

Quantum-Notebook: a Docker stack for quantum computing

Presenter:

Presenter: Antonio Falabella (INFN-CNAF)

Co-author

Dr. Silvio Pardi (INFN-Napoli)

Quantum Computing @ INFN Bologna 2022

Tools for Quantum Computing

- Today we have an increasing set of software for quantum computing that allows to
 - Design and describe quantum circuits
 - Interact with real quantum machines.
- Scientists who want to play with quantum circuits may profit of an environment properly configured on which develop their ideas.
- System administrators are called to support the final users by simplifying as much as possible the software installation and distribution.

JupyterLab



JupyterLab is a web-based interactive development environment for notebooks, code, and data, largely used by the scientific community.

Jupyter Docker Stacks provides a set of ready-to-run Docker images containing Jupyter applications and interactive computing tools.

- minimal-notebook
- base-notebook
- datascience-notebook
- pyspark-notebook
- r-notebook
- scipy-notebook
- tensorflow-notebook

<https://jupyterlab.readthedocs.io/en/stable/>

<https://github.com/jupyter/docker-stacks>

Quantum Notebook

The idea is to extend the Jupyter Docker Stacks with a new **ready to use image** (the Quantum Notebook) containing the most common tools for quantum computing.

The docker image can be deployed quickly over a standalone machine or a Cloud infrastructure.

Quantum Notebook is published on the INFN GIT repository:

https://baltig.infn.it/quantum_computing/quantum_notebook

List of selected libraries

- OPENQASM <https://github.com/openqasm/openqasm>
- QISKIT IBM <https://qiskit.org/>
- CIRQ <https://github.com/quantumlib/cirq>
- PyQUIL from Rigetti <https://github.com/rigetti/pyquil>
- ProjectQ <https://projectq.readthedocs.io/en/latest/index.html>
- myQLM https://myqlm.github.io/myqlm_specific/install.html
- QSHARP Microsoft <https://docs.microsoft.com/it-it/dotnet/core/install/linux-ubuntu>

Two approaches for Quantum Notebook

- **Standalone Docker Image**

- Following the Jupyter Docker Stacks project, this solution provides a ready to deploy docker image that can be used over any private resources.

- **Quantum Notebook as a service over INFN Cloud**

- This approach allow to deploy a Quantum Notebook as a service over the INFN Cloud taking advantage of the other Cloud services: remote network access, authentication and data persistency .

- # Copyright (c) Jupyter Development Team.
- # Distributed under the terms of the Modified BSD License.
- # Added Quantum Library support
- FROM jupyter/scipy-notebook
-
- # Installation Quantum libs
- RUN pip install --quiet --no-cache-dir \
- # Needed library
- # qat \
- # OPENQASM
- openqasm3 \
- # QISKIT IBM <https://qiskit.org/>
- qiskit \
- # CIRQ <https://github.com/quantumlib/cirq>
- cirq \
- # PyQUIL from righetti <https://github.com/rigetti/pyquil>
- pyquil \
- # ProkjectQ <https://projectq.readthedocs.io/en/latest/index.html>
- projectq \
- ipykernel \
- pylatexenc \
- pylatex &&\
- # python -m qat.magics.install && \
- fix-permissions "\${CONDA_DIR}" && \
- fix-permissions "/home/\${NB_USER}"

Standalone Docker image

The standalone version of Quantum Notebook can be run over every server, PC, laptop with docker server running.

```
[spardi@spardiui ~]$ docker run -p 10000:8888 d9cbfb7acf59
```

Entered start.sh with args: jupyter lab

Executing the command: jupyter lab

```
[I 2022-09-08 13:37:11.091 ServerApp] jupyterlab | extension was successfully linked.
[I 2022-09-08 13:37:11.104 ServerApp] nbclassic | extension was successfully linked.
[I 2022-09-08 13:37:11.106 ServerApp] Writing Jupyter server cookie secret to /home/jovyan/.local/share/jupyter/runtime
[I 2022-09-08 13:37:12.006 ServerApp] notebook_shim | extension was successfully linked.
[I 2022-09-08 13:37:12.053 ServerApp] notebook_shim | extension was successfully loaded.
[I 2022-09-08 13:37:12.055 LabApp] JupyterLab extension loaded from /opt/conda/lib/python3.10/site-packages/jupyterlab
[I 2022-09-08 13:37:12.055 LabApp] JupyterLab application directory is /opt/conda/share/jupyter/lab
[I 2022-09-08 13:37:12.059 ServerApp] jupyterlab | extension was successfully loaded.
[I 2022-09-08 13:37:12.082 ServerApp] nbclassic | extension was successfully loaded.
[I 2022-09-08 13:37:12.082 ServerApp] Serving notebooks from local directory: /home/jovyan
[I 2022-09-08 13:37:12.083 ServerApp] Jupyter Server 1.18.1 is running at:
[I 2022-09-08 13:37:12.083 ServerApp] http://67ec3f1082cf:8888/lab?token=27afd5e384f4f76203963d542709c8c7fb0bf09a21a36348
[I 2022-09-08 13:37:12.083 ServerApp] or http://127.0.0.1:8888/lab?token=27afd5e384f4f76203963d542709c8c7fb0bf09a21a36348
[I 2022-09-08 13:37:12.083 ServerApp] Use Control-C to stop this server and shut down all kernels (twice to skip confirmation).
[C 2022-09-08 13:37:12.093 ServerApp]
```

