NOνA Project Overview

John Cooper
Project Manager

November 6, 2008

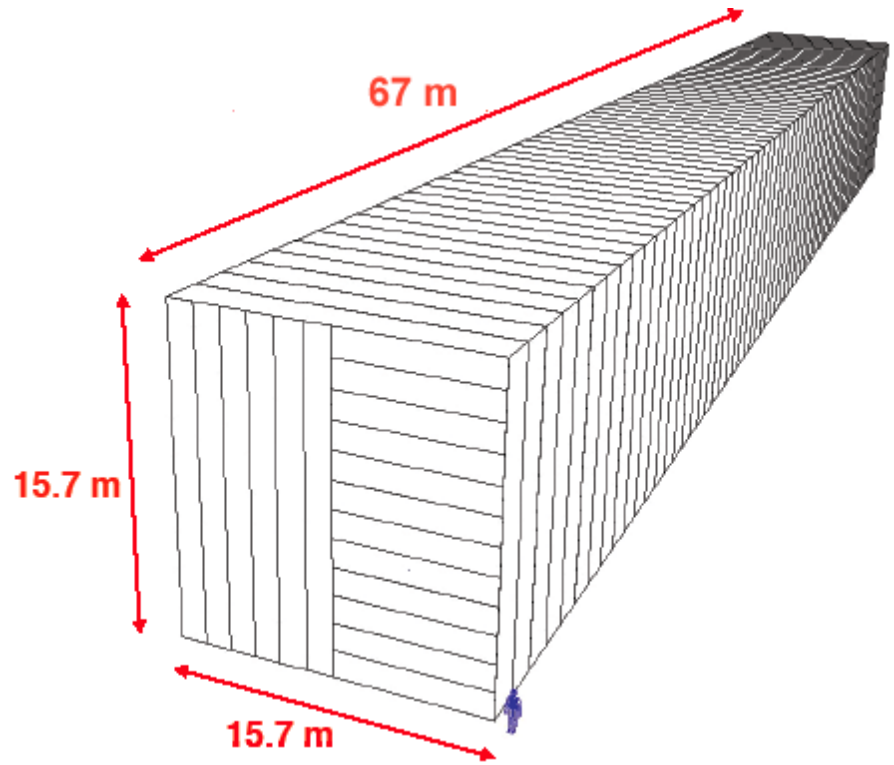
Project Overview

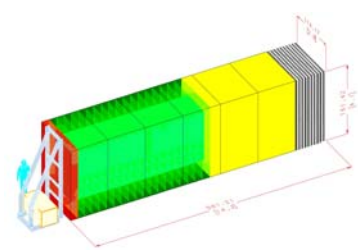
- **NOνA** = **N**uMI **O**ff-Axis **ν**$_e$ **A**ppearance
  - and **NuMI = Neu**trinos at the **M**ain **I**njector
- We are looking for muon neutrinos changing (oscillating) to electron neutrinos
  - Theory describes this by a parameter = "$\sin^2(2\ \theta_{13})$"
- We are looking for 2 GeV muon neutrinos to oscillate into electron neutrinos over a distance of 810 km from Fermilab
  - Off-Axis by 0.25º gets us a 2 GeV beam
  - The oscillation peaks at this L/E (810 km / 2 GeV), related to neutrino masses
    - The fact that neutrinos have any mass at all is a very new discovery
  - The neutrinos go underground from Fermilab to Minnesota
    - OK since neutrinos don't interact often with matter.
- We need:
  - A Far Detector (near the US/Canada border) to discriminate between the two types of neutrino interactions.
    - And it has to be big to see any events at all since neutrinos don't interact often with matter
    - This is a greenfield site, so building a detector hall is a big part of the project
  - A Near Detector at Fermilab must measure the neutrino components in the NuMI beam before any oscillations occur
    - It is much closer to the beam origin and sees a larger rate, therefore it can be small
  - All the beam we can get on the NuMI target
    - More beam gives more events
    - This requires an upgrade to the Fermilab accelerator complex

NOvA and θ_{13}

(ν_μ from NuMI oscillate to ν_e)

