Using the EUDET pixel telescope for continuing studies of silicon strip sensors with integrated pitch adapter

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On behalf of the SiLC Collaboration

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1. Introduction

The SiLC collaboration is pursuing research towards a new generation of silicon tracking devices for possible uses in future projects like the International Linear Collider (ILC). The core activities include new developments in silicon sensors, readout chips, mechanics and system integration, complemented by simulation.
To continue the effort of the collaboration to develop novel silicon strip sensors with on-sensor pitch adapters, a test beam at CERN will be performed between 27th of September and 11th October 2010. Similar sensors, like the ones that have been developed in 2009 and which have been partially tested during a previous beam test already will be subject to test. A second version of the sensors will be produced which are currently being processed and which are finished in beginning of August this year.
The EUDET pixel telescope will be used for tracking and triggering proposes. Four participants from Vienna will participate in the beam test for which we would like to apply for reimbursement.

2. Motivation

For any ILC experiment, material budget is a crucial point for its inner detectors. Therefore, different approaches to minimize the material budget are under investigation by the SiLC collaboration. One possibility is the material reduction of each detector module. To archive this, the different discrete components like pitch adapter and front-end hybrid must to be integrated directly into the silicon sensor.

A conventional module consists of a carrier structure supporting the silicon sensor, a pitch adapter and the front-end hybrid. As an intermediate step, we developed silicon sensors with an integrated fan-out, making an independent pitch adapter obsolete. Different layouts and concepts were designed and have been produced by the silicon foundry at ITE Warsaw (Poland) in 2009.
The different layouts of these new silicon sensors are compiled such that all of them fit onto a single 4” wafer, which reduces the mask and setup costs to a minimum. A drawing of the full wafer and some of the actual produced sensors is shown in figure 1.

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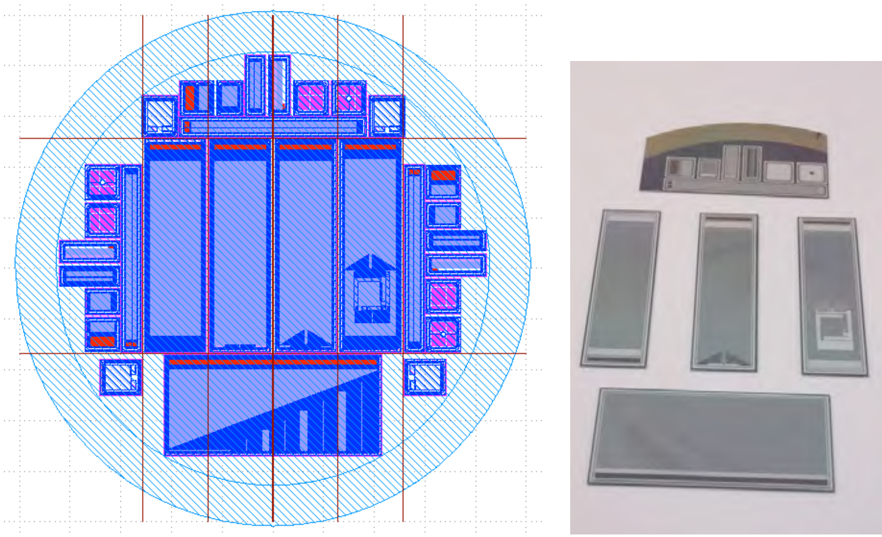

Figure 1: Layout of the full 4" wafer with five main sensors surrounded by test structures (left) and pictures of the actual processed devices.

This wafer houses five large sensors. Four of them have the same outer dimensions with 128 AC-coupled readout strips, while the fifth contains 512 strips. A set of different test structures, replicated three times, surrounds them. The sensors with 128 channels are called STD, PAS and PAD, respectively, depending on their configuration of the second metal layer for signal routing. All devices have been described in the request for the EUDET telescope in 2009.
Unfortunately, we discovered during analysis of last years test beam data (see EUDET memo 2009-18) that not all of the sensors were fully working. In fact, the most interesting sensors with double metal layer ("PAD") were suffering from many dead channels, which must have been produced during module assembly or wire bonding, respectively. Therefore, there is no clear result on the performance of these sensors.
Therefore, we want to continue the effort from last year and re-do some of our measurements with newly fabricated modules coming from a second production lot of the sensors from ITE. The sensors are currently being processed at the fab from ITE in Warsaw and will be available by beginning of August.

