

Summing board test at KNU

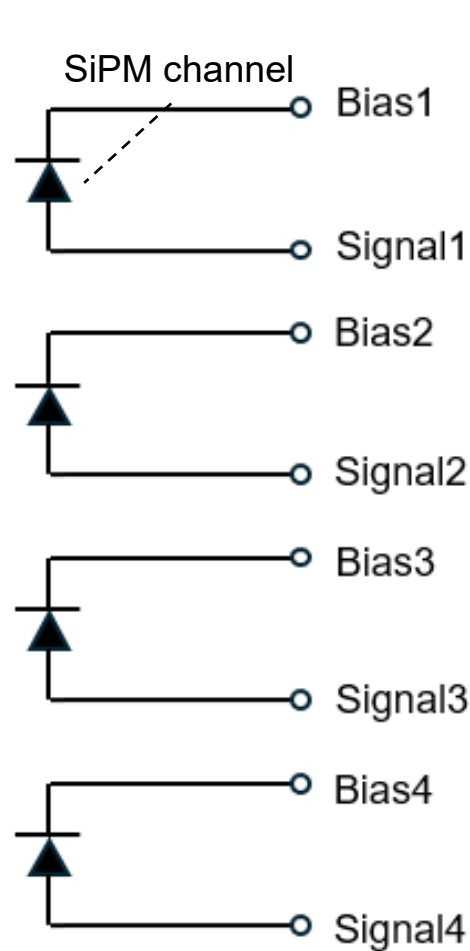
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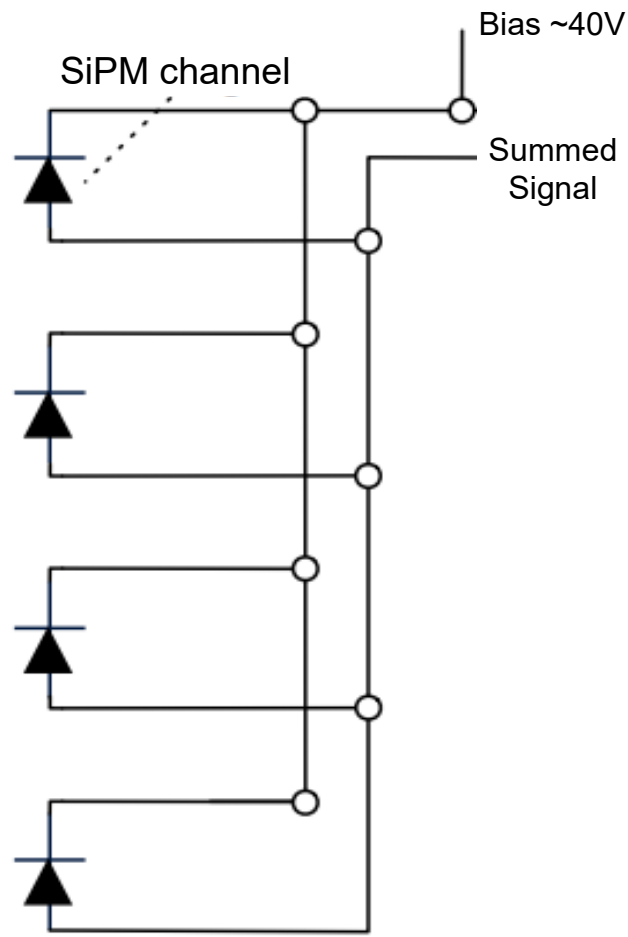
Summing Method

Individual readout



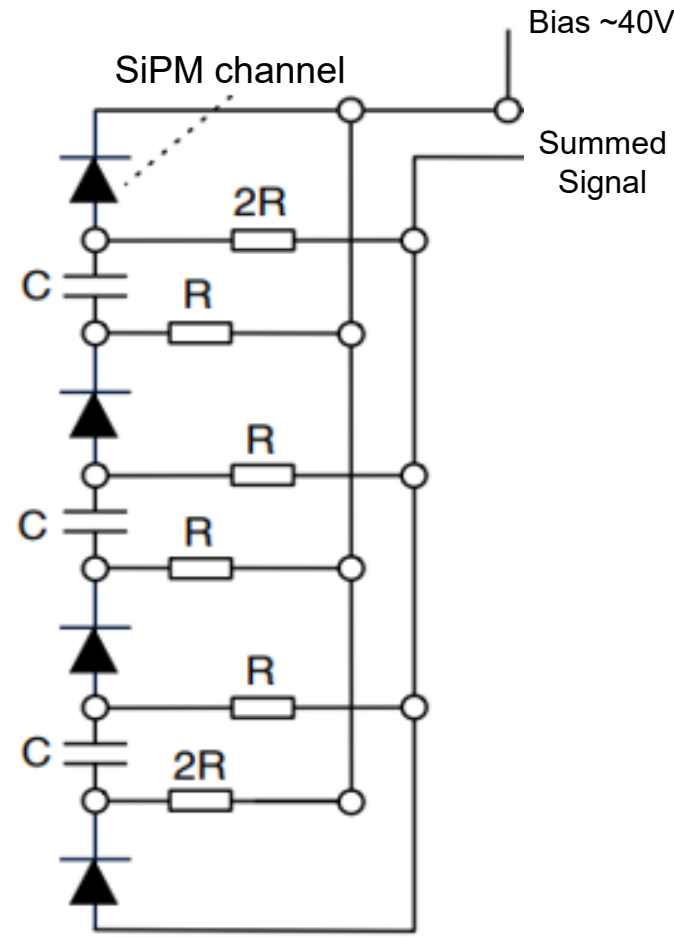
16-ch individual readout

Parallel summing



Broader pulse due to added SiPM capacitance

Hybrid summing



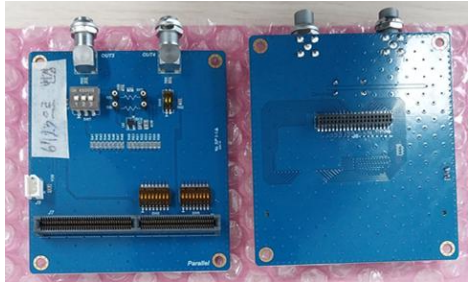
Parallel power, series signal

e-room tech Summing Board

- Hybrid summing
 - w/o op amp, w/ op amp (Board #1, LMH6629)
 - w/o op amp, w/ op amp (Board #2, LMH6723)
- Parallel summing
 - w/o op amp, w/ op amp (Board #3, LMH6629)
 - w/o op amp, w/ op amp (Board #4, LMH6723)
- Individual
 - SiPM 16ch individual readout (Board #5, #6)



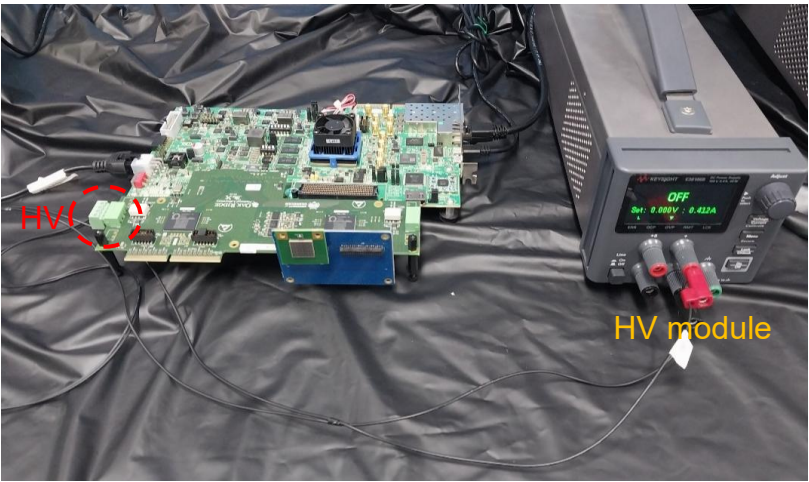
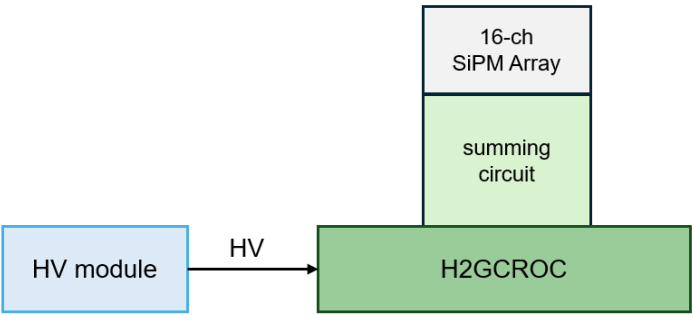
Hybrid summing



Parallel summing



Individual



e-room tech board

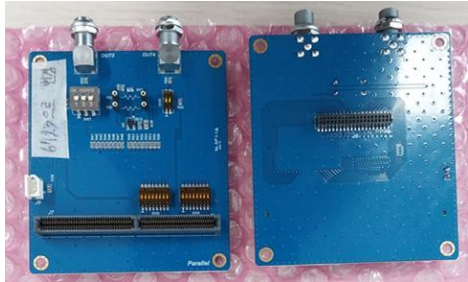
- HV supplied by H2GCROC
- **Requires 16 H2GCROC channel per a 16-ch SiPM array**
- Outputs with and without op amp
- LMH6629 exhibit significant heating and oscillation

e-room tech Summing Board

- Hybrid summing
 - w/o op amp, w/ op amp (Board #1, LMH6629)
 - w/o op amp, w/ op amp (Board #2, LMH6723)
- Parallel summing
 - w/o op amp, w/ op amp (Board #3, LMH6629)
 - w/o op amp, w/ op amp (Board #4, LMH6723)
- Individual
 - SiPM 16ch individual readout (Board #5, #6)



