1 Production of detector modules

1.1 Casting of fibre mats

Fibre mats are still fragile after taking them off the winding wheel. It has a tendency to split between adjacent fibres. Fibres near the edges are particularly prone to becoming separated from the ribbon. For this reason, the ribbon is cast in a bath of glue to ensure a thin protection film around the mat, which also creates a precise flat surface. To cast fibre mats they are placed in an casting mold made of aluminium (see figure 1. The fibre mat is positioed by means of its pins that are clicked into grooves machined at high precision into the casting mold. An endpiece is also added and aligned in the template with respect to the fibre centre by holes. A longhole as used for aligning the fibre mat is shown in figure 2 (top), together with the resulting pin on the fibre mat. Distance holders of 80 μm height guarantee the proper positioning of the fibre mat in the mold. The mold is closed by means of a glass plate and placed in a vertical position. Glue is filled into the mold from bottom to top. To ensure a good wetting of the glue the mold is heated to a temparature of 40°. After 2 days of curing the casted fibre mat can be taken from the mold. The height of the casted fibre mat is 1.45mm to be compared to about 1.2mm as specified for the uncasted fibre mat. A measurement on the uniformity of the fibre mat height and other measurements on the mechanical properties of casted fibres mat are summarized in appendix A. Optimization of the process parameters is ongoing. Two lines are followed: First, it is envisaged to build a casting mold allowing to cast to fibre mats at once. Secondly, we investigate process parameters (e.g. temparature) to reduce the curing time of the fibre mats in the mold.

1.2 Finishing of sub-modules

To guarantee the optimal light output of the fibre mat special care has to be taken for a very good cut quality transversal to the fibre direction. Before performing that cut the second endpiece is glued to the fibre mats (see figure 3). The endpieces comprise alignment holes for the positioning of the readout electronics. It needs to be mounted before performing the optical cut to avoid a gap between optical fibres and readout electronics. The cut is performed with a special three blade diamond milling head shown in figure 4. The final step to finish a sub-module is to glue the mirror on the far end of the fibres.

The resulting sub-module is robust and handleable without fear of damage. At that stage it is foreseen that the sub-modules undergo a thorough test procedure to guarantee its correct mechanical properties and functionality. Now sub-modules are safely protected and ready to be shipped to the module assembly centres.

Figure 1: 2.5m casting mold used to cover the raw fibre mats with a thin, protective layer of glue.

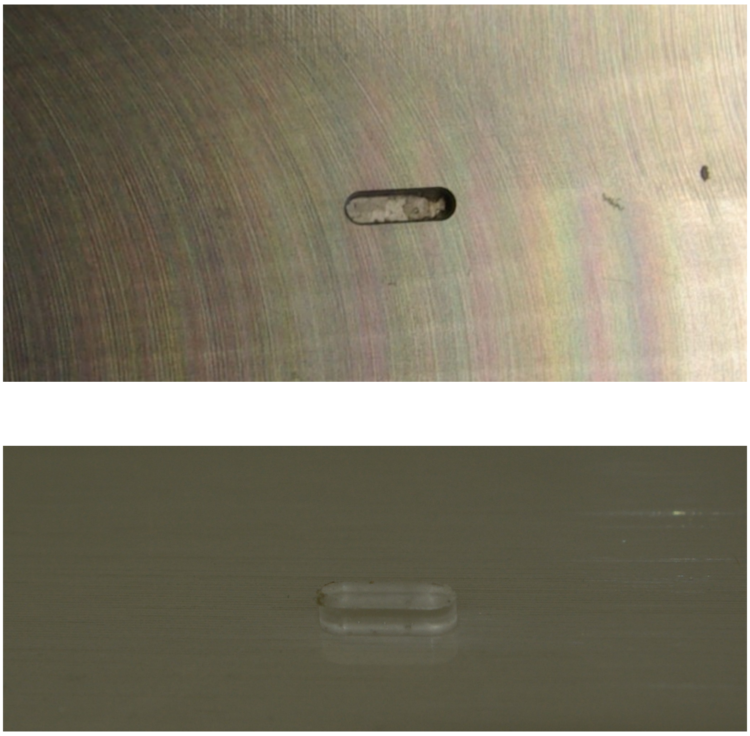


Figure 2: Top: Grooves in the casting mold used for positioning of pins; Bottom: Pins on a casted fibre mat

