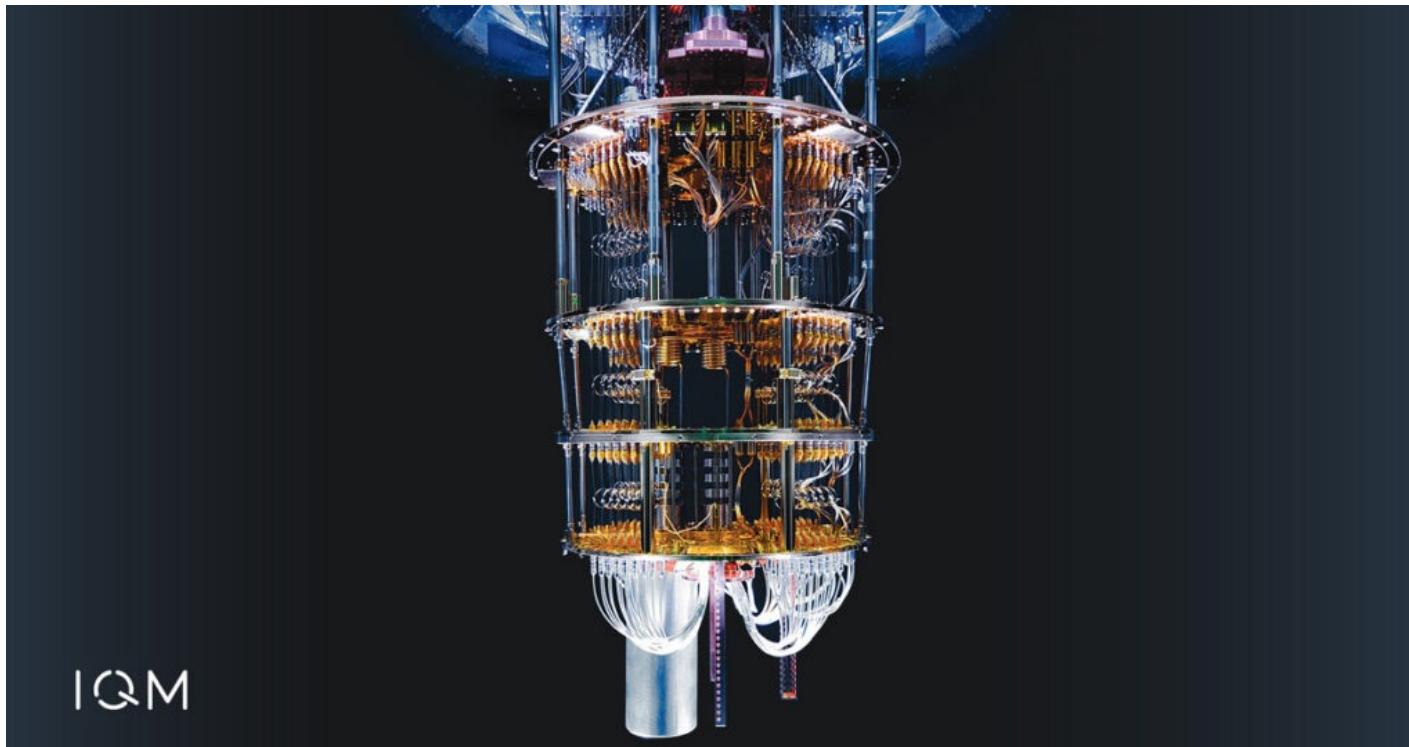


DeiC Q-Access Roadshow

March 5, 2025



Europe takes a quantum leap: LUMI-Q consortium signs contract to establish quantum computer in the Czech Republic



DeiC Q-Access Roadshow

March 5, 2025

Outline

- 1. Introduction to DeiC's Quantum Department**
- 2. Background on Quantum Computing**
 - a. Classical vs. Quantum
 - b. Algorithms
 - c. Applications
- 3. Landscape of Quantum Computing**
 - a. Hardware Implementations
 - b. Global Providers of Software and Cloud Access
 - c. Denmark's National Strategy and Initiatives
- 4. Overview of DeiC's Q-Access Initiative**
 - a. Two-mode Access Strategy
 - b. Consulting Service with Quantum Experts
- 5. Q-Access via Microsoft Azure**
 - a. Application and Evaluation Process
 - b. Step-by-step Demo
 - c. Provider Status Updates
- 6. Q & A with Q-Access Team and Microsoft**



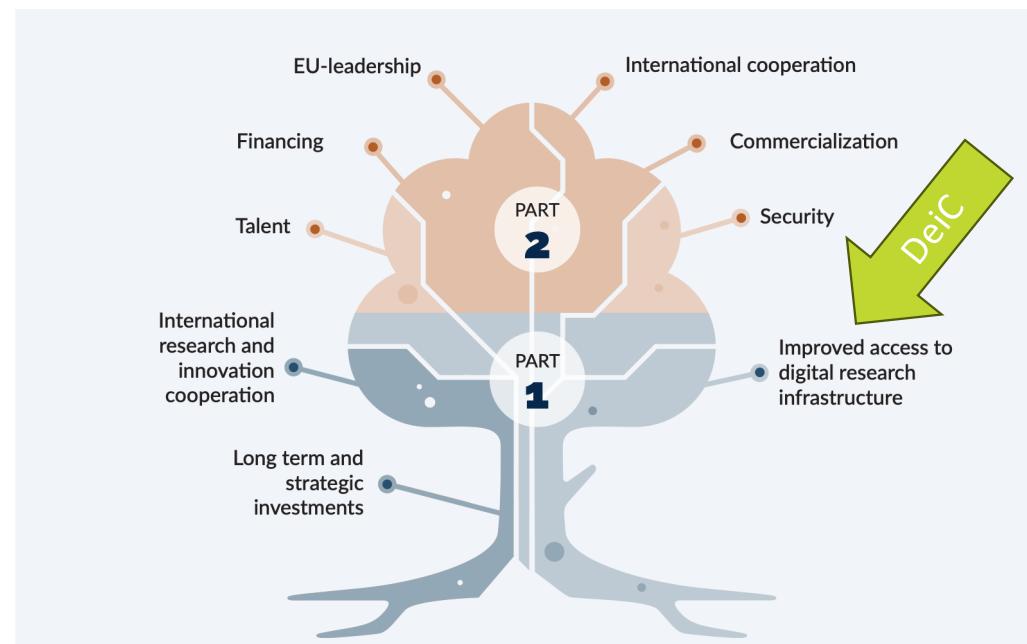
1. Introduction to DeiC's Quantum Department

The Objective of the Strategy for Quantum Technology - Part 1

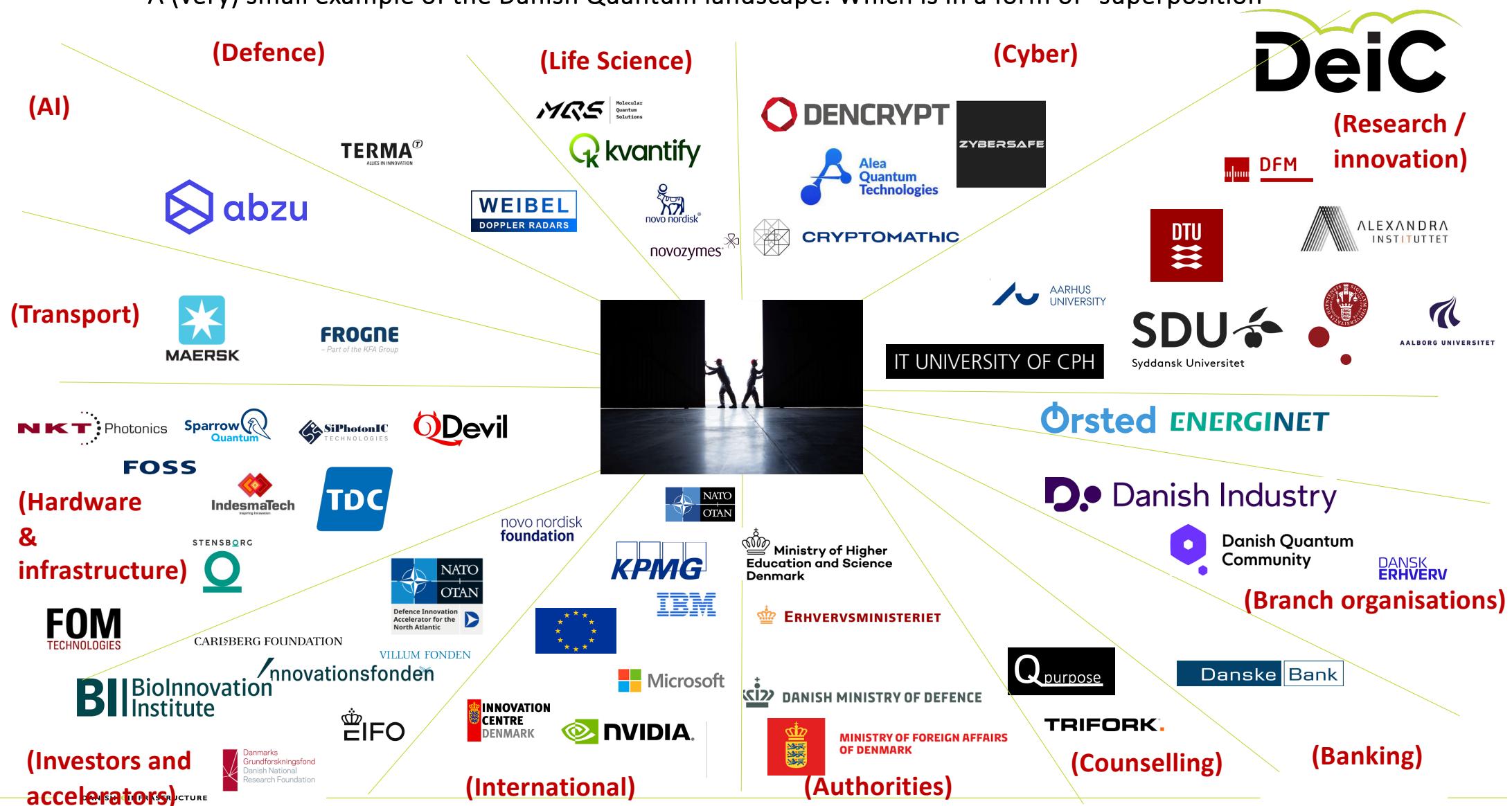
Denmark aims to have one of the world's leading quantum research environments and to have the ability to effectively translate research into new, usable technology.



