Spark protection scheme for the SAMPA-based ALICE TPC electronics

6th December 2018

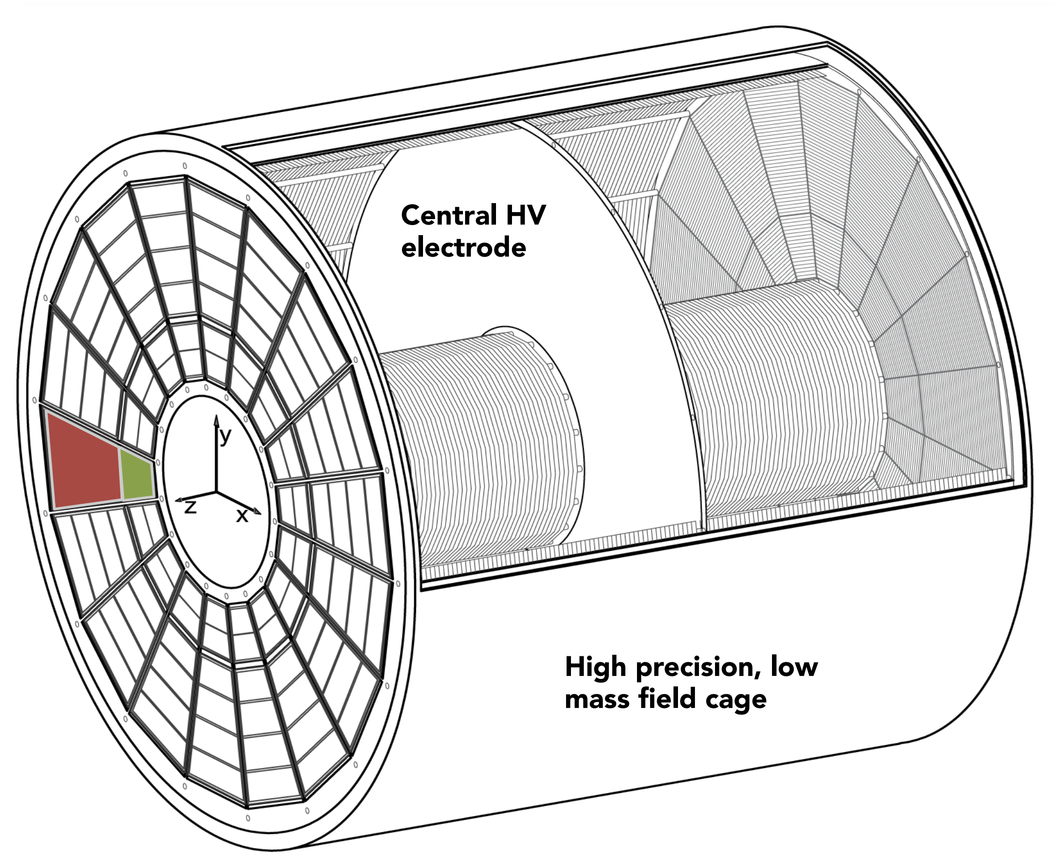
Christian Lippmann

GSI

Content

- **Overview**
- Issues found with input protection
- Testing
- Diode packages
- Resistors
- Tests with additional diodes
- System test status

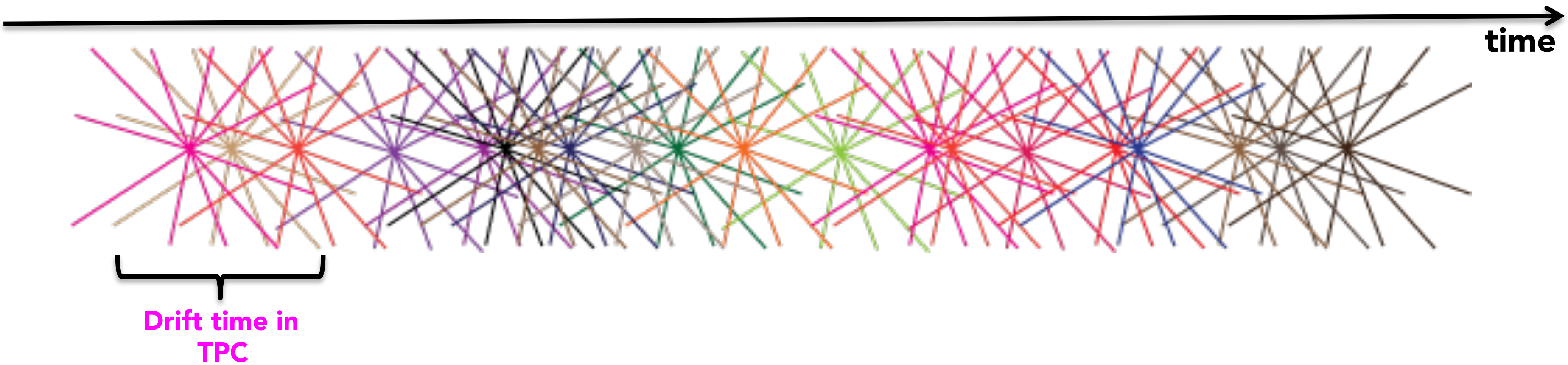
ALICE TPC overview



- Diameter: 5 m, length: 5 m
- Gas:
  - Ne–CO_2–N_2,
  - (Ar–CO_2 in 2015, 2016 and 2018)
- Max. drift time: ~100 μs
- 18 sectors on two sides
- Inner readout chambers: IROC
- Outer readout chambers: OROC

Continuous operation

Typical data taking with TPC in RUN3: High luminosity Pb-Pb collisions



- **Maximum drift time of electrons in TPC: ~ 100us**
- **Average event spacing: ~20us**

- **Event pileup**
- **Triggered operation does not make sense**
- **Minimize ion backflow (IBF) in different way**

