LGAD simulation

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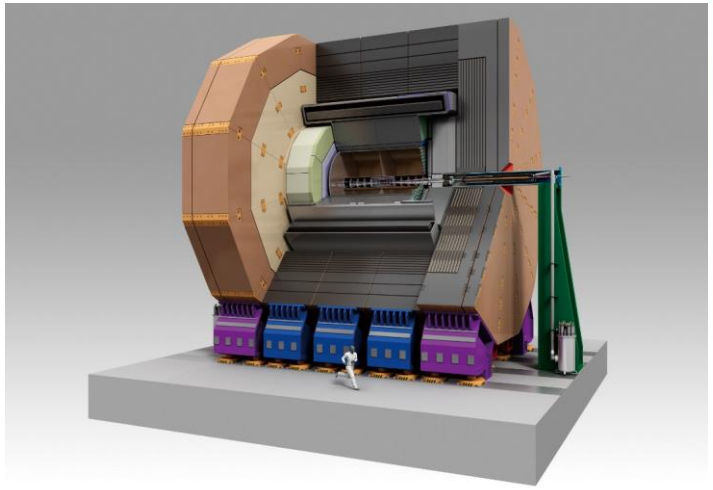
ILD and ECAL

ILD(International Large Detector)

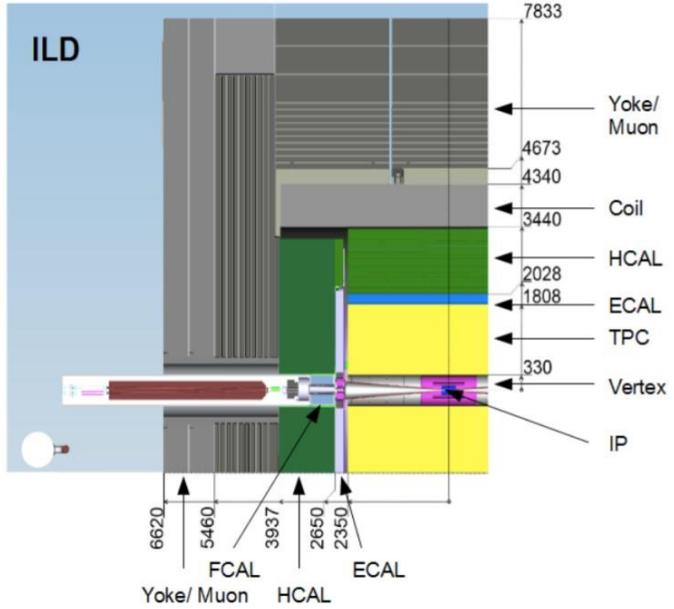
- ILC collision point detector
- Tracking detector :TPC
- Particle ID → energy loss (dE/dx) and momentum

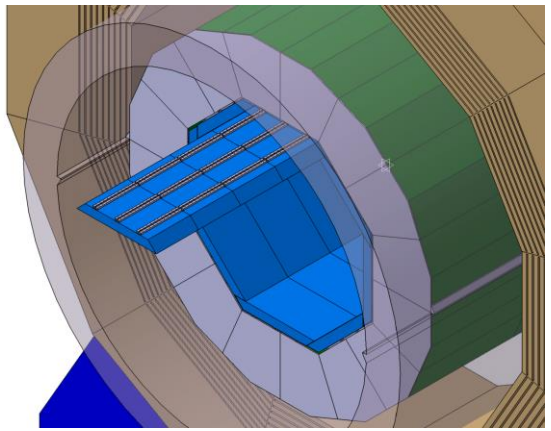
ECAL

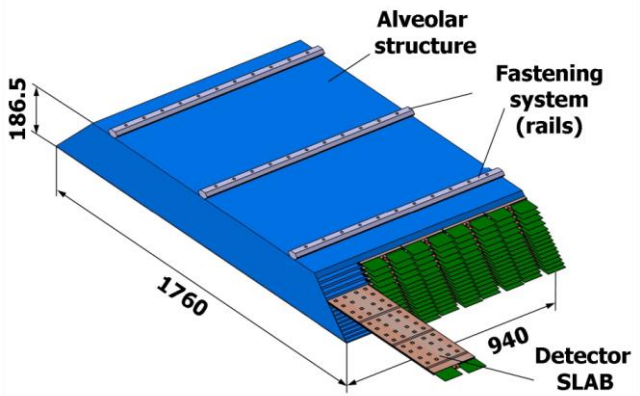
- SiW-ECAL : Absorption layers and detection layers are alternately accumulated
- Pixel size : $5.5 \times 5.5\ mm^2$



