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Beam Loss Monitor

User's Manual

Rev. 3.1

Record of updates

| Version | Date | Updates performed |
|---------|---------|---|
| 2.0 | 06/2017 | New release including BLM-DIF |
| 3.0 | 03/2018 | Review of the full manual. Obsoletes all previous versions |
| 3.1 | 12/2019 | Modification of the cover page and creation of the distributors' page |
| | | |
| | | |

DISTRIBUTORS

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GMW Associates

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www.gmw.com
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INITIAL INSPECTION

It is recommended that the shipment be inspected immediately upon delivery. If it is damaged in any way, contact Bergoz Instrumentation or your local distributor. The content of the shipment should be compared to the items listed on the invoice. Any discrepancy should be notified to Bergoz Instrumentation or its local distributor immediately. Unless promptly notified, Bergoz Instrumentation will not be responsible for such discrepancies.

WARRANTY

Bergoz Instrumentation warrants its beam current monitors to operate within specifications under normal use for a period of 12 months from the date of shipment. Spares, repairs and replacement parts are warranted for 90 days. Products not manufactured by Bergoz Instrumentation are covered solely by the warranty of the original manufacturer. In exercising this warranty, Bergoz Instrumentation will repair, or at its option, replace any product returned to Bergoz Instrumentation or its local distributor within the warranty period, provided that the warrantor's examination discloses that the product is defective due to workmanship or materials and that the defect has not been caused by misuse, neglect, accident or abnormal conditions or operations. Damages caused by ionizing radiations are specifically excluded from the warranty. Bergoz Instrumentation and its local distributors shall not be responsible for any consequential, incidental or special damages.

ASSISTANCE

Assistance in installation, use or calibration of Bergoz Instrumentation beam current monitors is available from Bergoz Instrumentation, 01630 Saint Genis Pouilly, France. It is recommended to send a detailed description of the problem by email to info@bergoz.com.

SERVICE PROCEDURE

Products requiring maintenance should be returned to Bergoz Instrumentation or its local distributor. Bergoz Instrumentation will repair or replace any product under warranty at no charge. The purchaser is only responsible for transportation charges.

For products in need of repair after the warranty period, the customer must provide a purchase order before repairs can be initiated. Bergoz Instrumentation can issue fixed price quotations for most repairs. However, depending on the damage, it may be necessary to return the equipment to Bergoz Instrumentation to assess the cost of repair.

RETURN PROCEDURE

All products returned for repair should include a detailed description of the defect or failure, name and fax number of the user. Contact Bergoz Instrumentation or your local distributor to determine where to return the product. Returns must be notified by fax prior to shipment.

Return should be made prepaid. Bergoz Instrumentation will not accept freight-collect shipment. Shipment should be made via UPS, FedEx or DHL. Within Europe, the transportation service offered by the Post Offices "EMS" (Chronopost, Datapost, etc.) can be used. The delivery charges or customs clearance charges arising from the use of other carriers will be charged to the customer.

SCOPE OF USE

Beam Loss Monitors based on PIN-photodiode signal coincidence detection can be used to evaluate beam loss of CW beam, long macropulses from synchrotrons, cyclotrons and high-repetition rate linacs. PIN-Photodiodes-based BLMs are of no use on beam with single pulses, e.g. laser-plasma accelerators, single bunch injection, low repetition rate linacs.

Why? Because PIN-photodiode-based BLM outputs a single pulse whether it is hit by one secondary electron or 1000 such electrons and requires 100ns to recover before the next hit. Thus, it is not an integrating loss monitor. It relies on the statistical probability of being hit by secondary electrons.

BLM MODELS

Identify whether the model is BLM-SE, i.e. with unipolar single-ended output, or BLM-DIF, i.e. with differential 100-ohm output.

Both models are equipped with two 7.34 mm² BPW34 PIN-diodes.

Note: BLM-XL with 150 mm² S2662 is an older model no longer manufactured. Older denomination BLM-XS is now known as BLM-SE.



QUICK CHECK

You can check immediately that your BLM is working.

