Development of Fast High Voltage Electronics for a Spark Chamber

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Introduction

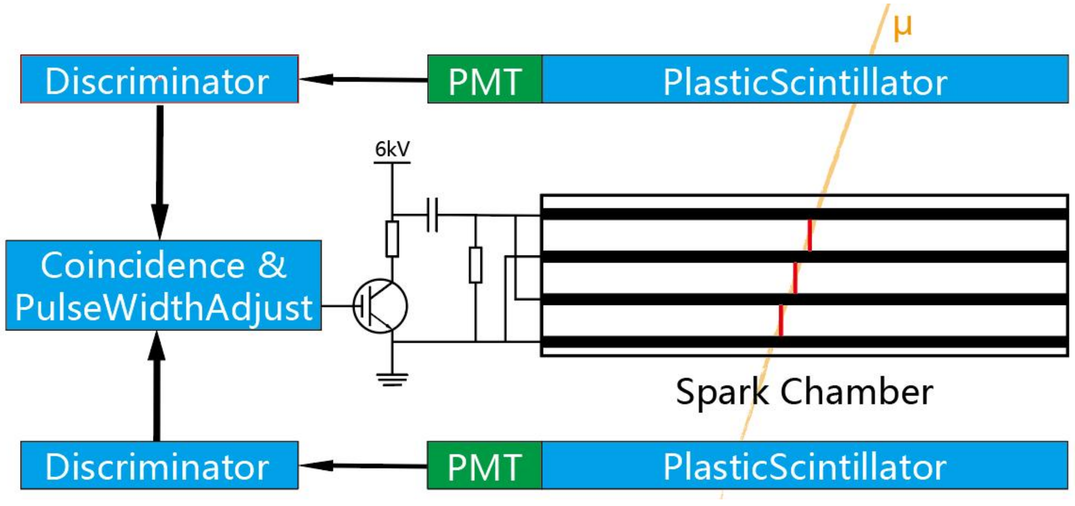
Motivation

Visualise muon trajectories in cosmic rays.

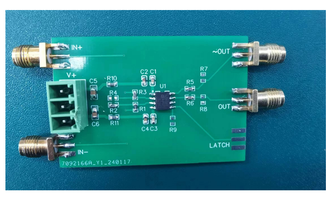
Estimate the muon mass with a respectively easy method.

Requirements

To achieve optimal spark efficiency, the system requires fast electronics capable of applying a voltage of at least 2.5kV across the gaps within a delay time of around 500 ns, which is shorter than the recombination time of several microseconds[9].



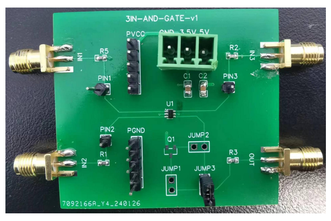
Trigger System



Discriminator

Based on AD8561 comparator[1]

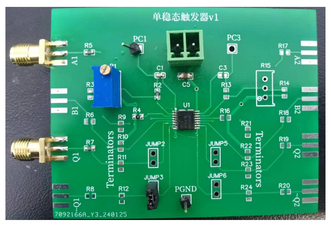
- 9.6 ns propagation delay
- Normal and complementary output mode



Coincidence

Based on NC7SV11P6X 3-in AND gate[2]

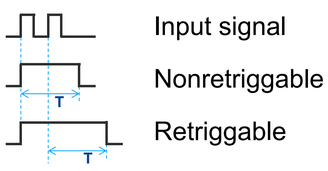
- 3 inputs
- 13.3 ns propagation delay



Pulse Width Adjust

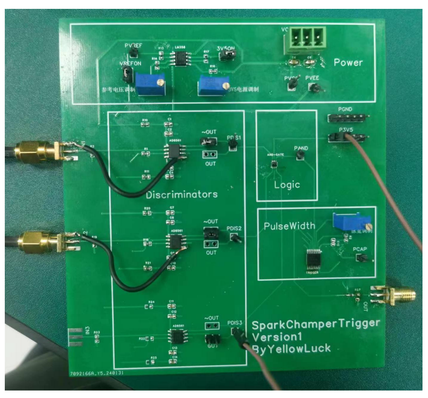
Based on CD74HC4538 Monostable Multivibrator[3]