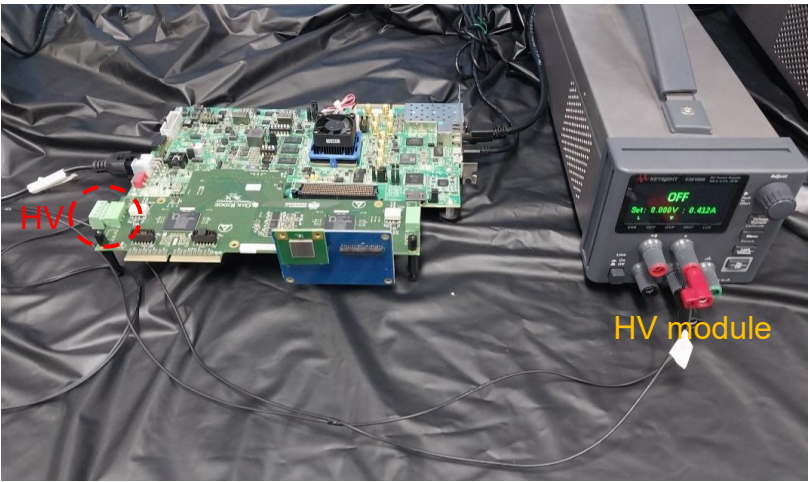
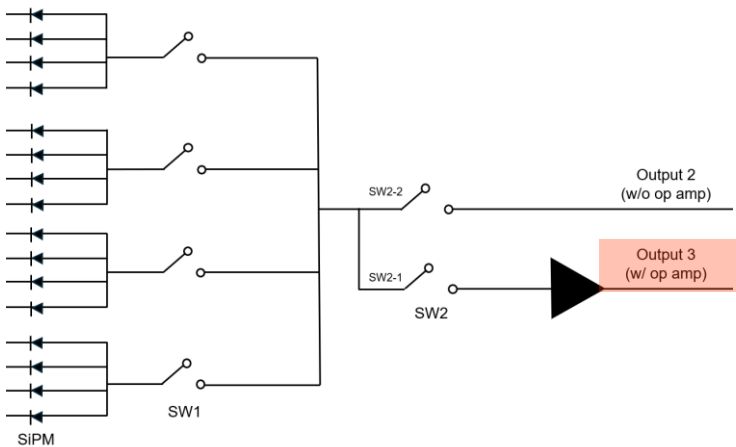
Hybrid summing



Parallel summing



Individual



e-room tech board

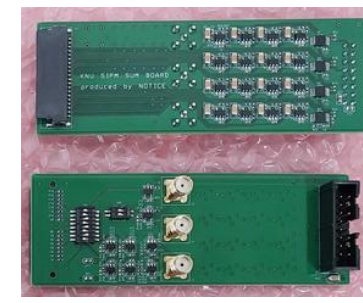
- HV supplied by H2GCROC
- Requires 16 H2GCROC channel per a 16-ch SiPM array**
- Outputs with and without op amp
- LMH6629 exhibit significant heating and oscillation

NOTICE Summing Board

- Hybrid summing
 - w/o op amp, w/ op amp (Board #7, #8)
- Parallel summing
 - w/o op amp, w/ op amp (Board #9, #10)
- SMA to H2GCROC (Board #11, #12)



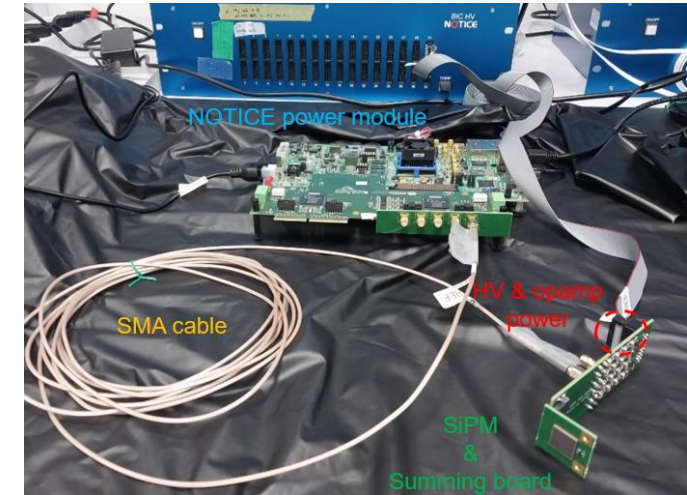
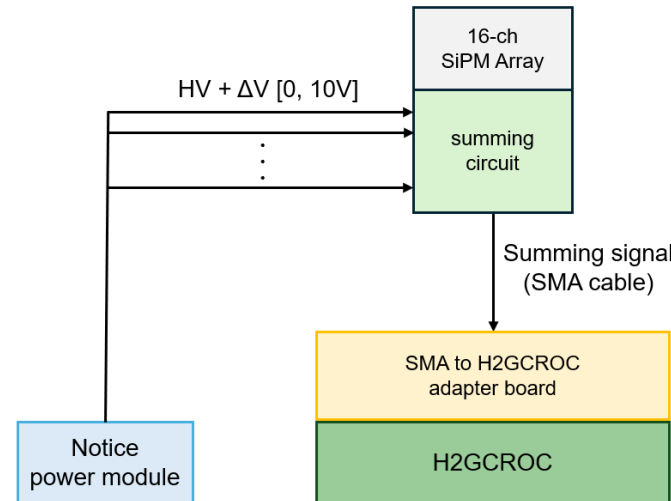
Hybrid summing



Parallel summing



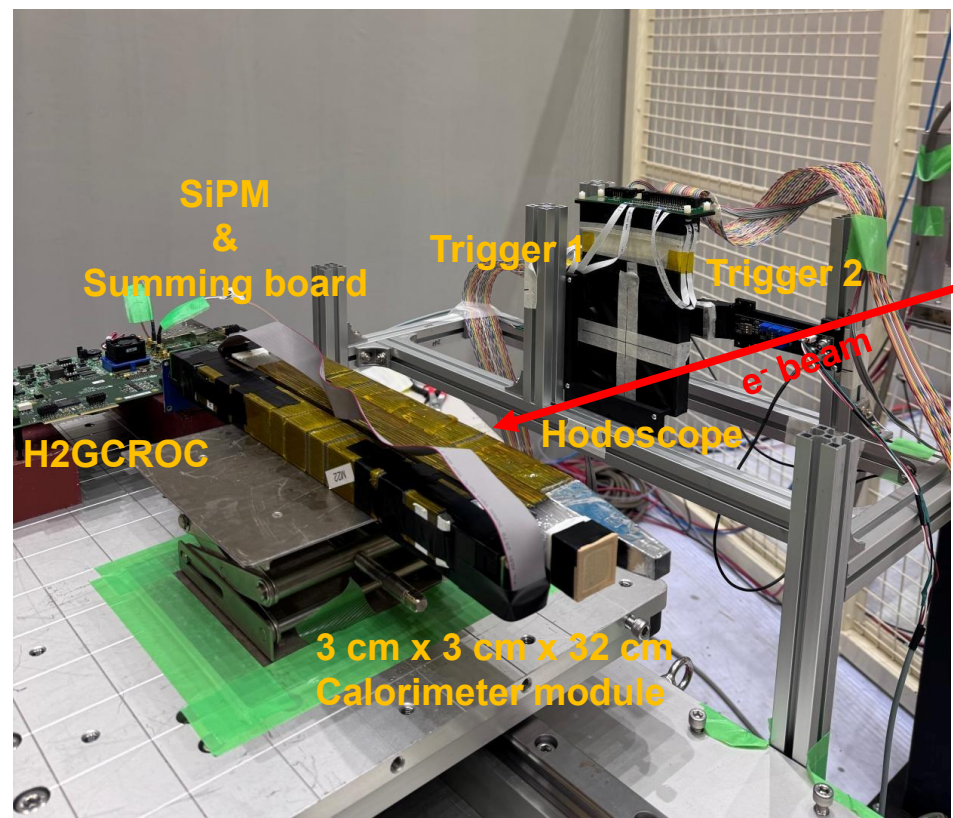
SMA to H2GCROC



NOTICE Board

- Independent HV control via NOTICE power module
- 12-bit DAC per-channel ΔV adjustment [0, 10 V]
- **Requires only 1 H2GCROC channel per a 16-ch SiPM array**
- Outputs with and without op amp

