A relation between track length and deposited energy in homogeneous calorimeter by GEANT4 simulation at high energy

Tohru Takeshita,
R.Terada and Y.Hasegawa
- Shinshu Univ.

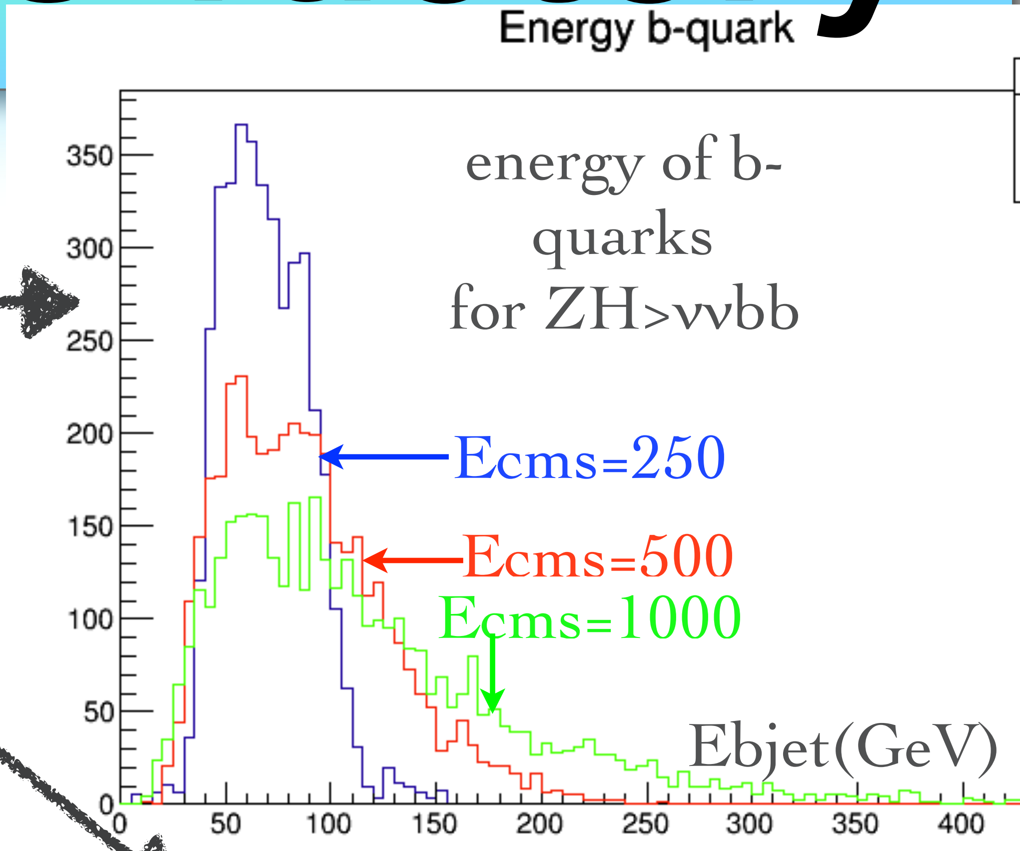
CHEF2019@Fukuoka

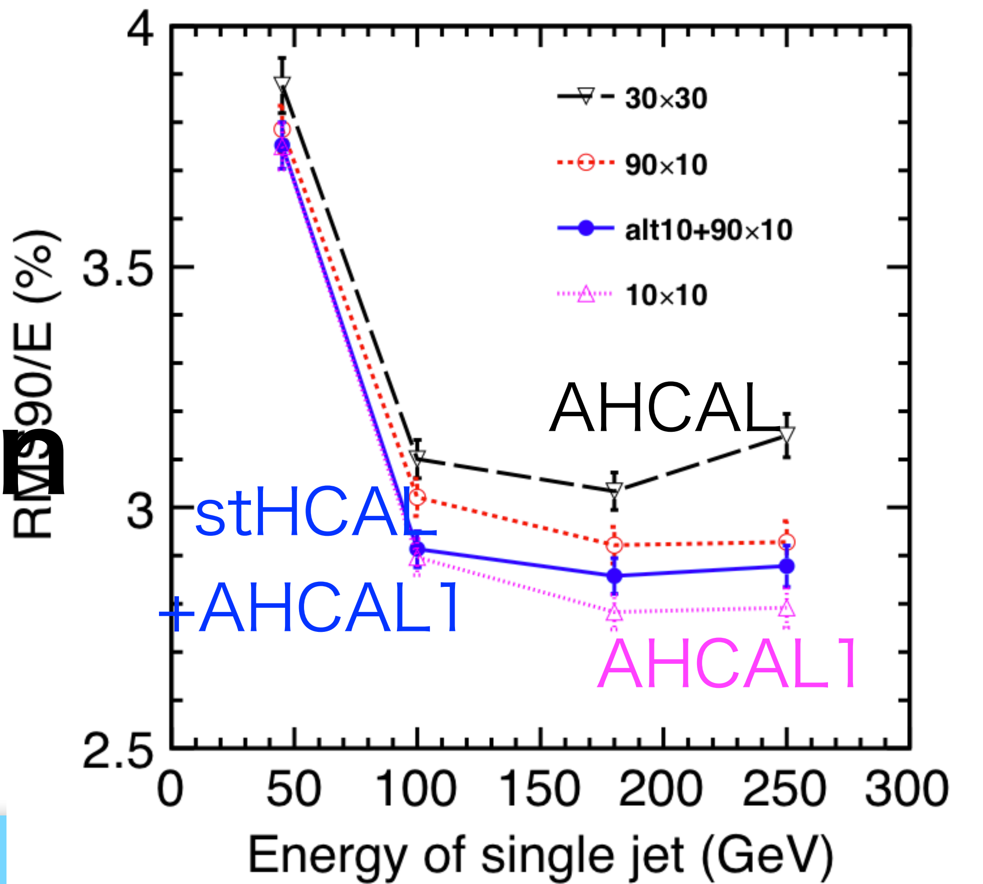
bbjes from Higgs factory

- Ebjet~50-100GeV at HF
- Energy Resolution of Jets (JER) PFA is degraded
- due to HCAL E-resolution
- PFA does work well at higher energies
- to improve Jet EReso. in 50-100 GeV region

intrinsic

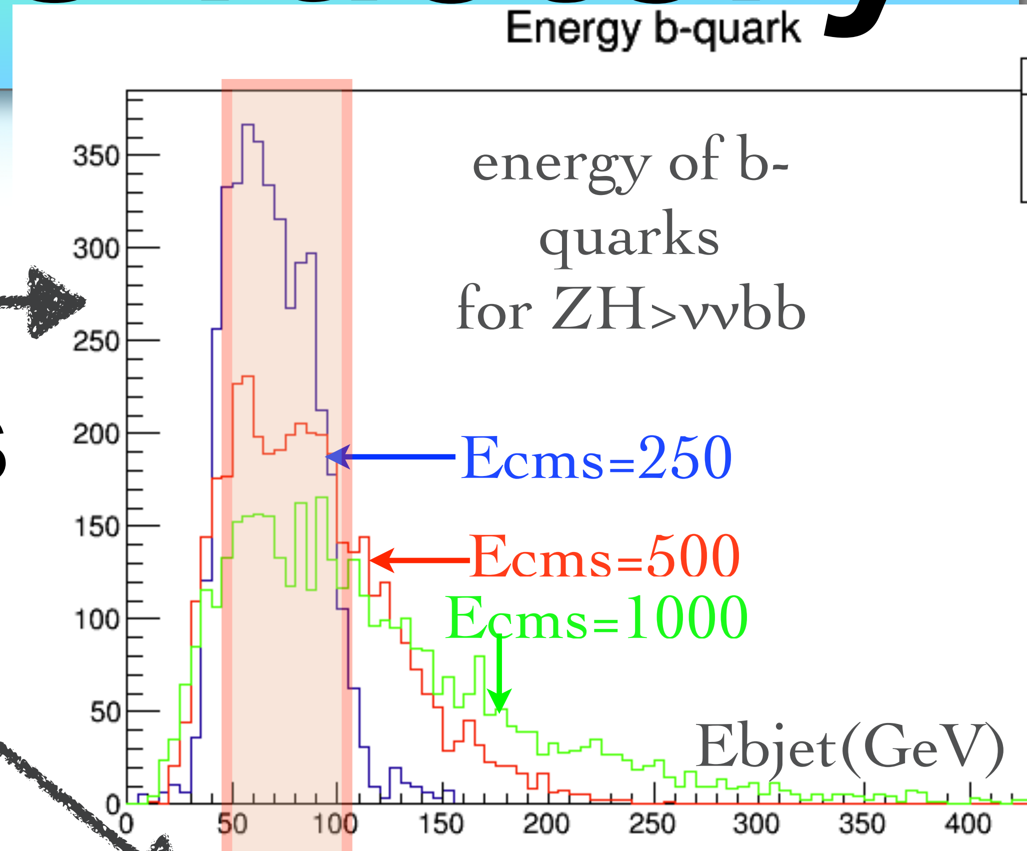
Eparticle<10GeV

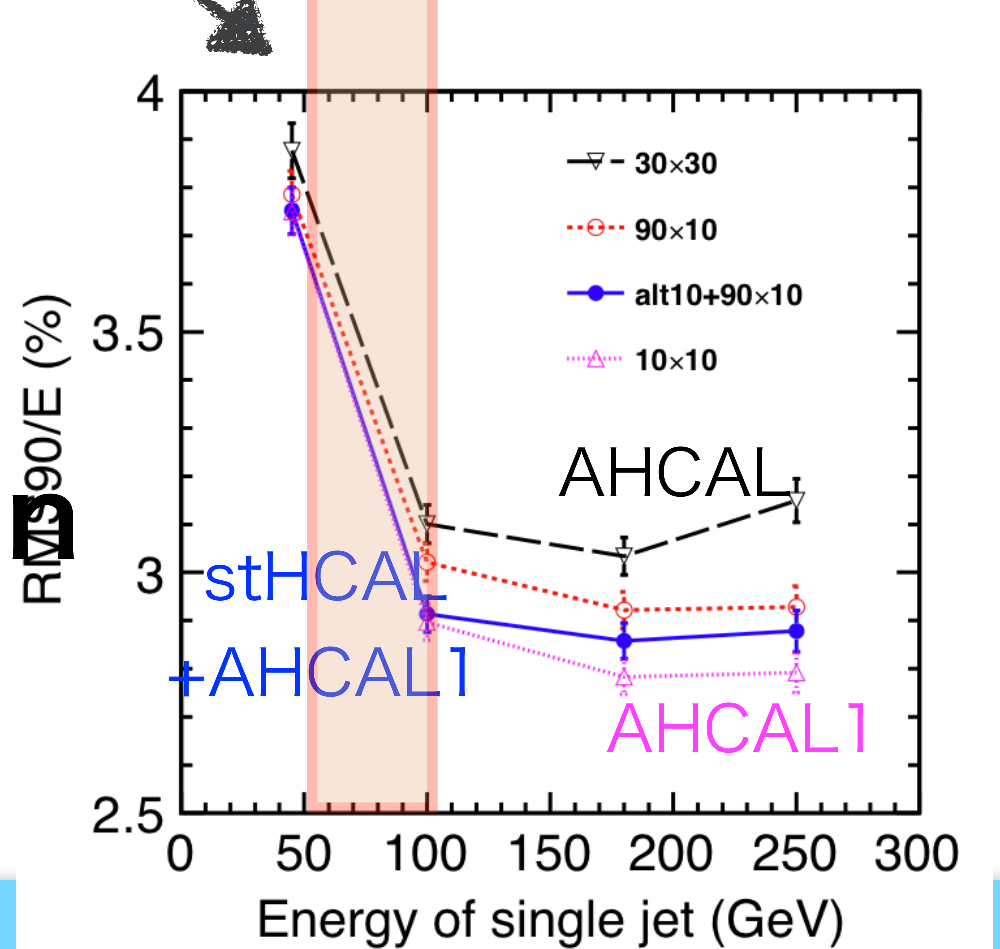




bbjes from Higgs factory

- Ebjet~50-100GeV at HF
- Energy Resolution of Jets (JER) PFA is degraded
- due to HCAL E-resolution
- PFA does work well at higher energies
- intrinsic
- to improve Jet EReso. in 50-100 GeV region
- Eparticle<10GeV





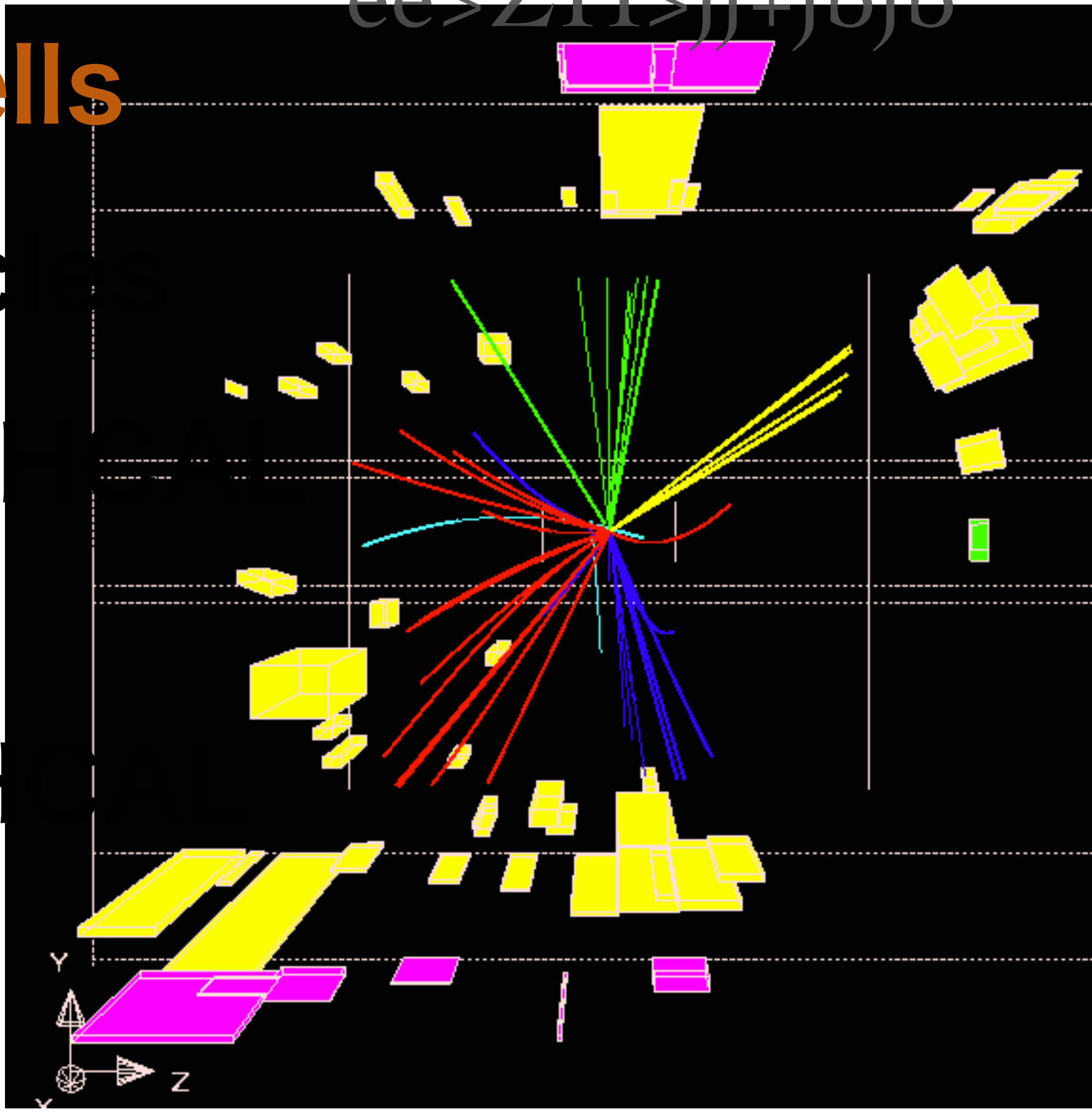
Particle Flow Algorithm

- PFA requires 3D calorimeter
- with fine segmented cells
- to separate each partic
- JetER is dominated by H
  R at lower energies
- intrinsic resolution of H
- measure total hadrons

best case

- hoping fine segmentation

ee>ZH>jj+jbjb



ILD at 250GeV

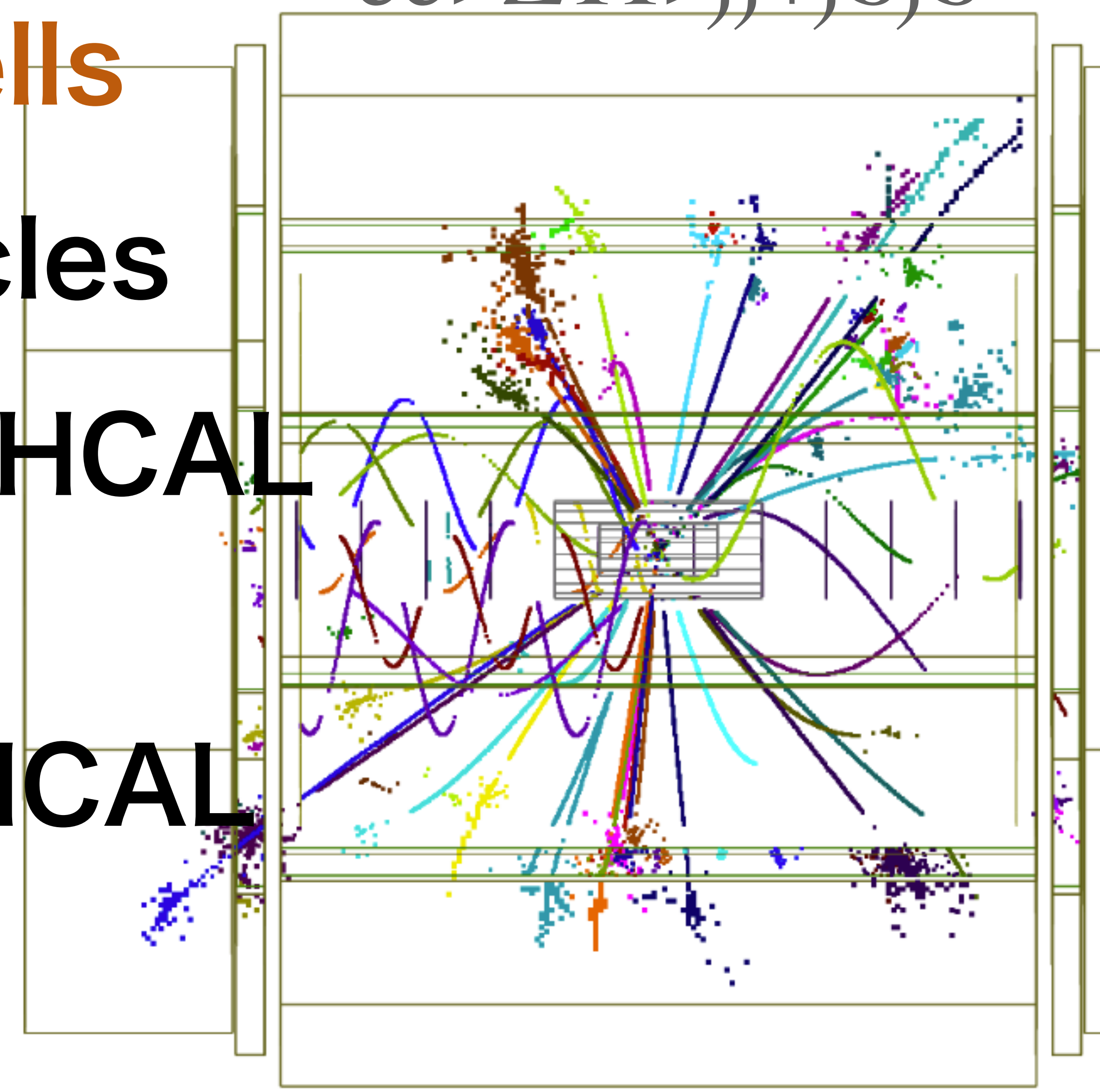
Particle Flow Algorithm

- PFA requires 3D calorimeter
- with fine segmented cells
- to separate each particles
- JetER is dominated by HCAL R at lower energies
- intrinsic resolution of HCAL
- measure total hadrons

