Signal Optimization with HV divider of MCP-PMT for JUNO
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Motivations

The Jiangmen Underground Neutrino Observatory (JUNO) is proposed to determine the neutrino mass hierarchy using a 20 kiloton underground liquid scintillator center detector (CD). One of the key is the energy resolution of the CD to reach <3% at 1 MeV, where totally 15,000 MCP-PMT will be used. The quality of PMT signals is a key for large-size and high-precision neutrino experiments while most of these experiments are affected by the overshoot of PMT signal from the positive HV scheme. The overshoot coupled with positive HV which is triggering dead time and precise charge measurement, we have studied to control it to less than ~1% of signal amplitude for a better physics measurement. Besides, we will show the study to optimize the MCP-PMT working configuration with JUNO for charge measurement in collection efficiency.

Overshoot with positive HV scheme

- Output signal (a)
  - Overshoot around 10%;
  - Positive HV divider;

- Analysis
  - Simplified circuit (a);
  - Discharge of C1 and C2;
  - \( R_1 \times C_1 \) and \( R_2 \times C_2 \);

- Experiments
  - \( C_2=22nF, R_2=50ohm, C_1=4.7nF, \) varying \( R_1\);
  - Cross check with \( C_2, R_2 \) and \( C_1 \);

- Optimized output signal (b)
  - Optimized circuit;
  - Overshoot around 1%;

- Overshoot model
  - \( C_2 = 22nF, R_2=50ohm; \)
  - Further simplified circuit (d);
  - Fourier transformation analysis.

\[
V_0(\omega) = V_1(\omega) \times H(\omega)
H(\omega) = \frac{j\omega}{j\omega + 1/\tau}
V_1(\omega) = -\frac{Q}{C_1} \times \exp(-\omega/\tau) \\
V_0(\omega) = \frac{Q}{C_1} \times \left(1/(\tau_1 - \tau)\right) \times (\tau_1 \exp(-\omega/\tau) - \tau \exp(-\omega/\tau_1))
\]

Overshoot ratio: \( \frac{V_o}{V_M} = \frac{\tau_1}{\tau} \) (consistent with experiment results)

Optimization the collection efficiency with HV divider

- Optimization of the divider ratio
  - HV divider;
  - Divider ratio: K-F1:F1-F2;
  - Optimal work configuration of PMT;

- Method of experiment
  - Gain@1*10^7 with EMF shielding;
  - Reference PMT: Hamamatsu PMT;
  - Keeping the PMT position the same;
  - MCP-PMT with HV divider of different divider ratio;
  - Detection efficiency: relative output charge;

- Results
  - Charge spectrum;
  - Mean charge;
  - K-F1:F1-F2 = 1;

References