Double Readout

sandwich calorimeter

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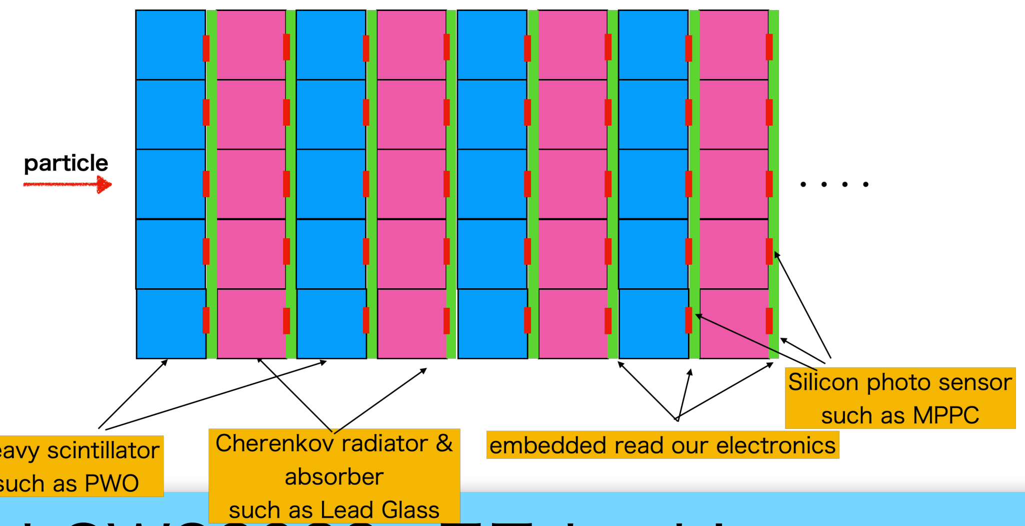
LCWS @SLAC May2023

- **Homogeneous calorimeter simulation**

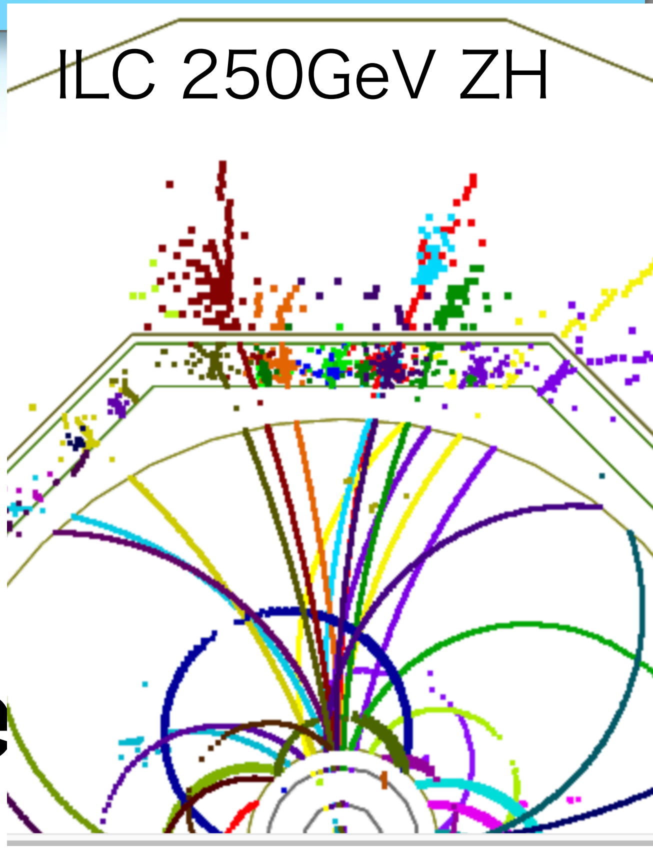
T. Takeshita *et al* 2020 *JINST* **15** C05015

- **Double Readout Sandwich Calorimeter**

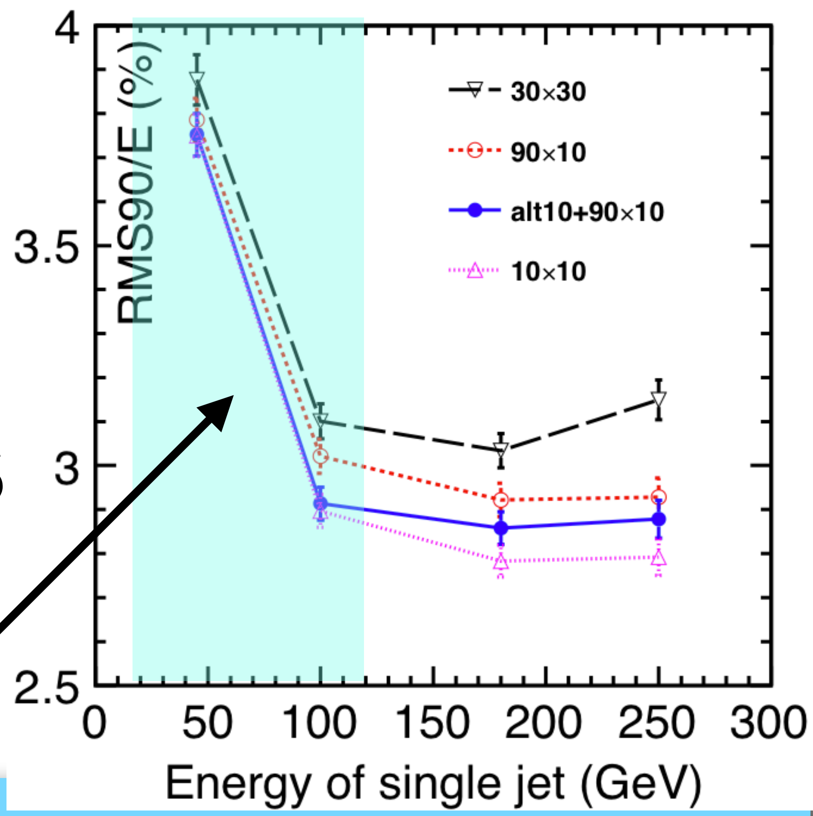
Segmented in three dimensions according to the physics requirements



Higgs Factory Cal.



- H -> b$\bar{b}$ -> 4 jets : Jet energy resolution (JER) is a matter to separate W/Z/H
- to improve JER, PFA plays a role
- PFA requires fine segmentation to calorimeters
  separation of showers
- performance of PFA depends on particle energy resolution
  at lower energy JETs

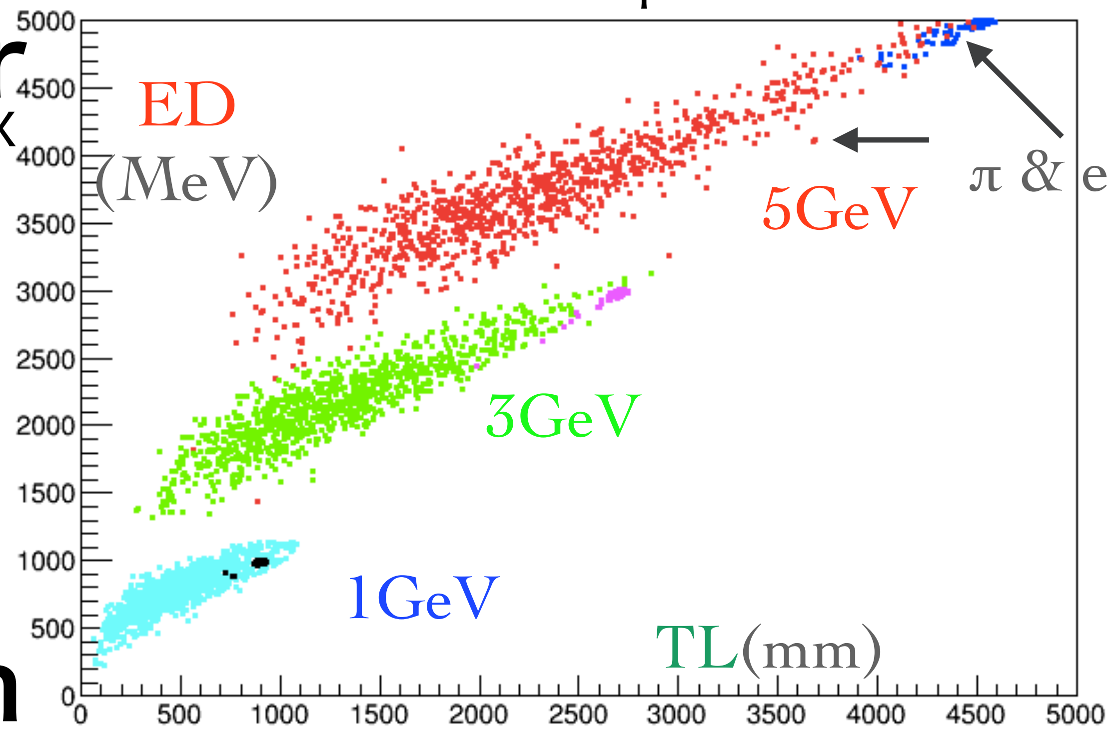


Homogeneous CAL

start from

- simulation with GEANT4.11.0 with FTFP_BERT
  photon statistics is not taken into account (2mx2mx2m)
- two parameters are to be measured
  - sum of Track Length (TL) ~ Cherenkov lights
  - sum of Energy Deposit (ED)~ Scintillation lights
    traditional cal.
- correlation : linear behavior
  without passing the origin
  - intercept → linearity
    calorimeter linearly
  - slope → constant
    independent of energy
    - common for e/pi/K/p/n

sim.
PbWO4 + pions



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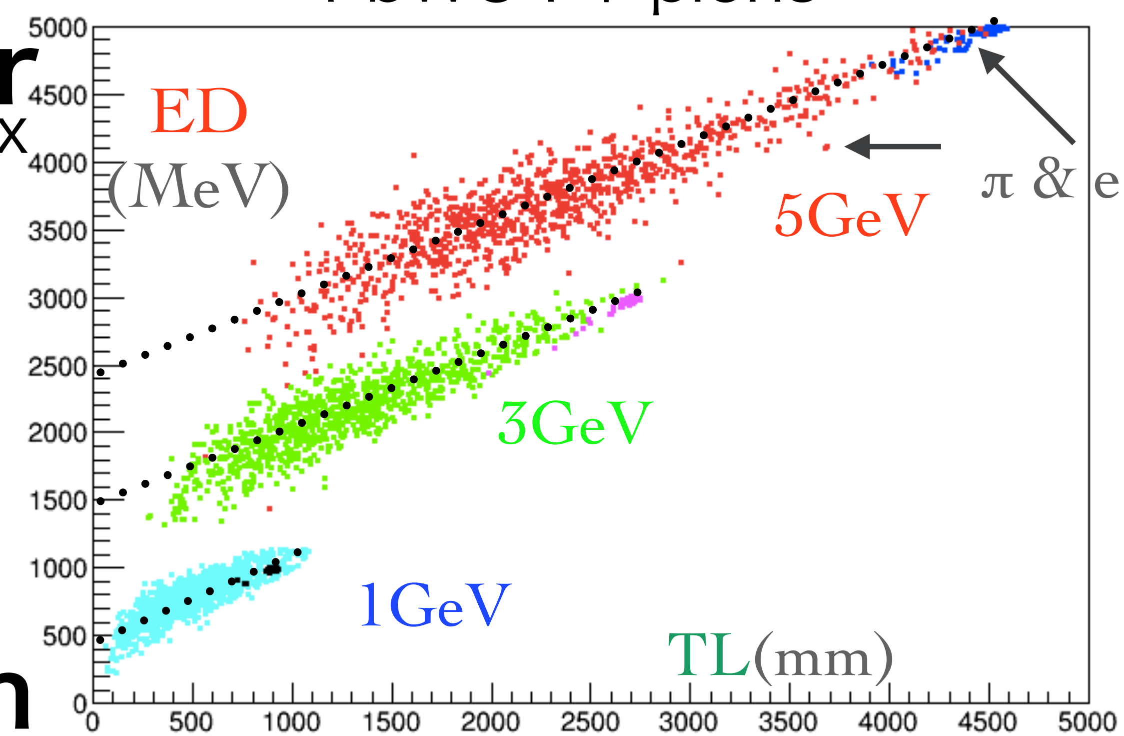

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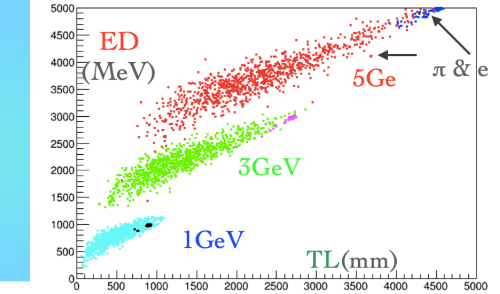
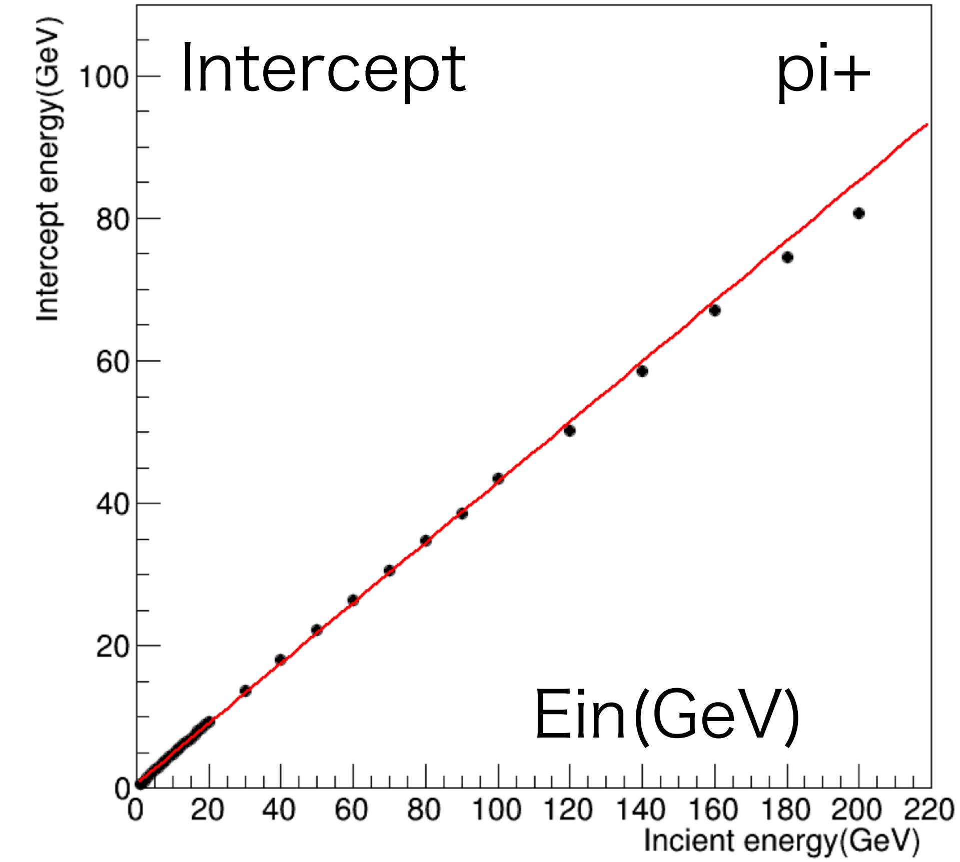
Intercept & Slope