best case

- hoping fine segmentation

ee>ZH>jj+jbjb



ILD at 250GeV

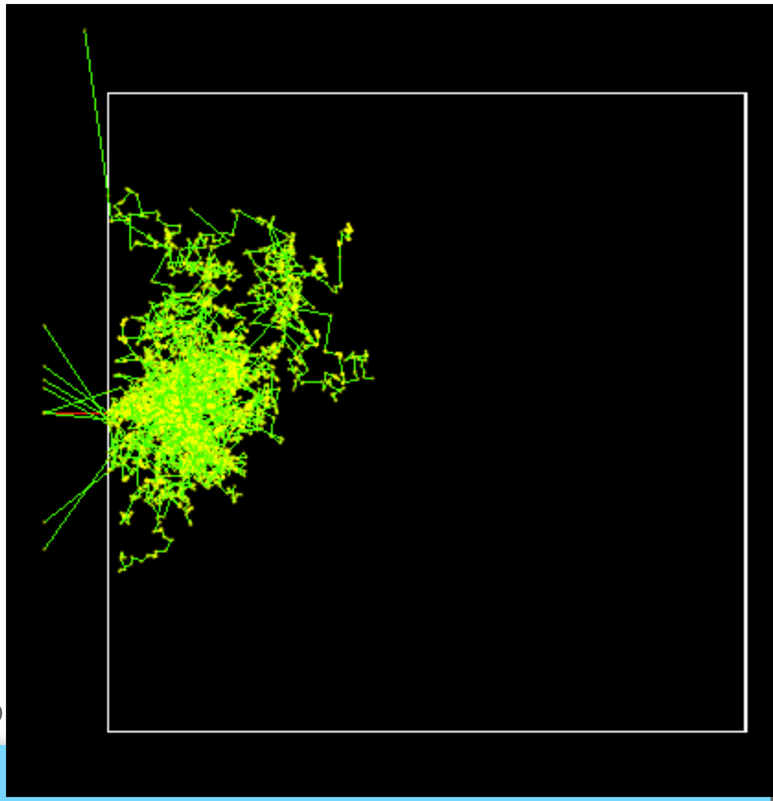
total measurements

- GEANT4 simulation 2mx2mx2m
  - time cut <100ns
  - Hadron model = FTFP-BERT
- homogeneous CAL. for exam:
  - absorber : PbWO4
  - λ_I=16, X_0=225
- two measures from the calorimeter
- TL ：Track length ∝ Cherenkov
- ED ：dEdx ∝ scintillation
- how much ER at best ?

  no photon statistics

PbWO4

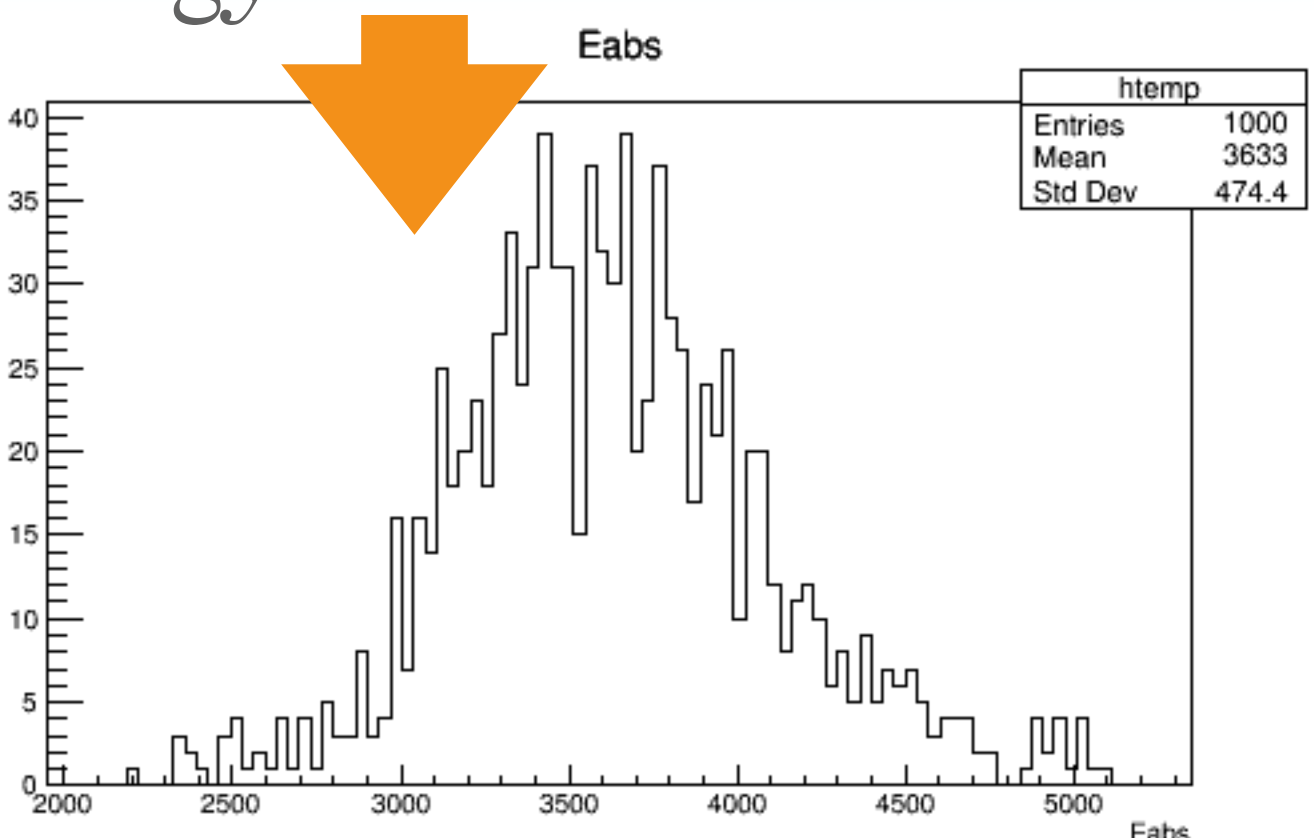
3 GeV pi-



green lines are neutrons

ED and TL for 5GeV pi-

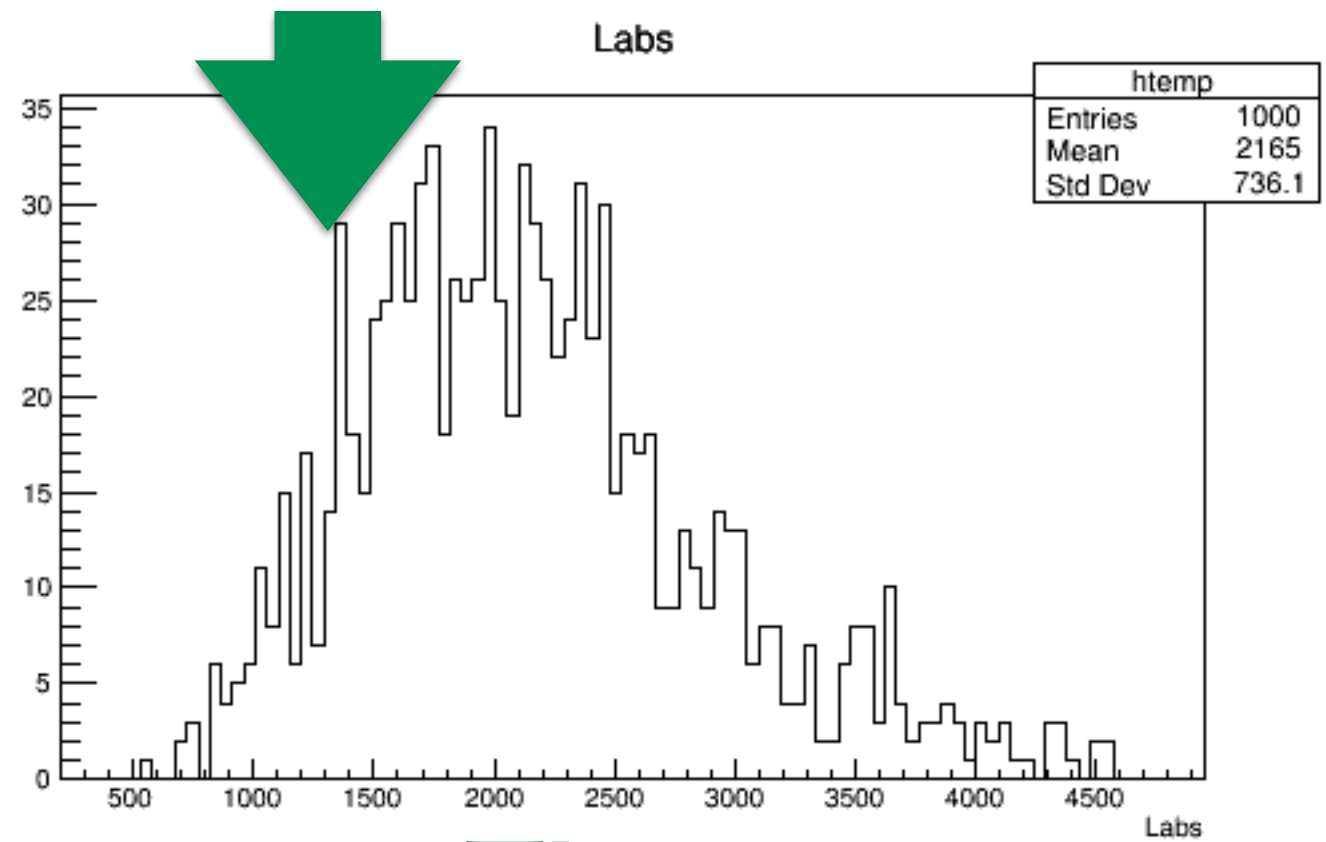
energy sum



ED (MeV)

resolution~13% @ 5GeV

Cherenkov sum



TL (mm)

