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

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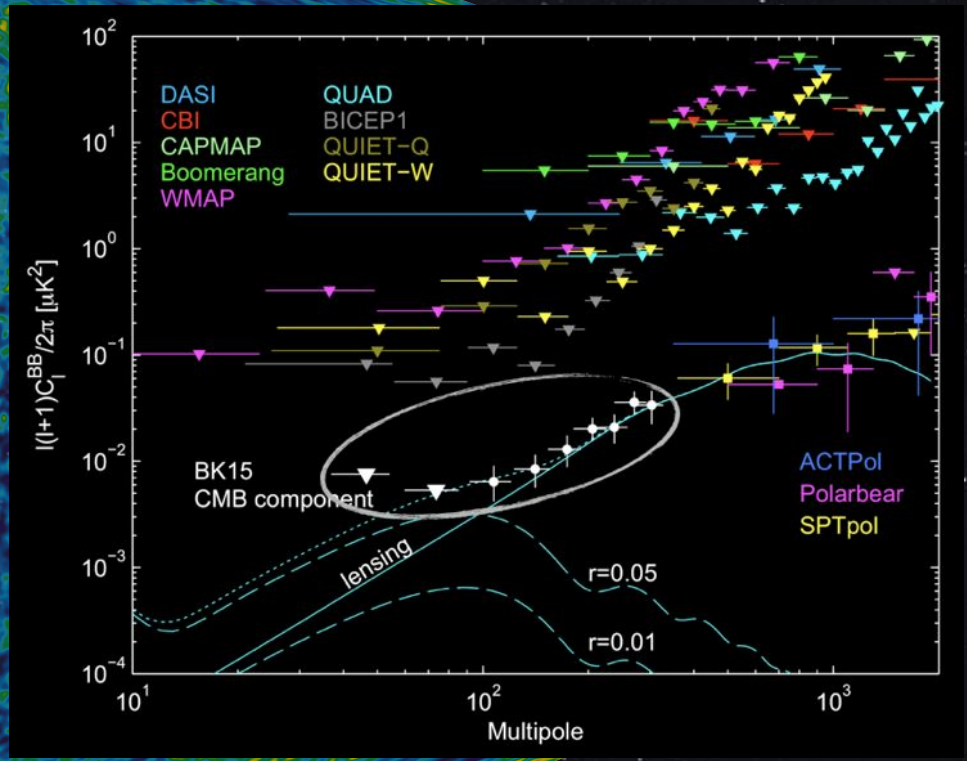
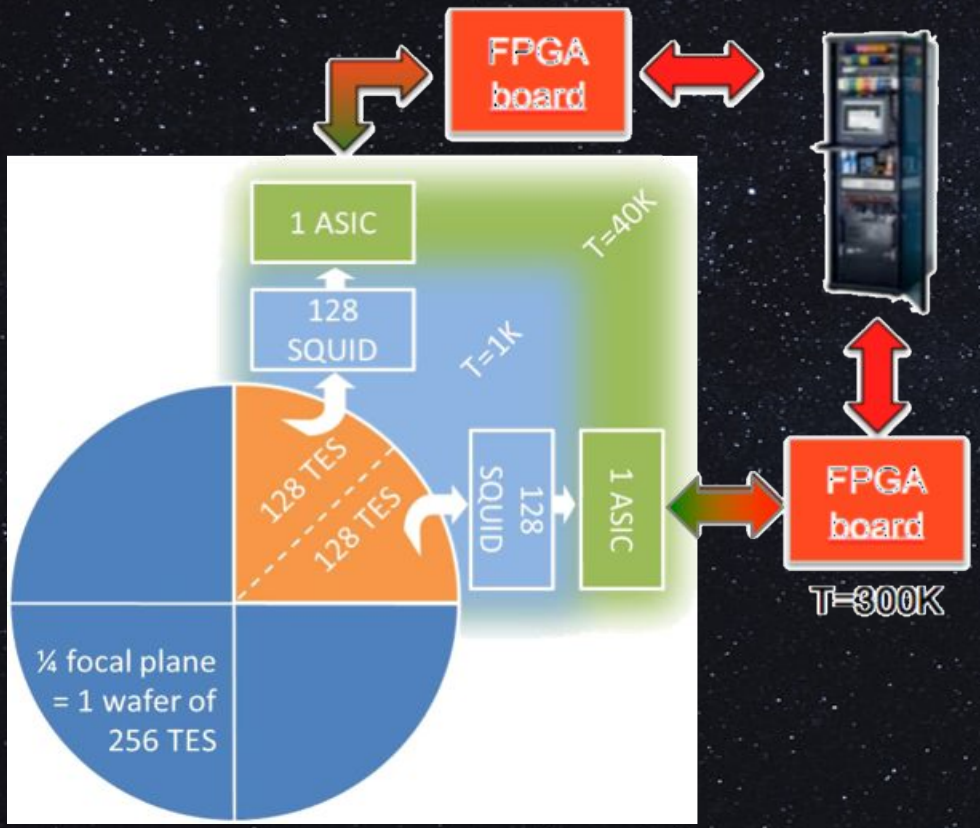
Challenges for primordial B-modes ...

- **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 >> E >> B
- **Lensing** : Gravitational lensing from Large Scale Structure deflects CMB photons (few arcmins) mixing Q and U therefore creating Lensing B from E



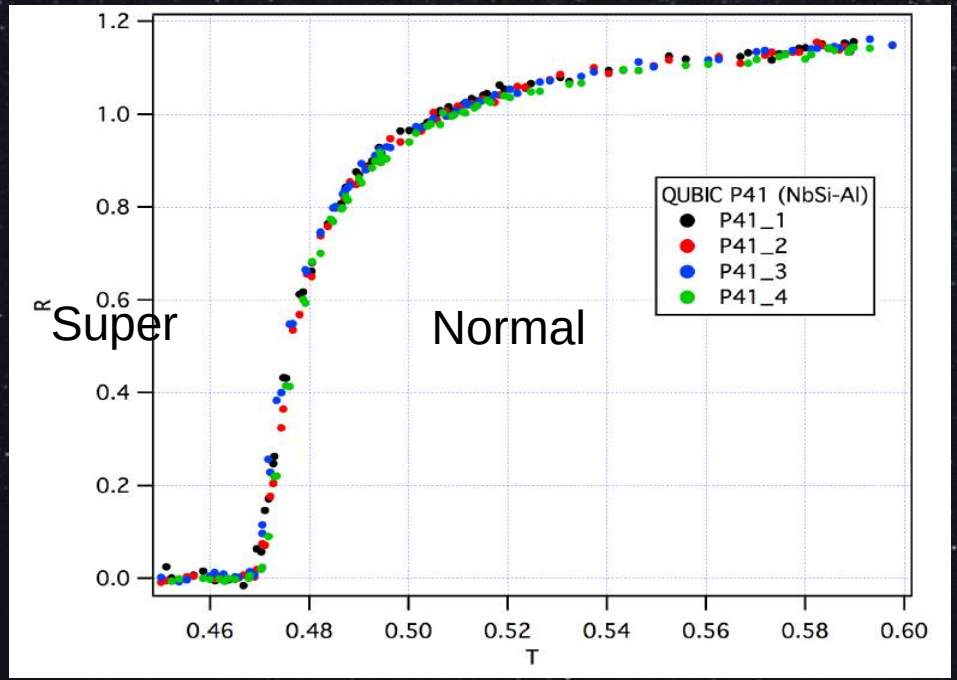
Detection Chain

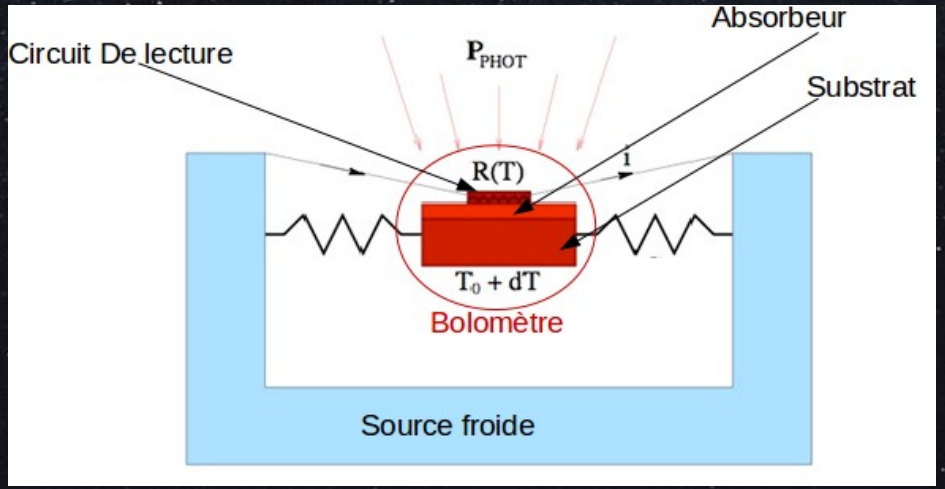


- Cold detection chain with high sensitivity bolometers (T~350mK)
- Low noise amplifier close to the bolometers (at 1K)
- Multiplexing system with to read 128 TESs and SQUIDs with 1 ASIC to limit the impact on the temperature of the electronic

Detection Chain : Transition Edge Sensors

- Superconducting Bolometers operate at 350 mK
- NbSi TES → Tc ≈ 400 mK
- Power received when heated → 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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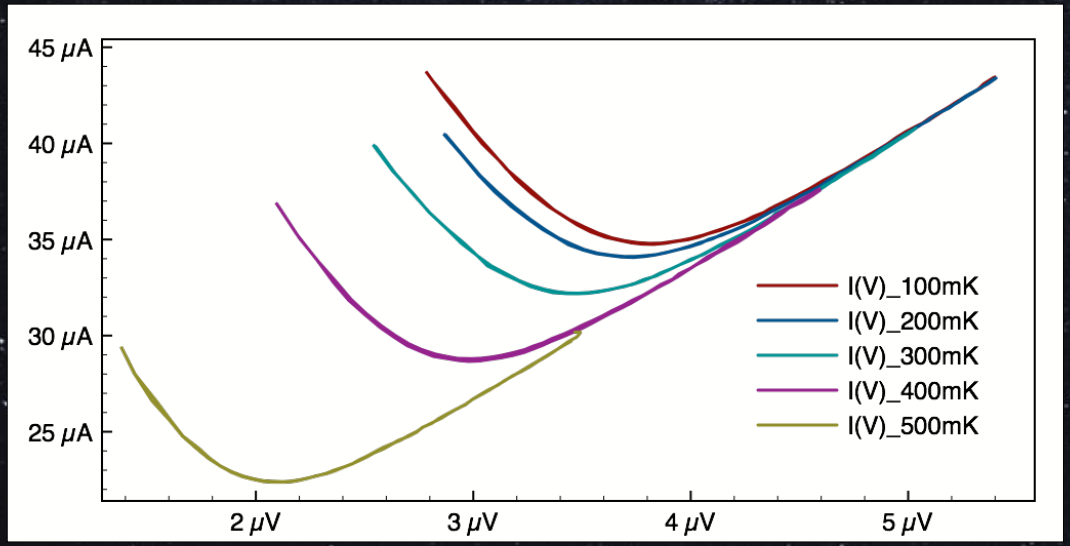
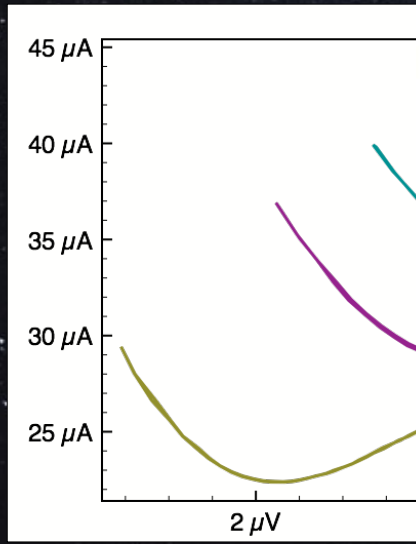
Electrothermal Feedback

