The Future of the Fermilab Accelerator Division in 10 minutes

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On behalf of the Accelerator Division at Fermilab
New Perspective 2020
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Fermilab Accelerator Complex

Bird’s-eye view of Fermilab beams
List of Upgrades and Future Plans

- NuMI beamline upgrades for 1-MW beam operations
- Mu2e plans
- IOTA studies
- Artificial Intelligent and Machine Learning efforts
- Fermilab Robotics
Planing to upgrade the beamline components to reach 1-MW beam power
Gradually increase the beam power with faster cycle times

<table>
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<th>2019 summer shutdown</th>
<th>2020 summer shutdown</th>
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<td>1 MW target installation</td>
<td>1 MW horn 1 installation</td>
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<tr>
<td>Target &amp; Horn 1 RAW (Radioactive Water) upgrade</td>
<td>Stripline air diverter T-block</td>
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<td>Target chase cooling / air upgrade</td>
<td>Target and horn 1 module drives</td>
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<td>Target chase supplemental shielding</td>
<td>Hadron beam monitor &amp; absorber</td>
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NuMI beamline Upgrades

We are getting ready to operate the NuMI beamline with 1-MW beam operations

1-MW horn 1 preparation is ongoing

1-MW NuMI target has been installed during the summer shutdown in 2019

Radioactive Water pump upgrades in 2019

Old hadron monitor will be replaced with a new hadron monitor in 2021
Mu2e beamline updates

Main Goal: The Mu2e experiment is looking for evidence that a muon can change into an electron and nothing else. This explains the Charged Lepton Flavor Violation (CLFV) in the Standard Model (SM) of particle physics.

- The Mu2e experiment is under construction at the Fermilab Muon Campus.
- The experiment will begin operations in 2022, and will require about 3 years of data-taking.
Mu2e beamline updates

There are future upgrades on building the apparatus. Stay tuned!

V907 is a vertical dipole
- pitched up to run muon beam to g-2
- pitched down to run protons to Mu2e
IOTA (Integrable Optics Test Accelerator)

The facility is dedicated to research and education in beam physics and accelerator technology

**Research Staging:**

**Nonlinear Integrable Optics**
- Phase I – Single-particle motion stability using electron beams
  - Run-1 2019, Run-2 2020
- Phase II – intense-beam studies with protons
  - 2021 and beyond

**Optical Stochastic Cooling**
- Without optical amplifier – Run-3 2020*(Delayed due to the covid19)
- With optical amplifier – 2022 and beyond

Reference:
AI / ML efforts

AD has started implementing AI technology to improve the accelerator system performance by considering following factors:

» Saving energy
» Identifying / predicting incidents
» Detecting anomaly
» Tuning beam parameters
» Optimizing beam quality
» Predicting beam parameters for QA

Example of predicting beam position: NuMI proton beam at the target
## AI / ML efforts

<table>
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<tr>
<th>Project</th>
<th>Description</th>
<th>Group</th>
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<tr>
<td>AI for superconducting magnet quenching</td>
<td>Early determination of conditions for superconducting magnet quenching</td>
<td>Cristian Boffo, Vittorio Marinozzi, Stoyan Stoynev et al</td>
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<tr>
<td>The ACORN: Accelerator Controls Operations Research Network</td>
<td>Modernize the accelerator control system and replace end-of-life accelerator power supplies to enable future operations of the Fermilab Accelerator Complex</td>
<td>Erik Gottschalk and the AD Controls Department</td>
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<tr>
<td>Automated image categorization and data mining for AD e-Log</td>
<td>The Main Control Room's e-log will use ML to automatically categorize all existing and future image attachments, and make text in the images searchable</td>
<td>Kyle Hazelwood, Jason St. John</td>
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<tr>
<td>NuMI beamline and target ML</td>
<td>NuMI beamline monitoring system for QA with ML predictions on beam parameters, identifying and predicting incidents</td>
<td>Athula Wickremasinghe, Katsuya Yonehara</td>
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<tr>
<td>User Facility AI proposals</td>
<td>AD Accelerator energy conservation AI, Anomaly detection, Data mining</td>
<td>William Pellico, Jason St. John et al</td>
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<td>Longitudinal Beam Tomography</td>
<td>Automatic disentangling of slip-stacked Main Injector bunches for precision characterization</td>
<td>Kyle J Hazelwood</td>
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<td>PIP2IT adaptive beam current signal monitoring</td>
<td>Environment-aware ML to remove noise artifacts from beam current measurement devices in low- and medium-energy sections of test stand</td>
<td>Eduard Pozdeyev, Michelle Ibrahim and Pavlo Lyalyutskyy</td>
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Robotics

AD scientists and engineers are introducing robotics to minimize the radiation exposure.

RVR (Remote Viewing Robot)
360 and regular cameras, both with real-time image and video streaming to an iPad or phone.

Future Upgrades:
- Adding radiation detectors
- Sensors to automate the robot
- Robotic arms

Project Leader: Kris Anderson

5-Axis Robotic Arm
Designed to mount onto RVR for remote-control camera positioning
* Now in testing stage
Project Leader: Noah Curfman

Magnetic Field-Mapping System – NuMI Horn
Updating the motion-control system that moves the 3D hall probe along the NuMI horn’s center axis while the horn pulses
- Open-source code to control new motor drive
- Linear position sensors
- Data acquisition system

Project Leader: Adam Watts
Robotics

UIC – Visually Identifying Objects Using Machine Learning System

Use computer vision and ML to identify and locate bolts on a flange arbitrarily oriented in space

Status
- ML algorithm to detect bolts of various sizes has been created, tested, and evaluated
- Working on object detection script to use with a commercial 3D stereo camera

Project Leaders:
- Katsuya Yonehara, Patrick Hurh

UIC – Radiation Mapping UAV

Outfit a quadcopter to produce a 3D coordinate map integrated with radiation data

Status
- Drone has been assembled
- Integration of temperature sensor (prototype), camera and Geiger-Mueller tube in progress
- Software development for data process in initial stages

Project Leaders:
- Katsuya Yonehara
- Patrick Hurh

List of other projects / proposals:
- UIC – Radioactive Dust Collector - PL: Noah Curfman, Rob Ridgway
- Robot Inside LAr Detector - PL: Bill Pellico, Mayling, Wong-Squires, Sam Zeller
- NIU Exoskeleton Study - PL: Mayling Wong-Squires, Don Peterson (NIU), Simon Kudernatsch (NIU)
Thank you!
On behalf of the Accelerator Division

Thanking to AD colleagues for doing all activities even with COVID19 difficult time

Fermilab