Link between Part 1 and Part 2



A (very) small example of the Danish Quantum landscape. Which is in a form of "superposition"

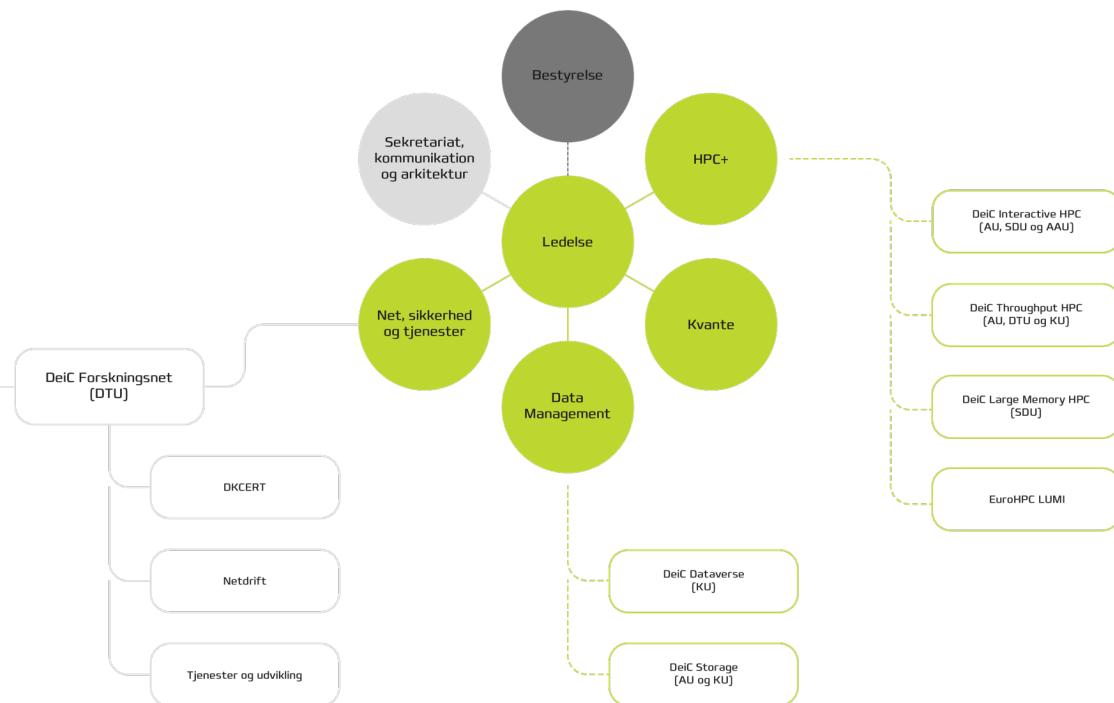


Overview of DeiC

The **Danish e-Infrastructure Consortium (DeiC)** develops and coordinates access to digital research infrastructure for Danish universities, enabling research and education at a high international level.



The research network is a high-speed network that connects Danish universities and research institutions.



DeiC's Quantum Department

DeiC's Quantum Department is the newest department in DeiC, established as part of the implementation of the Danish government's national quantum strategy.

Initiatives

Q-Competence

- Disseminate skills and increase understanding of the potential and risks of quantum technology.
- Financial support for developing quantum computing material and events.

Q-Algorithm

- DQA Academy to boost work in developing and testing quantum algorithms and the associated software stack.
- Scholarships for Ph.D. students and Postdocs.

Q-Access

- Calls for specialized access to quantum computers.
- Access via Microsoft Azure for testing.
- Consulting service with quantum experts.

Niels Bohr Quantum Summer School

Two-week summer school, for the next 4 years, for both Danish and international Ph.D. students to learn about quantum computing and attract talent to the quantum community in Denmark.

LUMI-Q

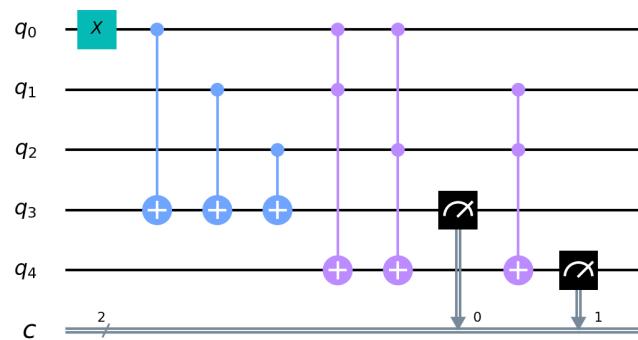
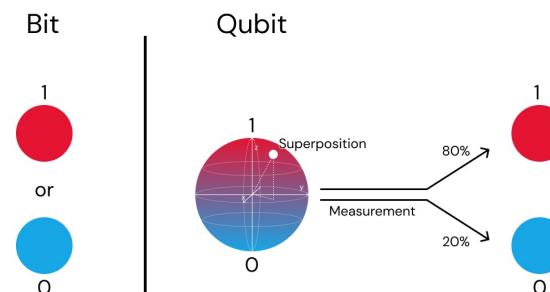
The LUMI-Q consortium has signed a contract to set up a quantum computer, purchased from IQM in Finland and deployed in the Czech Republic.

2. Background on Quantum Computing

Background on Quantum Computing

Classical vs. Quantum Bits

- Classical bits are either 0 or 1, while quantum bits (qubits) have a probability of being either 0 or 1 when measured.
- Qubits allow for an entirely new way of computing.
- Physical qubits are two-state physical quantum systems (ranging from photons to ions) located within a quantum processing unit (QPU).



Quantum Circuit Model

- A model for computation in which a sequence of quantum gates and measurements are applied to a set of qubits.
- Typically, this defines a single execution of a shot on a QPU.
- Gates are unitary operation on one or more qubits. In particular, they are always reversible, as opposed to measurements, and their complexity grows exponentially in the number of qubits.

Quantum Algorithms

- Leveraging this new way of computing requires both high-fidelity hardware implementations of qubits and gates as well as new quantum algorithms.

