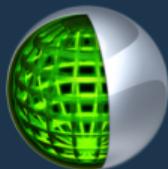
NUMA Prof

Performance tests



Perf

MATL



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Compilers



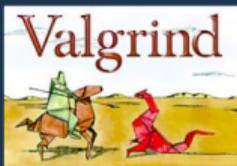
LLVM : Clang /
Clang ++ / FLang

Memory Profiler

MATL

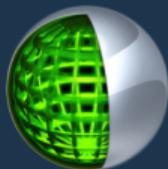
NUMA Prof

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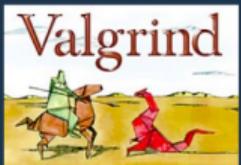
GNU : GCC / G++ /
GFortran

Memory Profiler

MATL

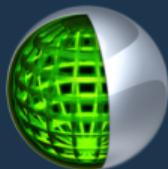
NUMA Prof

Performance tests



Perf

MARAO



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Memory Profiler

MATL

NUMA Prof

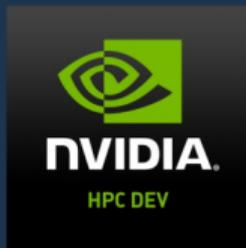
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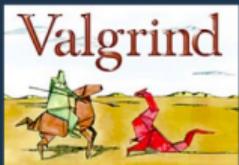
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nvc++ / nvfortran

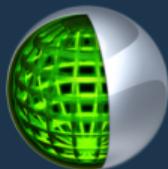
intel®
icpx / dpc++

Performance tests



Perf

MATRO



NSight

Memory Profiler

MATL

NUMA Prof

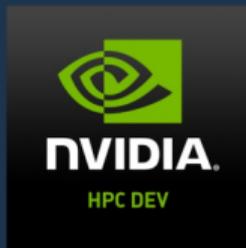
Compilers



LLVM : Clang /
Clang ++ / FLang



GNU : GCC / G++ /
GFortran



nvc++ / nvfortran

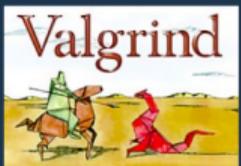
intel®

icpx / dpc++

Precision

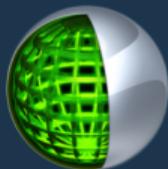


Performance tests



Perf

MATLAB



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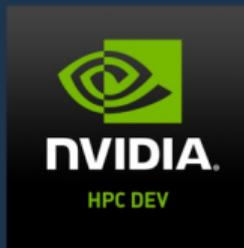
MATLAB

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Compilers



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nvc++ / nvfortran



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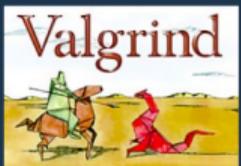
intel®

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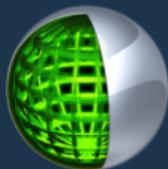


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NSight

Memory Profiler

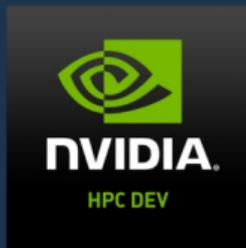
MATL

NUMA Prof

Compilers



LLVM : Clang /
Clang ++ / FLang



nvc++ / nvfortran



GNU : GCC / G++ /
GFortran

intel®

icpx / dpc++

Precision

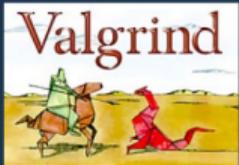


git



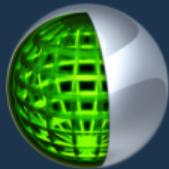
Gitlab

Performance tests



Perf

MARAO



NSight

Memory Profiler

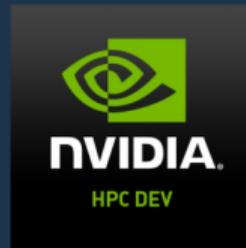
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Annecy

