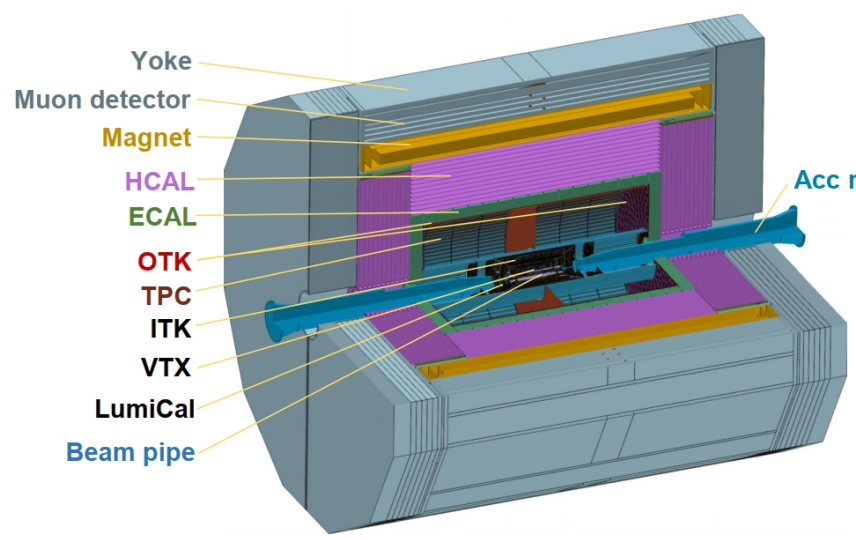


# Millimeter-Wave-Based Wireless Transmission System for CEPC Detector

Jun Hu<sup>1,\*</sup>, Chongyao Song<sup>1</sup>  
<sup>1</sup>Institute of High Energy Physics, CAS, Beijing, China

## 01. CEPC Background

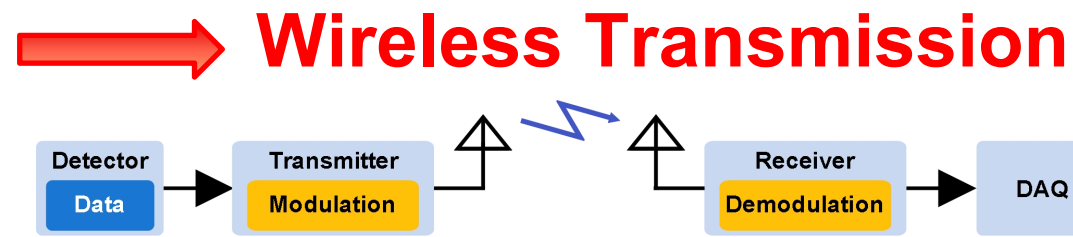


CEPC Reference Detector design

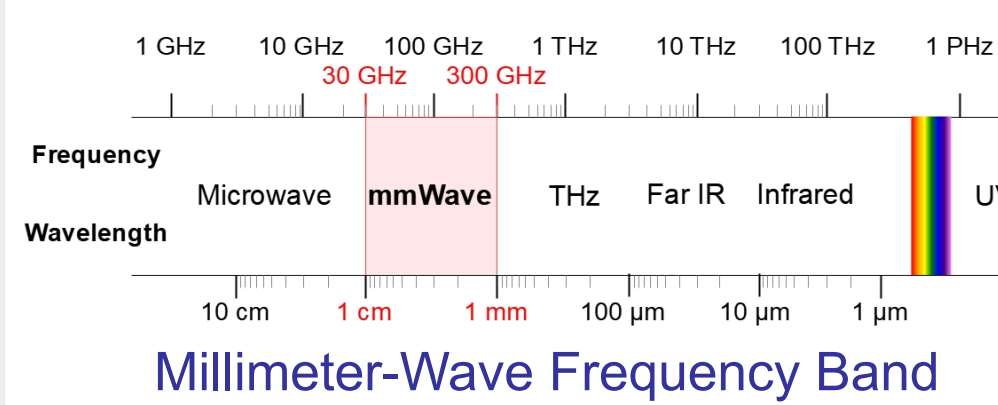
- The Circular Electron-Positron Collider (CEPC) is a next-gen high-energy physics facility designed to produce millions of Higgs bosons and enable precise studies of the Standard Model and new physical phenomena.

