

SiPM Production Testing Status for FD-HD

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Dune ITALIA

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SiPM Quality Assurance Test Setup

Purpose:

- Verify SiPM working parameters;
- Failure/mortality rate;
- Quality assurance;

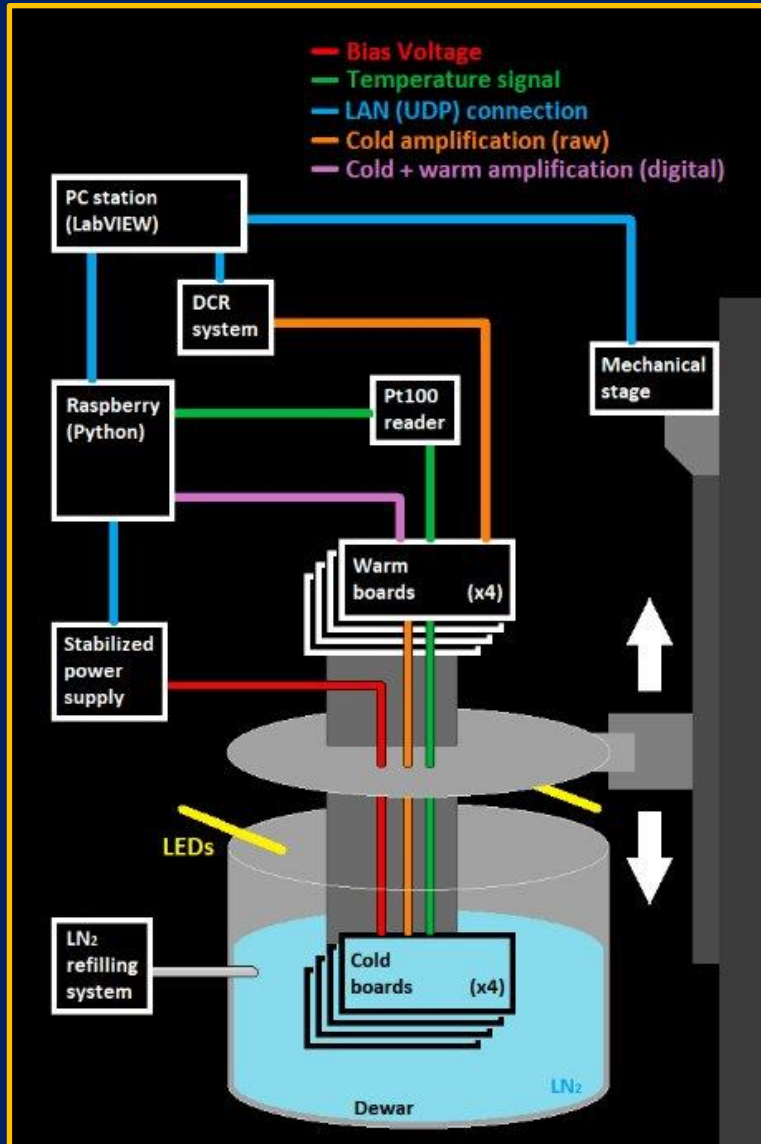
Test sites:

Bologna, Ferrara, Granada, Milano Bicocca and Prague;

Measurements performed:

- IV @ Room Temperature $\rightarrow R_q / V_{BD}$
- IV @ LN₂ $\rightarrow R_q / V_{BD}$
- Thermal Cycles
- IV @ LN₂ $\rightarrow R_q / V_{BD}$
- Extended IV @ LN₂ Temperature
 - Identification of anomalous I-V curves
- DCR @ LN₂ Temperature:
 - detection of noisy SiPMs