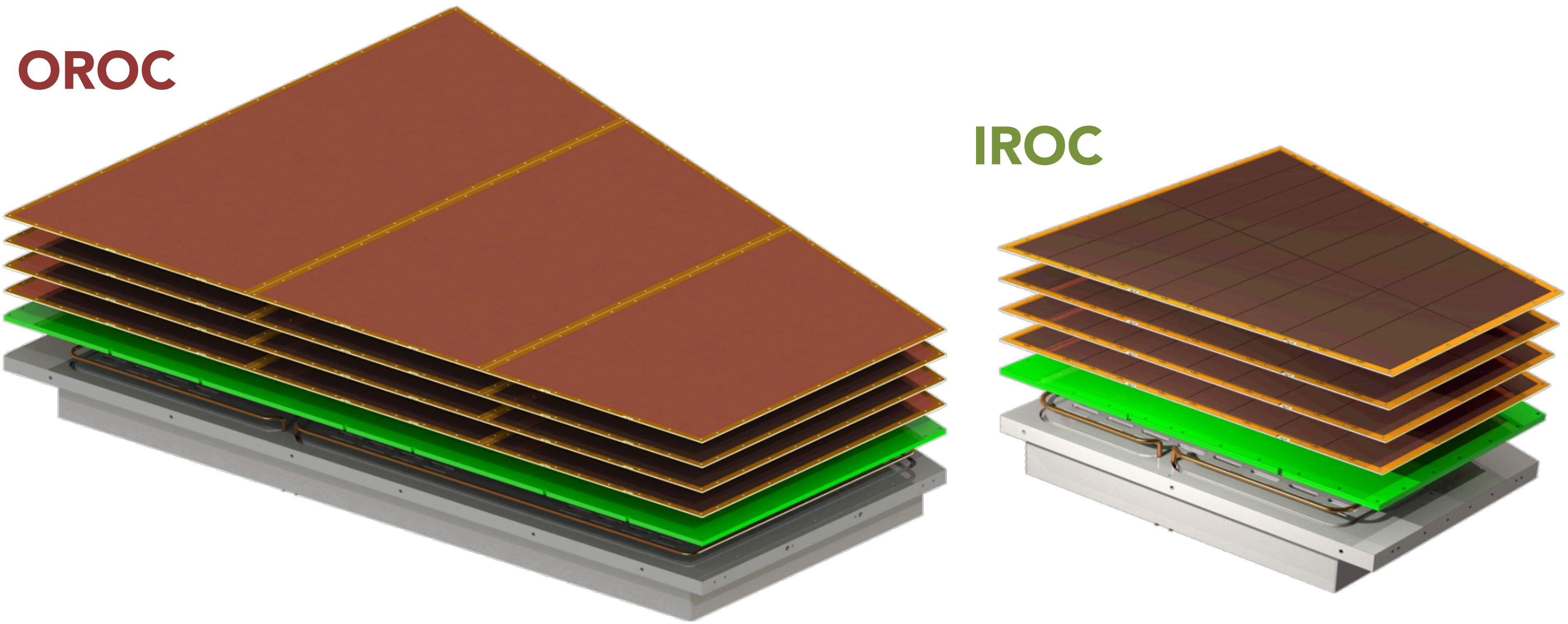
Continuous read-out
Micro Pattern Gas Detectors

