Double Readout sandwich calorimeter

Tohru Takeshita (Shinshu)

CALICE meeting at Göttingen 30Mar2023

- Homogeneous calorimeter simulation

- double readout sandwich calorimeter

Homogeneous CAL

- **simulation with GEANT4.11.0 with FTFP_BERT**
  photon statistics is not taken into account   (2mx2mx2m)

- **two parameters to measure**

  - **sum of Track Length (TL) ~ Cherenkov light**

  - **sum of Energy Deposit (ED)~ Scintillation light**
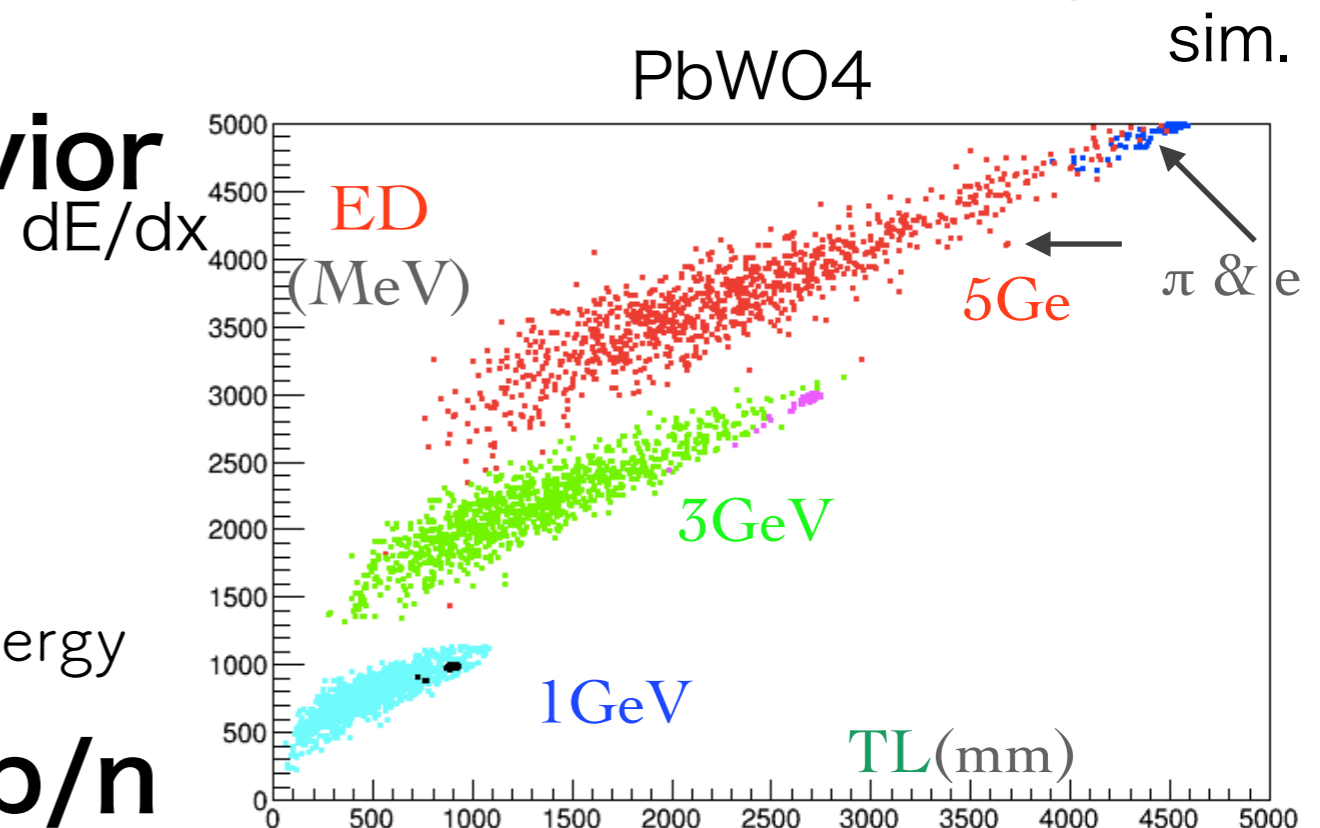
- **correlation : linear behavior**
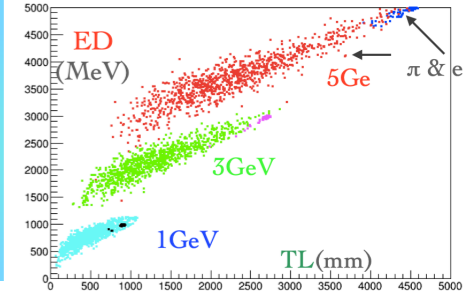 linearly fitted

  - **intercept → linearity**
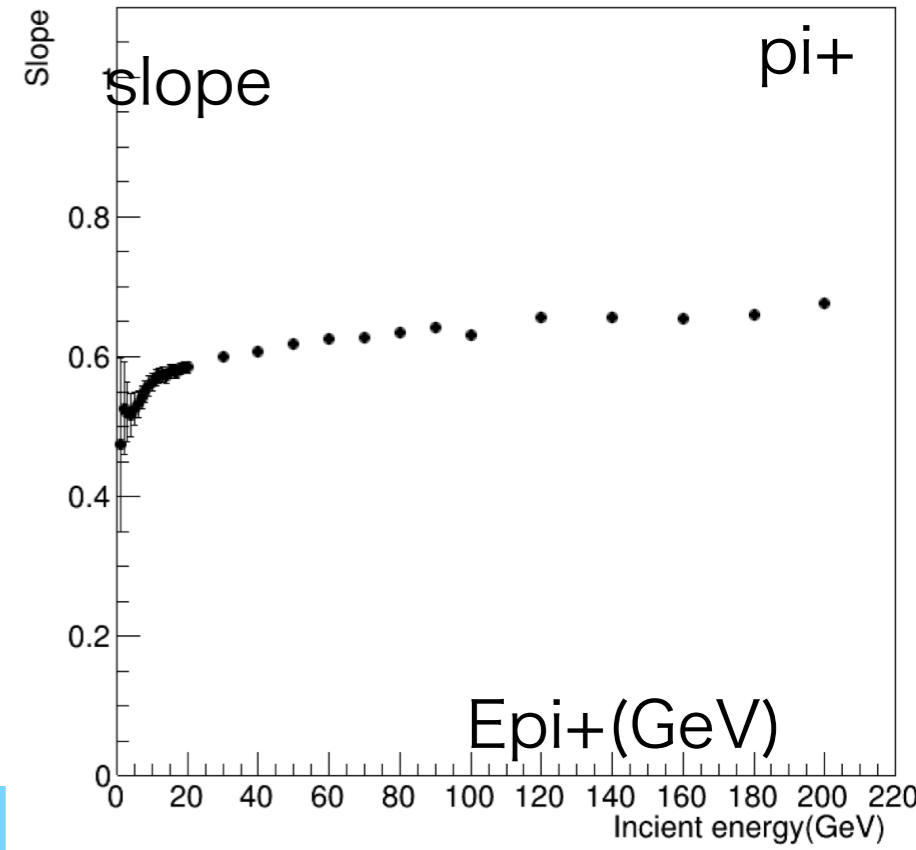
  - **slope → constant**
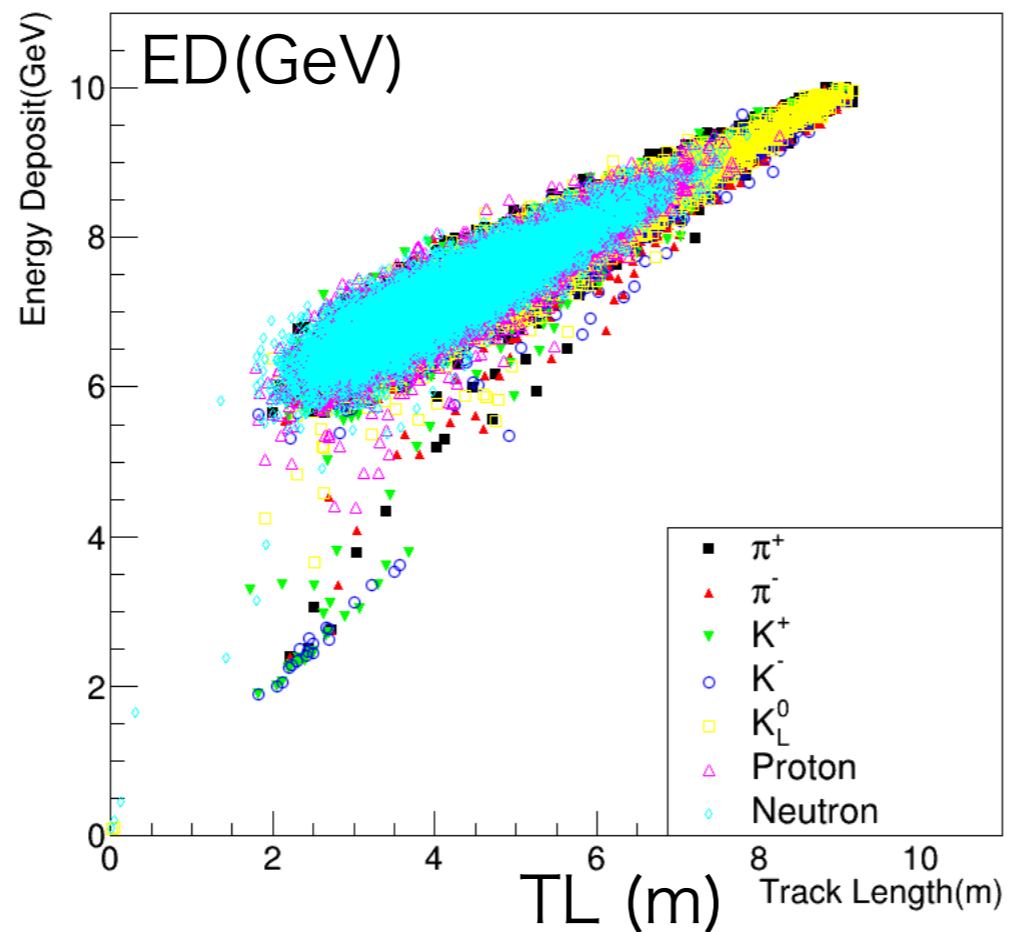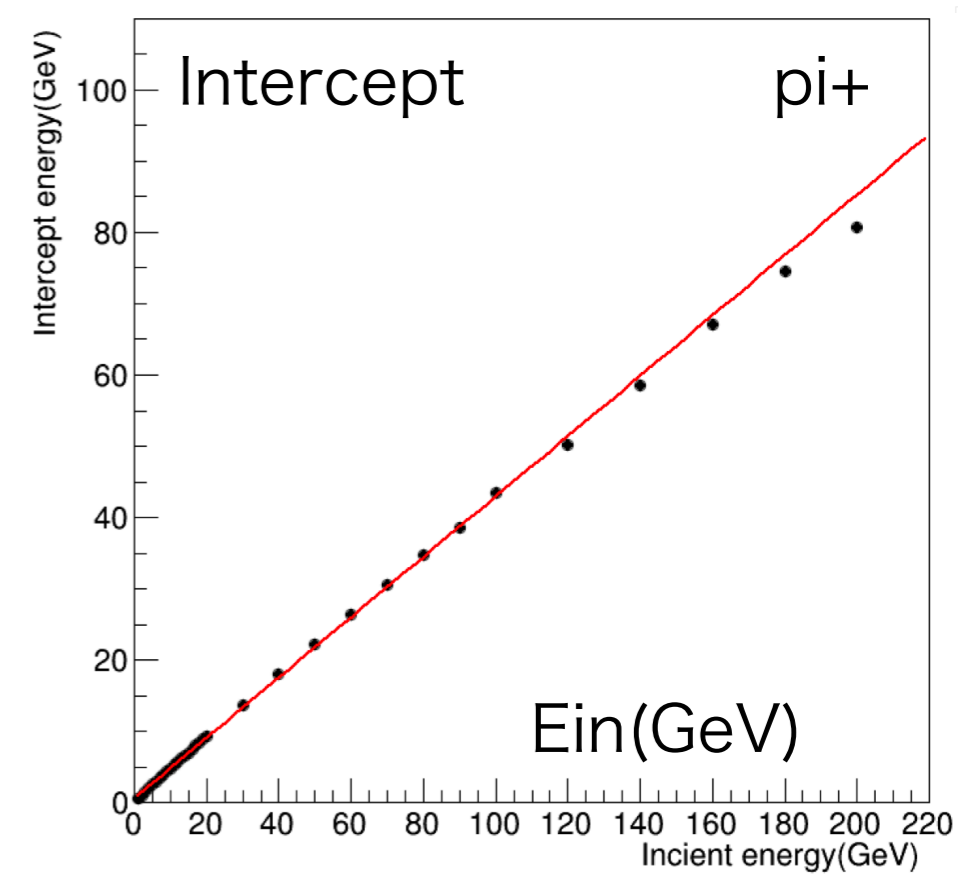   independent of energy

