Validation of the FRP production: samples for the qualification of the FRP vendors and experience from module-zero assembly.

The UTA team proceeded to the production and the assembly of a first field cage sub-module (module-zero) in order to test the quality of the production of the FRP I-beams from a few vendors. Three possible vendors were contacted; eventually two out of them (EPI and Roschling) provided pre-production samples for the module-zero assembly. The results of the module-zero assembly experience were presented and discussed at the ProtoDUNE-DP Technical Board on May 3rd.

Two sets of 6" and 3" FRP I-beams were produced by EPI and Roschling in order to assemble two sub-modules. Some FRP samples of 50 cm length with an ad hoc design and pattern of holes were also delivered to CERN in order to check the quality of the material, to perform some immersion tests in liquid argon and to tests the mechanical strength of the material. The aluminum profiles used for module-zero assembly were coming from a CERN pre-production sample.

The FRP samples received at CERN (Fig 1.) showed the good quality of the material and of the related machining. They underwent shock cooling tests in liquid argon without consequences. The mechanical strength of the material was tested by hanging loads much heavier than the maximal load in the field cage design. The breaking point was reached for a load of xxx kg (Adamo complete here with the test to be performed on Thursday).

Figure 1: FRP test sample received at CERN for tests at cold and mechanical strength tests

The assembly of module-zero allowed checking the quality of the material and the accuracy in the machining of the pattern of fixation holes and slots for the insertion of the aluminum profiles. It allowed as well establishing the cleaning procedures and quantifying the assembly time for the preparation and pre-assembly activities to be performed at UTA and for the final sub-modules assembly procedure foreseen at CERN.

Figure 2: Module-zero completely assembled. The aluminum profiles were precisely aligned at their flat ends during assembly. The alignment of the bent parts in the corner is not representative of the final assembly accuracy since in this pre-production sample the aluminum profiles were not all bent precisely in the same point.

No problems were encountered during the module-zero assembly (see Fig. 2), already providing the feeling that the pattern of holes and slots machined on the I-beams were well aligned within the required tolerances. The alignment accuracy of the aluminum profiles slots was first checked with a laser level (see Fig. 3) and then with more accurate measurements referred to the global pattern of fixation holes:

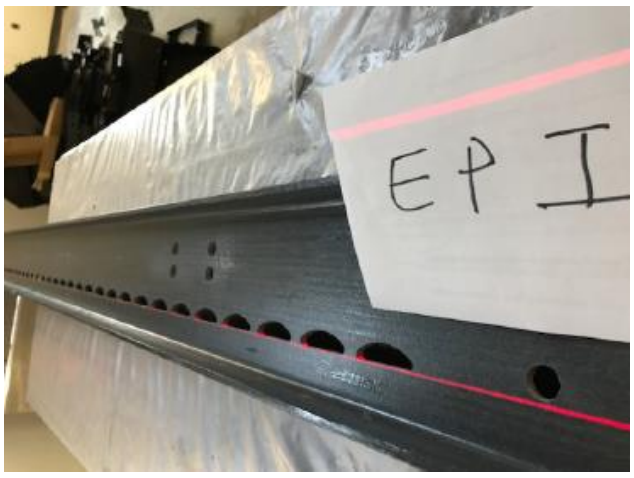

Figure 3: Checking the alignment of the pattern of aluminum profiles slots with a laser level

The accuracy of the relative alignment of the pattern of slots with respect to the fixation holes was then measured systematically and more precisely with typical measurement accuracy 0.2 mm. These results are reported in Fig. 4 and Fig. 5 for Roschling and EPI respectively. Measurements were performed on the relative distance between the flat part of the profile slots with respect to the lowest screw hole edge, since this dimension determines the relative alignment between the profile holes between two subsequent sub-modules. Entries in the histograms represent the deviation of the measured slot position with respect to its nominal position. For the Roschling sample the average of the measurements is -0.01 mm and the standard deviation 0.19 mm. For the EPI sample the average is 0.1 mm and the standard deviation is 0.16 mm.

