

with Wave Length Shifting Fibers

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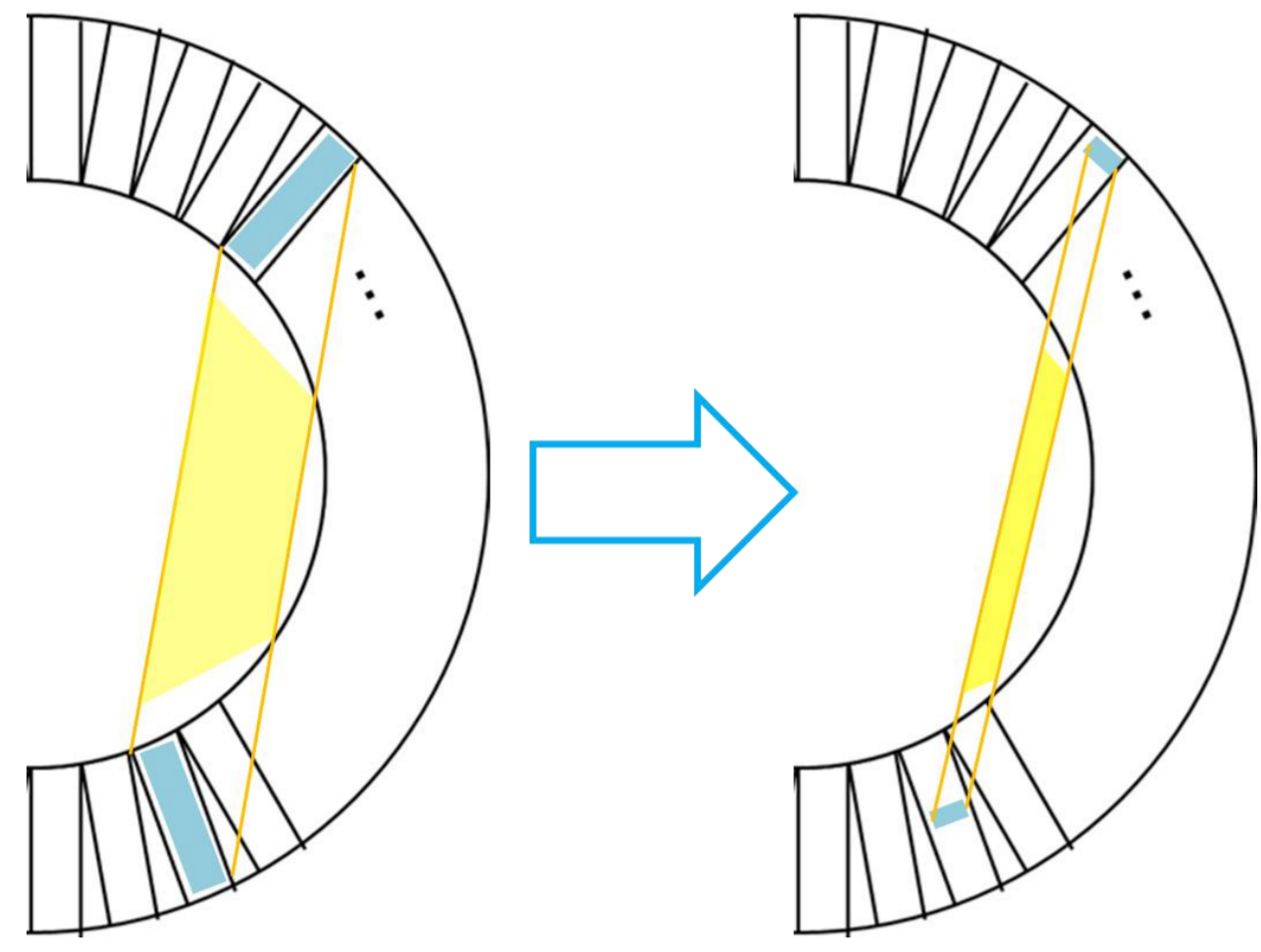
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Introduction – New type DOI PET detector



