Simulation study on performance of Sc-ECAL for ILD

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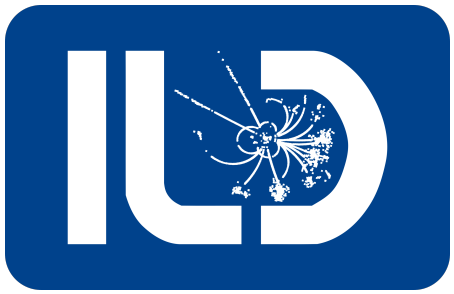
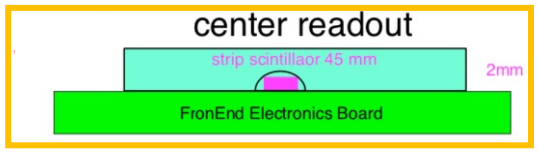
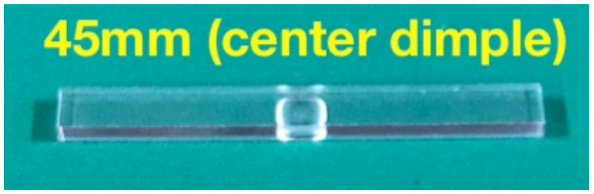


Sc-ECAL

- ECAL concept based on strip-shaped plastic scintillator readout by SiPM
- Virtual $5 \times 5\ \mathrm{mm}^2$ cell segmentation can be realized by strip x-y configuration
- Options for strip-SiPM optical coupling

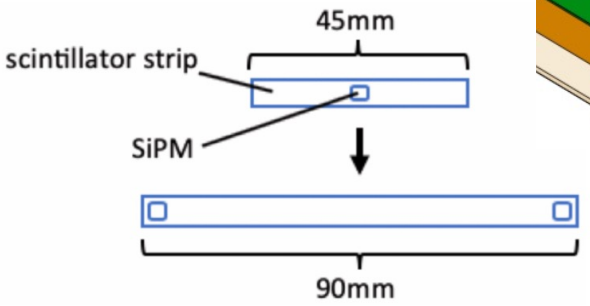


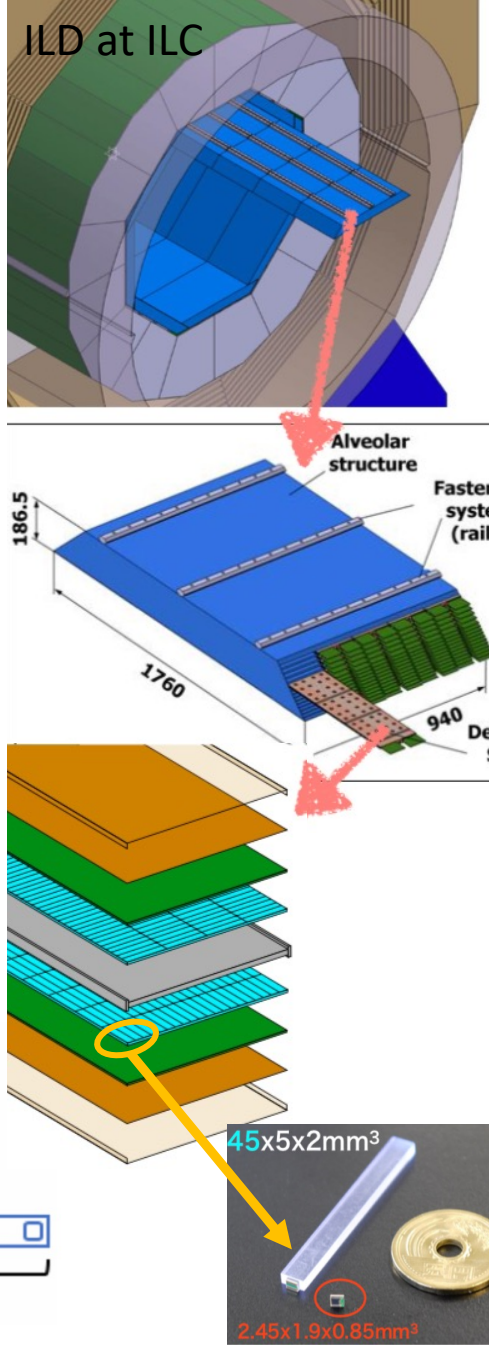


➡Center dimple readout is baseline option

- Double SiPM readout

➡ Another readout option under study
➡ Readout by two SiPMs at strip ends





ILD simulation study

- Simulation study on calorimeter performance with realistic conditions

- We plan to study

  ➡ Effect of hit position dependence on light yield
  ➡ Effect of gap/misalignment between strip and SiPM
  ➡ Performance improvement with double SiPM readout

- ILD model simulation

  ➡ Simulation for performance of ILD by the simulation tool (iLCSoft)
  ➡ ILD model version ILD_l5_o3_v02 (both ECAL and HCAL based on plastic scintillator)

- Topics for today

  ➡ Correction of the effect of gaps between ECAL modules on the simulated hit energy
  ➡ Apply the real strip effect (position dependence of light yield on a strip)
  in the ILD simulation

