M11-18

*pheno*PET: A dedicated PET Scanner for Plant Research based on digital SiPMs (DPCs)


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Introduction

In the framework of the German Plant Phenotyping Network (DPPN) we developed a novel PET scanner for imaging plants and crops.

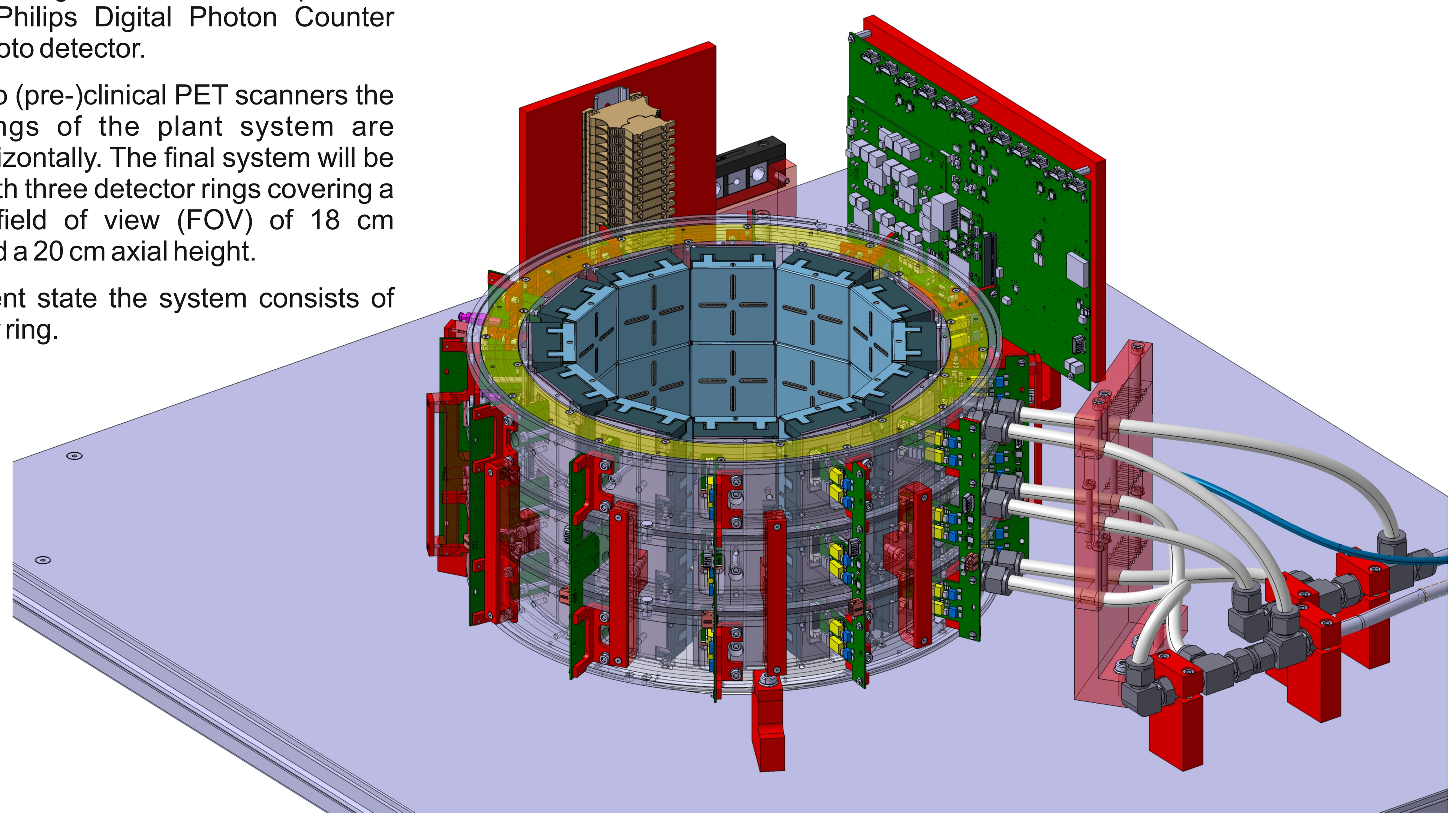
The observation of the carbon transport within the plant becomes possible by using $^{11}CO_2$ as PET tracer. The use of the rather short living isotope C-11 asks for a scanner with high dynamic range, i.e. fast timing and high data rates are important features which let us chose the Philips Digital Photon Counter (DPC) as photo detector.