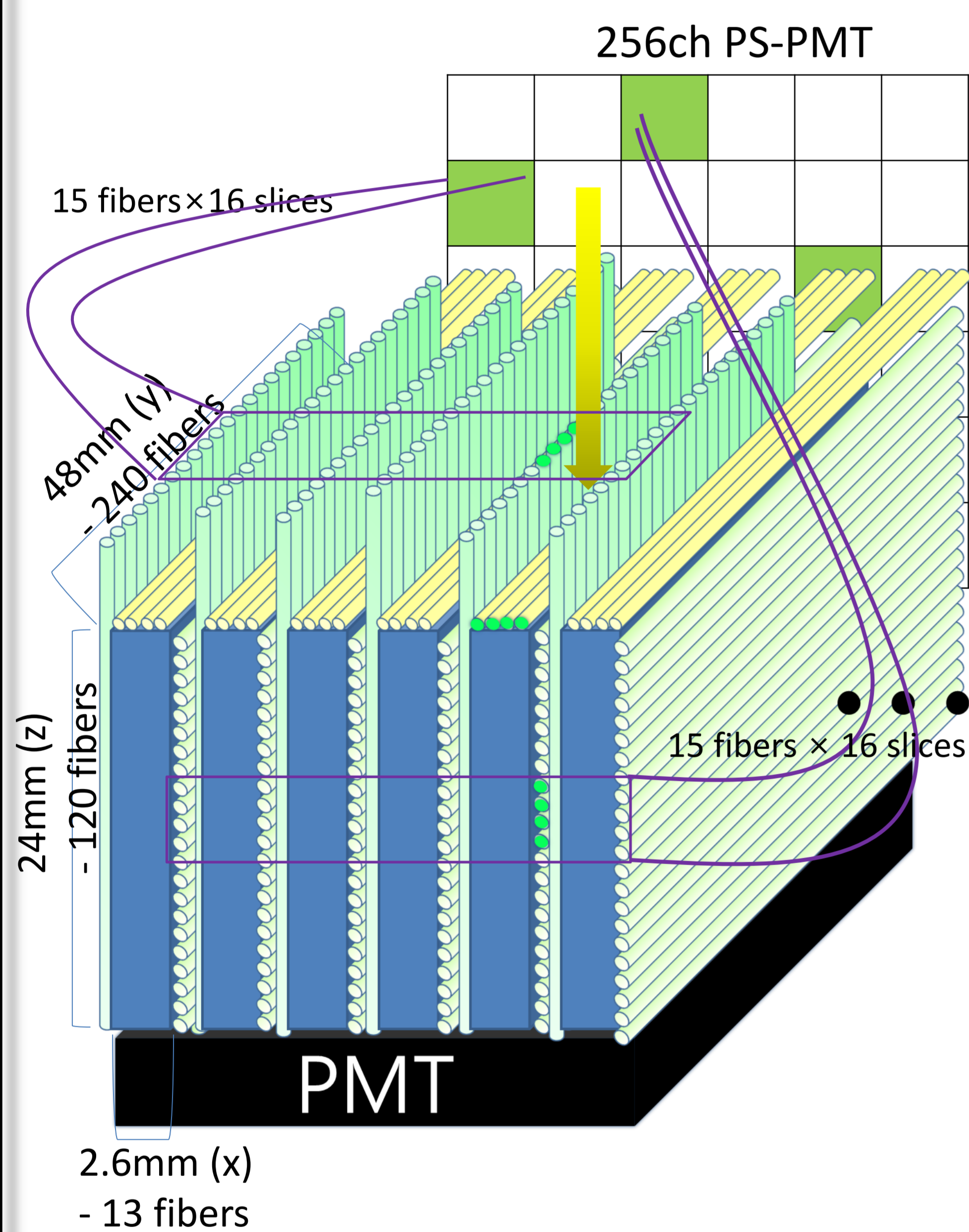
A positron emission tomography (PET) detector contains thick scintillators in radial direction to increase sensitivity. However, a parallax error makes a degradation of the spatial resolution.

The depth of interaction(DOI) PET detector is one way to achieve high resolution by determining the depth where most of gamma ray energy is deposited in the scintillator. Because a 2D or 3D profile is obtained for each element, the large amount of data makes the image reconstruction difficult.

We propose a new type DOI-PET detector with plate GSO crystals and wave length shifting fibers aiming simple data and an easier image reconstruction.

