References

[1] X. D. Xu, Y. Z. Sun, S. T. Wang, et al., Chin. Phys. C, 46(2022)111001.
[2] F. F. Duan, Y. Y. Yang, L. Jin et al., Phys. Rev. C, 105(2022)034602.
[3] K. Wang, Y. Y. Yang, V. Guimaraes et al., Phys. Rev. C, 105(2022)054616.
[4] Z. C. Zhang, X. Y. Wang, T. L. Pu, et al., Nucl. Instrum. Meth. A, 1016(2021)165740.
[5] B. F. Lv, C. M. Petrache, et al., Phys. Lett. B, 824(2022)136840.
[6] B. F. Lv, C. M. Petrache, et al., Phys. Rev. C, 105(2022)034302.
[7] B. F. Lv, C. M. Petrache, et al., Phys. Rev. C, 105(2022)044319.
[8] S. L. Jin, The Astrophysical Journal, 927(2022)116.
[9] S. Fu, Z. Y. Ding, Y. J. Zhang, et al., The Astrophysical Journal Letter, 934(2022)1.

3 - 25 The Introduction of Tianwen-1 Mars Energetic Particle Analyzer and Its First Scientific Result

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Mars is the fourth planet in the solar system and could become a destination for human existence. The radiation environment of Mars is much more severe than that of Earth due to the lack of a global magnetic in future field and a thick enough atmosphere. Once leaving the near-Earth environment and going into space, astronauts and spacecraft without the protection of the geomagnetic field are inevitably exposed to intense high energy particle radiation. Thus it is necessary to measure the background radiation environment both in the Martian atmosphere and the transfer orbit from Earth to Mars.

Mars Energetic Particle Analyzer (MEPA), jointly being designed and developed by scientists and engineers from Institute of Modern Physics and the Lanzhou Institute of Physics, is an important scientific payload aimed at studying the interplanetary and near-Mars space radiation environment onboard the orbiter of Tianwen-1. MEPA consists of two parts: sensor head and electronics system. The MEPA sensor head adopts $\Delta E{-}E$ method to identify

Table 1 The detection performance of MEPA instrument.

Radiation dose	LET in silicon	Particle species
Indirect measurment	0.2~1 200 KeV/μm	1~100 MeV/nuc proton/alpha
below 400 MeV		20~20 000 MeV B C N O Ne Mg Si

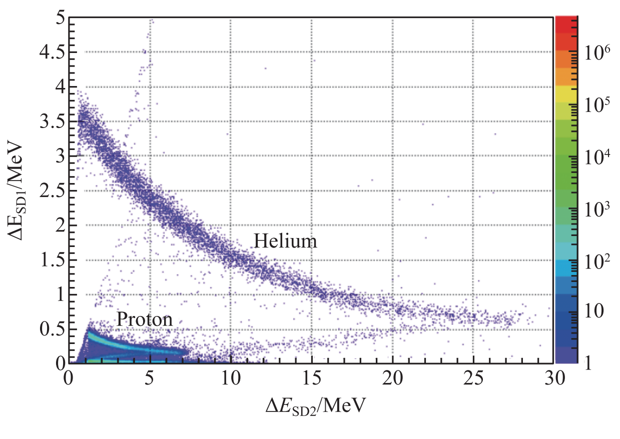

Fig. 1 (color online) The scattering plot of SEP events observed by MEPA.

the diverse species of charged particles in a wide energy range, the specific detection parameters of MEPA is listed in Table 1. In $\Delta E-E$ telescope system, SSD1 (ϕ8 mm with 15 μm thick) and SSD2 (ϕ26 mm with 300 μm thick) acts as $\Delta E1$ and $\Delta E2$ detectors respectively to identify charged particles with low energy. The CsI, acting as E detector with 32.5 mm thick, could stop and measure most of the energy of charged particles with relative high energy. Meanwhile the combination of SSD2 and CsI forms $\Delta E{-}E$ telescope to discriminate those faster charged particles. In order to ensure head sensor accept charged particles in the 60° field of view (FOV), the $\Delta E-E$ telescope is surrounded by two plastic scintillator detectors to eliminate particles coming from outside of the FOV. In-orbit data transferred back to ground indicates MEPA is in good work conditions and has an excellent particle identification as shown in Fig. 1.

