

QUART&T-Bologna Meeting

03/07/2025

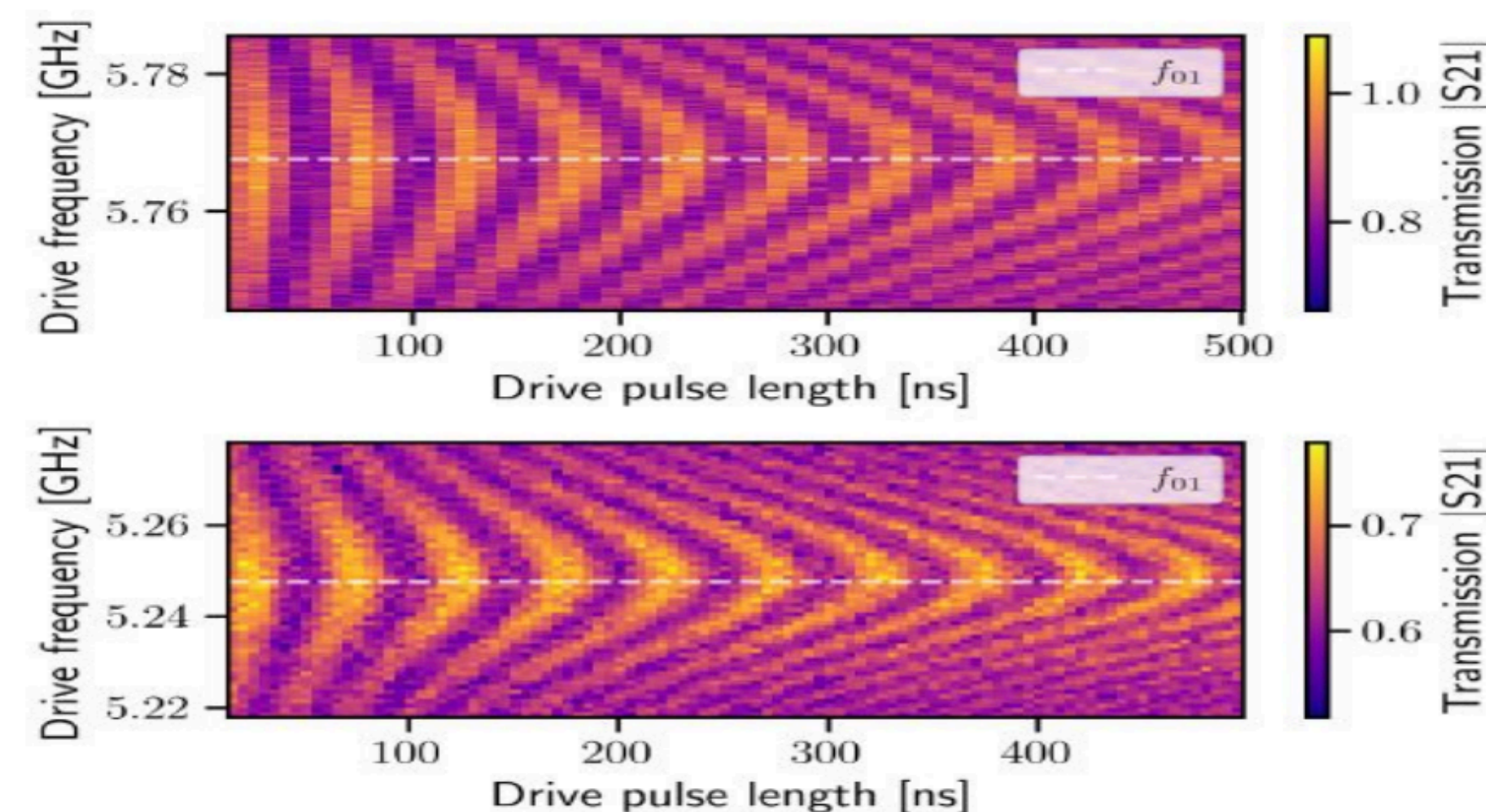
Matteo Franchini



Goal 2025/2026

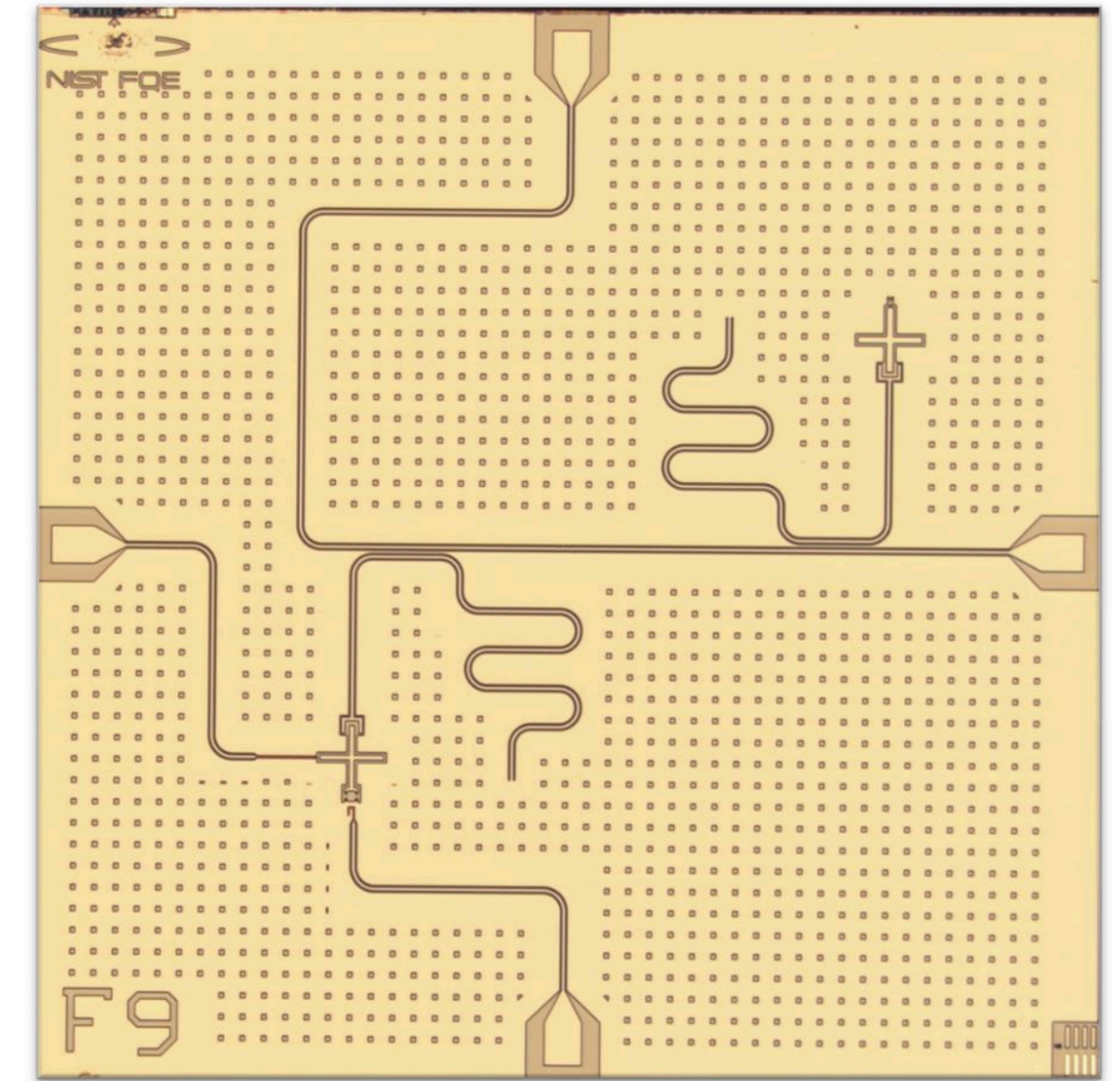
- * Design and produce *RFSoc board DAQ box* for transportable DAQ system
 - Include ZCU111, Wave generator, mixers, connectors, front-end, cooler ...
- * Configure ZCU111 using Qibo software for single and double qubit control/measure
 - Board limit is 4 qubit
 - Possible test/develop of Qibo for ZCU208 board