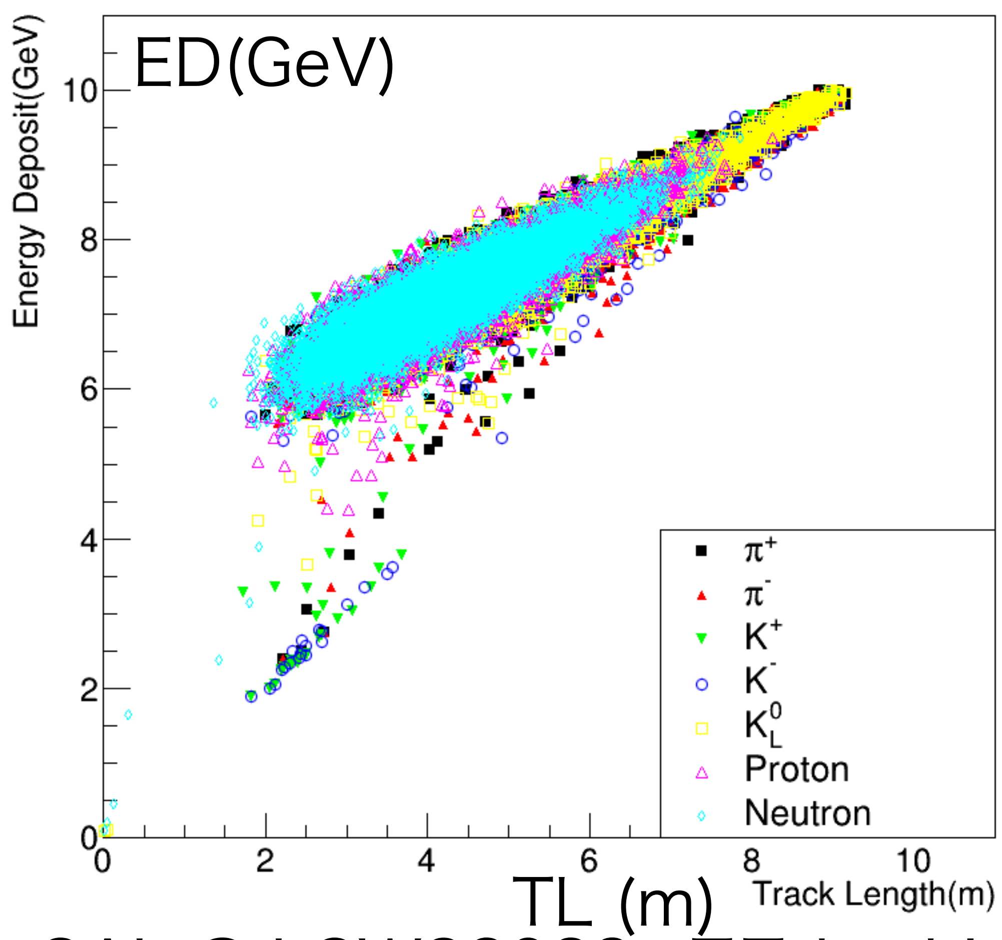
homo-cal

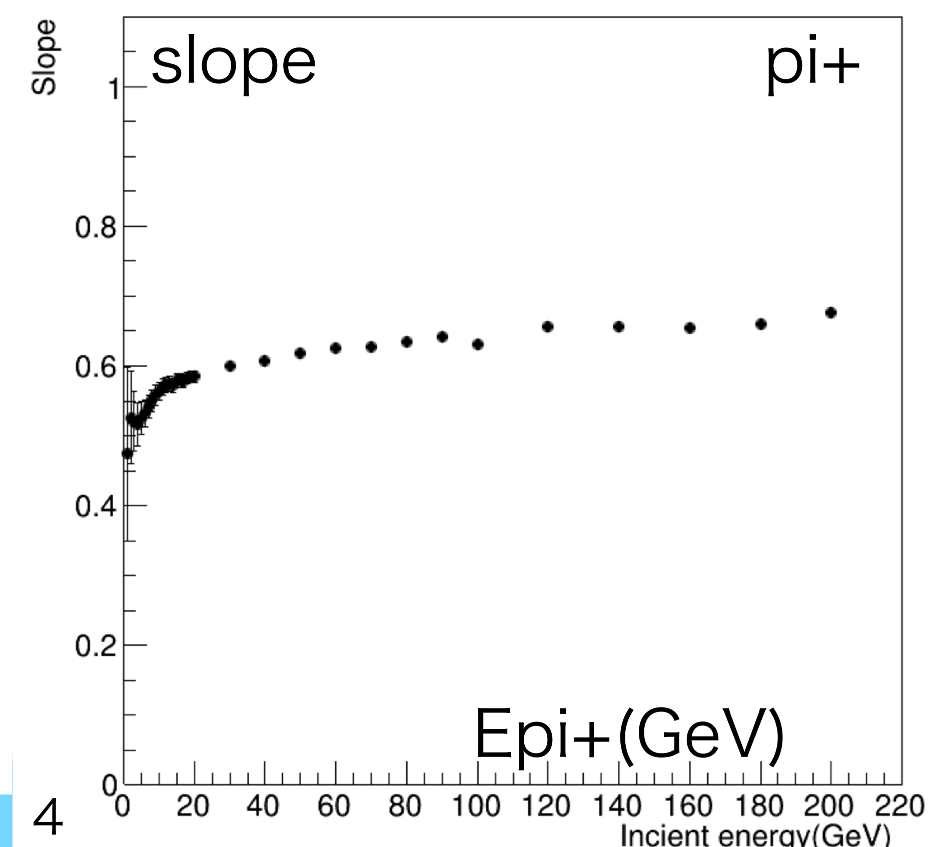


- **good linearity on intercept**

  work as a calorimeter
- **slopes are fairly constant**
  - **common for particles**



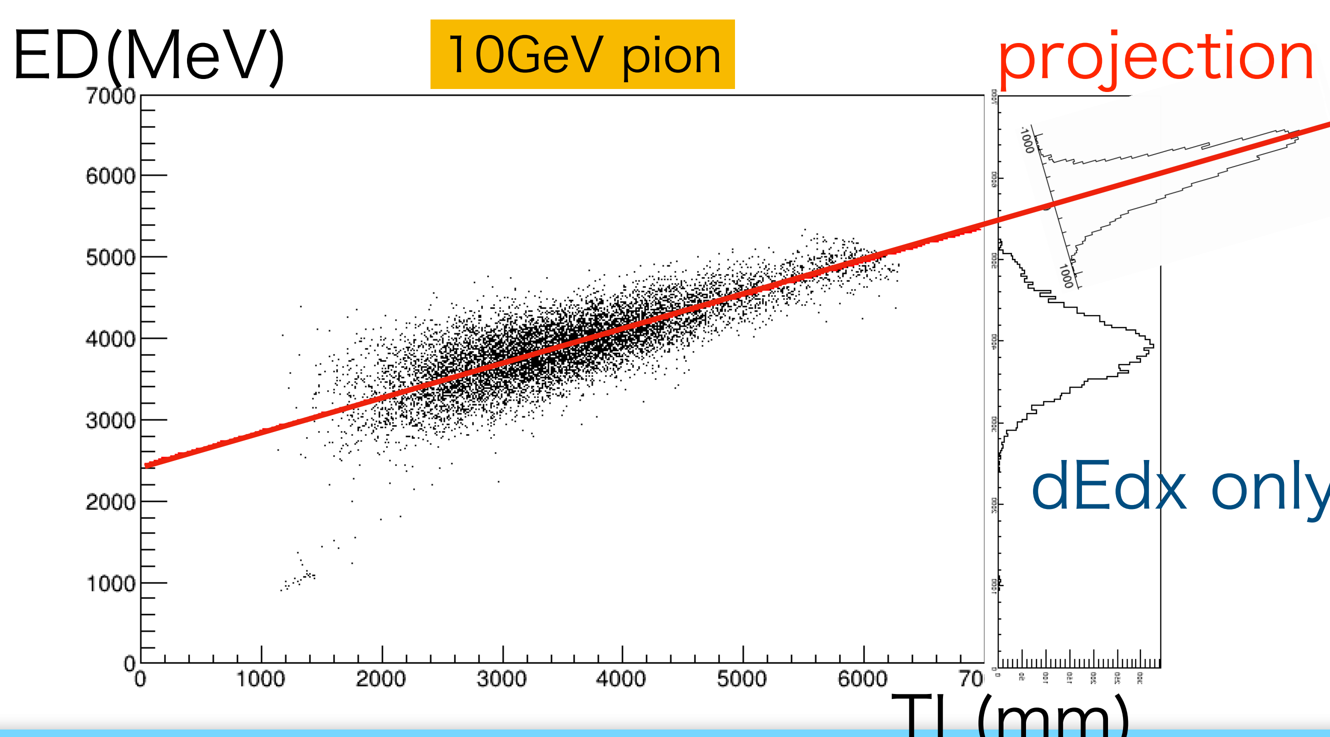


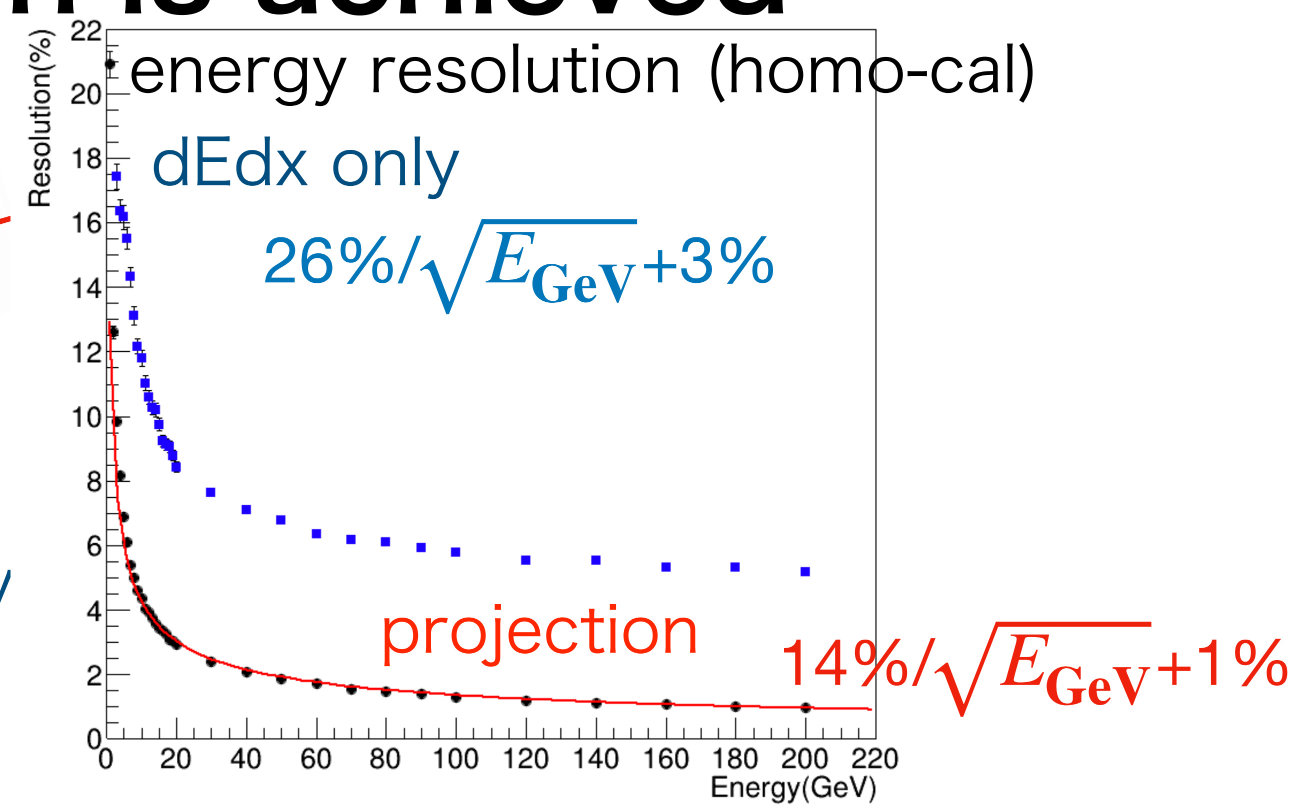


energy resolution

homo-cal

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

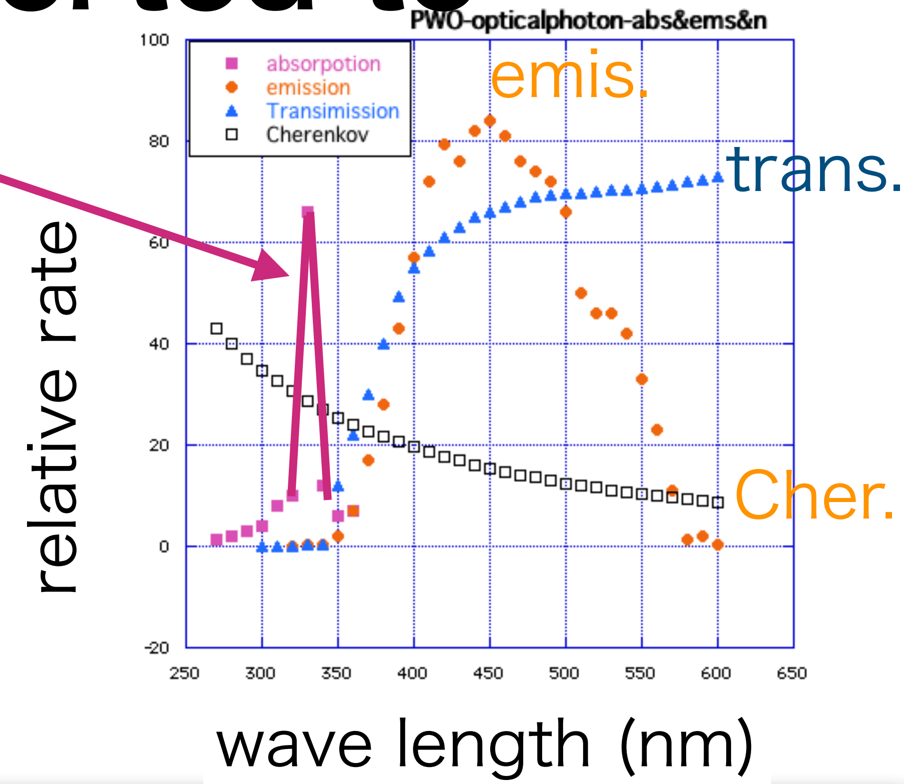




Cherenkov light

- Track Length ~ Cherenkov lights
- Cherenkov is low light and $1/\lambda^2$ (UV)
  - need heavy and UV transparent material
  - will be absorbed and converted to scintillation light