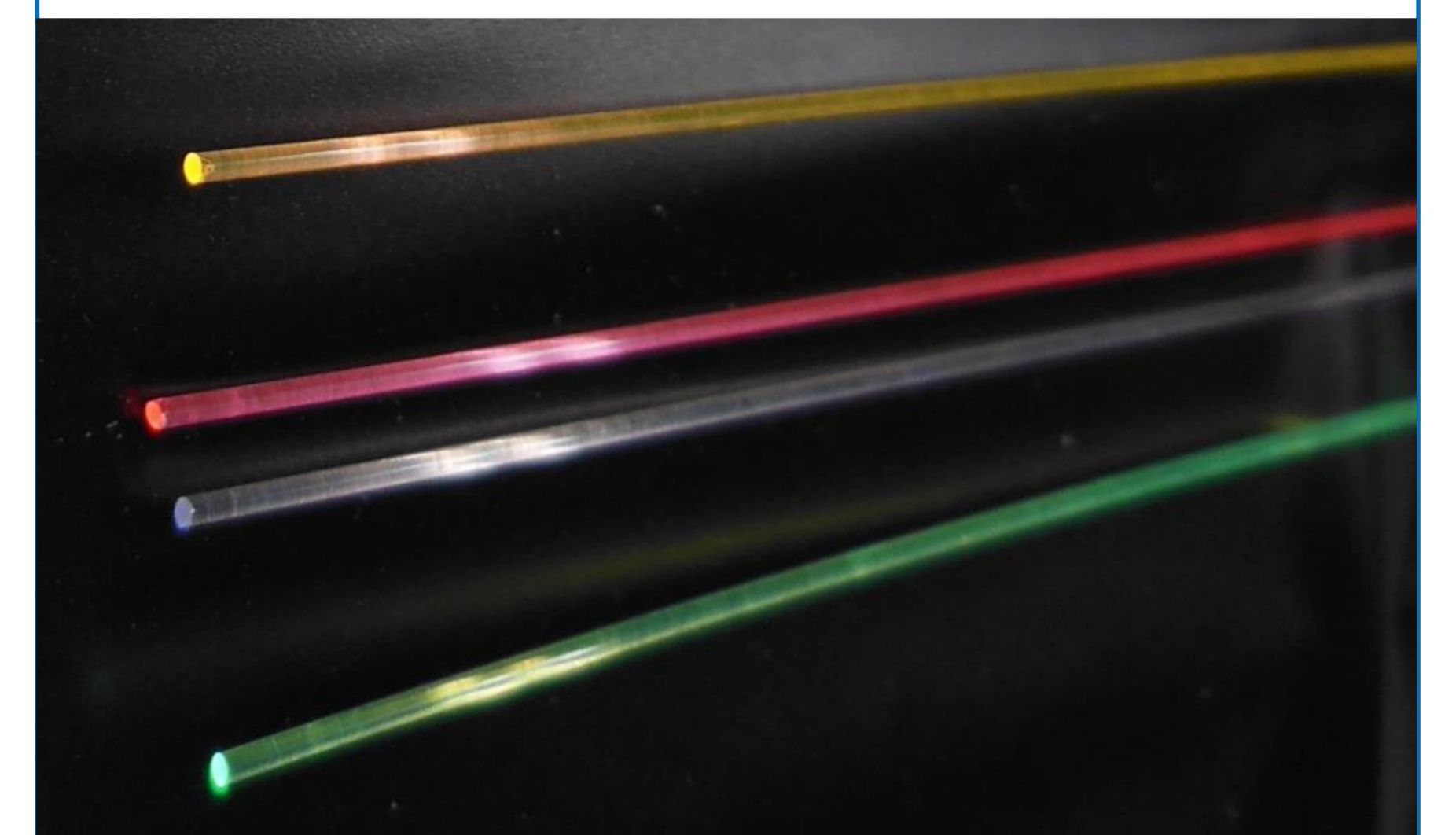
Construction

An element of New type 3D PET

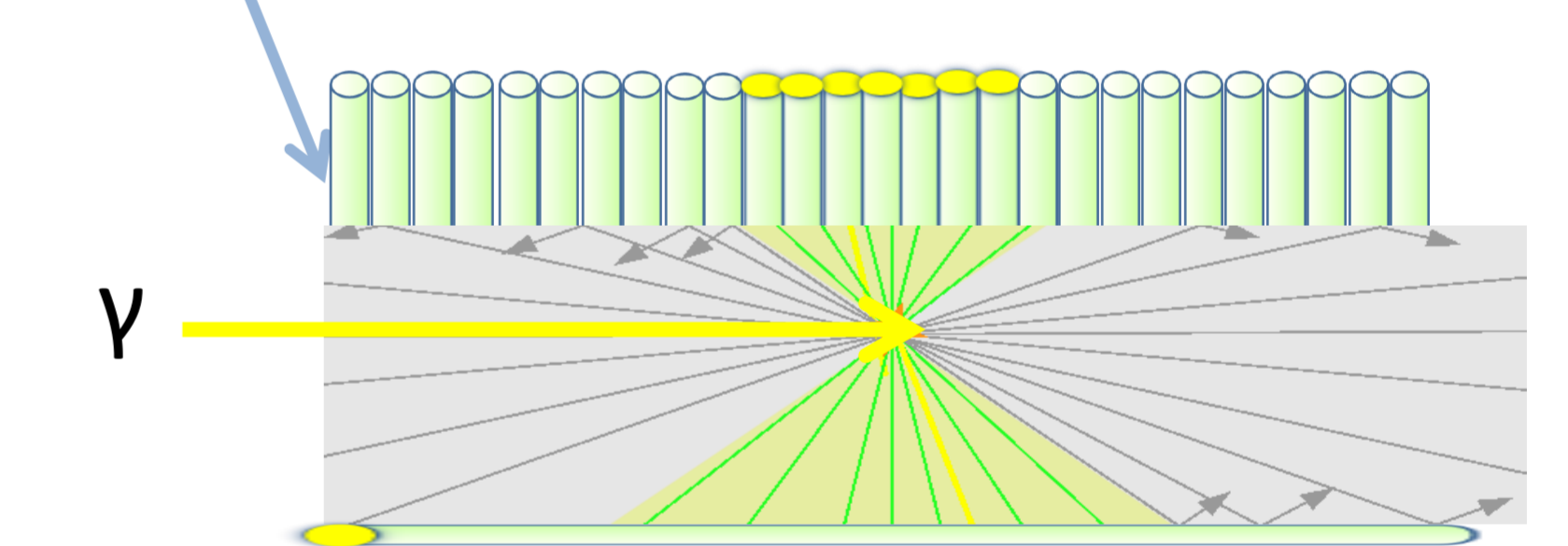


- An element block of the detector consists of 16 pieces of inorganic scintillator, one flat panel PMT, wave length shifting fibers and 256ch position sensitive(PS) PMT per six element blocks.
- Scintillator is the size of 2.6mm(x) × 48mm(y) × 24mm(z) and made of GSO crystal(inorganic) has more sensitivity to gamma ray than an organic scintillator.
- Scintillators are connected to a single anode flat panel PMT(50 mm × 50 mm) in order to measure an energy of an incident gamma ray and make a trigger.
- Scintillation lights whose angle is smaller than total reflection angle pass through the boundary while some of them are absorbed in the wave length shifting fiber.
- 120 and 240 wave length shifting fibers^{*1}(0.2 mmφ) are attached orthogonally to each wide side of the scintillator and 13 fibers to the narrow side.
- 15 Fibers attached on wide side of a scintillator are bunched together with fibers attached on other scintillator plates and make 16(240/15) and 8(120/15) fiber bunches in direction of y and z, as shown with the purple line in a left figure.
- Additionally 13 fibers attached on narrow side are bunched together and make 6 bunches.
- By connecting the PS-PMT with brunches (16+16+8), the position where gamma ray deposits its most energy can be measured.

*1Wave Length Shifting Fiber (WLSF)



Wave Length Shifter is excited by light of a specific wavelength range and re-emits light of a longer wavelength. The WLSF absorbs photons from its side and transmits the photons to its both ends.



Estimation of Photon Yield

- In case of PET, incident gamma ray has 0.511 MeV and it makes about 10 photons per 1 keV in GSO scintillator. A condition of total reflection between GSO and air cuts 5/6 photons.
