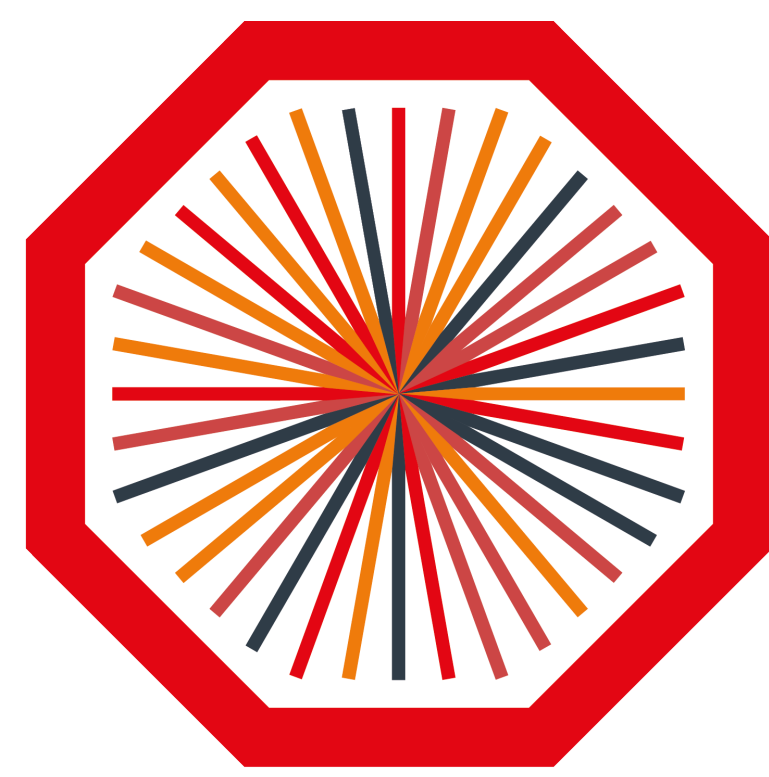
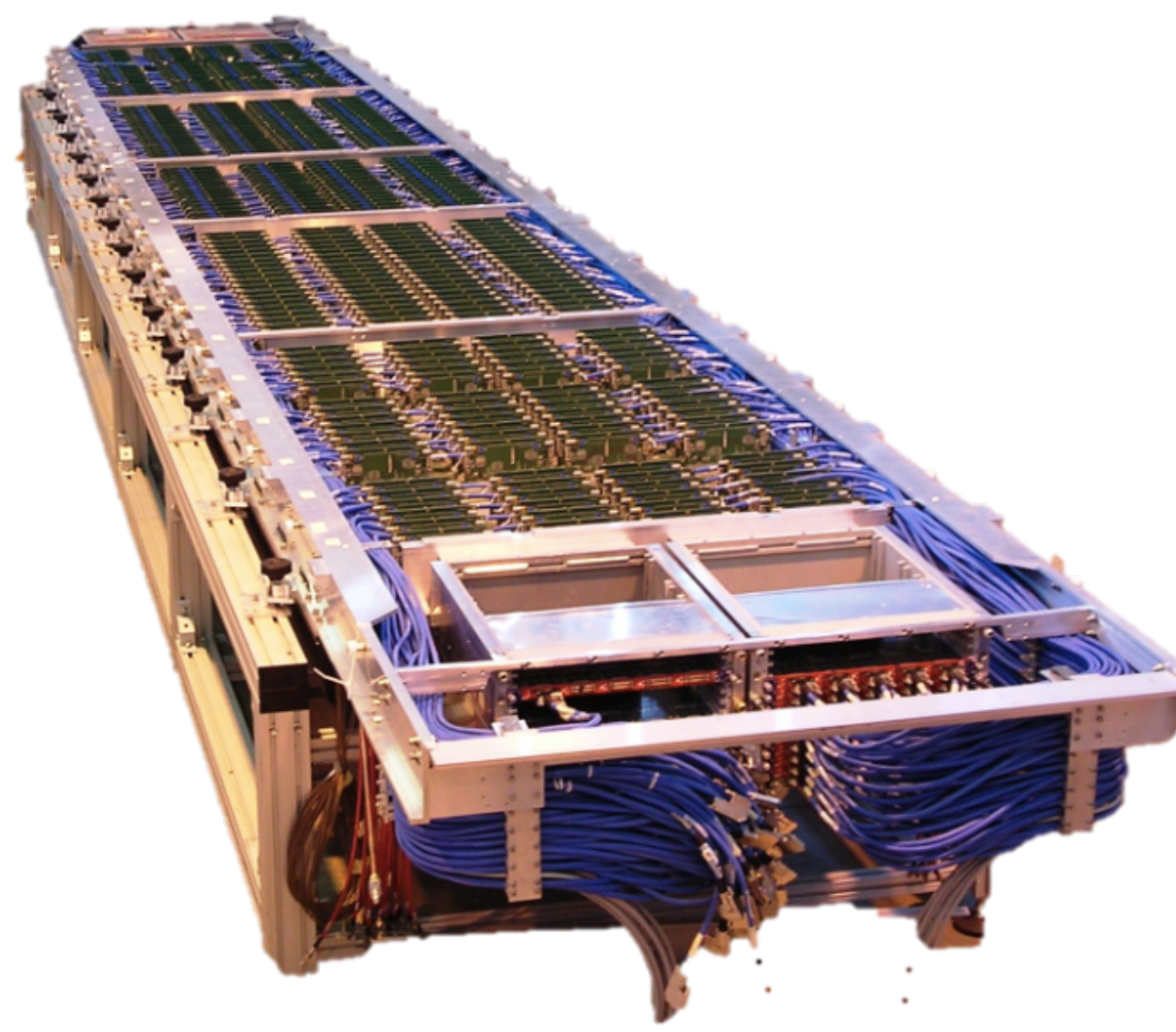




Istituto Nazionale di Fisica Nucleare  
Sezione di Bologna



**ALICE**

# Status rivelatore TOF, richieste 2024 e programma manutenzione straordinaria

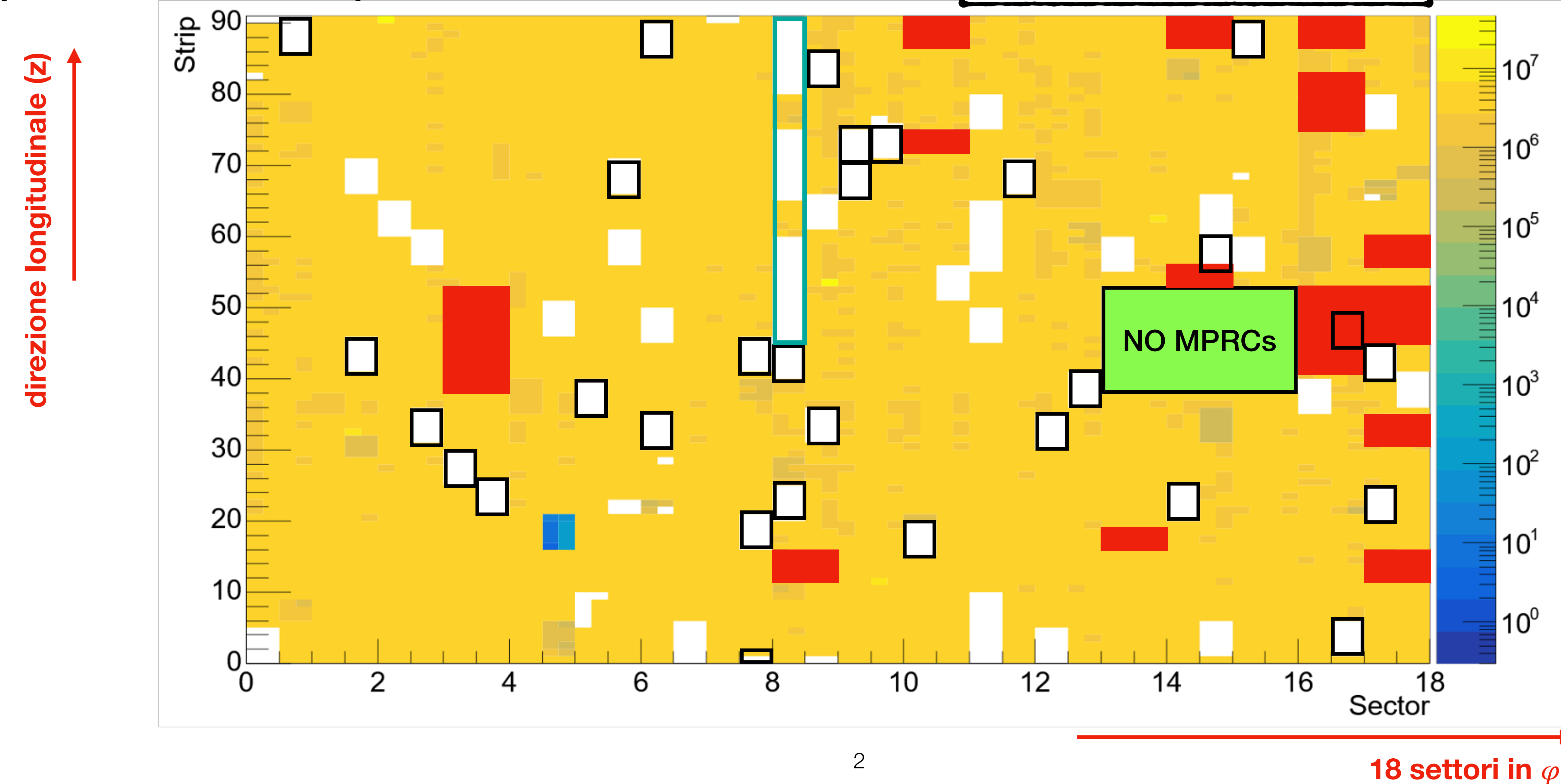
A. Alici, P. Antonioli

Riunione con INFN referee - Roma, 20-21 Luglio 2023

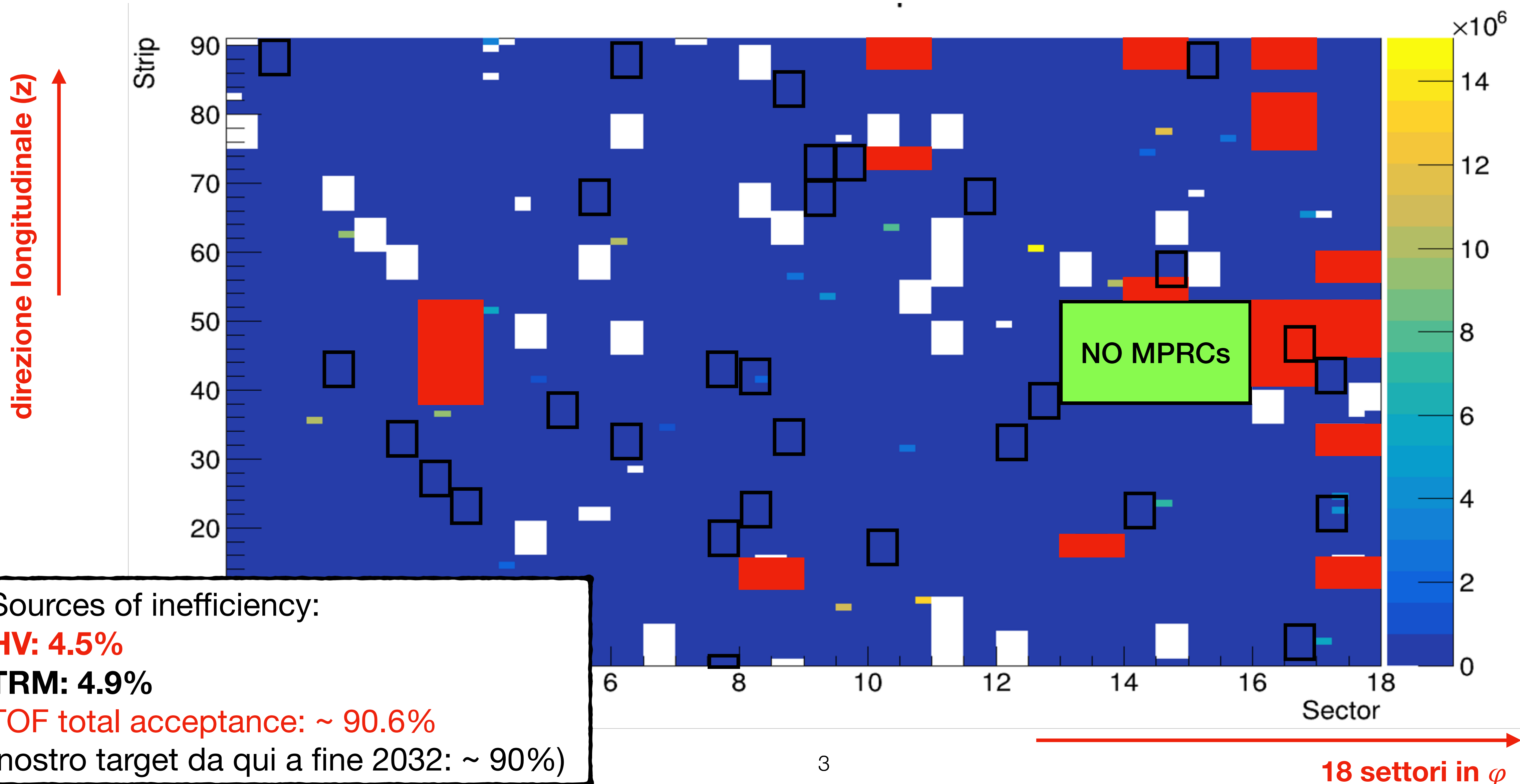
Sources of inefficiency:  
**HV: 4.5%**  
**TRM: 8.6%**  
**Cooling: 1%**

# TOF Active Channel Map before YETS

TOF total acceptance ~ 85.9%



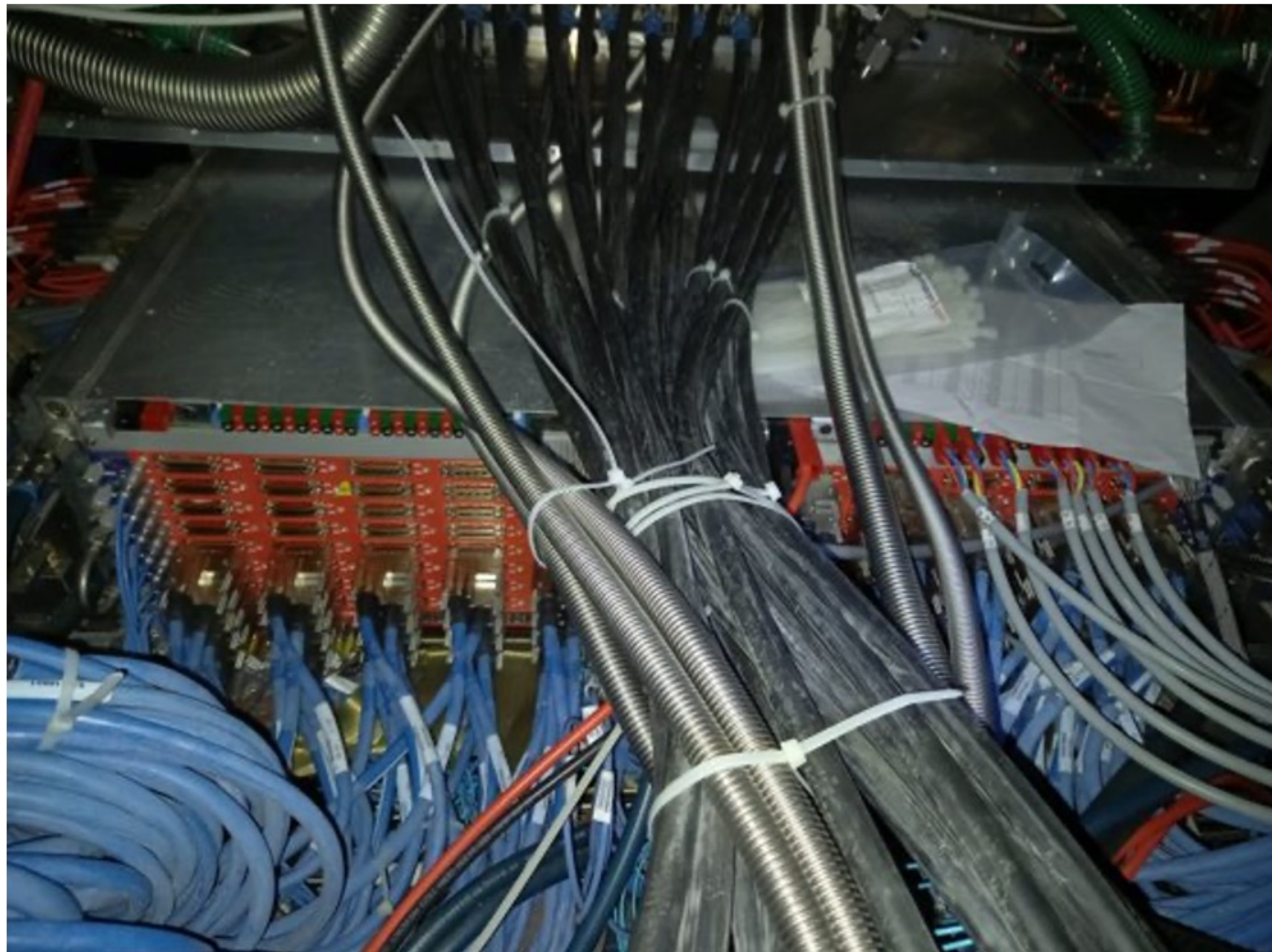
# TOF Active Channel Map after YETS





# TRM replacing campaign

Replacing even a single TRM sometimes requires uncabling multiple boards... Most of the times in extremely narrow spaces



- 34 TRMs reincluded in acquisition during YETS  
→ **19 TRMs replaced by spares**

**As of 12/06/2023** with **684** TRMs to serve TOF

- **651** are working
- **33** TRMs disabled (50% of them presumably not repairable)
- **Only 25 spares available now**



# TOF Active Channel Map



ALICE

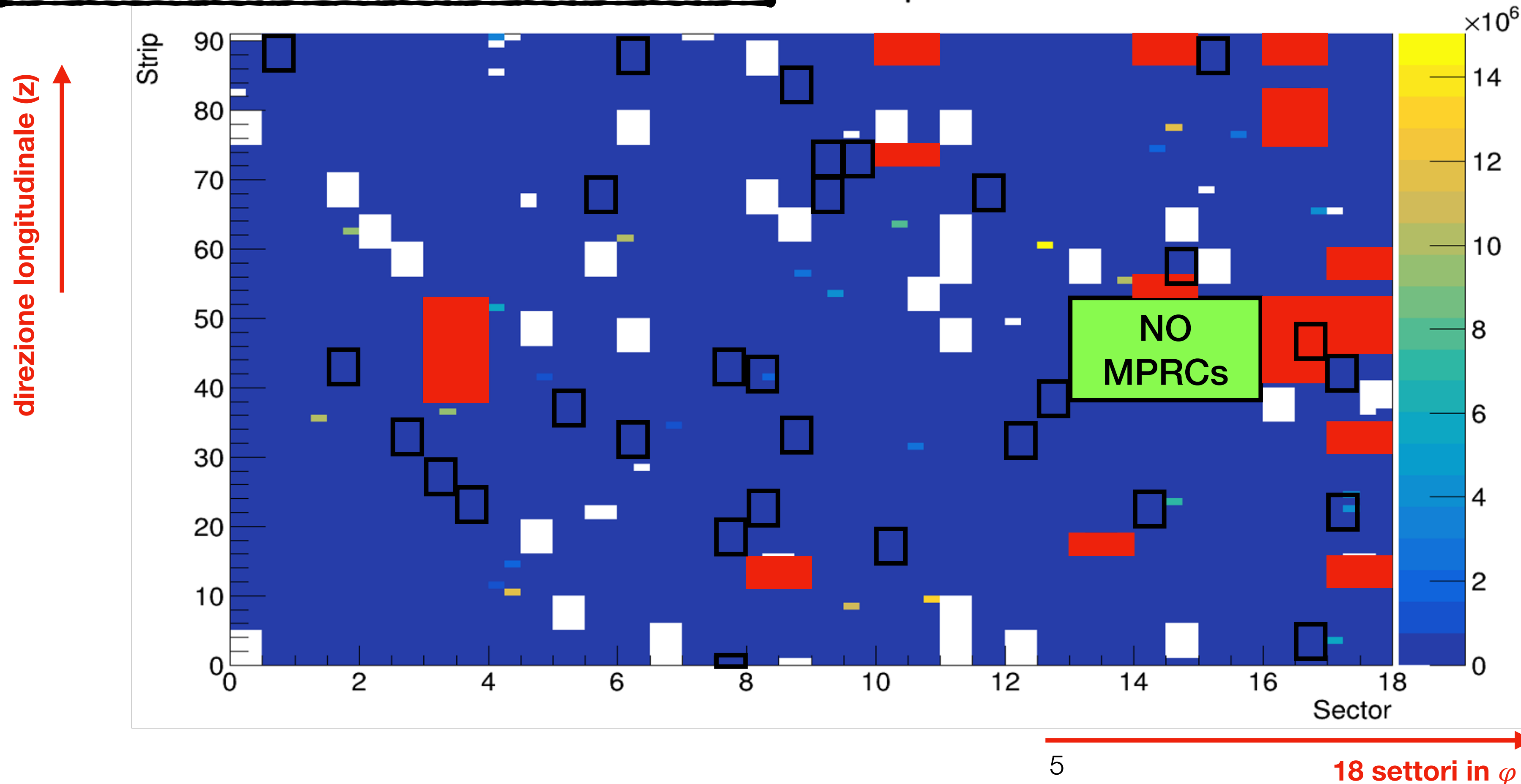
Sources of inefficiency:

**HV: 4.5%**

**TRM: 4.9%**

**TOF total acceptance: ~ 90.6%**

(nostro target da qui a fine 2032: ~ 90%)



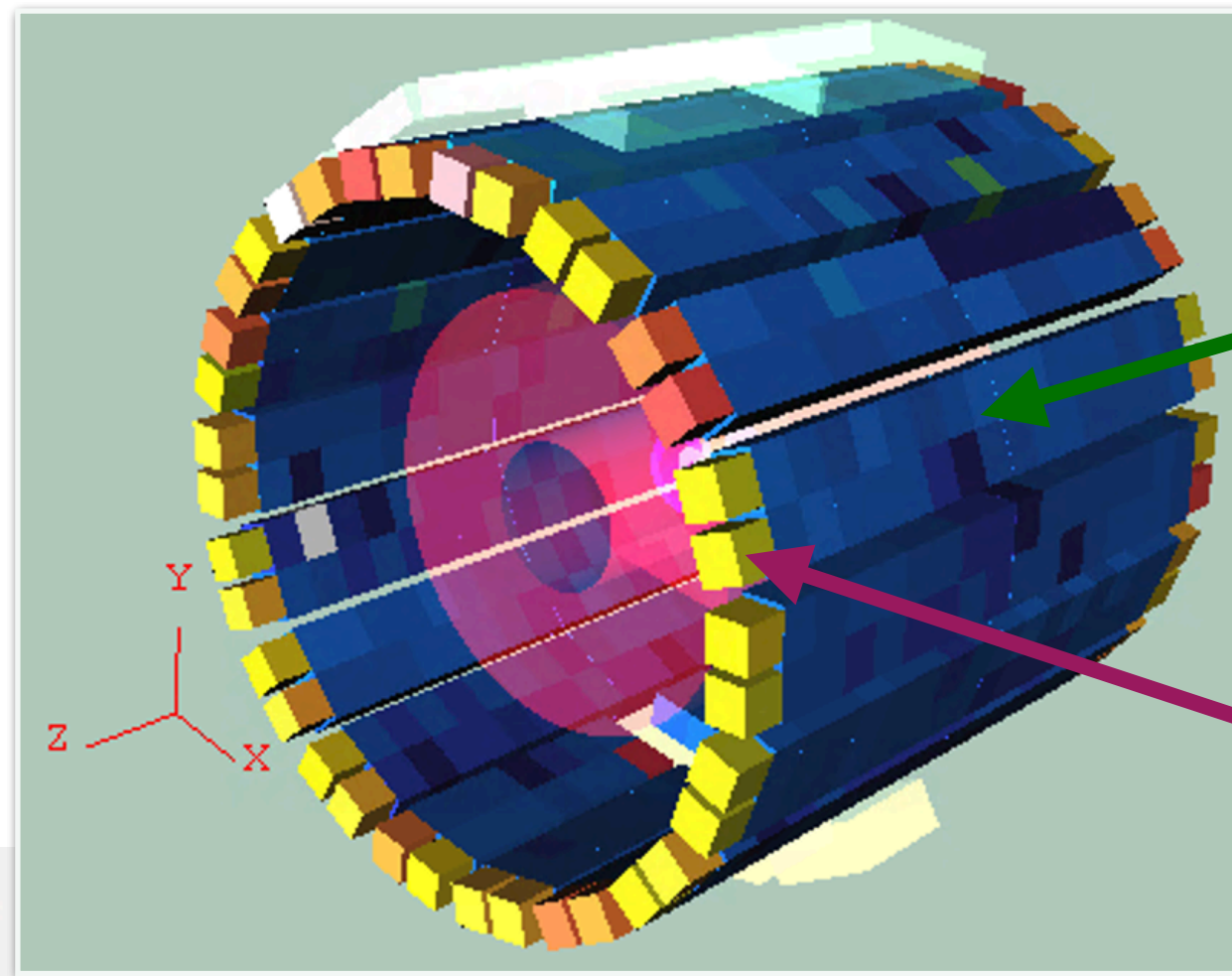
## Bring home messages

Dopo **15 anni** dall'accensione del rivelatore TOF:

- **nessun canale è stato spento per malfunzionamenti di un rivelatore MRPC**
- **nessun segno evidente di ageing delle MRPC: dark current totale per oltre 1500 MRPCs ~ 2  $\mu$ A**
- I canali spenti per problemi HV (canali rossi nella mappa a fianco) **non sono recuperabili...** se vogliamo mantenere il livello di accettazione ~ 90% dobbiamo necessariamente intervenire sulle **schede TRM**