mixing



- difficult to separate lights
- timing or signal shape

a new idea :DRSC

- separate Cherenkov radiator and Scintillation material with sandwich style

TL

active absorber

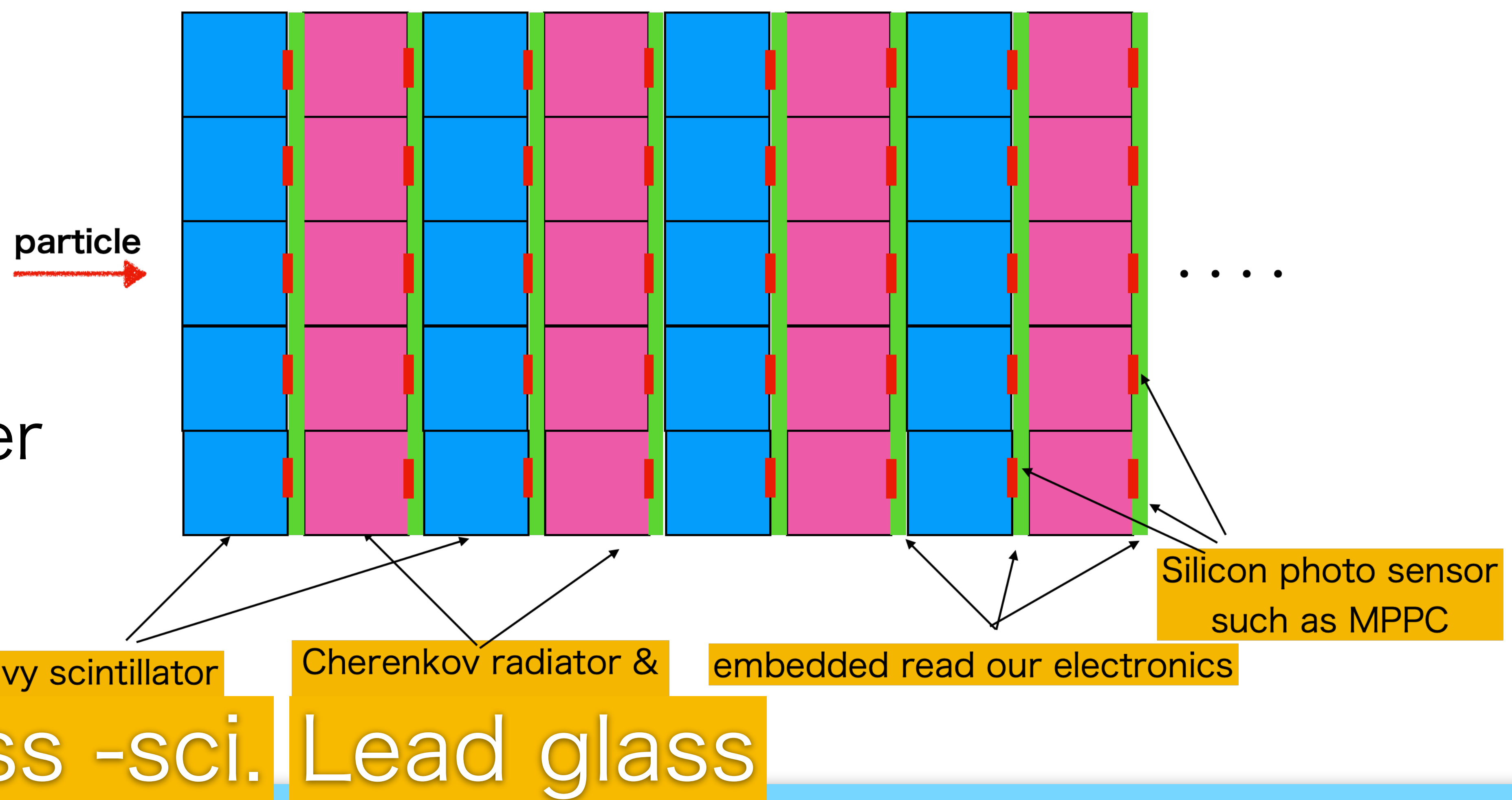
ED

- with highly granular option for PFA

- DRSC

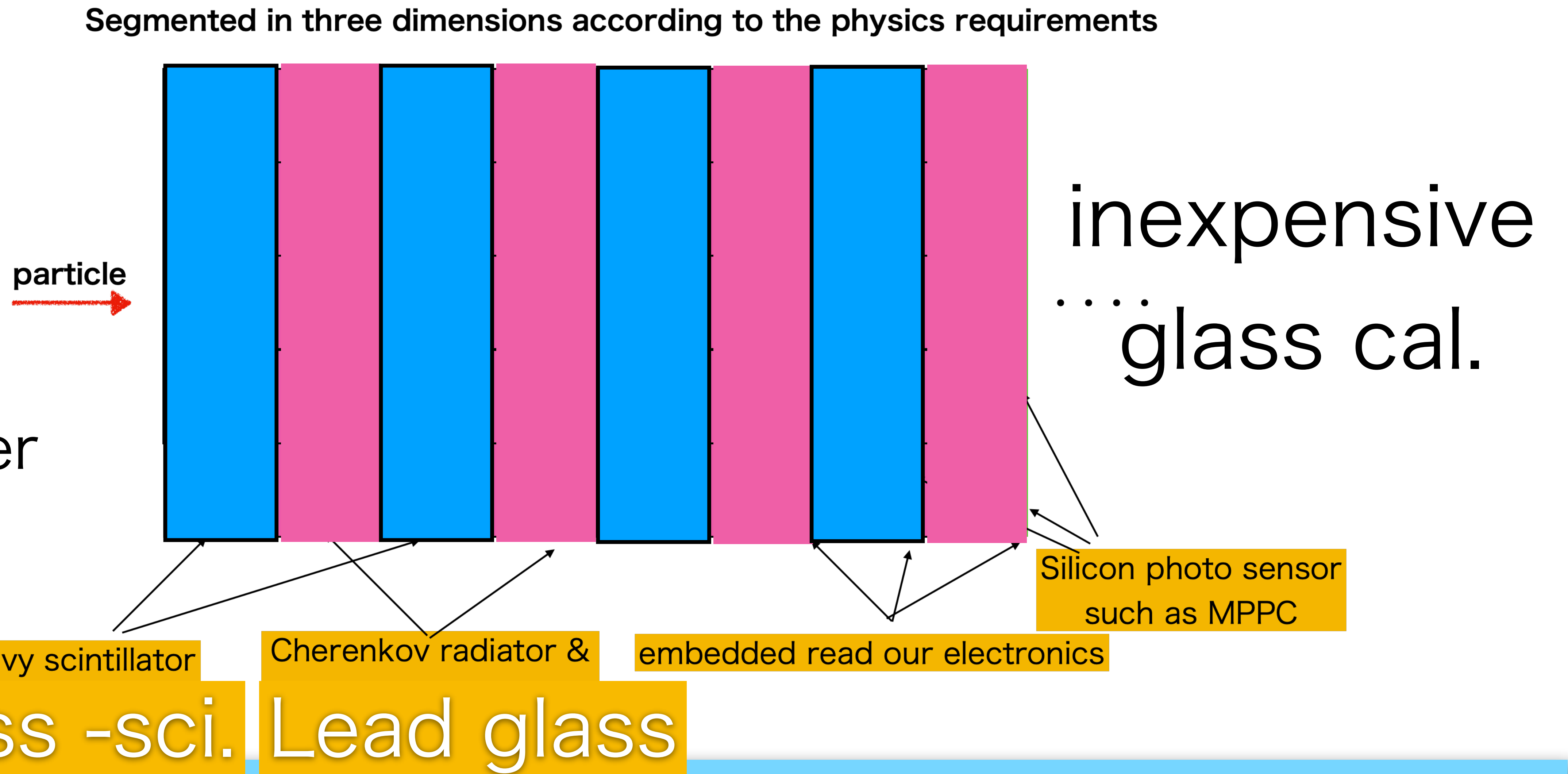
  Double
  Readout
  Sandwich
  Calorimeter

Segmented in three dimensions according to the physics requirements



a new idea :DRSC

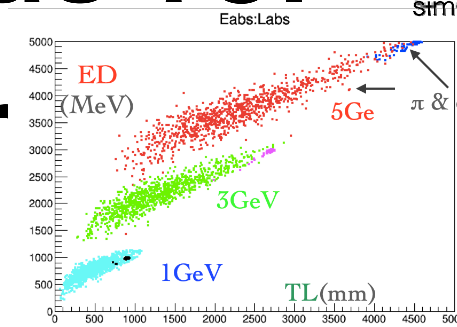
- separate Cherenkov radiator and Scintillation material with sandwich style
  TL active absorber
  ED
- with highly granular option for PFA
- DRSC
  Double
  Readout
  Sandwich
  Calorimeter



performance of DRSC

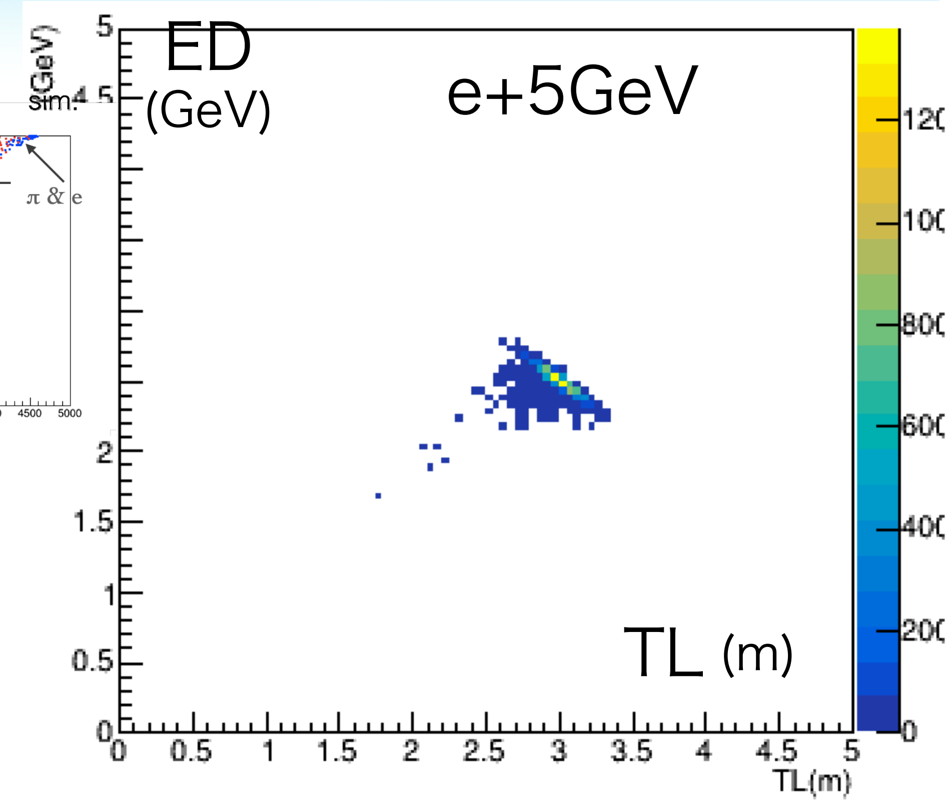
(2mx2mx2m cal)

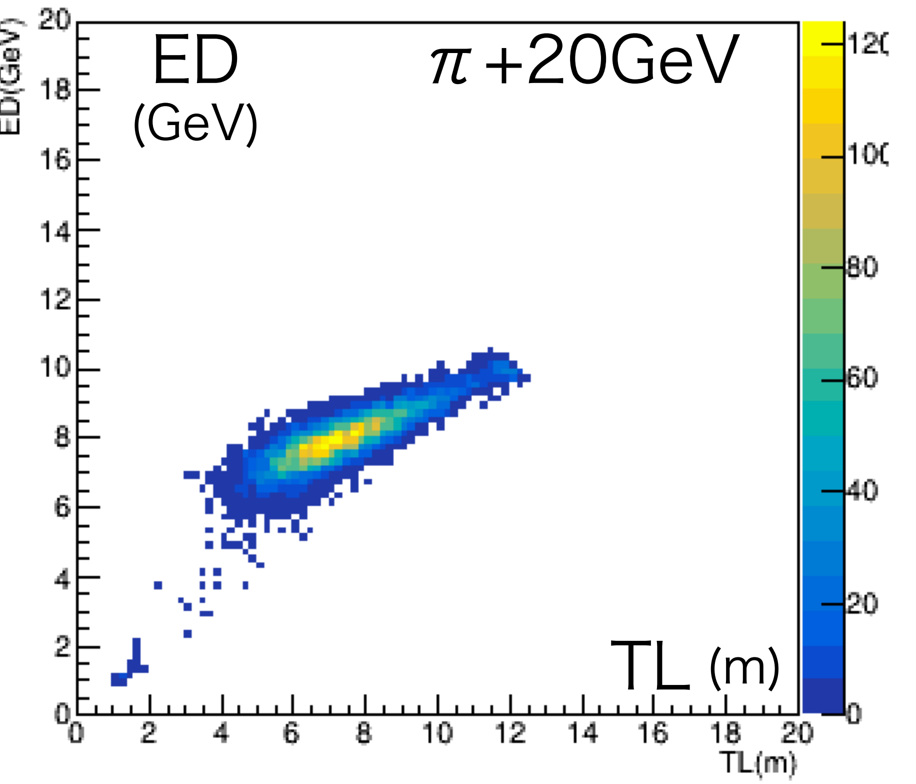
- ED vs TL relation holds for sandwich calorimeter

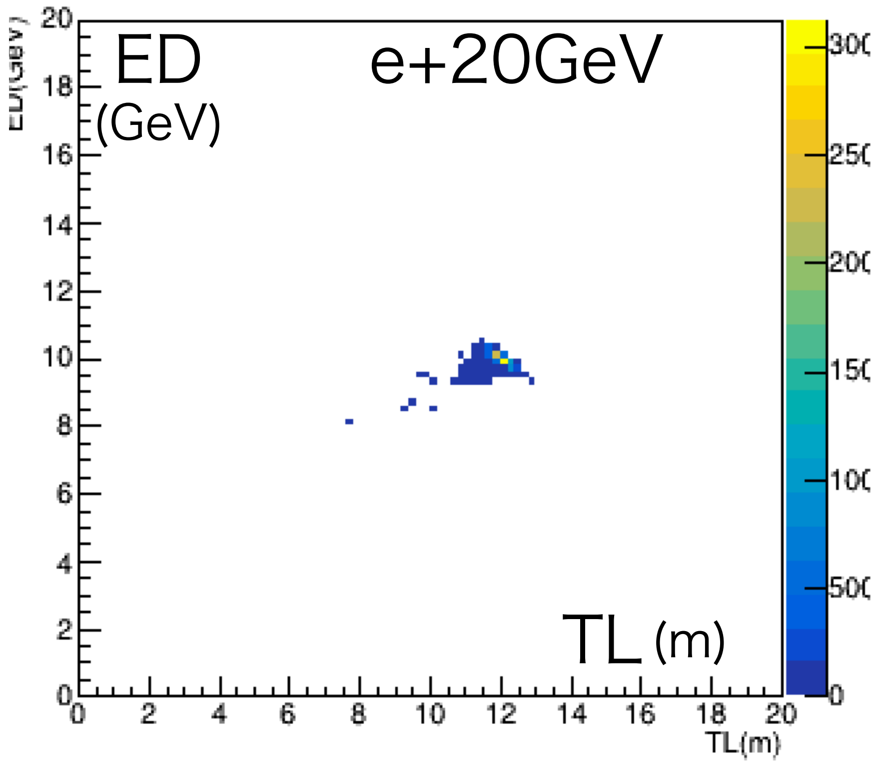


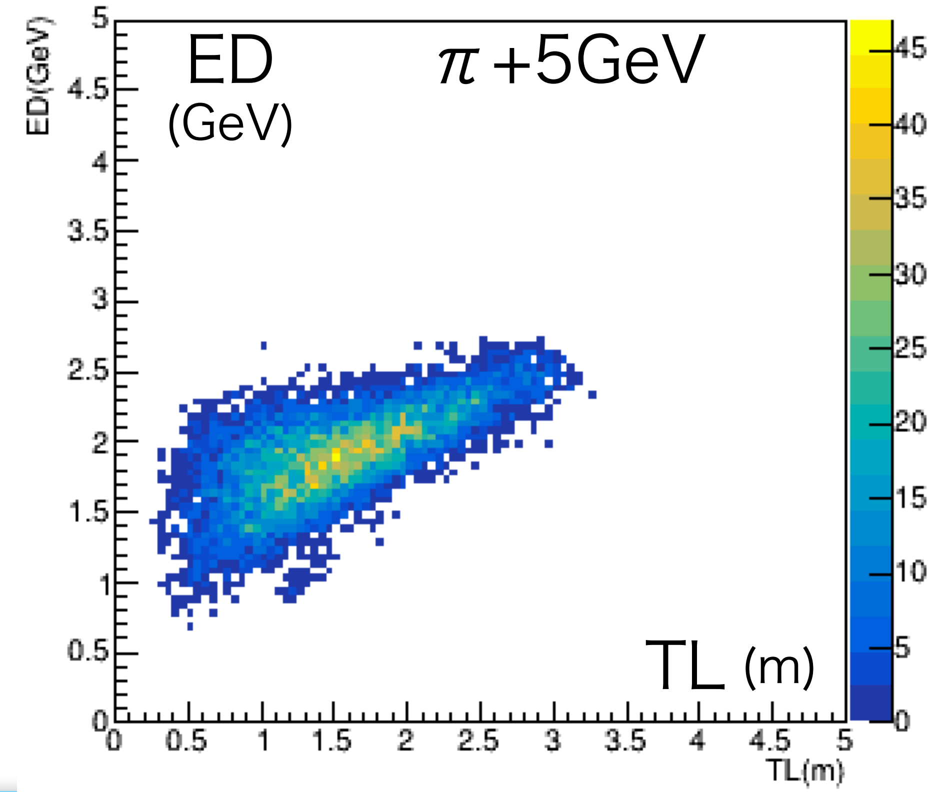
- for both e's and pions
- LG10mm+GSci.10mm

