Cold amp studies in Milano

DUNE electronics meeting
24th July 2019

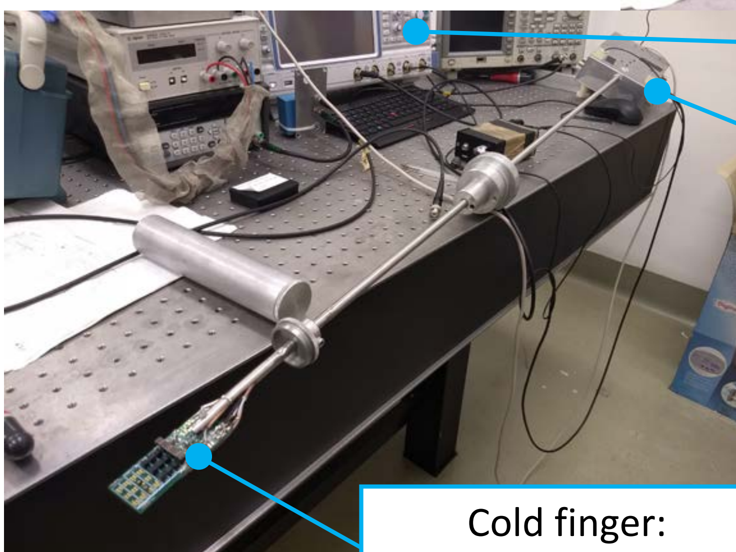
Paolo Carniti[1], Andrea Falcone[1], Claudio Gotti[1], Antonio Lucchini[2], Gianluigi Pessina[1], Stefano Riboldi[2], Francesco Terranova[1]