### Challenge:

- Low material budget
- High data rate
- Radiation tolerance



## 02. Millimeter-Wave Wireless



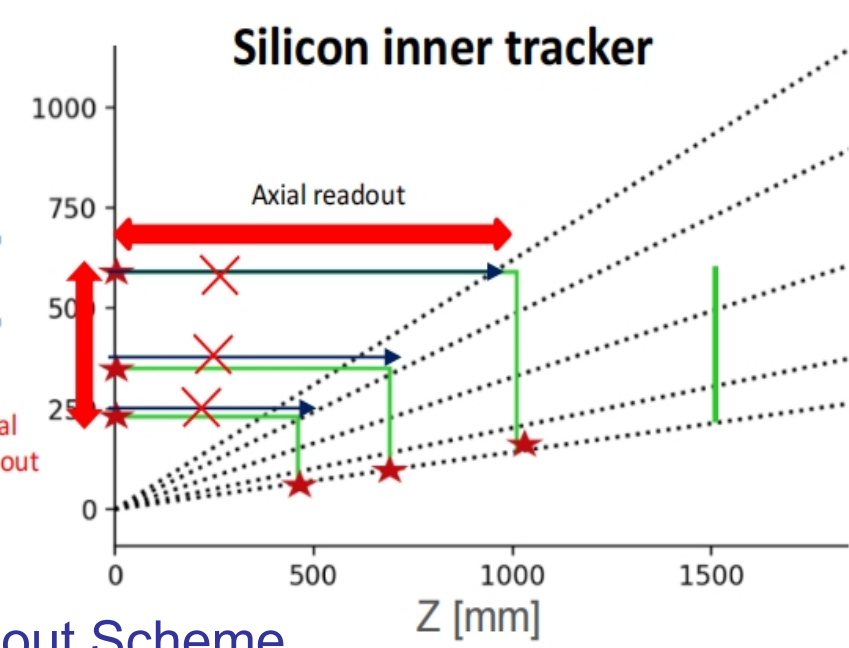
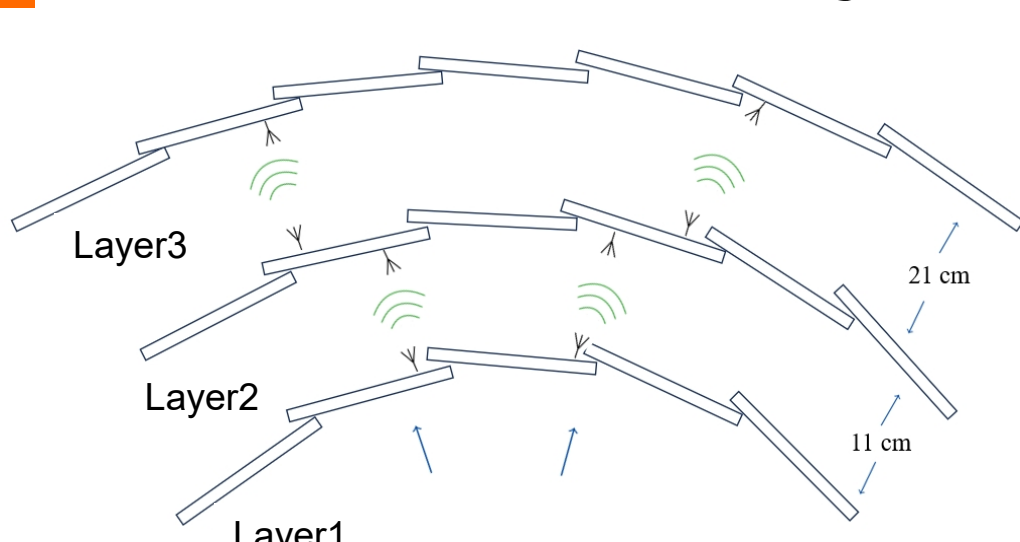
### Benefit of Wireless

- Reduce the material budget of cables, fibers and connectors,
- More convenient for installation and maintenance.

