



고려대학교
KOREA UNIVERSITY

hau
Hadron & Nuclear Physics Lab



LAMPS BTOF

June 19, 2020

MPPC Modeling(Avalanche Process)

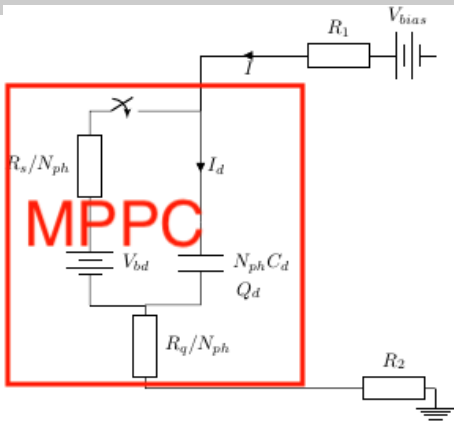


Figure: R_q : Quenching, R_s :Series, R_1, R_2 : HV Supply/Readout Circuit, C_d : Pixel Capacitance

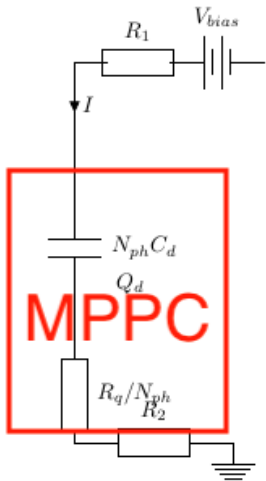
By defining

$$\begin{aligned} V_{over} &= V_{bias} - V_{bd} - I(0)R_1 \\ &= V_{bias} - V_{bd} - \frac{(V_{bias} - V_{bd})R_1}{R_1 + R_2 + (R_s + R_q)/N_{ph}} R_1 \end{aligned}$$

$$I = \frac{(V_{bias} - V_{bd} - V_{over} e^{-t/R_s C_d})}{R_1 + R_2 + (R_q + R_s)/N_{ph}}$$

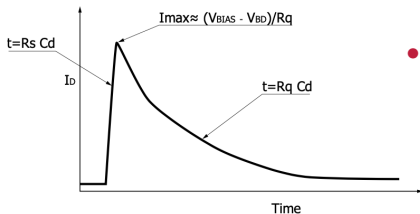
- Rise time = $R_s C_d \sim 10\text{ps}$: Does not depend on N_{ph} !
- $I(t \rightarrow \infty) \sim \frac{V_{over}}{R_q/N_{ph}} \sim N_{ph} * 10\mu\text{A}$
- Quenching process will start, when $I_d - I < 0$

MPPC Modeling(Restore Process)



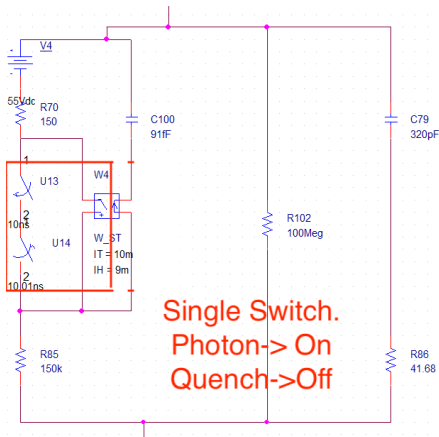
$$I = V_{over} / (R_1 + R_2 + R_s) e^{-t / (C_d (R_q + N_{ph} (R_1 + R_2)))}$$

- Falling(Restoring) time $\sim 10 \text{ ns} + N_{ph} * \alpha$



- MPPC Signal, according to this model.

