SiPM Summing Board Test at KNU

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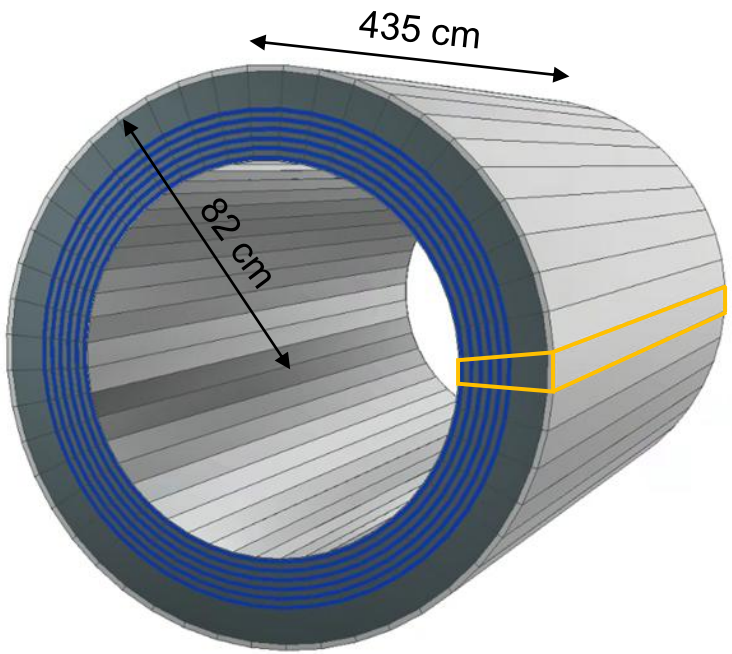
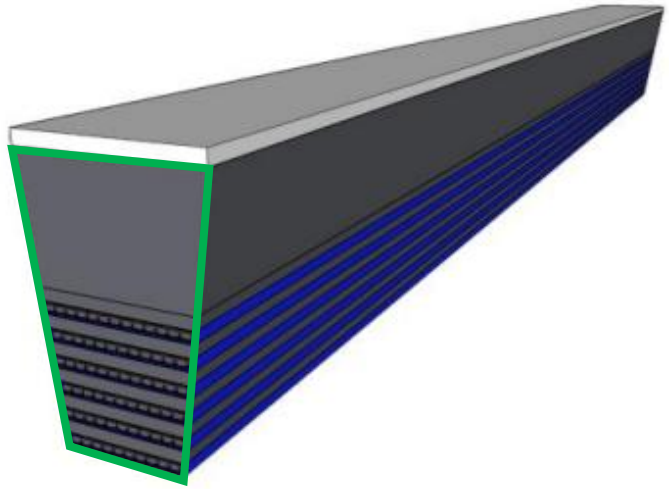
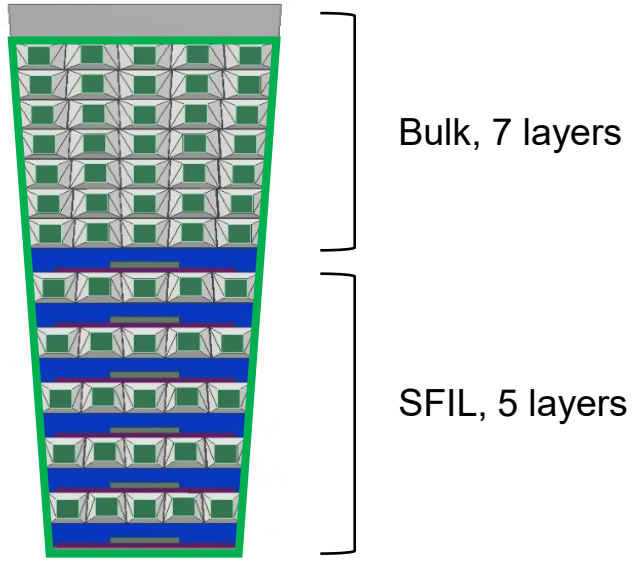
Introduction



Barrel imaging calorimeter



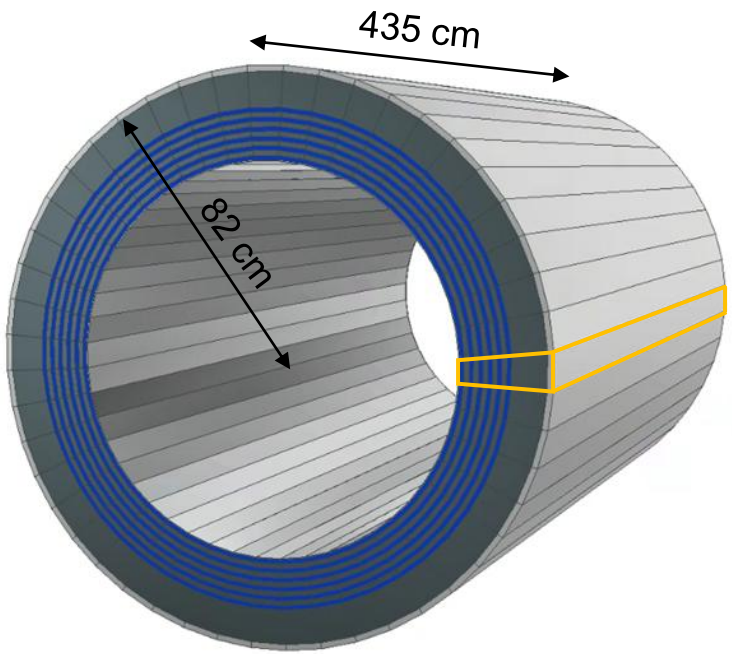
Sector



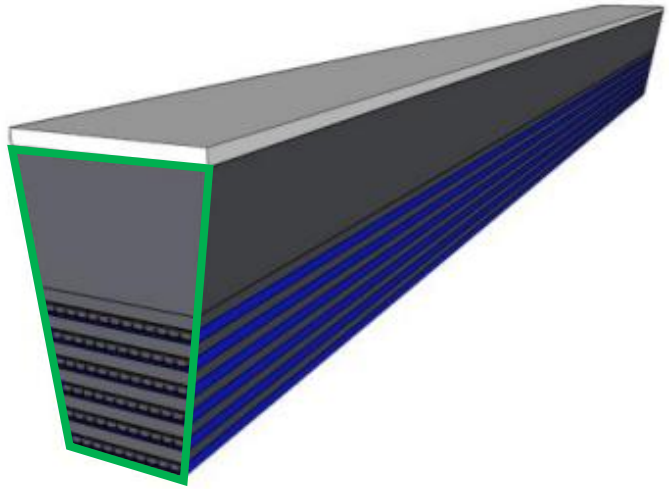
Sector end view

- 60 SiPMs (16-ch array) per sector end (5 x 12 layers = 60)
- Individual readout requires too many H2GCROC channels → 16-ch summing

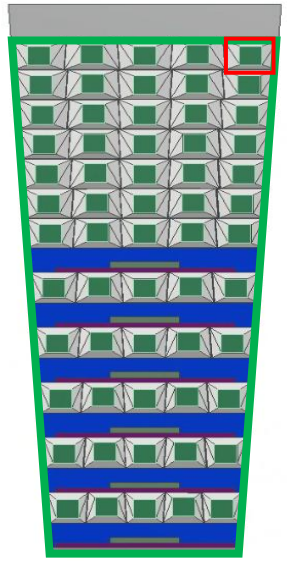
Introduction



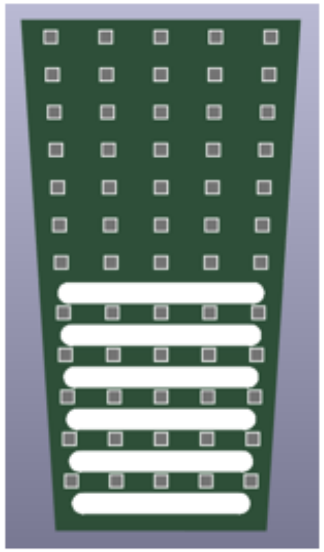
Barrel imaging calorimeter



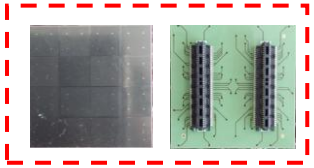
Sector



Sector end view



Trapezoidal board

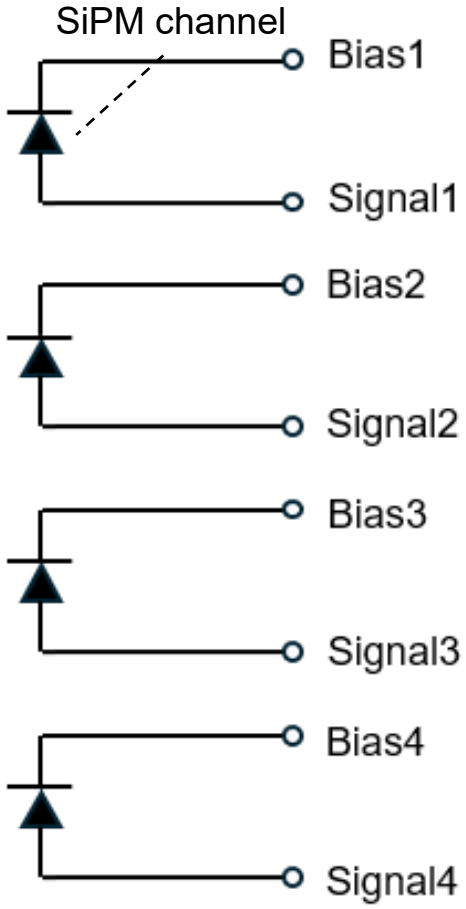


S14161-3050HS-04

- 60 SiPMs (16-ch array) per sector end (5 x 12 layers = 60)
- Individual readout requires too many H2GCROC channels → 16-ch summing

