SiPMs with plastic scintillators

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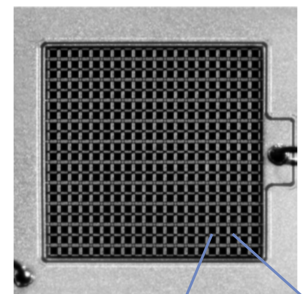
Introduction

- SiPMs were invented in the late 90s by Golovin and Sadygov, as single photon detectors
- In the last 10 years the performance in terms of efficiency and noise improved significantly
- Many experiment in different areas now use or plan to use SiPMs

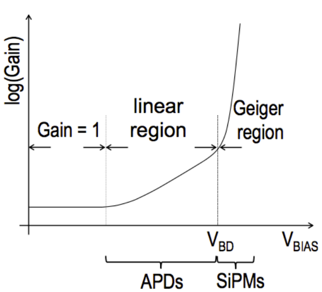
- Aim of this laboratory is the sharing of our experience on a specific application: ***photodetection of light produced in plastic scintillator by minimum ionizing particles***

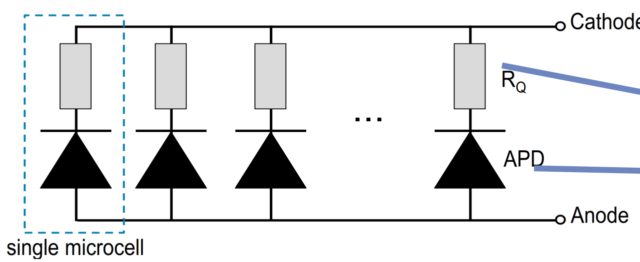
SiPM architecture

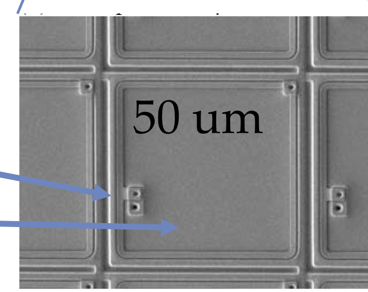
- A silicon photodiode with high gain
- p-n junction engineered to provide high field
  - Photon produces e-h pair
  - Avalanche multiplication
  - Cell (pixel) discharges
  - Avalanche is stopped by passive quenching



- Matrix of Geiger-mode pixels
  - Each pixels fires when hit by one photon (or by noise)
  - Signals from all pixels are summed







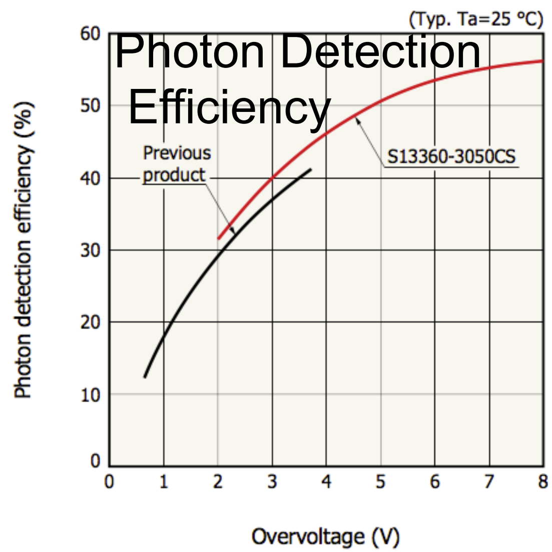
SiPM characteristics

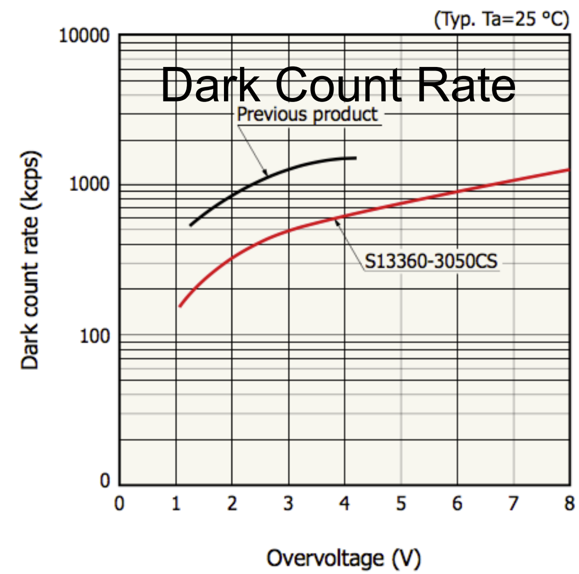
- High Quantum Efficiency
- Insensitive to magnetic field
- Small, cheap, robust

