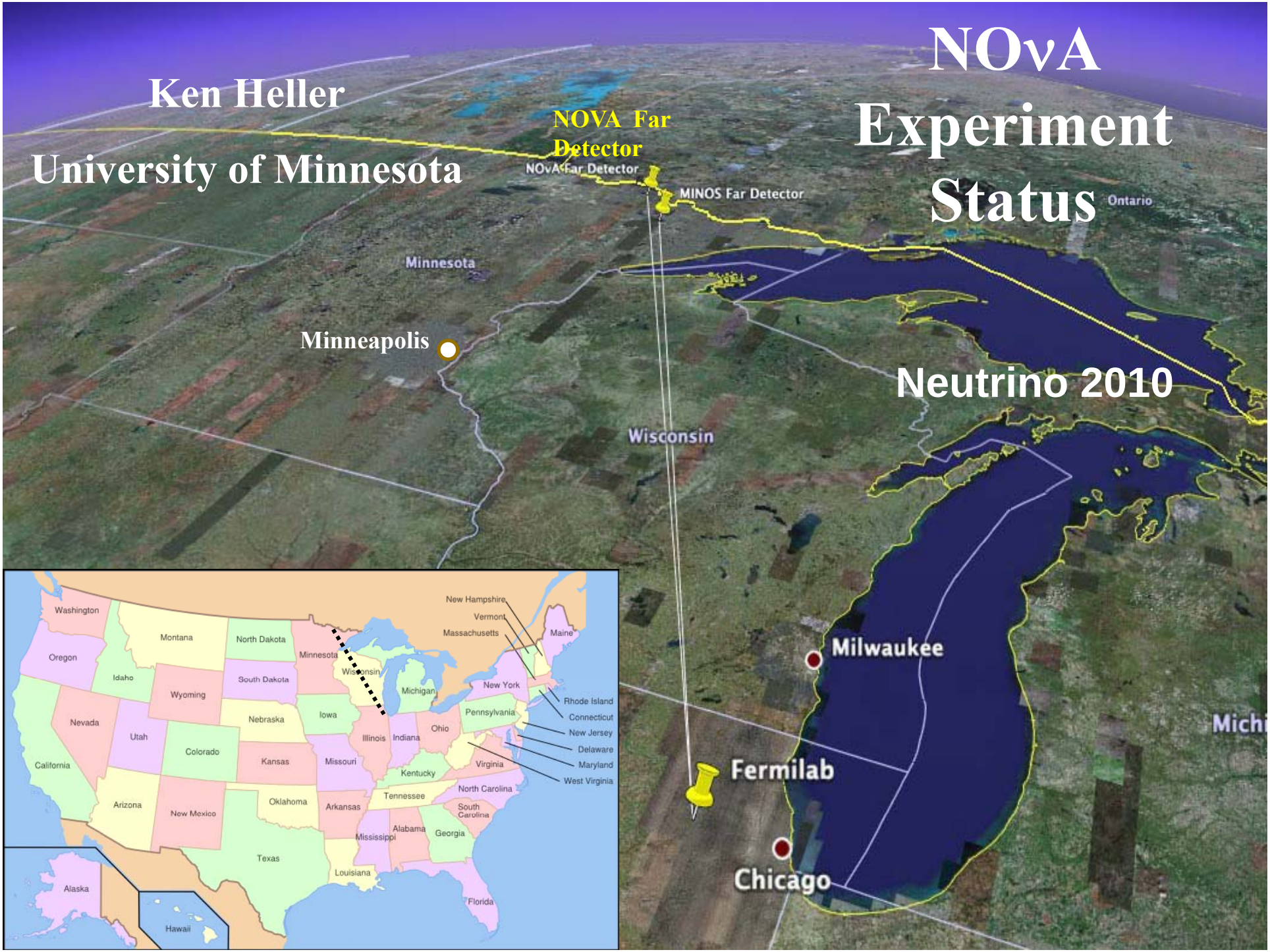
NOνA Experiment Status

Ken Heller

University of Minnesota

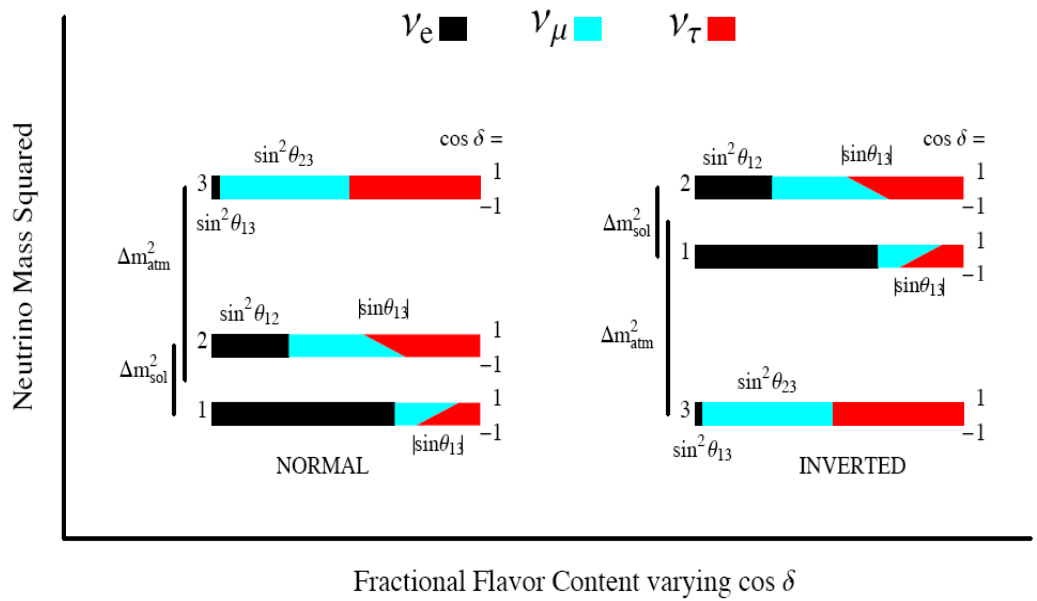


Neutrino 2010

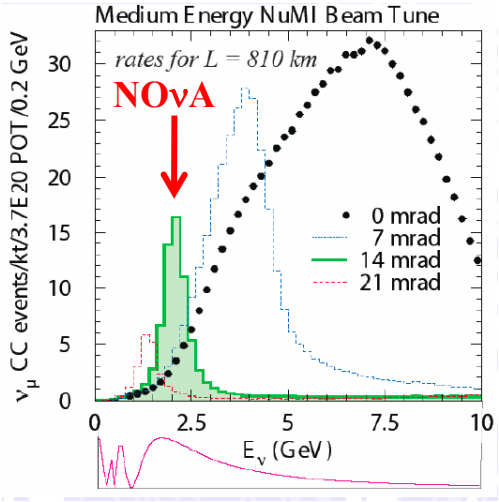
Outline

- The NOνA Experiment – A Brief Reminder
- NOνA Status and Schedule
  - Buildings
  - Fiber
  - Scintillator
  - PVC extrusions
  - Detector modules
  - Module assembly
  - Photodetector
  - Electronics
  - Data Acquisition (DAQ)
  - Software
  - Beam
  - Schedule to Data Taking

Physics Goals and Sensitivity of NOνA
See Poster
Gregory Pawloski



NOνA: NuMI Off-Axis ν_e Appearance Experiment



- **NOνA: a second-generation experiment**
  - **Fermilab NuMI beamline – off axis gives a narrow band beam**
    - **Upgrade to 0.7 MW**
  - **Near detector at Fermilab → Far detector in Northern Minnesota**
  - **Far detector is not underground**
- **Both detectors identical "totally active" tracking liquid scintillator calorimeters (near detector ~1.5% mass of far detector)**
  - **Order of magnitude improvement over current measurements of ν_e appearance and ν_μ disappearance.**
  - **Sensitive to Supernovas**
- **NOνA's unique feature 810 km long baseline km**
  - **Sensitive to neutrino mass ordering.**
  - **Measures θ_{13} and θ_{23}**

