A High Speed PC-Based Data Acquisition & Control System for Positron Imaging

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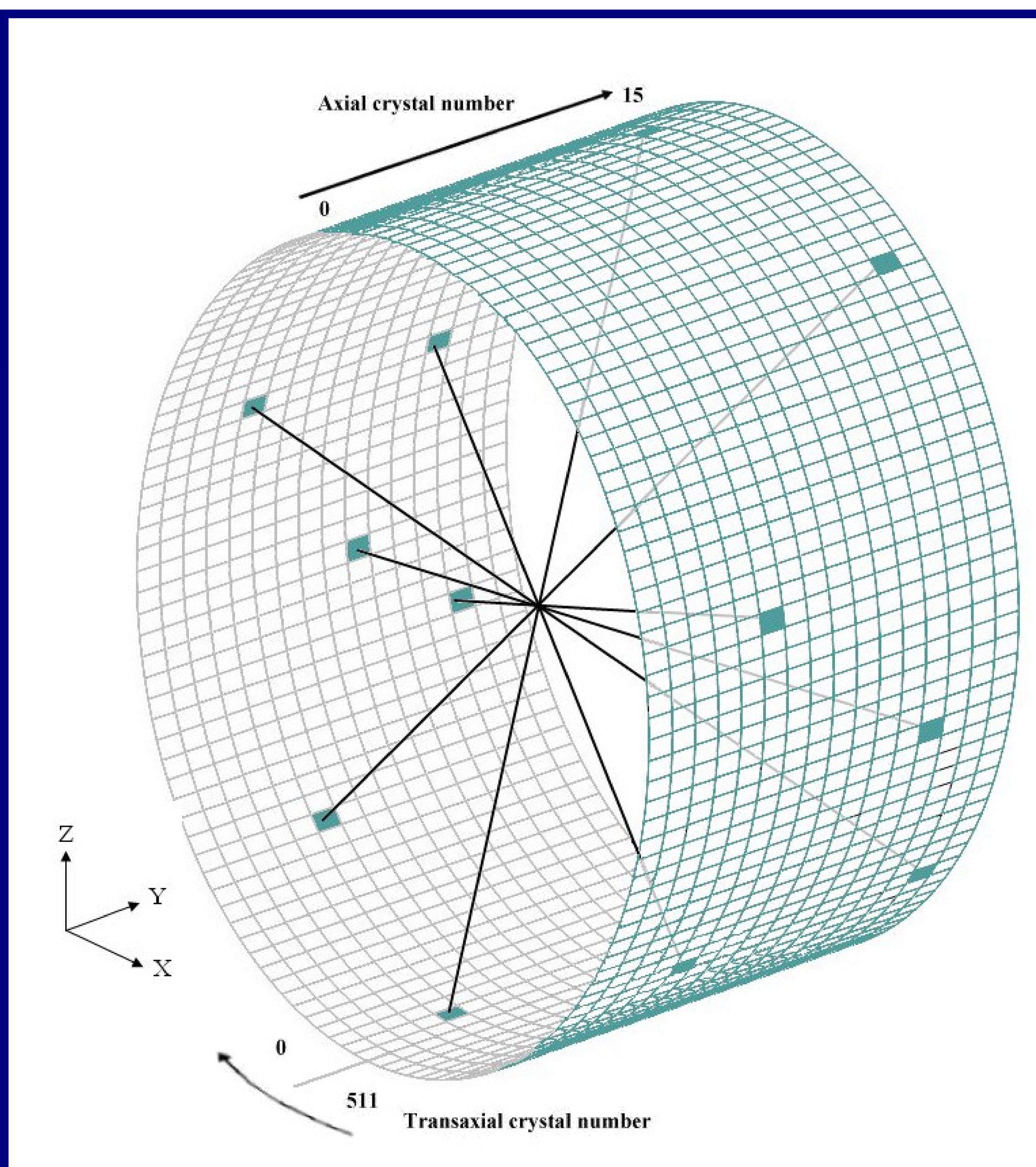
A modular positron camera with a flexible geometry suitable for performing Positron Emission Particle Tracking (PEPT) studies on a wide range of applications has been constructed. The demand for high speed list mode data storage required for these experiments has motivated the development of an improved data acquisition system to support the existing detectors. A high speed PC-based data acquisition system is presented. This device replaces old dedicated hardware with a compact, flexible device with the same functionality and superior performance. Data acquisition rates of up to 80 MBytes per second allow coincidence data to be saved to disk for real-time analysis or post processing. The system supports the storage of time information with resolution of a half millisecond and remote trigger data support. Control of the detector system is provided by high-level software running on the same computer.

