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

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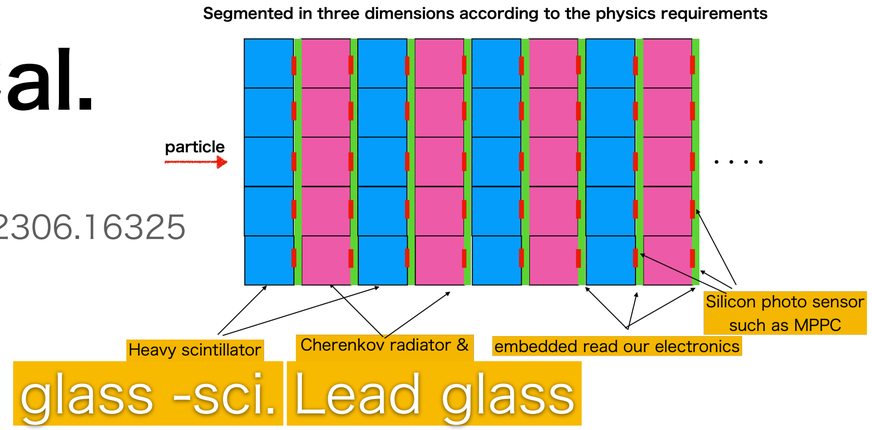
@CALOR2024

Shinshu U

- Homogeneous calorimeter simulation T. Takeshita *et al* 2020 *JINST* **15** C05015 DSC
- Double Readout GLASS Sandwich Cal.

radiation tolerance and cost effective

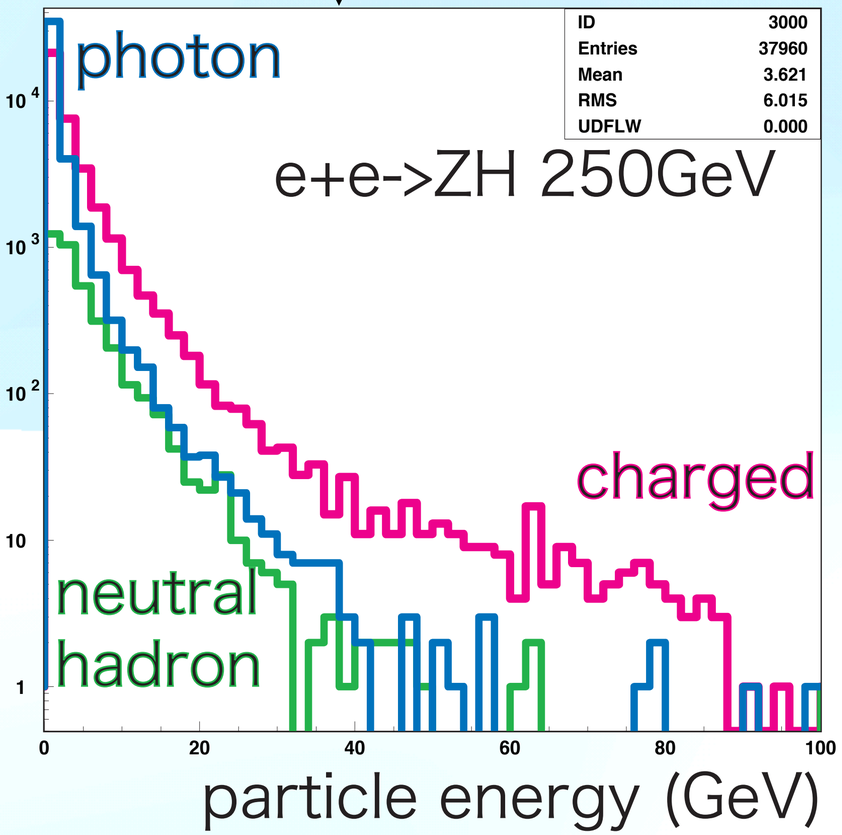
T.Takeshita & R. Terada, arXiv 2306.16325



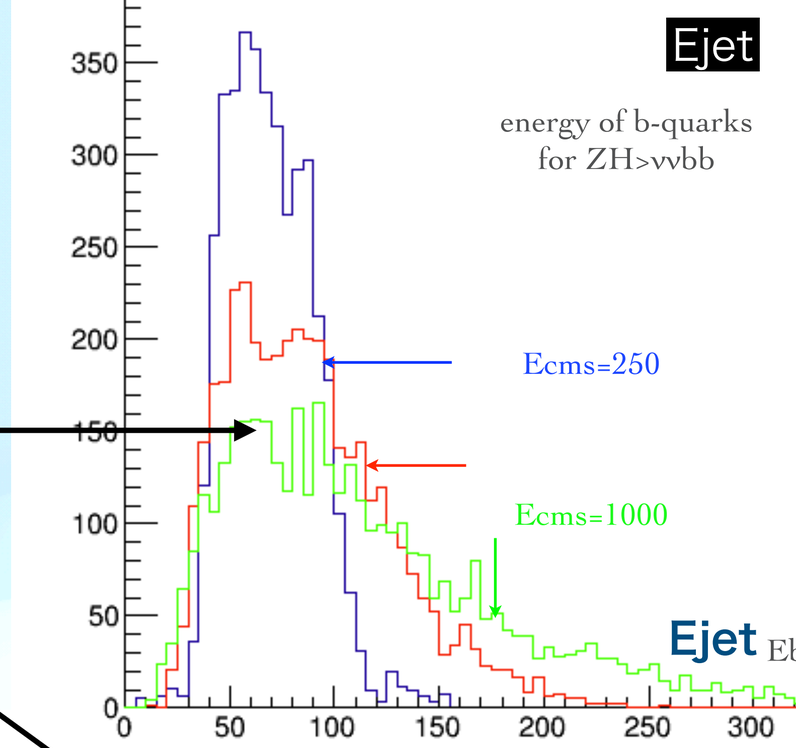
Particles in the Higgs Factory

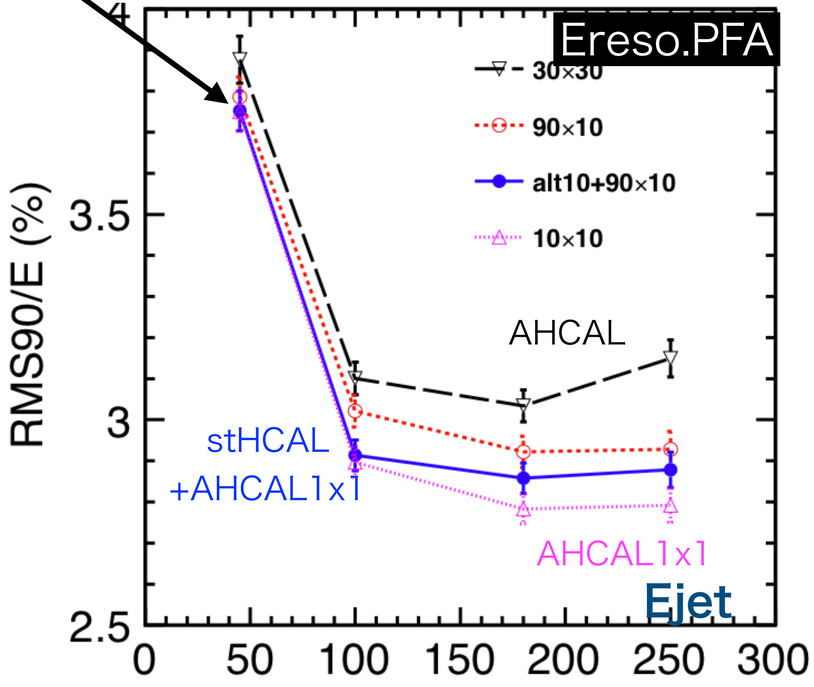
calorimeter

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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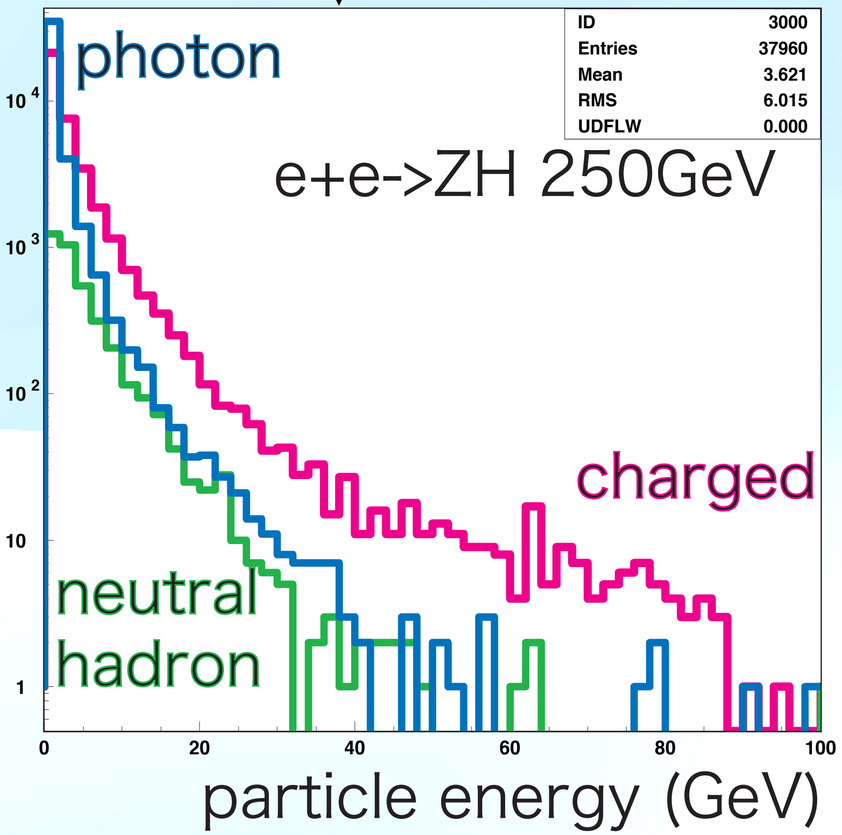