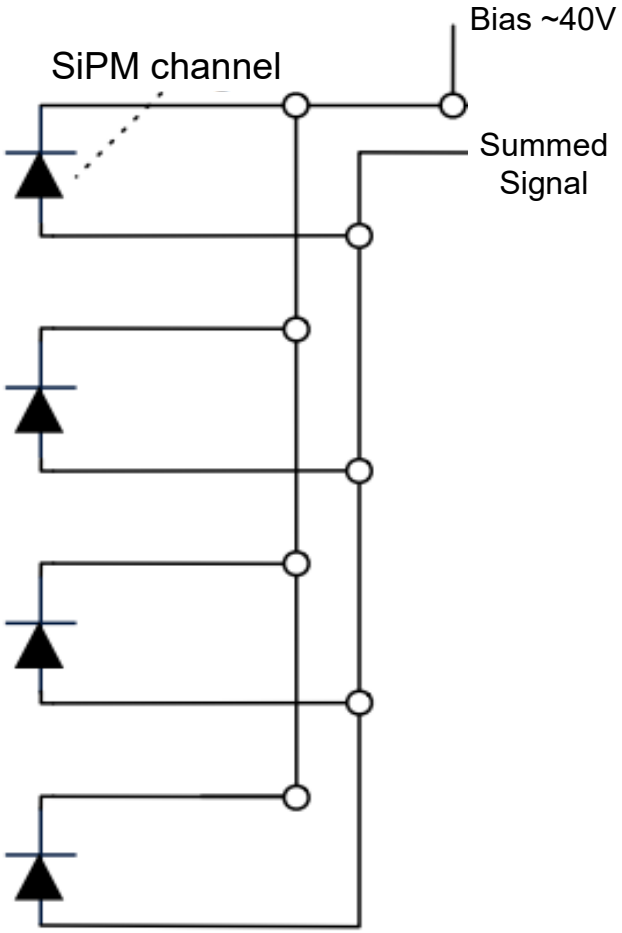
Summing Method

Individual readout



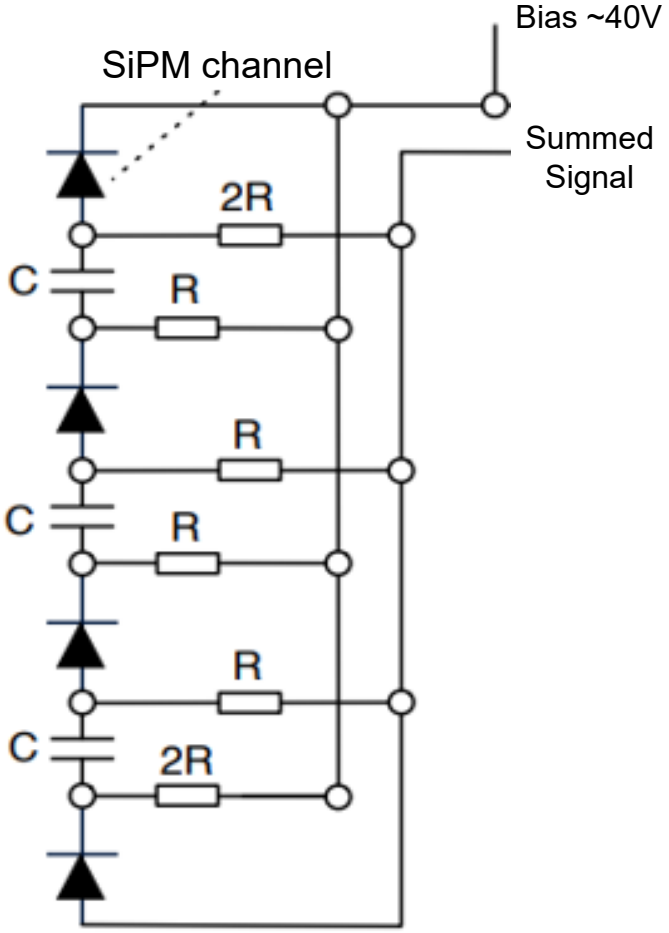
16-ch individual readout

Parallel summing



Broader pulse due to added SiPM capacitance

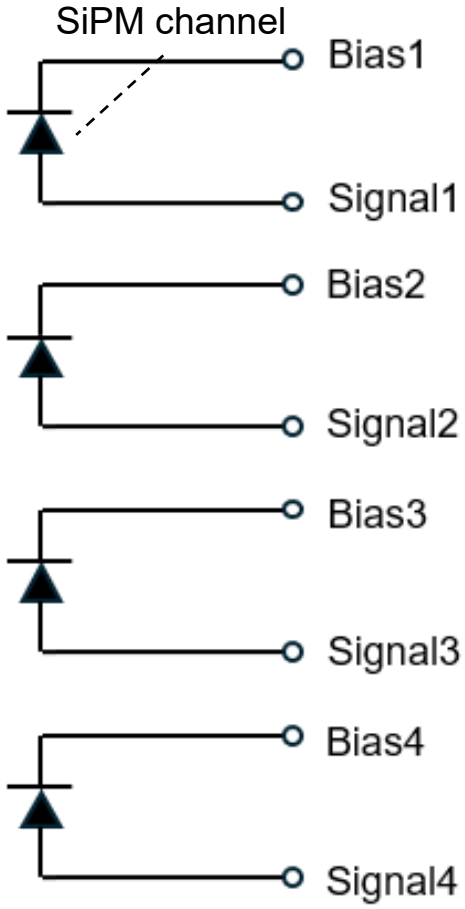
Hybrid summing



Parallel power, series signal

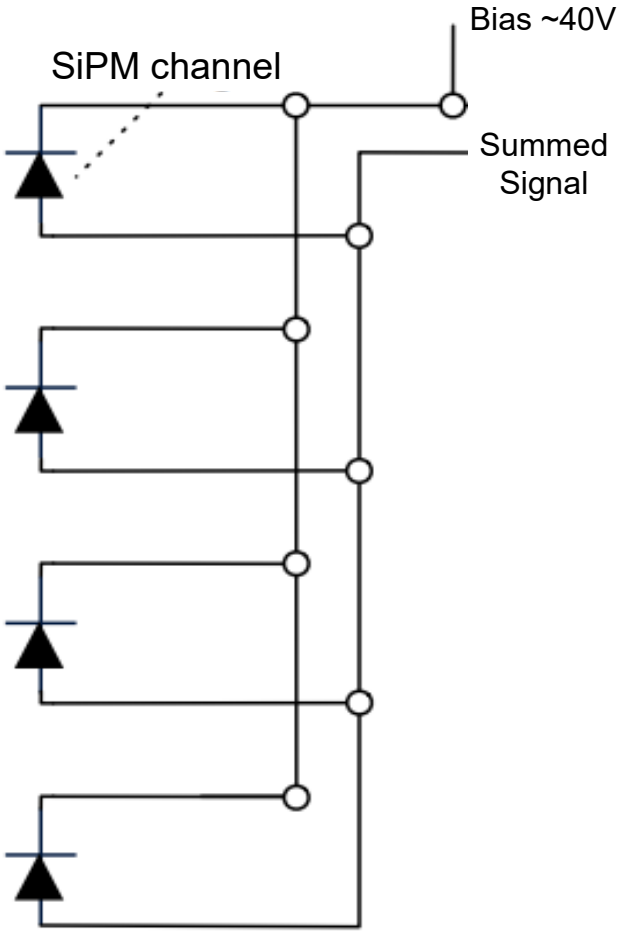
Summing Method

Individual readout



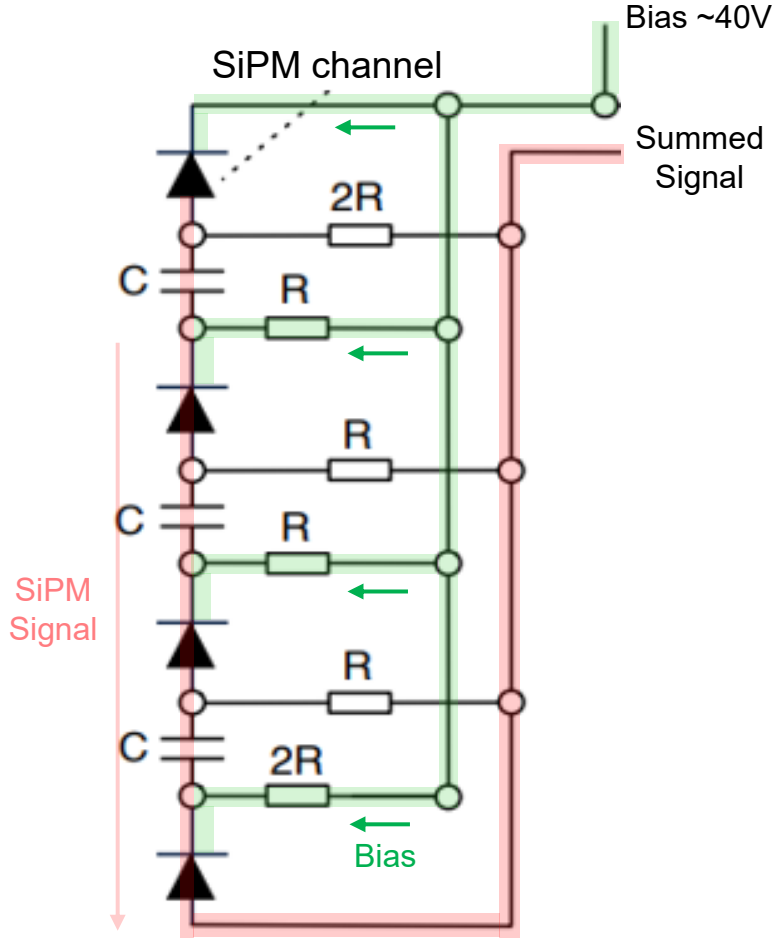
16-ch individual readout

Parallel summing



Broader pulse due to added SiPM capacitance

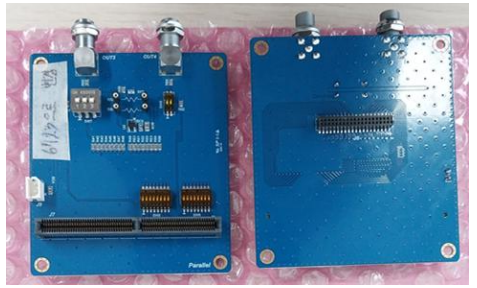
Hybrid summing



Parallel power, series signal

e-room tech Summing Board

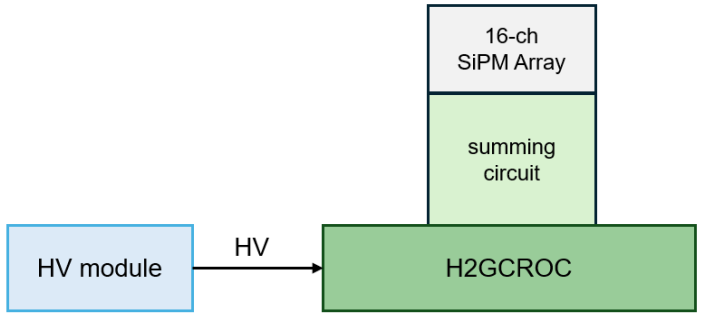
Hybrid summing

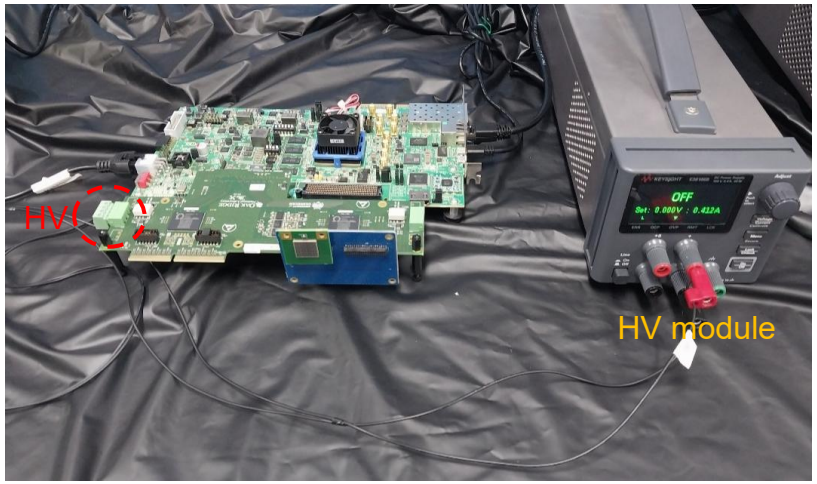


Parallel summing

Individual

- 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)





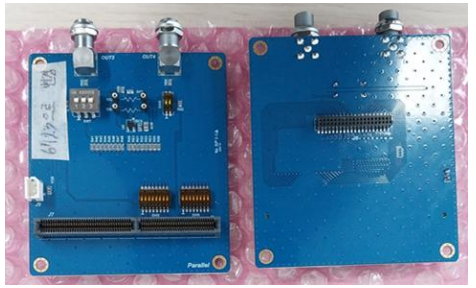
