Development of Large-Area Charged Particle Detector with Inorganic Scintillator Plates and Wavelength Shifting Fibers

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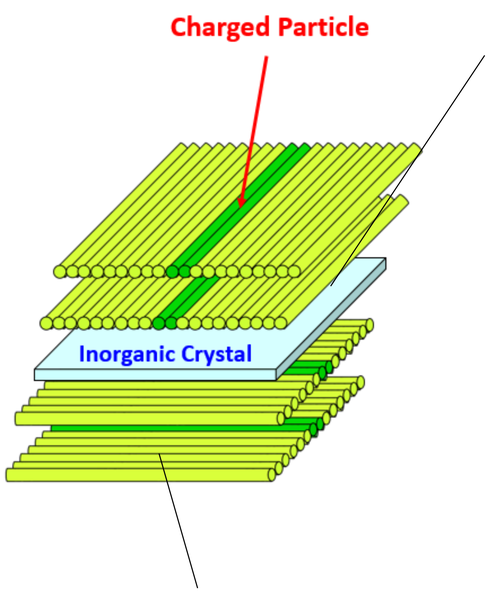
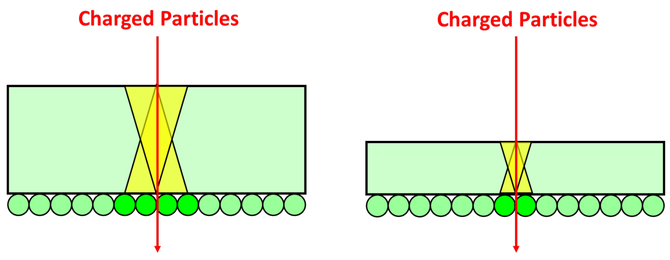
Abstract - We propose a large-area charged particle detector for high energy physics experiments. This detector includes inorganic scintillation crystals and wavelength shifting fibers, which enables us to detect charged particles with higher position resolution and lower cost than those of conventional photo detectors and drift chambers.

Overview of the Detection Part



An Inorganic Scintillation Crystal

- Scintillation light is released when charged particles pass thorough the crystal.
- The light with smaller incident angle than the critical angle goes outside the crystal.
- Its high density enables us to detect charged particles with higher position resolution; the emission region gets smaller as the crystal thinner.

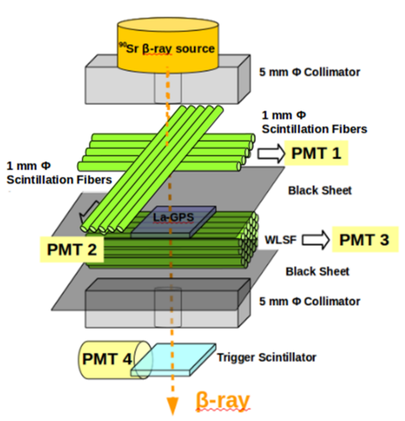


Several Layers of WLSF

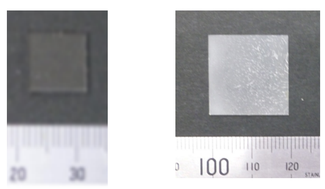
- A kind of an optical fibers
- They absorb the light of the particular wavelength and emit longer wavelength light.
- The size of the effective area is 1 m x 1 m.

One WLSF layer is composed of 5000 fibers of 0.2 mm in diameters.

Experimental



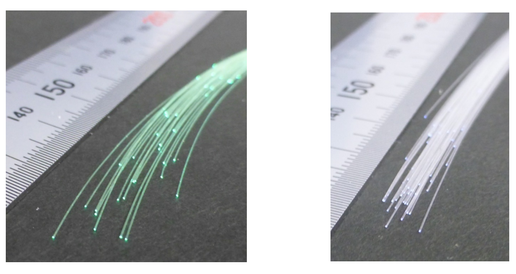
We measured the number of photoelectrons by changing the number of layers of WLSF. The setup of the experiment is shown on the left and the scintillation crystals and the WLSFs used in this experiment is shown below. Photomultiplier tubes of R9880U-210 series manufactured by Hamamatsu Photonics K.K. are used as the photodetectors, which have spectral response in the wavelength range of 230 nm to 700 mm[1].