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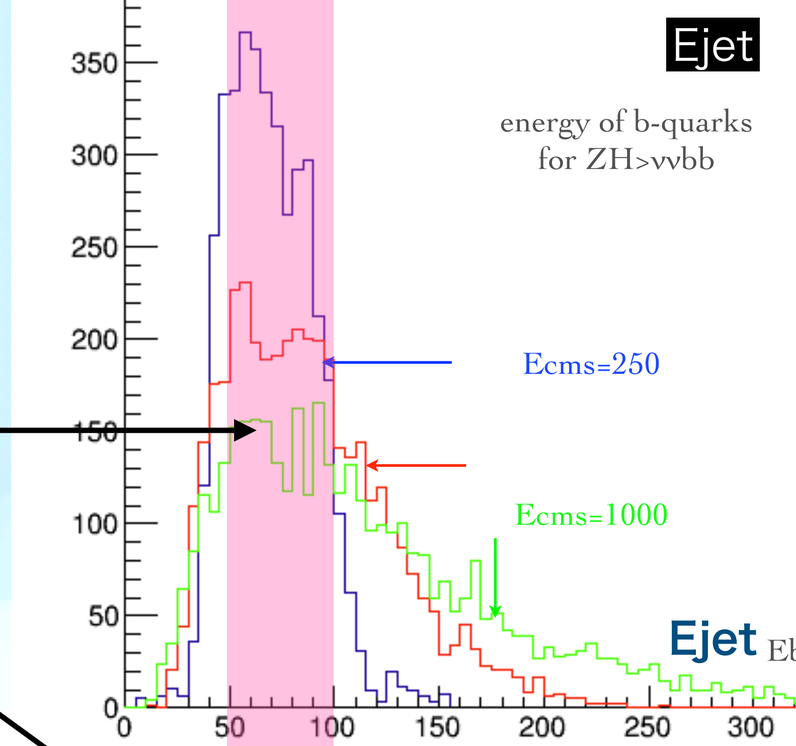
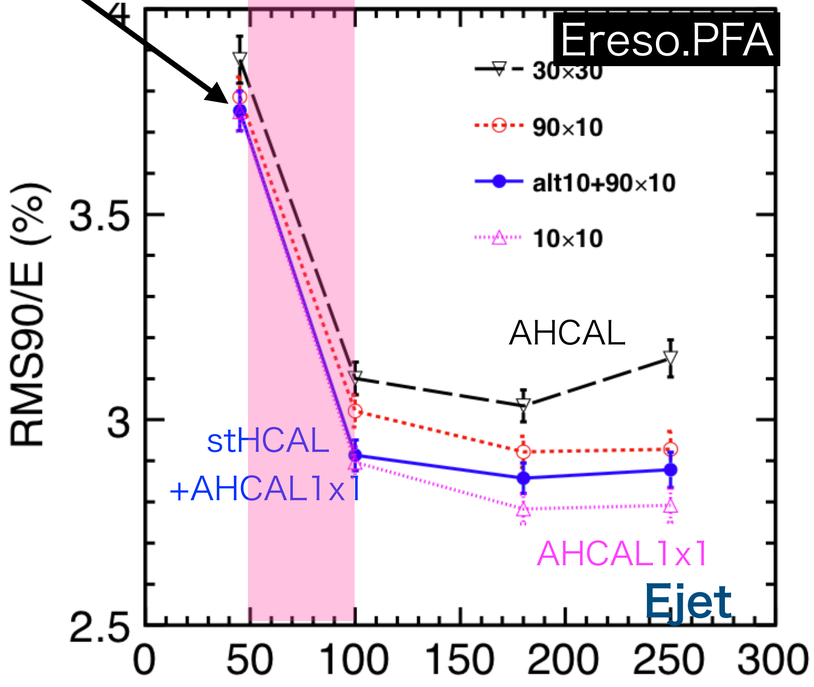




