ATLAS IBL Pixel Module Assembly

Abstract

This document describes the ATLAS pixel module and the assembly process. It has been prepared for the Module Assembly Final Design Review and updated for the Production Readiness Review.

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Rev.1 Module review

Rev.2 Add FEI4b bonding information

Rev.3 Added FEI4b further bonding information and assembly details

Rev.4 Revisited for Module PRR

Rev.5 Revisited with gluing information and wb link

1. Introduction

The IBL detector will be constituted by 14 staves, arranged in a cylinder around the beam pipe and providing support and cooling to the detector modules. The IBL has recently chosen a so-called "mixed scenario" approach, by using both planar and 3D sensor technologies. The mixed sensor scenario stave layout is shown in Figure. The 3D sensors populate the 2 extremities. The area covered with planar and 3D sensors is, respectively, 75% (equivalent to 24 FE-I4 chips per stave) and 25% (equivalent to 4+4 FE-I4 chips per stave). The modules have a fixed gap of 205 μm.

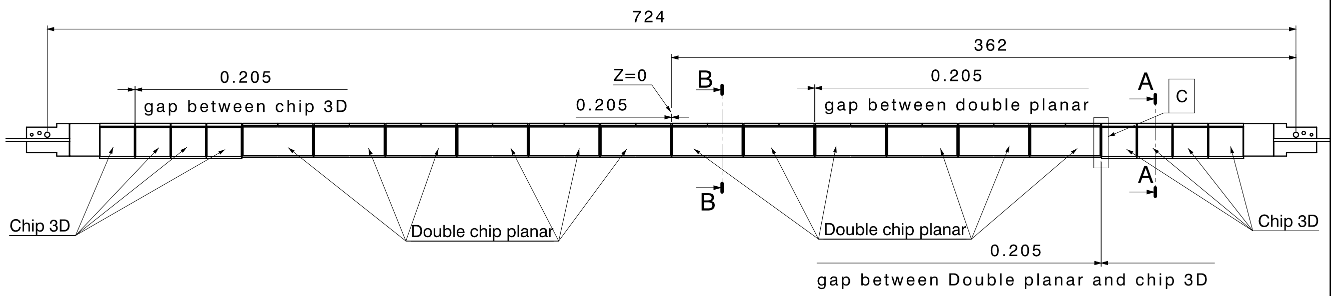


Fig.1 *Modules on the stave.*

2. Module Components

Modules are constitute by a sensor mated via bump-bonding to readout front-end chip(s). This assembly is in the following refer to as "Bare Module". On the back of the sensor, a flex hybrid, the "module flex", Ref.[1], is glued to provide the connection between the readout electronics and the external services. The following sections briefly describes the bare module and the flex module.

2.1. Bare Module (SC and DC)

Two types of modules will be installed in the IBL: double-chip planar modules (DC) and single-chip 3D modules (SC). Therefore a planar tile will be mated to 2 FEI4 chip while a 3D tile mates one FEI4 chip. They are geometrically compatible as the physical size of two single-chip 3D sensor assemblies is the same width as a single planar two-chip module. The planar and 3D modules differ slightly in sensor thickness: from 200 μm to 230 μm; and in rϕ where the 3D modules are 700 μm wider for HV connection. The 3D uses a single sided design (slim edge) having the high voltage connection being made on the same side as the bump-bonding. The differences in rϕ between the two sensor technologies are compatible with the overall IBL envelopes. In the bottom table are listed the geometric parameters for the sensors used in the IBL mixed scenario.

Structure	Planar	3D
Gap b/w modules	205 μm	205 μm
Sensor thickness	200 μm	230 μm
Module width (along z)	41 315 μm	20 450 μm
Bias tab / guard-ring extension (in rϕ)	630 μm	1 230 μm

2.2. Module Flex (SC and DC), see Ref. [1]

The module flex is glued on the back of the sensor and routes signals and power lines from the type0 cables (stave flex) to the Front-Ends and provides HV to the sensor itself. Type 0 cables are located longitudinally on the back of the stave and they have thin transversal 'wings', one per FE, that are the connection between the type0 and the module.

Two types of module flex are built to be compatible with the SC and the DC bare modules, see Figure 2. Both types have an extension that is used to connect the module with the system tests during the module qualification tests. Also a thick frame around the module flex allows easier handling of the module during assembly, testing, shipping and storage. The module flex will be singled out from the frame and the temporary extension cut just before the loading on the stave.

The DC module flex from the layout and schematic point of view is basically a pair of SC flex but it is preferred to have a unique flex instead of two. Although there will be two rows of pads for the final connection to the flex wings, the temporary connection is unique with a single connector for the two chips. In this way, the same adapter, see Appendix A, can be used to test SC or DC modules.

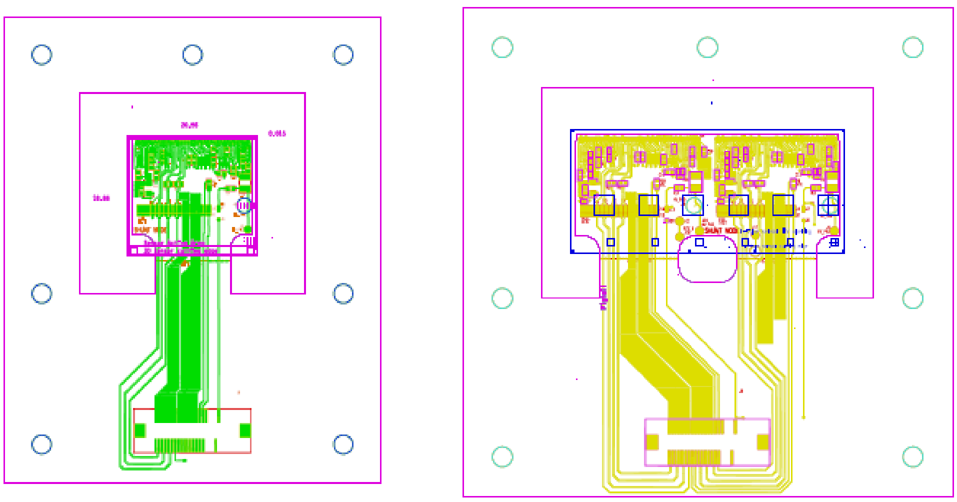
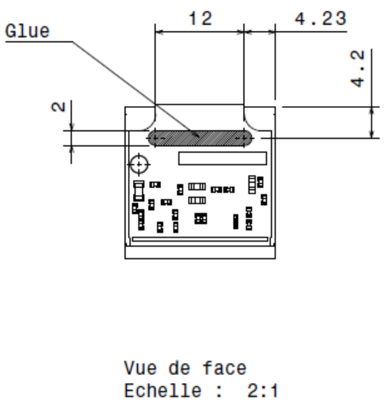


***Fig.2** Module flex for SC (left) and DC (right).*

3. Module Assembly

3.1. Introduction, requirements

The flex module is glued on the sensor backside with reasonable but not extreme precision meaning that it is necessary to visually access the sensor alignment marks and to be able to wirebond both to the front end and to the flex wings. Order of 100-200 um precision is therefore a reasonable precision required on the flex nominal position.
Other mechanical requirements, besides the positioning wrt to the sensor, are the envelope, in particular the HV capacitance and potting are critical, the tolerance to radiation that drives the choice of the material and glues. Also, the region where the flex stave wing will be glued needs to be glued to the sensor, see Figures below by UniGe.
Also the wirebondings needs to be strong enough. Apart checking with a pull test, design has to be optimized (see Ref.[1]), gluing has to be properly done and pads surface need to be clean.



