The DEPFET sensor as the first device under test using the EUDET JRA1 telescope

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Abstract

The DEPFET prototype system for the ILC is the first device under test using the EUDET JRA1 pixel telescope. This memo pictures different levels of DAQ integration and summarizes the experiences gathered during the 2007 CERN test beam period. It reports about the status of the DEPFET DAQ integration and presents very first results of the test beam. Finally it also provides a small guide for future users of the EUDET pixel telescope.

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1 Introduction

There are several new pixel technologies competing for the ILC vertex detector. The DEPFET (DEPleted Field Effect Transistor), a silicon sensor with a FET integrated into the sensor substrate as a first amplification stage, is one of them. For this purpose a prototype system was developed [1]. Furthermore the DEPFET system has also been successfully used as a telescope system [2]. Being part of the ILC community it was a natural step to get involved in the EUDET framework as the first device under test (DUT) using the EUDET JRA1 pixel telescope. The first part of this document reports about the current status of integrating the DEPFET data acquisition (DAQ) in the EUDET telescope DAQ. The second part describes the experiences gathered during the common test beam campaign at the H8 line at the SPS facility at CERN in October 2007 and presents first, preliminary results. The last chapter elucidates the next steps towards further integration of the DEPFET DAQ into the EUDET telescope DAQ.

2 DAQ Integration

There are several levels of integration of a device under test (DUT) into the EUDET telescope DAQ. The simplest one is by having two separated and independent DAQ systems for the telescope and the DUT. The only connection is a trigger-busy handshake protocol via a trigger logic unit (TLU) assuring that no new event is triggered while one of the participating devices is still busy with e.g. read out of the sensor. This can be expanded by receiving an individual trigger number from the TLU for each event. Using this procedure the data will be written to file in two separate data streams. A more sophisticated method is the integration of the DUT DAQ into the EUDET telescope DAQ framework. A key issue here is the modularity of the telescope DAQ which will be explained in more detail later. Here the DUT DAQ is steered by the telescope DAQ and the data is merged to one data stream and into one file. The first part of this chapter will cover the DEPFET DAQ and the second part will describe the integration of the DEPFET DAQ and the EUDET telescope DAQ on a trigger level, which was the status of the integration at the CERN test beam in 2007.

2.1 The DEPFET DAQ

The DEPFET DAQ is a very modular structure and very similar to the EUDET DAQ structure. Indeed both stem from the Bonn ATLAS pixel telescope DAQ [3]. Figure 1 shows a schematic of the DEPFET telescope DAQ: The basic idea is to have an independent *data producer* software task for each device participating in the test beam. This task is responsible for reading out the associated device, maintaining a memory and writing the data to this memory. Another task, the *data collector* task, is responsible for collecting the data from all producers belonging to an event and writing the complete event to file. Furthermore some fraction or the entire amount of data can be send to an *online monitoring* task. Here the user can check the quality of the data and the rough alignment. The start and stop procedure is controlled by another task, the *run control* task. The event integrity is assured by using a TLU: Each device which is busy and incapable of recording an event sends an according signal to the TLU. While any busy signal is active the TLU prohibit the relay of any new trigger signal. Since 2007 the DEPFET telescope uses the EUDET TLU and also records the trigger number send by the TLU. This increases the signal integrity even further. Another integrity check is done by the *data collector* task by combining only data with the correct trigger number to a common event.