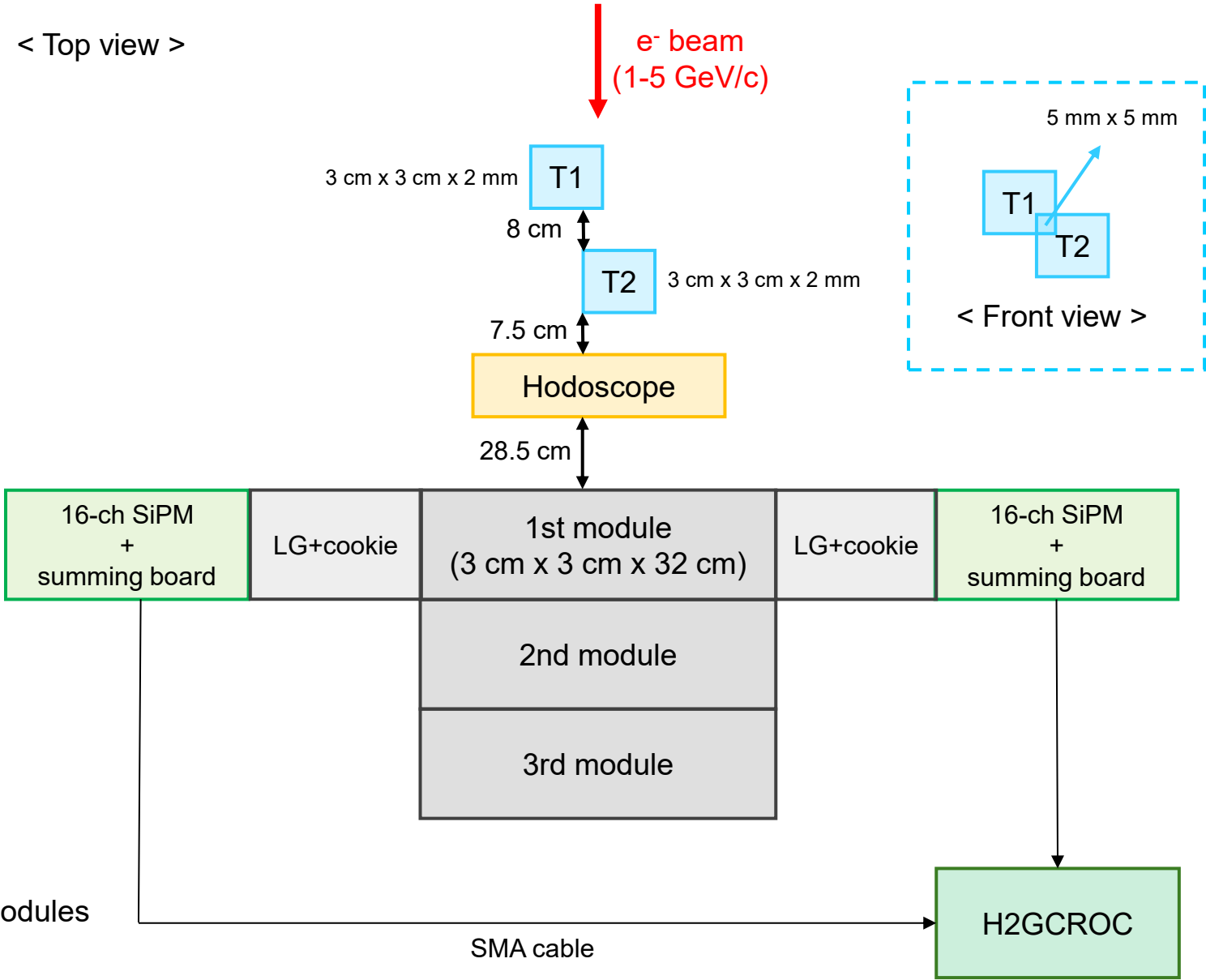
Test Setup at KEK PF-AR



Beam (GeV/c)	Trigger rate (Hz)
1	60
2	203
3	206
4	100
5	41

- 1–5 GeV/c e^- beams
- Readout from 1st, 3rd modules

< Top view >

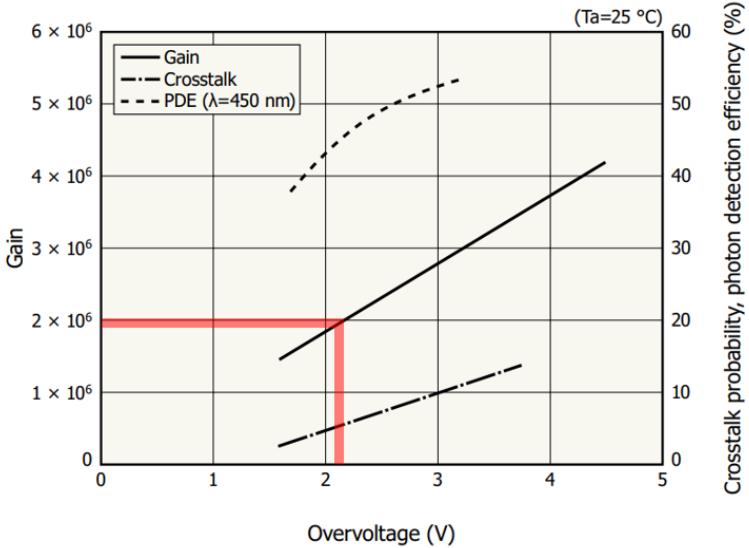


Dynamic Range Estimation

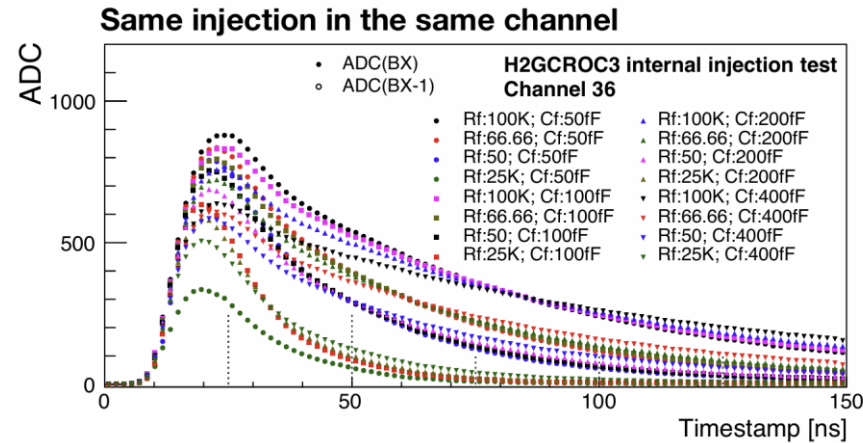
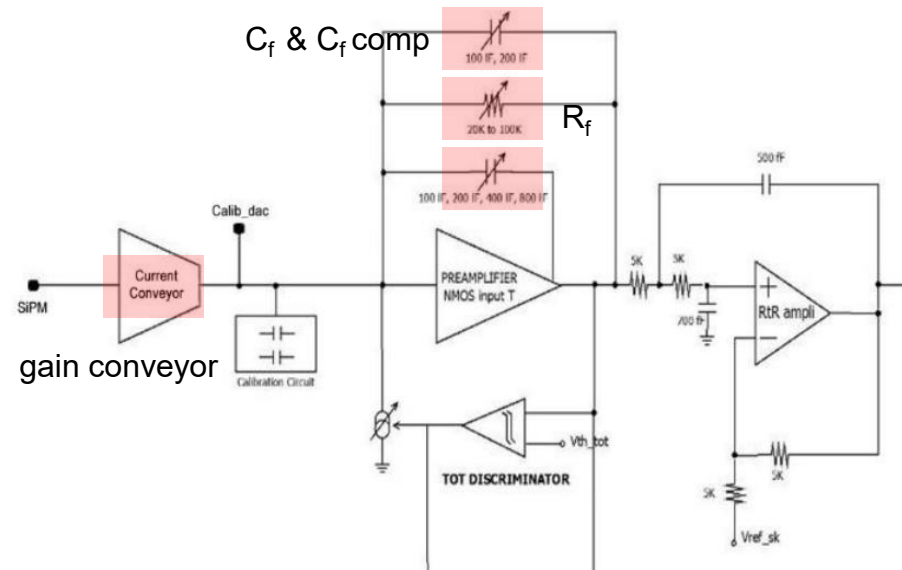
Simulated Edep, measured N_{pe} (2507 CERN TB) & expected charge

Beam (GeV/c)	Energy deposit (MeV, mean)			N_{pe} per SiPM (9cm ²)			Charge (pC, 16ch summing)		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
0.5	77	140	92	600	1100	700	192	352	224
1	98	246	208	700	1800	1500	224	576	480
2	129	417	435	1000	2800	3000	320	896	960
3	149	542	645	1100	3800	4500	352	1216	1440
4	165	655	845	1150	4500	6000	368	1440	1920
5	178	765	1042	1300	5500	7500	416	1760	2400

- Conversion from N_{pe} to Charge
 1. $N_{pe} \times \text{Gain} = \text{Number of electrons}$ ($V_{br}=38.5 \text{ V}$, $V_{op}=40.7 \text{ V}$)
 2. Multiply the number of electrons by $1.6 \times 10^{-19} \text{ C}$ to obtain the charge
- Blue cells indicate the KEK beam test data
- H2GCROC dynamic range in KEK beam test: **224 pC – 2400 pC**



