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CHARACTERIZATION OF SIPM'S

Masterthesis | 2024-25 | Danté Bouckhout

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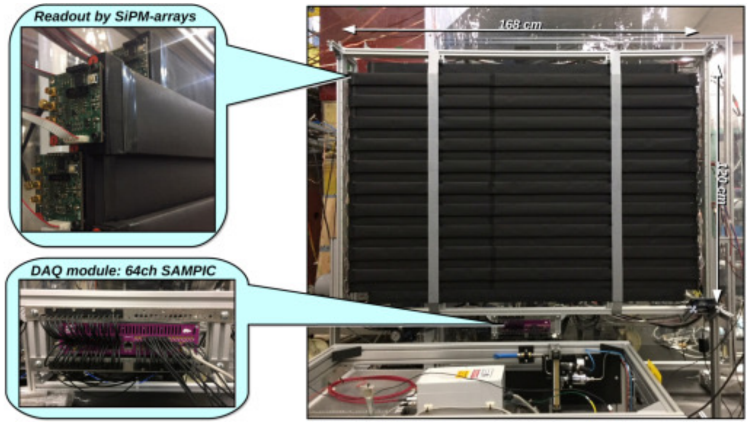
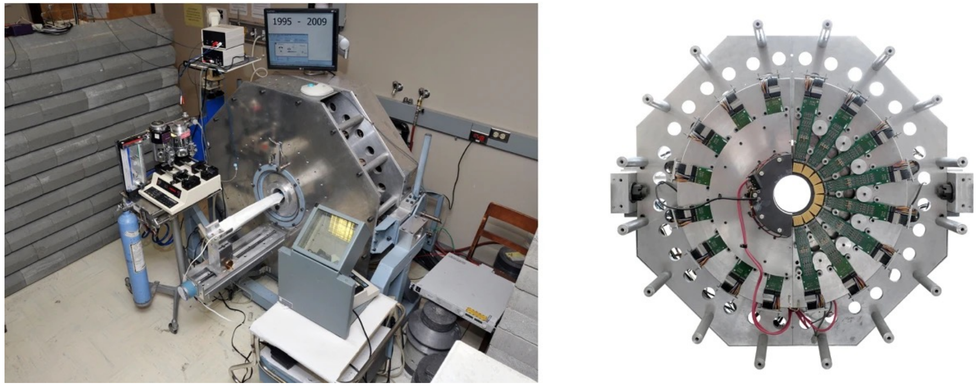
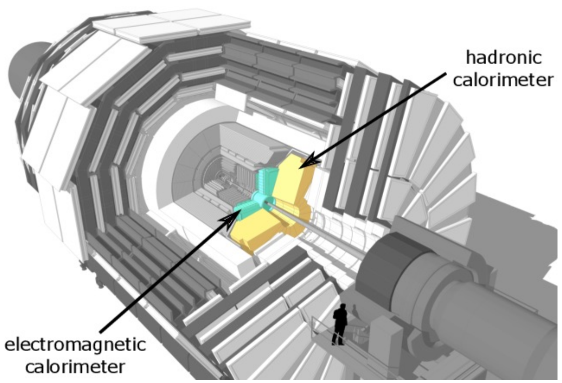
INTRODUCTION



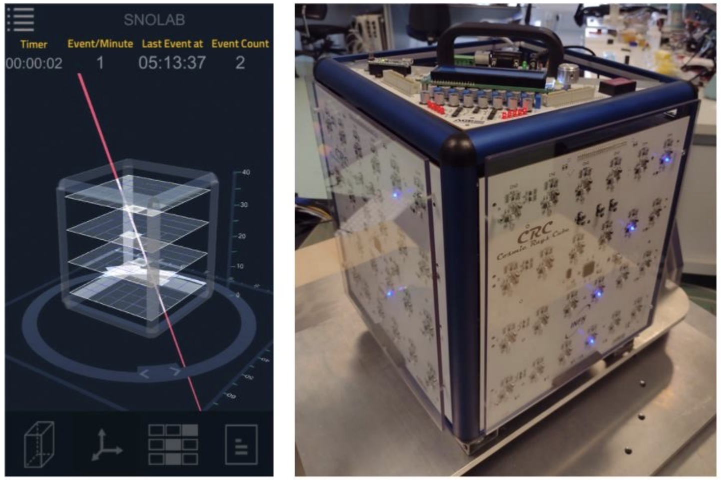
The timing detector prototype as seen in the testbeam area of the SHiP experiment



