Run13 Gluon Polarization Measurement by Central Arm Pi0

2013/11/04

Yoon Inseok.

S.N.U / RIKEN

@ Japan-Korea PHENIX Collaboration Workshop

Outline

- Physics motivation of the analysis.
- Introduction to PHENIX central arm.
- Event selection.
- Calculation of A_{LL} - current status.
- Future Prospect.

1. Motivation

- Measuring gluon spin component of proton spin.

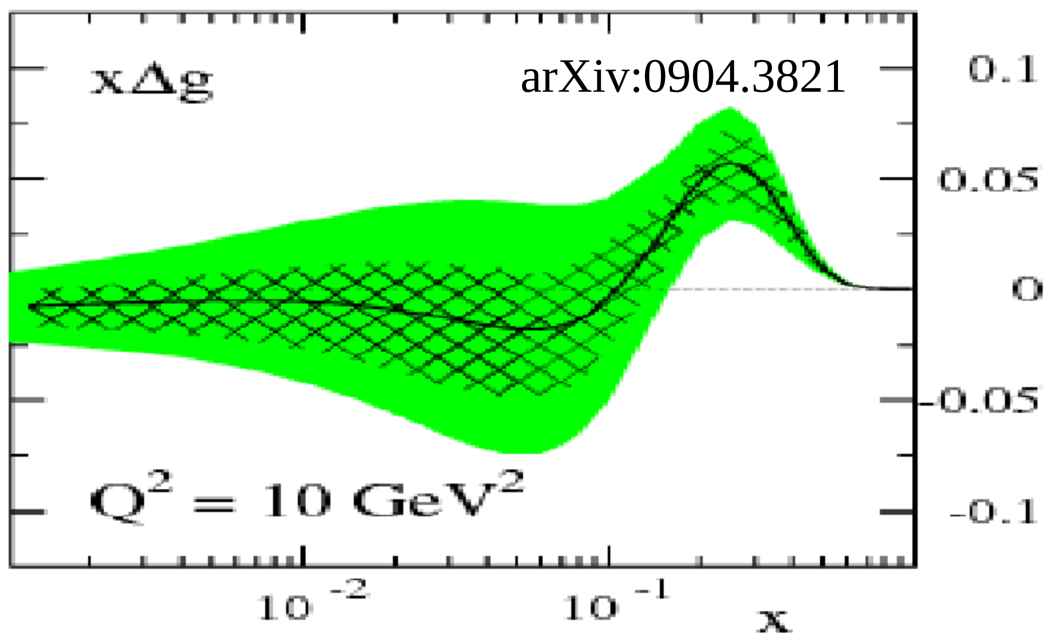
$$\frac{1}{2} = \int_0^1 dx\, [\frac{1}{2}\sum_q (\Delta q + \Delta\bar{q})(x,\mu^2) + \Delta g(x,\mu^2)] + L$$

PDFs of valence quarks : well measured.

PDFs of sea quarks and gluon : poorly measured.

- Gluon spin component

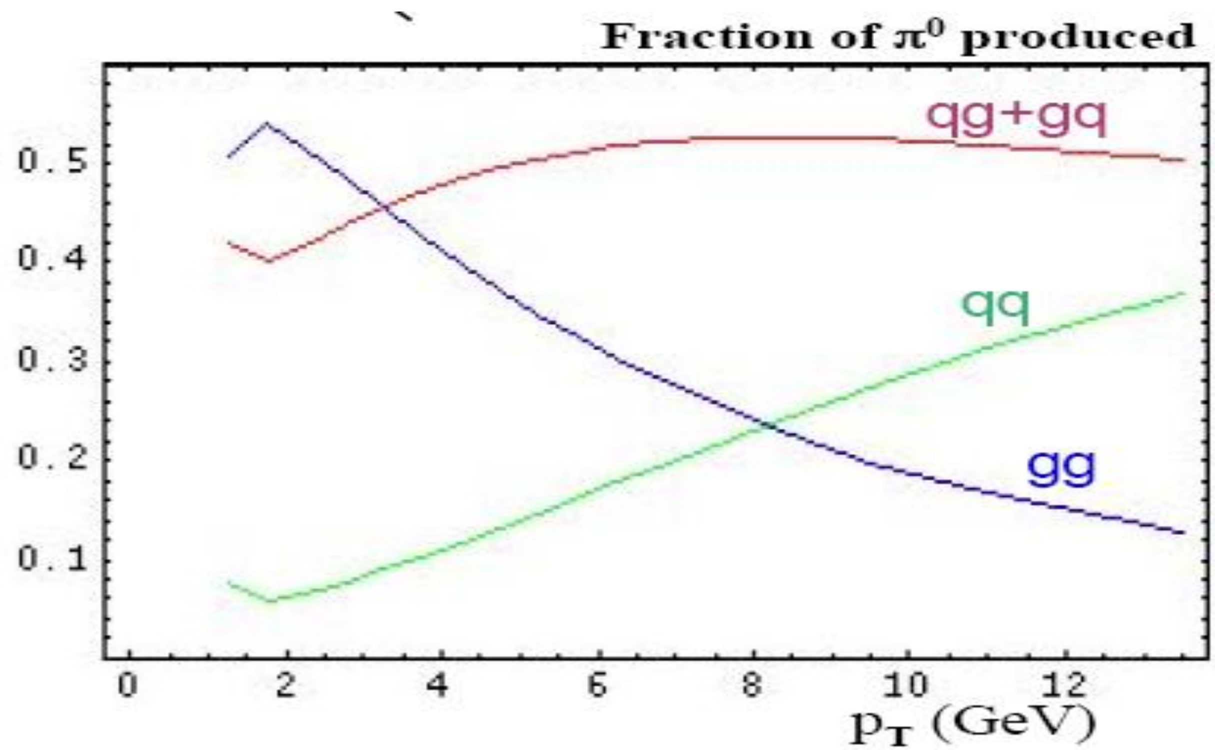
: A_{LL} of π^0, η and ETC.



- Why π^0 is good probe for measuring ΔG?

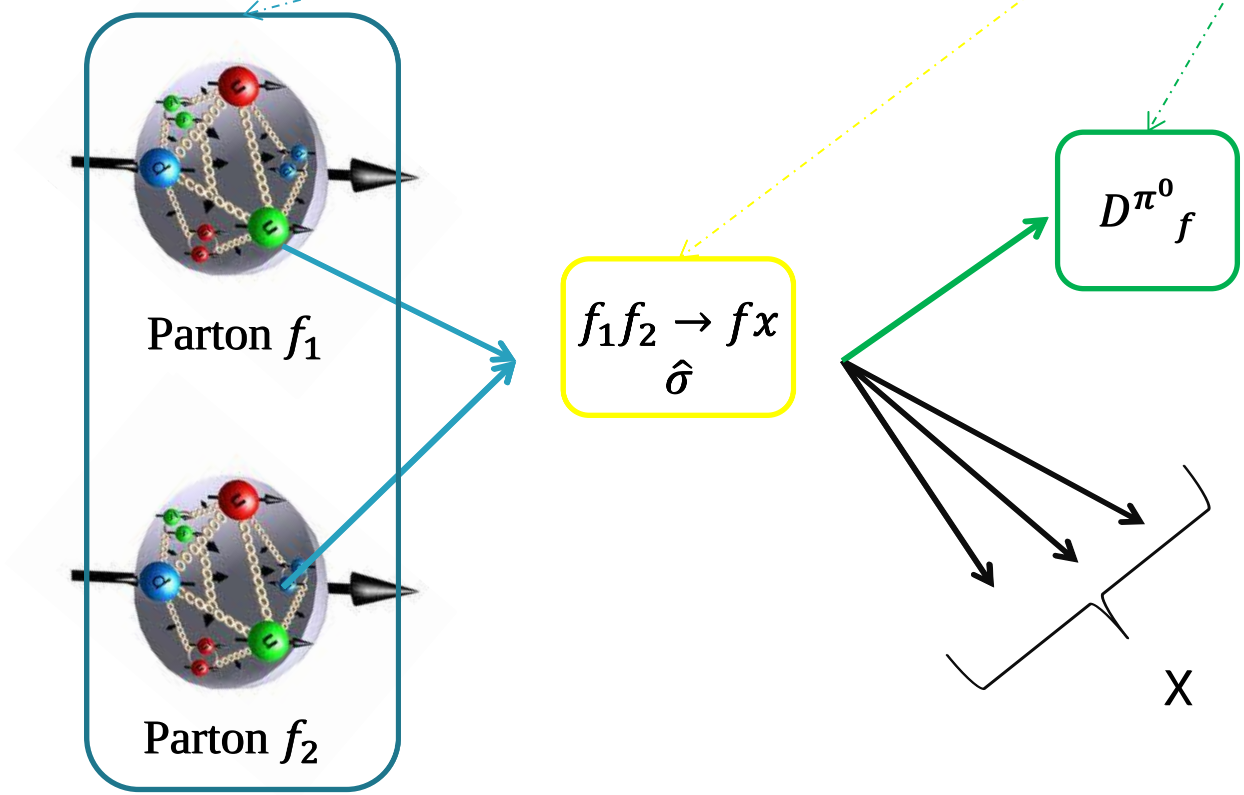
=> Many of π^0s are from gluon-gluon or qluon-quark scattering.
Very large sample of π^0s.

=> π^0 is good channel for measuring ΔG .
Measuring ${A_{LL}}^{\pi^0}$ is my analysis goal.

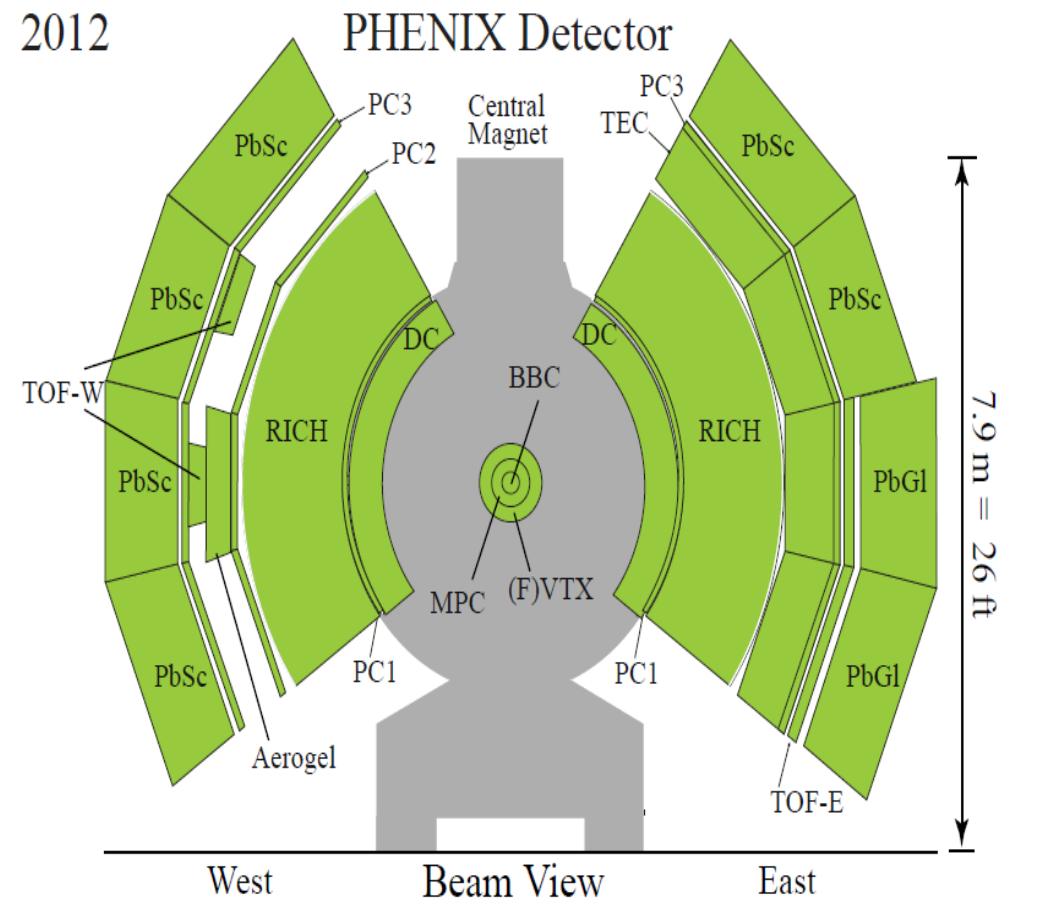


- A_{LL} consist of PDF, partonic reaction cross section and FF.