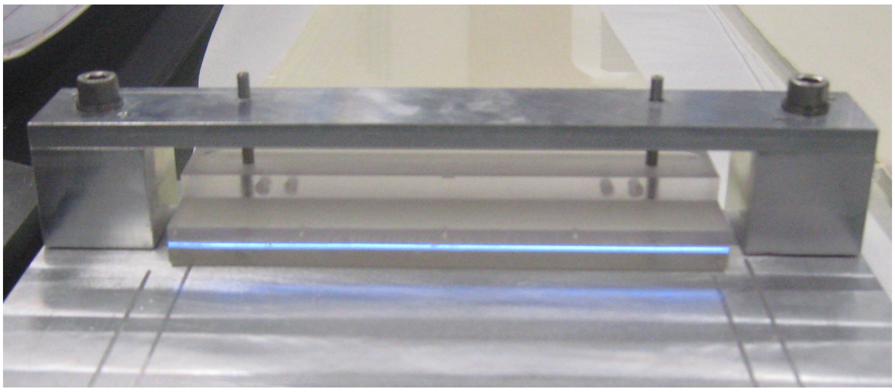


Figure 3: Alignment and gluing of the second end-piece in the gluing jig.

Figure 4: Three blade diamond milling head used for the optical cut of the fibre mat

1.3 Cutting sub-modules

To reach a minimal loss of acceptance at the boundary of two neighbouring sub-modules they have to be cutted to the appropriate width with a precision of better than 150μm. To guarantee that precision two parallel cuts are performed at the same time using a double blade circular mill. The set-up for cutting the sub-modules and the circular mill are shown in figure 5. The choice of the blade has been taken after a series of test. The advantage of that particular mill is that it efficiently removes the chips during milling and provides a reasonable cooling due to the good thermal conductivity of the blade. A uniformity of better than 100 μmm can be achived as shown in appendix A. Optimization of the processing parameter to perform the longitudinal cut is ongoing.

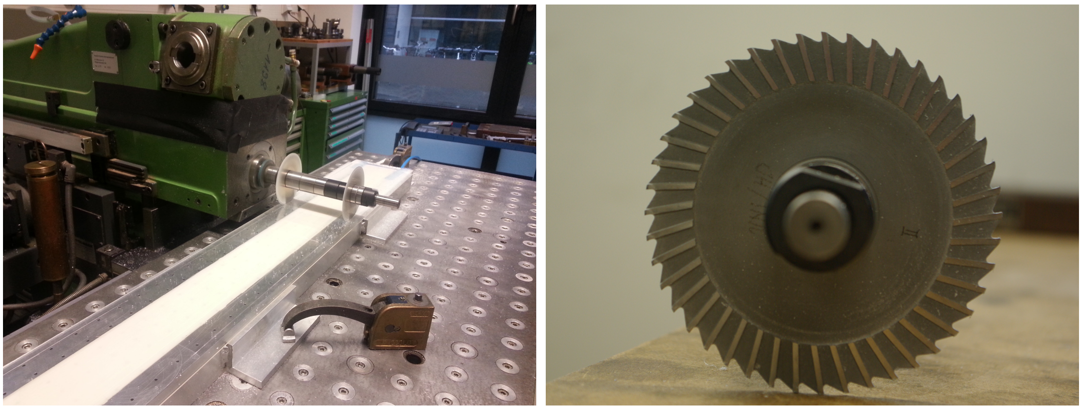


Figure 5: Cutting a fibre mat along the fibres. The right picture shows the circular mill used for that cut.

