Measurement of beam characteristics of Low-Energy Accelerators

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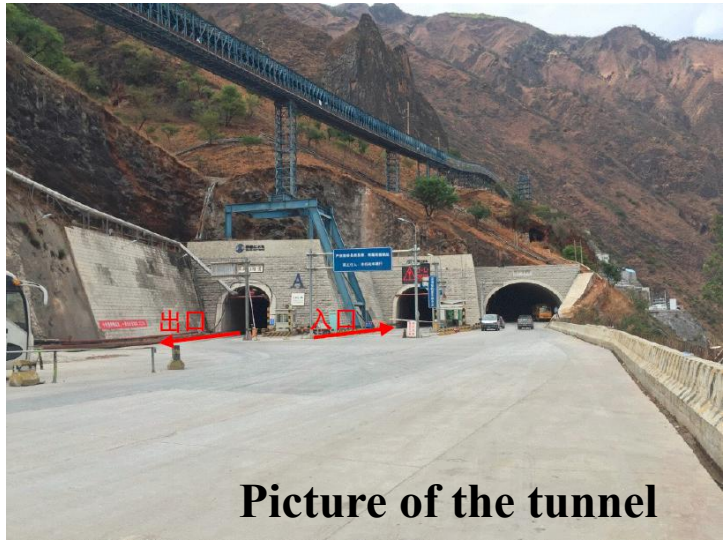
China JinPing underground Laboratory(CJPL)

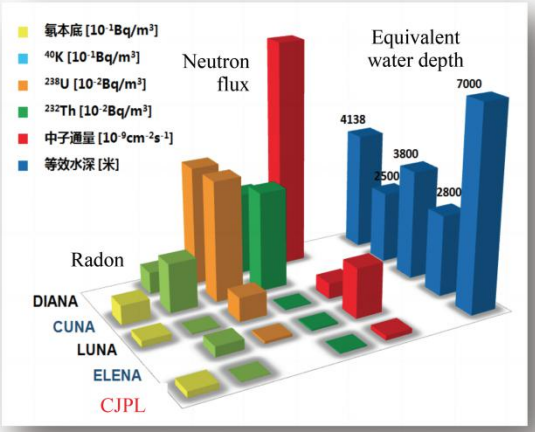
A traffic tunnel was finished the construction in Aug. 2008.



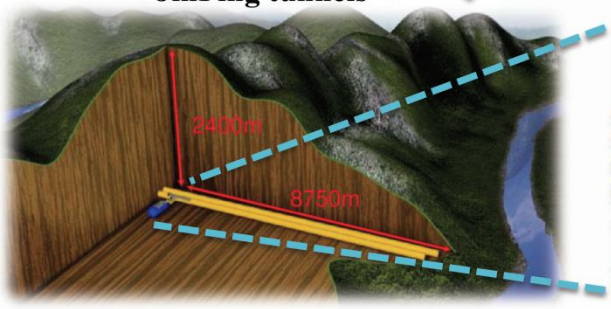
Picture of the tunnel

Jinping Underground laboratory for Nuclear Astrophysics (JUNA)