$$A_{LL}{}^{\pi^0} = \frac{\sigma^{\pi^0}{}_{++} - \sigma^{\pi^0}{}_{+-}}{\sigma^{\pi^0}{}_{++} + \sigma^{\pi^0}{}_{+-}} = \frac{\sum_{f_1,f_2,f} \Delta f_1 \otimes \Delta f_2 \otimes d\hat{\sigma}^{f_1 f_2 \to fX} \otimes D^{\pi^0}{}_f}{\sum_{f_1,f_2,f} f_1 \otimes f_2 \otimes \hat{\sigma}^{f_1 f_2 \to fX} \otimes D^{\pi^0}{}_f}$$



2. PHENIX Central System



$|\eta| < 0.35, \Delta\phi = 90^0$

EMCal :
PbSc, PbGl
Consists of many towers.
Measure energy, hit position and TOF.

BBC : Global event trigger

ERT (=EMCal and RICH Trigger)
: Main trigger for this analysis

3. Event Selection

- Event selection study for preliminary has been done.

- π^0 is reconstructed by two gamma which are detected by PHENIX EMCal.

- zVertex 30cm cut, min energy 200MeV for PbSc
  100MeV for PbGl

- EMCal warnmap has been generated.
  : Map of abnormal towers.

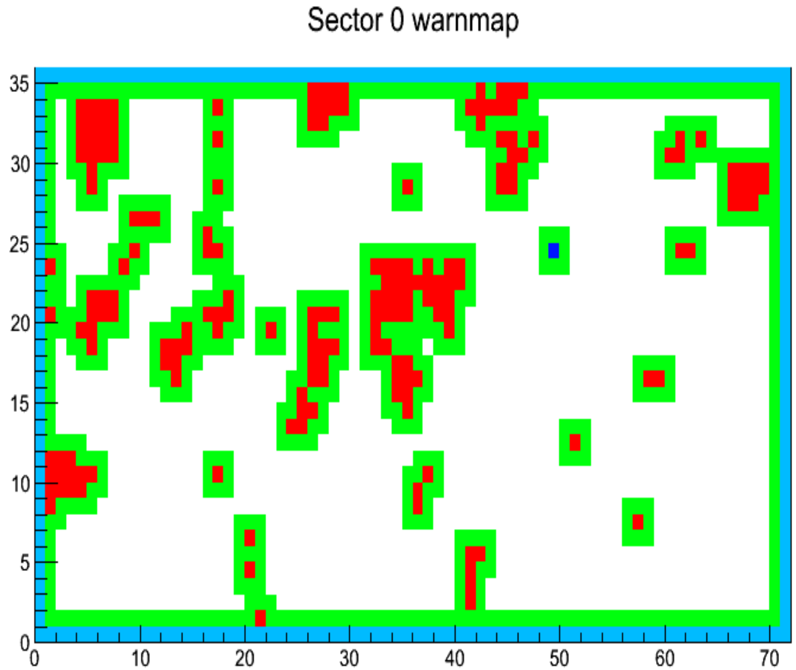
- Shower shape cut, charge veto cut and TOF cut are applied.
  : Cut parameters are optimized by drawing S/N ratio vs. cut parameter.

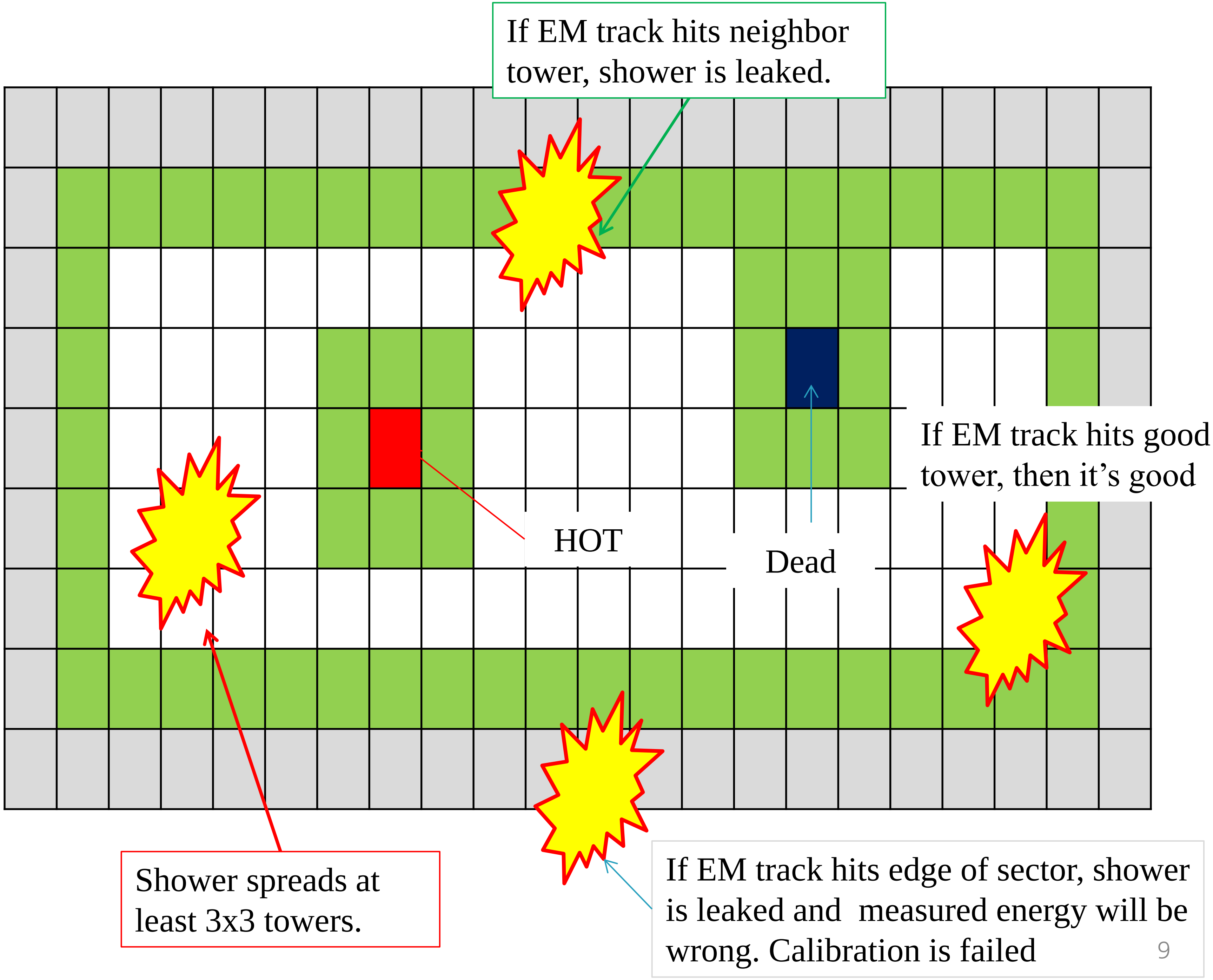
WarnMap Generation

- Warnmap is used to reject the events from abnormal towers.

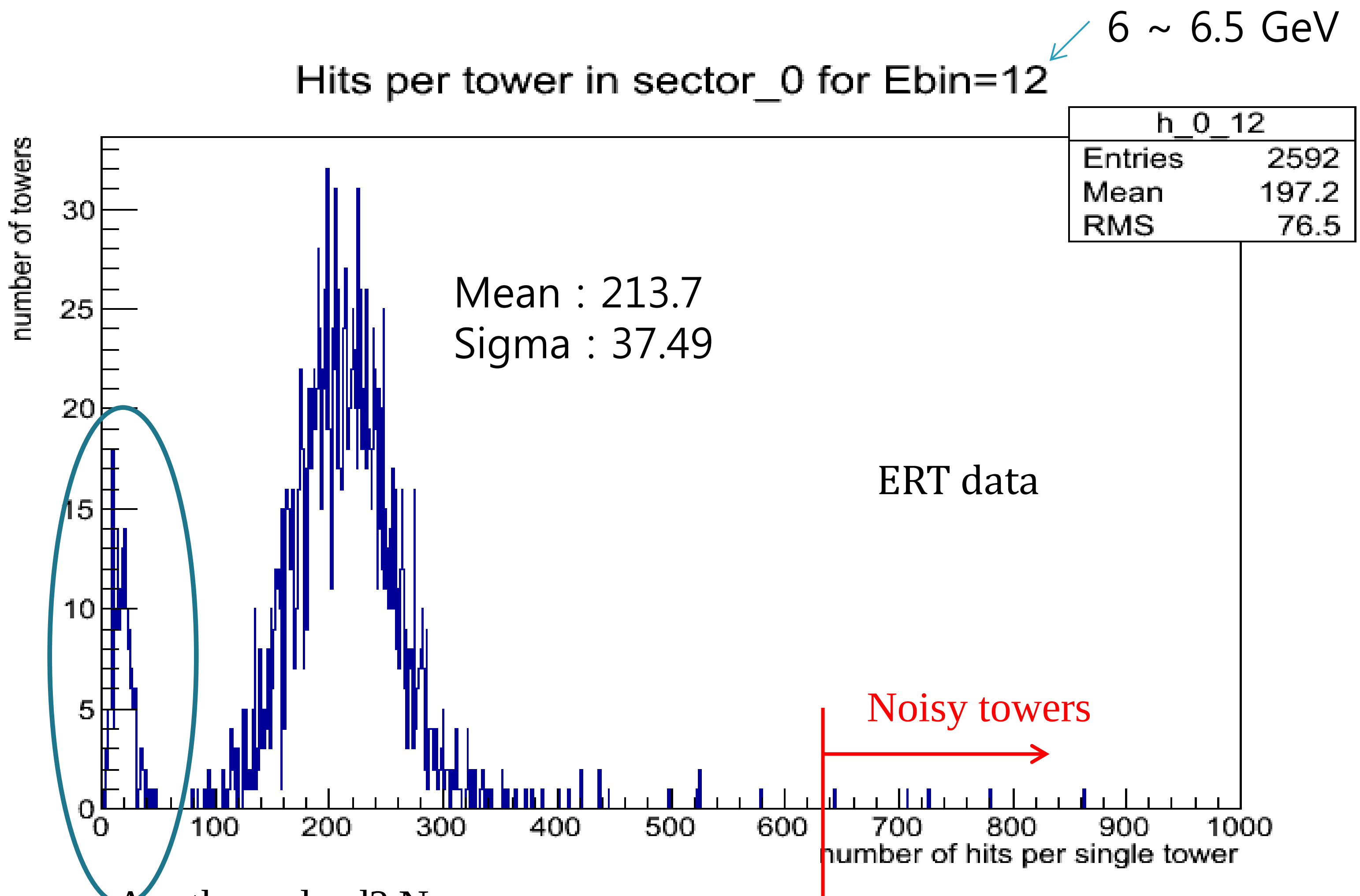
- Events from hot, dead, uncalibrated or neighbor of problematic tower are rejected.