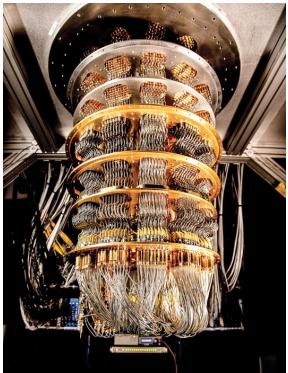
Algorithm	Problem	Quantum Complexity	Classical Complexity	Speedup
Shor's Algorithm	Factoring integers	$O(\text{poly}(N))$	$O(\exp N^{1/3} (\log N)^{2/3})$	Exponential
Grover's Algorithm	Unstructured search	$O(\sqrt{N})$	$O(N)$	Quadratic
HHL Algorithm	Solving certain linear systems $Ax = b$	$O(\text{poly}(\log N, 1/\epsilon))$	$O(\text{poly}(N, \log 1/\epsilon))$	Exponential
Hamiltonian Simulation	Simulating quantum systems (e.g. chemistry, materials)	$O(\text{poly}(\log M, t))$	$O(\text{poly}(M, t))$	Exponential

Applications

Domain	Example Use Cases	Algorithms
Cryptography	<ul style="list-style-type: none"> Breaking RSA/ECC (factoring, discrete log) Search for symmetric key attacks 	<ul style="list-style-type: none"> Shor's Algorithm Grover's Algorithm
Finance	<ul style="list-style-type: none"> Portfolio optimization Option pricing 	<ul style="list-style-type: none"> QAOA, Variational Algorithms Amplitude Estimation
Pharmaceuticals	<ul style="list-style-type: none"> Drug discovery Protein folding/structure optimization 	<ul style="list-style-type: none"> Hamiltonian Simulation Variational Quantum Eigensolver (VQE)
Machine Learning	<ul style="list-style-type: none"> Classification and clustering Generative models 	<ul style="list-style-type: none"> QNNs and QGANs HHL-based Linear Algebra
General Optimization	<ul style="list-style-type: none"> Combinatorial optimization Scheduling, resource allocation 	<ul style="list-style-type: none"> QAOA, Variational Algorithms Grover's Algorithm
General Linear Algebra	<ul style="list-style-type: none"> Solving large linear systems Matrix inversion 	<ul style="list-style-type: none"> HHL Algorithm Quantum Singular Value Transform

3. Landscape of Quantum Computing

Implementing a Quantum Computer

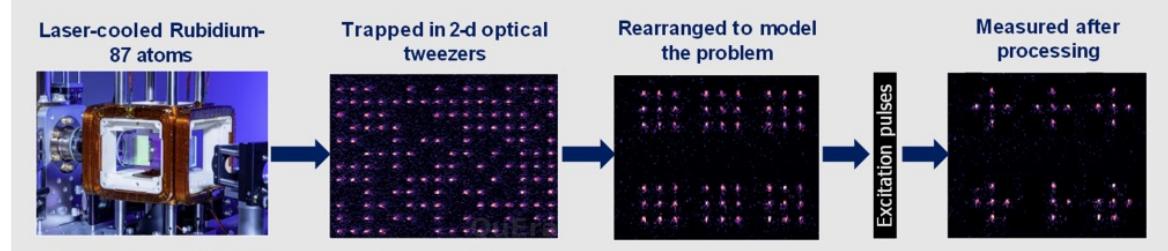


Leaders in Superconducting QC

IBM (🇺🇸)	D-Wave (🇨🇦)	Fujitsu (🇯🇵)
Google (🇺🇸)	Anyon (🇨🇦)	NEC (🇯🇵)
Amazon (🇺🇸)	Nord Quantique (🇨🇦)	Origin Quantum (🇨🇳)
Rigetti (🇺🇸)	Oxford Quantum Circuits (🇬🇧)	Huawei (🇨🇳)
SEEQC (🇺🇸)	QuantWare (🇫🇷)	Tencent (🇨🇳)
Qolab (🇺🇸)	Alice & Bob (🇫🇷)	
Bleximo (🇺🇸)	IQM (🇫🇮)	

Leaders in Neutral Atom QC

QuEra (🇺🇸)
Pasqal (🇫🇷)
Infleqtion (🇺🇸)
Atom Computing (🇺🇸)
planqc (🇩🇪)
NanoQT (🇯🇵)



Implementing a Quantum Computer

Leaders in Trapped Ion QC

Quantinuum (🇺🇸)

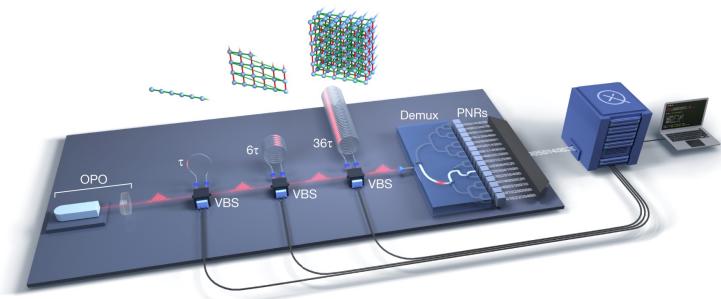
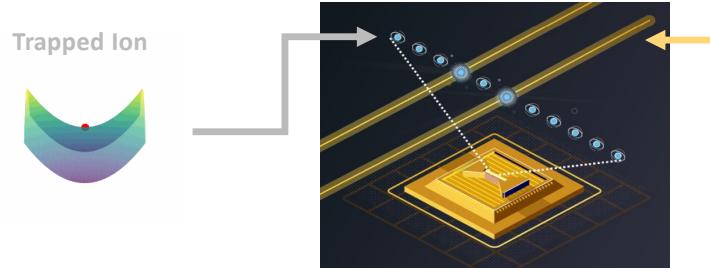
IonQ (🇺🇸)

Universal Quantum (🇬🇧)

Oxford Ionics (🇬🇧)

AQT (🇩🇪)

Qubitcore (🇯🇵)



Leaders in Photonic QC

Xanadu (🇨🇦)

PsiQuantum (🇺🇸)

ORCA Computing (🇬🇧)

QuiX Quantum (🇳🇱)

Quantum Computing Inc. (🇺🇸)

Quandela (🇫🇷)

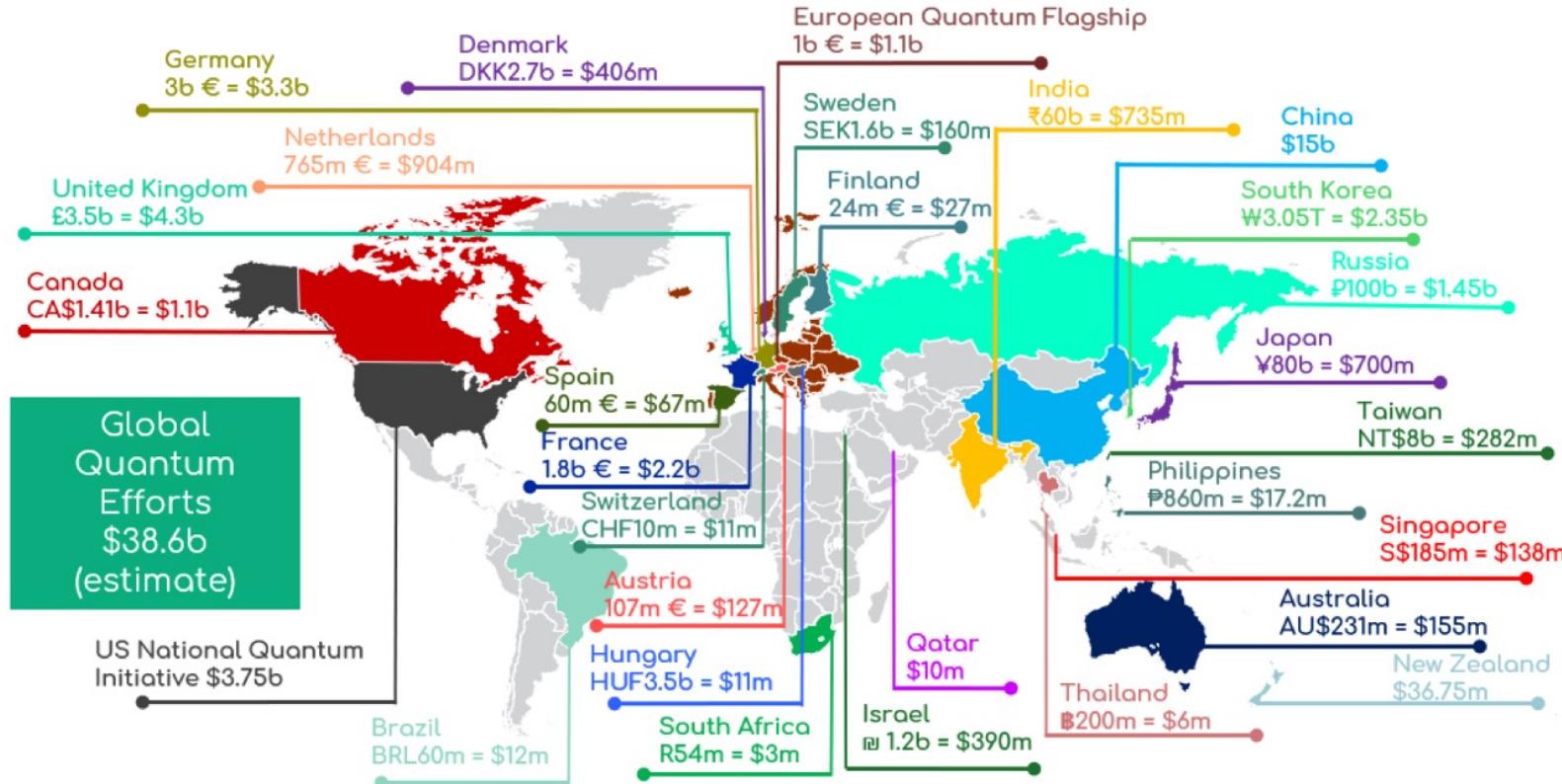
OptQC (🇯🇵)

