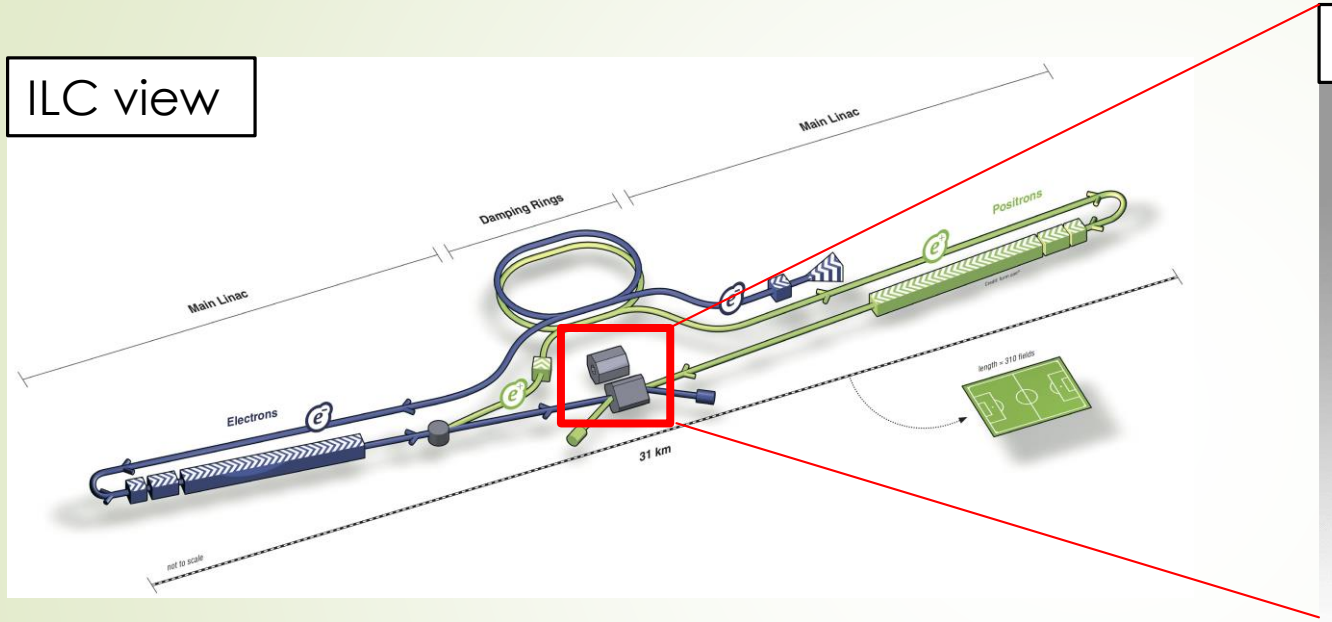
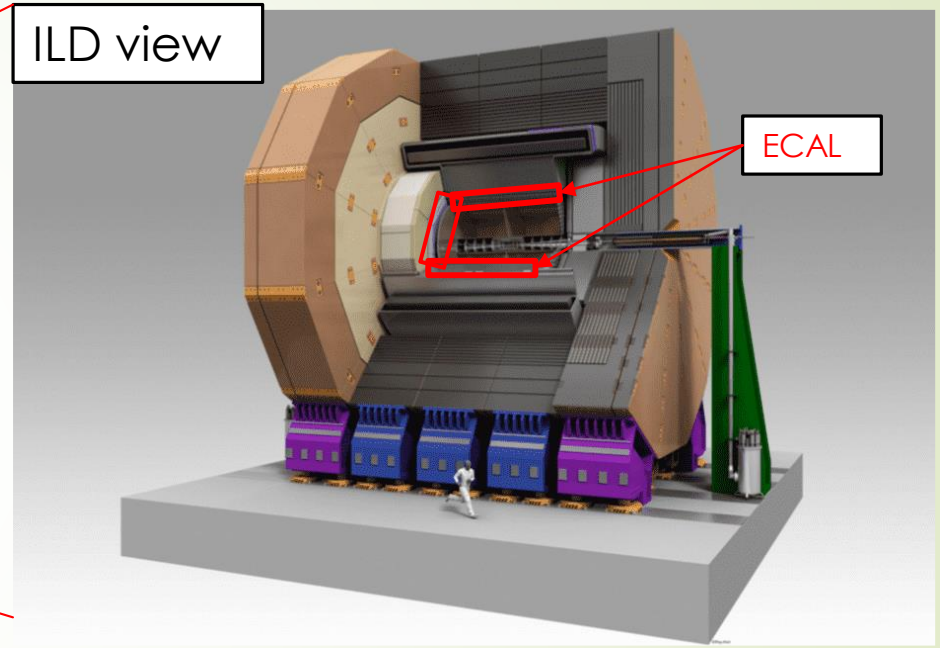
Performance evaluation and new development of prototype EBUs

Shinshu-University Yukinaru Tamaya

On behalf of Calice ScECAL

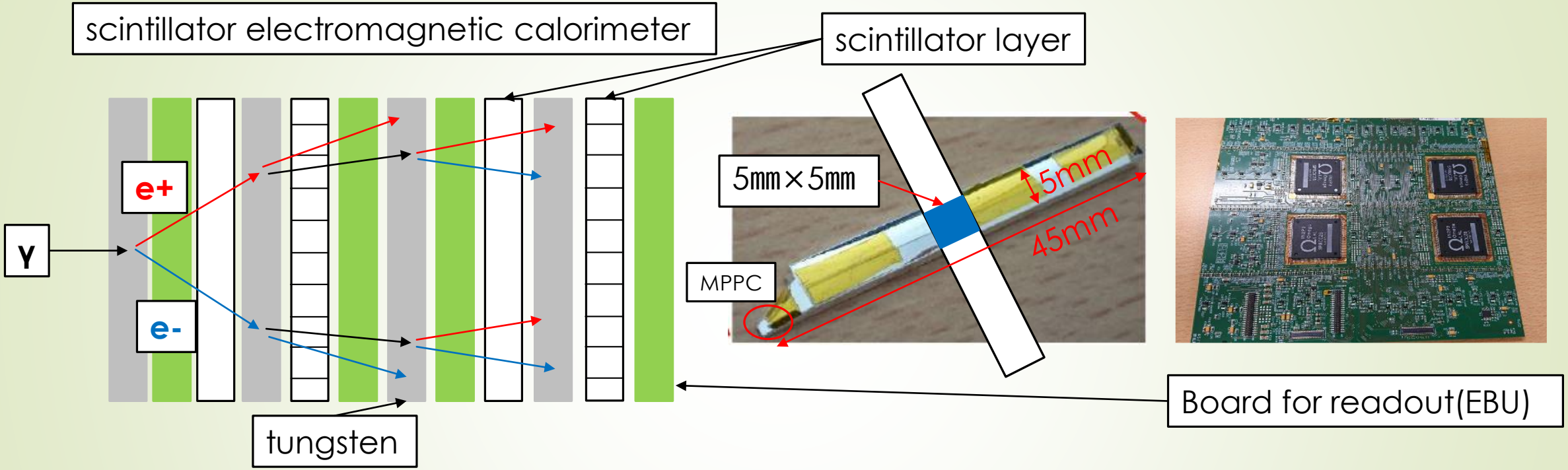
2 International linear Collider (ILC) and ILD





- 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.

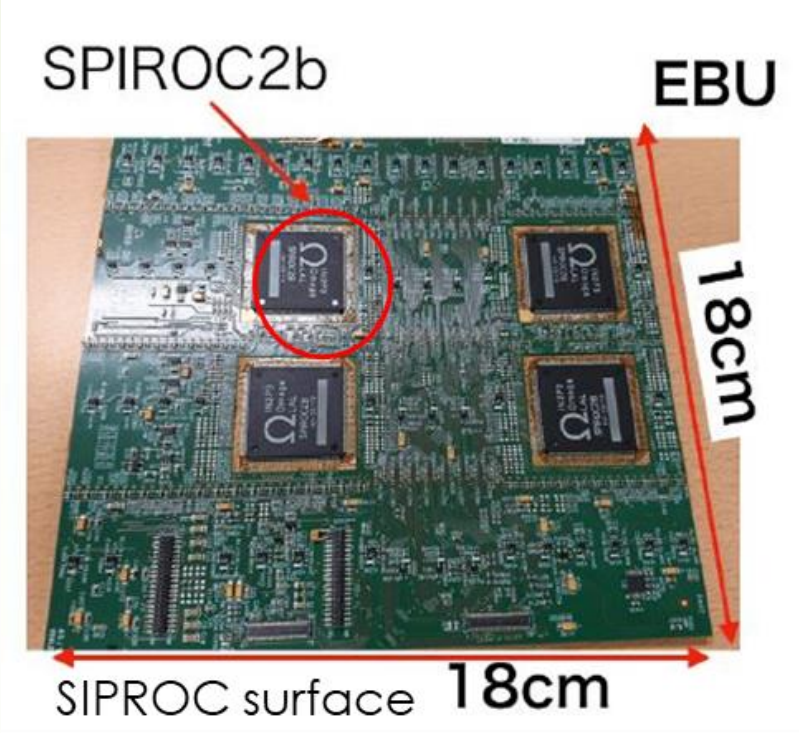
Scintillator electromagnetic calorimeter

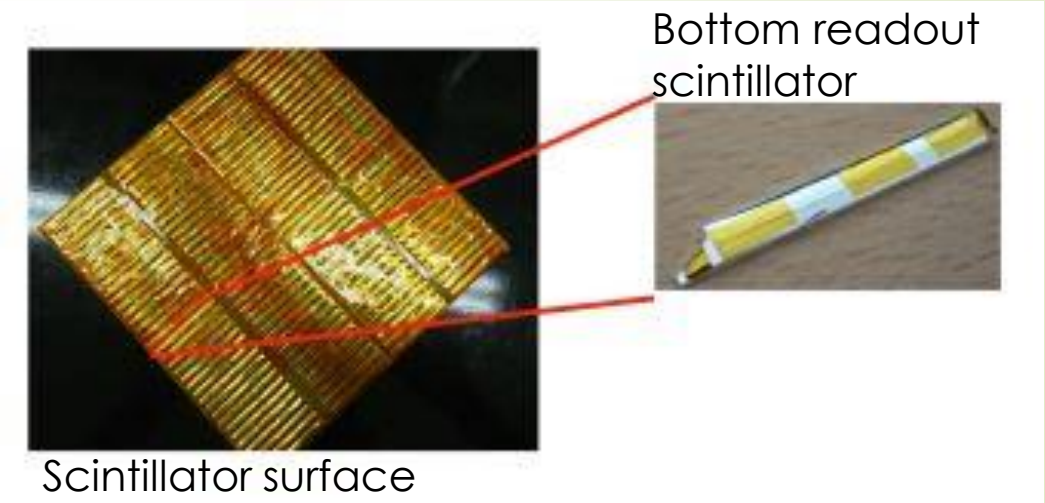


- Scintillator electromagnetic calorimeter adapts tungsten in absorption layers, scintillators and board for readouts(EBU) in detection layers.
- The size of scintillator is 45mm×5mm×2mm.
- Scintillator layer with crossed strips has 5mm×5mm spatial resolution.
- EBU is the front end of the data acquisition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

4 ECAL Base Unit(EBU)

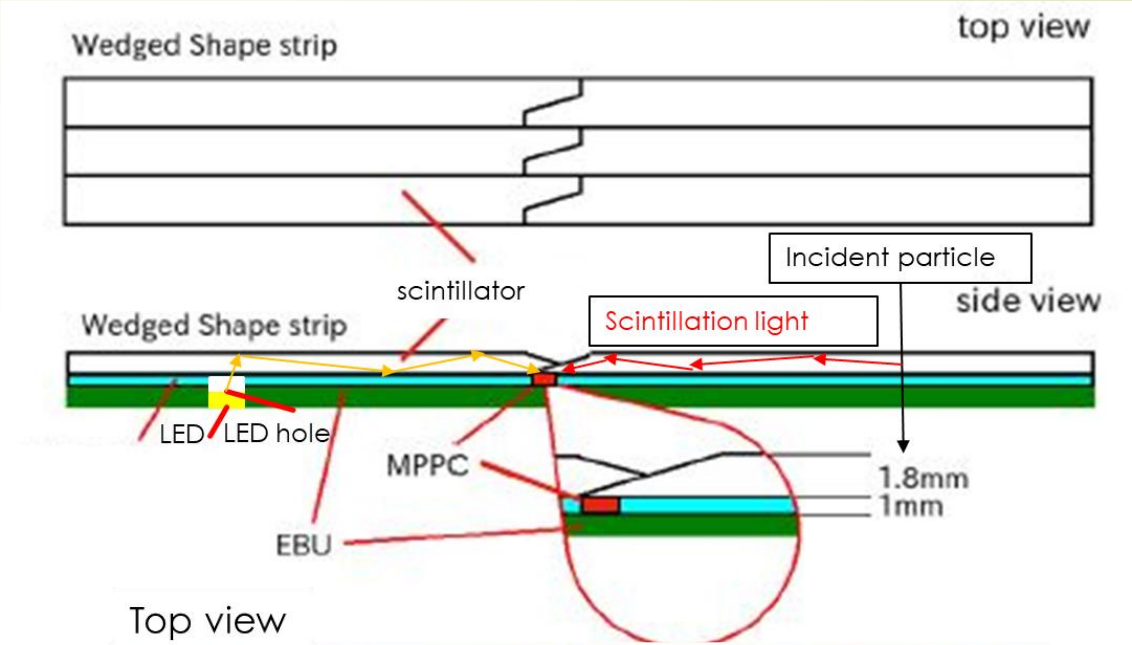
- EBU is fabricated by DESY.
- EBU consists of electric parts surface and scintillator surface.
- One EBU is a PC board with 144 MPPCs and 144 scintillators.
- One EBU is equipped with four ASICs called SPIROC2b which is developed by OMEGA group.
- One SPIROC2b can handle 36ch of MPPCs signals to amplify, shaping and digitize and adjust each applied voltage.

