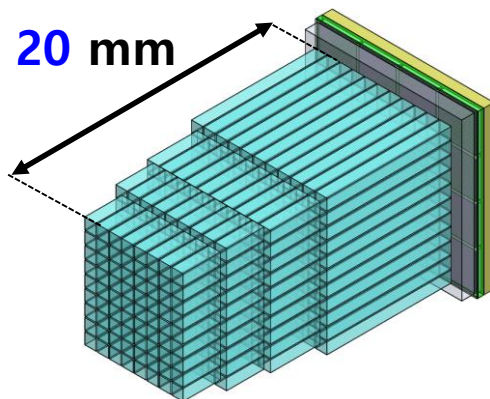

GATE simulation of a staggered 4-layer DOI PET scanner

<Staggered 4-layer DOI detector>



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Image Recon: 2019.06.04.Tuesday
Team Meeting: 2019.06.13.Thursday
GATE mailing list: 2020.03.07.Saturday

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Outline

- **GATE simulation of staggered 4-layer DOI PET**
 - LYSO crystal layer: 3+3+4+7 mm (17 mm)
- **Image reconstruction results of staggered 4-layer DOI PET**
 - Staggered 3-layer (4+4+7 mm) vs. 4-layer (3+3+4+7 mm)
- **GATE simulation output for 4-layer crystal (ROOT)**
- **Conclusions**

Staggered 4-layer PET geometries

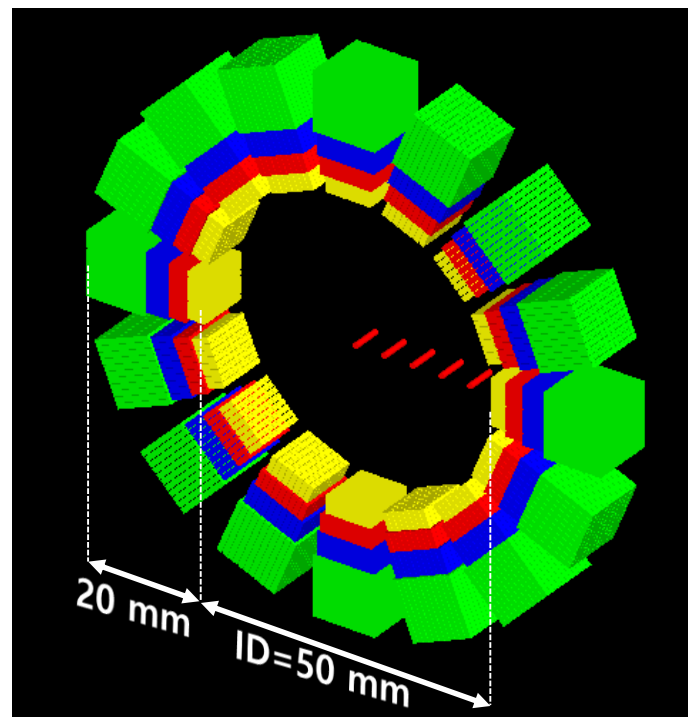
“PETscanner” system attachment

```
# =====  
#   ATTACH   SYSTEM  
# =====  
/gate/systems/PETscanner/level1/attach block  
/gate/systems/PETscanner/level2/attach crystal_1  
/gate/systems/PETscanner/level3/attach crystal_2  
/gate/systems/PETscanner/level4/attach crystal_3  
/gate/systems/PETscanner/layer1/attach crystal_4  
  
# (IMPORTANT) "level5" is not working (2019.05.23.KangHG)  
# Therefore, "layer1" was used for the crystal_4  
#/gate/systems/PETscanner/level5/attach crystal_4
```