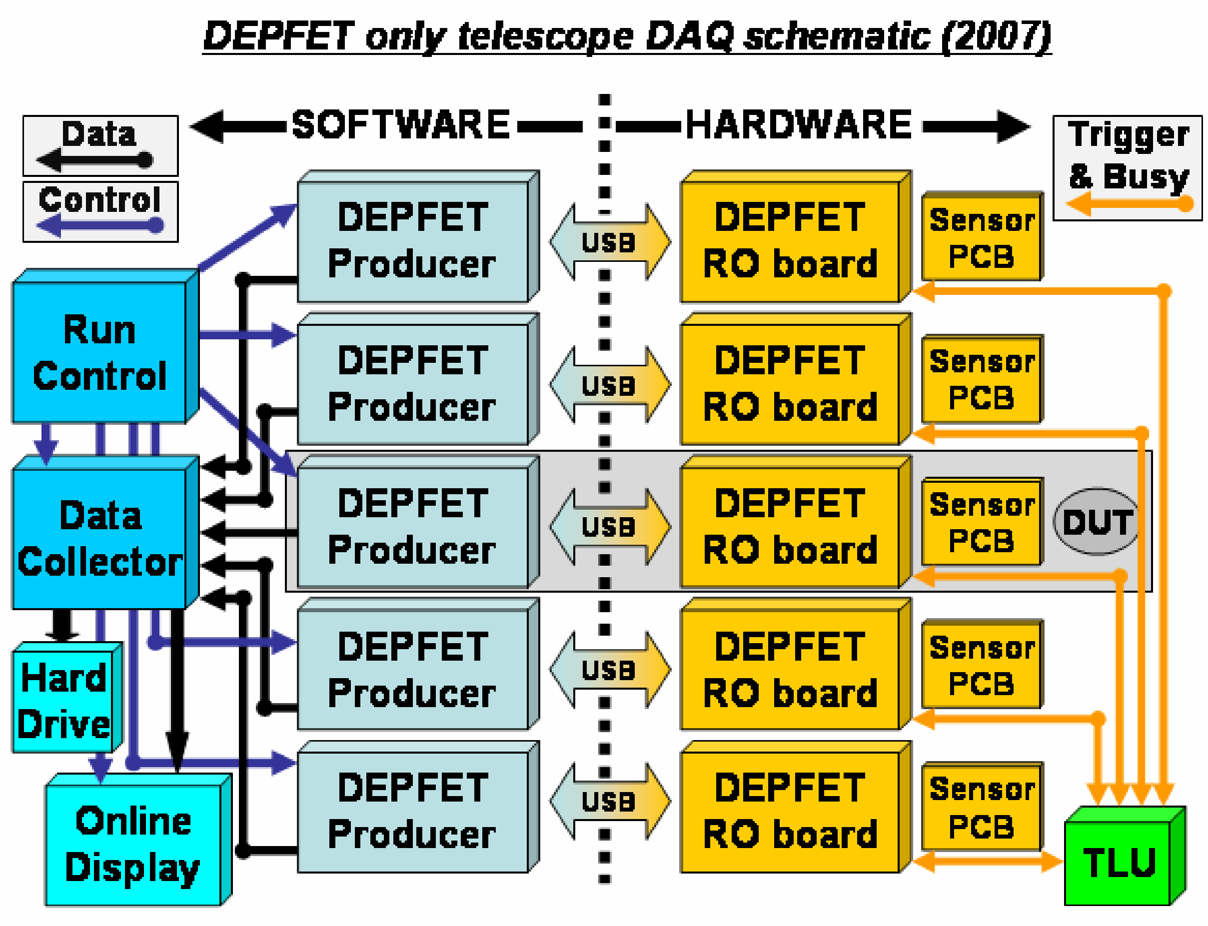

Figure 1: Schematic of the DEPFET telescope test beam DAQ. The right side covers the hardware with 5 DEPFET modules, each one consisting of a read out PCB (*RO board*) and a *sensor PCB* with the DEPFET matrix and the read out and steering ASICs. Event synchronization is done by a trigger logic unit (*TLU*) with a trigger-busy handshake protocol and a transmission of an individual trigger number for each event to all modules. The left side shows the software structure: Each DEPFET module has its own *producer* software task responsible for slow control, read out, and a first stage, low level data processing. Furthermore each producer has its own data memory. This memory is accessed by the *collector* task which is responsible for event building. The complete event with data from all modules is written to file and can be send to an online display for data quality monitoring. Finally a *run control* application starts and stops the DAQ system via window messages.

2.2 Integration on trigger level

The DEPFET DAQ integration during the CERN test beam season in 2007 happened on a trigger level (Figure 2): The event synchronization was ensured by the trigger-busy handshake of the EUDET TLU including the transmission of event numbers for each trigger, while having two separated data acquisitions for the DEPFET DUT and the EUDET telescope. This implies that no common online monitoring was available.

