The module flex design and test for the High-Granularity Timing Detector

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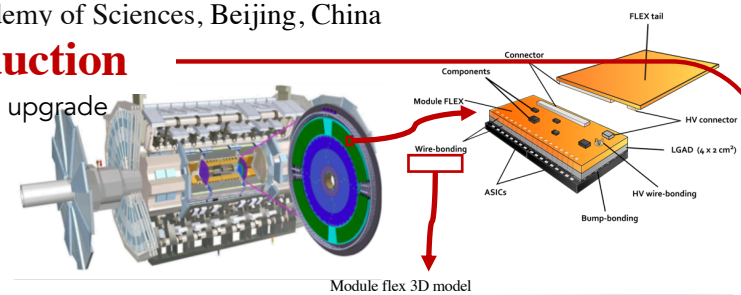
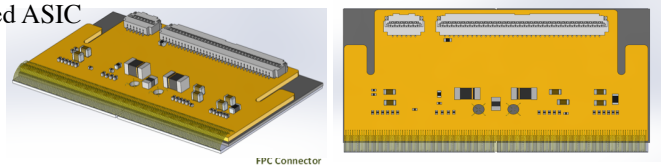
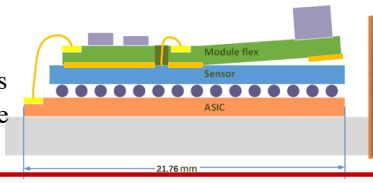
Introduction

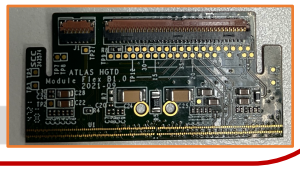
- High-Granularity Timing Detector for ATLAS Phase-II upgrade
  - based on low gain avalanche detector technology
  - providing a time resolution better than 50 ps per track
  - improving the forward objects reconstruction
- Module
  - basic component of the HGTD
  - consisting of a full size sensor bump-bonded to two dedicated ASIC
  - connected to PEB by module flex
- **Module flex**
  - A flexible printed circuit board with multiple layers
  - Module flex provide
    - analog and digital power for the ASIC chips
    - bias voltage for the sensor
    - connection, distribution and DC coupling of the data signals
  - IHEP will undertake ~ 4000 module assembly, of which module flex is completely designed and produced by IHEP.



Module flex 3D model

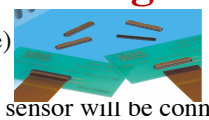


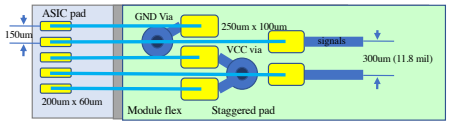




Design

- Components evaluation
  - High Voltage connector (800V bias voltage)
- Wire bonding design
  - ASIC signals, low voltage, bias voltage for sensor will be connected to module flex by wire bonding
- PCB design
  - Three grounding configuration
    - 6 layers flexible circuit boards
    - Three grounding configuration are designed as shown in **left table**
  - Thickness: 0.54 ± 0.08 mm including 0.10 mm stiffener
  - Impedance control
    - Single impedance: 50 ± 10% Ohm
    - Differential pair impedance: 100 ± 10% Ohm

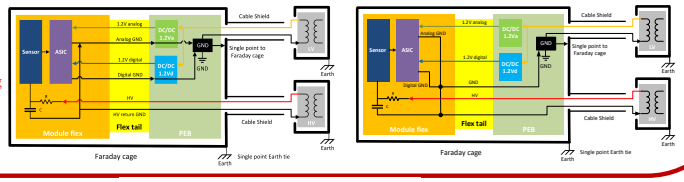




ASIC signal pads wire bonding design

Layer Name	Option A	Option B	Option C (one ground)
Top	HV Power and HV Ground, Signal lines	HV Power and HV Ground, Signal lines	HV Power and HV Ground, Signal lines
L2	Digital Ground (Plane)	Analog Ground (Plane)	Ground (Plane)
L3	Digital Power (Plane)	Digital Power & Digital Ground (Wires), Analog Power (Wires)	Digital Power (Plane)
L4	Analog Power (Plane)	Digital Power & Digital Ground (Wires), Analog Power (Wires)	Analog Power (Plane)
L5	HV Power and HV Ground, Signal lines	HV Power and HV Ground, Signal lines	HV Power and HV Ground, Signal lines
Bottom	Analog Ground (Plane)	Analog Ground (Plane)	Ground (Plane)

Grounding option



Simulation

- Voltage drop simulation configuration
  - Software: Cadence 16.6 Allegro PCB SI GXL
  - PDN Analysis: Static IR Drop
- Voltage drop simulation results
  - Three grounding configuration are simulated.
  - The specific simulation results are shown in the bottom table.

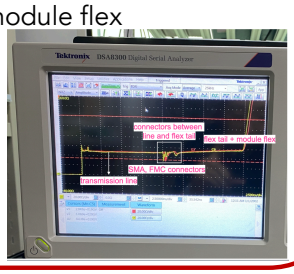
IR Drop Simulations For Module Flex			
Plane	Option A	Option B	Option C
	$Resistance_{max}$ [mΩ/cm]	$Resistance_{max}$ [mΩ/cm]	$Resistance_{max}$ [mΩ/cm]
Power digital	0.83	8.45	0.83
Power analog	0.69	6.77	0.70
Ground digital	0.86	5.88	0.48
Ground analog	0.96	0.72	

Testing

- Metrology measurements
  - satisfying the specification

	Length1[mm]	Length2[mm]	Width1[mm]	Width2[mm]	Thickness[mm]
Nominal	40.1	32	14.5	19.8	0.54
Measured	40.06±0.018	31.95±0.017	14.45±0.025	19.77±0.025	0.547±0.011

- Acceptance test for HV connector on module flex
  - withstand voltage up to 2400V
  - leakage current less than 1μA
- Impedance measurements
  - Single impedance: 53 – 60 Ohm
  - Differential impedance: 106 – 120 Ohm



Summary

- The first version module flex has been produced and tested
- Relevant test results satisfy the specification
- Plan to perform full module level test, determine which grounding configuration the module flex will use according to the noise level on module