Commissioning and Operation of the SST-1M Stereoscopic Imaging Atmospheric Cherenkov Telescopes

M. Heller[a]
for the SST-1M collaboration
Presented by J. Jurysek[b]
a Département de Physique Nucléaire, Faculté de Sciences, Université de Genève, 24 Quai Ernest Ansermet, CH-1205 Genève, Switzerland
b FZU - Institute of Physics of the Czech Academy of Sciences, Na Slovance 1999/2, Prague 8, Czech Republic

SST-1M
Single-Mirror
Small Size Telescope

Abstract: The SST-1M telescopes, developed by Czech, Polish, and Swiss institutions, are imaging atmospheric Cherenkov telescope prototypes with a 9.42 m² mirror and 5.6 m focal length. They feature a wide 9-degree field of view innovative camera and can detect gamma rays from several hundred GeV. The cameras consist of 1296 SiPM pixels and a digital readout system. Currently in commissioning at the Ondrejov Observatory, the system is collecting data and being calibrated for performance in both monoscopic and stereoscopic modes.

The SST-1M telescopes at the Ondrejov Observatory

- **Telescope**
  - Davies-Cotton optics (f/d = 1.4):
    - 4 m diameter (9.42 m² mirror area for 6.47 m² effective area)
    - Focal length of 5.6 m
- **Camera:**
  - 9.1° FoV
  - 1296 SiPM pixels (0.24°/pixel)
  - Fully digital readout (incl. trigger) 12 bits@250 Msps
- **Stereo observation at Ondrejov Observatory since 2023**

Pixel calibration

- Each night, before and after observations, dark count runs are acquired to **monitor the main characteristics of SiPMs**
- Using pulse finding algorithms, the gain, optical cross talk, dark count rate, sensor noise and electronics noises, are extracted
- All parameters are **stable within few percents** as visible in Fig. 5
- Before flat fielding, spread at camera level of parameters is below 8%
- Differences between cameras are expected due to different FADC manufacturer and modification for lower sensitivity to NSB