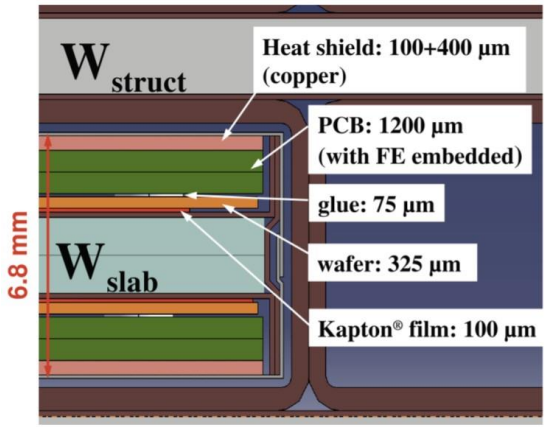
ILD







ECAL

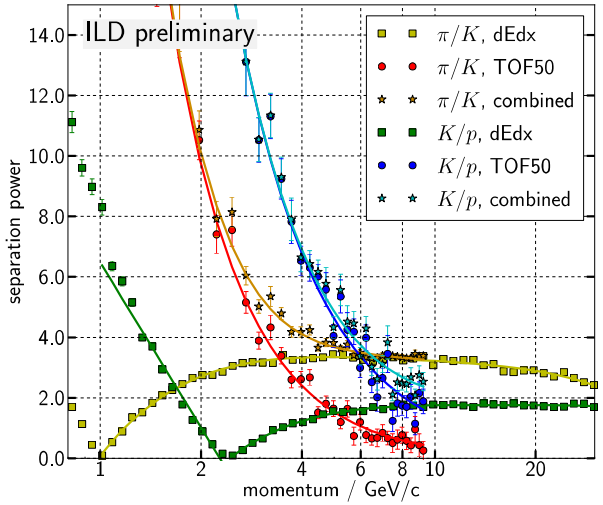


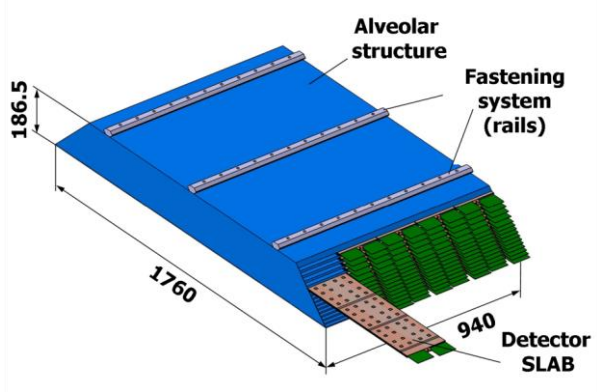
Structure of SiW-ECAL

LGAD

Timing resolution

- Possible to separate π/K/p up to 3~5 GeV by 50 ps ToF with dE/dx at TPC

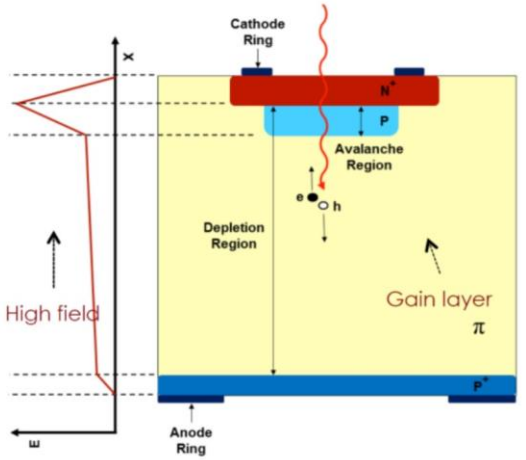




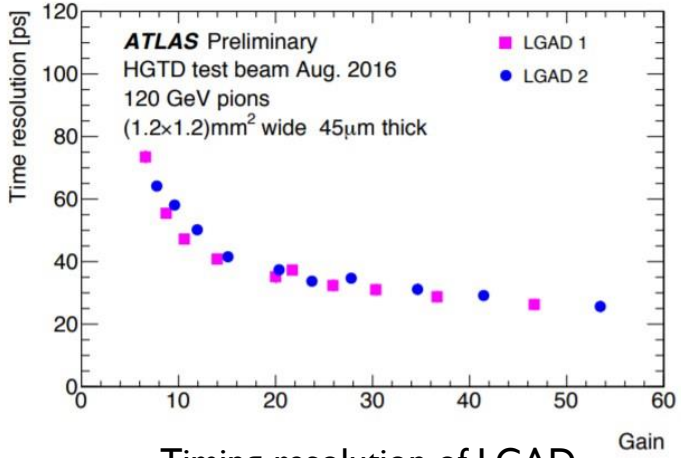
LGAD (Low Gain Avalanche Detector)

- A silicon sensor with avalanche amplification mechanism
- Higher timing resolution
- 26 ps timing resolution (study for ATLAS group)
- Particle ID

- How LGAD contributes to time resolution and particle identification when it is used as part of ECAL
- Position and number of LGAD in ECAL



Structure of LGAD

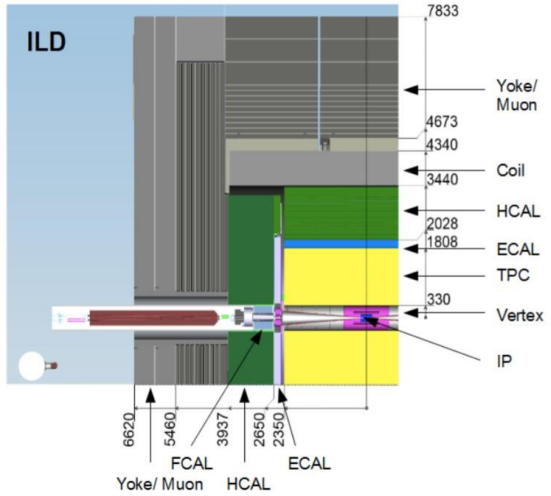


Timing resolution of LGAD (ATLAS group)

