AIDA-2020-MS99

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Milestone Report

Advanced mechanical distributed facility ready

Viehhauser, Georg (UOXF) *et al*

28 February 2019

The AIDA-2020 Advanced European Infrastructures for Detectors at Accelerators project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

This work is part of AIDA-2020 Work Package **9: New support structures and micro-channel cooling**.

Grant Agreement No: 654168

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Advanced European Infrastructures for Detectors at Accelerators
Horizon 2020 Research Infrastructures project AIDA-2020

MILESTONE REPORT

ADVANCED MECHANICAL DISTRIBUTED FACILITY READY

MILESTONE: MS99

Document identifier:	AIDA-2020-MS99
Due date of deliverable:	End of Month 46 (February 2019)
Report release date:	28/02/2019
Work package:	WP9 (NA8): New support structures and micro-channel cooling
Lead beneficiary:	UOXF
Document status:	Final

Abstract:

We report on the status of the mechanical characterization facility at the University of Oxford. This facility is now ready and has received the first user group. The full functionality of the facility will be developed in the coming months.

For more information on AIDA-2020, its partners and contributors please see www.cern.ch/AIDA2020

The Advanced European Infrastructures for Detectors at Accelerators (AIDA-2020) project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168. AIDA-2020 began in May 2015 and will run for 4 years.

Delivery Slip

	Name	**Partner**	**Date**
Authored by	G. Viehhauser A. Reichold	UOXF UOXF	25/02/2019
Edited by	S. El Yacoubi	CERN	27/02/2019
Reviewed by	D. Bortoletto [Scientific coordinator]	UOXF	28/02/2019
Approved by	D. Bortoletto [Scientific coordinator]		28/02/2019

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Executive summary

The purpose of the structure characterization facility is to allow external users access to instrumentation which provides realistic mechanical and thermal loads and measures the resulting deformations of the structures.

Available loads comprise mechanical loads from external vibrations or air flow, and thermo-mechanical loads from variations of the temperature environment.

Available deformation measurements are non-contact and are based on electrical (capacitive) and optical (laser triangulation, interferometry and photogrammetry) techniques. Where applicable, data is read out at sufficient frequencies to allow for spectral analysis of the structure response up to a few hundred Hz.

A dedicated area has been set up at the University of Oxford to host this facility.

The facility has welcomed its first user group at the beginning of 2019 and we are currently using these structures to develop the full functionality of the facility.

1. INTRODUCTION

The main mechanical requirement for light-weight support structures for future semiconductor tracking systems is positional stability of the sense elements, while material must be minimized. This optimization requires the verification of the stability performance under realistic loads.

Typically these loads are light and the resulting deformations small, requiring very precise position measurements.

The University of Oxford through its long involvement has acquired a wide range of precision survey instruments and experience in using these and the intent of this facility was to make this capabilities available to a wider community.

To assess the needs of the community this activity within the AIDA project was started with a survey of the interests of the community (AIDA 2020 Deliverable 9.5 [1]). From this survey we have identified the following key requirements:

Table 1: Key initial requirements for the structure characterization facility.

Length of structures to be tested	100 cm
Deformation measurement accuracy	Down to 1 µm
Cooling capabilities	CO_2 evaporative cooling
	Gas cooling (air)
Load infrastructure	Shaker table
	Environmental chamber
Other infrastructure	Thermal imaging

2. FACILITY SPACE

The facility is housed in the recently refurbished Heavy Lab area of the Physics Department at the University of Oxford.

3. FACILITY EQUIPMENT

3.1. LOADS

3.1.1. Vibration table

While shaker tables are a standard piece of equipment, the unusually low vibration levels of interest in the typical static environment in particle physics experiments makes standard shaker tables not suited for our purpose. We have therefore built our own light-weight vibration table, driven by a 10” speaker.

To monitor the vibration level of this table we are using MEMS-based accelerometers. The devices we are currently using (ADXL325) have an acceleration noise density of 250 µg/√Hz. In the future we would like to improve this performance. We have identified a more sensitive sensor (LIS344ALH, AND 50 µg/√Hz) and are currently designing an amplifier board for this sensor.

The response of this table is non-linear (the speaker-table combination has a resonance at about 16 Hz), but we have written software to calibrate this non-linearity to achieve a frequency-independent acceleration level.

