HEPiX Benchmarking Working Group Report

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Introduction

- The HEPiX Benchmarking Working Group is tasked with managing the standard CPU benchmark used by the WLCG experiments and the HEPiX community
    - Utilized for accounting of WLCG compute resources

- For many years, this was HEPSPEC06, the "all_cpp" subset of the SPEC CPU2006 benchmark

- In 2019 the group started developing a new benchmark based on actual containerized workloads from the WLCG experiments: HEPscore
    - *HEPscore23 was ratified by the WLCG HEPscore Deployment Task Force as a replacement for HEPSPEC06 in April 2023, after an extensive and multi-site measurement/reproducibility validation campaign*

- Also recently mandated by the WLCG Management Board to work on GPU benchmarking

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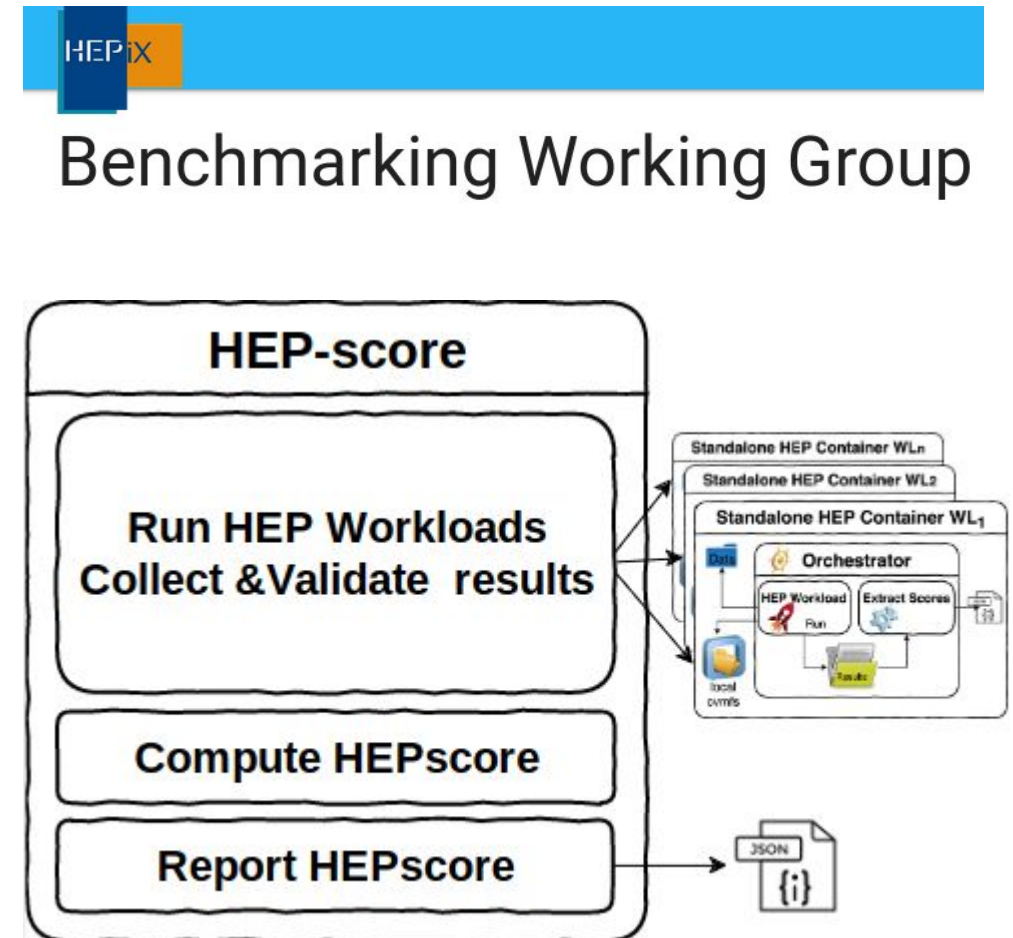
Introduction (Cont.)