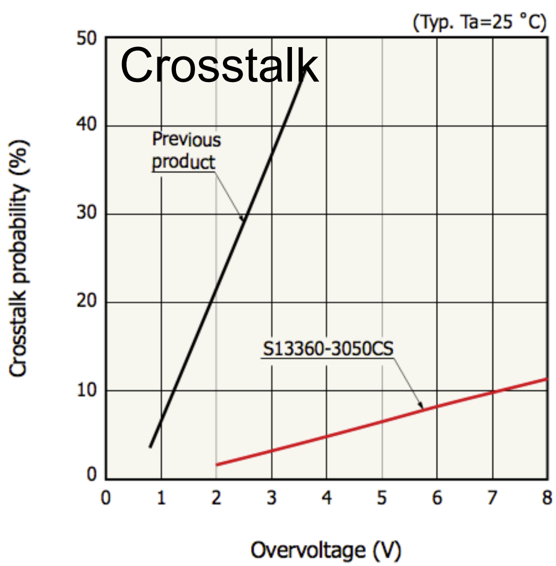
But

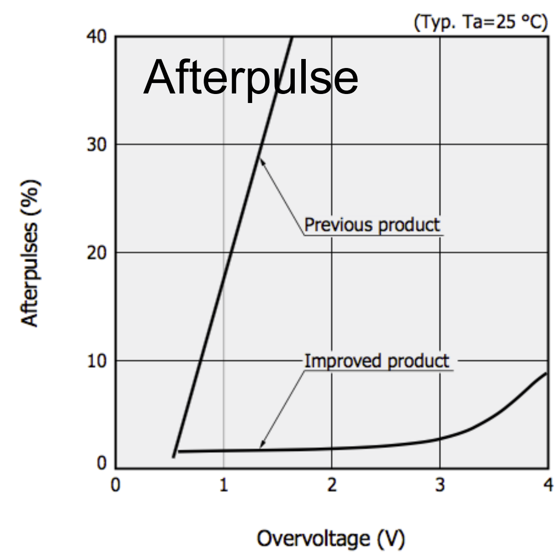
- Sensitive to temperature
- Suffers from radiation damage
- High Dark Count Rate

Performance improvements



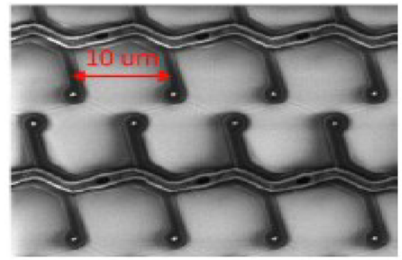






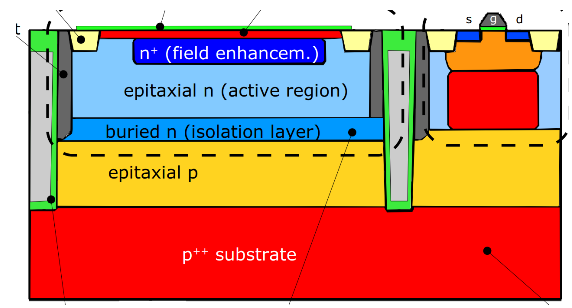
Recent SiPM trends

- Smaller microcells
  - More dynamic range
  - Better timing
  - Lower fill factor but improving

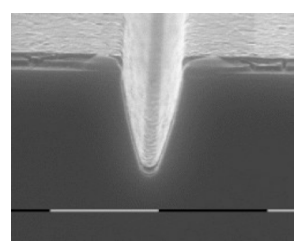


- Improved UV/IR sensitivity
  - For LXe/LAr scintillation light
  - For IR laser detection (LIDAR)

