Fermi National Accelerator Laboratory

Fermilab

Meson Area Maximum Credible Incident (MCI)

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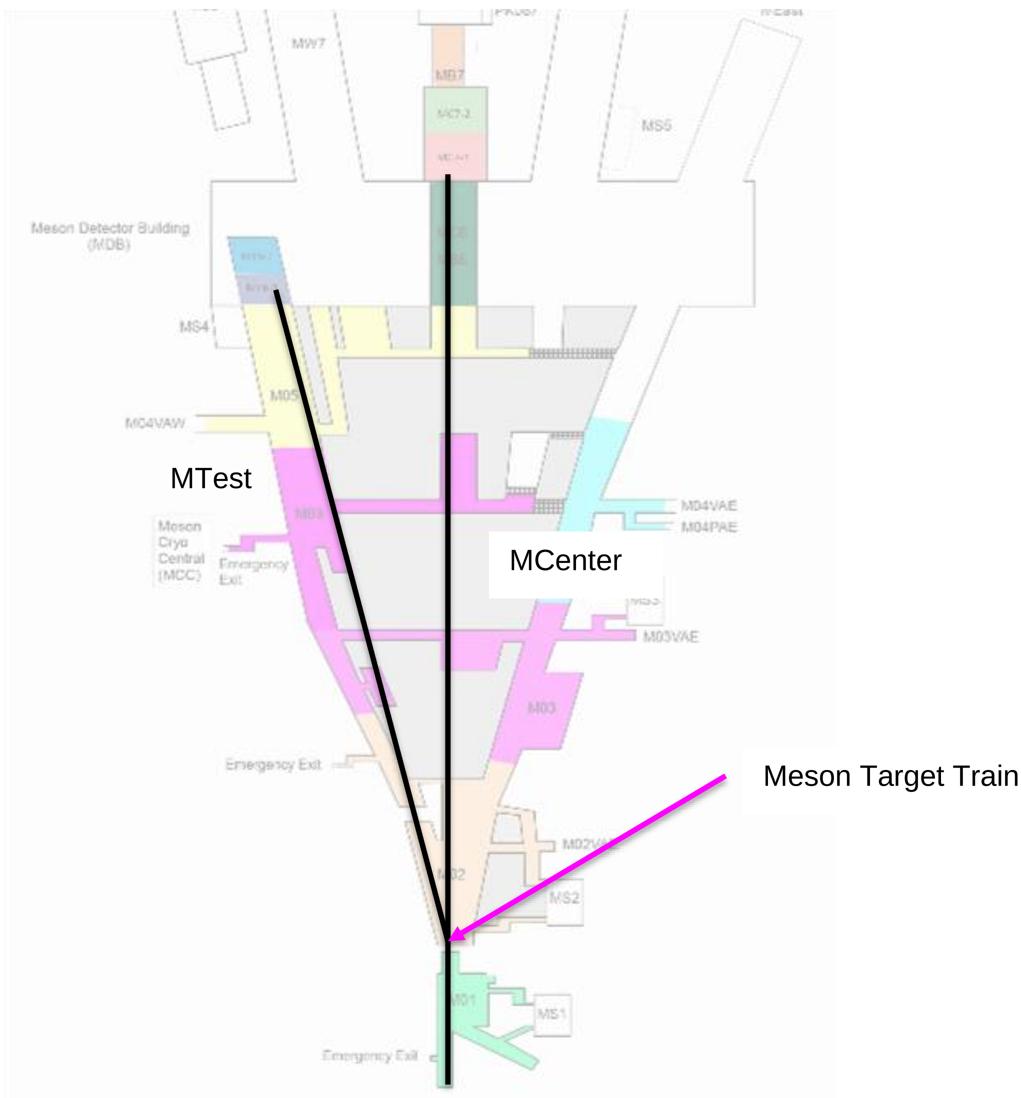
Scope

This document describes the Maximum Credible Incident (MCI) for the Meson Area.

