

TES detection-chain operation of the QUBIC instrument dedicated to the CMB observation

Guillaume Stankowiak

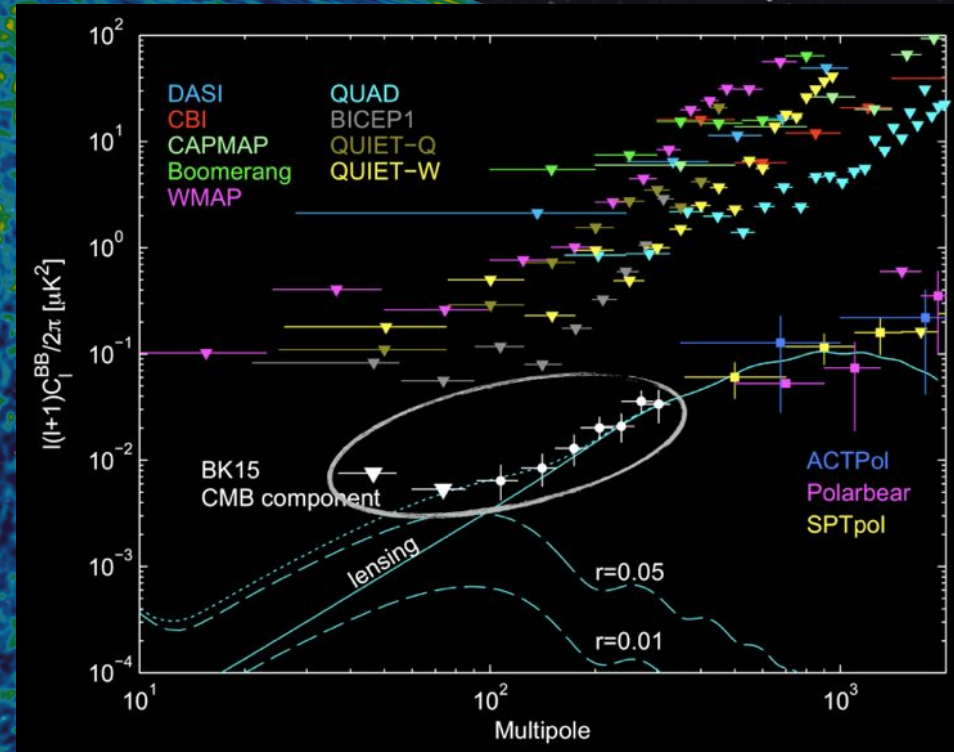
Advisors : Michel Piat & Jean-Christophe Hamilton

27 February 2020

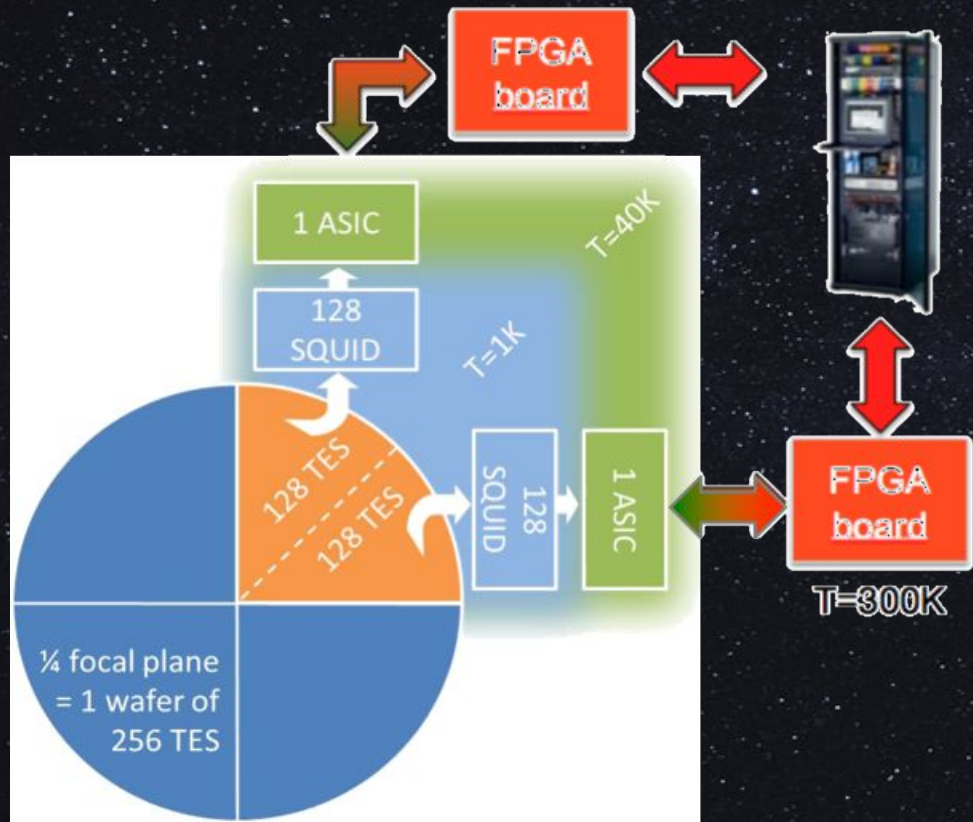


Challenges for primordial B-modes ...

- **High foregrounds** : Dust and Synchrotron emission
- **Small signal** : B-modes are smaller than 70nK (~500 times less than the anisotropy of temperature T)
- **Control of systematics** Xpol is a killer as $T \gg E \gg B$
- **Lensing** : Gravitational lensing from Large Scale Structure deflects CMB photons (few arcmins) mixing Q and U therefore creating Lensing B from E



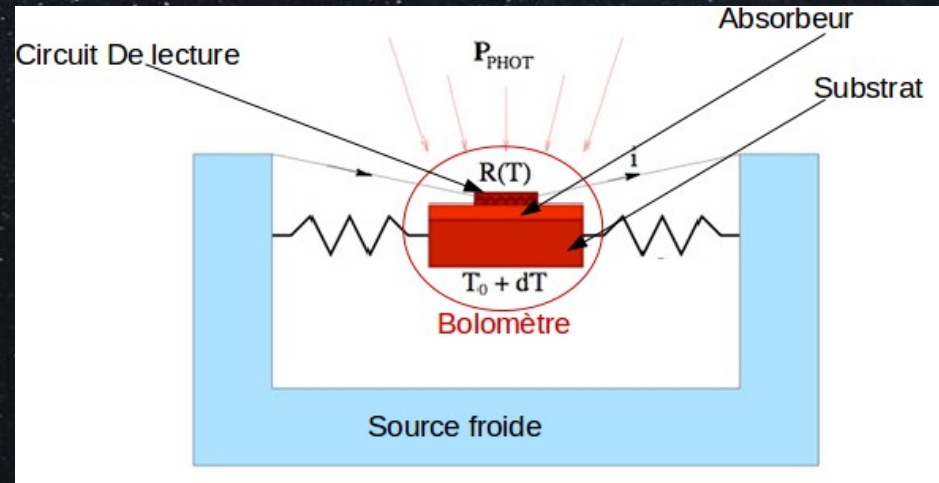
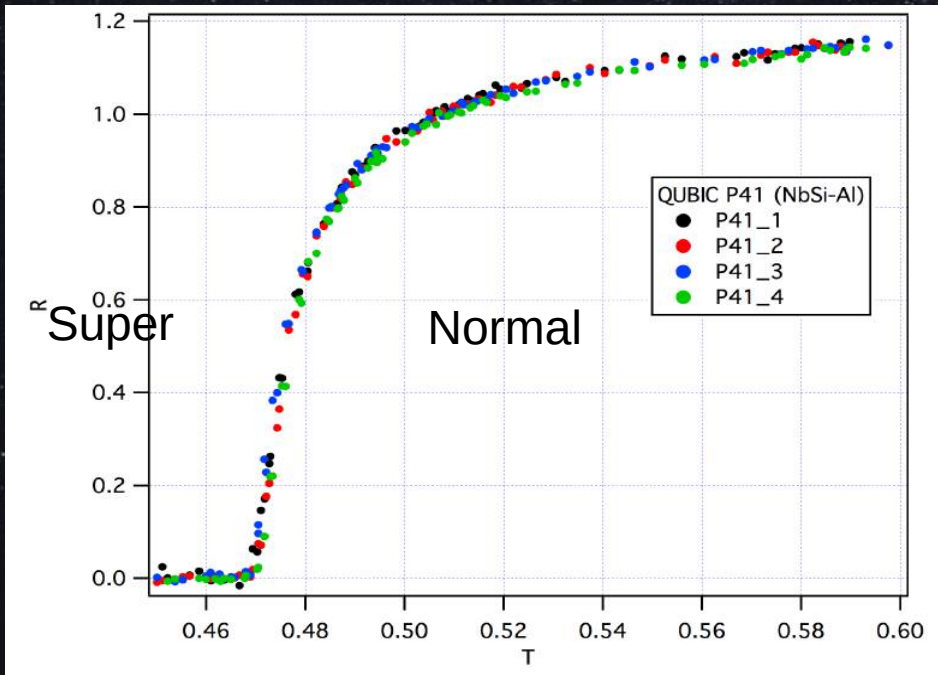
Detection Chain



- Cold detection chain with high sensitivity bolometers ($T \sim 350\text{mK}$)
- Low noise amplifier close to the bolometers (at 1K)
- Multiplexing system with to read 128 TESs and SQUIDs with 1 ASIC to limit the impact on the temperature of the electronic

Detection Chain : Transition Edge Sensors

- Superconducting Bolometers operate at 350 mK
- NbSi TES $\rightarrow T_c \approx 400$ mK
- Power received when heated \rightarrow measures the increasing temperature
- Large variation of $R(T)$



