Status on TSim-ecl and FAM monitoring

Insoo Lee[1], SungHyun Kim, Byunggu Cheon, Yuuji Unno

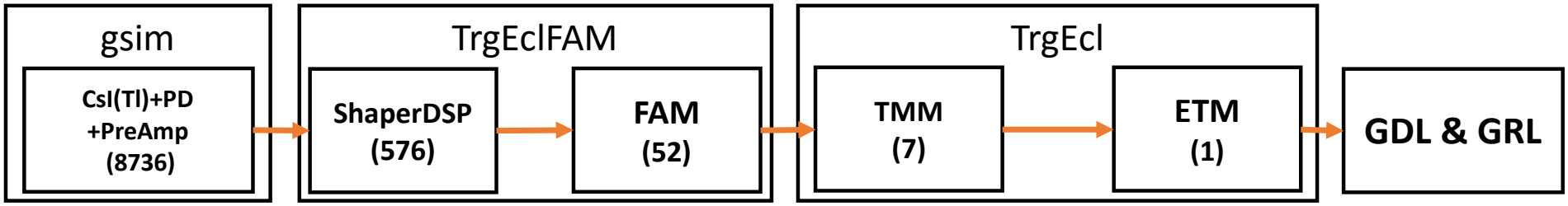
Department of Physics
Hanyang University
Seoul, Korea

Contents

- ECL Trigger simulation(TSim-ecl)
  - Status and software configuration
  - Clustering logic study (On going)
- FAM Monitoring
- Summary and plan

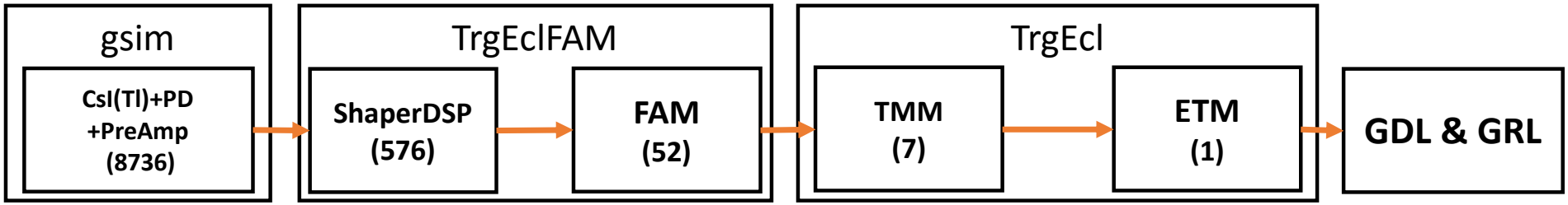
TSim-ecl

Status and software configuration



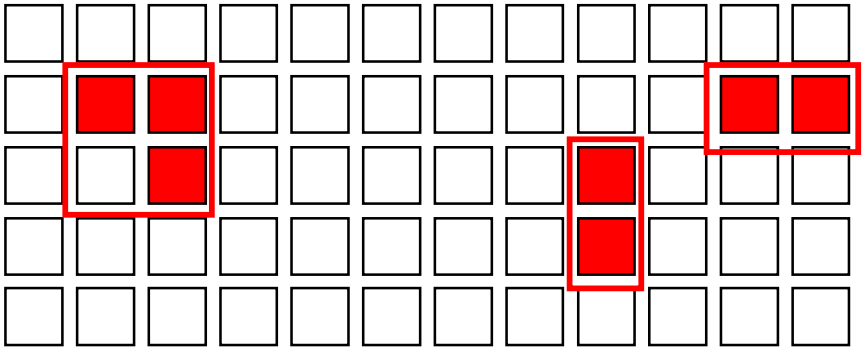
- First version of fast simulator is ready.
  - GSim part (8736 Xtals + PD + preAmp)
  - TrgECLFAM module (ShaperDSP + FAM)
    - Shaping and digitization
    - 3 types noise generation(serial, parallel, pile-up)
    - Measure energy and timing(1 method + 2 backup methods)
  - TrgEcl module (TMM+ETM)
    - Decide trigger conditions(physics, Bhabha, beam-background) and event-timing
    - ETM logic is same as Belle1(physics, Bhabha, background veto).
  - Latency
    - The latency of flight time is adjusted.
  - MC Matching

Status and software configuration



- Todo list
  - Study clustering logic
  - Bhabha : 2D(r- ϕ) → 3D(r-θ-ϕ)
  - Beam background veto
  - Noise covariance matrix
  - Firmware version
    - Clock synchronization
    - Integer version for firmware study
  - Consider latency between each module

Clustering study



:TC

:Hit TC

- Clustering – Grouping the connected TC hits, which come from one particle.
  - Belle
    - Only count the number of cluster using simple logic(ICN)
    - ICN > 3 as a physics trigger condition.
  - Belle II (Plan)
    - Keep ICN logic for count the number of cluster.
    - Implement an independent logic for grouping
    - Provide the energy, timing, position of clusters to GRL.
      - Energy: Sum of all TC Hit in cluster
      - Timing, position : Energy weighted timing and position
    - Using it in 3D Bhabha veto

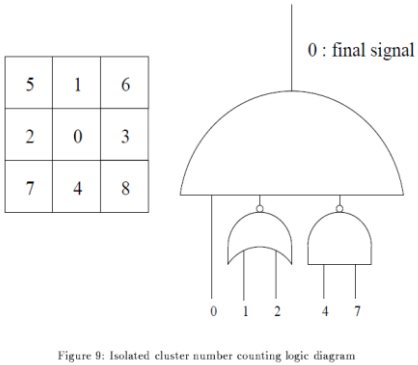
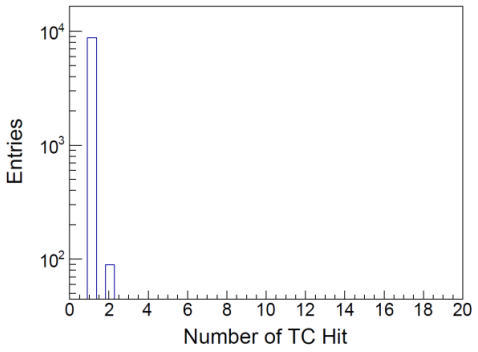
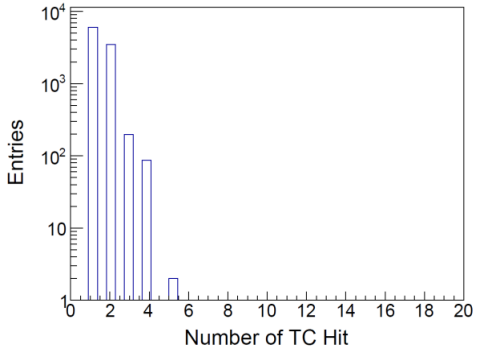
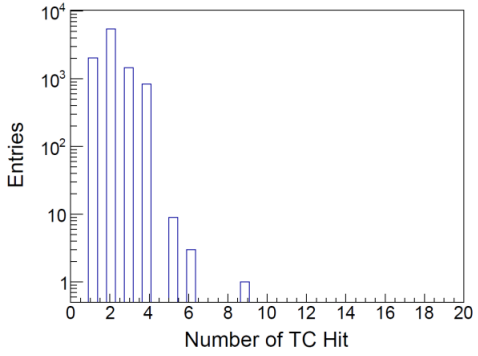
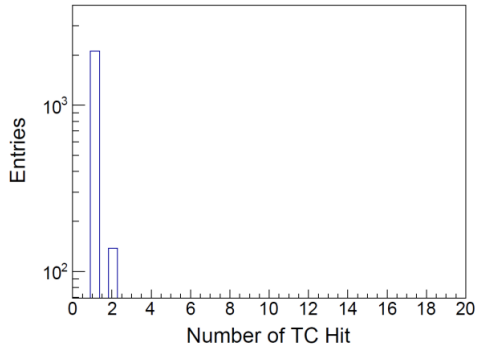
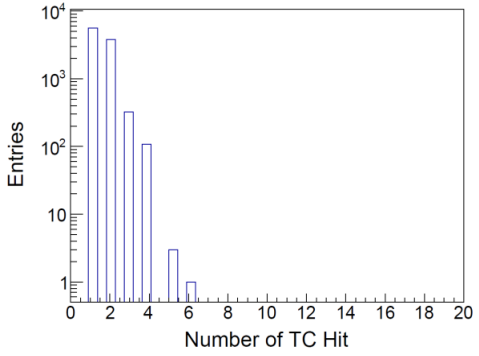
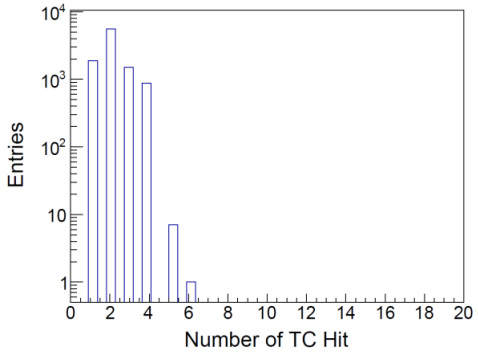
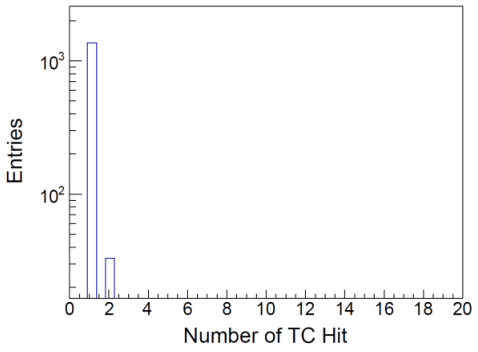
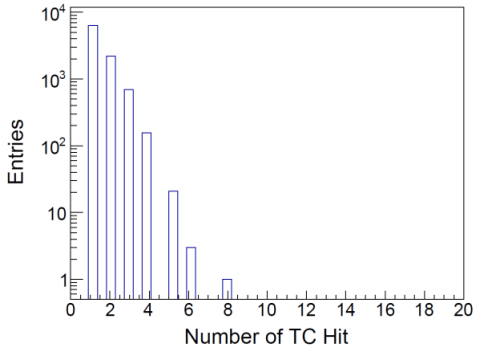
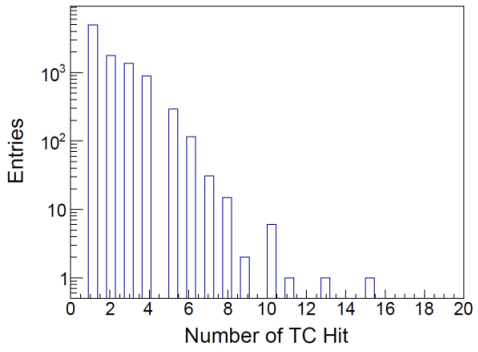


