# **Continuous Integration for the FairRoot Software Stack**

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#### Abstract

In this work we present recent improvements of the Continuous Integration (CI, see beside) for the FairRoot software stack (see beside). We discuss relevant development workflows and how they were improved through automation. Furthermore, we present our infrastructure detailing its hardware and software design choices. The entire toolchain is composed of free and open source software. Finally, this work concludes with lessons learned from an operational as well as a user perspective and outlines ideas for future improvements.

# Saving Energy (Ongoing work)

• Typically, the CI build farm has a low overall utilization with long idle periods and short peak loads

### **Continuous Integration**

Continuous Integration (CI) is a modern software engineering method to efficiently assure software quality. The underlying idea is to continuously rebase (pending) feature branches onto the latest version of the software repository and re-validate them by a set of checks in an automated fashion. This approach allows to naturally and efficiently resolve the merging of concurrent development activities (by one or multiple authors).

The (partial) automation of the software release process (e.g. generation of release assets, documentation, extended testing) including the automated deployment is sometimes described by the term Continuous Deployment (CD). However, the term CI is often understood to subsume CD as well. In this work we adopt this more general definition of CI.

## **The FairRoot Software Stack**

The FairRoot<sup>1</sup> software stack is a toolset for the simulation, reconstruction, and analysis of high energy particle physics experiments, currently used i.e. at FAIR/GSI, and CERN.



In the FairSoft<sup>2</sup> source distribution the most important software dependencies needed to run a FairRoot-based experiment software framework are released for Linux and macOS while further "system dependencies" are taken from the Linux distribution and the Homebrew project<sup>3</sup> on macOS. Notable packages in a FairSoft release are

- Deployed an energy monitor
- Implemented the Slurm Power Save Suspend and Resume hooks to shut off idle worker nodes and restart them on-demand (via BMC signals)
- No long term data available yet, evaluation in the proceedings paper

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This example shows how a link to the doxygen based documentation preview in a FairRoot pull request is provided to the reviewers/developers.

- Automated generation of documentation
- Advanced build log analysis with CDash<sup>5</sup> and the Warnings Next Generation Jenkins<sup>6</sup> Plugin

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Developers can discover performed checks directly integrated in the Repository User Interface (here github.com)

- Run Extensive Test Suites as part of the central CI cycle
- Test
  Preview
  Documentation

- ROOT (https://root.cern/),
- Boost (https://www.boost.org/),
- Geant3 (https://github.com/FairRootGroup/geant3),
- Geant4 (https://geant4.web.cern.ch/),
- VMC (https://github.com/vmc-project/vmc),
- HEPMC (http://hepmc.web.cern.ch/),
- Pythia6 (https://github.com/alisw/pythia6),
- Pythia8 (https://pythia.org/),
- Vc (https://github.com/VcDevel/Vc),
- VGM (https://github.com/vmc-project/vgm),
- CLHEP (http://proj-clhep.web.cern.ch/),
- DDS (http://dds.gsi.de/), and
- FairMQ (https://github.com/FairRootGroup/FairMQ).





This screenshot depicts a breakdown dashboard for the captured clang-tidy warnings for the FairRoot dev branch realized with the Warnings Next Generation Jenkins Plugin



This example shows the "changes" tab on a FairRoot pull request with a source code annotation about a clang-tidy warning directly in the github.com user interface (realized with the Warnings Next Generation Jenkins Plugin).



- Containerized Builds (on Linux) with Apptainer<sup>9</sup> (Singularity) to enable heterogneous and large build matrices
- **Container Definitions public** so the developer may re-use the build environment locally, e.g.



oras://ghcr.io/fairrootgroup/fairmq-dev/fedora-35-sif:latest <cmd>

will execute the given <cmd> in the same environment that is also used by FairMQ's CI jobs based on the Fedora 35 image.

