Development of a New type of Sandwich calorimeter with lead-glass and glass-scintillator

Shinsu U

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@CALOR2024 (Tsukuba)

- Homogeneous calorimeter simulation

application ↓

- Double Readout GLASS Sandwich Cal.

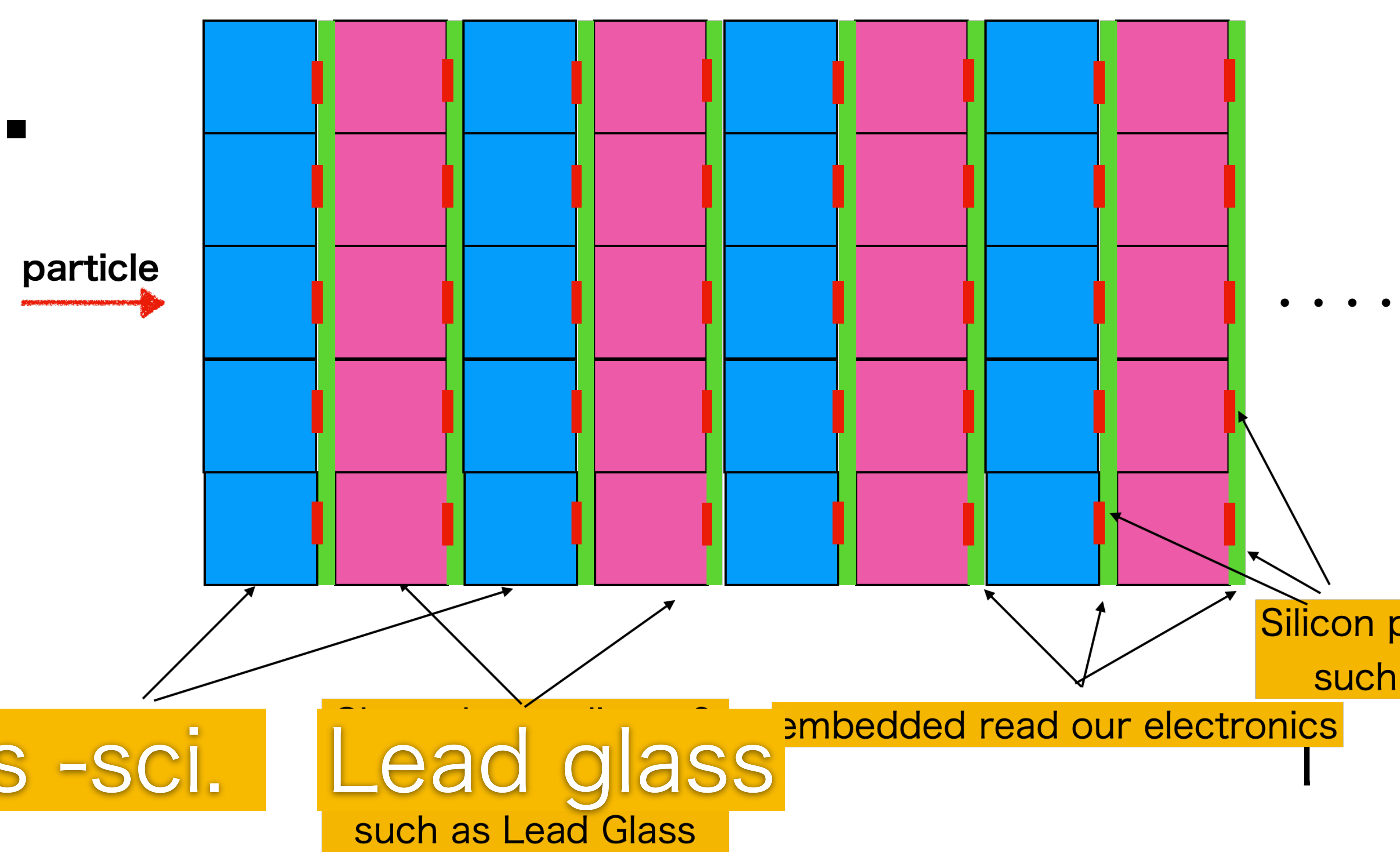
radiation tolerance and cost effective

T.Takeshita & R. Terada, arXiv 2306.16325

T. Takeshita *et al* 2020 *JINST* **15** C05015

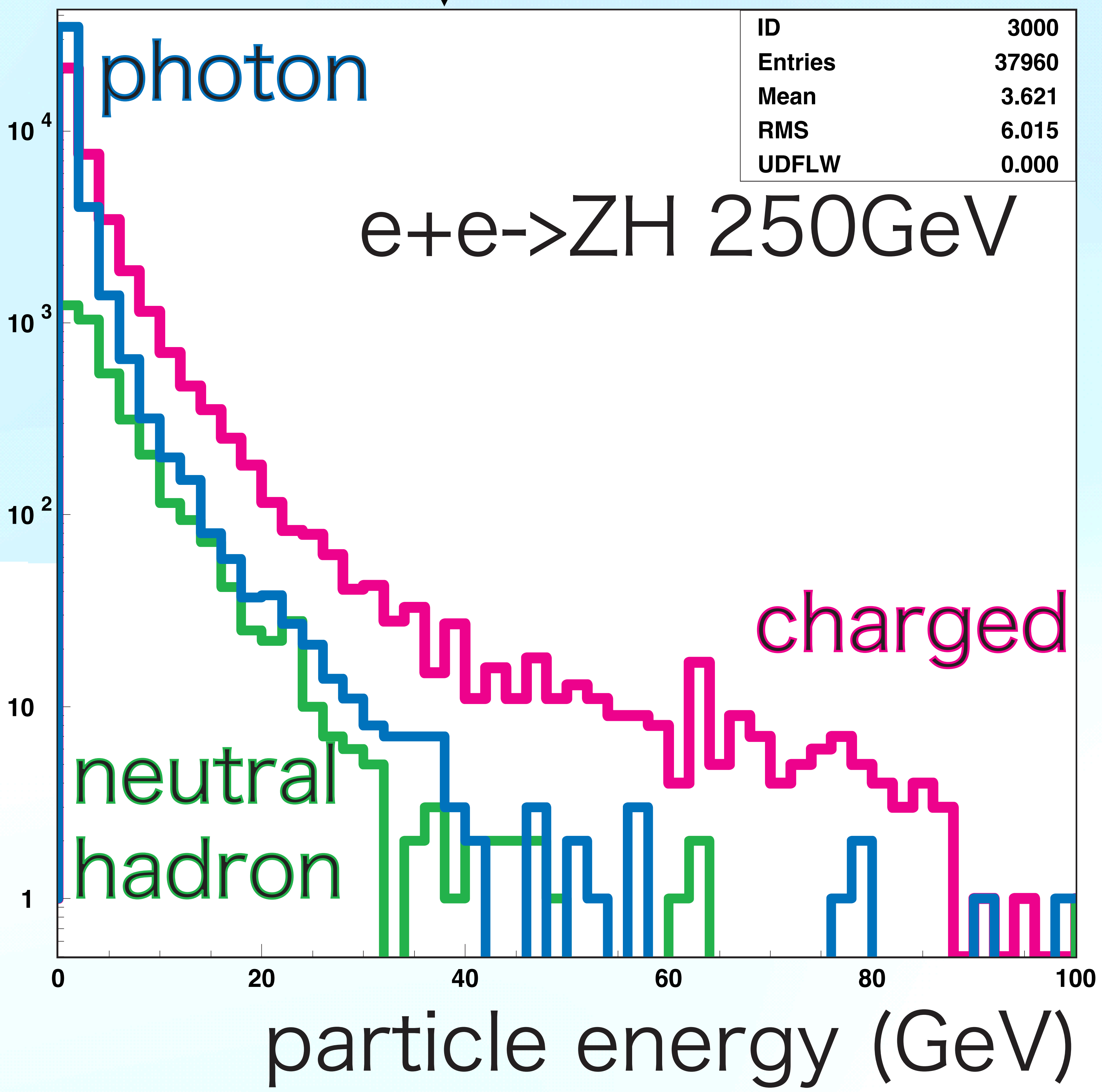
DSC

Segmented in three dimensions according to the physics requirements

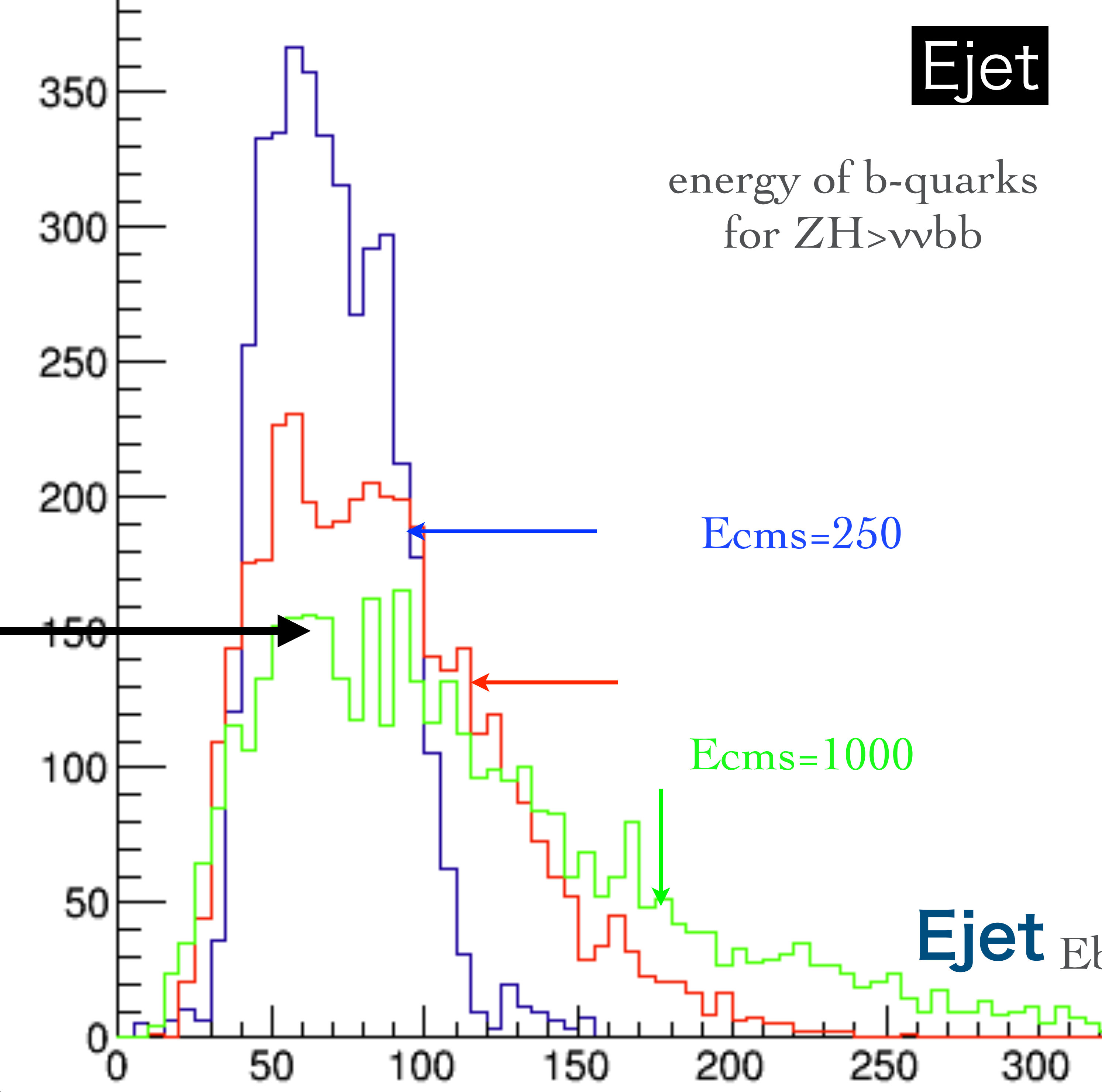


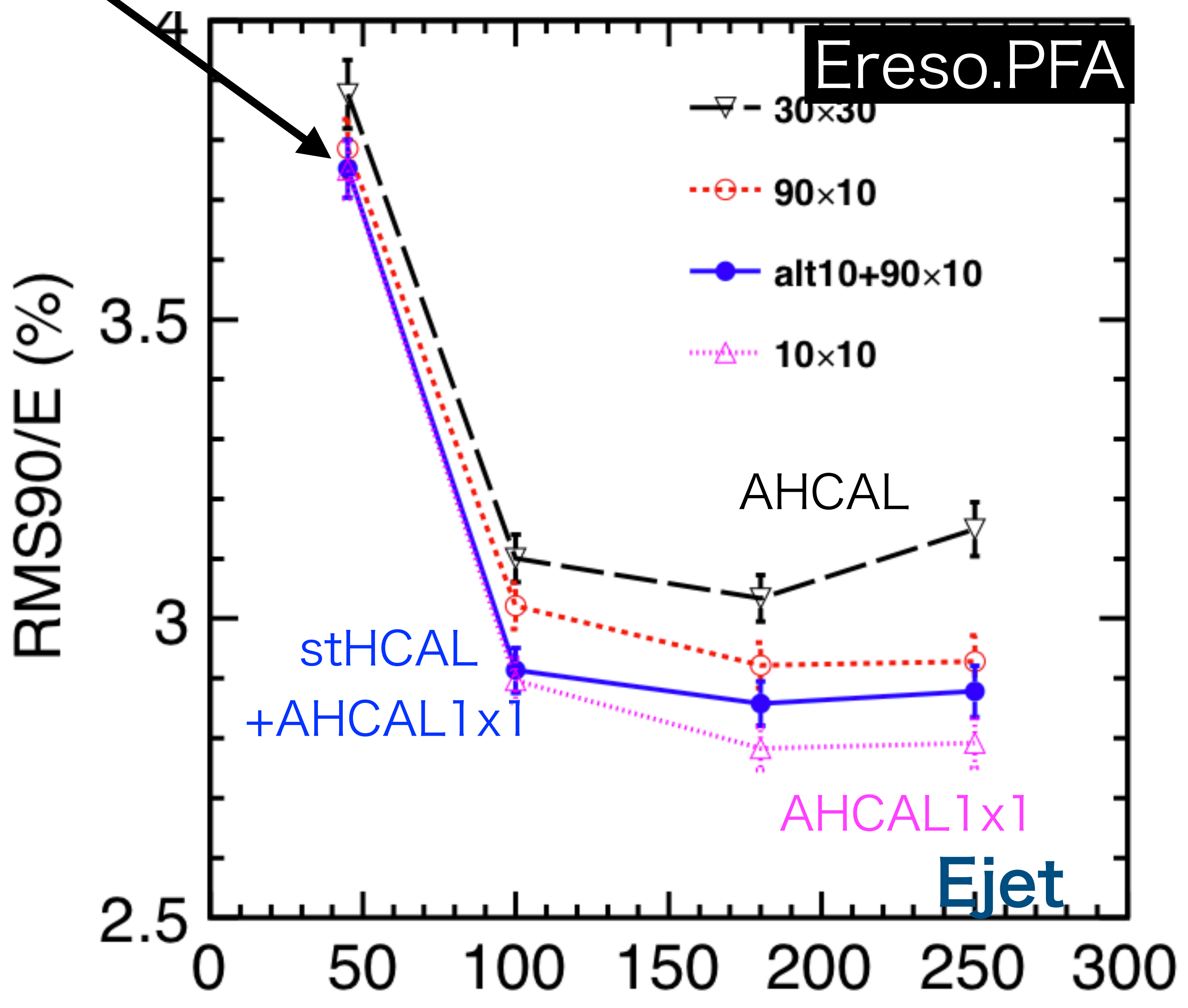
Particles in the Higgs Factory

calorimeter
particles (e/γ, π/K), mostly E<20GeV



- Ejet ~5-100 GeV
- PFA Jet Energy resolution is worse
- due to intrinsic Energy resolution of the calorimeter
- How to solve the problem >>>