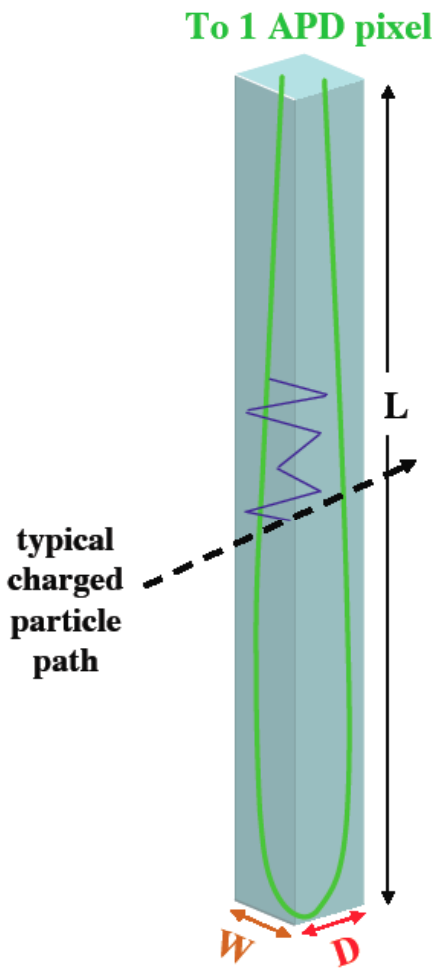
The NOνA Collaboration

Fermilab Meeting, April 2010

180 Scientists and Engineers from 26 Institutions

Argonne National Laboratory - University of Athens - California Institute of Technology - University of California, Los Angeles - Fermi National Accelerator Laboratory - Harvard University - Indiana University - Lebedev Physical Institute - Michigan State University - University of Minnesota, Duluth - University of Minnesota, Minneapolis - The Institute for Nuclear Research, Moscow - Technische Universität München, Munich - State University of New York, Stony Brook - Northwestern University - University of South Carolina, Columbia - Southern Methodist University - Stanford University - University of Tennessee - Texas A&M University - University of Texas, Austin - University of Texas, Dallas - Tufts University - University of Virginia, Charlottesville - The College of William and Mary - Wichita State University

NOνA Detector Element



Liquid scintillator in a cell

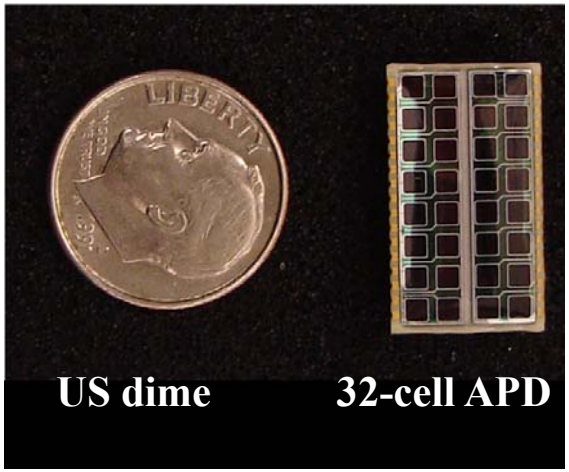
- 4 cm wide, 6 cm deep, 15.7 m long.
- Cell from highly reflective PVC.
- 32 cells in a PVC module.

Light collected by U-shaped wavelength-shifting fiber.

- 0.7 mm diameter.
- Both ends go into a pixel of a 32-pixel avalanche photodiode (APD).

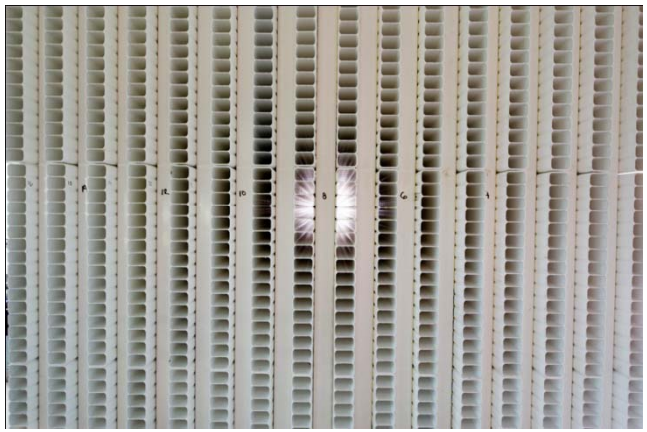
APD quantum efficiency of 85%.

- Gain of 100.
- Cooled to -15°C.

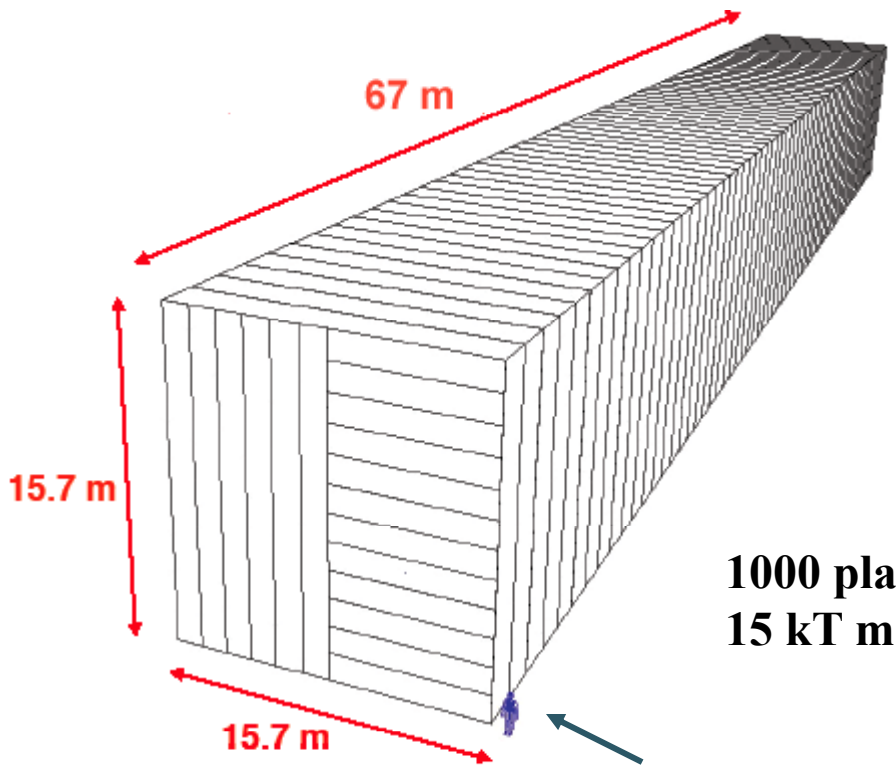


Far Detector

- Cells are in 16-cell PVC extrusion.
- Glue 2 extrusions together to make a 32 cell module.
- 12 modules make up a plane.
- Planes alternate horizontal and vertical.



Extrusion cells

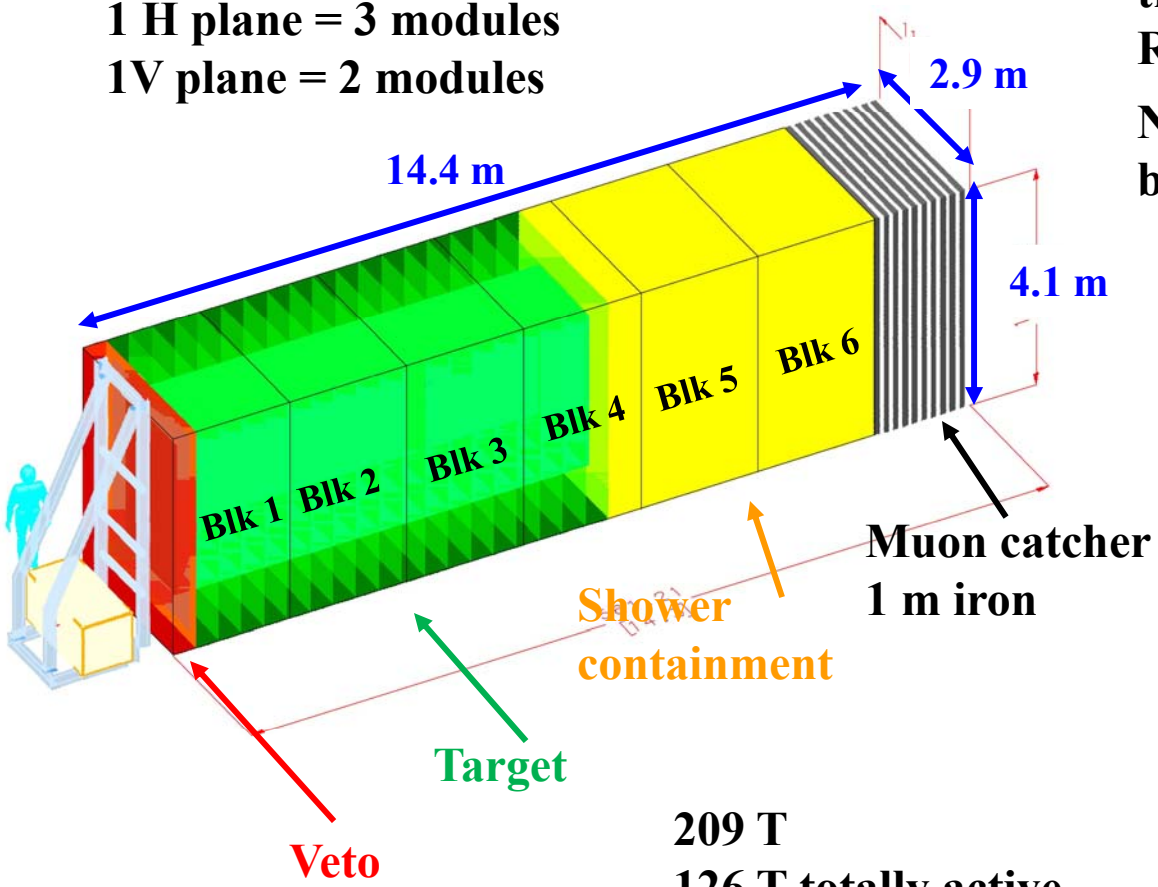


1000 planes , 380,000 channels
15 kT mass (~85% fudicial)