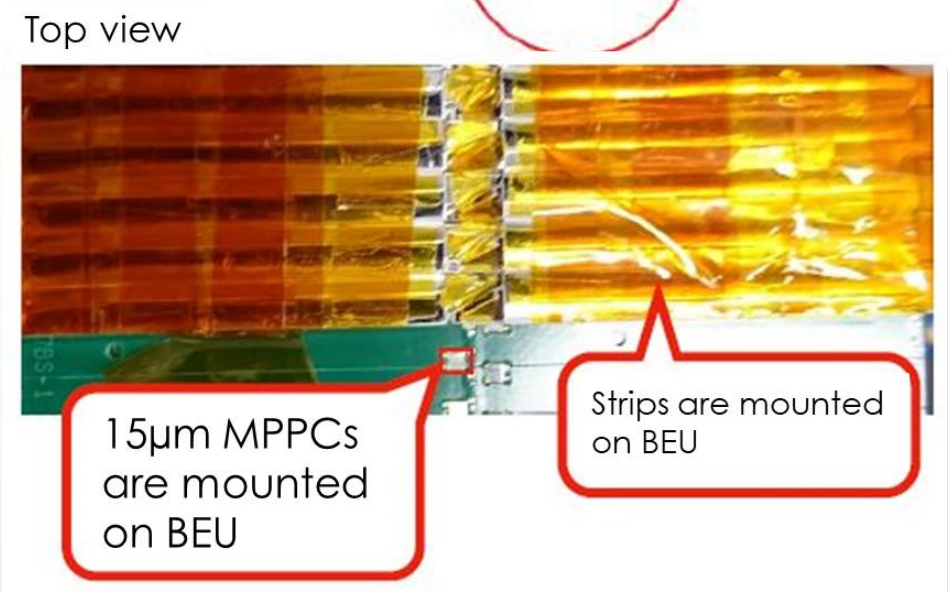




5 Bottom readout scintillator

- 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.
- For LED calibration of MPPCs, EBU equips LEDs for each MPPCs.





6 SPIROC2b on EBU

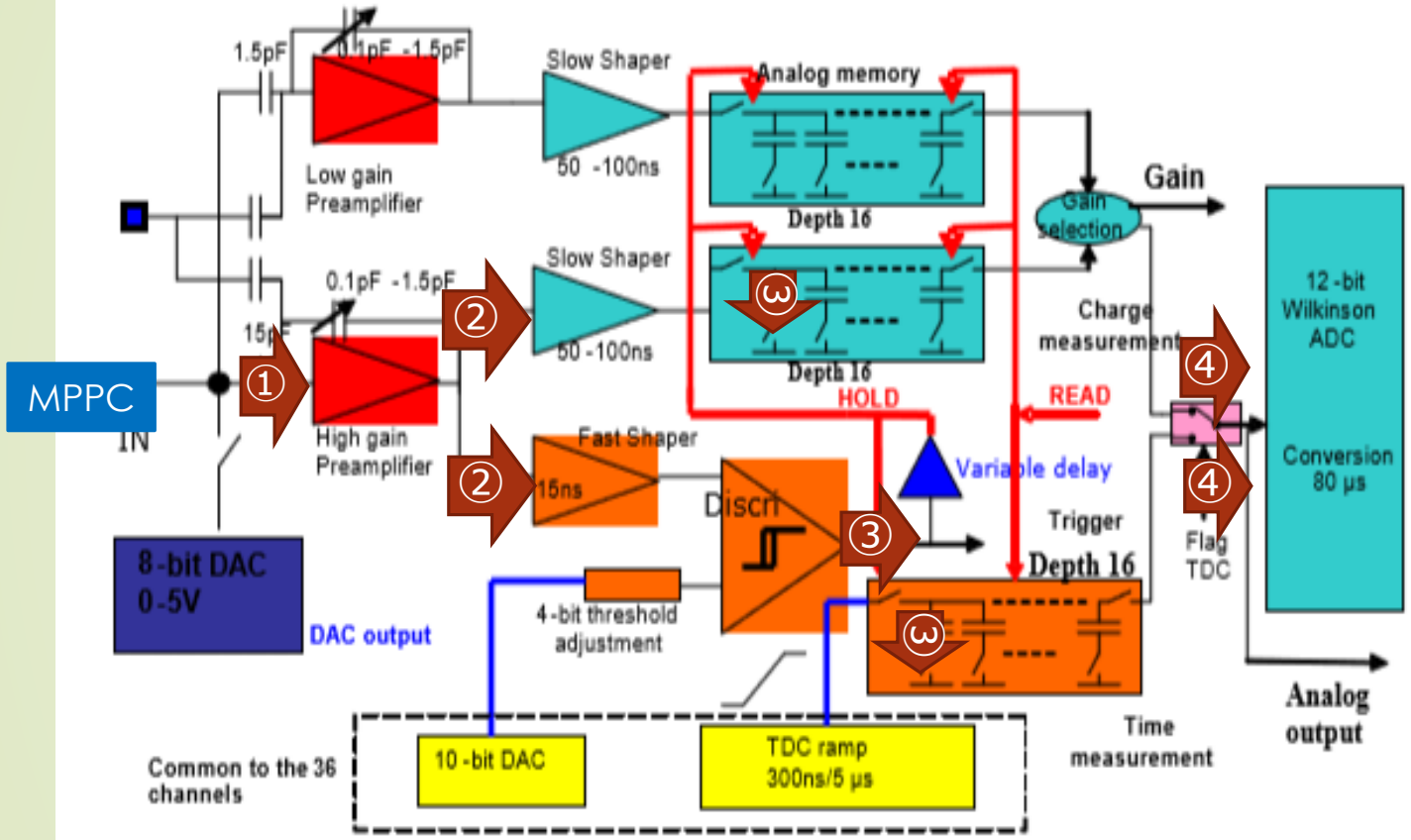


Figure 8: SPIROC one channel diagram

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.

7 LED calibration for each memory cell

SPIROC2b

SPIROC2b

Memory cell(0~15)

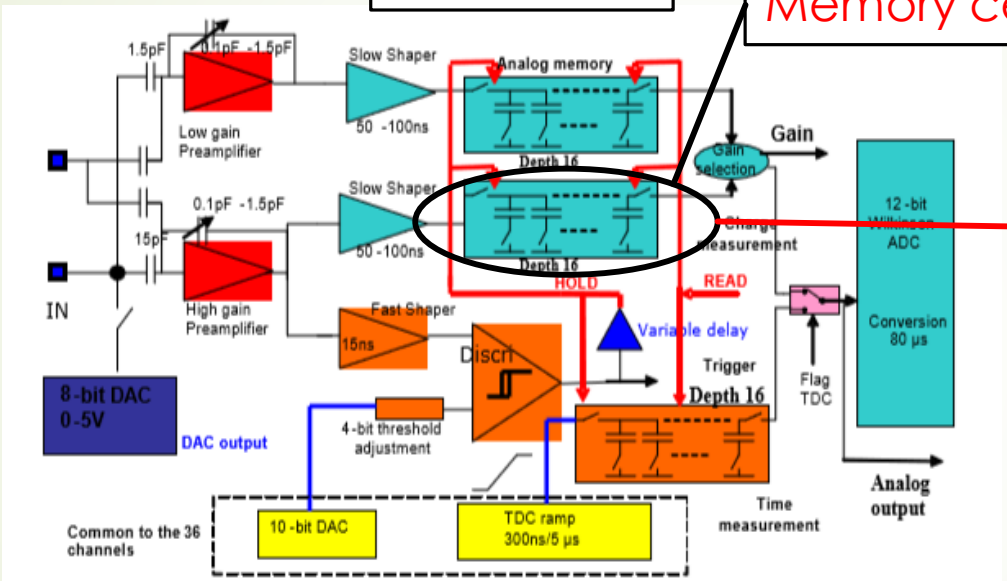
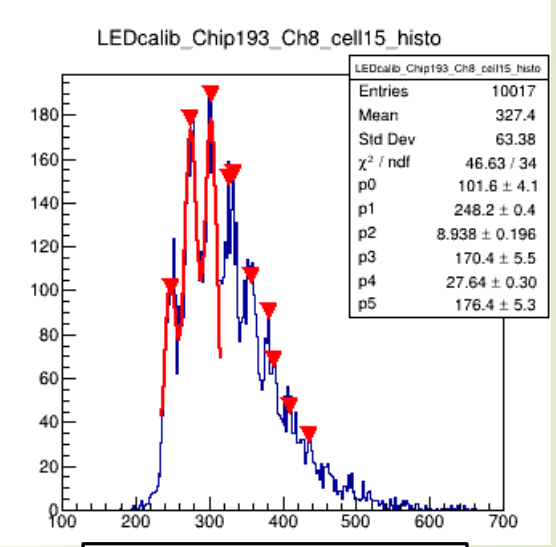


Figure 8: SPIROC one channel diagram



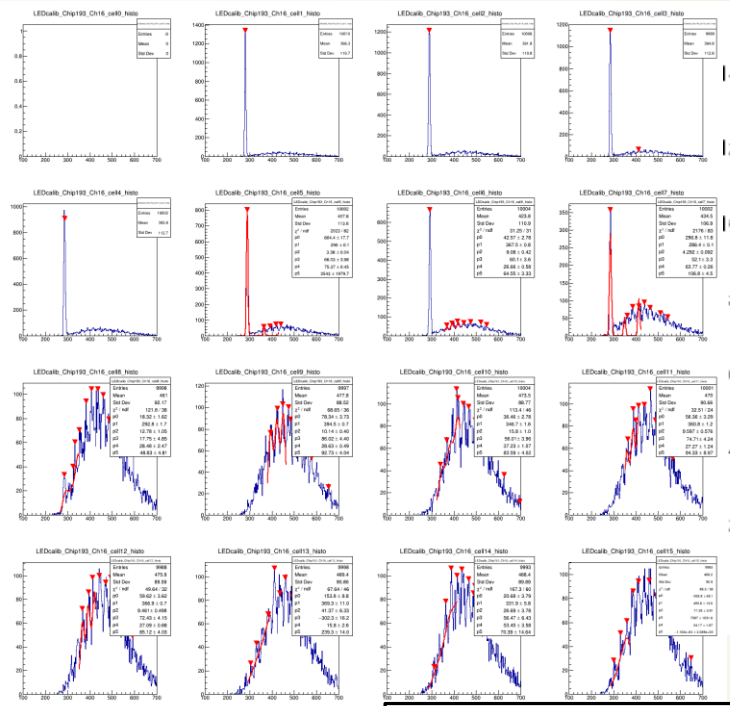
LEDcalibration

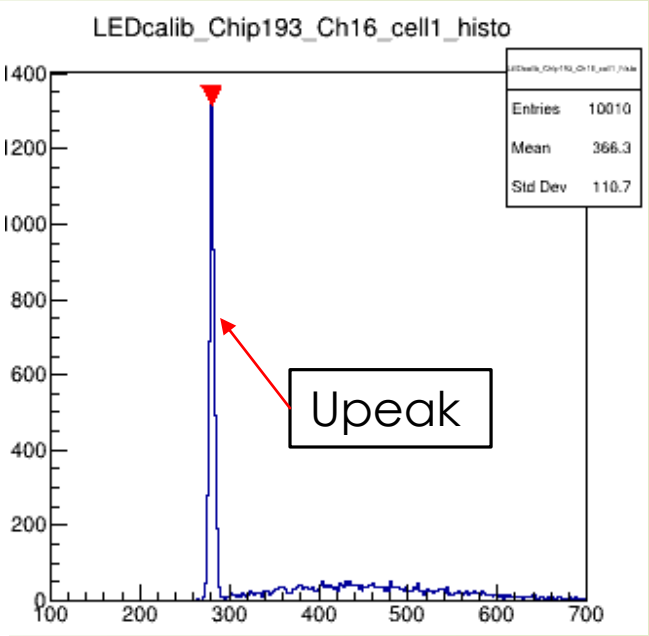
- As test of the memory cells, we measure LED calibration.
- The memory cells are properly functioning when photon peaks are separated.

8 Unidentified peak(Upeak)

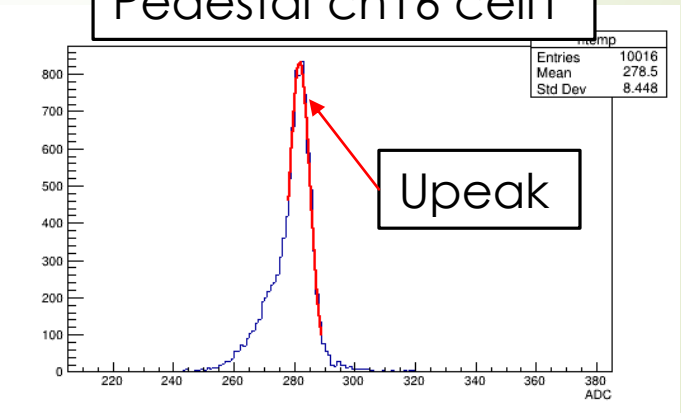
- There is sharp peak in lower memory cells(such as cell1～7 in ch16).
- We called the peak Unidentified Peak(Upeak).
- There is Upeak in Pedestal of lower memory cells, too.
- We have to identify the LED and Pedestal peaks by ignoring the Upeaks..