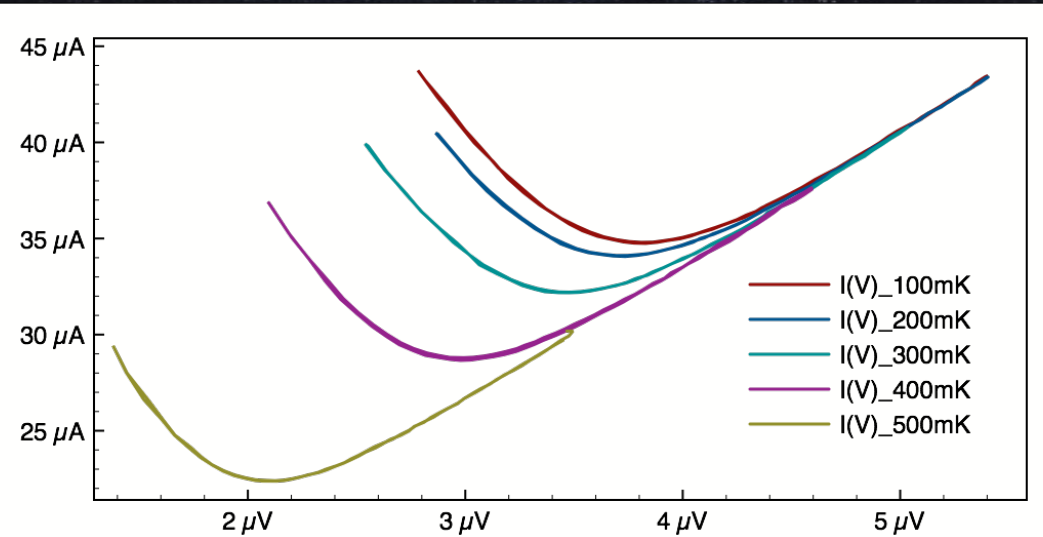
Detection Chain : Transition Edge Sensors

How can we have 256 TESs operating at the same Temperature ?

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Electrothermal Feedback



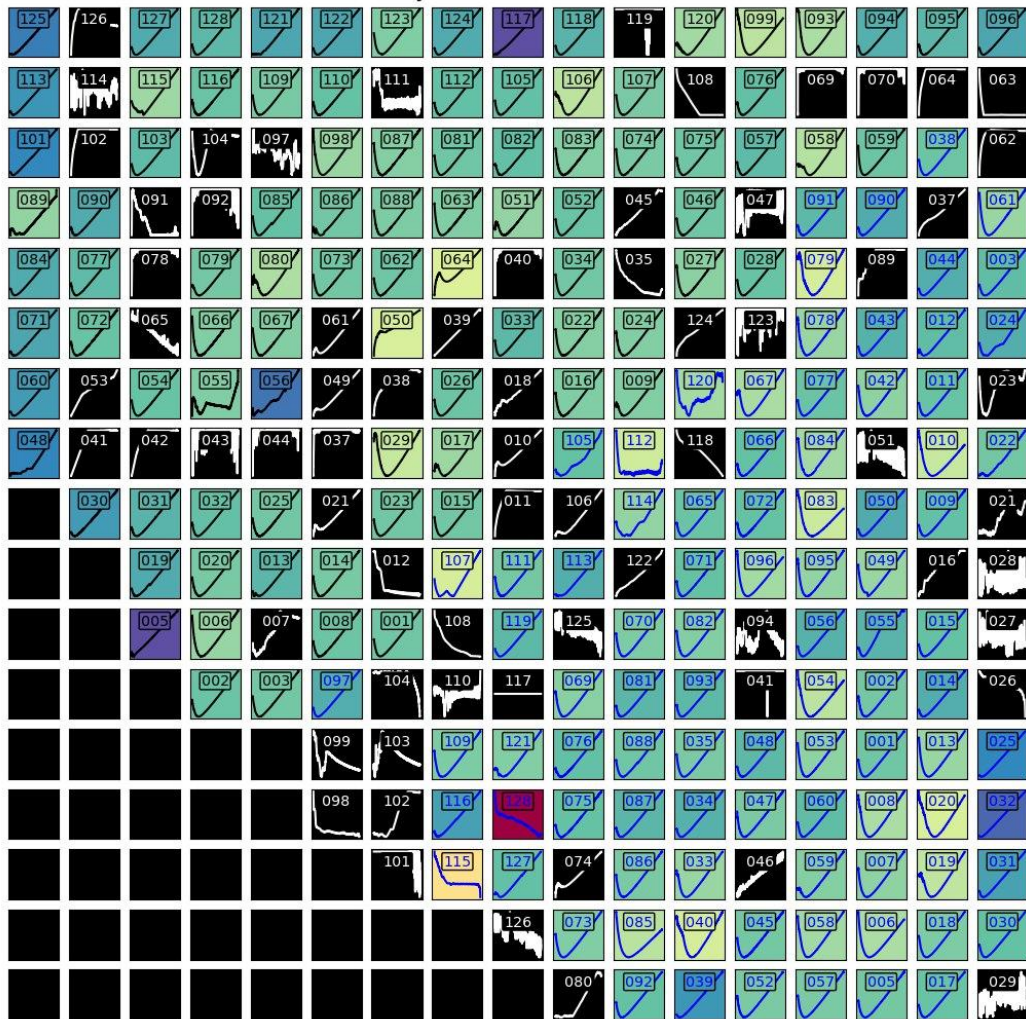
- Reaction to keep the TES in the transition phase

- $L = \frac{\partial T}{\partial P} \frac{\partial P_j}{\partial R} \frac{\partial R}{\partial T}$ Thermal transfer function
Electric transfer function

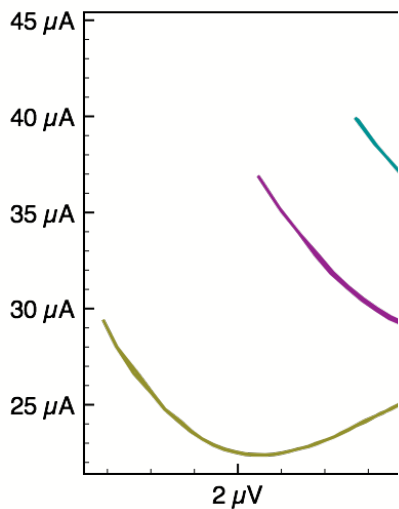
- $P_i \nearrow \Rightarrow T \nearrow \Rightarrow R(T) \nearrow \Rightarrow P_j(T) = V_{BIAS}^2 / R(T) \searrow$

- Allows one Temperature for a large number of TESs

QUBIC Focal Plane I-V curves: 2020-01-06 15.04.08 V-I 360mK
 2020-01-06 15:04:08 Array P87 ASIC#1 $T_{\text{bath}}=359.4\text{mK}$
 38 flagged as bad pixels : yield = 70.3%
 2020-01-06 15:04:08 Array P87 ASIC#2 $T_{\text{bath}}=359.4\text{mK}$
 37 flagged as bad pixels : yield = 71.1%
 overall yield 181/256 = 70.7%



How can we have



Position Edge Sensors

k

keep the TES in the
 ase

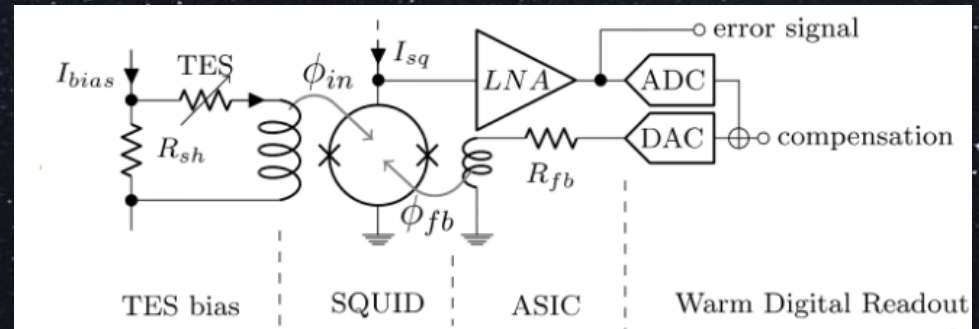
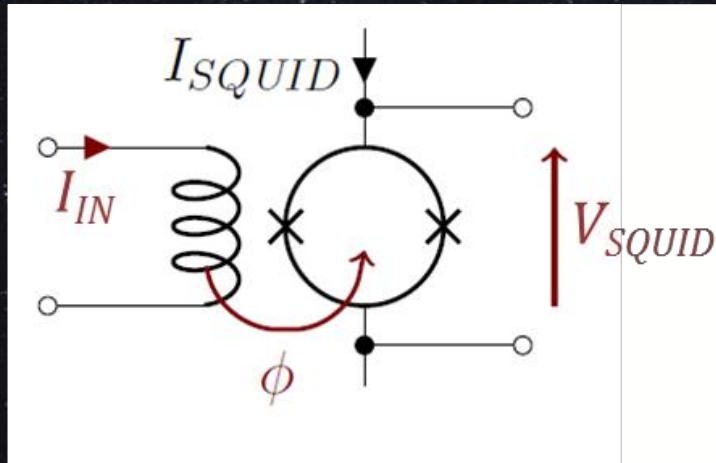
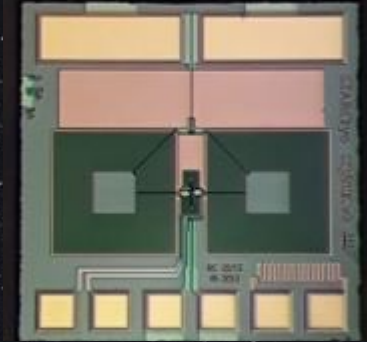
Thermal transfer function
 Electric transfer function

$$\Rightarrow R(T) \nearrow \Rightarrow P_j(T) = V_{\text{BIAS}}^2 / R(T) \searrow$$