TL ED









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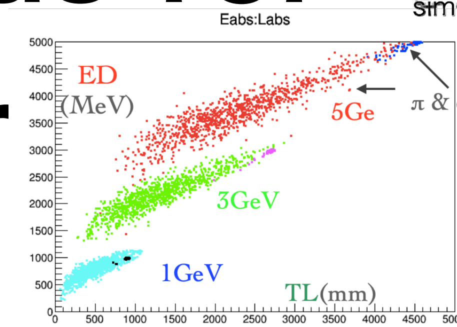

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TL ED

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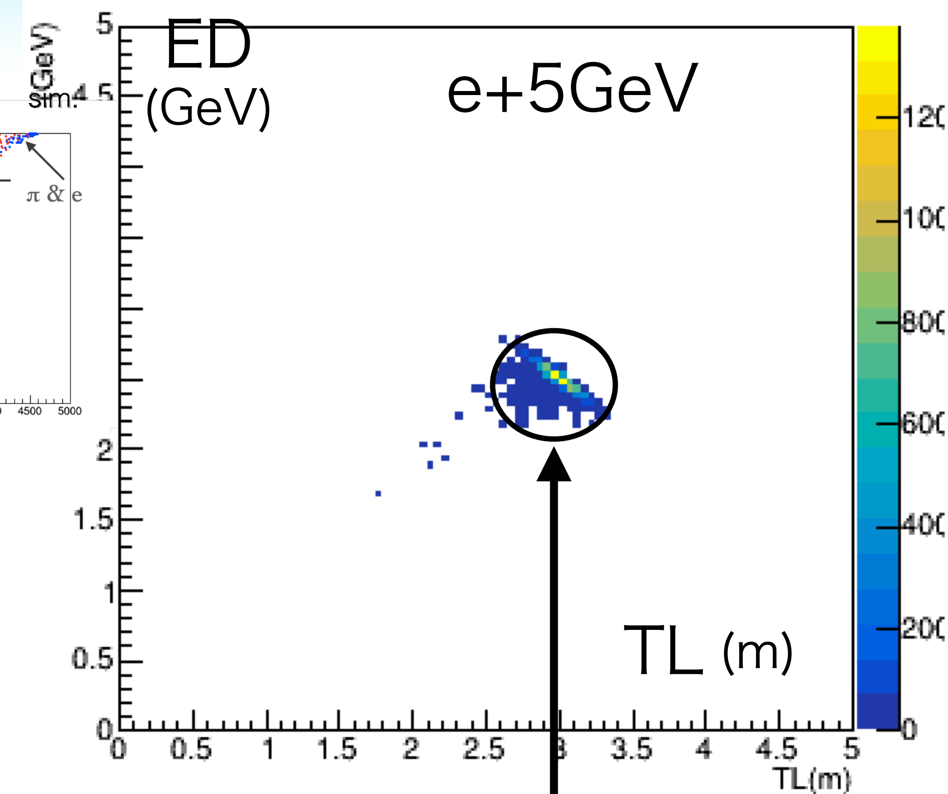
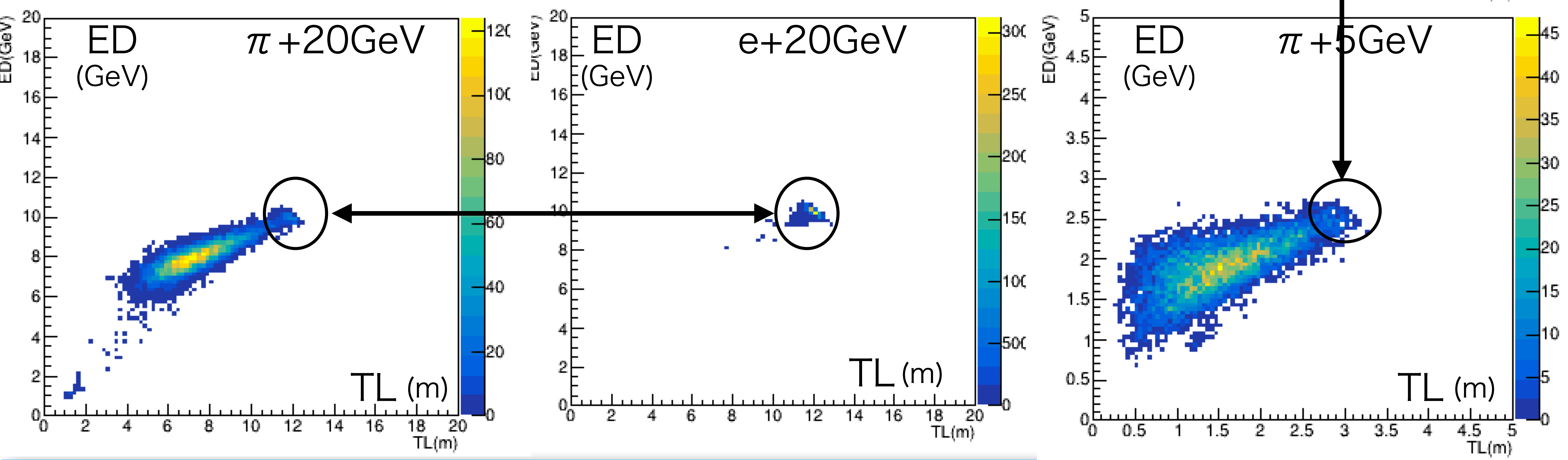
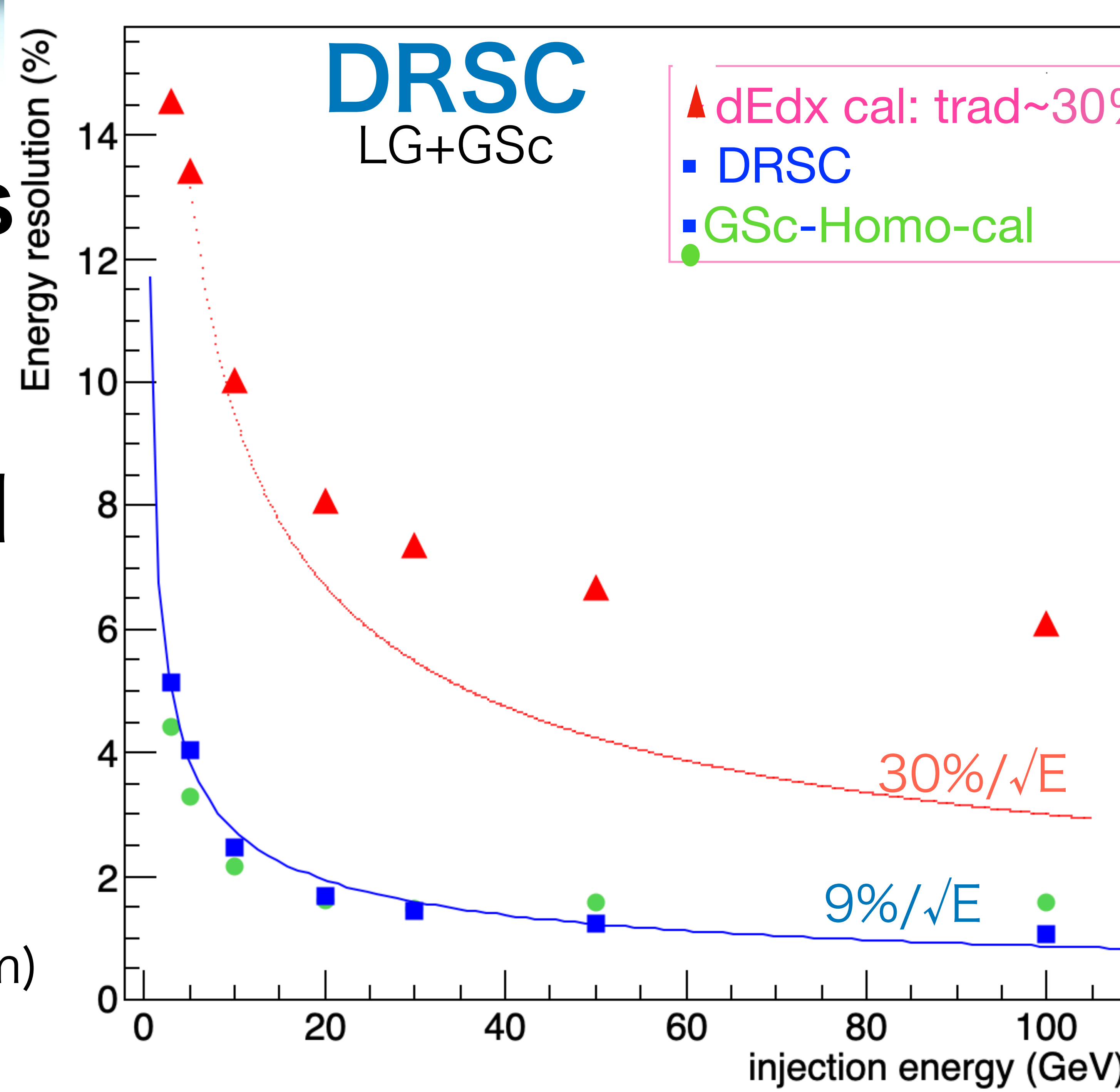




Eresolution of DRSC

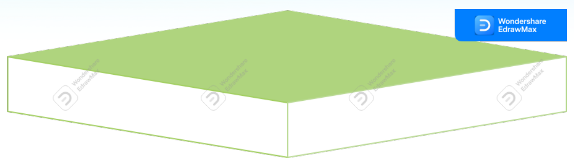
- ~9%/√E(GeV) with DRSC for electrons & hadrons
  - close to homo-cal
- much better than dEdx (traditional) calorimeter (const. term)



- study: photon statistics and prototype

Cherenkov light detection

- Lead glass : 1cm^{t} x10x10cm^{2}

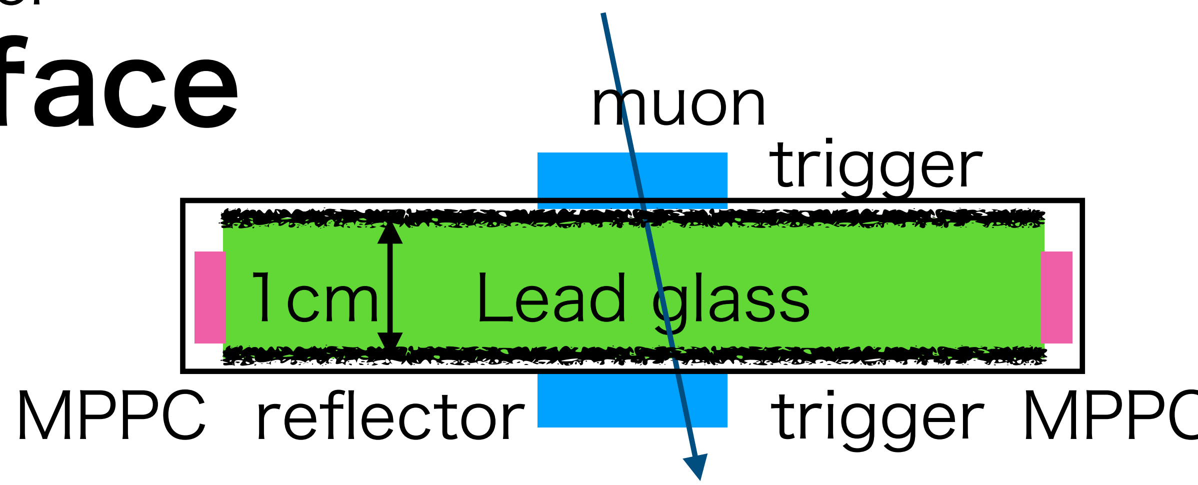


for test calorimeter

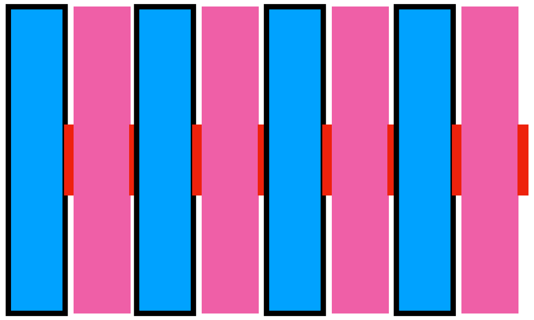
- unpolished 10x10 surface

diffusion

- polished at 1x10 side



- air coupled normal MPPCs
- 3cmx3cm trigger
- with cosmic muons
- 7p.e. by 6x6 mm



