CDT
CASCADE Detector Technologies GmbH

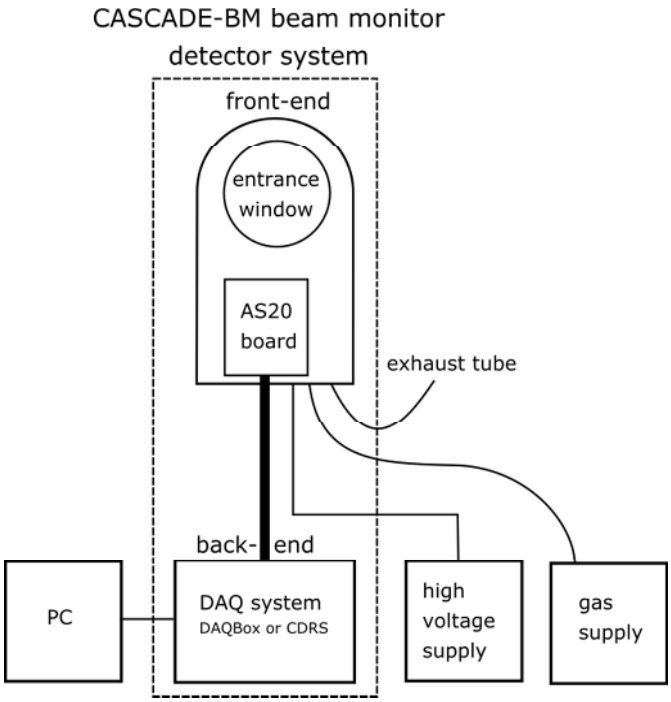
represented by
REPIC corp.
in Japan

Hans-Bunte-Straße 8-10
D - 69123 Heidelberg
Phone: +49 (0)6221 796 745 1
Fax: +49 (0)6221 796 745 3
Mobile: +49 (0)151 613 658 20
Internet: www.n-cdt.com

CASCADE-BM Beam Monitor Systems

CASCADE-BM position sensitive beam monitor detector systems are designed for high intensity neutron applications with thermal or cold neutron beams. They exploit the enormous counting rate capability of the GEM technology for beam monitor applications with very high needs in counting dynamics, contrast as well as background. The detector system consists of the detector itself, also called the front-end or beam monitor, and the data acquisition (DAQ) system, also called the back-end or readout system (see figures below). The front-end already includes the *AS20* readout board so that the output is completely digital. It has been proven to support a 1 kGy total ionising dose.

CASCADE-BM 2D-32 beam monitor detector system. The detector itself is shown on the right side with a transport secure shield (red) for the very thin entrance window. Gas supply pipes, a high voltage cable and a SCSI-III data cable are shown as well.



CASCADE-BM 2D-32 beam monitor detector system. The detector itself is shown on the right side with a transport secure shield (red) for the very thin entrance window. Gas supply pipes, a high voltage cable and a SCSI-III data cable are shown as well.

The detector may be employed in-line with the neutron guide or, alternatively as a monitor to be allocated in the beam just upstream or downstream of an instrument. In the latter application, position sensitive detection allows to identify the shadow of the sample downstream and thus to evaluate its allocation together with the beam-sample interaction probability. In this case the virtue of counting statistics can be fully exploited since signal to noise, or contrast, is purely determined by counting statistics and can be pushed to the level needed through signal accumulation. Detection with spatial resolution makes it possible to analyze data with respect to beam homogeneity and beam divergence, uncover and discriminate against any halo effects, and to correlate data with the beam structure itself. In chopped applications, sample interaction probability may additionally be determined for the full wavelength spectrum through a full time of flight acquisition on all 2D detector pixels simultaneously and synchronous to the chopper action.

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Picture of the ***CASCADE-BM 2D-32*** detector housing: neutron entrance window made of 100 µm Aluminum (right side), gas inlet and outlet as well as HV connector of type SHV and SCSI-III connector for the DAQ electronic readout and powering (left side).

The detector front-end is a hybrid, solid converter gas detector using a gas electron multiplier (GEM) foil and a drift electrode to carry a thin solid layer of natural Boron. The use of GEM technology allows high count rates up to 10^7 n/cm^{2}s and has the conceptual advantage of insensitivity to magnetic fields. The well-defined neutron absorption locus inside the thin boron layer provides sub microsecond absolute time resolution, which opens the door towards new TOF applications. Using GEM foils, the neutron detection bottleneck shifts to data read-out electronics and its bandwidth. *CASCADE* detectors use pre-amplifier ASIC readout chips chips, integrated inside the front-end on an *AS20* board, paired with an adaptable integrated FPGA data acquisition unit in the back-end to provide high rate capacity and real-time event reconstruction. The on-device electronics has been shown to support a 1 kGy total ionising dose.

