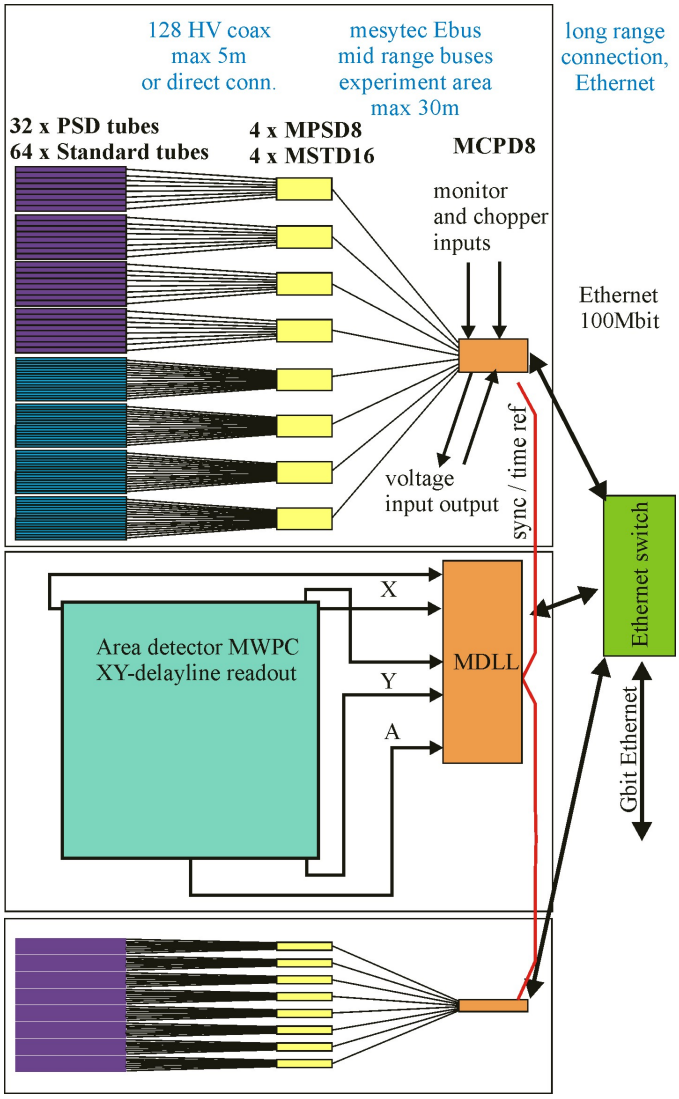
mesytec psd is a modular readout electronics system covering the requirements of modern neutron scattering instruments. These take advantage of position sensitive detector tubes, providing 6mm position resolution at 1m detector length and tube diameters in the range from 8mm to 25mm. The high position resolution allows getting closer to the sample and using a larger solid angle. This, as well as the high peak rates of modern TOF spectrometers, requires fast readout electronics that allows to register data at the detector rate limit (about 100kHz /tube) with lowest possible dead time ratio.

mesytec psd system provides readout electronics for position sensitive and standard tubes as well as for area detectors with delay line readout.
It consists of four different electronics modules and a related data acquisition and control software that can be modularly combined to meet individual instrument requirements.

Common **main features** are: high rate capability, low dead time, 100ns time stamping for all events, high modularity, built in test pulsers.

MPSD-8 is the front end module for up to eight 3He / BF3 position sensitive tubes. It transmits time stamped position and amplitude of neutron events with 10bit resolution, achieving a position resolution of 3mm (FWHM) at 400mm and 6mm at 1000mm tube length.
MSTD-16 is the corresponding front end for up to 16 standard detector tubes and transmits the incident time and amplitude of neutron events.
Both front ends provide remotely controlled threshold and gain settings.
Up to eight (also mixed) front end modules can be connected via point to point high speed buses to the central electronics module **MCPD-8.**
Its task is concentrating and transmitting data and handling control commands over a 100Mbit Ethernet interface to/from the control pc.
It additionally offers six chopper/monitor/counter inputs, two 12bit ADCs, two 10bit DACs and two TTL outputs. This allows flexible integration of environmental data/signals into the timestamped data stream.
For area detectors with delay line readout, **MDLL** offers a combined front end and central electronics.
Multiple MCPD-8 and/or MDLL can be easily put together to a common readout system to cover large detector setups. A sync line distributes a system wide time signal.