- **Sites may continue to use HEPSPEC06 (HS06) scores for previously pledges resources**
  - Resources purchased after April 2023 should be pledged with HEPscore23 instead
  - HEPscore23 is multiarch: supports transparent execution on both x86_64 and ARM

- **The working group develops a tool to simplify the execution of HEPscore23, other benchmarks (HEPSPEC06, DB12, etc.) and the automated reporting of results**
  - The HEP Benchmark Suite

- **The group also maintains a central repository allowing sites and procurements teams to store (via the Suite) and search benchmark results for different hardware**
  - https://w3.hepix.org/benchmarking/scores_HS23.html

- **Consists of members from several HEPiX and WLCG institutions**
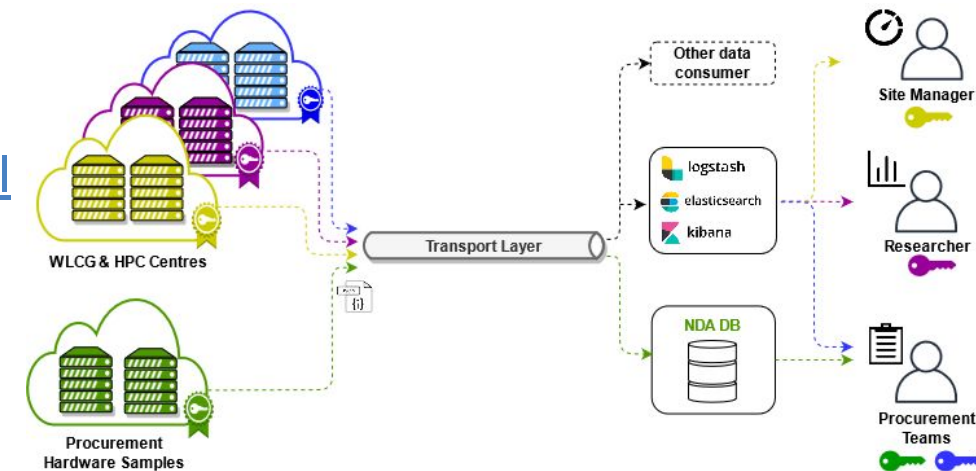
HEPscore23

- 7 workloads included

- All utilize a recent version of the WLCG experiments' software
  - Run 3 based (for the LHC experiments)

- 3 Single process workloads and 4 multi-thread/process workloads
  - In default configuration, utilizes all logical cores on the host

- Workloads evenly weighted
  - Geometric mean of sub-benchmark scores used to calculate single overall score

- Reference server:
  - Intel® Xeon® Gold 6326 CPU @ 2.90 GHz with hyperthreading enabled

Exp	Workload	x86_64 / aarch64	Sw version
ALICE	digi-reco	✅	O2/nightly-20221215-1
ATLAS	gen_sherpa (SP) (*) SP: Single Process	✅	Athena 23.0.3
	reco_mt	✅	Athena 23.0.3
Belle2	gen-sim-reco (SP)	✅	release-06-00-08
CMS	gen-sim	✅	CMSSW_12_5_0
	reco	✅	CMSSW_12_5_0
LHCb	sim (SP)	✅	v3r412

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HEPscore23 (Cont.)

