Center for Quantum Technology and Applications
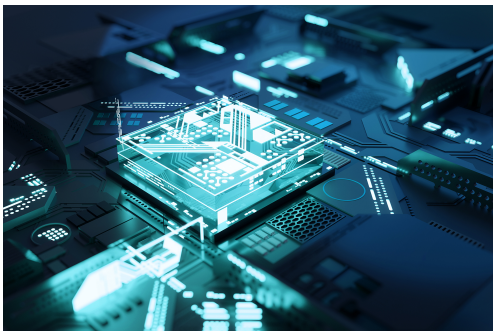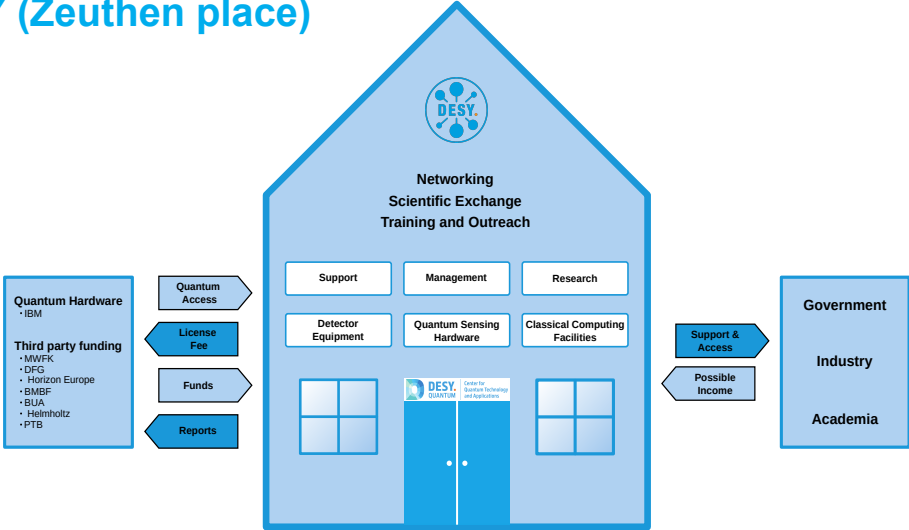
CQTA

Karl Jansen
Berlin, ISQCMC , 5.10.2023

DESY.

Overview
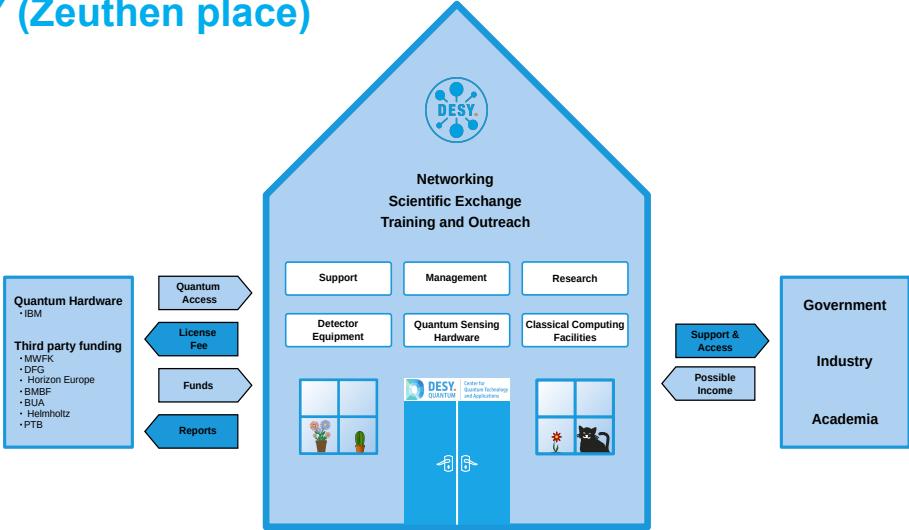

> Center for Quantum Technology and Applications
> Optimal Flight Gate Assignment
> Conclusion

Center for Quantum Technologies and Applications at DESY (Zeuthen place)

Networking
Scientific Exchange
Training and Outreach

Support | Management | Research

Detector Equipment | Quantum Sensing Hardware | Classical Computing Facilities

Quantum Hardware
· IBM

Third party funding
· MWFK
· DFG
· Horizon Europe
· BMBF
· BUA
· Helmholtz
· PTB

Quantum Access

License Fee

Funds

Reports

Support & Access

Possible Income

Government

Industry

Academia

# Center for Quantum Technologies and Applications at DESY (Zeuthen place)

The CQTA group

> The present group in Zeuthen

Quantum computing the flight gate assignment problem

> A classical optimization problem: flight gate assignment
(Y. Chai, L. Funcke, T. Hartung, S. Kühn, T. Stollenwerk, P. Stornati, K. Jansen,
arXiv:2302.11595)

> Find shortest path between connecting flights

> Different incoming and outgoing flights
need to be assigned to gates
$\rightarrow$ find optimal assignment

> Classical optimization problem
$\rightarrow$ quantum advantage?
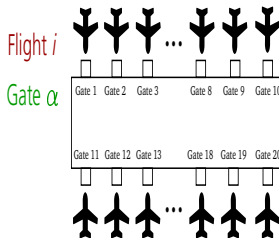
Quantum computing the flight gate assignment problem