Mixed setup with different detectors, integrated into one control environment.

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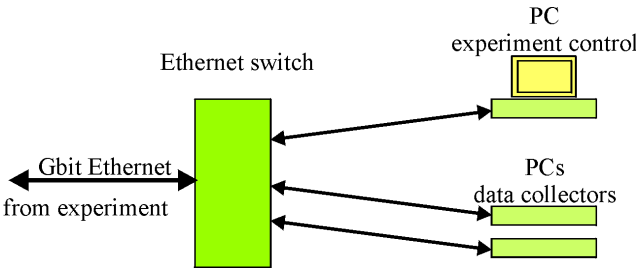
MCPD-8 and MDLL communicate with the control and data acquisition PCs using a UDP based protocol. The open source data acquisition and control software **mesydaq/ qmesydaq,** running on Linux OS, is provided for data acquisition, online visualisation and system control.



Set up with one control- and 2 data collector PCs.

Functional Overview

Readout path

The position sensitive detector tubes are read out in groups of eight which are connected to the single width NIM module MPSD-8+. Each of the modules buffers the time stamped position and amplitude data of the 8 connected detector tubes and transmits them over a fast serial bus to the central NIM module MCPD-8 (mesytec central processing device). The event bus is physically a coax wire. One MCPD-8 collects data of up to 8 MPSD-8+ or MSTD-16 modules, buffers the data and transmits it via Ethernet to one (or more) data collecting PCs. mesydaq software runs on Linux and handles incoming data. Data buffers are stored on hard disk and selected data displayed live in histograms.

Transmitted event data

The MPSD-8+ modules provide simultaneous amplitude and position data with 10bit resolution. MSTD-16 transmits amplitude data with 10bits. MDLL provides x-y-position (each 10bit resolution) and energy (8bit) or timing information and energy.

Remote control

To control the complete system, there is a data path back from the PC via Ethernet and event bus.
It is possible to configure gains, thresholds and test pulsers from the PC, make pulser test runs, and store the complete data set in a configuration file which is downloaded to the peripheral modules at the beginning of a new run. The control PC can, but need not be different from the data collecting PCs.

Diagnostics

A built in test pulser, which feeds directly to the detector inputs of the front end electronics, easily allows to check all the signal path from pre amplifier to the PC. The pulser can be remotely controlled by software.

Scalability

The mesytec psd system is fully modular, consisting of only two different mesytec module types (front end and central electronics) in a chain (both already combined in MDLL). All other components are easily available standard electronics like NIM crates and networking electronics. A basic setup for up to 64 position sensitive or up to 128 standard tubes consists of one MCPD-8 and max. eight MPSD-8+ / MSTD-16. It can be extended to an unlimited number of detectors by just adding further MCPD-8 plus front end electronics.
A single coaxial connection between the MCPD-8 or MDLL modules allows to synchronize start / stop and a run number of the complete setup and provides a precise time base from the "master" MCPD-8 to all connected "slave" MCPDs.

Time stamping

TOF setups and also setups with time variant parameters need precise timing information for individual events. Also the external signals from choppers, monitors or the auxiliary ADC inputs (each MCPD-8 provides two 12bit ADCs) can be labelled with the experiment time.

The mesytec psd system provides a time base with a precision of up to 10^{-7} (with an optional oven stabilized quartz). The counter step (resolution) is 100ns. The time stamp of 48bits length (running 325 days) allows a precise reconstruction of the experiment data, even if the events are collected on different collector PCs and are written to different files.
The time base is permanently synchronised over a sync line, which connects all MCPD-8 and MDLL modules in a setup.