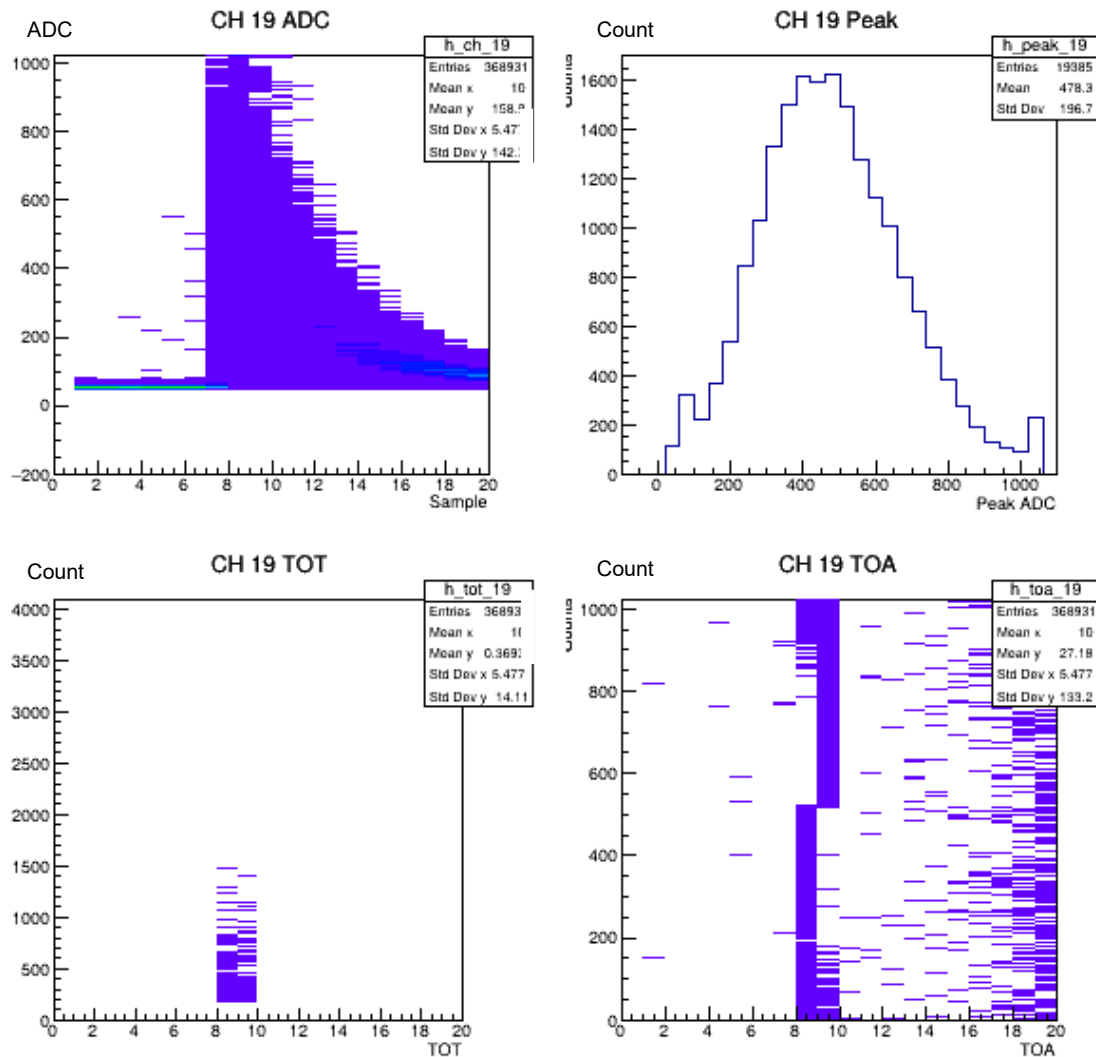
Electron Beam Test at KEK PF-AR



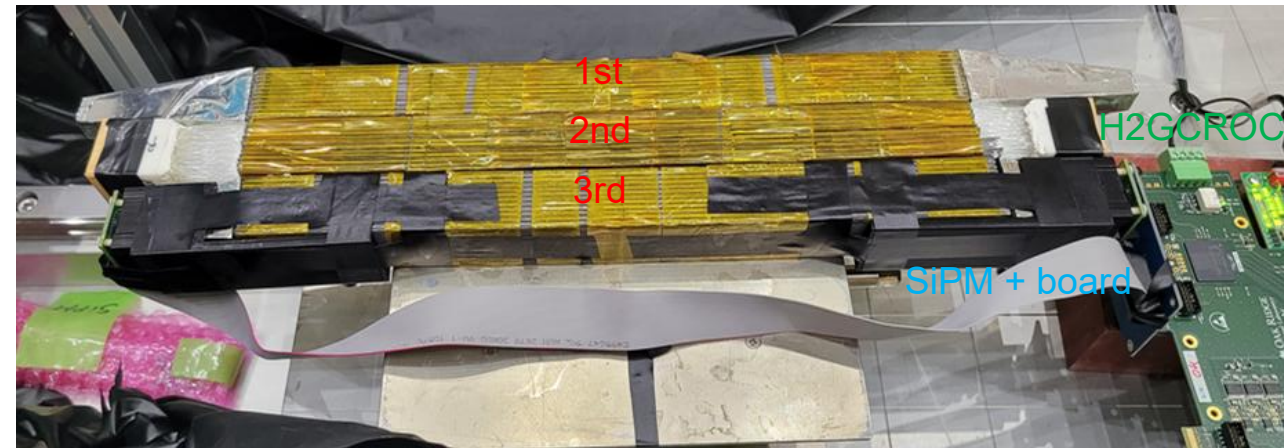
- R_f : lower Value $\rightarrow$ gain $\uparrow$
- C_f : lower Value $\rightarrow$ gain $\downarrow$, width $\downarrow$
- Gain conveyor: lower Value $\rightarrow$ gain $\downarrow$
- C_f comp: lower Value $\rightarrow$ gain $\downarrow$

	summing	momentum	position	parameter (Rf-Cf-Gain conveyor-Cf comp)
e-room (#5,6)	Individual	1-5GeV/c	1st, 3rd	8-10-12-10 (default param) 4-15-15-15 15-4-15-15
Notice (#7,8) e-room (#1,2)	Hybrid	1-5GeV/c	1st, 3rd	8-10-12-10 (default param) 4-1-1-15 15-1-1-15 15-1-1-1 (gain min)  gain↓
Notice (#9,10) e-room (#3,4)	Parallel	1-5GeV/c	1st, 3rd	8-10-12-10 (default param) 4-1-1-15 15-1-1-15 (gain min)

Individual Readout

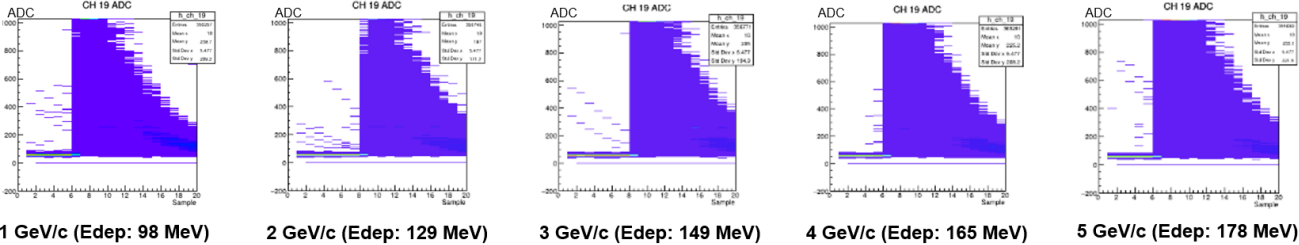


- Setup
 - 1GeV, 3rd, Edep: 149 MeV
 - param: 8-10-12-10 (default param)
 - 3cm x 3cm x 32cm calorimeter module
 - 5cm length Lightguide
- HV : 40.7 V
- H2GCROC parameter: 3 sets
- ADC, Peak ADC, TOT, TOA data acquired

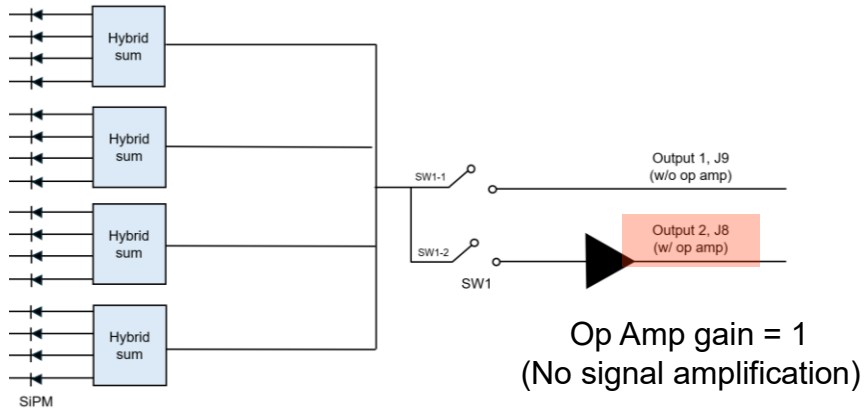
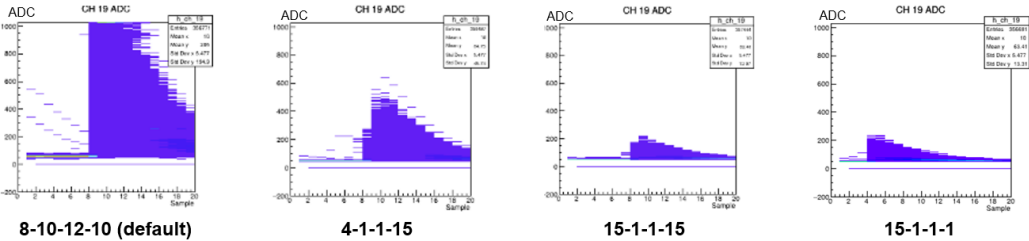


Hybrid Summing

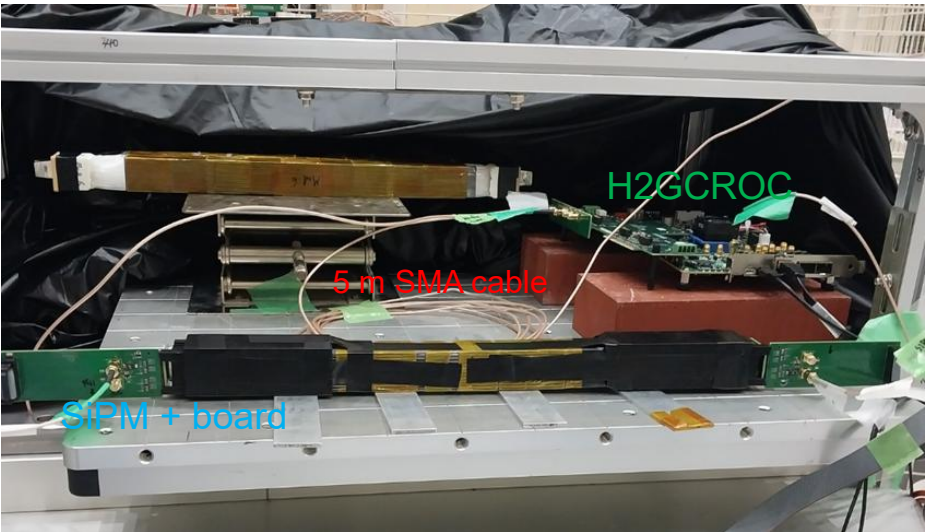
Hybrid, 1st, param: 8-10-12-10 (default)



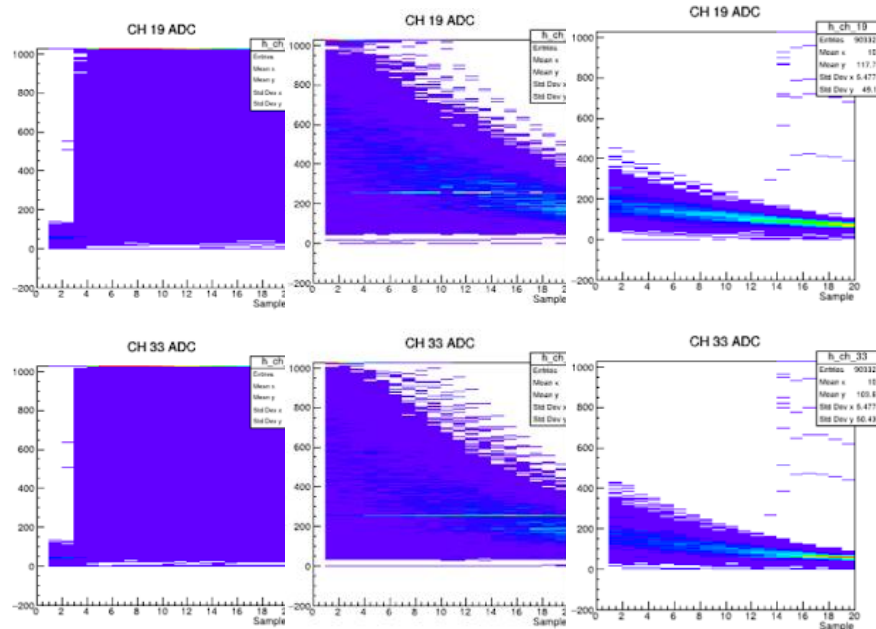
Hybrid, 1st, 3GeV/c (Edep: 149 MeV)



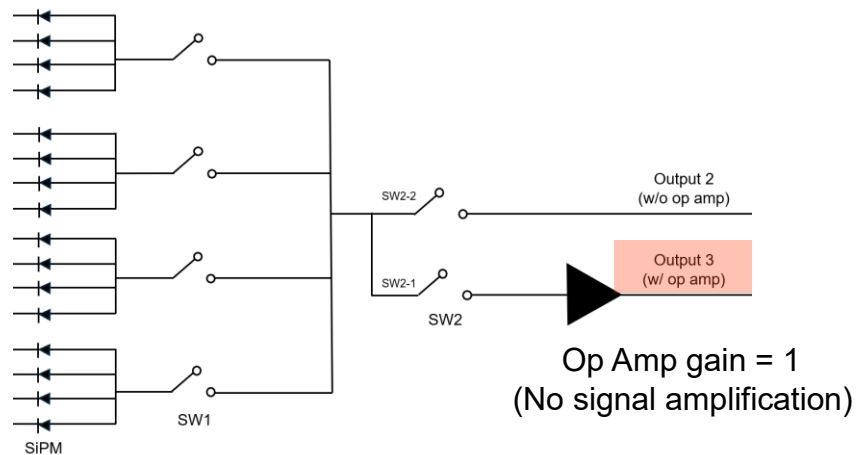
- Setup
 - 3cm x 3cm x 32cm calorimeter module
 - 5cm length Lightguide
- HV : Per-channel HV control (16-ch, ~40.7 V)
- H2GCROC parameter: 4 sets
- ADC, Peak ADC, TOT, TOA data acquired