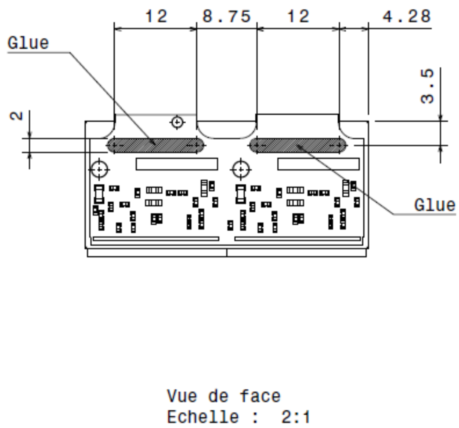


Figure: requirements for glue deposition under the wings.

In general the assembly procedure consists of: cleaning the flex, visual inspection of the bare module and IV scan (if planar), visual inspection and electrical test of the module flex, weighting parts (bare module and flex), aligning the flex to the module, depositing glue, gluing and curing. Bonn and Genova labs have very similar assembly procedures but mechanical tools have been autonomously developed. Therefore in the following the two procedures are described separately only when different.

During assembly operations and measurements are traced on a 'Traveler', see Ref. [2], on which also comments on the tests are tracked, as well the final sign-off before shipping to the loading site. When the modules are shipped, the traveller is scanned and the file stored on the raw data server (M*t*-*bb*-*ww*-*ss*/traveler, *t*=D,F,C indicates planar, FBD or CNM, *bb* is the batch, *ww* is the wafer, *ss* is the tile id on the wafer).

3.2. Parts preparation

3.2.1. Bare module

- Before assembly the bare module is carefully inspected, looking in particular for scratches on both sides. Alignment marks are checked as their integrity is crucial for further assembly steps. Integrity of all edges and corners is also checked: we have observed in the preproduction that FE corners can be easily damaged in the various steps of module flip-chipping and delivery.
- An IV curve is done at this stage for the DC modules, comparing the voltage breakdown with the values reported by wafer probing.
- Finally the bare module is weighted and value is stored on the traveler.

3.2.2. Module Flex

- The module flex is electrically tested. We have several steps of QA in Genova and in the productions firms, see Ref. [1], however before loading a quick electrical test is repeated in both labs. It consists in:

1. Visually check SMD soldering, pads and lines integrity.
2. Check continuity between the bridge and the connector
3. Check at the bridge the DI/Ck resistance
4. Check continuity between the bridge and the DOn/p FE pads
5. Check the HV filters resistance and continuity between the bonding ring and the connector
6. Check all SMD resistances

- Then the module flex is cleaned, see picture, following this procedure (already used for FEI3 module production):

1. Clean flex in Vigon A 200 (in Ultrasonic bath)
2. Rinse with warm water
3. Rinse with distilled water (in Ultrasonic bath)
4. put in clean water and measuring the conductivity in the bath >0,5µS is good
5. Dry at 50 - 70°C, 15 min
6. Clean in plasma oven (Bonn only, see picture; new, not applied at FEI3 Module production)

After cleaning a visual inspection is redone.

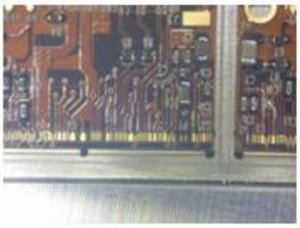
3.3.Module flex gluing procedure

3.3.1. Bonn

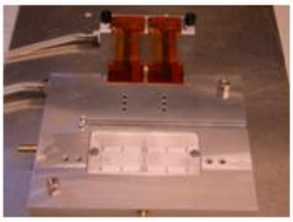
Once tested and cleaned the flex module is positioned (1.) on the assembly tool and aligned to alignment marks on the tool itself (2.). It is then removed with a special jig (3.) that keeps the flex module in a fixed position with respect to the assembly tool. The jig stands the module flex so that the bottom side is on the top and accessible. At this stage the glue is applied (4. and zoom): *a double tape strip of PPI RD-577F is attached under the front-end wirebonding pads, while dots of epoxy UHU EF 300* are deposited under the temporary bonding pads, around to the HV ring and close to the tape to better ensure attachment (see zoom). In the meanwhile the module is positioned and aligned on the module assembly tool (5.-6.). The module flex is then put back in its original controlled position and overlapped to the module (7). The critical region to be glued (bonding pads) are covered with a weight (20 gr per chip at bridge area, 100/150 gr on the FE area per SC/DC respectively, estimated ~half on the FE surface, see picture) and left for curing time (8).

1. Flex positioning

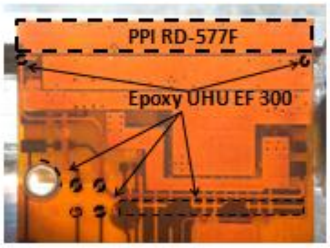
2. Flex alignment using the marks on the tool



3. Flex pull back



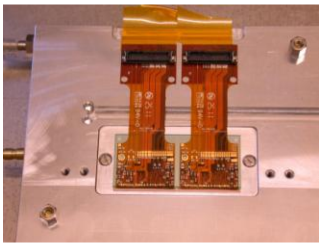
4. Apply of the glue

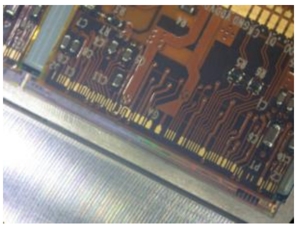


5. Module positioning

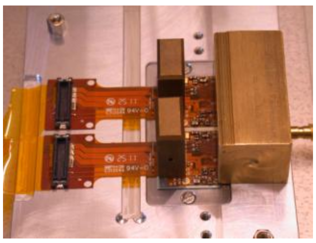
6. Module alignment using the marks on the tool