The Meson Area segment includes the following:

- The Meson Primary beamline (MPrimary), from M01 to the downstream end of the Meson Target Train, which terminates at the upstream end of the M02 enclosure.
- The Meson Test beamline (MTest), from the upstream end of M02 through M05.
- The Meson Center beamline (MCenter), from the upstream end of M02 through MC6.



Beam Parameters

The Meson Area segment receives primary beam (120 GeV protons) from the Switchyard Fixed Target Beamlines segment and delivers secondary beam to the Meson Switchyard 120 Experimental Areas.

The Meson Primary beamline receives beam from the Switchyard Fixed Target Beamlines segment, and delivers beam to the Meson Test or Meson Center beamlines. Simultaneous delivery is possible. The Meson Test and Meson Center beamlines contain targets. When the primary beam strikes the target, “secondary beam” is produced. The secondary beam is then transported through a beamline to the Meson Switchyard 120 Experimental Areas. The Meson Test beamline delivers secondary beam to the MT6 sections, located in the Meson Switchyard 120 Experimental Areas; the Meson Center beamline delivers secondary beam to the MC7 sections, located in the Meson Switchyard 120 Experimental Areas.

The MCI scenario for the Meson Area is 2.75E15 protons per hour, 4.2E13 protons per cycle, 55 second cycle time, 120GeV beam energy, missteered into a magnet, beam pipe, or buried pipe.

The MTest beamline evaluation considers three operating modes: “Diffracted Proton Mode”, “High Energy Pion Mode”, and “Low Energy Pion Mode”. Diffracted Proton Mode uses the MTest M01 Target and the M03 Pinhole Collimator to attenuate the beam by a factor of 8.4E-6. High Energy Pion Mode does not use the pinhole collimator; however, production rates have shown that the attenuation of the beam in this mode at 66GeV, the upper limit of the beam energy in this mode, is 2E-7. In Low Energy Pion mode, the primary beam is allowed past the M01 Target and is delivered to the MT4 Low Energy Pion Mode Target, located at FSCSz=5164’. This target attenuates the primary beam by a factor of 1E-5.

The table below compares the unprotected exposure in each of the above modes. To obtain exposure from secondary beam, the primary beam exposure is scaled by the yield and the ratio of the secondary to primary energy raised to the 0.8 power.

Mode	**Energy**	**Intensity**	**Yield**	**Exposure**	
	[GeV]	[protons per cycle]	[]	[mrem/cycle]	[mrem/hr]
Primary Beam	120	4.2E+13	1.0E+00	1.52E+07	9.95E+08
Meson Test - Diffracted Proton	120	4.2E+13	8.4E-06	128	8357
Meson Test - High Energy Pion	66	4.2E+13	2.0E-07	1.88	123
Meson Test - Low Energy Pion	30	4.2E+13	1.0E-05	50.1	3282

The ISA spreadsheets indicate that for any secondary beam 3 efd is required, regardless of mode or loss type, for the 100 <= D <= 500 range. We assume a hybrid scenario where primary beam is transported to the Low Energy Pion target, located in MT3 (the furthest primary beam may be transported), and Diffracted Proton mode thereafter (which give the maximum exposure per cycle).

The MCenter beamline evaluation assumes that the primary beam reaches the MC6 Target, in the MC6 Enclosure at FSCSz=5728'. The MC6 Target is required to be in place before beam operation is authorized; if the target is not in place, then the secondary beam is not produced. The MC6 Target attenuates the primary beam by a factor of 4.7E-4. The upper limit of the secondary beamline energy is 90GeV.

The table below compares the unprotected exposure in each of the above scenarios. To obtain exposure from secondary beam, the primary beam exposure is scaled by the yield and the ratio of the secondary to primary energy raised to the 0.8 power.

Mode	Energy	Intensity	Yield	Exposure	
[]	[GeV]	[protons per cycle]	[]	[mrem/cycle]	[mrem/hr]
Primary Beam	120	4.2E+13	1.0E+00	1.52E+07	9.95E+08
Meson Center - Pion	90	4.2E+13	4.7E-04	5.68E+03	3.71E+05

Meson Primary

Meson Primary extends from the upstream end of Meson Enclosure M01 to the end of the Meson Target Train, which terminates at the upstream end of Enclosure M02.