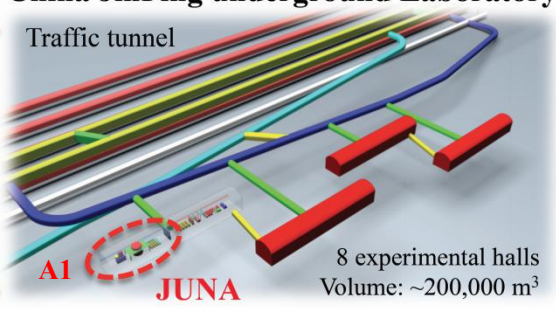
Radiation Background Level



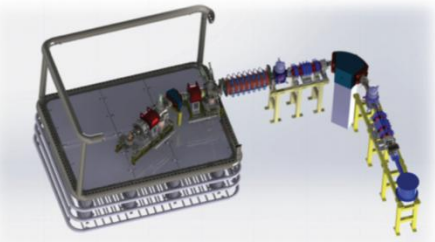
JinPing tunnels



China JinPing underground Laboratory



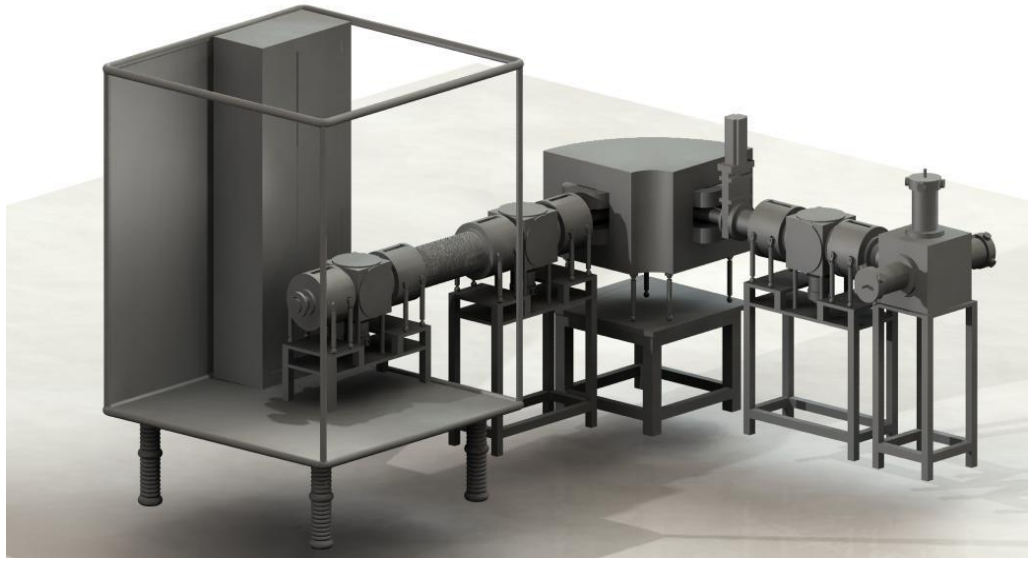
JUNA 400kV accelerator



Prof. Weiping LIU will show the details of CJPL and JUNA projects in session 11, Friday.

The characteristics of beam

- **The JUNA 400 kV accelerator was finished the construction in May of this year and now is operating at CIAE.**
  - **Absolute energy**
  - **Energy spread**
  - **Long-term energy stability**



Absolute energy measurement

- **Resonance reaction**
  - A number of known resonances in proton induced reaction:

    $^{24}Mg(p, \gamma)^{25}Al$, $^{27}Al(p, \gamma)^{28}Si$,……
  - Disadvantage: only cover a narrow energy range.

- **Non-resonance reaction**
  - $^{12}C(p,\gamma)^{13}N$
  - can determine the absolute proton energy over a wide energy range.

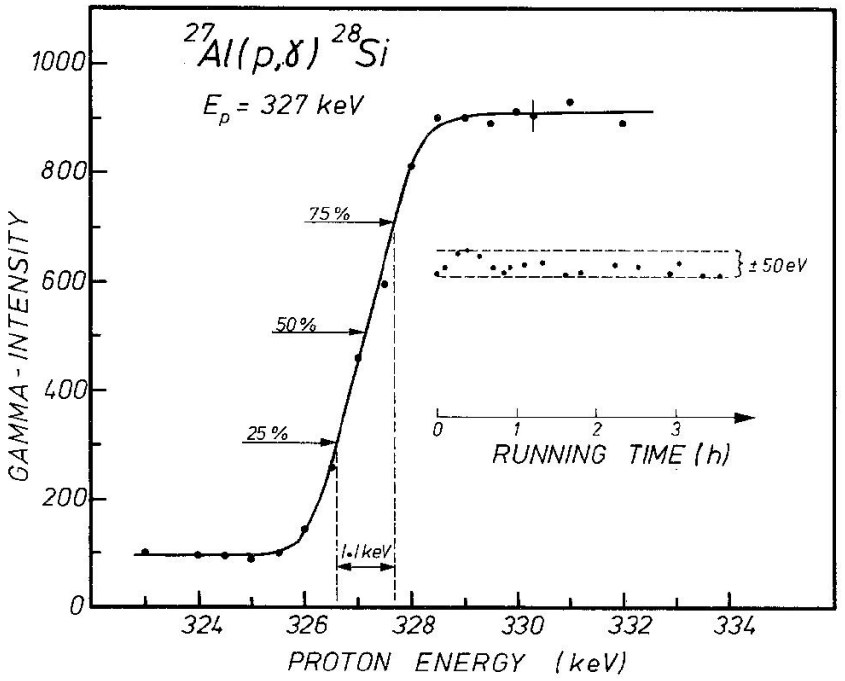


Fig. 2. Thick-target yield curve of the 327 keV resonance of $^{27}Al(p,\gamma)^{28}Si$. The line through the data points is to guide the eye. An experimental energy spread of 1.1 keV is deduced from the 25 and 75 % points. The inset shows the results of the energy stability test

T. Freye et al., Z. Physik A 281, 211-218 (1977)

Studies of $^{12}C(p,\gamma)^{13}N$

- An advantage in using carbon as target was that the results are not influenced by any C-deposition on the target during the runs.

- The expected γ-ray energy from $^{12}C(p,\gamma)^{13}N$:

