Double readout sandwich calorimeter for high energy particles

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JPS @Tohoku U, Sep2023

Shinshu U

- **Homogeneous calorimeter simulation**

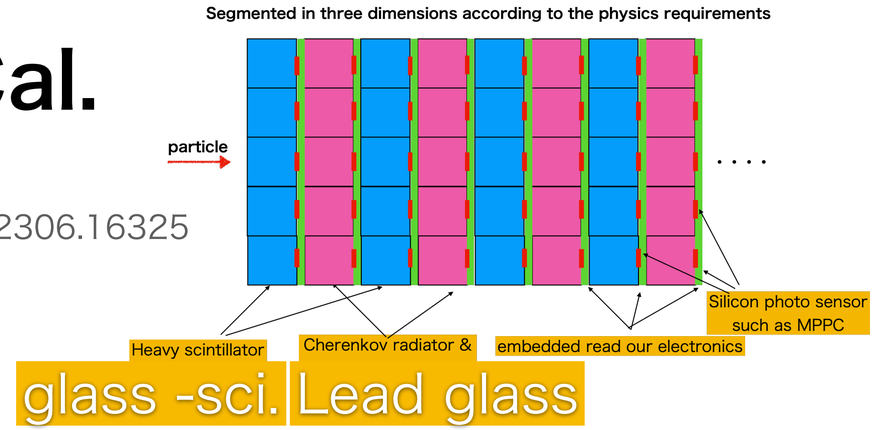
  一様均質

- **Double Readout GLASS Sandwich Cal.**

  radiation tolerance and cost effective

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

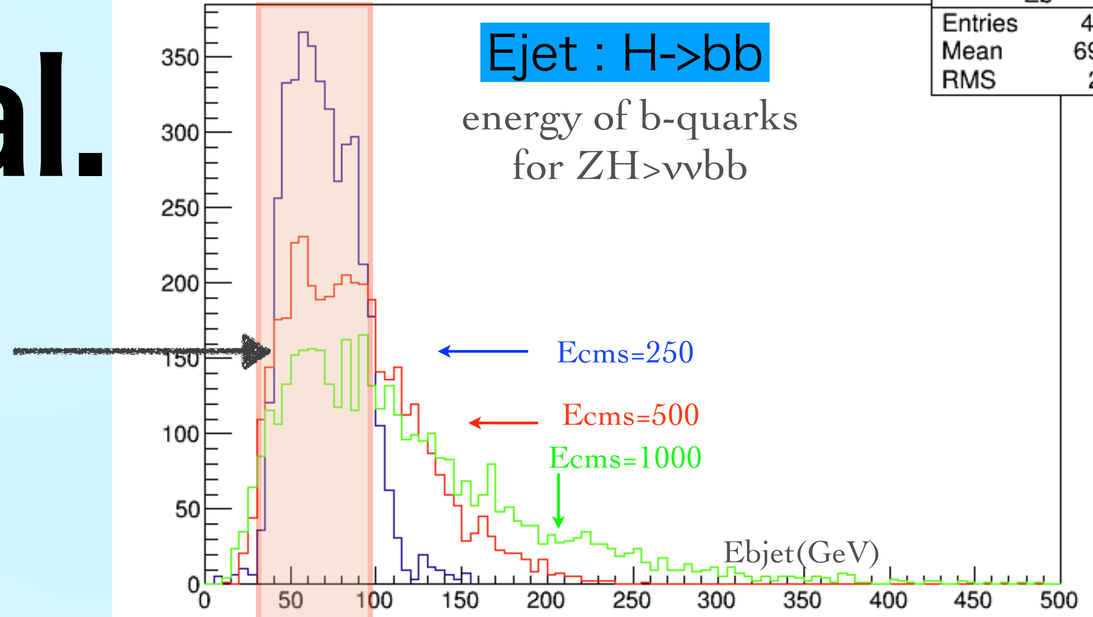
T.Takeshita & R. Terada, arXiv 2306.16325

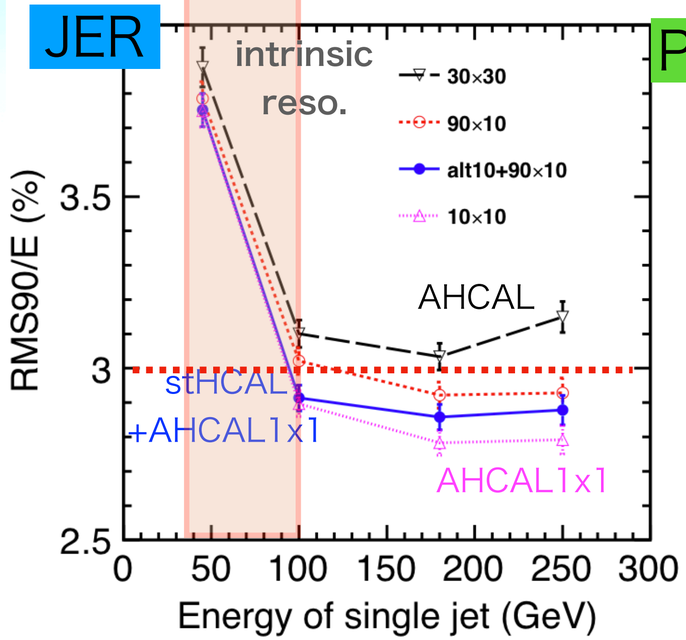


T.Takeshita

Higgs Factory Cal.

- Ebjet~50-100GeV dominates at Higgs Factory
- Energy Resolution of Jets (JER) is degraded due to intrinsic HCAL resolution
- PFA does work well at higher energies
  - fine segmented calorimeter
- to improve JER in 50-100 GeV region
  - ~ Eparticle <~ 10GeV
- Double readout sandwich Cal.

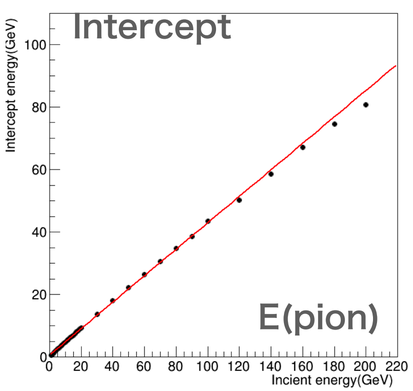




W/Z/H separation

start from

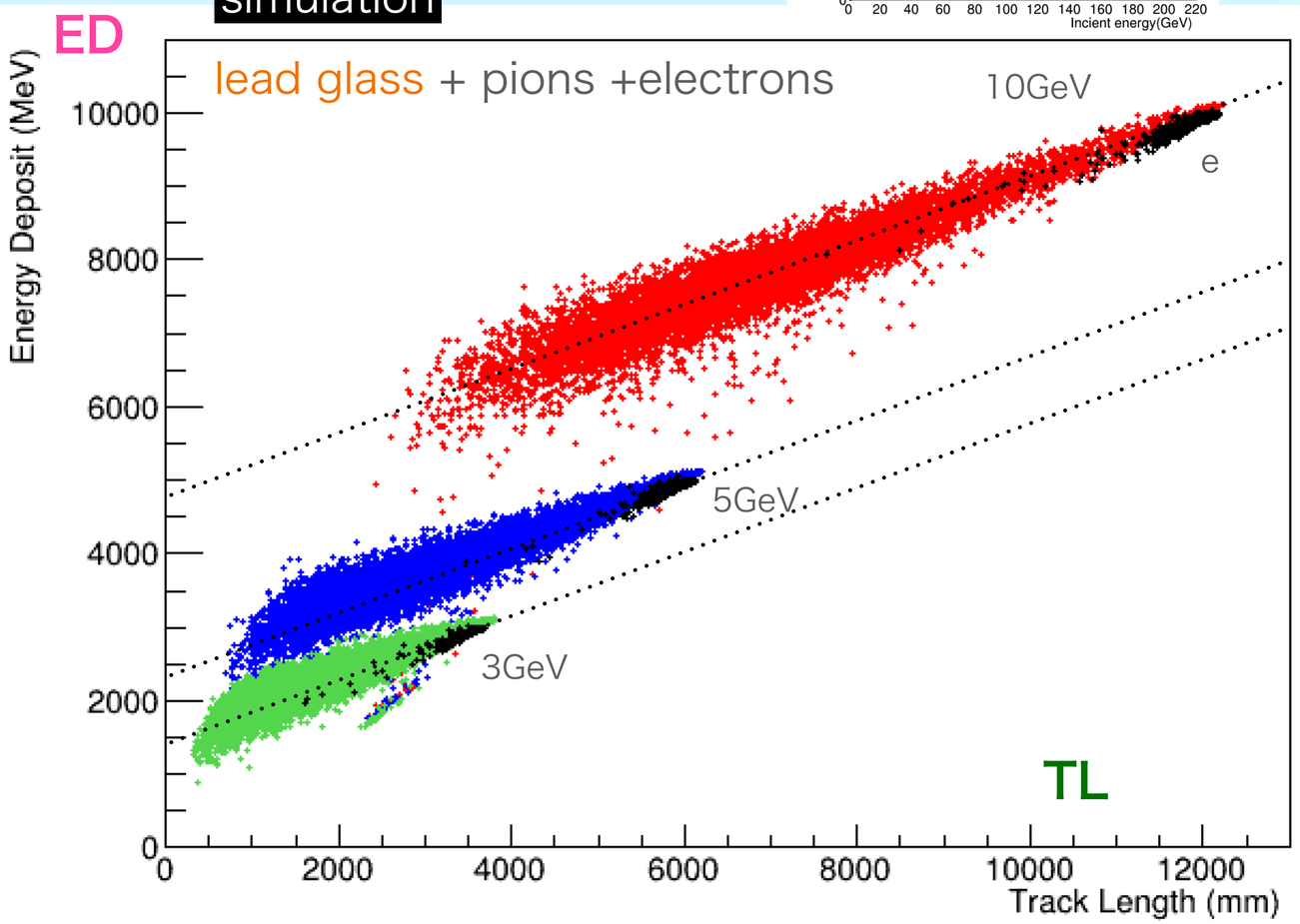
Homogeneous CAL



two parameters are to be measured

- **sum of Track Length (TL) ~ Cherenkov lights**
- **sum of Energy Deposit (ED)~ Scintillation lights**
- **correlation : linear behavior**
- **intercept → linearity** without passing the origin
- **slope → constant** independent of energy
  - **common for e/pi/K/p/n**

simulation



photon statistics is not taken into account

simulation with GEANT4.11.0 with FTFP_BERT (2mx2mx2m)

