NuMI Beamline Radiological Safety (Breakout)

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CD-2/3a Director's Review of NOνA

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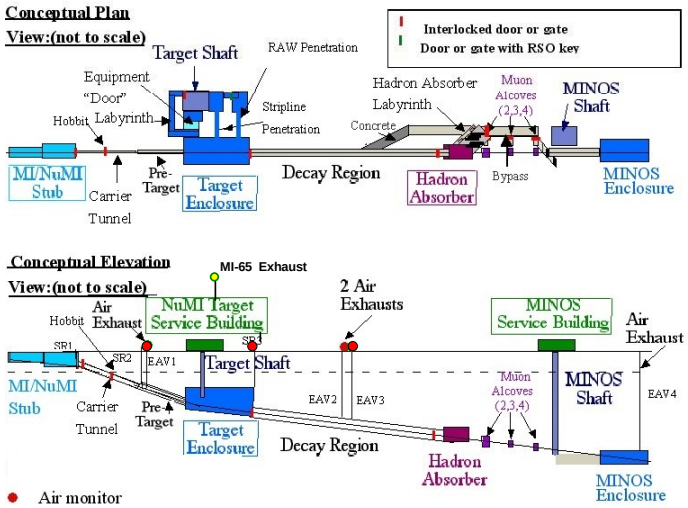
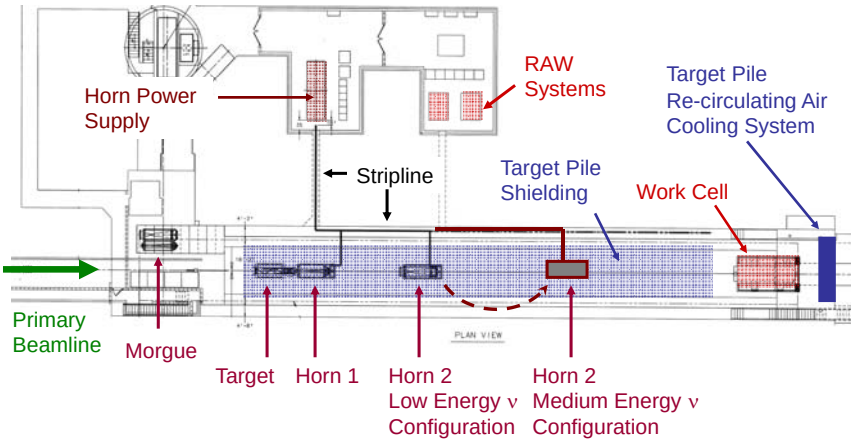
NuMI Beamline Radiological Safety



Target Hall



NuMI Beamline Radiological Safety

- Look at radiological issues and modifications required to operate NuMI beam line at 700 kW
- Design for 25% more power – 850kW (safety factor and operational considerations).
- Comply with Fermilab Radiological Control Manual (FRCM).
- Add shielding, control emissions, discharges and redesign components to be able to operate NOvA.

Radiological guidelines

- Shielding design follows the Fermilab Radiological Control guidelines.
- ALARA principles of time, distance and shielding is worked into the design of the facility.
- Dose to public and workers minimized.
- Protect natural resources, minimal or no significant effects on environment.
- All releases below DOE, State and Federal limits and guidelines
- Follow up by routine monitoring, sampling, surveys etc.

Description & Scope

- Radiological safety issues for the 700 kW beam
  - Shielding assessment
  - Groundwater and surface water
  - Air emissions
  - Primary RAW systems
  - Prompt radiation
  - Residual activation
  - Summary

Earth shielding

- The NUMI extraction line would require 23.8 ft. of earth shielding for 1.64E17 protons/hr (850kW), if the berm is categorized as minimal occupancy.
- Nominal shielding for the NUMI extraction line is 24.5 feet, which is enough for 2.81E17 protons/hr (1.5MW), if the berm is categorized as minimal occupancy.
- Because of the 3 degrees down slope of the carrier pipe, there is sufficient earth shielding for the rest of this beam line.

Groundwater

- Combined hydrogeological measurement and Monte Carlo were used to estimate the production ratio of ^{3}H to ^{22}Na.