ZCU111 (Gen. 1) DAC up to 6 GSPS



Goal 2025/2026

- * Simulation and design of real qubit for physical purpose
 - Currently for neutrino interaction in dense environment
 - Other theoretical ideas...
 - Integrating Purcell Filter for noise reduction
- * Production of the chip
- * Measure on real qubit!!
 - Milano?
 - Frascati? (Qsight sw...)
 - FBK?



Purchase & Plan

* 2025 purchase ongoing

- VF100 board
- Signal Generator up to 15GHz
- High quality Mixers
- Some not comprehensive signal filters
- Differential converter -> single ended DC
- Box

* 2026

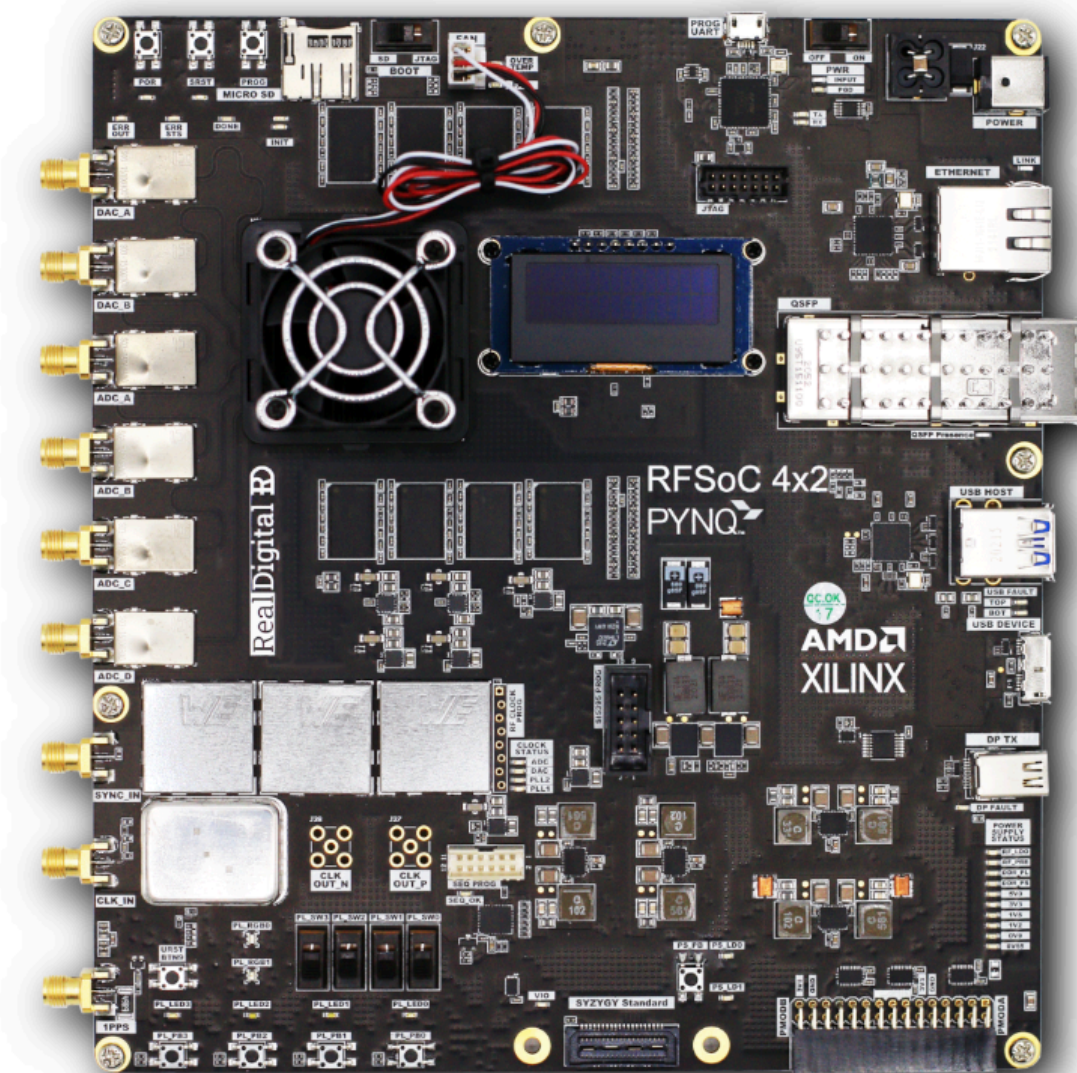
- Filters, connectors, cables, cooling, ...
- RFSoc 4x2 (single-qubit DAQ + signal gen. up to 10GHz)
- Simulation and DAQ PC - 128 GB RAM



