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Advanced European Infrastructures for Detectors at Accelerators

Milestone Report

Commissioning of Fibre Test benches

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MILESTONE REPORT

COMMISSIONING OF FIBRE TEST BENCHES

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Abstract:

For measurements of scintillating fibres, several test benches have been developed and commissioned within WP14 Task14.2.1, such as set-ups for attenuation length measurements, a test bench for the investigation of timing properties, and mechanical and data acquisition tools for studying the performance of scintillating fibres using high energy particles in beam tests. A high-level overview of the different setups is given in this document.

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

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Delivery Slip

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Executive summary

For the measurement of different properties of scintillating fibres, several test benches have been developed and commissioned within WP14 Task14.2.1. These include set-ups for attenuation length measurements, a test bench for the investigation of timing properties, and mechanical and data acquisition tools for studying the performance of scintillating fibres using high-energy particles. The test benches are operational, and have been used for first measurements.

1. INTRODUCTION

An essential part of the activities in WP14 is the development and construction of test infrastructures for calorimeter elements to support the R&D activities in the area of calorimetry for current and future collider detectors. Task 14.2 focuses on calorimeters with optical readout and is subdivided in two subtasks, subtask 14.2.1: *"Test benches for characterisation of organic and inorganic scintillator fibres for future calorimetry"* and subtask 14.2.2: *"Test Benches for the Characterisation of highly granular Calorimeter Elements with Scintillator and SiPM Readout"*.

In the frame of subtask 14.2.1, several test setups have been developed for the characterisation and performance study of different types of fibres (heavy crystal fibres and light fibres based on SiO_2).

- Attenuation length measurement benches at CERN at UNIMIB
- Uniformity measurement bench at ETHZ
- Pump and probe setup for timing properties investigation at Vilnius
- Test stand for the evaluation of light attenuation variation during irradiation at Brunel
- Co^{60} irradiation bench at CERN
- A setup to study SiO_2:Ce fibres as wavelength-shifters by ETHZ
- An absorber made of 0.75W/0.25Cu to evaluate the calorimetric performance of scintillating fibres
- A data acquisition system for high energy beam tests set-up

These different test benches provide an infrastructure for the in-depth investigation of optical and radiation hardness properties of all types of scintillating fibres as well as their test in a calorimeter prototype. In the following section a short description of these benches will be given. For a more detailed description of the individual setups refer to [1].

2. OPTICAL CHARACTERISATION: LIGHT ATTENUATION TEST BENCH

Several complementary optical characterization benches have been setting up and commissioned at different participating institutes, summarised in the following.

2.1. @CERN

In order to quantify the optical quality of the fibres and measure the propagation of the light along them, a setup to measure the light attenuation has been built at CERN. It is based on a double-sided readout with two PMTs (see Fig.1). The sample to be measured is hold with two V-shaped mechanical supports. This makes sure to minimize the contact points when measuring the samples with no cladding/wrapping. Direct coupling with no optical coupling media (dry contact) is used as standard measurement since this minimizes the measurement error. The sample is excited with a light source of wavelength chosen to match one of the excitation bands of the scintillating material.

2.2. @UNIMIB

In order to quantify the optical absorption of (scintillating) optical fibres a setup has been developed at UniMIB.

The measurement system is composed of a Perkin Elmer Lambda 950 double beam spectrometer equipped with an accessory (see Fig.2), which is able to inject and collect light into, and from, suitably designed optical fibres. The spectrometer is by itself able to cover the entire spectral range from 190 to 3300 nm (from UV to near infrared) with a maximum photometric range of the order of 6 absorbances. The accessory for fibre measurements is composed of two curved mirrors and two lenses to focus the light beam on the fibre core and match the numerical aperture of the fibres with that of the instrument.

