Enabling Julia code to run at scale with artefact caching

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Challenges in computational High-Energy Physics

- Research in High-Energy Physics (HEP) is computationally intensive.
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- Current paradigm: Performance-critical code is written in C++, with significant use of Python.
  - Leading to the need to interface these two, rather different, languages.

Julia for HEP

- Julia is a high-level, general-purpose language, with dynamically typed characteristics and a REPL.
  - → Ease of use, promoting high productivity workflows.

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→ Julia has drawn considerable attention in the HEP community[1,2].

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Our goal:

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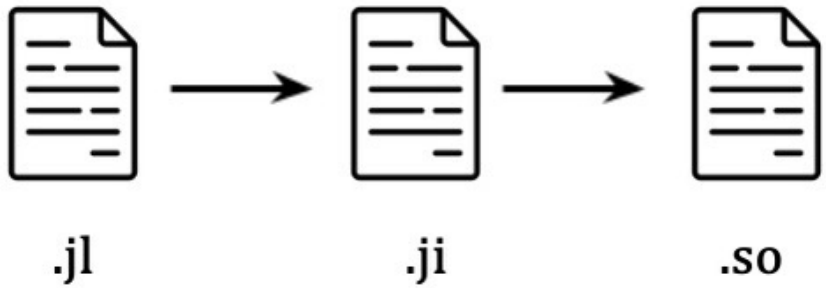
Our goal:

- Leverage Julia's potential to run in distributed contexts

Making cache files relocatable



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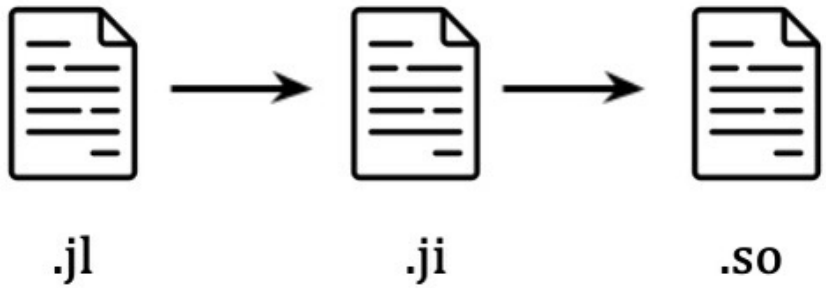

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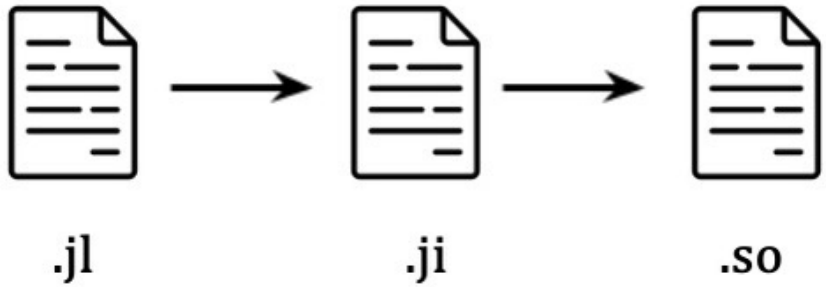

The variable `Base.DEPOT_PATH` controls where cached compiled package images are stored.

```
[eaguerov@pcphsft90]~% julia -e "println(Base.DEPOT_PATH)"
["/home/eaguerov/.julia", "/home/eaguerov/.julia/juliaup/julia-1.11.0-rc1+0.x64.linux.gnu/loca
l/share/julia", "/home/eaguerov/.julia/juliaup/julia-1.11.0-rc1+0.x64.linux.gnu/share/julia"]
[eaguerov@pcphsft90]~% ls .julia/compiled/v1.11/BitFlags/
[eaguerov@pcphsft90]~% julia -e "using BitFlags"
Precompiling BitFlags...
  1 dependency successfully precompiled in 1 seconds
[eaguerov@pcphsft90]~% ls .julia/compiled/v1.11/BitFlags/
sbYUO_k6ZNm.ji  sbYUO_k6ZNm.so
```

Making cache files relocatable

- → First entry of `DEPOT_PATH` must be writable, while others entries are treated as read-only.
- → Multiple Julia projects (within the same node) use the same local DEPOT_PATH. Julia decides if cache file is stale at runtime.
- → Can be set before startup on the terminal

```
export JULIA_DEPOT_PATH="/foo/bar:\$JULIA_DEPOT_PATH"
```

Making cache files relocatable (2)

Prior to Julia 1.11, the following would invalidate a cache file:

1. The **absolute path** of the generated cache file.
2. The file's modification time (mtime).
3. Incompatible image targets for the host's instruction set architecture (ISA).