Test rate: 2400 SiPMs/month @ each site



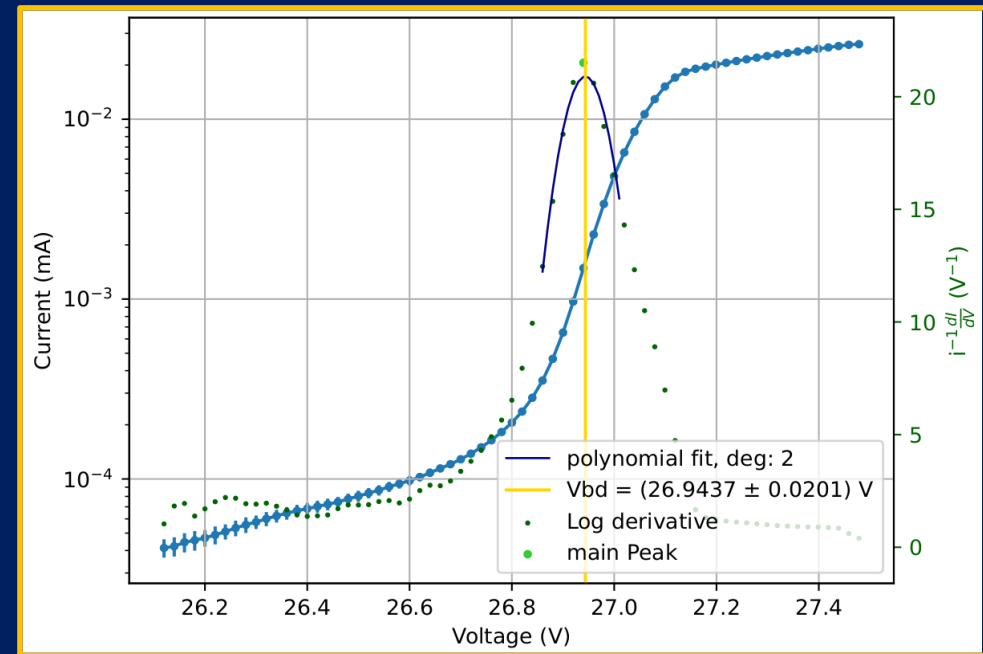
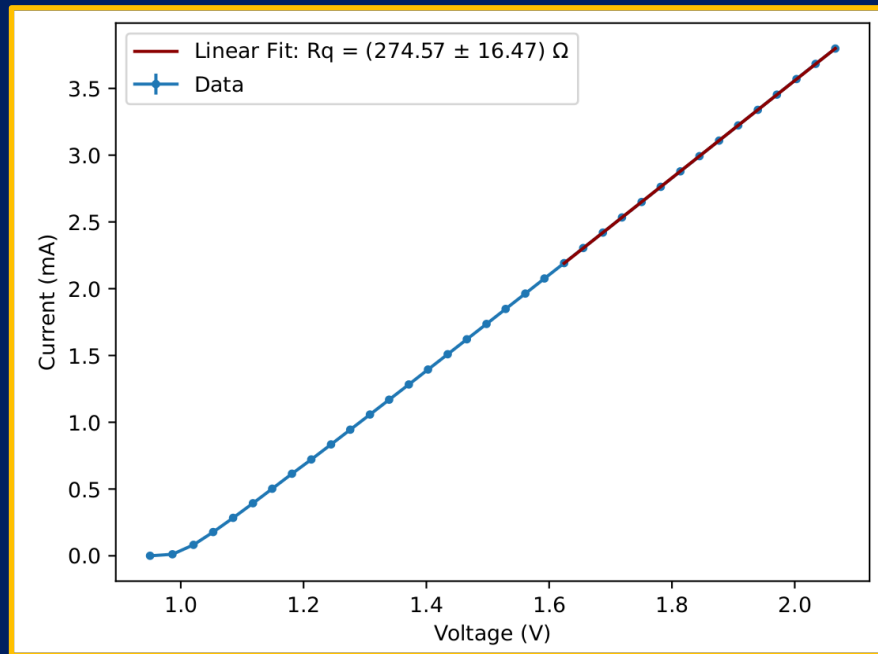
Warm boards + front-end cards:

- 4 motherboards/system;
- 15 front-end cards/motherboard;
- 120 independent channels;
- Current measurement/digitalization;
- Signals acquisition;
- Power supply.