Temperature for a large
 ESs

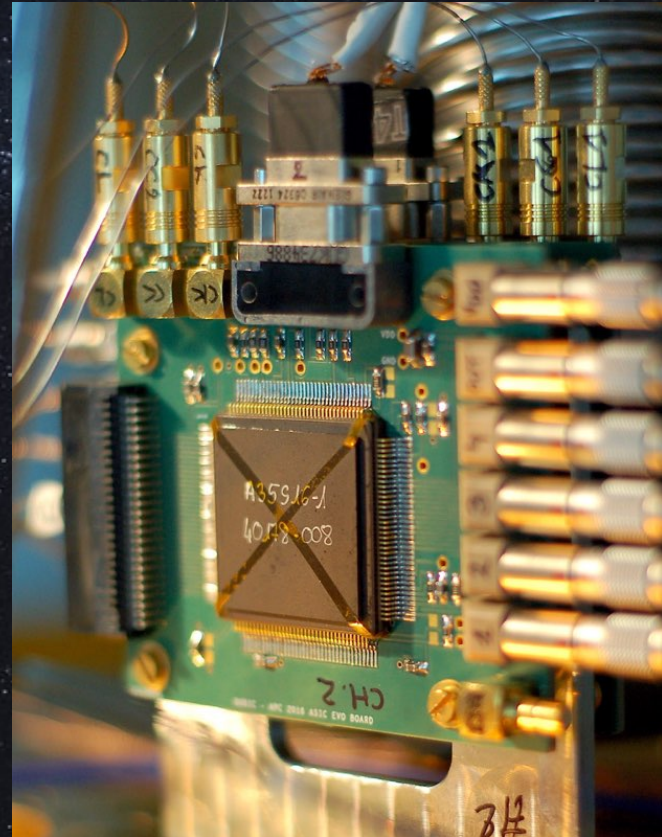
Detection Chain : Superconducting QUantum Interference Devices

- Can be installed very close to the detectors (operate at 1K)
- $R_{in}=0\Omega$
- Low noise transimpedance amplifiers (SQUID+Lin)
- Allow Time Domain Multiplexing with a dedicated cryogenic ASIC

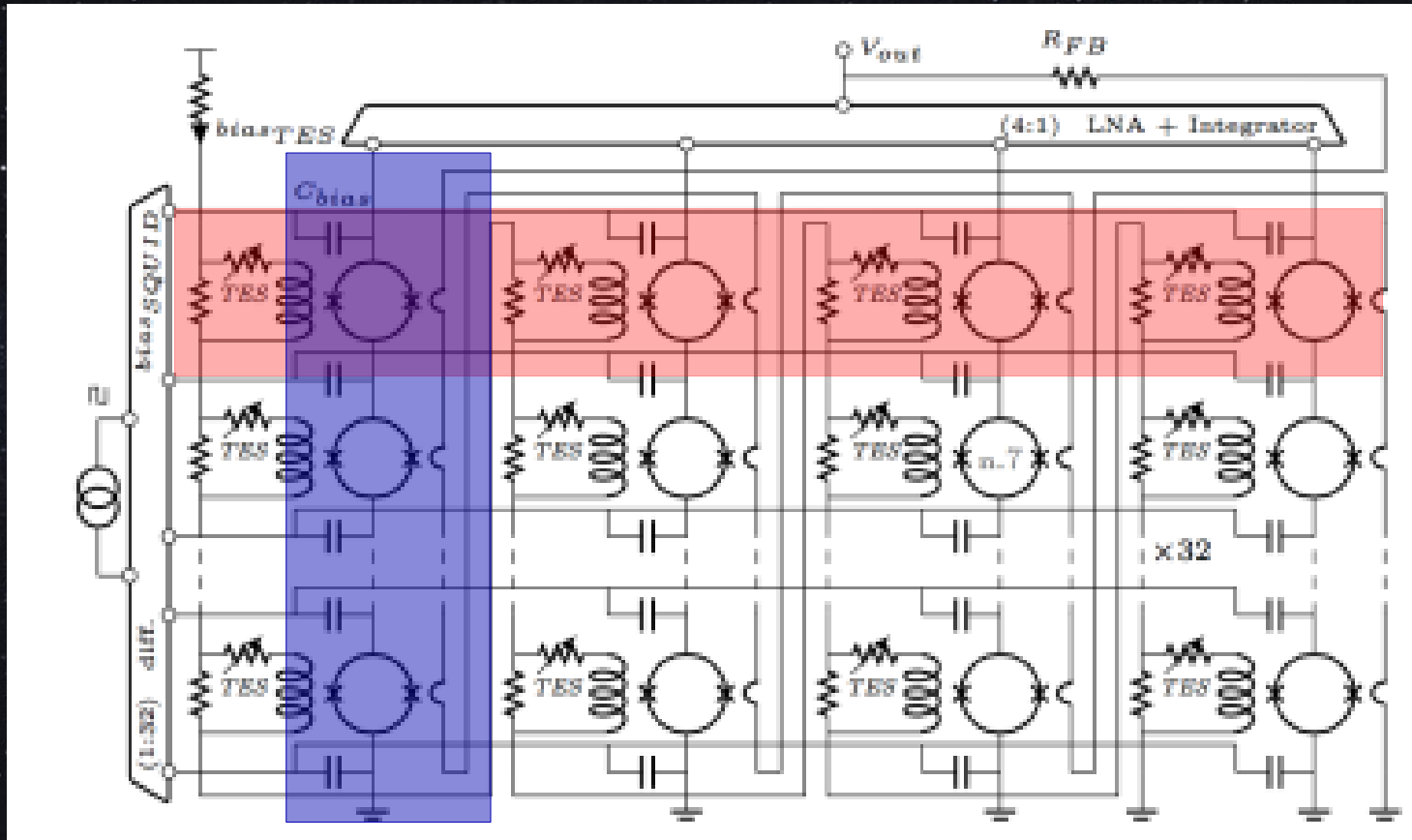


Detection Chain : Application-Specific Integrated Circuit

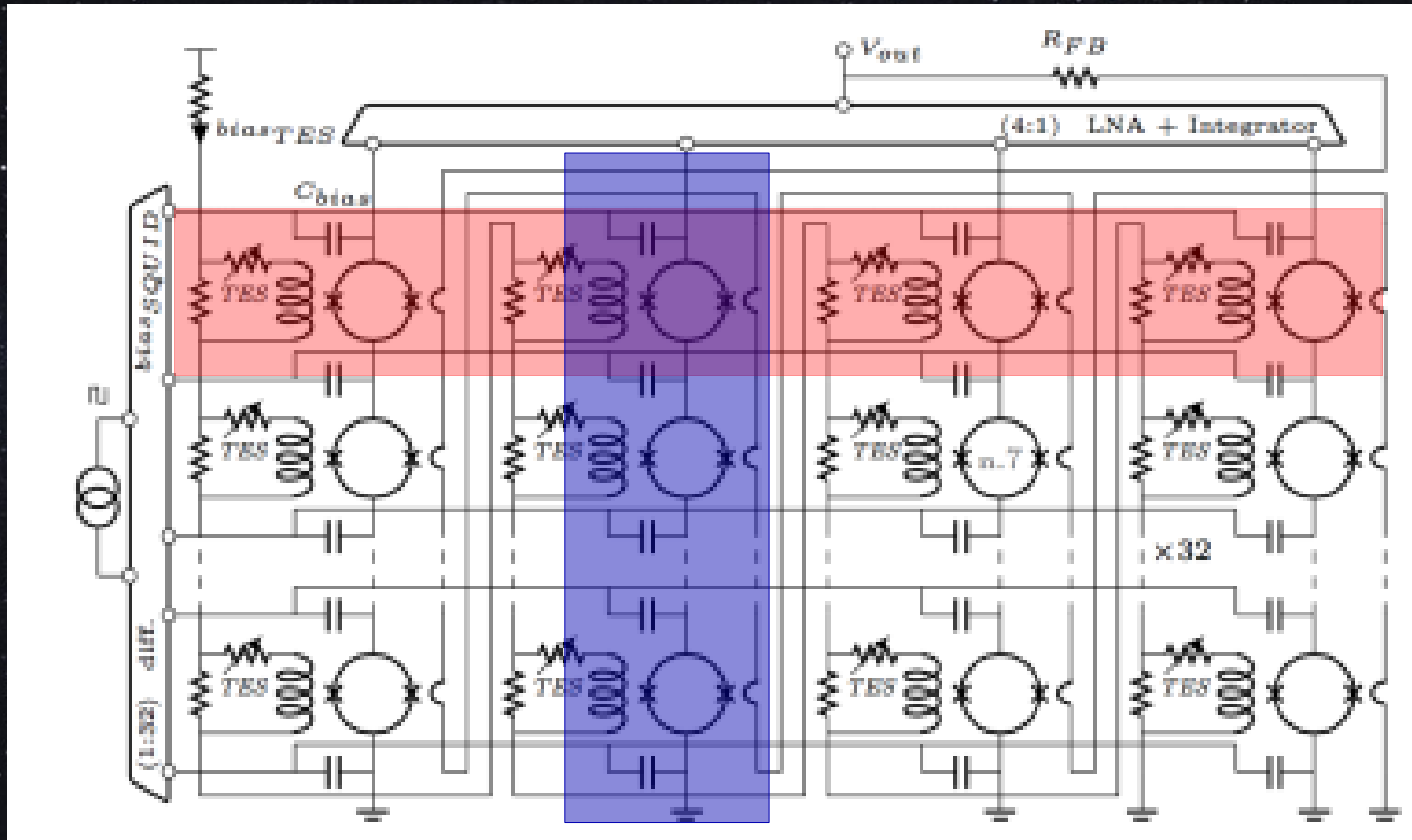
- Readout electronics at low temperature
- 128-multiplexing factor
 - 4 columns
 - 32 SQUIDS in series
- Line addressing : bias power supply
- Columns addressing : 4-input low noise amplifier



