The Design and Prototyping of GE21 GEM Electronic Board

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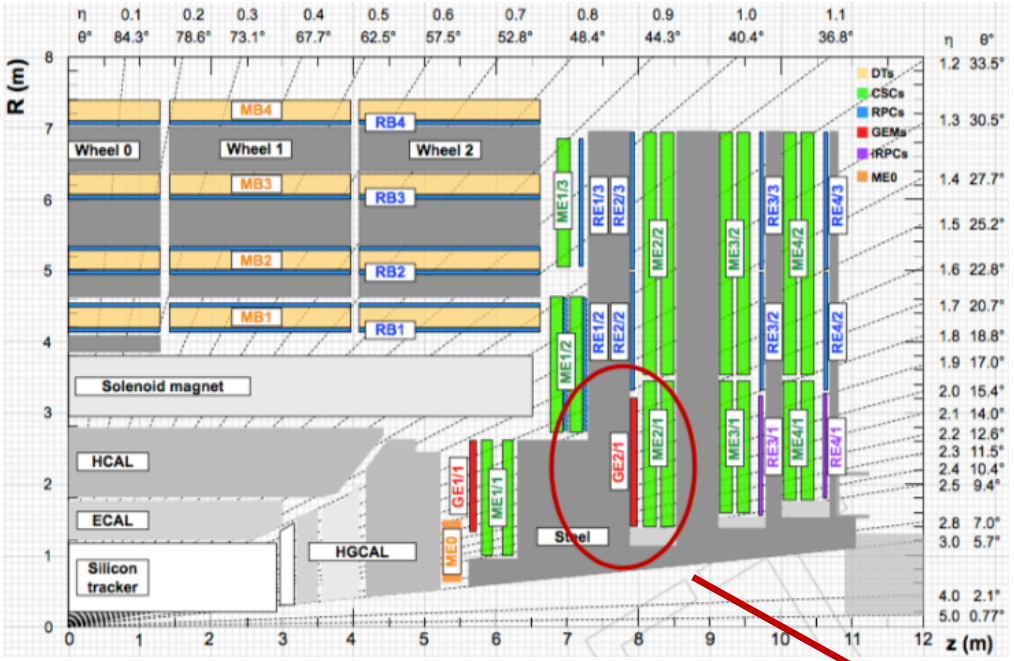
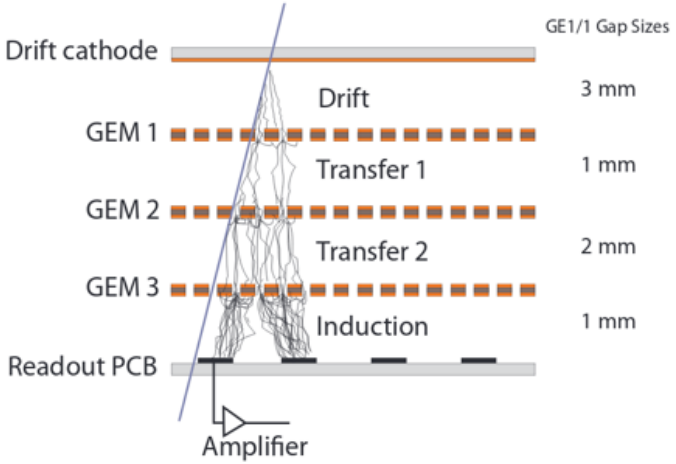
Outline

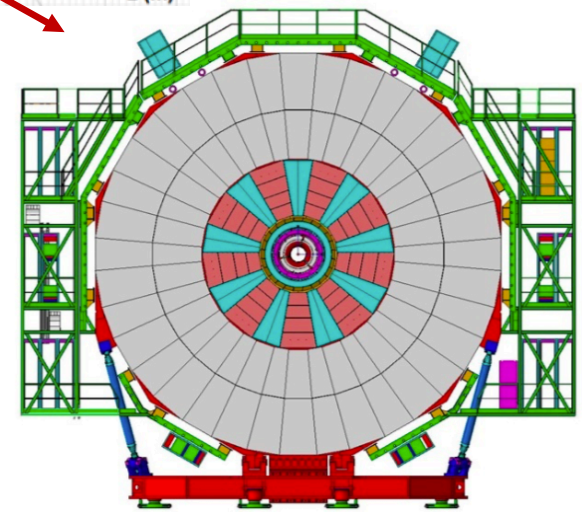
- Introduction
- GEM Electronic Board (GEB) Requirement and Design
- GE2/1 GEB Prototype and Test
- Summary

