STAR SSD ladder status

Before upgrading the SSD with new readout electronics, it has been asked to SUBATECH to test all the SSD ladders including the spare ones. This document is the report of the ladder tests and repair if possible.

Brief description of the STAR SSD :

The SSD consists in a barrel with a radius of 23 cm and is composed of 20 space frame carbon beams (ladder) each supporting 16 detection modules (Figure 1). Each module is composed of one double-sided silicon strip detector, two hybrid circuits equipped with analogue readout electronics. On both ends of each ladder, two electronics boards are controlling the modules and are converting the analogue signal sent to readout boards located on the TPC wheel.

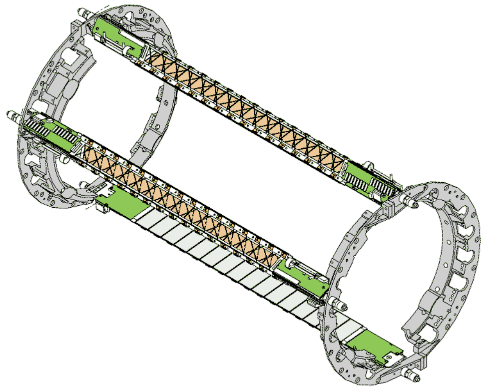


Figure 1: The 4 sectors assembled with 3 ladders installed

Each SSD ladder is composed of the following elements (Figure 2):

- 16 modules aligned along the ladder axis (the beam axis)
- one pair of ADC board and Control board located at each end of the ladder and dedicated to the digitization and the control of the signals coming from respectively the N side and the P side of the modules
- a low mass carbon fiber beam supporting the modules and the electronic boards,
- additional mechanical pieces to attach the ladder to the clamshell and to connect the ladder to the air cooling tubes

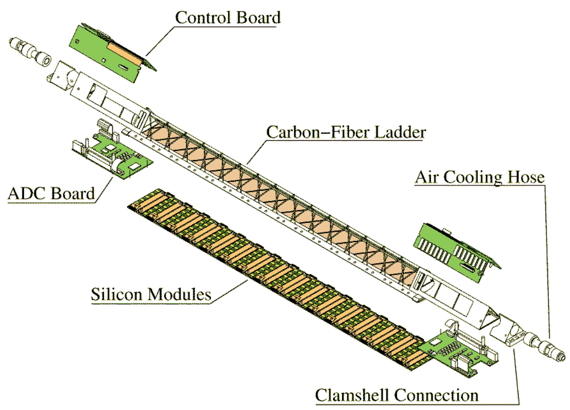


Figure 2: Exploded view of an equipped ladder

A module is the basic element of the SSD and integrates a silicon wafer and its front-end electronics. Each module is composed of (Figure 3):

A double sided silicon strip detector:
- size : 42 mm * 75 mm,
- 768 micro-strips per side of detector,
- a pitch of 95µm,
- 35mrad stereo angle between P and N strips.

Two hybrid circuits, each composed of:
- one flexible circuit (made of kapton and copper) glued on a carbon fiber stiffener,
- around 50 SMD components (resistors and capacitors),
- 6 analogue readout chips : ALICE128C,
- 1 multi-purpose control chip dedicated to temperature measurements, low and high voltage monitoring: COSTAR.

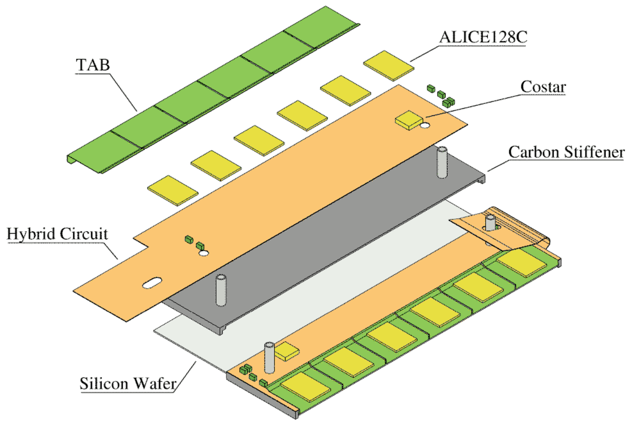


Figure 3: Exploded view of a detection module

To be operational, a module needs to be setup. This is done by the way of the JTAG bus. The 6 ALICE128 and the costar are daisy chained.
Several features are available:
- Initialisation of the ALICE128 by programming the biasing parameters , those chips are equipped with a DAC (digital to analogue converter) to generate the biasing current/voltage needed by the preamplifiers,
- Bypass of one ALICE128 during data acquisition if there is a problem,
- Setup the pulse generators (one per channel) to the desirable value,
- Setup the mask which defines what channel will be fired by the pulse generator,
- Read the COSTAR parameters: temperature and low voltage power supply monitoring,

The JTAG chain is a kind of loop with which the data sent to the devices can be readout. So one test, during the initialisation of the ladder, is to check if the modules are correctly programmed. If the data don't come back properly, it means that the JATG chain is broken somehow (bad chip, broken strip, broken wire bond …).

