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COMMISSIONING OF THE SEM-GRID MONITORS FOR ELENA

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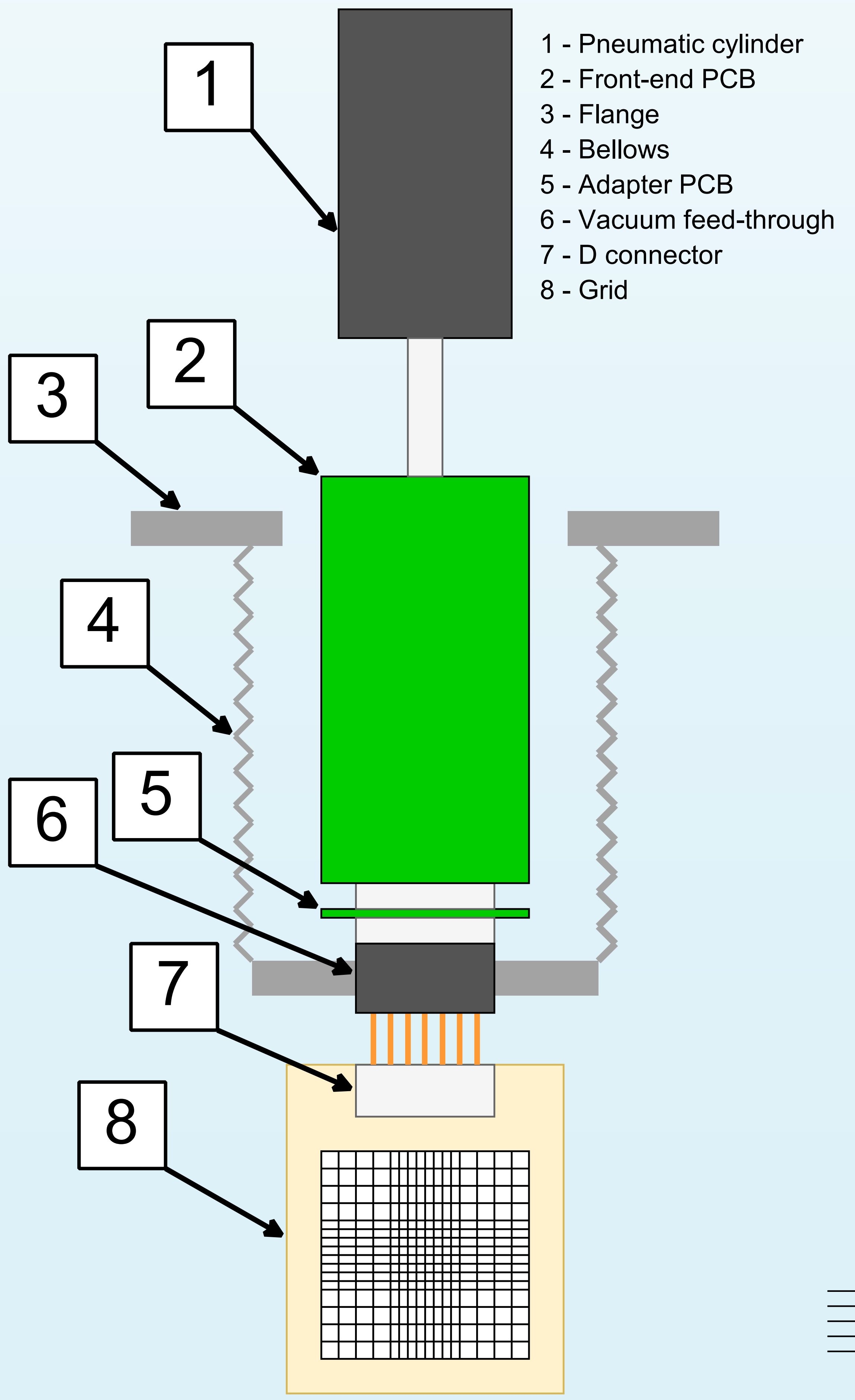
Abstract