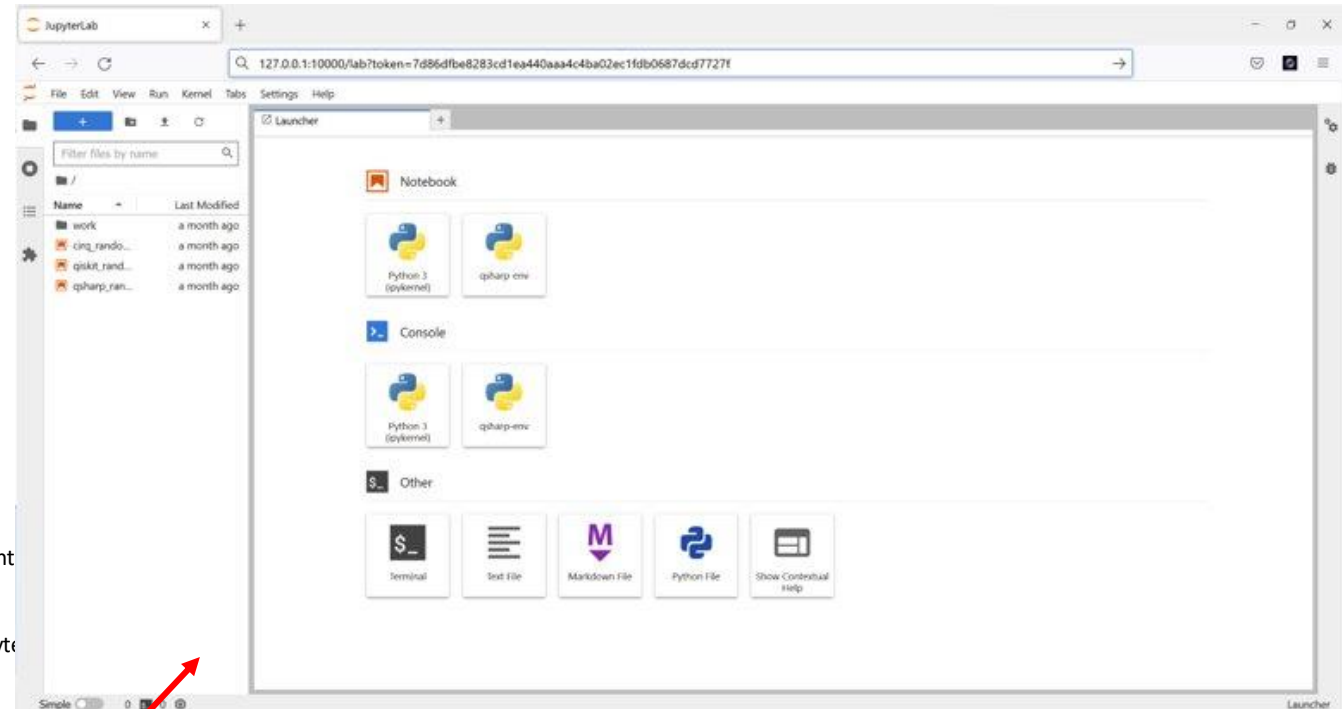
To access the server, open this file in a browser:

<file:///home/jovyan/.local/share/jupyter/runtime/jpserver-7-open.html>

Or copy and paste one of these URLs:

<http://67ec3f1082cf:8888/lab?token=27afd5e384f4f76203963d542709c8c7fb0bf09a21a36348>

or <http://127.0.0.1:8888/lab?token=27afd5e384f4f76203963d542709c8c7fb0bf09a21a36348>




Filter files by name [Search Icon]

/


Name	Last Modified
work	a month ago
• cirq_random_byte.ipynb	a month ago
• qiskit_random_byte.ipynb	a month ago
• qsharp_random_byte.ipynb	a month ago