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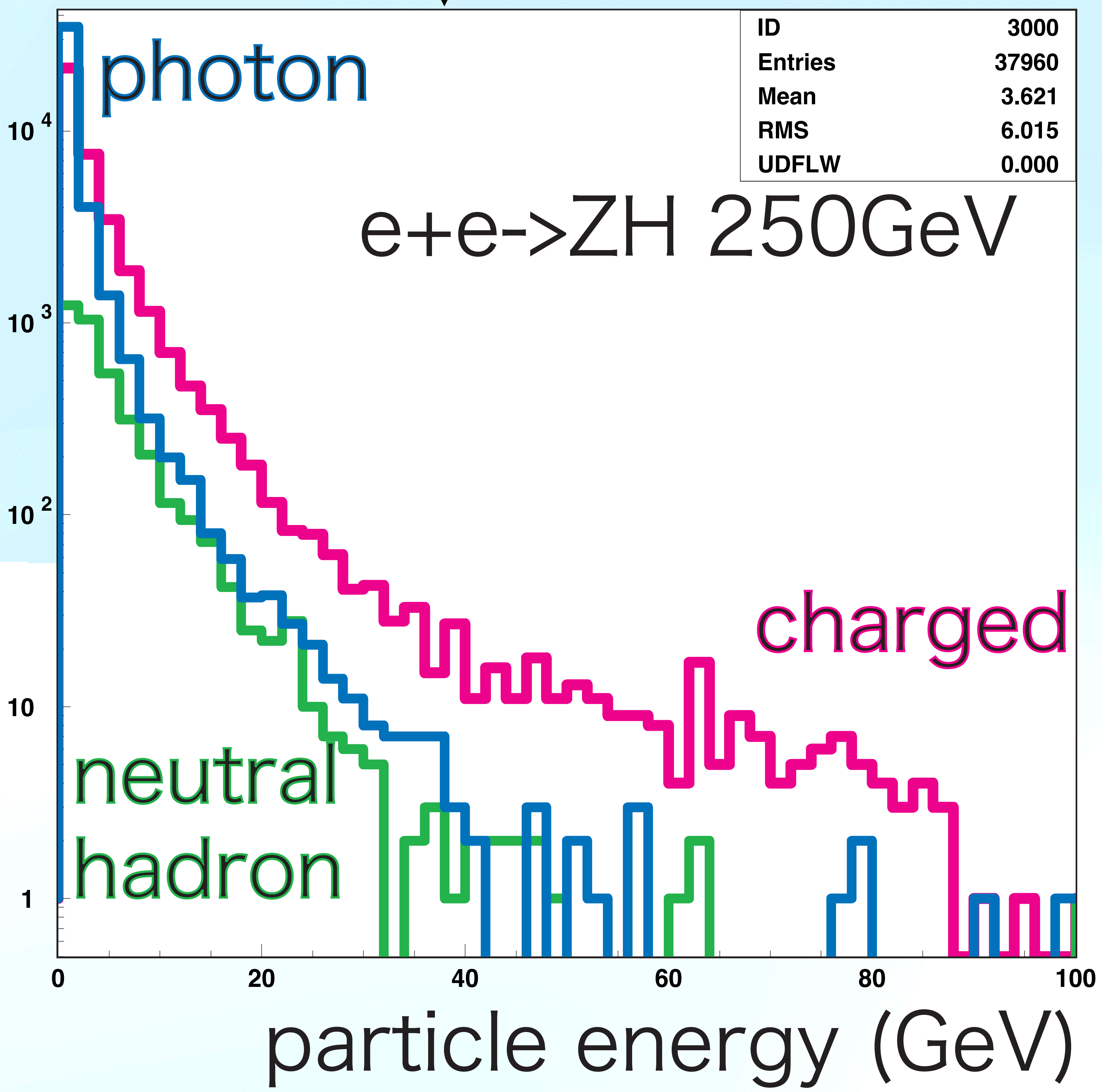

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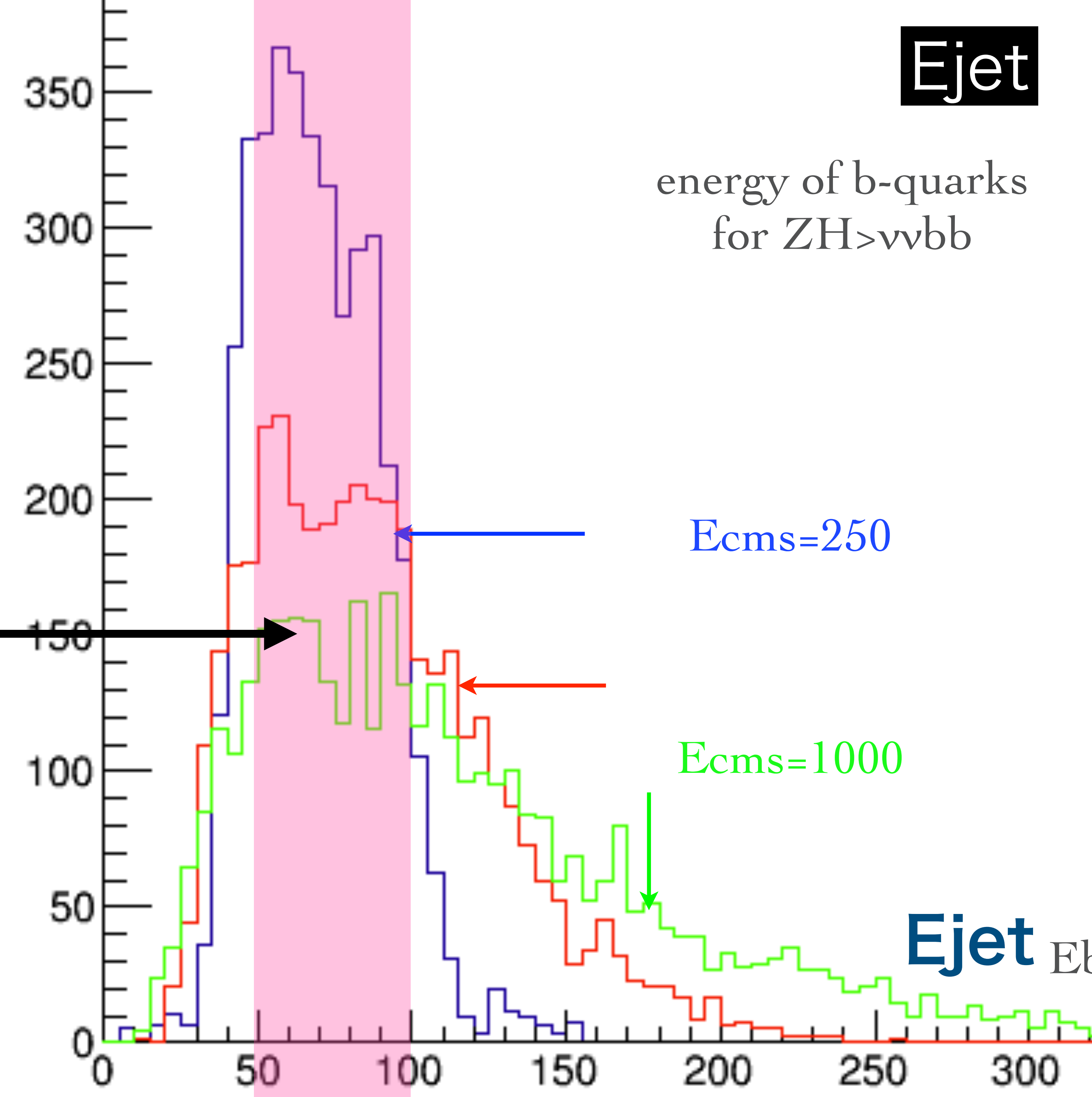
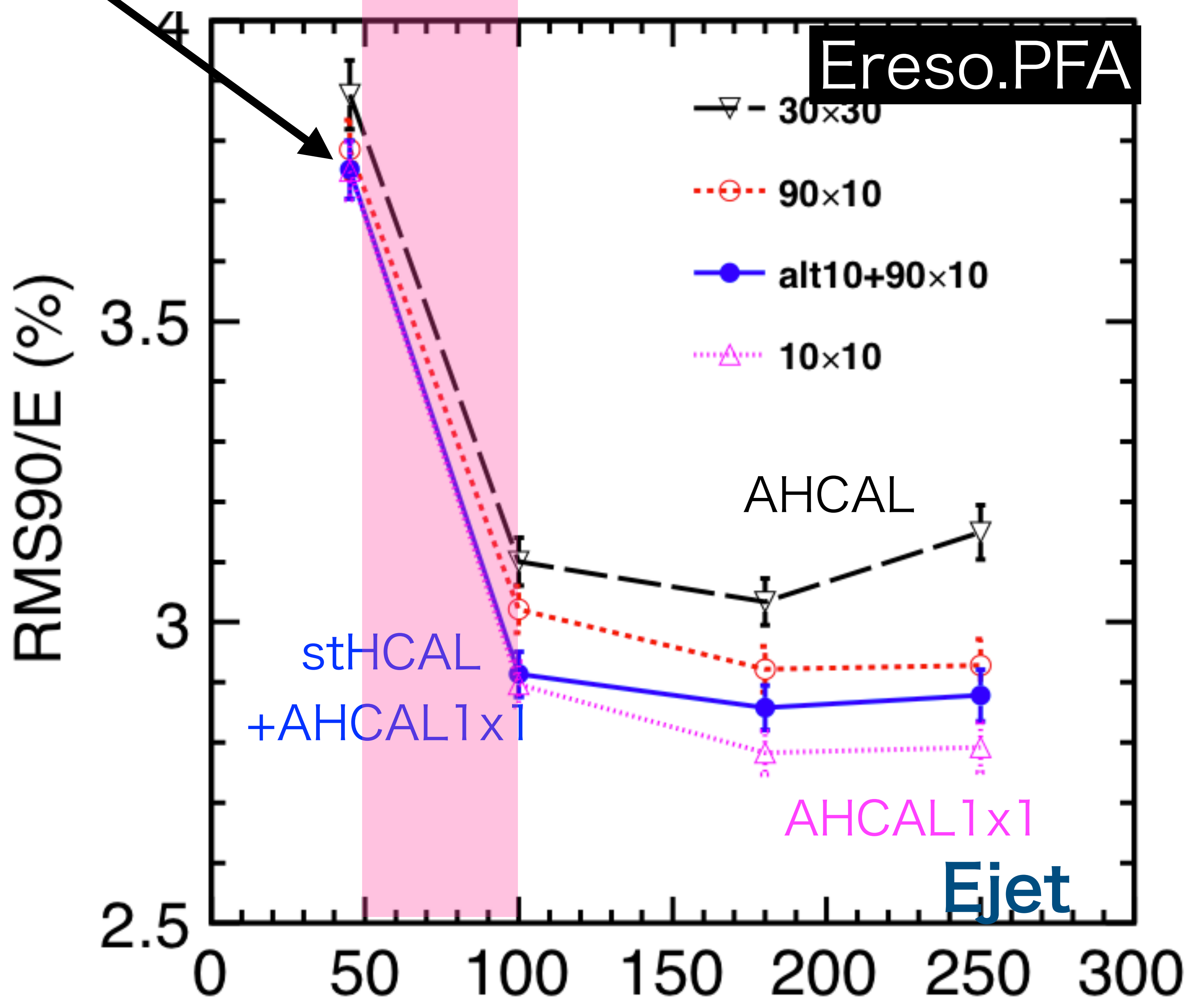