2.3. @ETHZ

A laboratory test bench has been set up and commissioned for the measurement of the signal uniformity of scintillating fibres along their length (Fig. 3). The bench has been commissioned by measuring the light uniformity response of scintillating fibres with and without aluminisation at the end opposite to the photodetector. A ^{90}Sr source is used for the excitation of the fibres. Measurements show that, while uniformity is only slightly affected and remains within the 5% of the measurement accuracy, the aluminisation allows collecting 25% more signal.

3. PUMP AND PROBE TEST BENCH @VILNIUS

The test bench for pump and probe studies (TBPP) is dedicated to monitor the dynamics of i) two–photon absorption, ii) population of photo-excited states, and iii) free carrier absorption in scintillation materials. The TBPP is based on the Yb:KGW femtosecond laser PHAROS emitting 200 fs pulses at 1030 nm (200 μJ pulse energy, 30 kHz repetition rate). The output of the laser is split into two parts and used to pump two optical parametric amplifiers (OPA) "Orpheus" providing 200 fs pulses continuously tuneable between 630–2600 nm (the range can be extended down to 315 nm by frequency doubling). Fixed harmonics of fundamental PHAROS radiation (2nd – 515 nm, 3rd – 343 nm, 4th – 257 nm) can also be used for photoexcitation. The samples under study are probed either by the output of one of the OPA or by a white-light-supercontinuum (spectral range 410–800 nm) generated in a sapphire plate. The delay between pump and probe is varied optomechanically, the time resolution of the system is limited at 200 fs by laser pulse duration (see Fig. **4** and 5).

4. TEST STAND FOR EVALUATION OF LIGHT ATTENUATION VARIATION DURING IRRADIATION @ BRUNEL.

A fibre test stand to enable the determination of real-time degradation of transparency in optically transparent fibres during irradiation has been designed and is being commissioned at Brunel University London. Real-time measurement of what could be fairly short-lived colour centres is potentially important for an understanding of issues relating to particular scintillating or wave-length-shifting fibres that are considered for use in new designs of calorimeters with optical readout.

Since the radiation is produced by a high-intensity ^{60}Co source which will rapidly damage any electronic systems within the irradiation encoluse, a test stand has been designed based on a remote light source and spectrometer. Due to the chicanes in the shielding these need to be located at least 20 m from the radioactive source during exposure. This is achieved with a fibre-coupled light source and a fibre-coupled UV-visible spectrometer. These instruments are then connected by 20 m long pure-silica core step-index fibres to the test stand itself (see Fig.6).

5. CO^{60} IRRADIATION BENCH @ CERN

In order to study the radiation hardness of the samples, a secured ^{60}Co source of high activity (2.5 GBq) is available at the CERN group laboratory (see Fig.7). Samples can be exposed to the gamma rays at a rate of ~1 Gy/day.

Access to a ^{60}Co source allowing higher dose rate (500Gy/h) near CERN is also available for AIDA-2020 project as well as the PS proton irradiation facility, IRRAD, at CERN. These irradiation facilities will allow evaluating the radiation behaviour of the investigated materials at the radiation level required in future high-energy experiments.

6. AN ABSORBER MADE OF 0.75W/0.25CU TO EVALUATE THE CALORIMETRIC PERFORMANCE OF SCINTILLATING FIBRES

In order to evaluate the energy resolution of a fibre based calorimeter in high-energy particle beams, a dedicated prototype has been built in a configuration where the fibres are pointing to the beam, commonly referred to as SPACAL.

The setup is composed of an absorber made of 40 plates of 0.75W/0.25Cu with grooves of 1.1x1.1mm^2 (see Fig.8 left). The plates are stacked together and fixed by two stainless steel plates at the top and bottom of the module. The absorber contains a total of 1200 holes and has an overall dimension of 60x60x200mm^3. The dimension has been defined in order to achieve full energy containment of electromagnetic showers with an energy of up to ~200 GeV for scintillating and/or Cerenkov fibres of density between 2.7 and 7.3 g/cm^3.