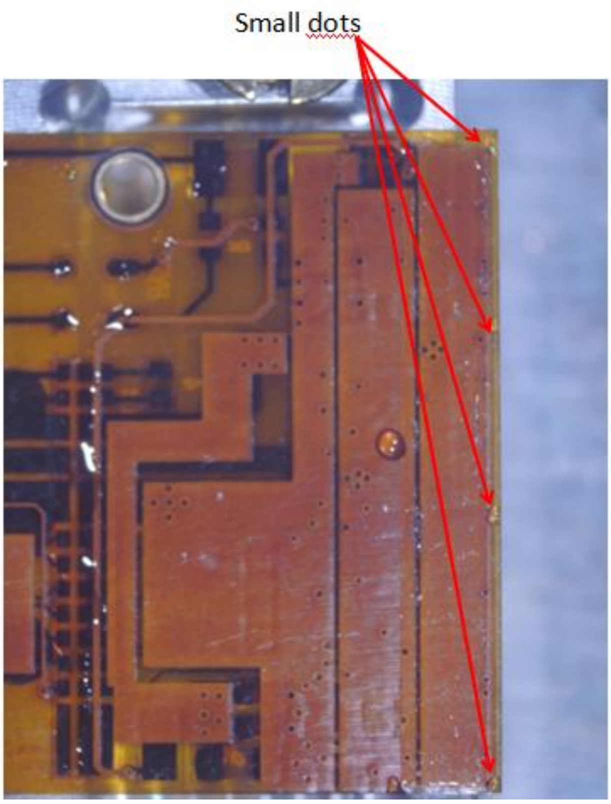
7. Put back Flex on the module Flex and check position





8. FE bonding and bridge bonding area fixed with weight

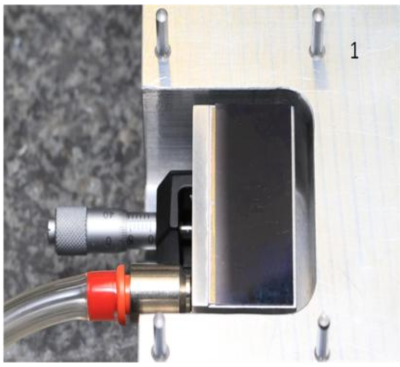


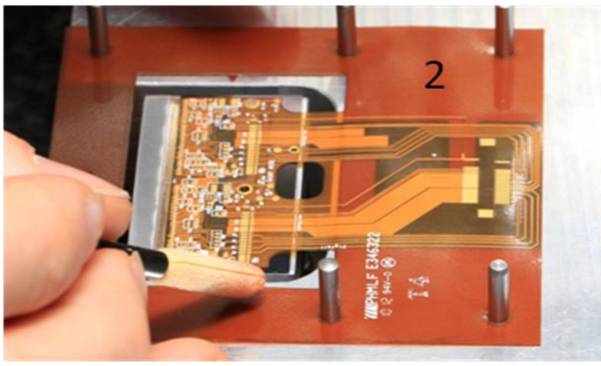


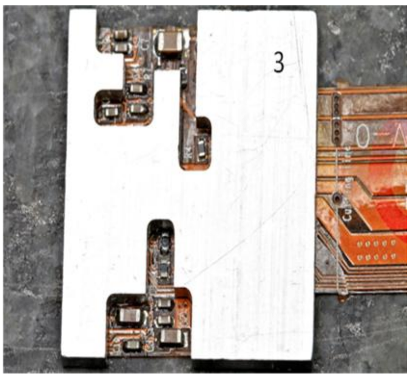
3.3.2. Genova

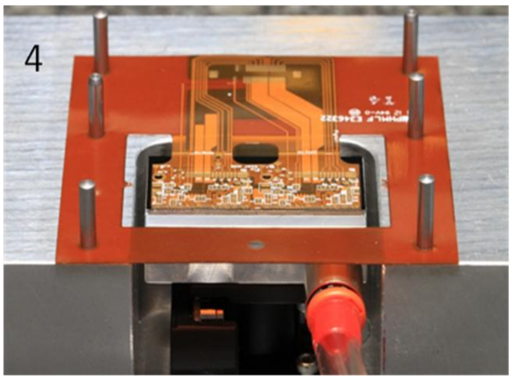
Similar procedure has been finalized in Genova. As for the Bonn procedure, only DC tools are shown. Tools devoted to the SC assembly are very similar and available, see more pictures in [3].

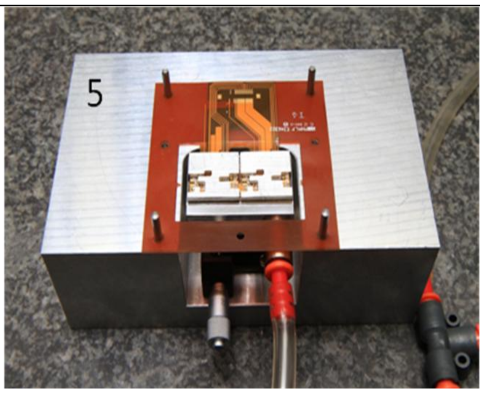
The bare module is positioned on the assembly tool plane (1): the jig holding the module has the possibility to be moved in z (the vertical axes) while alignment on the horizontal plane is obtained via mechanical steps. The flex module is then put on the top of the bare module using alignment pins that fit in the frame (2). If any residual misalignment is there, the bare module is aligned under microscope. Then the bare module is kept in position via vacuum. The module flex is removed, its bonding pads are gently cleaned using a fibreglass pen. Then it is turn so to have its bottom accessible. The same glue deposition pattern as Bonn is used, tape under the FE pads, liquid glue dots elsewhere. The tape is Arclad, used in the Atlas Pixel Endcap modules, and glue is Araldite 2011. To deposit glue, a special jig shaped to deal with the SMD components envelope is put on top of the module pigtail (3) so that the bottom surface is flat. Then the module flex is put back on the assembly jig. Alignment is checked once more and when is fine the module is brought in contact with the flex using the z-axes movement (4). Finally the SMD-shaped metallic mask (actually it is in plexiglass) is put on top of the flex (5) and a weight of ~ 200gr per FE is left on top during the curing time (6).

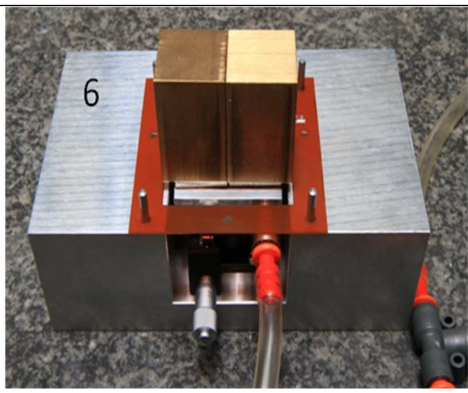












4. Module Wirebonding

Once the module is assembled, wirebondings are done to the FE(s), the HV sensor pad, to the temporary bridge on the extension.
Both Bonn and Genova use for all the Al bondings a 25 μm wire diameter and same wirebonding schema. A pictorial document on FE-Flex wirebondings is available, Ref. [4].

4.1. FE-flex

Wirebonding are done from the flex (source) to the FE (destination).
Bonding schema is added in the appendix (with Gadc_Vref_p pad 43 bonded to cap C17).

The wirebonding sequence needs to be as follows to prevent ESD discharges and possible damages to the FE regulators.