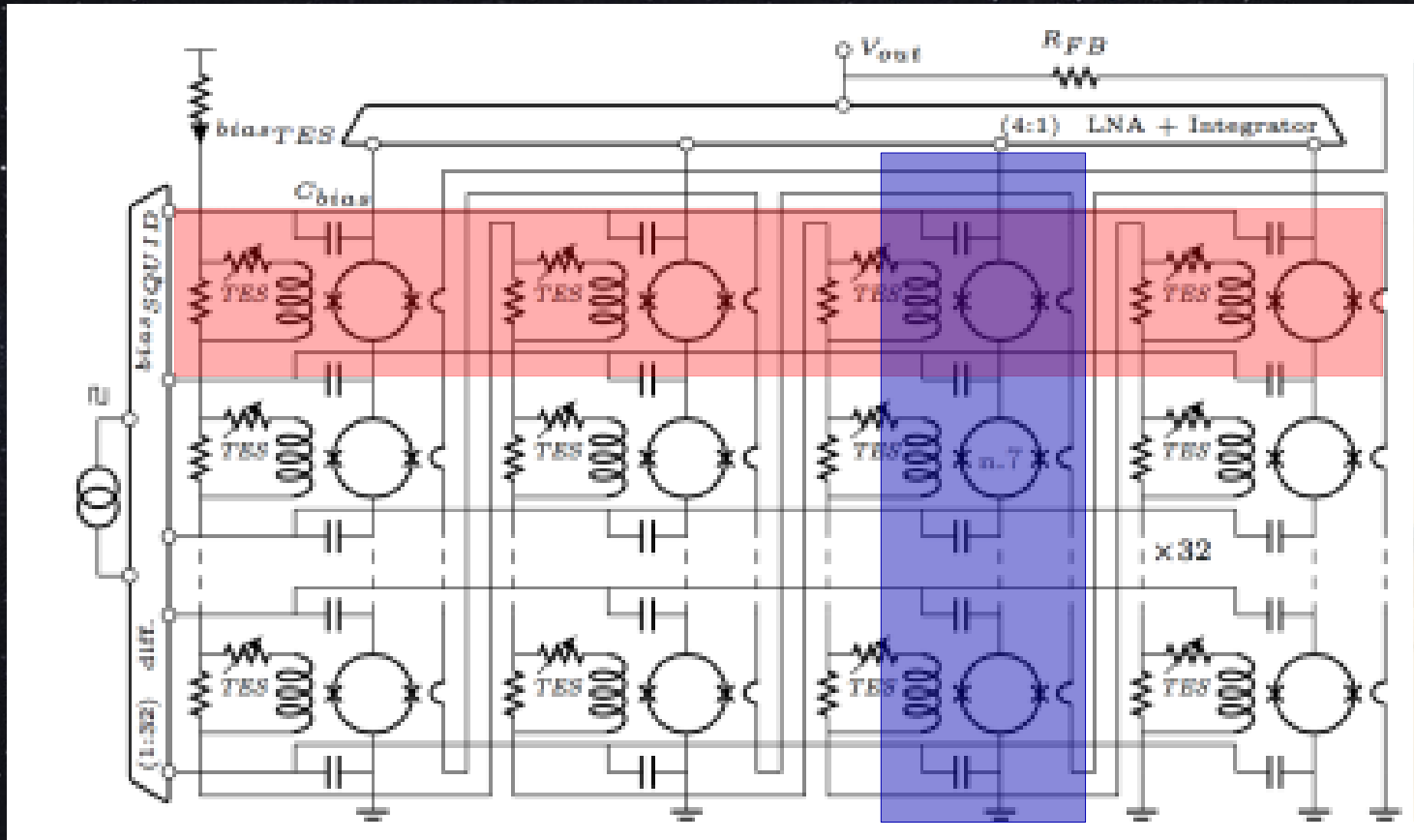
vDetection Chain : Application-Specific Integrated Circuit



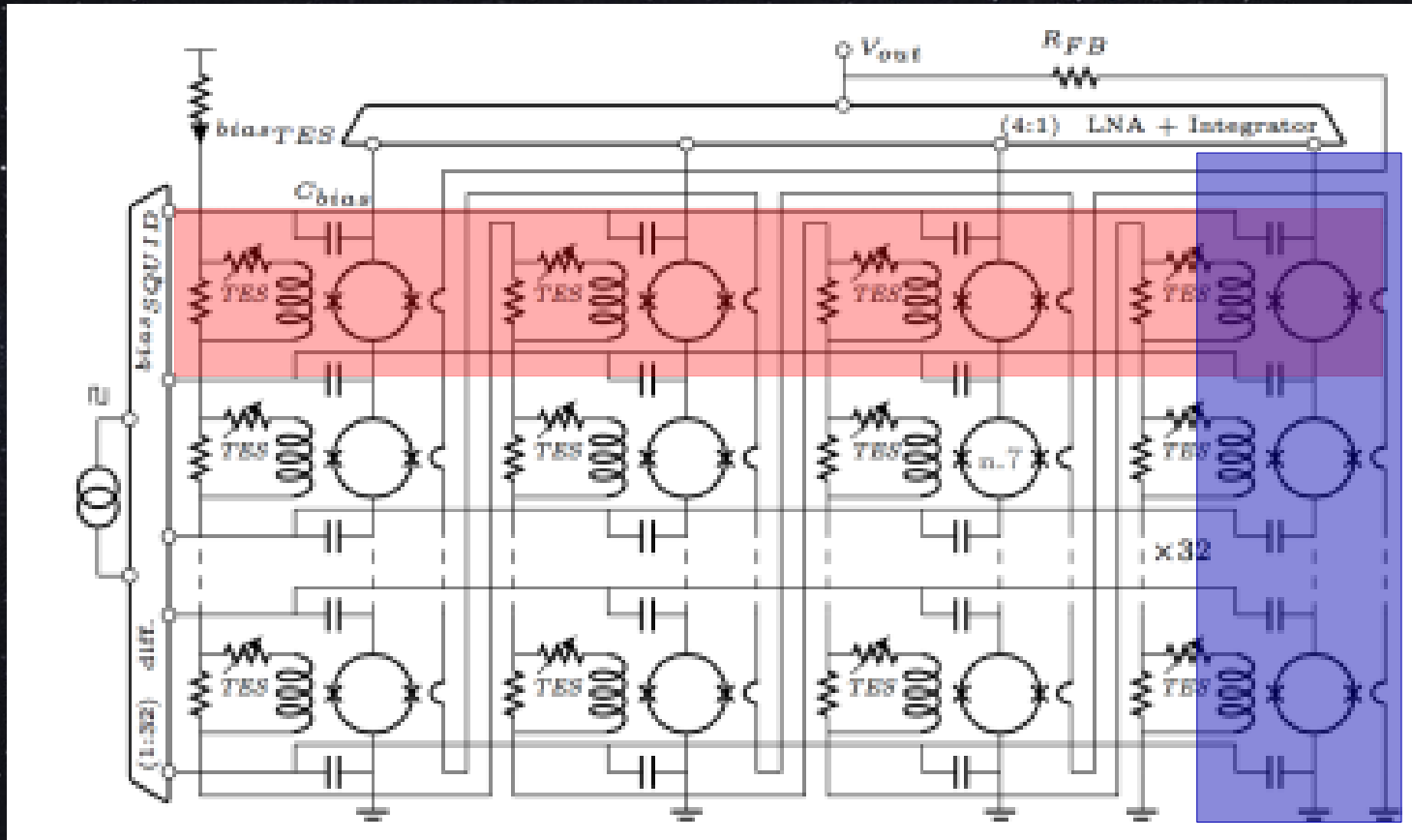
Detection Chain : Application-Specific Integrated Circuit



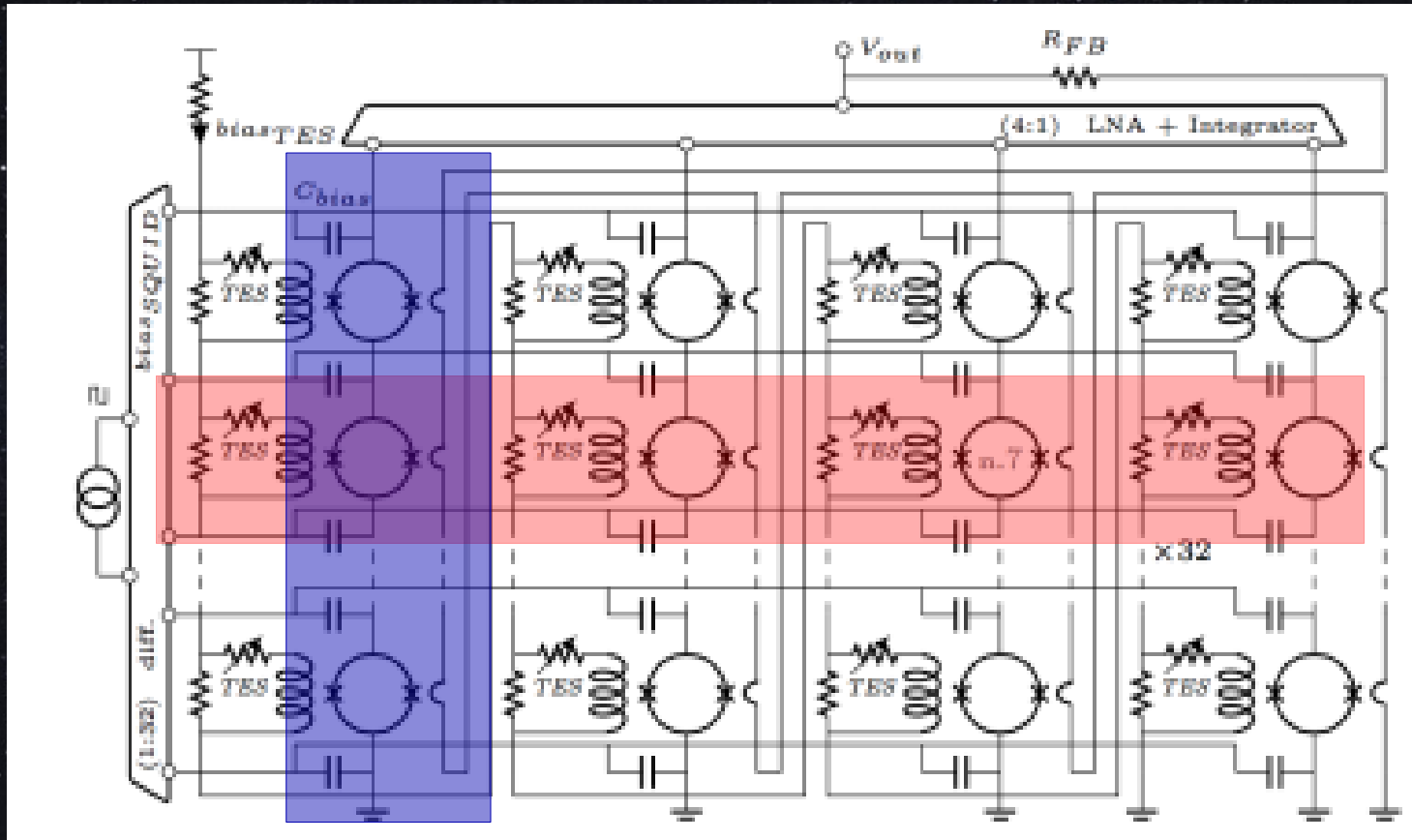
Detection Chain : Application-Specific Integrated Circuit



