Achievement in Beam Power Records for the NOvA Target System

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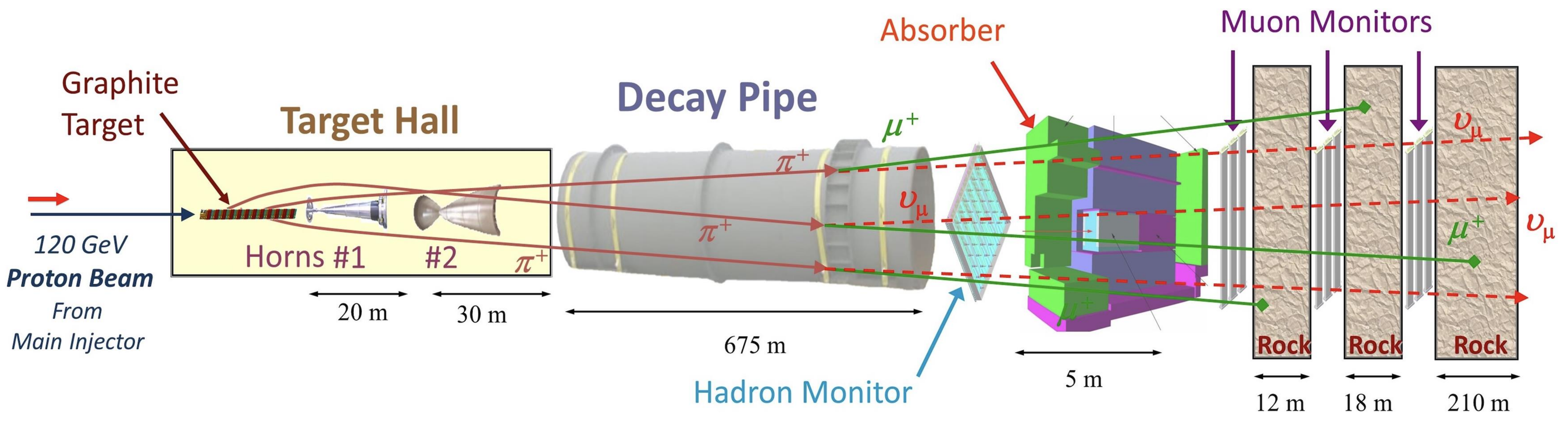
Introduction

We began upgrading the NOvA target system for 1-Mega Watt (1-MW) beam operation in 2017. Major challenges included maintaining the quality of neutrino beams with reliable instrumentation, reducing instantaneous beam heating on the target, increasing cooling power to handle the high-power beam, and controlling tritium water production rate. We finally achieved a one-hour beam power record of **1.018 MW** in Summer 2024. This milestone demonstrates our capability to operate at 2+ MW beam power for the future Long Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE).