- Bond VrefOutDig_P, BgVrefdg_P: 21, 115
- Bond first Reg2 gnd and Vin (B5, B3) and then Reg1 gnd and Vin (119, 121)
- Then bond the rest of the chip by INCREASING PAD NUMBERS
- Bond last Vref1 (117)

Notes (see figures below):

1) The Chip ID bits (63,64,65) are all wirebonded, so GA is initially 7 for the DC and SC modules. One GA bonding is then pulled on FE1 of DC so to set GA to 7/6 for the DC FE 0/1 respectively. The GA address on SC will be assigned and relative wirebonding will be removed once the position of the stave will be known at the loading site.
2) IRefTune bits (122-125) are all wirebonded so to set IrefTune to 1000 as IRefTune_3 is wirebonded to VCC and the others to GND. As IRefTune_3 has an internal pull down, all the other an internal pull up by removing the wirebondings all IRefTune values may be set.
3) All the pads have one wirebond except Digital regulator input/output and Gnd (119,120/121) and analog input/output (B3,B4,B5) where 2/3 wirebondings are done.
4) Additional 7 bondings are done on each FE (on unused FE pads) to be pulled to qualify the wirebonding quality together with the GA and Iref pads.

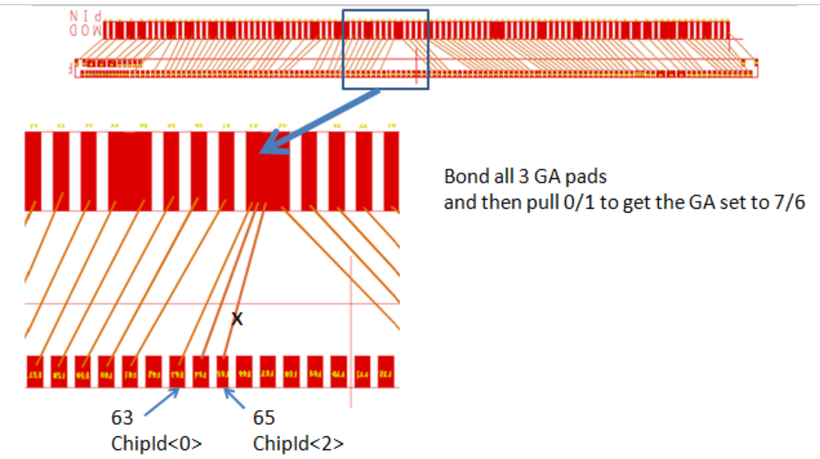
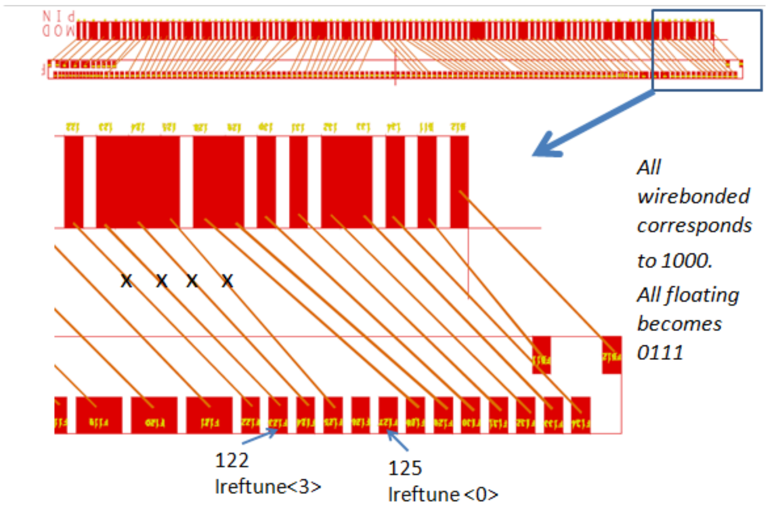


Figure: details of chip GA bondings



MSB, Ireftune 3, is internally pulled low and rest are internally pulled high.

Figure: details of chip IREF bondings

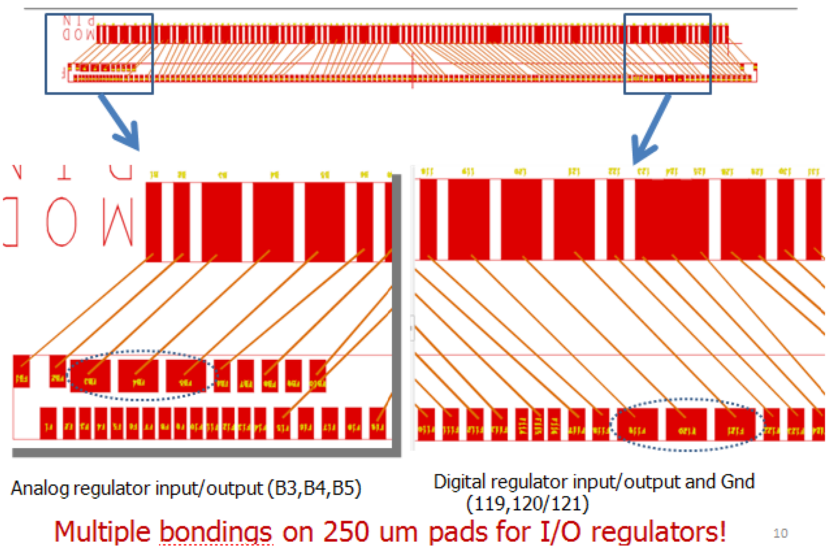


Figure: details of chip regulators bondings

4.2. Test bondings on the bridge

The test or bridge wire bondings (see fig. 3) are done to allow the test via the temporary extension and connector. A large pad is devoted to pull test wirebondings.
These wirebonding will be removed at the stave loading site, just before the module gluing on the stave.

