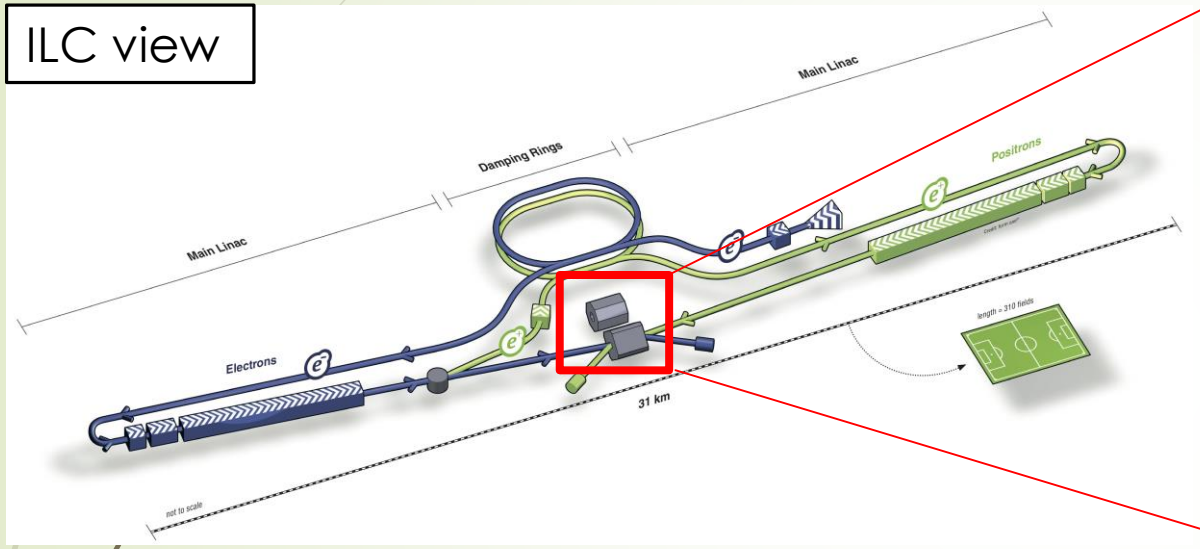
Performance evaluation of read out board (EBU) for scintillator electromagnetic calorimeter

Shinshu-University Yukinaru Tamaya

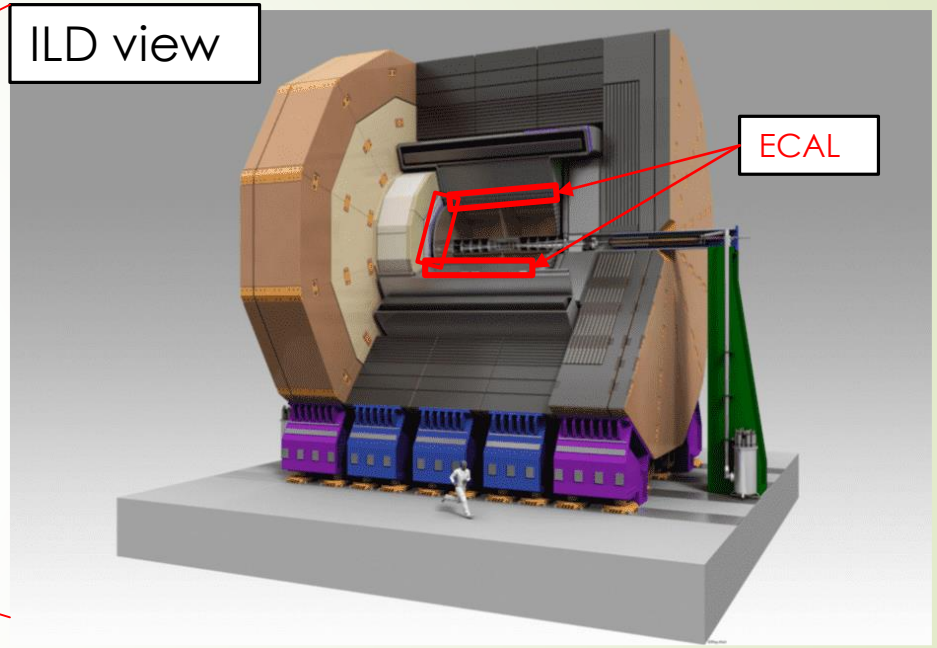
On behalf of Calice ScECAL

International linear Collider (ILC) and ILD

ILC view

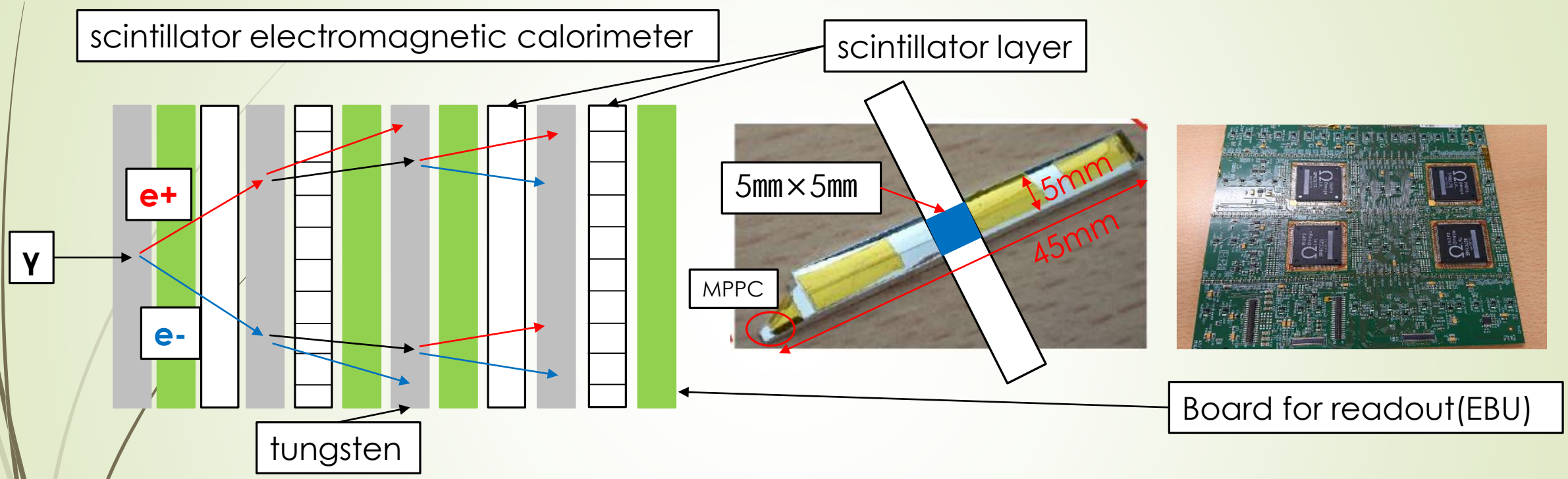


ILD view



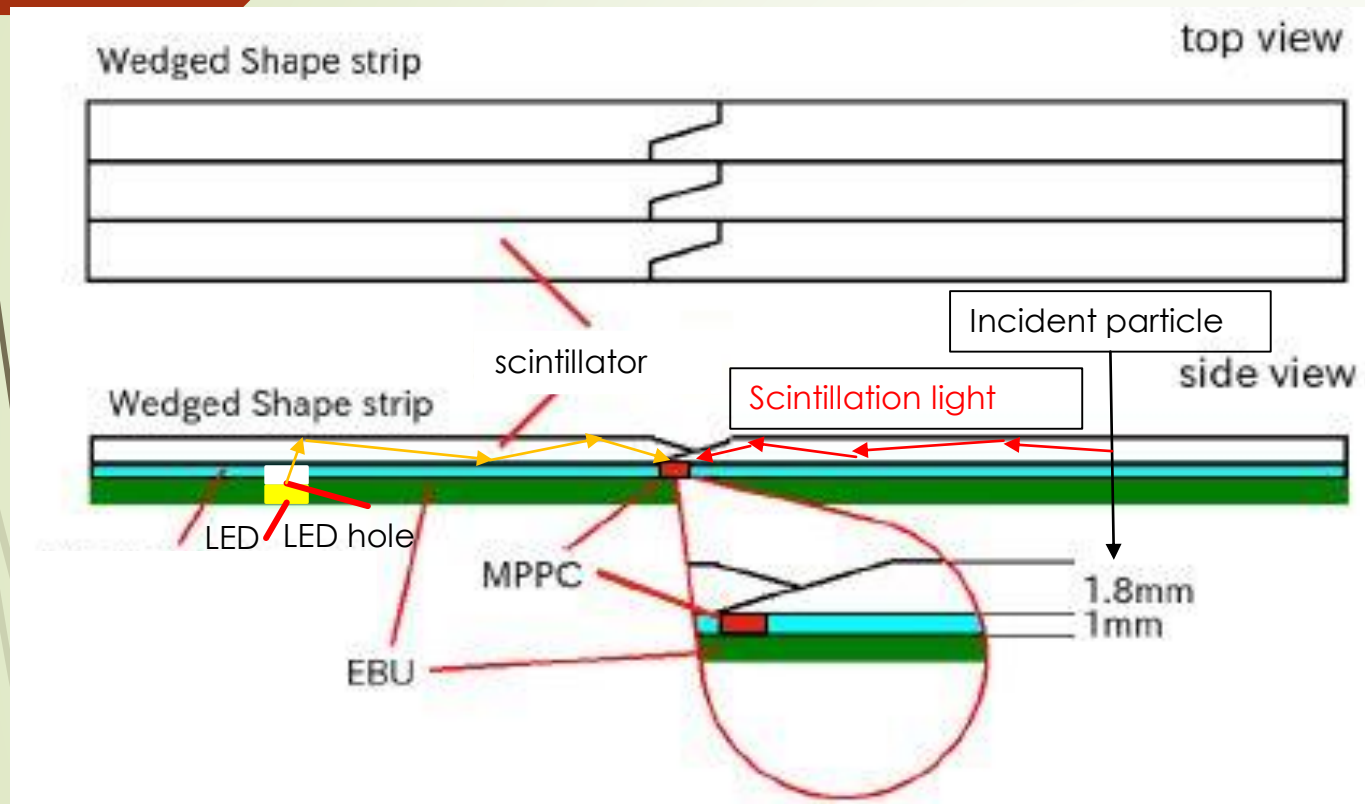
- ILC has 250 GeV energy of the center of mass, and measures Higgs particle precisely.
- ILD is planned as one of the measuring instruments of ILC, and uses a method called Particle Flow Algorithm (PFA).
- The electromagnetic calorimeter (ECAL) used in PFA mainly measures the energy of photons and achieves particle separation in jets.
- The calorimeter requires high positional resolution.

Scintillator electromagnetic calorimeter

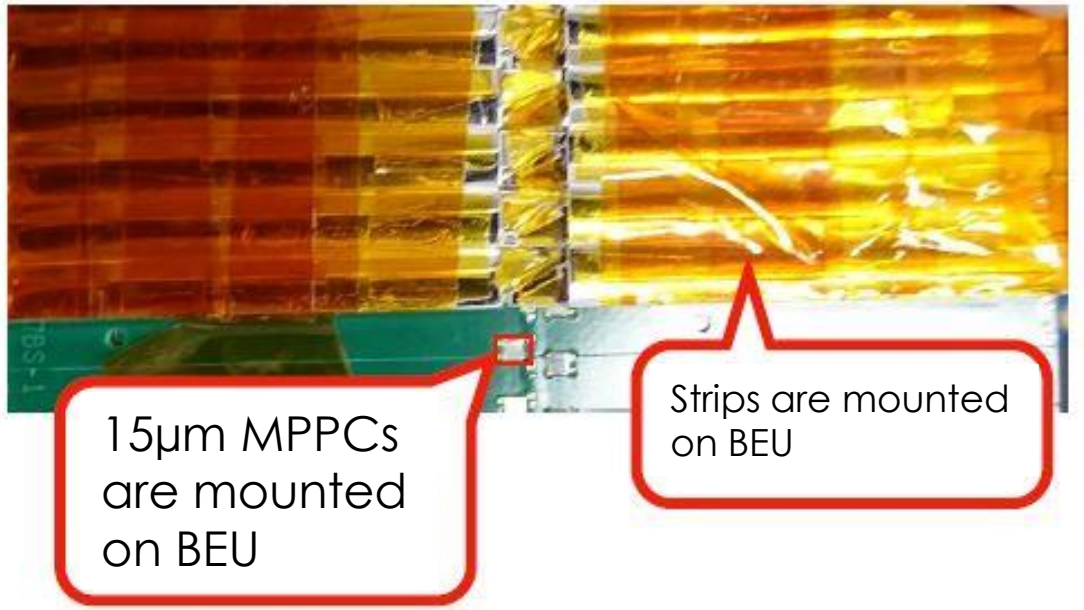


- Scintillator electromagnetic calorimeter adapts tungsten in absorption layers, scintillators in detection layers and board for readouts(EBU).
- The size of scintillator is 45mm×5mm×2mm.
- Scintillator layer with crossed strips has 5mm×5mm spatial resolution.
- EBU is the data acquisition system(DAQ) for the calorimeter.
- EBU equips scintillators and MPPCs which detect scintillation light.

Bottom readout scintillator

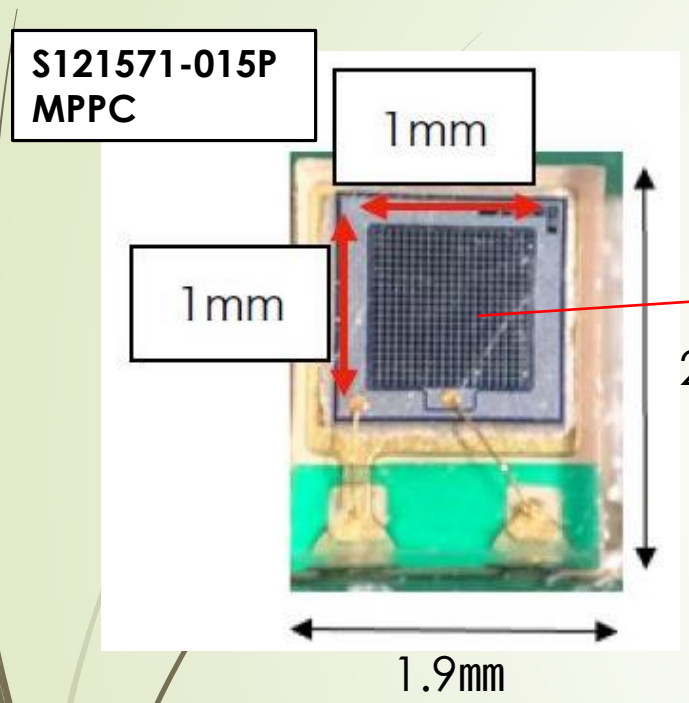


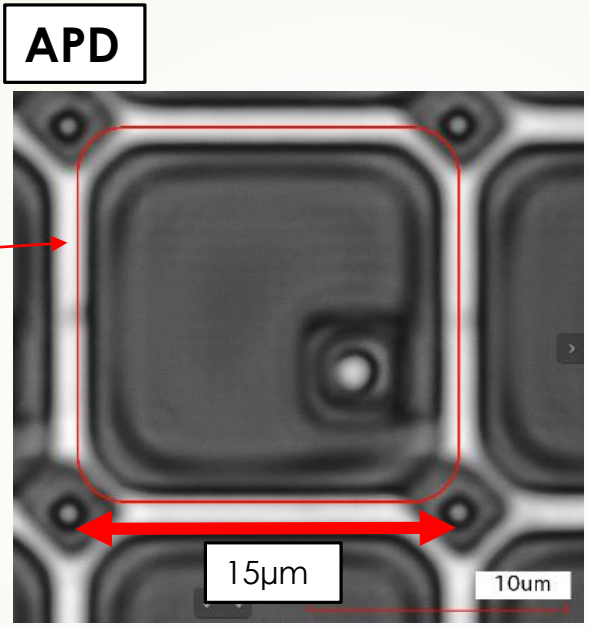
Top view

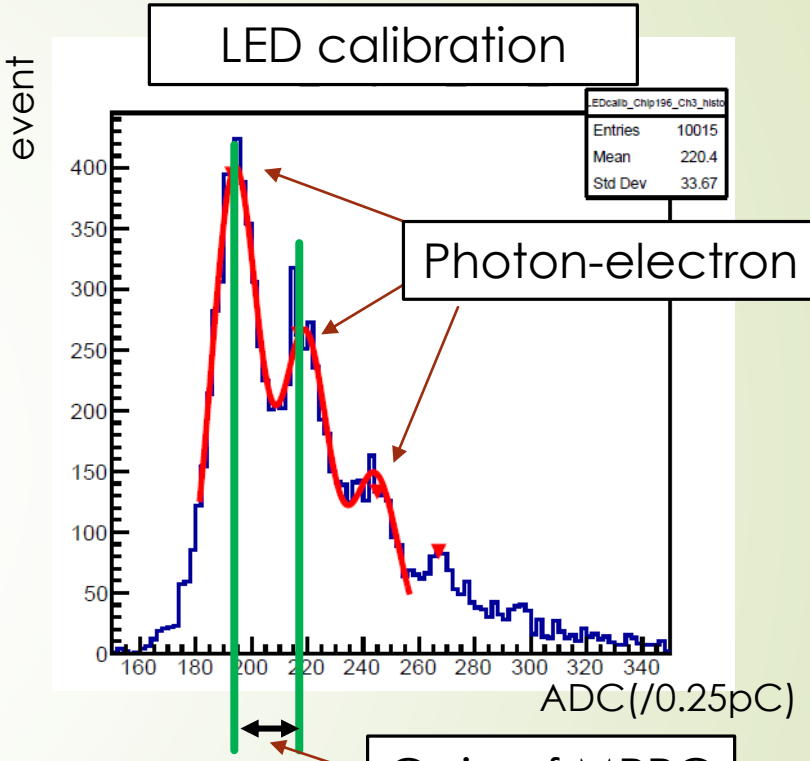


- MPPC is installed at the bottom of the scintillator. This is called bottom readout.
- For bottom readout, MPPC is soldered on the EBU bottom and set under the scintillator.
- In order to collect scintillation light effectively, the scintillator has wedged shape.
- The insensitive area is eliminated by bottom readout.
- For LED calibration of MPPCs, EBU equips LEDs.

Multi-Pixel Photon Counter(MPPC)



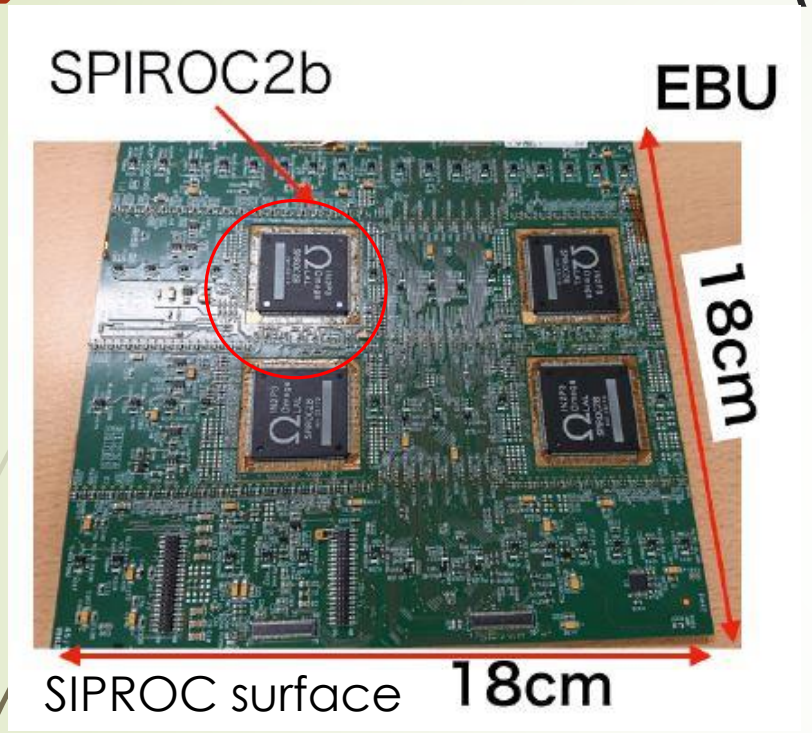


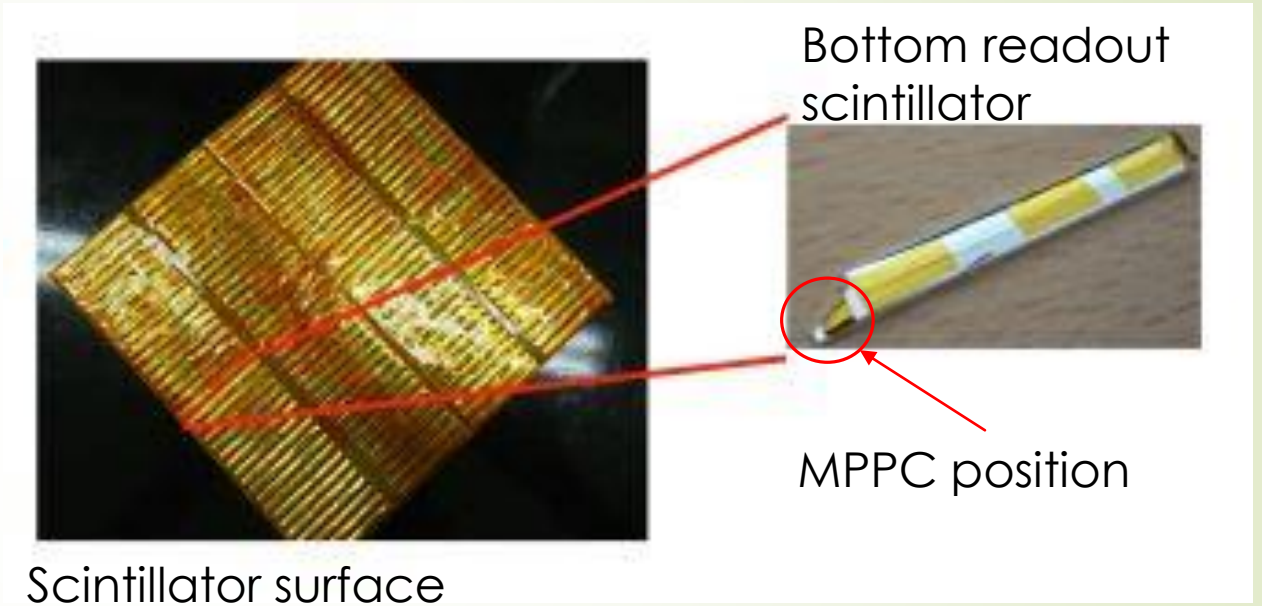


- MPPC is developed by Hamamatsu Photonics, Shinshu University and other universities.
- We Use MPPC of 1×1㎟ photosensitive surface for scintillator electromagnetic calorimeter. 5000 of APD of 15μm pitch are placed in photosensitive area.
- Gain of MPPC can be calibrated by LED light.

- Feature of MPPC
1. magnetic field resistance
2. low voltage operation
3. high multiplication factor of $\times 10^5$
4. operable at normal temperature

ECAL Base Unit(EBU)





- EBU is fabricated by DESY.
- EBU consists of SPIROC surface and scintillator surface.
- One EBU is a PC board with 144 MPPCs and 144 scintillators.
- One EBU is equipped with four ASICs called SPIROC2b which is developed by OMEGA group.
- One SPIROC2b can control 36ch of MPPCs and adjust each applied voltage for a channel.

SPIROC2b on EBU

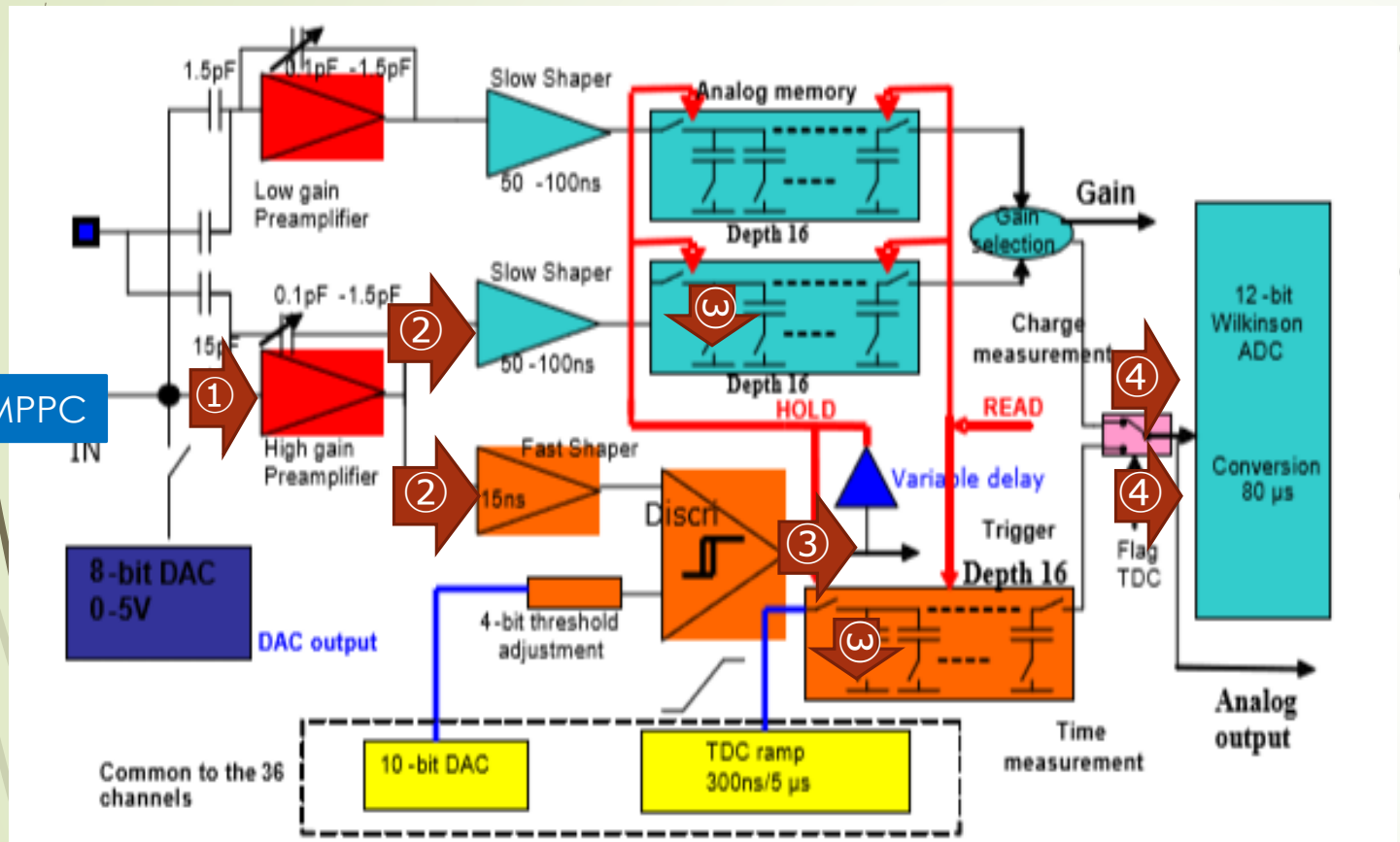


Figure 8: SPIROC one channel diagram

When charged particle passes one scintillator,spiroc2b processes the signal with four stage.

