Mass tests facility Status Report

DUNE PRR: FD1 PDS SiPMs

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Contents

- Mass tests purposes & protocol;
- CACTUS system apparatus;
- Future steps;
- Measurements and results;
- Conclusions









SiPM massive tests

Check SiPM working parameters;

Purposes: Failure/mortality rate;

• Quality assurance;



Measurements & parameters:

- IV@roomT \rightarrow (FW) R_q^{RT} + (REV) V_{bd}^{RT} ;
- IV@LN2T \rightarrow (FW) $R_q^{LN2T_pre}$ + (REV) $V_{bd}^{LN2T_pre}$;
- Thermal cycles;
- IV@LN2T \rightarrow (FW) $R_a^{LN2T_post}$ +(REV) $V_{bd}^{LN2T_post}$;
- Extended <u>IV@LN2T</u> → dark current
- DCR@LN2 T \rightarrow global-DCR total dark signals, AP, CT + bursts







The mass test set-up



Cryogenic Apparatus for Continuous Tests Upon SiPM

- Custom setup developed by INFN and Universities of Ferrara and Bologna;
- Massive tests on the entire SiPMs production to perform the quality assurance of all the sensors;

Features: modularity / automatic /easy replication









The mass test set-up

Motherboards + front-end cards:

- 4 motherboards/system;
- 15 front-end cards/motherboard;
- 120 independent channels;
- Current measure/digitalization;
- Signals acquisition;
- Supply power.

Cold boards:

- 4 boards/system;
- 5 arrays/board;
- 120 SiPM;
- Temperature monitor;
- Bias voltage.