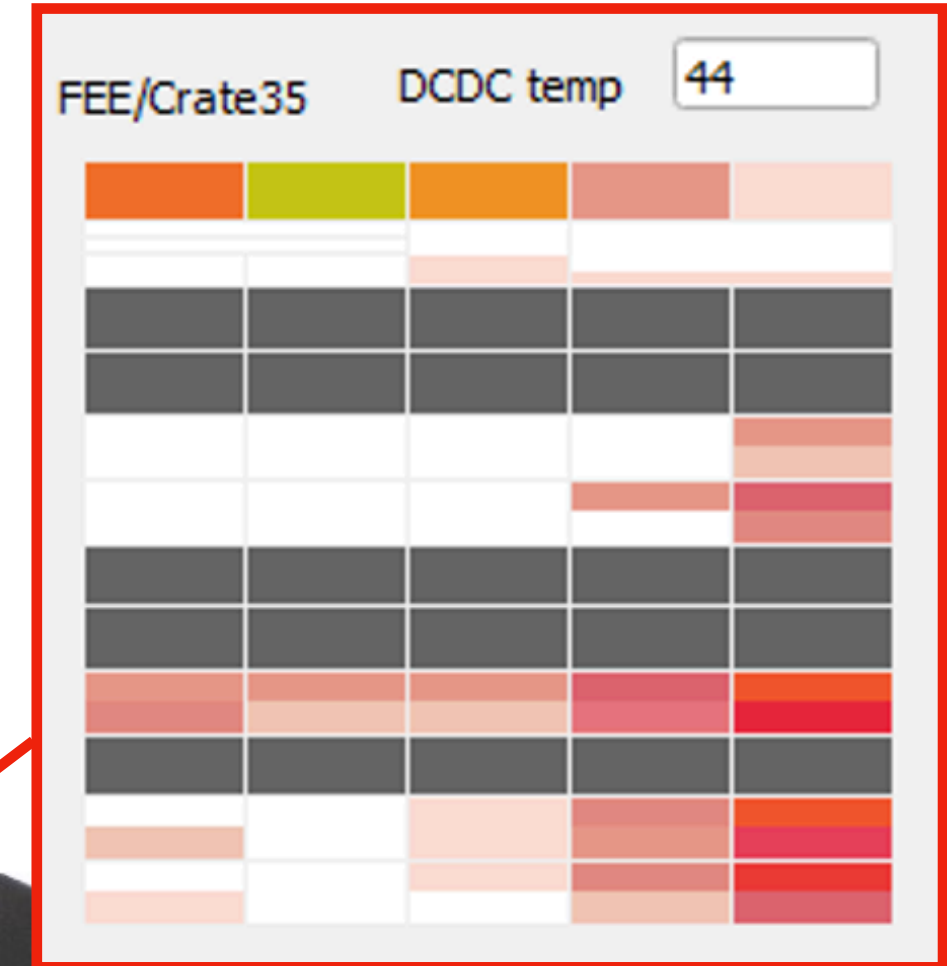
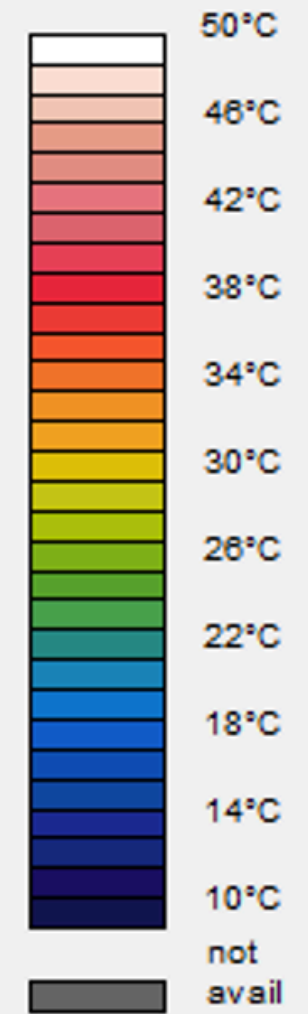
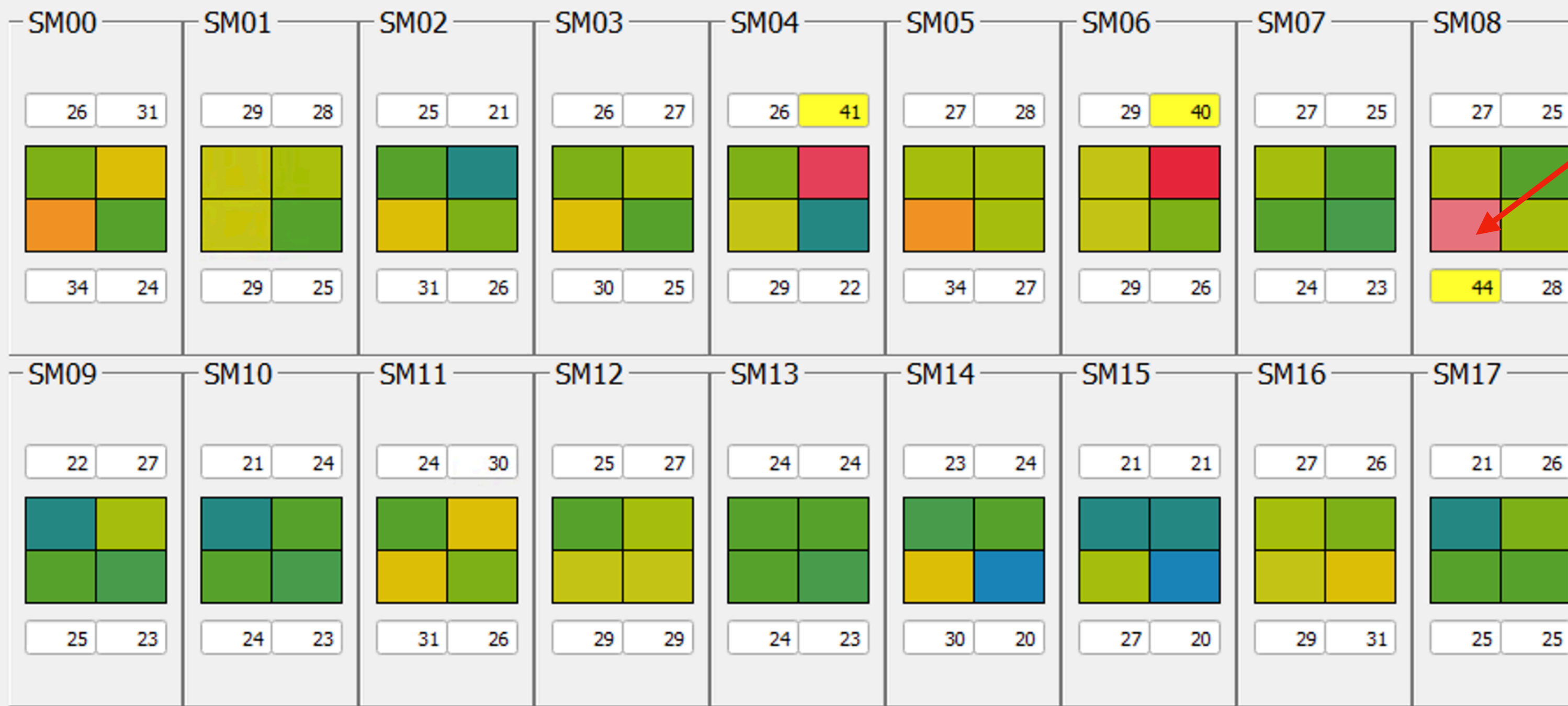
# TOF VME crate cooling issue (1)



FE electronics temperature

RO electronics temperature

DCDC Temperature









# The anti-corrosion inhibitor saga



- Deposits in the cooling plant due to galvanic corrosion. TOF failed to design cooling avoiding mixing copper and aluminium. CERN EN/CV failed to alert ALICE and INFN engineers during cooling design review (2007). Amen.
- CERN EN/CV proposed to insert a corrosion inhibitor in 2017 with an official report, but it removed it in 2019 without informing ALICE (and TOF)
- Following renewed strong request ([June 2022 TB](#)) via TC, CERN EN/CV explained they were finalising some chemical analysis to validate the product
- In July 2022 CERN EN/CV told us everything was ok and they could insert it even during September TS. We agreed to do this during YETS.
- **BUT:** now CERN EN/CV is making chemical analysis of Cu deposit in the cooling plant and they are saying the inhibitor can not be added if there is too much Cu...
- During this YETS they then emptied and refilled the whole cooling plant, but still Cu concentration is too high according to them (**0.94 ppm**: really?). Until next YETS nothing will happen...

## In short:

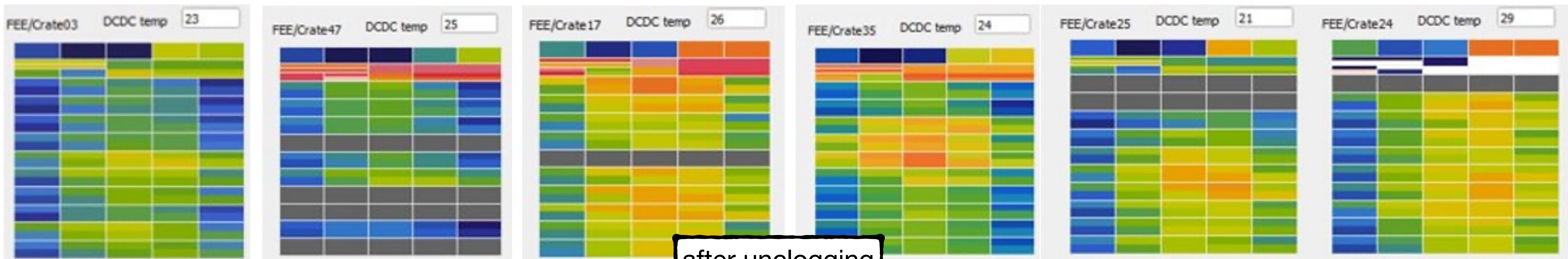
- CERN EN/CV failed, once again and since 6 years now, to add the corrosion inhibitor
- **CERN EN/CV proved confused** (to say the least) in proposing, planning and executing operations
- **ALICE management weight is now needed to go somewhere. Technical Coordinator and Spokesperson have been informed.**



# Cooling intervention during 2022 YETS

Before YETS few crates were experiencing high temperatures → multiple trials using acids and a pressure pump did not lead to significant results. New procedure performed during YETS → 6 crates unclogged successfully

End of 2022 situation



after unclogging



# Cooling intervention during 2022 YETS

Before YETS few crates were experiencing high temperatures → multiple trials using acids and a pressure pump did not lead to significant results. New procedure performed during YETS → 6 crates unclogged successfully



- Deposit on crates pipes and turbolators dissolved using phosphoric acid (5-10% conc.) **left to act for 1 or 2 days**
- Pressure wash needed to break down the hardest deposits left after the acid bath → in some occasions they were able to block also valves used for the job
- All crates involved showing a nominal flow  $>2$  l/min after the treatment
- **Crates temperature stable even after cooling plant restart**, but corrosion inhibitor still NOT included...



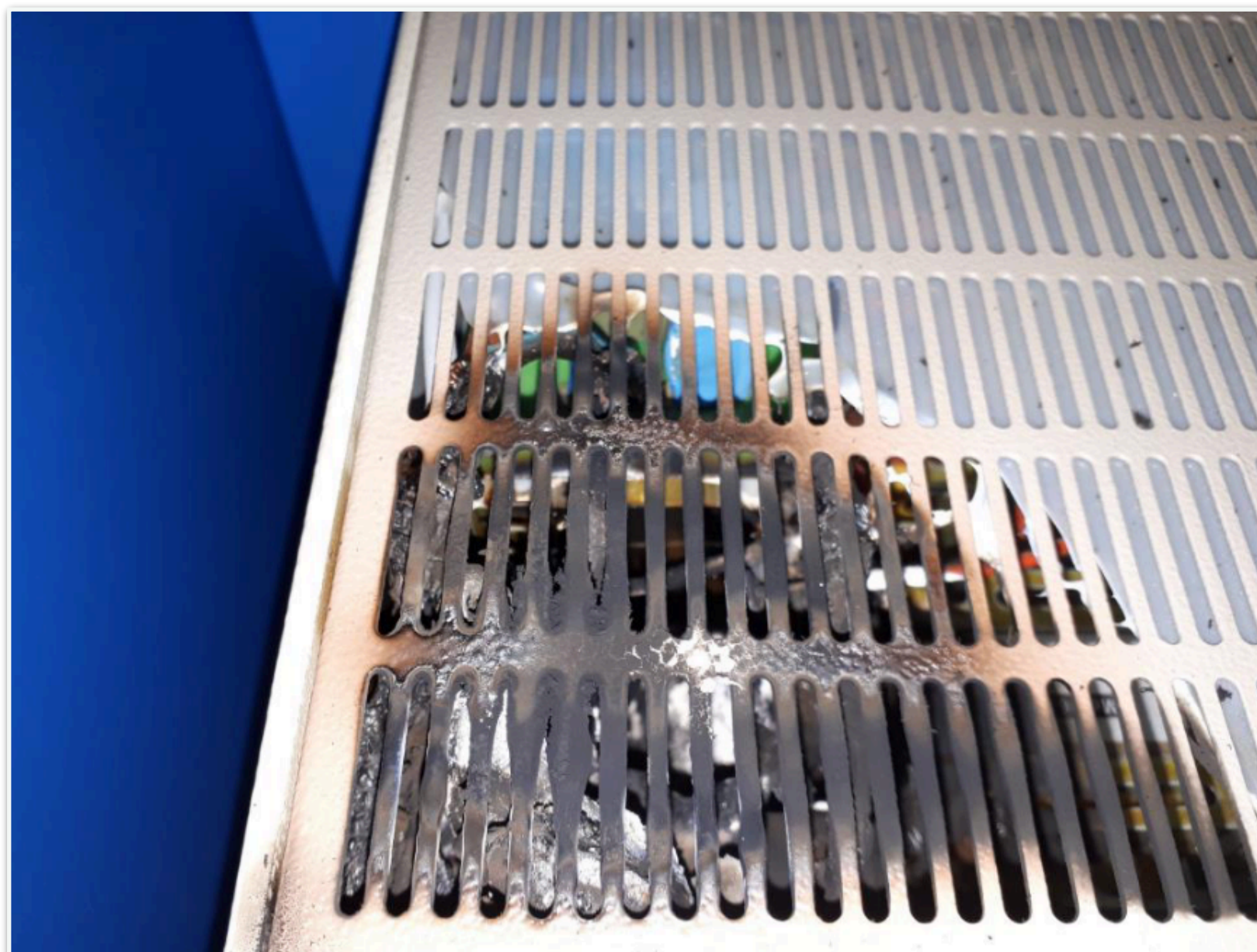


# A3000NF burned capacitor

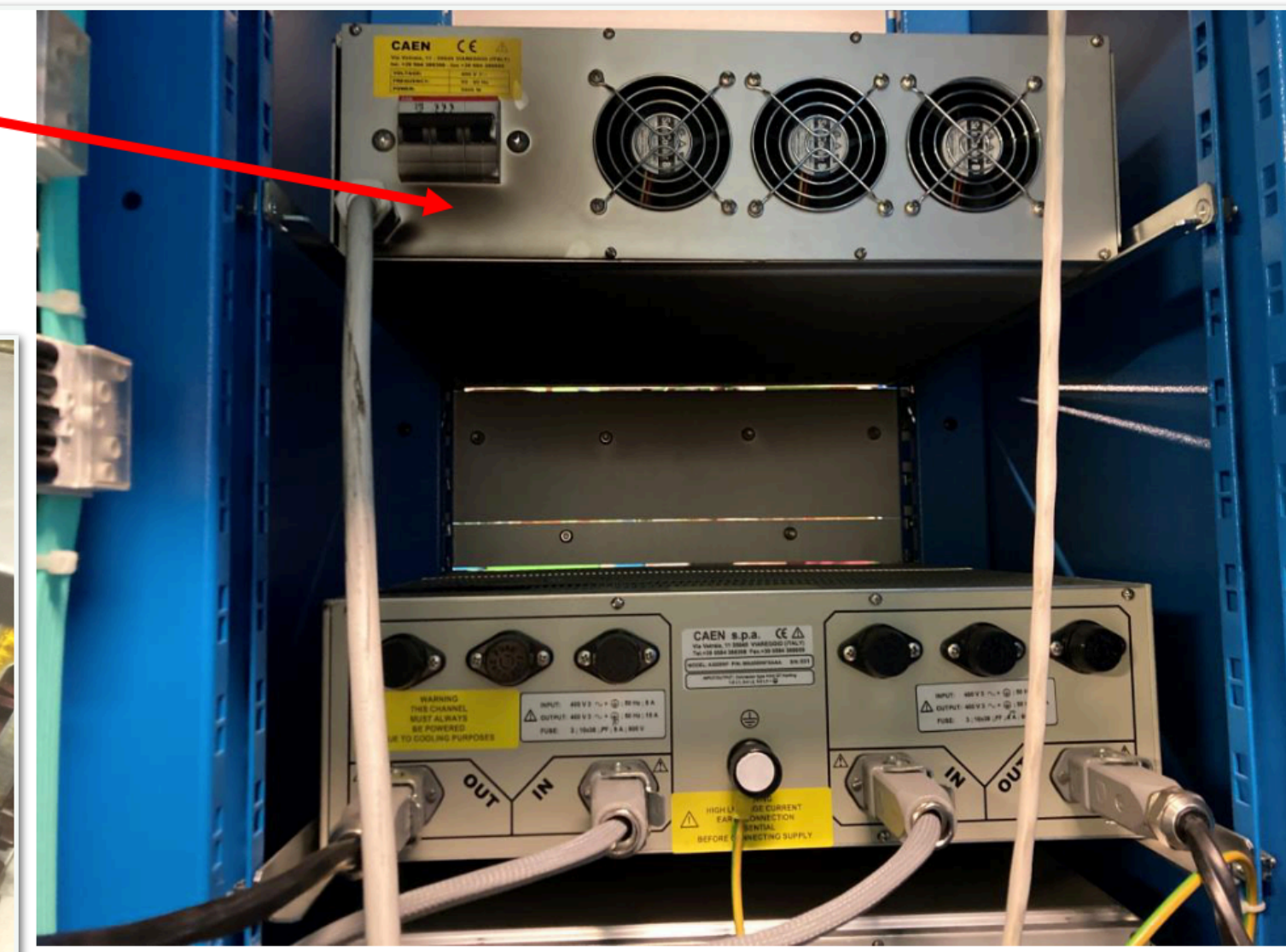
**A3000NF** 3-phase notch filter for a A3486 (in order to be CE compliant on harmonic current emissions).

- 24 installed in 12 racks in the ALICE cavern (+ 2 spares) —> 26 filters in total
- (a) two typology of capacitors installed are reaching their end life, for a total number of 12 capacitor for each A3000NF. Few problematic modules in ATLAS investigated by CAEN, problem originated from a capacitance that overheated and then burned out (20% higher load in ATLAS wrt ALICE)
- (b) considering that the replacement of the capacitors will require the disassembling of the whole module, it's worth probably evaluate the replacement of the fan units too, that could face age-related issues
- (c) finally, it is possible to add a protection that disables the device in case of overheating of the capacities subject to this type of event

15/03/2019



Traces of the smoke/fire/flash (soot) on the device above the failing filter



12/04/2023



# A3000NF burned capacitor



**A3000NF** 3-phase notch filter for a A3486 (in order to be CE compliant on harmonic current emissions).

- 24 installed in 12 racks in the ALICE cavern (+ 2 spares) → 26 filters in total
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- (b) considering that the replacement of the capacitors will require the disassembling of the whole module, it's worth probably evaluate the replacement of the fan units too, that could face age-related issues
- (c) finally, it is possible to add a protection that disables the device in case of overheating of the capacities subject to this type of event
  
- a. 750/1000 € (Capacitance replacement + test at CERN) x 26 units = **19.5/26 k€**
- b. 250/300 € (Fans replacement, optional) x 26 units = **6.5/7.8 k€**
- c. 200 € (Capacitance overheating protection, optional) x 26 units = **5.2 k€**

Total cost (option a): **19.5/26 k€**

Total cost (option a+b+c): **31.2/39 k€**

## Richiesta nei preventivi 2024 (su capitolo APPARATI)

Intervento sostituzione capacito 2.5 k€ costo capacitori + 750 € per modulo, sostituzione ventole 300 € per modulo, sistema di protezione 200 € per modulo → 35 k€ (ANTICIPABILI)



# 2022 operations in a nutshell

## Running time

In 2022 TOF has been in readout **99.4% of the time**. 0.6% missing because of:

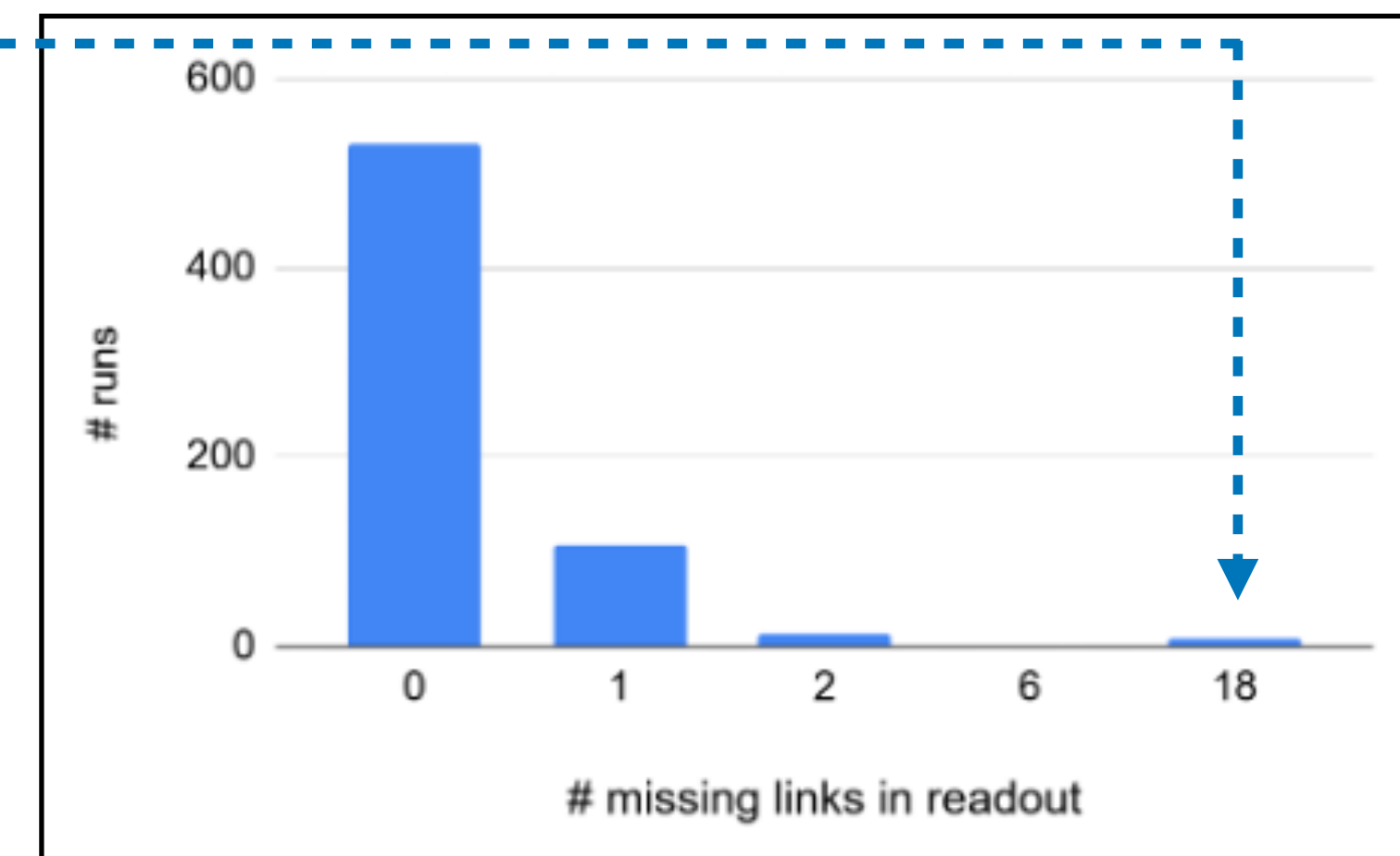
- fill 8027,8033 (July) lost due to compressor going in segmentation fault, fixed within 2 days
- 60' run (September) missed having lost one CAEN mainframe

**80% of the runs with 72 links in readout (96% of the runs with  $\geq 71$  links)**

## End-of-run reasons

TOF stopped or prevented to start 18 runs (2.7% of the total) in pp@13.6 TeV:

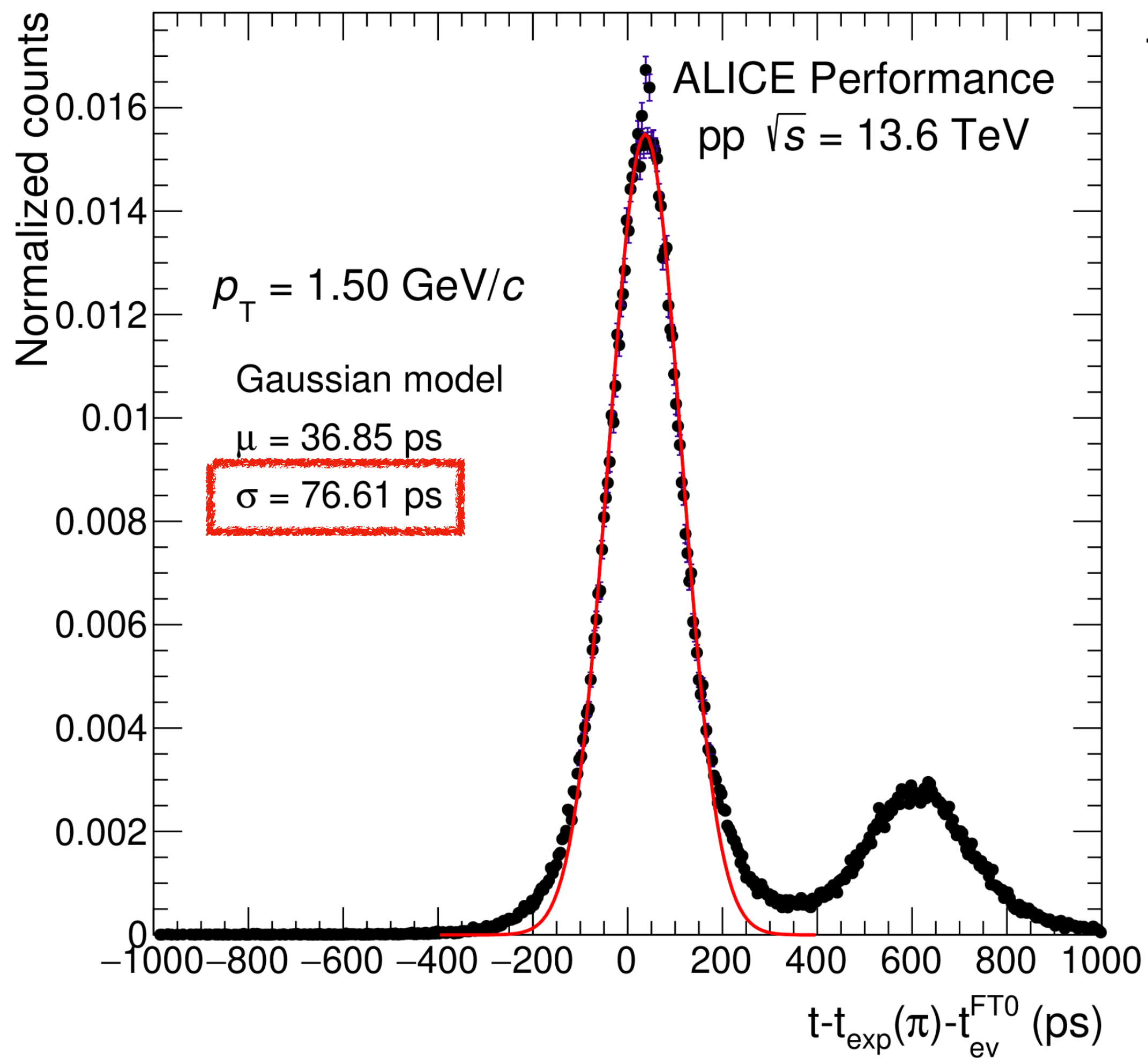
EOR Reason	Occurrences
Compressor crash (Fixed)	5
QC task for trending	3
DCS SOR error	7
Bad data	3