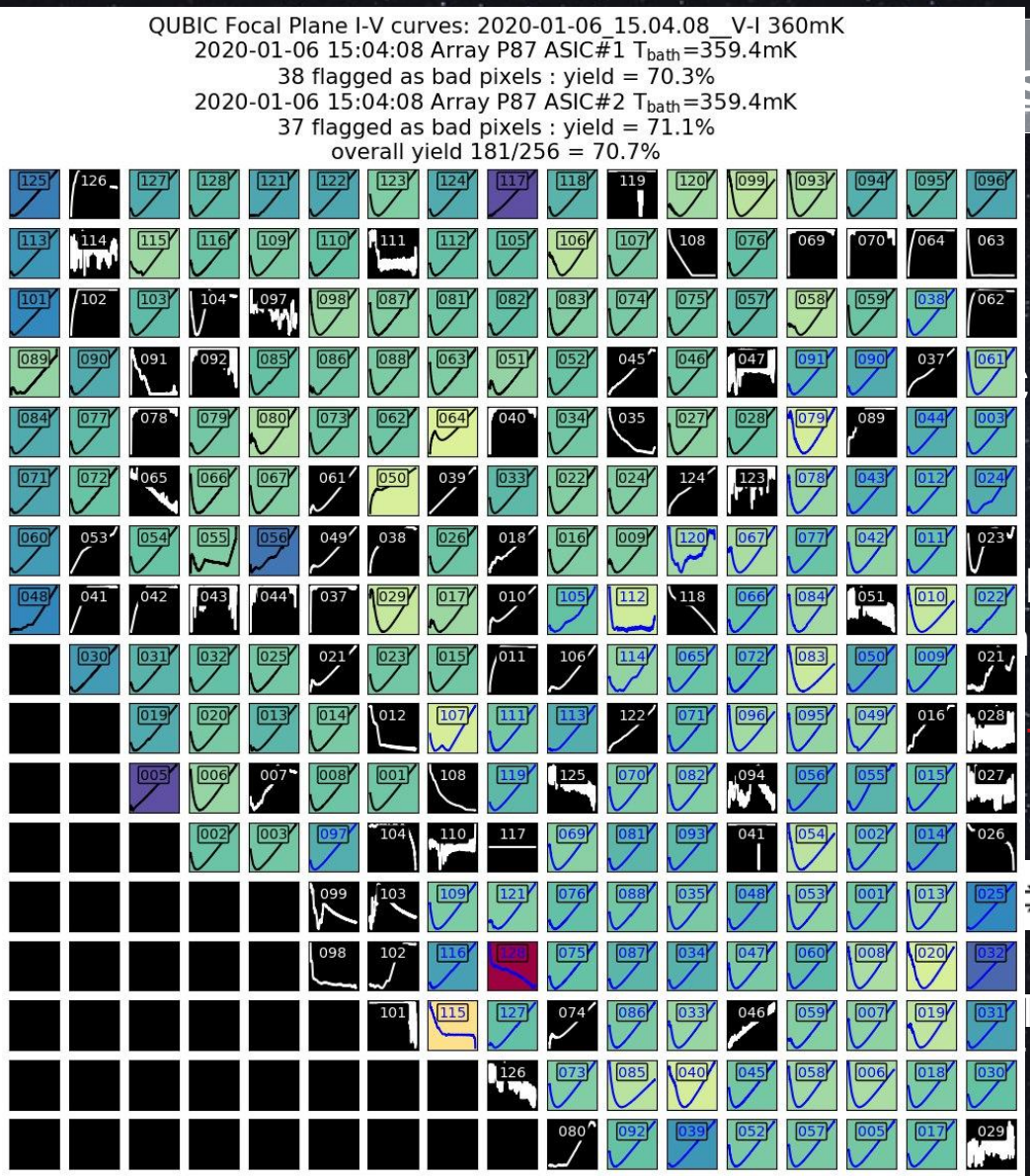


- Reaction to keep the TES in the transition phase
- $L = \frac{\partial T}{\partial P}\frac{\partial P_J}{\partial R}\frac{\partial R}{\partial T}$ Thermal transfer function Electric transfer function
- $Pi\nearrow \Rightarrow T\nearrow \Rightarrow R(T)\nearrow \Rightarrow Pj(T)=V_{BIAS}^2/R(T)\searrow$
- Allows one Temperature for a large number of TESs

sition Edge Sensors

How can we have





k

keep the TES in the
ase

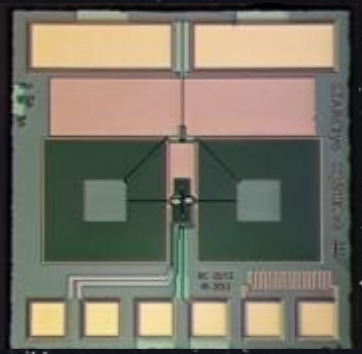
Thermal transfer function
Electric transfer function

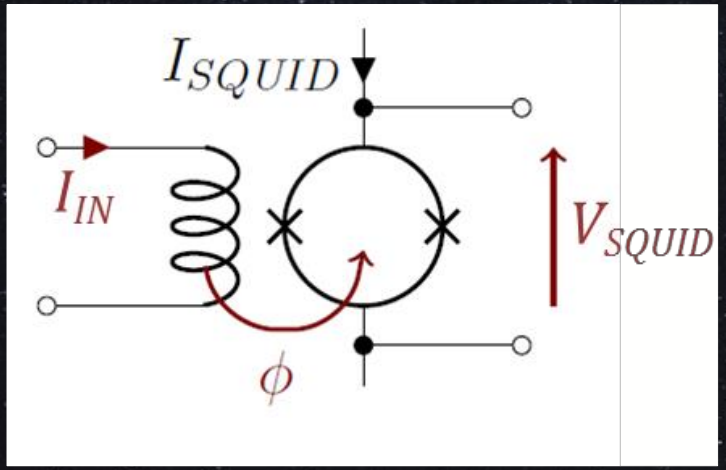
$\Rightarrow R(T)\nearrow \Rightarrow Pj(T)=V_{BIAS}^2/R(T)\searrow$

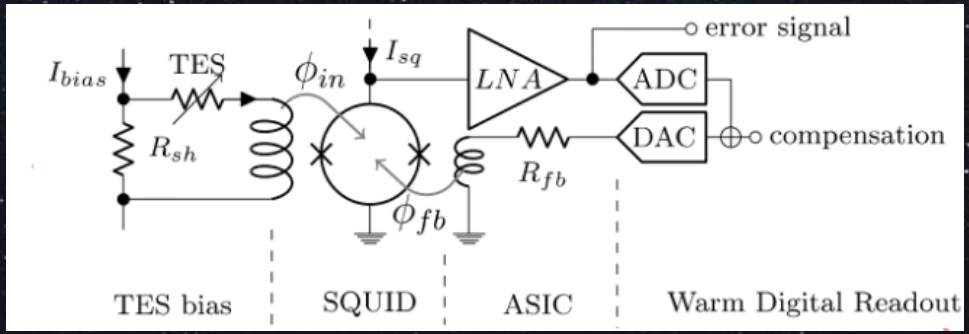
Temperature for a large
ESs

Detection Chain : Superconducting QUantum Interference Devices

- Can be installed very close to the detectors (operate at 1K)
- Rin=0Ω
- Low noise transimpedance amplifiers (SQUID+Lin)
- Allow Time Domain Multiplexing with a dedicated cryogenic ASIC