start from

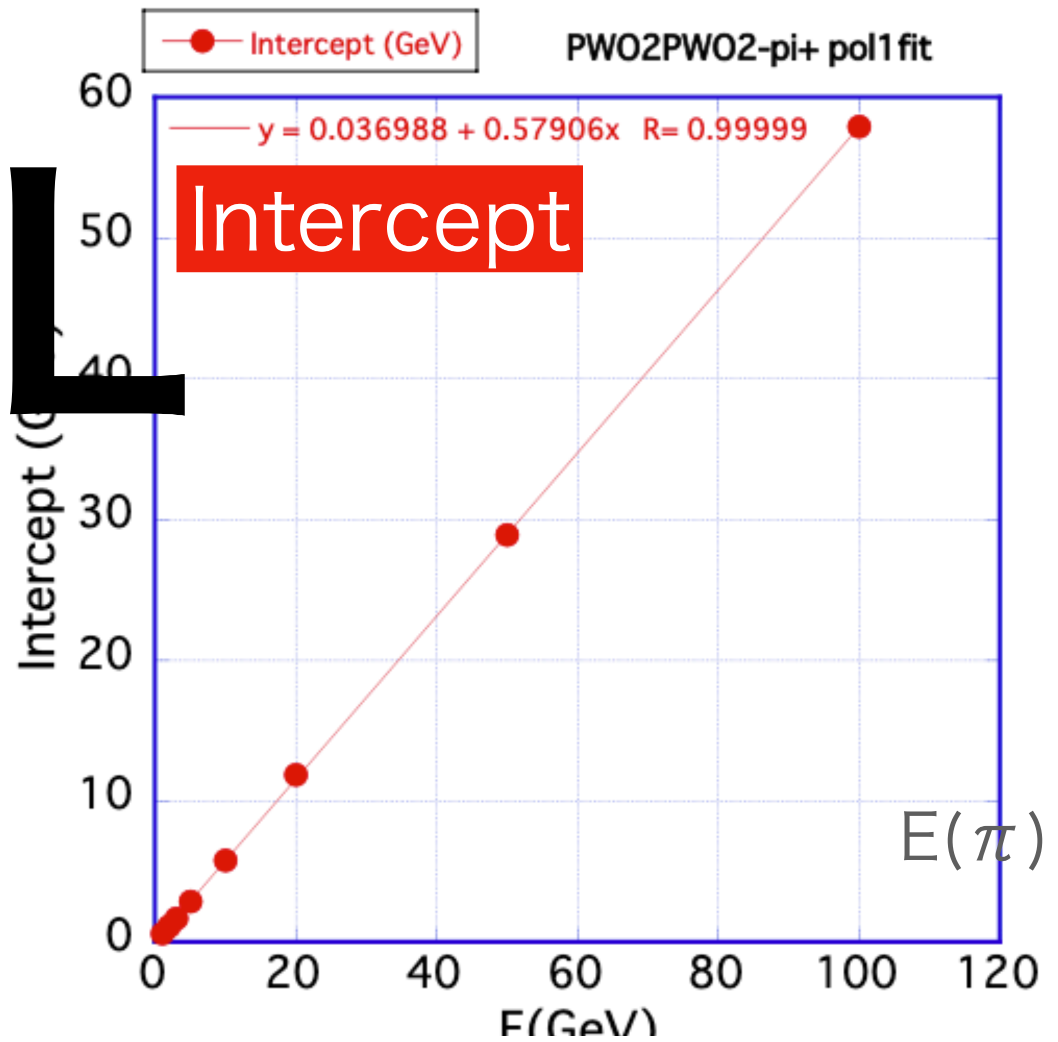
Homogeneous CAL

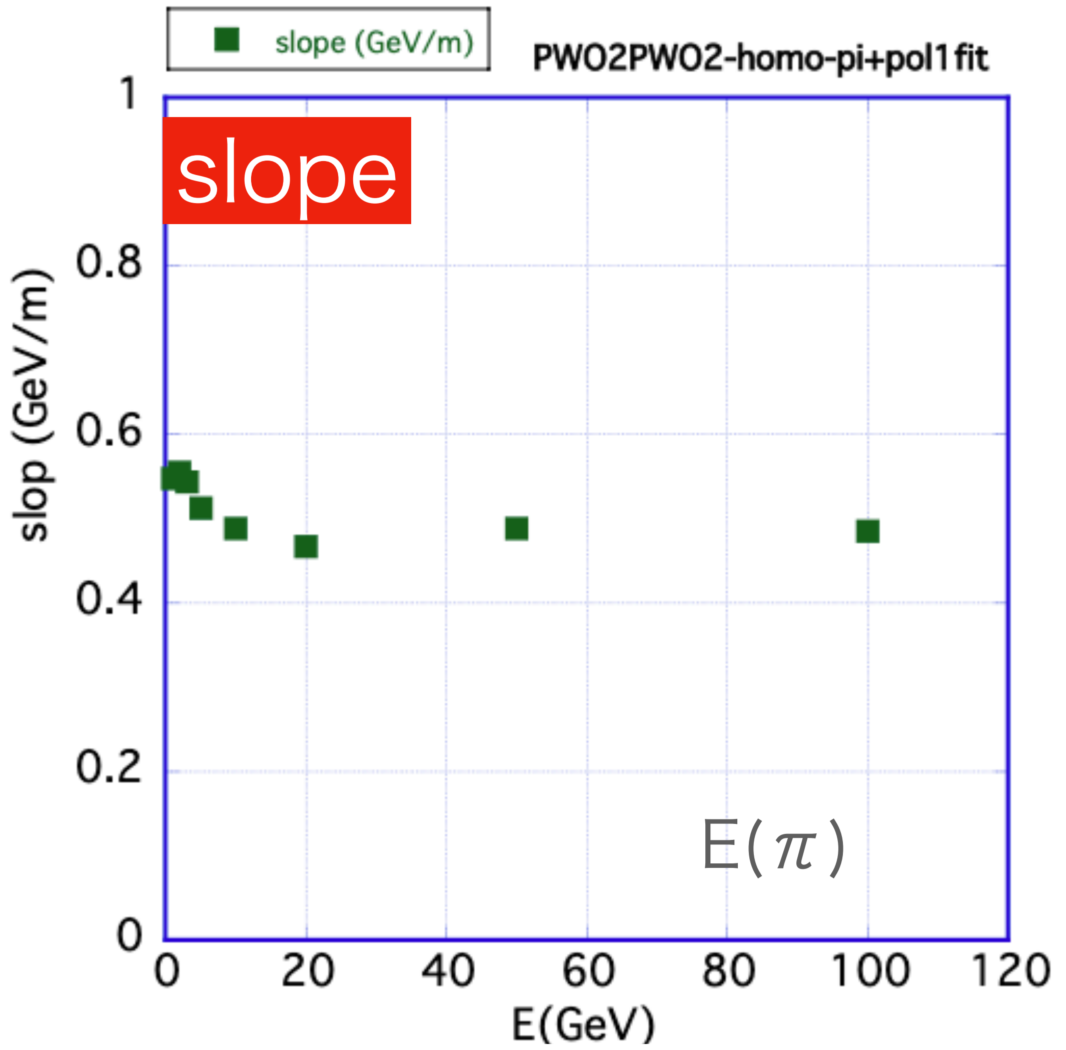
Energy measurement

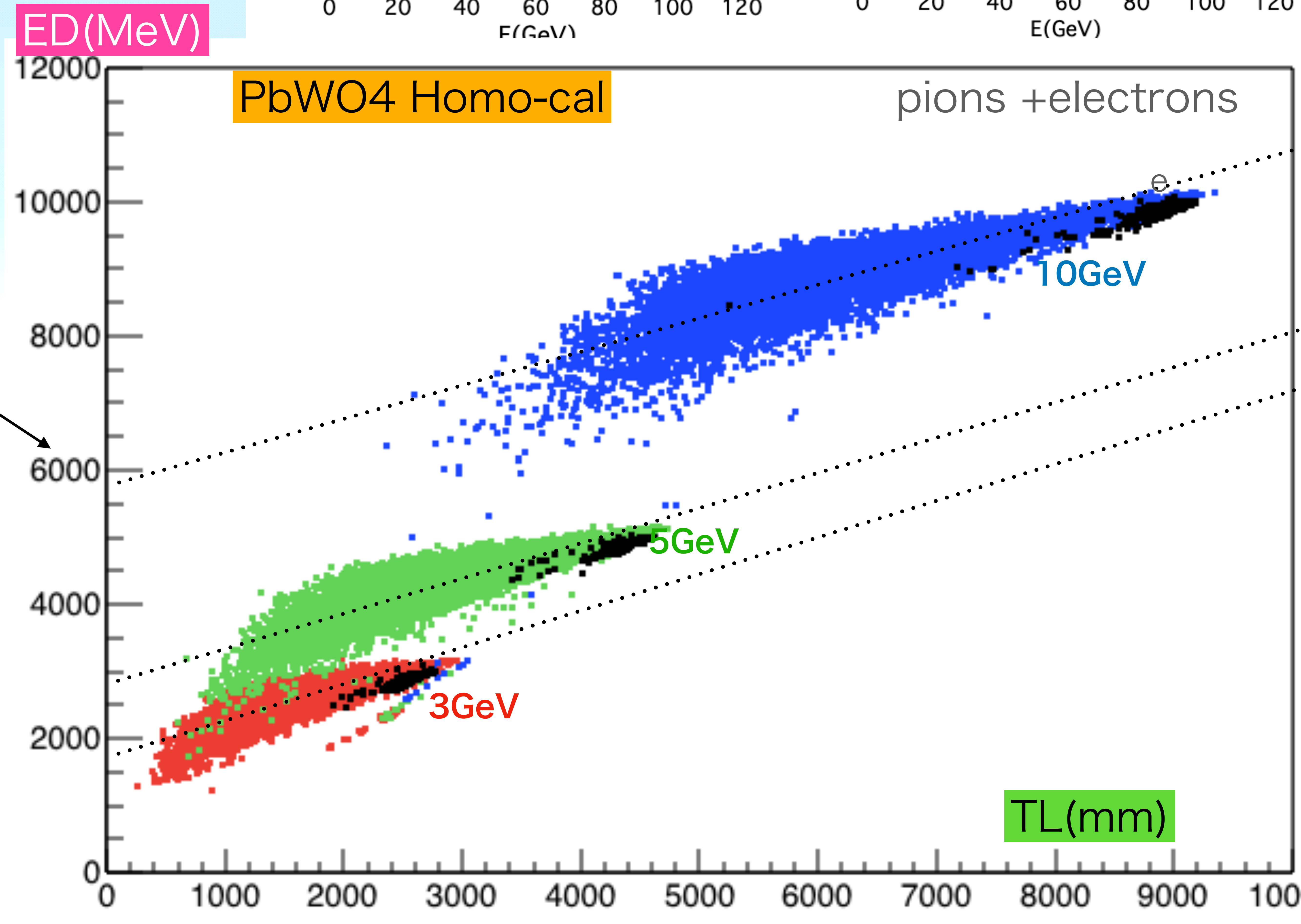
simulation

two parameters are suitable

- sum of Track Length (TL) ~ Cherenkov lights
- sum of Energy Deposit (ED) ~ Scintillation lights
- strong correlation between ED and TL







Relations

without passing the origin

- strong correlation : simple linear behavior
- intercept → linearity
- slope → constant

independent of energy

common for e/π/K/p/n

photon statistics is not taken into account

simulation with GEANT4.10.07with FTFP_BERT

(2mx2mx2m)

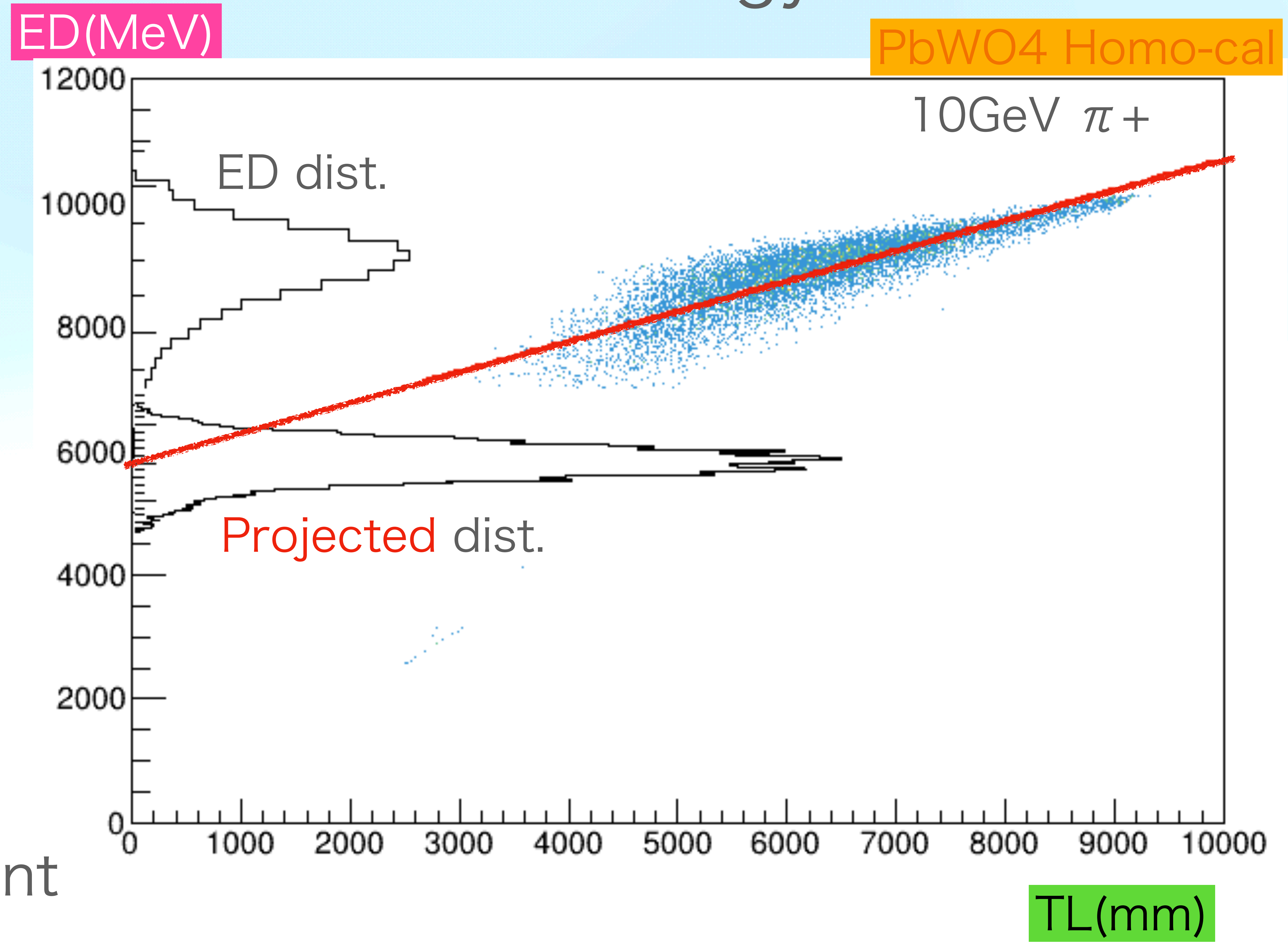
CALOR2024 : T.Takeshita

energy resolution

From the correlation plot to the energy resolution

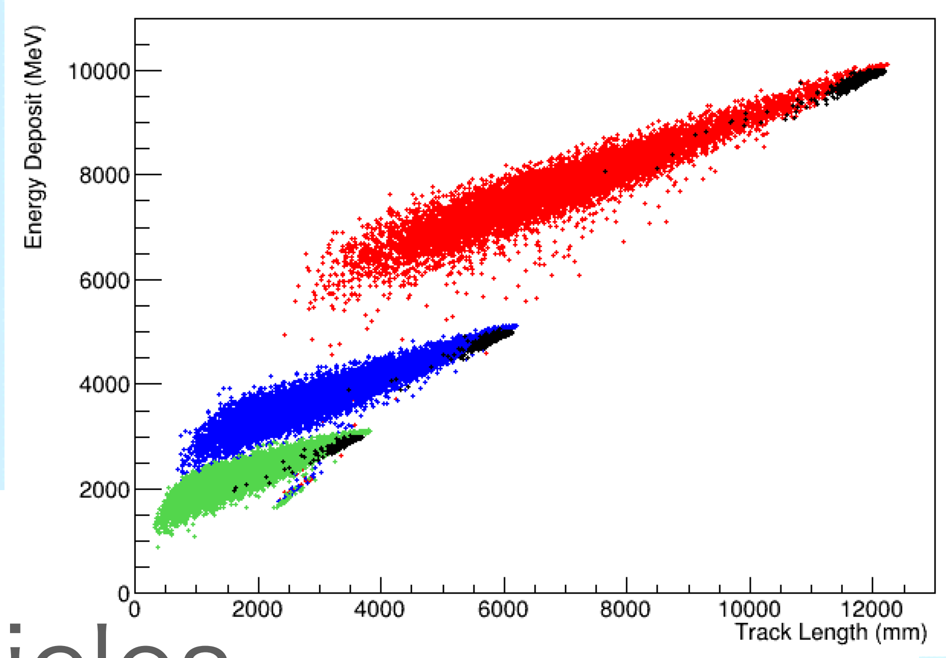
- good correlation between ED and TL
- Energy measured by the intercept
- energy resolution is expressed by width projected to fitted line
- fine energy resolution is achieved than ED distribution

