



Hybrid CPU, GPU, QPU infrastructure for hybrid quantum-classical computing use cases development with secure QKD/PQC links

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Current challenge in quantum networking

Existing QKD networks cannot extend quantum communication channels over long distance single span

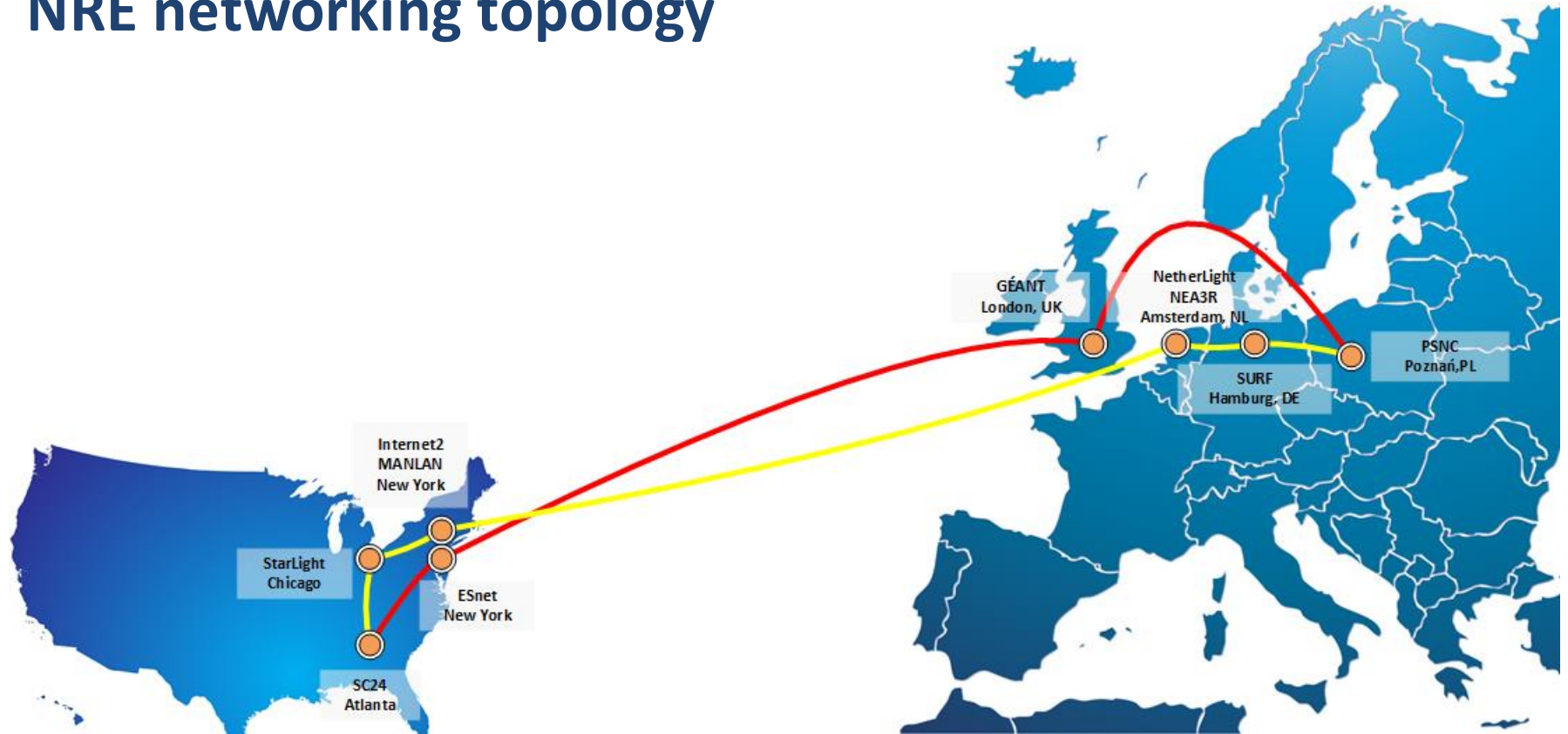
Hybrid PQC - QKD setup and use case

- Using QKD Key Management System (KMS) it is possible to scale the QKD networks and its topologies and introduce hybrid classical links with PQC encryption to transmit keys between KMS system and nodes where physical QKD link cannot be established
- Such hybrid approach enables scaling and building large QKD KMS networks