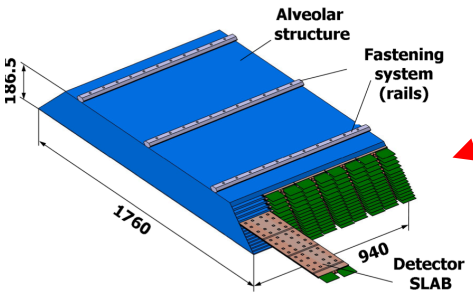
ILD simulation study

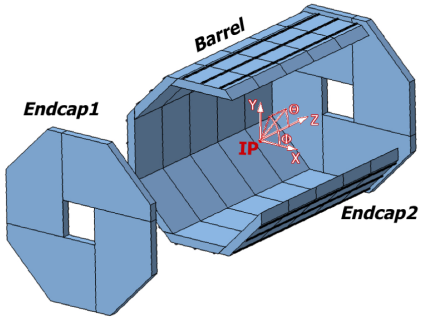
Correction of gap effect on ECAL

- Correction of the gap effect on ScECAL

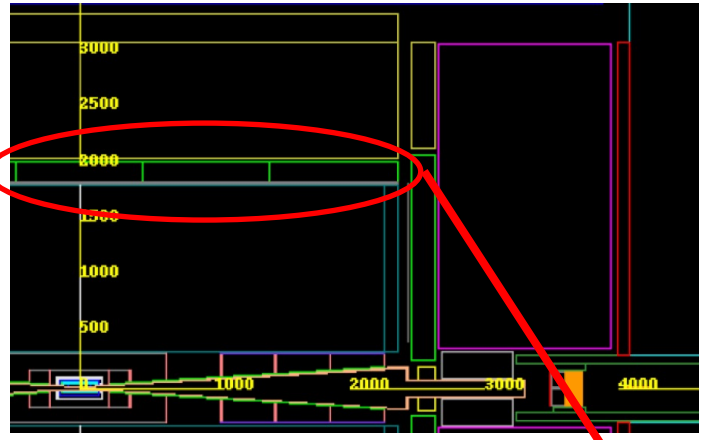
  ➡ ECAL barrel consists 5 ECAL modules
  ➡ ECAL modules consists 5 EBU slabs

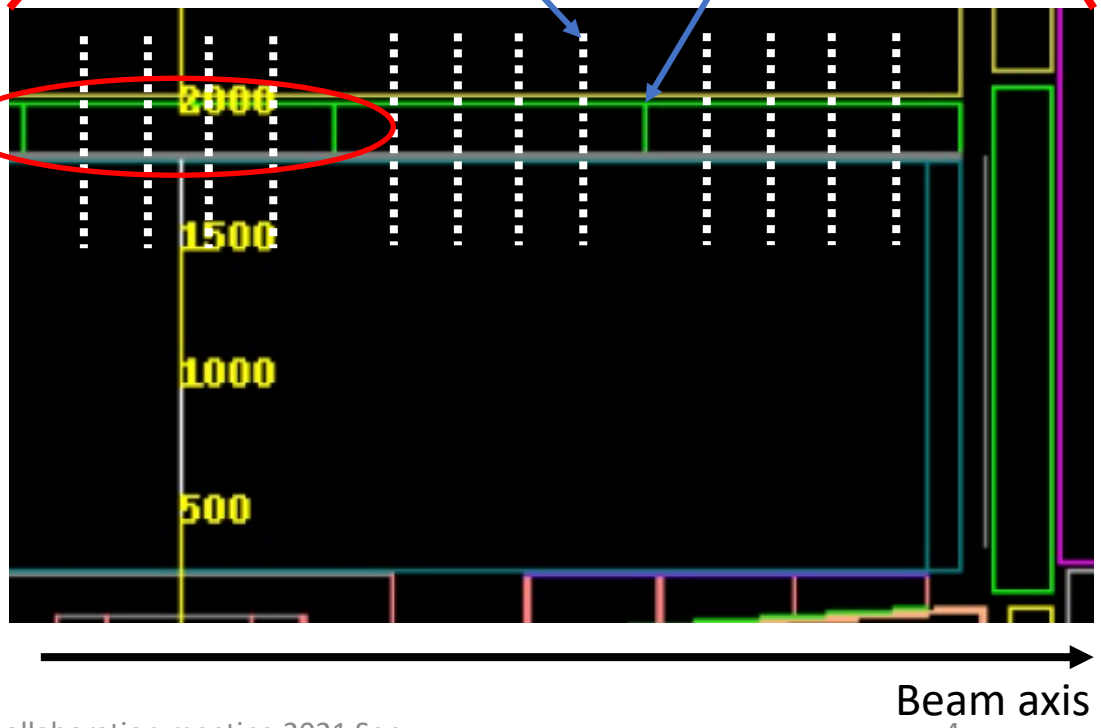
- There are 4 gaps between modules and 20 gaps between slabs in barrel area along beam direction