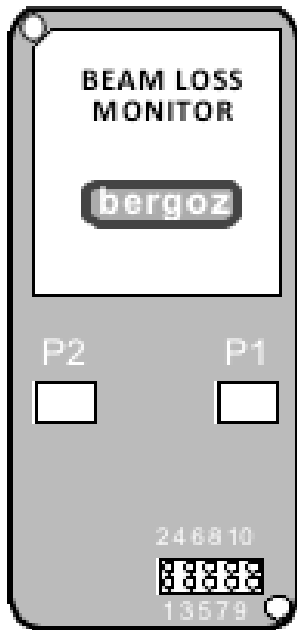
To check the spurious count rate in each channel, this is what you need:

- BLM-SE or BLM-DIF
- Oscilloscope ≥ 100 MHz bandwidth
- Power supplies: +5V, -5V, +24...25V
- Resistor 4.7 k Ω $\geq 1/8$ W

To check the actual count rate from secondary MIP electrons (minimum ionizing particles), a source decaying in beta- > 900 keV is needed, e.g., Americium. These sources are not commonly available.

Identify the connections

Model BLM-SE



HE10 Pin#.....Function

- 1Ground
- 2+ 5V
- 3n/c
- 4- 5V
- 5Enable/Disable B
- 6+24...25V
- 7n/c
- 8Ground
- 9Enable/Disable A
- 10Output

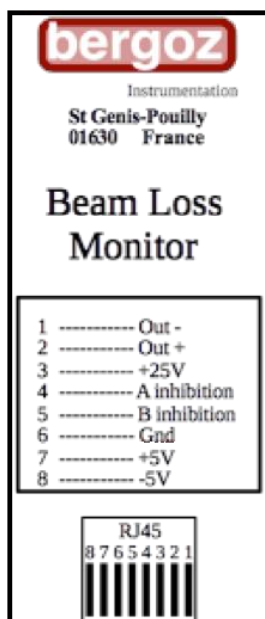
Connect the power supplies to BLM-SE:

- GroundPin 1
- +5V.....Pin 2
- 5V.....Pin 4
- +24...25VPin 6

Connect the oscilloscope:

- OutputPin 10
- GroundPin 8

Model BLM-DIF



RJ45 Function RJ45 color by RJ45 color by
 Pin# EIA/TIA T568A..... EIA/TIA T568B

- 1 Out- Green/White Orange/White
- 2 Out+ Green Orange
- 3 +24...25V Orange/White Green/White
- 4 Enable/Disable A Blue Blue
- 5 Enable/Disable B Blue/White Blue/White
- 6 Ground Orange Green
- 7 +5V Brown/White Brown/White
- 8 -5V Brown Brown

Connect the power supplies to BLM-DIF:

| | | | |
|----------------|------------|-------------------------------|--------------------------------|
| | | RJ45 color by EIA/TIAT568A | RJ45 color by EIA/TIA T568B |
| Ground..... | Pin 6..... | Orange..... | Green |
| +5V..... | Pin 7..... | Brown/White..... | Brown/White |
| -5V..... | Pin 8..... | Brown..... | Brown |
| +24...25V..... | Pin 3..... | Orange/White..... | Green/White |

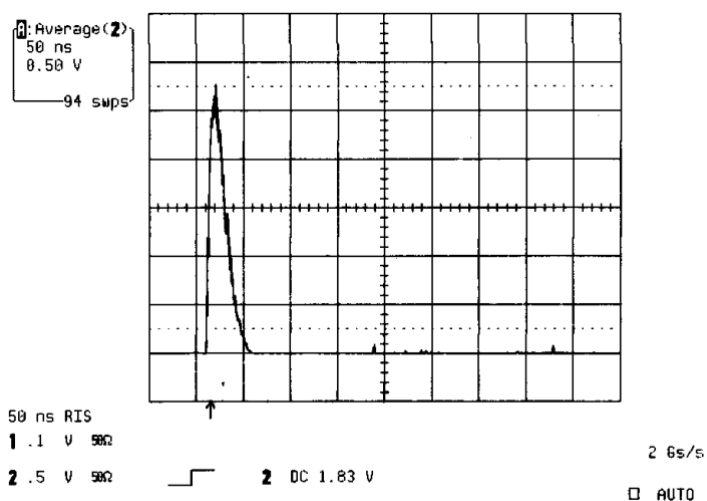
Connect the oscilloscope Input channels 1 and 2 to:

| | | | |
|-------------|------------|------------------|--------------|
| Out-..... | Pin 1..... | Green/White..... | Orange/White |
| Out+..... | Pin 2..... | Green..... | Orange |
| Ground..... | Pin 6..... | Orange..... | Green |

Check #1

- Display the spurious counts of channel A:
- Channel B must be enabled (as if it had received a hit at the same time):
 - Connect Enable/Disable channel B to +5V thru the 4.7kΩ resistor.
 - The oscilloscope displays the spurious counts in channel A.
- To display the spurious counts of channel B:
 - Connect Enable/Disable channel A to +5V thru the 4.7kΩ resistor.
 - The oscilloscope displays the spurious counts in channel B.