Figure 9: Isolated cluster number counting logic diagram

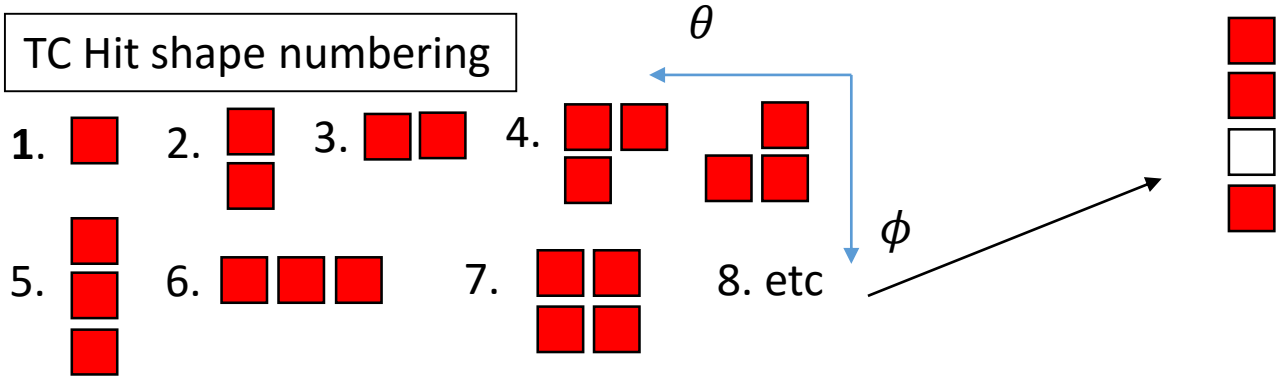
- Study procedure (in the beginning)
  - Check the TC hit pattern of one particle
    1. Shoot **one** particle having various momentum.
       - $e^{\pm}, \gamma, \pi^{\pm}$ with 0.1~0.3 GeV, 1.0~3.0 GeV, 8.0~9.0 GeV (10k samples)
    2. Check the number of TC Hit and TC hit patterns.
  - Check energy loss of clusters ($E_{cluster}/E_{total\ TC\ hit}$) with cluster algorithms

The number of TC Hit

10k samples

	0.1~0.3 GeV	1.0~3.0 GeV	8.0~9.0 GeV
γ			
$e^{\pm}$			
$\pi^{\pm}$			

Check TC Hit patterns(%)



γ

Momentum (GeV)	1	2	3	4	5	6	7	8
0.1 ~ 0.3	99.0	0.6	0.4	0	0	0	0	0
1.0 ~ 3.0	61.7	19.8	14.7	1.7	0	0	0.8	1.3
8.0 ~ 9.0	20.6	32.8	21.6	13.4	0.2	0	7.8	3.5

$e^{\pm}$

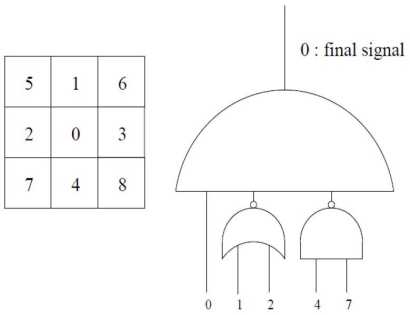
Momentum (GeV)	1	2	3	4	5	6	7	8
0.1 ~ 0.3	93.8	5.2	1.0	0	0	0	0	0
1.0 ~ 3.0	57.1	23.2	13.9	2.5	0.4	0	1.0	1.9
8.0 ~ 9.0	19.1	33.5	21.7	13.9	0.2	0	8.2	3.4

$\pi^{\pm}$

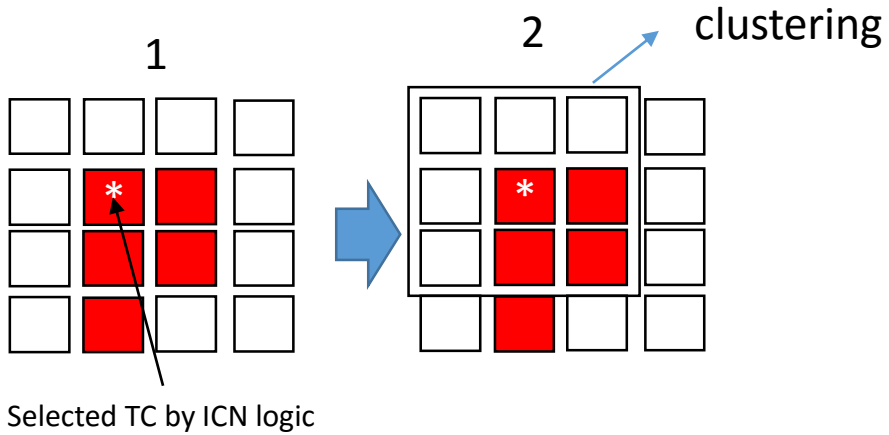
Momentum (GeV)	1	2	3	4	5	6	7	8
0.1 ~ 0.3	97.7	1.7	0.4	0	0	0	0.2	0
1.0 ~ 3.0	67.5	11.4	7.6	4.6	0.5	0.1	0.5	7.8
8.0 ~ 9.0	52.5	9.5	6.7	10.7	0.9	0.2	4.3	15.1

- 1~7 patters are ~97% except for $\pi^{\pm}$
- ETC(#8) Hits are mainly made of the TC hits coming from the interaction with inner-detectors.
- Most of TC hits are made up within 3x3 TCs.

Clustering logic(1)

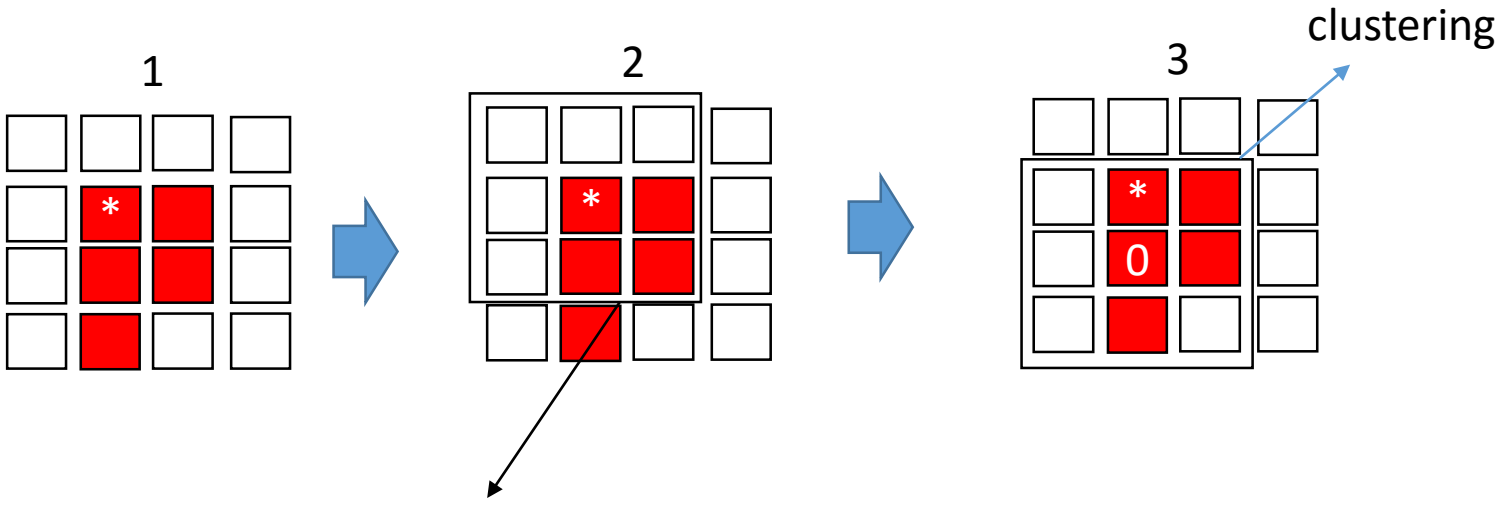


ICN logic



- Method1
  1. Find TC Hits * satisfy the ICN logic,
  2. Grouping 8TCs + selected TC * as 1 cluster.
  - Problem
    - Consider only ICN logic condition to find cluster.
    - Don't consider energy of TC 0. ➔ Center may not have the highest energy than other TCs in cluster.

Clustering logic(2)



- Method2
  1. Find TC Hits * satisfy the ICN logic,
  2. Find the highest energy TC 0 in 3x3 TCs from selected TC*.
  3. Group 3x3 TCs from the highest energy TC as 1 cluster.

Energy loss by Clustering

Method 1

γ

Momentum (GeV)	R=1(%)	R<1(%)
0.1 ~ 0.3	100	0.0
1.0 ~ 3.0	98.7	2.8
8.0 ~ 9.0	96.2	3.8

$e^{\pm}$

Momentum (GeV)	R=1(%)	R<1(%)
0.1 ~ 0.3	100	0.0
1.0 ~ 3.0	97.7	2.3
8.0 ~ 9.0	96.4	3.6

$\pi^{\pm}$

Momentum (GeV)	R=1(%)	R<1(%)
0.1 ~ 0.3	100	0.0
1.0 ~ 3.0	91.6	8.4
8.0 ~ 9.0	83.7	16.3

Method 2

Momentum (GeV)	R=1(%)	R<1(%)
0.1 ~ 0.3	100	0.0
1.0 ~ 3.0	98.7	2.8
8.0 ~ 9.0	96.4	3.6

Momentum (GeV)	R=1(%)	R<1(%)
0.1 ~ 0.3	100	0.0
1.0 ~ 3.0	97.7	2.3
8.0 ~ 9.0	96.6	3.4

Momentum (GeV)	R=1(%)	R<1(%)
0.1 ~ 0.3	100	0.0
1.0 ~ 3.0	92.1	7.9
8.0 ~ 9.0	84.7	15.3

- Energy ratio $\mathrm{R} = E_{cluster}/E_{total\ TC\ hit}$
- Percentage of R=1 are correspond to the pattern 1,2,3,4,7 in Method1.
- Method2 can cover the some 5,6 patterns.