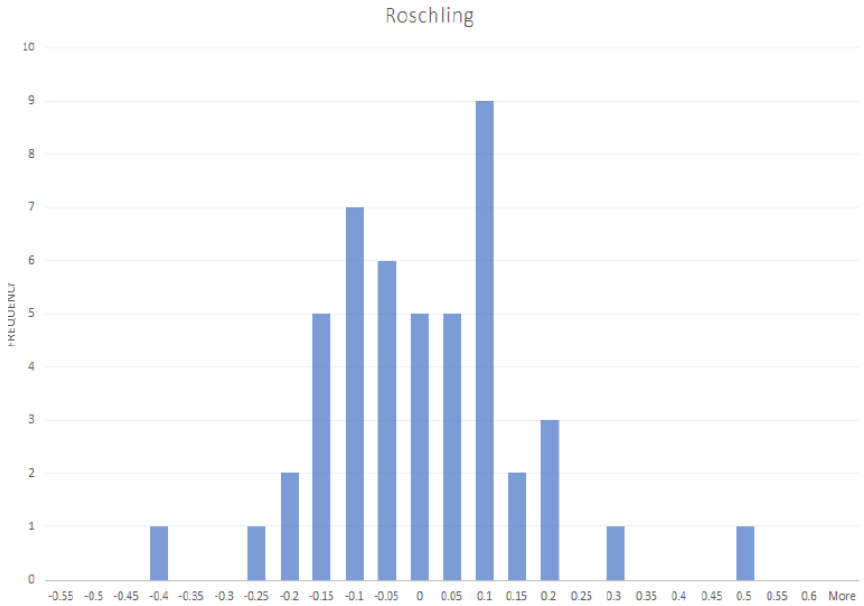

Figure 4: Distribution of the deviations of the nominal positions of the slots measured with respect to the fixation holes pattern for the Roschling sample

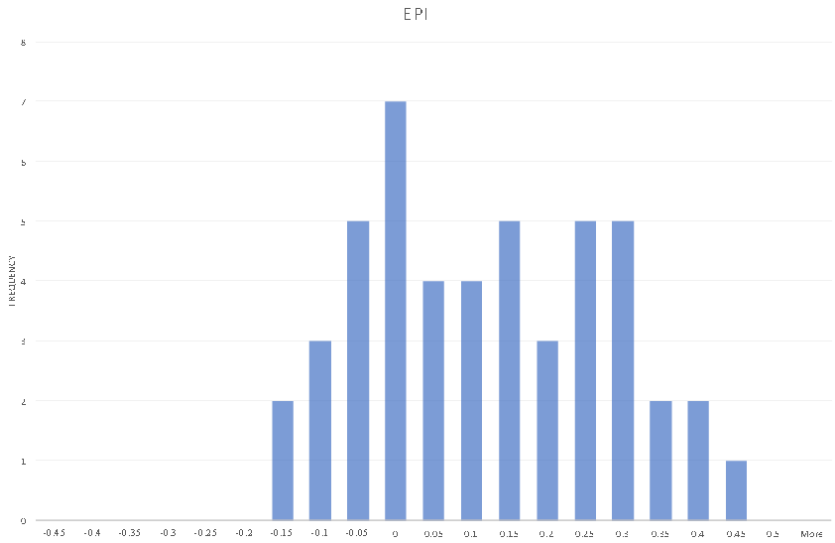

Figure 3: Distribution of the deviations of the nominal positions of the slots measured with respect to the fixation holes pattern for the Roschling sample

Both samples show that the machining of the material was performed according to specifications by drilling a global pattern of slots and fixation holes with the required relative accuracy.

Given:

a) the visual inspection and quality of the material and machining
b) the measurements performed on the hole pattern geometry
c) the experience from module-zero assembly
d) the cryogenic tests and mechanical strength test

the pre-production material examined so far corresponds to the expectations and requirements specified by ProtoDUNE dual-phase.

For an almost equivalent production cost, preference is given to Roschling since this company demonstrates more care and precision. The machining process of Roschling reduces the amount of burr, flaps and fibers, which helps reducing time for cleaning, which takes the most time. In addition, this company provides the FRP threaded rods and nuts to the single phase drift cage group. Finally, the communications of the company responsible have been prompt and the company is very responsive to our requests.

In the light of all these considerations green light is given by the ProtoDUNE dual-phase Technical Board to start the FRP I-beams production.