

# Development of a Wireless Data and Control Transmission Application for CEPC

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# Outline

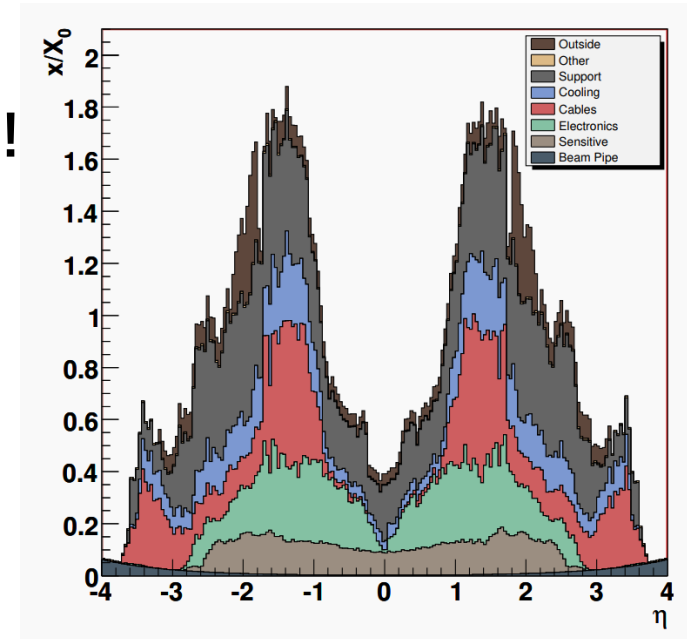


- Motivation
- Technology Feasibility Studies
  - WiFi
  - Millimeter Wave (60GHz)
  - Optical wireless communication (OWC)
- Plan
- Summary

# Motivation

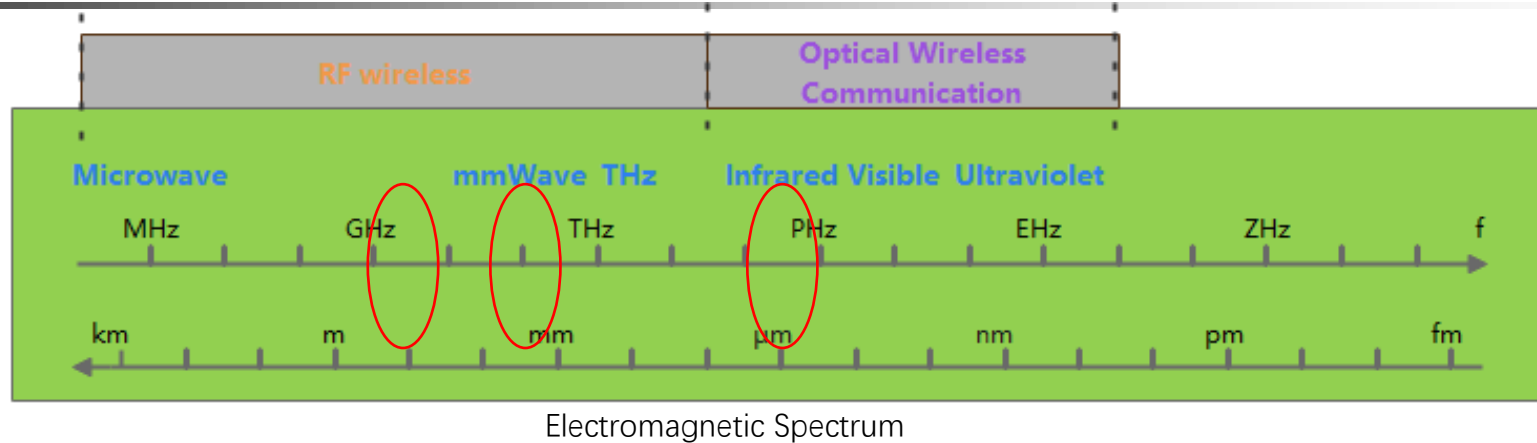


- Wireless transmission Advantages
  - Reducing the material budget of cables, fibers and connectors, while also reducing the dead zone.
    - > **Improve the detection efficiency and resolution!!!**
  - Broadcast links simplify the clock and control signal topology in complex detector system.
  - More convenient for installation and maintenance.