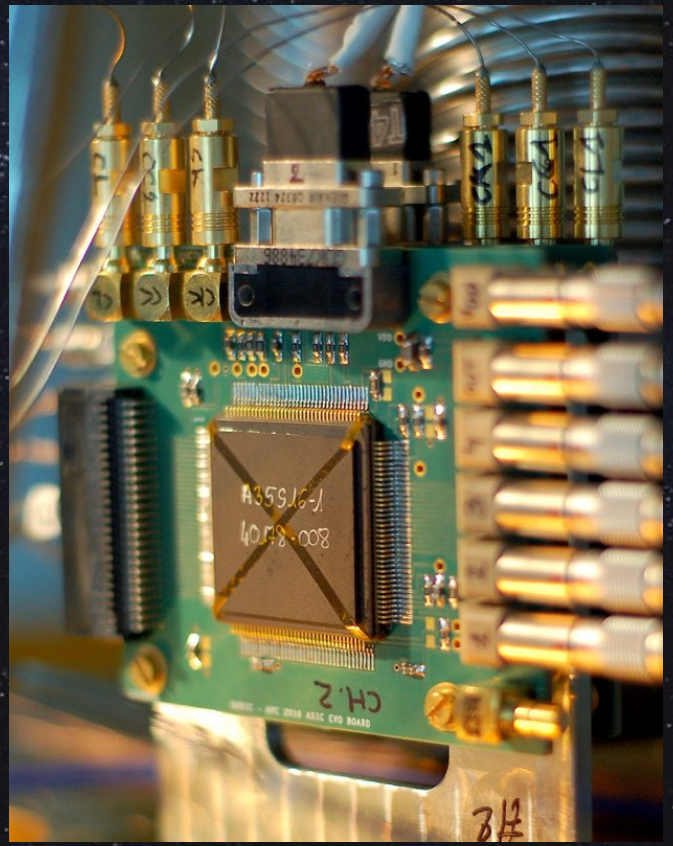




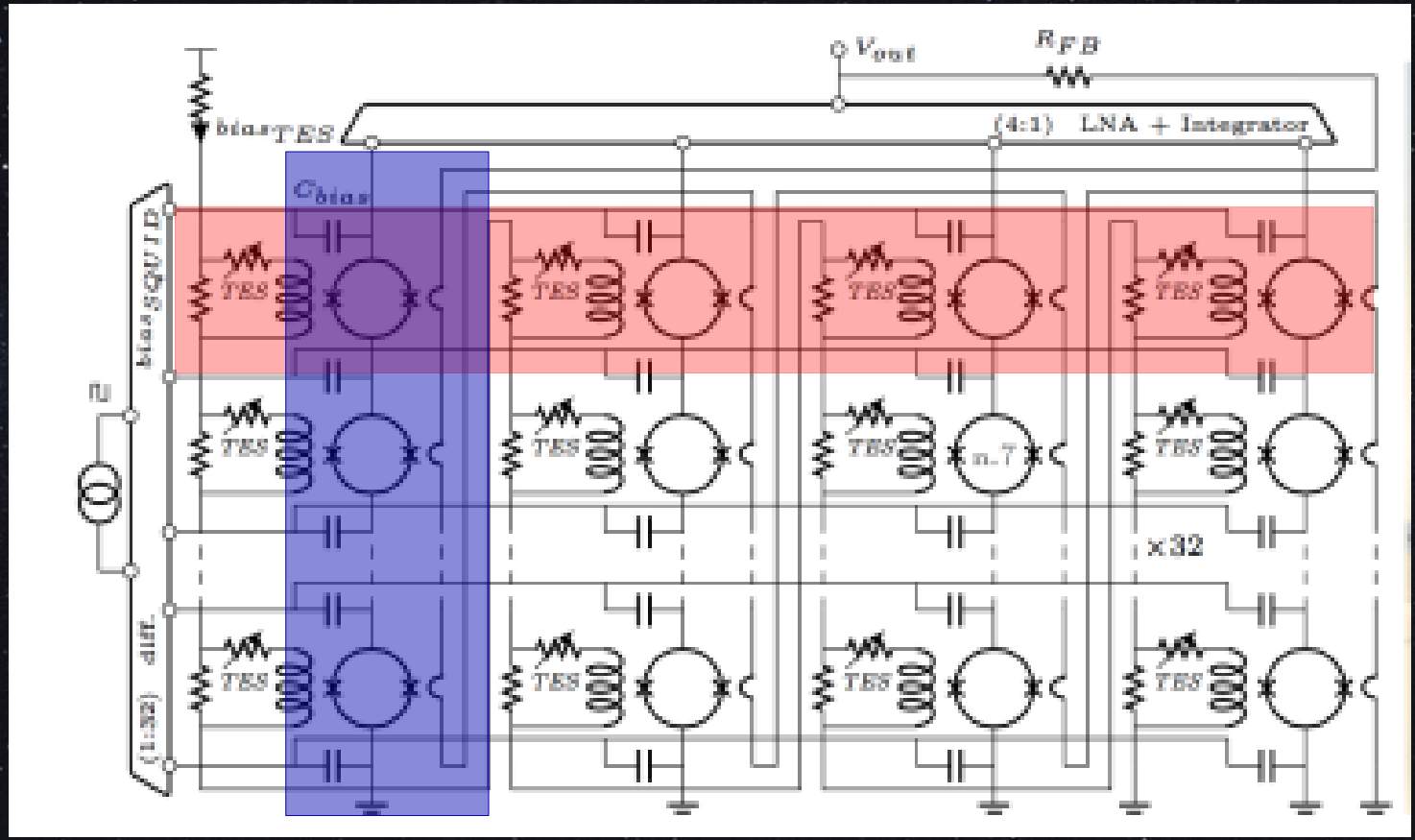


Detection Chain : Application-Specific Integrated Circuit

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



vDetection Chain : Application-Specific Integrated Circuit



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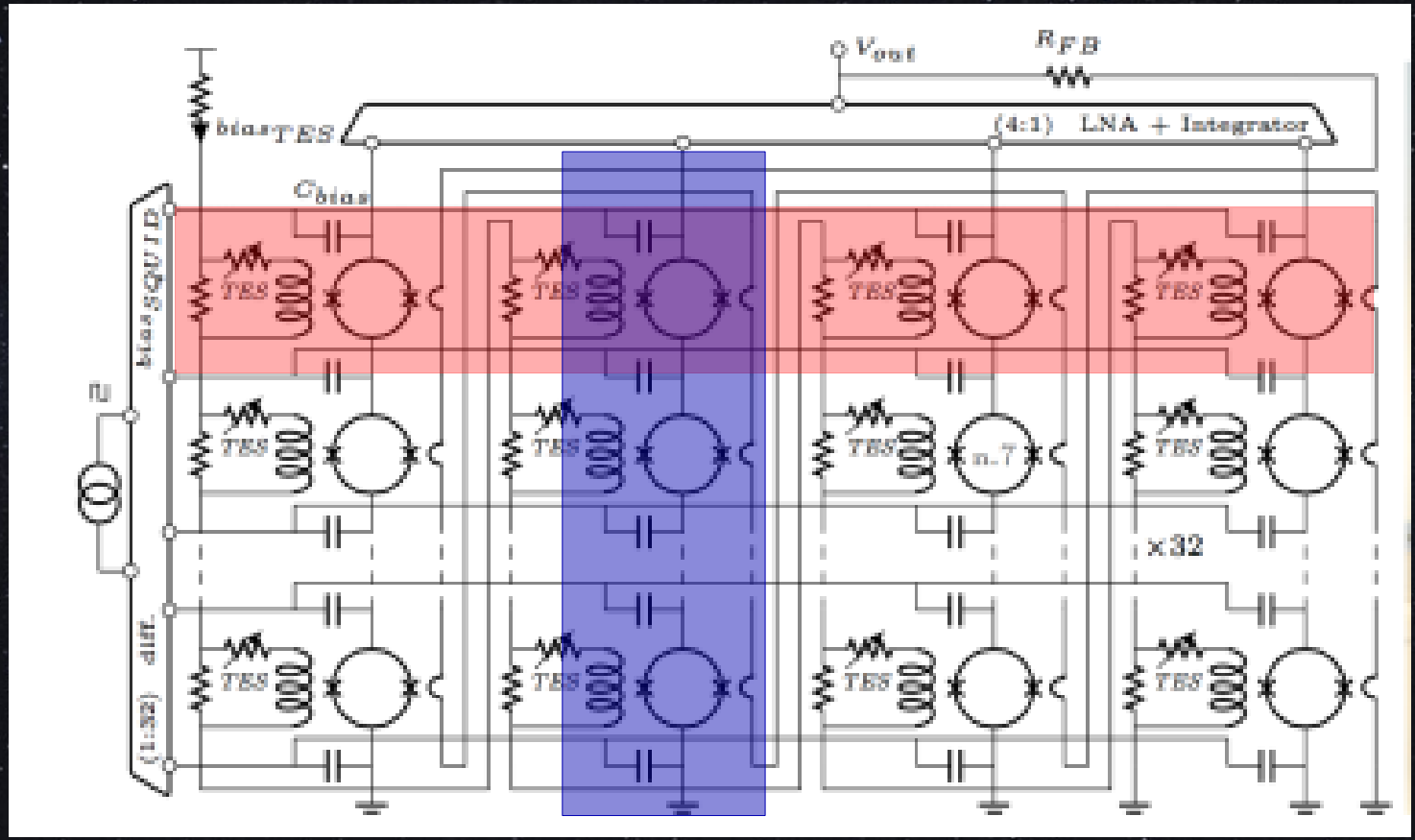

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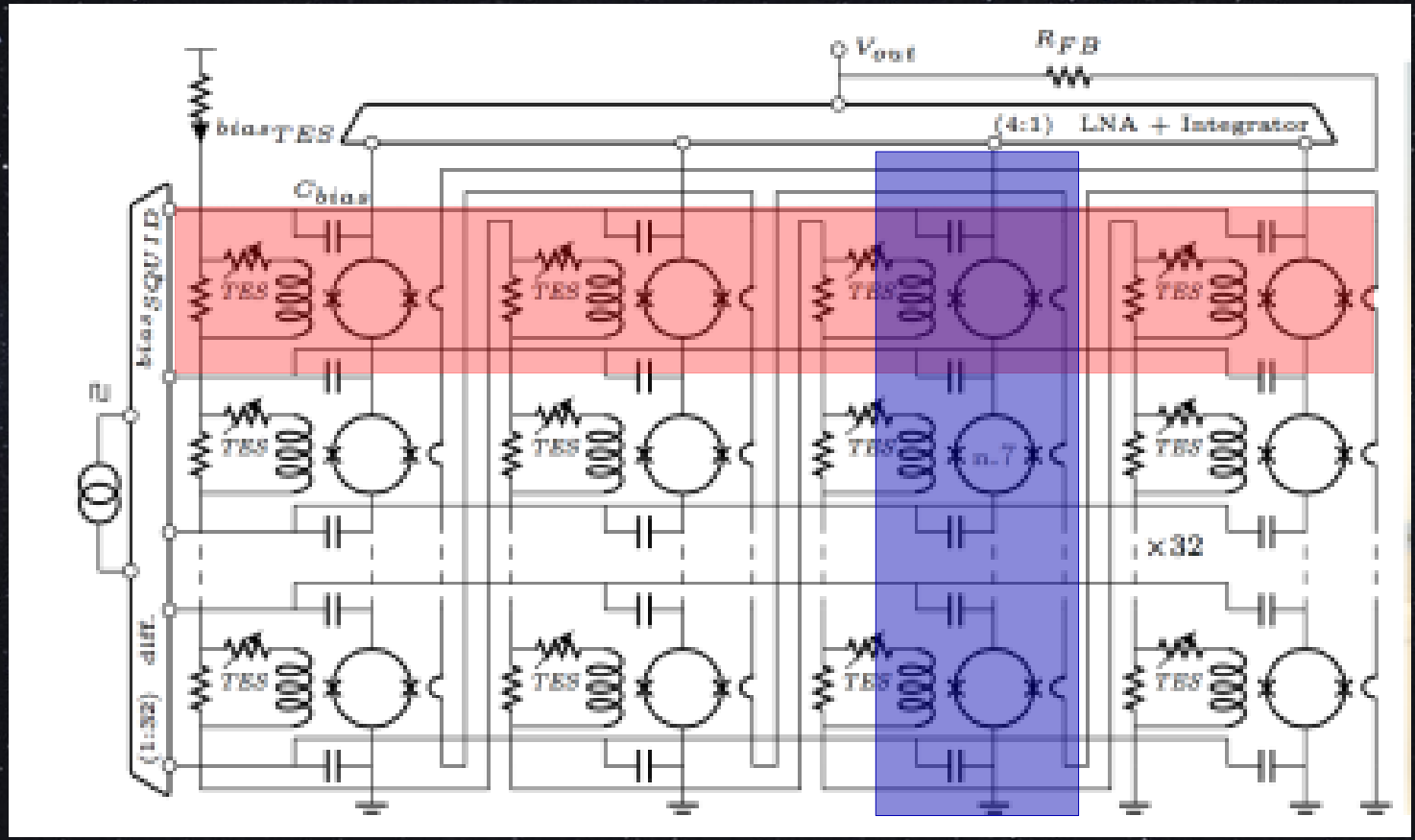