  - **common for e/pi/K/p/n**

Intercept & Slope

- ## good linearity on intercept
  work as a calorimeter

- ## slopes are almost constant

- ## slopes are same for particles

energy resolution

- good correlation between ED and TL

- Energy measured by the intercept

- energy resolution is expressed by intercept width : projected to dEdx=ED axis

- fine energy resolution will be achieved

energy resolution (homo)

dEdx only

$26\%/\sqrt{E_{\mathbf{GeV}}}+3\%$

$14\%/\sqrt{E_{\mathbf{GeV}}}+1\%$

projection
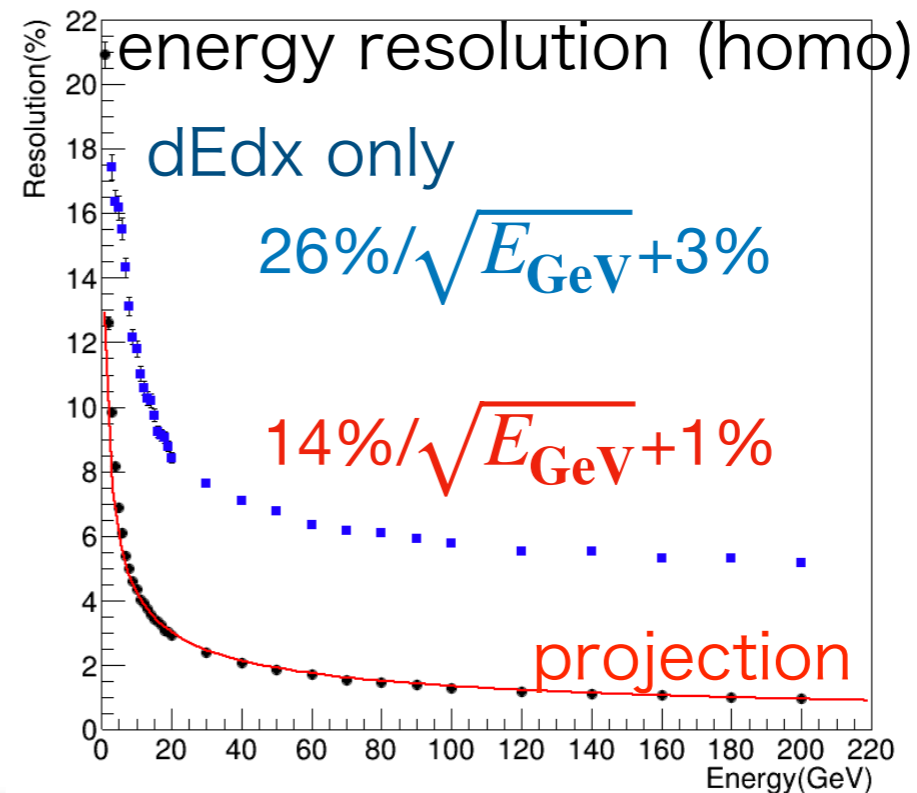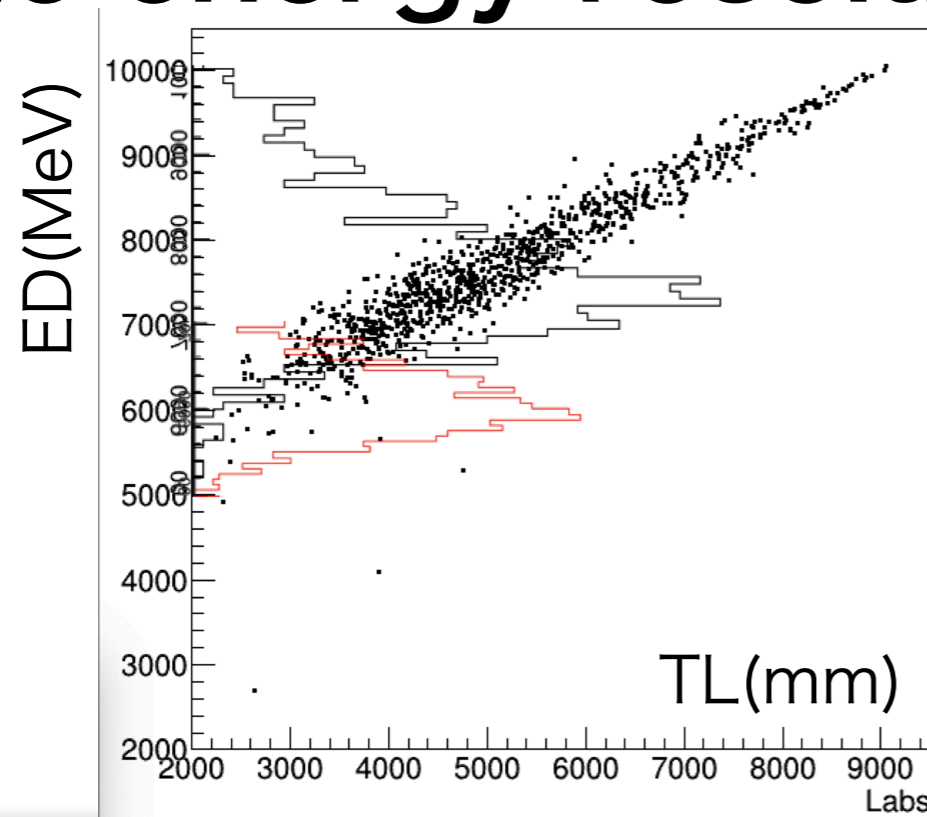
Cherenkov light