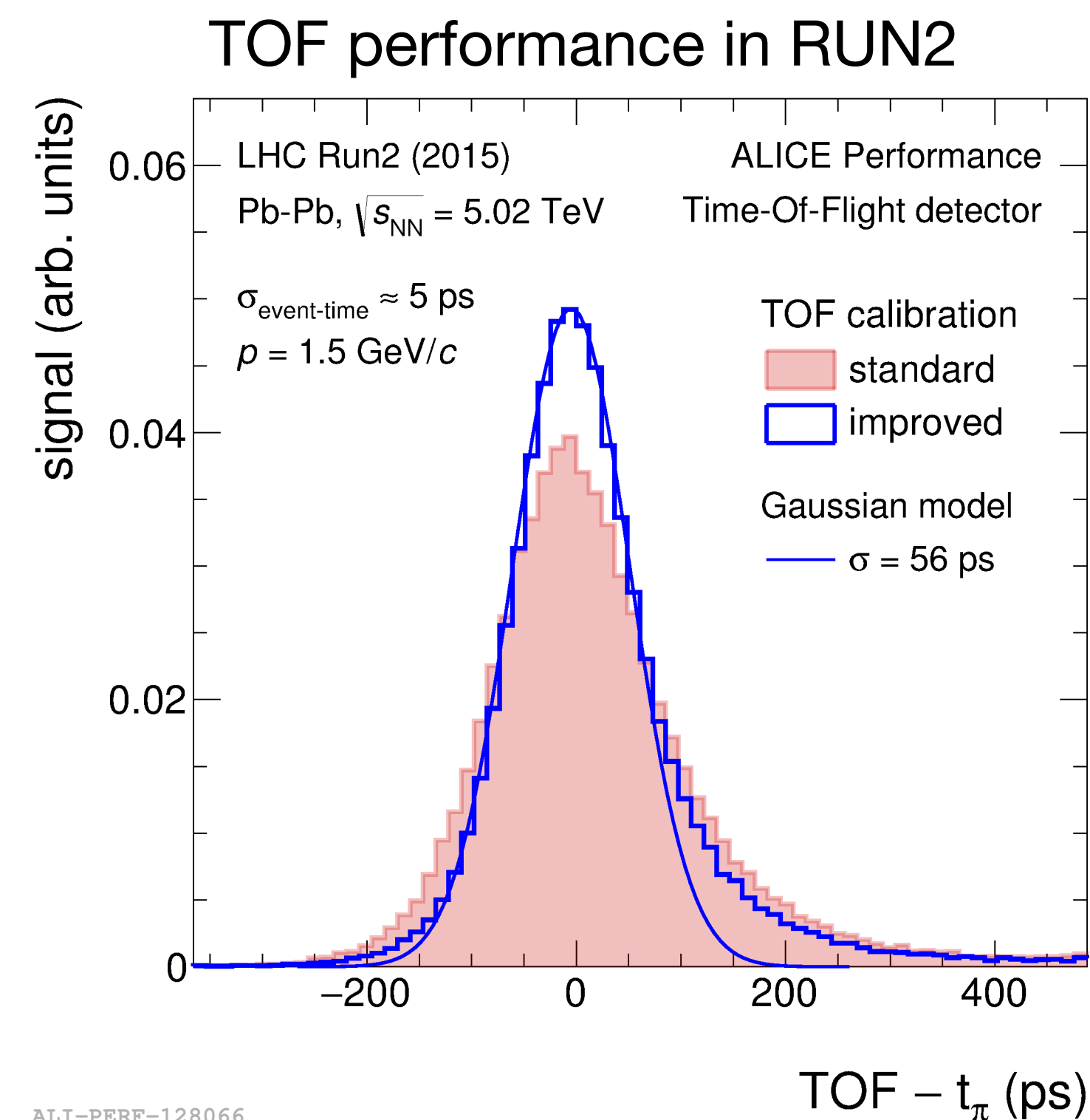
Note: experience gained in 86 “pilot beam runs” (pp @ 900 GeV) helped quite a lot to improve TOF stability!  
**(with 900 GeV pp pilot beams TOF stopped 12.7% of the runs)**



# TOF performance



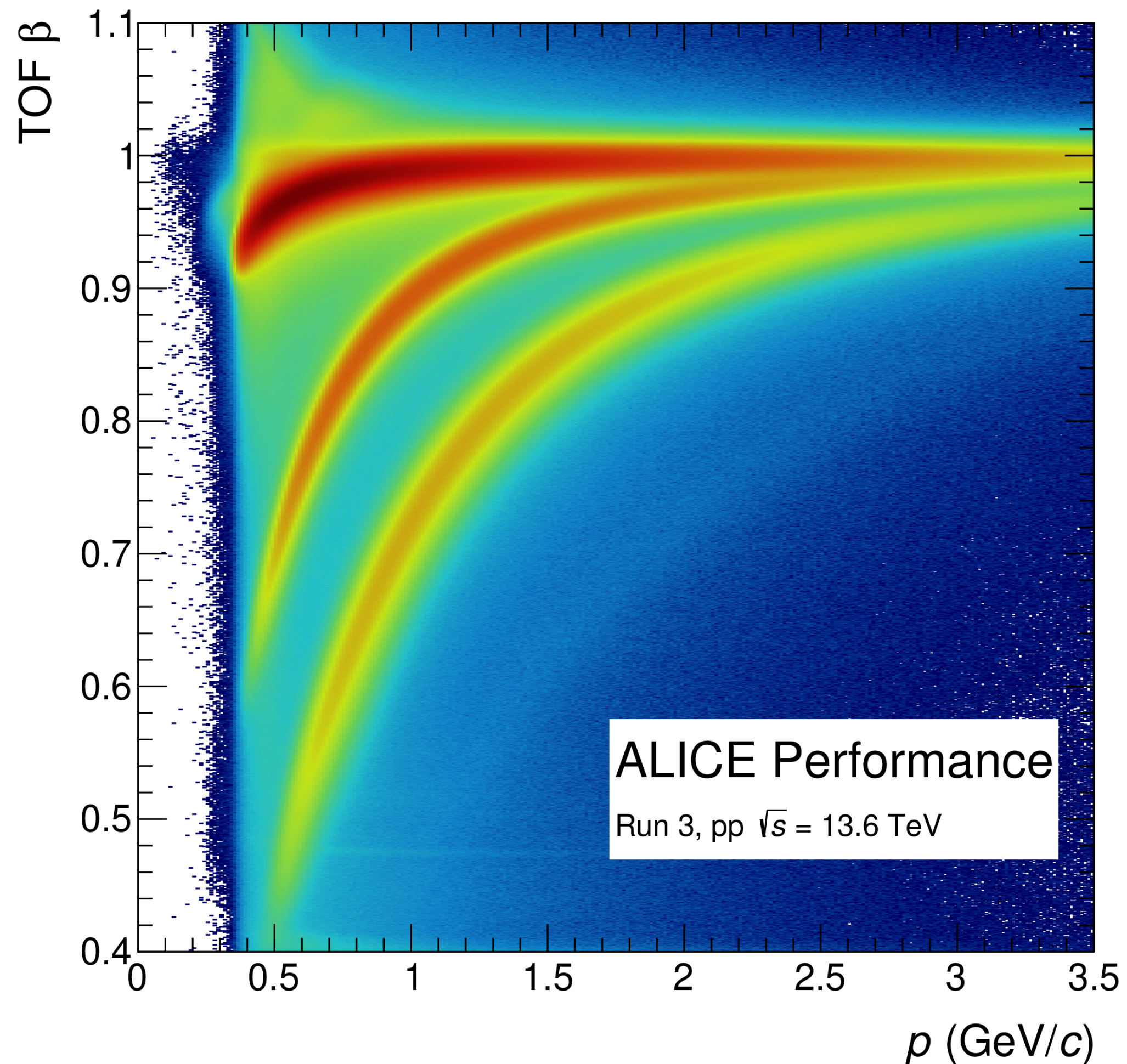
TOF is performing well in Run 3 → **80 ps** now reached... still **room of improvements** in parallel with improvement on the reconstruction quality (tracking)



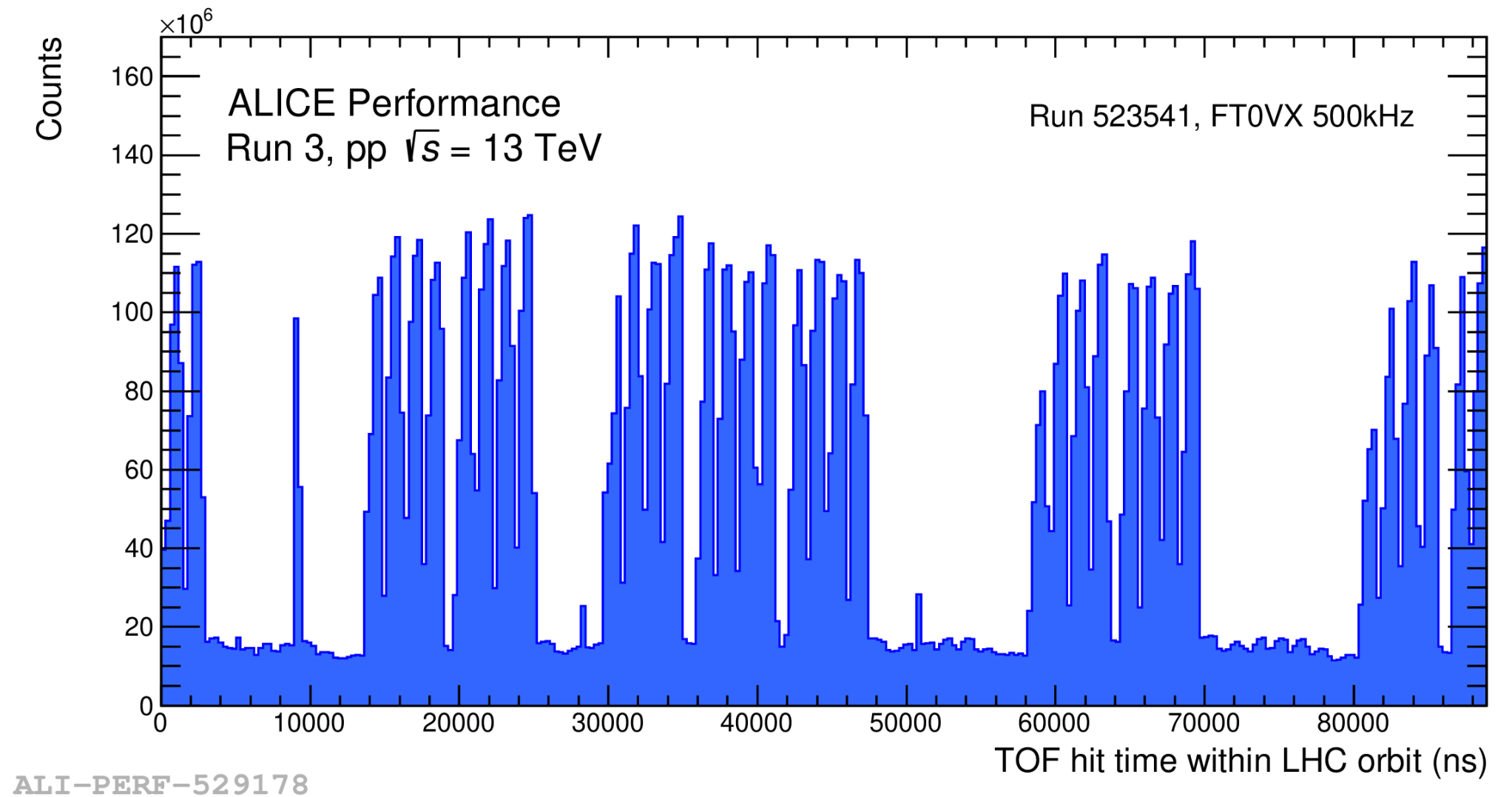


# TOF performance

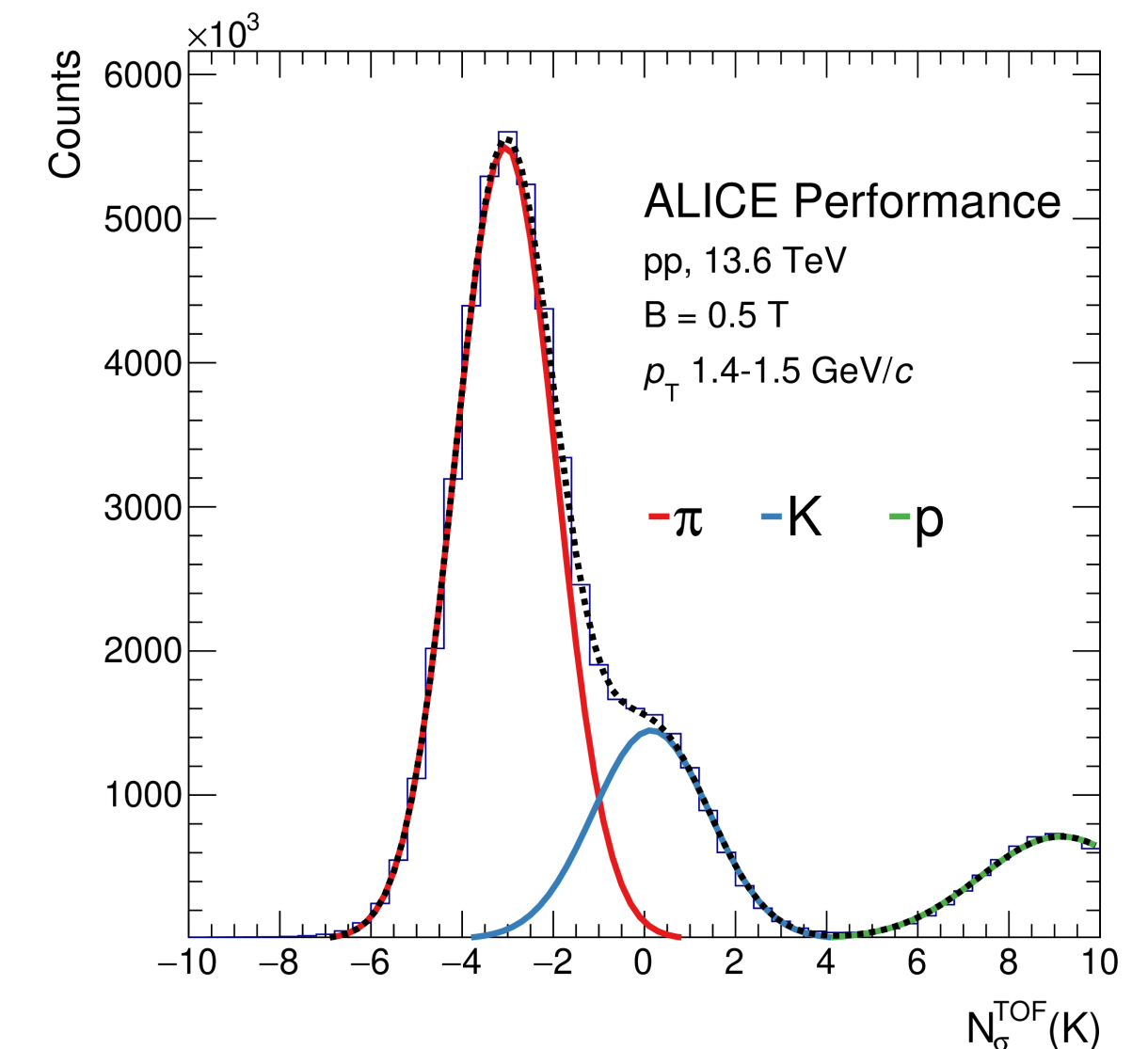
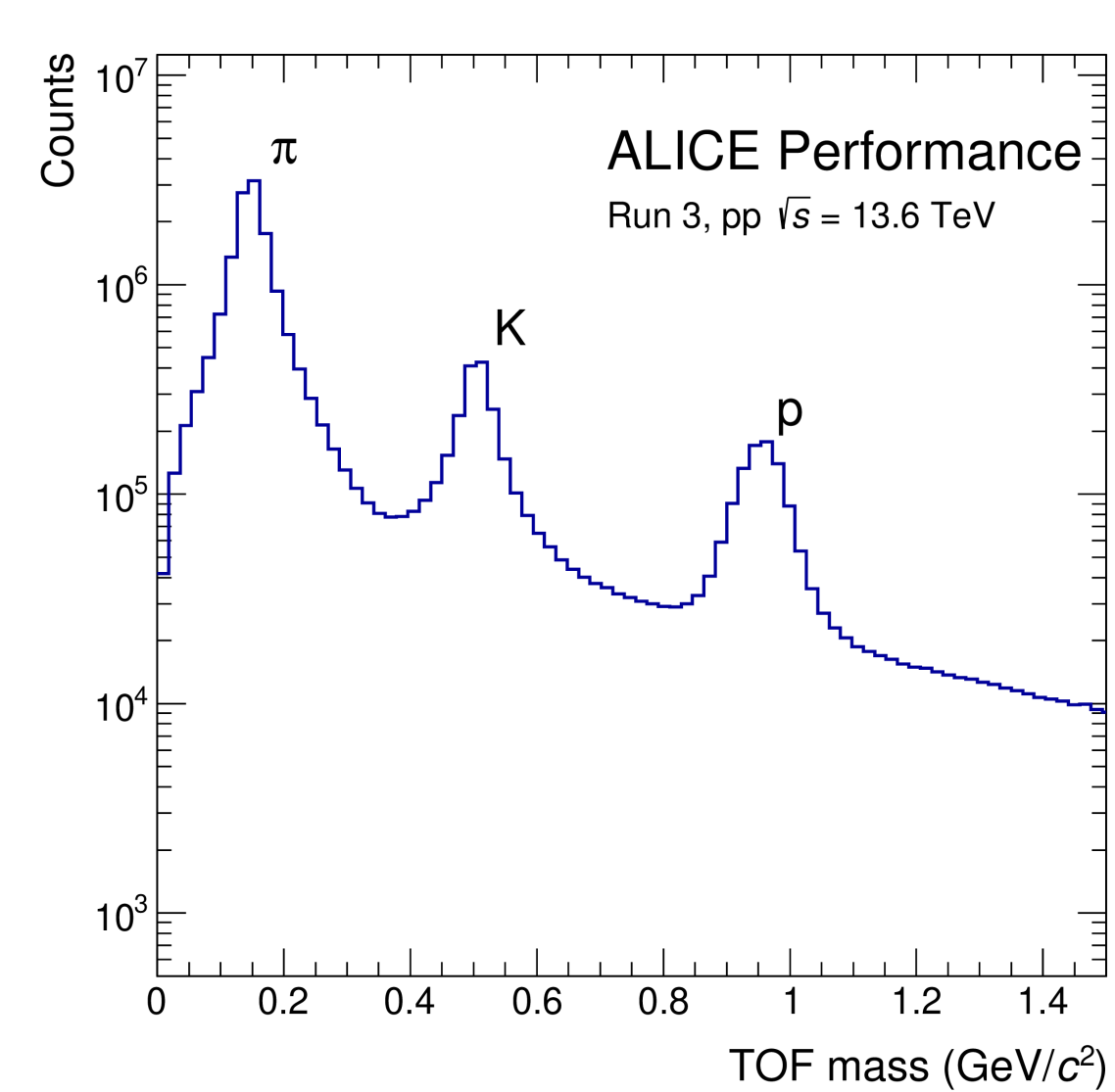
TOF Beta vs Momentum. Results from the offline analysis from AODs of the pilot run data with 13.6 TeV collisions in LHC22q apass3.



Continuous readout: TOF hit time distribution within LHC orbit (88.92 microseconds)



ALI-PERF-529178



ALI-PERF-528567

# Stato completamento milestones 2023



## Milestones TOF 2023:

30/11/2023 Partecipazione a presa dati con collisioni pp e Pb-Pb → **completato 50%**

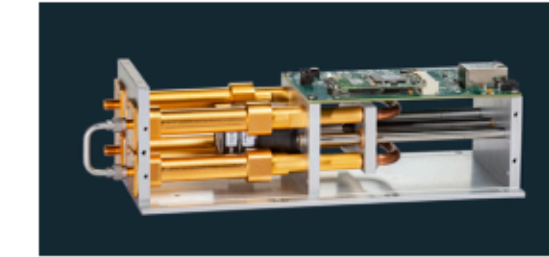
31/12/2023 Realizzazione scheda test board per TRM2 e test picoTDC con FEA ALICE TOF → **completato 80%**

La scheda test board e' in consegna a fine luglio (o agosto) e test con FEA sono stati effettuati con successo.

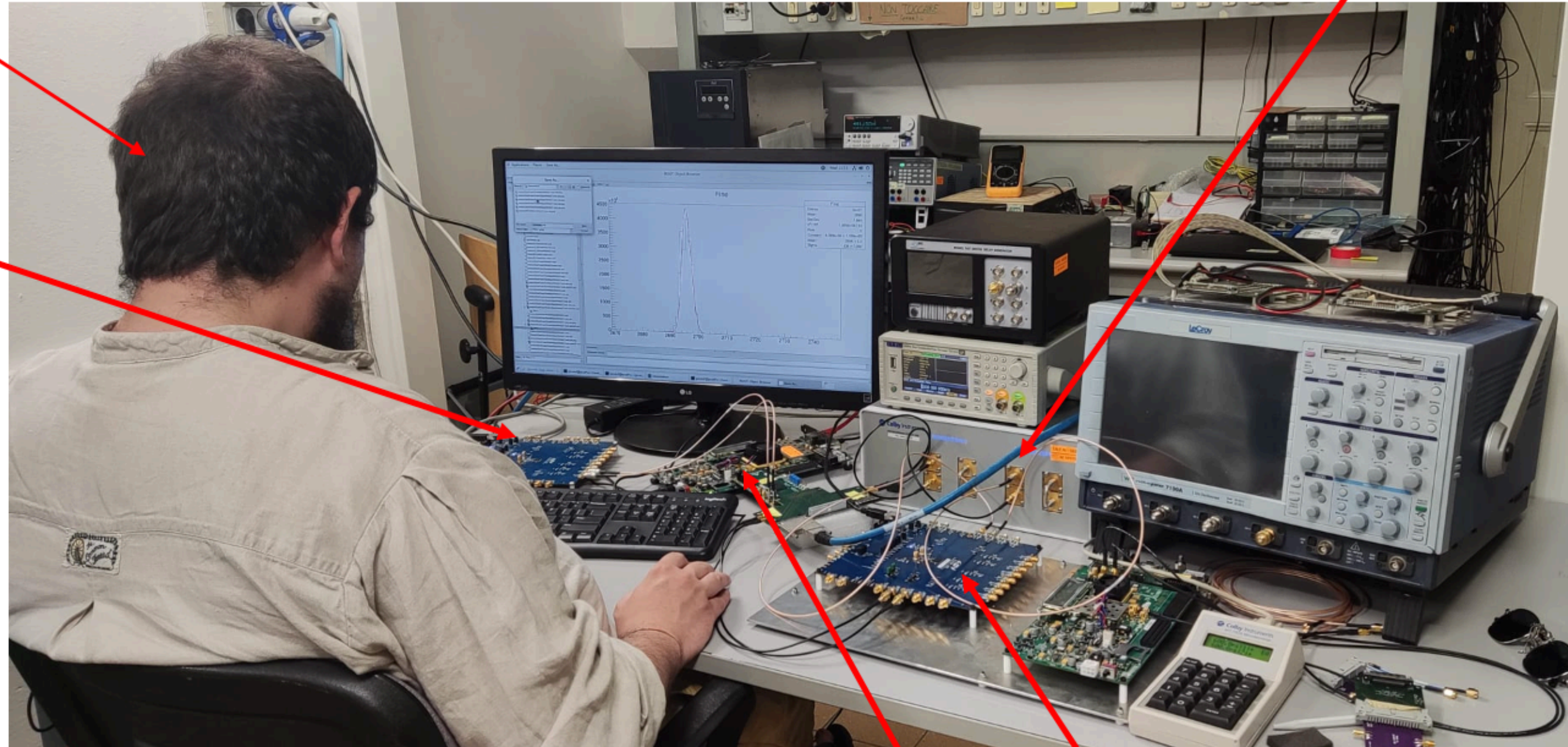


# Test setup: learning and testing picoTDC

Colby electromagnetic trombone for ps (0.5 ps precision!) calibrated delays



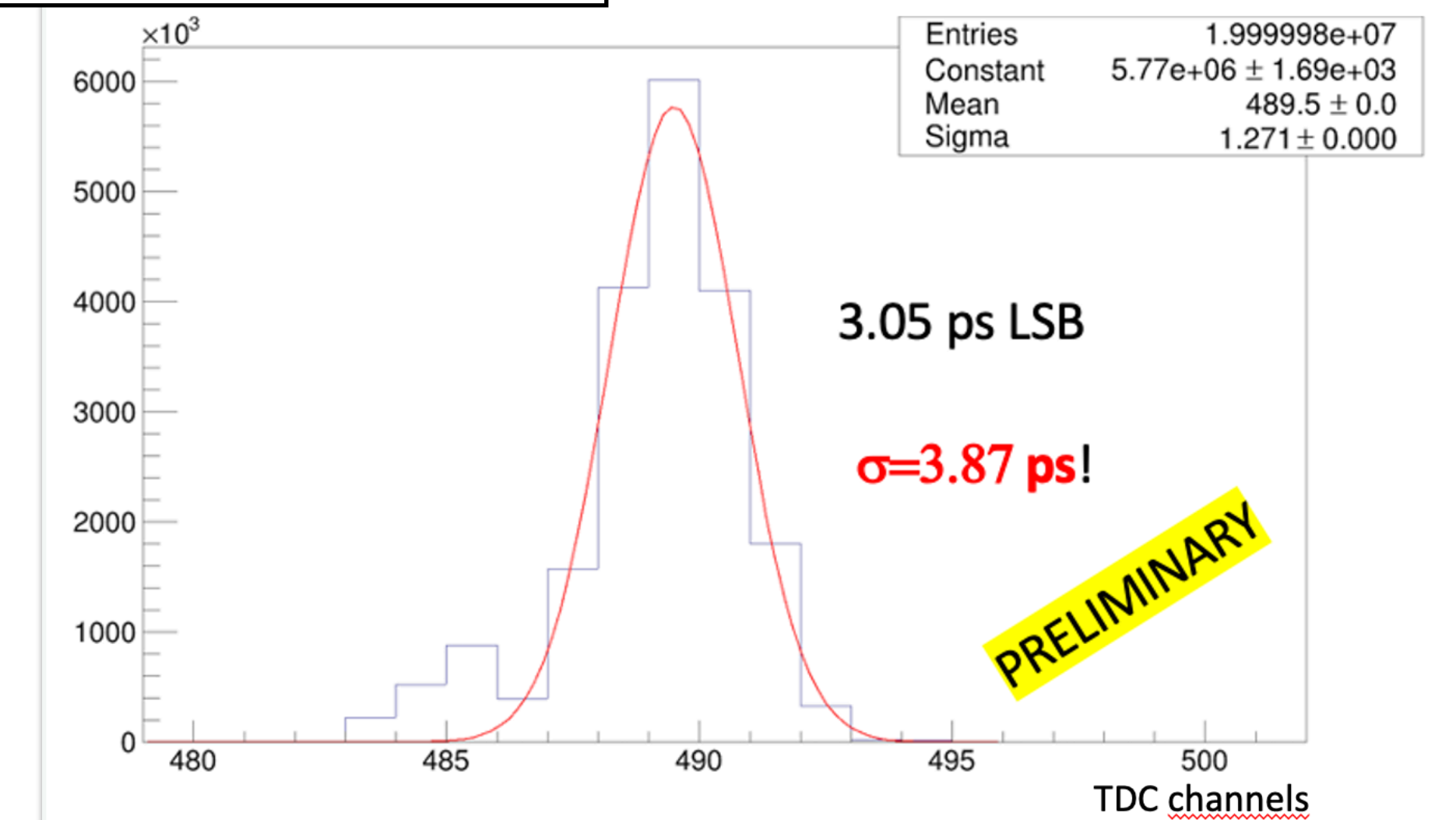
Master student



LHC clock input to picoTDC via high precision clock card (<100 fs jitter)