Demonstration of a worldwide communication infrastructures collaboration

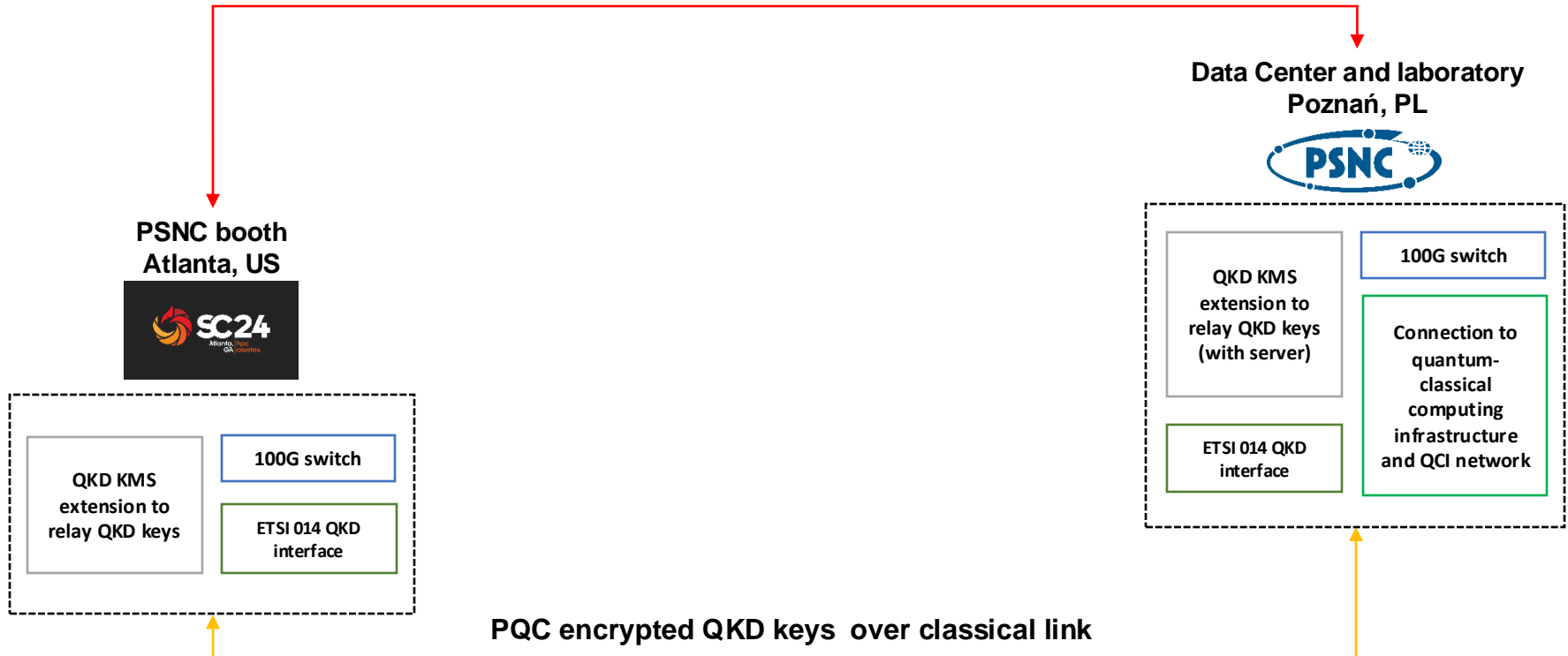
- For the purpose of this demonstration the dedicated end-to-end 100G links between PSNC in Poland and SC24 venue in Atlanta were established
- They included ETSI 0014 QKD interfaces connected to MACSec enabled network switches
- The setup was used to access hybrid quantum–classical computing infrastructure for multi QPU, GPU, CPU use case

NRE networking topology



Hybrid quantum-classical hardware NRE demonstration

Encrypted traffic for distributed hybrid Quantum Computing +
classical use case/algorithm