In contrast to (pre-)clinical PET scanners the detector rings of the plant system are oriented horizontally. The final system will be equipped with three detector rings covering a transverse field of view (FOV) of 18 cm diameter and a 20 cm axial height.

In the present state the system consists of one detector ring.

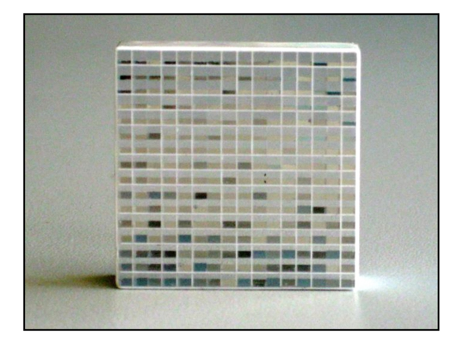
Design

Each of the three detector rings is formed by 12 detector modules. A liquid cooling system keeps the detectors below 5°C and limits the dark count rate. Rings and electronics are placed in an optically and thermally isolating box which is flushed by dry air in order to avoid condensation.

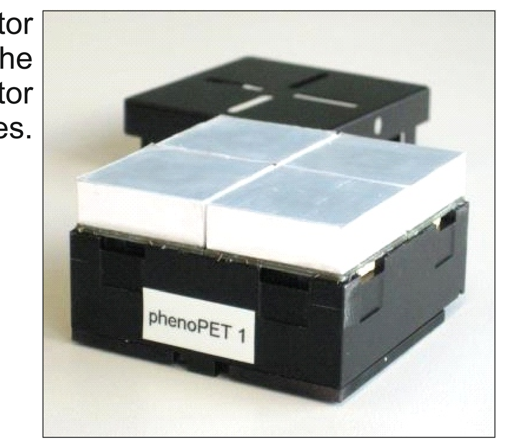


Detector

Each detector module accommodates four 8×8 pixel Digital Photon Counter devices DPC-3200-22-44 [1] connected to a PCB. A scintillator matrix with 16×16 individual LYSO scintillators is attached to each device. Crystal size is 1.85×1.85×10 mm³. The matrices (*Crystal Photonics*) are composed with both reflective and transparent contact faces between the crystals in order to optimize crystal identification [2].



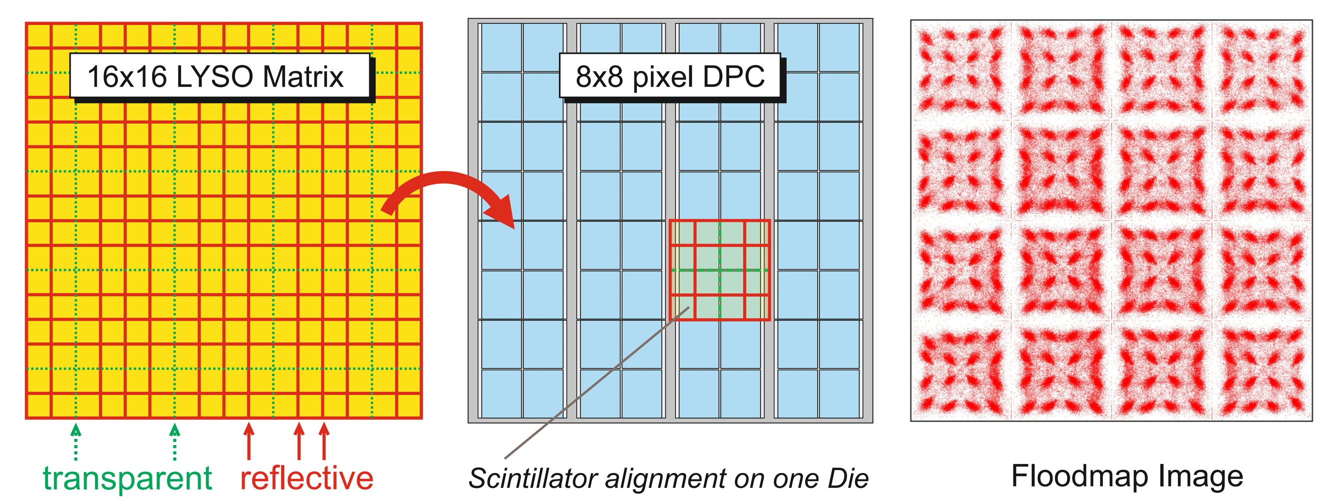
Scintillator matrix with „controlled cross talk"



Opened detector module showing the four scintillator matrices.