ECAL



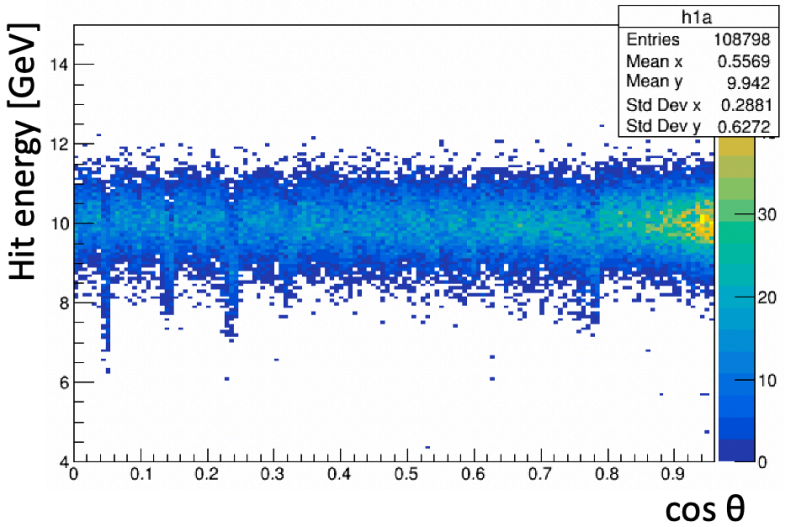


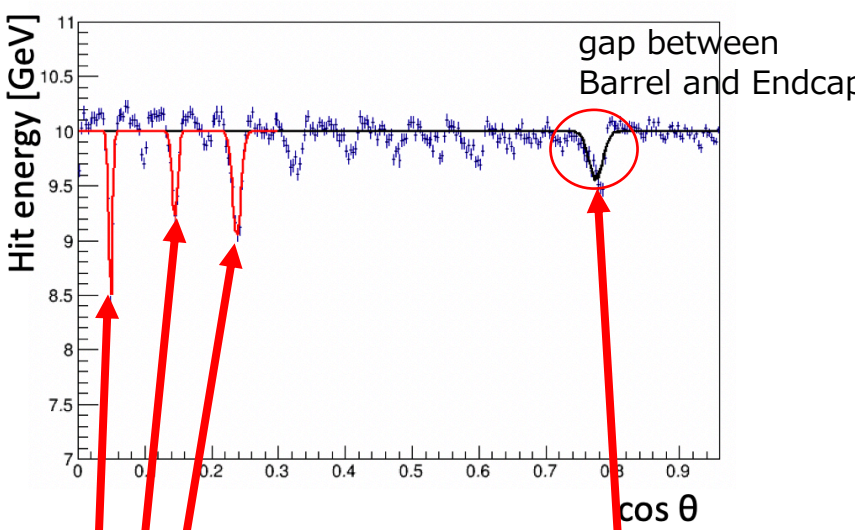
ILD simulation study

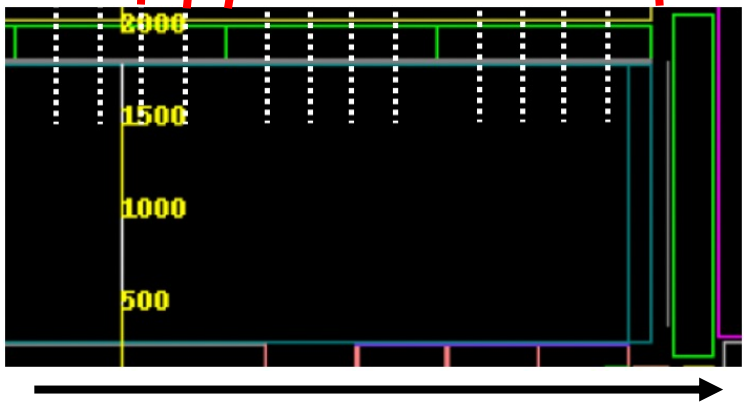
Correction of gap effect on ECAL

・Angular distribution of simulated hit energy along beam direction

➡ Deficit of reconstructed energy around the gaps between ECAL modules







・First 3 deficits (red line) + barrel & endcap boundary (black line) are corrected

$$E_{mod} = \frac{E_{true}}{E_{true} - E_{fit}} \times E_{hit}$$

E_{true}：true energy （10 GeV）

E_{fit}：Energy deficit obtained by fitting

ILD simulation study

Correction of gap effect on ECAL

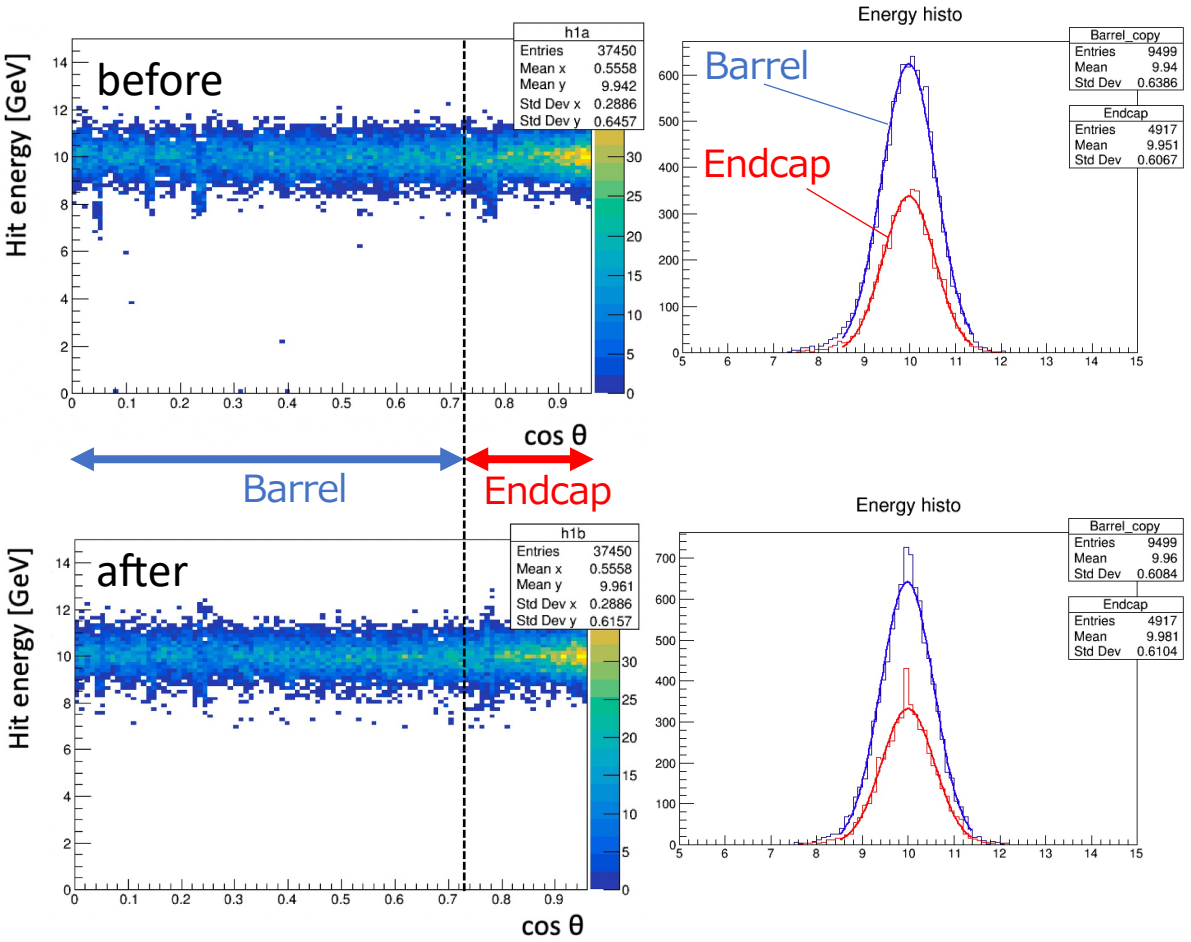
- Angular distribution of simulated hit energy along beam direction

  ➡ Deficit of reconstructed energy around the gaps between ECAL modules

- The nonuniformity has been mitigated to some extent and the tale has been pulled back