LED calibration in ch16



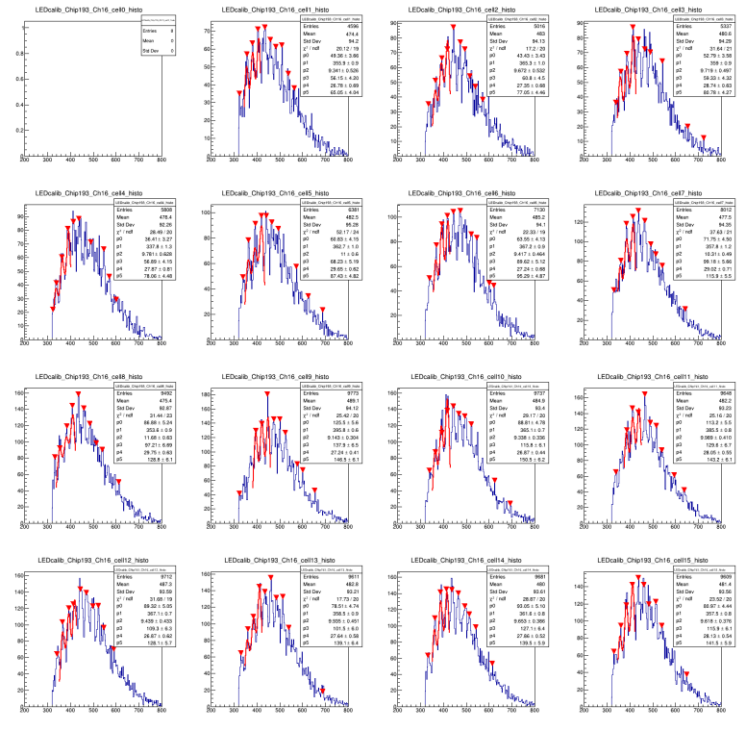


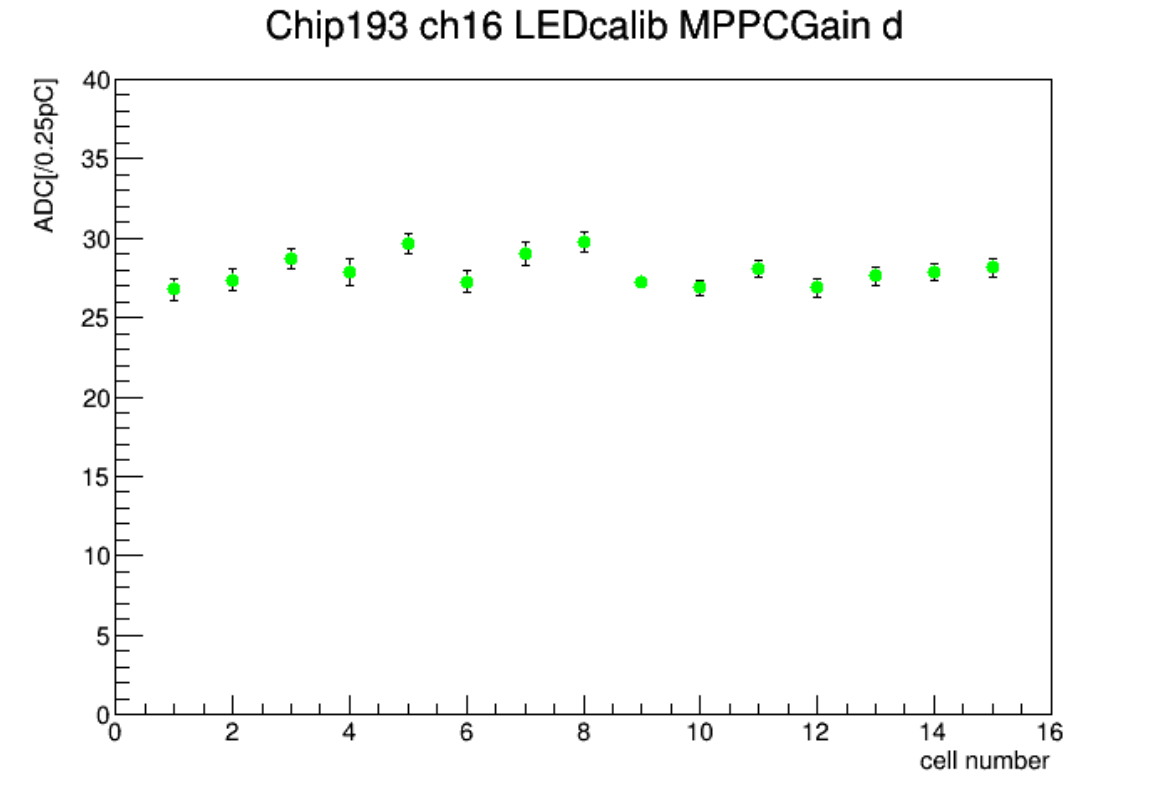
Pedestal ch16 cell1



9 LED calibration for each memory cell without Upeak

LED calibration in ch16 without Upeak



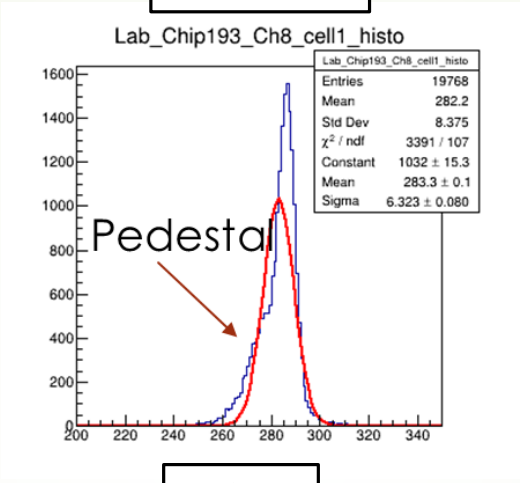


- We measure MPPC Gain without Upeak.
- Value of MPPC Gain in all memory cells are constant.

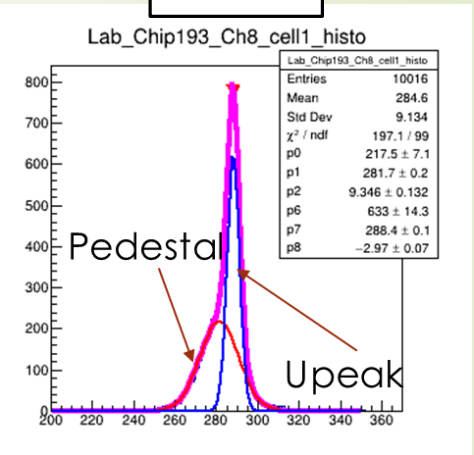
10 Redefine Pedestal measurement

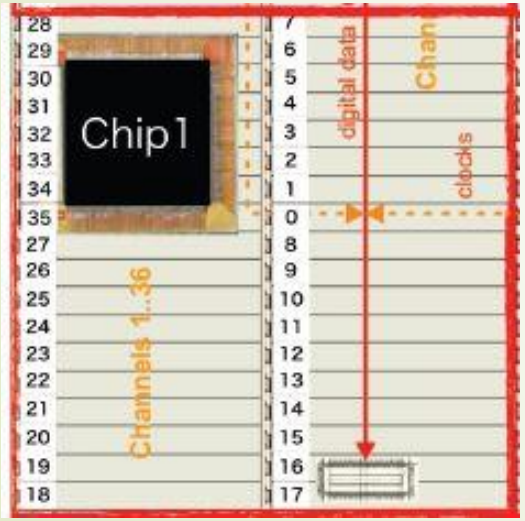
- We redefine that Pedestal is double gaussian distribution in lower memory cells.
- Pedestal is gaussian distribution in all memory cells.

before



after





Blue : gaussian distribution

Yellow: : non-gaussian distribution

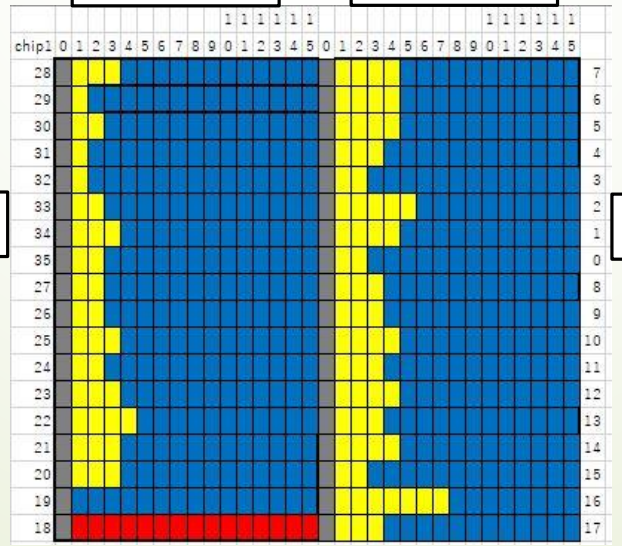
Red : broken

chip1

Memory cell

Memory cell

ch



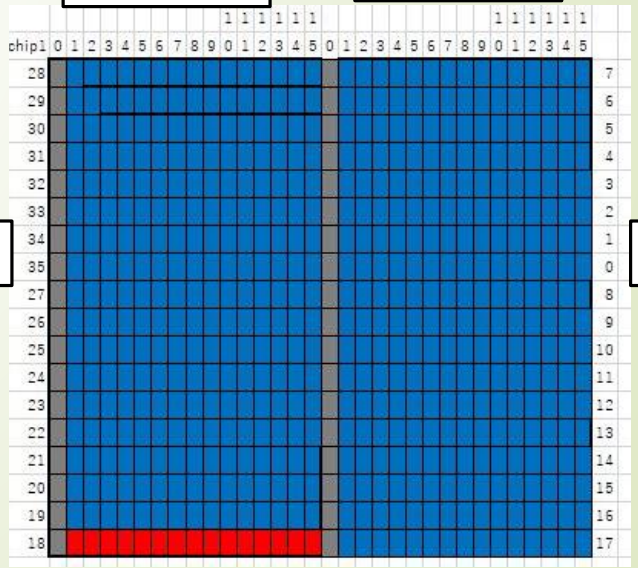
ch

chip1

Memory cell

Memory cell

ch

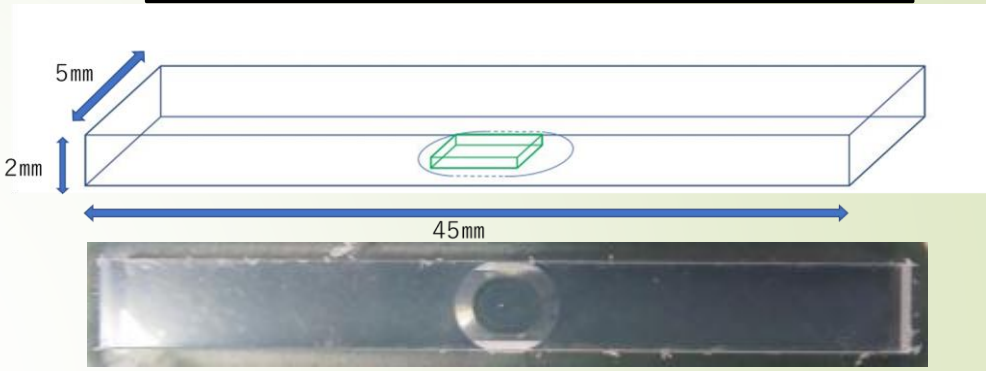


ch

11 Center hole readout EBU

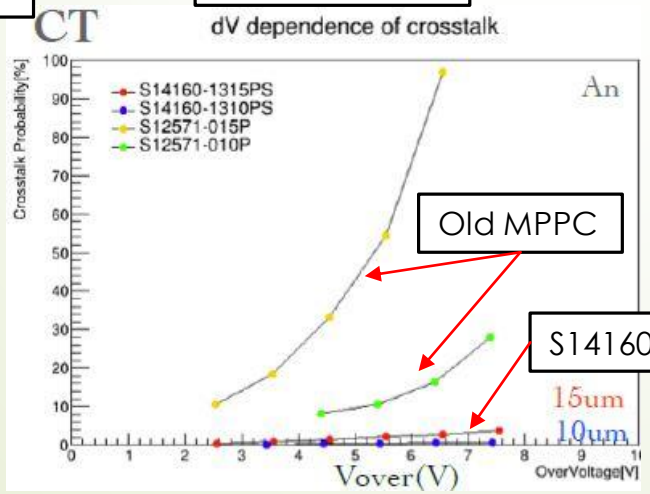
- We are developing a new prototype EBU.
- New prototype EBU is equipping center hole readout scintillator strips.
- S14160 type MPPC on center hole readout EBU has cross talk less than old MPPC.

Center hole scintillator(SCSN)

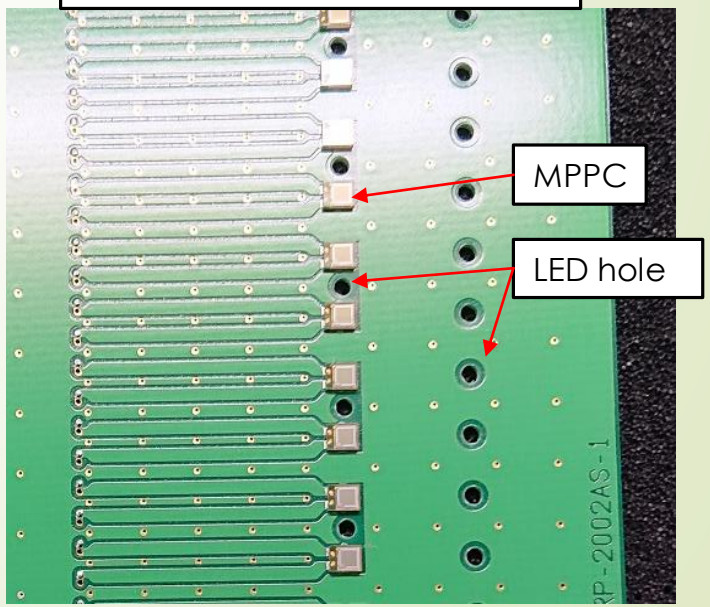


S14160 type MPPC

Cross talk

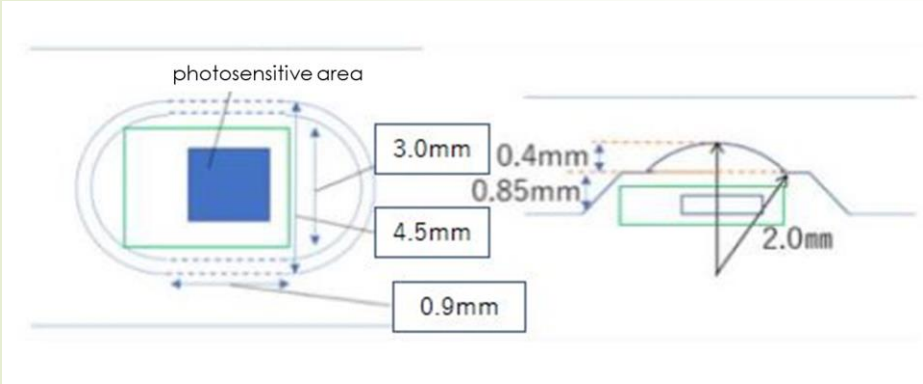


Center hole readout

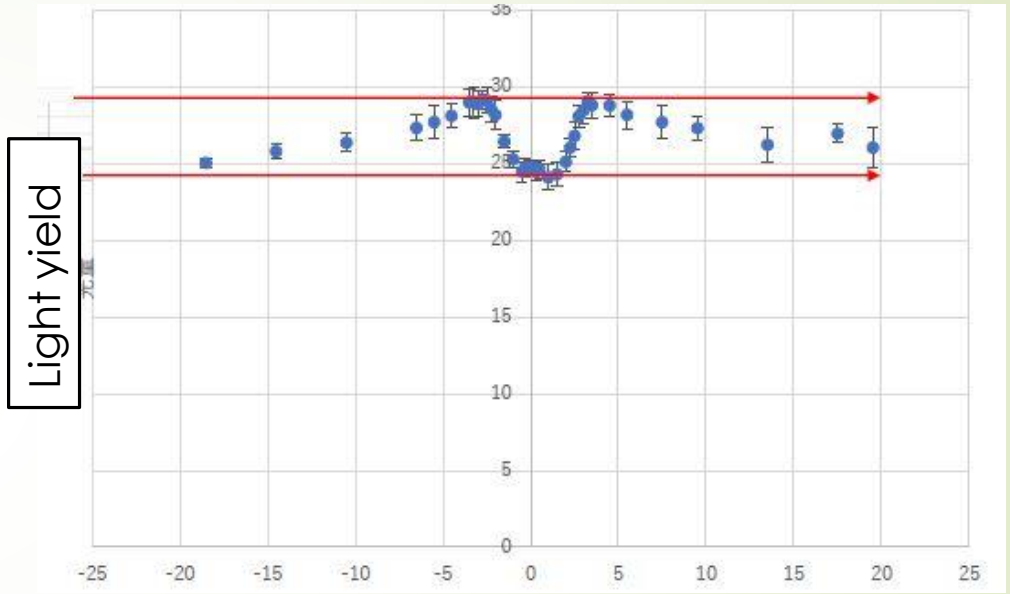


Center hole scintillator

Shape of center hole (shirai model)



Unifomity of light yield in shirai model

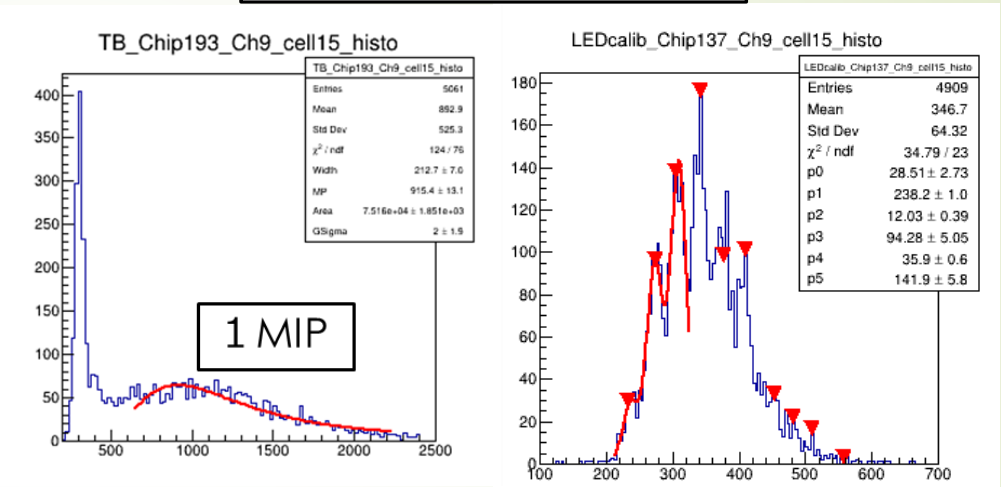


- We made center hole scintillator(shirai model).
- Feature of Shirai model has a depression of sphere.

