Irradiation of LTC1668 at LNL in 2021-2022

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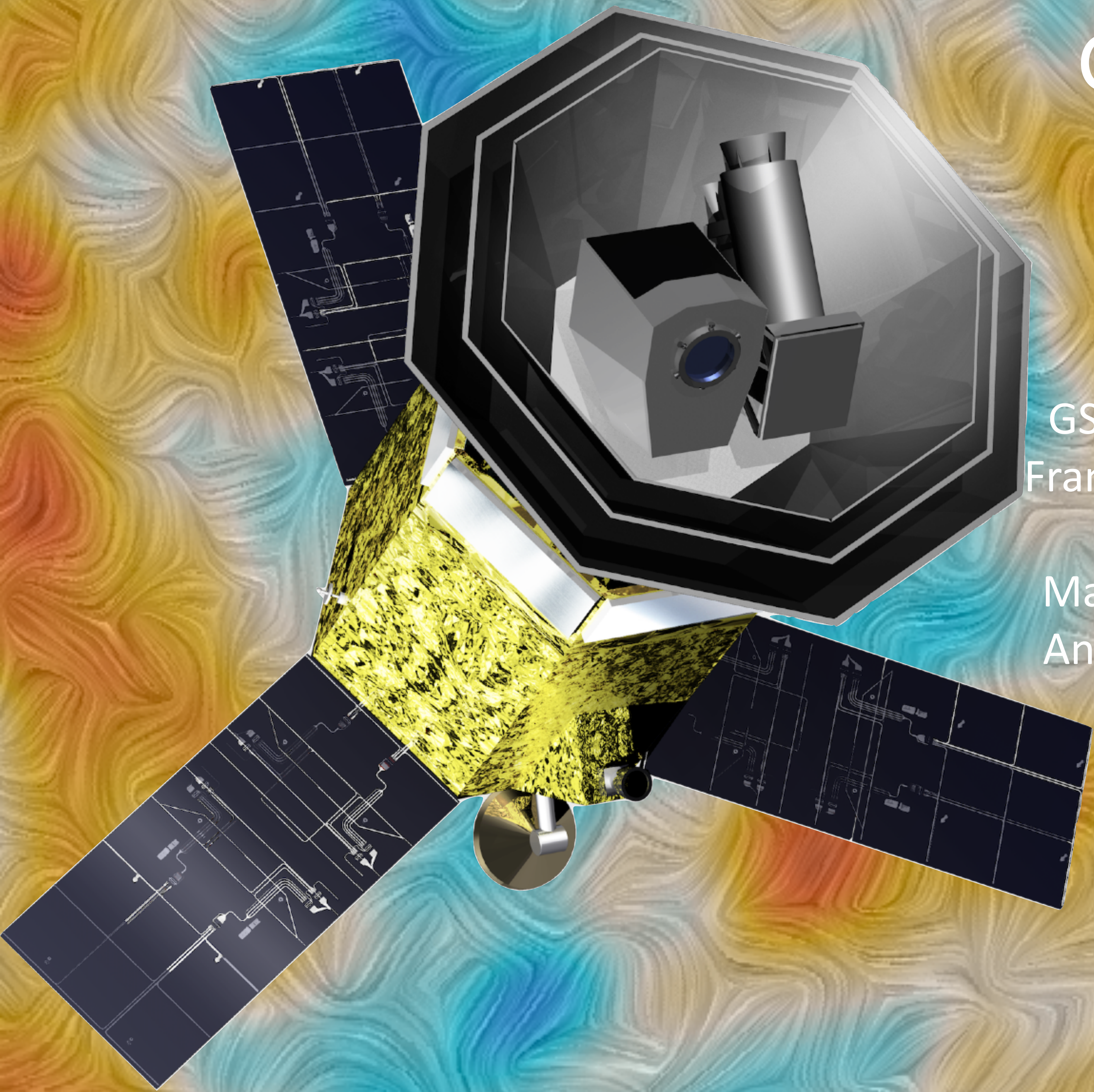


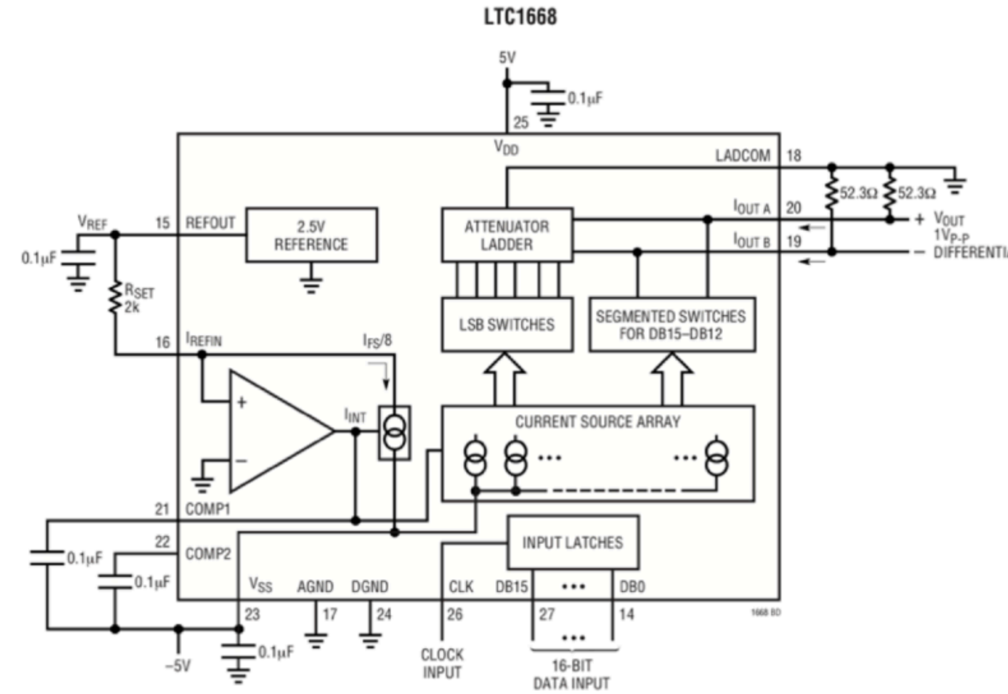
GS, Luca Galli, Donato Nicolò, Andrea Tartari, Franco Spinella, Marco Francesconi, Alessandro Profeti, Angelo Cotta Ramusino, Roberto Malaguti, Mario Zannoni, Stefano Della Torre, Andrea Limonta, Jeffery Wyss, Luca Silvestrin, Mario Tessaro

24/03/2023

Statement of the problem

LiteBIRD warm readout foresees the use of LTC1668 16 bit DAC due to its lower power consumption compared to already qualified components.

Part description:	LTC1668 16–bit, 50Msps DAC
Manufacturer:	Linear Technology
Package:	28–pin SSOP
Technology:	BiCMOS
Samples used:	Tested 3 samples out of a package of 10
Die area:	2×2.95 mm^2 = 5.9 mm^2



- According to the ECSS requirements we must test
  - Radiation tolerance (TID)
  - Single-event effects with ions (SEE: SEL, SEU, SET)
  - Single event effects with protons (in case of low LET threshold)
- “Particle physics experience” and access to facility can give preliminary results


ECSS-Q-ST-60-15C
1 October 2012

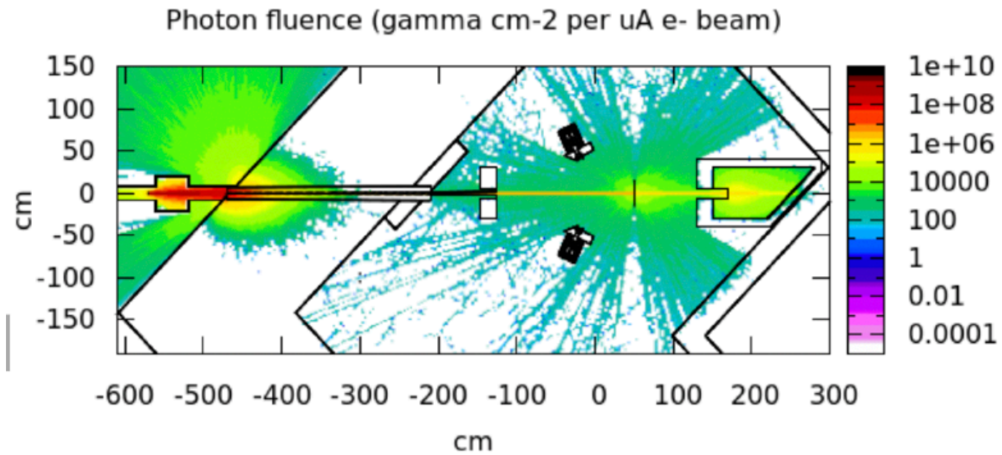
EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

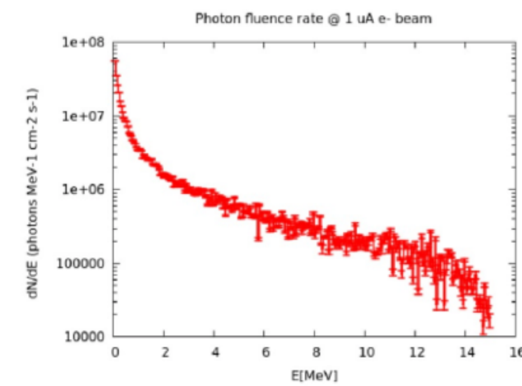
Space product assurance

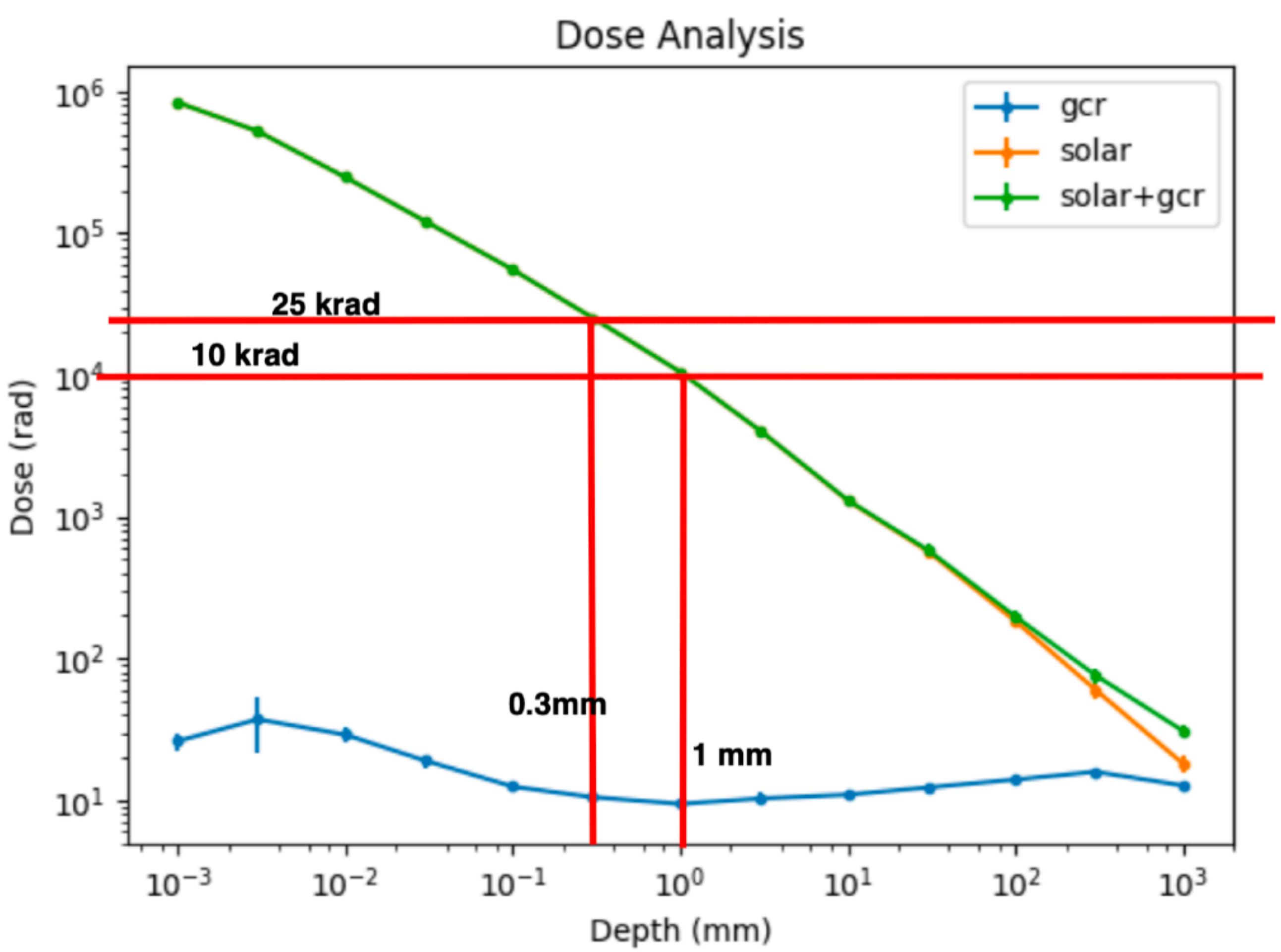
Radiation hardness assurance - EEE components

Irradiation test

- GELBE (Dresden)
  - The γELBE facility provides an optimal very intense photon field for irradiation studies: Brehmsstrahlung photons up to 15 MeV energy