- But there are strange peaks at 10 GeV

  ➡ Must be bug in the correction processor

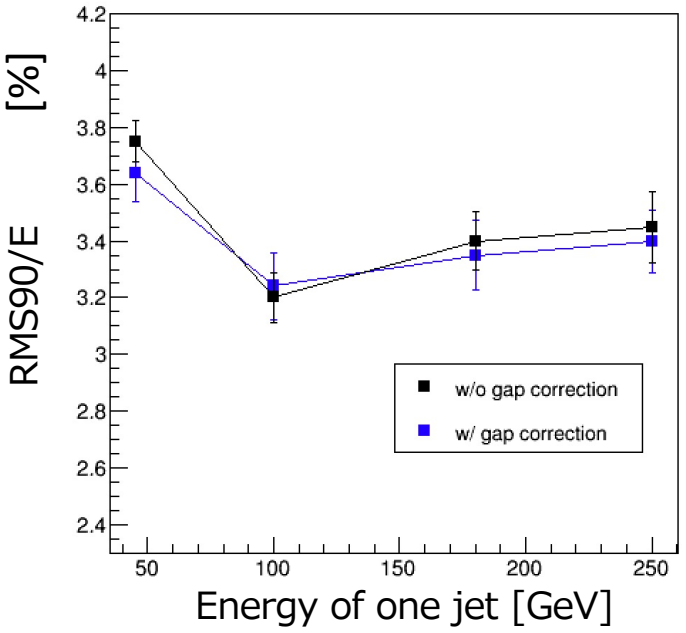


ILD simulation study

Correction of gap effect on ECAL

- Jet energy reconstruction

➡ Jet energy reconstruction with the gap correction
➡ Reasonable resolution obtained
➡ Slight improvement with gap correction



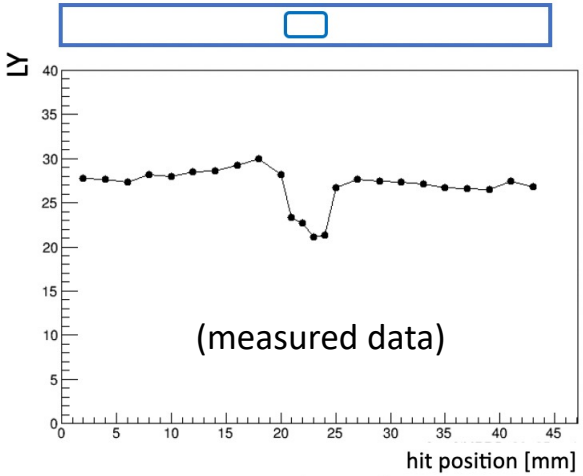
RMS90 : Root Mean Square calculated from the event excluding 10 % outliers.
We define RMS90/mean90(E) as jet energy resolution.

ILD simulation study

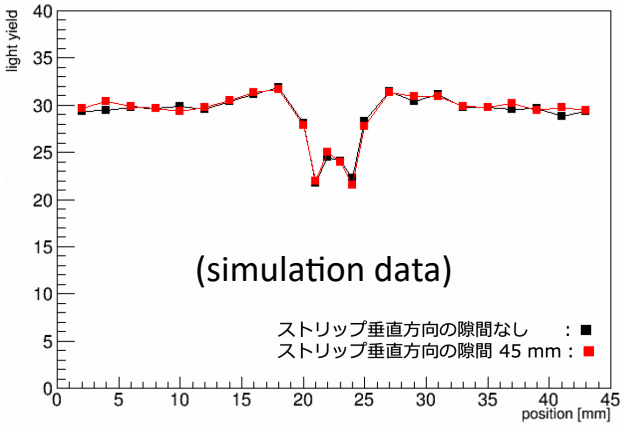
Implementation of position dependence of light yield

- New processor to give energy weight to simulated hit to include position dependence of light yield

- The correction for the position dependence is not done yet to see how it affects the calorimeter performance



45 mm single readout



➡ Light yield around dimple is smaller due to dimple

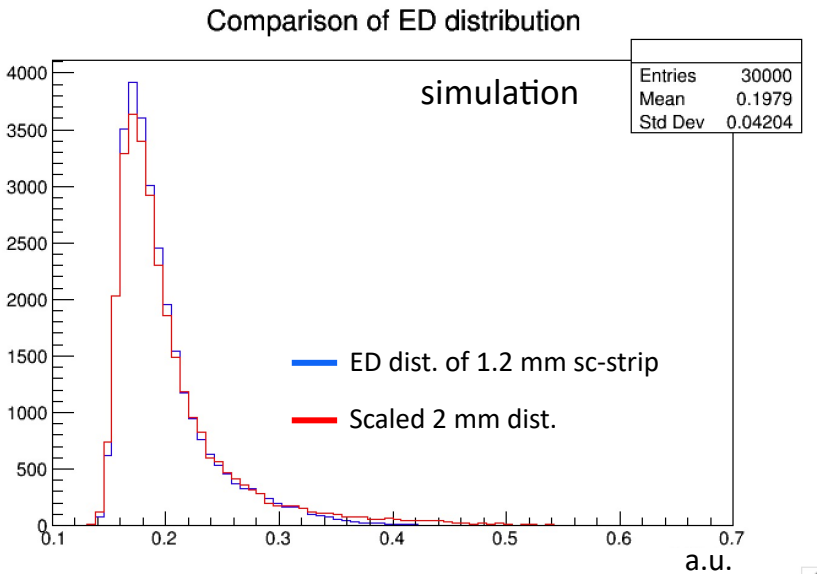
ILD simulation study

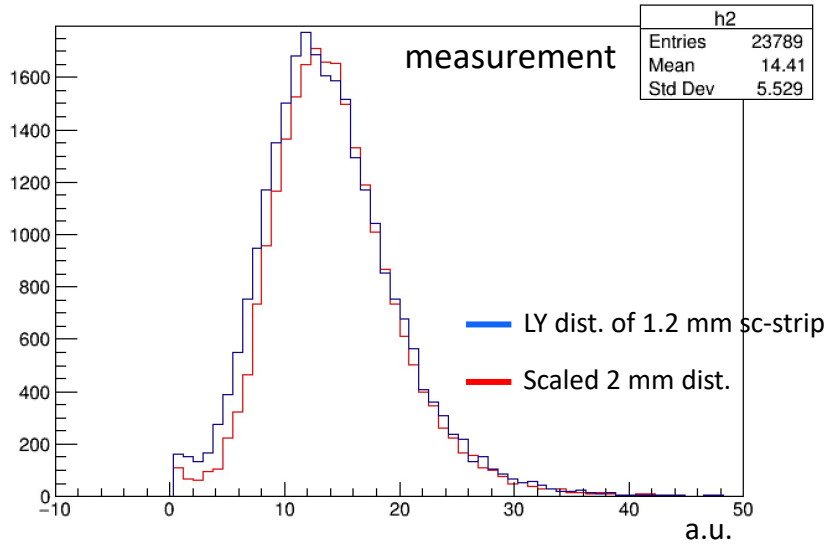
Implementation of position dependence of light yield

