高海拔宇宙线观测站
Large High Altitude Air Shower Observatory

西南交通大学
Southwest Jiaotong University

Relationship study between RREA process and atmospheric altitude

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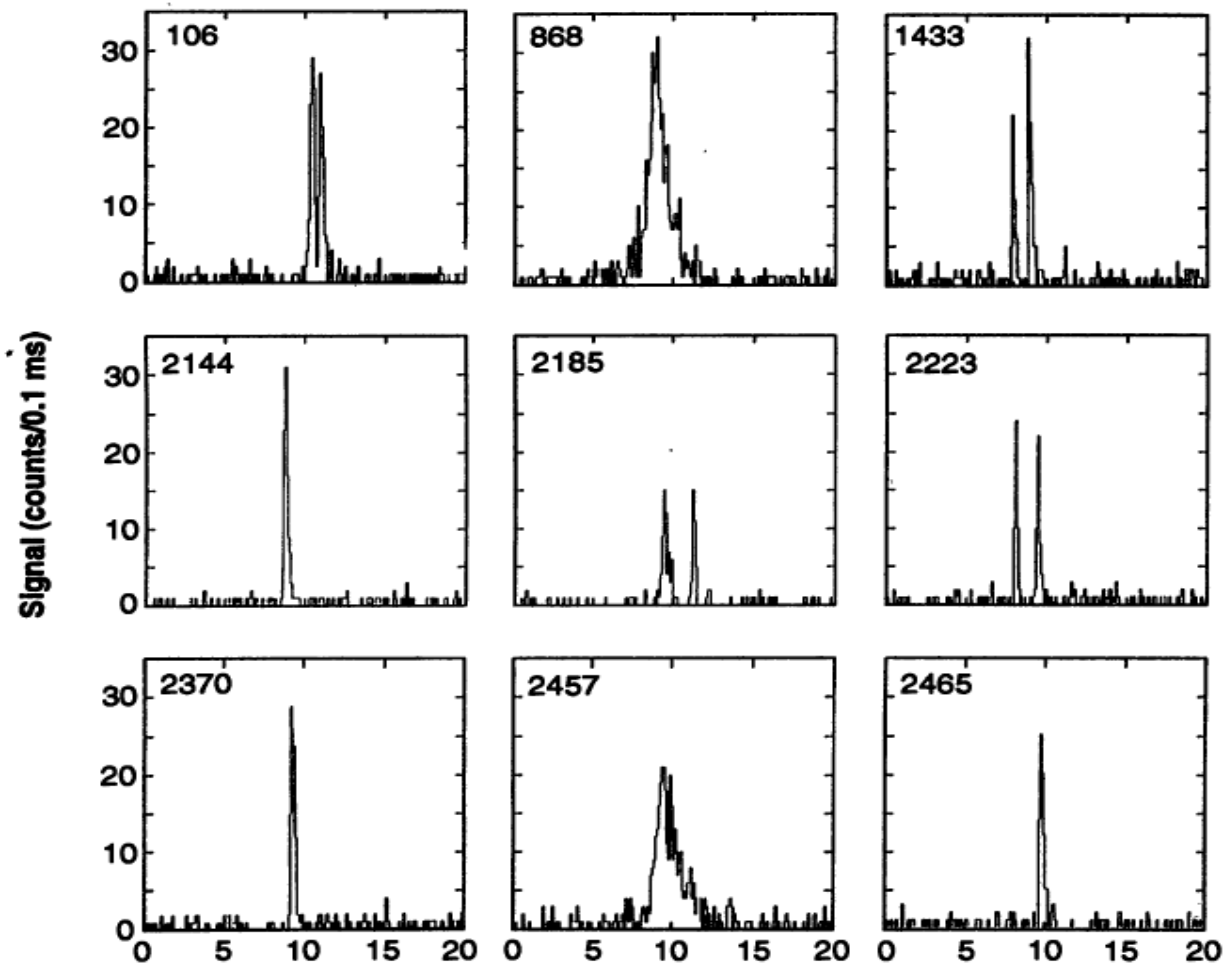
POS-40

Outline

- Introduction
- Simulation results
  1）Altitude dependence of secondary particle production in the RREA process
  2）Altitude dependence of particle evolution after leaving the RREA region
  3）Altitude dependence of RREA particles measured at ground-level
- Summary

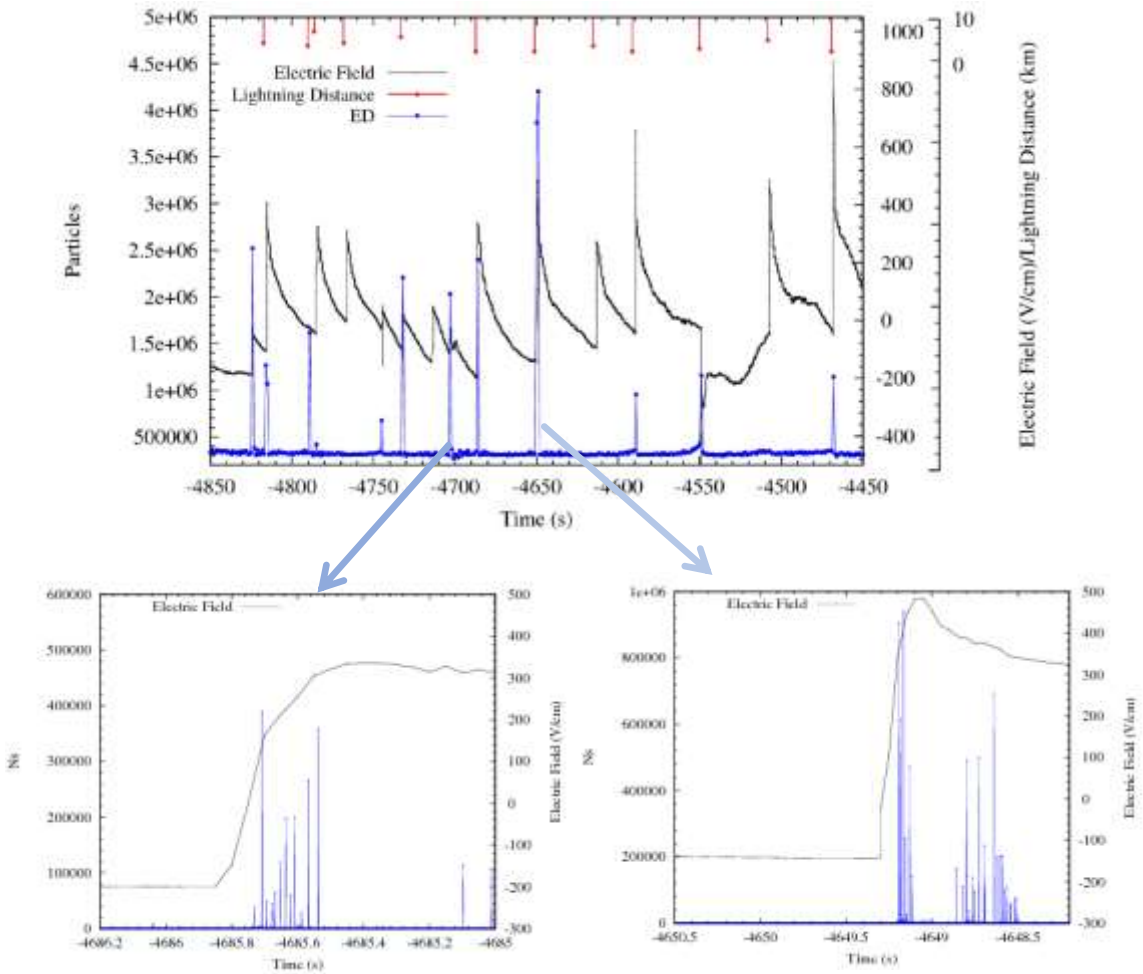
Terrestrial gamma-ray flashes(TGFs)

