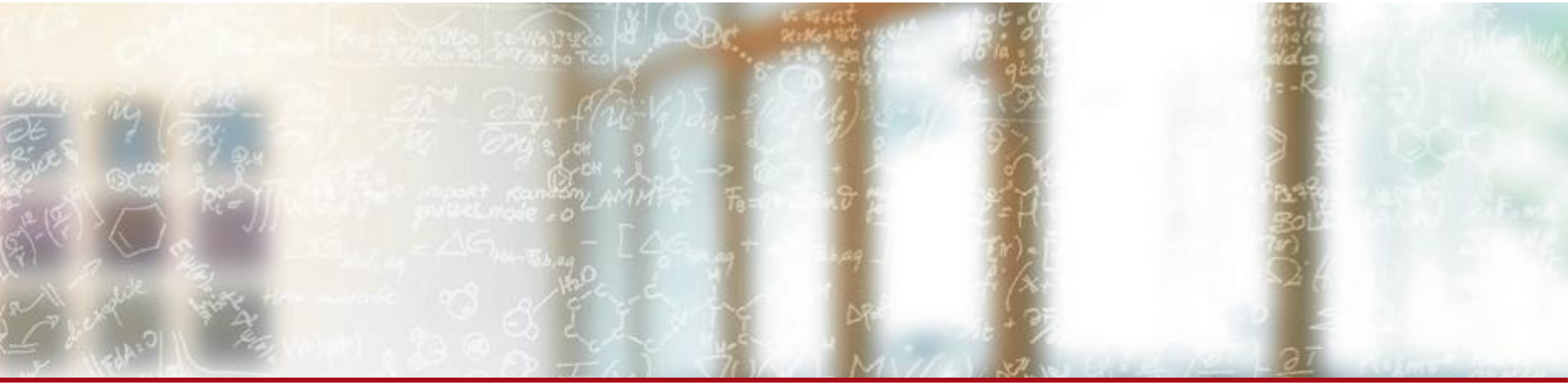
CSCS
Centro Svizzero di Calcolo Scientifico
Swiss National Supercomputing Centre

ETH zürich



CI/CD on Alps

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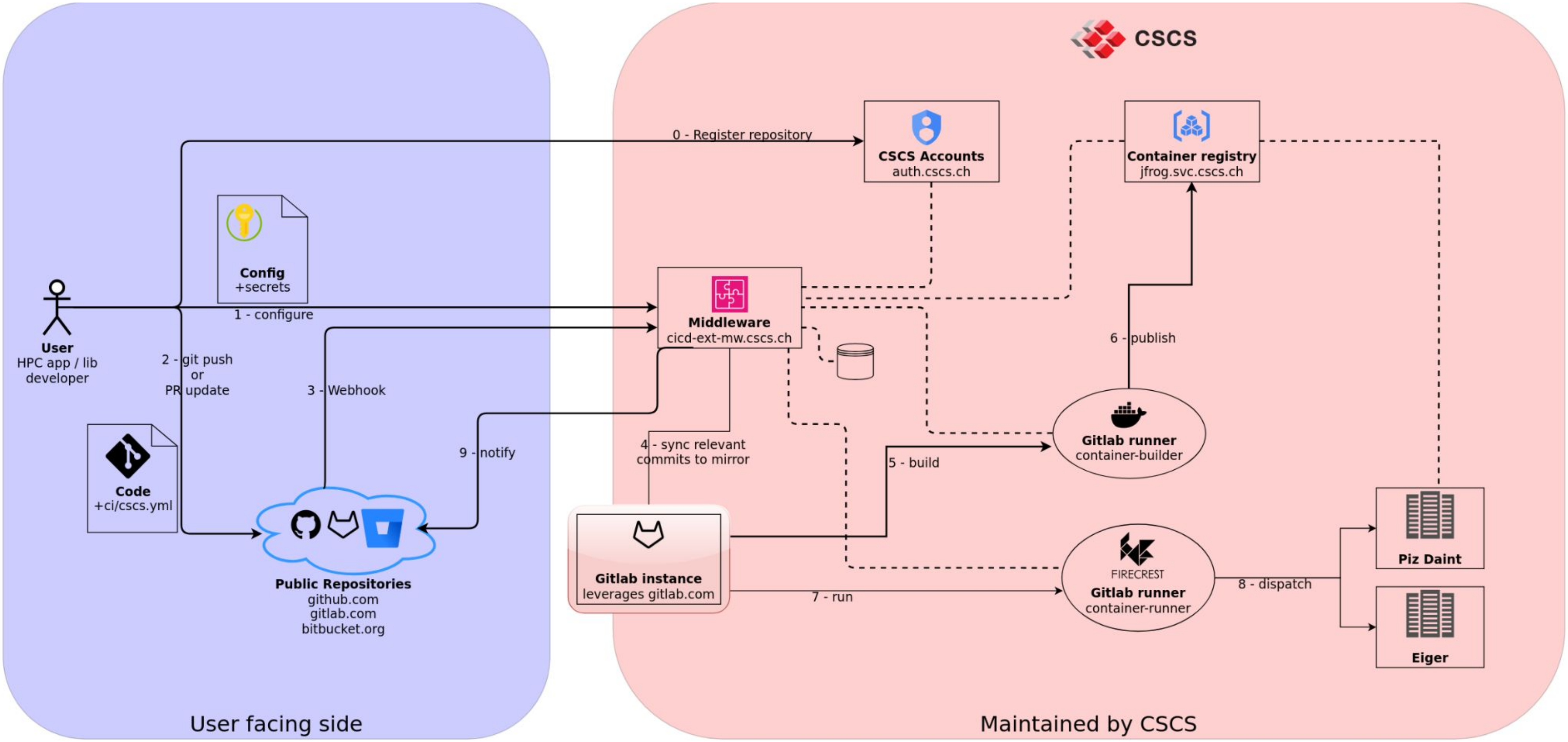
CI/CD at CSCS