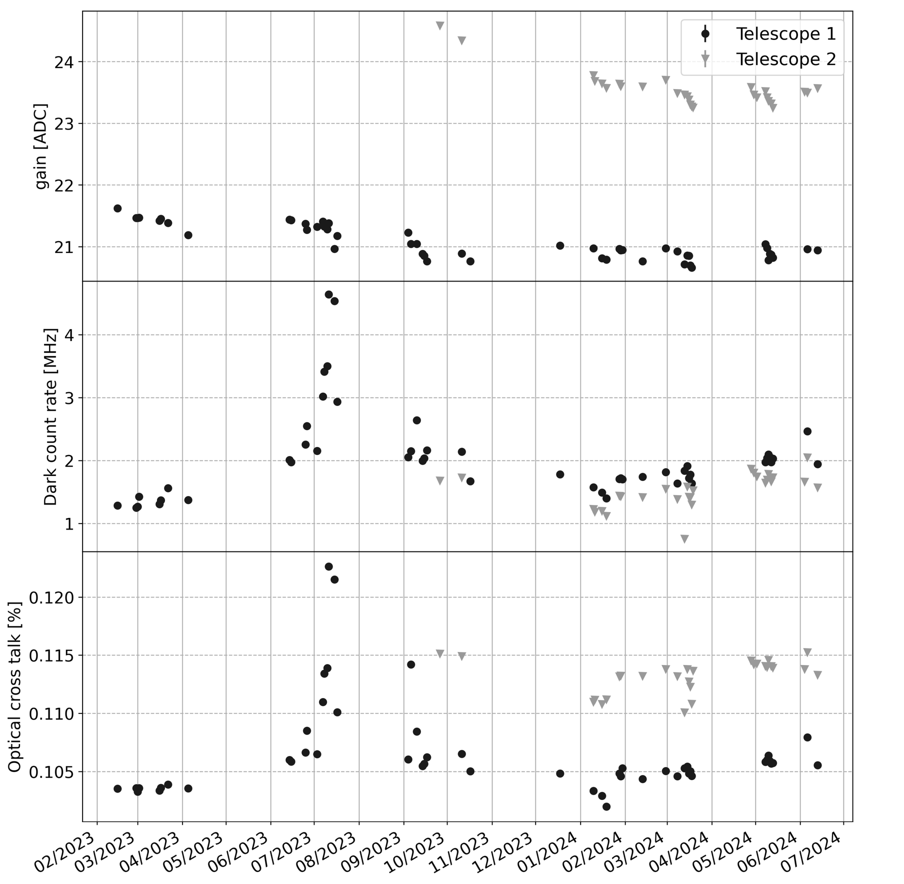


Fig. 5: Average pixel parameters as function of time

Remote observations

- Telescopes are controlled entirely remotely through GUI
- Full automatisation of observations via scheduler is planned for the coming months
- For each observation thresholds and pixel characteristics are extracted
- Regular monitoring of the environment is performed, e.g. see Fig. 1 for trigger scan:
  - Azimuthal dependency for NSB wall explained by presence of nearby villages and Prague
  - Well known proton rate Zenith dependency

