

# Technical White Paper: AI-Enabled Beta Attenuation Monitoring

## *Real-Time Ambient Particulate Matter (PM2.5/PM10) Measurement*

**Author:** Narayanasamy Ravichandran, Indusmation LLC

**Date:** May 2026

**Subject:** Advanced Particulate Monitoring & Technology Transfer

## 1. Executive Overview

The global demand for high-precision ambient air quality monitoring has necessitated the transition from manual gravimetric methods to automated, real-time systems. The Indusmation Beta Attenuation Monitor (BAM) utilizes the physics of beta-ray absorption to

provide continuous, high-resolution measurements of PM2.5 and PM10 concentrations. By integrating modern AI-enabled data processing with a ruggedized industrial architecture, this system offers a reliable, low-maintenance solution for environmental regulatory compliance.

## 2. The Principle of Beta Attenuation

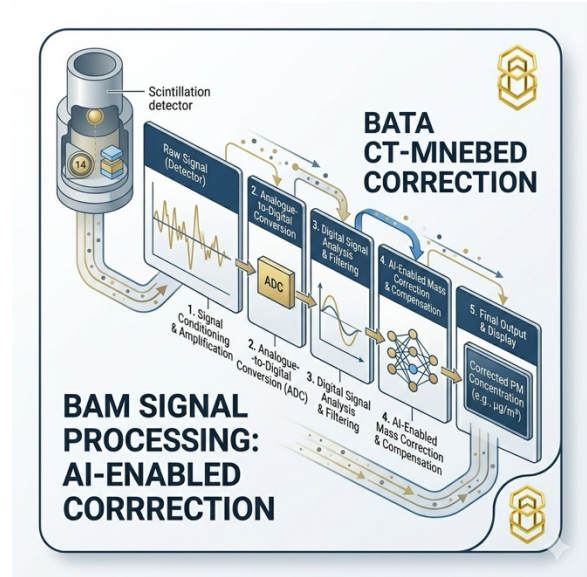
The core measurement principle relies on the **Beer-Lambert Law** applied to subatomic particles. A small Carbon-14 ( $^{14}\text{C}$ ) source emits a constant stream of low-energy beta particles (electrons).

- **The Baseline:** A clean filter tape is measured to establish a "zero" attenuation reference.
- **The Loading:** Ambient air is drawn through the tape at a controlled volumetric flow rate, depositing particulate matter.
- **The Measurement:** The beta-ray flux is measured after passing through the loaded tape. The reduction in count rate is directly proportional to the mass of the sampled dust, independent of its chemical composition or color.

## 3. Scintillation Detection & Signal Processing

Unlike traditional Geiger-Müller tubes, our BAM system utilizes a high-sensitivity **Scintillation Probe** coupled with a Silicon Photomultiplier (SiPM).

- **High Dynamic Range:** Capable of detecting concentrations from  $0.1 \mu\text{g}/\text{m}^3$  to  $10,000 \mu\text{g}/\text{m}^3$ .
- **Temperature Stability:** Integrated thermal compensation ensures that the electronics remain drift-free in extreme ambient conditions ( $-20^\circ\text{C}$  to  $+50^\circ\text{C}$ ).



## 4. AI-Enabled Data Correction

The primary challenge in BAM technology is the "Moisture Effect." High humidity can cause particles to swell, leading to over-reporting. Our system solves this through:

- **Smart Inlet Heating:** An AI-driven PID controller monitors ambient RH% and adjusts the inlet heater only when necessary, preserving the integrity of volatile organic compounds (VOCs).
- **Neural Network Refinement:** The onboard STM32F4 processor runs a lightweight edge-AI model that cross-references pressure, temperature, and flow data to provide a "Corrected Mass" output that aligns with federal reference methods (FRM).

## 5. Mechanical & Embedded Architecture

The system is built for 24/7 autonomous operation in remote field sites:

- **Filter Tape Management:** A precision stepper-motor drive ensures 60+ days of unattended operation per roll.
- **Volumetric Flow Control:** A mass flow sensor and variable-speed pump maintain a constant 16.7 L/min flow, ensuring the aerodynamic cut-point of the PM10/PM2.5 inlets is maintained.
- **Connectivity:** Integrated Modbus TCP/IP, 4-20mA, and optional IoT cloud telemetry for real-time environmental reporting.

## 6. Technology Transfer & Manufacturing

Indusmation LLC provides a complete **Technology Transfer Package** for this BAM platform, including:

- **Full BOM & Source Files:** Optimized for indigenous manufacturing using global-standard components.
- **Calibration Standards:** Proprietary span-foil kits for field-validating the beta-ray mass calibration.
- **Firmware Blueprints:** Comprehensive logic for the AI correction algorithms and motor synchronization.

[