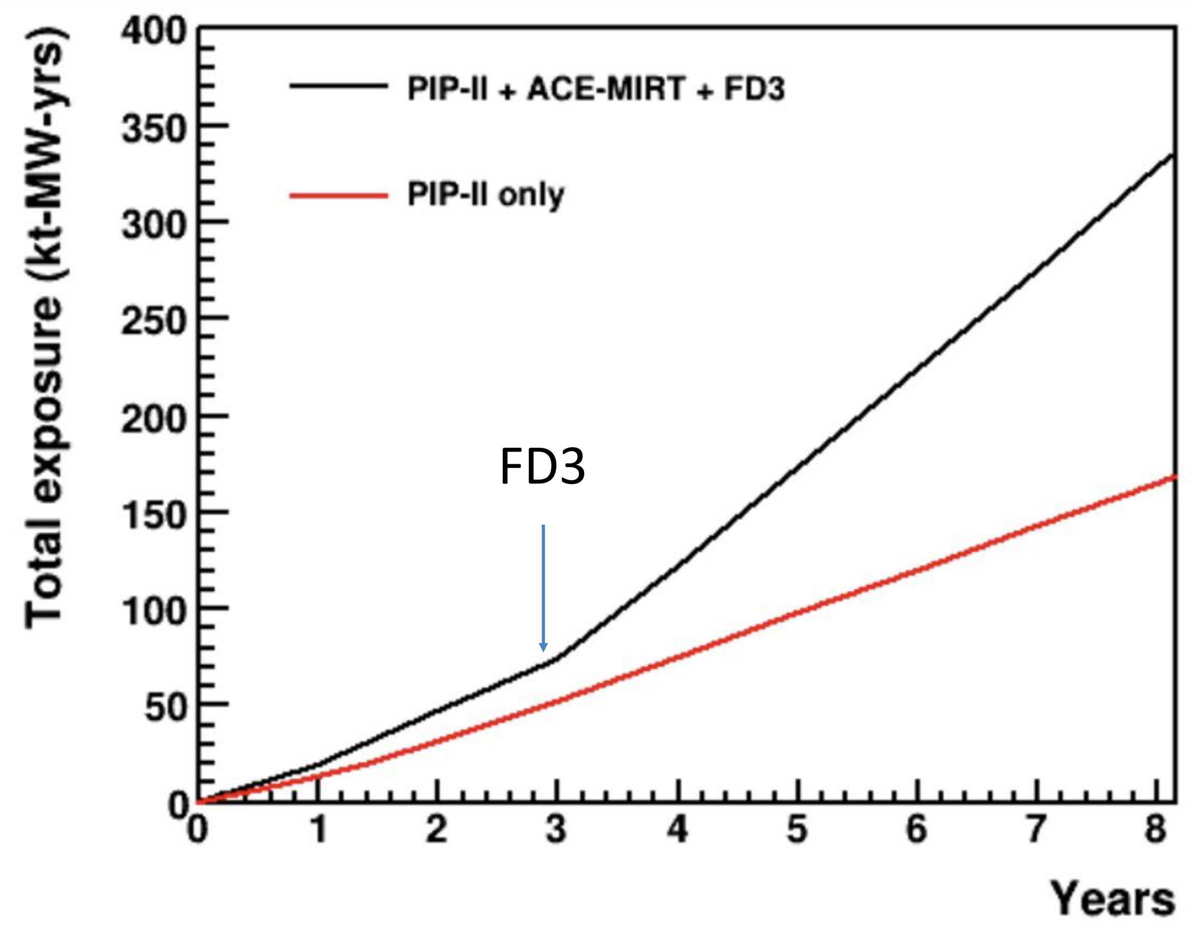
Layout of the NOvA target system

Present and future beam power upgrade:

Accelerator Complex Evolution-Main Injector Ramp and Targetry R&D (ACE-MIRT)

The Fermilab Accelerator Complex will operate with fast Main Injector ramp rate to increase the Protons On Target. This project is called ACE-MIRT. The table shows the current time structure of the beam and the future plan.

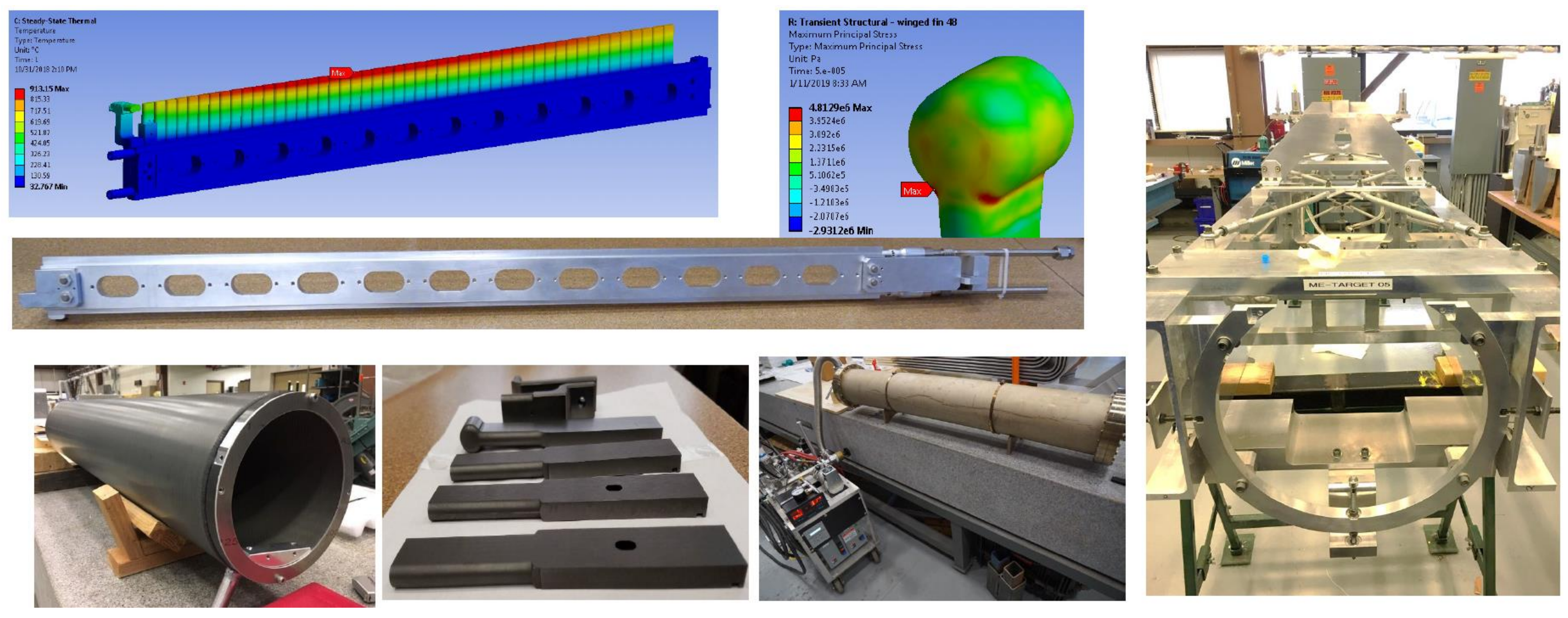
			PIP-II Booster		
Operation scenario	**Design**	**Present**	**PIP-II**	**ACE-MIRT**	
MI 120 GeV ramp rate (sec)	1.333	1.067	1.2	0.9	0.7
Booster Intensity (e12)	4.5	5.6	6.5		
Booster ramp rate (Hz)	15		20		
Number of batches for 120 GeV	12		12		
MI Power (MW)	0.865	**1.018**	1.2	1.7	**2.14**
cycles for 8 GeV	6		12	6	2
Available 8 GeV power (kW)	29	36	83	56	24