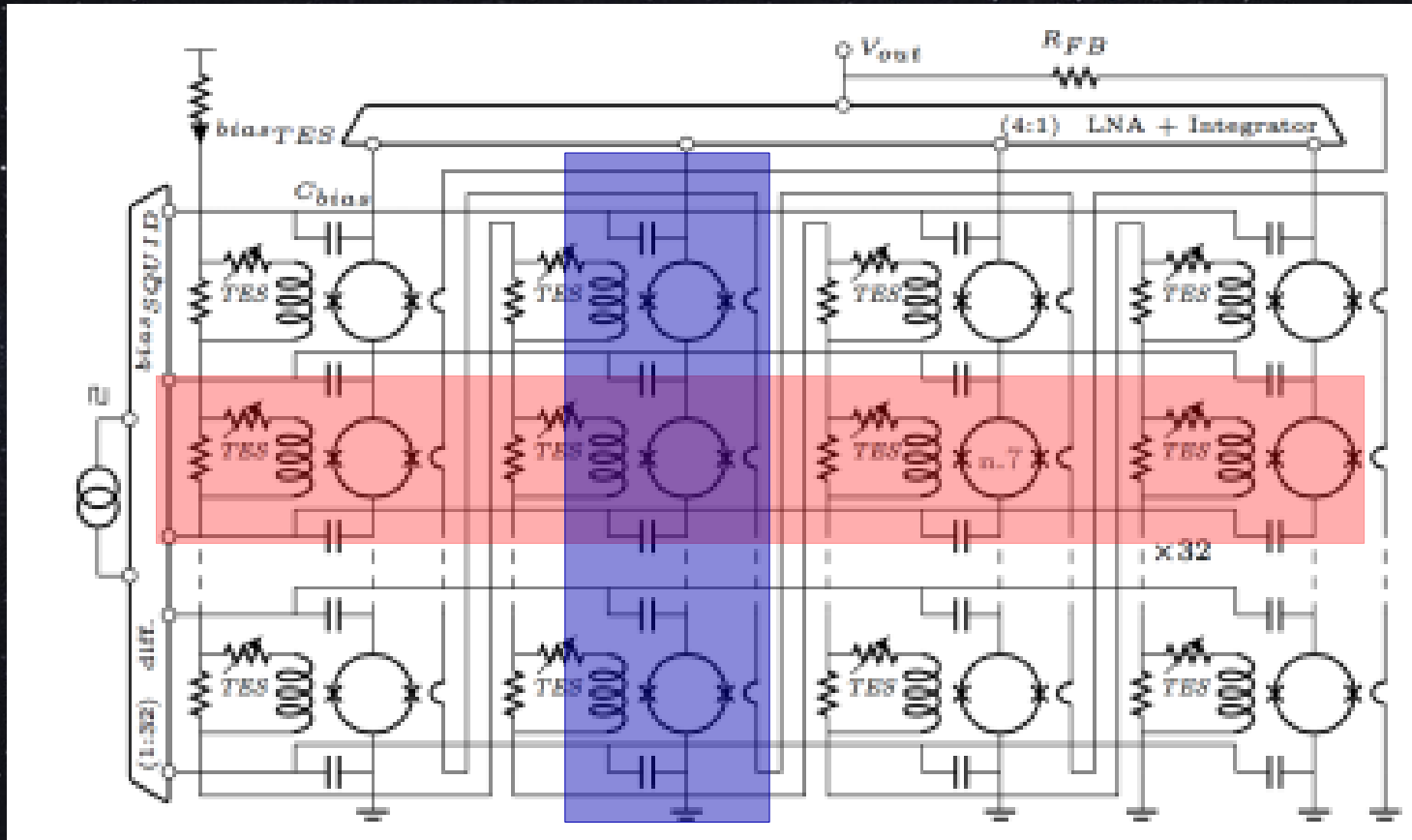
Detection Chain : Application-Specific Integrated Circuit



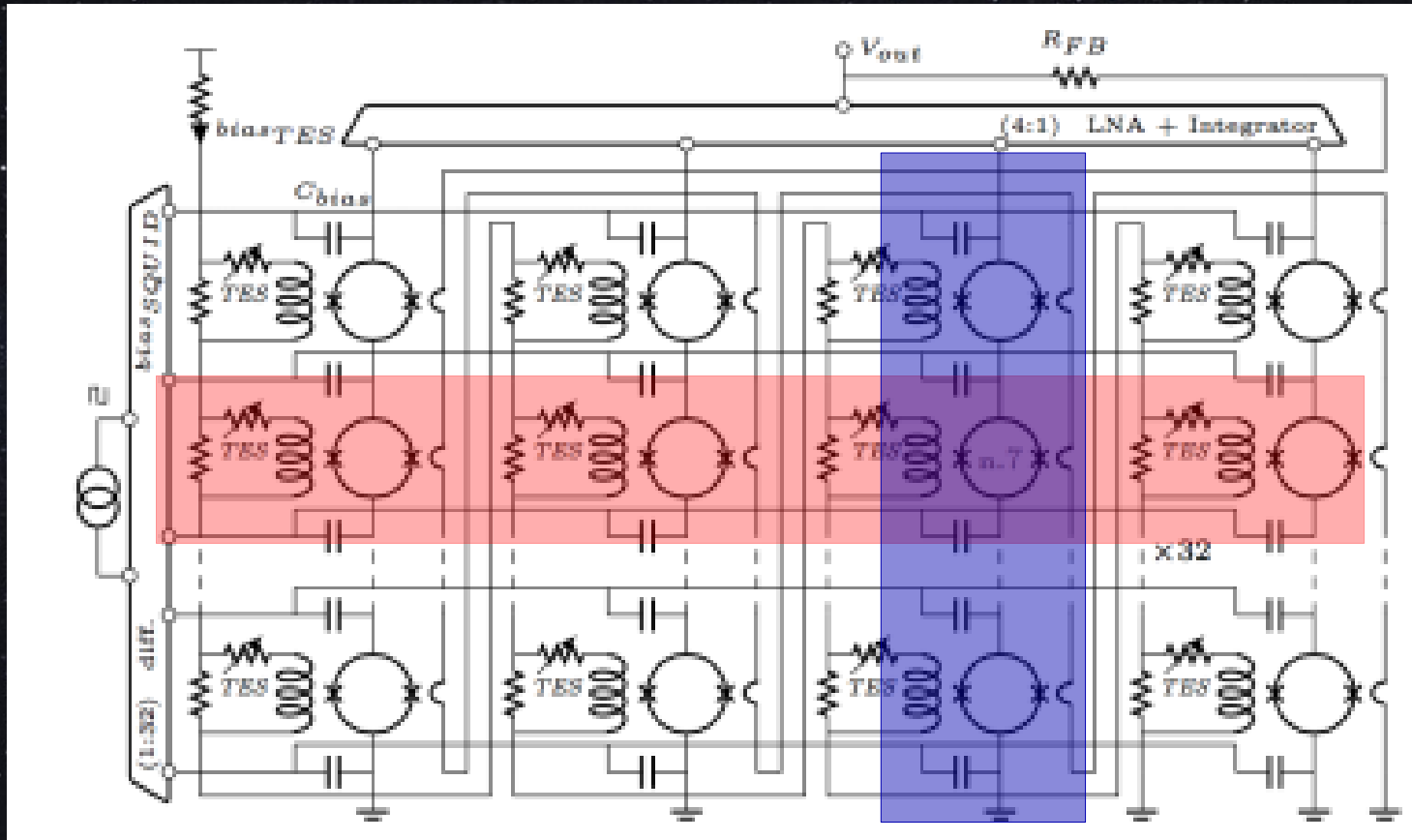
Detection Chain : Application-Specific Integrated Circuit