Simulation and time information

Data

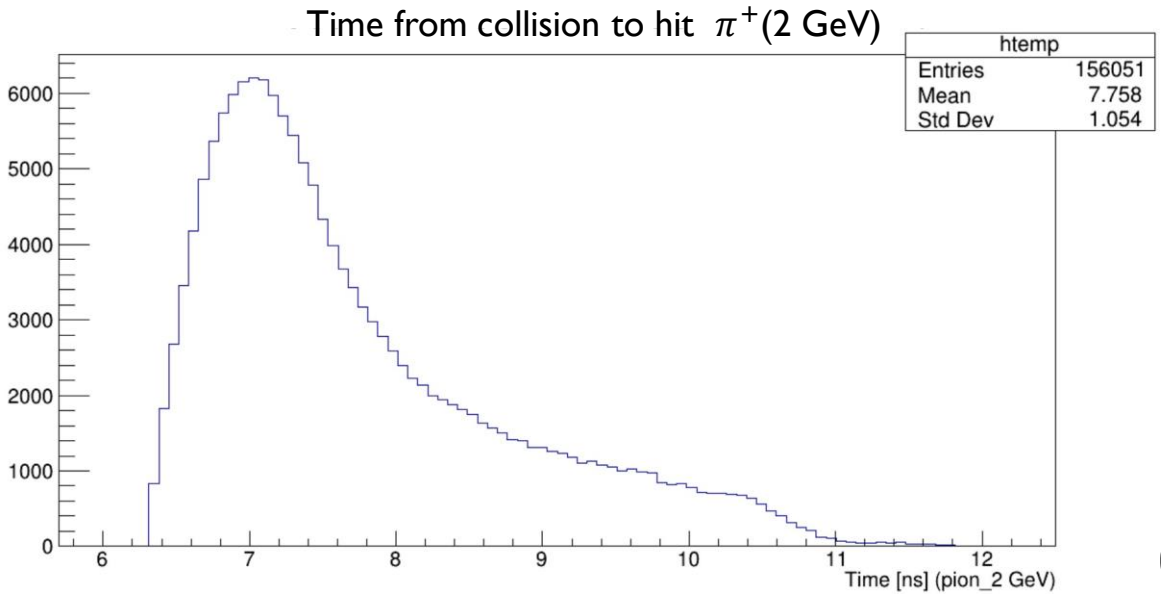
- single particle PDG=211 (π^+) and PDG=321(K^+)
- ILD detector simulation
- ILC soft : v01-19-04
- Energy : 1 , 2 , 5 , 10 GeV
- 10000 event
- mcTime <12 ns (mcTime : Time from IP to ECAL hit)
- Hit the barrel part of ECAL



Time

- Time of each hit
- Error due to sensor time resolution are not considered
- The distance from the IP to ECAL is about 1.8 m ~

  → The time from IP to ECAL is about 6.1 ns ~
- The result of time distribution is reasonable



Calculation method of mass

- Particle path l (Spiral movement)

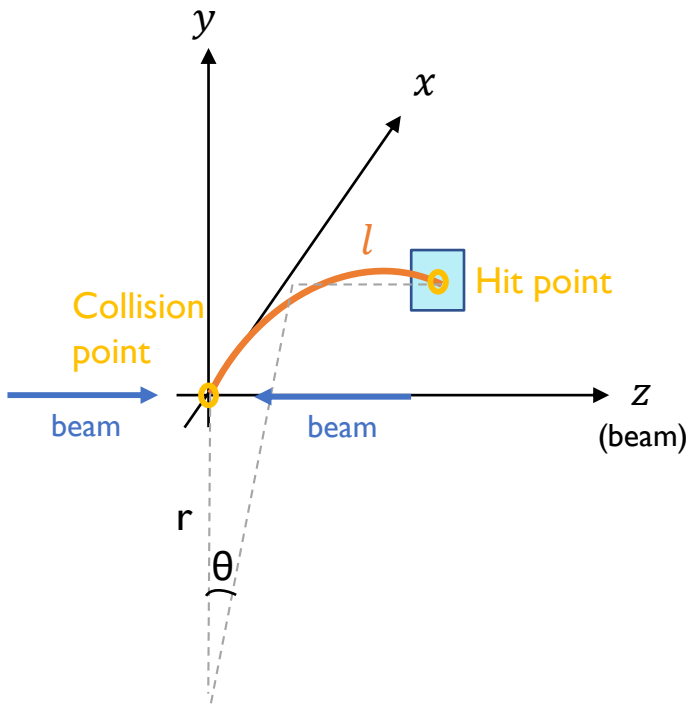
  Orbital radius r

  Magnetic field $B = 3.5$ T

  Momentum $\boldsymbol{p} = (p_x, p_y, p_z)$

$$l = \sqrt{(\theta r)^2 + z^2}$$

$$\theta r = 2rArcsin\left(\frac{\sqrt{x^2+y^2}}{2r}\right), \quad r = \frac{p}{0.3B} = \frac{\sqrt{{p_x}^2+{p_y}^2}}{0.3B}$$



- Mass of particle m

  Energy E

  Time from IP to ECAL hit t

$$m = E\sqrt{1-\beta^2} = E\sqrt{1-\frac{(\theta r)^2 + z^2}{(ct)^2}}$$

$$\beta = \frac{v}{c} = \frac{l}{ct}$$

→ Calculate the particle mass for each event by averaging the masses of multiple hits in one event

Result $\pi^{\pm}$: mass [each hit]

Data

single particle PDG=211 ($\pi^{\pm}$)