Crystal Identification

The DPC consists of 16 Dies, each holding 4 pixels. The Dies trigger independently. 16 crystals each match on one Die and spread their light in a definite way on the four pixels.



Scintillator alignment on one Die

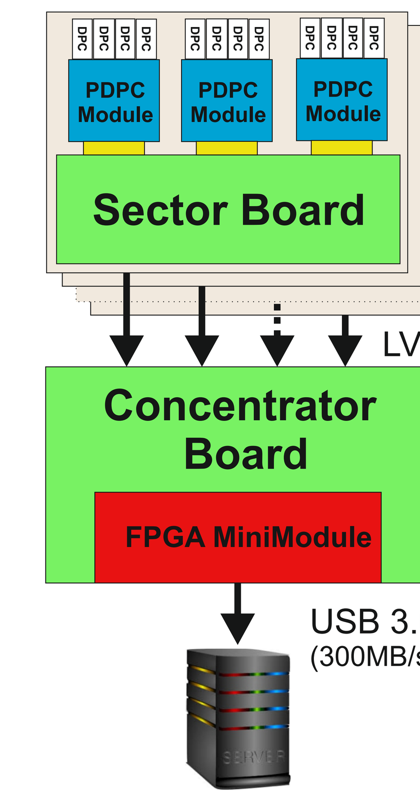
Floodmap Image

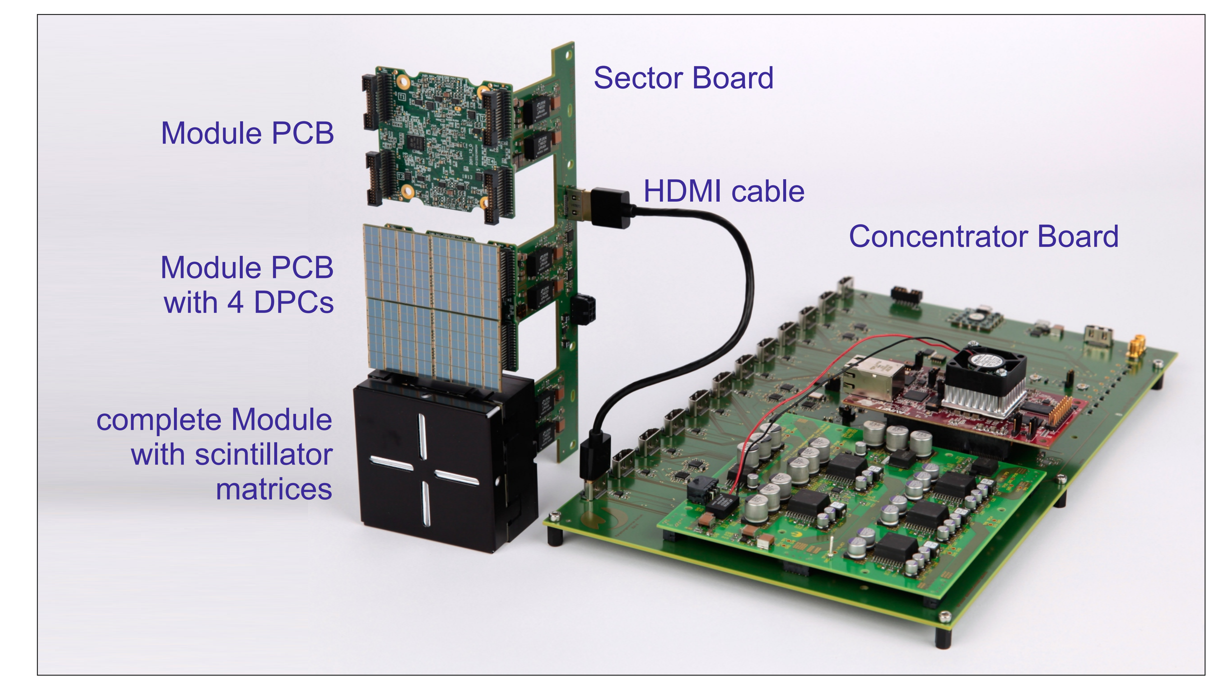
Hardware

Data acquisition and first preprocessing is already performed on the FPGAs within the Detector Module. For further processing and coincidence sorting we developed a central Concentrator Board that employs a Kintex-7 FPGA Mini-Module (*Xilinx*) [3].

12 Sector Boards connect 3 Modules each and route the data via standard HDMI cables to the Concentrator Board. We use one LVDS pair per Module allowing 50 MB/s data rate.