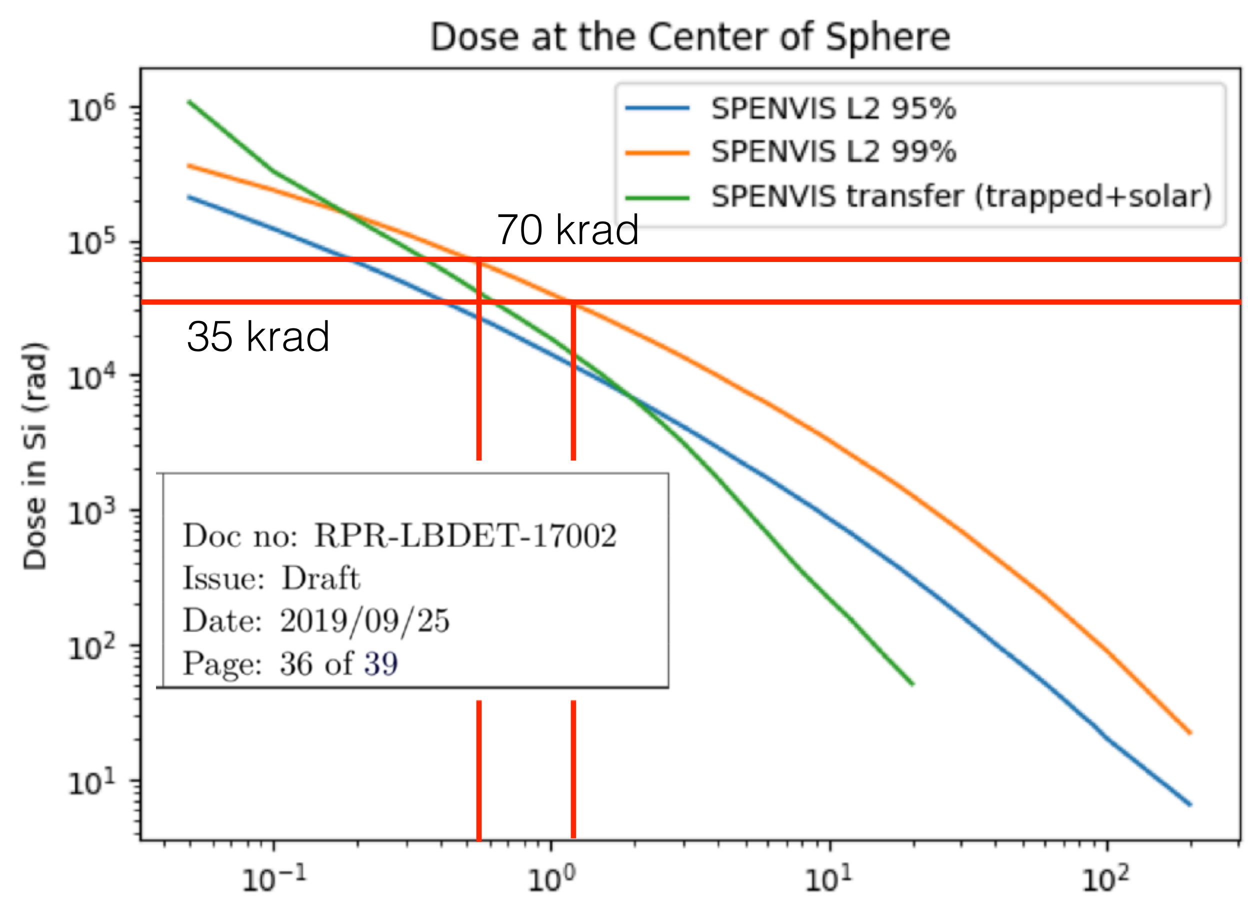
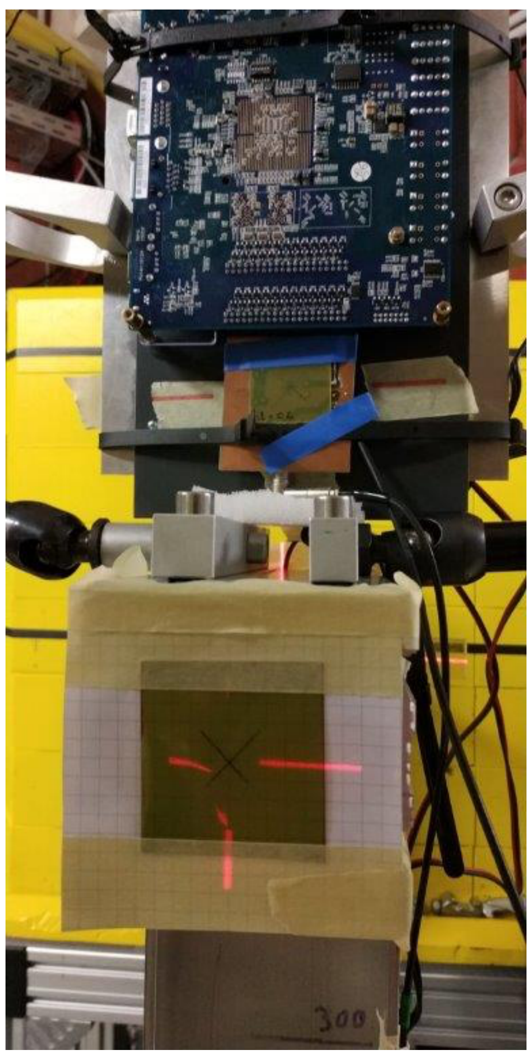


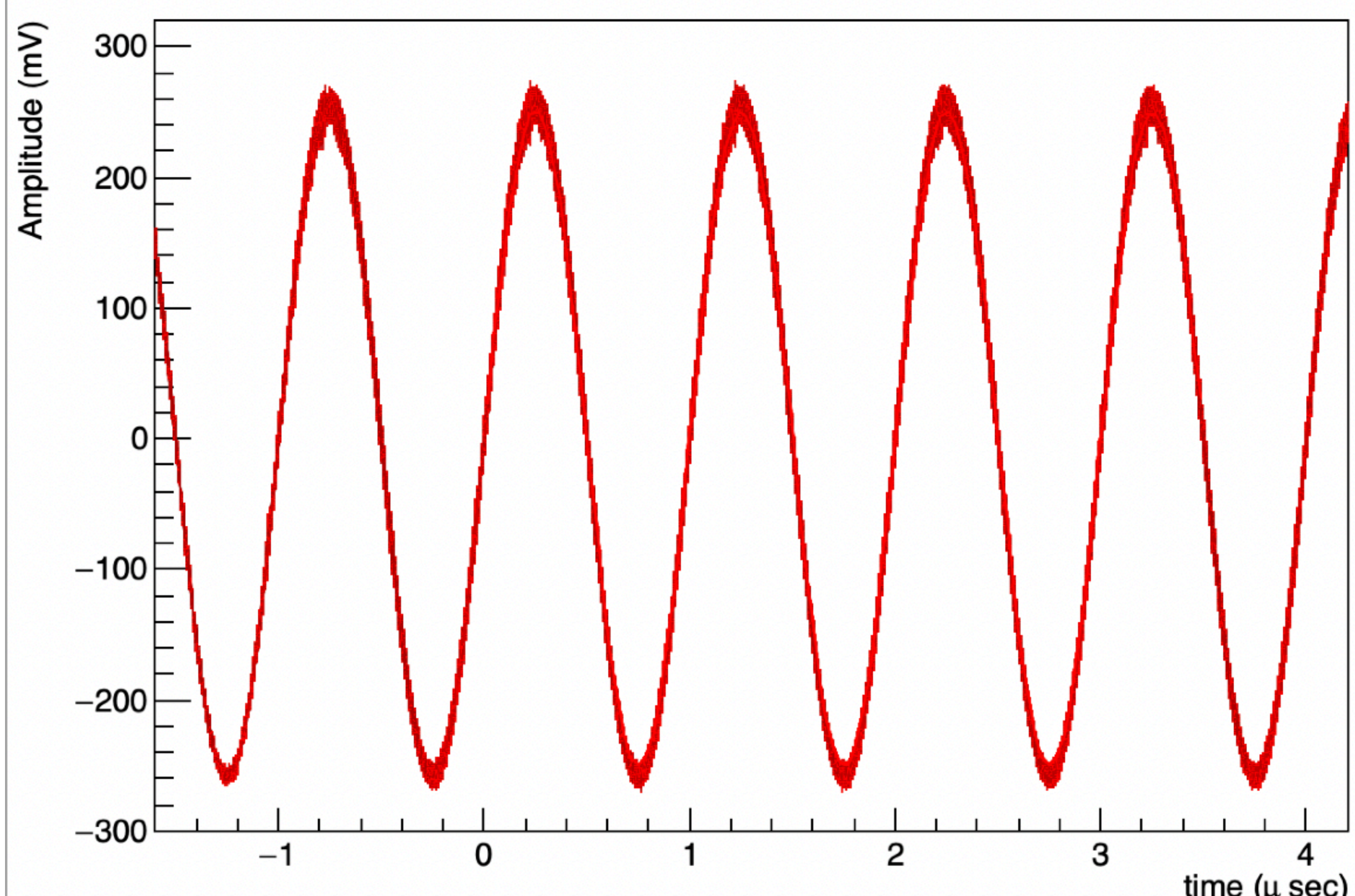
Figure 11.1. Dose depth curve at L2 for 3.25 years starting from 2027 pulse three month for transit to L2 (Courtesy; A. Kibayashi).

Irradiation test

- γELBE (Dresden)
  - One single LTC1668 DAC on a mezzanine plugged to a dedicated Cyclone V demo-board (test done back in 2019)
    - ~10.9 krad/h x 6.5 hours ⇒ ~70 krad total dose

- Full DAC range spanned with 1 MHz sinusoid
- recorded every 30 seconds
- no significant decrease in amplitude nor difference in waveform/Fourier transform observed.

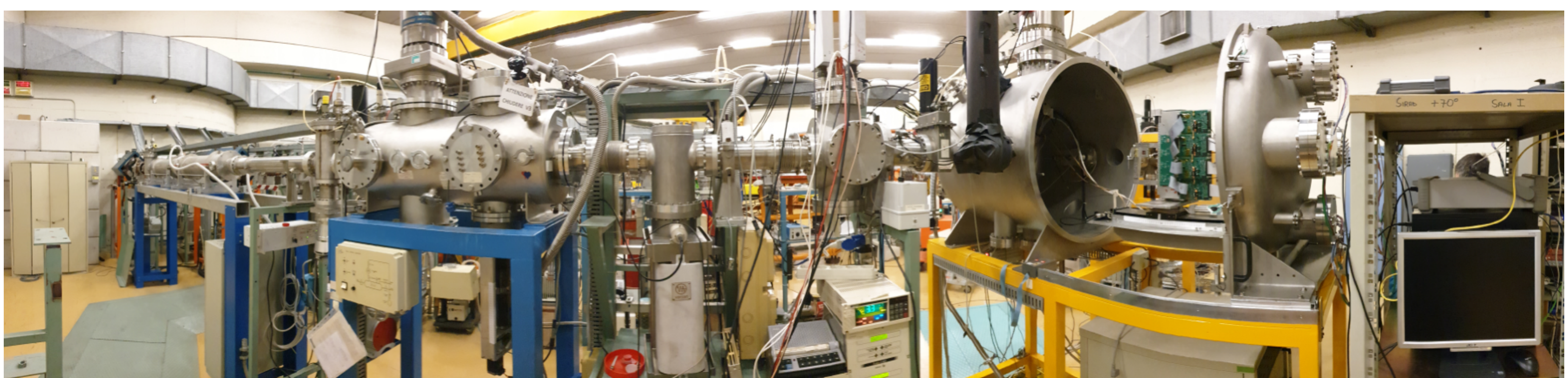




>700 superimposed

LTC1668 SEE test @LNL

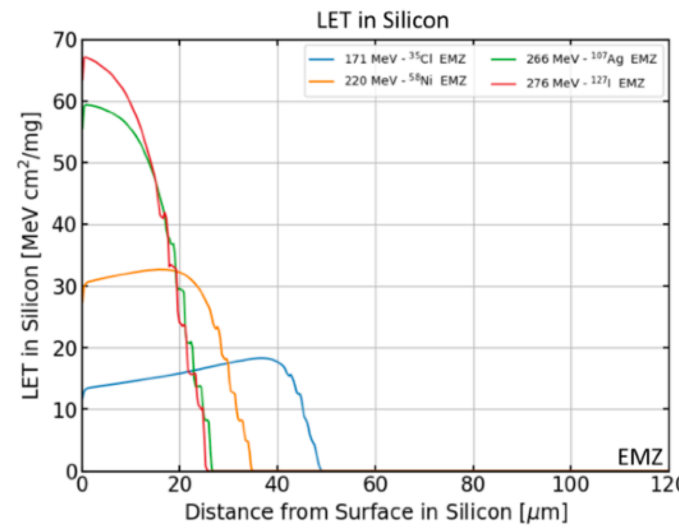
- Two full beamtime days at LNL Tandem accelerator on 24 and 25 Feb 2021.
  - We were assigned one extra day (originally requested) on June 27, 2022.
- Characterize Single-Event Effects on LTC1668
  - SEL (latch-ups), SEU (upsets = permanent bit flips), SET (transients = temporary bit flips)
- Long preparation and successful measurements
  - GS, Luca Galli, Donato Nicolò, Andrea Tartari, Franco Spinella, Marco Francesconi, Alessandro Profeti, Angelo Cotta Ramusino, Roberto Malaguti, Mario Zannoni, Stefano Della Torre, Andrea Limonta, Jeffery Wyss, Luca Silvestrin, Mario Tessaro.
- Mainly collaboration between IINFN/PI INFN/MIB and INFN/FE
- Needed to
  - procure LTC1668 components
  - decapsulate
  - store in a “safe” place