traditional E measurement



particle response

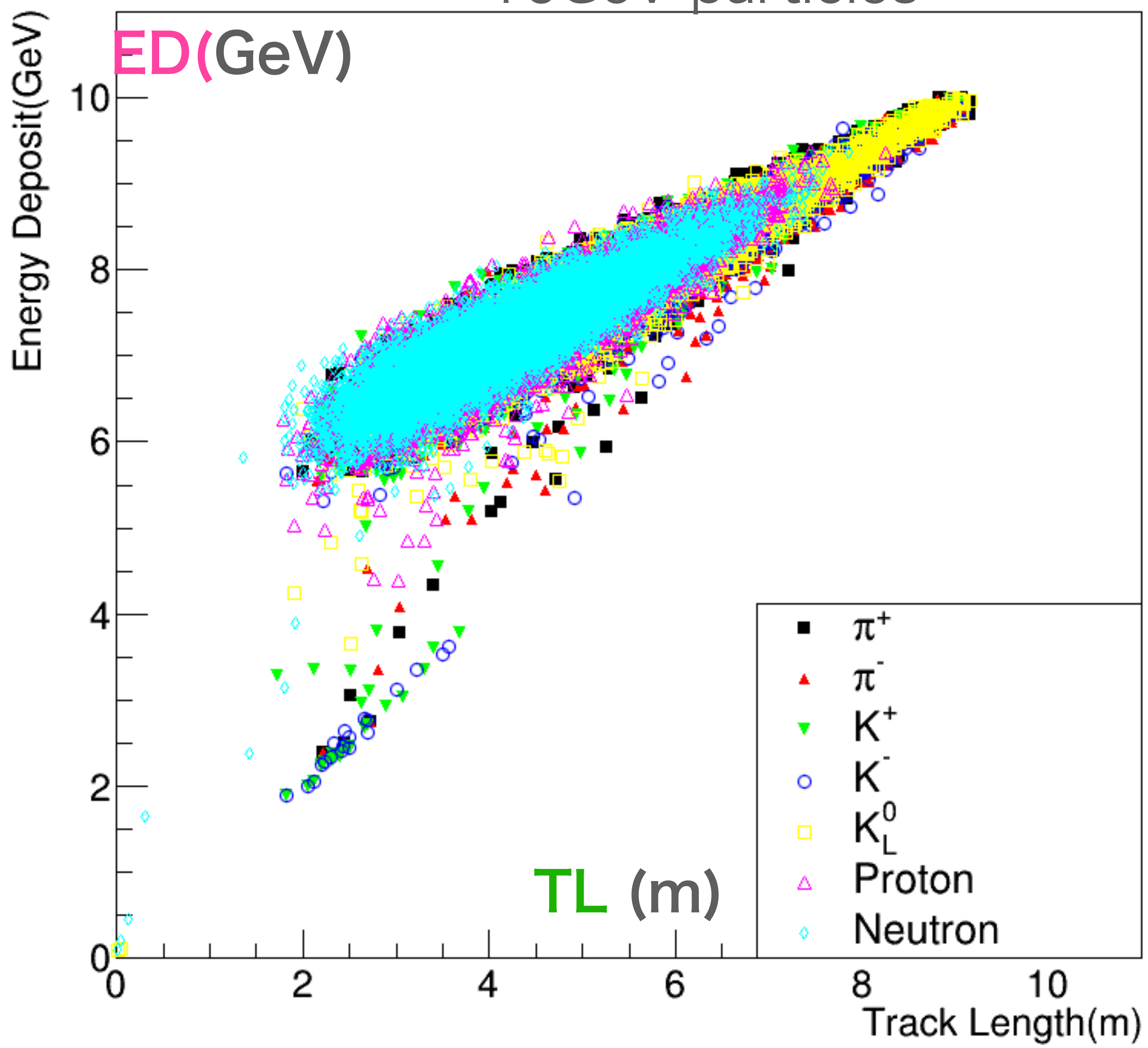
λ_I=8



- good linearity with intercept
- slopes are fairly constant
- intercept and slope are

common for particles (π,K,p,n)

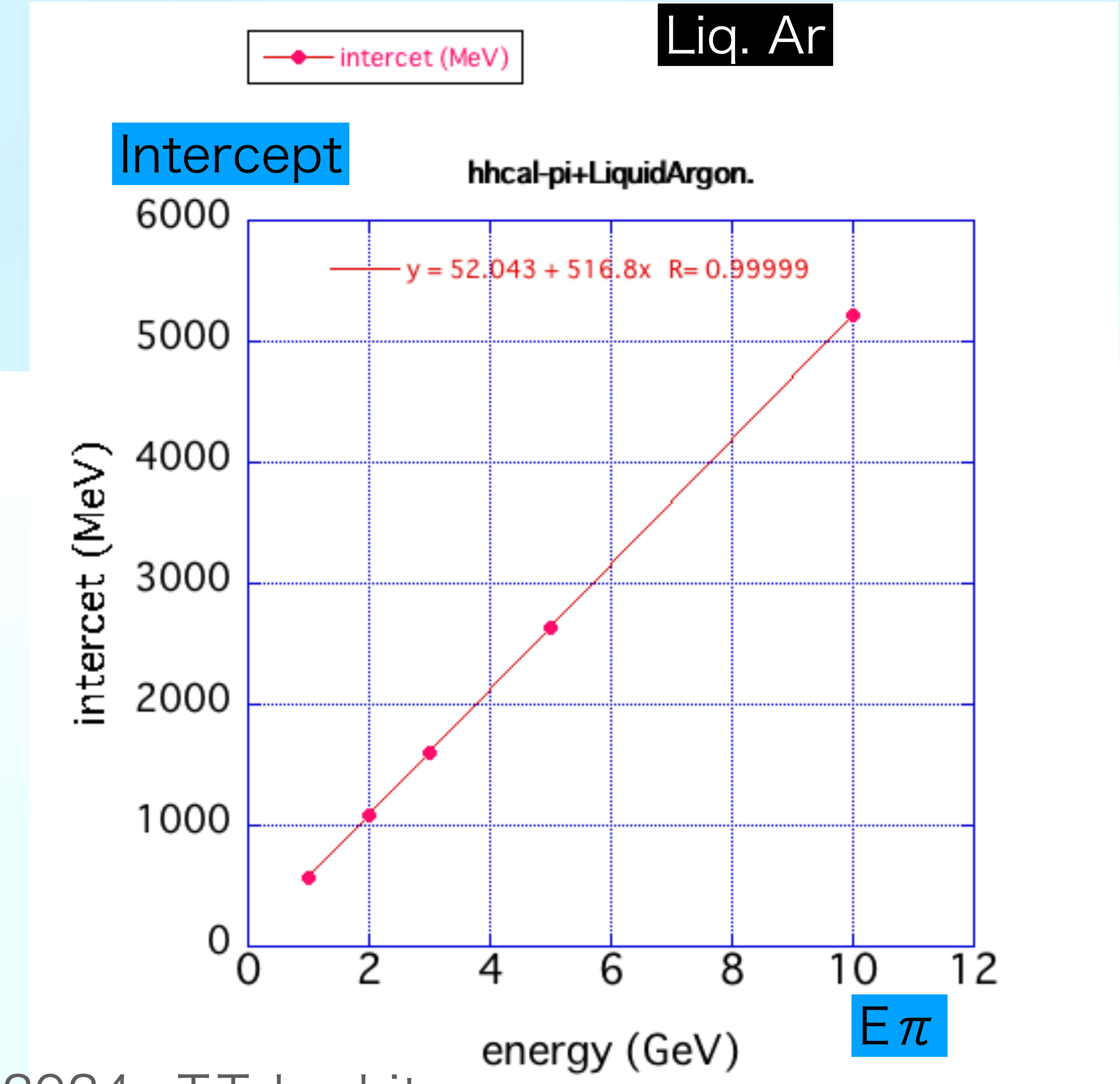
10GeV particles

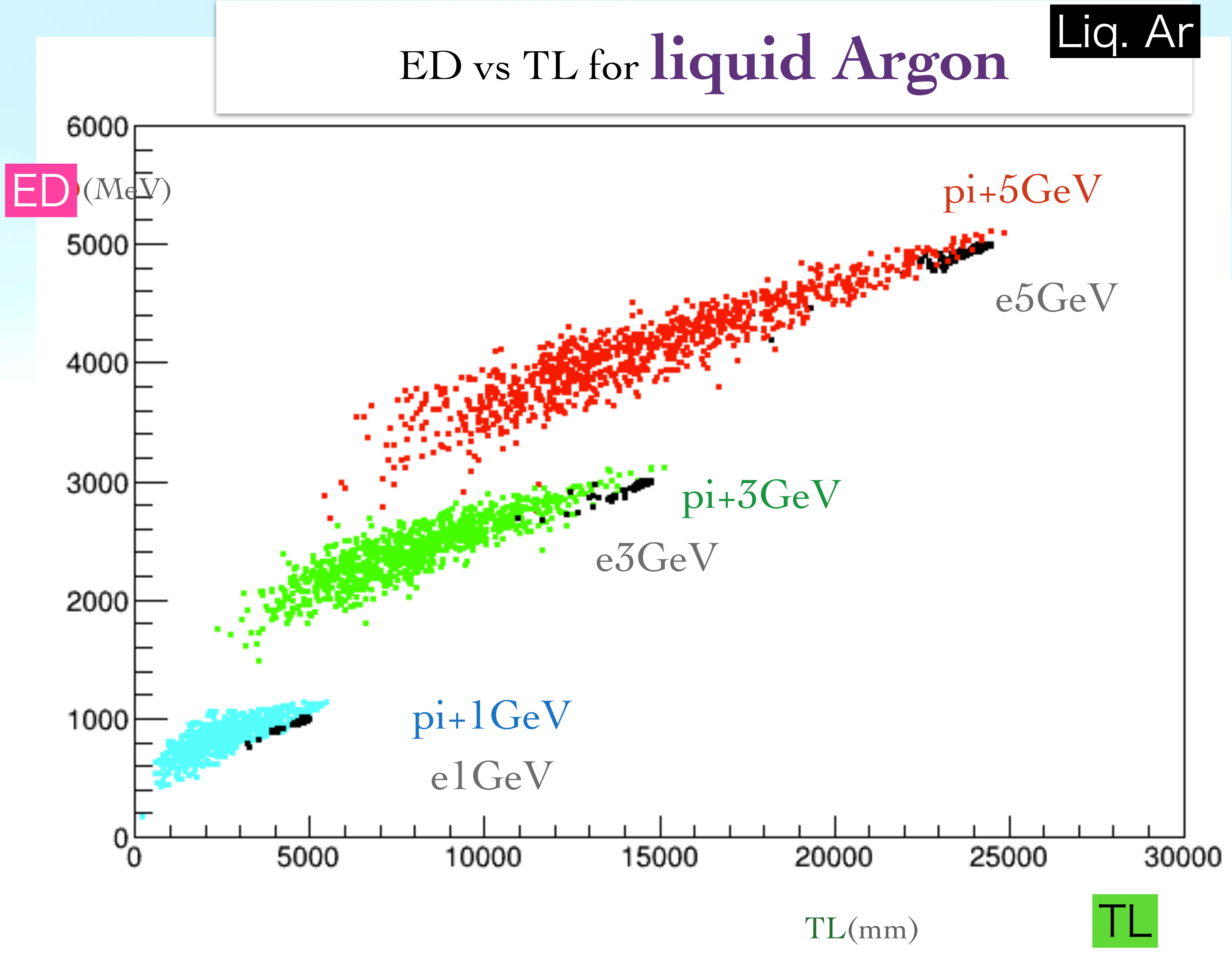


Different detector material

Liquid Argon & CsI are simulated

ED vs TL

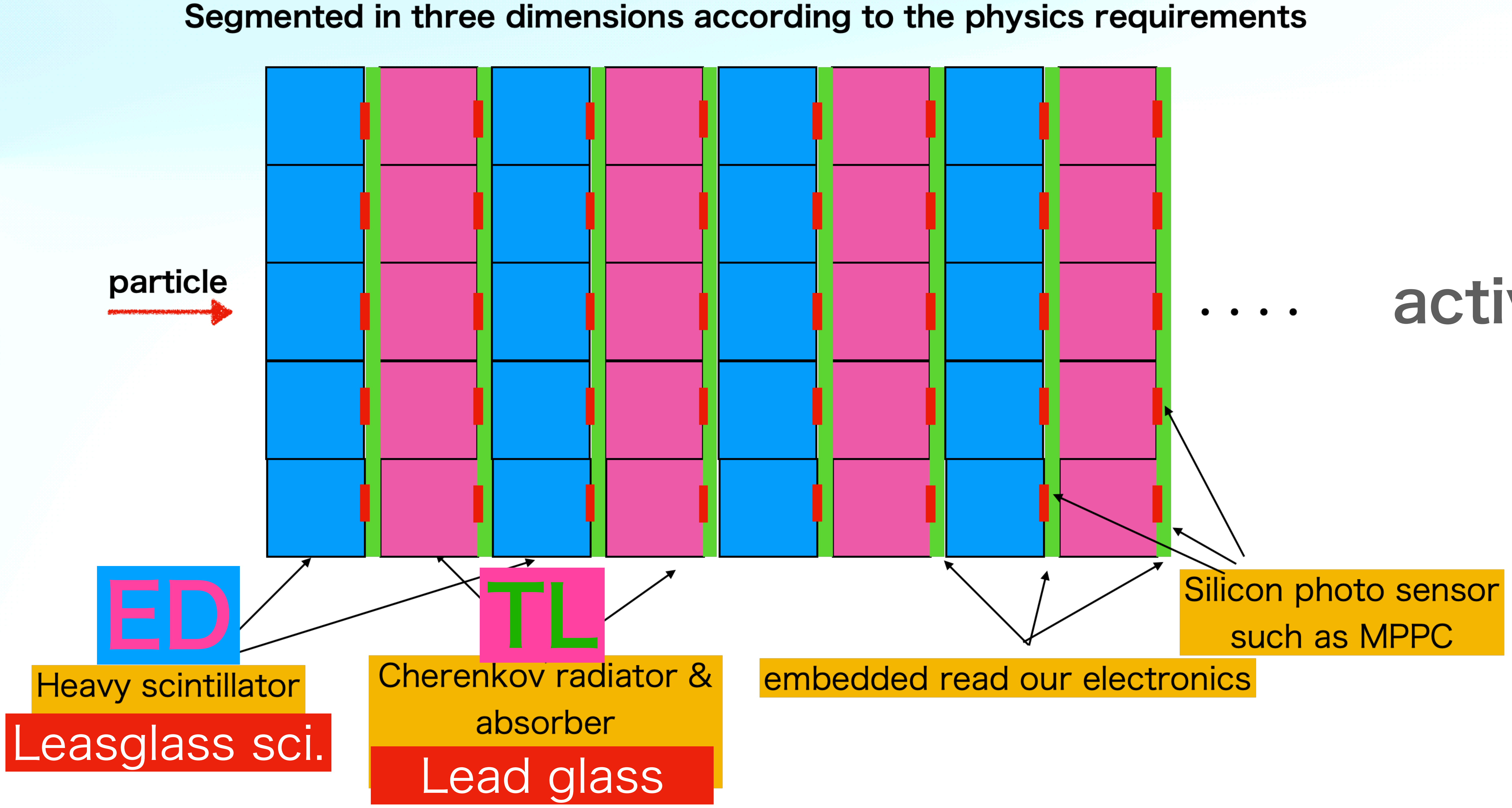




a new idea :Double readout Sandwich Calorimeter of glass

- separate Cherenkov radiator and Scintillation material with sandwich style coupled to highly granular option of PFA
- fully active and clear separation of Cherenkov and scintillation lights