Finally a USB 3.0 connection sends the data to the computer system for storage and reconstruction.





Processing

The data processing will be performed in the firmware of either the module or the concentrator board. The hardware will produce coincidence data, image reconstruction is then realized on a workstation using the PRESTO C++ library [4].

Clustering

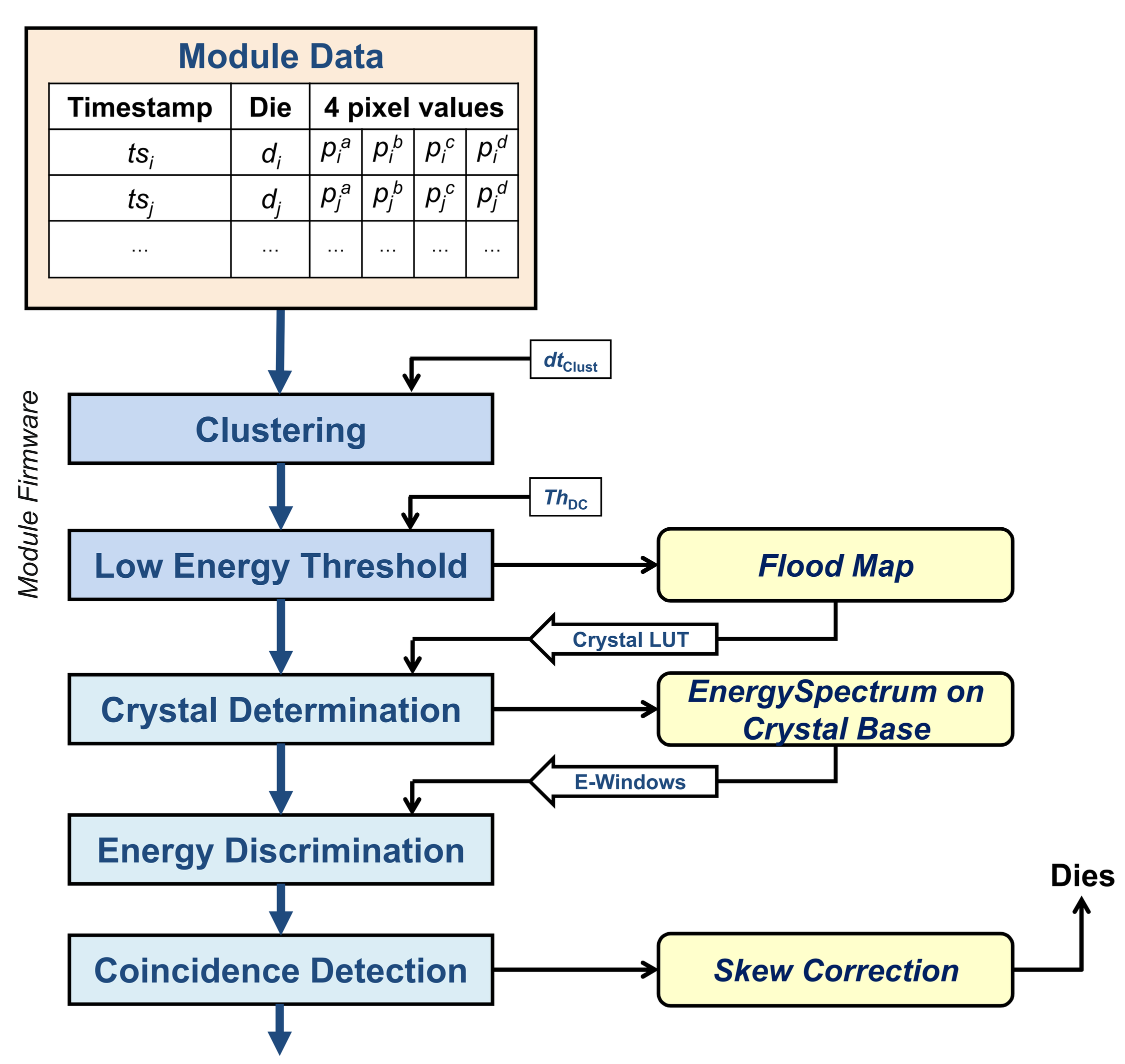
Crosstalk may cause more than a single Die to trigger on the same event. This is identified by close timestamps on neighboring Dies. The event position is assumed on the Die with the strongest signal. We integrated the Clustering already in the module firmware.