- Useful links:
  - CSCS Documentation: https://confluence.cscs.ch/x/UAXJMw
  - Gitlab documentation: https://docs.gitlab.com/ee/ci/yaml/
  - CI variables:

    https://docs.gitlab.com/ee/ci/variables/predefined_variables.html
- Getting access for CI/CD at CSCS:
  - Open a Service Desk ticket to register your git repository
  - Follow the rest of the steps described in above “CSCS Documentation” (section “Enable CI for your project”)

CI/CD architecture



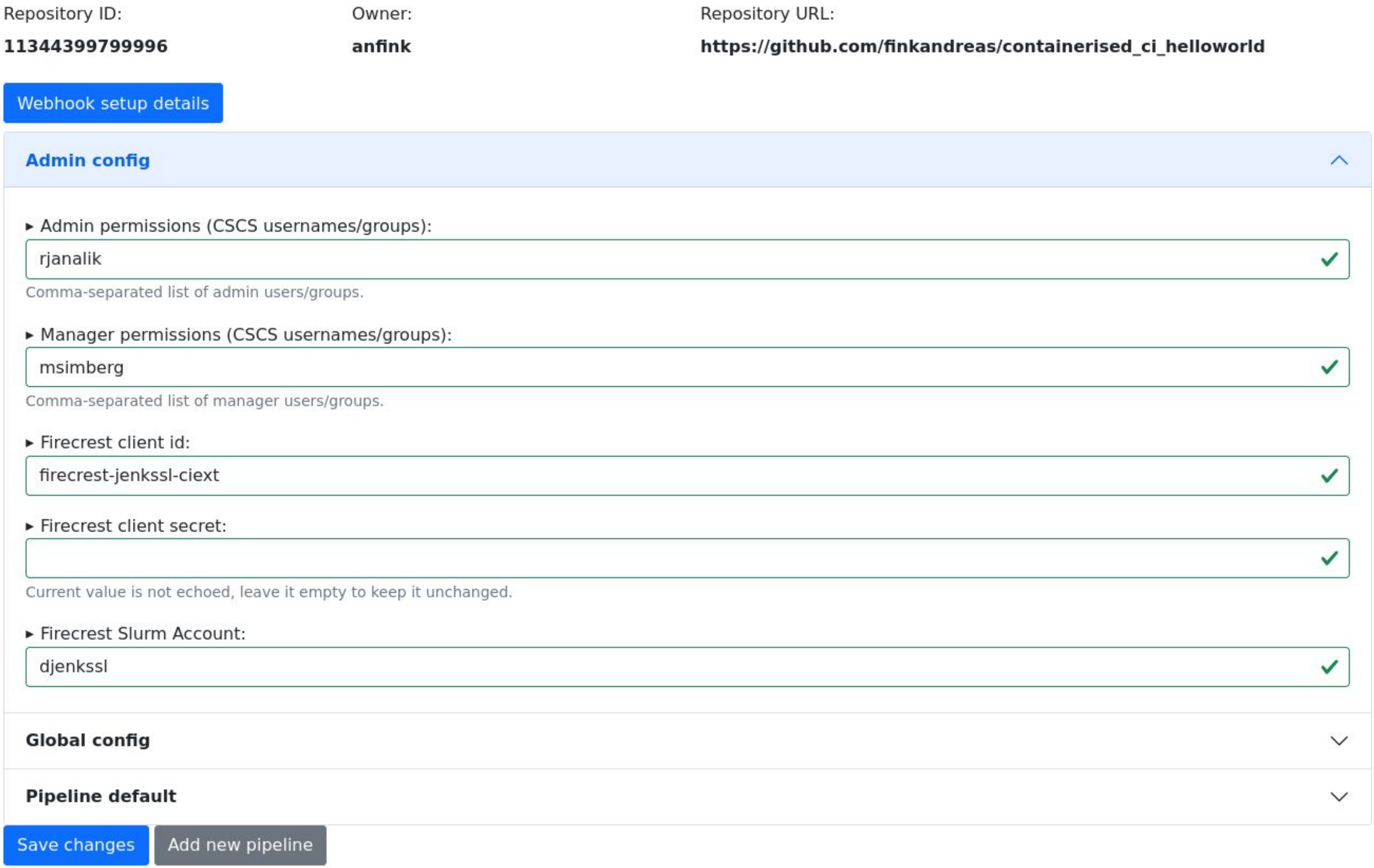
Your source code will be mirrored to gitlab.com

Visibility in gitlab.com will be private, if the source repository is private

Set up repository configuration

- Registered repositories can be found at
  https://cicd-ext-mw.cscs.ch
  - You can have “owner”, “admin” or “manager” access rights
  - “owner” and “admin” can change the repository configuration
  - “manager” can restart CI jobs

Set up repository configuration - Admin config



Repository ID: 11344399799996

Owner: anfink

Repository URL: https://github.com/finkandreas/containerised_ci_helloworld

▸ Admin permissions (CSCS usernames/groups): rjanalik ✓

Comma-separated list of admin users/groups.