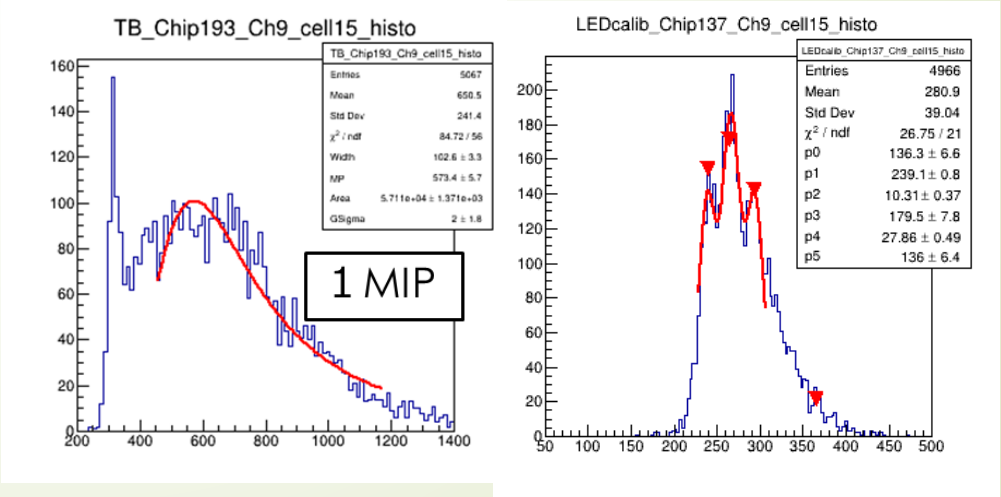
13 MPPC for center hole readout EBU

- There are two type of S14160 type MPPC.
- S14160- 1315PS has APD of 15μm pitch.
- S14160-1310PS has APD of 10μm pitch.
- Two type MPPC can measure MIP and LED calibration on EBU so we can mount 10μm or 15μm type MPPC on EBU.
- We have decided to use S14160-1315PS MPPC to mount on EBU.

APD of 15μm pitch



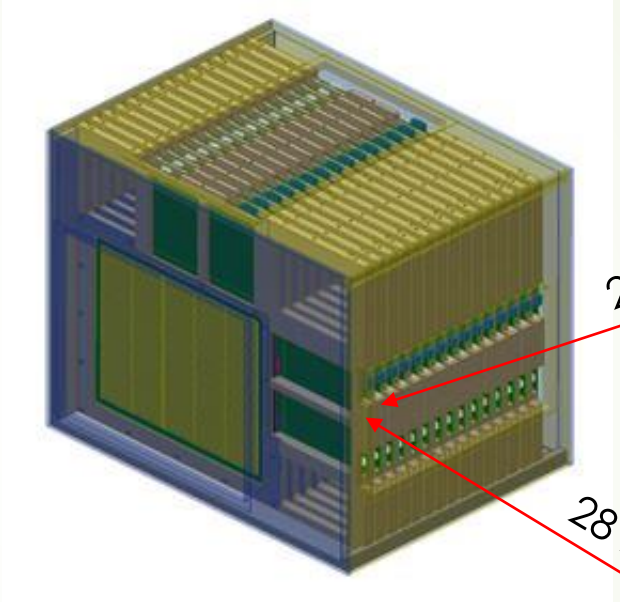
APD of 10μm pitch



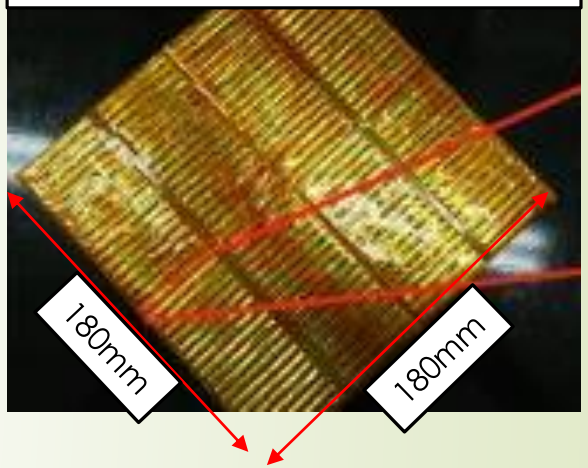
Beam test in DESY with USTC and IHEP

- We(Shinshu and Tokyo/ICEPP) will carry out a beam test with USTC and IHEP at DESY.
- We plan that shinshu's 2 layers EBU mount in USTC's the structure, and we will take data of 30 layers EBU.
- we have to unity shinshu's DAQ system(use CCC and LDA) and USTC's DAQ system(use FELIX).

Structure to mount 30 layers EBU*



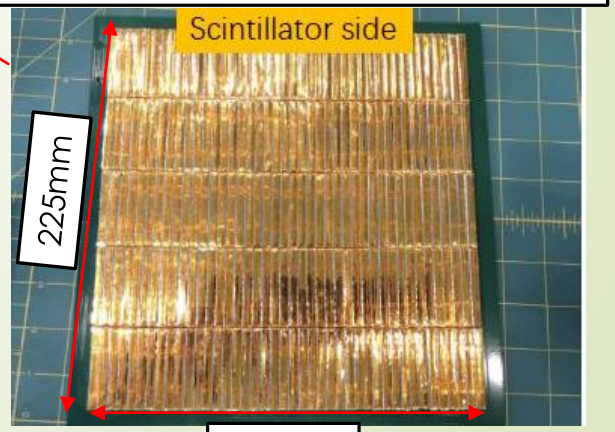
Shinshu's EBU is 2 layers



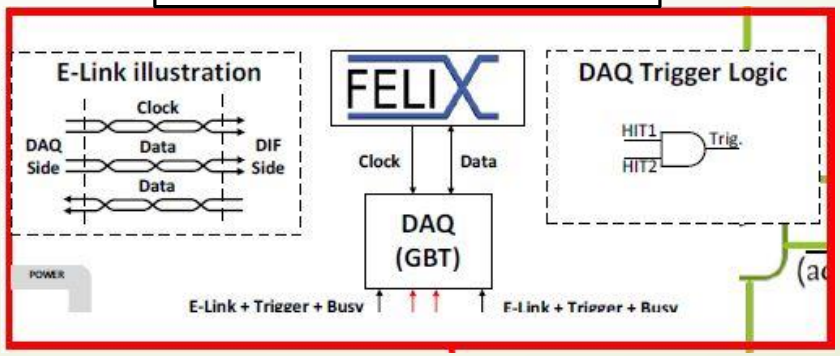
2 layers

28 layers

USTC's EBU is 30 layers*
And ICEPP's EBU is 2 layers



USTC's DAQ system*



※Reference figure author : Yazhou Niu

summary

- Bottom readout EBU

There is Upeak in Pedestal and LED calibration of lower memory cells.

We can take MPPC Gain in each memory cells according to remove or ignore Upeak.

We have redefined Pedestal. we used double gaussian fitting so Pedestal is gaussian distribution in all memory cells.

- Center hole readout EBU

We made center hole scintillator (shirai model).

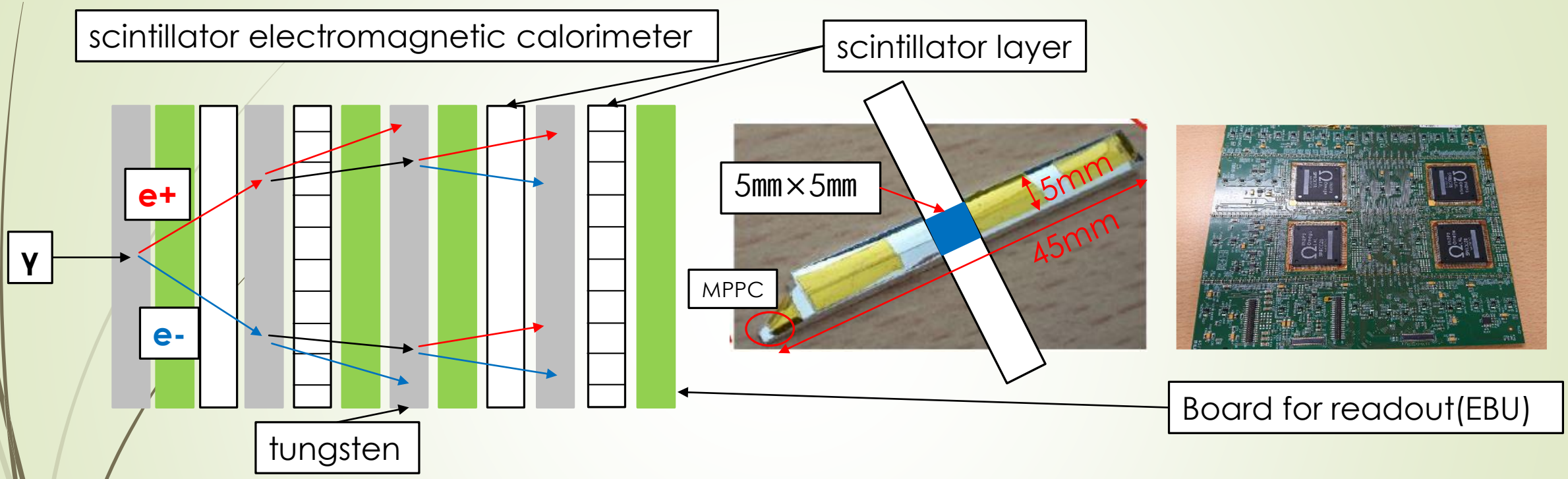
We have decided to use 15μm of S14160 type MPPC on center hole readout EBU.

- Beam test with USTC and IHEP

We are preparing the structure to combine 2 layers EBU.

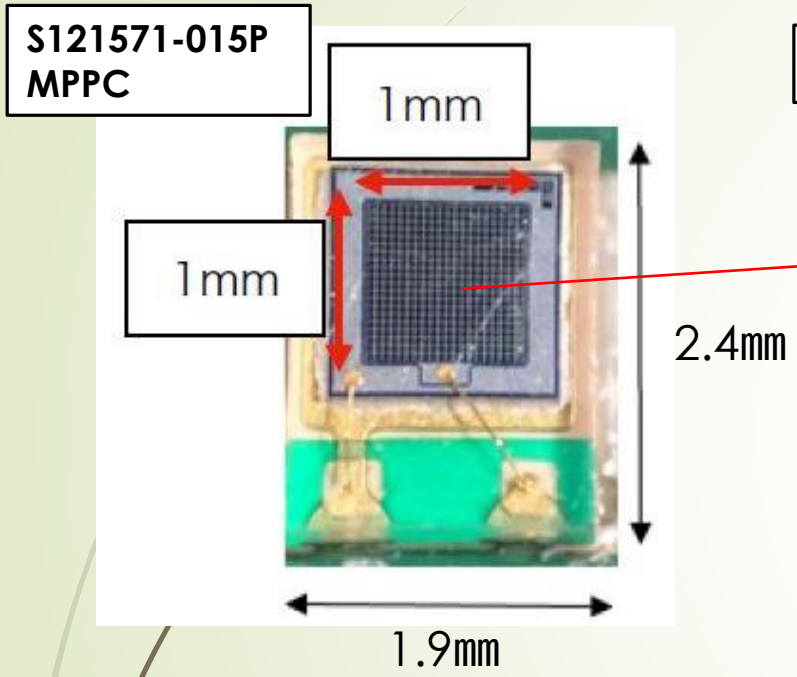
Back up

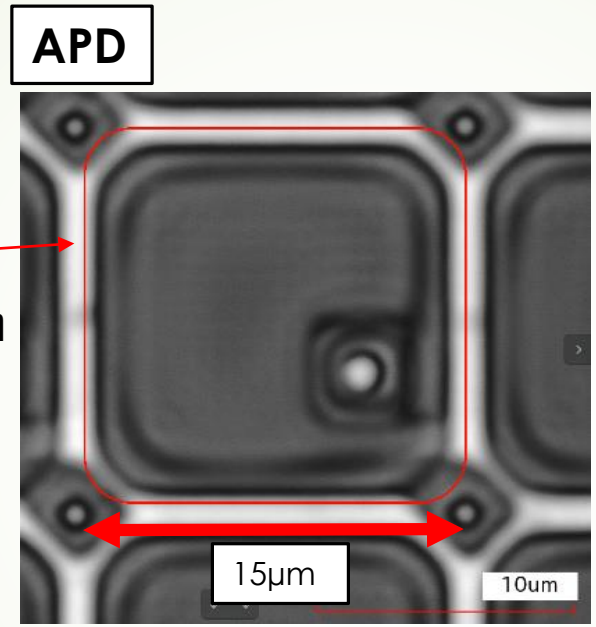
Scintillator electromagnetic calorimeter