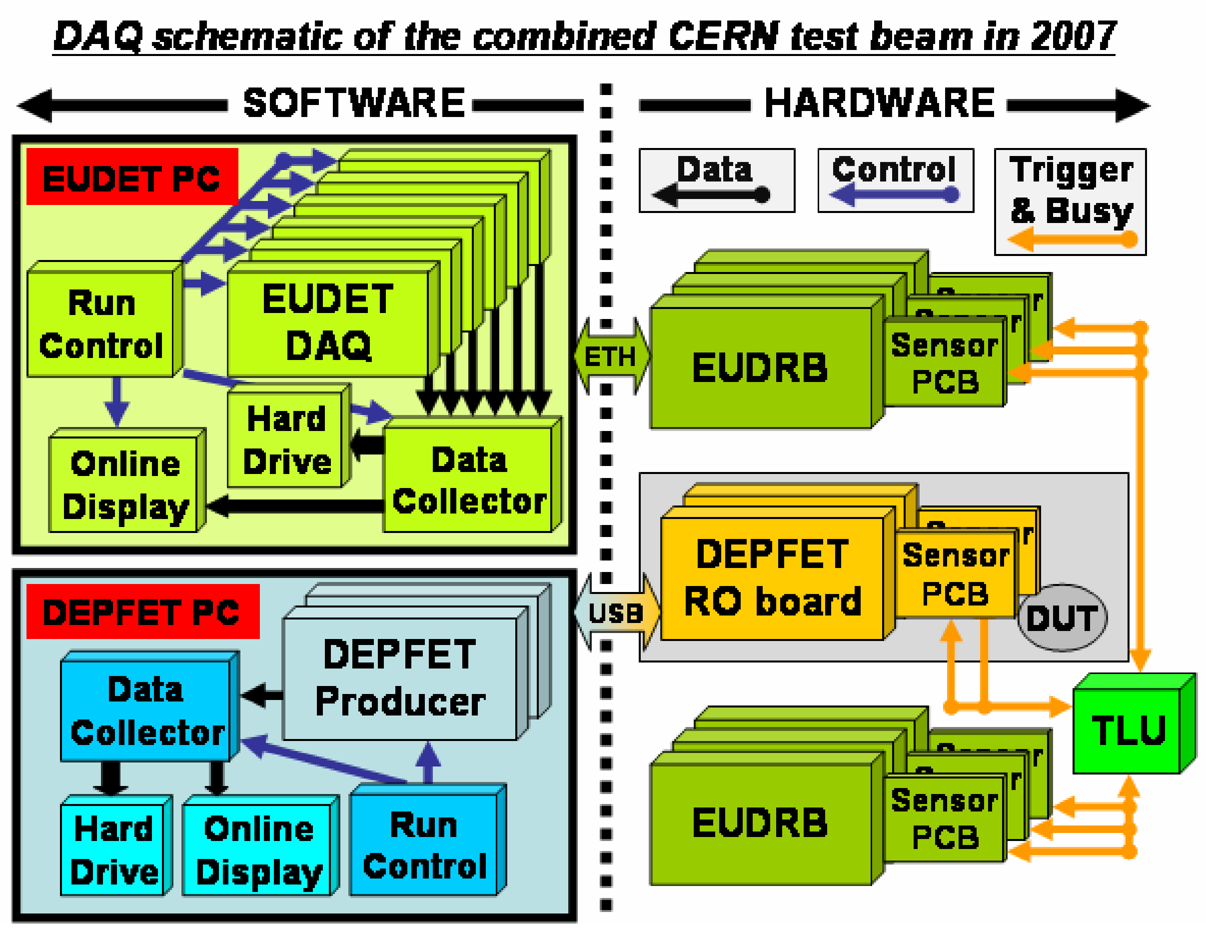

Figure 2: Schematic of the DEPFET and EUDET telescope DAQ integration during the CERN test beam season in 2007: The right side covers the hardware with 2 DEPFET DUT and 6 EUDET telescope planes. Event synchronization is done by a trigger logic unit (*TLU*) with a trigger-busy handshake protocol and a transmission of an individual trigger number for each event to all modules. The left side shows the software structure: Two separated DAQ systems were running on two PC.

3 The 2007 CERN test beam campaign

A pure DEPFET telescope system (see Figure 1) was used for one and a half weeks at the H8 beam line at he SPS at CERN to study the DEPFET sensor. This was immediately followed by almost a week of running two DEPFET modules as DUT with the EUDET pixel telescope. The level of DAQ integration at this point is described in section 2.2. Although the DUT was ready for deeper level of DAQ integration this could not be tested due to a lack of time. A total of roughly 250k events were taken with the DEPFET as a DUT, of which the first 35k events had only one and the rest of the data two DUT in the beam.

3.1 First results

Due to the fact that DEPFET DUT and EUDET telescope data was written into separate data files with different data format no common online monitoring was available during the test beam. Therefore data was taken without the possibility to check for alignment by e.g. correlating the coordinates of hits in the DUT planes and in the telescope planes. Furthermore no common analysis framework could be used, though efforts to integrate DEPFET data in to the EUDET analysis framework are ongoing (see section 5). The results presented here are based simply on comparing hit positions in the telescope planes and the DEPFET planes taken from text files generated by the EUDET telescope and DEPFET DUT online monitoring. In this case the hit position is the seed, i.e. the central pixel of a cluster without using any form of position reconstruction algorithm. The results shown here cover only a small fraction of the data taken (≈ 7k events).