Test results summary:

There is no dead ladder anymore. It was only due to damaged or aged ADC or connection boards.

Basic statistic:

- Number of fully good ladders: 6 ladders (LAD02, LAD04, LAD05, LAD18, LAD22, LAD25).

- Number of ladders with one bad hybrid (half module): 7 ladders (LAD03, LAD06, LAD11, LAD12, LAD14, LAD17, LAD20).
  (Those ladders may be fully "good" if the bias of the module is forced.)

- Number of ladder with several bad modules: 9 ladders.
  - LAD08: 2 hybrids partially dead,
  - LAD23: 2 hybrids, bias need to be forced,
  - LAD09: 1 module (2 hybrids) disconnected (HV trip),
  - LAD13: 3 hybrids, bias need to be forced,
  - LAD 15: 3 hybrids, one can be improved,
  - LAD24: 3 hybrids, bias need to be forced,
  - LAD10: 2 modules (4 hybrids) disconnected (HV trip),
  - LAD16: 5 hybrids, 1 module (2 hybrids) disconnected (HV trip), 2 hybrids partially dead, 1 missing due to disconnection of the module.
  - LAD 01: 8 bad hybrids.

High voltage trip:

Ladders with a real high voltage trip: LAD16, LAD10 and LAD09.
High voltage trip due to bad cooling: LAD24.

Explanations of the comment:

The bias need to be forced:

- When there is a JTAG problem, it means that the 6 chips (ALICE128) on the hybrids are not properly programmed.
- Most of the time, the JTAG loop is broken somewhere, so the control of the ALICE128 programming is not possible and then the hybrid circuit is bypassed by the test software for the data acquisition.
- What "bias need to be forced" means: whatever the results of the ALICE128 programming, the hybrid circuit is still considered as good and is included in the data acquisition. So if the loop is broken after the last chip, the module will behave correctly, that already happened a few times in 2004 (mentioned in this document).
- Another possibility is one ALICE128 doesn't work properly and crashed the hybrid functioning when it is biased. The solution is to bypass this ALICE128 using the JTAG bus, so only 128 strips are lost.

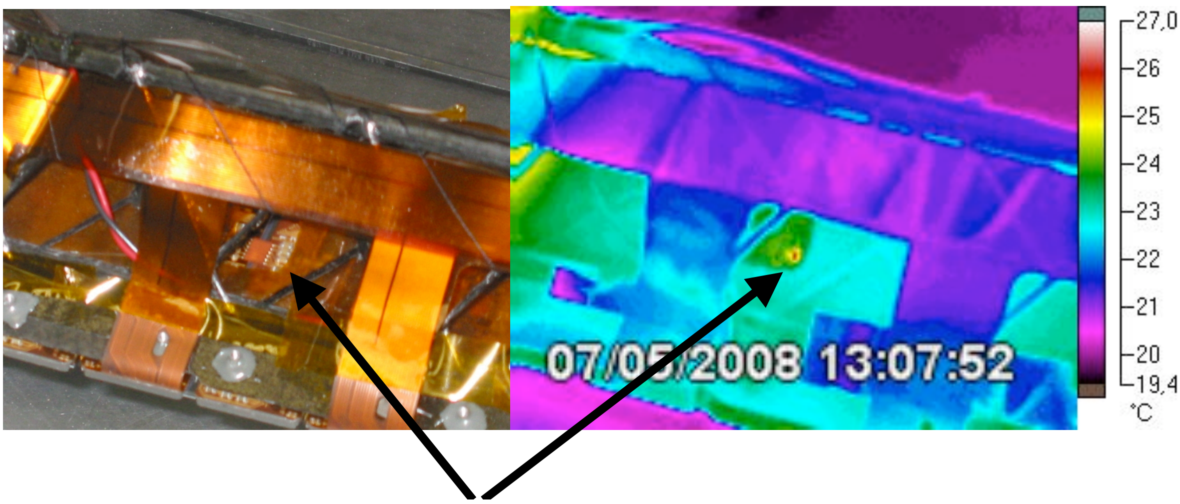
For the moment, the test software at Subatech does not allow to force the biasing of a hybrid circuit. It has to be implemented.

The high leakage current may come from the HV coupling capacitor on the module:

- Few ladders have a high leakage when biased
- This problem was located and it comes from one or two modules.
- The SSD detection modules have been equipped with high voltage coupling capacitors to reduce the noise picked up by the high voltage power supply coming from the south platform.
- Those capacitors are probably responsible for the high leakage current.
- So what has to be done is: to identify the capacitor, to remove it from the module and if possible to replace it.
- This operation will need a special tooling and can be dangerous for the rest of the ladder. So that must be investigated before starting the repair.

