Simulation Techniques for High Performance and High Definition Computer Aided Tomography

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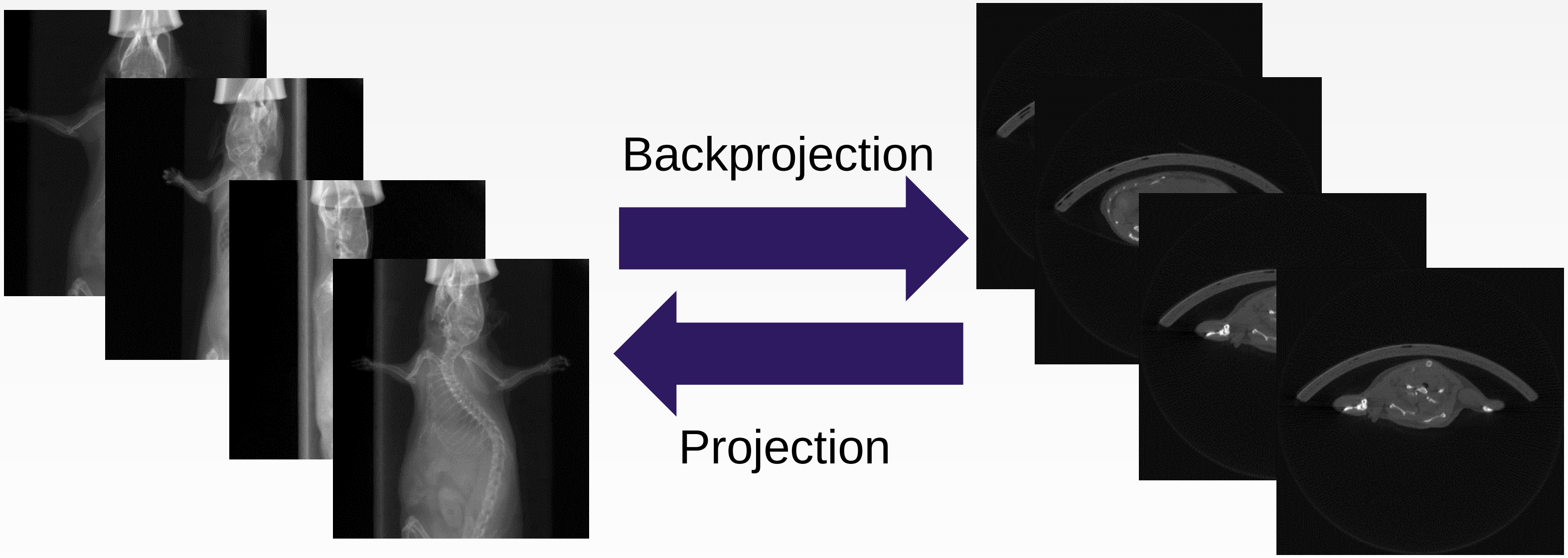
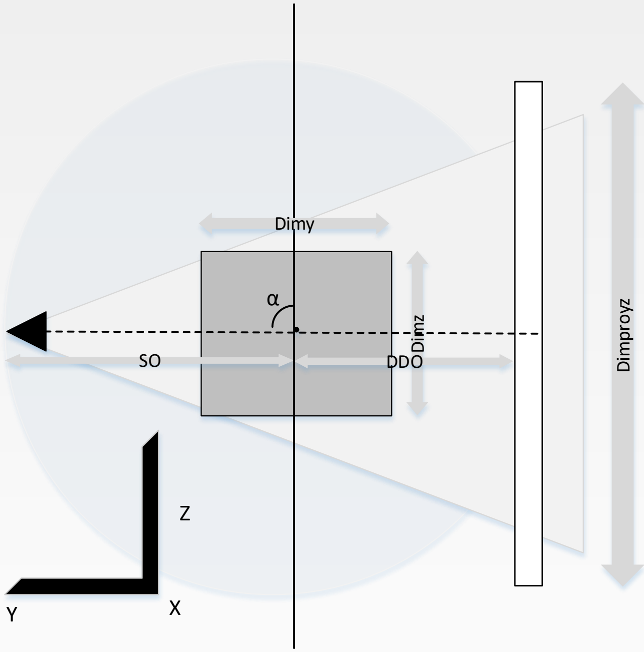
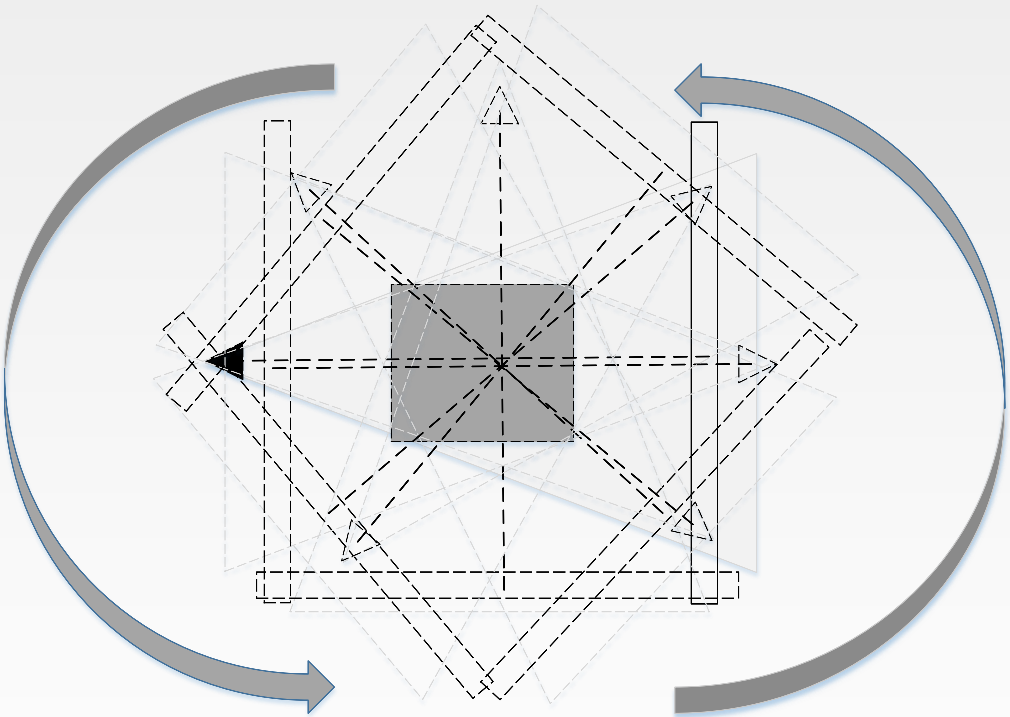
Introduction