Type of Operations	Estimated Maximum Tritium Level	Estimated Maximum Sodium-22 Level
NuMI/NOvA 850 kW	4 pCi/ml	0.4 pCi/ml
Groundwater Regulatory Limits	**20 pCi/ml**	**0.4 pCi/ml**

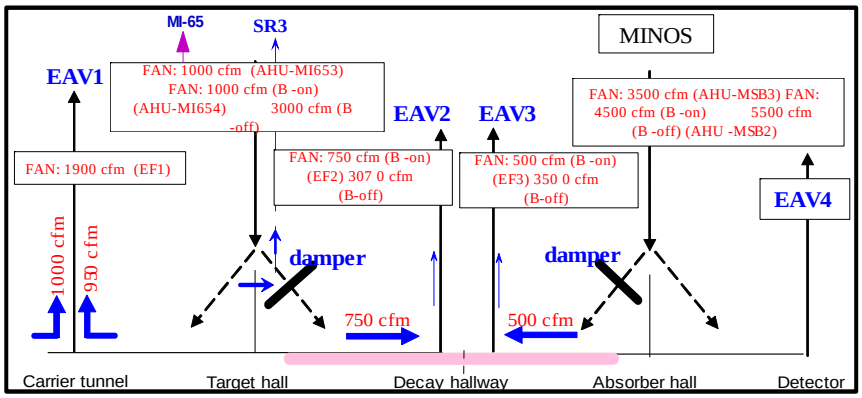
- All inflow is pumped to the surface (no regulatory violations)
- Hydrogeology experts say that it is highly unlikely that any water from the vicinity (less than 9 ft.) of the NuMI tunnel will flow away. Monitoring wells show no contamination.
- For wells **detection limit** of ^{3}H was used to extrapolate to NOvA concentrations.
- Further measurements with more POT will improve these predictions which are the upper bounds of concentrations expected. (on going)

Surface water

- Tritium from other sources such as air, shielding or RAW could find its way to the sump pits, which are pumped to the Lab's surface ponds.
- The cooling ponds are underlain with naturally occurring clay to prevent mixing with surface waters.
- Estimates are based on the conservative drought conditions.
- Creeks that enter or leave the site are "waters of state or surface water" per our NPDES permit. On site ponds and ditches are not.

Phase	Tritium (Sump)	Tritium (Pond)	Sodium-22 (Sump Water)	Sodium-22 (Pond Water)
NuMI/NOvA	57 - 113 pCi/ml	14 - 28 pCi/ml	< 0.7 pCi/ml	< 0.2 pCi/ml
DOE Surface Water Regulatory Limits	**2,000 pCi/ml**	**2,000 pCi/ml**	**10 pCi/ml**	**10 pCi/ml**

Air emissions-1



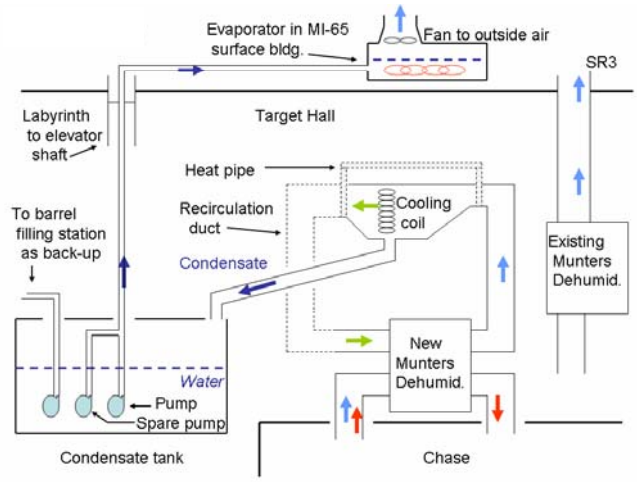
Air emissions-2

	MINOS Present	NOvA design	NOvA design
Source of Radionuclide Air Emissions	Maximum Release (Curies/yr)	Maximum Release (Curies/yr)	Maximum Dose at Site Boundary (mrem/yr)
Fermilab Site Wide Total	**36**	**147**	**0.05**
Regulatory Limits (NESHAP Permit)	**2,000 Curies/year**	**2,000 Curies/year**	**10**

Tritium Release:
Scaling from 2005 measurements to 850 kW, 40 Ci/year, which corresponds to 0.0002 mrem/yr dose at site boundary (negligible).

Air emissions-3

(Off project, will be installed in 2007 shutdown)



RAW systems-1

- Primary cooling water for the target, horns, decay pipe and the absorber become radioactive. ^{3}H and ^{7}Be are the relevant radioisotopes.
- Hydrogen gas is also produced due to radiolysis of the water, which is mitigated.
- RAW tanks are sampled frequently.
- RAW systems concentration levels, the neutrino program schedule, operational impact to other parts of the accelerator complex, and ALARA principles are all considered when determining the appropriate timing for water replacement.