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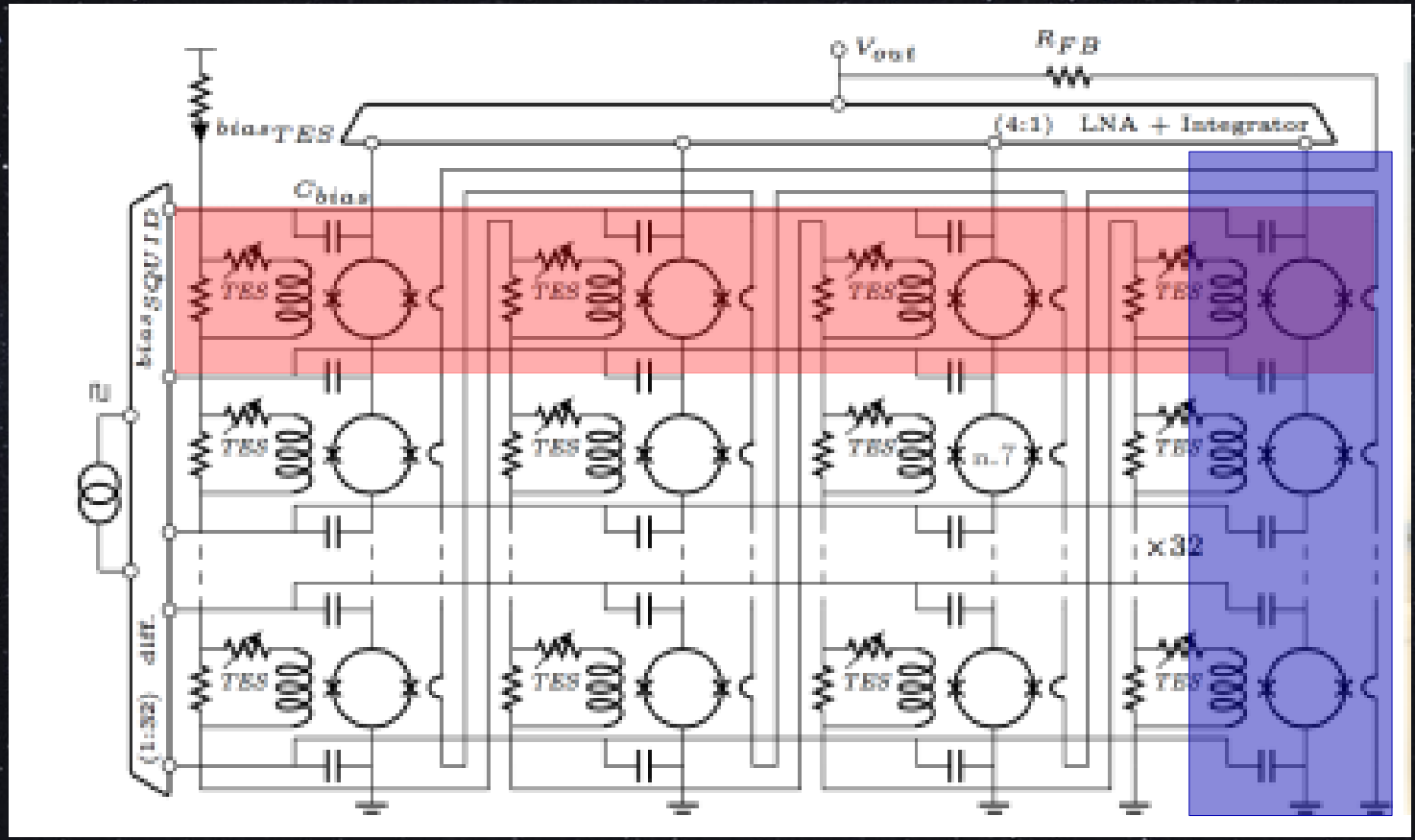

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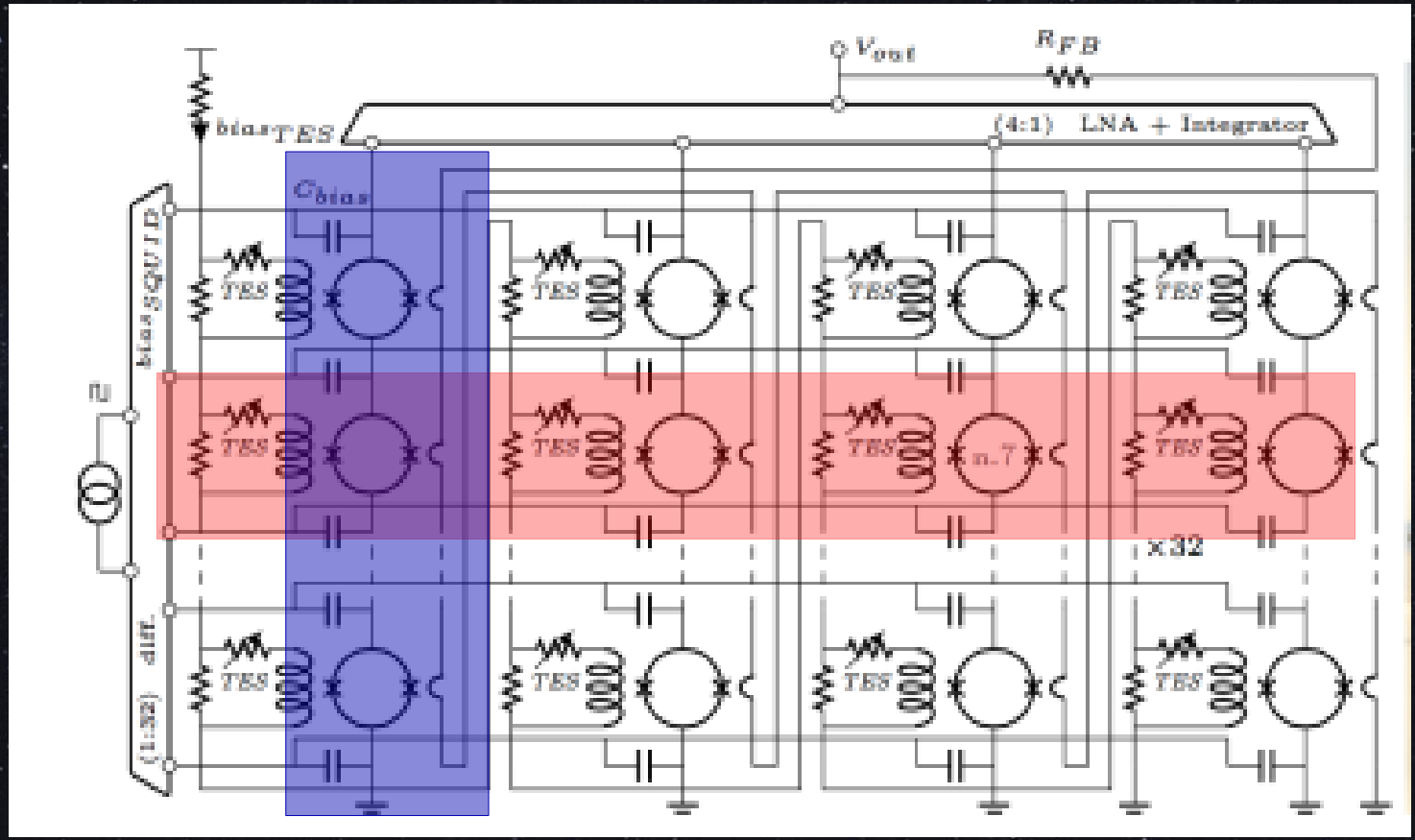

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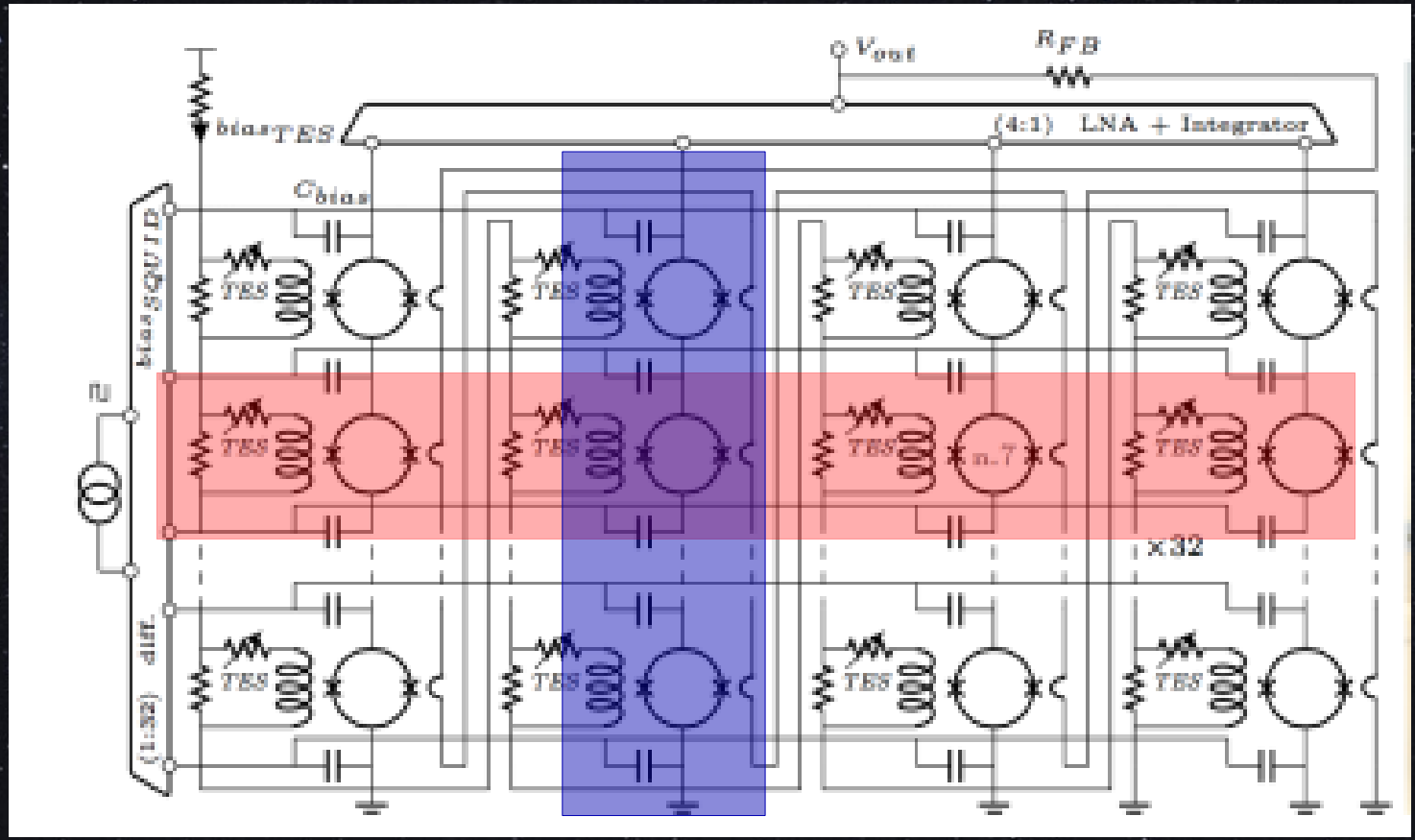