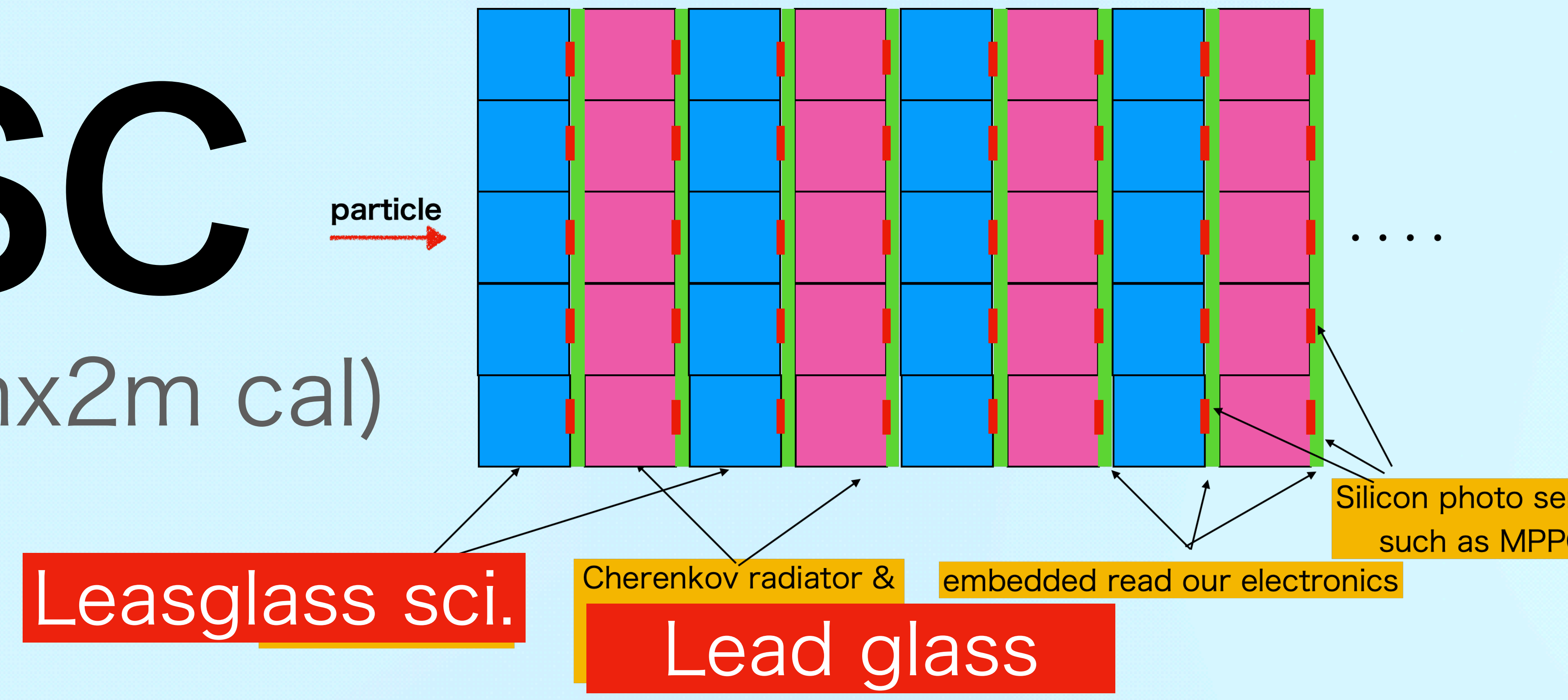
Double readout Sandwich Calorimeter



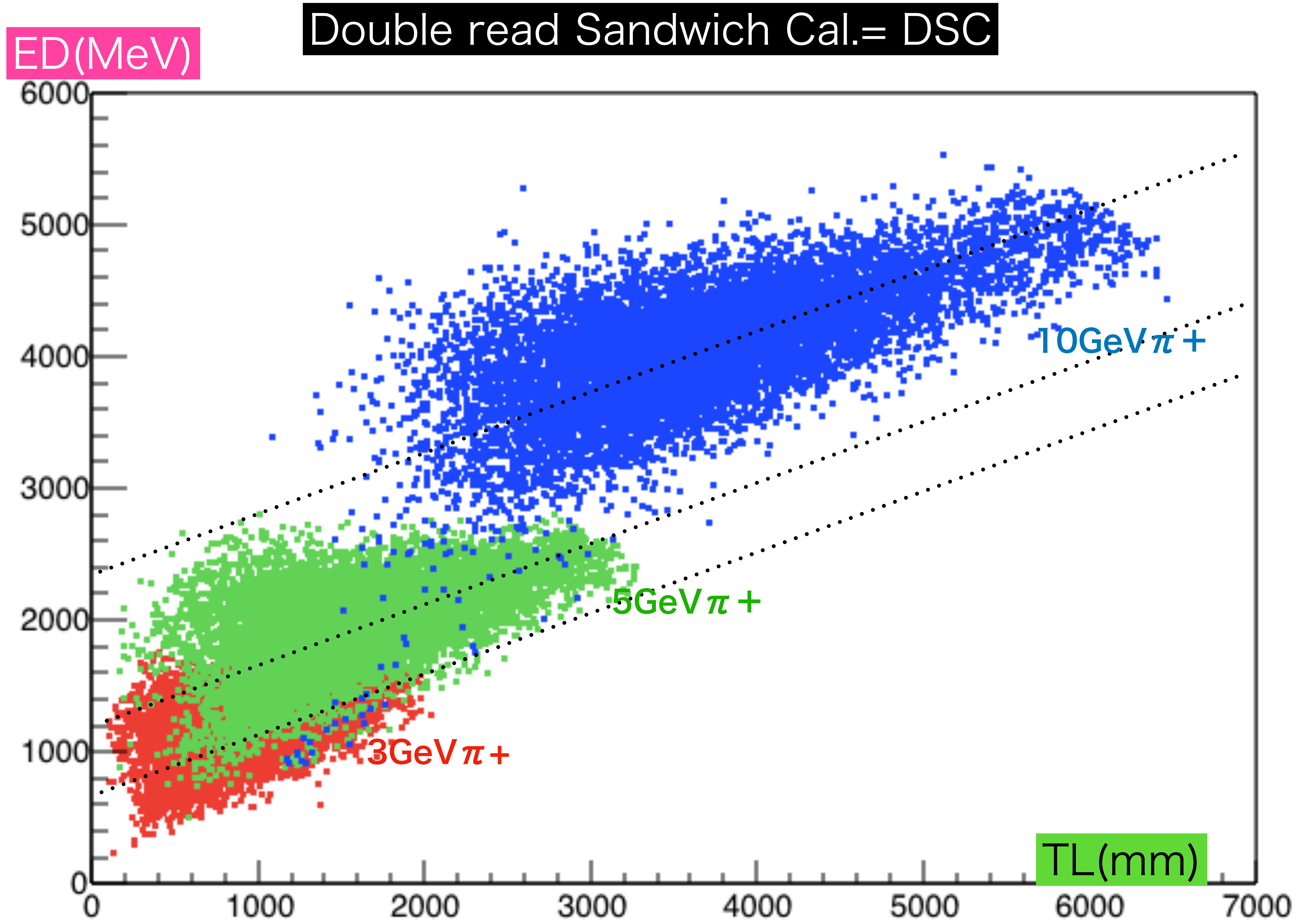
active absorber cal.

performance of DSC

Double read Sandwich cal. simulation (2mx2mx2m cal)



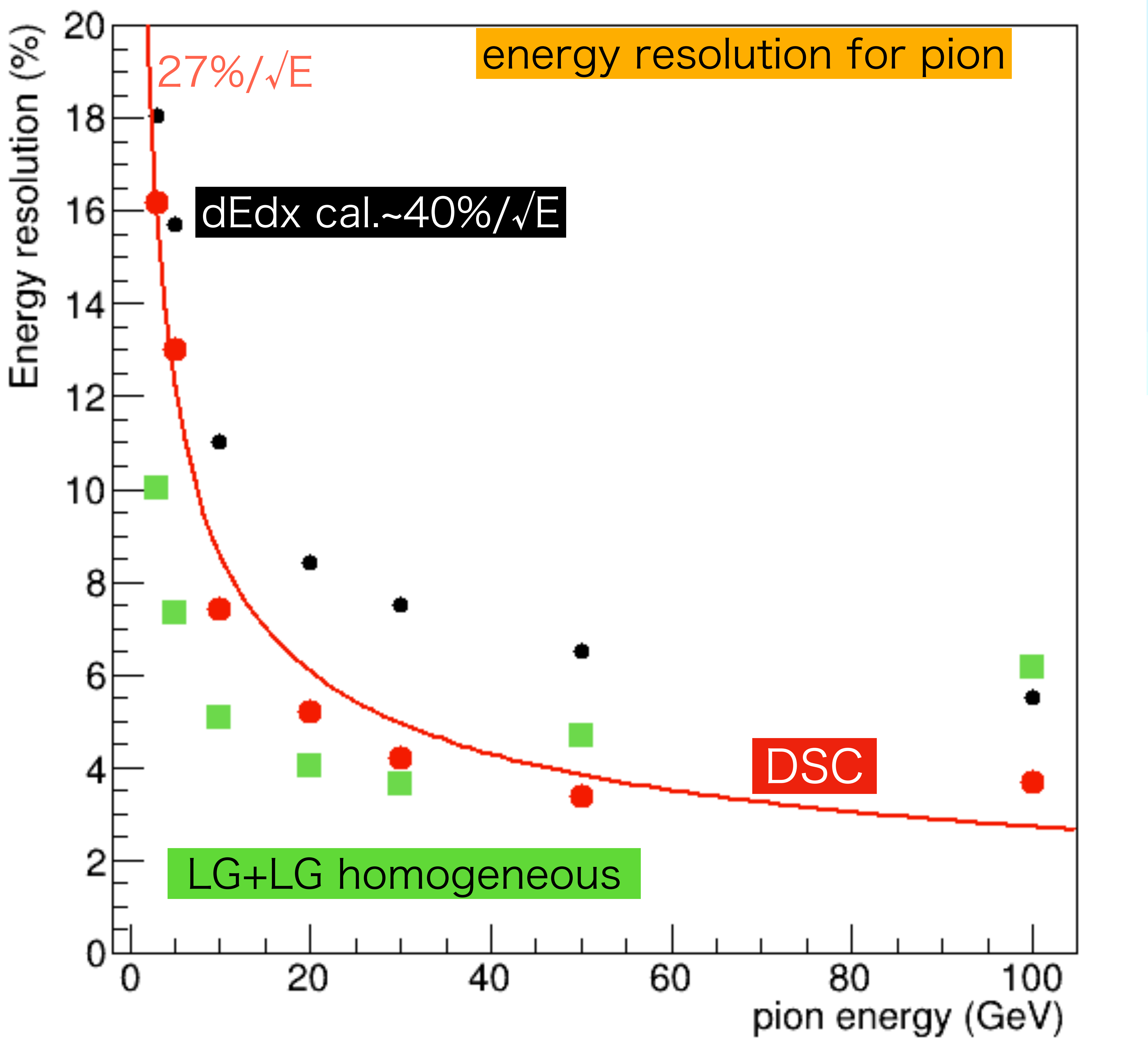
- ED vs TL relation holds for DSC sandwich calorimeter
- LG2cm+LGSci.2cm 50layers
- distributions are wider than homogeneous cal.
- sampling fraction is 0.5 while Homogeneous cal. =1
- linear behavior with intercept



Energy resolution of DSC

~ 27%/√E(GeV) with DSC for hadrons

- close to homogeneous cal.
- todo
  - remove punch through
  - prototype optimization
  - effect of photon statistics