The Extra Low ENergy Antiproton ring (ELENA) is a compact ring for the further deceleration and cooling of the 5.3 MeV antiprotons delivered by the CERN Antiproton Decelerator. It decelerates antiprotons to a minimum energy of 100 keV, creating special challenges for the beam instrumentation. These challenges have been addressed by an extremely sensitive SEM-Grid (Secondary Emission Monitor) monitor which is also compatible with the Ultra High Vacuum (UHV) requirements of ELENA. Since November 2019, ELENA's H^- ion source has been used to test the SEM-Grid monitors and, since July 2020, the monitors have been used to commission the ELENA transfer lines. In this paper, a summary of the features of the SEM-Grid will be given together with an overview of its commissioning activities. An ingenious technique for testing the integrity of the grid wires which are not directly accessible will also be described.

Mechanics



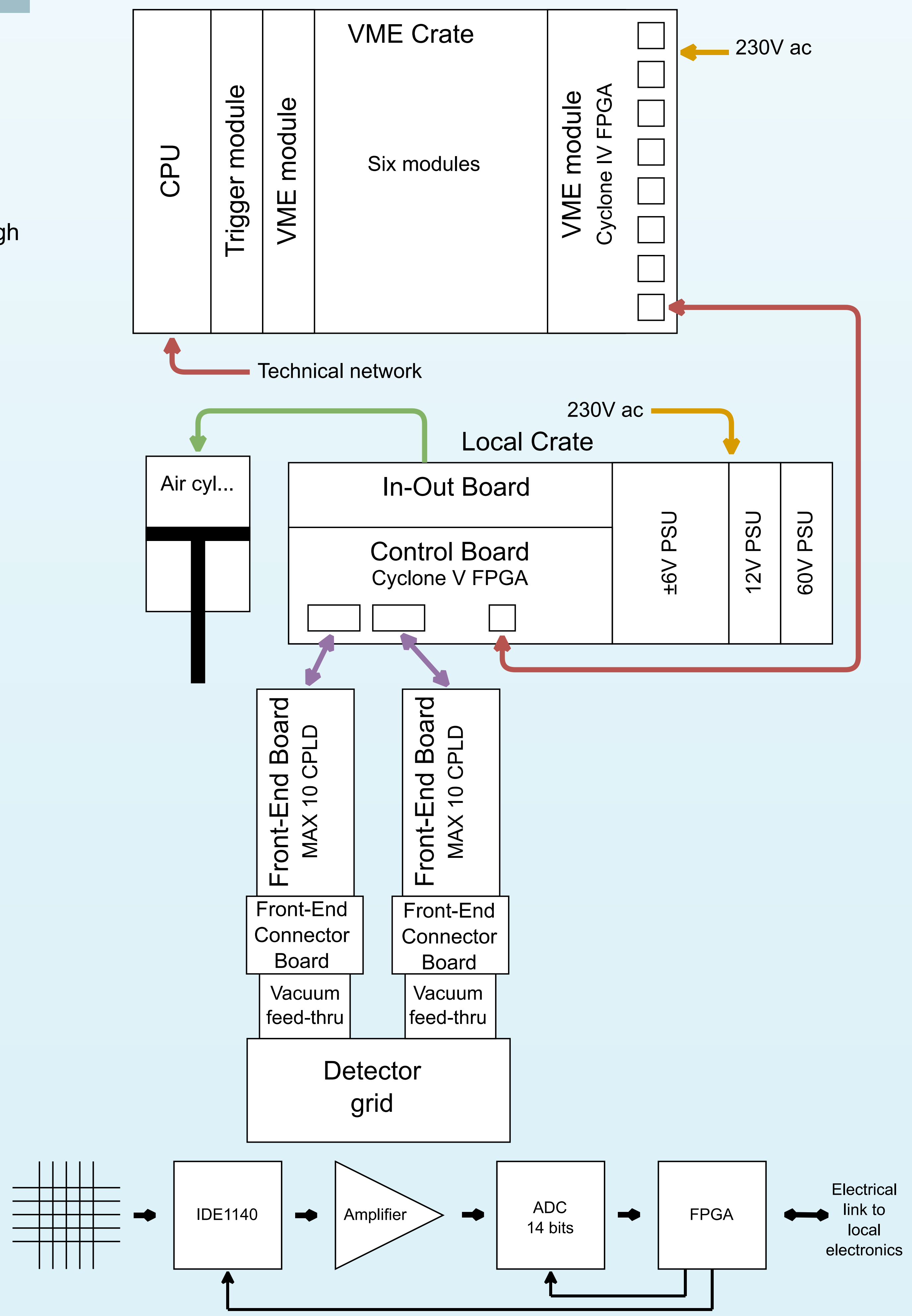
1 - Pneumatic cylinder
2 - Front-end PCB
3 - Flange
4 - Bellows
5 - Adapter PCB
6 - Vacuum feed-through
7 - D connector
8 - Grid

