

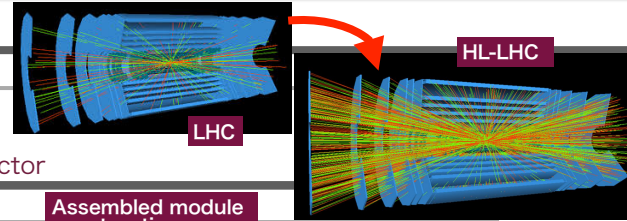
Module Development for the Phase-2 ATLAS ITk Pixel Upgrade

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on behalf of the ATLAS Collaboration

Upgrade for HL-LHC

Requirement for inner detector with higher luminosity

- Radiation tolerance: 2.0×10^{16} 1MeV \cdot n_{eq}/cm^2 at innermost layer
- High track-multiplicity and event rate
- Upgrade is necessary for ITk PIXEL, the most inner tracker in ATLAS detector

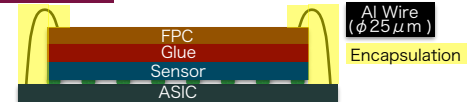


Development of ITk Pixel detector module

- **Sensor:** p-type bulk material and small pixel size
- **FE chip:** GHz readout, and small pixel size
- **Other components:** radiation tolerance minimum material

Each development proceeds in parallel to be assembled as the "module".

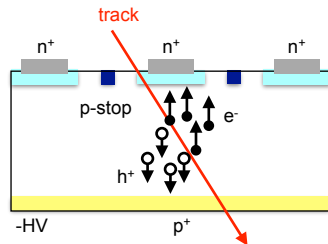
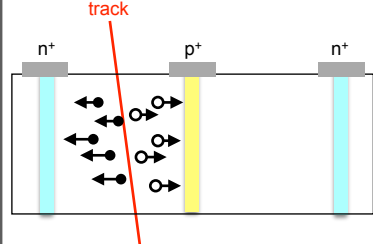
Assembled module construction



Radiation Tolerant Sensor

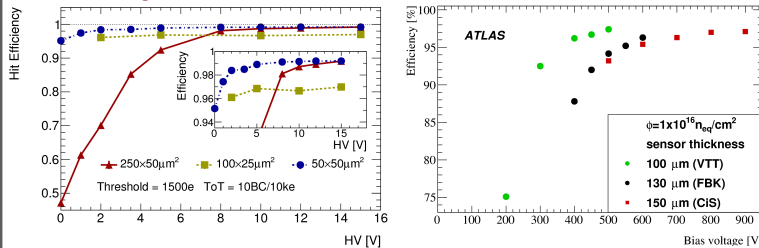
- **Innermost: 3D sensor**
- Radiation tolerance
- Low power dissipation

- **Other layers: Planar**
- n⁺-in-p type
- Thinned to 100-150 μm



Small pixel size: $50 \times 50 \mu m^2$ or $25 \times 100 \mu m^2$

Efficiency measured w/ irradiation



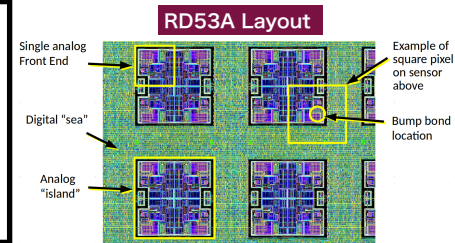
- Achieved high efficiency even after fluence of 10^{16} n_{eq}/cm^2 .
- Use of planar and 3D sensor is established for HL-LHC
- Next step: for mass production

Rapid-readout ASIC: RD53

- Radiation hardness is required for ASIC too
- 65nm CMOS process(500 Mrad target)

Remarkable

- RD53 collaboration: ATLAS&CMS
- low noise rate with low threshold ($<10^{-6}$ @600e⁻)
- Highest data rate ~1.28 Gbps

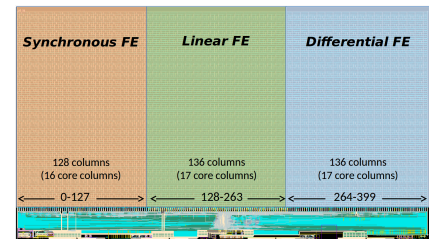


- Ongoing about efficiency and feature of such a new FE chip.

- 3 different layouts of the analog frontend
- comparison in point of:

- Noise
- Efficiency
- Tolerance
- Stability

- Testbeam and irradiation will give a knowledge for the next step.



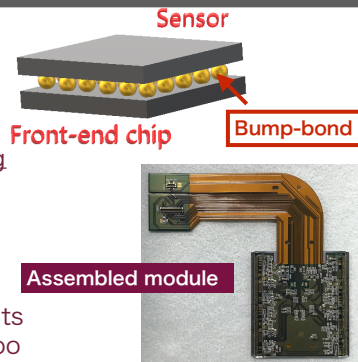
Assembly and relating components

- **Flip-chip using bump bonding technique**

- High yield from all vendors
- Production rate should be high
- Technical development is ongoing

- **Module assembly**

- Sequence development on going:
 - Attachment
 - Wire bonding
 - Encapsulation
- Finalizing quality control requirements
- High production rate for this step too



- Material study of module components
- Compound - Glue - Flexible PCB

- Radiation

- Gamma/Proton irradiation test
- Thermal damage by CTE difference
- Thermal cycling/shock

For mass production phase, not only the development of sensors and electronics, but also these fundamental and mechanical studies are necessary.

Summary

Reference: Technical Design Report for the ATLAS Inner Tracker Pixel Detector(CERN-LHCC-2017-021) RD53 collaboration(<http://rd53.web.cern.ch/rd53/>)

- ITk Pixel detector requires high radiation tolerance and data rates due to high instantaneous luminosity.
- Development of sensors, readout chips and other components well under way.
 - Sensor: Both types show good performance.
 - First RD53 front-end chips under investigation in modules, system aspects are to verify next.
 - Further requirements: Glue is almost fixed. Encapsulant selection needs more detailed investigation.