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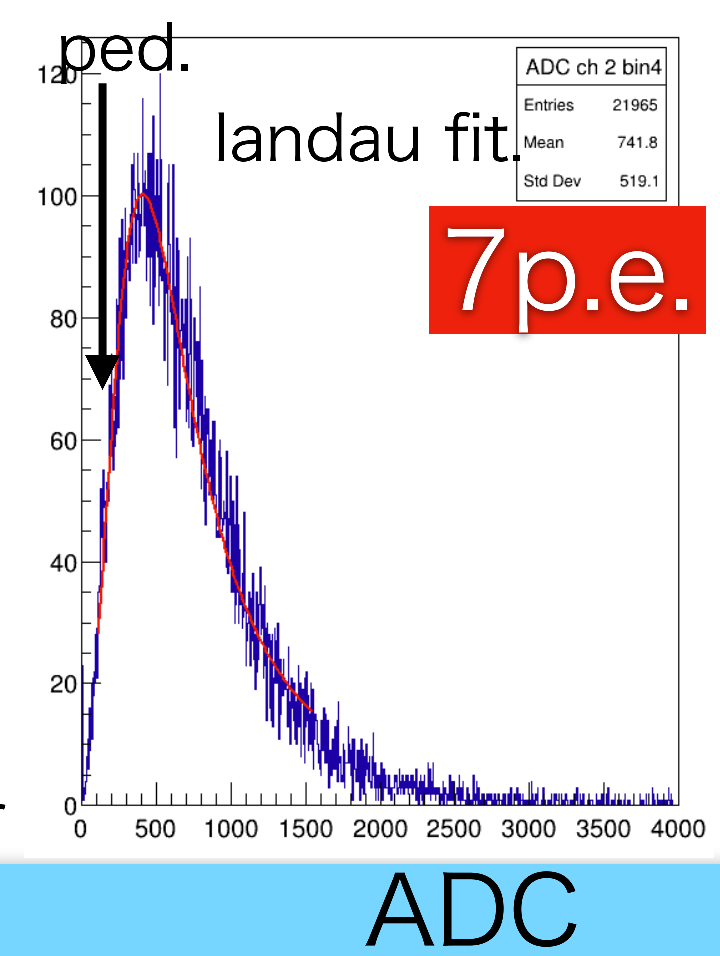
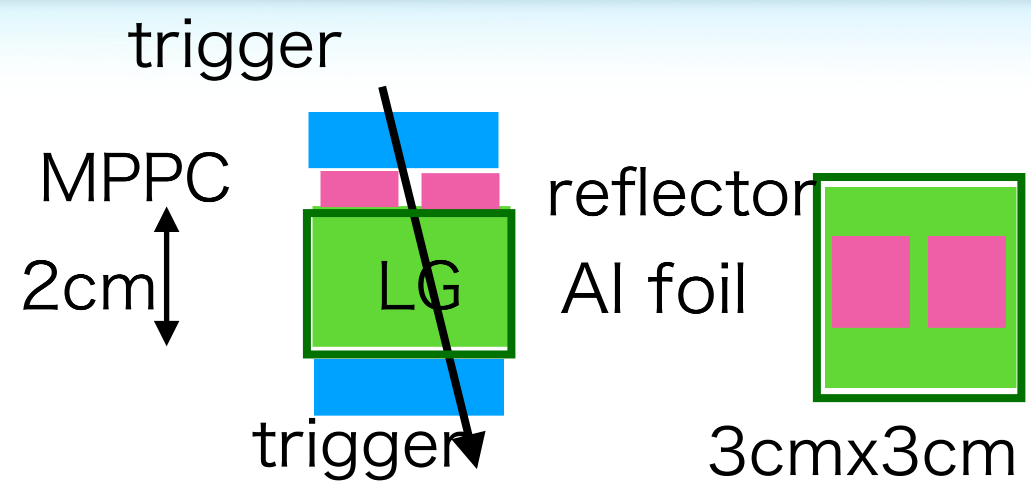
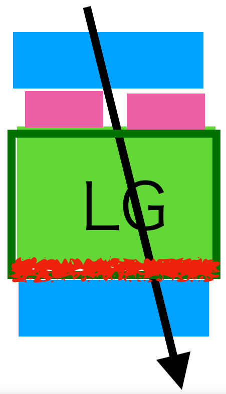


Cherenkov light detection

- LG: $2cm^t \times 3 \times 3cm^2$
  PFA cal.
- all polished &1 non-pol.
- air coupled MPPCs
- UV and normal MPPC 6mmx6mm
- trigger (3cmx3cm)
- with cosmic muons

