Testbeam studies on Cold Noise and Cracking in ITk Strips modules.

BTTB Workshop.

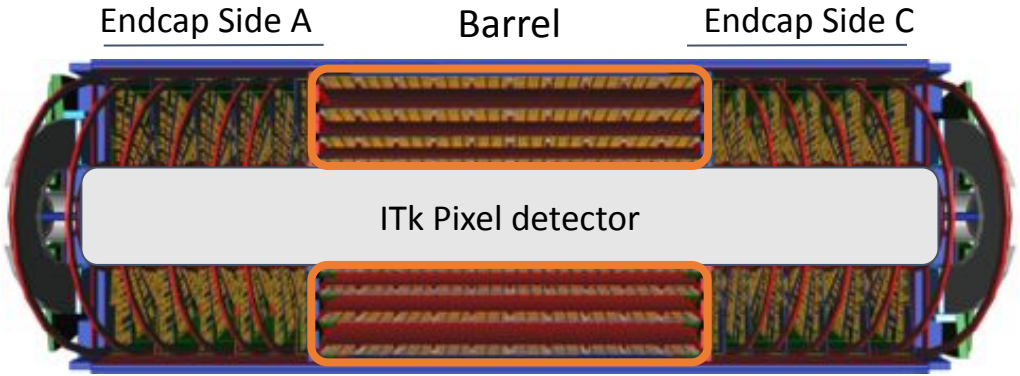
Eduardo Torres on behalf of ITk Strips testbeam group

Outline

- Introduction to ITk.
- Introduction to Cold Noise and Cracking.
- Testbeam studies in Cold Noise and Cracking.

ITk

- New inner tracker for the ATLAS experiment.
  - Designed to cope with the harsher conditions that will be produced by the HL-LHC.
  - Full silicon design, with electronics glued into the silicon sensors.
  - The combination of sensor with the electronics is known as **modules**.
- Divided into two Sub-systems.
  - Pixels, for the innermost part of ITk.
  - **Strips** for the outer part of ITk.



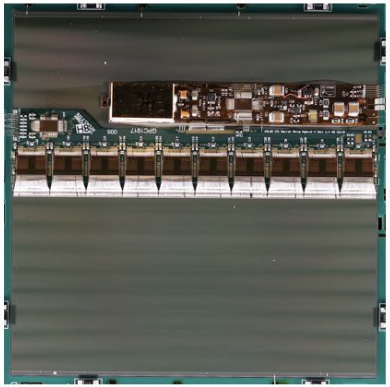
- Higher radiation tolerance
- Finer granularity
- Higher trigger rate
- Less material in the tracking volume

For ITk Strips:

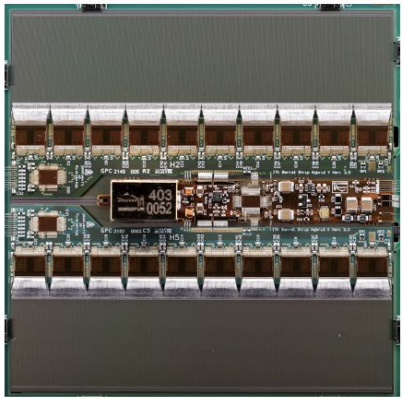
- coverage up to = 2.7
- ~ 18000 strip sensors
- ~165 m2 of silicon
- ~ 60 million channels

ITk Strips

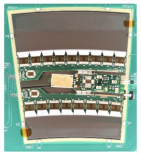
- There are eight different modules types.
  - Two types in the barrel: **Short Strip** (SS) and **Long Strip** (LS) modules.
  - Six types in the Endcap: **R0 to R5**.
  - R0 to R2 are single sensor modules while R3 to R5 are double sensor modules.