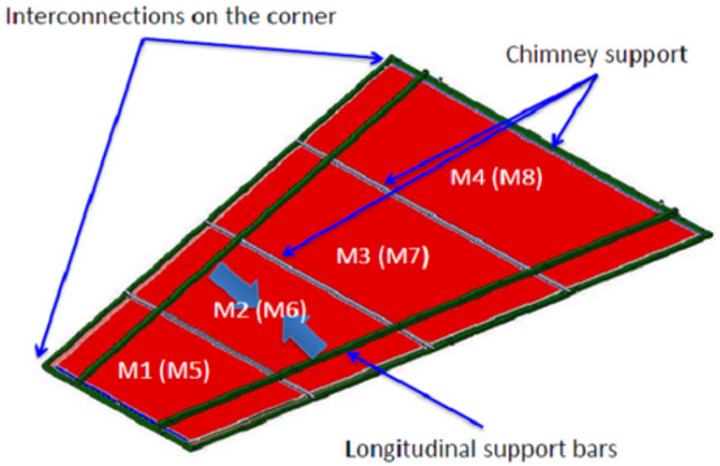
CMS Muon Upgrade-- GE2/1



- Requirement to improve capabilities of the Level-1 muon trigger in CMS detection
  - GEM (Gas Electronic Multiplier) : high gain, reliably operation at hit rate of MHz/cm^2, longevity stability
  - GEM technology are applied in GE1/1, GE2/1, ME0 detectors in CMS endcaps
  - GE21 chamber system consists of 72 chambers arranged in 2 layers endcap(blue and red)
  - 2 types of chamber-–front &back chamber aim to minimize dead area of detection
  - 4 triple GEM modules per chamber(M1-4 or M5-8)

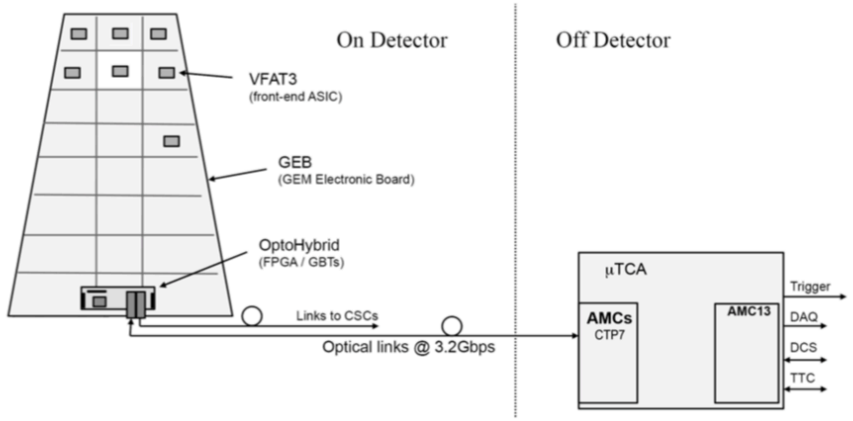




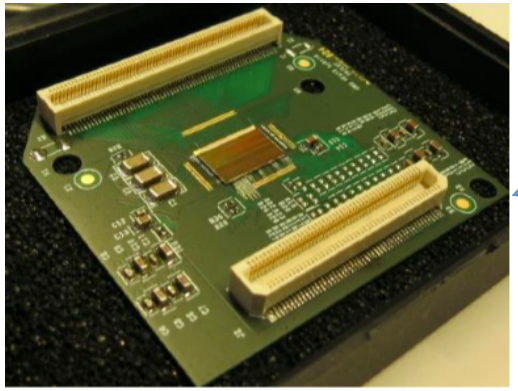


GE2/1 Front-End Electronics

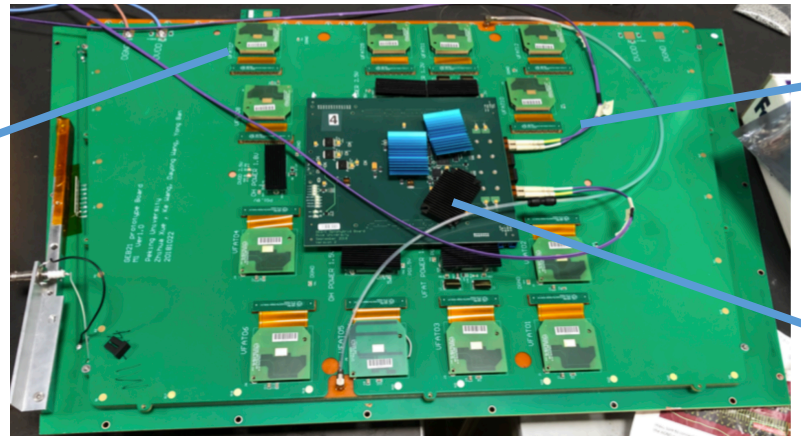
- On chamber electronics (learn from GE1/1)
  - VFAT3 ASIC(12 for each module)
    Reading out the signals from triple GEM modules
  - GEB(1 for each module)
  - Plug-in card(a packaged VFAT3 on a Rigid+ Flex PCB)
    The flex part absorbs residual misalignment of GEB vs ROB
  - Optohybrid board(1 for each module)
    A multiplier board to collect and concentrate the track data and trigger data from on-chamber electronics and send it to off-detector electronics with optical links.