The light produced by a group of 11x11 fibres is readout simultaneously with a photodetector (PMT or SiPM) optically coupled to the end of fibres through an optical light guide in order to increase the light collection and reduce the channel counts (See Fig.8 right). The module consists thus of a 3x3 channel array, where each channel is about the width of one Moliere radius and contains 80%-90% of the shower. If needed the read-out granularity can be increased by developing a new system of light guides and by increasing the number of photodetectors.

7. A DATA ACQUISITION SYSTEM FOR HIGH-ENERGY BEAM TESTS

A data acquisition for high-energy beam test setups has been developed, commissioned and maintained under the responsibility of one postdoctoral researcher (F. Micheli, ETHZ), who has been hired through AIDA-2020 for this purpose. It has been used for the tests performed in 2015 in the H4 beam line at the CERN SPS accelerator.

The DAQ system allows to read out and reconstruct the information provided by the wire chambers and hodoscopes positioned along the beam line and thus to associate the particle impact point to each event. The software is also configurable to read-out the information from a multi-channel ADC and from a CAENV1742 5Gs/s digitizer with 32 channels capable to provide detailed sampling of pulse shapes and excellent time resolution. The DAQ system is synchronized with the beam signal provided by the synchrotron facility (e.g. PS or SPS) and requires a trigger which can be provided by standard scintillators.

The software also includes tools for data quality monitoring (DQM) which produce a quick analysis of the data to monitor the beam intensity, position, etc. and a user interface GUI to control both the DAQ and DQM.

All software is available via github and can be downloaded and reproduced on multiple machines with small changes in configuration files:

https://github.com/cmsromadaq/H4DAQ

https://github.com/cmsromadaq/H4DQM

https://github.com/cmsromadaq/H4GUI

8. CONCLUSION

In the last two years several complementary test stands have been produced and commissioned in different institutes to characterize the optical, the radiation hardness and the performance under high-energy particle beam. These different infrastructures are now available to test any type of fibres. During this first period of the project, the various test stands developed have already been used to characterize several types of crystals and quartz fibers to investigate fast timing processes and to evaluate the performance with high energy beam. Examples of these measurements are given in [1]. These characterization will be further pursued in the next years.

9. REFERENCES

[1] Auffray E et al. (2017)
Fibre test benches for the characterisation of media for calorimeters with optimal readout
AIDA-2020-NOTE-2017-004A

[2] Smith D R, Hobson P R (2016)
Spectrometer Testing: Dark frame evaluation of StellarNet Black Comet spectrometer,
Brunel_Spectrometer_Testing_TN_001.01, http://bura.brunel.ac.uk/handle/2438/14089

Figures of several benches developed and commissioned

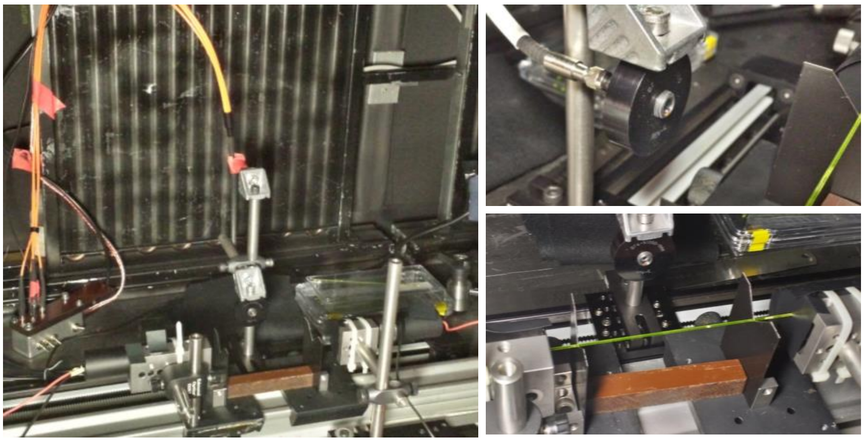

Fig. 1. *Setup for the measurement of the attenuation curves of the fibre-shaped samples equipped with a multi-wavelength LED pulser. The light is first coupled to optical fibres to bring the excitation light close to the samples with a collimator.*