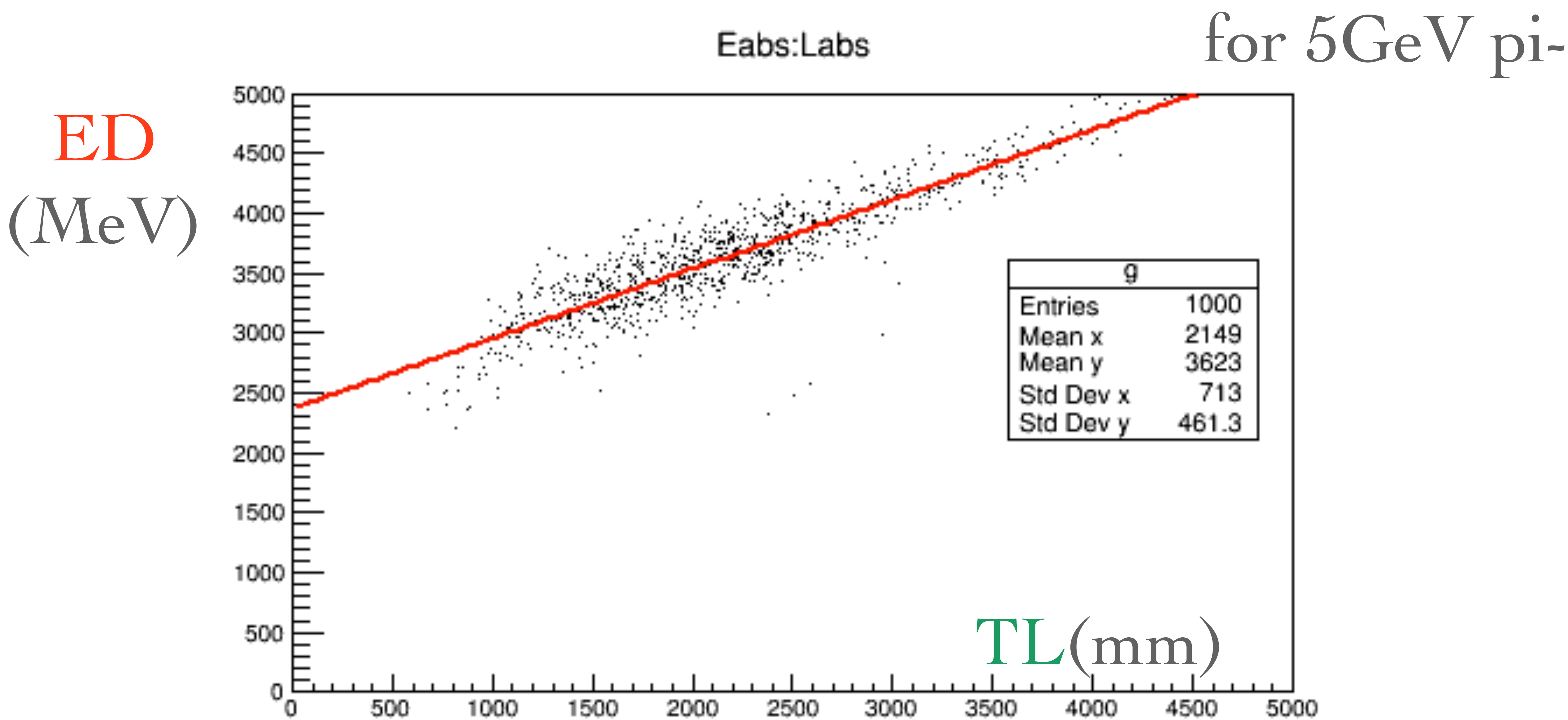
resolution~30% @ 5GeV

ED=sum of energy deposit
~ sum of scintillation lights in PbWO4

TL= sum of track lengh
~ sum of Cherenkov lights in PbWO4

ED vs TL

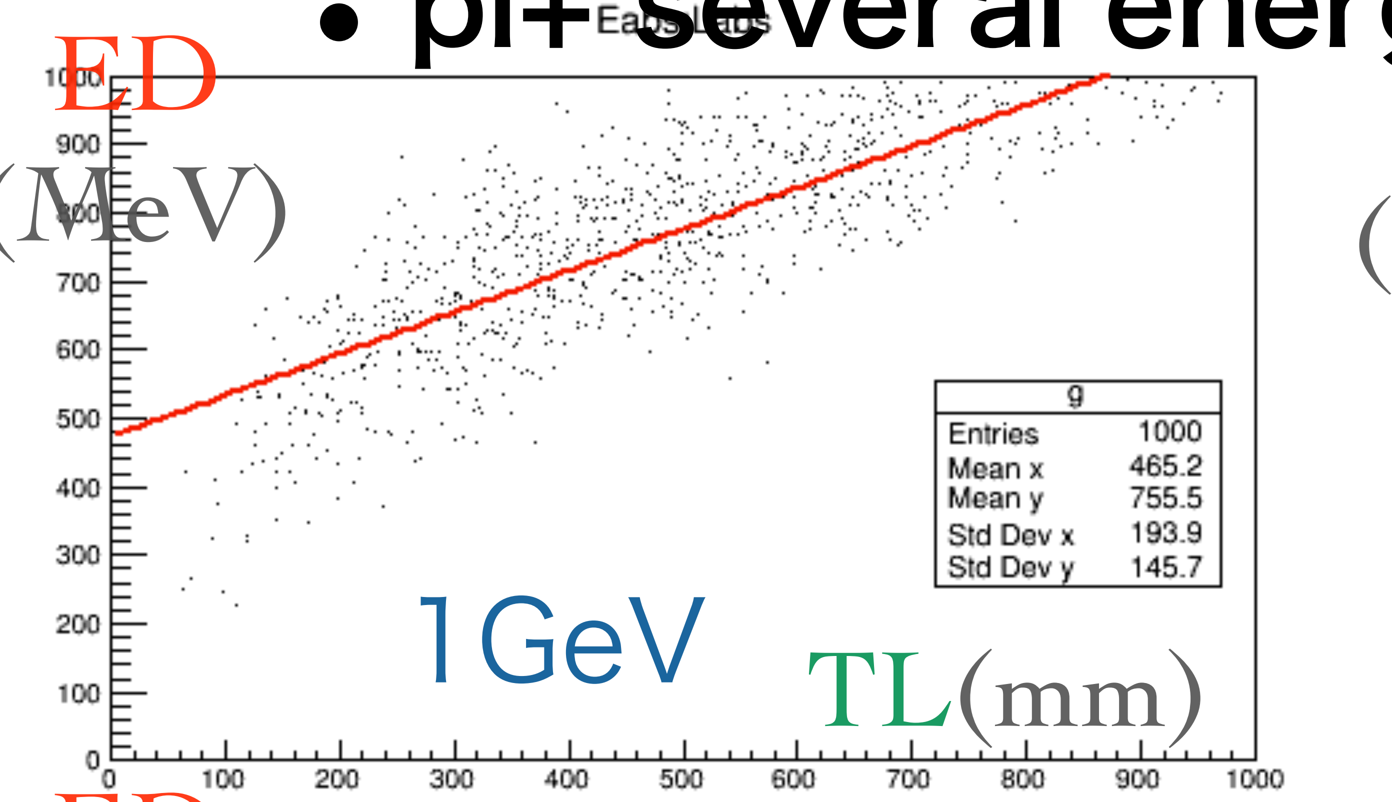
- strong correlation between ED vs TL

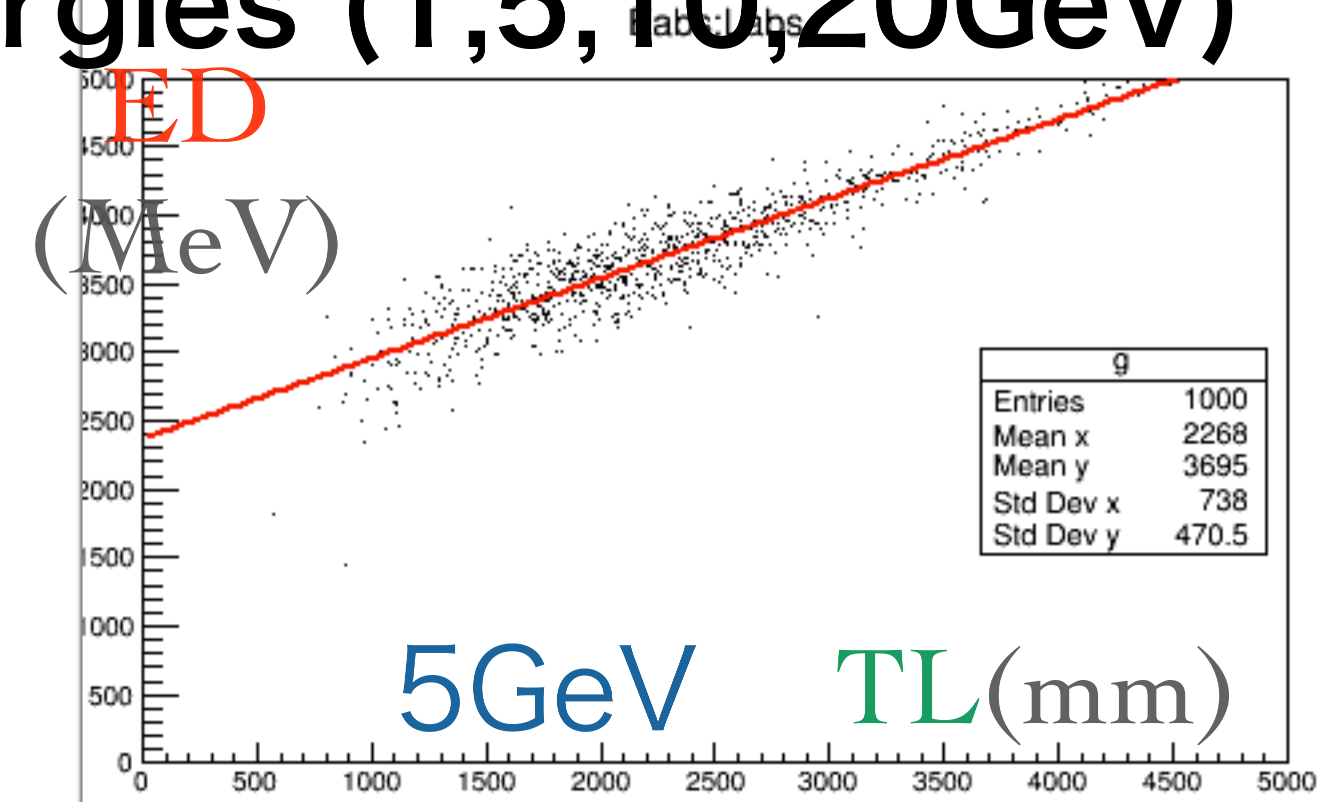


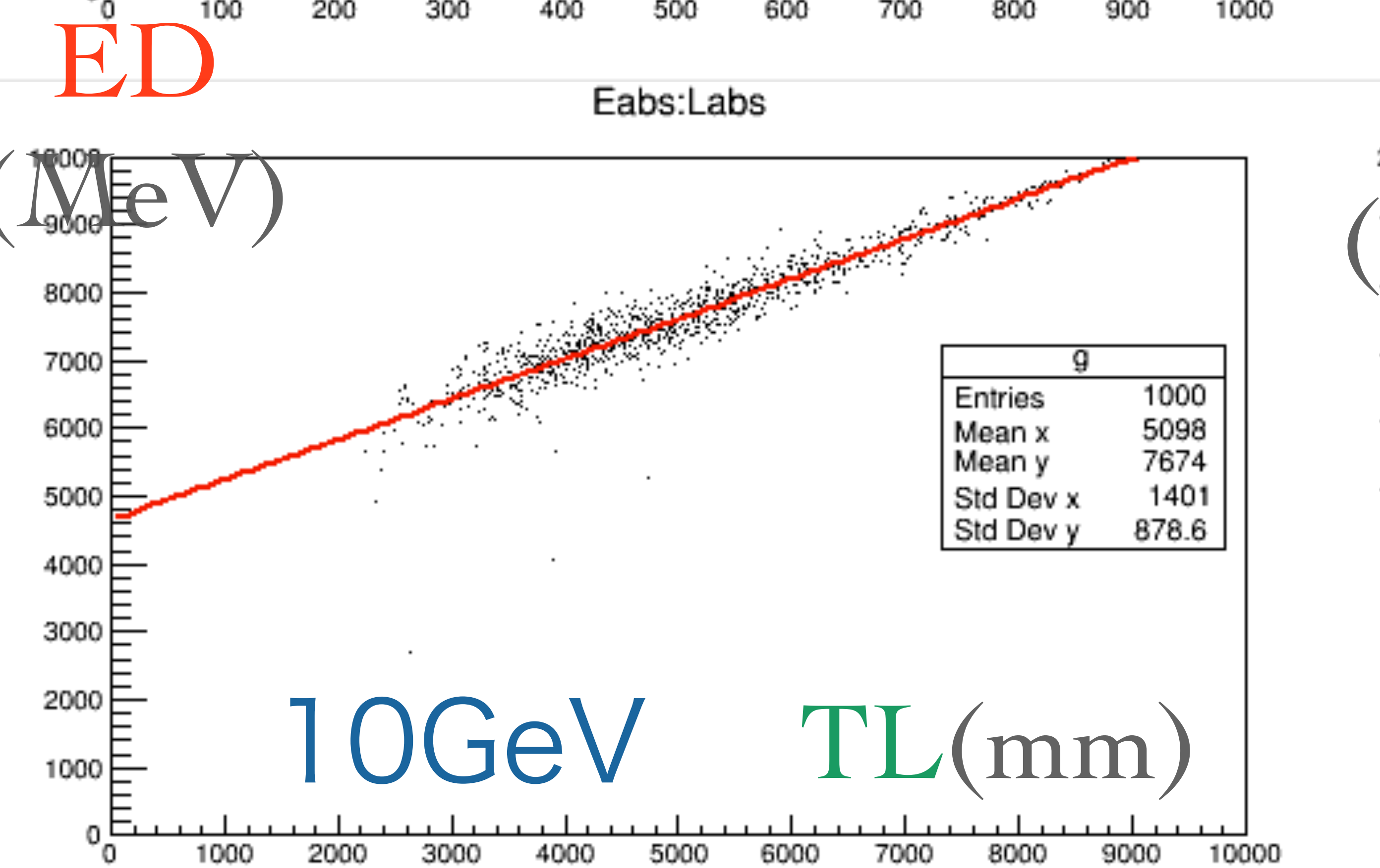
- approx. in linear with constant term in ED

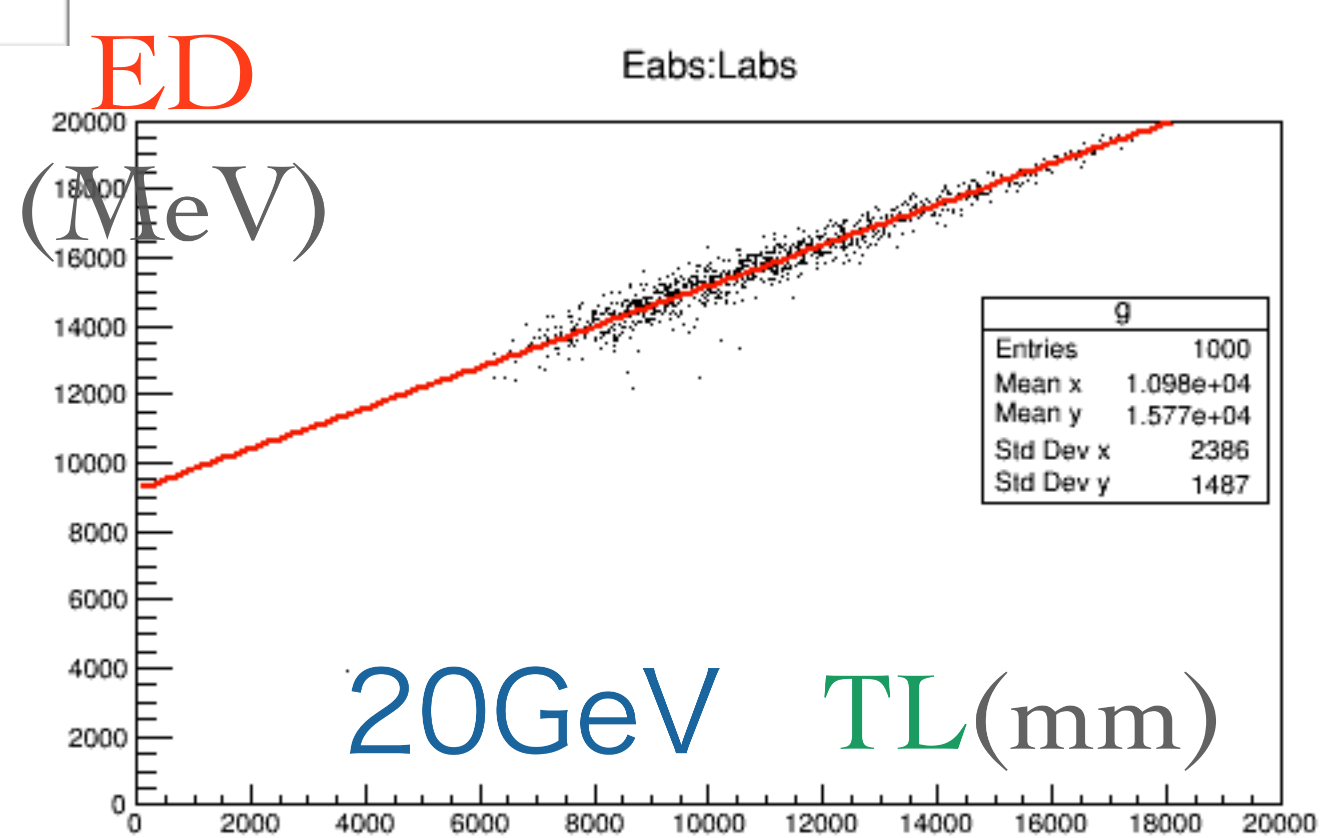
ED vs TL for pi+

- pi+ several energies (1,5,10,20GeV)





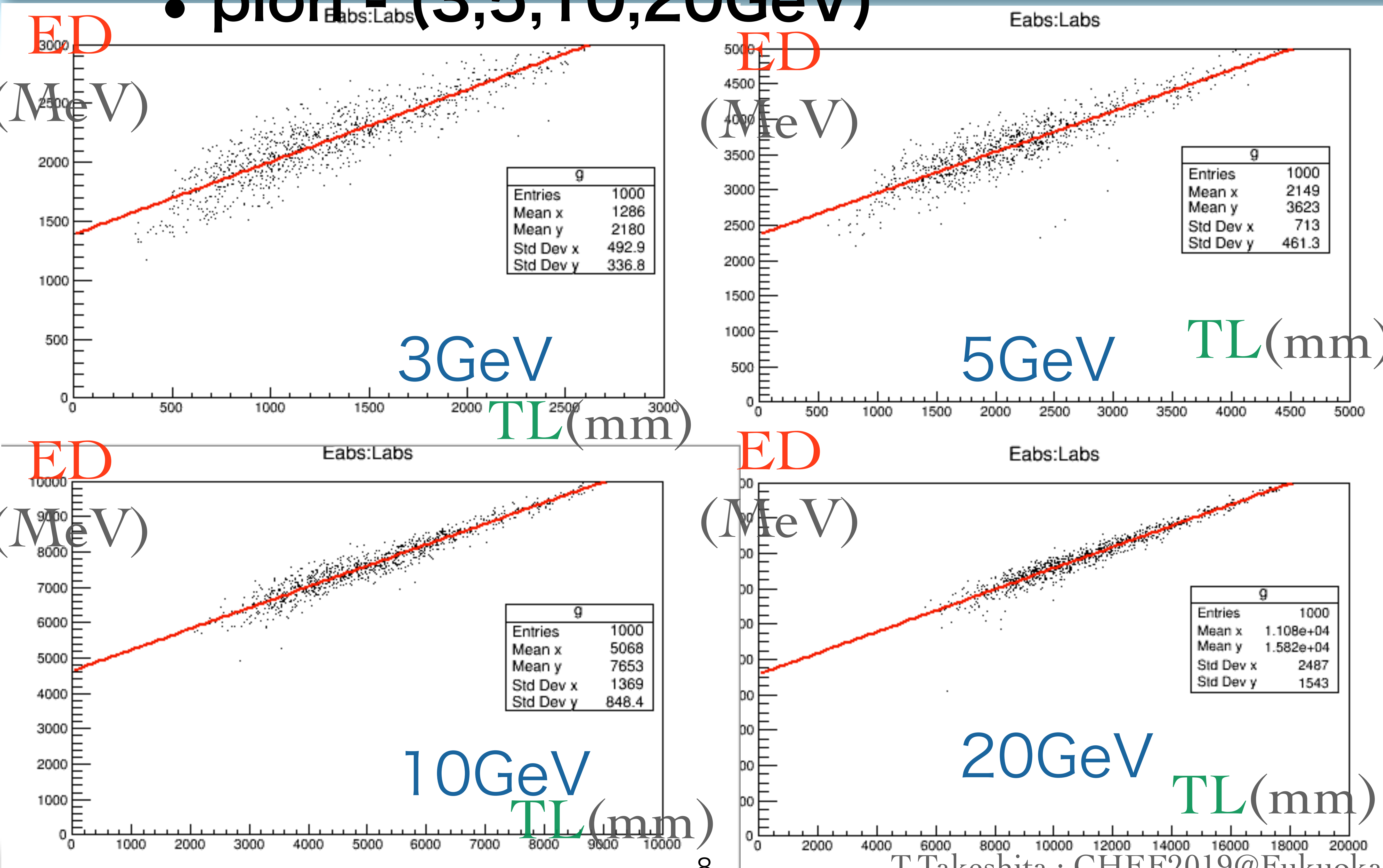




ED vs TL

for pi-

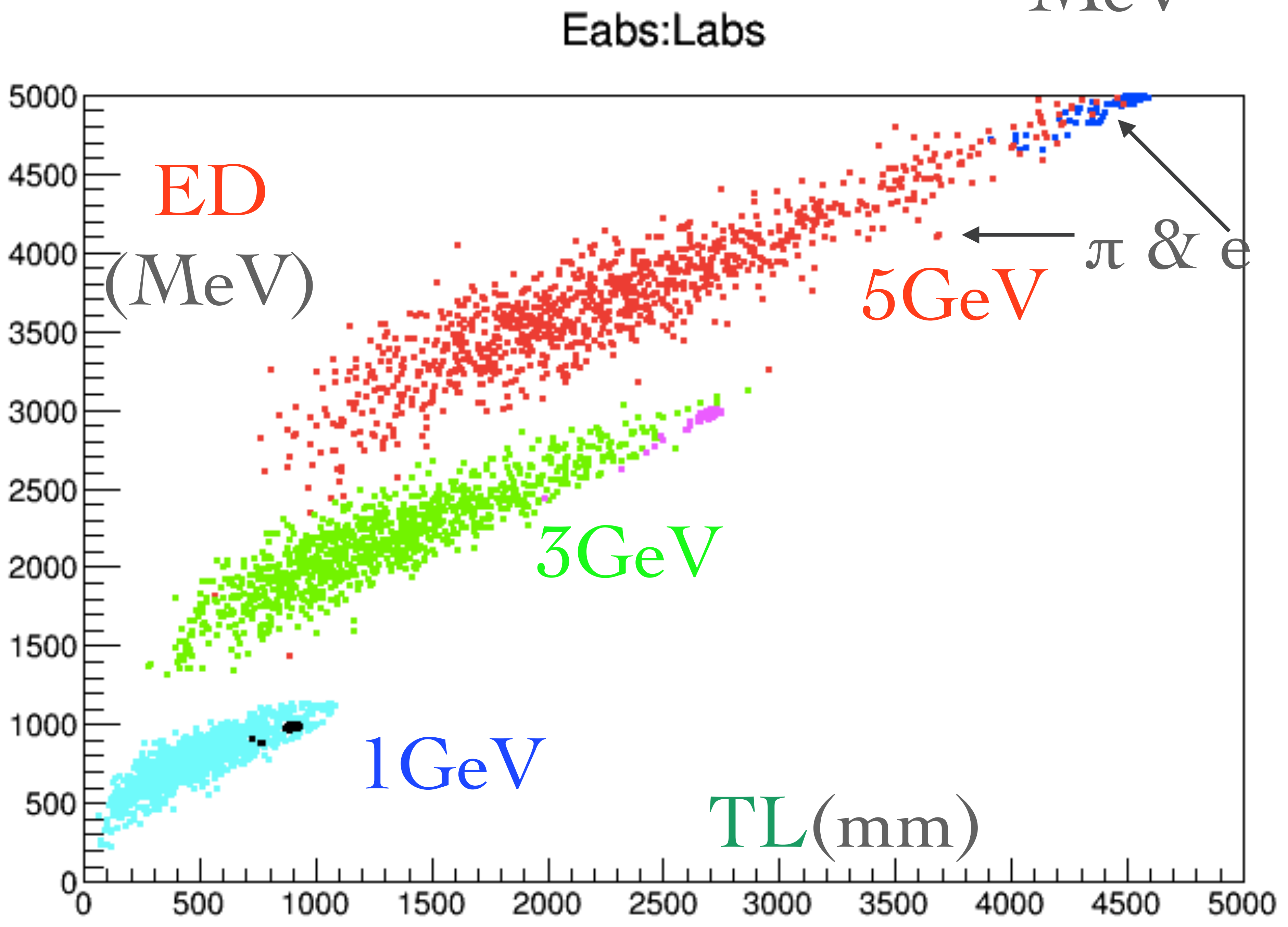
- pion - (3,5,10,20GeV)