3. Modules

We have already assembled a total number of nine modules with the sensors described in the previous section by using a frame of Isoval-11, which is a glass-cloth impregnated epoxy laminate, together with a printed circuit board (PCB) housing the APV25 readout chips. Each of those chips can be used to read out 128 strips of the sensor. For the newly produced PAD sensors, the same layout of the frame and the hybrid will be used.
Figure 2 shows a rendering how such a module will look like and figure 3 a picture of the PCB already equipped with two readout chips and other electronics.

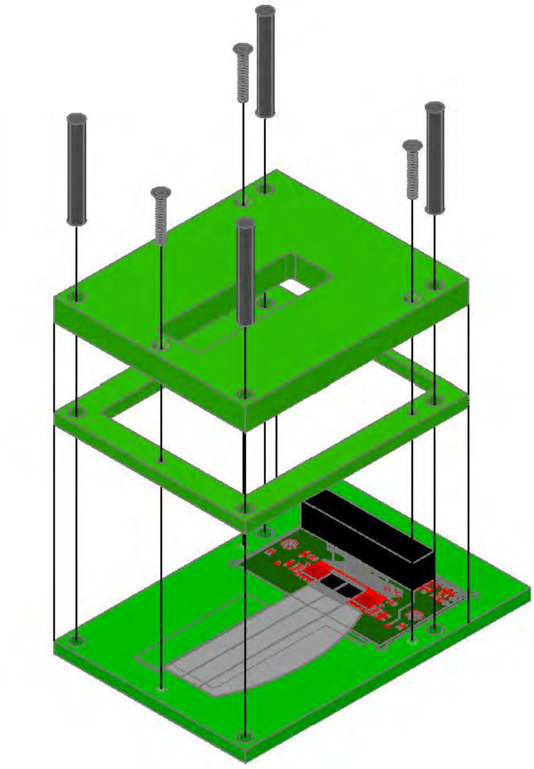

Figure 2: CAD drawing of module assembly

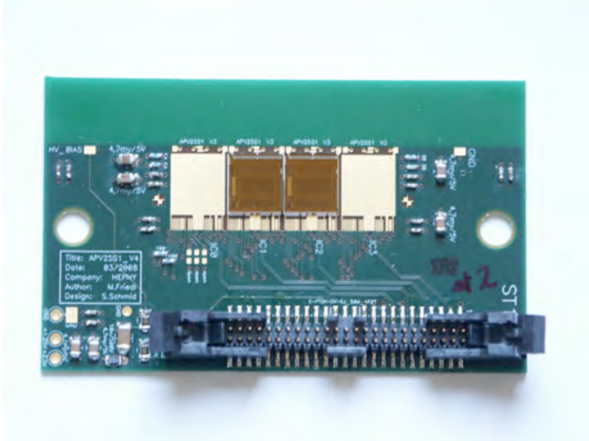

Figure 3: Front-end Hybrid

We have assembled modules with the following sensors:

- Two standard sensors without any integrated routing (“STD”)
- Two sensors where there are routing lines in the first (readout) metal (“PAS”). A picture of one of the modules can be seen in figure 4.
- Two sensors with routing in a dedicated second metal layer (“PAD”)
- Three sensors with 512 strips and two metal layers (see figure 5)

