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Connecting HEPCloud with quantum applications using the Rigetti platform

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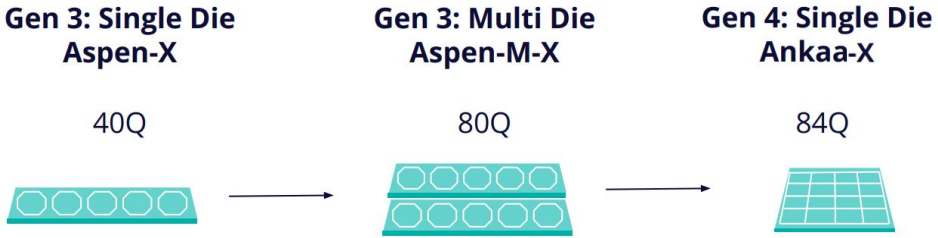
In partnership with:

rigetti

Rigetti Computing QPUs

- A full stack quantum computing systems company, with hardware at our core
- Rigetti's Mission - Build the world's most powerful computers to help solve humanity's most important and pressing problems
- QCS™ Delivering Hybrid Quantum Computing - High performance integration of QPU with key classical resources
- Aspen™ M3 - 80Q processor based on scalable multi-chip technology
- Ankaa™ Chips - Next generation of chips with external launch anticipated in 2023



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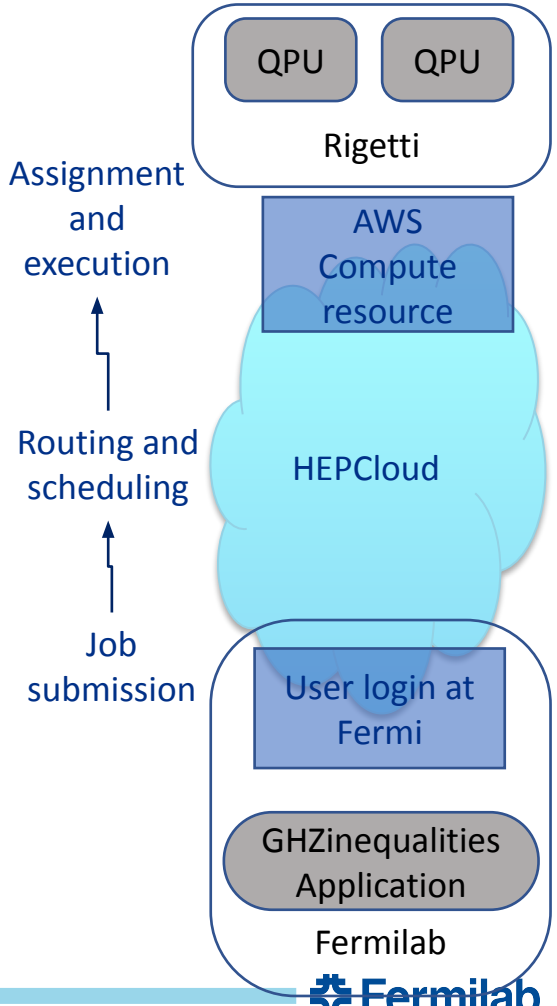
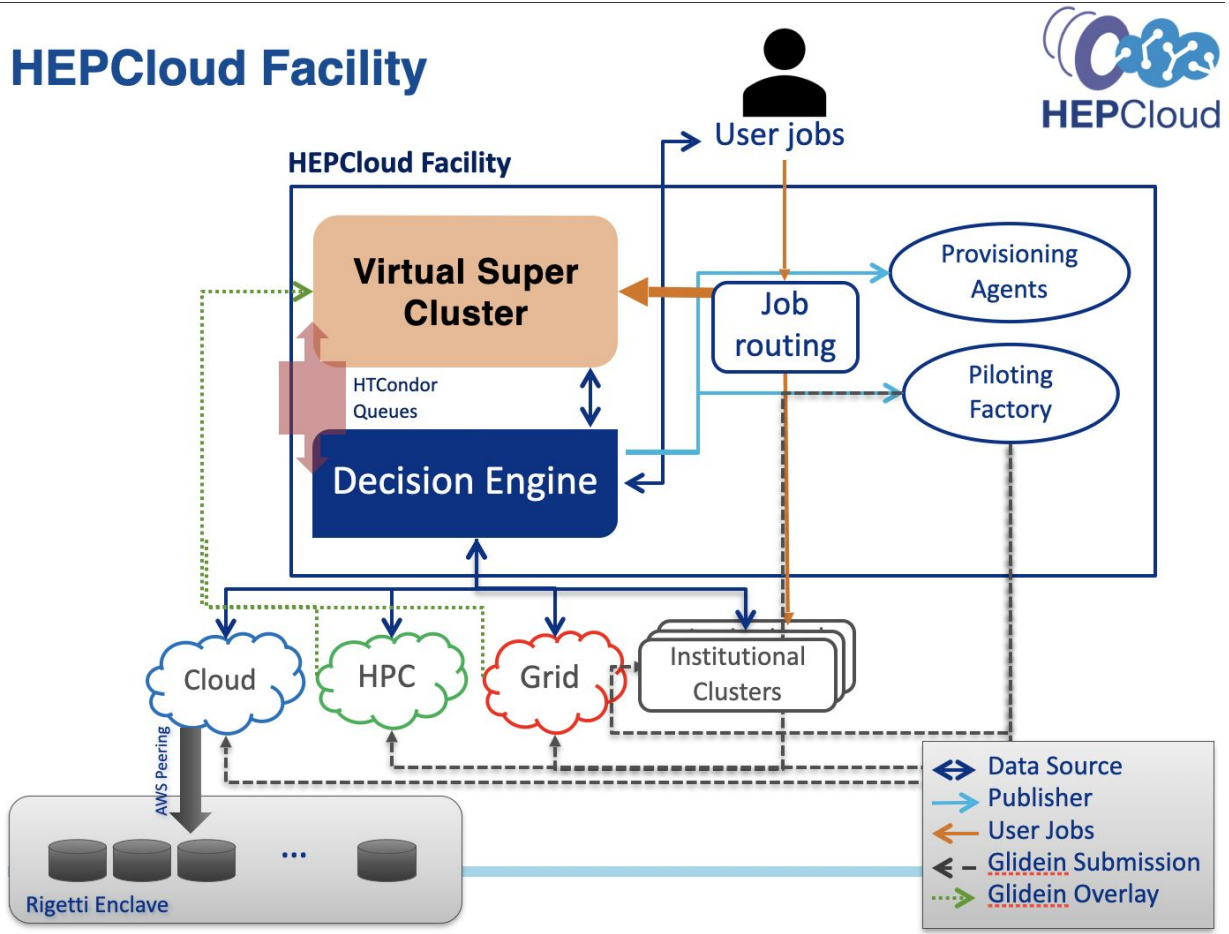
Rigetti/HEPCloud project: Goals