ED vs TL

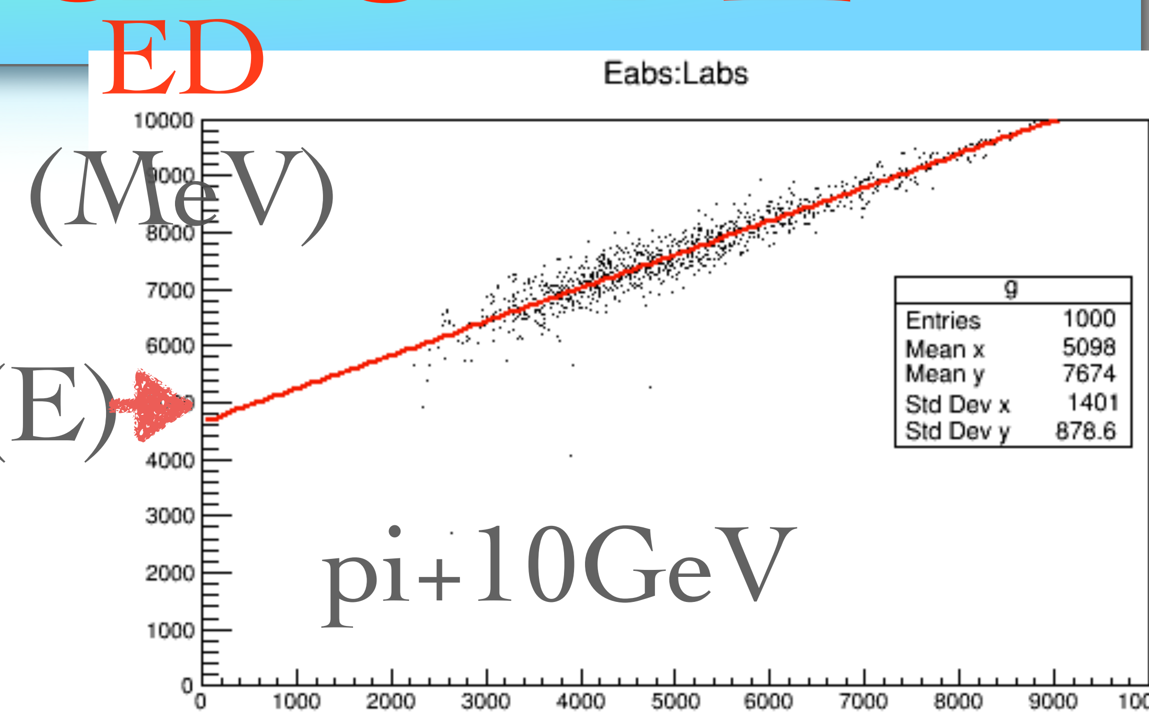
constant slop for pi+ and e-

ED=A(E)+B*TL
MeV mm

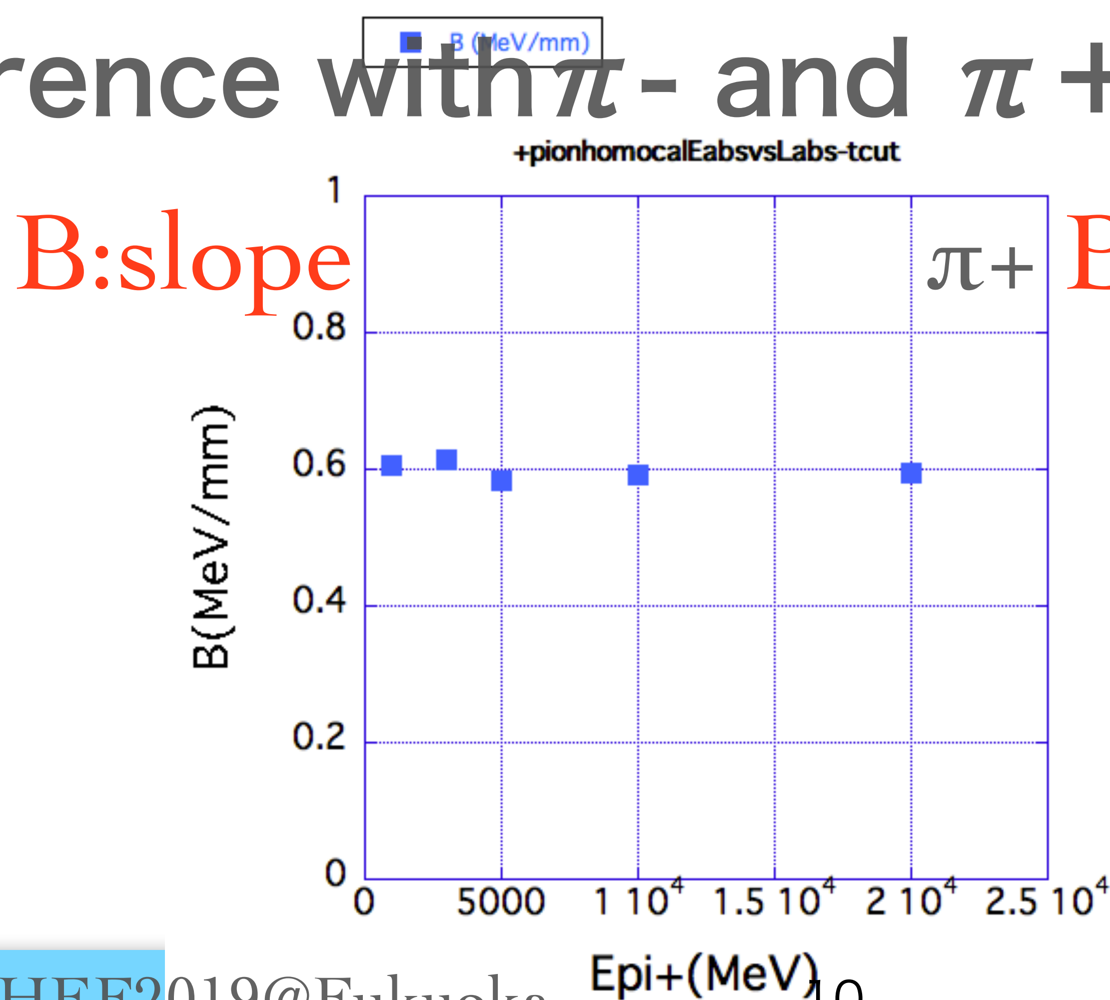


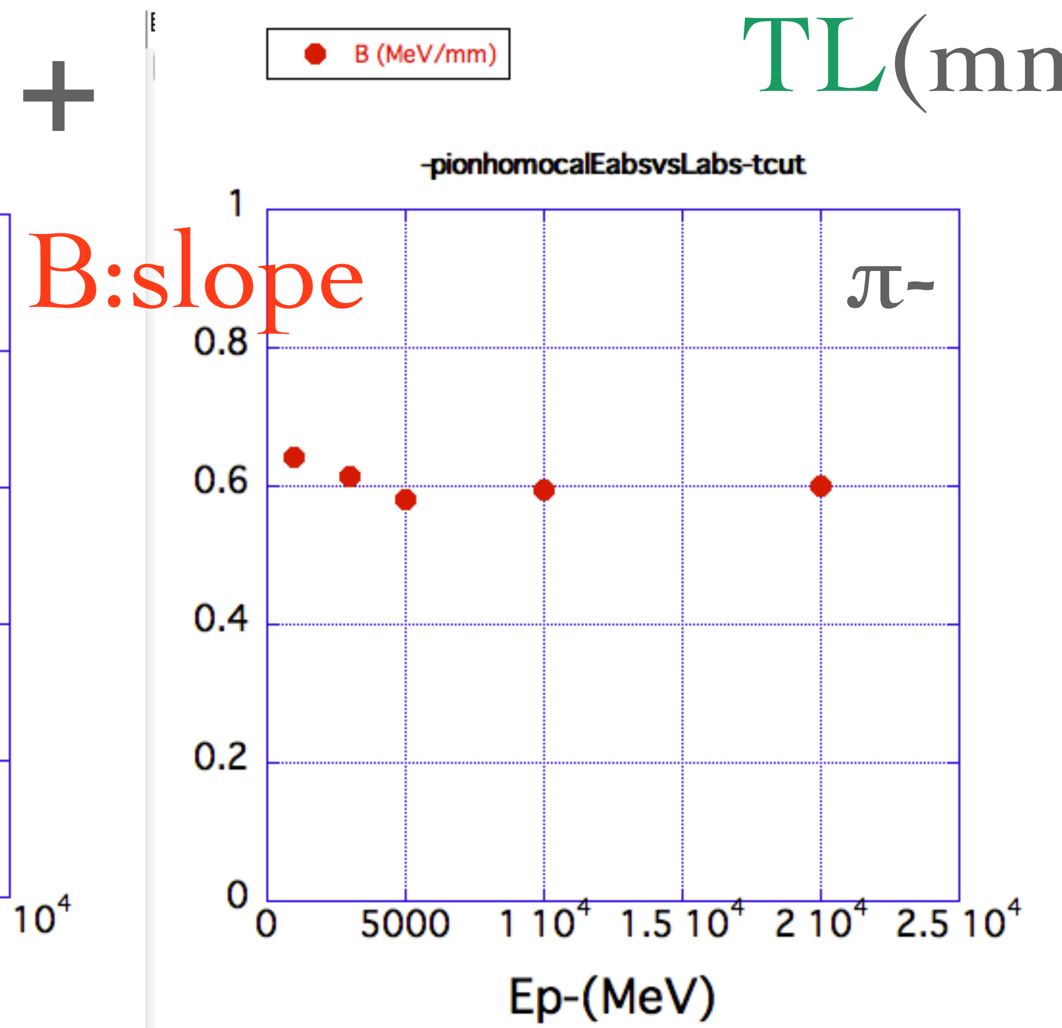
slop of ED and TL

- when fitted with linear
  ED=A(E)+B*TL
- slope=B is constant for all energies E>1GeV



- no difference with π- and π+

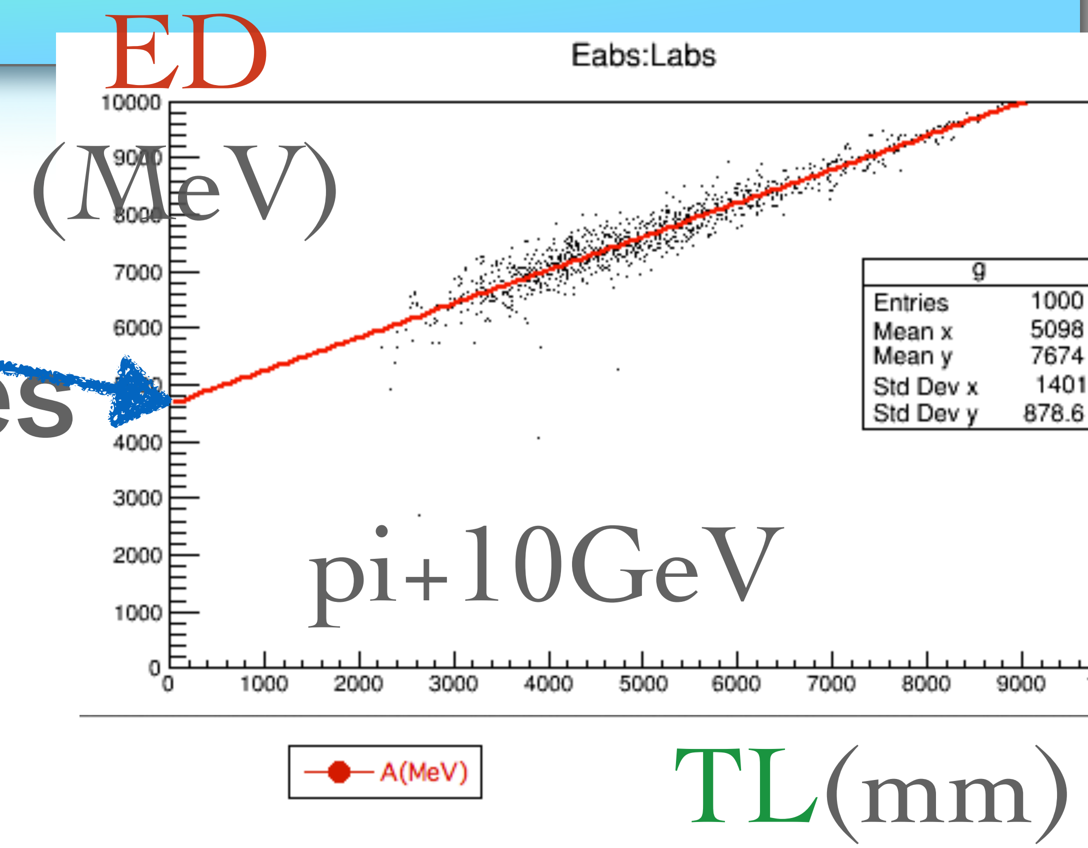


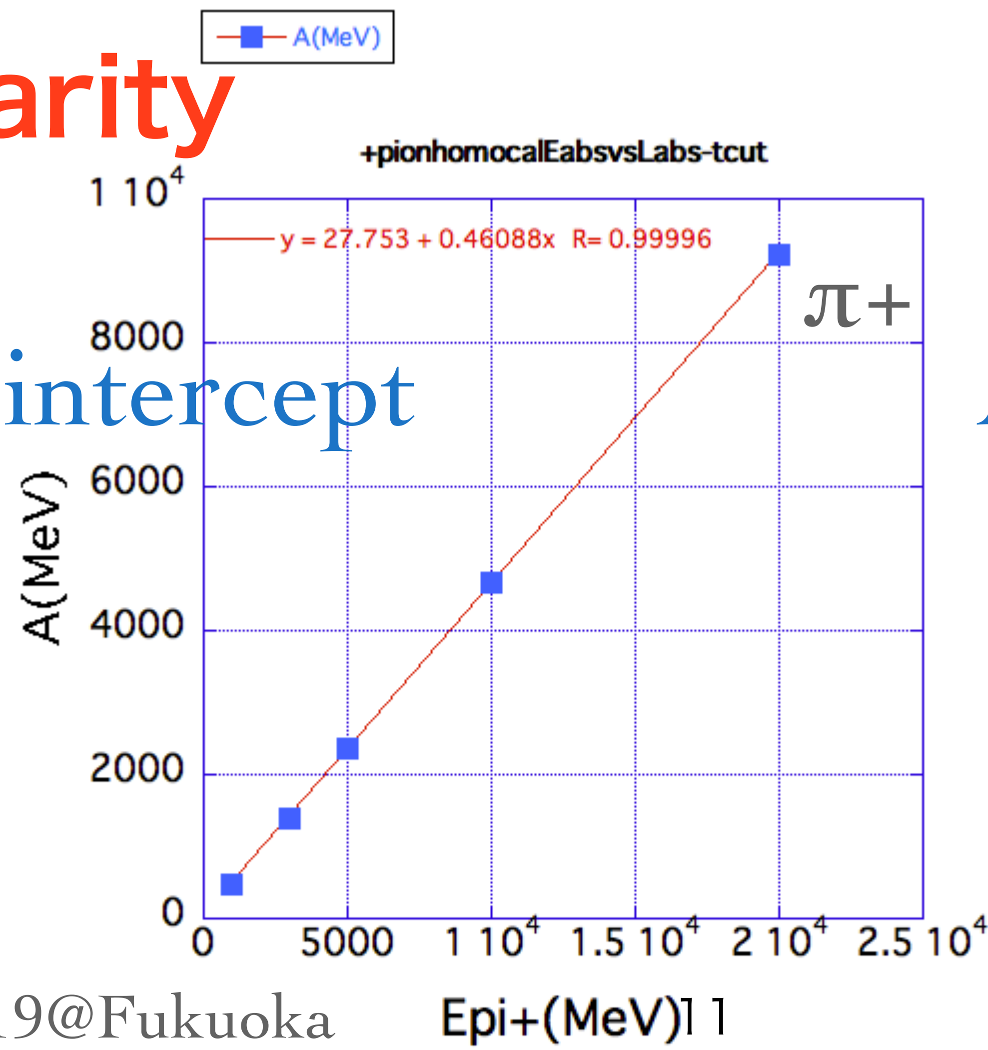


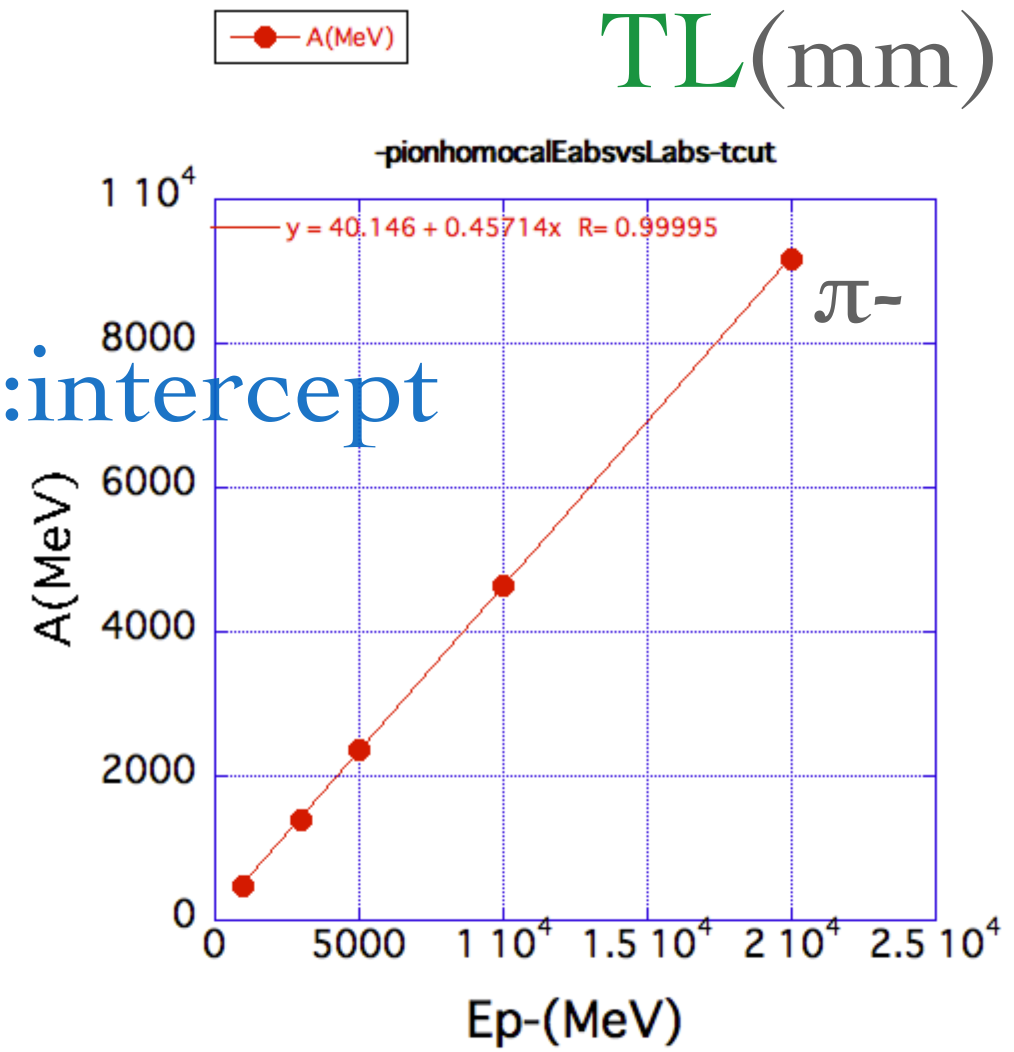
intercept of fitted line

ED=A(E)+B*TL

- intercept (cut) A(E) is
- linear with injected energies
- same to π- and π+
- good linearity



