# Cryogenics for Quantum Computer Upscale challenges

Global Markets & Technologies

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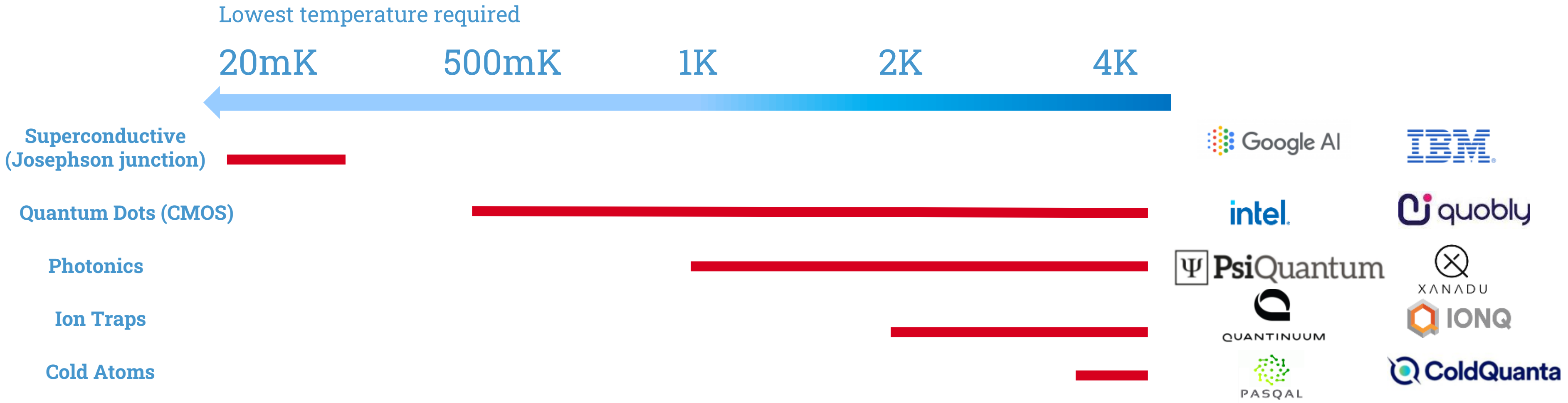
# Agenda

- Cryogenics for Quantum Computing
- Upscale challenges for Cryogenics
- Cryogenic distribution design as a key challenge
- Conclusion

# Cryogenics for Quantum Computing : Technologies

**The promise is to unlock computing speed by using quantum entanglement.**




Several technologies are on the run,
**all requiring cryogenic temperatures.**

Companies with ambitious roadmaps are working to **industrialize and up scale solution.**