Introduction

ELENA is a small synchrotron of 30.4 m circumference constructed recently at CERN and sketched in Fig. 1. The purpose of the machine is to decelerate antiprotons coming from the Antiproton Decelerator at 5.3 MeV beam energy down to 100 keV. Multiple branching electrostatic transfer lines lead to the experimental zones. All the transfer lines are equipped with multiple SEM-Grid Profile Monitors to enable accurate and automated steering of the beam.

These monitors and electronics were initially developed by the ASACUSA collaboration based on an earlier design used in the radiofrequency quadrupole decelerator facility, and then productionised, assembled, installed, and commissioned by CERN. Numerous issues were resolved during this process. The monitors were installed to observe protons, antiprotons and H^- ions with energies in the range 100 keV to 5.3 MeV.

Electronics



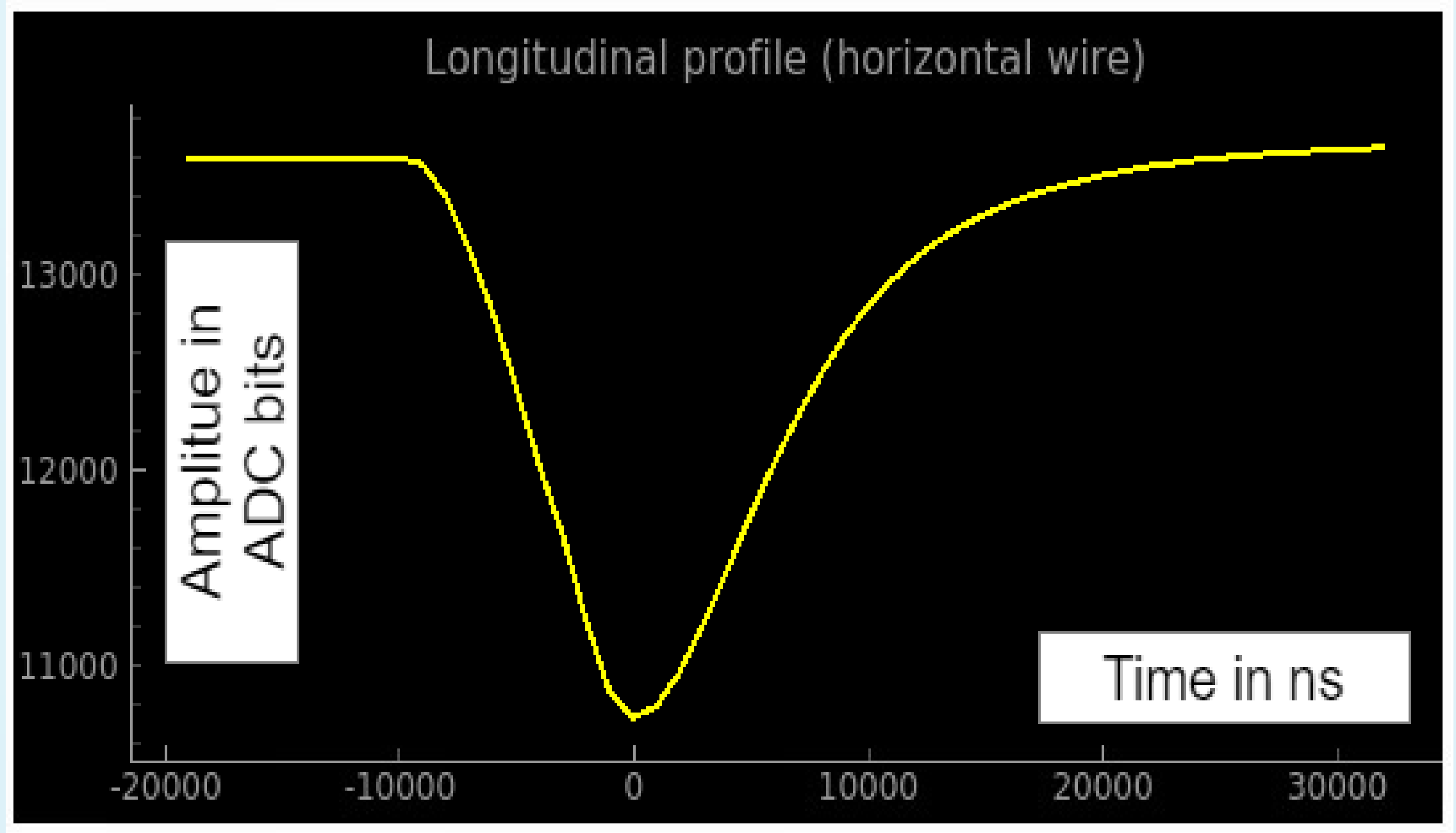
Sensitivity

With the H^- source configured to produce small, low-energy bunches, a typical bunch contains about 5×10^6 particles. The sense wires are Ø20 µm on a 500 µm pitch, so 4% of the beam hits a sense wire of each plane. A well focused beam has a diameter of 5 mm and so hits about ten wires. Therefore there are about 20,000 beam interactions per wire. A proton of energy E = 100 keV striking the Au surface of a sense wire is expected to liberate around 2 secondary electrons, which provides a total charge of approximately 6 fC for 20,000 protons. The ASIC noise is about 0.06 fC and the amplifier and ADC do not add significantly to this. Therefore the expected signal-to-noise ratio is of order 100:1, which correlates well to what has been observed. Tests indicate a similar sensitivity between H^- ions and antiprotons, but the mechanisms by which electrons are liberated in the antiproton case are not fully understood. Besides the contributions from charged pions and nuclear fragments that emerge from antiproton annihilations, there are expected to be some Auger electrons.

There is an offset in the measured signal from each wire, but this offset is stable and the acquisition software records it in the absence of beam and then subtracts it from subsequent readings.