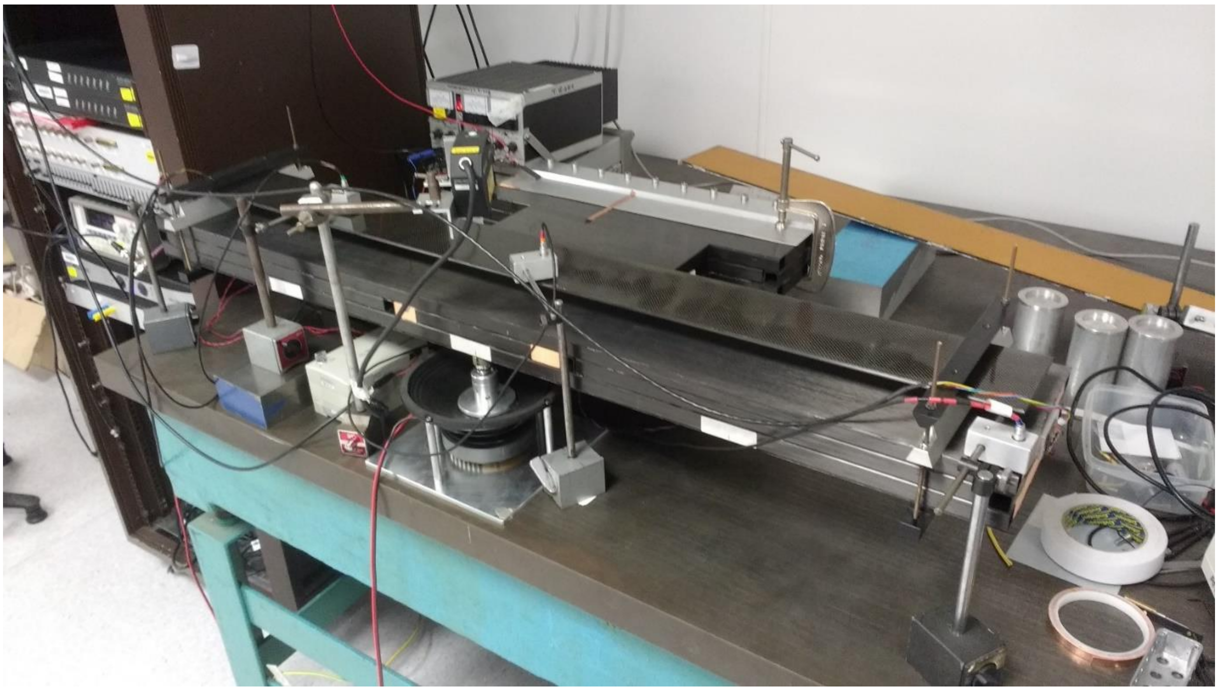

Figure 1: Shaker table with 1 m carbon fibre plank prototype.

3.1.2. Environmental chamber

For the AIDA facility we have procured, on STFC funds, a large thermal chamber (Weiss WVC C1500-70) with a test volume of 1100×1475×950 mm^3. The temperature range is -70°C to +180°C with the humidity controlled between 20%RH to 90%RH above 10°C.

Figure 2: Thermal chamber. Closed (left), open (right).

3.1.3. Air flow cooling system

For this facility we have been constructing an air flow system. Currently this system is partially operational. An air flow with a velocity of up to 6.2 m/s can be provided, but the heat exchanger unit and its instrumentation need to be completed.

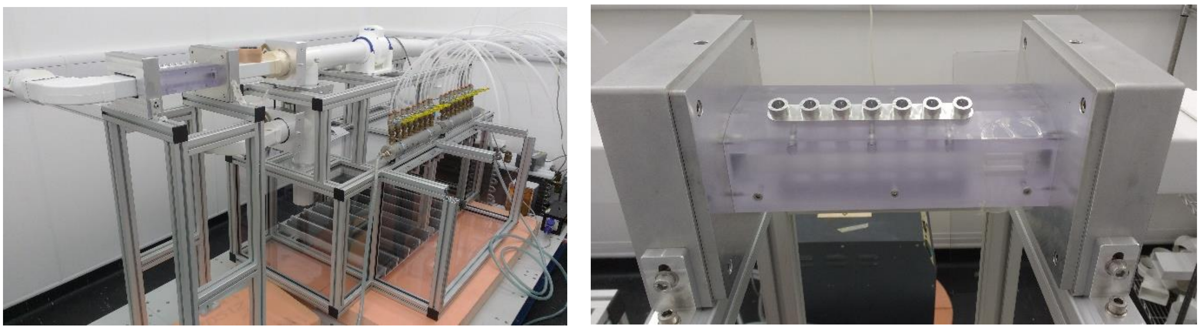

Figure 3: Air flow cooling system. Overview (left), test volume with senor access ports (right).