1.4 Module assembly

A detector module is assembled from 8 sub-modules prepared as described before. This is done by means of a full size (5m x 0.53m) template, machined from two pieces at very high precision. This procedure has been successfully applied in the construction of the OT detector modules of similar size (5m x 0.34m). The advantage is the template gives the precise alignment of the detector modules and the reproducability is intrinsically guaranteed. The first step of module assembly is to align the 8 sub-modules in the template. To align the fibres the template contains a groove. The alignment pins in the sub-module (see figure 2) are clicked into the groove. Like this the alignment is transferred from the pins produced during winding of the fibre mat, via the sub-module to the final detector module. After alignment of sub-modules the end-plug is positioned across the end-pieces. This is done by alignment pins and the corresponding alignment holes in the endpieces and the template. Glue is applied and the half panel (one piece of 5m x 0.53m) is positioned on top. A good bond is ensured by pressing the panels by means of weights to the sub-modules.

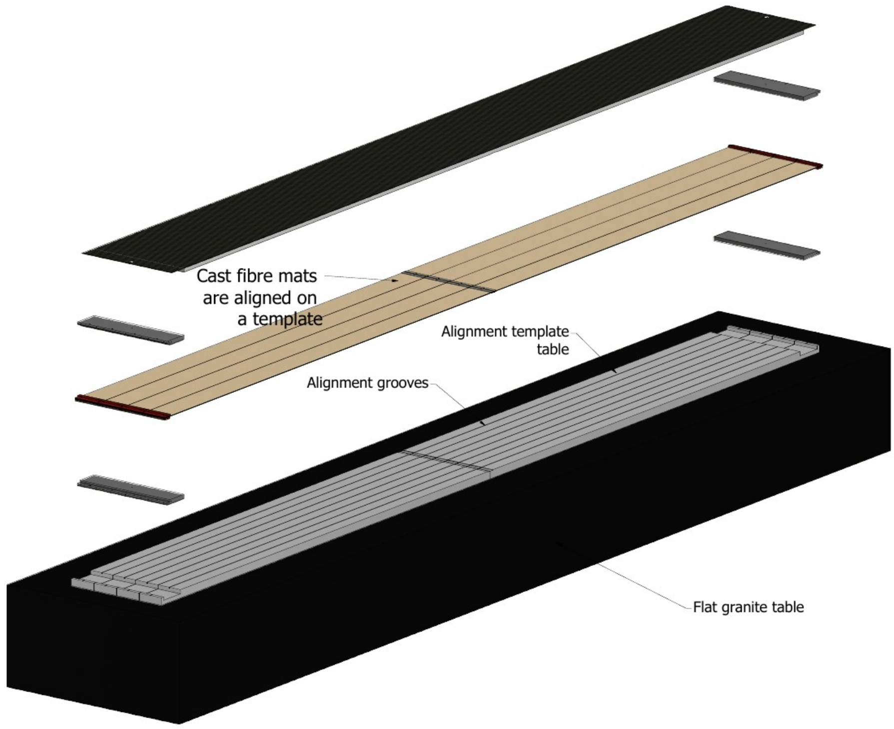


Figure 6: Exploded view of set-up in first step of module assembly.

Figure 7 shows the corresponding production step while constructing a testbeam module made from one sub-module.
The good alignment of the detector modules using that method is demonstrated in figure 8 in appendix A. For that measurement a detector half module (one CFRP glued, the other not) is laid on coordinate measurement table. No mechanical fixation is used. The edges of the pins are measured with a precision of $\sim 10-15\mu$m. The deviation from a straight line is shown. The RMS of that measurement is 21μm.
After curing (~24hours) the half module is taken out of the template, turned over. End-plugs and are aligned on the half module in a different template, glue is applied and the second half panel is bonded to the module. The final step in the module assembly is to close the module by wrapping it in a light and gas tight envelope. Gas-tightness is required to avoid humidity penetrating to the cold part of the detector. The concept has been proven by the construction of a full width, 1m long detector module using this assembly strategy. It has been equipped with 4 sub-modules (3 dummy modules and 1 fibre mat).