Radiation length distribution  
in CMS tracker

# Technology Feasibility Studies



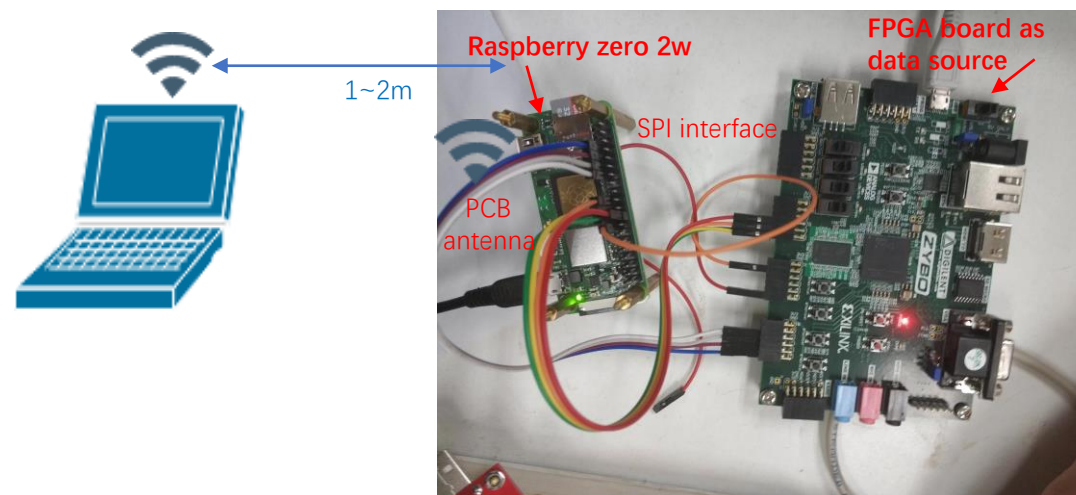
- WiFi (2.4GHz, 5GHz)
- Millimeter Wave (60GHz)
- Optical wireless communication (OWC) / Free Space Optical(FSO)

# WiFi

Years	802.11 standard	Frequency Band	Name	Top Speeds
2009	802.11n	2.4 GHz or 5 GHz	WiFi 4	0.6Gbps
2013	802.11ac wave1	5 GHz	WiFi 5	6.93Gbps
2015	802.11ac wave2	5 GHz		
2019	802.11ax	2.4 GHz or 5 GHz	WiFi 6	9.6Gbps
		2.4 GHz or 5 GHz 6 GHz	WiFi 7	46Gbps

- A large number of similar modules can be purchased on the market, with universal SPI, i2c, USB, and PCIe interfaces.
- Most of them can easily find software and drivers to make them work.
- Difficult and no need to design with WiFi client chips.