Satellite-based experiments （CGRO/BATSE）



Ground-based experiments

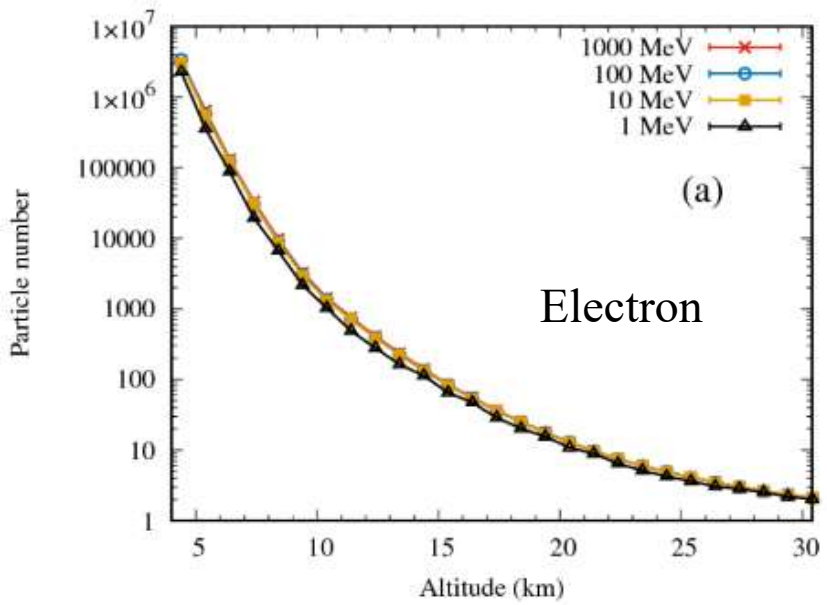
Thunderstorm 20220616

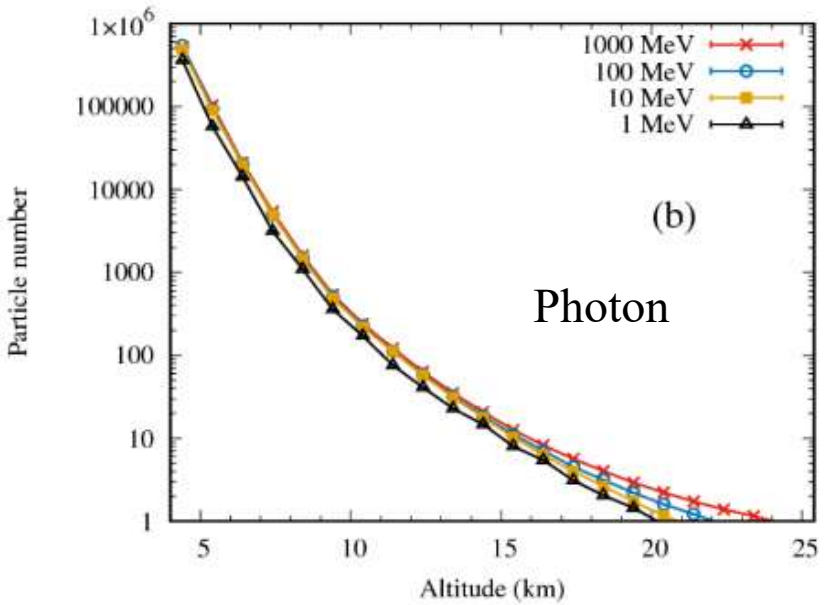


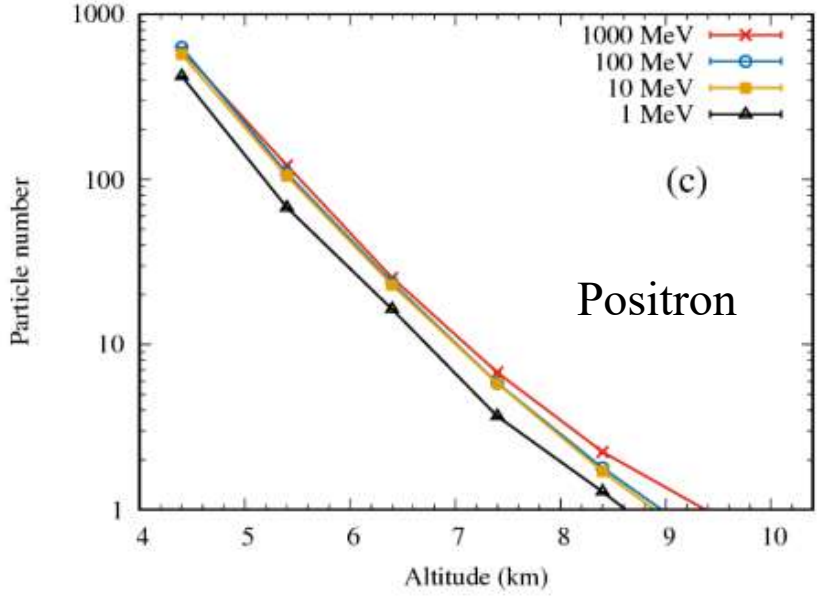
- Most studies on the generation mechanism of TGF are based on the RREA process.