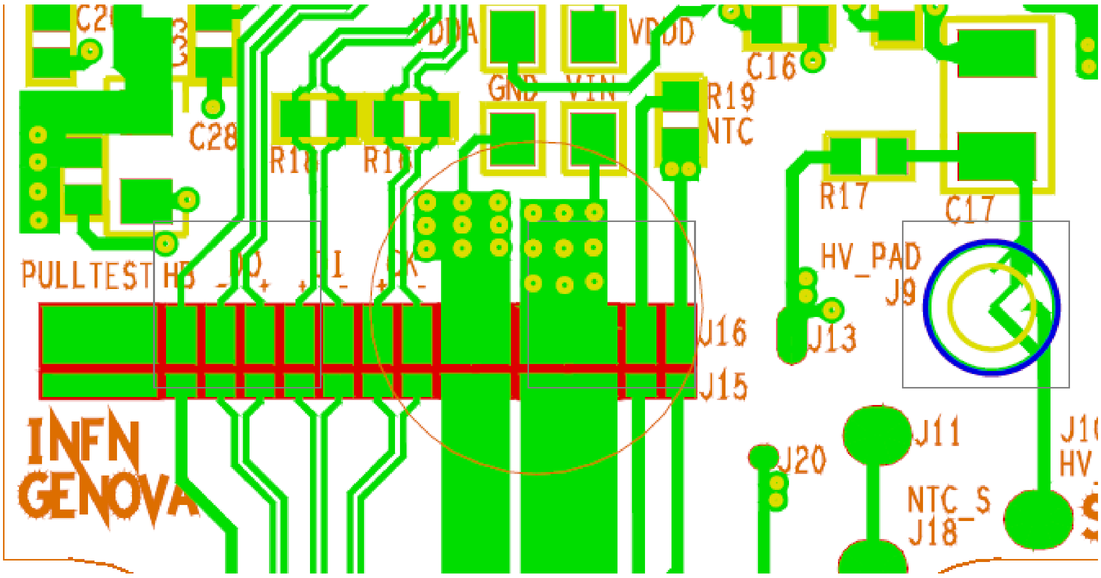
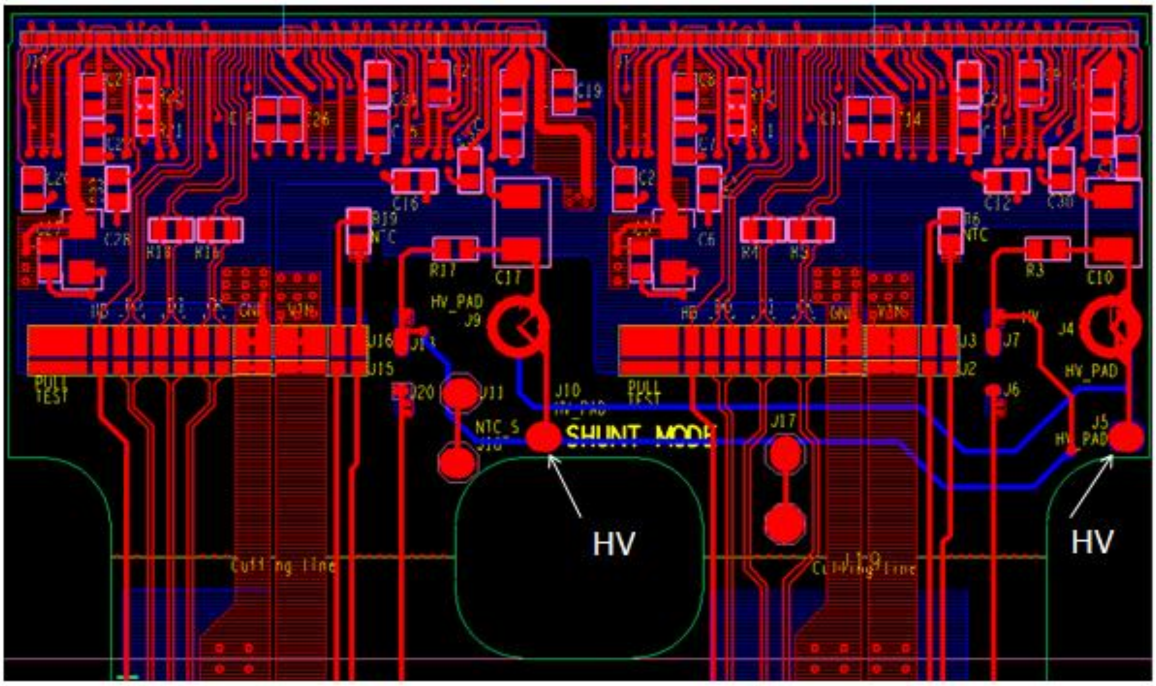


Fig.3 *detail of the test bonding pads where temporary bondings to the connector are done.*

4.3. HV bondings

Multiple HV bondings are done from the metal ring to the sensor (DC/SC) and to the bottom corner pad to the sensor (SC only). Notice that in the DC modules redundancy is assured by two bonding rings, one for each FE. To avoid possible envelope issues, we have decided not to use in DC the extra sensor squared pads in the back of the sensors.



4.4. Pull test in Bonn and Genova

The main quality control tool at our disposal is destructive pull tests of representative wire bond samples. For this scope, extra bondings are done and then pull.
In the picture the pull tester in Genova. In the bottom pictures some examples for qualification in Genova and Bonn.

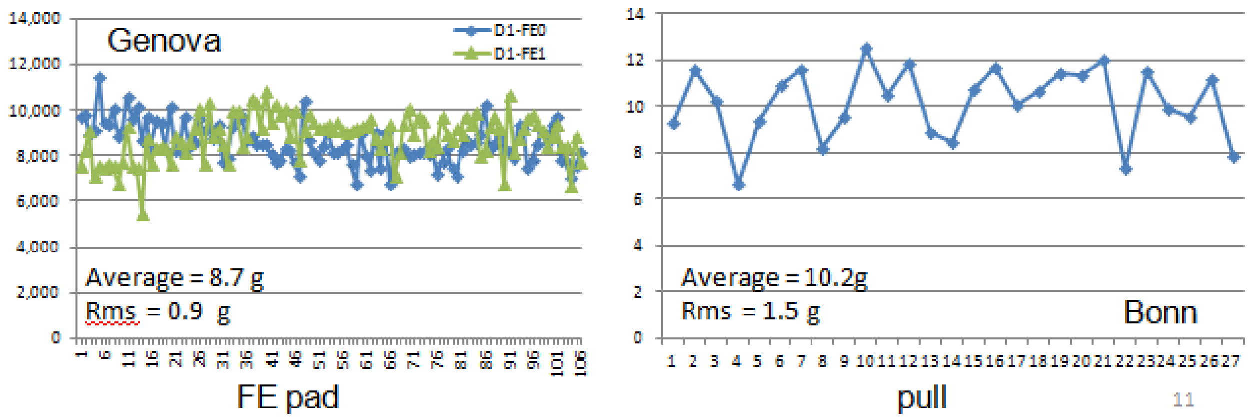
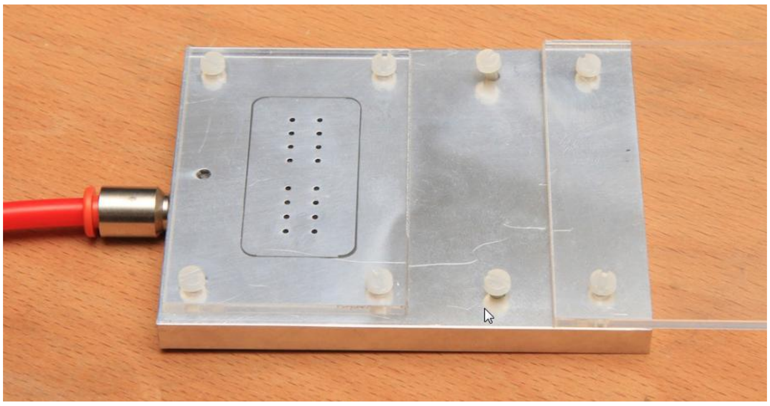


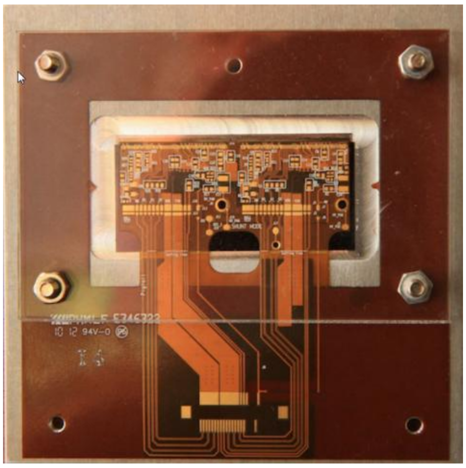
Fig.4 *Pull test in Genova lab and pulls resultsinGenova/Bonn.*