Credited Engineering Controls

The purpose of this section is to provide the information necessary to understand the engineering controls that are used to prevent or mitigate the consequences of the maximum credible incident in Meson Primary. Engineering controls can be classified as passive or active. This section presents a separate discussion of the engineering controls that fall under each classification.

Passive Credited Engineering Controls

Passive controls are element of the facility design that require no action to function properly. These are fixed elements of the beam line that take direct human intervention to remove. The enclosures are designed and constructed as permanent concrete and earth-covered radiation shielding that use a combination of permanent shielding, movable shielding, and penetration shielding to protect personnel from radiological exposure due to the MCI.

Permanent Shielding Including Labyrinths

The required amount of shielding is determined using the Incremental Shielding Assessment (ISA) spreadsheets. The required amount of shielding varies based on one of three categories of losses: loss on a magnet within an enclosure, loss on a long, thin pipe within an enclosure, and loss on a thick pipe buried in soil. The required amount of shielding also varies depending on the exposure limit. The amount of shielding is specified in terms of equivalent feet of dirt (efd), which takes into account the effectiveness of various materials compared to soil (for example, concrete is more effective than soil).

Meson Primary is assessed using the ISA spreadsheets. The relevant sections of the longitudinal and transverse sheets are shown below.

Longitudinal Range	Location	Fixed Shielding (efd)	Movable Shielding (efd)	Current Shielding (efd)	Category	Required (efd)	Difference (efd)
3967-4003	M01	15.7		15.7	4A	13.9	1.8
4003-4062	M01	16.5		16.5	4A	13.9	2.6
4062-4160	M01	20.4		20.4	4A	13.9	6.5
4160-4300	M01	16.4		16.4	4A	13.9	2.5
4300-4340	meson target train	25.8		25.8	4A	13.9	11.9

Transverse Station (ft)	Location	Fixed Shielding (efd)	Movable Shielding (efd)	Current Shielding (efd)	Category	Required (efd)	Difference (efd)
ME13975	M01	15.8		15.8	4A	13.9	2.0
ME14000	M01	15.7		15.7	4A	13.9	1.8
MC14035	M01	20.7		20.7	4A	13.9	6.8
ME14050	M01	21.3		21.3	4A	13.9	7.4
ME24250	M01	19.0		19.0	4A	13.9	5.2

Meson Primary has adequate shielding to insure less than 500 mrem exposure outside the berm. There is at least 1 efd defense-in-depth on the berm covering Meson Primary.

Movable Shielding

The access door to the Meson Target Train rail spur must contain 13.1 efd. Although assessed as a penetration (refer to worksheet MCP06), the shielding is design to be moved, and is included here.

Penetration Shielding

The following penetrations are required to be filled/shielded.

Location		**Removable Shielding**
Enclosure	**Z-Location**	
	(feet)	**(efd)**
M01	4128 (MS1)	2.65
M01	4144 (MS1)	2.65
M01	4158 (MS1)	2.65

Active Credited Engineering Controls

Active engineered controls are systems designed to reduce the risks from the MCI to an acceptable level. The active controls in place for Meson Primary are discussed below.

Radiation Safety Interlock System

The Meson Primary enclosure, M01, employs a Radiation Safety Interlock System (RSIS). This same system also protects enclosures F1, F2, and F3 in the Switchyard Fixed Target Beamlines segment; and enclosures M02, M03, M04, and M05 in the Meson Area. The characteristics of the system are described in Section I of the Fermilab SAD.

Meson Primary has adequate passive credited engineering controls, therefore, interlocked radiation monitors are not required.

Access to M01 is via interlocked gates. The RSIS inhibits beam transport by controlling redundant critical devices, S:MLAM1 and S:V204, located in Enclosure C of the Switchyard Fixed Target Beamlines segment.