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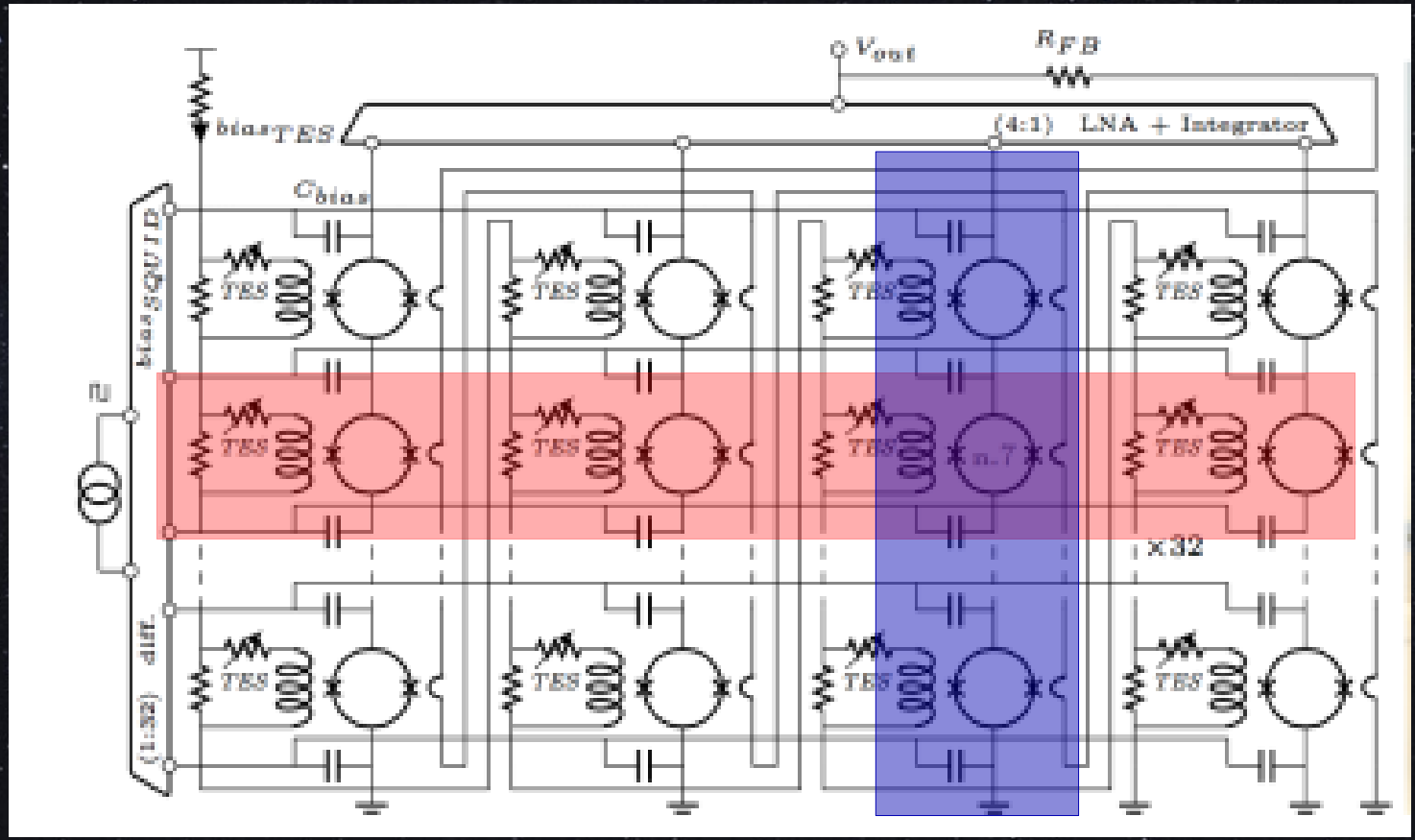

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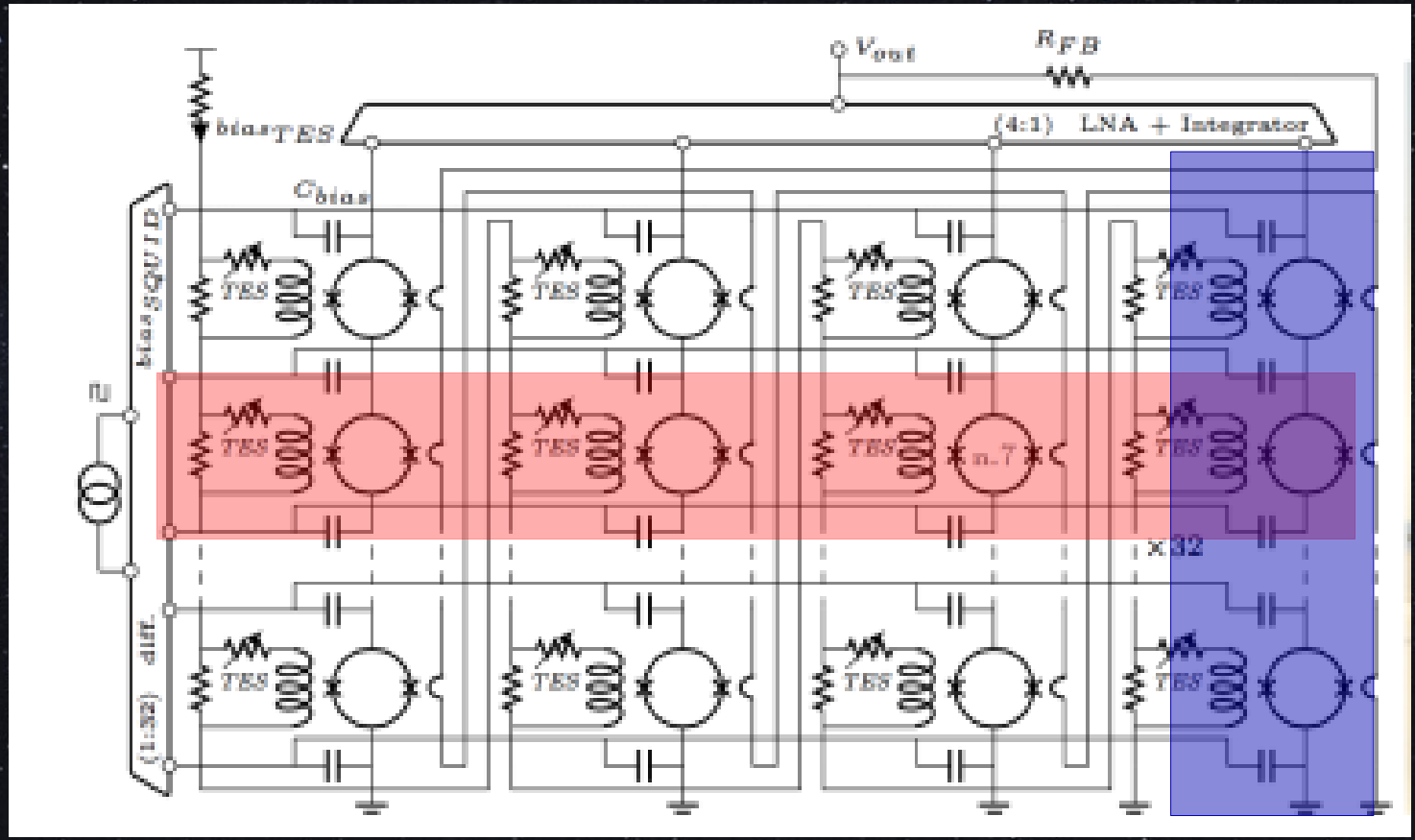
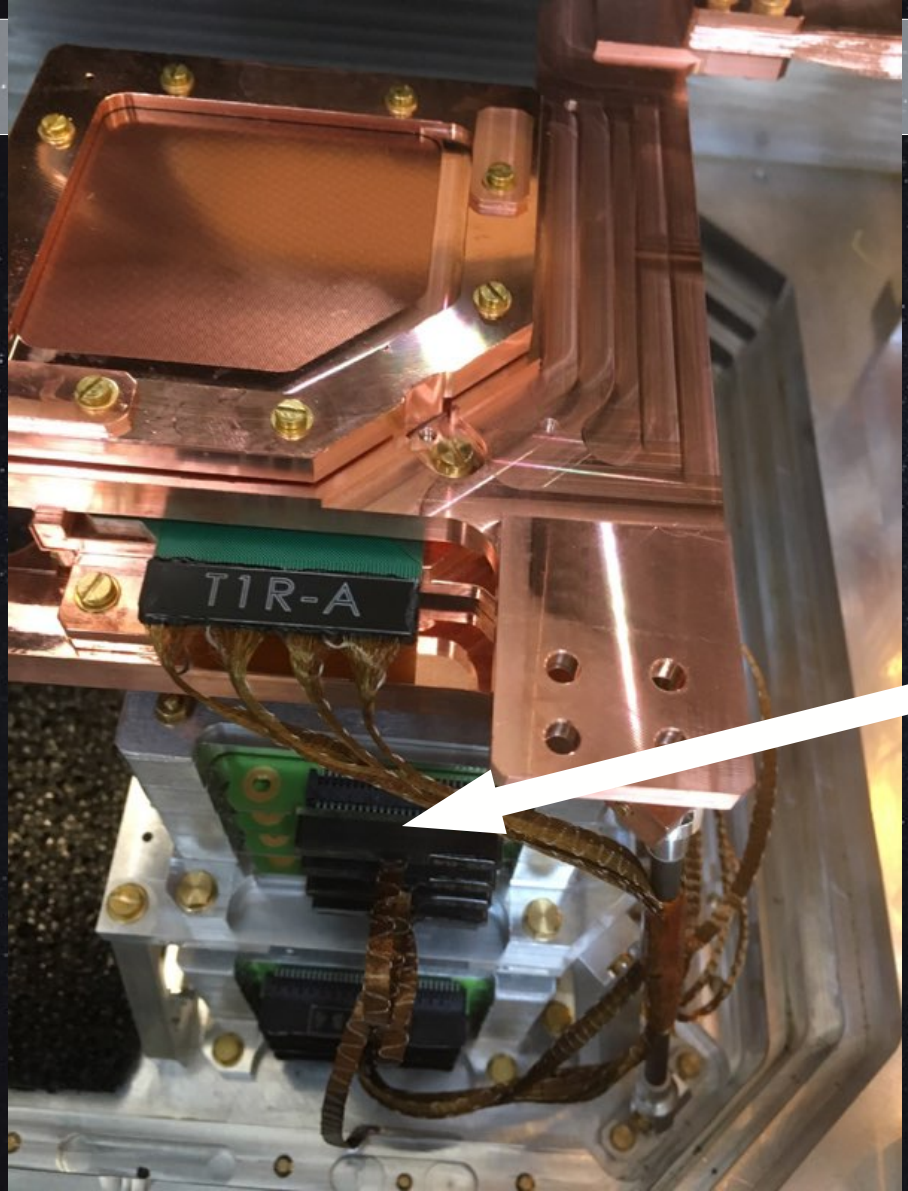
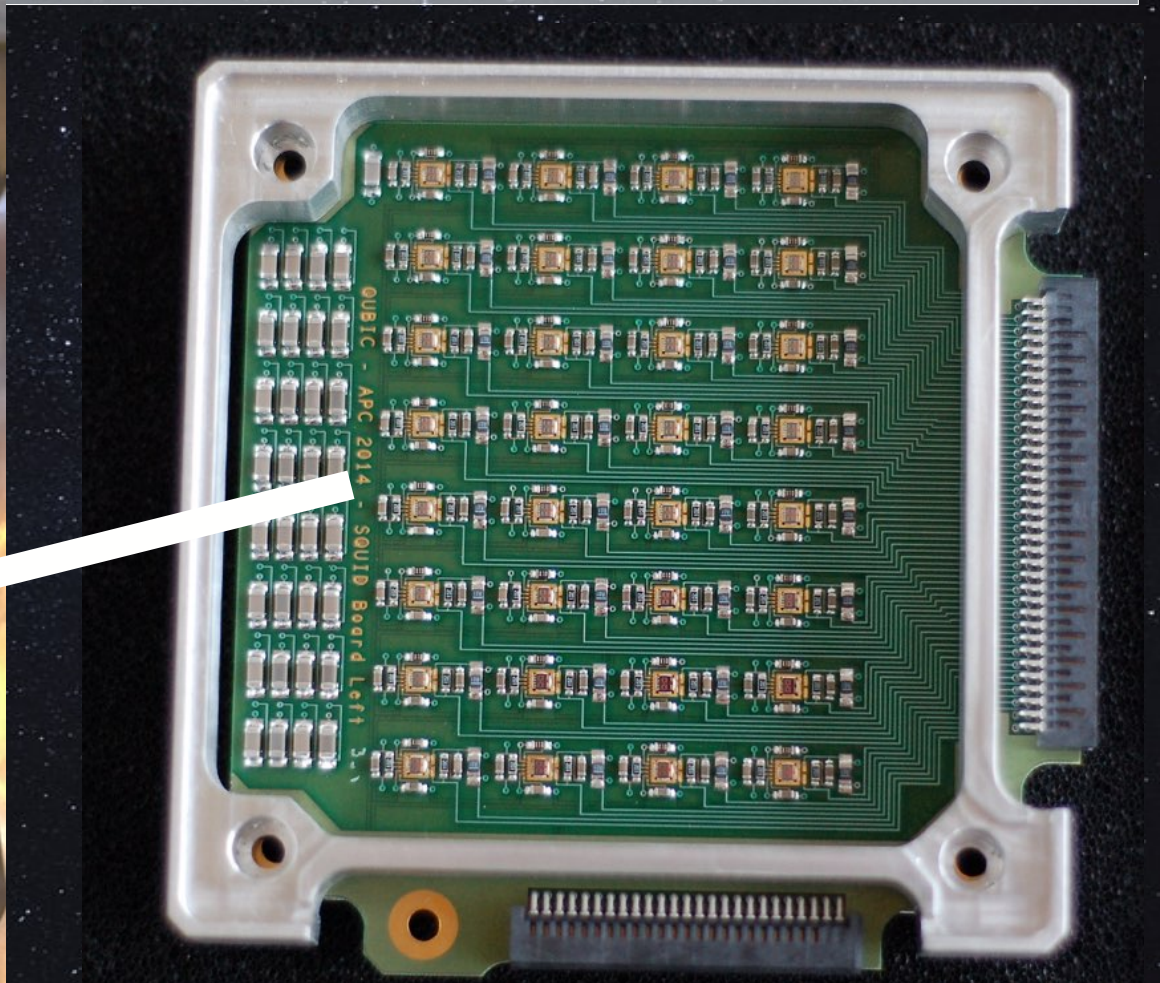