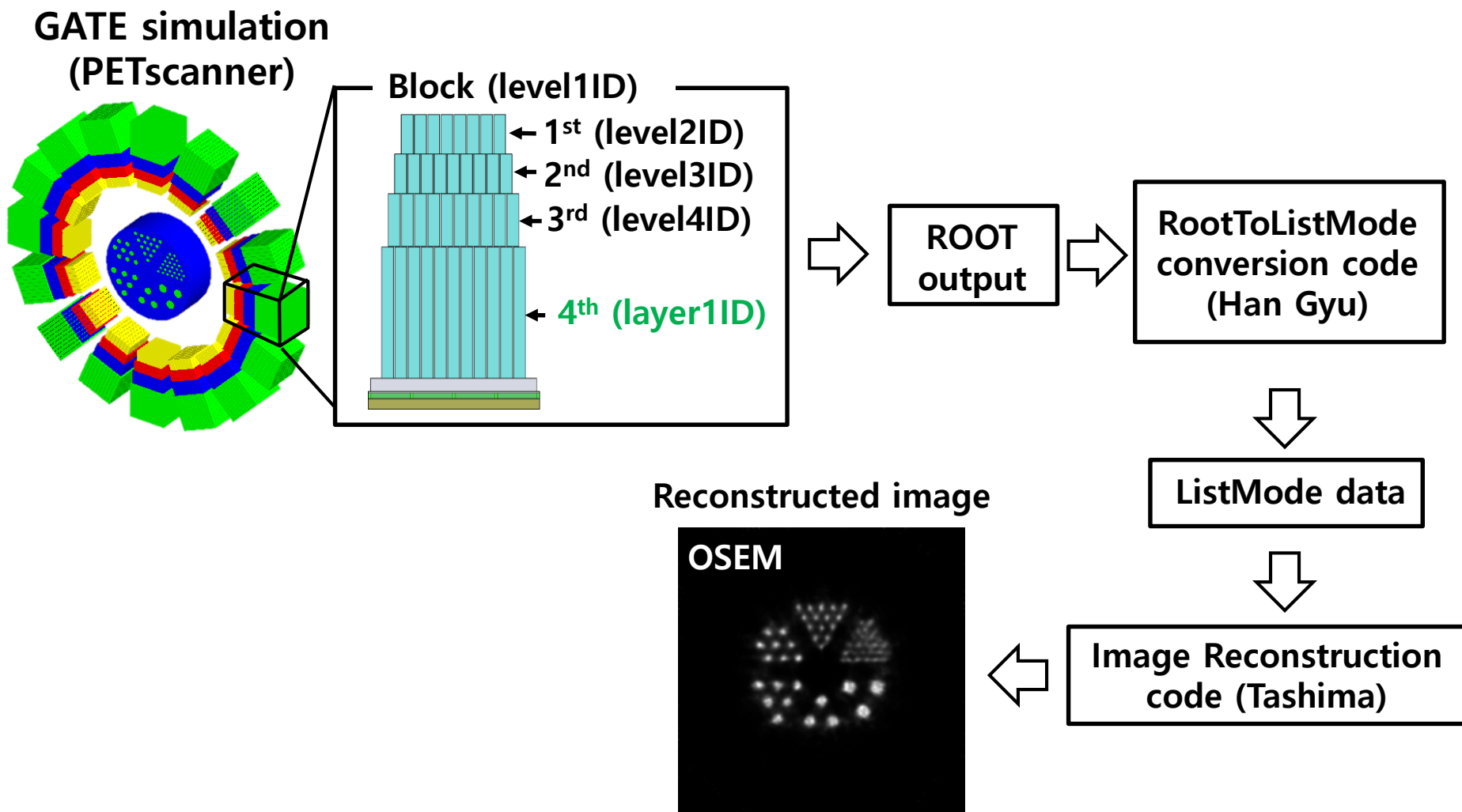
Problem: “level5” is not working for PETscanner