- HEPscore23 performs better on newer CPU microarchitectures than HEPSPEC06
  - It is a more accurate representation of the modernization that has taken place in HEP applications compared to HS06
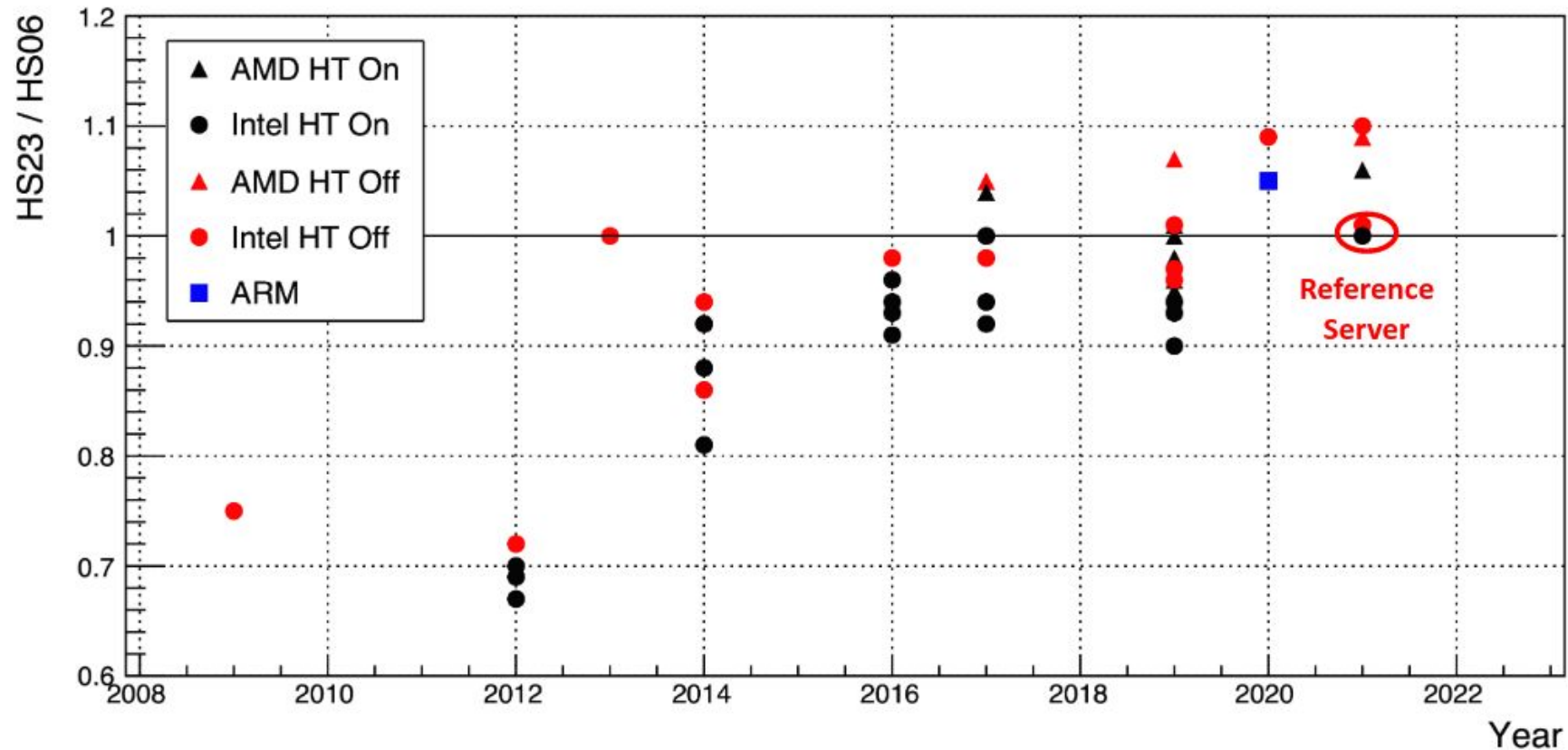
HS23/HS06 Ratios by CPU Model Year

HEPscore23 (Cont.)