> binary variables encoding gates and flights

$$x_{i\alpha} = \begin{cases} 1, & \text{if flight } i \in F \text{ is assigned to gate } \alpha \in G \\ 0, & \text{otherwise} \end{cases}$$
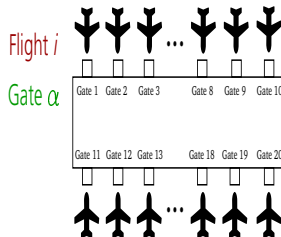
$x \in \{0,1\}^{F \otimes G} \rightarrow x$ binary variable $\rightarrow x \in \{-1, 1\}$

eigenstate of third Pauli matrix σ_z

> leads to mathematical description of Hamiltonian
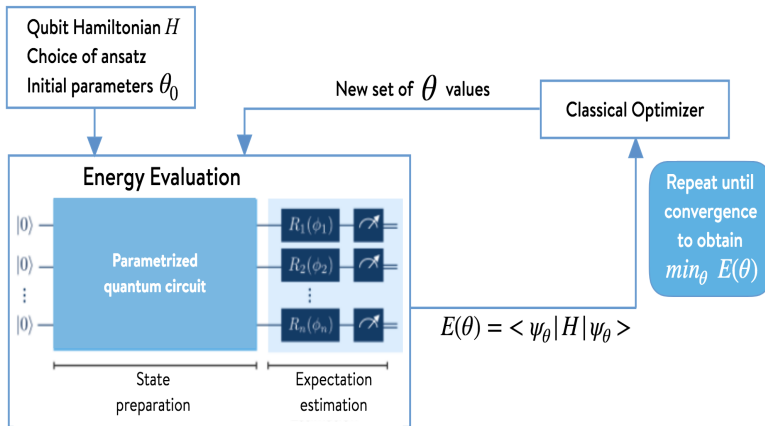
$$H = \sum_{j=1}^{n} Q_{jj} \sigma_j^z + \sum_{\substack{j,k=1 \\ j<k}}^{n} Q_{jk} \sigma_j^z \otimes \sigma_k^z$$

> Task: find lowest energy $\Leftrightarrow$ shortest path

> Same mathematical description for problems in **traffic, logistics, particle tracking,**

...

Flight i

Gate α

Gate 1 Gate 2 Gate 3   Gate 8 Gate 9 Gate 10

Gate 11 Gate 12 Gate 13   Gate 18 Gate 19 Gate 20

Variational Quantum Eigensolver (VQE)

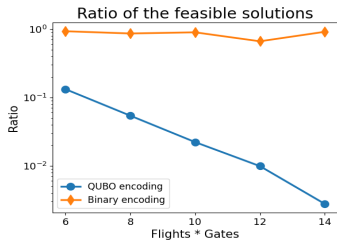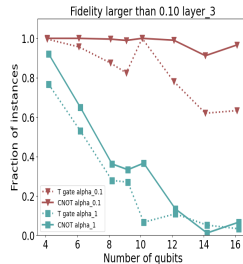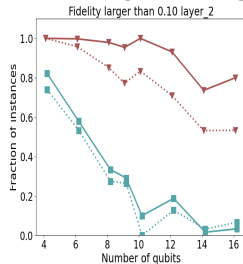> a hybrid quantum/classical variational approach

Quantum computing the flight gate assignment problem

> Started with QUBO implementation
> Implementation of various improvements
  – using binary encoding
  – reformulation of Hamiltonian through projectors
  – Using Conditional Value at Risk (CVaR)
> see indications of improvement through entanglement
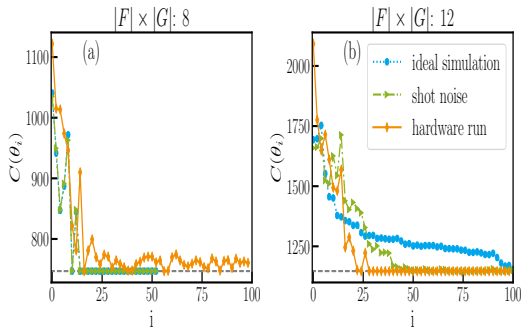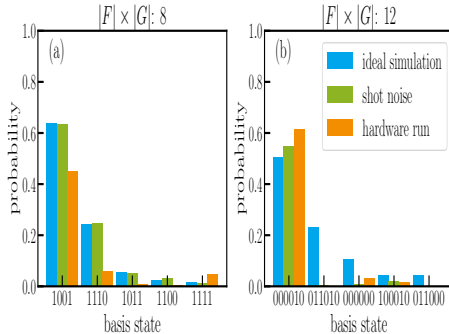

Feasible ratio   **role of entanglement**

Quantum hardware runs of flight gate assignment problem

(Y. Chai, E. Epifanovsky, K. Jansen, A. Kaushik, S. Kühn, arxiv:2309.09686)

> hardware runs on IonQ's Aria trapped ion quantum computer
> circuit: efficientSU2
> real VQE and inference runs

Convergence   **probabilities**