Control panel

| ED TEST STATE | | auto/manual | UserCommister | auto setup sequend | ce | | TESTIOG | | | STOP SC | ROLL TEST LOG |
|---|--|--|---|---|----------------|----------|--|--|---|---------|---------------|
| Go To Position EXEC TE | | MANUAL | CONFIRM STEP | standby | 0 | RUNNING | 2022-10-06 15:27:32 - START S | ETUP CHECK | | | |
| | | | | Check Setup | 0 | NOT DONE | 2022-10-06 15:27:34 - SETUP S 2022-10-06 15:27:36 - STARTIN | aved Ig positioning se | SSION | | |
| HECK SETUP AND CONFIRM | | FWD/REV SELECTION | | SCAN SIPMs | 0 | NOTDONE | 2022-10-06 15:28:03 - OPENING MS RESOURCE RUNNING 2022-10-06 15:28:03 - MOVER READY RUNNING | | | | |
| | | FWD ENABLED REV ENABLED | | IV Curve (ROOM) | 0 | NOTDONE | 2022-10-06 15:28:03 - Going to 2022-10-06 15:29:20 - POSITIO | N REACHED DONE | mm) RUNNING | | |
| | | | | IV Curve (LN2) | 0 | NOTDONE | 2022-10-06 15:30:09 - STARTIN 2022-10-06 15:30:12 - OPENIN 2022 10:06 15:30:12 - MONTR | G MS RESOURCE R | UNNING | | |
| eratures 2 °C (0 to 255) 10 | | Enable MS MS STATUS | | Go To Position | 0 | NOTDONE | 2022-10-00 15:30:12 - Moren Report Roman T (600 mm) RUNN 2022-10-06 15:30:12 - Going to position Room T (600 mm) RUNN 2023-10-06 15:31:33 - DOSTION PEACHED DONE OK | | (600 mm) RUNNIN | IG | |
| | | POSITION (mm) | | Thermal cycles | les 0 NOTDONE | | 2022-10-06 15:49:00 - INIT TEST | | | | |
| +C LED | port | MS ON SPEED (m | m/s) READY | DCR Measurement | 0 | NOTDONE | 2022-10-06 15:48:00 - START C 2022-10-06 15:48:00 - CONFIG | ONFIG TEST TEST DONE | | | |
| 0N | COM5 | [0 | | TEST FINISHED | 10 | NOT DONE | 2022-10-05 15:48:00 - CHECK ! 2022-10-06 15:48:01 - LOAD LA | SETUP FILE AST SEUP | | | |
| k setup Scan SiPMs Med | chanical Stage 1V C | URVE DCR measuremen | nt | - | | | 2022-10-06 15:48:01 - START S | ETUP CHECK | | | |
| DaughterBoards | | | | | | | | | Test RESULT NOT | DONE | |
| | | | | | | _ | | | | | DONE |
| ARRAY CLUSTER | R | | | UNDER TES | 51 | | | | | | |
| ARR | AY 1 | ARR | AY 2 | ARRAY 3 | 3 | 080 | ARRAY 4 | Log | ARRAY 5 | | |
| COLCODE | | | | | | | | | | | GUDAL |
| 200928A7S406700 | OCER200050 | 200928A7540670 | 0CER200044 | 200928A75406700CE | R2000 | 48 200 | 928A7S406700CER200030 | 2009284 | 754. 700CER200 | 0026 | |
| 200928A75406700 G Rq = 68,43 Ohm Vbd = 51,48 V DCR = 23,6 mHz/V Vbd = 51,33 V DCR = 23,6 mHz/V | 0CER200050 mm^2 mm^2 | 200928A75406701 Rg = 70,84 Ohm Vbd = 51,33 V DCR = 23,6 mHz/V Rg = 69,75 Ohm Vbd = 51,33 V DCR = 23,6 mHz/V | mm*2 mm*2 | Rq = 68,55 Ohm Vbd = 51,45 V DCR = 23,6 mHz/mm^A Rq = 70,86 Ohm Vbd = 51,40 V DCR = 23,6 mHz/mm^ | R2000 | 148 200 | Rq = 67.43 Ohm Vbd = 51,52 V DCR = 23,6 mHz/mm*2 Rq = 67.63 Ohm VDCR = 23,6 mHz/mm*2 | 200928Å Rg = VB = DCR = VB d DCR | 69,02 Ohm * NaN V = 23,6 mHz/mm^2 68,58 Ohm = 51,48 V = 23,6 mHz/mm^2 | 0026 | |
| 200928A75406700 G Rg = 68,430m Vo = 51,48 V Vo = 51,48 V Vo = 23,6 mHz/V Vo = 23,6 mHz/V Rg = 94320m Vo = 21,3 mHz/V | mm*2 mm*2 mm*2 | 200928A75406701 Rg = 70,84 Ohm VDC = 31,35 VDC = 23,6 mHz/ VDC = 23,6 mHz/ VDC = 23,6 mHz/ VDC = 23,6 mHz/ VDC = 23,6 mHz/ | nm+2 nm+2 nm+2 | 200928A75406700CE Rq = 68,55 Ohm Vod = 51,48 V DCR = 23,6 mHz/mm ² Rq = 70,86 Ohm Vod = 51,40 V DCR = 23,6 mHz/mm ² Pdq = 51,60 Hz DCR = 23,6 mHz/mm ² | N2 N2 N2 | | Ra = 47,43 Orbin Wea = 51,25 Q* DCR = 23,5 G*Hz/mm*2 DCR = 23,6 d*Hz/mm*2 | 200928Å | 40,02 Ohm Han V Han V 23,6 mHz/mm*2 51,46 V 51,46 V 23,6 mHz/mm*2 46,69 Ohm 51,40 V 23,6 mHz/mm*2 | | |
| 200928A75406700 | 00CER200050 mm^22 mm^22 mm^22 | 200928475406701 Rg = 70,16 CMm Rg = 0,13 V DCR = 23, smbt/ Rg = 0,75 CMm Rg = 0,75 CMm VDCR = 23, smbt/ Rg = 13,4 V DCR = 23, smbt/ Rg = 70,60 CMm VDCR = 23, smbt/ VDCR = 23, smbt/ Rg = 70,60 CMm | mm ⁺ 2 | Ra = 64,35 Othe Vod = 51,46 V DCR = 23,5 mHz/mm ² Ra = 70,86 Othe Vod = 51,46 V DCR = 23,5 mHz/mm ² Ra = 70,86 Othe Vod = 51,46 V DCR = 23,5 mHz/mm ² Ra = 64,79 Othe Vod = 51,36 V DCR = 23,5 mHz/mm ² DCR = 23,5 mHz/mm ² | R2000 | | Rg = 67,43 Ohm PGR = 23,2 Ohm PGR = 23,2 Ohm PGR = 23,2 Ohm PGR = 24,2 Ohm PGR = 23,6 Birt/Jmm*2 | 200928Å Rg = DCR Ved UbdR Ved UbdR Ved UbdR Ved UbdR Ved UbdR | Von ProcER201 68,52 Ohm Na V 23,6 mHz/mm*2 23,6 mHz/mm*2 23,6 mHz/mm*2 68,55 Ohm 51,48 V 23,6 mHz/mm*2 68,52 Ohm 51,40 V 23,6 mHz/mm*2 51,24 V 23,6 mHz/mm*2 | | |
| $\label{eq:response} \begin{array}{c} 200928A75406700\\ R_0=63,4000\\ 000=72,4000\\ $ | mm*2 mm*2 mm*2 mm*2 mm*2 | 200928475406700 Rg = 70,64 Otem Rg = 70,64 Otem Rg = 60,75 Otem Color = 23,6 mHz/ Color = 23,6 mHz/ Color = 23,6 mHz/ Rg = 70,06 Otem Rg = 62,76 Otem Rg = 70,06 Otem Rg = 70,000 Otem Rg = 70,0000 Otem Rg = 70,000 Ote | mm ⁺ 2 mm ⁺ 2 mm ⁺ 2 | Rq = 64,55 Ohm Void = 51,46 V Void = 51,47 V Void = 51,38 V | R2000 | | Rg = 67,43 Ohm VG = 67,43 Ohm VG = 51,52 M VG = 51,52 M VG = 51,52 M VG = 51,52 M VG = 51,55 M VG = 51,55 M VG = 51,55 M VG = 51,55 M VG = 51,35 M VG = 23,5 M Rg = 67,53 Ohm Ng = 67,53 Ohm VG = 23,5 M VG = 23,5 M | 200928Å Re = Ved Ved Re = Ved Ved Ved Ved Ved Ved Ved Re = Ved Ved Ved Re = Ved Ved Ved Re = Ved Ved Re = Ved Ved Ved Ved Ved Ved Ved Ved Ved Ved | 6,82 Chan 6,82 Chan 1,84 Y 21,6 eHz/mm ⁺ 2 45,95 Chan 6,59 Chan 2,5,6 Hz/mm ⁺ 2 2,6,80 Chan 2,5,6 Hz/mm ⁺ 2 2,5,6 Hz/m ⁺ 2 2,5 Hz/m ⁺ 2 | | |