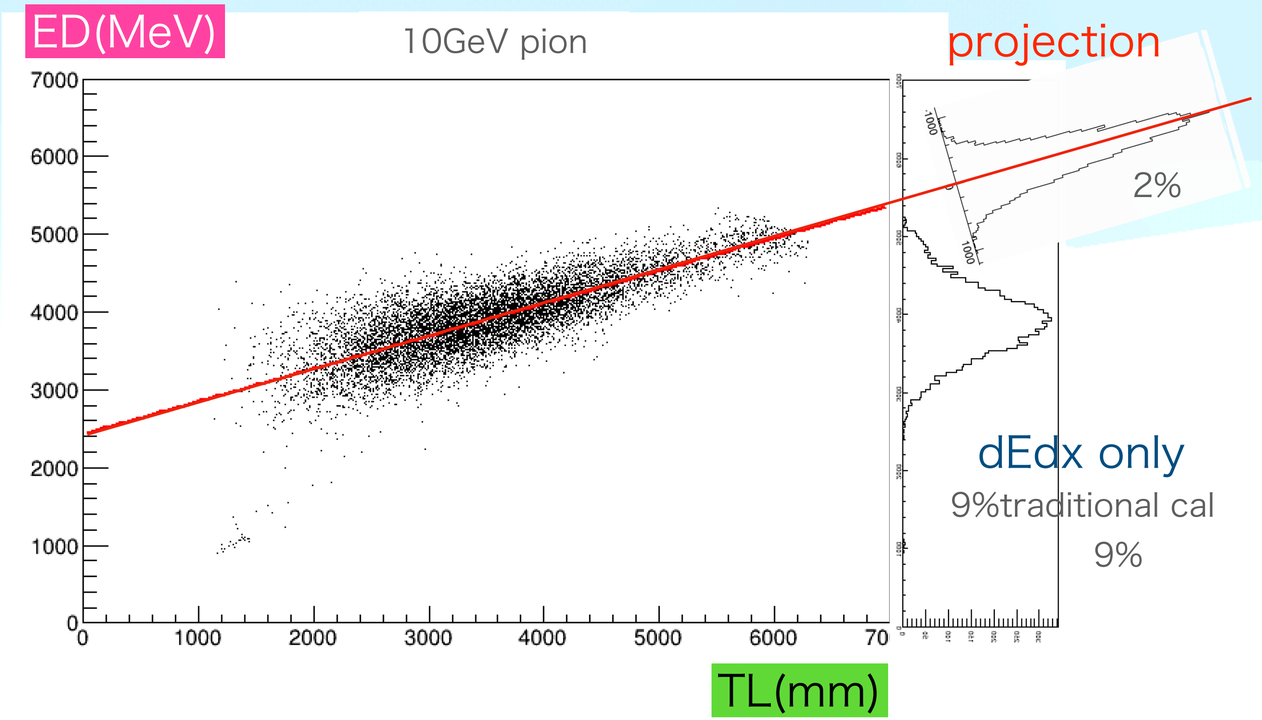
T. Takeshita *et al* 2020 *JINST* **15** C05015

energy resolution

- 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 : 2.1% (8.9% for trad. cal)@10GeV

From the correlation plot to the energy resolution (homo-cal)

simulation

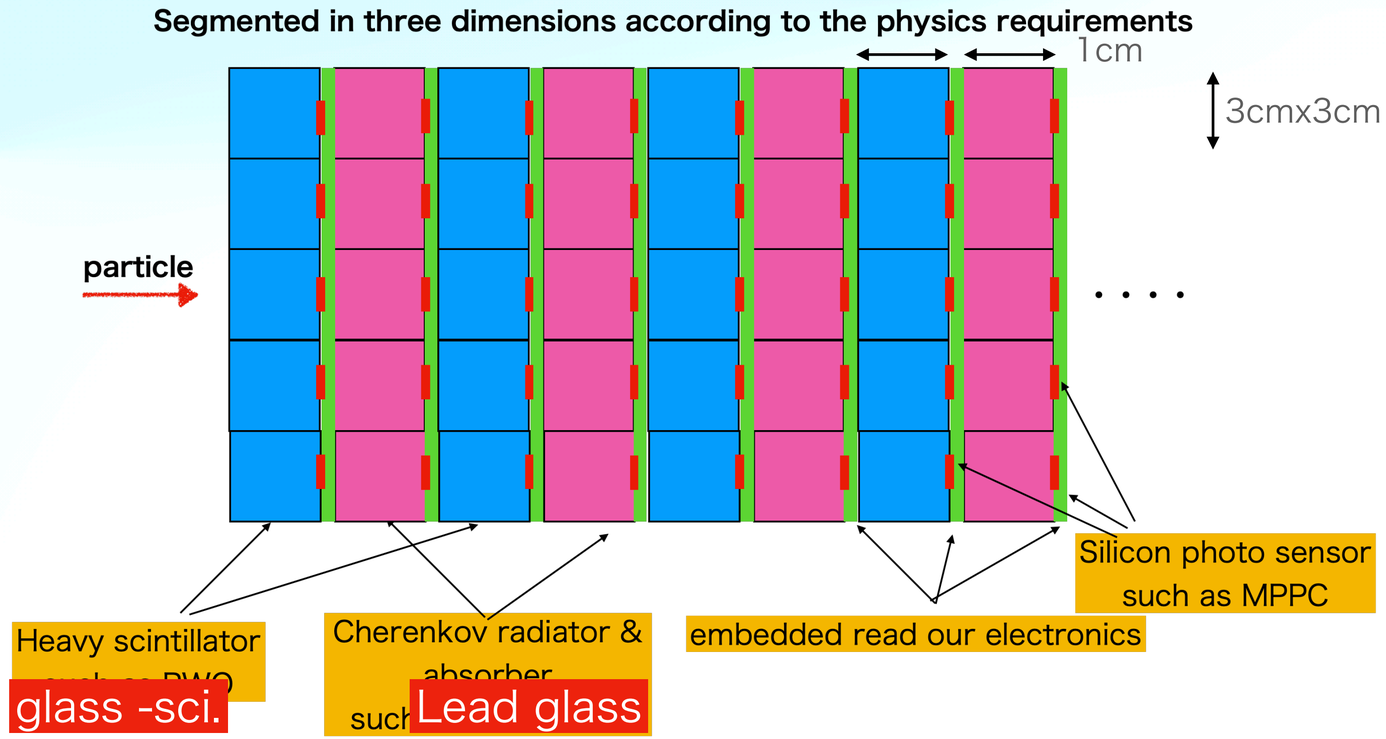


problem Homogeneous cal. : Large scintillator block: cost, uniformity ..,

a new idea : Double readout Sandwich Calorimeter of glass

separate Cherenkov radiator and Scintillation material with sandwich style
with highly granular option for PFA
DSC

Double readout Sandwich Calorimeter



active absorber

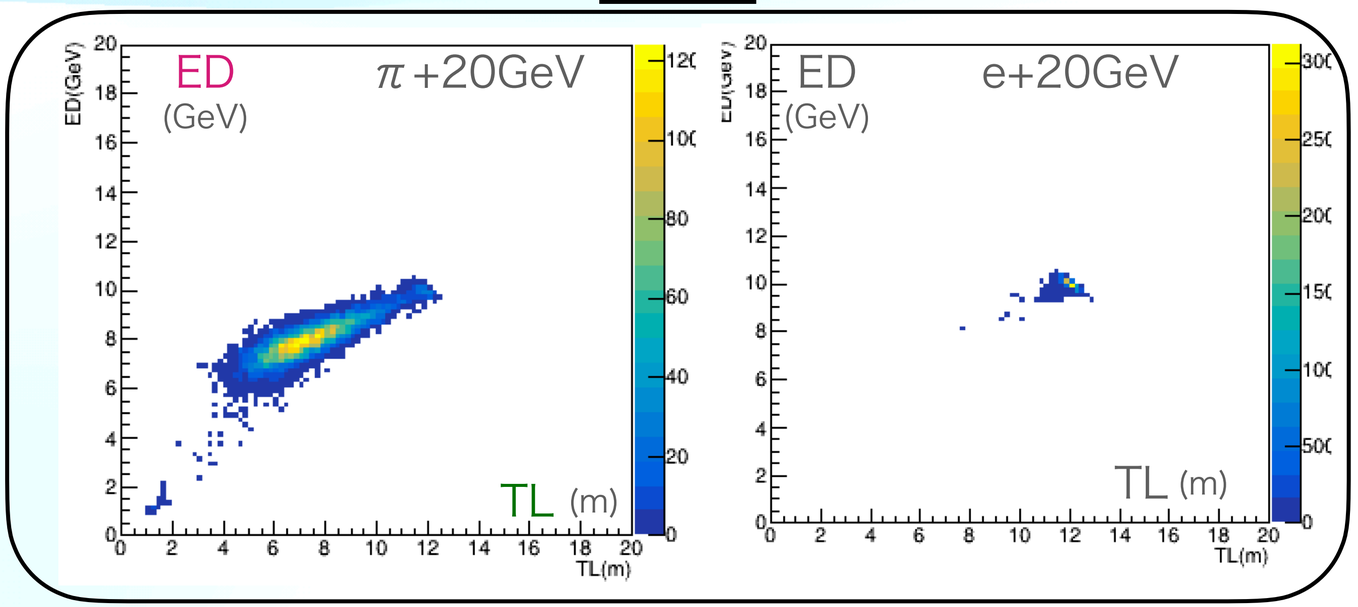
simulated

performance of DSC (2mx2mx2m cal)