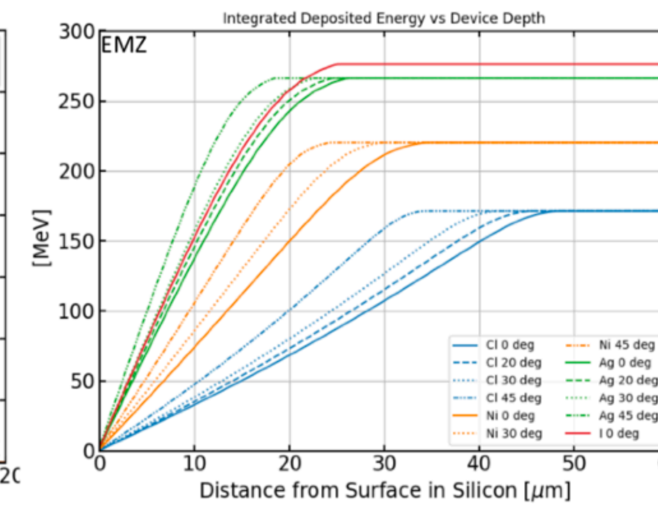


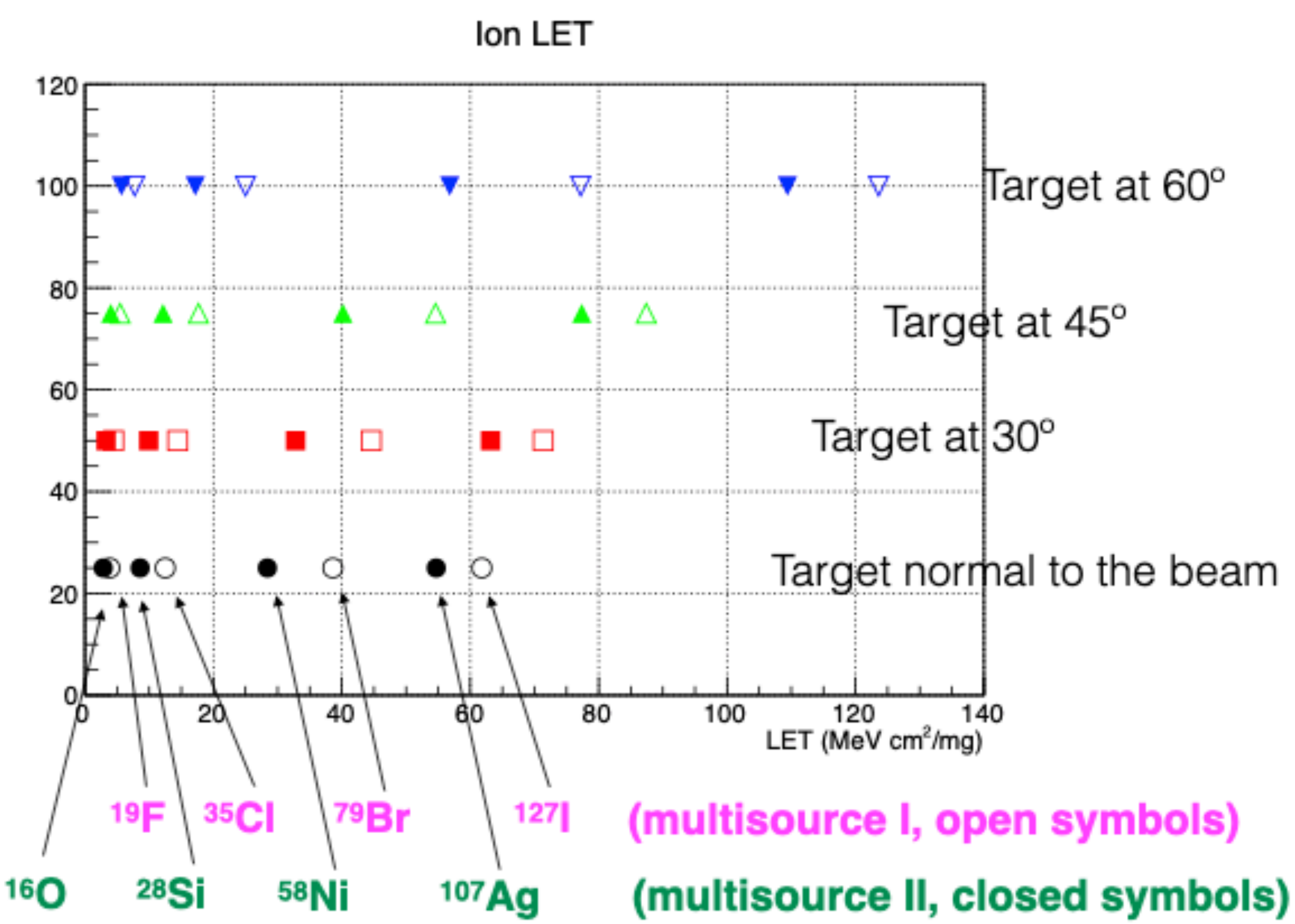
SIRAD Facility

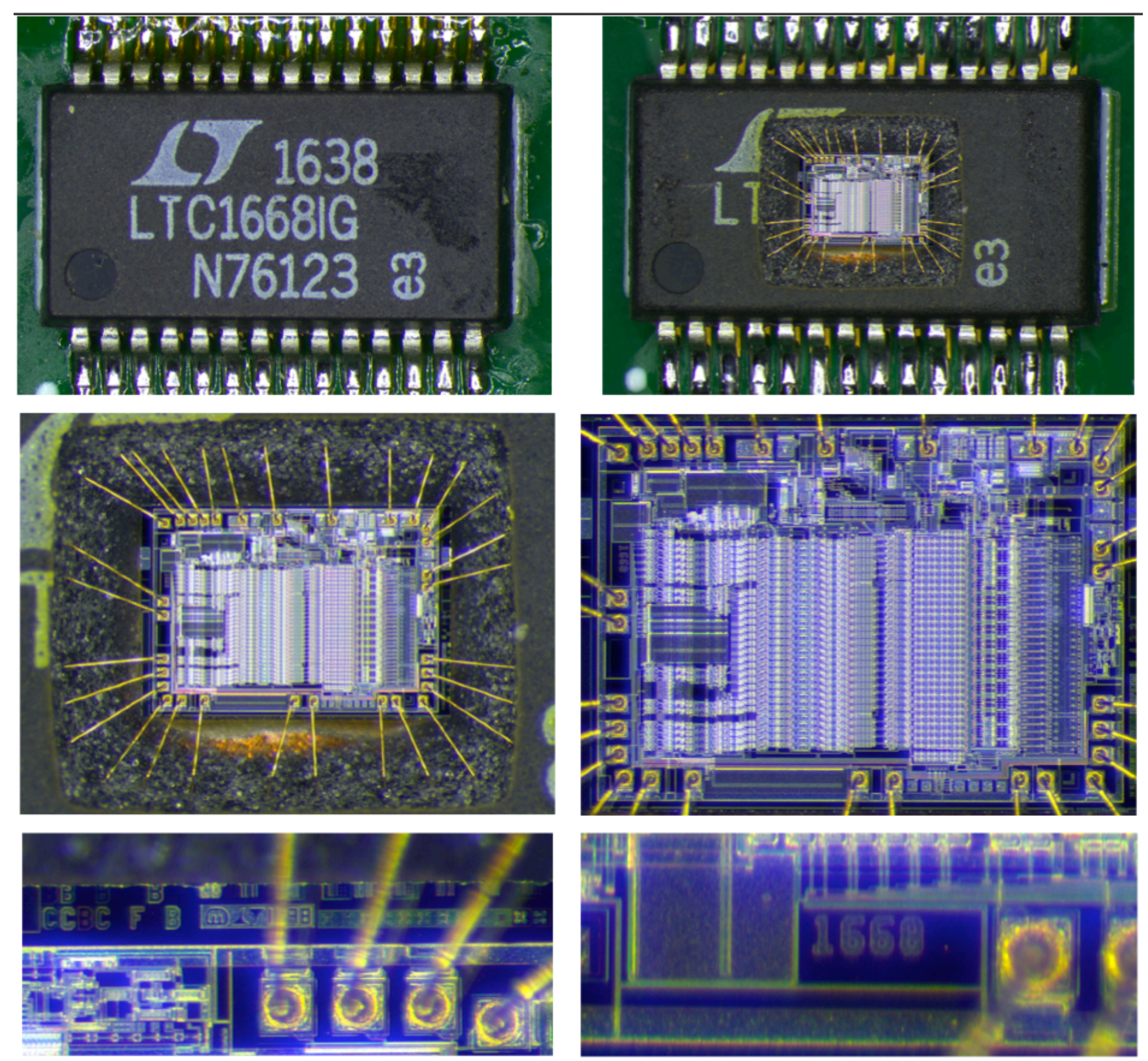
- Sirad and LNL was selected for easy of access and availability of ions

Ion	Energy (MeV)	Range in Si (μm)	LET in Si (MeV cm² /mg)
^{35}Cl	160, 171	46, 49.1	13.05, 12.5
^{58}Ni	220	33.7	28.4
^{79}Br	228	31.2	41.96
^{107}Ag	266	27.6	54.7
^{127}I	249, 276	27.9	61.8, 63.66