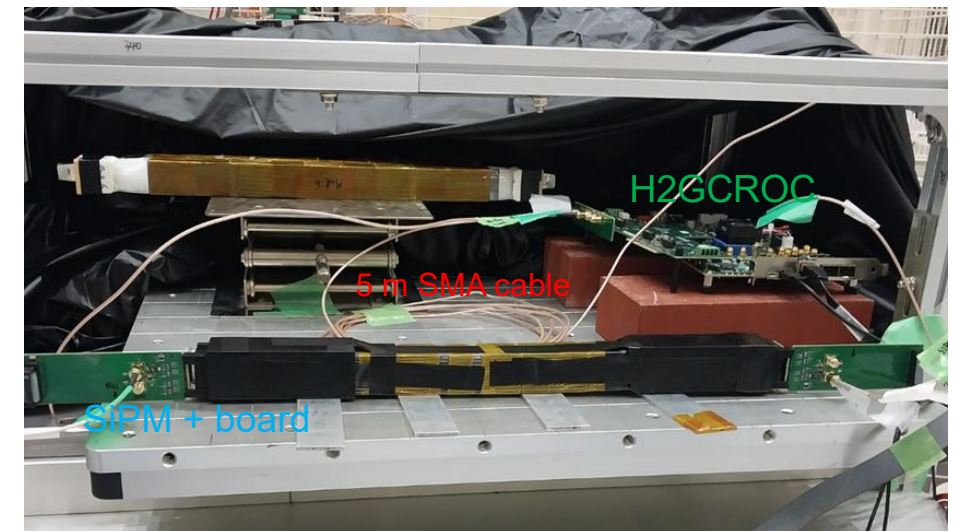
Parallel Summing



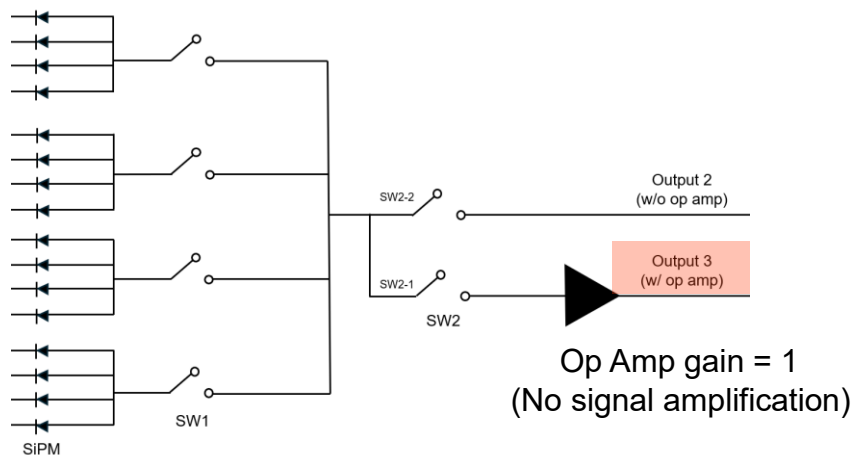
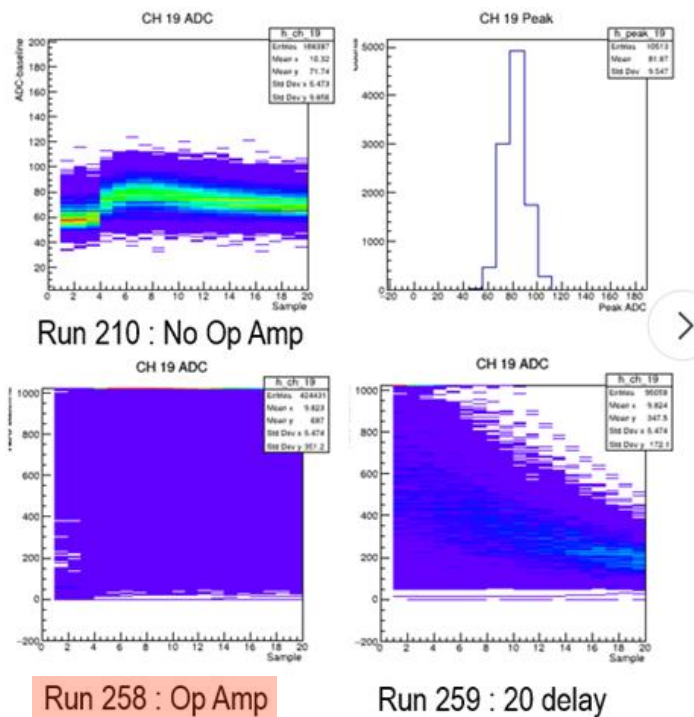
Delay 20 sample Delay 20 sample



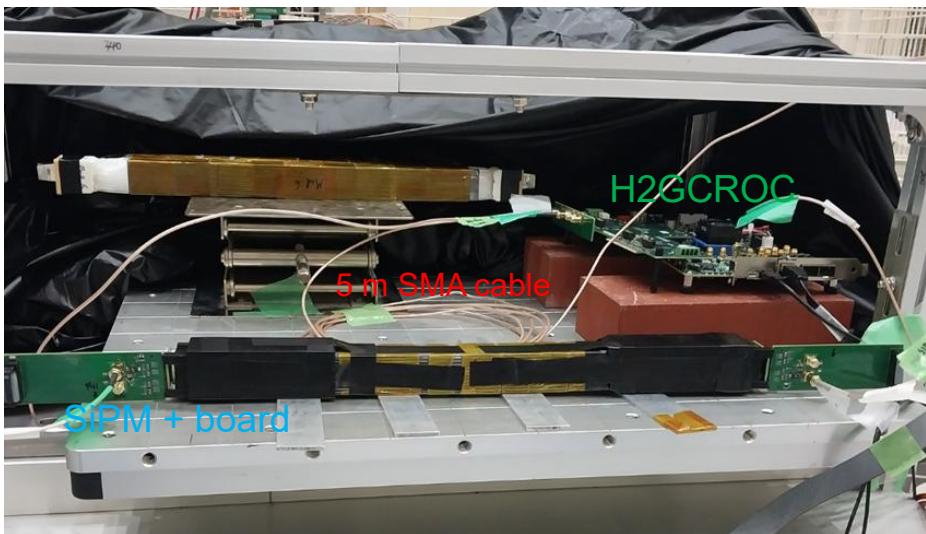
- Setup
 - 1 GeV/c, 3rd, Edep: 149 MeV
 - param: 8-10-12-10 (default param)
 - 3cm x 3cm x 32cm calorimeter module
 - 5cm length Lightguide
- HV : Per-channel HV control (16-ch, ~40.7 V)
- H2GCROC parameter: 3 sets
- ADC, Peak ADC, TOT, TOA data acquired



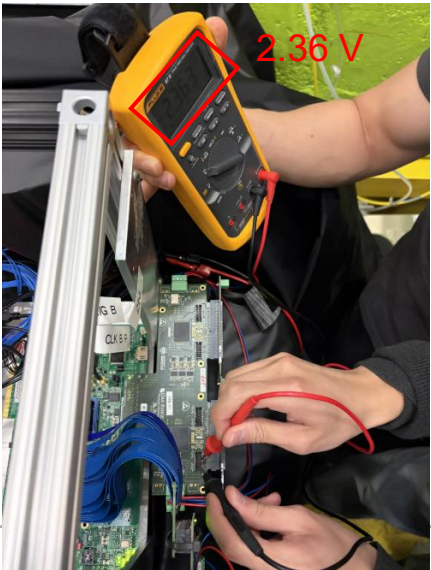
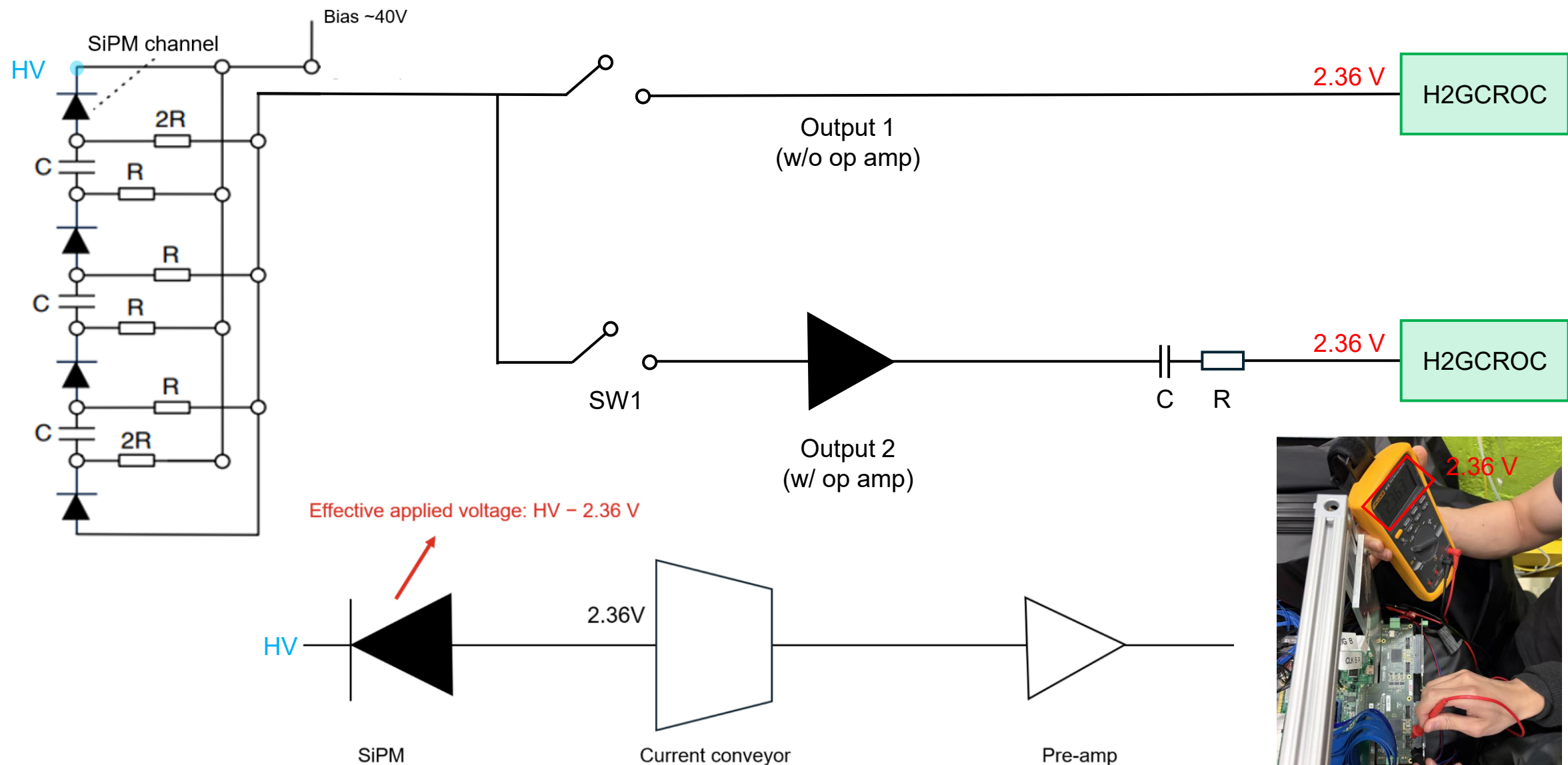
Parallel Summing