The detector housing is made of two aluminum flange parts to minimize potential activation problems in an intense neutron radiation field. The beam monitor is constructed with the aim to minimize material in the beam. The detector entrance window is intentionally kept thin (100 µm of aluminum or less if needed) to maximize the probability for neutrons to traverse the detector.

Furthermore It includes a low mass position sensitive readout structure that determines the exact position of incidence by sharing the charge cloud between readout channels of two orthogonal coordinates: the electrons created by one neutron are collected by electrodes in x and y direction, detecting an event at coordinate (x, y). The electrodes are effectively turned from 2x32 1D strips into 32x32 2D pixels (1mm x 1mm). This is made possible by a filigree structure of interwoven readout electrodes in x and y direction on the readout pcb that covers the full sensitive area of the detector. The resulting analogue signals are routed to an internal *AS20* pre-amplifier board, containing 64 readout channels. The *CASCADE-BM 2D-32* detector has 2x32 electrodes so that one electrode can be routed to one readout channel, forming one strip. The *CASCADE-BM 2D-100* has twice the number of electrodes. It can be configured to use two *AS20* boards for a resolution of 64x64 pixels (1.56mm x 1.56mm), or route two electrodes to one readout channel so that two

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neighboring electrodes form one strip, halving resolution in both dimensions (3.12mm x 3.12mm). The table below lists all possible configurations.

CASCADE-BM	2D-32	2D-100	2D-customized
Outer dimensions	216mm x 102mm x 15mm	299mm x 200mm x 20mm	customized geometries possible
Total weight	1100 g	1500 g	
Mounting on a beam pipe	Six through holes (4mm diameter) around the entrance window	Six through holes (4mm diameter) around the entrance window	

Each readout channel provides a rate capability of 300 kHz (at 10% dead time). The overall rate capability over the sensitive area is determined by the need to distinguish two almost simultaneous hits: signals on readout channels x0, x1, y0 and y1 at the same time cannot be correlated to two 2D events unambiguously. This may be viewed as a pile-up on the area. In practice, the overall rate capability is found to be about 1 MHz in this 2D/correlated mode. It can be enhanced even further if the electrodes are read out uncorrelated, i.e. x and y coordinates are determined separately so the 1D strips are not turned into 2D pixels. In this example the detector would register four events at the 1D coordinates x0, x1, y0 and y1. With 32 channels per dimension this results in a rate capability of 5 MHz, with 64 channels (two *AS20* boards) in 10 MHz. This mode is referred to as 1D/uncorrelated mode.

The *CASCADE-BM* beam monitor detector system is conceived as a standalone, position sensitive neutron detection device, where the pre-amplifier readout electronics (front-end ASIC) is already integrated inside the device. The beam monitor can be operated with the CDT provided *CASCADE DAQBox* via USB or, in a more advanced system, with the CDT provided *CDRS* DAQ system, which can be seamlessly integrated into a full instrument control.

CASCADE-BM	2D-32	2D-100		2D-customized
Size of sensitive area [mm x mm]	32 x 32	100 x 100		YY x ZZ
Overal electronics readout channels available	64 (one AS20)	64 (one AS20)	128 (two AS20)	customized
Array size [readout strips]	32 x 32	32 x 32	64 x 64	Y x Z (Y+Z = 64)
Pixel size [mm]	1,0	3,12	1,56 x 1,56	1,56
Image size [pixel]	1024	1024	4096	customized
Individual electronics channel/strip read-out bandwidth [kHz] (at 10% dead time)	300	300	300	300
2D overall rate capability [MHz] (at 10% dead time)	1	1	2	customized
1D overall rate capability [MHz] (at 10% dead time)	5	5	10	customized

Further, a high voltage supply (up to -1000 V) and a continuous flow of counting gas need to be supplied for operation. The counting gas, usually a mixture of Argon and CO_2 in a ratio of 85/15 to