- Extensive studies on multiple CPU models and architectures have shown the benchmark to be highly reproducible
 - Scatter of results less than 0.5% on all systems in the CERN testbed
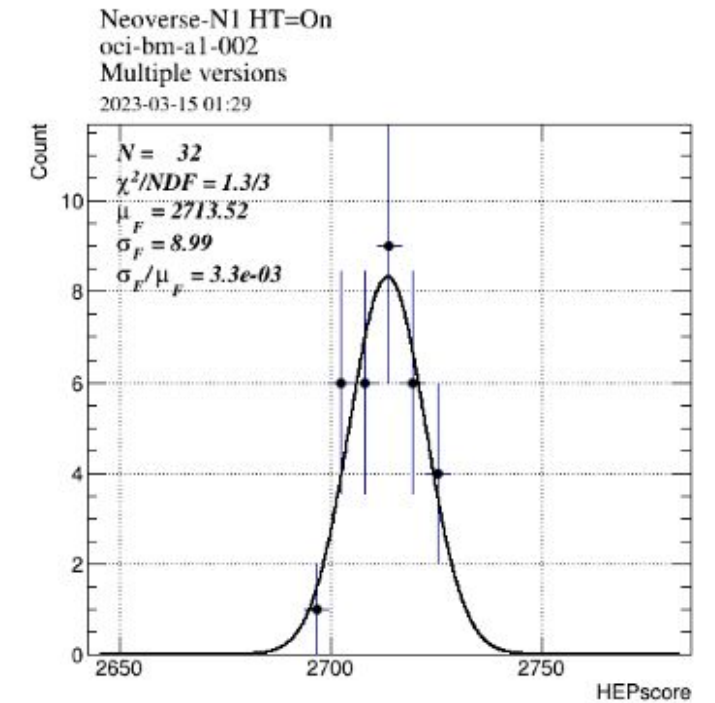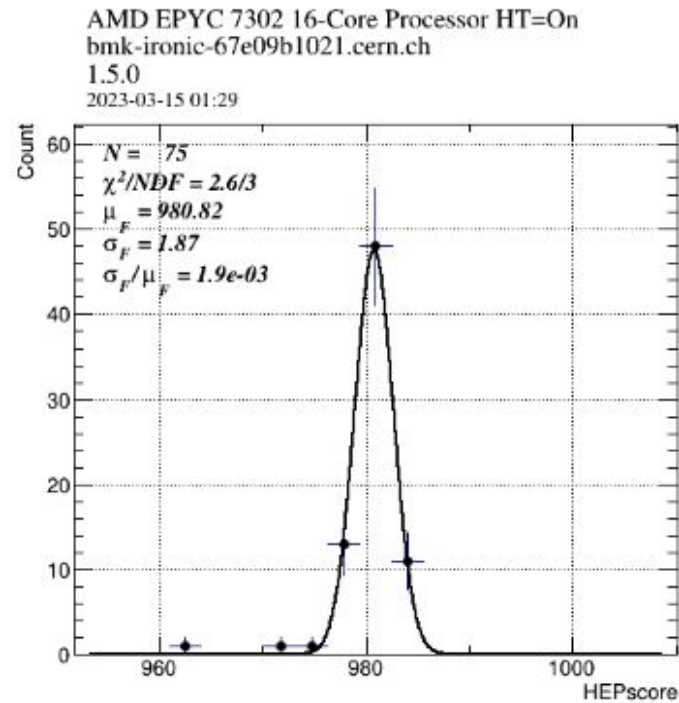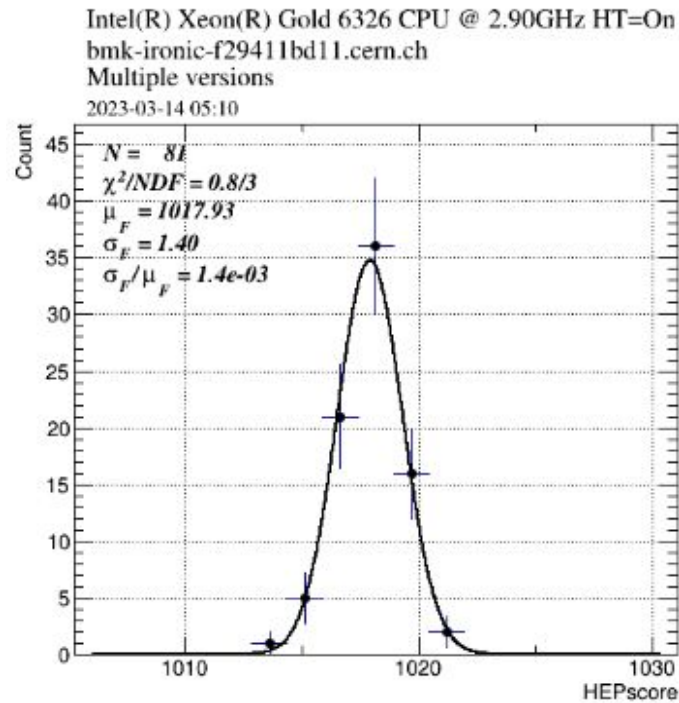
hep-score Application Updates