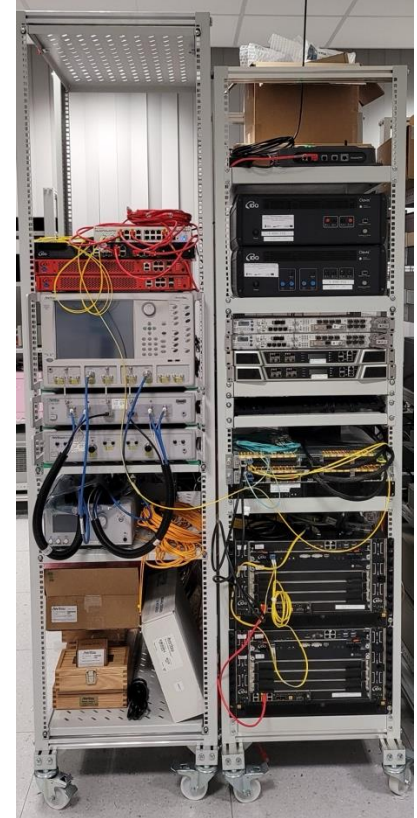


Hardware setup at end nodes

Atlanta, US



Poznań, PL



Hybrid PQC + QKD KMS Setup

QMS Web App admin

Home > Dashboard

Elements list Network graph

Type your search

Solteris_Atlanta
Solteris
NODE

Solteris_Poland
Solteris
NODE

CONSLINK_Solteris_Atlanta_Solteris_Poland
BufferRate: 200
CONSUMER LINK

QKDLSSPQC_Solteris_Atlanta_Solteris_Poland
QKDLSSPQC
PROVIDER

NODELINK_Solteris_Atlanta_Solteris_Poland
NODE LINK

CONSLINK_Solteris_Atlanta_Solteris_Poland
CONSLINK_Solteris_Atlanta -> CONSLINK_Solteris_Poland
PATH

CONS_Solteris_Atlanta
ETSI REST 014
CONSUMER

CONS_Solteris_Poland
ETSI REST 014
CONSUMER

PQC_Solteris_Atlanta
QKDLSSPQC
PROVIDER

PQC_Solteris_Poland
QKDLSSPQC
PROVIDER

PQCLINK
BufferRate: 100
PROVIDER LINK

Network graph

```

graph TD
    S_A[Solteris_Atlanta] --- CONSLINK[CONSLINK_Solteris_Atlanta_Solteris_Poland] --- S_P[Solteris_Poland]
    S_A --- NODELINK[NODELINK_Solteris_Atlanta_Solteris_Poland] --- S_P
    S_A --- PQC_A[PQC_Solteris_Atlanta]
    S_P --- PQC_P[PQC_Solteris_Poland]
    PQC_A --- PQCLINK[PQCLINK] --- PQC_P
  
```

Alarms

Element name	App name	Session name	Severity	User message	Detail	Occur time ↓	Release time
Solteris_Atlanta	QNC	N/A	Critical	Network cable disconnected	enp1s0f3	15/11/2024 15:26	
Solteris_Atlanta	QNC	N/A	High	Power supply unit out	Power Supply #2	07/11/2024 12:16	
Solteris_Atlanta	QNC	N/A	High	Power supply unit out	Power Supply #1	07/11/2024 12:16	
Solteris_Poland	QNC	N/A	High	Power supply unit out	Power Supply #2	07/11/2024 11:40	
Solteris_Poland	QNC	N/A	High	Power supply unit out	Power Supply #1	07/11/2024 11:40	
Solteris_Poland	QNC	N/A	Critical	Network cable disconnected	enp2s0f2	07/11/2024 11:23	
Solteris_Poland	QNC	N/A	Critical	Network cable disconnected	enp2s0f1	07/11/2024 11:23	
Solteris_Poland	QNC	N/A	Critical	Network cable disconnected	enp1s0f2	07/11/2024 11:23	
Solteris_Poland	QNC	N/A	Critical	Network cable disconnected	enp1s0f3	07/11/2024 11:23	

Hybrid PQC + QKD Hybrid PQC + QKD KMS setup

The screenshot displays the QMS Web App interface for configuring a Hybrid PQC + QKD KMS setup. The interface is dark-themed and includes a navigation bar at the top with the text "QMS Web App" and a user profile icon labeled "admin". Below the navigation bar, there is a breadcrumb trail "Home > Paths".