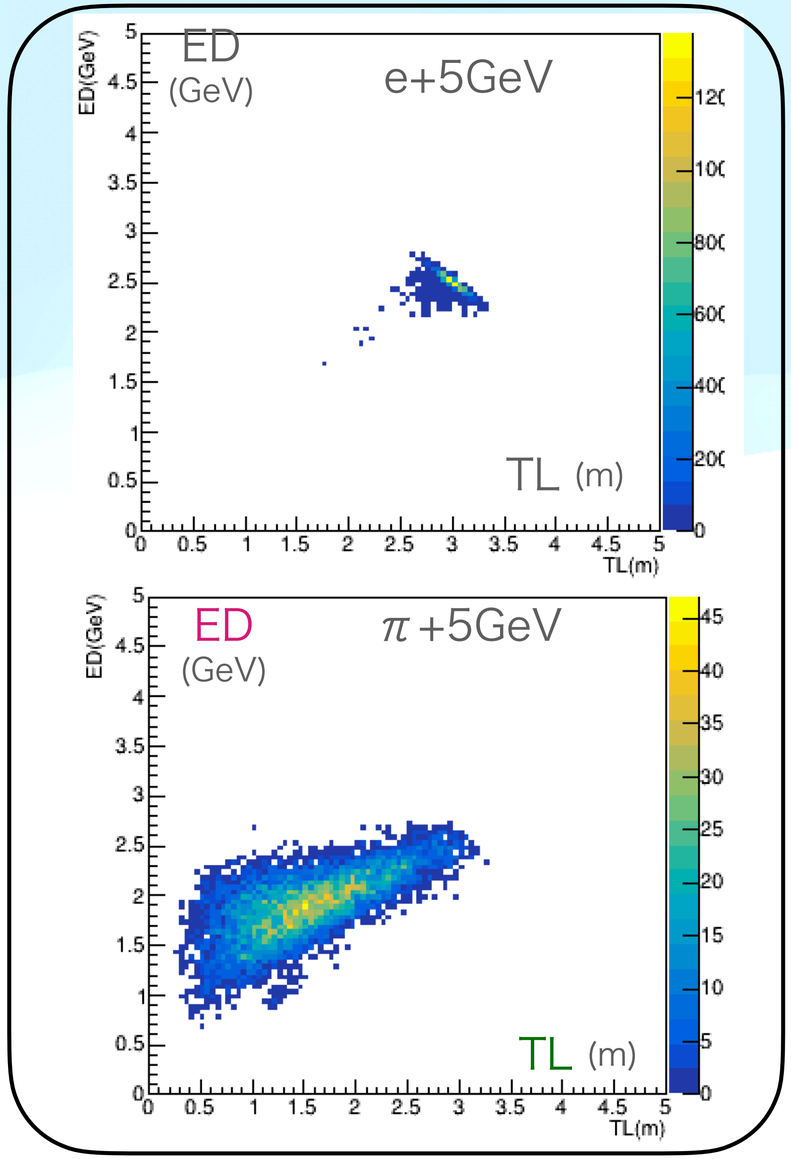
ED vs TL relation holds for sandwich calorimeter for both e's and pions

LG10mm+GSci.10mm 100layers

20GeV



5GeV



simulated

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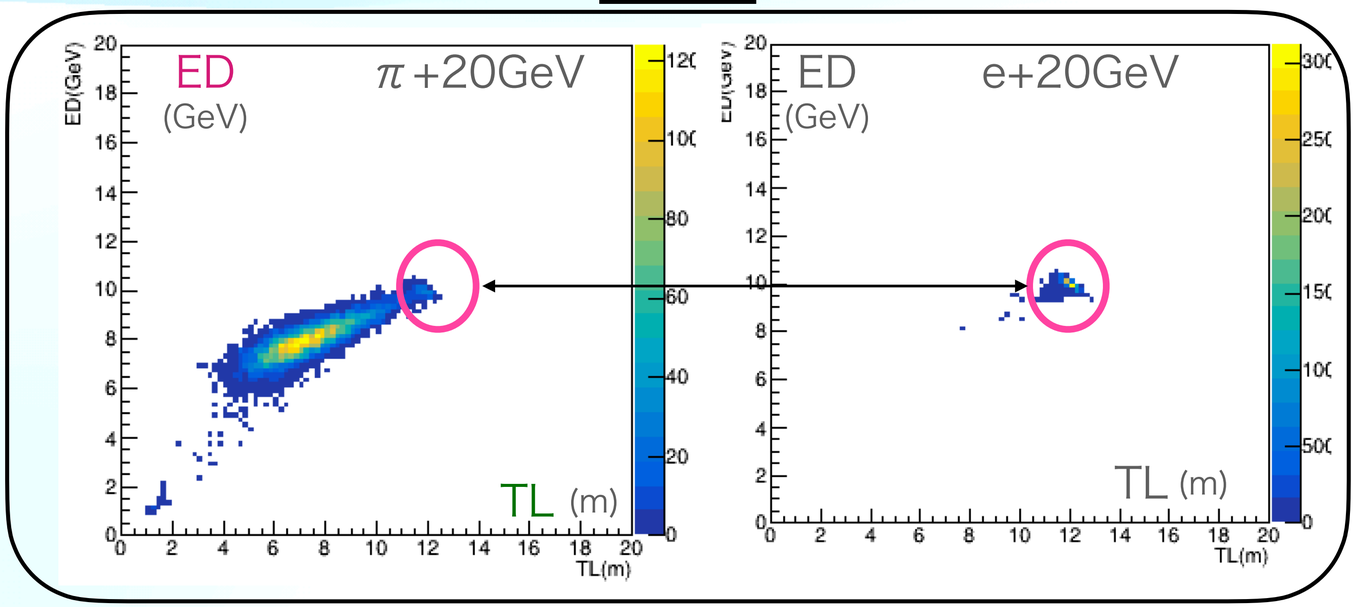
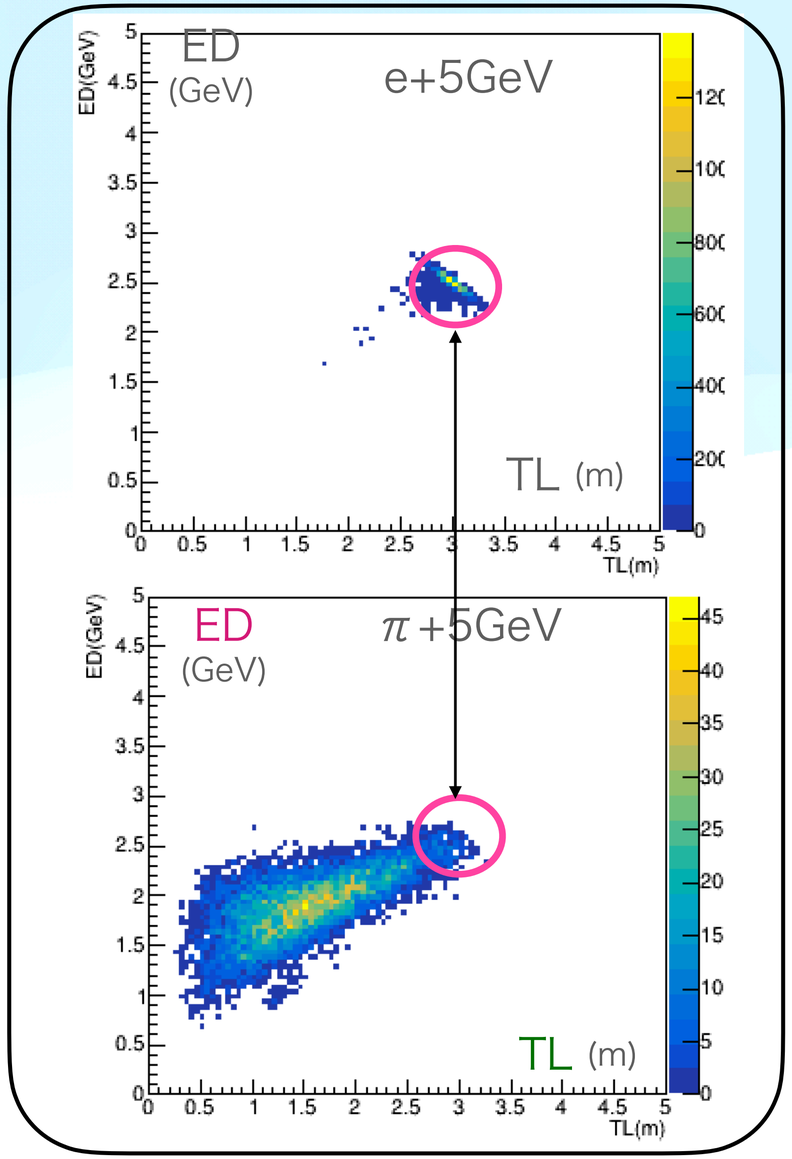