Crystal Determination

The four Die pixel values generate a position via Anger logic. The crystal is identified by means of a Look up Table that derived from the floodmap.

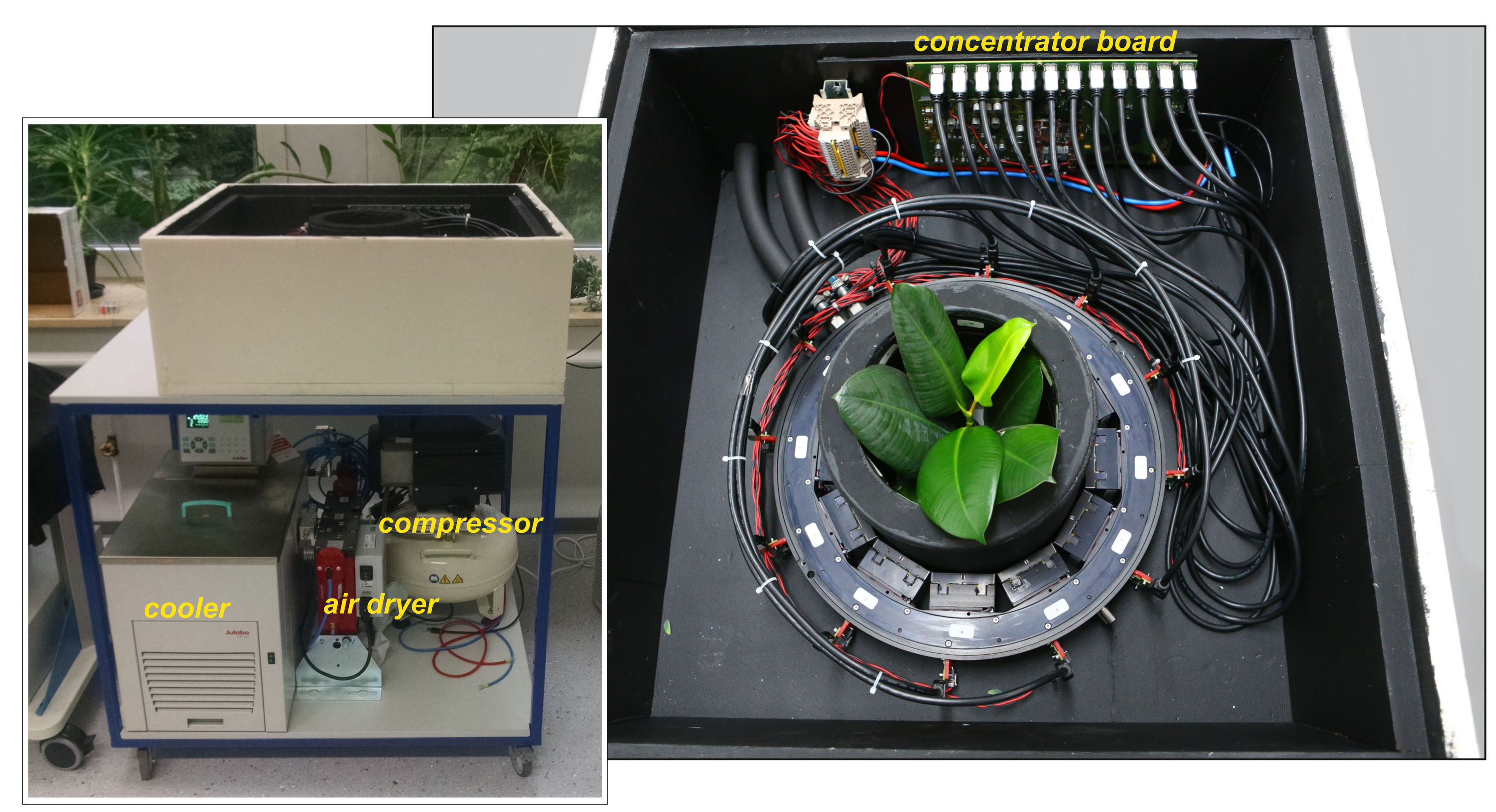
Skew Correction

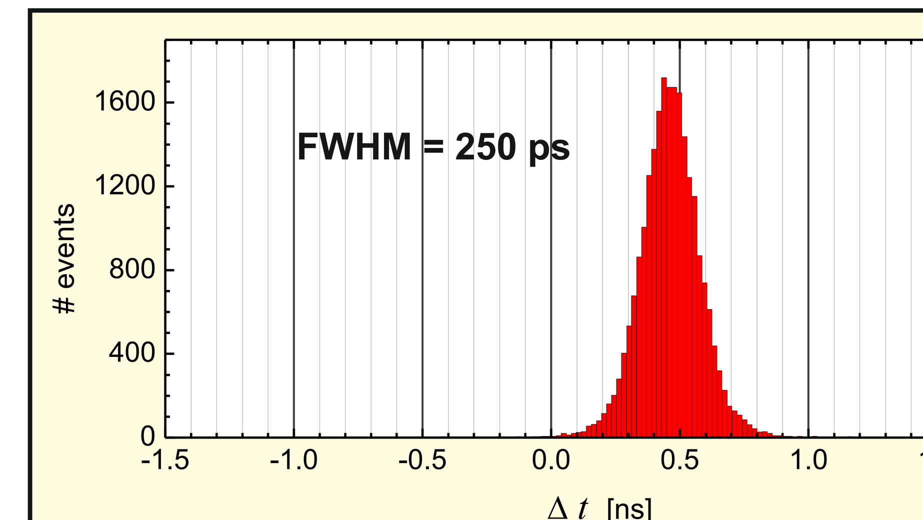
The timestamps generated from different Dies show offsets