### Features:

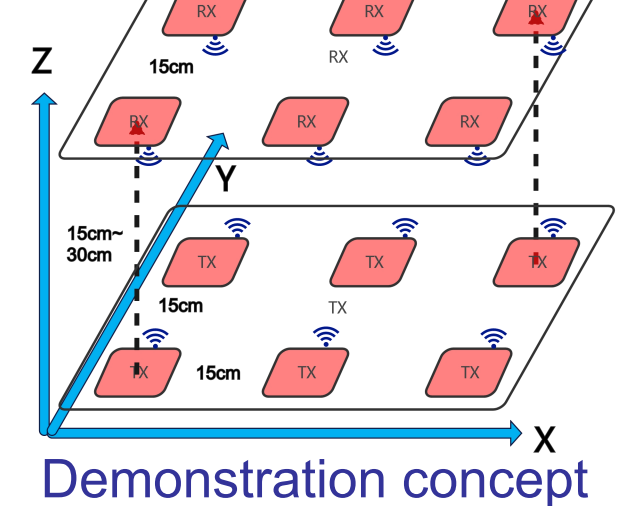
- High bandwidth availability
- Highly directional beams
- Compact component size
- Antenna miniaturization, even enabling seamless integration into chips
- Low interference resulting from high signal loss in free space.
- Moderate technological maturity

## 03. Research Objectives



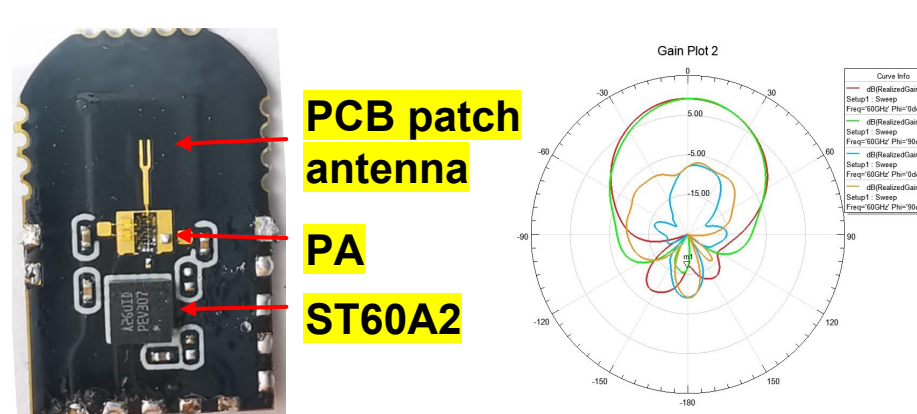
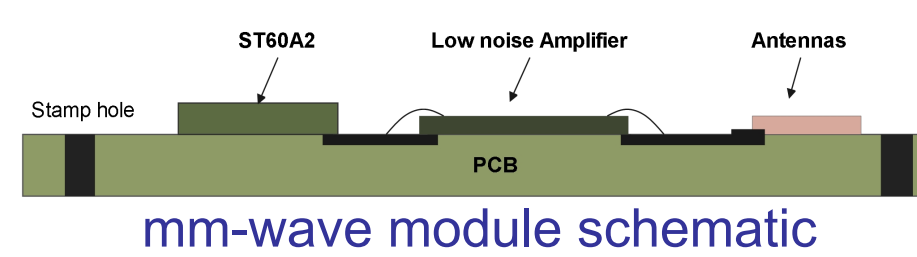
Radial Readout Scheme

- Develop a prototype adopting millimeter-wave wireless technology
- Interlayer spacing: 15 cm-30 cm
  - Transmission rate: > 1 Gbps
  - High-radiation environment