Waveforms look like this:



Note: BLM-DIF displays two pulses on channel 1 and channel 2 in opposite polarity.

Check #2

If a beta- source with E>900 keV is available, display the counts from MIP secondary electrons (minimum ionizing particles); do not pull-up Enable/Disable A nor B. Bring the high-energy beta- source and the BLM closer to each other, observe the increase in the count rate.

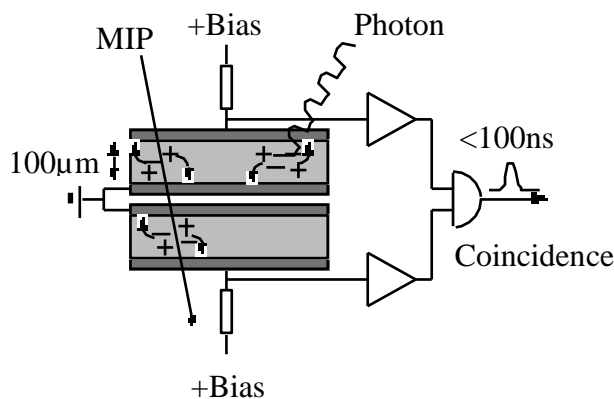
OPERATING PRINCIPLE

Detector Type

The detector is sensitive to MIPs (minimum ionizing particles) produced when an accelerated particle hits the wall of the vacuum chamber.

Refer to Annex I: "Electron Beam Loss Monitor" by W. Bialowons, F. Ridoutt and K. Wittenburg for the mechanism of beam loss in FODO structures due to accelerated particles scattering on residual gas molecules nuclei or vacuum chamber walls.

The detector is composed of two PIN-diodes mounted face to face to form a 2-channel coincidence detector.



Signal processing

When an ionizing particle hits a PIN-diode, an electric charge is produced. A bias voltage allows collection of this charge. It is amplified to a level high enough for conventional logic. An AND-gate detects the coincidence of pulses from the two PIN-diodes.

MIPs cause ionizations in both PIN-diodes, a coincidence occurs and an output pulse is generated. Photons do not cause ionization in both PIN-diodes. So, the coincidence circuit does not produce a pulse for photons.

The amplification gain of each channel is adjusted with a potentiometer.

Efficiency of the detector

Overall, MIPs are detected with an efficiency > 30 %. See Annex III: "Radiation Resistance of Beam Loss Monitor" by K. Wehrheim and K. Wittenburg.

The size of the PIN-diodes mounted on the circuit determines the detector's solid angle. The coincidence scheme rejects very effectively the spurious noise from each channel to a figure well below 1 count/s.

The channel gains can be adjusted to obtain negligible spurious count rates: < 0.1 count/min. See Annex II "A Beam Loss Monitor for HERA" by S. Schlögl and K. Wittenburg. It rejects equally effectively the X-ray background typical of electron/positron storage rings.

Dynamic range

It is determined by the spurious noise of the detector and the maximum count rate. It exceeds 108. The spurious noise, in the absence of any background, is well below 1 count/s.

In the presence of an intense X-ray background, the BLM must be shielded by 3 cm of lead to maintain the spurious count rate below 1 count/s. Without a lead shield, the spurious count rate has been observed on HERA to reach 100 counts/s.

The detector recovers 100 ns after a hit, leading to 10 MHz maximum count rate.

Radiation resistance

Prototypes similar to production units were tested at DESY for radiation hardness. The unit under test was still working after 108 Rads dose (!). See Annex III: "Radiation Resistance of Beam Loss Monitor" by K. Wehrheim and K. Wittenburg.

CALIBRATION

BLM circuits are calibrated ex-factory for a spurious count rate of 10 kHz \pm 800 Hz.

Discriminator readjustment on P1 and P2 is needed when the PIN-diodes are changed for another type (larger, smaller). Background count can be performed on line.

On-the-bench verification / discriminator readjustment

To adjust the spurious count rate, power up the BLM. Connect a frequency counter on the output.