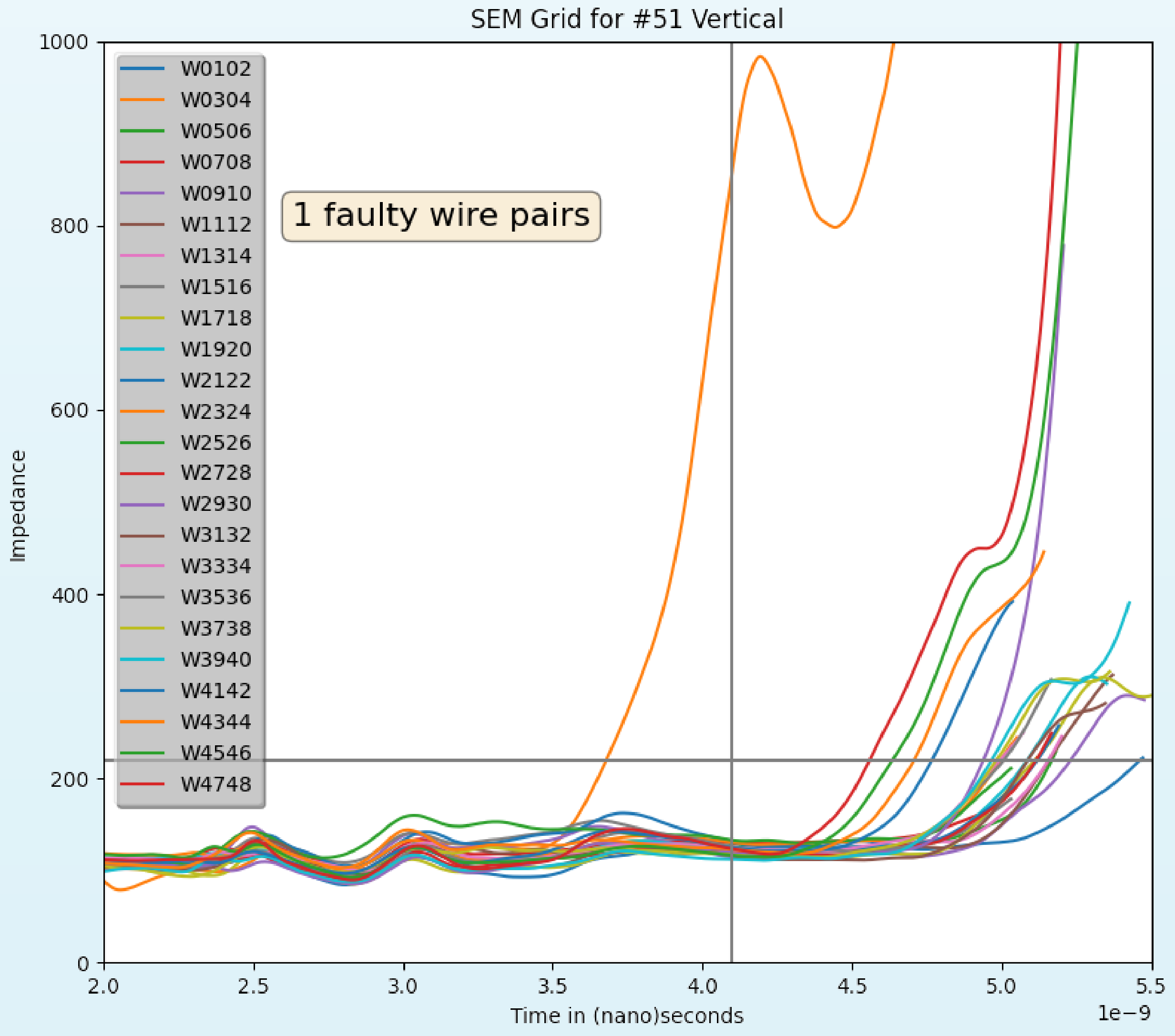
Triggering

Timing of the acquisition to better than 500 ns is essential to obtaining a good and repeatable beam profile. Triggers are provided from the H^- source, the injection from the AD, and the two extraction kickers. Once the beam has circulated in ELENA it is split into four bunches. For each monitor, the trigger source and target bunch number can be selected, and there is a programmable delay after which the sample-and-hold circuits of the ASIC are triggered. To tune the delay, a longitudinal acquisition mode is provided in which a single grid wire is sampled continuously at up to 10 MHz. When the results are displayed it is easy to see any adjustment that may be needed to the timing. The figure below shows a correctly adjusted delay with the signal peak aligned to time 0. During operation, different bunches may be sent to different transfer lines, so the beam server software updates the bunch number at the start of each cycle.



Time Domain Reflectometry (TDR) Testing of Sensor Wires

One of the recurring challenges during the installation of the SEM-Grids was to verify the condition of the grids when it was not possible to send beam to the monitor. For example, many monitors were installed before the source and ion-switch were fully operational. It was also helpful to be able to verify the grid before the installation of the monitor. In collaboration with our colleagues in the Beam Position Monitoring section we used a handheld Radio-Frequency Analyser (the Agilent Fieldfox N9917A) to measure the impedance along an adjacent pair of sensor wires. This was facilitated by a specially designed PCB which routed the sensor wires in pairs from the vacuum feed-through to a matrix of SMA connectors. The impedance of the connection to each pair of sensor wires was then controlled and repeatable. The RF Analyser transmitted a signal at a rapidly swept frequency into the pair of wires, and analysed the echoes returned from each change of impedance. Thus it was possible to compare the impedance of a grid under test with a "known good" grid and easily detect any anomalies in the sensor wire impedance, even for a grid which was installed and under vacuum. This technique could not determine which of the pair of wires was faulty, but it provides a report of how many pairs were faulty. The figure below shows an example of data from a grid with a single faulty pair. The early increase of impedance of the orange line is clearly visible.



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