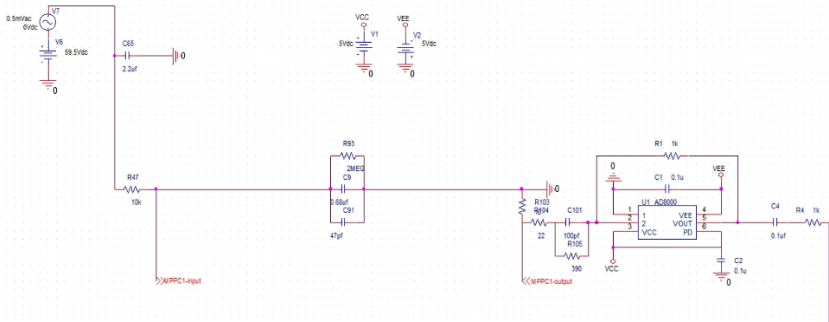
MPPC PSpice



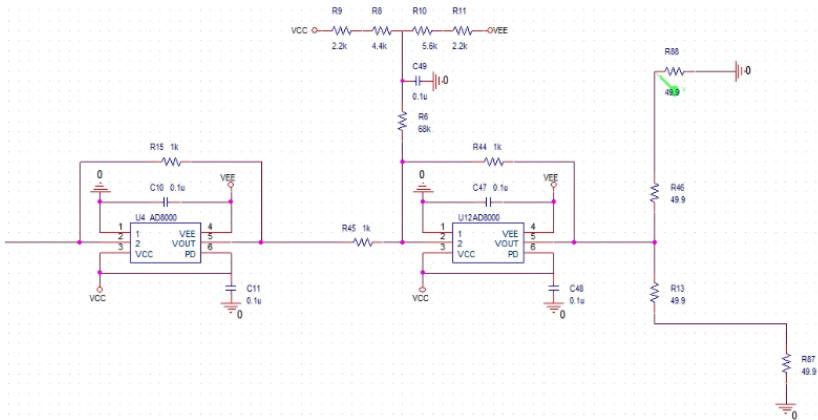
Single Switch.
Photon-> On
Quench->Off

- Upstream: HV, Downstream: Output
- R102 for Dark current($\sim 0.5\mu\text{A}$)
- Red box is a **Single Switch** in effect.(Looks complicated due to limitation of PSpice)
- Unfired pixels are implemented(C79-R86 line)

Readout Circuit-Differentiator



Readout Circuit-Mixer



PSpice Result(Current on C_d)

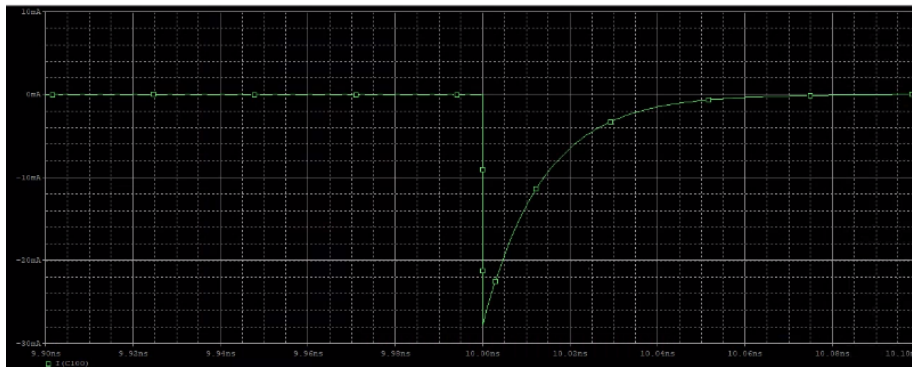


Figure: 9.9 ns~10.1 ns:-30 mA~10 mA

PSpice Result(MPPC Output Current)

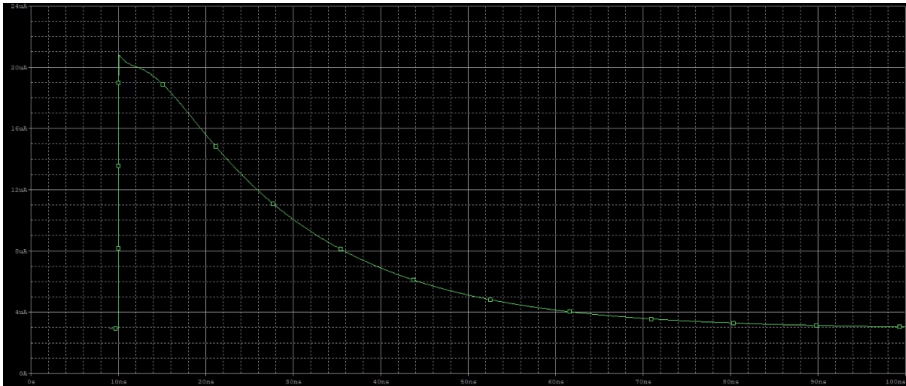


Figure: 0 ns~100 ns:0 μA~24 μA

PSpice Result(Final Readout)