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These issues are partially resolved by:

1. The candidate release Julia 1.11-rc only considers relative path of package files
2. Copying with a procedure that respects mtime `rsync` vs `cp` when cache files are generated from a non-host machine.
3. Julia's built-in cross-compilation capabilities, by setting the environment variable `JULIA_CPU_TARGET`

Julia's Cross-compilation

Julia interfaces to the LLVM compiler to set image targets.

```
export JULIA_CPU_TARGET="generic;sandybridge;haswell,clone_all"
```

You could see your current image and cpu targets with `JLOptions()` and `Base.current_image_targets()`

```
[eaguerov@pcphsft90]~% export JULIA_CPU_TARGET=generic
[eaguerov@pcphsft90]~% export JULIA_DEPOT_PATH=/eos/user/e/eaguerov/julia:
[eaguerov@pcphsft90]~% julia -q
(v1.11) pkg> add BitFlags
   Resolving package versions...
  No Changes to `/eos/home-e/eaguerov/julia/environments/v1.11/Project.toml`
  No Changes to `/eos/home-e/eaguerov/julia/environments/v1.11/Manifest.toml`
Precompiling project...
  1 dependency successfully precompiled in 2 seconds

julia>
[eaguerov@pcphsft90]~% ls /eos/user/e/eaguerov/julia/compiled/v1.11/BitFlags/
sbYUO_SBlWU.ji  sbYUO_SBlWU.so
[eaguerov@pcphsft90]~% julia -e "println(Sys.CPU_NAME)"
ivybridge
```

Practical implications

At CERN we could leverage the use of the Cern Virtual machine File System (CVMFS) to make precompiled files available.

- All projects can see the same node, effectively sharing an entry in the `DEPOT_PATH`.
  - → We prepare precompiled artifacts for each workflow in turn, "rsyncing" the cache files to that node.

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- Then execute the publication:
  - Open a transaction
  - Copy files to the correct path in `/cvmfs/`
  - Publish and close transaction[1]

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  - Copy files to the correct path in `/cvmfs/`
  - Publish and close transaction[1]
- Use this cache directory in CVMFS as read-only in the `DEPOT_PATH` list

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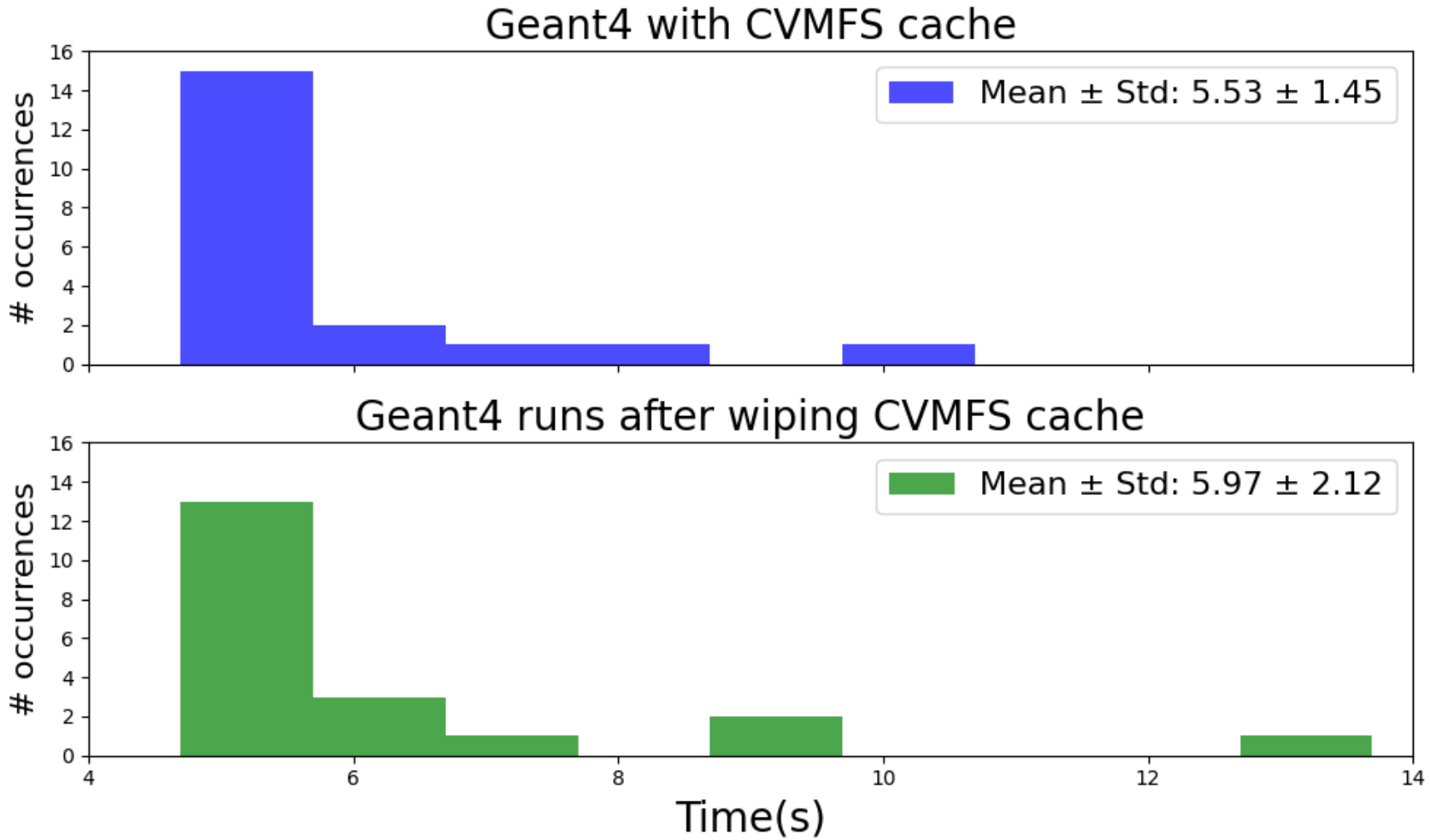
Testing this framework with two example workflows