VC707 + picoTDC demo board

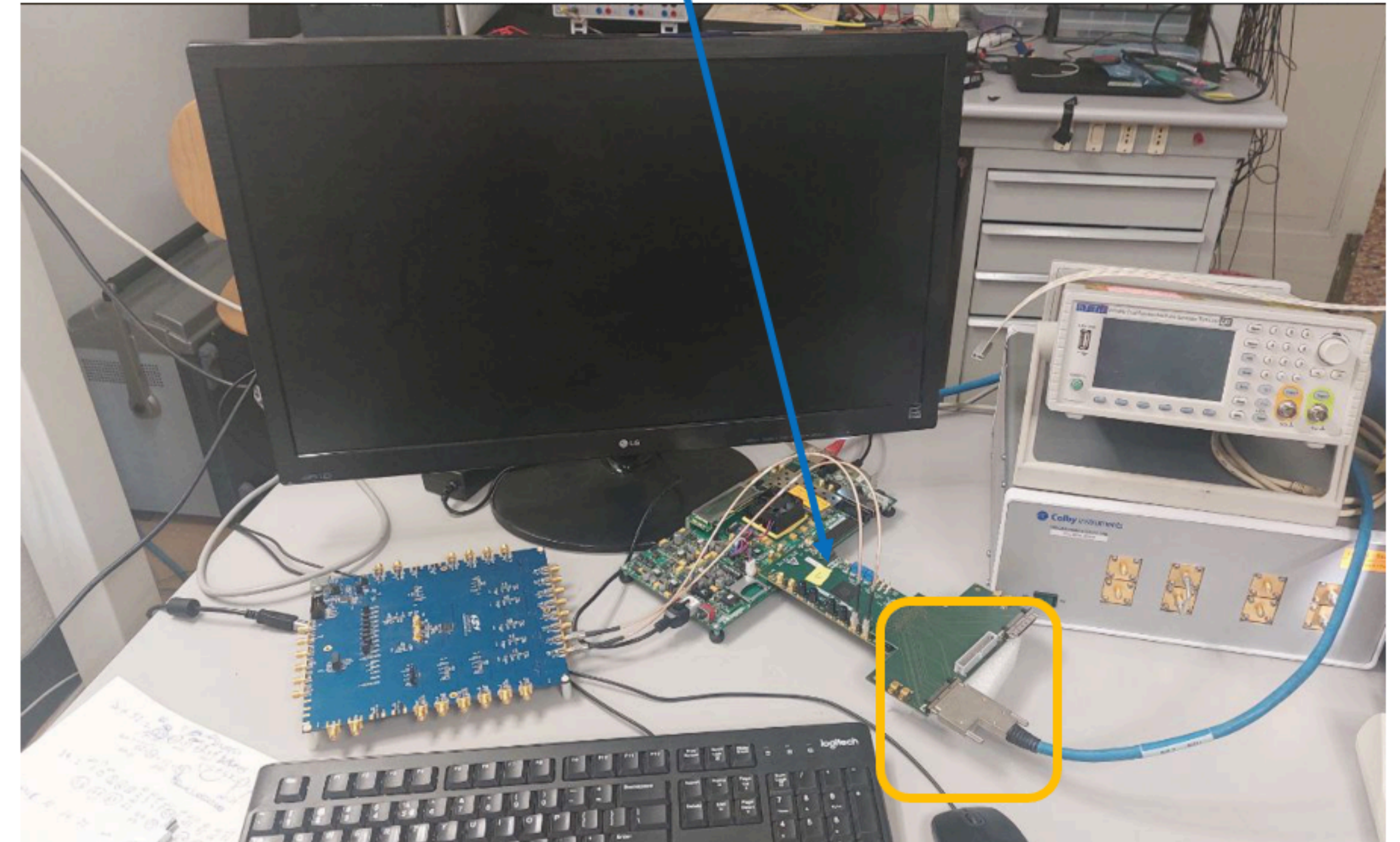
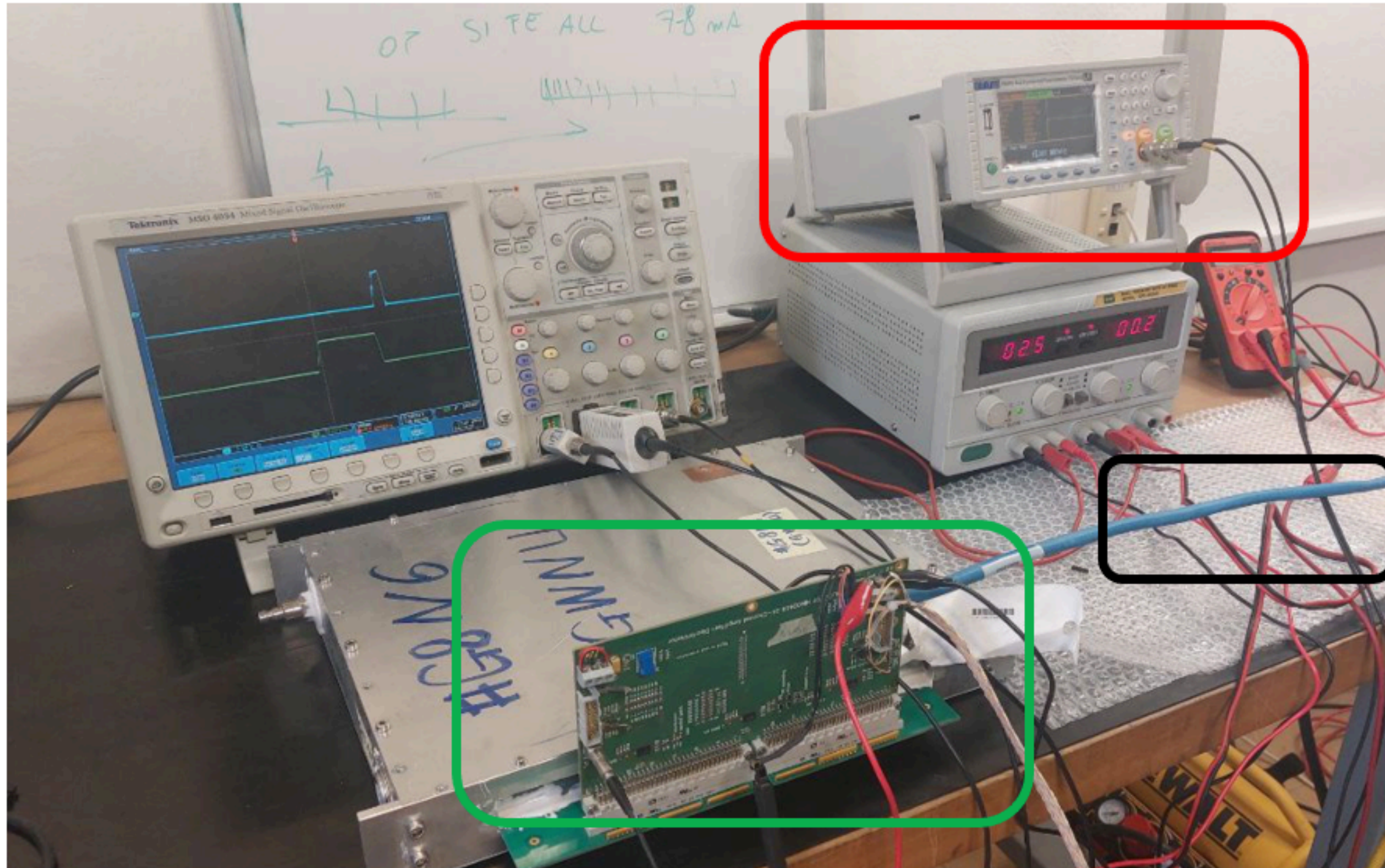
Pulser line via high precision clock card (<100 fs jitter)





# Test setup: testing TOF chain up to picoTDC

Pulser → NINO TOF FEA → VHDCI ("TOF") cable → VHDCI-FMC adapter → picoTDC



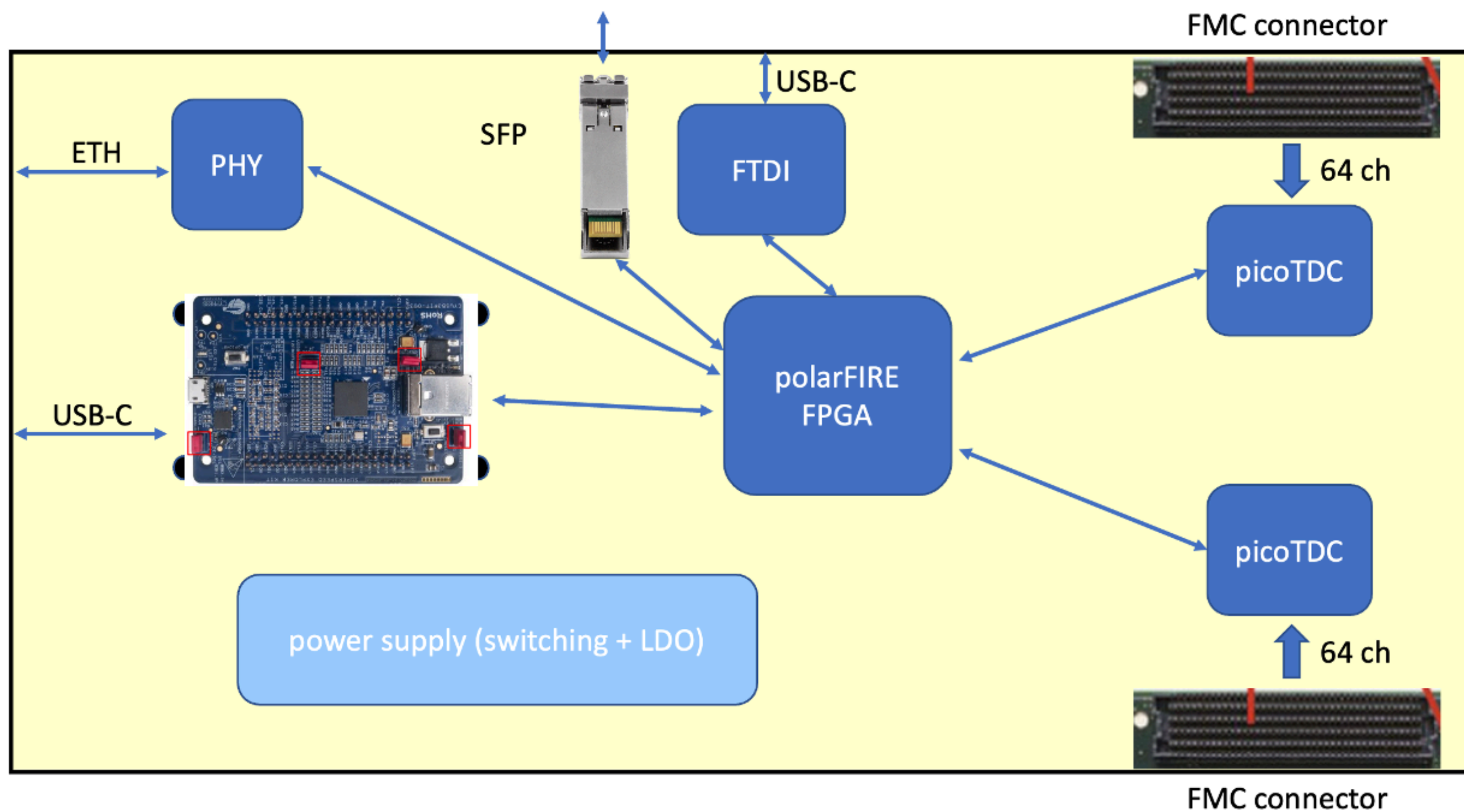
As expected not particular issues between NINO FEA + picoTDC (both sides speak LVDS)

## Next steps

→ resolution measurement via "physical delay lines" (different cables) using NINO as "pulser"



# TRM2 test board: conceptual design



## Refined design:

- 2 USB interfaces
- 1 Eth0: IPBUS
- 1 SFP: plan to use CONET IP

This card is “general” (gym for TRM2, but also used for AIDAInnova (MRPC timing) and potentially for ALICE 3

## Design choices:

- learn new building bricks of TRM2
- portable & easy to use
- pluggable to different FE-ASIC via FMC
- Candidate FPGA used
- Card to be delivered by mid-July
- Expected to take data on test beams end of October (using IPBUS) for MRPC studies (NINO) and SiPM (using another ASIC)

By end of the year we will be in the position to define TRM2 specs with CAEN and move ahead with prototypes!



# Stato completamento milestones 2023



## Milestones TOF 2023:

30/11/2023 Partecipazione a presa dati con collisioni pp e Pb-Pb → **completato 50%**

31/12/2023 Realizzazione scheda test board per TRM2 e test picoTDC con FEA ALICE TOF → **completato 80%**

La scheda test board e' in consegna a fine luglio (o agosto) e test con FEA sono stati effettuati con successo.

## Richieste extra 2023:

- sblocchi missioni sub judice
  - **9.5 k€** per partecipazione a presa dati Pb-Pb → **SBLOCCATI**
- sviluppo scheda di readout TRM2:
  - **50 k€** s.j. alla finalizzazione di un preventivo full-pledged da parte della ditta CAEN → **SBLOCCATI**
  - **50 k€** NDB → **ASSEGNATI** (comprensivi di 10311,88 € da prelevare su fondo TOF core)





# TOF 2024 e richieste

## Richieste 2024:

### Milestones TOF 2024:

11/11/2024 Partecipazione costante e regolare alla presa dati con collisioni pp e con ioni

31/12/2024 Produzione e test prototipi schede di readout TRM2 in crate ALICE-TOF

### • **missioni**

- missioni per data taking/mobilità generale/responsabilità (basate su M&O-A, FTE e responsabilità come da tabelle/librone) - **155 k€**
- interventi tecnici per manutenzioni HV (1 persona per 2 settimane) + 2 persone per 1 settimana per manutenzione impianto raffreddamento crate elettronica ALICE-TOF (TOF VME crate cooling pipes) - **5 k€**
- missioni per sessioni di lavoro in sede CAEN - **2 k€**
- missioni per test beam ALICE3 (**23.5 k€**) e ITS3 (**3 k€**)

### • **apparati**

- richiesta per intervento di sostituzione capacitori per raggiunta fine-vita su 26 moduli CAEN A3000NF (**35 k€**) e sviluppo e produzione 100 schede TRM2 (**700 k€** s.j. alla produzione e test di 5 prototipi di TRM2 board in crate ALICE-TOF)

### • **inventario**

- ALICE3: materiale da test beam e laboratorio per misure accurate di timing e di caratterizzazione sensori - **41 k€**

### • **consumo**

- ALICE3: 2 cavi triassiali Keithley per picoamperometro - **1 k€**
- metabolismo da laboratorio - **3.5 k€**

### • **licenze software**

- 2 licenze Microchip (ex Microsemi) - **2.5 k€**
- 2 licenze Synopsys TCAD - **3.5 k€**



# BACKUP



ALICE



# Where we left off... DC/DC accident (1)

**Two critical hardware failures** in 2020/2021: burning of the internal Mosfet on the **Solid State Fuse** (which controls the power ON/OFF of the DC/DC channels with 48V input) installed on all TOF DC/DC converters during the refurbishment campaign 2018-2020.

First failure difficult to interpret because it occurred on a crate in which the DCDC temperature interlock was mistakenly disabled (it stayed at a temperature higher than 53°C for about 5 hours ). The second event triggered a severe warning...

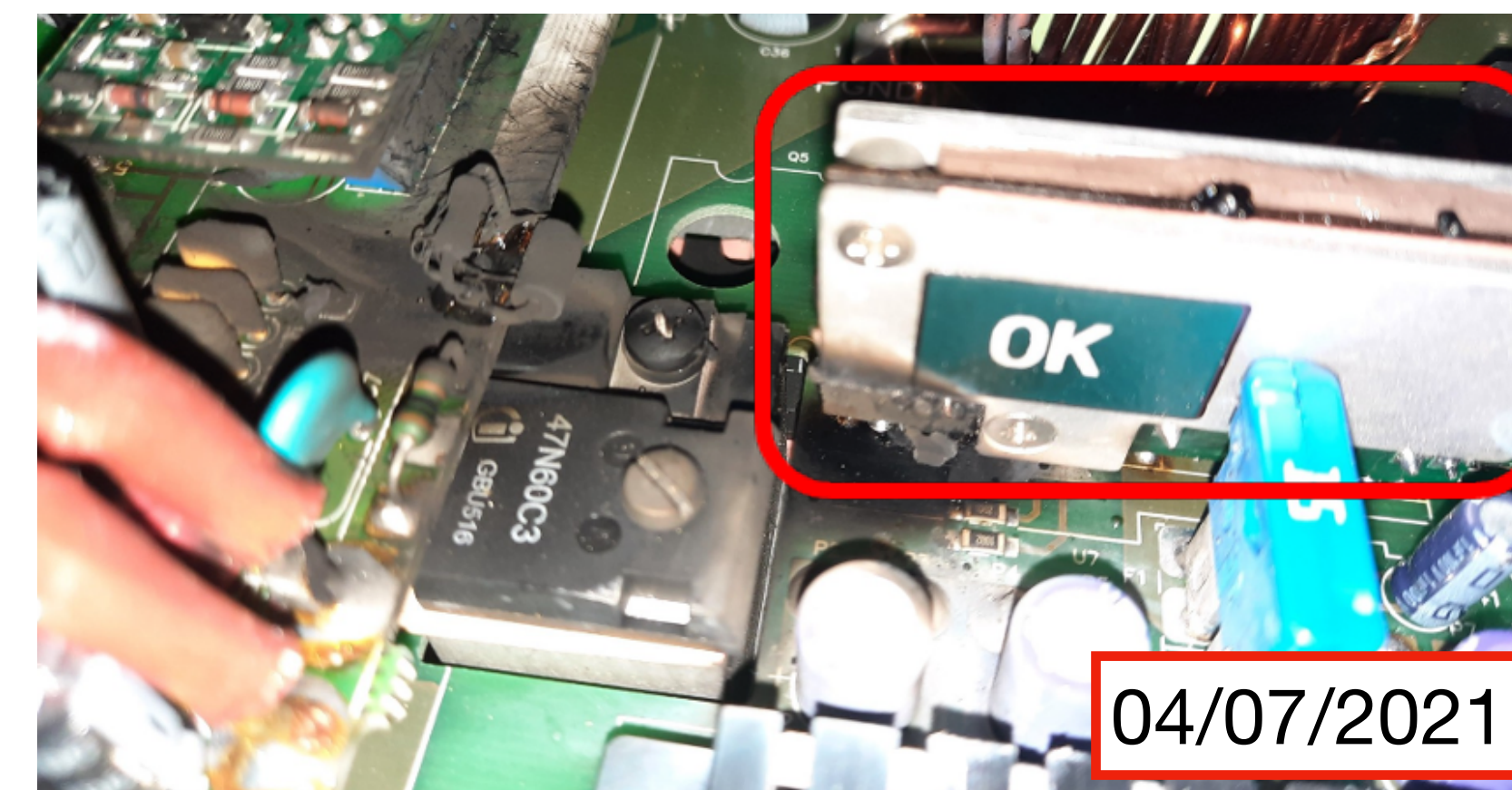
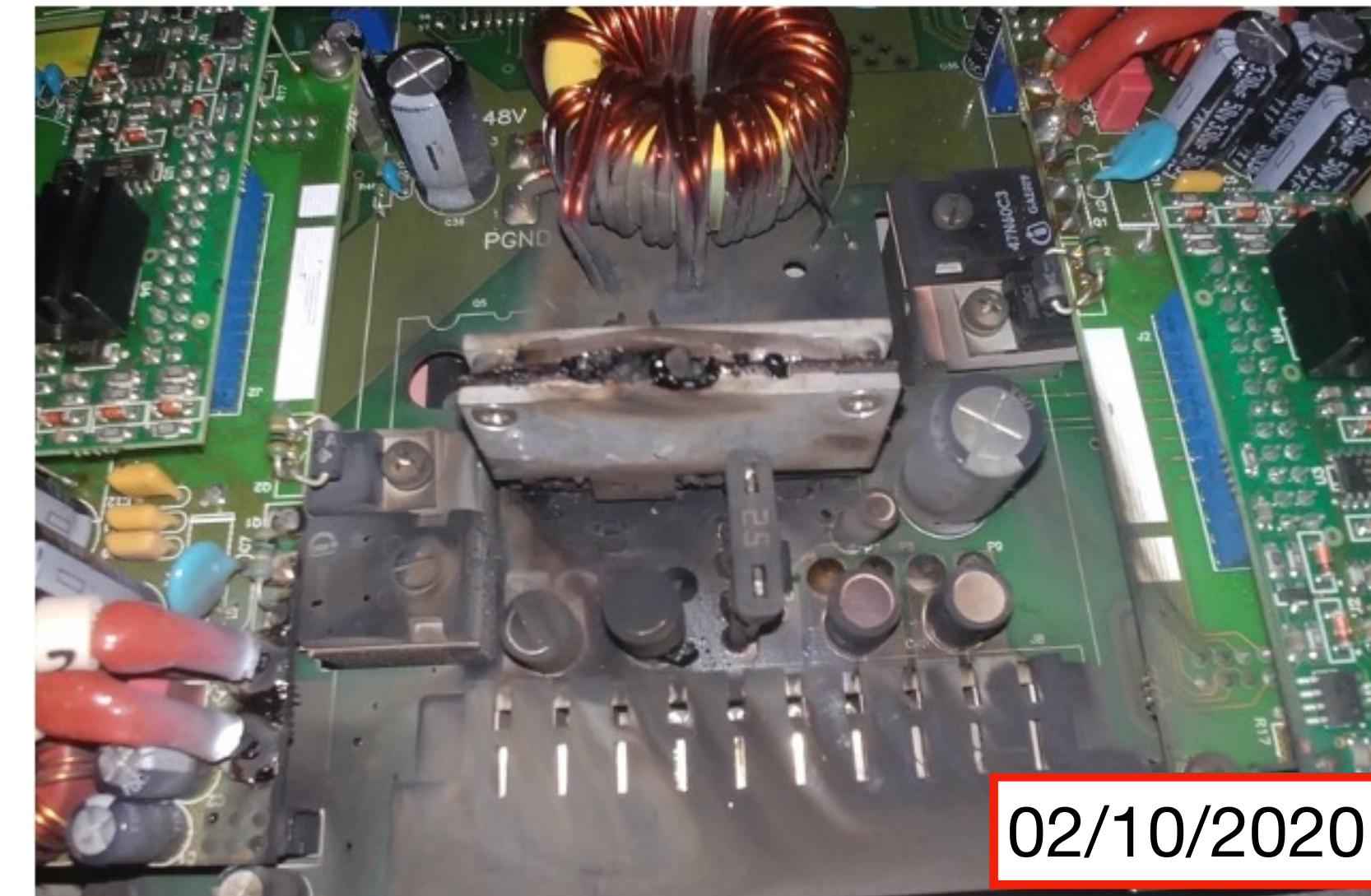
## Problem:

At power-up the circuitry is very quick (1 ms) and capacitive load of the line is high (4 mF) → high transient current! It was found CAEN validated the scheme with a 48V Power Supply power limited (600W). This unrealistic test setup "protected" the circuitry. But ALICE-TOF Power Supply have 4kW power.....

**Short-term mitigation approach:** shutdown of 64/72 TOF crates, 8 crates operated half-power

**Tested solution:** removal of the component (control with 2 ext. Mosfet) + 47 uA capacitor to reduce peak and slow ramp-up.

**Rework completed between end of 2021 and beginning of 2022.**

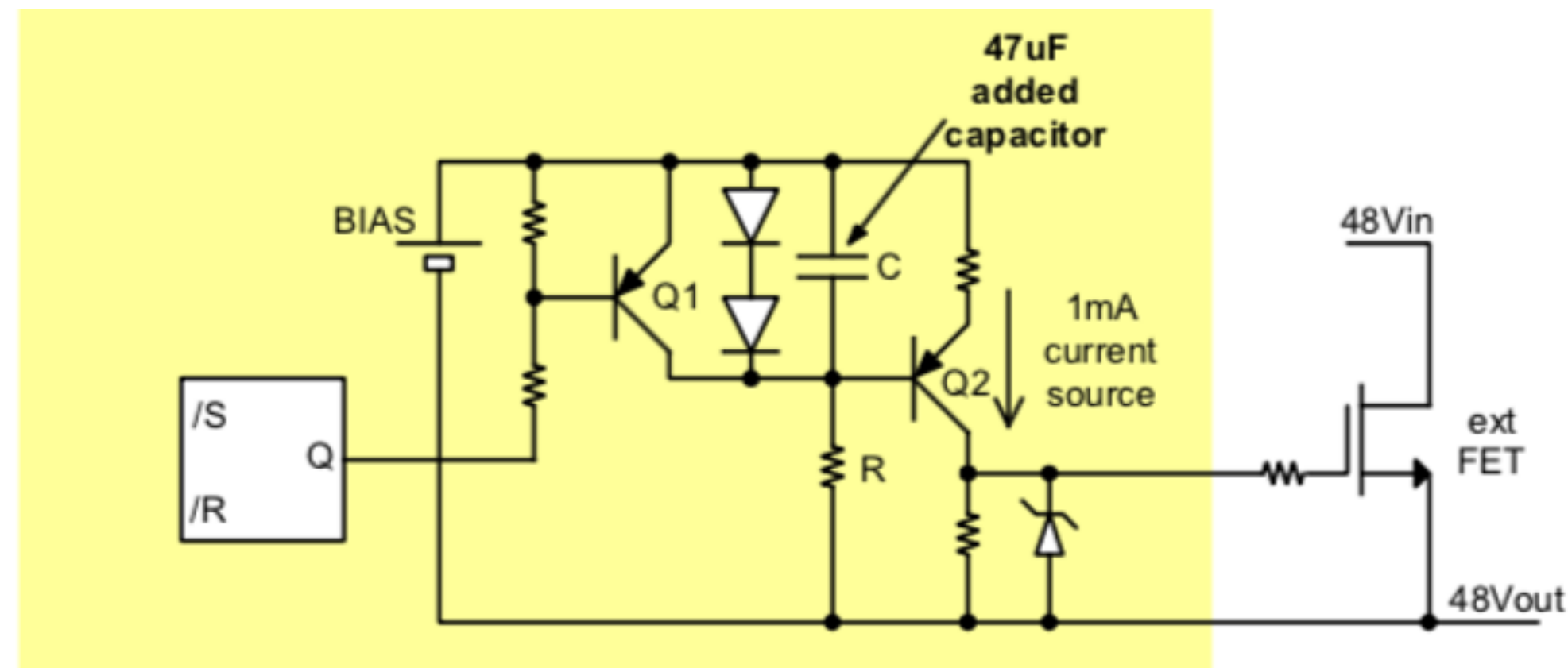
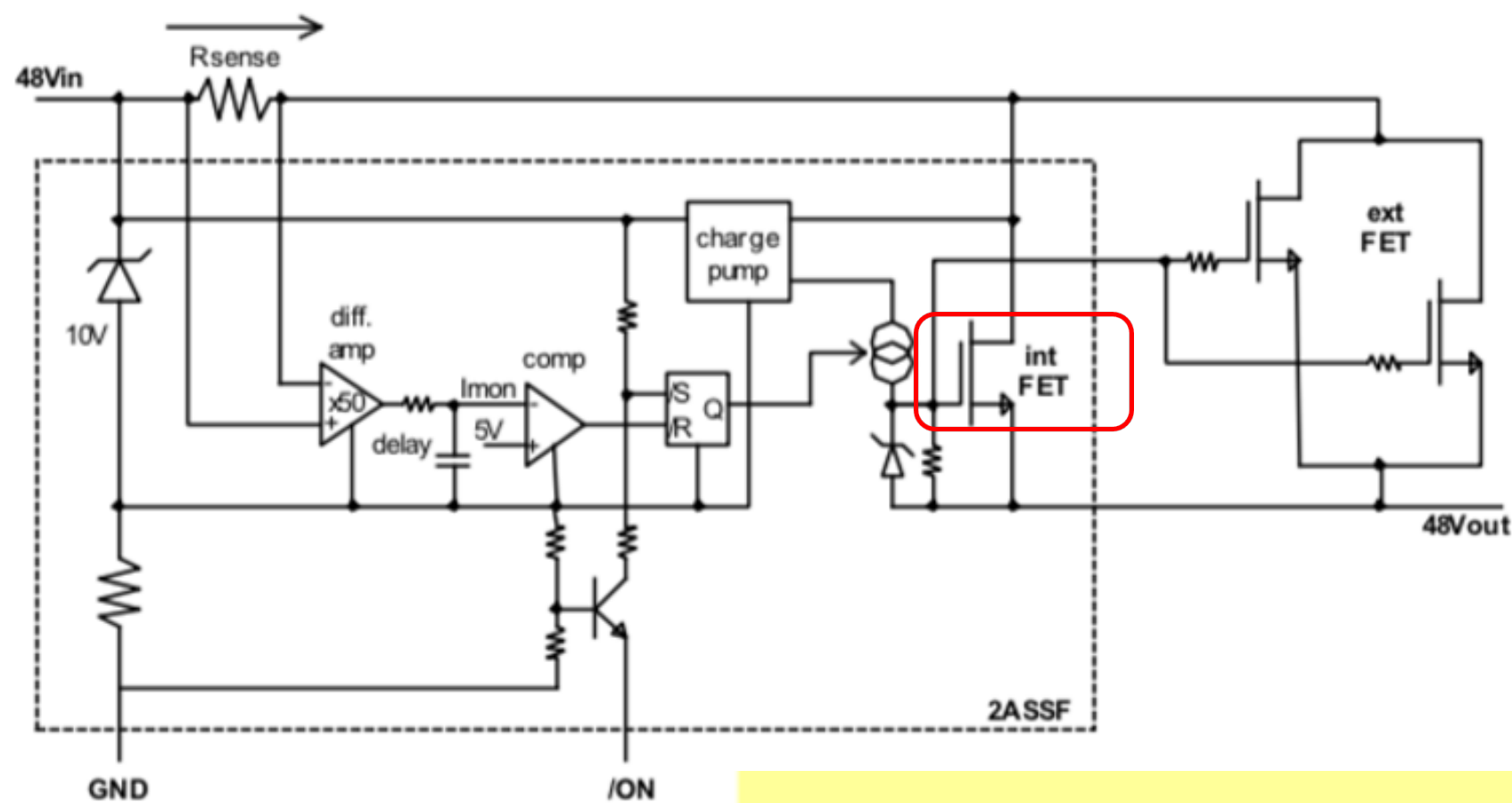




# DC/DC accident (2)

**Tested solution:** removal of the component (control with 2 ext. Mosfet) + 47 uA capacitor to reduce peak and slow ramp-up.