Standard physicist

Near Detector

1 blk ~ 78 modules
1 H plane = 3 modules
1V plane = 2 modules



209 T
126 T totally active
23 T fiducial

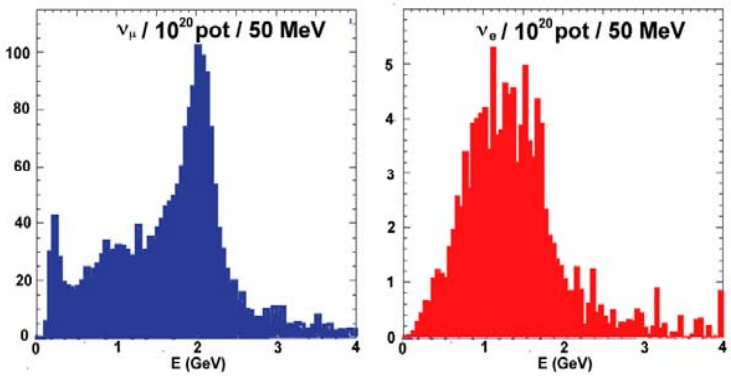
Near Detector prototype built on the surface in NUMI off-axis beam. Runs for ~1 yr

Near detector put in the NUMI beam tunnel off axis.

Building Status - NDOS

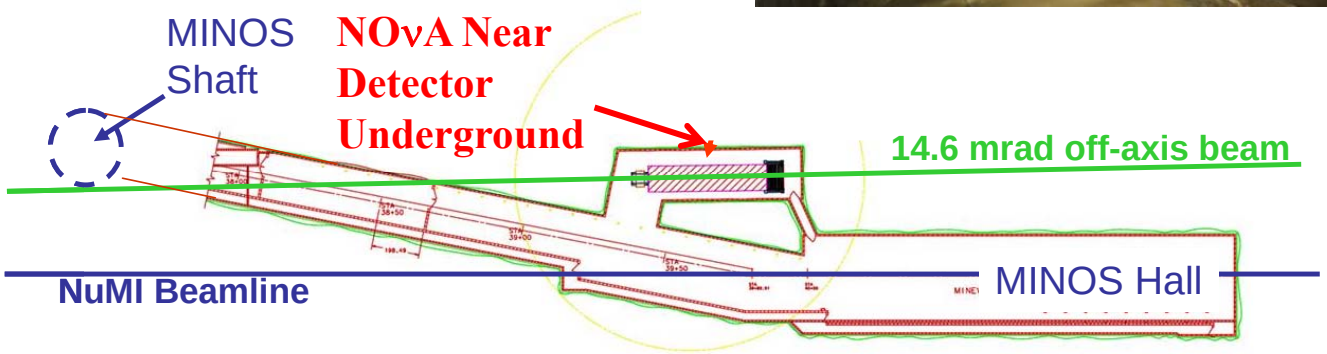
Detector Prototype: Near Detector On Surface (NDOS)

107 mr off axis ν beam

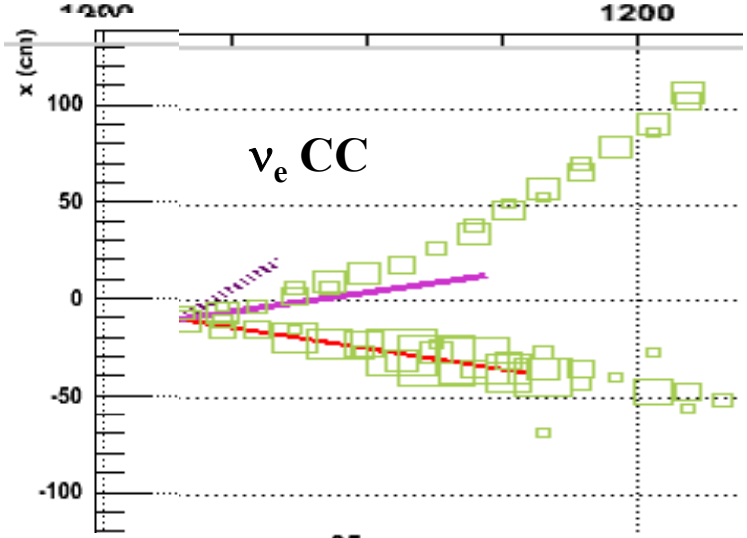


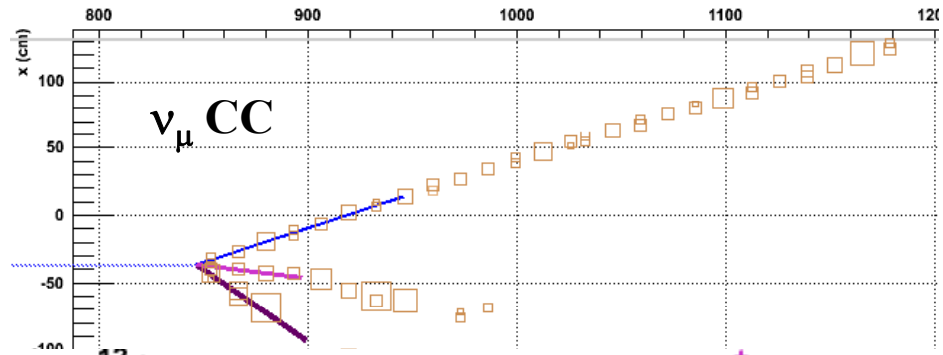
Simulates far detector building

Building is complete
Movable platform finished, July
Install blocks - July

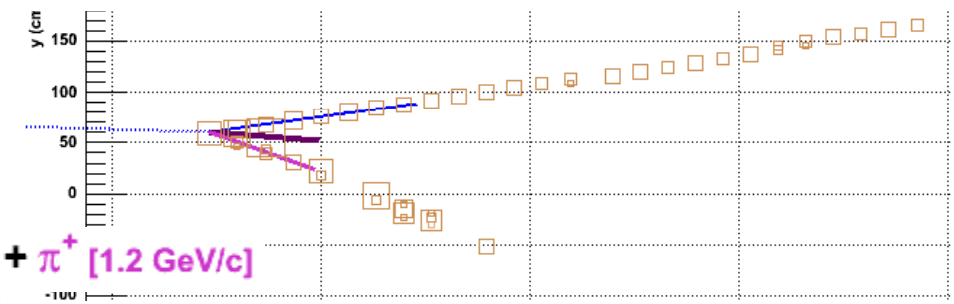


NDOS Event Simulations

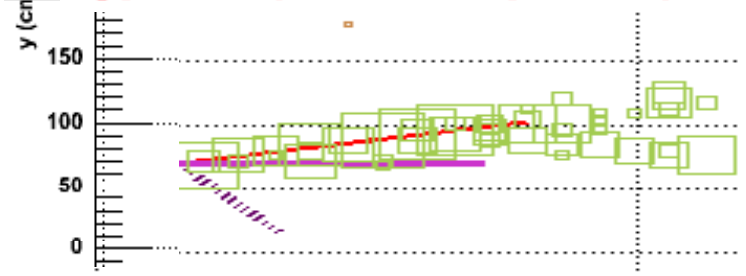


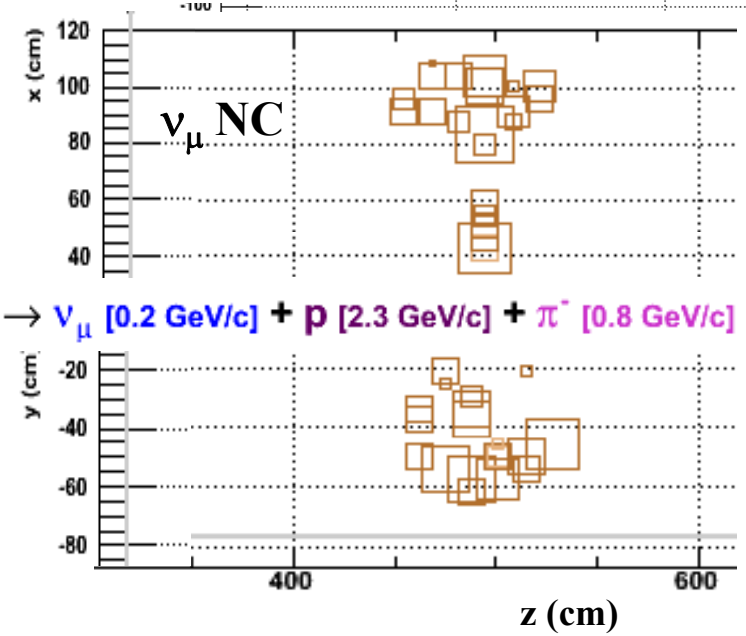


ν_μ [2.1 GeV/c] + ^{12}C → μ [1.2 GeV/c] + p [0.8 GeV/c] + π^+ [0.6 GeV/c]