Major upgraded Items

1-MW target and cooling water system

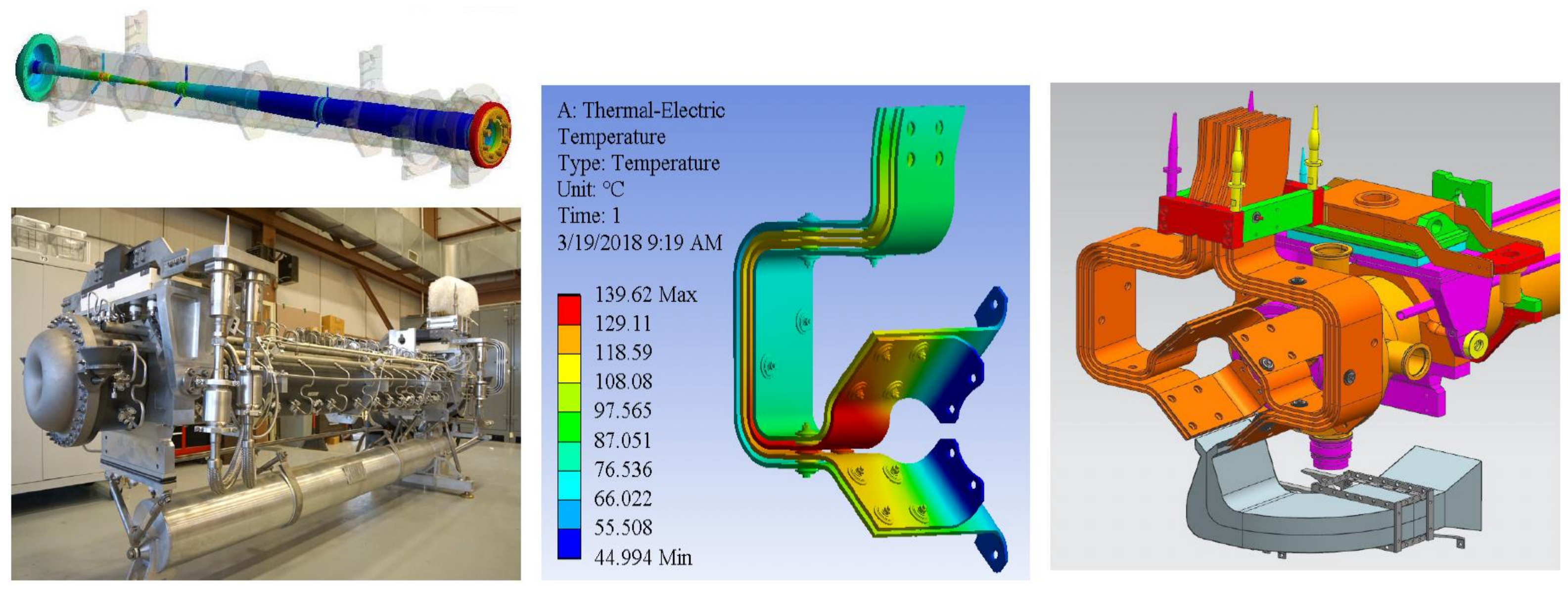
The new 1-MW target and cooling water system have been in operation since 2019. It is designed to accept a Protons On Target intensity of 6.5e13 POT, which is the design value of the ACE-MIRT project.