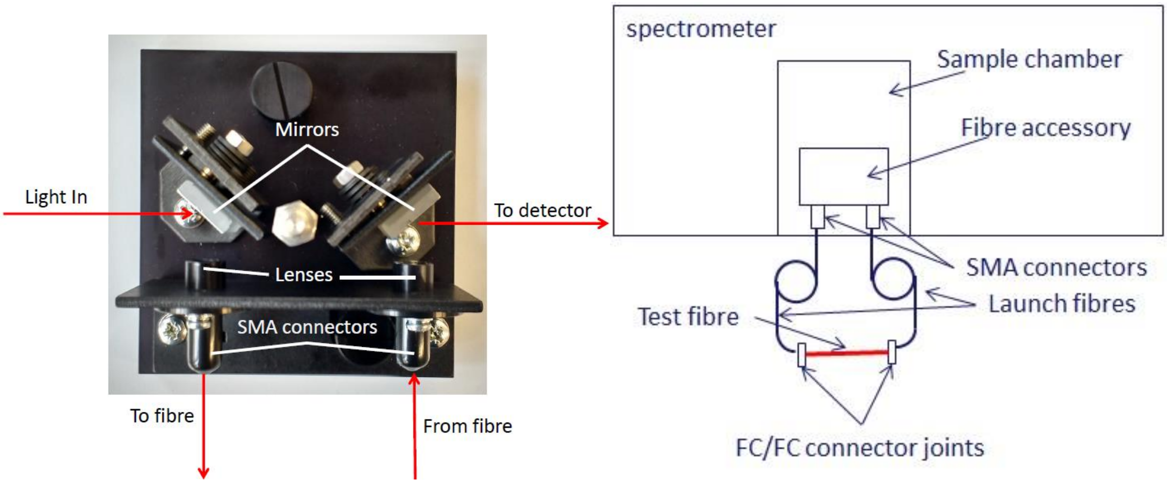

Fig. 2. *Left panel: picture of the Perkin Elmer accessory for optical absorption measurements on optical fibres. Red arrows, optical path. Top cover removed. Right panel: scheme of the complete spectrophotometer system.*

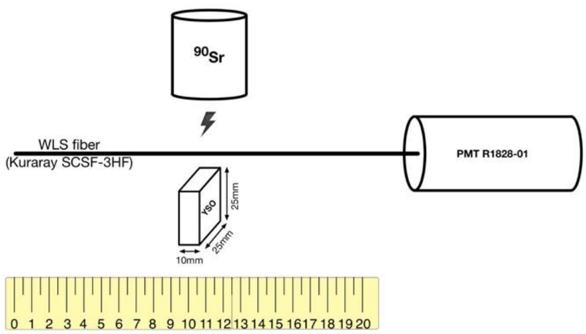

Fig. 3. *Schematics of the laboratory setup developed for fibre uniformity measurements*

