Ladder Performance

WBS: 3.01

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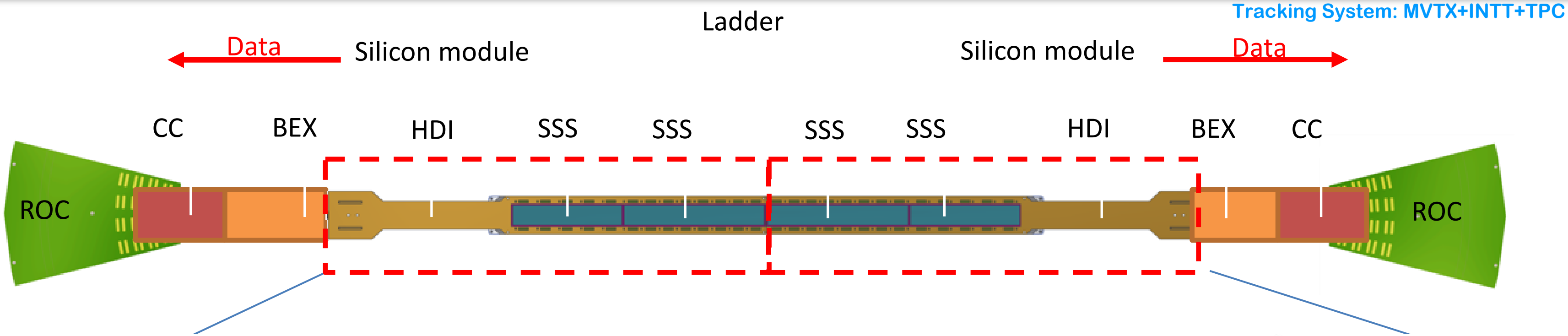
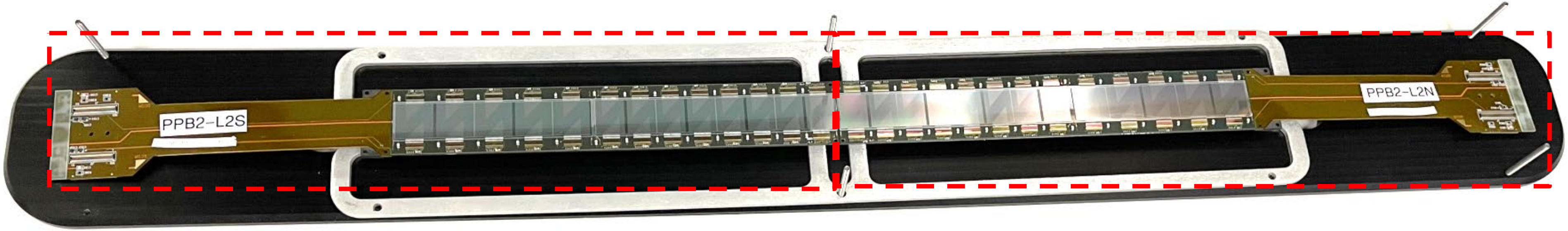
The INTT ladders

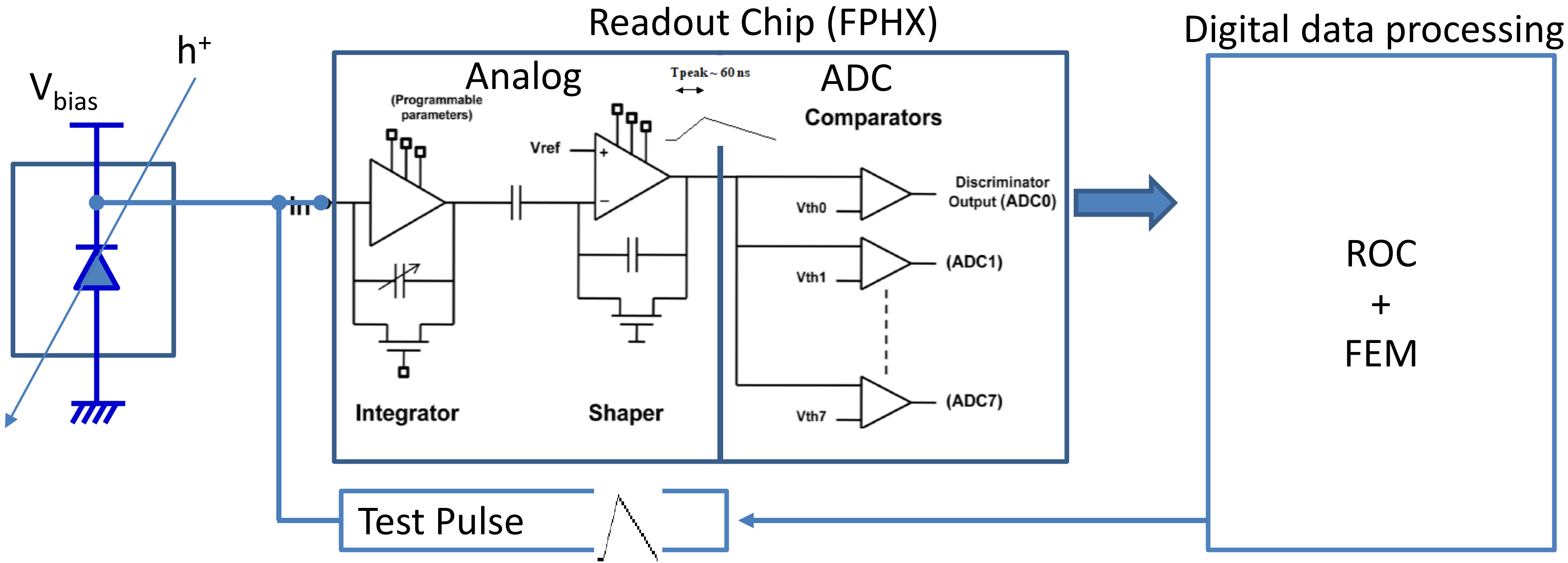




- Si : 320um thick
- Channel size : 78um x 16mm(20mm),

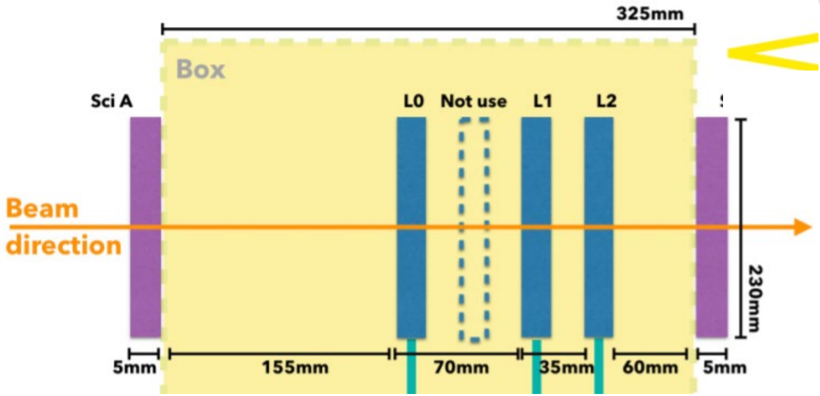
- Nchannels : 128 x 26 x 2 = 6656
  Ch / chip = 128
  Readout Chip (FPHX) = 26 x 2