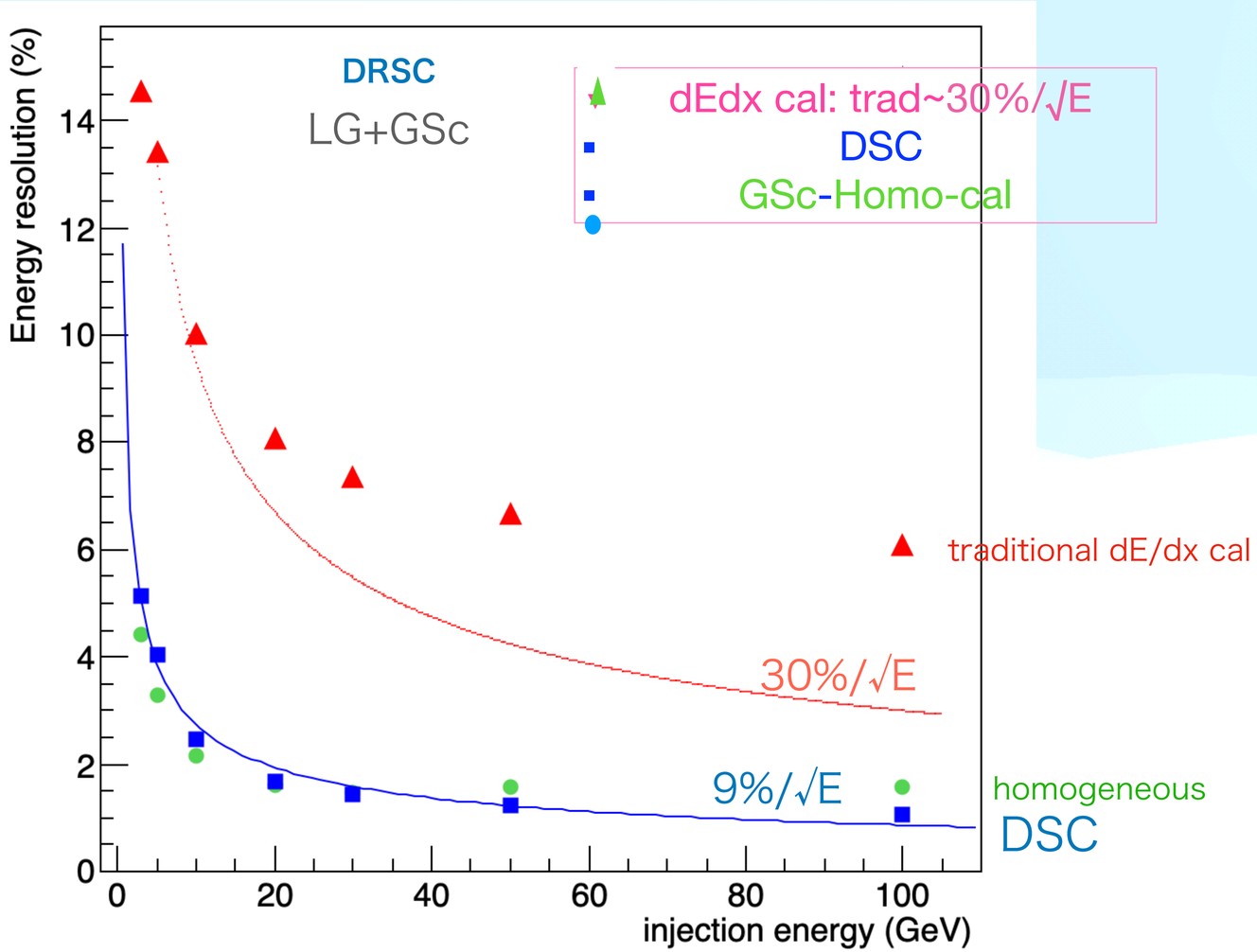
5GeV



simulated

Energy resolution of DSC

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



- study: photon statistics and prototype

Cherenkov light detection

Lead glass :

1cm^{t}x10x10cm^2

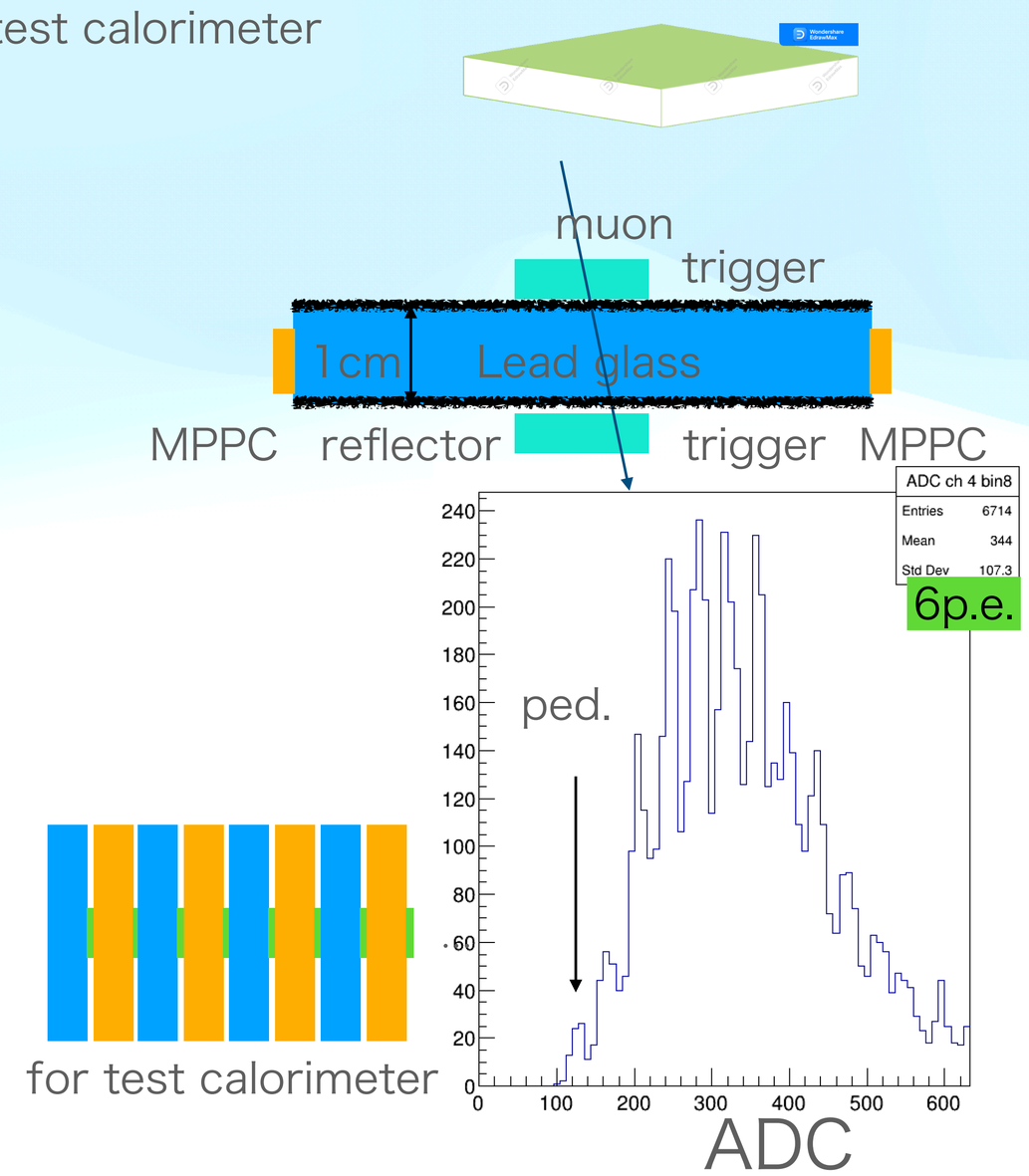
frosted 10x10 surface

polished at 1x10 side

by a 6x6 mm^2 MPPC

grease coupled results

~6p.e.



Cherenkov light detection cont.

PFA cal.