5. Handling tools for test, shipping, storage

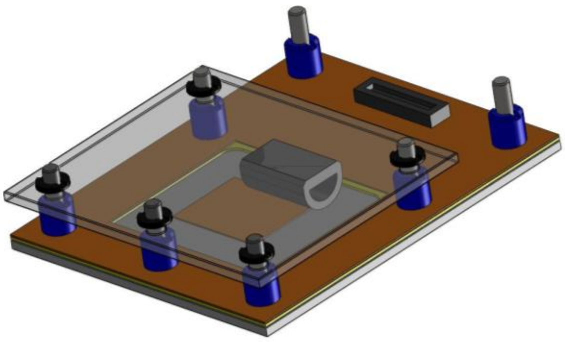
5.1. General requirements

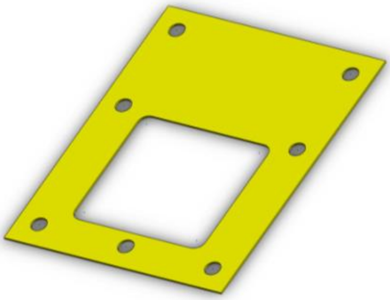
Tools to handle the modules during the test have been developed in both labs.
In the following a picture of the Genova plate used during tests and wirebonding and one for the storage.

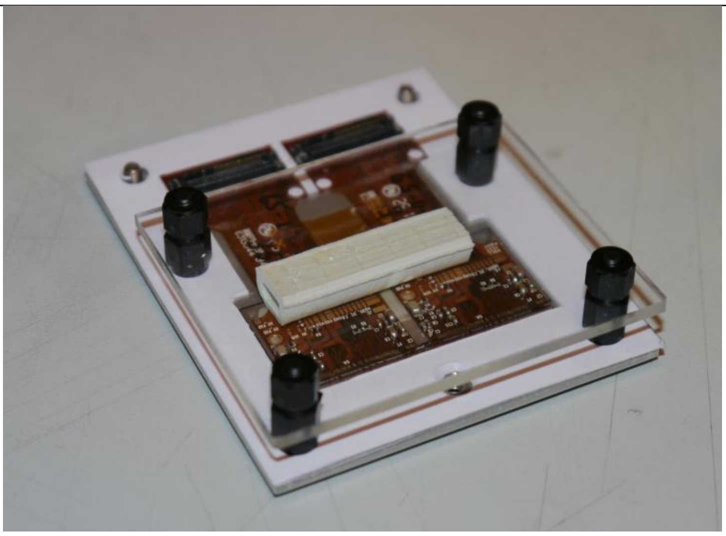




Besides plates for handling and testing, Bonn will also produced several plates for modules shipping and storage that are shown in the sketches and in the figure. A rubber thickness prevents the module to move in the vertical direction.







6. Production facility

Enough tools have been prepared so to allow to assemble up to 4 modules per day, either DC or SC.

7. References

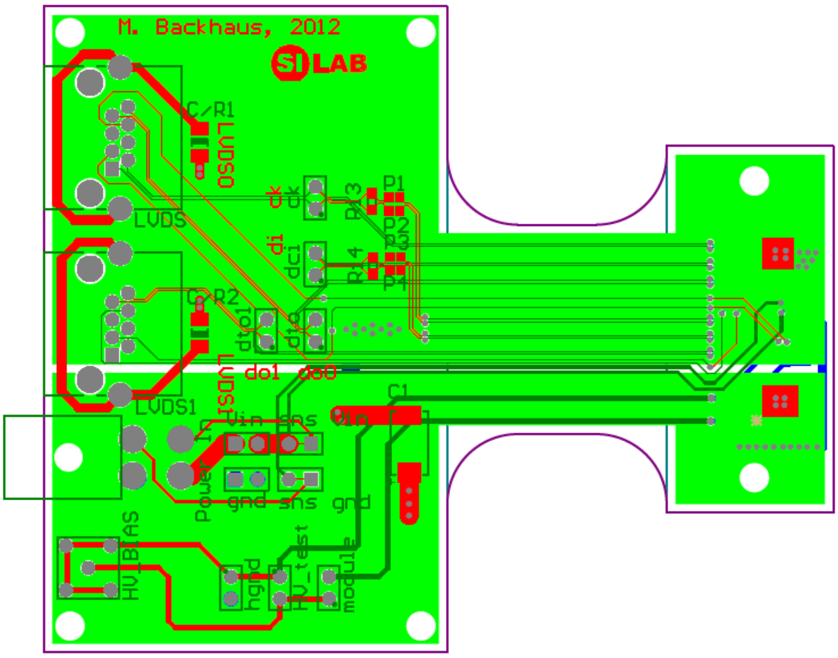
[1] Flex Module ATU-SYS-EP-0007-V4, https://edms.cern.ch/file/1221314/2/ATU-SYS-EP-0007_V4.pdf and files in https://edms.cern.ch/document/1221314/2

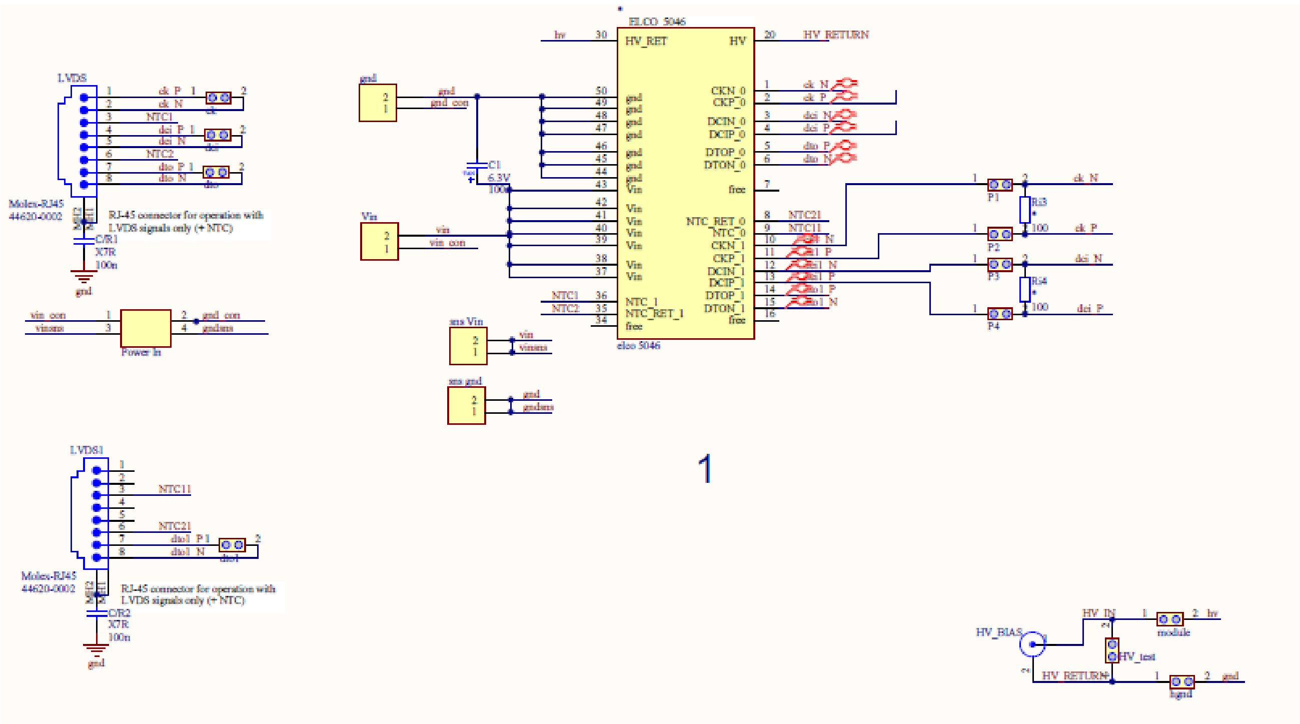
[2] Assembly pictures in Genova http://www.photoshop.com/users/nannino/albums/e8fb281d2b2b43b988d2a68854fbcab8