LAPP

~ 40 people

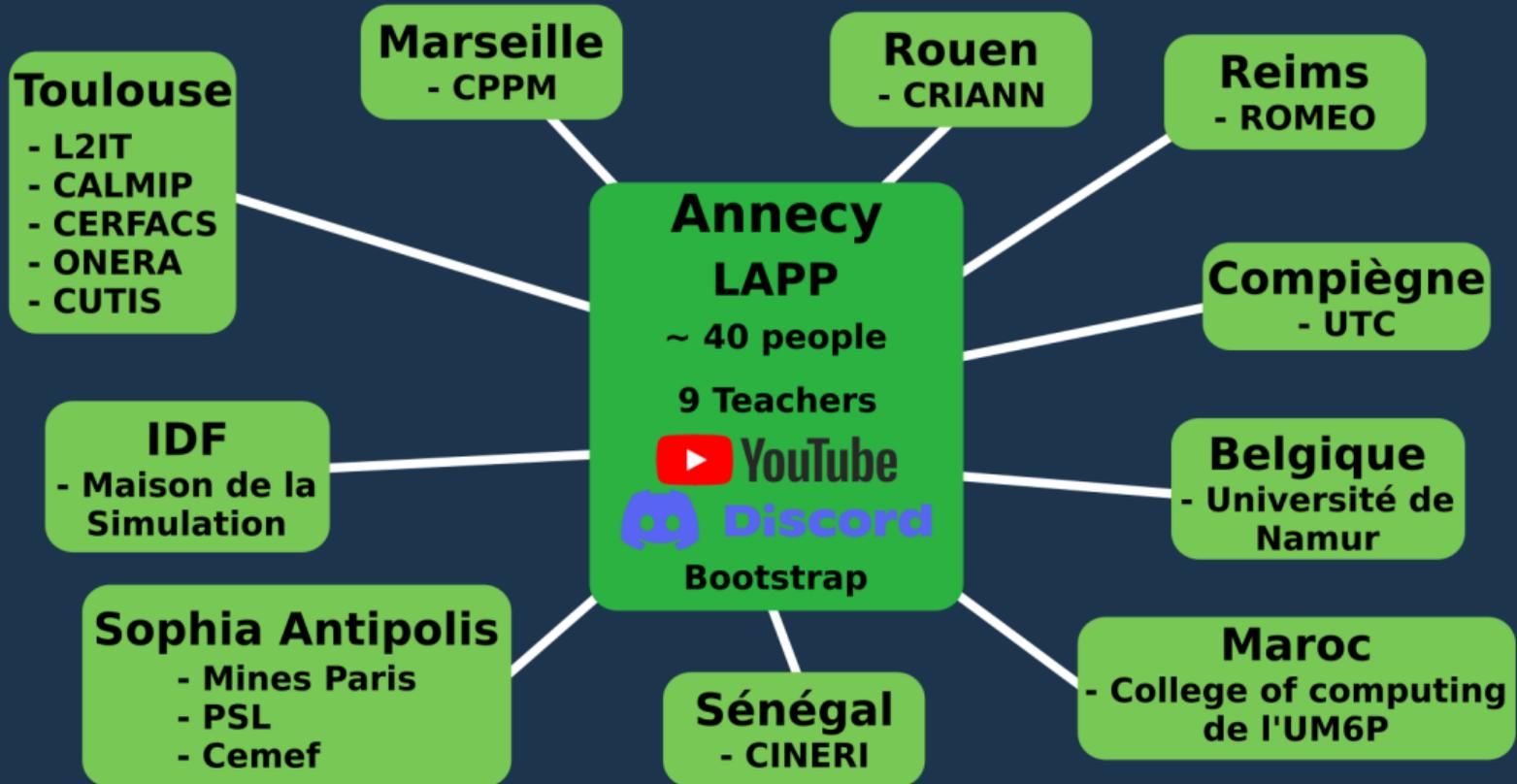
9 Teachers

 **YouTube**

 **Discord**

Bootstrap

Multi-site diffusion



Following Lectures

Following Lectures



Following Lectures

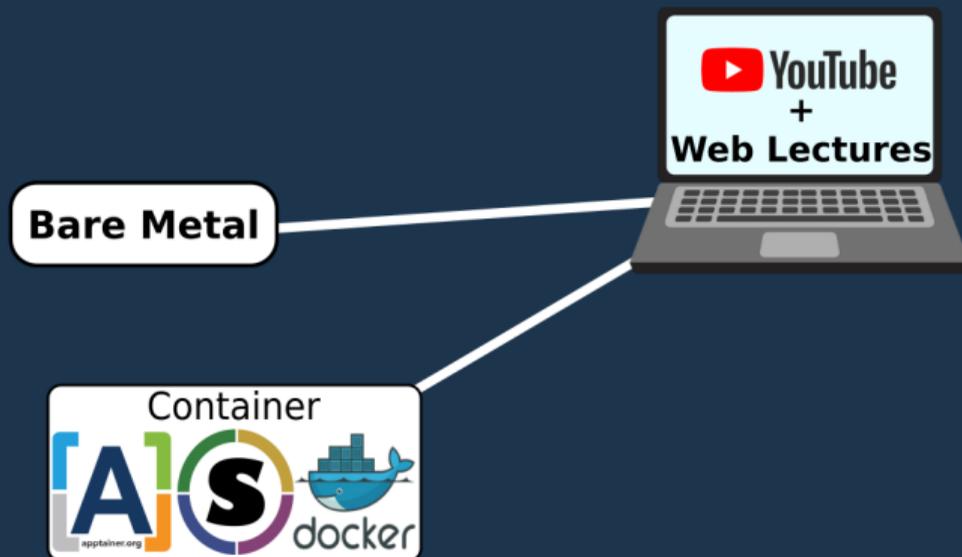


Following Lectures

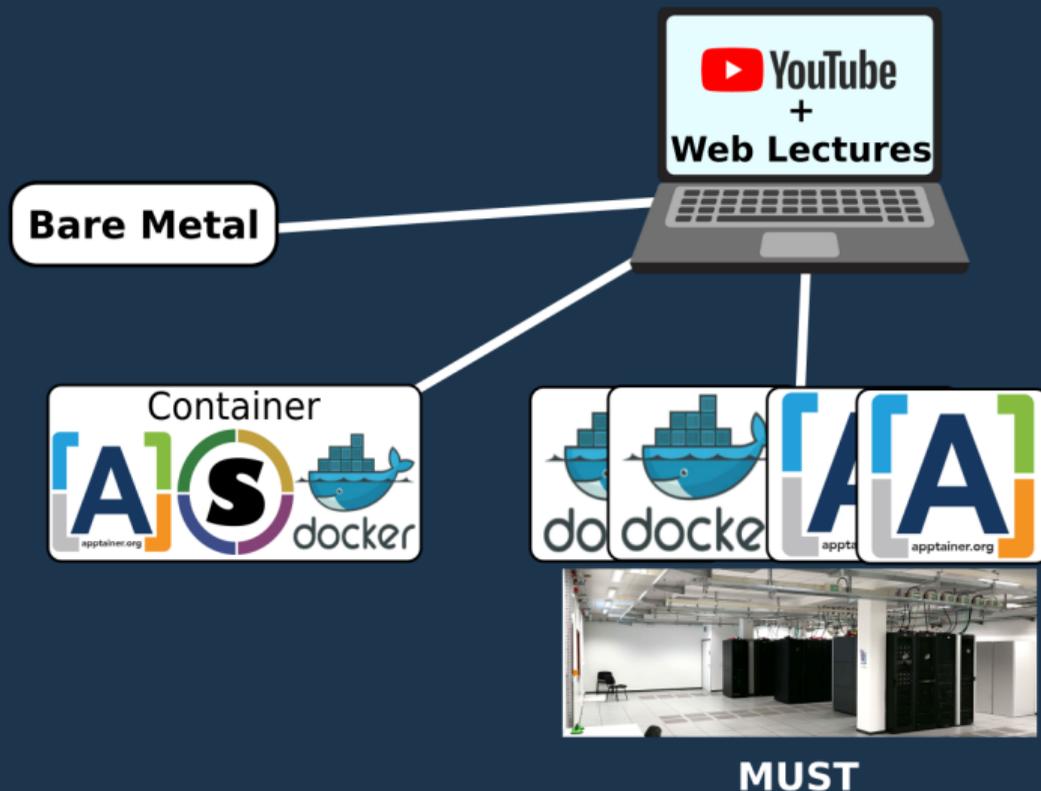
Bare Metal



Following Lectures



Following Lectures



MUST

Following Lectures



Following Lectures

Hardware :

- CPU : Intel, AMD
- GPU : NVidia CC >= 6, AMD

Bare Metal



MUST



CERFACS

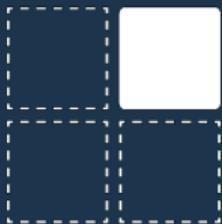


ROMEO



CRIANN

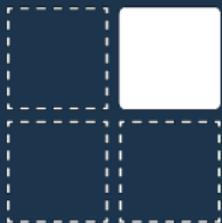




CODE RECKONS

Science to the CORE

intel® EVIDEN
an atos business



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Computing center access

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Engineers helping at bootstrap day

- **9** teachers
- **18** webinars (almost **weekly** from **January** to **June**)
- **3** connection modes
- **12** Satellittes Sites over **4** countries (**France, Belgium, Morocco, Senegal**)
- **642** Attendees
 - ~**400** people following school on **YouTube**
 - ~**200** people following school on **Discord** (**530 Discord accounts** created)
- ~**50** Containers-lectures compatible with **Docker, Apptainer, Podman, Kubernetes** and **OpenStack**
- **Lectures available on laptop/remote server/HT condor/slurm (Intel / AMD)**
- **60h** of streamed lecture after editing (127 GB)
- **1 bootstrap day** (Annecy + Toulouse)
- **1 extra day** (hands on + discussion) @ Annecy

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Next school : 23 june - 04 July 2025