La-GPS (C&A Corporation)[2]
Chemical Composition:
$(La_{0.75}Ga_{0.24}Ce_{0.01})_2Si_2O_7$
Emission wavelength: 390 to 410 nm
Density: 5.3 g/cm^3

High-growth-rate La-GPS (right side)

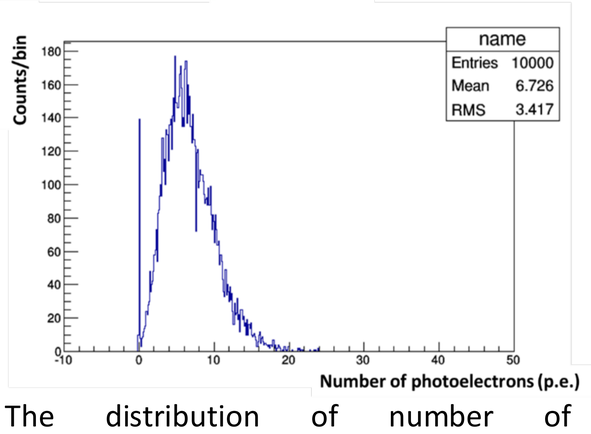
- A scintillator which is crystalized at the higher rate than the conventional one.
- It contains micro bubble and is not transparent completely.
- Much more reasonable than the conventional one.



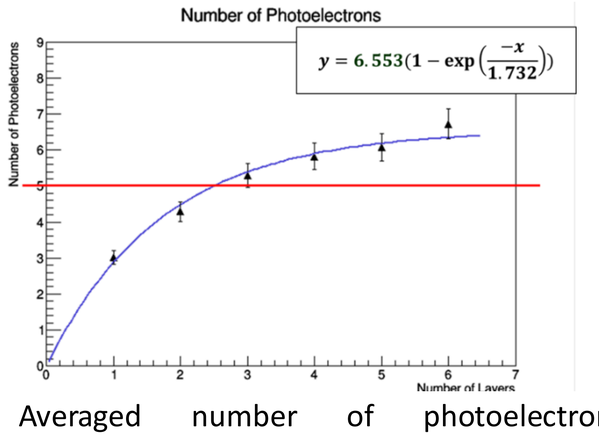
Left: Y-11 (300) MJ WLSF (Kuraray)[3]
Absorption Peak: 430 nm
Emission Peak: 476 nm

Right: B-3 (300) MJ WLSF (Kuraray)[3]
Absorption Peak: 351
nm
Emission Peak: 450 nm

Results

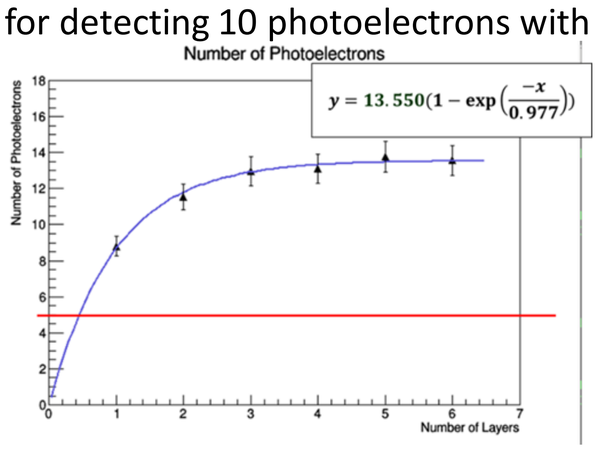


The distribution of number of photoelectrons detected (0.50 mm La-GPS crystal, 6 layers **Y-11 (300) MJ** WLSF on one-side reading)

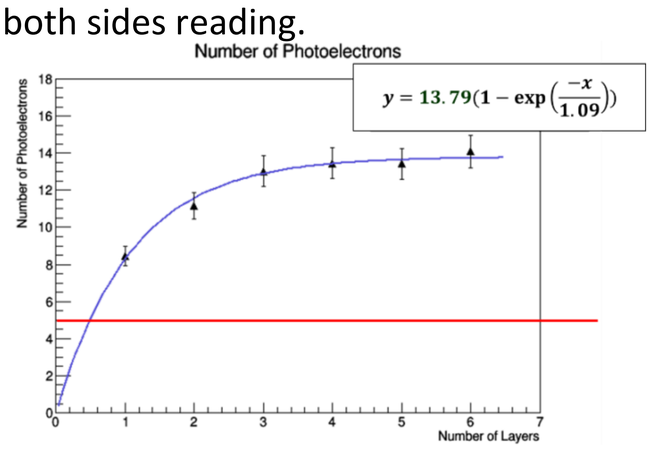


Averaged number of photoelectrons detected by changing the number of WLSF layers (0.50 mm La-GPS crystal, **Y-11 (300) MJ** WLSF)

- The number of photoelectrons is saturated at **6.55** for La-GPS.
- When using Y-11 and 0.50 mm La-GPS crystal, **3** WLSF layers are enough for detecting 10 photoelectrons with both sides reading.