The Sherbrooke small animal PET, the first PET with APDs



Location of the HGCAL at the CMS endcap



SNOLAB SiPM detector for live cosmic rays

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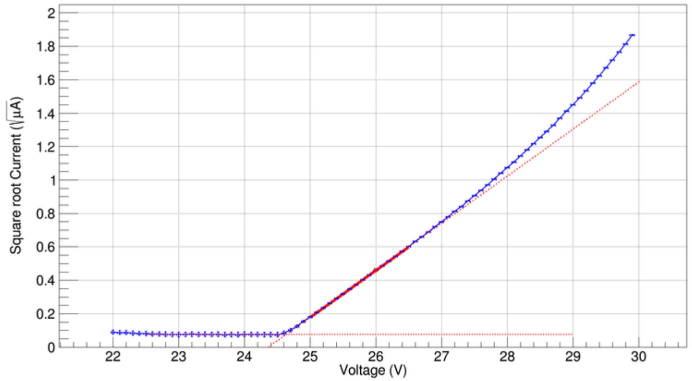
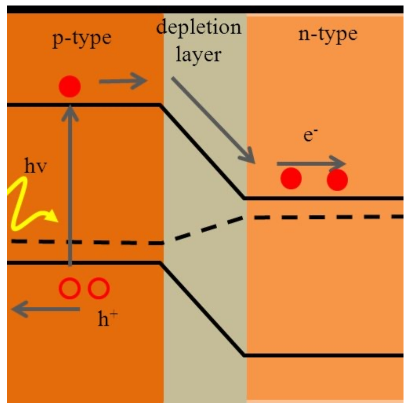
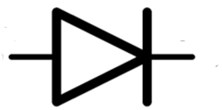
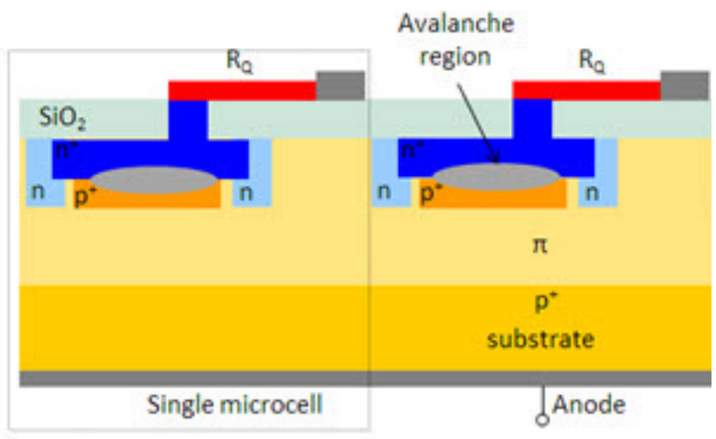
SILICON PHOTOMULTIPLIER

- Array of SPAD's
  - Single photon avalanche diode
  - Diode in reversed bias
  - Photon creates e^{-}, h^{+} pair
  - Breakdown Voltage -> accelerated e^{-} creates more e^{-}, h^{+} pair
  - Avalanche is self sufficient -> Quenching needed