The number of RREA particles as a function of altitude

- Seed electron: 1,10,100,1000 MeV
- Electric field strength: 2.2 times E_{th}
- Thundercloud thickness: 1000 m



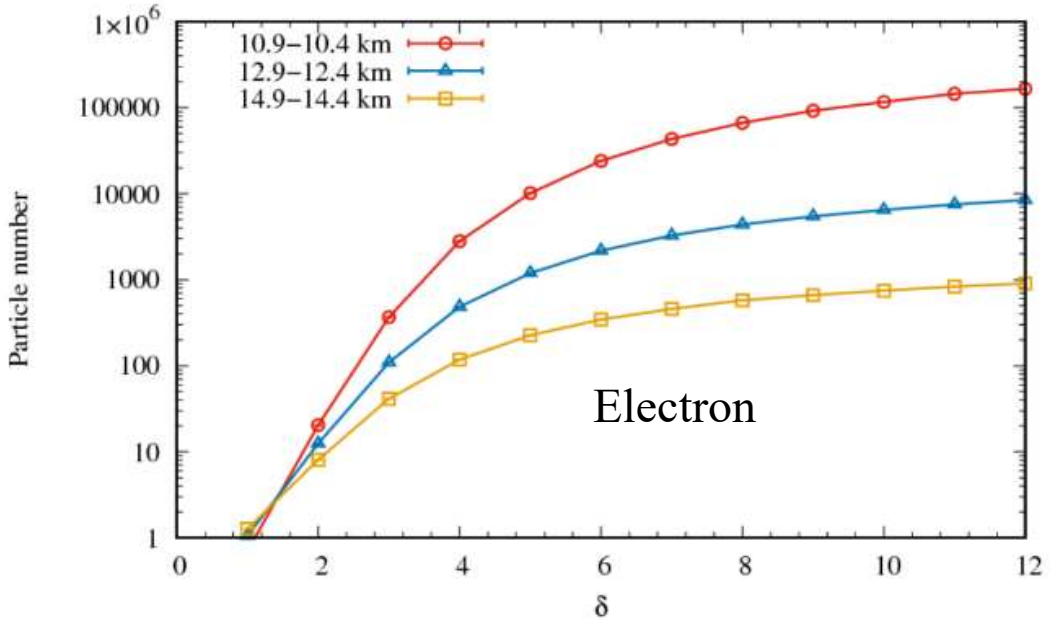


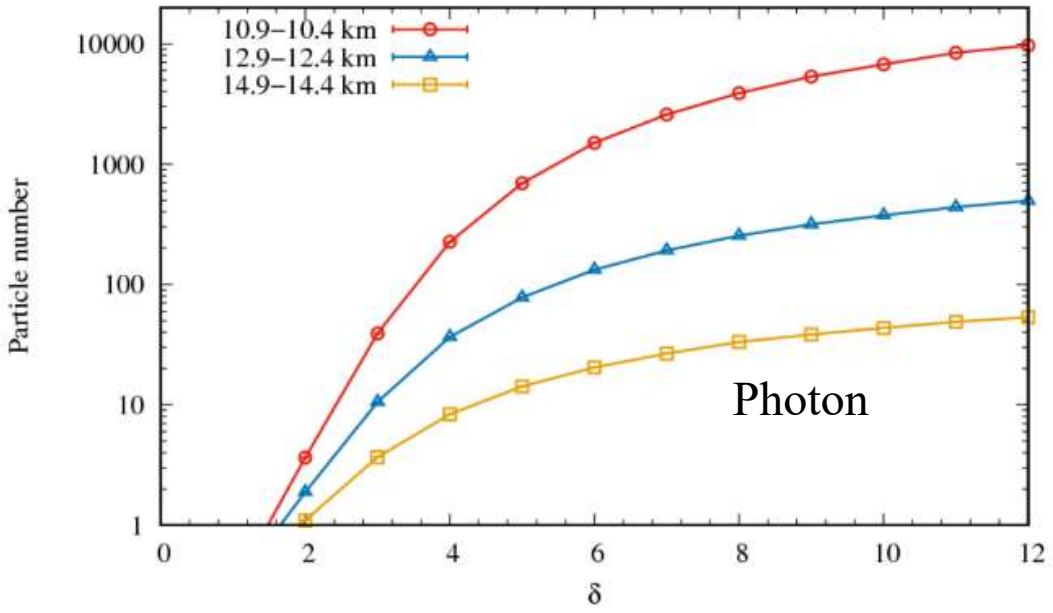


- The number of RREA particles decreases with altitude.
- The number of RREA particles exhibits a weak dependence on the energy of seed electrons.

The number of RREA particles as a function of δ at different altitudes

- Seed electron: 10 MeV
- Thundercloud thickness : 500 m





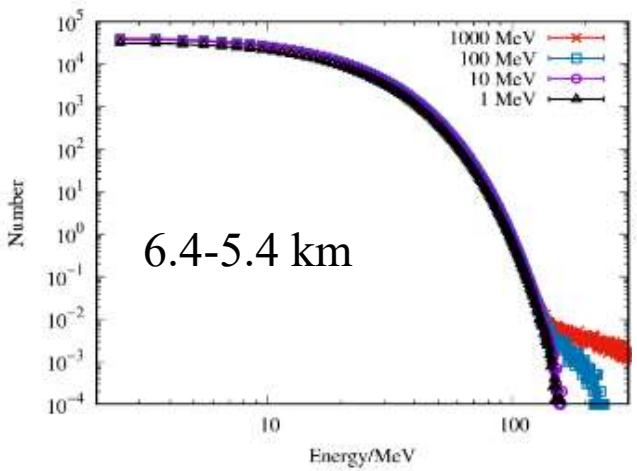
$$\delta = E/E_{\mathrm{th}}$$

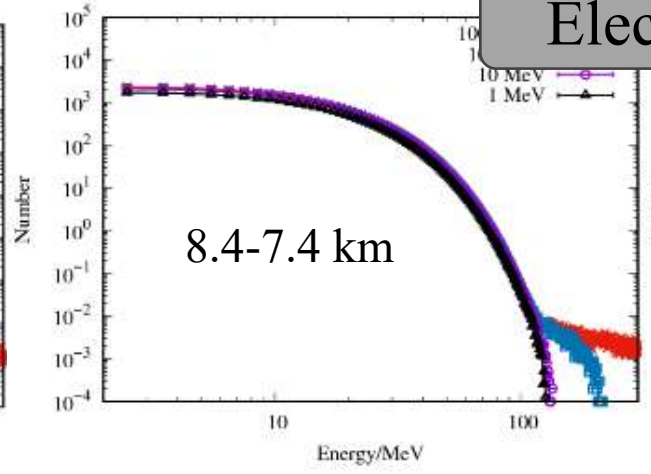
- The number of RREA particles increases with δ.
- The number flattens out when δ exceeds a critical value.