e-room tech board

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

e-room tech Summing Board

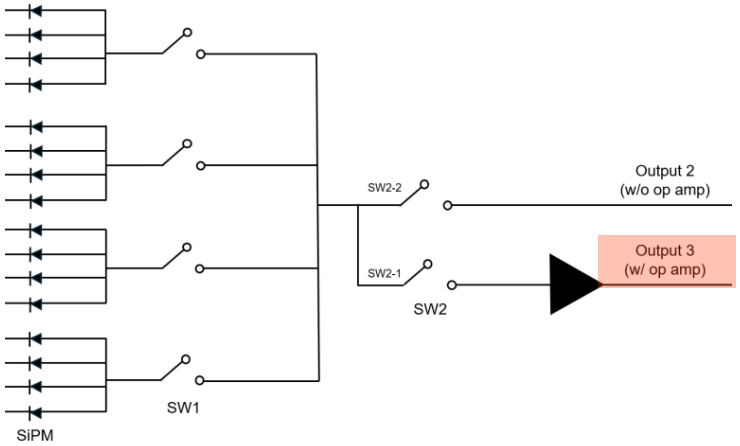
- Hybrid summing
  - w/o op amp, w/ op amp (Board #1, LMH6629)
  - w/o op amp, w/ op amp (Board #2, LMH6723)
- Parallel summing
  - w/o op amp, w/ op amp (Board #3, LMH6629)
  - w/o op amp, w/ op amp (Board #4, LMH6723)
- Individual
  - SiPM 16ch individual readout (Board #5, #6)

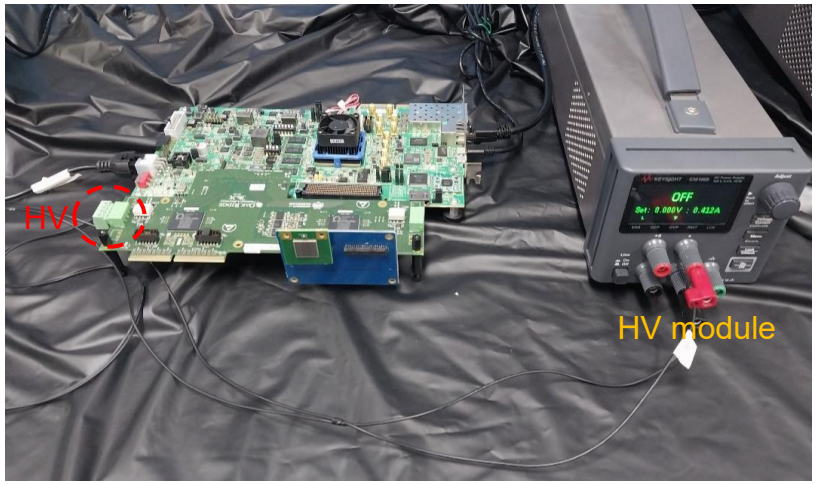
Hybrid summing



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

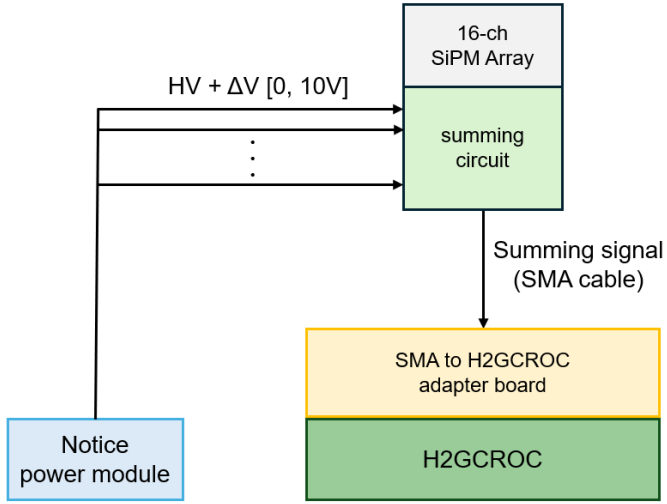
NOTICE Summing Board

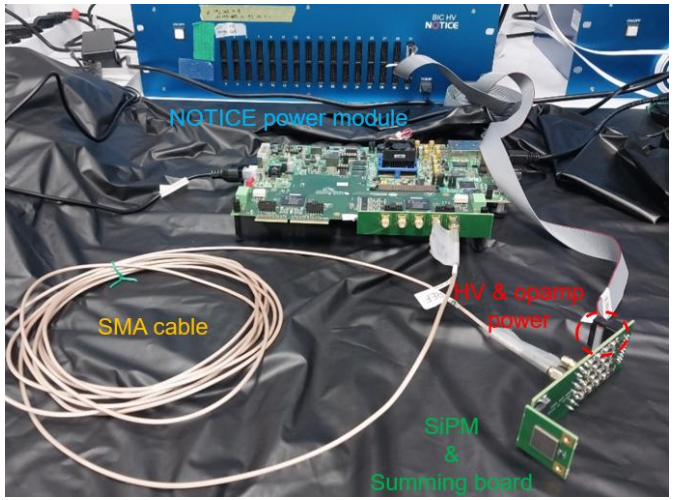
Hybrid summing

Parallel summing

SMA to H2GCROC

- Hybrid summing
  - w/o op amp, w/ op amp (Board #7, #8)
- Parallel summing
  - w/o op amp, w/ op amp, 4ch summing (Board #9, #10)
- SMA to H2GCROC (Board #11, #12)