From Top Left: FEA temperature simulation, simulated temperature of winged fin at accidental condition, target chase frame, Helium gas leak test, target fins, and target canister

1-MW horn system and Air diverter

The new 1-MW horn features powerful cooling capabilities. Especially, the stripline temperature is maintained by an air diverter.



From Left: Horn 1 and FEA temperature simulation of inner conductor, simulated stripline temperature, structure of air diverter

Optimize proton beam spot size at the target

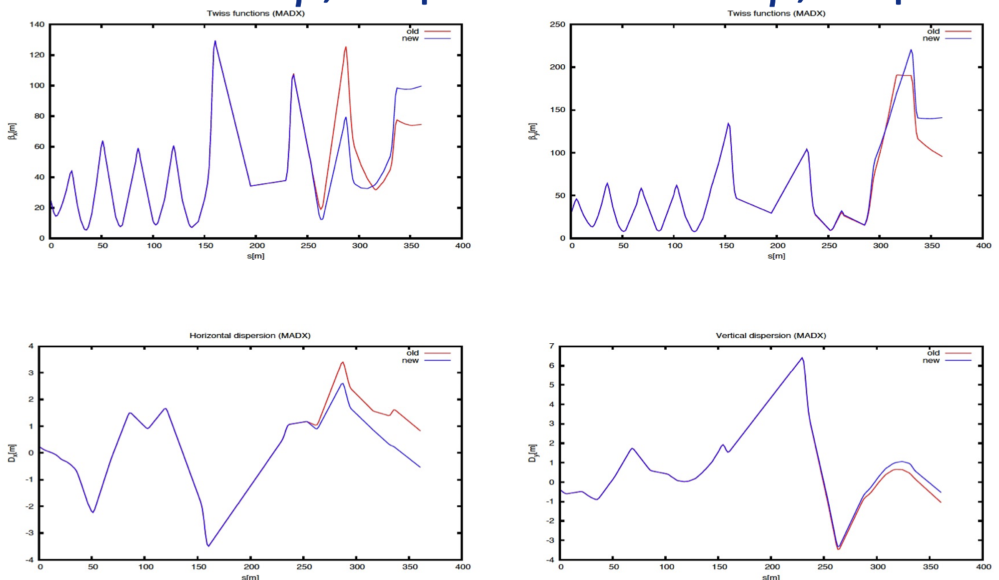
The NuMI beam transport optics is optimized to minimize instantaneous beam heating on the target.

Quad current list (unit Amp)

	Present	Option 1	Option 2
QF109	61.194	61.194	61.194
QD110	-25.340	-25.340	-25.340
QD111	-325.491	-325.490	-325.491
QF112	342.141	342.140	342.141
QD113	-341.895	-342.060	-338.100
QF114	326.580	326.080	323.071
QF115	14.092	25.340	43.800
QD116	-63.165	-71.658	-75.698
QF117	50.513	51.199	57.202
QD118	-36.901	-32.500	-42.391
QF119	-6.084	-23.190	-4.040
QD120	-156.016	-170.700	-196.339
QF121	35.143	44.299	46.946

QF: Quadrupole Focusing in horizontal plane
QD: Quadrupole Defocusing in horizontal plane
Number: Location (bigger is closer to the NuMI target)

Horizontal β, Disp. Vertical β, Disp.



Red: Present
Blue: Option2

- Option 1 is lower current strength but dispersion at the target is non-zero
- Option 2 is higher current but dispersion at the target is close to zero

ACKNOWLEDGEMENT
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