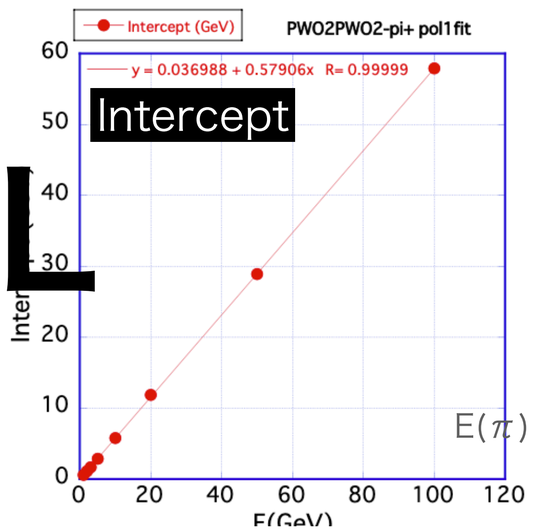
start from

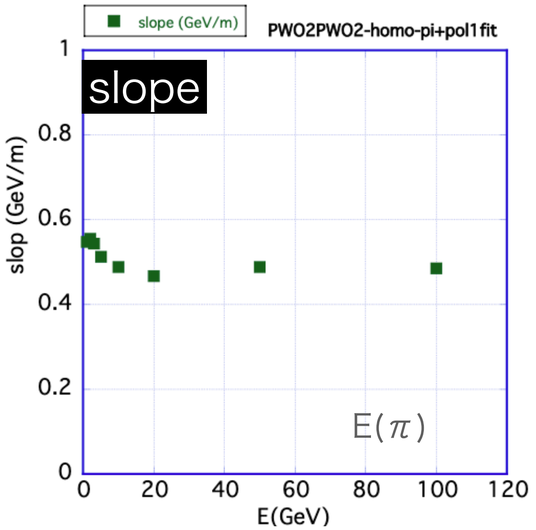
Homogeneous CAL

simulation

two parameters are suitable to be measured

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





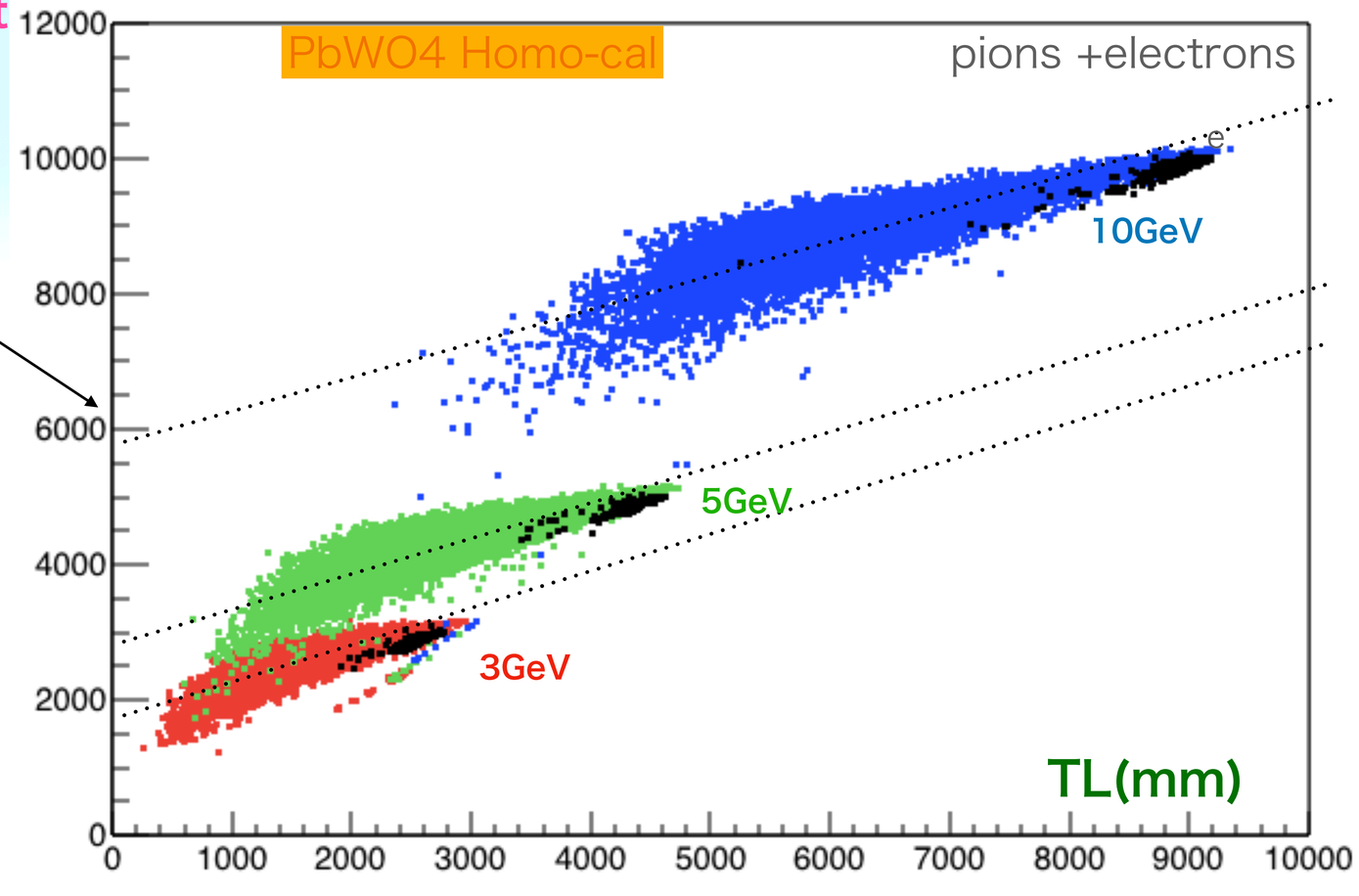
Relations

without passing the origin

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

independent of energy

common for e/pi/K/p/n



photon statistics is not taken into account

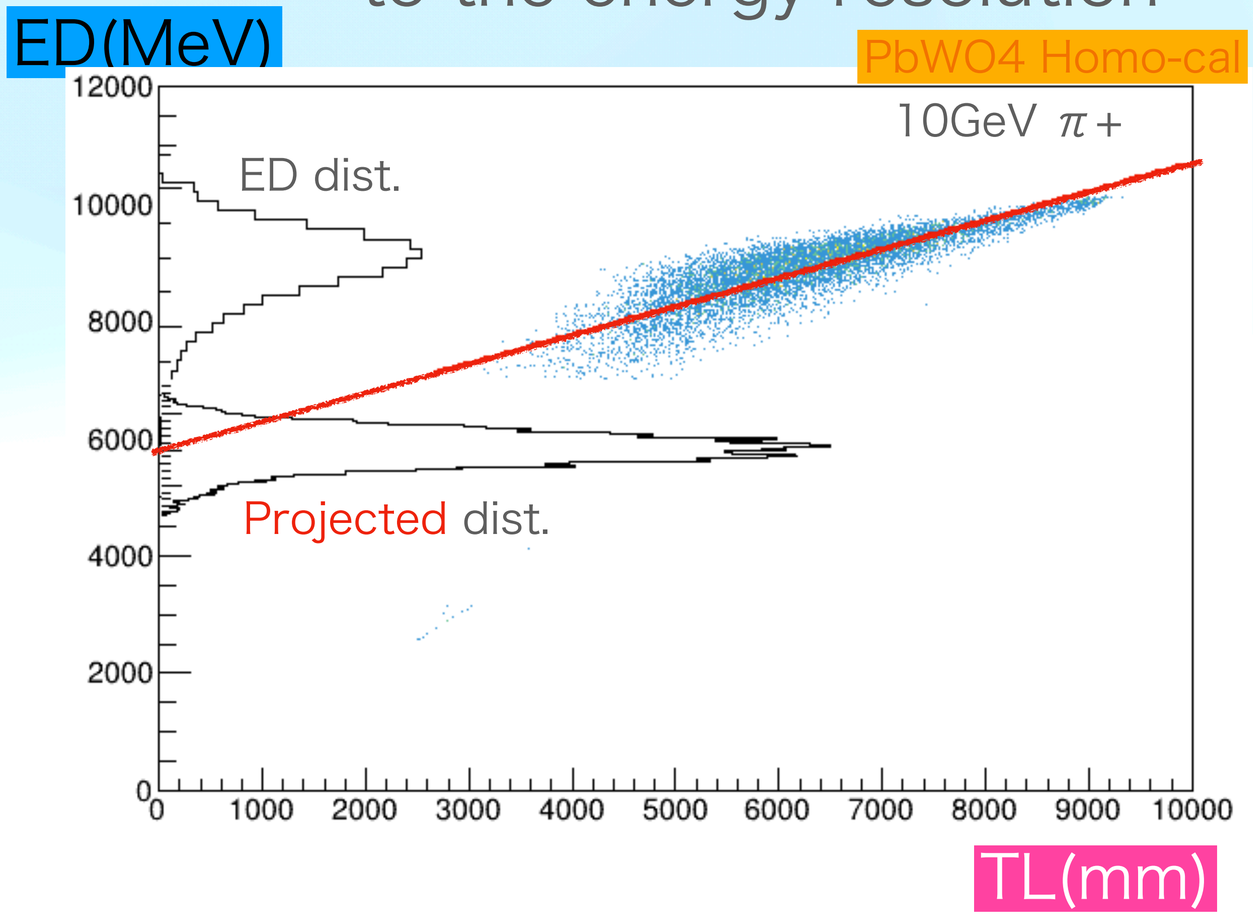
simulation with GEANT4.10.07with FTFP_BERT

(2mx2mx2m)

energy resolution

From the correlation plot to the energy resolution

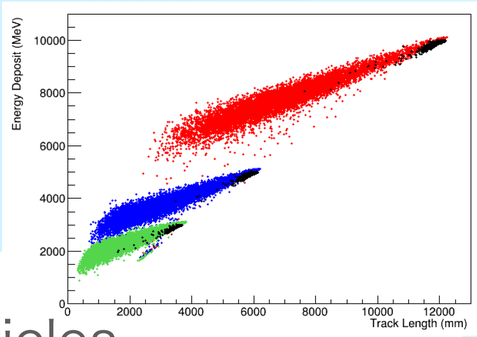
- good correlation between ED and TL
- Energy measured by the intercept
- energy resolution is expressed by width projected to fitted line
- fine energy resolution is achieved than ED distribution



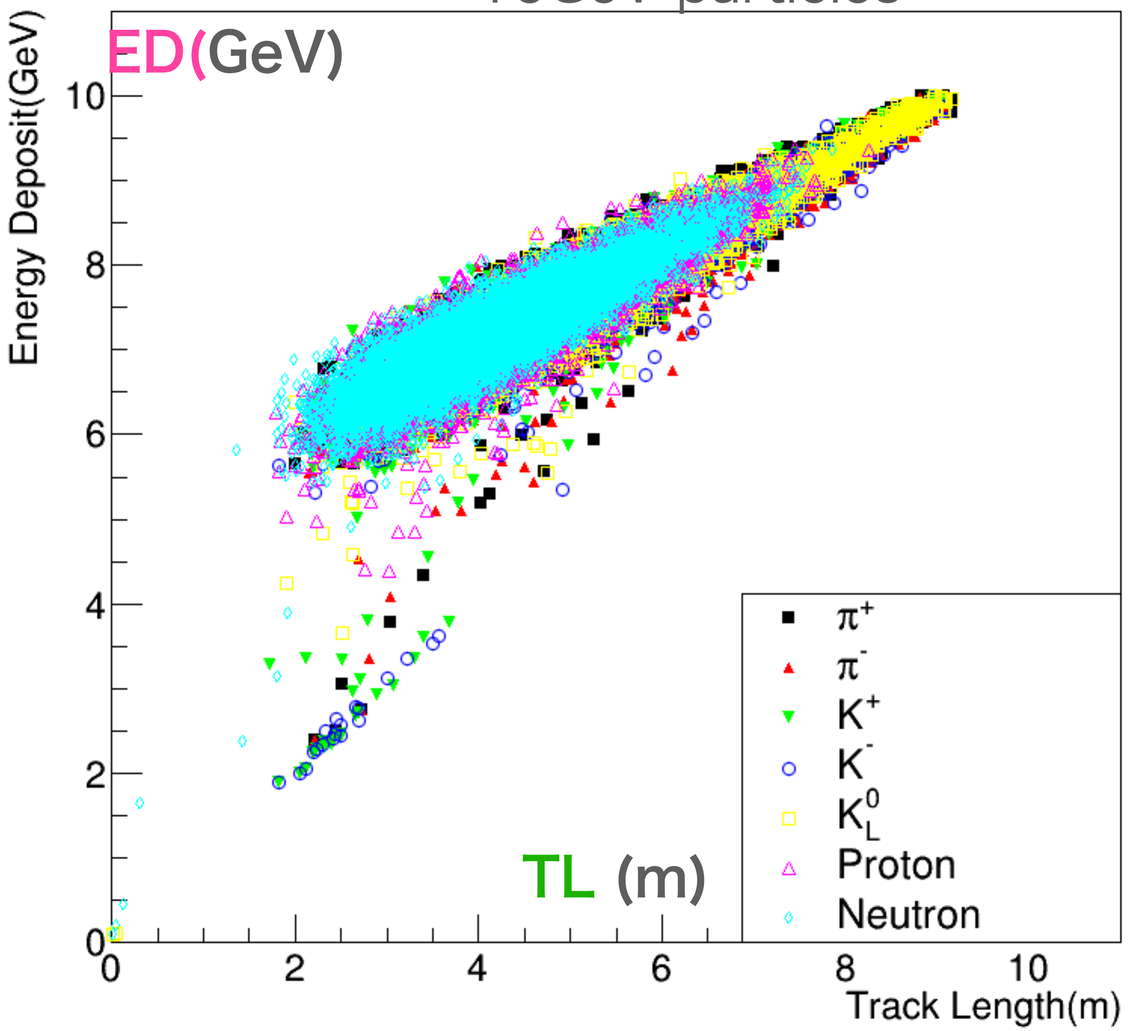
particle response

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

common for particles (π,K,p,n)