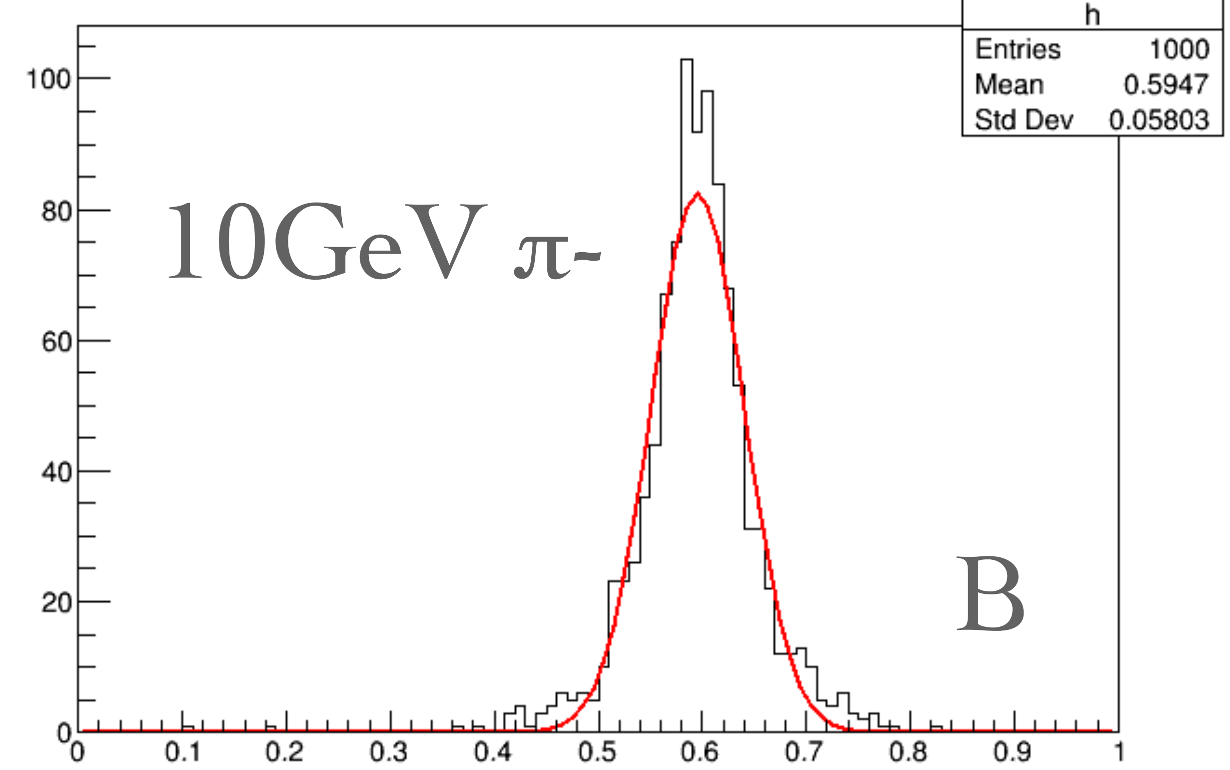


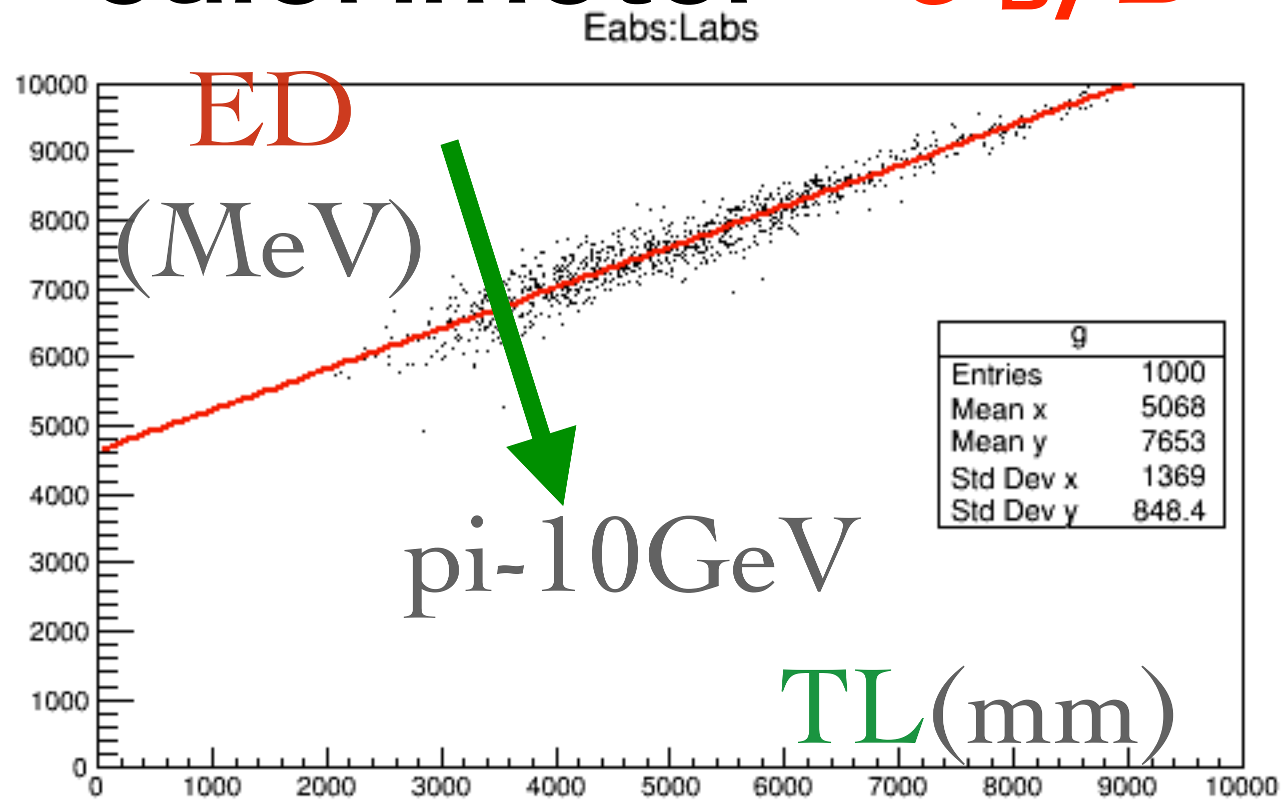


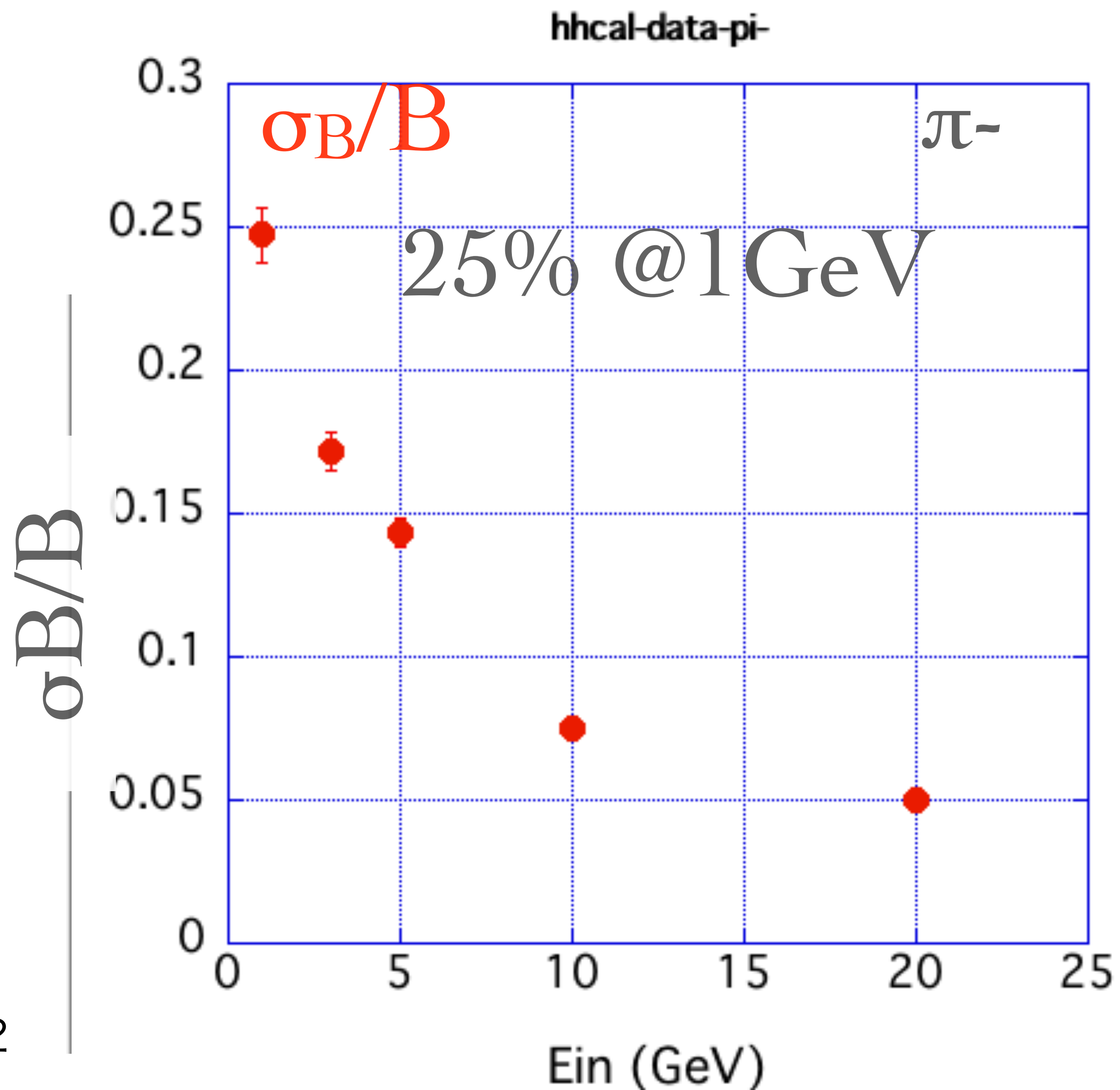
Resolution

ED=A(E)+B*TL

- B=(ED-A(E))/TL
- B is independent on E
- resolution of the calorimeter ~σ_B/B







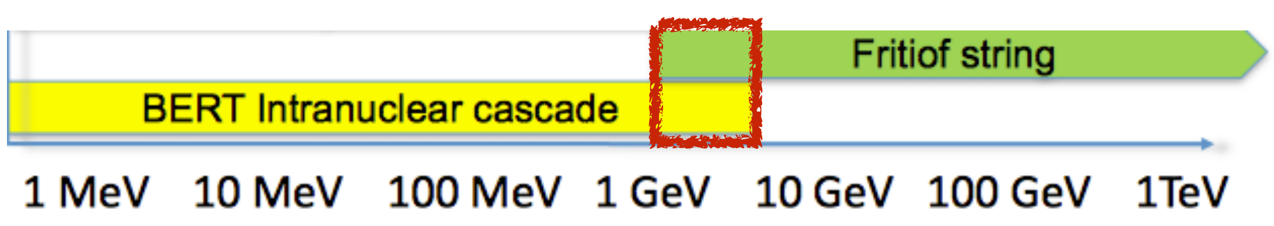
Energy resolution

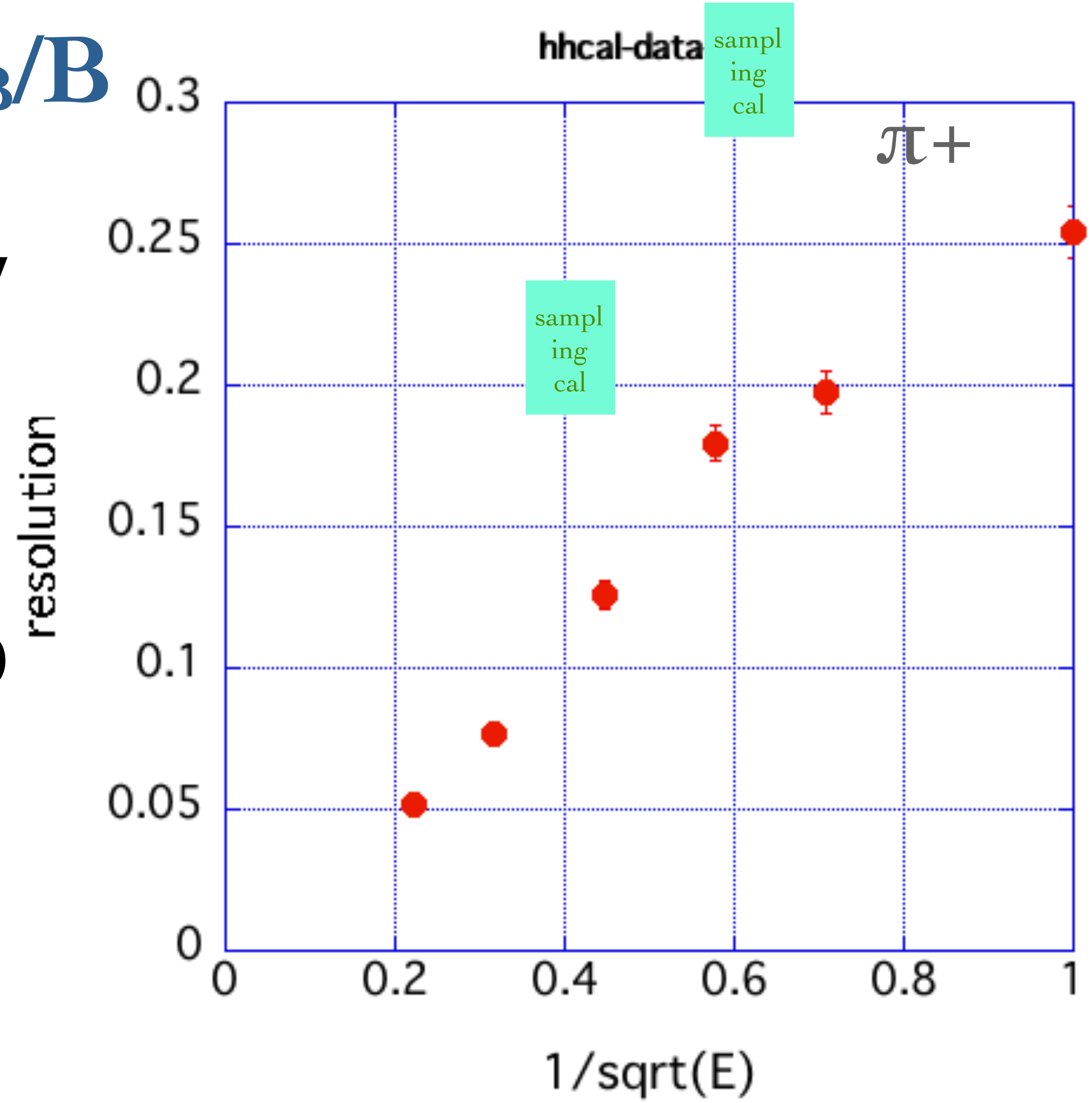
sampl ing cal

ED=A(E)+B*TL

$\sigma_B/B \sim 25\%/\mathrm{sqrt}(E)$

- energy resolution= σ_B/B
- σ_B/B scales in 1/ sqrt(E(GeV))
- kink at ~5GeV due to
- Hadron model in G4