- Found that the shape of the energy deposit distribution doesn't depend on the energy deposit (simulation)

- The same for the light yield (measurement)

➡ The effect of the position dependence of the strip response can be included in simulation by scaling the energy deposit based on the observed position dependence of the light yield

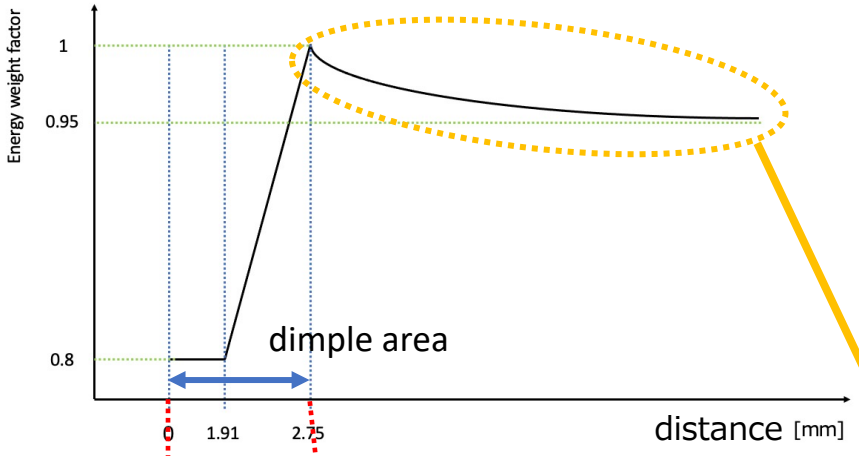




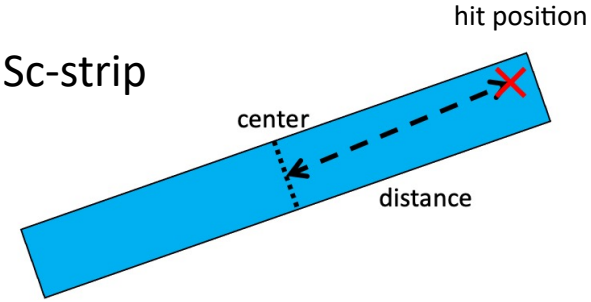
ILD simulation study

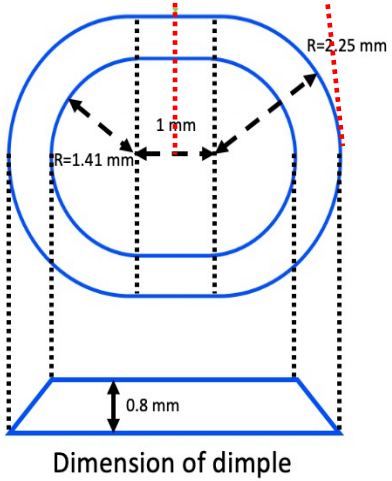
Implementation of position dependence of light yield

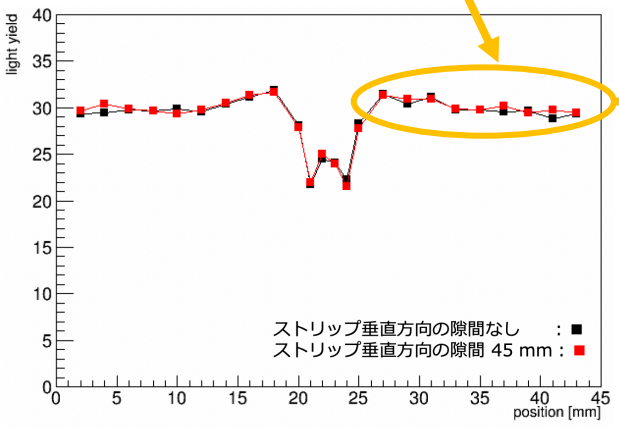
- Implemented energy weight factor

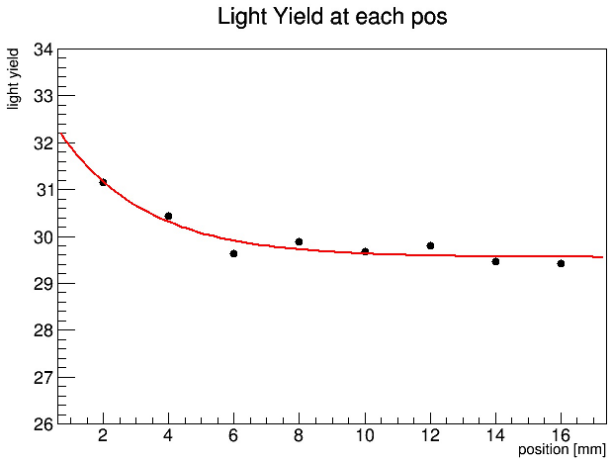


(distance)
= (distance between center of strip and hit position)