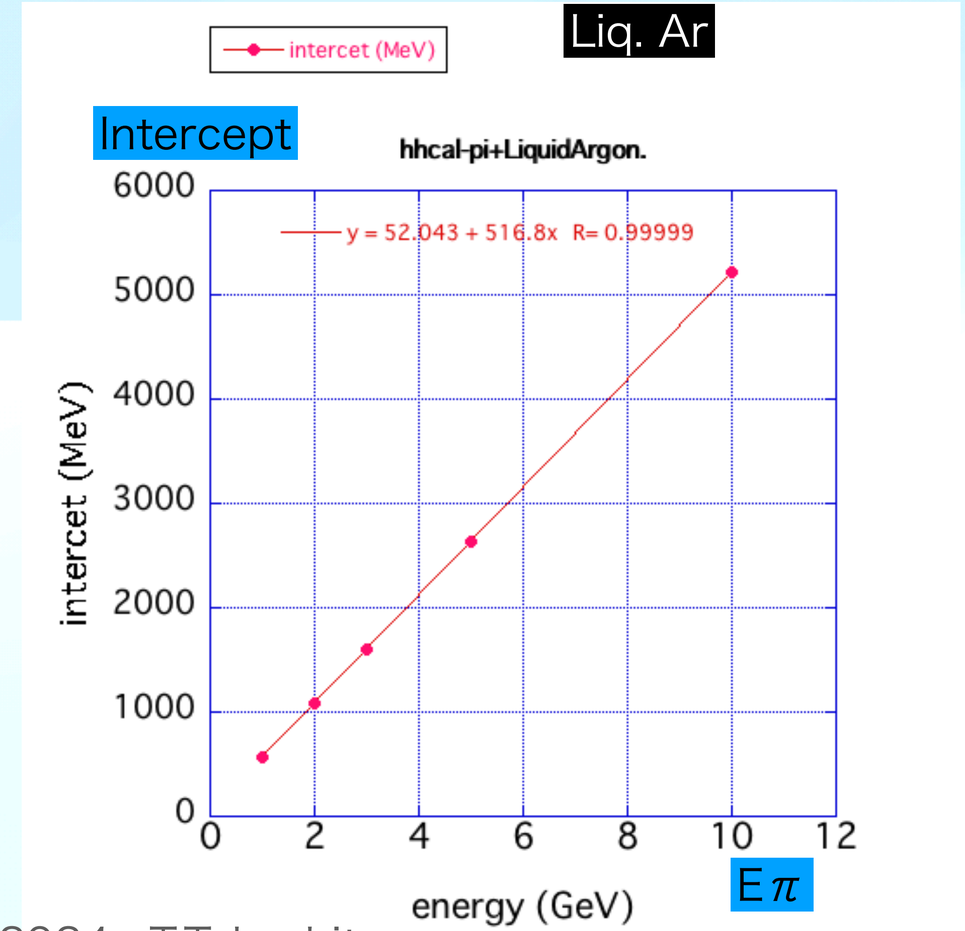
10GeV particles

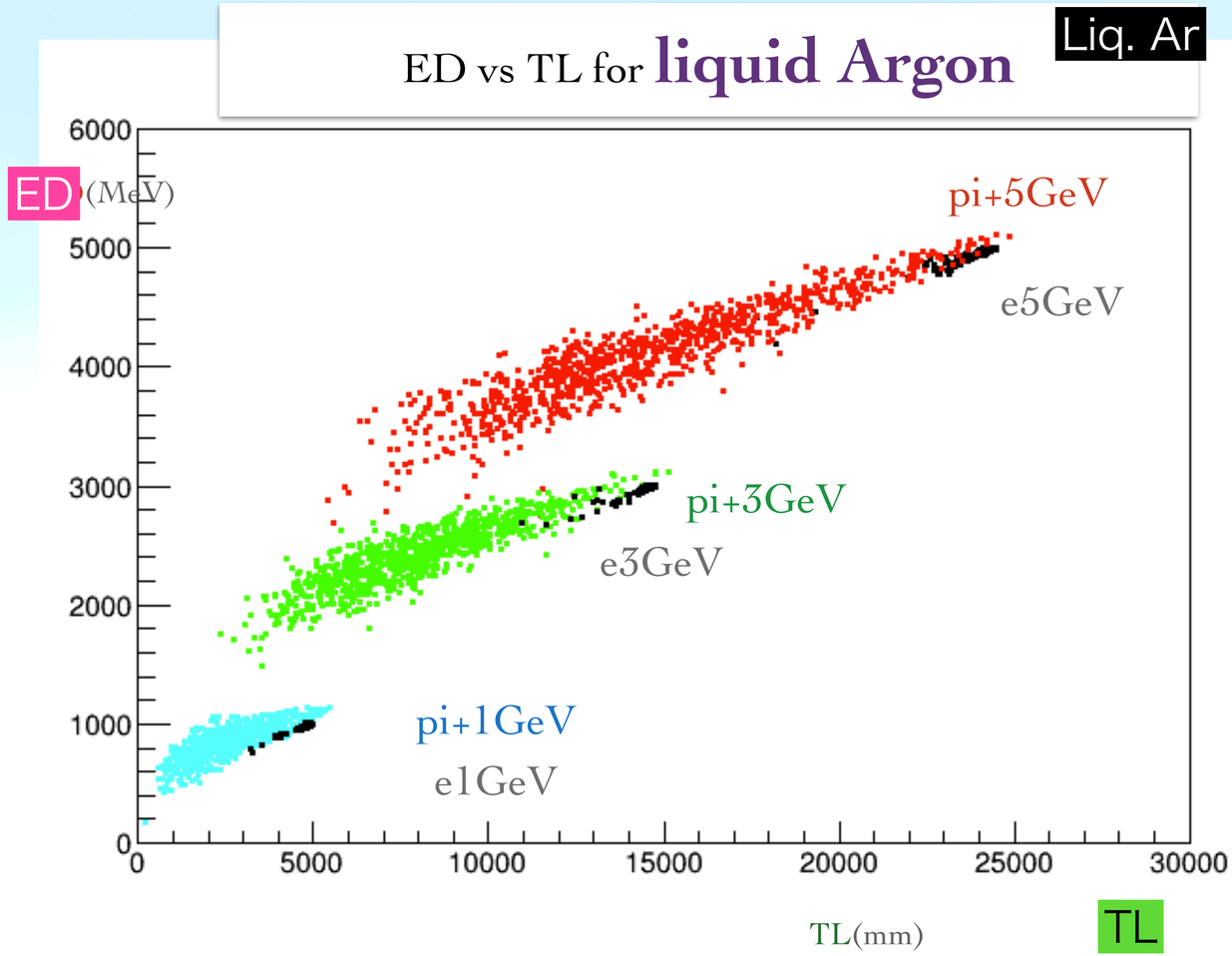


Different detector material

Liquid Argon & CsI are simulated

ED vs TL



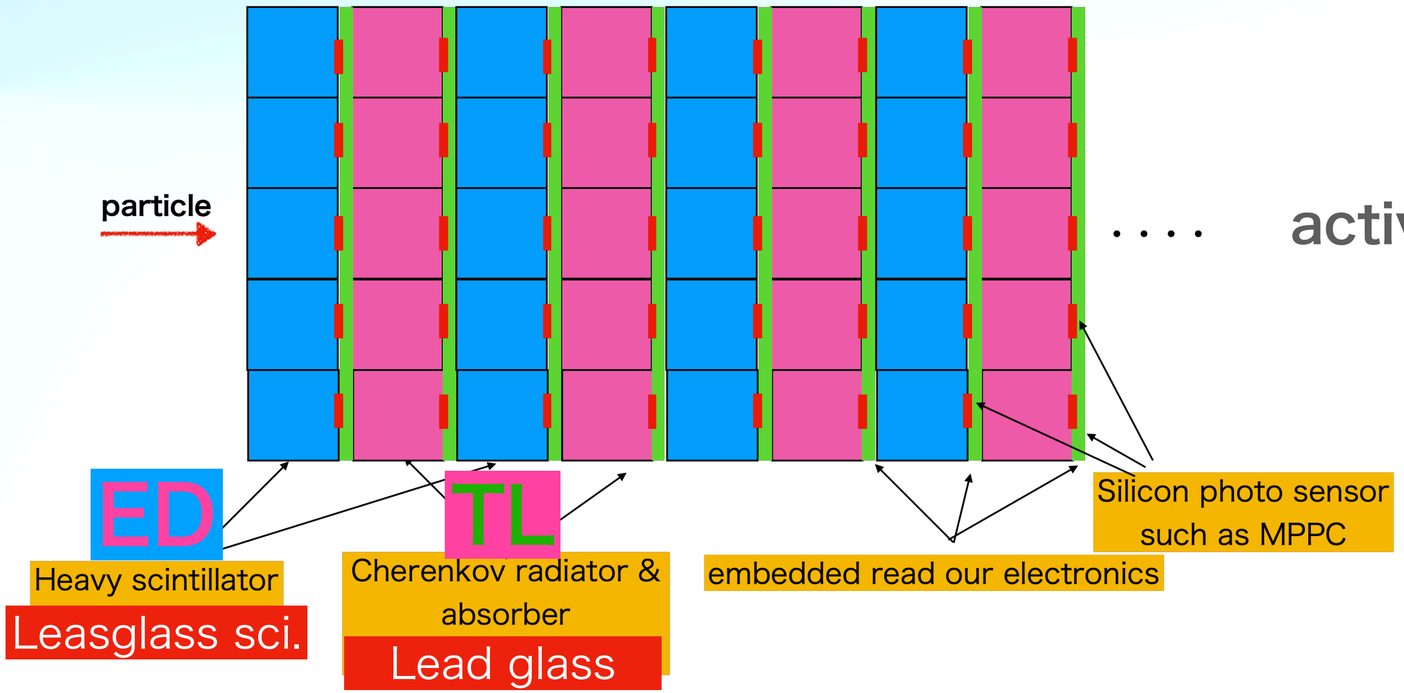


a new idea :Double readout Sandwich Calorimeter of glass

- 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

Segmented in three dimensions according to the physics requirements