[3] Module Assembly and testing traveler, https://edms.cern.ch/file/1221780/1/FlexModuleTraveler_IBL_0_3.pdf

[4] WB_inspection_reference, https://edms.cern.ch/file/1221780/1/WB_inspection_reference_v3.pdf

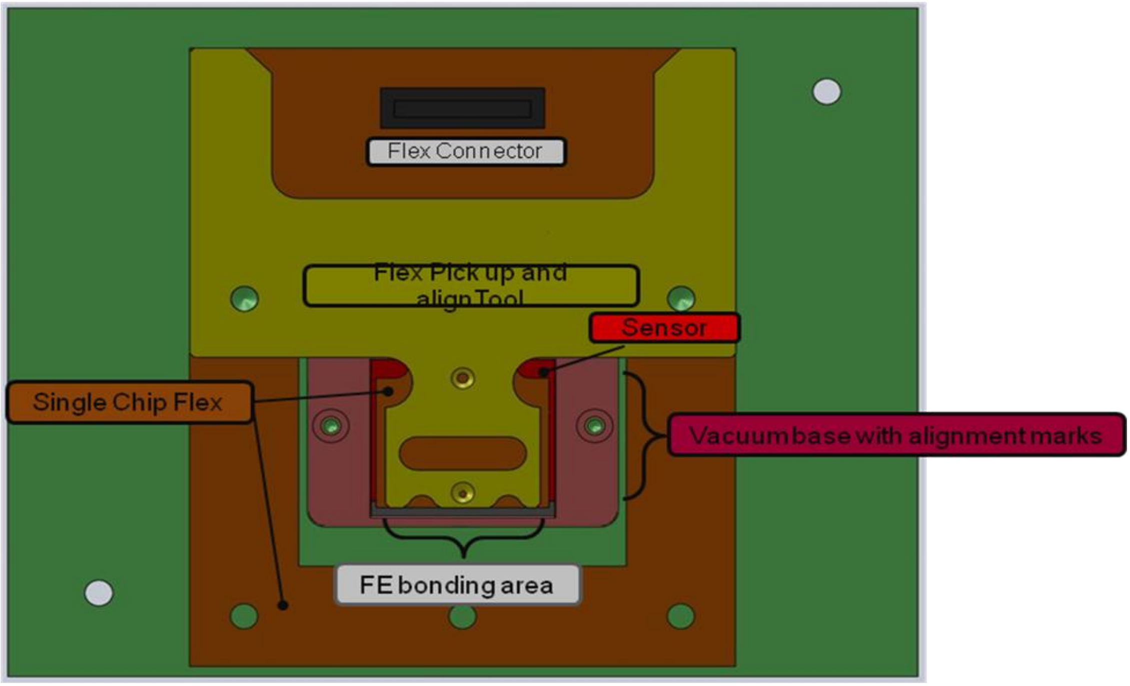
8. Appendix A: Adapter in Test Setup



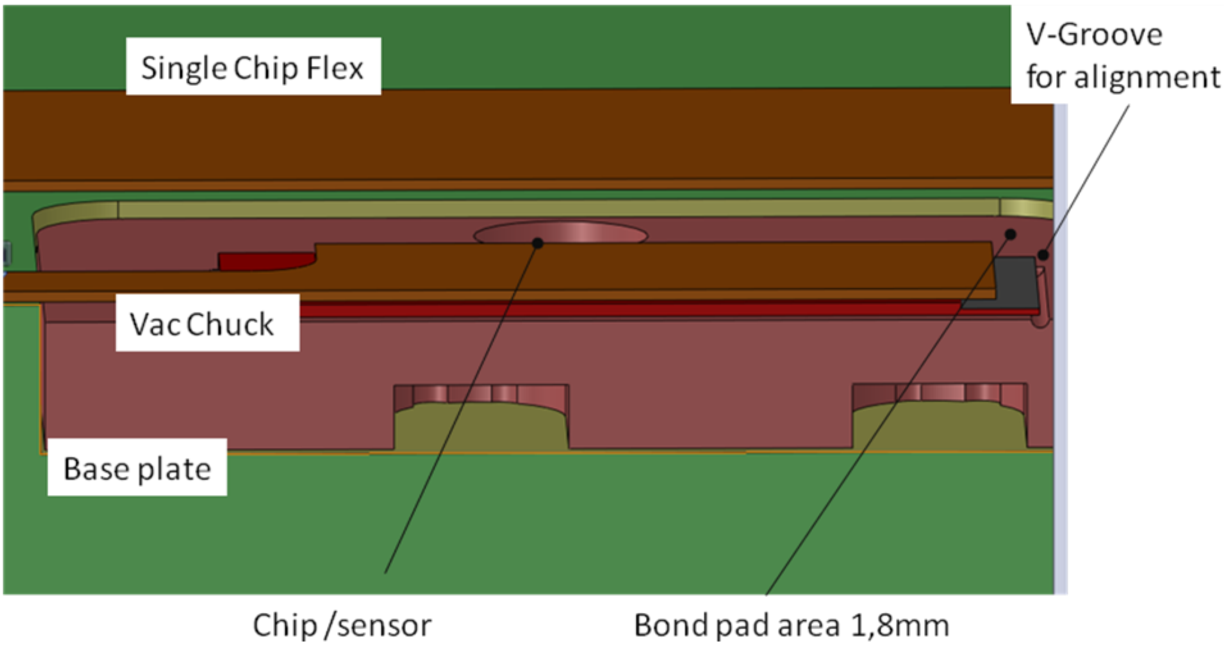