1 , 2 , 5 , 10 GeV

Cut

0 ns < mcTime[0] <12 ns

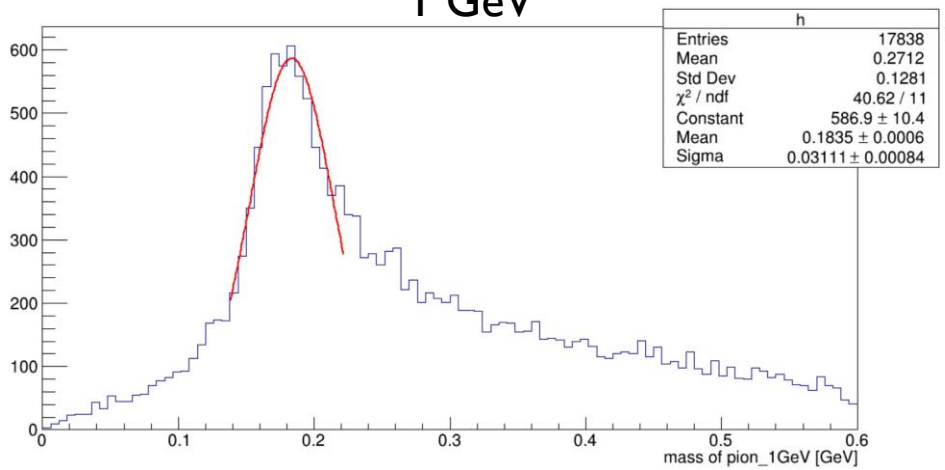
PDG=211

Mass of $\pi^{\pm}$

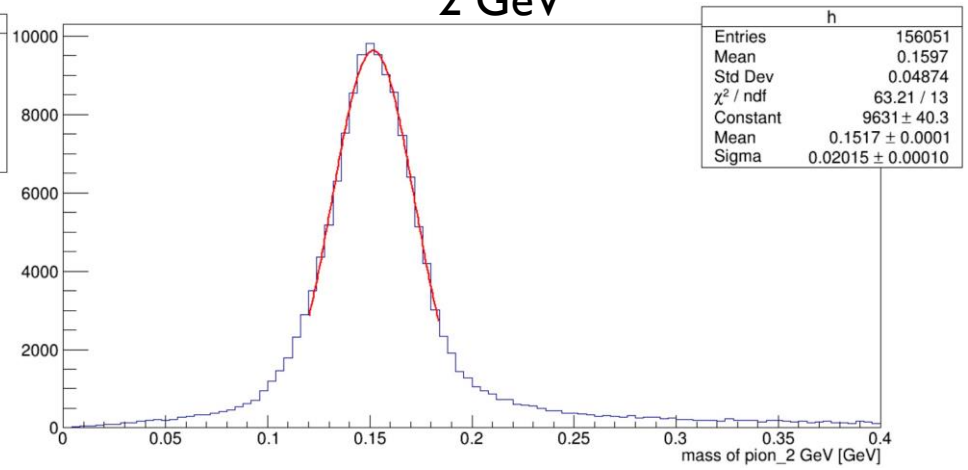
about 139 MeV

- The value of this distribution is deviated and is large.

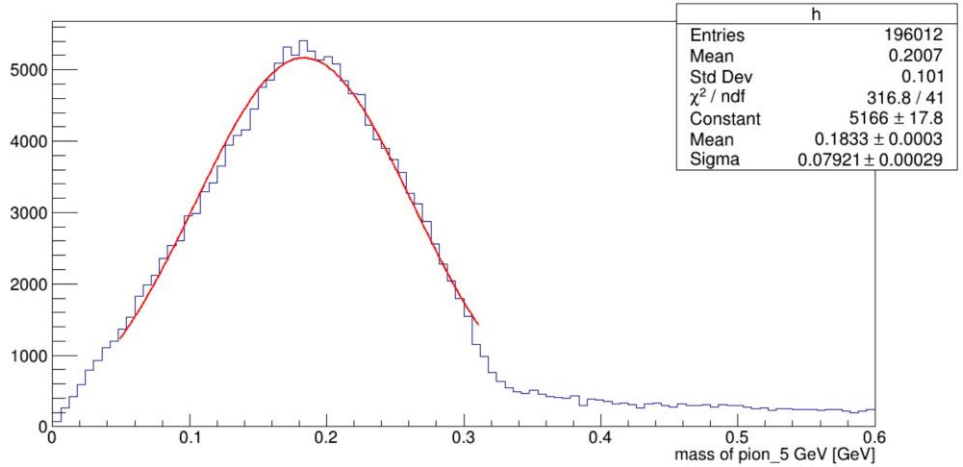
1 GeV



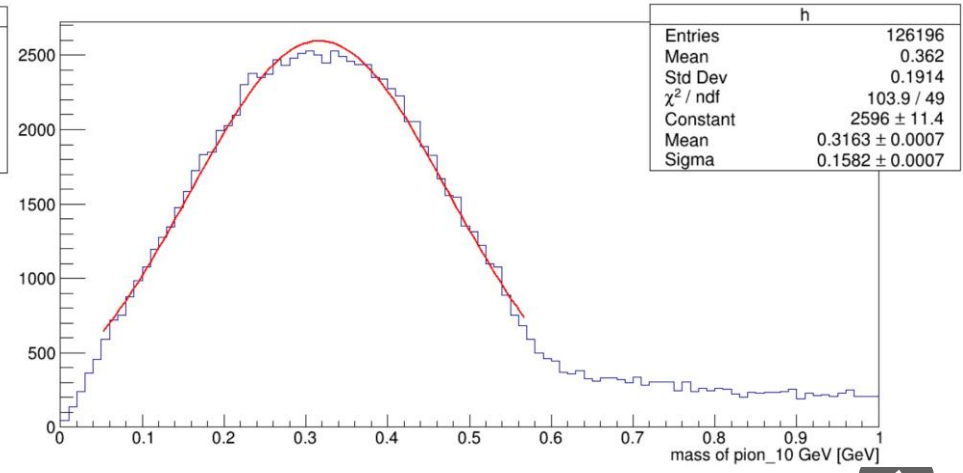
2 GeV



5 GeV



10 GeV



Result $K^{\pm}$: mass [each hit]

Data

single particle PDG=321 ($K^{\pm}$)