- Introduce HEPCloud, a standard HEP toolchain for physics analysis, into Superconducting Quantum Materials and Systems Center @ Fermilab
- Provide researchers with common interface for running algorithms and experiments on quantum and classical resources (local and remote from Fermilab site)
- Integrate Rigetti quantum resources into HEPCloud
- Simplify management of resources and adding users as SQMS program grows to include more quantum devices





Key Features of HEPCloud:

Ability to provision resources simultaneously across commercial clouds, high performance computing, grid computing, and local institutional clusters

Ability to *track* resource usage and make sure users only use what they are allocated

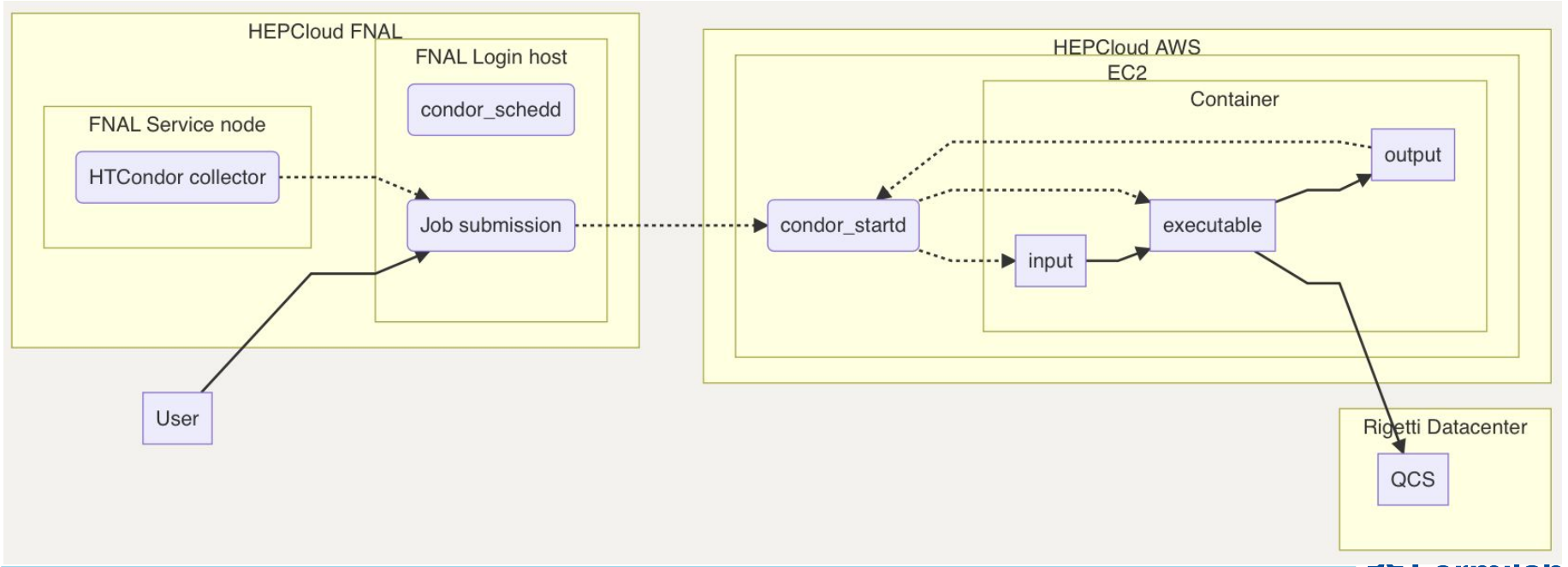
Ability to securely manage authentication credentials