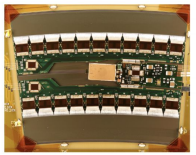
Long strip



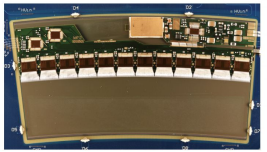
Short strip



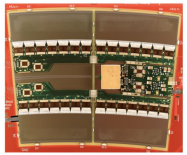
R0



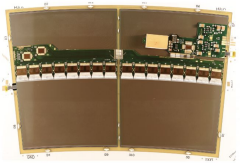
R1



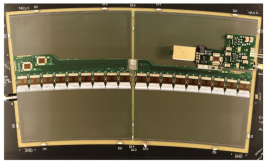
R2



R3



R4

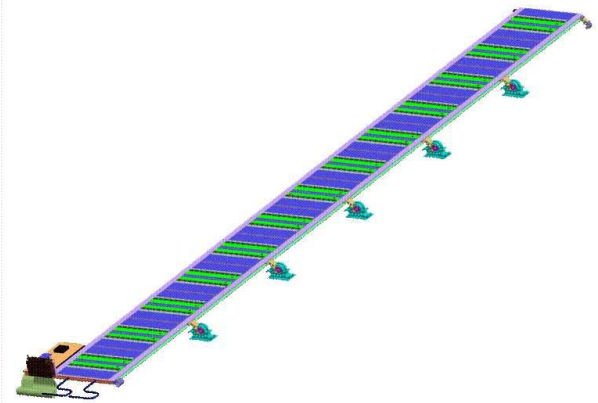


R5

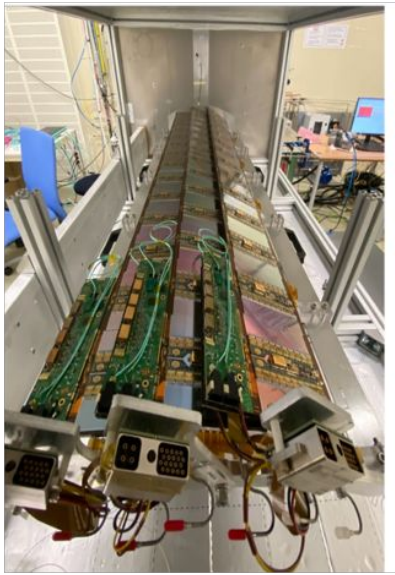
https://cds.cern.ch/record/2888039/plots

Barrel

- The barrel modules are glued into **staves**.
  - The barrel is composed of 4 layers of staves. For a total of 392.
  - 28 modules per stave. For a total of 10976 modules installed.
- Two flavours of staves
  - Shot Strip staves. Cover the two innermost layers.
  - Long Strip staves. Cover the two outermost layers



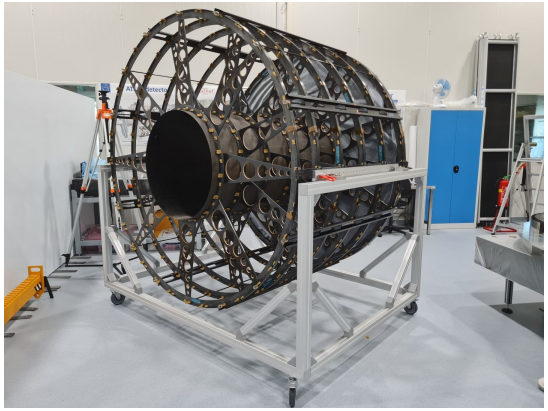
Stave design



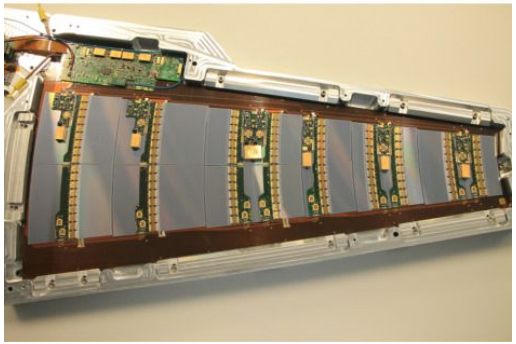
System test at CERN. Photo by Emily Rose Duden.

Endcap

- The endcap modules are glued into **petals**.
  - There are six disks per endcap and 32 petals per disks. In total 384 petals.
  - Each petal has 12 modules. In total 4608 modules.