- Digital circuit integration
  - CMOS gates for active quenching, amplifiers, …

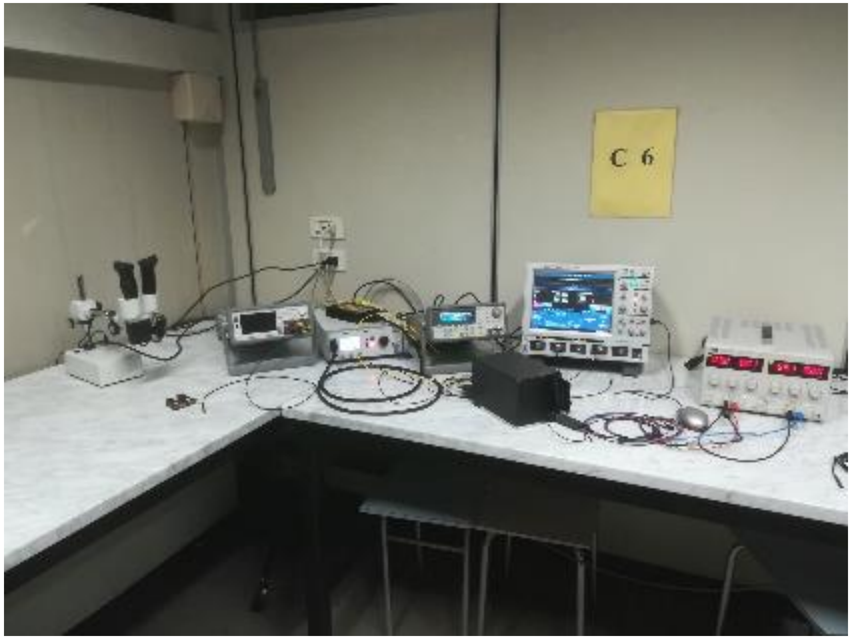


- Noise reduction
  - Trenches, guard rings around cells



Goals - 1

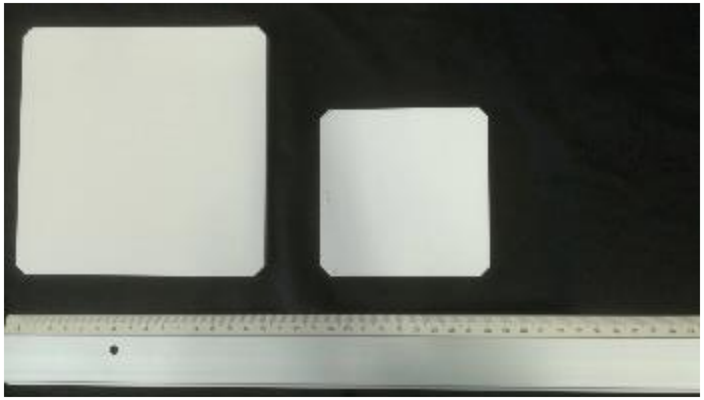
- For those of you who did not have the chance to work with SiPMs yet, we will show some examples
    - Samples of different area, pixel size, packages..
    - Measurement of the IV curve and choose working point
    - Looking at signals on the scope, with high band preamplifier
    - Shape of signal by illuminating with laser and LED
    - Integrated charge spectrum for calibration with charge amplifier



Goals - 2

- Coupling SiPM to plastic scintillator
  - light collection with WLS fiber or direct coupling?

- Different types of scintillator wrapping/coating:
  - Aluminized mylar, tyvek, teflon, white painting, black painting
  - What's best for mip detection, calorimetry, timing?
  - optical coupling of SiPM to scintillator or WLS…very critical!



