

Development and Validation of a Thermal Protection Circuit Breaker for the CMS RPC Front-End Electronics

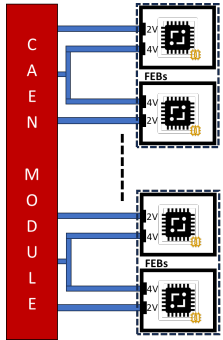
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Introduction

The problem

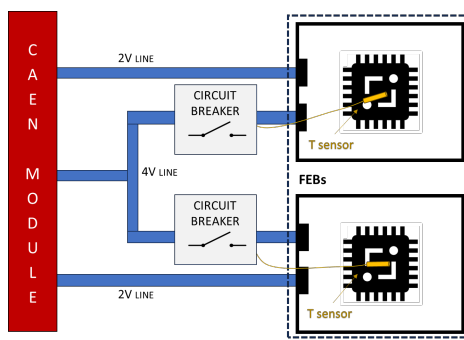


1ST
CHAMBER

- The single CAEN module supplies 4 chambers, with two power line: a 2V, and a 4V line. Each chamber is composed by two FEBs.
- Each FEB is equipped with internal temperature sensor.
- If a temperature raise happens on a single FEB, over a determined threshold, the whole CAEN module is switched off.
- Requirement of a solution which is able to isolate a single FEB in over-temperature.

4TH
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The solution

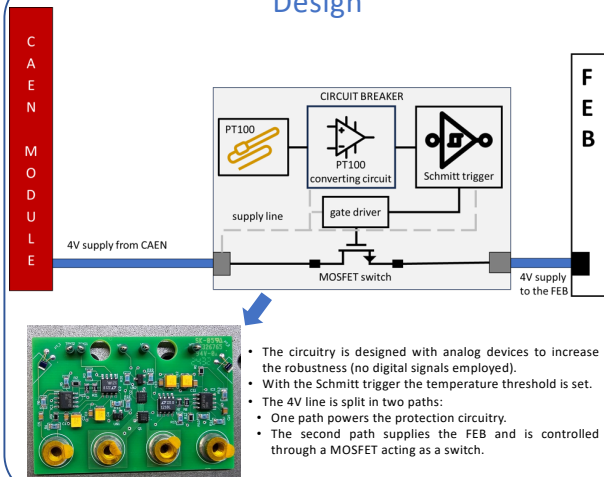


- The CAEN module supplies two voltages to the single FEB:
 - 4V, 2.5A;
 - 2V, 7A.
- The interruption of one voltage line causes the FEB shutdown.
- Need of a Circuit Breaker to shut down one FEB in case of temperature raise.

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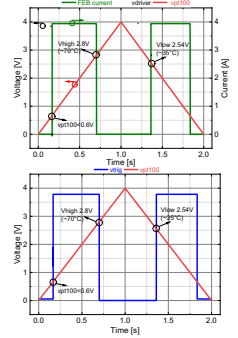
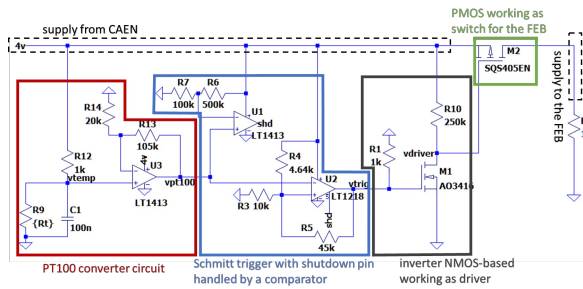
Proposed circuitry

Design



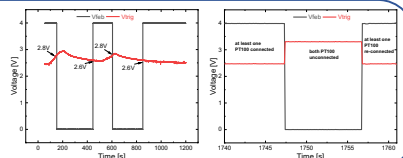
- The circuitry is designed with analog devices to increase the robustness (no digital signals employed).
- With the Schmitt trigger the temperature threshold is set.
- The 4V line is split in two paths:
 - One path powers the protection circuitry.
 - The second path supplies the FEB and is controlled through a MOSFET acting as a switch.

Numerical simulation



Validation test

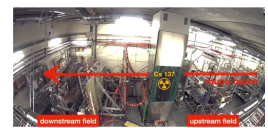
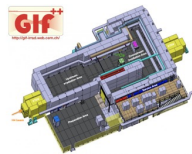
The final design is based on a redundancy, the proposed Circuit Breaker comprises two simulated circuits.
When both PT100 goes over the high threshold ($\sim 70^\circ\text{C}$) 4V line is opened.
When one PT100 goes under the low threshold ($\sim 40^\circ\text{C}$) 4V line is closed.
If both PT100 get broken, 4V line is opened.



Experimental test with detector and conclusion

Experimental Setup

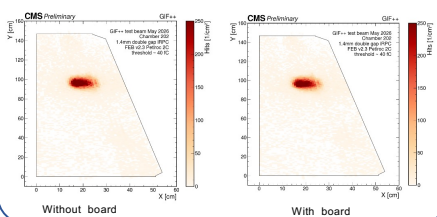
A setup of 2 iRPC detectors was made in CERN Gamma Irradiation Facility (GIF++) in May 2026 to reproduce CMS conditions. Two production iRPC chambers were exposed to different γ -background rates with a $10 \times 10 \text{ cm}^2$ muon beam. HV scans evaluated FEB and chamber performance with and without the circuit breaker. The FEB uses the PETIROC2C ASIC, optimized for RPC operation with a 40 fC charge threshold



Performance Results

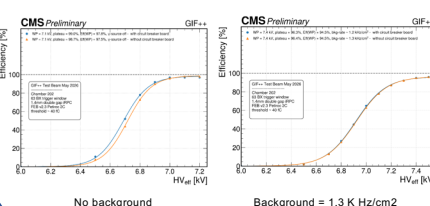
2D Hit Profile

The figures below show a 2D hit profile of the number of muon hits in the strips of a 1.4 mm double gap iRPC chamber. Data were taken at working point of 7 kV, with and without the Thermal circuit breaker connected.



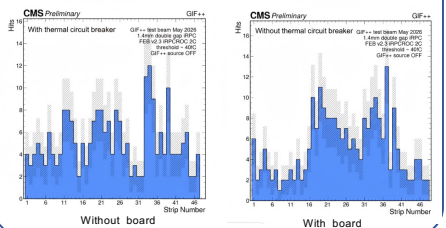
Muon Detection Efficiency

Following 2 plots show the muon detection efficiency measured with a 63-bunch-crossing trigger window at 0 and 1.3 kHz/cm² γ -background rates, with and without the thermal circuit breaker.



Noise Rate

The following figures show the strip noise distribution of the iRPC detector. Data were collected using random triggers at a 7 kV working point, with and without the thermal circuit breaker.



Conclusion: Measurements of iRPC chamber with and without the thermal circuit breaker show no degradation in chamber efficiency with and without background, detector noise, or overall performance. The circuit breaker therefore provides a safe and effective protection solution for FEBs of iRPC chambers.