3.2. SURVEY INSTRUMENTATION

3.2.1. Capacitive displacement sensors

For displacement measurements of conductive surfaces we can use a system of Micro-Epsilon capaNCDT 6100 capacitive sensors with CS1 sensor heads. This system has a resolution of 150 nm over a range of 1 mm. The sensor head has a diameter of 10 mm. Currently we are using four channels of the system for AIDA-related measurements, but we have another eight units in the department.

3.2.2. Laser triangulation

For larger dynamic range we have a laser triangulation sensor (Keyence LK-081), which has a range of ±15 mm and a resolution of about 3 µm.

Figure 4: Displacement sensors. Capacitive sensor head (left), laser triangulation sensor (right). Note laser point on device under test at bottom.

3.2.3. FSI

Frequency Scanning Interferometry is an interferometric distance measurement technique, which allows for absolute distance measurements with an absolute accuracy of 5×10^{-7} m and a scan resolution of approximately 30 nm. We have procured, on STFC funds, a commercial system with currently four lines-of-sight, which can easily be upgraded to more channels. The system uses laser light in the infrared (1550 nm) and can measure distances up to 20 m.

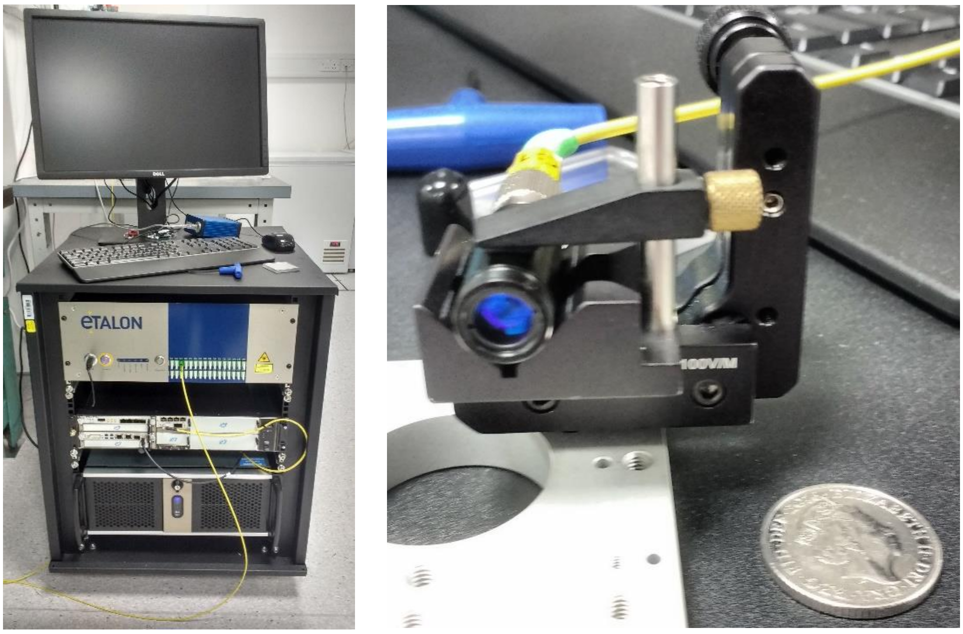

Figure 5: FSI system. Readout unit (left), collimator (right).

3.2.4. Photogrammetry

For the measurement of static deflection of large objects we have a V-STARS/S photogrammetry system. This is a 3D coordinate measurement system that uses a single camera to make fast, accurate measurements. The V-STARS/S system is capable of measurement accuracies better than 5µm + 5µm/m (0.025mm @ 4m).

