LAMPS BTOF
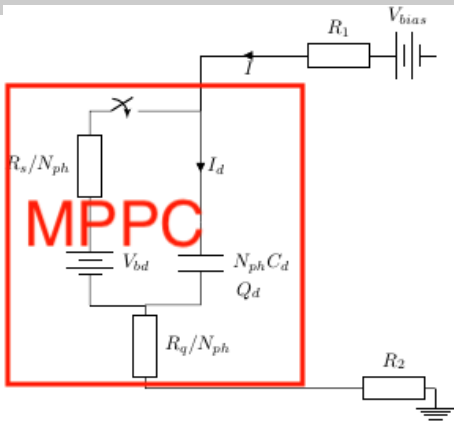
June 19, 2020

MPPC Modeling(Avalanche Process)

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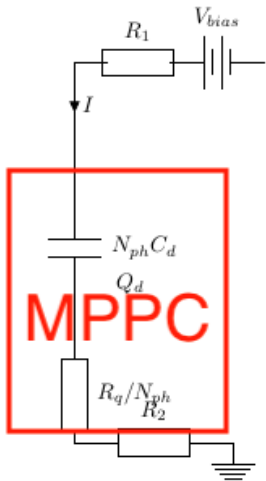
By defining

$$V_{over} = V_{bias} - V_{bd} - I(0)R_1$$

$$= V_{bias} - V_{bd} - \frac{(V_{bias} - V_{bd})R_1}{R_1 + R_2 + (R_s + R_q)/N_{ph}}R_1$$

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

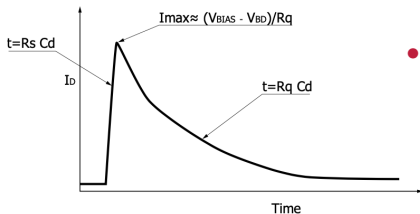- Rise time$=R_sC_d \sim 10$ps: Does not depend on N_{ph}!
- $I(t \rightarrow \infty) \sim \frac{V_{over}}{R_q/N_{ph}} \sim N_{ph} * 10\mu A$
- Quenching process will start, when $I_d - I < 0$

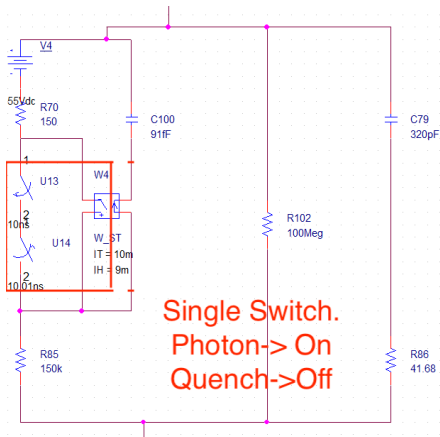고려대학교
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MPPC Modeling(Restore Process)

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

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

$I_{max} \approx (V_{BIAS} - V_{BD})/R_q$

$t=R_s C_d$

I_D

$t=R_q C_d$

Time

- MPPC Signal, according to this model.

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MPPC PSpice

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

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Readout Circuit-Differentiator

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Readout Circuit-Mixer

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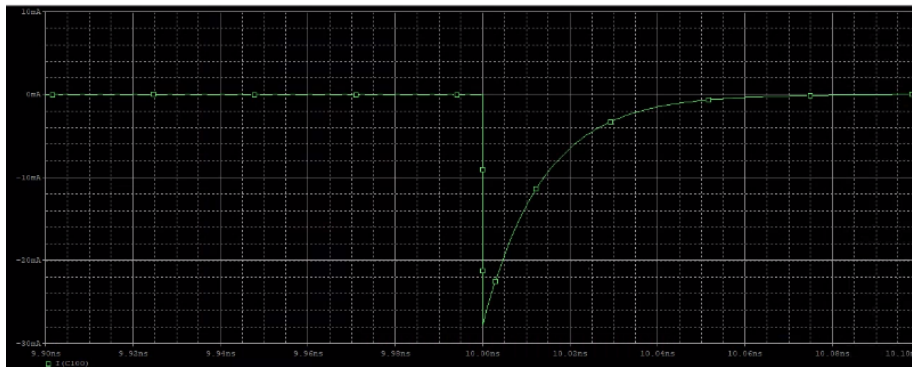KOREA UNIVERSITY