We selected two use cases to test the influence of precompilation caching:

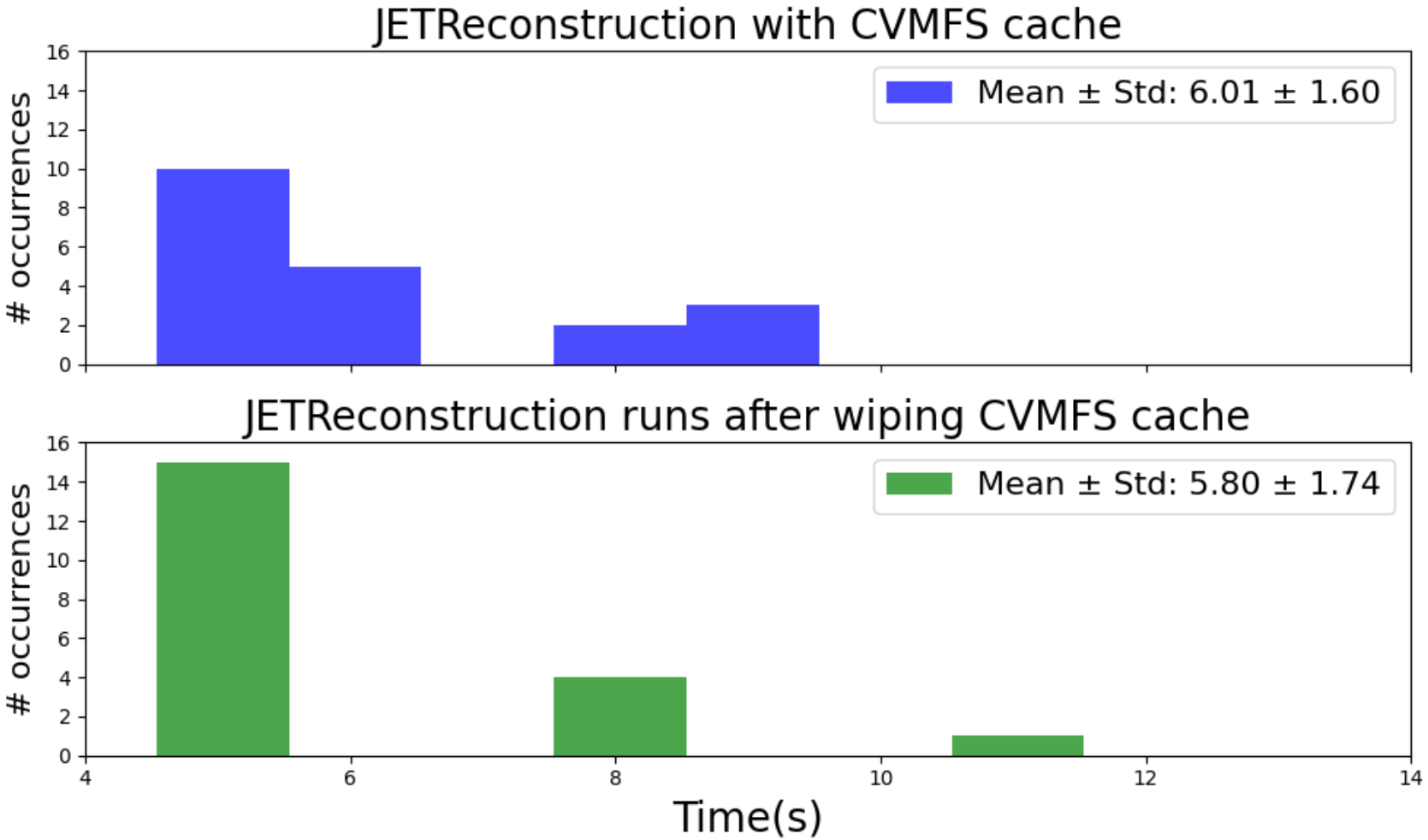
	JET	Geant4
Without cache	90 ± 7	270 ± 80
With CVMFS Cache	6 ± 2	6 ± 1

Table: Time in seconds it takes for Julia to start running the workflow.

Testing Julia's performance integrated with CVMFS



Results (3): Testing Julia's performance integrated with CVMFS



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We proceeded with a PR for our use case:

- Added support for multiple Project.toml files.
- Added support for precompilation of workflows.

Summary

- ✓ Julia was found to greatly reduce startup time by making use of precompiled objects for multiple micro-architectures.
- ✓ Julia is able to integrate to CernVM-FS with virtually no cost in performance.
- ✓ We contributed to a ready-to-use julia package to automatically populate different applications into directory.


CERN