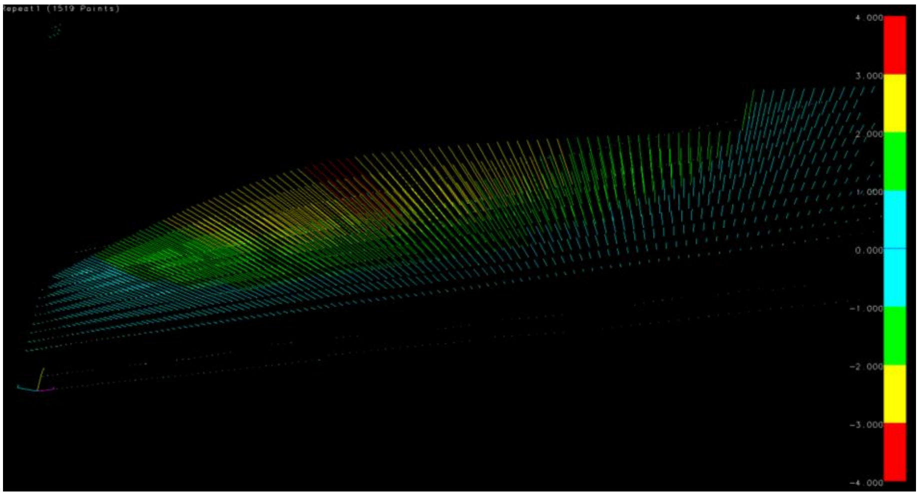

Figure 6: VSTARS survey system: Survey of the deformation of the ATLAS barrel strip staves under a static load at the edge. The stave is 1.2 m long and 12 cm wide.

3.2.5. Readout

We are currently using a 16 channel 12-bit ADC system to read out all data used for correlations and spectral analysis, controlled by Labview via GPIB.

3.2.6. Further equipment

Further equipment for survey and thermal imaging are available, but are not listed in detail, as they have not been used yet as part of the facility.

4. FIRST USE CASE

On February 4th, 2019 the facility has been visited by its first users, a group from the University of Bristol, which wanted to measure the response of detector ladders from the PLUME project [2] to vibrations and air flow. Two mechanical prototypes were supplied, both with silicon sensors and wirebond connections. No FEA had been performed for these ladder designs, so that no information was available on the mechanical performance prior to our measurements.

4.1. STUDIES PERFORMED

One of the two ladders has been tested extensively in the vibration setup. We have identified frequencies for the first three modes from these measurements and studied the mode shapes for these modes (Figure 9 and Figure 10). Further studies are ongoing, investigating different ladder and sensor support methods.

Figure 7: Plume ladders in the vibration setup (left) and in the air flow setup (right, note green/gold circuit board within semi-transparent air channel).

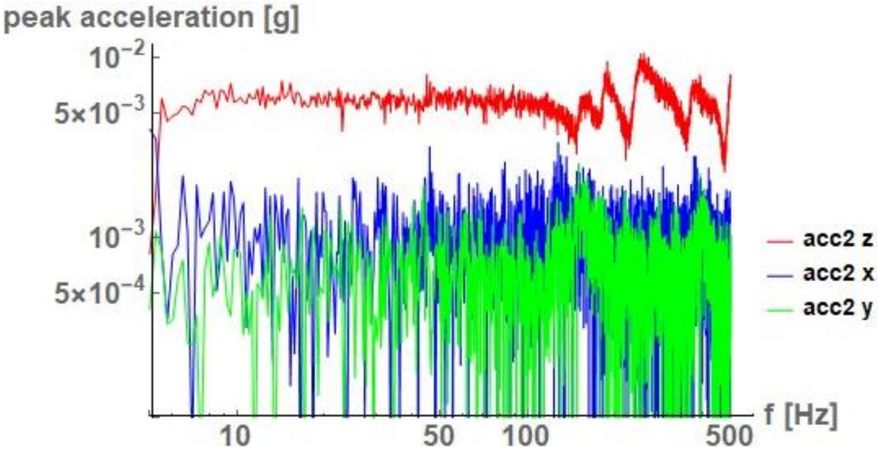

Figure 8: Vibration table acceleration spectrum. The z-direction is perpendicular to the table surface, x and y in this plane (indicative of sensor sensitivity).