Endcap structure built at NYKHEF

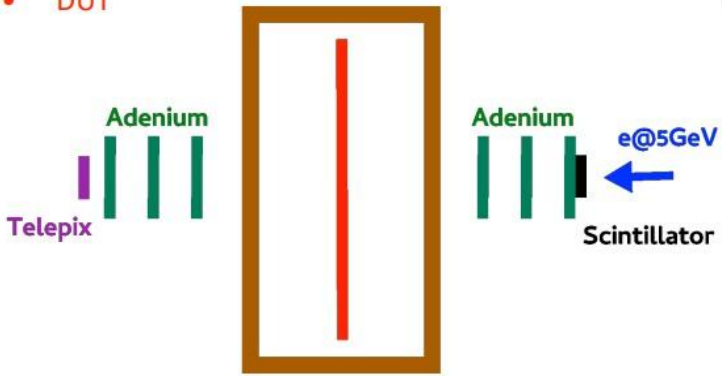


Top: Empty core. Bottom: full loaded petal

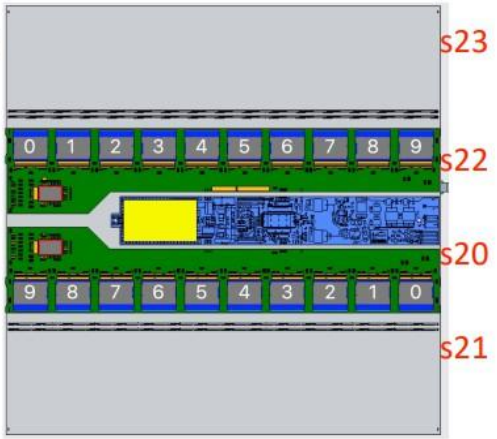
ITk strips testebeam setup

Specification requirements at the end of lifetime:
- Efficiency >99%
- Noise occupancy <0.1%

Test beam setup @DESY
- Adenium telescope
- Telepix timing plane
- Scintillator trigger signal
- DUT cooling box
- DUT

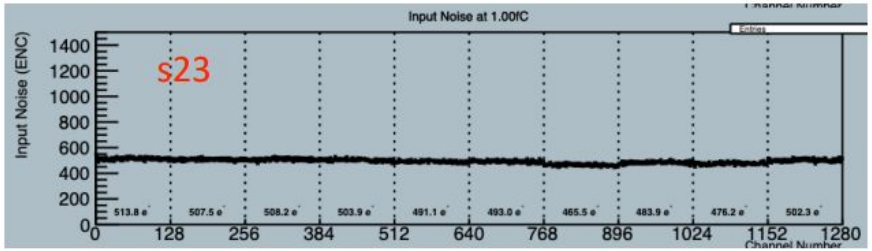


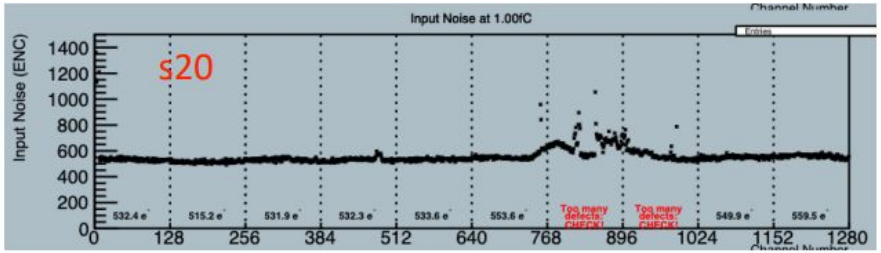
Testbeam convention:

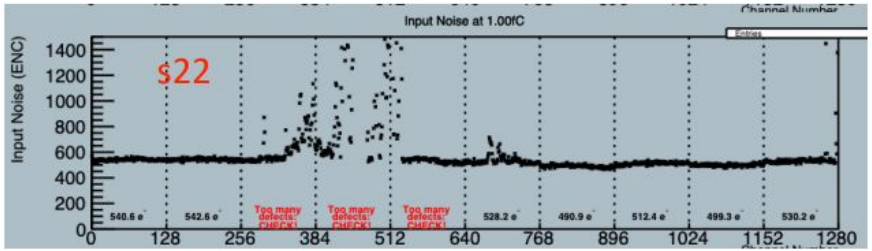


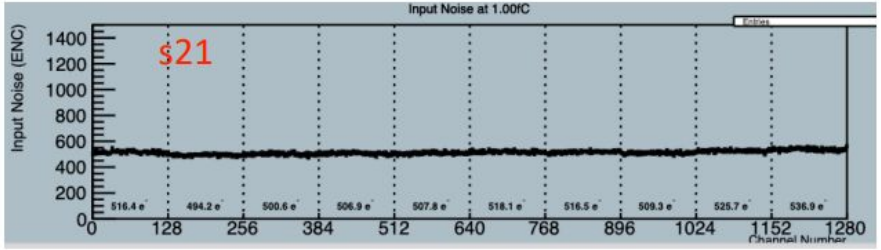
Cold Noise

- High noise channels observed during cold module testing.
  - The opposite of what it is expected with silicon sensors.
  - Barrel modules were affected but also some endcap modules types.
- Cold Noise seems to be produced due to coupling between mechanical vibrations produced on DC-DC switching circuit on powerboards and electronic noise.





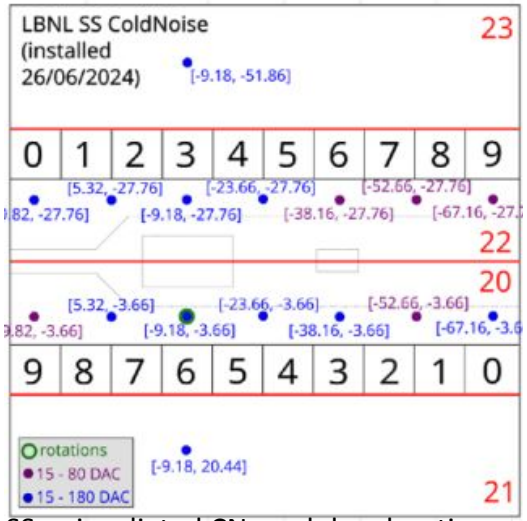




Unirradiated SS CN module

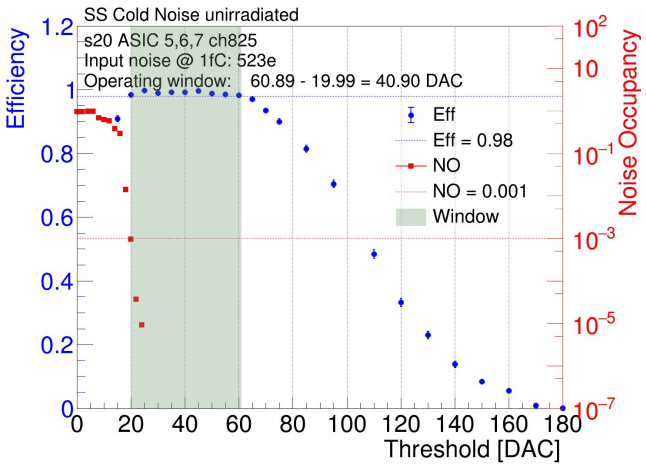
Cold Noise on Testbeams.

- The testbeam studies has focused on analysing the impact of CN in the operational windows of the different modules' types.
  - Larger levels of noise complicate the finding of operational window.
  - The operational window has to be calculated strip by strip for CN modules.



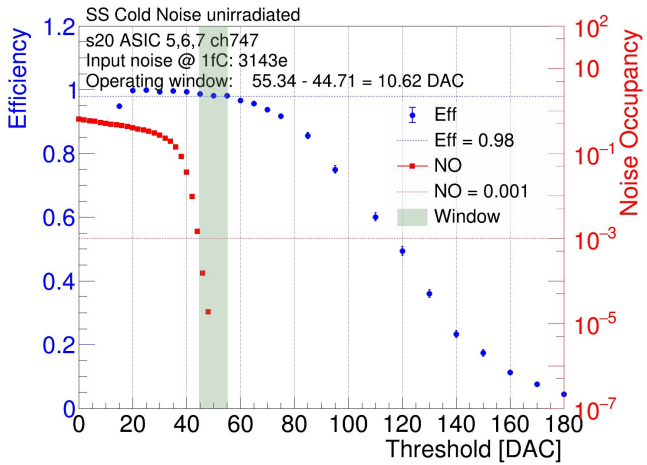
SS unirradiated CN modules shooting points.