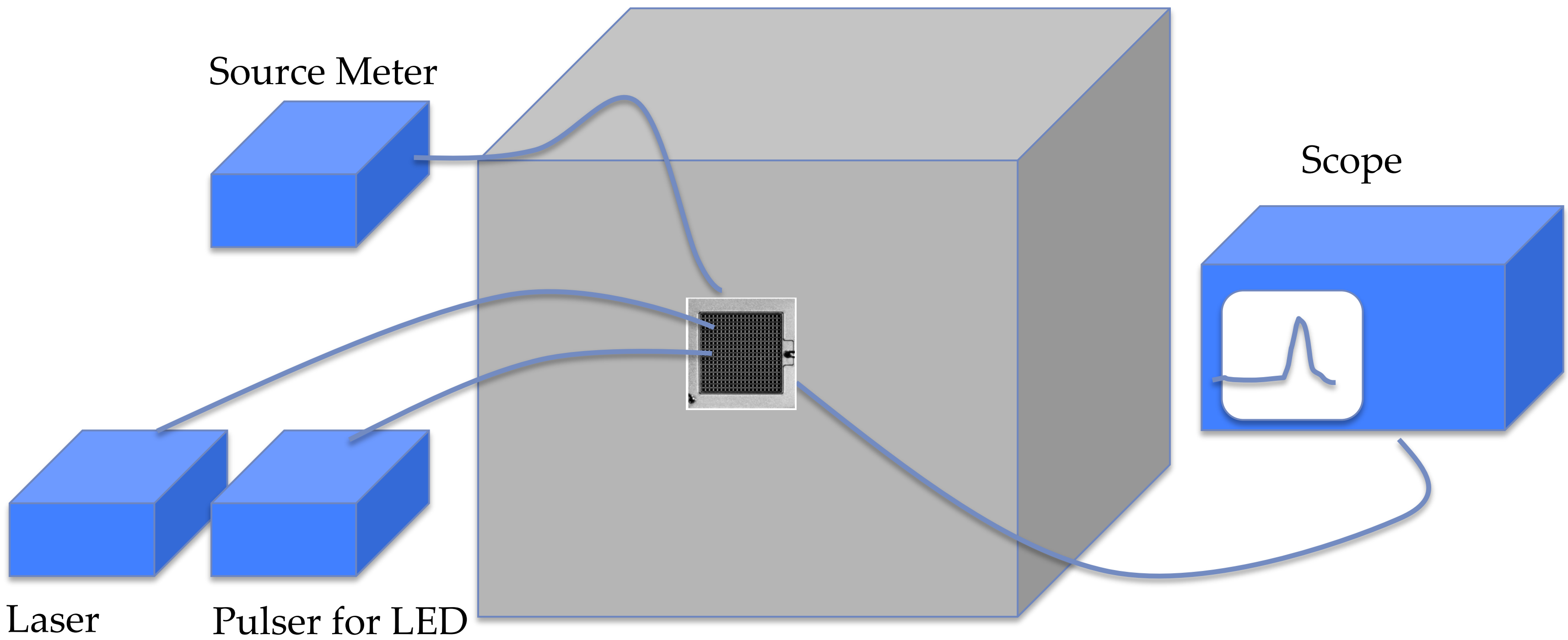
Goals - 3

- Optimize plastic scintillator tile for timing (SHiP r&d)
  - target resolution < 600 ps
  - maximum size of tile
  - SiPM direct coupling
  - optimal SiPM size and number of SiPMs/tile
  - FE electronics (amplifier + digitizer SAMPIC)

- Optimize plastic scintillator tile for calorimetry (ENUBET r&d)
  - WLS light collection
  - high efficiency
  - best achievable timing