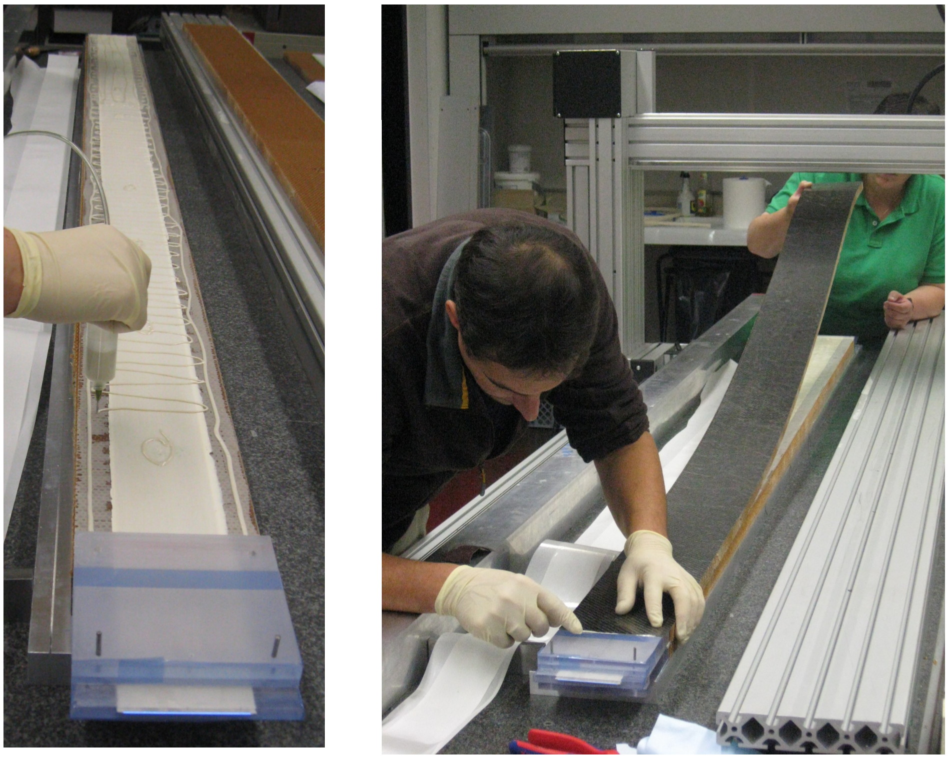


Figure 7: Gluing a half panel to a sub-module while constructing a testbeam module made of one sub-module. In the final production this step is performed for eight sub-modules at a time.

2 Module mass and Young's modulus

2.1 Module mass

To verify that the specifications concerning the material budget can be met detector prototypes and components have been weighted and if possible compared to specifications. The components are

- panels of 2.5m x 0.13m produced by AD-CO.
- panels of 2.5m x 0.13m produced by FACC.
- an uncasted fibre mat produced by Aachen.
- a casted fibre mat produced by Dortmund and casted in Heidelberg.
- a dummy detector module of 2m x 0.53m by FACC. The sub-modules not available at the time of construction is mimiced by the use of 1mm thick polystrol panels.

The result of the measurements is shown in table **??**.

	Producer	Measured [g/m^2]	Expected acc. to specification [g/m^2]
Panels	FACC AD-CO	1800 2400	1880 not specified
Fibremat uncasted	Ac	1223	1250
Fibremat casted	Do + Hd	1512	1500
Dummy module (after correction	FACC	3640	3580 (assuming a casted fibre mat of 1512g/m2 as measured. It includes also 2x100g/m2 of glue to bond sub-module to CFRP, as specified by FACC
Testbeam-like module	AD-CO + Hd	to be measured	not specified

2.2 Young's modulus

Young's modulus has been measured for the 2m x 0.53m FACC dummy module described above, as well as for a testbeam module made from FACC panels and a sub-module produced in Heidelberg from a mat produced in Dortmund. The module assembly has been performed in Heidelberg. The measurement of Young's modulus for the AD-CO testbeam-like module will be added soon. For comparison Young's modulus measured for a short (2.5m x 0.34m) detector module of the Outer Tracker is given, too. The results are:

- FACC dummy module (5m x 0.53m): 1.73GPa
- FACC test-beam module (2.5m x 0.13m): 1.49GPa
- AD-CO test-beam like module (2.5m x 0.13m): to be measured
- OT detector module (2.5m x 0.34m): 1.24GPa