$$E_\gamma \approx Q + (12/13)E_p + \Delta E_{DS} - \Delta E_R$$

Q = 1943.5±0.3 keV*

ΔE_{DS}: the Doppler shift

ΔE_R: the nuclear recoil

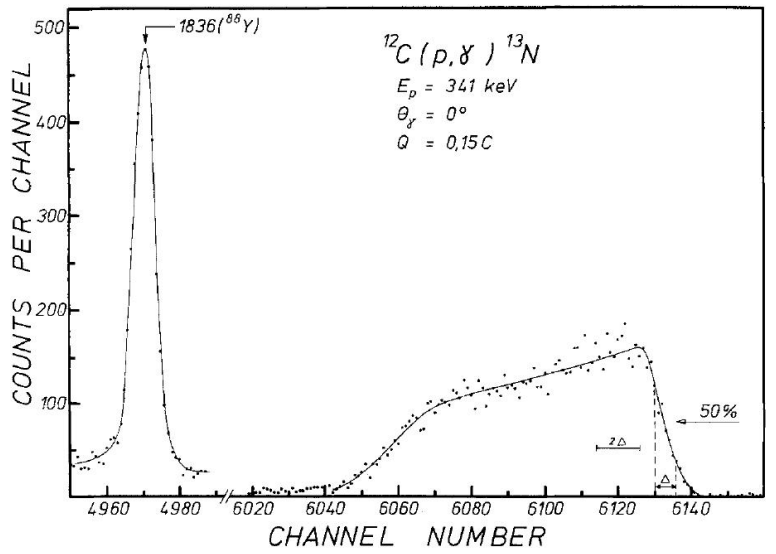


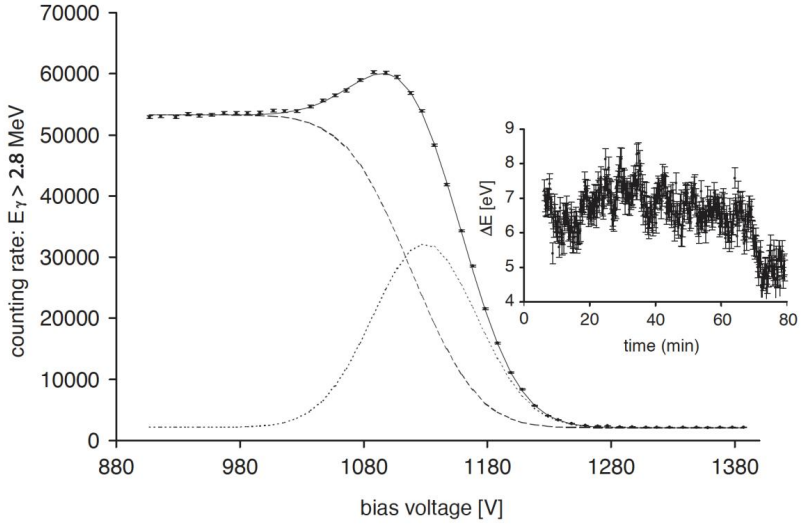
Fig. 3. Relevant part of the γ-ray spectrum for the capture transition of $^{12}C(p,\gamma)^{13}N$ at E_p = 341 keV and θ_γ = 0°. Also shown is the 1836 keV line from a ^{88}Y source recorded concurrently during the run. The lines through the data points are to guide the eye. The spectrum was taken with a 13 keV thick target and recorded over an accumulated charge of 0.15 C

*F. Ajzenberg-Selove, Nucl. Phys. A 523 (1991) 1

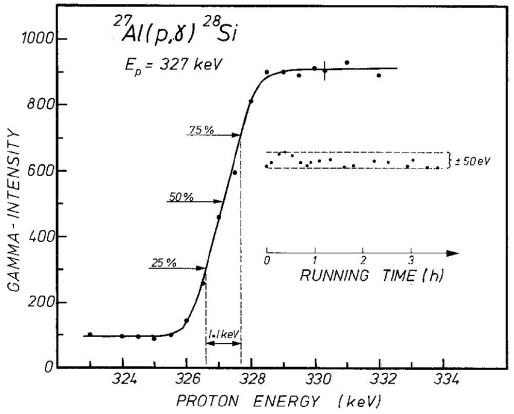
T. Freye et al., Z. Physik A 281, 211-218 (1977)

Energy spread and Long-term energy stability

- The energy spread is determined by fitting the γ yield curve with a **Gaussian** followed by an **error function**.
- The increase of the yield from the thick target yield plateau before the steep drop is due to the **Lewis effect**, which is only visible for narrow resonances and a low energy spread of the beam.
- The energy stability of the beam was investigated near the midpoint (50% yield point) of the γ yield curve, where the yield variation was translated into an variation ΔE.