**Rework completed between end of 2021 and beginning of 2022.**



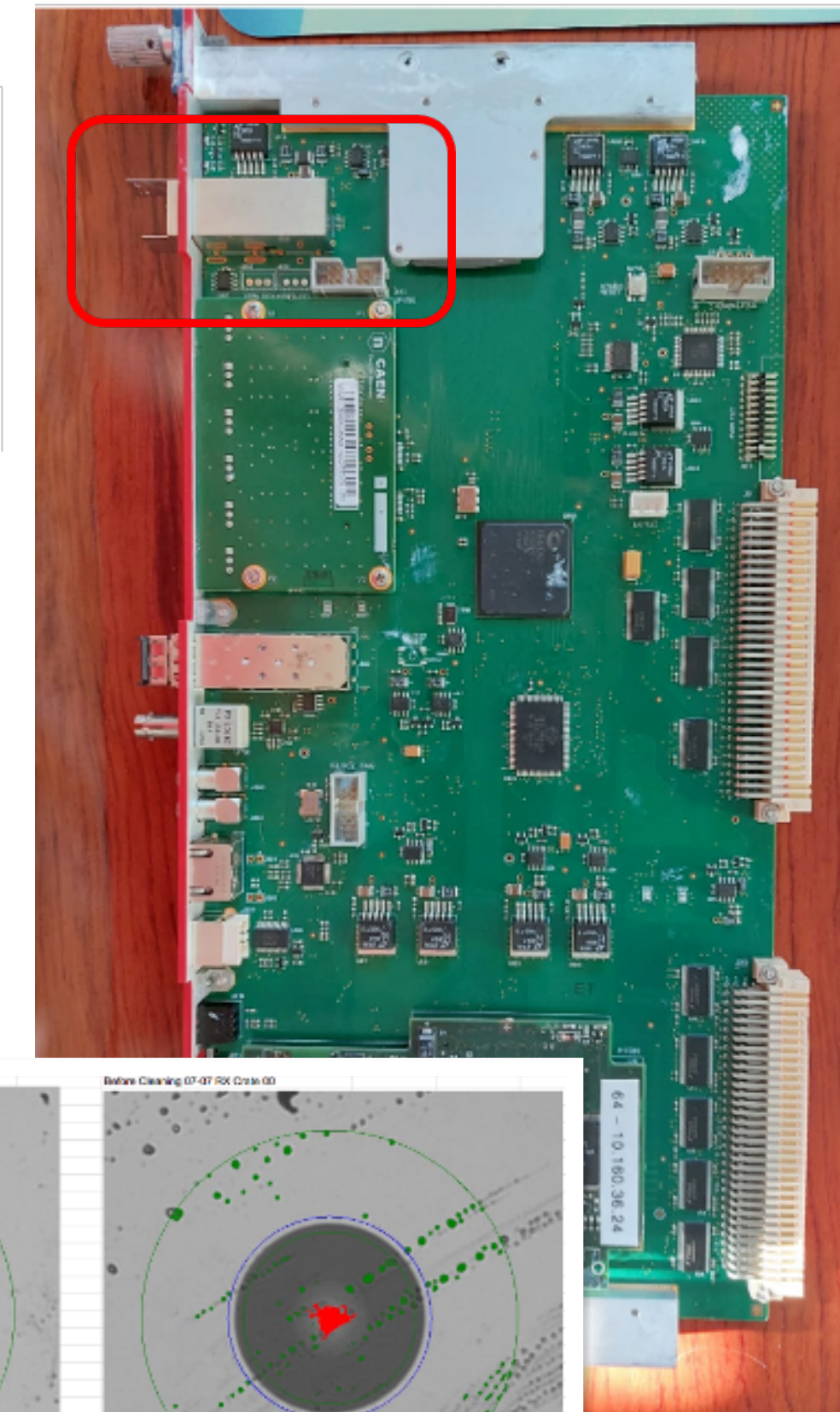
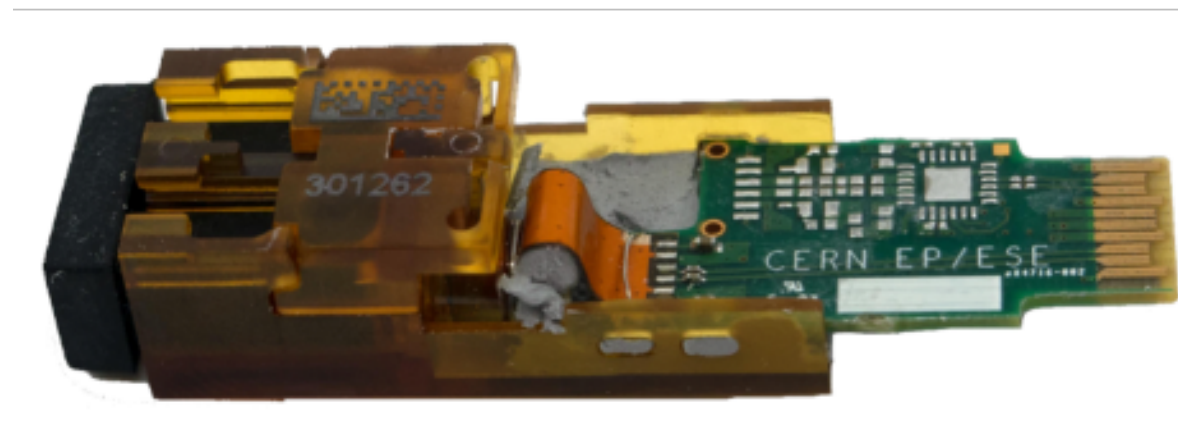
Intervento effettuato da tecnici CAEN nella settimana 22-26/11/2021 direttamente al sito ALICE P2, **nessun costo per INFN** a parte quello per missioni personale per rimuovere e reinstallare **216 DCDC converters** → **problema risolto!**



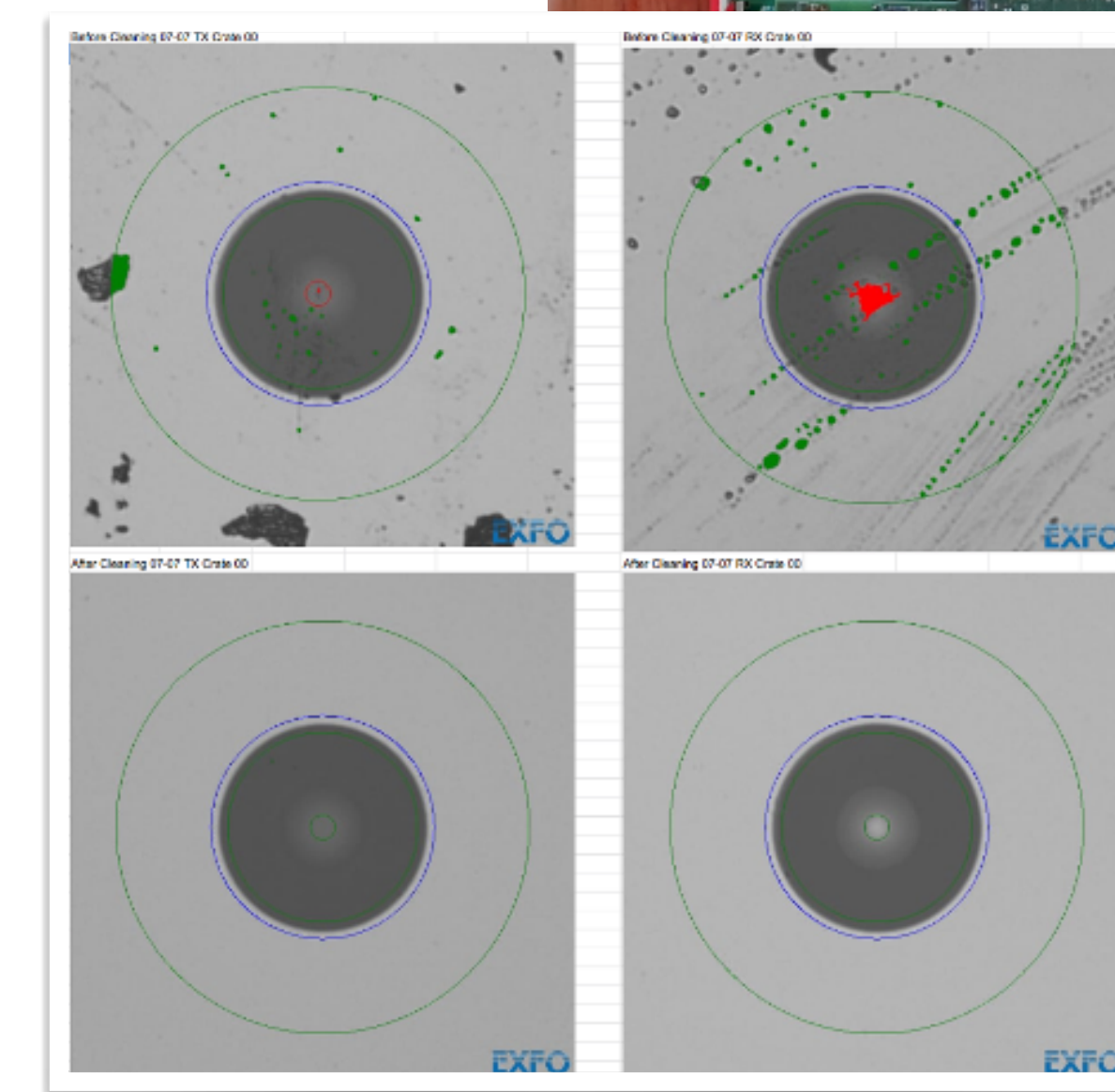
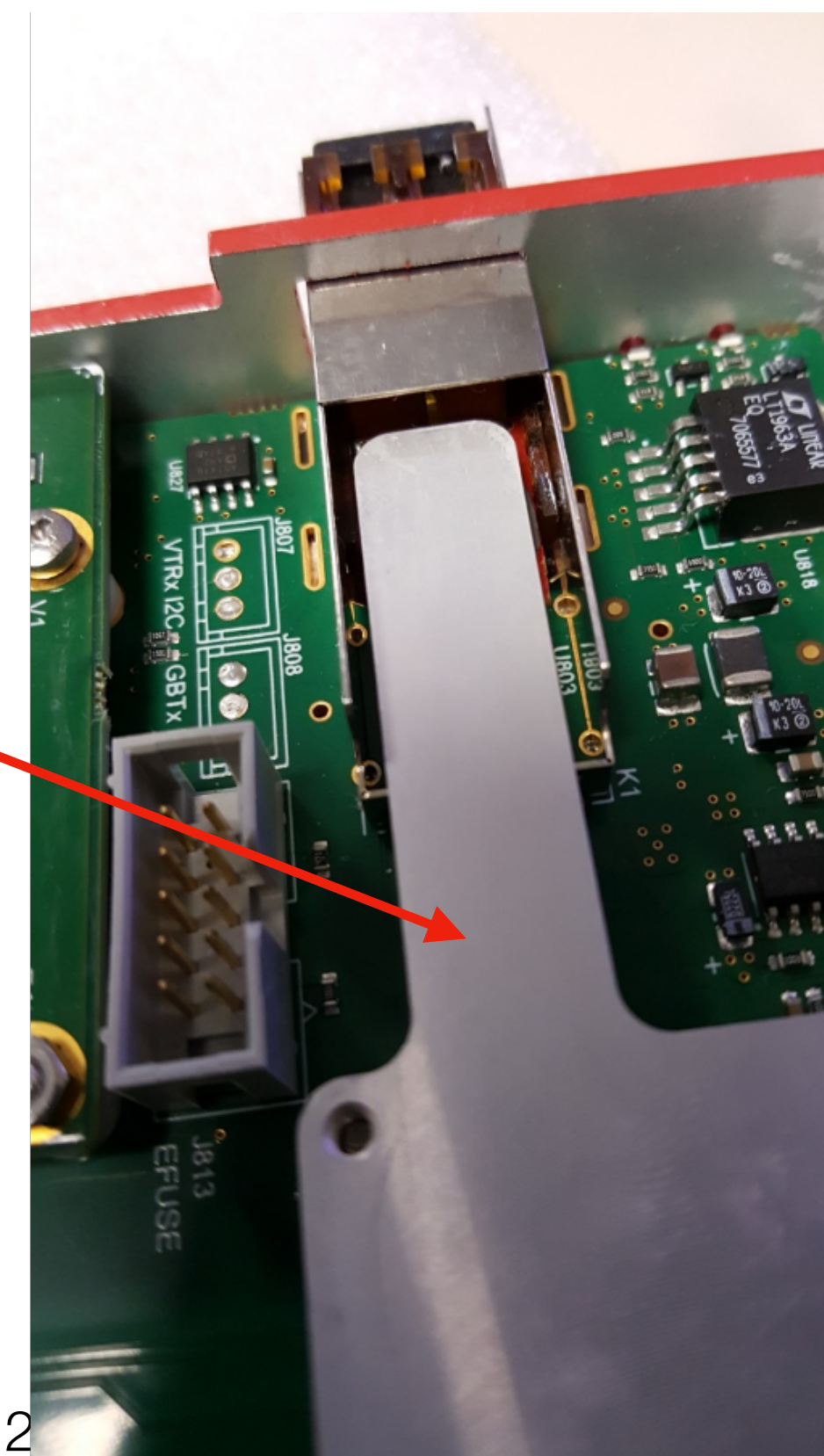
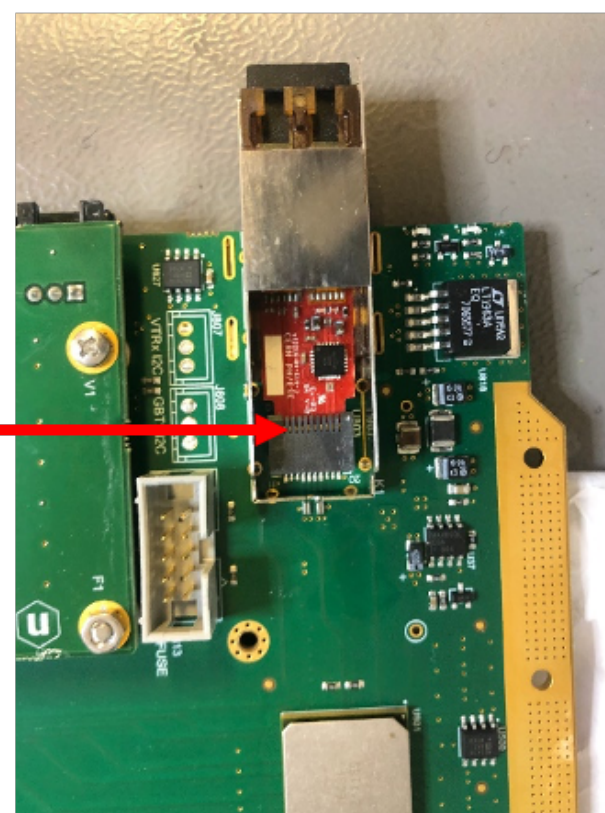
# VTRx and DRM2 enhanced cooling (1)

- perdita di connessione a causa di outgassing di alcuni componenti dello schedino VTRx
- tutti i 72 schedini sono stati rimossi in Agosto 2021, “baked” e reinstallati sul TOF → **nessun link lost so far!** → dal nostro punto di vista **problem solved**
- ALICE aveva chiesto di investigare la possibilità di potenziare il cooling dello schedino VTRx, soluzione studiata insieme a CAEN (grosso svantaggio: la soluzione proposta rende impossibile l'estrazione dello schedino dalla board DRM2)

VTRx

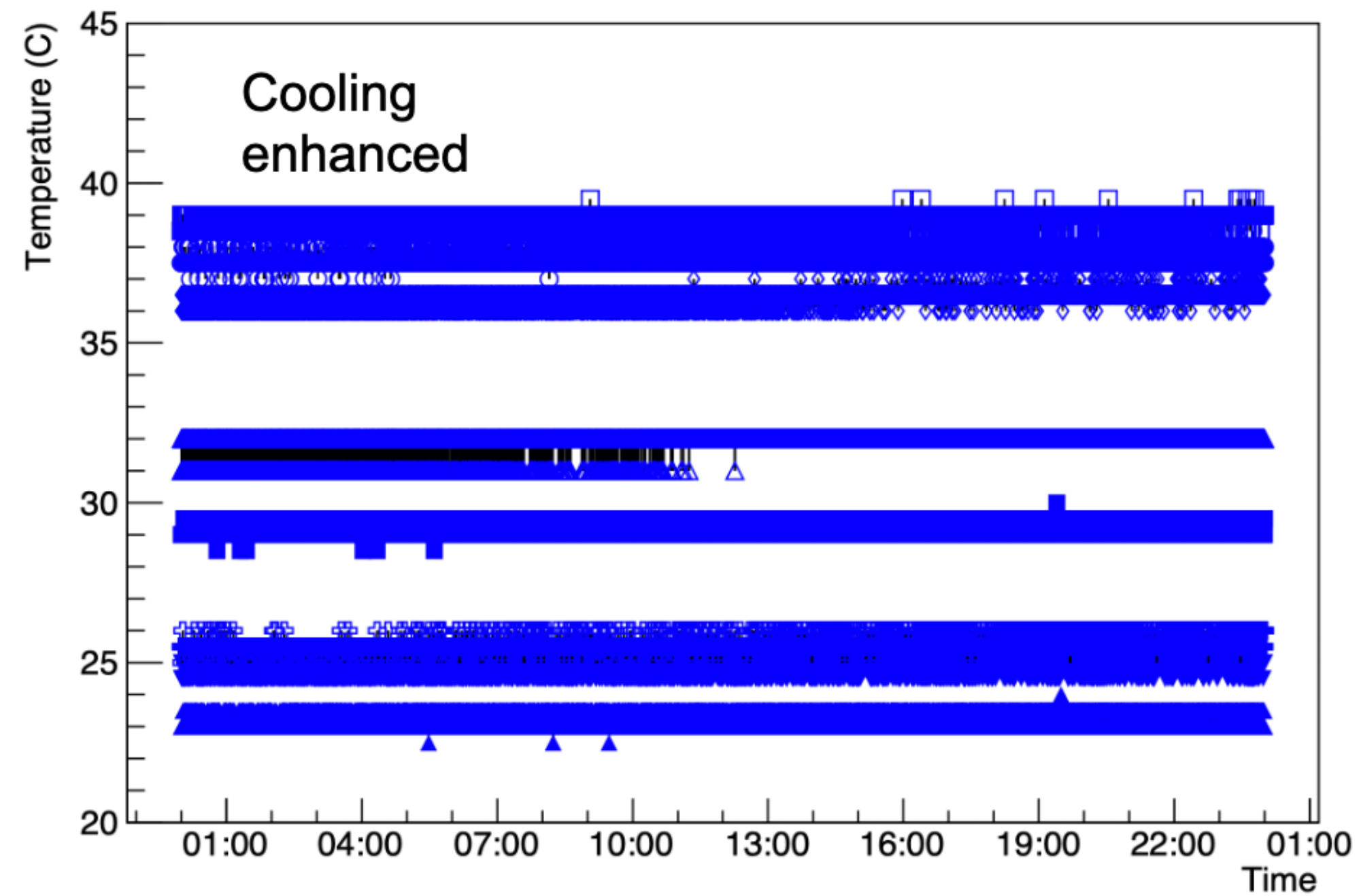
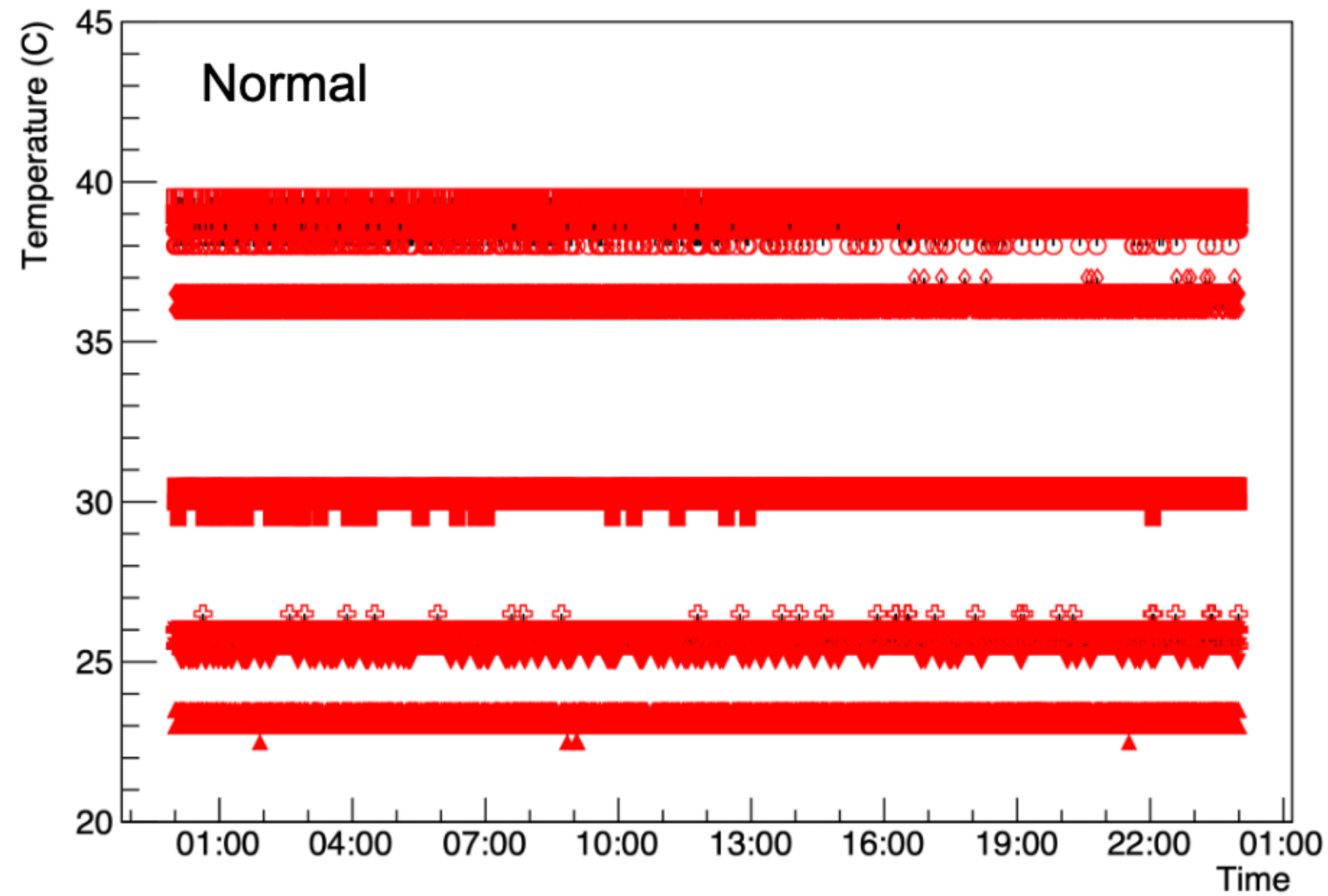