To-do list for clustering study

- Check connected gap event.
- Check efficiency with the various physics samples.
- MC Matcher module for Cluster
- Update Bhabha veto logic

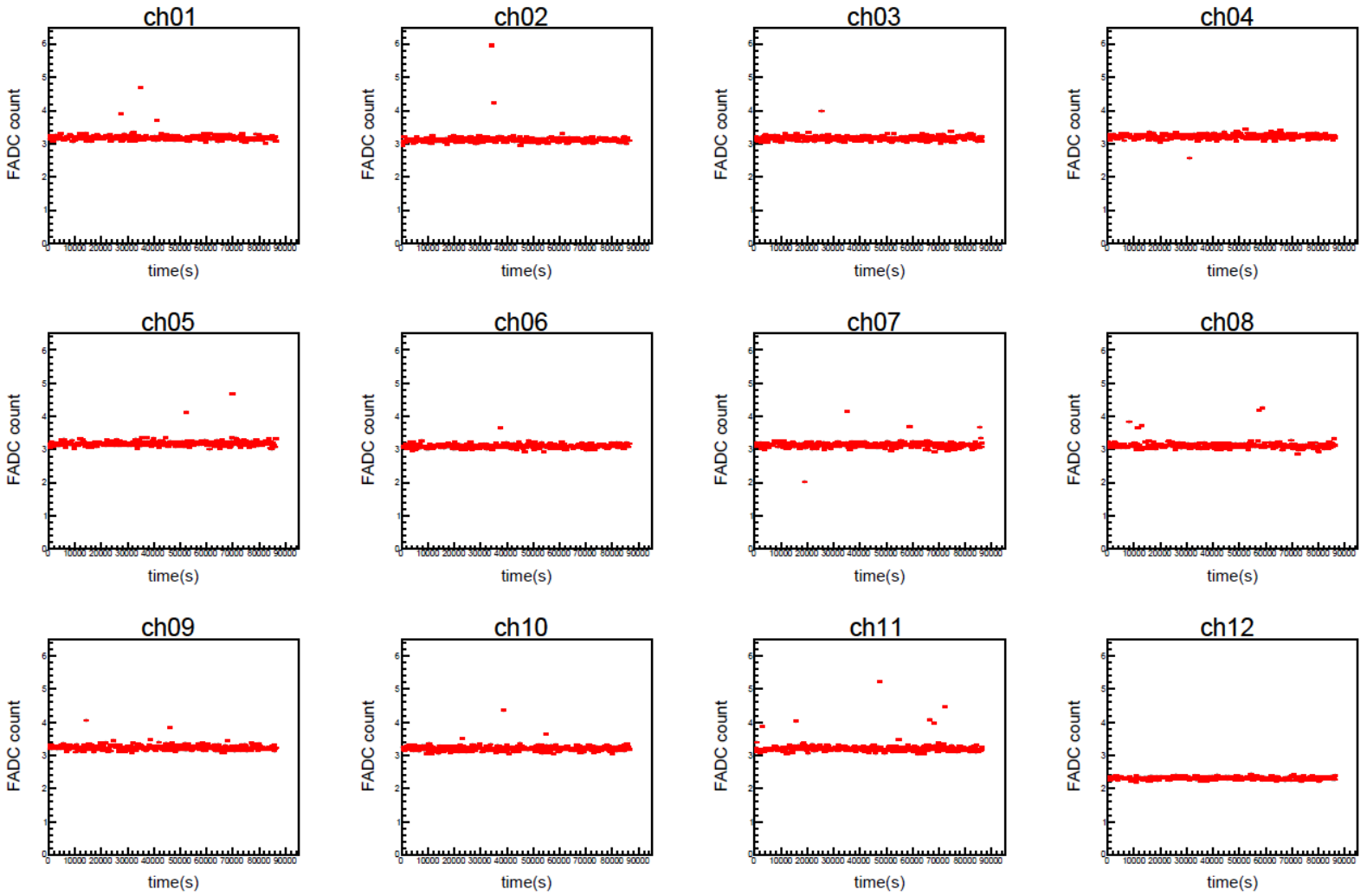
FAM Monitoring

FAM Monitoring

- New trg-ecl guys in KU(Youngjun Kim, Wonji Choi) are working on development of FAM monitoring program.
- First working version has been prepared.
  - We check following contents of FAM per 10 min.
    - Coh. noise, incoh. noise, noise ratio, pedestal, and temperature with time.
    - Save the data in a text file classified by each day.
- The program is executed when FAMs are free.(night time, weekend, hollyday)