New Readout chambers

18 sectors on two sides → 72 chambers

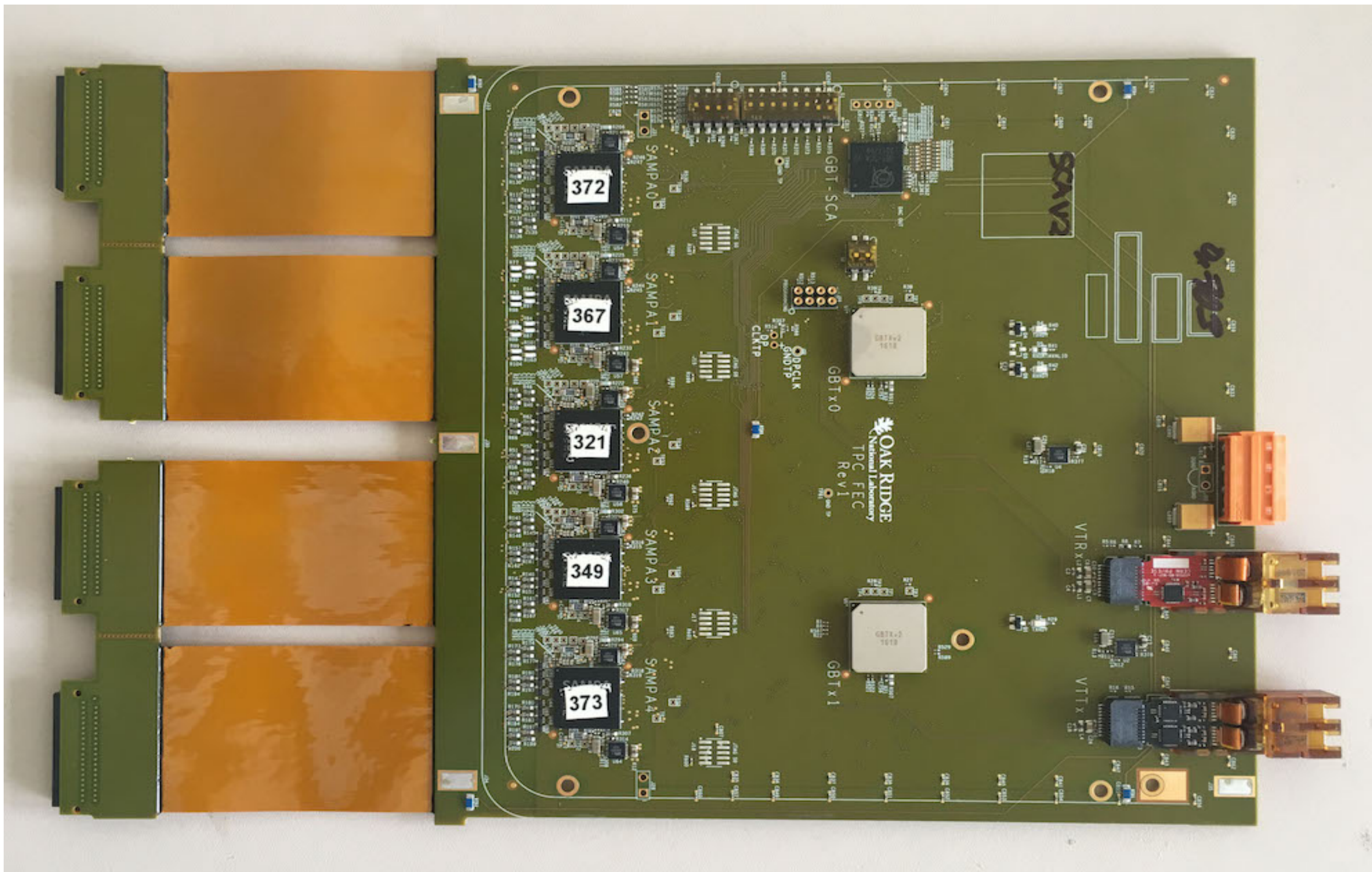
Inner readout chambers: IROC

Outer readout chambers: OROC



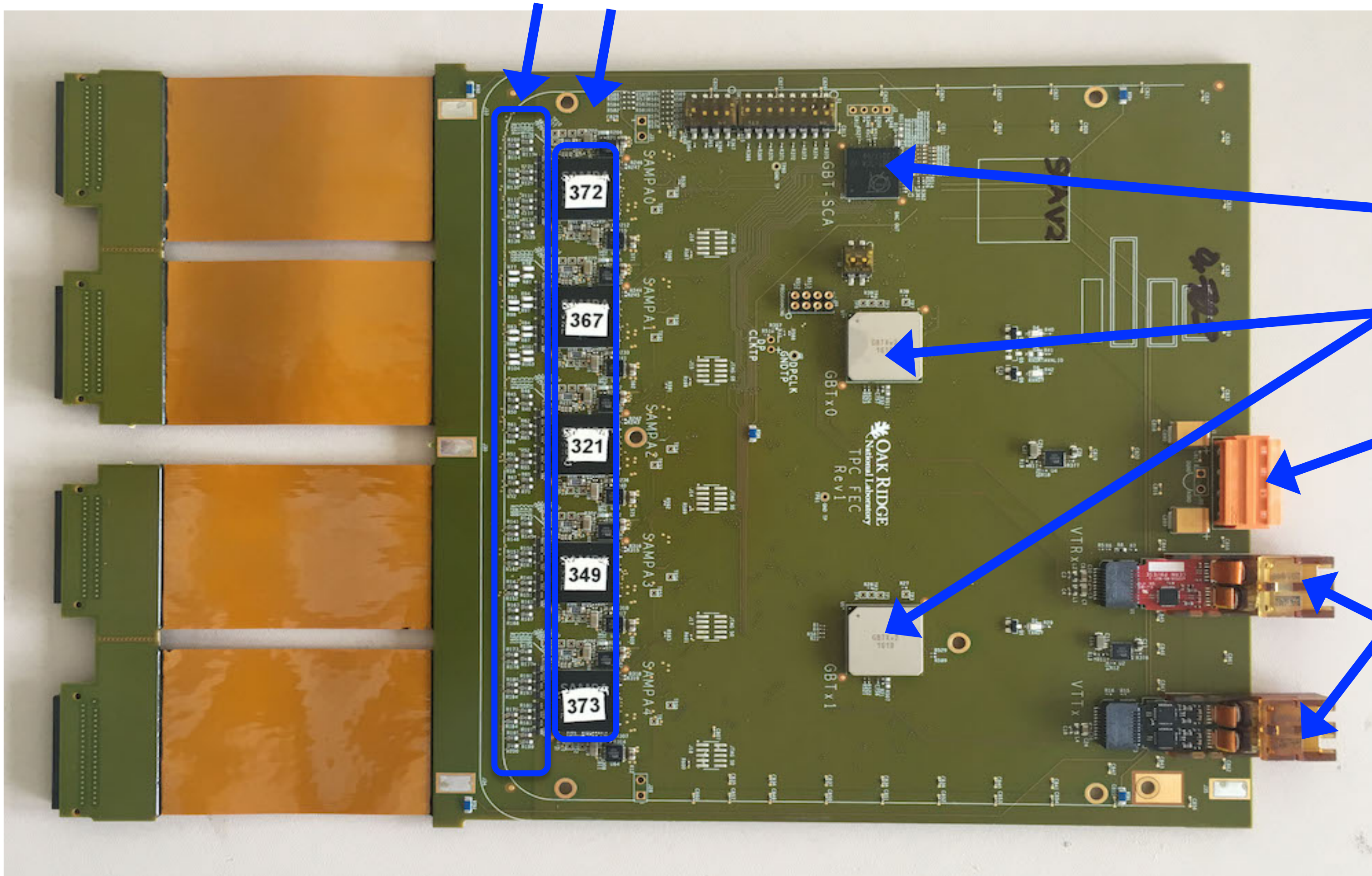
New TPC FEC (1)

TPC Front End Card Rev 1 with integrated flexible signal cables (rigid flex)



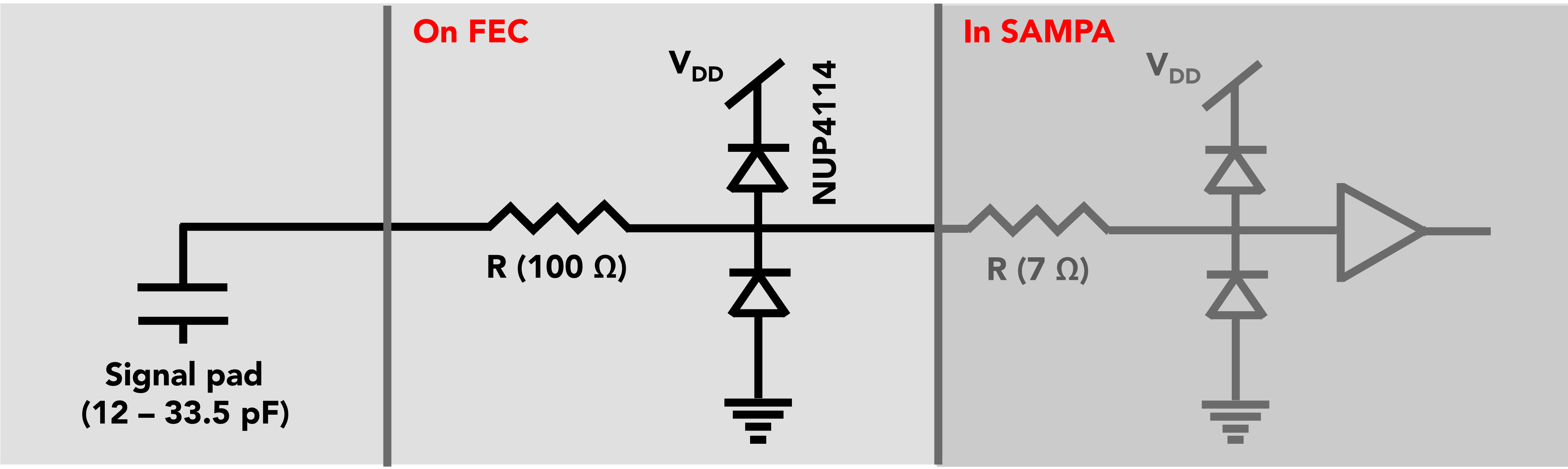
New TPC FEC (2)