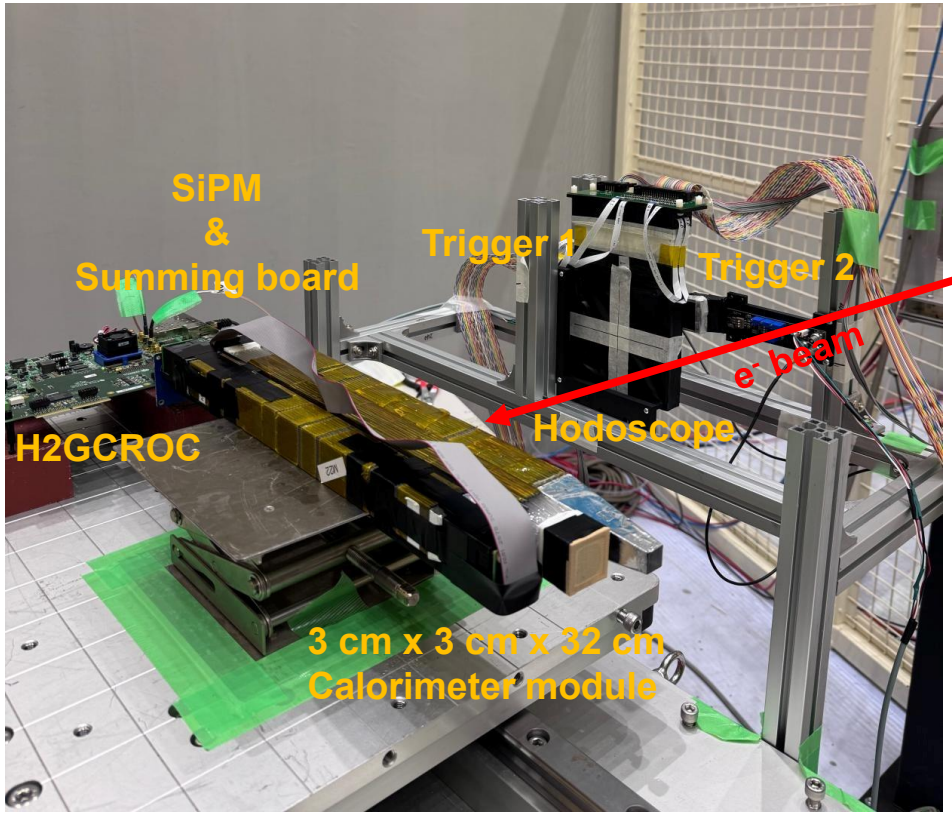




NOTICE Board

- 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

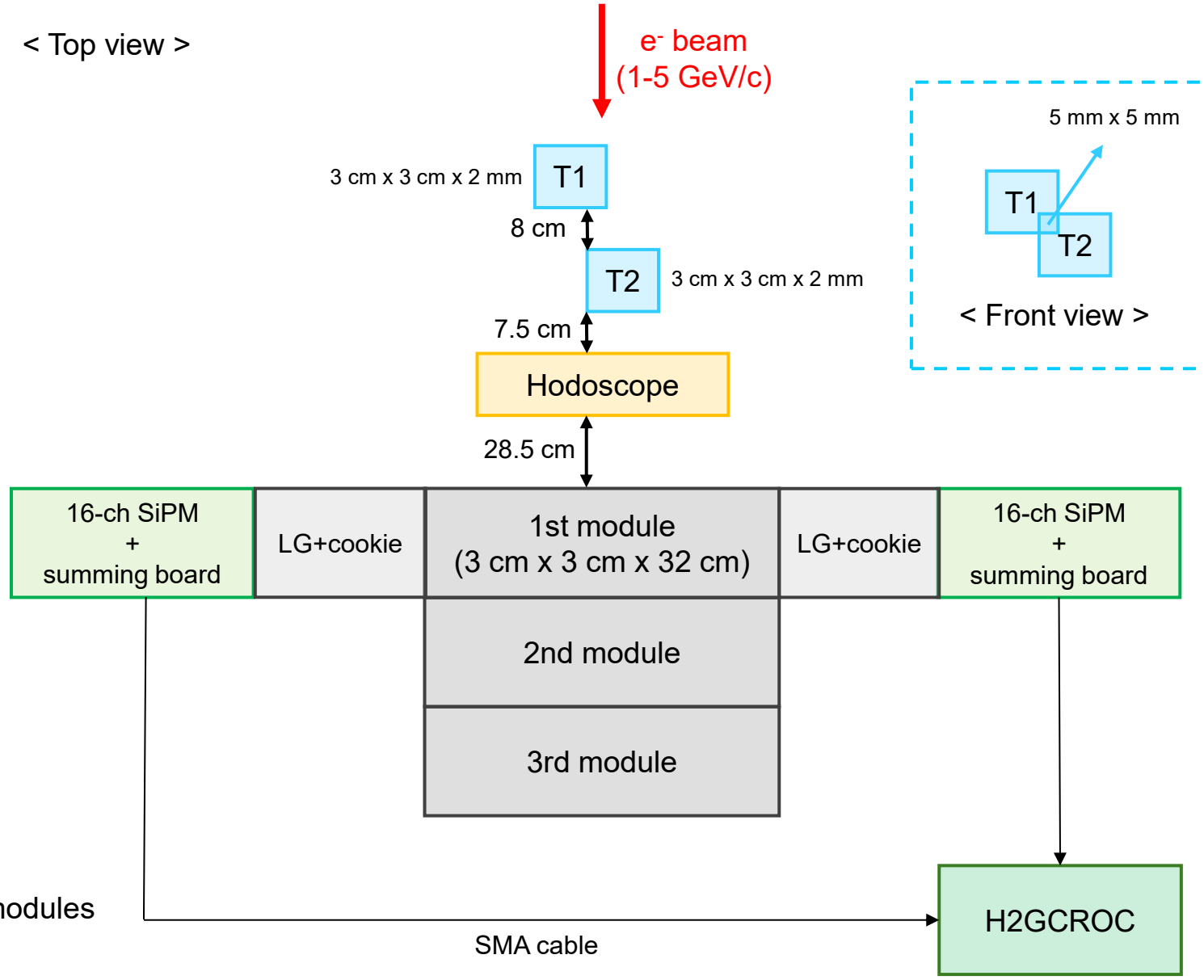
Test Setup at KEK PF-AR



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 >



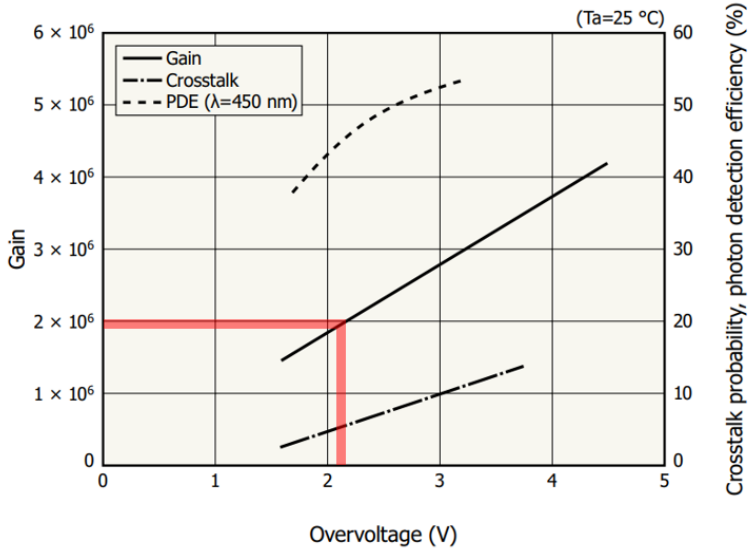
Dynamic Range Estimation

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

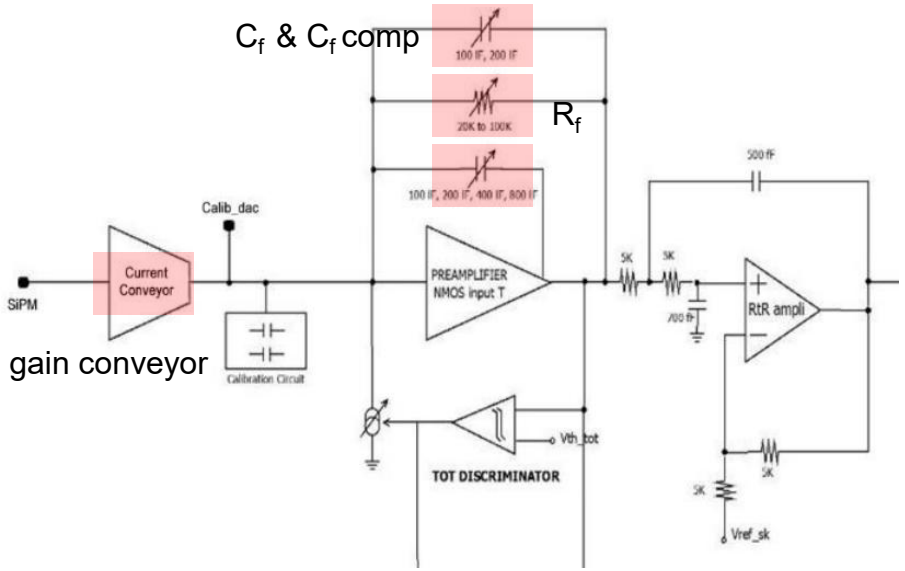
	Energy deposit (MeV, mean)			N_{pe} per SiPM (9cm^2)			Charge (pC, 16ch summing)		
Beam (GeV/c)	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
0.5	77	140	92	600	1100	700	192	352	224
1	98	246	208	700	1800	1500	224	576	480
2	129	417	435	1000	2800	3000	320	896	960
3	149	542	645	1100	3800	4500	352	1216	1440
4	165	655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

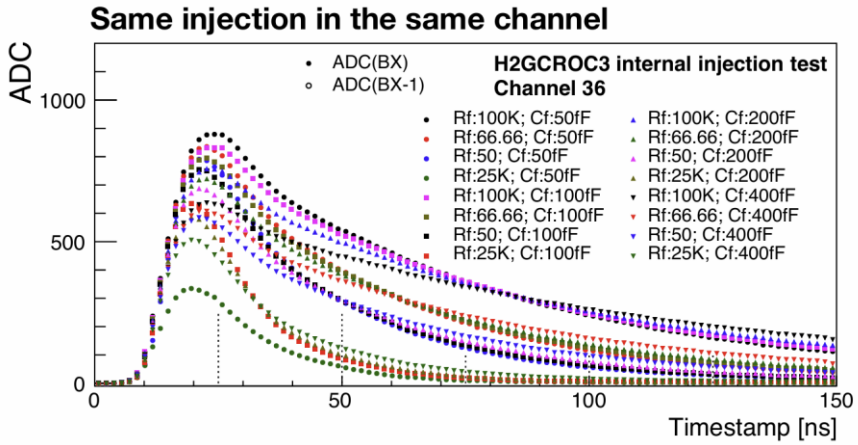
- Conversion from N_{pe} to Charge
  1. N_{pe} × Gain = Number of electrons (V_{br}=38.5 V, V_{op}=40.7 V)
  2. Multiply the number of electrons by 1.6 x 10^{-19} C to obtain the charge