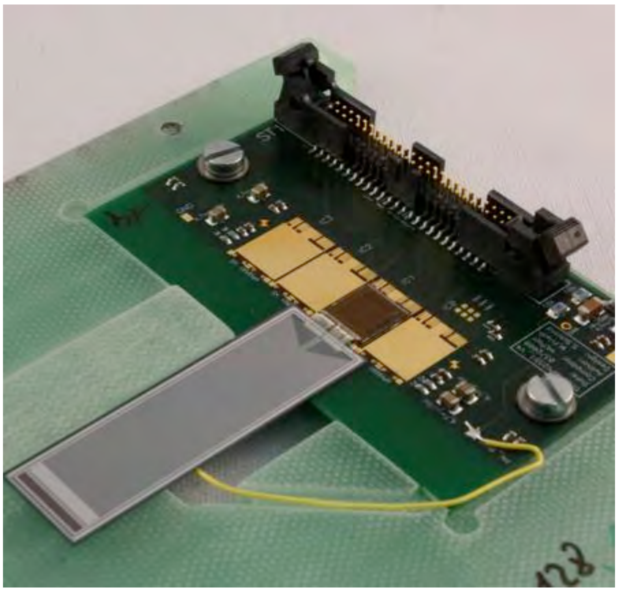

Figure 4: PAS sensor connected to front-end hybrid equipped with a single APV25 readout chip

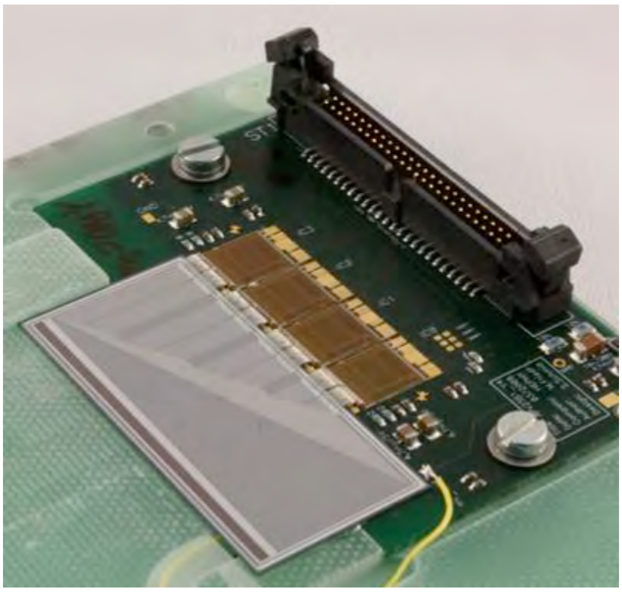

Figure 5: 512-strip-sensor connected to front-end hybrid equipped with four APV25 readout chips

Since the design of these modules has already be performed last year and the outer dimensions are fully identical to the first lot, it will be rather fast to assembly new modules with sensors from the second production lot.

All modules will be assembled into a stack to be installed in the centre of the EUDET telescope to perform track reconstruction (see figure 6)