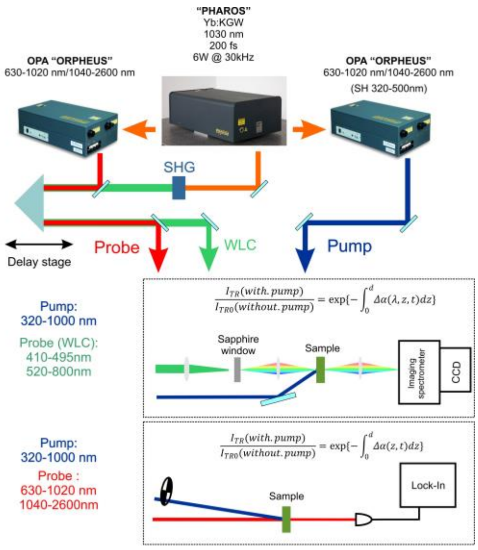

Fig. 4. *Schematic outline of pump and probe configurations*

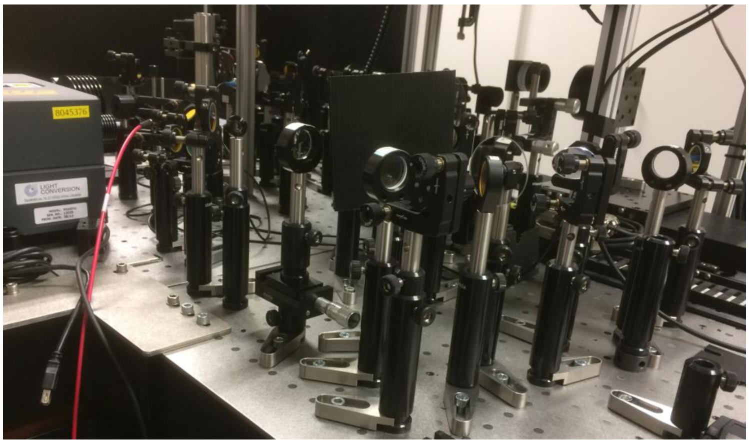

Fig. 5. *Test bench for pump and probe study*

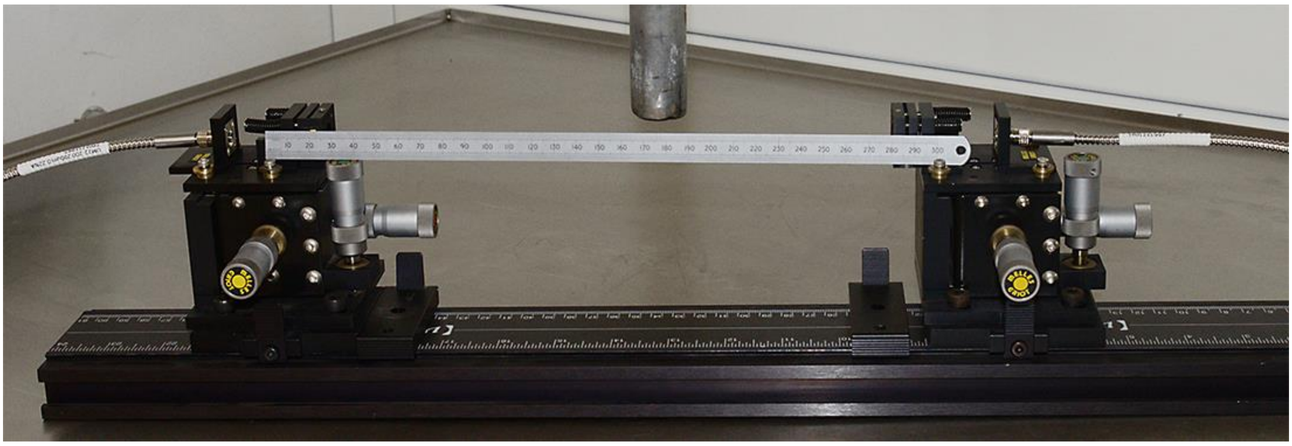

Fig. 6. *Fibre test bench. The two optical fibres, connecting the remote spectrometer and light source respectively, come from left and right and light is focussed onto the fibre under test by silica lenses located within the precision manual x-y-z stages. The* ^{60}*Co radioactive source, when exposed, is located at the bottom of the steel tube seen in the centre of this photograph. The fibre under test is placed in a holder (not shown) located in the gap between the stages.*