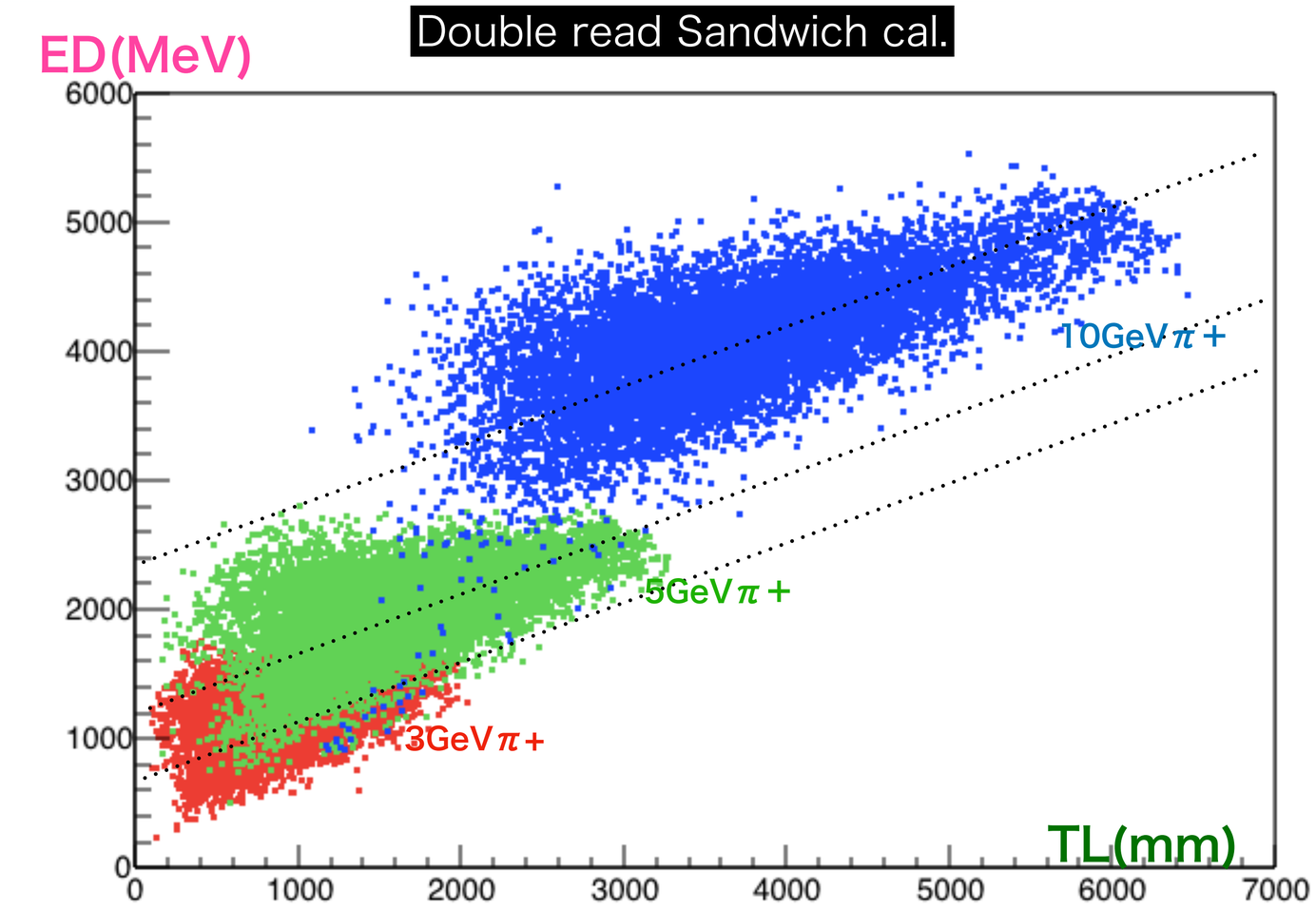
Double readout Sandwich Calorimeter



performance of DSC (2mx2mx2m cal)

Double read Sandwich cal. simulation

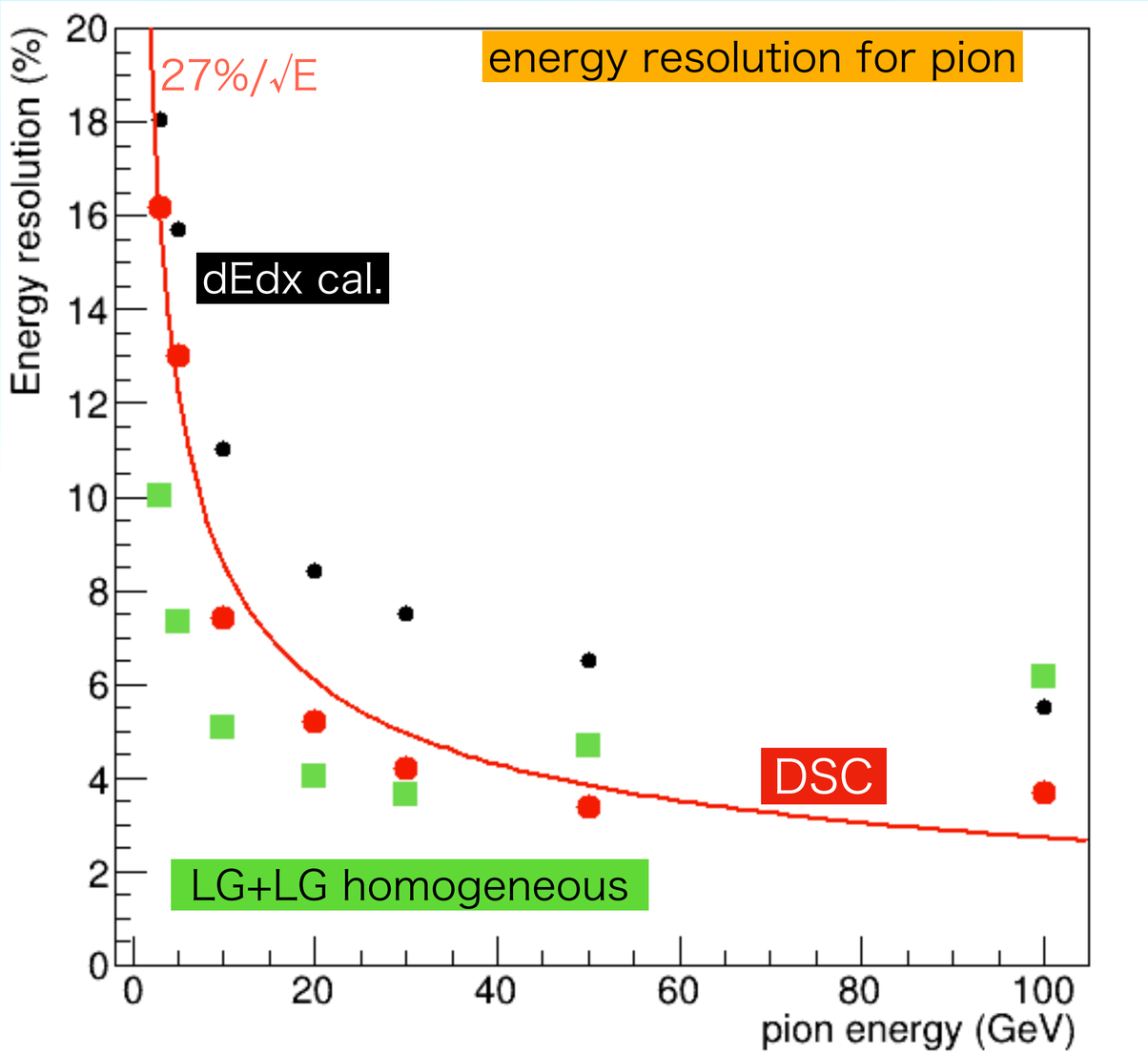
- ED vs TL relation holds for sandwich calorimeter
- LG2cm+LGSci.2cm 50layers
- distributions are wider than homogeneous cal.
- sampling fraction is 0.5 while Homogeneous cal. =1