in the range of ~1ns. For precise timing these need to be determined and corrected.



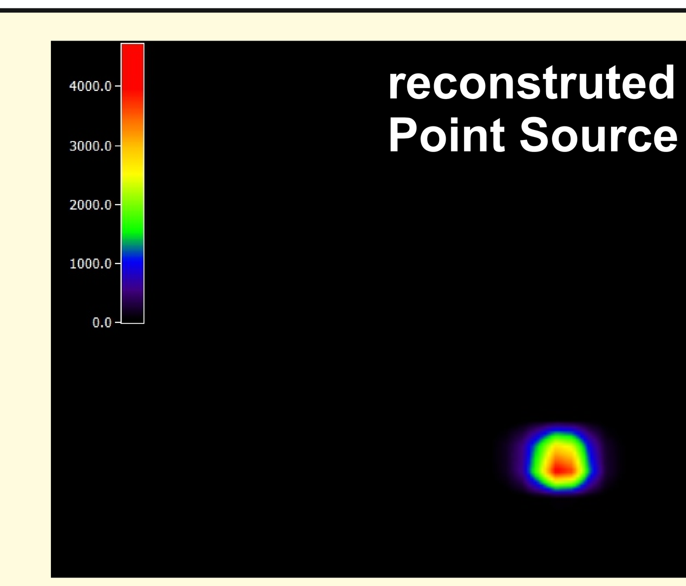
1-Ring System & 1st Results

Presently we have a system running that consists of a single ring with 12 Modules. Crystal Determination and Coincidence Processing is still realized offline in software.