- 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



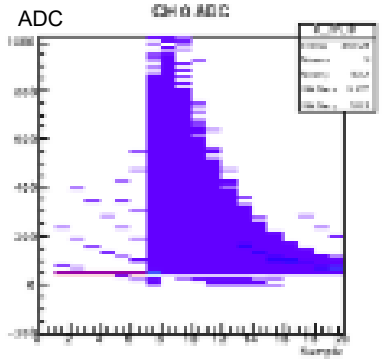


- R_f: lower Value → gain↑
- C_f: lower Value → gain↓, width↓
- Gain conveyor: lower Value → gain ↓
- C_f comp: lower Value → gain ↓

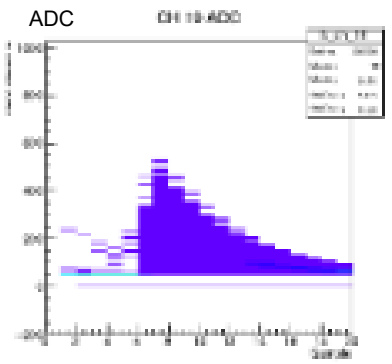
	summing	momentum	position	parameter (Rf-Cf-Gain conveyor-Cf comp)
e-room (#5,6)	Individual	1-5GeV/c	1st, 3rd	8-10-12-10 (default param) 4-15-15-15 15-4-15-15
Notice (#7,8) e-room (#1,2)	Hybrid	1-5GeV/c	1st, 3rd	8-10-12-10 (default param) 4-1-1-15 15-1-1-15 15-1-1-1 (gain min) ↓ gain↓
Notice (#9,10) e-room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

Electron Beam Test at KEK PF-AR

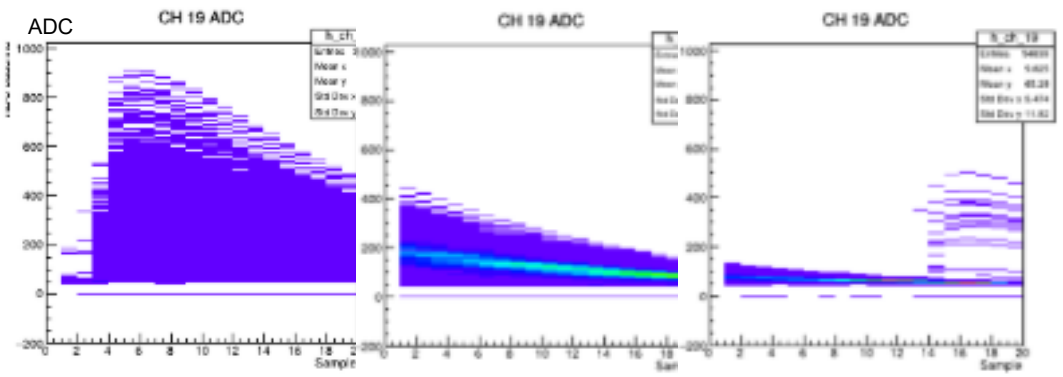
3 GeV/c, 3rd, Edep: 645 MeV



Individual, param: 8-10-12-10 (default)



Hybrid, param: 15-1-15-15



Parallel, param: 15-1-15-15

	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
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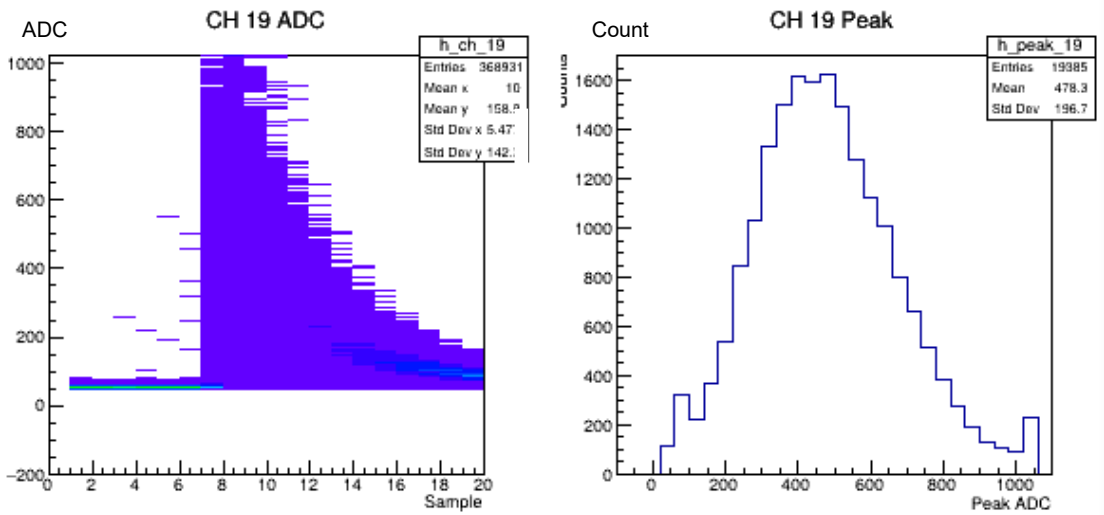
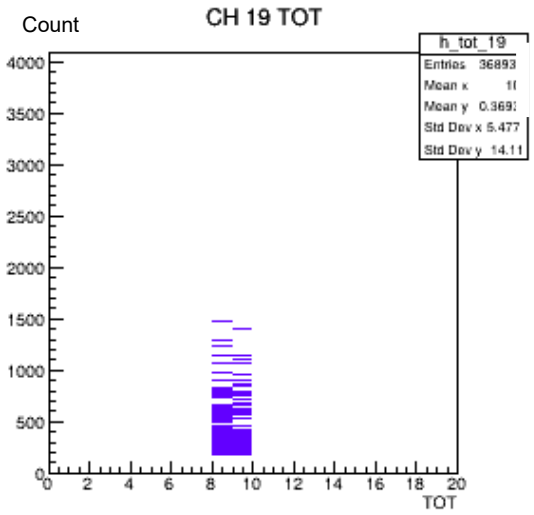
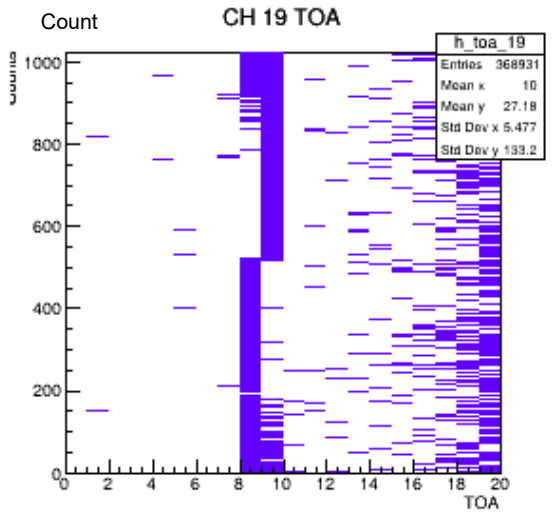
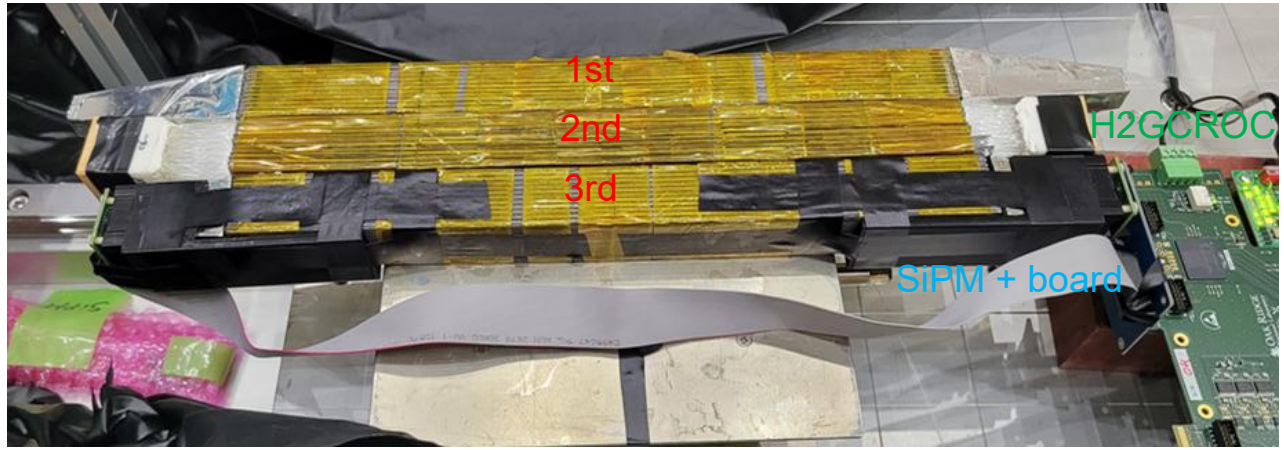
Individual Readout





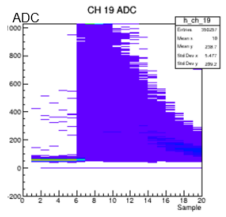


- Setup
  - 1GeV, 3rd, Edep: 149 MeV
  - param: 8-10-12-10 (default param)
  - 3cm x 3cm x 32cm calorimeter module
  - 5cm length Lightguide
- HV : 40.7 V
- H2GCROC parameter: 3 sets
- ADC, Peak ADC, TOT, TOA data acquired

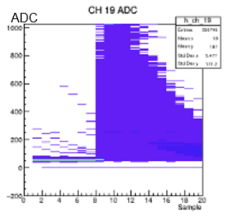


Hybrid Summing

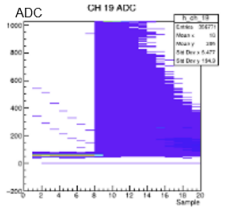
Hybrid, 1st, param: 8-10-12-10 (default)



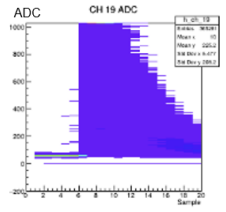
1 GeV/c (Edep: 98 MeV)