▸ Manager permissions (CSCS usernames/groups): msimberg ✓

Comma-separated list of manager users/groups.

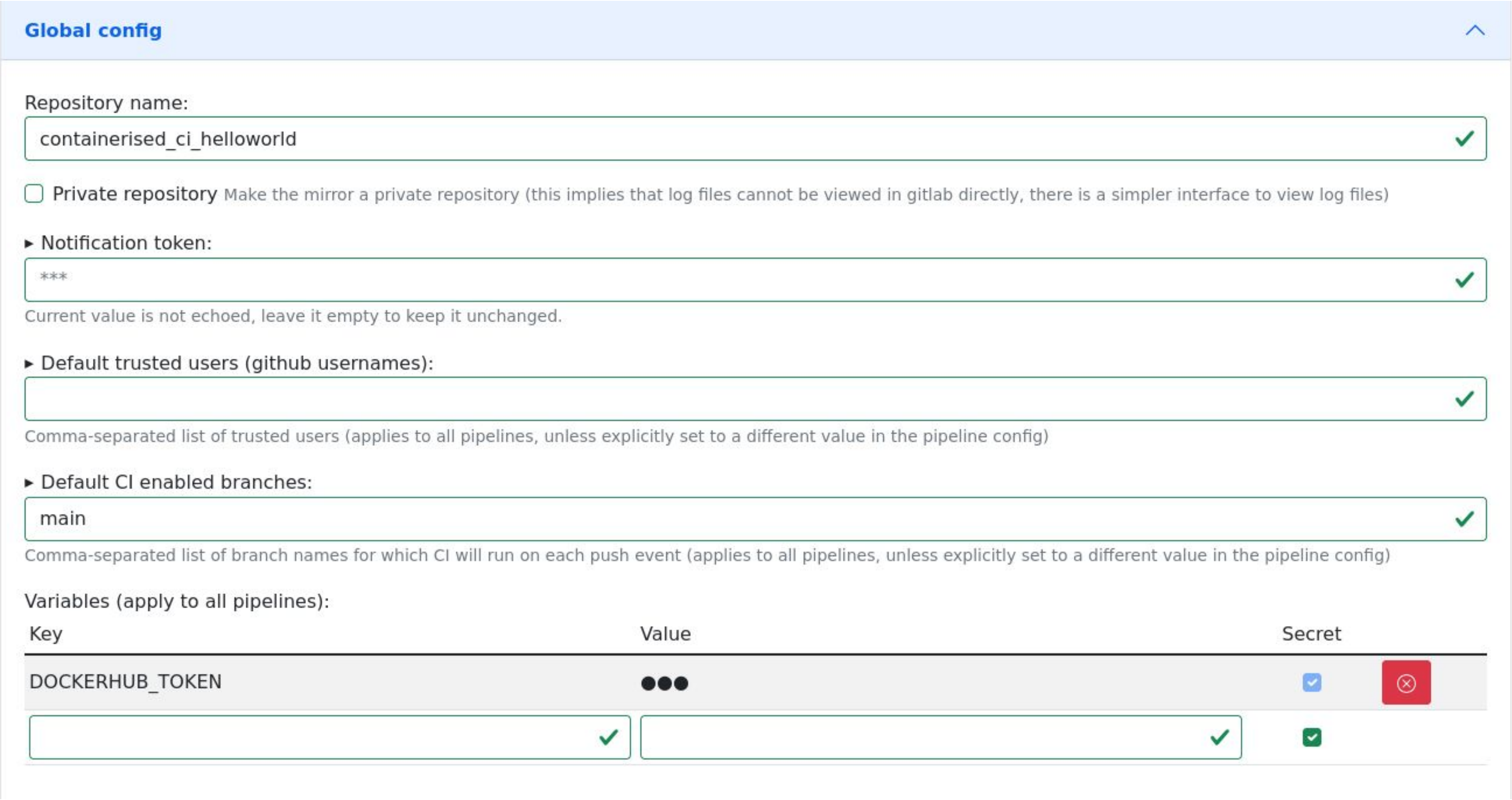
▸ Firecrest client id: firecrest-jenkssl-ciext ✓

▸ Firecrest client secret: ✓

Current value is not echoed, leave it empty to keep it unchanged.

▸ Firecrest Slurm Account: djenkssl ✓

Set up repository configuration - Global config



Global config

Repository name:

containerised_ci_helloworld ✓

□ Private repository Make the mirror a private repository (this implies that log files cannot be viewed in gitlab directly, there is a simpler interface to view log files)

▸ Notification token:

*** ✓

Current value is not echoed, leave it empty to keep it unchanged.