MPSD-8 and MSTD-16 use their own time base (100ns step) to label the incoming events in their buffer. When the events are sent to the MCPD-8 via event bus, the time delay from receiving the event at MPSD-8 input to transmitting it to MCPD-8 via data bus is added to the event information. The receiving MCPD-8 adds this time offset to the event time stamp. So the full electronics chain runs with 100ns timing resolution.

Also up to six digital inputs (for example choppers, monitor inputs...) and 4 internal timer sources can create time stamped events and feed it into the data stream. The created events may also contain data from the two MCPD-8 ADC inputs or counter information (monitor counters, chopper counters).

Rate capability, dead time

For a perfect readout electronics, the dead time of the system should only be determined by the detector properties. The detector front end electronics is designed to reject wrong positions when two neutron events occur in the same tube within the signal decay time of the first one (pile up rejection). For R&S tubes with 1 inch diameter and 8 bar pressure, 3µs were found to be the optimum dead time. Colliding events can be recognized when they are separated by more than 500ns and are then eliminated from data stream. For thinner tubes with faster charge rise / decay time the dead time is slightly shorter.

The MPSD-8 uses two very fast, precisely calibrated converters to digitize position and amplitude of 8 Detectors. This converter almost adds no dead time because the analogue electronics section is used to buffer the two amplitudes of each of the 8 detectors for up to three conversion times.

A rate and dead time example for a TOF setup with fast detectors (3µs dead time):
MPSD-8+ is receiving an elastic Bragg peak (arrives before inelastic neutrons) on one tube with 100kHz, the other tubes will have a rate of 10kHz. So at the position of the Bragg peak, at the moment the elastic neutrons hit the detector (some us) this detector will have a detector induced dead time ratio of 30% and 0.1% converter dead time. The other detectors of the same module at the same time will have a detector dead time of 3% and 0.1% converter dead time. After the elastic peak has passed, the rate will usually decay by orders of magnitudes, and the dead times will be negligible. No additional dead time is added through all the processing chain down to the PC.
A system with 128 detector tubes (16x MPSD-8,
2x MCPD-8) will process a peak rate of 12.8MHz
(detector limit 100kHz per detector) and an average rate of 4MHz.

The MCPD-8 is capable to receive the full rate simultaneously on all 8 buses. So it adds no dead time. The events are buffered in a large data buffer (1Mbyte resulting in 128kevents) and are finally sent over the Ethernet connection. The event transmission rate to the Ethernet for typically 6bytes (10bit amplitude, 10bit position and time stamp) per event +5% protocol overhead, the maximum Ethernet rate will be around 2Mevents/s.

Electronics modules:

MPSD-8+, MCPD-8 and MDLL in 1/12 NIM cases
(MSTD-16 is mechanically identical to MPSD_8+)

MPSD-8+ in standalone case, e.g. for mounting directly behind the detector bank

Measured position resolutions with MPSD-8+

Type	Length [mm]	Diameter [mm]	Resolution [mm] FWHM
RS / GE 8 bar 3He	350	25.4	2.5
RS/GE 12 bar 3He	1000	8	6
RS/GE 20 bar 3He	400	8	3
Toshiba (6 kΩ total res.)	2000	25.4	25

resistive anode wires typ. 7kΩ /m

Software

qmesydaq, a Linux based open source software is provided with the mesytec psd system.
Based on a version provided by mesytec, there are now also versions actively developed at the neutron scattering centers in Berlin (HZB / BER-II) and Munich (FRM-II).

qmesydaq can be used for data acquisition, storage and replay of listmode data and histograms, online visualisation and remote control of all hardware components of the readout system.
Software interfaces allow integration into existing instrument control systems (e.g. CARESS, TACO, ...).

The specification for the UDP based data transfer and command protocol is also open source. Thus even an own software development from scratch is possible (and has already been done by some users).