TPC Front End Card Rev 1 with integrated flexible signal cables (rigid flex)



Spark protection

- SAMPA: Device-level ESD protection for handling (diodes and 7 Ω series resistor)
- System-level protection on FEC: Diodes and resistors



- Resistor value (100 Ω) chosen based on tests with SAMPA MPW2 and prototype GEM chamber

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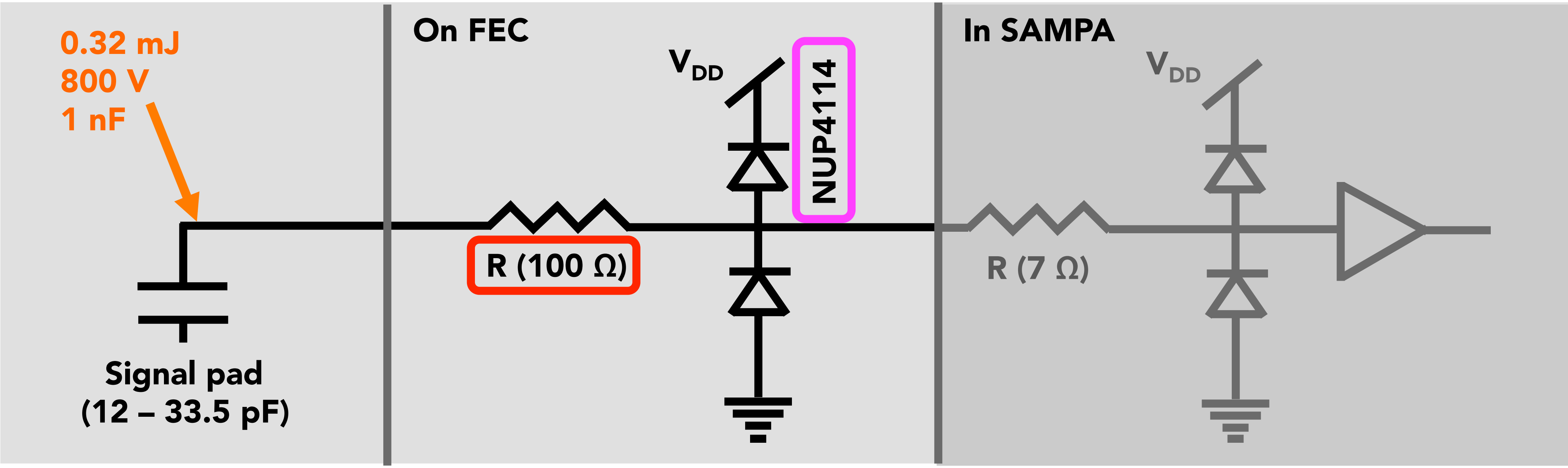
Problems found (1)

2 Problems:

1. Protection resistors may get damaged by (a few) discharge pulses with the expected pulse energy (while the SAMPA is protected)

2. Availability of the back-to-back diode package (NUP4114) used so far on all prototypes became critical (full quantity only end of January 2019)

Problems found (2)



Issues:

1. NUP4114 diode package not available in sufficient numbers until end of January 2019
2. Resistor (SMD, 0603 package) not reliable after discharges

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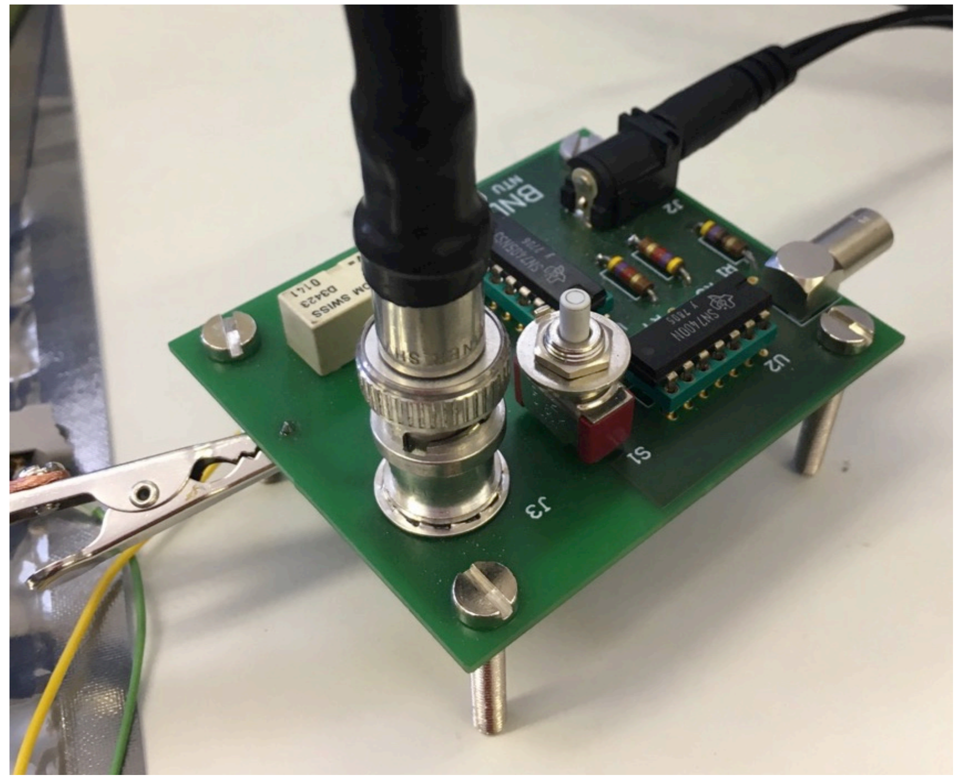
ATLAS "chip killer"