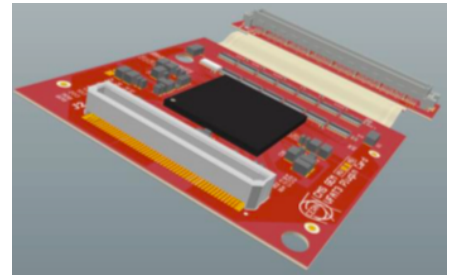
Architecture of the GE1/1 electronics system



VFAT3 chip



Architecture of the GE2/1 on chamber electronics

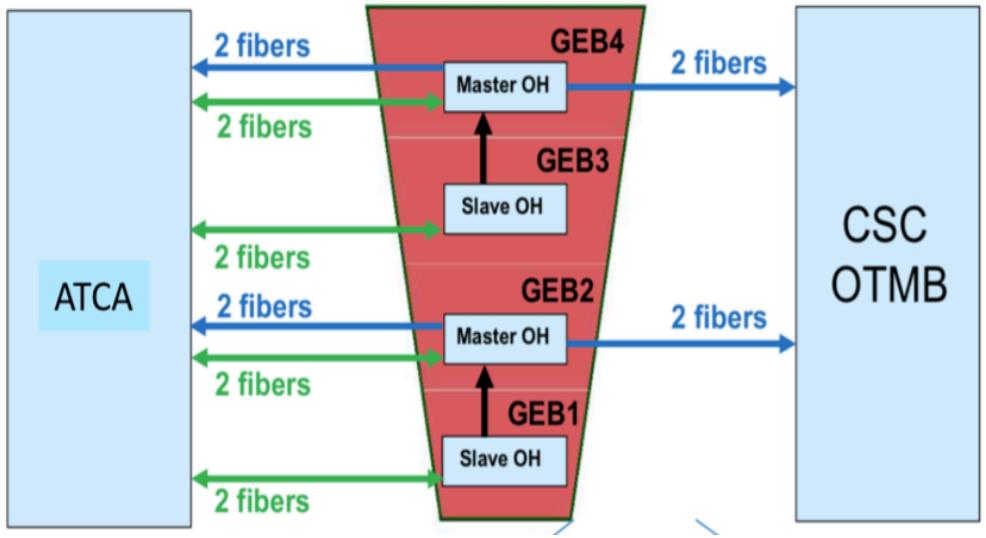


PlugIn card

Opto-hybrid

GE21 GEB requirements

- GEM Electronic Board (GEB) is a crucial element for GEM chamber design
  - A. Transmit signals between VFAT3 ASIC and Optohybrid board
  - B. Power supply and distribution to VFAT3 ASIC and Optohybrid board
  - C. Provided electrical shielding to the detectors located in the top of the readout board



CMS GE2/1 system overview

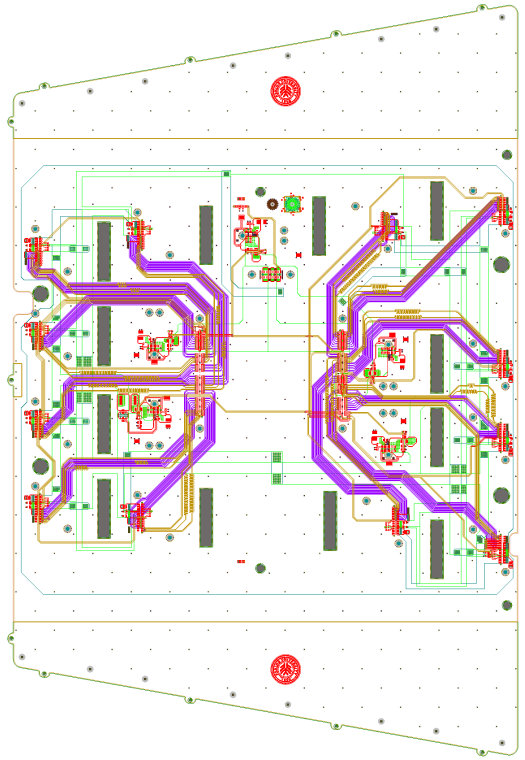
- GEB Design: simpler PCB Design, shorter traces, better signal integrity
  - Transmit signals from 12 VFATs to one Optohybrid
  - Trigger signals route in GEB including 9 differ pair signals: signal[8..1]&Strobe signal
  - E-Port signals route in GEB including 3 differ pair signal: RXD & RXDCLK & TXD signal
  - One Reset LVCMOS signal for VFAT