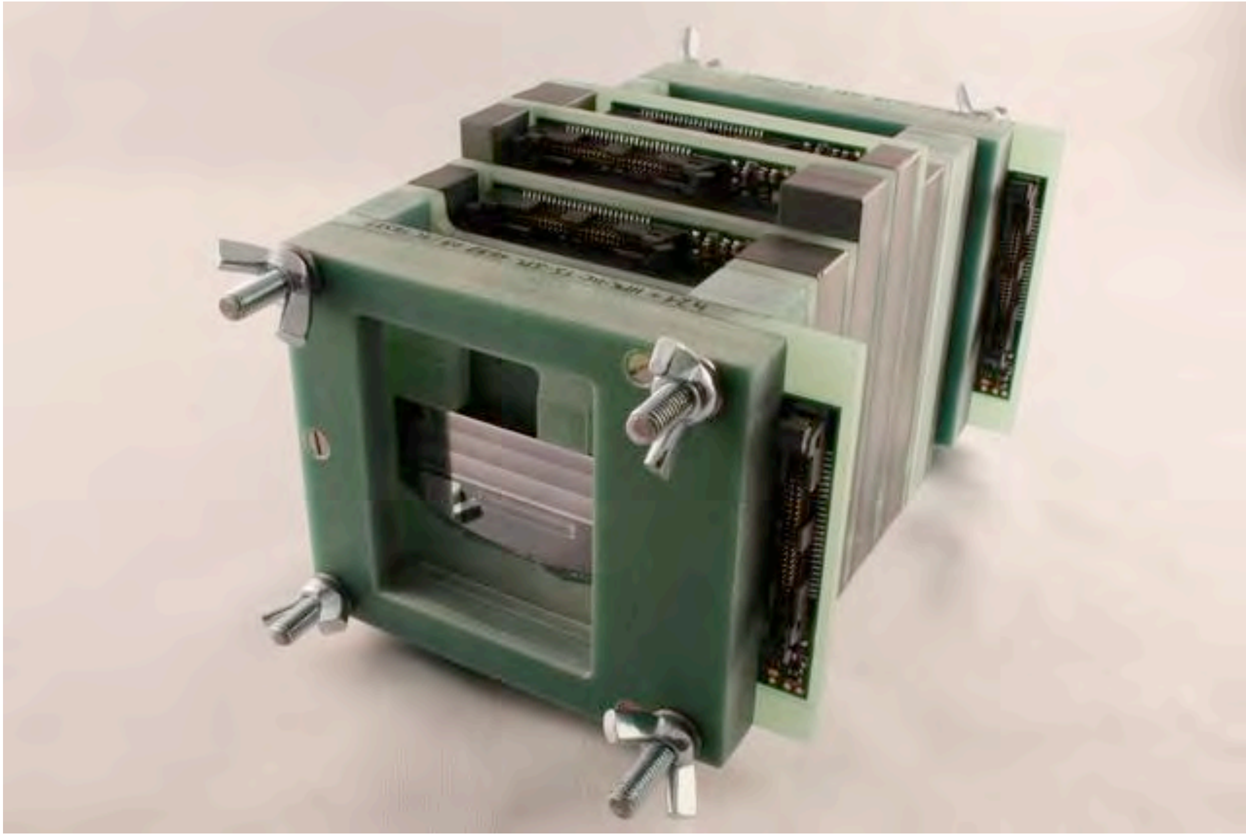

Figure 6: Stack of modules as being installed during the beam test. The first and the last sensor are mounted horizontally to provide height information of the incident particles.

4. Data Acquisition

HEPHY Vienna has more than ten years of experience with the operation of APV-type front-end chips and was the first group to read out full-size detector modules equipped with APV6 (CERN, 1998) and APV25 (PSI, 2000) in beam tests.
For this purpose, several test systems have been designed and built and the related software for data taking and analysis was programmed.
The readout system, as sketched in figure 7, contains a 9U VME crate with a single controller (NECO) and a fan-out unit (SVD3_Buffer) as well as several FADC modules with built-in processing capabilities. The readout is done via VME (beam test configuration). On the front-end side, which can be located up to 30m away, there are repeater boxes (DOCK) that connect to the front-end hybrids. The system has been adapted recently to be compatible with the EUDET pixel telescope, which means that the trigger information (including time-stamps) from the TLU is directly included into our VME hardware.