# Cryogenics for Quantum Computing : Roadmaps

Equiv. Power@4.5K
Tens of kW

kW

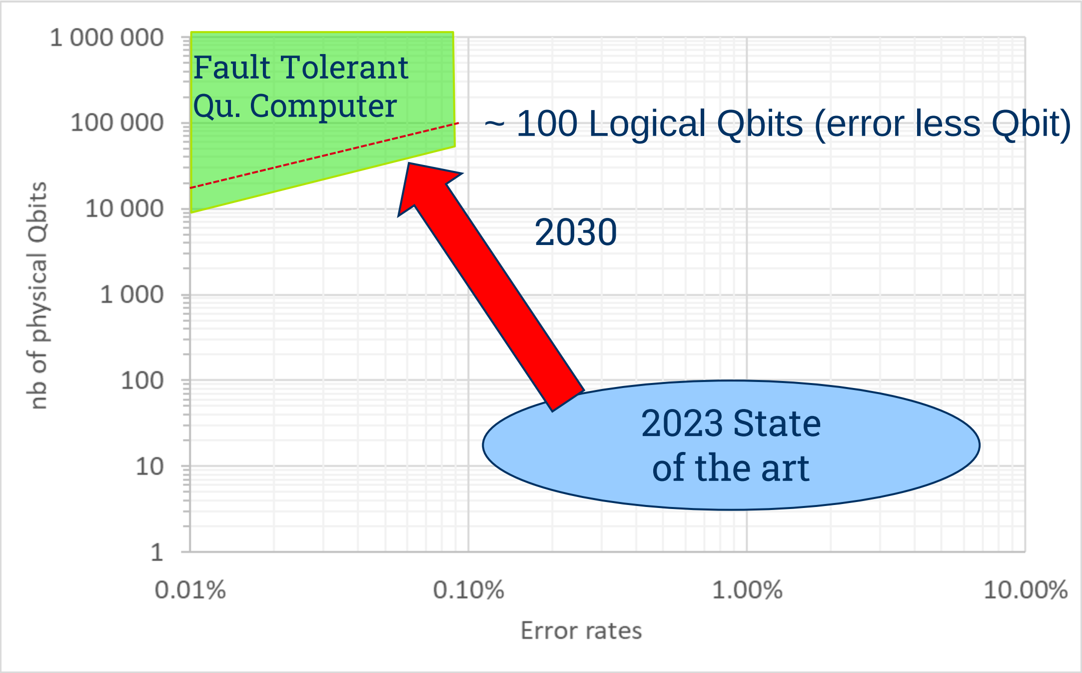
W

A **Quantum Bit** is the smallest phys. brick of Qcomputer, like a **transistor** for **classical computer**

**Q-Bit** makes errors: many Q-bits can simulate an error less Qbits (a logical Qbit)

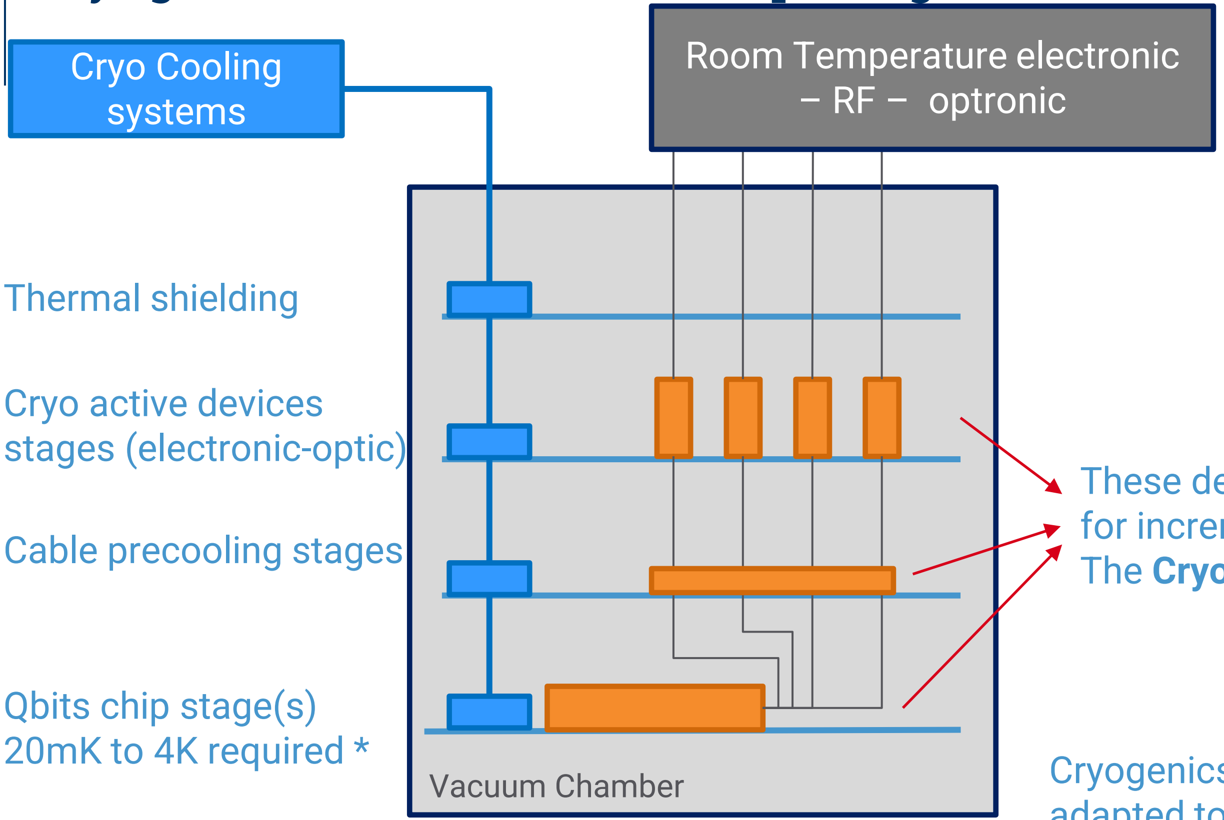
**Reducing error rates** reduced the number of physical Qbits required