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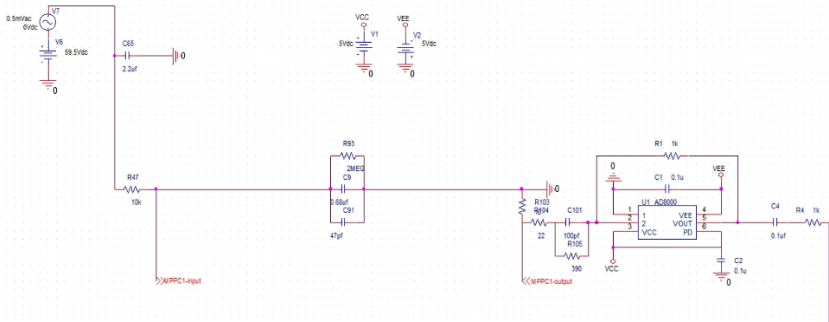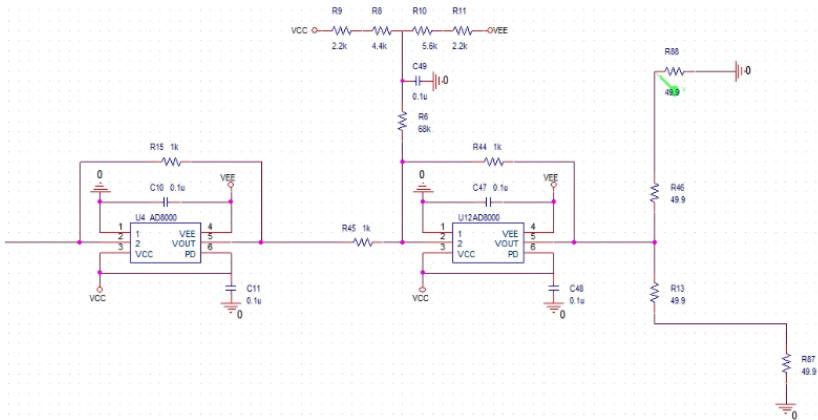
PSpice Result(Current on C_d)

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

PSpice Result(MPPC Output Current)
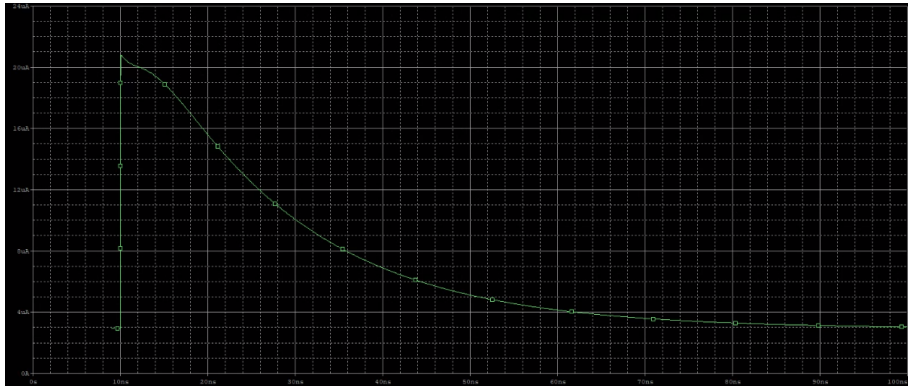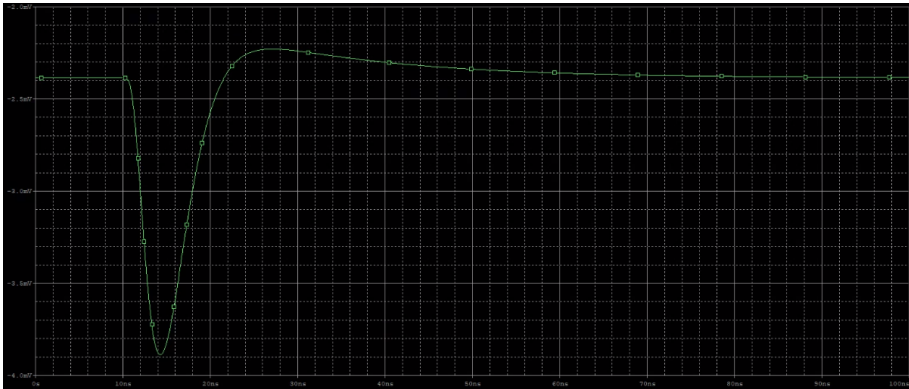

Figure: 0 ns~100 ns:0 μA~24 μA

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PSpice Result(Final Readout)