Solution: “layer1” for the 4th layer DOI crystal

GATE “PETscanner” simulation



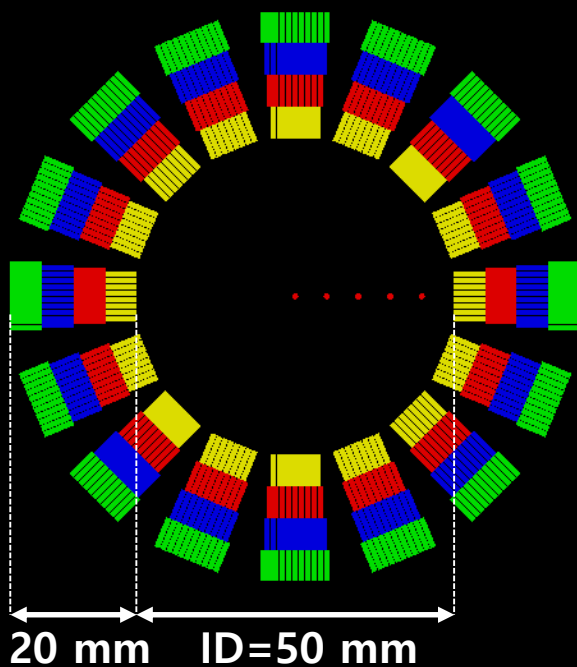
GATE PETscanner ROOT output analysis



Comparison of PET image quality with different crystal configurations

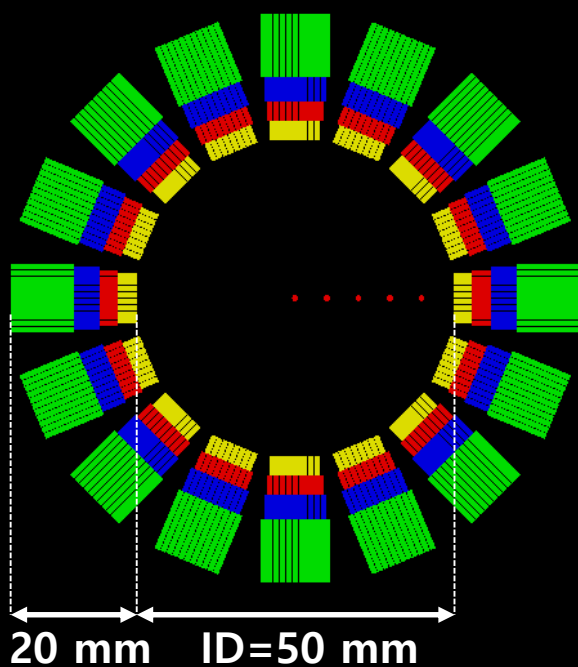
Staggered 4-layer PET geometries

5+5+5+5 mm



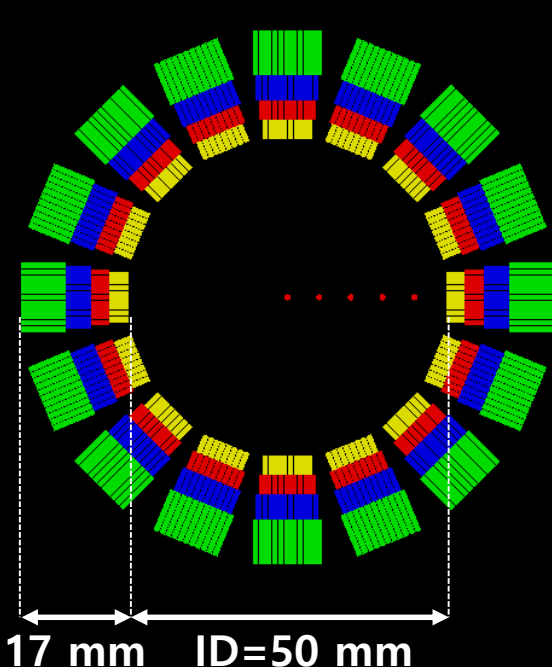
20 mm ID=50 mm

3+3+4+10 mm



20 mm ID=50 mm

3+3+4+7 mm



17 mm ID=50 mm

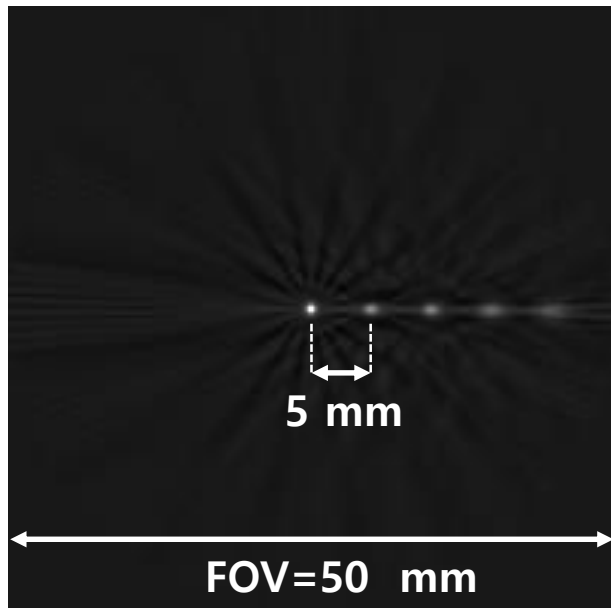
Sensitivity 1.41%

1.61%

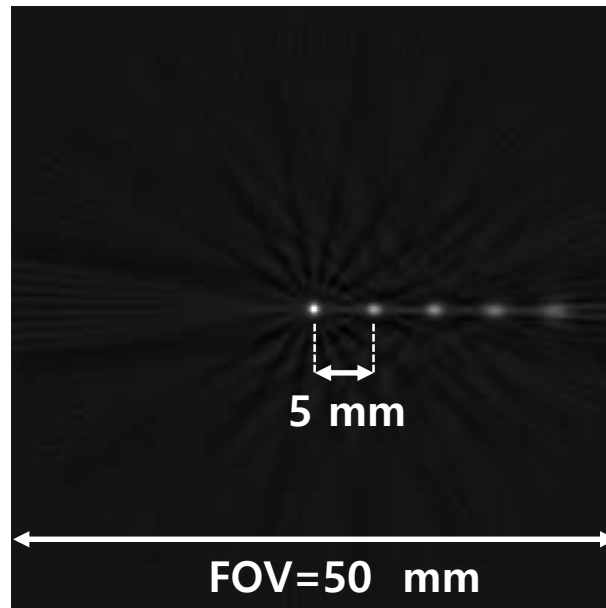
1.35%

Staggered 4-layer (FBP)