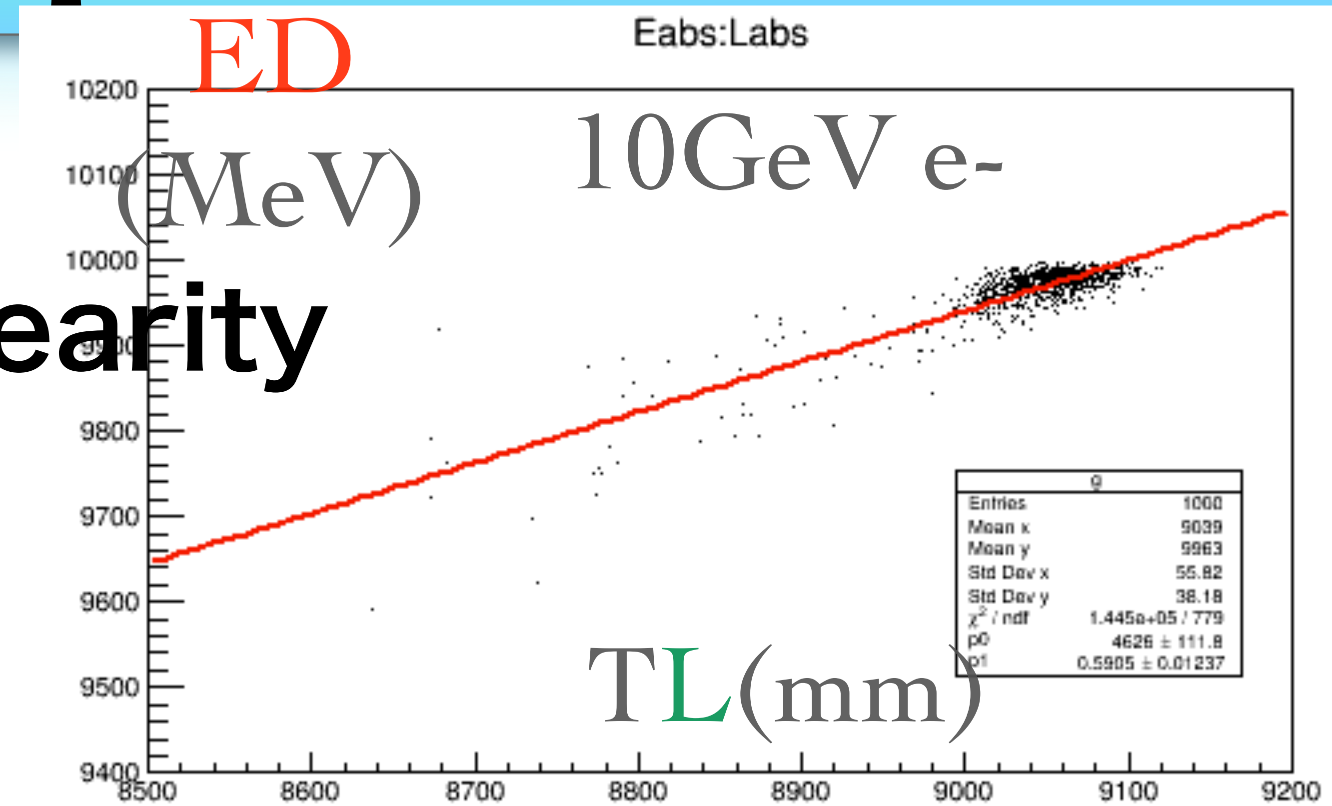


50,20,10,5, 3 ,1GeV

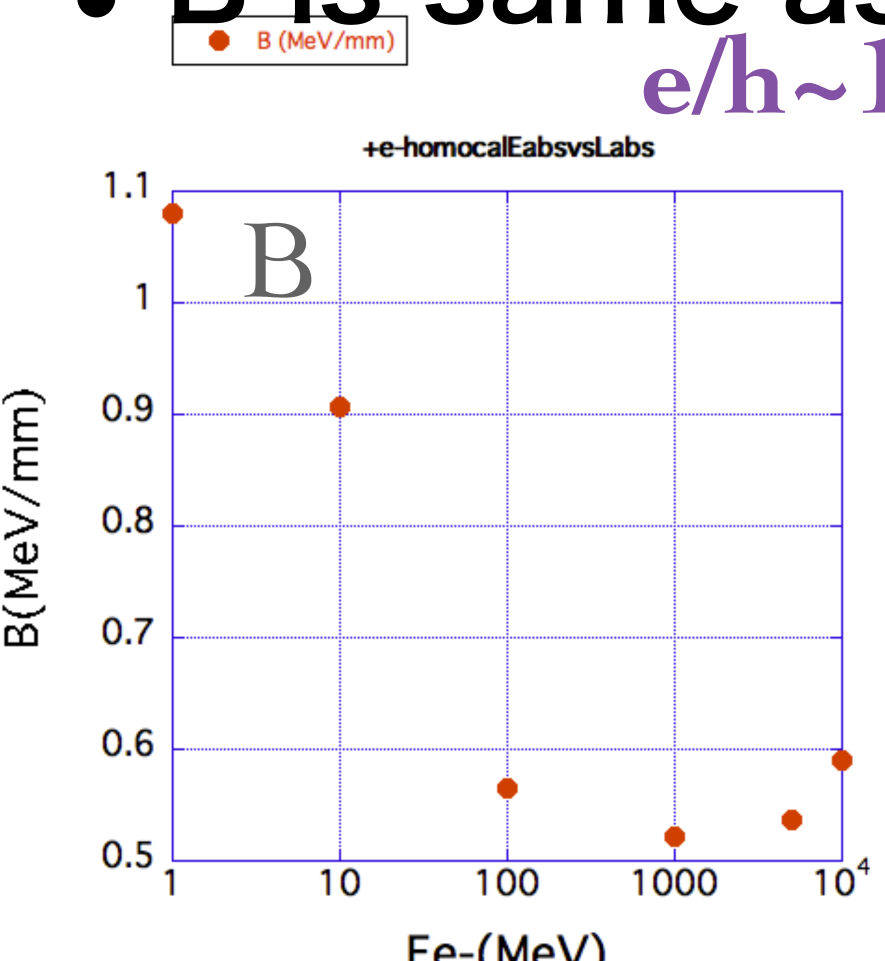
EM response

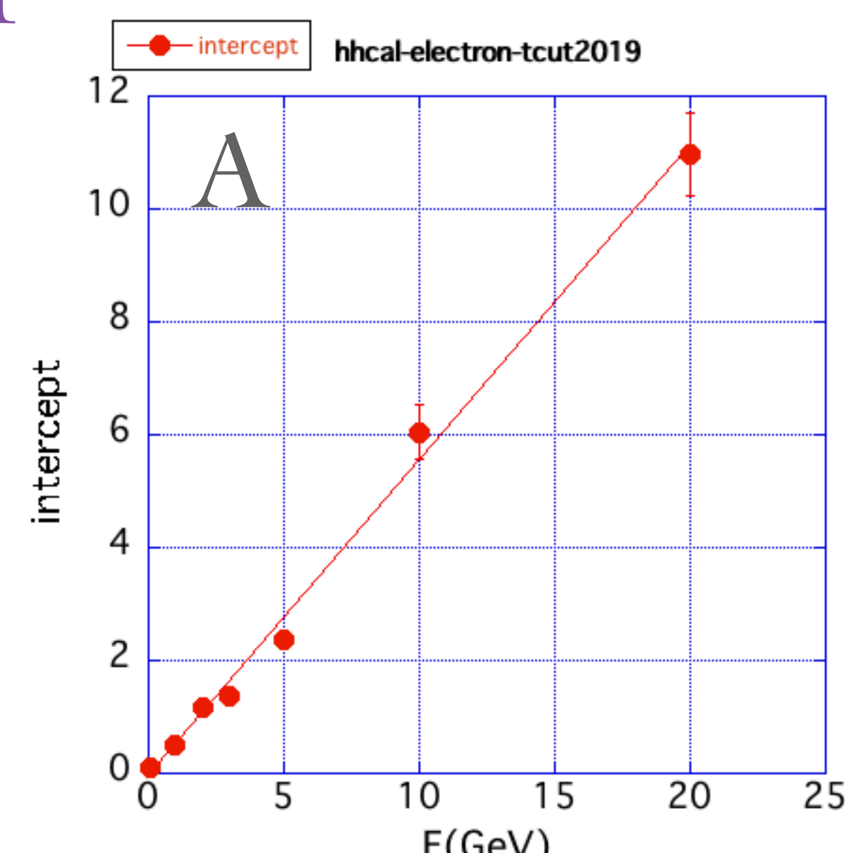
ED=A(E)+B*TL

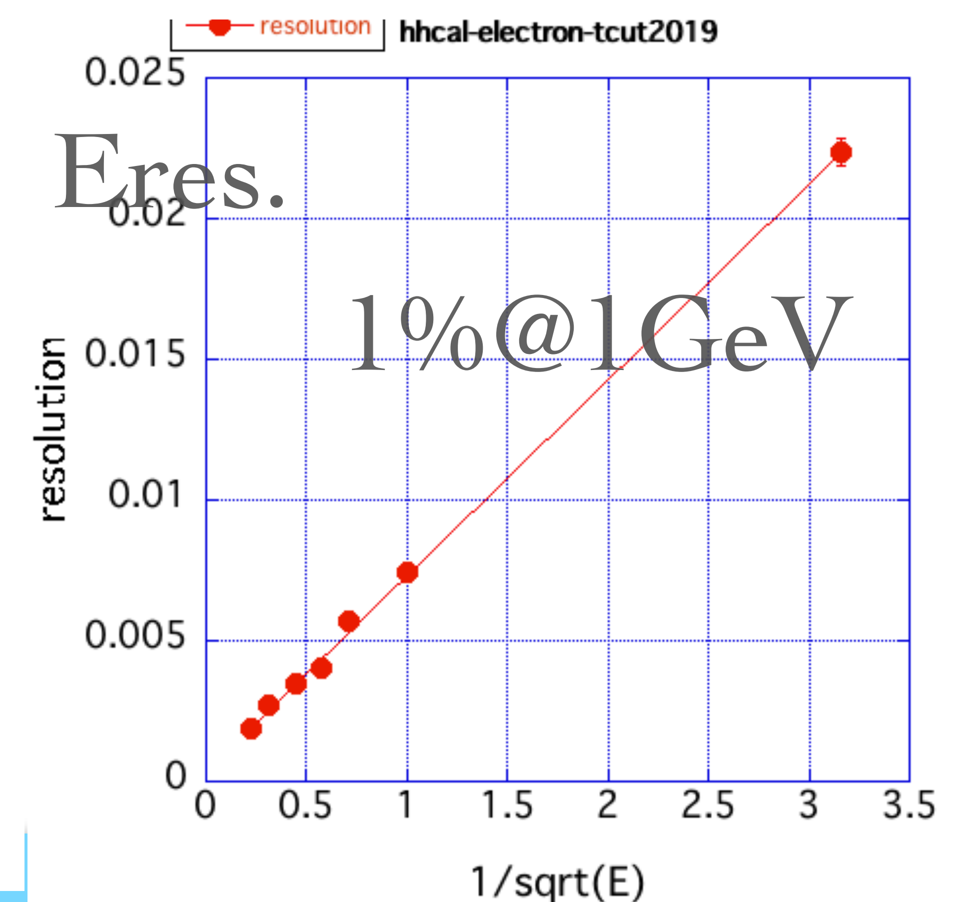
- ED vs TL :
- A(E) shows good linearity
- B is const. at E>100MeV
- B is same as ~ π+-



e/h~1

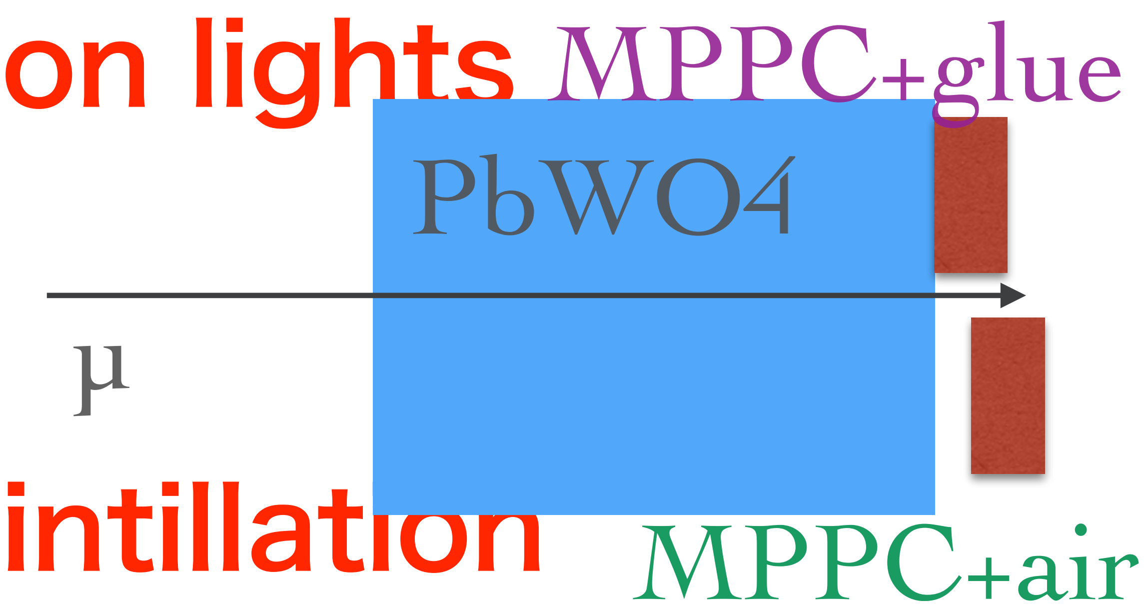






how to measure

- energy resolution ~ 25%/ sqrt(E)
- from ED and TL
- use heavy crystal such as PbWO4
- ED ~ dE/dx ~ scintillation lights
- TL ~ Cherenkov lights



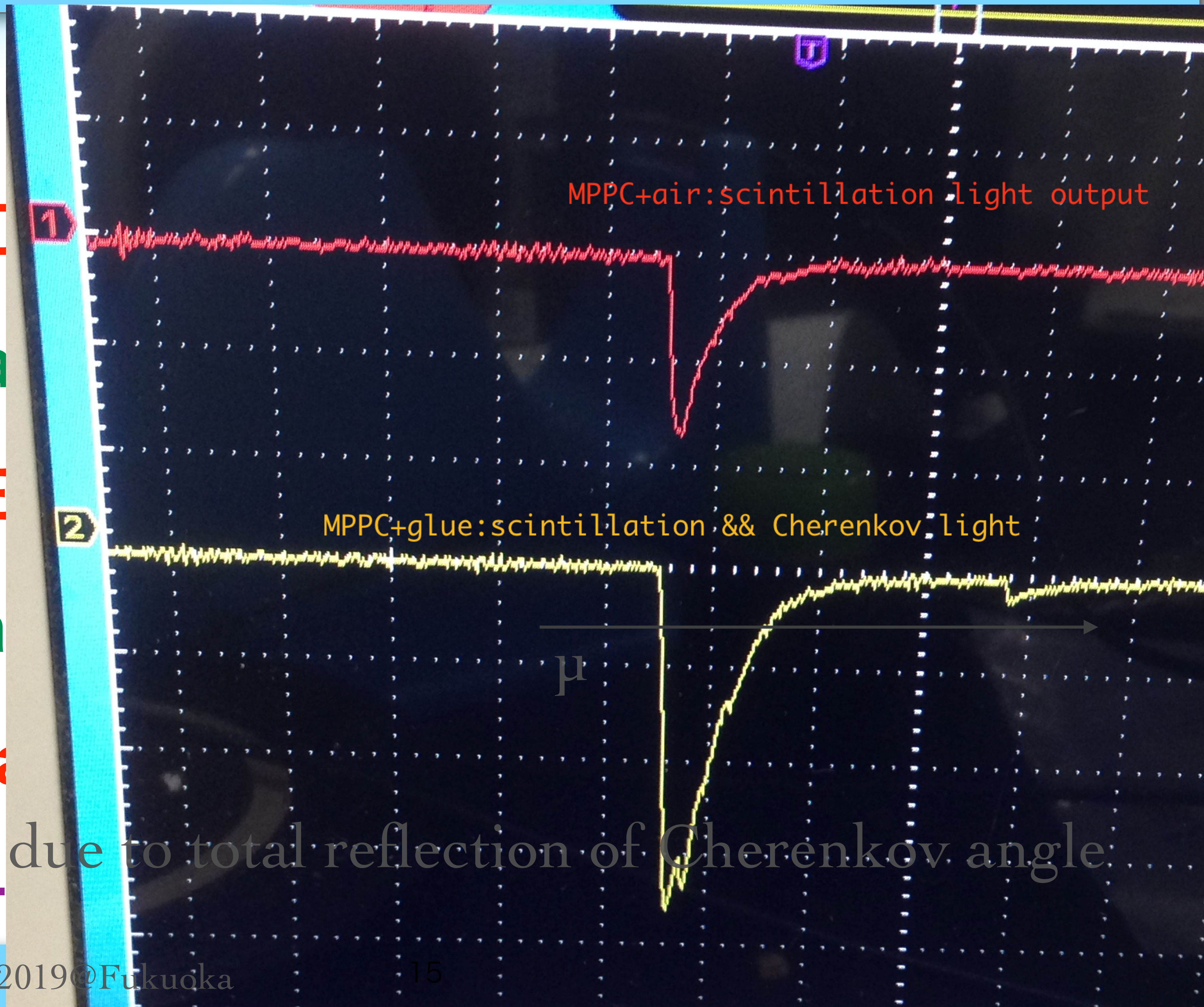
- MPPC+air coupling: scintillation

due to total reflection of Cherenkov angle

- MPPC+glue : Cherenkov + scintillation

how to measure

- energy
- from ED
- use hea
- ED ~ dE
- TL ~ Ch
- MPPC+a
- MPPC+



summary and outlook

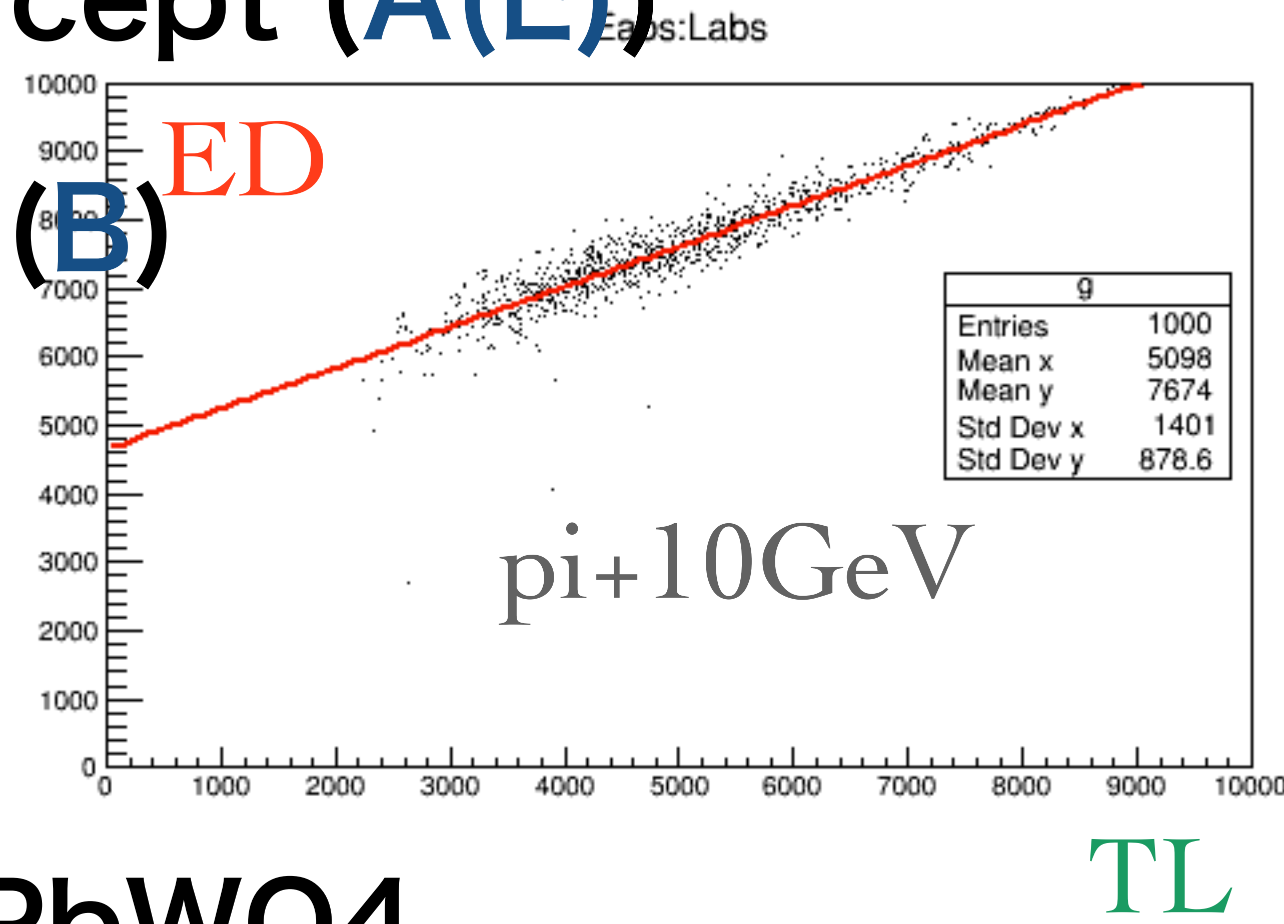
- homogeneous calorimeter is simulated
- found a linear relation between ED and TL

