24th IEEE Real Time Conference – Quy Nhon, Vietnam, 22-26 April, 2024

中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

Study on the Timing Performance of the SiPM

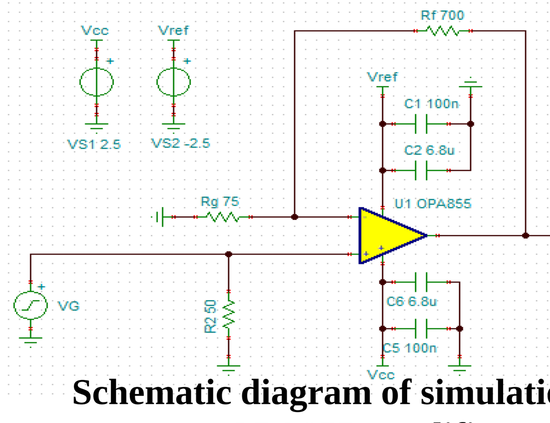
Peng Hu, Min Yan, Sen Qian, On behalf of the PMT Laboratory
Institute of High Energy Physics, Chinese Academy of Sciences

Introduction

Silicon Photomultipliers (SiPMs) are new type of high-performance semiconductor detectors, which inherit most of the advantages of semiconductor detectors and have good performance in terms of gain, signal-to-noise ratio and response speed. SiPM also has high photon detection efficiency and excellent time resolution, which is comparable to high-performance PMT. A fast-timing amplifier circuit board based on the OPA855 has been designed, which was used to evaluate timing performance of three types of SiPMs (Hamamatsu, SensL and NDL). The rise time of SensL J-30035 fast output port can reach 500 ps, the limit time resolution is 22.2 ps. The rise time of NDL 11-3030C-S is 1~2 ns, and the limit time resolution is 21.8 ps. The rise time of Hamamatsu S13360-1325CS is 1~2 ns, and the limit time resolution is 193.6 ps. Therefore, SensL J-series SiPMs have the best timing characteristics. This study aims to promote the implementation of the calorimeter scheme with high time resolution based on SiPM readout.

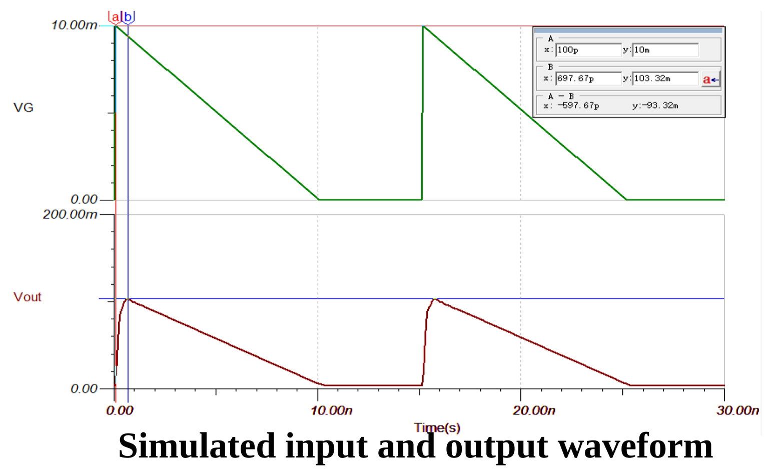
1. Design of fast-timing amplifier circuit

Candidate Amplifiers	OPA847I DBVT	OPA855	OPA856	OPA858	LMH6629	AD8099
Gain Bandwidth (GHz)	3.9	8	1.1	5.5	4	3.8
VOLTAGE NOISE (nV/$\sqrt{Hz}$)	0.85	0.98	0.9	2.5	0.69	0.95
Stable Gain	>= 12	>= 7	>= 1	>= 7	>=10	2~10
Slew rate (V/μs)	950	2750	350	2000	1600	<=1350
Typical RT (ps)	1000	170	750	300	550	600