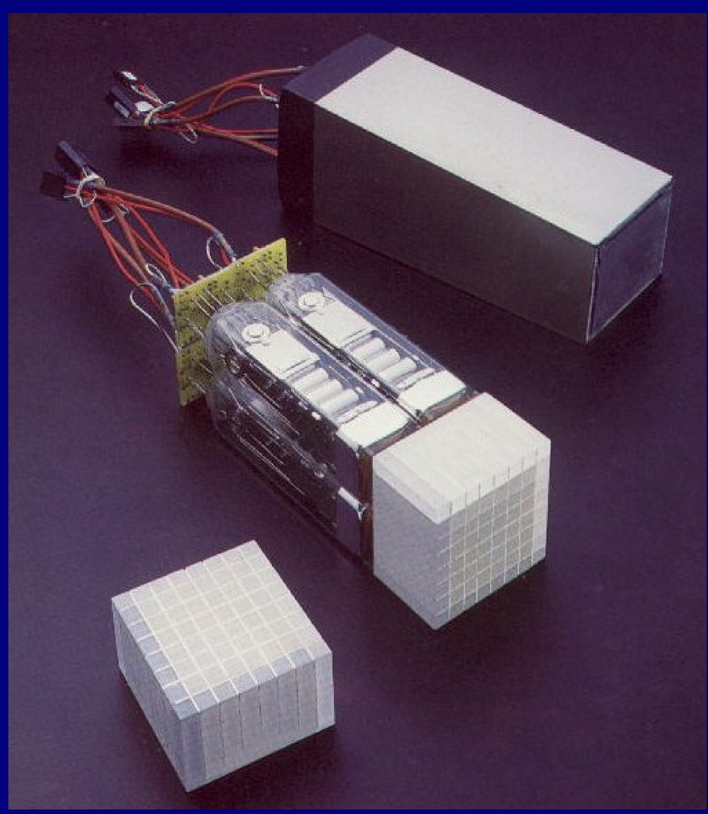
Modern positron imaging devices utilise a large number of small gamma ray detectors arranged around the object under study. Position dependent event data is then derived from the detector response to collinear gamma ray emissions arising from positron annihilation within the field of view. Operated in coincidence, the detection of both gamma rays in the system defines a line-of-response (LOR) along which the annihilation is said to have occurred (figure right). These LOR data can then be used to reconstruct a quantitative map of tracer concentration over a volume (Positron Emission Tomography (PET)), or used to rapidly locate a single radioactive tracer particle present in the field of view by triangulation (Positron Emission Particle Tracking (PEPT)).