- If number of hits per single tower is too big or too small, the tower is considered to be hot or dead.




If EM track hits neighbor tower, shower is leaked.
If EM track hits good tower, then it's good
HOT
Dead
Shower spreads at least 3x3 towers.
If EM track hits edge of sector, shower is leaked and measured energy will be wrong. Calibration is failed

Finding Hot Towers



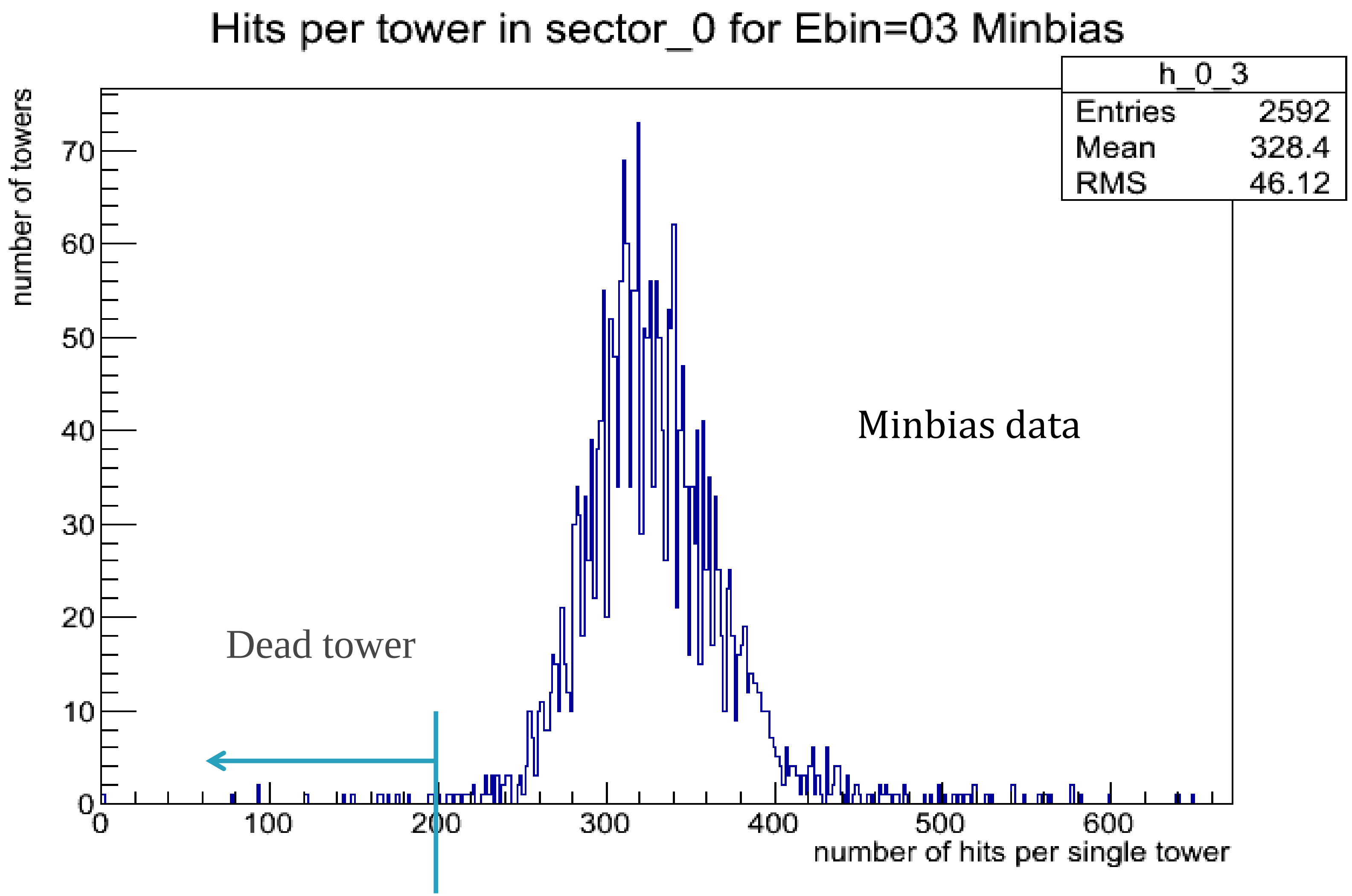
Are those dead? No.
Dead tower + live tower which trigger is dead.

⇒Because ERT broken tower can't pick up high energy photon,
Number of high energy photon hits of the tower is lower.

ERT broken tower can pick up photon from pion decay still, if other tower is fired.
⇒ So it shouldn't be masked.

- To distinguish dead tower and live tower which trigger is dead, minbias data is used.

Finding Dead Towers



Shower Shape Cut

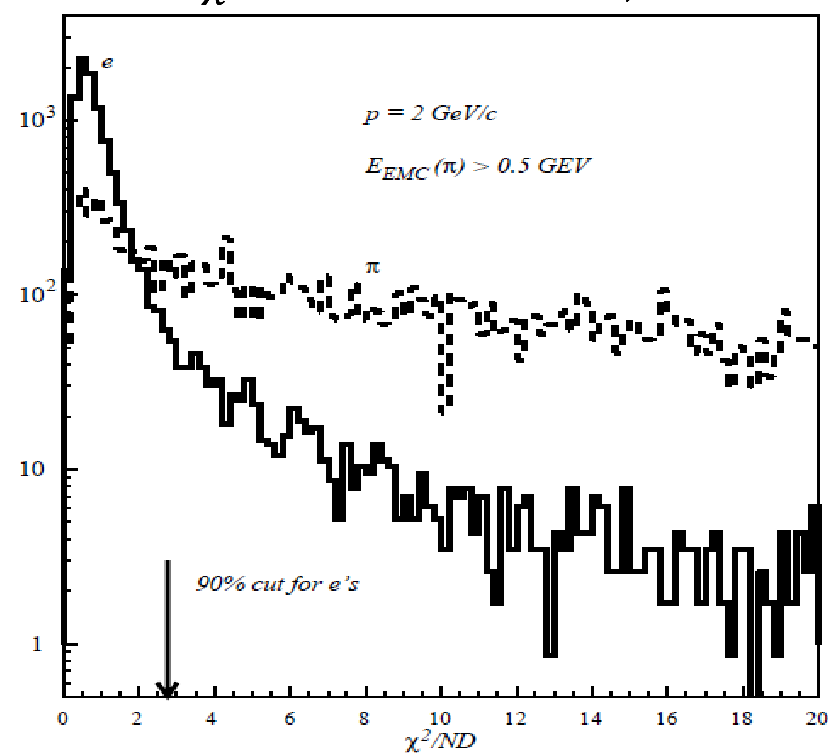
- To reduce background from hadronic event.

- Compare measured shower shape with shower of electron beam by calculating $\chi^2 = \sum_i (E_i{}^{elec} - E_i{}^{meas})^2 / \sigma_i{}^2$

- Conventional 2% cut is applied.
(= Level of killing 2% of real EM)

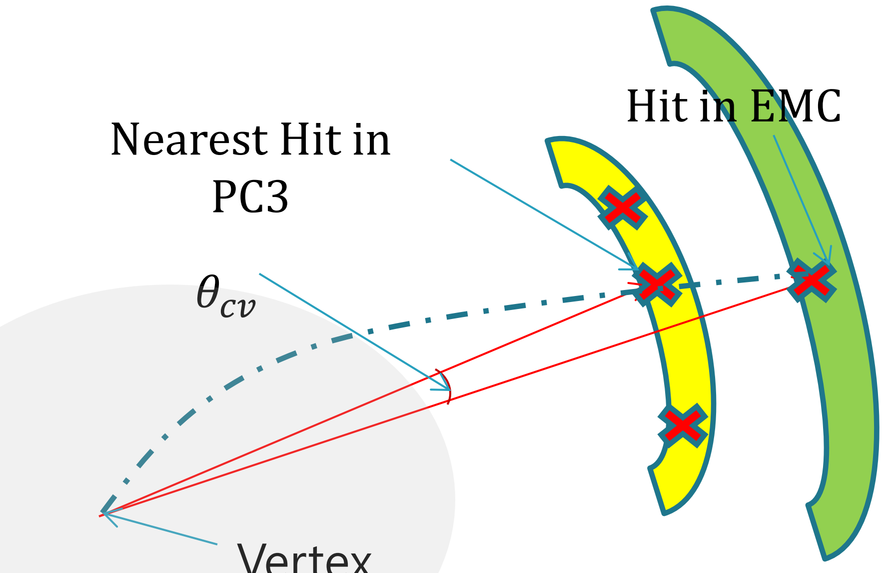
- 30% of background is suppressed.
10% of signal is lost

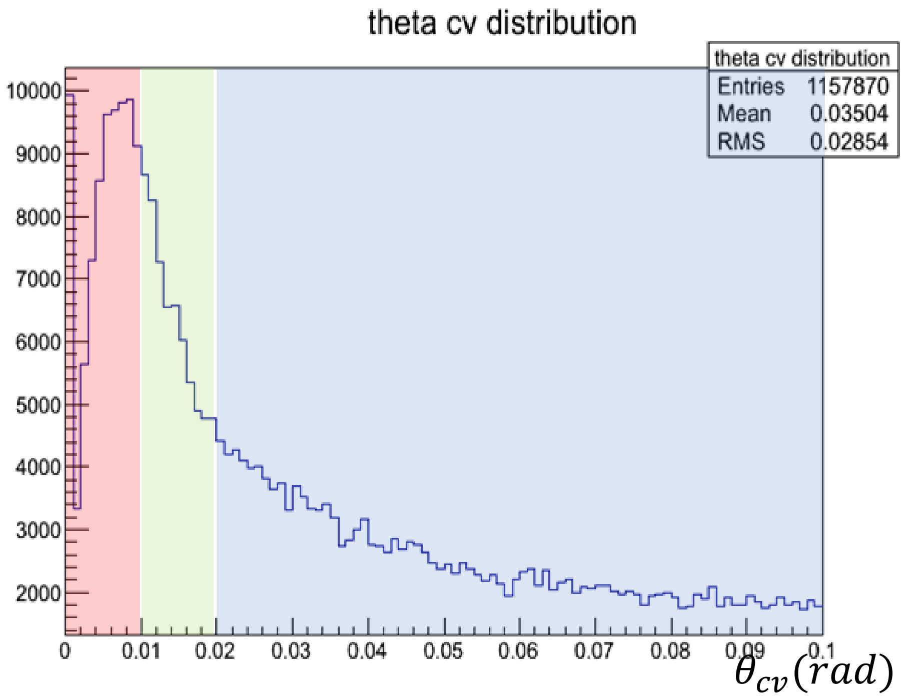
χ^2 distribution of e^-, π



Charge Veto cut

- To reduce background from charged track.
- Charged track is bent in central magnet. So by calculating θ_{cv}, charged track can be distinguished.