1 , 2 , 5 , 10 GeV

Cut

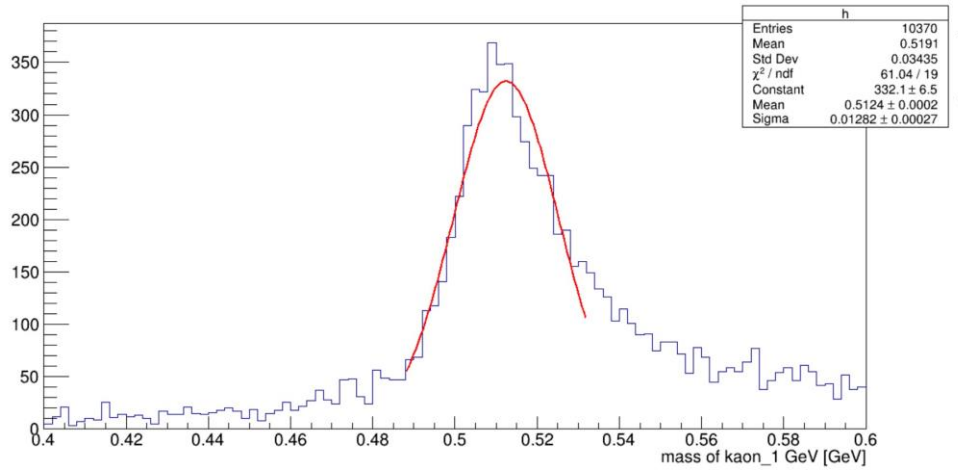
0 ns < mcTime[0] <12 ns

PDG=321

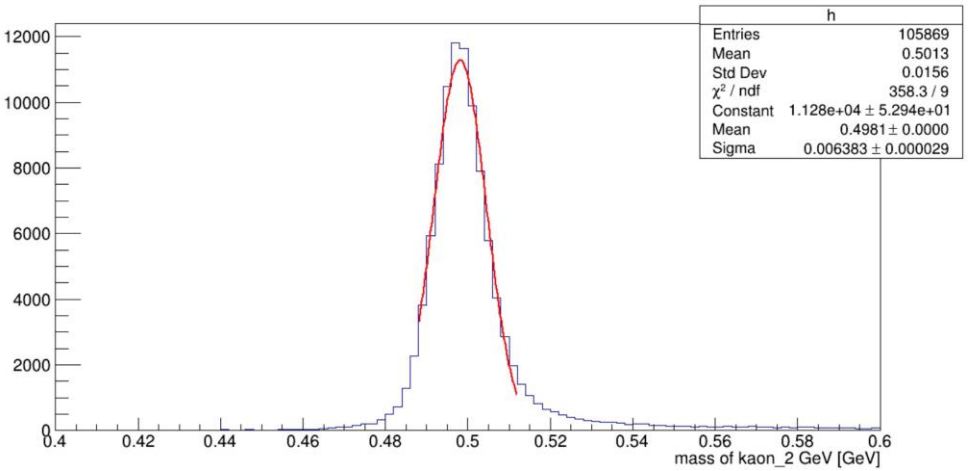
Mass of $\pi^{\pm}$

about 494 MeV

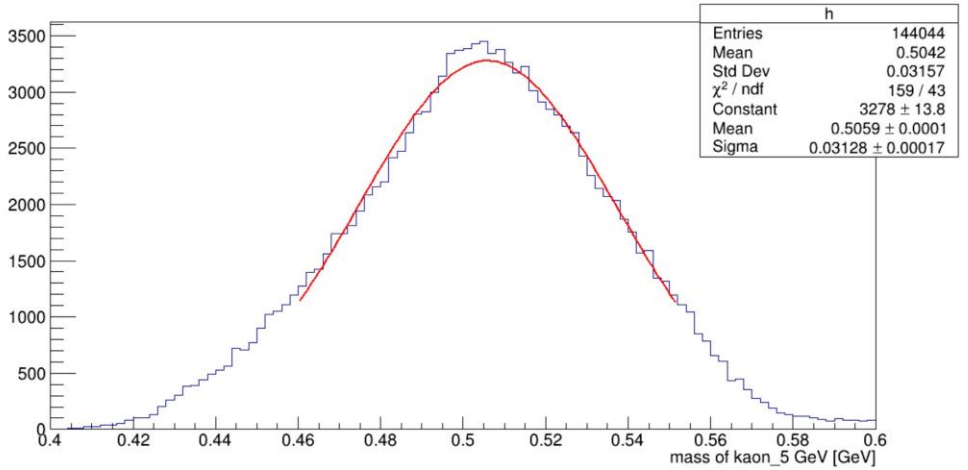
1 GeV



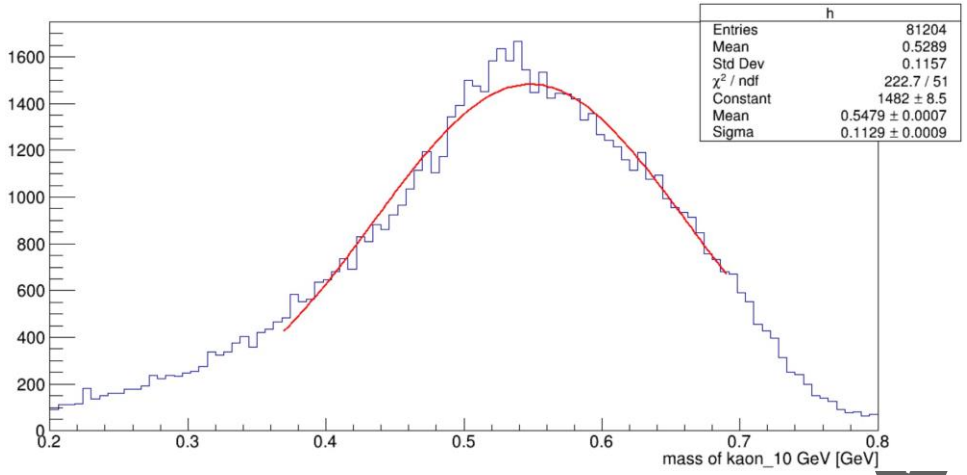
2 GeV



5 GeV



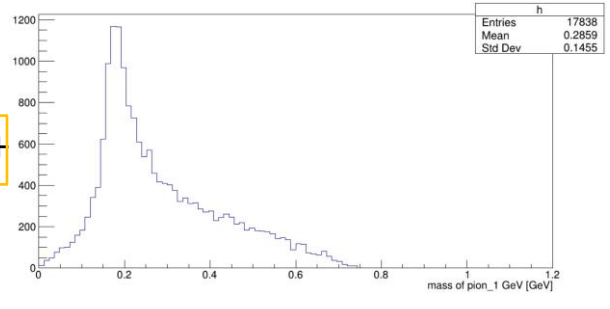
10 GeV

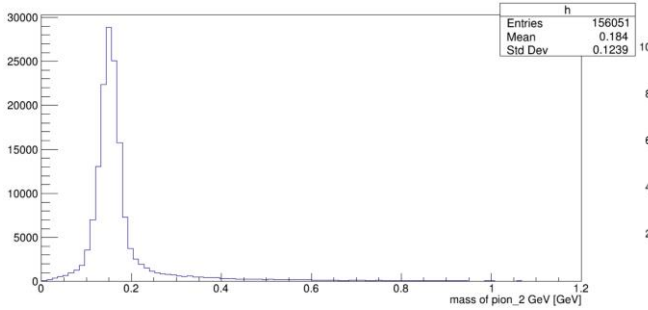


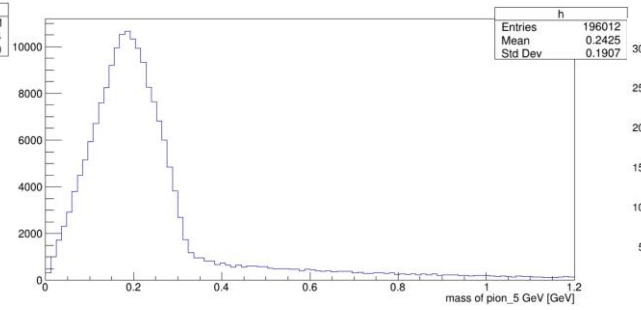