A PerformancePlots

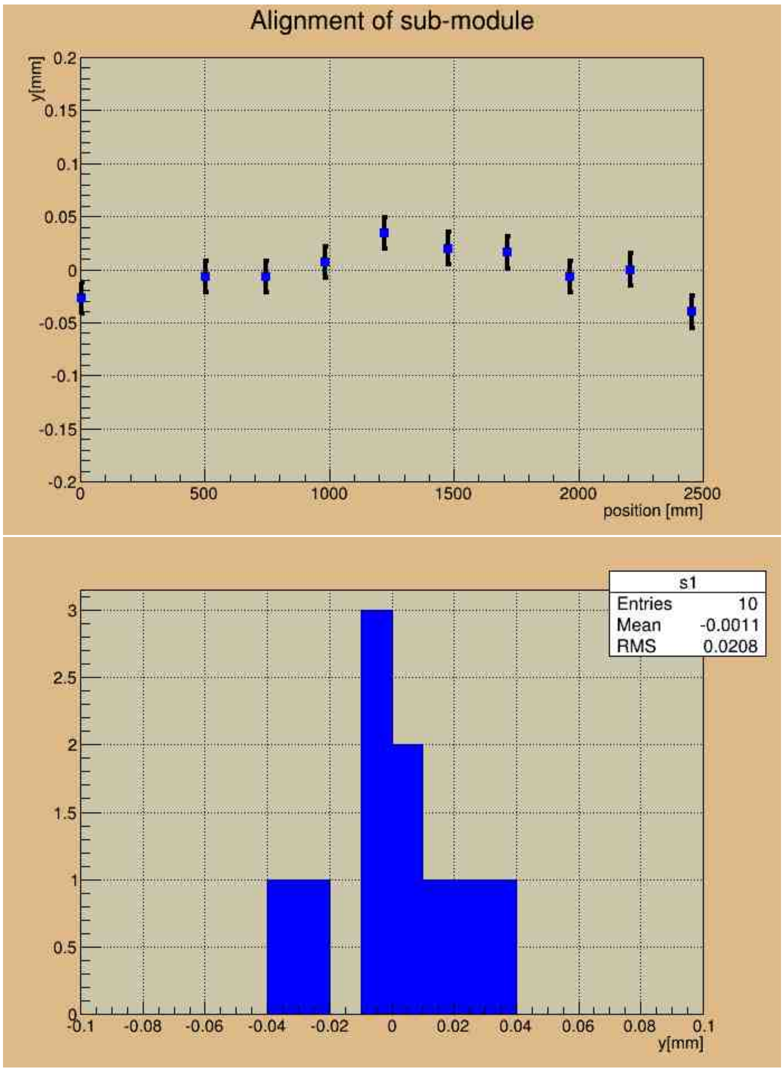


Figure 8: Straightness of alignment pins along the fibres. A slight banana shaped is introduced because the prototype casting form is made of 3 parts not perfectly aligned. The casting forms for the serial production will be made from a single piece, therefore no effect is expected here.

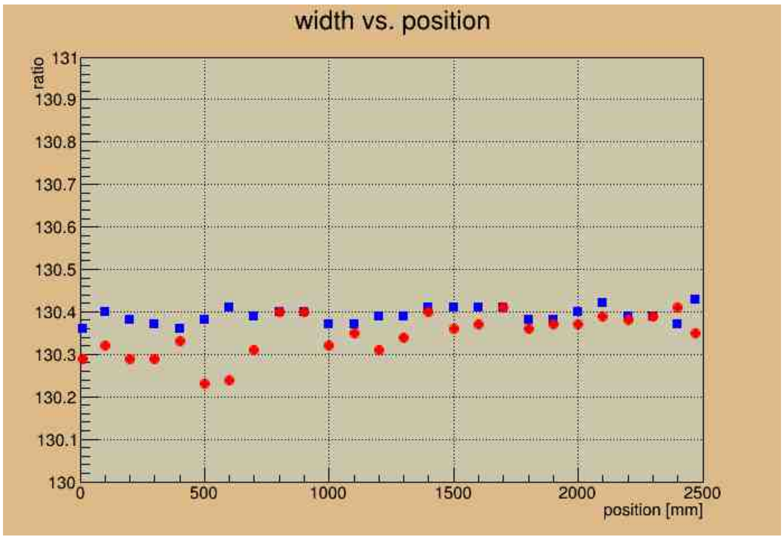


Figure 9: Measured sub-module width of two different detector modules: The red data points show a worse uniformity. This is probably because that sub-odule did not cure for a sufficient long time and the mat was still too soft, resulting in a worse quality of the cut.