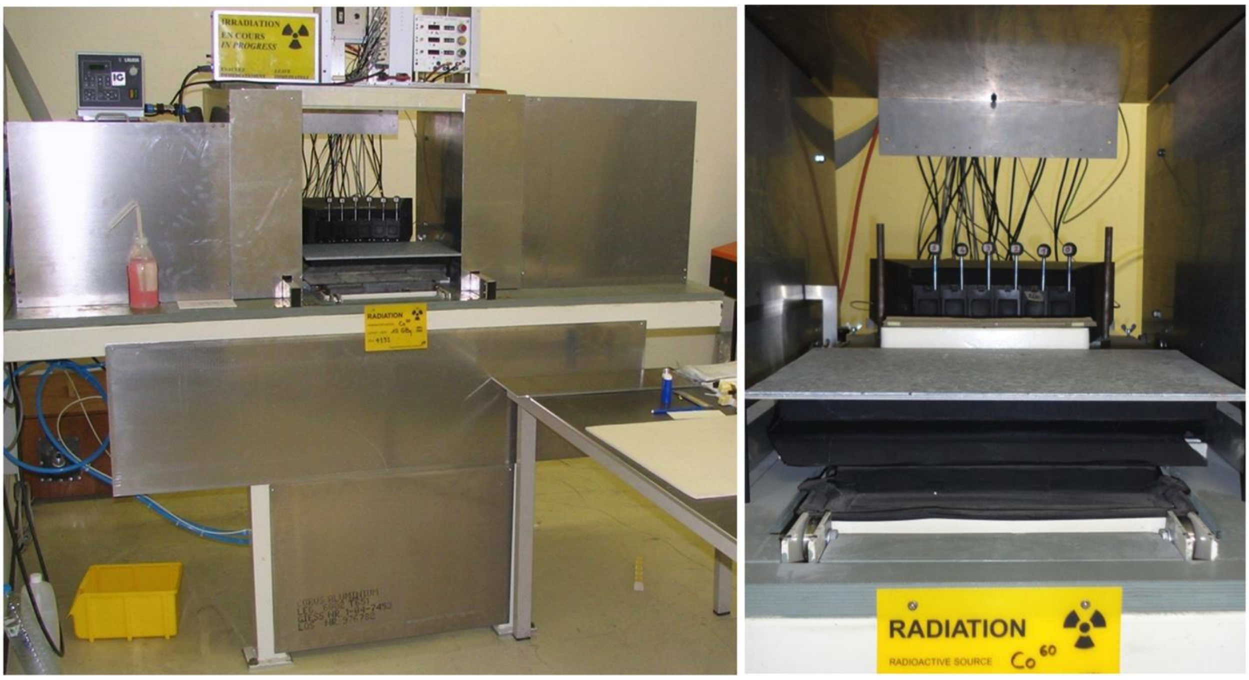

Fig. 7. *Pictures of the ^{60}Co radioactive source used for studies of radiation hardness.*

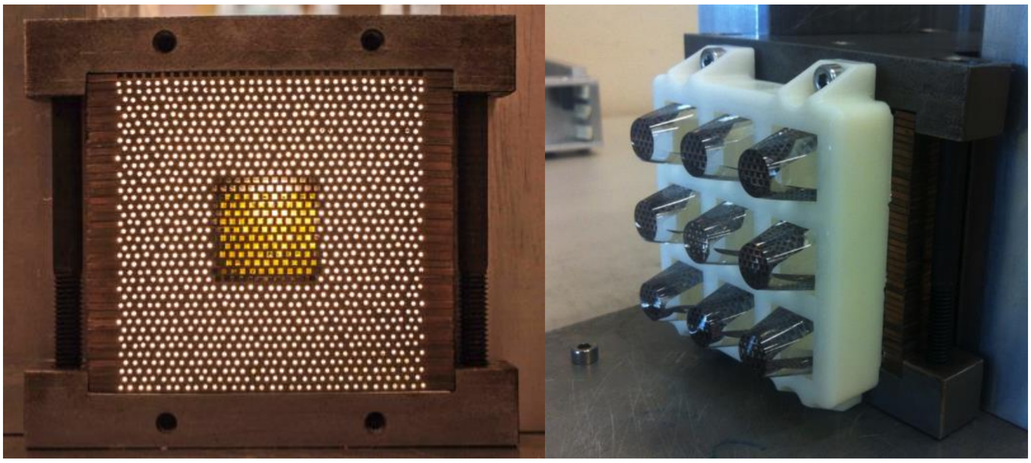

Fig. 8. *Left: completed absorber made of 40 plates, right: Light guide at the end of the fibres*