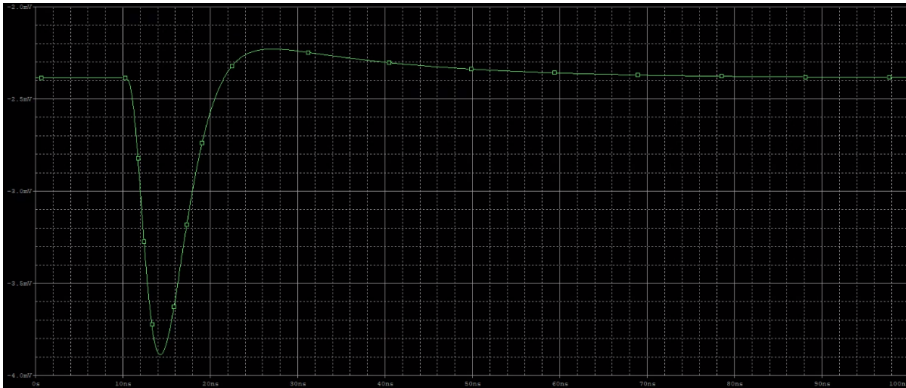


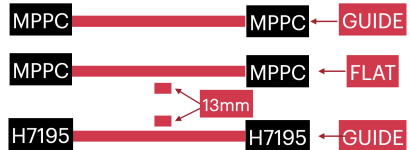
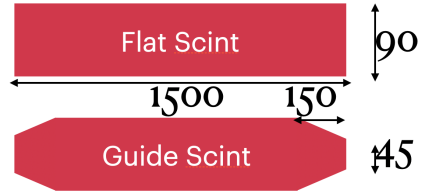
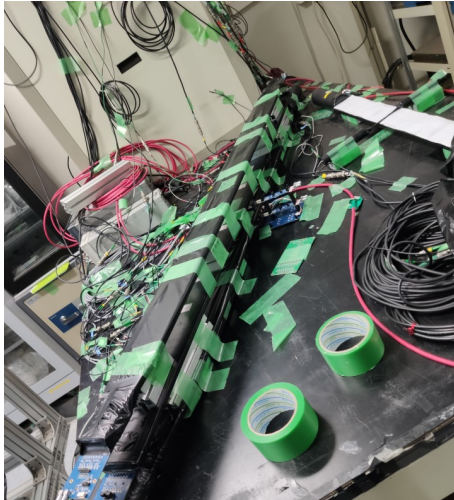
Figure: 0 ns~100 ns: -4 mV~-2 mV

Real Circuit Signal



Figure: Gain at last OpAmp is X3

LAMPS BTOF Testbench



LAMPS BTOF Testbench

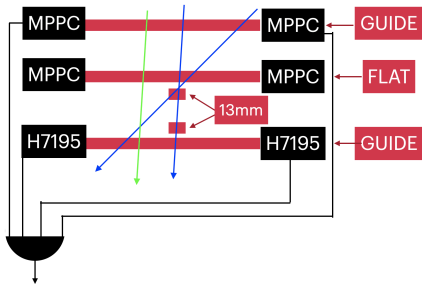


Figure: Blue: survive from cut, Green: dead from cut

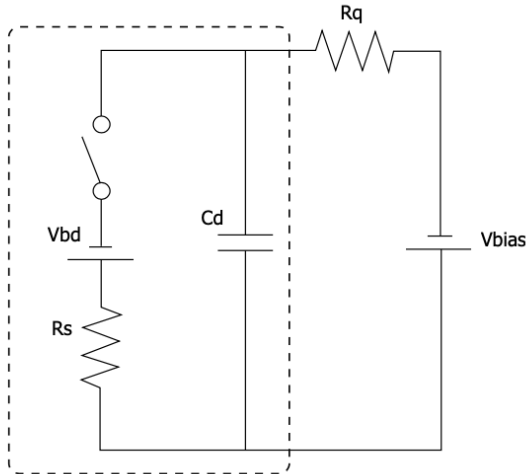
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det1 : 297.242 +/- 9.15252 ps
det2 : 115.307 +/- 23.5937 ps
det3 : 233.402 +/- 11.6559 ps
..
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Figure: Time resolution after Timewalk correction. 115→H7195(Bottom), 297→Flat(Middle),233→Top. Preliminary result.

- Online Trig: 2 BTOF coincidence
- Offline Cut: 1 13mm scint.(Only one seg).
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BACKUP

Hamamatsu Model



- V_{bias} Supply and Readout circuit is not implemented

Derivation of Equation on Slide 2

$$V_{bias} - V_{bd} - I(R_1 + R_2 + (R_q + R_s)/N_{ph}) + I_d R_s / N_{ph} = 0 \quad (1)$$

$$V_{bd} - Q_d / (N_{ph} C_d) - I_d R_s / N_{ph} = V_{bd} - Q_d / (N_{ph} C_d) + \frac{R_s}{N_{ph}} \frac{d}{dt} Q_d = 0. \quad (2)$$

