SST-1M IACTs : Commissioning and Preliminary Observation Results

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on behalf of the SST1M collaboration

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Outline

1. Instrument Overview
2. Analysis Pipeline
   - On site Calibration
   - Monte-Carlo Simulation
   - Performances
3. Commissioning results
   - Crab observations
   - Extragalactic sources

SST-1M project

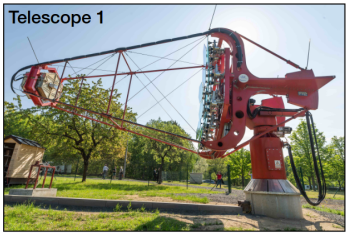
- 2 prototypes of Tcherenkov telescopes
- Consortium of research institutions from Poland, Switzerland and Czech Republic
- SST-1M was initially designed to be part of The CTA Observatory.
- It was reviewed and satisfied all the CTA requirements. Another design was however chosen.
- Two SST-1M prototype telescopes were relocated from Poland to the Czech's Republic and are being commissioned in the Ondrejov Observatory (alt 500m).

Ondřejov Observatory

SST-1M Commissioning

- Telescope installation :
  - Telescope 2 : February 2022
  - Telescope 1 : November 2022
- First Crab observation campaign
  - >5 sigma detection in mono and pseudo-stereo
  - Pos ICRC(2023)741 / TevPA 2023
- Stereo Observations:
  - White Rabbit synchronization & SWAT deployed in April 2023
- July 2023 : First detection of extragalactic source : 1ES 1959+650
- Winter 2023-2024 : Stereo Crab observation campaign
- Summer 2024 : First extended source observation campaign (still ongoing) : Dragonfly nebula (MGRO J2019+37)

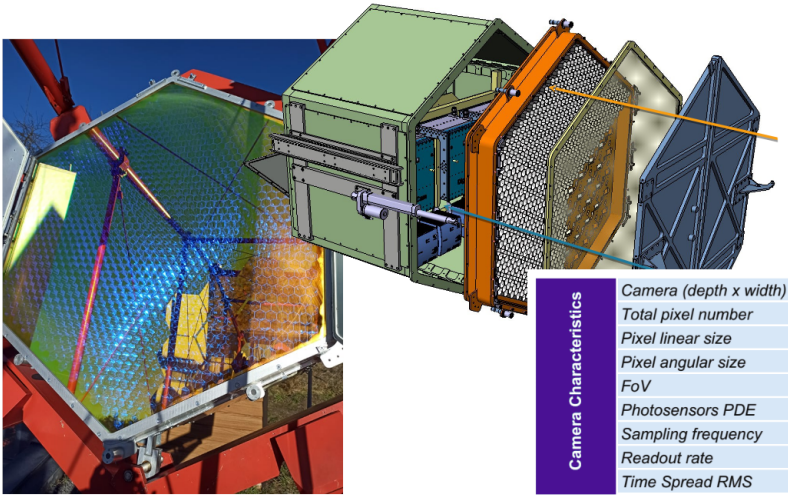
SST-1M telescopes

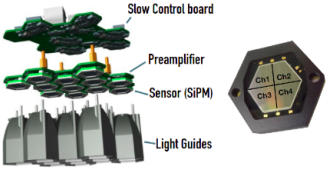


- 18 mirrors facets
- 4m diameter
- 5.6m Focal lenght
- 9.1° FOV
- 6.47 m² mirror effective area

- Observations are carried out entirely remotely, targeting fully robotic operations via scheduler.

SST-1M camera : Digicam

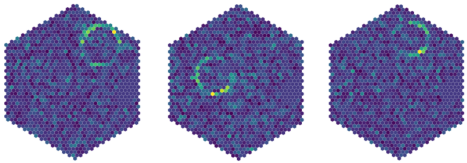




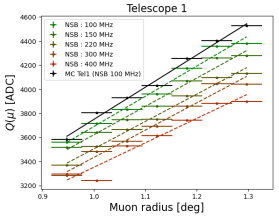
Camera Characteristics		
	Camera (depth x width)	60 cm x 90 cm
	Total pixel number	1296
	Pixel linear size	23.2 mm
	Pixel angular size	0.24°
	FoV	9.1°
	Photosensors PDE	> 30%
	Sampling frequency	250 MHz
	Readout rate	0.6-1 kHz
	Time Spread RMS	< 0.25 ns

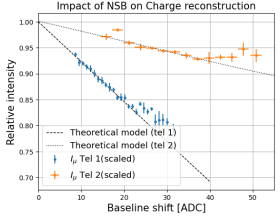
Calibration from Muons

- Muons are known to be valuable test beams for IACT's astronomy
  - Typical ring images at the focal plane
  - Light intensity is proportional to the ring radius



- SiPM characteristics (gain, optical efficiency, x-talk) is affected by the NSB level.
  - Studied through electronic MC [1]
- This effect and the optical efficiency of the telescope can be evaluated using muons.
- Observation with moonlight.