Launcher

Notebook




Python 3 (ipykernel)




qsharp-env

Console

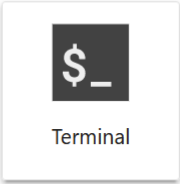


Python 3 (ipykernel)




qsharp-env


Other




Terminal




Text File



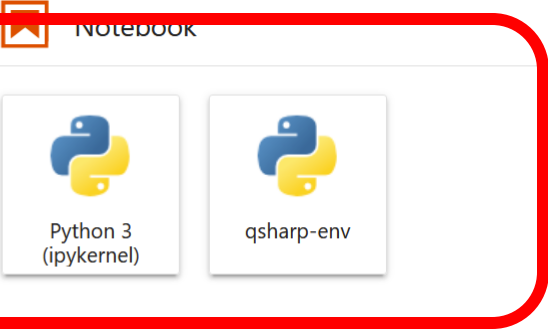
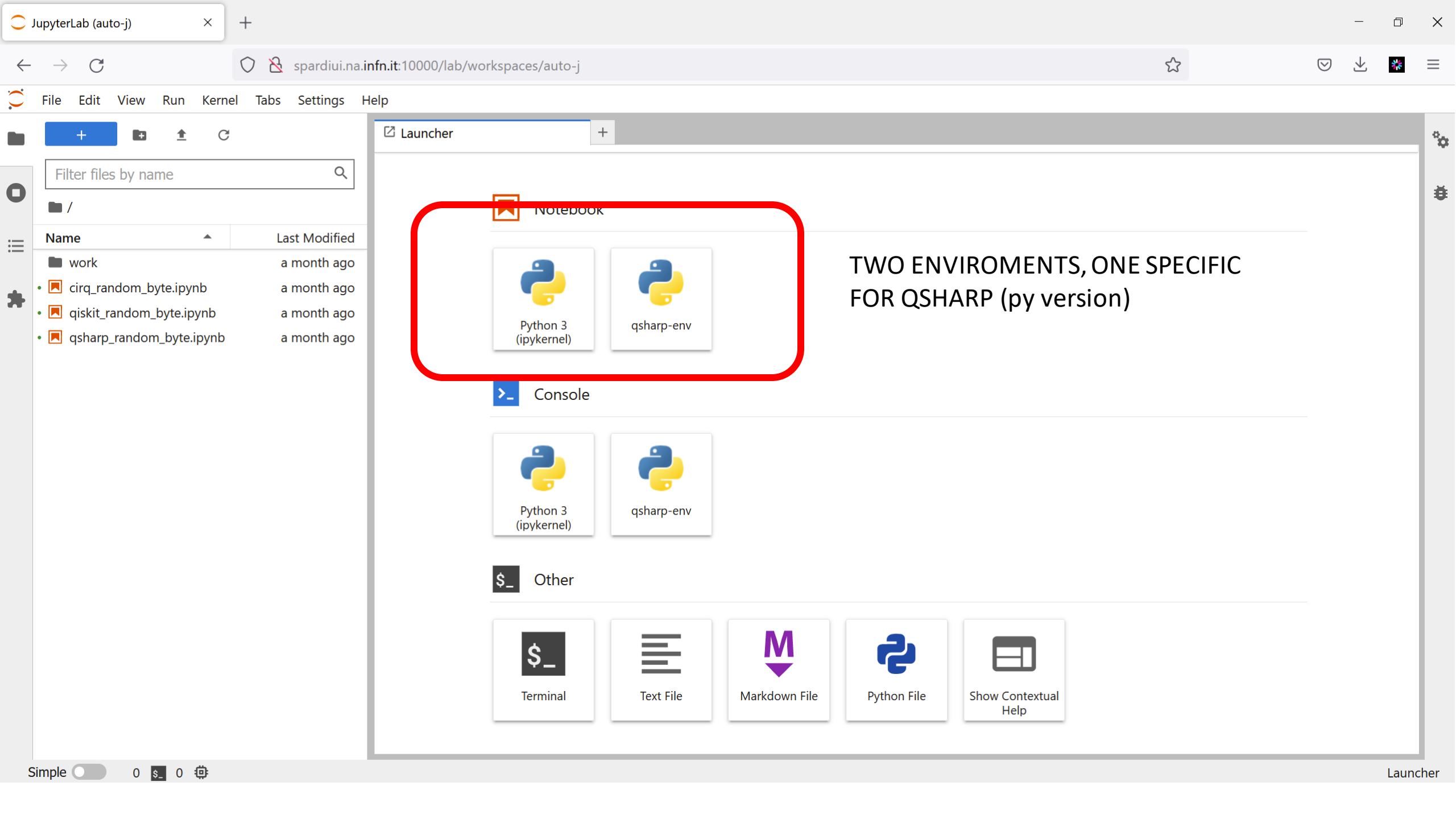
Markdown File



Python File

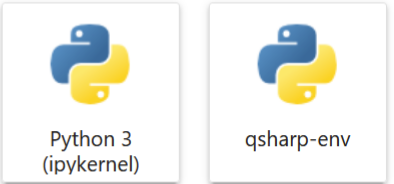


Show Contextual Help



TWO ENVIROMENTS, ONE SPECIFIC FOR QSHARP (py version)