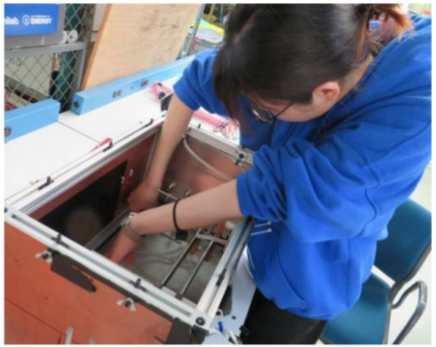
Sensor + Readout Schematics

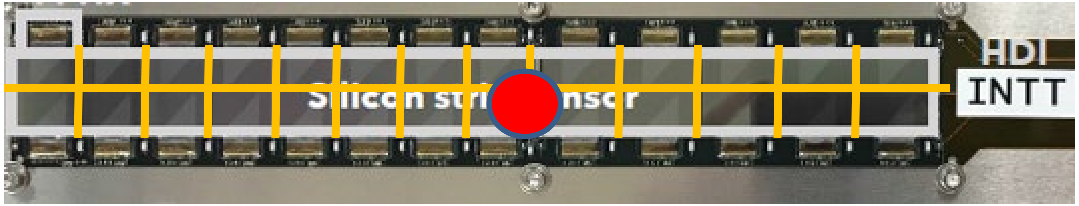


- Performance is studied using:
  - Charged particle by beam test, cosmic ray and RI sources
  - Test pulse for Readout electronics

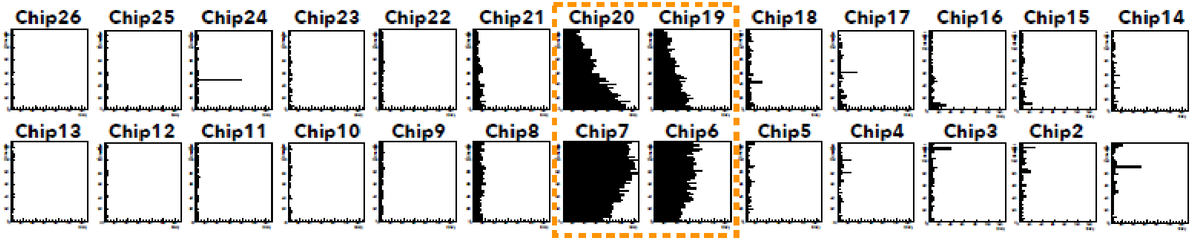
Beam Test Setup in 2019







Beam spot = chip 6,7,19,20



Beam test at FNAL 2019

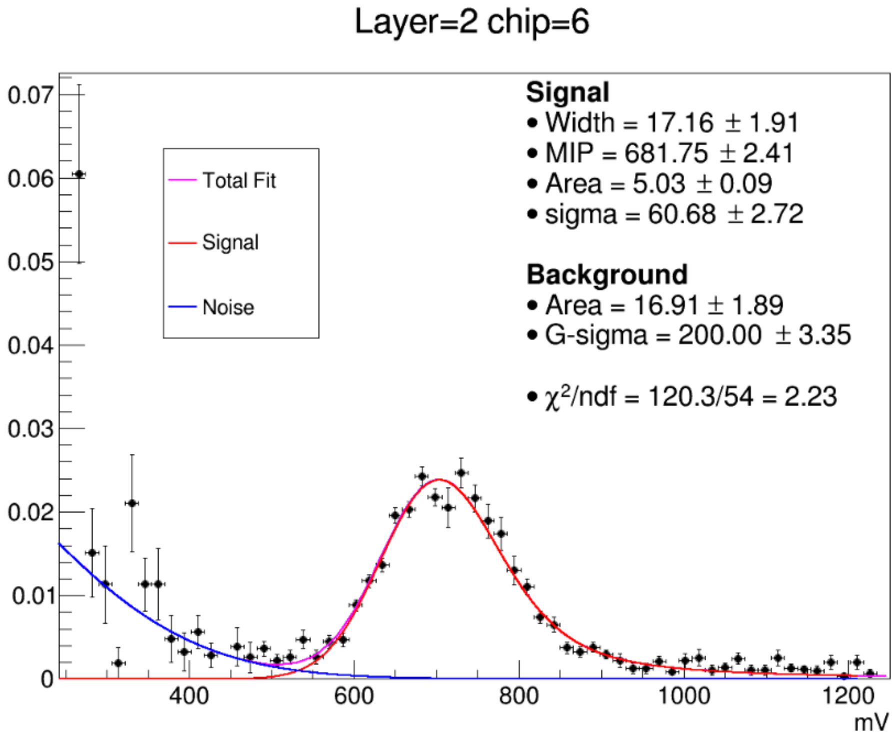
Proton beam w/ 120 GeV

Beam position is clearly seen

- MIP peak
- Efficiency

MIP peak in the beam test

- MIP peak measurement with 3bit ADC
  - **Scan with fine ADC threshold**
- MIP peak clearly seen
  - **separated from noise**
- MIP peak puzzle
  - **The peak is ~700mV from the beam test and cosmic ray.**
  - **E_{loss} ~ 100keV in 320um Si**
    - **Expected ~ 600mV**
  - **Conversion formula from Eloss to the measured voltage fixed**



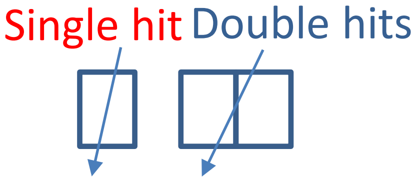
Conversion formula (Eloss/strip → V)

$$V(mV/strip) = G * \frac{E_{loss}}{3.6eV} + O$$

Gain value (G) (mV/fC)
Offset (O) (mV)