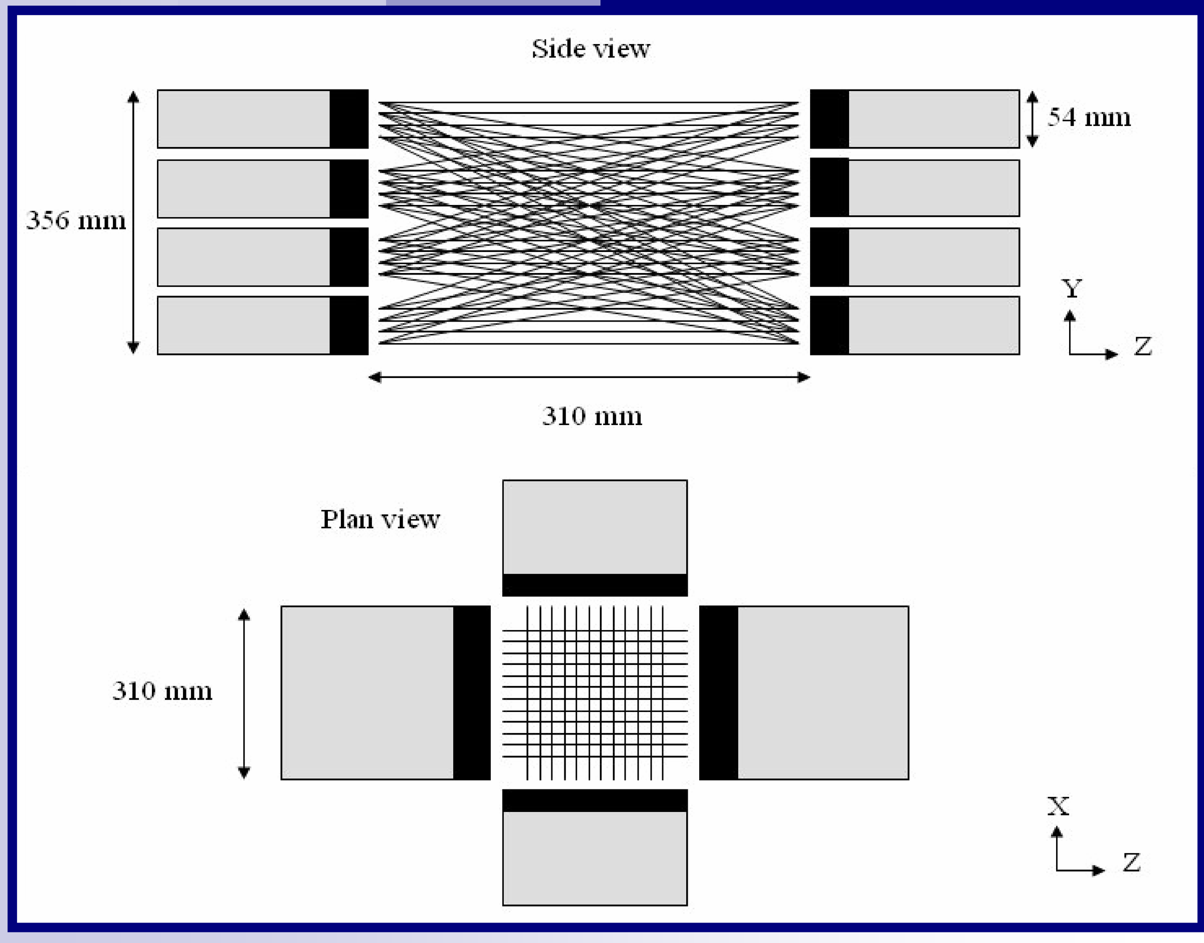


A number of LORs from a point source are shown interacting within a cylindrical detector array. LORs are described by a signal comprising the transaxial crystal number (0 - 511) and the axial crystal number (0 - 15) for the end points of the LOR.

At the University of Birmingham modified medical PET cameras are used to study industrial systems and fluid flows in engineering applications using PEPT. The development systems are based on the ECAT design series produced by CTI/Siemens. Typically these cameras consist 128 individual detector blocks, each containing an array of 8 x 8 Bismuth Germanate (BGO) scintillator crystals (image right).