Averaged number of photoelectrons detected by changing the number of WLSF layers (0.50 mm La-GPS crystal, **B-3 (300) MJ** WLSF)

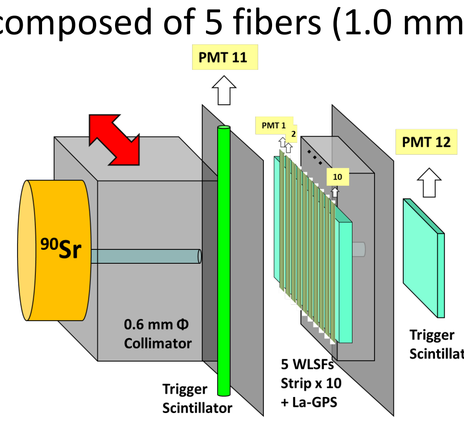


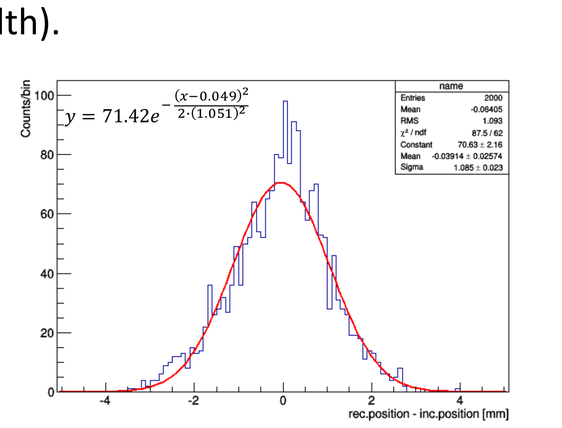
Averaged number of photoelectrons detected by changing the number of WLSF layers (0.55 mm High-growth-rate La-GPS crystal, **B-3 (300) MJ** WLSF)

- The number of photoelectrons is saturated at **13.55** for La-GPS.
- When using B-3 and 0.50 mm La-GPS crystal, **1** WLSF layer is enough for detecting 10 photoelectrons with both sides reading.
  (better result than 3 layers for 1.0 mm crystal[4])
- The number of photoelectrons is saturated at 13.79 for 0.55 mm high-growth-rate La-GPS (**12.54** for 0.50 mm high-growth-rate La-GPS).
- When using B-3 and 0.50 mm high-growth-rate La-GPS crystal, **1** WLSF layer is enough for detecting 10 photoelectrons with both sides reading.
- Detection efficiencies are 98.3 to 98.6% for La-GPS crystal 97.0% for high-growth-rate La-GPS crystal (one-side reading).

Rough Estimation of the Position Resolution

The position resolution is estimated using 10 WLSFs strips. Each strip is composed of 5 fibers (1.0 mm width).





As a result of 6 times measurements, the position resolution is 1.068 ± 0.017 mm in sigma. This value is expected to be smaller if using strips composed of less number of fibers.

Conclusion

We propose the large-area charged particle detector with inorganic scintillator plates and wavelength shifting fibers. It is confirmed that photons from La-GPS can be read out with WLSF B-3 (300) MJ and Y-11 (300) MJ. When using B-3 (300) MJ, the more photoelectrons can be obtained and 1 WLSF layer is enough for detecting 10 photoelectrons with both sides reading. The same result is obtained when using high-growth-rate La-GPS. By using these inorganic crystals, “high position resolution” and “lower cost” detector can be made. The position resolution is smaller than 1.068 mm.

In addition, photo detectors are suitable for measurements at high event rate. This detector may take the place of other detectors like drift chambers in high energy physics experiments.

Acknowledgment

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Reference

[1] Hamamatsu Photonics K.K., Photomultiplier tube R9880U-210 Available: https://www.hamamatsu.com/jp/en/R9880U-210.
[2] C&A Corporation, Product Information. Available: www.c-and-a.jp/GPS.html
[3] Wavelength Shifting Fibers, Kuraray. Available: kuraraypsf.jp/psf/ws.html
[4] T. Mizuno et al. “Development of Large-Area Charged Particle Detectors with High Position Resolution and Low Cost”, 2006 IEEE Nuclear Science Symposium Conference.