>_ Console



\$_ Other



JupyterLab (auto-j) | spardiui.na.infn.it:10000/lab/workspaces/auto-j

File Edit View Run Kernel Tabs Settings Help

Filter files by name

Name	Last Modified
work	a month ago
• cirq_random_byte.ipynb	a month ago
• qiskit_random_byte.ipynb	a month ago
• qsharp_random_byte.ipynb	a month ago

CODE EXAMPLES

Launcher

Notebook

- Python 3 (ipykernel)
- qsharp-env

Console

- Python 3 (ipykernel)
- qsharp-env

Other

- Terminal
- Text File
- Markdown File
- Python File
- Show Contextual Help

Simple 0 \$ 0

Launcher

Filter files by name

Name	Last Modified
/	
work	a month ago
circ_random_byte.ipynb	a month ago
qiskit_random_byte.ipynb	a month ago
qsharp_random_byte.ipynb	a month ago

```
[5]: ## Programming Quantum Computers
## by Eric Johnston, Nic Harrigan and Mercedes Gimeno-Segovia
## O'Reilly Media
## More samples like this can be found at http://oreilly-qc.github.io
#
from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister, execute, Aer, IBMQ, BasicAer
import math
## Uncomment the next line to see diagrams when running in a notebook
%matplotlib inline

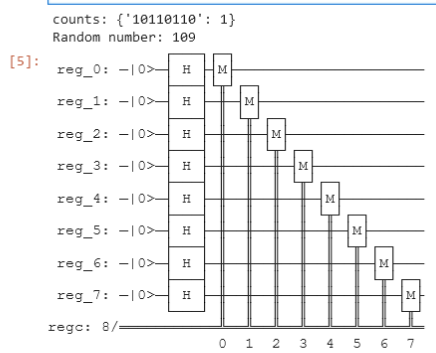
## Example 2-2: Random byte
# Set up the program
reg = QuantumRegister(8, name='reg')
reg_c = ClassicalRegister(8, name='regc')
qc = QuantumCircuit(reg, reg_c)

qc.reset(reg) # write the value 0
qc.h(reg) # put it into a superposition of 0 and 1
qc.measure(reg, reg_c) # read the result as a digital bit

backend = BasicAer.get_backend('statevector_simulator')
job = execute(qc, backend)
result = job.result()

# Convert the result into a random number
counts = result.get_counts(qc)
print('counts:', counts)
for key, val in counts.items():
    n = sum([int(x) << i for i, x in enumerate(key)])
    print('Random number:', n)
#outputstate = result.get_statevector(qc, decimals=3)
#print(outputstate)
qc.draw() # draw the circuit
```

QISKIT EXAMPLE



[]:

INFN Cloud Image

A screenshot of a web browser showing the JupyterHub login page. The browser's address bar displays `https://hub-bari.cloud.infn.it/hub/login`. The page features the INFN logo in the top left corner. A large black number '1' is overlaid on the page. The main heading reads "OAuth 2.0 Authentication integrated with INFN IDP". Below this heading is an orange button labeled "Sign in with OAuth 2.0".

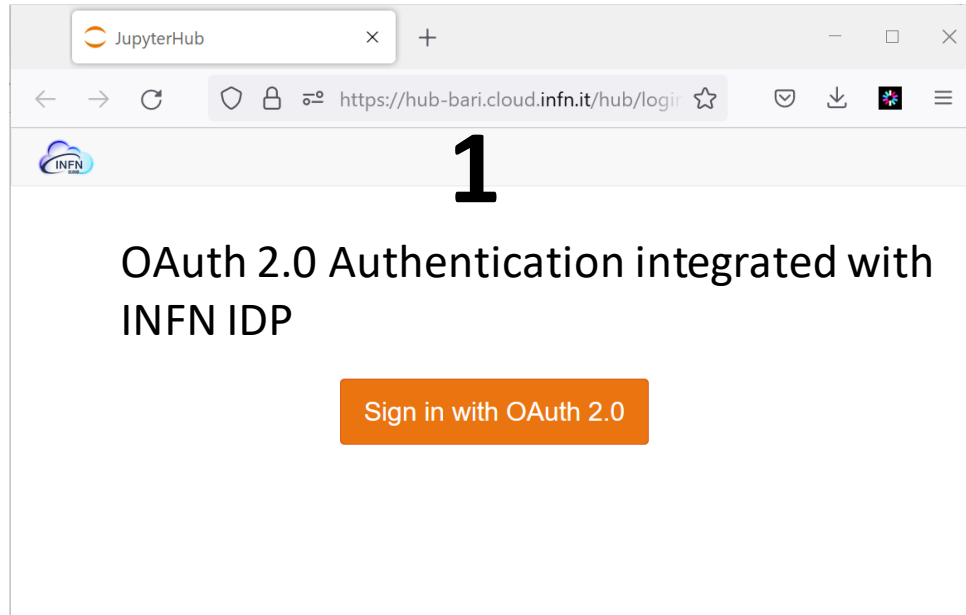
A screenshot of the JupyterHub user interface. The browser's address bar shows `https://hub-bari.cloud.infn.it/user/spardi`. The page includes a navigation bar with "Logout" and "Control Panel" buttons. Below the navigation bar are tabs for "Files", "Running", and "Clusters". The "Files" tab is active, displaying a file browser interface. The text "Select items to perform actions on them." is visible above a table of files. The table has columns for "Name", "Last Modified", and "File size".