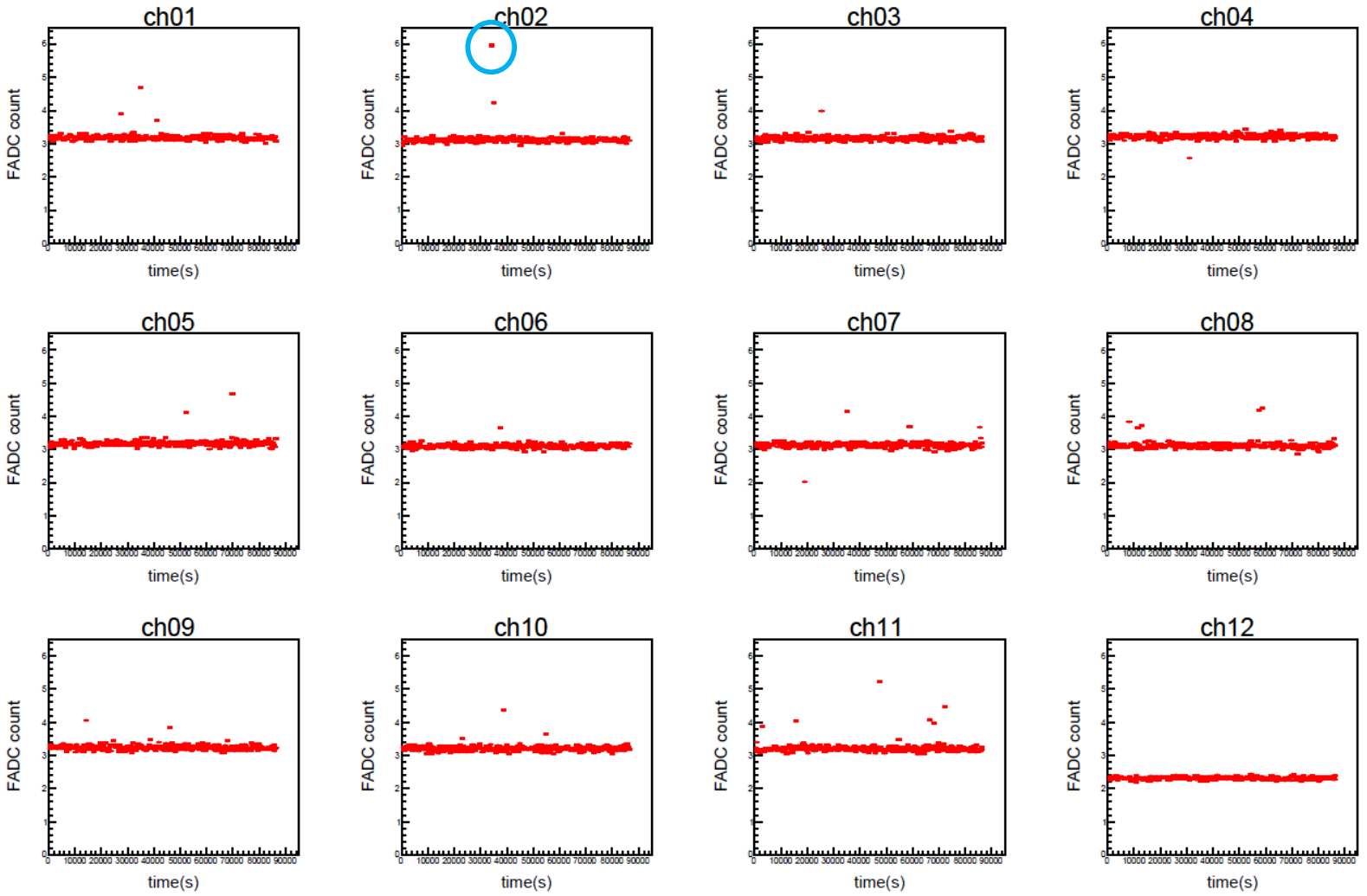
Example of monitoring result

- Noise – FAM#11 on 04. Sep. 2016

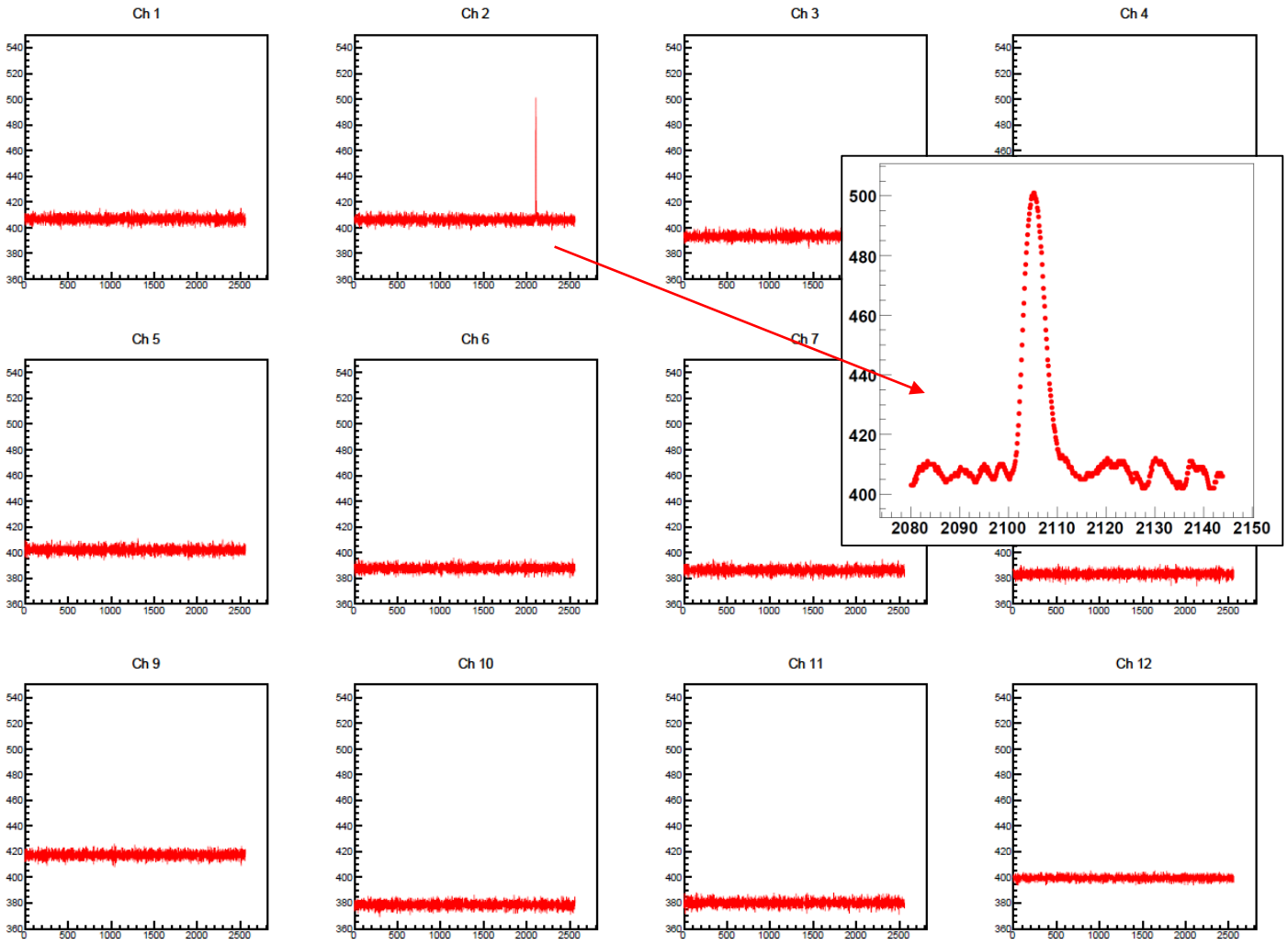


Example of monitoring result

- Noise – FAM#11 on 04. Sep. 2016

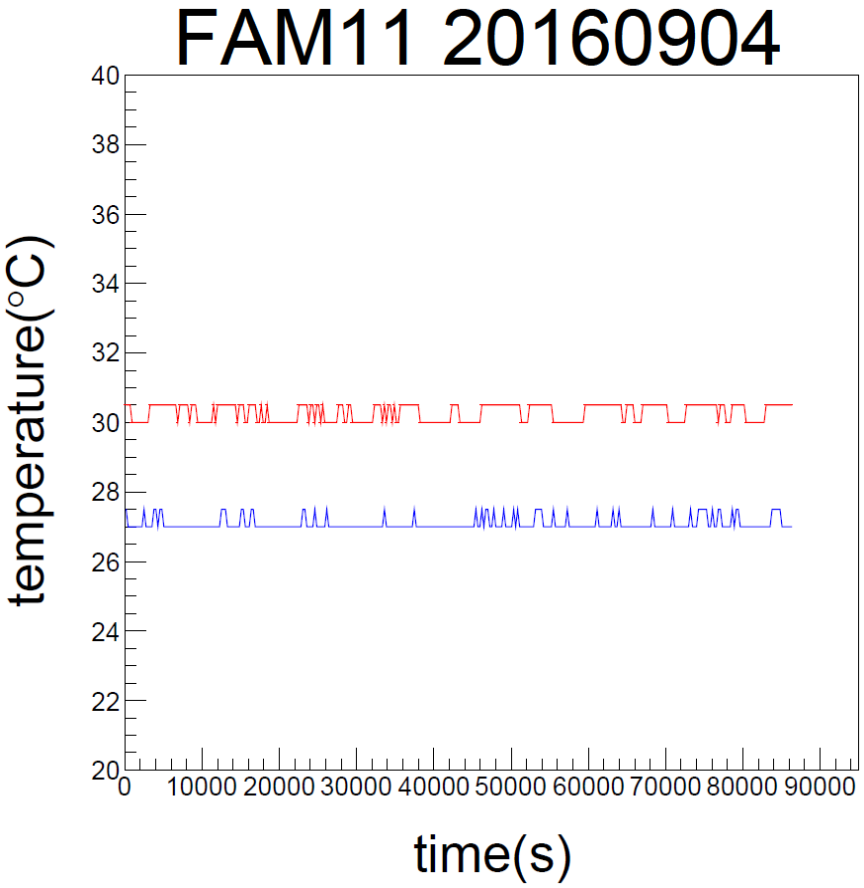


FAM# 11 at 09:28 on 04. Sep. 2016



Example of monitoring result

- Temperature– FAM#11 on 04. Sep. 2016

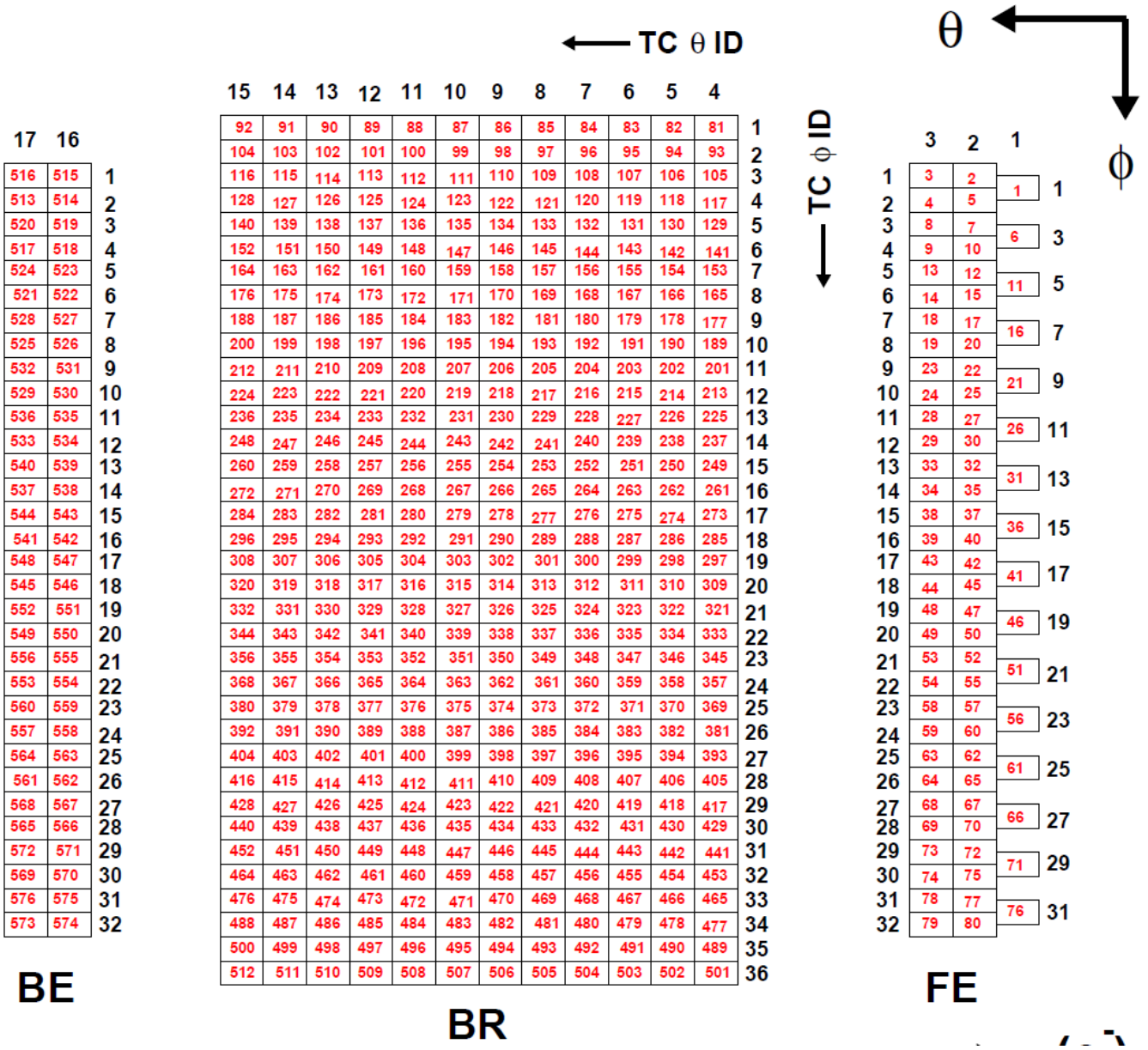


Plan for FAM Monitoring

- Add “hit rate” as checking component
- Energy calibration for each TC
- Timing adjustment
- Noise matrix preparation