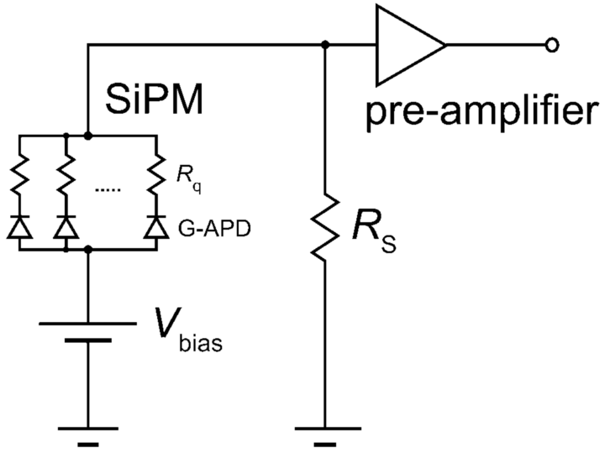


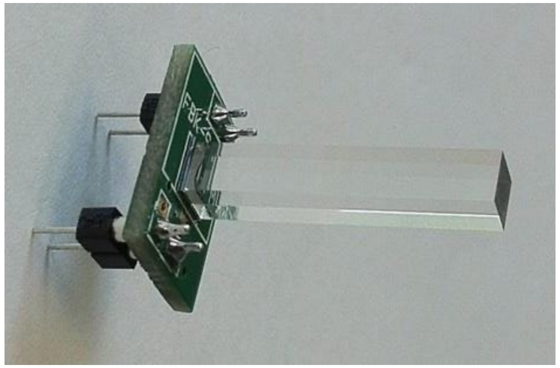


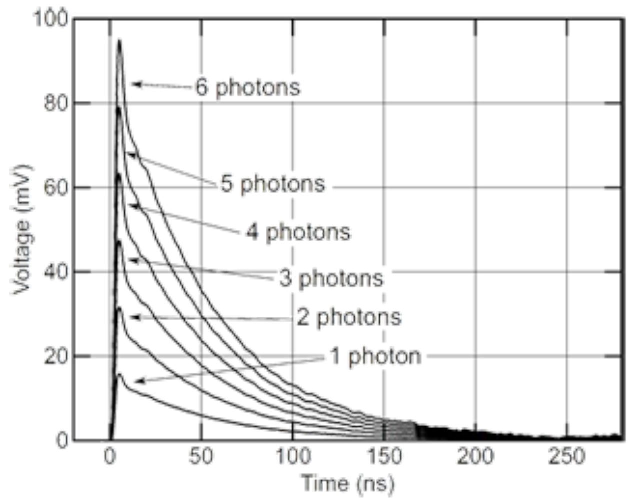


SILICON PHOTOMULTIPLIER

- SiPM outputs sum of all SPAD charge contributions
  - Photons easily countable
- Particle detection
  - used together with scintillator







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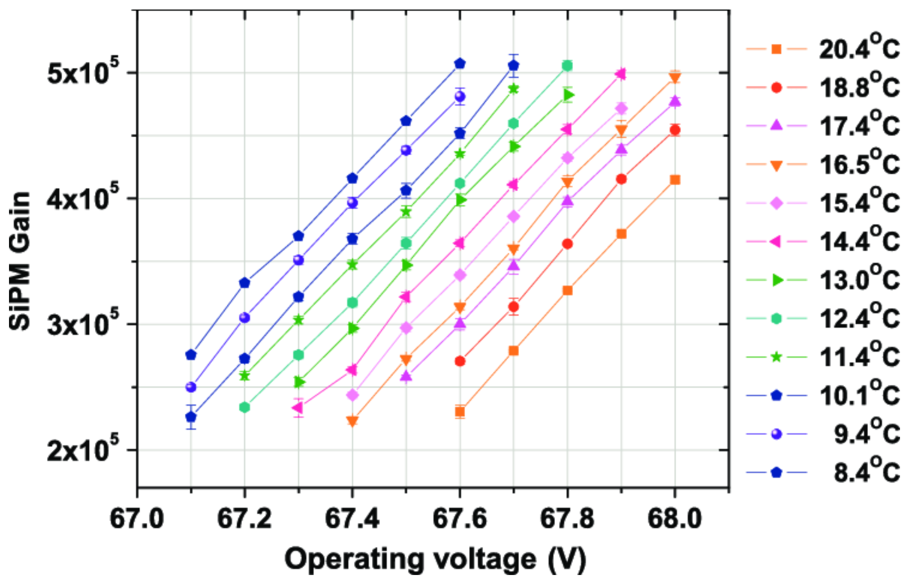
CHARACTERISTICS

- Gain
  - Charge produced by one photon
  - Influences the sensitivity and accuracy of the SiPM
  - Varies with temperature
- Dark Count Rate
- Breakdown voltage
- Afterpulsing & crosstalk
- Photon detection Efficiency