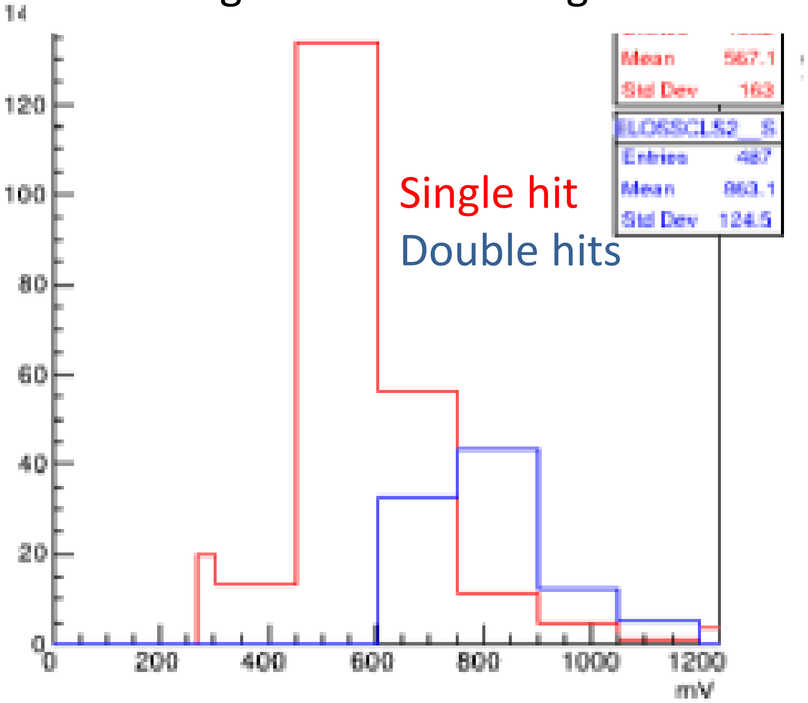
MIP peak by cosmic ray

$$V = G * \frac{E_{loss}}{3.6eV} + O$$



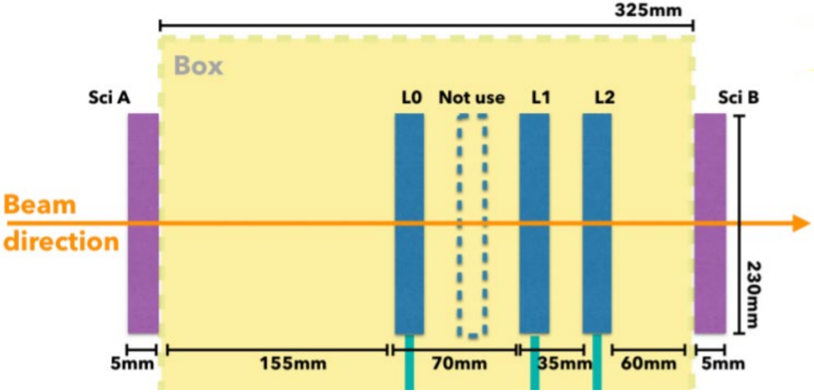
Gain (mV/fC)	100 (85~100)
Offset (mV)	198

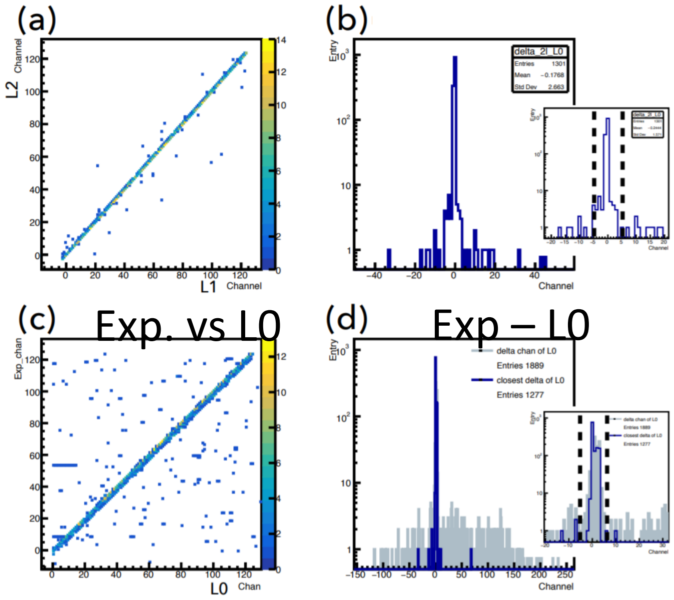
Pulse height after clustering



- MIP peak ~ 600mV
  - Double hits are ~200mV higher from single hit
    - Double hit : V1 + V2 = MIP + offset * 2
    - Single hit : V1 = MIP + offset
  - MIP peak is nicely reproduced by ToyMC & GEANT w/ Gain + Offset
- Raw ADC have ~200mV offset
  - Confirmed by test pulse

Efficiency in beam test 2019





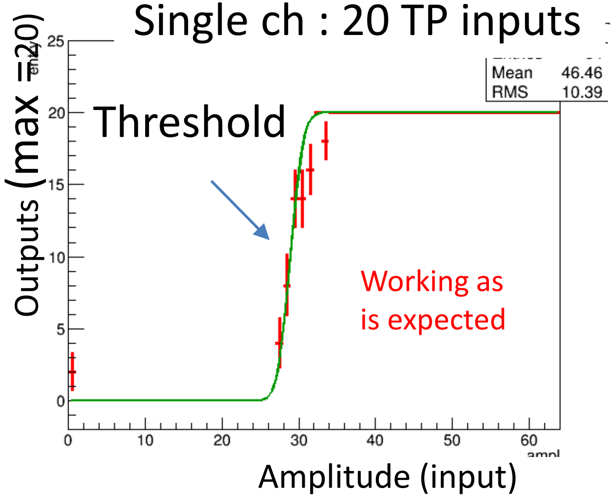
- Analysis cuts
  - **For L1&L2: single hit & ADC>3**
    - **L0 : multiple hits & No ADC cuts**
  - **Correlated hits in 3 layers**
- Efficiency
  - $\epsilon(L0) = \frac{N(L0+L1+L2)}{N(L1+L2)}$

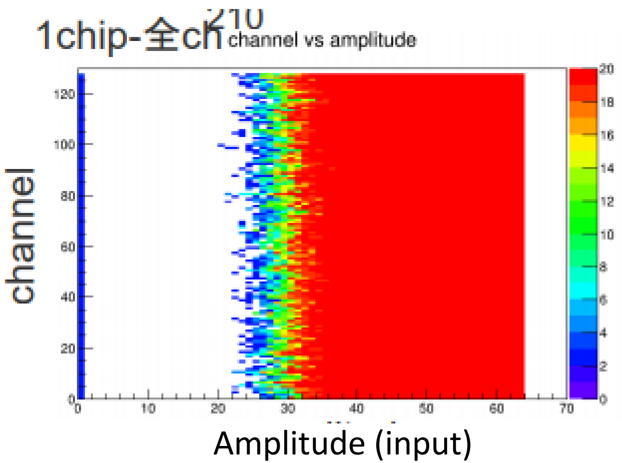
- Efficiency ε(L0)=96.0 ± 0.6 %
  - consistent w/ result in 2018 (95.8 ± 0.2 %)
  - S/N from MIP suggests higher efficiency
  - Investigating why the efficiency drop occurs
    - Hypothesis is the timing of signal processing

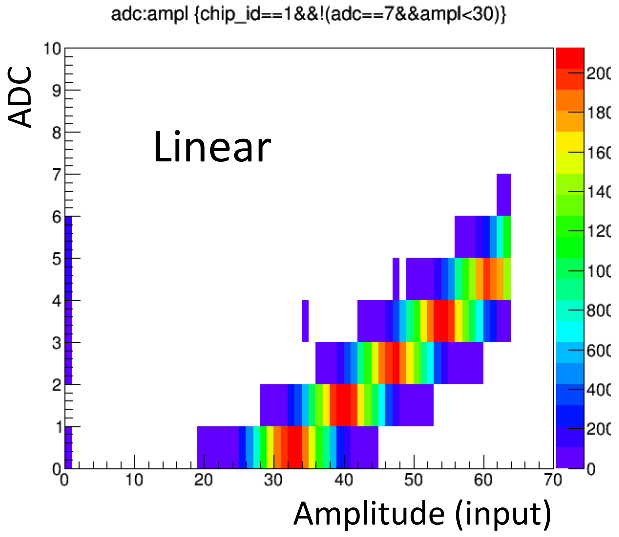
Test pulse response

- Scan ADC with changing TP input amplitude
  - **Bias voltage is applied to Sensor**
- Results:
  - **ADC threshold clearly seen**
  - **Linearity between ADC (output) vs amplitude (input)**