- Baseline
  - as seen 810 km away Northern Minnesota
  - New building
- Beam
  - 700 kW or 36 x 10^{20} protons / 6 yrs
- Far Detector
  - 930 planes of liquid scintillator contained in PVC cells, glued together for a total mass of 14,000 metric tons (14 kilotons).
  - Looking for a 15 to 100 event signal
  - Backgrounds (~22 events) are <u>important</u>
- Near Detector
  - Small new cavern at Fermilab, 300 ft underground
  - 215 tons made with the same technology
  - tells us the beam composition <u>before</u> oscillations (about half the background is ν_e in the beam)





NOvA Project History

- **November 28, 2005 DOE CD-0 approved**
- **April 4, 2006 DOE CD-1 Review to validate conceptual design & cost estimate.**
  - Project presented $ 197–256 M cost range for 25 kiloton detector with best estimate at $247M.
  - Results: Overall, the committee judged that the project is ready for CD-1. the Conceptual Design Report is complete and comprehensive. The cost and schedule ranges are appropriate.
- **December 20, 2006 OMB instructs DOE to combine NOvA detector & "Proton Plan 2"**
  - New TPC set at $ 260 M by Jan 1.(!)
  - Took several months for projects to be combined into one team and one schedule
- **May 11, 2007 CD-1 approved by Ray Orbach**
  - Cost range of $ 244 – 293 M for a 20 kiloton detector, now includes Accelerator part
  - TPC guidance set at $ 260 M, "best case earned contingency to allow for 20 kilotons"
  - Phased CD-3a / 3b planed, CD-4 in FY13
- **June 19, 2007 DOE-FSO / Fermilab Directorate Joint Review of NOvA EVMS**
  - Results: overall consensus is that the NOvA project has a considerable amount of the performance management system already in place, and is only lacking a few products or further development of existing materials.

NOvA Project History continued

- **October 23-25, 2007 DOE CD-2/3a Review (IPR)**
  - Integral cost and year by year obligation profile matched funding profile ($260M TPC)
  - Results: Main conclusion of the review was that the project was ready for CD-2 but needed additional flexibility either in scope or cost.
    - CD-3a list of critical path and long leadtime items endorsed.
  - Discussions with OHEP resulted in a new cap of $ 270 M and an agreement to write the PEP for a 14 kt base scope but leave Open Plan RLS at 15 kt.
- **November 26-30, 2007 DOE OECM CD-2 (EIR)**
  - Reviewed the same RLS and cost as the IPR review in October ($ 260 M, 15 kt)
  - Results: Overall conclusion is that the project can be successfully executed and the performance baseline validated once the project team resolves the 5 major findings and has an acceptable plan in progress to resolve the other 18 findings.
    - 5 major findings resolved by December 15, 2007.

- **Scheduled, then cancelled: Dec 19, 2007 DOE CD-2 ESAAB**
  - **FY08 Omnibus Bill: "zero for NOvA"**
  - **January, 2008: shutdown of project**
    - **Fermilab people assigned to other tasks**

NOvA Project History continued

- **February, 2008: OHEP asks us to re-plan for FY09 start**
  - President's FY09 budget has NOvA at $ 37 M, New funding profile from OHEP
  - TPC increased to $ 278 M to include one more year of escalation
  - Project assumes a restart on Feb 1, 2009 to allow for a CR in FY09

- **April 30 Lehman CD-2 mini-Review**
  - Results: Overall, it was judged that the project is ready for CD-2. The project has revised the project cost and schedule following being zeroed out in the FY 2008 budget.
- **June-Aug Interactions with EIR, Evidence Files, CD-2 mini-Review**
  - Project provided Evidence Files for 5 major findings and 11 findings
  - August 6 Out-Brief Result: The project team's response to the CAP recommendations was generally satisfactory, and the resulting documents were updated appropriately. The revised project planning and documentation is sufficient for CD-2, Approve Performance Baseline.