TuringQ (🇨🇳)

eleQtron (🇩🇪)

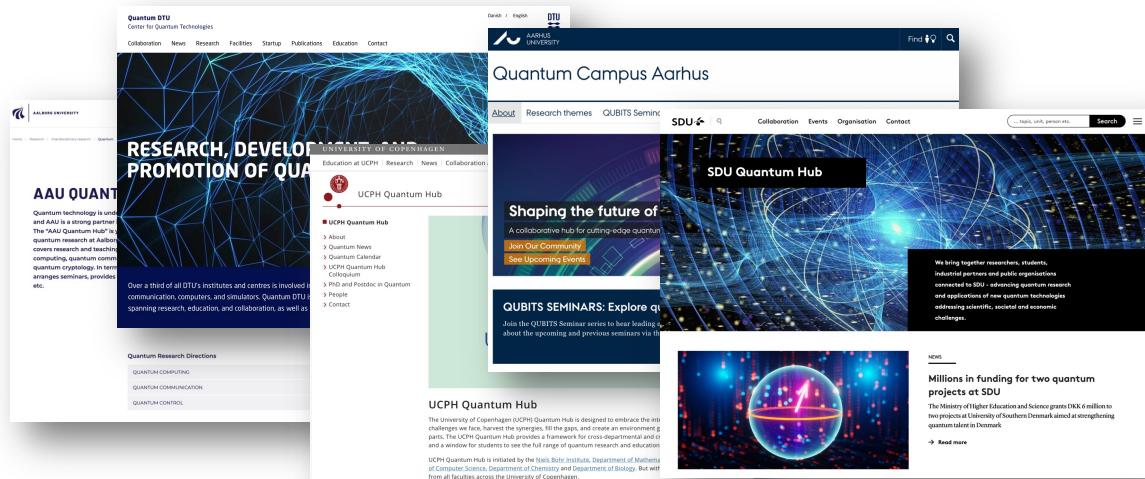
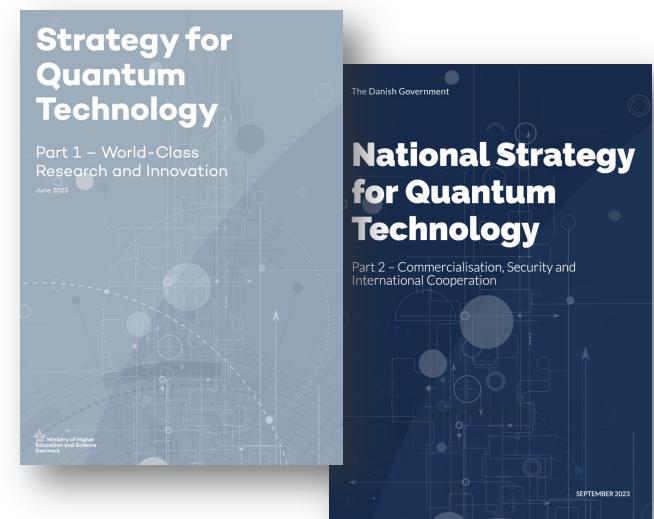
NQCG (🇳🇴)

Global Landscape of Quantum Computing



Denmark's National Quantum Strategy

- The Danish government has committed to invest 1.000.000.000 DKK into quantum research and innovation from 2023 to 2027.
- Quantum Hubs** have been established at 5 of the Danish research universities: KU, DTU, SDU, AU, AAU

4. Overview of DeiC's Q-Access Initiative

- a. Two-mode Access Strategy
- b. Consulting Service with Quantum Experts

Two-Mode quantum access



Yearly budget –2027: 12 million DKK

- Est. 1 million kr for Mode 1
- Est. 11 million kr for Mode 2



Mode 1: Microsoft Azure Quantum - cloud computing platform

- **Simple online request** form with quick response
- Access to quantum simulator and hardware from IonQ, Quantinuum and Rigetti
- Access **worth of up to 25.000 kr.** (can be requested multiple times)

Roadshow purpose



Mode 2: Selected quantum computers for specialized research needs

- Evaluation by international scientific committee
- Two annual calls for research project proposals
- Apply for access worth of up to est. 7 milion Kr

Q-Access consulting service



- Fill out the form below to consult with experts in quantum computing from DeiC
 - <https://deic-backoffice.atlassian.net/servicedesk/customer/portal/3/group/4/create/34>

DeiC Backoffice Help / Quantum Back Office

Quantum Back Office

Welcome! You can raise a request for Quantum Back Office using the options provided.

What can we help you with?

Consult with Experts in Quantum Computing
Fill out the form below to consult with experts in quantum computing from DeiC.

Required fields are marked with an asterisk.*

Raise this request on behalf of*

Muyang Liu (muyang.liu@deic.dk)

Summary *

Consult with Experts in Quantum Computing

DeiC provides comprehensive support to researchers across Denmark, enabling them to harness the power of quantum computing for their projects. Fill out the form below to consult with experts in quantum computing from DeiC, who can understand your computational needs and provide support for leveraging quantum computing systems relevant to reaching your research goals.

Required fields are marked with an asterisk.*

Background

1. What is your research field, your specific area, and your current project?*

Short written response

Normal text B I ... = A = i = “ – ABC

2. Where does your research fall on the scale from experimental to theoretical?*

Single choice *

Select...

3. How familiar are you with quantum computing?*

Single choice *

Select...

4. How familiar are you with programming?*

Single choice *

Select...

5. If applicable, how are you currently using quantum computing or programming in your project?

Short written response

Normal text B I ... = A = i = “ – ABC

Message

1. Select a topic*

Multiple choice *

Select...

2. If you selected other, please describe your topic.

Short written response

Normal text B I ... = A = i = “ – ABC

3. Describe your questions and goals for the consultation.*

Label *

Normal text B I ... = A = i = “ – ABC

4. Add any relevant attachments.

Add attachment that you think will help solve the issue.

Drop files to attach or [browse](#)

5. Q-Access via Microsoft Azure

- a. Application and Evaluation Process
- b. Step-by-step Demo
- c. Provider Status Updates

Q-Access via Azure

- Access to Azure for testing worth up to **25.000 DKK** can be applied for by filling out a simple form at:
<https://deic-backoffice.atlassian.net/servicedesk/customer/portal/3/group/4/create/35>



- Evaluation process – within a week**

Application form

- Fill a simple online form as below (+ accept the term of service) !

DeiC Backoffice Help / Quantum Back Office

Quantum Back Office

Welcome! You can raise a request for Quantum Back Office using the options provided.

What can we help you with?

 **Request Access to Microsoft Azure Quantum**
Using the below form, you can apply for a quota to use Microsoft Azure Quantum.

Required fields are marked with an asterisk *

Raise this request on behalf of *

 Muyang Liu (muyang.liu@deic.dk)

Summary *

DeiC provides access to the [Microsoft Azure Quantum cloud service](#) to Danish academia, industry, and the public sector (see the FAQ for more information on eligibility). This access is intended to allow users to explore and test a variety of quantum platforms. Users requiring more significant access to a specific platform can apply for such access from one of the DeiC Q-Access calls.

Through Microsoft Azure Quantum, users have access to a diverse portfolio of quantum simulators and quantum computers from Quantinuum, IonQ, Quantum Circuits Inc., Rigetti, and Pasqal. Because this access is intended for testing, we strongly encourage users to start with testing the various free simulators (from [Microsoft](#) and their [backend providers](#)) before moving on to actual hardware tests.

Using the below form, you can apply for a quota to use Microsoft Azure Quantum (see [Azure Quantum pricing](#) for more information). The standard initial resource quota is 10.000 DKK in Azure Quantum Credits. However, it is possible to apply for up to 25.000 DKK. Moreover, it is possible to apply for more credits multiple times once your quota has been used up.

Allocated resources can be used up until 30/06/2025, at which point unused resources will be returned to the pool, and a new usage period will begin. Users will be asked to fill out a short report on their usage, which will be required for future allocations of resources.



Background

Full Name *

What area are you in? *

Select...

Describe the project that the access will be used for and who will be using it. *

If you are in academia and applying for access for a project involving a Postdoc, PhD or Master's student who will be using the access, please provide their details. If you are in industry or the public sector, please describe how the project is new and different from current activities.