Simple condor_submit interface for users.

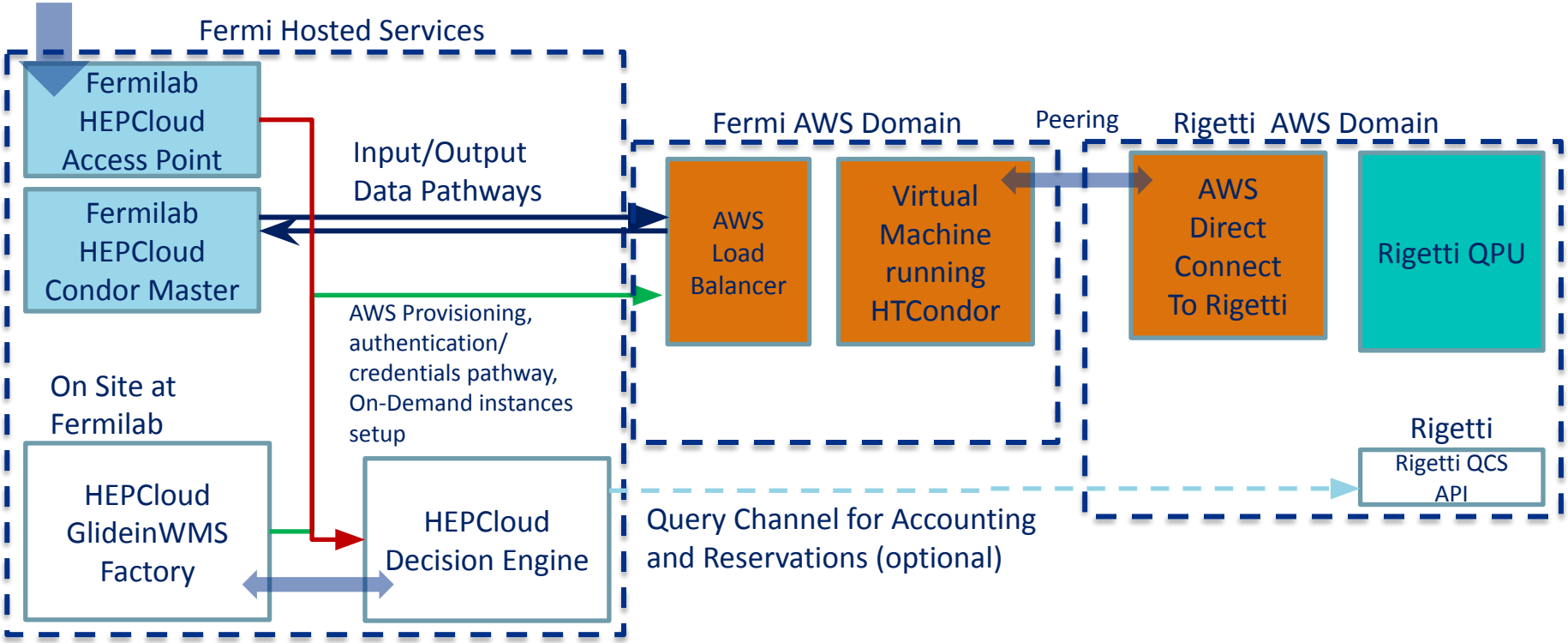
Network peering

Rigetti data center close to Amazon us-west-1

Rigetti connects via AWS Direct Connect, then peers with customer



HEPCloud-Rigetti Pre-Production (Aug ’22)