GE21 GEB design

- Route parameters of signal width and distance between pairs are simulated and calculated accurately to control the characteristic impedance of GEB(100Ω).
- We decide on the length of RXD and RXDCLK signal in the GEB being the same reduce the timing resolution of the detector.
- Essential part for chamber operation: Delivery power to VFAT3 and Optohybrid
  - 1.2V Digital power and 1.2 Analog power for 12 VFAT3 hybrids
  - 1.2V, 1.5V, 2.5V voltage for Optohybrid
- Shielding design in GEB
  - Shielding layer put on the bottom of the GEB, eyelets put above to connect with the chimneys/chamber.

	Layer Name	Type	Material	Thickness (mm)	Dielectric Material	Dielectric Constant	Pullback (mm)	Orientatic	Coverlay Expansior
	Top Ov...	Overlay							
	Top So...	Solder ...	Surfac...	0.01016	Solder ...	3.5			0
1	Top La...	Signal	Copper	0.035				Top	
	Dielect...	Dielectric	Core	0.16	FR-4	4.2			
2	Signal 1	Signal	Copper	0.018				Not All...	
	Dielect...	Dielectric	Prepreg	0.13		4.2			
3	DGNG1	Interna...	Copper	0.018			0.508		
	Dielect...	Dielectric	Core	0.08		4.2			
4	POWER	Interna...	Copper	0.036			0.508		
	Dielect...	Dielectric	Prepreg	0.076		4.2			
5	AGND	Interna...	Copper	0.036			0.508		
	Dielect...	Dielectric	Core	0.08		4.2			
6	DGND2	Interna...	Copper	0.018			0.508		
	Dielect...	Dielectric	Prepreg	0.13		4.2			
7	Signal 2	Signal	Copper	0.018				Not All...	
	Dielect...	Dielectric	Core	0.16		4.2			
8	Bottom...	Signal	Copper	0.035				Bottom	
	Bottom...	Solder ...	Surfac...	0.01016	Solder ...	3.5			0
	Bottom...	Overlay							

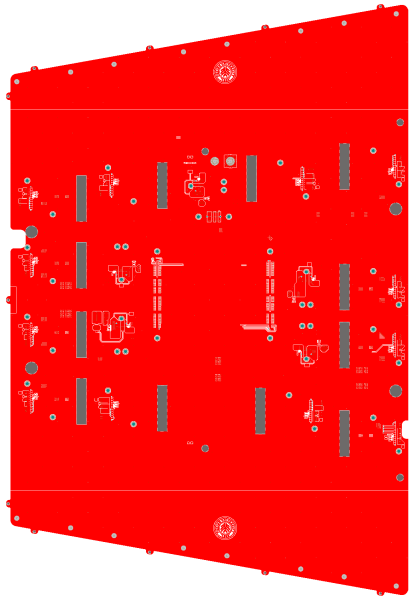
- 8 layer: Top layer, Signal1, DGND1,POWER,AGND,DGND2,Signal2,Bottom layer
- 8-layer symmetrical stack-up design for GEB to ameliorate the mechanic bending caused by high temperature during manufacturing because of large area PCB



