**Functional Requirement Specification**

**Performance of the MI EBP**

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| **Prepared by:** Randy Thurman-Keup  | Fermilab AD | keup@fnal.gov |
| **Approved by:**Nathan Eddy | Fermilab AD | eddy@fnal.gov |
| **Approved by:**Ioanis Kourbanis | Fermilab AD | ioanis@fnal.gov |
| **Approved by:**Paul Czarapata | Fermilab AD | pcceed@fnal.gov |
| **Approved by:**John Anderson | Fermilab AD | jea@fnal.gov |

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# Introduction

The current P5-endorsed long-range plan for Fermilab calls for beam power in the Main Injector (MI) in excess of 2 MW. Measurements of the transverse profile of these high-intensity proton beams are difficult. Traditional approaches typically involve the insertion of something physical in the beam to determine its size. However, with the expected beam power, such devices don’t survive well. The Main Injector currently has an Ionization Profile Monitor (IPM) for measuring transverse profiles. The IPM is non-intercepting and should work at higher beam intensities; however, there would be concern about micro-channel plate lifetimes. Previously the MI had Flying Wire profile monitors, but do to issues of wire breakage they were removed. A possible replacement for the Flying Wires is an Electron Beam Profiler (EBP) utilizing electron beam deflection by the proton beam. Like the IPM, it is also a non-intercepting device capable of operation at higher beam intensities. In addition, it can make measurements of individual bunches, in contrast to the IPM which averages over a Booster batch, and the initial operation will provide a measure of bunch length, offering the potential for intrabunch measurements.

# Scope

The EBP is initially an experiment to determine the feasibility of using such a device with the beam structure of the MI. The EBP will determine horizontal beam sizes near the 620 quadrupole magnet. The ultimate goal is to develop the experiment into an operational device. This specification establishes the range of beam parameters that will be initially investigated with regards to the capabilities of the EBP.

# Key Assumptions, Interfaces and Constraints

## MI Beam Parameters

Typical MI beam parameters relevant for EBP measurements are listed in Table 1.

Table 1. Typical MI beam parameters.

|  |  |
| --- | --- |
| Beam energy | 8 – 120 GeV |
| Particles per bunch | (4x1010 – 10x1010) |
| rms bunch length | 1 – 2 ns |
| Horizontal rms beam size | 0.5 – 3 mm  |
| Horizontal Beta / dispersion at Q620 (design, not measured) | 50 m / -0.04 m |
| Vertical rms beam size | < 1 mm |

## Electron Beam Parameters

Typical electron beam parameters for the EBP are listed in Table 2.

Table 2. Typical electron beam parameters.

|  |  |
| --- | --- |
| Beam energy | 5 – 15 keV |
| Beam current | 0.1 – 5 mA |
| Horizontal rms beam size @ proton beam location | 0.1 – 0.2 mm  |
| Horizontal rms beam size @ detecting screen | 0.3 – 0.4 mm |
| Vertical rms beam size @ proton beam location | 0.1 – 0.2 mm |
| Vertical rms beam size @ detecting screen | 0.3 – 0.4 mm |

## Operational Interface

The EBP will initially be used and controlled by an expert. Once the capabilities are understood, the device should be useable by a non-expert and controllable through ACNET in a way consistent with other Instrumentation department diagnostics.

# Functional Requirements

* The EBP should be able to measure the beam size with a resolution no worse than 200 m. This is approximately twice the expected size of the electron beam at the location of the proton beam. The accuracy of the measurement will need to be evaluated in the initial experimental phase of the device.
* The EBP should be able to make a measurement both at 8 GeV and at 120 GeV during the same cycle and provide the beam sizes and centroids as ACNET variables.
* The EBP should be able to measure the beam size of a single bunch.
* The EBP timing should be user selectable both for start time during the cycle and for bunch number.
* The EBP should satisfy all MI vacuum requirements.
* Since the electron beam generates x-rays, the EBP must be inhibited from being turned on when tunnel accesses are in progress.

# References

[1] R. Thurman-Keup, *Electron Beam Profiler for the Main Injector*, APT Seminar, BEAMS-DOC-4619.

[2] R. Thurman-Keup, *Electron Beam Profiler for Project-X*, BEAMS-DOC-3352.