Demonstration concept

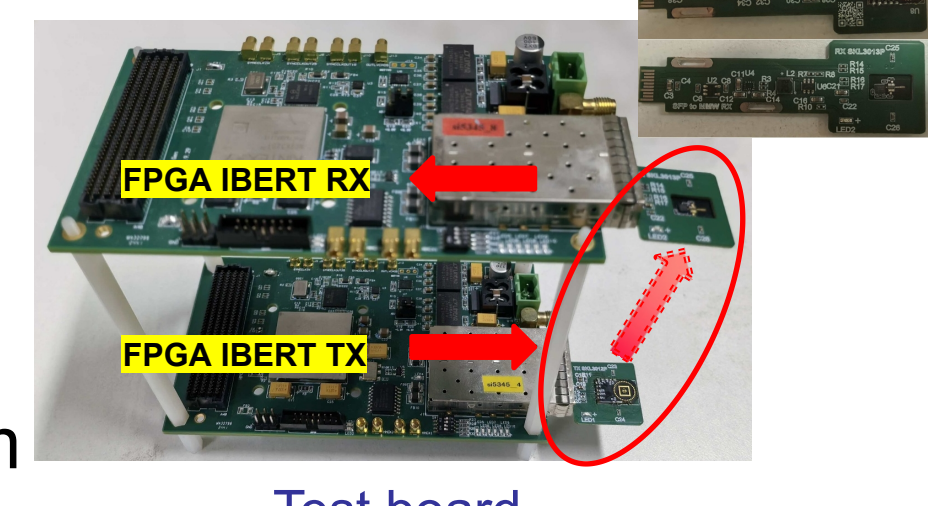
## 04. Enhanced Millimeter Wave Module



- ST60A2 + PA (60 GHz)
- PCB patch antenna
- Stamp hole interface
- Dimensions: 14 mm x 9 mm

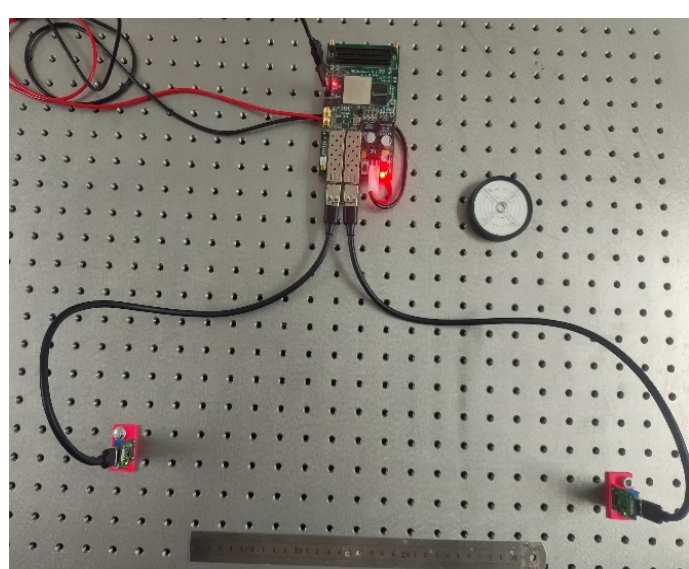
### Link Budget estimation:

- ST60A2: 28 dB@5 Gbps
- Tx/Rx antenna gain: 9 dB
- Amplifier gain: 19 dBi
- Total LB: ~ 65 dB
- Free-space transmission distance: 70 cm



Test board

## 05. Performance Test



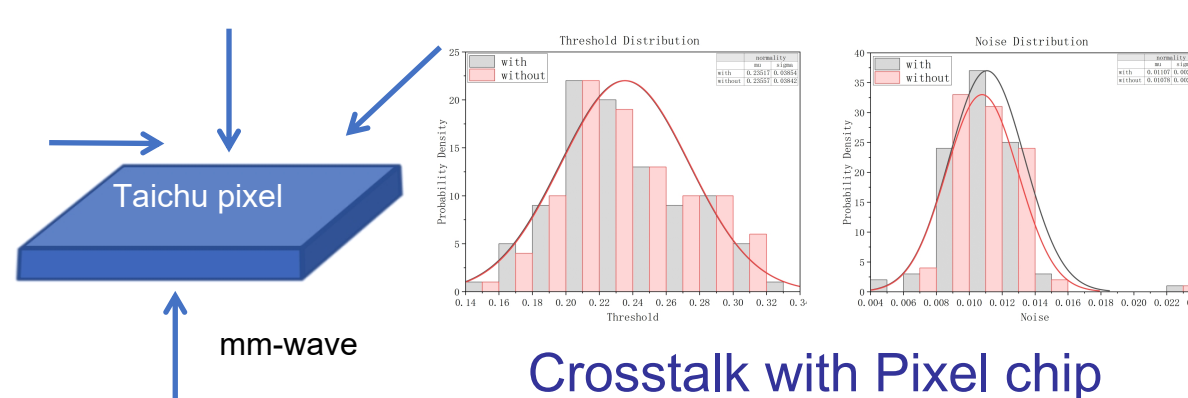
Line Rate (Gbps)	Distance (cm)
1.25	67.5
4	50
5	45
6.6	22.5