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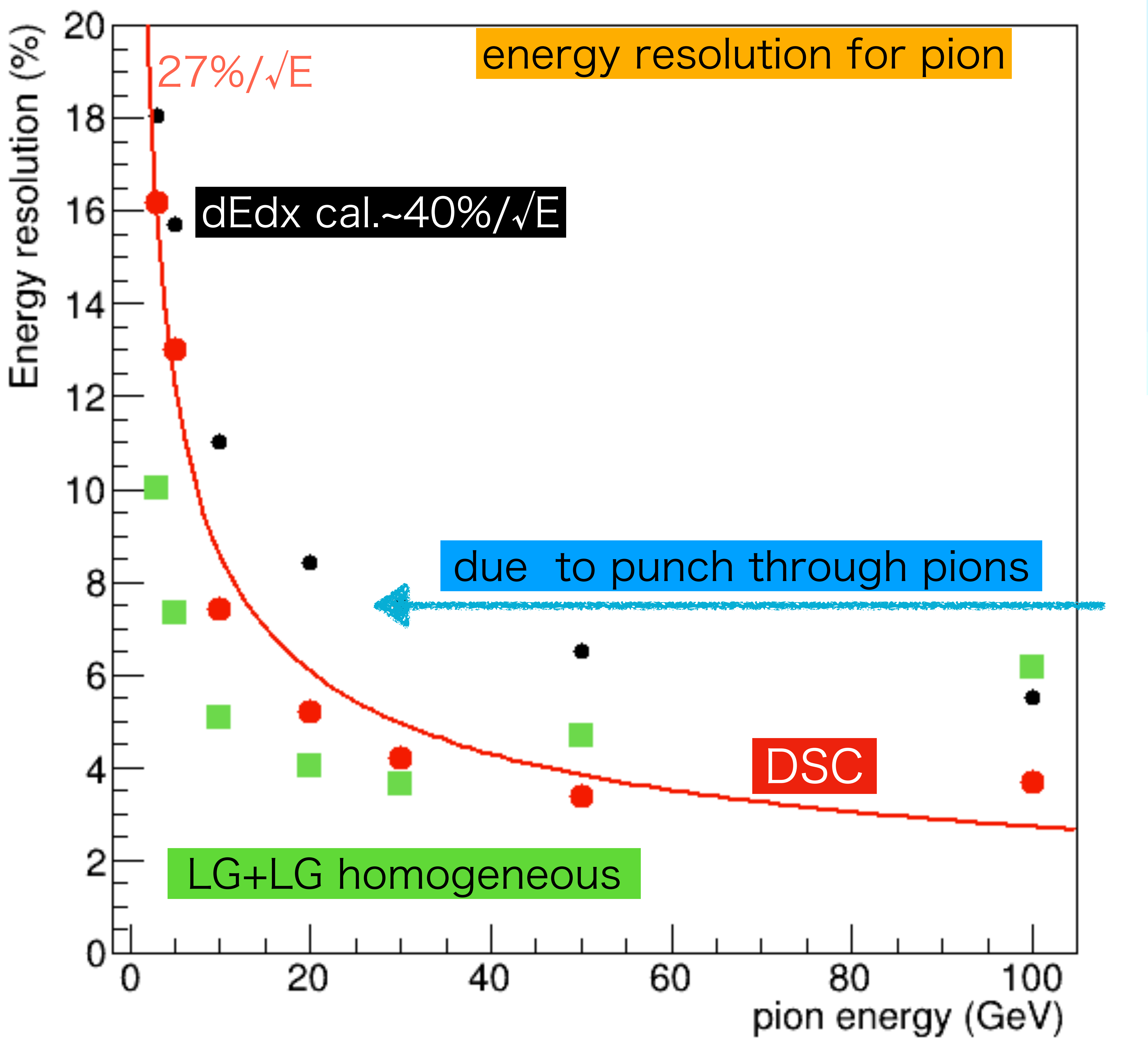
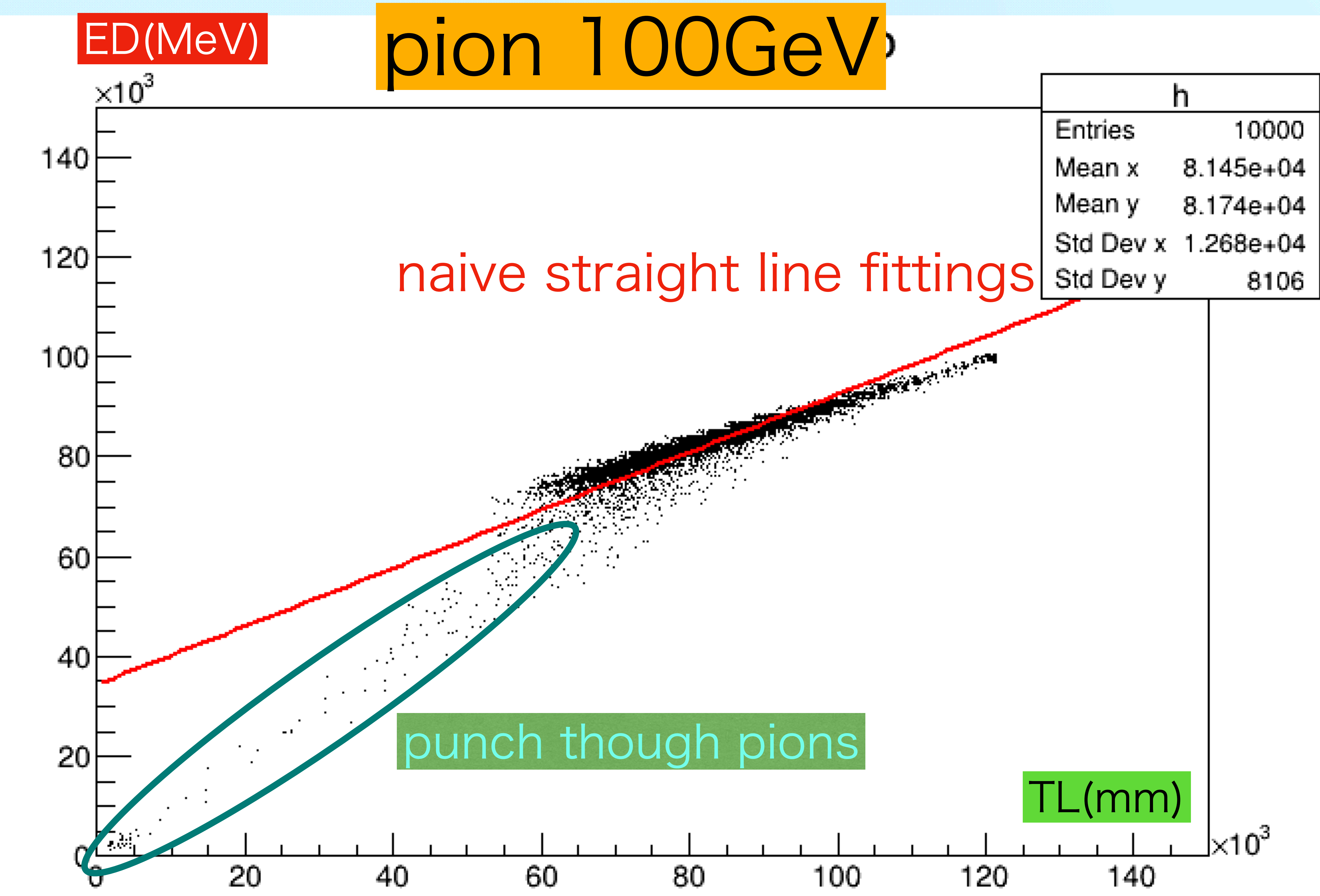


effect of punch through pions

- fitted line in red ends up not accurately representing the distribution
- naive linear fitting is affected by low E events
- due to punch though pions
- in this analysis, does not remove those events



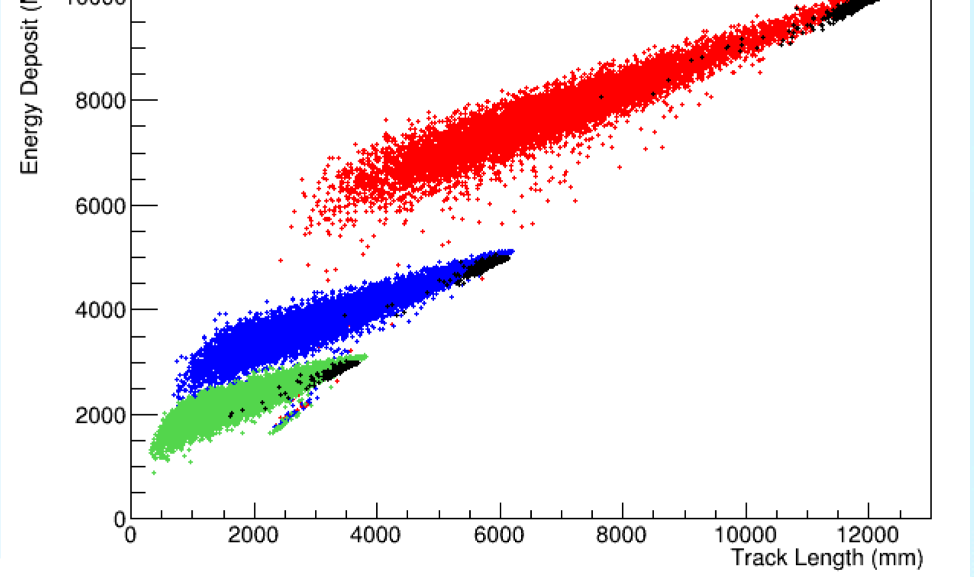
reason of intercept

when a particle stops in a shower

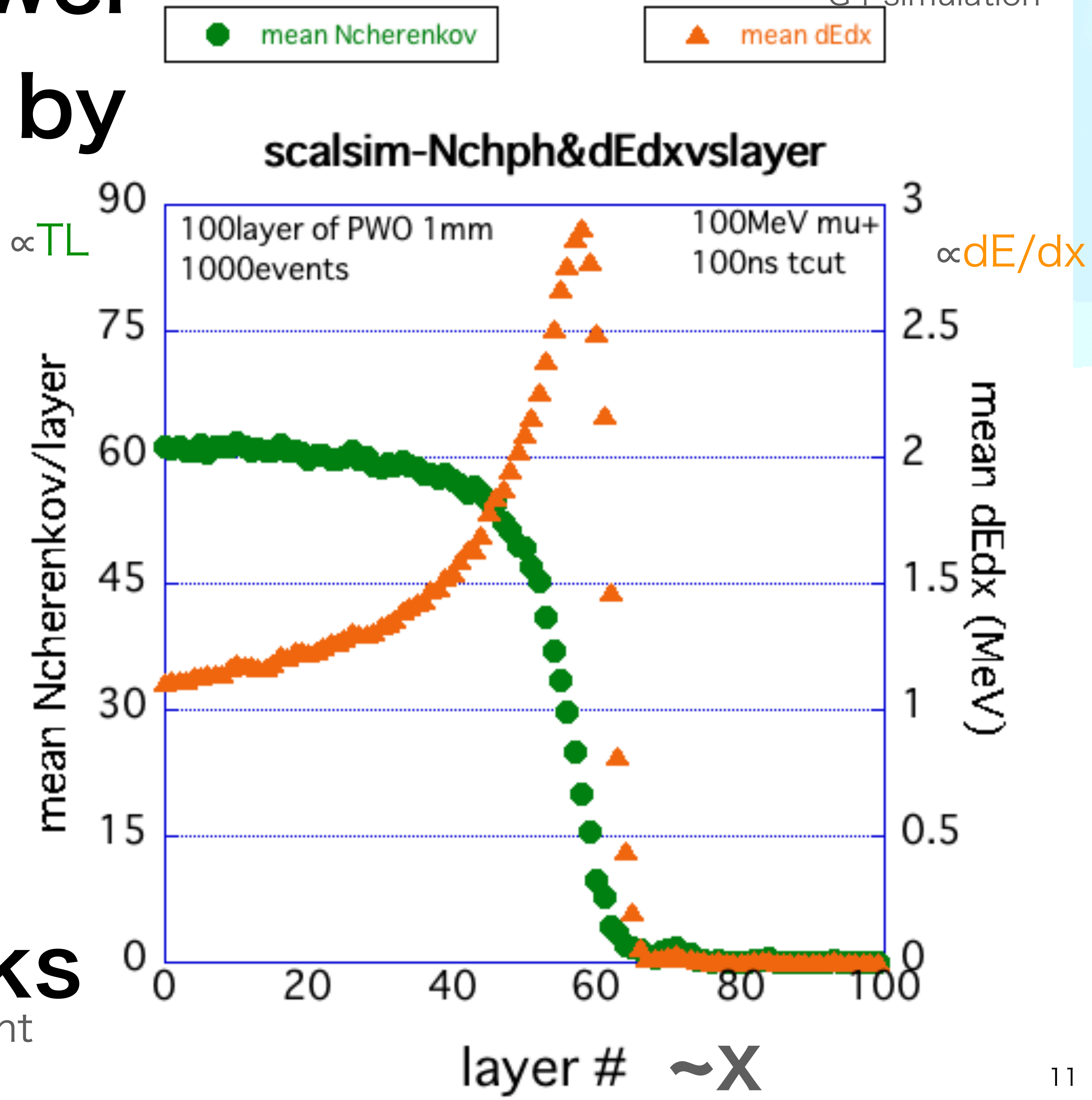
- Bragg peak will be detected by only scintillator
- no peak by Cherenkov
  - Cherenkov threshold exists
- intercept corresponds to counting the number of stopping particles when they release energy as Bragg peaks

linearity

no contribution to Cherenkov light measurement



G4-simulation



TL ~ Cherenkov light

$$\frac{dE}{d\omega} = \frac{\alpha\hbar}{c}\omega L \sin^2\theta$$

Frank-Tamm

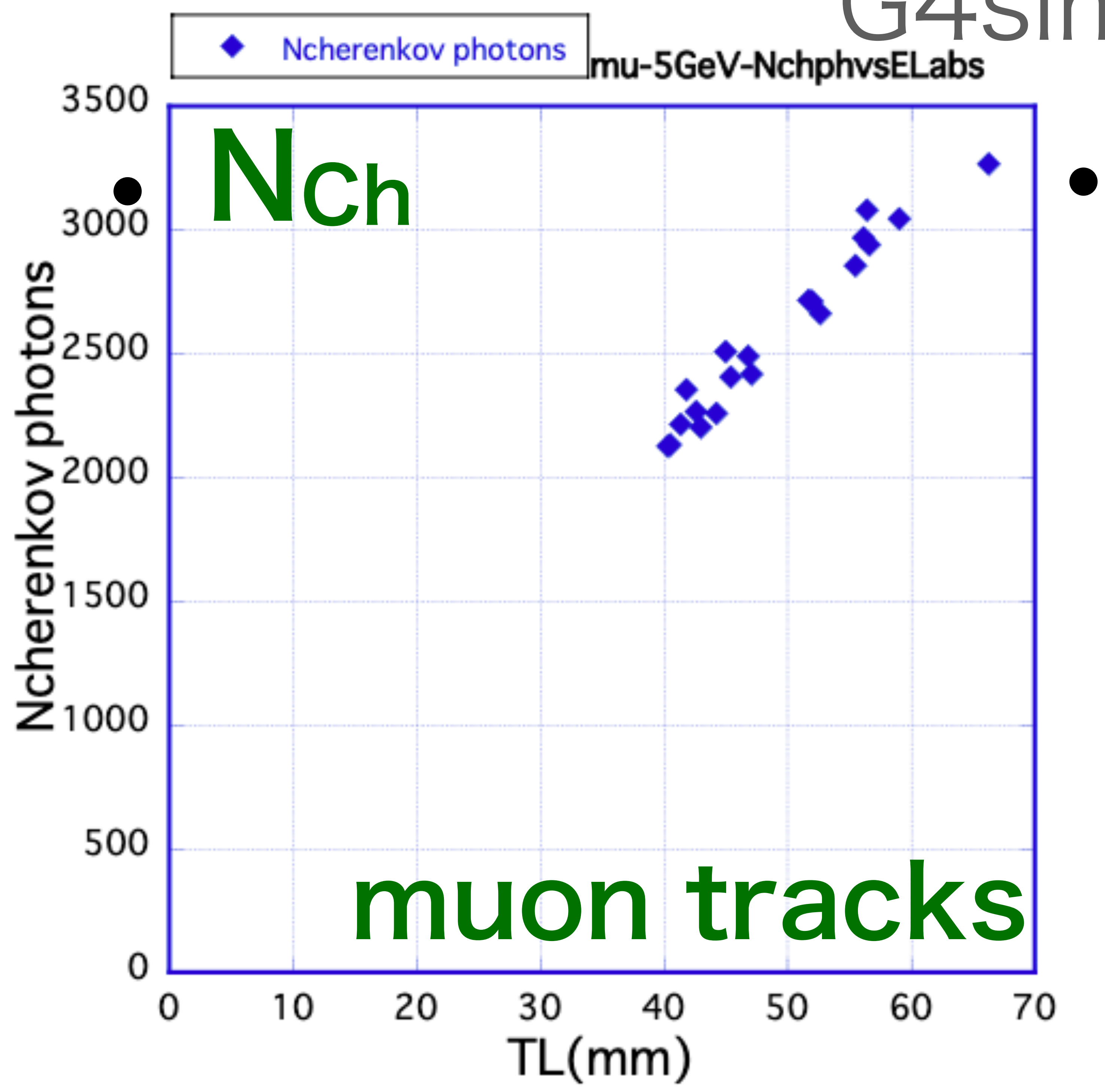
$$\frac{d^2N}{d\omega dx} = \frac{\alpha}{c}\sin^2\theta = \frac{\alpha}{c}\left(1 - \frac{1}{\beta^2 n^2}\right)$$