- hep-score application v1.5 released in March 2023
  - Current stable version, and default version used for suite execution

- Expect v1.6 release in the near future
  - Several v1.6 release candidates (rc) made available for testing
  - Many new features and bugfixes, including:
    - Allow registry to be overridden via the command line and options field
    - Add support for lists of registry types, with one to utilize selectable via the '-i' option
    - Configurable number of cores to be loaded (ncores) to be passed to the workloads, if the workloads implement this feature
    - Unset problematic Singularity/Apptainer environment variables

```
$ hep-score -i dir -n 2 /tmp
2023-10-11 23:14:23 hepscore [INFO] HEPScore23 Benchmark
2023-10-11 23:14:23 hepscore [INFO] Config Hash:          f5216b9cd1e2d5bd8c799ead4fa7c4ecd3f39c71d7cd624d6025056906204856
2023-10-11 23:14:23 hepscore [INFO] HEPscore version:     1.6.0.0rc4
2023-10-11 23:14:23 hepscore [INFO] System:               Linux test00.sdcc.bnl.gov x86_64
2023-10-11 23:14:23 hepscore [INFO] Container Execution:  singularity
2023-10-11 23:14:23 hepscore [INFO] Implementation:       apptainer
2023-10-11 23:14:23 hepscore [INFO] Registry:             dir:///cvmfs/unpacked.cern.ch/gitlab-registry.cern.ch/hep-benchmarks/hep-workloads
2023-10-11 23:14:23 hepscore [INFO] Output:               /tmp/HEPscore_11Oct2023_231423
2023-10-11 23:14:23 hepscore [INFO] Date:                 Wed Oct 11 23:14:23 2023

2023-10-11 23:14:23 hepscore [INFO] Executing 3 runs of atlas-gen_sherpa-ma-bmk [v2.0_x86_64]
2023-10-11 23:14:23 hepscore [INFO] Enforcing run of each workload on only 2 cores
2023-10-11 23:14:23 hepscore [INFO] Starting run0
```

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HEP Benchmark Suite Application Updates

- Suite v2.2 released in June 2023
  - Current stable version, and default version used for suite execution with run_HEPscore.sh
  - Numerous changes, including:
    - Multi-python version and platform wheel builds
    - Support for builtin hepscore configurations
    - The inclusion of a script (populate_cache.py) to pre-populate Singularity/Apptainer/Docker caches with workload images

- Expect v3.0 release in the near future
  - Release candidates (rc) available for testing
  - Includes support for time series plugin extensions

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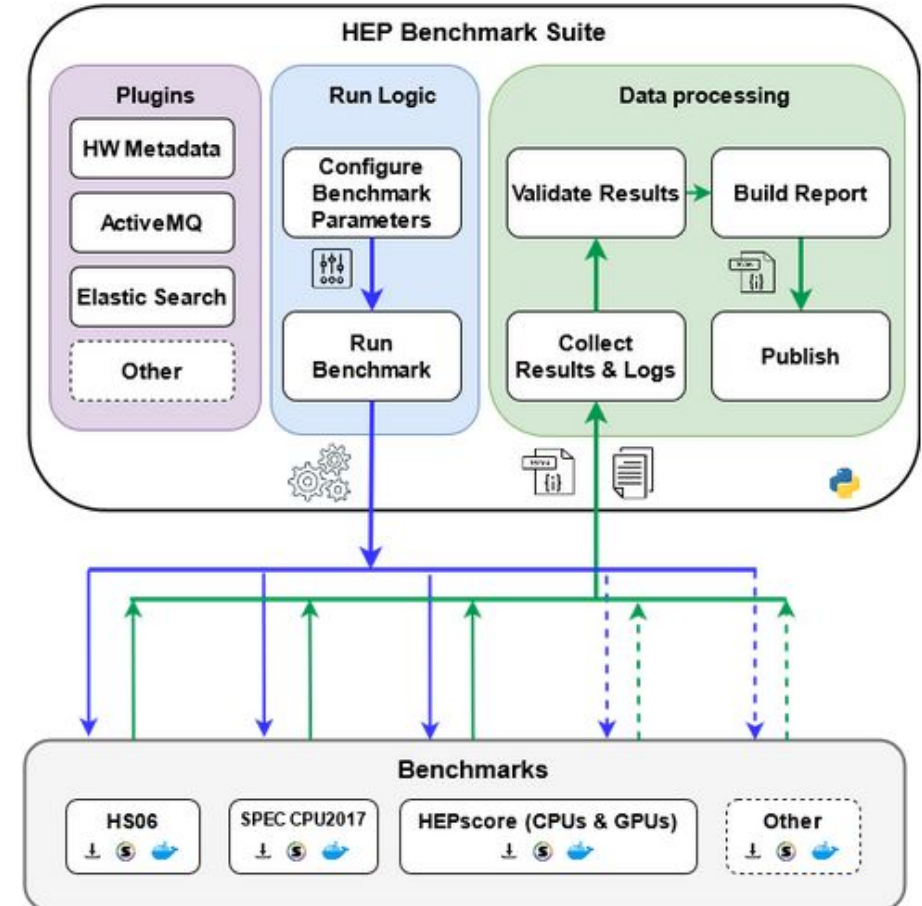
HEP Benchmarking Suite Time Series Plugins