Mass of π^+ and K^+

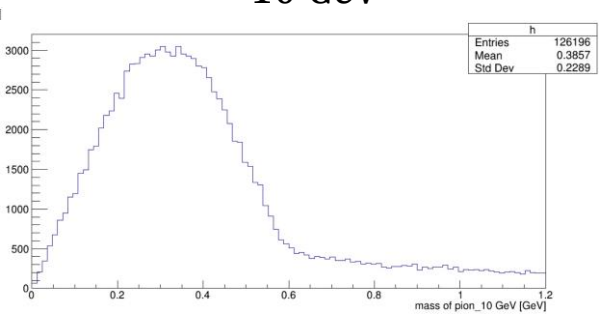
1 GeV | 2 GeV | 5 GeV | 10 GeV

π^+

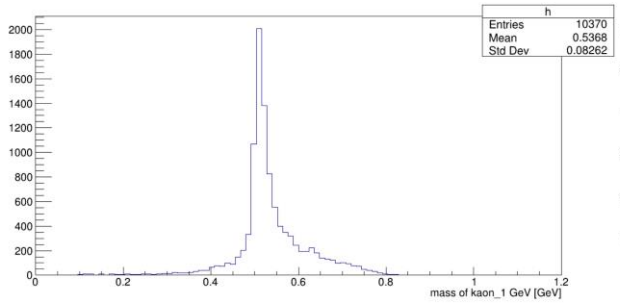


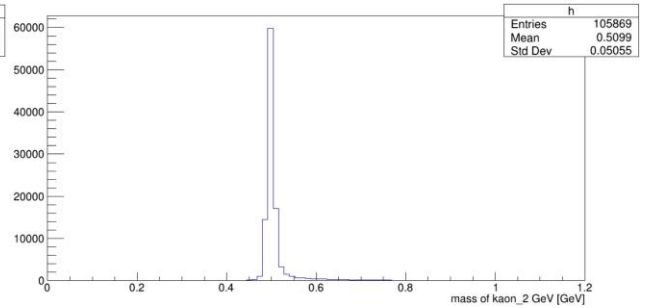


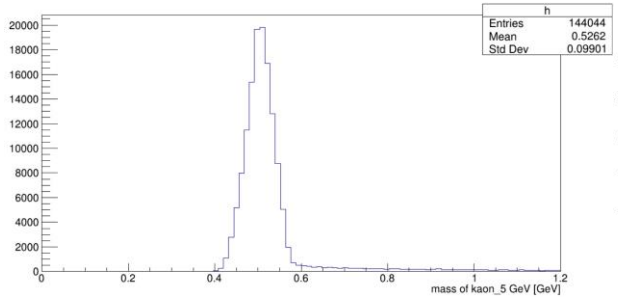


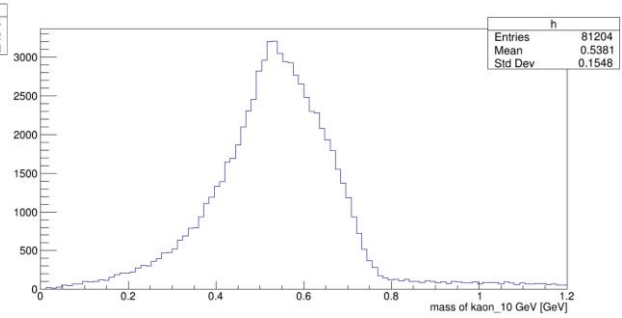


K^+









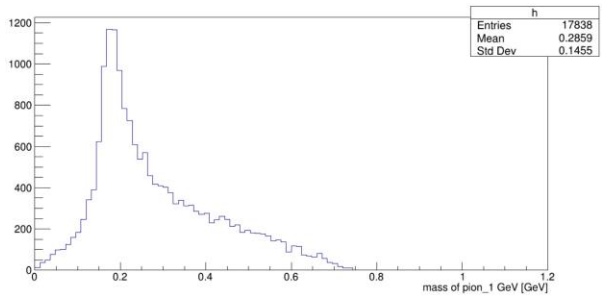
- π^+ and K^+ can be identified up to 5 GeV.

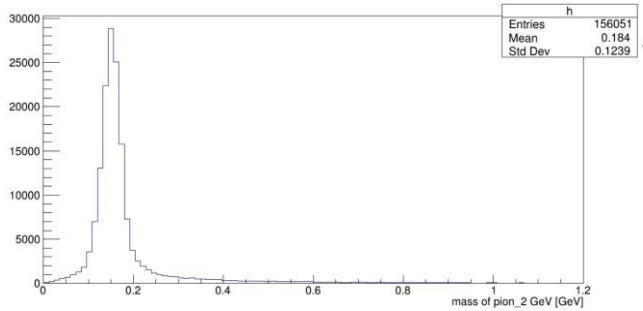