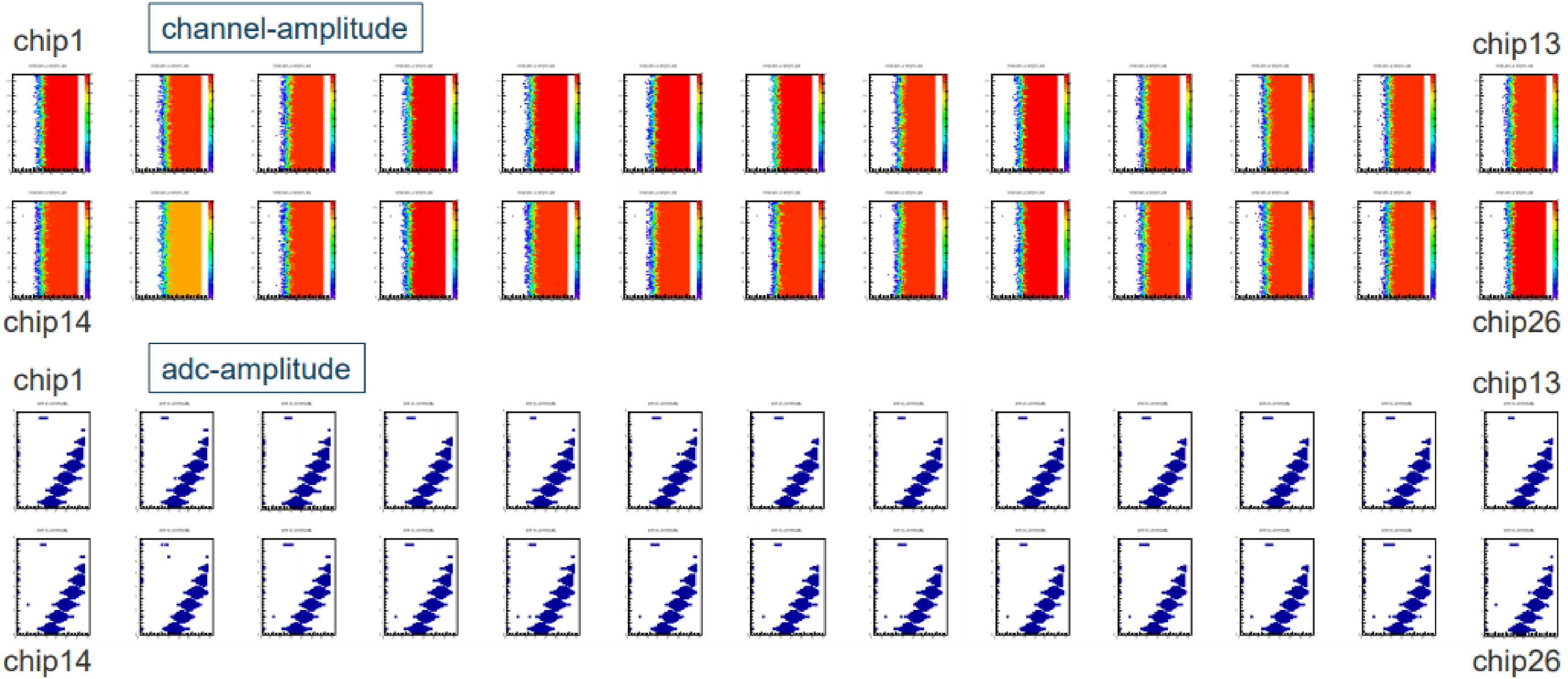
Single ch : 20 TP inputs







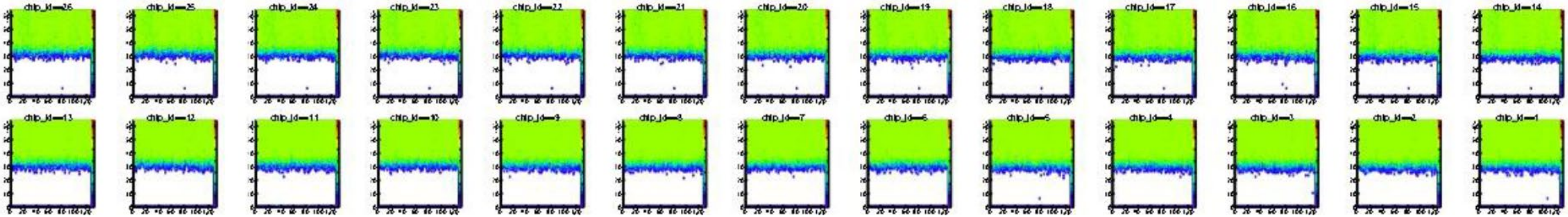
TP response for one module



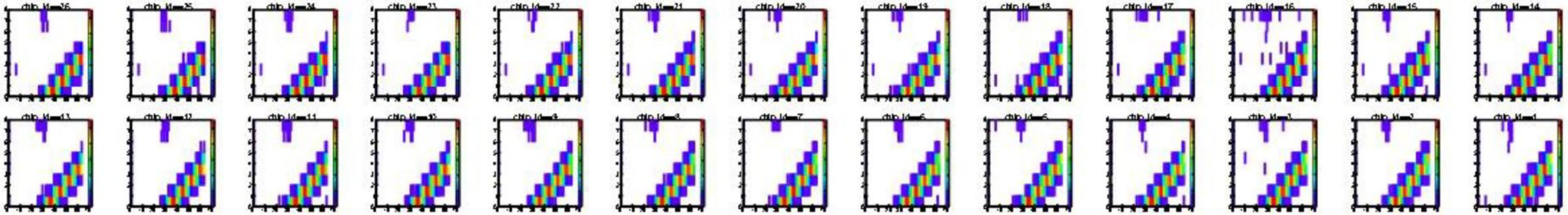
- All channels work nicely
- TP is useful for health check of the readout chain