3.1.1 Hit Multiplicity

For most of the time the particle flux was rather high leading to a high hit multiplicity per event. Figure 3 shows the hit per event (hit multiplicity) distribution of a DEPFET DUT vs. a EUDET telescope plane (left image) and of one telescope plane vs. another telescope plane (right image). The hit multiplicity for a telescope plane peaks at roughly 50 hits per event whereas the DEPFET DUT has generally two to four hits per event. This is due to the smaller sensitive area of the DEPFET sensor which is approx. 1/10 of the telescope sensor and an inhomogeneous beam illumination of both sensor types.

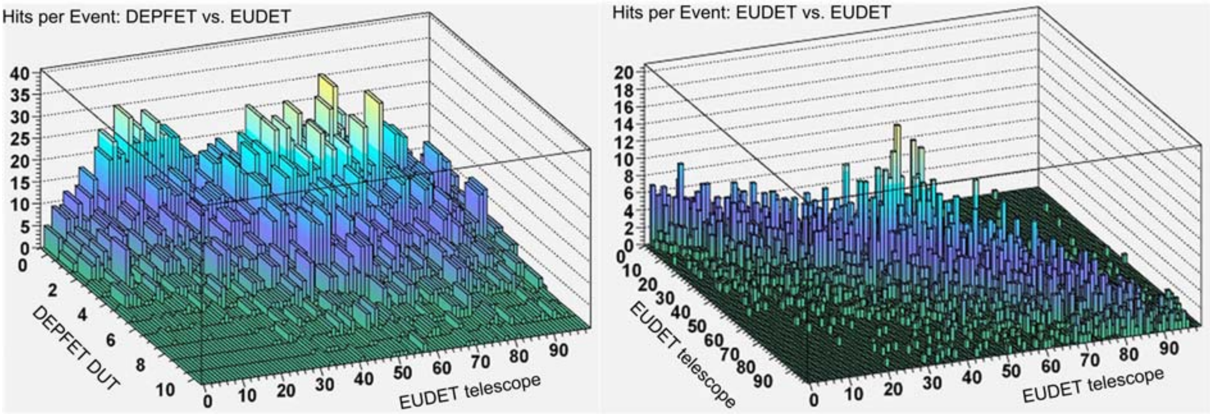

Figure 3: The event multiplicity distribution of a DEPFET DUT vs. a EUDET telescope plane 3 (left image) and telescope plane 2 vs. telescope plane 3 (right image).

3.1.2 Hit Position Correlation

A simple way to check the rough alignment and event synchronization of devices in a test beam is to plot the hit position in one axis for different devices, e.g. plot the DEPFET x-position vs. the EUDET x-position. Hits steaming from the same particle traversing the planes will then appear as a diagonal line in the plot. While in case of hit multiplicity positions from different particles will contribute to a background. Due to the high hit multiplicity only a very weak signature can be seen in Figure 4 und 5. Figure 4 shows the correlation position between the DEPFET DUT x-position and telescope plane 2 y-position (the DEPFET sensor is tilted by 90º with respect to the telescope sensor). Along this axis the DEPFET DUT is well aligned with the telescope and lies fully within the telescopes pixel sensor. Figure 5 on the other hand displays that the DEPEFT DUT y-axis is only partially covered by the telescope. Furthermore only a correlation in three out of five telescopes plane was found for the analyzed data set. This misalignment is caused by the missing common online monitoring. However the DUT position relative to the telescope was changed in later runs to correct for this mismatch. The analysis of these data sets is ongoing. Anyhow the correlation presented here shows clearly that the DEPFET DUT was successfully running with the EUDET telescope.

3.1.3 Recommendations for other EUDET telescope users

For users who plan to use the EUDET telescope on a basis of trigger level integration it is highly recommended to have a quick check for the alignment of the DUT with respect to the telescope. This can be simply done by writing the seed positions to a file and correlate the positions offline with the telescope positions after taken a run, analogue to the described method above.

