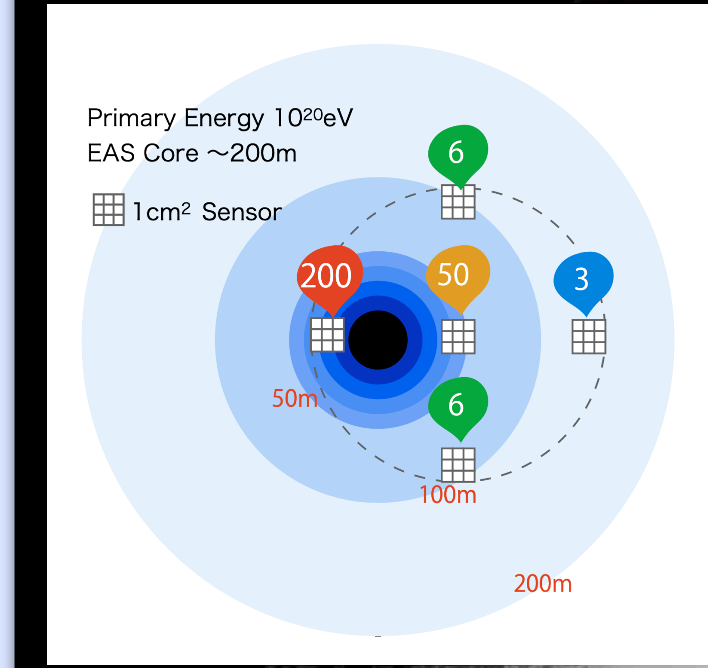
Observing Ultra-High Energy Cosmic Rays using Camera Image Sensors

Wakiko Takano and Kinya Hibino, Kanagawa University, Rokkakubashi 3-27-1, Yokohama, Japan, Email: r201970105fg@jindai.jp

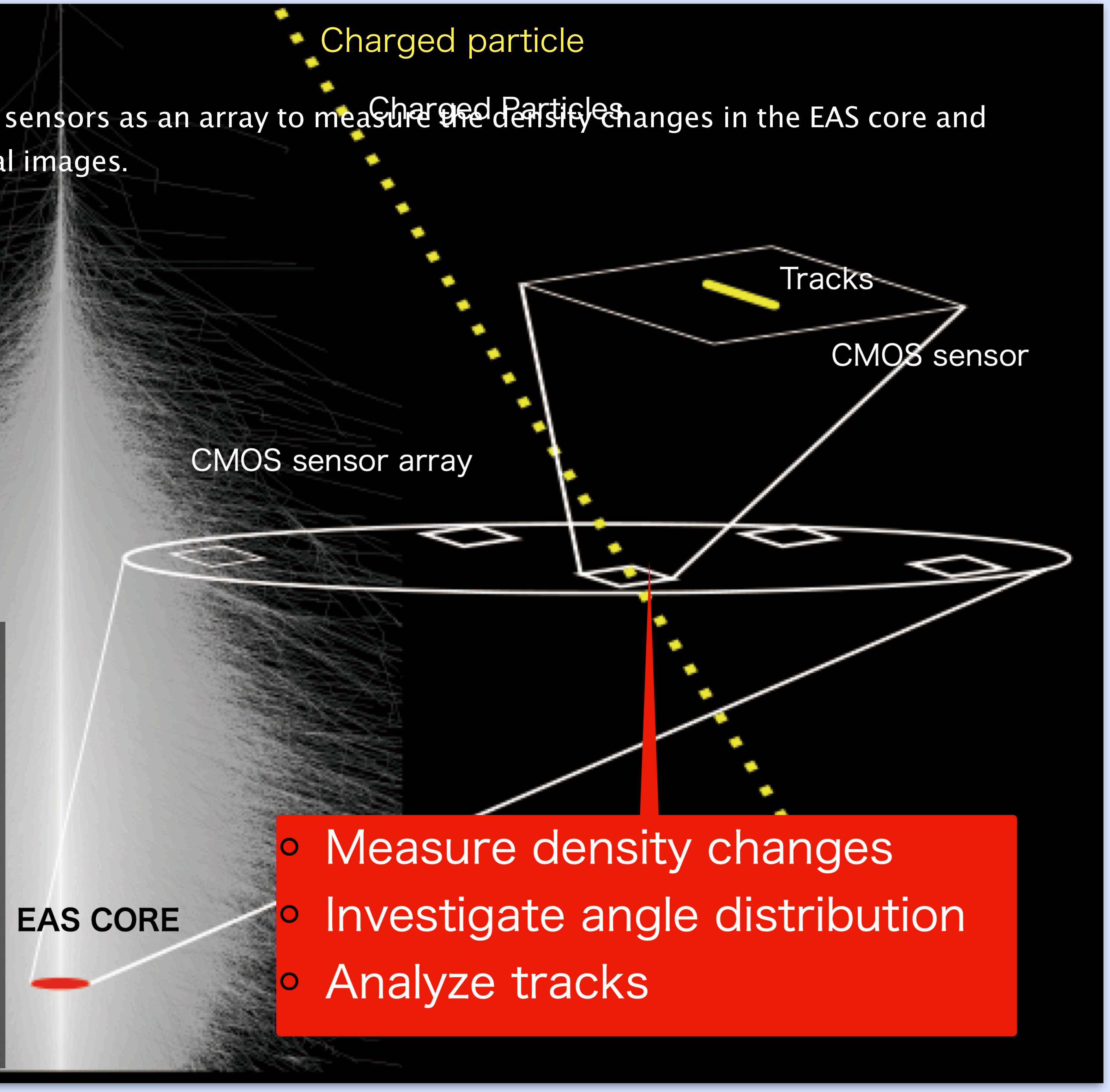
We propose a new approach for observing UHECR by detecting charged particles in the core region of EAS using a cost-effective and compact detector with a CMOS camera image sensor. This idea is for expanding the observation area low cost and obtaining more data statistics effectively.