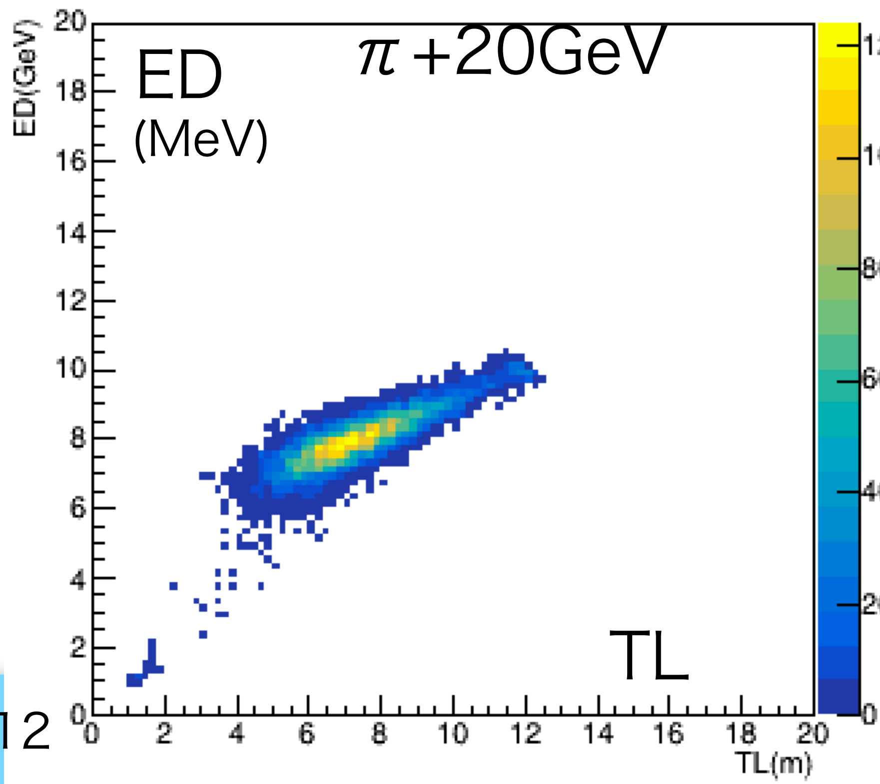


	normal (p.e.)	UV (p.e.)
all polish	1.2	1.1
1 non polish	3.3	3.0



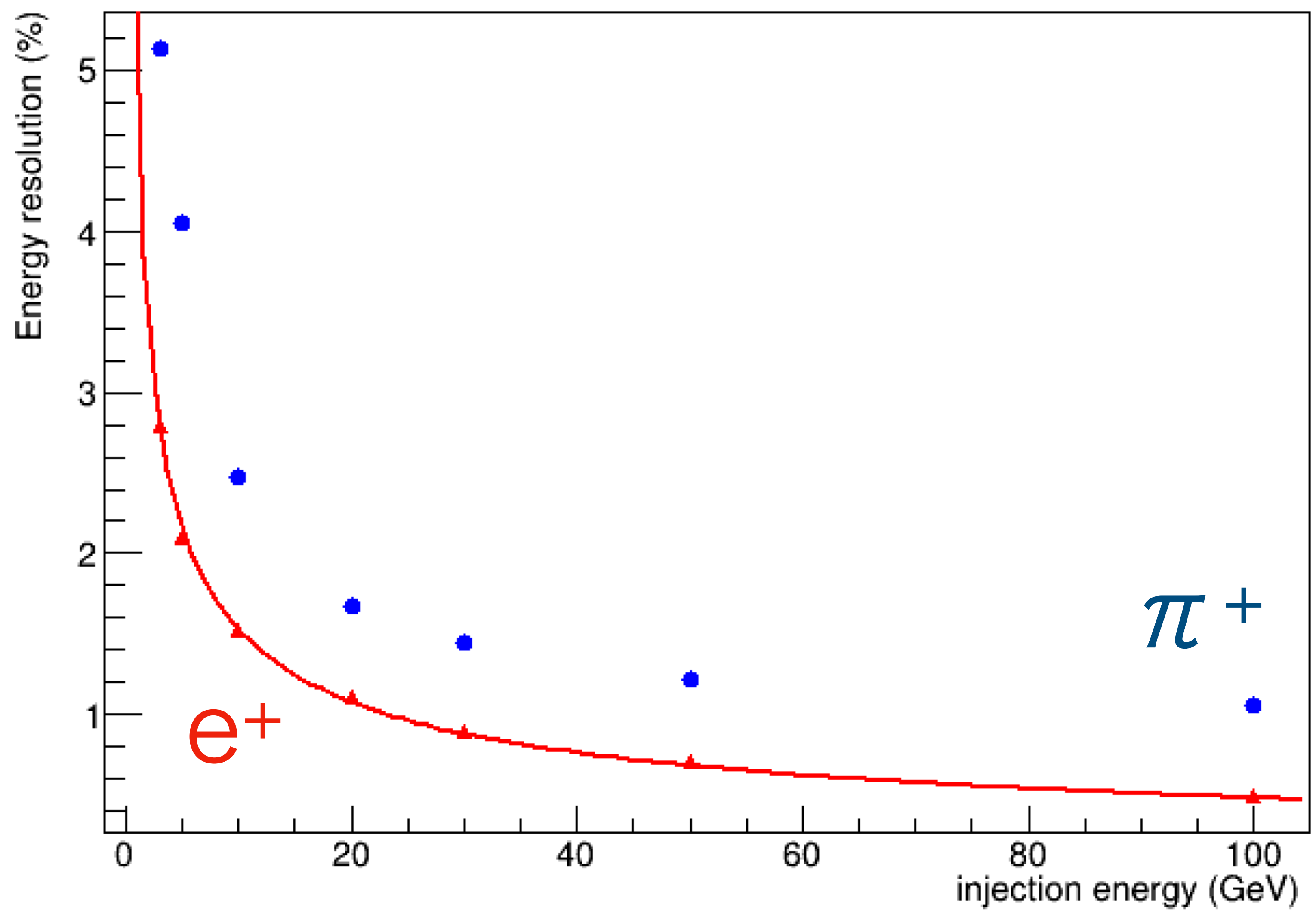
summary and outlook

- 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



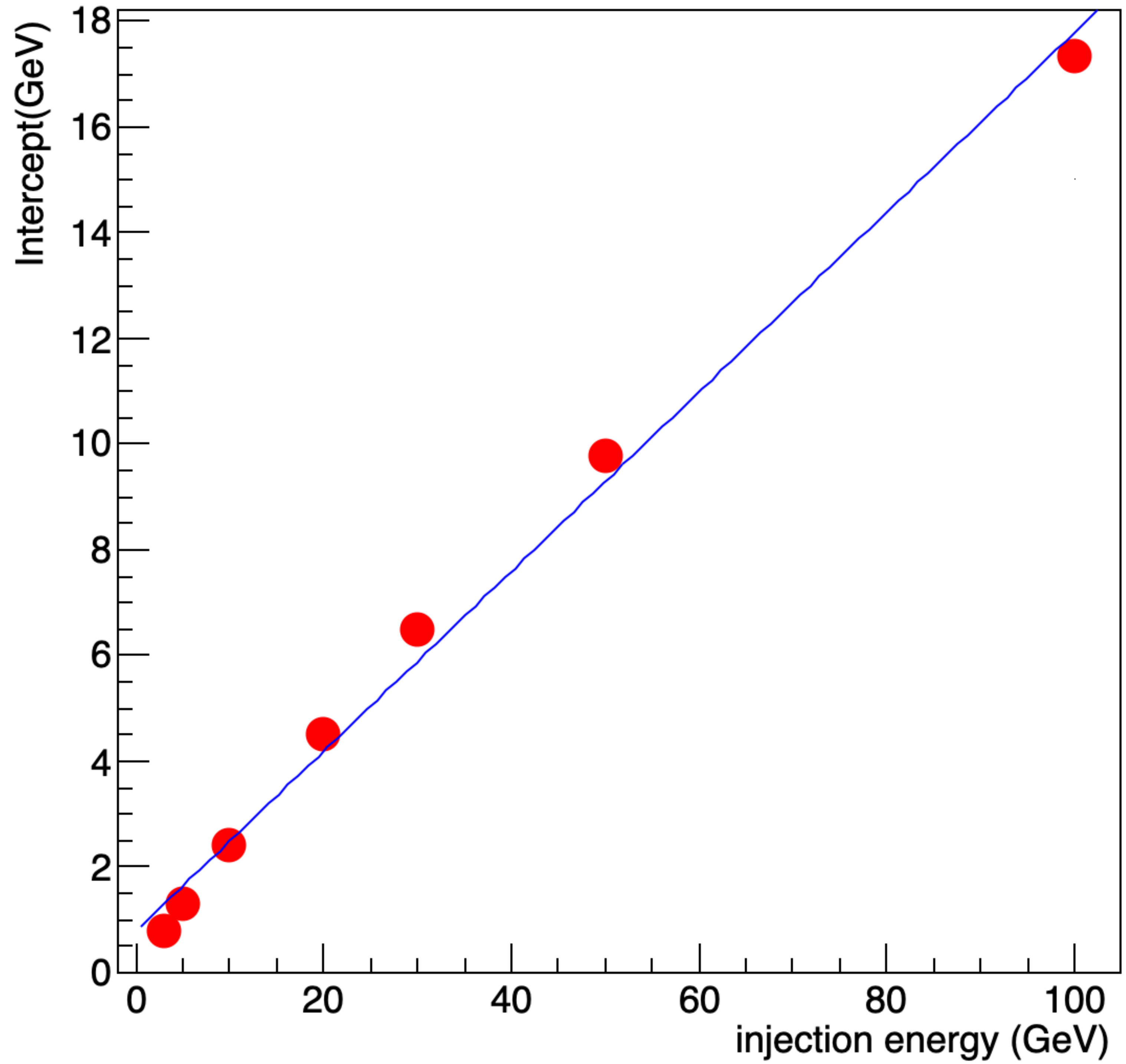
electrons on DRScal

- electron energy resolution
- ~ 4.8%/√(E) ~ Lead Glass ECAL of OPAL



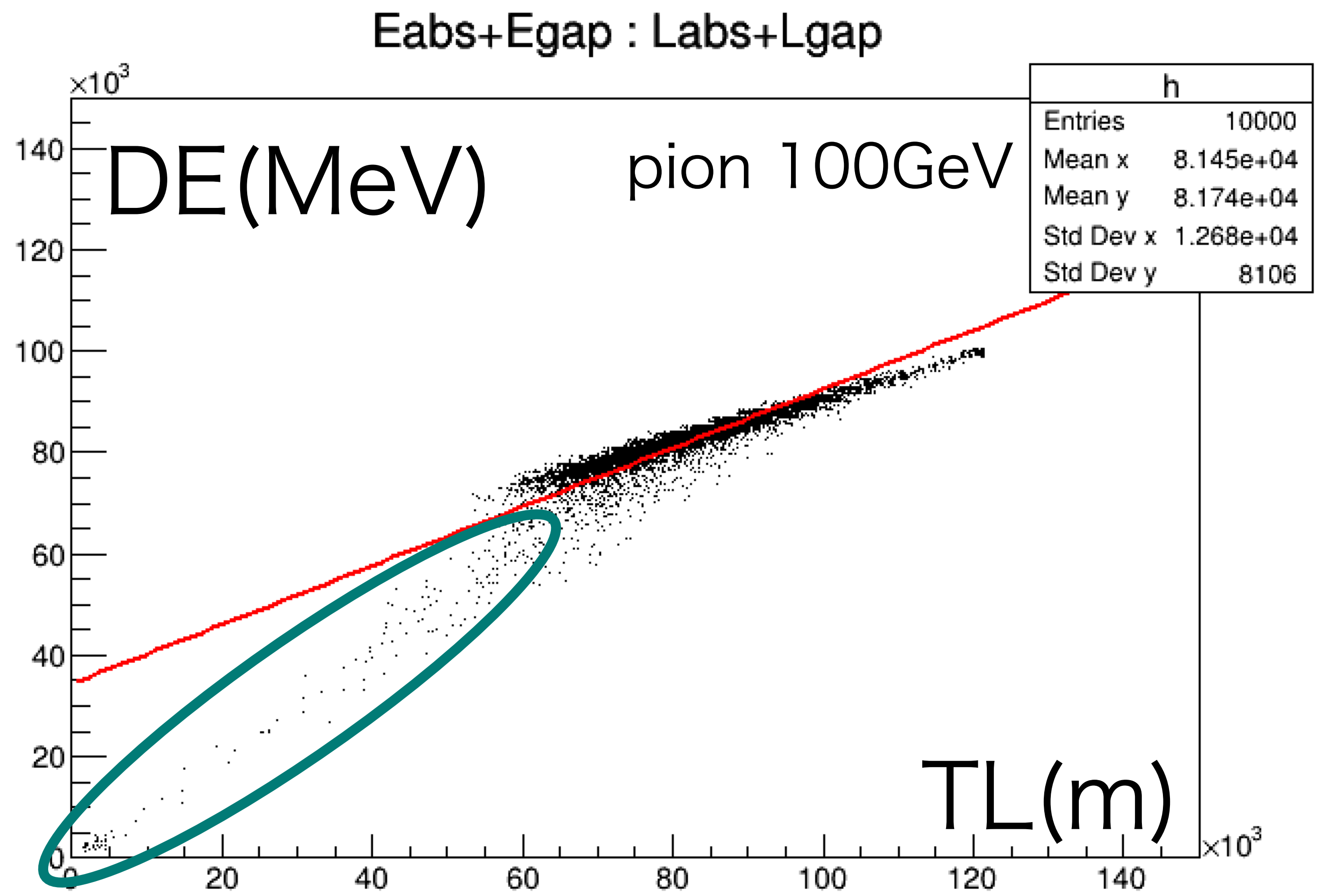
DRDCal Intercept

- Inetercept



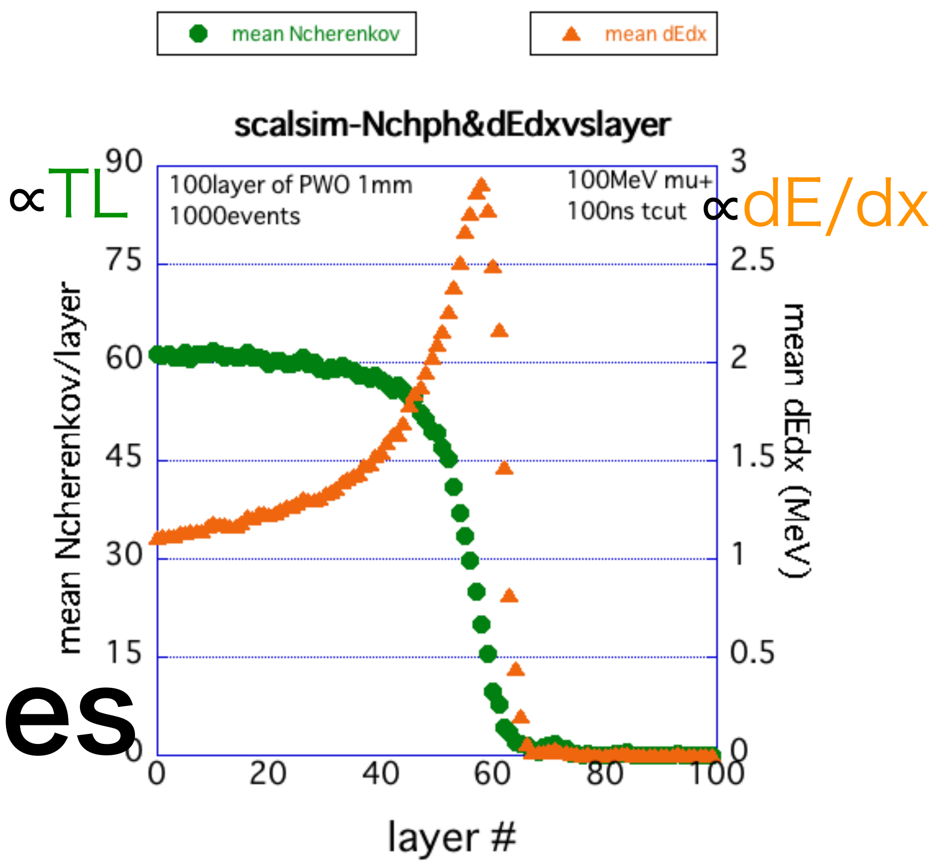
homogeneous cal.

- effect of punch though pions (muon)
- fitting deteriorated



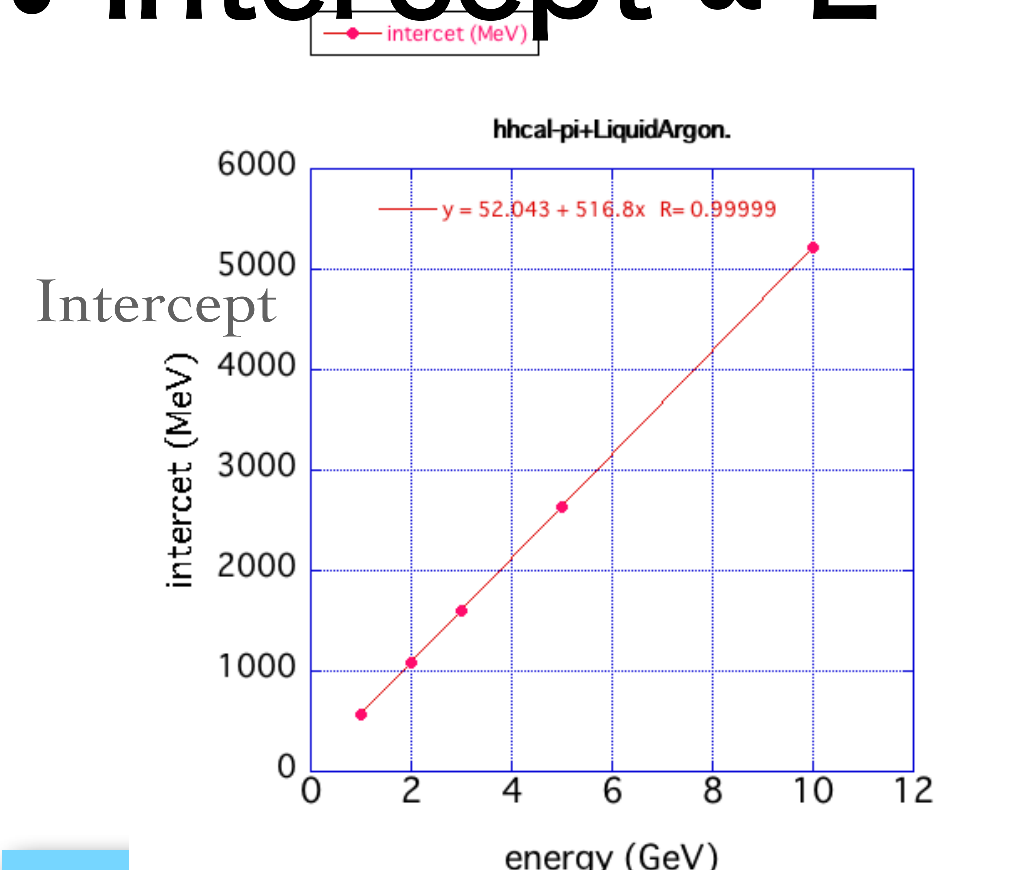
reason of intercept

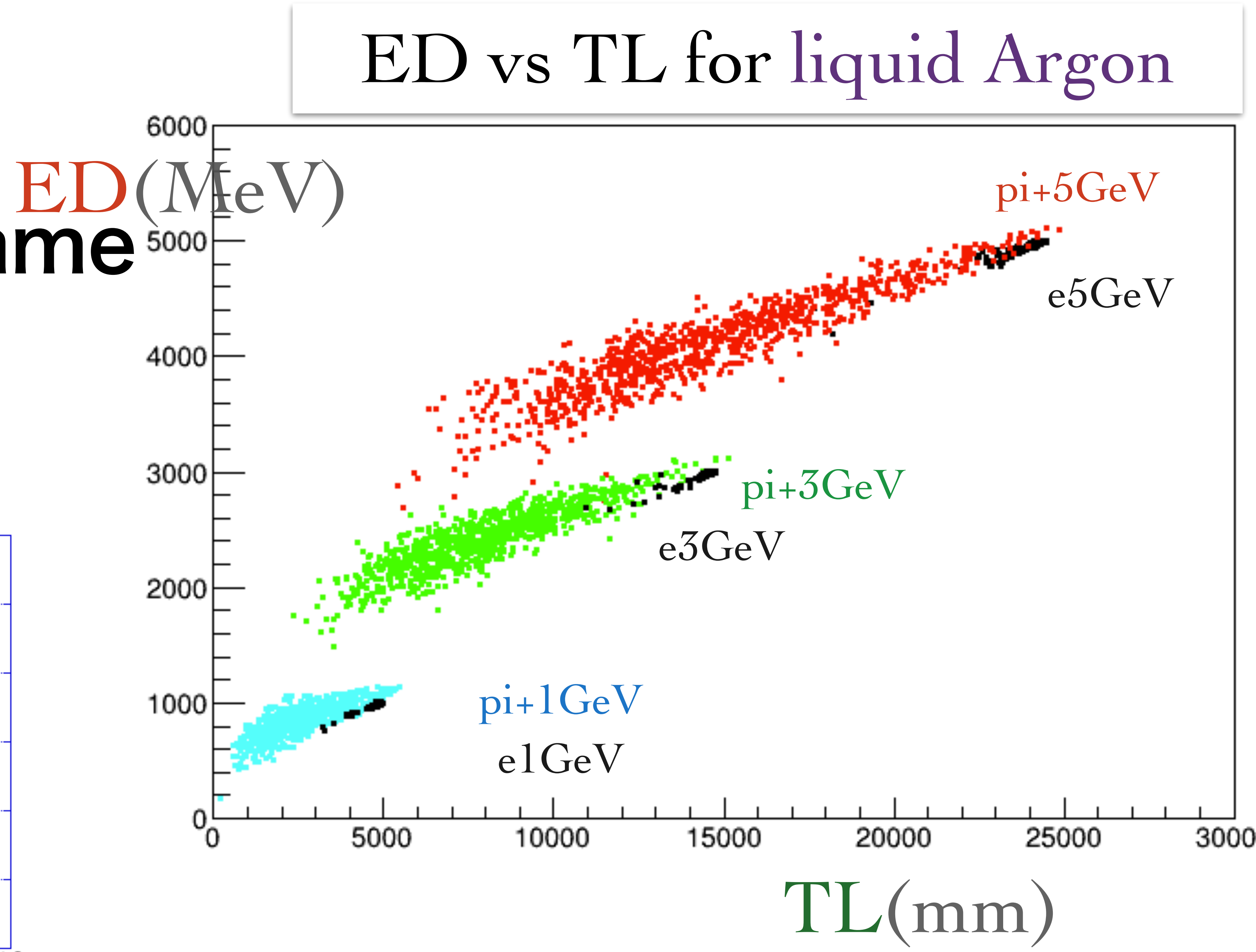
- when particles stop in a shower
  - Bragg peak will be detected by scintillator
  - no peak for Cherenkov
- intercept corresponds to number of stopping particles