2023/10/24



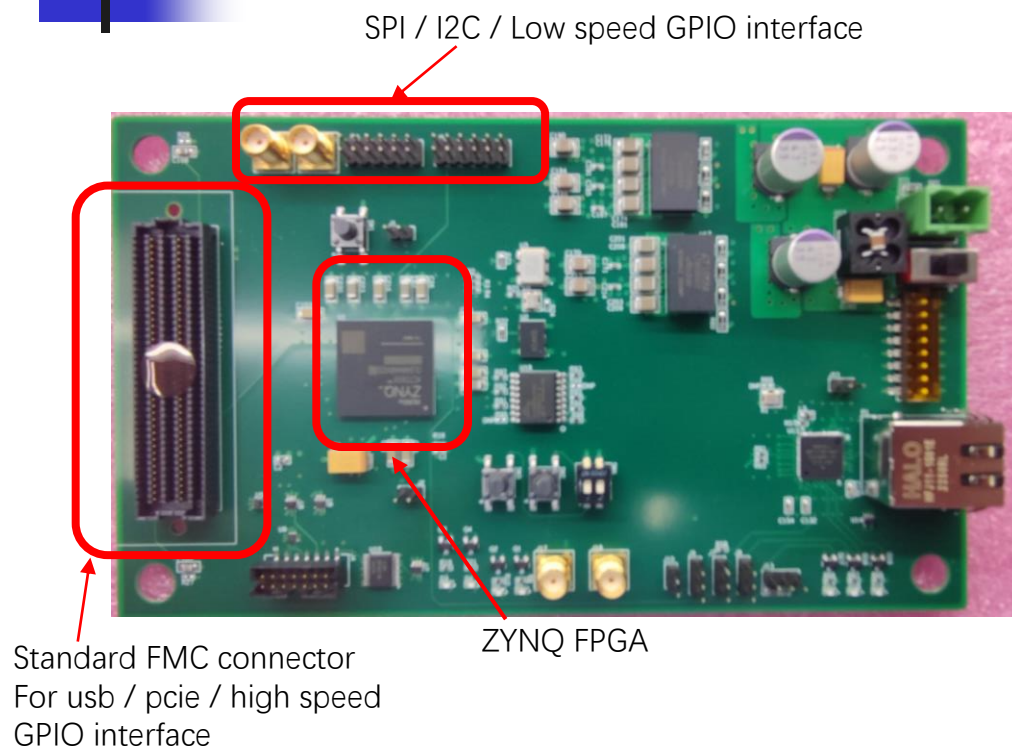
Test setup based on Raspberry board

- Test with commercial board - Raspberry PI zero 2w



- Mature SOC system, support 2.4GHz 802.11b/g/n.
- Module size: 6.5cmX3cm, Power consumption: ~2W, Cost: ¥120.
- Communicate with FPGA board through 2 SPI buses, one receiving and one transmitting.
- Communicate with PC can achieve up to 22.03 Mbps in both uplink and downlink bandwidth through wireless.
- More test with multi-channel is needed

# WiFi

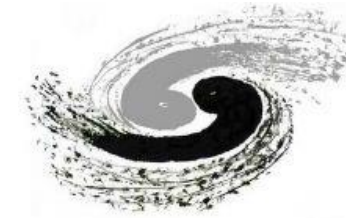


WiFi modules

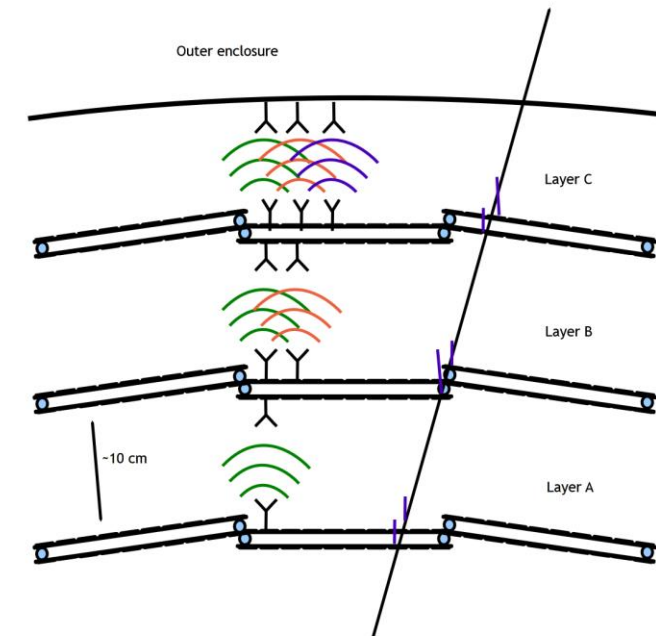
- A ZYNQ evaluation board was designed to verify different WiFi modules, avoiding duplicate driver software development work.
  - 2 kinds of low speed interface modules has been tested

- The main work is embedded system development and driver porting.
- Possible WiFi application scenarios
  - Far from the front-end
  - Low bandwidth transmission
  - DCS control information

# Millimeter Wave



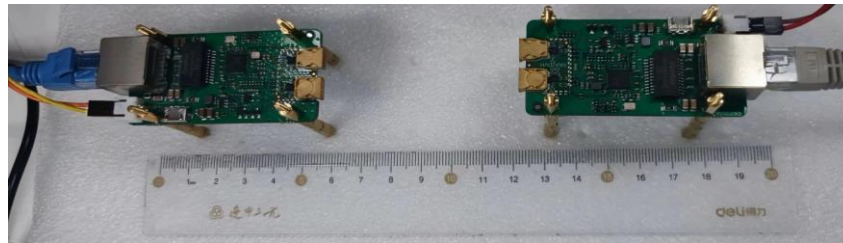
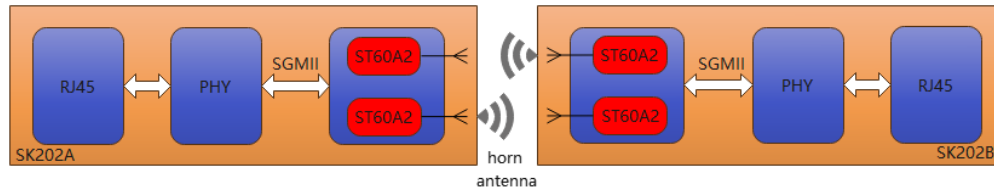
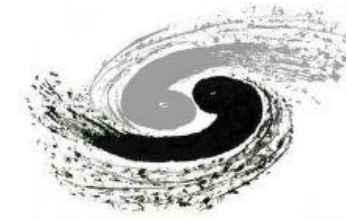
- Definition : 1-10mm wavelength ( 30-300GHz carrier frequency)
- Features
  - Huge bandwidth with lower power
  - Small antenna size
  - Large loss in free space, means lower interference,
  - High density possible
- A lot of ASICs for Radiation hard requirement are available with mature technology