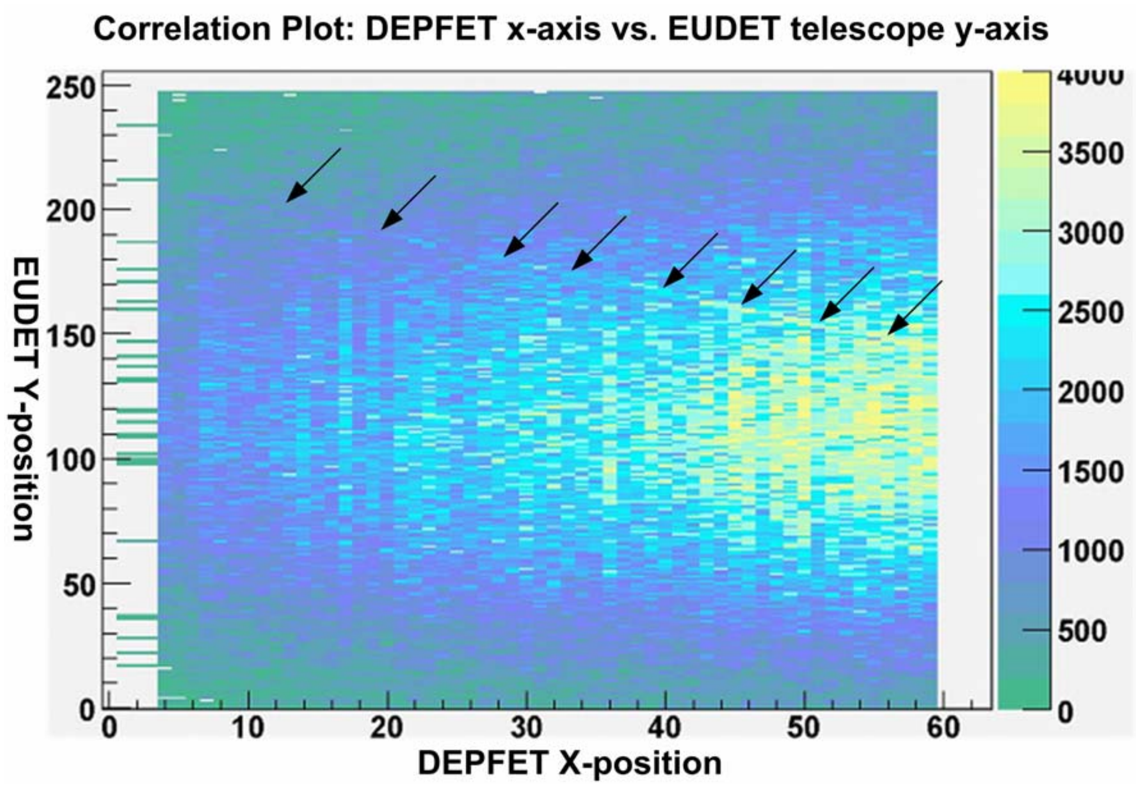

Figure 4: Correlation of hit positions of the x-axis of the DEPFET DUT vs. the y-axis of the EUDET telescope plane 2. The sensors are tilted by 90° with respect to each other. Due to the high hit multiplicity the background is very large, but the correlation reveals a full coverage of the DEPFET DUT for this axis.