A. Formicola et al., NIM A 507 (2003)



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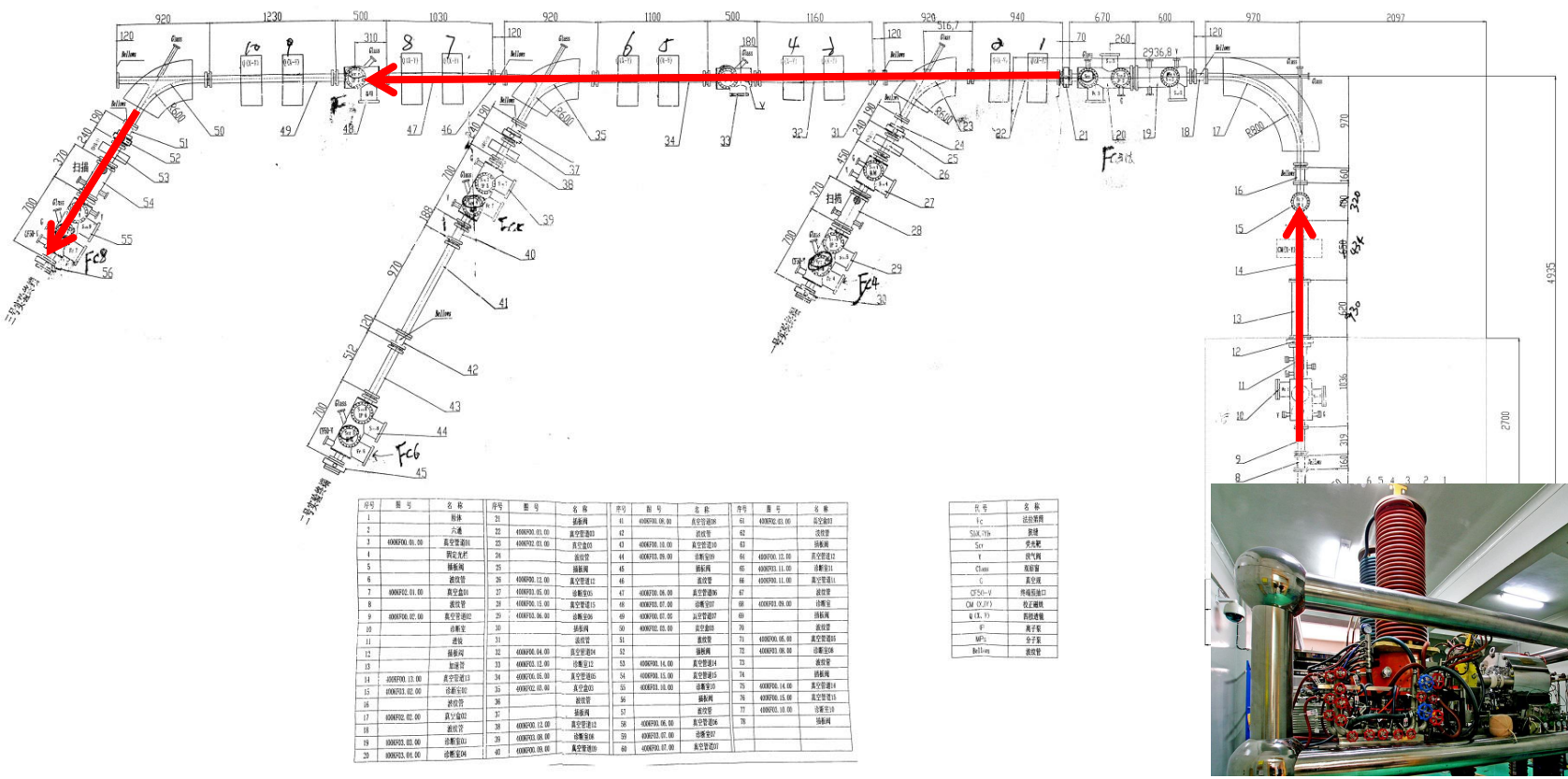
T. Freye et al., Z. Physik A 281, 211-218 (1977)