Proposal of radial data readout for fast trigger by WADAPT Collaboration.  
*Multi Gigabit Wireless Data Transfer in Detectors at Future Colliders*  
<https://www.frontiersin.org/articles/10.3389/fphy.2022.872691/full>



# Millimeter Wave



Test with SK202 evaluation boards



- Test with evaluation boards – SK202
  - The commercial 60GHz RF chip ST60A2 transceiver from ST Microelectronics company.
  - Up to 6.25 Gbit/s data rate.
  - The chip power consumption:  
44mW@TX, 27mW@RX, 3.5uW @ OFF
  - Cost: ¥100.

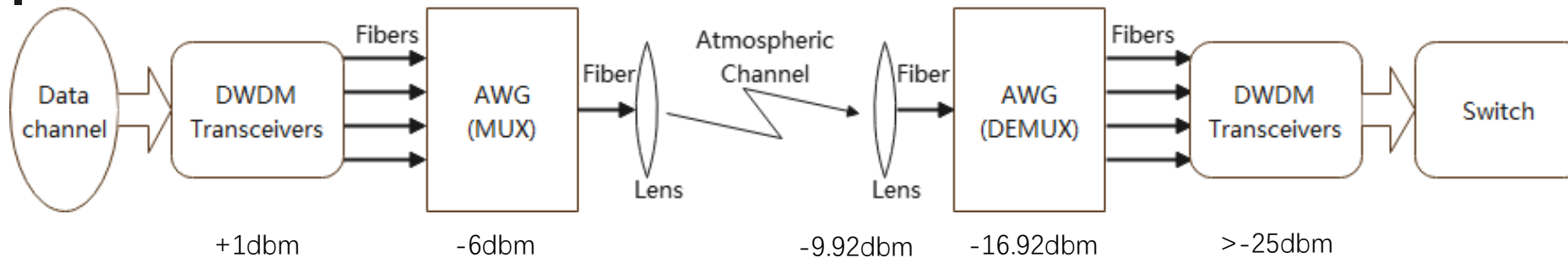
Distance (cm)	Bandwidth (Mbps)	Packet loss rate
1	914	0.031%
3	917	0.061%
5	915	0.05%
6	913	0.13%
>6	No link	No link

Test result at different distances of TX/RX

- 2 laptops use Iperf3 software to send data to each other, The test results shows
  - The transmission speed can reach more than 900Mbps when the distance is less than 5 cm.
  - No link when the distance is over 6 cm
  - When the horn antenna angle has 2 mm mismatch, the link is not stable.
- New custom evaluation board need to be designed with higher bandwidth.



# Optical Wireless

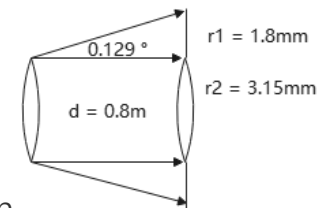


Free Space Optical(FSO) test setup structure

- Data channel : Maybe from endcap of detector
- Dense Wavelength Division Multiplexing (DWDM) transceivers:
  - Up to 11.3Gb/s data links
  - Power Consumption: 1.6W
  - Average Optical Power: 1~5dBm
  - Optical Extinction Ratio: 8.2dB
  - Receiver Sensitivity (Average Power): -25dBm