TP response for one module

Amplitude vs Channels



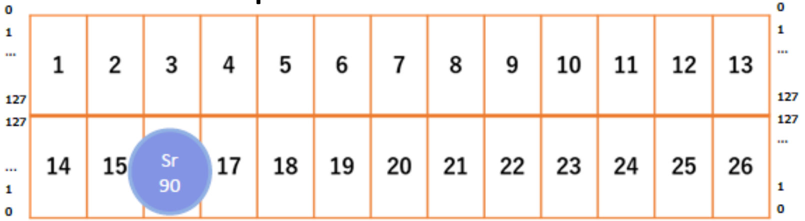
ADC vs Amplitude

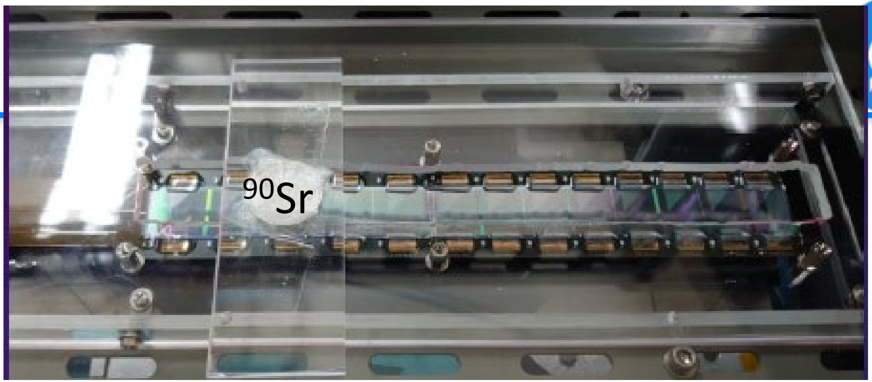


- All channels work nicely
- TP is useful for health check of the readout chain

^{90}Sr response

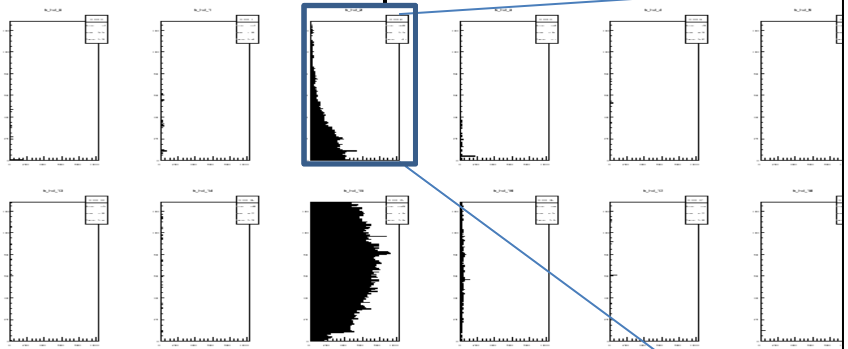
^{90}Sr on Chip=3 and 16



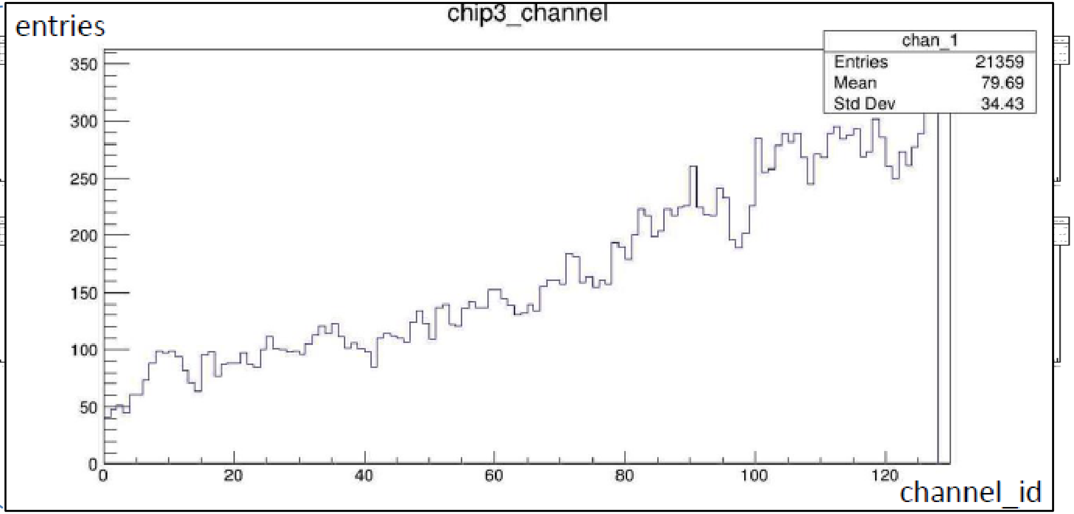


Trigger scintillator is placed behind the sensor

Chip3



Chip16



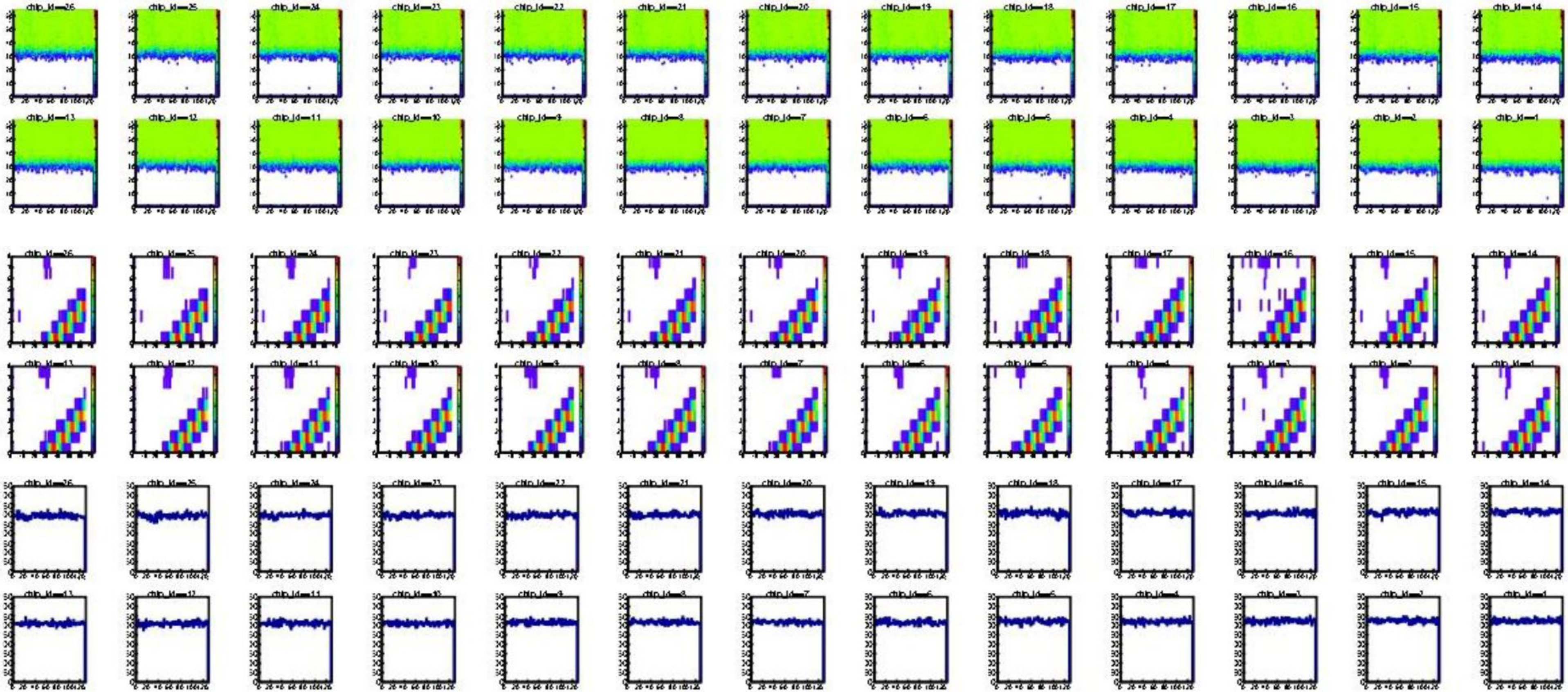
- e⁻ from ^{90}Sr is also seen.
  - **Good to use for sanity check during the mass production**