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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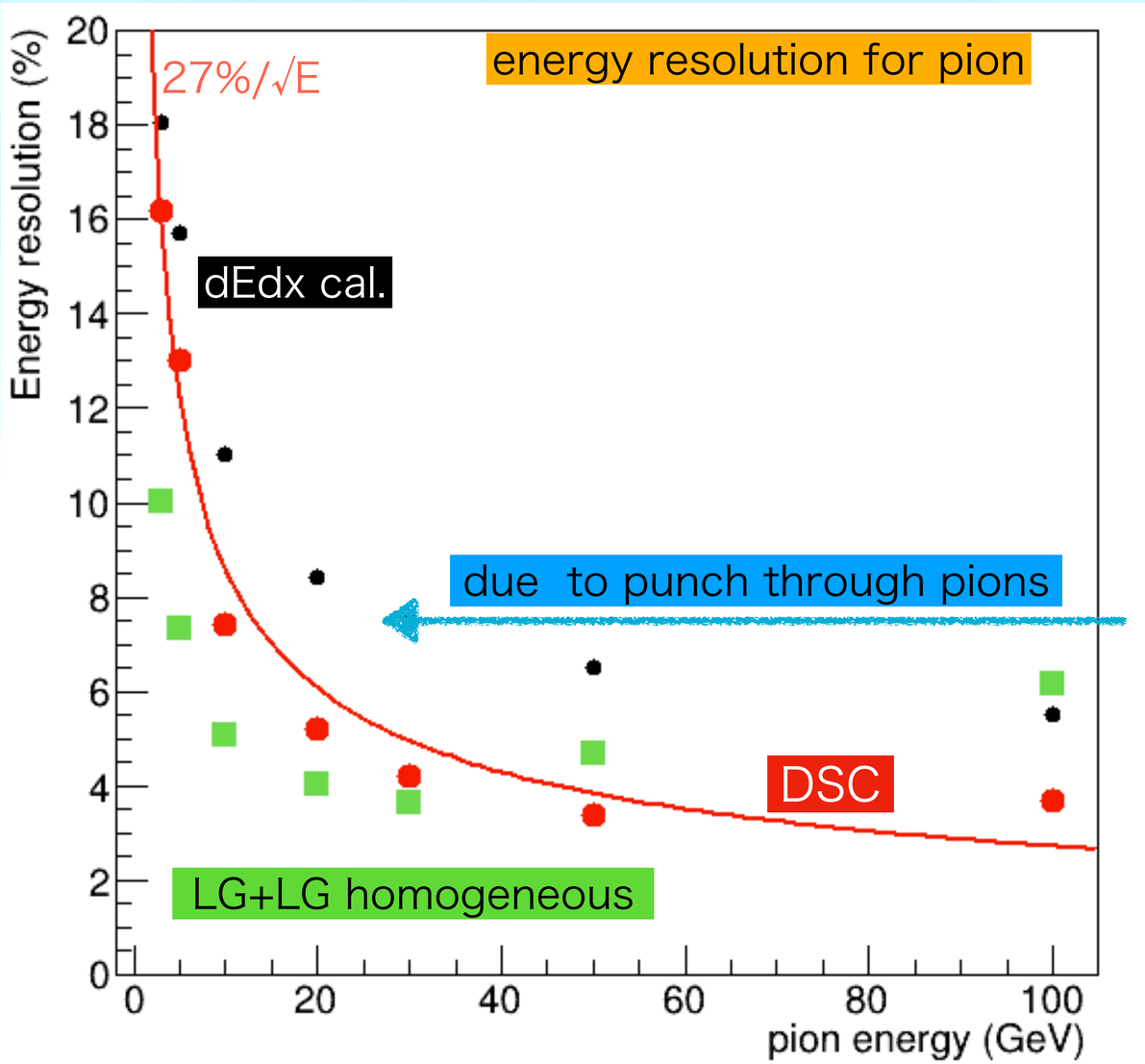
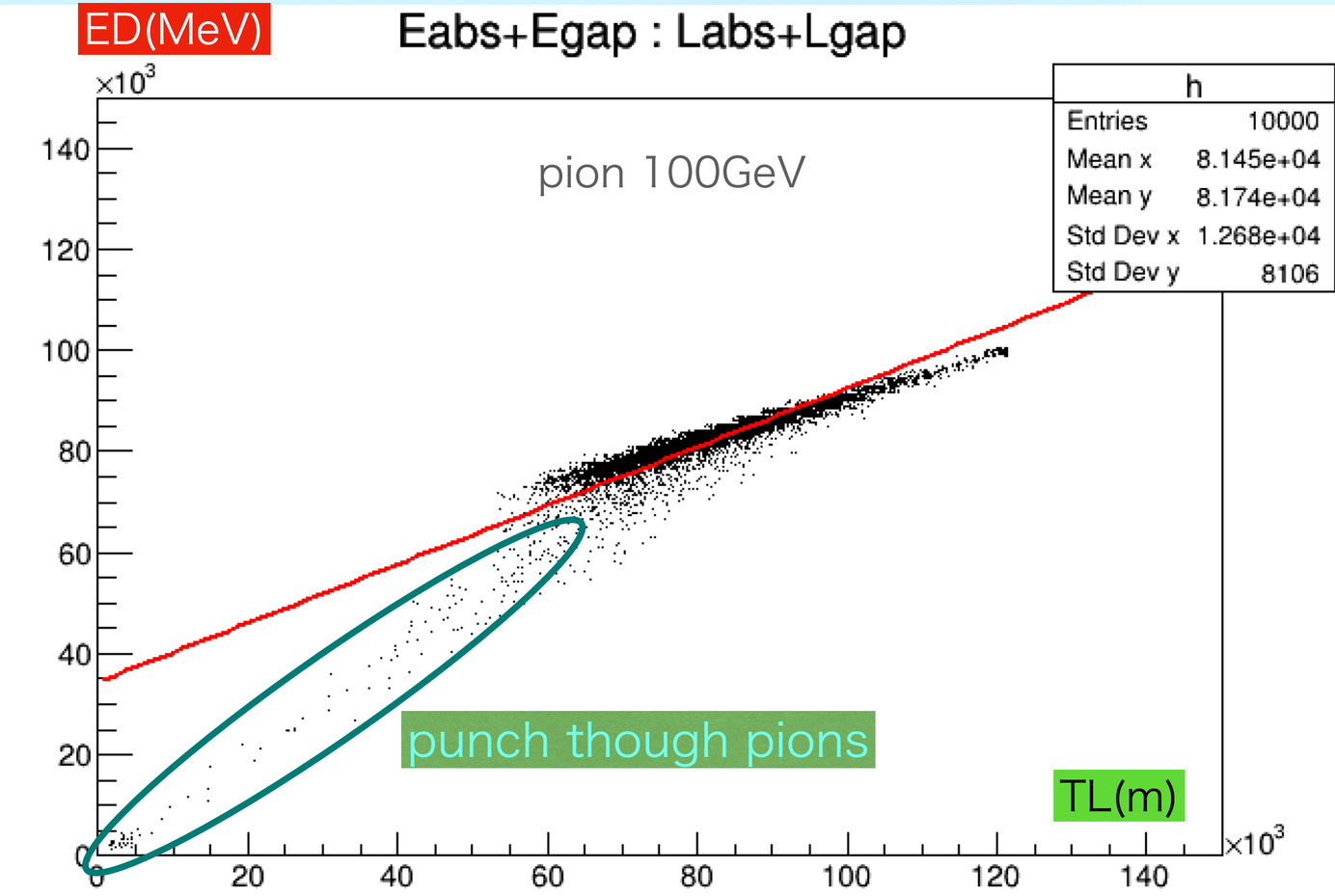


effect of punch through pions

naive strait line fittings are not representing the distribution

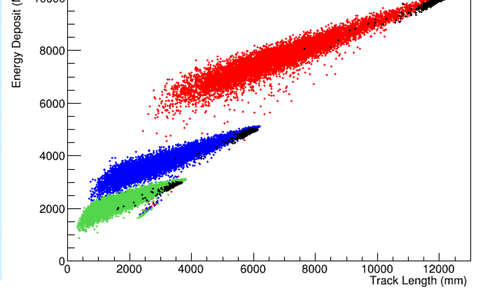
- fitted line in red ends up not accurately representing the distribution
  deteriorate line fitting
- naive linear fitting is affected by low E events
- due to punch though pions
- in this analysis, I did nothing to remove those events