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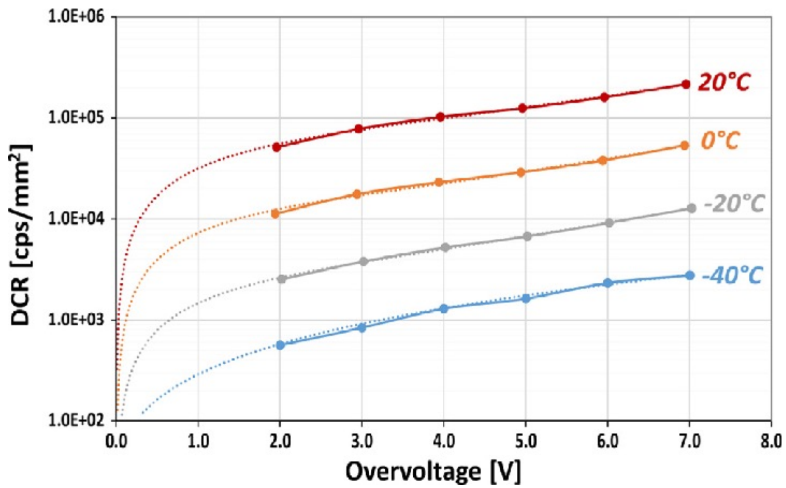
CHARACTERISTICS

- Gain
- Dark Count Rate
  - Rate of pulses generated in absence of light
  - From thermal electrons
  - Can overwhelm low-light signals
- Breakdown voltage
- Afterpulsing & crosstalk
- Photon detection Efficiency



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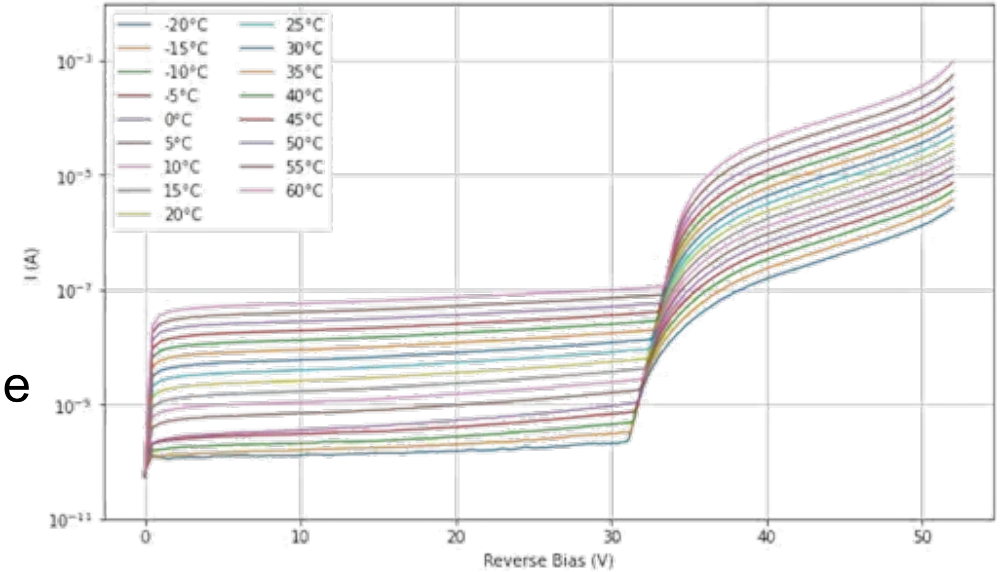
CHARACTERISTICS

- Gain
- Dark Count Rate
- Breakdown voltage
  - voltage at which the SiPM operates in Geiger mode
  - increases with temperature, affecting the optimal bias voltage setting
- Afterpulsing & crosstalk
- Photon detection Efficiency



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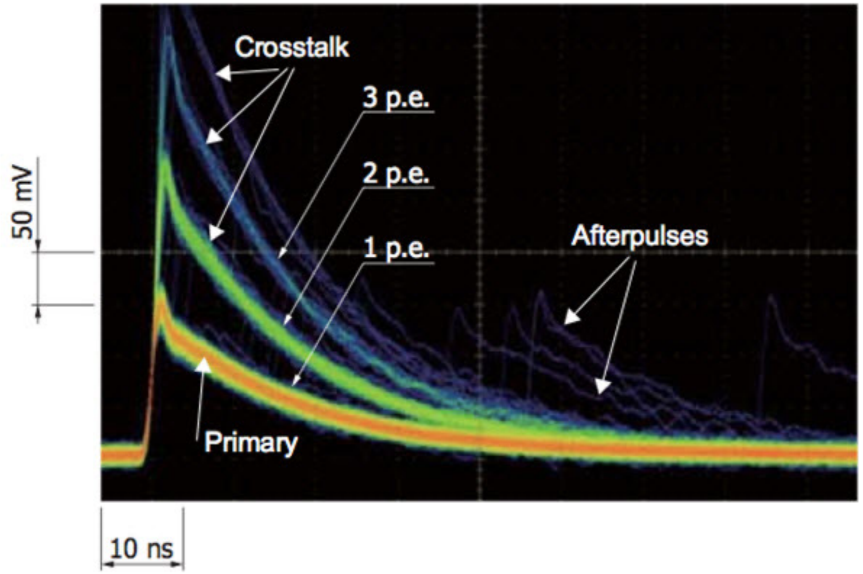
CHARACTERISTICS