Enhanced Cooling (CE) heatsink

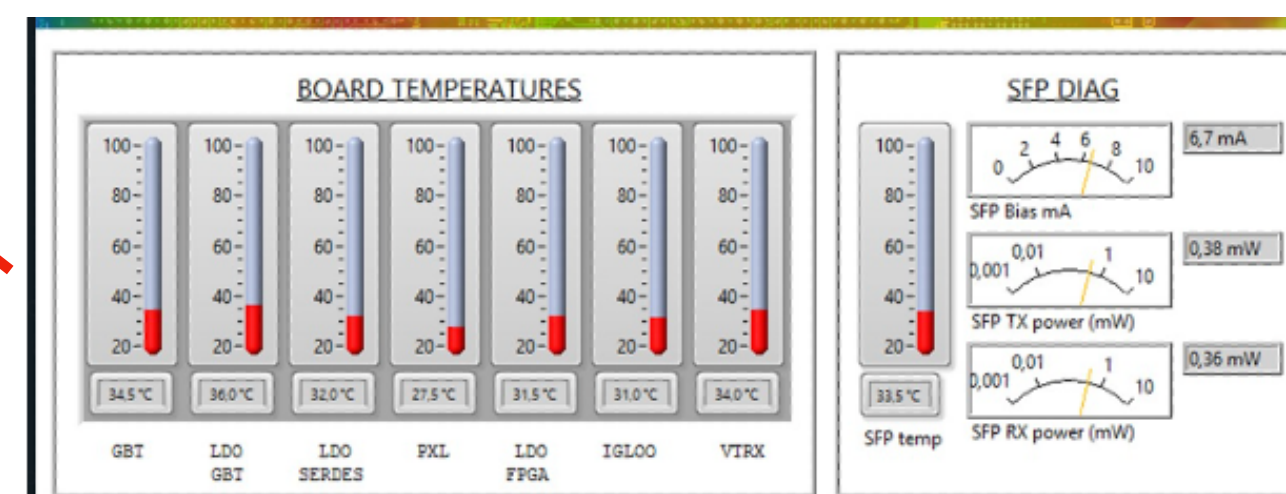
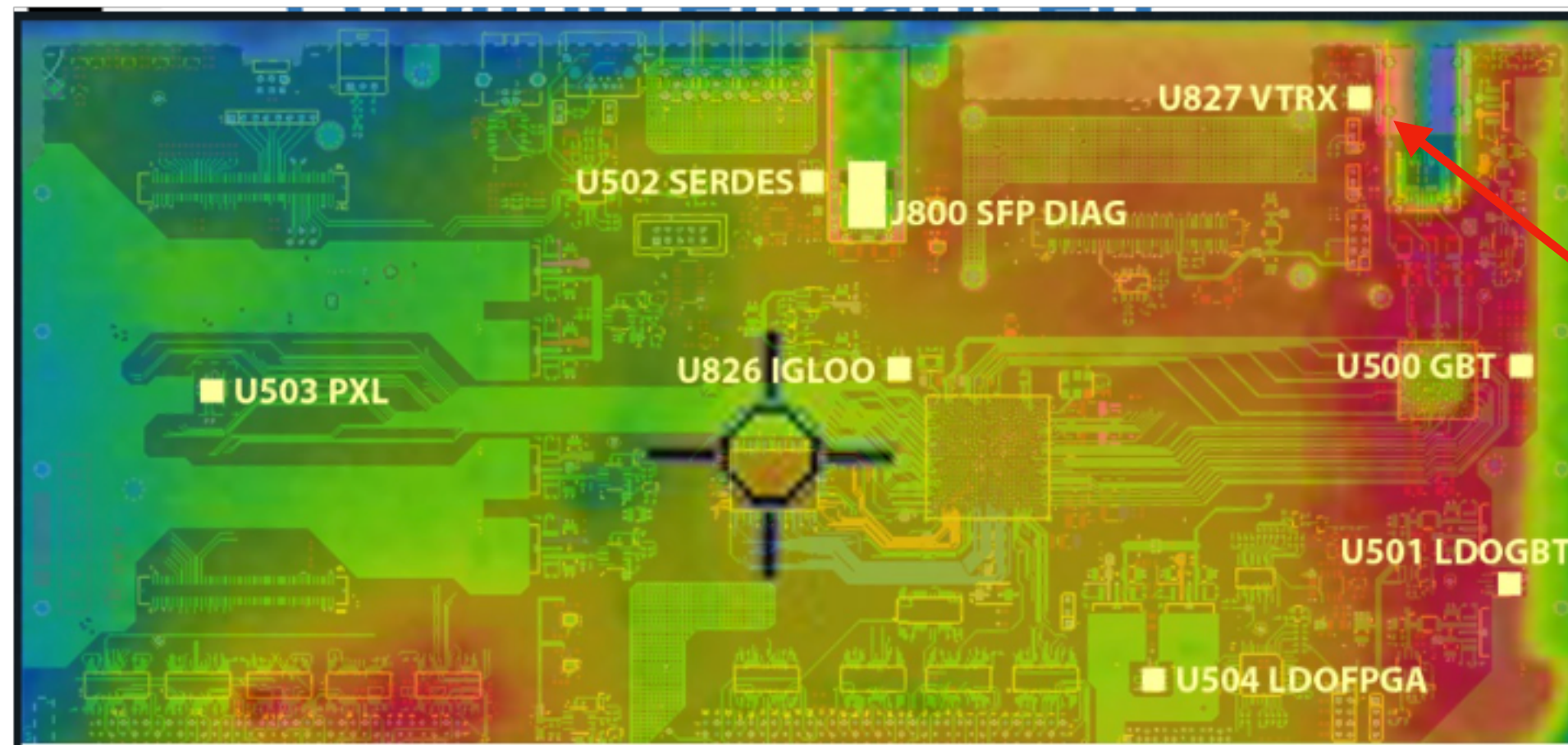




# VTRx and DRM2 enhanced cooling (2)

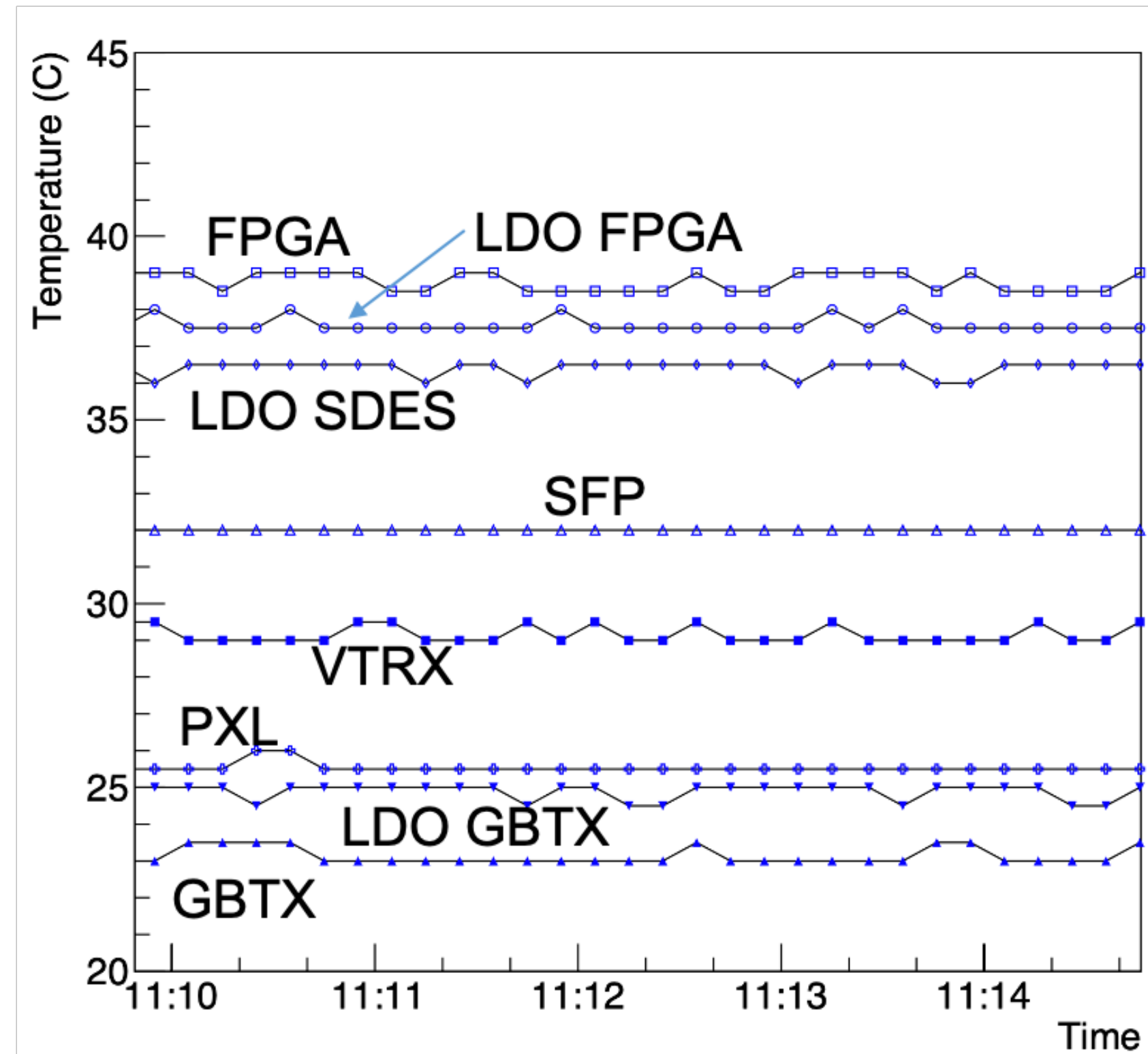
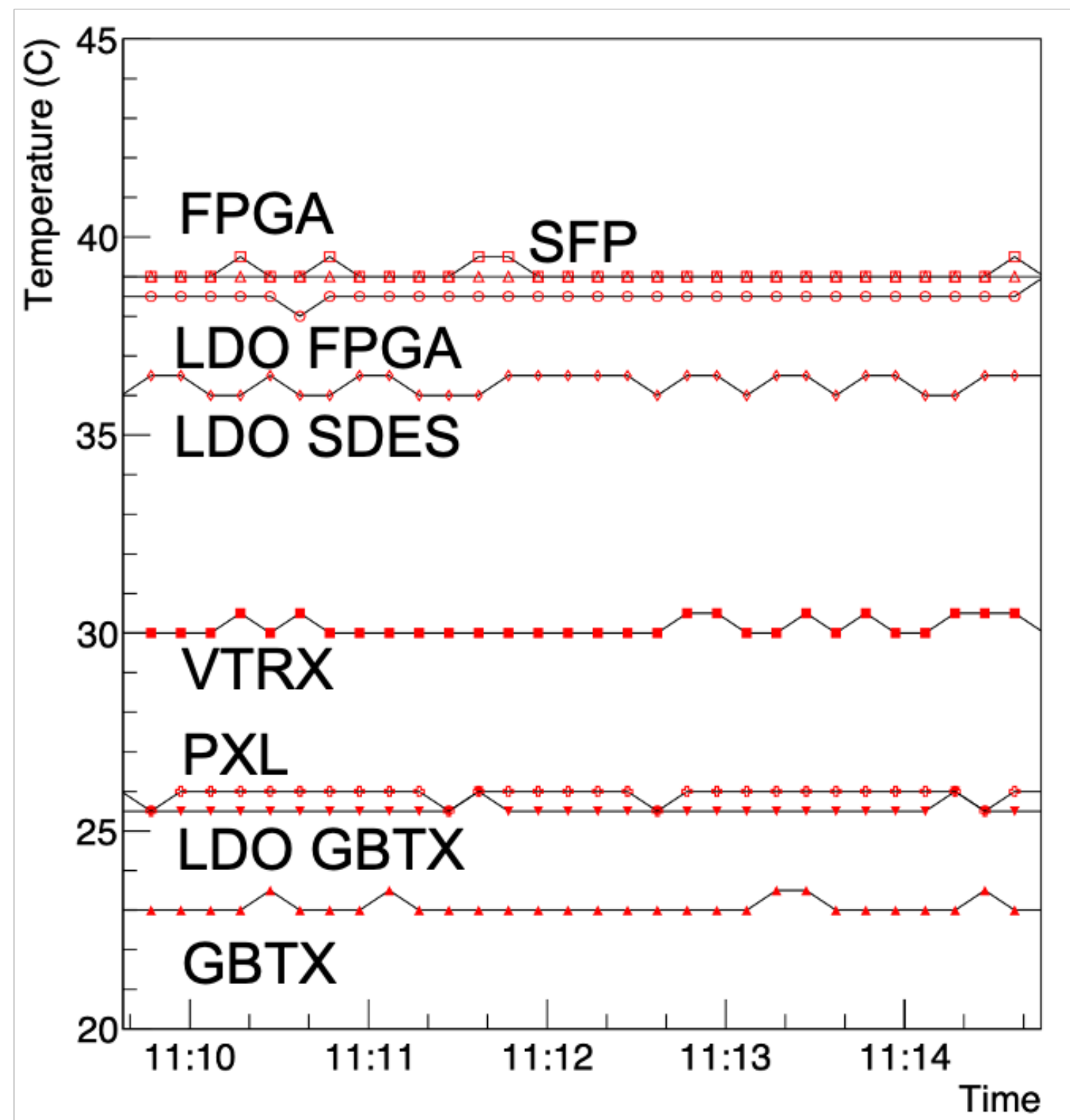


- Heatsink arrived 03/02/2022 in Bologna
- Crate in Bologna, with cooling circulating (15° C) + full power + DAQ running
- T sensors read every 10 seconds for one day
- VTRx sensor is the one important!





# VTRx and DRM2 enhanced cooling (3)



- the enhanced cooling solution moderately improved cooling in VTRx area. Further tuning and optimization remains possible
- if we install CE solution we loose the possibility to replace on the spot the VTRx without extracting the card
- engineering cost of CE was **6 KEU (nessuna richiesta extra a INFN)**, for all cards would be **20 KEU** + 2/3 months effort and mission costs for personnel at CERN (**non faremo richieste straordinarie per questo item nel 2022**)

## Decision:

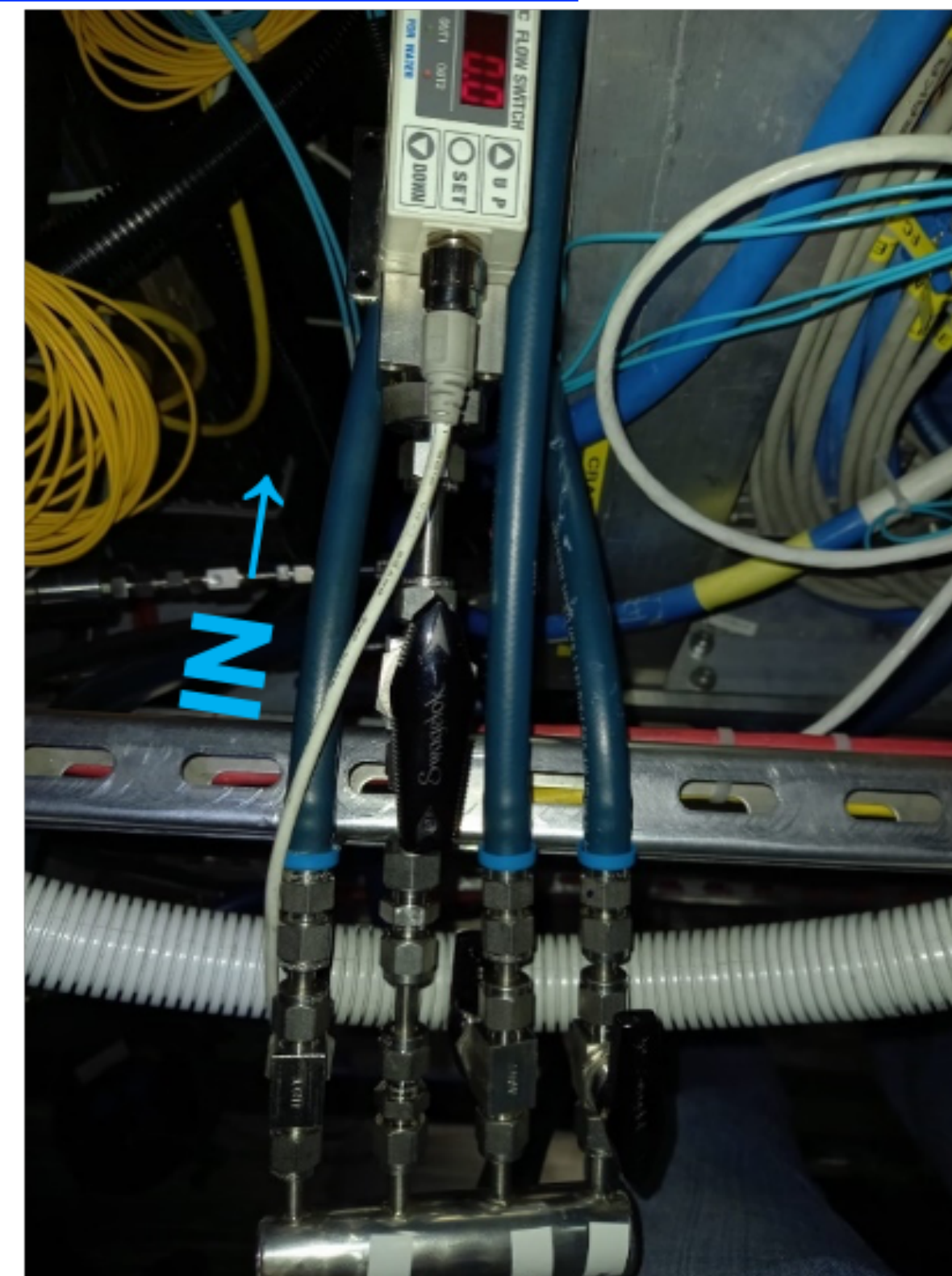
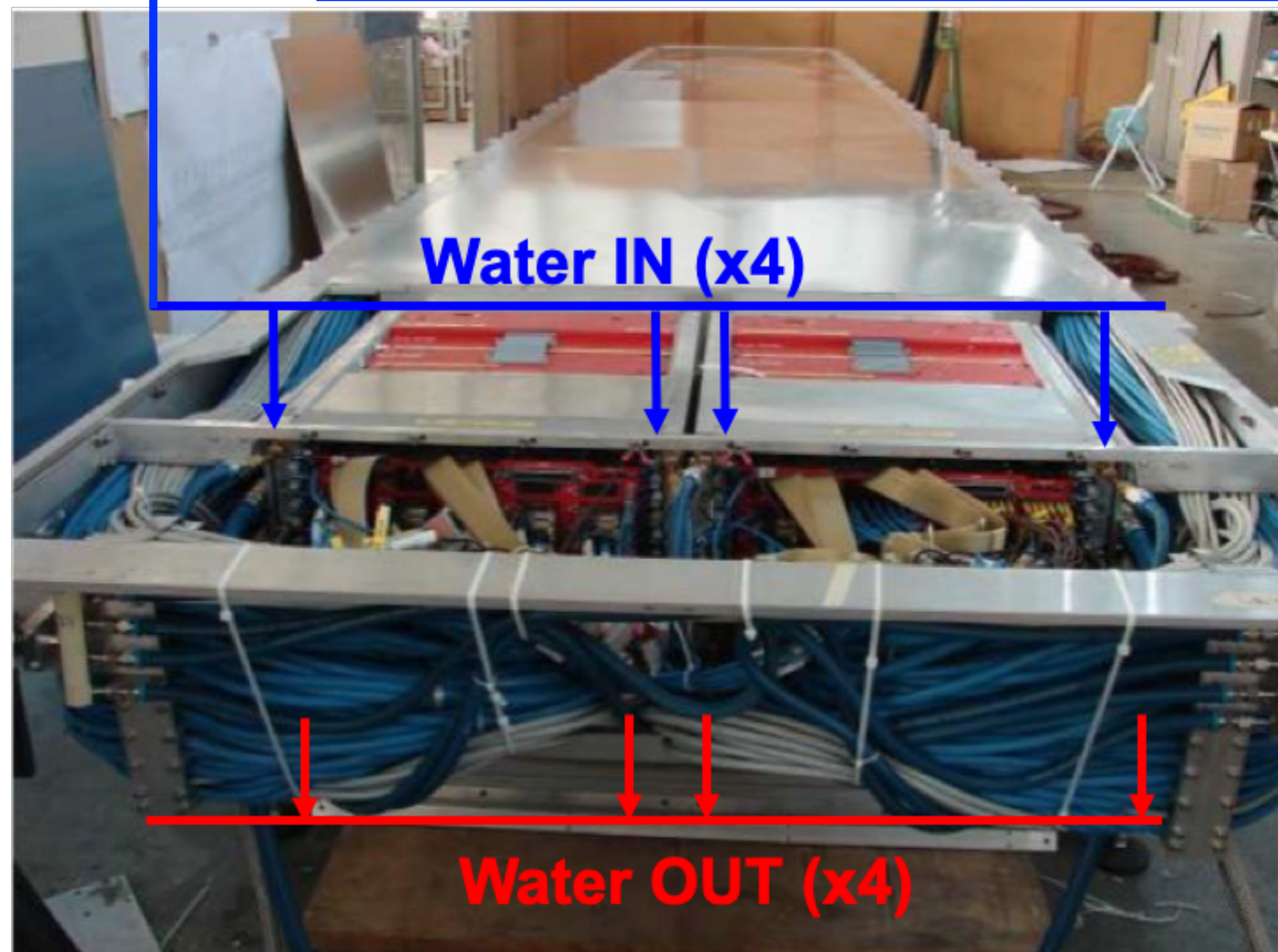
- TOF won't order and won't install additional heatsinks for VTRx
- some sample of monitoring of fibers will happen during YETS
- monitoring of situation will continue and this decision might be eventually revised in June 2023



# TOF VME crate cooling issue (3)

- Several attempts to fix the problem in the past (included industrial acid usage) didn't solve the problem
- New attempt in January with the installation of **valves + flowmeter** to (try to) balance the water pressure on the 4 parallel lines (forcing the water circulation in the clogged line)

- ogni linea in ingresso in un settore (SM) viene divisa in **4 linee parallele** (due scambiatori di calore per crate VME)
- ogni settore in parallelo con **altri 5 settori**

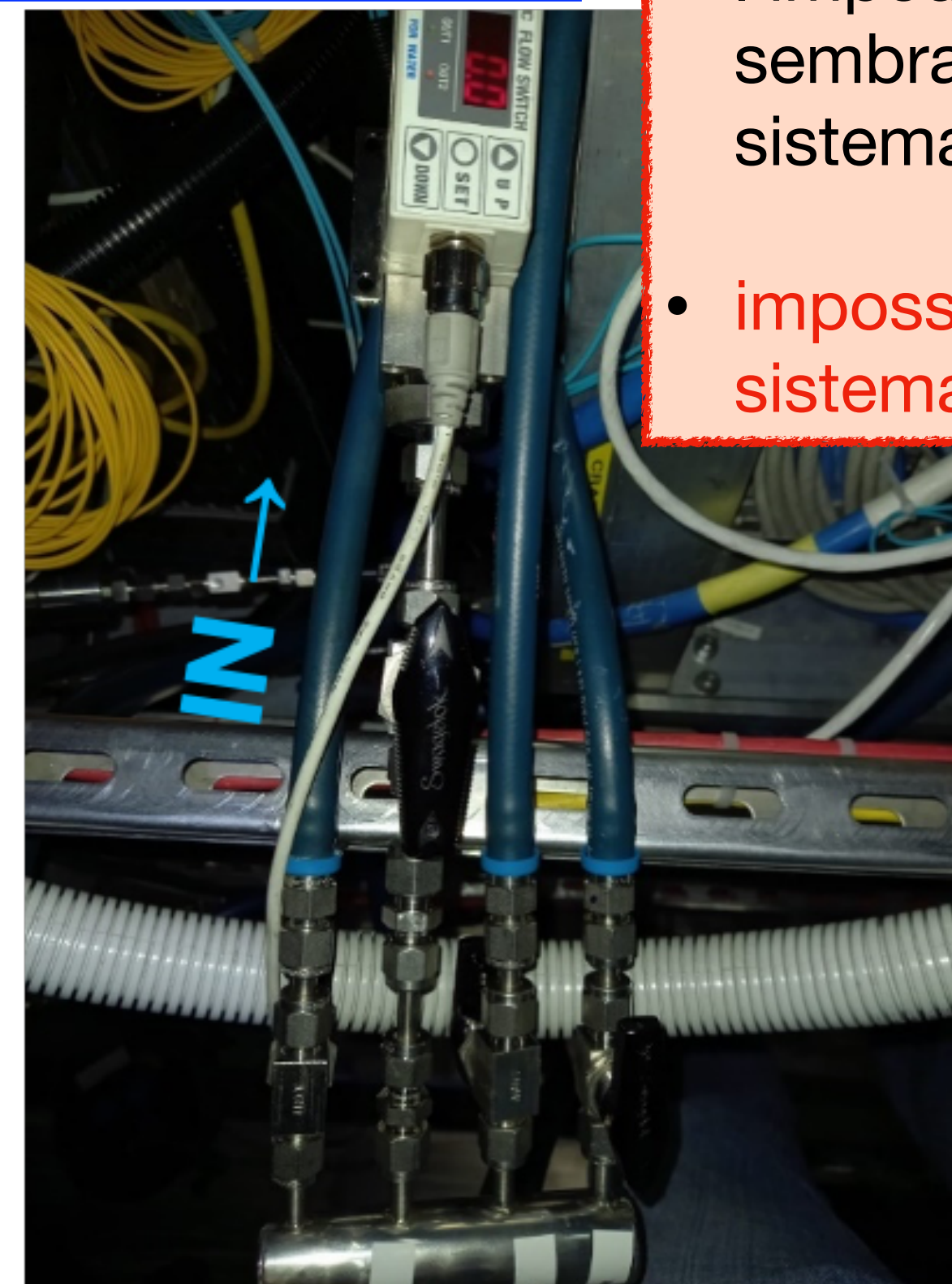
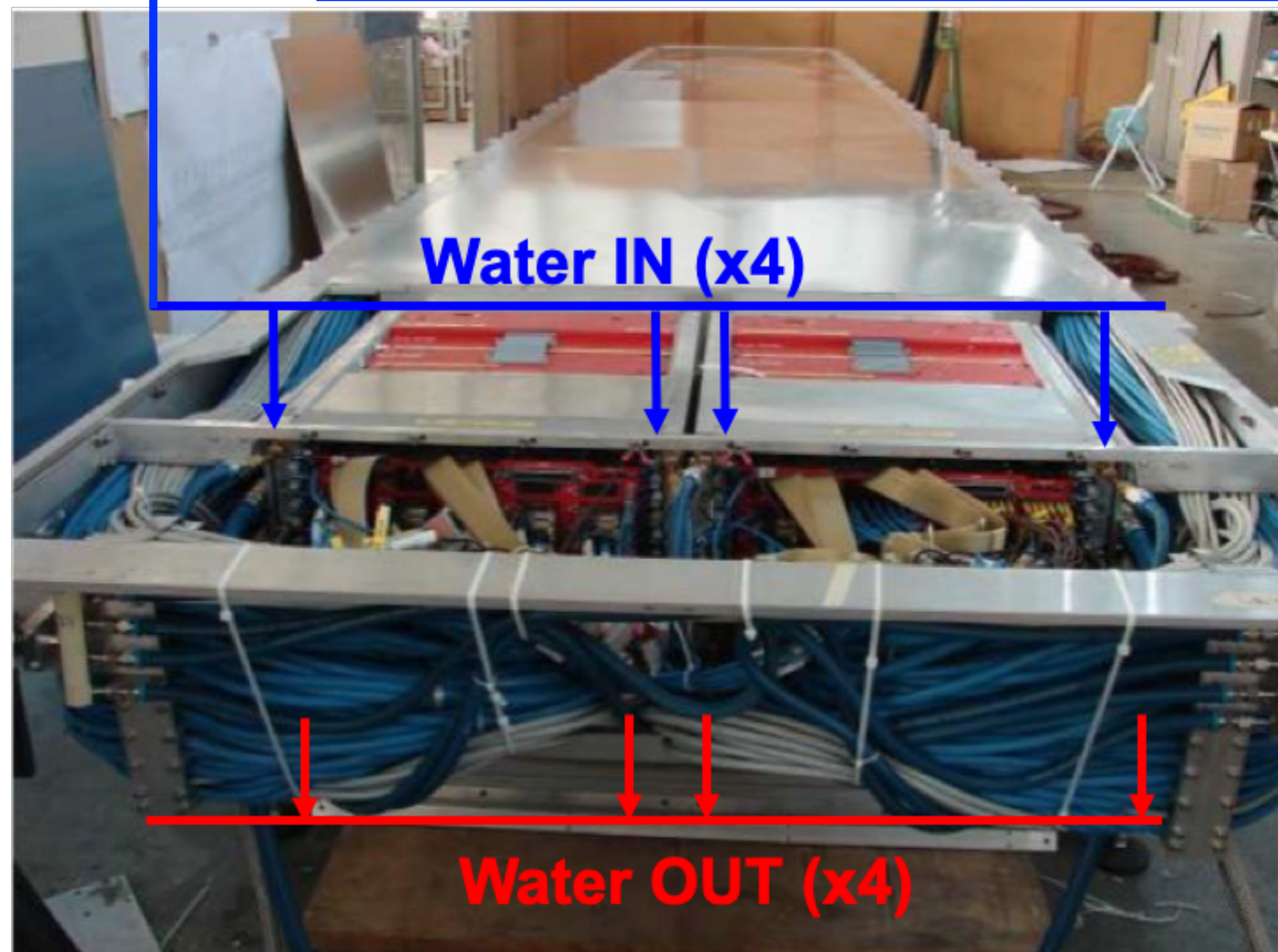