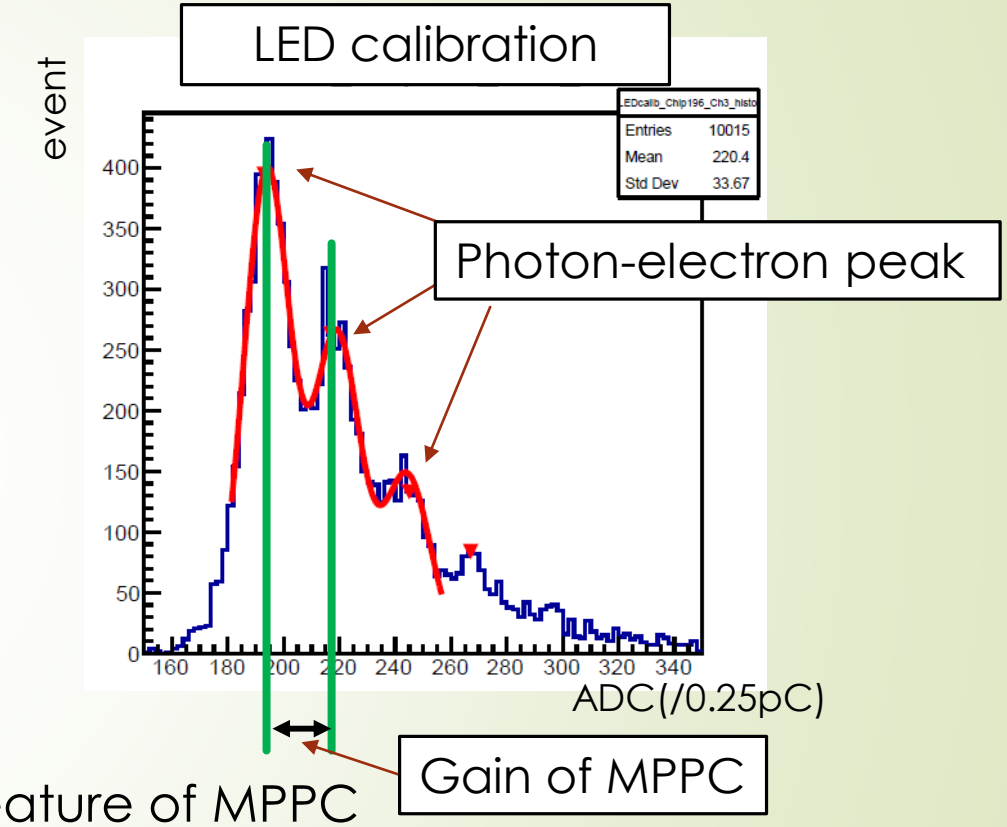


- Scintillator electromagnetic calorimeter adapts tungsten in absorption layers, scintillators in detection layers and board for readouts(EBU).
- The size of scintillator is 45mm×5mm×2mm.
- Scintillator layer with crossed strips has 5mm×5mm spatial resolution.
- EBU is the data acquisition system(DAQ)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

Multi-Pixel Photon Counter(MPPC) on bottom readout EBU







- MPPC is developed by Hamamatsu Photonics, Shinshu University and other universities.
- We Use MPPC of 1×1mm² 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

SPIROC2b on EBU

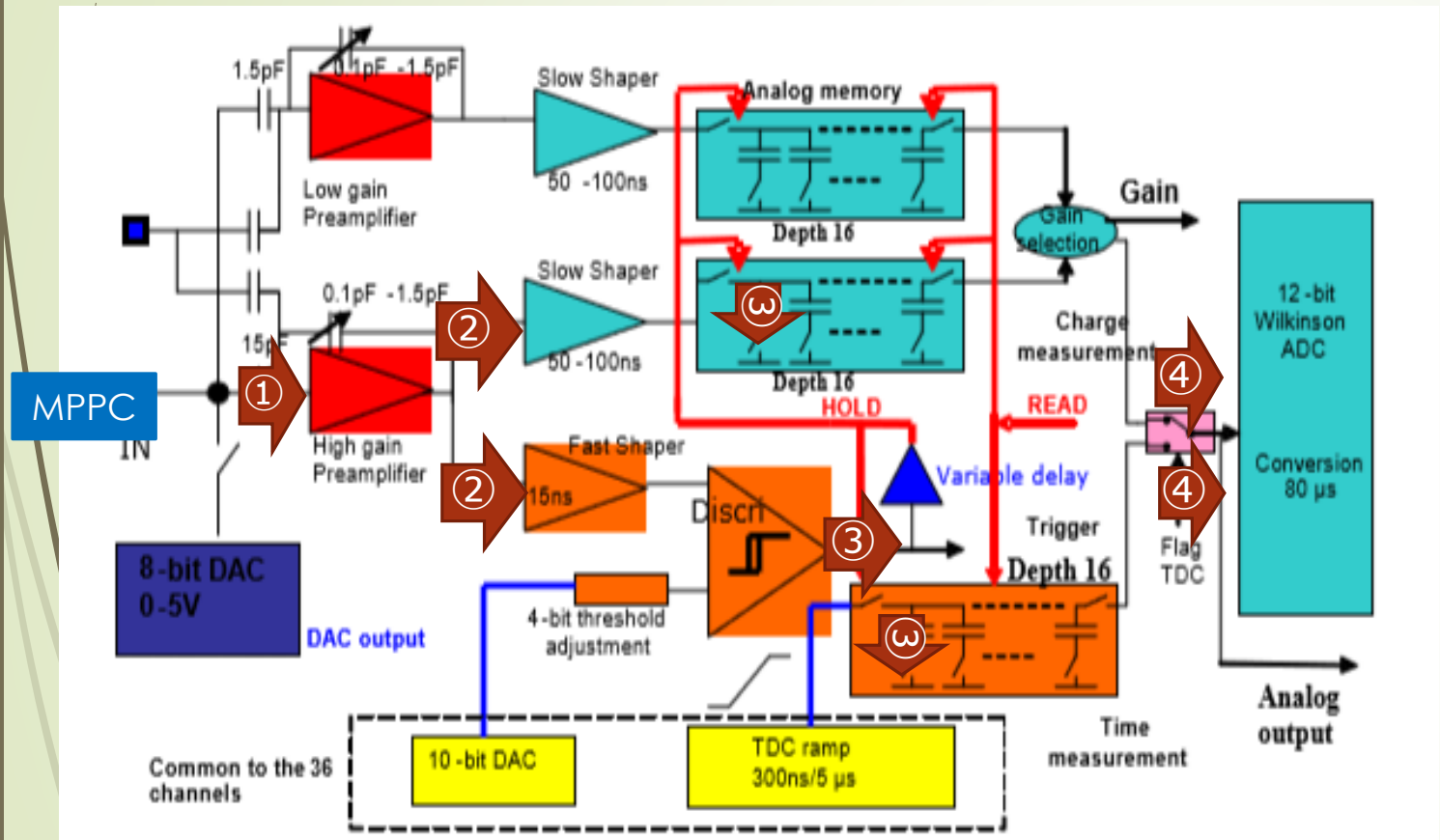


Figure 8: SPIROC one channel diagram

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

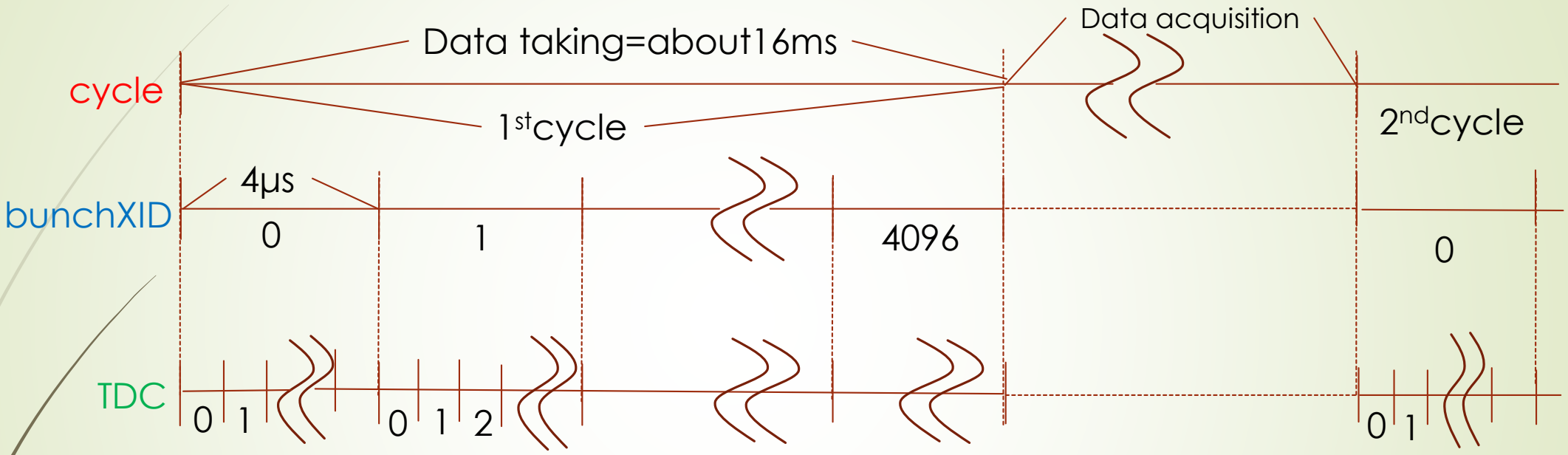
① The signal flows from the MPPC, and the signal is amplified by the preamplifier of the charge multiplier type.

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.

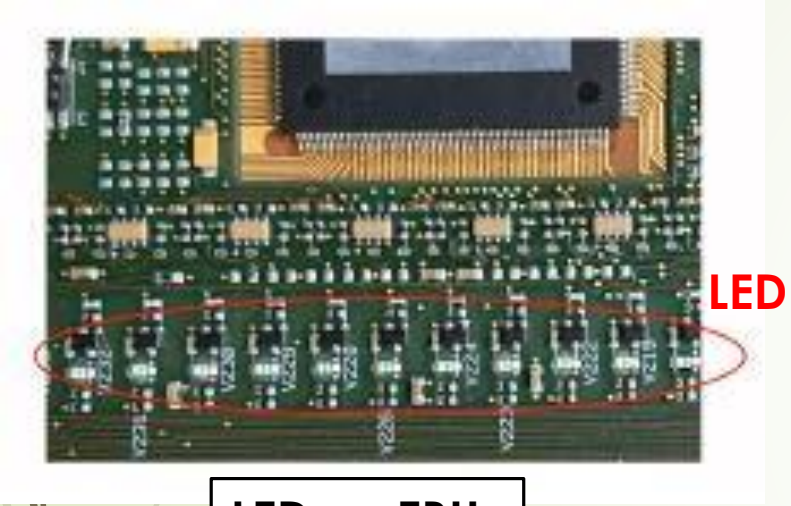
④ ①～③ if the operation occurs 16 times, or if it exceeds the predetermined time, the signal that has been temporarily stored flows to the ADC.

Time measurement of EBU

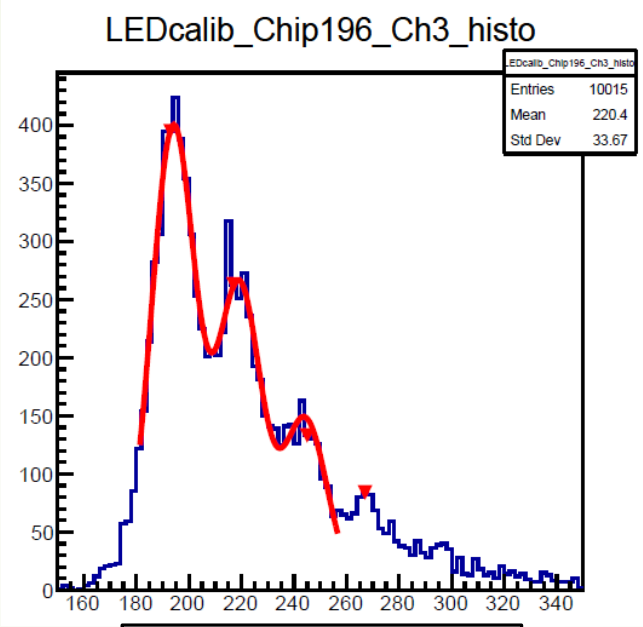


- Cycle : a cycle consists of data taking time and data acquisition time. When memory cells are fully used until 16ms or they are not fully used till 16ms (named timeout), cycle goes to next.
- bunchXID : BunchXID measures time information when the signal is stored in the memory cell with 4μs time interval.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

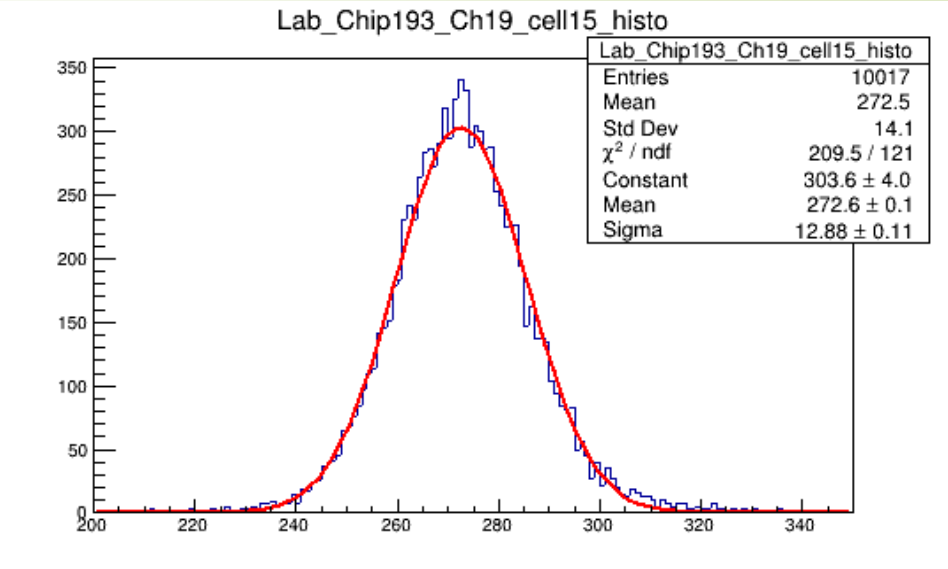
LABmode(Pedestal measurement and LED calibration)