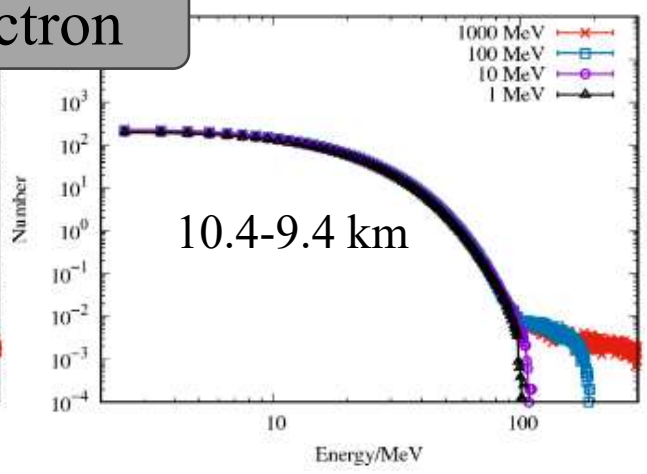
Energy distributions of secondary particles at different altitudes

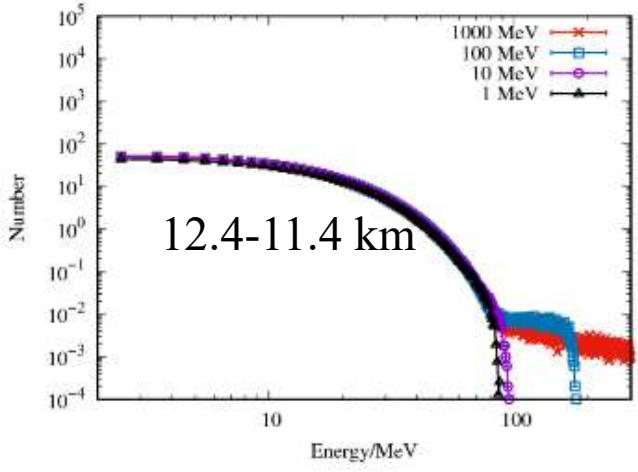
- Seed electron: 1,10,100,1000 MeV
- Electric field strength: 2.2 times E_{th}
- Thundercloud thickness: 1000 m

