

SQMS-INFN: un anno dopo...

lele tripiccone

INFN - Sezione di Ferrara

tripiccone@fe.infn.it

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On the Menu today

- SQMS: “cose dette...”
- SQMS: chi siamo, cosa vogliamo
- Spunti di quello che diranno i vari speaker
- Situazione Post-Docs
-

The DOE-SQMS Center

The goal of the SQMS project has to be bold enough to make funding agencies happy

With the **Superconducting Quantum Materials and Systems** Center (SQMS), we bring the power of DOE laboratories, together with industry, academia and other federal entities, to “achieve transformational advances in the **major cross-cutting challenge** of understanding and eliminating the decoherence mechanisms in superconducting 2D and 3D devices, with the final goal of enabling construction and deployment of superior quantum systems for **computing and sensing**.”



The DOE-SQMS Center

The goal of the SQMS project has to be bold enough to make funding agencies happy

Processor Metrics	Leading Systems	Center Prototypes (3 yr)		Center Device Goals (5 yr)	
		2D-Alpha (estimate)	SRF-Alpha (estimate)	SQMS-2D (estimate)	SQMS-3D (estimate)
Number of qubits	53	128	>100	256	>200
Connectivity graph (qubit:neighbors)	1:4	1:3	1:10	1:3	1:200
Qubit T_1 lifetime, us (median)	70	200	400,000	400	1,000,000
Gate time, ns (median)	20	50	2000	40	100
Coherence/gate time ratio	1,000	4,000	20,000	10,000	100,000,000
Single qubit gate fidelity (%)	99.85	99.6	99.5	99.95	99.95
Two qubit gate fidelity (%)	99.65	99.2	99.5	99.9%	99.95
Achievable circuit depth (1/error)	300	100	200	1,000	2,000

The Timeline

- Marzo 2020: progetto presentato al DOE
- Settembre 2020: Progetto informalmente approvato dal DOE
- Ottobre 2020: Inizio ufficiale del progetto
- Febbraio 2021: MoU tra INFN e FNAL
- Aprile 2021: Progetto "ufficialmente riconosciuto" dall' INFN
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- Settembre 2025: Chiusura formale del progetto

- SQMS € 1137420
- SQMS-FOE € 237250

Chi siamo??

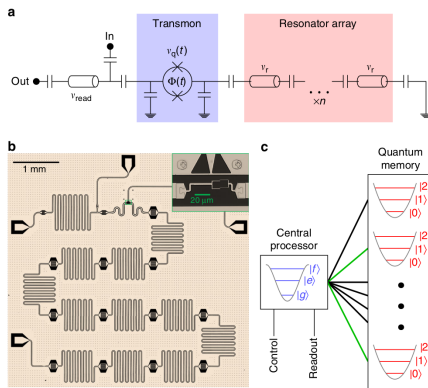
Struttura	Coordinatore locale
GGI	S. De Curtis
LNGS	C. Bucci
LNL	G. Ruoso
Sezione di Ferrara	R. Tripiccone
Sezione di Firenze	L. Banchi
Sezione di Padova	C. Braggio
Sezione di Pavia	L. Maccone
Sezione di Roma I	L. Cardani

Approssimativamente 20+ persone attualmente nella mailing list.

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The fundamental bet:

- start from this “general purpose” QC-architecture:



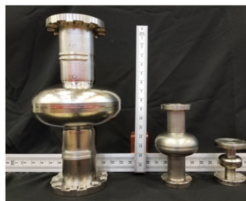
$$H = h\nu_q(t)a^\dagger a + \frac{1}{2}h\alpha a^\dagger a(a^\dagger a - 1) + \sum_k h\nu_k b_k^\dagger b_k + \sum_k hg_k(b_k + b_k^\dagger)(a + a^\dagger)$$

- each (poorly engineered) “resonator” is a two-state qbit; this is an 11 qbit Q-computer

The DOE-SQMS Center

The fundamental bet:

- replace solid-state waveguides by superior quality SRF resonators



[Fermilab SRF resonators](#)

$$Q > 10^{10}$$

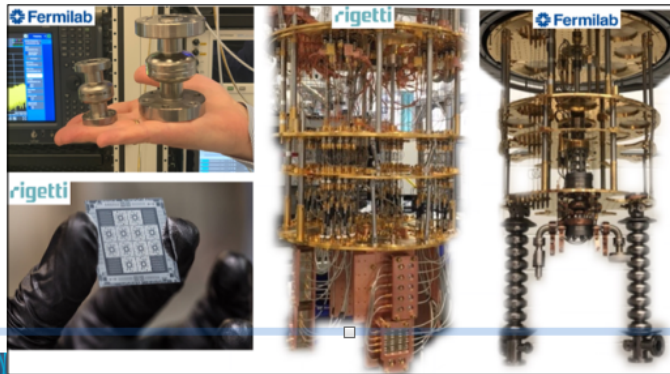
$$T_{\text{coherence}} > 1 \text{ s}$$

- hope to control up to $2^{14} \simeq 16000$ energy levels in each cavity;
couple together 9(+9) cavities;
equivalent system of $9 \times 14 \geq 120$ qbit (the qdit approach).

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A theory + technology challenge:

ONE nine cell SRF cavity + **ONE** transmon =
SQMS 100+ qubits processor



Cosa vogliamo fare

- our view: team with a large/high level community, learn & contribute
- Our contributions / expectations →
 - theory at the foundational / metrological levels
 - theory and algorithms for quantum applications
 - measure and mitigate the negative impact of radioactive background
 - contribute/improve our expertise in superconducting cavities
 - couple transmons and (B -friendly) cavities
 - find the axion
 - make LNGS (and other places?) a national test/characterization facility for Quantum devices
 - Ph.D. schools/workshops/conferences at GGI (and elsewhere)
 - help young people enter this field

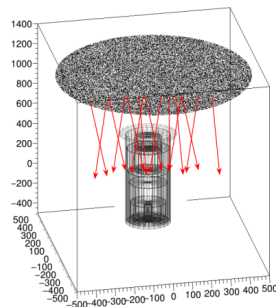
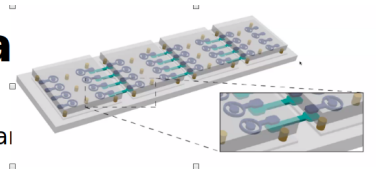
Updates from INFN-Roma

- Inter-laboratory comparison for Round Robin

- Most of the components for the cryostat procured and (almost) installed
- Waiting for room-T electronics from FNAL, to be delivered by end of October
- Participation to 2 working groups to establish measurement protocol

- Evaluation of the contribution of radioactivity to SQMS prototypes

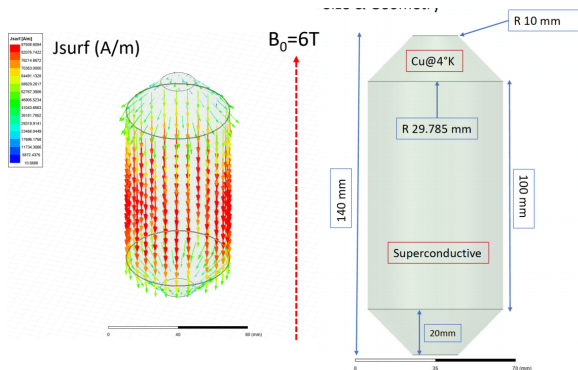
- Measurements of the majority of components done or ongoing
- Simulations ongoing
- New device to measure phonon transmission in Rigetti processor



INFN NbTi-Cavity at 3.9 GHz for FNAL

Mode	TM010
Frequency	3.965 GHz
Expected quality factor (B=0, NbTi walls, Cu endcaps)	1.64×10^6

- Fabrication at LNF
- NbTi Sputtering at LNL
- Measurements at FNAL at 4K in 6T magnet