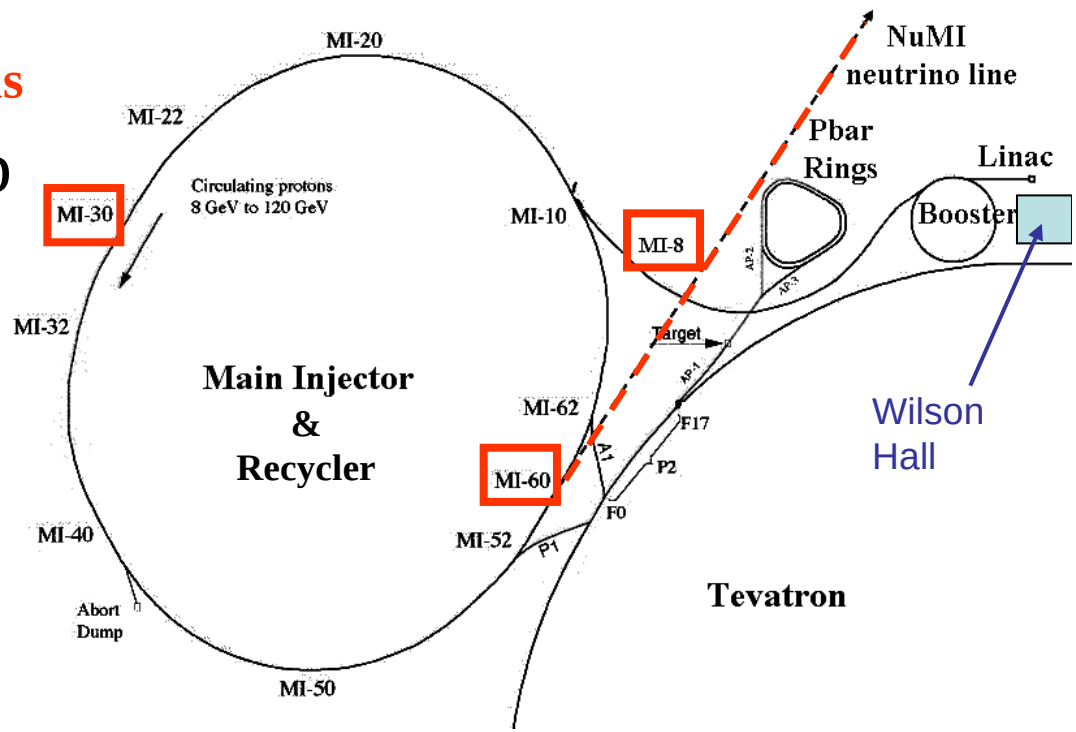
NOvA Project History continued

- **July 1, 2008 President signs Supplementary Appropriations Bill**
  - July 3 this results in $ 9.5 M for a NOvA restart
  - Funds in August fin plan to Fermilab ($9.234 M after SBIR tax)
  - We agree with OHEP to attempt restart by advancing our Feb 1, 2009 scheduled items to Sept 1, 2008
    - Restart proves difficult since personnel were scattered to other projects in the interim
    - Got to about 50% strength during Sept-Oct
    - Still not back to full strength
- **August 19, 2008 ESAAB for CD-2**
  - Board recommends approval
- **September 15, 2008 CD-2 approved by Ray Orbach**
- **October 1, 2008 FY09 Continuing Resolution begins**
  - NOvA gets $ 11.5 M during this 5 month CR ($3M Coop Agree, $8.5M Fermilab)
  - Combined with the carryover from FY08 Supplementary, we have $ 19.4 M
  - We intend to advance the Feb 1, 2009 tasks as much as possible and not adjust the schedule again until the FY09 final overall budget is known (March?). Probably adjust for our CD-3b Review sometime in spring/summer
- **October 24, 2008 CD-3a approved by Dennis Kovar**
  - $ 19 M of items for NOvA (but limited during CR to ~$8.2M in MIE)