The main configuration area is titled "Paths" and includes several controls: "Filters", "Groups" (with a dropdown arrow), "Selected KMS Node" (with a dropdown arrow), "Primary path" (with a green square indicator), "Secondary path" (with a blue square indicator), and a "DEPLOY GROUP" button.

The configuration panel is divided into two main sections:

- Consumer connections:** This section includes an "ADD CONNECTION" button and a list of connections. One connection is visible: "CONSLINK_Solteris_Atlanta_Solteris_Poland" with a sub-label "Solteris_Atlanta → Solteris_Poland". Below this, there are fields for "Source Consumer" (CONSLINK_Solteris_Atlanta) and "Destination Consumer" (CONSLINK_Solteris_Poland). There are also fields for "KMS Vid" (V3000000100001) and "KMS Vid" (V3000000200001).
- Path configuration:** This section includes fields for "Primary path" (Solteris_Atlanta → Solteris_Poland) and "Secondary path". There is a "CREATE SECONDARY PATH" button.

Below the path configuration, there are several configuration parameters:

- Fall over period:** 30
- Fall over mode:** Automatic
- Max key count within buffer:** 100
- Max key number per request:** 2
- Min key size allowed:** 256 bit
- Max key size allowed:** 256 bit
- Default size of key:** 256 bit
- Min key request interval:** 250 mSec
- Minor key store rate warning threshold:** 10 %
- Major key store rate warning threshold:** 30 %
- Critical key store rate warning threshold:** 20 %
- Pre shared key:** 8BE493F32866EE40FDB3F29AD

On the right side of the interface, there is a world map showing a green line connecting two locations, likely representing the physical connection between the source and destination consumers.

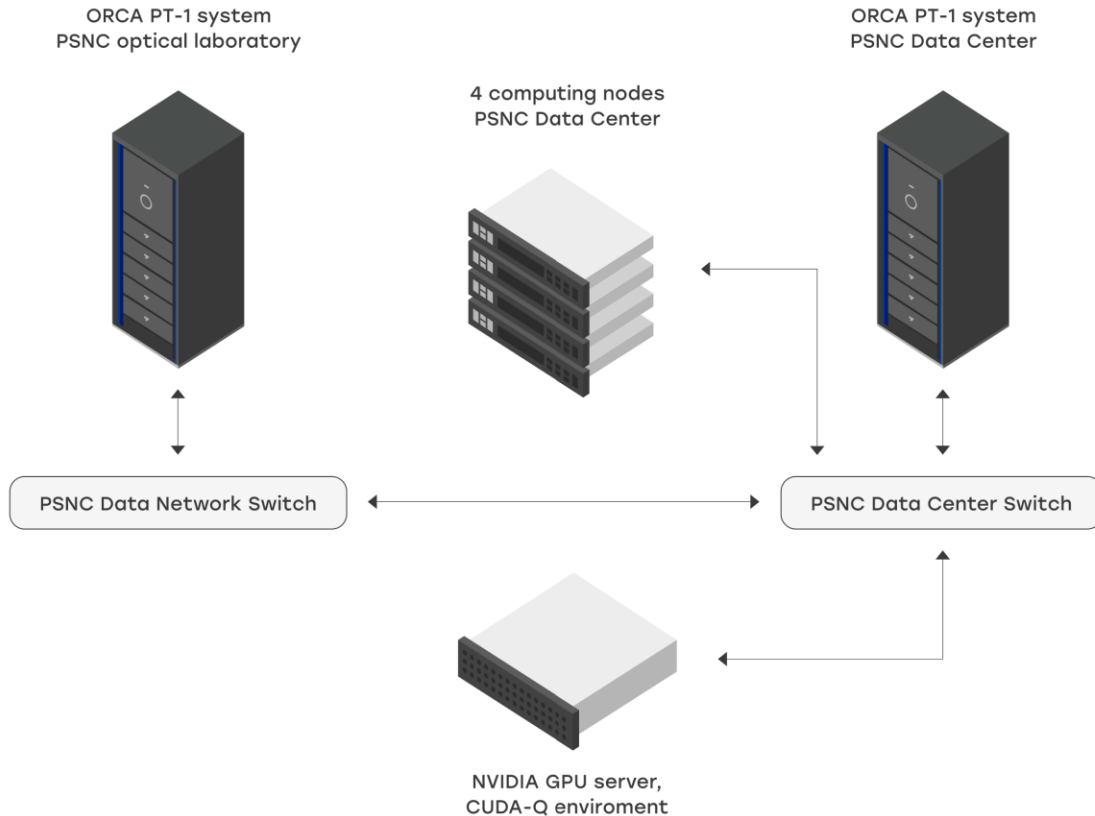
Example ETSI GS QKD 0014 calls for the demonstration

```
$ curl --cert KME1.crt --key KME1.key -H "Content-
Type:application" -X POST -d '{"number": 2, "size": 256}'
https://KME1/api/v1/keys/CONS_Solteris_Atlanta/enc_keys
{
  "keys": [
    {
      "key": "hqj8fP3WEsk0DL5KAsPBI4RHyQ32eIk5phPSDXqI1AE=",
      "key_ID": "0502c714-981a-4c17-81b8-0bfda7750a87"
    },
    {
      "key": "8I6vOJgjUAoqFNWijtZPOI5uArTHj9nvNWWvSkIDDD0=",
      "key_ID": "5009cb97-70f4-48e2-bcc7-a5c2219a1cd9"
    }
  ]
}
```