Cold boards:

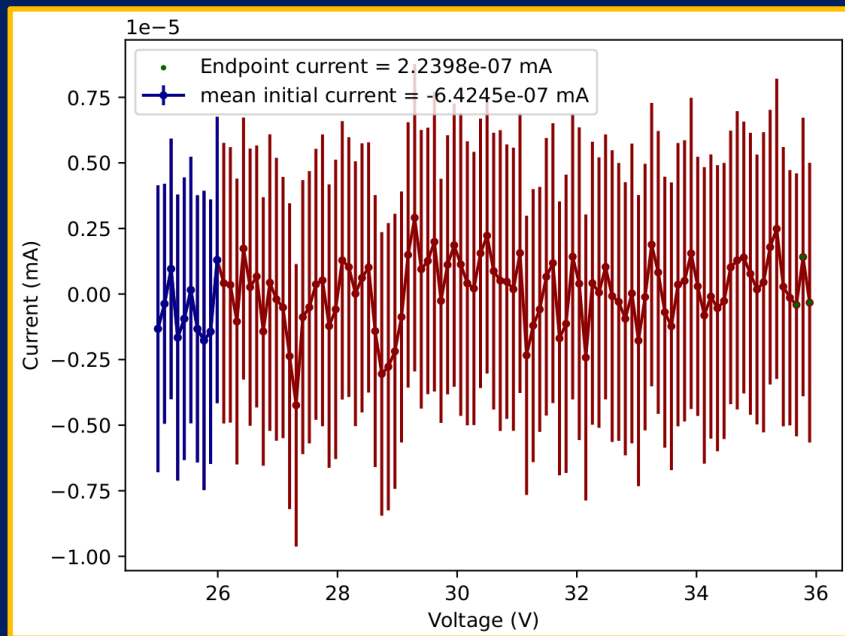
- 4 boards/system;
- 5 arrays/board;
- 120 SiPM;
- Temperature monitor;
- Bias voltage

Examples of LN₂ Measurements



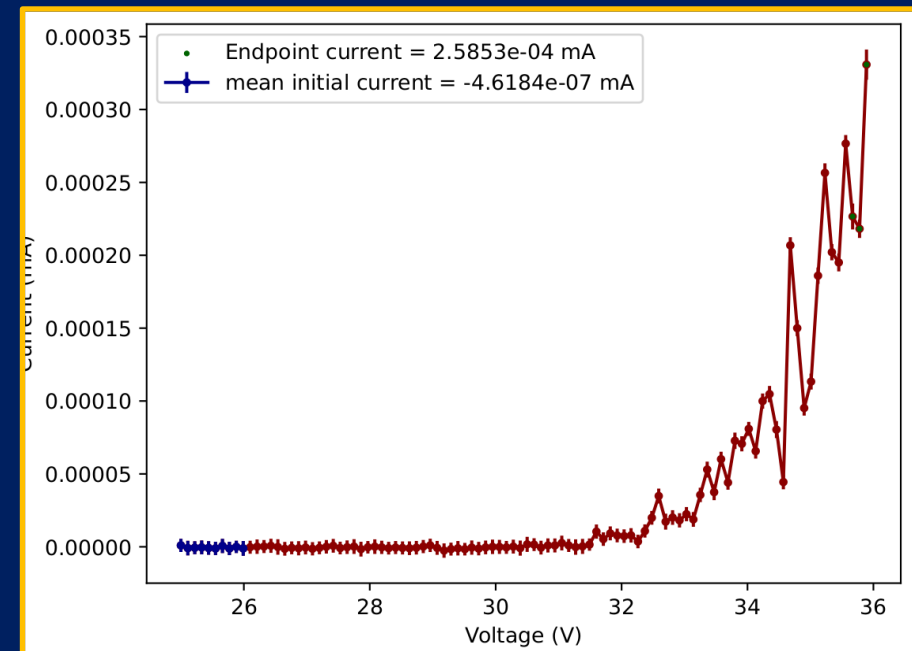
Extended IV examples

Normal SiPM: mHz DCR



Current below CACTUS electric noise (20nA)

Anomalous SiPM: KHz DCR



Count ~ 32kHz -> Current ~ uA

Bologna site

Team:

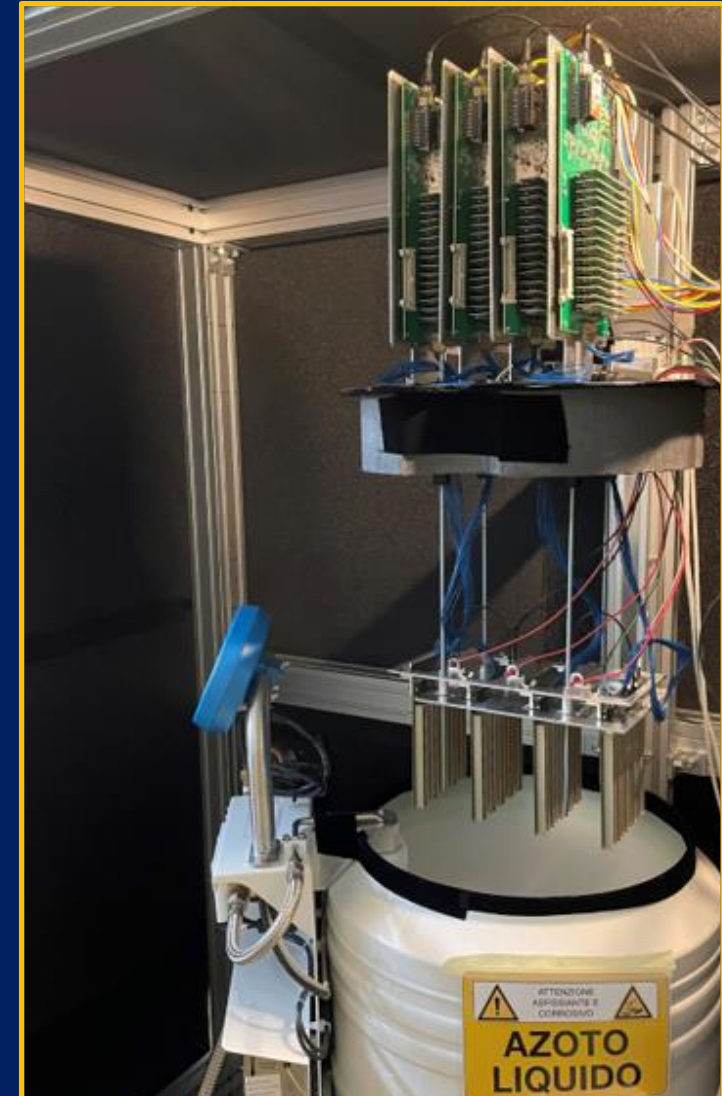
- 8 people involved in testing and analysis

Testing Overview:

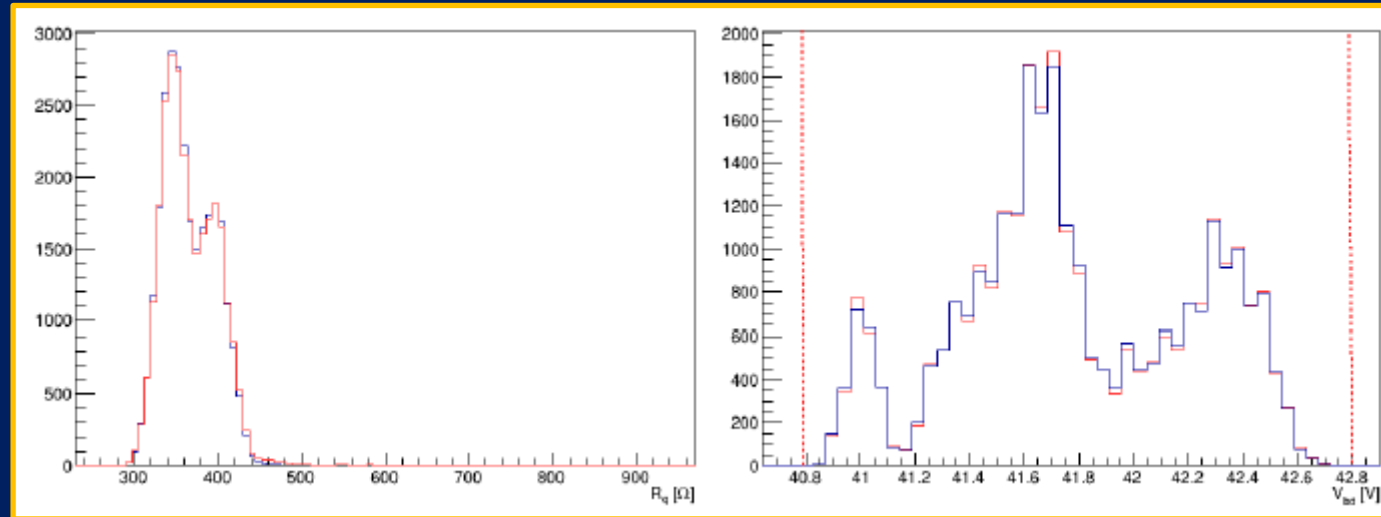
- Test rate: ~ 2400 SiPMs per month
- HPK tests completed:
 - 9 boxes from the HPK Spanish lot
 - 4 boxes from the HPK Italian lot
- FBK ongoing tests:
 - 1 box of the FBK production lot received (1/2 tested)
 - 1 box in arrival

Issues Encountered:

- Noisy channels during DCR measurement → issue resolved
- One channel disconnected (ARDU-0 SiPM-9):
Seems a problem in the warm board → in contact with Marco.