- Track length ~ Cherenkov lights

- Cherenkov is low light and $1/\lambda^2$

  - need heavy and UV transparent material

  - will be absorbed and converted to scintillation light
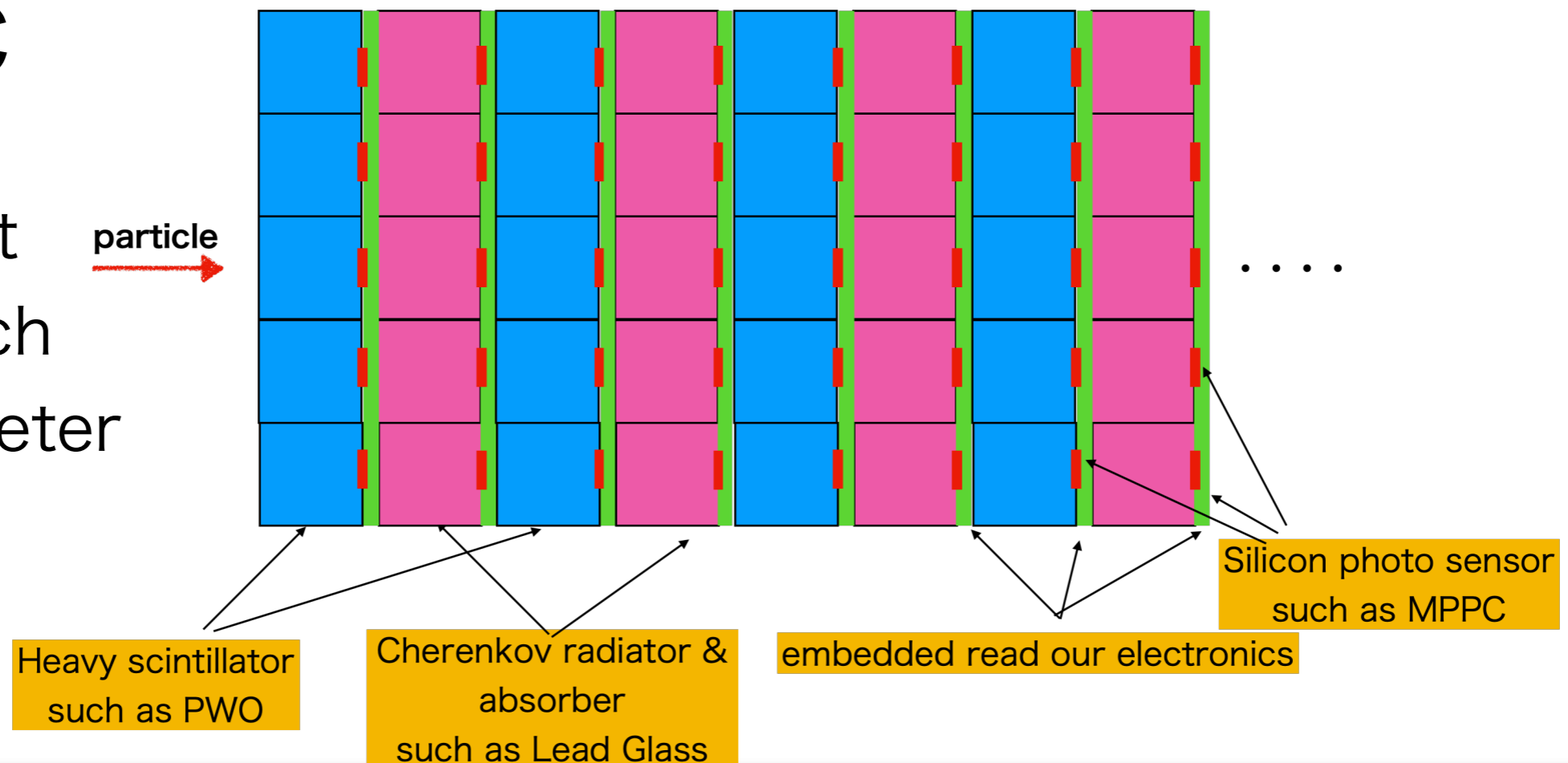
- difficult to separate lights
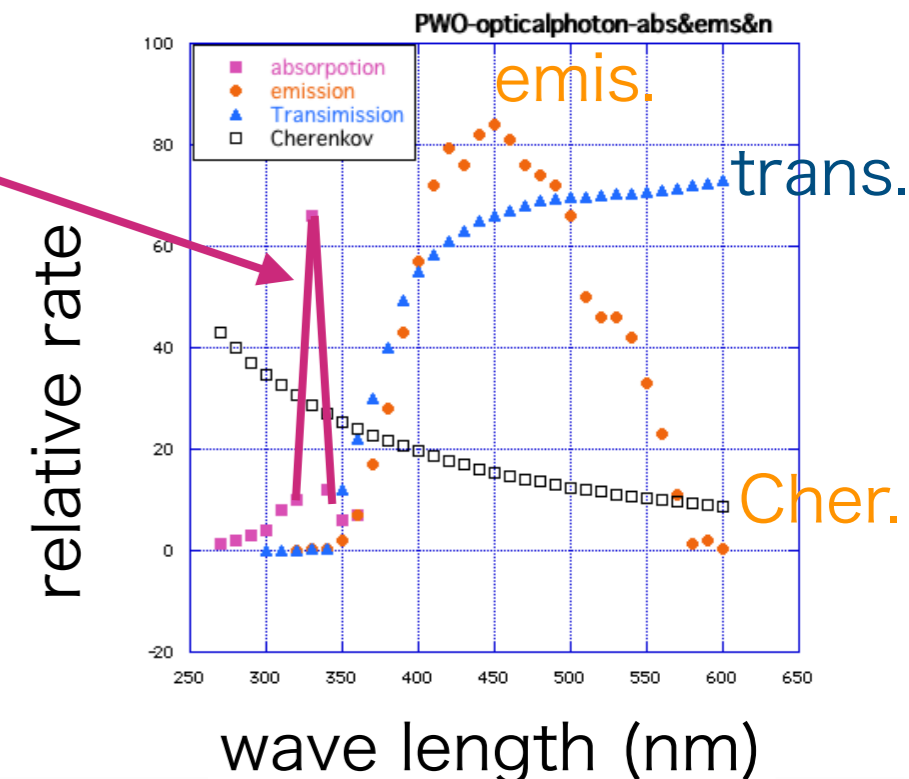
a new idea :DRSC

- separate Cherenkov radiator and
Scintillation material with sandwich cal.
- with highly granular option for PFA

- DRSC
Double
Readout
Sandwich
Calorimeter

Segmented in three dimensions according to the physics requirements

particle

....

Heavy scintillator
such as PWO

Cherenkov radiator &
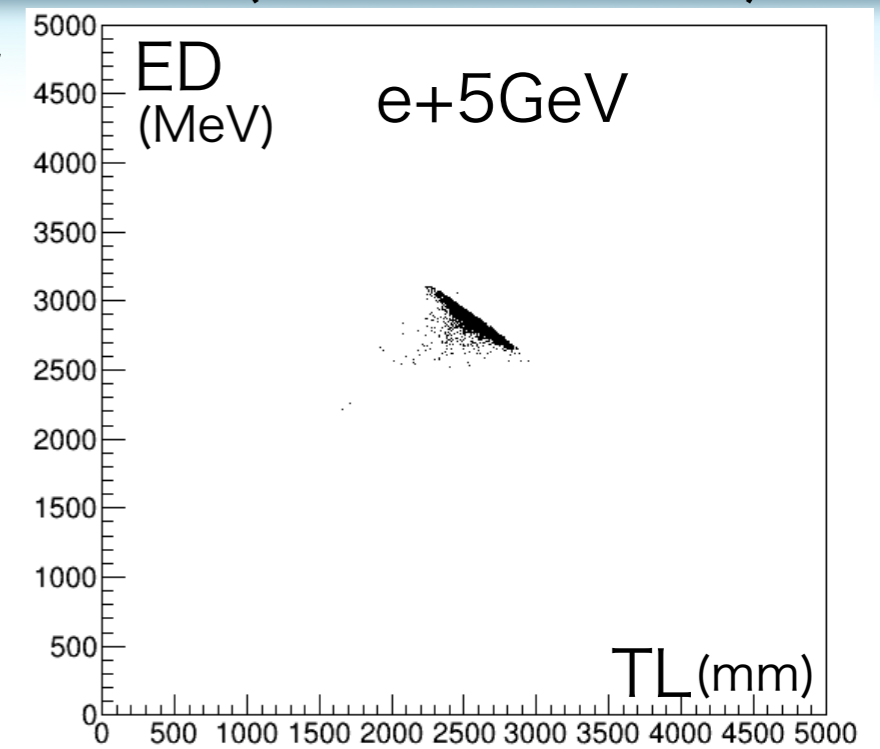absorber
such as Lead Glass

embedded read our electronics

Silicon photo sensor
such as MPPC

performance of DRSC
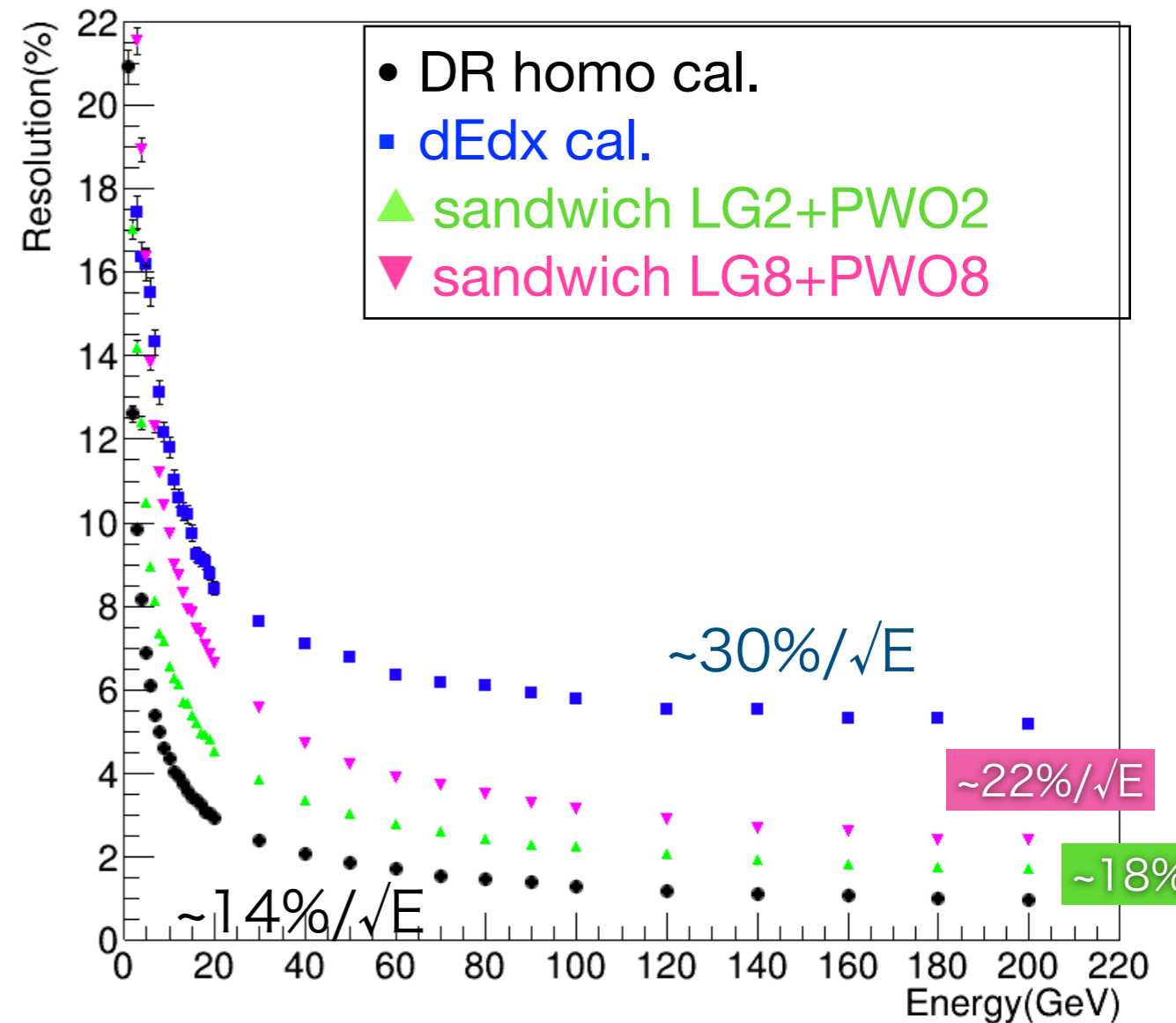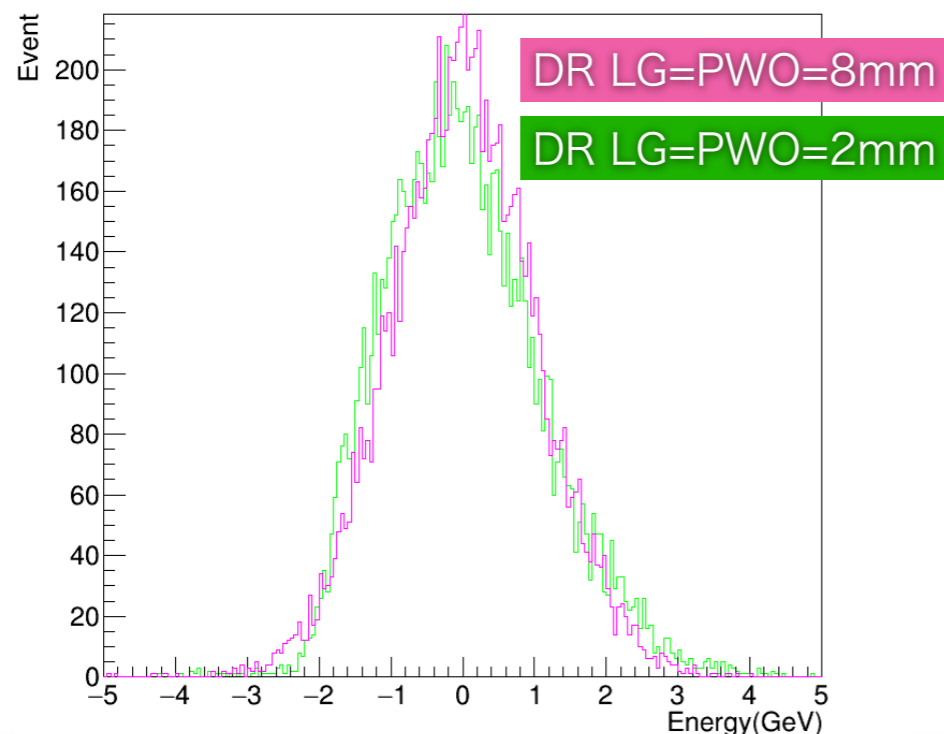(2mx2mx2m cal)