- Gain
- Dark Count Rate
- Breakdown voltage
- Afterpulsing & crosstalk
  - Secondary pulses caused by trapped charges from a previous event.
  - Signals generated in neighboring cells due to charge carriers triggering adjacent pixels.
- Photon detection efficiency



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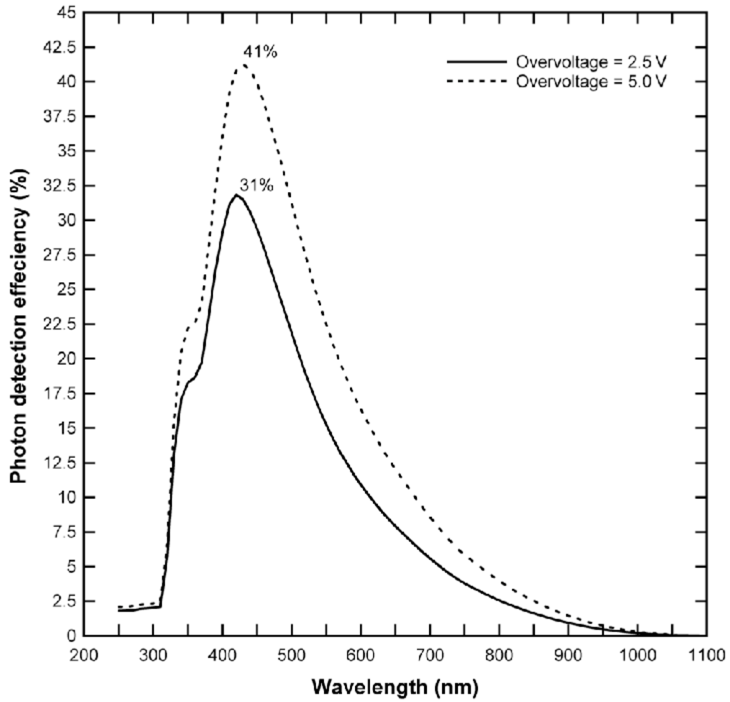
CHARACTERISTICS

- Gain
- Dark Count Rate
- Breakdown voltage
- Afterpulsing & crosstalk
- Photon detection Efficiency
  - Probability that incoming photon is successfully detected
  - vary with temperature, bias voltage, and photon wavelength



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COMPARING TO PMT

- Advantages
  - Cheaper
  - Lower bias voltages
  - Smaller volume

- Disadvantage
  - For low E photon
    more noise and worse PDE

	PMT	SiPM
Range (nm)	300-800	400-1000+
Internal Gain	10^5-7	10^5-7
Power Draw	Up to 1000V	Less than 100V
Dynamic Range	5 Decades (Fortessa)	7.2 Decades (Quanteon)[3]
Low Light Detection	Large active area and very rare dark counts	Array of microcells increases active area, more common dark counts (vs PMT) increasing with temperature
Noise	Relatively low until the ~800nm mark, increases with voltage and higher emission wavelengths	Noisier than PMT except at ~800nm+, but comparable over whole range