➡ Using fitting function of simulated (normalized) LY distribution

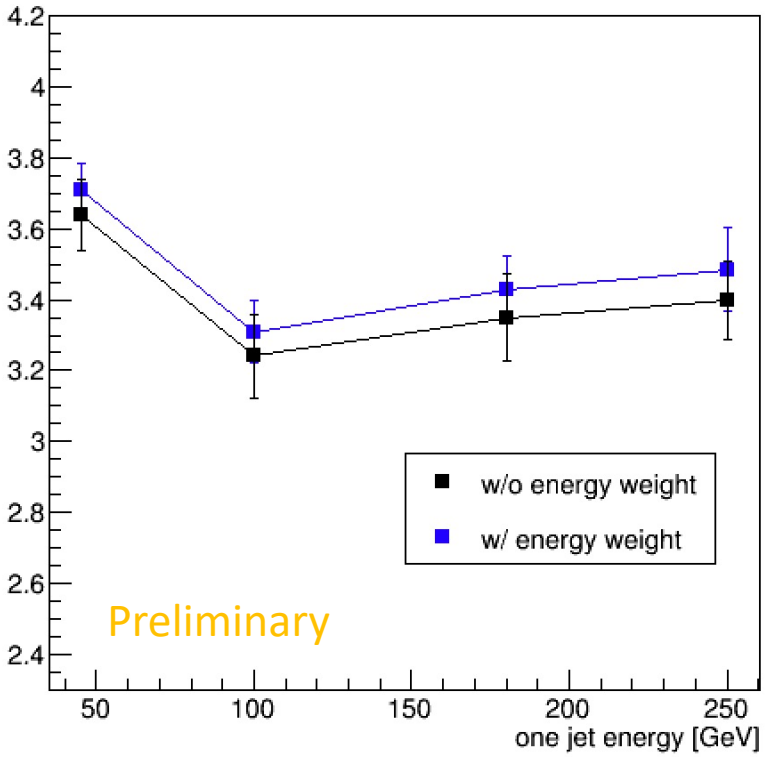
ILD simulation study

Implementation of position dependence of light yield

- Jet energy resolution

  ➡ JER is slightly worsened

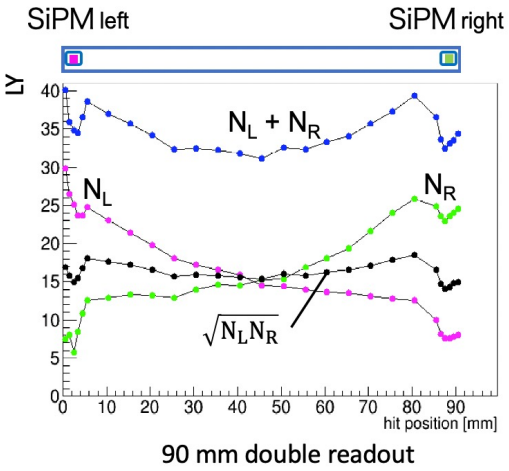
  ➡ Expected to be recovered by correcting for the hit position dependence in the reconstruction



ILD simulation study

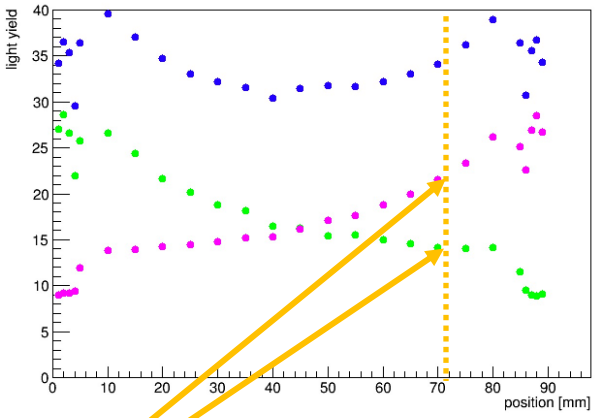
Plan to implement the double SiPM readout

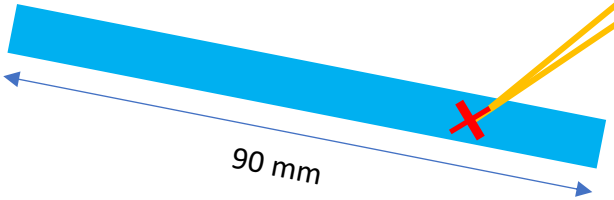
measurement



90 mm double readout

simulation





- Divide the energy deposit information of a hit into two according to the DR data

- Issues

➡ How to incorporate the divided data into the simulation

➡ How to reproduce other DR effects (noise reduction by coincidence etc.) on the simulation

Summary and Prospects

- ILD simulation study for Sc-ECAL is ongoing

- The effect of the gap correction is studied

- Implementation of the hit position dependence of light yield on a scintillator strip is in progress

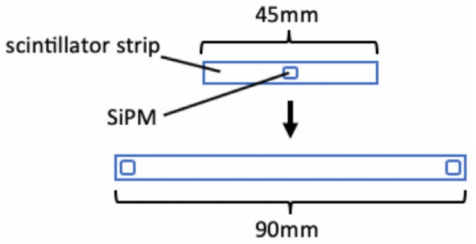
  ➡ Standard 45 mm scintillator-strip response has been tested
  ➡ Slight worsening in JER observed
  ➡ Trying to recover by correcting for the position dependent response

- Next Plan

  ➡ Study for the double SiPM readout effects on ILD simulation
  ➡ Investigate the effect of misalignment/gap between strips

Backup

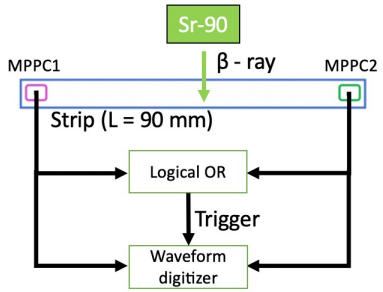
Double SiPM readout

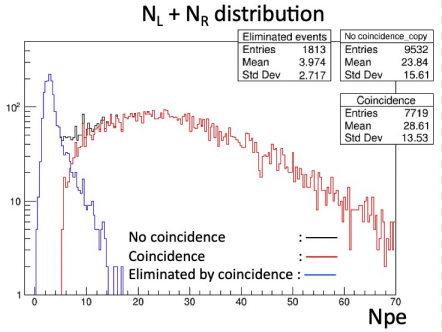


- Possible advantages
  - Eliminating noise by taking coincidence between two SiPM readouts
  - Hit position on a strip can be reconstructed with 20 mm resolution
    ➡ Possibility of solving ghost hit
  - Higher light yield than single readout by summing two SiPM readouts
- Further studies on performance for double SiPM readout are in progress