When measuring BLM-DIF output, either Out+ or Out- can be monitored.

To readjust channel A, apply +5V via a 4.7k Ω resistor to "Enable/Disable B". Adjust potentiometer P1 till 9.6~10.4 kHz output.

To calibrate channel B, apply +5V via a 4.7k Ω resistor to "Enable/Disable A". Adjust potentiometer P2 till 9.6~10.4 kHz output.

On-line check

Apply \geq +1V alternately to Enable/Disable A and Enable/Disable B. Observe the count rate to be in range 9.6~10.4 kHz.

Enable/Disable A resp. Enable/Disable B draws 120 μ A from +1 V.

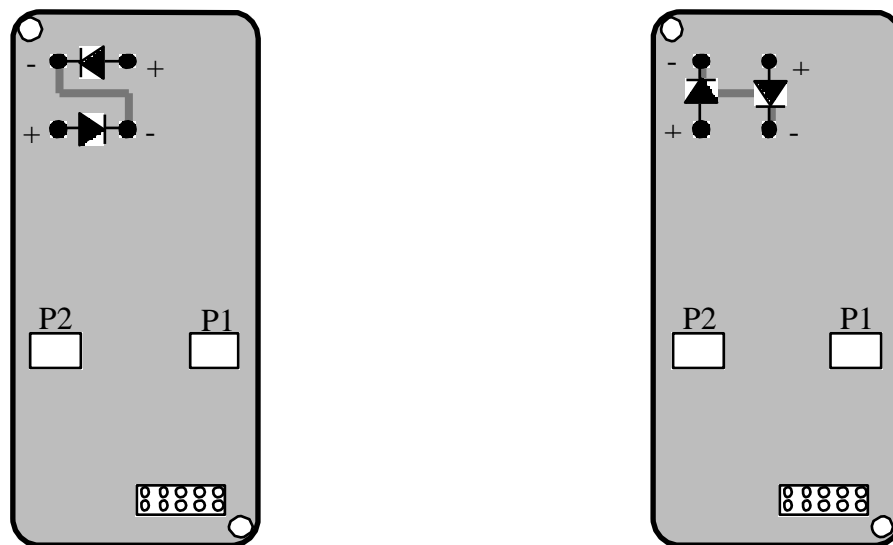
CHANGING THE PIN-PHOTODIODES

PIN-photodiodes can be changed by the user for a larger-area model. Two similar diodes per BLM are required.

Instructions

- Make sure the BLM works properly before modification: See QUICK CHECK, in this manual.
- Remove the printed circuit from its enclosure:
- BLM-SE: Pull gently on the copper shield, the PCB is glued to the bucket.
- BLM-DIF: Remove the (4) screws off the bakelite box bottom.
- Desolder the copper shield and remove it.
- Desolder the PIN-diodes and remove them.
- Install the new PIN-diodes. They should be facing each other. Their active areas should overlap each other.!

Beware of the PIN diodes polarity. There are two possible configurations with the correct polarity:



Note the common cathodes

WARNING: Installing PIN-diodes with the wrong polarity voids the warranty.

- Execute a QUICK CHECK before the copper shield is re-soldered.
- Re-solder the copper shield. Make sure the copper shield does not touch the PIN-diodes leads! If needed, use polyvinyl adhesive tape to isolate the inside of the shield.
- Re-adjust the BLM discriminator levels P1 and P3. See CALIBRATION in this manual.
- Please note: large area PIN-photodiodes have more dark current, so the span of P1 and P2 covers a wider range and their adjustment on 10 ± 0.4 kHz dark current is more “touchy”.

COMPTON ELECTRONS SHIELD

Production of Compton electrons in the BLM PIN-photodiodes has been observed on very-high energy leptons accelerators (HERA-e, LEP).

The consequence of Compton electrons production in one PIN-photodiode is that it may cause ionization in the other PIN-diode. As a result, the PIN-photodiodes produce pulses which are coincident and the BLM gives an output pulse. On very high energy leptons accelerators, these Compton electrons increase the background noise significantly¹.

The increase in background noise reduces the BLM useful dynamic range. A way to avoid this problem was sought. It was proposed² to install a shield between the two PIN-photodiodes.

This proposed improvement was successfully tested at both LEP and HERA:
It reduces the Compton electron-induced noise significantly. The shield is made out of 200 μm thick copper foil. It is grounded via a high value resistor to prevent static charge build-up.