- ED vs TL relation holds for sandwich calorimeter

- for both e's and pions

- LG8mm+PWO8 125layers
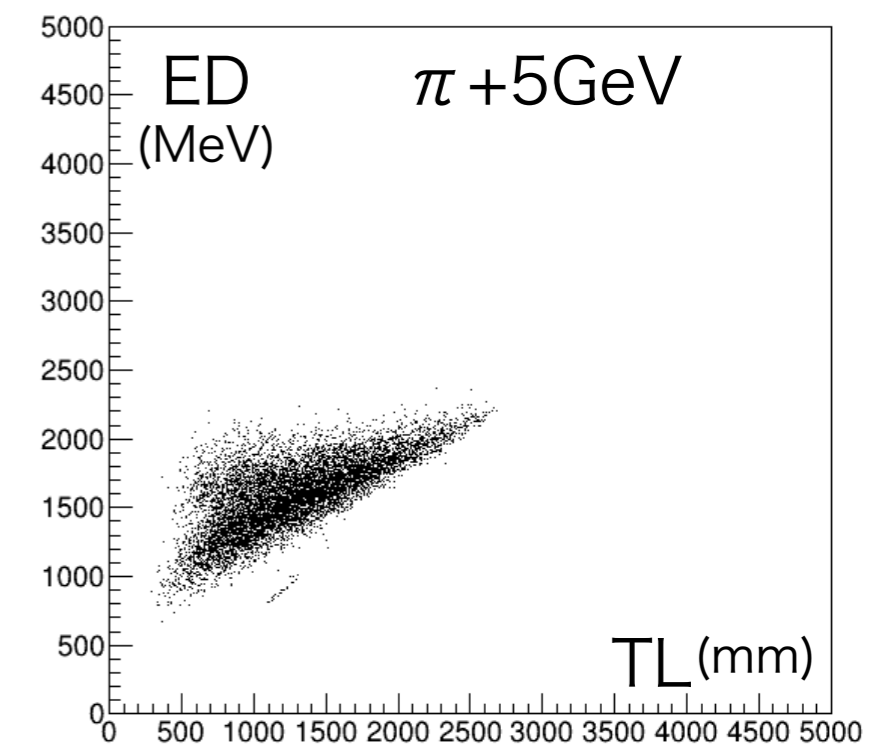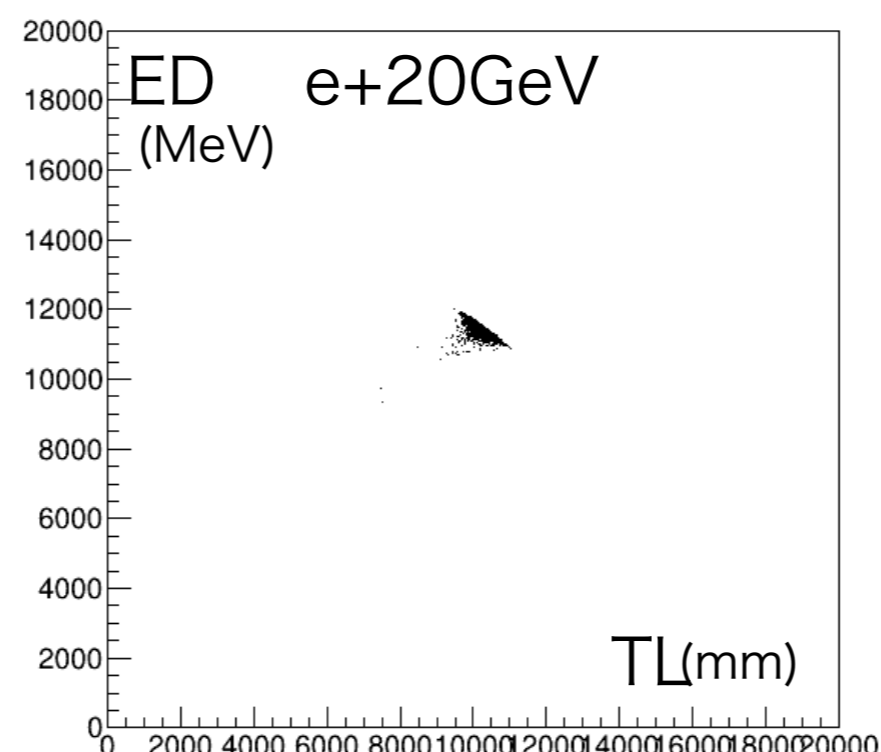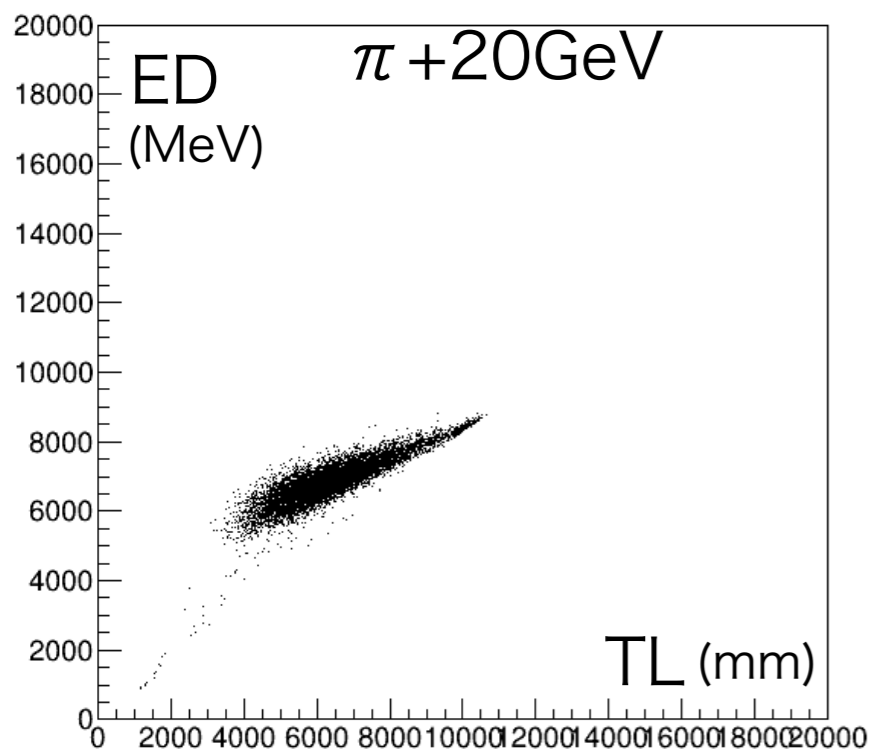
resolution of DRSC

- ~20%/√E(GeV) with DRSC
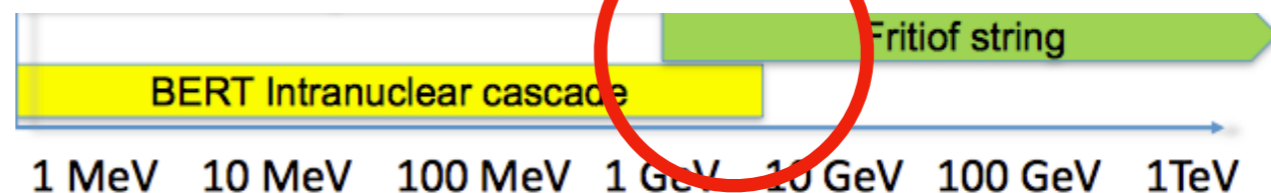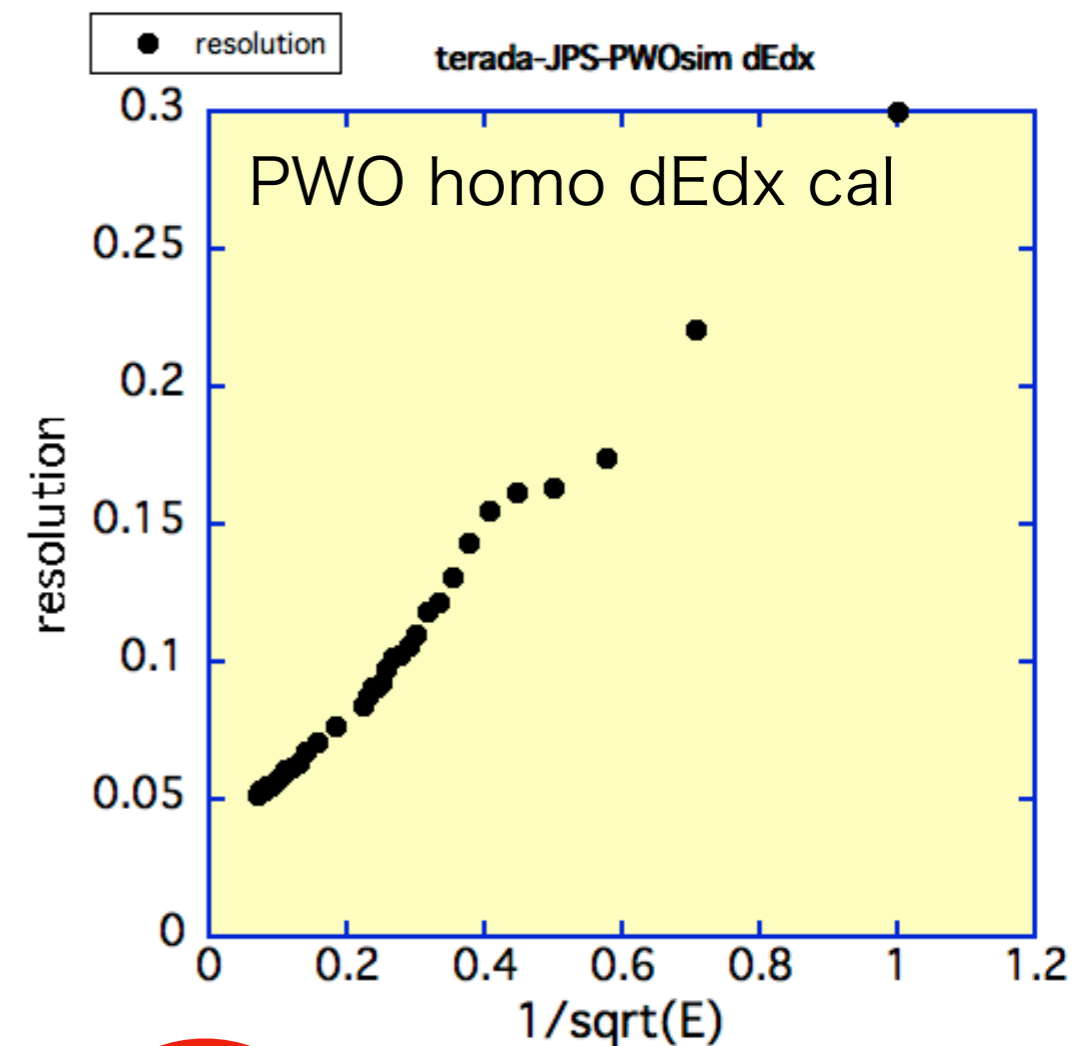
- much better than dEdx calorimeter : traditional cal.