RAW systems-2

(accident with RAW systems not an environmental concern)

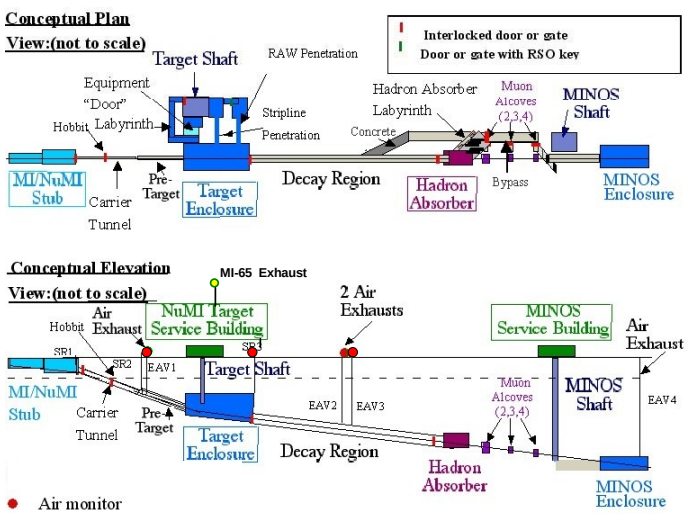
	^{3}H		^{7}Be		Total Volume	
	Ci/cc	Ci	Ci/cc	Ci	Gallons	
Target	1.50E-06	0.17	8.71E-06	0.99	30.00	
Horn 1	1.02E-05	4.46	5.17E-05	22.50	115.00	
Horn 2	3.22E-06	1.14	1.87E-05	6.65	94.00	
Decay Pipe	5.07E-09	0.01	2.94E-08	0.08	725.00	
Hadron Abdsor	3.99E-08	0.02	2.32E-07	0.12	135.30	
Total	1.50E-05	5.81	7.93E-05	30.34	1099.30	
No Inflow	Net H-3 Concentration =		1.40E-06	Ci/ml =	1.40E+06	pCi/ml
	Net Be-7 Concentration		7.29E-06	Ci/ml =	7.29E+06	pCi/ml
	Total Inflow/yr	85731480	Gallons/yr	3.24529E+11	ml/yr	
	inflow = 163 gpm					
Including Inflow	Net H-3 Concentration =		1.79E+01	pCi/ml		
	Net Be-7 Concentration =		9.35E+01	pCi/ml		
	% of Surface Discharge Limit					
		10.2%				
	0.89%		9.35%			
	^{3}H		^{7}Be			

Hydrogen gas evolution from RAW systems

	Gallons of H_2/year	Gallons of H_2/day	Gallons of water lost/yr	
	170.4	0.4	0.1	Horn 1
	365.7	1.1	0.1	Retention tank1
TOTALS=	*536.1*	*1.5*	*0.2*	
	14.7	0.0	0.0	Horn 2
	85.2	0.2	0.0	Retention tank2
TOTALS=	*100*	*0.2*	*0.04*	
Air concentration in the RAW room= 0.003% per day				

- RAW tanks are continuously purged with argon
- No where near the explosion level (~4%)