Work in progress by Yajun He



SS unirradiated no CN region.

Work in progress by Yajun He

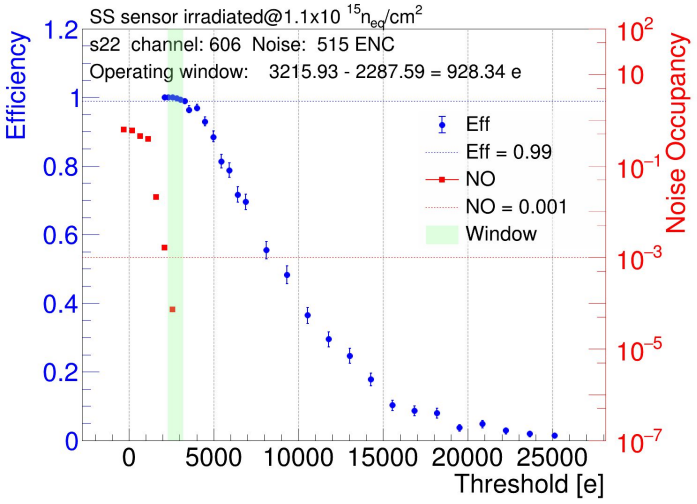


SS unirradiated CN region.

Cold Noise on Testbeams.

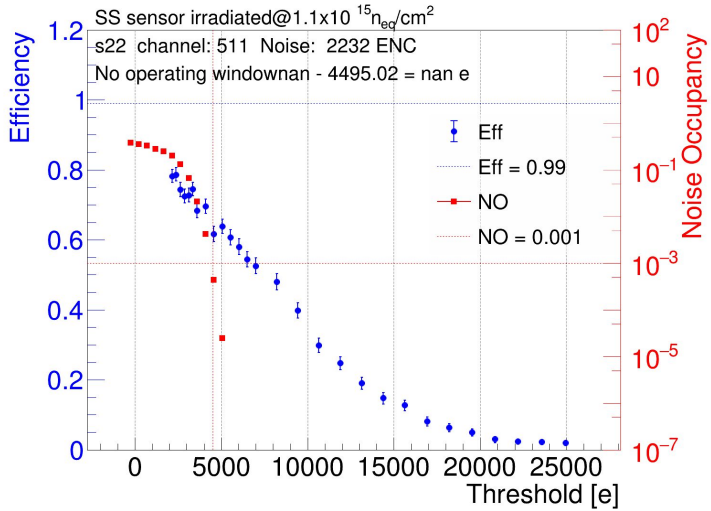
- The CN studies has been also performed in irradiated modules.
  - Irradiated modules has smaller operational windows.
  - CN can make impossible to find operational windows.

Work in progress by Yajun He



SS irradiated noCN region

Work in progress by Yajun He

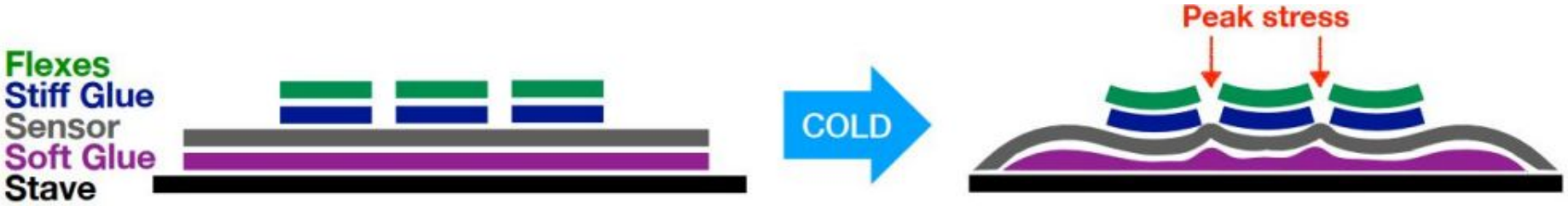


SS irradiated CN region

Cracking

- Cracking of sensors during QA of **loaded objects**.
- Studies has shown higher mechanical stress in certain regions of modules due to different thermal coefficients.
- One solution and one mitigation strategy.
  - Interposer solution.
  - Improved nominal mitigation strategy.