LED on EBU



LED calibration

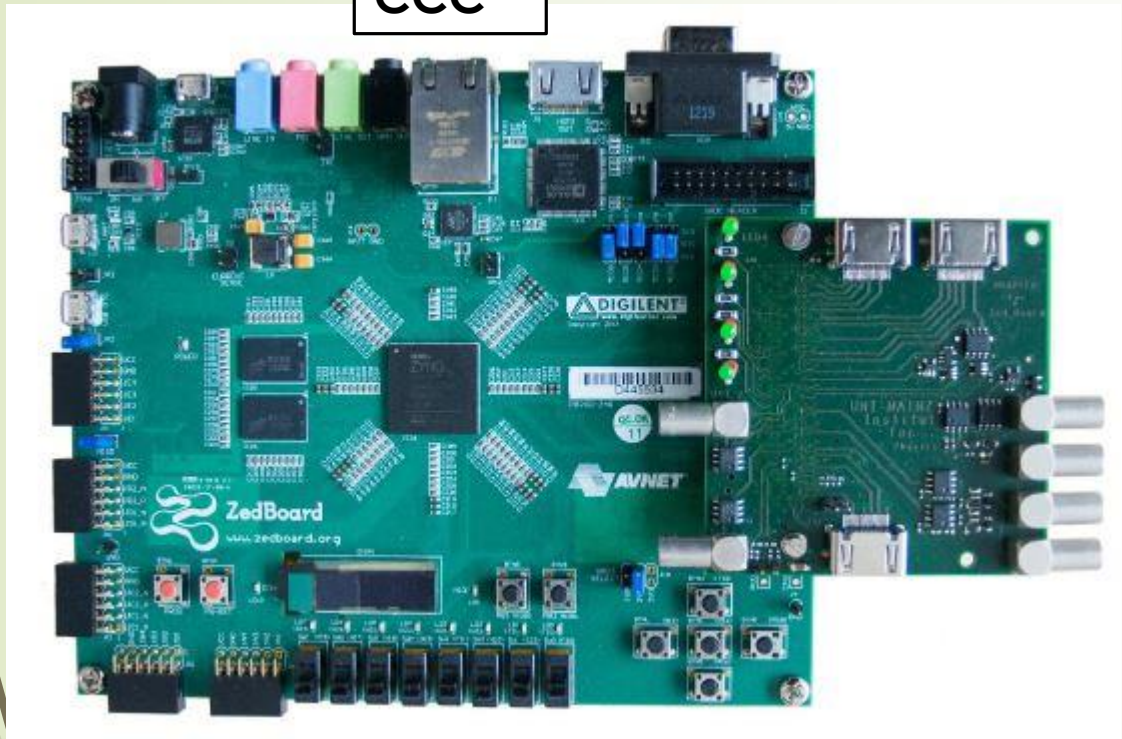


Pedestal measurement

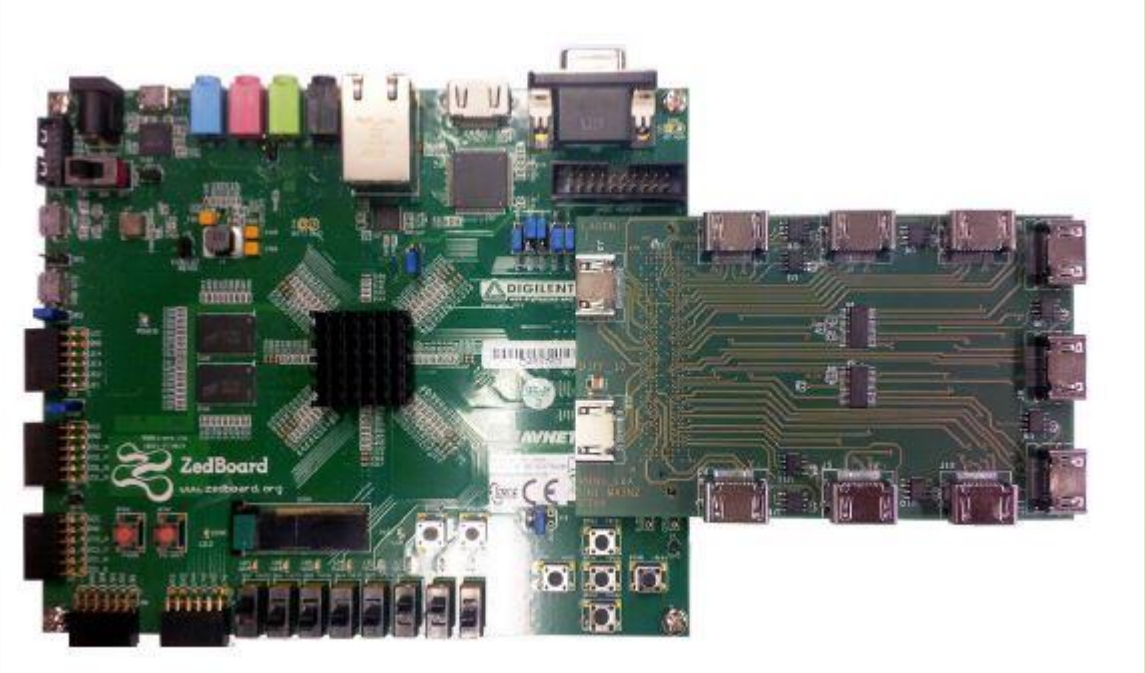
- The LABmode can be triggered from the outside and can be triggered at the moment when the LED shines.
- In LABmode, Pedestal measurement per cells is available by use not LED.
- But don't measure MIP in LABmode because don't work discriminator in spiroc2b.
- Therefore, Pedestal has not bunchXID.

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

CCC

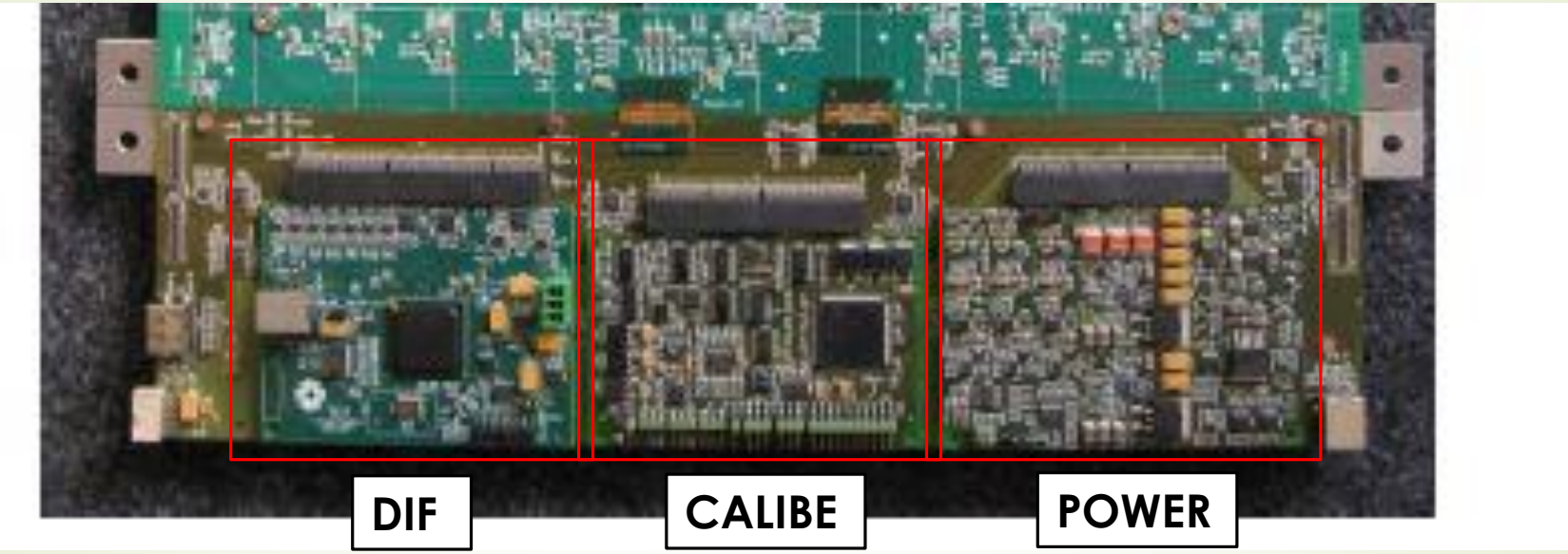


LDA



- 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



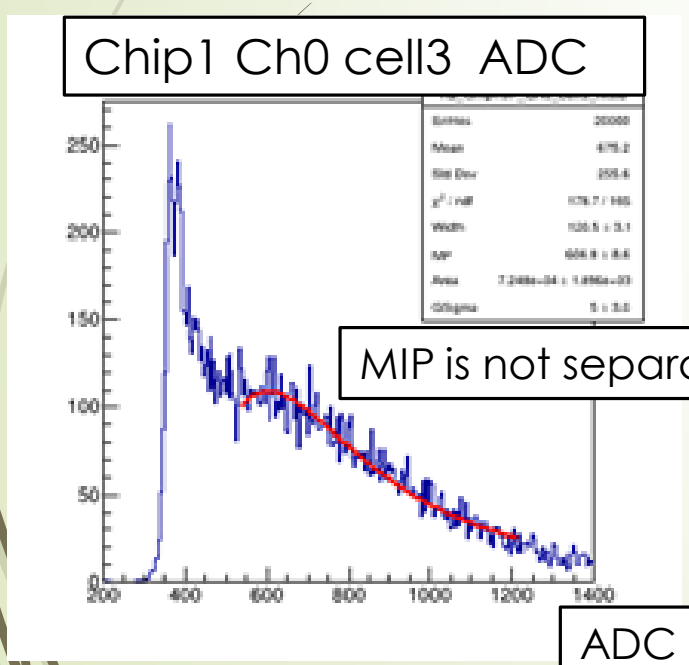
- DIF:Manages exchanges between SPIROC2b, POWER, and CALIB. The FPGA on DIF converts the clock received from CCC to DIFclock and generates the setting signal of SPIROC2b
- CALIB : Supply voltage to LED in EBU.
- POWER : Supply voltage to EBU for necessary to work.

MIP measurement with BunchXIDcut

MIP measurement

Chip1 Ch0

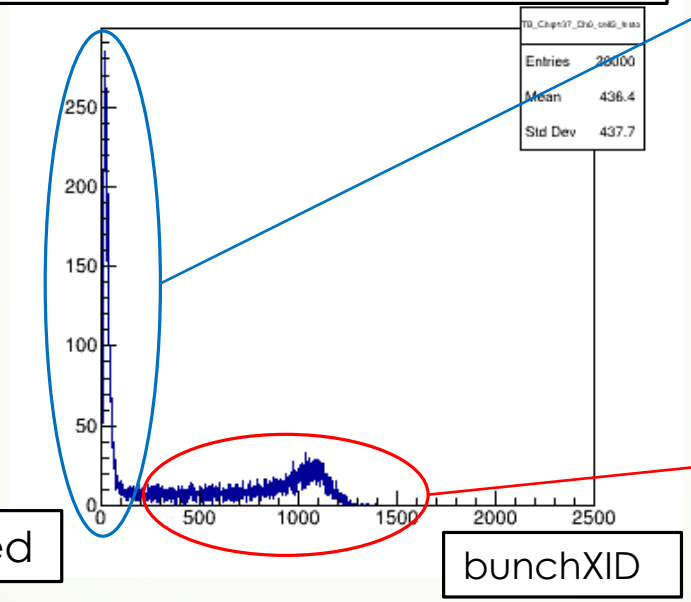
Chip1 Ch0 cell3 ADC



MIP is not separated

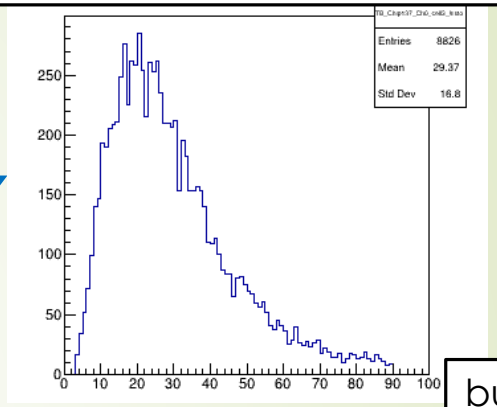
ADC

Chip1 Ch0 cell3 bunchXID



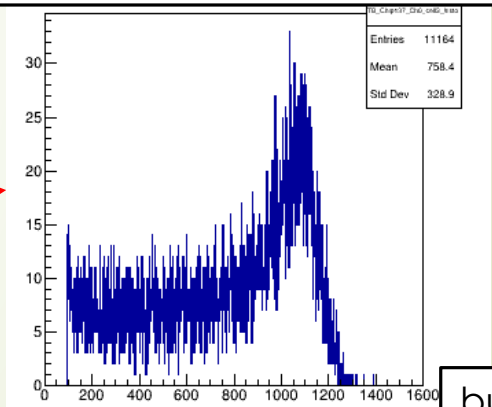
bunchXID

Small number bunchXID signal



bunchXID

Large number bunchXID signal



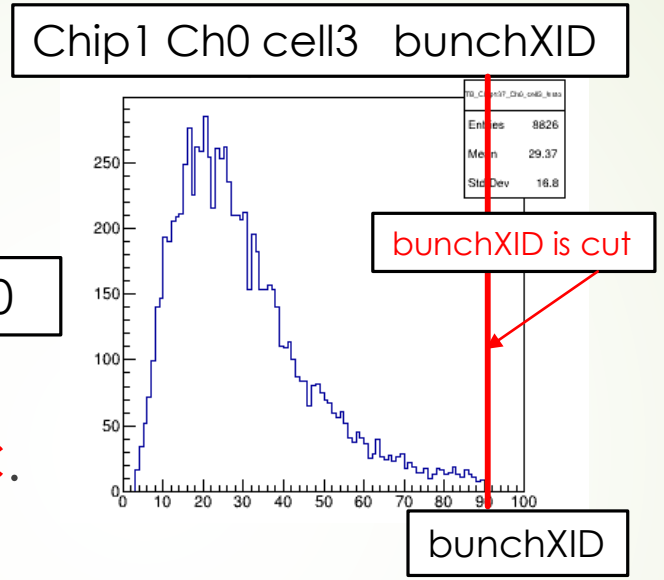
bunchXID

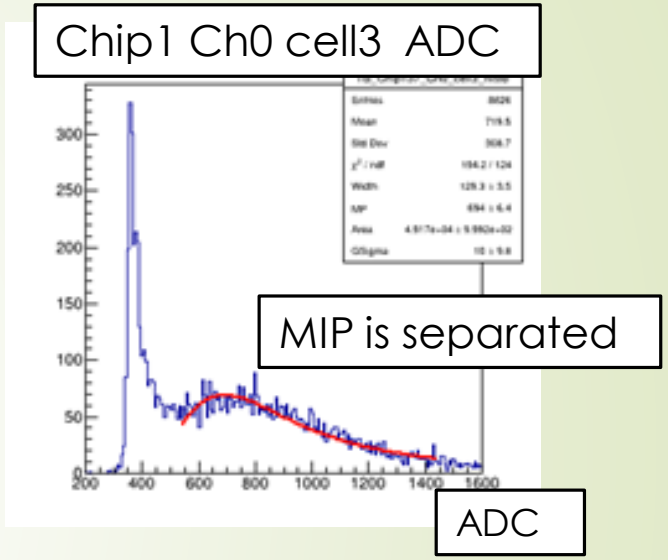
- We have looked into the ADC distribution for which is the non MIP separated channel.
- There are two peaks in the bunchXID distribution.
- We have Investigated the ADC distributions with two bunchXID regions.