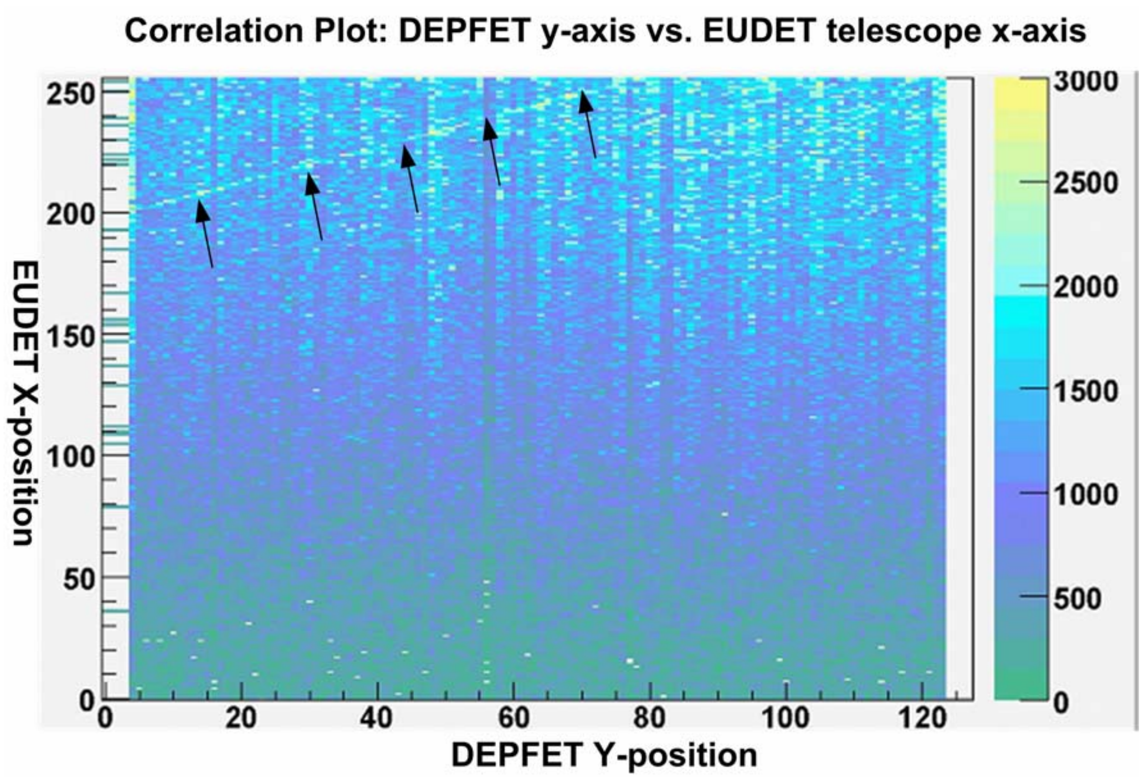

Figure 5: Correlation of hit positions of the y-axis of the DEPFET DUT vs. the x-axis of the EUDET telescope plane 2. The sensors are tilted by 90° with respect to each other. Due to the high hit multiplicity the background is very large. The correlation reveals that the DUT is only partially covered along this axis.

4 Next Steps towards a common DAQ

A common DAQ for the EUDET telescope and a DUT can be arranged by either running the DUT and the telescope DAQ on two different PC and even two different operation systems or by running it as a complete integrated DAQ on one PC. The basic principle is however he same.

Two separated DAQ PC

Running both DAQ on separate PC has the advantage of avoiding data loss due to CPU overload and allowing to run the DUT DAQ on its original environment. Figure 6 illustrates the principle layout. Both PC are linked via a high speed Ethernet TCP/IP network. The data acquisition is centrally steered (start, stop, run number, etc.) by the *run control* on the EUDET telescope PC and send via network to the DUT PC. On the other side the DUT producer writes the data to a common memory block either located at the DUT or the telescope PC. This memory block is accessed by the *data collector* for event building. The *data collector* might also feed a common online data monitoring. Although this scheme was planned to be executed during the last CERN test beam and basically all necessary coding was done restrictions from the Windows operation system on TCP/IP data transfer prohibited a successful full scale test. As a result the DEPFET DAQ software will soon be ported to Linux.