① The signal flows from the MPPC, and the signal is amplified by the preamplifier of the charge multiplier type.

② Amplified signal is divided into a slow shaper (Tp50ns) and a fast shaper (Tp15ns).

③ When signal flowing through the fast shaper exceeds a predetermined threshold, the signal flowing through the Slow shaper is stored in the memory cell up to 16 depth, and at the same time TDC ramp voltage is also saved.

④ ①～③ if the operation occurs 16 times, or if it exceeds the predetermined time, the signal that has been temporarily stored flows to the ADC.

MIP and Pedestal measurement for each memory cell

SPIROC2b

SPIROC2b

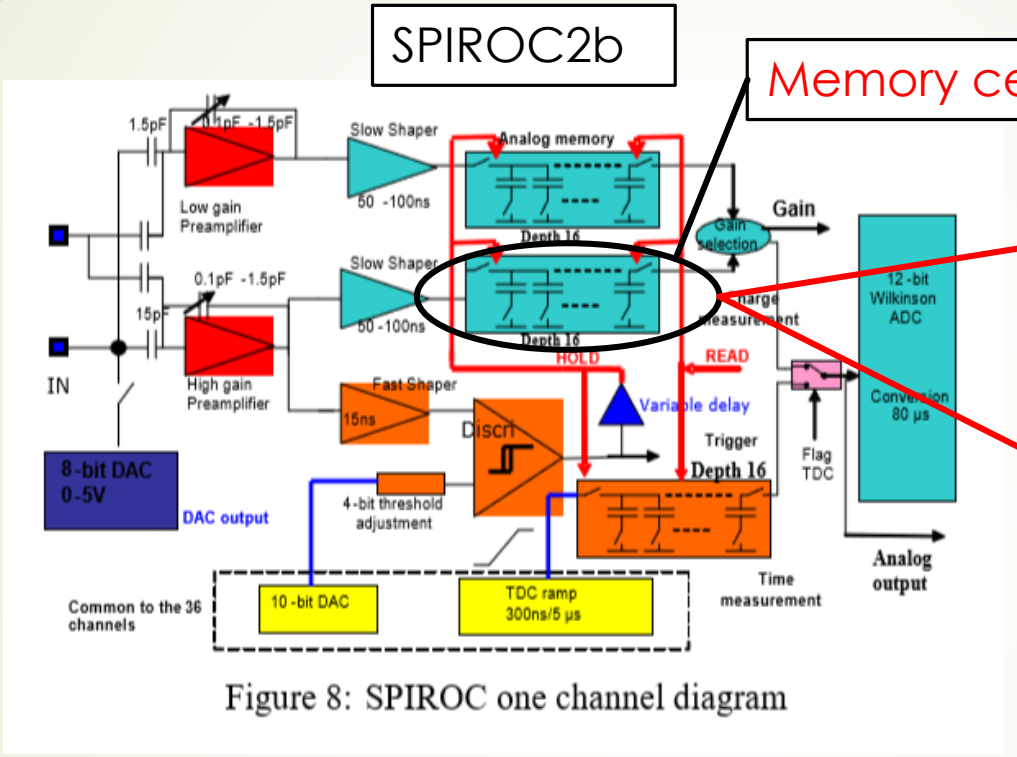
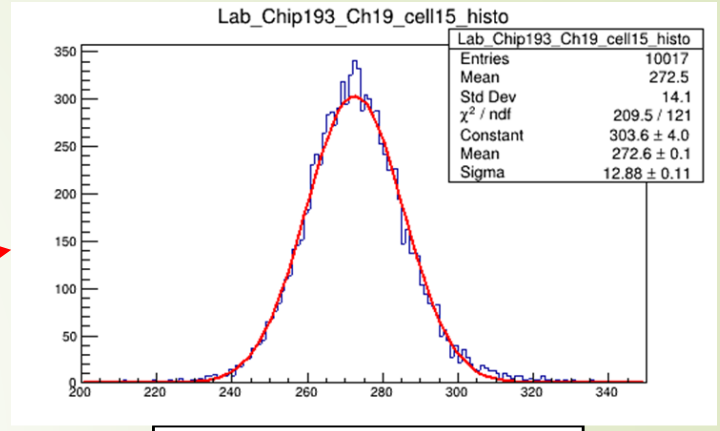
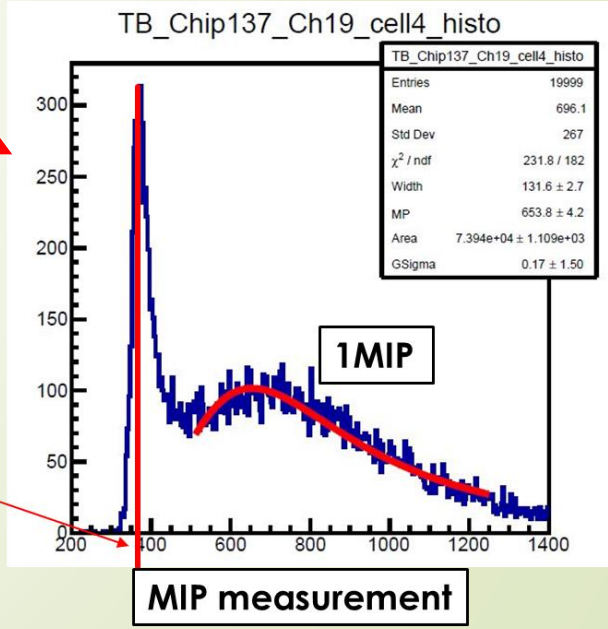


Figure 8: SPIROC one channel diagram

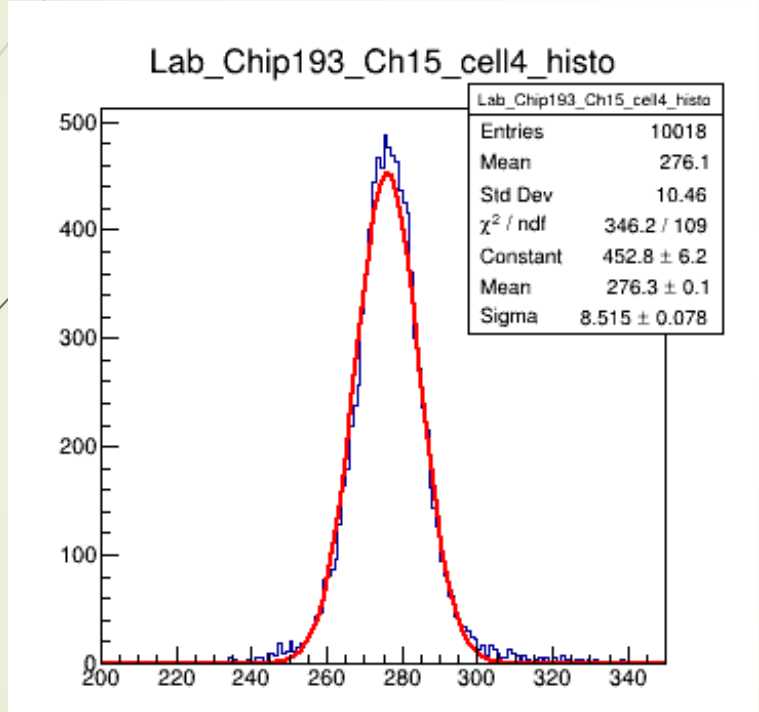




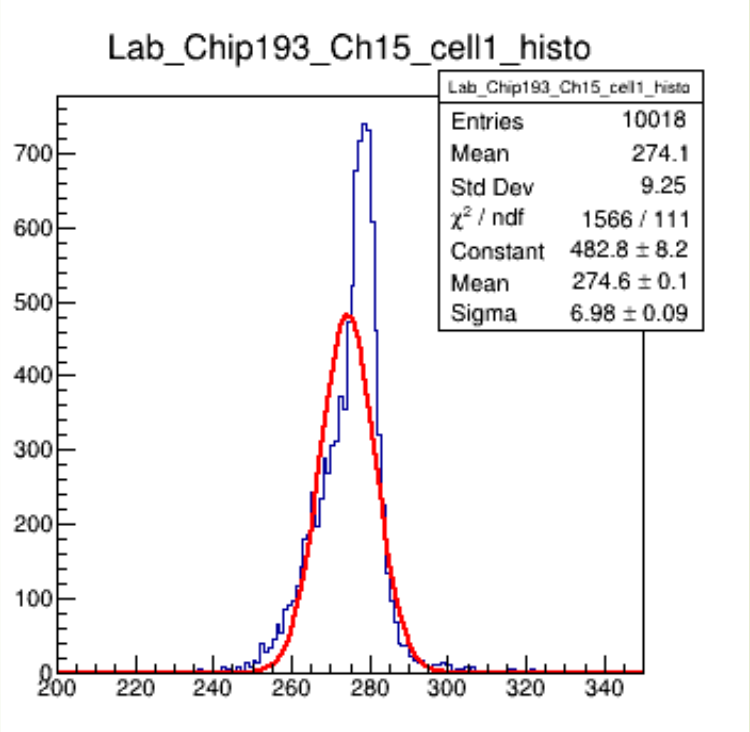
- As test of the memory cells, we measure pedestals and MIP.
- The memory cells in a channel are properly functioning when the pedestal shapes are gaussian distributions.
- The memory cells in a channel are properly functioning when the MIP signals are separated from the tail of pedestal.

Pedestal measurement

Pedestal is gaussian distribution

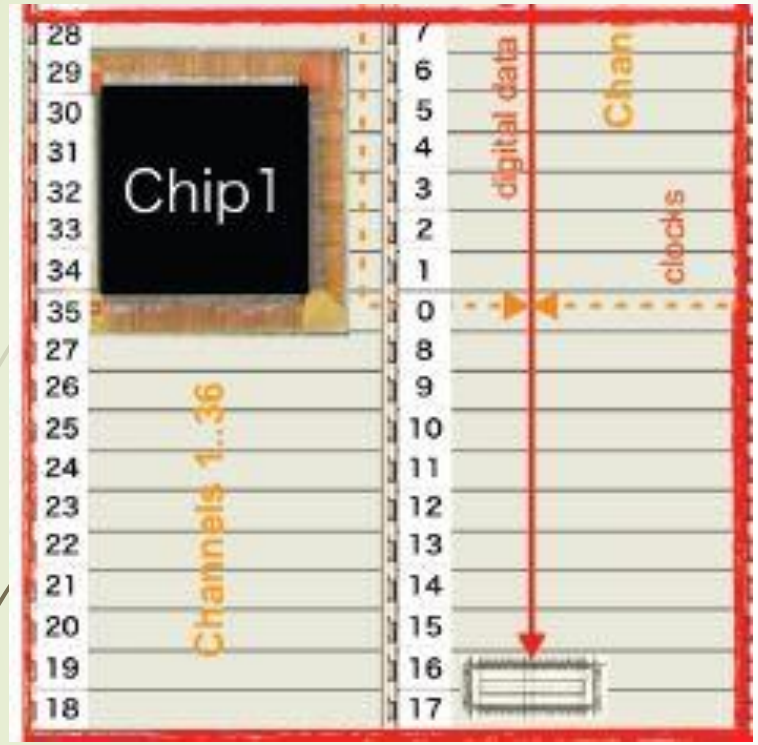


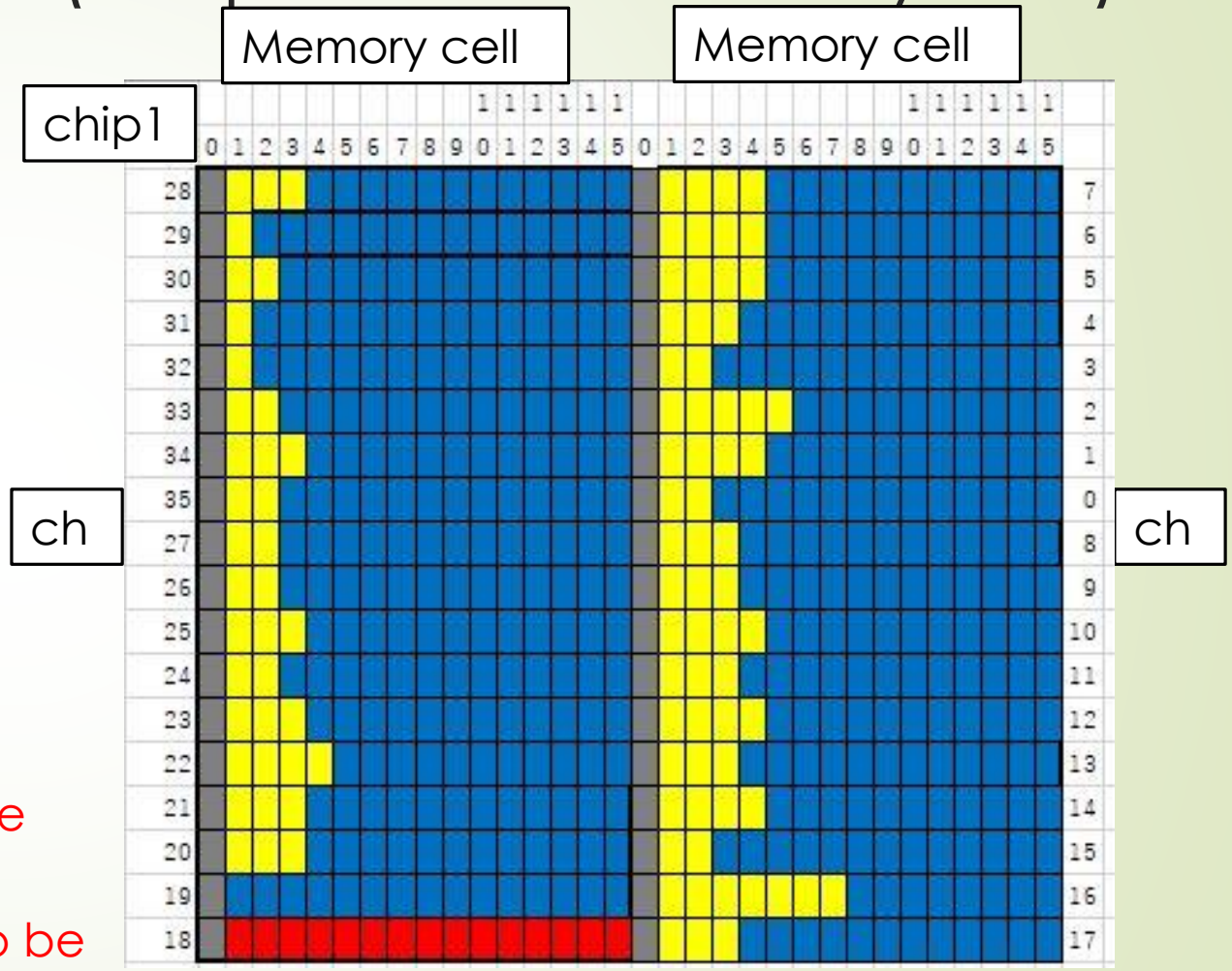
Pedestal is non gaussian distribution



- We measured pedestals of all chips(SPIROC), channels and memory cells.
- The types of pedestal distribution were classified into two types for each channel and memory cell.
- Two types are gaussian distribution and non gaussian distribution.

Pedestal measurement(Chip1,ch VS memory cell)





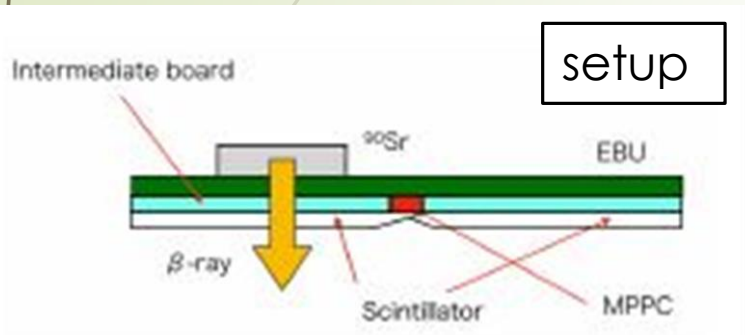
- We found higher memory cells tend to be classified into gaussian distribution.
- But we found lower memory cells tend to be classified into non-gaussian distribution.
- This trend is common for all four SPIROC chips.

Blue : gaussian distribution

Yellow: : non-gaussian distribution

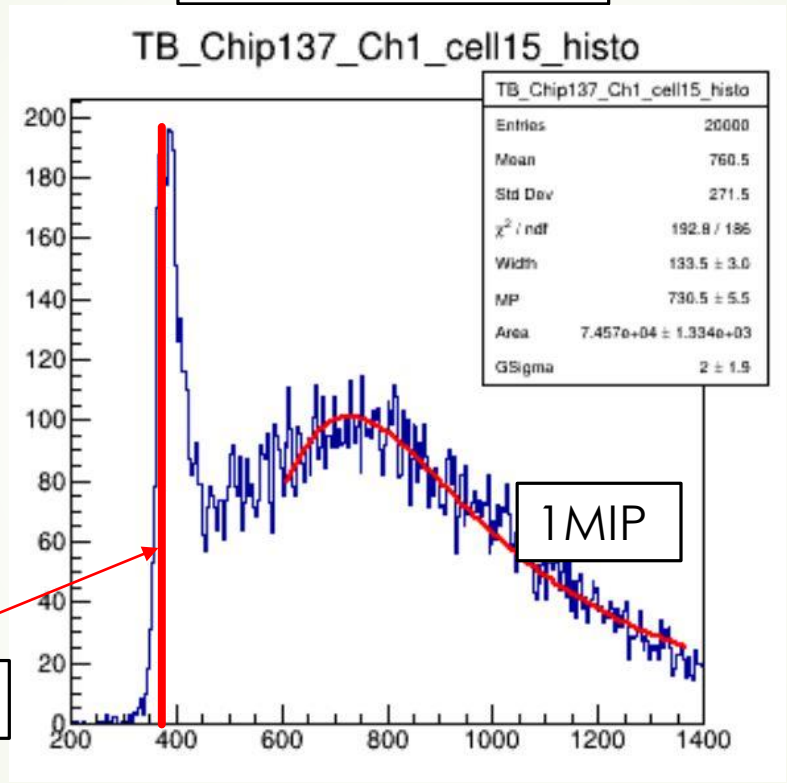
Orange : noisy Red : broken

MIP measurement use β ray of 90Sr

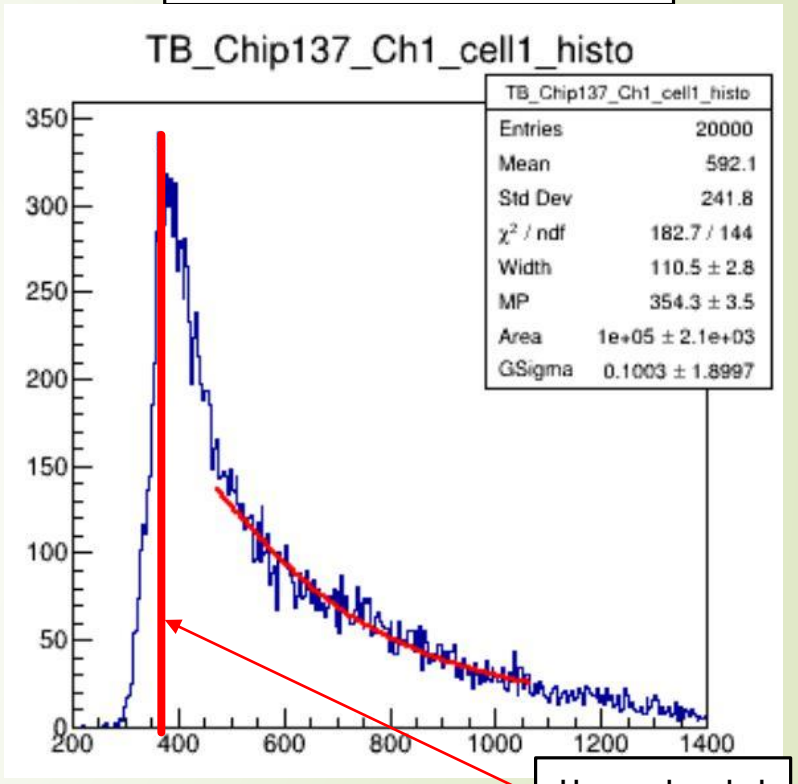


Use 90Sr without collimater, MIP measurment

MIP is separated

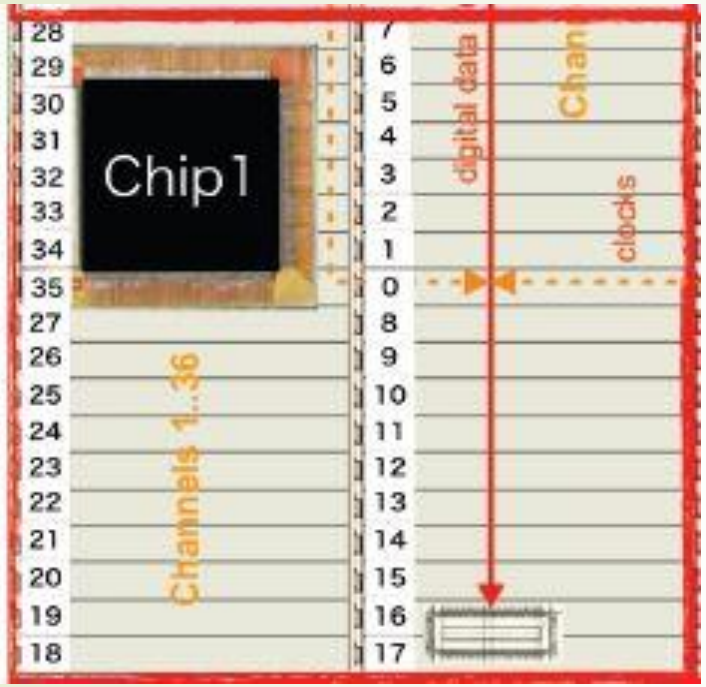


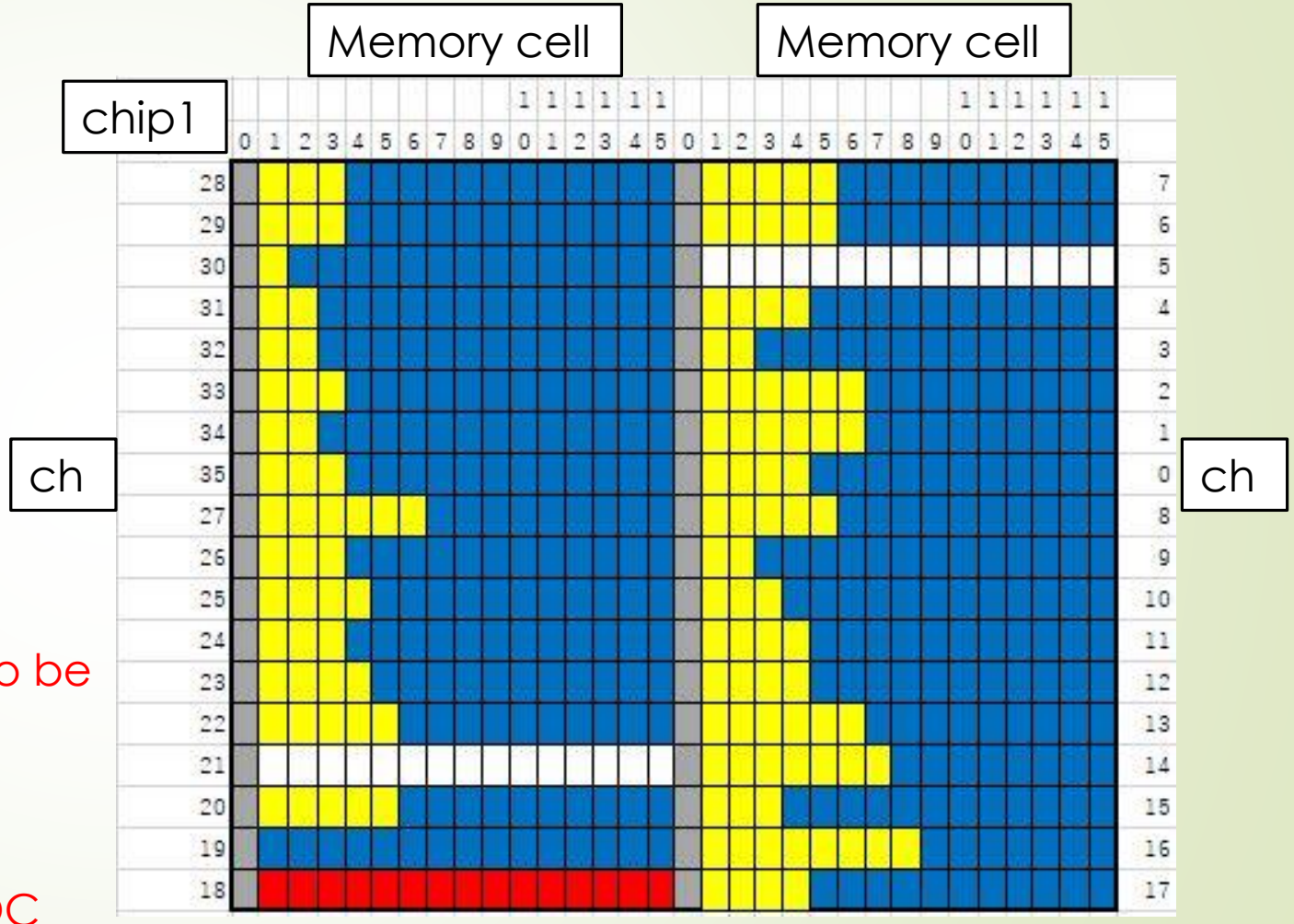
MIP is not separated



- MIP measurement was performed by injecting 90Sr β ray through the EBU.
- It was measured whether the MIP was separated for each memory cell.
- The types of ADC distribution were classified into two types for each channel and memory cell.
- Two types are MIP separated and MIP non separated.