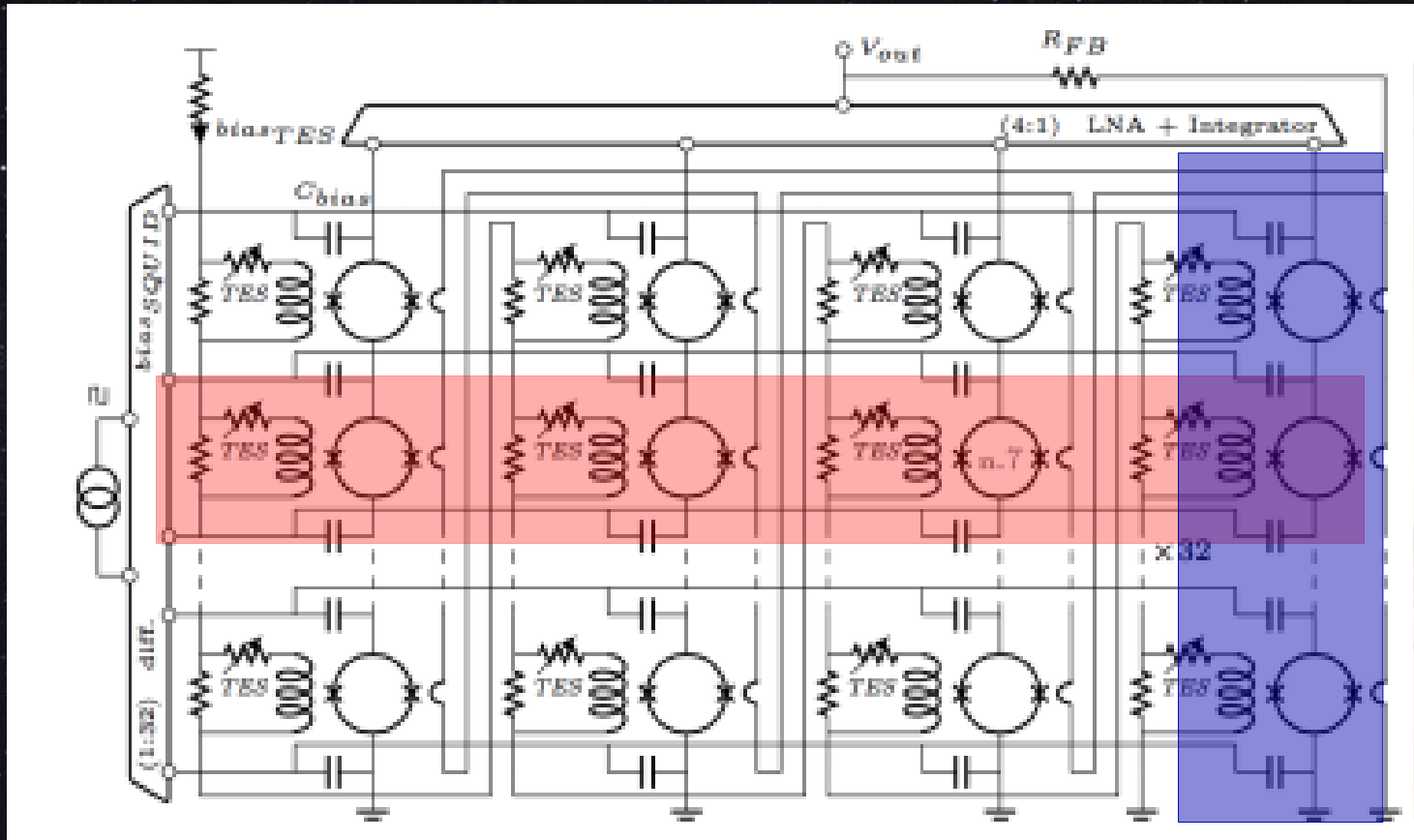
Detection Chain : Application-Specific Integrated Circuit



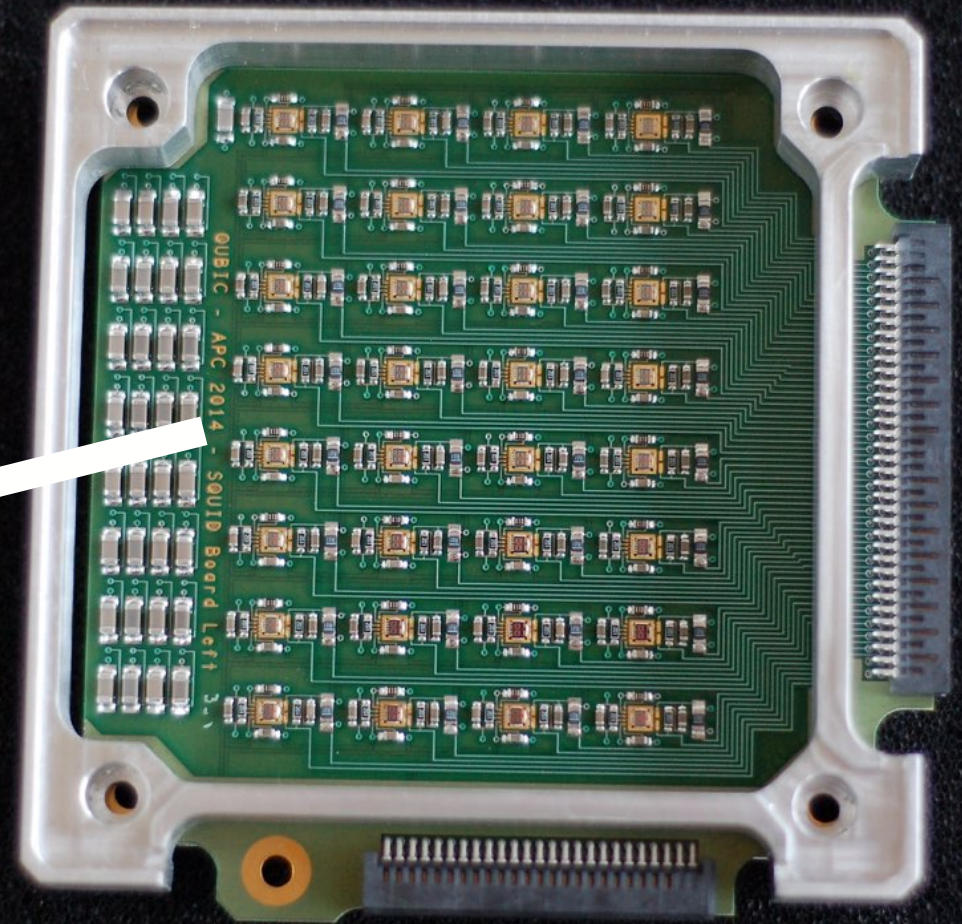
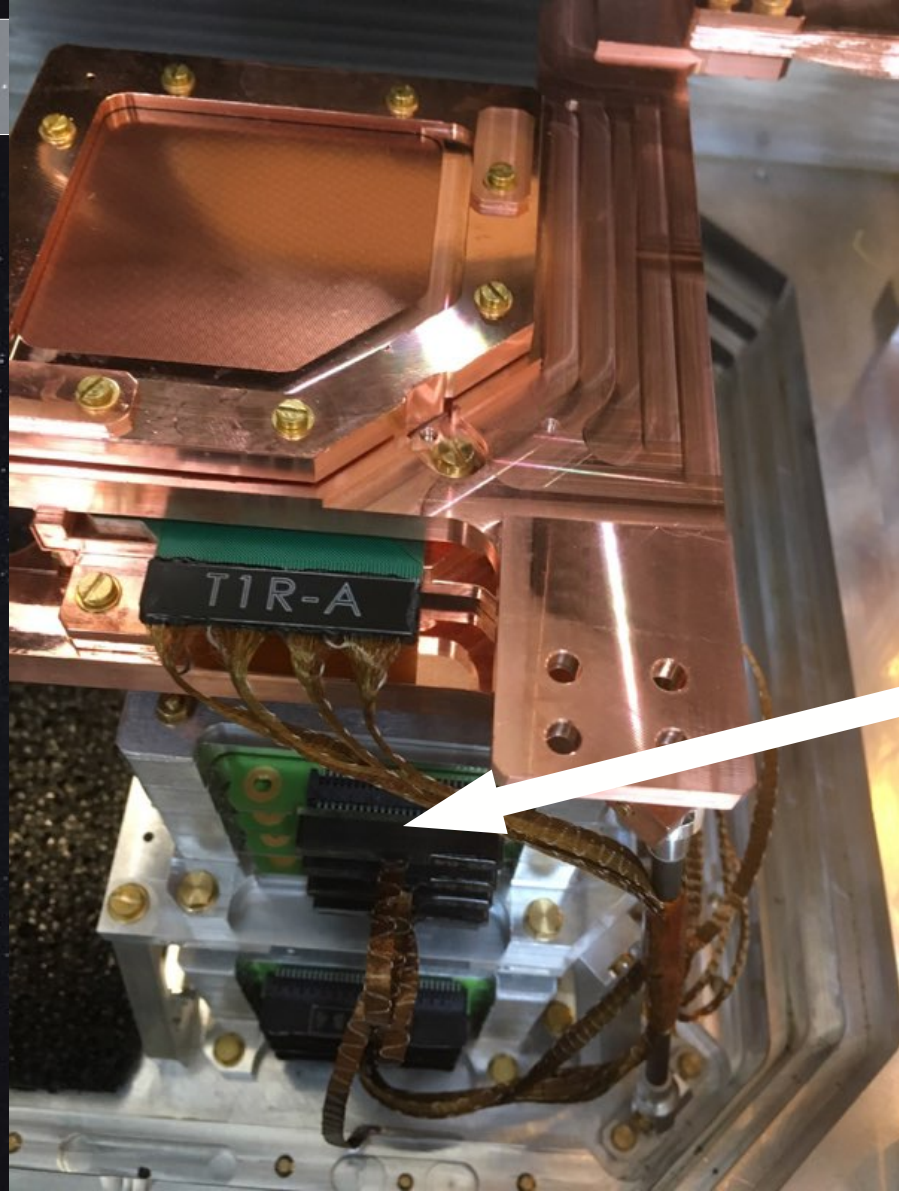
Detection Chain : Application-Specific Integrated Circuit