Gain= 1+R_f/R_g

Schematic diagram of simulation with OPA855 amplifier

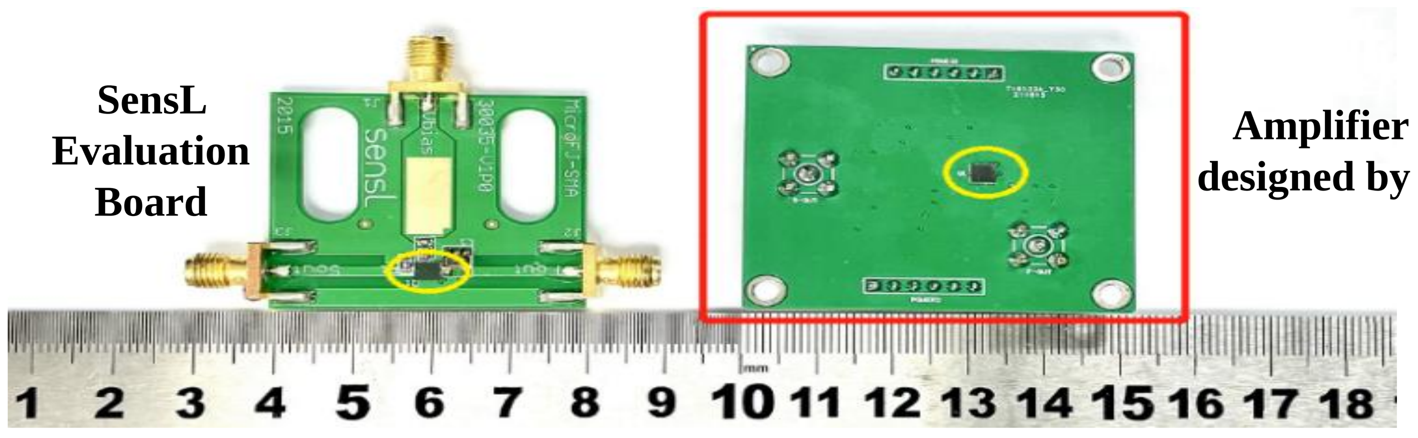


Simulated input and output waveform

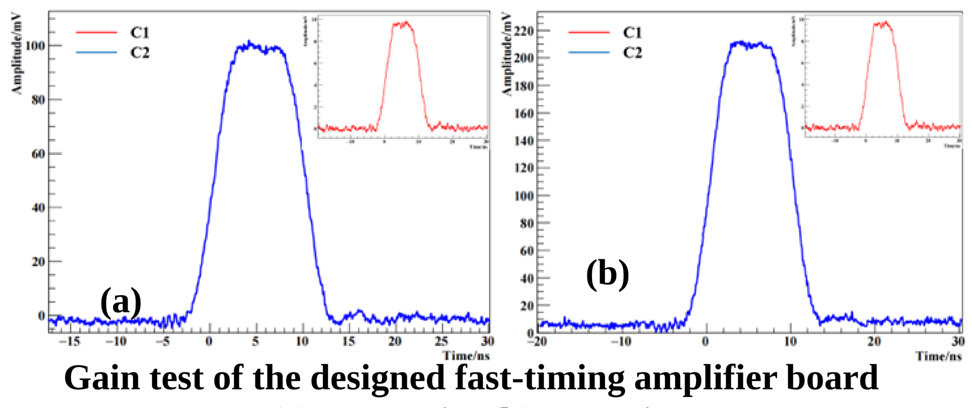
- OPA855 - broadband, low-noise operational amplifier with bipolar inputs for broadband transimpedance and voltage amplifier applications.
- A TINA-TI simulation was used to design the amplifier circuit board.