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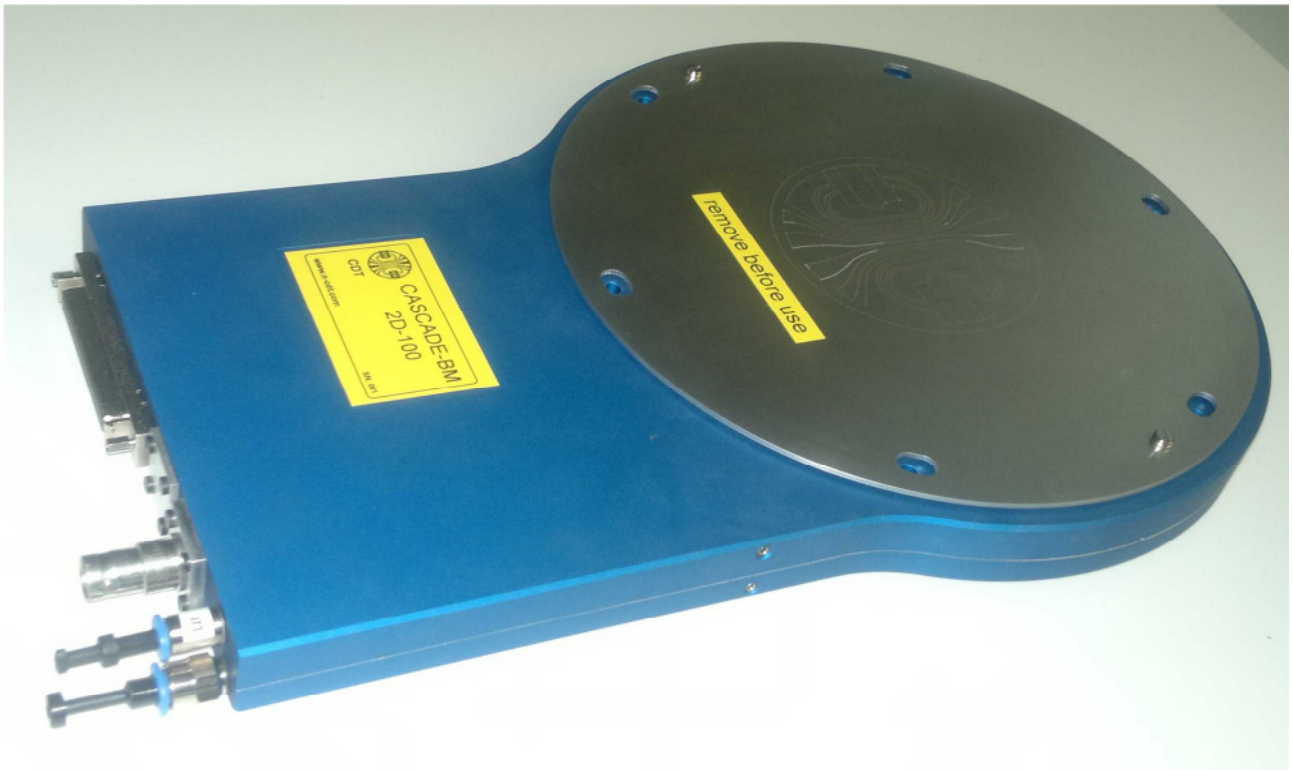
70/30 by volume, needs to be supplied at an overpressure of about 100 mbar. An internal capillary then maintains a purging flow of less than 10 ml/min through the detector.

Optional, the detector can be realized as a dual dynamic position sensitive beam monitor (*CASCADE-BM 2DD-x*). In this version, it is possible to operate the monitor on a fully open beam as well as on a chopped beam. This is related to the fact, that the readout plane by construction is sensitive on either side. So the monitor can be equipped with two full detector stacks, comprising one part with the standard very thin natural Boron coated drift electrode and the other with a thicker isotopically pure ^{10}B coated drift electrode as well as a signal amplifying GEM foil each, that sandwich the readout plane. The two detector stacks provide a detection efficiency for thermal neutrons that may be customized to differs by two orders of magnitude through different Boron deposition amounts. They may individually be switched operative, so that the overall dynamic range of the setup extends yet further by two orders of magnitude.

CASCADE-BM		**2D-32**	**2D-100**
available Detection efficiencies [%] for thermal neutrons	standard	0,05 … 1,0	
	dual dynamic I	(0,01+1,0) … (0,05+4,7)	
	dual dynamic II	(0,01+1,0) … (0,05+8,4)	
	high efficiency I	9,0	
	high efficiency II	12,2	
	high efficiency III	15,0	



Photography of the ***CASCADE-BM 2D-100*** detector: neutron entrance window made of 100 µm Aluminum (right side, here protected with transport aluminum shield), gas inlet and outlet as well as HV connector of type SHV and SCSI-III cable-connector for the DAQ electronic readout and powering.