From Eq.(2),

$$Q_d = Q_0 e^{-t/R_s C_d} + N_{ph} C_d V_{bd} = N_{ph} C_d (V_{bd} + V_{over} e^{-t/R_s C_d}) \quad (3)$$

where $Q_0 = C_d (V_{bias} - I(0)R_1 - V_{bd}) = C_d V_{over}$. Eq.(1) becomes

$$V_{bias} - Q_d / C_d - I(R_1 + R_2 + (R_q + R_s)/N_{ph}) = 0 \quad (4)$$

hence

$$I = (V_{bias} - V_{bd} - V_{over} e^{-t/R_s C_d}) / (R_1 + R_2 + (R_q + R_s)/N_{ph}). \quad (5)$$

Derivation of Equation on Slide 3

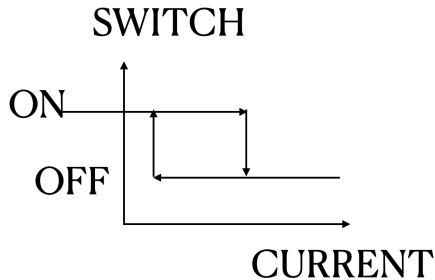
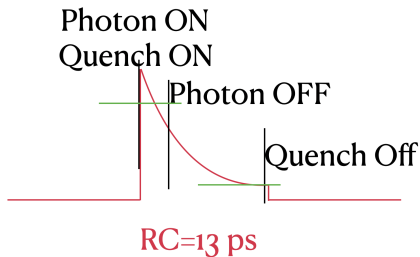
$$V_{bias} - Q_d / (N_{ph} C_d) - I(R_1 + R_2 + R_q / N_{ph}) = 0 \quad (6)$$

$$Q_d = N_{ph} C_d V_{bd} + Q_0 e^{-t / (C_d (R_q + N_{ph} (R_1 + R_2)))} \quad (7)$$

and current

$$I = V_{over} / (R_1 + R_2 + R_s) e^{-t / (C_d (R_q + N_{ph} (R_1 + R_2)))} \quad (8)$$

Current Switch @ PSpice



BTOF Raw Data(2D ADC W/WO Cut)

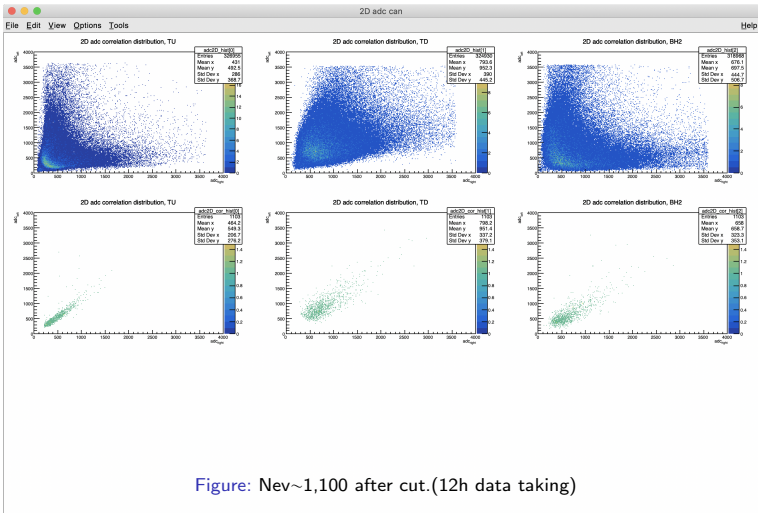
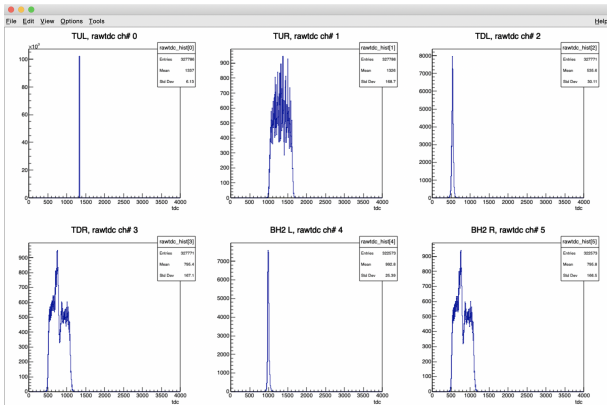


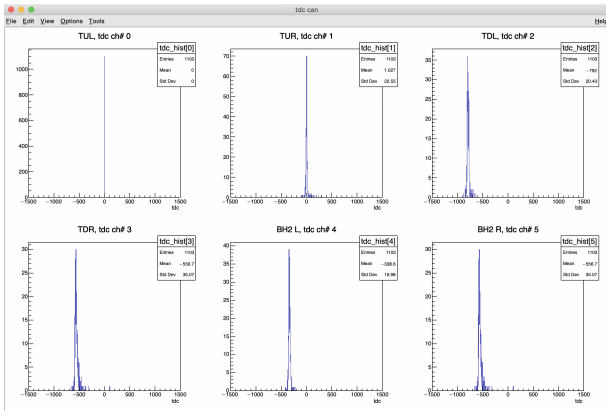
Figure: Nev~1,100 after cut.(12h data taking)