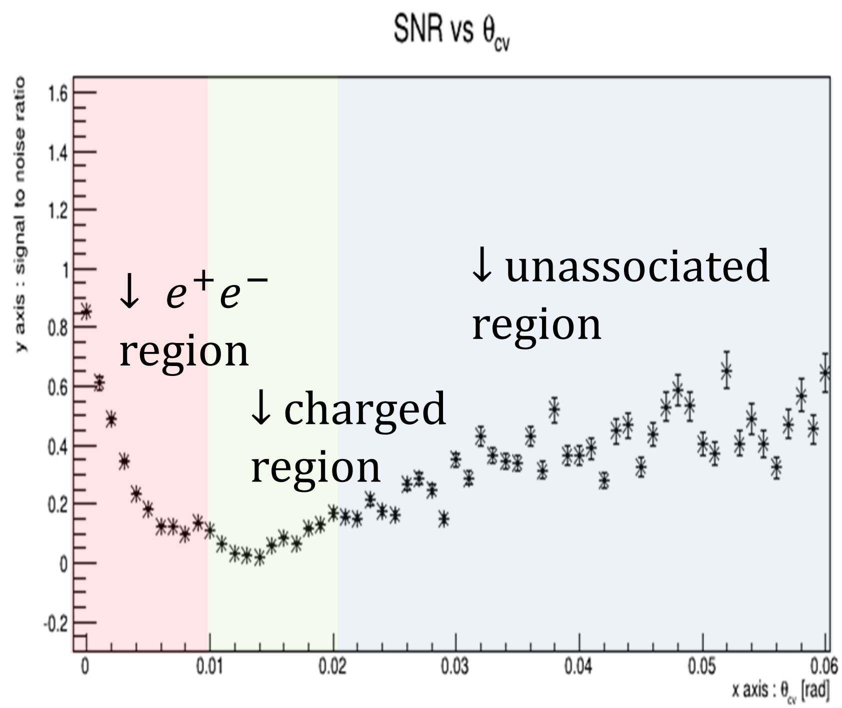
- Divide θ_{cv} bin by 1mrad, and draw diphoton invariant mass and calculate S/N ratio for each θ_{cv} bin.

- Draw S/N ratio vs. θ_{cv} bin.

- The S/N ratio drops in mid region. This mid region is dominated by charged tracks. The region is excluded.

- 25% of background is suppressed.
  14% of signal is lost

- Cluster energy dependence will be included after getting preliminary result.



TOF Cut

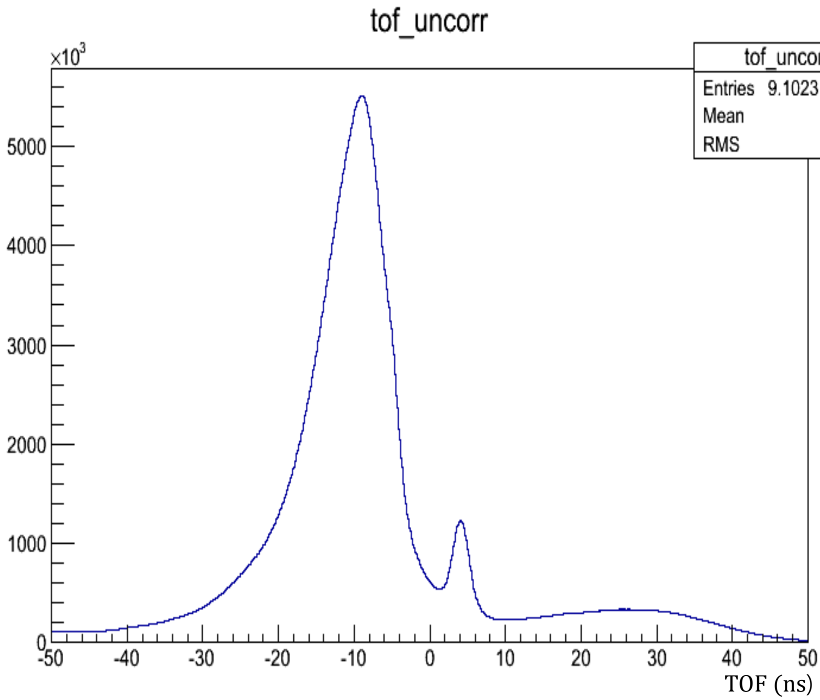
- To reduce background from ghost cluster.

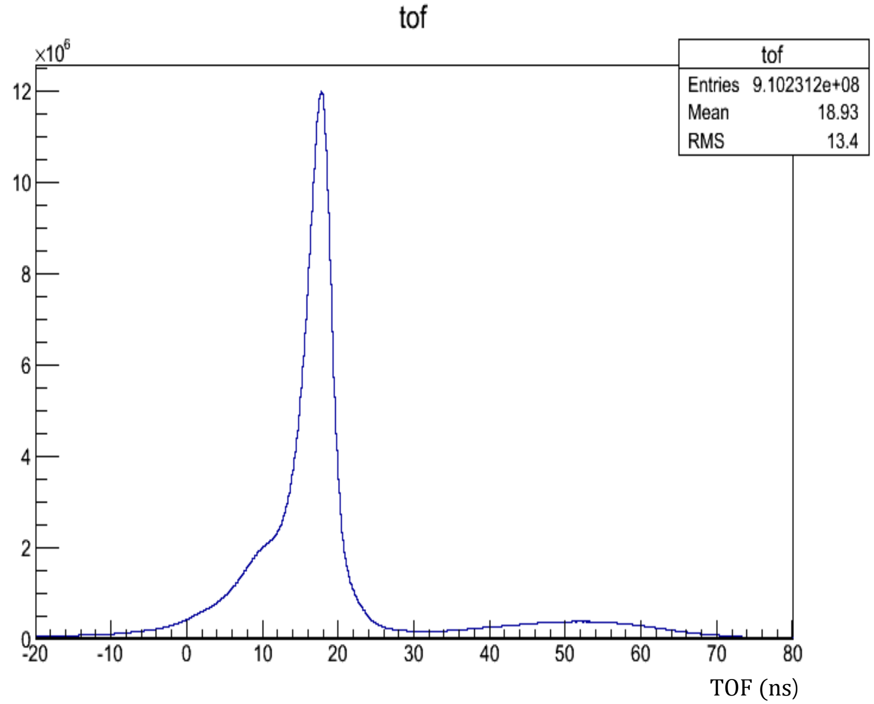
- Ghost cluster : cluster from previous bunch crossing.
  Cluster in EMCal can remain up to 3 bunch crossing.
  Ghost cluster can make syst. uncertainty.

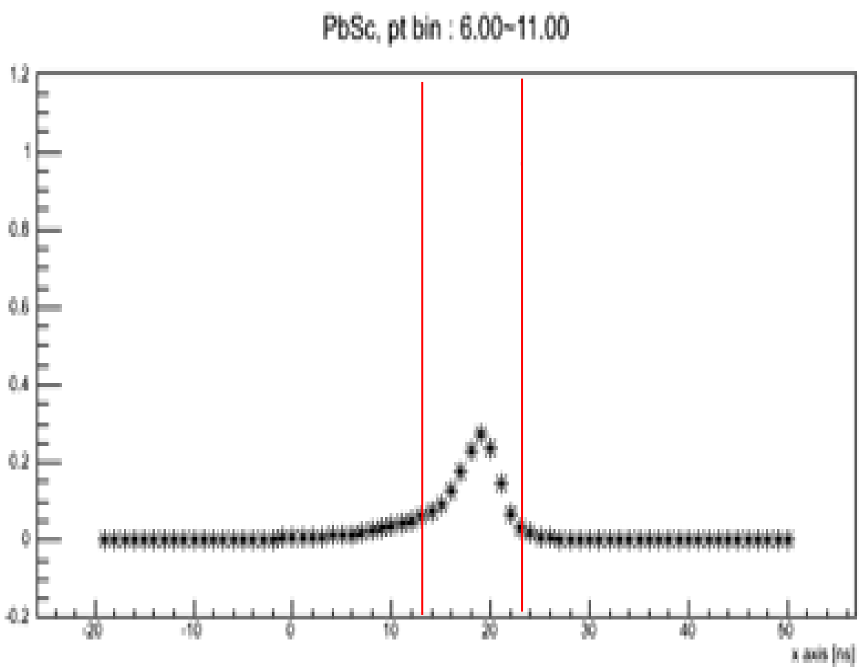
- To apply TOF cut, EMCal TOF tower by tower calibration has been done.

- TOF Cut parameter is determined by drawing S/N ratio vs. the parameter.

- 11% of background is suppressed.
  8% of signal is lost.

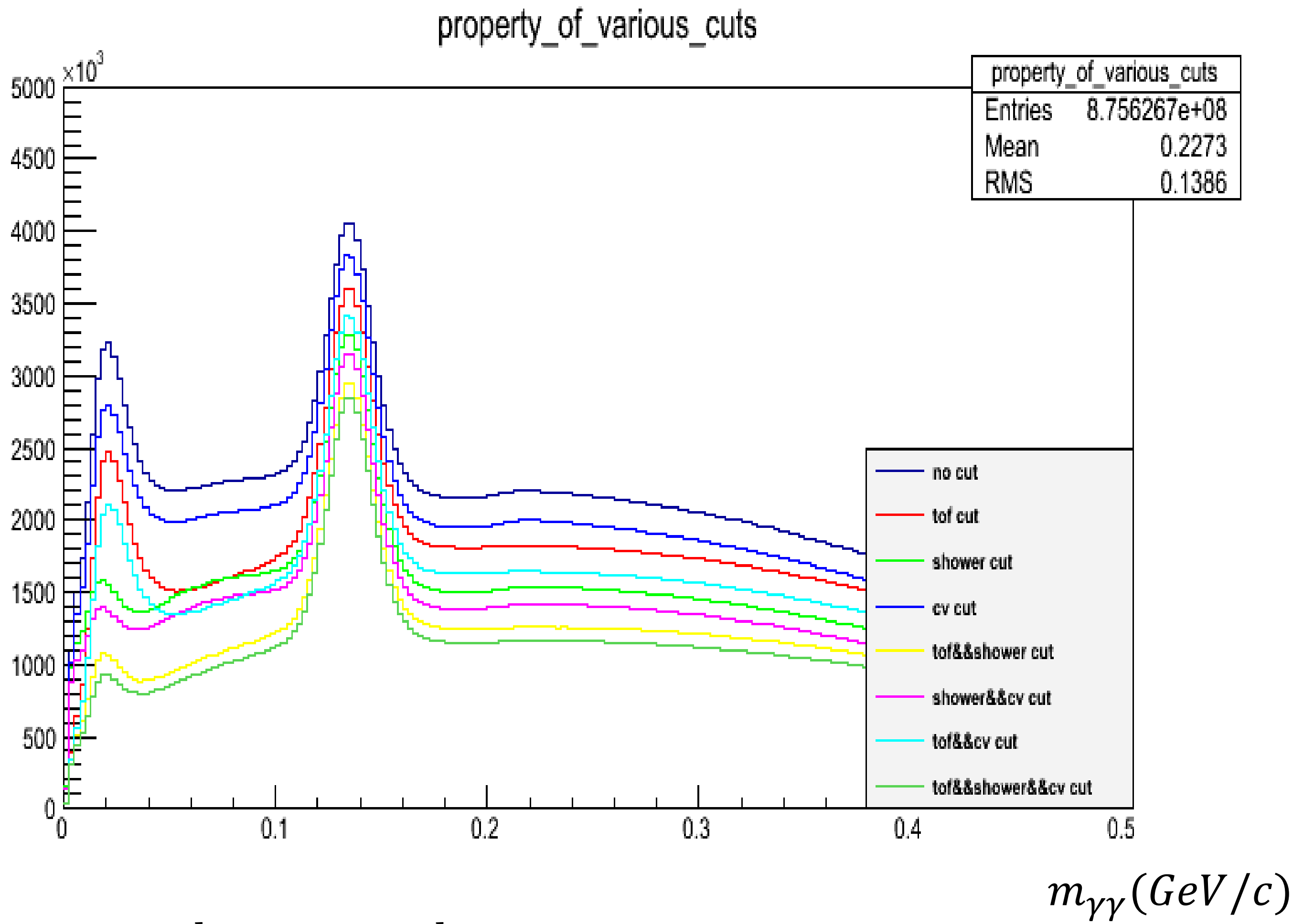






- Precise calibration will be done soon.