ν_e [2.8 GeV/c] + ^{35}Cl → e^- [1.4 GeV/c] + n [0.7 GeV/c] + π^+ [1.2 GeV/c]





ν_μ [2.6 GeV/c] + ^{12}C → ν_μ [0.2 GeV/c] + p [2.3 GeV/c] + π^- [0.8 GeV/c]

Far Detector Hall

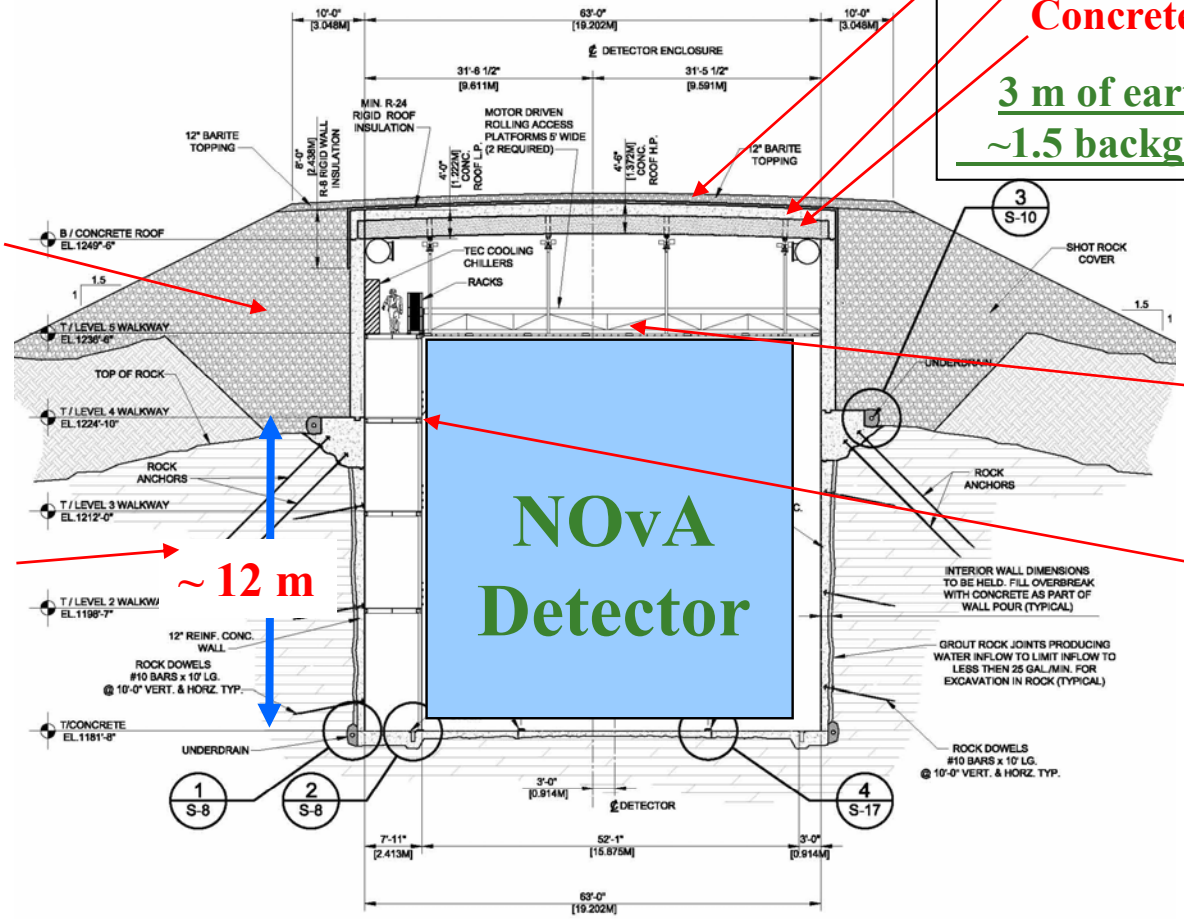
Cross section as seen by the neutrino beam
19 m wide x 22 m high

15 cm barite
Cast Concrete
Concrete Planks

3 m of earth equivalent
~1.5 background event in 6 yrs

Excavated granite

Solid granite (bathtub for 100% secondary containment)



Rolling access bridges

4 catwalks, electronics on top catwalk

Far Detector Laboratory

Far Detector Hall Status

Floor

Started: 10May10

Scheduled Complete: 24Jun10

Walls

Started:20May10

Scheduled Complete: Aug10

Roof

Scheduled Complete: Sep10

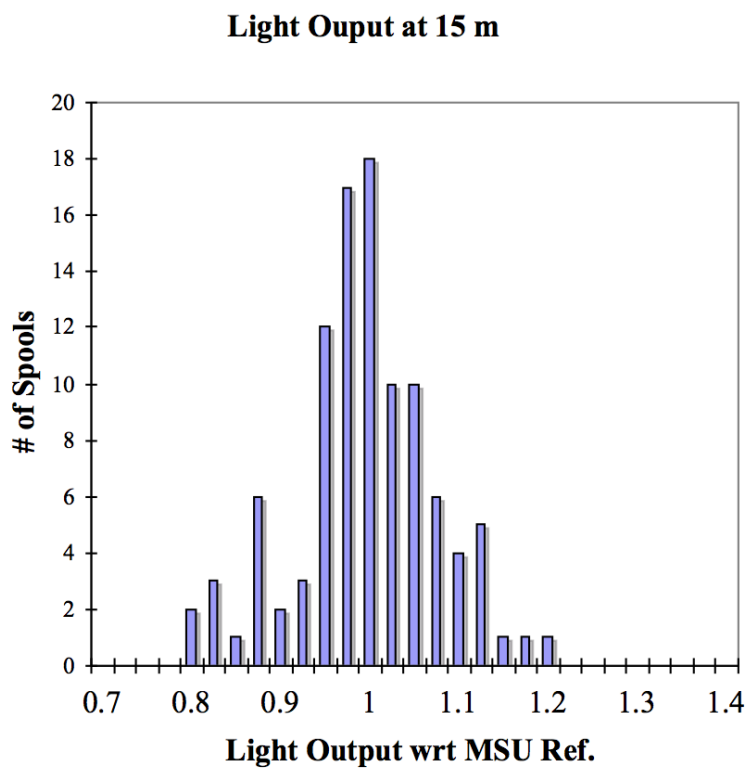
Shielding

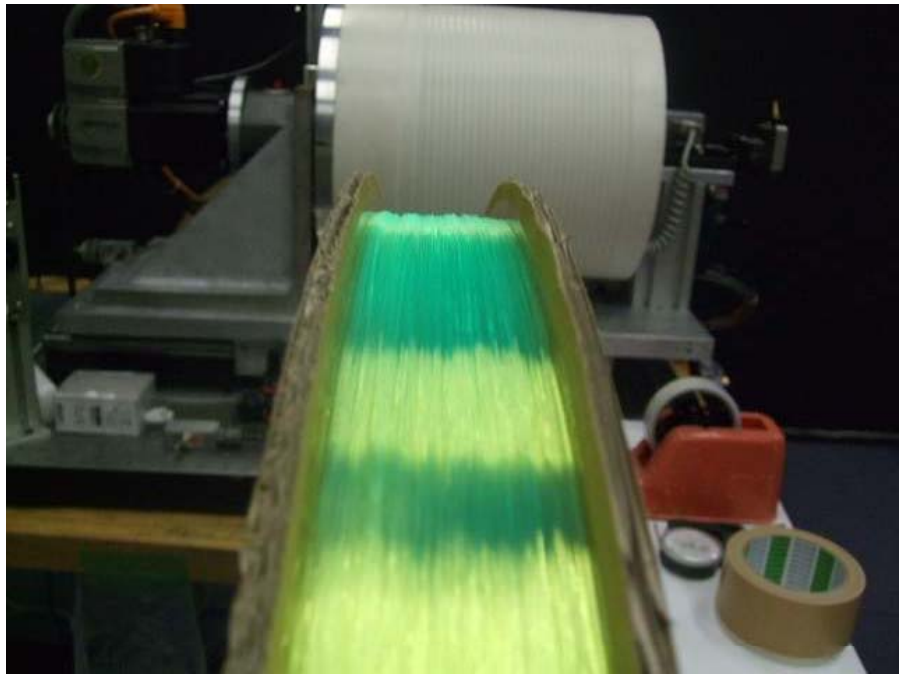
Scheduled Complete: Oct10

Fiber

Need ~ 12,000 km of 0.7 mm diameter wavelength shifting fiber from Kuraray
So far ~10% received and tested