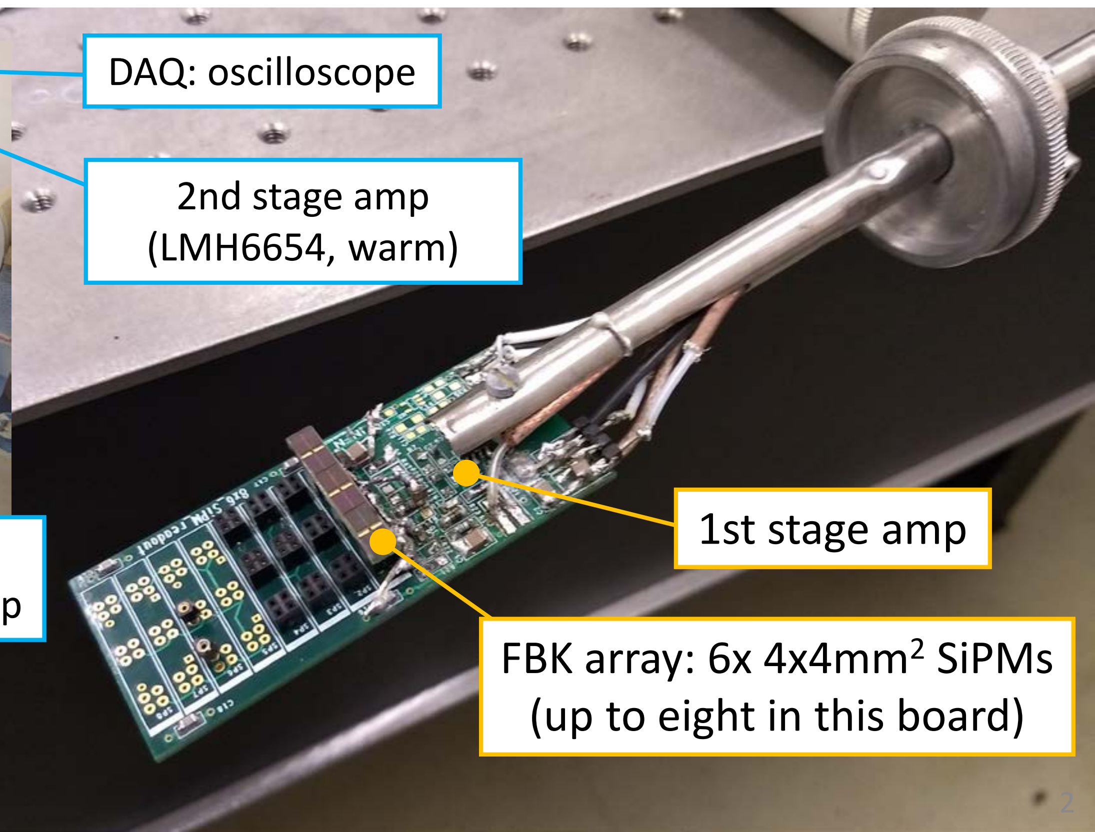
[1]INFN and Univ. Milano Bicocca

[2]INFN and Univ. Milano

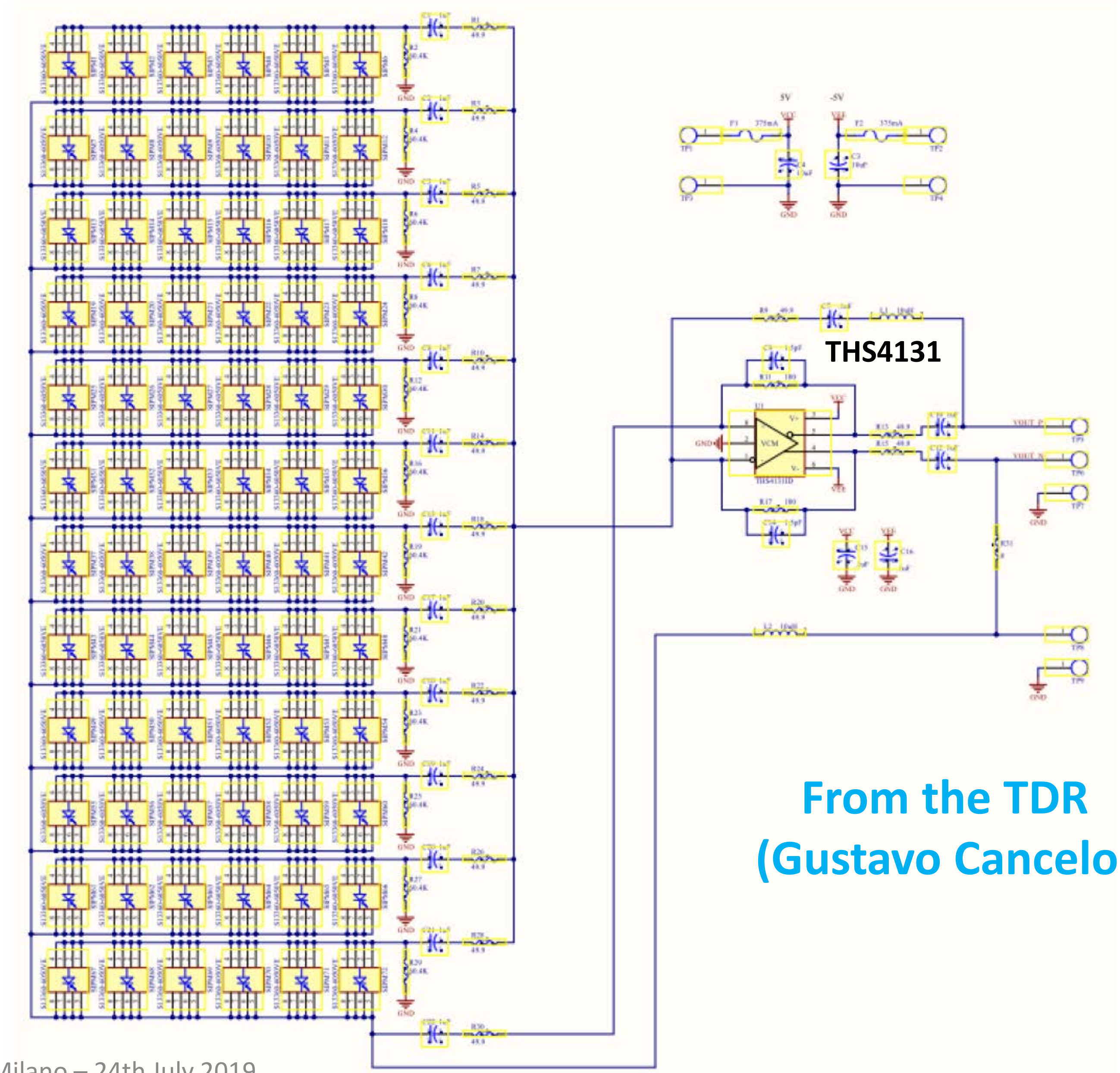
Brief overview

- Starting point: we needed a cold amplifier to characterize SiPMs from FBK
- After a phone meeting with Gustavo last march, we started to use the THS4131 (as in DUNE TDR)
- Then we tried to further tune the cold amplifier for FBK SiPMs
- **Results on FBK SiPMs described at other meetings**
- **The following slides will focus on cold electronics**