- LG: 2cm^t x3x3cm^2
  all polished &1 non-pol.
  grease coupled MPPCs
  UV and normal MPPC
  6mmx6mm
- UV light does not transmit in LG
- polishing effect

trigger (3cmx3cm)
with cosmic muons

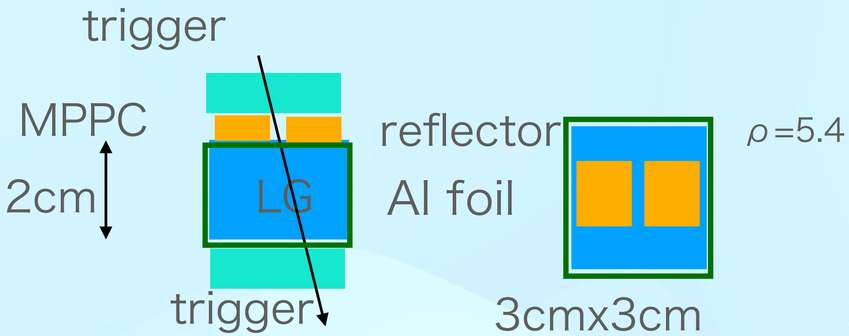
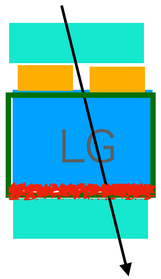


Photo Det / Glass	(lead glass) normal (p.e.)	(lead glass) uv (p.e.)
all polish	12	12
1 unpolish	8	8



Effect of frosting / polished

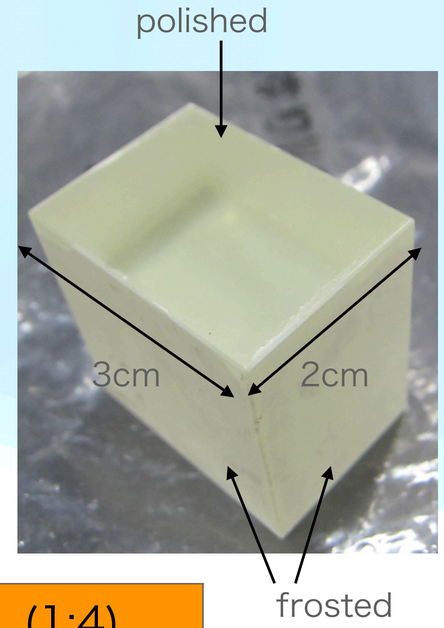
LY and timing with 3x3x2cm3 LG

6mmx6mm Normal MPPC greased readout

frosted surface : diffuse with changing the angle

⭐fully **frosted surfaces** have the biggest Light Correction

timing resolution ~100ps



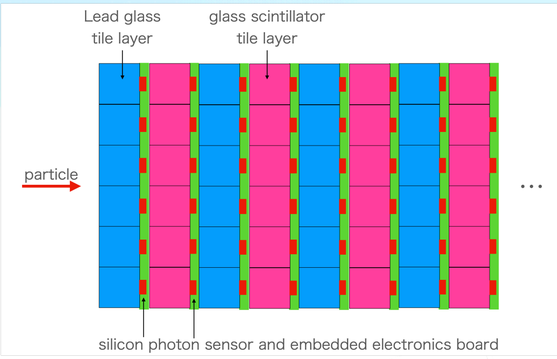
3x3:3x2

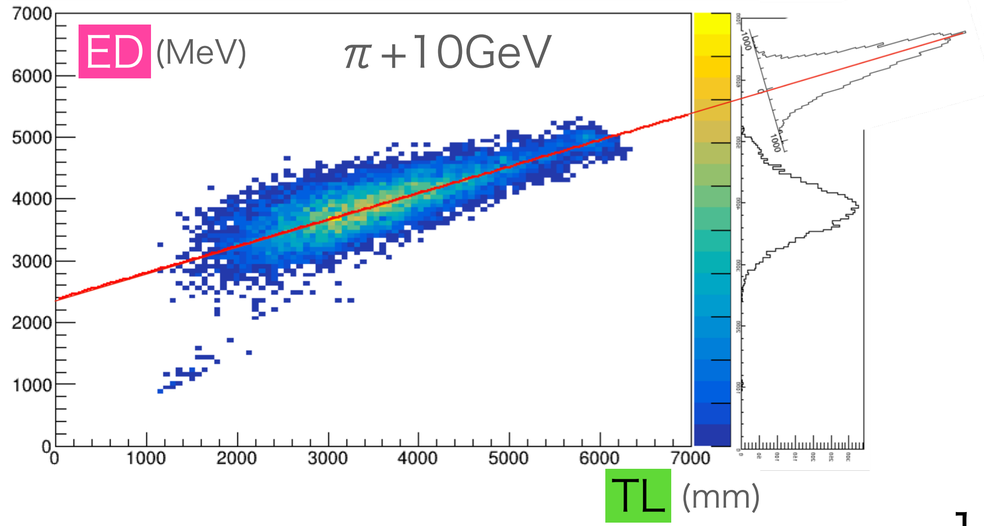
2cmt

LY(p.e.)	(0:0)	(1:0)	(2:0)	(2:2)	(2,3)	(0:4)	(1:4)
top RO	11.5	7.7	X	X	X	12.5	12.8
side RO	13.2	10.5	8.4	11.0	15.3	X	X
dT(ps): top RO	115	128	X	X	X	94	111
dT(ps): side RO	120	109	118	136	112	X	X

summary and outlook

- Double readout glass sandwich calorimeter
- a relation between sum of Track Length (Cherenkov) and Energy Deposit (scintillation) leads fine energy resolution from sim.
- actual implementation is proposed as DSC with fine energy resolution
- R&D for DSC is on going
  - production of scintillating glass by Koshimizu lab…

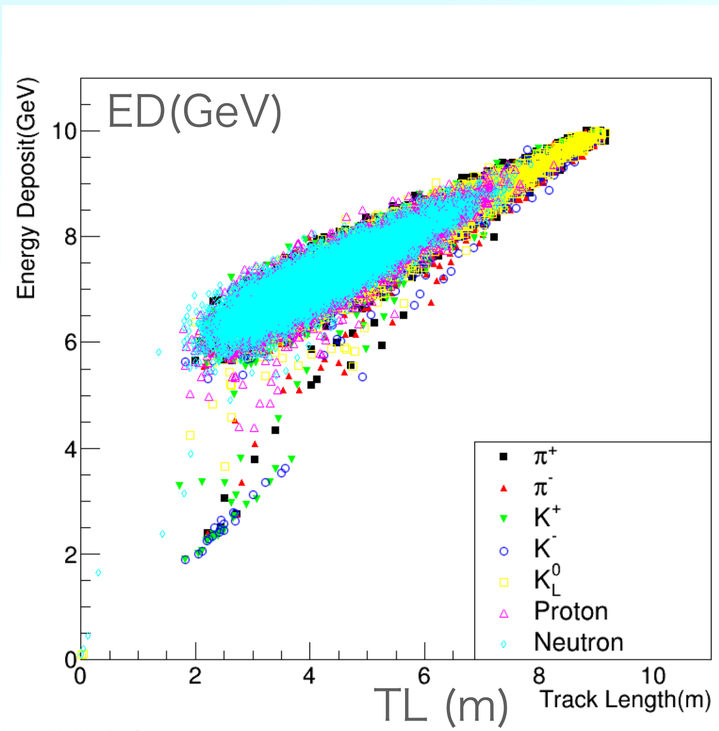




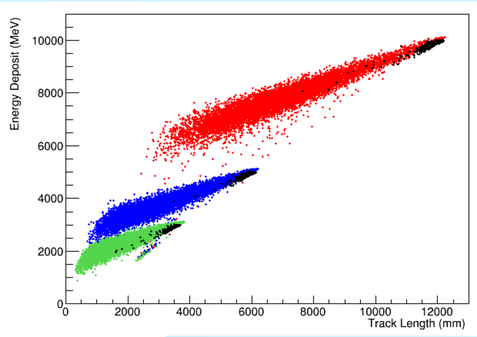
Intercept & Slope

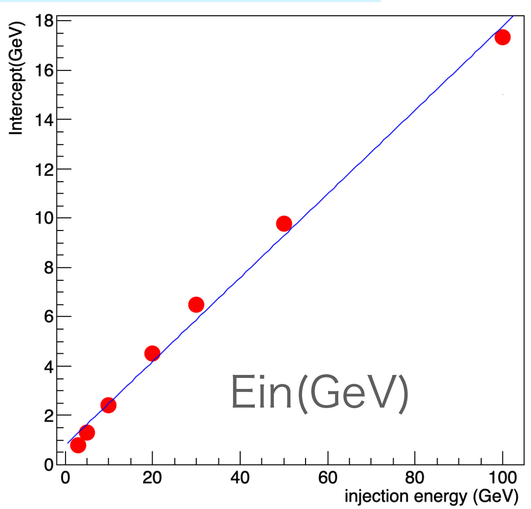
work as a calorimeter

good linearity on intercept
slopes are fairly constant
common for particles

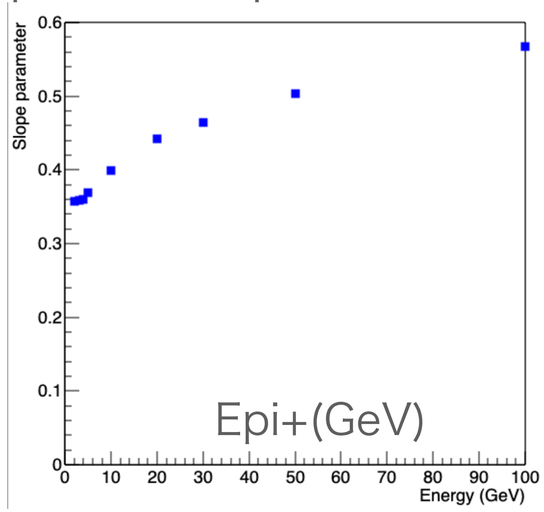


Intercept pi+





slope pi+



Cherenkov light

Track Length ~ Cherenkov lights

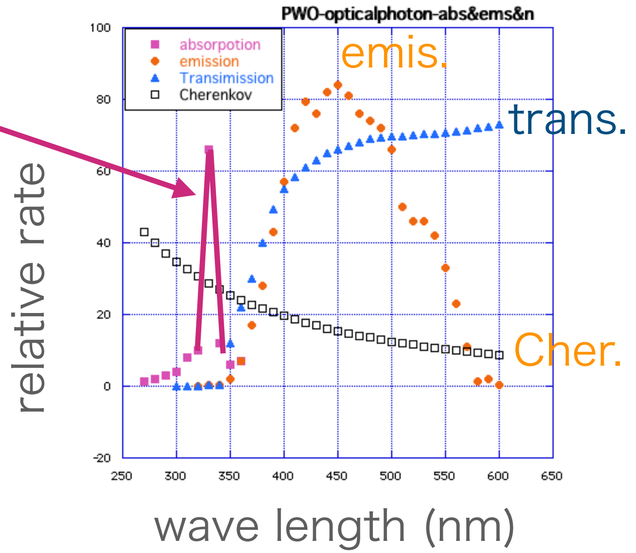
Cherenkov is low light and $1/\lambda^2$ (UV)