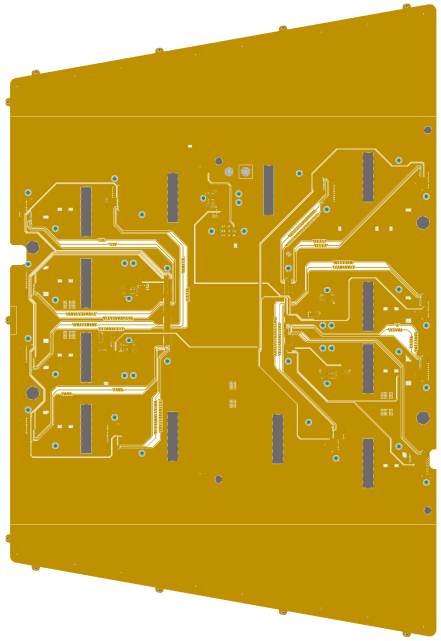
GEB M5 route layout

GE21 GEB M5 Design PCB

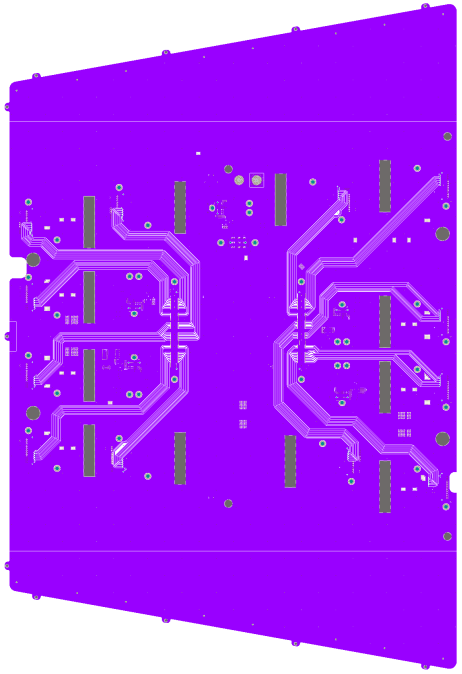
Besides AGND, DGND1 and DGND2, POWER layers for power and ground distribution



