

# CRYOGENIC APPLICATIONS - SUMMARY

- Part 1 – yet another contribution
- Part 2 – summary and outlook

# RELIABILITY ISSUES OF SIPMS FOR LARGE SCALE APPLICATIONS

Vishnu Zutshi, NIU

A problem: (take DUNE as an example)

- You want to build ~\$500M experiment and use SiPMs as a readout technique
- You select the best product offered by the vendors and meeting your requirements
- You (or the review committee) read the fine print of the data sheet



Screen Shot 2018-06-15 at 00:20:03

SMT Package Specifics			
	1mm	3mm	6mm
	10010, 10020, 10035, 10050	30020, 30035, 30050	60035
Package dimensions	1.5 x 1.8 mm <sup>2</sup>	4 x 4 mm <sup>2</sup>	7 x 7 mm <sup>2</sup>
Recommended operating temperature range	-40°C to +85°C		

**Is it a problem??**

# PART II: FLASHBACK

- What did we hear/learn about
  - There is a lot of fundamental physics of semiconductors which ought to guide new detectors design and/or characterization and calibration strategies (Gianmaria Collazuo in absentia)
  - Readout of SiPMs for cryogenic applications presents new sets of challenges which are being implemented or researched world wide (Wataru Ootani, Adriano Di Giovanni, Christopher Hils)
  - Testing /characterization of SiPMs at cryogenic temperatures presents a set of new challenges. Sharing the experience will be very helpful. (Andrii Nagai)
  - Cold applications in large experiments bring new aspects, like reliability to the front. Close collaboration between the users and vendors is necessary. (Vishnu Zutshi)
  - It is very interesting to try to develop analytic approach/understanding. (Mainz Think Tank – Maik Biroth)

# CONTRIBUTIONS TO THE WHITE PAPER

- Need advice/recommendation
  - ‘memory dump’ of the present knowledge/experience – too voluminous and maybe not be instructive
  - Attempts to standardize - too early?
  - Tie too the other areas/subjects - cols applications present fundamentally new problems and/or specific technical issues (cryogenic)

# PRE-PROTODUNE R&D

- Sustained photosensor R&D for DUNE carried out primarily at CSU, Hawaii and IU.
- Devices from a number of vendors tested especially Hamamatsu and SensL
- After pulsing issues (cryogenic temperatures) with Hamamatsu devices of that era were observed
- Also packaging was susceptible to cracking though not necessarily correlated with changes to electrical properties
- SensL devices did not show any anomalies physically or electrically
- SensL C-Series device chosen as the photosensor for protoDUNE