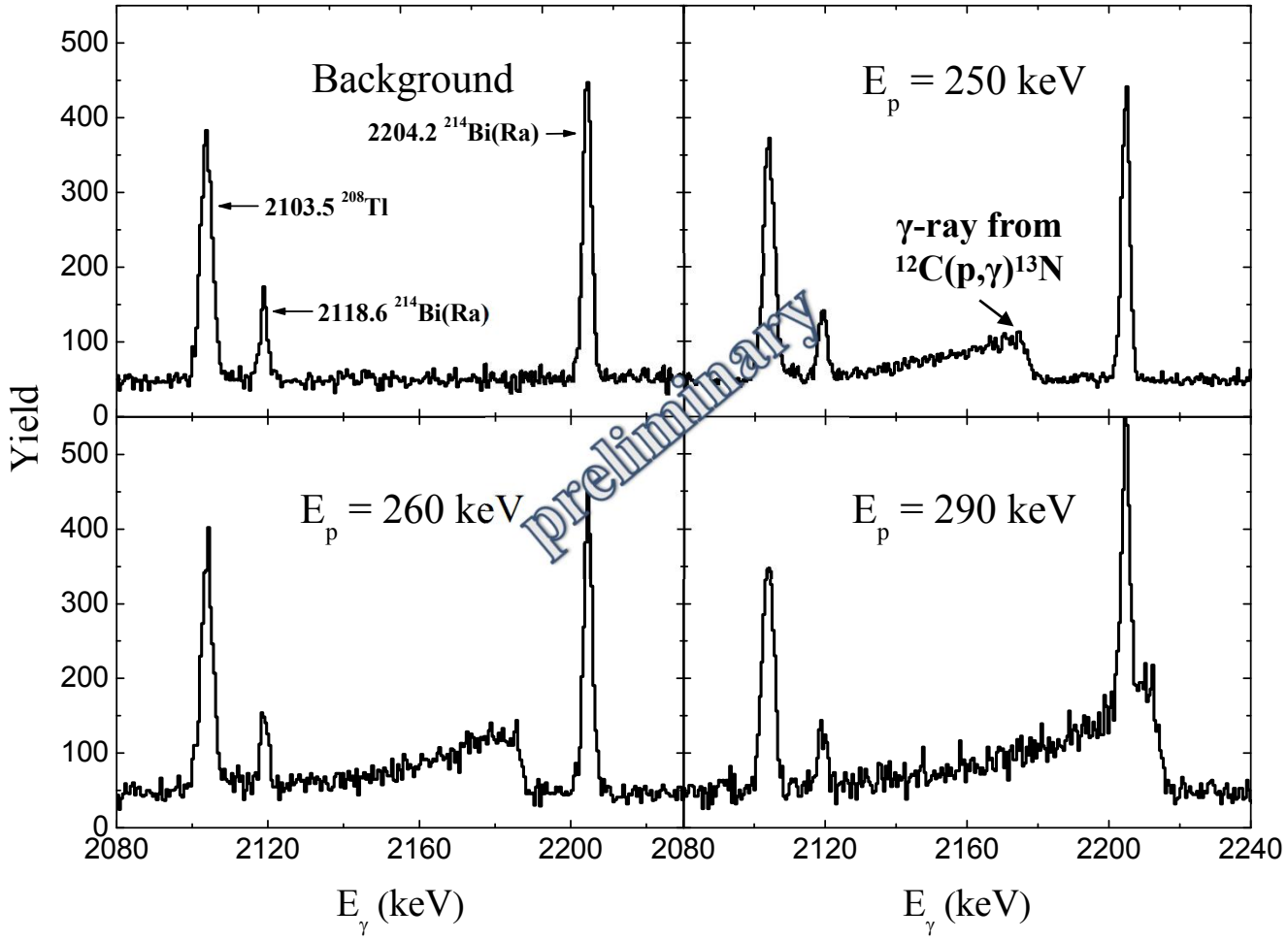
Experiments at 320 kV platform

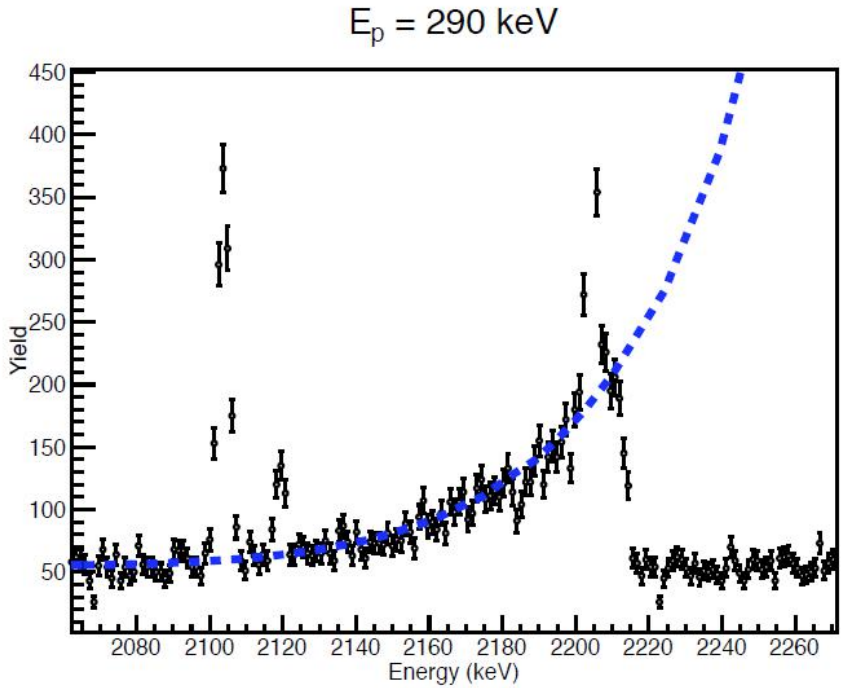
- ✧ Study the method using non-resonance reaction $^{12}C(p,\gamma)^{13}N$ to calibrate the proton beam energy.
- ✧ Estimate the energy spread of beam and long-term energy stability with resonance reactions $^{27}Al(p,\gamma)^{28}Si$ and $^{24}Mg(p,\gamma)^{25}Al$.



Results of the experiment

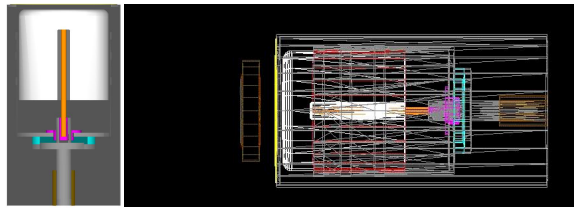
Studies of $^{12}C(p,\gamma)^{13}N$ reaction at E_p = 250, 260 and 290 keV