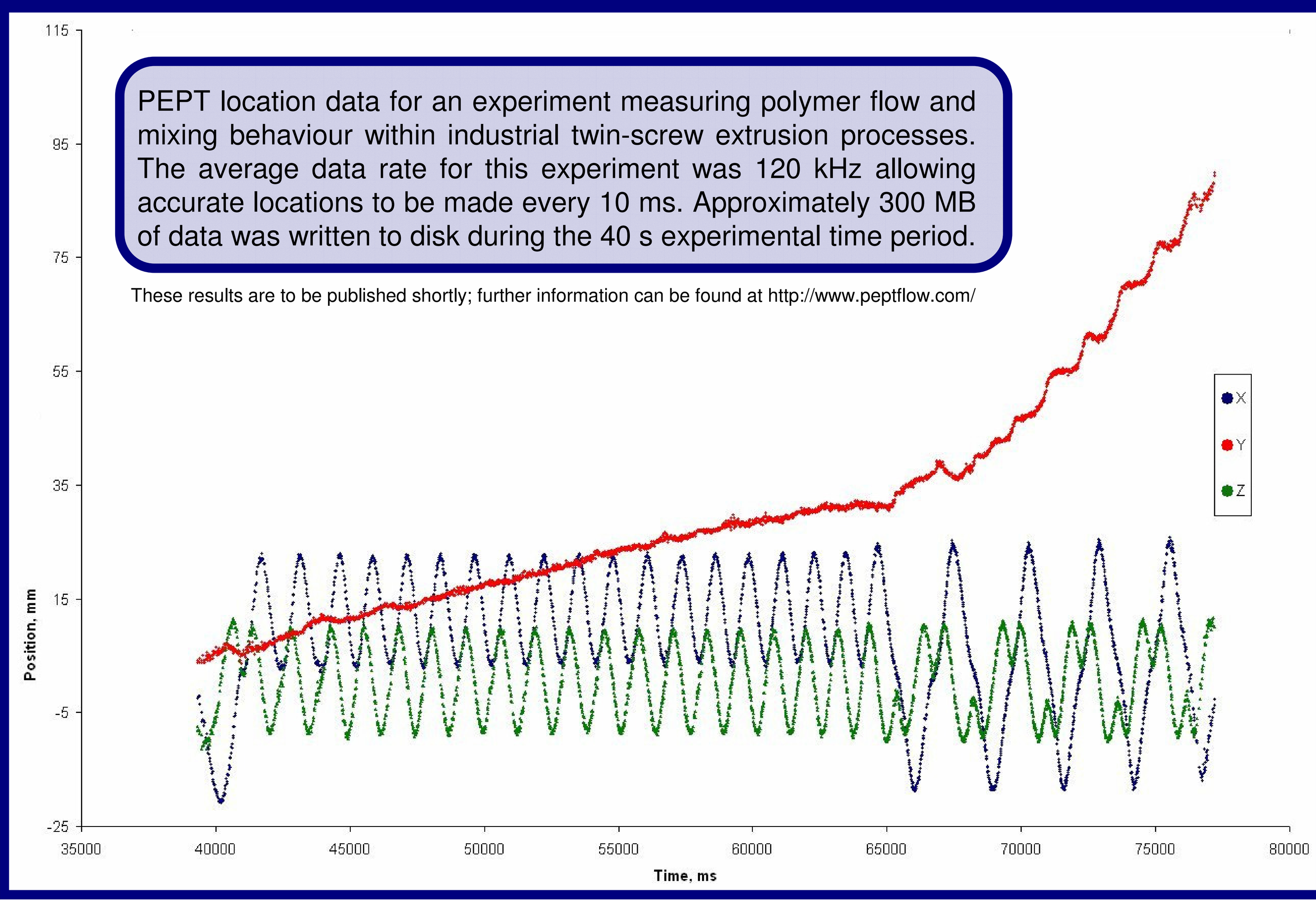
Due to the modular construction of the original devices; where the detectors are arranged together in a number of identical small sub-systems it has proved possible to remove the detectors from the gantry frame and arrange them in different geometries, thus forming a modular positron camera (below).





Custom support gantries have been constructed to hold the modular detector elements around the apparatus under study. An example geometry is given (left) with some of the allowed LORs shown to illustrate the field of view.

In a PEPT experiment a single radioactive tracer particle (activity 30 – 50 MBq) is frequently located using triangulation over a small number of LORs (right).