Performance summary

- MIP measurement
  - Mip peak clearly seen from beam test and cosmic ray
  - MIP peak is consistent with the expected value with the gain + offset
- Efficiency in beam test
  - $96.0 \pm 0.6\%$ due to the readout timing
  - Investigating the time scan in the readout chain using cosmic ray
- Test pulse is used for ch-by-ch health check of the readout
  - **RI source is also useful to check the sensor + RO**
- Evaluation test will be used for the mass production of the ladder

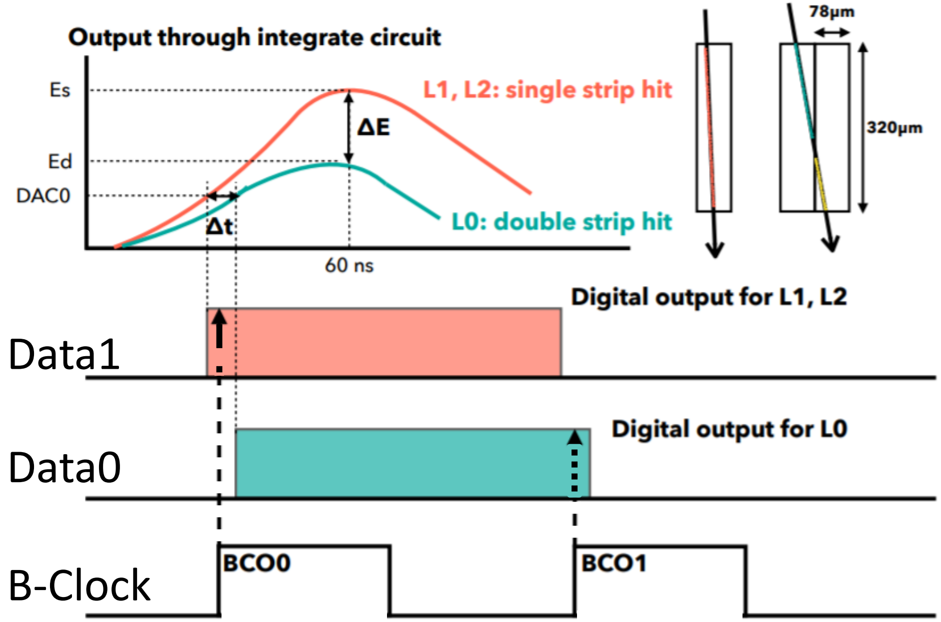
Back Up

TP response for one module



- TP is useful for health check of the readout chain

Slowing Effect on Efficiency



- Slewing effect may cause the efficiency loss
  - **If Data0 pulse is small, data0 can be latched by one clock later than Data1.**
- To study this effect, we calculate the efficiency with the different clock timing
  - **Timing can be changed by ADC**
- Efficiency
  - **Different timing : 97.2 ± 1.0 %**
  - **Default : 96.0 ± 0.6 %**
  - **Slewing effect = readout timing is an possible cause of the efficiency loss.**

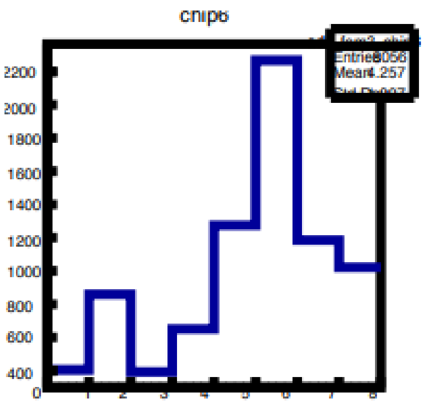
We will study the timing effect at the next beam test.

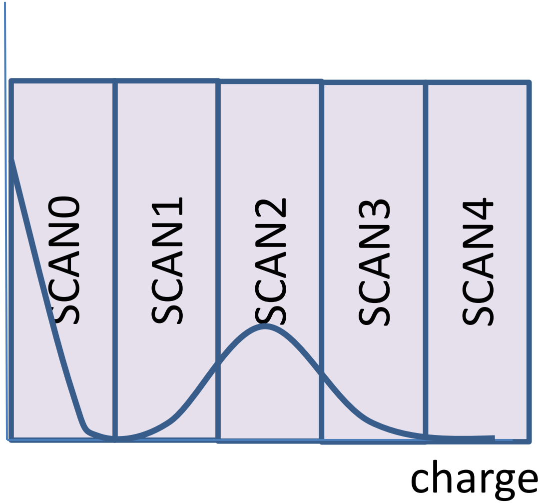
This effect will be cross-checked by Cosmic ray measurement.

MIP measurement with FPHX chip

- 3 bit ADC but these threshold can be set 8 bit DAC width.
- MIP Scan
  - **Took data with changing DAC value to cover the full MIP**

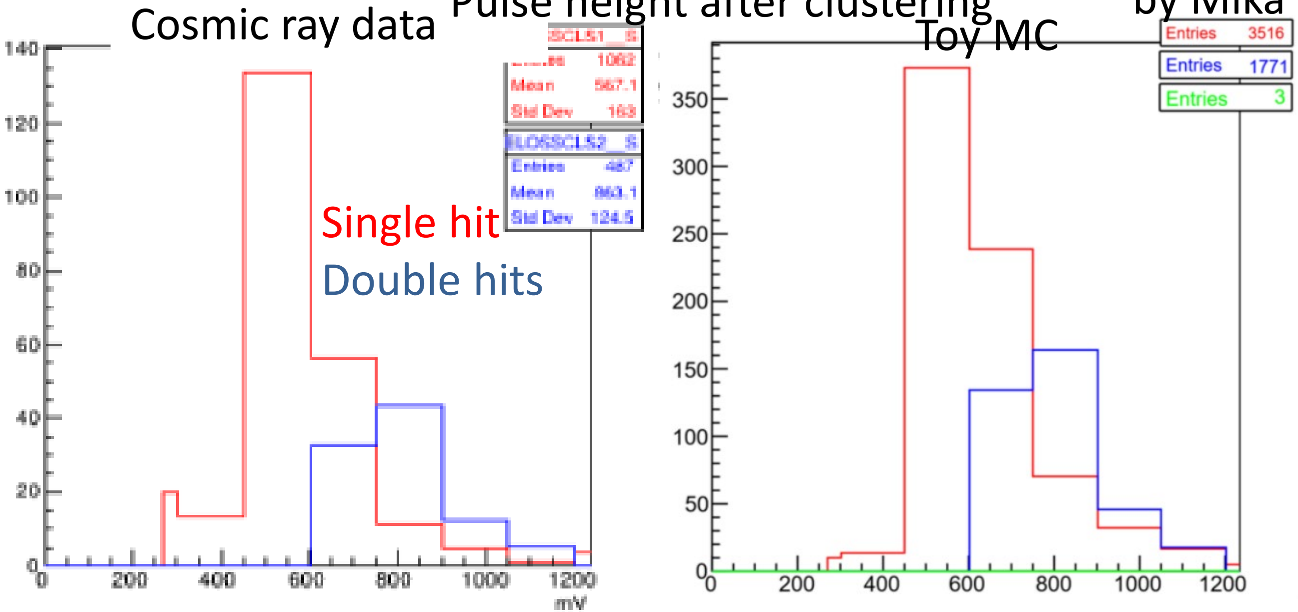
ADC (3bit)	**DAC (8bit)**
0	**20**
1	**25**
2	**48**
3	**98**
4	**148**
5	**172**
6	**223**
7	**248**