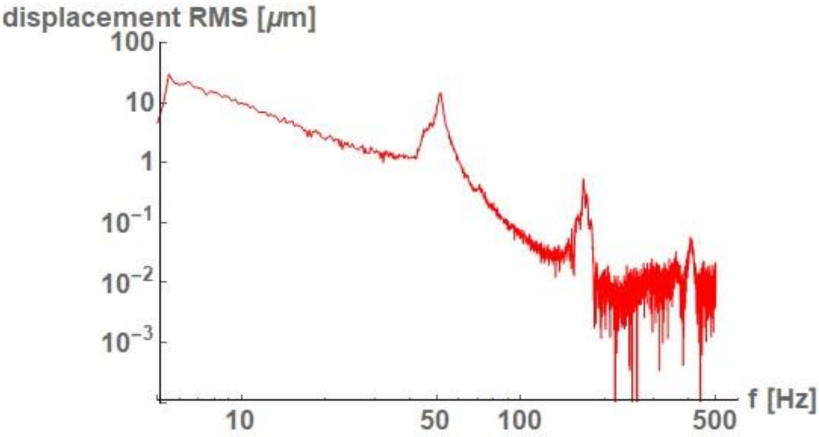

Figure 9: Plume ladder vibration response to the excitation shown in figure 8. Displacement RMS at ladder end, measured with capacitive sensor (left). Note sensitivity down to 10 nm. Three resonances can be identified (at 51.5, 170 and 408 Hz).

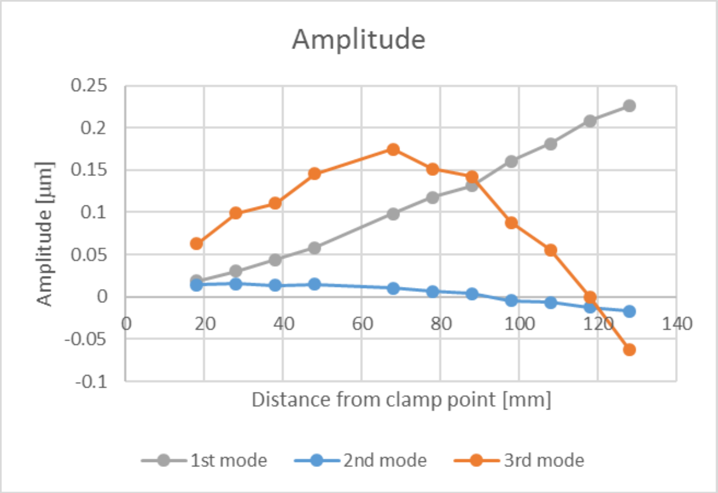

Figure 10: Mode shapes for the first three modes of the PLUME ladder.

The other ladder has been placed into the air flow setup. Installation in the prepared holder was successful. However, when we attempted to measure the deformation using the FSI system we realized that silicon, being transparent in the infrared, is not a suitable reflective surface. Two solutions will be pursued: First, we will try to stick a small mirror onto small non-silicon surface areas. Because of the small exposed areas this needs to be carefully done. Second, we plan to use the laser triangulation sensor, but this requires production of new adapter parts for the setup.

4.2. LESSONS LEARNED

One of the lessons learned from these prototypes is that the measurement of the position of silicon surfaces poses unexpected problems. The difficulties to get a useful reflection for the FSI system has been mentioned above, but even with the capacitive systems there have been issues, where we have learned that even though a measurement with one sensor works perfectly well, several sensors facing the silicon sensors along the ladder influence each other, producing low frequency noise at the level of up to 100 µm. Such an inter-sensor effect has not been observed before with other materials.

5. FUTURE PLANS

In the near future we will continue the studies of the PLUME ladders as discussed above. We will also complete the air flow system, so that we can study cooling performance as well. On a longer timescale we want to perform measurements for other international users.

REFERENCES

[1] Viehhauser, G. (2016) *Advanced Mechanical Distributed Facility requirements*, AIDA-2020-D9.5, http://cds.cern.ch/record/2205793.

[2] PLUME Collaboration, A. Nomerotski et al., *PLUME collaboration: ultra-light ladders for linear collider vertex detector*, Nucl. Instr. Meth. A650 (2011) 208-212.

ANNEX: GLOSSARY

Acronym	**Definition**
ADC	Analogue-to-Digital Converter
FEA	Finite Element Analysis
FSI	Frequency Scanning Interferometry
GPIB	General Purpose Interface Bus (IEEE 488)
MEMS	Micro-Electro-Mechanical Systems
PLUME	Pixelated Ladder with Ultra-Low Material Embedding