K27 dye @ 300 ppm, S-type



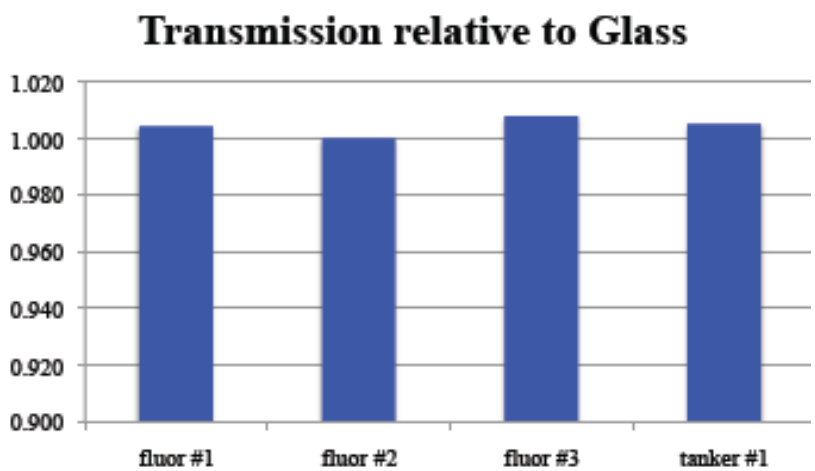


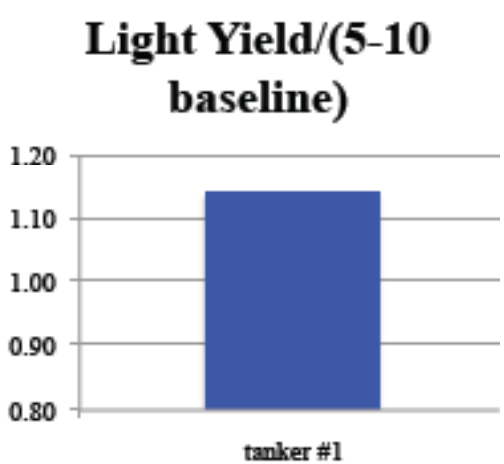
Michigan State

Scintillator Oil Using Commercial Mixing

component	purpose	mass fraction	volume (gal)	tot mass (kg)
mineral oil	solvent	94.90%	304.218	981.7
pseudocumene	scintillant	4.99%	15.5	51.6
PPO	waveshifter #1	0.110%	0.3	1.14
bis-MSB	waveshifter #2	0.0015%	0.0	0.016
Stadis-425	antistatic agent	0.0003%	0.0	0.003
tocopherol (Vit.E)	antioxidant	0.0010%	0.0	0.010
Total		100.0%	320.0	1,034.5

11 M liters mineral oil
400,000 liters pseudocumene

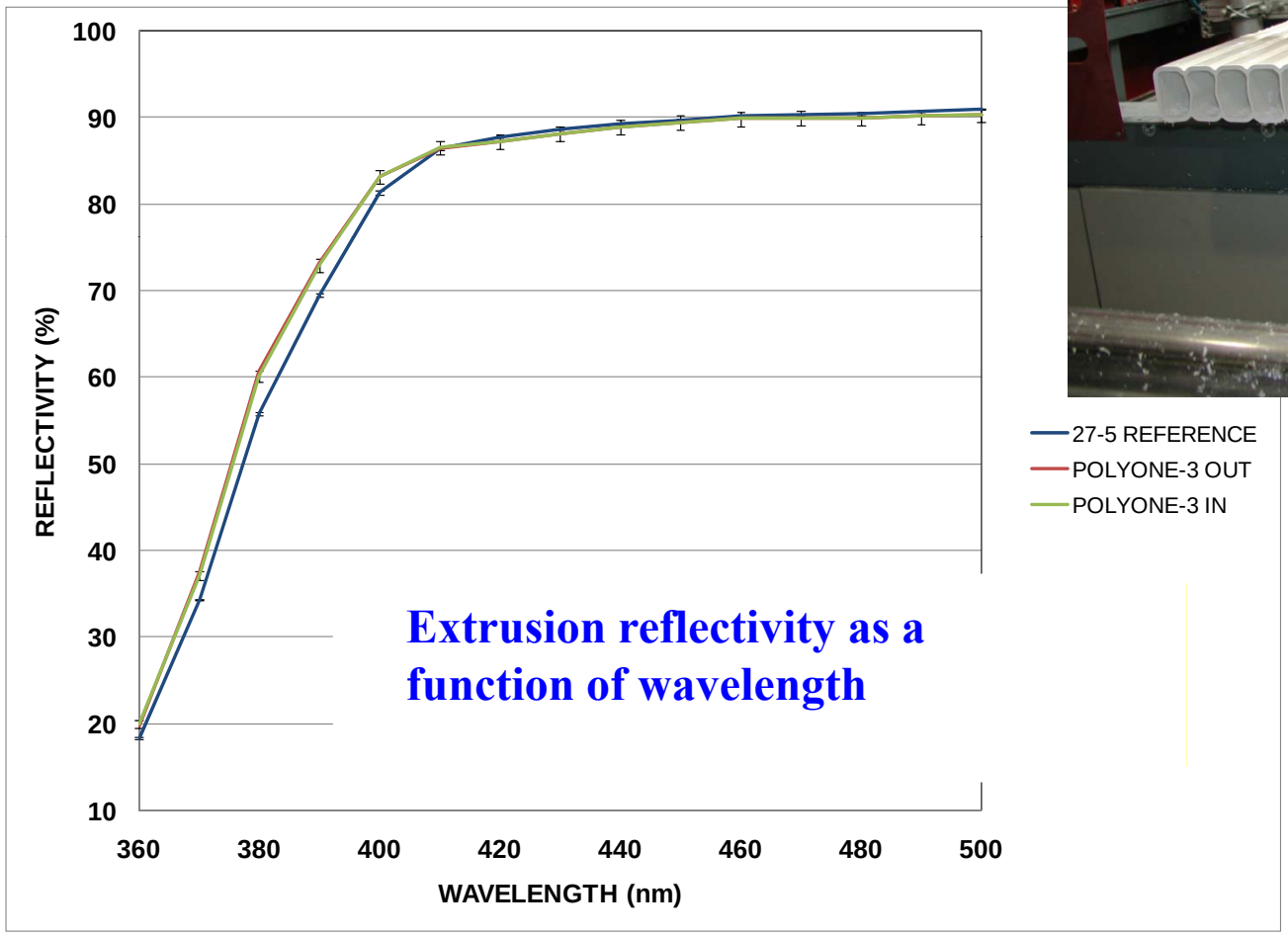




Indiana & Fermilab

PVC Extrusions

15% Anatase titanium dioxide



- **All NDOS extrusions produced.**
- **Retooling for far detector extrusions (430 kg/hr)**
- **Production begins in August 2010**