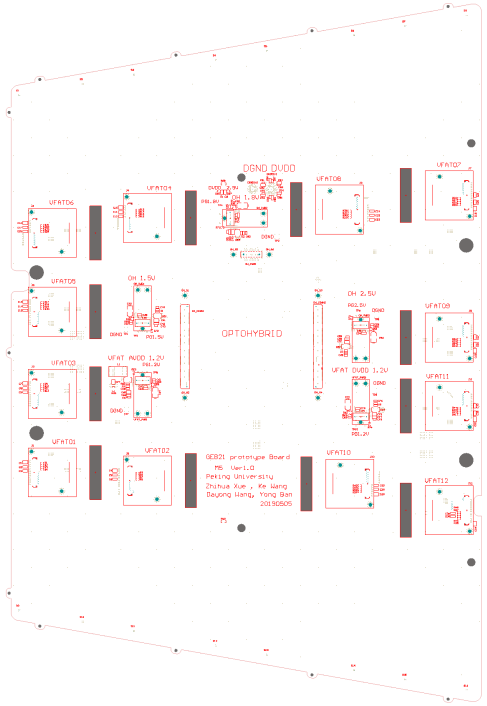
Top Layer



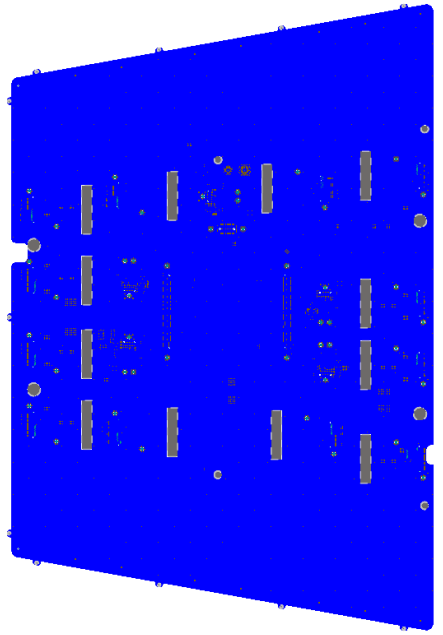
Signal1 Layer



Signal2 Layer

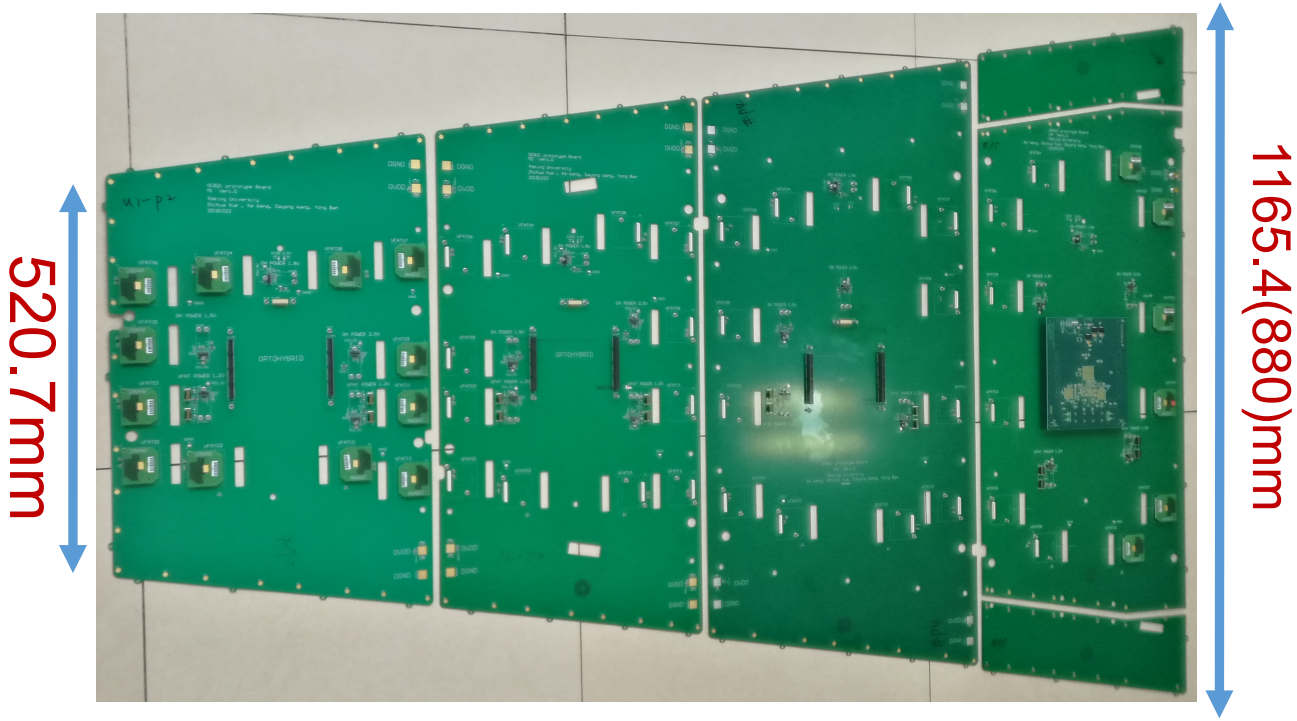


Silk Screen Layer

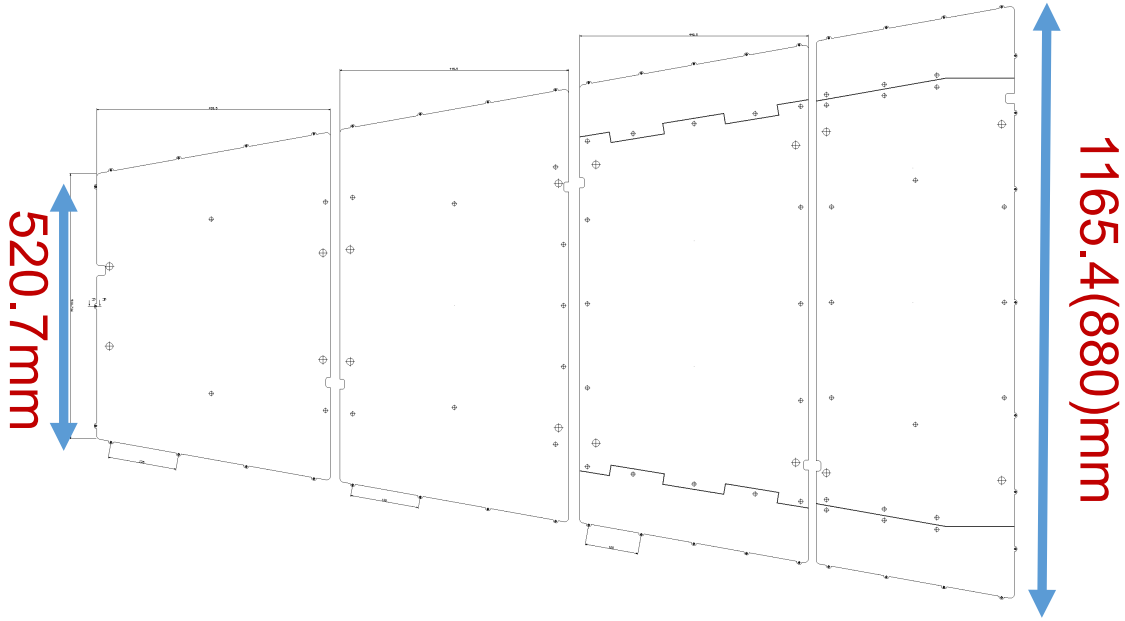


Bottom Layer (shielding layer)