Different detector material

- Liquid Argon, & CsI are simulated
- ED vs TL
- Slopes are same
- Intercept ∝ E





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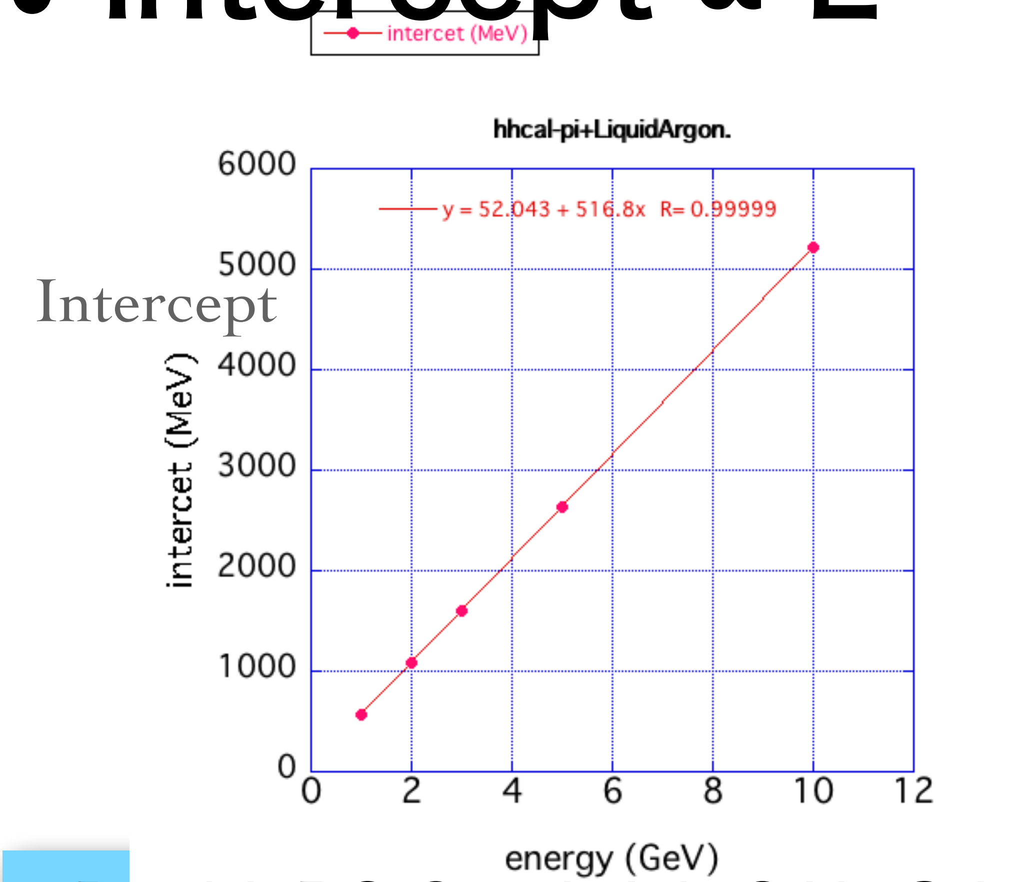
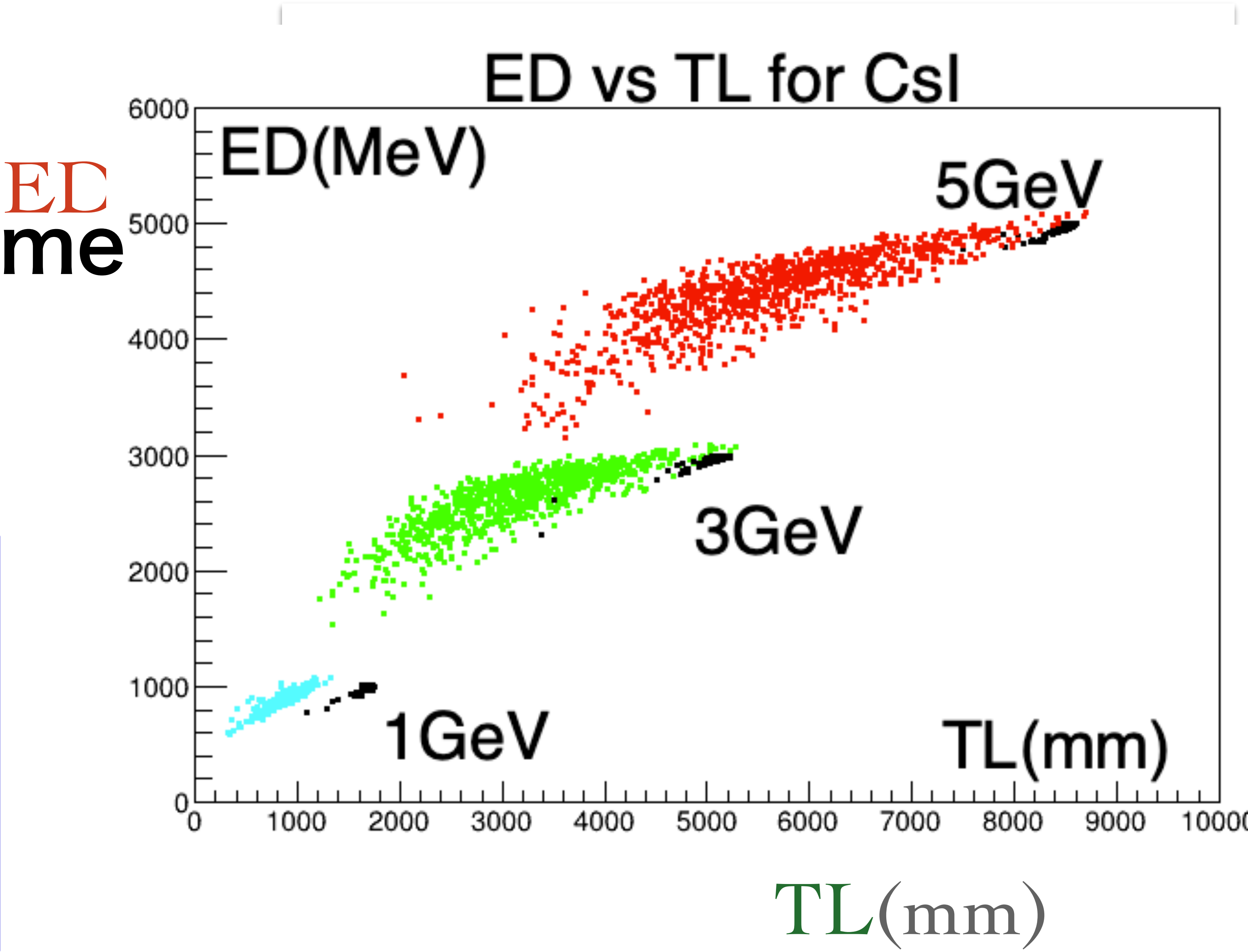
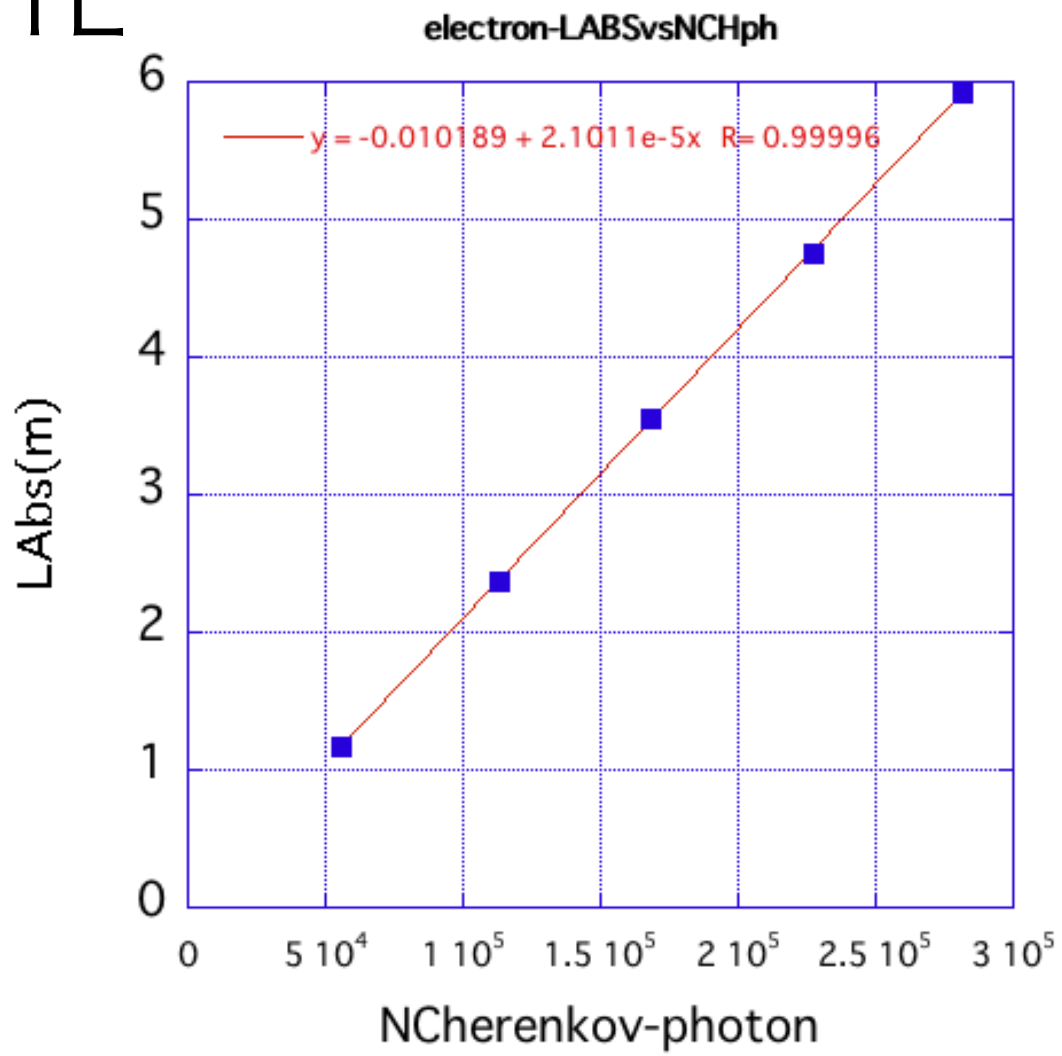