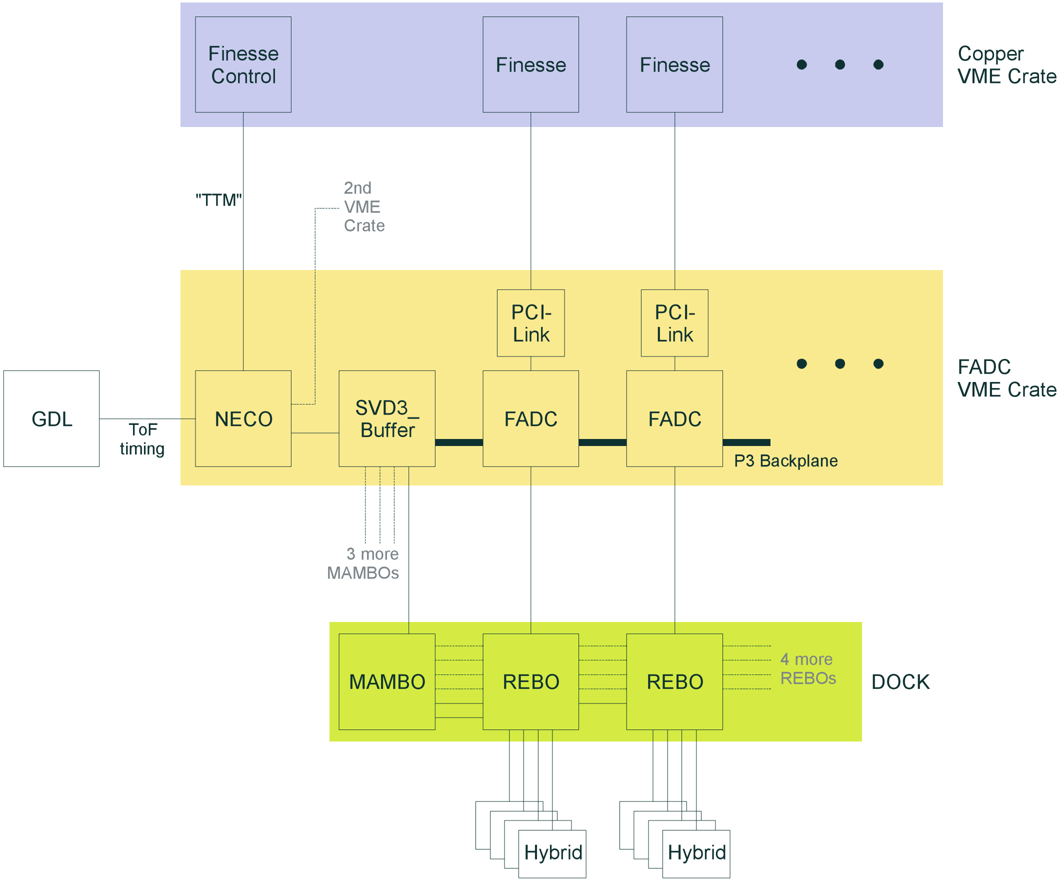

Figure 7: DAQ system components

The electronics rack in the counting house of a previous testbeam is shown in figure 8. The 9U VME modules control and read out the front-end electronics connected by the blue cables. One is the controller, one is a fan-out and two are FADC modules with integrated data processing. The white cable pair interfaces to the readout PC. The NIM crate on top contains some trigger logic and counters.

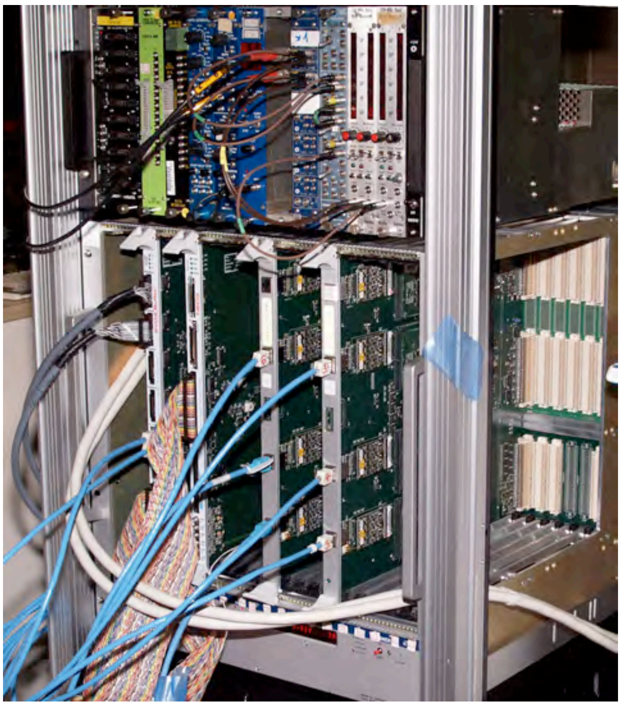

Figure 8: APVDAQ system during a former beam test

Figure 9 shows a screenshot of the DAQ software. The graph corresponds to a scope picture (raw data) of six consecutive readout frames of a single APV chip with 128 strip values multiplexed in each frame, where frames are spaced by 25ns. The shaper output waveform (50ns peaking time) of a strip with a particle hit is clearly visible. Multiple samples around the peak have been used to determine the particle timing with an accuracy of a few nanoseconds.