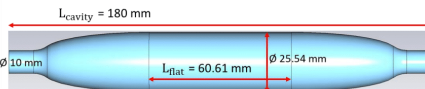
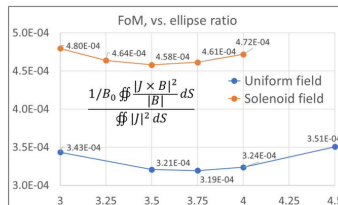
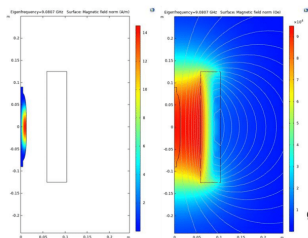
Ansys Hfss simulations (S.Tocci, LNF)

$R_s^{Cu} = 2.8 \text{ m}\Omega$, in Ansys obtained by using a conductivity of $2e+9 \text{ S/m}$

FNAL Nb3Sn Cavity at 9 GHz for LNF

Frequency 9.08 GHz

L=250 mm, ID=118 mm, OD=208 mm
Maximum B_0 on the axis 9.2T

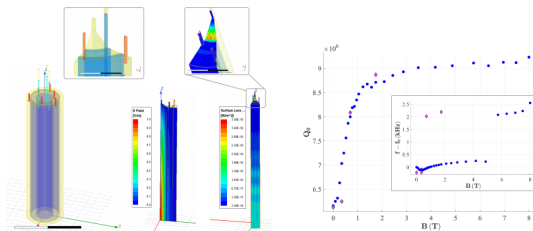


Optimized geometry with solenoid field. Ratio is 3.5

M.Checchin (FNAL)

Cose fatte / cose in corso : 3

- **Dielectric cavity:** paper draft finalized



- **Post Doc recruitment:** 2 candidates applied, interview (zoom) on the 19/10/2021
- Invitation to a negotiated procedure tender for the award of a contract for the supply a cryostat with a **dilution refrigerator** was sent to 5 vendors.
On 22/10/2021 we will know which ones have applied.

- **Haloscope readout by an itinerant counter:**
 - initial tests on copper cavity done,
 - ~ 3 design of T-field magnet finalized



Cose fatte / cose in corso : 4 - Theory

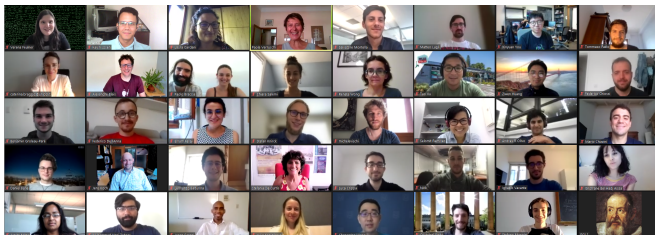
Lista parziale:

- Squeezing metrology for axion searches or dark photon searches
- Using similar ideas to find "the most quantum state".
- Quantum computers for foundational tests of quantum mechanics
- Noise demolition schemes for quantum tomography
- (and demonstrations on Rigetti's quantum computers)
- Multiparameter digital quantum metrology

Cose fatte / cose in corso : 5

Scuole / Conferenze SQMS:

- Scuola Estiva (21 Giugno - 2 Luglio, 2021, online)



- Nuova edizione (Luglio 2022??? a Arcetri???)
- Conferenza di SQMS (+ altri DOE centers) a Erice (Marzo 2022)
- possiamo mandare $\simeq 5 \cdots 8$ studenti (magistrali) come summer-student a FNAL nel 2022
- possiamo/vogliamo ospitare $4 \cdots 5$ studenti americani in Italia nel 2022?

Situazione Post-Docs

Where	Start date	Months	
Total months		168	224000
"Upper" limit		240+24	631000
LNGS	2021-sec.half	24	62000
LNF	2023-firs.half	24	
Firenze	2022-sec.half	24	
Padova	2021-sec.half	24	62000
Pavia	2021-sec.half	24	50000
Roma I	2021-sec.half	24	
Pavia	2021-sec.half	24	50000

- per il momento solo 2 (o magari 1.5) Assegnisti...
- → Alberto Riccardi
- → Simanray Sadana

That's all folks!!



Thank you very much for your attention!!