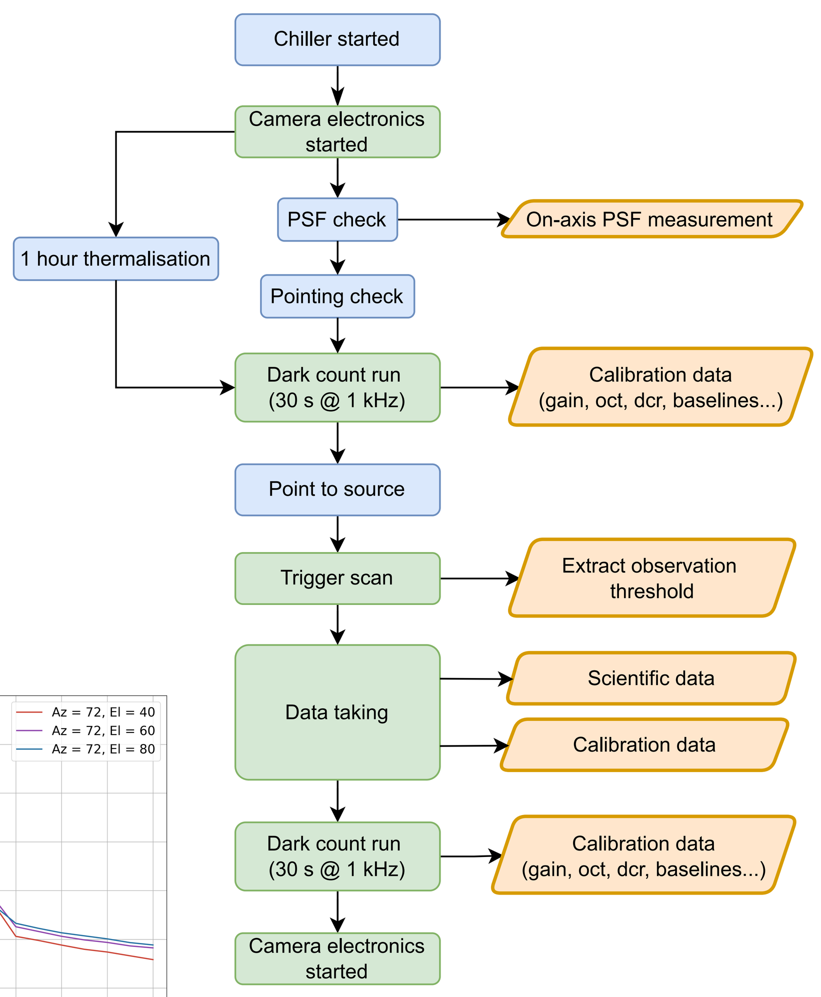


Fig. 2: Observartion sequence

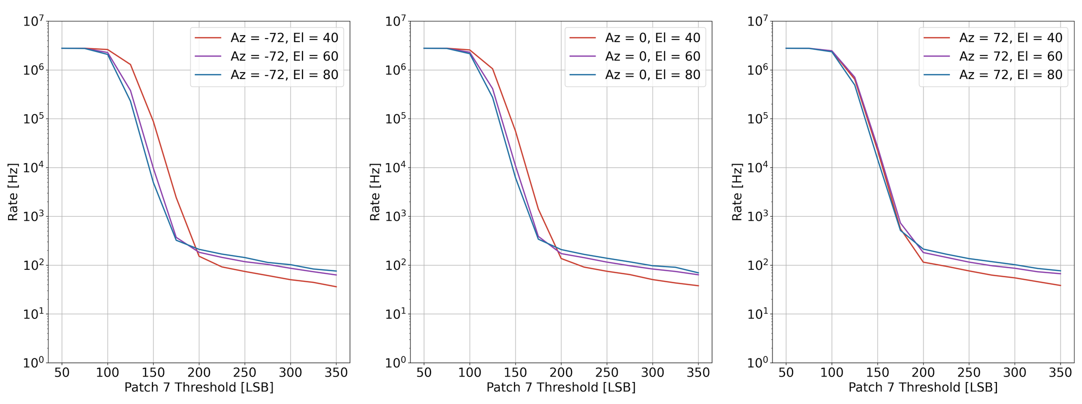


Fig. 1: Result of trigger scan for a grid of (Az, El) position

Optical Throughput calibration and NSB related correction with muons

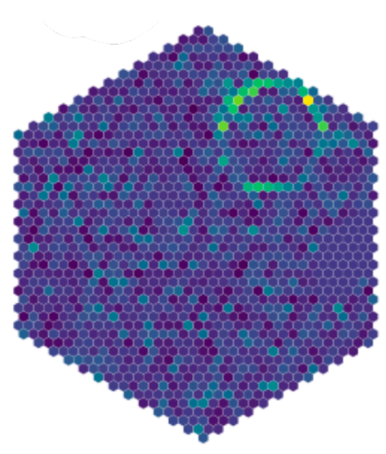


Fig. 6: Typical Muon event in SST-1M camera

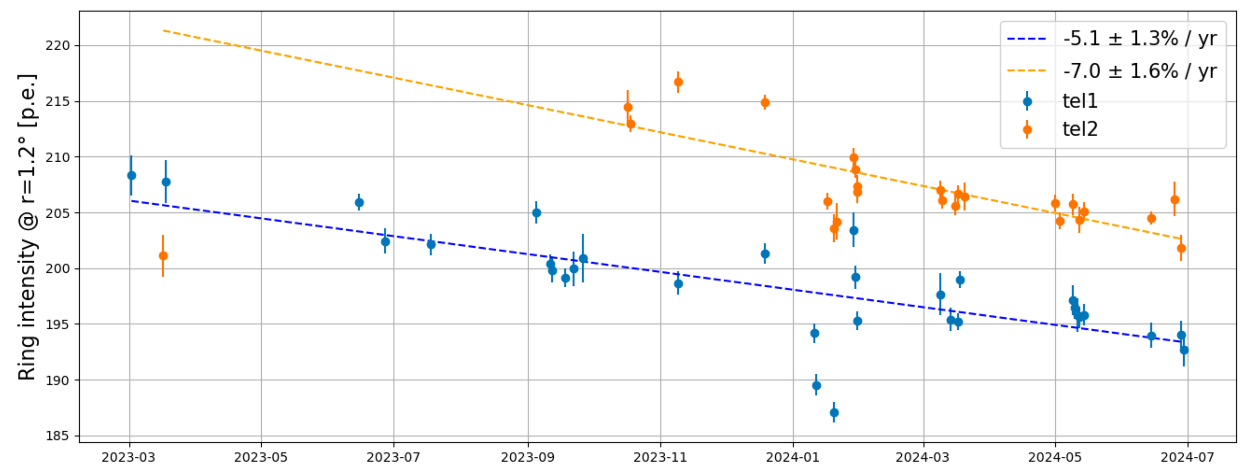


Fig. 7: Ring intensity for a radius of 1.2° as function of time

- Muons are used for monitoring of global optical throughput
  - We observe about 5 to 7 % loss per year including mirror and entrance window degradation
- SiPM characteristics (gain, optical efficiency, x-talk) are affected by the NSB level due to voltage drop:
  - Studied through electronics Toy MC
  - The model developed provides a good agreement with relative intensity loss derived from the muon analysis
  - Tel2 was improved wrt Tel1 to be less sensitive to NSB