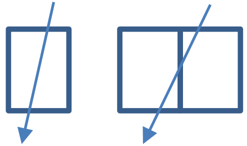




MIP peak by cosmic ray

Pulse height after clustering — by Mika





$$V = G * \frac{E_{loss}}{3.6eV} + O$$

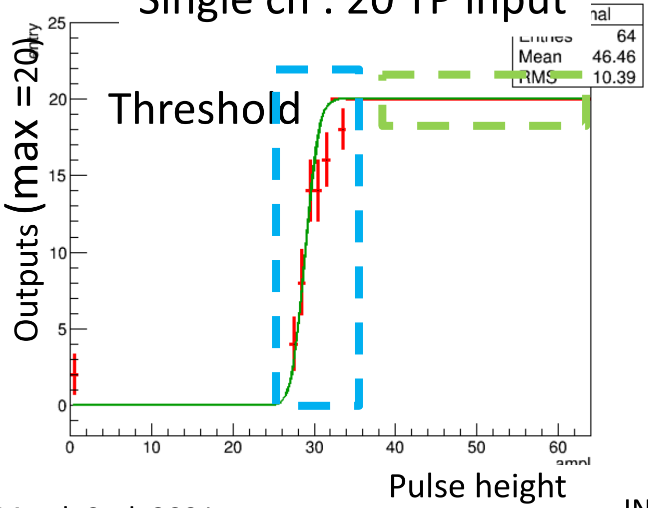
	Original	NEW
Gain (mV/fC)	300	100 (85~100)
Offset (mV)	0	198

- Double hits are shifted ~200mV higher from single hit
  - **If no offset, these should be the same**
- Data is nicely reproduced by ToyMC w/ Gain + Offset
  - **Single and double hits peaks are nicely consistent**
  - **GEANT model also reproduce the MIP peak**
- **MIP peak puzzle is fixed with new conversion formula**

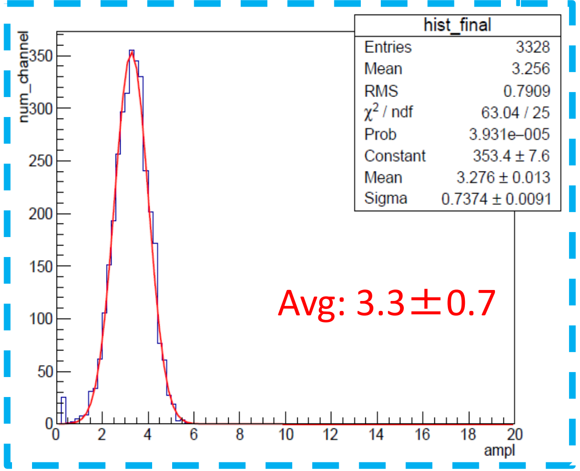
Result2: noise and data error rate

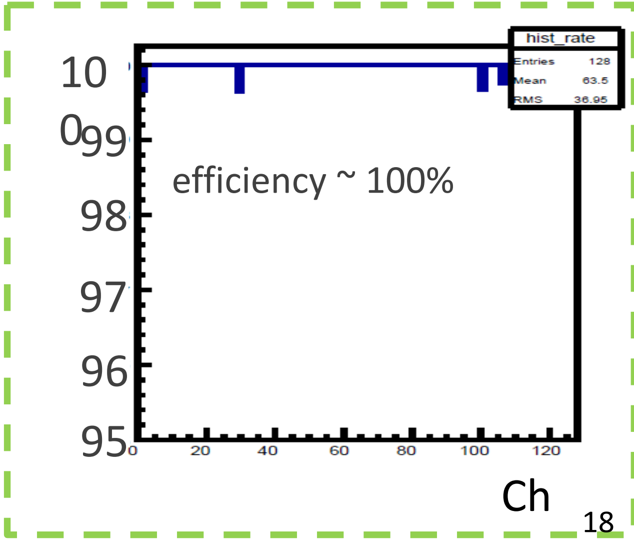
- Noise: check the slope of the threshold
  - **Width represents noise level**
- Transfer efficiency: check if all the data comes with high amplitude

- These tests should used for the ladder (readout) QA for the mass production



Noise : Width of the slope

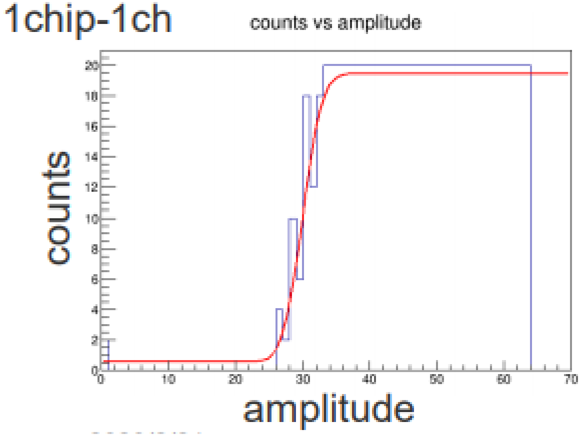




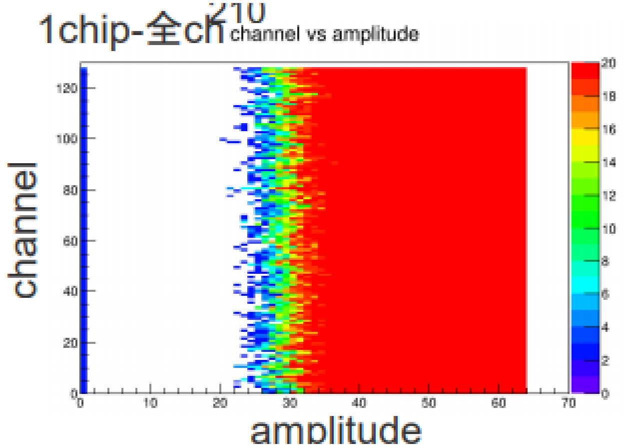
Readout Check by Test pulse

- TP injected to a channel with changing pulse heights
  - 10 TP for an amplitude (Amplitude : unit of TP pulse height (1-64))
- Results
  - Data comes out above the threshold for 128 channels
  - Linearity of ADC comfirmed