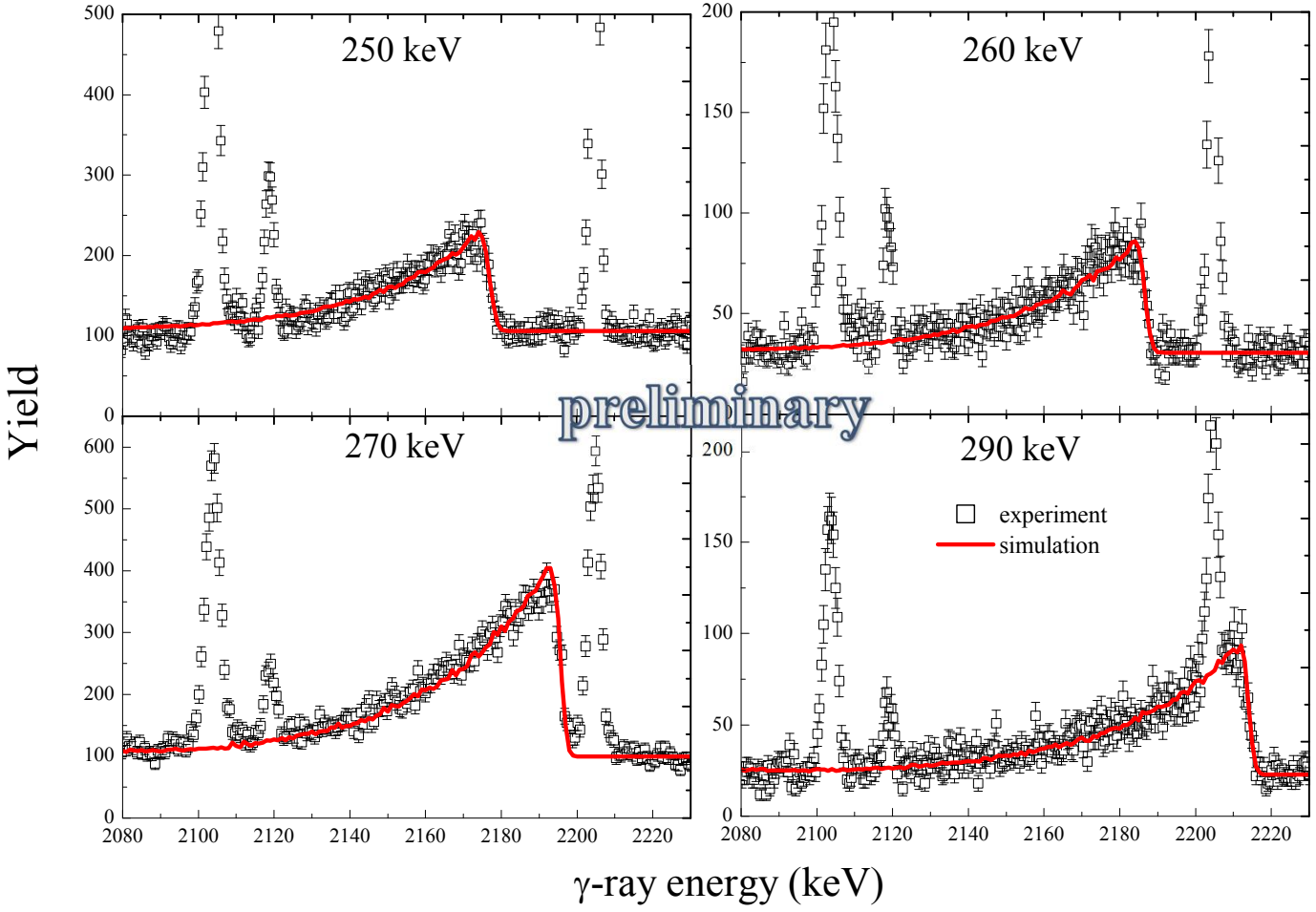


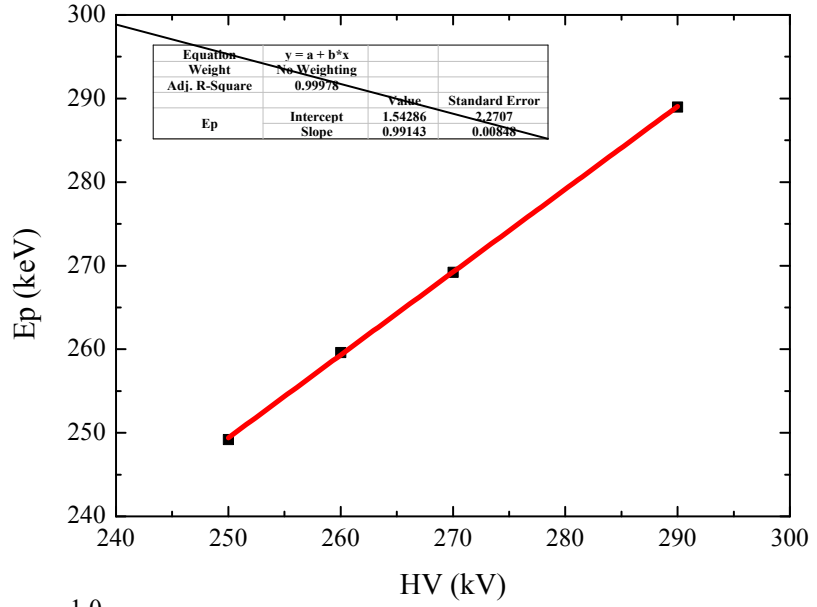
The blue dashed line shows the cross section of $^{12}C(p,\gamma)^{13}N$.