**Cooling power** is linked to the number of **physical Qbits**.




The challenge is to increase the number of physical qbits and reducing the error rates by 2030 (~100 000 to 1 000 000 Qbits)

# Cryogenics for Quantum Computing : Quantum computer module

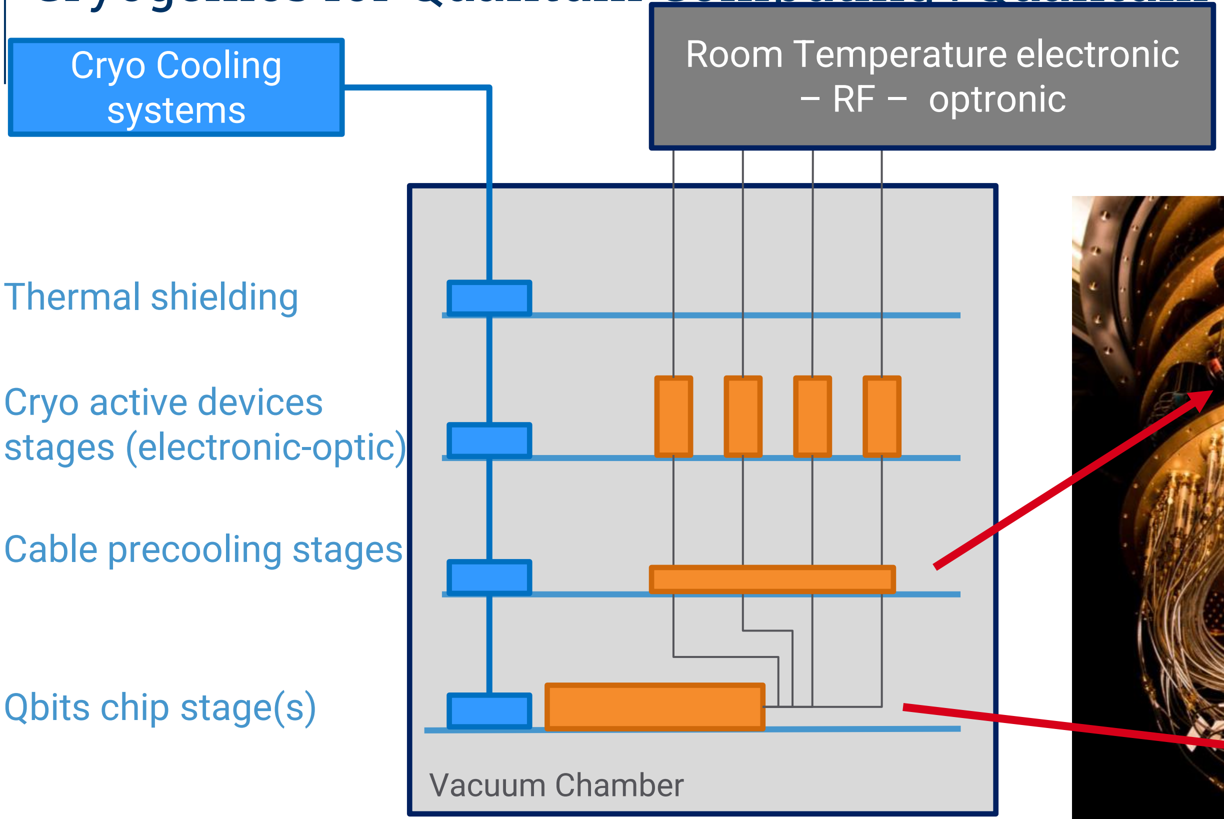


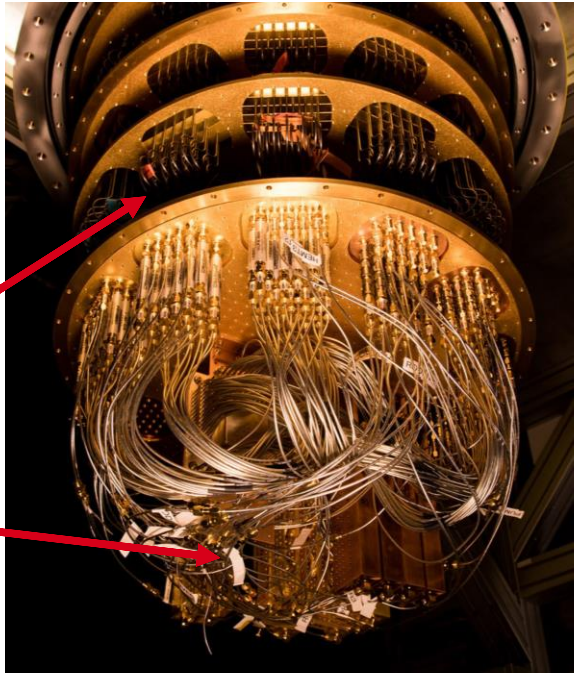

These devices have to be easily **replaceable** for incremental improvement or maintenance: The **Cryomodule** need a **dedicated design**