Meson Test

The Test Meson beamline begins at the upstream end of enclosure M02 and extends through enclosures M03 and M05. The Meson Test beamline delivers secondary beam – primary beam that has passed through a target -- to the MT6 enclosures, part of the Meson Switchyard 120 Experimental Areas.

Primary targets, that is, targets which receive primary beam, are located at the upstream end of the Meson Target Train, and in the MT3 section of the M03 enclosure.

Credited Engineering Controls

The purpose of this section is to provide the information necessary to understand the engineering controls that are used to prevent or mitigate the consequences of the maximum credible incident in Meson Test. Engineering controls can be classified as passive or active. This section presents a separate discussion of the engineering controls that fall under each classification.

Passive Credited Engineering Controls

Passive controls are element of the facility design that require no action to function properly. These are fixed elements of the beam line that take direct human intervention to remove. The enclosures are designed and constructed as permanent concrete and earth-covered radiation shielding that use a combination of permanent shielding, movable shielding, and penetration shielding to protect personnel from radiological exposure due to the MCI.

Permanent Shielding Including Labyrinths

The required amount of shielding is determined using the Incremental Shielding Assessment (ISA) spreadsheets. The required amount of shielding varies based on one of three categories of losses: loss on a magnet within an enclosure, loss on a long, thin pipe within an enclosure, and loss on a thick pipe buried in soil. The required amount of shielding also varies depending on the exposure limit. Finally, the required amount of shielding varies depending on the type of beam – primary or secondary. The secondary beam will have momentum and flux differing from the primary beam. No distinction is made as to particle type – protons are always assumed.

The amount of shielding is specified in terms of equivalent feet of dirt (efd), which takes into account the effectiveness of various materials compared to soil (for example, concrete is more effective than soil).

Meson Test is assessed using the ISA spreadsheets. The relevant sections of the longitudinal and transverse sheets are shown below. “P” indicates primary beam; “S” indicates secondary beam.

Beam Type	Longitudinal Range	Location	Fixed Shielding (efd)	Movable Shielding (efd)	Current Shielding (efd)	Category	Required (efd)	Difference (efd)
P	4340-4605	M02	19.3		19.3	4A	13.9	5.4
P	4605-4710	PIPE	25.3		25.3	4C	16.3	9.0
P	4710-4716	M02	18.2		18.2	4A	13.9	4.3
P	4716-4841	PIPE	23.5		23.5	4C	16.3	7.3
P	4841-4889	M03	15.5		15.5	4B	11.4	4.1
P	4889-4989	PIPE	17.7		17.7	4C	16.3	1.5
P	4989-4995	M03	11.9		11.9	4B	11.4	0.5
P	4995-5043	PIPE	17.4		17.4	4C	16.3	1.1
P	5043-5164	M03	13.5		11.9	4A	13.9	-1.9
S	5164-5590	M03,4,5	11.9		11.9	4A	3.0	8.9
S	5590-5618	M05	6.9		6.9	4C	3.0	3.9

Beam Type	Transverse Station (ft)	Location	Fixed Shielding (efd)	Movable Shielding (efd)	Current Shielding (efd)	Category	Required[1] (efd)	Difference (efd)
P	ME24250	M01	19.0		19.0	4A	13.9	5.2
P	ME24375	M02	21.6		21.6	4A	13.9	7.7
P	MC24480	M02	22.3		22.3	4A	13.9	8.4
P	MC24540	M02	21.6		21.6	4A	13.9	7.7
P	MC24550	M02	17.4		17.4	4A	13.9	3.5
P	MC34775	M02	22.2		22.2	4C	16.3	6.0
P	MC34973	M03	18.1		18.1	4C	16.3	1.9
P	MC34985	M03	13.1		13.1	4B	11.4	1.8
P	ME35003	M03	19.8		19.8	4C	16.3	3.6
P	ME35005	M03	19.8		19.8	4C	16.3	3.6
P	MC35025	M03	17.3		17.3	4C	16.3	1.1
P	MC35065	M03	13.6		13.6	4A	13.9	-0.3
S	MC45297	M04	12.7		12.7	4A	3.0	9.7
S	MC55520	M05	14.3		14.3	4A	3.0	11.3

Low Energy Pion Target Region

There is one region which the ISA spreadsheet indicates insufficient shielding: the 5043-5164 region (location of the target for "Low Energy Pion Mode").