Scheme made by Andrew Blue



- When cooling down, the sensor wants to bend up.
- The attachment to the local support constraints this effect, creating local bent regions with high stress
- Peak stress occurs in gaps between flexes.

Interposers

- Solution based on adding an extra layer of kapton between the hybrids and sensor.
- Success in solving cracking.
- Concerns related to production rates and development.
- Need to add an extra step in the production chain.

Scheme made by Carles Solaz

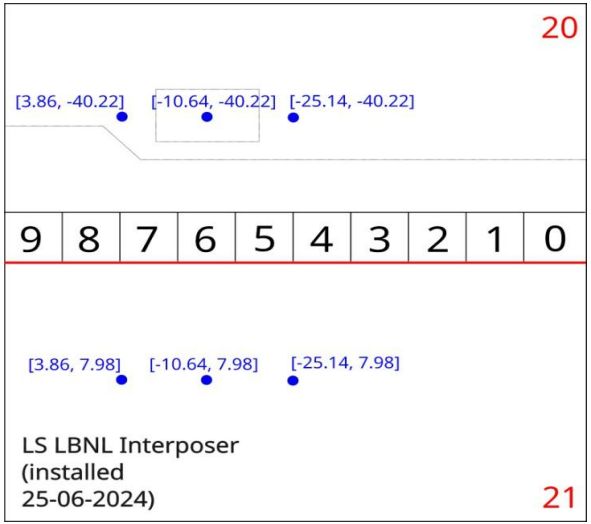
- Add soft glue under flexes to decouple thermal stress
- Simulation predicts up to ~95% stress reduction
- More complex to integrate into workflow

Scheme made by Carles Solaz.

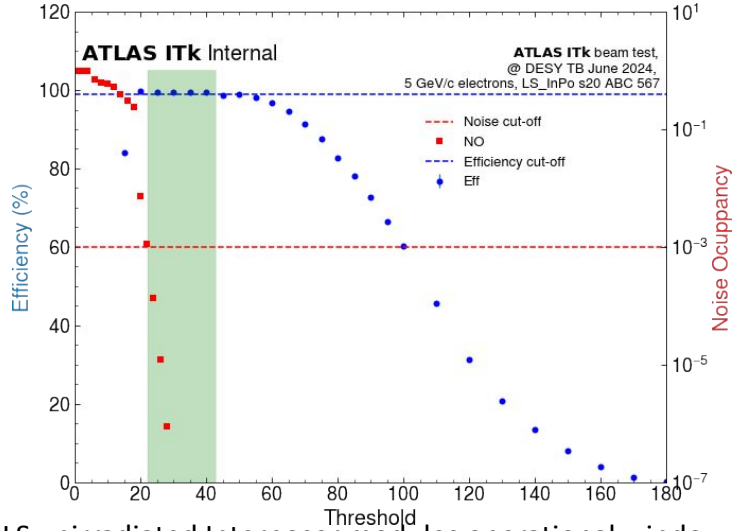
Cracking in testbeam

- The testbeam studies has focused on studying the impact of interposer on modules' operational window.
- First interposed modules were tested at testbeam before and after irradiation.
- Key to understand if the interposer affects the predicted performance of the modules.

Work in progress.



LS unirradiated Interposer modules shooting points.



LS unirradiated Interposer modules operational window s20.

Conclusion

- The testbeam studies has been key to understand the problems ITk strips collaboration was facing.

- The studies has shown the behavior of CN in modules and different irradiation conditions.

- In the case of the cracking issue, it has shown the feasibility of the interposer solution under beam conditions.

Acknowledgments

- The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF).

- The ITk strips testebeam team.

Backup

Improved nominal

- More information in Luise Poley ITk week talk .
- Solution based on changing glue patterns in hybrids and petal cores.
- Mitigation of cracking observed.
- Easier to implement into production workflow.