Detection Method

We place CMOS camera image sensors as an array to measure the density changes in the EAS core and analyze the tracks in the digital images.



When the EAS core hits the sensor array, each sensor will have multiple hits, even with a small detection area such as 1 cm², as shown in the figure above. The measured density is compared to the known lateral distribution of particle density, and the primary energy is reconstructed.



From the effective area and the flux of the primary cosmic rays, the required number of arrays can be estimated according to the expected rate of events. To detect more than one EAS of 10^{20} eV per year, we estimate to need 3,200 arrays which is equivalent to an effective area of $\sim 10^8$ m².

Flux	Effective Area	→	Number of Arrays
10^{-8} particles m^{-2} year^{-1}	31400 m²	→	~3,200

Simulation (EAS Core)

We have performed the Corsika simulation to study the UHE air shower core. Figure 1 shows the density distribution of the charged particles in the core. If the energy is 10^{20} eV and the location is within 10 m of the core, the density is greater than 10^7 particles per 1 m². This means that more than 1000 particles hit a small sensor of 1 cm² at a time. The density distribution of the particles depends on the energy of the primary particles. Figure 2 shows the angular distribution of charged particles. The higher the energy of the primary particles, the more the angle distribution concentrates in the incident angle of the primary particles. Figure 3 shows the energy distribution of charged particles. The particle with high energy distributes more in the core area.