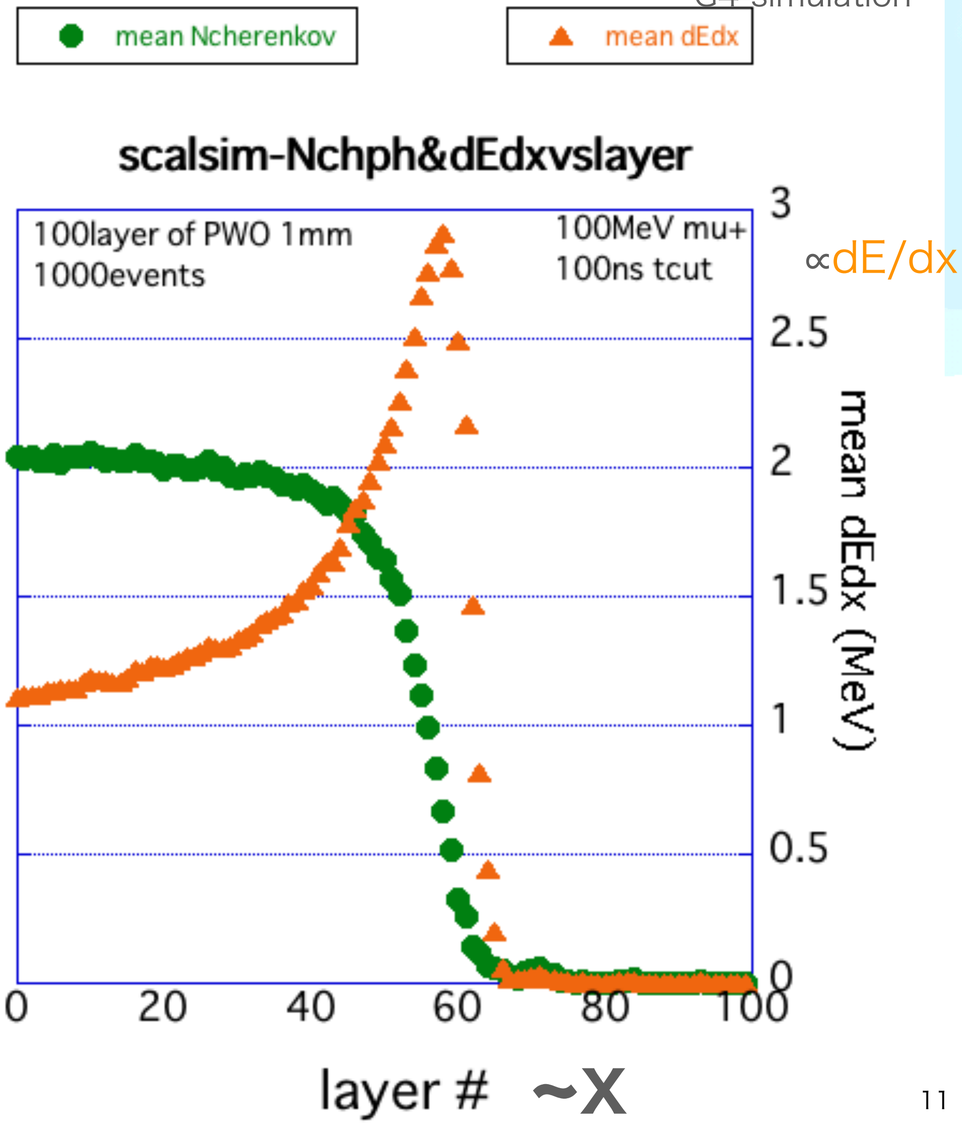
reason of intercept

when a particle stops in a shower

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



G4-simulation



no contribution to Cherenkov light measurement

TL ~ Cherenkov light

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

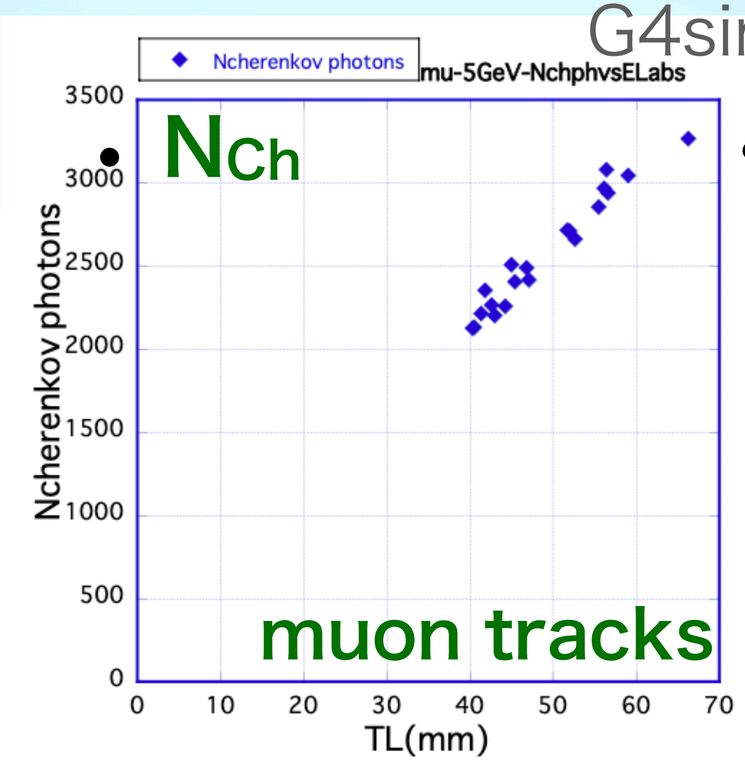
Frank-Tamm

- Cherenkov radiation energy loss
- Cherenkov photons = N
- $N_{Ch} \propto x = TL$

$n(\omega) \sim n$.

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

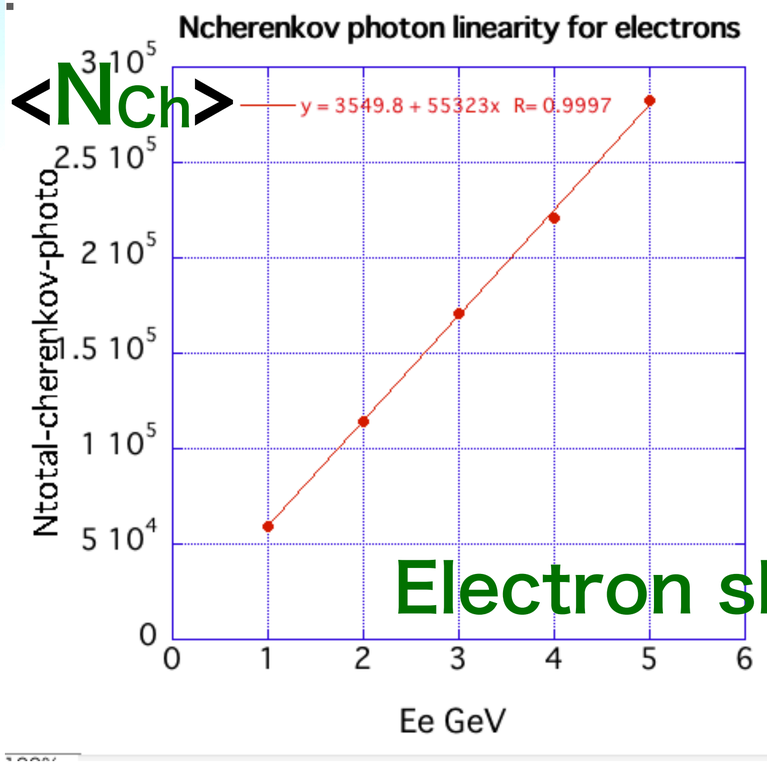
G4sim.



- N_{Ch}

muon tracks

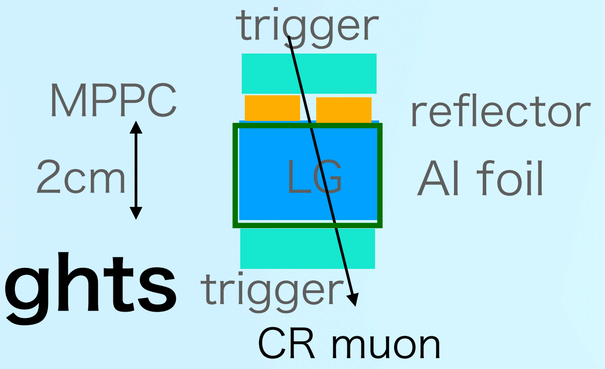
G4sim.



- $<N_{Ch}>$

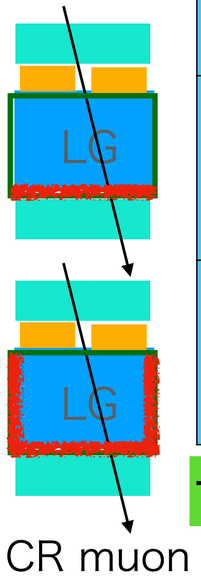
Electron shower

Feasibility of the DSC



Cherenkov tile will generate small number of lights

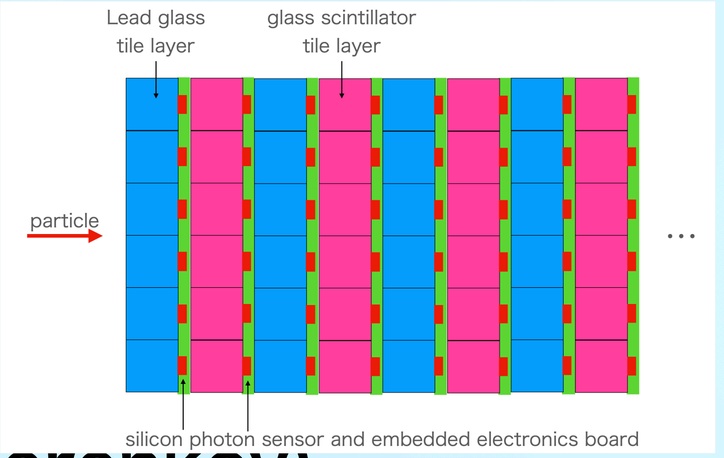
- **LG: 2cm^t x3x3cm^2** (PFA cal.)
  all polished &1 non-pol.
  grease coupled MPPCs
  UV and normal MPPC
  6mmx6mm
- **LY is good for the calorimeter**
- UV light does not transmit in glass
- polished surface can increase collection efficiency



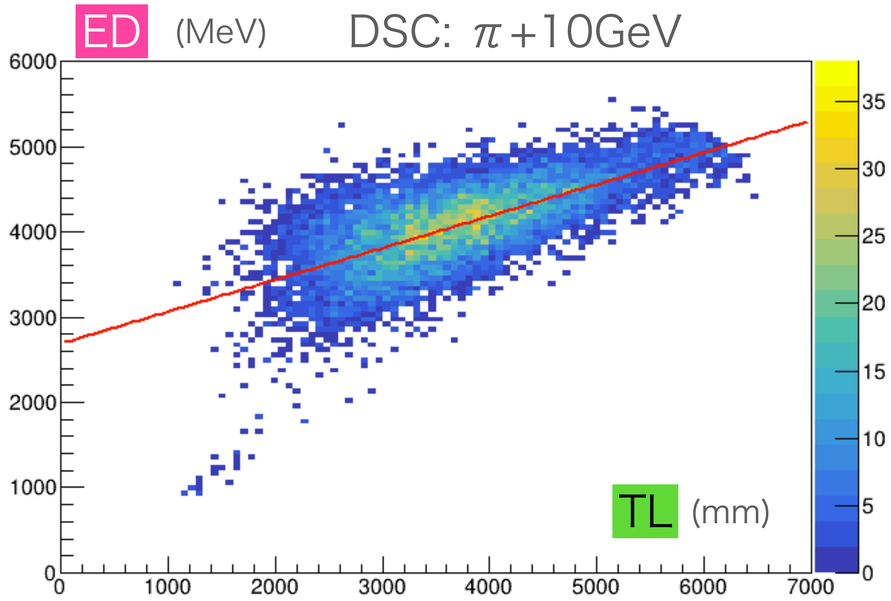
LY(pe)	normal PPD	UV PPD
all polished	12	12
1 unpolish	8	8
4 unpolish	15	-