- Medical imaging CT (**C**omputed **T**omography).
  - Convert 2D projections (aka radiographies) to a 3D volume.
  - Why? To obtain a view of what is inside the patient.
  - Two main analytical operators in CT applications:



Introduction: Geometry





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Motivation

- Goal: to obtain better image quality.
  - Less radiographies implies less radiation dose.
- Iterative algorithms can obtain good results:
  - More computationally expensive than traditional solutions.
  - Large amount of input, output, and **intermediary data**.

Good use case for HPC/BigData

Embarrasingly parallel algorithms = Backprojection and projection

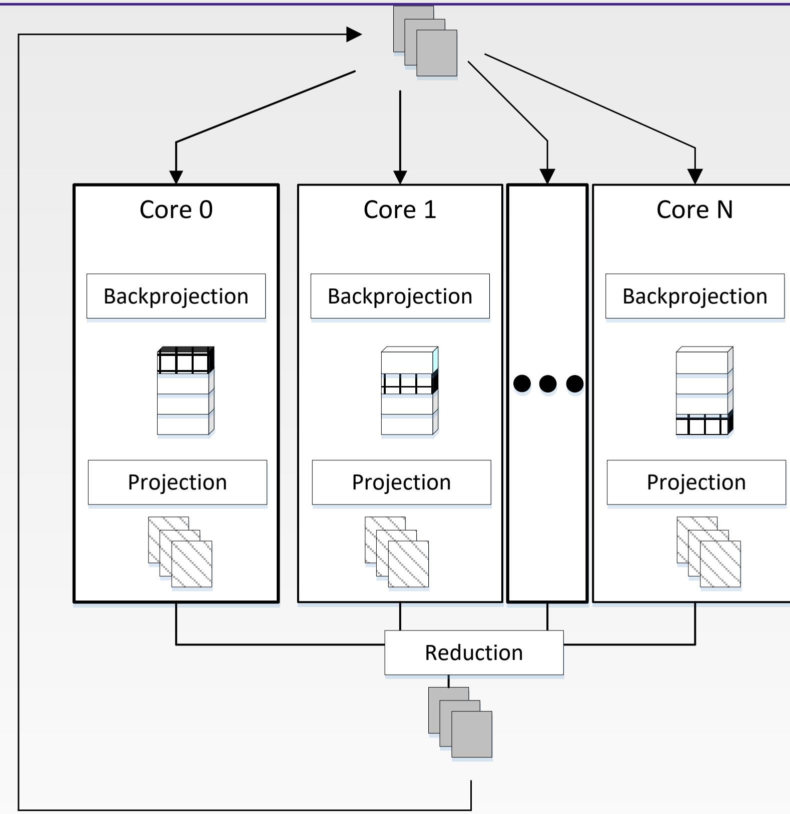
Iterative workflow = Iterative algorithms