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

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Real Circuit Signal

Figure: Gain at last OpAmp is X3

LAMPS BTOF Testbench

Flat Scint — 90

1500   150

Guide Scint — 45

MPPC	———————————————	MPPC	← GUIDE
MPPC	———————————————	MPPC	← FLAT

13mm

| H7195 | ——————————————— | H7195 | ← GUIDE |

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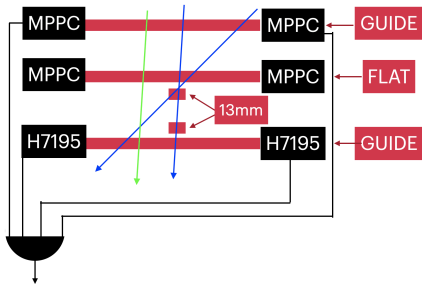KOREA UNIVERSITY

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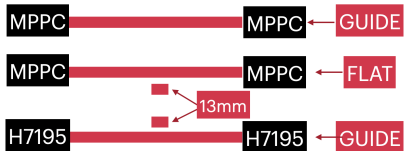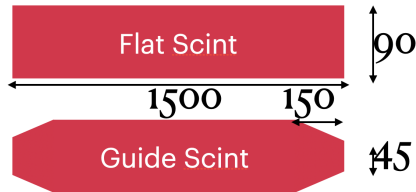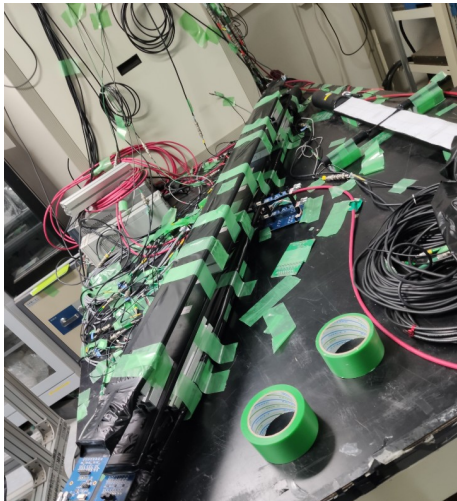
LAMPS BTOF Testbench

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

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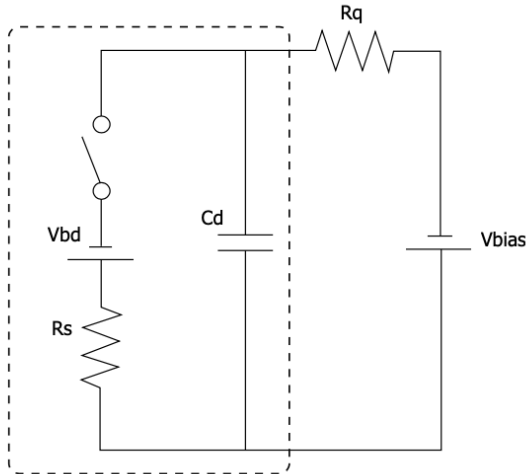
Figure: Time resolution after Timewalk correction.
115→H7195(Bottom), 297→Flat(Middle),233→Top.
Priliminary result.

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

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BACKUP

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Hamamatsu Model

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

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Derivation of Equation on Slide 2

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

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

From Eq.(2),

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

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

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

hence

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

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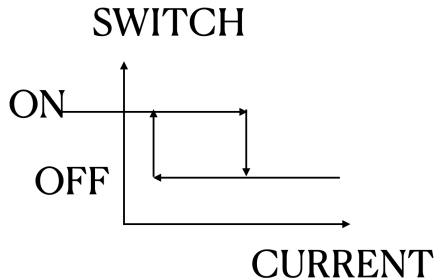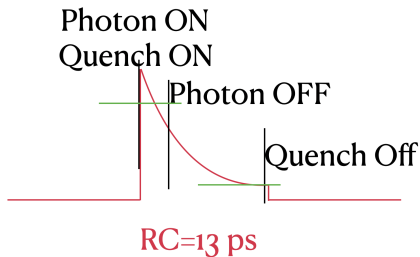
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Derivation of Equation on Slide 3