- 14ns ~ 23ns : accepted.



- After the event selection study,
  Signal to noise ratio is increased by 70%.

- Number of π^0 : 4.6×10^5

5. A_{LL} Calculation

- $A_{LL} = \frac{1}{P_B P_Y} \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$

- In experimental sense, $\sigma = \frac{N}{L \times \varepsilon \times acceptance}$

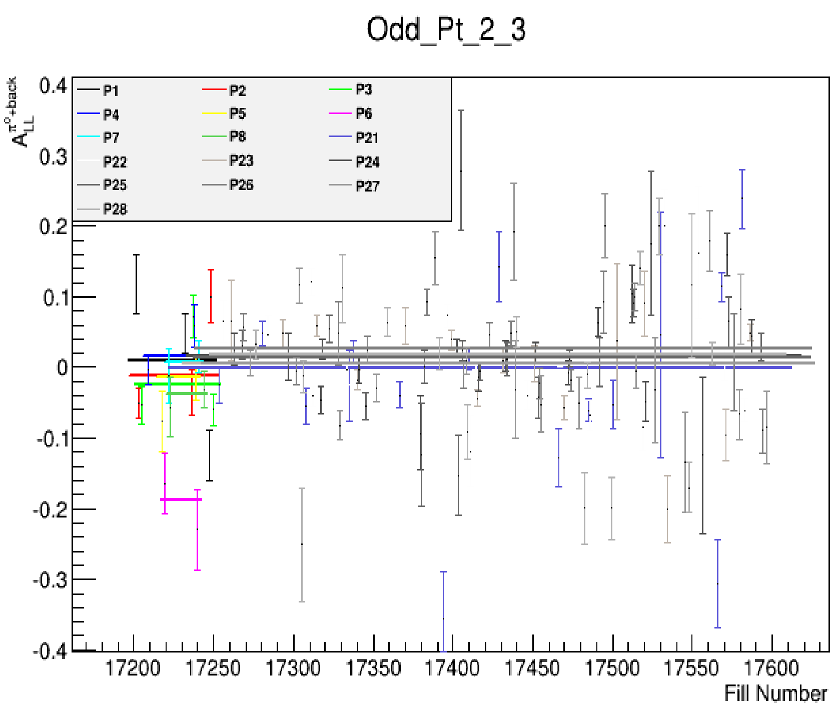
- $A_{LL} = \frac{1}{P_B P_Y} \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_B P_Y} \frac{\frac{N_{++}}{L_{++} \times \epsilon_{++} \times acceptance} - \frac{N_{+-}}{L_{+-} \times \epsilon_{+-} \times acceptance}}{\frac{N_{++}}{L_{++} \times \epsilon_{++} \times acceptance} + \frac{N_{+-}}{L_{+-} \times \epsilon_{+-} \times acceptance}}$

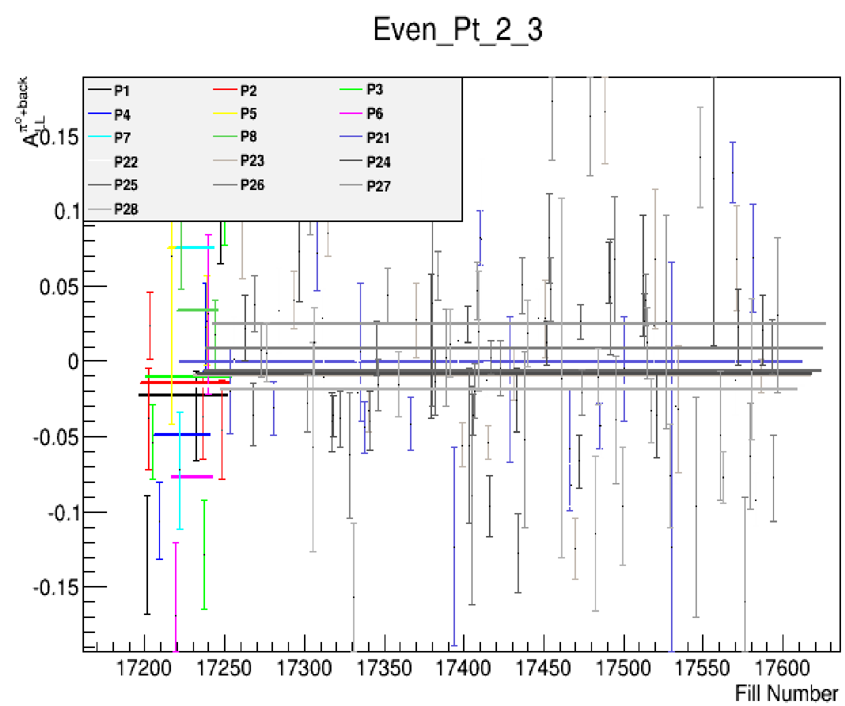
- Acceptance for the ++ and +- should be same. We assume trigger efficiencies for the ++ and +- are same. This assumption gives systematic uncertainty.

- $A_{LL} = \frac{1}{P_B P_Y} \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_B P_Y} \frac{\frac{N_{++}}{L_{++}} - \frac{N_{+-}}{L_{+-}}}{\frac{N_{++}}{L_{++}} + \frac{N_{+-}}{L_{+-}}} = \frac{1}{P_B P_Y} \frac{N_{++} - R N_{+-}}{N_{++} + R N_{+-}}$, $R = \frac{L_{++}}{L_{+-}} = \frac{{N_{++}}^{BBC}}{{N_{+-}}^{BBC}}$

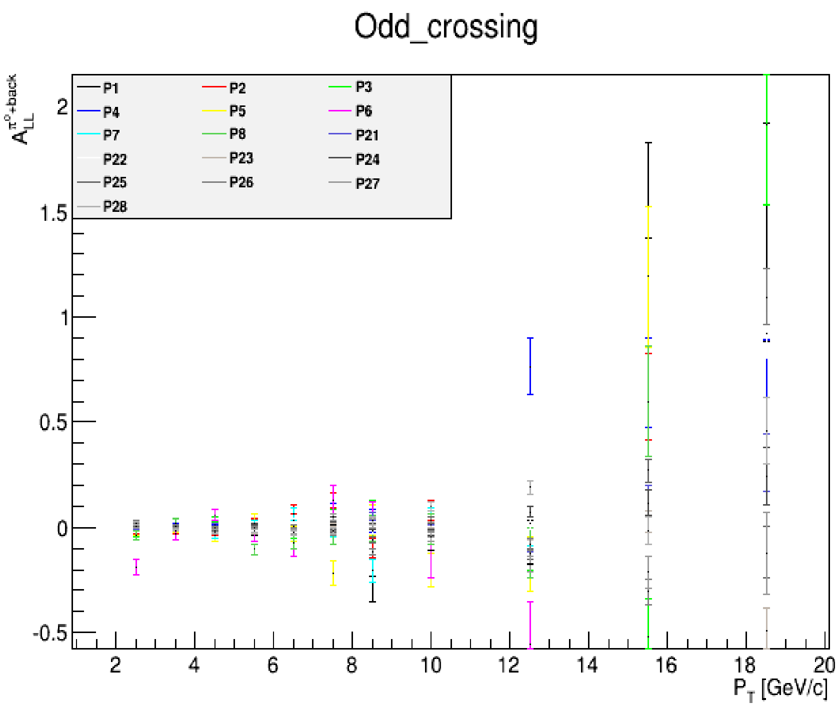
- A_{LL} is calculated fill by fill basis.

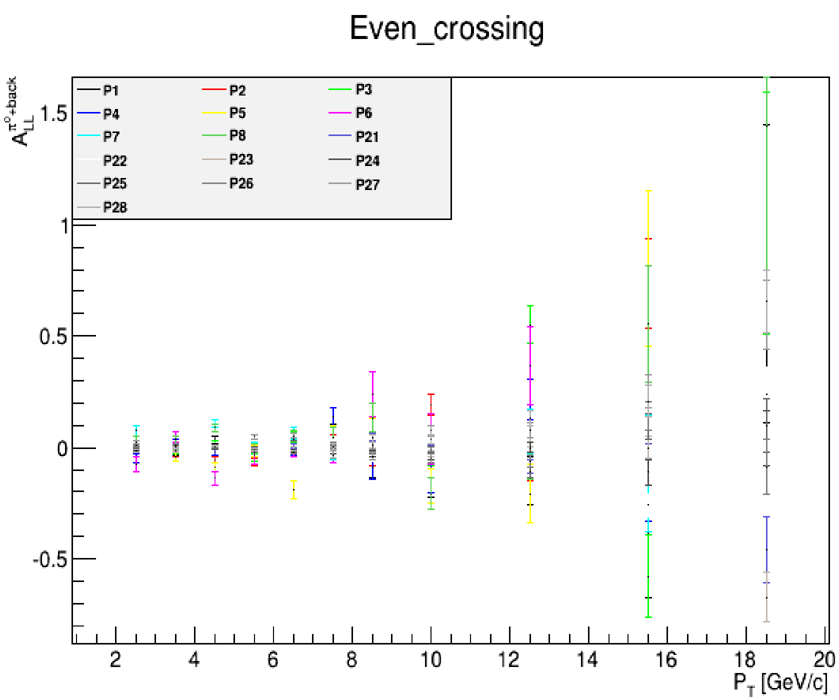
- Fit the fill by fill A_{LL} with constant function to get representative A_{LL} over fill #.
  The fitting should be done separately odd or even crossing and spin pattern by pattern.
  ∵ Trigger efficiency is different for odd and even crossing.
  ∵ Pattern by pattern analysis is needed because of ghost cluster.





- This is my current status.
- Stat. uncertainty estimation is needed.
- Syst. uncertainty check. : pattern, crossing, A_L check, ETC.
- Cross check with previous result and debugging is needed.