# TOF VME crate cooling issue (4)

- Several attempts to fix the problem in the past (included industrial acid usage) didn't solve the problem
- New attempt in January with the installation of **valves + flowmeter** to (try to) balance the water pressure on the 4 parallel lines (forcing the water circulation in the clogged line)

- ogni linea in ingresso in un settore (SM) viene divisa in **4 linee parallele** (due scambiatori di calore per crate VME)
- ogni settore in parallelo con **altri 5 settori**



- Anche chiudendo tutte le altre linee e portando il flusso al massimo consentito non siamo riusciti a far circolare acqua nello scambiatore intasato
- l'impedenza dello scambiatore di calore sembra dominare l'impedenza totale del sistema
- impossibile risolvere il problema agendo sul sistema esternamente al crate



# TOF VME crate cooling issue (5)

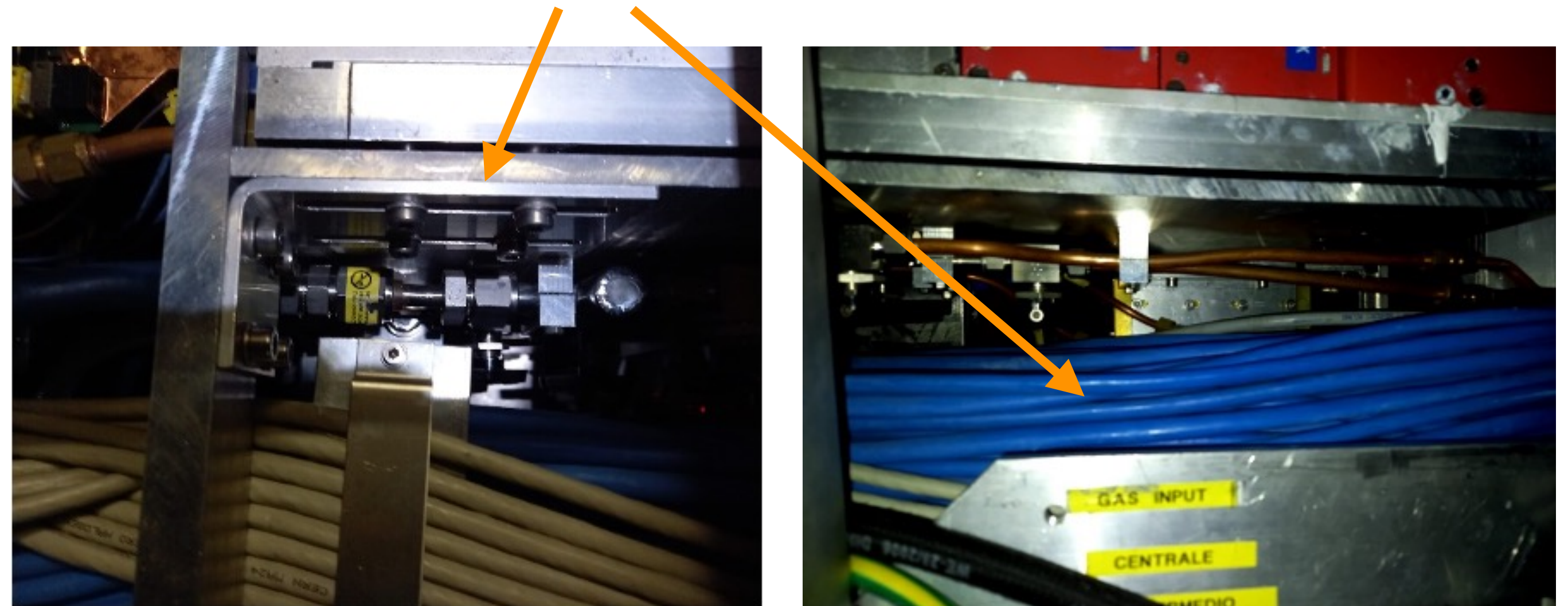
## Next steps:

- reintroduce a anti-corrosion inhibitor as a matter of priority
- invasive intervention during the next YETS:
  - option A: uninstall (replace) the cooling plates (heat exchangers) —> many mechanical interferences, surveys indicated that likely this solution is not feasible...
  - option B: free the heat exchangers from springs and deposits with a kind of tunnel digger —> many technical issues (lack of space, **rimozione dei detriti...** )
  - option C: new cooling plates on top (in close attach) to the clogged ones —> lack of space...

Side IN: only 14 mm between the two cooling plates



Side OUT: gas and FEA cooling valves, HV distribution boxes, signal cables... we need to dismount all to uninstall the plates...





# TOF Active Channel Map

Sources of inefficiency:

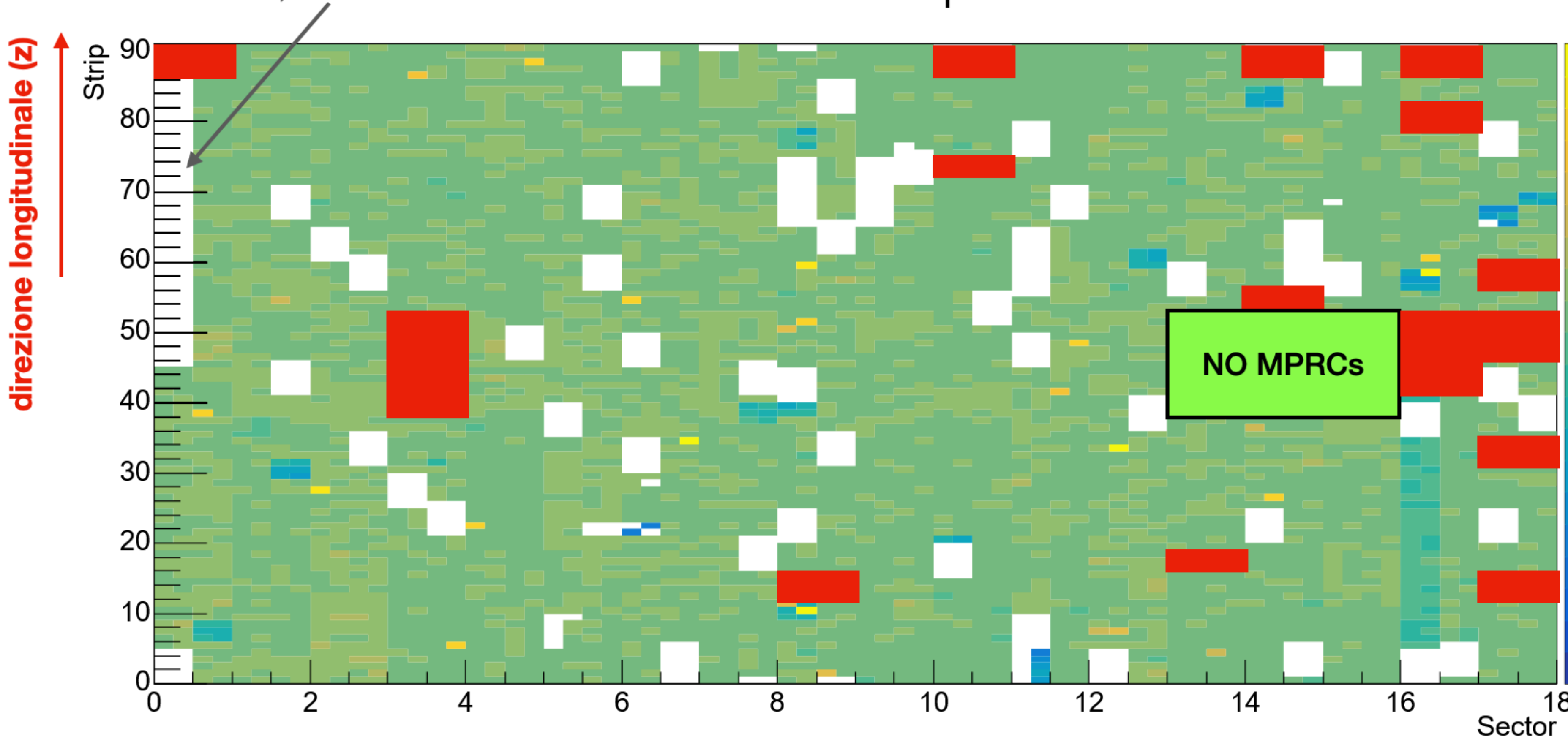
**HV: 4.5%**

**TRM: 8.5%**

**DCDC: 1.4%**

Crate 03, 48VPwS in FAIL

TOF hit map



**18 settori**

## Bring home messages

Dopo **14 anni** dall'accensione del rivelatore TOF:

- **nessun canale è stato spento per malfunzionamenti di un rivelatore MRPC**
- **nessun segno evidente di ageing delle MRPC: dark current totale per oltre 1500 MRPCs ~ 2 uA**
- I canali spenti per problemi HV (canali rossi nella mappa a fianco) **non sono recuperabili...** se vogliamo mantenere il livello di accettazione ~ 90% dobbiamo necessariamente intervenire sulle **schede TRM** (oltre che sui singoli DCDC converter)





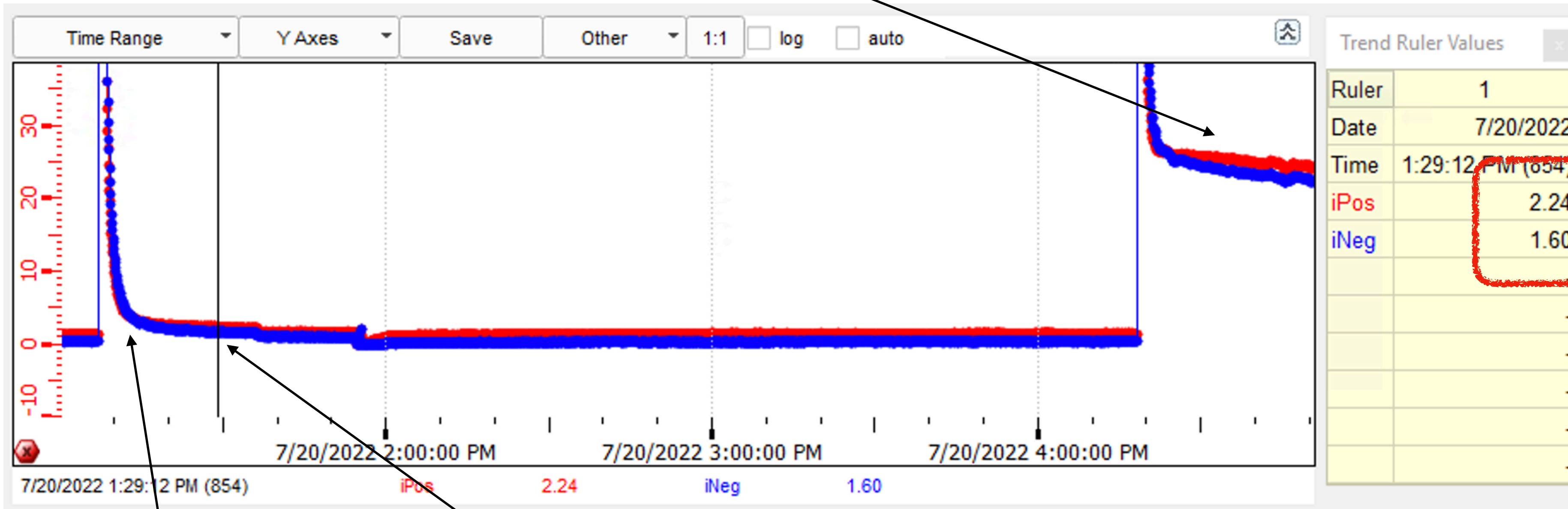
# TOF Dark Current

corrente TOF con collisioni

## Bring home messages

Dopo **14 anni** dall'accensione del rivelatore TOF:

- **nessun canale è stato spento per malfunzionamenti di un rivelatore MRPC**
- **nessun segno evidente di ageing delle MRPC: dark current totale per oltre 1500 MRPCs ~ 2 uA**



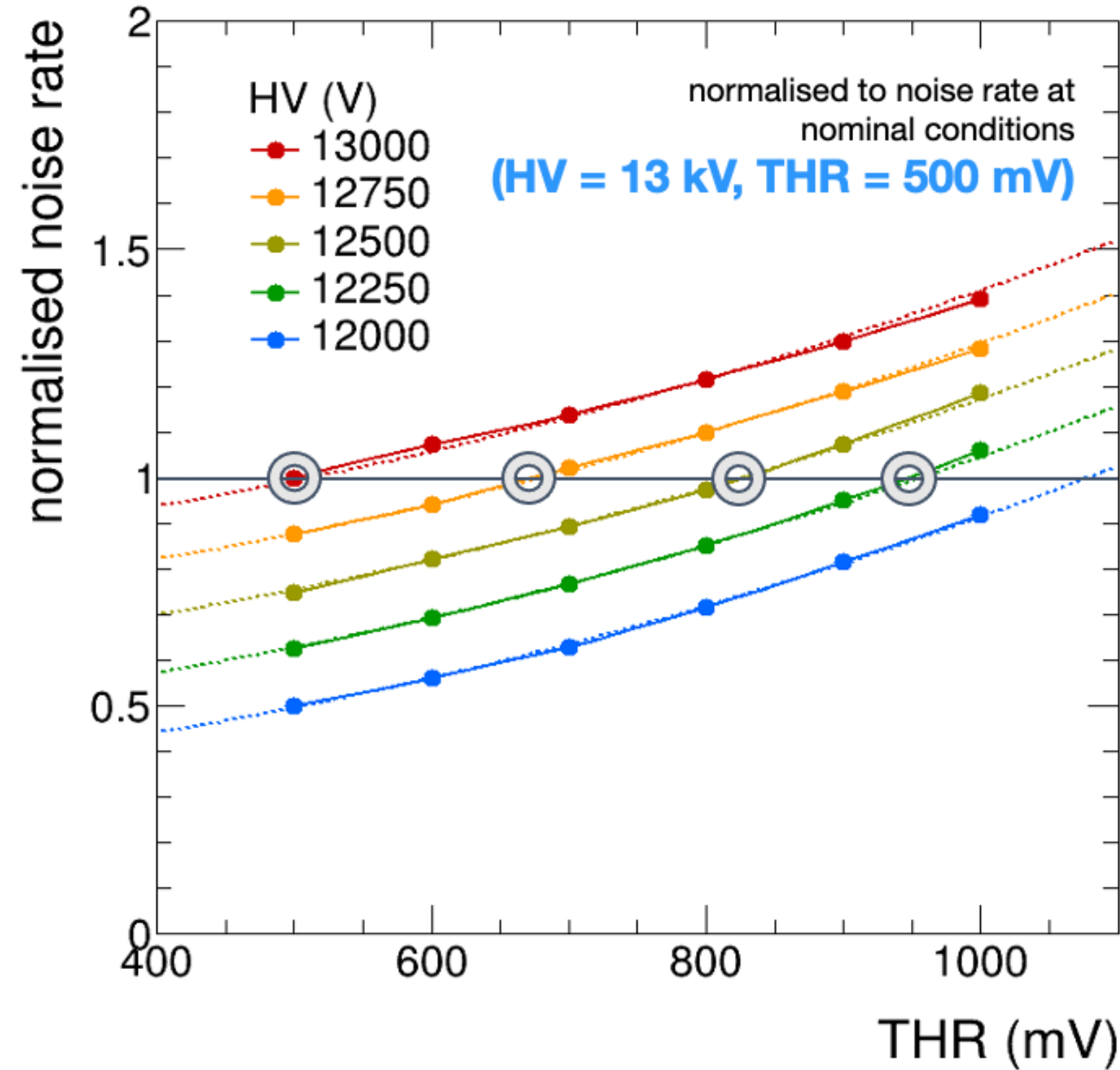
MRPC ramp-up

dark current (MRPC ON a tensione nominale - no beam)

- corrente "positiva": 2.24 uA
- corrente "negativa": 1.6 uA



# HV scan con pilot beam (1)



- Goal: trovare un nuovo punto di lavoro che permetta di avere la stessa efficienza applicando una tensione minore alle MRPC (per ridurre stress sui connettori HV)
- noise scan (no efficiency!) fatto nel 2018 per individuare condizioni di noise costante a diversi valori di tensione

- Efficiency studies vs HV and threshold repeated during 2021 Pilot Beam
- count the number of track with hit in the TPC and in (TPC+TOF)
- the lower side of the TOF is used for the measurements while the upper side is used as candle

### Standard Conf.:

- HV = 13000 V
- Threshold 500 mV

Upper side:  
**(TOF+TPC)/TPC: 0.319**

Lower side:  
**(TOF+TPC)/TPC: 0.316**

Reference Ratio (up/low):  
Upper/lower = **1.009 (3)**

### Conf. 3:

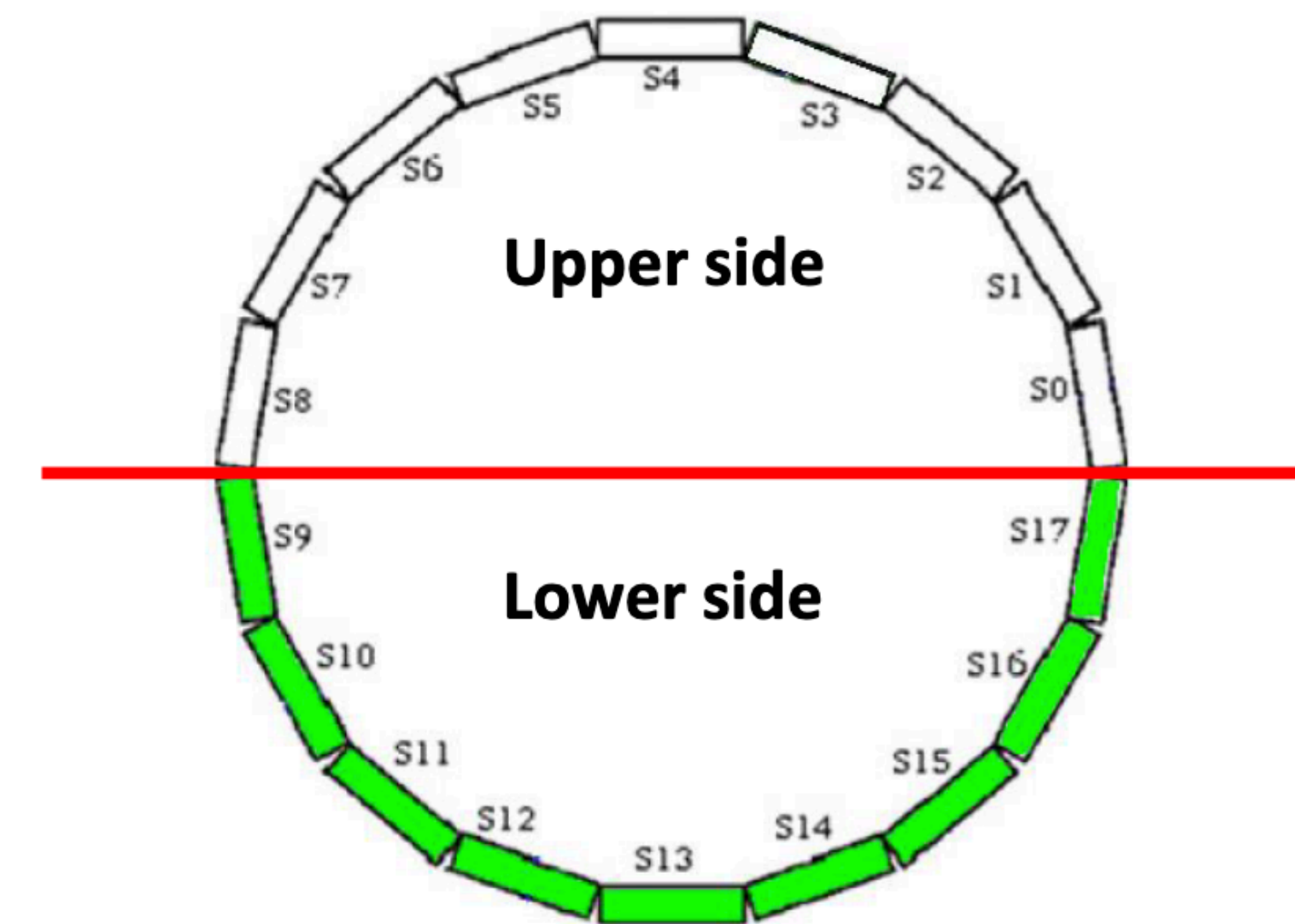
- HV = 12500 V
- Threshold 950 mV

Upper side:  
**(TOF+TPC)/TPC: 0.338**

Lower side:  
**(TOF+TPC)/TPC: 0.334**

Ratio (up/low):  
Upper/lower = **1.012 (3)**

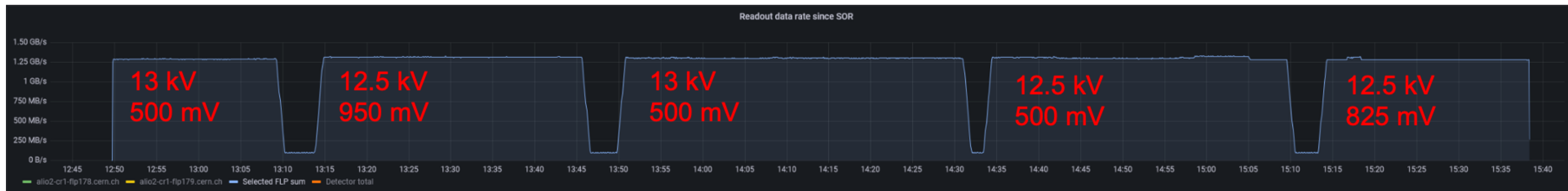
$$\frac{\text{Reference}}{\text{Conf. 3}} = \mathbf{0.997 (4)}$$





# HV scan con pilot beam (2)

- New HV vs threshold scan on 3rd June 2022
- goal: checking that in the new working point (12.5 kV; 950 mV) the TOF matching efficiency doesn't deteriorate significantly
- **a reduced HV (12.5 kV instead of 13 kV) could prevent the aging of TOF HV unipolar cable connectors**
- Voltage settings based on previous scan in 2021 with half of the detector acceptance
- scan done **without stopping the run** to minimize the change in the detector condition with time
- need reconstruction to see results (**should arrive soon!**)



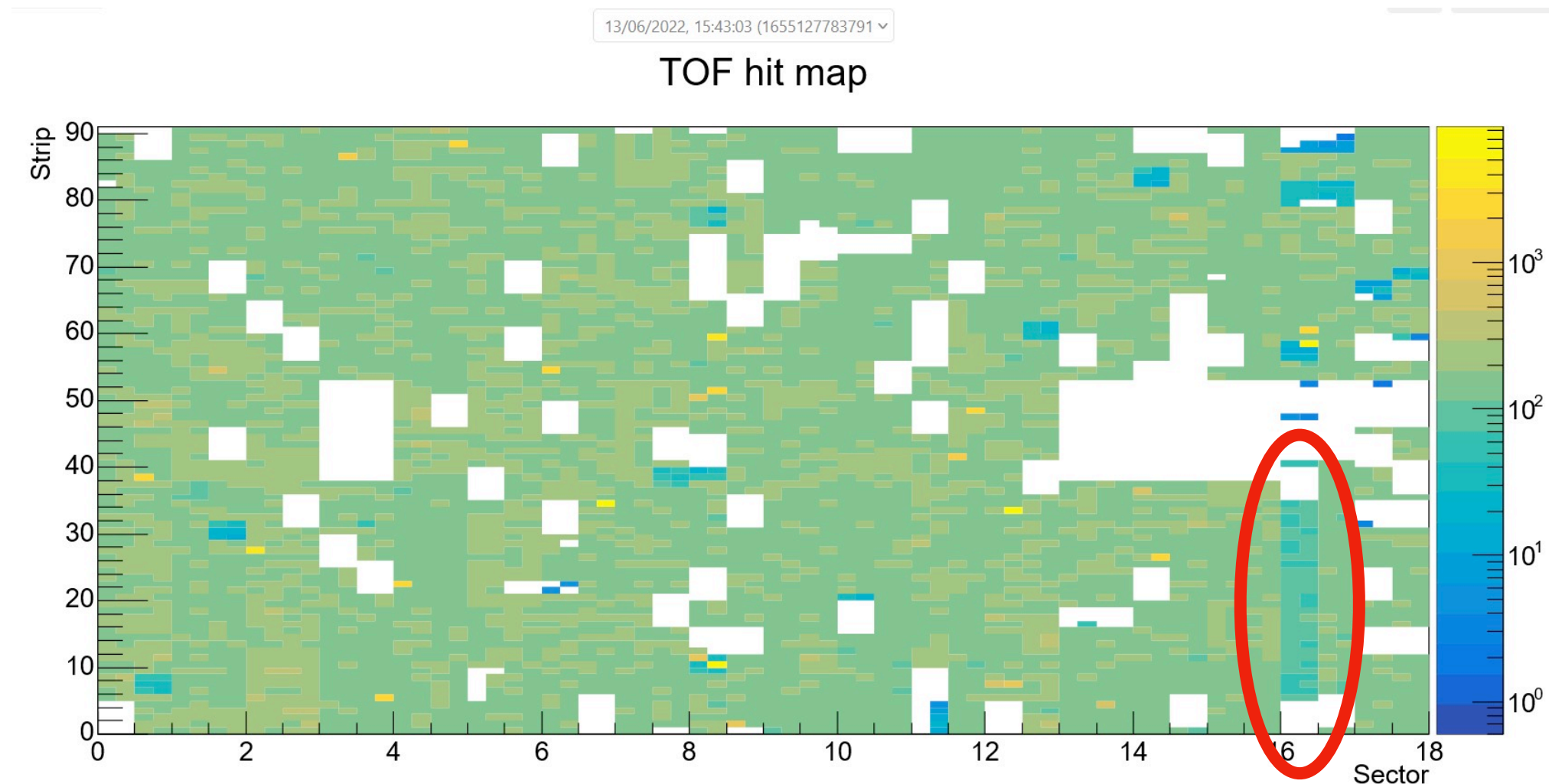
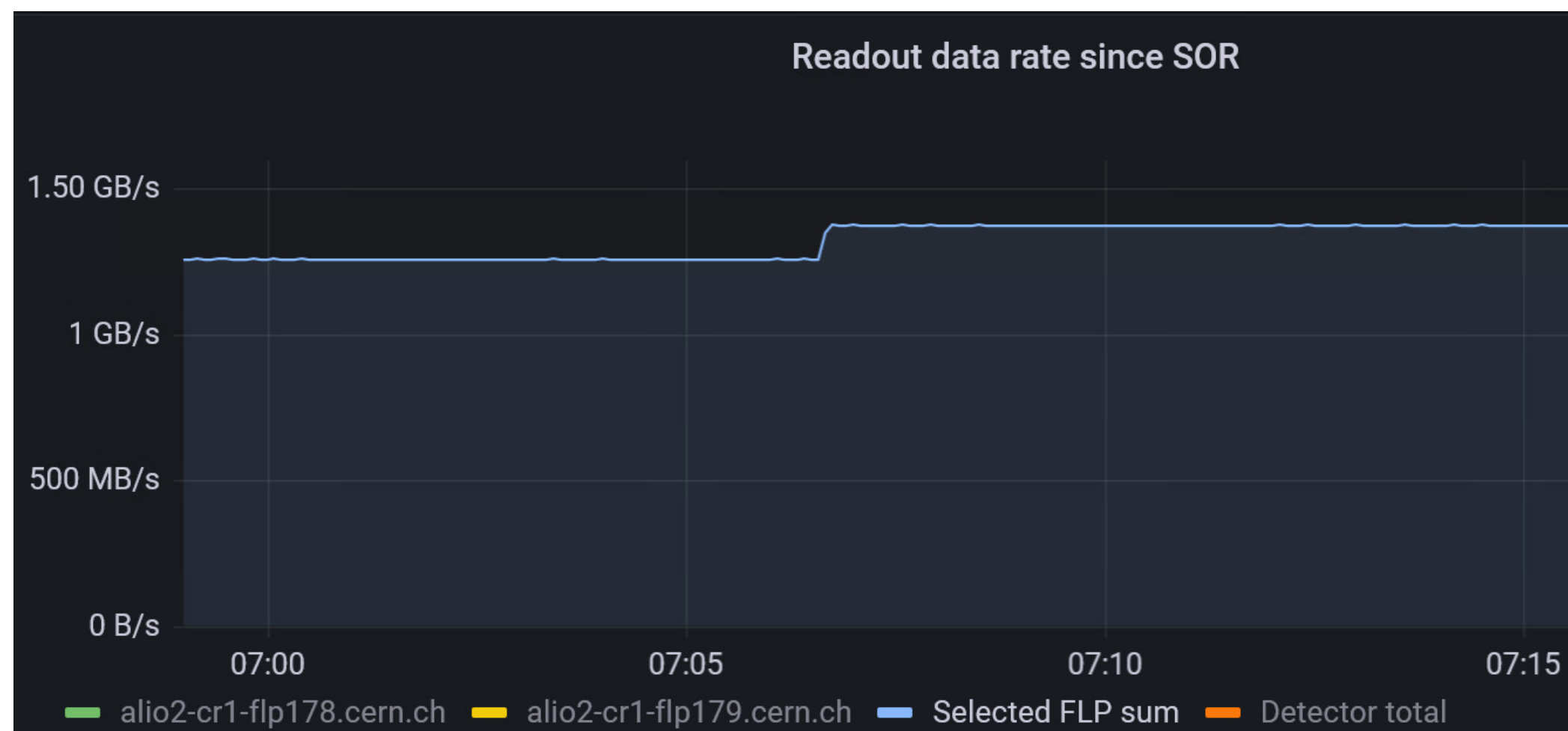