Source: Uchicago, B. Ladd, **PMT vs SiPM: A Photon Finish**

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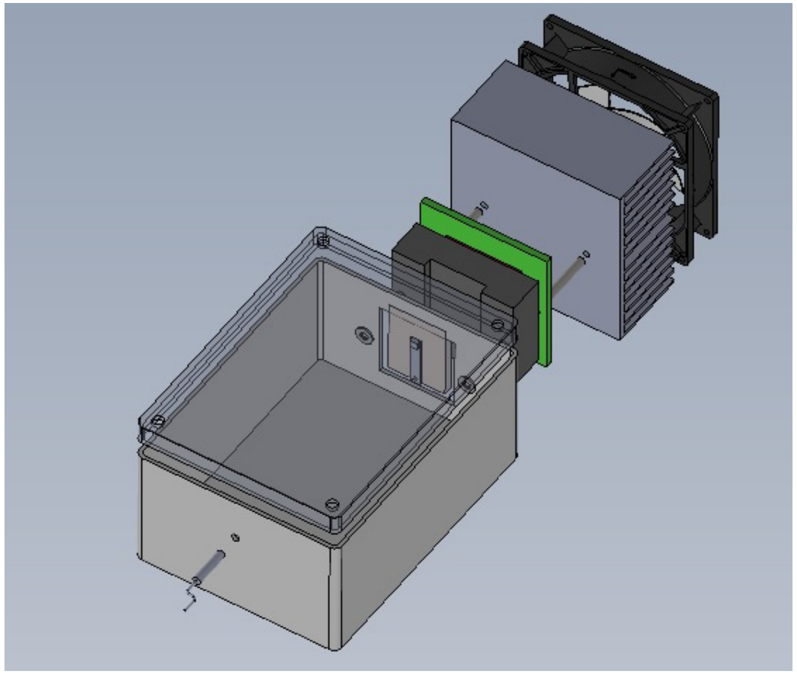
SETUP

- Temperature controlled light-tight box
  - Peltier elements
  - Arduino
  - Controlled photon input
  - Temperature + env sensors
- Front end electronics
  - Amplifier
  - Signal shaper



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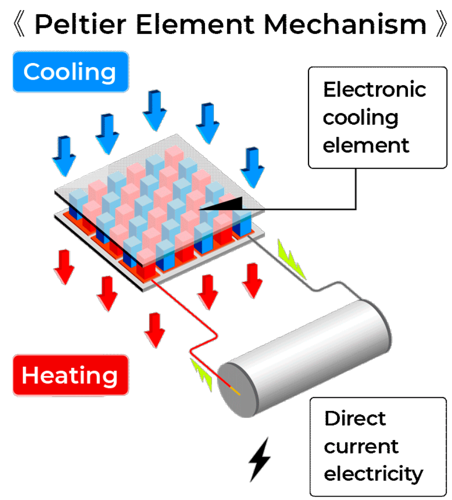
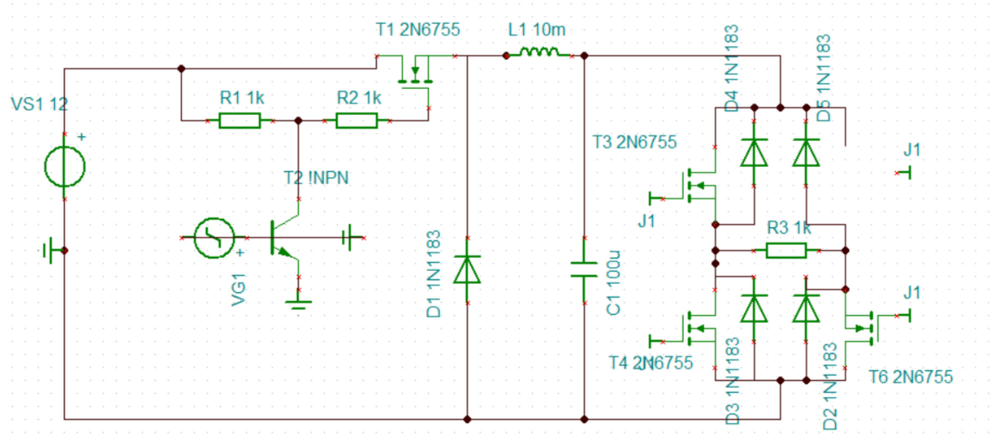
PELTIER COOLING

- PWM of arduino into LC and H-bridge
  - Controll peltier to heat or cool side with SiPM
- Automative setup
  - Using arduino to read temperature and adapt Peltier current





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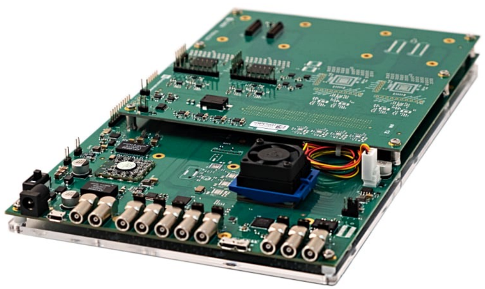
FUTURE

- Making of the box
  - Light tightness, ease of use
- SiPM readout
  - Also automatable
- Using SiPM and scintillator grids to track particles

Lokalenverhuur voor jeugdverenigingen



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