The SST-1M camera prototype performances and calibration for the CTA SST-1M Project

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The CTA context

- CTA is the new generation ground-based very high energy gamma-ray instrument
- 3 sizes of telescopes to cover 4 orders of magnitude in energy
- 2 sites (Northern and Southern sky)

Small Sized Telescopes

SST (S: 70, N: 0) | MST (S: 25, N: 15) | LST (S: 4, N: 4)

~4 m | ~23 m | ~12 m
Overview of the SST-1M telescope

# Mirrors | 18
---|---
# Pixels | 1296
Field of View | 9.1°
Focal length | 5.6 m
Pixel angular size | 0.24°
Pixel linear size | 23.2 mm
Mirror area | 9.42 m²
Mirror effective area | 6.47 m²
D80 | 11.3 mm / 0.12°
D80 requirement | 23 mm / 0.24°
The Photo Detection Plane (PDP)

- 1296 pixels (SiPM + Light guides) developed @ UniGE
- Aluminum Back Plate with water cooling
- Automatic bias voltage compensation for T variation through Slow Control
- Borofloat entrance window coated with AR filter + Cut-off Filter (540 nm)
Triggering and readout system
(DigiCam)

- Continuous sampling at 250 MHz with FADC
- PDP DC coupled to DigiCam
  - Baseline shift to measure Night Sky Background (NSB)
- Digital pixel sum for the trigger
  - Highly flexible trigger implementation in FPGA

Trigger condition:
Digital cluster signal > Threshold
Camera Test Setup (CTS)

- **Camera Test Setup (CTS):**
  - Full coverage of the camera (1 pulsed + continuous LED per pixel)
  - Light tight mechanical support to allow on-site calibration
  - Fully controllable by telescope software
    - Automatized calibration data taking
- **Usage**
  - Cable mapping, dead pixels, shower injection, pixel characterization
  - Extraction of SiPM parameters: Dark count rate, Optical crosstalk, Electronic noise, Gain, etc.
- **Systematic uncertainties assessed with MC**
Gain measurements with pulsed light

- Illumination under **multiple pulsed light** level (CTS or Flasher)
- **Multi-Gaussian** fit to extract gain
  \[ f(x) = \sum_{n=0}^{k} \frac{1}{\sqrt{2\pi}\sigma_n} \exp \left( - \left( \frac{x - (nG + B)}{\sqrt{2}\sigma_n} \right)^2 \right) \]
  \[ \sigma_n^2 = \sigma_e^2 + n\sigma_s^2 \]
- **Gain equalization** via FADC gain adjustment (+/- 5%)
  - 7% → 1.6% spread (without outliers)

**Gain** spread ↔ **Trigger** uniformity
Charge and time resolution

- **Charge** resolution ↔ **Energy** resolution
- ~ 12% at 100 p.e.
- To be assessed for all pixel with CTS
  → Below CTA requirements

- ~ 200 ps time resolution @ 100 p.e.
- To be done as function of NSB level
Trigger rate

- Dead time free:
  - Readout window 200 ns
  - Maximum trigger rate 5 MHz
- Maximum readout rate ~3.5 kHz
- CTA required event rate
- Cosmic interacting with SiPMs:
  - Camera horizontal
  - Camera vertical

→ No event dropped @ CTA required rate
Monte Carlo Camera validation

• Simulation of camera response at different NSB conditions
• 2 independent Monte Carlo simulations (CARE + ToyMC)
• Low level distribution in good agreement (PDP MC validated)
• High level distribution (trigger rate) to validate
  – Pixel level simulations
Expected performances (Monte Carlo)

- Simulation with CORSIKA+GrOptics+CARE 500Hz trigger rate simulated
- **Energy threshold**: 0.3 TeV (in dark night conditions)
- Further improvements possible by developing new trigger logic (flexible implementation with Digital Trigger)
First observations of the Crab Nebula

- First light on 30th of August 2017
- Observations at IFJ Krakow
  - not ideal > 1 GHz NSB / pixel
  - Rarely clear sky
- 1h20 of observation of the Crab (Standard candle in gamma-ray astronomy)
  - Event excess of atmospheric air showers pointing towards optical center of camera (4.2 sigma)
- Currently (July-August) observing gamma ray sources:
  - 1ES 1959+650
  - 1ES 2344+51.4
  - Mrk 501
  - IC 310
  - None detected yet
    - Low flux compared to Crab
    - High NSB
→ Crab observations starting in September
Conclusions and Outlooks

• First observations with the SST-1M telescope confirmed its capabilities for gamma-ray astronomy.
• Automated calibration for production phase ready
• Performance reach CTA goals and give margin for further development (dedicated trigger algorithm, higher rate, etc.)
• 2\textsuperscript{nd} observation campaign ongoing with full system automatized
  – From data taking to data processing
  – Looking for a better site for prototyping phase