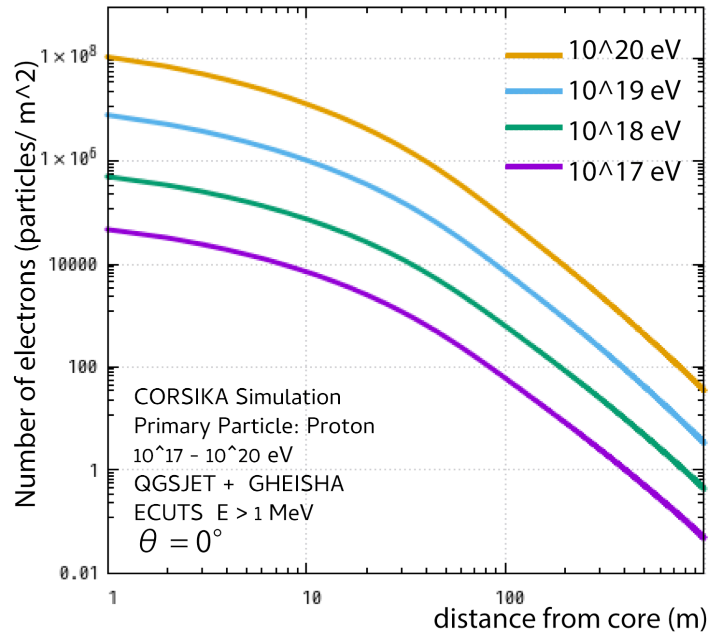


Figure 1: Density distribution

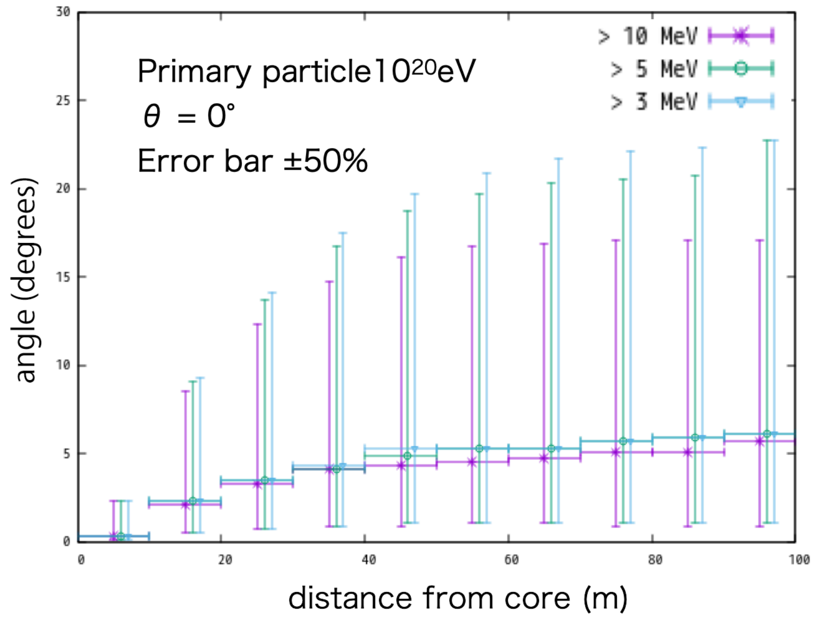


Figure 2: Angular distribution

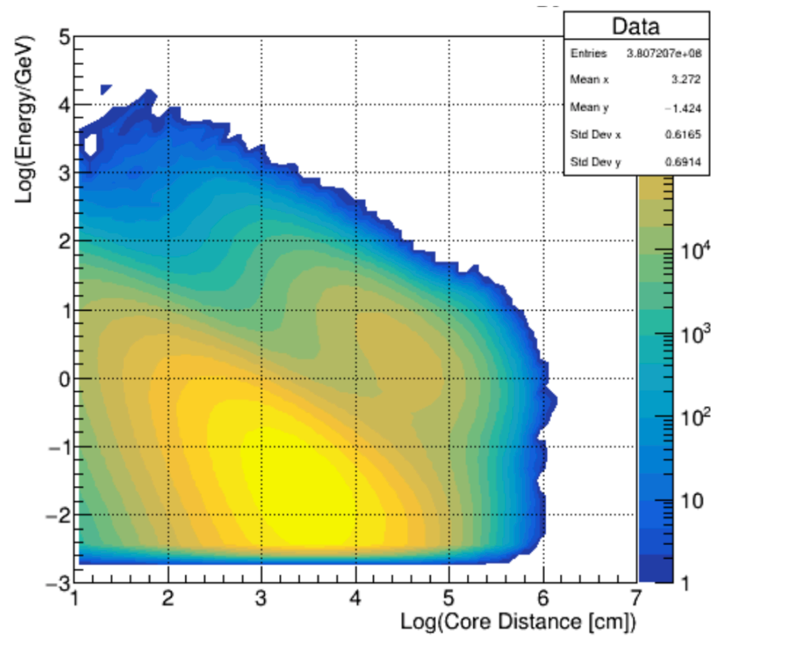


Figure 3: Energy distribution (2D)