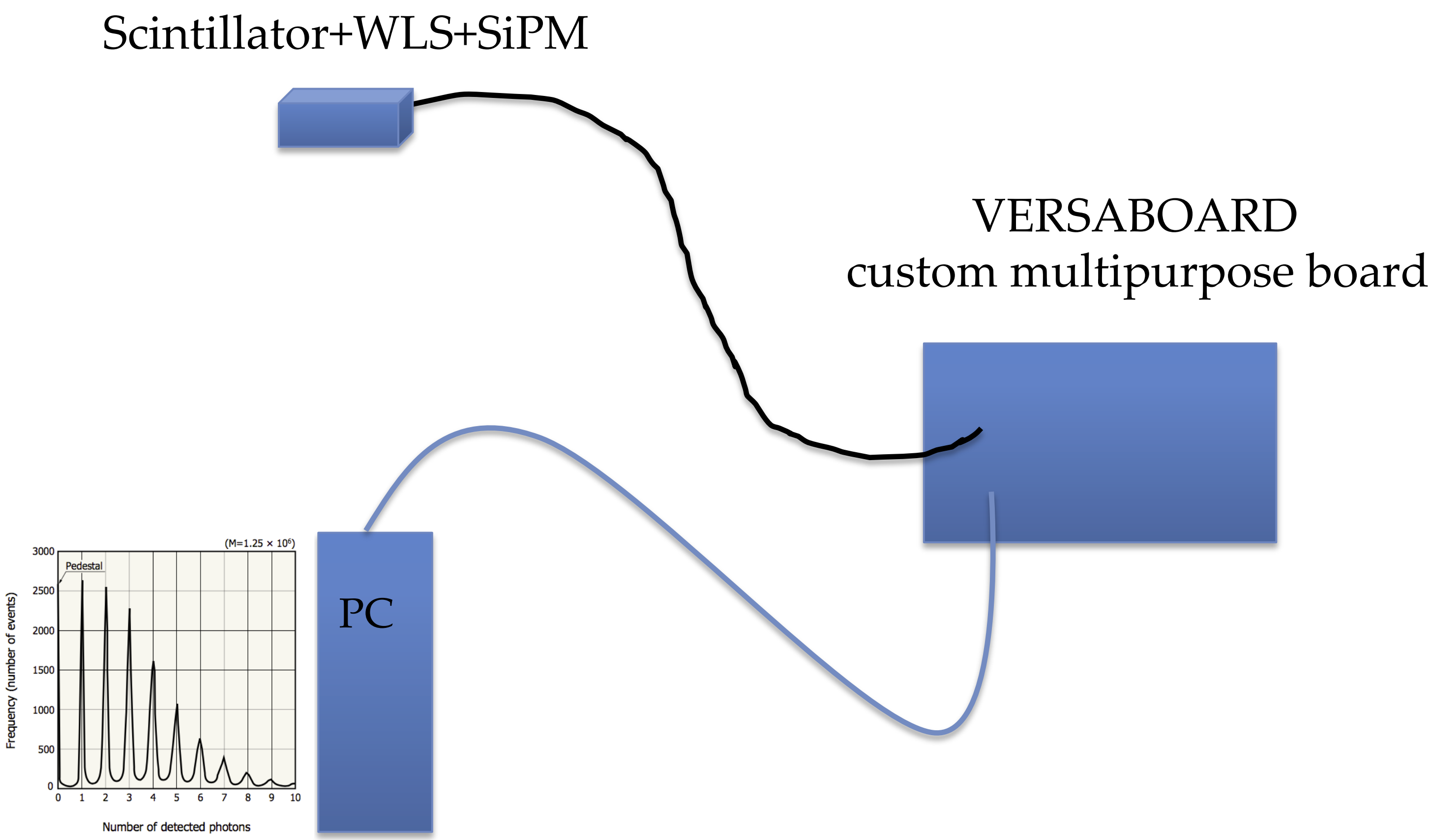
Setup 1

- Measure breakdown voltage with I-V curve
- Illuminate with Laser or LED: look at signal on scope