- Cherenkov radiation energy loss
- Cherenkov photons = N

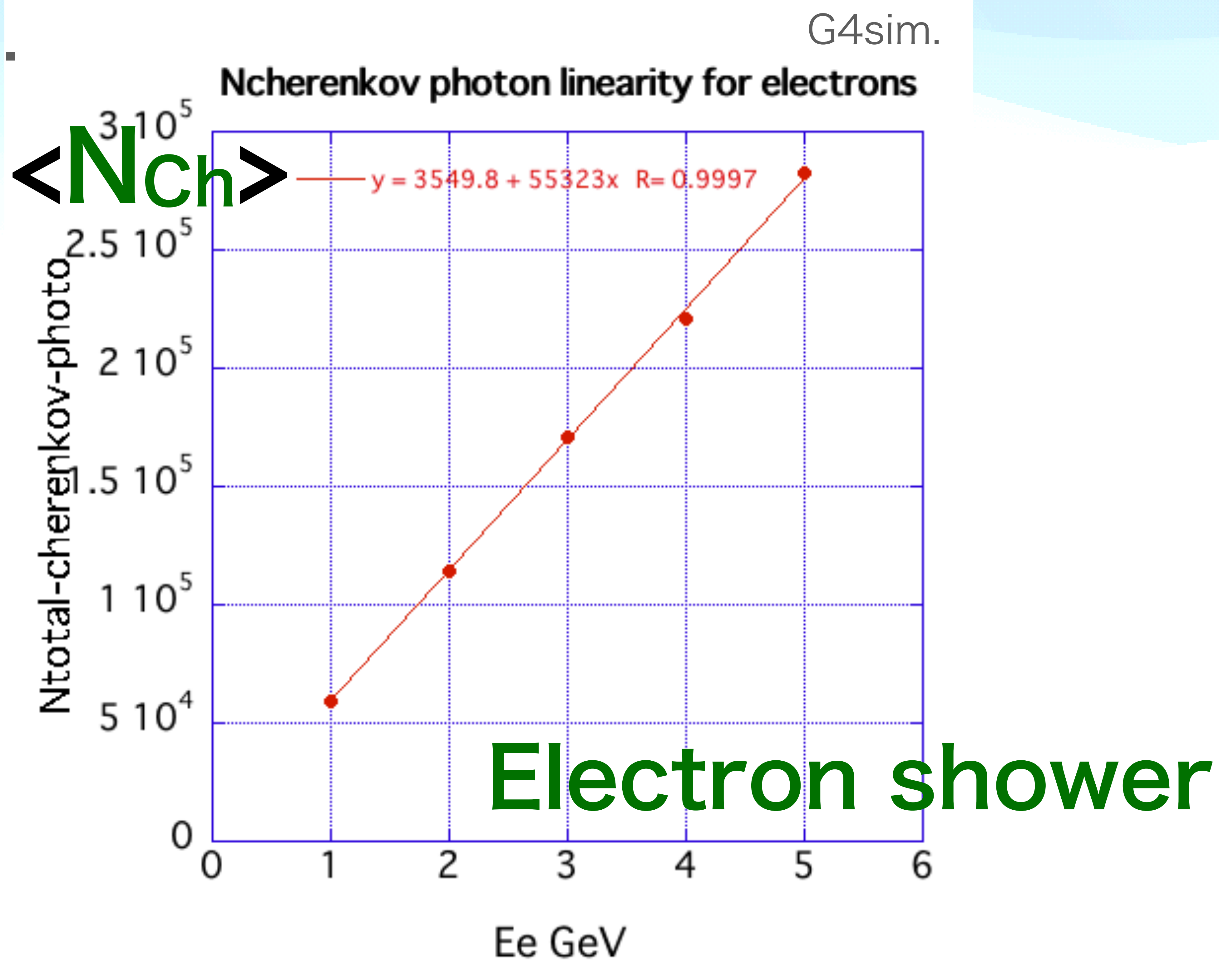
n(ω)~n .

- $N_{Ch} \propto x$ =TL

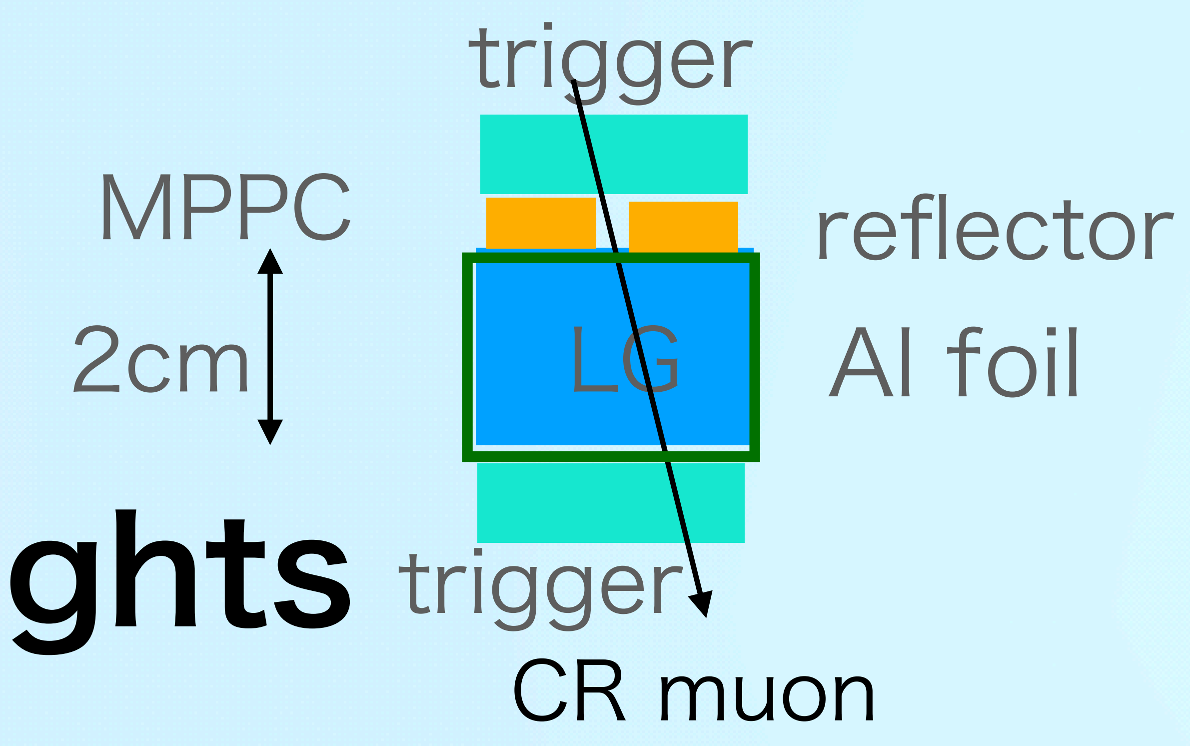
G4sim.



G4sim.



Feasibility of the DSC



Cherenkov tile will generate small number of lights

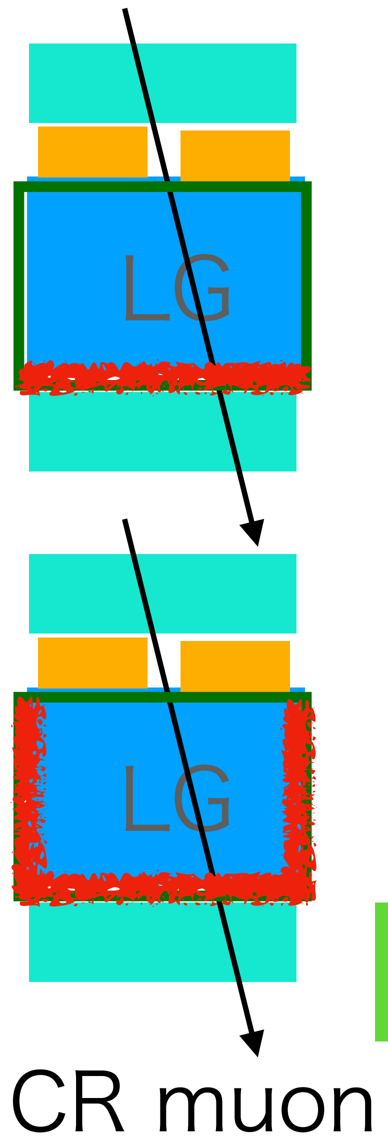
- LG tile : 2cm^t x3x3cm^2 (PFA cal.)

  all polished &1 non-pol.

  grease coupled sensors of

  UV and normal MPPC

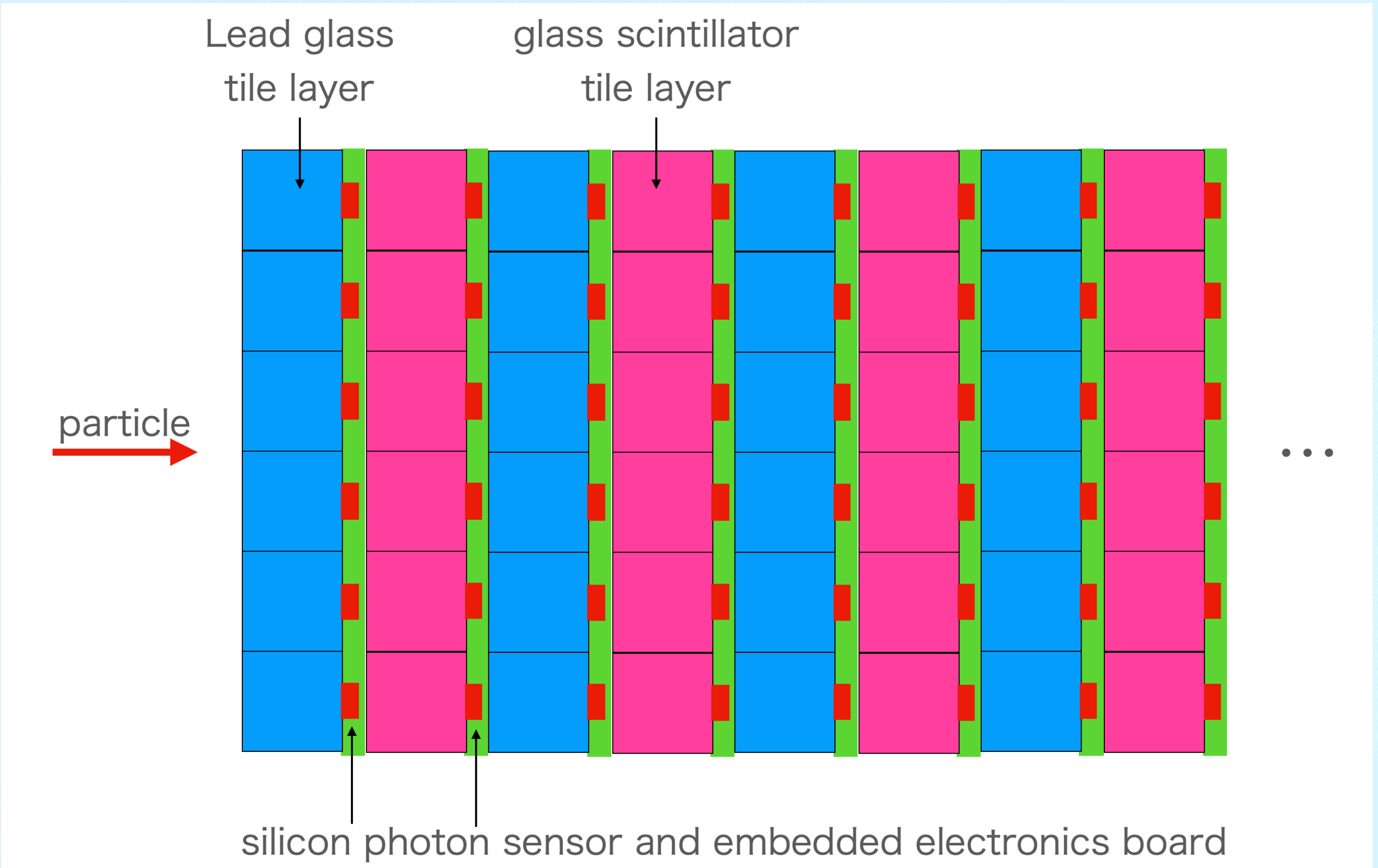
  6mmx6mm
- LY by MIP is good for the calorimeter
- UV light does not transmit in glass
- polished surface can increase collection efficiency