Argonne & Fermilab

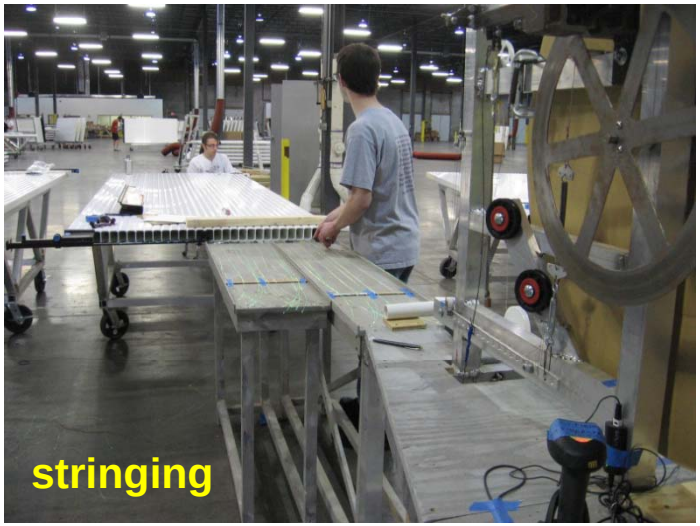
Detector Module Production

70% of NDOS modules produced – finished July 2010

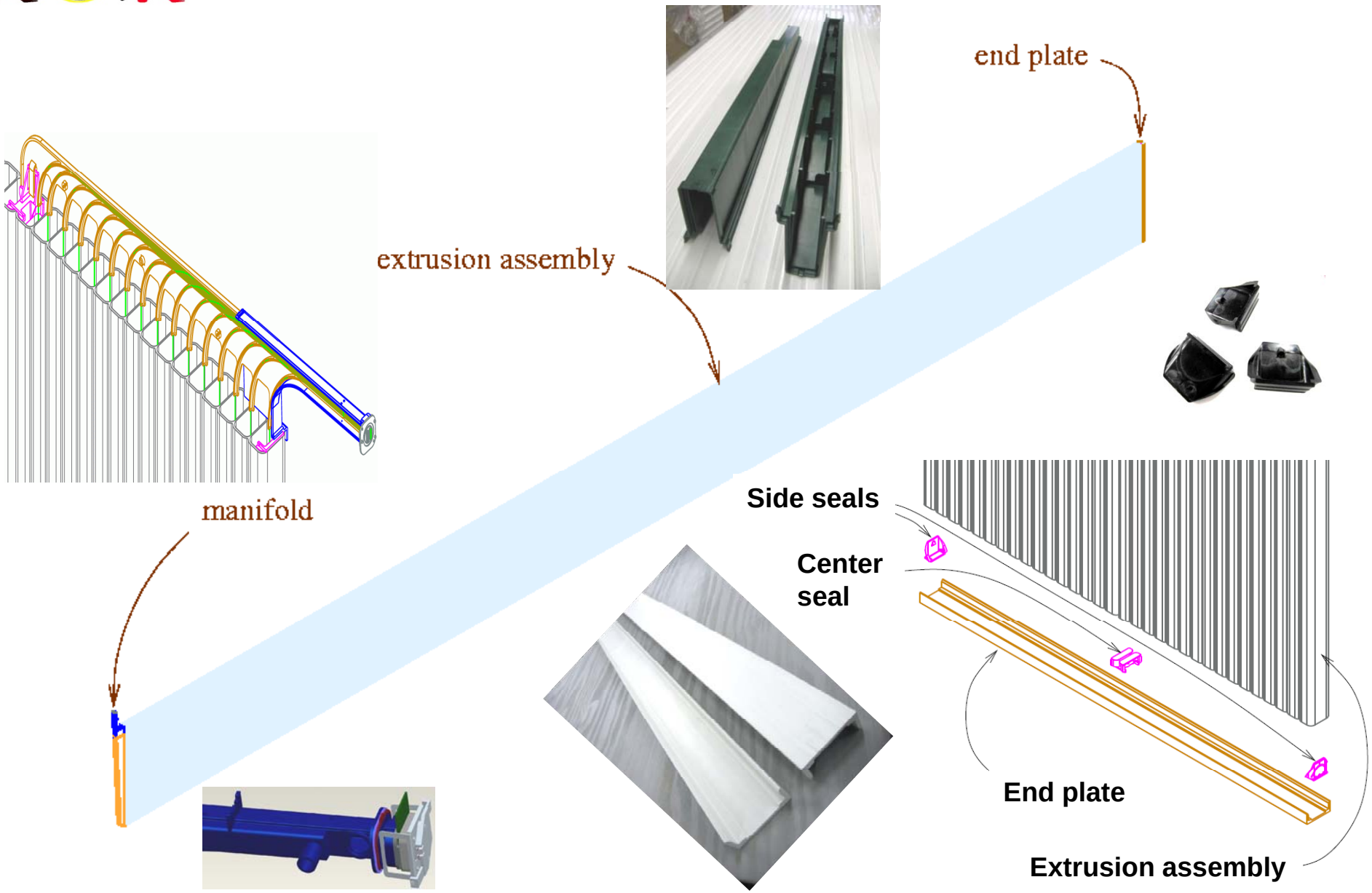
Factory now tooling for Far Detector modules

Far Detector module production begins – April 2011

Minnesota



Seal both ends of extrusion



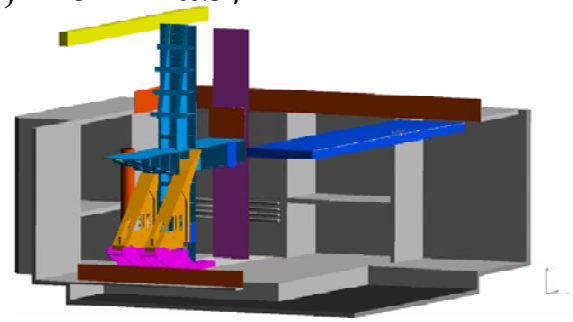
Block Assembly & Installation

NDOS tests Far Detector assembly and alignment procedure

- First 2 blocks in MINOS near detector building
- Third block being assembled at Argonne
- NDOS completed August 2010

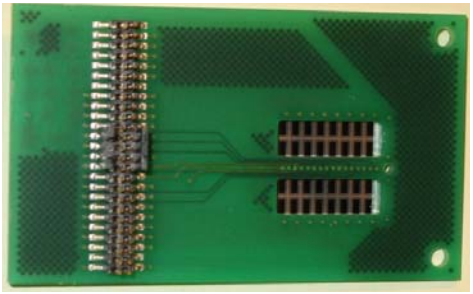
Argonne, Fermilab,

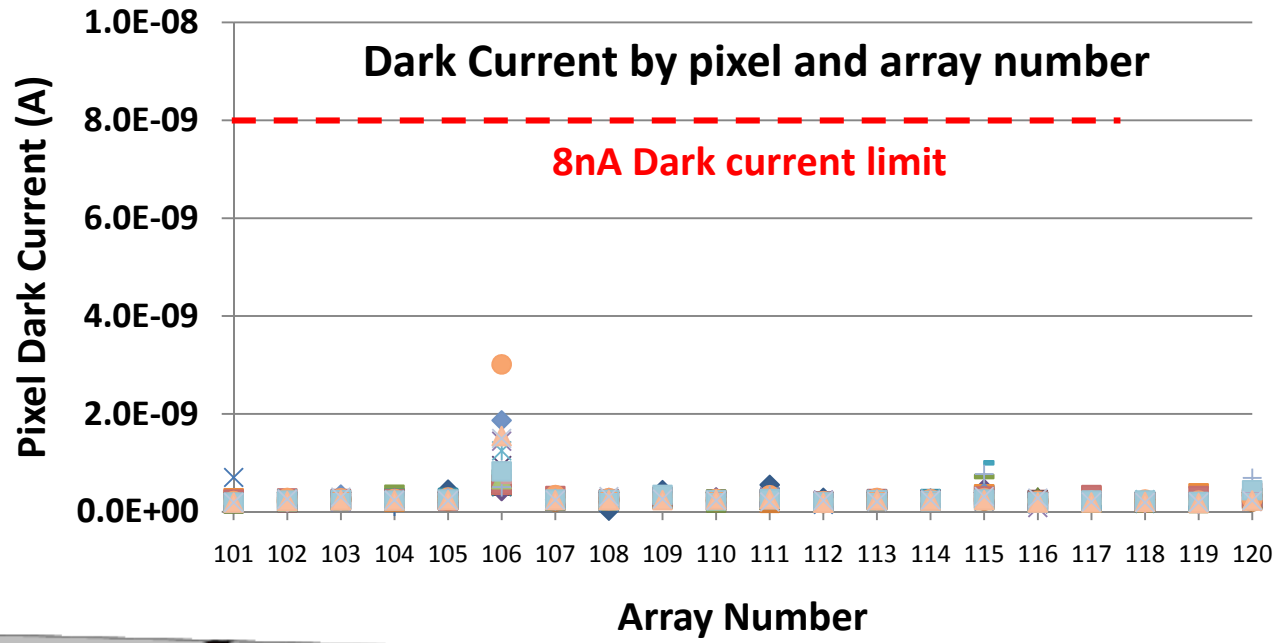
Full Height Prototype ready for assembly at CDF building