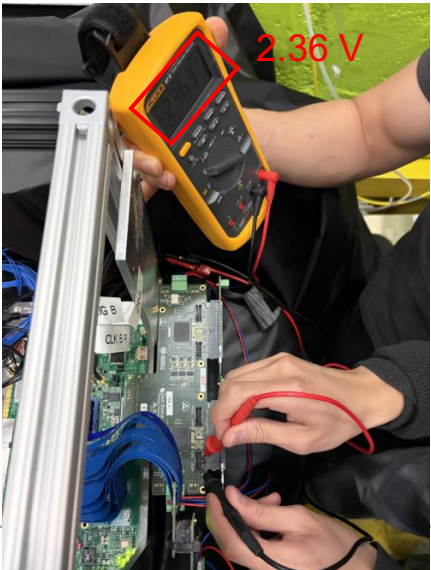
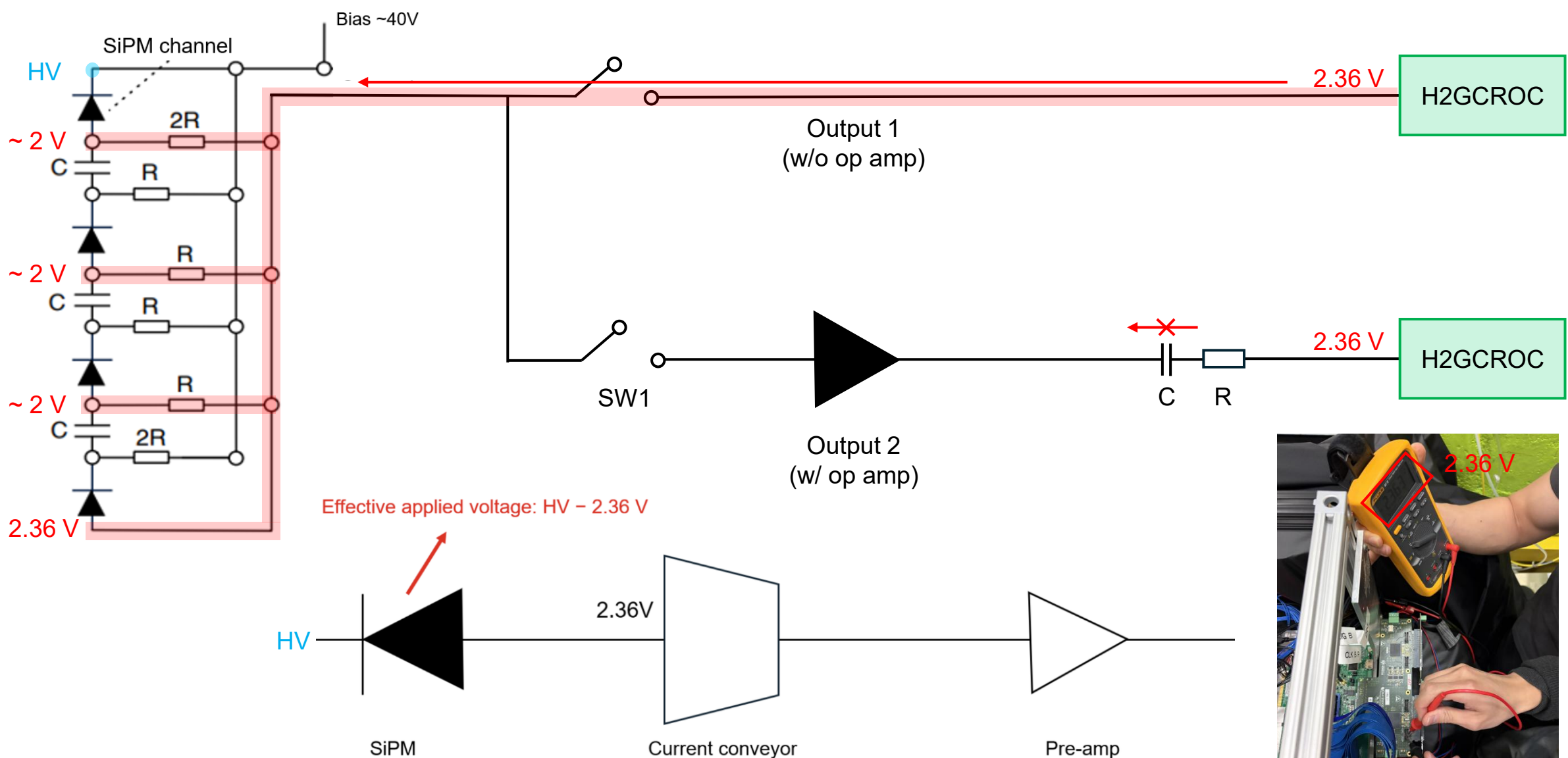
- Setup
 - 1 GeV/c, 3rd, Edep: 149 MeV
 - param: 8-10-12-10 (default param)
 - 3cm x 3cm x 32cm calorimeter module
 - 5cm length Lightguide
- HV : Per-channel HV control (16-ch, ~40.7 V)
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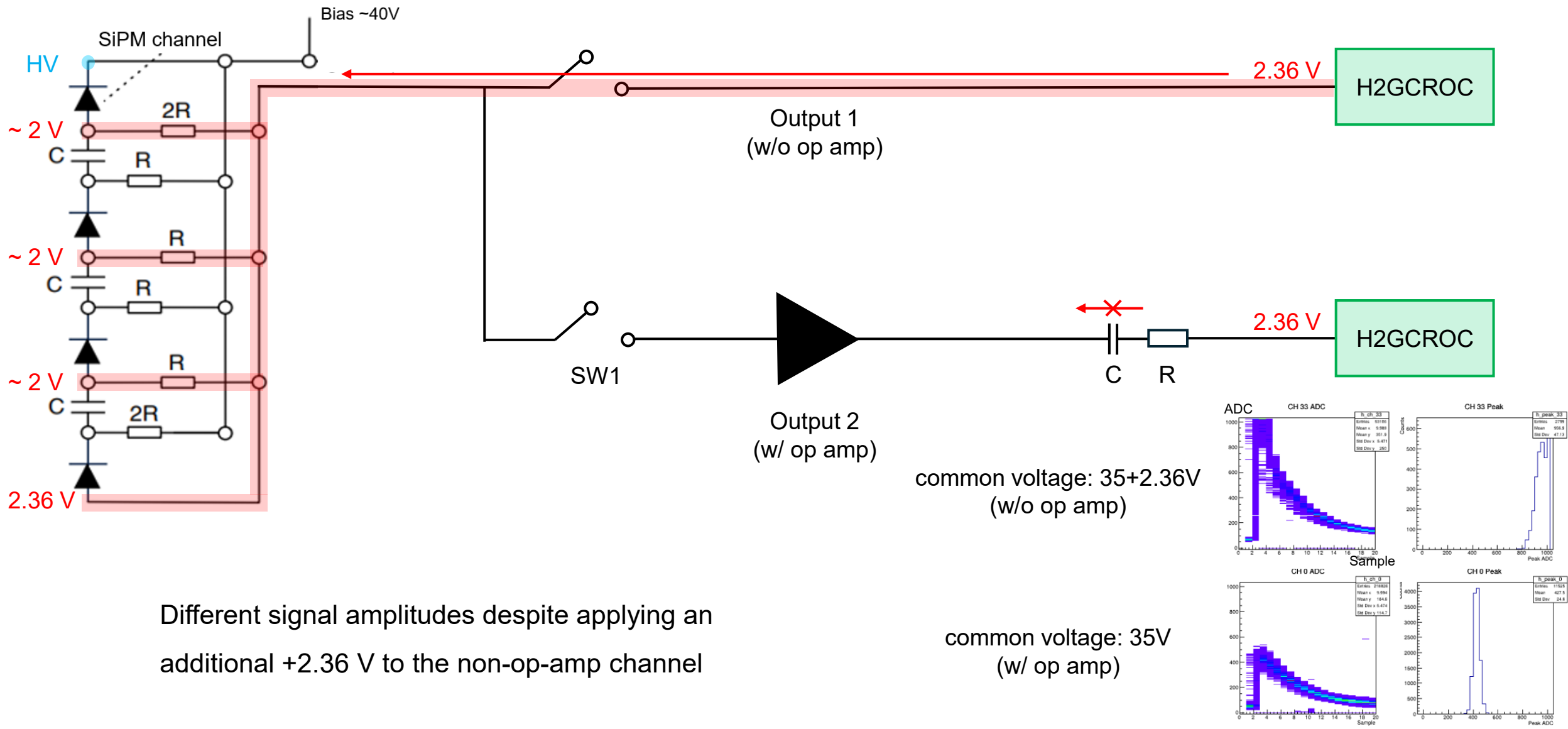
Hybrid summing with ac coupling