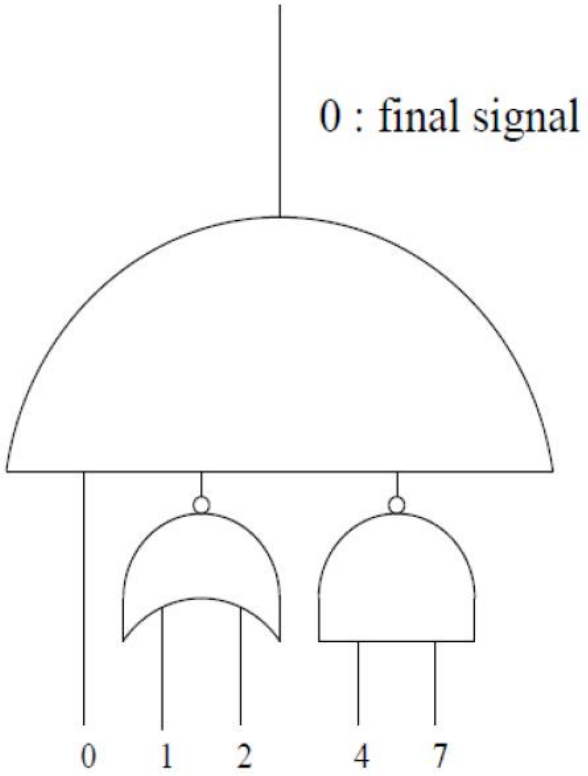
Back up

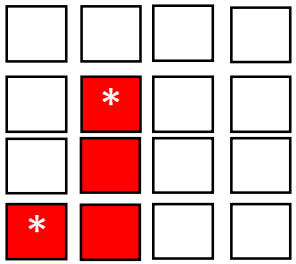
TC Map



Weak point of ICN

5	1	6
2	0	3
7	4	8





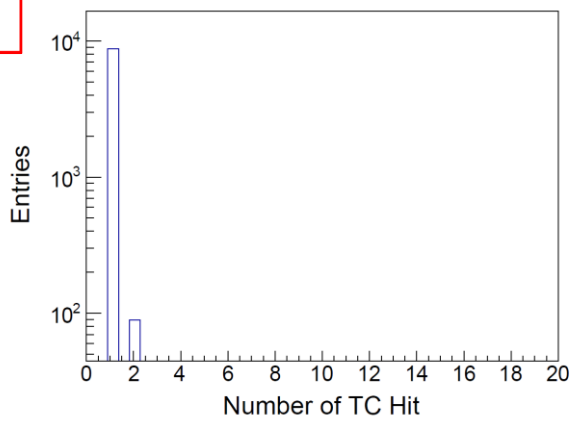
Number of TC Hit

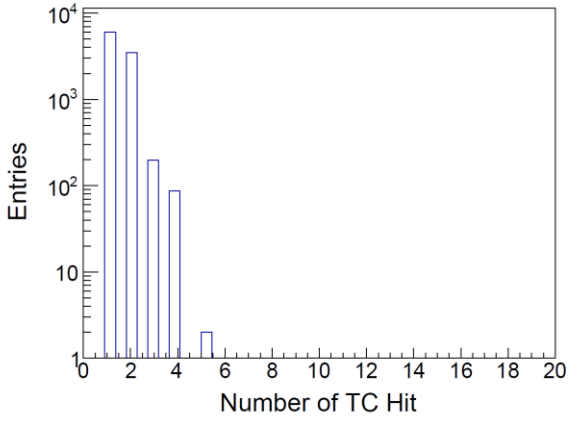
0.1~0.3 GeV

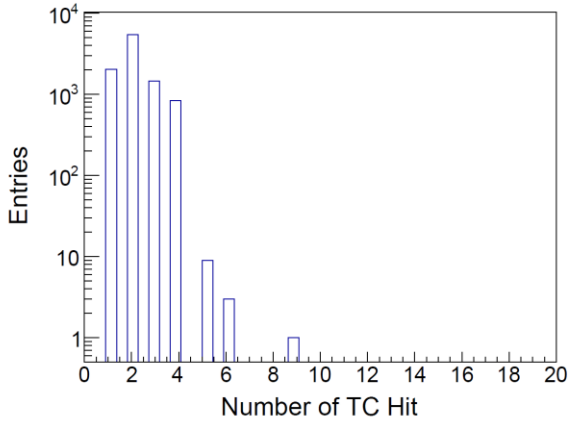
1.0~3.0 GeV

8.0~9.0 GeV

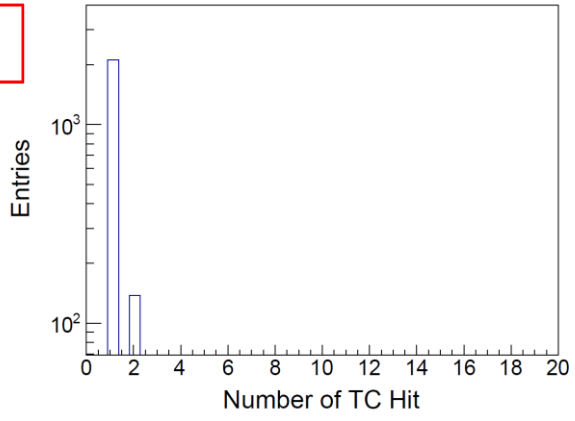
γ

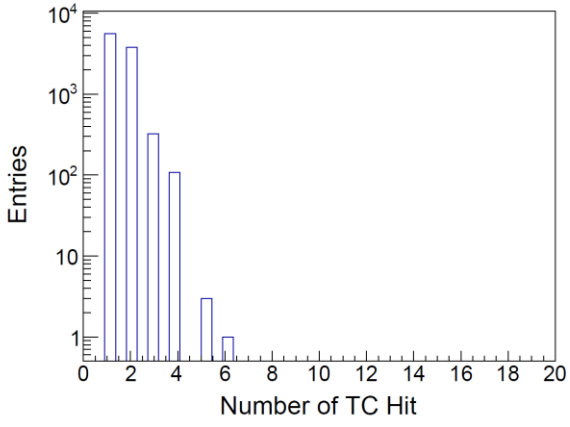


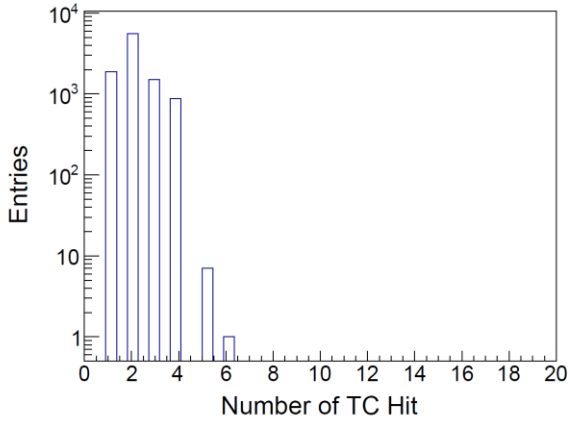




$e^{\pm}$







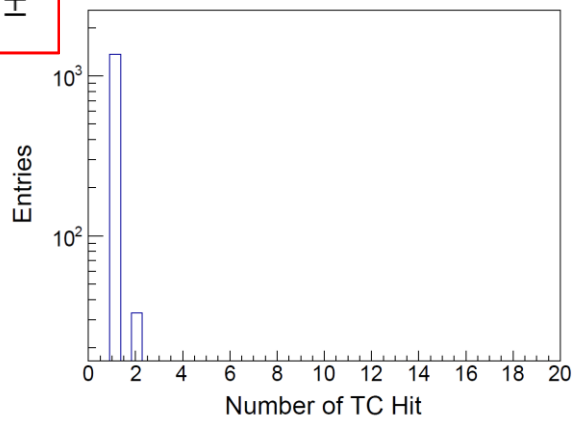
Number of TC Hit

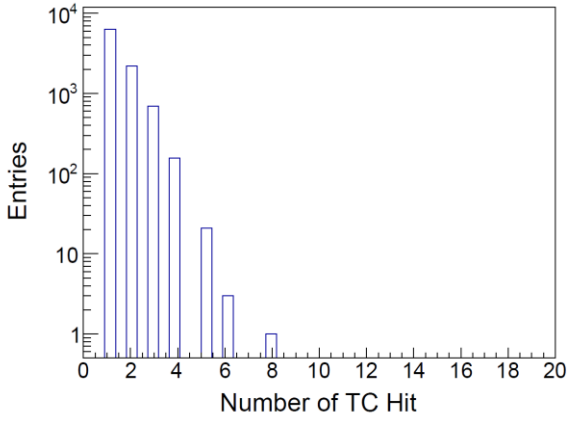
0.1~0.3 GeV

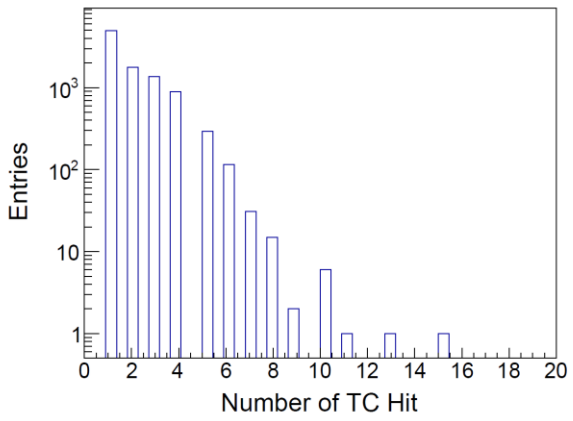
1.0~3.0 GeV

8.0~9.0 GeV

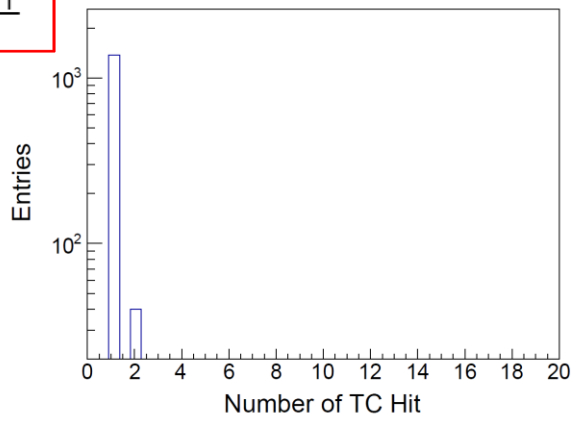
$\pi^{\pm}$

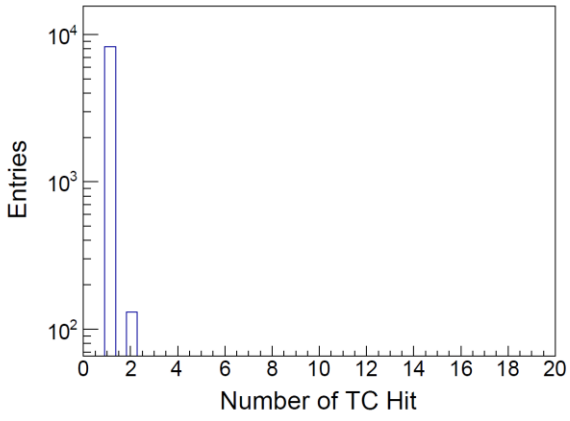


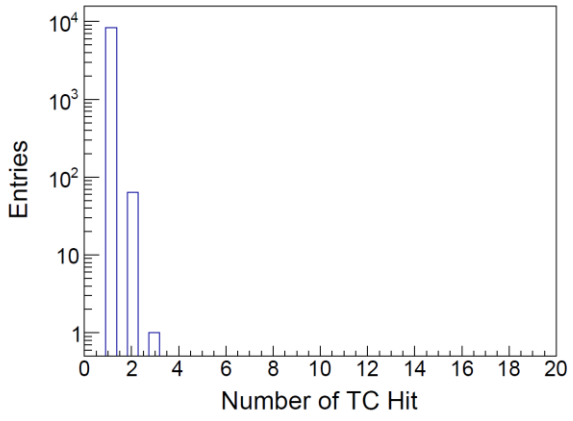




$\mu^{\pm}$







Pattern check (%)

γ

Momentum (GeV)	1	2	3	4	5	6	7	8
0.1 ~ 0.3	99.0	0.6	0.4	0	0	0	0	0
1.0 ~ 3.0	61.7	19.8	14.7	1.7	0	0	0.8	1.3
8.0 ~ 9.0	20.6	32.8	21.6	13.4	0.2	0	7.8	3.5

$e^{\pm}$

Momentum (GeV)	1	2	3	4	5	6	7	8
0.1 ~ 0.3	93.8	5.2	1.0	0	0	0	0	0
1.0 ~ 3.0	57.1	23.2	13.9	2.5	0.4	0	1.0	1.9
8.0 ~ 9.0	19.1	33.5	21.7	13.9	0.2	0	8.2	3.4

$\pi^{\pm}$

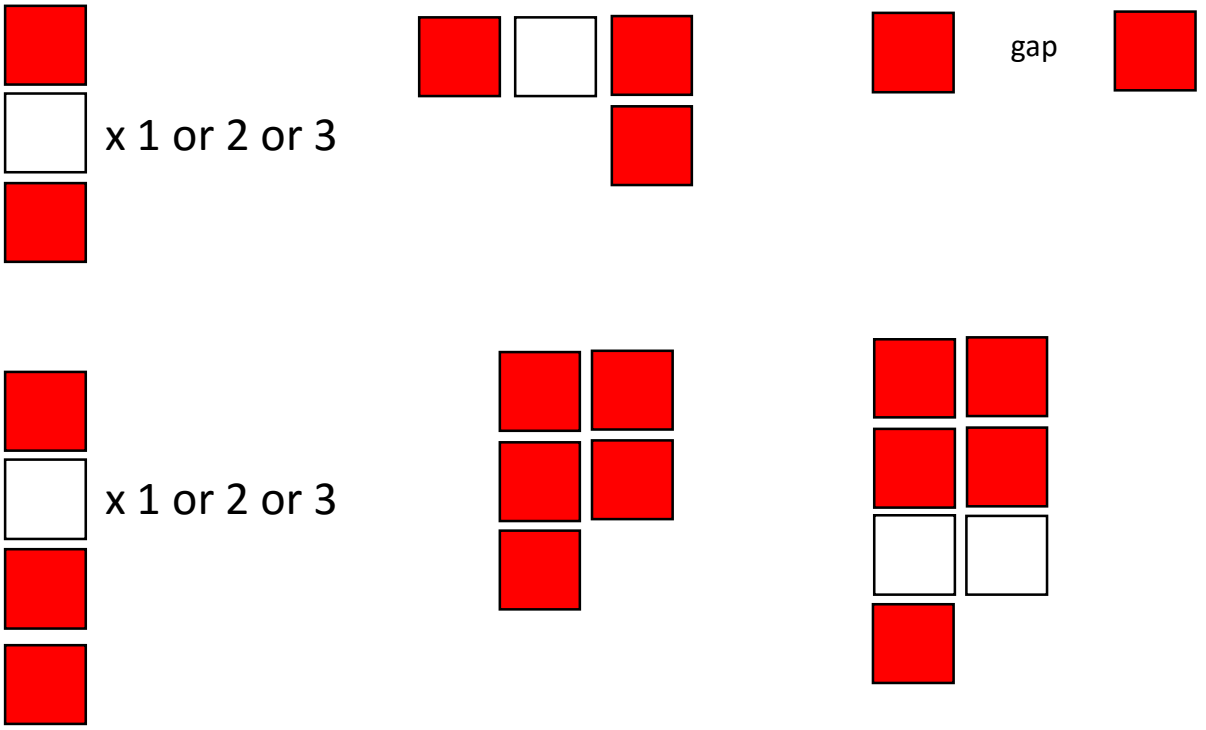
Momentum (GeV)	1	2	3	4	5	6	7	8
0.1 ~ 0.3	97.7	1.7	0.4	0	0	0	0.2	0
1.0 ~ 3.0	67.5	11.4	7.6	4.6	0.5	0.1	0.5	7.8
8.0 ~ 9.0	52.5	9.5	6.7	10.7	0.9	0.2	4.3	15.1

$\mu^{\pm}$

Momentum (GeV)	1	2	3	4	5	6	7	8
0.1 ~ 0.3	97.2	2.5	0.2	0	0	0	0	0.1
1.0 ~ 3.0	98.4	1.3	0.9	0	0	0	0	0
8.0 ~ 9.0	99.2	0.4	0.4	0	0	0	0	0

- 1~7 patterns are ~98% except for $\pi^{\pm}$.
- Only $\pi^{\pm}$ have the pattern 6. 
- $\pi^{\pm}$ have too much shape #8(etc) because of secondary particles?