ERASynth+ Signal Generator

1.809,00 €

inkl. MwSt., zzgl. Versand

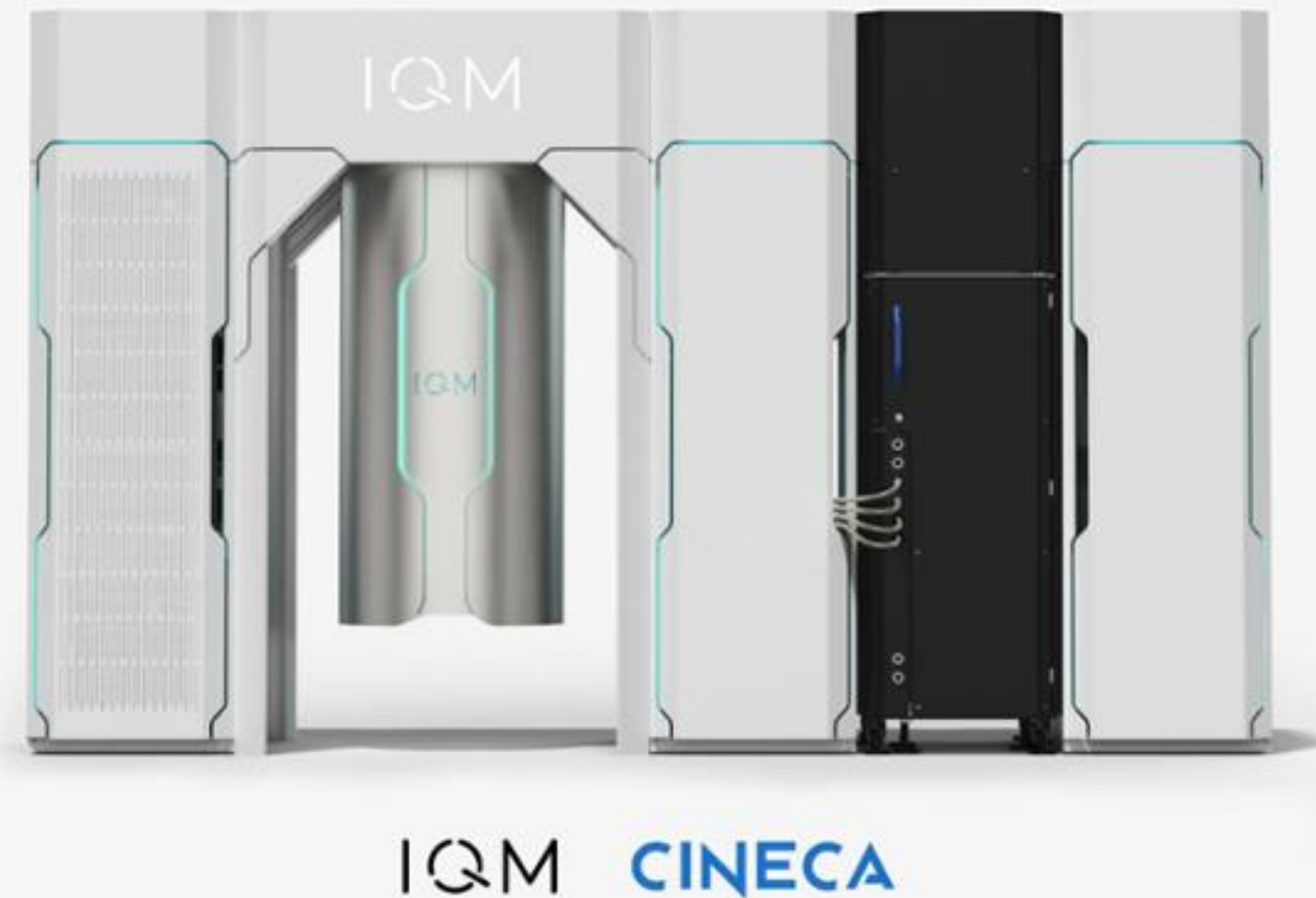


QML and beyond

- * Banchi will start QML work, mainly on error mitigation or design optimisation
- * Design QML circuit for future QUARTET architecture.
 - Study optimal design Q-GAN by UNIBO math group - possible interest in collaboration
 - Shadows of quantum machine learning for q. training-only (specific application)
 - Quantum unsupervised learning
- * Use CINECA resources for QML works

Understanding Quantum Machine Learning

Jun 25, 2025 - Jun 27, 2025



Conclusion

- * Still some money for missions... hurry up!

<https://docs.google.com/spreadsheets/d/1Y1yoTb-3HlNYb-A45cGQ95Tvyp9Qbf9RIXtETkcag4I/edit?gid=0#gid=0>

- * IQIS 2025 - **Bologna** 8-12 settembre - <https://events.unibo.it/iqis-2025/registration>

- * Next Meeting end July

- * Curiosity of today: "Limite quantistico infranto: risultato storico" <https://www.tomshw.it/scienze/protocollo-quantistico-raggiunge-precisione-limite-2025-07-02>