- Worst case (discharge propagation to pad plane, 0.32 mJ into pad) can be simulated with capacitor and HV
- ATLAS "chip killer" makes such tests straightforward
- 1 nF, 1 kV capacitor



Thank you to ATLAS, BNL and University of Athens
George Iakovidis, Venetios Polychronakos

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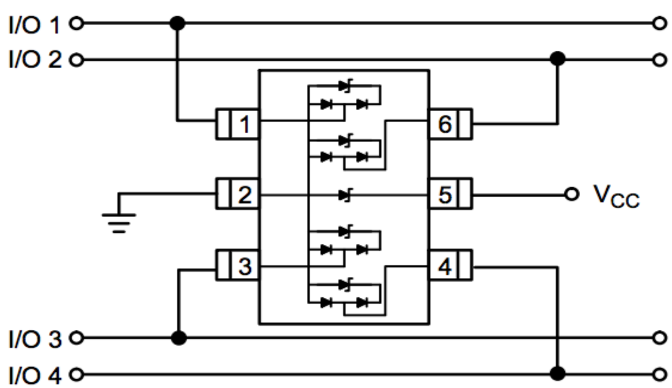
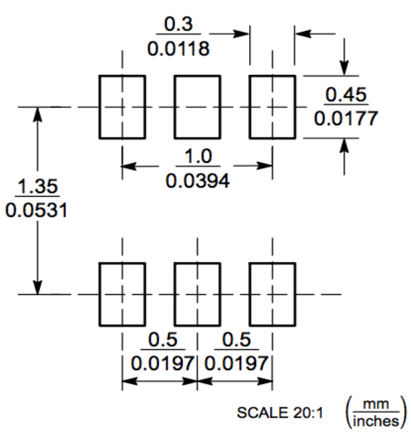
NUP 4114 diode package

Package: SOT563

http://www.onsemi.com/pub/Collateral/NUP4114-D.PDF

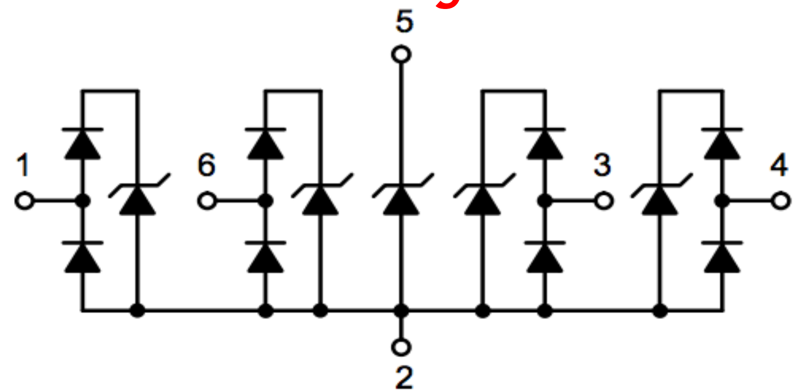


SOLDERING FOOTPRINT*

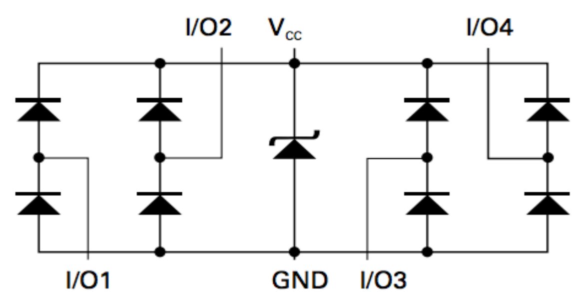


Problem: Circuit diagram was updated some years ago, part number not changed!

This is current diagram:



This used to be the diagram:



SP3004 diode package

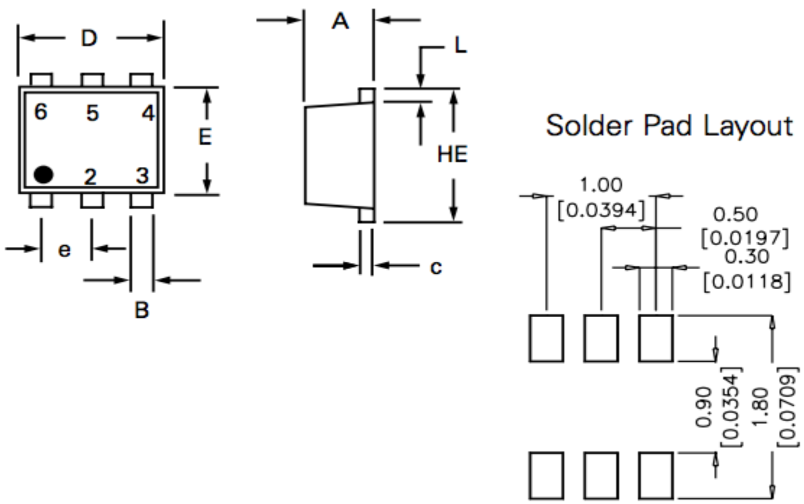
Alternative product: Littlefuse SP3004 Series

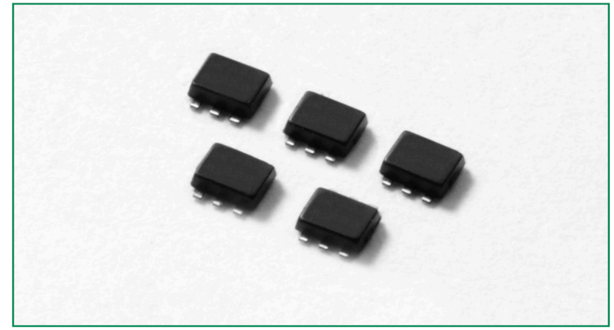
Same package available: SOT563, pin compatible

http://m.littelfuse.com/~/media/electronics/datasheets/tvs_diode_arrays/littelfuse_tvs_diode_array_sp3004_datasheet.pdf.pdf