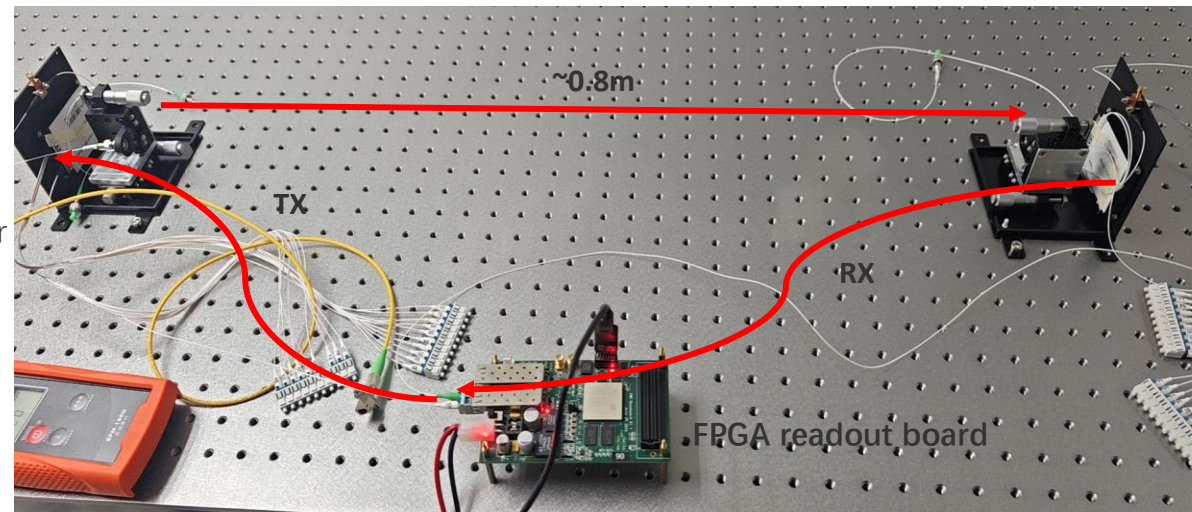
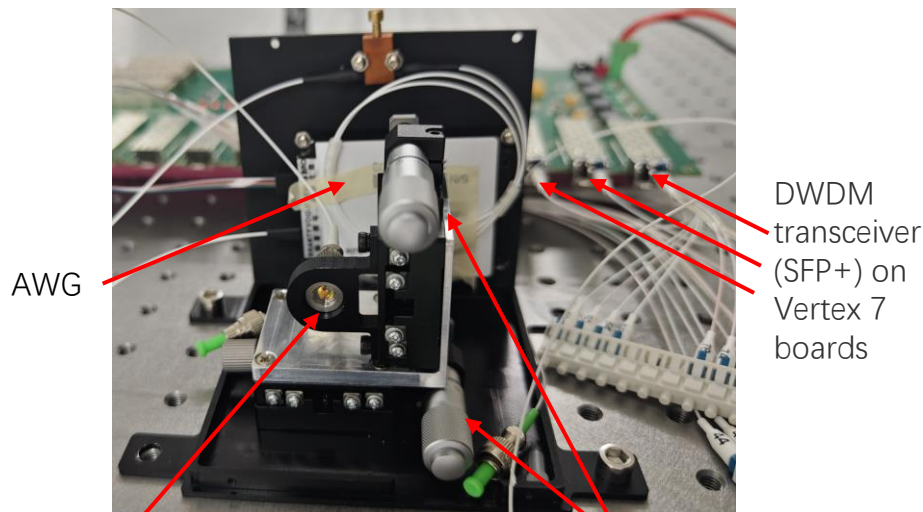


- Arrayed Waveguide Grating (AWG)
  - Center Wavelength: 1550nm
  - Attenuation : -7db
  - Center Wavelength Spacing: 100GHz
  - Channels support: 20 bidirectional maximum

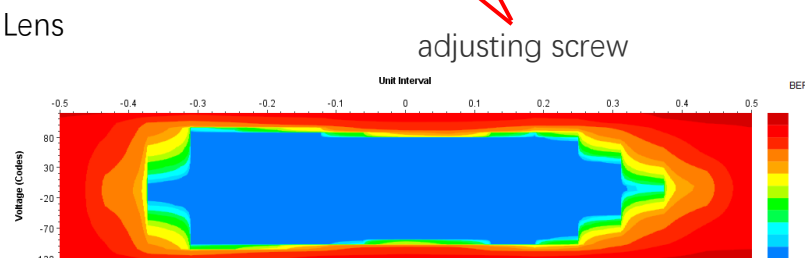


- Lens :
  - Divergence : 0.129°@1550nm
  - $\eta = \frac{P_2}{P_1} = \left( \frac{r_2}{r_1 + r_2} \right)^2 = \left( \frac{3.15}{1.80 + 3.15} \right)^2 = 0.405 = -3.92\text{db}$