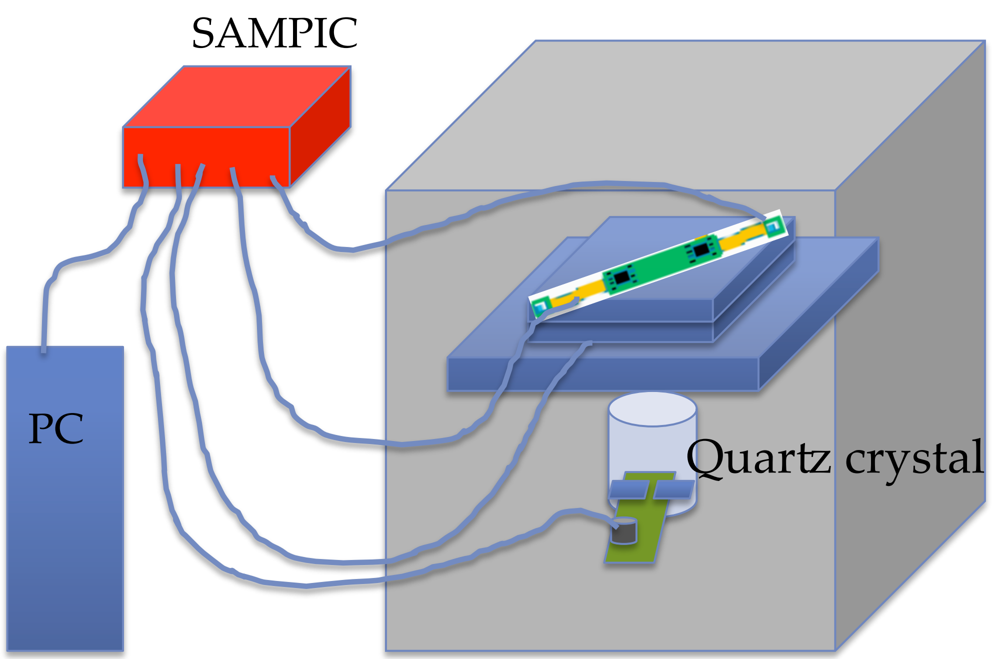
Setup 2

- Integrated charge spectrum



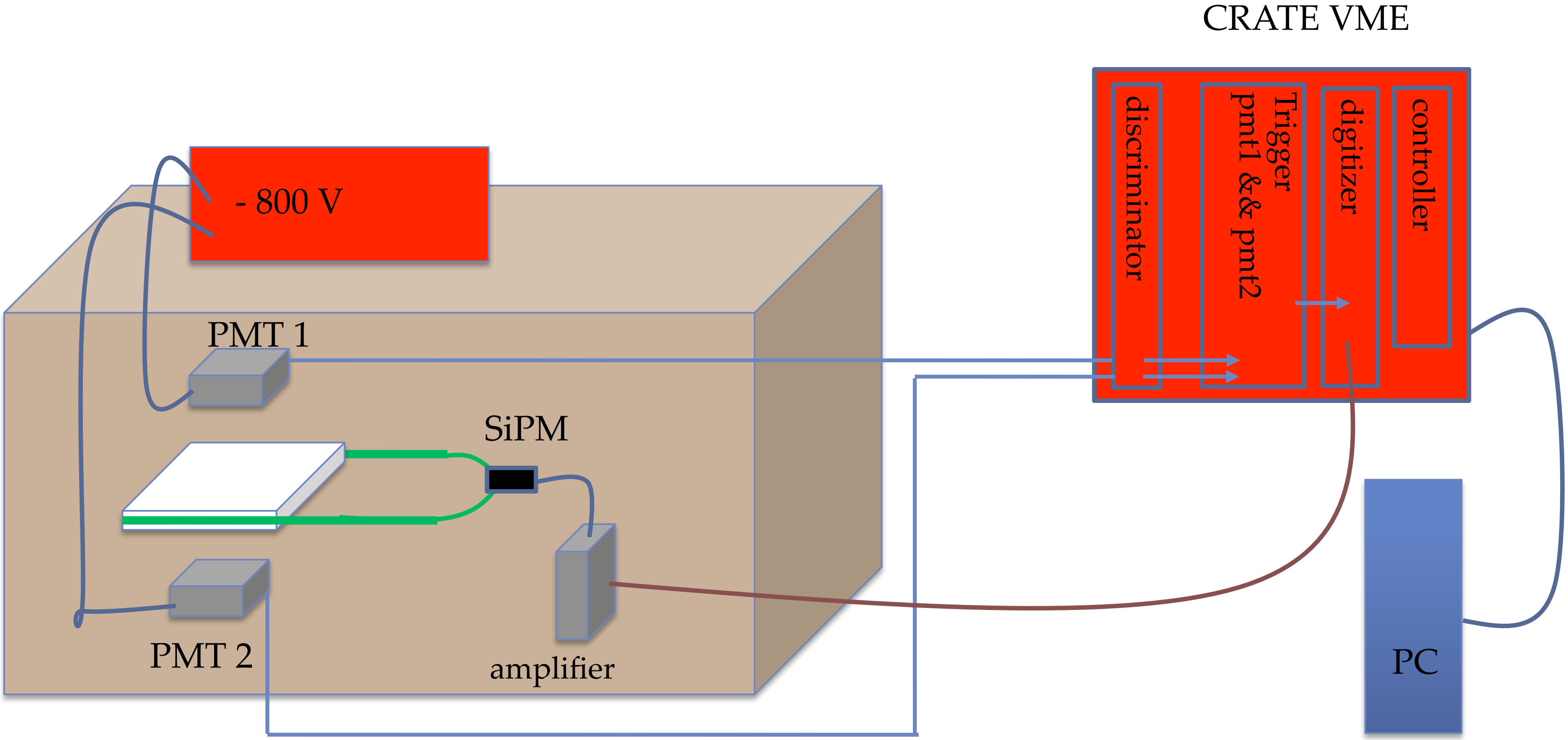
Setup 3

- Test time resolution on different tiles:
  - two sizes
  - different coatings or dressing
  - Readout and trigger by SAMPIC digitizer
- Time reference provided by Cherenkov detector
  - quartz crystal readout by two 6x6 mm2 SiPM



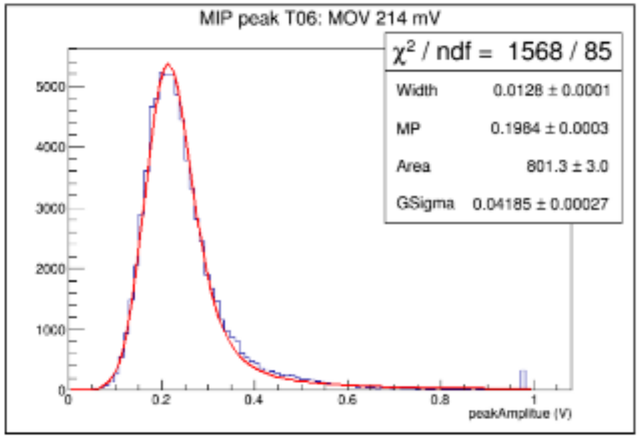
Setup 4

- Test time resolution and efficiency of a tile with 2 WLS shifter fibers readout by SiPM



Setup 4

- Acquire cosmic ray muons triggering with two PMT
- Analog signals (Slow and Fast) from SiPM acquired by means of a waveform digitizer controlled via VME
- Data file processed offline to reconstruct the pulse amplitude of the analog signal