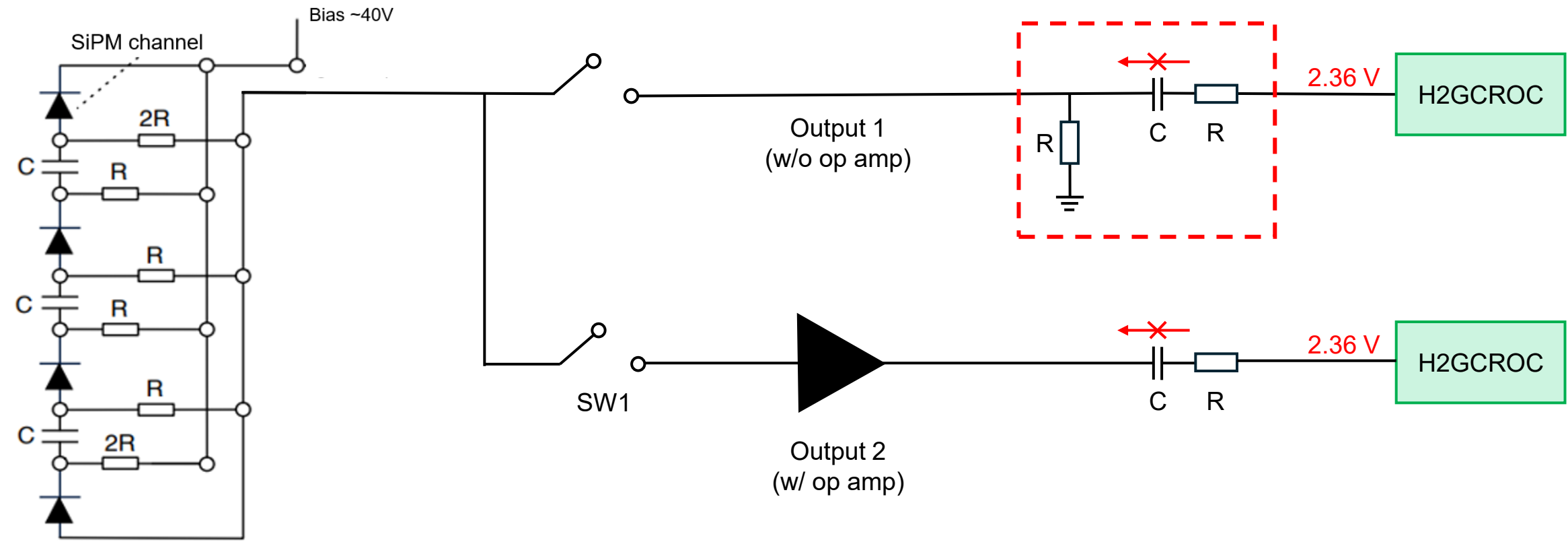
Hybrid summing with ac coupling



Hybrid summing with ac coupling

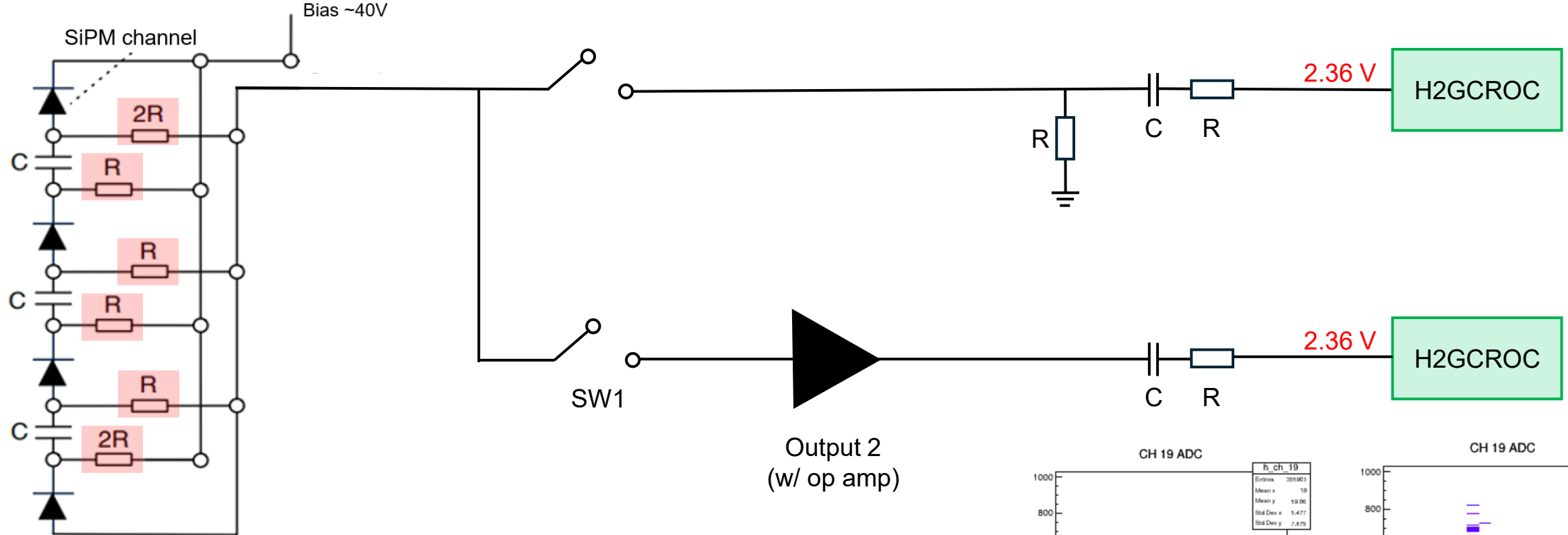


Hybrid summing with ac coupling

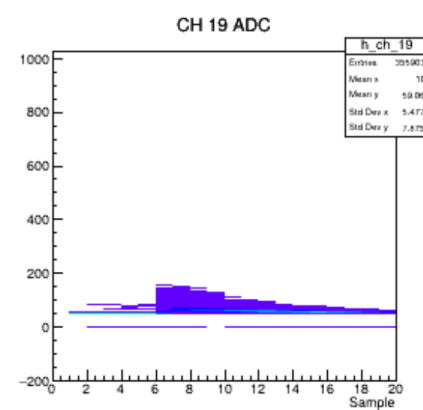


Added a resistor and AC coupling to block reverse DC current flow (red box)

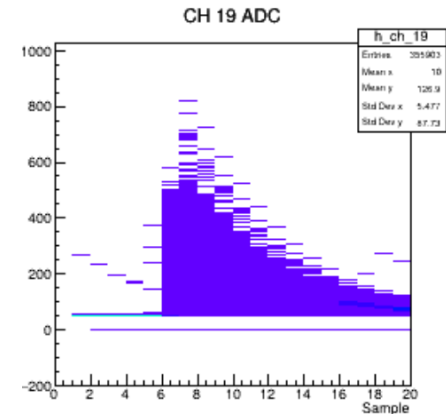
Hybrid summing resistor selection



- Lower R improves tolerance to high beam rates but reduces gain (x 0.4)
- Expected maximum NPE for the August CERN beam test: ~21,000
- Also consider the resolution at low energy deposition