- **HEP Benchmark Suite extended to support executing commands while benchmarks are running (and also before and after) and record time series data: CommandExecutor plugin**
  - Can be used to record energy consumption, load, memory use, CPU frequency
    - via ipmitool, uptime, free, etc.

- **Can be correlated with the benchmark score measurements**
  - Increasing interest in energy/performance studies in WLCG

Example: Plugin Configuration

Plugins' Report

Rebuild time series from stored data
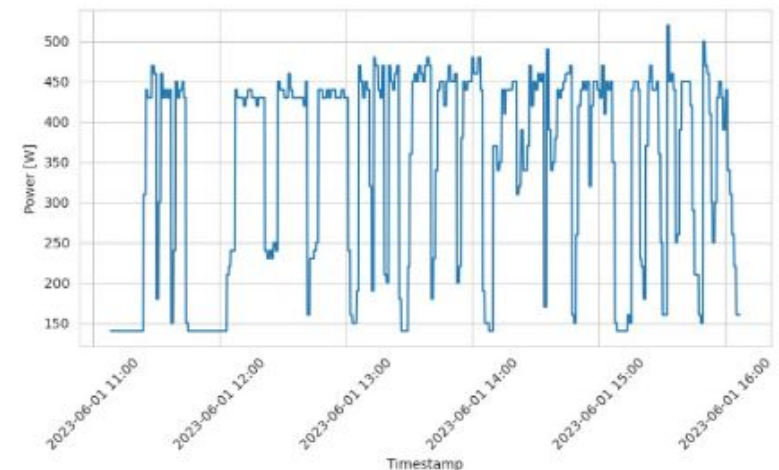
# Preparation of HEPscore GPU Workloads

- CERN student project to measure energy efficiency on GPU workloads

- Utilized containerized Madgraph workload ported to CPU and GPU with the CommandExecutor HEP Benchmark Suite time series plugin