need heavy and UV transparent material

will be absorbed and converted to scintillation light

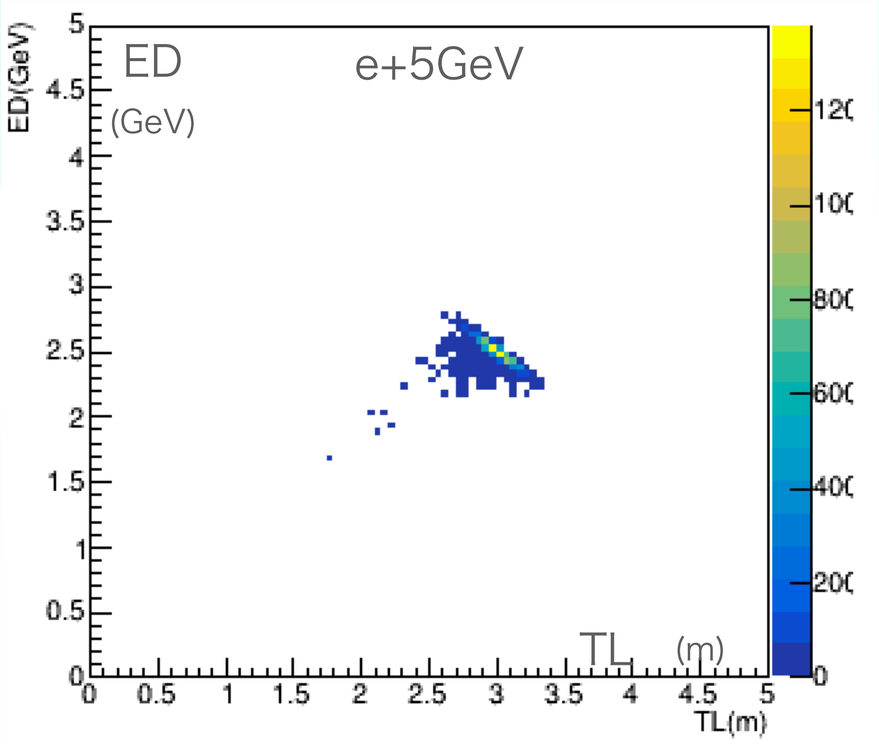
difficult to separate lights

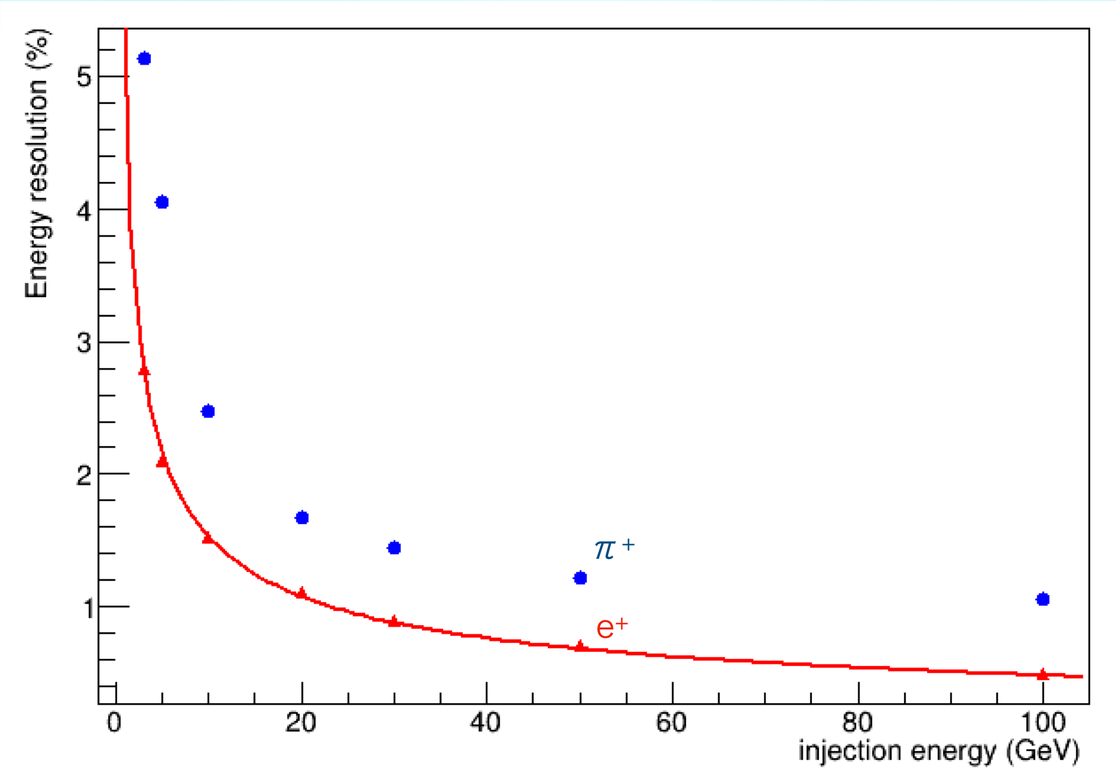
timing or signal shape mixing



electrons on DSC

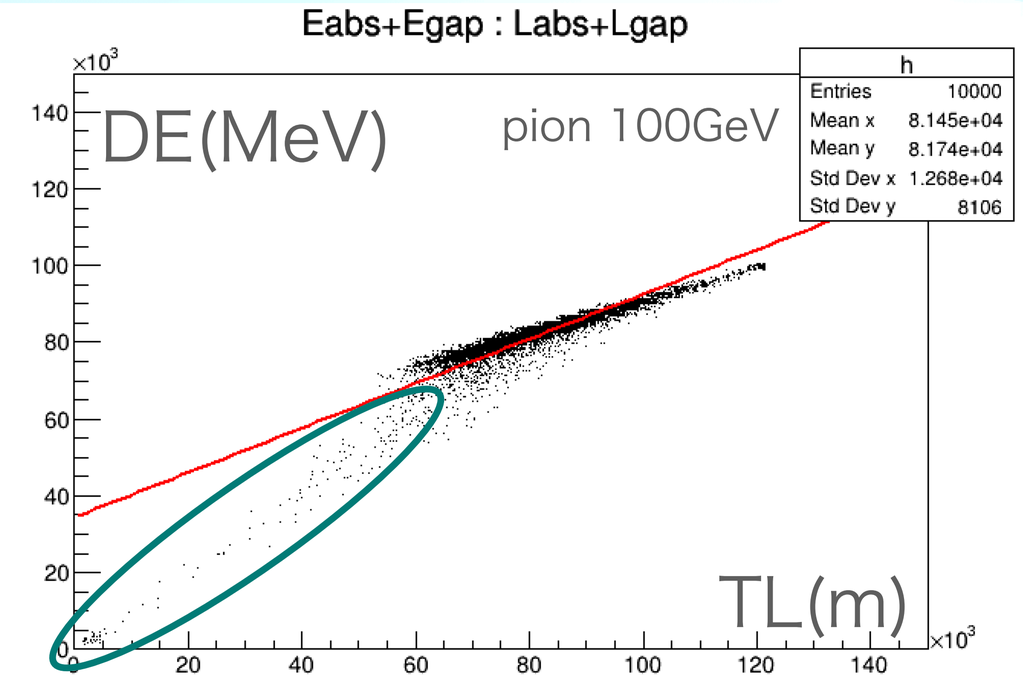
electron energy resolution
~ 4.8%/√(E) ~ Lead Glass ECAL of OPAL





homogeneous cal.

effect of punch though pions
(~muon)
fitting deteriorated
leads slop parameter
bending