It will be confirmed if the leakage is coming from the HV coupling capacitor by using a thermal camera (image on right).

The result is below:



Leaking capacitor

A window has been opened in the kapton layer (dedicated to air flow) and after biasing the ladder (only the high voltage) one can see the leaking capacitor hotter than the other components on the hybrid circuit. The ladder was biased at 45V and the high voltage current was around 800µA.

Active area calculation:

The active area is calculated taking in account all the bad modules listed above without any repair. This means that any successful repair (bias forced or high voltage capacitor changed) will improve the active area.
Two cases can be considered:

- Case 1: when one hybrid circuit is off, then the module is considered useless as a tracking point of view,
- Case 2: when one hybrid circuit is off, the other side of the module can still be used for the tracking software.

Ladder number	Number of bad hybrid	Number of bad module	Percentage case 1	Percentage case 2
08	1	0	93,75%	96,88%
03	1	0	93,75%	96,88%
09	0	1	93,75%	93,75%
24	3	0	81,25%	90,63%
17	1	0	93,75%	96,88%
12	1	0	93,75%	96,88%
18	0	0	100,00%	100,00%
06	1	0	93,75%	96,88%
04	0	0	100,00%	100,00%
05	0	0	100,00%	100,00%
10	0	2	87,50%	87,50%
15	3	0	81,25%	90,63%
25	0	0	100,00%	100,00%
16	2	1	81,25%	87,50%
23	2	0	87,50%	93,75%
11	1	0	93,75%	96,88%
01	6	1	56,25%	75,00%
20	1	0	93,75%	96,88%
22	0	0	100,00%	100,00%
13	3	0	81,25%	90,63%
14	1	0	93,75%	96,88%
02	0	0	100,00%	100,00%
		mean value	90,91%	94,74%

The mean value is calculated with the 22 ladders, the 2 worst ladders can be removed increasing this value.

Detailed report

LAD08 position: **20** sector: **top**

Status in run 7: Pside : 13P one bad chip
Nside : ok

Status after test/repair:

- Pside: 4P one chip dead,
  15P first chip Ok, 5 other chip dead
- Nside: Ok
- Vbias = 50V, Ibias = 36μA

Comment: nothing can be done.

LAD03 position: **01** sector: **top**

Status in run 7: Pside : Ok
Nside : Ok

Status after test/repair:

- Pside: 8P JTAG programming not Ok
- Nside: Ok
- Vbias = 50V, Ibias = 49μA

Comments: 8P was ok in summer 2004, bias need to be forced

LAD09 position: **02** sector: **top**

Status in run 7: High voltage trip

Status after test/repair:

- Module 10P-7N responsible for the high leakage current (disconnected)
- Pside: Ok except 10P
- Nside: Ok except 7N
- Vbias = 50V, Ibias = 35μA

Comment: the high leakage current may come from the HV coupling capacitor on the module, repairable ???? To be investigated.

LAD24 position: **03** sector: **north**

Status in run 7: High voltage trip
Pside : Ok
Nside : Ok

Status after test/repair:

- No high voltage trip (cooling responsible)
- Pside: JTAG problem with 11P and 14P
- Nside: JTAG problem with 1N
- Vbias = 40V, Ibias = 30µA

Comment: 1N was already unstable in 2004 test, bias need to be forced. 11P and 14P: bias need to be forced?

LAD17 position: **04** sector: **north**

Status in run 7: Pside : Ok
Nside : 5N noisy

Status after test/repair:

- Pside : JTAG problem with 12P
- Nside : Ok
- Vbias = 50V, Ibias = 45µA

Comment: 12P bias need to be forced.

LAD12 position: **05** sector: **north**

Status in run 7: Pside : Ok
Nside : Ok

Status after test/repair:

- Pside : JTAG problem with 1P
- Nside : Ok
- Vbias = 50V, Ibias = 40µA

Comment: ladder Ok when bias of1P forced.

LAD18 position: **06** sector: **north**

Status in run 7: Pside : Ok
Nside : dead

Status after test/repair:

- Pside : Ok
- Nside : Ok after changing connection board
- Vbias = 70V, Ibias = 60µA

Comment: ladder Ok.

LAD06 position: **07** sector: **north**

Status in run 7: Pside : dead
Nside : dead

Status after test/repair:

- Pside : Ok after changing the ADC board
- Nside : JTAG problem with 13N
- Vbias = 46V, Ibias = 50µA

Comment: ladder Ok, the bias of 13N need to be forced.