MIP measurement with BunchXIDcut

bunchXID is less than 90

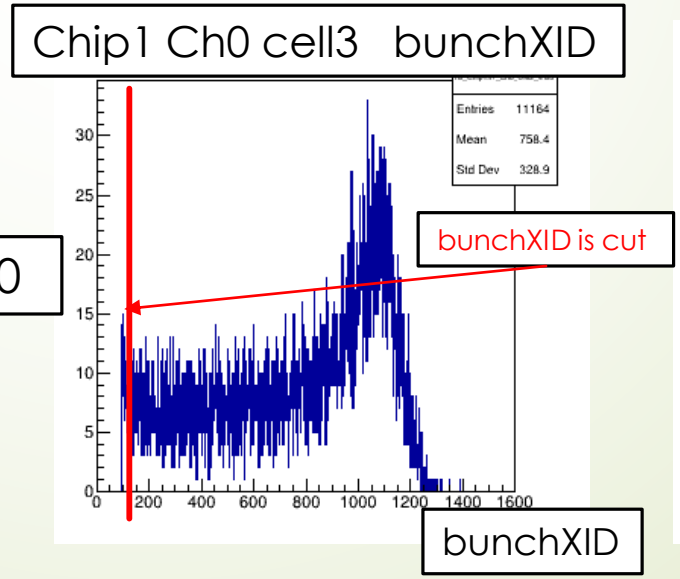
- When bunchXID is less than 90, MIP is separated in ADC.

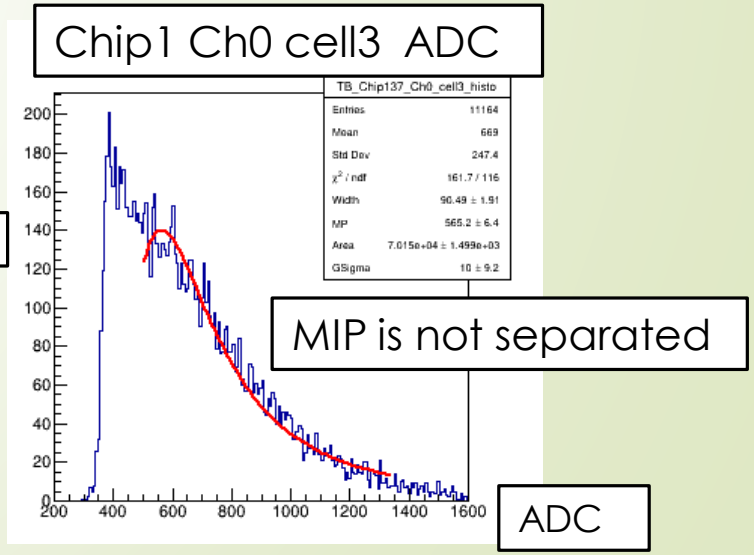




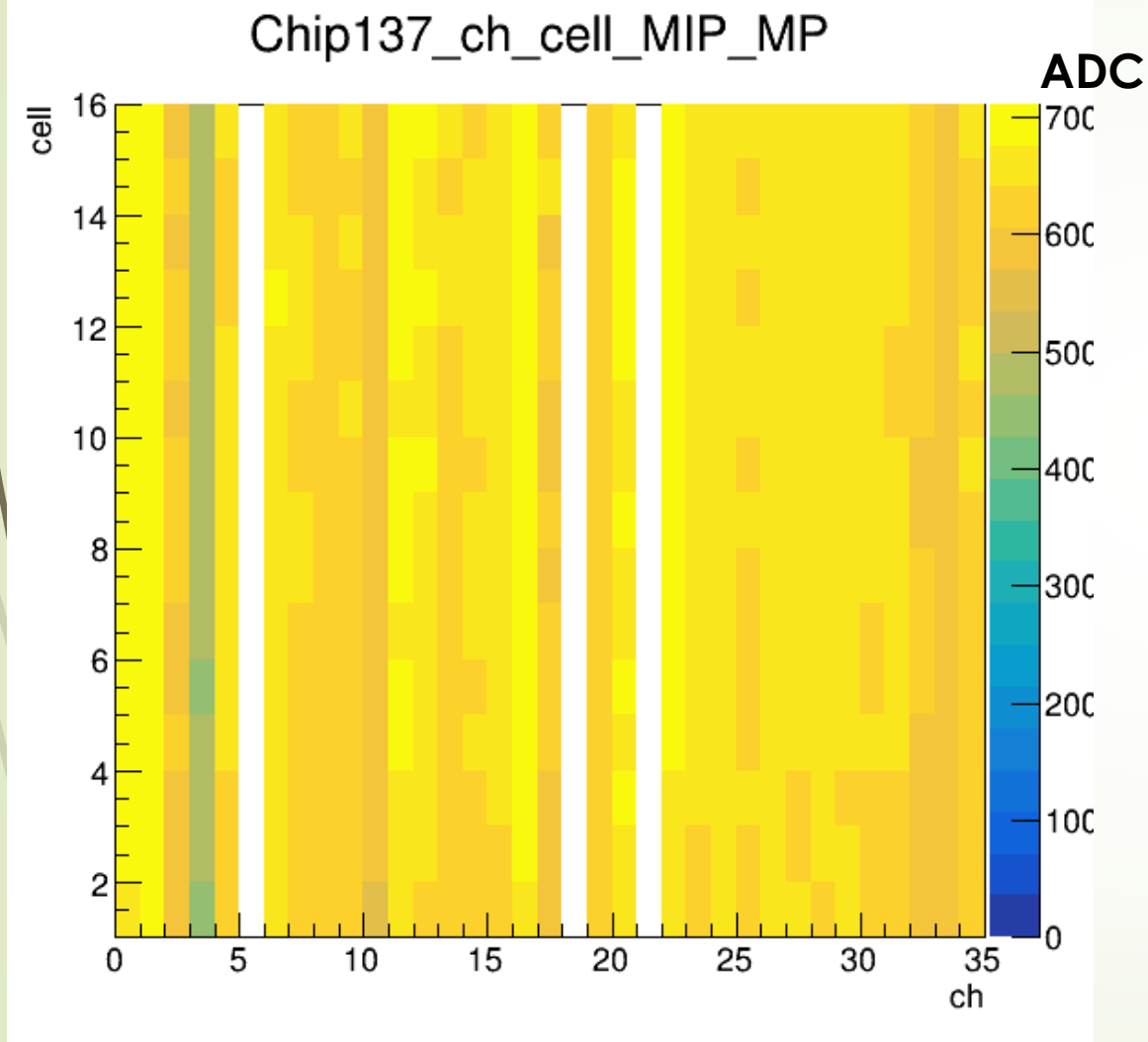
bunchXID is more than 90

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





MIP measurement (chip1,ch VS memory cell)



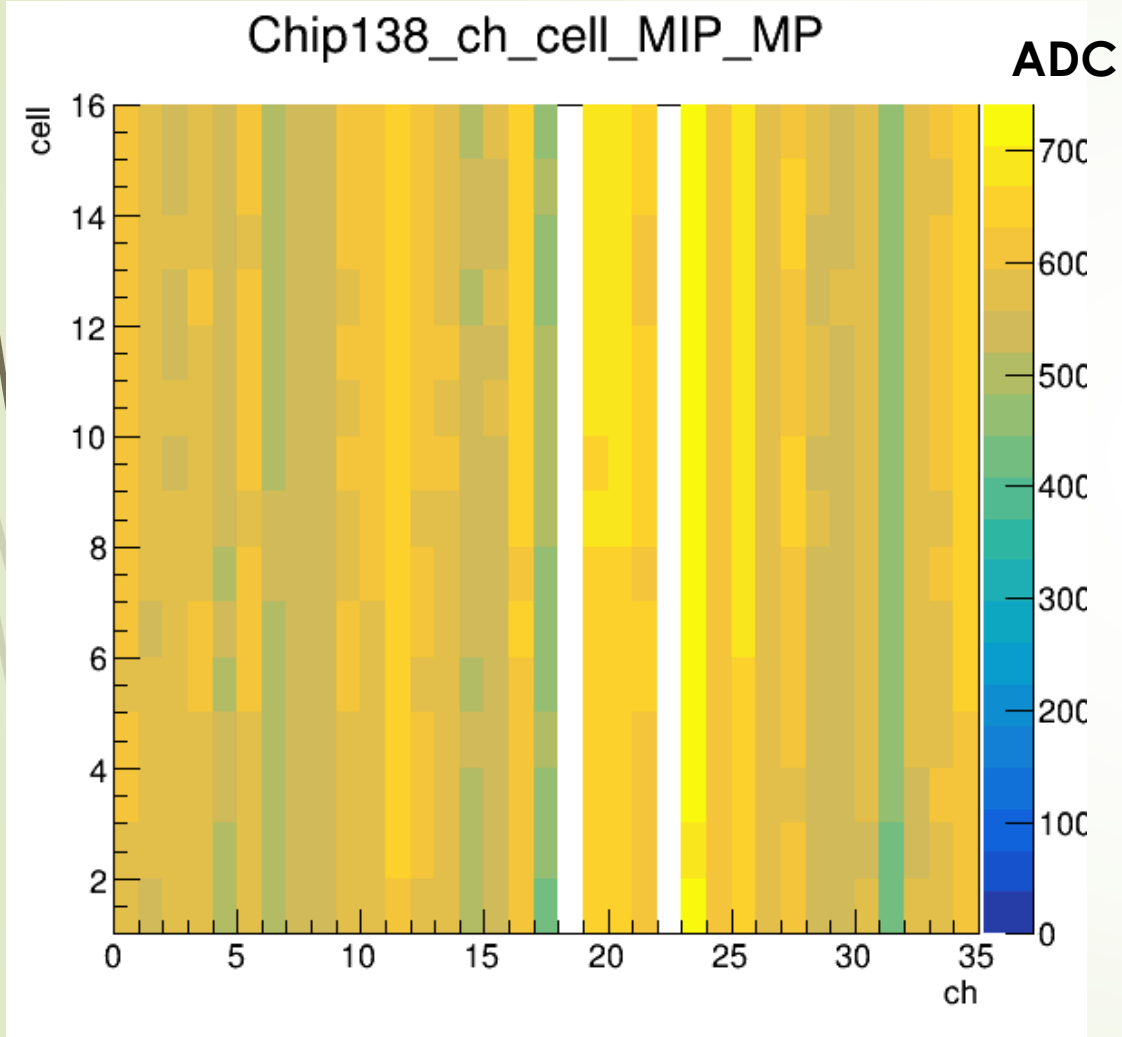
White : problem of MPPC and scintillator coupling

Blue : MIP is separated

Yellow: : MIP is not separated

Orange : not well separated Red : broken

MIP measurement (chip2,ch VS memory cell)



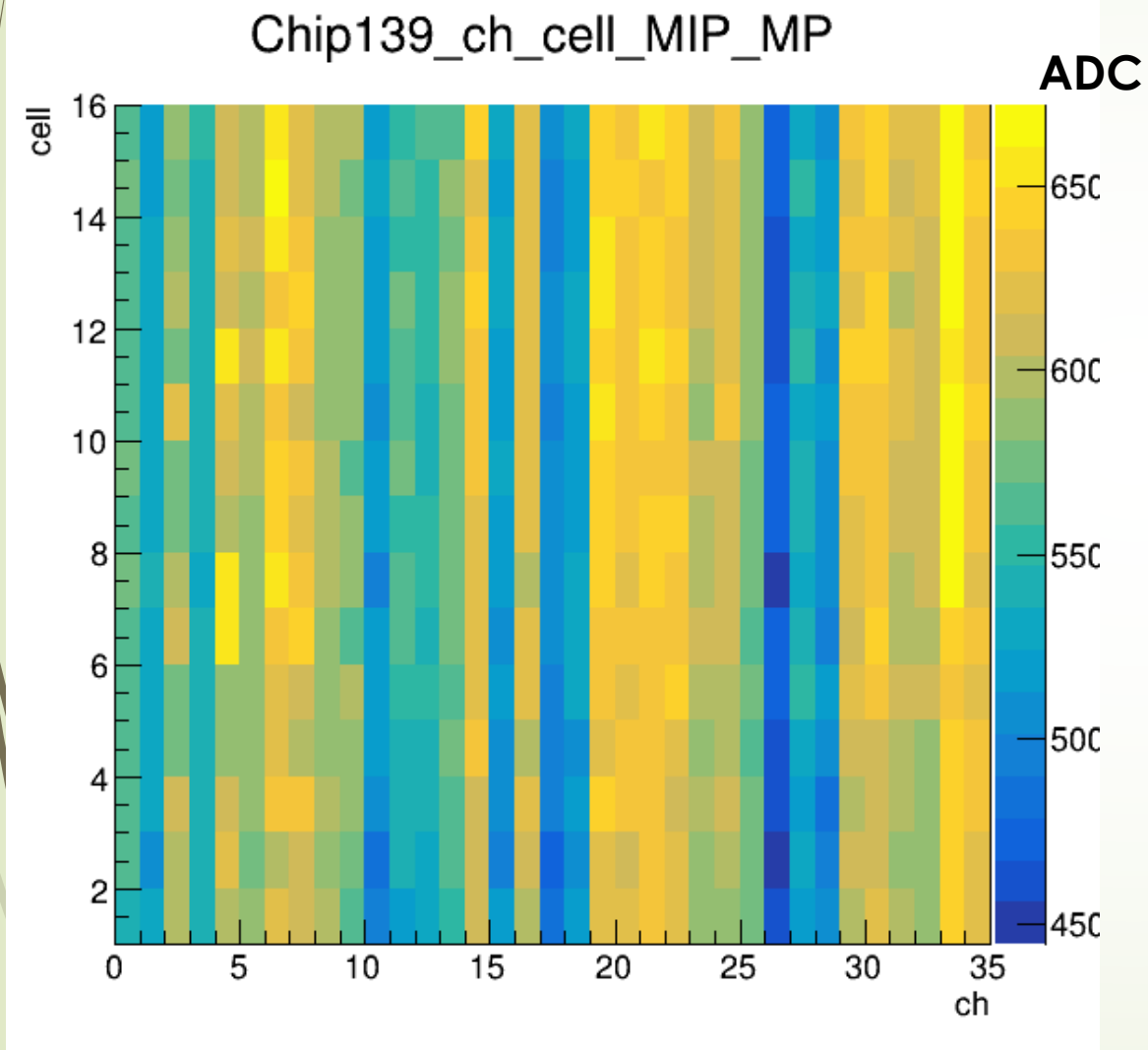
White : problem of MPPC and scintillator coupling

Blue : MIP is separated

Yellow: : MIP is not separated

Orange : not well separated Red : broken

MIP measurement (chip3,ch VS memory cell)