  (However, error due to sensor timing resolution are not considered.)

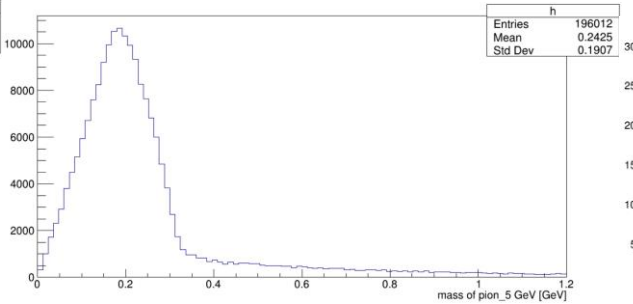
π^+ Mass : each hit and event

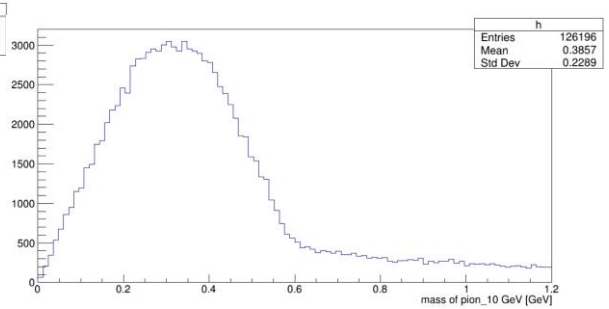
1 GeV | 2 GeV | 5 GeV | 10 GeV

each hit

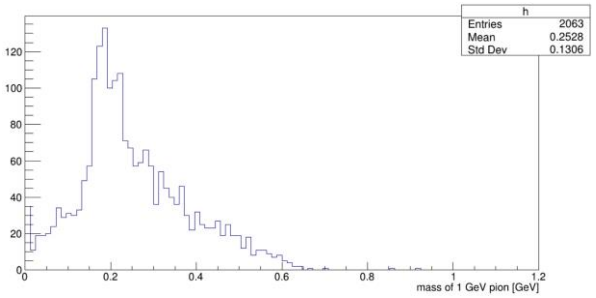


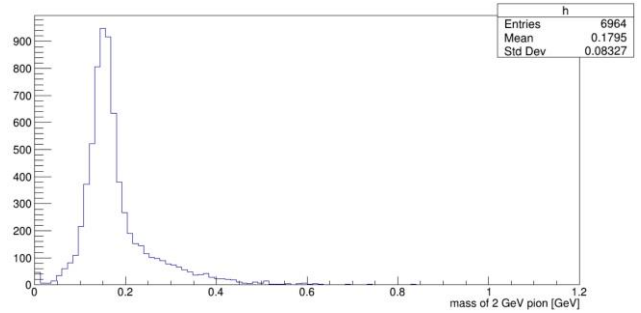


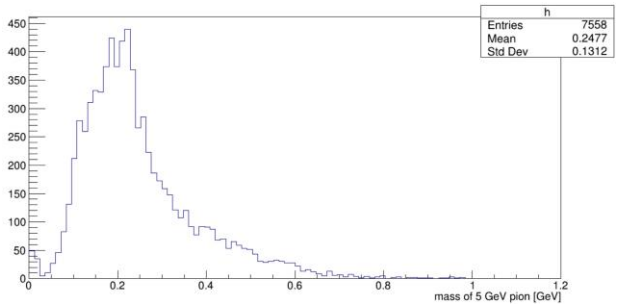


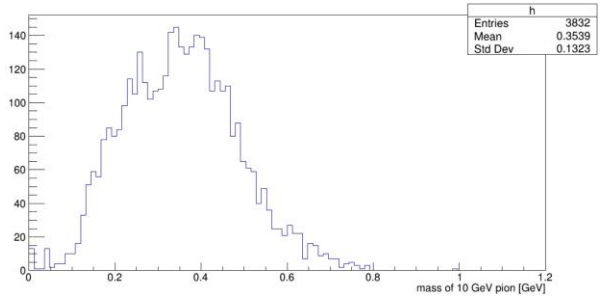


each event (average mass)