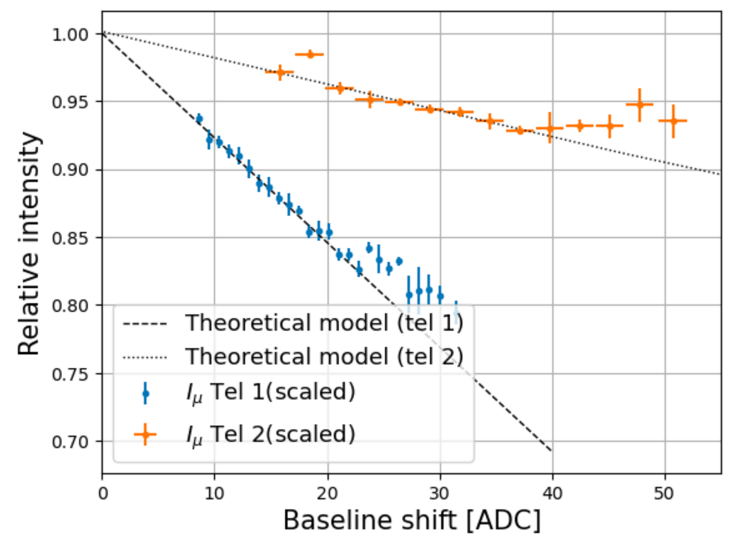


Fig. 8: Relative signal intensity decrease due to NSB light

Stereo operation

- Both cameras timestamps are synchronized through a **White Rabbit** switch that gets its external timing reference from **GNSS module**
- Upon reception of complete and valid events, the camera servers of each telescope sends timestamps to a software array trigger which search for coincidence
- Fig. 3 and 4 show that central value and width of coincidence window can be adjusted according to pointing direction for a better rejection of random coincidences

- **Future developments:**
  - Pointing dependent coincidence window
  - Hardware array trigger (inter-telescope triggering via white rabbit links)

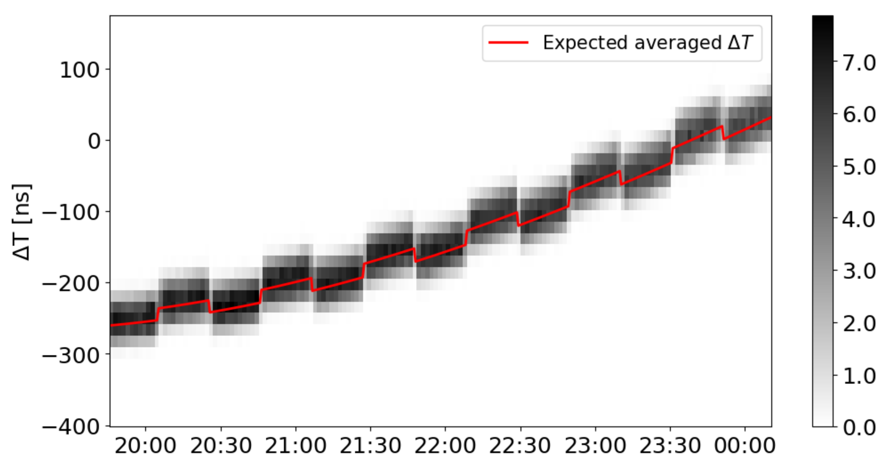


Fig. 3: Difference between timestamps of Tel1 and 2 for selected stereo triggered events as function of time