The Generic Shielding Criteria (ref. TM-2550) are used at Fermilab to determine shielding adequacy and to screen for situations that may require more detailed analysis. These criteria are encoded into spreadsheets for three common beam loss scenarios that are then scaled to various beam parameters using well-known scaling laws. For most areas, the criteria for a point-loss is used and then scaled by energy, intensity, and geometry to the relevant loss conditions.

The equation used is:

Dt = 3.38*log10[(1.6E14 protons/4.2E13 protons)*(1.33 s/55 s)*((3'/6.5')^2)]

Where 21', 1.6E14 protons, 1.33 s, and 3' are assumptions in the Generic Shielding Criteria.

The result is -9.7 ft., that is, 9.7 ft. less than that required under the generic situation (21 ft.), or 11.6 ft.

At MT3, the generic shielding criteria indicate a requirement of 11.6 feet of soil-equivalent shielding to protect areas that may be occupied to less than 500 mrem/hour under MCI conditions. Since the minimum shielding between the beamline and the surface in this region is 13.5 feet, the existing shielding is deemed acceptable, and no remediation is needed.

This region is below the 500 mrem in an hour threshold. There is not a shielding failure. An interlocked detector is not needed.

MT3 Cryo Penetration

The MT3 Cryo labyrinth is presently protected by a chipmunk. Two memoranda, (MTest Cryo Laby Low energy 2E14" and "MT-6 Z5115 Hard Component 2E14"" assess the locations at 1.67E12 protons per hour with a 60 second cycle time, and a single pulse of 2.5E13 protons. In both cases, 120 GeV protons are assumed. The analysis looks at a position 13' from the labyrinth exit, the location of the radiation fence. The results are summarized in the following table:

Analysis (at fence)	Analyzed		MCI		
	[protons/cycle]	[mrem/cycle]	[protons/cycle]	[mrem/cycle]	[mrem/hr]
Low Energy	5.00E+13	0.17	4.20E+13	0.14	9.3
Hard Component	5.00E+13	0.75	4.20E+13	0.63	41

Caption: MT3 Cryo Labyrinth Analysis

There is a ~50x reduction in dose from the labyrinth to the fence, which would result in 2515 mrem/hr (= 50 x (9.3+41) mrem/rh). This requires a credited radiation detector.

The "chipmunk trip calculator_7_21_15.xlxs" spreadsheet provided in Beams Document 4732-v8, "Chipmunk and TLM radiation detector trip calculators" is used to calculate the expected dose base on a specified trip level.

The model assumes four seconds of non-MCI beam, 51 seconds without beam (consistent with a 55 second cycle time), then 55 second accident cycles (four seconds at MCI intensity and 51 seconds without beam). This continues until a "trip" is indicated, after which the model assumes no beam for the remainder of the hour.

Setting the trip level is 495 mrem/hr would result in a 154 mrem exposure.

Permanent Shielding Including Labyrinths - Conclusion

Meson Test has adequate shielding to insure less than 500 mrem exposure outside the berm. There is at least 0.5 efd defense-in-depth on the berm covering Meson Test.

Movable Shielding

Movable shielding is not listed in Meson Test.

Penetrations

The following penetrations are required to be filled/shielded.

Location		Removable Shielding
Enclosure	**Z-Location**	
	(feet)	
M02	4350	Duct filled with 20 feet of sand
M02	4438 (MS2)	4.5 efd
M02	4467 (MS2)	4.5 efd
M02	4495 (MS2)	4.5 efd
M02	4550	Duct filled with 20 feet of sand

Active Credited Engineering Controls

Active engineered controls are systems designed to reduce the risks from the MCI to an acceptable level. The active controls in place for Meson Test are discussed below.