ED=A(E)+B*TL

- good linearity by intercept (A(E))
- fine energy resolution(B)

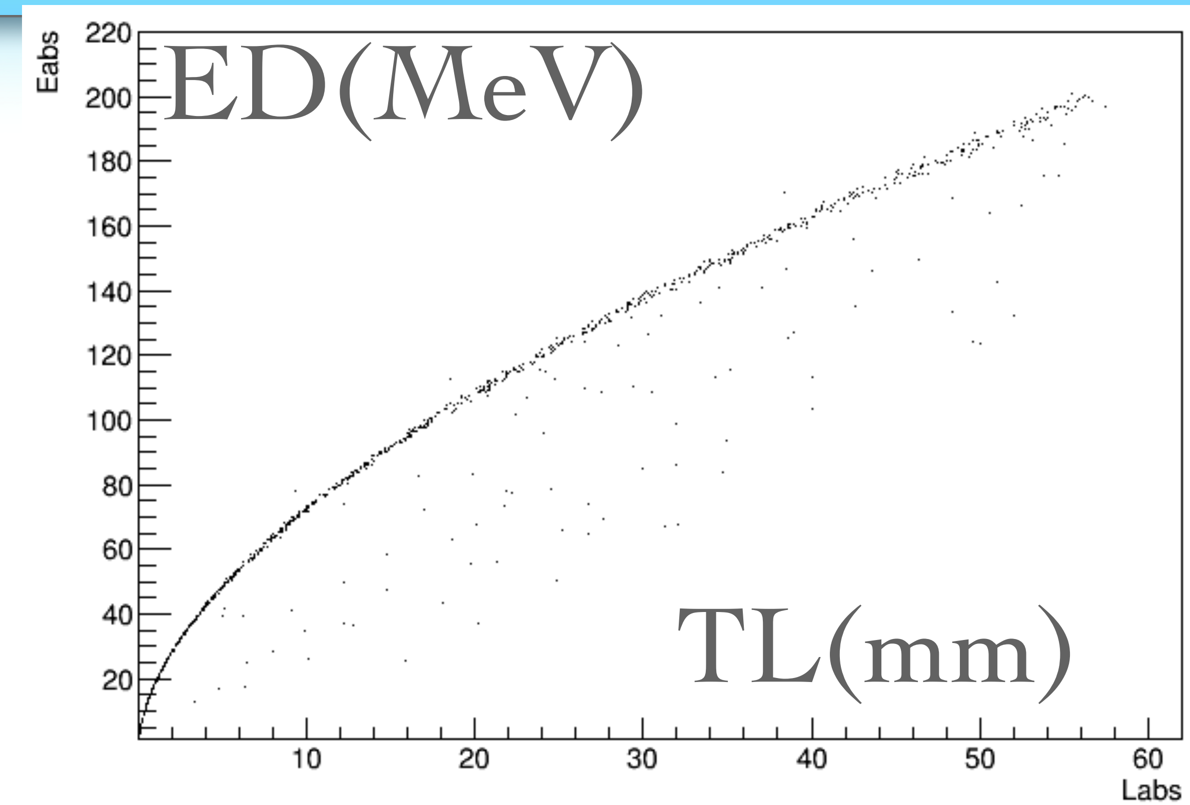
for pions no photon stat.

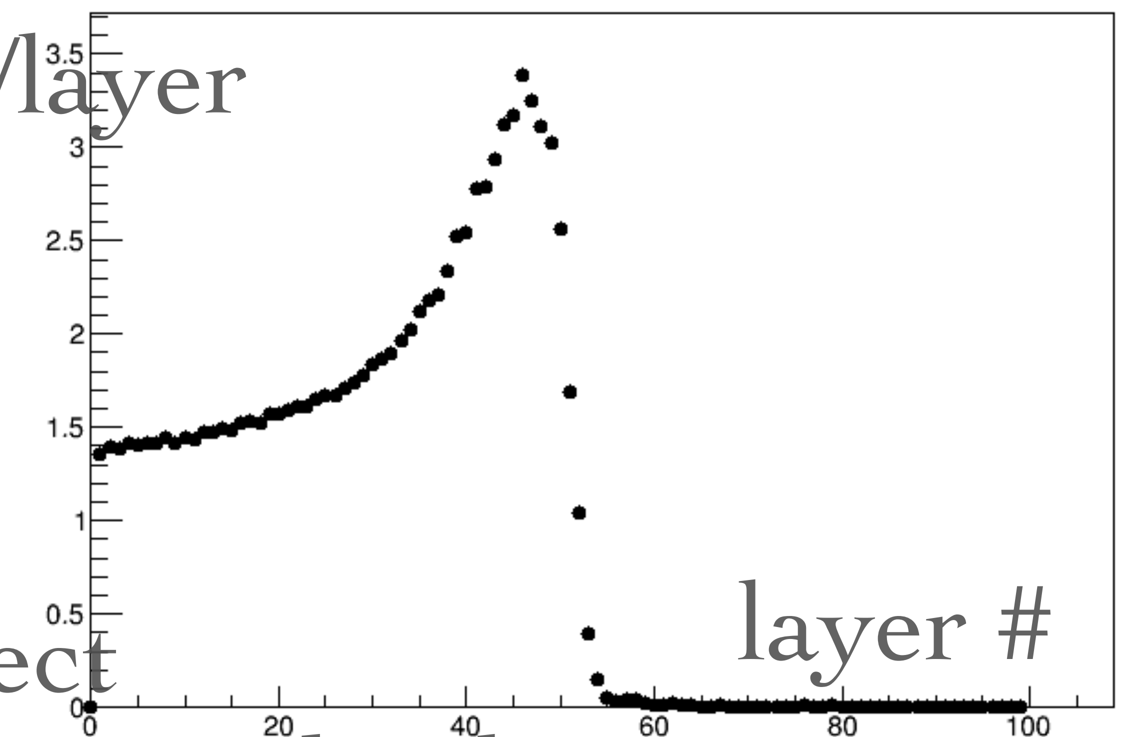
- ED ~ scintillation light
- TL ~ Cherenkov light
- test calorimeter with PbWO4



discussion

- reason of intercept
- muon+ : <200MeV
  uniform injection
- non-linear
  response close to
  0=ED
- due to Bragg curve

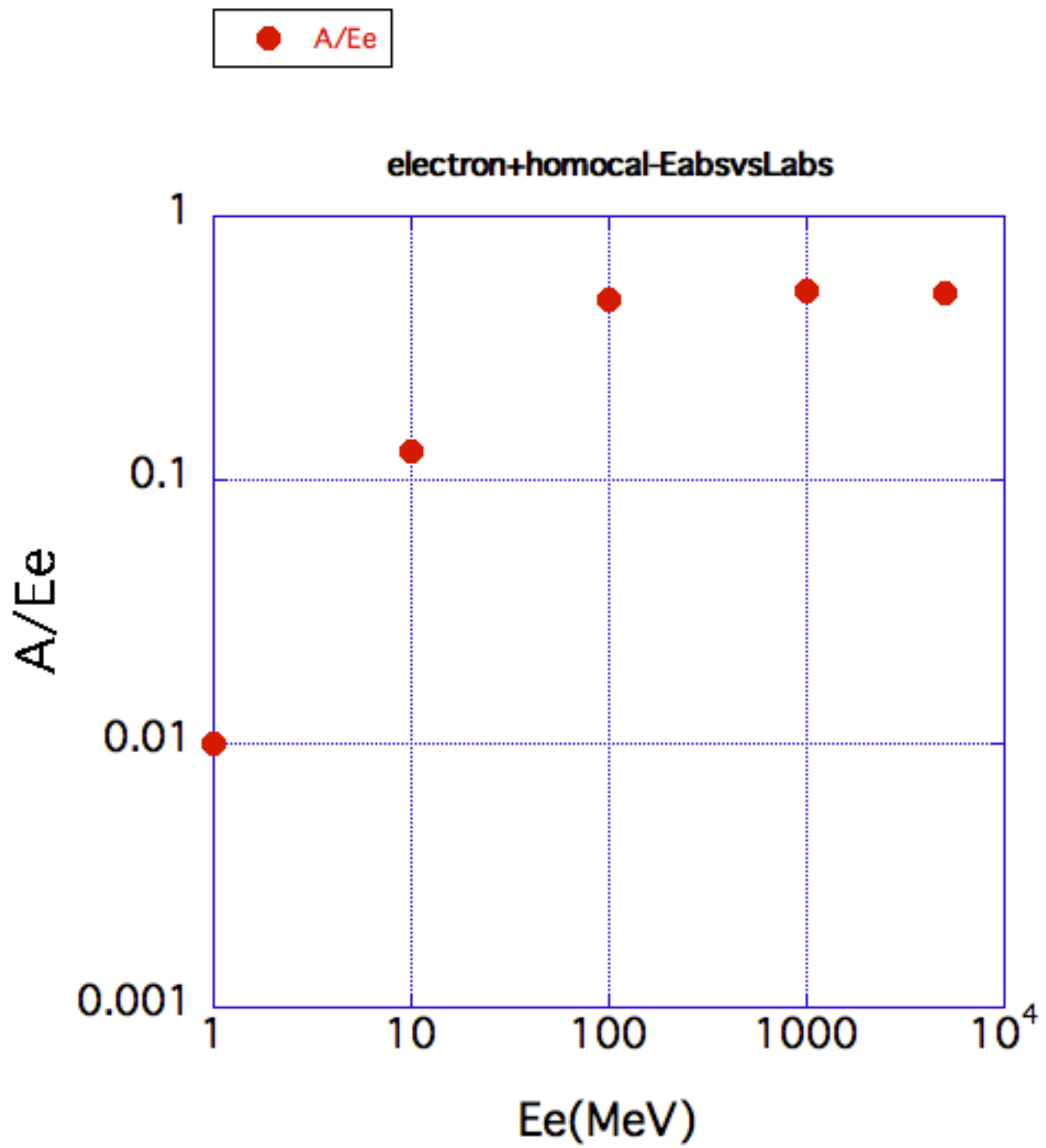




100MeV mu+ inject
1mmPb/layer

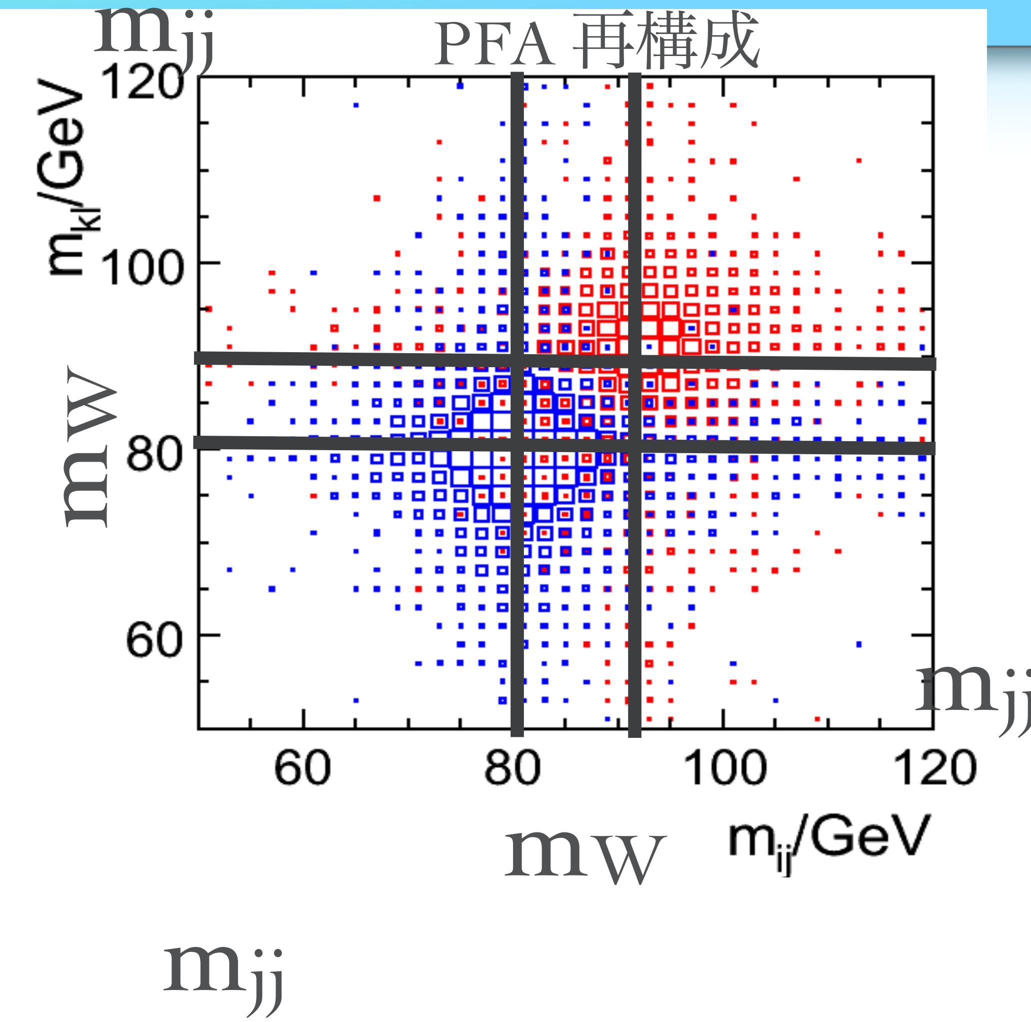
discussion

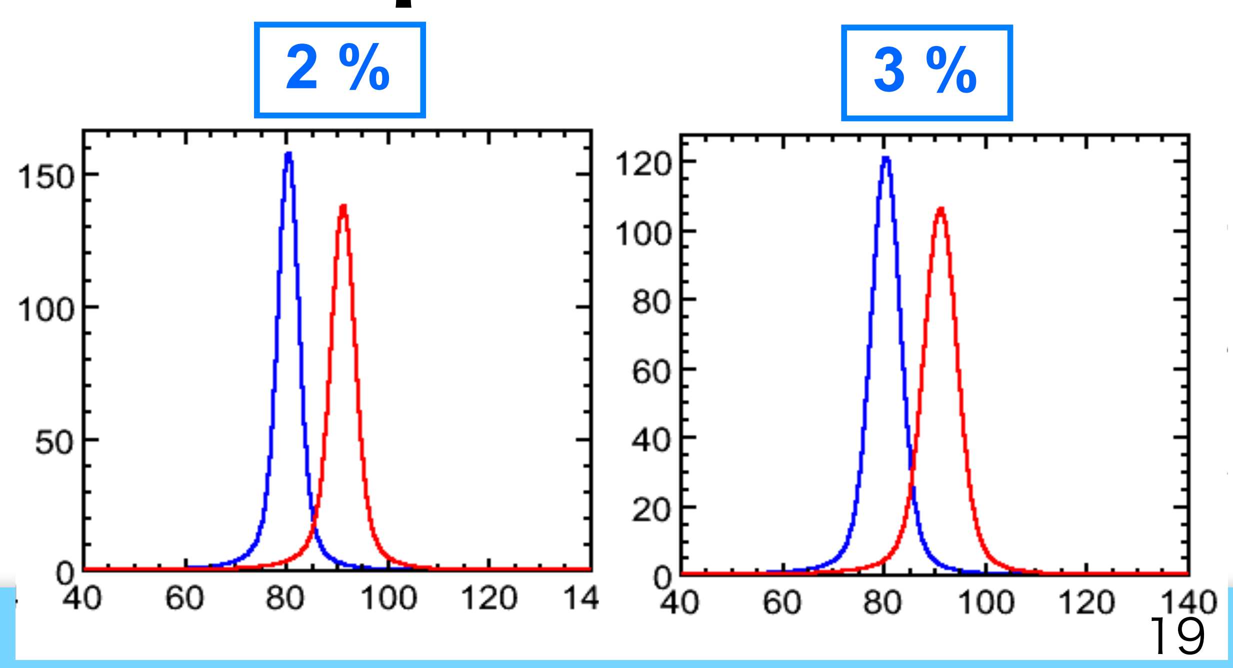
- electron cases are tested
- A/Ee ~ const. at Ee>100MeV where EM shower dominates
- at lower Ee, close to zero



PFA performance

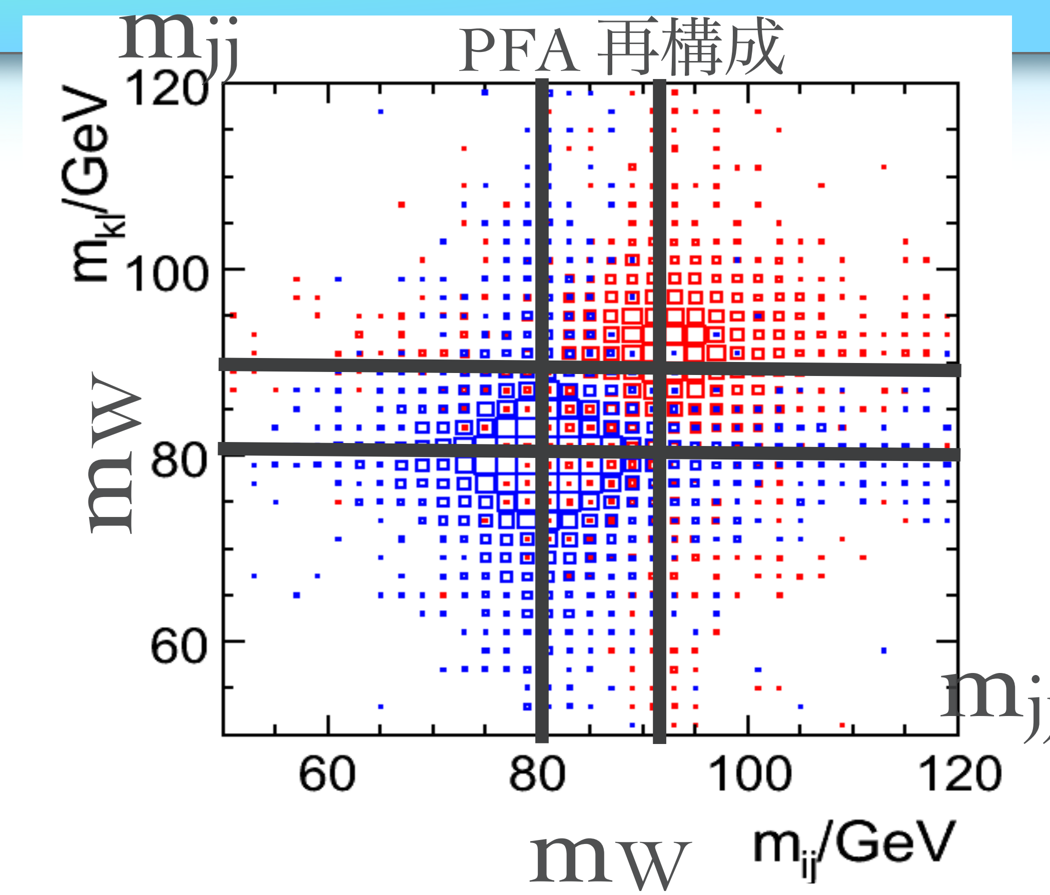
- PFA utilises
- tracker for charged
- ECAL for photons
- HCAL for KoL
- can separate W and Z