2. Evaluation of fast-timing amplifier board

SensL Evaluation Board



Amplifier Board designed by our Lab

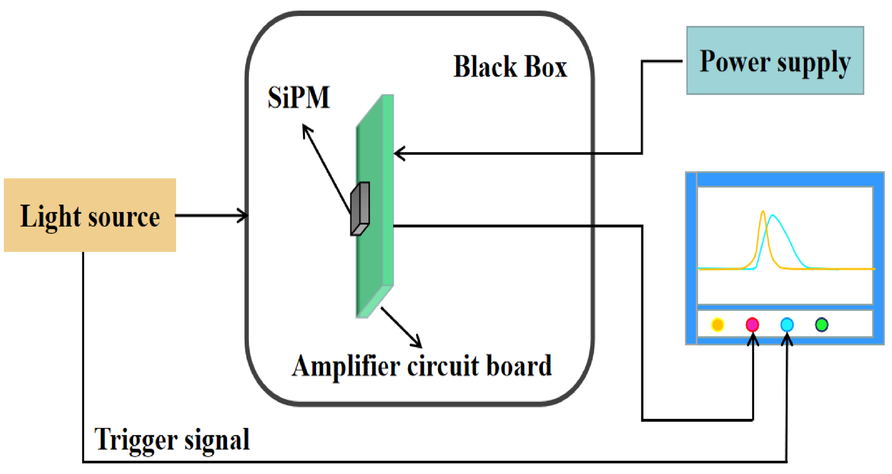


Gain test of the designed fast-timing amplifier board (a)10.3x gain, (b) 21x gain

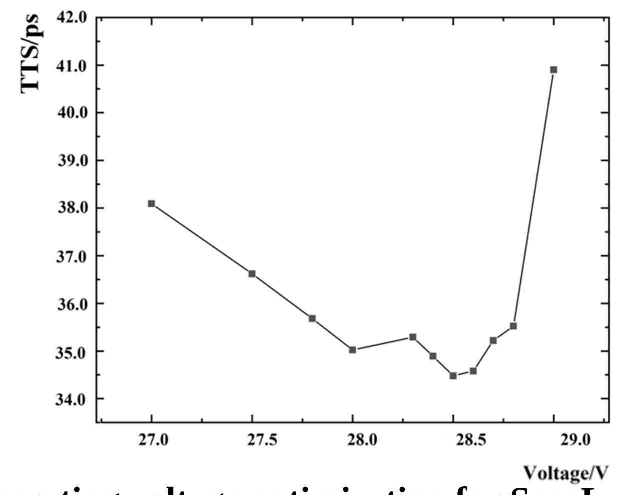
Parameters	Target	Simulated	Measured
Gain1	>10	10.3	10.5
Gain2	>20	21	21
Noise (mV)	1	0.5	0.8
Power (mW)	50	-	40

- The fast-timing amplifier board designed by our lab can be compatible with SiPMs from different manufactures (Hamamatsu, SensL and NDL).
- Two different gain option have been designed and tested by changing the feedback resistance (0.75 KΩ ~ 10.3, 1.5 KΩ ~ 21), with a noise level of 0.8 mV and a power consumption of 40 mW.

3. Measurements of the time resolution limit for different SiPMs



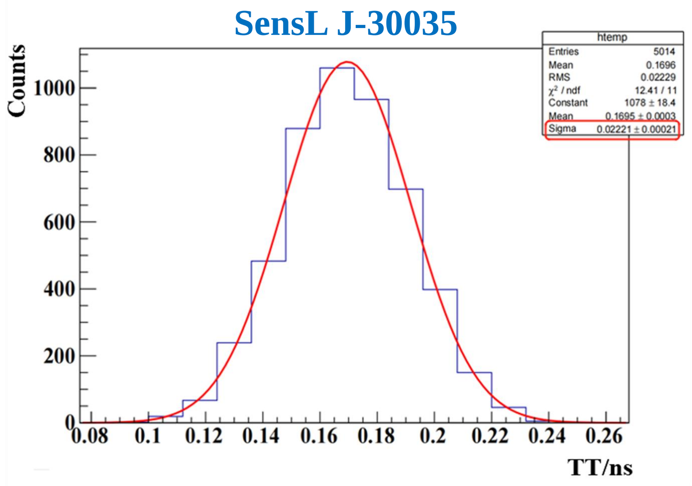
Schematic diagram of the test system for time resolution