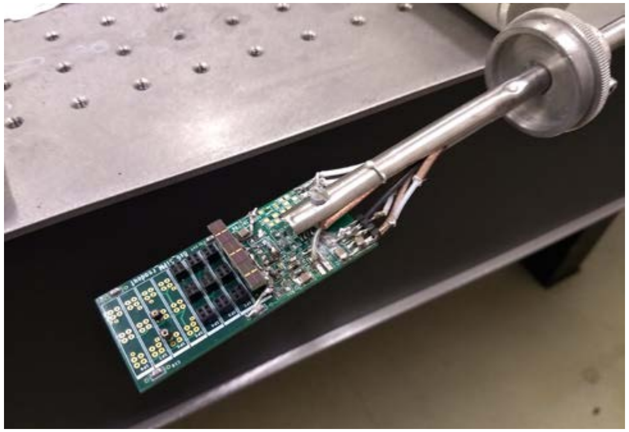
TDR schematic



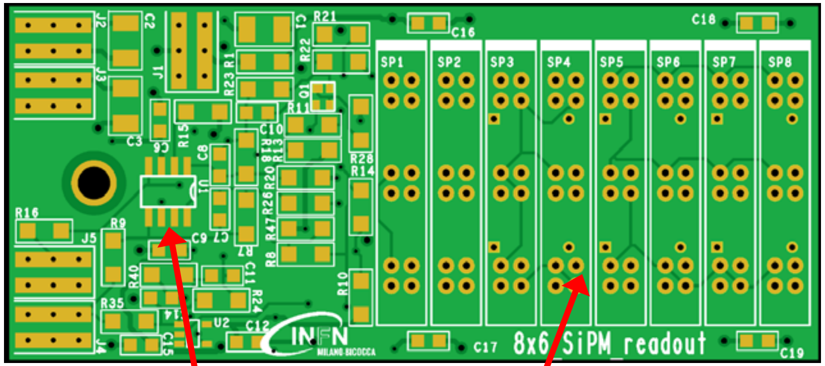
From the TDR (Gustavo Cancelo)

PCB for FBK SiPMs

- Designed for 8x FBK tiles (6x 4x4 mm^2 SiPMs each)
- Option for 6x Hamamatsu 6x6 mm^2 for comparison
- Flexibility to test different amplifiers and configurations



FRONT

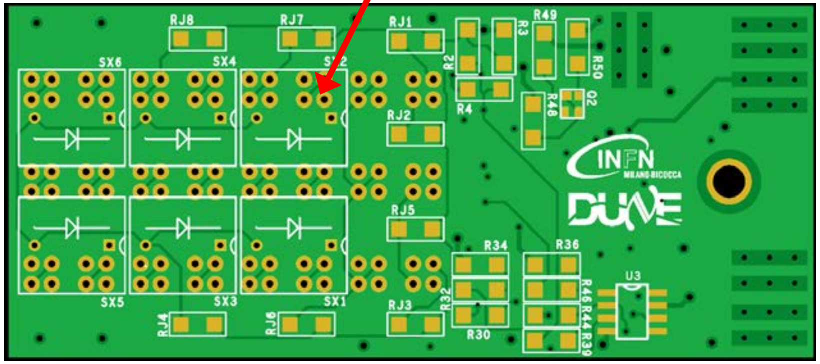


Amplifier

FBK SiPMs

BACK

Hamamatsu SiPMs



Reading out FBK SiPMs

Operation of the THS4131 with FBK SiPMs looked sub-optimal:

1) Noise

- The first FBK SiPMs we measured had quenching resistor at cold of several MΩ
- Tail much longer than Hamamatsu (>1 us at cold); amplitude much lower
- Larger weight of low frequency noise
- Triggering with the oscilloscope was difficult