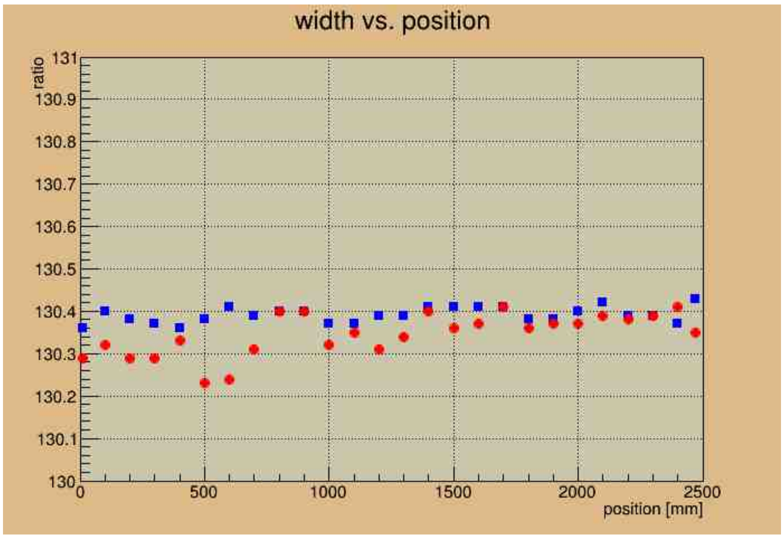


Figure 10: Measured thickness of sub-module used for the test beam.