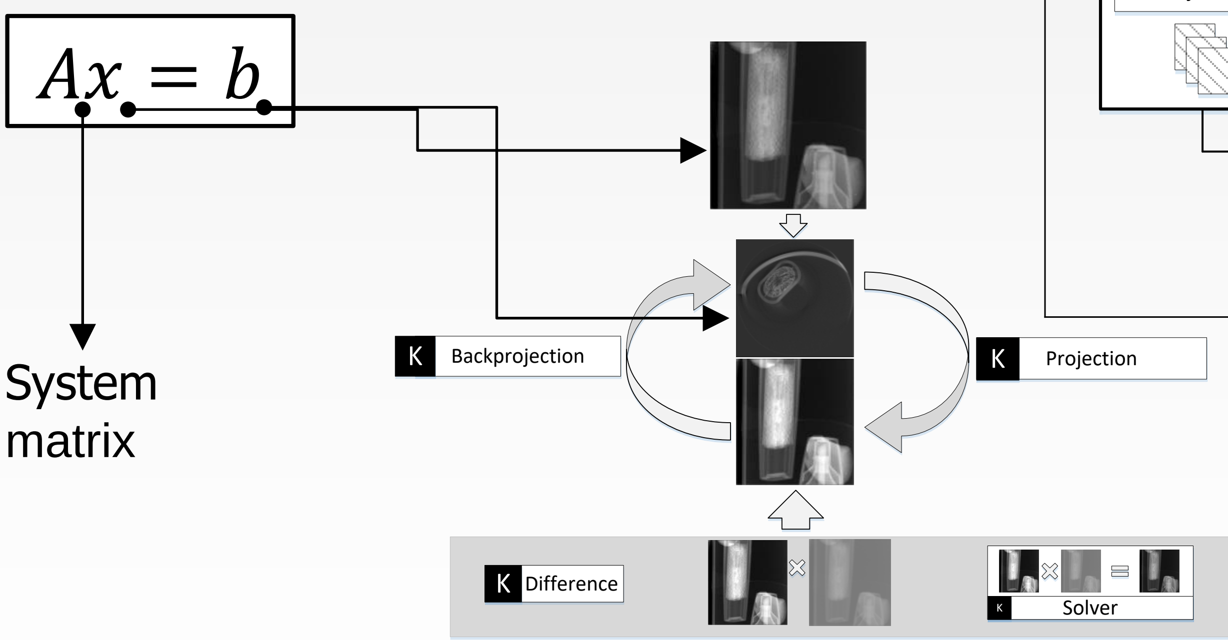
Objectives

- **O1**: To increase the quality of CT images with novel simulation techniques.
- **O2**: To propose and evaluate new programming models for the efficiency of medical image data processing.
- **O3**: To increase the performance of CT simulation algorithms through optimization and adaptation to high-performance heterogeneous devices.

Proposed Solution:

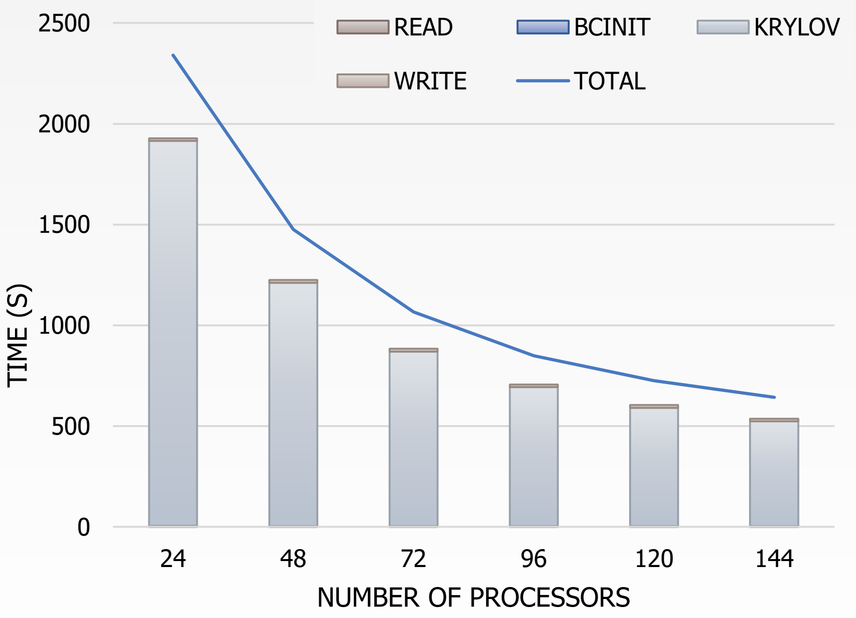
- Main points of synchronization:
  - Reduction of the projections
  - Iterative solver normalizations



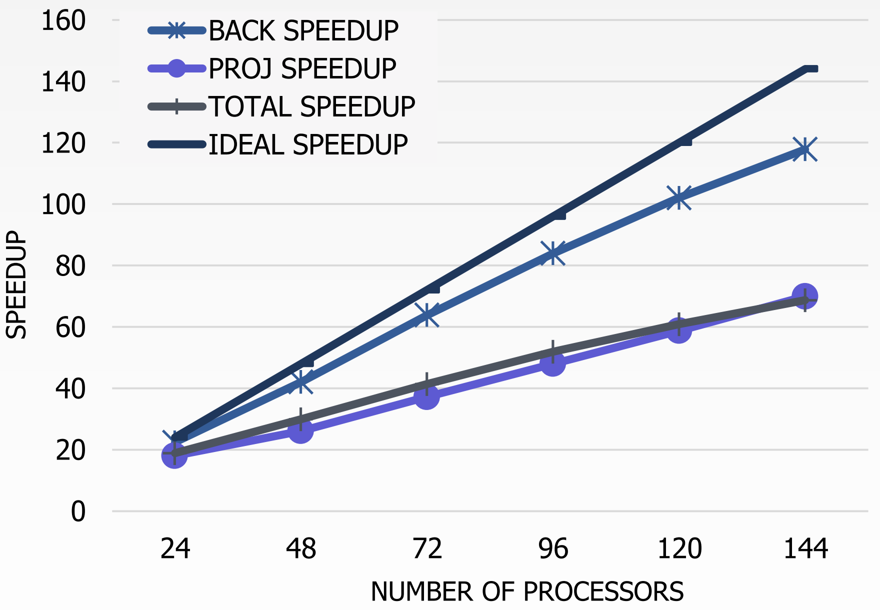


Proposed Solution: HPC

- Distributed hybrid **MPI/OpenMP** approach:
  - Using PETSc (based on MPI) for obtaining a distributed version of the solver
  - Intra-node parallelization through the use of OpenMP
    - Backprojection
    - Projection



12 nodes, 12 cores, MPI with OpenMP.