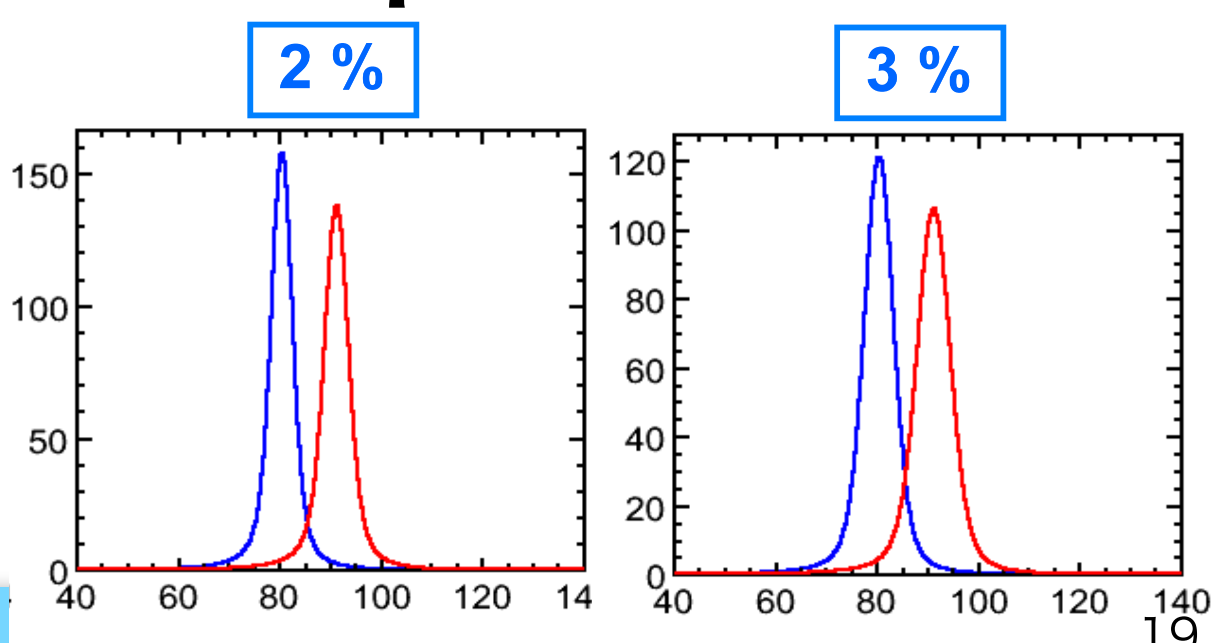


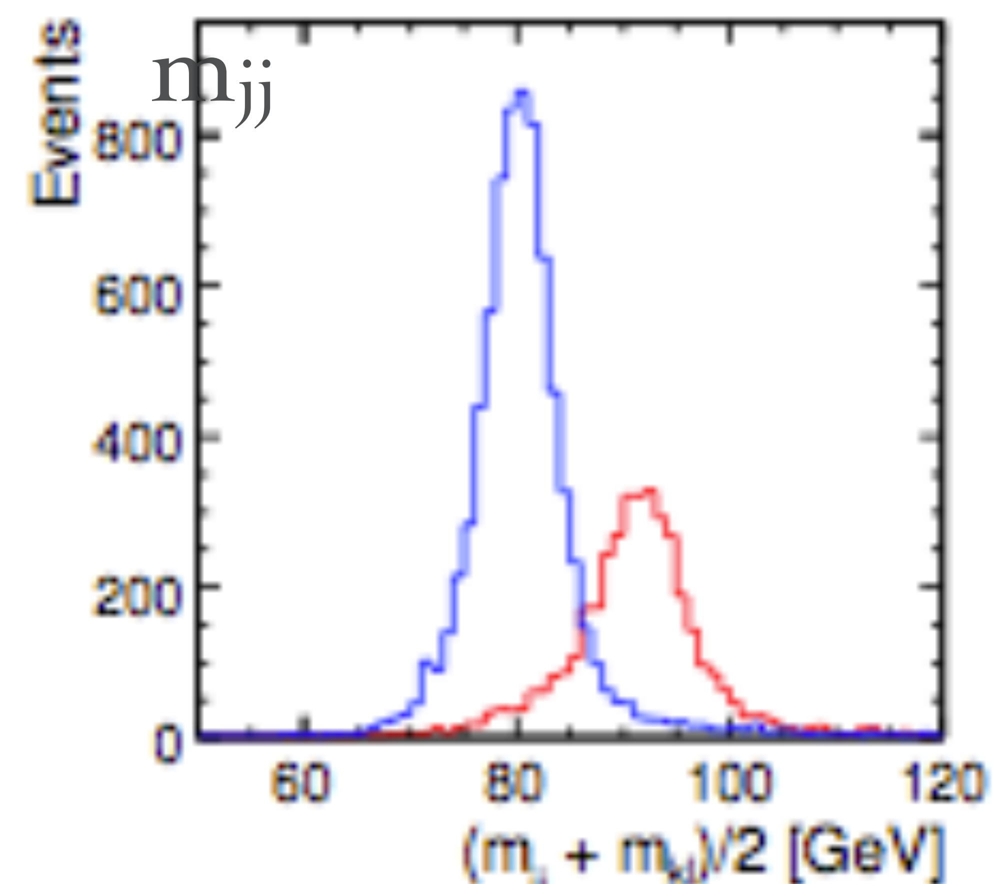


PFA performance

- PFA utilises
- tracker for charged
- ECAL for photons
- HCAL for KoL
- can separate W and Z



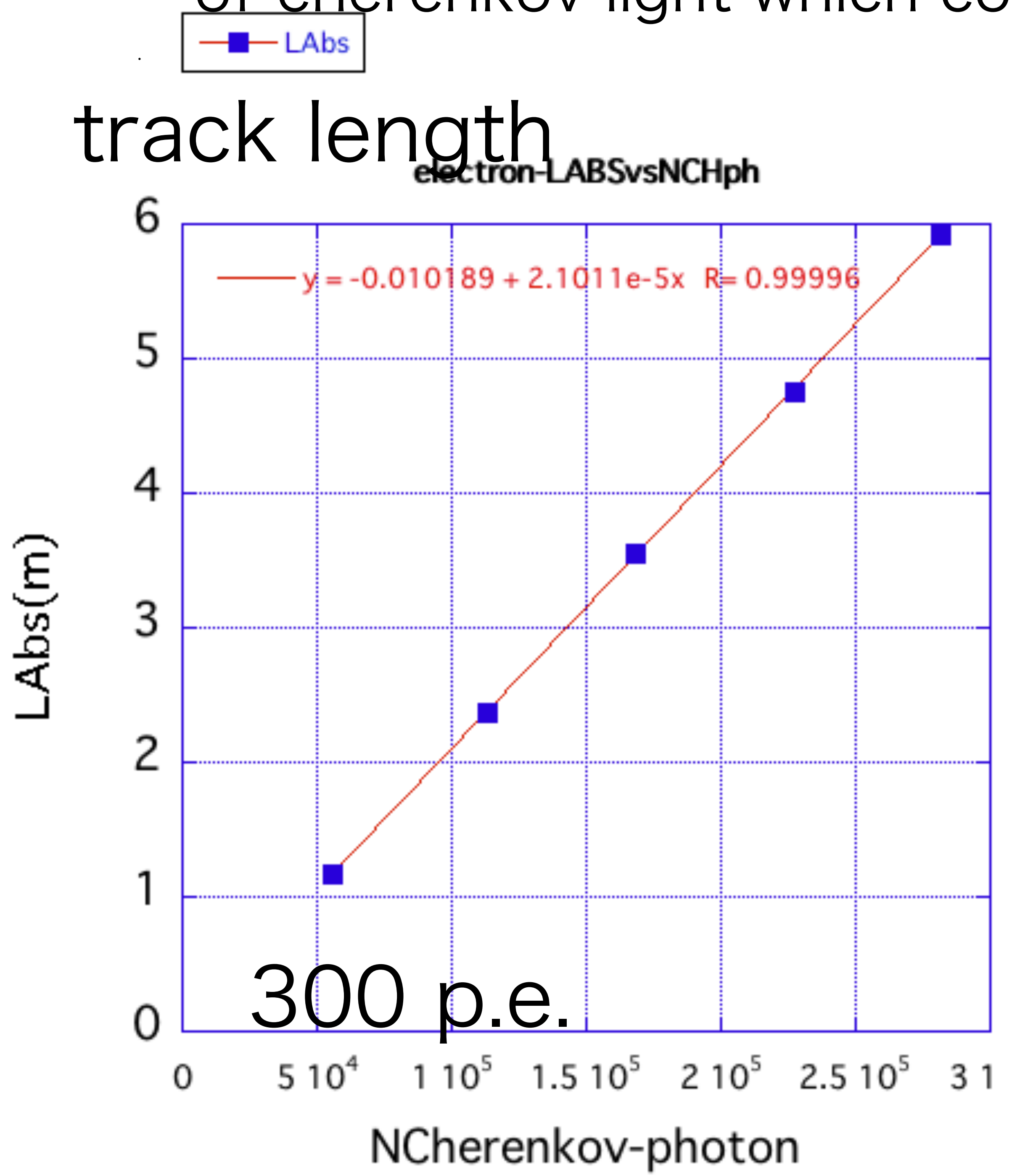


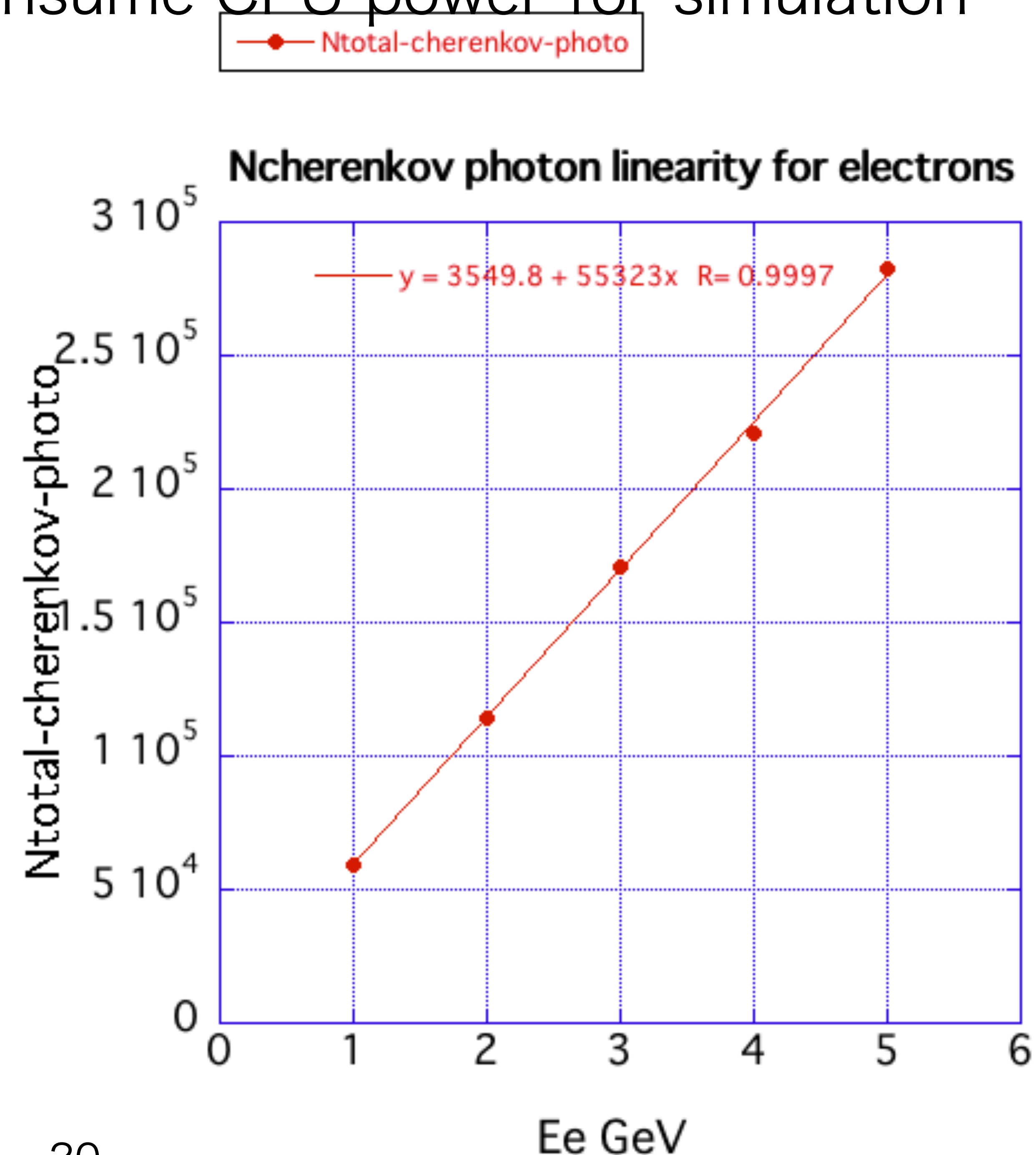


track length vs Ncherenkov light for electrons

- nice correlation : we can use track length instead of number of cherenkov light which consume CPU power for simulation

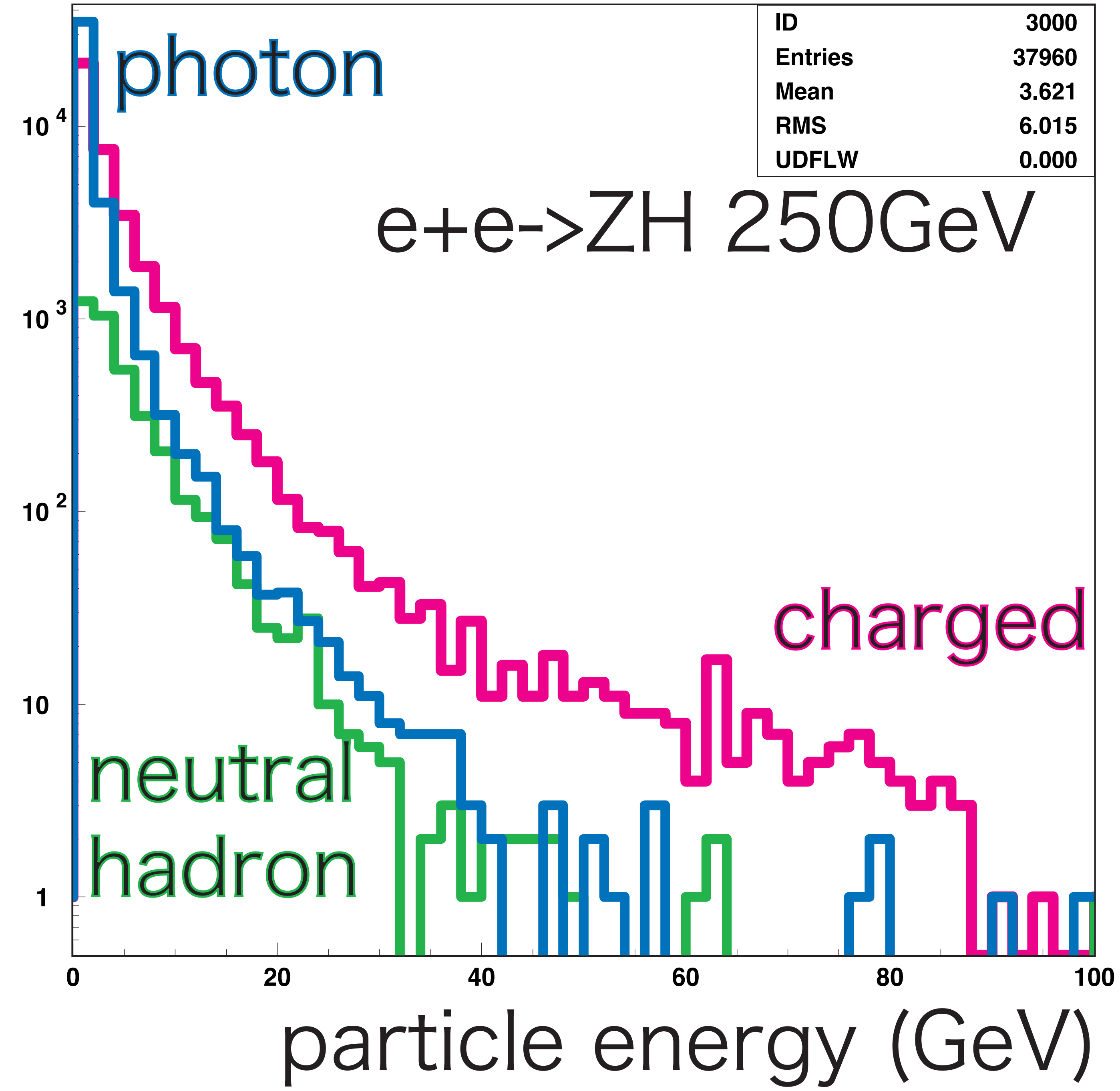
track length





particle energy in jet

- particle energy distribution
- E<10 GeV dominating



PbWO4

Scintillation properties of lead tungstate (PbWO4) crystals:

Density (g.cm^{-3})	8.28
Radiation length (cm)	0.92
Decay constant (ns)	6/30
Emission peak (nm)	440/530
Light yield (% that of NaI:Tl)	0.5
Melting point (°C)	1123
Hardness (Mho)	/
refractive Index	2.16
Hygroscopicity	none
Cleavage	101