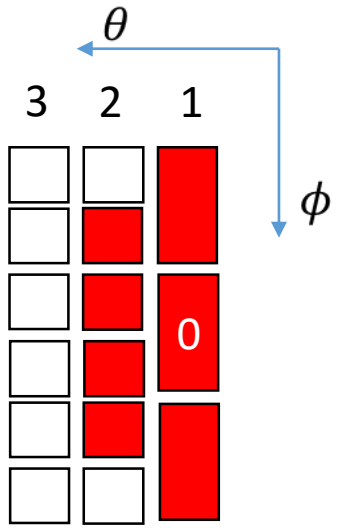
Patterns of ETC(#8)

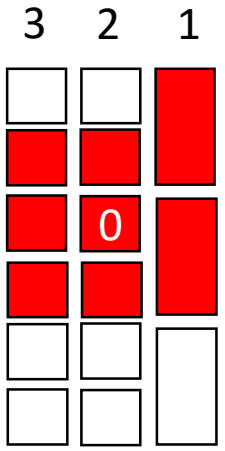


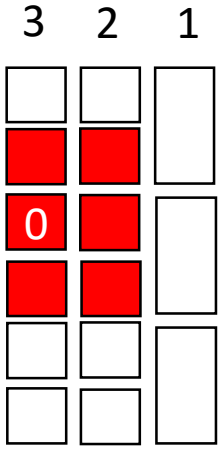
- Most of #8 patterns come from the radiation or 2nd particles(Energy asymmetric is shown)

Clustering range

- FWD Endcap
  - Center TC θid =1 ?
    - TCs of θid =0 cover 2 ϕid range of other TC's
    - ➔7 TCs around the center + center
  - Center TC θid =2 ?
    - 8 TCs + center
  - Center TC θid =3 ?
    - Same as BWD endcap

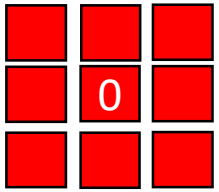


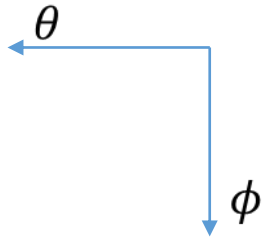




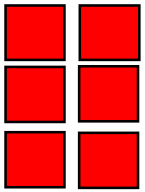
Clustering range

- Barrel
  - 3x3 TCs
  - 8 TCs + center TC



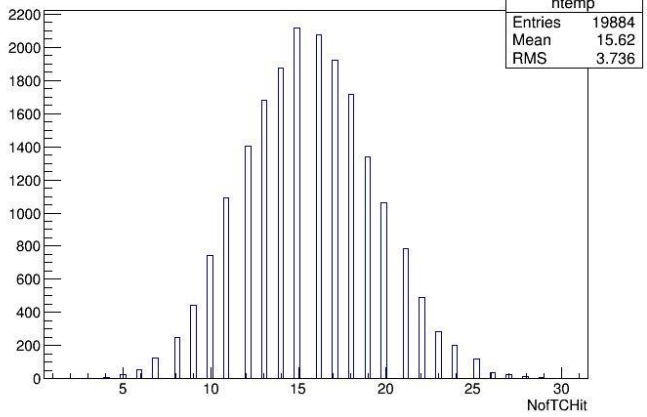


- BWD Endcap
  - 3x2 TCs
  - 5 TCs + center TC

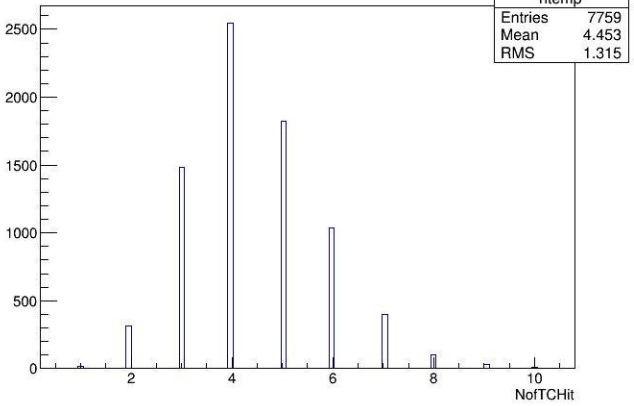


Number of TC Hit

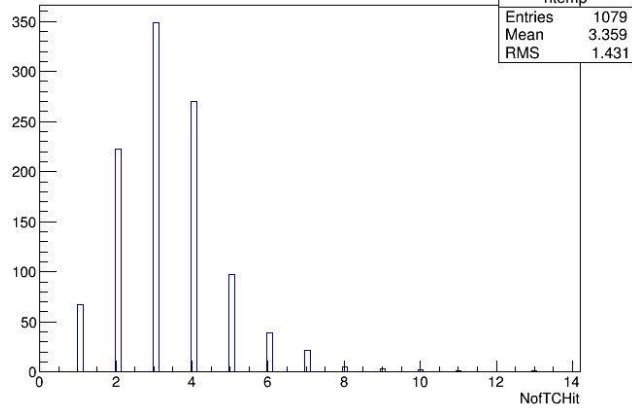
Y(4S)



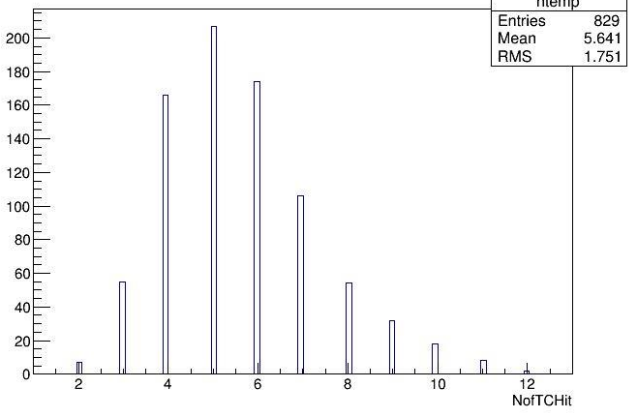
Bhabha



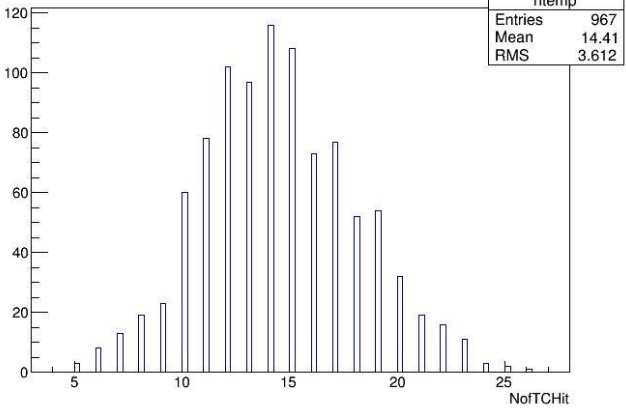
ISR($ee \rightarrow \mu\mu$)



ISR($ee \rightarrow \pi\pi$)

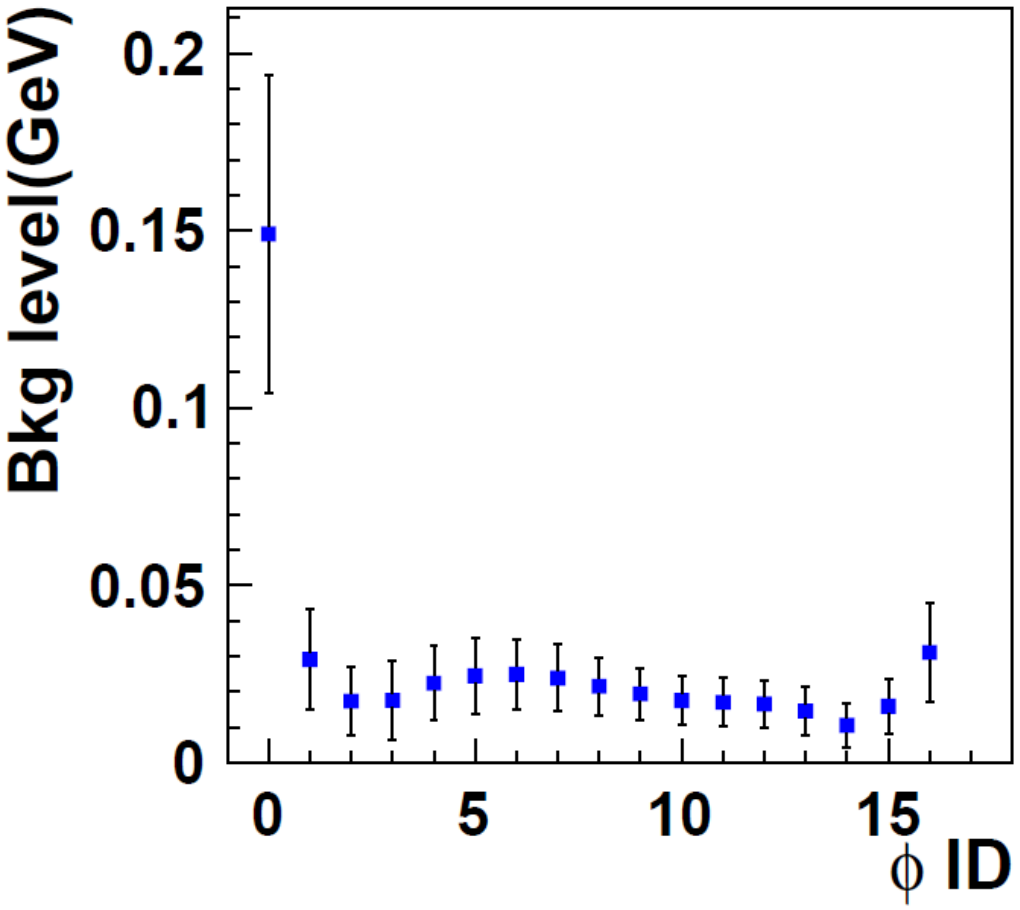


Continuum



BKG level vs θ ID

BKG level vs θ ID



Blue point : Mean of project distribution

Error bar : RMS of project distribution

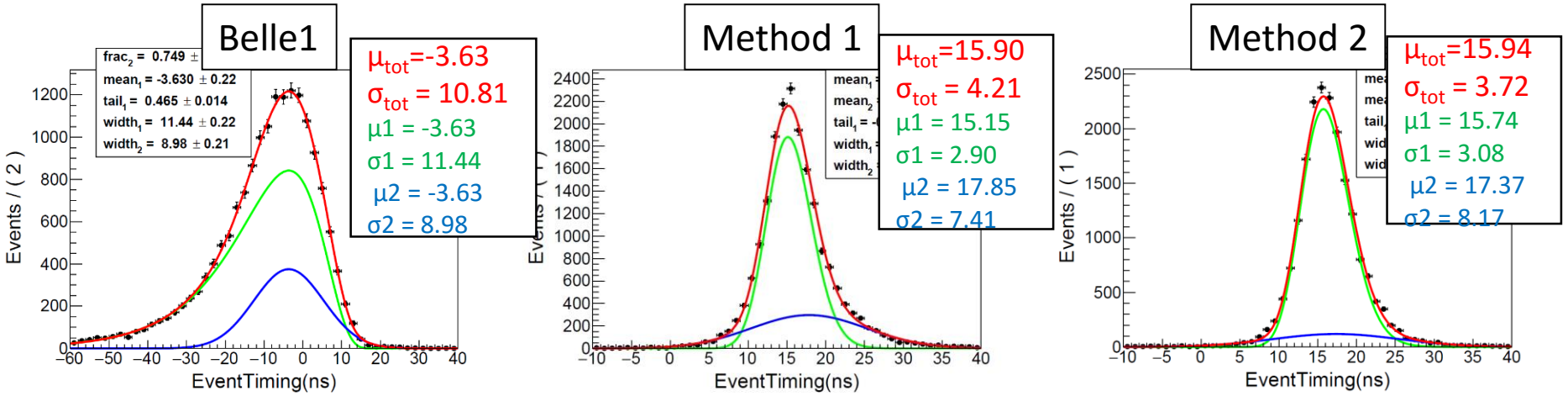
FAM Electric Noise calibration (Rough Estimation)