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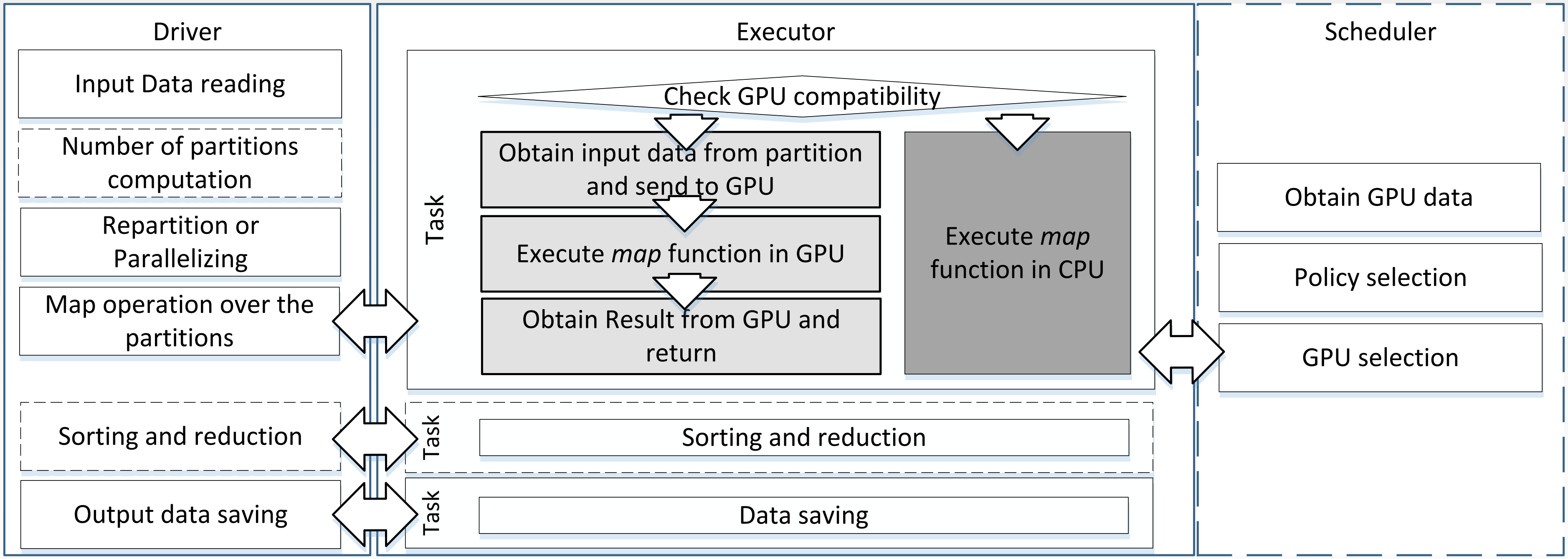
Proposed Solution: High Performance for Big Data