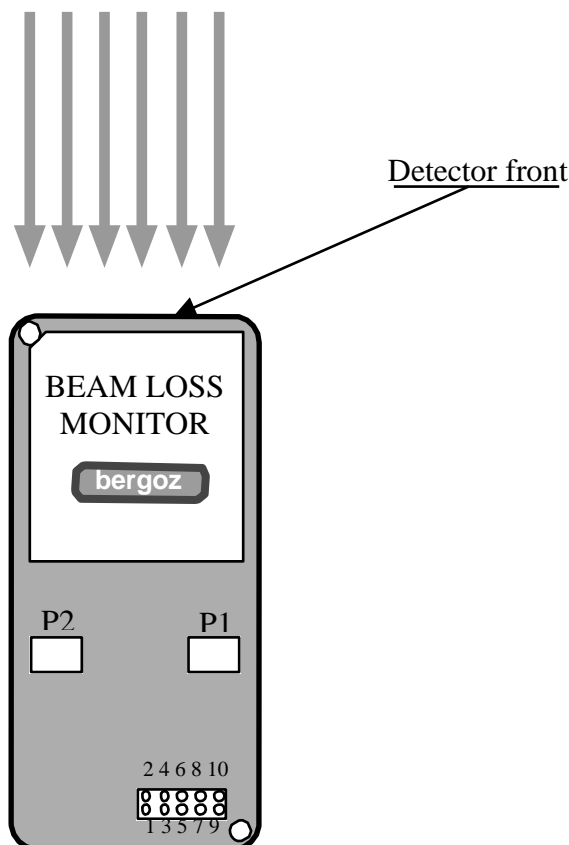
¹ Improvement in the useful dynamic range of the LEP Beam Loss Monitor, T.Spickermann, CERN, and K.Wittenburg, DESY, to be published

² Private communication, K.Wittenburg.

INSTALLATION

Mechanical mounting

The BLM must be oriented facing the particles to be detected:



Mathematical simulation would indicate where beam loss is most likely to occur (See Annex I for FODO structure beam loss). BLMs will generally be placed with the front applied against the magnets.

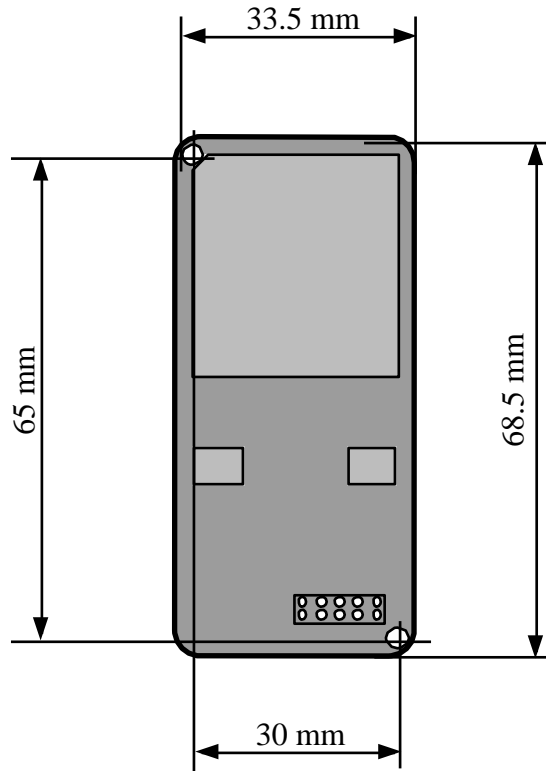
BLM-SE can be screwed on brackets with two M3 screws. M3 screws will gently make their way into the $\varnothing 2.8\text{mm}$ holes of the ABS plastic.

BLM-DIF features 4 mounting holes.