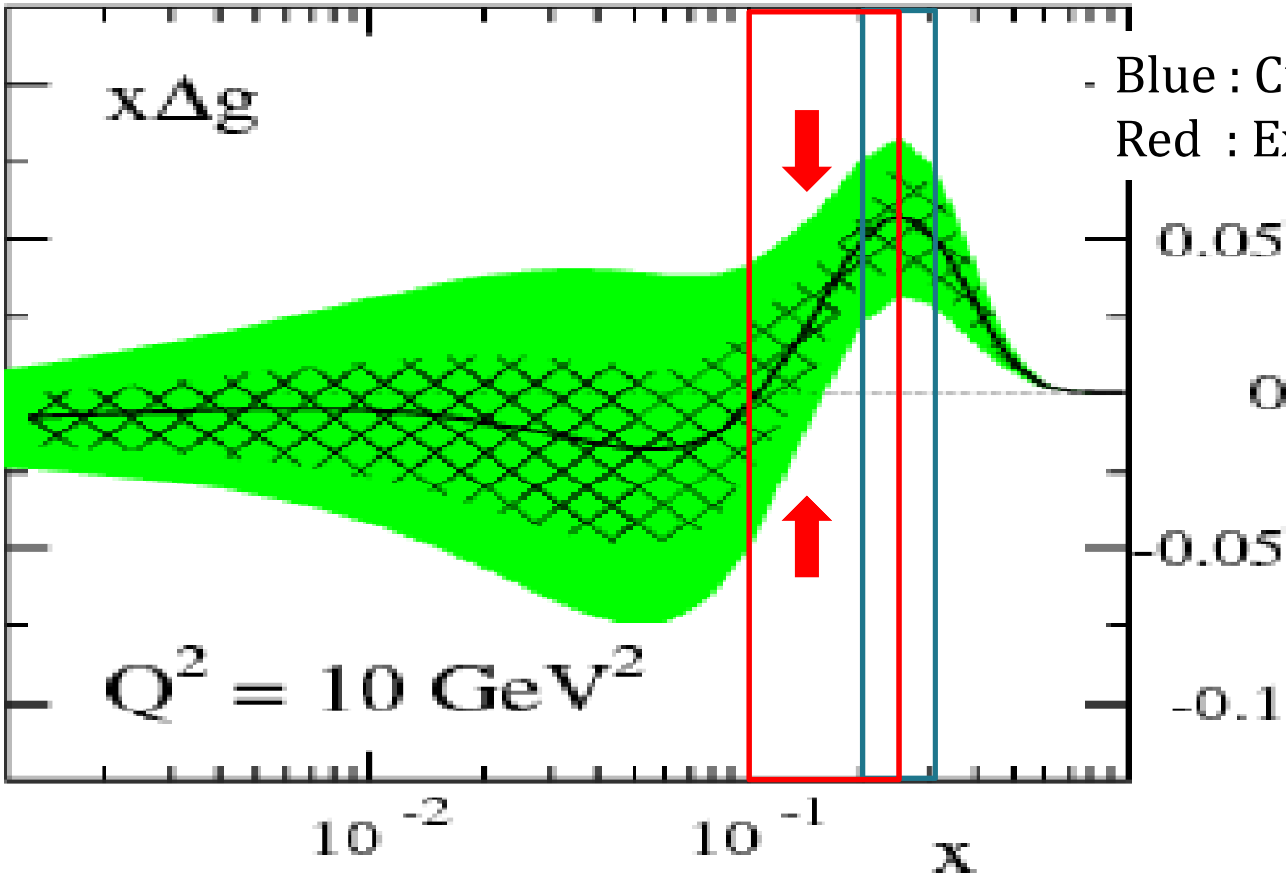




6. Future Prospect

- Compared with previous analysis with Run09 data, the analysis with Run13 data can access **lower Bjorken x region** with **smaller statistical uncertainty**.

	Run09	Run13
$\sqrt{S}$	200GeV	510GeV
Bjorken x region	0.02 ~ 0.3	0.01 ~ 0.25
Integrated Luminosity	15 pb^{-1}	145 pb^{-1}
$L \times {P_B}^2 \times {P_Y}^2$	1.4 pb^{-1}	14.7pb^{-1}



- Blue : Current Run09 region
  Red : Expected Run13 region.

• Run13 510GeV analysis can access low Bjorken x region with much smaller error band. So the analysis can contribute to constrain polarized gluon distribution function.

7. Summary

- Event selection study has been done.

  : EMCal Warnmap generation and TOF calibration has been done.

  Various cut parameters are optimized.

- Now A_{LL} calculation and uncertainty estimation are ongoing.

  : Stat. uncertainty estimation

  Syst. uncertainty check. pattern, crossing, A_L check, ETC.

- The analysis with Run13 data can access lower Bjorken x region with smaller uncertainty.

Back Up

Interpretation of S/N ratio vs. θ_{cv}

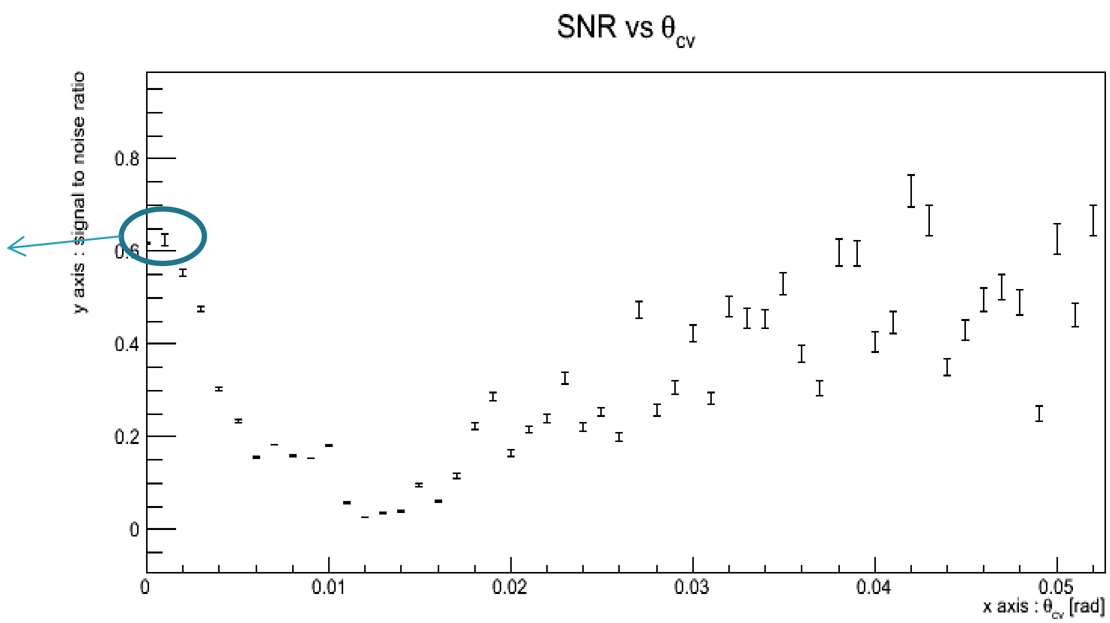
- If $\theta_{cv} = 0$,

  No hit in pc3, corresponding track : charge neutral.

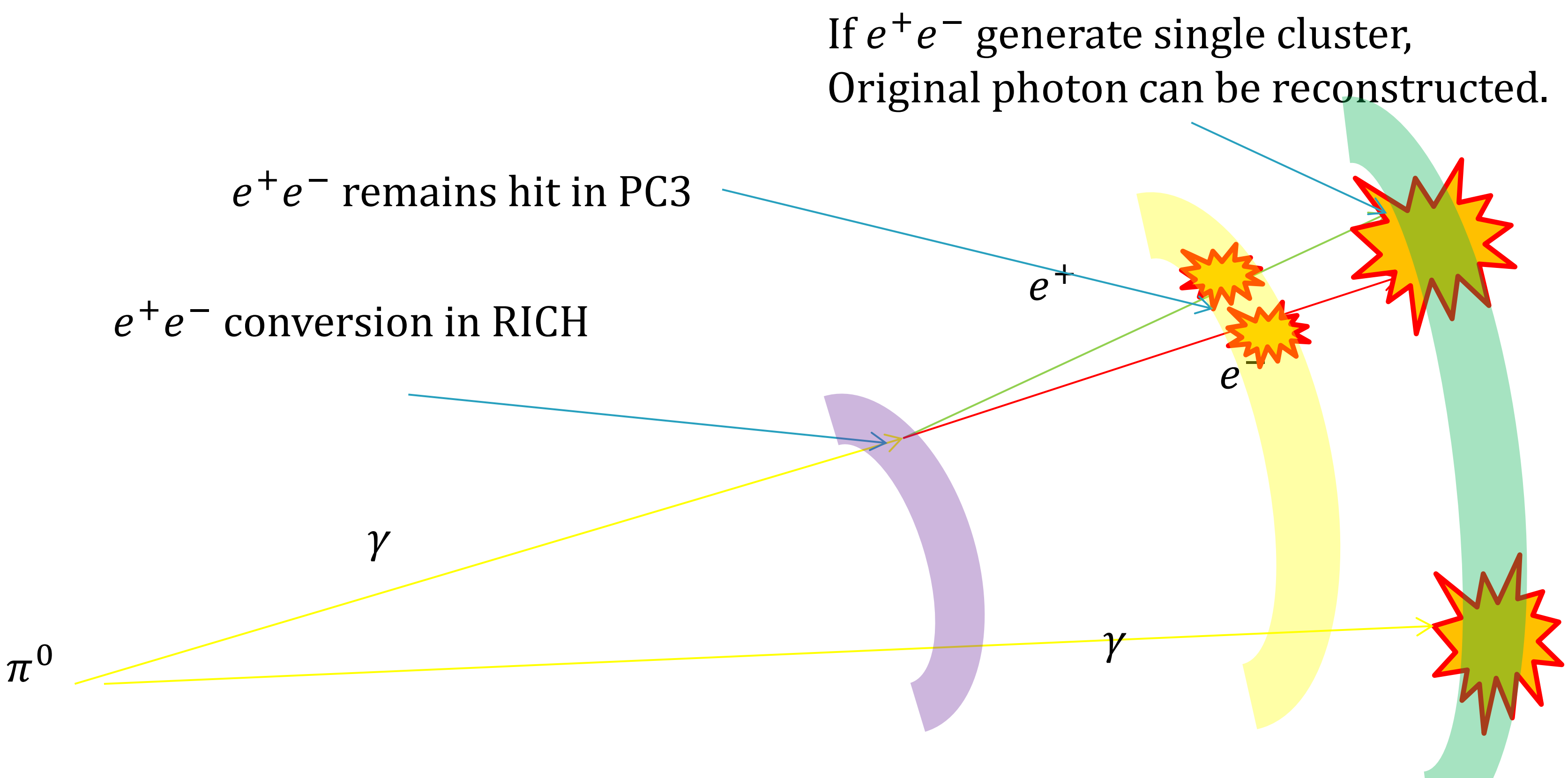
  => photon. Photon from pion decay will be mixed in the region.

  => If above is true, S/N should be high for the region.

S/N high when $\theta_{cv} = 0$

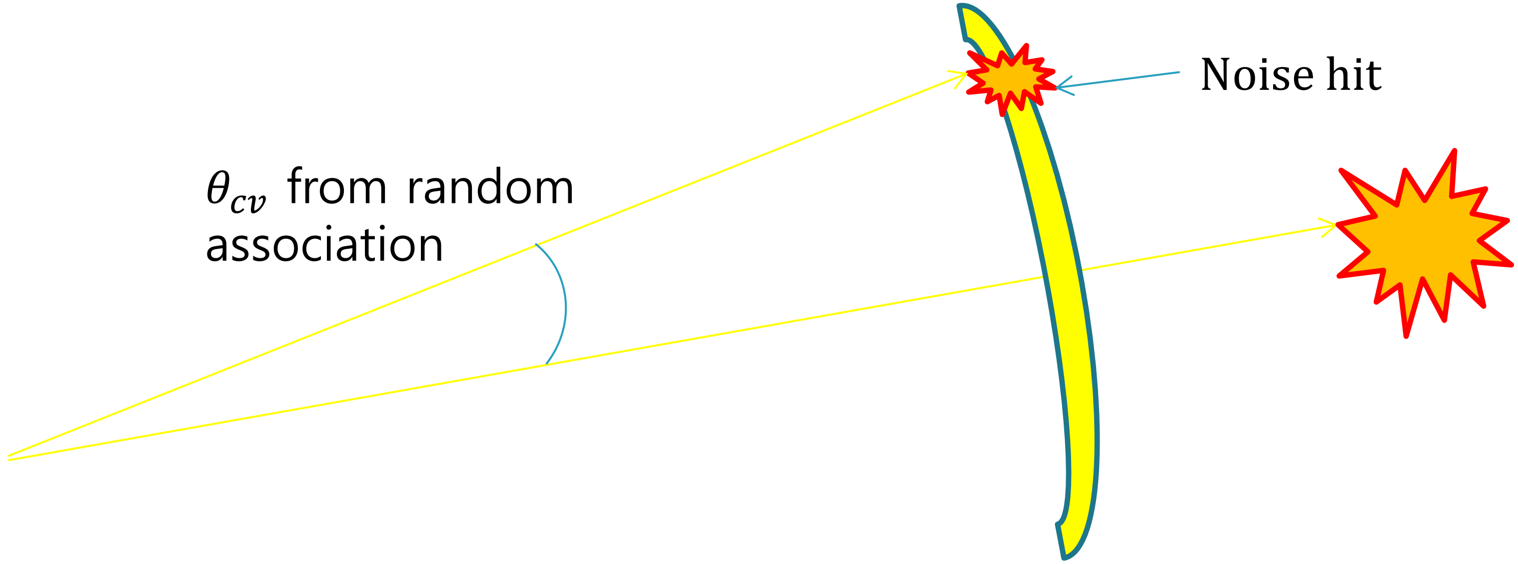


- If θ_{cv} small but not zero,
  Track isn't charge neutral because it remains hit in pc3.
  However S/N still high.
  => 2% $\gamma \rightarrow e^- e^+$ in RICH.
    Because RICH is outside of magnet, if opening angle is small, $e^- e^+$ pair can generate single cluster in EMCal.