▸ Default trusted users (github usernames):

✓

Comma-separated list of trusted users (applies to all pipelines, unless explicitly set to a different value in the pipeline config)

▸ Default CI enabled branches:

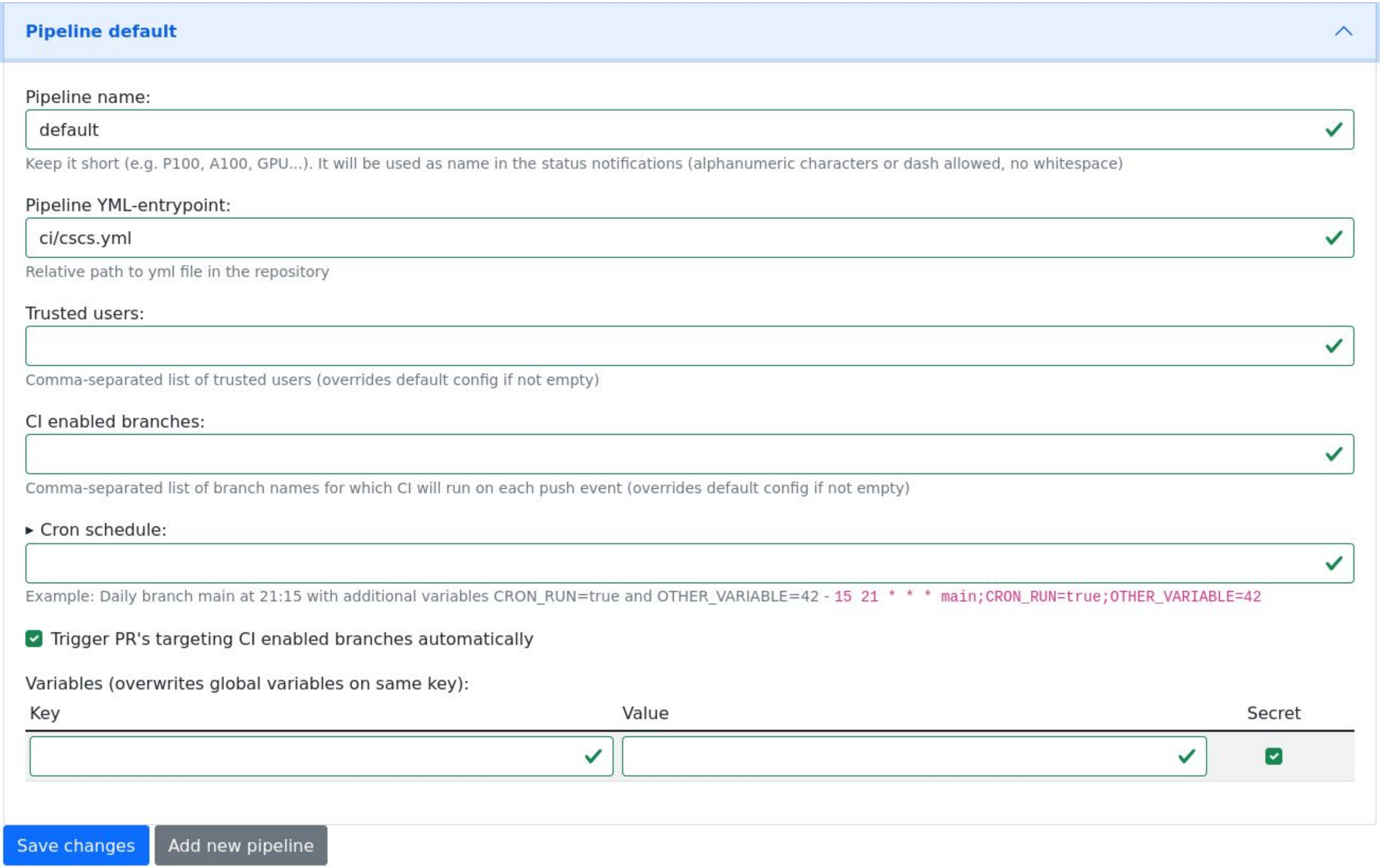
main ✓

Comma-separated list of branch names for which CI will run on each push event (applies to all pipelines, unless explicitly set to a different value in the pipeline config)

Variables (apply to all pipelines):

Key	Value	Secret	
DOCKERHUB_TOKEN	●●●	☑	⊗
✓	✓	☑	

Set up repository configuration - Pipeline config



Pipeline default

Pipeline name:

default ✓

Keep it short (e.g. P100, A100, GPU...). It will be used as name in the status notifications (alphanumeric characters or dash allowed, no whitespace)

Pipeline YML-entrypoint:

ci/cscs.yml ✓

Relative path to yml file in the repository

Trusted users:

✓

Comma-separated list of trusted users (overrides default config if not empty)

CI enabled branches:

✓

Comma-separated list of branch names for which CI will run on each push event (overrides default config if not empty)

▸ Cron schedule:

✓

Example: Daily branch main at 21:15 with additional variables CRON_RUN=true and OTHER_VARIABLE=42 - `15 21 * * * main;CRON_RUN=true;OTHER_VARIABLE=42`

☑ Trigger PR's targeting CI enabled branches automatically

Variables (overwrites global variables on same key):

Key	Value	Secret
✓	✓	☑

Pipeline triggers

- Push events to CI enabled branches
- PR events targeting CI enabled branches
  - automatic triggering if PR is from an in-repo branch
  - automatic triggering if PR is from a fork, but a trusted user
- Comment event “*cscs-ci run pipeline_name*”
  - Pipeline only starts if a trusted user comments on the PR
- Cron schedule for periodic builds
- API endpoint

Runners - .container-builder

```
some job name:
  extends: .container-builder-cscs-zen2
  variables:
    DOCKERFILE: ci/docker/Dockerfile
    PERSIST_IMAGE_NAME: $CSCS_REGISTRY_PATH/x86_64/my_image:$CI_COMMIT_SHORT_SHA
```

Variables:

- *DOCKERFILE*: relative path to Dockerfile (mandatory)
- *PERSIST_IMAGE_NAME*: Where the container image will be stored
- *CSCS_BUILD_IN_MEMORY*: Put the whole build process in memory
- *DOCKER_BUILD_ARGS*: equivalent to *--build-arg* for *docker build*
- *CSCS_REBUILD_POLICY*: Rebuild *always* or *if-not-exists*
- *SECONDARY_REGISTRY*: Push image to a second target path
- *SECONDARY_REGISTRY_USERNAME:* Username for second target path
- *SECONDARY_REGISTRY_PASSWORD*: Password for second target path
- *CUSTOM_REGISTRY_USERNAME*: Username if not pushing to CSCS registry
- *CUSTOM_REGISTRY_PASSWORD*: Password if not pushing to CSCS registry

Runners - .container-runner

```yaml
job1:
  extends: .container-runner-daint-gh200
  image: $CSCS_REGISTRY_PATH/aarch64/my_image:$CI_COMMIT_SHORT_SHA
  script:
    - /usr/bin/my_application /data/some_input.xml
  variables:
    CSCS_ADDITIONAL_MOUNTS: '["/capstor/scratch/cscs/<my_username>/data:/data"]'
```

Variables:

- *GIT_STRATEGY*: Clone source code if needed
- *CRAY_CUDA_MPS*: Allow multiple MPI ranks per GPU
- *CSCS_ADDITIONAL_MOUNTS*: Mount host paths inside the container runtime

Runners - .container-runner-lightweight

```yaml
job:
  extends: .container-runner-lightweight-zen2
  image: docker.io/python:3.11
  script:
    - ci/pipeline/generate_pipeline.py > dynamic_pipeline.yaml
  artifacts:
    paths:
      - dynamic_pipeline.yaml
```

Variables:

- *KUBERNETES_CPU_REQUEST*: Request that many CPUs
- *KUBERNETES_CPU_LIMIT*: Limit job to that many CPUs
- *KUBERNETES_MEMORY_REQUEST*: Requested amount of memory
- *KUBERNETES_MEMORY_LIMIT*: Limit amount of memory

Notes:

- LIMIT must always be larger than REQUEST
- Runner allows 1-4 CPUs and less or equal than 4Gi memory
- Maximum runtime 60 minutes
- Works only with public images

Runners - .f7t-controller

```
job:
  extends: .f7t-controller
  script:
    - CLUSTER=eiger
    - SUBMISSION="$(firecrest submit --system $CLUSTER --account
$CSCS_CI_DEFAULT_SLURM_ACCOUNT script.sh)"
    - JOBID=$(echo "$SUBMISSION" | grep "jobid" | sed -e
's/.*jobid[^0-9]*\([0-9]\+\),/\1/')
    - |
      while firecrest poll-active --raw --system $CLUSTER | grep $JOBID ; do
        echo "job is still in queue/running"
        sleep 30
      done
```

Notes:

- You are running on a machine that has the firecrest client and the pyfirecrest library installed.
- firecrest client just works
- code using pyfirecrest can use the environment variables *AUTH_TOKEN_URL*, *FIRECREST_URL*, *FIRECREST_CLIENT_ID* and *FIRECREST_CLIENT_SECRET*

Runners - .reframe-runner

```
job:
  before_script:
    - git clone -b alps https://github.com/eth-cscs/cscs-reframe-tests
    - pip install -r cscs-reframe-tests/config/utilities/requirements.txt
    - sed -i -e "s/account=csstaff/account=$CSCS_CI_DEFAULT_SLURM_ACCOUNT/"
          cscs-reframe-tests/config/systems-firecrest/eiger.py
  variables:
    FIRECREST_SYSTEM: 'eiger'
    FIRECREST_BASEDIR: /capstor/scratch/cscs/jenkssl/reframe-runner
    RFM_VERSION: ‘4.6.2’
    RFM_FIRECREST: '1'
    RFM_CONFIG: cscs-reframe-tests/config/cscs.py
    RFM_CHECKPATH: cscs-reframe-tests/checks/microbenchmarks/mpi/halo_exchange
```

Notes:

- You are running on a machine that has the firecrest client and the pyfirecrest library installed.
- The requested ReFrame version is available
- ReFrame does not have direct access to the filesystem of the cluster so the stage directory will need to be kept in sync through FirecREST
- Further information at https://github.com/eth-cscs/cscs-reframe-tests/blob/alps/config/systems-firecrest/README.md

Parametrizing jobs - extends

```
.build_helper:
  variables:
    DOCKERFILE: ci/docker/Dockerfile
    PERSIST_IMAGE_NAME: $CSCS_REGISTRY_PATH/$ARCH/my_image:$CI_COMMIT_SHORT_SHA
build x86_64:
  extends: [.container-builder-cscs-zen2, .build_helper]
build aarch64:
  extends: [.conainer-builder-cscs-gh200, .build-helper]
```

- Helper blocks should start with a DOT, otherwise they are treated by gitlab as a full job which will be added to the pipeline
- Common things are in the helper blocks, variations are the instantiations

Parametrizing jobs - parallel:matrix

```yaml
build:
  stage: build
  extends: .container-runner-lightweight-zen2
  image: docker.io/ubuntu:24.04
  script:
    - echo $MY_VAR1 $MY_VAR2
  parallel:
    matrix:
      - MY_VAR1: [some_value, other_value]
        MY_VAR2:
          - var2_value
          - var2_other_value
          - var2_third_value
```

- Create for each combination in parallel:matrix a job
- Some restrictions apply for the variable values due to gitlab
  - All restrictions are described at https://docs.gitlab.com/ee/ci/yaml/#parallelmatrix

Parametrizing jobs - dynamic child pipelines

```yaml
stages: [generate, run]

gen_pipeline:
  stage: generate
  extends: .container-runner-lightweight-zen2
  image: docker.io/python:3.11
  script:
    - ci/pipeline/generate_pipeline.py > dynamic_pipeline.yaml
  artifacts:
    paths:
      - dynamic_pipeline.yaml

trigger child pipeline:
 stage: run
  trigger:
    include:
      - artifact: dynamic_pipeline.yaml
        job: gen_pipeline
```

- The generated file is itself a fully valid pipeline YAML file
- Allows to generate pipelines where the number of jobs is dynamic

Container builder API service

- Documentation at https://confluence.cscs.ch/x/UQXJMw
- Uses CSCS API gateway at https://developer.cscs.ch

```
# Generate access token - valid for about 5 minutes
$ ACCESS_TOKEN="$(curl  -u <your-consumer-key>:<your-consumer-secret> --silent -X POST
https://auth.cscs.ch/auth/realms/firecrest-clients/protocol/openid-connect/token -d
"grant_type=client_credentials" | jq -r '.access_token')"

# helper variables
$ API=”https://api.cscs.ch/ciext/v1/container/build”
$ AUTH=”Authorization: Bearer $ACCESS_TOKEN”

# Build container image
$ curl -H “$AUTH” --data-binary @path/to/Dockerfile "${API}?arch=x86_64"

# Build container image in custom registry
$ curl -H “$AUTH” \
    -H "X-Registry-Username <your-dockerhub-username>" \
    -H "X-Registry-Password: <your-dockerhub-token>" \
    --data-binary @path/to/Dockerfile \
    “${API}?arch=x86_64&image=docker.io/<your-dockerhub-username>/my_image_name:latest"
```

Container builder API service

- Documentation at https://confluence.cscs.ch/x/UQXJMw
- Uses CSCS API gateway at https://developer.cscs.ch

```
# Generate access token - valid for about 5 minutes
$ ACCESS_TOKEN="$(curl  -u <your-consumer-secret>:<your-consumer-secret> --silent -X
POST https://auth.cscs.ch/auth/realms/firecrest-clients/protocol/openid-connect/token
-d "grant_type=client_credentials" | jq -r '.access_token')"

# helper variables
$ API=”https://api.cscs.ch/ciext/v1/container/build”
$ AUTH=”Authorization: Bearer $ACCESS_TOKEN”

# build container image with build context
$ cd path/to/build_context
$ tar -czf - . | curl -H “$AUTH” \
    --data-binary @- \
    “${API}?arch=x86_64&dockerfile=relative/path/to/Dockerfile"
```

Container builder API service vs container-builder

API build

```
$ cd path/to/build_context
$ tar -czf - . | curl -H “$AUTH” \
    -H "X-Registry-Username <your-dockerhub-username>" \
    -H "X-Registry-Password: <your-dockerhub-token>" \
    --data-binary @- \
“${API}?arch=x86_64&dockerfile=relative/path/to/Dockerfile&image=docker.io/<your-dockerhub-use
rname>/my_image_name:latest”
```

CI yaml

```
some job name:
  extends: .container-builder-cscs-zen2
  variables:
    DOCKERFILE: relative/path/to/Dockerfile
    PERSIST_IMAGE_NAME: docker.io/<your-dockerhub-username>/my_image_name:latest
    CUSTOM_REGISTRY_USERNAME: ‘<your-dockerhub-username>’
    CUSTOM_REGISTRY_PASSWORD: ‘<your-dockerhub-token>’
```