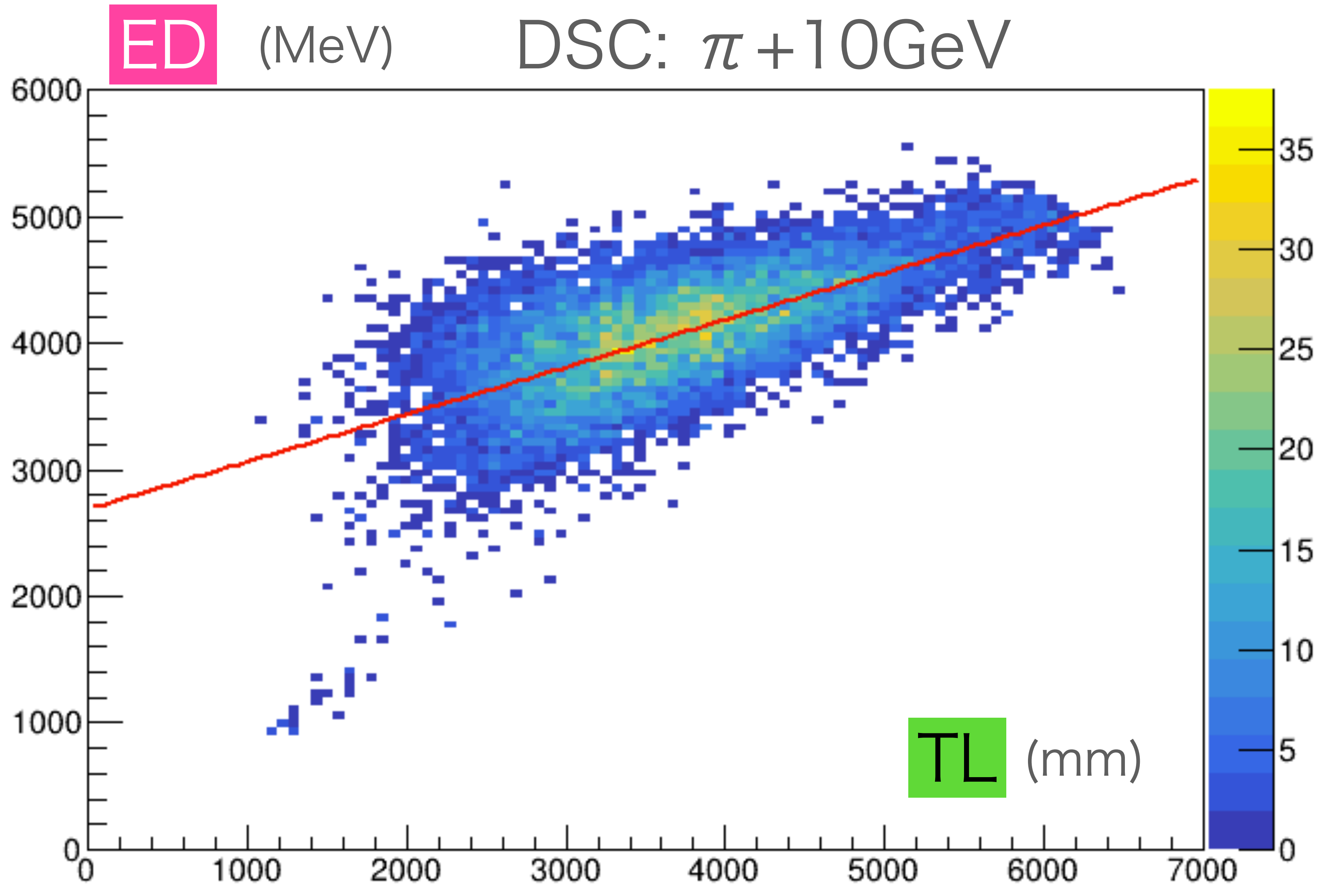
LY(pe)	normal PPD	UV PPD
all polished	12	12
1 unpolish	8	8
5 unpolish	15	-

timing resolution < 100ps

summary and outlook



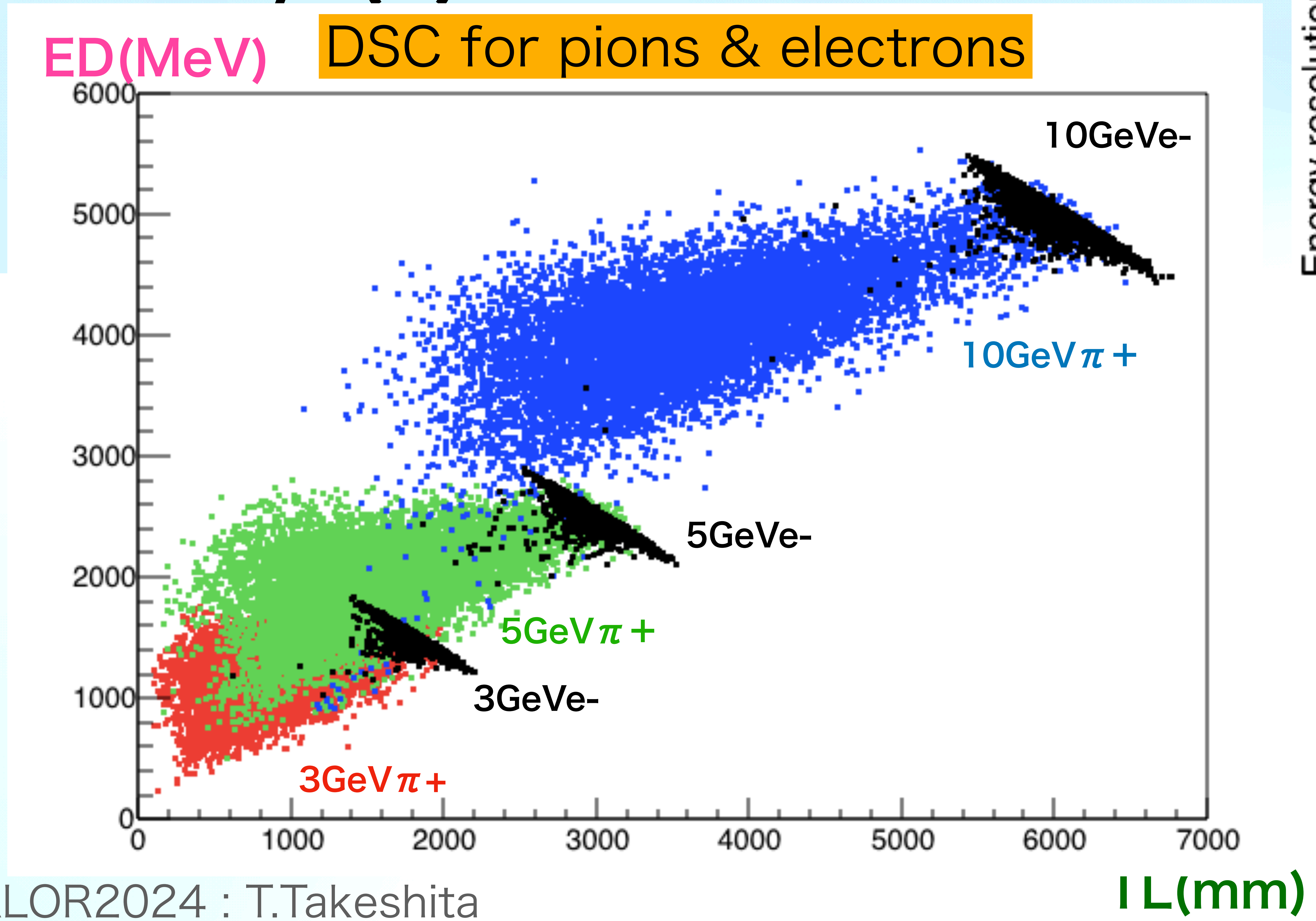
- Double readout glass sandwich calorimeter
  < Homogeneous cal. simulation
- linear correlation between sum of Track Length (Cherenkov) and Energy Deposit (scintillation) guides this study
- actual implementation is proposed as Double read glassSC with fine energy resolution than traditional dEdx CAL
- R&D for DSC is on going
  - remove punch through pions
  - Cherenkov light in the sci-glass
  - production of scintillating glass with Quantum nano-Dots

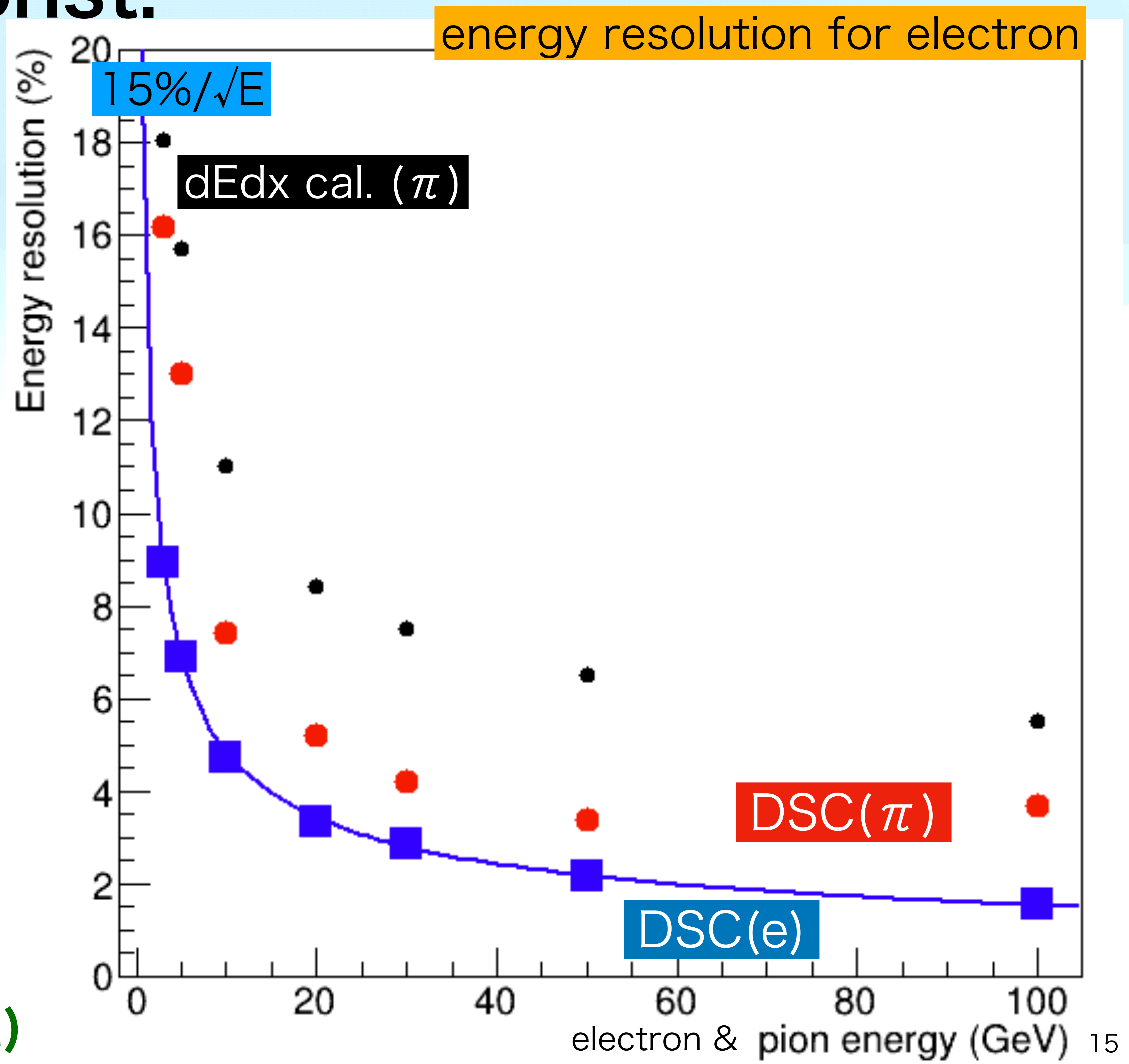


electrons on DSC

- electron energy resolution
- sum of ED(LG) and TL(LG) =const.

~ 15%/√(E)



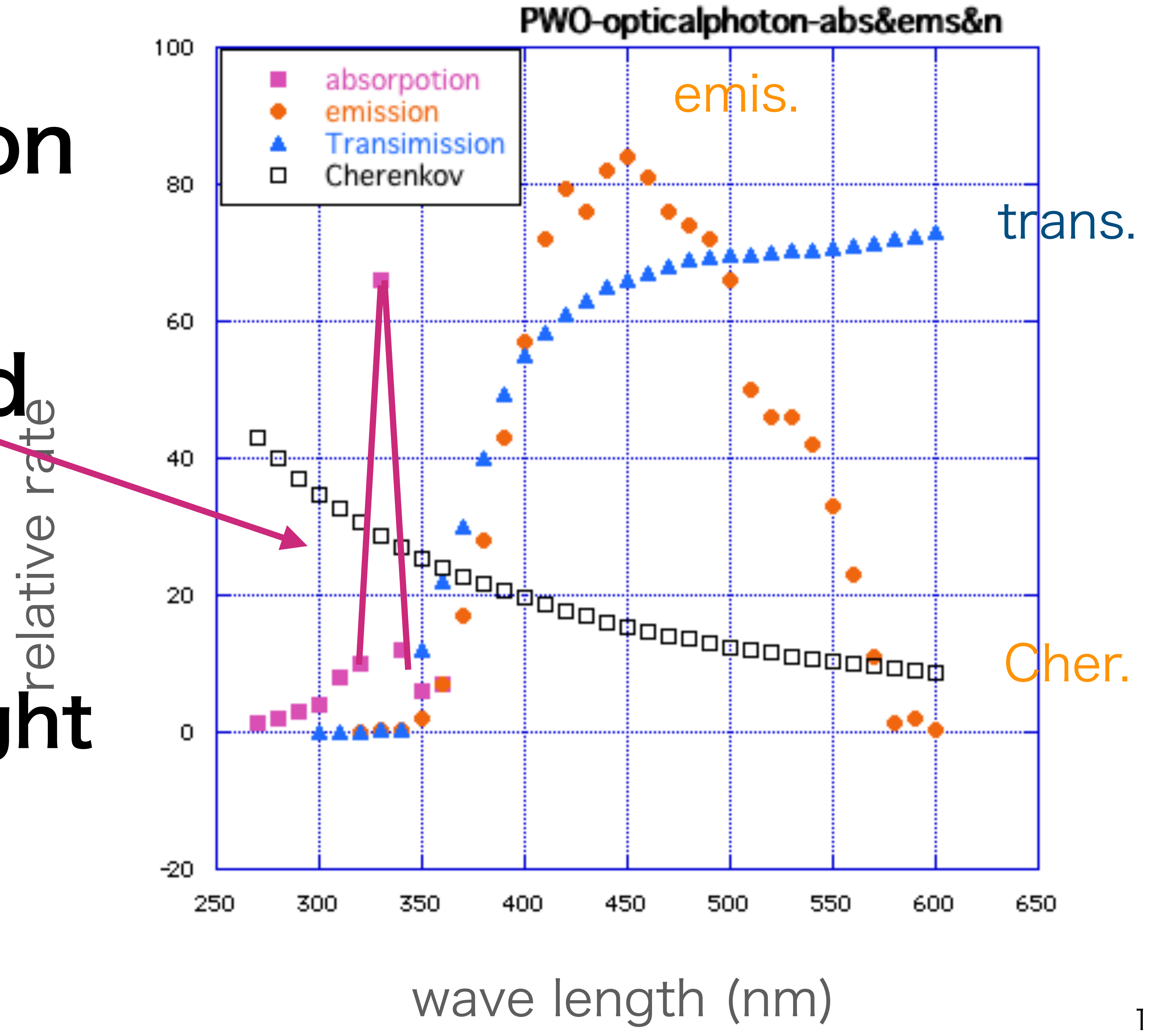


Separation of Cherenkov & Scintillation light

- scintillator such as PWO generates Cherenkov lights inside as well,
- Cherenkov is dominated in the UV region ~$1/\lambda^2$ (UV)
- UV light will be absorbed and converted to scintillation light
- we count Cherenkov light as scintillation light
- Separation of Cherenkov and scintillation light is not an easy task

mixing

PWO optical properties



DSC

LG 4mm + Plastic Scintillator 8mm
sandwich calorimeter
NO correlation
need heavier scintillator