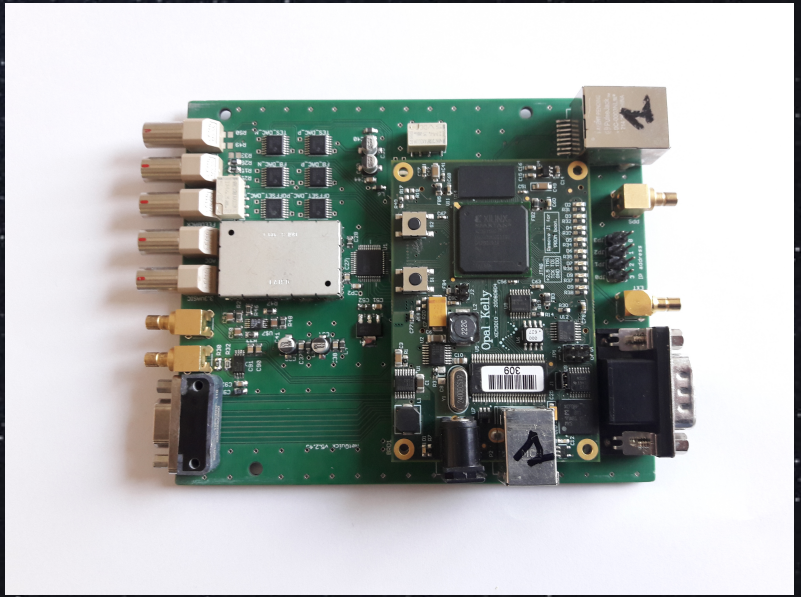
Detection Chain





Detection Chain : Field-Programmable Gate Array

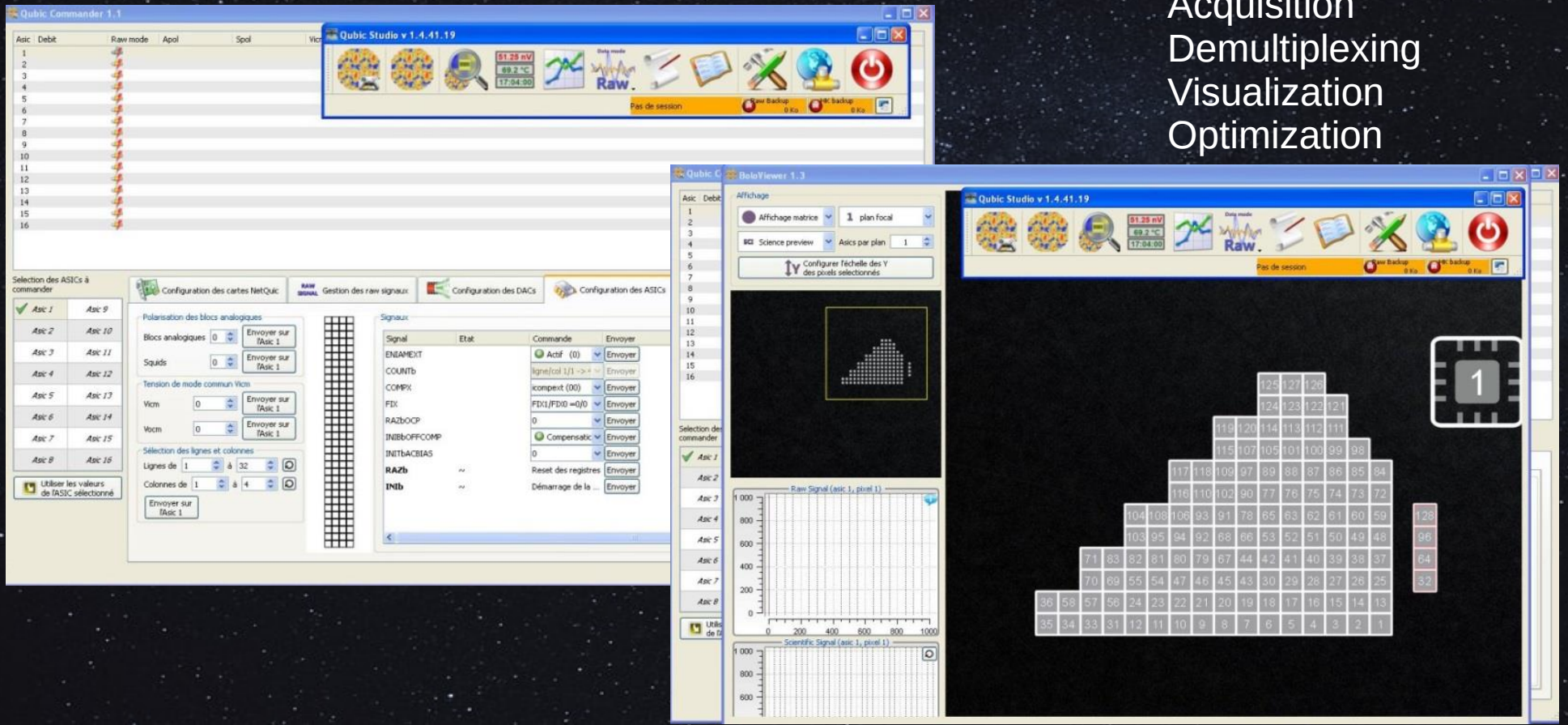
- FPGA used as a hardware interface to communicate with QubicStudio (software developed by IRAP for the use of QUBIC experiment)
- Clock synchronization for all the ASICs
- Data acquisition (demultiplexing signal)