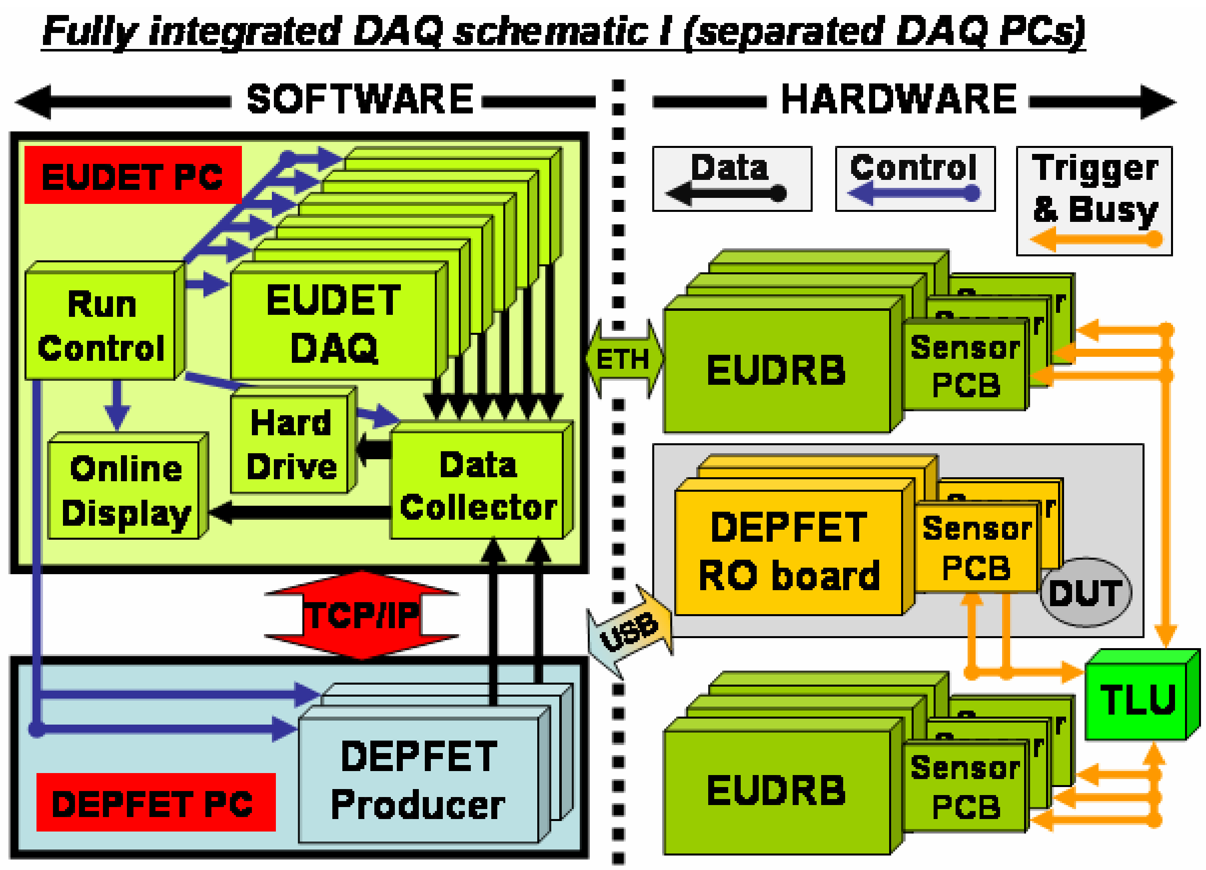

Figure 6: Schematic of running a common DAQ on two separate PC. The DUT *producer* receives start and stop commands from the *run control* and sends its data to a memory block. This memory block is accessed by the *data collector* for event building. A common *online monitoring* is feed by the *data collector*. The PC are linked via a high speed Ethernet TCP/IP network.

One common DAQ PC

A common DAQ running on the same PC is sketched in Figure 7. Apart from the Ethernet link it is identical to the separate PC solution. This version is not favoured for the DEPFET system as the CPU load might decrease the event rate and the DUT DAQ software has likely to be installed on the EUDET PC at the test beam site adding to the setup time before data taking can start.