Normal text 

Access Usage

Describe your intended use for the access. *

Normal text 

Have you applied for Microsoft Azure Quantum access from DeiC in the past? *

Yes
 No

Required Resources

Does the standard initial resource quota of 10.000 DKK suffice for your needs? *

Yes
 No

Customized user group in DeiC plan



Why split the user groups

- a) It can take up to 24 hours for Microsoft to update a resource group's real cost, rendering it ineffective for limiting user spending based on usage.
- b) Currently, Azure does not offer adequate controls to limit user spending.

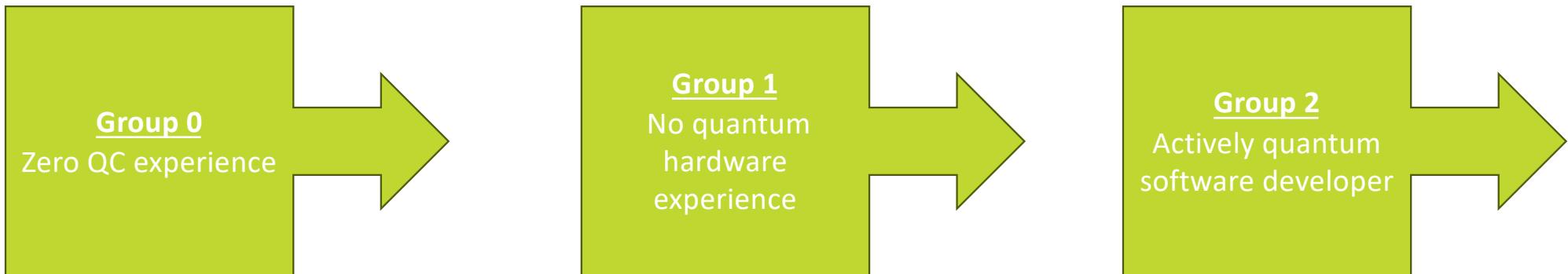
Intermediate solution

- a) Users will be split into two(three) groups, each with different levels of access to Azure (see next slide).
- b) The separation of multiple groups is especially important for mitigating risk.
- c) Most of the development and testing should take place on simulators due to high cost of QPU.

DeiC's Support

- a) Actively developing a set of supporting materials.
- b) Share regular updates on the status of Azure's quantum providers .

Customized user group in DeiC plan



- Recommend to use a free browser interface simulator
<https://quantum.microsoft.com/en-us/tools/quantum-coding>
- Can get access to quantum simulators from Microsoft and Quantinuum
- Indirectly access to allocated QPU resources on Azure
- Submit requests to DeiC via an online form
- DeiC performs submitted jobs
- Direct access to allocated QPU resources on Azure
- Responsible to cover the cost if significantly exceeding allocation

How to submit a job for users in Group 1



Fill out an online form with the following information

- a) User's name and e-mail address
- b) Script to be executed on Azure + A Brief description
- c) Confirmation that the script fits the standards outlined below
 - The file has been successfully tested on a simulator (along with the values of the parameters used)
 - The output from the simulator
 - Specific QPU to be used for the job
 - Parameters of the script to be used for the job
 - Cost estimate for resources necessary to complete the job (e.g, unit of HQC on Quantinuum system)

After submitting the form, a DeiC quantum expert will

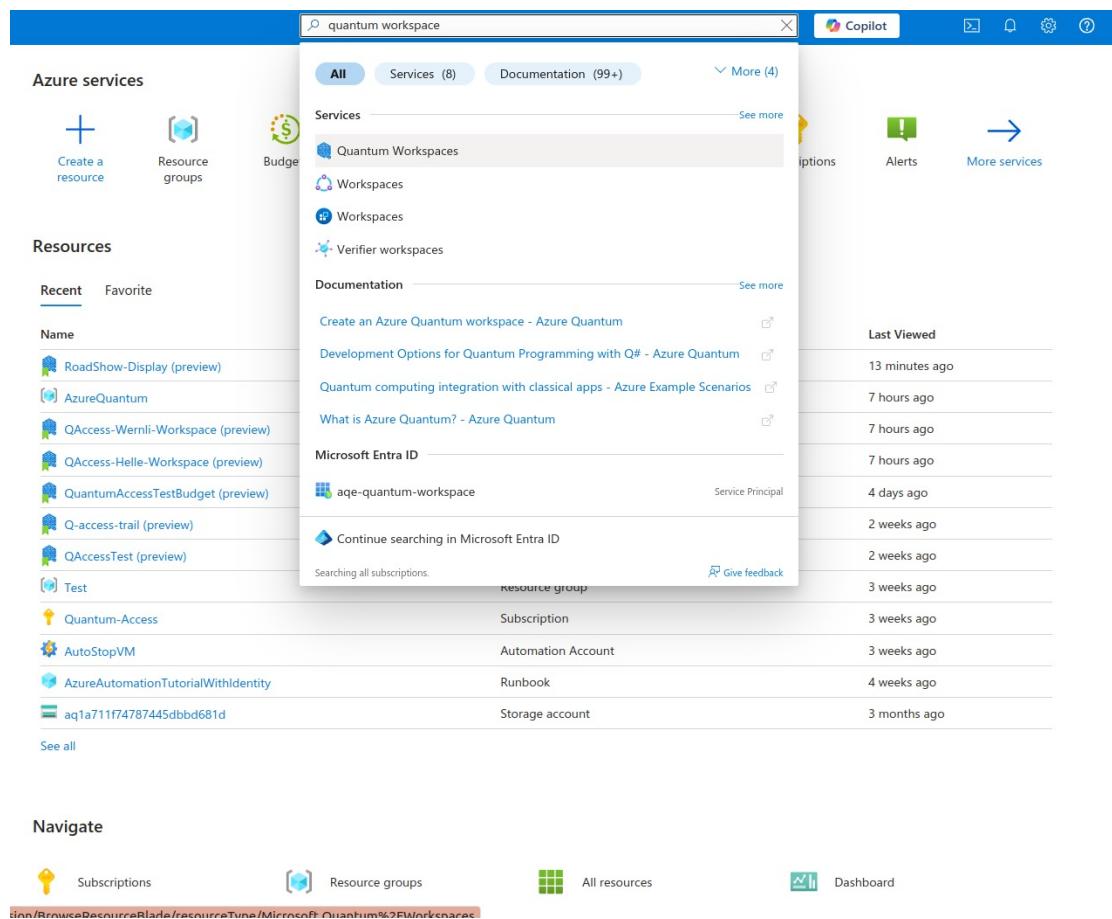
- a) Follow up and resolve any questions, execute the job on a QPU
- b) Return the output of the job to the user
- c) The job output follows Azure's format; users must handle their own post-processing

Step-by-step Demo of Using Azure – Group 2 Users



1) Log in to Azure

- Go to <https://portal.azure.com>
- Use the credentials associated with your organization or Microsoft account



The screenshot shows the Azure portal homepage. At the top, there is a search bar with the text "quantum workspace". Below the search bar, there are three main sections: "Azure services", "Resources", and "Documentation".

- Azure services:** Includes buttons for "Create a resource", "Resource groups", and "Budget".
- Resources:** Shows a list of recent and favorite resources. Recent resources include "RoadShow-Display (preview)", "AzureQuantum", "QAccess-Wernli-Workspace (preview)", "QAccess-Helle-Workspace (preview)", "QuantumAccessTestBudget (preview)", "Q-access-trail (preview)", and "QAccessTest (preview)".
- Documentation:** Shows links to "Create an Azure Quantum workspace - Azure Quantum", "Development Options for Quantum Programming with Q# - Azure Quantum", "Quantum computing integration with classical apps - Azure Example Scenarios", and "What is Azure Quantum? - Azure Quantum".

On the right side, there is a sidebar with "Last Viewed" resources, including "aqe-quantum-workspace" (Service Principal), "Quantum-Access" (Subscription), "AutoStopVM" (Automation Account), "AzureAutomationTutorialWithIdentity" (Runbook), and "aq1a711f74787445dbbd681d" (Storage account). The "Last Viewed" list shows items from 13 minutes ago to 3 months ago.