Line rate & transmission Distance performance test

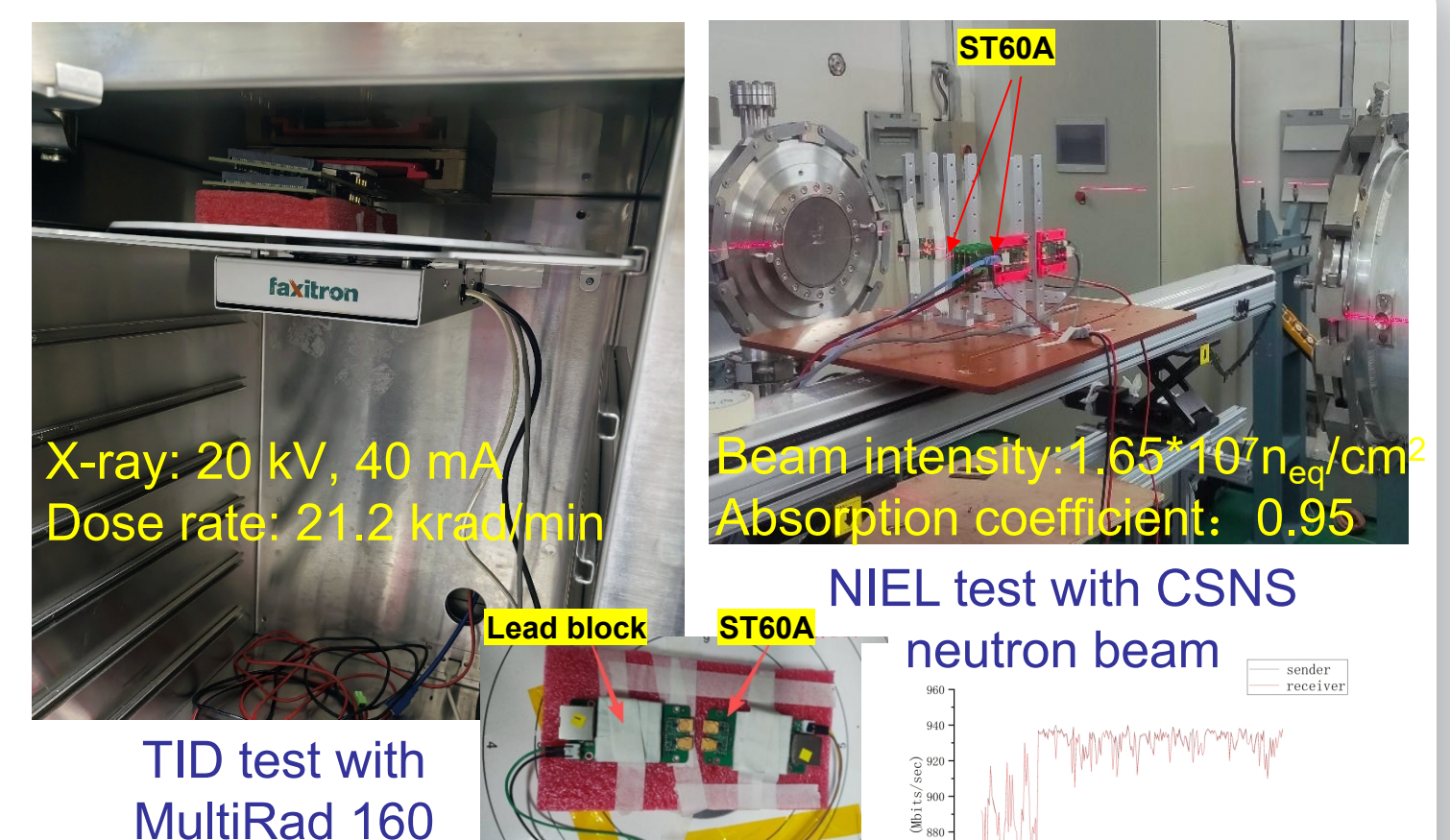
IBERT test at 1.25Gbps, 4Gbps, 5Gbps, 6.6Gbps

### Penetration capability

Material	Thickness	Penetration
Paper	2mm	✓
Plastic	2mm	✓
FR4 PCB	1.6mm	✗
Flex	0.2mm	✗