energy resolution

- compare dEdx cal. and DRSC in terms of 1/√E

- dEdx cal. suffers from. Hadron model interference?
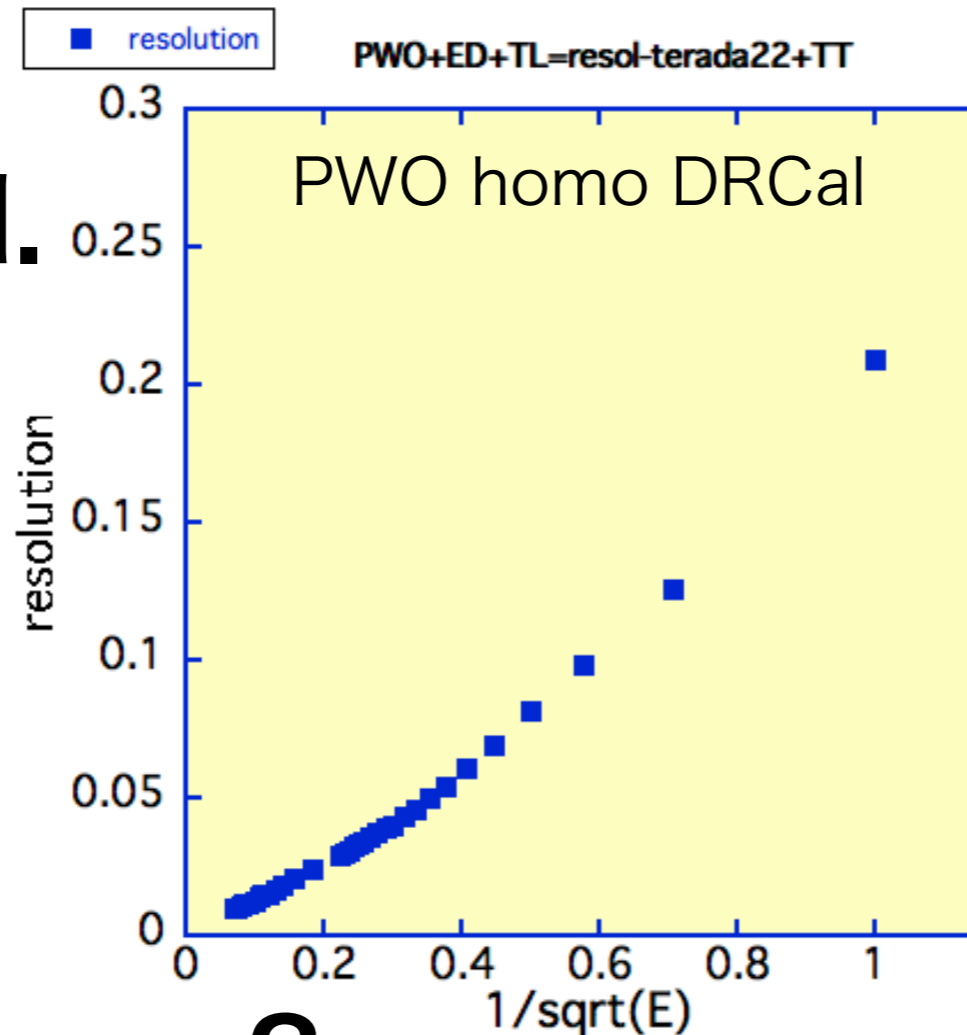
hardware development

- **Cherenkov detection in Lead Glass and UV transparent radiator**

- **VUV-MPPC**

Transmittance

visible light

Glass
厚9mm

Lead Glass

LX-57B
14mm
11mm
9mm
7mm
6mm

$n \sim 2$
$\rho \sim 6$

λ (nm)

JGS1

UV grade Fused Silica is synthetic amorphous silicon dioxide of extremely high purity

PDE

PDE

(Typ. Ta=25 °C)
- · - S13360-**50PE
— S13360-**50CS

PDE

VUV4-50ump
VUV3-50ump

JGS1

$n = 1.4$
$\rho \sim 2.2$

Ultraviolet Grade Fused Silica (JGS1)

wavelength(nm)