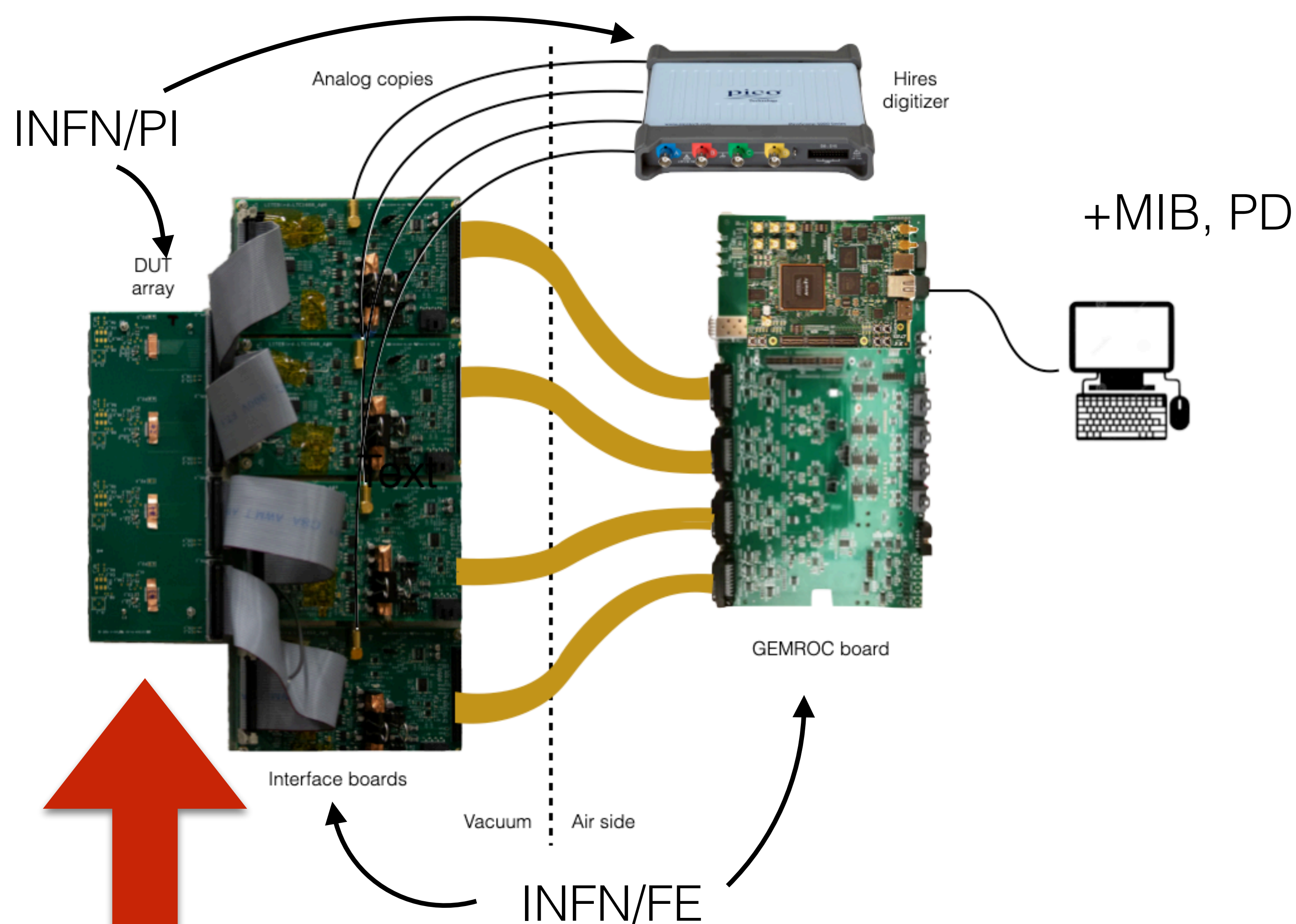


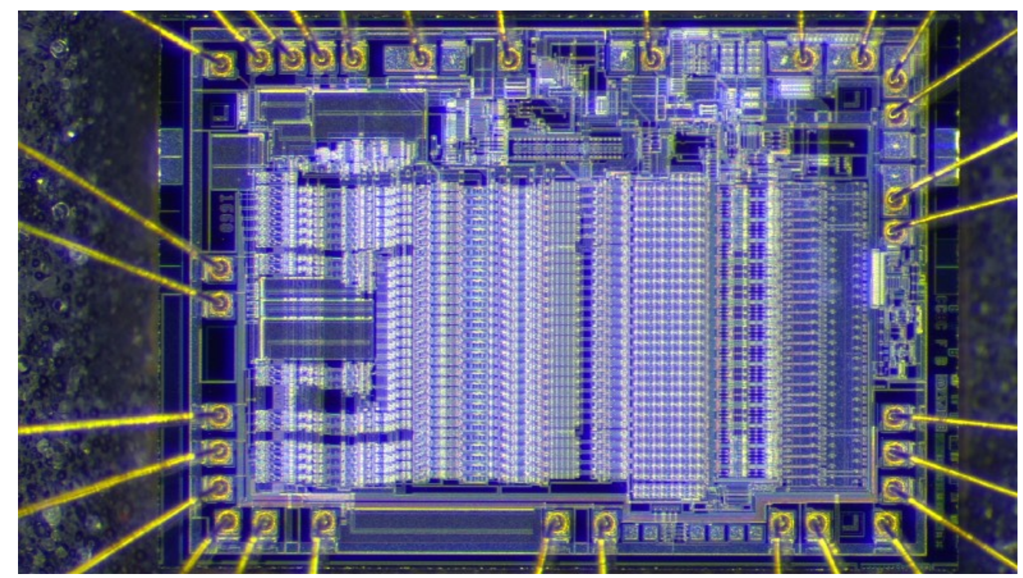


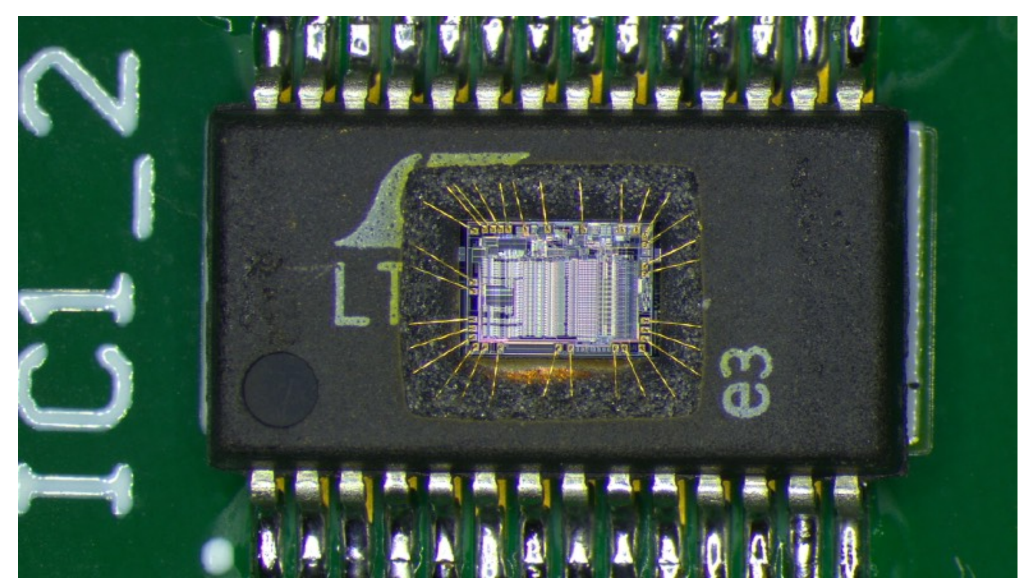


LTC1668 SEE test

- Search for latch-ups (SEL) and "bit flips" (permanent and transient – SEU, SET)
- SEL & SEU
  - Device characterization i.e. in DC
    - freezing of DAC and readout with a 24-bit ADC
    - dump at 26 kHz (9 kHz analog band)
- SET
  - Check of operation at high frequency
    - Picoscope to distinguish transients from definitive bit-flips
  - 13 samples decapsulated

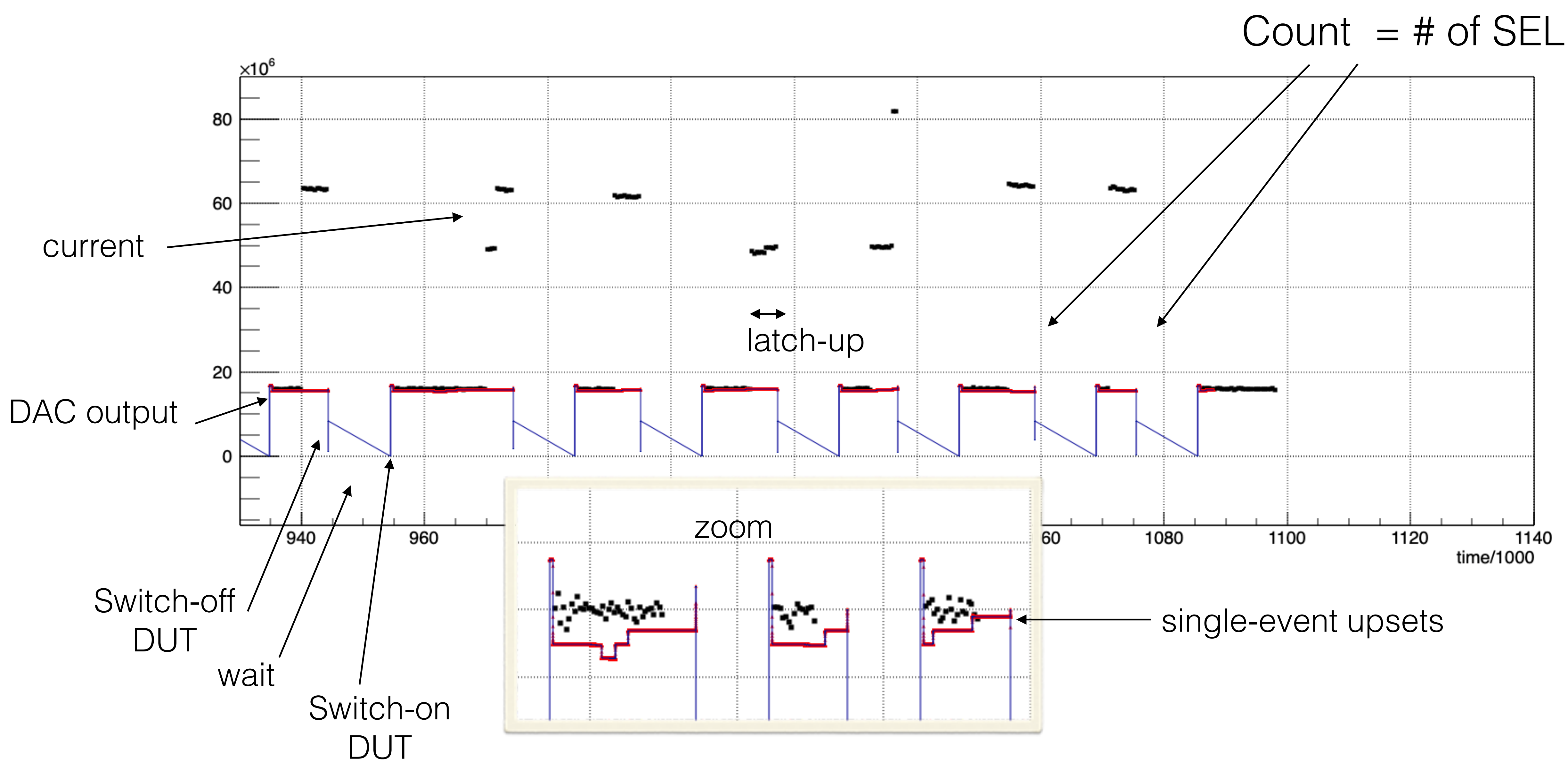






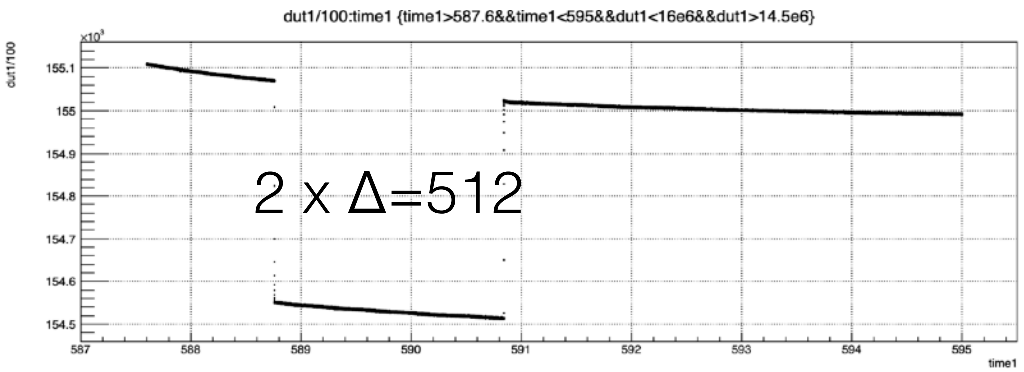
Typical running procedure: SEL

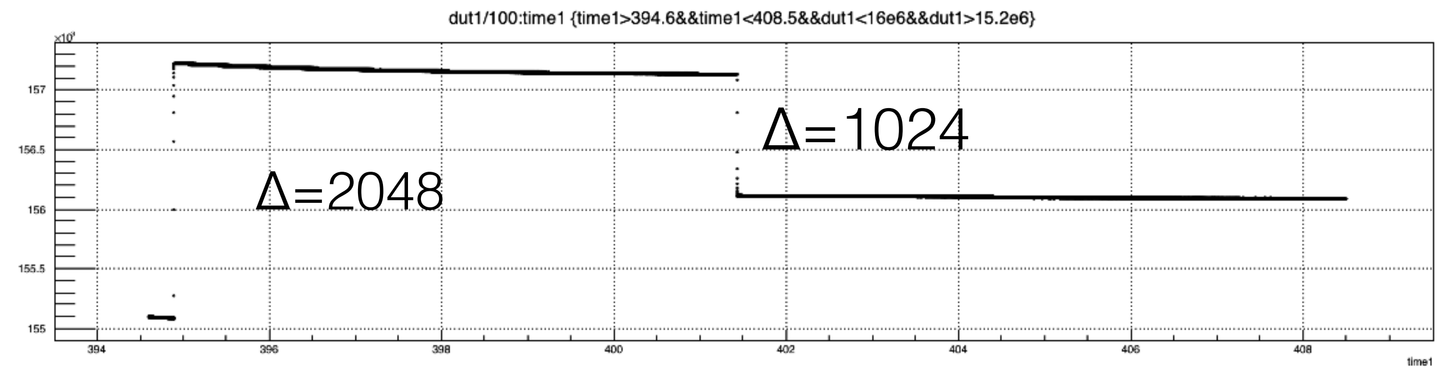
- Set up DUT with specific pattern (ex. 0xB000, 0x1000)
  - Start data taking
  - Open beam shutter
  - Record slow control signals
- Monitor DUT I_{pos}, I_{neg}, Temperature (typical 26 mA, 2.8 mA, 30 °C resp)
  - Whenever one of these goes over threshold
    - count (100 → 20 samples) to monitor the trend (a few seconds)
    - switch off the DUT, wait for (20 → 10 sec), switch on DUT
- Count number of SEL, SEU, SET → take care of live time!