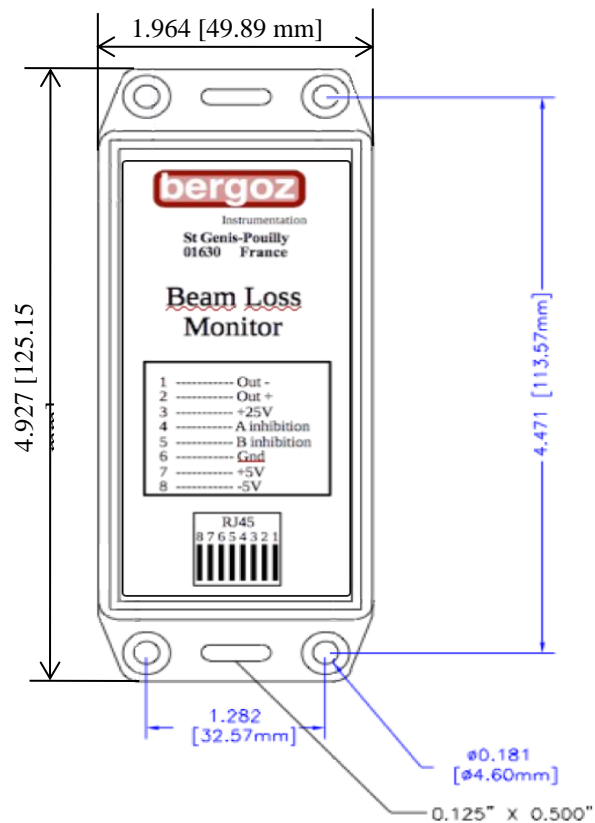
Yet, it is preferable to attach the BLM with Velcro tape.

Mounting holes

BLM-SE



BLM-DIF



BLM CONNECTIONS

BLM-SE connects with a female HE10 connector e.g., 3M, type 3473-6000.

Output with a 50-ohm coaxial cable connects to pin 10, ground on Pin 8.

At DESY, RG-59 75-ohm coax cables are used for distances up to 100 meters without problems (K. Wittenburg, private communication, Febr. 9, 1995). For cables longer than 100 meters, a small amplifier is added in front of the scaler.

BLM-DIF connects to an RJ45 plug.

A recommended alternative is using Ethernet cable. Pair impedance is 100 ohms.

Cat.5 or higher is recommended. It is not necessary that each pair is individually shielded because only one pair carries a pulsed signal.

F/UTP aka FTP, S/UTP and SF/UTP are suitable. UTP must be avoided.

STP is a generic name to describe S/UPT or SF-UTP. It is suitable.

For long runs of cable, an overall shield and individual shielding of each pair is preferable for RFI rejection: S/FTP or F/FTP are recommended for long runs or high-noise areas.

For acronyms, see:

<http://www.belden.com/blog/datacenters/STP-UTP-FTP-Cable-More-7-Types-When-to-Use-Them.cfm>

OUTPUT SIGNAL PROCESS

Controls would use scalers with single-ended input or 100-ohm differential input.

Laboratory tests can be made using a frequency counter.

SPECIFICATIONS

| | |
|--------------------------|--|
| MIP detection efficiency | > 30% |
| PIN-photodiode surface | 7,34 mm ² |
| Spurious count rate | < 0.1 Hz |
| | Up to 100Hz under 6e3 Grey/yr SR background |
| | < 1Hz under 6e3 Grey/yr SR background with 3cm lead shield |
| Maximum count rate | 10 MHz |
| Enable/Disable A control | ≥+1V, 120 μA |
| Enable/Disable B control | ≥+1V, 120 μA |
| Power supplies | |
| +5V | < 50mA, typ. 45mA |
| -5V | < 80mA, typ. 72mA |
| +24...25V | < 10mA, typ. 4 mA with BPW34B PIN-diodes |

| | BLM-SE: | BLM-DIF: |
|--------------------------|----------------------|-----------------------|
| Output | positive TTL 50 ohms | differential 100 ohms |
| Cable driving capability | > 200m RG213 | >200m Cat.5 STP |
| Connector | 10-pin HE10 male | RJ45 jack |
| Mating connector | 10-pin HE10 female | RJ45 plug |
| Size | 69 x 34 x 18 mm | 12.5 x 50 x 21 mm |

ACKNOWLEDGMENTS

The conceptual design of this Beam Loss Monitor is the work of several individuals at DESY-PKTR, over many years. I wish to thank them all here for their unique contribution to a very effective beam diagnostic tool, particularly Kay Wittenburg who has been the driving force all along.

The contribution of Bergoz Instrumentation was to redesign the circuit. Surface mounted components allowed to make it smaller and more economical to assemble. Minor design changes were made.

DESY granted Bergoz Instrumentation a license to use the original concept of the PIN-Photodiodes Beam Loss Monitor, to further develop it, to build and sell instruments based on this principle.

Saint Genis Pouilly, last revised March 2018