MIP measurement use β ray of 90Sr(chip1,ch VS memory cell)





- We found higher memory cells tend to be classified into MIP separated.
- But we found lower cells tend to be classified into MIP non separated.
- This trend is common for all four SPIROC chips.
- The result are similar for the pedestal shape measurement.

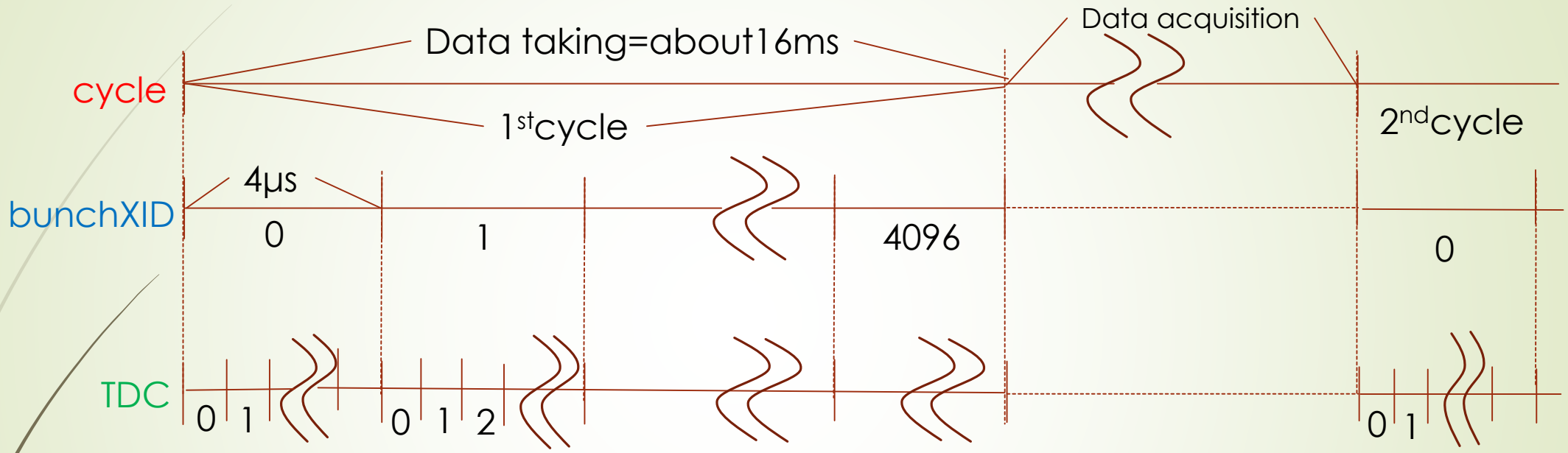
White : problem of MPPC and scintillator coupling

Blue : MIP is separated

Yellow: : MIP is not separated

Orange : not well separated Red : broken

Time measurement of EBU



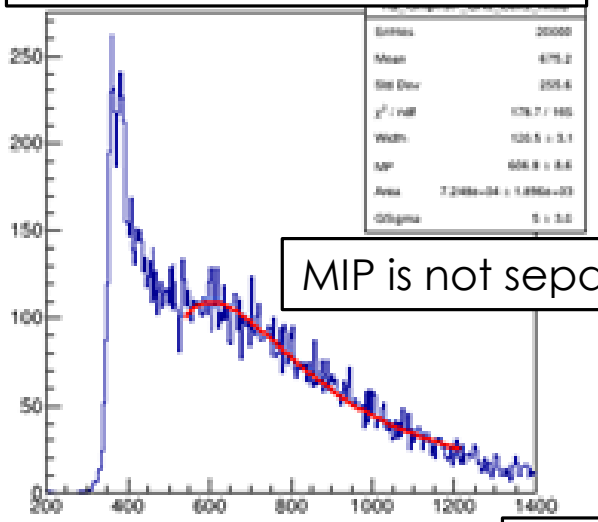
- Cycle : a cycle consists of data taking time and data acquisition time. When memory cells are fully used until 16ms or they are not fully used till 16ms (named timeout), cycle goes to next.
- bunchXID : BunchXID measures time information when the signal is stored in the memory cell with 4μs time interval.
- TDC : TDC measures time information in a bunchXID.

MIP measurement with BunchXIDcut

MIP measurement

Chip1 Ch0

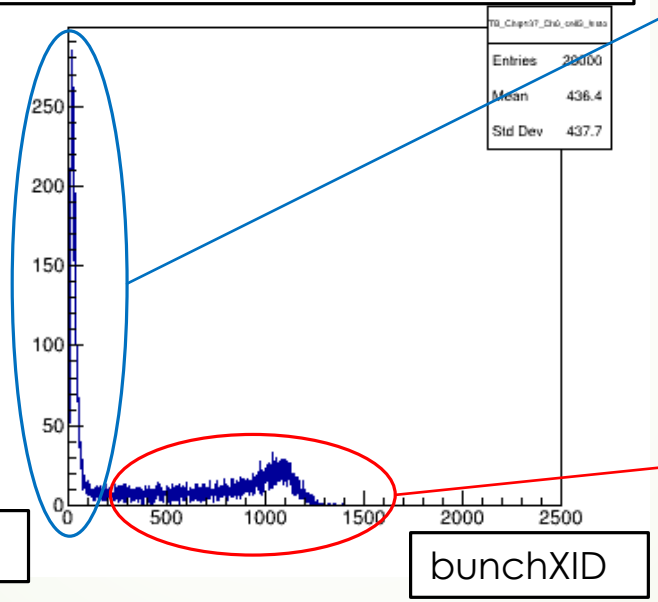
Chip1 Ch0 cell3 ADC



MIP is not separated

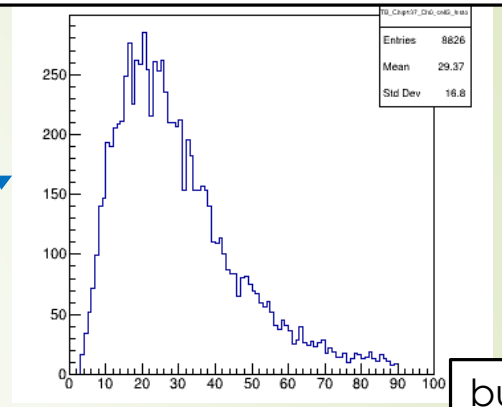
ADC

Chip1 Ch0 cell3 bunchXID



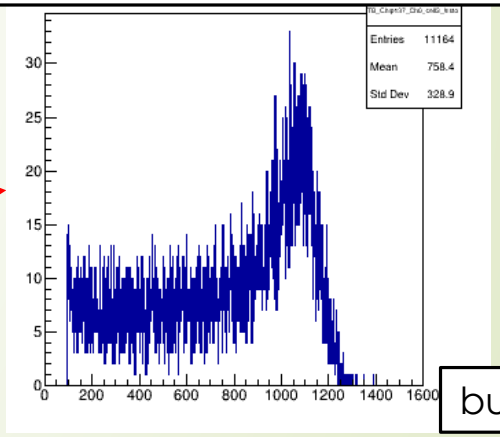
bunchXID

Small number bunchXID signal



bunchXID

Large number bunchXID signal



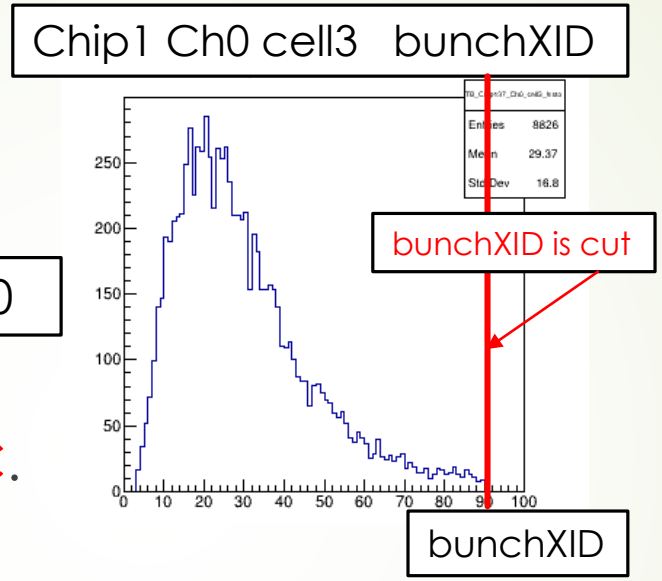
bunchXID

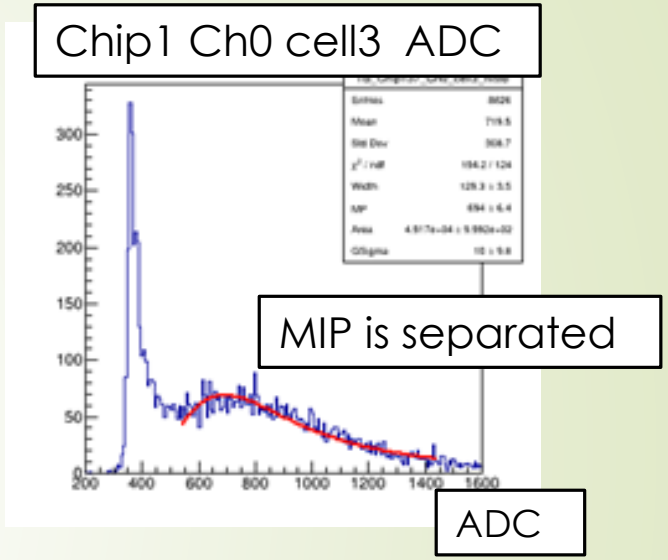
- We have looked into the ADC distribution for which is the non MIP separated channel.
- There are two peaks in the bunchXID distribution.
- We have Investigated the ADC distributions with two bunchXID regions.

MIP measurement with BunchXIDcut

bunchXID is less than 90

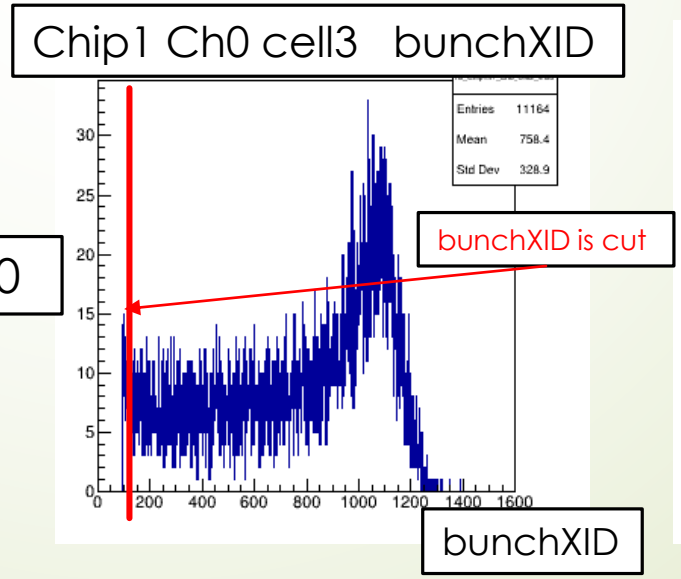
- When bunchXID is less than 90, MIP is separated in ADC.

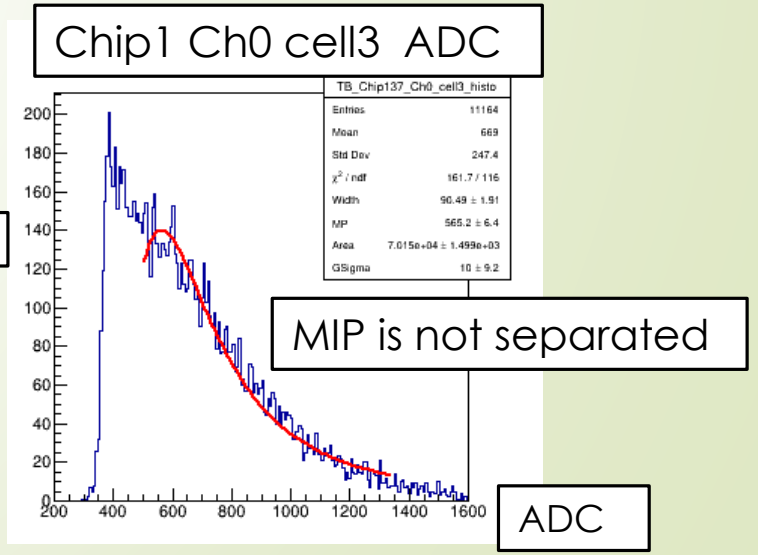




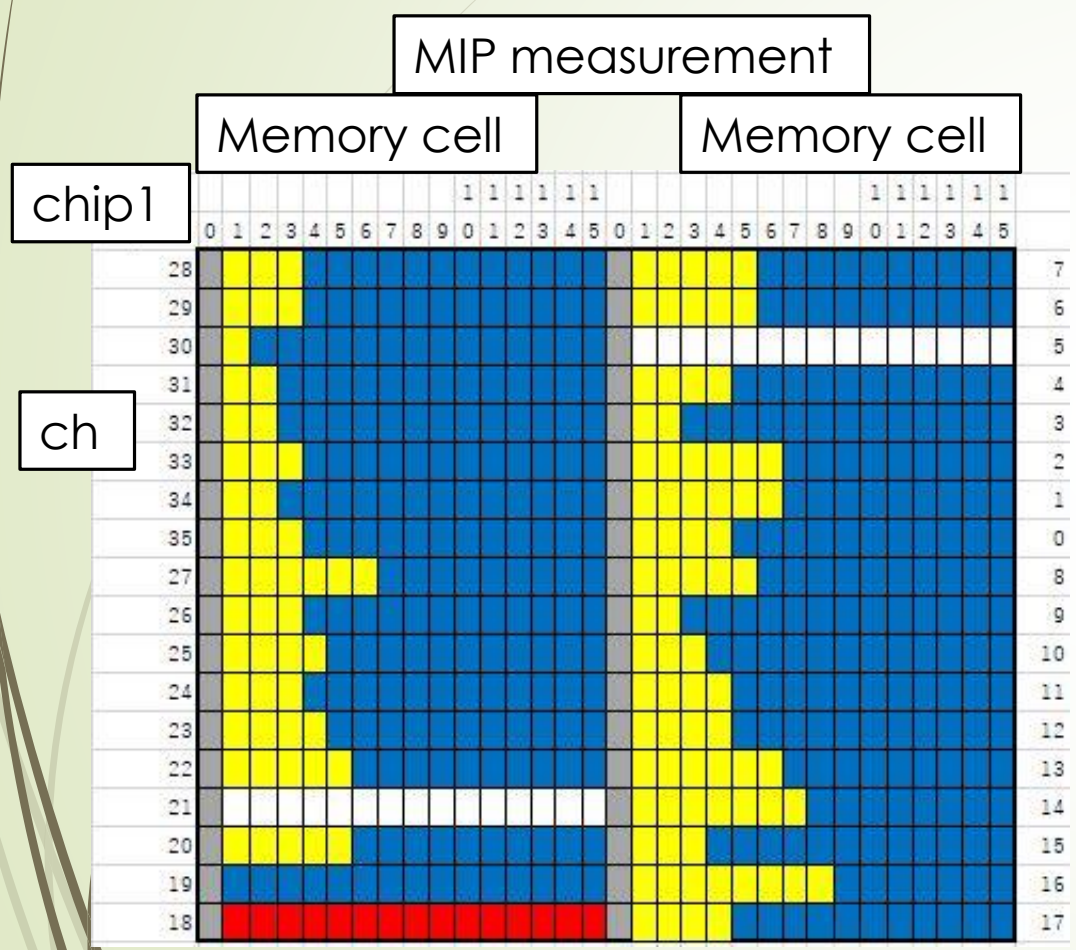
bunchXID is more than 90

- When bunchXID more than 90, MIP is not separated in ADC.

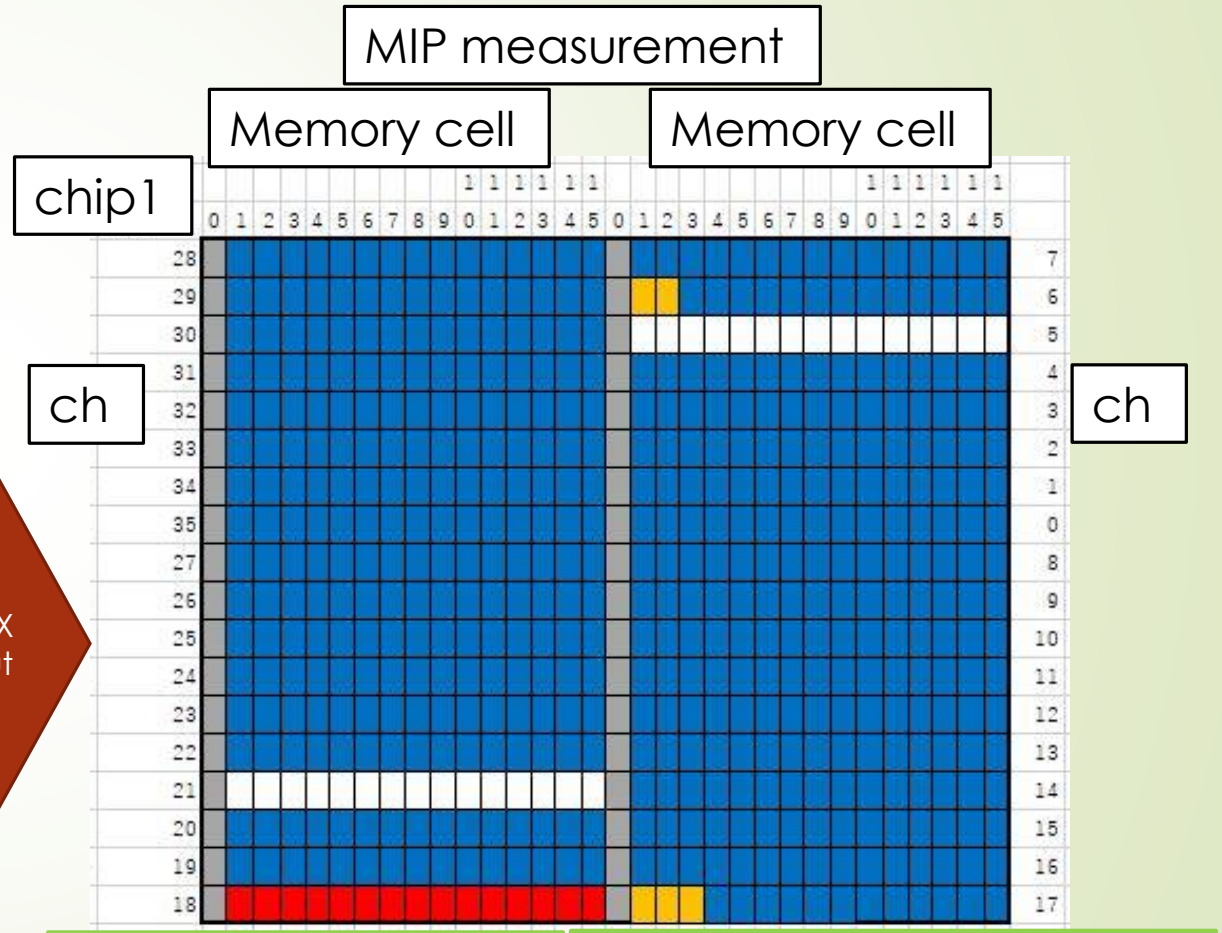




MIP measurement with BunchXIDcut (VS memory cell)



bunchX ID is cut



- When bunchXID is cut out the large numbers, MIP's are separated in almost all memory cells.

White : problem of MPPC and scintillator coupling

Blue : MIP is separated

Yellow: : MIP is not separated

Orange : not well separated Red : broken

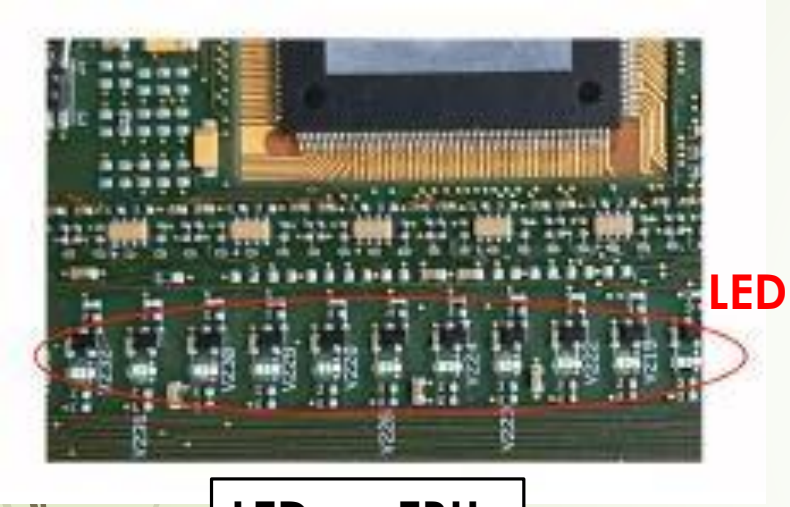
summary

- EBU is the data acquisition system(DAQ) for the scintillator EM calorimeter of the ILD.
- As test of the memory cells in EBU, we have measured the pedestals and MIP peaks.
- We found higher memory cells tend to be classified into gaussian distribution of pedestal and MIP separated.
- But we found lower memory cells tend to be classified into non-gaussian distribution of pedestal and MIP is not separated.
- When buchXID are cut out the large numbers, all memory cells is properly functioning at MIP measurement.

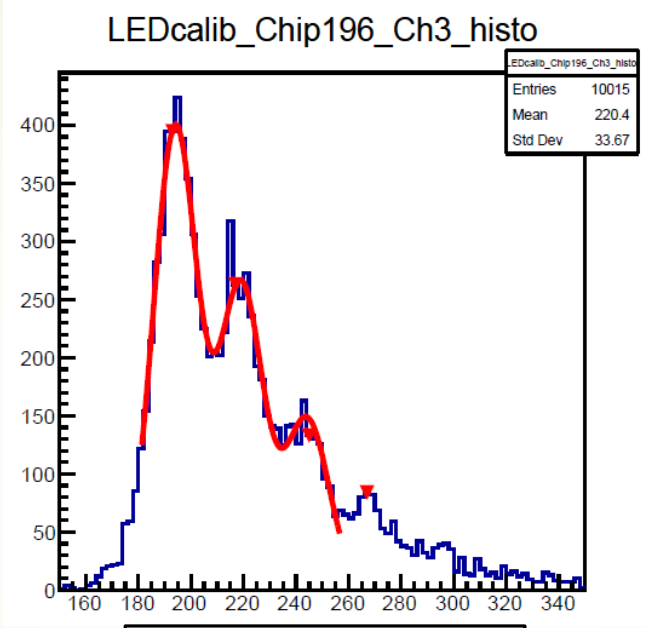
- **Next**
- Investigate the pedestal distribution for lower memory cells.
- investigate non-MIP separated distributions with bunchXID cut of memory cells.
- We will measure the gain of the MPPC using the LED light in each memory cells.