B Figures

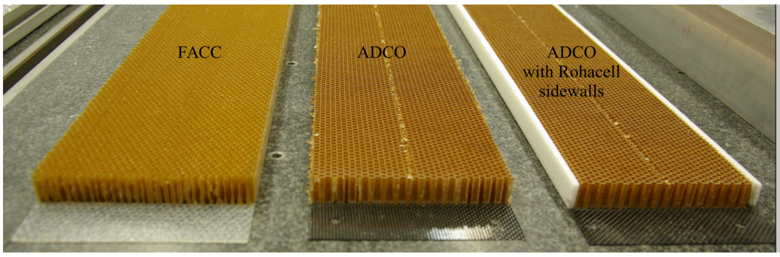


Figure 11: Panels.pdf

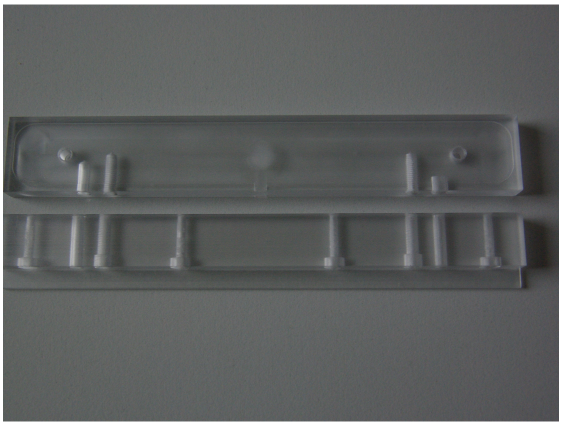


Figure 12: EndPieces.pdf

Figure 13: CastingMold.jpeg

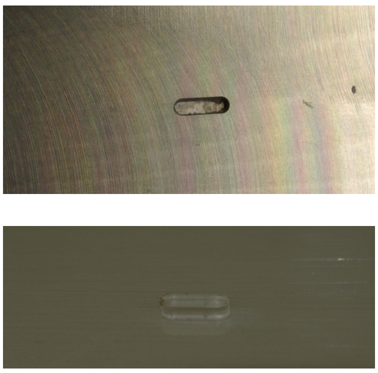


Figure 14: Pins.pdf

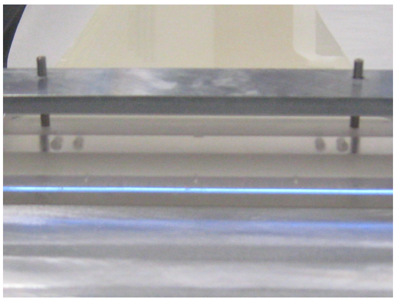


Figure 15: GluingEndPieces.pdf

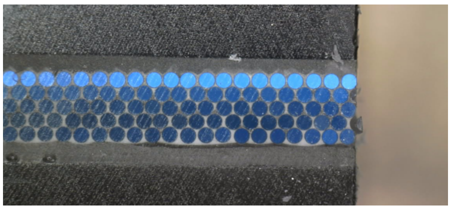
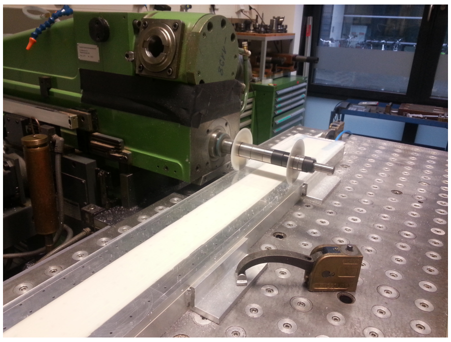


Figure 16: DiamondHead.pdf and CrossSectionFibres.pdf



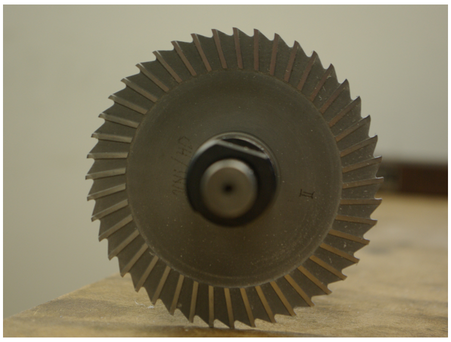


Figure 17: LongitudinalCut.pdf and KreisFraeser.pdf

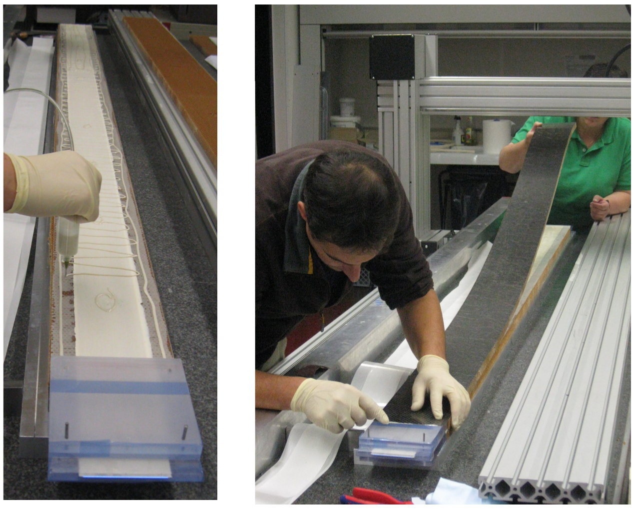


Figure 18: GluingHCandEndplug1.pdf

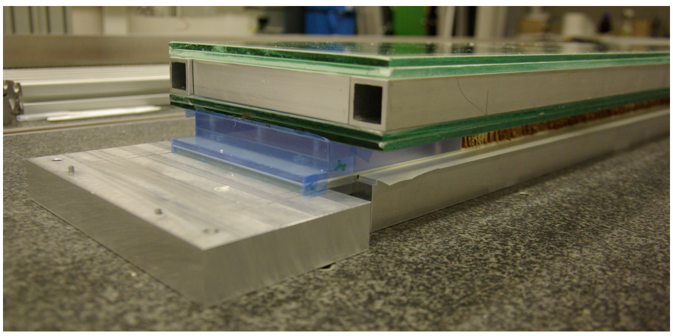


Figure 19: GluingHCandEndplug2.pdf