Electron

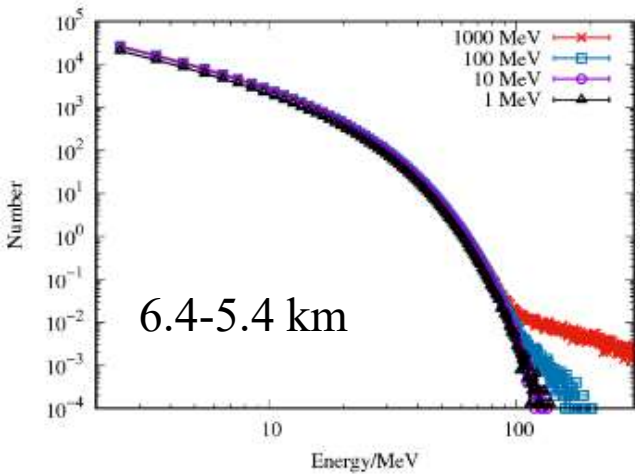


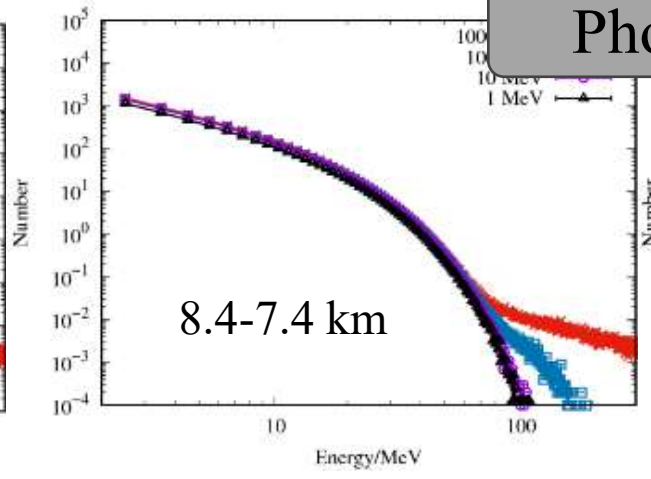


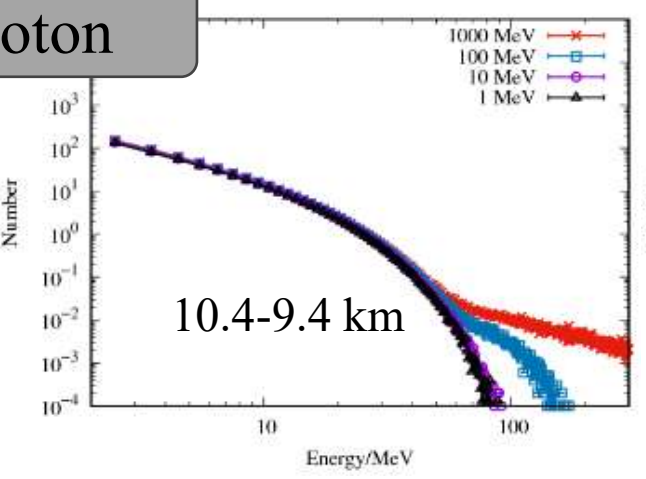


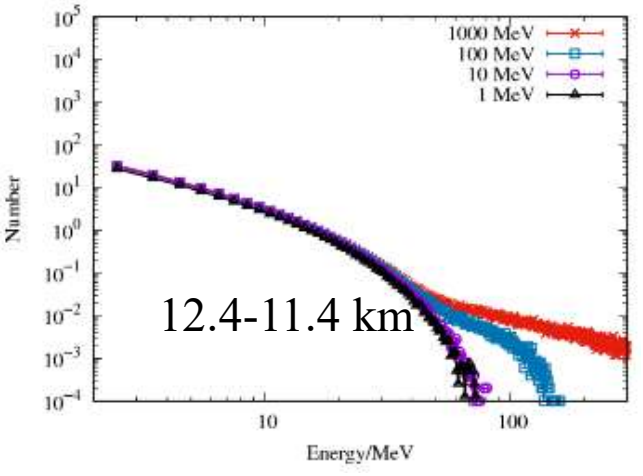


Photon





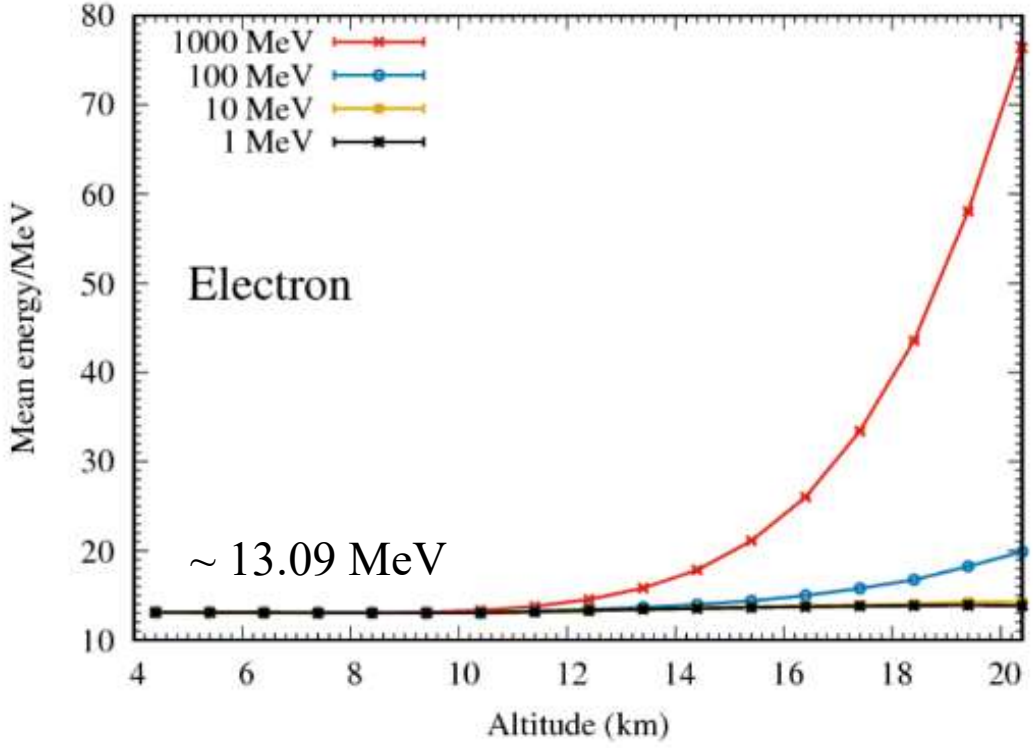


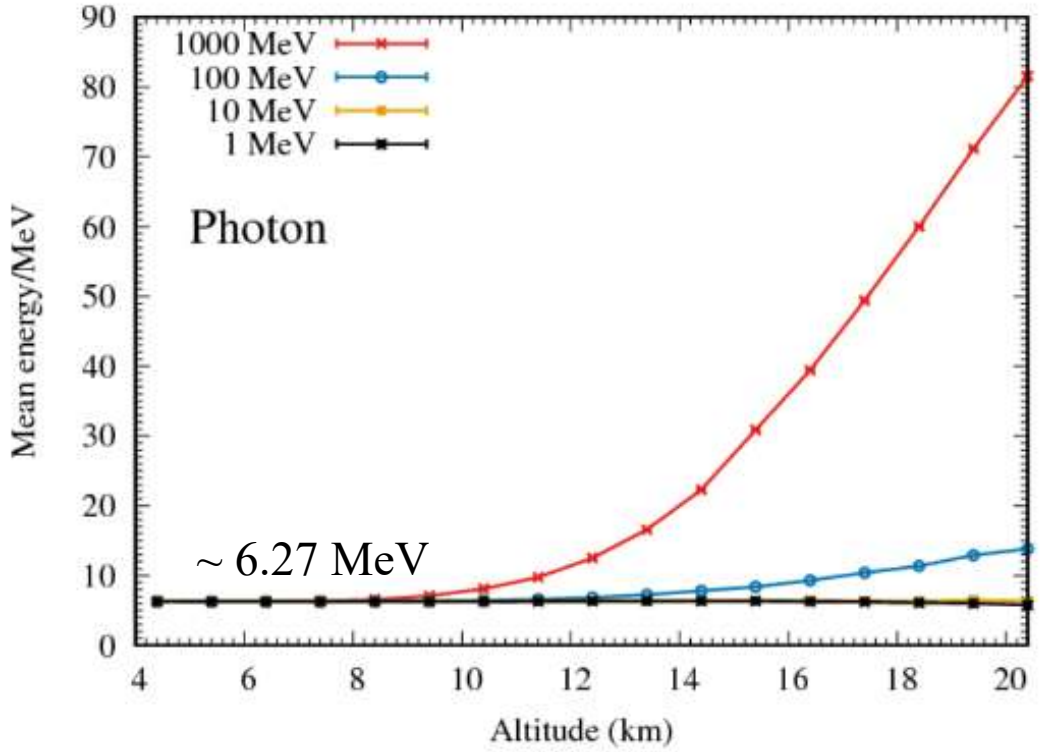


➢ As altitude increases, the distribution becomes increasingly dependent on the seed electron energy.

Mean energy of secondary particles as a function of altitude

- Seed electron: 1,10,100,1000 MeV
- Electric field strength: 2.2 times E_{th}
- Thundercloud thickness: 1000 m