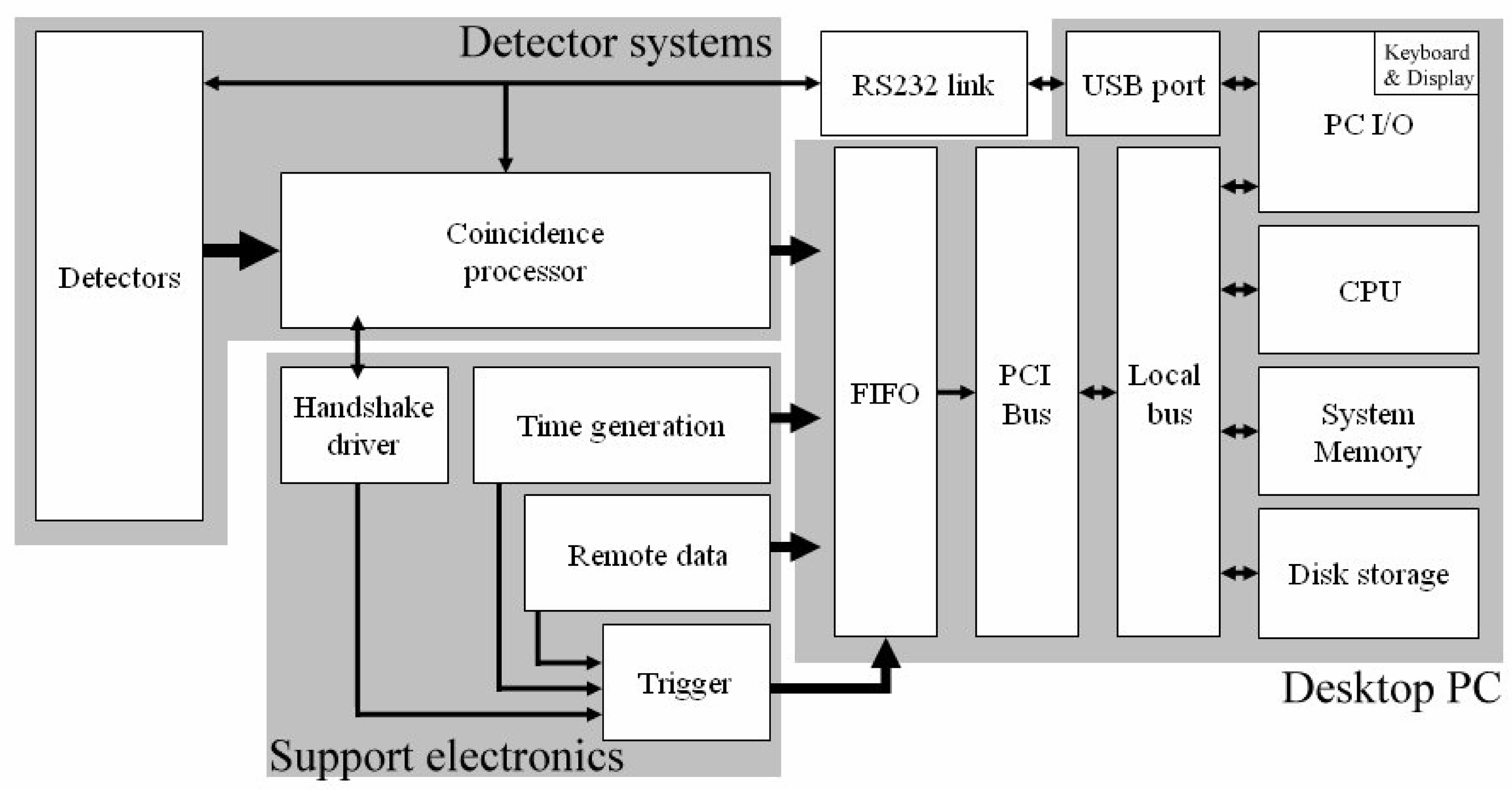
PEPT location data for an experiment measuring polymer flow and mixing behaviour within industrial twin-screw extrusion processes. The average data rate for this experiment was 120 kHz allowing accurate locations to be made every 10 ms. Approximately 300 MB of data was written to disk during the 40 s experimental time period.

These results are to be published shortly; further information can be found at http://www.peptflow.com/

The demand for high speed list mode data storage required for PEPT experiments has motivated the development of an improved data acquisition system. This is based around the PCI-7300A Digital I/O Card manufactured by Adlink technologies inc. It features 80 MBytes per second, 32-bit data transfer via direct memory access (DMA) along the PCI bus, with a further 8-bits auxiliary I/O and simple handshaking/trigger process capability. In order to interface with the existing coincidence processor system a small number of dedicated support circuits have been built. These use TTL technology and deal with the handshaking requirements, time information insertion and remote trigger handling.

The block diagram (right) illustrates the acquisition system architecture. The detectors and coincidence processor are controlled by serial commands issued via the USB port. Data from the individual detector modules undergoes coincidence processing and the resultant coincidence data word is captured following successful handshaking. Timing information and remote trigger data is inserted into the data stream by triggering data capture as events occur.

Captured data is transferred as a block from the local FIFO (First In First Out memory block) to a circular buffer sitting in system memory via DMA along the PCI and system busses. Data is then transferred to disk during the acquisition, this can be transferred to removable media (CD/DVD) after the experiment is completed. The computer resources can be used for processing the data, performing data analysis, and displaying real-time LOR or PEPT data.



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During initial trials sustained data acquisition rates of approximately 120 kHz have been demonstrated. Short bursts of above 1.7 MHz have been seen during periods where the tracer particle was located in an area of high sensitivity. This corresponds to writing between 1 to 15 Mbytes per second to disk.

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