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Software Stack

Applications are distributed via Docker container–

Runs same in batch as interactively

Can run against the QVM simulator or against real devices

CentOS base image

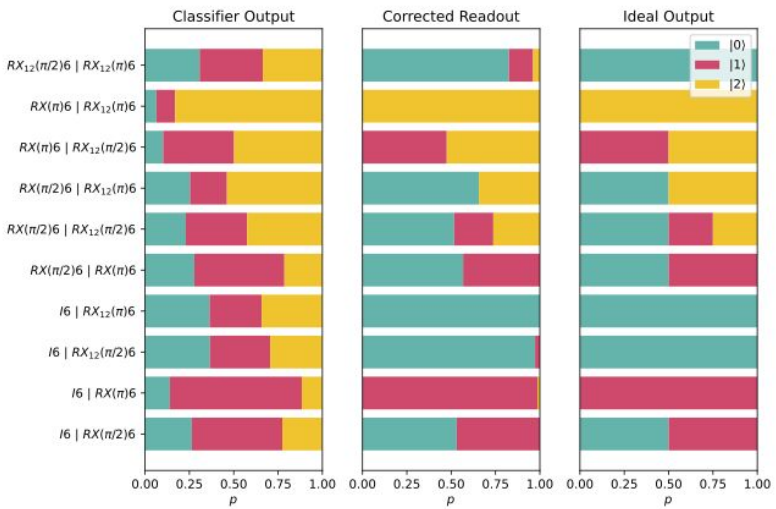
Python3, pyQuil®

Rigetti QCS API

Forest® toolkit

HTCondor takes care of passing input and output and credentials to the Docker container which is on the AWS VM.

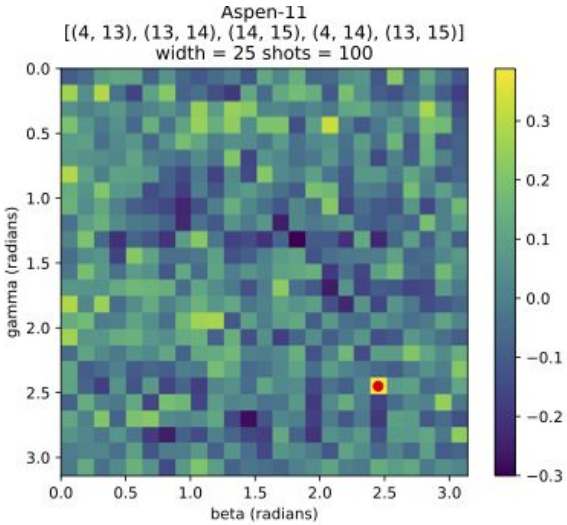
Working Example Applications



Qutrit simulation

Also run, the Mermin inequalities (not shown).

All 3 complete with 15-minute time reservation on Aspen-11



MaxCutQAOA simulation

All 3 programs were initially distributed as Jupyter notebooks, had to convert to regular python to run in batch.

User Authentication, Submission, and Accounting

User gets a reservation from Rigetti web UI

User modifies their submit file to have a timing setting to match that reservation.

User submits the job

Decision Engine checks if the user (and the organization as a whole) still have enough balance to run.

HTCondor transfers input files and credentials to the execution virtual machine on behalf of the user.

The job is executed and output is transferred back.

Rigetti/HEPCloud project: status

- Completed first phase of testing in late November 2021
  - Established a connection between Fermilab/HEP batch job system tools (HEPCloud) and Rigetti QPUs utilizing Amazon Web Services.
  - Successfully ran Mermin-Klyshko inequalities test on Aspen 11 (from Emanuelle Dalla Torres)
- Second phase completed and documented August 2022
  - Successful multiple application submission to demonstrate efficient filling of reservation slots
  - System manages credentials on behalf of multiple users.
  - User instructions and examples for running jobs through this system
  - HEPCloud Decision Engine successfully queried remaining acct. balance.
- Team: Jon Cotton, Joe Gross, Karina Castano Munoz, Christina Young; Steve Timm, Andrew Norman, Jim Kowalkowski, Patrick Riehecky

Future provisioning enhancements

Current pre-production system only uses 1 VM which talks to one QPU

Future plans:

Launch virtual machines as they are needed based on user demand.

Allow for multiple simultaneous users of the system, more than one job, more than one QPU

Allow for dynamic selection of virtual machine types based on ratio of classical:quantum computing

Test the use case of many classical VMs to one QPU.

Have the decision engine automatically make the reservations instead of just querying system for existing reservations.

Acknowledgements

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