- Almost no mutual interference

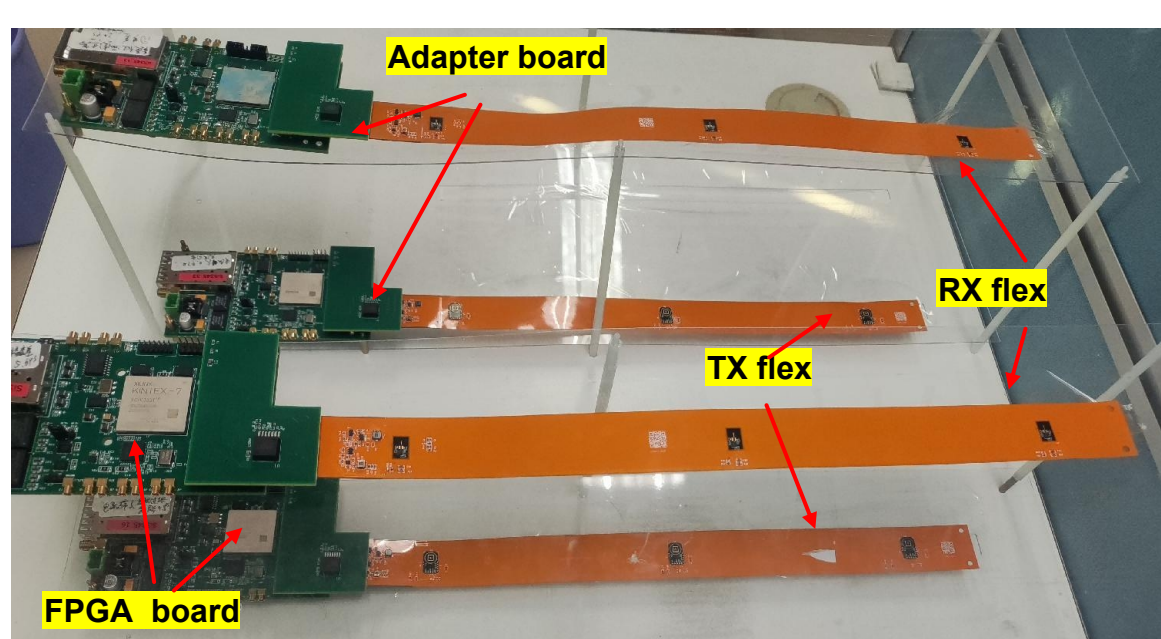


### Radiation Hardness

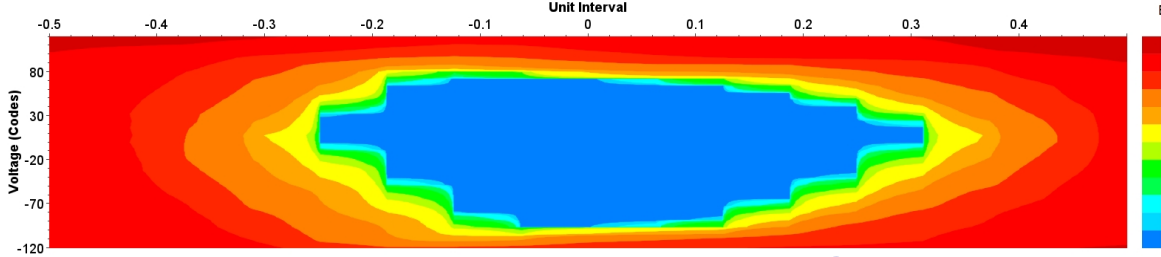
- TID: 7 Mrad (5.5 hours)
- NIEL:  $1.2 \times 10^{12} n_{eq}/cm$  (21 hours)

Bandwidth during irradiation

## 06. Multi-Channel Integration



Multi-channel demonstration



RX Eye diagram at 3.125Gbps

### Technical Parameters

- Architecture: FPGA data source + Flex RF node
- Layout: 2x3 transmission pairs arranged on XY plane
- XY plane spacing: 15 cm
- Z-axis transmission distance: 15-30 cm
- Line rate: 3.125 Gbps
- Bit error rate: < 1E-14

## 07. Conclusion

- Developed enhanced millimeter wave modules and complete 60 GHz wireless readout multi-channel demonstration.
- Achieved stable crosstalk-free transmission up to 18.75 Gbps.
- Features high throughput, low material budget and radiation tolerance.
- Modular design facilitates multi-channel expansion and diverse application.