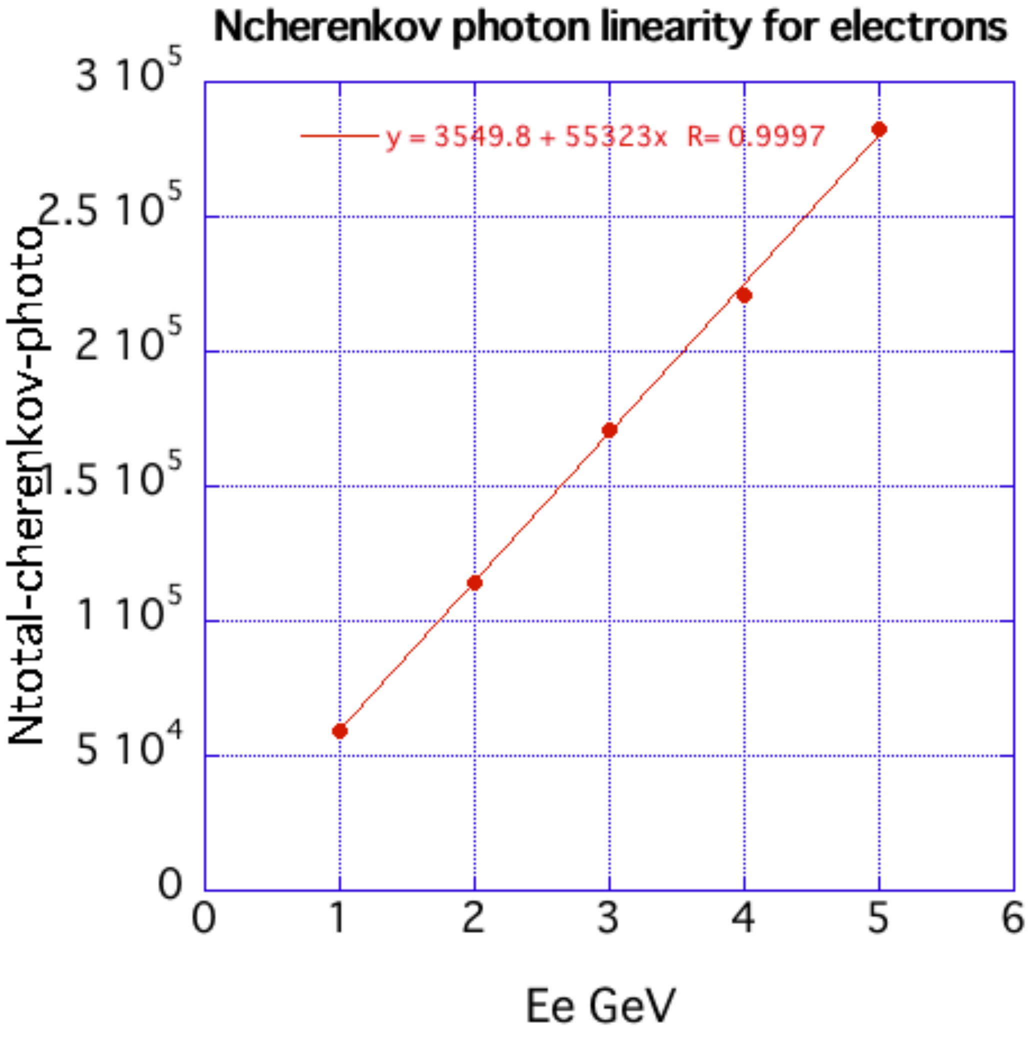


TL vs Cherenkov light

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

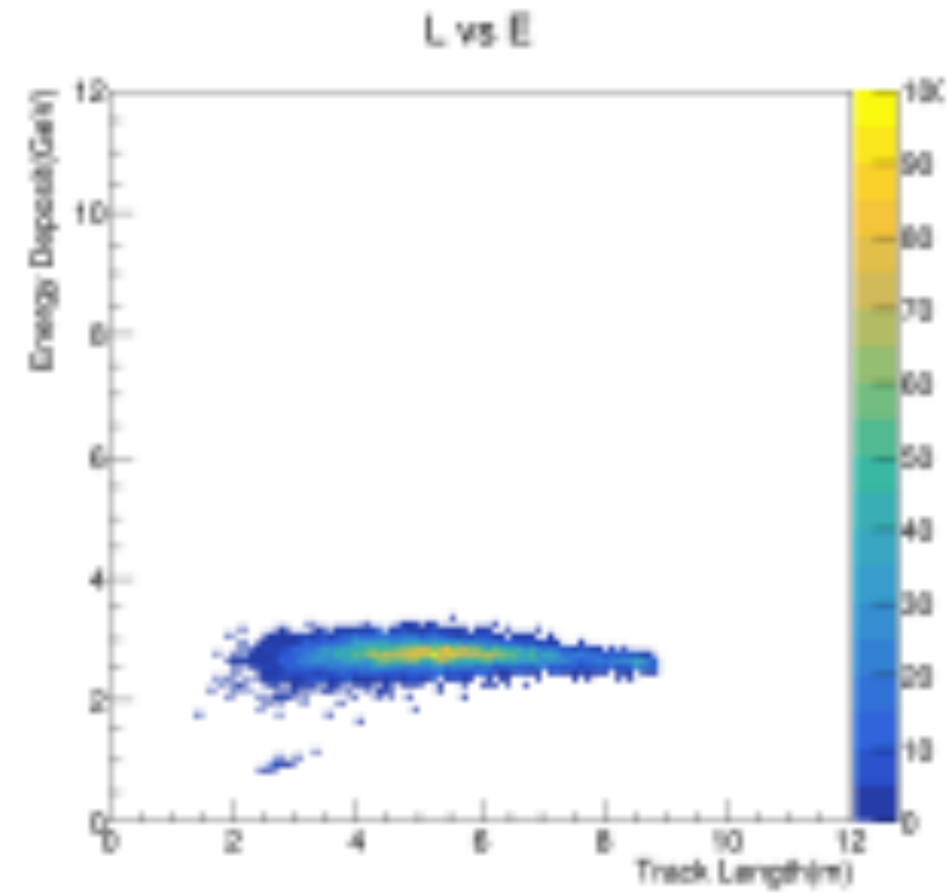
TL





DRSC

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

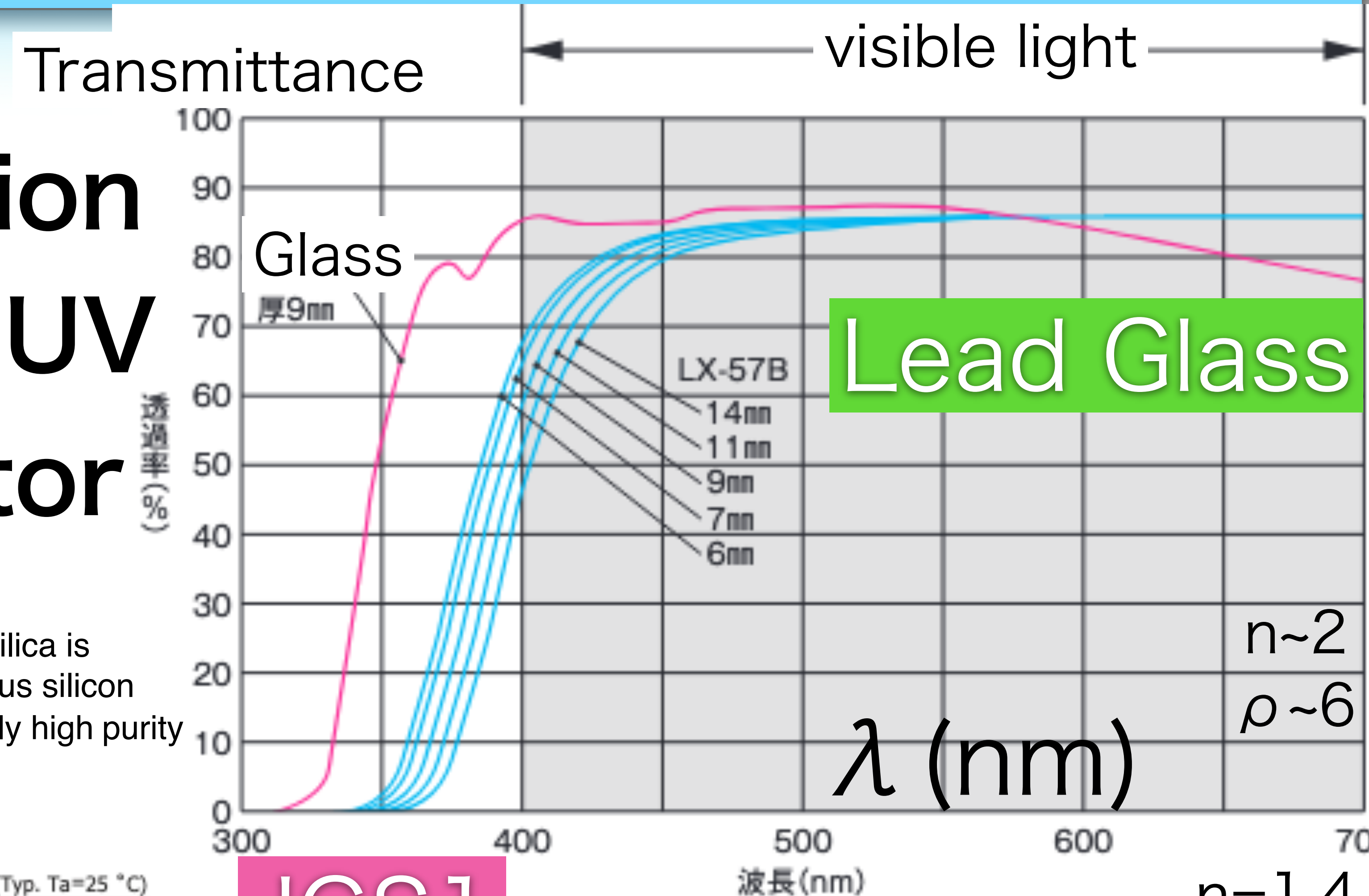


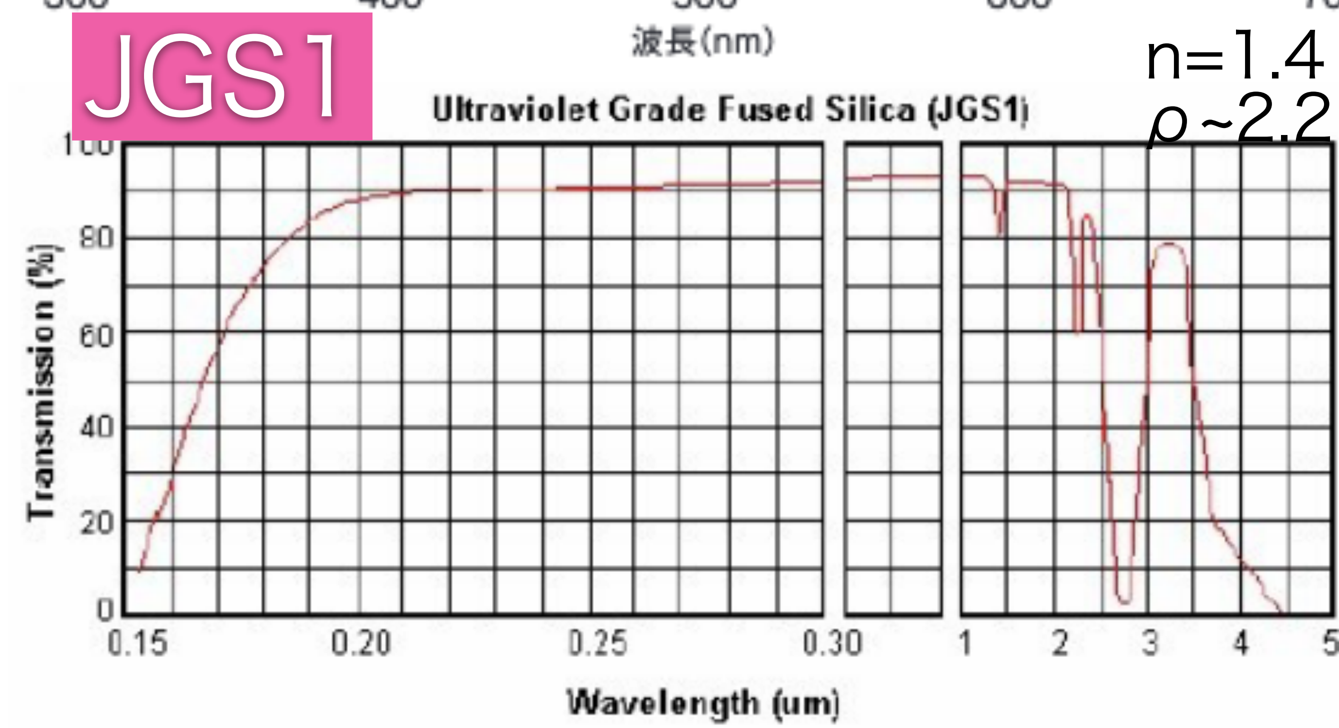
wave length features

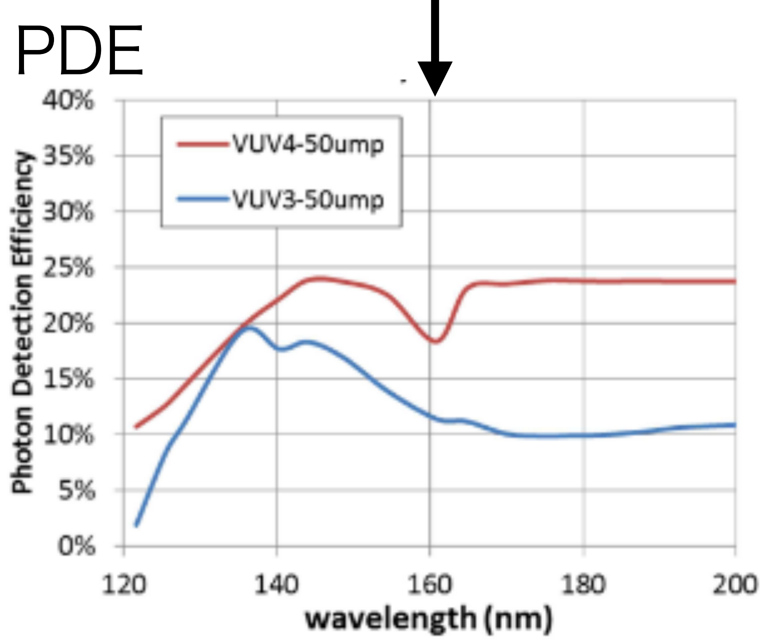
- Cherenkov detection in Lead Glass and UV transparent radiator
- VUV-MPPC

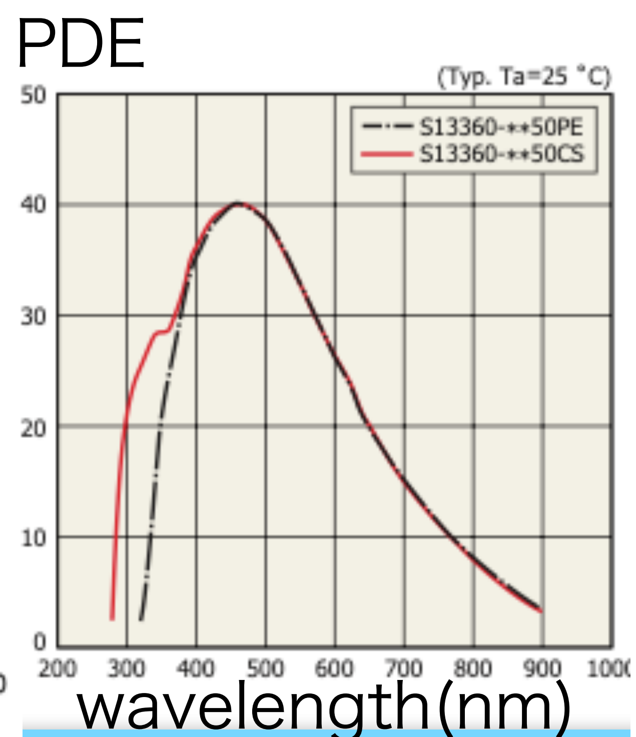
JGS1

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



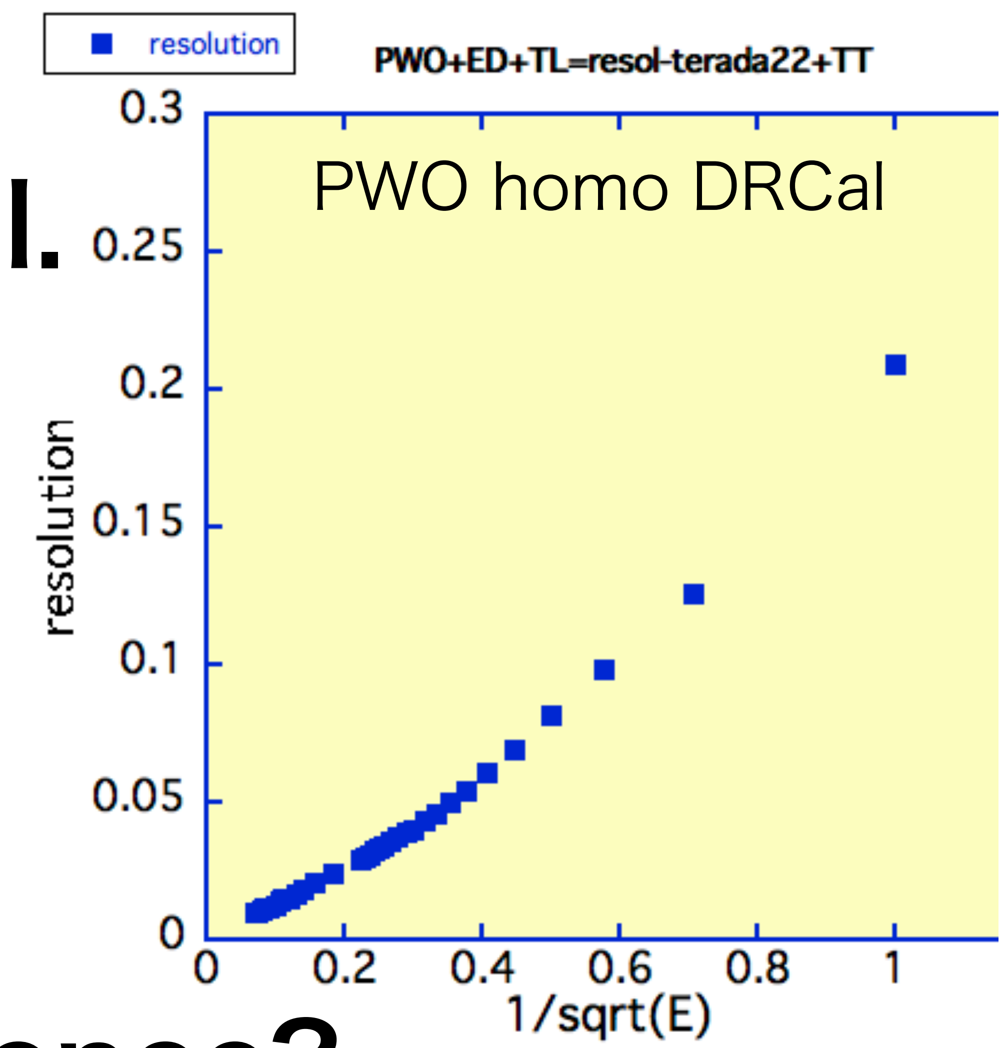


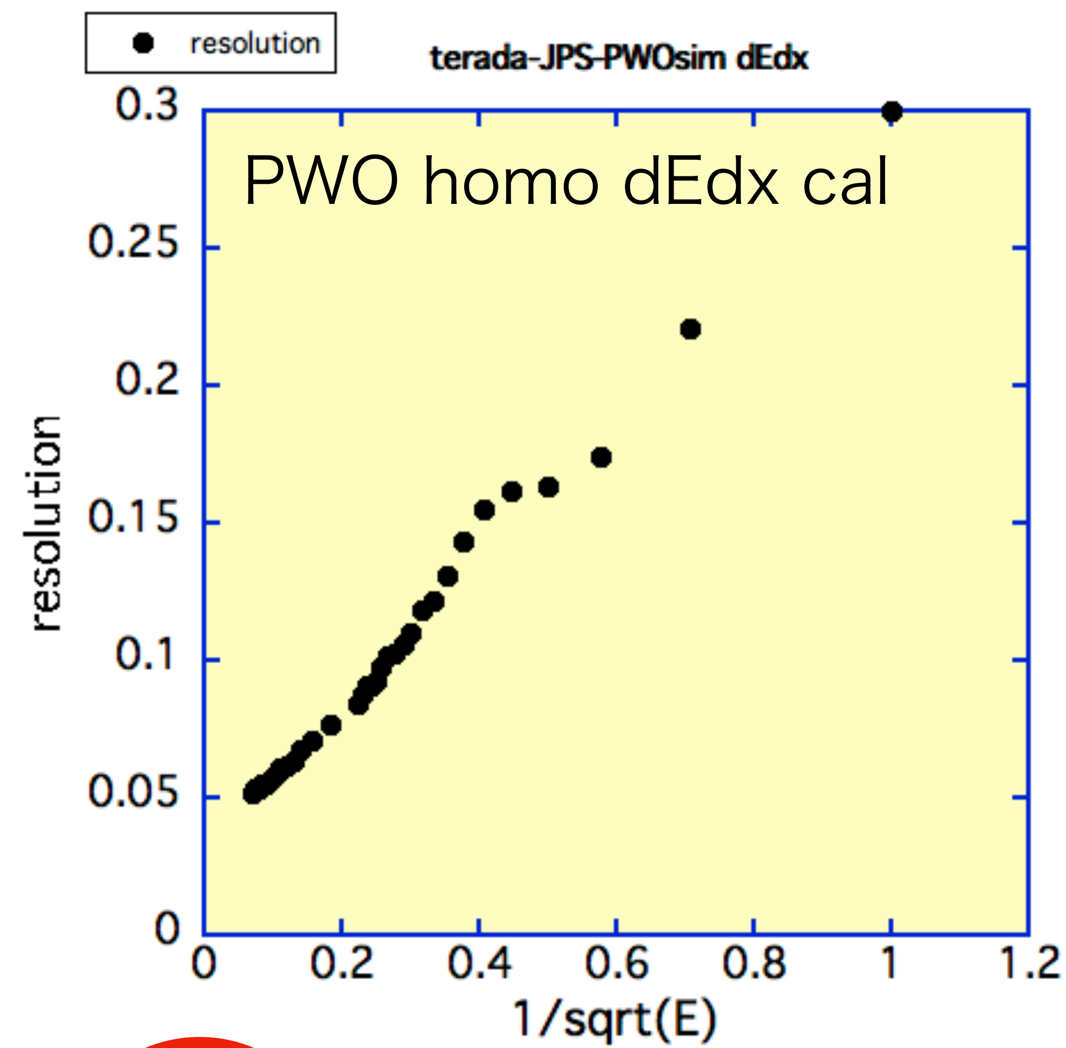


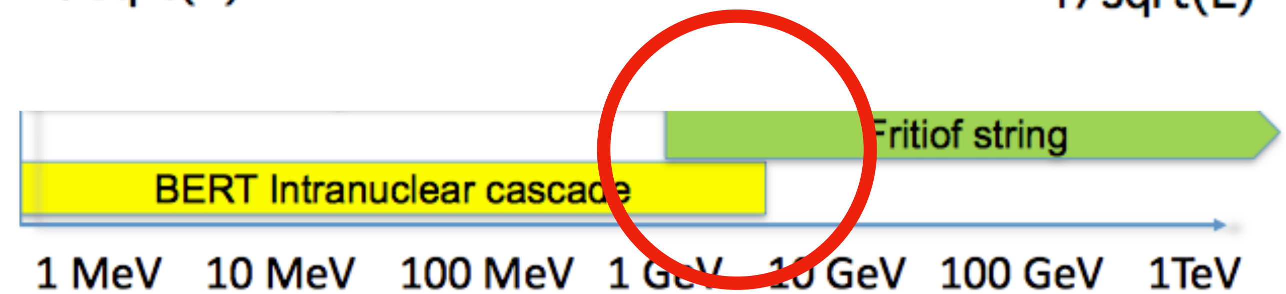


energy resolution

- compare dEdx cal. and DRSC in terms of 1/√E
- dEdx cal. suffers from. Hadron model interference?







test module

- Double read Sandwich Calorimeter
- test module