Accelerator and NuMI Upgrades

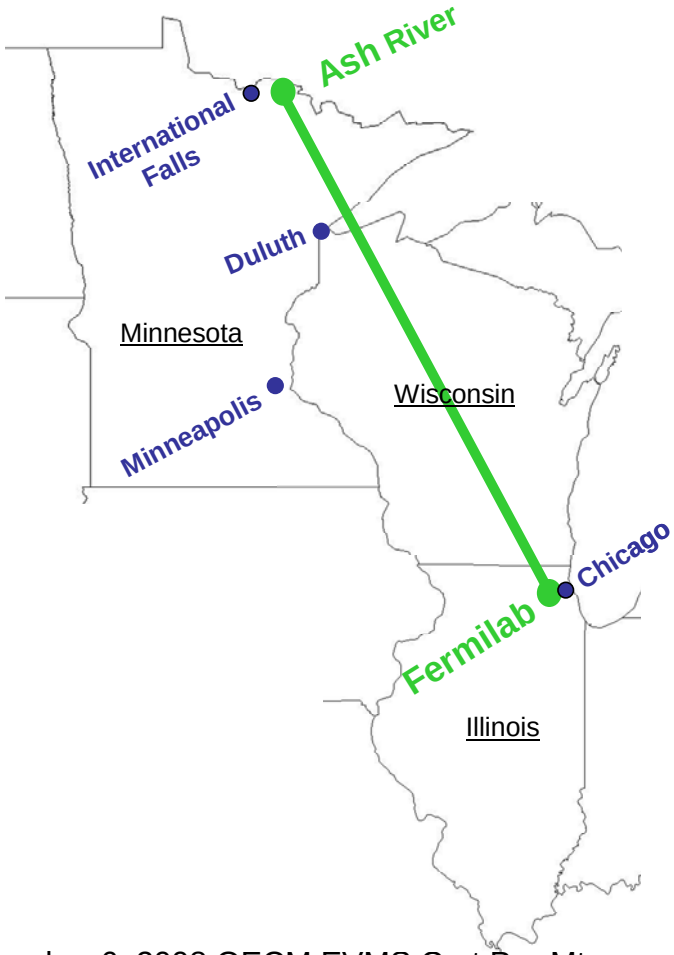
Increase beam power from 400 kW to 700 kW.

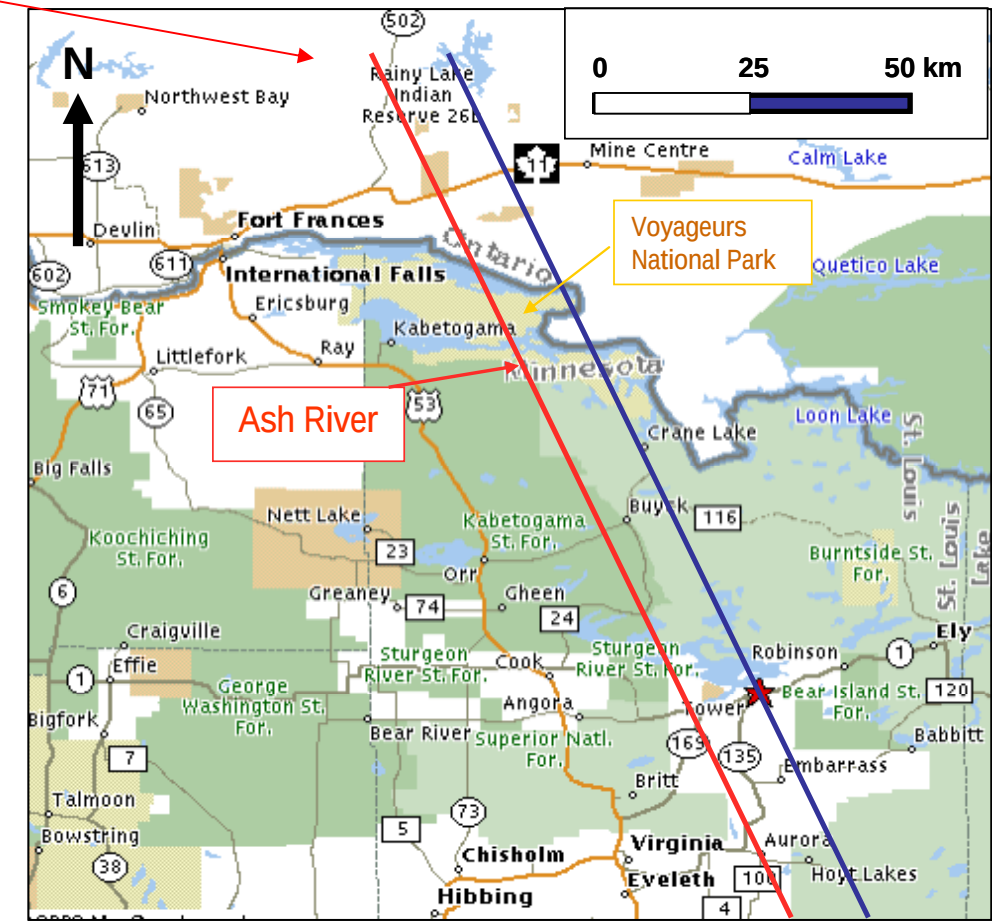
- Recycler at Fermilab
  - gets converted from anti-proton storage ring to a proton storage ring/ pre-injector into the Main Injector once the Tevatron Collider program ends
  - New injection and extraction lines to/from MI.
  - These lines (+ abort) **require 4 new kicker systems**
- Main Injector at Fermilab
  - Cycle time reduced from 2.2 sec to 1.5 sec since stack in Recycler
  - Reduce further to 1.33 seconds with 2 more RF stations at MI-60 204 GeV/sec → 240 GeV/sec
  - Upgrade one quad power supply system for increased ramp rate