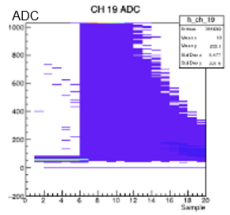
2 GeV/c (Edep: 129 MeV)



3 GeV/c (Edep: 149 MeV)

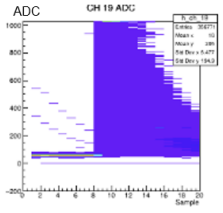


4 GeV/c (Edep: 165 MeV)

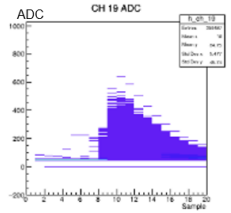


5 GeV/c (Edep: 178 MeV)

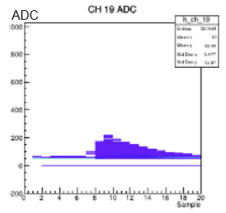
Hybrid, 1st, 3GeV/c (Edep: 149 MeV)



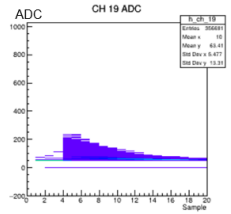
8-10-12-10 (default)



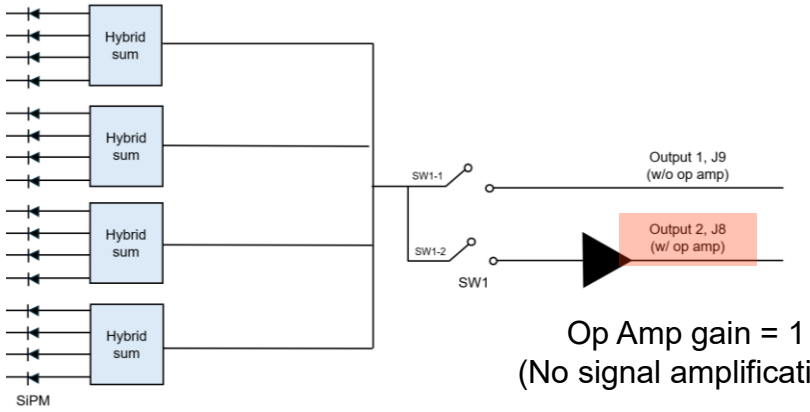
4-1-1-15



15-1-1-15

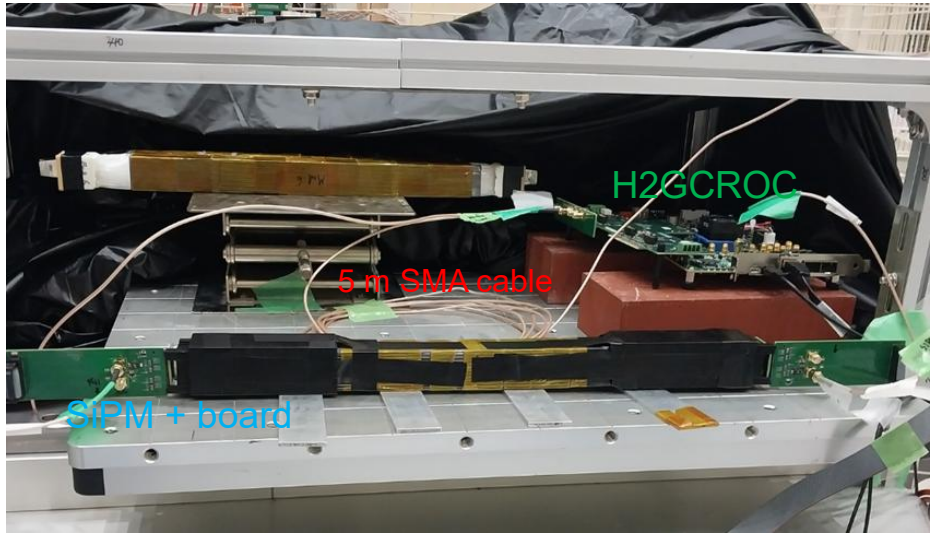


15-1-1-1

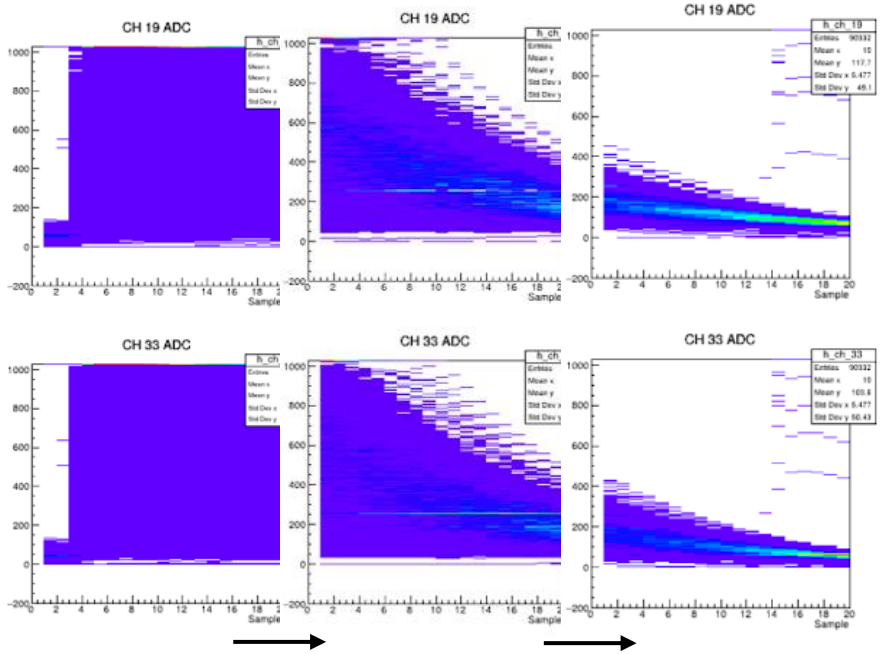


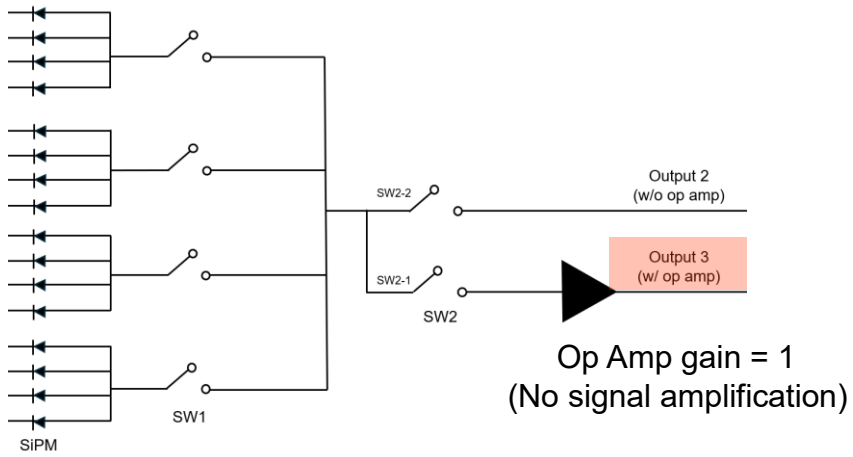
Op Amp gain = 1
(No signal amplification)

- 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
- Signal attenuation in the cable→ Only op-amp output transmitted



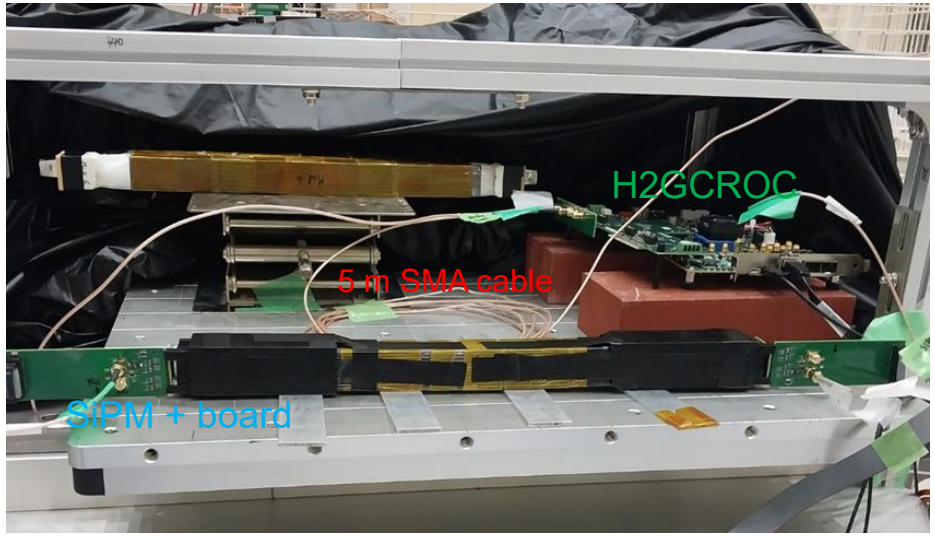
Parallel Summing





Op Amp gain = 1
(No signal amplification)

- 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
- Signal attenuation in the cable → Only op-amp output transmitted



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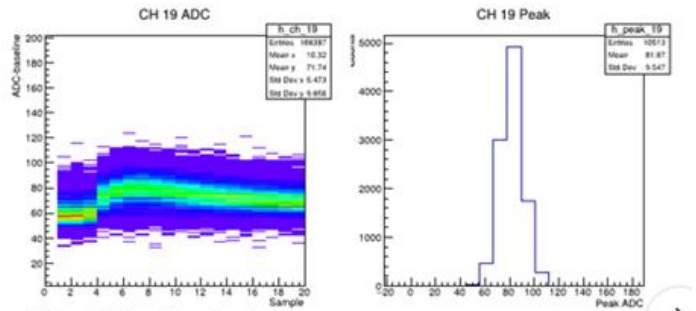