DoubleRO Sandwich CAL @ CALICE2023 : T.Takeshita
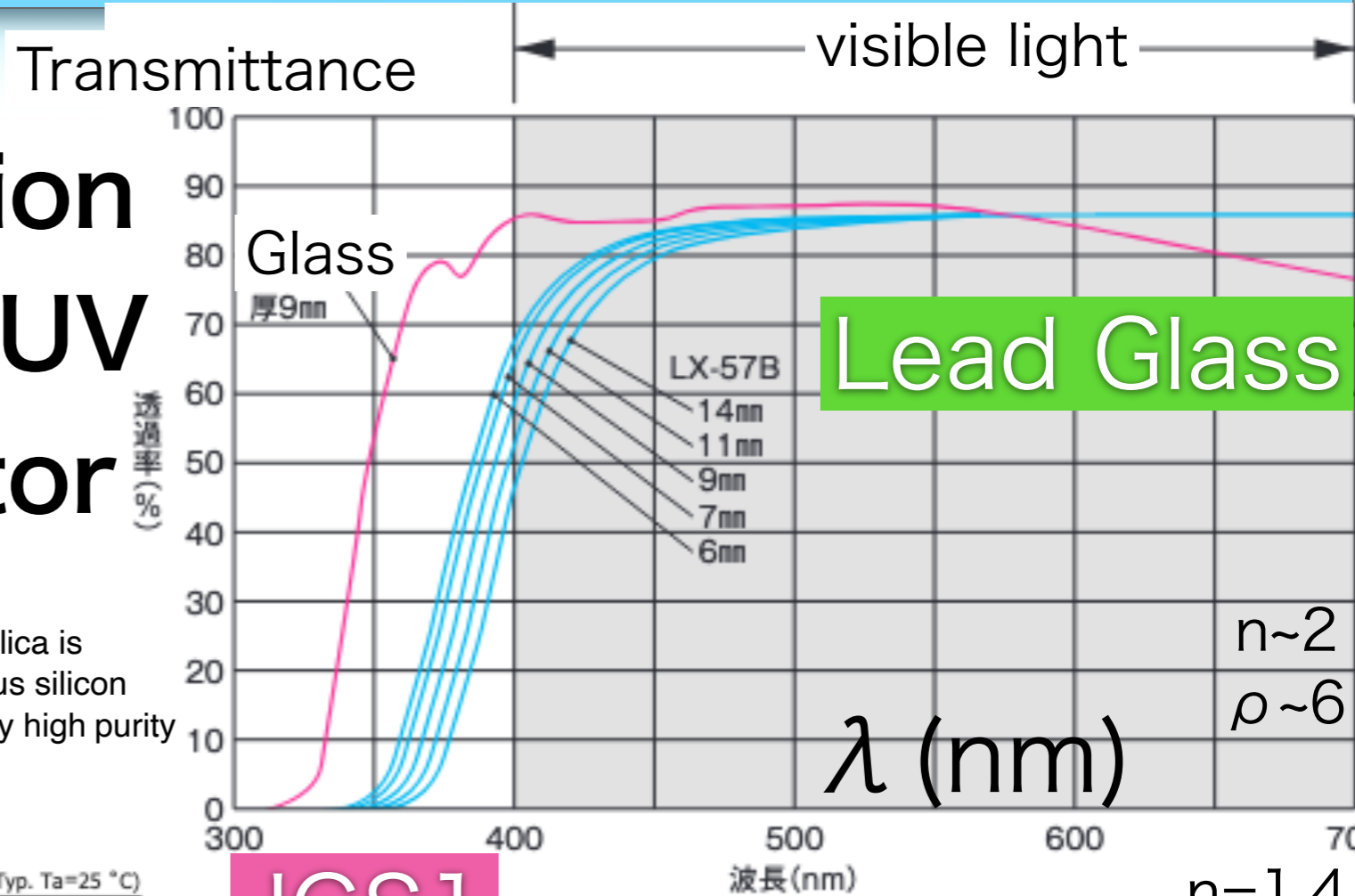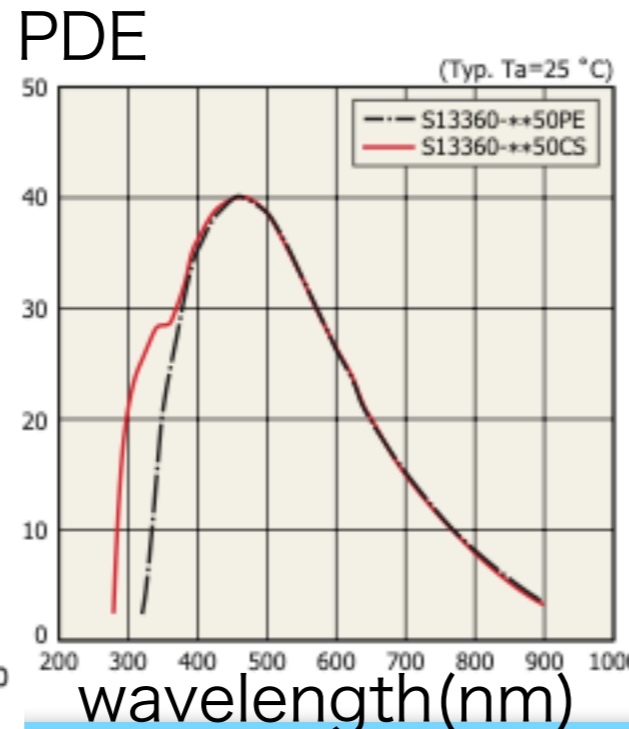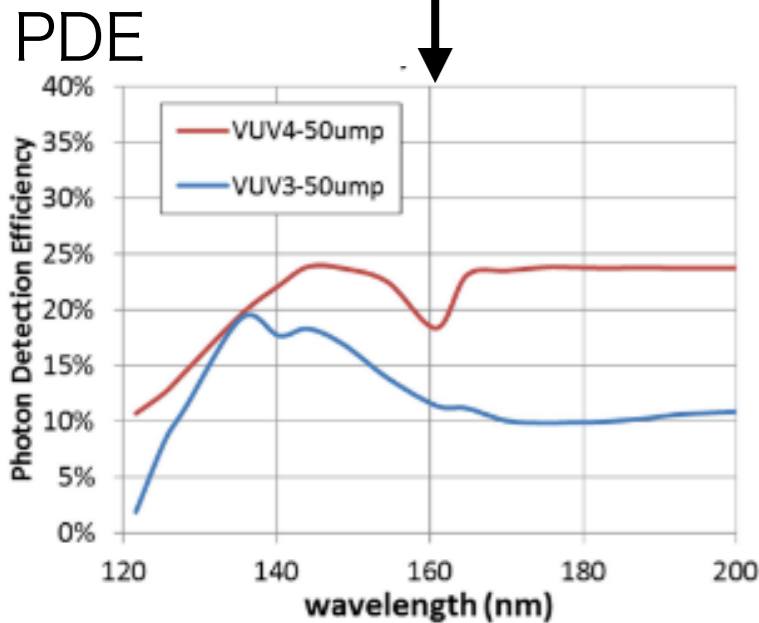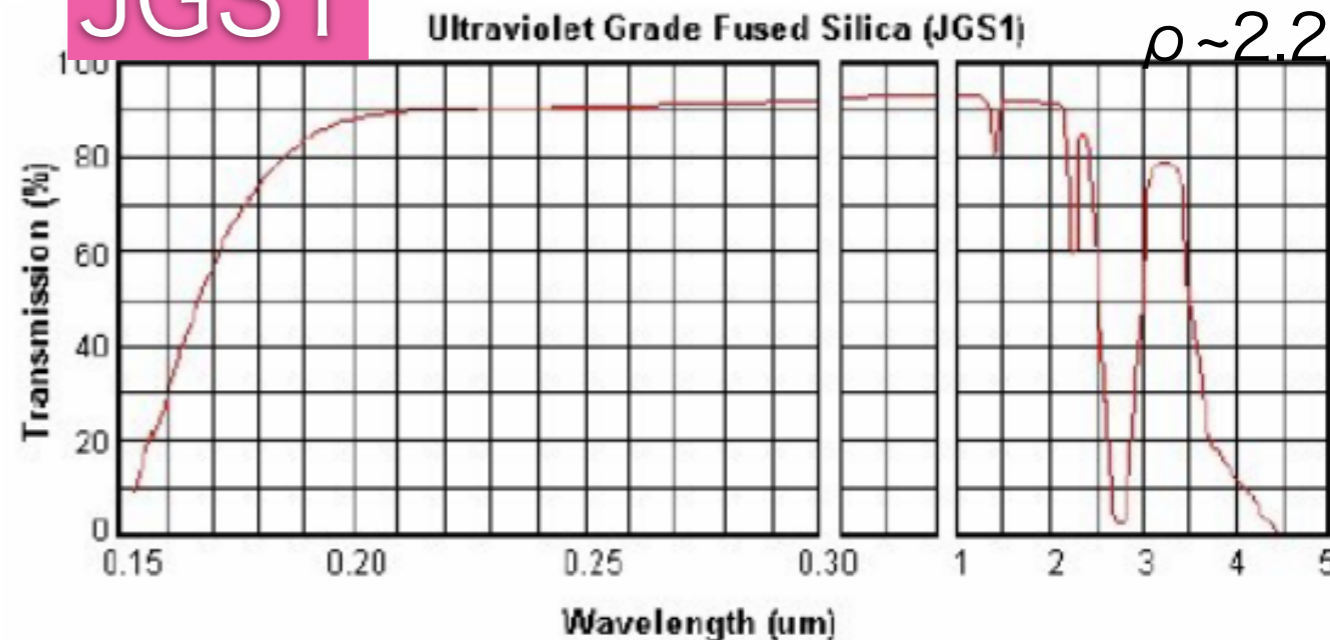
hardware development

- **Cherenkov detection in Lead Glass block**

  for PFA

  - **3cmx3cm blocks**

    grease required

  - **10cmx10cm x1cm**

    - **4x(3mmx3mm) MPPC**

      normal

    - **side read with air**

      rough (unpolished)

    - **7pe/MIP**

MPPC1-G
3x3mm2

Trigger
Grease

Cosmic muon

SF6

MPPC2-A
3x3mm2

Air

Trigger

n=1.8, ρ =5.2

trigger

MPPC | 10x10x1:SF6 | MPPC

trigger

n=1.7, ρ =4.4

ped.

landau fit.

ADC ch 2 bin4	
Entries	21965
Mean	741.8
Std Dev	519.1
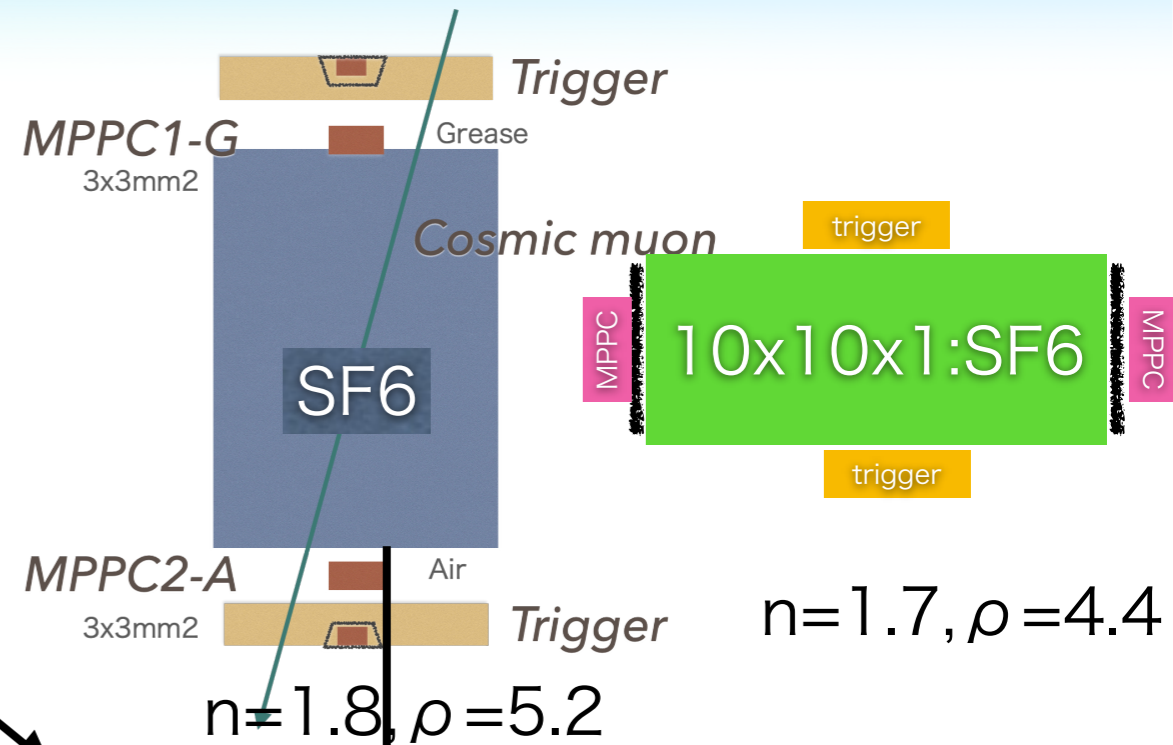
L(cm)	Grease (p.e.)	Air (p.e.)
4cm SF6	35 3x3mm²	7 3x3mm²
2.5cm LX	at work	3 6x6mm²
1cm SF6	at work	7 6x6mm²
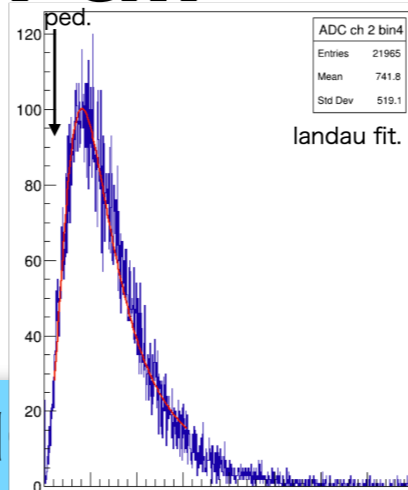
hardware development