Backup

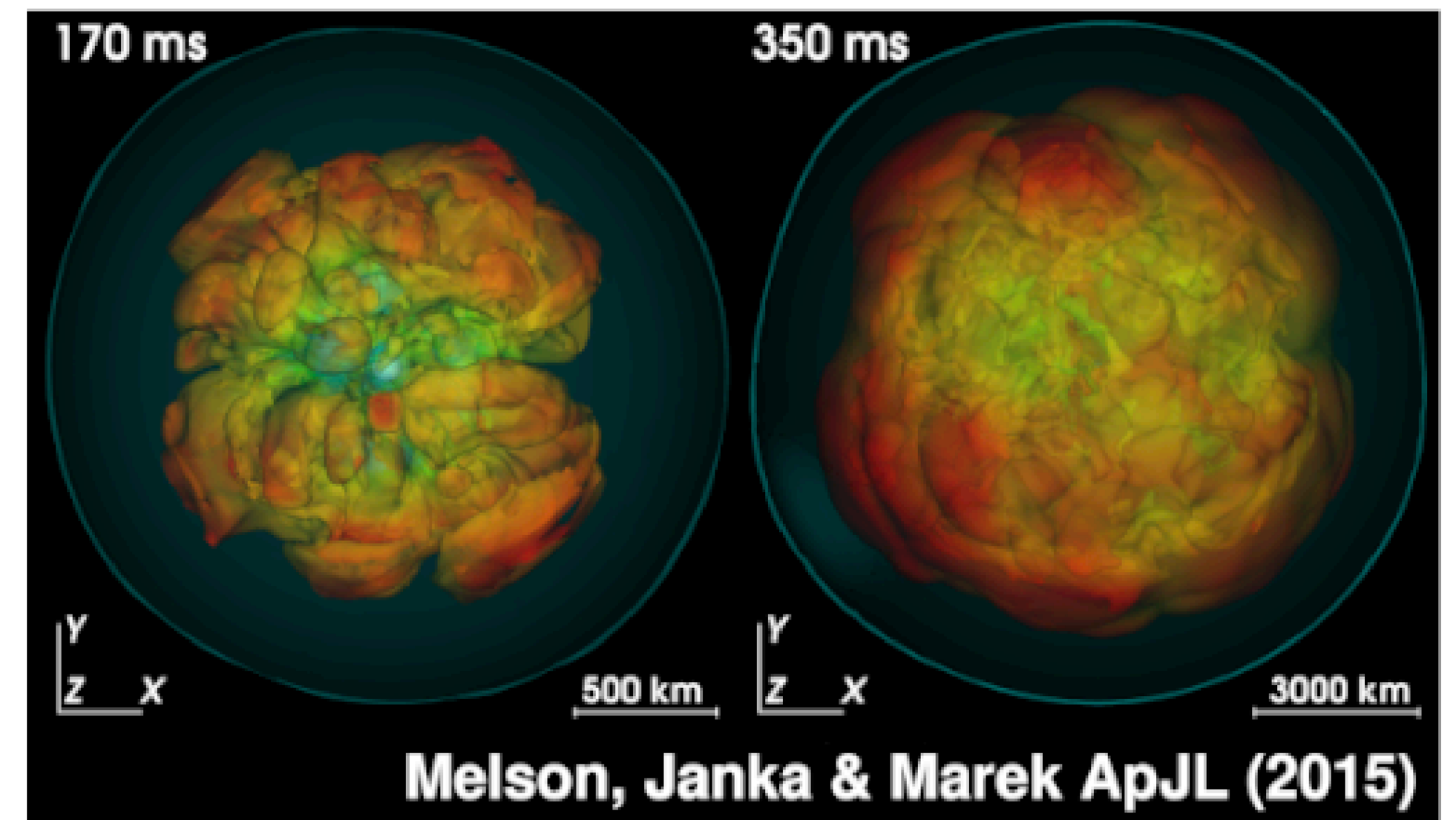
Neutrinos oscillations in dense environments

- * In **high-density neutrino environments** — such as supernovae, neutron star mergers, or the early universe — neutrino flavor oscillations are significantly affected by neutrino-neutrino interactions.
- * Until now, approaches have relied on the mean-field approximation. However, to understand the role of **quantum correlations, such as entanglement**, an exact solution is necessary.
- * The Hamiltonian for a two flavors oscillation can be written as:

$$H = \sum_{k=1}^N \vec{b} \cdot \vec{\sigma}_k + \sum_{p < q}^N J_{pq} \vec{\sigma}_p \cdot \vec{\sigma}_q$$

with $\vec{\sigma}_k = (\sigma_k^x, \sigma_k^y, \sigma_k^z)$

- * By now with only 2 flavors direct map to spin 1/2 degrees of freedom (qubits) and only one- and two-body interactions \Rightarrow only $O(N^2)$ terms
 - **Issue:** all-to-all interactions are difficult with reduced connectivity



Neutrinos oscillations in dense environments

- * **Fully exploit all-to-all interactions** in full analog simulations for simple geometries

- * perform **hybrid analog digital simulations** obtaining:

- useful depth reductions if we could implement

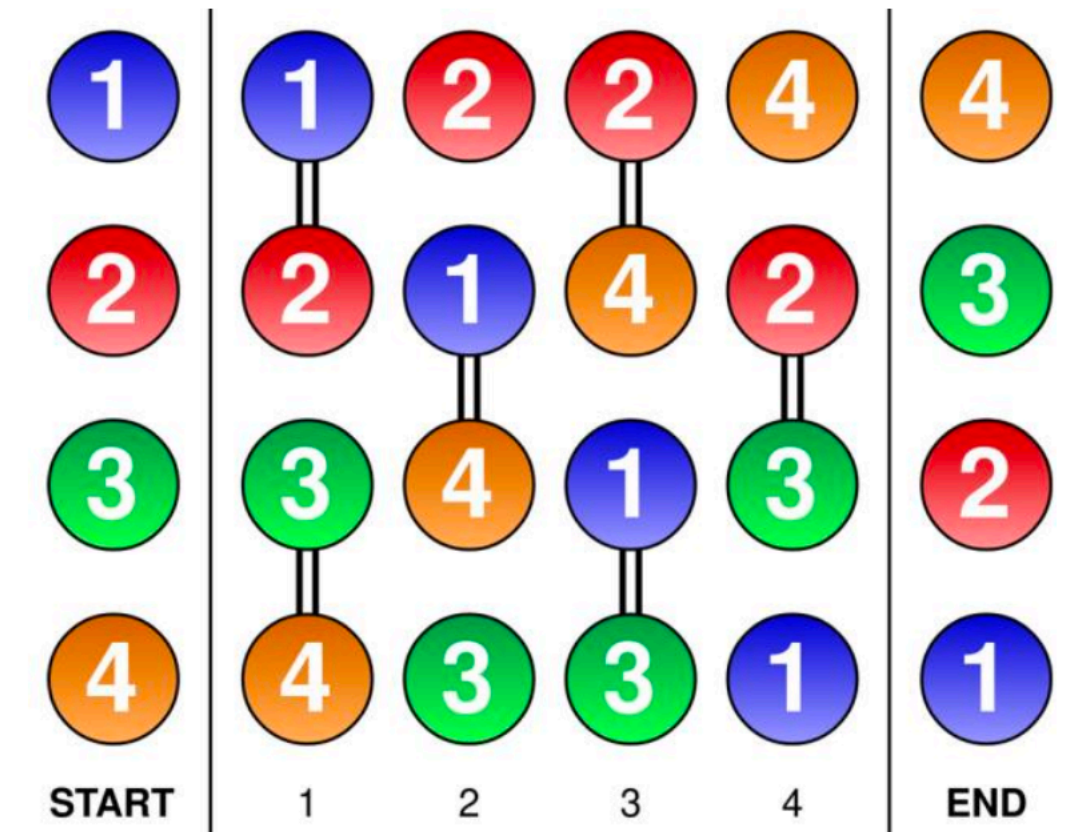
$$U_{really-nice}(\vec{\theta}) = \exp(i \sum_{i,j} \theta_{ij} Z_i Z_j)$$

- study 3 flavour problem on quTrits

- * **Idea:** use the energy repulsion between $|00\rangle$, $|02\rangle$ and $|11\rangle$ to realize an effective ZZ interaction on the computational subspace;

[Nature 460, 240–244 (2009)]

- * Ongoing work on this thread **[more info by Simona]**



Scheme to realize a single time-step simulation.

Each double line is formed by $3 \binom{N}{2} \text{CNOT} + 15 \binom{N}{2}$ single qubit gates.

**Needs to find other TH tasks for different chip design. Pederiva? Some ideas here in Bologna (Elisa).
New master student involved.**

Preventivi 2026 and next

INFN-BO					
Capitolo	Descrizione	1st Y [k€]	2nd Y [k€]	3rd Y [k€]	Total [k€]
Consumo	Consumo generale RF (filtri, connettori ecc.)	4	6	6	16
Consumo	2 mixer RF MM1-0212LS , 2 splitter/combiner RF	1.5	0	0	2.5
Inventario	Scheda VF-100 per accedere a tutti i canali ADC/DAC della scheda ZCU111 (già presente in sezione)	6	0	0	6
Inventario	Generatore RF TTi (10-6000 MHz) per up/down conversion analogica	0	6	0	6
Licenze-SW	Contributo CNAF per licenza Ansys	2.5	2.5	2.5	7.5
Missioni	Missioni presso altri laboratori per sessione di lavoro congiunte e misure	6	6	6	18
Total		20	20.5	14.5	55