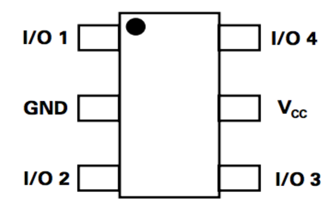
The ATLAS NSW group are using this component. They have moved to this product because of the circuitry changed in the NUP4114

Package Dimensions — SOT563

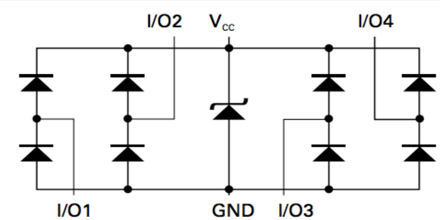




Pinout



Functional Block Diagram



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MELF example

- ATLAS TRT and NA62 straw. No channel lost in all these years
- MELF resistors TOKEN RDM16
- Double protection diodes (BAV99 A7W, 1 channel per package)
- Problem: Takes a lot of space! MELF hardly available with short lead times

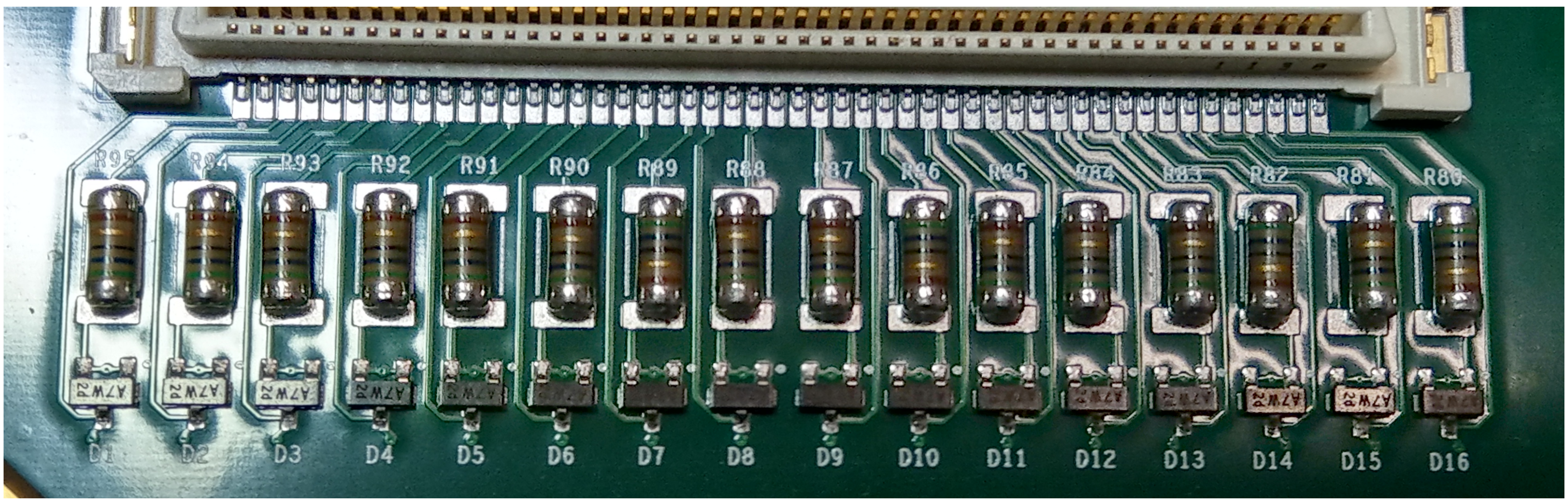
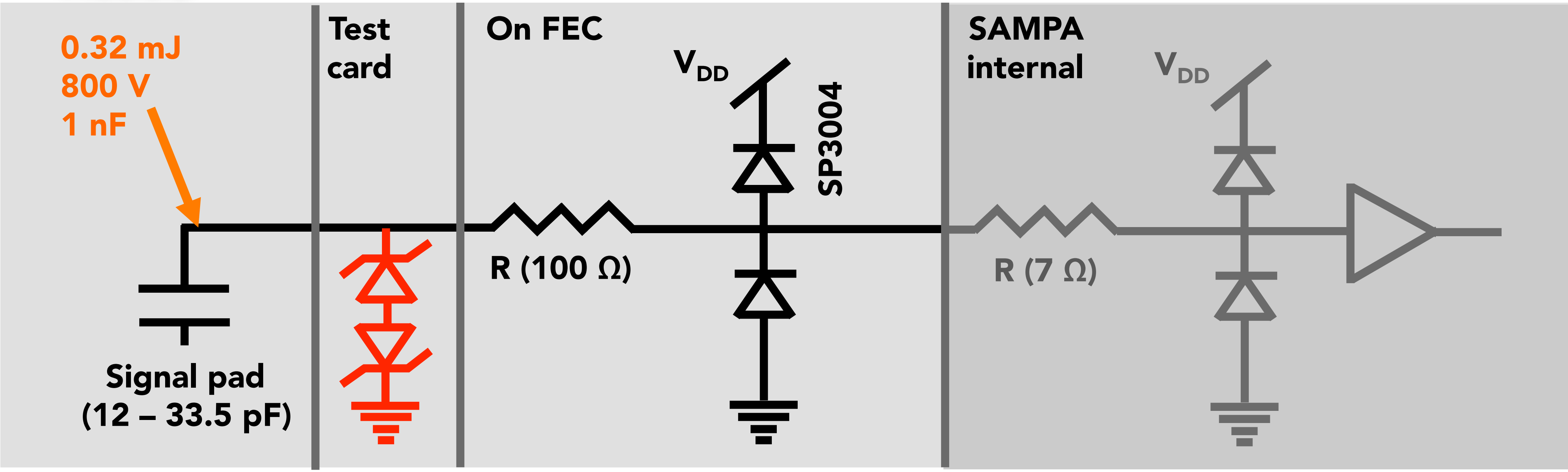