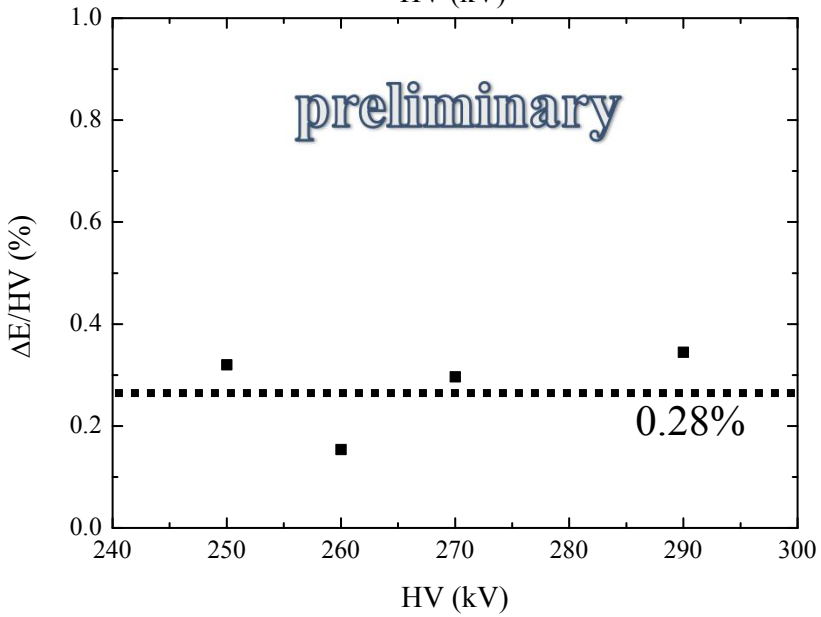
Absolute energy of proton beam



The absolute energy of proton beam is determined by fitting the experimental data with GEANT4 simulation result.