GE2/1 GEB prototypes



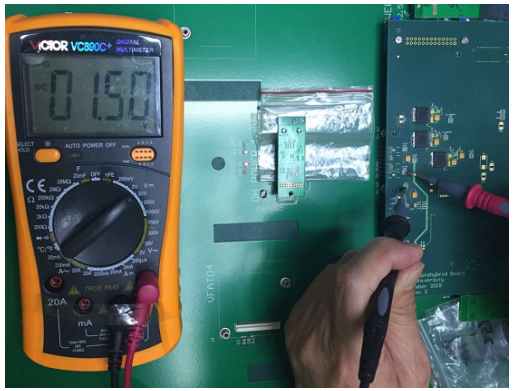
GE2/1 GEB M1-M4 Prototype Board

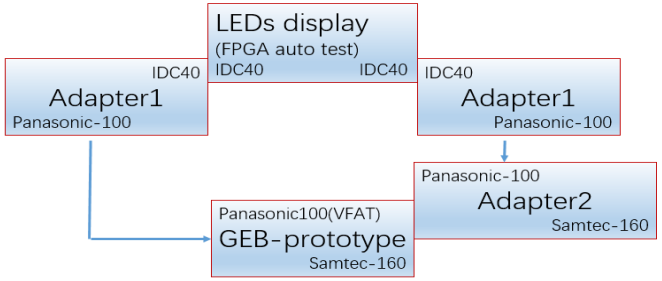


GEB M5-M8 Layout

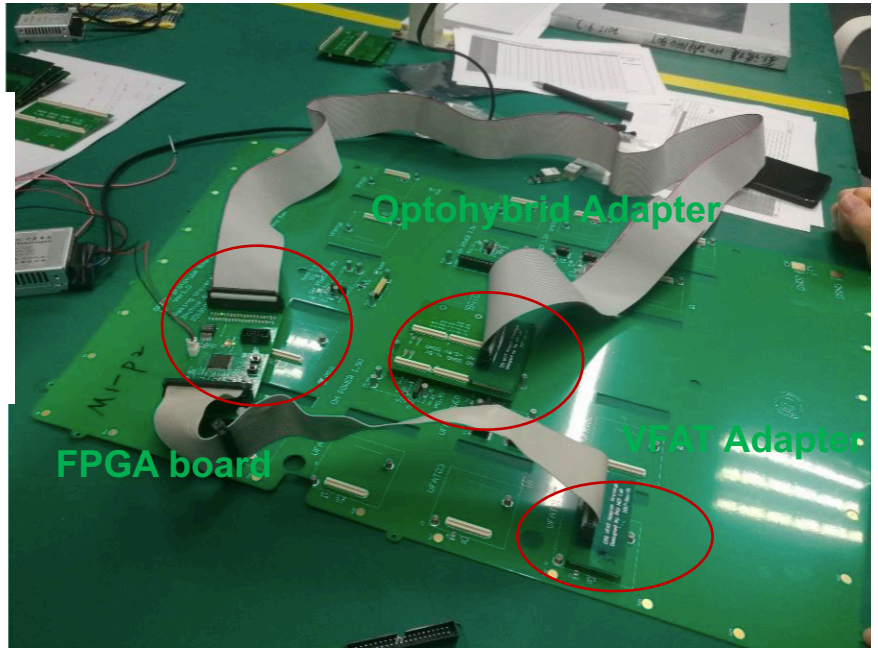
GE2/1 GEB prototype QC test

- Test goal for GE2/1 prototype by PKU is to check the signal Connectivity between VFAT3 hybrid and Optohybrid and make sure the power for each part is delivered correctly.
  - Power test in GEB