timing resolution < 100ps

summary and outlook



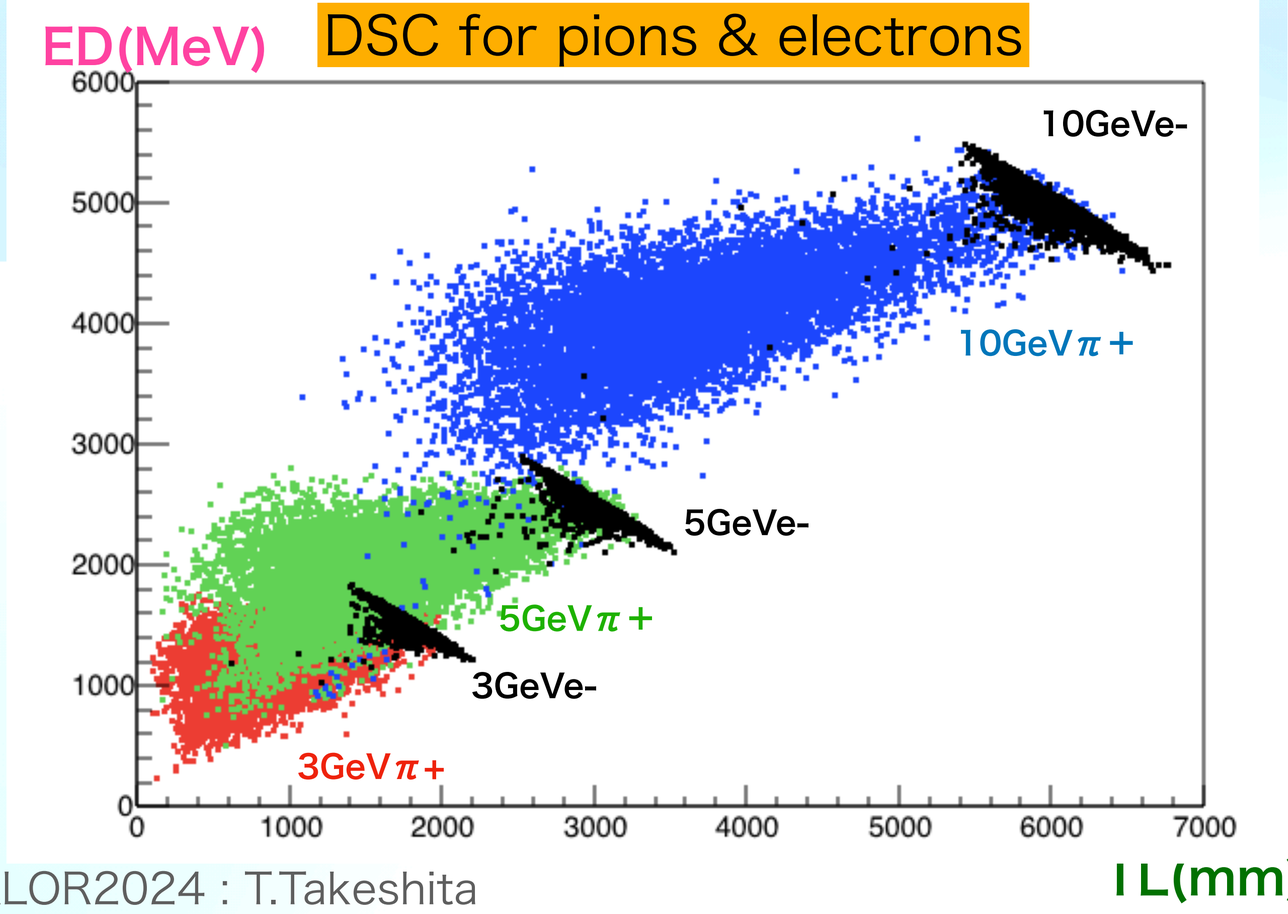
- Double readout glass sandwich calorimeter
  < Homogeneous cal. simulation
- linear correlation between sum of Track Length (Cherenkov) and Energy Deposit (scintillation) guides studies
- actual implementation is proposed as DglassSC with fine energy resolution
- R&D for DSC is on going
  - how to throw away punch through pions
  - Cherenkov light in the sci-glass
  - production of scintillating glass with Quantum Dots

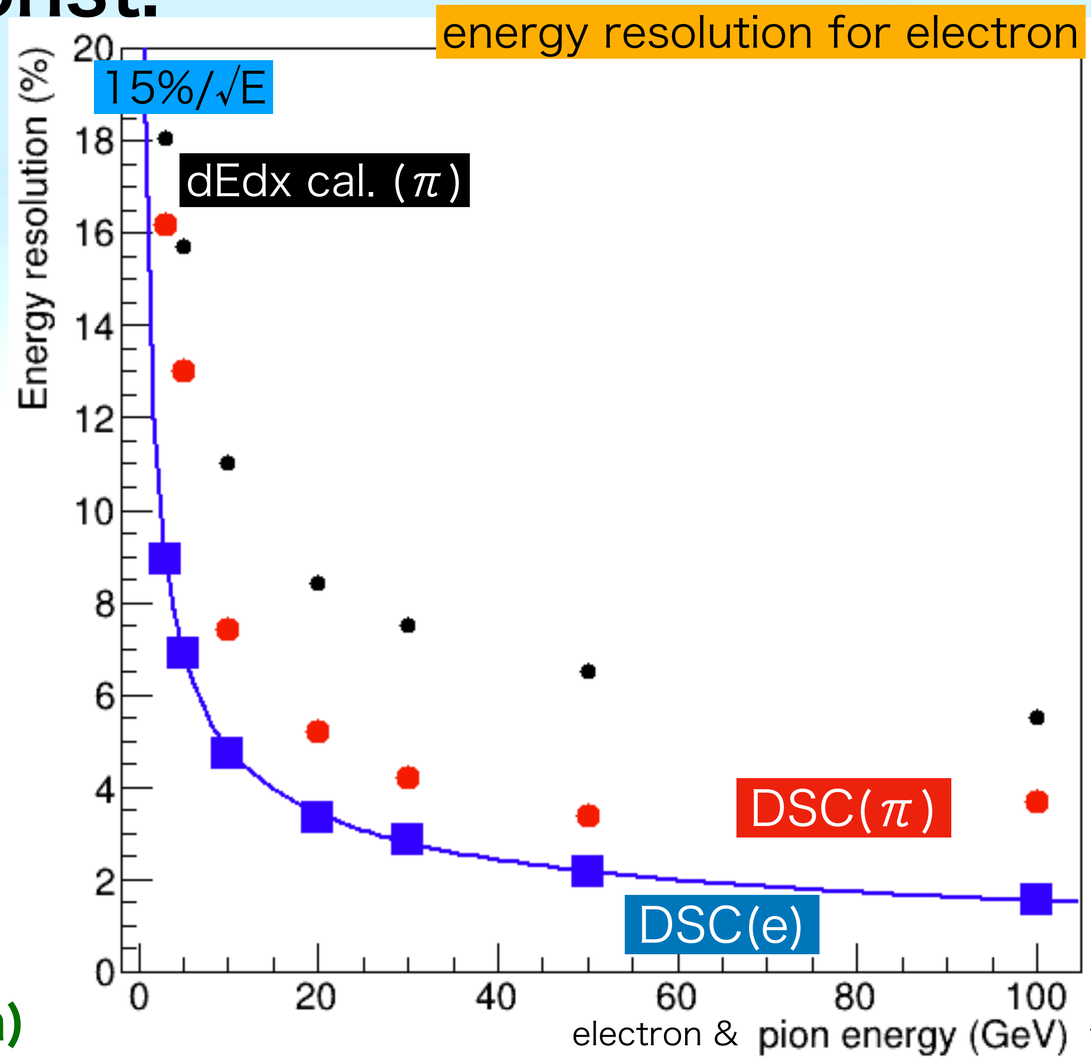


electrons on DSC

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

~ 15%/√(E)



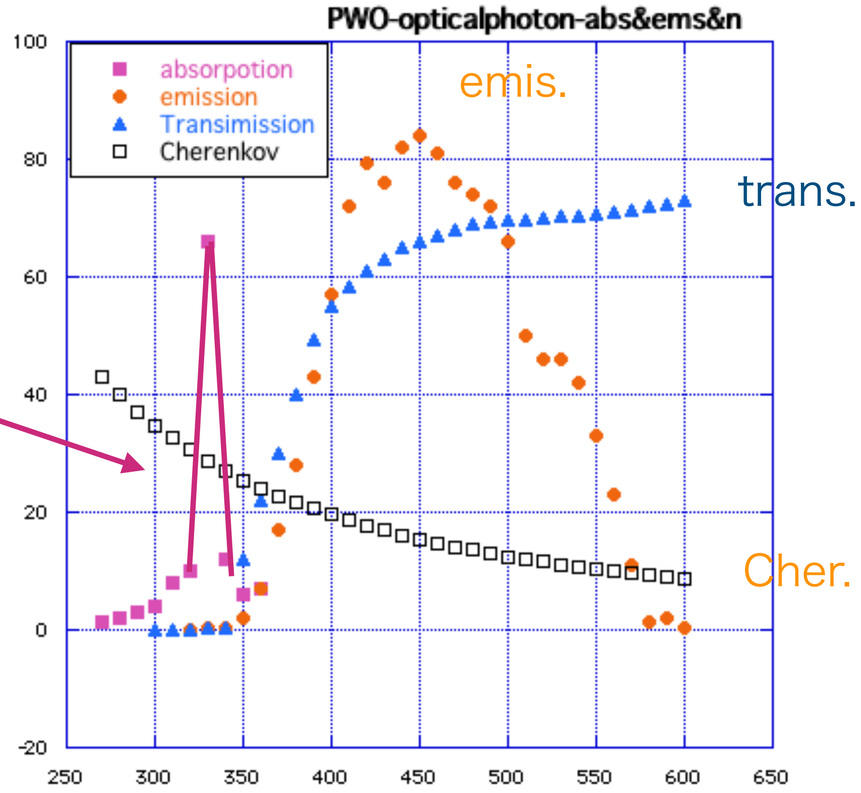


Separation of Cherenkov & Scintillation light

- 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