Photo by Peter Lichard

Resistor test summary

Name	Type	Size	Power rating	Resistance (Ω) after 1 spark	Resistance (Ω) after 11 sparks	Resistance (Ω) after 201 sparks
Default resistor (Yageo)	Thick film SMD	0603		100	102	✗
YAGEO RT0603FRE07100RL	Thin film SMD	0603	0.1 W	107	200	✗
Vishay MCT0603MD1000DP500 (automotive qualified)	Thin film SMD	0603	0.15 W	101	102	105
TE Connectivity RP73PF1J100RBTDF	Thin film SMD	0603	0.166 W	100	103	✗
Vishay PCAN0603E1000BST3	Thin film SMD	0603	0.5 W	✗		
ROHM ESR03EZPJ101 (anti-surge, discharge resistant)	Thick film SMD	0603	0.25W	100	100	102
ROHM KTR03EZPF1000 (high voltage, automotive)	Thick film SMD	0603	0.1 W	100	100	101
ROHM SFR03EZPF1000	Thick film SMD	0603	0.063 W	100	150	500
BOURNS CRS0603AFX-1000ELF (pulse withstanding)	Thick film SMD	0603	0.125 W	100	100	100
MULTICOMP MCHVR03JTEX1000 (high voltage rated)	Thick film SMD	0603	0.1 W	100	100	103
VISHAY MCT06030C1000FP500 (automotive)	Thick film SMD	0603	0.125 W	100	101	✗
VISHAY CMA02040X6809GB300 (automotive, high pulse load)	Carbon film MiniMELF	1.4 x 3.6 mm2	0.4 W	100	100	100

TVS diode test boards




Semtech 3321ZA, recommended by ATLAS, 4.2 pF, ultra-small


Semtech 3321P, only 0.35 pF

Test boards designed by Michel Morel, CERN EP-ESE. Thank you!

TVS test summary

Name	Stand-off voltage	Capacitance	Size	Resistance (Ω) after 1 spark	Resistance (Ω) after 11 sparks	Resistance (Ω) after 201 sparks
Semtech RCLAMP3321P.TNT	3.3 V	0.35 pF	1 x 0.6 mm^2	100	100	100
Semtech UCLAMP3321ZATFT	3.3 V	4.2 pF	0.6 x 0.3 mm^2	100	100	100

- **Very good protection against large number of discharges with both TVS diodes**
- **Larger capacitance of 3321ZA is more "noisy"**
- **Resistor value could be decreased, from 100 Ω probably to 10 Ω (as in ATLAS), with benefit of reducing noise (not tested)**
- **For the TPC FEC we did not have the time for an additional prototype cycle, so this option was excluded unfortunately**

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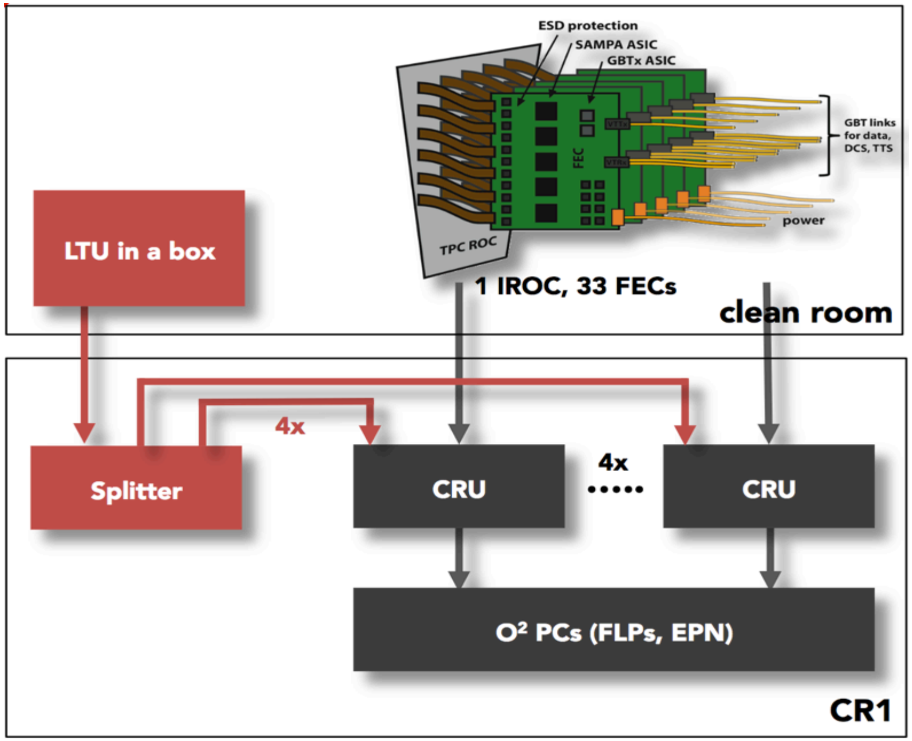
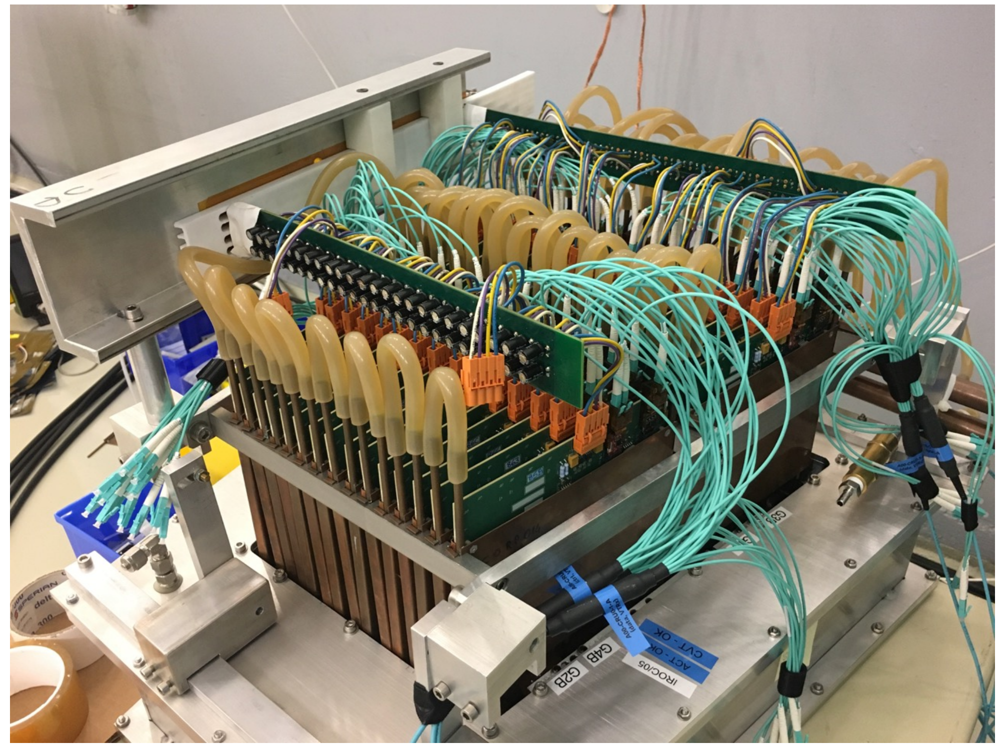
IROC test setup