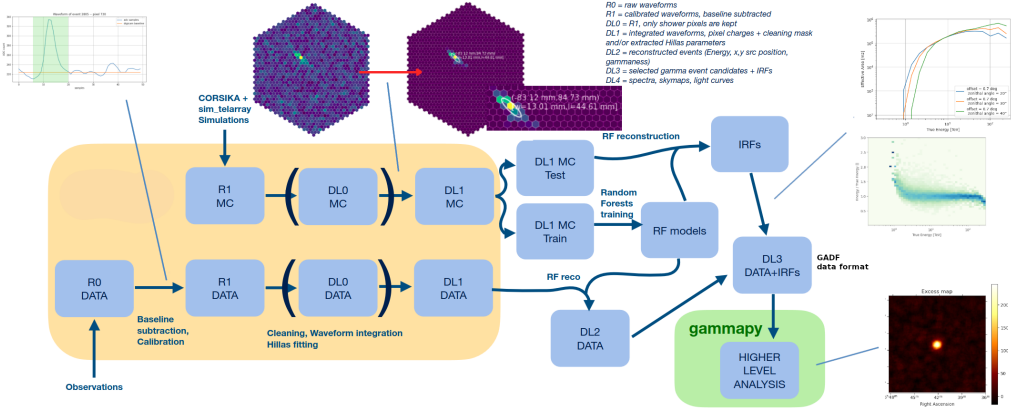




[1] SiPM behaviour under continuous light [10.1088/1748-0221/14/12/P12016]

sst1mpipe : SST-1M analysis pipeline

- Analysis pipeline is heavily based on `ctapipe` and inspired by `lstchain` and `magic-ctapipe`
- Event reconstruction and classification is done using random forest trained on Monte-Carlo
- Now in public repository: `https://github.com/SST-1M-collaboration/sst1mpipe`

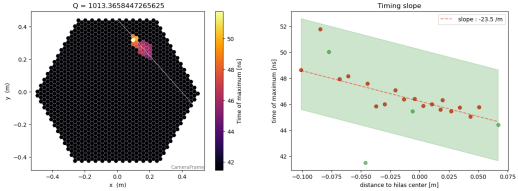


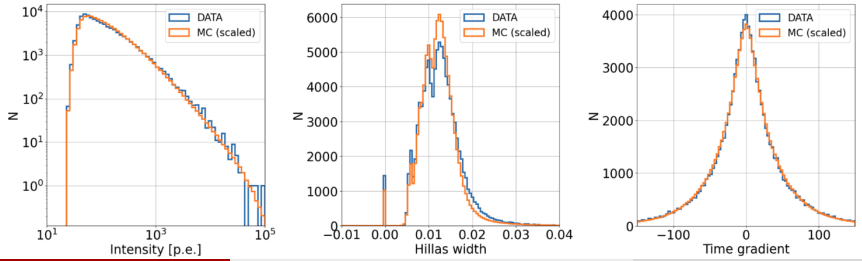
Jurysek et al. (2024). sst1mpipe: v0.4.1. 21 March 2024. Zenodo

MC-Data comparison

- Data : taken at zenith angle between 18° and 22°
- MC : Proton spectrum at 20° zenith angle

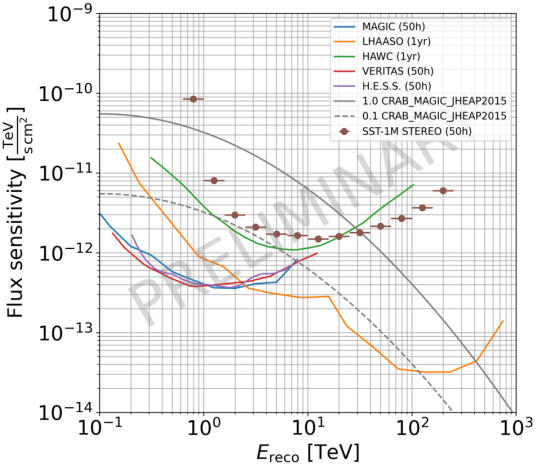
Time gradient:





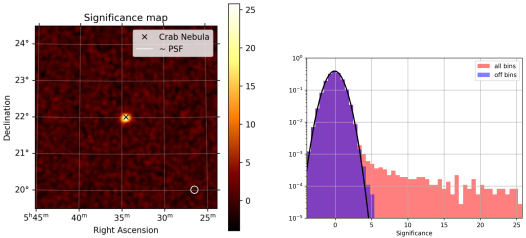
SST-1M performances

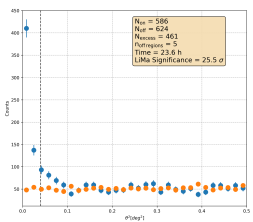
- Low altitude of the site lead to an energy Threshold of > 1TeV
- Ongoing work to lower the instrument threshold
  - Cleaning optimization
  - Trigger algorithm

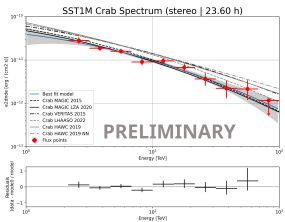


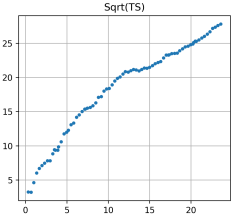
Crab Stereo observation

- Livetime after quality cuts : 23.6 h
- Observation wobble : 0.7° & 1.4° offset
- Data set zenith angles range from 28° to 45°
- Crab is seen at 5σ in $\sim$1.5h of observation.