Multi-QPU, multi-GPU, multi-CPU hybrid setup

- PSNC designed and integrated a hybrid setup, consisting of a multi-CPU HPC cluster connected to a virtualized NVIDIA GPU cluster and two ORCA PT-1 quantum computers
- Specific software, including NVIDIA CUDA-Q library was installed for hybrid quantum-classical algorithm execution. Quantum Computer simulator is also available in the implemented environment
- SLURM licence mechanism is used to access and reserve QPUs
- A hybrid neural network consisting of classical and quantum layers for biological image classification use case was implemented

Multi-QPU, multi-GPU, multi-CPU hybrid setup



Usage of slurm with licence mechanism for QPU access

```

mslysz@quantum-ui/home/quantum/demo
[mslysz@quantum-ui demo]$ s1
NODELIST                STATE CPUS   S:C:T     MEMORY   AVAIL_FEATURES GRES
quantum-cpu-01         idle  128    2:32:2    2063752   (null) (null)
quantum-cpu-02         idle  128    2:32:2    2063752   (null) (null)
quantum-cpu-03         idle  128    2:32:2    2063752   (null) (null)
quantum-cpu-04         idle  128    2:32:2    2063752   (null) (null)
quantum-gpu-01         idle   64    2:16:2    515579    Tesla_V100 gpu:1
[mslysz@quantum-ui demo]$ sbatch -L orca1:1,orca2:1 slurm_multi_demo.sh
Submitted batch job 399
[mslysz@quantum-ui demo]$ sq
JOBID PARTITION NAME   ST          SUBMIT_TIME      TIME  TIME_LIMIT NODES NODELIST(REASON) NODELIST  MIN_CPUS CPUS TRES_PER FEATURES USER
  399      all test     R 2024-10-11T17:20:18  0:06   30:00     1 quantum-gpu-01  quantum-gp 2      2  gres/gpu (null)  mslysz
[mslysz@quantum-ui demo]$

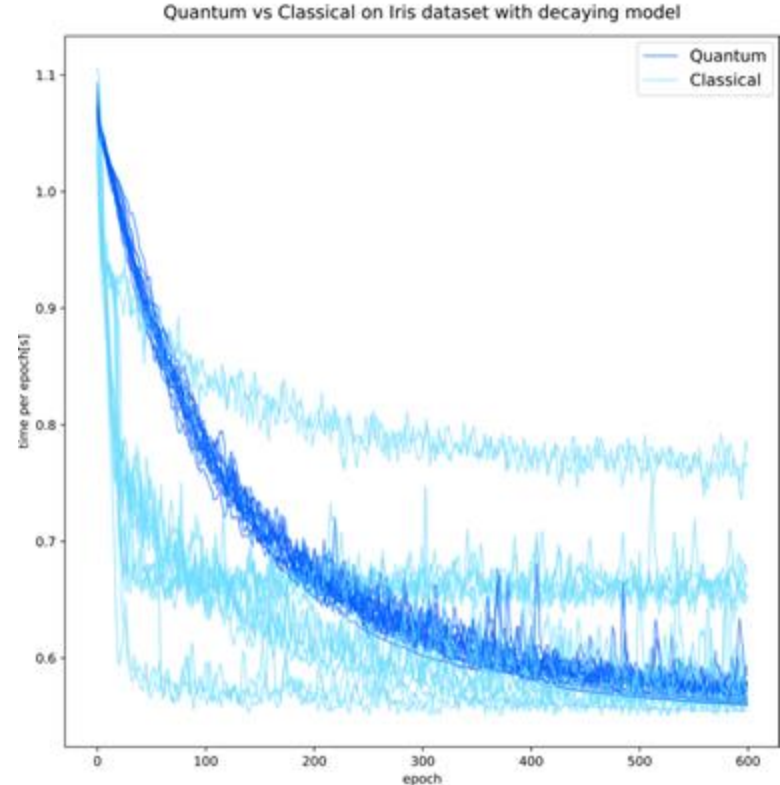
```