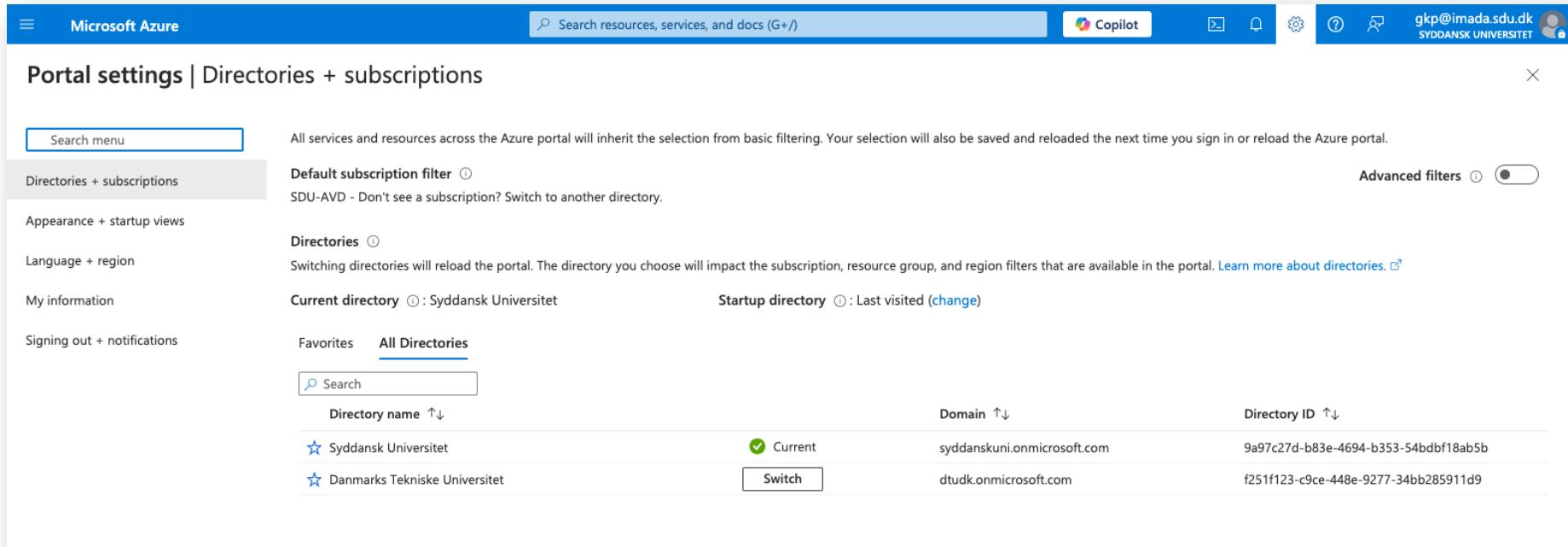
At the bottom, there is a "Navigate" bar with links to "Subscriptions", "Resource groups", "All resources", and "Dashboard". The URL in the browser address bar is "https://portal.azure.com/#resourceType/Microsoft.Quantum%2FWorkspaces".

2) Navigate to your Quantum Workspace

- Use the search bar at the top to find "Quantum Workspaces".
- You must be in the DTU directory to access resources allocated from DeiC's Q-Access initiative.

Accessing Allocated Resources for Users in Group 2

Note: You must be in the DTU directory to access resources allocated from DeiC's Q-Access initiative.



Microsoft Azure

Search resources, services, and docs (G+/)

Copilot

gkp@imada.sdu.dk SYDDANSK UNIVERSITET

Portal settings | Directories + subscriptions

Search menu

Directories + subscriptions

Default subscription filter ⓘ

SDU-AVD - Don't see a subscription? Switch to another directory.

Advanced filters ⓘ

Appearance + startup views

Directories ⓘ

Switching directories will reload the portal. The directory you choose will impact the subscription, resource group, and region filters that are available in the portal. [Learn more about directories.](#)

Language + region

My information

Current directory ⓘ: Syddansk Universitet

Startup directory ⓘ: Last visited ([change](#))

Favorites All Directories

Search

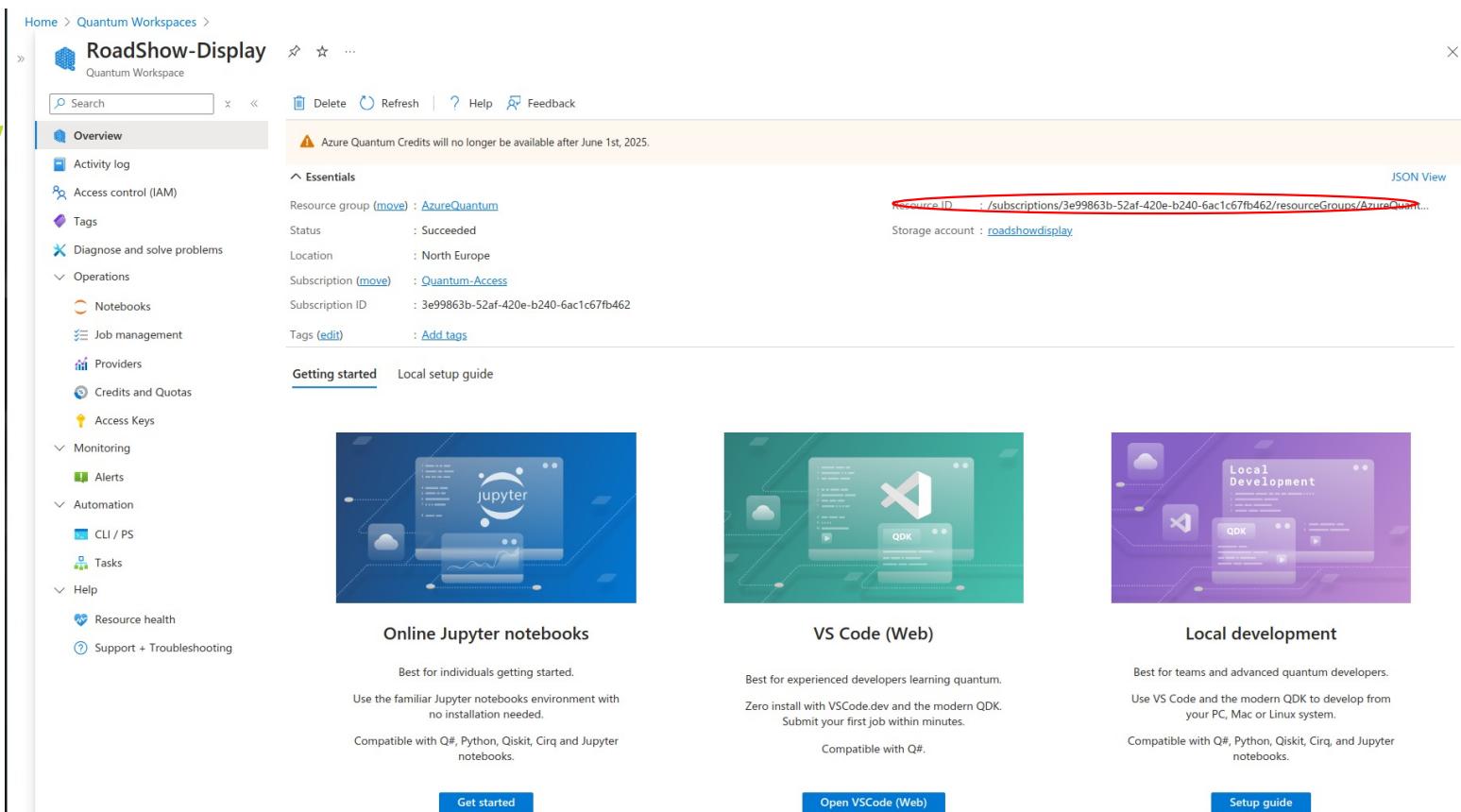
Directory name ↑	Domain ↑	Directory ID ↑
STAR Syddansk Universitet	syddanskuni.onmicrosoft.com	9a97c27d-b83e-4694-b353-54bdbf18ab5b
STAR Danmarks Tekniske Universitet	dtudk.onmicrosoft.com	f251f123-c9ce-448e-9277-34bb285911d9

Switch

The Quantum Workspace Overview

Workspace Essentials:

- **Displays general workspace info:**
Subscription ID, status, resource group, region.
- **Contains key inputs to job initiative:**
resource_id, location



The screenshot shows the Azure Quantum Workspace Overview page for a workspace named 'RoadShow-Display'. The page includes a sidebar with navigation links like Overview, Activity log, Access control (IAM), Tags, Diagnose and solve problems, Operations (Notebooks, Job management, Providers, Credits and Quotas, Access Keys), Monitoring (Alerts), Automation (CLI / PS, Tasks), Help (Resource health, Support + Troubleshooting), and a JSON View link. The main content area displays workspace details: Resource group (AzureQuantum), Status (Succeeded), Location (North Europe), Subscription (Quantum-Access), Subscription ID (3e99863b-52af-420e-b240-6ac1c67fb462), and Tags (Add tags). A warning message states: 'Azure Quantum Credits will no longer be available after June 1st, 2025.' On the right, a 'Resource ID' is highlighted with a red box: '/subscriptions/3e99863b-52af-420e-b240-6ac1c67fb462/resourceGroups/AzureQuantum/providers/Microsoft.Quantum/Workspaces/RoadShow-Display'. Below this, a 'Storage account' is listed as 'roadshowdisplay'. The page also features three cards: 'Online Jupyter notebooks' (Best for individuals getting started, using the familiar Jupyter notebook environment with no installation needed, compatible with Q#, Python, Qiskit, Cirq, and Jupyter notebooks), 'VS Code (Web)' (Best for experienced developers learning quantum, using VSCode.dev and the modern QDK, compatible with Q#), and 'Local development' (Best for teams and advanced quantum developers, using VS Code and the modern QDK to develop from your PC, Mac or Linux system, compatible with Q#, Python, Qiskit, Cirq, and Jupyter notebooks). Each card has a 'Get started' button, an 'Open VSCode (Web)' button, and a 'Setup guide' button.

```
from azure.quantum import Workspace
from azure.quantum.qiskit import AzureQuantumProvider

workspace = Workspace(
    resource_id = "/subscriptions/3e99863b-52af-420e-b240-6ac1c67fb462/resourceGroups/AzureQuantum/providers/Microsoft.Quantum/Workspaces/RoadShow-Display",
    location = "northeurope")

provider = AzureQuantumProvider(workspace)
```