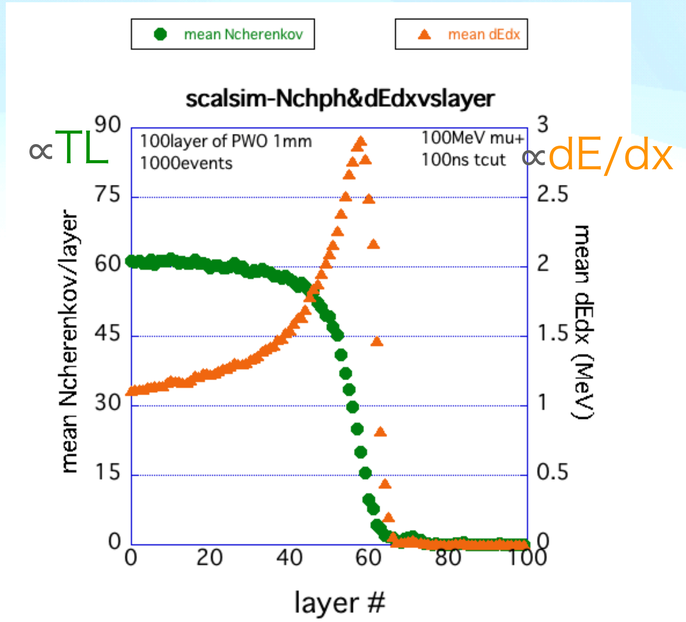
reason of intercept

when particles stop in a shower

Bragg peak will be detected by scintillator

no peak for Cherenkov

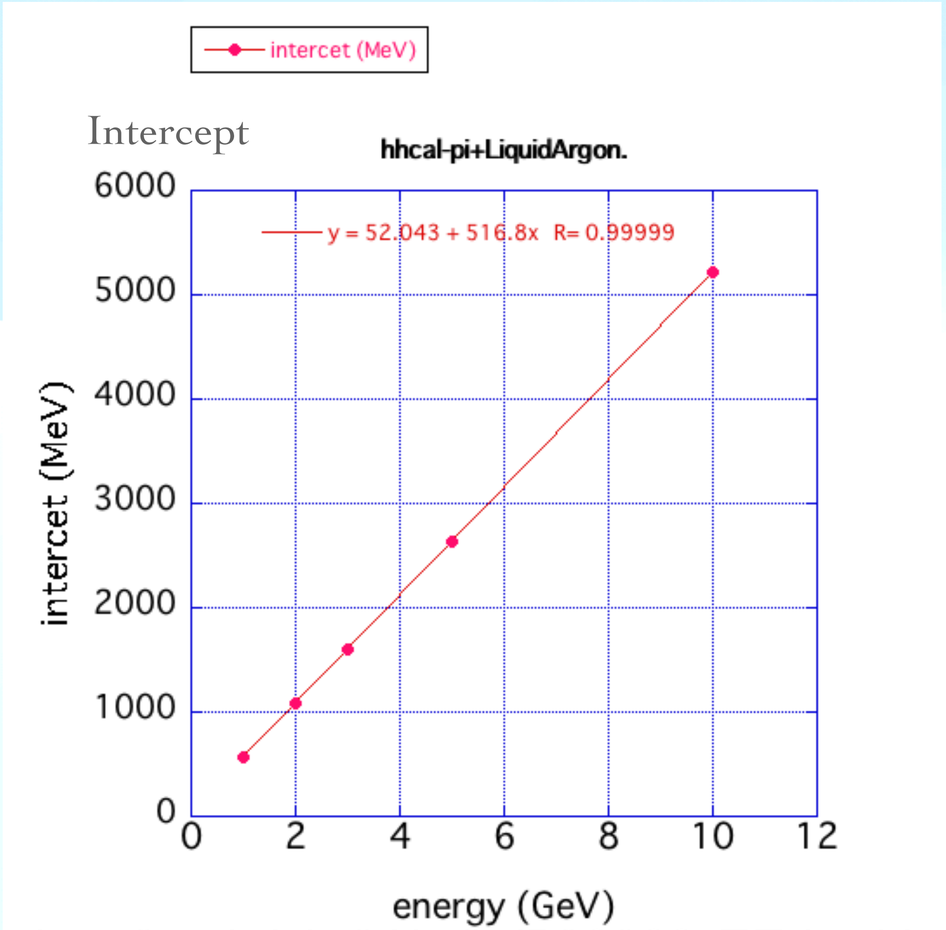
- intercept corresponds to number of stopping particles