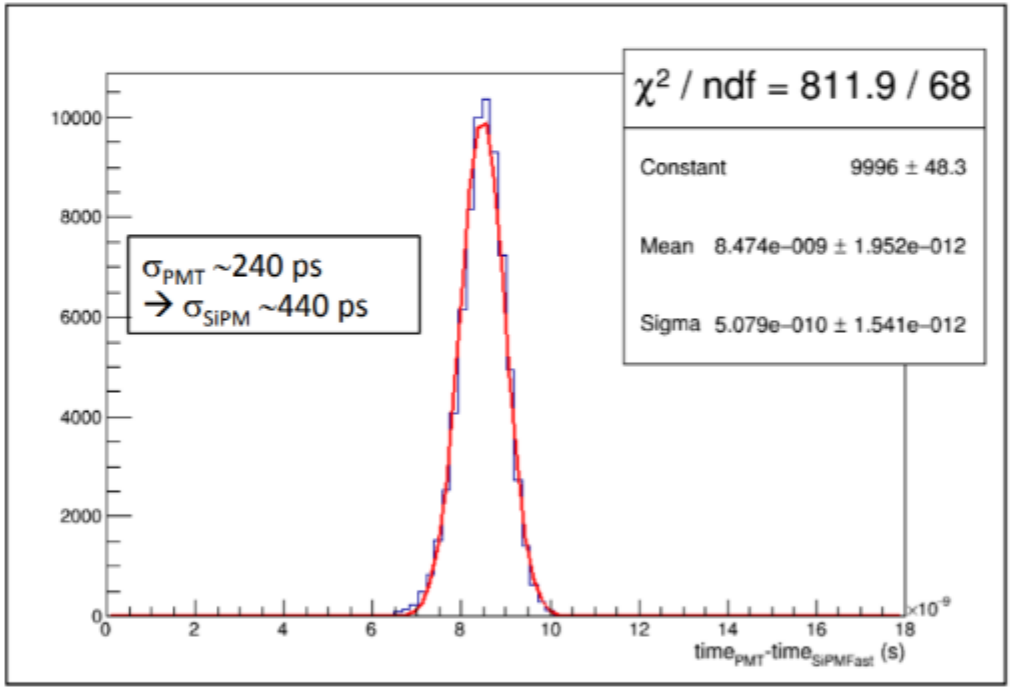


- Analysis to test time resolution and efficiency of a tile with 2 WLS shifter fibers readout by SiPM

Setup 4

- Timing measurement

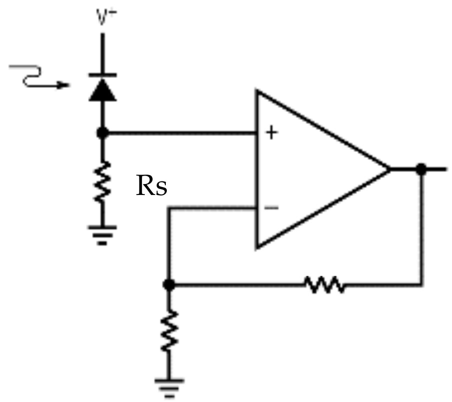
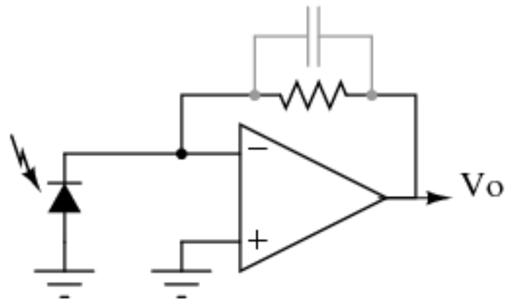
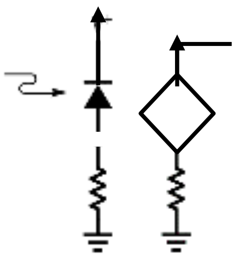
Timing PMT - Fast