Cryogenics cooling systems have to be adapted to the **specific needs** (Power, Temperature, Form)

(*) depending of technology used

# Cryogenics for Quantum Computing : Quantum computer module



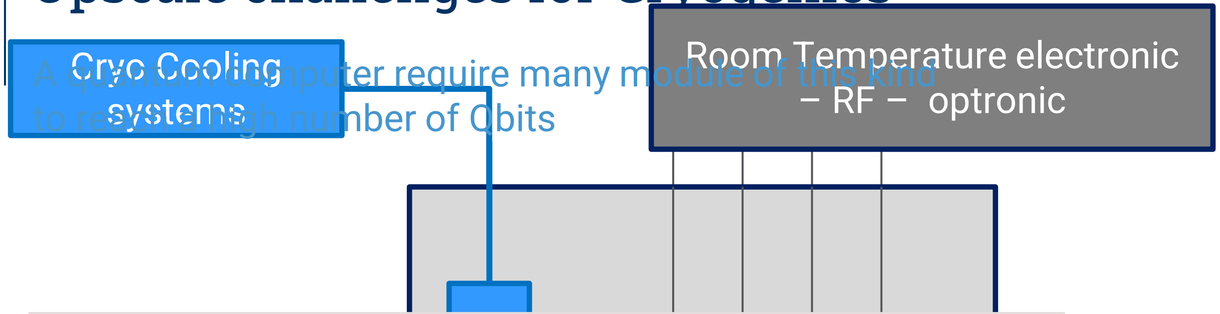



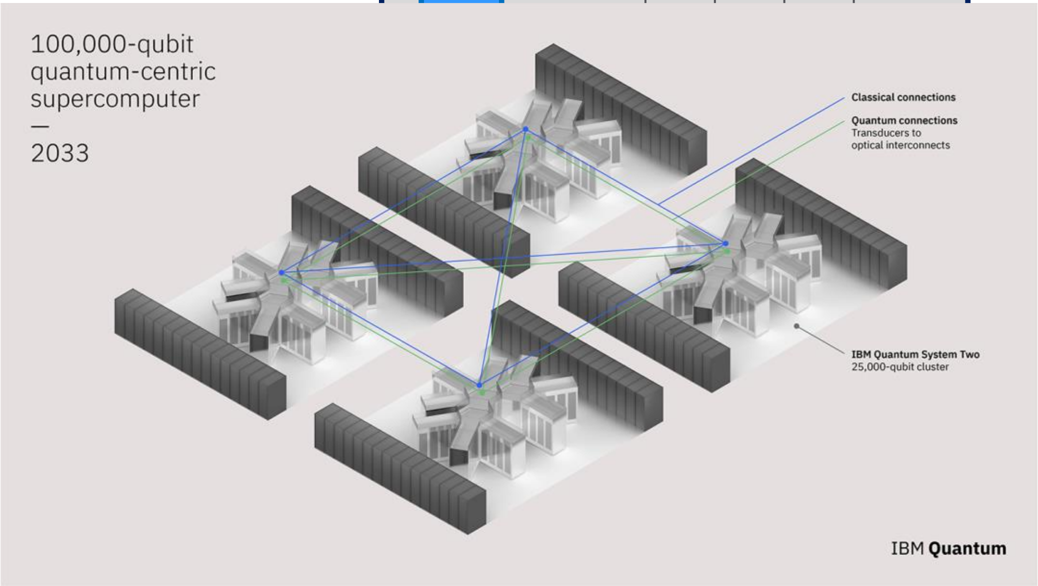
Josephson type

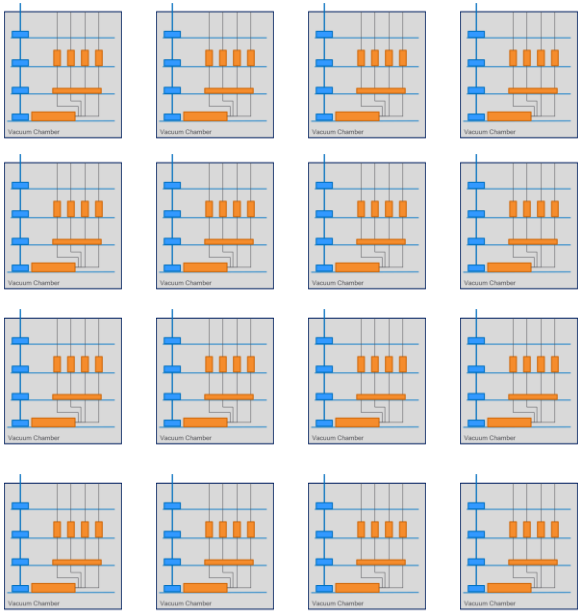
Credit: Google AI

# Upscale challenges for Cryogenics

A quantum computer require many module of this kind to reach a high number of Qbits