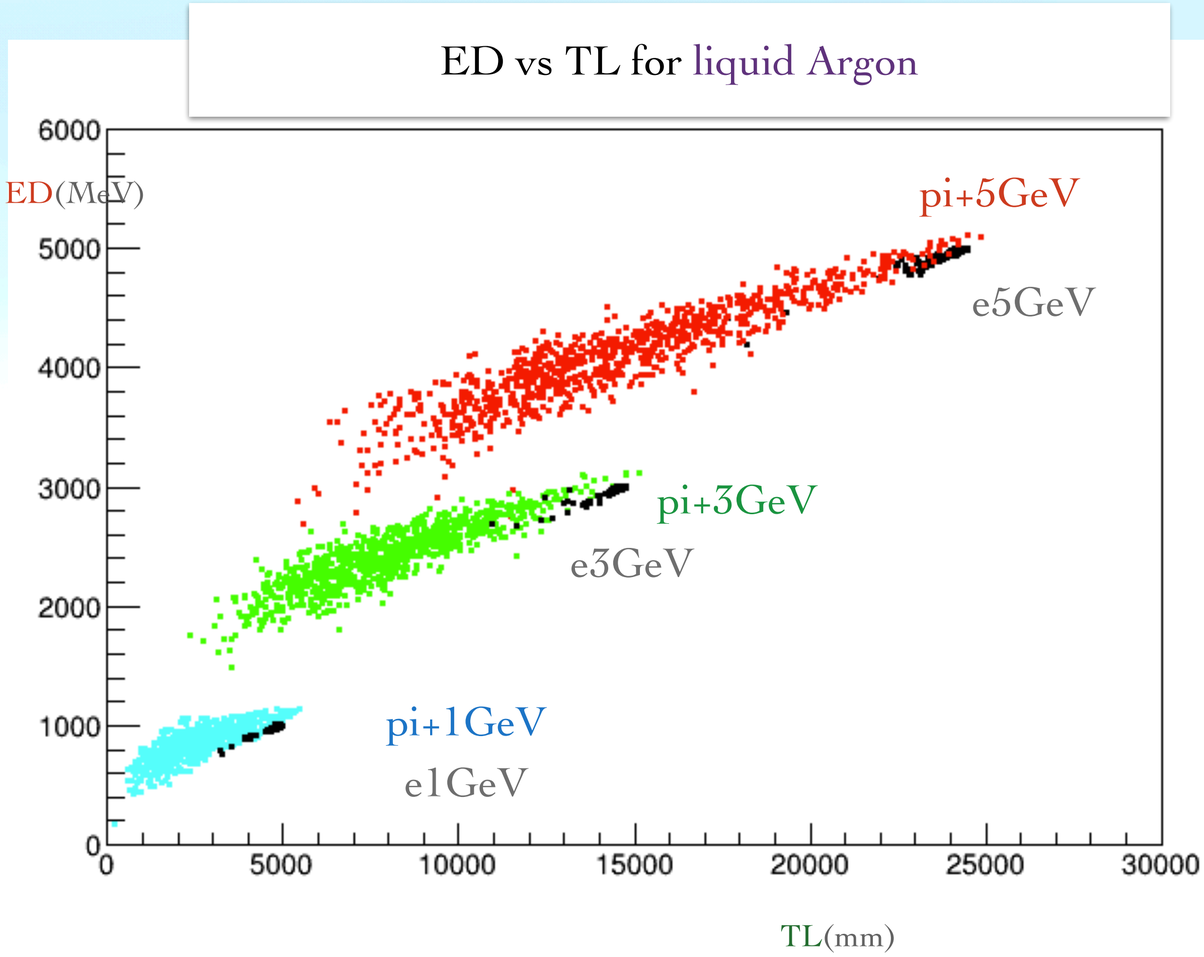


Different detector material

Liquid Argon, & CsI are simulated

ED vs TL

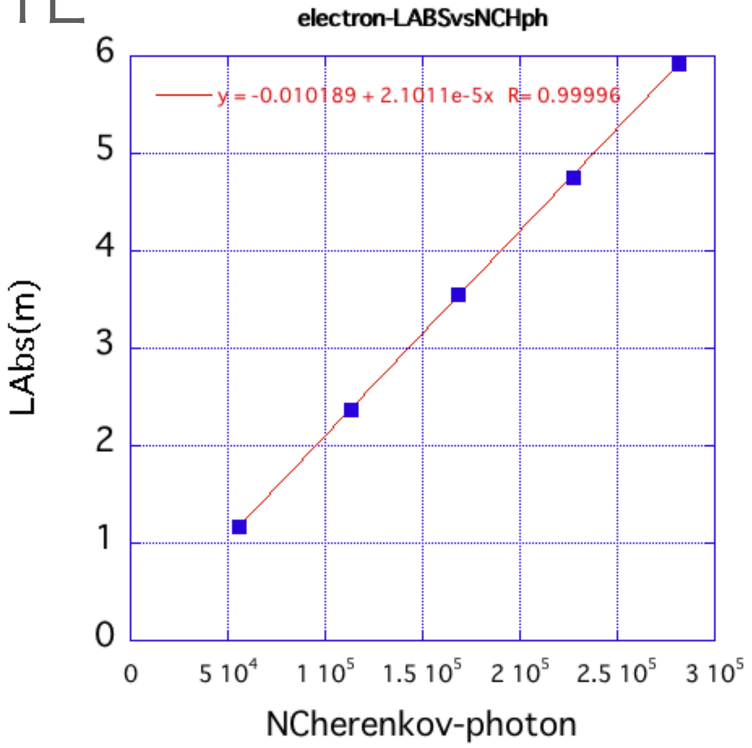


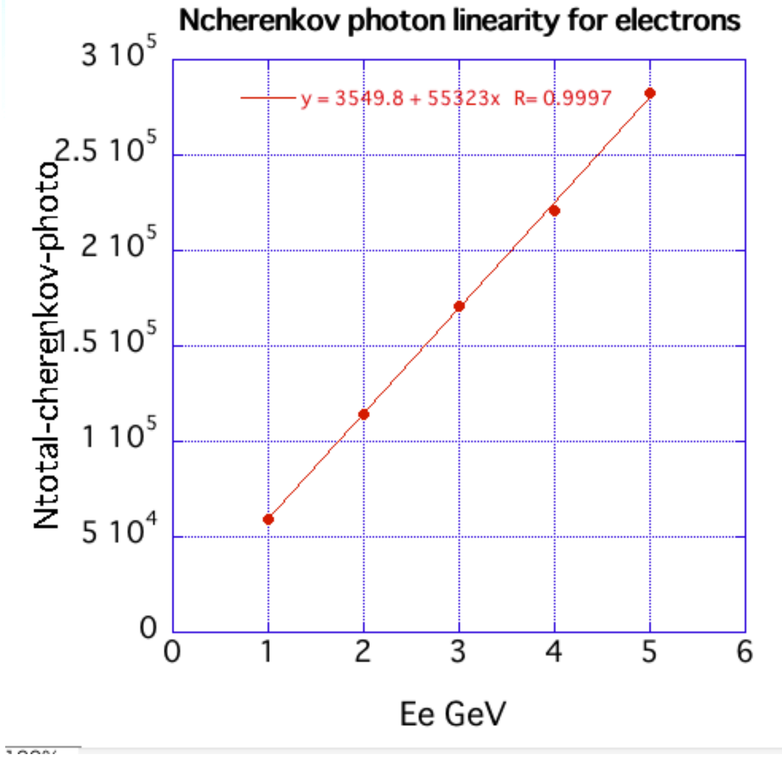


TL vs Cherenkov light

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

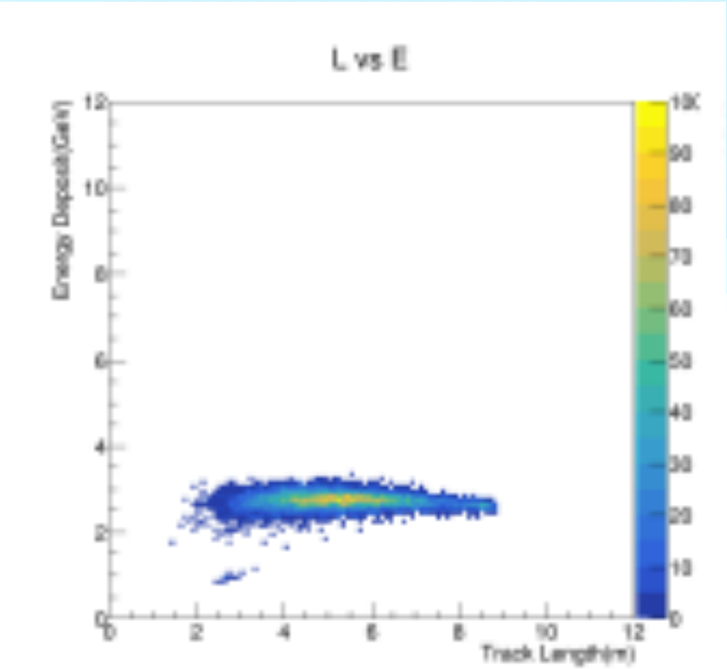
TL





DSC

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

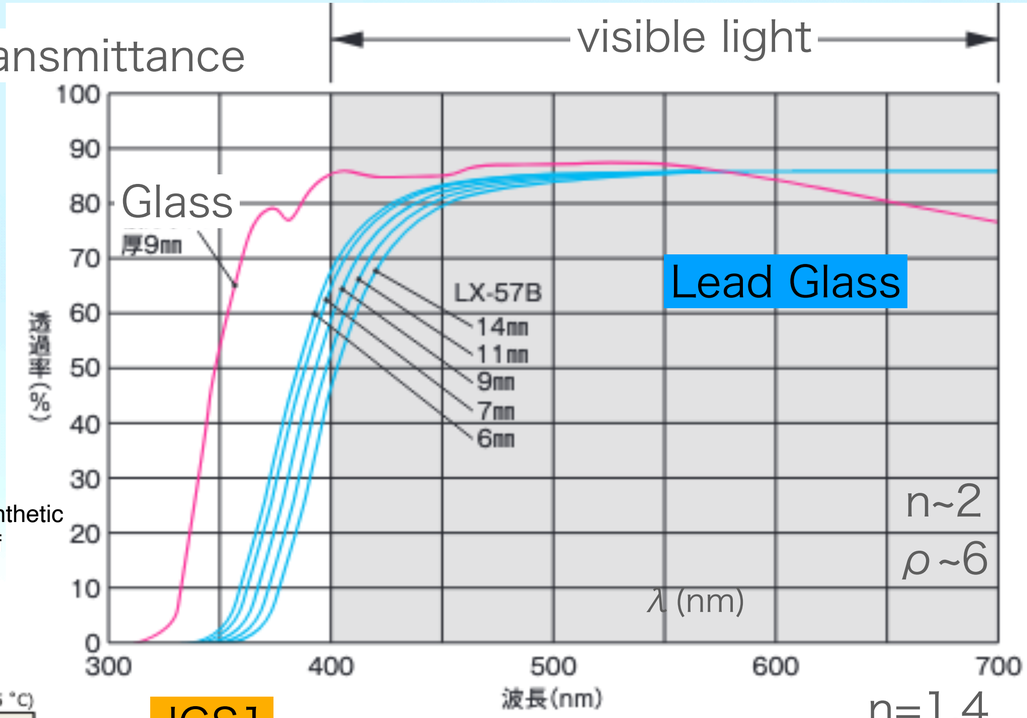


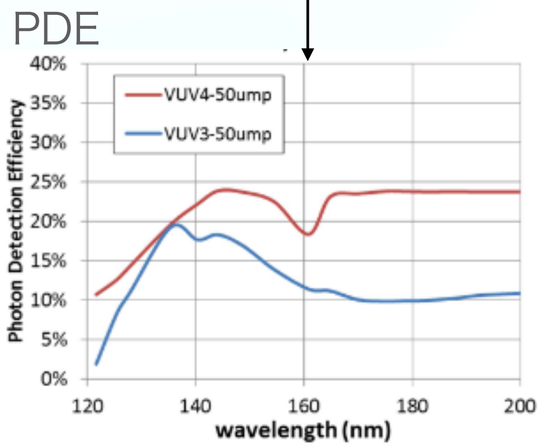
wave length features

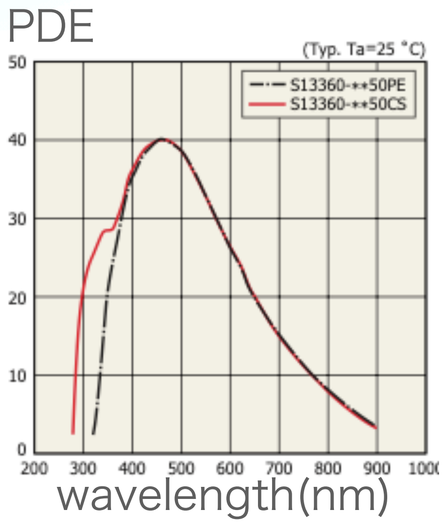
Cherenkov detection in Lead Glass and UV transparent radiator VUV-MPPC

JGS1

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

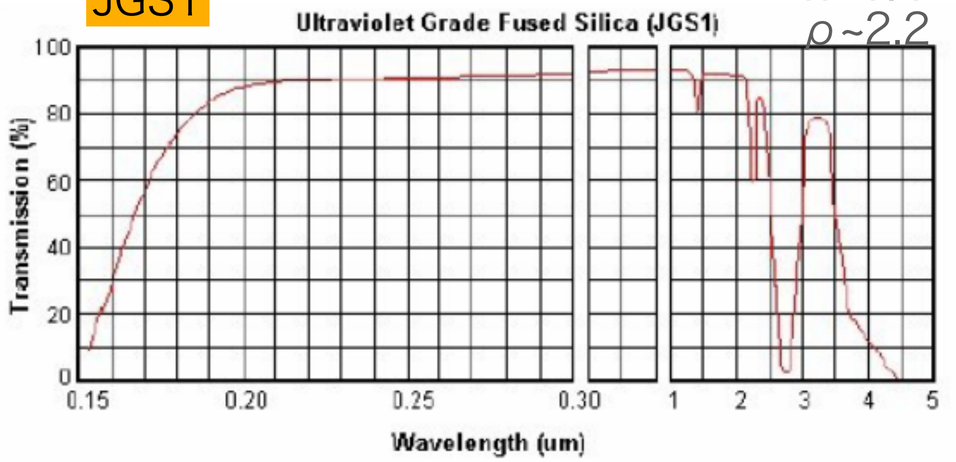






JGS1

n=1.4
ρ~2.2



- すりガラス（表面ザラザラ）
- frosted glass by etc hall : フッ化水素アンモニウム…20%
  不活性成分…80%　　（腐食）＞ザラザラは均一
- サンドブラスト法　　（砂吹き法）マスキング