Ash River Site

- Farthest site from Fermilab within the US and accessible by road
  - 810.5 km from Fermilab, just 1.5 miles south of Voyageur National Park
  - 11.8 km west (red line) of the NuMI beam (blue line) & 14.6 mrad off-axis.





Far Detector Hall

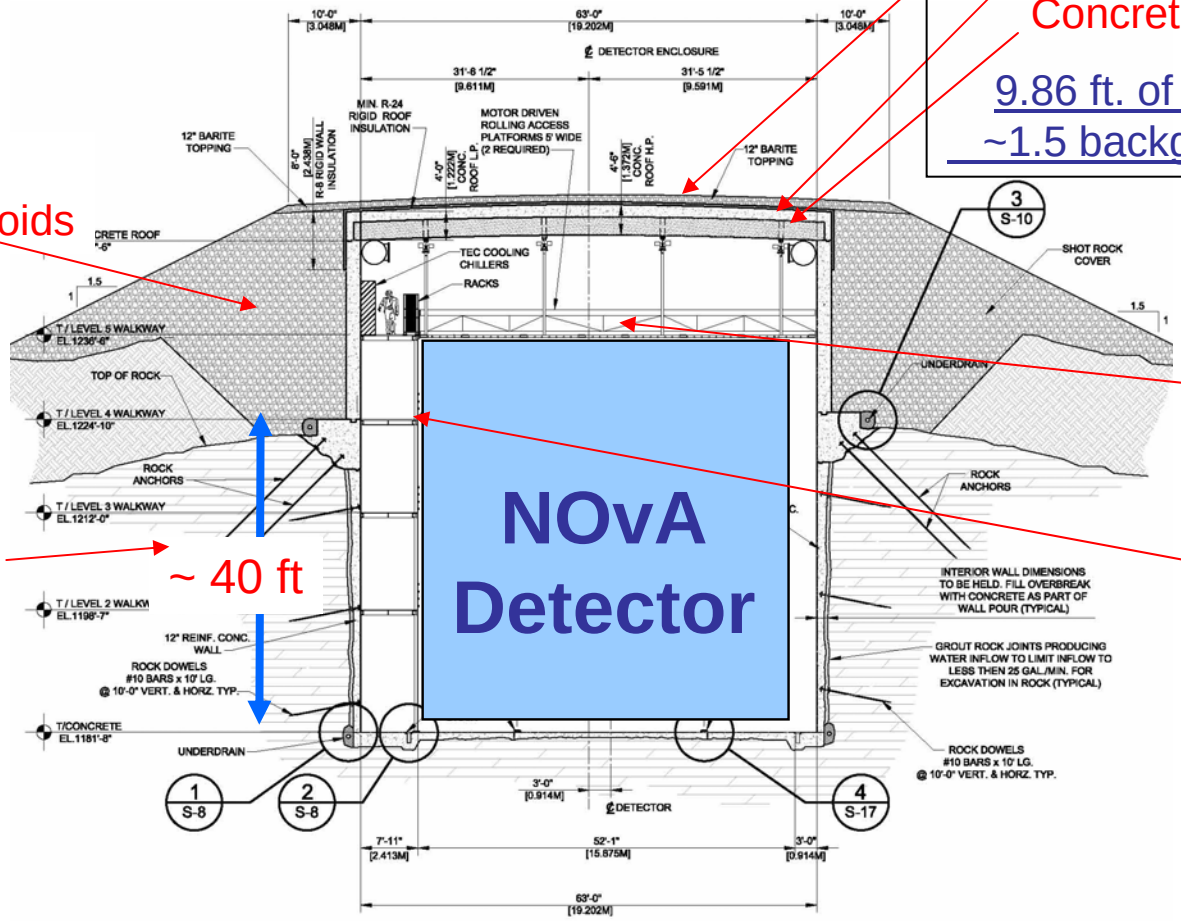
Cross section as seen by the neutrino beam
63 ft wide by 71 ft high by 471 ft into the page

