



NuMI Target System

Katsuya Yonehara NBI Workshop 10/22/2019



Neutrinos at the Main Injector (NuMI)

- Produce intense neutrino beam for oscillation experiment
- Deliver beam to MINOS, MINERVA, and NOvA



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Neutrino Physics by using NuMI beam

Long-baseline oscillation experiments

The MINOS+ Concept MINOS



Neutrino scattering experiments

ArgoNeuT in the NuMI beam line

- First LArTPC in a low (1-10 GeV) energy neutrino beam.
- Acquired 1.35 × 10[∞] POT, mainly in v_µ mode.
- · Designed as a test experiment.
- But obtaining physics results!
 ArgoNeuT tech-paper:





The MINER ν A detector provides a fine-grained view of neutrino-nucleus interactions

Publication of physics result in Major Journal

- MINOS (2005 2016)
 - 4 PRD and 3 PRL in 2016 2019
- MINERvA (2010 2019)
 - 5 PRD and 2 PRL in 2018 2019
- NOvA (2014 now)
 - 2 PRD and 1 PRL in 2018 2019

NuMI target system

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Proton beam into NuMI target

Achieved in Spring 2019

FY20 Plan

- Start from November 2019 to May 2020
- Maximum beam power 777 kW
- Run 1.2 sec duty cycle and 1.4 sec rep rate with g-2/BNB/SY beam operation

Beam exposure of NuMI target system

- MET-03 target just used for one year operation
- Total accumulation of MET-03 is 5.5e20 POT
- MET-04 is a spare for 700 kW operation

J. Hylen

MET-02 target

	NuMI horns since 2005 start	Pulses	Start date	End date	Start date	End date
PH1-01	failed water line	24,200,000	2005	Jun-2008	2005	Jun 2008
PH1-02	removed for 700 kW upgrade	45,900,000	Jun-2008	Jun-2012		
PH1-04	Stripline fatigue on 700 kW modification	26,960,000	Aug-2013	Jun-2015	2005	Dec-08
PH1-03	operating	52,390,424	Oct-2015	running	Aug-13	Jun-15
PH2-01	H.S. steel washer caused stripline failure	28,100,000	2005	Dec-2008	Jun-08	Jun-12
PH2-02	operating	121,350,424	Dec-2008	running	Dec-08	running

10-year operation

NuMI AIP Upgrade

- Upgrade Target system for 1-MW operation
- Construction start from 2018 and complete in Summer Shutdown 2020
 - MET-05 target capable to accept 1-MW beam
 - Modify horn stripline and air diverter
 - Yun He and Kris Anderson will show more detail

Summary of Tasks in Summer Shutdown 2019

Job/Week	1	2	3	4	5	6	7	8	9	10	11	12
Tar/H1 RAVV skid work - Des												
Horn-1 Target Pile RAVV												
Fitters Des												
Mez fitting work.												
Lee Hammond												
Mez SCHWHX Replacement												
Lee Hammond												
Mez Chiller PM - Prism												
Lee Hammond												
Chase Cooling HVAC/Fitting												
Lee Hammond												
Transfer MET-02 to C0												
Install MET-05					MET-03 to						Install	Install
Crowley & Lolov					Morgue						MET-05	MET-05
Replace Stipline Hardware												

- 12-week plan, started from 7/09/19
- Major activities are for upgrading to the NuMI-AIP 1-MW target system
- MET-05 target has been installed in the target chase
 - Ready for beam based alignment
 - Neutrino beam operation after the alignment

NuMI-AIP Team in Summer 2019

Thank you all for your hard works and tremendous supports to accomplish the summer project!

G. Lolov

Major modification which can impact on ν beam parameter

- Increase target fin width to reduce thermal shock
 - 7.4 mm to 9.0 mm
 - RMS beam size change from 1.3 mm to 1.5 mm
- Add winged fin
 - First four fins are replaced to the winged fin
- Increase inner diameter of baffle
 - 13 mm to 15 mm
- Add water cool on the downstream Be window

Fins, Winged fin, and Budal Monitor fins

New baffle

New DS Be window **Fermilab** & water line

Upgrade cooling system & Remove old target

- RAW skid
- Horn 1 suction line
- Mez chiller
- Add/new cooling coil in TH
- MET-02 to C0, MET-03 to Morgue
 - Plan to autopsy MET-02 and MET-03

MINOS ND terminated

- Since MINERvA completed operation in 2019, the MINOS ND operation is terminated
- We lost the most convenient neutrino detector to quickly check the quality of neutrino beam
- We investigate the function of muon monitor to diagnose the condition of NuMI target system

Search for Sterile Neutrinos with the MINOS Long-Baseline Experiment pp 135-152

Study beam monitor system

Can we reconstruct the neutrino flux at NOvA ND/FD from beam monitor signal?

 Nuon-monitor
 tatb

Study Muon Monitor Signal

• Characterize the horn focusing power by using muon monitors at various horn currents (Horn current scan)

Beam centroid on Muon Monitor 1

Beam centroid on Muon Monitor 1

• $\overrightarrow{r_{2,\pi}} = \widehat{M} \cdot \overrightarrow{r_{1,p}}$ and \widehat{M} can be a beam transfer matrix

Distance from target (mm)

• Analytical model reproduces $\vec{r_2} = (x_2, \theta_{x_2}, y_2, \theta_{v_2})$

- Higher E_{π} diverge more
- Horizontal (x) track is symmetry while vertical (y) one is asymmetry due to the NuMI target geometry
- The model predicts that the observed slope and offset in the beam scan should be unique

Machine Learning in NuMI Target system

A. Wickremasinghe

 Linear correlation suggests to utilize the Muon Monitor to diagnose the healthiness of target system by using ML system
 Prediction of muon monitor1 <X>

- Introduce Machine Learning to daily-base monitor MM signal
- Accuracy +/-0.5 mm

Summary

- Upgrade NuMI Target system
 - Install MET-05 target
 - New cooling system ready to operate
 - Work on horn stripline and air diverter
- FY20 run will start next week
 - Beam power up to 777 kW
 - Or > 680 kW with synergistic operation
- Study beam monitor system
 - Capability of reconstruct neutrino flux at NOvA ND/FD