HPK summary plots



Ferrara site

Team:

- 6 people involved in testing and analysis

Testing Overview:

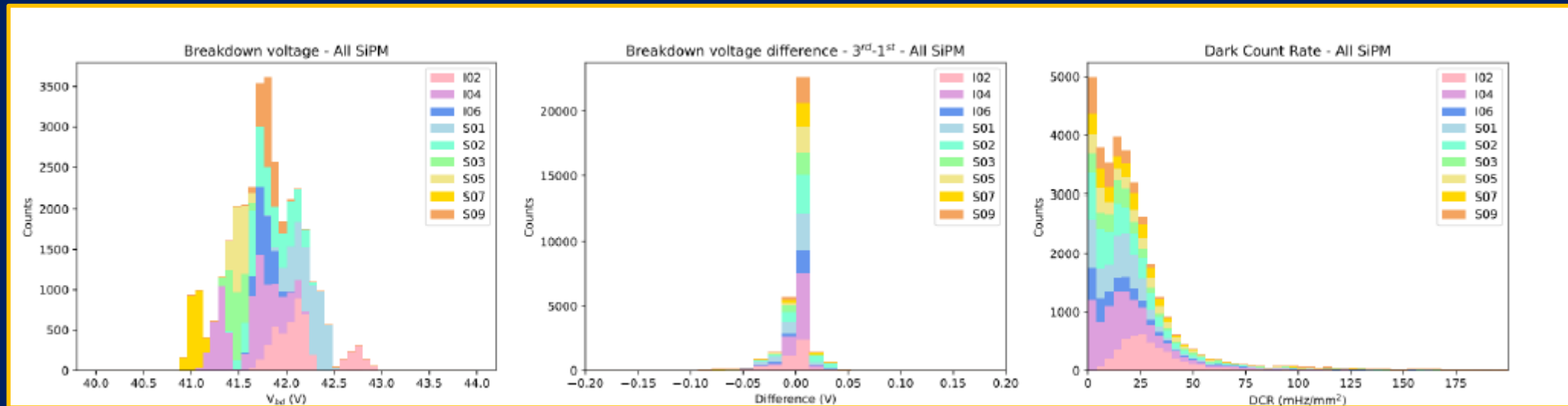
- Test rate: ~ 2400 SiPMs per month
- HPK tests completed:
 - ~21.6k sensors HPK Spanish lot
 - ~12k sensor HPK Italian lot
- FBK ongoing tests:
 - 3 boxes completed;

Issues Encountered (FBK):

- 9 boards with issues in high DCR found/extended IV



HPK summary plots



Granada Site

Team:

- 4 people involved in testing and analysis

Testing Overview:

- Test rate: ~ 2400 SiPMs per month
- HPK tests completed
- FBK ongoing tests:
 - 1 box completed;
 - 1 box ongoing

Issues Encountered (FBK tests):

- 9 failed board Broken SiPMs during the 1st thermal cycle + SiPMs detached



Milano Site

Team:

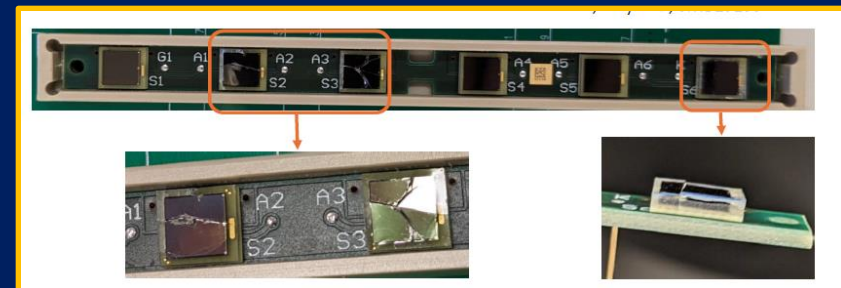
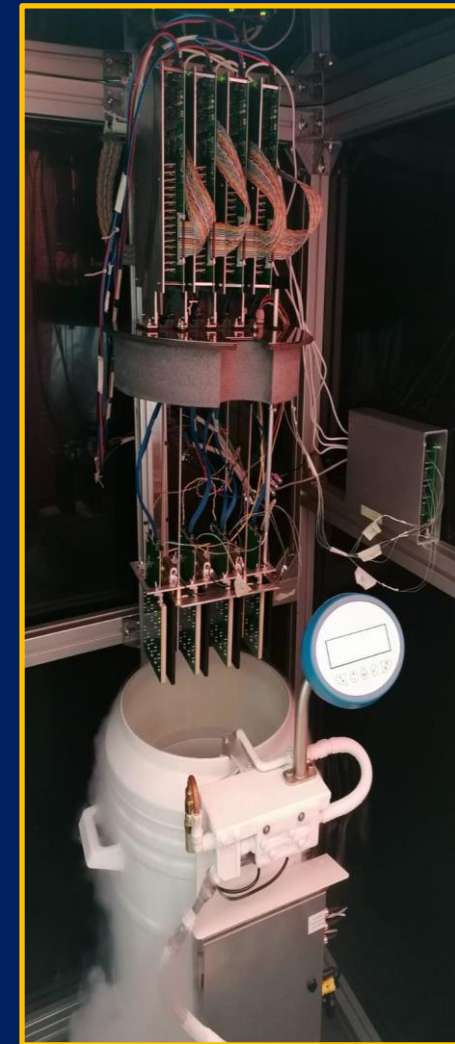
- 6 people involved in testing and analysis

Testing Overview:

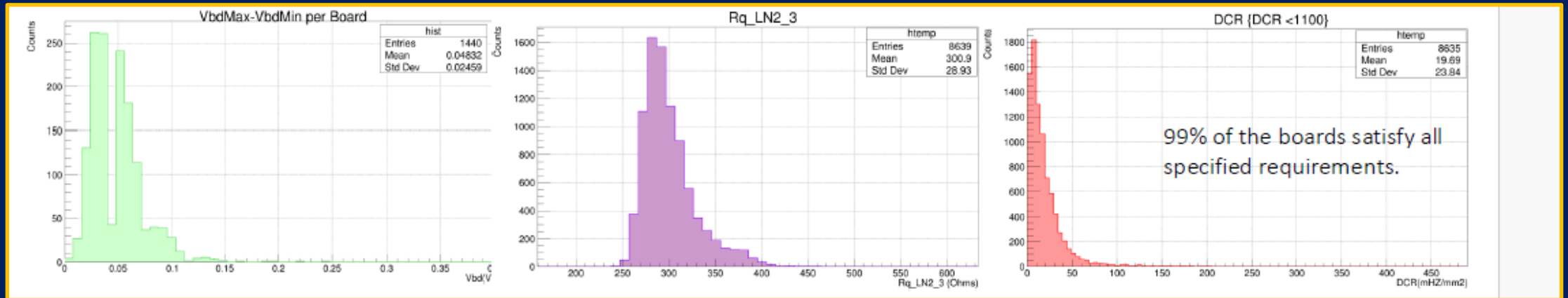
- Test rate: ~ 2400 SiPMs per month
- HPK tests:
 - 8 boxes from the HPK Spanish lot.
 - 6 boxes from the HPK Italian lot.
- FBK ongoing tests:
 - 3 boxes from the FBK Spanish lot

Issues Encountered (FBK tests):

- Boards with broken SiPMs.
- Forward IV curve: low current is observed for some SiPM.
- Reverse IV curve was not obtained.