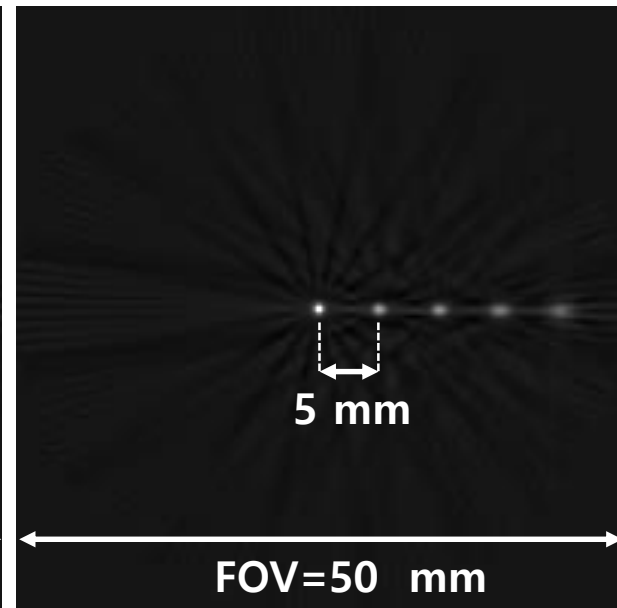
5+5+5+5 mm



3+3+4+10 mm



3+3+4+7 mm



The “3+3+4+7 mm” shows the **best spatial resolution!**

Voxel: $0.25 \times 0.25 \times 0.25 \text{ mm}^3$

200×200×44, Float 32-bit

Source diameter = 0.1 mm

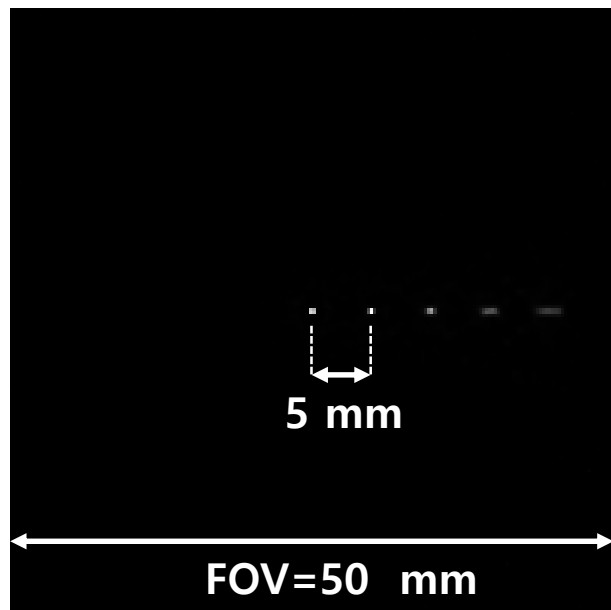
OSEM

#of subset = 8

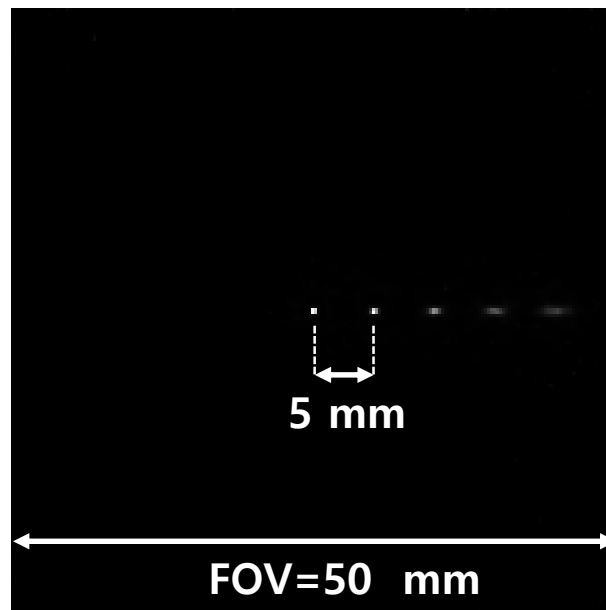
#of iteration= 10

Staggered 4-layer (OSEM)