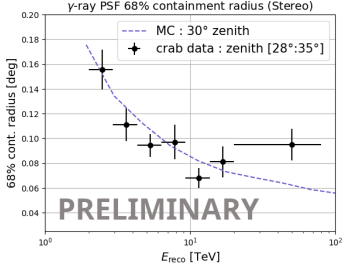


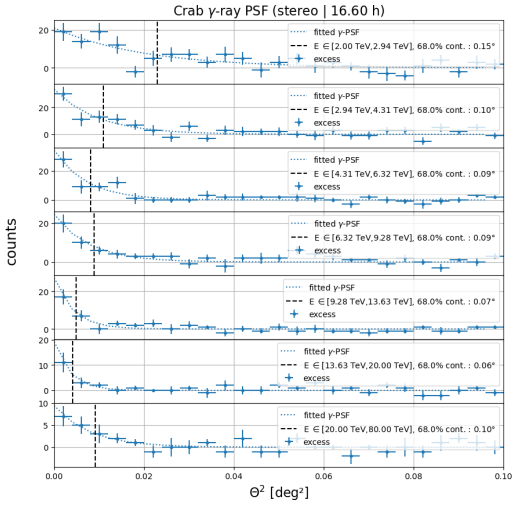




Gamma-ray PSF

- Gaussian gamma-ray PSF is fitted on the excess for different bin in reconstructed energy.
- Same procedure with MC simulations shows good agreement.

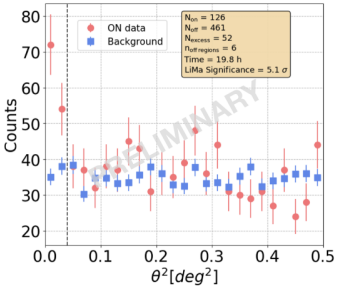




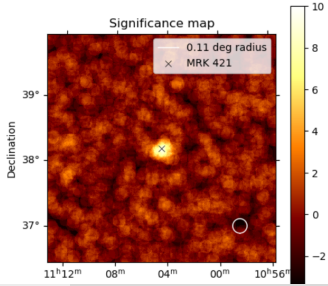
Other observation and Commissioning Science

- Monitoring nearby AGN
  - Automatic data processing in the morning
  - High state of Mkn 421 : ATel #16533
- Follow up of MWL/MM alerts
- Observation campaign during increased activity

1ES 1959+650 (Mono summer 2023)

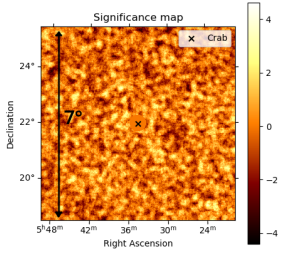


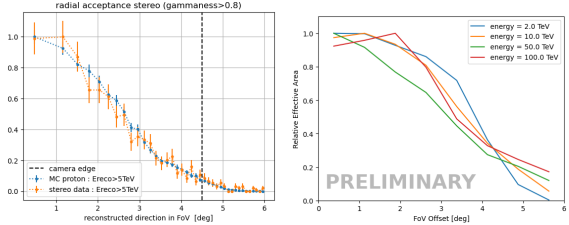
Mkn 421 : 5.3h in high state (17th March 2024)

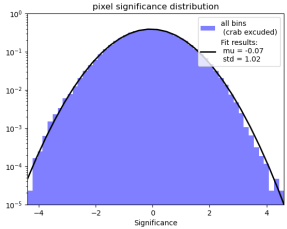


Potential for extended sources

- First phase of the commissioning was focused on point like sources.
- With a wide ($\sim 9^\circ$) FOV and good resolution SST-1M have a great potential for the observation of Extended sources.
- No loss in effective area up to $\sim 1.5^\circ$ offset
- Radial acceptance is well understood
- Long integration time needed







Conclusion & perspectives

- The SST-1M telescopes has proven to meet the expected performance
- The analysis pipeline is still rapidly evolving
  - Targeting High-NSB/Moonlight
- Future commissioning science prospect:
  - TOO (Flaring blazar, GRB, GW NS merger...)
  - Extended sources observation : ongoing observation campain on Dragonfly nebula
- Future of SST-1M telescopes?
  - We are exploring new possibilities for observation sites
  - Complementing another γ-ray observatory

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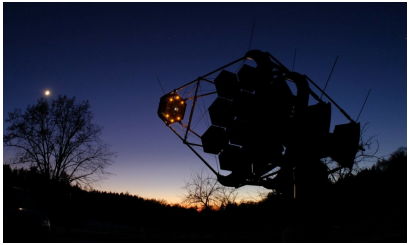

Thank you