Labview interface

29/11/2022



• A unique Labview interface allows to perform each step of the quality assurance tests

At the end, a panel shows the final report and if the SiPMs are in specs.









Acquisition example

IV curve:

- The system sets the voltage and measures the current flowing through each SiPM simultaneously (different parameters can be set);
- R_q and V_{bd} estimations from online fits of the data;



Global DCR:

• The system sets the over-voltage and measures the total counts above 0.5 p.e. in a defined time window.







Performance

Features:

- 55 liters liquid Nitrogen auto refilling system;
- 120 parallel channels;
- Voltage precision 10mV;
- DC acquisition mode;
- Measured current range from 10nA to 3mA;
- AC acquisition mode;
- Programmable threshold DCR;
- 60cm translator stage.

Complete quality assurance tests for 120 SiPM in parallel!











Measurements and commissioning phase

During April and May 2022 Bologna and Ferrara groups received and performed the complete characterization of:

- ~4200 HPK sensors;
- ~3200 FBK sensors;











Measurements and commissioning phase

During the thermal cycles in LN2 the humidity freezes inside the connector of the cold boards \rightarrow in this case it is impossible to measure R_q and V_{bd}





A new connector has been identified suitable for the application (EQCD-020-23.62-SBR-SBR-1-B)

better "protection" from humidity without loss of electrical connection







HPK loads Vbd @ LN2

Vbd spreads in Loads LOADs 0001-0029 - LN2 third cycle @FE, 2022/04









HPK loads R_q @ LN2

Rq spreads in Loads LOADs 0001-0029 - LN2 third cycle @FE, 2022/04









HPK loads DCR @ LN2

DCR spreads in Loads LOADs 0001-0029 - LN2 third cycle @FE, 2022/04









FBK loads Vbd @ LN2

Vbd spreads in Loads LOADs 001-008 - LN2 third cycle

@FE, 2022/05









FBK loads R_q @ LN2

Rq spreads in Loads LOADs 001-008 - LN2 third cycle @FE, 2022/05









FBK loads DCR @ LN2



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INFN

Sorted V_{bd} on FBK sample LN₂











Replication of the mass test facility

- Warm electronics
- **Cold electronics**
- **Mechanics** (flange, cold boards support)

Step motor

- **Dewar 55 It (**with automated refill system)
- **Black box** for housing of the apparatus
- **Power supply** (V_{bias} Source measure Unit) \rightarrow in charge of the hosting labs

- \rightarrow provided by Fe-Bo
- \rightarrow provided by Fe-Bo
- \rightarrow provided by Fe-Bo
- \rightarrow in charge of the hosting labs
- \rightarrow in charge of the hosting labs
- \rightarrow in charge of the hosting labs
- **Power supply** (step motor, warm electronics, DCR system) \rightarrow in charge of the hosting labs







Conclusions

- Bologna and Ferrara sites: SiPM massive test system CACTUS;
- CACTUS can measure IV-curve ($\rm R_q$ and $\rm V_{bd}$) and global-DCR for 120 SiPMs in parallel;
- CACTUS can perform a variable number of thermal cycles following programmable profiles;
- Till now we tested ~4200HPK and ~3200FBK SiPMs;
- Cold Bord for replicas already produced;
- New groups involved in SiPM characterization (Milano, Prague, Granada).