2) Flexibility

- With a single stage opamp, room for tuning is limited
- Closed-loop gain and bandwidth are linked and depend on input impedance (SiPM capacitance)
- There is only one «free» parameter, R_F, which then needs to satisfy constraints on gain and dynamic range

Noise at cold

- Series (voltage) noise gives the dominant contribution
- THS4131 at 77K: we measured 1.2 nV/√Hz, similar to room T
- Low frequency noise 2x-3x larger w.r.t. room T

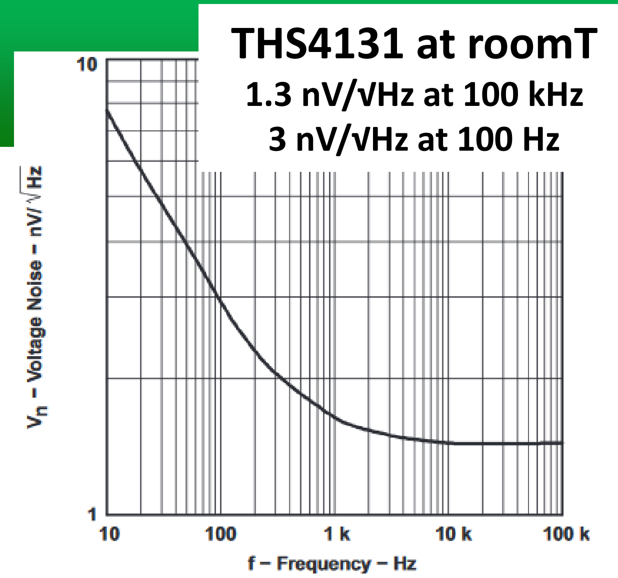
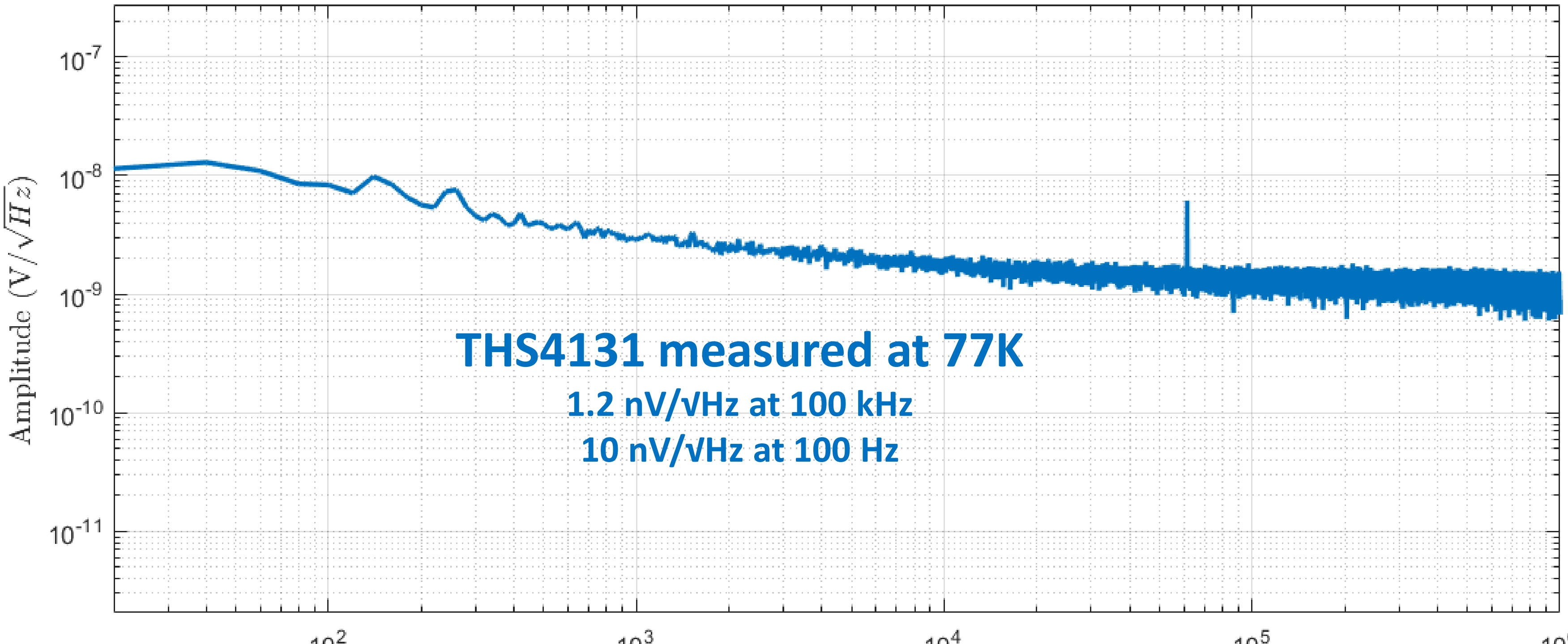
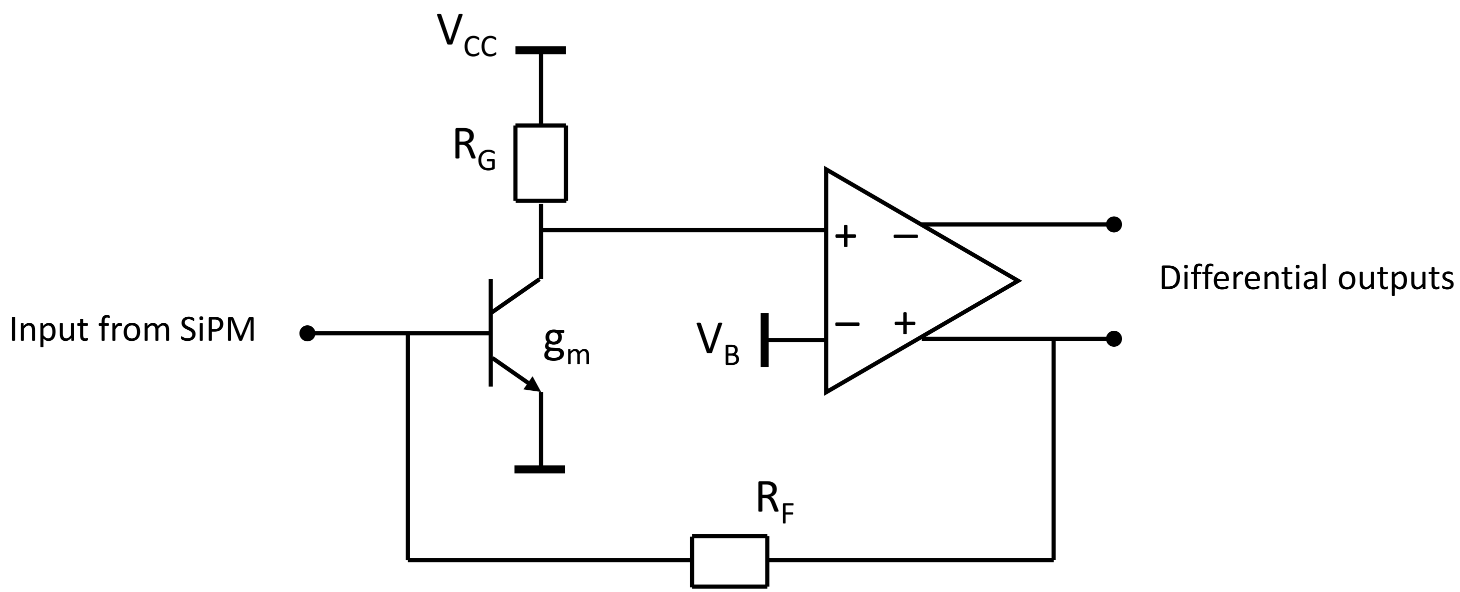