Detection Chain : Application-Specific Integrated Circuit

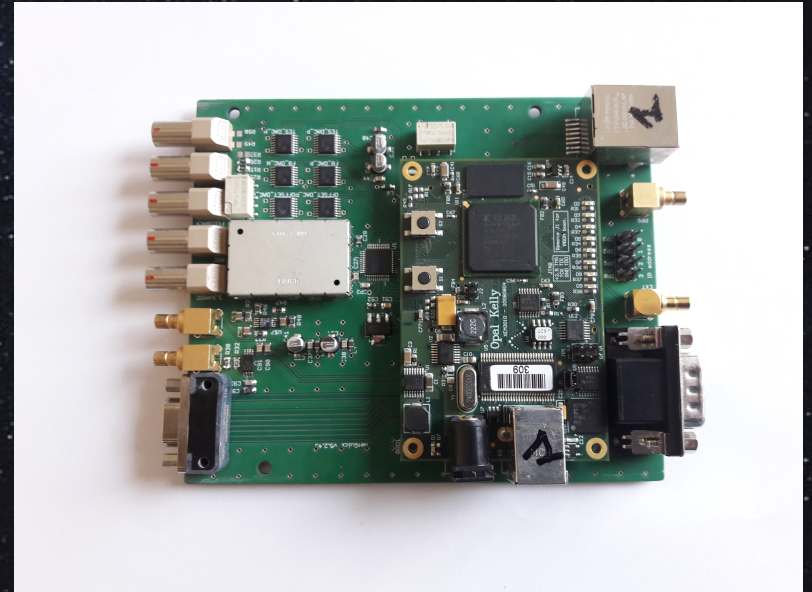


Detection Chain



Detection Chain : Field-Programmable Gate Array

- FPGA used as a hardware interface to communicate with QubicStudio (software developed by IRAP for the use of QUBIC experiment)
- Clock synchronization for all the ASICs
- Data acquisition (demultiplexing signal)



Detection Chain : Field-Programmable Gate Array

Software QUBIC studio:

ASIC parameterization
Acquisition
Demultiplexing
Visualization
Optimization

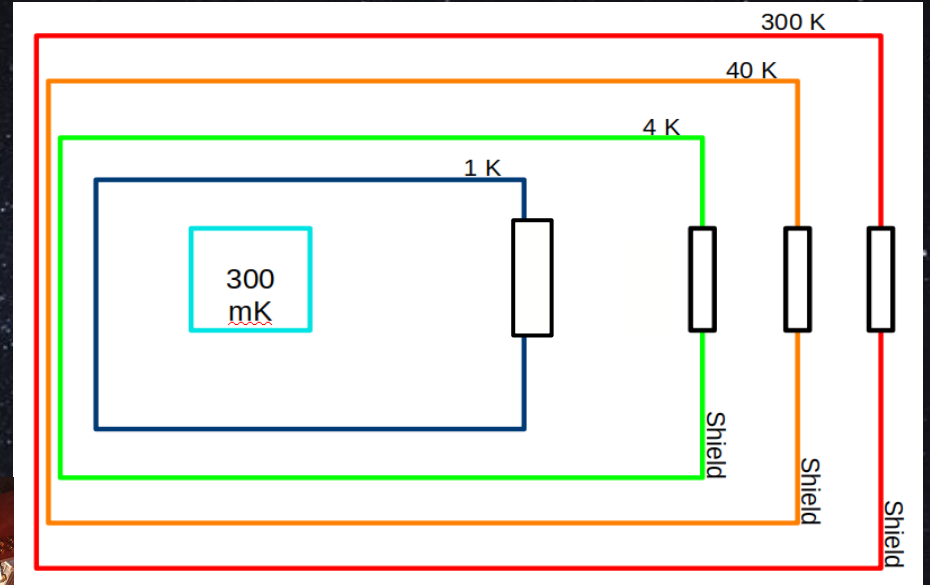
The screenshot displays the QUBIC Studio v1.4.41.19 interface, which is used for configuring and monitoring the detection chain. The interface is divided into several panels:

- Top Panel:** Shows system status including voltage (51.25 mV), temperature (49.2 °C), and time (17:04:30). It also features a 'Raw' data stream icon and a 'Pas de session' indicator.
- Left Panel:** A list of ASICs (Asic 1 to Asic 16) with checkboxes for selection.
- Configuration Panels:** Includes 'Configuration des cartes NetQuic', 'Gestion des raw signaux', 'Configuration des DACs', and 'Configuration des ASTCS'. The 'Configuration des ASTCS' panel shows a table of signals and their states.
- Signal Table:**

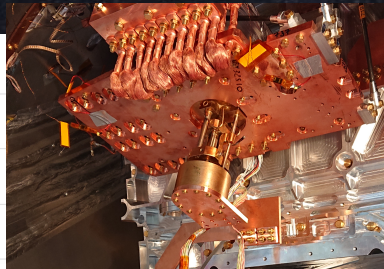
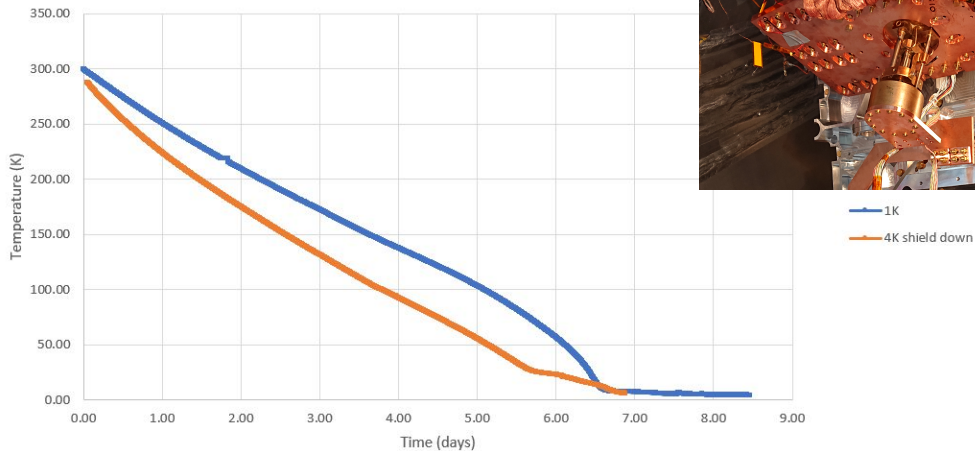
Signal	Etat	Commande	Envoyer
ENBAMENT	Actif (00)	Envoyer	Envoyer
COUNTb	ligne[col 1] -> 4	Envoyer	Envoyer
COMPX	icompt (00)	Envoyer	Envoyer
FIX	FDX1/FDX0 = 0/0	Envoyer	Envoyer
RAZBOOP	0	Envoyer	Envoyer
INIBBOFFCOMP	Compensatic	Envoyer	Envoyer
INITBACBIAS	0	Envoyer	Envoyer
RAZb	Reset des registres	Envoyer	Envoyer
INb	Démarrage de la ...	Envoyer	Envoyer
- Right Panel:** Displays a 'BoloViewer 1.3' window showing a heatmap of the detector array. The heatmap shows a triangular pattern of data points, with a '1' in a box indicating a specific pixel. Below the heatmap are two plots: 'Raw Signal (asic 1, pixel 1)' and 'Scientific Signal (asic 1, pixel 1)'. The 'Raw Signal' plot shows a signal amplitude over time, and the 'Scientific Signal' plot shows a similar signal with a different scale.

Cryogenic System

- Two Pulse Tubes to cool down 40K and 4K shields
- He4 fridge to cool down the 1K box
- He3 sorption fridge to reach the 300 mK for the detectors stage

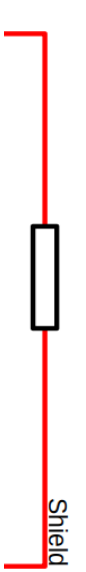
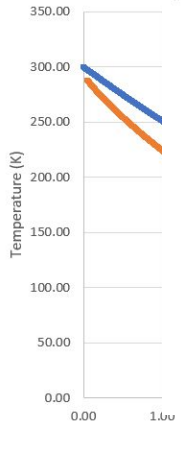
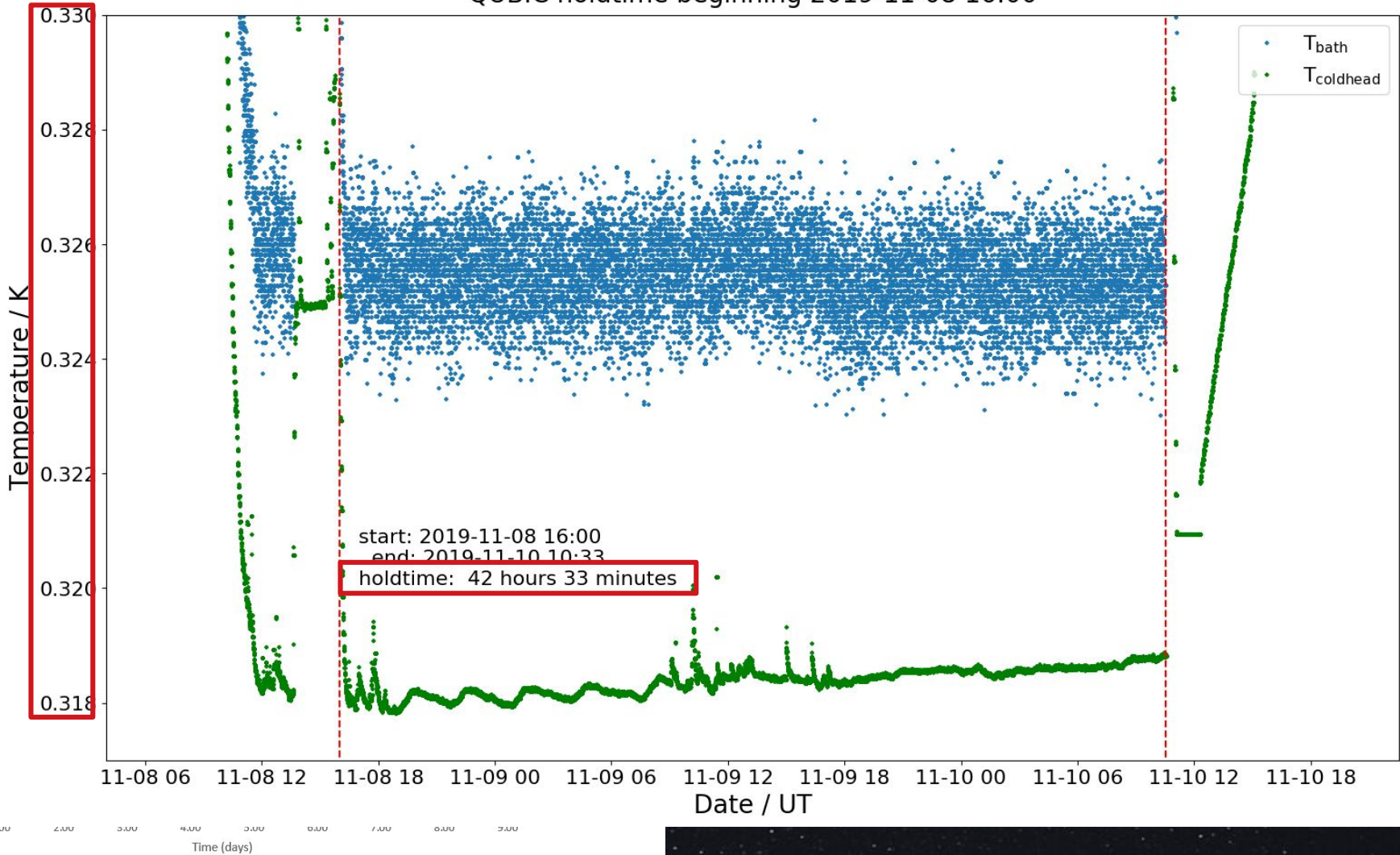