MEPA was launched with the TW-1 spacecraft in July, 2020 to start exploration of space radiation environment. Unlike galactic cosmic rays whose flux is stable for a long time, SEP (solar energetic particle) events are sporadic and unpredictable during any Solar cycle. Their flux is several orders of magnitude higher than the background cosmic rays, which not only has a great impact on the interplanetary and near-earth space radiation environment, but will also pose a huge threat to space missions such as manned spaceflight and deep space exploration. On November 29, 2020, MEPA observed the first large widespread SEP event of solar Cycle 25 at 1.39 astronomical unit. At the time of eruption of the SEP event, Tianwen-1 and Earth were approximately on the same magnetic field line, meaning that TW-1 and near-Earth spacecraft could observe solar energetic particles from a distance of tens of millions of kilometers, which provided a rare opportunity to study the effects of energetic particle propagation. In Fig. 2, by comparing proton time-intensity profiles in similar energy bins from MEPA and near-Earth spacecraft, it is found that the magnetic field line associated with Tianwen-1 and near-Earth spacecraft is not connected to burst source regions on the sun's surface and interplanetary shock, which means that the observation by TW-1 and near-Earth spacecraft is due to cross-field diffusion. Meanwhile the comparison of proton fluence spectra at the two locations showed similar double-power law spectral characteristics and the proton time-intensity profiles showed a typical reservoir phenomenon during the SEP decay phase. They suggested that the double-power-law spectrum is most likely generated in the source region of the shock acceleration, and vertical diffusion is a key factor in explaining the SEP reservoir phenomenon during this event.

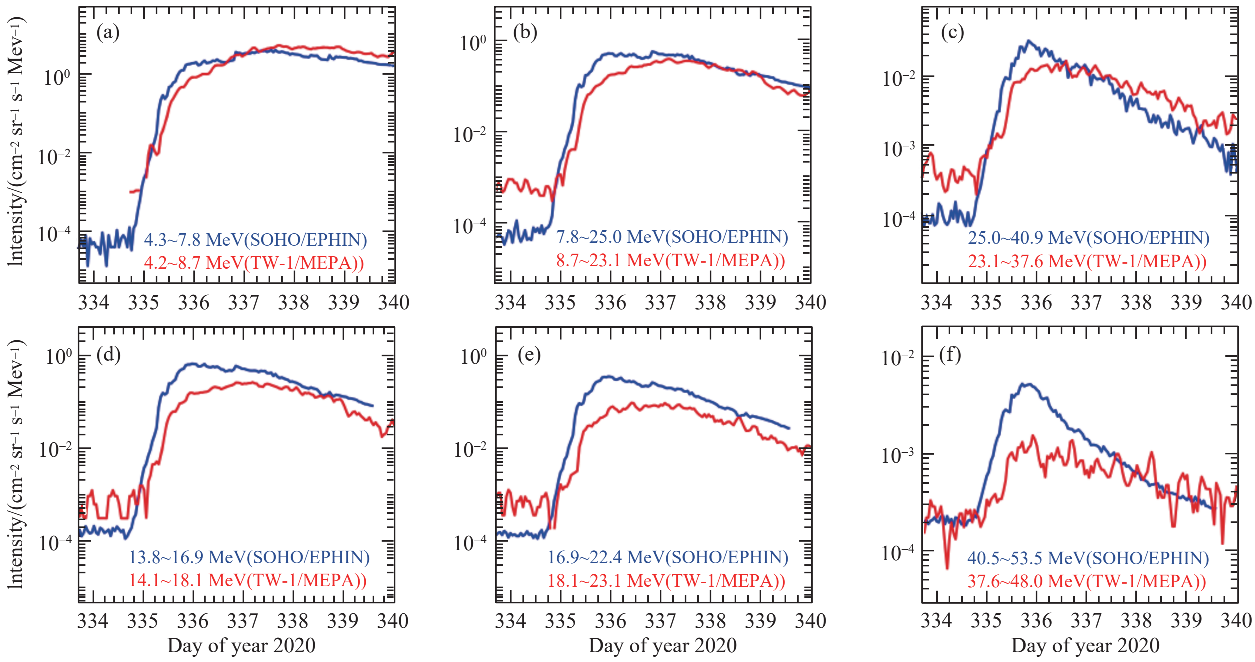

Fig. 2 (color online) Comparisons of the observed proton time-intensity profiles between MEPA and SOHO at similar energies.

This SEP event is only a moderate event with the maximum energy of the accelerated protons around 60 MeV. It is estimated that for atmospheric depths of 20 $g\cdot cm^{-2}$, only protons with initial energy above 150 MeV can penetrate the Martian atmosphere and arrive at the surface. Nowadays, the stronger SEPs are inevitable in solar maximum years (25 solar phase), which could significantly increase radiation dose near or on the Mars. MEPA is currently operating in a 265 km × 12 000 km elliptical orbit and will keep continuous observation of energetic charged particles from SEPs. By comparison with data from other near-Mars orbiter and on-Mars landers, it will improve our understanding of Martian radiation environment and help design future crewed missions to Mars.

Reference

[1] S. Fu, Z. Y. Ding, Y. J. Zhang, et al., The Astrophysical Journal Letter, 934(2022)1.