- Retriggerable and nonretriggable mode
- Rising edge or falling edge trigger
- Adjustable output pulse width T
- 68ns propagation time delay



All in One Trigger System

- 3 coincidence channels
- Optional veto channels
- Adjustable discriminator reference voltage
- Adjustable output pulse width
- 66ns propagation delay

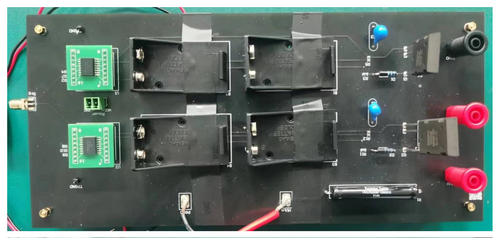


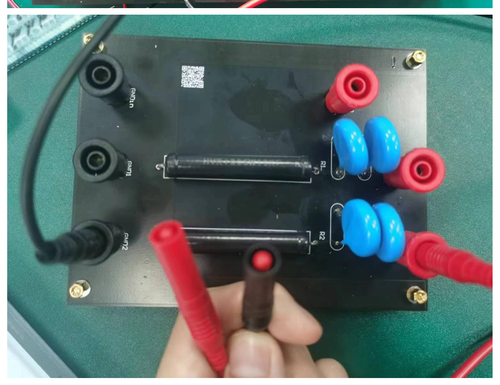
High Voltage Generator

High Voltage Generator

Based on ISO5851 IGBT Gate Driver[4] and IXEL40N400 IGBT[5]

- Capable of generating an 8kV voltage across the gaps using two 4kV withstand IGBTs
- 414ns delay time
- 363ms dead time sourced from capacitors recharging
- Safe connections