Back up

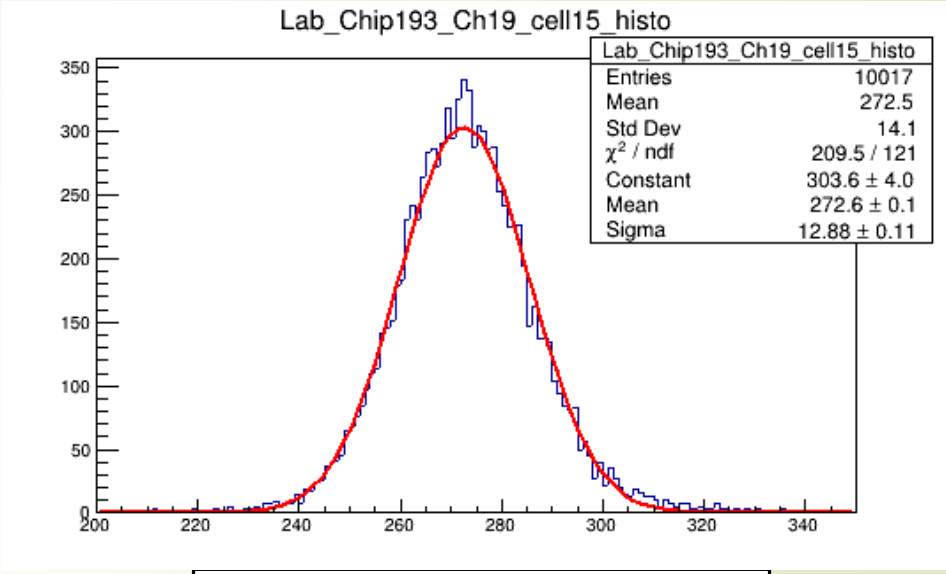
LABmode(Pedestal measurement and LED calibration)



LED on EBU



LED calibration

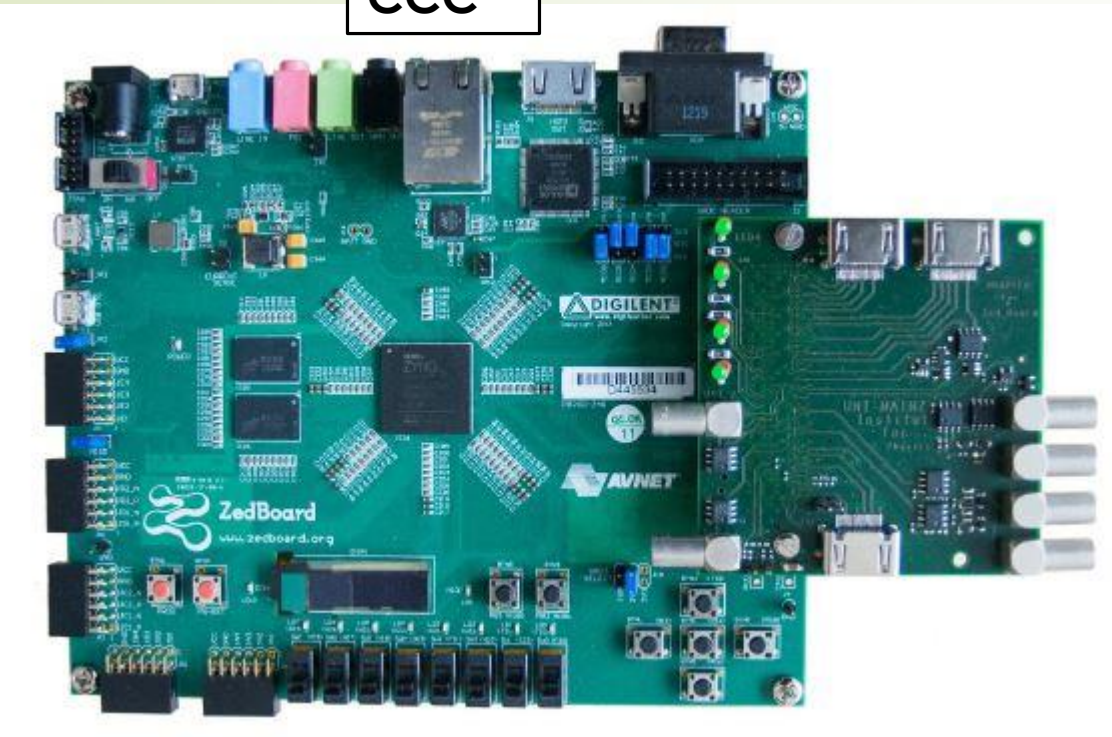


Pedestal measurement

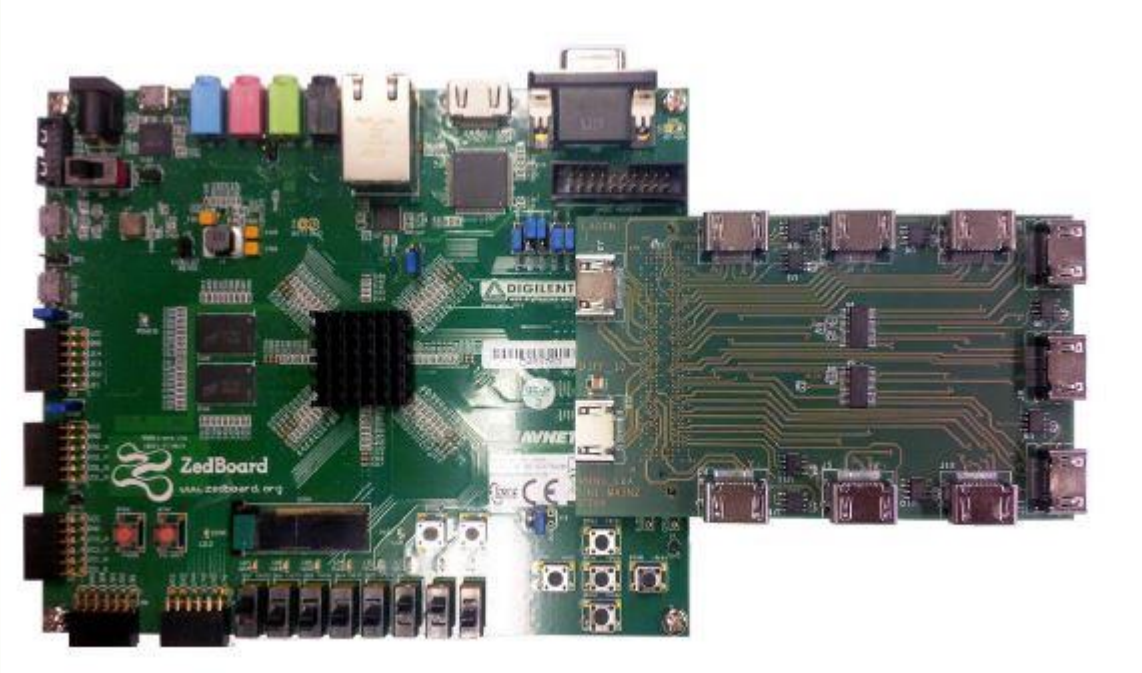
- The LABmode can be triggered from the outside and can be triggered at the moment when the LED shines.
- In LABmode, Pedestal measurement per cells is available by use not LED.
- But don't measure MIP in LABmode because don't work discriminator in spiroc2b.
- Therefore, Pedestal has not bunchXID.

LDA(Link Data Aggregator)
CCC(Clock and Control Card)

CCC

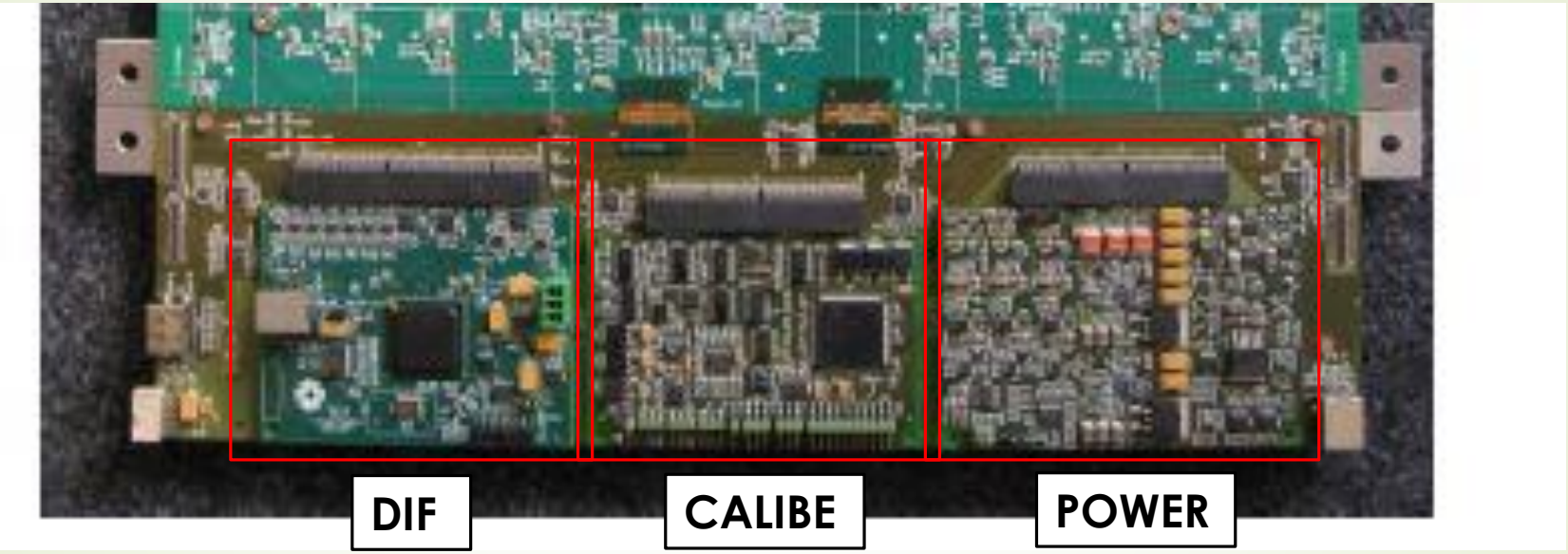


LDA



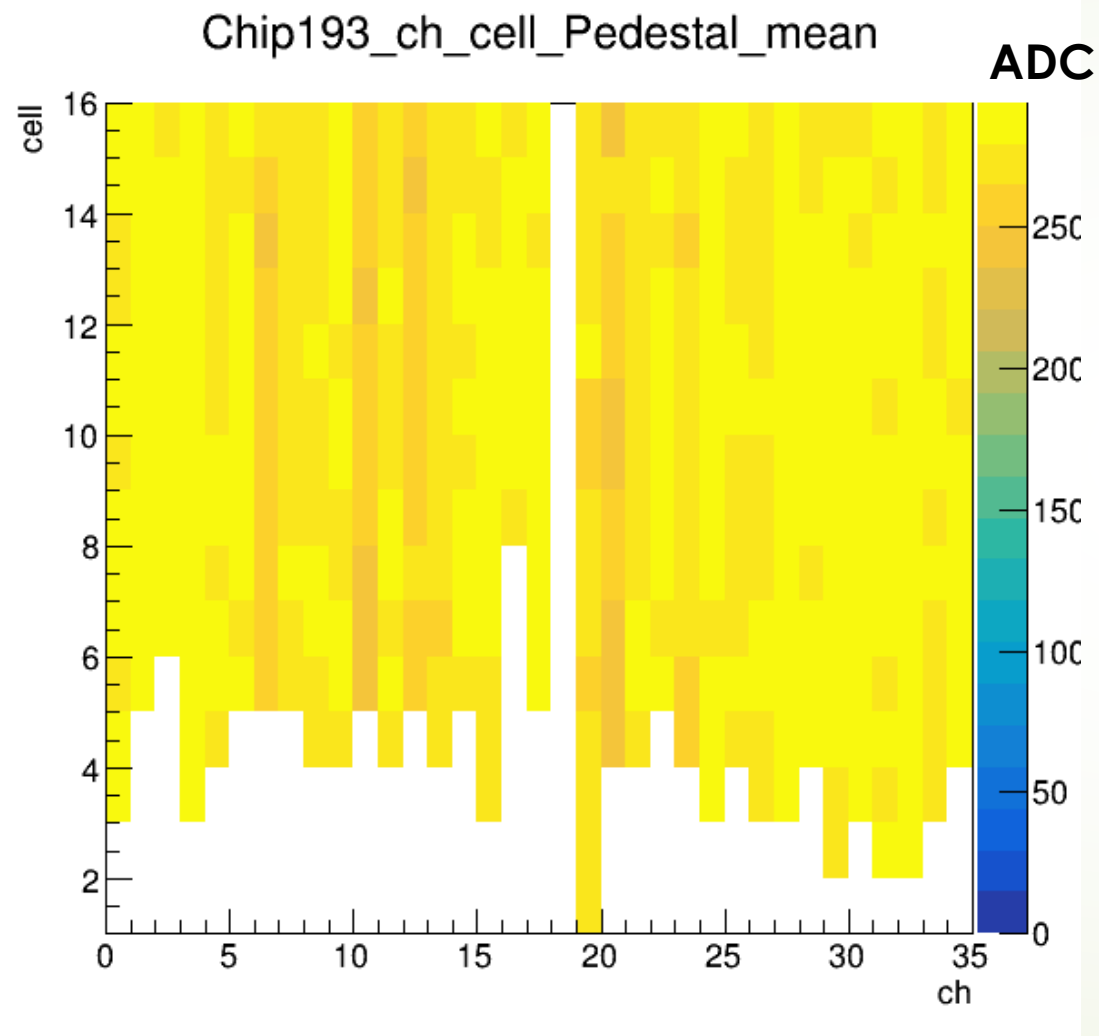
- CCC distributes clock of 5MHz and clock of 40MHz , and trigger for varidationmode ,and external trigger for Labmode to EBU.
- LDA distributes clocks received from CCC to multiple EBUs at the same time. The busy signal and data from EBU are transferred to CCC using HDMI and transferred to a personal computer using HUB, enabling synchronization with other measuring instruments and data acquisition.

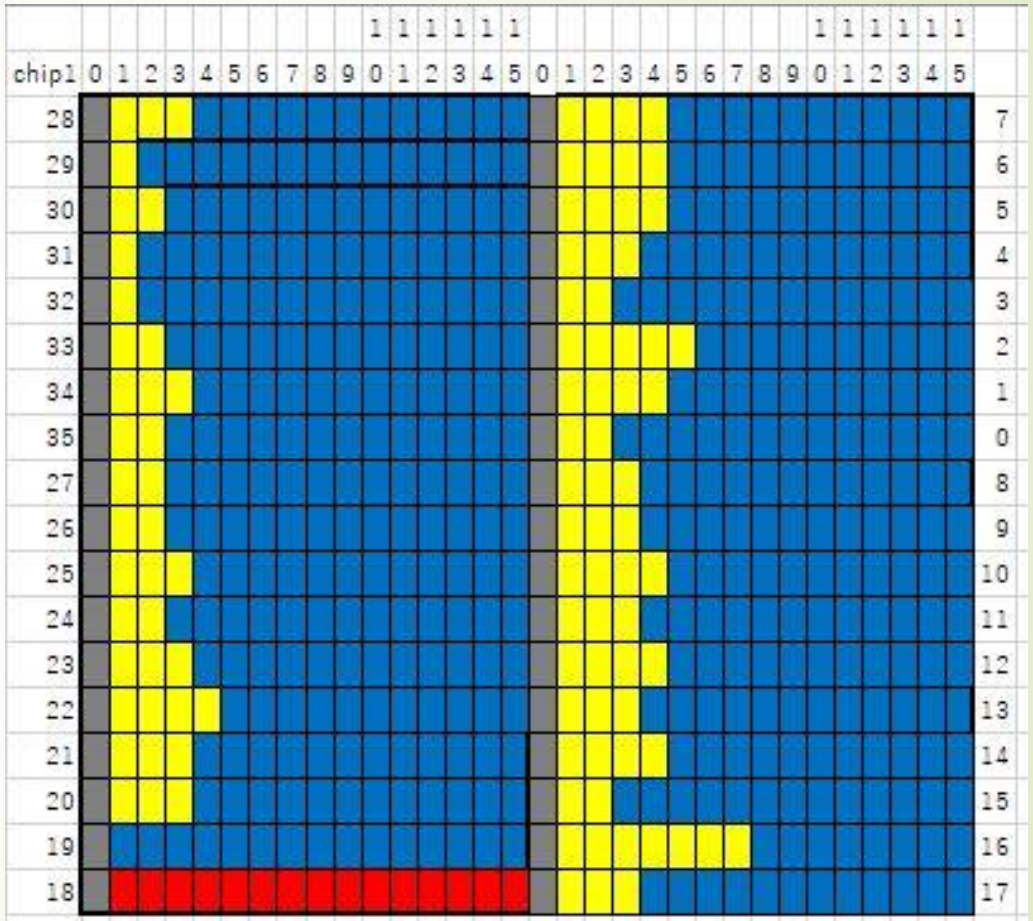
DIF(Detecter Interface board)
CALIB
POWER



- DIF:Manages exchanges between SPIROC2b, POWER, and CALIB. The FPGA on DIF converts the clock received from CCC to DIFclock and generates the setting signal of SPIROC2b
- CALIB : Supply voltage to LED in EBU.
- POWER : Supply voltage to EBU for necessary to work.

Pedestal measurement(Chip1、chVScell)



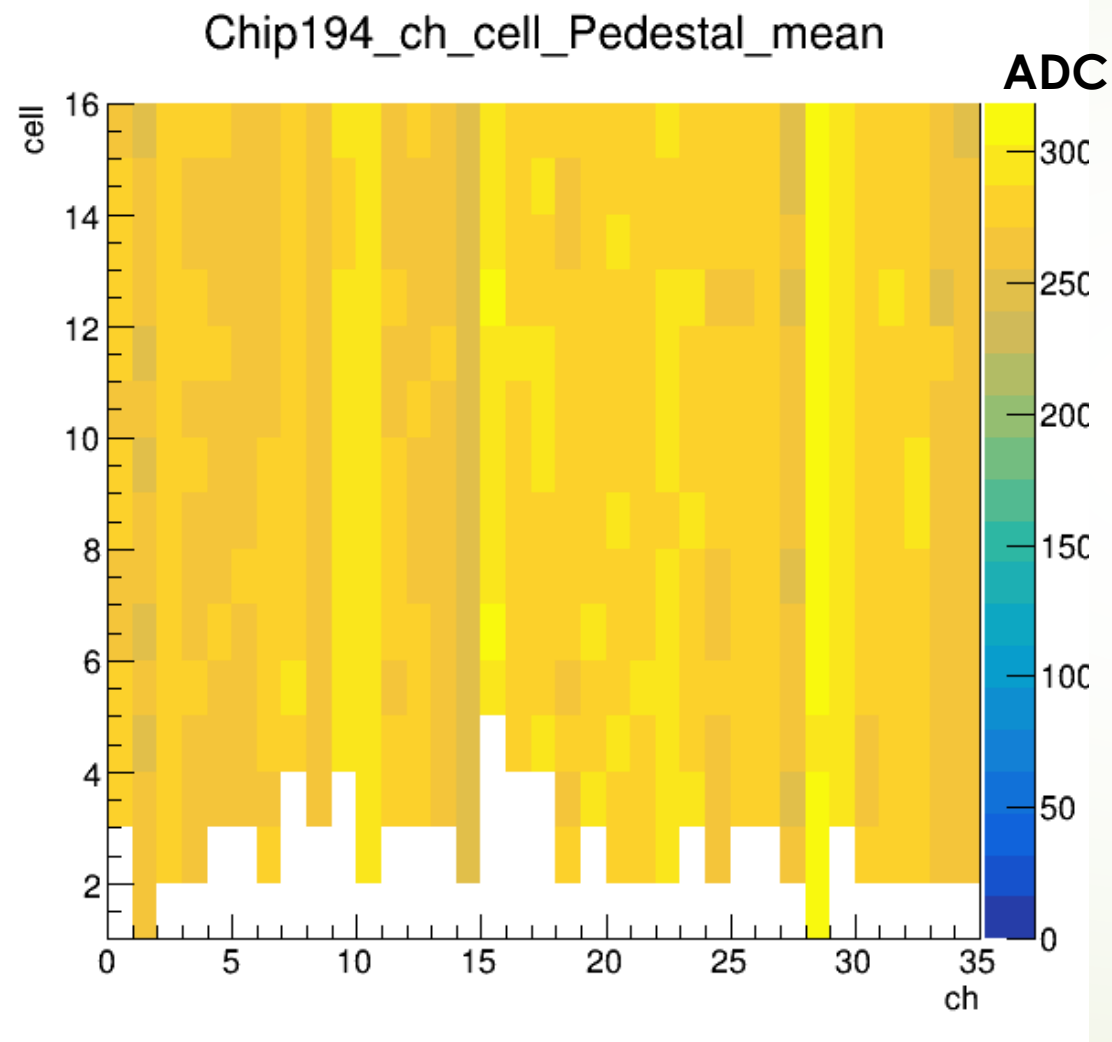


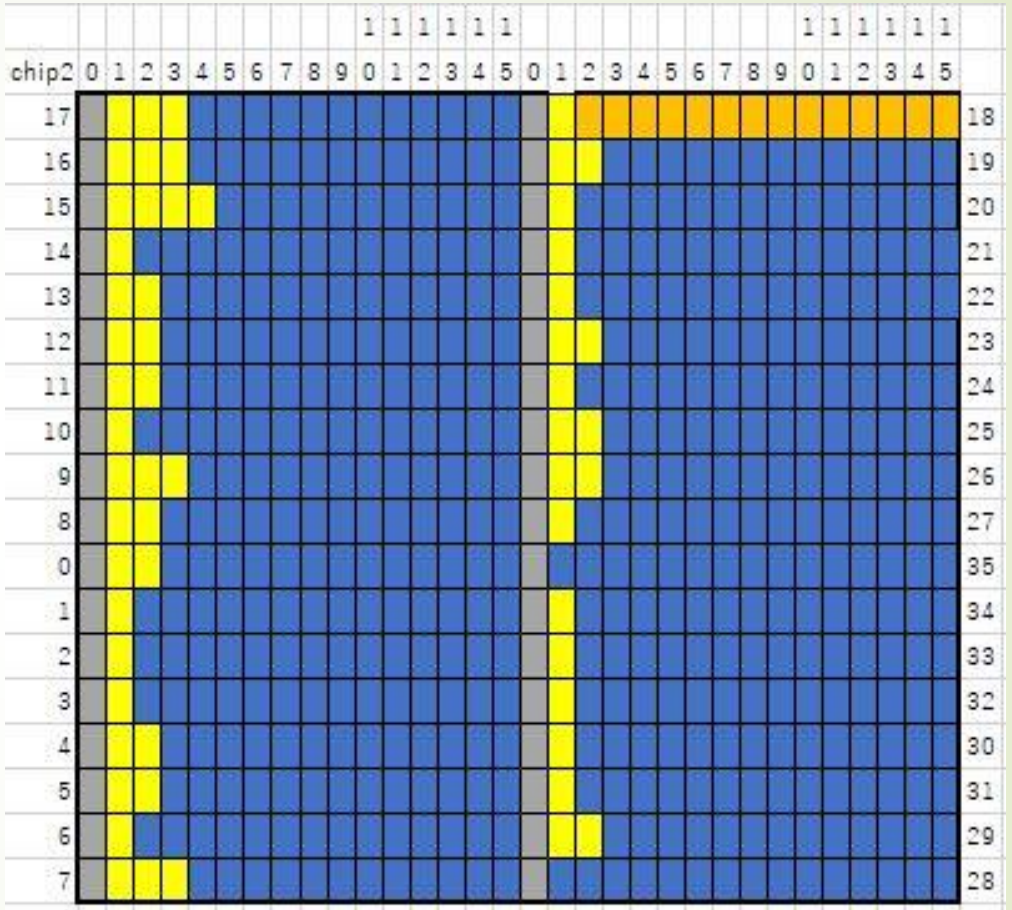
Blue : gaussian distribution

Yellow: : non-gaussian distribution

Orange : noisy Red : broken

Pedestal measurement(Chip2、chVScell)



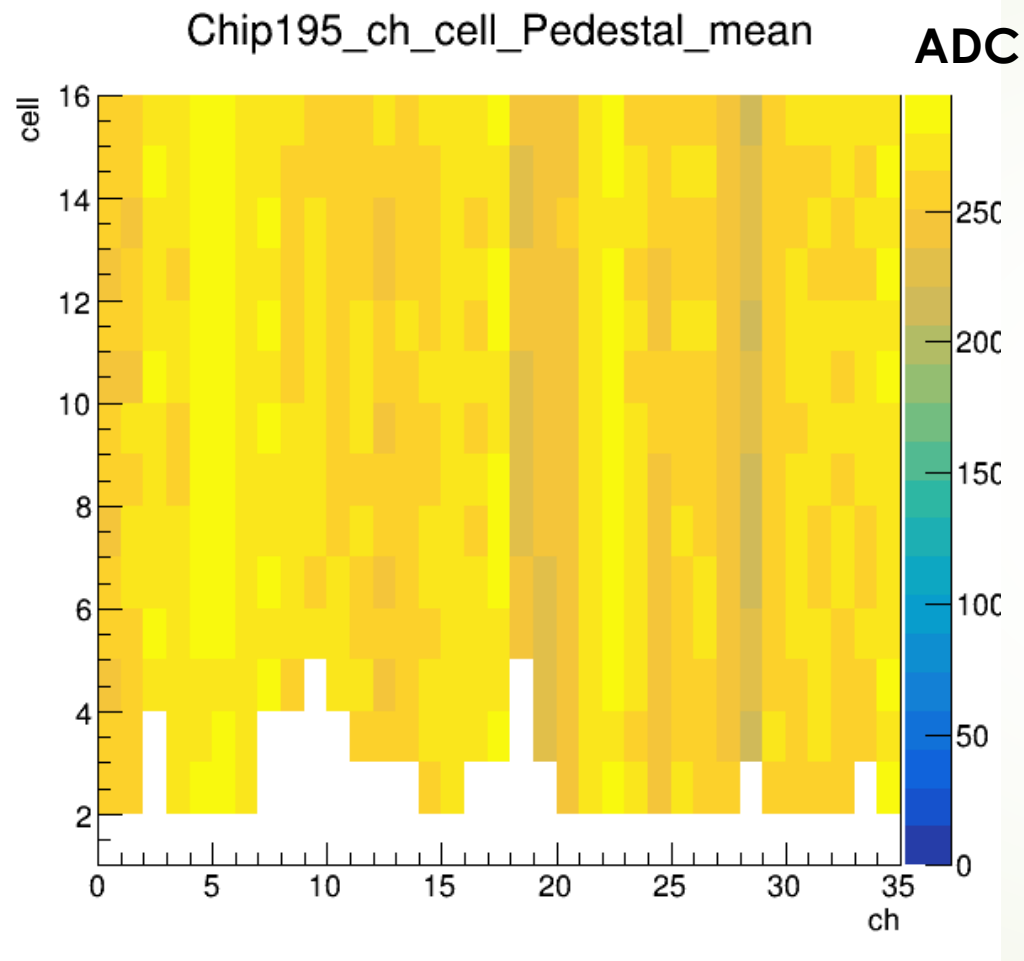


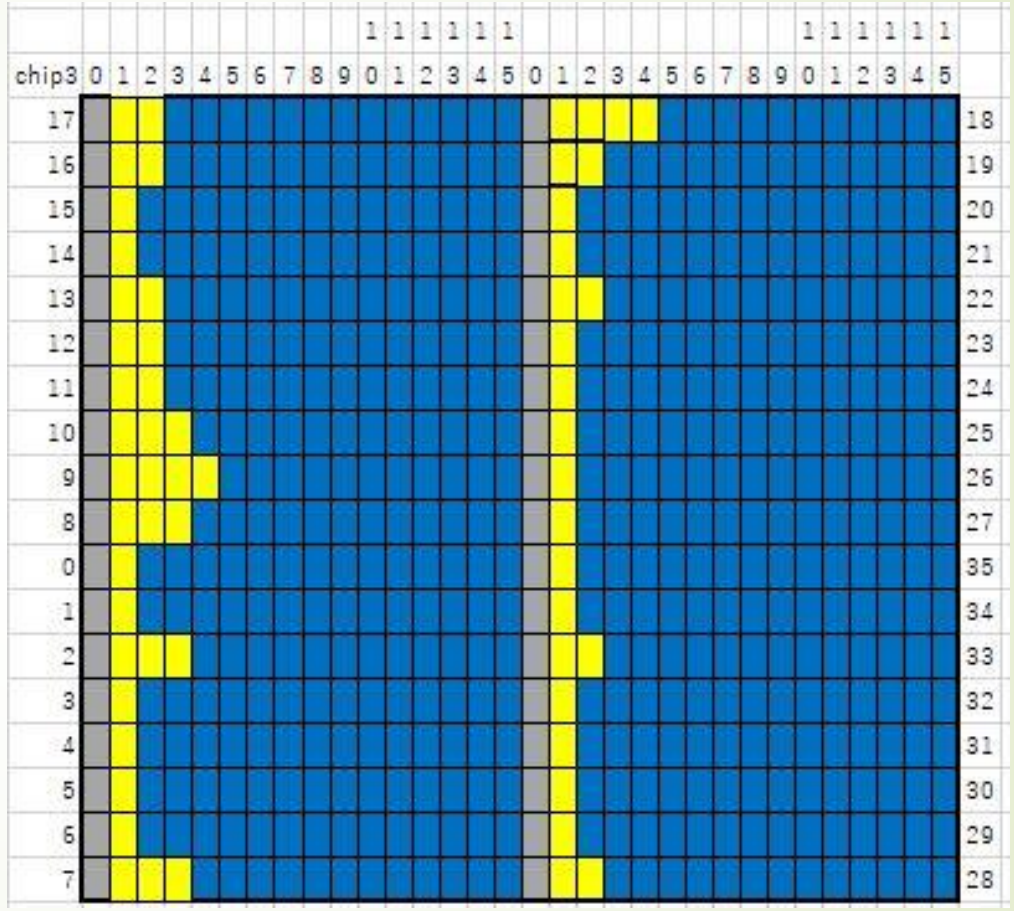
Blue : gaussian distribution

Yellow: : non-gaussian distribution

Orange : noisy Red : broken

Pedestal measurement(Chip3、chVScell)