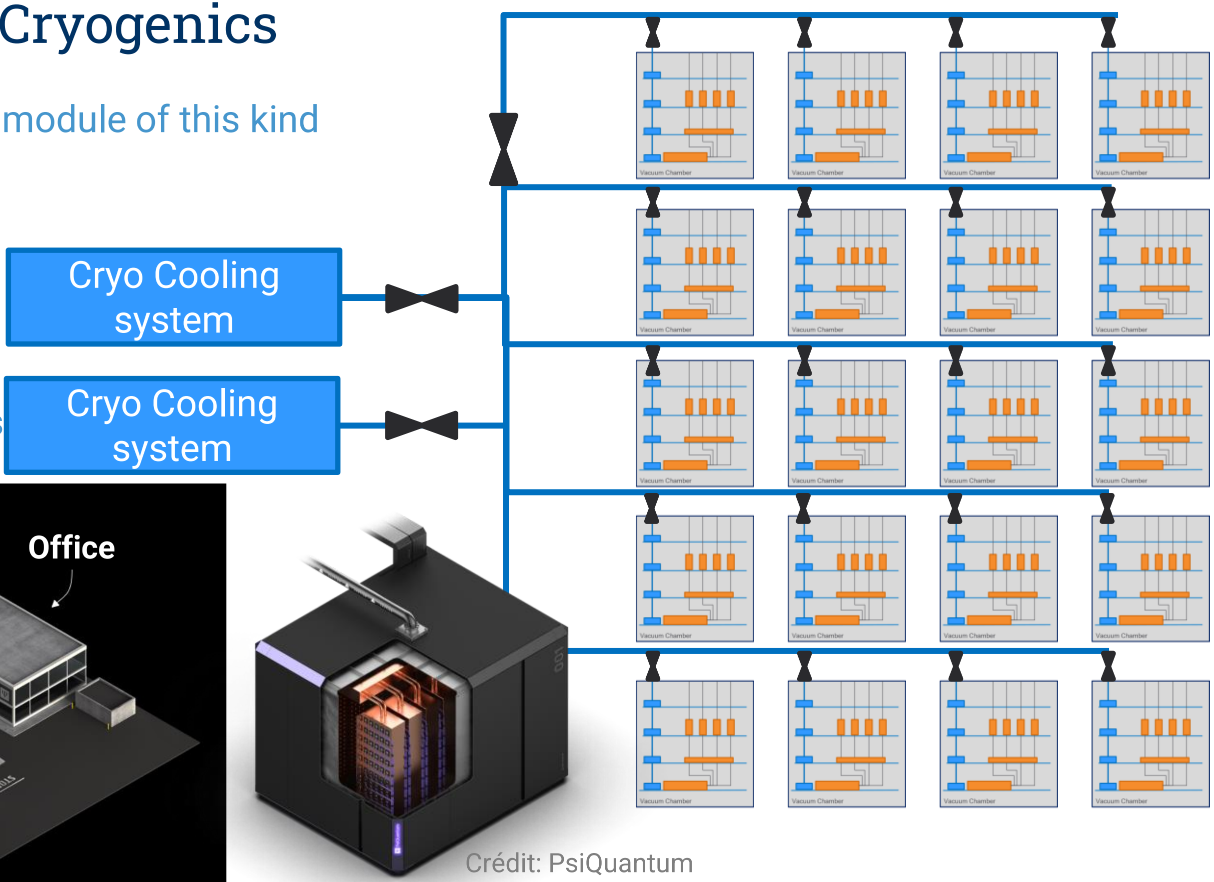

Crédit: IBM

# Upscale challenges for Cryogenics

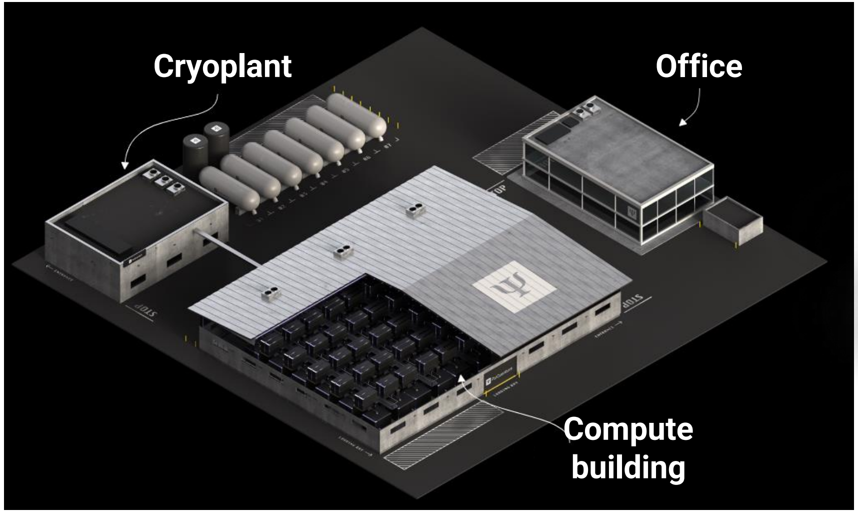
A quantum computer require many module of this kind to reach a high number of Qbits.

Cooling system has to be:

- **Efficient**
- **Reliable** – allow redundancy
- Allow module **maintenance**
- **Extend** the number of modules




Crédit: PsiQuantum




Valves & cryogenic lines need dedicated cooling power.