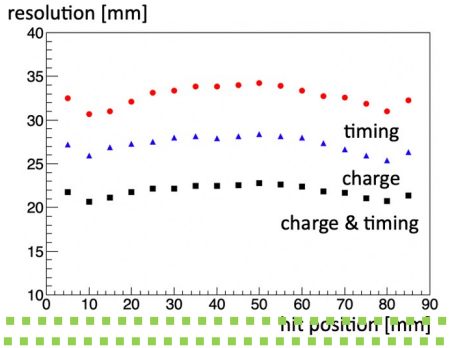
Measured performance

Noise suppression by coincidence

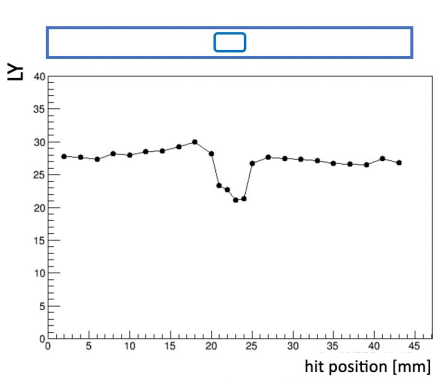




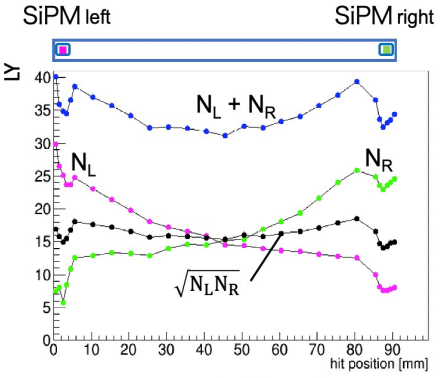
Position resolution



Light yield



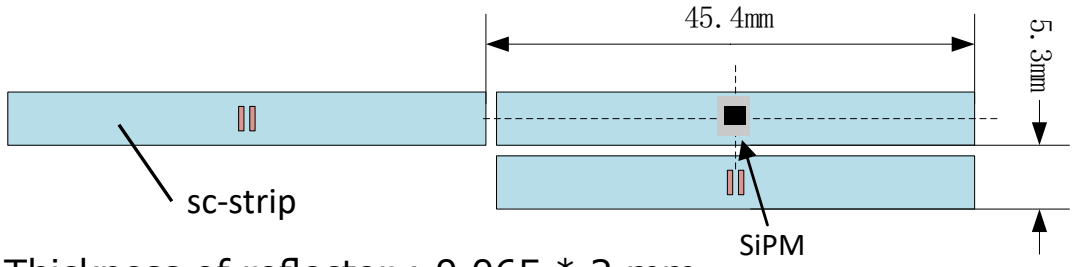
45 mm single readout



90 mm double readout

Possible SiPM-strip misalignment on EBU

・Layout of strips on readout board (ECAL Base Unit, EBU)

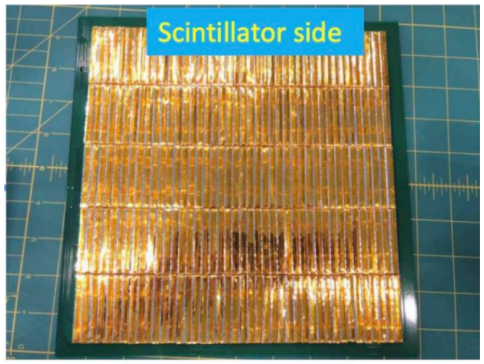


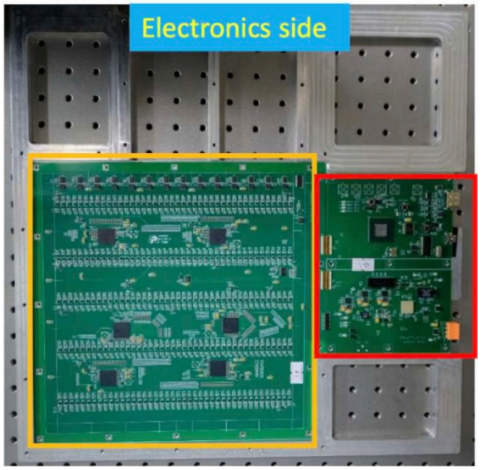
Thickness of reflector : 0.065 * 2 mm
Thickness of Kapton tape : 0.05 * 2 mm

・Each strip wrapped with ESR film (2 x 65 μm-thick) and Kapton tape (2 x 50 μm-thick)

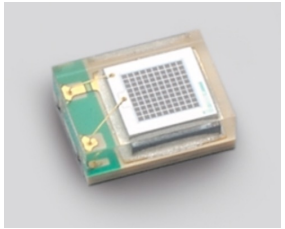
➡ Gap between strips up to 0.2 mm
➡ Possible shift of strip assembly as a whole?

・The effect of strip-SiPM misalignment on the light yield distribution is investigated by simulation