Build context is the repository source code

Rebuilding images only when needed

```
build image:
  extends: .container-builder-cscs-zen2
  stage: build
  before_script:
    - export TAG=`cat ci/docker/Dockerfile | sha256sum - | head -c 16`
    - export PERSIST_IMAGE_NAME=$CSCS_REGISTRY_PATH/img:$TAG
    - echo "TAG=$TAG" > build.env
  artifacts:
    reports:
      dotenv: build.env
  variables:
    DOCKERFILE: ci/docker/Dockerfile
    CSCS_REBUILD_POLICY: "if-not-exists"
```

- Use hash of Dockerfile as a tag
- Save the tag as an artifact to use it in other stages / jobs
- Set `CSCS_REBUILD_POLICY: "if-not-exists"`

Rebuilding images only when needed

```
build image:
  extends: [.container-builder-cscs-zen2, .dynamic-image-name]
  stage: build
  variables:
    DOCKERFILE: ci/docker/Dockerfile
    PERSIST_IMAGE_NAME: $CSCS_REGISTRY_PATH/img
    WATCH_FILECHANGES: “ci/docker/Dockerfile”
    CSCS_REBUILD_POLICY: "if-not-exists"
```

- Extend from .dynamic-image-name
  - Computes hash of files listed in $WATCH_FILECHANGES
  - Sets $BASE_IMAGE in the artifact
- Set `PERSIST_IMAGE_NAME` without tag
- Set `CSCS_REBUILD_POLICY: "if-not-exists"`

Building multiarch images

```
build multiarch image:
  stage: build_multiarch
  extends: .make-multiarch-image
  variables:
    PERSIST_IMAGE_NAME_X86_64: "<input x86_64 image>"
    PERSIST_IMAGE_NAME_AARCH64: "<input aarch64 image>"
    PERSIST_IMAGE_NAME: "<output multiarch image>"
```

- Use *.make-multiarch-image* runner template
- Takes two existing images
  - *PERSIST_IMAGE_NAME_X86_64*
  - *PERSIST_IMAGE_NAME_AARCH64*
- Creates a multiarch image
  - *PERSIST_IMAGE_NAME*

Spack base images

- Available at
  - $CSCS_REGISTRY/docker-ci-ext/base-containers/public
  - ghcr.io/eth-cscs/docker-ci-ext/base-containers/spack-base

- Preinstalled Spack with reasonable defaults and helper scripts

Multi-stage docker build:

1. Install dependencies with Spack install helper script

```
$ spack-install-helper --target <target arch> <list of specs>


$ spack-install-helper --target alps-gh200 "git" "cmake" "valgrind" "python"
```

2. Copy only installed software without Spack and other build dependencies

Spack base image

```
FROM
ghcr.io/eth-cscs/docker-ci-ext/base-containers/spack-base:spack0.21.0-ubuntu22.0
4-cuda12.4.1 as builder

RUN spack-install-helper --target alps-gh200 \
    "git" "cmake" "valgrind" "python"

# end of builder container, now we are ready to copy necessary files

# copy only relevant parts to the final container
FROM
ghcr.io/eth-cscs/docker-ci-ext/base-containers/spack-helper:ubuntu22.04-cuda12.4
.1

# it is important to keep the paths, otherwise your installation is broken
# all these paths are created with the above `spack-install-helper` invocation
COPY --from=builder /opt/spack-environment /opt/spack-environment
COPY --from=builder /opt/software /opt/software
COPY --from=builder /opt/._view /opt/._view
COPY --from=builder /etc/profile.d/z10_spack_environment.sh
/etc/profile.d/z10_spack_environment.sh

# Some boilerplate to get all paths correctly - fix_spack_install is part of the
base image
# and makes sure that all important things are being correctly setup
RUN fix_spack_install
```

Use images built in CI pipeline

- Images built in the CI pipeline are pushed to CSCS JFrog registry
- Main use case: CI pipelines
- If the image is in directory */public/* it can be accessed from CSCS
  - You can find the URL at the end of the build job log
  - Not recommended to use the images on JFrog directly
- Instead you can push the images to your registry by setting these variables in the .container-builder-* job
  - *SECONDARY_REGISTRY*
  - *SECONDARY_REGISTRY_USERNAME*
  - *SECONDARY_REGISTRY_PASSWORD*

- Be careful if you push images to directory */public/*, it can be accessed by everyone who knows the URL
  - Make sure such images do not contain any information that should be kept private, e.g. secrets, tokens, …

Full containerized CI example

- Split building images into two stages
  - Dependencies
    - Base images with preinstalled Spack
    - Rebuild only when dependencies change
  - App image
    - Copy source code from git repository
    - Build the app
    - Rebuild every time
- Build multiarch image to support different architectures
- Run tests

Example: Four stages

```
include:
  - remote:
'https://gitlab.com/cscs-ci/recipes/-/raw/master/templates/v2/.ci-ext.yml'

stages:
  - build_base
  - build_app
  - build_multiarch
  - test
```