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

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

and current

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

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Current Switch @ PSpice

Photon ON
Quench ON
Photon OFF
Quench Off

RC=13 ps

SWITCH
ON
OFF
CURRENT

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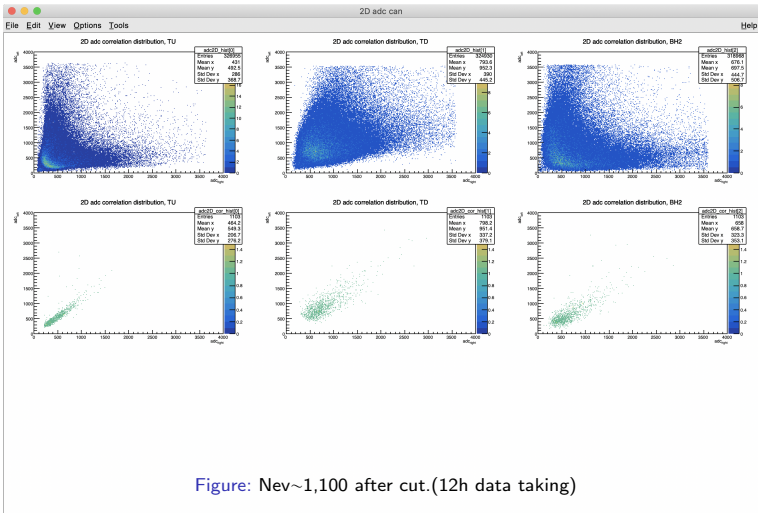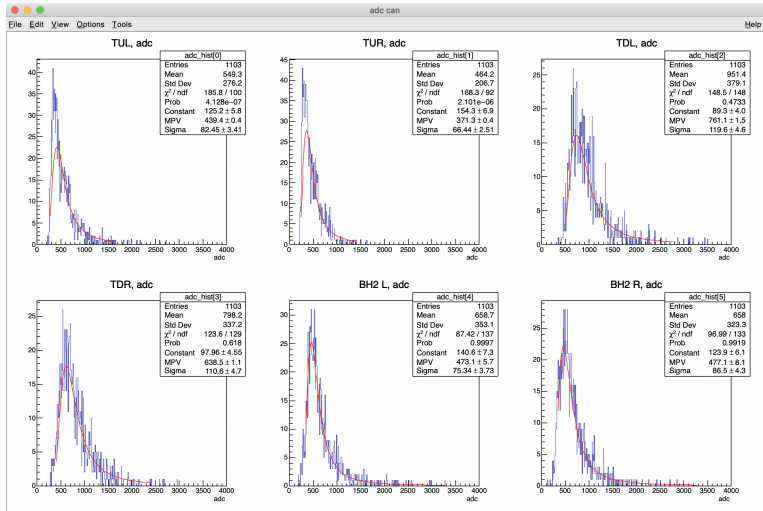

Figure: Nev~1,100 after cut.(12h data taking)

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BTOF Raw TDC
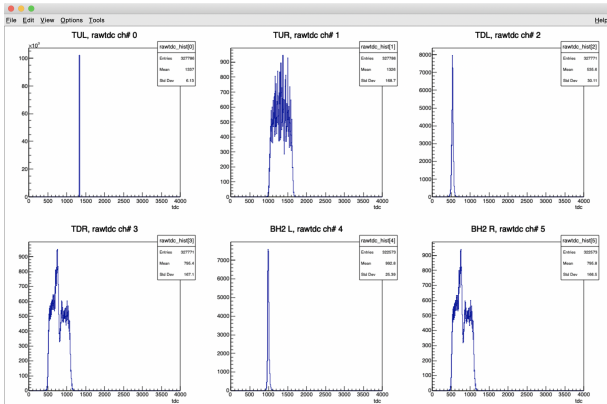
- TUL Defines the timing(Reference)

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BTOF TDC With Cut

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

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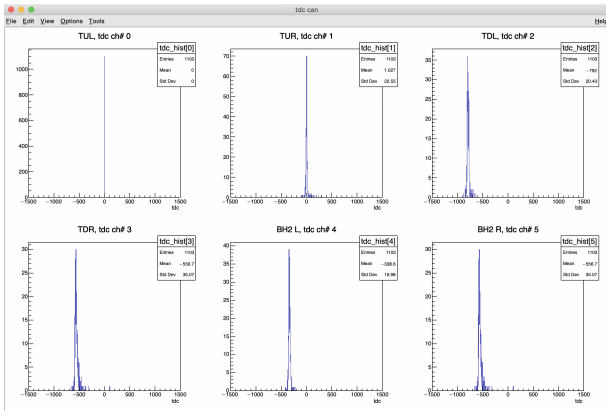
ADC Spectrum(Fit quality is bad)

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Timewalk

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LAMPS BTOF Holder

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BTOF with TPC Frame

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