Mise en froid janvier 2019

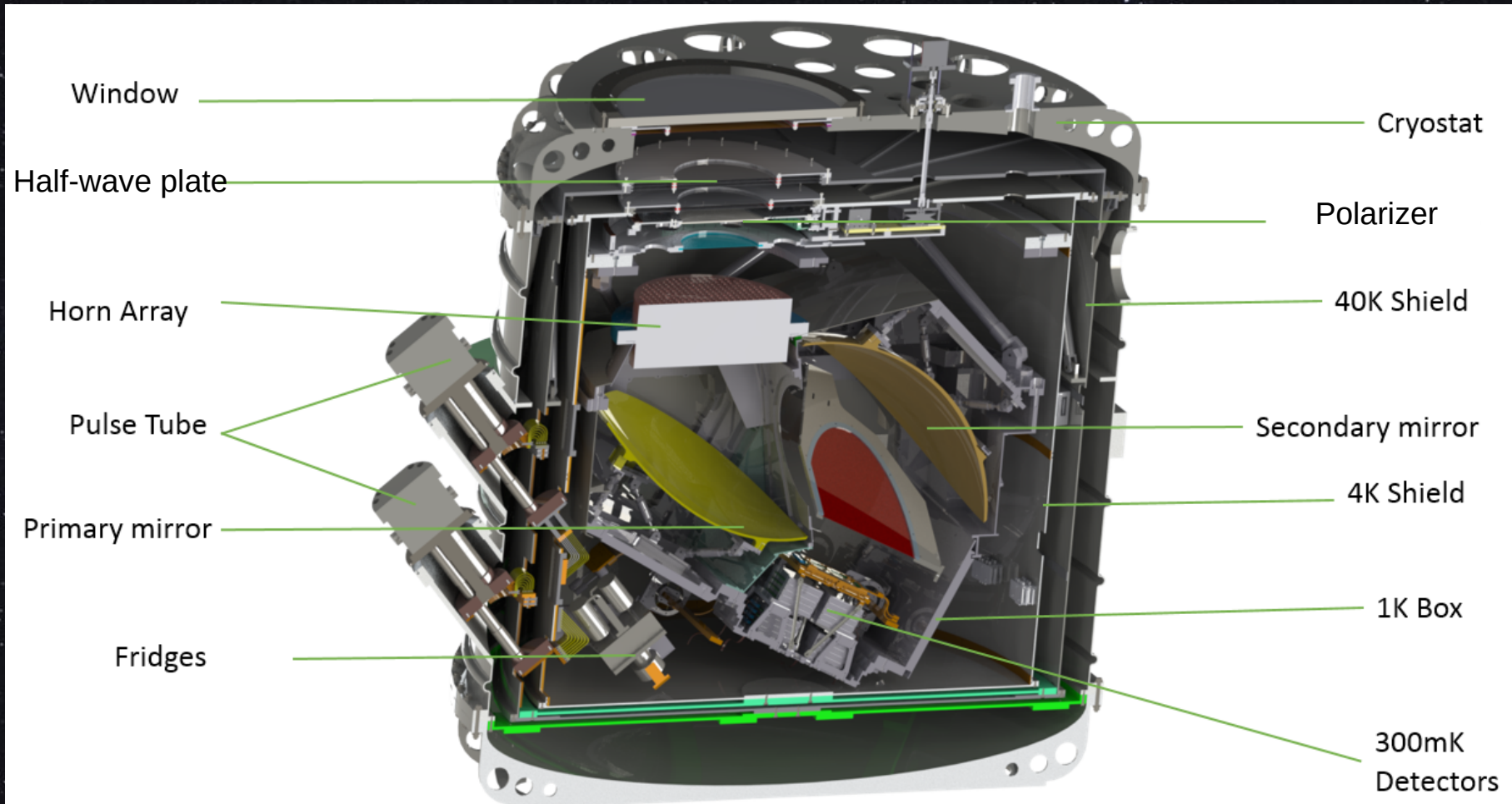


- Cool down time : ~ 8 days (150 kg to cool down at 1K)

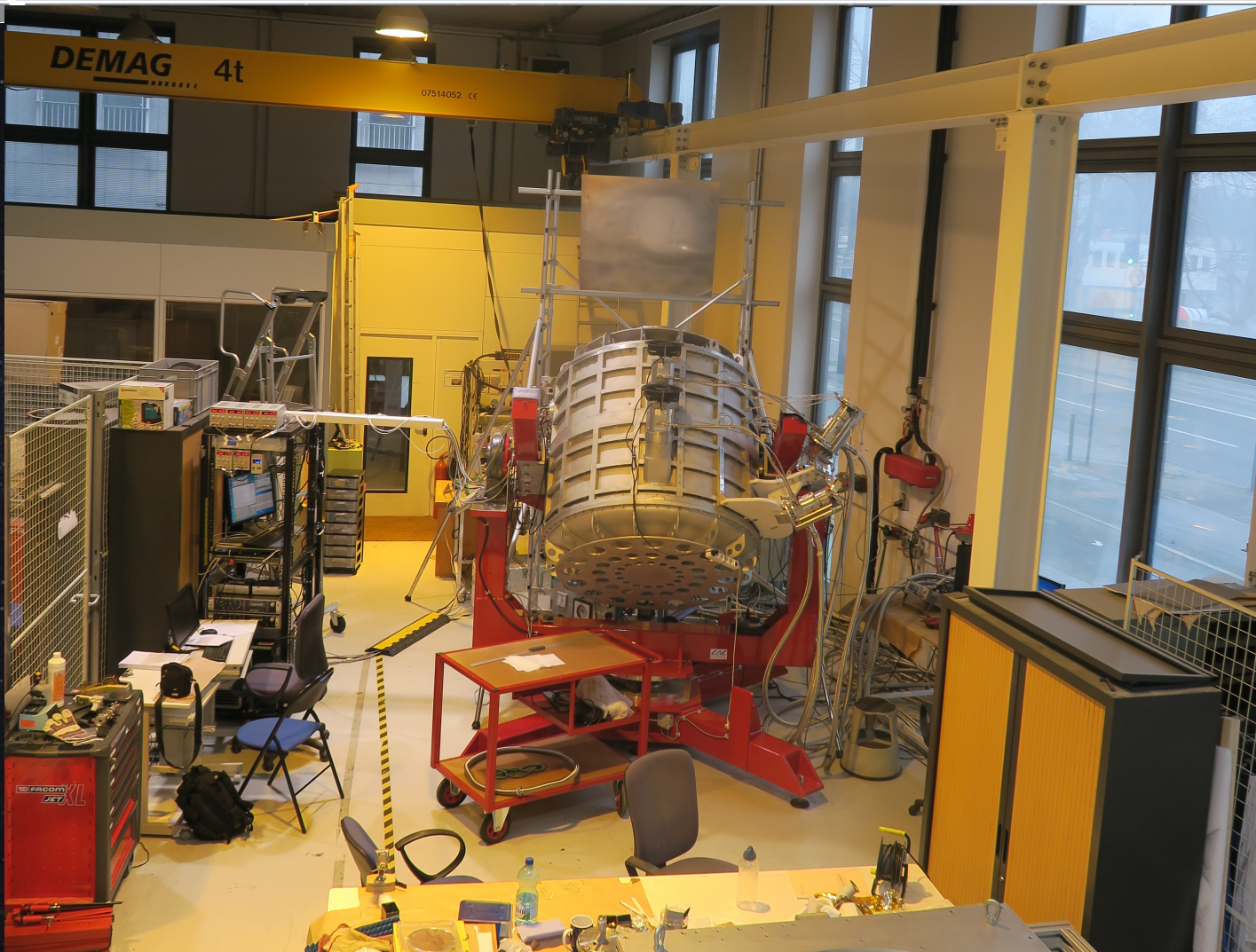
QUBIC holdtime beginning 2019-11-08 16:00



The Q and U Bolometric Interferometer for Cosmology (QUBIC)



The Q and U Bolometric Interferometer for Cosmology (QUBIC)



Thanks for your attention