Radiation Safety Interlock System

The Meson Test enclosures, M02, M03, M04, and M05 employ a Radiation Safety Interlock System (RSIS). This same system also protects MT6 Section 1 and MT6 Section 2 in the Meson Area. The characteristics of the system are described in Section I of the Fermilab SAD.

Meson Test requires an interlocked radiation detector at the MT3 Cryo labyrinth, as discussed previously.

Access to M02, M03, M04, and M05 is via interlocked gates. The RSIS inhibits beam transport by controlling redundant critical devices, F:MW1W and MT3 Beam Stop. F:MW1W is located in M01; inhibiting this device prevents primary beam from traversing the Meson Target Train. The MT3 Beam Stop prevents beam transport beyond M03.

The MTest Primary Logic Chassis in the MTest Critical Device Controller prevents unattenuated beam reaching the MT6-1 and MT6-2 enclosures by ensuring that secondary beamline is properly configured for one of the three possible modes. A target must be in place; a fixed-aperture collimator, if required, is in position; power supplies for key momentum-selection magnets will operate within the specified current range.

Meson Center

The Test Center beamline begins at the upstream end of enclosure M02, and extends through enclosures M03 and M05. The Meson Center beamline delivers secondary beam – primary beam that has passed through a target -- to the MC7 enclosure, part of the Meson Switchyard 120 Experimental Areas.

A primary target, that is, a target which receive primary beam, is located at the upstream end the MC6 enclosure.

Credited Engineering Controls

The purpose of this section is to provide the information necessary to understand the engineering controls that are used to prevent or mitigate the consequences of the maximum credible incident in Meson Test. Engineering controls can be classified as passive or active. This section presents a separate discussion of the engineering controls that fall under each classification.

Passive Credited Engineering Controls

Passive controls are element of the facility design that require no action to function properly. These are fixed elements of the beam line that take direct human intervention to remove. The enclosures are designed and constructed as permanent concrete and earth-covered radiation shielding that use a combination of permanent shielding, movable shielding, and penetration shielding to protect personnel from radiological exposure due to the MCI.

Permanent Shielding Including Labyrinths

The required amount of shielding is determined using the Incremental Shielding Assessment (ISA) spreadsheets. The required amount of shielding varies based on one of three categories of losses: loss on a magnet within an enclosure, loss on a long, thin pipe within an enclosure, and loss on a thick pipe buried in soil. The required amount of shielding also varies depending on the exposure limit. Finally, the required amount of shielding varies depending on the type of beam – primary or secondary. The secondary beam will have momentum and flux differing from the primary beam. No distinction is made as to particle type – protons are always assumed.

The amount of shielding is specified in terms of equivalent feet of dirt (efd), which accounts for the effectiveness of various materials compared to soil (for example, concrete is more effective than soil).

Meson Center is assessed using the ISA spreadsheets. The relevant sections of the longitudinal and transverse sheets are shown below. "P" indicates primary beam; "S" indicates secondary beam.

Beam Type	Longitudinal Range	Location	Fixed Shielding (efd)	Movable Shielding (efd)	Current Shielding (efd)	Category	Required[1] (efd)	Difference (efd)
P	4340-4566	M02	18.6		18.6	4A	13.9	4.7
P	4566-4656	M02	18.9		18.9	4A	13.9	5.0
P	4656-4709	M02	21.5		21.5	4A	13.9	7.6
P	4709-4936	PIPE	24.3		24.3	4C	16.3	8.0
P	4936-4986	M03	17.5		17.5	4A	13.9	3.6
P	4986-5297	PIPE	19.1		19.1	4C	16.3	2.8
P	5297-5353	M04	15.1		15.1	4B	11.4	3.7
P	5353-5518	PIPE	18.9		18.9	4C	16.3	2.6
P	5518-5603	M05	15.5		15.5	4A	13.9	1.6
P	5603-5662	MC6	15.0		15.0	4A	13.9	1.1
P	5662-5733	MC6		7.8	7.8	4A	13.9	-6.1
S	5733-5790	MC6		6.6	6.6	4A	3.0	3.6
S	5790-5793	MC6		3.3	3.3	4A	3.0	0.3
S	5793-5798	MC6		0.0	0.0	4A	3.0	-3.0