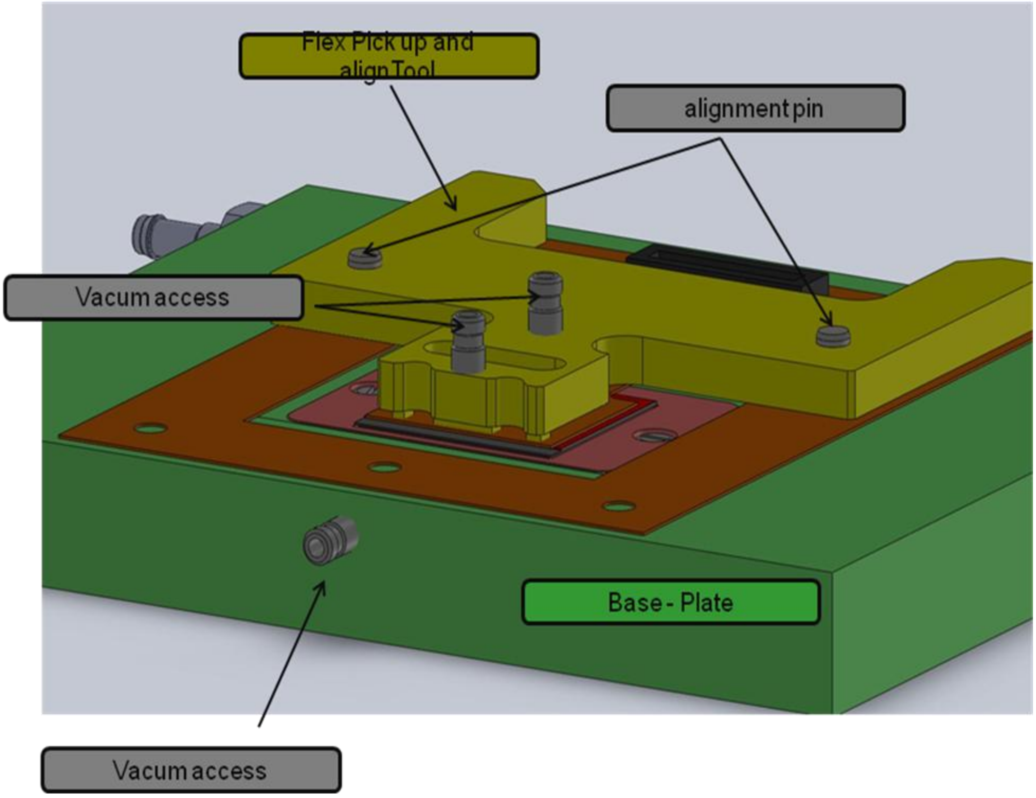
9. Appendix B

Drawings for SC in Bonn

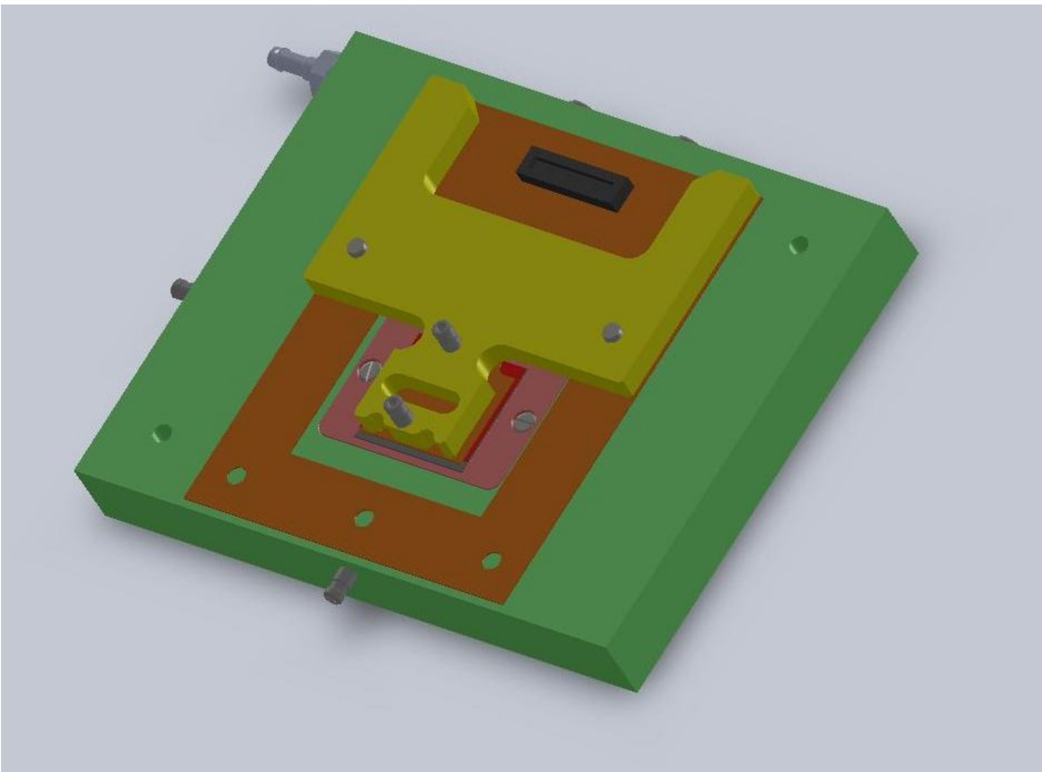


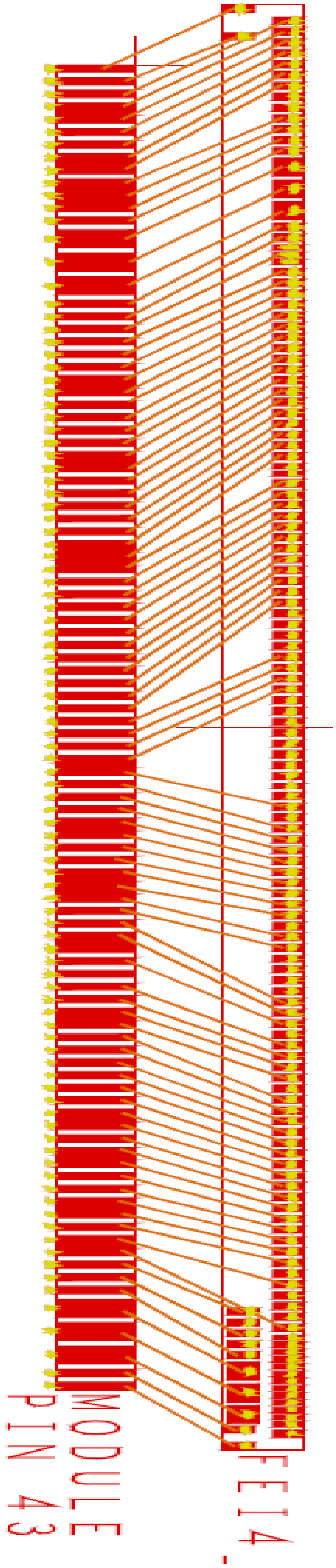
Tooling Single chip Flex assembly





Flex Pick up and alignTool
alignment pin
Vacum access
Base - Plate
Vacum access





MODULE
PIN 43
FEI4_