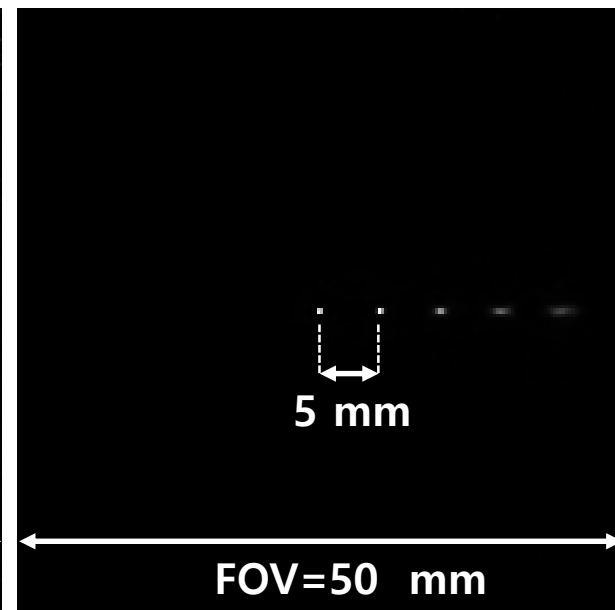
5+5+5+5 mm



3+3+4+10 mm



3+3+4+7 mm



The “3+3+4+7 mm” shows
the **best spatial resolution!**

Voxel: $0.25 \times 0.25 \times 0.25 \text{ mm}^3$

200×200×44, Float 32-bit

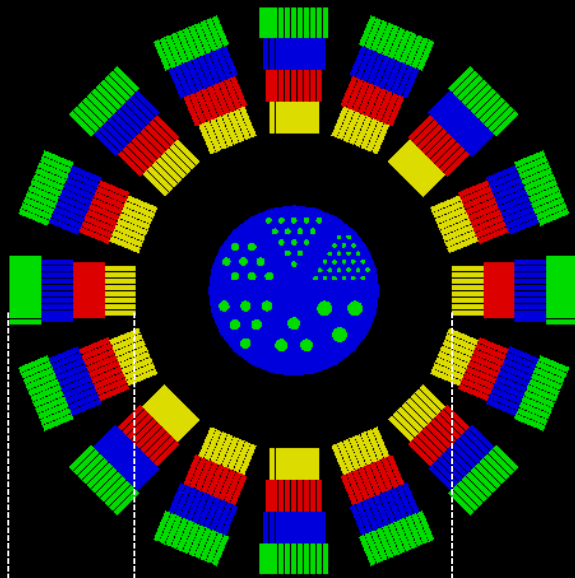
Source diameter = 0.1 mm

Staggered 4-layer PET geometries

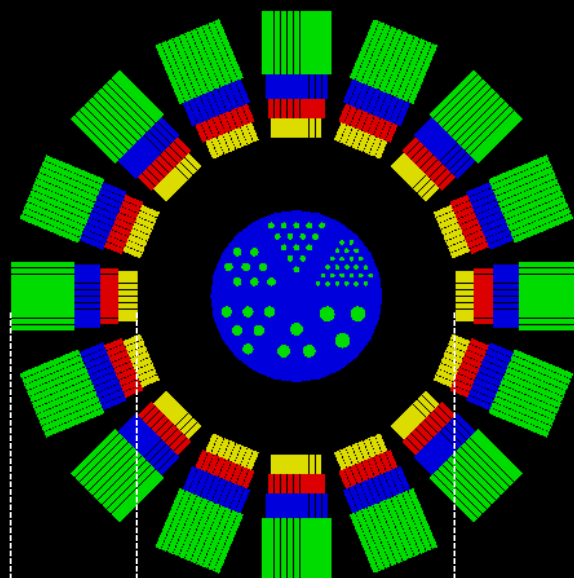
5+5+5+5 mm

3+3+4+10 mm

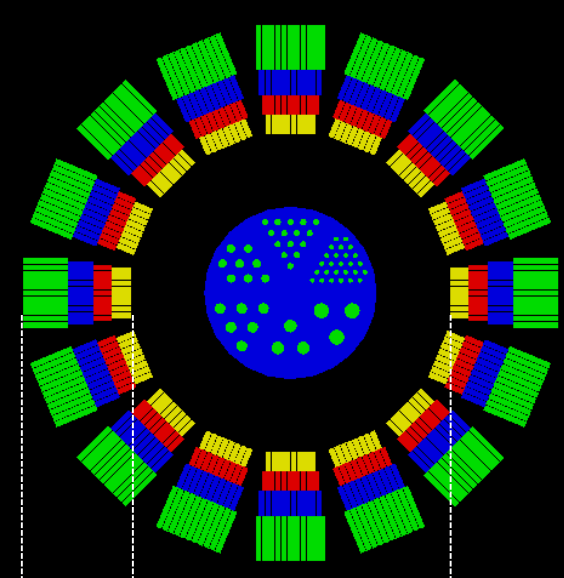
3+3+4+7 mm



20 mm ID=50 mm



20 mm ID=50 mm



17 mm ID=50 mm

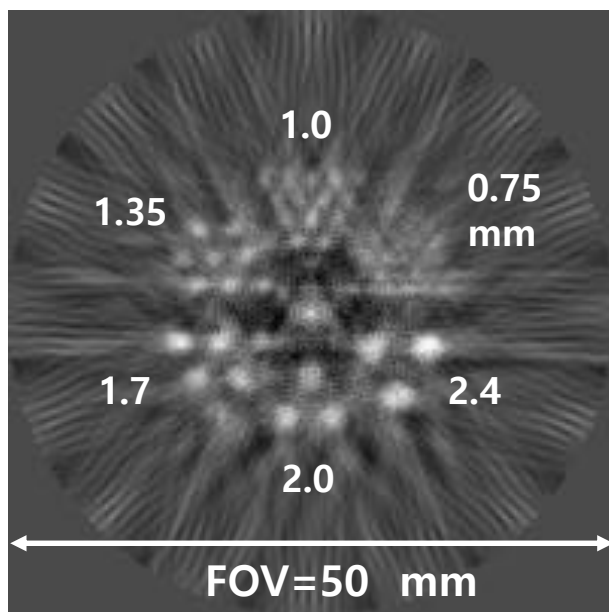
Sensitivity 1.41%

1.61%

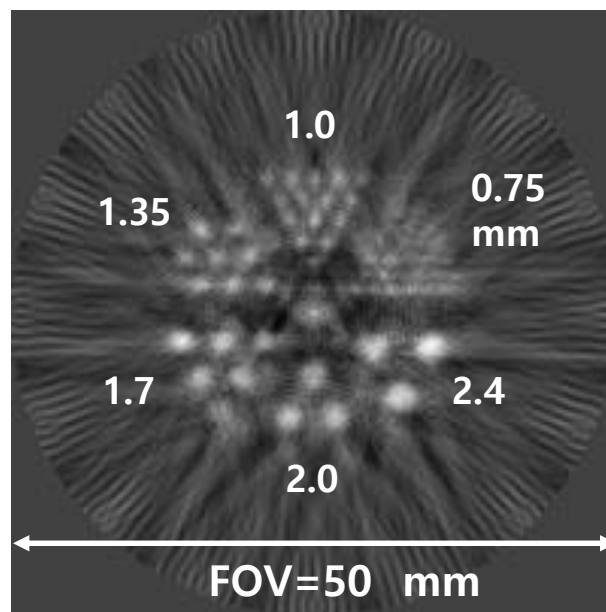
1.35%

Staggered 4-layer (FBP)

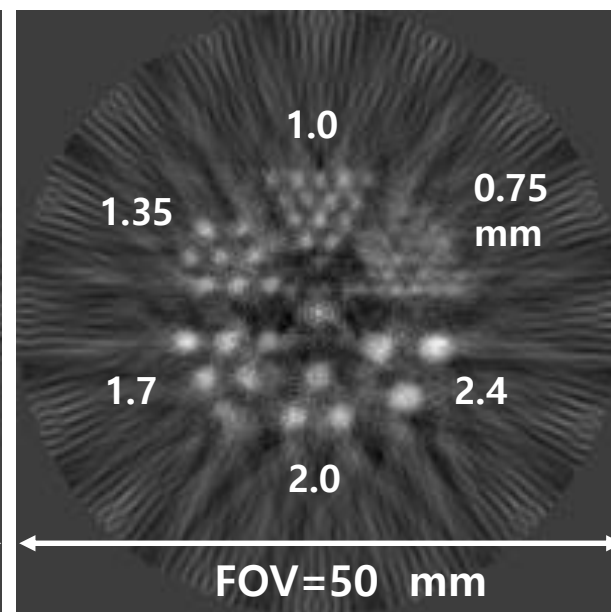
5+5+5+5 mm



3+3+4+10 mm



3+3+4+7 mm



Voxel: $0.25 \times 0.25 \times 0.25 \text{ mm}^3$

200×200×44, Float 32-bit

Ultra-Micro hot (300 kBq/ml)