Mean	1 FADC count by Rough Estimation (E = 200MeV)		Noise Measurement FADC count (σ) (± 0.000x)		Noise in Electronics Board	
Channel	FAM 1 (MeV)	FAM 2 (MeV)	FAM 1	FAM 2	FAM 1 (MeV)	FAM 2 (MeV)
1	5.1	5.7	2.2	2.3	11.2	12.9
2	4.7	5.3	2.2	2.3	10.4	12.0
3	4.8	4.6	2.3	2.2	10.9	10.2
4	4.7	4.3	2.2	2.2	10.4	9.7
5	4.4	4.3	2.2	2.3	9.8	9.8
6	4.7	4.4	2.3	2.2	11.1	9.8
7	4.4	3.9	2.2	2.2	9.8	8.8
8	4.8	4.1	2.1	2.3	10.0	9.3
9	4.1	4.0	2.3	2.3	9.3	9.1
10	4.3	4.0	2.2	2.2	9.5	8.9
11	3.7	3.8	2.3	2.2	8.4	8.4
12	3.4	4.3	1.7	1.7	5.8	7.4

Resolution of event-timing

- Physics trigger : $E_{tot} > 1\ GeV\ or\ ICN > 3$ with bhabha veto
- Sample : 20,000 events Y(4S) + Beam Background
- Expected value of event timing: 14.96 ns (event timing of only γ)

Fitting result of event timing distribution (ns)

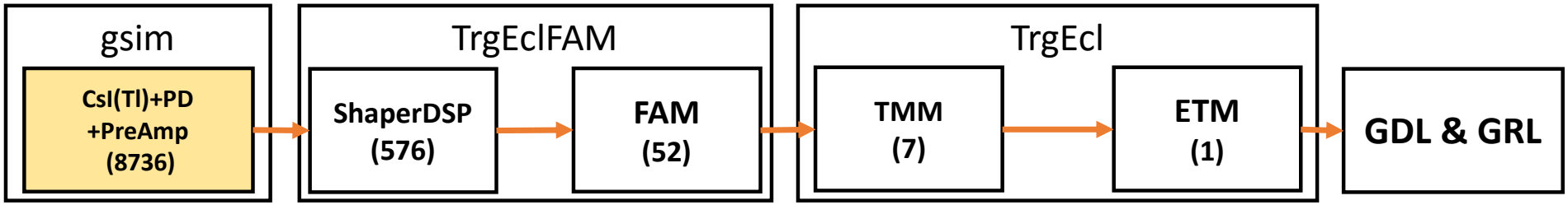


- The best resolution is method 2 ($\sigma_{total} = 3.72\ ns$).

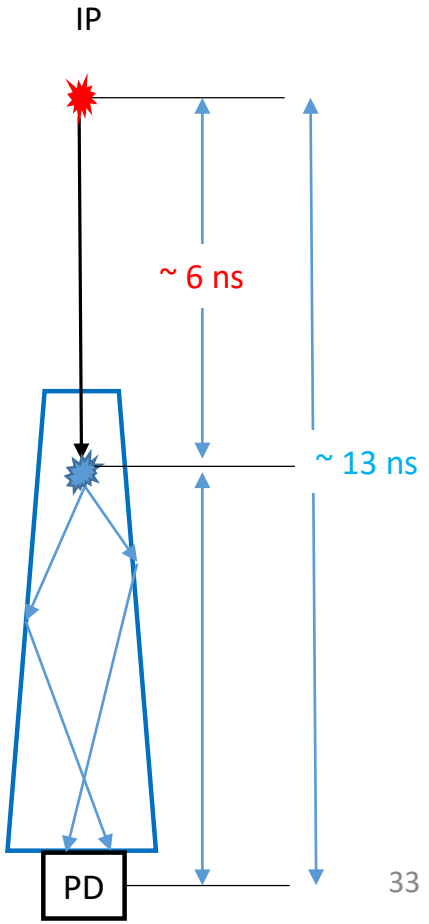
Fitting error <0.03

- If we consider the green Gaussian results(corresponding to high energy TC timing) in m1(2.90) and m2(3.08), the resolution is satisfied with the DAQ requirements (10 ns) within 3 sigma.
- Mean values of m1, m2 has ~ 0.9 ns shift from the expected value.
- We will choose method2 for Belle II ECL timing

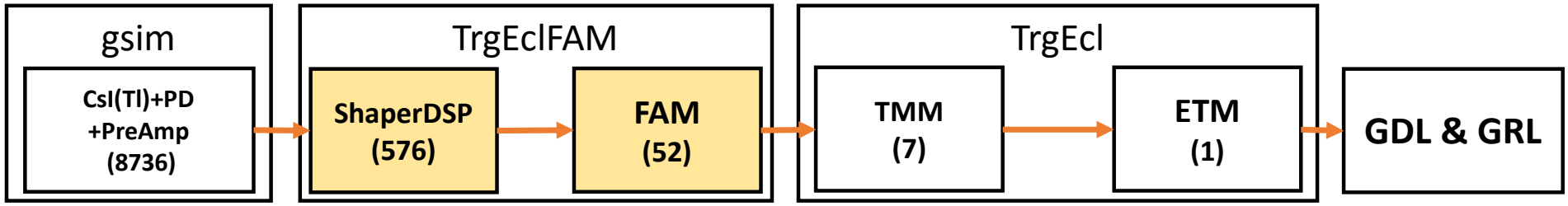
Gsim part



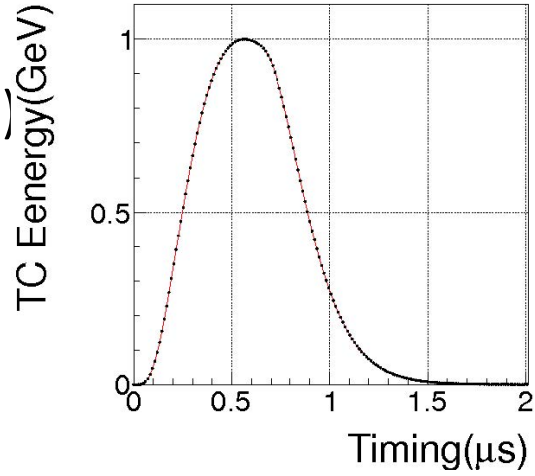
- 8736 CsI(Tl) crystals.
  - τ = 1 μs
  - 6 x 6 cm front face
- Time range : -4.0 ~ 4.0 μs
- Particles are shot at 0 s in IP.
  - (= average timing ~13ns)
- Divide 8 μs 80 bins(0.1 interval)
- Send Xtal's energy, timing to ShaperDSP



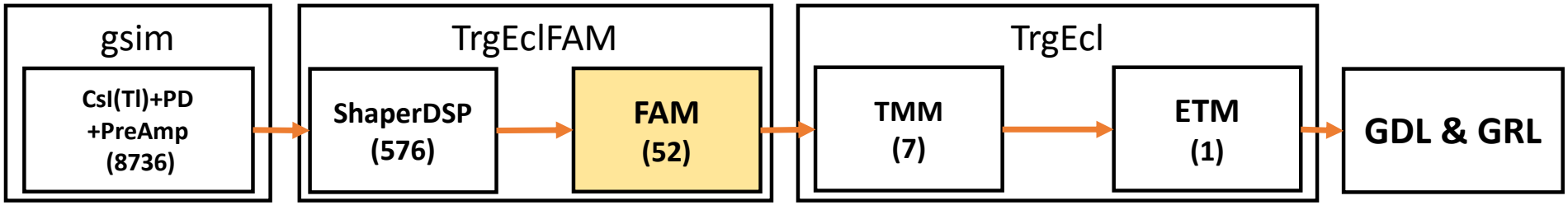
TrgEclFAM



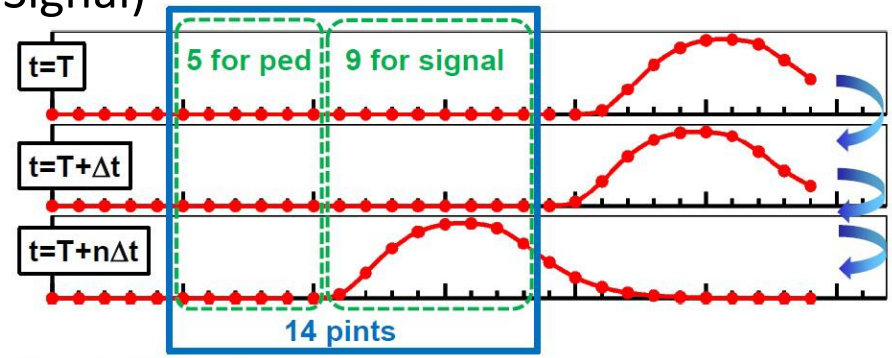
- ShaperDSP
  - Add 8736 to 576 Trigger Cells(4x4 Xtals → 1TC)
  - Emulate signal shape using PDF based on Xtal components(shaping width ~ 1 μs)
- FAM
  - Digitize analog TC signals
  - Add three kinds of noises
  - Energy & Timing measurement
    - Fit method, two methods as backup/reference
    - Apply E_{TC} > 100 MeV threshold



TrgEclFAM



- Measure TC timing and Energy
  - Fit method(96 ns sampling)
    - Use minimum χ^2 fit
    - Check 14 bins (5 pedestal, 9 Signal)