# Run-over-Error procedure in action



- Implementato nel nostro DCS il monitoring del data rate da ogni singolo crate
- se da un crate si interrompe la trasmissione dati, lo status DCS del TOF viene portato in **RECOVERING**, e il link corrispondente viene messo in pausa - **tutti gli altri link continuano a trasmettere dati**
- operazioni di recovery sul crate (in questo caso, reset FPGA su DRM2 e riconfigurazione schede di readout su tutto il crate)
- una volta recuperato il link, la presa dati viene riabilitata
- le informazioni su link on/off e timestamp viene salvata nei dati

Crate	Status	DAQ	IRQ #	Average MB/s	Inst. MB/s	SOX	Last	EOX
00	RE	ON	4481	7.36	7.33	11:34:22	11:39:27	11:28:52
01	RE	ON	5433	8.92	8.87	11:34:22	11:39:27	11:28:52
02	RE	ON	4478	7.36	7.33	11:34:22	11:39:27	11:28:52
03	RE	ON	5432	8.91	8.87	11:34:22	11:39:27	11:28:52
04	RE	ON	4967	8.11	8.07	11:34:22	11:39:28	11:28:52
05	RE	ON	4975	8.13	8.13	11:34:22	11:39:28	11:28:52
06	RE	ON	4475	7.35	7.33	11:34:22	11:39:28	11:28:52
07	RE	ON	5435	8.89	8.87	11:34:22	11:39:28	11:28:52
08	RE	ON	5038	8.23	8.20	11:34:22	11:39:28	11:28:52
09	RE	ON	4980	8.12	8.07	11:34:22	11:39:28	11:28:52
10	RE	ON	117	0.00	0.00	11:34:22	11:39:28	11:28:52
11	RE	ON	4980	8.12	8.07	11:34:22	11:39:28	11:28:52
12	RE	ON	4475	7.35	7.33	11:34:22	11:39:28	11:28:52
13	RE	ON	4475	7.35	7.33	11:34:22	11:39:28	11:28:52
14	RE	ON	4475	7.35	7.33	11:34:22	11:39:28	11:28:52
15	RE	ON	4475	7.35	7.33	11:34:22	11:39:28	11:28:52
16	RE	ON	4475	7.35	7.33	11:34:22	11:39:28	11:28:52
17	RE	ON	5440	8.88	8.87	11:34:22	11:39:28	11:28:52
18	RE	ON	4498	7.37	7.33	11:34:22	11:39:28	11:28:52
19	RE	ON	5439	8.88	8.87	11:34:22	11:39:28	11:28:52
20	RE	ON	4329	7.10	7.13	11:34:22	11:39:27	11:28:52
21	RE	ON	5433	8.91	8.87	11:34:22	11:39:27	11:28:52
22	RE	ON	4013	6.58	6.53	11:34:22	11:39:27	11:28:52
23	RE	ON	5433	8.91	8.87	11:34:22	11:39:27	11:28:52
24	RE	ON	4561	7.47	7.47	11:34:22	11:39:28	11:28:52
25	RE	ON	4480	7.34	7.33	11:34:22	11:39:28	11:28:52
26	RE	ON	4993	8.15	8.13	11:34:22	11:39:28	11:28:52
27	RE	ON	4481	7.34	7.33	11:34:22	11:39:28	11:28:52
28	RE	ON	4964	8.13	8.13	11:34:22	11:39:27	11:28:52
29	RE	ON	4007	6.58	6.53	11:34:22	11:39:27	11:28:52
30	RE	ON	4964	8.13	8.07	11:34:22	11:39:27	11:28:52
31	RE	ON	4969	8.14	8.13	11:34:22	11:39:27	11:28:52
32	RE	ON	4091	6.69	6.67	11:34:22	11:39:28	11:28:52
33	RE	ON	5014	8.21	8.20	11:34:22	11:39:28	11:28:52
34	RE	ON	4012	6.57	6.60	11:34:22	11:39:28	11:28:52
35	RE	ON	3089	5.03	5.07	11:34:22	11:39:28	11:28:52
36	RE	ON	4960	8.13	8.13	11:34:22	11:39:27	11:28:52
37	RE	ON	5436	8.91	8.87	11:34:22	11:39:27	11:28:52
38	RE	ON	4479	7.36	7.33	11:34:22	11:39:27	11:28:52
39	RE	ON	4482	7.36	7.33	11:34:22	11:39:27	11:28:52
40	RE	ON	4482	7.34	7.33	11:34:22	11:39:28	11:28:52
41	RE	ON	5437	8.89	8.87	11:34:22	11:39:28	11:28:52
42	RE	ON	4483	7.34	7.33	11:34:22	11:39:28	11:28:52
43	RE	ON	5437	8.89	8.87	11:34:22	11:39:28	11:28:52
44	RE	ON	4485	7.34	7.33	11:34:22	11:39:28	11:28:52
45	RE	ON	5438	8.90	8.80	11:34:22	11:39:28	11:28:52
46	RE	ON	4487	7.35	7.33	11:34:22	11:39:28	11:28:52
47	RE	ON	3555	5.80	5.80	11:34:22	11:39:28	11:28:52
48	RE	ON	4481	7.34	7.33	11:34:22	11:39:28	11:28:52
49	RE	ON	4481	7.34	7.33	11:34:22	11:39:28	11:28:52
50	RE	ON	4481	7.34	7.33	11:34:22	11:39:28	11:28:52
51	RE	ON	4481	7.34	7.33	11:34:22	11:39:28	11:28:52
52	RE	ON	4481	7.34	7.33	11:34:22	11:39:28	11:28:52
53	RE	ON	4970	8.12	8.13	11:34:22	11:39:28	11:28:52
54	RE	ON	4483	7.34	7.33	11:34:22	11:39:28	11:28:52
55	RE	ON	4485	7.34	7.40	11:34:22	11:39:28	11:28:52
56	RE	ON	4014	6.57	6.60	11:34:22	11:39:28	11:28:52
57	RE	ON	4481	7.34	7.33	11:34:22	11:39:28	11:28:52
58	RE	ON	3583	5.85	5.87	11:34:22	11:39:28	11:28:52
59	RE	ON	5045	8.24	8.27	11:34:22	11:39:28	11:28:52
60	RE	ON	4480	7.34	7.40	11:34:22	11:39:28	11:28:52
61	RE	ON	4968	8.12	8.07	11:34:22	11:39:28	11:28:52
62	RE	ON	4480	7.34	7.33	11:34:22	11:39:28	11:28:52
63	RE	ON	4010	6.57	6.60	11:34:22	11:39:28	11:28:52
64	RE	ON	4484	7.36	7.33	11:34:22	11:39:28	11:28:52
65	RE	ON	4974	8.12	8.13	11:34:22	11:39:28	11:28:52
66	RE	ON	4572	7.49	7.47	11:34:22	11:39:28	11:28:52
67	RE	ON	5515	9.01	9.00	11:34:22	11:39:28	11:28:52
68	RE	ON	4014	6.57	6.53	11:34:22	11:39:28	11:28:52
69	RE	ON	4975	8.12	8.07	11:34:22	11:39:28	11:28:52
70	RE	ON	4976	8.12	8.07	11:34:22	11:39:28	11:28:52
71	RE	ON	5141	8.38	8.40	11:34:22	11:39:28	11:28:52



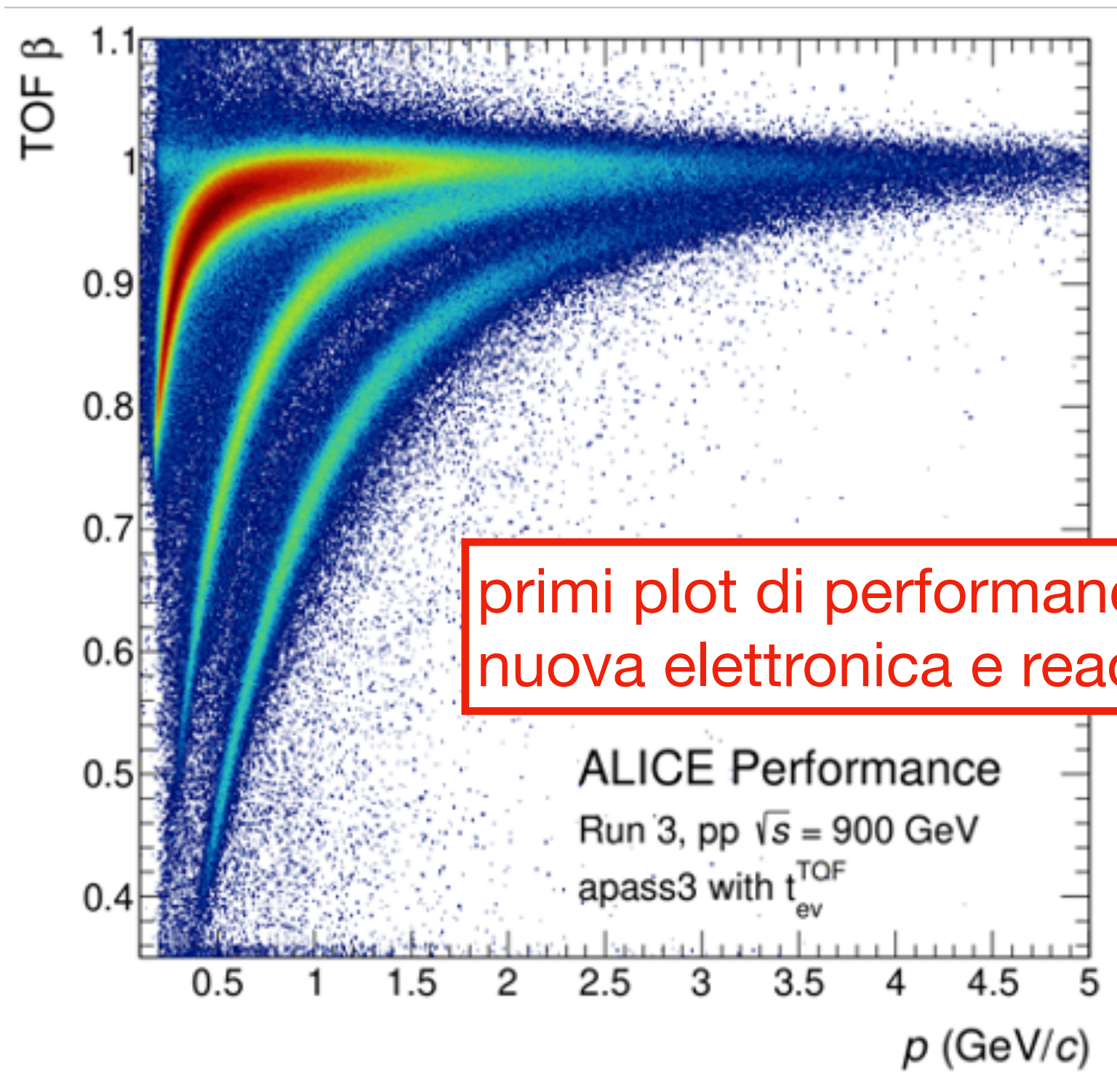


# Where we are... 2021 LHC pilot run

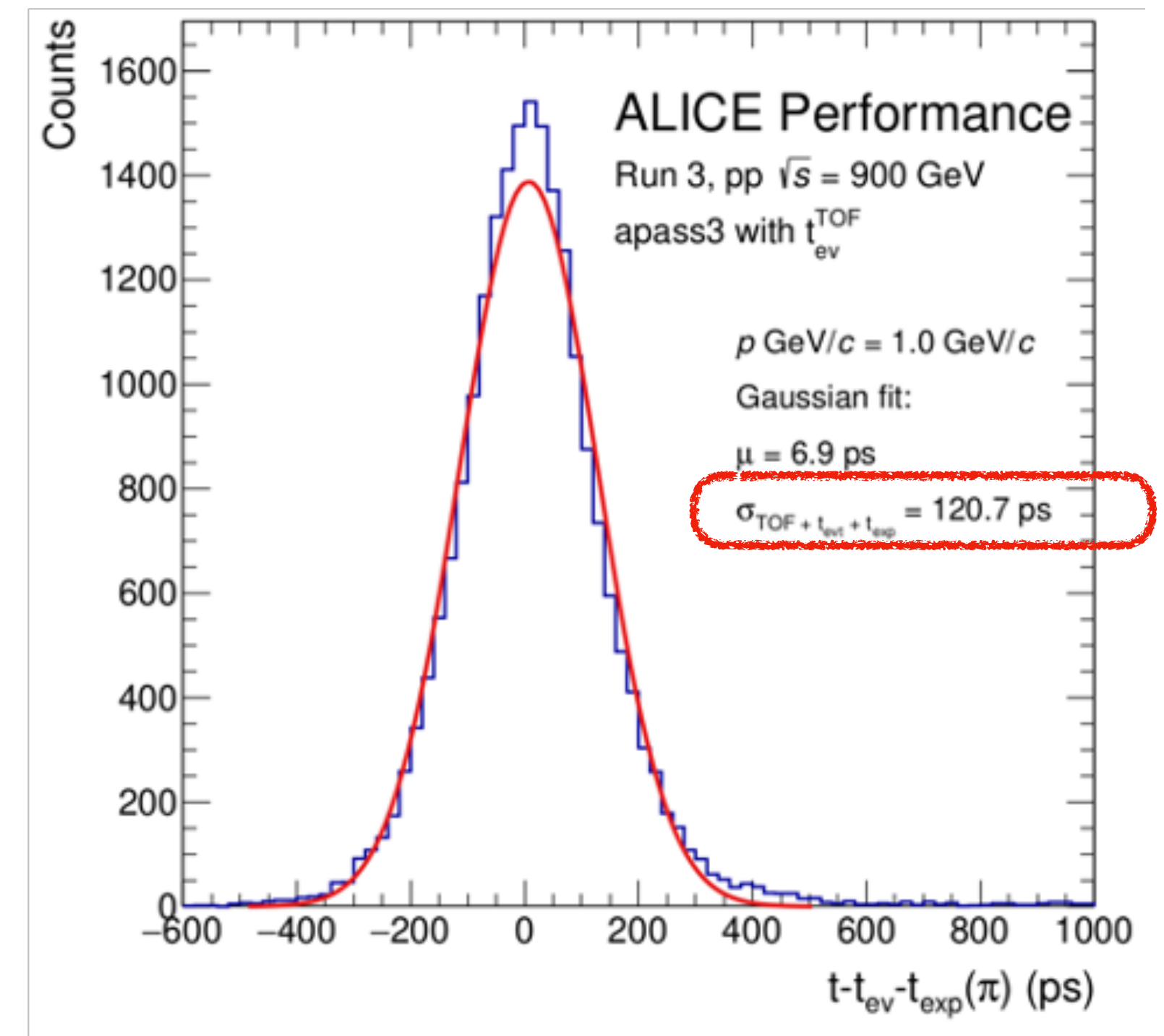
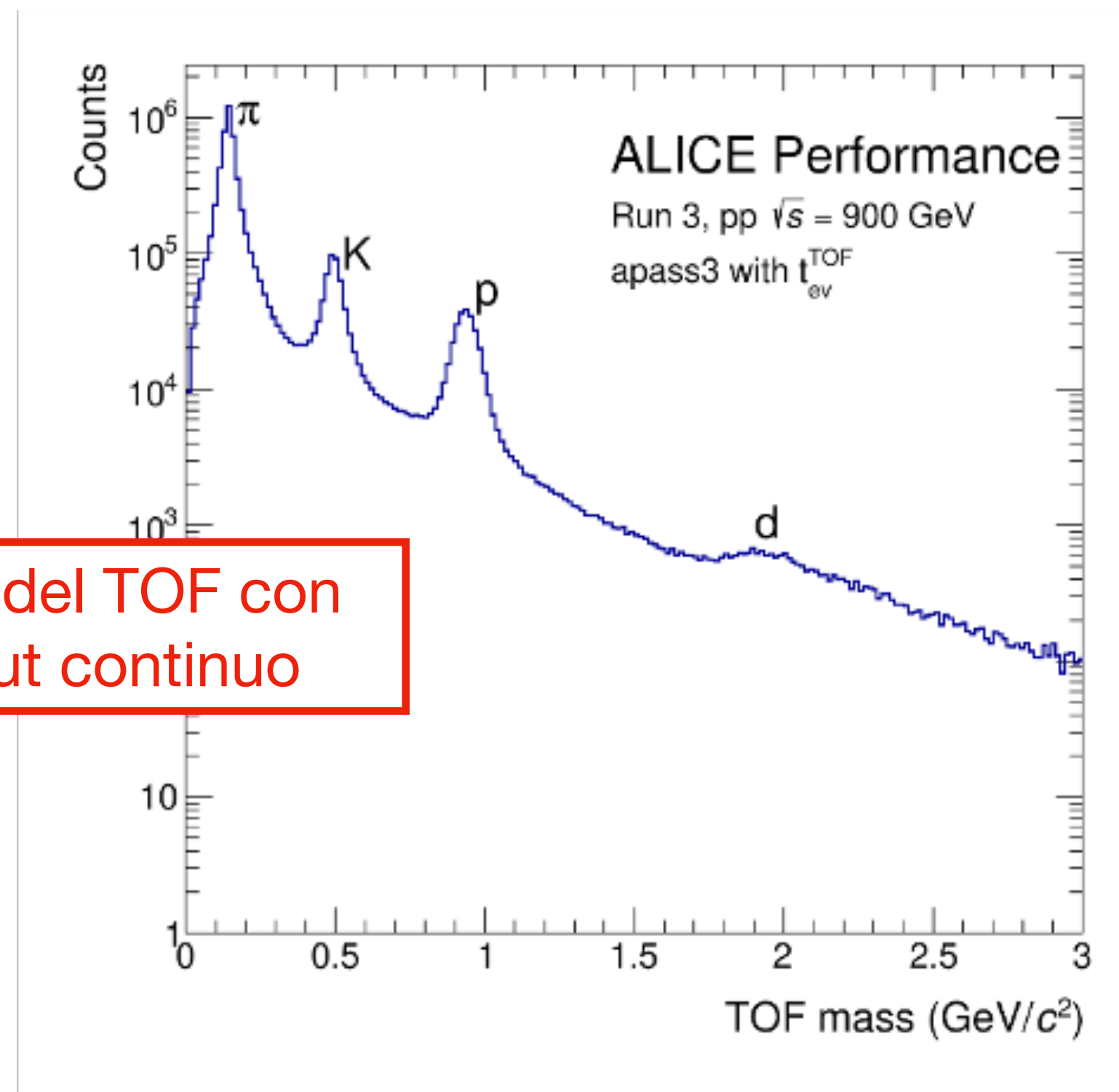
20/10/2021 - 01/11/2021 circulating beams at injection energy, pre-commissioning of LHC key systems

**Wed 27/10 Stable Beam for the first time after LS2**

TOF already able to provide physics since the very 1<sup>st</sup> day of data taking



primi plot di performance del TOF con nuova elettronica e readout continuo





# TOF performance

**Measurement of anti-<sup>3</sup>He nuclei absorption in matter and impact on their propagation in the Galaxy**

Nature Physics **19**, 61-71 (2023), <https://doi.org/10.1038/s41567-022-01804-8>





# TRM autopsy

“extraction” year	not reparable TRM
2010	3
2017	5
2018	4
2022(3)	11

24 TRM already lost in action

## Point of failures of not reparable TRM

- FPGA AP750 Actel - no longer produced
- rework of FPGA is however challenging
- difficult to make additional HPTDC piggy back (many failures in soldering, “old” chips/BGA damaged?)



As of 12/6/2023 with 684 TRM to serve TOF

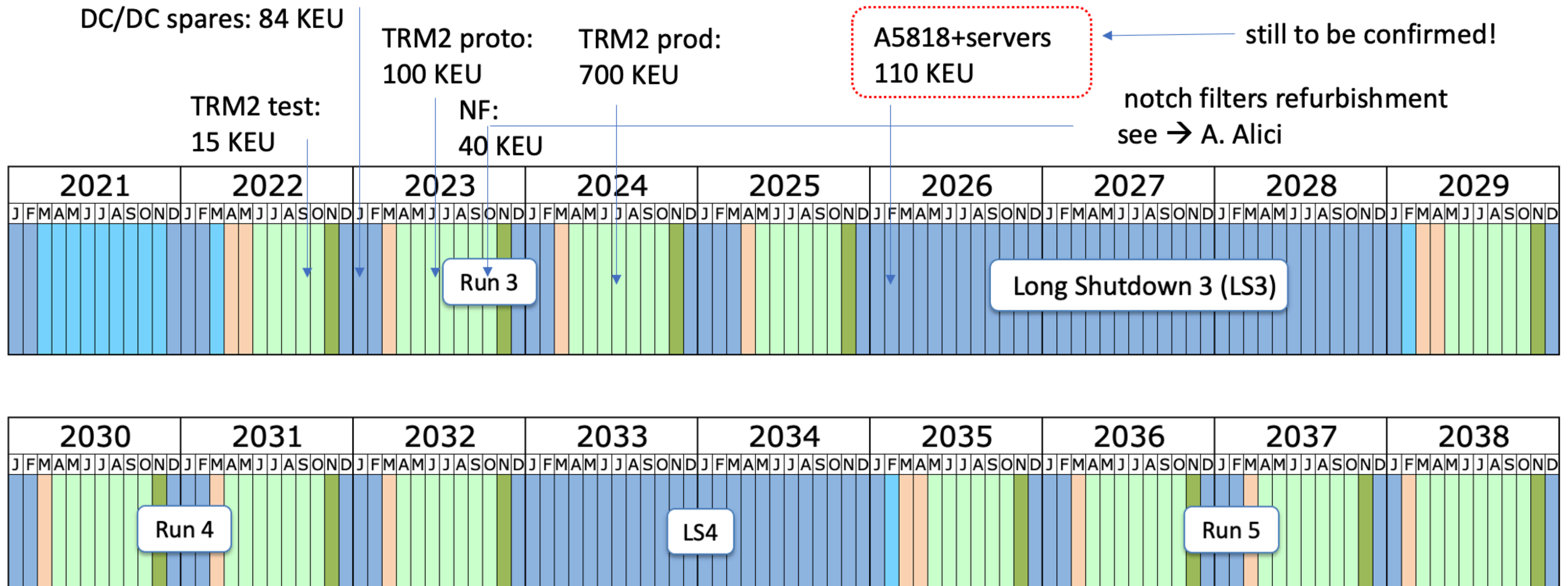
- 657 are working
- 33 are dead “trapped” inside detector, likely 50% of them not reparable + 5-10 problematic
- 25 spares available

Based on last year statistics, we expect 8-10 TRMs not reparable/year (from 19 extracted 11 not reparable). However, it could be we already don’t have enough TRM spares (out of 33 OFF, what if > 25 not reparable?).

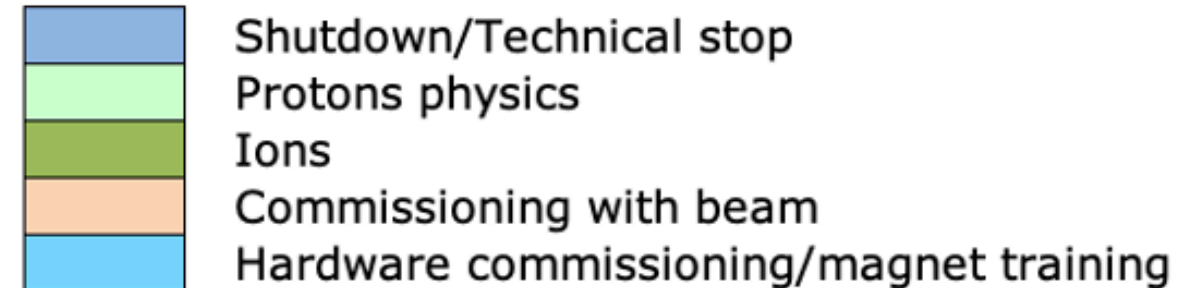
**NOTE:** Since 2019 CAEN agreed with CERN to cancel clause of substitution of irreparable modules for TRM in the CERN-CAEN general maintenance contract



# TOF extraordinary maintenance: current overview



Last updated: January 2022



**TOF extraordinary maintenance:**

- 1 MEU in 4 YEARS