Figure 24. Voltage Noise vs Frequency



BJT + opamp

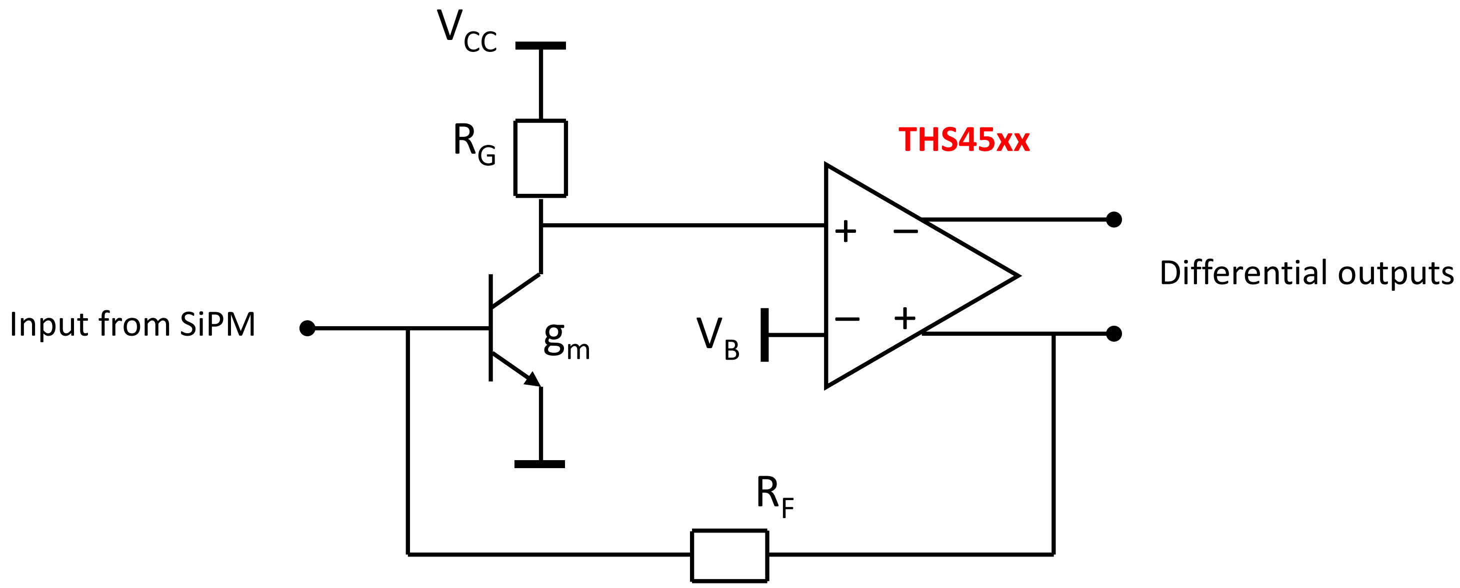
Aiming for lower noise and higher flexibility, we moved to a 2-stage design:



- The collector of the BJT is set to V_B and its bias current is $I_B=(V_{CC}-V_B)/R_G$
- The transconductance is $g_m = I_B/(kT/q) = I_B/6.6$ mV at 77K → 45 mA/V with I_B=0.3 mA at 77K
- The gain of the BJT is $g_m R_G$ → **noise of the opamp becomes negligible**
- White noise at the input of the BJT is $\sqrt{(2kT/g_m)}$ → **0.3 nV/√Hz** with I_B=0.3 mA at 77K
- The input is single-ended, but it should not be a problem (the amplifier is close to the SiPMs)