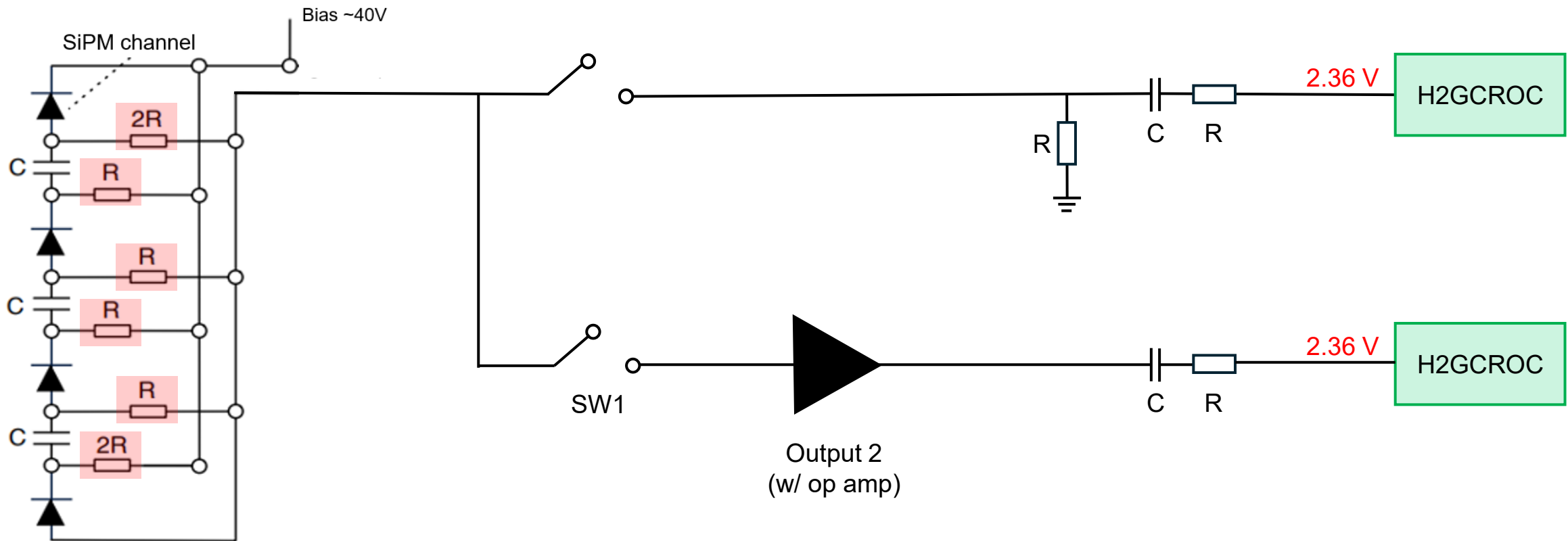


1 GeV, 1st
(98 MeV, 700 N_{pe} , x 0.025)



5 GeV, 3rd
(1042 MeV, 7500 N_{pe} , x 0.025)

Hybrid summing resistor selection



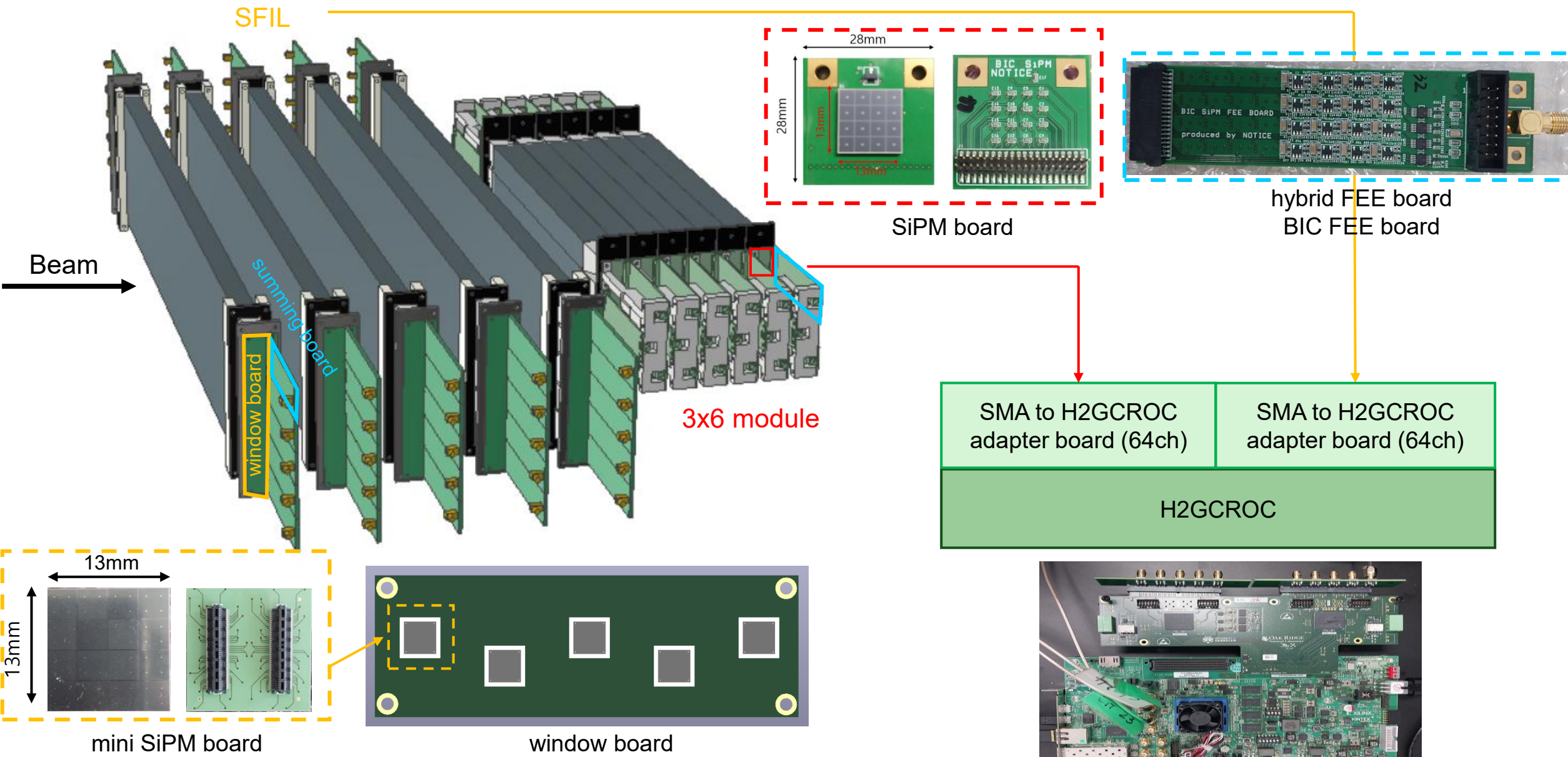
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Voltage Drop vs. Beam Rate for R = 100 Ω and 1 kΩ

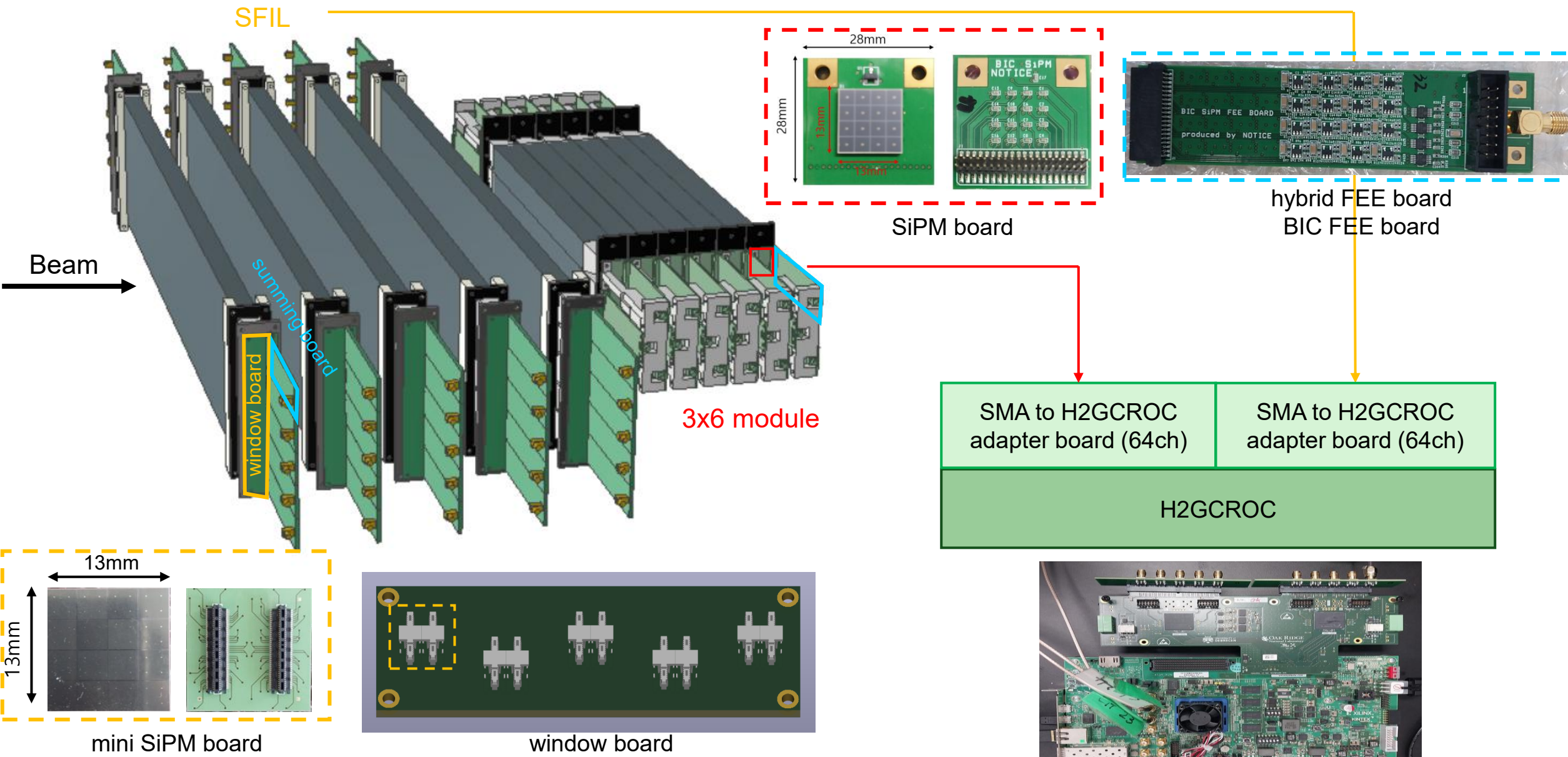
Voltage drop	Max rate @100Ω	Max rate @ 1kΩ
10 mV	91 kHz	9.1 kHz
100 mV	550 kHz	55 kHz

Calculated based on an Edep of 900 MeV (~6000 N_{pe}, 2000 pC)

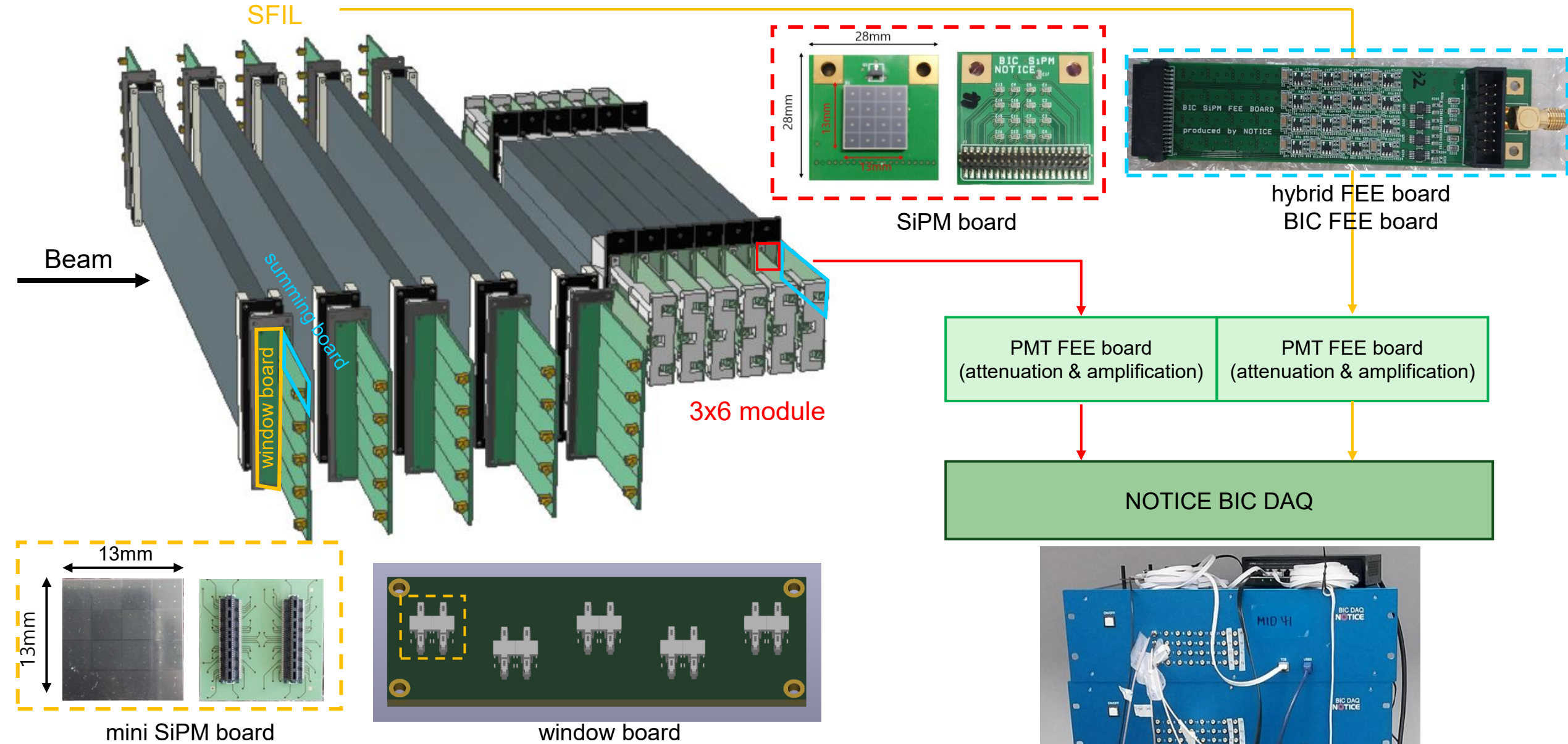
August CERN Setup



August CERN Setup



August CERN Setup



Backup