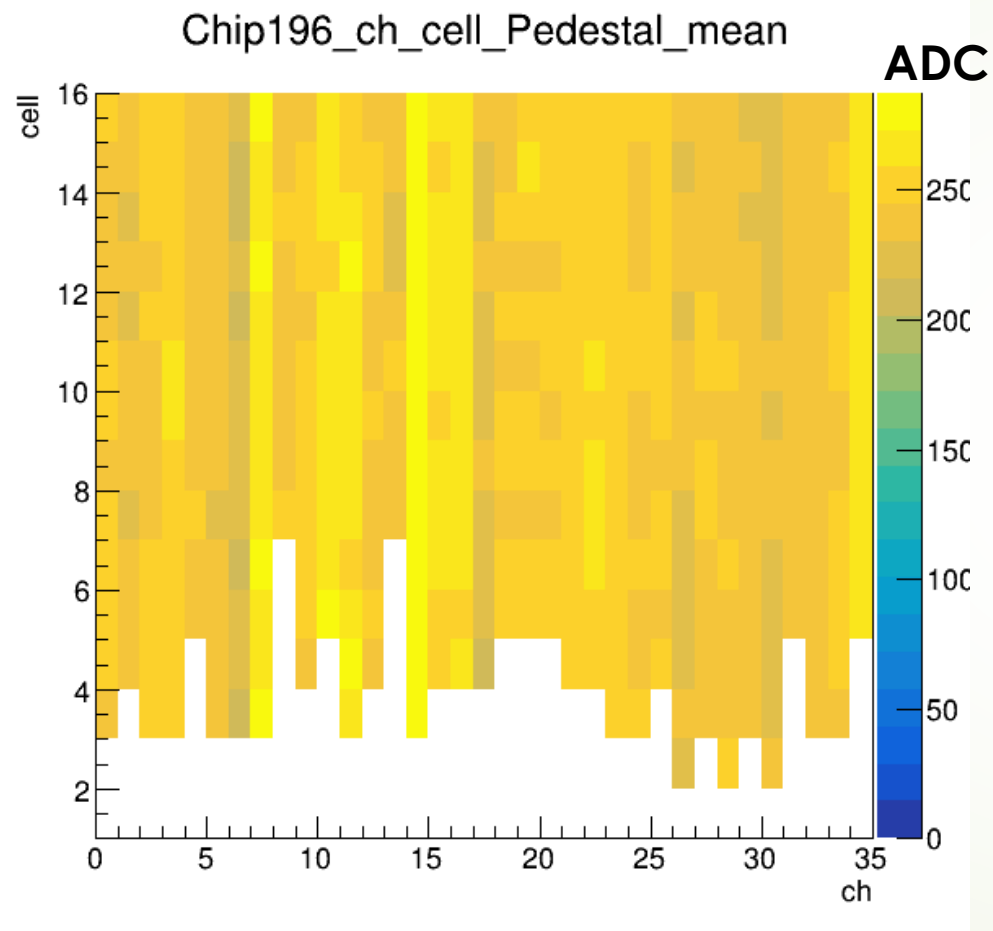


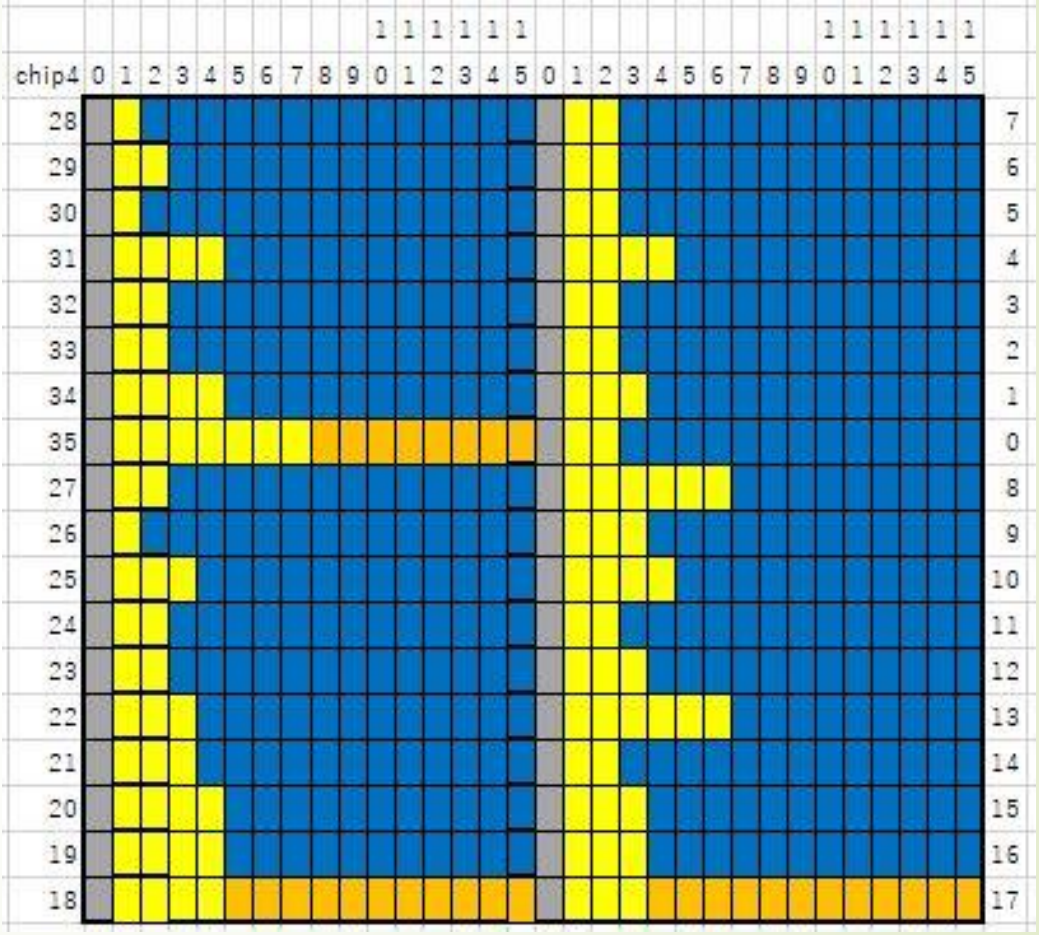
Blue : gaussian distribution

Yellow: : non-gaussian distribution

Orange : noisy Red : broken

Pedestal measurement (Chip4、chVScell)





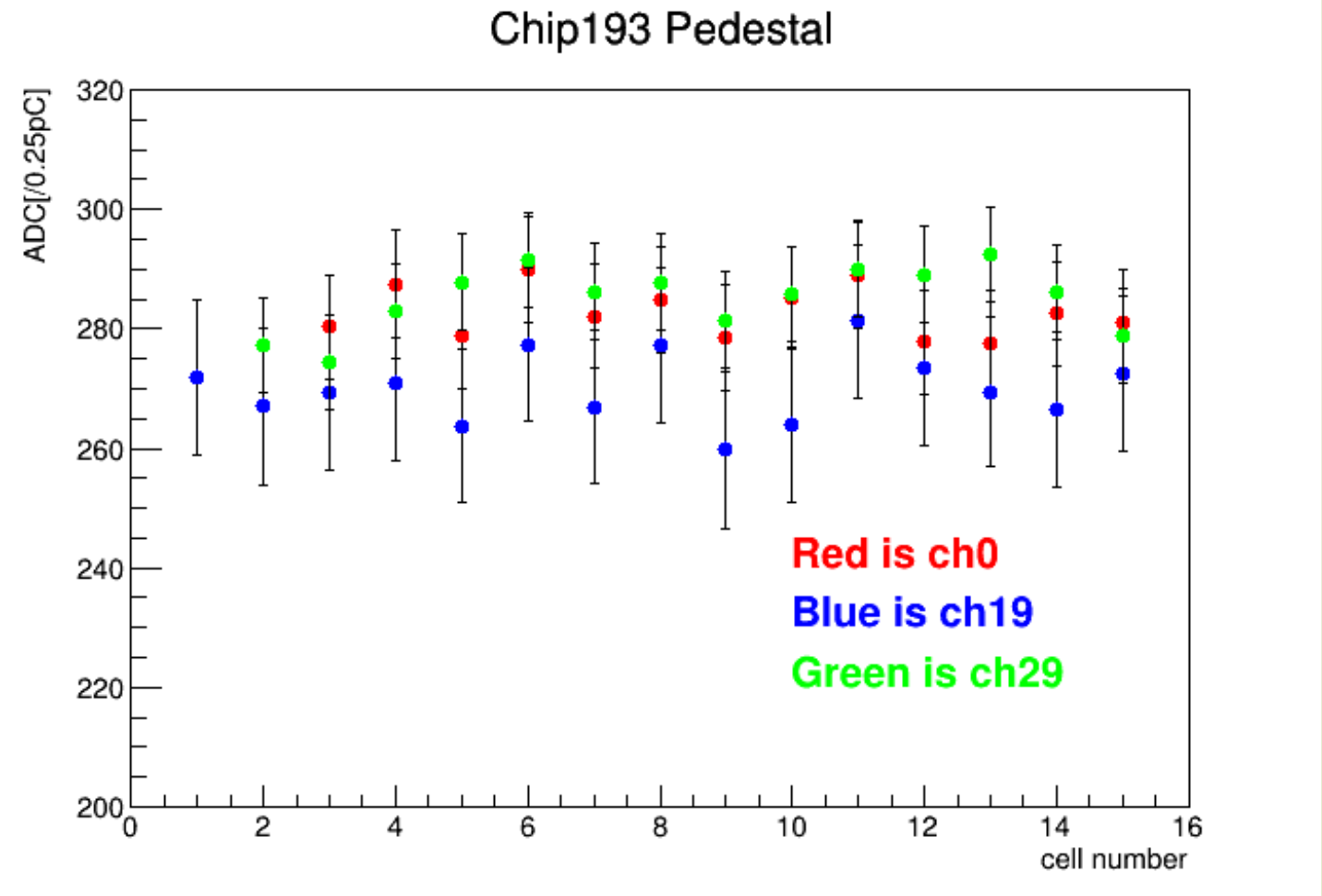
Gaussian distribution of pedestal
1824/2160cells in 4chips

Blue : gaussian distribution

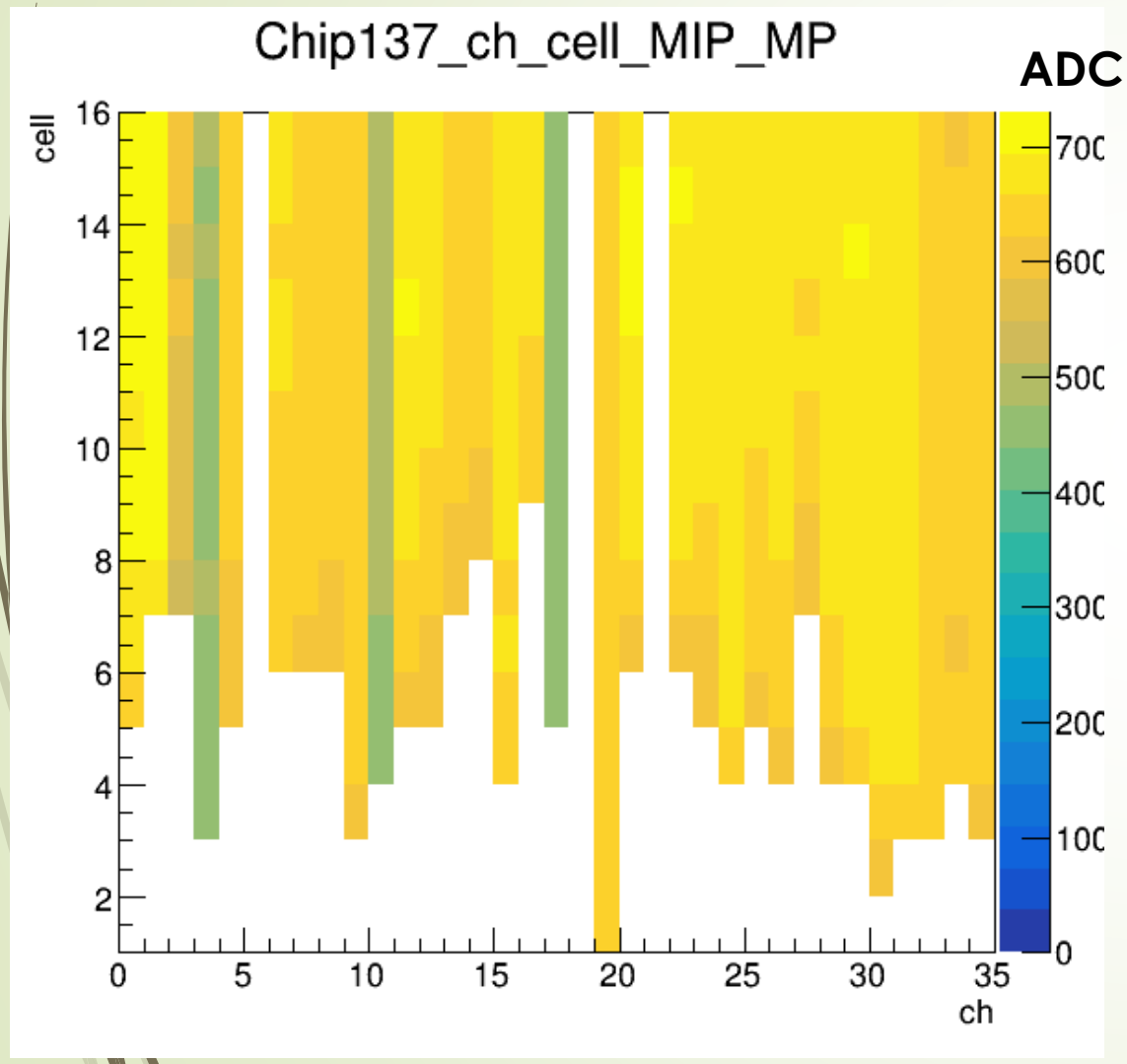
Yellow: : non-gaussian distribution

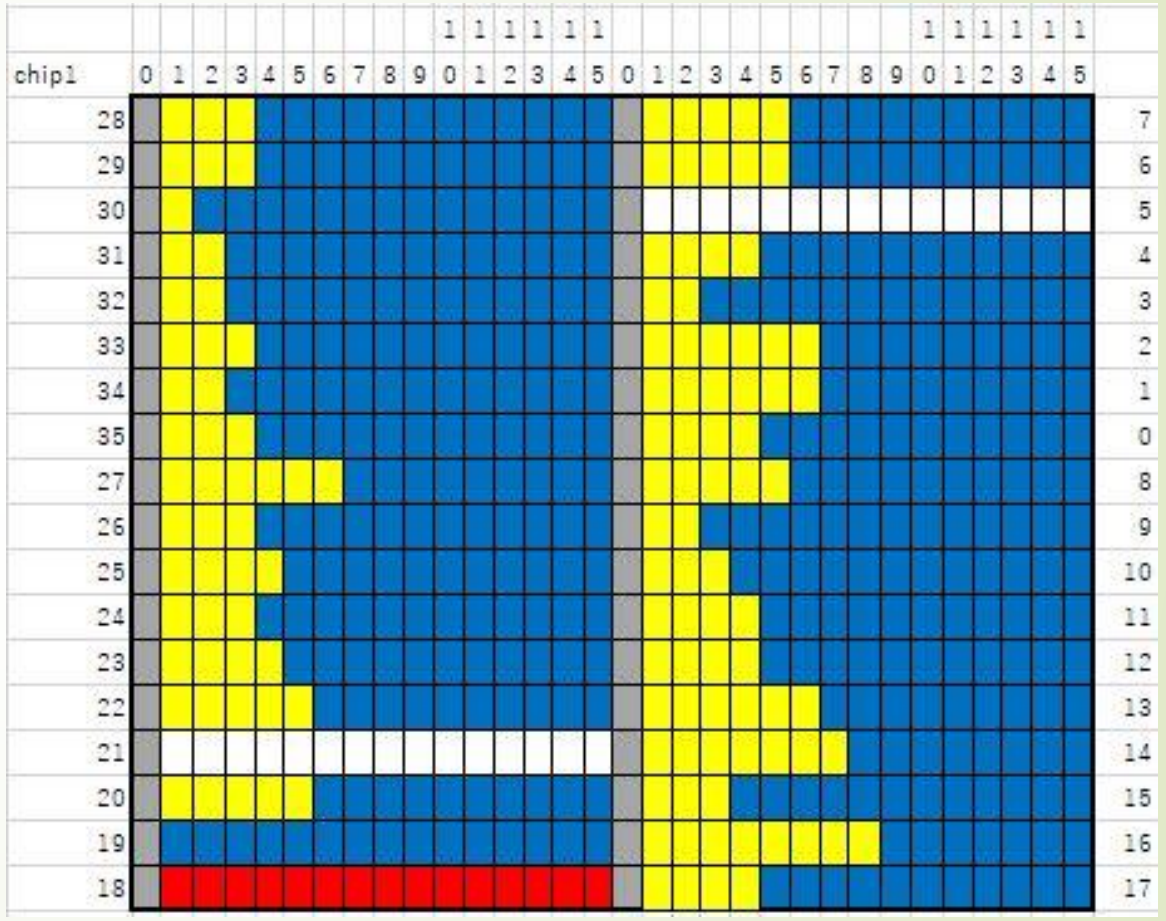
Orange : noisy Red : broken

Pedestal measurement channel



MIP measurement (chip1,ch VS memory cell)





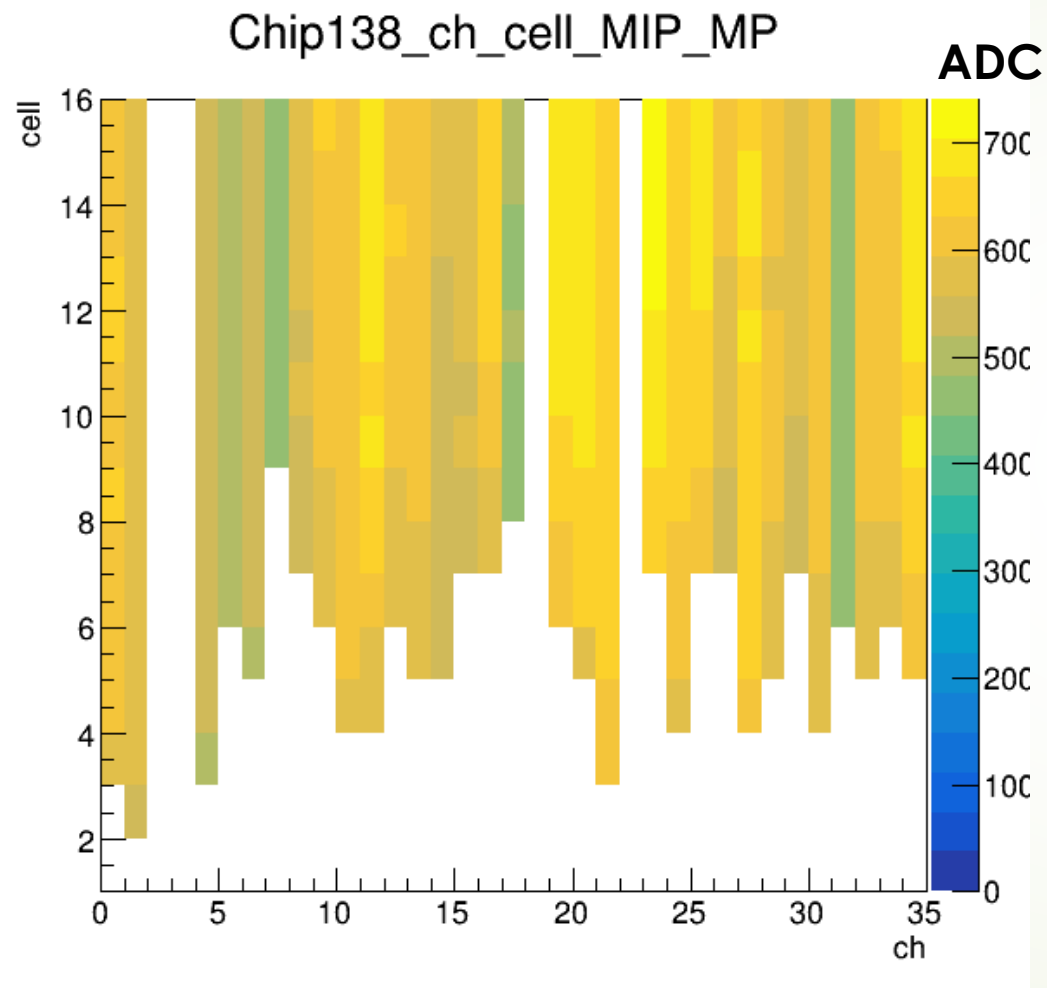
White : problem of MPPC and scintillator coupling

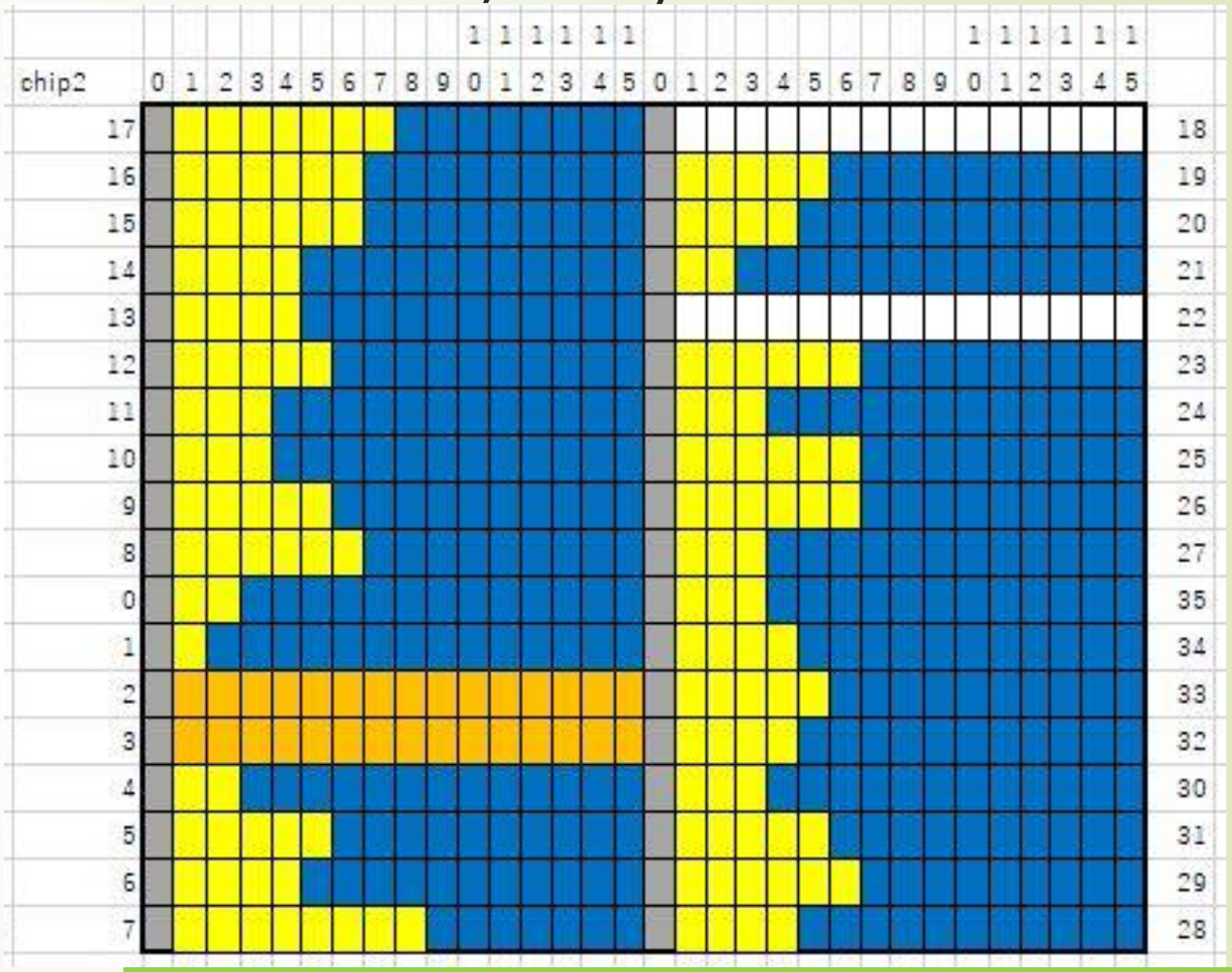
Blue : MIP is separated

Yellow: : MIP is not separated

Orange : not well separated Red : broken

MIP measurement (chip2,ch VS memory cell)