Prompt Radiation



Prompt Radiation

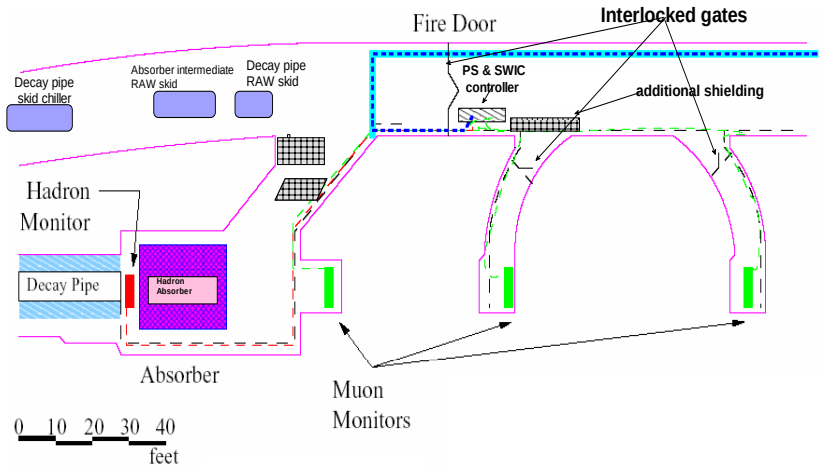
Region	Normal Loss		Accidental Loss	
	Exit Dose Rate unshielded		Exit Dose Rate unshielded	
	(mrem/hr)	Comment	(mrem/hr)	Comment
Survey Riser SR-1	7.3*	existing plug mitigates	119*	Existing plug mitigates to less than 0.05 mrem/hr
Air Vent EAV-1	< 0.17	OK (loss rate 1E-4)	< 0.002*	OK
Survey Riser SR-2	0.5*	existing plug mitigates	12*	existing plug mitigates
Target Hall labyrinth	0.009*	OK (close to measurements)	0.2*	OK
Target Hall Equipment Door	0.3	Post as Controlled Area Min. Occup.	0.2	OK
Stripline Penetration	0.2	Existing shielding mitigates		
RAW Penetration	0.2*	Pipes will fill voids. Area inaccessible		
Survey Riser SR-3	<0.17	OK		

* Means number based on calculations

No star means number based on scaled measurements

<0.17 values scaled up from background

Prompt Radiation

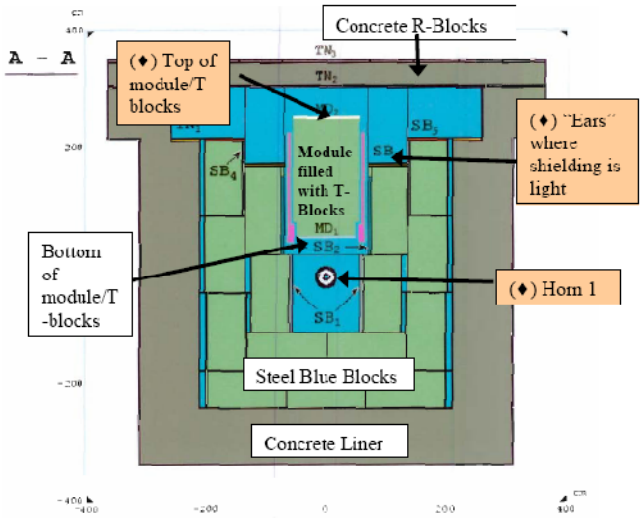


Prompt radiation

Region	Normal Loss	
	Exit Dose Rate unshielded	
	(mrem/hr)	Comment
Vent EAV-2	<0.17	OK
Vent EAV-3	<0.17	OK
Absorber Labyrinth	3.6	Post as Controlled Area Min. Occup.
Muon Alcove 2	36	Door posted and interlocked
Muon Alcove 3	3.6	Door posted and interlocked
Muon Alcove 4	0.3	Door posted and interlocked
MINOS Hall (muons)	0.07*	Move radiological boundary or post
Bypass tunnel(muons)	0.19	

There are no credible accident scenarios for these locations.
Area upstream of the Muon Alcove 4 will be posted as Radiation Area.

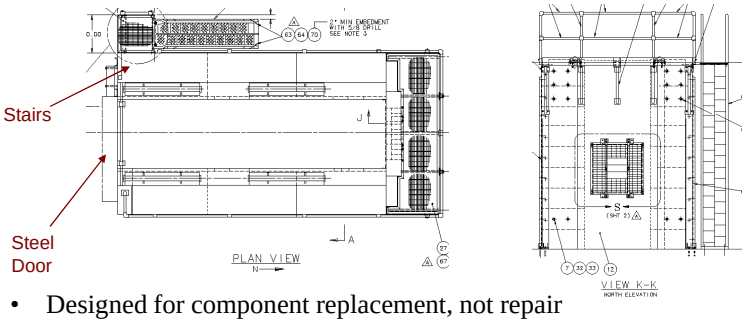
Residual Activation



Residual Activation

Time	Protons on Target	Power (kW)	Target (R/hr)	Target module/carrier (mR/hr)	Horn 1 (R/hr)	Above Horn 1 Module, by "gaps" (R/hr)	Horn 1 T-Blocks Top (mR/hr)	Horn 2 (R/hr)
MARS predicted	1.40E+20	400			160	4	4	
Spring 2006 shutdown	1.40E+20	250	1.2	50 to 150	80	200	75	5 to 8
2009 install part I	9.00E+20	250-400	2.4	100 to 300	120	300	110	8 to 12
MINERνA install part II	1.20E+20	400	2.6	170	136	340	128	11
ME running for 10 years	6E20/yr	850	9.4	786	629	1.6	584	52