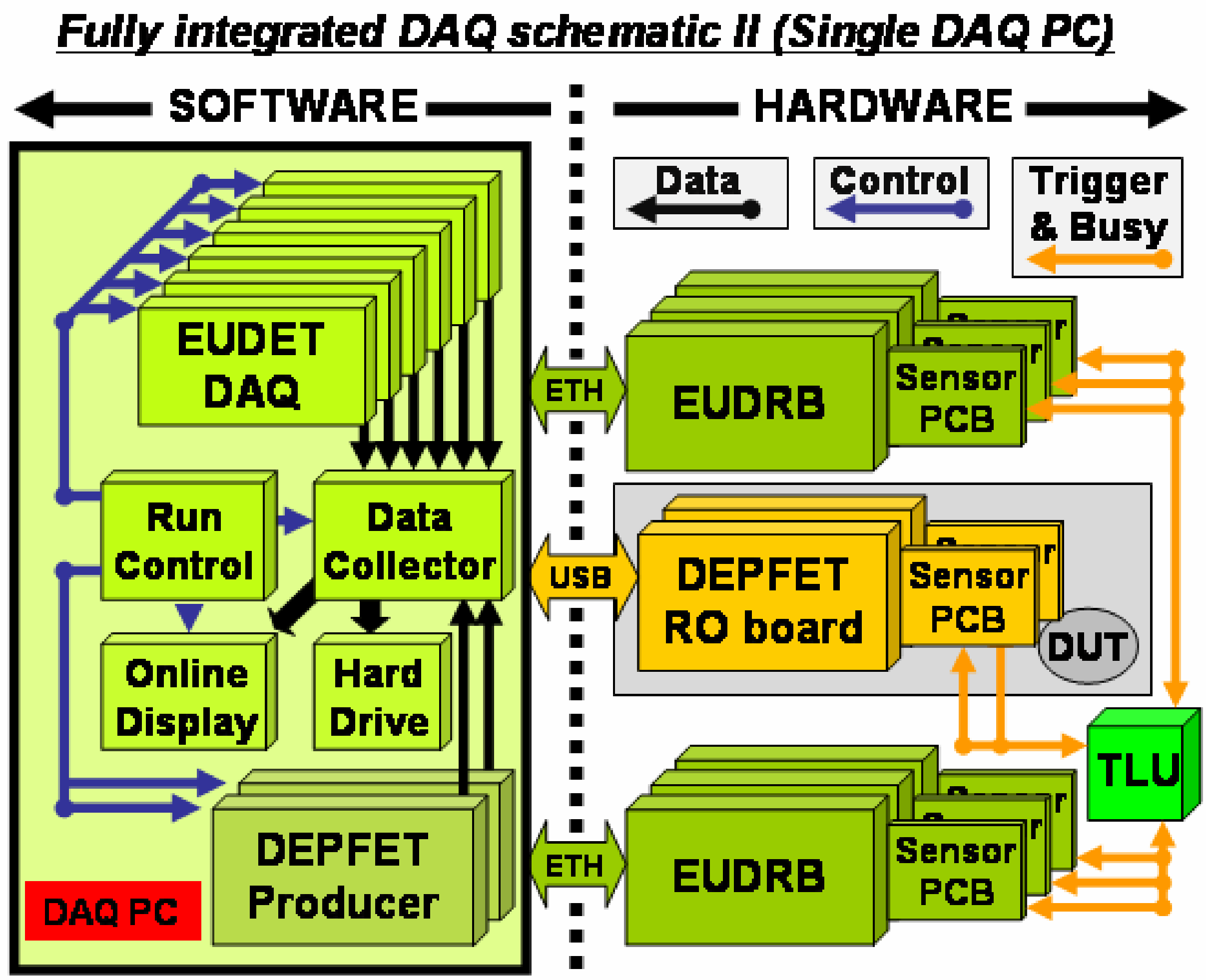

Figure 7: Schematic of running a common DAQ on two separated PC. The *DUT producer* receives start and stop commands from the *run control* and sends its data to a memory block. This memory block is accessed by the *data collector* for event building. A common online monitoring is feed by the *data collector*.

5 Integration in the ILC analysis framework

The analysis software currently used in the DEPFET community is based on root and is not designed for or compatible with the EUDET pixel telescope. The option of expanding the code to integrate EUDET telescope data is not pursued at the moment. Instead efforts are ongoing to integrate the DEPFET data into the ILC analysis frame work including converting to LCIO data format and extending the Merlin analysis to facilitate DEPFET specific data reduction steps (e.g. double row wise common mode corrections). As the ILC analysis framework has a large momentum and will be fostered in the future this step is also recommended for other telescope users in spite of the initial extra work.

6 Conclusion

During the CERN test beam season in 2007 the DEPFET prototype system for the ILC has been successfully operated as a DUT with the EUDET pixel telescope. The DAQ integration happened on a trigger level using the EUDET trigger logic unit. Both trigger-busy handshake protocol as well as TLU trigger number generation has been used to ensure event synchronization. First results from a simple seed position correlation between DUT and telescope carried out on a small fraction of the data revealed a successful operation with full event synchronization. Due to the missing common online data monitoring the DEPFET DUT was only partially covered by the telescope sensors. Yet in the so far not analyzed data corrections were made for this. First test with running a common DAQ were promising but yielded in low performance due to operation system restrictions. As a result the DEPFET DAQ is currently ported to Linux. Furthermore efforts are ongoing to convert DEPFET data to the LCIO format to utilise the ILC analysis framework.

6.1 Recommendation for other telescope users

With experience gathered during this CERN test beam as the first EUDET pixel telescope DUT the following steps are advised for other EUDET telescope users:

- The EUDET TLU does not only provide a rigger-busy handshake protocol but also a individual event number for each trigger. Making use of this ensures data integrity even further.
- While running with DAQ integration on trigger level but with two different DAQ and separate data streams no common online monitoring is available. Therefore it is recommended to write the seed positions to a text file and compare them offline with the telescope hits after a run is taken. This way a full coverage of the DUT by the telescope sensor can be ensured.
- For the alignment procedure beam intensity with low hit multiplicity is advised.
- The ILC software framework provides a full scale test beam analysis tool including tracking. By converting the native DUT data to LCIO format and some adoptions of the software a powerful test beam analysis tool is available.
- Long term users should move to a common DAQ.

Acknowledgement

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