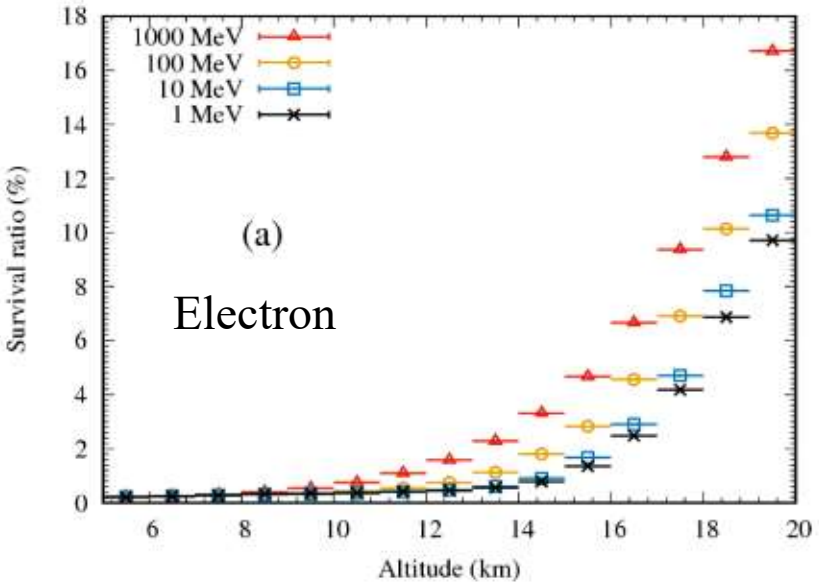


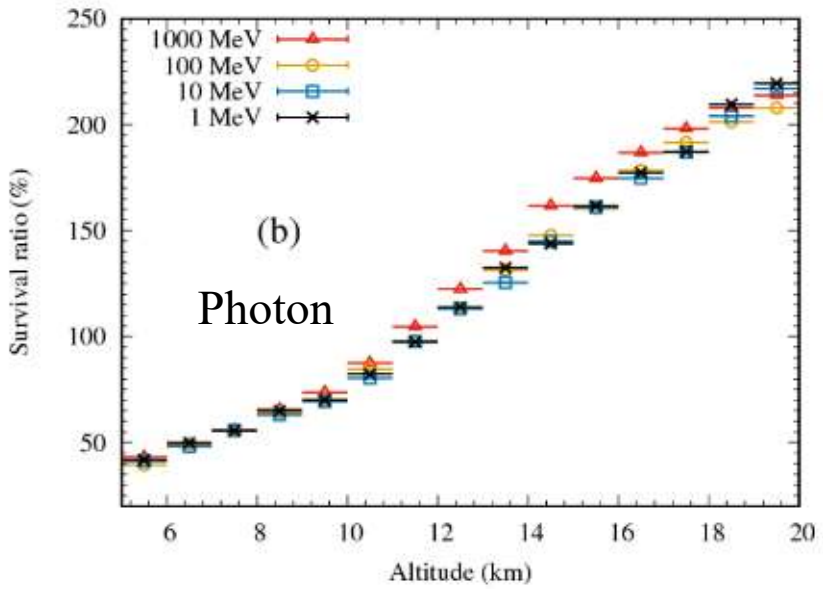


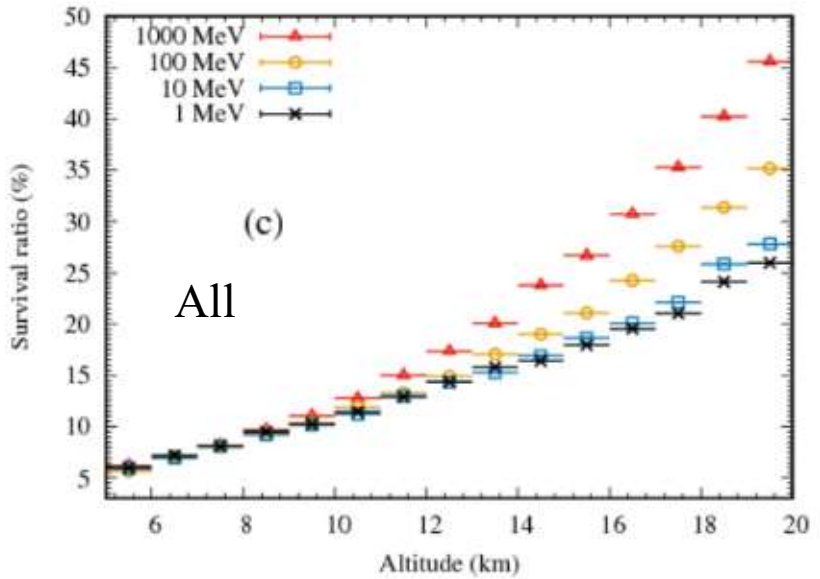
- At lower altitudes, the mean energy shows a weak dependence on seed electron energy and altitude.
- At higher altitudes, for higher seed electron energies, the mean energy increases with altitude.

The survival ratio of secondary particles as a function of altitude

- Seed electron: 1,10,100,1000 MeV
- Electric field strength: 2.2 times E_{th}
- Thundercloud thickness: 1000 m





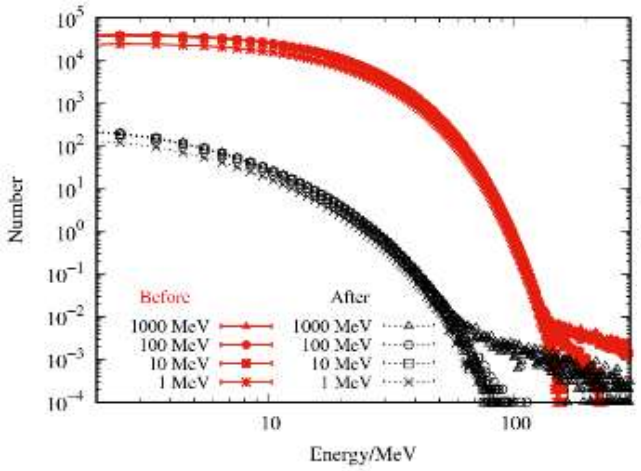


- The survival ratio of RREA particles increases with altitude.
- At lower altitudes, the survival ratio shows a weak dependence on seed electron energy and altitude.

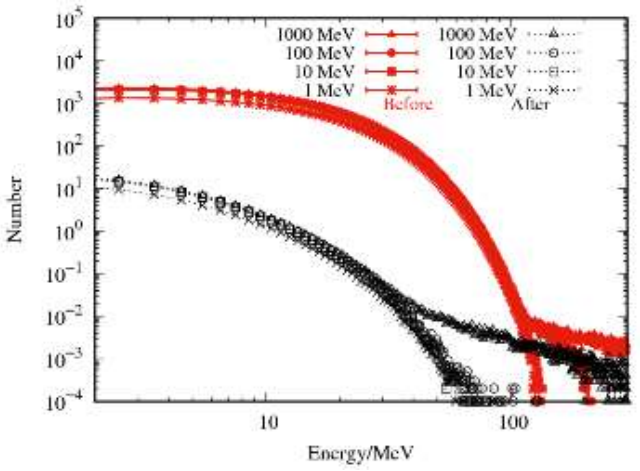
Energy distributions of secondary electrons before and after attenuation

- Seed electron: 1,10,100,1000 MeV
- Electric field strength: 2.2 times E_{th}
- Thundercloud thickness: 1000 m