OSEM

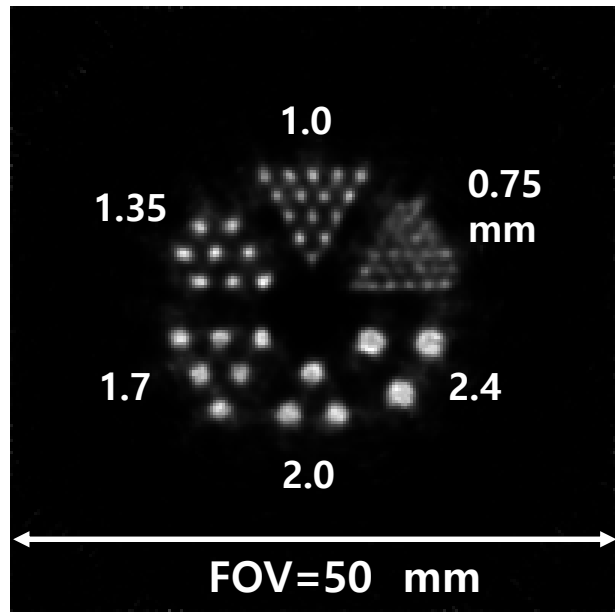
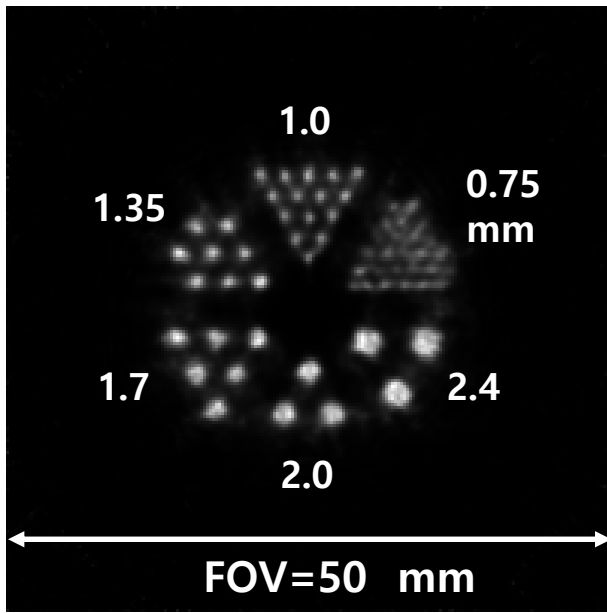
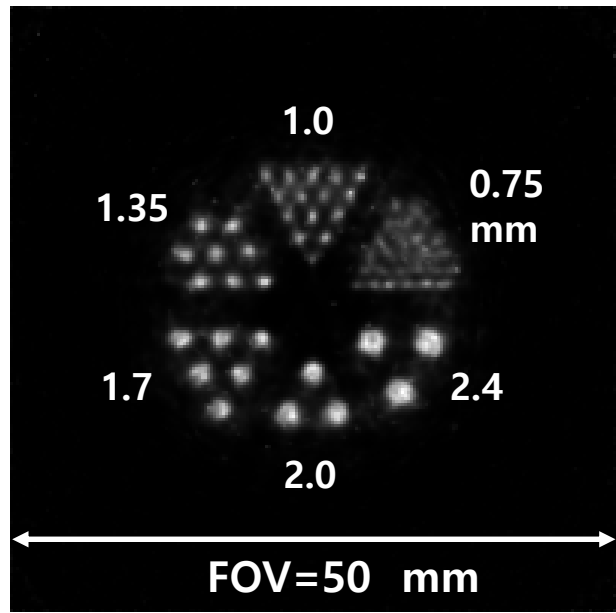
#of subset = 8
#of iteration= 10

Staggered 4-layer (OSEM)

5+5+5+5 mm

3+3+4+10 mm

3+3+4+7 mm



The "3+3+4+7 mm" shows the **best spatial resolution!**

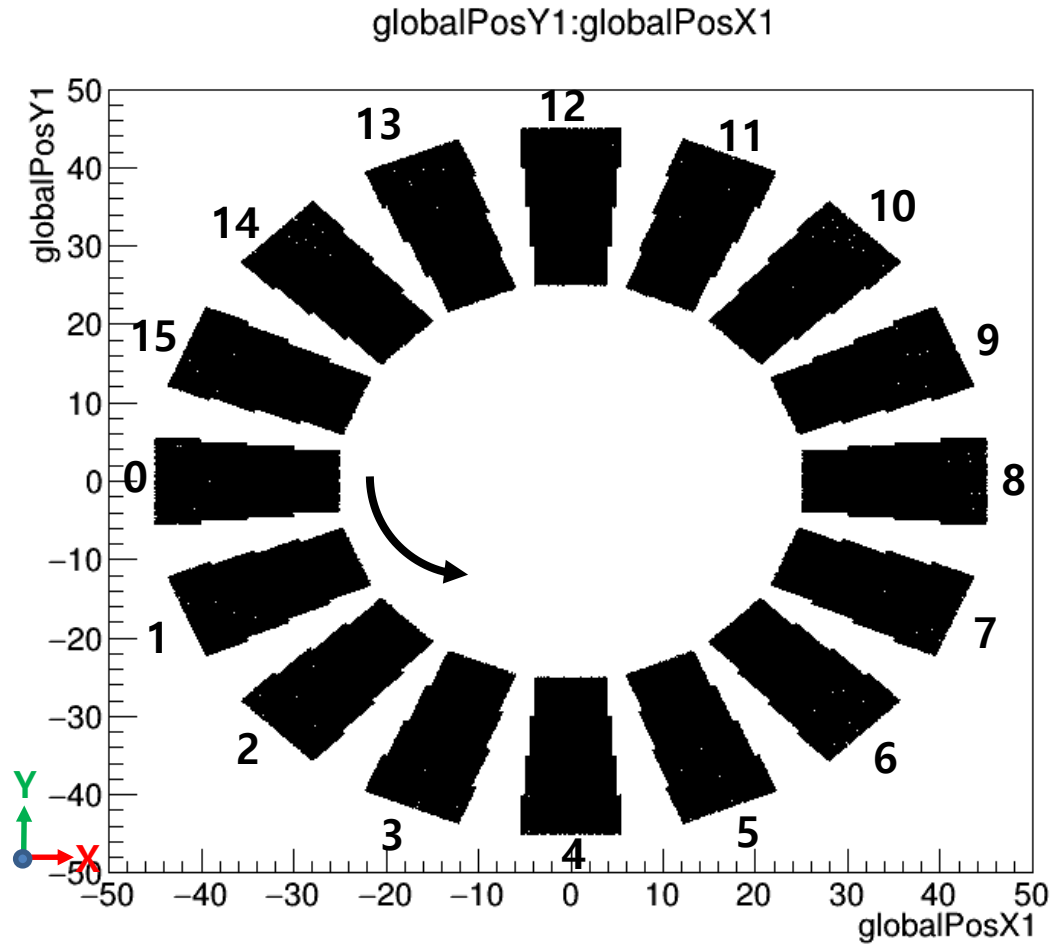
Voxel: $0.25 \times 0.25 \times 0.25 \text{ mm}^3$
200x200x44, Float 32-bit