BJT + opamp

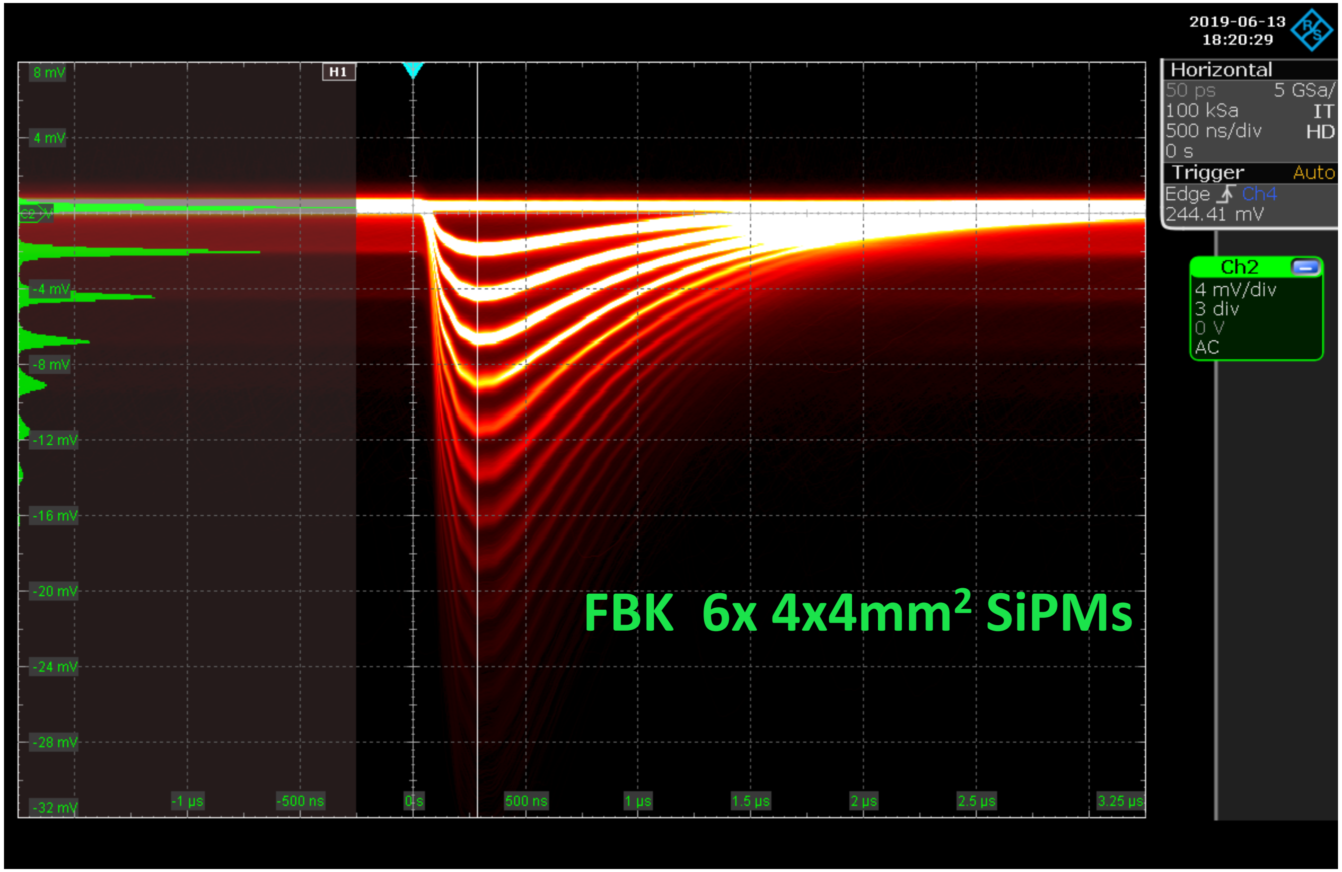
Since the noise of the opamp is now negligible, we are free to choose the opamp based on bandwidth, power consumption, dynamic range.



- The THS45xx family looks particularly promising
- THS4531 → supply current is 0.3 mA, ≈1/10 of the THS4131 at 77K
- THS4521 and THS4551 → supply current is 1 mA, same bandwidth as THS4131
- All the THS45xx family have rail to rail output stage → higher dynamic range than THS4131
- **Increased flexibility and lower power consumption**

BJT + opamp

- Tests with FBK SiPMs look very promising
- Excellent p.e. separation at Vov=3V (S/N>10)
- Risetime ≈ 80 ns, further tuning possible
- More tests with larger ganged area are planned



Specifications?

- Gain (dynamic range)?
- Bandwidth?
- Differential output: need to drive 50 Ω terminated lines?
- Power consumption per channel?
- Other requirements?

Conclusions

- In the readout of large arrays of FBK SiPMs, voltage noise (white and low freq) proved to be a critical factor
- To reduce noise, we added a BJT in front of the differential opamp, reaching 0.3 nV/√Hz , 4x lower than with an opamp alone
- This design also allows to increase the flexibility of the amplifier, by providing an additional handle (the gain of the BJT stage) to decouple bandwidth and gain of the amplifier as a whole
- Since the gain of the opamp is now negligible, other amplifiers can be used (THS45xx family: rail to rail output and lower power consumption)
- We are working on a paper of the 2-stage amplifier, that will include all the details and measurements

Thanks!