FBK results



Prague Site

Team:

- 2 physicists, 2 engineers and students for testing & evaluating

Testing Overview:

- Test rate: ~ 2400 SiPMs per month
- HPK tests completed (Spanish & Italian lot):
- FBK ongoing tests:
 - 3 boxes completed;

Issues Encountered:

- FBK with broken / detached sipms after 1st thermal cycle (or after the 2nd)



Delivery	Box	Boards	Bad boards
3	4	500	4
5	6	500	9
7	9	500	18

MASSIBO test setup

An additional setup (@Valencia):

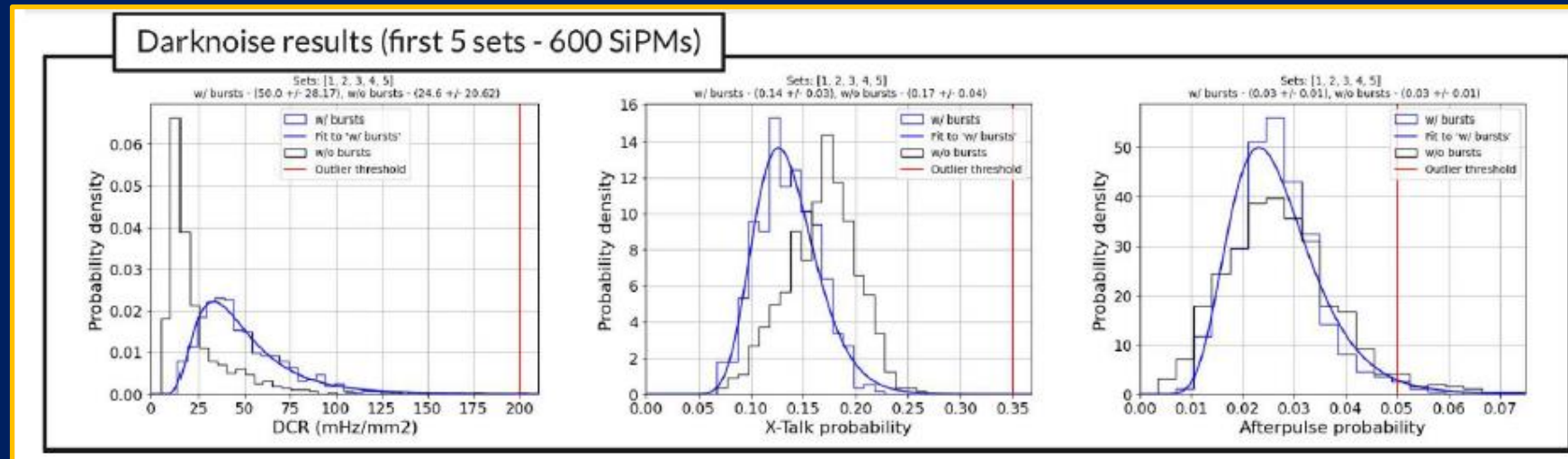
- handles ~5% of the boards.
- These are tested for parameters not covered by standard mass testing, such as:
 - Cross-talk
 - After-pulse probability
 - Gain
 - High-precision DCR (Dark Count Rate)

MASSIBO (Valencia setup)

- Work team:
 - 1 PhD student, 1 Postdoc and 1 Engineer
- Measurements taken by this setup:
 - DCR
 - XTP
 - APP

Tested:

-1200 HPK SiPMs have been measured.
~3000 HPK SiPMs + ~3000 FBK SiPMs will be measured.



Statistics SiPM tests



- ~100k SiPMs (Spanish lot) *100% Delivered and tested*
- ~60k SiPMs (Italian lot) *100% Delivered and tested*
- Failure board rate: *0.3%*

- ~100k SiPMs (Spanish lot) *24.4% Delivered and tested*
- ~40k SiPMs (Italian lot) *Afterwards*
- Failure board rate: *1.4%*

Total: 299,568 SiPMs -> 61.5% tested

DUNE HWDB

- selected to store the measurement data generated by SiPM Quality Assurance sites.
- So far, we have uploaded over 6,000 items to the development version of the HWDB.
- A preliminary script is employed to download the spreadsheet, which is accessible in the image section, using the board's serial number.
- We will soon begin uploading our data to the production version. The final details of the schema are currently being finalized.

Conclusions

- All sites are continuing with the FBK SiPM tests.
- HPK SiPM tests are complete (0.3% of failed boards).
- FBK NUV-HD-Cryo3T SiPMs: 150000 sensors to be produced and tested
- FBK sensor failure rate due to high DCR 0.2%;
- FBK sensor overall failure rate: 1.4%
→ currently under investigation with FBK
- MASSIBO will proceed with testing the HPK –Italian lot.
- We will soon start uploading the data to the production version of the DUNE HWDB.