Beam Type	Transverse Station (ft)	Location	Fixed Shielding (efd)	Movable Shielding (efd)	Current Shielding (efd)	Category	Required (efd)	Difference (efd)
P	MC24540	M02	21.7		21.7	4A	13.9	7.8
P	MC24550	M02	16.7		16.7	4A	13.9	2.8
P	MC34985	M03	19.7		19.7	4A	13.9	5.9
P	ME35003	M03	22.3		22.3	4A	13.9	8.4
P	ME35005	M03	22.3		22.3	4A	13.9	8.4
P	MC65655	MC6	16.9		16.9	4A	13.9	3.0
P	MC65662-E	MC6	28.0		28.0	4A	13.9	14.2
P	MC65662-W	MC6	39.1		39.1	4A	13.9	25.2

P	MC65664-E	MC6	22.2		22.2	4A	13.9	8.3
P	MC65670-W	MC6	29.7		29.7	4A	13.9	15.8
P	MC65673-W	MC6	48.2		48.2	4A	13.9	34.3
P	MC65679-W	MC6	26.4		26.4	4A	13.9	12.5
P	MC65682-W	MC6	16.5		16.5	4A	13.9	2.6
P	MC65685-W	MC6	13.2		13.2	4A	13.9	-0.7
P	MC65701-W	MC6	16.5		16.5	4A	13.9	2.6
P	MC65715-W	MC6	9.9		9.9	4A	13.9	-4.0
P	MC65719-W	MC6	13.2		13.2	4A	13.9	-0.7
P	MC65722-W	MC6	9.9		9.9	4A	13.9	-4.0
P	MC65728-W	MC6	9.9		9.9	4A	13.9	-4.0
S	MC65733-E	MC6	26.5		26.5	4A	3.0	23.5
S	MC65734-W	MC6	16.5		16.5	4A	3.0	13.5
S	MC65735-W	MC6	13.2		13.2	4A	3.0	10.2
S	MC65739-W	MC6	16.5		16.5	4A	3.0	13.5
S	MC65741-E	MC6	24.9		24.9	4A	3.0	21.9
S	MC65742-W	MC6	11.6		11.6	4A	3.0	8.6
S	MC65743-W	MC6	14.9		14.9	4A	3.0	11.9
S	MC65747-W	MC6	19.8		19.8	4A	3.0	16.8
S	MC65749-E	MC6	26.5		26.5	4A	3.0	23.5
S	MC65750-W	MC6	14.9		14.9	4A	3.0	11.9
S	MC65754-W	MC6	19.8		19.8	4A	3.0	16.8
S	MC65755-W	MC6	16.5		16.5	4A	3.0	13.5
S	MC65757-W	MC6	11.6		11.6	4A	3.0	8.6
S	MC65759-E	MC6	24.9		24.9	4A	3.0	21.9
S	MC65759-W	MC6	11.6		11.6	4A	3.0	8.6
S	MC65765-W	MC6	13.6		13.6	4A	3.0	10.6
S	MC65767-E	MC6	18.2		18.2	4A	3.0	15.2
S	MC65775-E	MC6	8.3		8.3	4A	3.0	5.3
S	MC65788-E	MC6	11.6		11.6	4A	3.0	8.6
S	MC65790-W	MC6	3.3		3.3	4A	3.0	0.3
S	MC65791-E	MC6	8.3		8.3	4A	3.0	5.3

The longitudinal table indicates two regions of insufficient shielding, both within the Meson Detector Building; this is also show in the transverse table. These regions will require interlocked detectors, discussed below.

The berm above the Meson Center beamline Meson has adequate shielding to ensure less than 500 mrem exposure. There is at least 1.0 efd defense-in-depth on the berm covering Meson Center.

Movable Shielding

The MC6 enclosure is constructed from movable shielding.