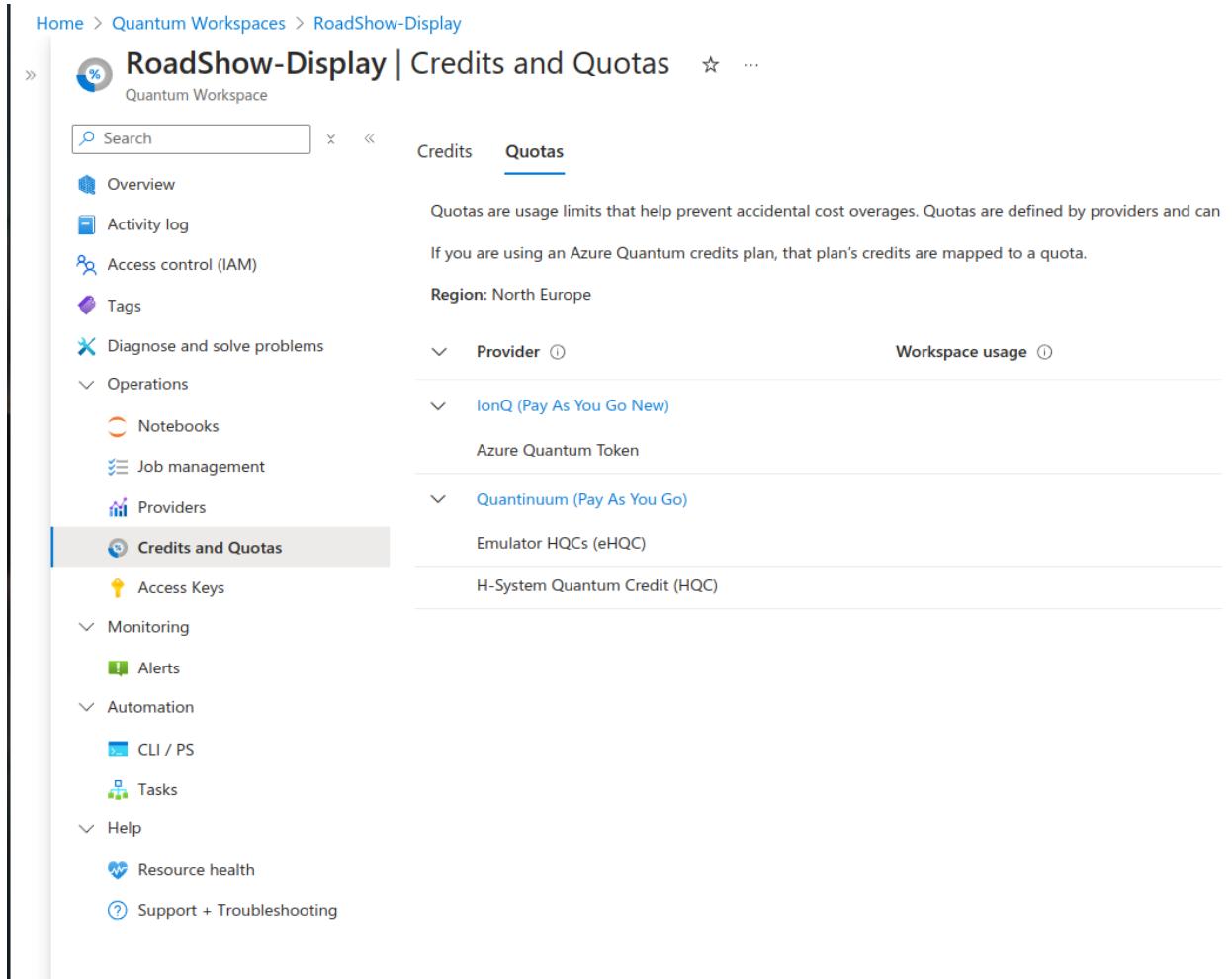
The Providers Tab

1. List of Allocated Providers

- Status of providers (see next slides).
- Management of providers (done by DeiC).

2. Credits & Quotas

- Shows the whole DeiC's plan usage (not your personal allocation), because quota allocation happens at the subscription level.



Home > Quantum Workspaces > RoadShow-Display

RoadShow-Display | Credits and Quotas

Search

Credits Quotas

Quotas are usage limits that help prevent accidental cost overages. Quotas are defined by providers and can be mapped to a credits plan.

If you are using an Azure Quantum credits plan, that plan's credits are mapped to a quota.

Region: North Europe

Provider Workspace usage

IonQ (Pay As You Go New) Azure Quantum Token

Quantinuum (Pay As You Go) Emulator HQCs (eHQC) H-System Quantum Credit (HQC)

Credits and Quotas

- Access Keys
- Monitoring
- Alerts
- Automation
- CLI / PS
- Tasks
- Help
- Resource health
- Support + Troubleshooting

Azure Provider Status Updates

- DeiC's quantum department will give **monthly updates** on the status of Azure's quantum providers, as well as communicate with Microsoft and the providers to ensure full transparency on QPU availability.

Azure Status Update: February 2025

IonQ

Aria-1 and Aria-2 are unavailable due to “planned and unplanned maintenance” and are expected to be down until February 13 and March 28 respectively, but the IonQ simulator is still available.

Quantinuum

H1-1, the syntax checker, and emulator are all available. Note that reported average queue times are unreliable due to Quantinuum's uptime schedule of 1:00 – 10:00 am UTC+1 for running jobs.

Rigetti

Ankaa-9q-3, Ankaa-3, and the simulator are all available. However, Ankaa-3 will not show up as a target unless you are running the latest version of the Azure Quantum Python library (<https://pypi.org/project/azure-quantum/2.3.0/>).

Pasqal

Pasqal is still in private preview and is not currently available through DeiC's provided access.

Azure Provider Status Updates – March 4, 2025



IonQ	Quantum Computing	Pay As You Go New		Available
ionq.qpu.aria-1 			Available	3m
ionq.qpu.aria-2 			Unavailable	N/A 
ionq.simulator 			Available	<1m
Quantinuum	Quantum Computing	Pay As You Go		Available
quantinuum.qpu.h1-1 			Available	13h 2m
quantinuum.sim.h1-1sc 			Available	<1m
quantinuum.sim.h1-1e 			Available	1h 23m
Rigetti Quantum	Quantum Computing	Pay As You Go		Available
rigetti.sim.qvm 			Degraded	<1m
rigetti.qpu.ankaa-3 			Available	<1m

Submitting Job – online Jupyter notebook



In the left-hand panel of the workspace, click on “Operations”

- 1) Click 'Notebook' on the scroll down menu
 - a. Provide necessary parameters of the script to be used for the job
- 2) Click 'Run all' (or individual cells) to submit the job