Detection Chain : Field-Programmable Gate Array

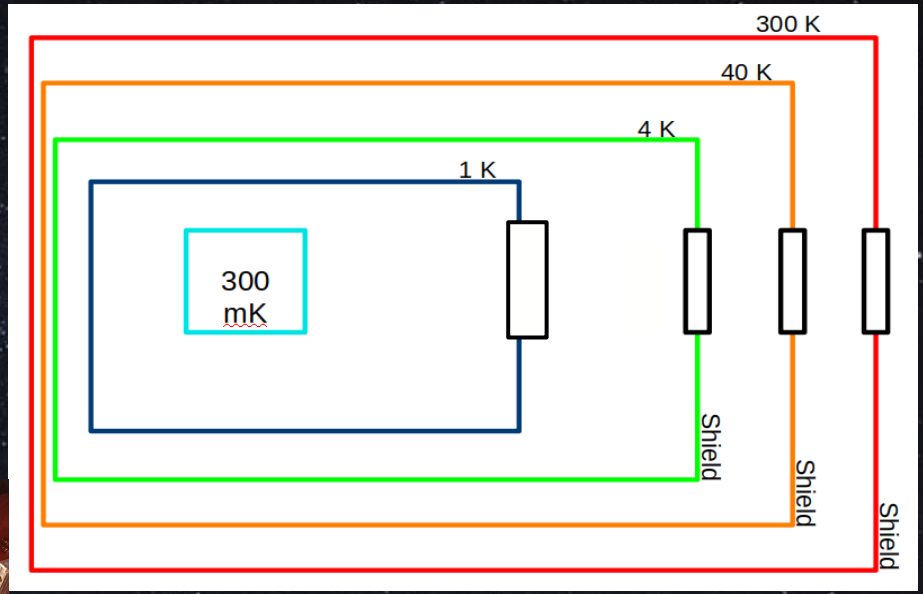
Software QUBIC studio:

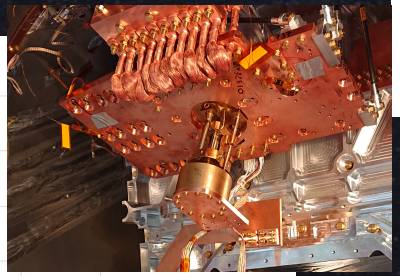
ASIC parameterization
Acquisition
Demultiplexing
Visualization
Optimization

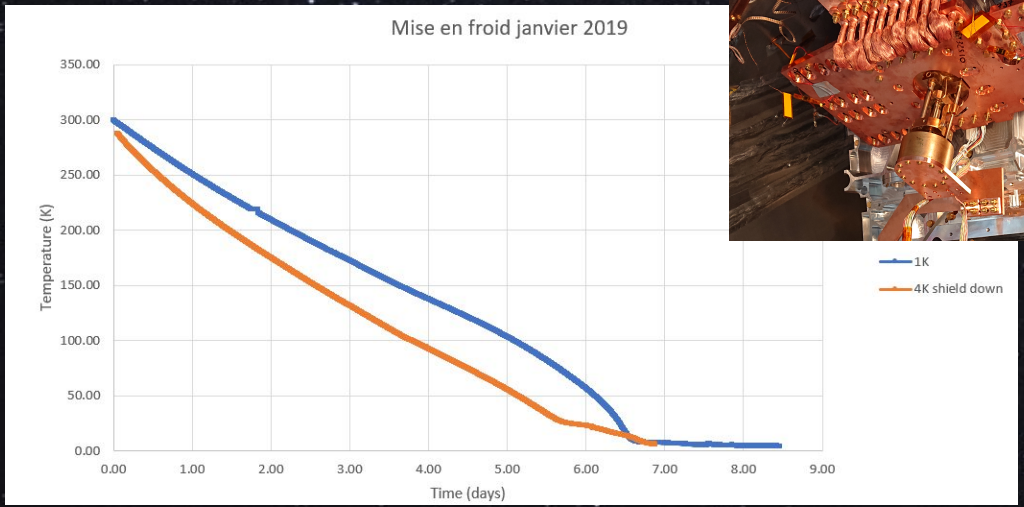


Cryogenic System

- 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

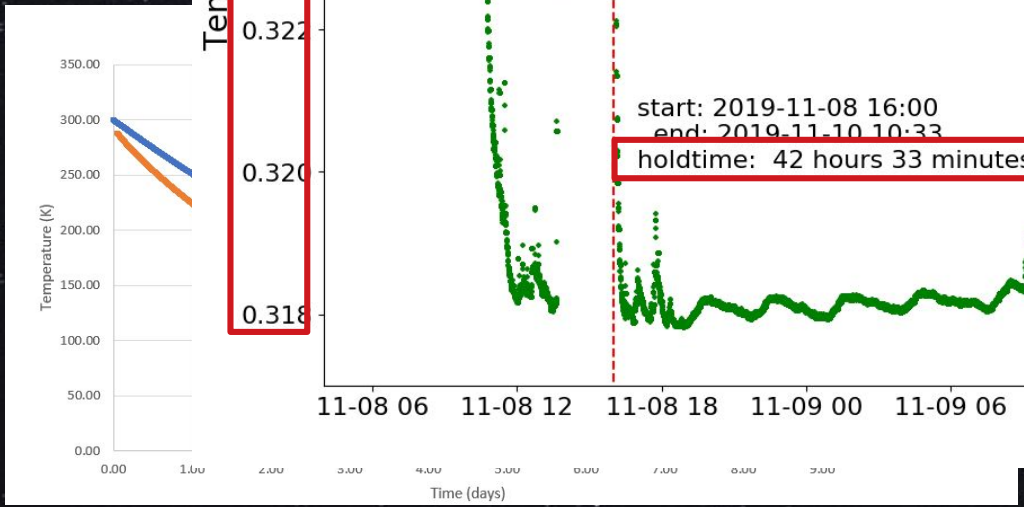


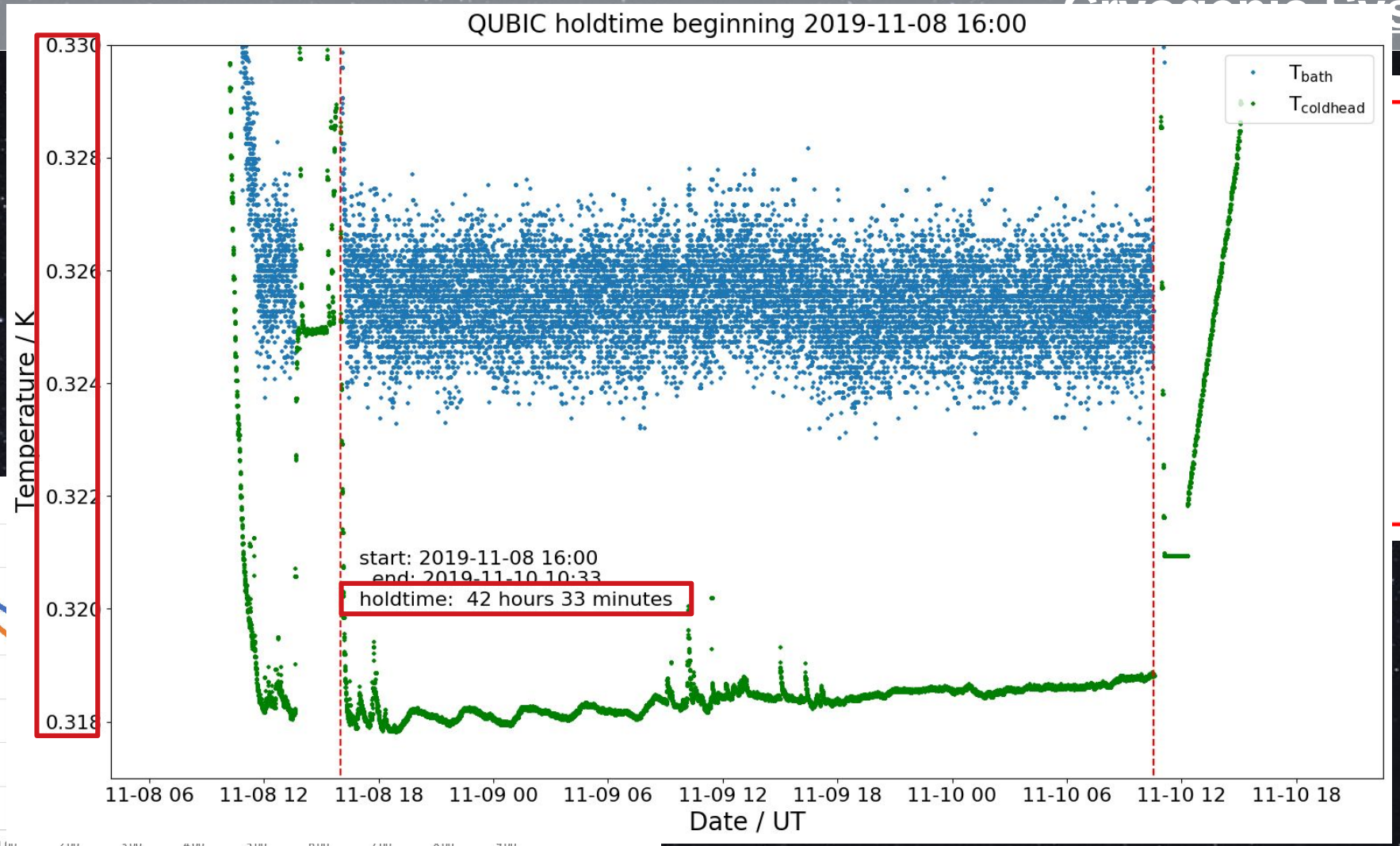




- Cool down time : ~ 8 days (150 kg to cool down at 1K)