# Functionalities vs efficiency

## A distribution with

## 1) Few cryomodules (Tarla):

**2 modules – 1 control cold box**

**Cryomodules ~ 200 Wex@4.5K**

**Helial Refrigerator ~ 250 Wex**

**Distribution efficiency ~ 80%**

## 2) Numerous cryomodules (Spiral 2):

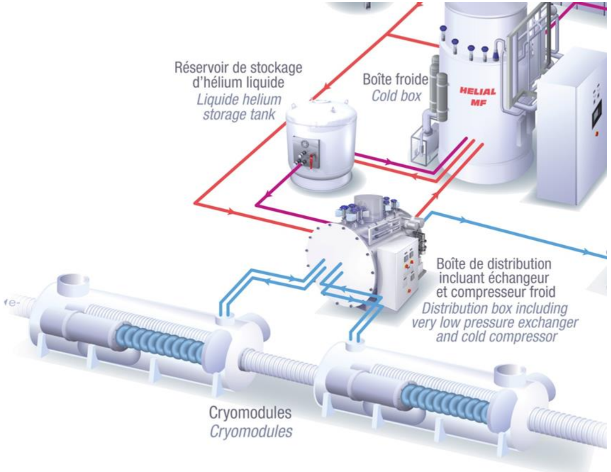
**19 modules – 19 control boxes**

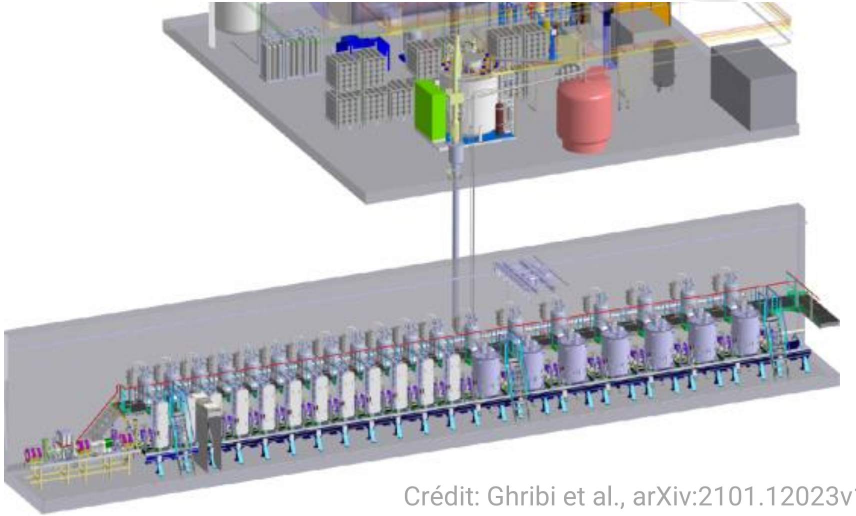
**Cryomodules ~ 400 Wex**

**Helial Refrigerator ~ 1200 Wex**

**Distribution efficiency ~ 33%**

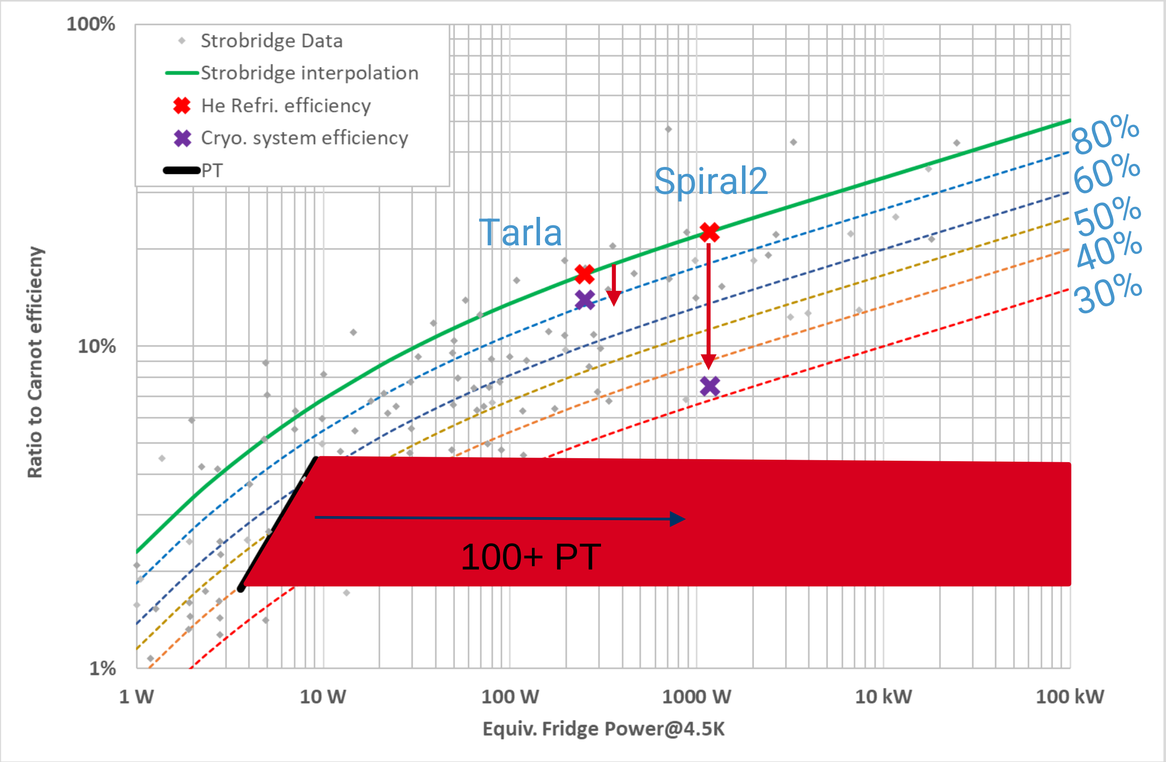
**=> Choice of distribution impact the fridge operation and specification**



Crédit: Ghribi et al., arXiv:2101.12023v1

# Cryogenic distribution design as a key challenge




Distribution can lower significantly the cryo. system Carnot efficiency

Distribution efficiency

Standard Pulse tube have distrib. efficiency ~100%

but with the upscale a **Helium Fridge** with a distribution is still **more efficient**

# Conclusion & Outlooks

- **Quantum computing** is a **fast developping** technology with a need of **high cryogenic power**
- The **efficiency** of the overall **cryogenic system** will depend on the **complexity** of the **cryo distribution.**
- The **cryogenic system** has to be **thought** as a whole **from cryomodule to cryoplant** to get the best tradeoff between **functionalities and efficiency.**
- The development of **quantum computing require the expertise of the cryogenic community from mK fridge up to Liquid Helium plant.**