BTOF Raw TDC



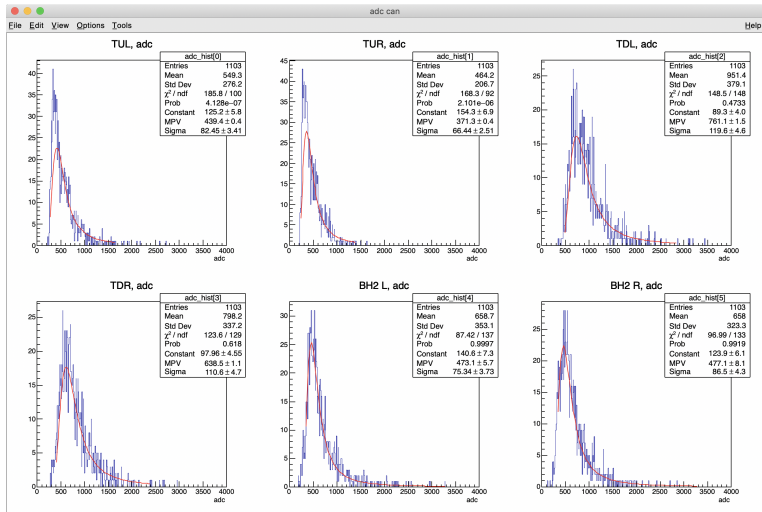
- TUL Defines the timing(Reference)

BTOF TDC With Cut

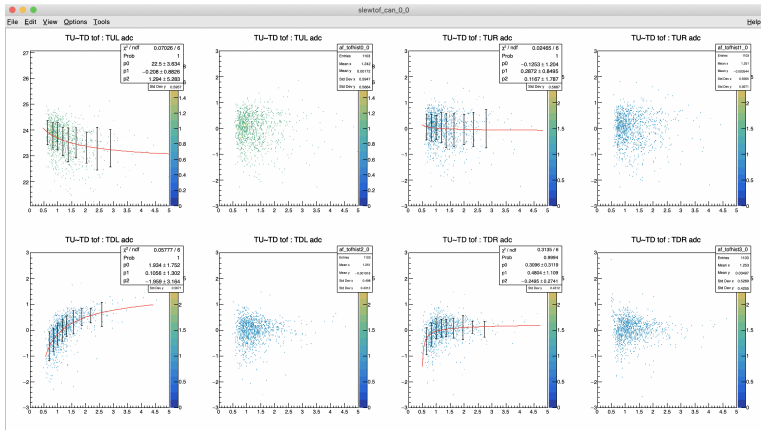


- $TDC = TDC(Det) - TDC(TUL)$

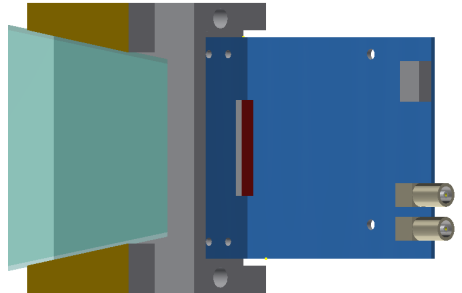
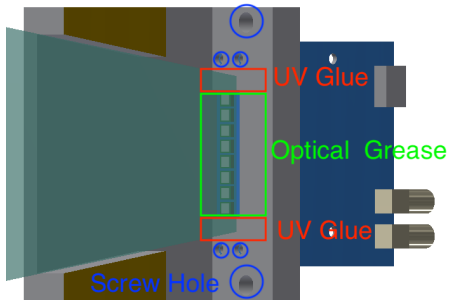
ADC Spectrum (Fit quality is bad)



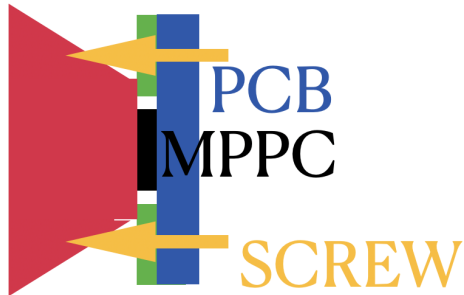
Timewalk



LAMPS BTOF Holder



SCINT HOLDER



BTOF with TPC Frame