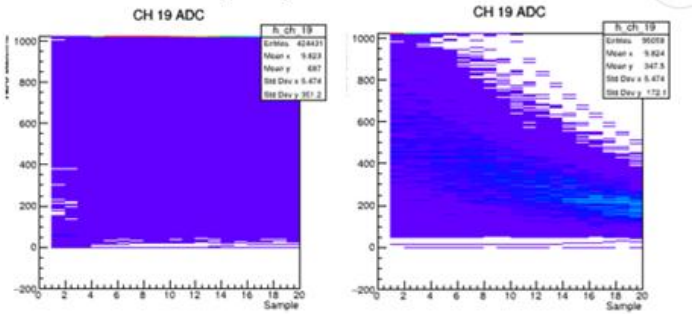

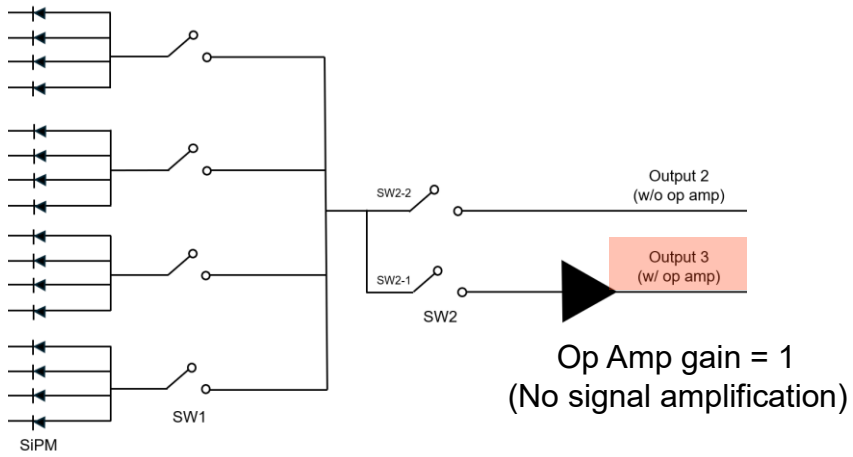

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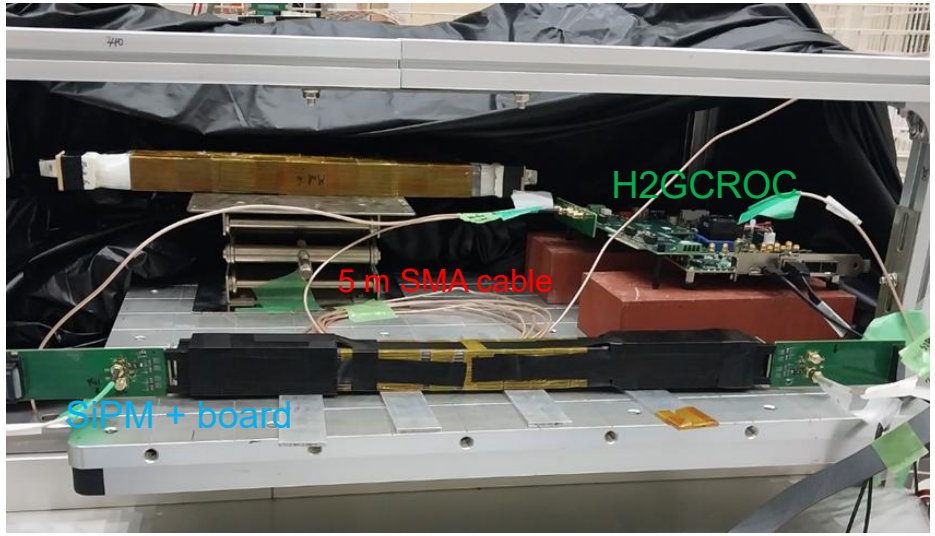
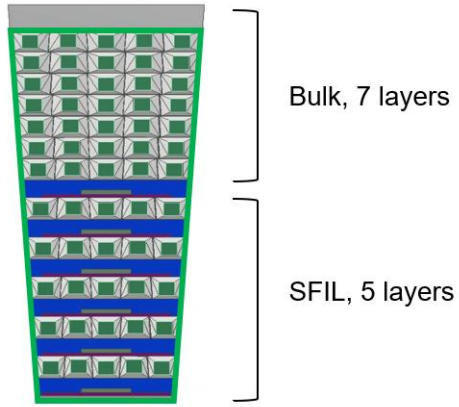


Summary

- Individual readout of BIC SiPMs requires many H2GCROC channels
- Compared readout schemes: individual, parallel, and hybrid
- Data collected with 1–5 GeV/c electron beams from the 1st and 3rd modules at KEK
- Collected ADC, Peak ADC, TOT, and TOA data over 224–2400 pC
- Beam tests showed significant cable attenuation without an op amp
- Designing readout boards for the Bulk and SFIL for the August CERN beam test
- Performing detailed analysis of the KEK beam test data.