- About a half of photons are absorbed and re-emitted in WLSF. Only 5 % of them satisfy the condition of total reflection and are transmitted to each end of a fiber.
- Quantum efficiency of PS-PMT is 25%.

$5000 \times (1/6) \times (1/2) \times 0.05 \times (1/4) \approx 5$ photons
 Detection efficiency of a bunch = $1 - e^{-4} \approx 98\%$
 Detection efficiency of 3D position = $(0.98)^3 \approx 94\%$
(we take 4 instead of 5 because 5 was obtained in an ideal condition)

Cost Estimation

Another intention of this proposal is to reduce the cost for producing the detector. Now we estimate the cost of materials for the manufacture of this system.

Material	Price	Price for an element block
16 GSO slice	500\$	500\$
Flat Panel PMT	200\$	200\$
256ch PS-PMT	480\$	80\$
WLSF	300\$/13km	100\$
Other electrics	100\$	100\$

From this table we can estimate the cost of materials for an element block to 1,000\$ or for this DOI-PET to 100,000\$ +α

Summary

- We propose a new type DOI(depth of interaction)-PET detector using total reflect condition and wave length shifting fibers. (we could not perform experimented evaluation owing to delay of delivery of the GSO slices from the company)
- This PET detector has ±1.3 mm resolution of x direction, ±1.5 mm resolution of y and z direction.
- Only 41(16+16+8+1) signals from an element block are read out for the energy information in order to set the trigger level and 40 are for the position information.
- It has 94% of detection efficiency of 3D position with easy setting threshold with flat panel PMT(7% of energy resolution).
- The position is easily calculated with the binary information without a complex data analysis.
- Above characteristics give us an easier image reconstruction.
- Low Cost, High Performance