LAD04 position: **08** sector: **north**

Status in run 7: Pside : 9P noisy
Nside : noisy with pedestal variation

Status after test/repair:

- Pside : ok
- Nside : ok
- Vbias = 52V, Ibias = 33µA

Comment: ladder Ok, noise not investigated.

LAD05 position: **09** sector: **north**

Status in run 7: Pside : 10P with dead strip
Nside : Ok

Status after test/repair:

- Pside : dead strips not investigated
- Nside : Ok
- Vbias = 55V, Ibias = 25µA

Comment: ladder Ok.

LAD10 position: **10** sector: **bottom**

Status in run 7: High voltage trip
Pside: 9P pedestal value higher than 255,
13P strange pedestal value
Nside: Ok

Status after test/repair:

- Modules 2P-15N and 5N-12P responsible for the leakage (disconnected)
- Pside: Ok except for 2P and 12P
- Nside: Ok except for 5N and 15N
- Vbias = 45V, Ibias = 55µA

Comment: the high leakage current may come from the HV coupling capacitor on the module, repairable???? To be investigated.

LAD15 position: **11** sector: **bottom**

Status in run 7: Pside: Ok
Nside: Ok

Status after test/repair:

- Pside: 4P 3 first chips Ok, 3 last Nok
- Nside: 9N dead
6N 2 first chips Ok, 4 others Nok
- Vbias = 40V, Ibias = 54µA

Comments: chip4 of 4P has to bee bypassed (summer 2004 test results).

LAD25 position: **12** sector: **bottom**

Status in run 7: Pside: Ok
Nside: Ok

Status after test/repair:

- Pside: Ok
- Nside: Ok
- Vbias = 45 V, Ibias = 45µA

Comment: ladder Ok.

LAD16 position: **13** sector: **south**

Status in run 7: High voltage trip
Pside : problem with 5P and 6P
Nside : Ok.

Status after test/repair:

- High leakage current due to module 15P-2N (disconnected)
- Pside 1P chip 6 missing (JTAG and DAQ)
  6P 4 chips missing
- Nside 1N noisy and non functioning when 2N disconnected.
- Vbias = 45V, Ibias = 42µA

Comment: the high leakage current may come from the HV coupling capacitor on the module, repairable???? To be investigated.

LAD23 position: **14** sector: **south**

Status in run 7: Pside : Ok
Nside : data problem with 15N

Status after test/repair:

- Pside : Ok
- Nside : JTAG problem with 15N and 16N (7 alice detected)
- Vbias = 45V, Ibias = 47µA

Comment: ladder should Ok with 15N and 16N if bias forced.

LAD11 position: **15** sector: **south**

Status in run 7: Pside : Noisy
Nside : Ok

Status after test/repair:

- Pside need a fine tuning of the power supply
  16P pedestal collapsing after a while
- Nside Ok
- Vbias = 53V, Ibias = 42,5μA

Comment: Ladder Ok except 16P.

LAD01 position: **16** sector: **south**

Status in run 7: Pside : JTAG problem with 4P, 7P, 8P, 12P
Nside : JTAG problem with 1N

Status after test/repair:

- Pside JTAG problem with 4P, 5P, 7P, 8P, 12P, 13P
- Nside JTAG problem with 1N and 10N
- Vbias = 37V, Ibias = 65μA

Comment: first ladder built. It suffers from a non stabilized process of connecting the ladder cable to the module (using anisotropic conductive film). To improve the status of the ladder, the bias of the modules can be forced.

LAD20 position: **17** sector: **south**

Status in run 7: Pside : 5P bias forced
Nside : Ok.

Status after test/repair:

- Pside JTAG problem with 5P
- Nside Ok
- Vbias = 65V, Ibias = 44µA

Comment: ladder ok with bias of 5P forced.

LAD22 position: **18** sector: **south**

Status in run 7: Pside Ok
Nside 11N undefined problem

Status after test/repair:

- Pside : Ok
- Nside : Ok after disconnecting and reconnecting 11N
- Vbias = 53V, Ibias = 30µA

Comment: ladder ok

LAD13 position: **19** sector: **south**

Status in run 7: Pside Ok
Nside 6N high pedestal, 11N noisy

Status after test/repair:

- Pside JTAG problem with 3P (already missing in 2004 test)
- Nside JTAG problem with 6N and 13N
- Vbias = 50V, Ibias = 45µA

Comment: the bias of the modules can be forced.

LAD14 spare

Status after test/repair:

- Pside : JTAG problem with 13P
- Nside : OK
- Vbias = 40V, Ibias = 66µA

Comment: ladder should be ok with the bias of 13P forced.

LAD02 spare

Status after test/repair:

- Pside : Ok
- Nside : Ok
- Vbias = 55V, Ibias = 33µA

Comment: good ladder.