	Name	Last Modified	File size
<input type="checkbox"/>	0		
<input type="checkbox"/>	cloud-storage	3 mesi fa	
<input type="checkbox"/>	examples	3 mesi fa	
<input type="checkbox"/>	local	3 mesi fa	

A screenshot of the JupyterHub server options page. The browser's address bar shows `https://hub-bari.cloud.infn.it/hub/spaw`. The page features the INFN logo and navigation links for "Home" and "Token". The user is logged in as "spardi" and has a "Logout" button. The main heading is "Server Options". Below this heading, the text "You are logged in as a beta-tester" is displayed. There are three input fields: "Select your desired image:" with the value "ntum_notebook/allinone", "Select your desired number of cores:" with the value "1", and "Select your desired memory size:" with the value "2GB". Below these fields is a URL: `baltig.infn.it:4567/quantum_computing/quantum_notebook/allinone`.

A screenshot of the JupyterHub server starting up page. The browser's address bar shows `https://hub-bari.cloud.infn.it/hub/spaw`. The page features the INFN logo and navigation links for "Home" and "Token". The user is logged in as "spardi" and has a "Logout" button. The main heading is "Server requested". Below this heading, the text "Your server is starting up." and "You will be redirected automatically when it's ready for you." is displayed. At the bottom of the page, there is an "Event log" section.