# Optical Wireless



Optical Power received : -13.36dBm



Summary	Metrics	Settings
Name: SCAN_84	Open area: 14784	Link settings: N/A
Description: Scan 84	Open UI %: 64.71	Horizontal increment: 8
Started: 2023-Oct-23 18:31:53		Horizontal range: -0.500 UI to 0.500 UI
Ended: 2023-Oct-23 18:31:58		Vertical increment: 8
		Vertical range: 100%

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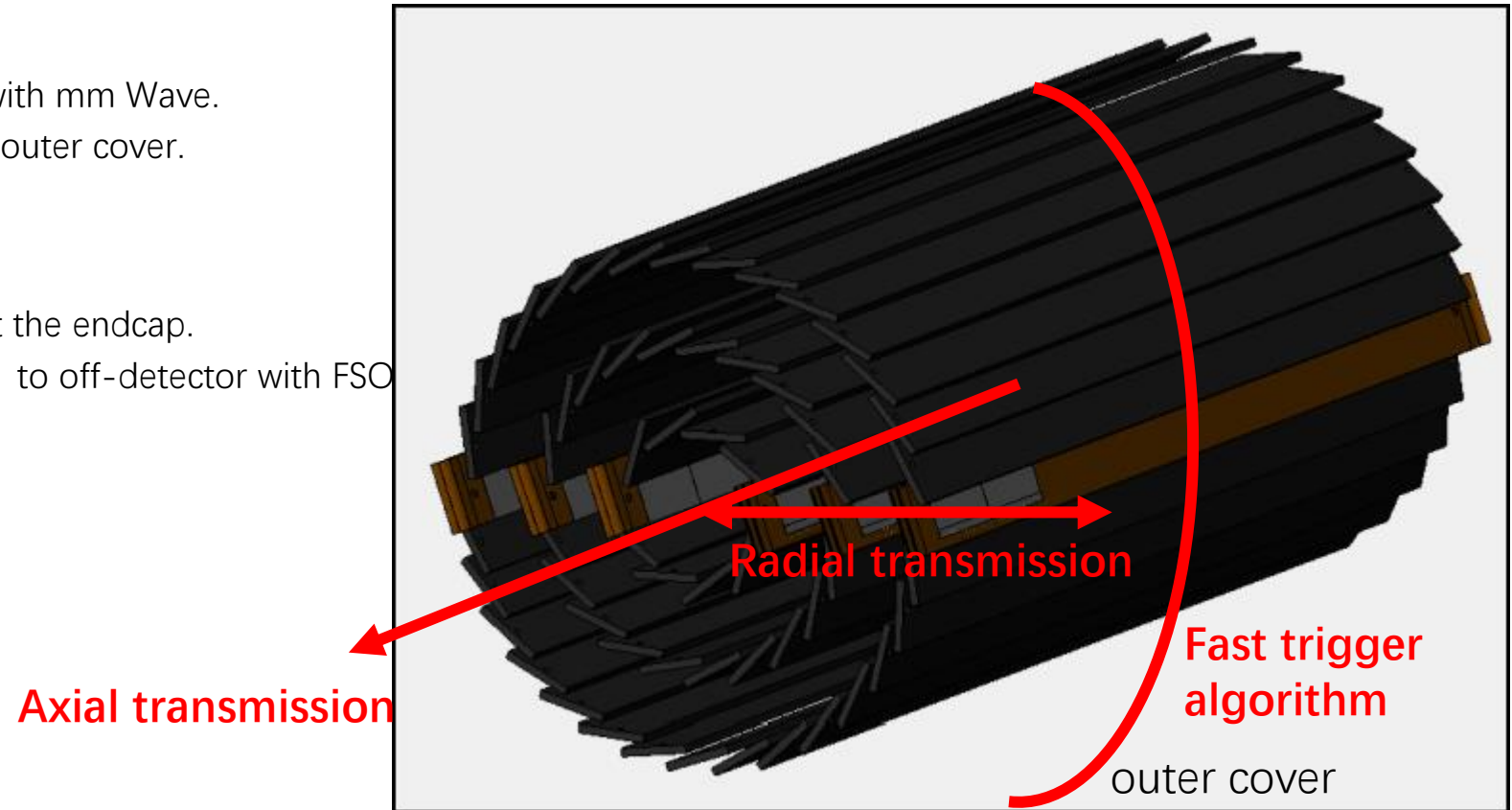
ibert eye pattern