Ultra-Micro hot (300 kBq/ml)

GATE simulation output (ROOT)

Block detector (level1ID)

Block ID is sorted by "level1ID"



Block detector (level1ID=0)

Crystal layer is sorted by

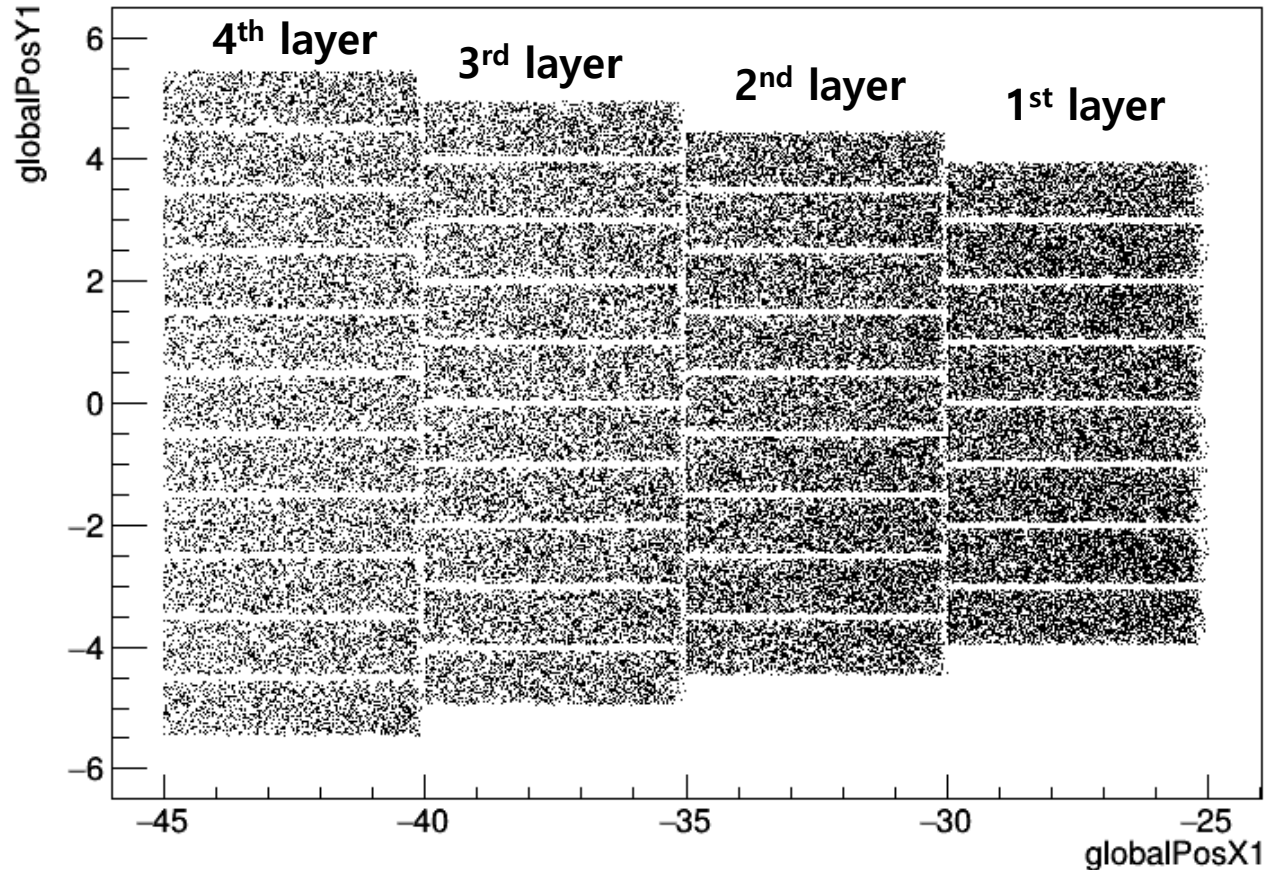
“level2ID” (1st layer)

“level3ID” (2nd layer)

“level4ID” (3rd layer)