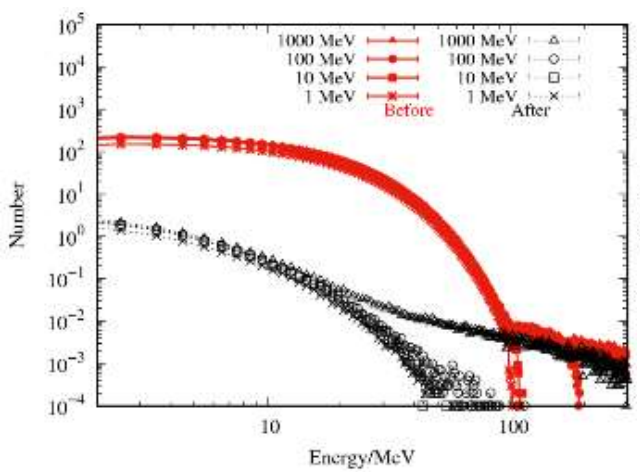
6.4-5.4-4.4 km



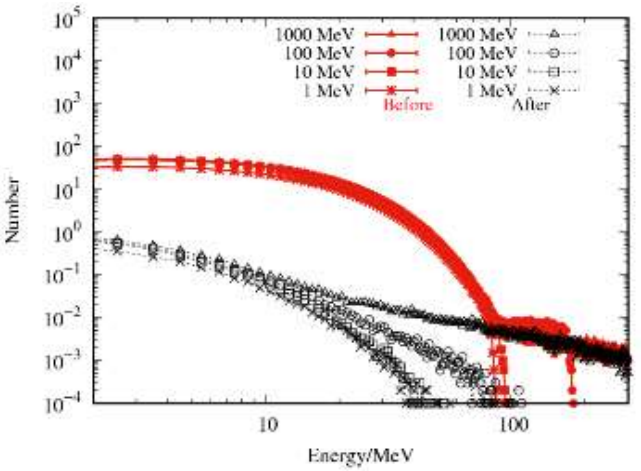
8.4-7.4-6.4 km



10.4-9.4-8.4 km



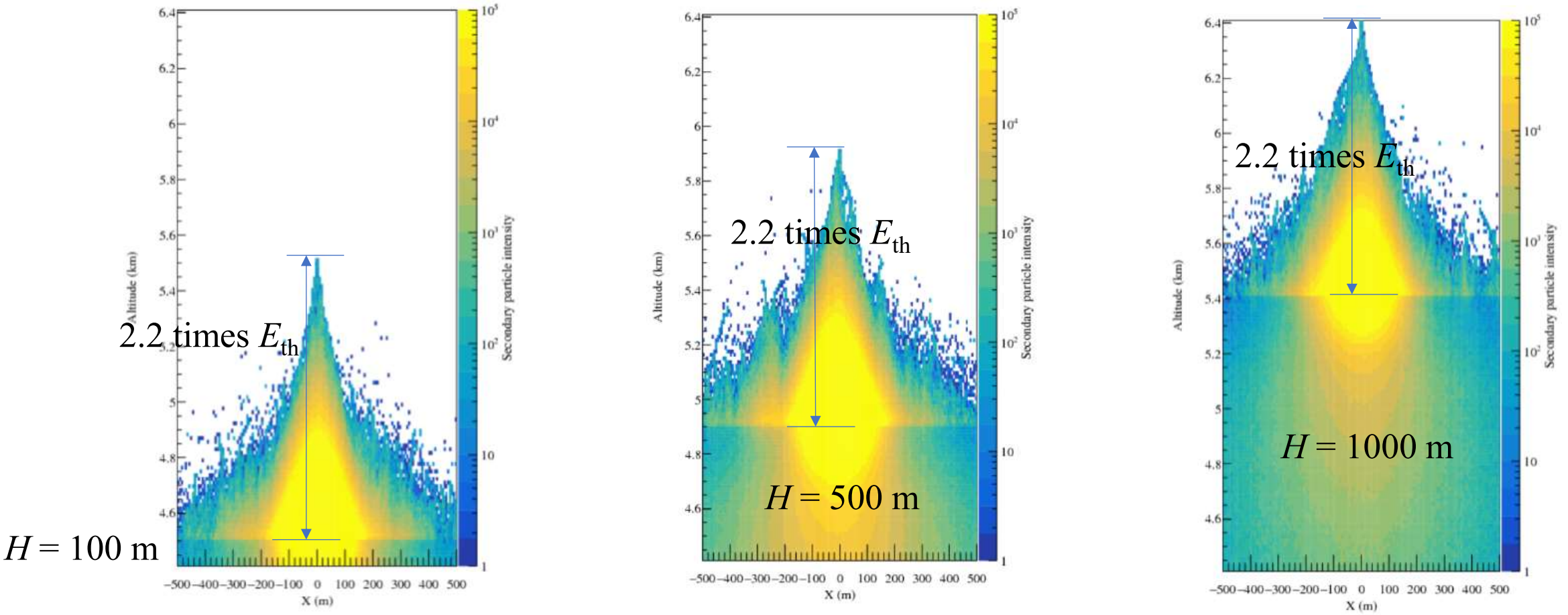
12.4-11.4-10.4 km



- Low-energy particles attenuate more severely, while high-energy particles are less affected.
- After attenuation, the fraction of high-energy particles becomes larger.

RREA process and the subsequent attenuation to the LHAASO site

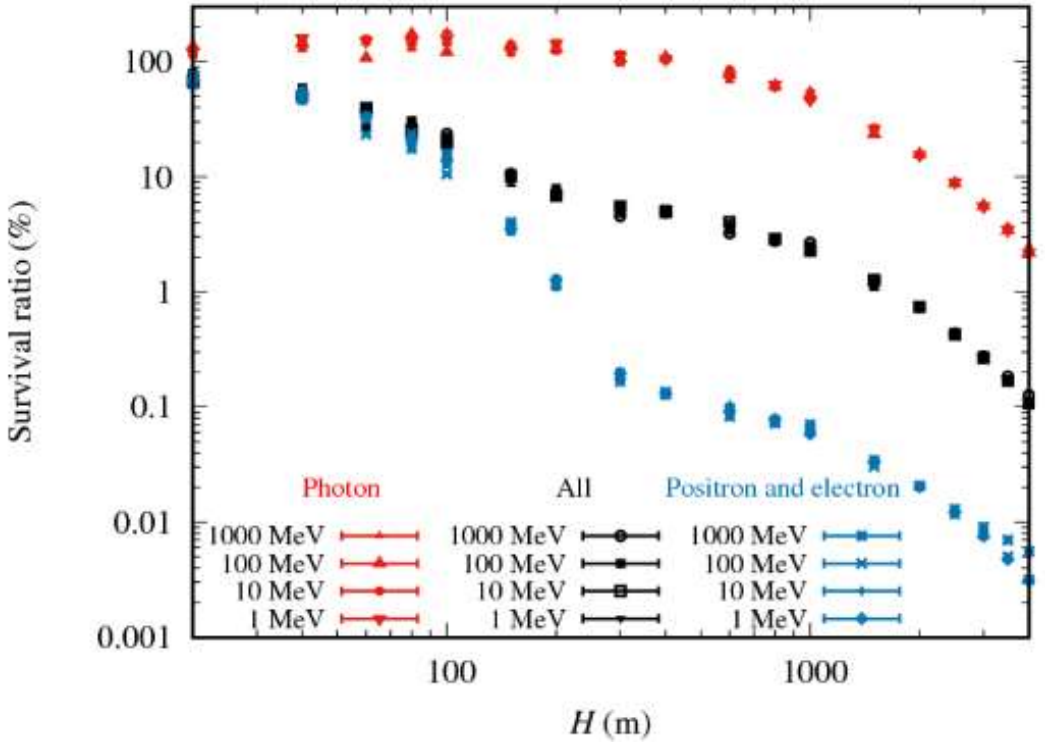
- Seed electron: 10 MeV
- Electric field strength: 2.2 times E_{th}
- Thundercloud thickness: 1000 m