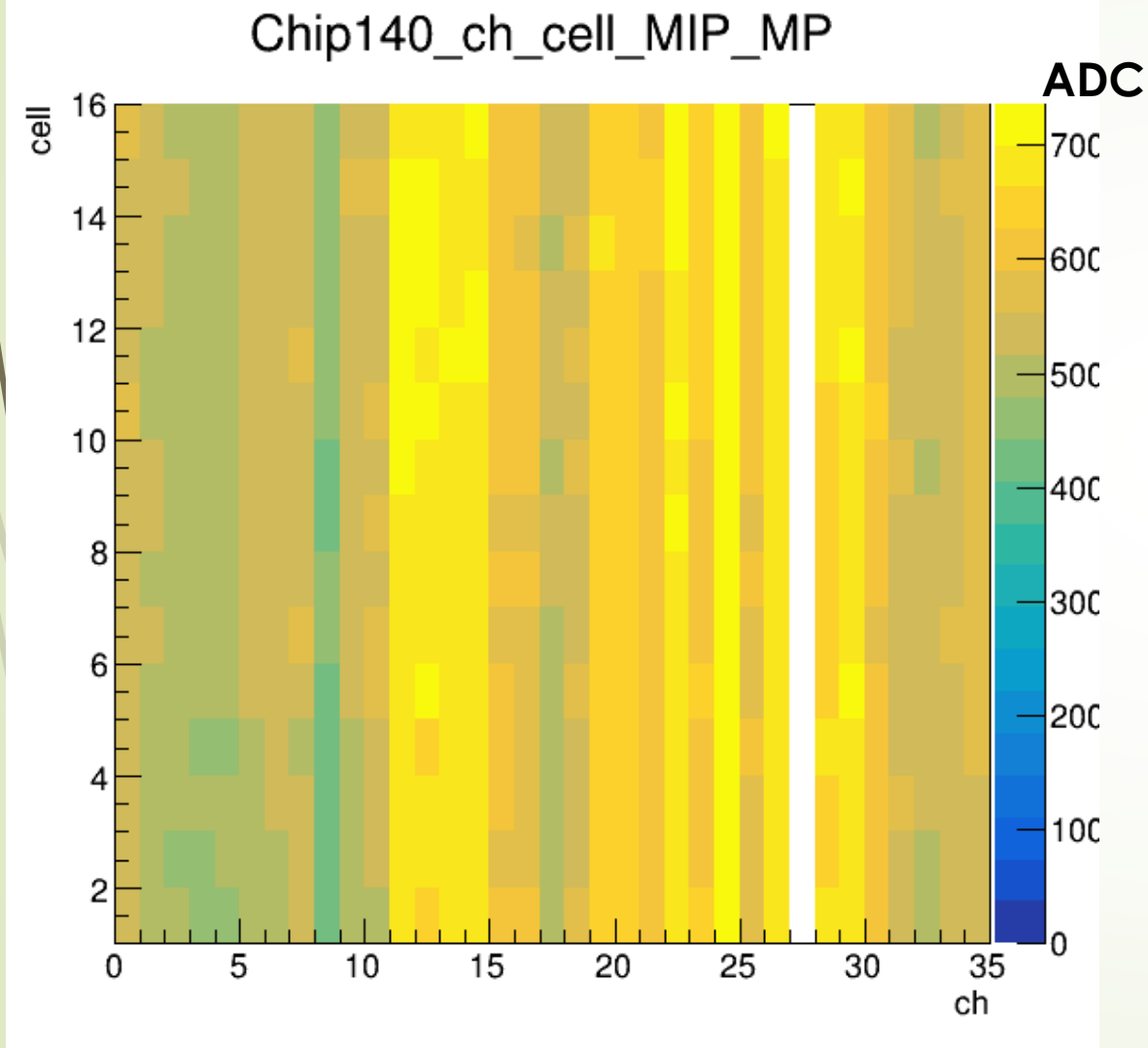
White : problem of MPPC and scintillator coupling

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

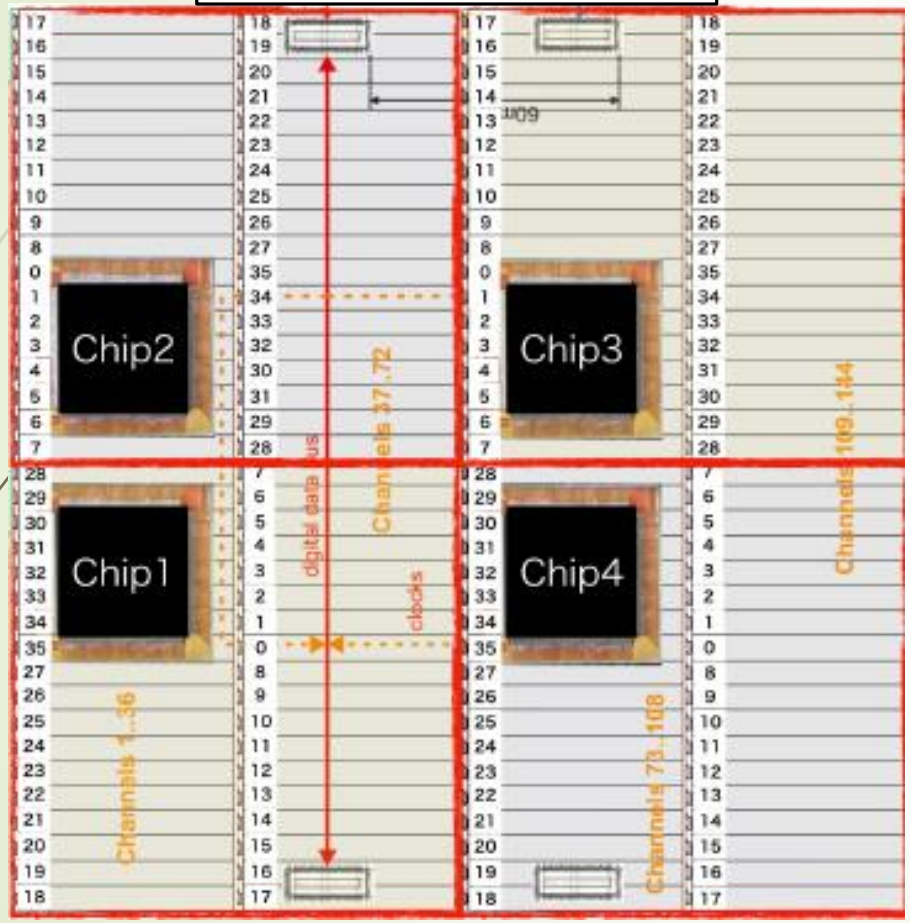
Blue : MIP is separated

Yellow: : MIP is not separated

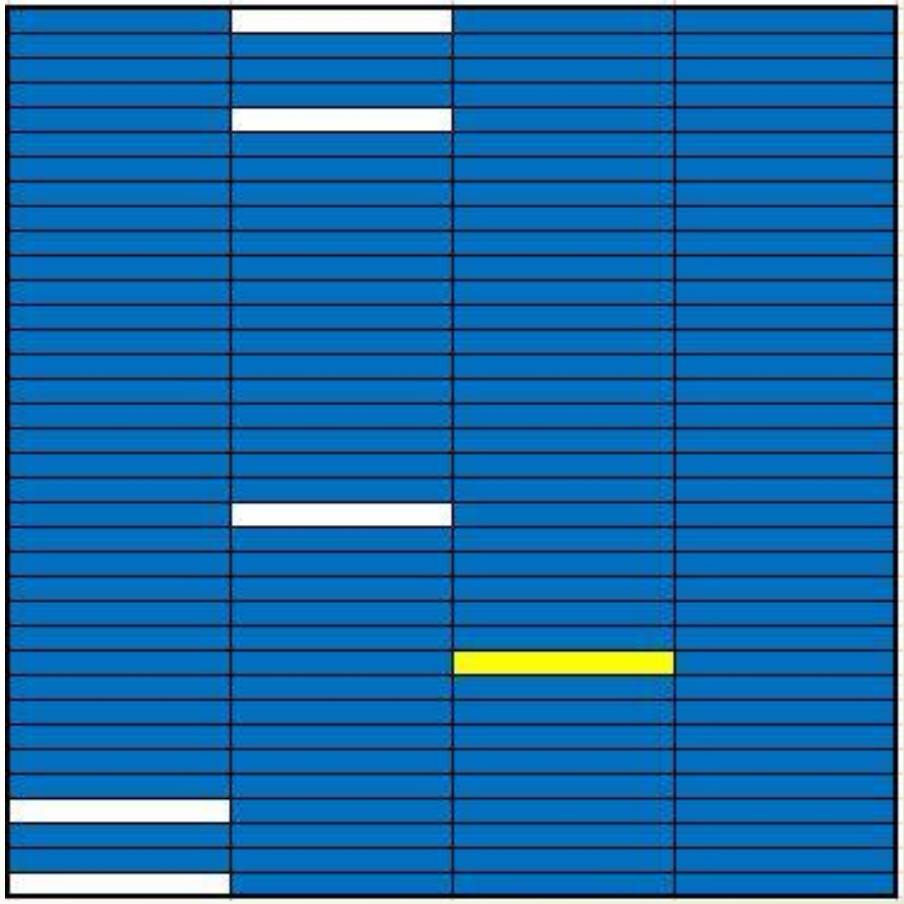
Orange : not well separated Red : broken

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

channel-map of EBU



Map of result of 90Sr test



- 138/144ch confirms 90Sr peak is separation.

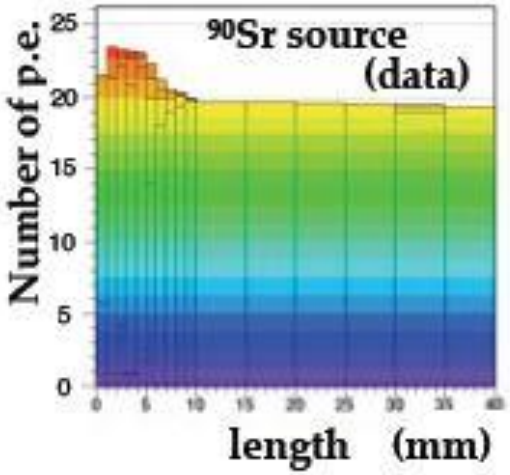
MIP is separation
MIP is not well separated
MIP is not measurment

Wedge shape scintillator

Bottom readout design by Tokyo group

Scintillator in reflector film

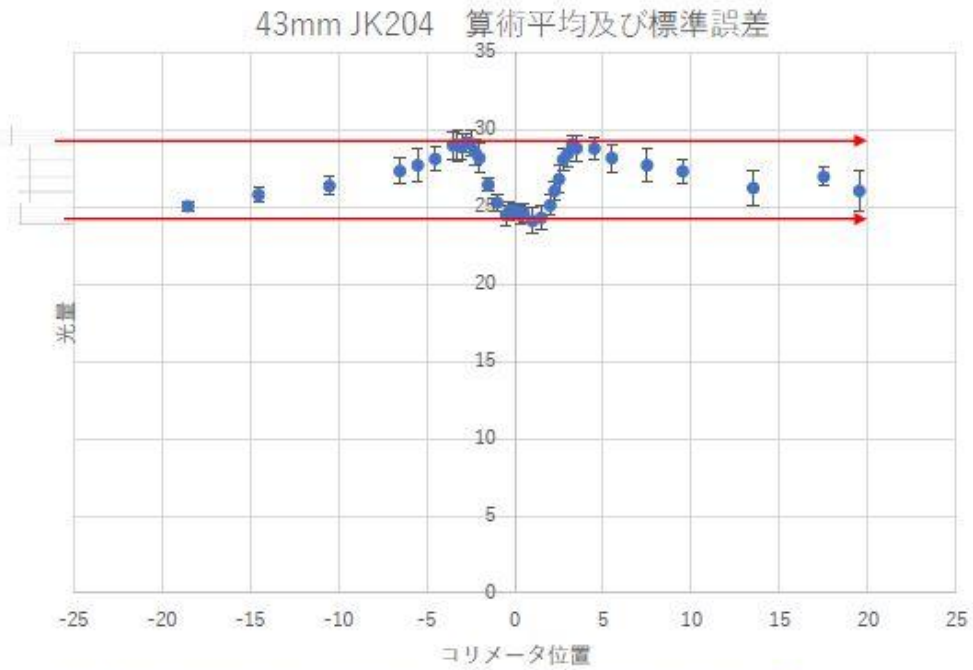
No dead volume due to MPPC.

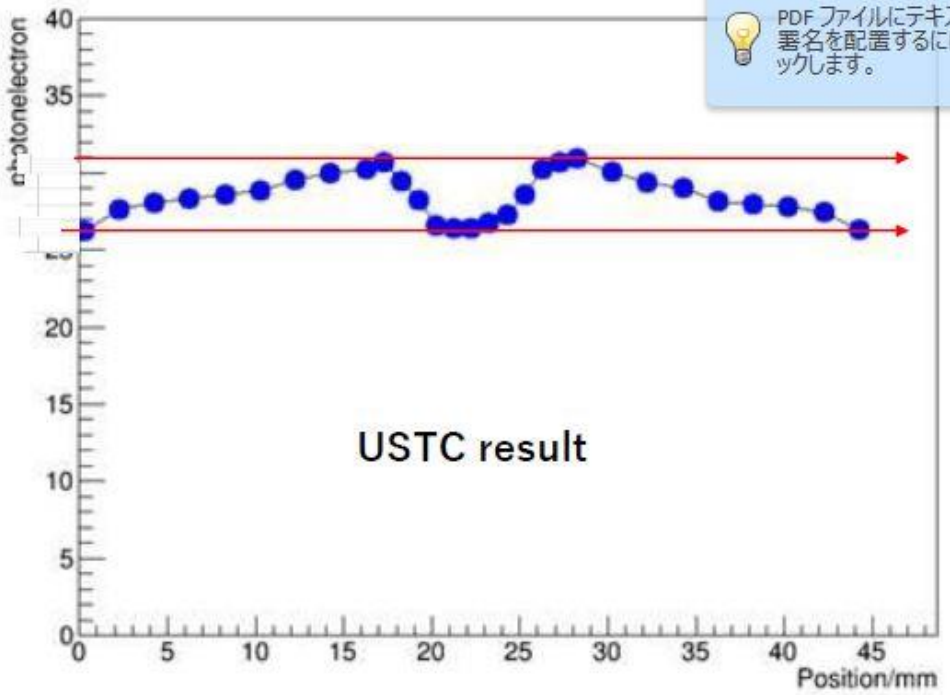


Totally good uniformity of the photon yield, and enough p.e.

From K.Kotera at SCINT 2015 @ Berkeley

Compare USTC model with shirai model





白井型	各位置の標準誤差の算術平均	1.6%
	各位置の標準偏差の算術平均	2.8%
	両隣の測定点の距離の平均を重みとした加重平均	26.7
	算術平均	26.8

光量	JK204	USTC(プロット図より)
中央値	26.7	28.6
最小値	24.2	26.3
最大値	29.2	30.9
(max-min)/median	0.19	0.16