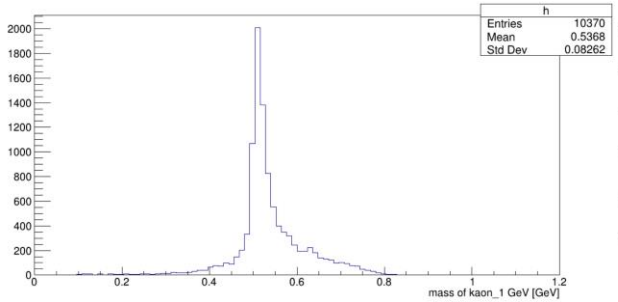


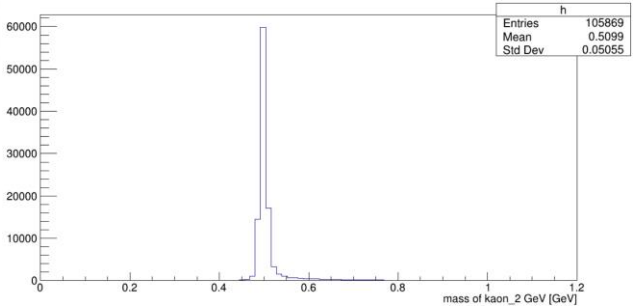
- I can't see the expected improvement in distribution for each event.

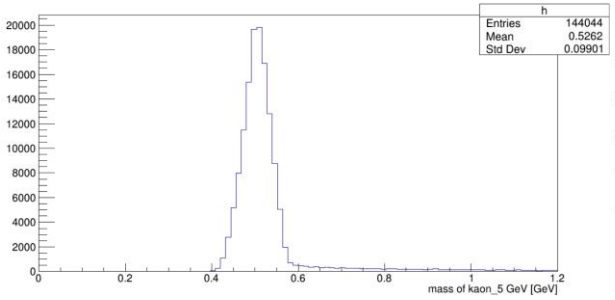
K^+ Mass : each hit and event

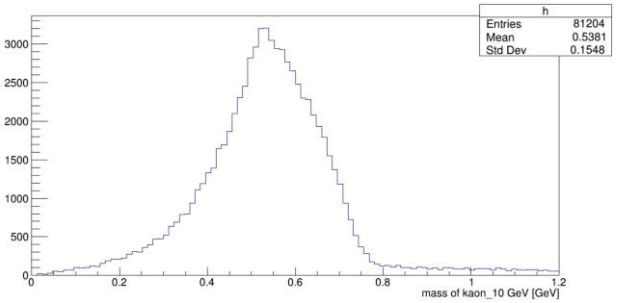
1 GeV | 2 GeV | 5 GeV | 10 GeV

each hit

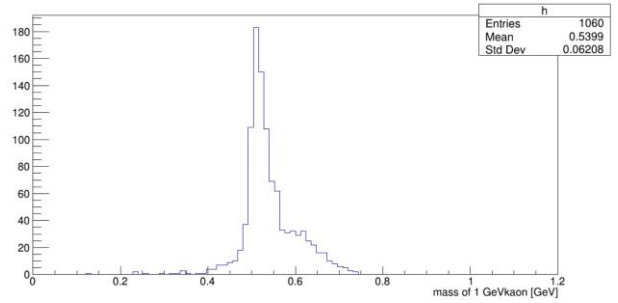


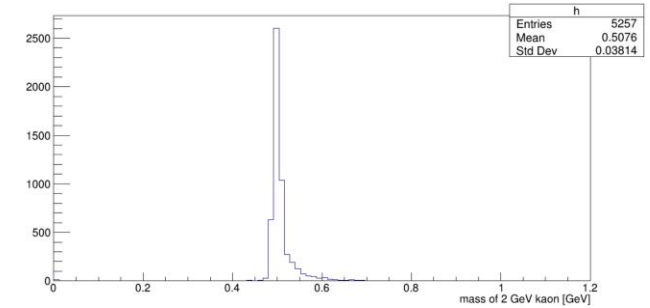


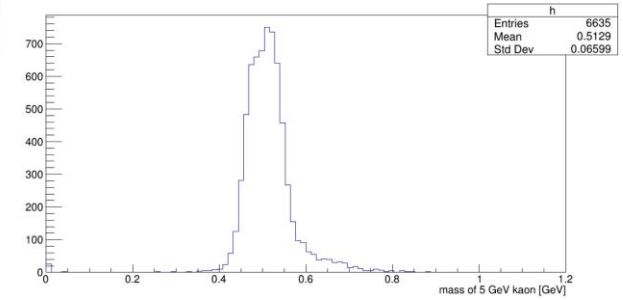


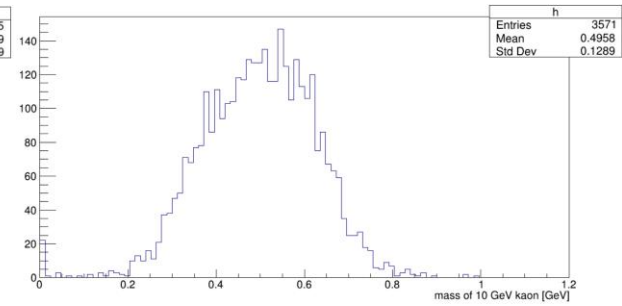


each event (average mass)









- I can't see the expected improvement in distribution for each event.

Summary

- LGAD has higher timing resolution and improve resolution of ECAL
- Calculate mass of particle with single particle data of π^+ and K^+ for each event
- Calculate for each hit → each event : However, I can't see the expected improvement in distribution for each event.

Next step

- Simulate the difference in resolution and particle ID by combining LGAD with ECAL
- Make LGAD prototype and simulation