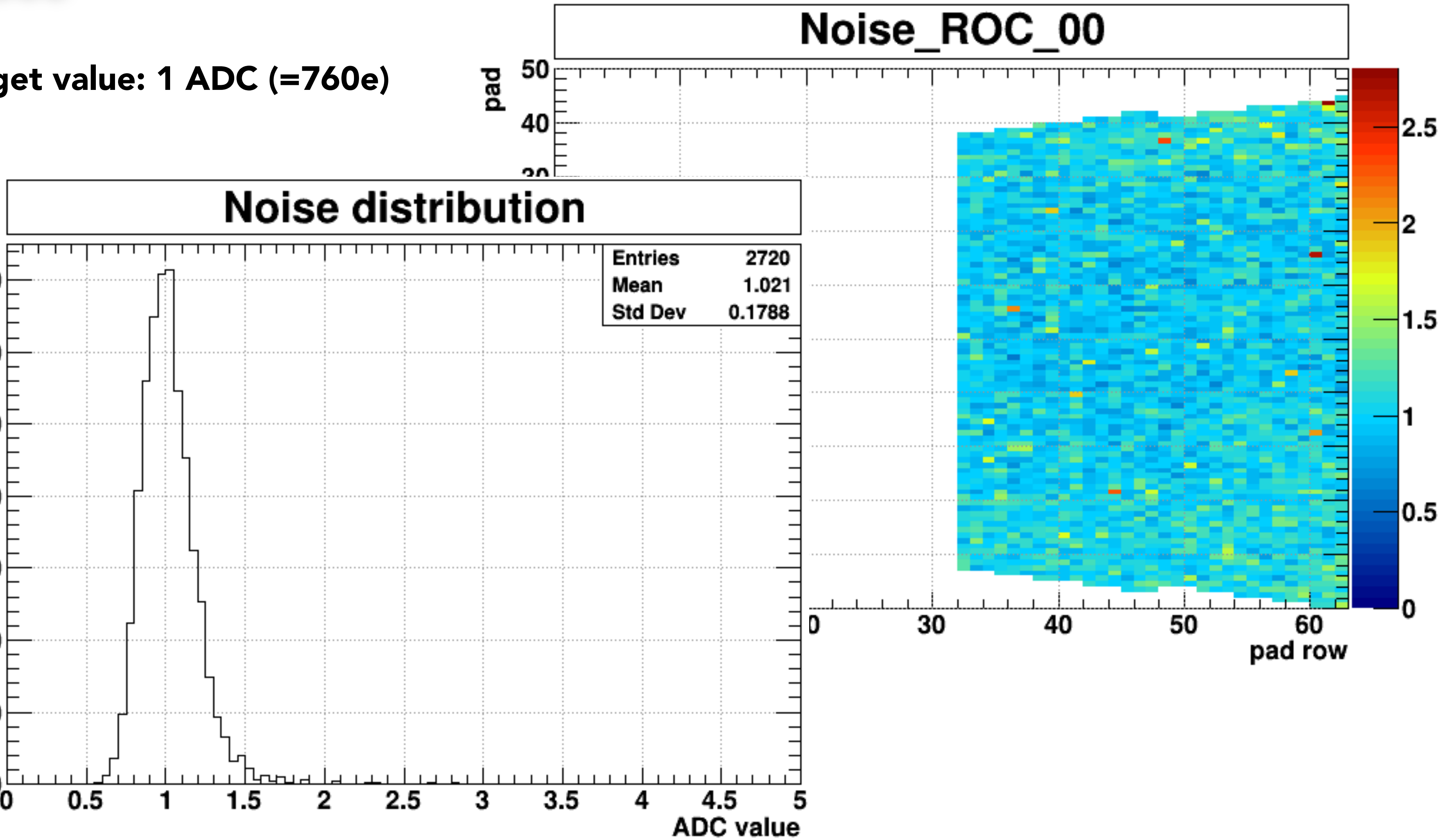


Purpose : Test of a fully equipped IROC to evaluate mechanical aspects and performance under realistic conditions

- **33 Front-End-Cards, cooling and final LV system**
- **IROC and FECs located in clean room where TOC upgrade will take place**

Noise results

Target value: 1 ADC (=760e)



Summary and outlook

- ALICE TPC FECs based on SAMPA ASIC and GBT readout
- Input protection resistor found to be un-reliable in discharge tests with first FEC versions
- Input protection diodes were changed from NUP4114 (not recommended by ATLAS NSW, lead times not compatible with FEC production schedule) to SP3004 (recommended by ATLAS NSW)
- Testing performed with pulse injection board developped for ATLAS (thanks to University of Athens and BNL) and with real sparks from GEM stack
- Careful choice of series resistor (automotive industry) leads to reliable spark protection
- Additional protection layer (Semtech TVS diode, recommended by ATLAS NSW) looks great in tests, but could not be added to FEC layout due to scheduling reasons
- Successful full system tests