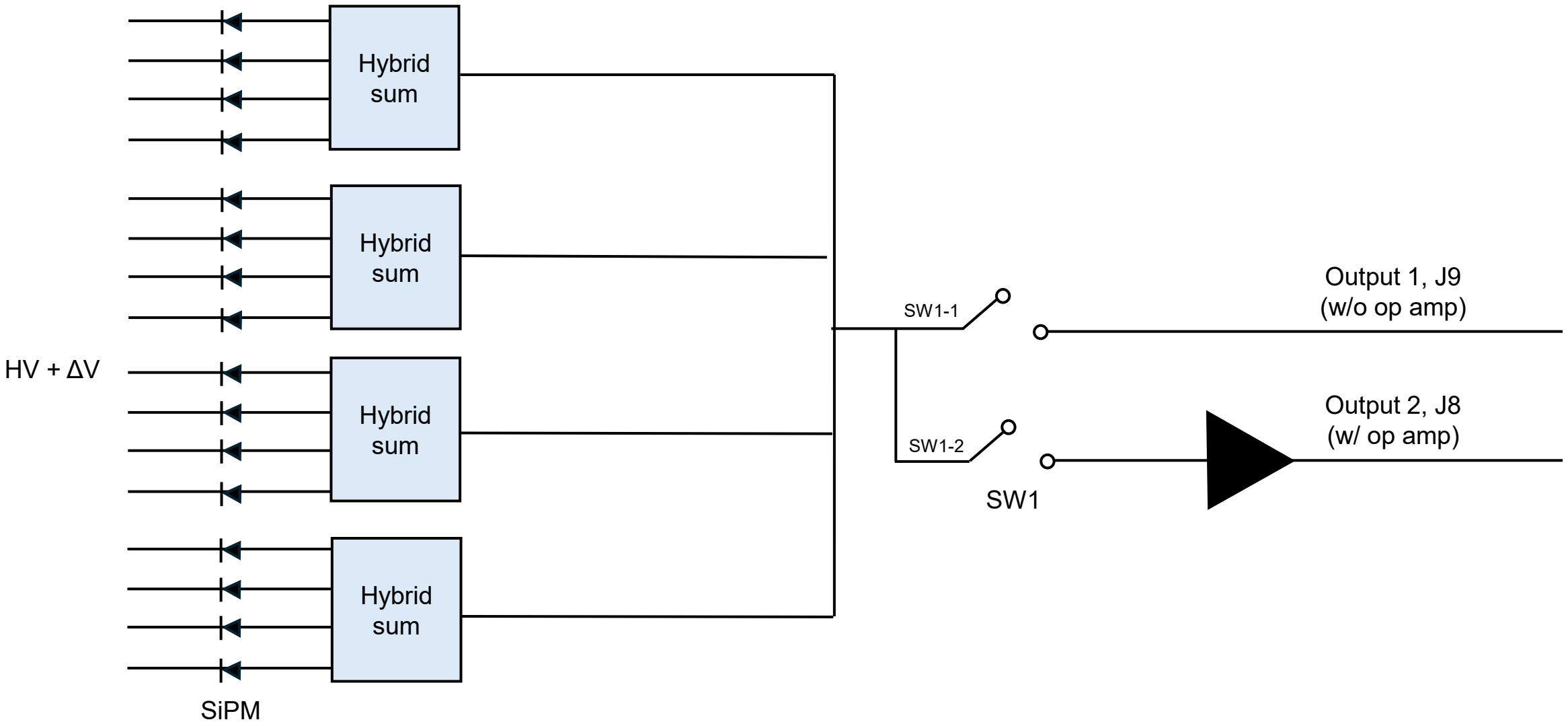
Trapezoidal board mounted on the bulk



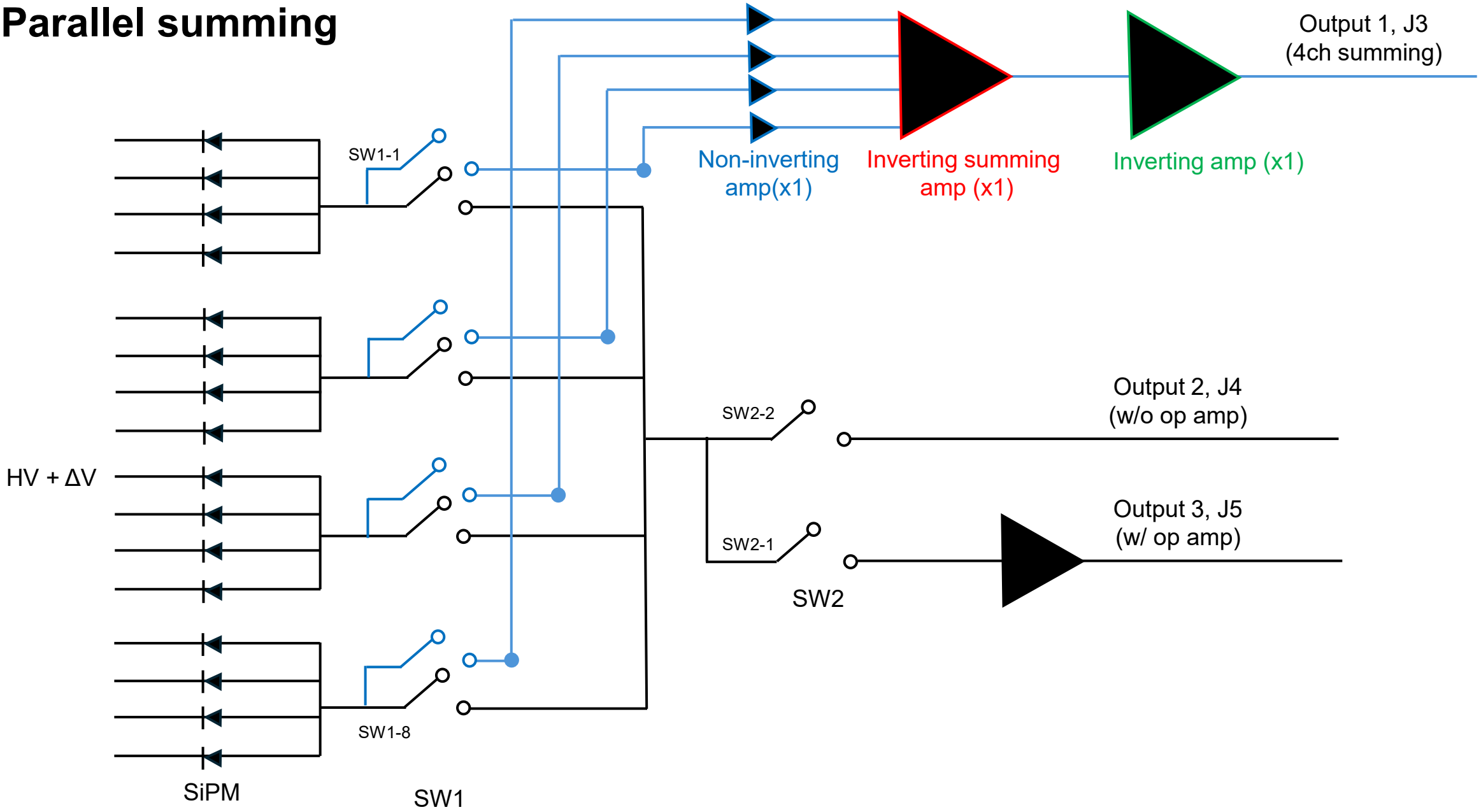
Sector end view

Backup

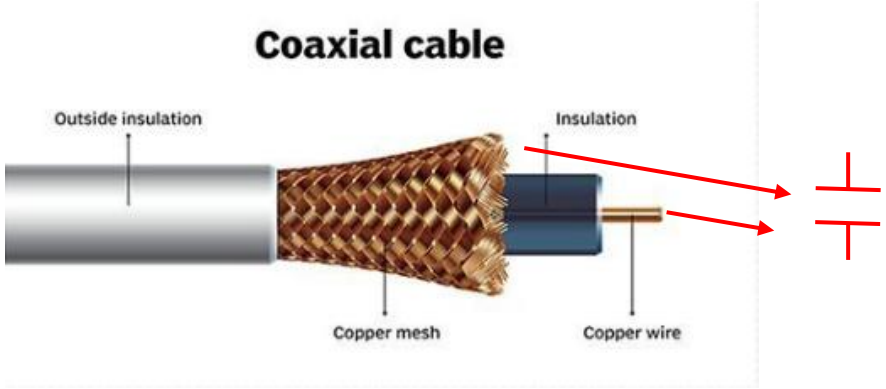
Hybrid summing



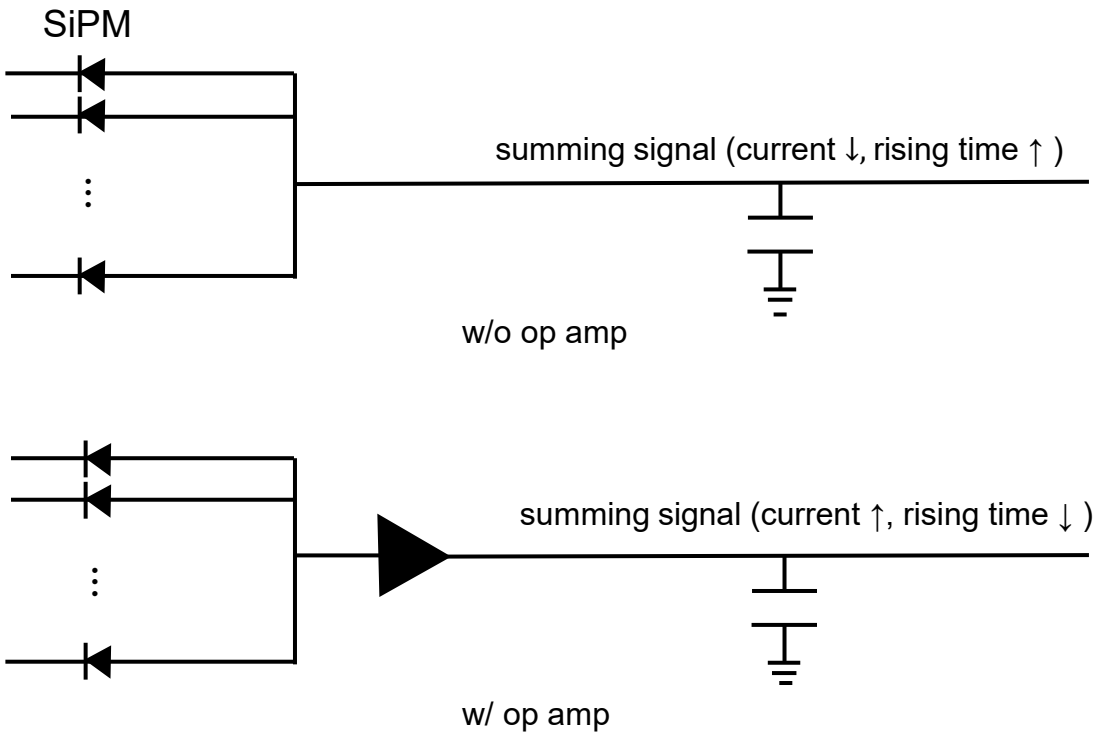
Parallel summing



Op-amp comparison

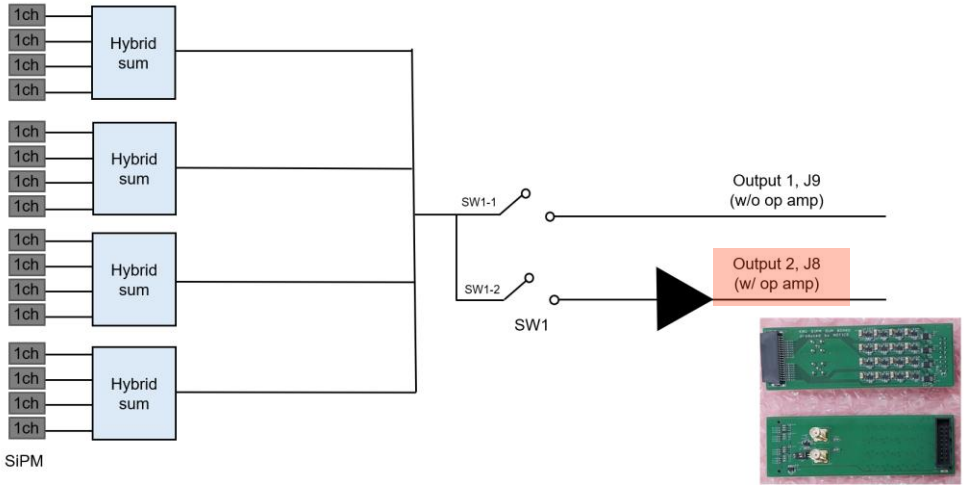


Cable capacitance may increase the rise time

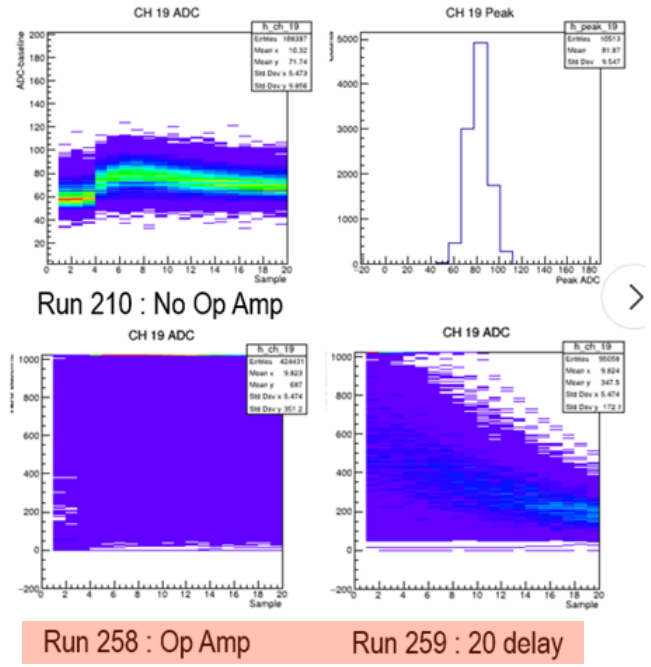


Product	Small signal Bandwidth (MHz)	Noise level (nV/√Hz)	Slew rate (V/μs)	Power (W/cm²)	Price (USD)	Remark
LMH6714	400 @ gain = 2	3.4	1800	1.21	2.87	CFA, V_{op} = 10V
LMH6723MF	290 @ gain = 1	4.3	400	0.124	3.5	CFA, V_{op} = 5V
OPA 656	550 @ gain = 1	6	400	3.23	12.7	VFA, V_{op} = 10V
LMH6629MFE	950 @ gain = 10	0.69	1100	1.005	6.5	VFA, V_{op} = 3.3V

Op-amp comparison



3rd. Preamp **default**, **Parallel** sum



- Without an op amp, the signal is lost due to cable attenuation
- Op amp performance ↔ Power dissipation (trade-off)
- Study cable attenuation and compare op amps

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