Slurm screenshot with licence mechanism used

- SLURM licence mechanism allows to reserve one or both ORCA PT-1 quantum computers.
- SLURM allows efficient job queuing and monitoring.

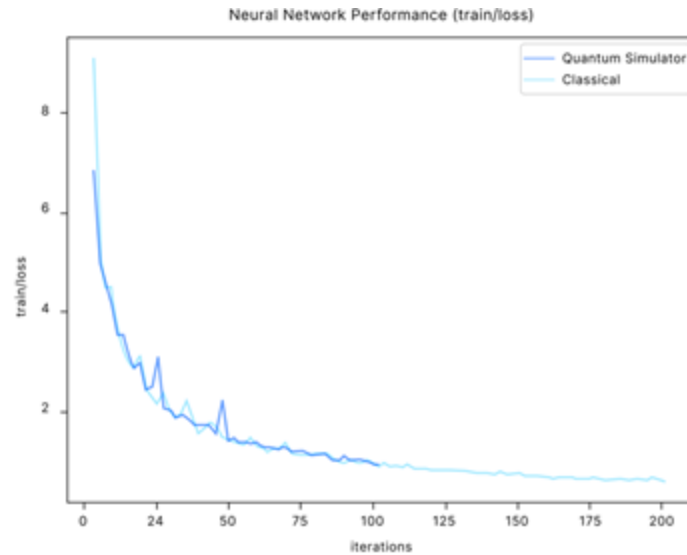
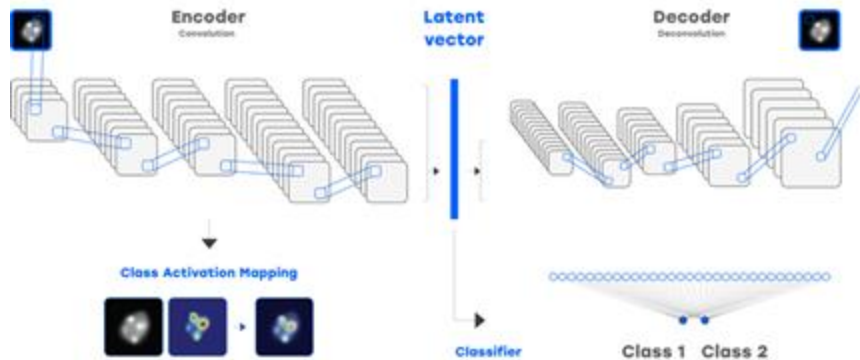
Use case development - initial tests

- Initial tests on smaller models and datasets were performed to test the setup.
- Quantum neural network shows more stable learning process and yields more stable results.



Multi-QPU, multi-GPU, multi-CPU hybrid setup

- NucAI nuceli classifier for detecting SCA_7 in test subject's cells





Thank You

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