Variation of Server Power Consumption with Time

CPU-only run
CPU + GPU-run
GPU power consumption for CPU+GPU run
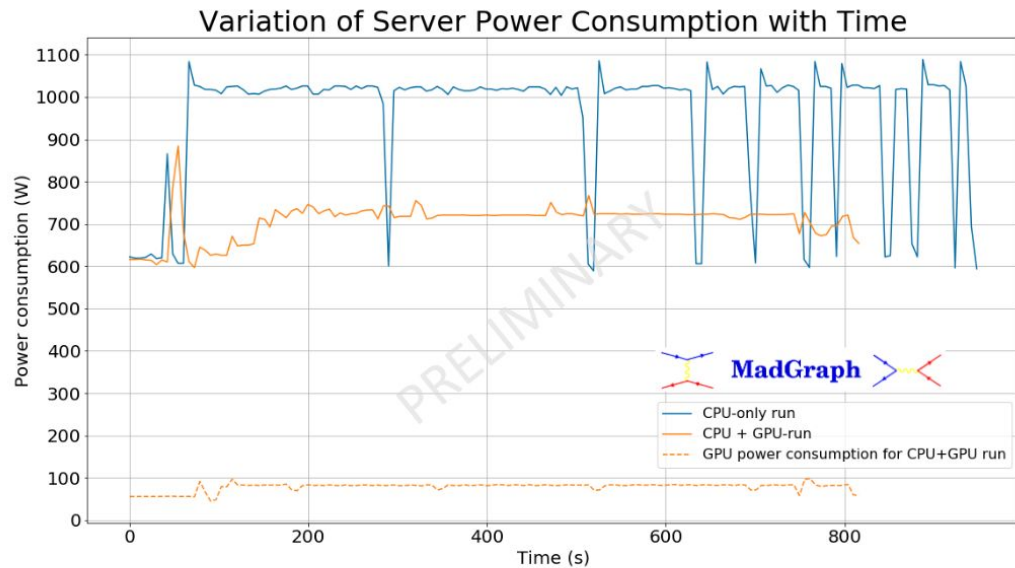
Keshvi Tuteja

Server Specs:
- **CPU**
  Intel Platinum 8362 @ 2.80GHz
  Cores per socket: 32
  Sockets: 2

- **GPU**
  Model name: Nvidia L4
  Total board power: 72 W
  GPU clocks: 2 GHz (Boost)


Containerized MadGraph
Server
CPU   GPU
Benchmark Suite
Analysis
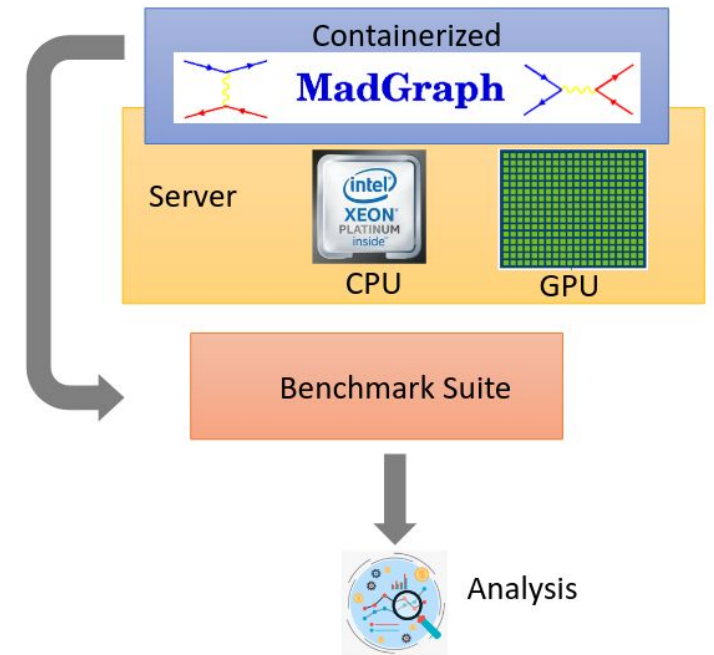
Keshvi Tuteja