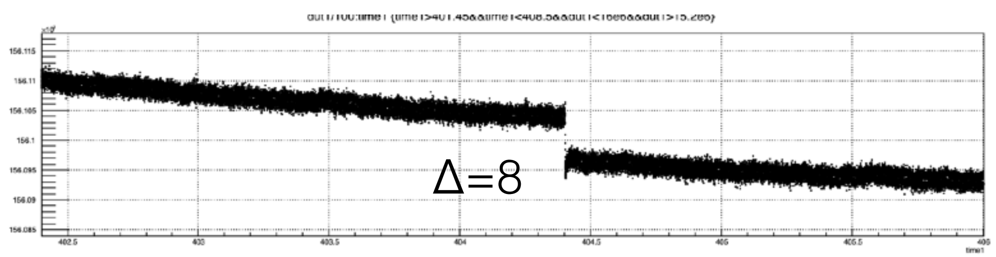


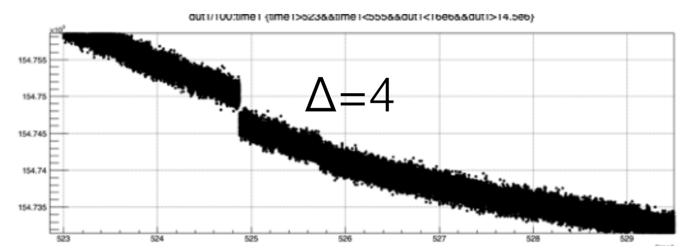
Sensitivity to SEU

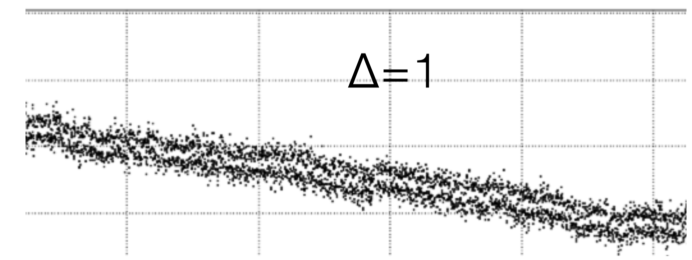
- Check that we could observe the bit-flips



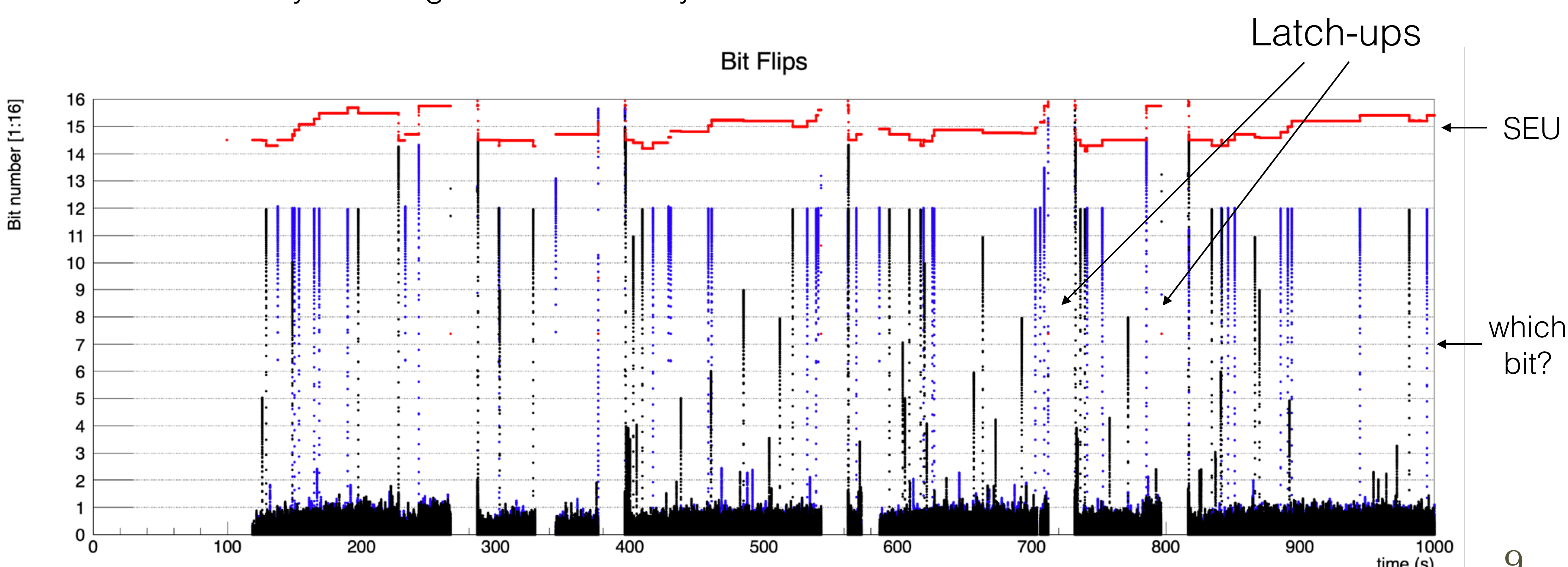








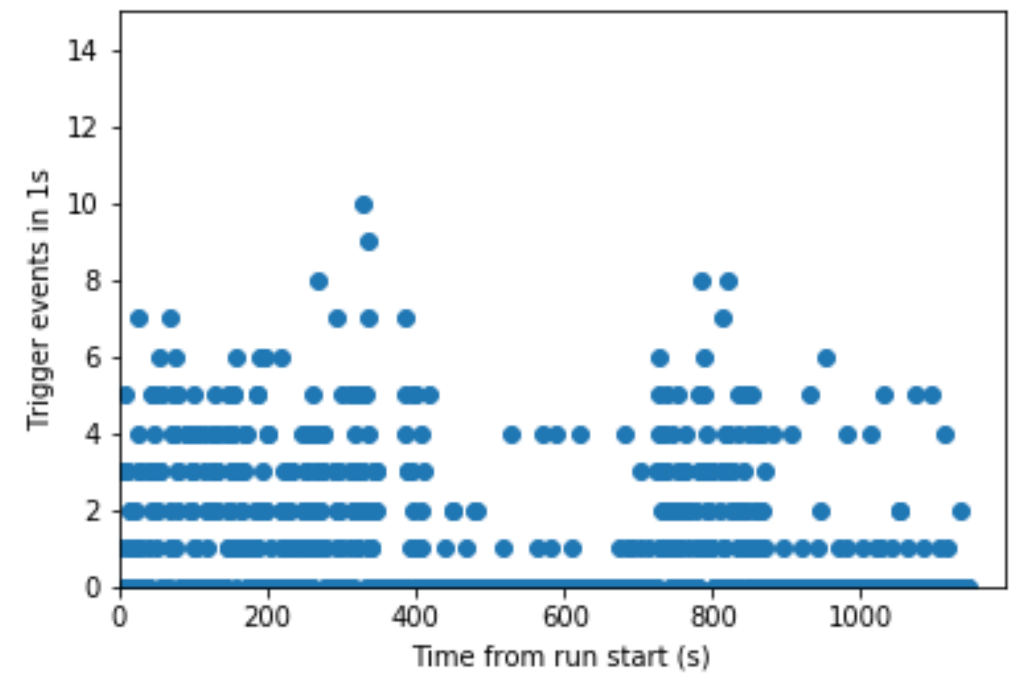
- Automated analysis recognizes confidently Δ>1



Sensitivity to transients: SET

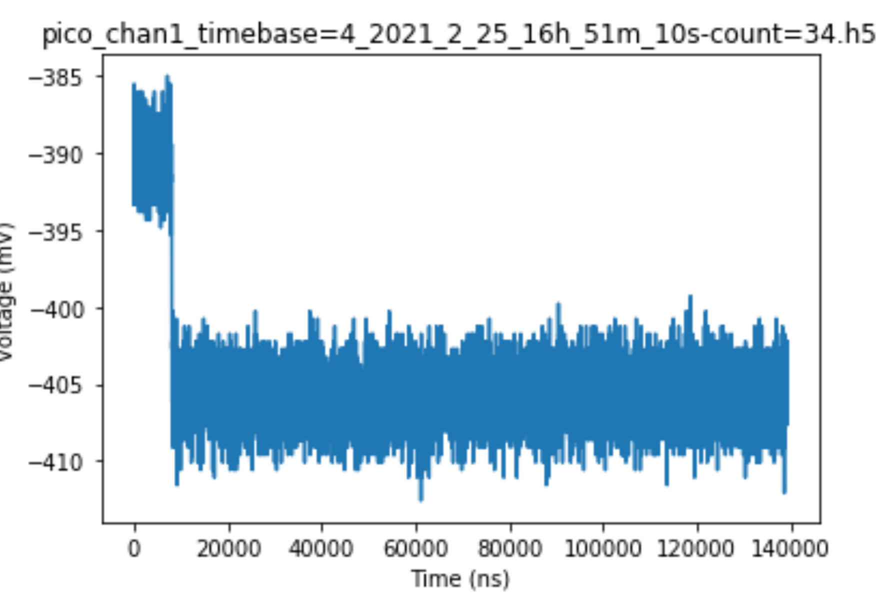
- Many more transients recorded by PicoScope
  - SET > SEU > SEL

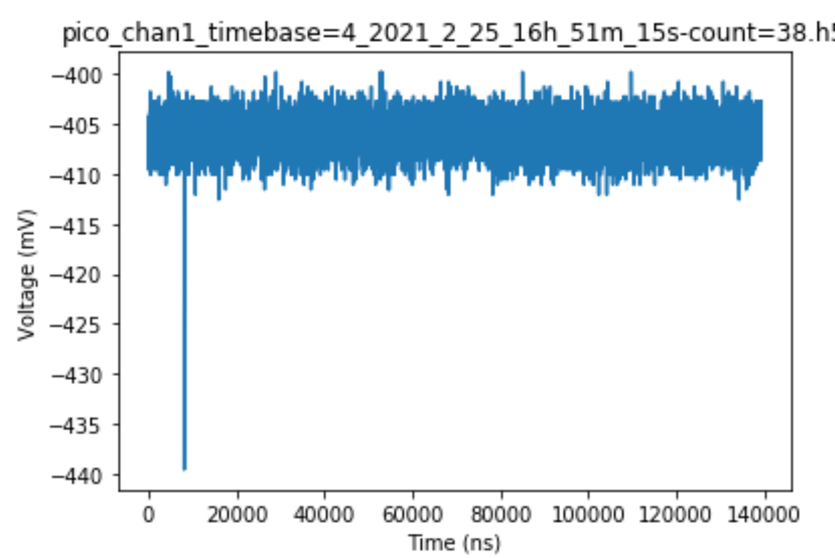
- Procedure to recognize, classify, understand SETs.