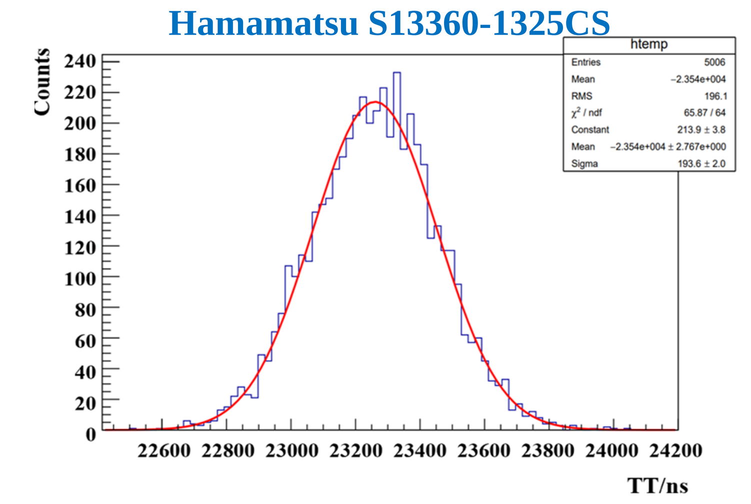
operating voltage optimization for SensL J-30035 (same procedure for the other two SiPMs)

- The light source is a ps laser driven by a ps signal generator that also provides synchronizing signal; signal waveform is sampled with oscilloscope (40 GS/s & 4 GHz).
- The transition time spreads (TTS) at different operating voltages have been measured with fixed light intensity, which was used to obtain an optimized operating voltage.
- The rise time and time resolution limit of SiPMs from SensL, NDL and Hamamstsu have been measured at optimized operating voltage, which can be seen in right figures and table.

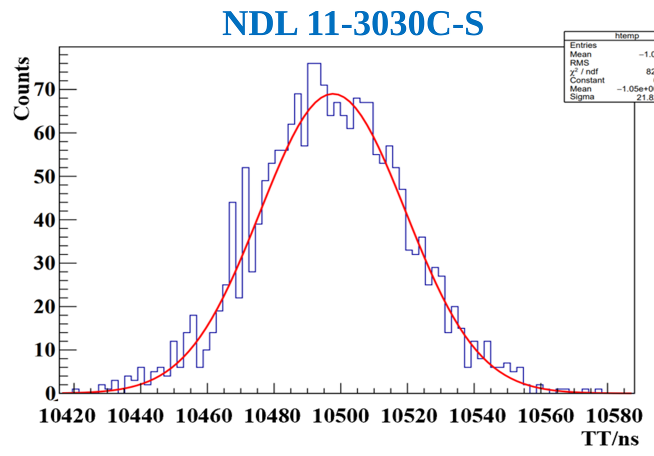
SensL J-30035



Hamamatsu S13360-1325CS



NDL 11-3030C-S



Parameters	SensL J-30035	NDL 11-3030C-S	Hamamatsu S13360-1325CS
Optimized Voltage (V)	28.5	41.0	58.0
Rise Time (ns)	0.5	1.5	1.5
Time Resolution Limit (ps)	22.2	21.8	193.6

4. Conclusions

- **A fast-timing amplifier board based on OPA855 operational amplifier has been designed by our lab, which can be used to achieve a high pre-amplification and a good timing performance with a noise level of 0.8 mV and a power consumption of 40 mW.**
- **The fast-timing amplifier board is compatible with SiPMs from NDL, SensL and Hamamatsu, which facilitates the timing characteristic test.**
- **Based on the fast-timing amplifier board, an excellent time resolution of ~ 20 ps can be obtained for NDL and SensL SiPMs, and the rise time can be as good as 0.5 ns for SensL SiPMs, having great potential in timing measurement.**

Acknowledgement

This work was supported by the Youth Innovation Promotion Association CAS.

Corresponding author : qians@ihep.ac.cn