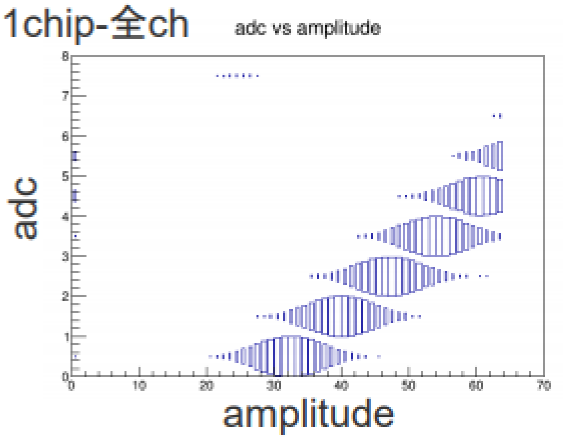
TP response for a channel



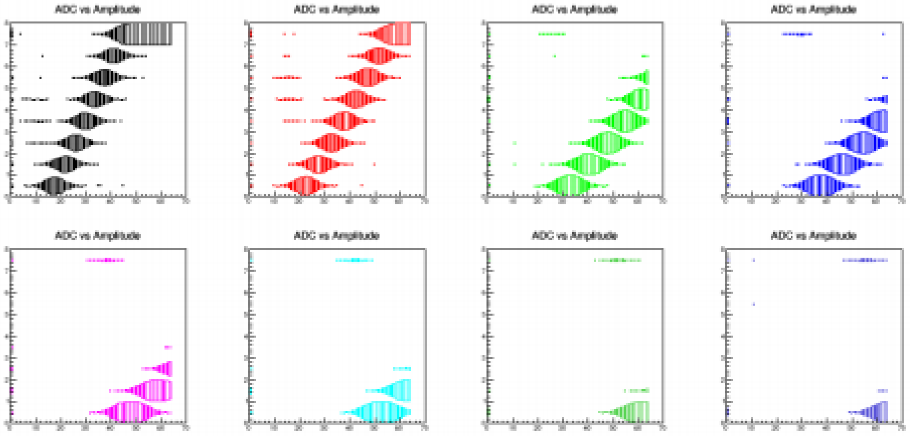
TP for a chip (128ch)



ADC vs Amplitude



adc vs amplitude



DAC	Value	Voltage[mv]
DAC 0	20	290
DAC 1	25	310
DAC 2	30	330
DAC 3	35	350
DAC 4	40	370
DAC 5	45	390
DAC 6	50	410
DAC 7	55	430

ゲイン値番号	これまで	今回
GSel=0	46	200
GSel=1	50	150
GSel=2	60	100
GSel=3	67	85
GSel=4	85	67
GSel=5	100	60
GSel=6	150	50
GSel=7	200	46

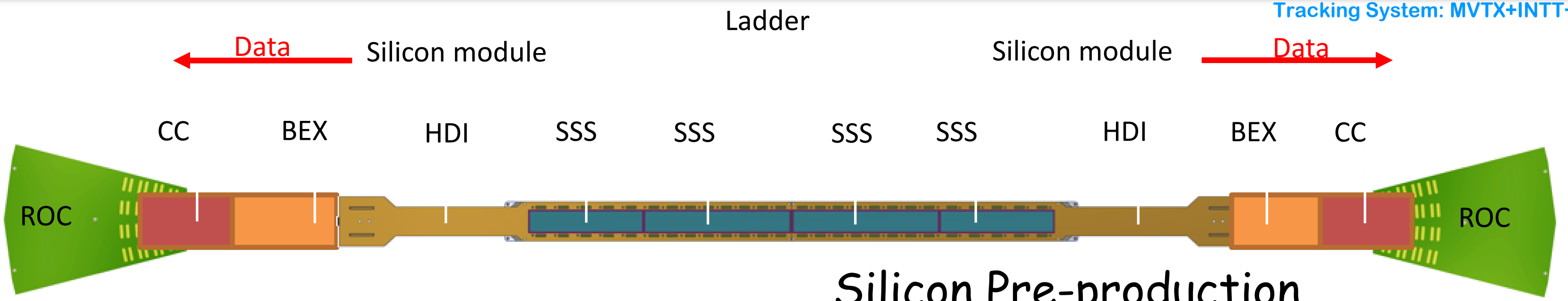
- 宇宙線測定からゲイン値の設定を誤って解釈していたことがわかり、テストパルスでも同様の結果を確認することができた

【問題点】

- ゲイン値の設定を変更することでオフセットの値も変わっているように推測できる

The INTT Components

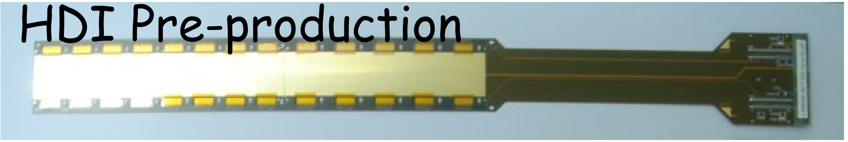
Tracking System: MVTX+INTT+TPC



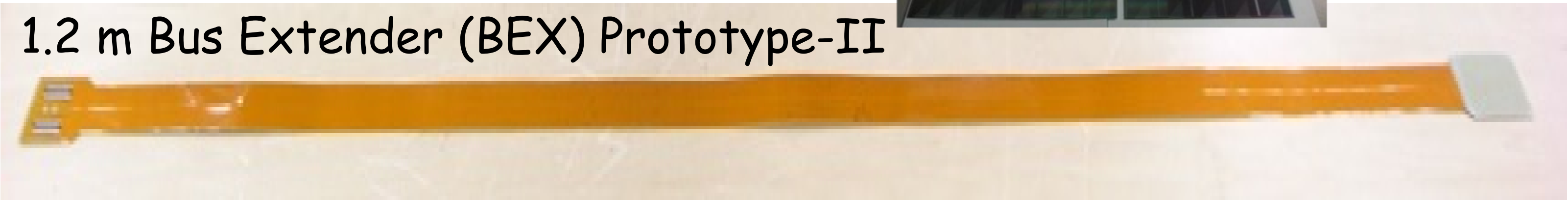
Silicon Pre-production

FPHX Productic

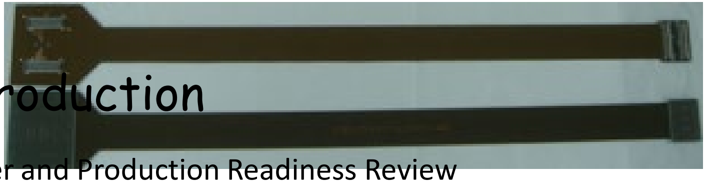
HDI Pre-production



1.2 m Bus Extender (BEX) Prototype-II



Conversion Cable (CC) Pre-Production



INTT module

- Si : 320um thick
- Channel size : 78 x 1200um(),
- Nchannels : 128 x 26 = 3328
  - **Ch / chip = 128**
  - **Readout Chip (FPHX) = 26**