Residual Activation (Existing Work Cell)



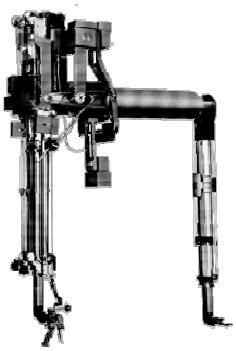
- Designed for component replacement, not repair
  - Have used for minor repairs
- 3 ft concrete side walls
- Steel door and steel end wall
- Supports weight of module and component
- Equipped with Lift Table to unmount/mount components
- Pb glass windows in beam right side wall and end wall

Existing Work Cell

- Horn 1 water line insulator repair required 16 techs each performing 6-12 sec tasks
- Long handled tools used
- Requires lots of planning people and time
- Not practical at higher NOvA residual dose rates,

Work Cell Upgrade Concept

(NuMI Upgrades & Operations – Off-project)

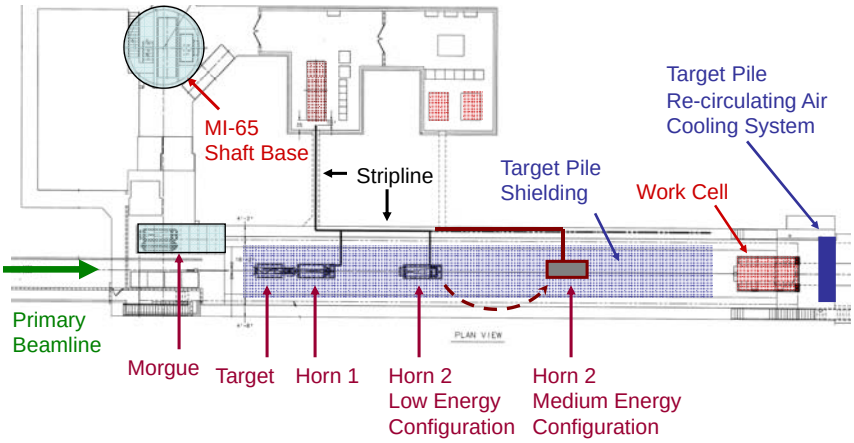


Currently in conceptual design stage

- 9" Modular steel shielding extension to Work Cell
- Tele-manipulator station with Pb glass window
- Ability to configure shielding to place tele-manipulator station at repair area of component
- May require lift table replacement/upgrade
- "Portable" Tele-manipulator station to remove manipulators up-shaft for repair and maintenance
- Requires design of special manipulator tool set
- Requires incorporation of tool set features in design of new Horns and Targets
- Requires knowledge of repair/volume reduction tasks
- Contamination issues need to be addressed
- Requires modifications to Work Cell area (provide level work surface)
- Requires training of tele-manipulator operators and stocking of tele-manipulator parts

Radioactive Component Removal Plan

(NuMI Upgrades & Operations – Off-project)



- Design shelf system for optimized temporary storage in morgue area.

Long-Term Storage

(NuMI Upgrades & Operations – Off-project)

- Long-Term storage achieved by:
  - Removing components from Morgue
  - Transport from Target Hall to MI-65 shaft base
  - Transport up-shaft to MI-65 building
  - Transport to onsite storage location
  - Offload and storage
- This plan requires:
  - Coffins (shielded containers)
  - Transport Cart System
  - Lifting and Handling Fixtures
  - Temporary shielding (if coffins not adequate)
  - Volume Reduction (if coffins too large and/or too heavy)

Summary

- Shielding assessment: No need for additional shielding for minimal Occupancy is required.
- Groundwater and surface water: fine, adding more measures.
- Air emissions: At the site boundary total emissions produce 0.05mrem/yr, which is less than 0.1 mrem/yr EPA limit.
  - Looking for ways to reduce further.
- Primary RAW systems: Radioisotopes build up higher by a factor of 1.7, disposal similar to current NuMI RAW disposal.
- Prompt radiation: Bypass tunnel starting at Muon Alcove 4 will be posted as radiation area with some possible posting changes at Target Hall Shaft area.
- Residual activation: upgraded work-cell extension shielding, additional remote handling capability and new disposal scheme design in progress (Off-project).
- Guesstimate 0.5 person-rem/shutdown-week.