

Underground Nuclear Astrophysics Experiment JUNA in China

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Underground Nuclear Astrophysics Experiment in China (JUNA) will take the advantage of the ultra-low background in Jinping underground lab. A 400 kV high current accelerator with an ECR source and γ , neutron and charged particle detectors will be set up. We plan to study directly a number of nuclear reactions important to hydrostatic stellar evolution near their Gamow window energies such as $^{25}\text{Mg}(p,\gamma)^{26}\text{Al}$, $^{19}\text{F}(p,\alpha)^{16}\text{O}$, $^{13}\text{C}(\alpha,n)^{16}\text{O}$ and $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$, by the end of 2019.

KEYWORDS: direct measurement, underground laboratory, Gamow window.

1. Underground physics

Direct measurement of the cross sections for the key nuclear reactions crucial to hydrostatic stellar evolution within Gamow window is important for solving key scientific questions in nuclear astrophysics [1]. The direct measurement of astrophysical reaction rates on stable nuclei require high-intensity beams and extremely low background, which represents enormous the major challenge at the frontiers of nuclear astrophysics. The largest challenge is the small cross section amid with large natural background. With the ultra-low background in deep underground environment, direct measurement of these key reactions in underground lab becomes a frontier in the field of experimental nuclear astrophysics. The first underground based low-energy accelerator facility, LUNA [2, 3] at Gran Sasso underground laboratory has successfully demonstrated the feasibility of meeting these challenges.

China JinPing underground Laboratory (CJPL) was established from a constructing hydro-power plants in the Jinping mountain, Sichuan, China [4, 5]. The facility is located near the middle of traffic tunnel. The facility is shielded by 2400 m of mainly marble overburden, with radioactively quiet rock. Its ultra-low cosmic ray background, which is about 2 orders of magnitude lower than that in Gran Sasso, makes it into an ideal environment for low background experiment. CJPL phase I (CJPL-I) now housing CDEX [6] and PandaX dark matter experiments. CJPL phase II [7] (CJPL-II) is available by the beginning of 2016 for much larger scale underground experiments (120,000 m³ volume). JUNA will be one of its major research programs in CJPL-II [8].

2. Nuclear reactions

2.1 $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ reaction

The $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ reaction is quoted as the holy grail in nuclear astrophysics [9]. The uncertainty of this reaction affects not only the nucleosynthesis of elements up to iron, but also the evolution of the massive stars and their final fate (black hole, neutron star). The cross section of this reaction has to be known within an uncertainty less than 10% at helium burning temperatures ($T_9=0.2$), corresponding to a Gamow window around $E_{c.m.}=300$ keV. It is extremely difficult to determine the reaction cross