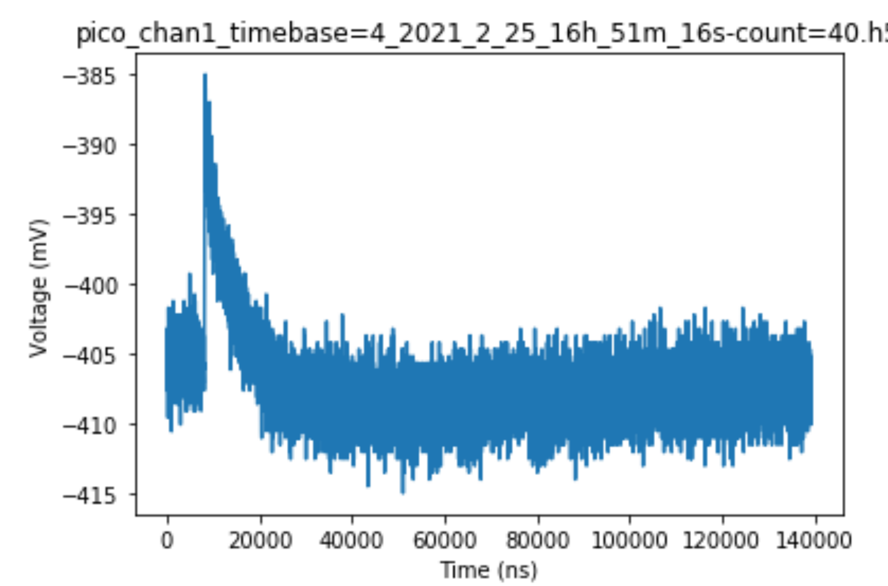


Typical events

Latch-up | **Short transient (~10 ns)** | **Long transient (~10 μs)**

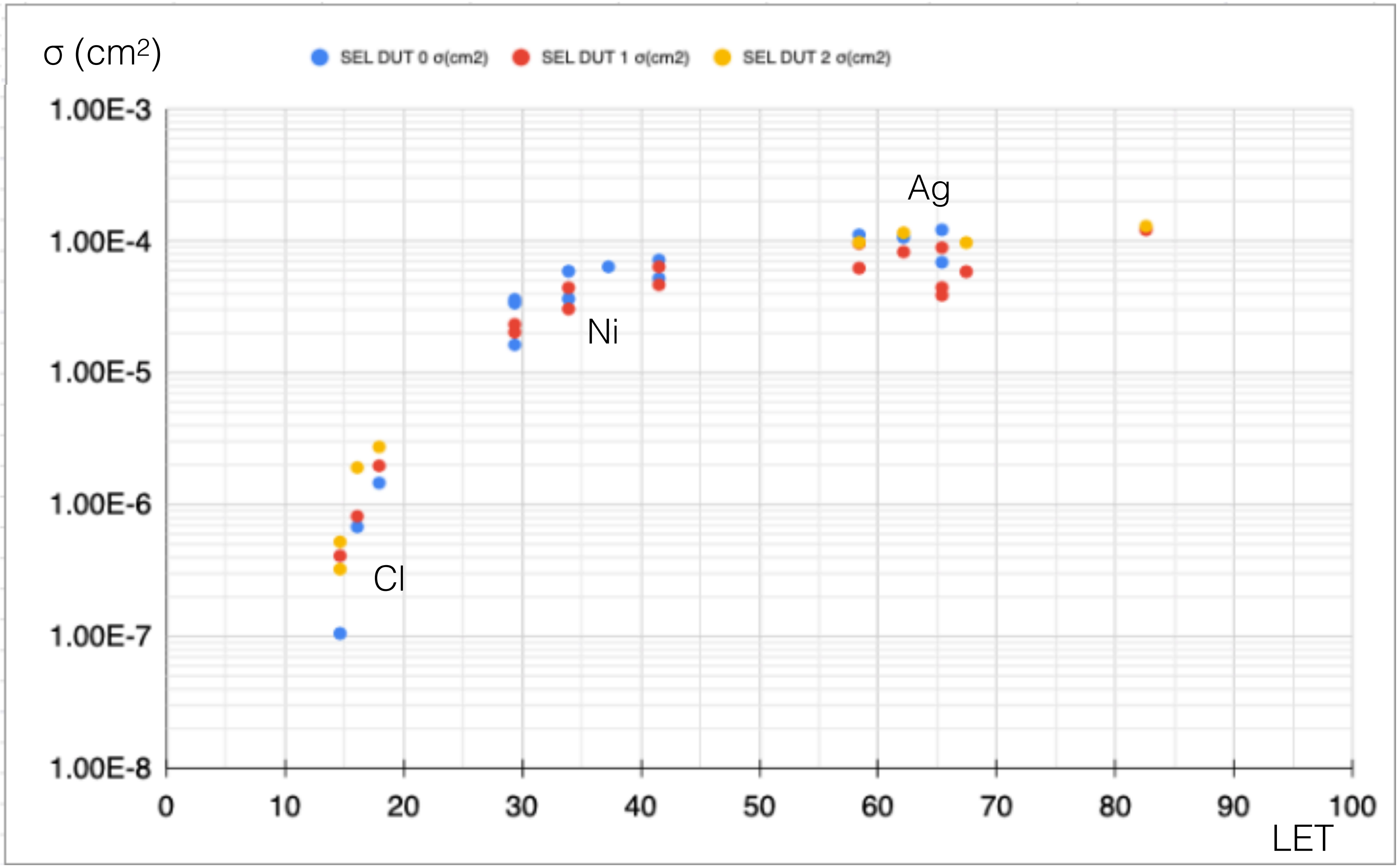






LTC1668 SEE test @LNL

- We complemented the measurements of 2021



- Good compatibility between datasets

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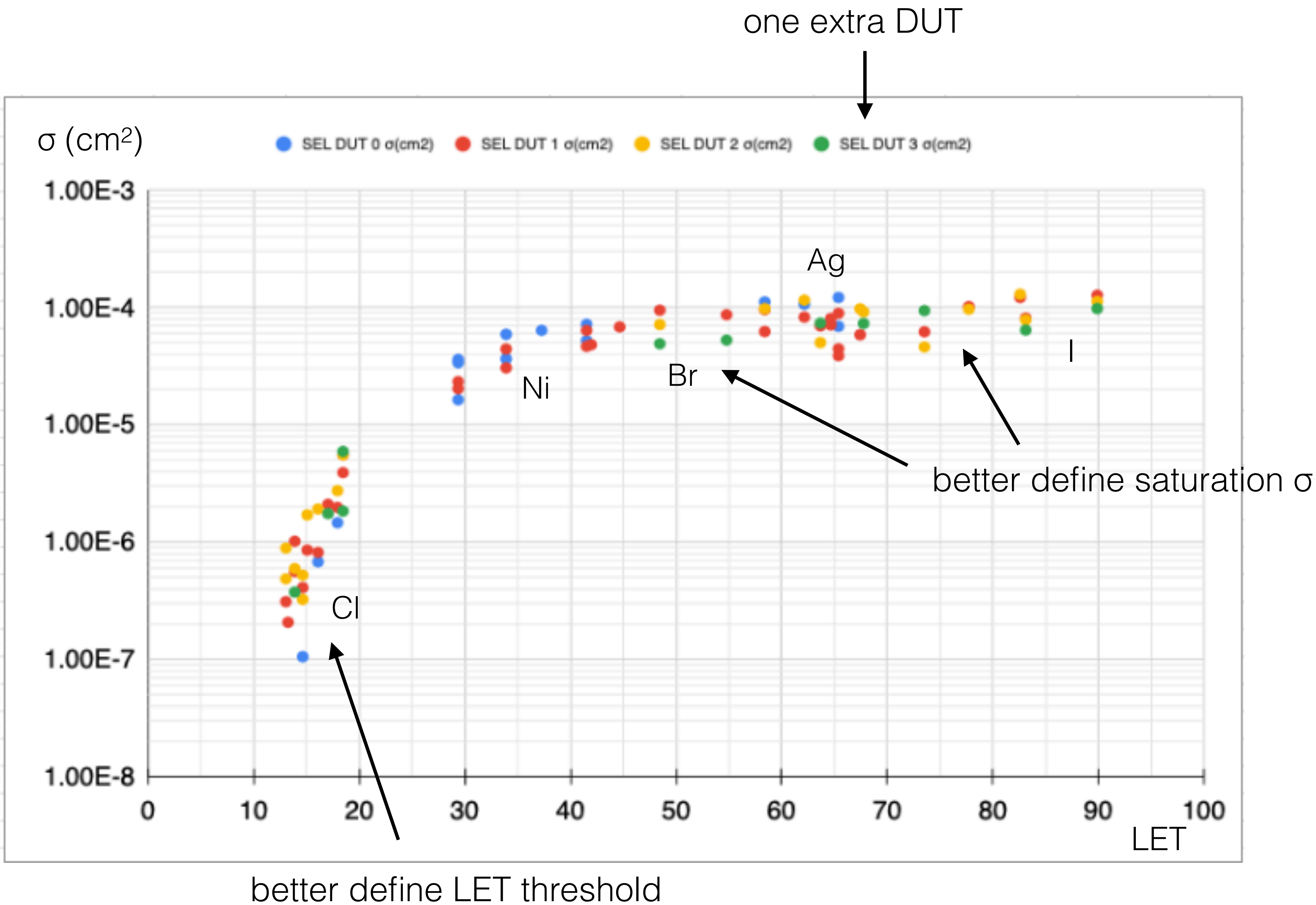
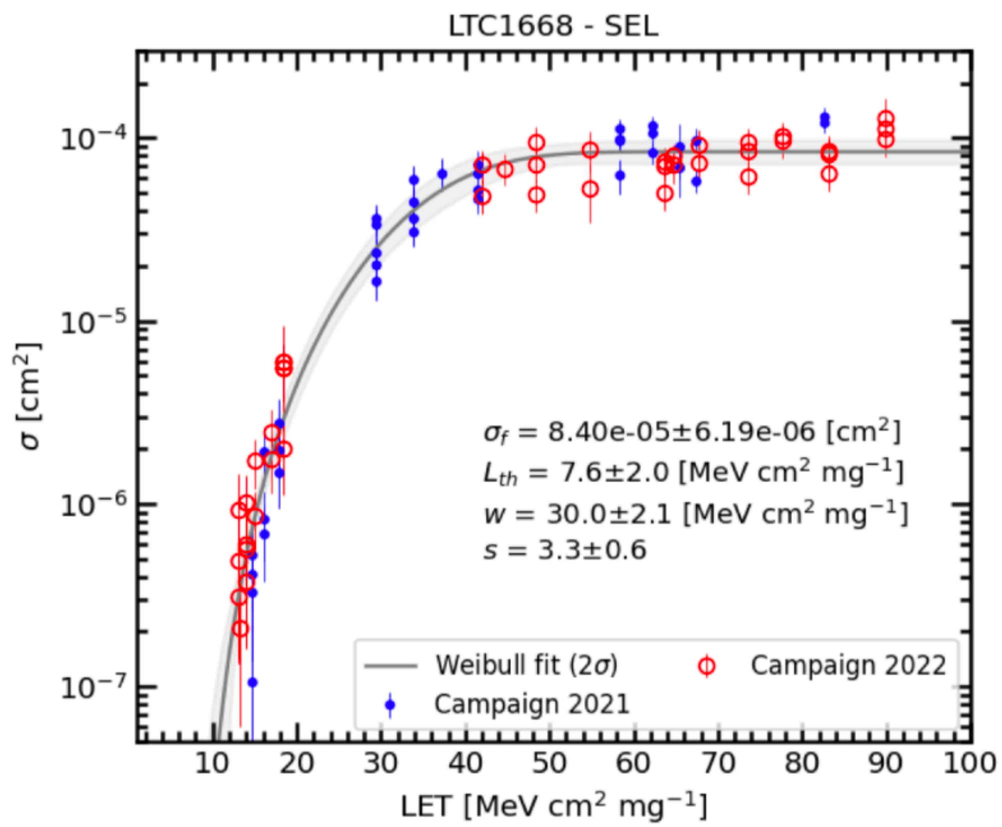
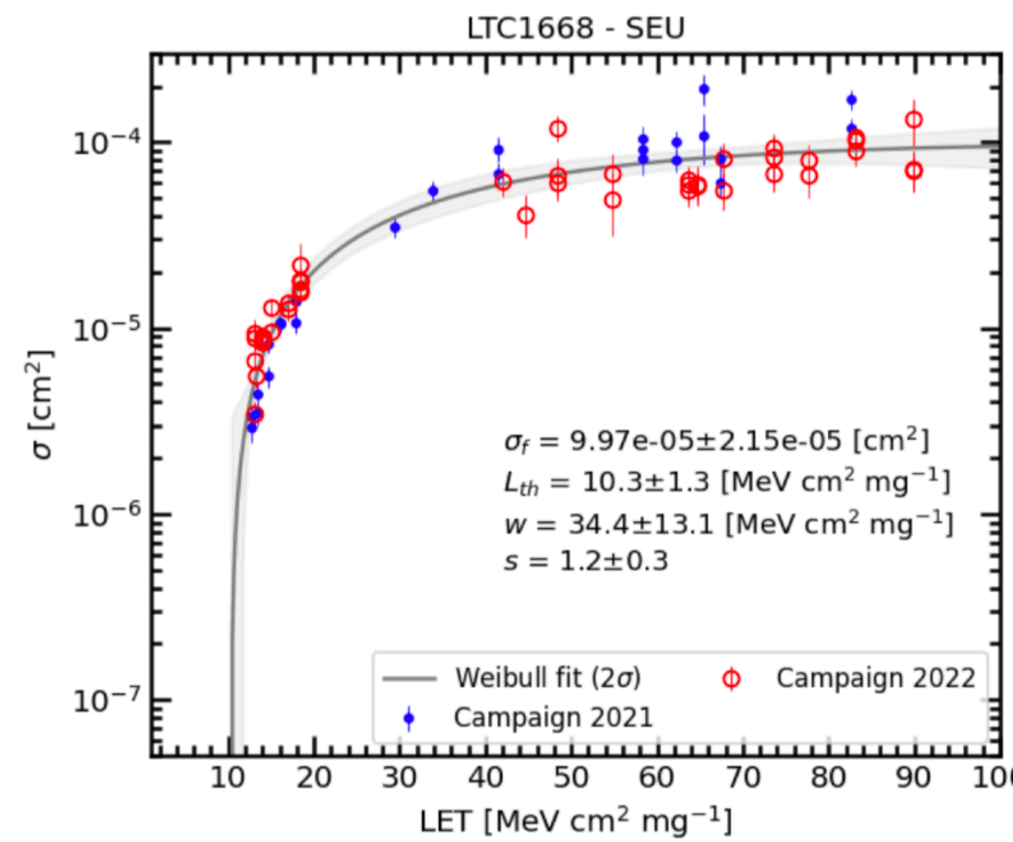