- **Cherenkov detection in UV region**

- **radiator : JGS1(1cm)**
  3cmx3cm

- **UV & normal MPPC**

- **6x6mm²**
  coupling

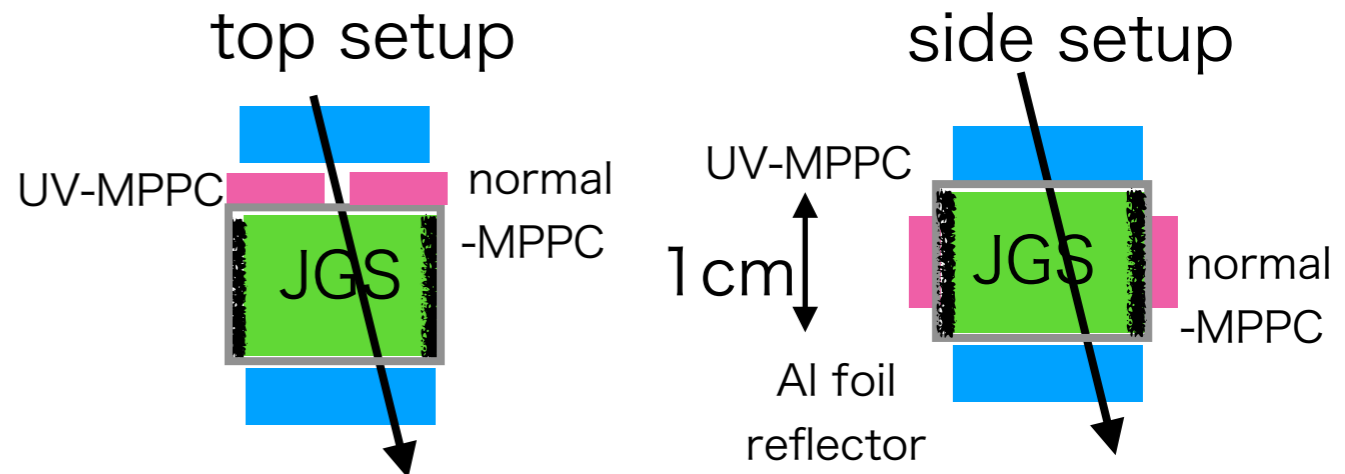- **air & silicon grease**

- **4 unpolished surface**
  inexpensive

top setup

side setup

UV-MPPC   normal-MPPC   UV-MPPC   JGS   normal-MPPC

JGS   1cm

Al foil reflector

| JGS1	Grease top	Air top	Air side
UV (p.e.)	2.7	0.5	3.8
Normal (p.e.)	1.7	0.6	2.5

summary and outlook

- Double Readout sandwich calorimeter

- a relation between sum of Track Length (Cherenkov) and Energy Deposit leads fine energy resolution from sim.

- actual implementation is proposed as DRSC

- R&D for DRSC is on going

  - Cherenkov light detection
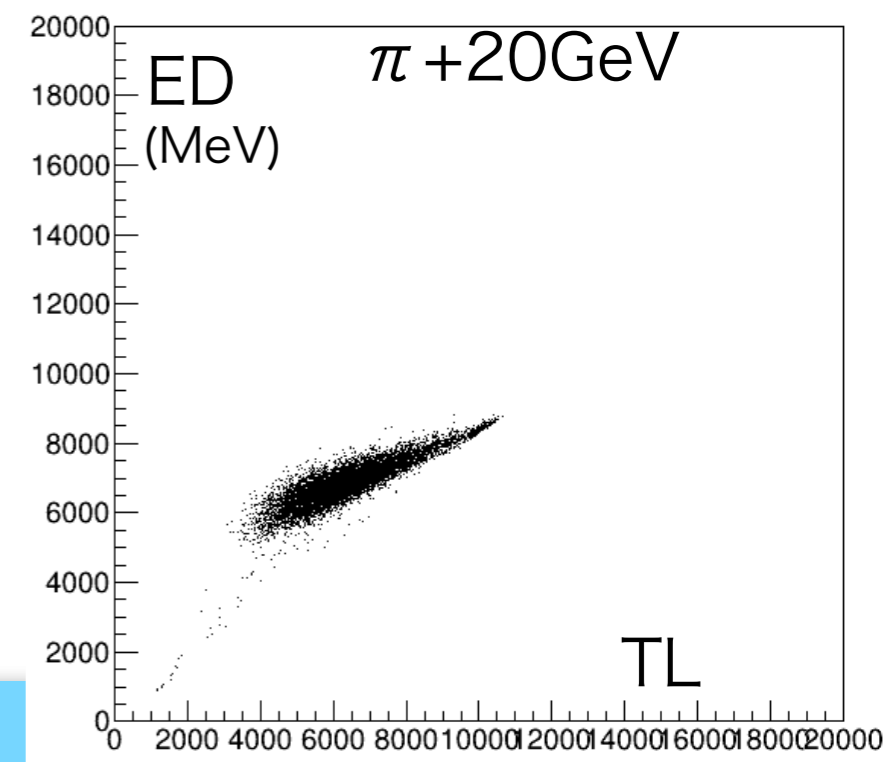
reason of intercept

- when particles stop in a shower

  - Bragg peak will be detected by scintillator

  - no peak for Cherenkov

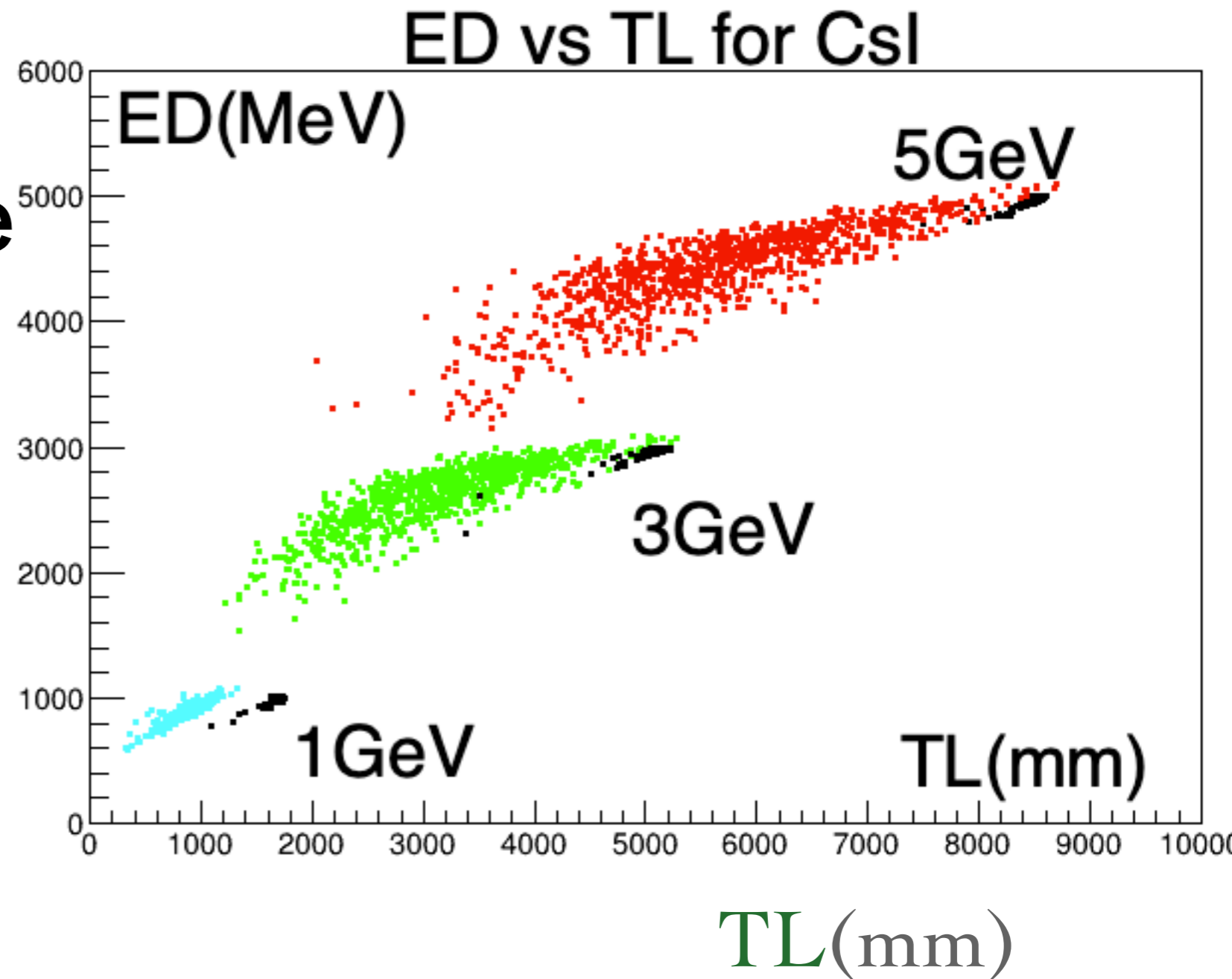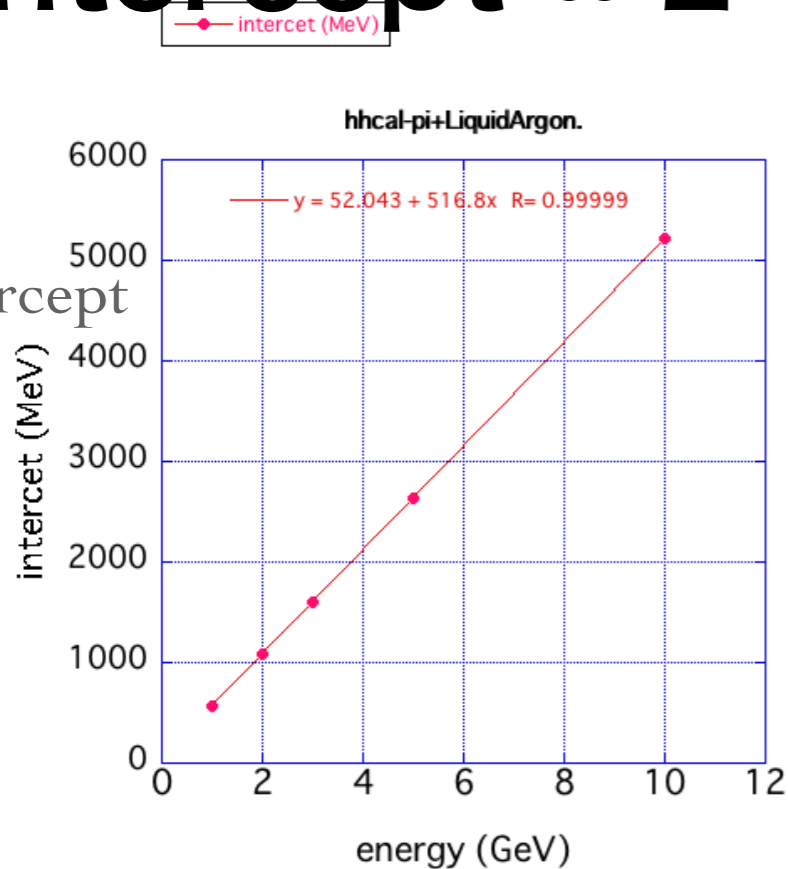- intercept corresponds to number of stopping particles
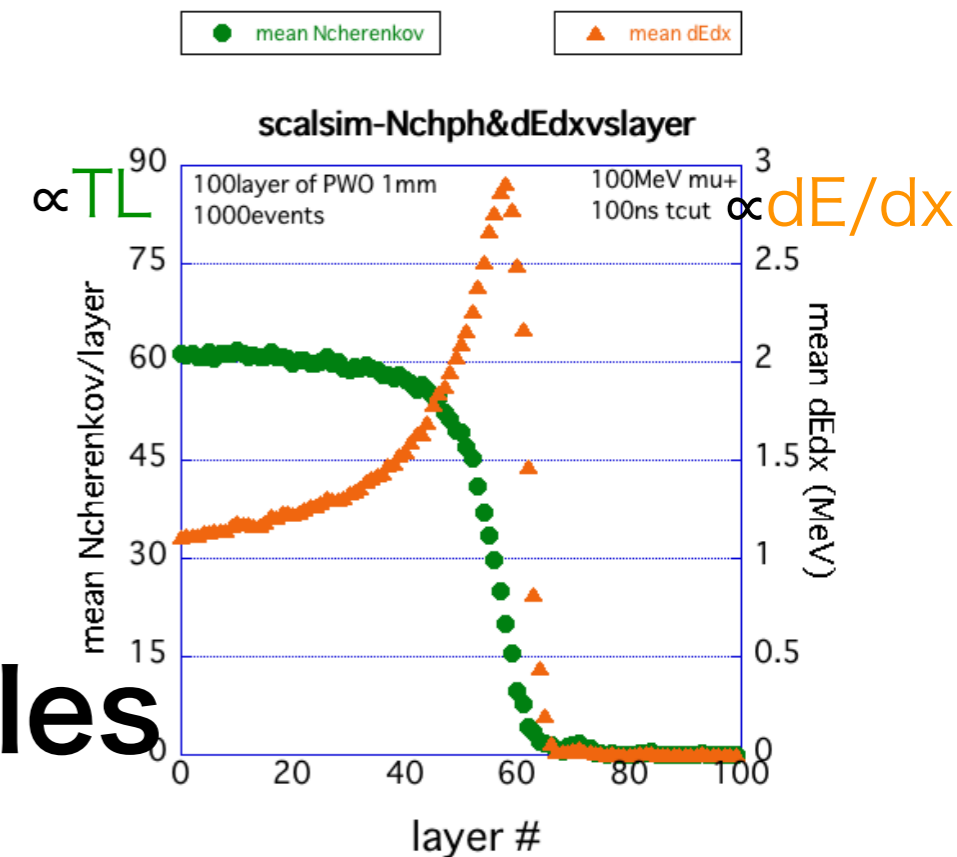
Different detector material