- Other GPU hep-workloads containers available: Simpletrack, HLT-CMS, MLPF

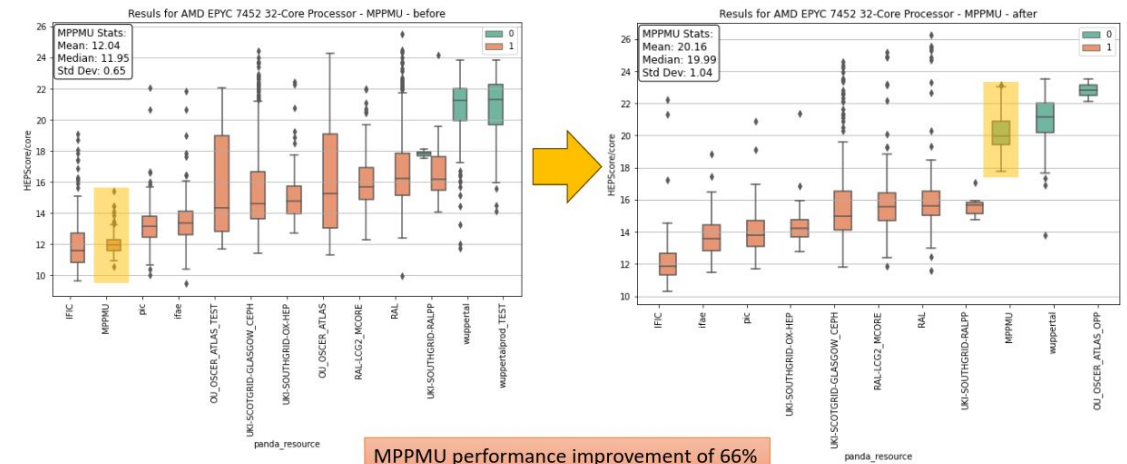**Brookhaven** National Laboratory

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Studies on Grid Jobs

- Ran HEPscore23 via PanDA to continuously measure grid site performance

- Was utilized to determine some underperforming sites, including one where HT was incorrectly disabled
  - The group worked with site admin on correcting: resulted in a 66% performance improvement
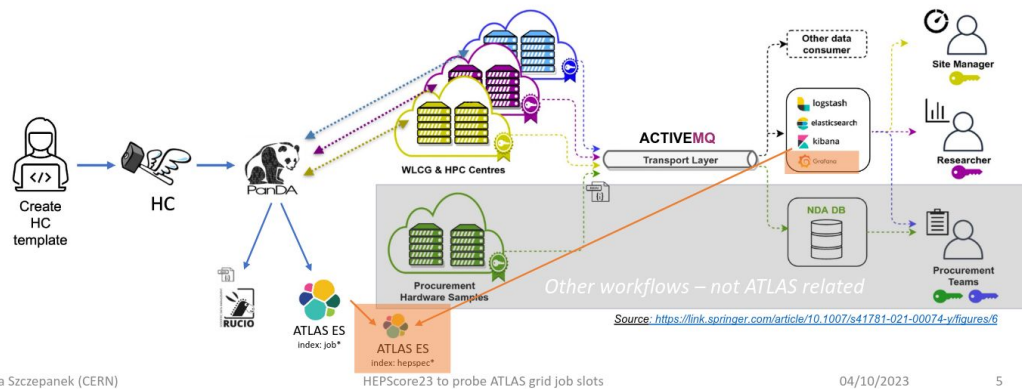
Support via GGUS

- Benchmarking support via GGUS available since April 2023

    - Have received a number of tickets

    - Prefered mechanism for support due to its inherent history tracking
        - Still receiving some requests via email

- Suite result JSON that users have any issues submitting through the application can be sent via GGUS as an attachment

Contributors Needed

- Developing, maintaining and supporting HEPscore23, the HEP Benchmark Suite, and our results table requires significant effort
  - Many of the working group's participants are contributing part time
  - A number of members are students with temporary appointments/internships

- We are looking for additional members of the HEPiX community to contribute
  - Testing benchmarks
  - Development of benchmark workload containers
  - Development of the hep-benchmark-suite and hep-score applications

- If you are interested, please contact the co-chairs:
  - Domenico Giordano <Domenico.Giordano@cern.ch>
  - Michele Michelotto <Michele.Michelotto@pd.infn.it>

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Conclusions

- **HEPscore23 was adopted as the standard WLCG CPU benchmark in April 2023**
  - Support available via GGUS if needed

- **The hep-score and hep-benchmark-suite applications continue to be updated with new features**
  - Expect new releases in the coming weeks

- **A new CommandExec plugin for the hep-benchmark-suite application allows for execution of commands and recording of time-series data while benchmarks are executing**
  - Permits the collection of power usage data (i.e. via ipmitool), and other system characteristics such as memory use over time

- **Studies of numerous grid site performance via HEPscore23 have successfully been completed via PanDA**
  - Allowed the working group to help improve the performance of one of the sites measured

- **Development and testing of GPU hep-workload containers is continuing to progress**

- **We are looking for additional members of the HEPiX community to join our efforts**

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