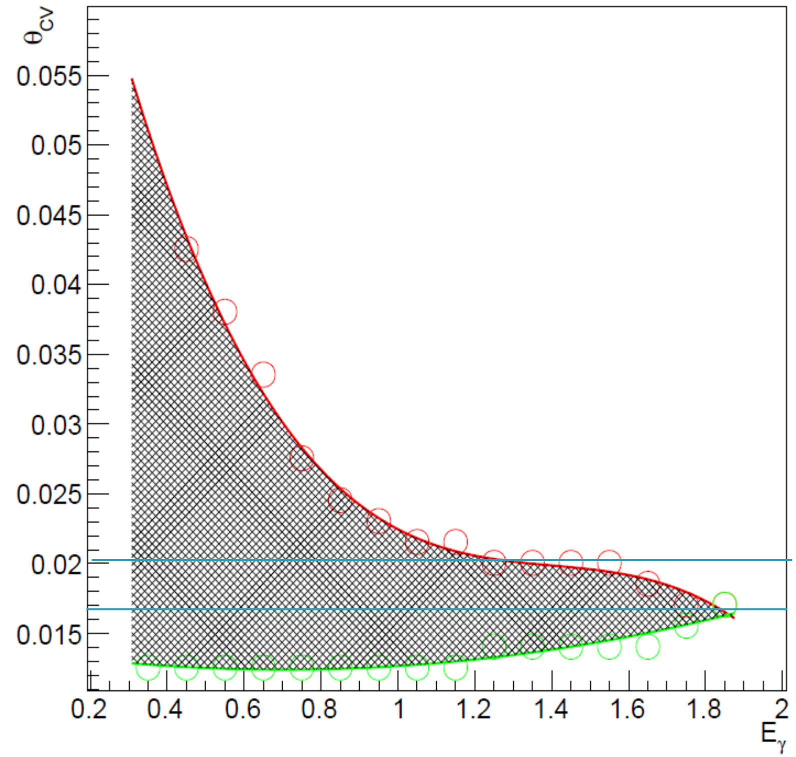
- Moderate θ_{cv}
  Charged track has some finite θ_{cv}. Small S/N ratio support this idea.
  Cluster in the region is rejected.

- Large θ_{cv}
  Prob.(combinatorial association of an EMCal cluster with an unrelated PC3 hit) $\propto \tan(\theta_{cv})$. $\therefore$ random association dominates in the region.
  Reincreasing S/N ratio support this idea.



- Because θ_{cv} depends not only charge but also $P_t \propto E$,
  Energy dependence should be included.
  Including energy dependence won't be considered until preliminary is got.

Optimized Run09 charge veto cut



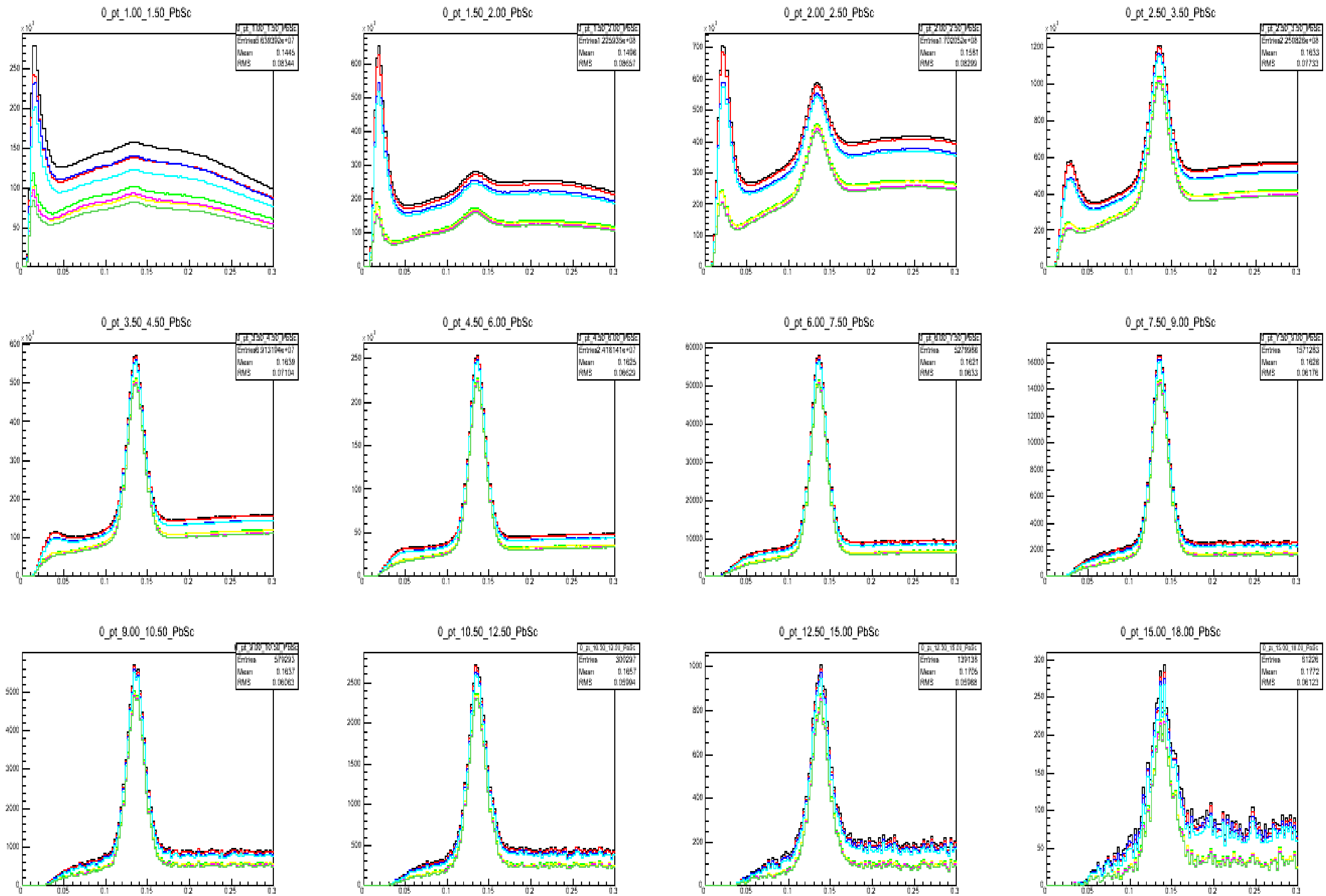
- After applying three cuts,
  40~70% of Background is suppressed. 30~40% of pion is lost.

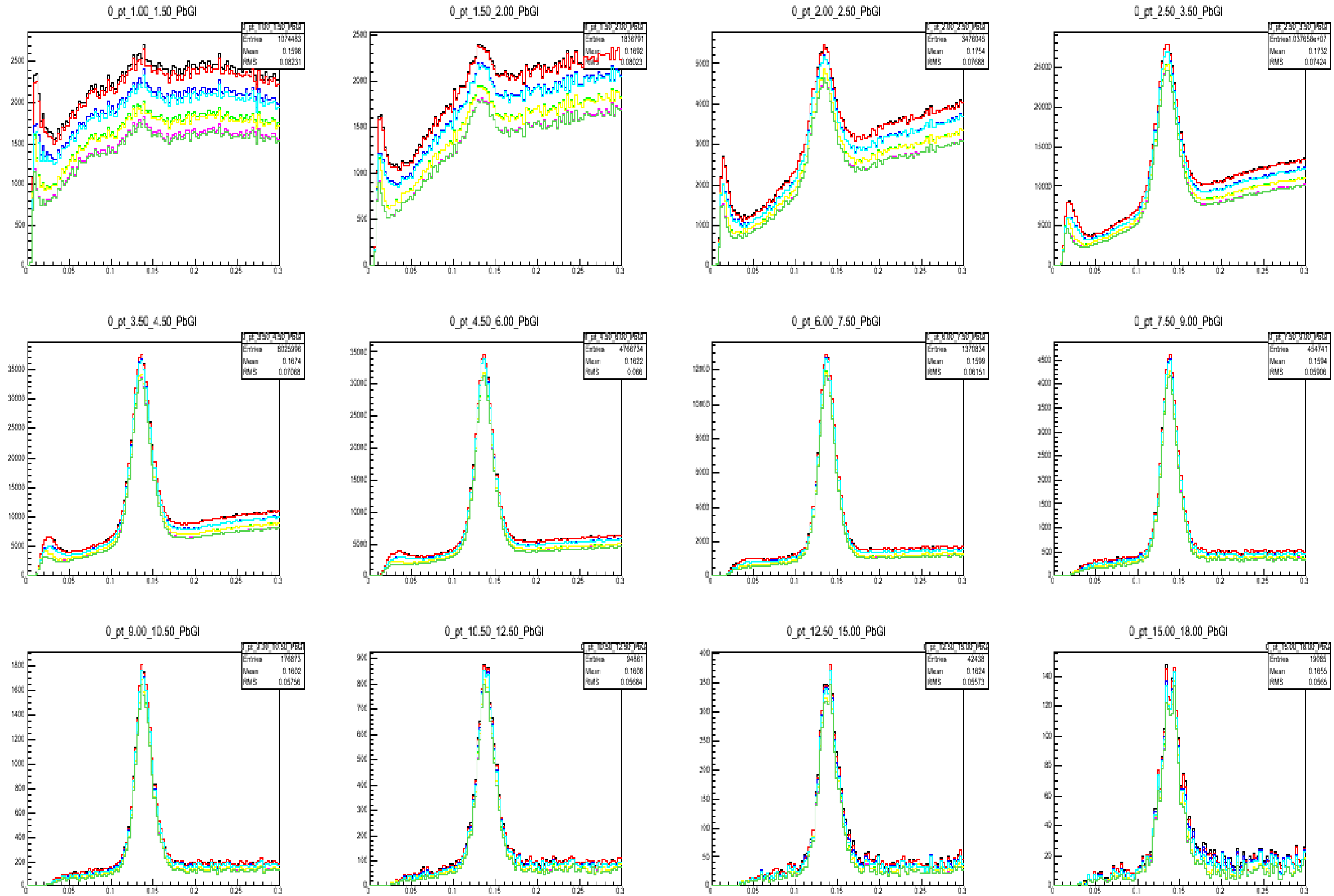
$$remaining\ pion\ ratio = N_{after}{}^{\pi^0} / N_{before}{}^{\pi^0}$$