“**layerID**” (4th layer)

globalPosY1:globalPosX1 {level1ID1==0}



1st layer level2ID (blockID =0 && DOI=0)

$$\text{Crystal ID1} = \text{Ny1} - \text{level2ID} \% \text{Ny1} - 1$$



$\text{Ny1} = 8$


| | | | | | | | | |
|---|----|----|----|----|----|----|----|----|
| 7 | 15 | 23 | 31 | 39 | 47 | 55 | 63 | 71 |
| 6 | 14 | 22 | 30 | 38 | 46 | 54 | 62 | 70 |
| 5 | 13 | 21 | 29 | 37 | 45 | 53 | 61 | 69 |
| 4 | 12 | 20 | 28 | 36 | 44 | 52 | 60 | 68 |
| 3 | 11 | 19 | 27 | 35 | 43 | 51 | 59 | 67 |
| 2 | 10 | 18 | 26 | 34 | 42 | 50 | 58 | 66 |
| 1 | 9 | 17 | 25 | 33 | 41 | 49 | 57 | 65 |
| 0 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 |

$$\text{Nz1} = 9$$

$$\text{Ring number1} = \text{floor}(\text{level2ID} / \text{Ny1})$$

2nd layer level3ID (blockID =0 && DOI=1)

Crystal ID2= $Ny2 - \text{level3ID} \% Ny2 - 1$



$Ny2=9$

| | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|
| 8 | 17 | 26 | 35 | 44 | 53 | 62 | 71 | 80 | 89 |
| 7 | 16 | 25 | 34 | 43 | 52 | 61 | 70 | 79 | 88 |
| 6 | 15 | 24 | 33 | 42 | 51 | 60 | 69 | 78 | 87 |
| 5 | 14 | 23 | 32 | 41 | 50 | 59 | 68 | 77 | 86 |
| 4 | 13 | 22 | 31 | 40 | 49 | 58 | 67 | 76 | 85 |
| 3 | 12 | 21 | 30 | 39 | 48 | 57 | 66 | 75 | 84 |
| 2 | 11 | 20 | 29 | 38 | 47 | 56 | 65 | 74 | 83 |
| 1 | 10 | 19 | 28 | 37 | 46 | 55 | 64 | 73 | 82 |
| 0 | 9 | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 |

$Nz2=10$

Ring number1= $\text{floor}(\text{level3ID}/Ny2)$

3rd layer leve43ID (blockID =0 && DOI=2)

Crystal ID3= $Ny3 - \text{level4ID} \% Ny3 - 1$

| | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|
| 9 | 19 | 29 | 39 | 49 | 59 | 69 | 79 | 89 | 99 |
| 8 | 18 | 28 | 38 | 48 | 58 | 68 | 78 | 88 | 98 |
| 7 | 17 | 27 | 37 | 47 | 57 | 67 | 77 | 87 | 97 |
| 6 | 16 | 26 | 36 | 46 | 56 | 66 | 76 | 86 | 96 |
| 5 | 15 | 25 | 35 | 45 | 55 | 65 | 75 | 85 | 95 |
| 4 | 14 | 24 | 34 | 44 | 54 | 64 | 74 | 84 | 94 |
| 3 | 13 | 23 | 33 | 43 | 53 | 63 | 73 | 83 | 93 |
| 2 | 12 | 22 | 32 | 42 | 52 | 62 | 72 | 82 | 92 |
| 1 | 11 | 21 | 31 | 41 | 51 | 61 | 71 | 81 | 91 |
| 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 |



$Ny3=10$

$Nz3=10$

Ring number3= $\text{floor}(\text{level4ID}/Ny3)$

4th layer **layerID** (blockID =0 && DOI=3)

Crystal ID₄= Ny₄-**layerID**%Ny₄-1

| | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|-----|-----|
| 10 | 21 | 32 | 43 | 54 | 65 | 76 | 87 | 98 | 109 | 120 |
| 9 | 20 | 31 | 42 | 53 | 64 | 75 | 86 | 97 | 108 | 119 |
| 8 | 19 | 30 | 41 | 52 | 63 | 74 | 85 | 96 | 107 | 118 |
| 7 | 18 | 29 | 40 | 51 | 62 | 73 | 84 | 95 | 106 | 117 |
| 6 | 17 | 28 | 39 | 50 | 61 | 72 | 83 | 94 | 105 | 116 |
| 5 | 16 | 27 | 38 | 49 | 60 | 71 | 82 | 93 | 104 | 115 |
| 4 | 15 | 26 | 37 | 48 | 59 | 70 | 81 | 92 | 103 | 114 |
| 3 | 14 | 25 | 36 | 47 | 58 | 69 | 80 | 91 | 102 | 113 |
| 2 | 13 | 24 | 35 | 46 | 57 | 68 | 79 | 90 | 101 | 112 |
| 1 | 12 | 23 | 34 | 45 | 56 | 67 | 78 | 89 | 100 | 111 |
| 0 | 11 | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 |



Ny₄=11



Nz₄=11

Ring number₄= floor(**layerID**/Ny₄)

Conclusion and future plans

- **The GATE simulation of staggered 4-layer PET scanner** was performed.
 - **Problem:** "PETscanner" does not allow us to use "level5"
 - **Solution:** Attach the 4th layer crystal to "layer0"
- **The staggered 4-layer DOI PET scanner** showed a spatial resolution of **0.75 mm (FBP)**.
 - 5+5+5+5 mm (20 mm) : Sensitivity= 1.41%
 - 3+3+4+10 mm (20 mm) : Sensitivity= 1.61%
 - 3+3+4+7 mm (**17 mm**) : Sensitivity= **1.35%** (Best spatial resolution)
- **The imaging performance results of the staggered 4-layer DOI PET** will be presented in **2020 IEEE MIC**.