SiPM readout electronics

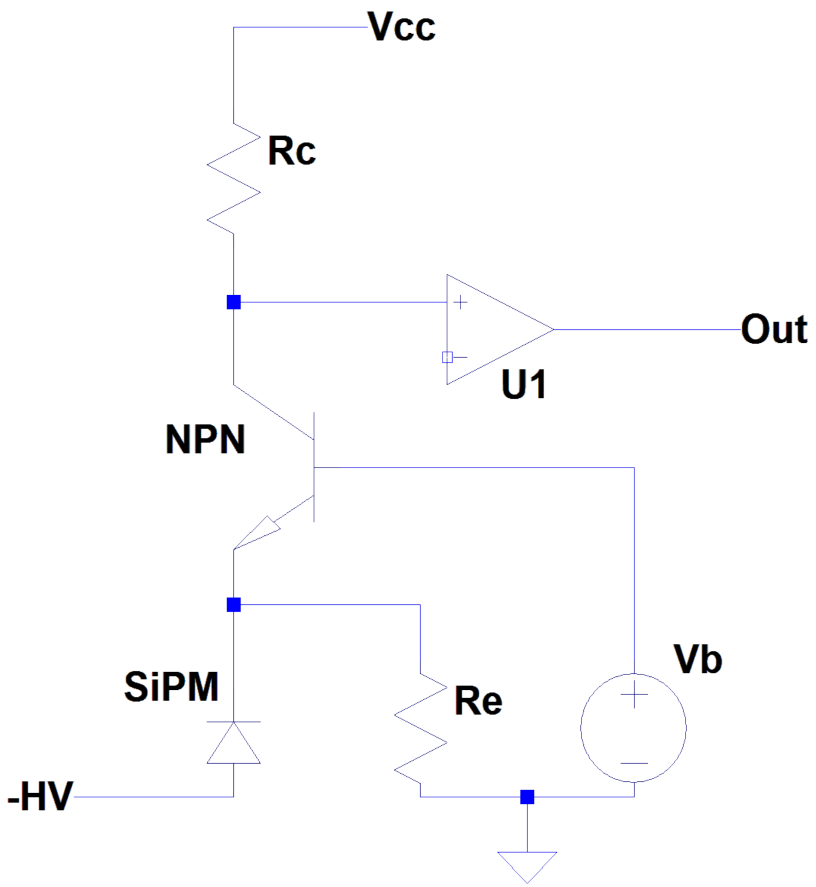
- For typical scintillator light pulses, SiPMs require further signal amplification before digitization.
    - O(100) photons, O(10^6) Gain => ~few pC signals
- Different circuit architectures are in use, both discrete and in ASIC form
    - Voltage Amplifiers
    - Transimpedance Amplifiers
    - Current mirrors
    - ASICs are superior for dense detectors, but large experiments with sparse channels can benefit from discrete amplifiers mounted close to SiPMs

Common SiPM amplifier types

V/V	Charge sensitive	Current buffer
		
Simplest type	Faster	Highest speed
Timing limited by SiPM capacitance	Provides charge integration	Best dynamic range

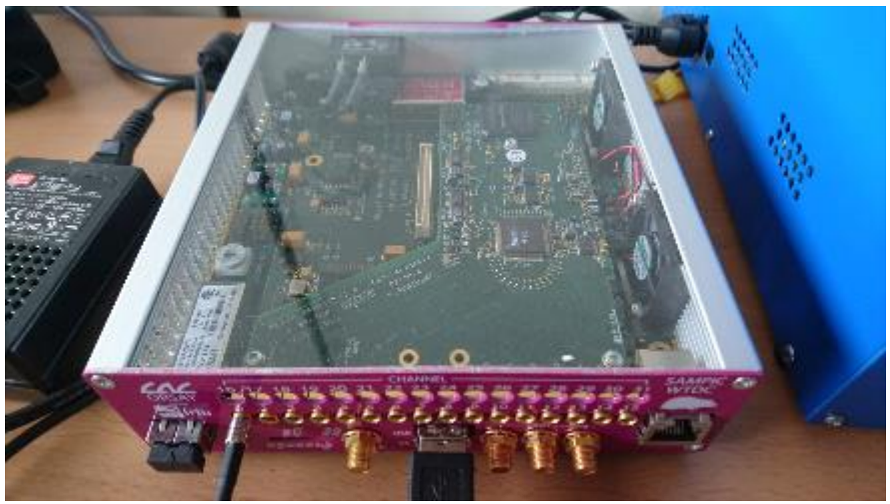
Our implementation

- Common base transistors offers low input impedance
  - Limits the effect of large SiPM capacitance
  - But... Chance of ringing
- Low overall gain
  - Second stage with OpAmp THS4303, G=10
  - Power consumption significant but not problematic, thanks to "low density" of frontend channels
- Very fast



The SAMPIC digitizer

- ASIC develop by LAL – Orsay:
  - 16 channels (each equipped with programmable threshold
  - 64 analog switched capacitor sampling cells per channel
  - 11 bit Wilkinson ADC per cell
  - time window at 3.2 GS/s = 20 ns



- Capable of <10 ps resolution thanks to waveform interpolation

Simulation

- Light emission and propagation + SiPM response is simulated by Fluka
- Comparison with real tiles/SiPM, allows to tune MC free paramenters
- After tuning with data, MC can be use to simulate different tile configurations/geometries
- Code almost ready for the comparison with real data