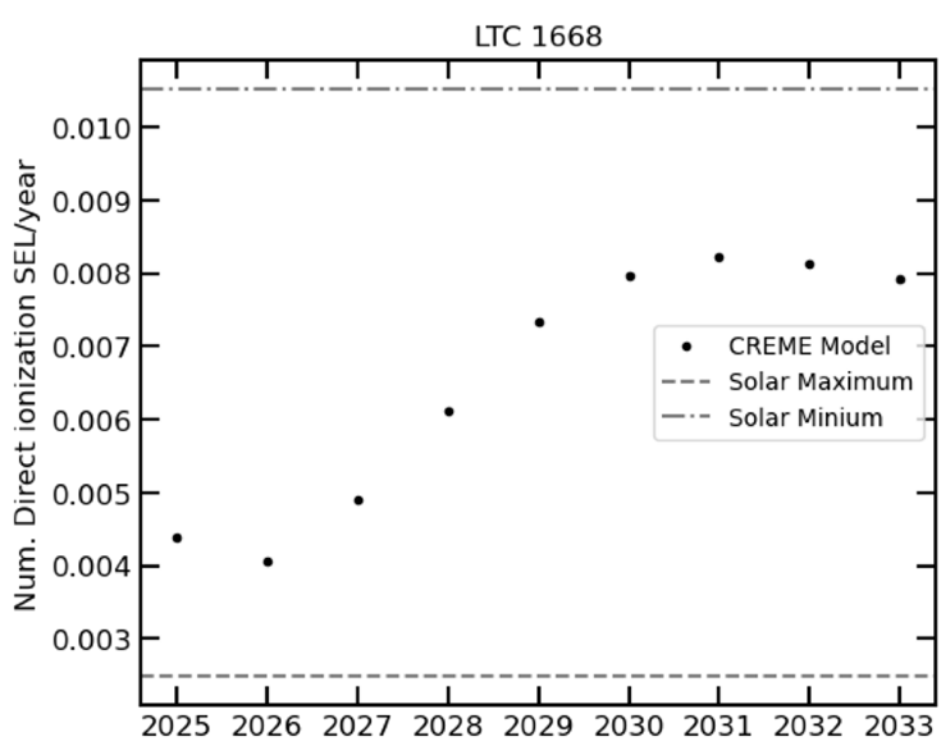
- Good compatibility between datasets

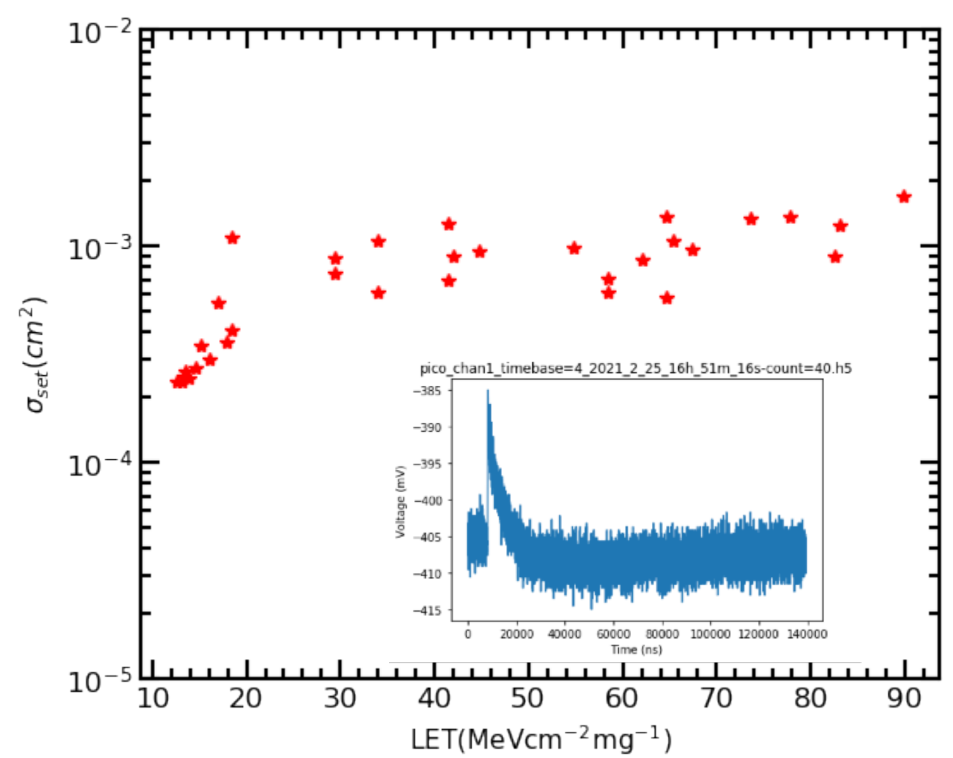
Some results

- Latch-ups, upsets and transients were observed at a threshold < 20 MeV cm2 mg–1
- Measurements between two campaigns very compatible



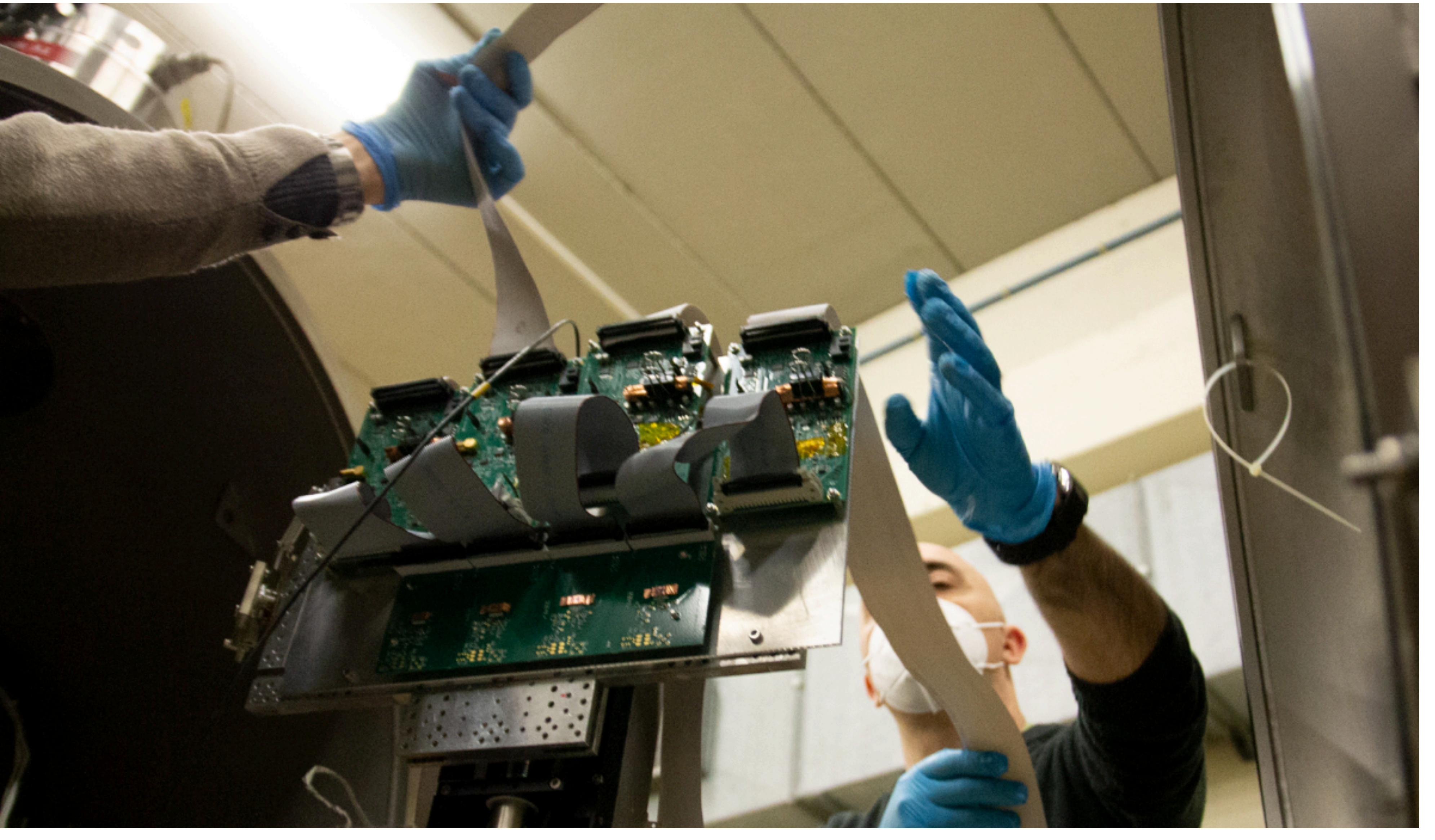






Installation

- Some problems at the beginning…. cables too short!



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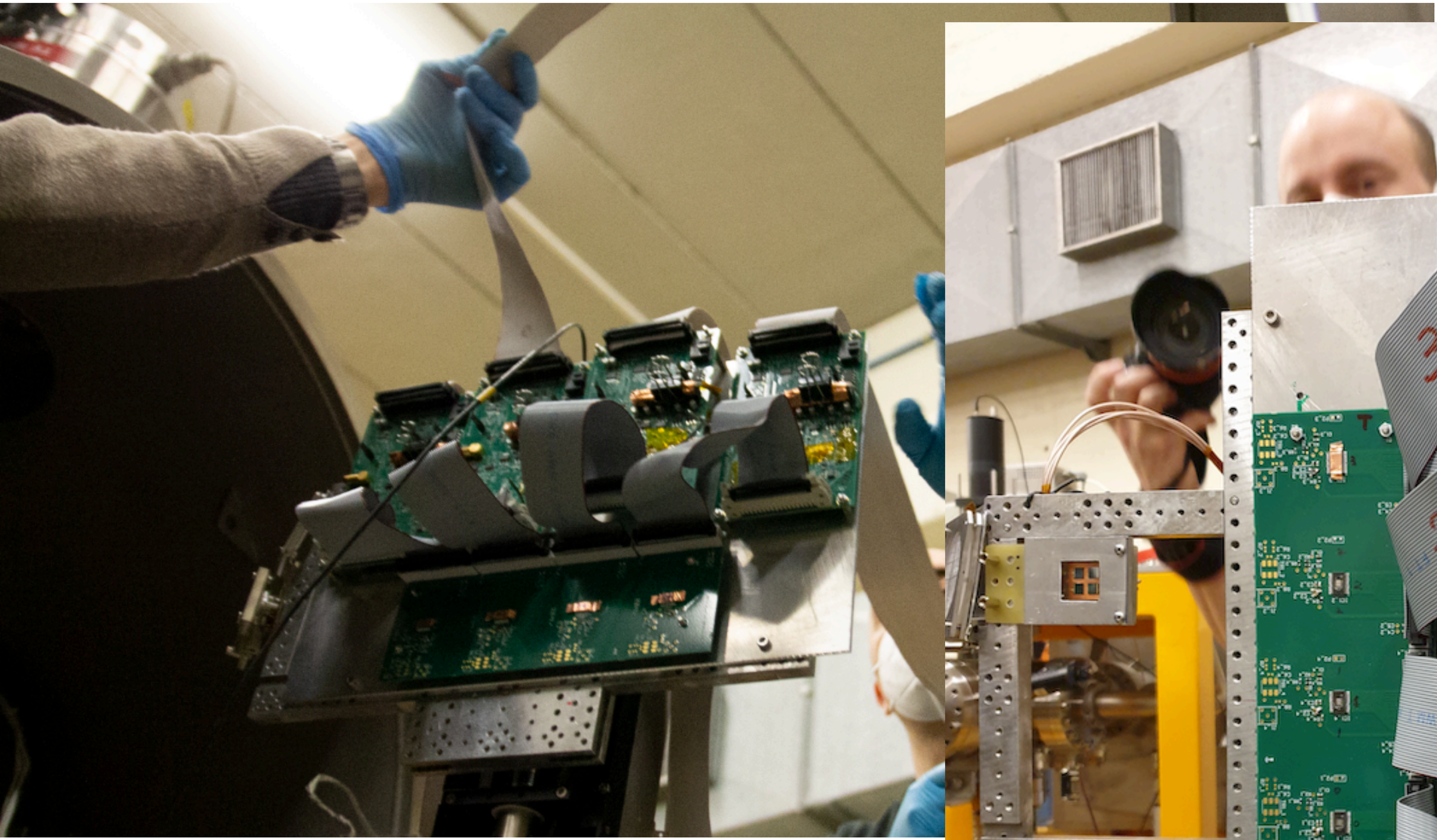