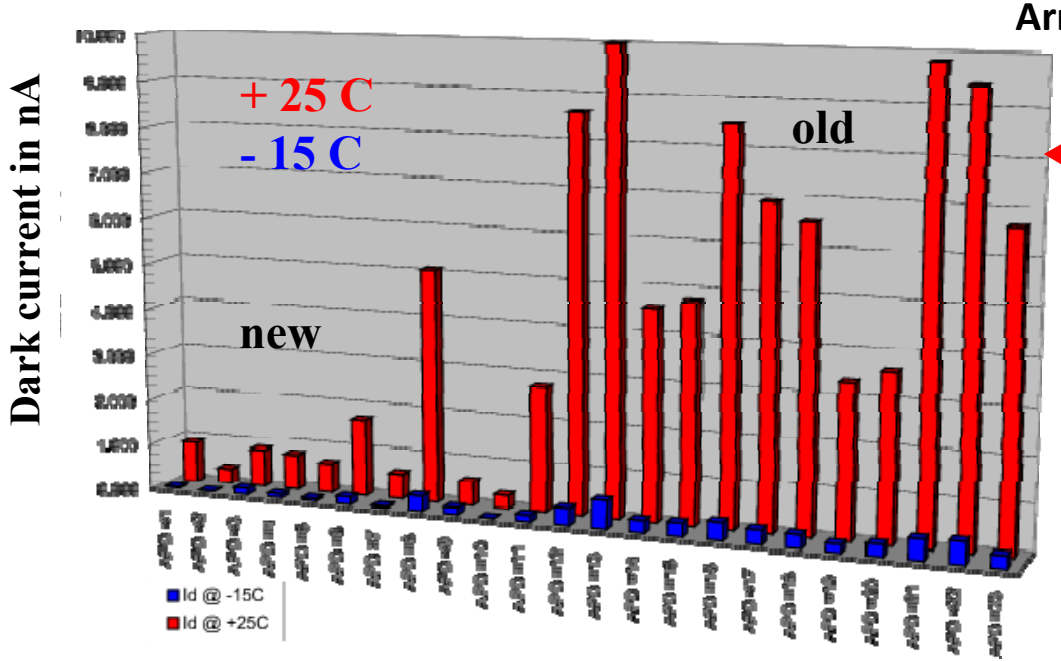
Photodetectors – Avalanche Photodiode

Hamamatsu APD





CalTech, Minnesota



← **8nA Dark current limit**

Operating temperature 15 C cooled by TEC

Last 20 APDs more than meet specs

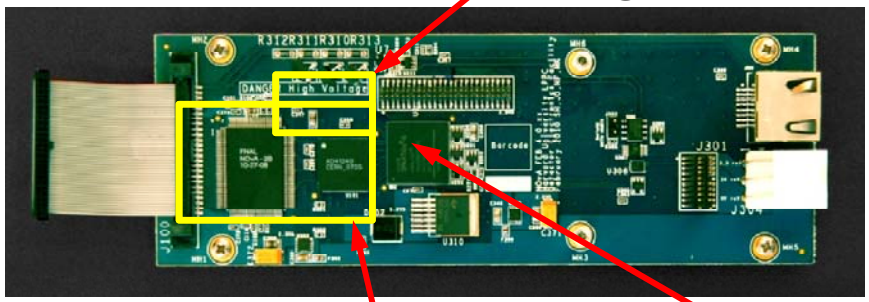
NDOS APDs Aug 2010

Electronics and DAQ

Mounted on module – 32 channels
~375 ns double pulse discrimination
~10 ns resolution
NDOS FEBs August 2010

Front End Board

HV Regulator



Smaller analog and ADC section
Shorter signal paths

Smaller, cheaper FPGA

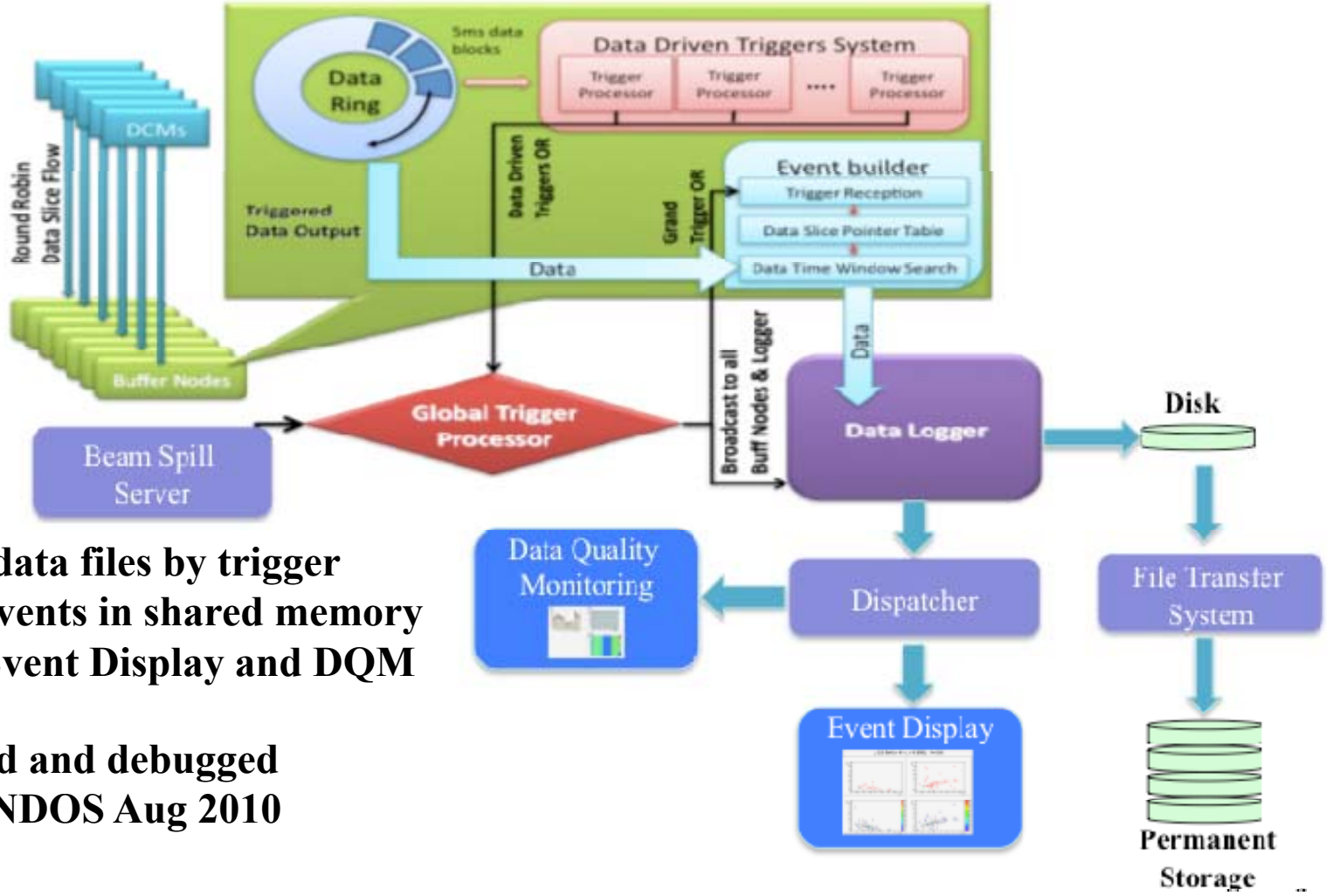
Data Concentrators for NDOS built and being tested with FEB

Timing Distribution units for NDOS being built tested

All DAQ electronics & computers in hand for NDOS

Harvard, Caltech, Fermilab

DAQ Software



Writes out data files by trigger type, puts events in shared memory for online Event Display and DQM

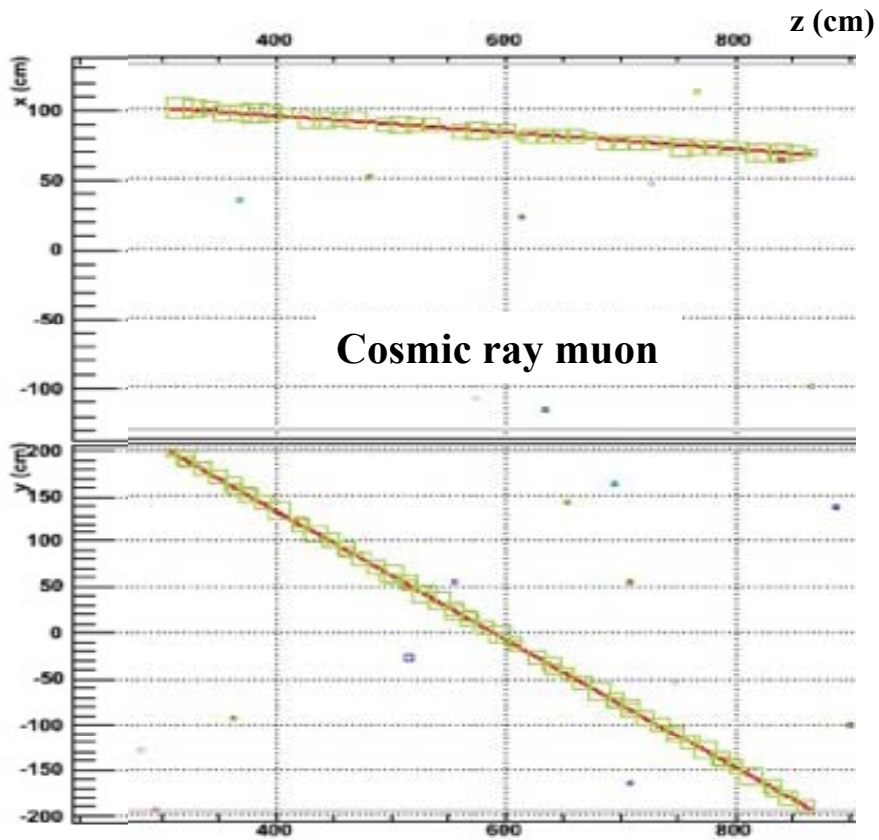
Being tested and debugged
Ready for NDOS Aug 2010