Example: base image

```
build_base_image_x86_64:
  extends: [.container-builder-cscs-zen2, .dynamic-image-name]
  stage: build_base
  variables:
    DOCKERFILE: ci/docker/Dockerfile.base
    WATCH_FILECHANGES: 'ci/docker/Dockerfile.base'
    PERSIST_IMAGE_NAME: $CSCS_REGISTRY_PATH/baseimg-x86_64
    CSCS_REBUILD_POLICY: "if-not-exists"
    DOCKER_BUILD_ARGS:
'["IMG_BASE=ghcr.io/eth-cscs/docker-ci-ext/base-containers/spack-base:spack0.21.
0-ubuntu22.04-cpu",
"IMG_HELPER=ghcr.io/eth-cscs/docker-ci-ext/base-containers/spack-helper:ubuntu22
.04-cpu", "TARGET=alps-zen2"]'
```

Example: base image

```
build_base_image_aarch64:
  extends: [.container-builder-cscs-gh200, .dynamic-image-name]
  stage: build_base
  variables:
    DOCKERFILE: ci/docker/Dockerfile.base
    WATCH_FILECHANGES: 'ci/docker/Dockerfile.base'
    PERSIST_IMAGE_NAME: $CSCS_REGISTRY_PATH/baseimg-aarch64
    CSCS_REBUILD_POLICY: "if-not-exists"
    DOCKER_BUILD_ARGS:
'["IMG_BASE=ghcr.io/eth-cscs/docker-ci-ext/base-containers/spack-base:spack0.21.
0-ubuntu22.04-cuda12.4.1",
"IMG_HELPER=ghcr.io/eth-cscs/docker-ci-ext/base-containers/spack-helper:ubuntu22
.04-cuda12.4.1", "TARGET=alps-gh200"]'
```

Example: app image

```yaml
build_app_image_x86_64:
  extends: .container-builder-cscs-zen2
  stage: build_app
  needs:
    - job: build_base_image_x86_64
      artifacts: true
  variables:
    DOCKERFILE: ci/docker/Dockerfile.app
    PERSIST_IMAGE_NAME: $CSCS_REGISTRY_PATH/appimg-x86_64:$CI_COMMIT_SHORT_SHA
    DOCKER_BUILD_ARGS: '["IMG=$BASE_IMAGE"]'


build_app_image_aarch64:
  extends: .container-builder-cscs-gh200
  stage: build_app
  needs:
    - job: build_base_image_aarch64
      artifacts: true
  variables:
    DOCKERFILE: ci/docker/Dockerfile.app
    PERSIST_IMAGE_NAME: $CSCS_REGISTRY_PATH/appimg-aarch64:$CI_COMMIT_SHORT_SHA
    DOCKER_BUILD_ARGS: '["IMG=$BASE_IMAGE"]'
```

Example: multiarch app image

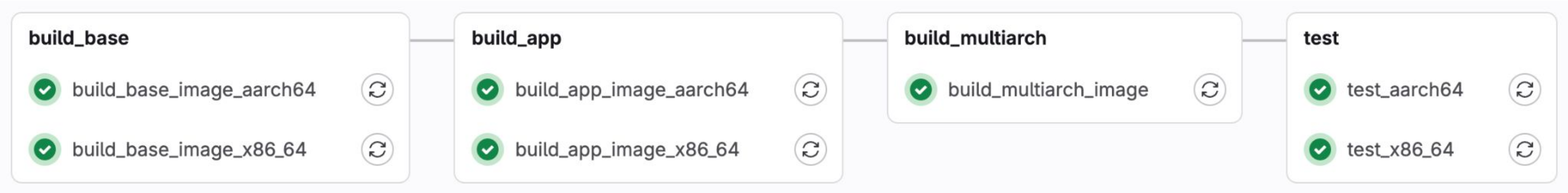
```
build_multiarch_image:
  stage: build_multiarch
  extends: .make-multiarch-image
  variables:
    PERSIST_IMAGE_NAME_X86_64:
"$CSCS_REGISTRY_PATH/appimg-x86_64:$CI_COMMIT_SHORT_SHA"
    PERSIST_IMAGE_NAME_AARCH64:
"$CSCS_REGISTRY_PATH/appimg-aarch64:$CI_COMMIT_SHORT_SHA"
    PERSIST_IMAGE_NAME: "$CSCS_REGISTRY_PATH/appimg:$CI_COMMIT_SHORT_SHA"
```

Example: run tests

```yaml
test_x86_64:
  stage: test
  extends: .container-runner-eiger-mc
  image: $CSCS_REGISTRY_PATH/appimg:$CI_COMMIT_SHORT_SHA
  script:
    - /helloworld/build/hello
  variables:
    SLURM_JOB_NUM_NODES: 2

test_aarch64:
  stage: test
  extends: .container-runner-todi-gh200
  image: $CSCS_REGISTRY_PATH/appimg:$CI_COMMIT_SHORT_SHA
  script:
    - /helloworld/build/hello
  variables:
    SLURM_JOB_NUM_NODES: 2
```

Example: Done



build_base

- ✓ build_base_image_aarch64
- ✓ build_base_image_x86_64

build_app

- ✓ build_app_image_aarch64
- ✓ build_app_image_x86_64

build_multiarch

- ✓ build_multiarch_image

test

- ✓ test_aarch64
- ✓ test_x86_64

Questions?