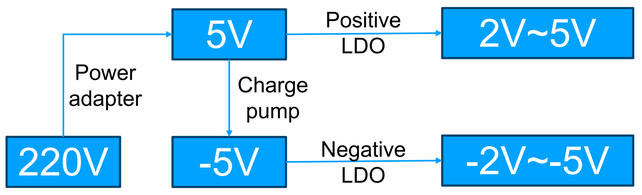


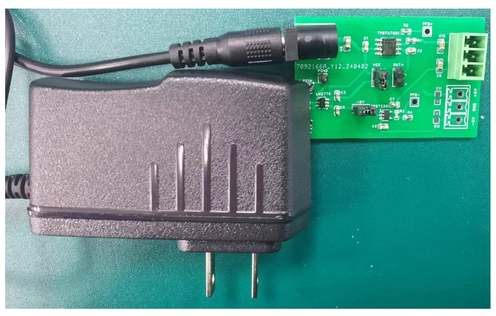


Power Supply

Low Voltage Power

Based on TPS7A7001[6], TPS72301[7] LDOs and LM2776[8] charge pump



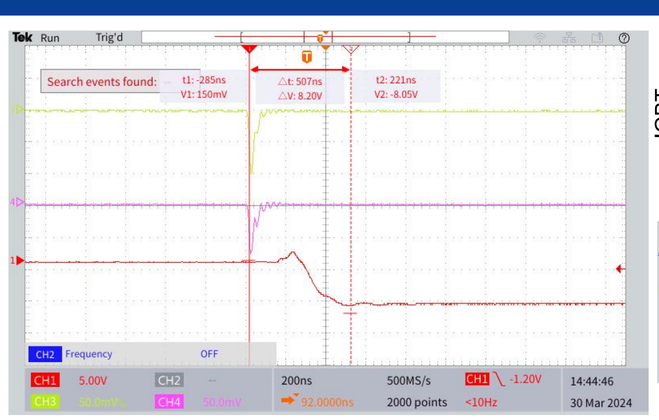


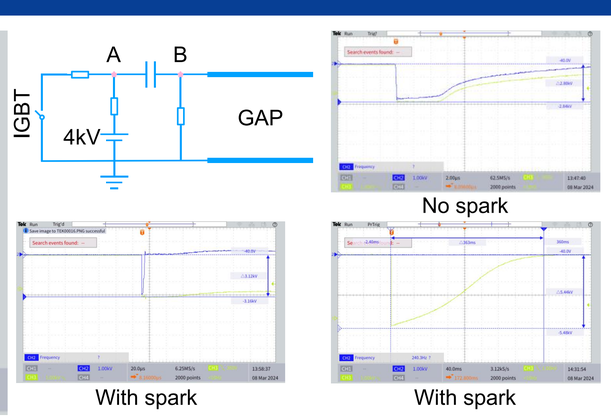
High Voltage Power

Based on NHR 40 60r module

- Capable of generate maximum 6kV and 2mA high voltage output

Results





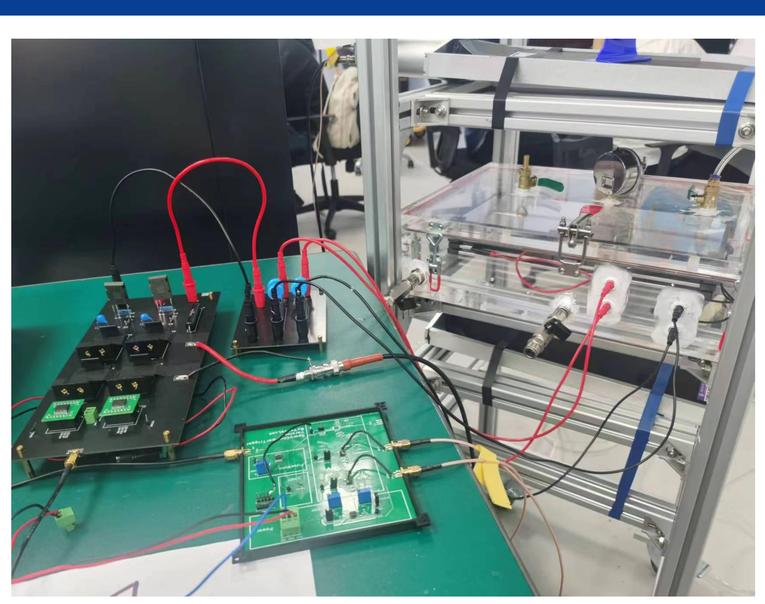
No spark

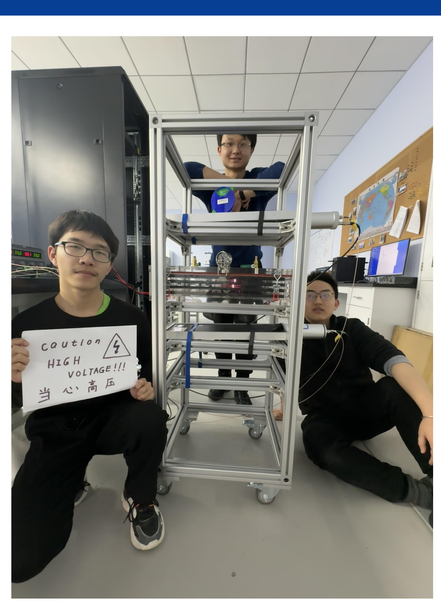
With spark

With spark

CH3 & CH4: PMT outputs
CH1: Voltage between gap
Total propagation delay 507ns

Blue line: Voltage of B
Green line: Voltage of A
Clearly notice the discharge process





Reference

[1] AD8561 datasheet: https://www.analog.com/cn/products/ad8561.html
[2] NC7SV11P6X datasheet: https://www.onsemi.com/products/timing-logic-memory/standard-logic/logic-gates/nc7sv11
[3] CD74HC4538 datasheet: https://www.ti.com.cn/product/cn/CD74HC4538
[4] ISO5851 datasheet: https://www.ti.com.cn/product/cn/ISO5851
[5] IXEL40N400 datasheet: https://www.littelfuse.cn/products/power-semiconductors/discrete-igbts/npt/very-high-voltage_npt/ixel40n400.aspx
[6] TPS7A7001 datasheet: https://www.ti.com.cn/product/cn/TPS7A7001
[7] TPS72301 datasheet: https://www.ti.com.cn/product/cn/TPS723
[8] LM2776 datasheet: https://www.ti.com.cn/product/cn/LM2776
[9]W A Wenzel. Spark chambers. Annual Review of Nuclear Science,14(1):205–238, 1964.