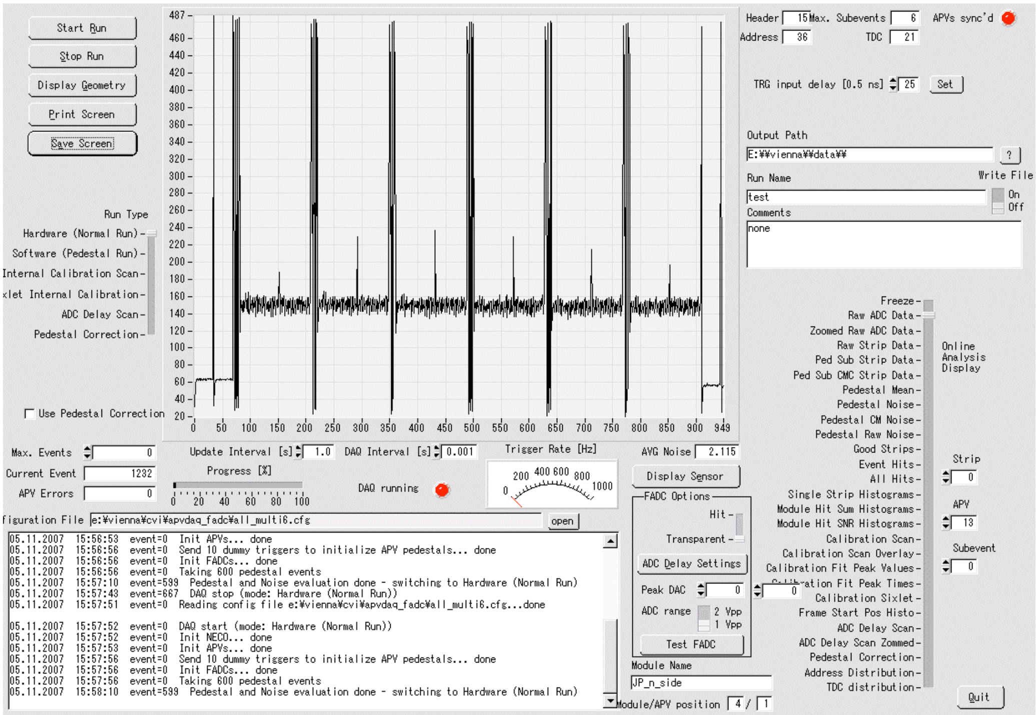

Figure 9: Screenshot of DAQ sytem

5. Measurement program

During the assigned beam time (27. September to 11. October 2010) at the H6 line of CERNs SPS accelerator (North Area), we will use charged hadrons, mainly pions with 120 GeV energy, to simulate minimum ionizing particles. The settings from last years run will be applied.
The measurement program consists not only of the measurements on the newly designed sensors with integrated pitch-adapter from the second lot, but for comparison reasons also the full number of modules from 2009 will be re-tested.

6. People and Funds

The people participating in the measurements and the setup of the system are members of the SiLC collaboration. The preparation of the test beam is coordinated by Thomas Bergauer (HEPHY Vienna), who is in close contact to Marcos Fernandez Garcia of CERN, Ivan Vila of Santander, Zdenek Dolzeal of Charles University Prague and Aurore Savoy-Navarro of LPNHE Paris as the SiLC coordinator. Four to six people from HEPHY Vienna and 2-3 persons from Santander will participate in the test beam in person for installation, setup and data taking. Several people from Charles University Prague will be responsible for the analysis of the testbeam data.

7. Conclusions

This test beam session together with the EUDET telescope allows an unique possibility to test novel silicon strip sensors with new routing techniques directly implemented onto the sensor. It will be a continuation of the long-term program of the SilC collaboration to develop lightweight silicon detector modules. The problems with the sensors from last year will hopefully be addressed by a new production at ITE Warsaw. Once these sensors are ready, they will be mounted immediately onto modules to be ready for end of September.

Results of those tests have important influence on the future silicon sensor development of the SiLC collaboration and for optimizing silicon strip detectors for future HEP experiments.