# NOTE THAT...

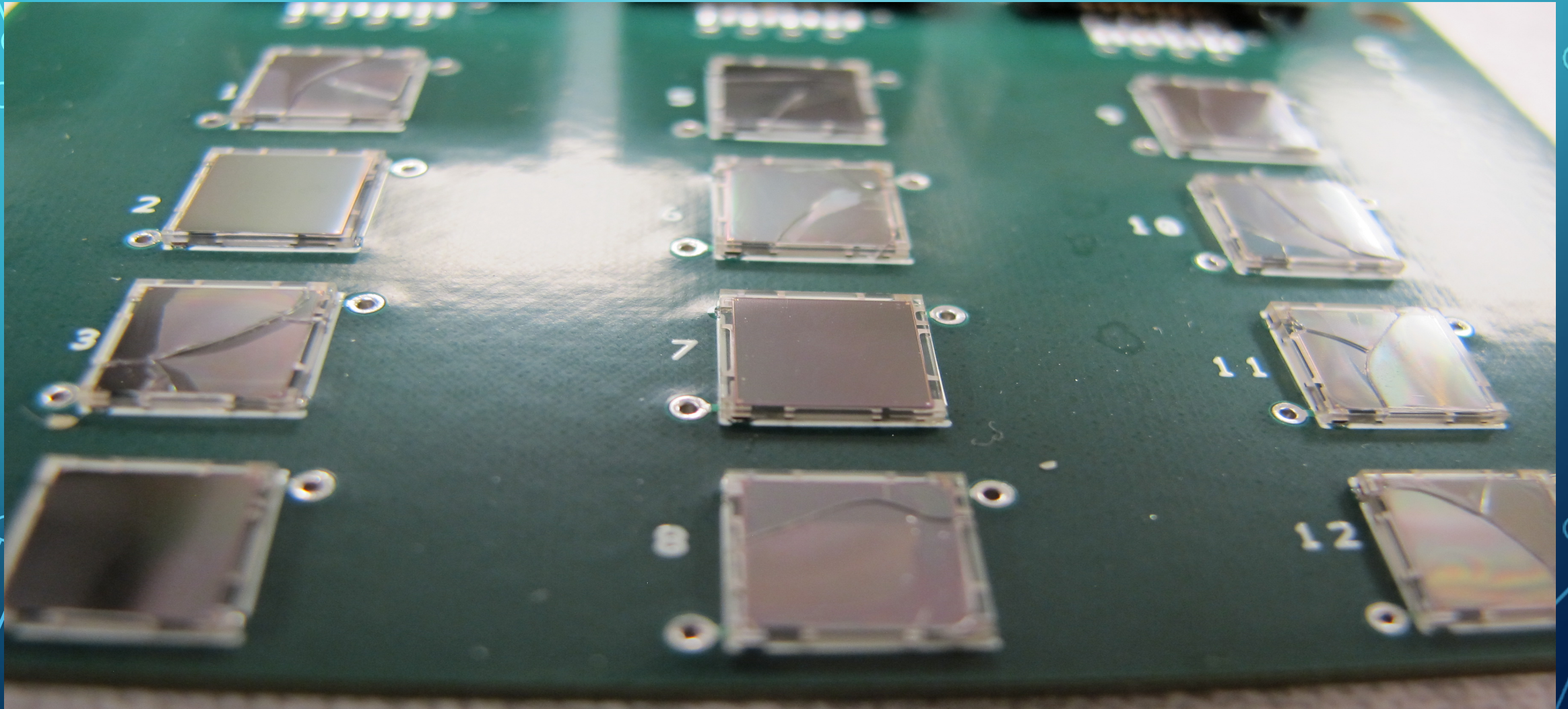
- The devices were being operated way outside their recommended operational temperatures
- Since operation at these cryo temperatures was not certified by vendors the fact that devices worked without issues was in some sense good luck
- This also meant that changes in the production process could have unforeseen consequences at LAr or LN<sub>2</sub> temperatures since they were in principle outside the range of applicability of the devices as tested by vendors



# PROTODUNE EXPERIENCE

- 1700 MicroFC-60035-SMT were ordered
- Same part number as was used in years of pre-protoDUNE R&D
- After arrival, the devices were mounted on readout boards while observing all soldering and humidity constraints recommended by the vendor
- A very significant fraction (upto 50%) started physically cracking on their very first dipping into LN<sub>2</sub>
- This (the cracking) was independent of whether the devices were mounted or unmounted
- The cracking rendered the devices non-functional
- Dipping procedures had not been modified

# THE COLD (VERY COLD) SHOWER





# CONVERSATION WITH SENSL

- Probably a “...mold compound change...” was the culprit
- The devices exhibited no issues within the vendor specified operability ranges
- We were definitely operating outside that range
- What can be done to avoid a repeat of this unfortunate situation especially since going to the “old formulation” may not be feasible for the vendor
- Possible paths:
  - Process control
  - “cryo” testing as part of vendors program
  - Self-packaging

# PROCESS CONTROL

- Once you are happy with a set of devices; request the vendor for the exact same product (same part number is not enough)
- Sounds easy but may not be practically feasible
- Fast-moving field with process improvements
- What does “exactly same” mean? What are the relevant changes to this application?
- Vendor privileged information

# SELF-PACKAGING

- Since the issue is mostly about the packaging and not the silicon, the experiment takes it upon itself to package the device
- Probably the safest bet
- However, requires a large infrastructure, know-how, manpower etc.
- The costs may out-weigh the benefits unless one is looking for a very custom arrangement

# VENDOR TESTING

- May offer the happy medium
- If a “cryo” testing suite could be part of the vendors QA/QC process a number of issues may be put to rest
  - Would the vendors consider entertaining such a request?
  - What would the request be? What testing (and it would have to be fairly simple and efficient) would we be interested in?
  - With what frequency?