Simulation (Response of CMOS Sensor)

Result by the Geant4 Simulation in Fig.4. The left is the energy deposit of electrons. The minimum ionization loss is reached at 0.2 to 1 MeV. The right shows that the length of a track is proportional to the angle of incidence of the particles. The simulation was performed assuming that the thickness of the depletion layer was 20 μm. However, if the thickness of the depletion layer in the sensor is not correct, the incident angle is not estimated from the length of the track.

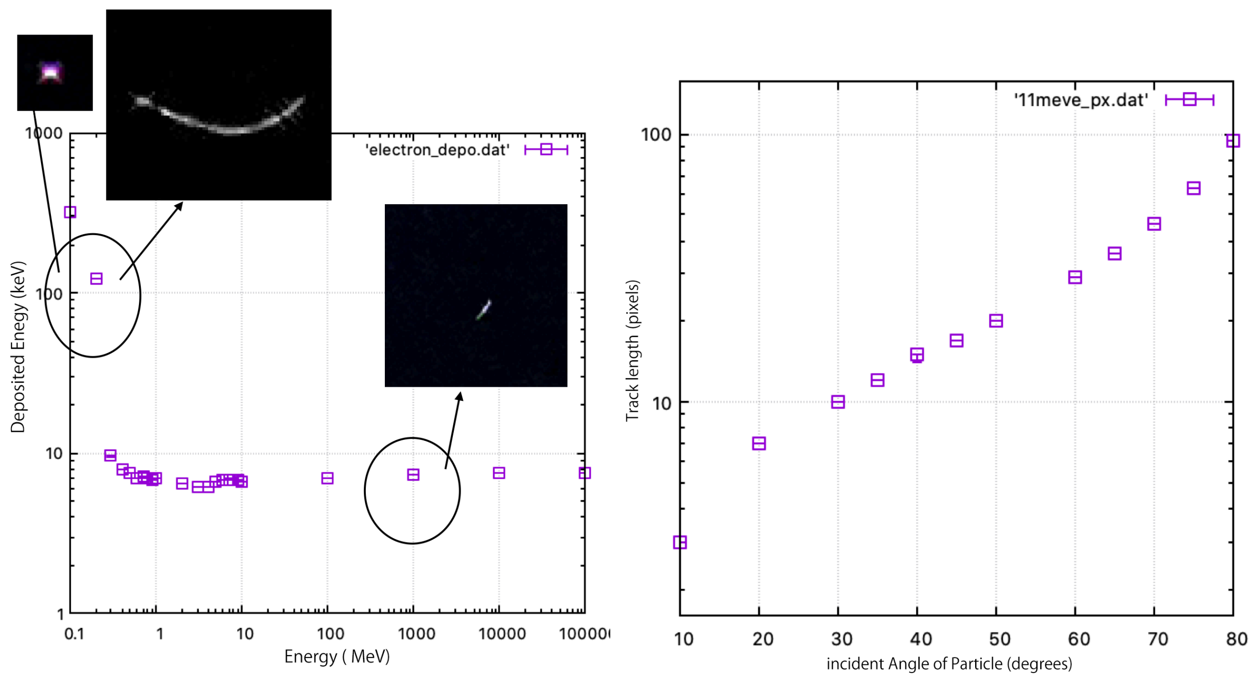


Figure 4: Result by the Geant4 Simulation

Measurement of Depletion Thickness

We measured the thickness of the depletion layer of the sensor by using cosmic-ray signals. The depletion layer of the sensor used this time was estimated to be 12-19 μm (see our proceedings in detail).