- Easily compatible with current readout electronics for MOST2 prototype (SFP+ connector)
- Kintex7 FPGA board use ibert test in loopback mode
  - Optical Power received : -13.36dBm > -25dBm
  - 32-PRBS error rate <  $1.0 \times 10^{-12}$  @ 4Gbps
- Higher speed and more channels test need to be done with Vertex 7 board

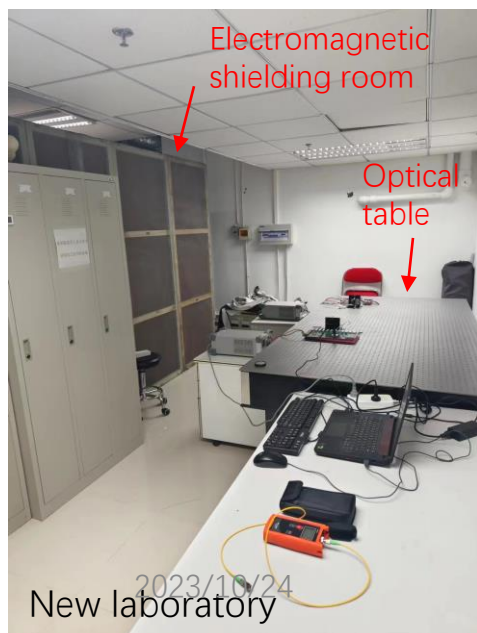
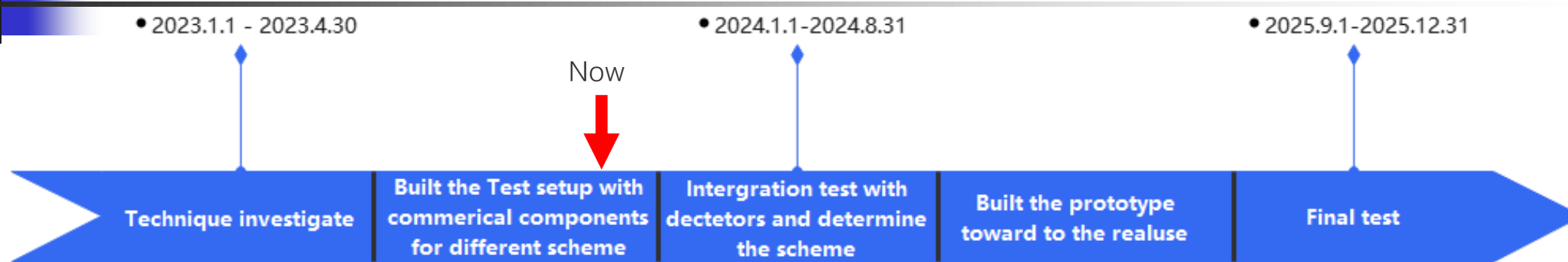
# Preliminary idea



- Radial transmission
  - Short distance transmission with mm Wave.
  - First fast trigger generator in outer cover.
- Axial transmission
  - Data Aggregate few points at the endcap.
  - Longer distance transmission to off-detector with FSO



# Plan



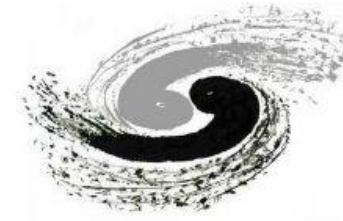
- Proof concept demonstrator with commercial components
  - Multi-channel cross talk test
  - Wireless noise to the detector module

- Develop the core transceiver / driver custom chips for radiation hard

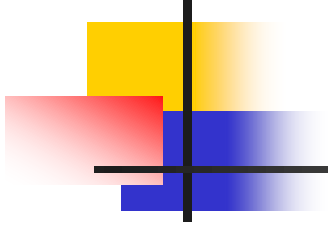




# Summary



- Some specific wireless technologies are selected and the testing started.
- Need carefully proof concept demonstrator with thorough test.
- In-depth discussions about the structure and mechanical design of detector.
- Still open to exploring alternative technologies and other innovative ideas.



Thank you