Simulation and design of the HT-KZ Ultra-high energy cosmic rays detector system for cosmic rays with energies above 10^{17} eV

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One of the remaining mysteries in HEP is the origin and the nature of the Ultra-high energy Cosmic Rays (UHECR). When primary cosmic particle enters the atmosphere, it causes extensive air shower (EAS) that can be detected. There is an active project at Nazarbayev University (NU) to construct the HT-KZ (HorizonT-Kazakhstan) detector system in collaboration with FIAN TyanShan high-altitude Science Station. A significant part of this process is the simulation, testing and construction of individual particle detectors due to the requirements of robustness and high linear range of such detectors combined with low cost and long-term operations with minimal maintenance.

**MOTIVATION**

- The Horizon-T experiment has confirmed the “multimodal” EAS originating from 2-3 UHECRs arriving almost simultaneously with the distances from each other on the order of hundreds meters.
- There seems to be no anisotropy in the detected events (no direction to origin(s) if any)
- Plausible explanations of this discovery currently include:
  - a decay of the very unknown heavy parent into several UHECRs
  - from some exotic source (dark matter decay/ejection etc...)
- More data is required before a statement with some certainty can be made. A second system to verify results is needed.
- Utilizing new approach of mapping cascade curve to signal shape – needs fast detectors and fast DAQ signal recording

**TOTAL SCHEMATIC OF HT-KZ SYSTEM**

- Modules are to be on the roofs of NU
  - Energy sensitivity: E ≥ 10^{17} eV
  - Time resolution ~1ns using modern photodetectors and DAQ
  - >1 event/km² per day with E above is expected (~1000 per year)
  - Offline global trigger from time stamp
  - Individual module trigger rate < 10/sec estimated dead time <= 1%
  - Total data per module <200kbyte/s
  - Each module will be independent - 3 particle detectors per module with X-Y-Z alignment

**SIMULATION RESULTS**

- Geometries to be tested
  - Square, circle
  - PMT placement: edge, center, away
  - Uniformity (edge effects)
  - Possible detection medium: glass, Cerenkov plastic or fast plastic scintillator (both Eljen [7])

**PARTICLE DETECTOR R&D**

- Detector simulation was performed
  - PMT is placed on the front side; air waveguide causes more uniform detection distribution than the face touching arrangement.
  - Cerenkov plastic gives better photon production and enables uniform & efficient detection probability then glass; scintillator gives more light.

**DAQ**

- Using CAEN [5] DT 5743 ADC
  - Trigger level and logic are software controlled
  - 12.5bit 250Vpp; Dead time 125μs
  - 3.2 GSample/s max (plan to use 0.8gs/s)
  - 40bit internal time stamp 5ns resolution

**FUTURE PLANS**

- Detector R&D finishing
  - Attempting other options for detection medium
  - Testing other possible geometries and PMT placements (check for the rise time and signal width)
- Pulse synchronization R&D – requires improvements in the DAQ software: work in process
- Constructing detection units and installation on the rooftops of NU
- Installation arrangement will depend on the simulation results
- Collecting first data and comparing with the existing outcomes

**REFERENCES**