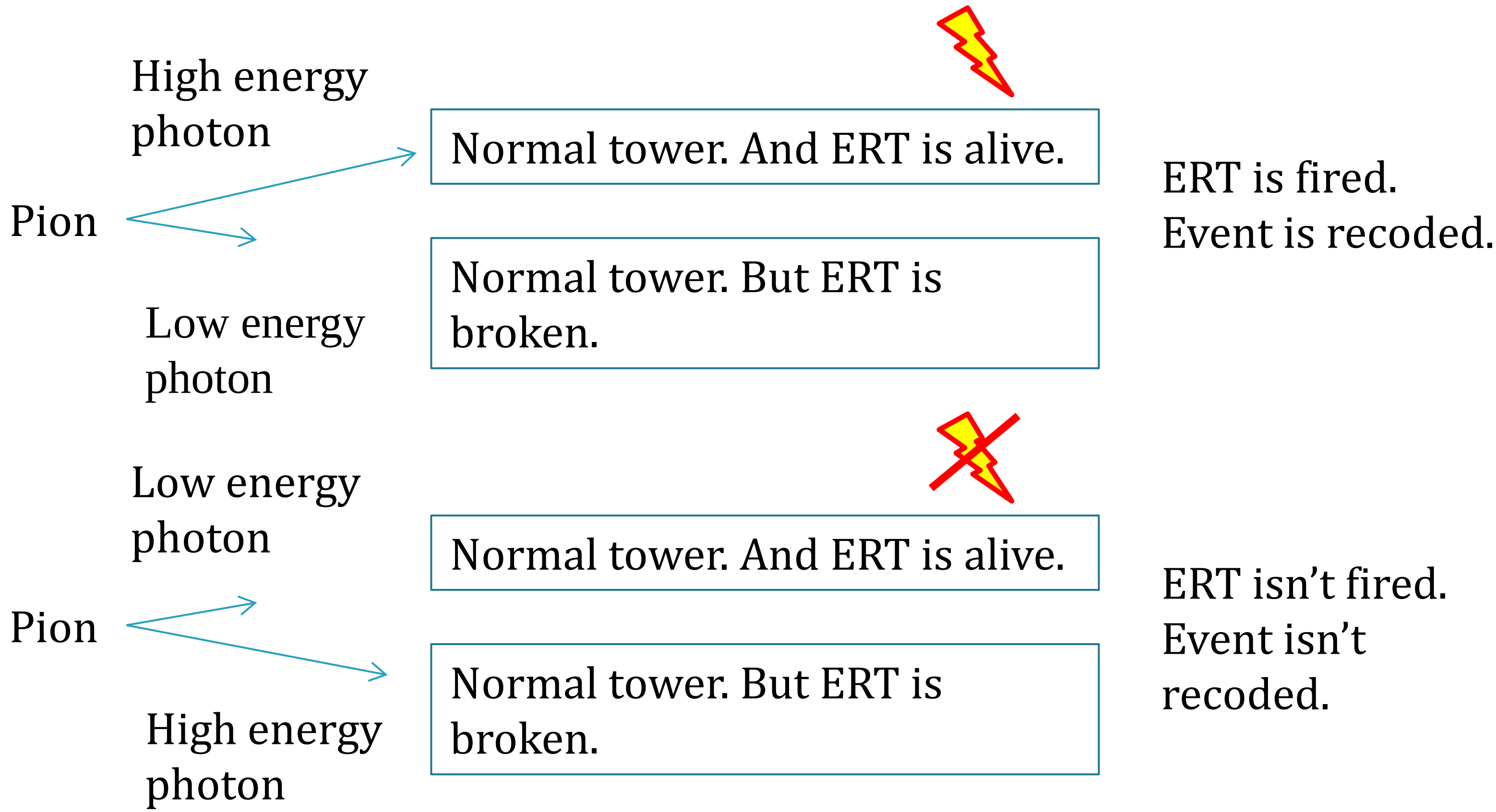
$$background\ suppression = 1 - N_{after}{}^{back} \Big/ N_{before}{}^{back}$$

$$remaining\ background = N_{after}{}^{back} \Big/ (N_{after}{}^{pion} + N_{after}{}^{back})$$

			remaining pion		suppressed background		remaining background	
	7	shower_tof_cv_cut	PbSc	PbGl	PbSc	PbGl	PbSc	PbGl
pt	bin	1~1.5	0.003005	0.63654	1.14207	0.48233	0.958574	0.939093
pt	bin	1.5~2	0.541534	0.730942	0.735531	0.446414	0.833226	0.799433
pt	bin	2~2.5	0.623793	0.772661	0.608207	0.431508	0.712061	0.559721
pt	bin	2.5~3.5	0.685417	0.798614	0.51766	0.416088	0.548643	0.393706
pt	bin	3.5~4.5	0.715092	0.788303	0.481133	0.417266	0.356867	0.284319
pt	bin	4.5~6	0.722752	0.779456	0.49216	0.432147	0.243535	0.211883
pt	bin	6~7.5	0.71693	0.783841	0.523311	0.460766	0.195409	0.167208
pt	bin	7.5~9	0.722041	0.788083	0.562806	0.479778	0.174939	0.156099
pt	bin	9~10.5	0.712045	0.7827	0.599113	0.527771	0.156794	0.131003
pt	bin	10.5~12.5	0.691366	0.755587	0.623609	0.548869	0.14191	0.126314
pt	bin	12.5~15	0.678071	0.763871	0.669911	0.627164	0.140133	0.11945
pt	bin	15~18	0.644382	0.738204	0.738205	0.632409	0.166805	0.088956


0_pt_1.00_1.50_PbSc
0_pt_1.50_2.00_PbSc
0_pt_2.00_2.50_PbSc
0_pt_2.50_3.50_PbSc
0_pt_3.50_4.50_PbSc
0_pt_4.50_6.00_PbSc
0_pt_6.00_7.50_PbSc
0_pt_7.50_9.00_PbSc
0_pt_9.00_10.50_PbSc
0_pt_10.50_12.50_PbSc
0_pt_12.50_15.00_PbSc
0_pt_15.00_18.00_PbSc

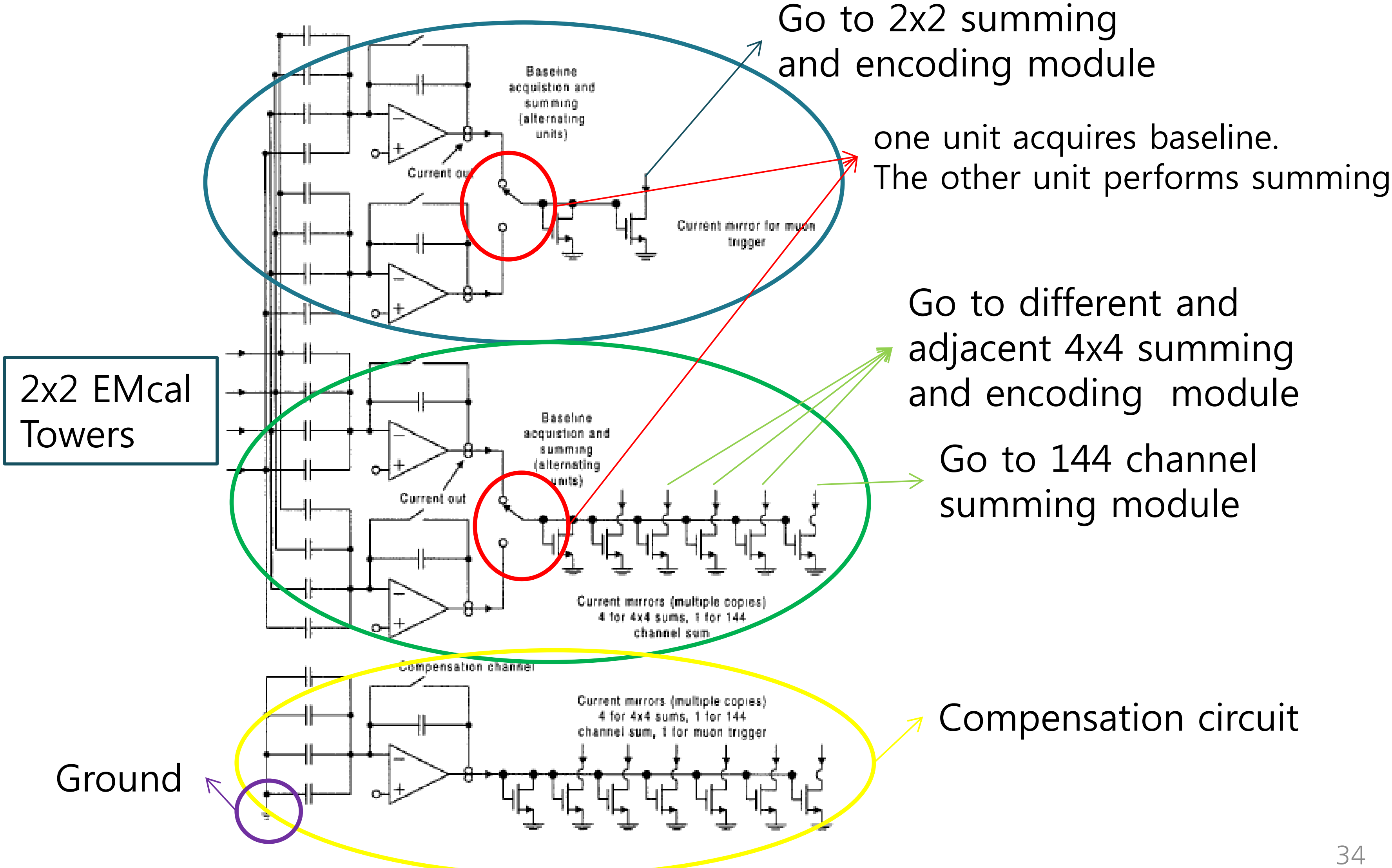

0_pt_1.00_1.50_PbGl
0_pt_1.50_2.00_PbGl
0_pt_2.00_2.50_PbGl
0_pt_2.50_3.50_PbGl
0_pt_3.50_4.50_PbGl
0_pt_4.50_6.00_PbGl
0_pt_6.00_7.50_PbGl
0_pt_7.50_9.00_PbGl
0_pt_9.00_10.50_PbGl
0_pt_10.50_12.50_PbGl
0_pt_12.50_15.00_PbGl
0_pt_15.00_18.00_PbGl



⇒ERT broken tower can't pick up high energy photon. So number of high energy photon hits of the tower is lower. That's the origin of left peak.

ERT broken tower can be used to reconstruct pion event, still.
=> So it shouldn't be masked.

EMCal trigger - ASIC in FEM



• Let N_g = average number of ghost clusters and N_r = average number of real clusters

After abort gap, for each bunch crossing, number of cluster is
$N_0 = N_r$
$N_1 = N_r + N_g$
$N_2 = N_r + 2N_g$
$N_3 = N_r + 3N_g$
$N_4 = N_r + 3N_g$
….

For spinpattern ++--++-- and ++++----
Number of cluster for same helicity crossing = $N_0 + N_1 + \ldots = 2N_r + N_g + \ldots$
Number of cluster for opposite helicity crossing = $N_2 + N_3 = 2N_r + 5N_g + \ldots$

For different spinpattern --++--++, and ++++----
Number of cluster for same helicity crossing = $N_2 + N_3 = 2N_r + 5N_g + \ldots$
Number of cluster for opposite helicity crossing = $N_0 + N_1 + \ldots = 2N_r + N_g + \ldots$

That's why combinatoral background could be different for different spin pattern because of ghost cluster.