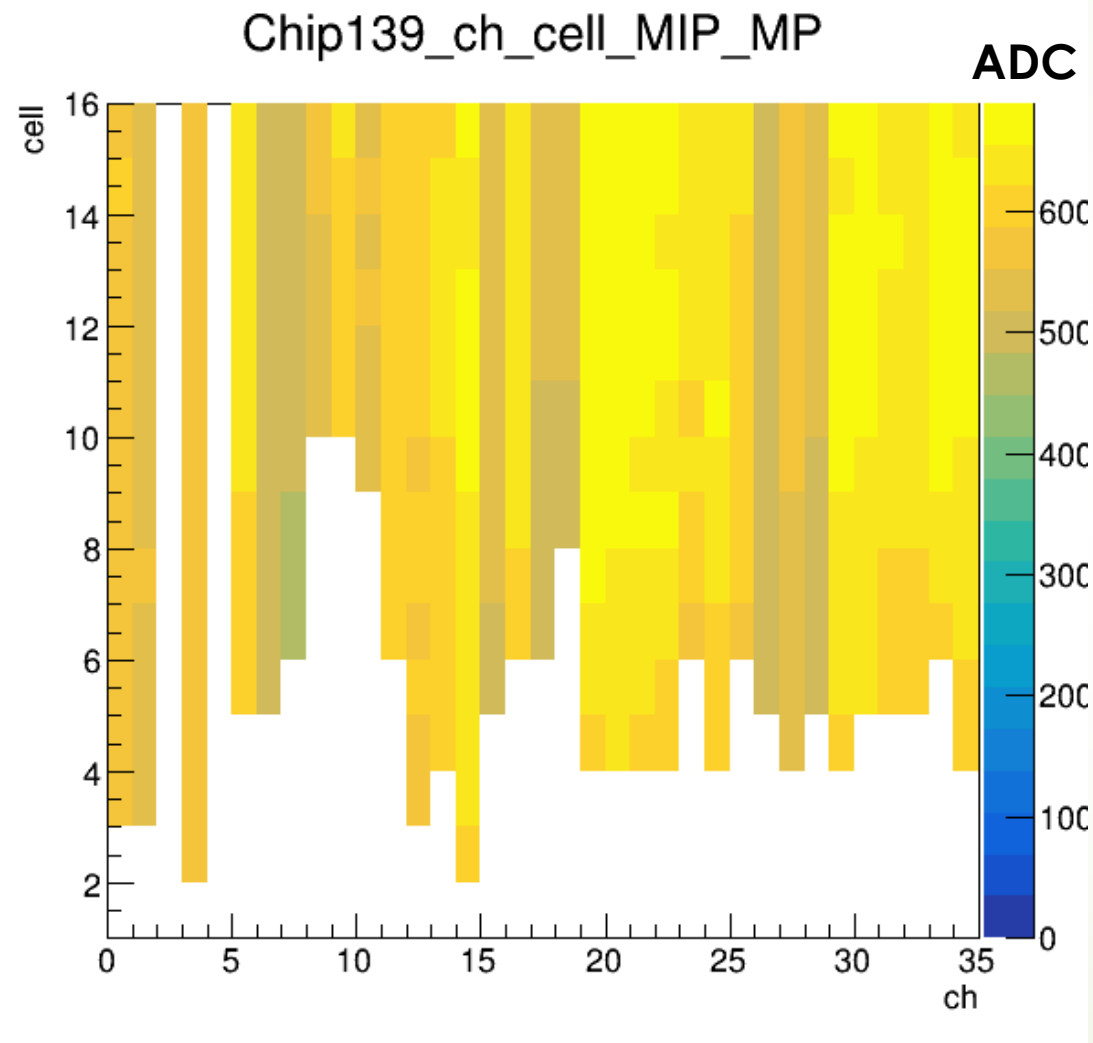
White : problem of MPPC and scintillator coupling

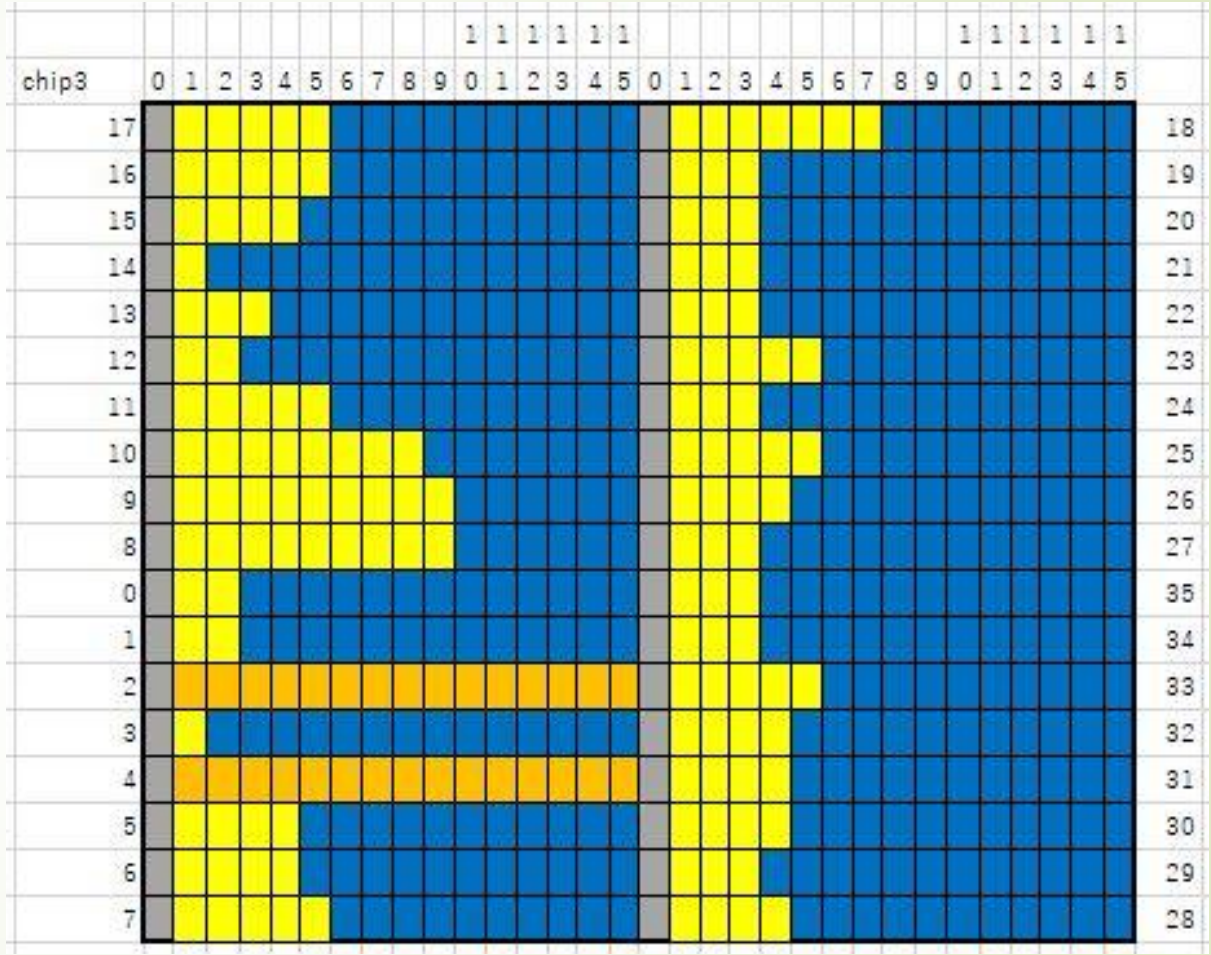
Blue : MIP is separated

Yellow: : MIP is not separated

Orange : not well separated Red : broken

MIP measurement (chip3,ch VS memory cell)





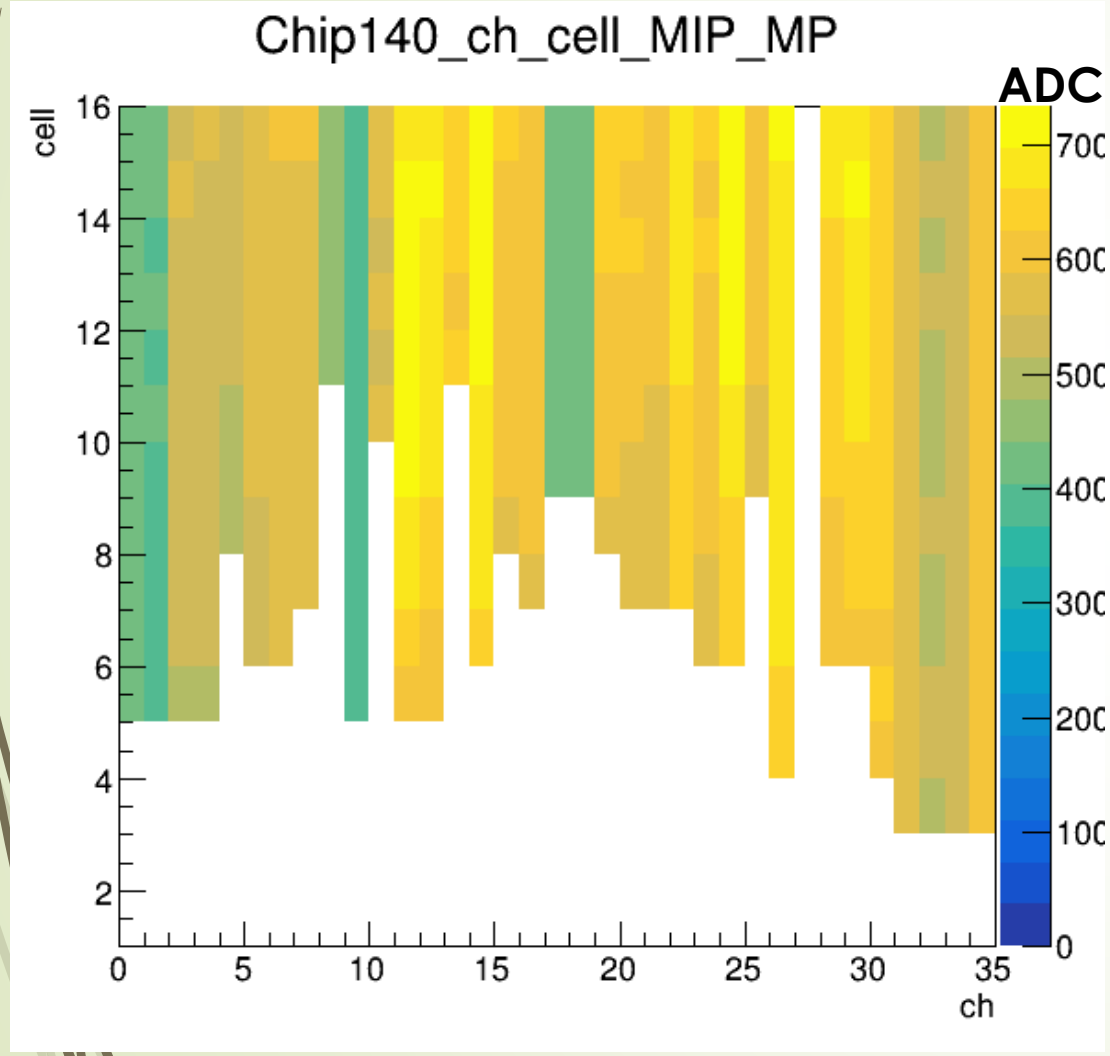
White : problem of MPPC and scintillator coupling

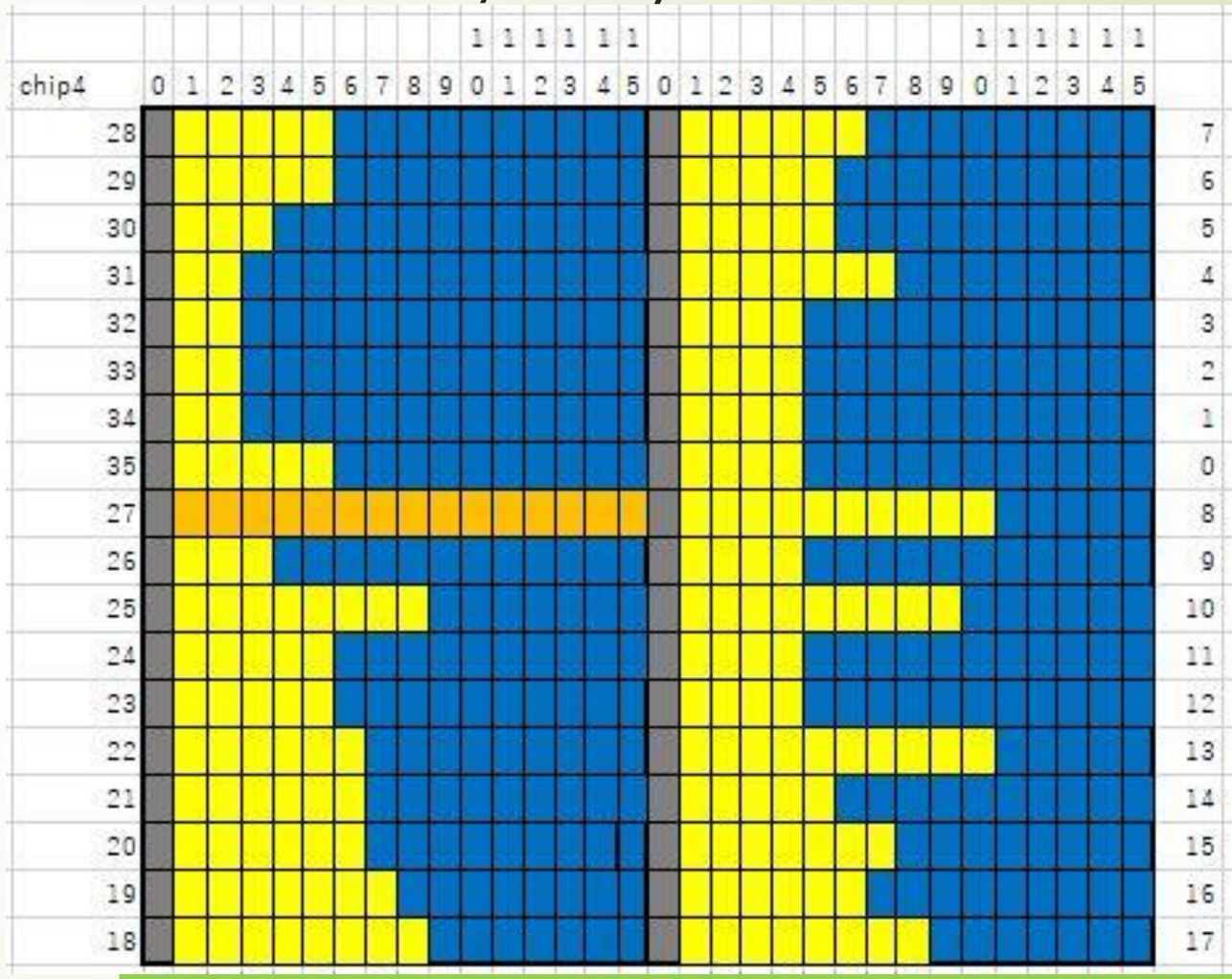
Blue : MIP is separated

Yellow: : MIP is not separated

Orange : not well separated Red : broken

MIP measurement (chip4,ch VS memory cell)





White : problem of MPPC and scintillator coupling

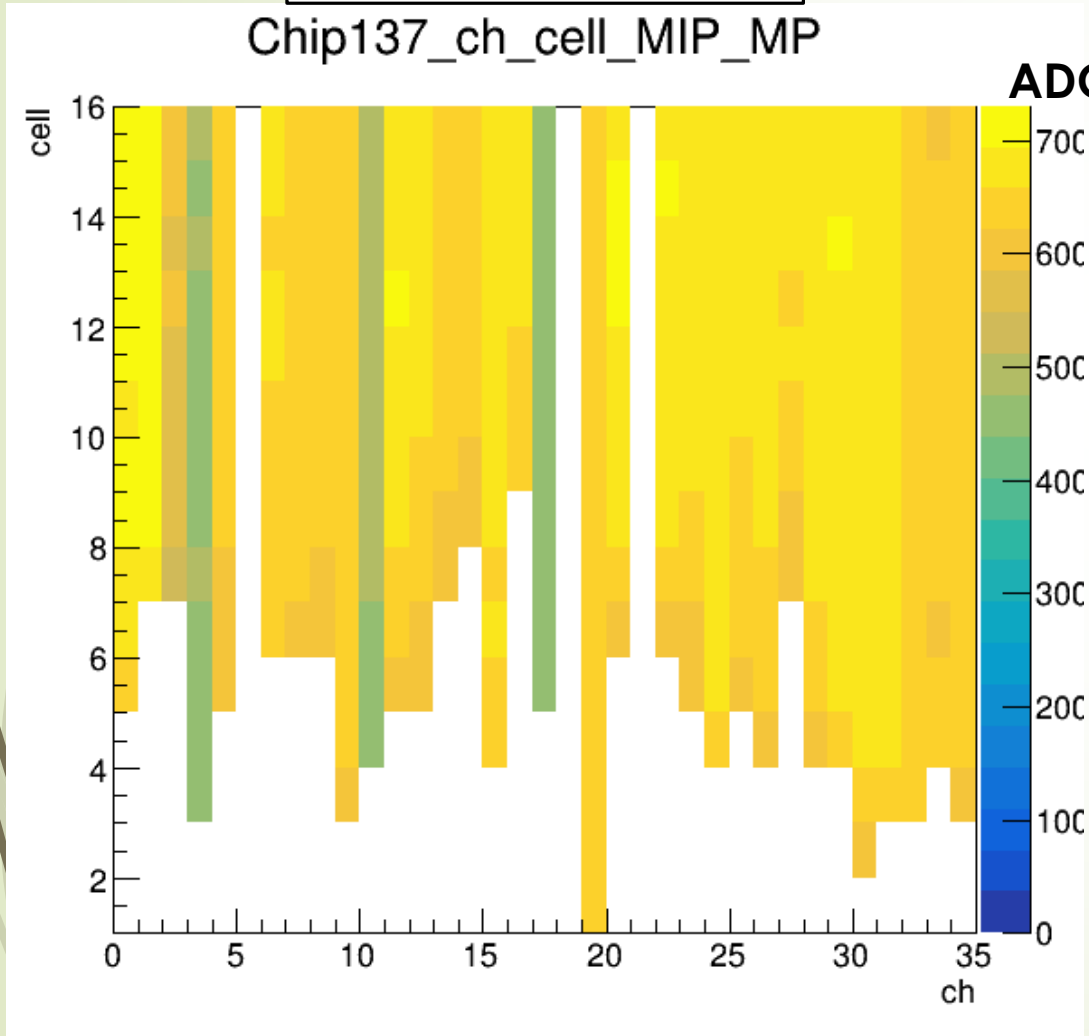
Blue : MIP is separated

Yellow: : MIP is not separated

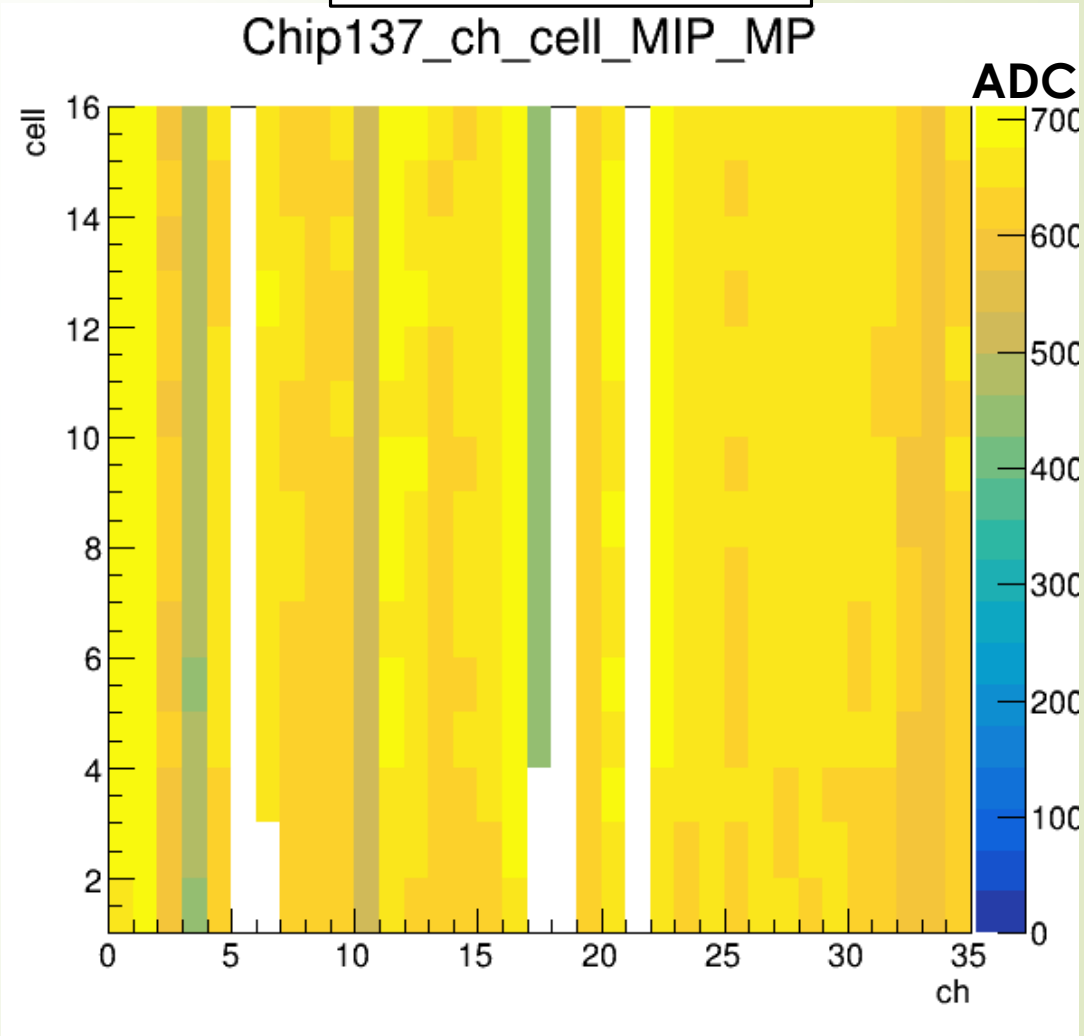
Orange : not well separated Red : broken

MIP measurement with bunchXIDcut(chip1)