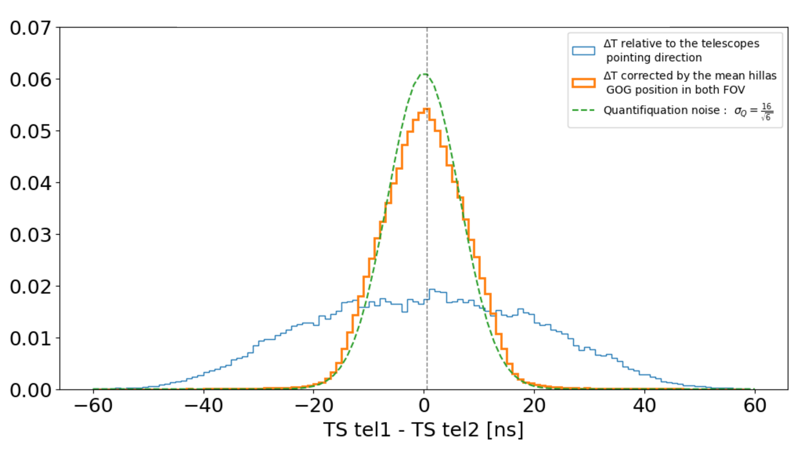
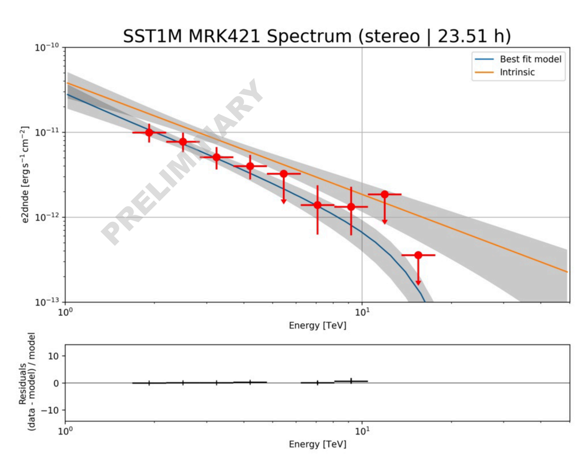


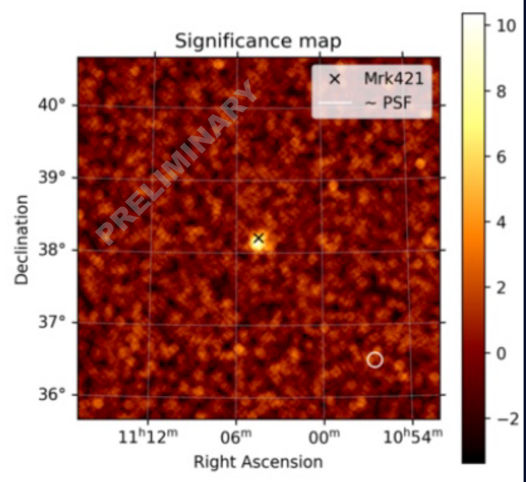
Fig. 4: Projection of time differences from Fig. 3

Summary

- The commissioning of the SST-1M operated in stereo mode is coming to an end with great success: **See talk from J. Jurysek on Wed 4th Sept. at 14:30 in Room 431 for results on the observation of astronomical sources:**

- **Appetizer, Mrk 421 mid-term monitoring:**
  - First extragalactic source detected in stereo mode (Spring 2024)
  - High state detected on 15 March 2024: ATel #16533
  - Remarkable gamma PSF and background homogeneity





- Consolidation of the overall design (hardware, control software, etc..) in view of its deployment in more favorable observation site!
- **Visit** www.sst-1m.science **for more information!**

ACKNOWLEDGEMENTS
This publication was created as part of the projects funded in Poland by the Minister of Science based on agreements number 2024/WK/03 and DIR/WK/2017/12. The construction, calibration, software control and support for operation of the SST-1M cameras is supported by SNF (grants CRSII2_141877, 20FL21_154221, CRSII2_160830, _166913), by the Boninchi Foundation and by the Université de Genève, Faculté de Sciences, Département de Physique Nucléaire. The work is supported by the projects of Ministry of Education, Youth and Sports of the Czech Republic: MEYS LM2015046, LM2018105, LM2023047, LTT17006, EU/MEYS CZ.02.1.01/0.0/0.0/16_013/0001403, CZ.02.1.01/0.0/0.0/18-_046/0016007 Czech Republic.