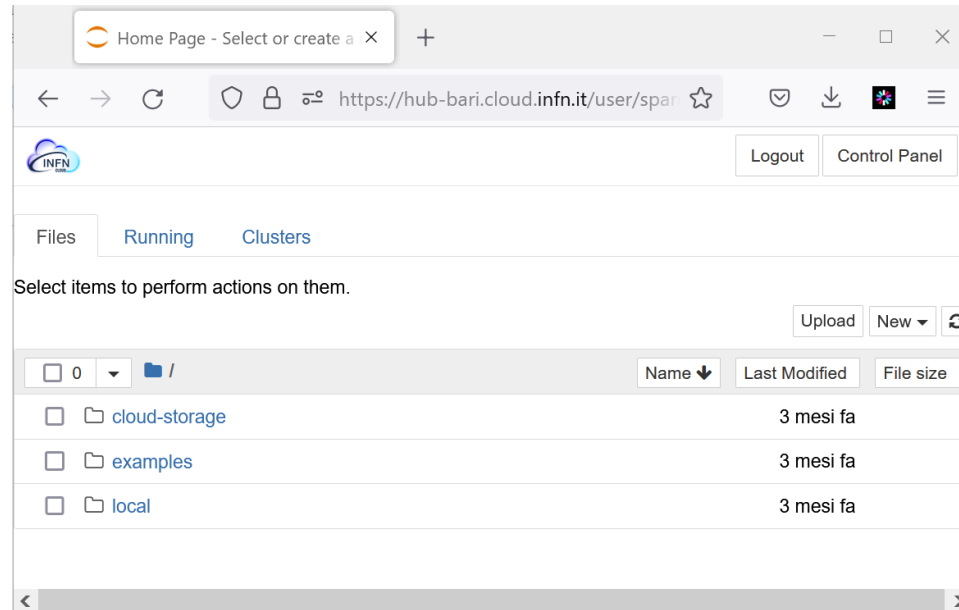
INFN Cloud Image



1

OAuth 2.0 Authentication integrated with INFN IDP

Sign in with OAuth 2.0



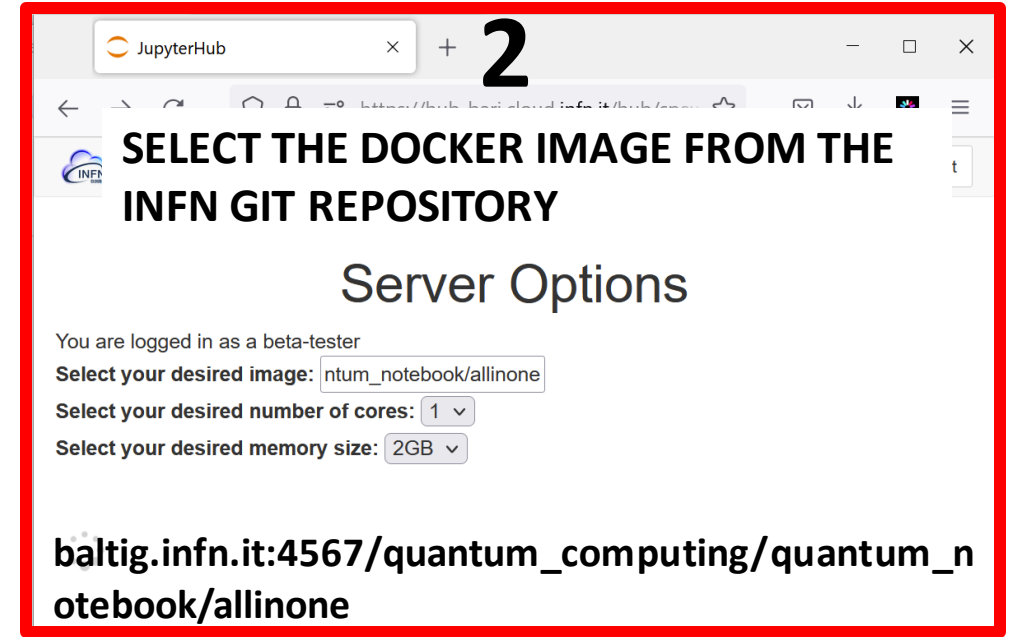
Logout Control Panel

Files Running Clusters

Select items to perform actions on them.

Upload New ↕ ↻

<input type="checkbox"/>	0	▼	▼	▼	▼	▼	▼	▼
<input type="checkbox"/>	cloud-storage							3 mesi fa
<input type="checkbox"/>	examples							3 mesi fa
<input type="checkbox"/>	local							3 mesi fa



2

SELECT THE DOCKER IMAGE FROM THE INFN GIT REPOSITORY

Server Options

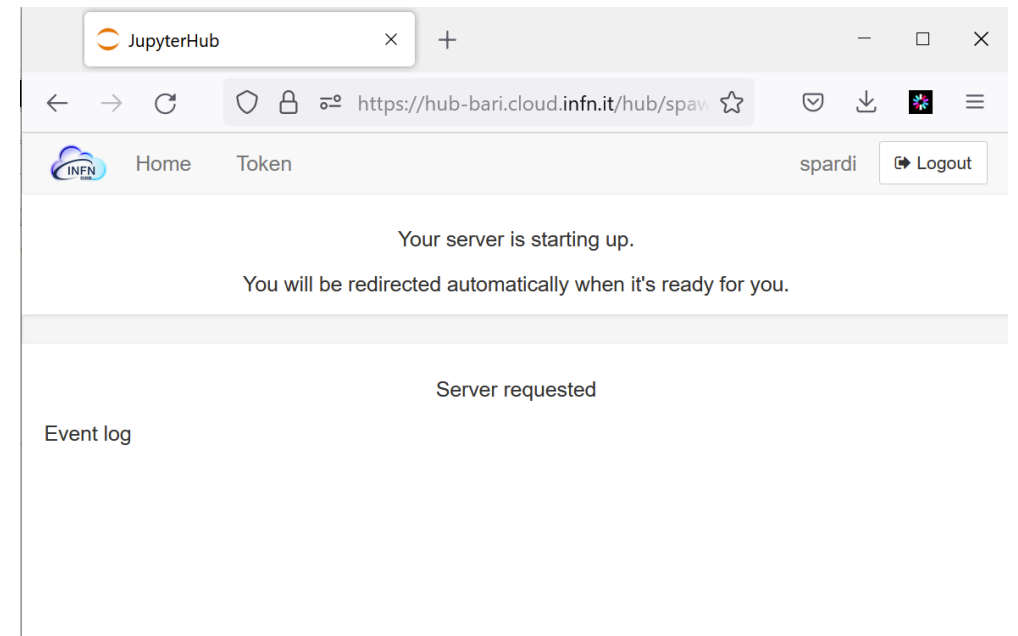
You are logged in as a beta-tester

Select your desired image:

Select your desired number of cores:

Select your desired memory size:

baltig.infn.it:4567/quantum_computing/quantum_notebook/allinone



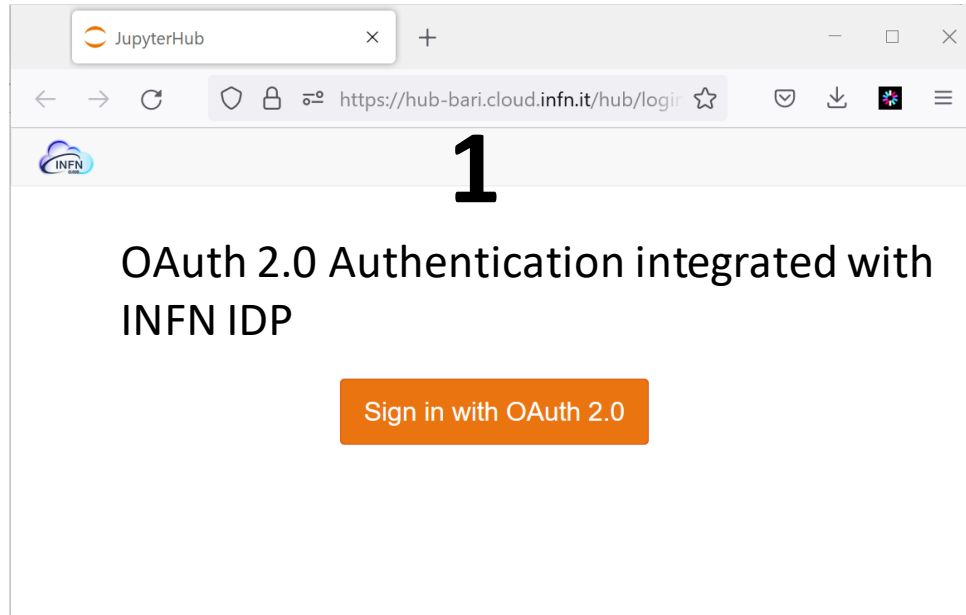
Logout spardi Logout

Your server is starting up.
You will be redirected automatically when it's ready for you.

Server requested

Event log

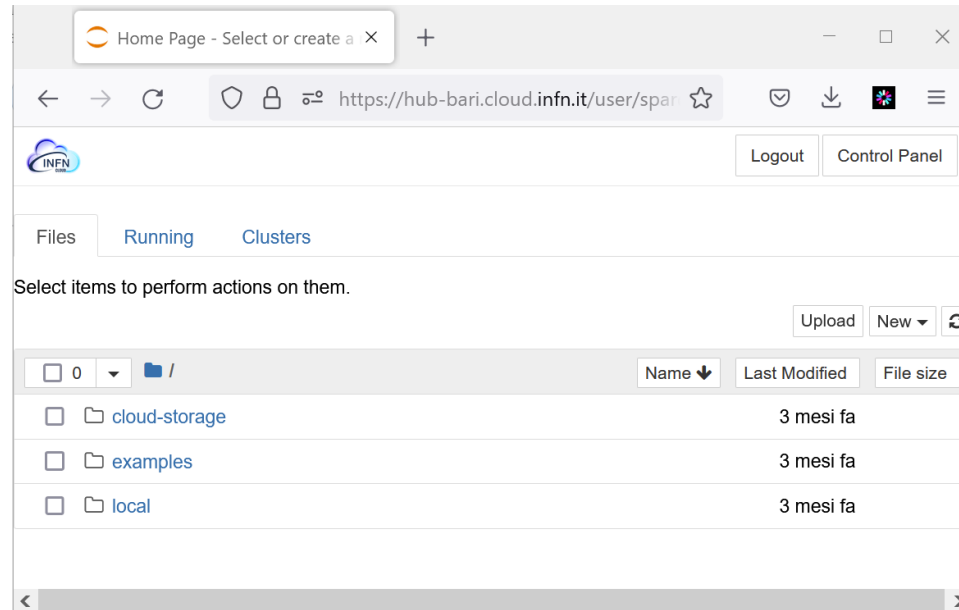
INFN Cloud Image



1

OAuth 2.0 Authentication integrated with INFN IDP

Sign in with OAuth 2.0



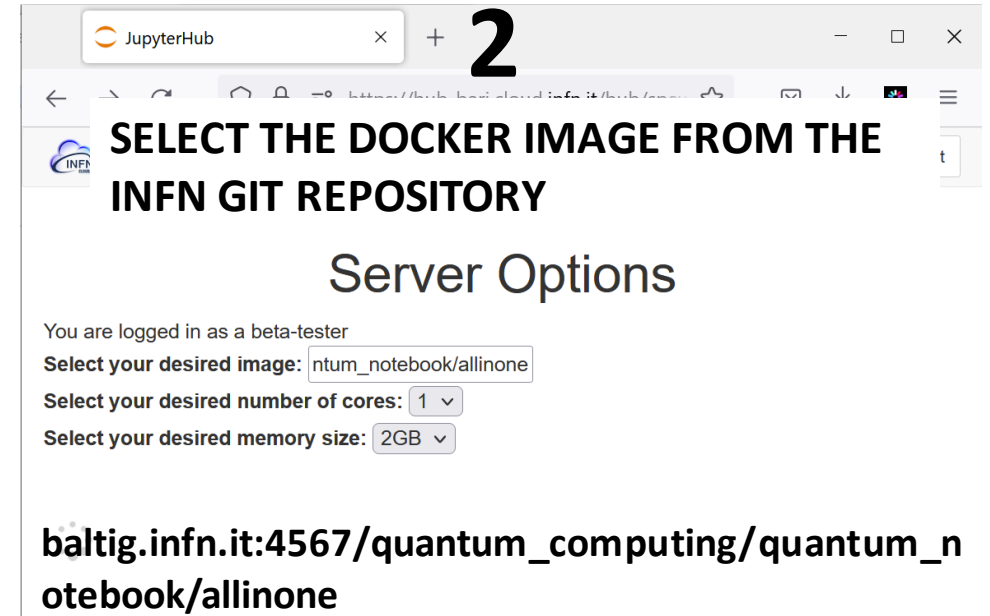
Logout Control Panel

Files Running Clusters

Select items to perform actions on them.