Before bunchXIDcut

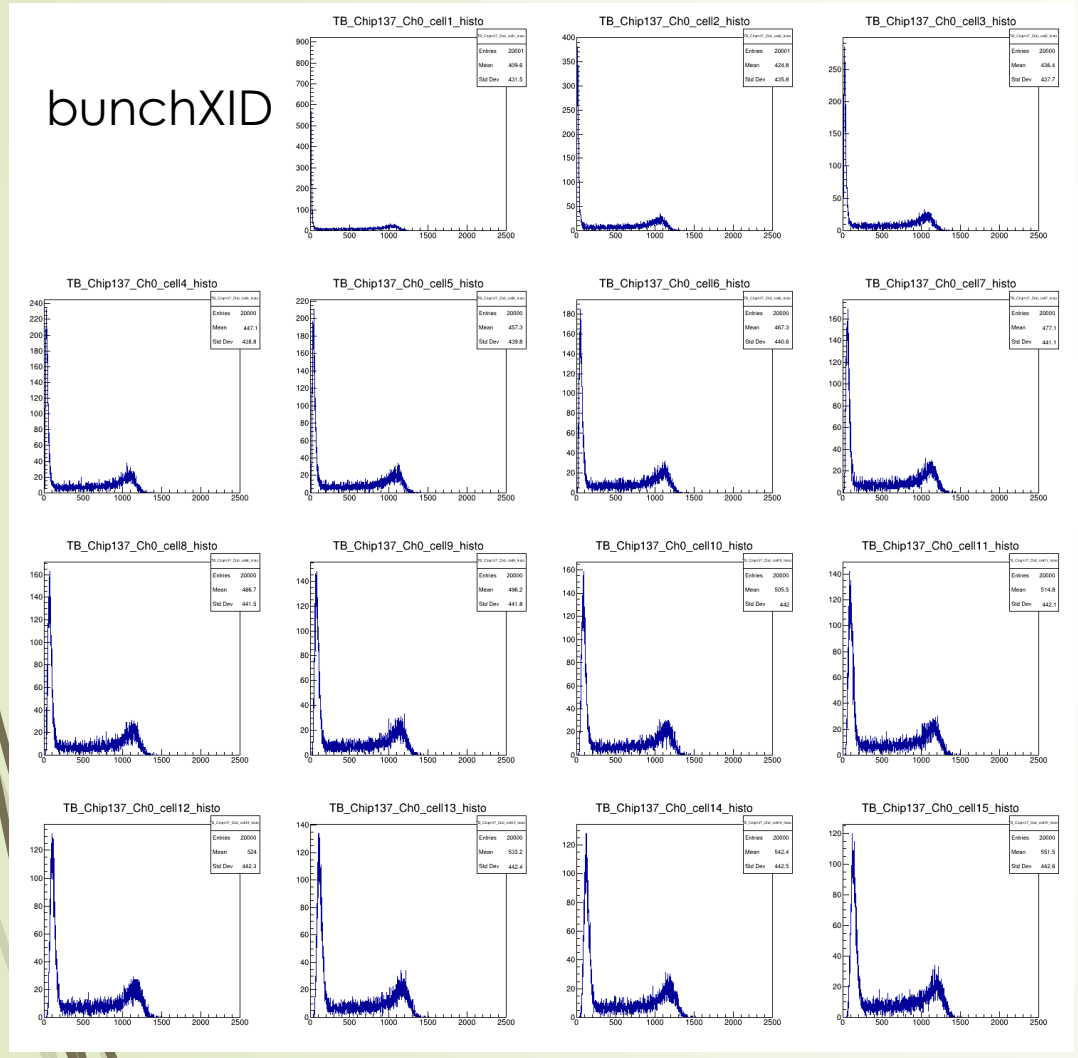


After bunchXIDcut

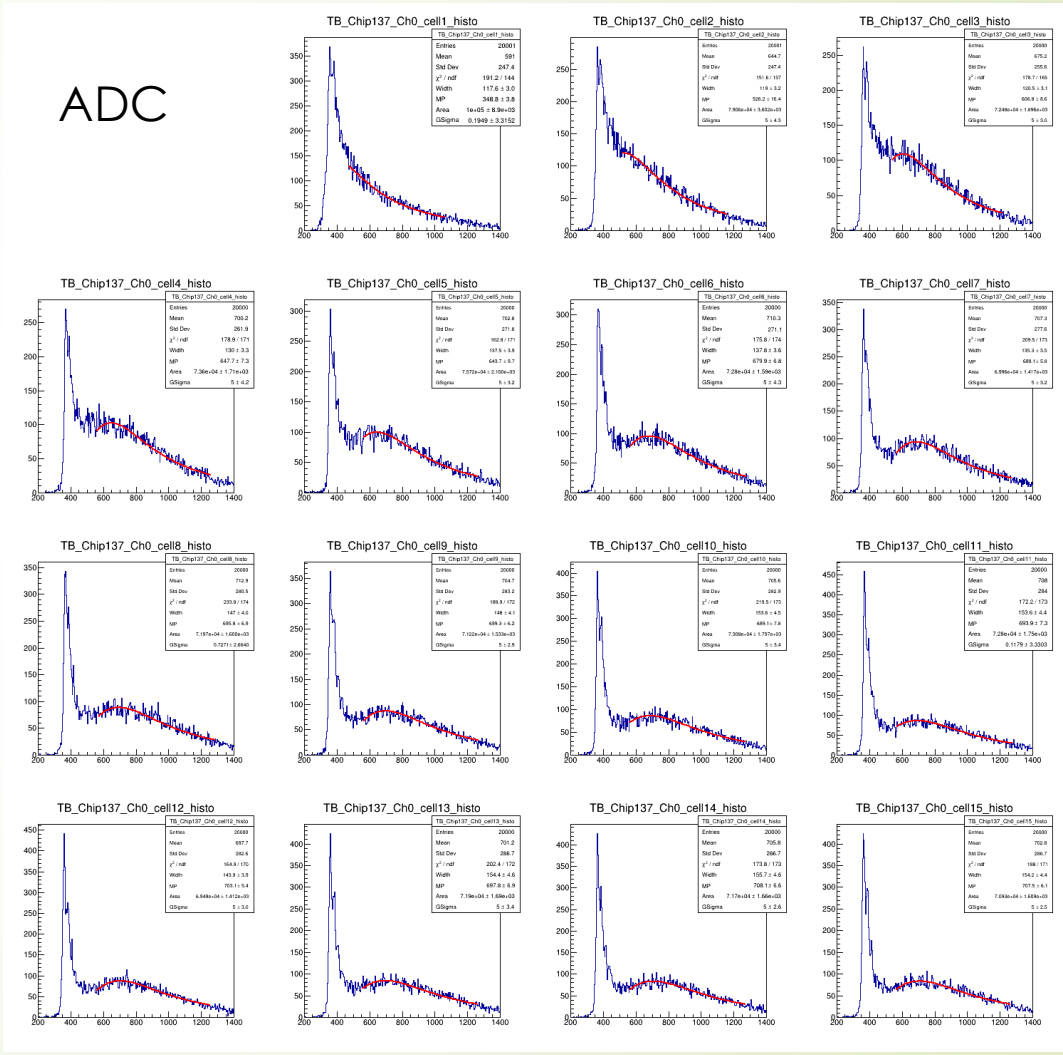


Chip1 ch0 all cells before bunchXIDcut

bunchXID

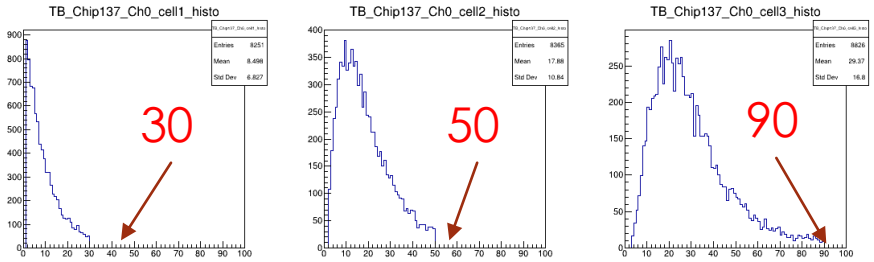


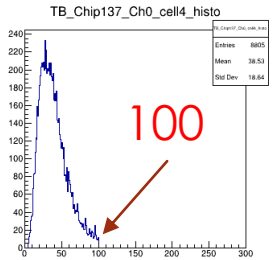
ADC

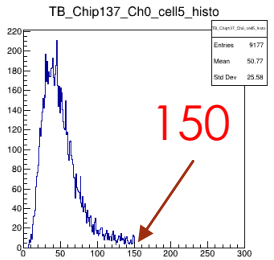


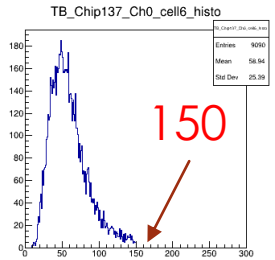
Chip1 ch0 all cells after bunchXIDcut

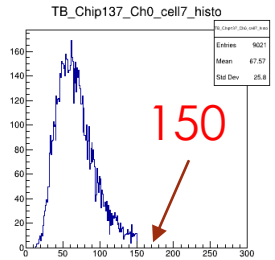
bunchXID

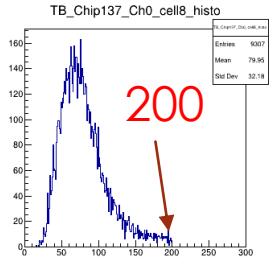


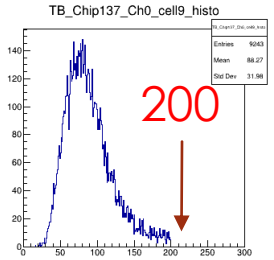


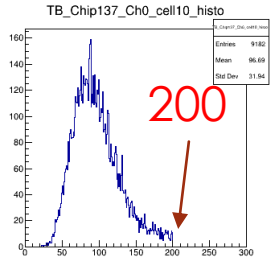


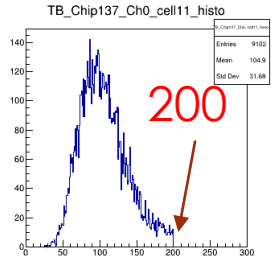


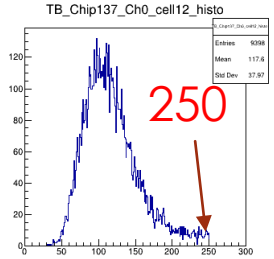


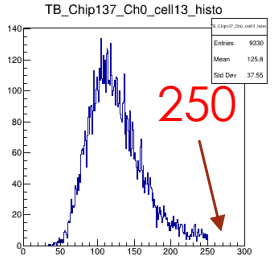


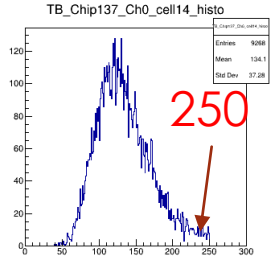


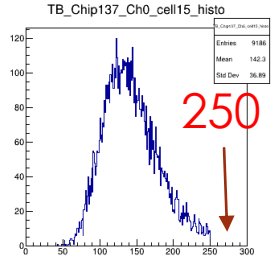












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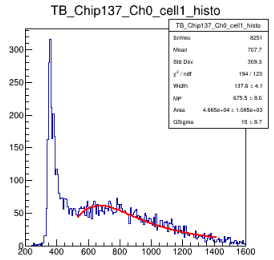
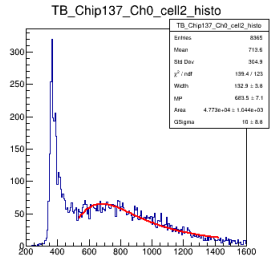
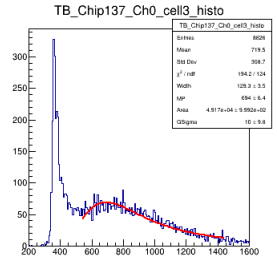
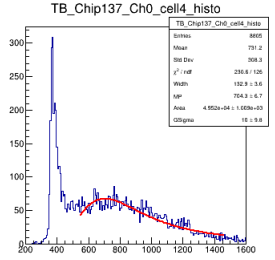
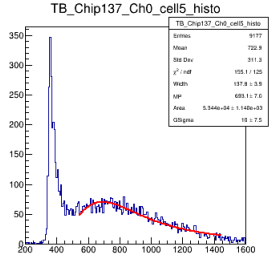
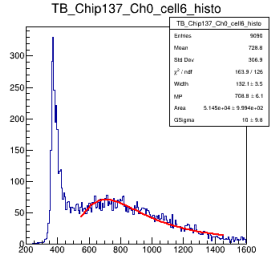


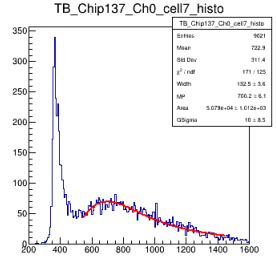


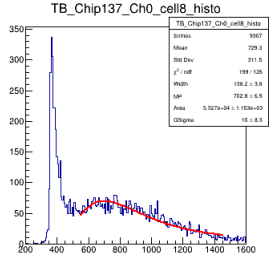


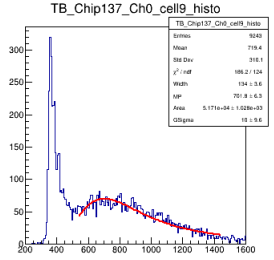


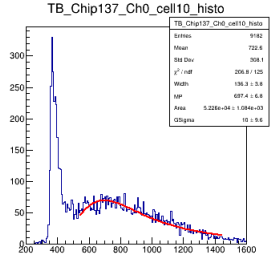


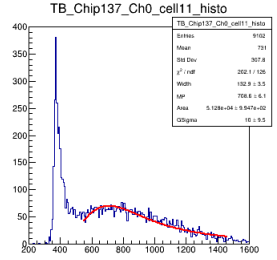


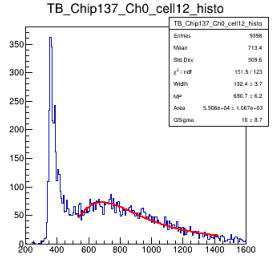


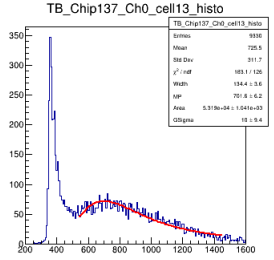


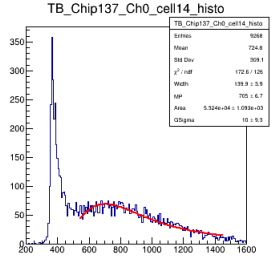


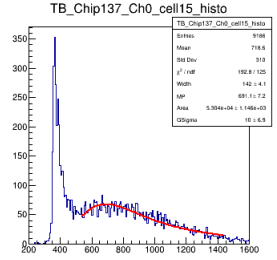








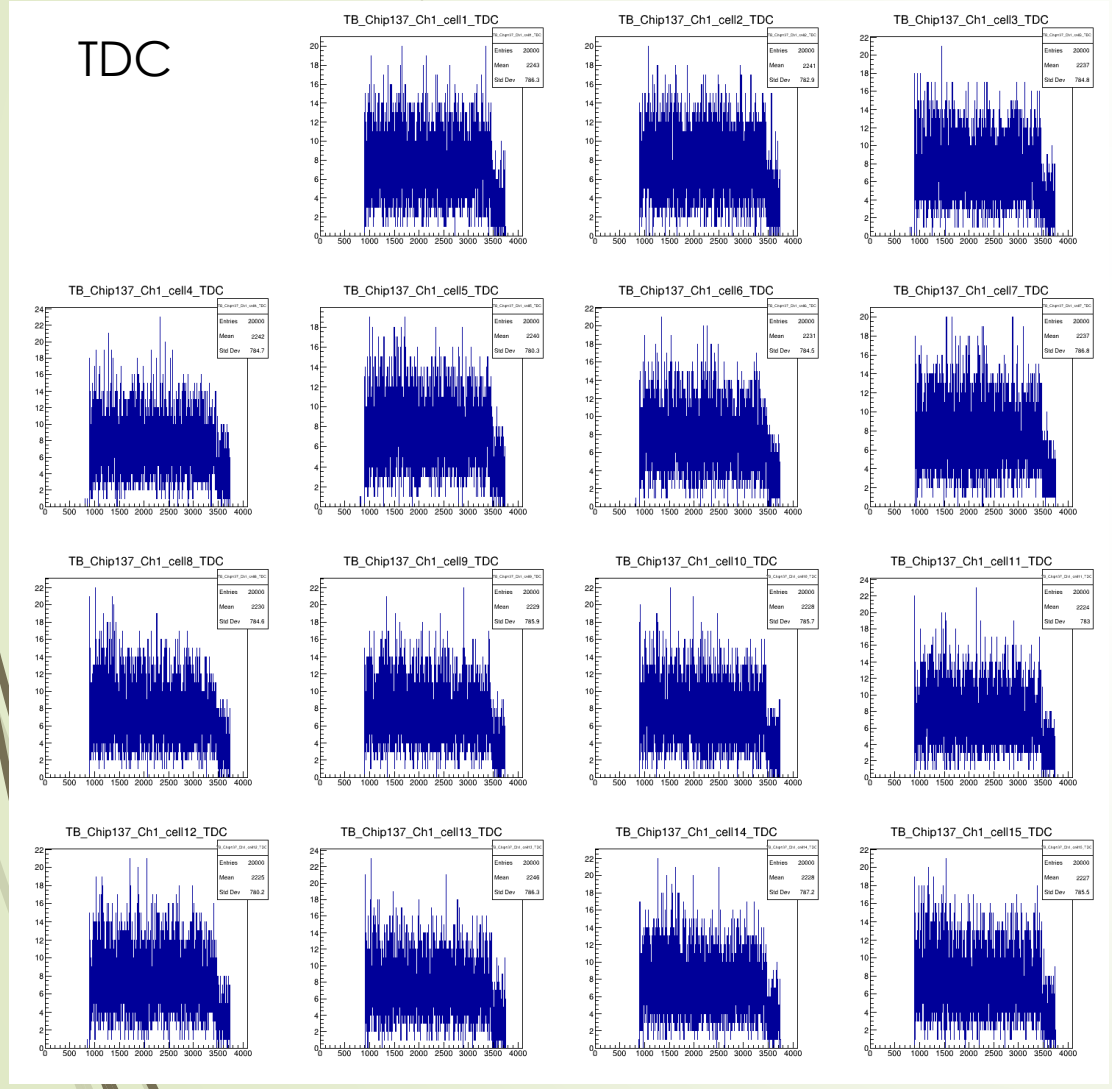




TDC with bunchXIDcut chip1 ch1

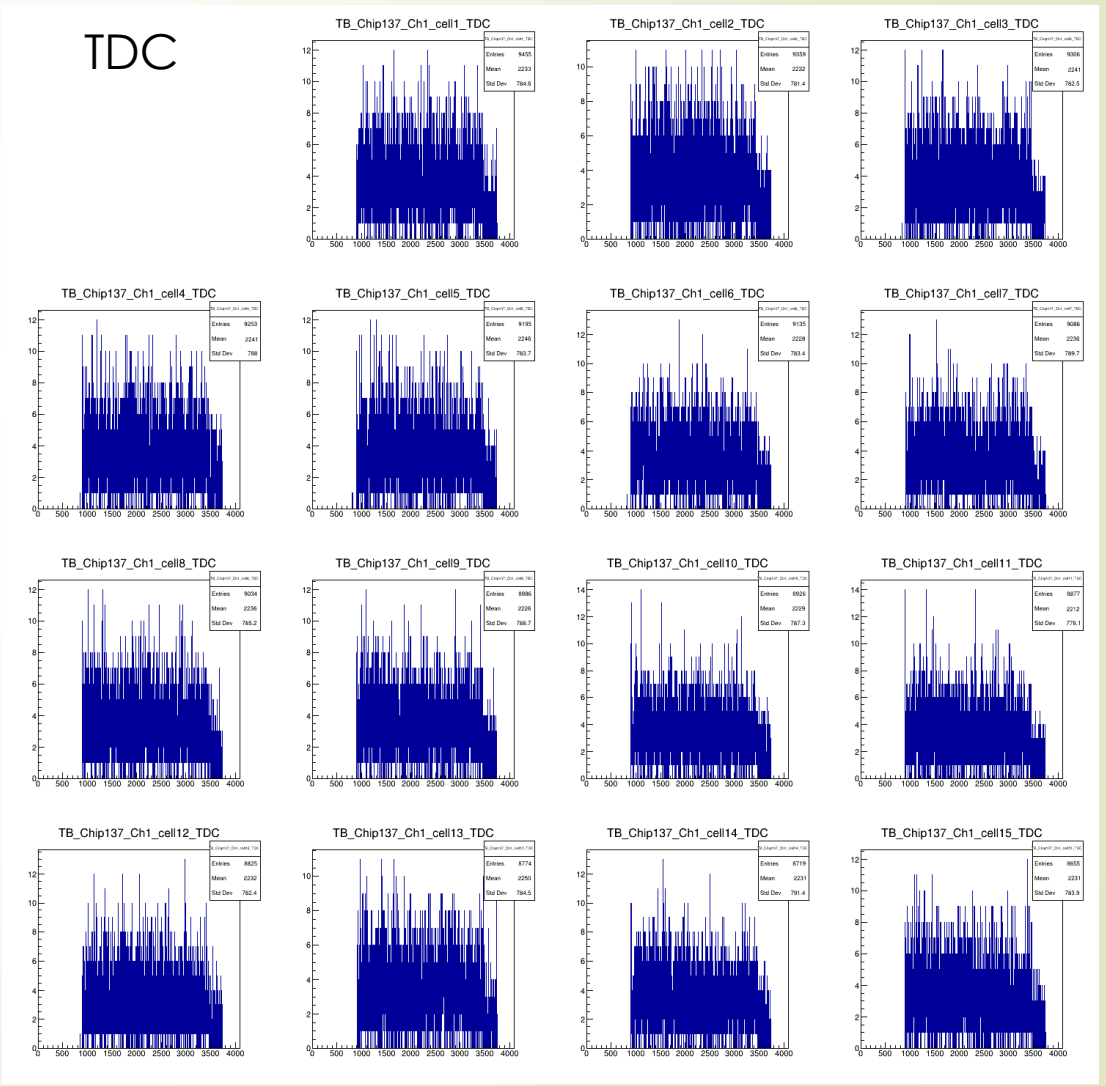
Before bunchXID cut

TDC



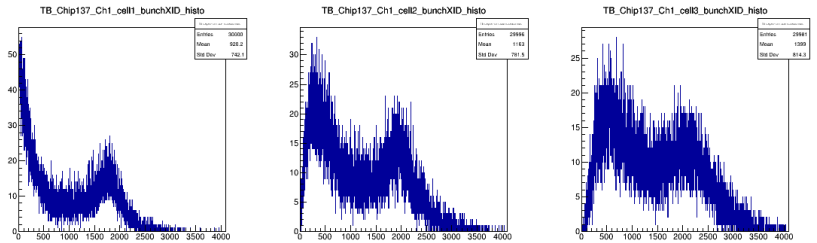
after bunchXID cut

TDC

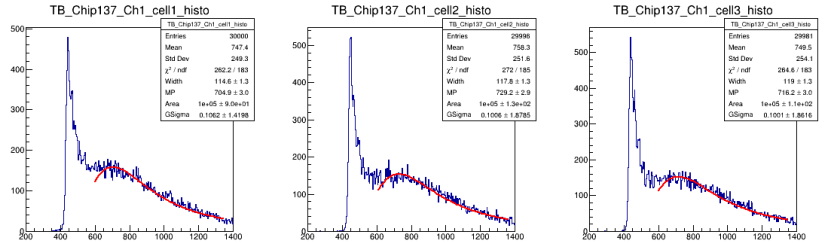


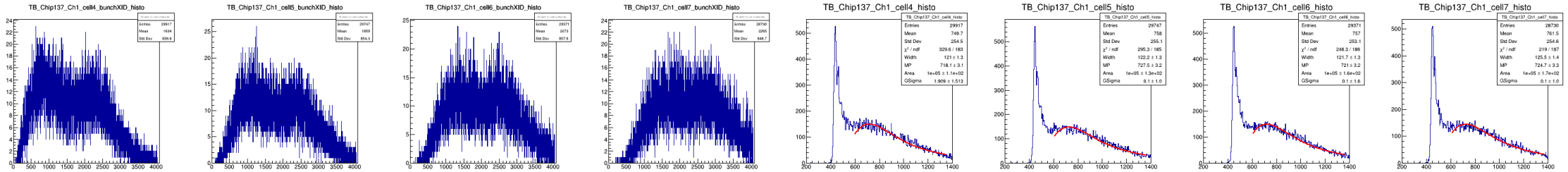
MIP measurement with collimater(Chip1ch1)