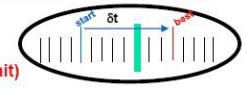


In each Δt interval,

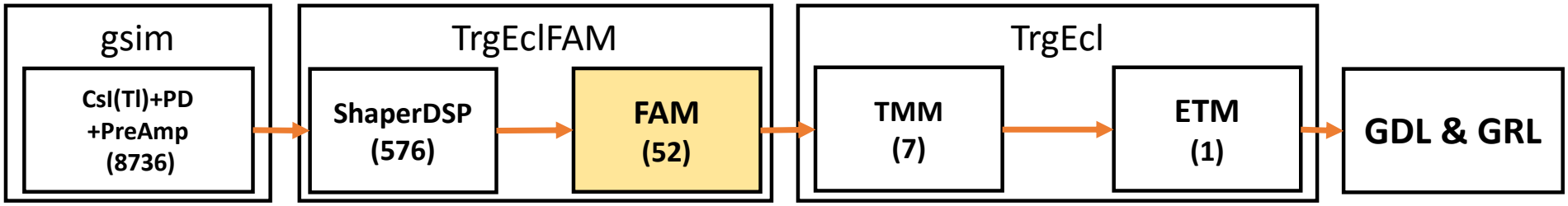
$$\chi^2 = \sum_{ij} \{ y_i - Af(t_i - \delta t - t_0) - P \} S_{ij}^{-1} \{ y_j - Af(t_j - \delta t - t_0) - P \}$$

y_i = data point
A = amplitude
S = covariance matrix
P = pedestal

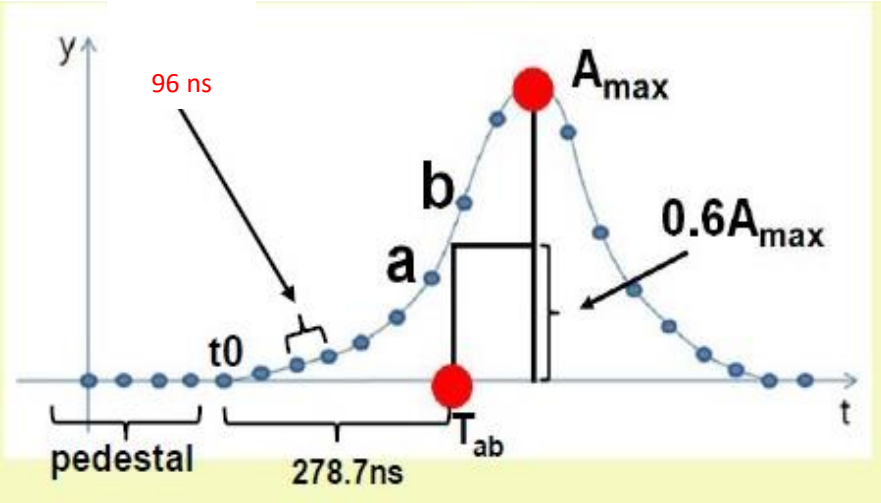
f = fit function(signal+noise)
t_i = time of each point for fit
t_0= signal starting time
δt = time shift for best(1ns unit)



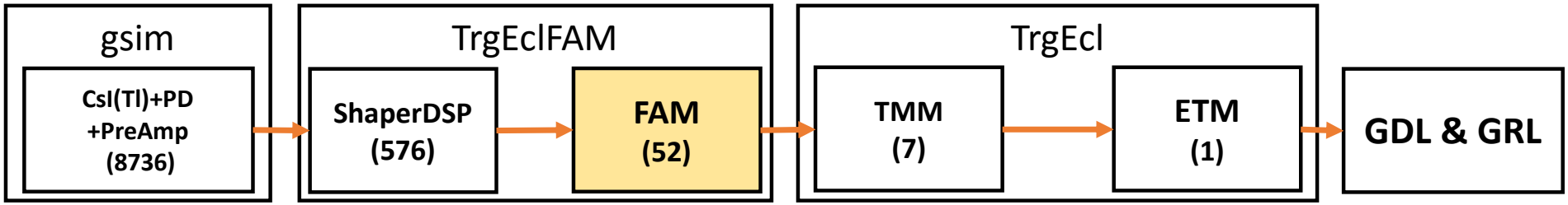
TrgEclFAM



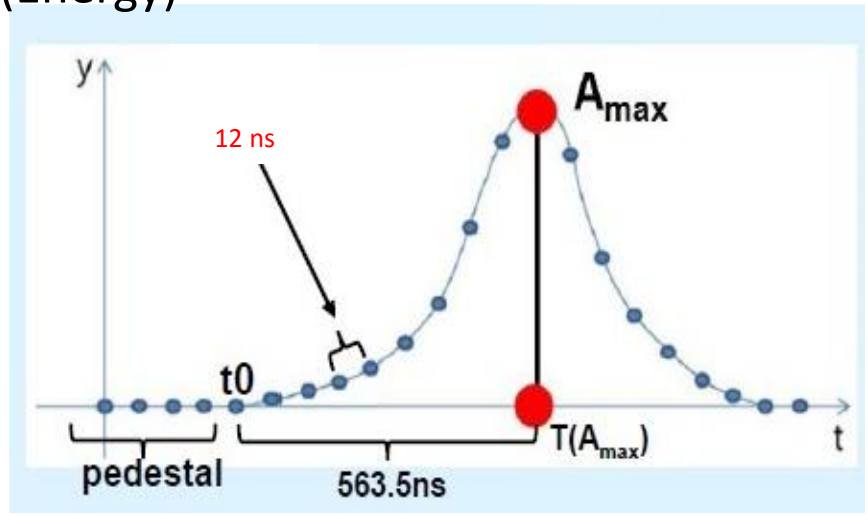
- Measure TC timing and Energy
  - Back up method 1 (96 ns sampling)
    - Pick up highest point as A_{max} (Energy)
    - Find 0.6 × A_{max} point T_{ab}
    - Timing t_0 = T_{ab} – 278.7 ns



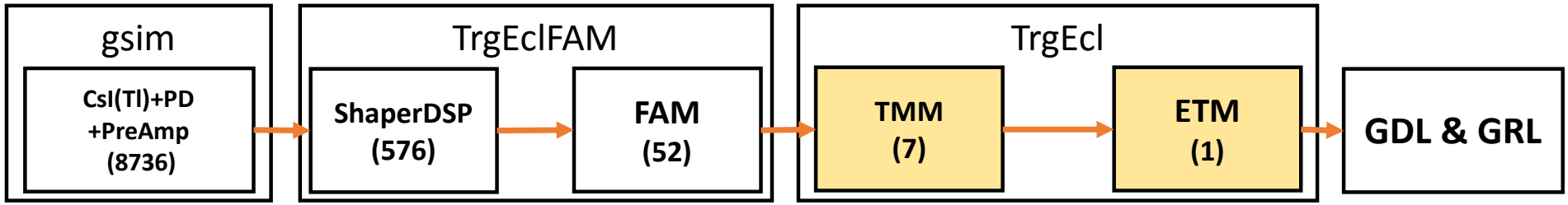
TrgEclFAM



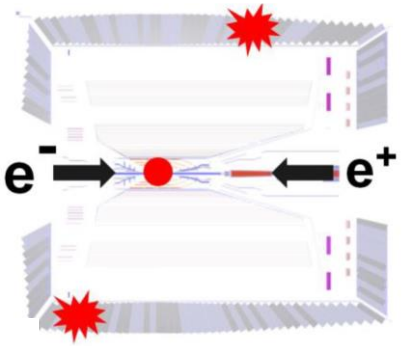
- Measure TC timing and Energy
  - Back up method 2 (12 ns sampling)
    - Belle method
    - Pick up highest point as A_{max} (Energy)
    - Timing $t_0 = T_{max} - 563.5$ ns

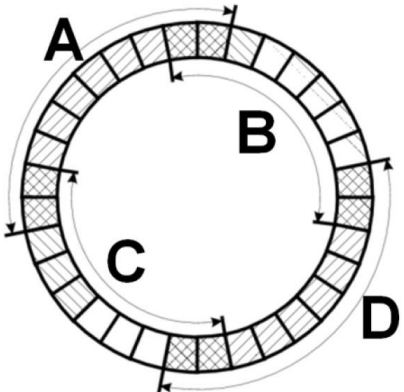


TrgEcl module



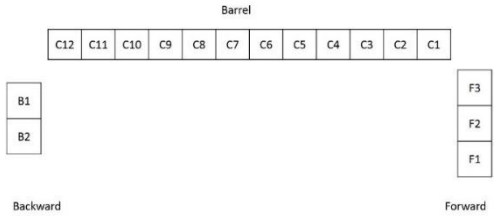
- TMM merger FAM signals and send it to ETM.
- ETM makes trigger decision and timing, then send it to GDL and GRL.
  - Timing decision(Belle)
    - timing = The fastest TC timing.
    - TC Hits within 500ns are used to decide trigger conditions.
  - Physics trigger
    - E_{total} > 1GeV || ICN >3 (with Bhabha trigger veto)
  - Bhabha trigger(Belle)
    - back-to-back topology(2D(r-θ))
  - BeamBKG trigger
    - bkg = ((ICN_A > 0&ICN_D > 0) or (ICN_B > 0&ICN_C > 0))
    - !bkg & barrel || !bkg & forward-endcap



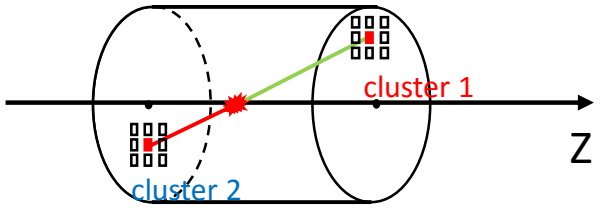


Status on Tsim-ecl(3-D Bhabha veto logic)

- Bhabha Veto logic study
  - In Belle(2-D)
    - Use r- θ information
    - Veto rate ~ 99%
    - Affect τ τ and low multiplicity events.



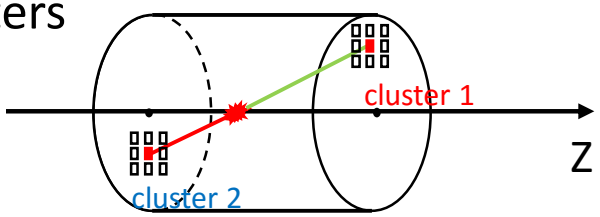
  - In Belle II (expectation)
    - Use r-θ-φ (3-D) information
      - Use timing, energy of Clusters
    - Veto rate should be ~99%
    - Avoid the effect to τ τ and other low multiplicity events.



Bhabha in CM frame

Status on Tsim-ecl(3-D Bhabha veto logic)

- Current 3-D Bhabha veto logic
  - Use Belle clustering logic
    - Find 2 highest clusters
  - Check back-to-back topology of the two clusters
- Result of the current logic
  - Bhabha veto : ~ 99%
  - τ→μγ ,τ→eγ can be improved by 3-D.
  - Has room to improve with detail study



Bhabha in CM frame

Physics trigger eff. with Bhabha veto logic

Physic mode	Physics trigger Eff. With Belle Bhabha veto (%)	Physics trigger Eff. With 3-D Bhabha veto(%)
Y(4s)	99.94	99.97
τ→μγ	81.37	83.52
τ→eγ	58.27	73.00
τ→generic	94.02	93.77

Sample : 1000 events
Physics trigger : E_{total} > 1GeV || ICN >3