Upload New ↕ ↻

<input type="checkbox"/>	0	▼	▼	▼	Name ↓	Last Modified	File size
<input type="checkbox"/>	cloud-storage					3 mesi fa	
<input type="checkbox"/>	examples					3 mesi fa	
<input type="checkbox"/>	local					3 mesi fa	



2

SELECT THE DOCKER IMAGE FROM THE INFN GIT REPOSITORY

Server Options

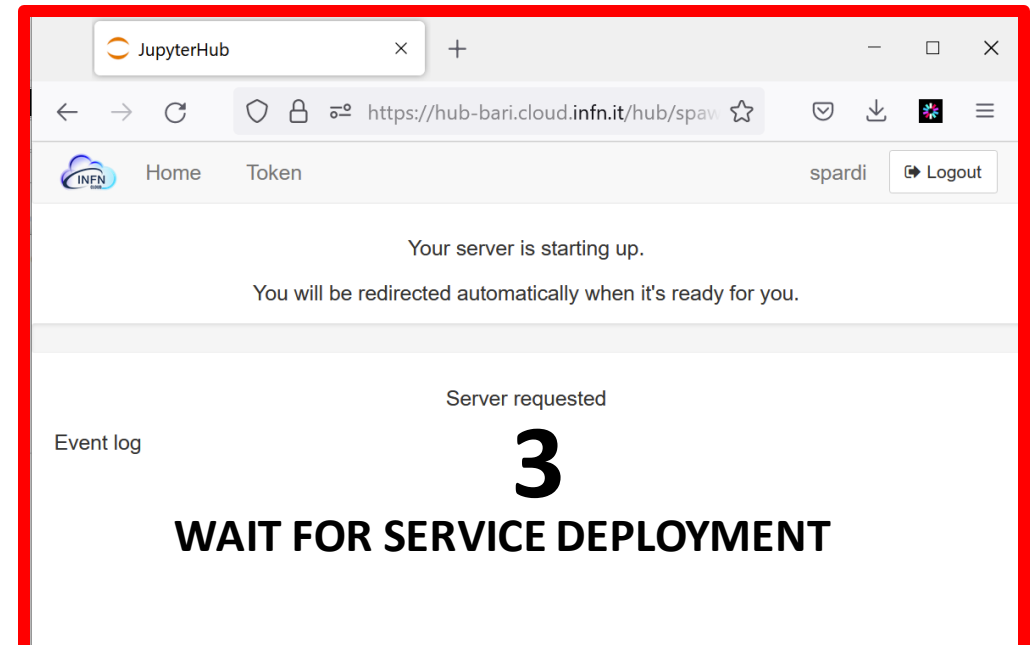
You are logged in as a beta-tester

Select your desired image:

Select your desired number of cores:

Select your desired memory size:

baltig.infn.it:4567/quantum_computing/quantum_notebook/allinone



JupyterHub

Home Token spardi Logout

Your server is starting up.
You will be redirected automatically when it's ready for you.

Server requested

Event log

3

WAIT FOR SERVICE DEPLOYMENT

INFN Cloud Image

1

OAuth 2.0 Authentication integrated with INFN IDP

Sign in with OAuth 2.0

2

SELECT THE DOCKER IMAGE FROM THE INFN GIT REPOSITORY

Server Options

You are logged in as a beta-tester

Select your desired image:

Select your desired number of cores:

Select your desired memory size:

quantum_computing/quantum_n

4

QUANTUM NOTEBOOK READY!

Select item

	Name	Last Modified	File size
<input type="checkbox"/>	/		
<input type="checkbox"/>	cloud-storage	3 mesi fa	
<input type="checkbox"/>	examples	3 mesi fa	
<input type="checkbox"/>	local	3 mesi fa	

3

WAIT FOR SERVICE DEPLOYMENT

Server requested

Event log

Your server is starting up.

directed automatically when it's ready for you.

spardi Logout

Conclusions

- A Quantum Notebook as been created with two possibile deployment:
 - Standalone Docker Image
 - Quantum Notebook as a service over INFN Cloud
- The docker image contains the latest versions of the some of the most used Quantum libraries however it is very easy to exented for additional needs .
- Possibile usage: Researchers, Students, preparation of tutorials, summer schools etc.