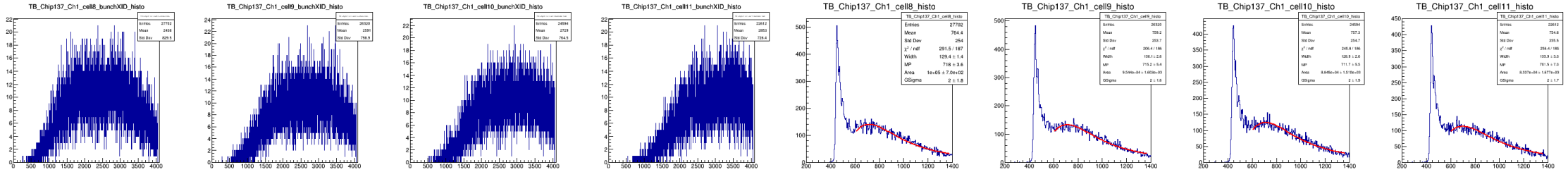
bunchXID

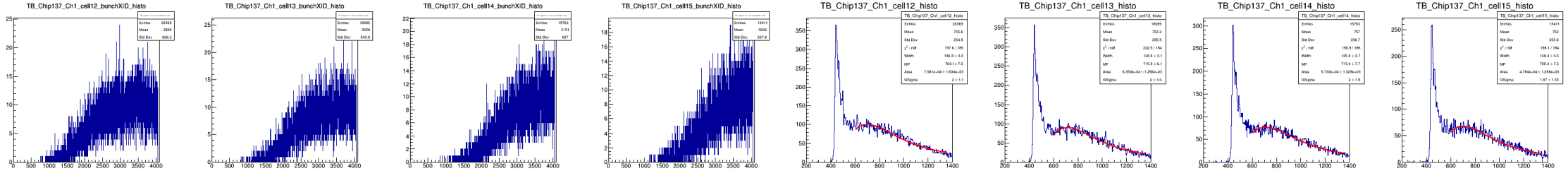


ADC



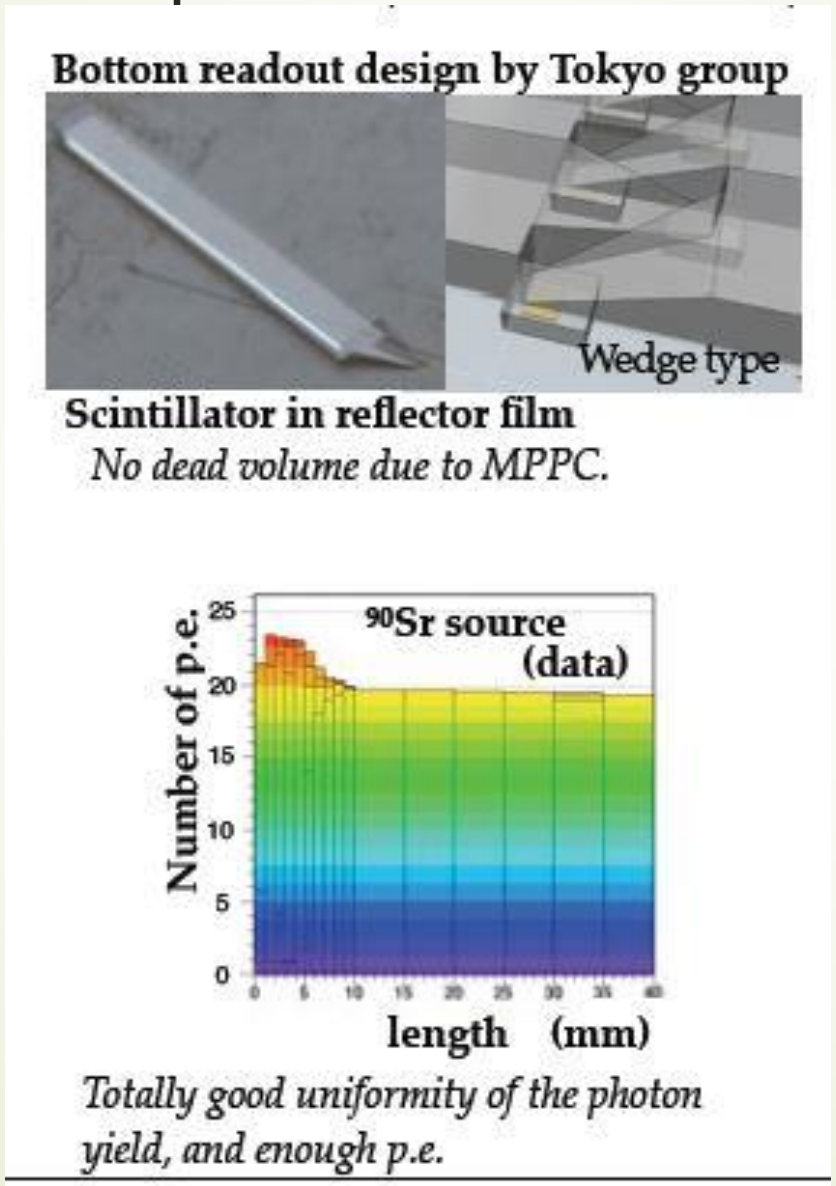






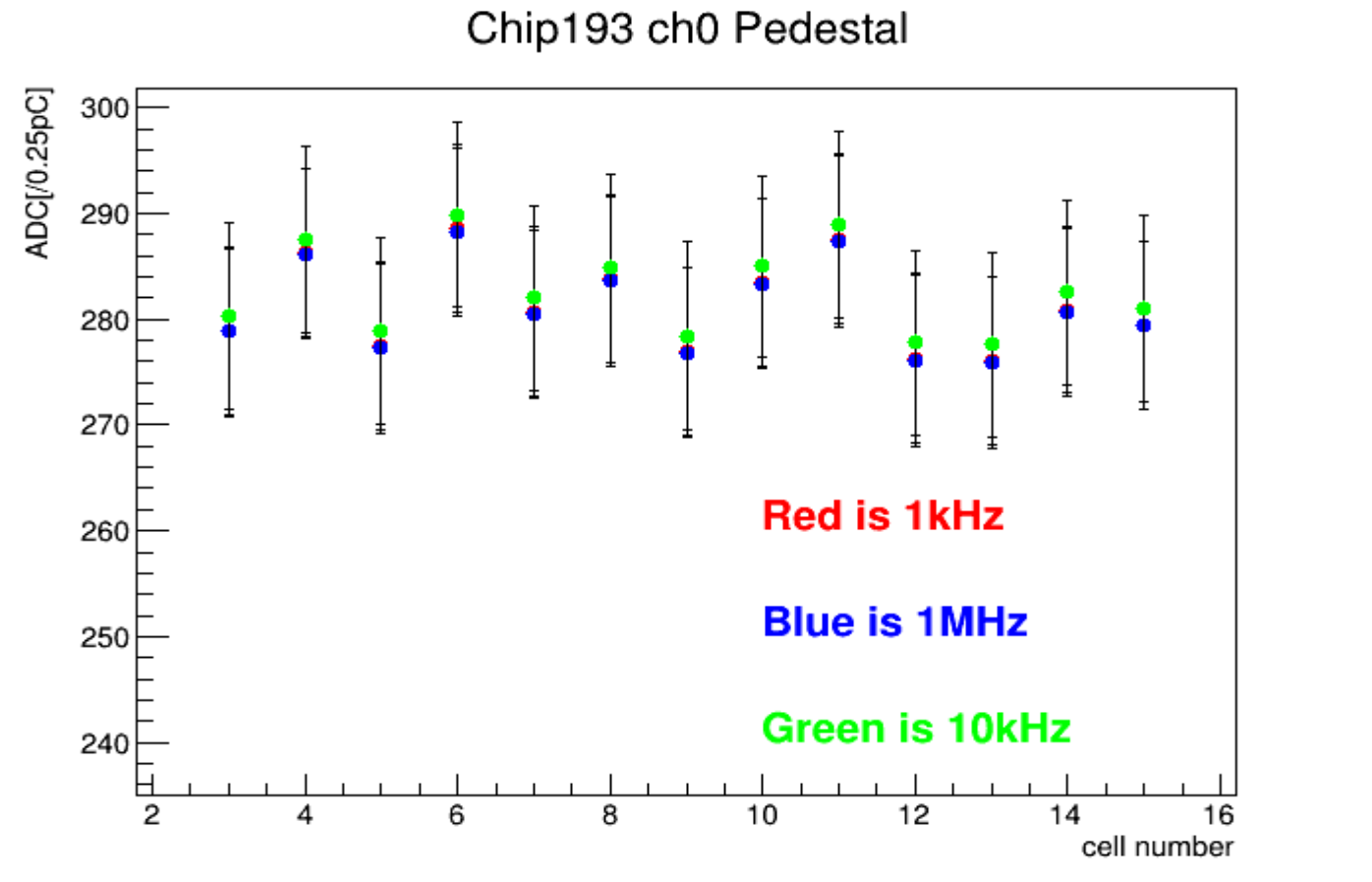
- Φ＝1.5mm

Wedge shape scintillator



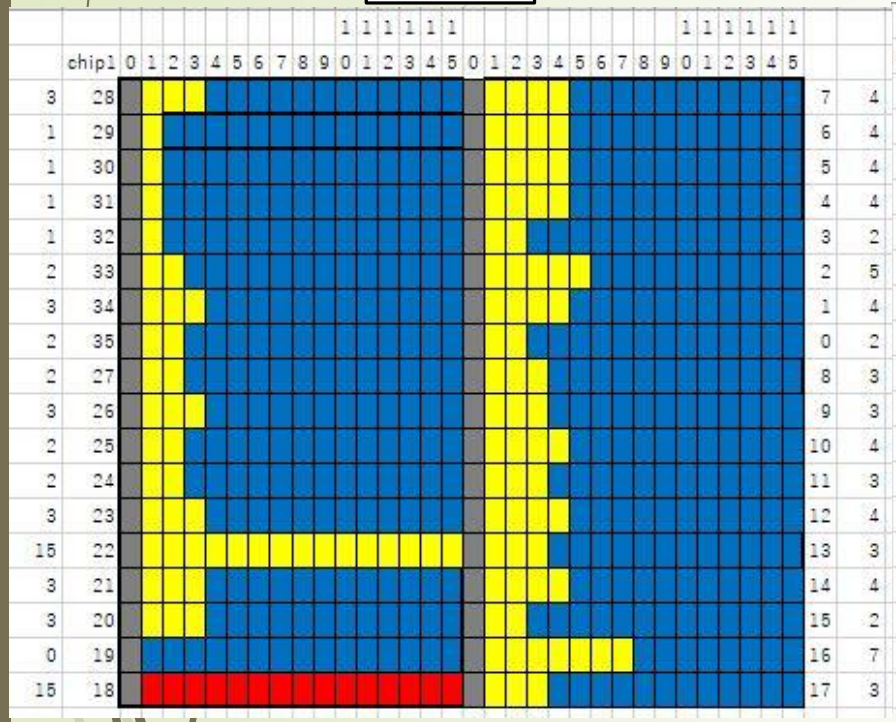
From K.Kotera at SCINT 2015 @ Berkeley

Pedestal measurement with clock changed

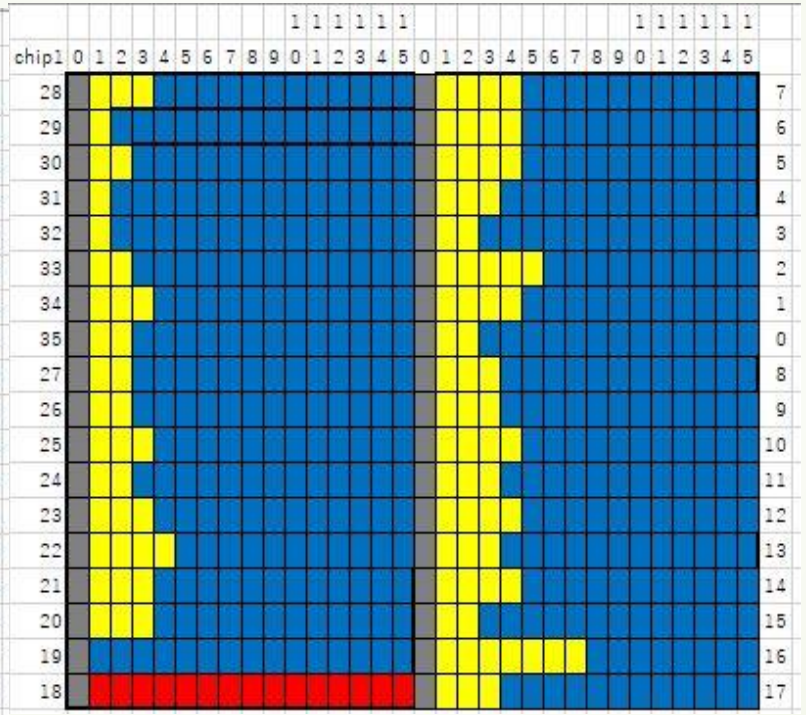


Pedestal measurement with clock changed

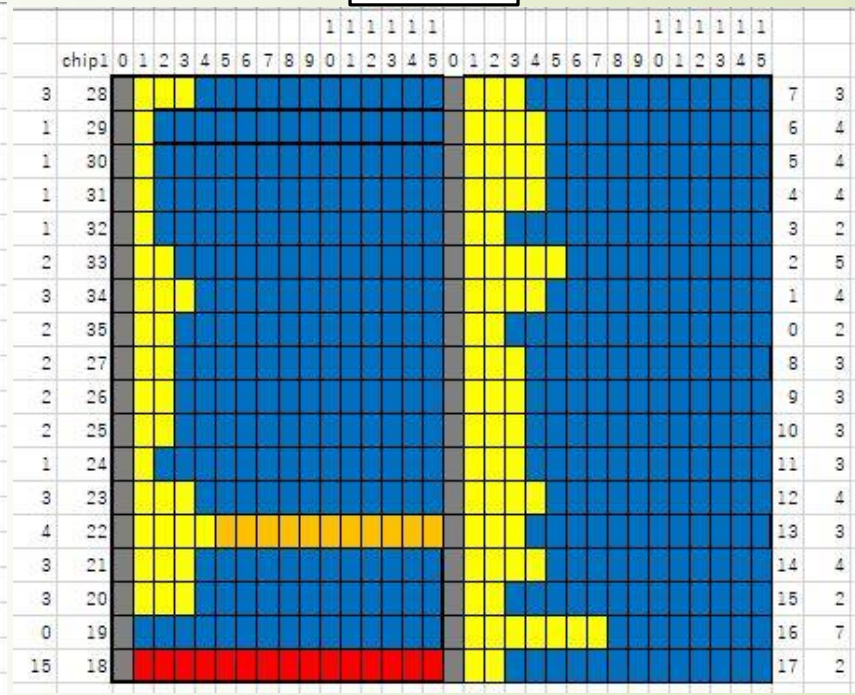
1KHz



10KHz



1MHz



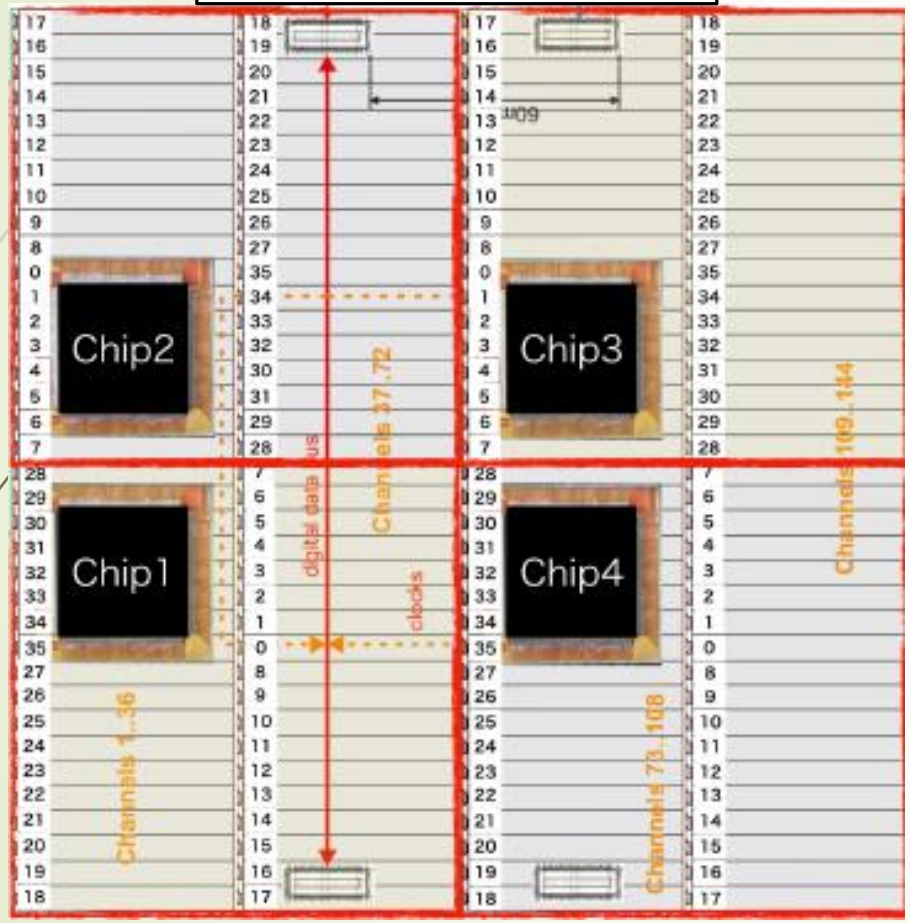
Blue : gaussian distribution

Yellow: : non-gaussian distribution

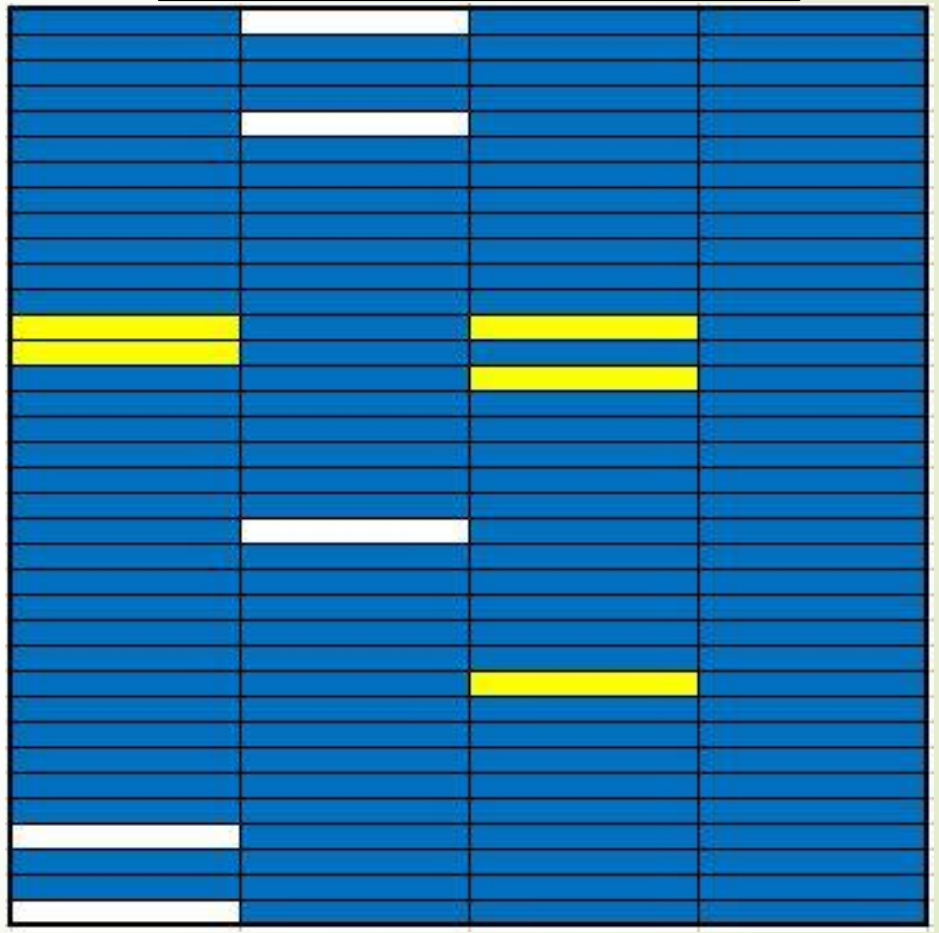
Orange : noisy Red : broken

Use 90Sr without collimater, MIP measurement(at all channel)

channel-map of EBU



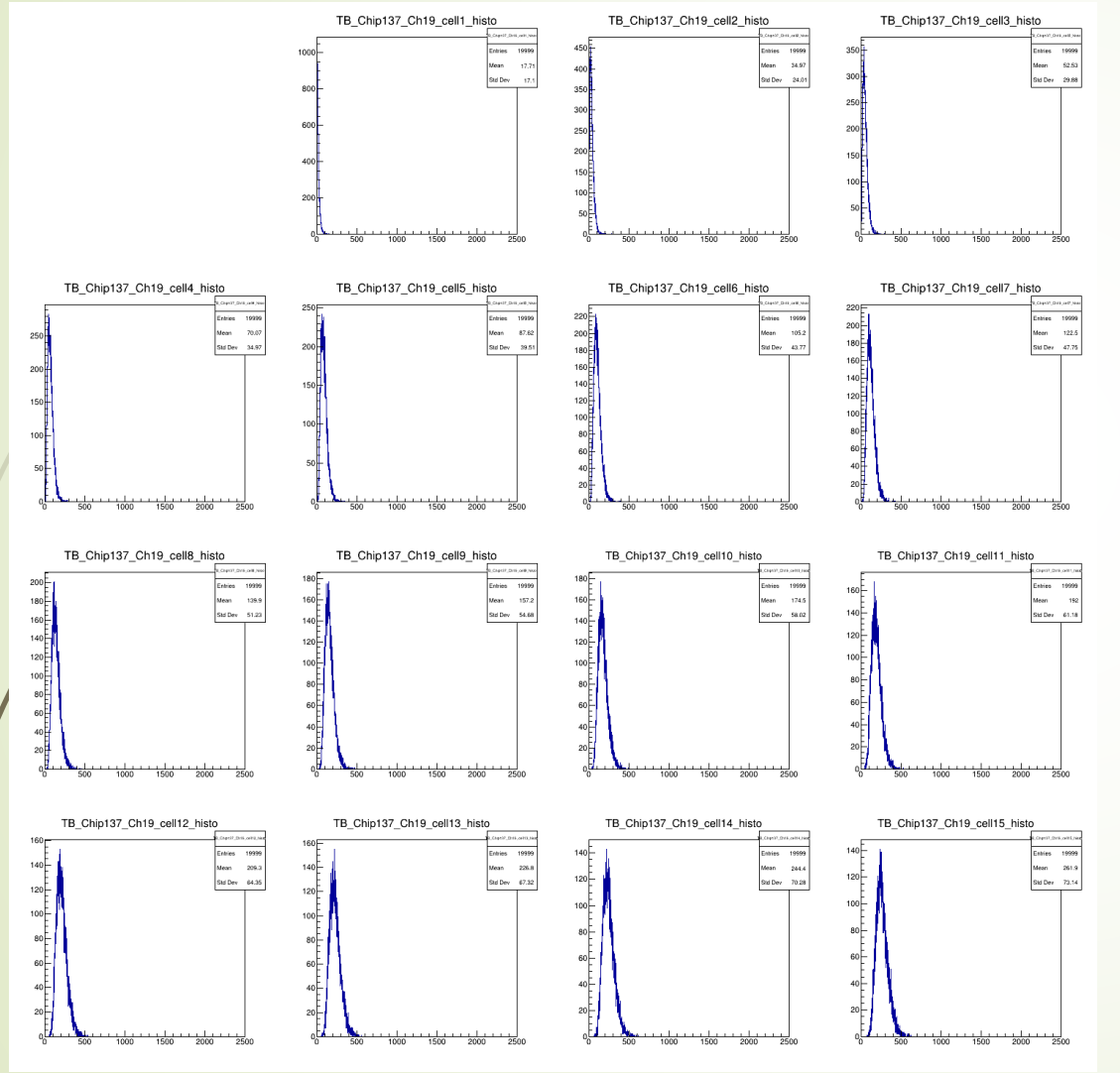
Map of result of 90Sr test

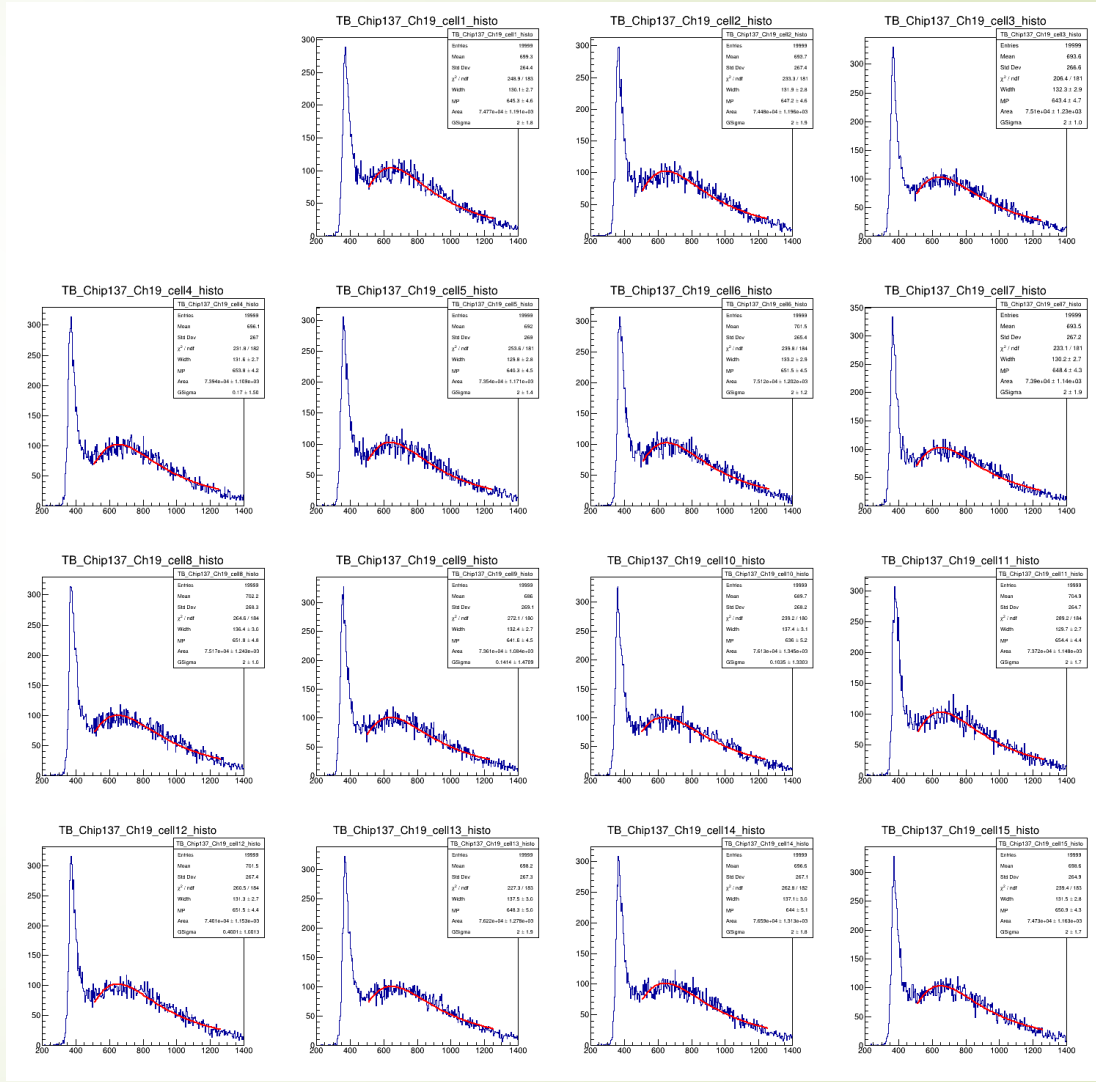


- 134/144ch confirms 90Sr peak is separation.

MIP is separation
MIP is not well separated
MIP is not measurment

Chip1 ch19 ADC, bunchXID

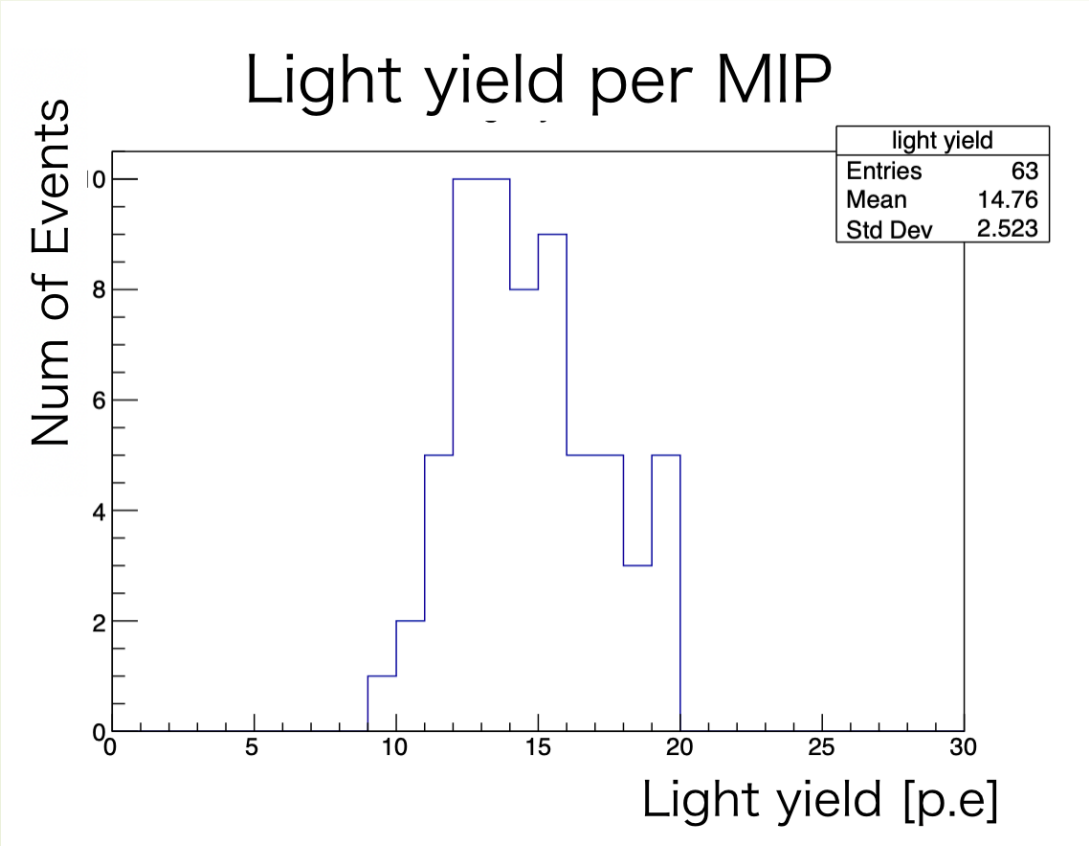




- Only ch19's bunchXID shows that.

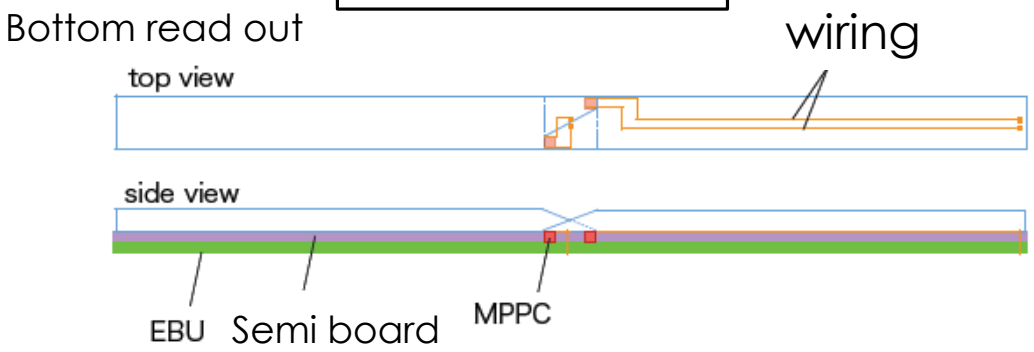
Light yield per 1MIP at bottom readout

- From Yoshimura at Shinshu-University in 2018

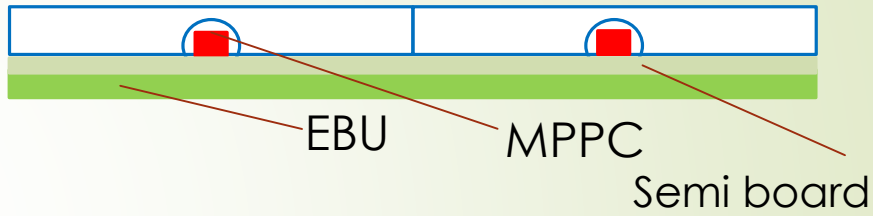


Direction to new EBU

bottomreadout



Centerholereadout



- The new EBU will make a hole in the center of the scintillator and put the MPPC in the hole.
- EBU and MPPC join EBU and MPPC by using intermediate base.
- Eliminates insensitive areas just like wedge scintillators.

※2014年度修士論文東京大学大学院　家城斉『国際リニアコライダーのためのシンチレータ電磁カロリメータの新しいシンチレーション光読み出しデザインの開発』より引用