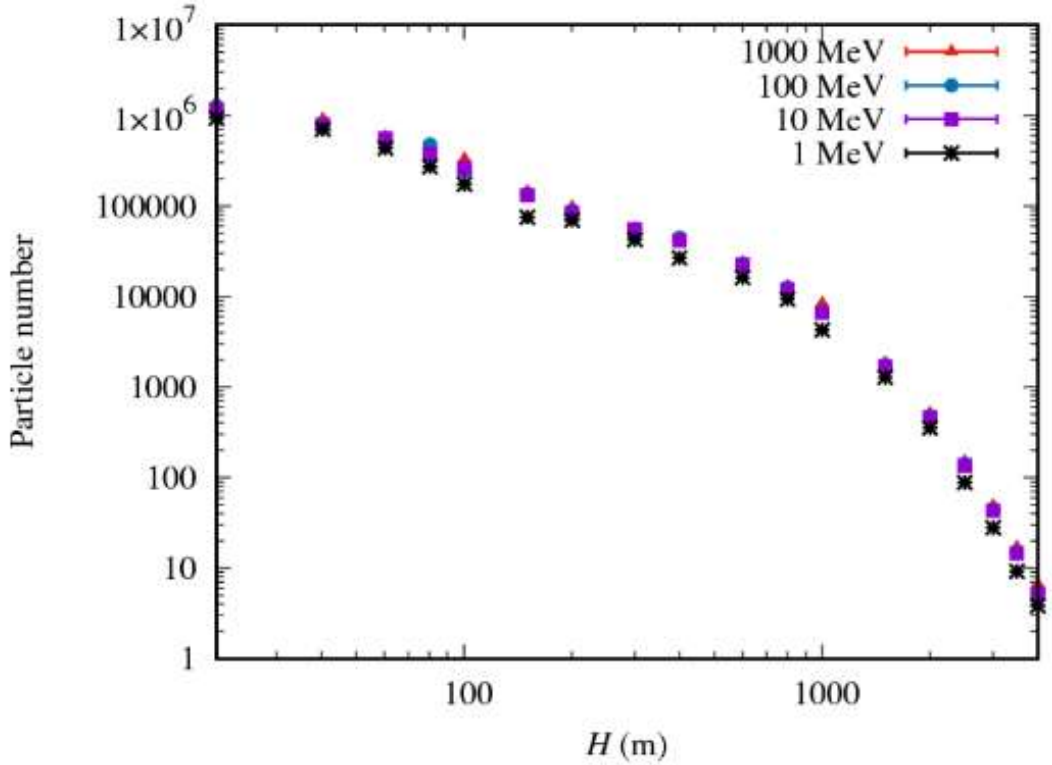


- After leaving the electric field region, particles attenuate rapidly as the attenuation distance increases.

The survival ratio and number of secondary particles as a function of attenuation distance

- Seed electron: 1,10,100,1000 MeV
- Electric field strength: 2.2 times E_{th}
- Thundercloud thickness: 1000 m





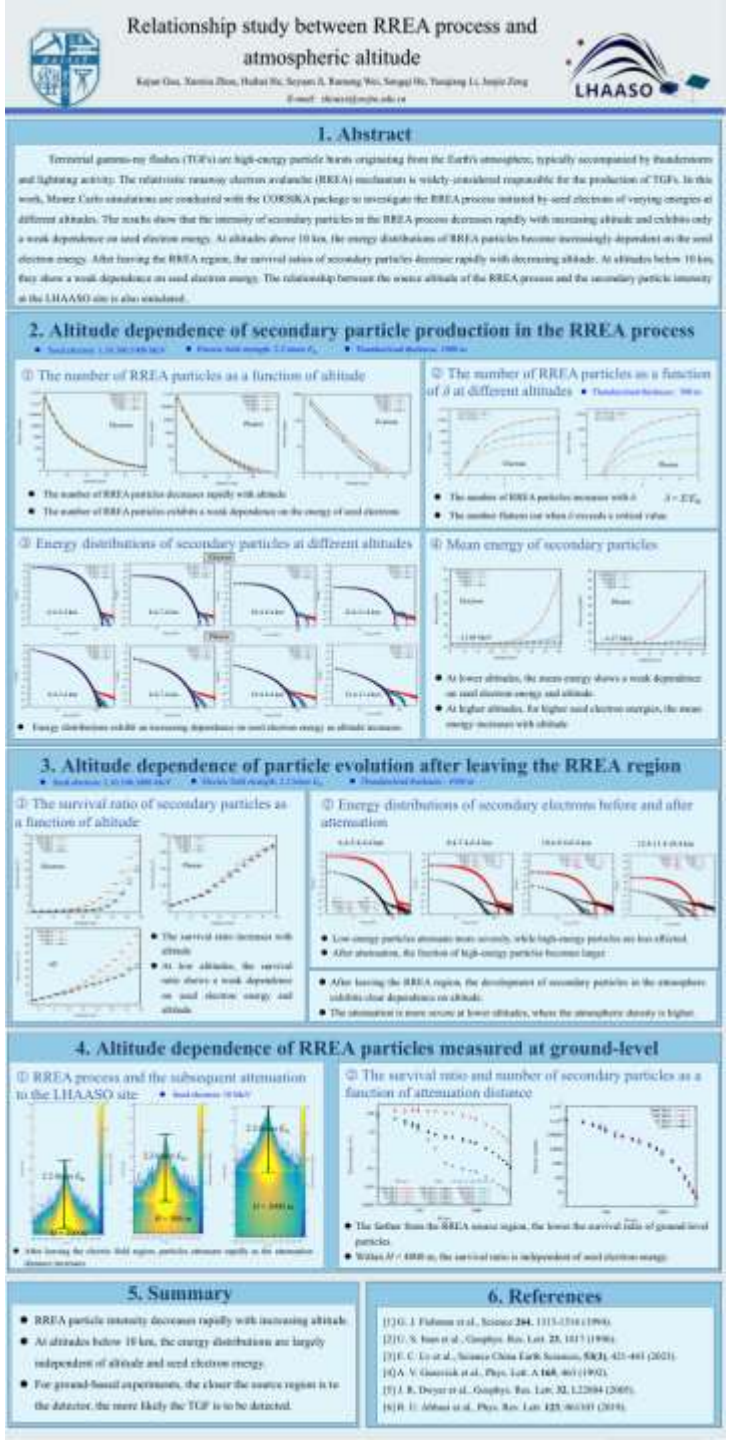
- The farther from the RREA source region, the lower the survival ratio of ground-level particles.

Summary

- RREA particle intensity decreases with increasing altitude.
- At altitudes below 10 km, the energy distributions are largely independent of altitude and seed electron energy.
- The survival ratio of RREA particles increases with altitude, and at low altitudes it shows a weak dependence on seed electron energy and altitude.
- For ground-based experiments, the closer the source region is to the detector, the more likely the TGF is to be detected.

POS-40

Thank you !



Relationship study between RREA process and atmospheric altitude

LHAASO

1. Abstract

2. Altitude dependence of secondary particle production in the RREA process

① The number of RREA particles as a function of altitude

② The number of RREA particles as a function of δ at different altitudes

③ Energy distributions of secondary particles at different altitudes

④ Mean energy of secondary particles

3. Altitude dependence of particle evolution after leaving the RREA region

① The survival ratio of secondary particles as a function of altitude

② Energy distributions of secondary electrons before and after attenuation

4. Altitude dependence of RREA particles measured at ground-level

① RREA process and the subsequent attenuation to the LHAASO site

② The survival ratio and number of secondary particles as a function of attenuation distance

5. Summary

- RREA particle intensity decreases rapidly with increasing altitude.
- At altitudes below 10 km, the energy distributions are largely independent of altitude and seed electron energy.
- For ground-based experiments, the closer the source region is to the detector, the more likely the TGF is to be detected.

6. References