Fermilab, Minnesota

Calibration Software

Cosmic ray and NDOS events

- **Muon pulse height (dE/dx)**
- **Muon track length**
- **Stopping muons**
- **π^0 reconstruction**



NDOS evts/yr	$\nu_\mu + \bar{\nu}_\mu$	$\nu_e + \bar{\nu}_e$
CC Events (1.6-2.4 GeV)	6700 (2300)	320
Quasielastic CC (1.6-2.4 GeV)	3400 (690)	160
NC Events	3000	

Increase NUMI Beam to 700 kW

	NuMI Achieved	NuMI Design	NOνA
Beam Power (kW)	370 (~hour) 325 (one day)	400	700
ν Energy Spectrum	Low Energy	Low Energy	Medium Energy
Cycle time (s)	2.2	1.87	1.33
Intensity (ppp)	4.4×10^{13}	4.0×10^{13}	4.9×10^{13}
Spot Size (mm)	1.1	1.0	1.3

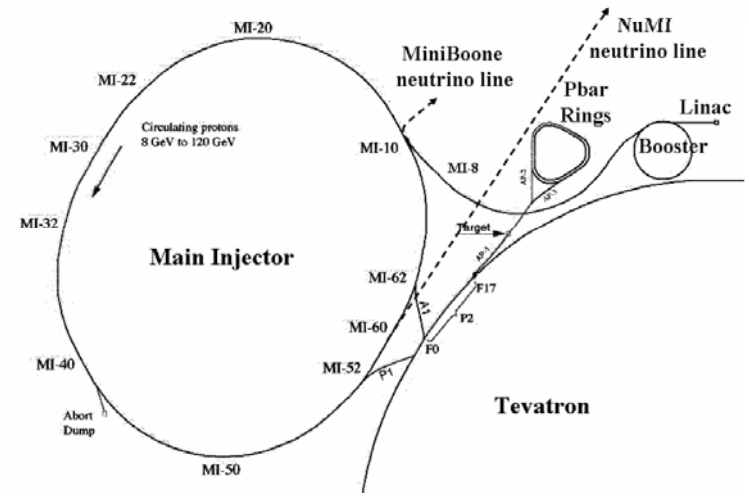
Only 10-20 % increase in per pulse intensity

Stresses mitigated by larger spot size

Most of power increase from faster cycle time

NUMI Beam to 700 kW

- Changes to the FNAL Accelerator complex to
  - Recycler from pbar to proton ring
    - Injection and extraction lines – need bigger aperture
    - Associated kickers and instrumentation
    - 53 MHz RF – for slip stacking
  - Shorten MI cycle to 1.33 seconds
    - RF upgrades
    - Power Supply upgrades
  - NuMI target station to 700 kW
    - Target
    - Horns
- On course for shutdown Mar 2012
  - Changeover shutdown: 6 Dec 2011
    - 53 MHz RF task critical path
  - Installation shutdown Mar 2012 - Feb 2013

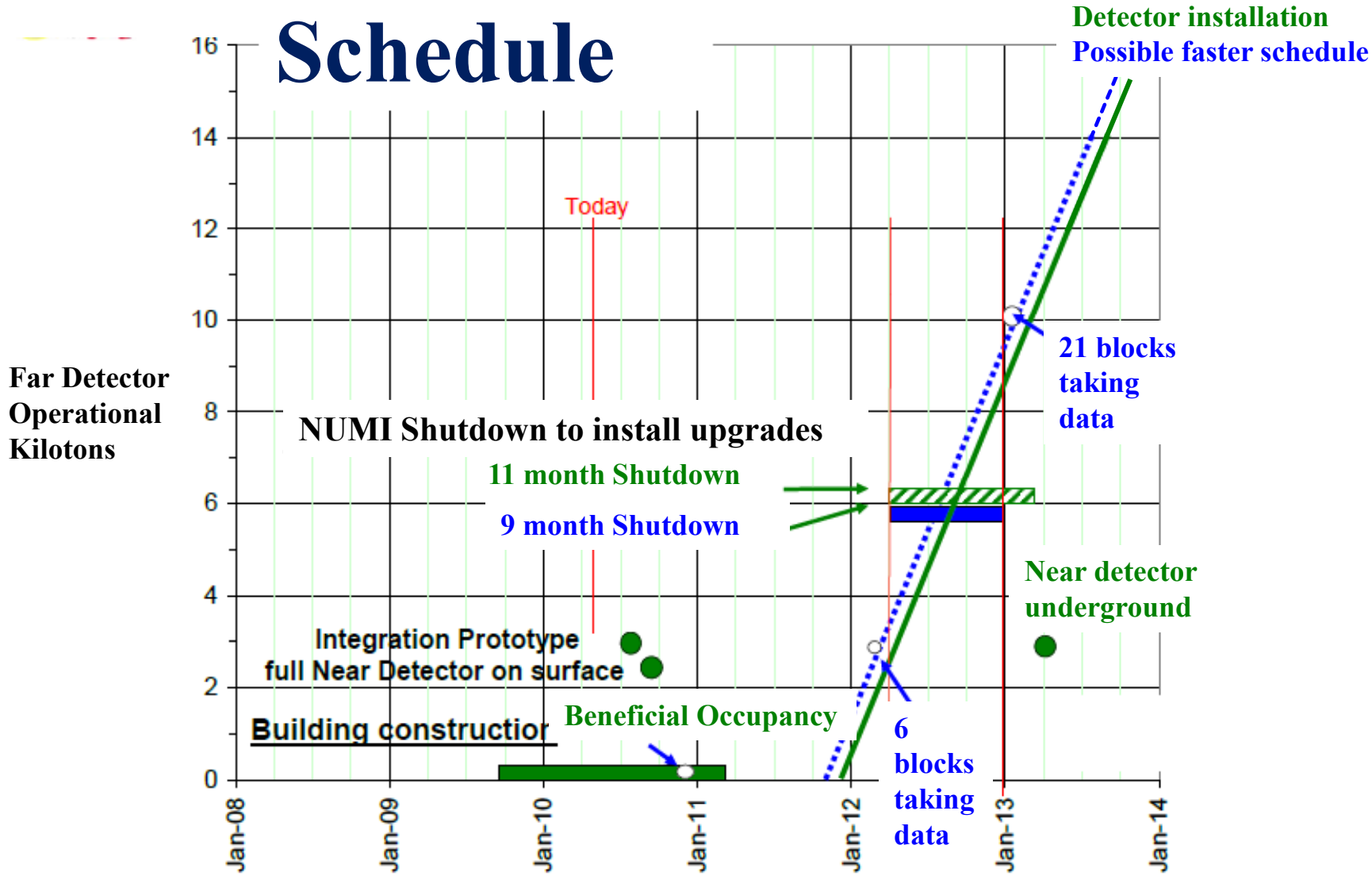


Fermilab

Schedule

NDOS operational	Winter 2010
Far detector building complete	Winter 2010
Start of far detector assembly	Fall 2011
Start of long shutdown for NuMI upgrades (determined by Collider run)	Fall 2011
First 2.5 kT operational	Winter 2011/12
Full far detector operational	Spring 2013

Schedule


Detector installation
Possible faster schedule
Far Detector
Operational
Kilotons
16
14
12
10
8
6
4
2
0
Today
NUMI Shutdown to install upgrades
11 month Shutdown
9 month Shutdown
21 blocks
taking
data
Near detector
underground
Integration Prototype
full Near Detector on surface
Building constructior
Beneficial Occupancy
6
blocks
taking
data
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14