The Coincidence Peak obtained from 2 Dies shows a FWHM of 250 ps. With careful skew correction this can be achieved for the complete scanner.



First image of a point source at the edge of the FOV

References

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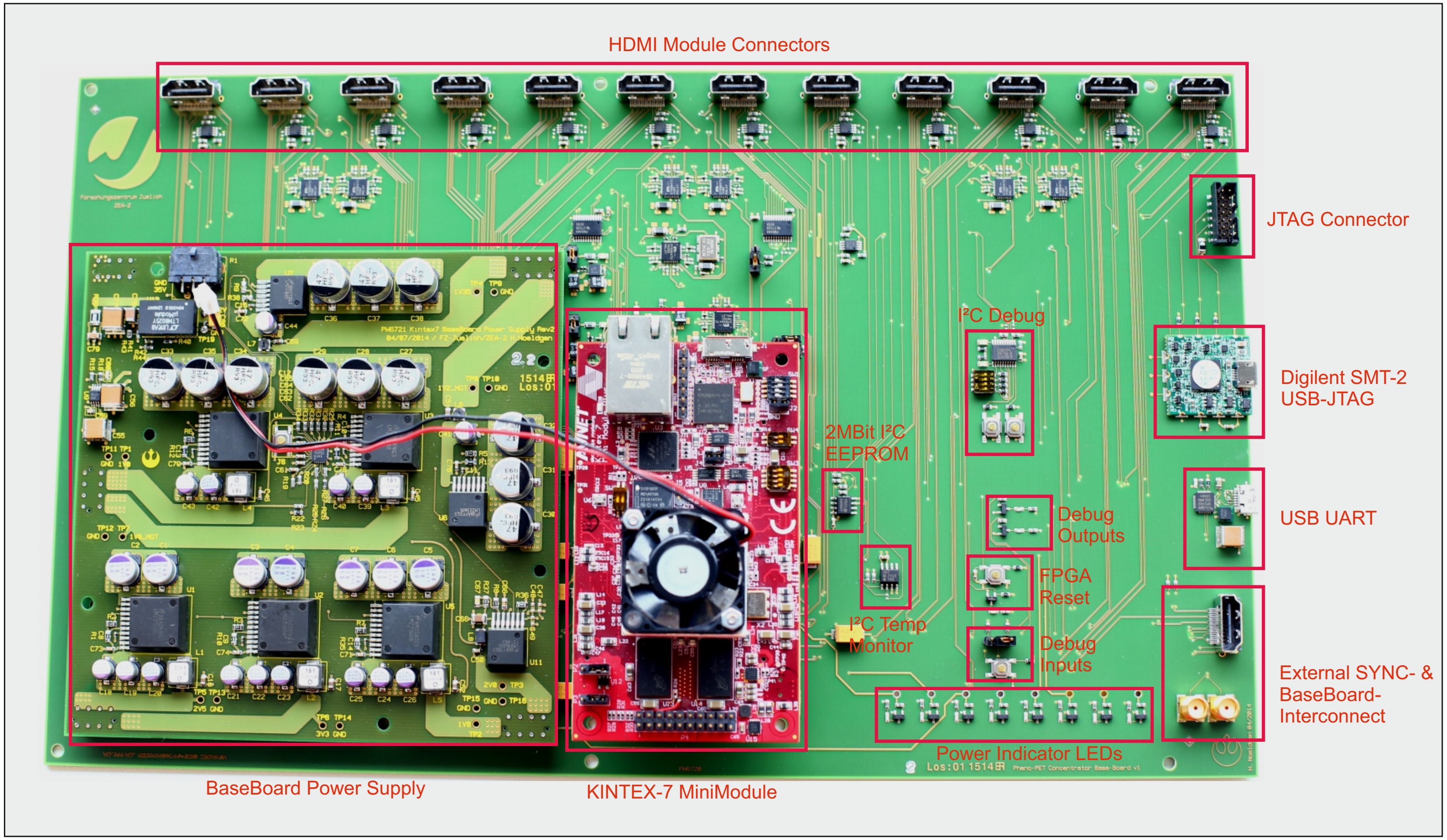

The Concentrator Board