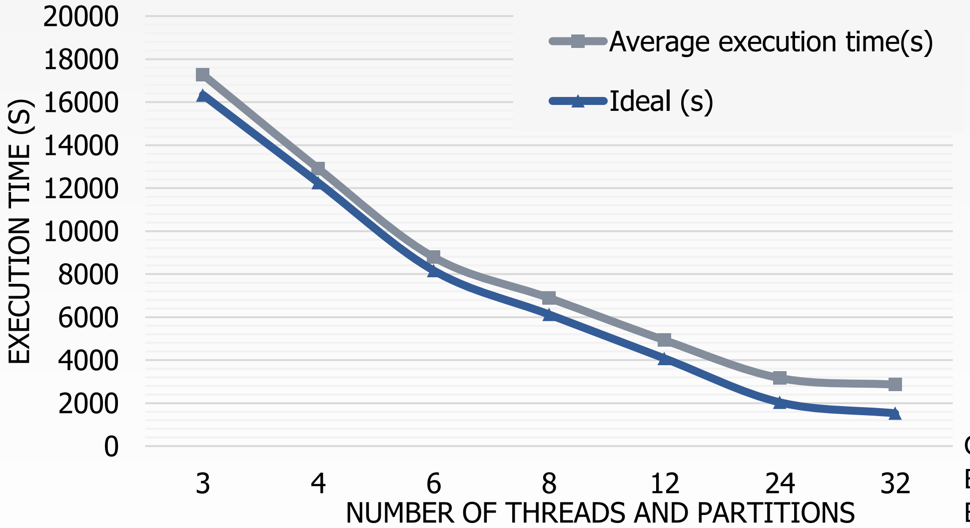
- **PySpark**



- Backprojection & Projection = Map Tasks

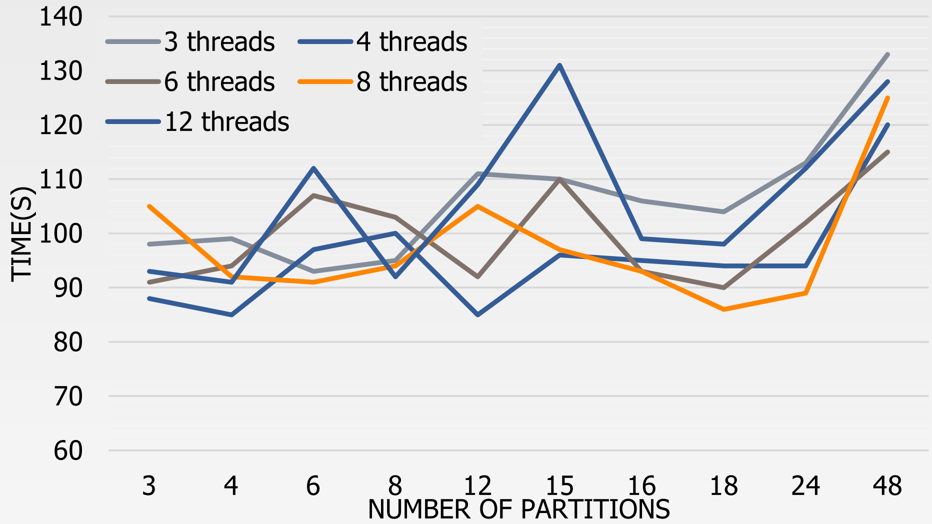
Proposed Solution: HP for Big Data (Homogeneous)

- Tasks are scheduled as normal but executed using native code **(C with or without OpenMP parallelization**).
- Average overhead of the framework (one executor): 40s
- OpenMP used when distributing over several nodes = MPI/OpenMPlike hybrid approach.
- Executor could also be used for distributing work in one node.



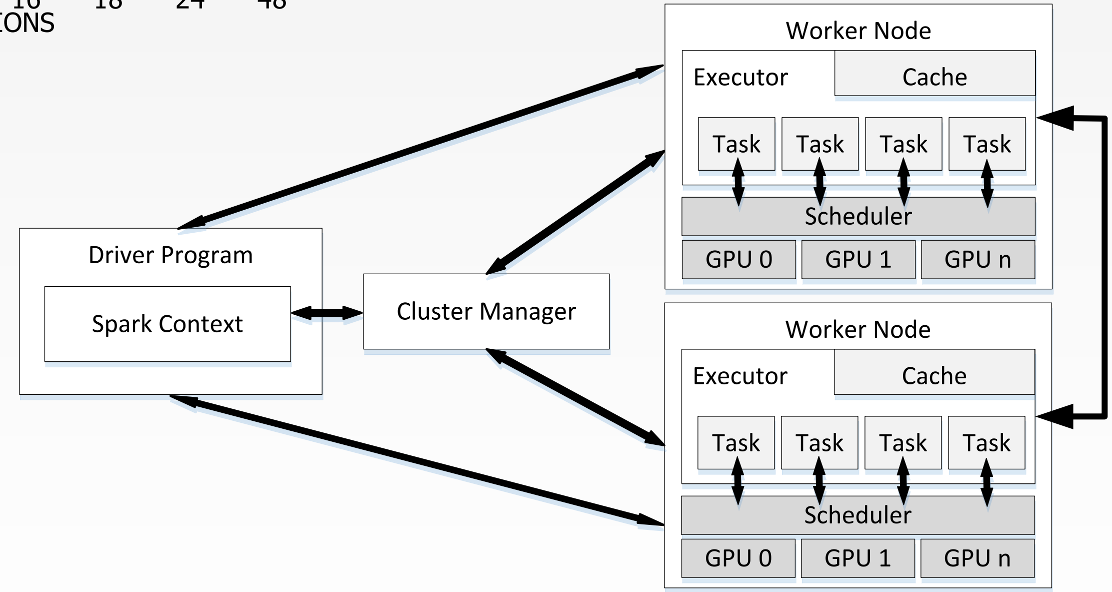
One node, 32 cores, C without OpenMP, Each thread correspond to an executor. (ONLY BACKPROJECTION).

Proposed Solution: HP for Big Data (Heterogeneous)



One node, 32 cores, GPU, Round Robin(ONLY BACKPROJECTION).

- Execution of the map tasks in **GPUs**.
- Inclusion of an **intra-scheduler** in each worker node.



Conclusions and Further Steps

- Development of modular backprojection and projection operators that can be used in new CT algorithms (O1).
- Finalizing profiling and evaluating the previously presented approaches (O2, O3).
- Adaptation to new paradigms (O2, O3; Currently Ongoing):
  - Employ a mixed HPC-Big Data platform that can provide the best from both worlds:
    - Programmability, **Data Management**, and Fault Tolerance (**Big Data**)
    - Performance, Optimization, and **Heterogeneous Architectures Support** (**HPC**).

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