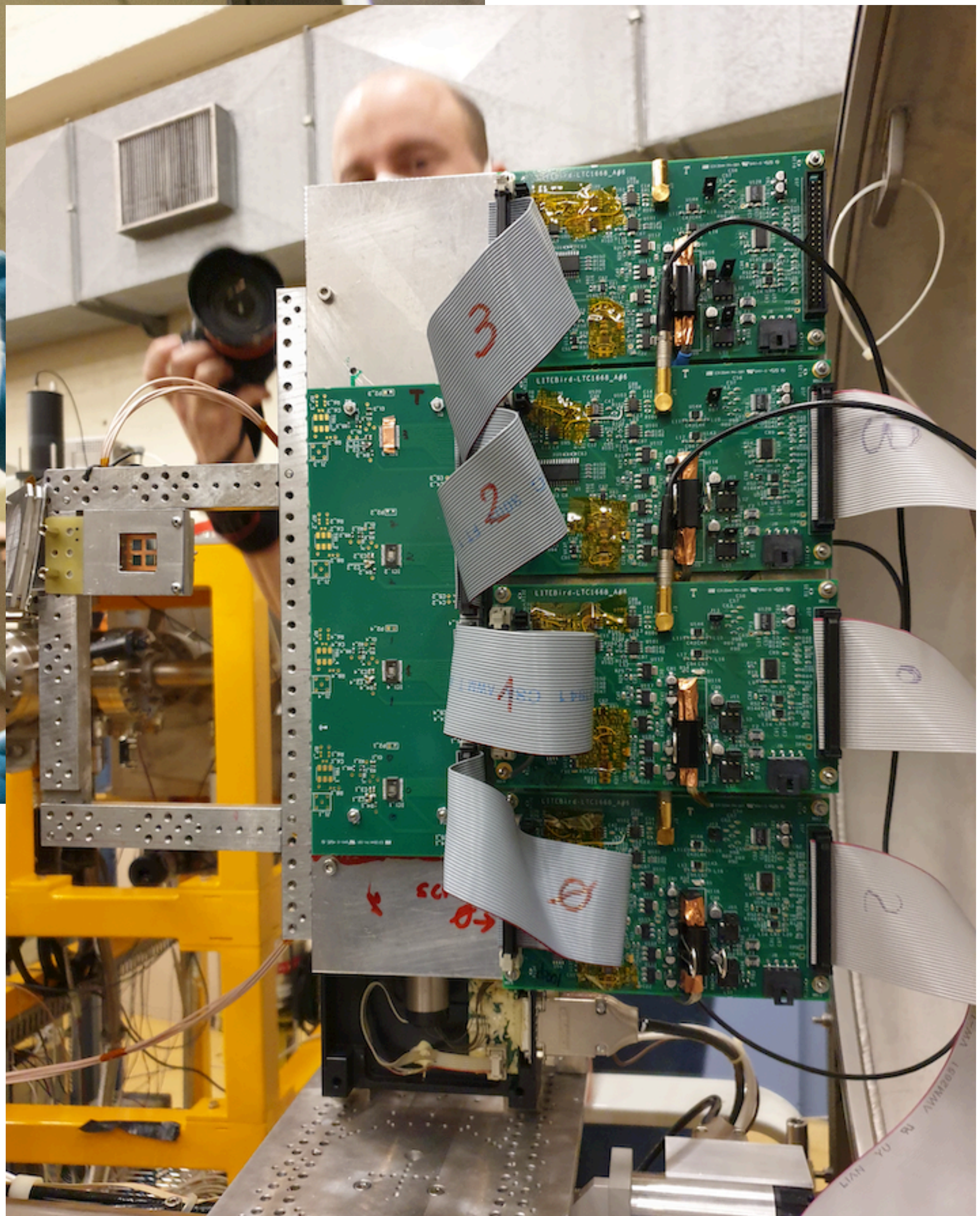

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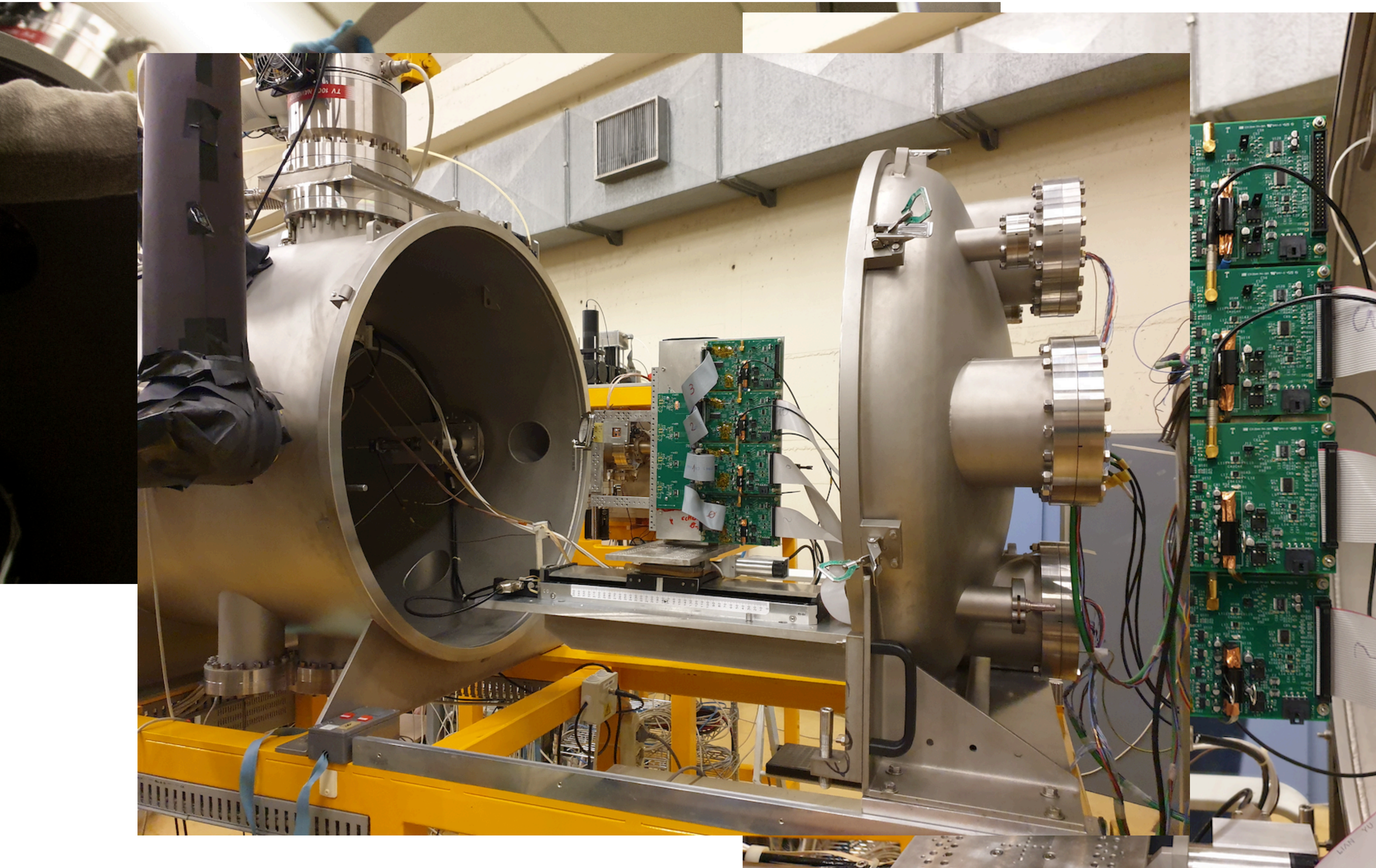
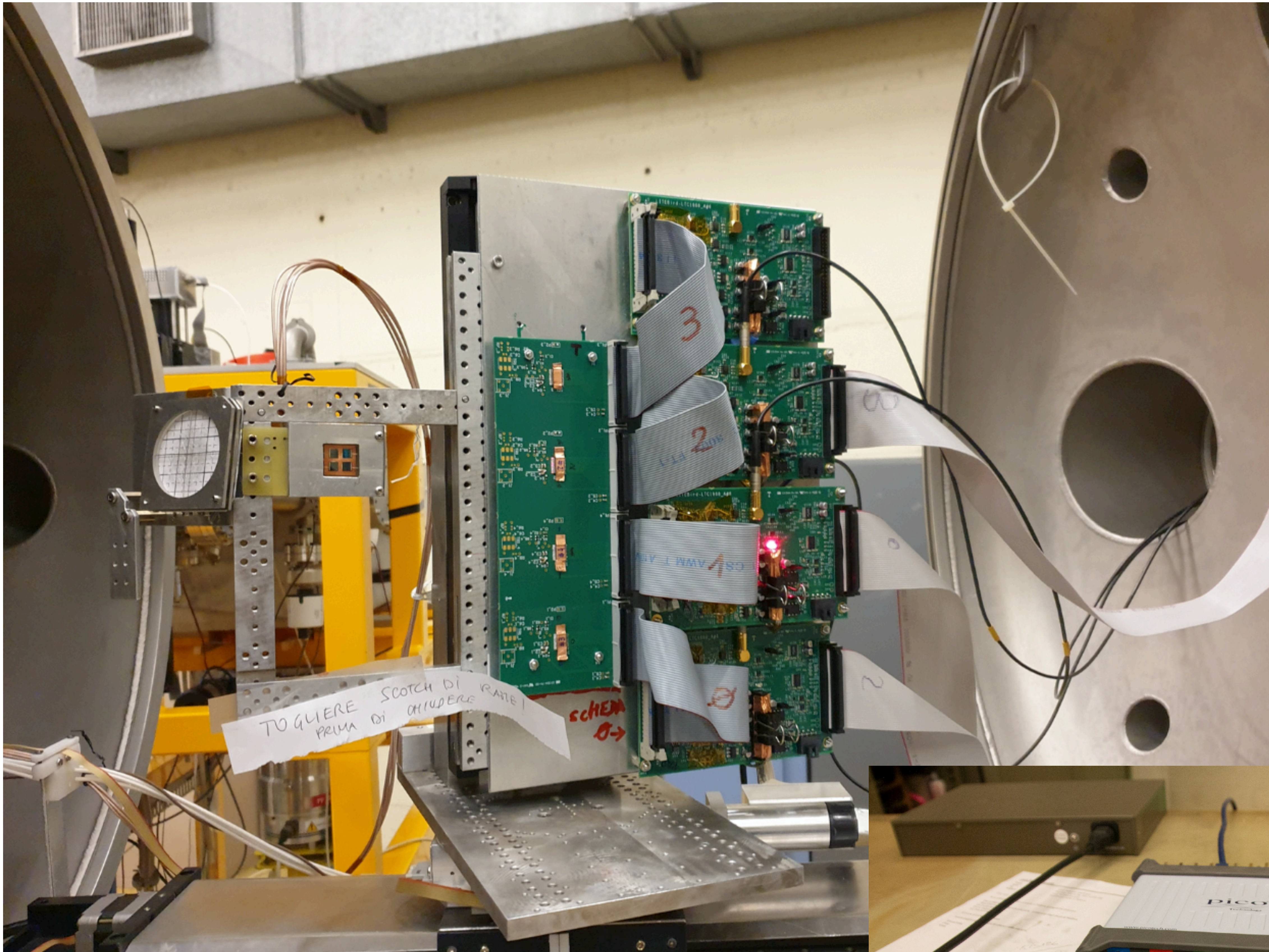
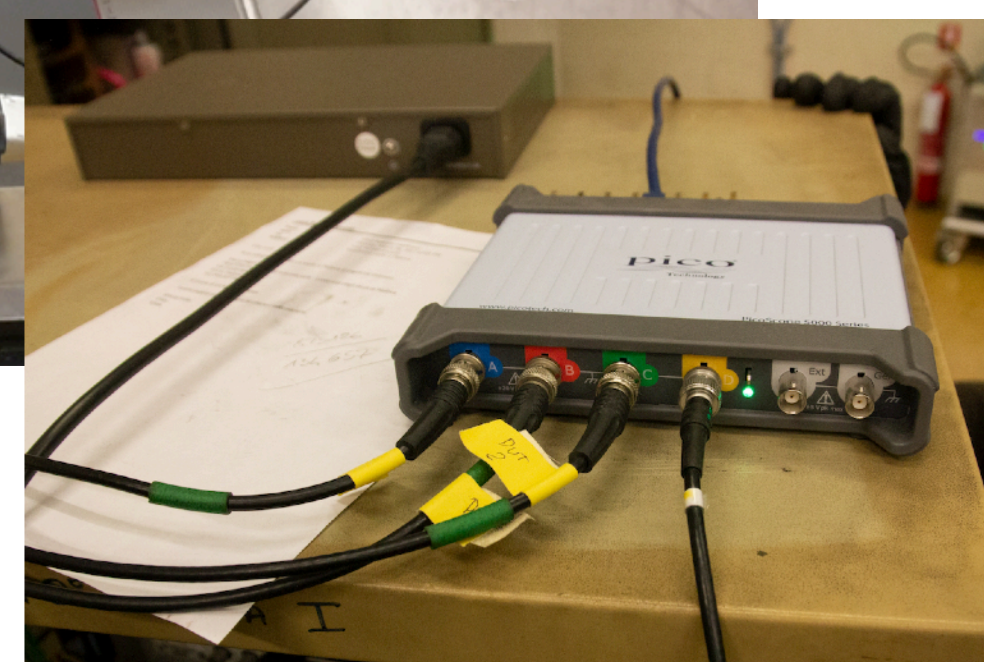



TOGLIERE SCOTCH DI RAME!
PRIMA DI CHIUDERE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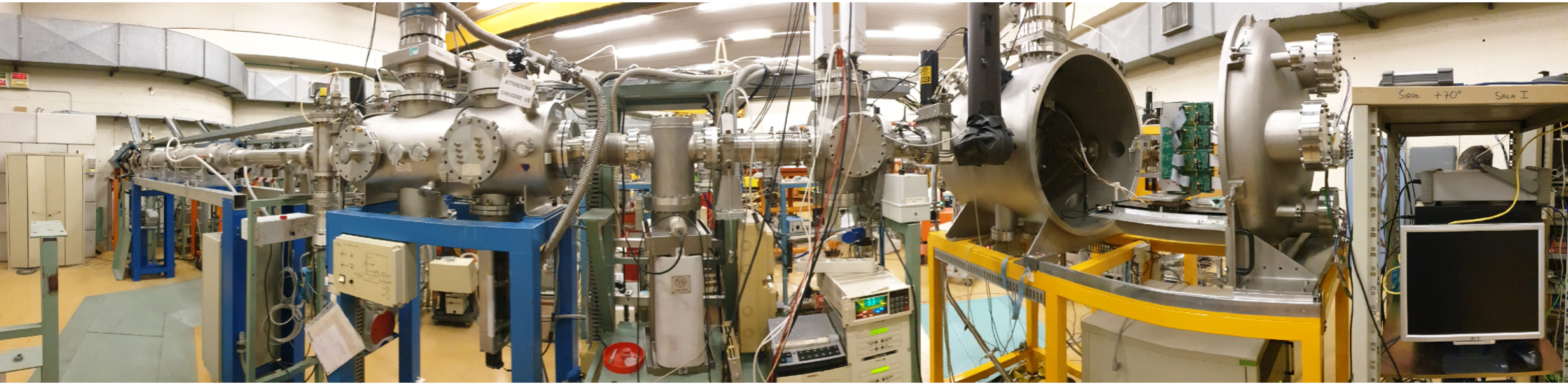
ATTENZIONE
CHIUDERE V3
SIRAD +70° SALA I

Conclusions and Future

- Preliminary measurements show that LTC1668 can be used for LiteBIRD
- Need to set-up a strategy for phase B, C, D.
- test with protons?
- Following ECSS-Q-ST-60-15C

4.4 Phasing of RHA with the different phases of a space project

4.4.1 Phase 0: Mission analysis, Phase A: Feasibility

Mission environment is defined and top level radiation requirements can be derived. RHA requirements (e.g. RDM) are tailored to the specific project needs. Preliminary radiation characterization studies can be started to help technology selection and design trade-off activities.

4.4.2 Phase B: Preliminary definition

For SRR, Mission environment and RHA requirements are finalized. Electronic design and spacecraft layout are defined. Preliminary shielding analyses can be started as well as radiation characterization activities.

4.4.3 Phase C: Detailed definition

Radiation characterization tests are performed. Equipment shielding analyses , equipment circuit design analyses (e.g. WCA, SEE analysis) are performed.. Radiation analysis and WCA reports are provided in equipment CDR data package. When necessary, impact of radiation effect at equipment level is analysed at upper (subsystem and system) levels and document in upper levels CDR data packages. At the end of phase C, most of the RHA work is completed.

4.4.4 Phase D: Qualification and production

Remaining RHA activities are radiation tests on flight lots (e.g. RVT). At this stage of program development, radiation effects issues resulting in redesign activities are very costly.