



Radiation Physics Form No. 105:

Request for Approval to use Interlocked Detectors in Lieu of Passive Shielding

Purpose:

The purpose of this form is to document the review and approval of Director's Exceptions prepared in the implementation of FRCM Article 811.2 concerning the use of interlocked detectors in lieu of passive radiation shielding.

Justification

In this section, after reviewing FRCM Article 811.2, the Division/Section/Center making the request for the Director's Exception shall write a justification of this request providing sufficient details to facilitate an adequate review. Citation of detailed reference materials on accessible websites with links provided in this section or otherwise made available to the ES&H Director is acceptable. Especially important is the need to clarify those details that render the use of passive shielding impractical aside from financial costs assessed in the next section. References to available shielding assessment documentation should be made. Planned schedule information should also be provided.

The Mu2e project is an upgrade to existing Fermilab accelerator facilities that allows the use of the former Antiproton Source as a source of protons to the Mu2e pion production target. The facilities being upgraded for Mu2e were originally designed low power secondary beam (for a beam power of approximately 13 watts). The beam power requirement for the Mu2e experiment is 8 kW, which is considerably in excess of the original design. Substantial upgrades to the existing shielding would be required to meet the FRCM shielding requirements for the Mu2e design beam power were only passive shielding used in the upgraded Radiation Safety system. The Mu2e project therefore proposes to augment the existing shielding with interlocked detectors. Full details of the Mu2e radiation shielding analysis are reported in the Mu2e preliminary shielding assessment is given in document number 4513 in the Accelerator Division document database at the following URL:

<https://beamdocs.fnal.gov/AD-private/DocDB/ShowDocument?docid=4513>

The principle justification for the use of interlocked detectors is the following:

- The Mu2e experiment utilizes existing facilities for which adequate passive shielding upgrades would be very difficult and cost prohibitive to implement.
- Some of the existing facilities will not support the load of sufficient additional shielding without substantial reconstruction.
- Active protection will be required during the installation and commissioning phase of the Mu2e project to allow installation work to proceed during beam commissioning of accelerator upgrades. The Mu2e Accelerator upgrades have been designed for low beam loss at design intensity to allow this mode of operation. Significant savings in cost and design effort would be realized if active protection were a permanent part of the radiation protection plan for Mu2e.

Cost Analysis

This shall include an approximate comparison of the cost with and without passive shielding including an assessment of the cost of active systems needed (e.g., electronic berms, interlocked detectors, network of loss monitors, etc and their long-term operational costs.) The cost of active systems needed shall be complete ones including estimated costs of additional support systems, etc.

Were the Mu2e shielding requirements to be met entirely by passive shielding, the shielding of the AP service buildings would require substantial augmentation and several feet of dirt would need to be added to the berms over the Antiproton Source beam enclosures.

Early in the conceptual design phase of the Mu2e project it was determined that it would not be possible to add sufficient shielding between the floor of the AP service buildings and the top of the beam enclosure. FESS estimated the cost to construct a 8 foot concrete shield over the AP10, AP30 and AP50 service buildings at approximately \$12M. This cost is documented in Mu2e document #3758 (<http://mu2e-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=3758>). It should also be noted that, even with this additional shielding, interlocked detectors would still be required.

The existing beam enclosures were designed for the overburden of the existing berms and cannot bear the additional weight of the dirt that would need to be added to the berms to meet the passive shielding requirements for Mu2e beam. These beam enclosures would essentially need to be rebuilt. A cost estimate for this undertaking has not been prepared, but it is likely that the total cost would exceed \$10M.

The alternative to passive shielding is the use of interlocked radiation detectors. There are two options for systems meeting this purpose and their costs are estimated as follows:

Option 1 – Total Loss Monitoring Systems

The cost to install the Total Loss Monitor (TLM) interlocked radiation detectors systems is reported in the following BOEs (Mu2e documents 1890, 1891, and 2120):

<http://mu2e-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=1890>

<http://mu2e-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=1891>

<http://mu2e-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=2120>

The total M&S is \$82.6 k and total labor is 1076 hours.

Option 2 – Chipmunk Interlocked Radiation Detectors

If chipmunk interlocked radiation detectors have to be used, the estimated cost to build and install them is \$10K each. About 235 chipmunks would be required assuming a 15 foot spacing. Forty-five chipmunks presently exist at the former Anti-proton source facilities. About 190 additional chipmunks would be required to be built and installed at an estimated cost of \$10k each or about \$1.9M. The cost to design and modify facilities to accommodate the additional utilities, relay rack space, electric power, cable trays, etc. to support such an array of chipmunks has not yet been included in the cost analysis.

The cost to perform annual calibration and maintenance of a chipmunk and a TLM system should be similar. For Mu2e, about 235 chipmunks or about 14 TLM electrometers would be

required. The cost of maintaining TLM systems would be about 16% of that required for chipmunks.

Conclusion

This section shall state the conclusion.

The cost of the upgrades to existing facilities were the FRCM shielding requirements to be met entirely by passive shielding is in the tens of millions of dollars. These upgrades would be a significant undertaking that would likely impact the project schedule. Active protection in the form of interlocked detectors is therefore a necessary part of the Mu2e project.

The laboratory has a long history of successfully using interlocked radiation detectors in lieu of passive shielding. As we enter the intensity frontier with machines capable of producing and transporting megawatt level beam power, reliance upon reliable active systems with moderate passive shielding must become the standard. Machines which are shielded totally passively could never sustain beam losses even momentarily to challenge such massive shields.

Concurrences (Contingent on approval of the Shielding Assessment):

Project Lead:	<u>Ray Roy</u>	Date: <u>1/22/14</u>
D/S/C RSO:	<u>Wayne Schmitt</u>	Date: <u>1/22/14</u>
D/S/C Head:	<u>C. Nagar 11291</u>	Date: <u>1/22/14</u>
ESH Director:	<u>Moussa Muellet</u>	Date: <u>1-29-14</u>

Approval (Contingent on approval of the Shielding Assessment)

Fermilab Director	<u>M. S. Kelly</u>	Date: <u>2-5-14</u>
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