#### **Build Farm**

- 5 Linux hosts (20-28 CPU cores, 128-256GB RAM each) + 3 Mac minis (2x x86\_64, 1x aarch64) for **public, untrusted** CI jobs
- 3 Linux hosts (20-28 CPU cores, 128-256GB RAM each) for private, trusted CI (mainly CD) jobs
- All hosts have direct attached SSD storage suitable for **cross job build caches**
- Job run times range from a few minutes to multiple hours < 6h depending on repo and change.

#### Infrastructure

The relevant source code repositories are hosted in a heterogeneous environment, some are on github.com, some on various GitLab<sup>6</sup> instances. GitLab natively comes with a Cl service. As of ~2021 only, github.com started to offer a Cl service. Because we started to use the Cl method before, we operate a Jenkins Cl service as well. In anticipation of the still quickly changing Cl service landscape, we aim to keep a **weak** dependency on those Cl services only. In addition, we want to support multiple instances in parallel and still share our build farm. To achieve this, Cl jobs are scheduled onto the build farm via a shared queue - realized with the Slurm<sup>4</sup> resource manager.

#### **Lessons Learned**

- Long Running CI jobs are acceptable
- Design CI checks cleanly from the bottom up and avoid unnecessary dependencies on the CI system

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12526 FairMQ PR-420 fedora-35-x86_64-gcc-11	alfaci	PD	0:00 (Priority)
12527 FairMQ PR-420 static-analyzers	alfaci	PD	0:00 (Priority)
12528 FairRoot PR-1155 build/centos-7-x86_6	alfaci	PD	0:00 (Priority)
12529 FairRoot PR-1155 build/centos-7-x86_6	alfaci	PD	0:00 (Priority)
12530 FairRoot PR-1155 build/debian-10-x86_	alfaci	PD	0:00 (Priority)
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12533 FairRoot PR-1155 build/debian-10-x86	alfaci	PD	0:00 (Priority)
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12535 FairRoot PR-1155 build/centos-7-x86_6	alfaci	PD	0:00 (Priority)
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12537 FairRoot PR-1155 build/debian-10-x86_	alfaci	PD	0:00 (Priority)
12538 FairRoot PR-1155 build/ubuntu-20.04-x	alfaci	PD	0:00 (Priority)
12539 FairRoot PR-1155 check/format	alfaci	PD	0:00 (Priority)
12540 FairRoot PR-1155 build/fedora-33-x86_	alfaci	PD	0:00 (Priority)
12520 FairMQ PR-420 thread-sanitizer	alfaci	R	1:31 lxci001
12521 FairMQ PR-420 fedora-32-x86_64-gcc-10	alfaci	R	1:30 lxci002
12522 FairMQ PR-420 fedora-33-x86_64-gcc-10	alfaci	R	1:29 lxci003
12523 FairMQ PR-420 fedora-34-x86_64-gcc-11	alfaci	R	1:29 lxci004
12524 FairMQ PR-420 {address,leak,ub}-sanit	alfaci	R	1:29 lxci005
alfaci@lxci001:~\$			
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The screenshot shows the status of the SLURM job queue filled with various CI jobs (R for Running, PD for Pending)



#### **Ongoing and Future Work**

- Publish pre-built CI container images on a registry and/or CVMFS<sup>8</sup>, so the developer can re-create a CI environment for a local interactive debugging session.
- Deploy and Operate a Github Actions Runner and explore if Jenkins can be phased out

#### References

[1] FairRoot - https://fairroot.gsi.de/
[2] FairSoft - https://github.com/FairRootGroup/FairSoft
[3] Homebrew - https://brew.sh/
[4] Slurm - https://slurm.schedmd.com/
[8] CVMFS - https://cernvm.cern.ch/fs/
[5] CDash - https://www.cdash.org/
[9] Apptainer - https://apptainer.org/
[6] GitLab - https://about.gitlab.com/
[7] Jenkins - https://www.jenkins.io/

All URLs have been last visited on 19th October 2022.

#### https://indi.to/FfQGy

GSI Helmholtz Centre for Heavy Ion Research GmbH, Darmstadt, Germany

workload manager

**CI Build Farm**