The screenshot shows the Azure Quantum workspace interface. On the left, a sidebar menu is open, with the 'Operations' section expanded. The 'Notebooks' item is highlighted with a red circle and a red box. On the right, a Jupyter Notebook titled 'hello-world-qiskit-quantinuum' is displayed. The top navigation bar shows 'Runtime' and 'File' menus, with 'File' highlighted with a red circle. The 'File' menu has 'Run all' selected. The notebook content includes a title 'Hello, world: Submit a Qiskit job to Quantinuum' and a section 'Submit a simple job to Quantinuum using Azure Quantum' with code snippets. A red circle labeled '2' is placed over the 'Run all' button in the top right of the notebook cell.

```
from azure.quantum import Workspace
from azure.quantum.qiskit import AzureQuantumProvider

workspace = Workspace(
    resource_id = "/subscriptions/3e99863b-52af-420e-b240-6ac1c67fb462/resourceGroups/AzureQuantum/providers/Microsoft.Quantum/Workspaces/RoadShow-Display",
    location = "northeurope")

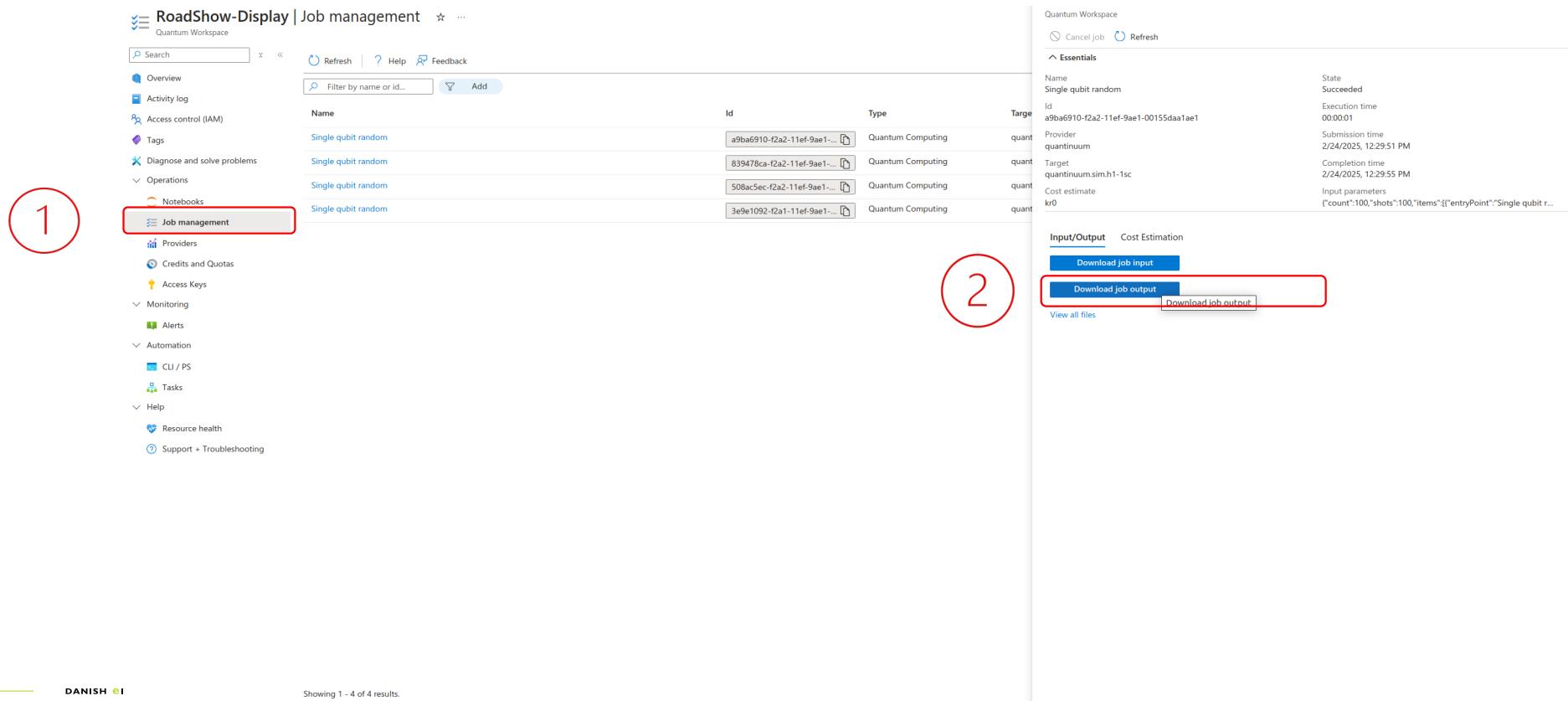
provider = AzureQuantumProvider(workspace)
```

```
from qiskit import QuantumCircuit
from qiskit.visualization import plot_histogram
```

Viewing Job Results



- 1) Select Your Job in the “Job management” list.
- 2) Download Button: Allows you to **export** results locally as JSON format



The screenshot shows the RoadShow-Display interface with two main panels. The left panel is titled "RoadShow-Display | Job management" and contains a sidebar with various navigation items. The "Job management" item is highlighted with a red box and a circled '1'. The right panel shows a table of job results with columns for Name, Id, Type, Target, and State. A specific job is selected, and its details are shown in the "Essentials" section. The "Input/Output" section contains three buttons: "Download job input" (highlighted with a red box and circled '2'), "Download job output" (highlighted with a red box and circled '2'), and "Download job output".

Name	Id	Type	Target	State
Single qubit random	a9ba6910-f2a2-11ef-9ae1-00155daa1ae1	Quantum Computing	quant	Succeeded
Single qubit random	839478ca-f2a2-11ef-9ae1-...	Quantum Computing	quant	
Single qubit random	508ac5ec-f2a2-11ef-9ae1-...	Quantum Computing	quant	
Single qubit random	3e9e1092-f2a1-11ef-9ae1-...	Quantum Computing	quant	

Job management

Essentials

Input/Output

Download job input

Download job output

Download job output

Pricing plans for Azure Quantum providers



- **Price Model 1 - usage unit** counted by an explicit formula depends on number of operations and shots



$$HQC = 5 + C(N_{1q} + 10N_{2q} + 5N_m)/5000 \quad \bullet \quad 1 \text{ HQC} = \$ 12.5 \text{ (15)}$$



IONQ

$$AQT = m + 0.000220 \cdot (N_{1q} \cdot C) + 0.000975 \cdot (N_{2q} \cdot C)$$

- N_{1q} is the number of single-qubit operations in a circuit.
- N_{2q} is the number of native two-qubit operations in a circuit. Native gate is equivalent to CNOT up to several single-qubit gates.
- N_m is the number of state preparation and measurement (SPAM) operations in a circuit including initial implicit state preparation and any intermediate and final measurements and state resets.
- C is the shot count.

For IonQ:

- \$ 0.000220 / 1-qubit-gate shot
- \$ 0.000975 / 2-qubit-gate shot

m is the minimum price per program execution

- \$ 97.50 if error mitigation is on
- \$ 12.4166 if error mitigation is off

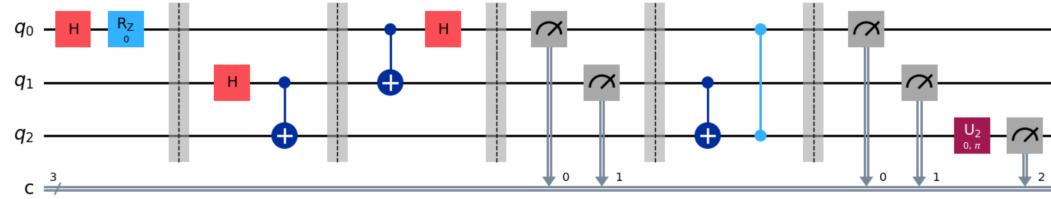
- **Price Model 2 - charges for job execution time** on their quantum processors



- USD 0.013 per 10-millisecond increment of job execution time

Example: Quantum Teleportation

- Designing circuits
- Estimating cost
- Submitting jobs
- Interpreting results



```

from qiskit import QuantumCircuit

def initialize_state(theta):
    qc = QuantumCircuit(1, name='initialize_state')
    qc.h(0)
    qc.rz(theta, 0)
    return qc

def create_Bell_pair():
    qc = QuantumCircuit(2, name='create_Bell_pair')
    qc.h(0)
    qc.cx(0,1)
    return qc

def entangle_with_Bell_pair():
    qc = QuantumCircuit(2, name='entangle_with_Bell_pair')
    qc.cx(0,1)
    qc.h(0)
    return qc

def measure_and_communicate_classically():
    qc = QuantumCircuit(2, 2, name='measure_and_communicate_classically')
    qc.measure([0,1], [0,1])
    return qc

def quantum_teleportation():
    qc = QuantumCircuit(3, name='quantum_teleportation')
    qc.cx(1,2)
    qc.cz(0,2)
    return qc

```



Azure Local Development using VS Code

See our DeiC quantum consultant's screen.

DeiC Q-Access Roadshow

March 5, 2025

Resources

- Q-Access Website: <https://deic.dk/da/q-access>
- IBM Quantum Learn: <https://learning.quantum.ibm.com/>
- Qiskit Documentation: <https://docs.quantum.ibm.com/>
- Microsoft Azure Documentation: <https://learn.microsoft.com/en-us/azure/quantum/>
- Quantinuum TKET Documentation: <https://docs.quantinuum.com/tket/>
- Xanadu's Strawberry Fields: <https://strawberryfields.ai/>
- Tensorflow Quantum Machine Learning: <https://www.tensorflow.org/quantum>



DeiC Q-Access Roadshow

March 5, 2025



Thank you all for listening!

Stick around for a Q&A session and hands-on support
with the Q-Access Team and Microsoft.