- **Liquid Argon**, & CsI are simulated

- **ED** vs **TL**

- Slopes are same

- Intercept ∝ E

ED

intercet (MeV)

Intercept

hhcal-pi+LiquidArgon.

y = 52.043 + 516.8x R= 0.99999

intercet (MeV)

6000

5000

4000

3000

2000

1000

0

0   2   4   6   8   10   12

energy (GeV)

ED vs TL for CsI

ED(MeV)

6000

5000

4000

3000

2000

1000

0

5GeV

3GeV

1GeV

TL(mm)

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

TL(mm)

TL vs Cherenkov light

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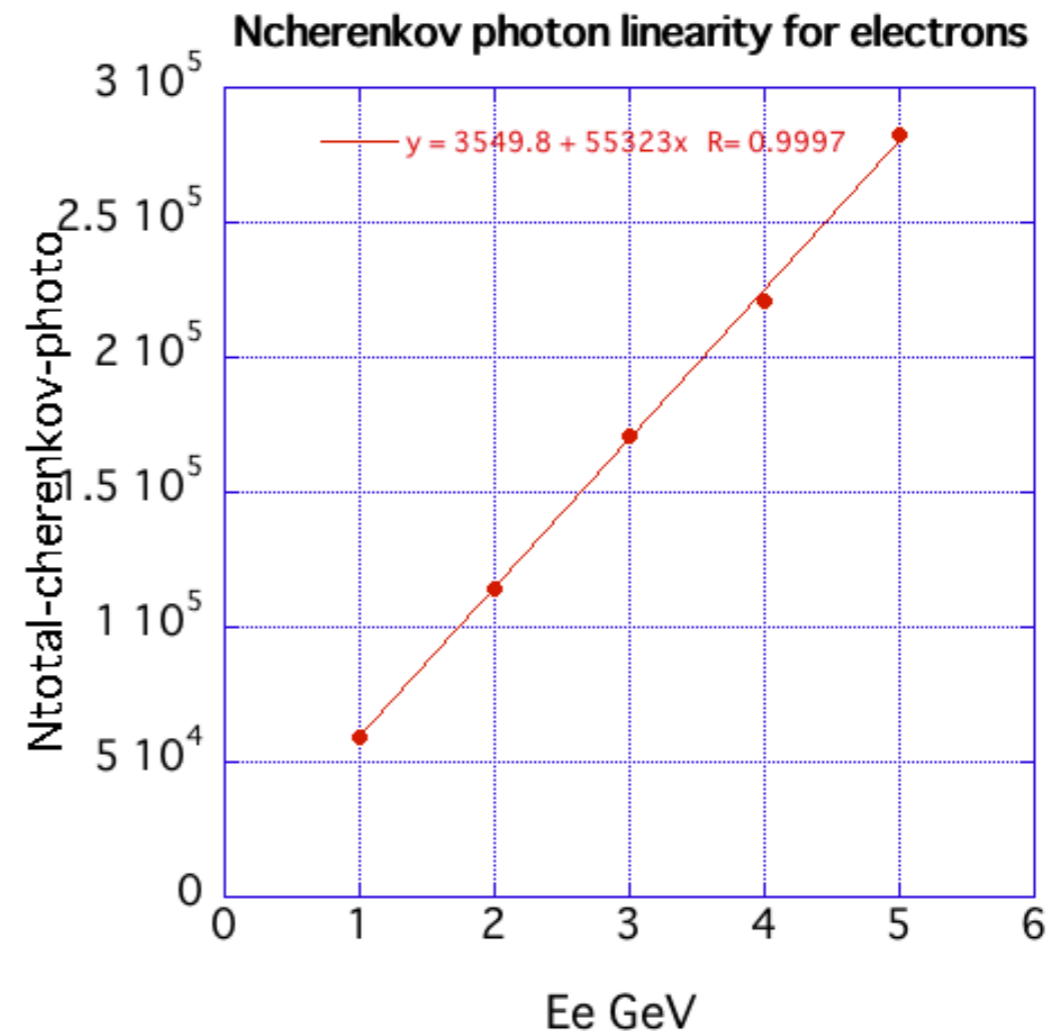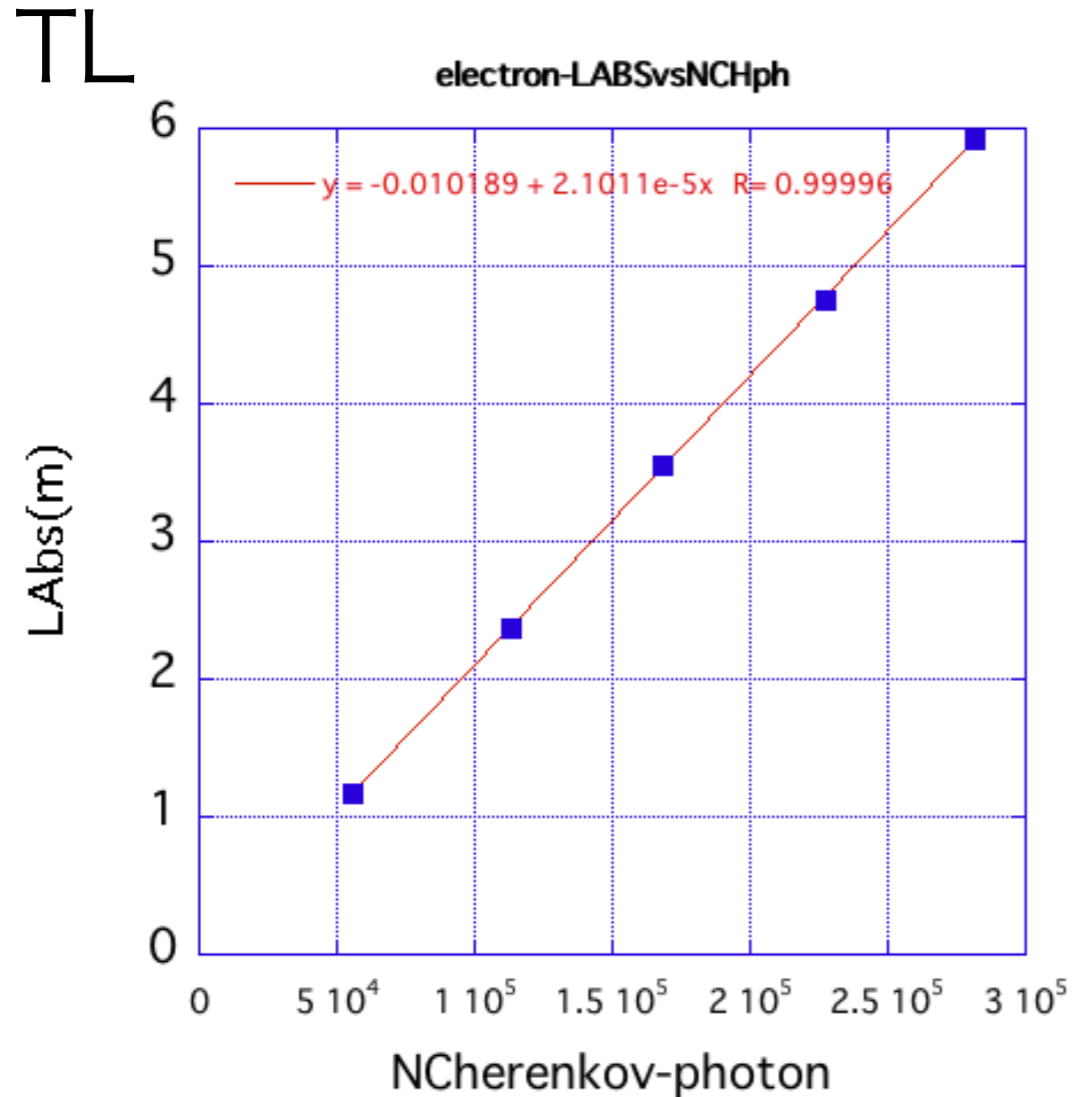
DRSC

- LG 4mm + Plastic Scintillator 8mm sandwich cal

- need heavier scintillator

JGS1	Grease top	Air top	Air side
UV (p.e.)	2.7	0.5	3.8
Normal (p.e.)	1.7	0.6	2.5

L vs E