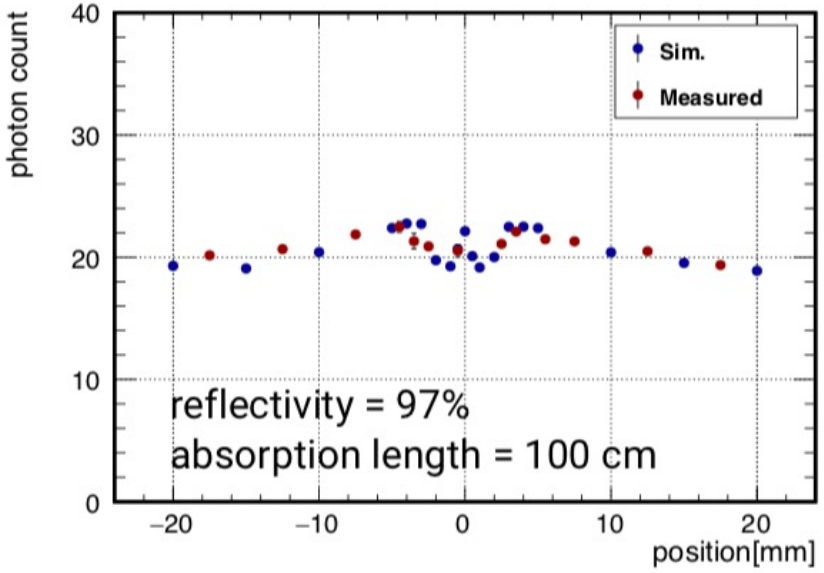


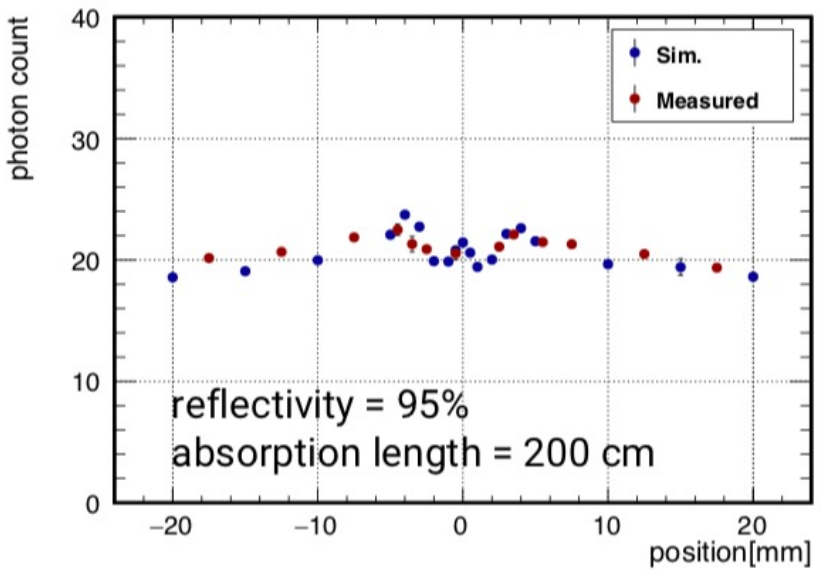
ECAL Base Unit (EBU)



MPPC : S12571-015P
(1 x 1 mm^2 15μm-pixel)
hit position[mm]

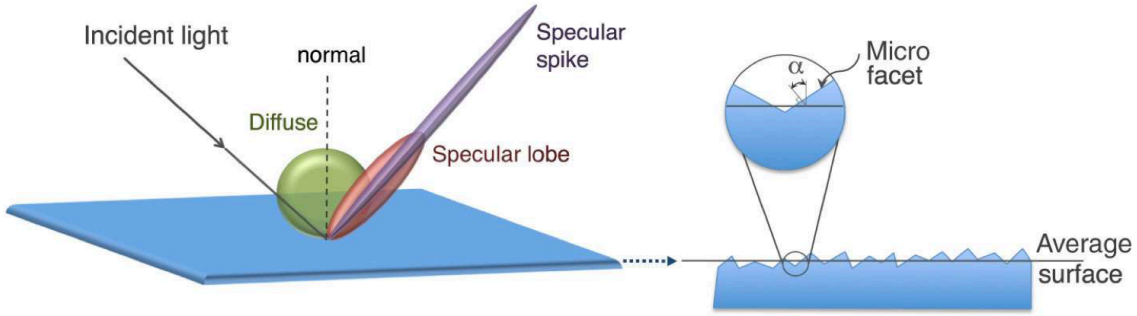
Optimization of parameters for Geant4 Optical Photon simulation





The parameters were
optimized by T. Mogi (ref. LCWS2019)

パラメータ名	設定値
Specular Spike	0
Specular Lobe	0.9
Diffuse Lobe	0.1
Back Scattering	0
発生光量 (photons/1 MeV e^-)	1,800
屈折率	1.58
吸収長 (cm)	250
反射率	0.98
表面粗さ (rad)	0.1



Parameter calibration and energy linearity check

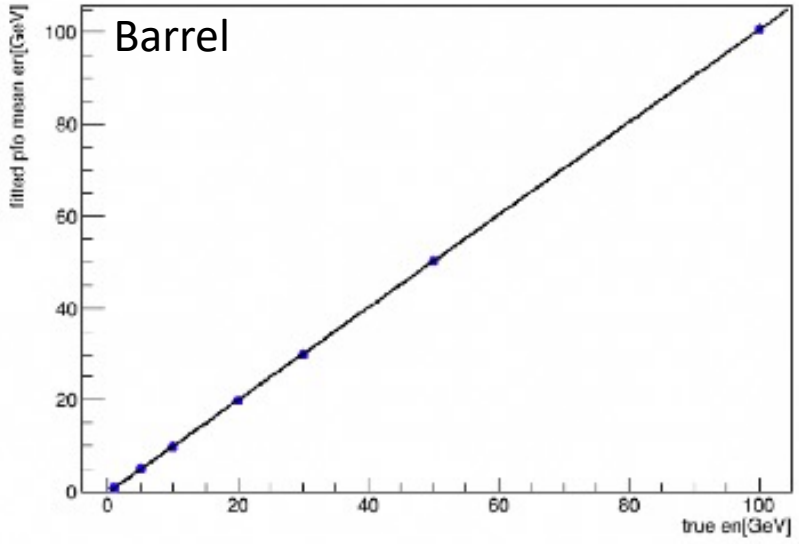
・Parameter calibration of current version

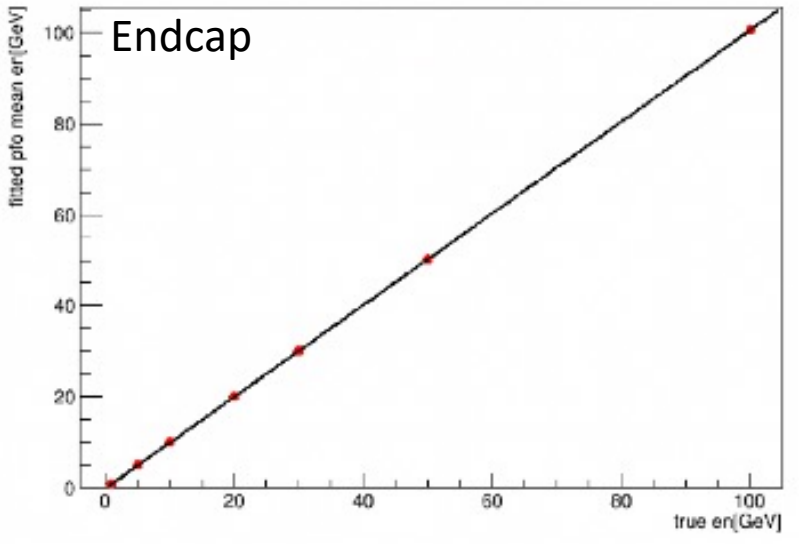
➡ Use MC photon at some different energies
➡ Decided parameters for this ILD model version

ppd_mipPe (p.e.)	10
ppd_npix (pixel)	10000
EcalBarrel/EndcapMip	0.0002629 0.0002655
EcalBarrel/ EndcapEnergyFactors	0.00758 0.01515 0.00810 0.01619
PandoraEcalToEMScale	1.031

・Linearity of energy

➡ Inject photon at different energies (1, 5, 10, 20, 30, 50, 100 GeV)
➡ Linearity is good





Verification of Landau distribution scaling

- Comparison of ED distribution for each strip thickness