connectivity test schematic

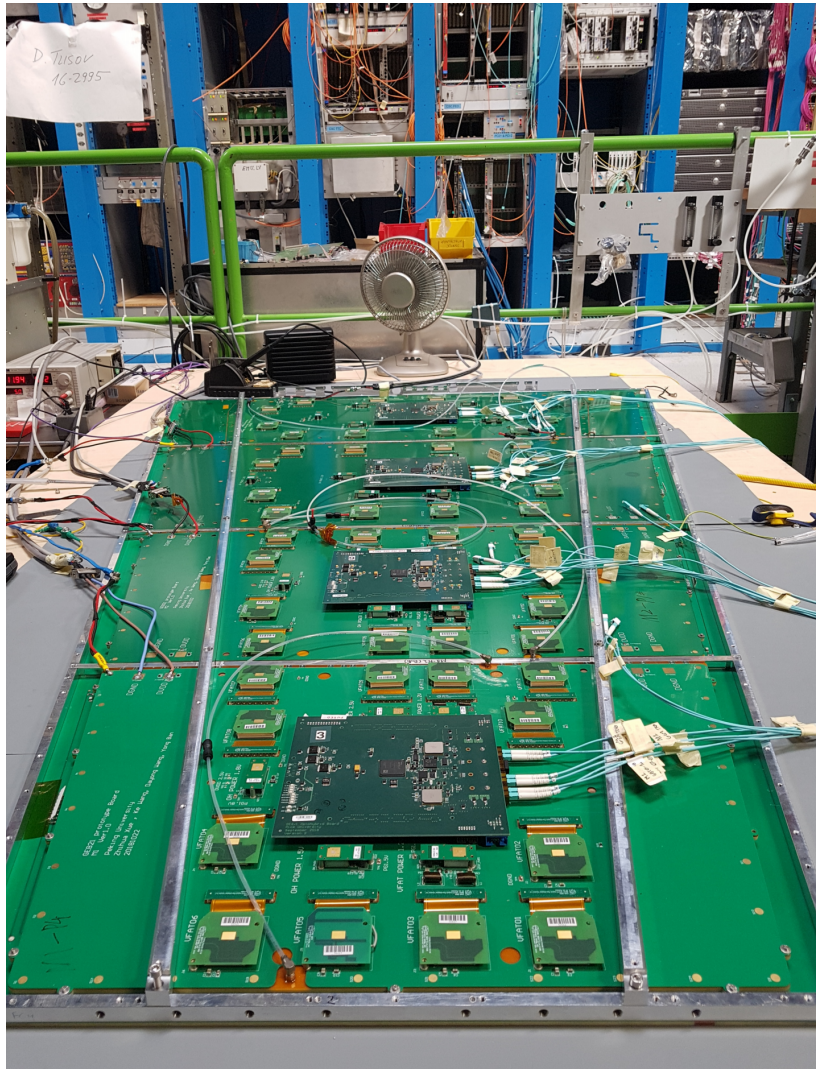


GE2/1 GEB M1 connectivity test in Shenzhen

  - Connectivity for VFATs and Optohybrid
  - Standoff alignment and torque test
  - Bending test

- So far, GE2/1 GEB M1-M5 prototypes are all produced in Shenzhen and passed electrical tests by electronic equipment designed by PKU.
- The results of test show the R&D of GE21 GEB prototype is successful by PKU.

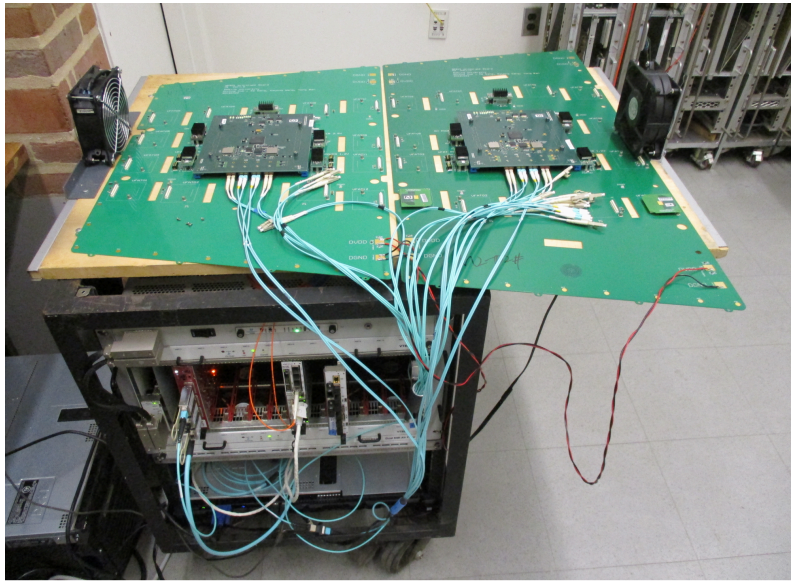
GE21 GEB test in CERN & Rice Univ.



✓ Power test of GE2/1 GEBs

OH	Sleep Mode	Run Mode
1.5V supply	1.522	same
1.8V supply	1.866	same
2.5V supply	2.572	same
TP1	1.198	same
TP2	1.007	same
TP3	0.991	same

VFAT	Sleep Mode	Run Mode
C1	1.208	1.180
C5	1.207	1.178
C15	1.213	1.185
C20	1.214	1.198



Data Transmission Test in M1 and M2 in RICE Univ.

✓ Communication to all VFATs on GEBs is good, Tracking data path works well with GEB in front-end electronics. All differential inputs from VFAT connectors to Artix-7 FPGA are OK.

✓ No errors in ~1 hour(BER<10^{-13})

✓ All four chambers (M1-M4) are fully instrumented and working

Summary

- ✓ GEB plays an important role in the CMS GEM front-end electronics for chamber operation, Routing and design in an 8-layer GEB is challenging.
- ✓ Peking University group are fully responsible for the CMS GE2/1 GEB design, produce and test. It is the first time that GEB design & production & test are undertaken independently in China.
- ✓ GE2/1 GEB M1-M5 prototypes are produced and passed each test in China & CERN & Rice Univ. also compatibility operation is well with other mechanic structures.
- ✓ The M6, M7, M8 prototypes will be produced end of October.