Penetrations

The following penetrations are required to be filled/shielded.

Location		**Removable Shielding**
Enclosure	**Z-Location**	
	(feet)	**(efd)**
M02	4350	Duct filled with 16.5 feet of sand
M03	4985	MCenter sight riser filled with 16.5 feet of sand
M04	5300	MCenter sight riser filled with 13 feet of sand
M05	5510	MCenter sight riser filled with 15.5 feet of sand

Active Credited Engineering Controls

Active engineered controls are systems designed to reduce the risks from the MCI to an acceptable level. The active controls in place for Meson Test are discussed below.

Radiation Safety Interlock System

The Meson Center enclosures, M02, M03, M04, M05, and MC6 employ a Radiation Safety Interlock System (RSIS). This same system also protects MC7 and MB7, part of the Meson Switchyard 120 Experimental Areas. The characteristics of the system are described in Section I of the Fermilab SAD.

Access to M02, M03, M04, M05, and MC6 is via interlocked gates. The RSIS inhibits beam transport by controlling redundant critical devices, F:MC1D and MC2 Beam Stop. The F:MC1D magnet is located in M01; inhibiting this device prevents primary beam from traversing the Meson Target Train. The MC2 Beam Stop prevents beam transport beyond M02.

The current monitor on the MC6D magnet string is an input to the MCenter CDC. This magnet string is located immediately downstream of the primary target. The current is specified to prevent beam greater than 90 GeV from traversing the secondary beamline; the current must be less than 575 amps.

The ISA spreadsheets indicate insufficient shielding above the MC6 enclosure, located within the Meson Detector Building. The 5662-5733 region is referred to as the "MDB MC6" region. The 5793-5798 region is referred to the "MDB Catwalk".

MDB MC6

The "chipmunk trip calculator_7_21_15.xlsx" spreadsheet provided in Beams Document 4732-v8, "Chipmunk and TLM radiation detector trip calculators" is used to calculate the expected dose base on a specified trip level.

The model assumes four seconds of non-MCI beam, 51 seconds without beam (consistent with a 55 second cycle time), then 55 second accident cycles (four seconds at MCI intensity and 51 seconds without beam). This continues until a "trip" is indicated, after which the model assumes no beam for the remainder of the hour.

MDB Catwalk

The approved MCenter shielding assessment assumes that an accident pulse of 120 GeV primary protons at 1E13/pulse and with a secondary yield of 4.7E-4 can be transported to this location. In this case, the accident dose rate is calculated using the Malensek method as 86 mrem/pulse. Since scaling by energy would not result in a meaningful difference, we will ignore it and scale this dose rate to:

D = (86 mrem/pulse) * (4.2E13/1E13) * (3600/55) = 2.36E4 mrem/hour

Summary

Four interlocked radiation monitors ("Chipmunks") are required to provide sufficient coverage above MC6 – three spaced longitudinally above the enclosure and a fourth at the catwalk. The radiation monitor on the MC6 catwalk must be set to trip on a single pulse.

The table below summarizes the dose without and with a Chipmunk in place.

Location	**Present**	**Required**	**Limit**	**Dose without chipmunk**		**Chipmunk trip setting**	**Dose with Chipmunk**
	[efd]	[efd]	[mrem]	[mrem]	[mrem/cycle]	[mrem/hr]	[mrem]
MDB MC6 US	13.2	13.9	500	806	12.3	440	114
MDB MC6 Mid	9.9	13.9	500	7628	117	440	146
MDB MC6 DS	9.9	13.9	500	7628	117	440	146
MC6 Catwalk	0	3.0	5000	23600	361	440	361

Conclusion

In the event of an MCI in the Meson Area with all credited controls in place, a worker in a service building would receive a total dose less than 5 rem in one hour and an individual on the berm would receive a total dose less than 500 mrem. The location with the highest possible dose resulting from the MCI would be the MC6 Catwalk, which is protected by an interlocked detector. This would result in a dose to an individual of approximately 361 mrem in one hour.