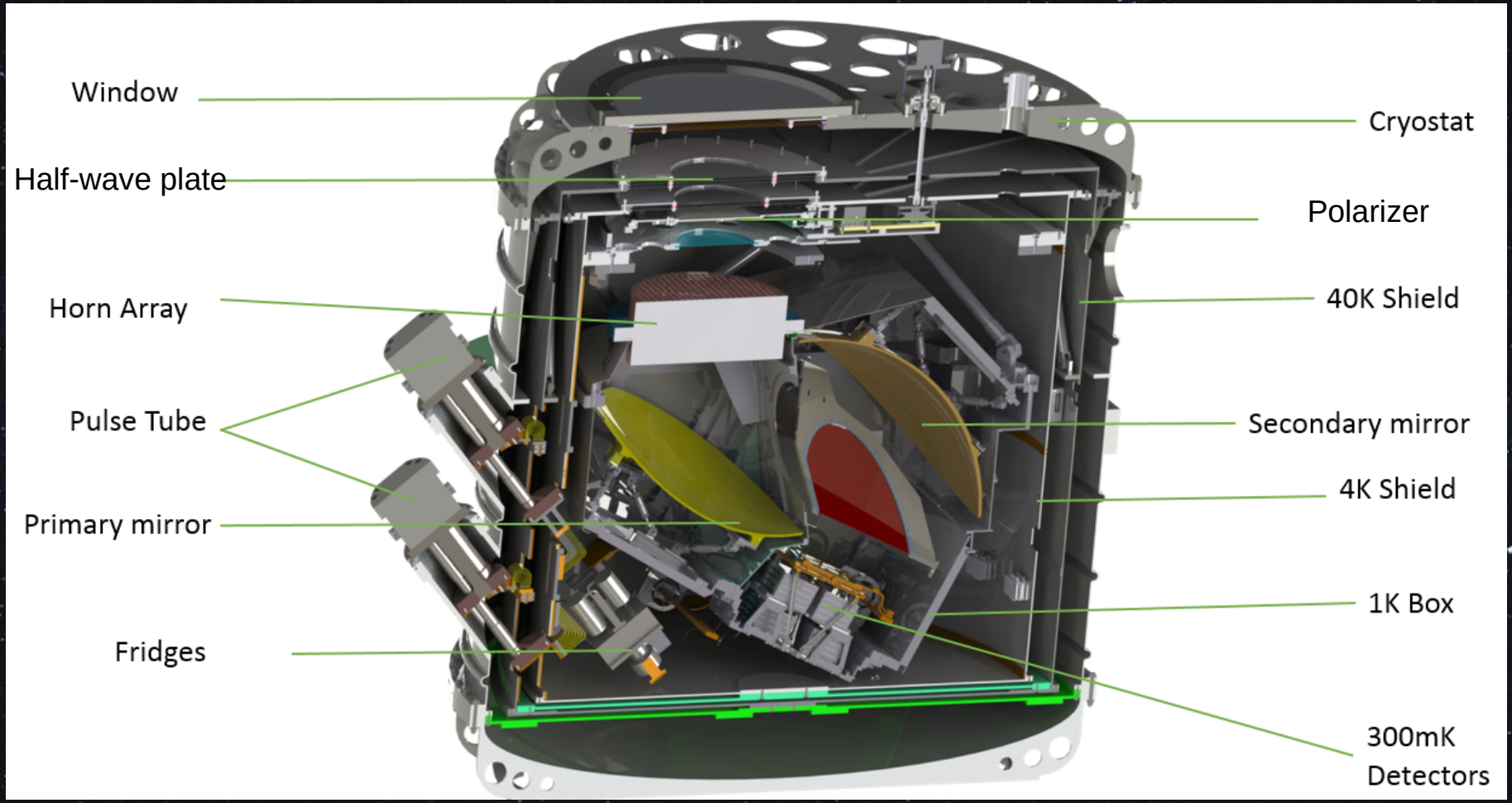
-
-
-


350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Temperature (K)
0.00
Time (days)


QUBIC holdtime beginning 2019-11-08 16:00
Temperature / K
0.330
0.328
0.326
0.324
0.322
0.320
0.318
T_{bath}
$T_{coldhead}$
start: 2019-11-08 16:00
holdtime: 42 hours 33 minutes
11-08 06
11-08 12
11-08 18
11-09 00
11-09 06
11-09 12
11-09 18
11-10 00
11-10 06
11-10 12
11-10 18
Date / UT

Shield

The Q and U Bolometric Interferometer for Cosmology (QUBIC)



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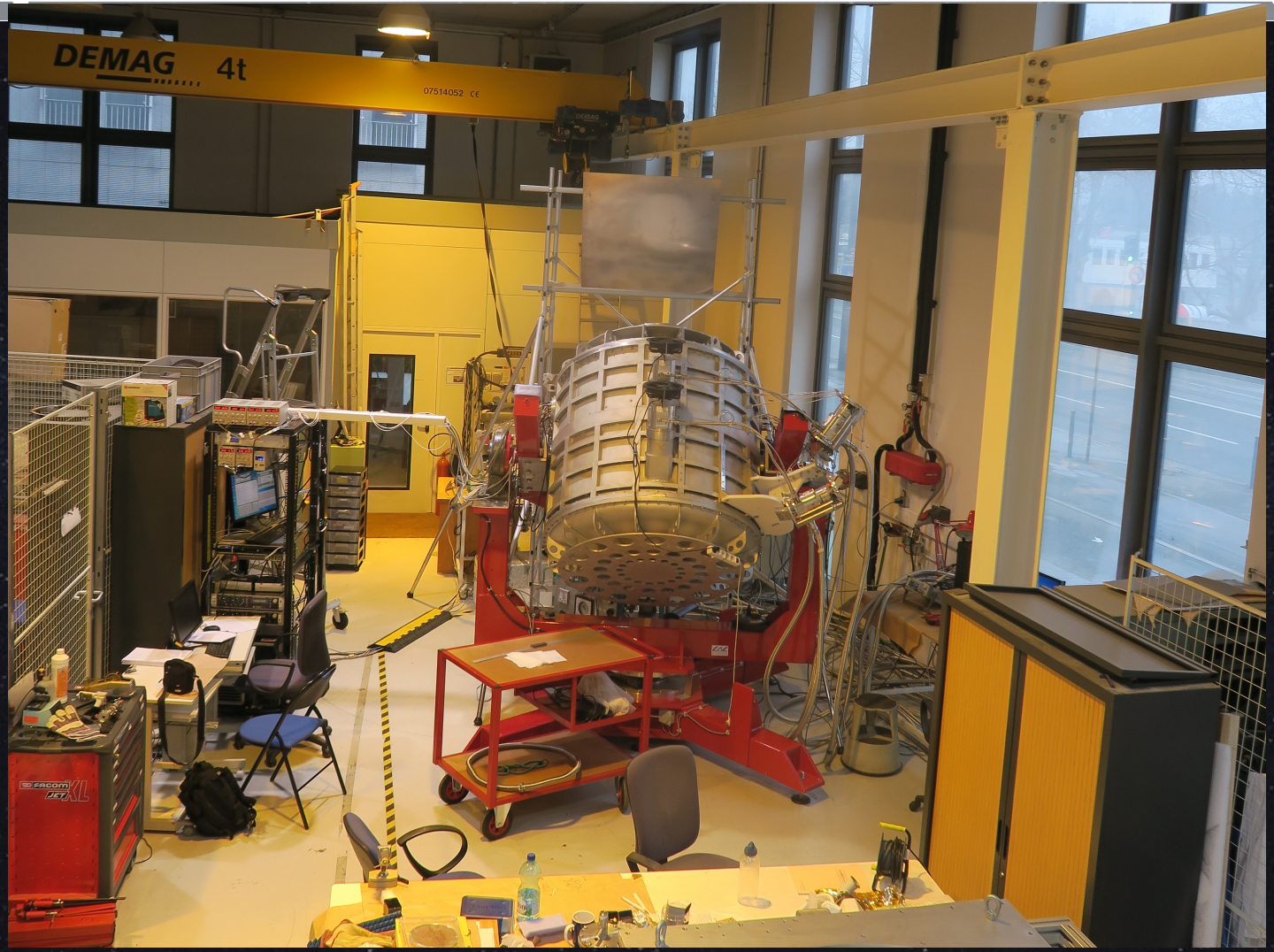
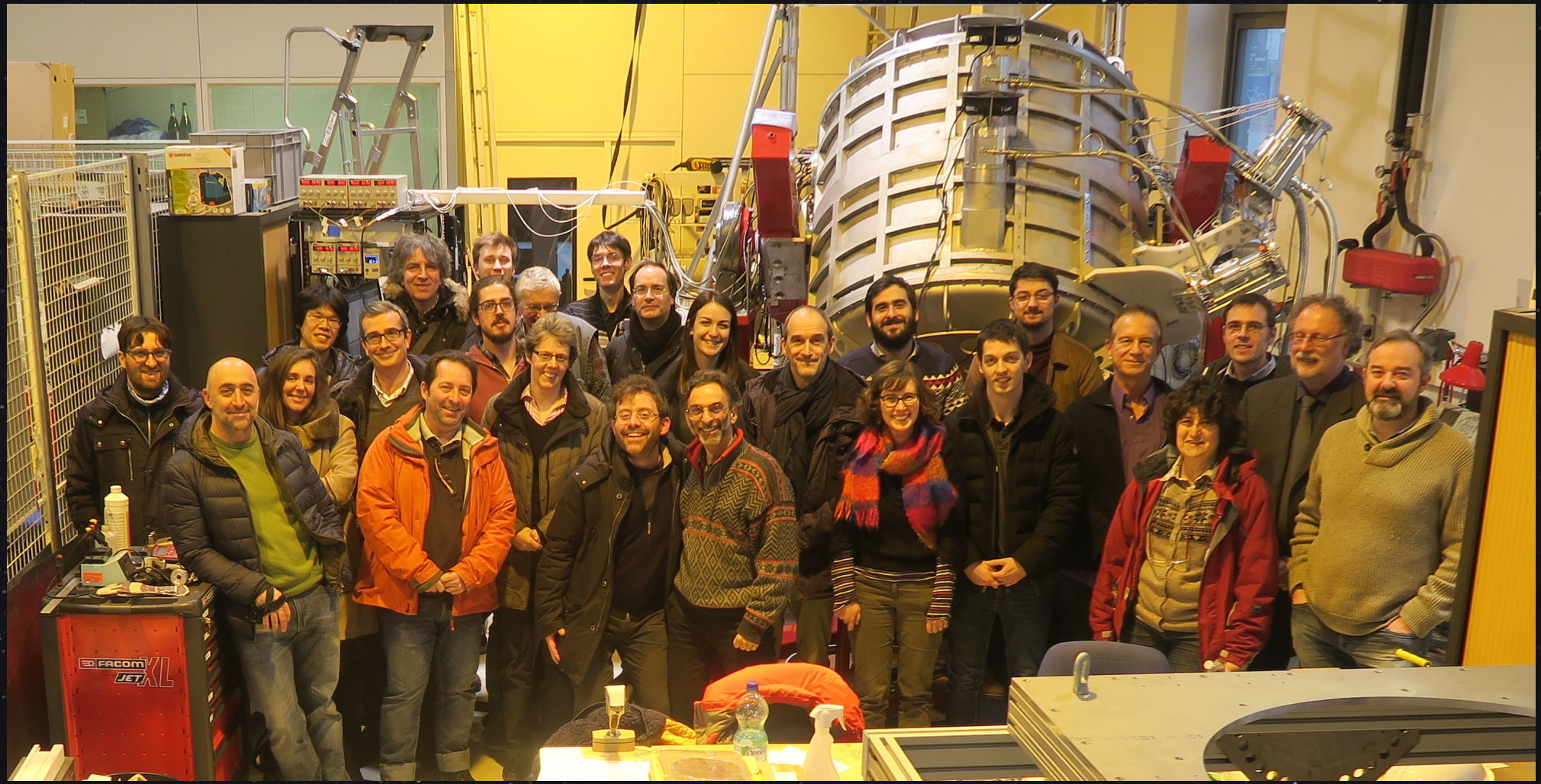
Thanks for your attention