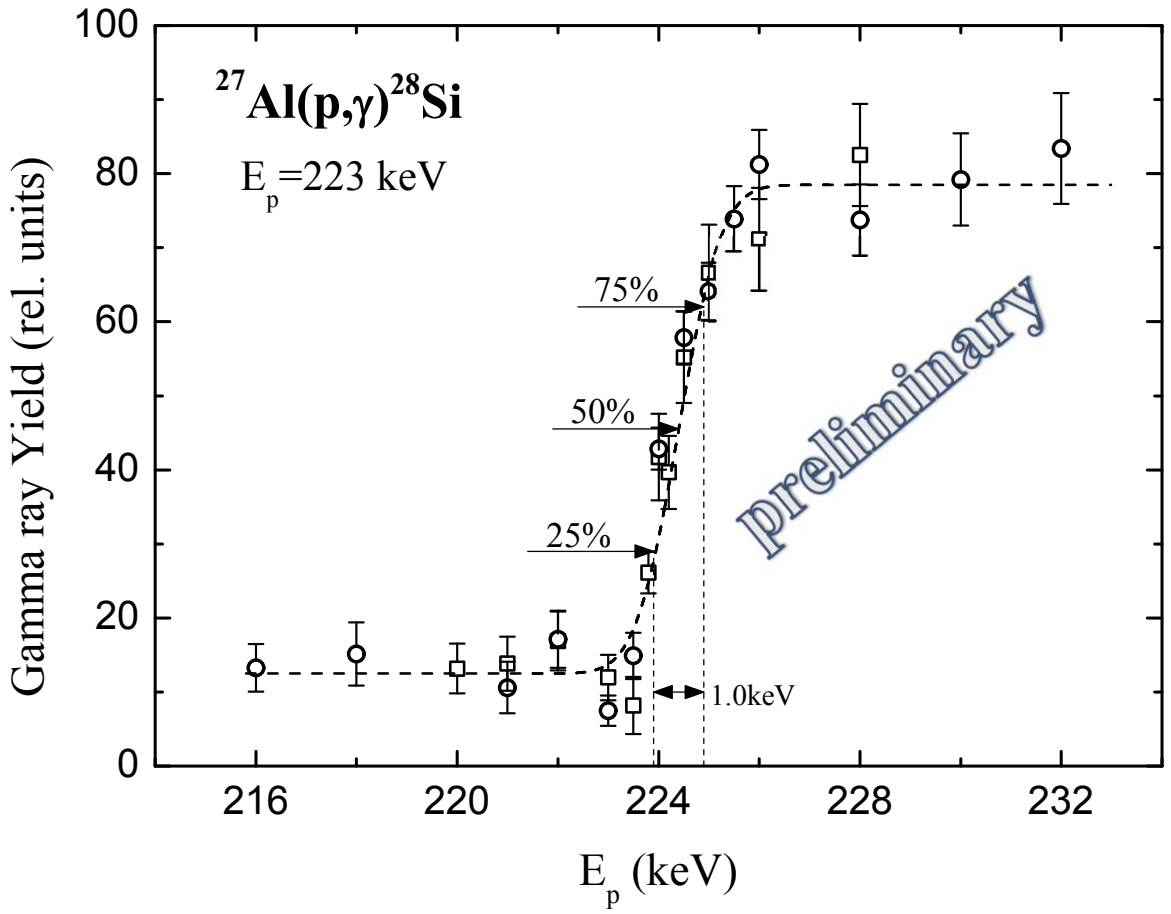


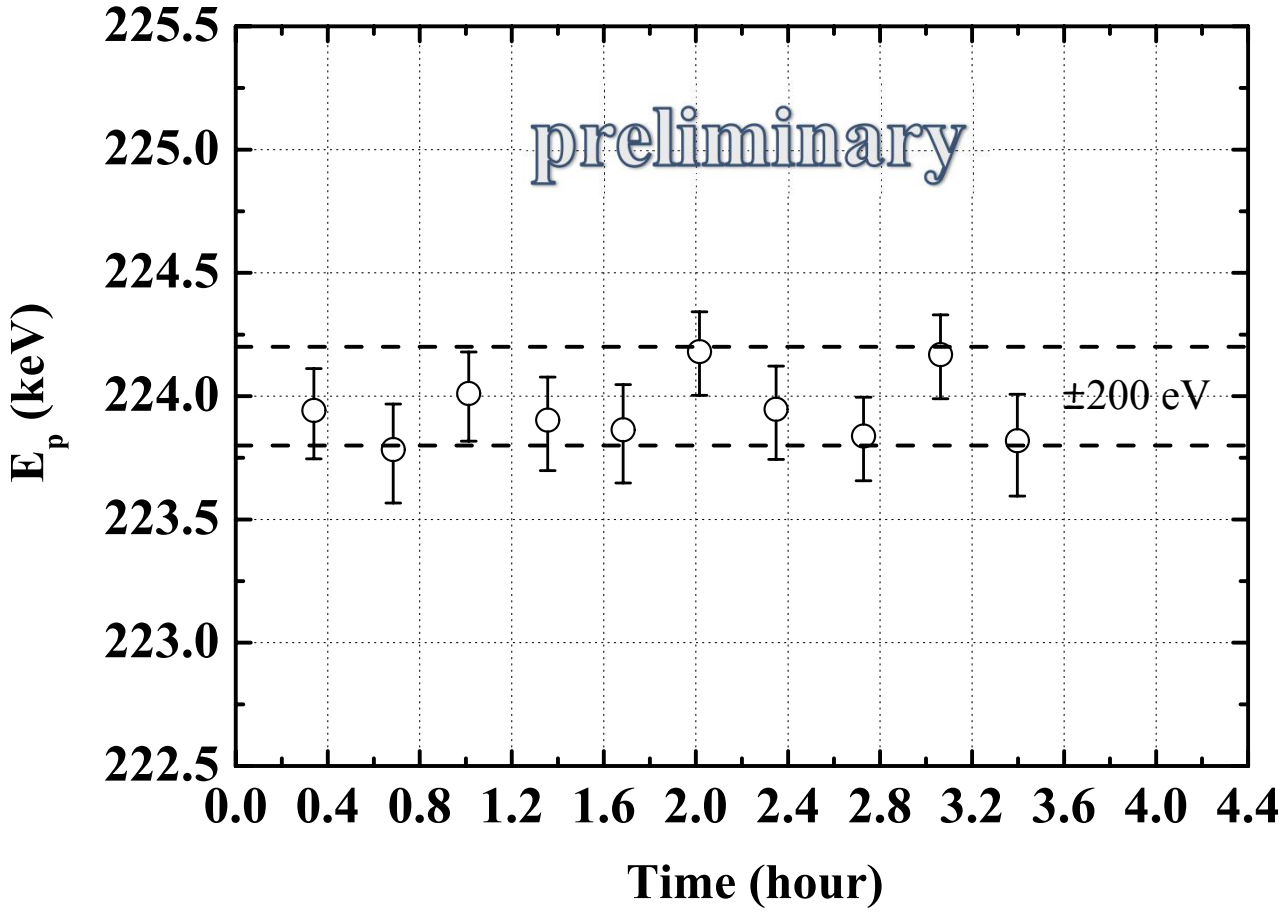




Estimate energy spread and Long-term energy stability

- The results of $^{27}Al(p,\gamma)^{28}Si$ resonance reaction at 223 keV.
- The data of $^{24}Mg(p,\gamma)^{25}Al$ is still in analysis.





Summary

- ✓ China JinPing underground Laboratory (CJPL) is under construction, and the experiment for Nuclear Astrophysics is one of the major research programs.
- ✓ The methods to determine the absolute energy, energy spread and long-term stability of proton beam have studied at 320 kV research platform in the Institute of Modern Physics, Lanzhou, China.
- ✓ The JUNA 400 kV accelerator was finished the construction and will be ready for the testing experiments in this August.

Thank you very much !!!
Welcome to Shandong University(Weihai)