6 inches barite
Cast Concrete
Concrete Planks

9.86 ft. of earth equivalent
~1.5 background event in 6 yrs

Excavated granite with voids

Solid granite (bathtub for 100% secondary containment)

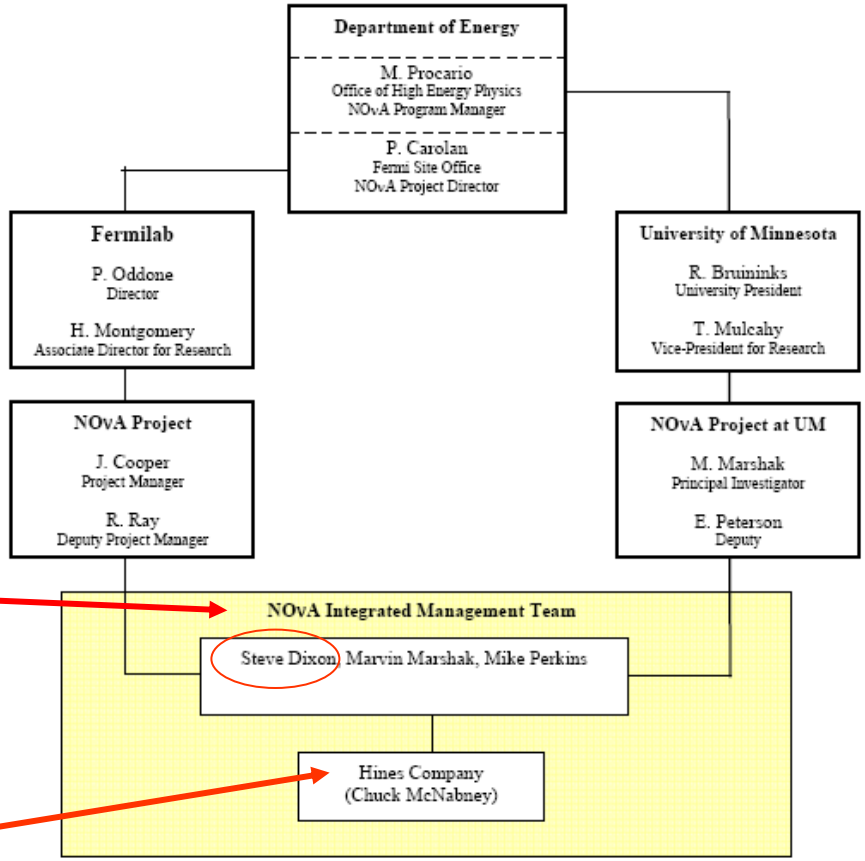


Rolling access bridges

4 catwalks, electronics on top catwalk

Ash River Organizational Wrinkle

- The University of Minnesota received a DOE Cooperative Agreement grant for the building (Marvin Marshak is P.I.)
  - UM acquired the land and easements for the access road
  - UM will own and operate the building
- Official part of the Acquisition Strategy adopted as part of the CD-1 approval on May 11, 2007
  - An MOU between UM and the Fermilab Project are part of the scope of work
- The signed MOU is in place
  - Integrated Construction Team
  - Use UMinn procurement rules, but consensus with Project on larger questions, e.g. AE design firm, major contractors
    - Succeeded on "project management" firm
  - In the MOU, UMinn agreed to and now reports monthly to Project Office
  - Earned Value computation is being done

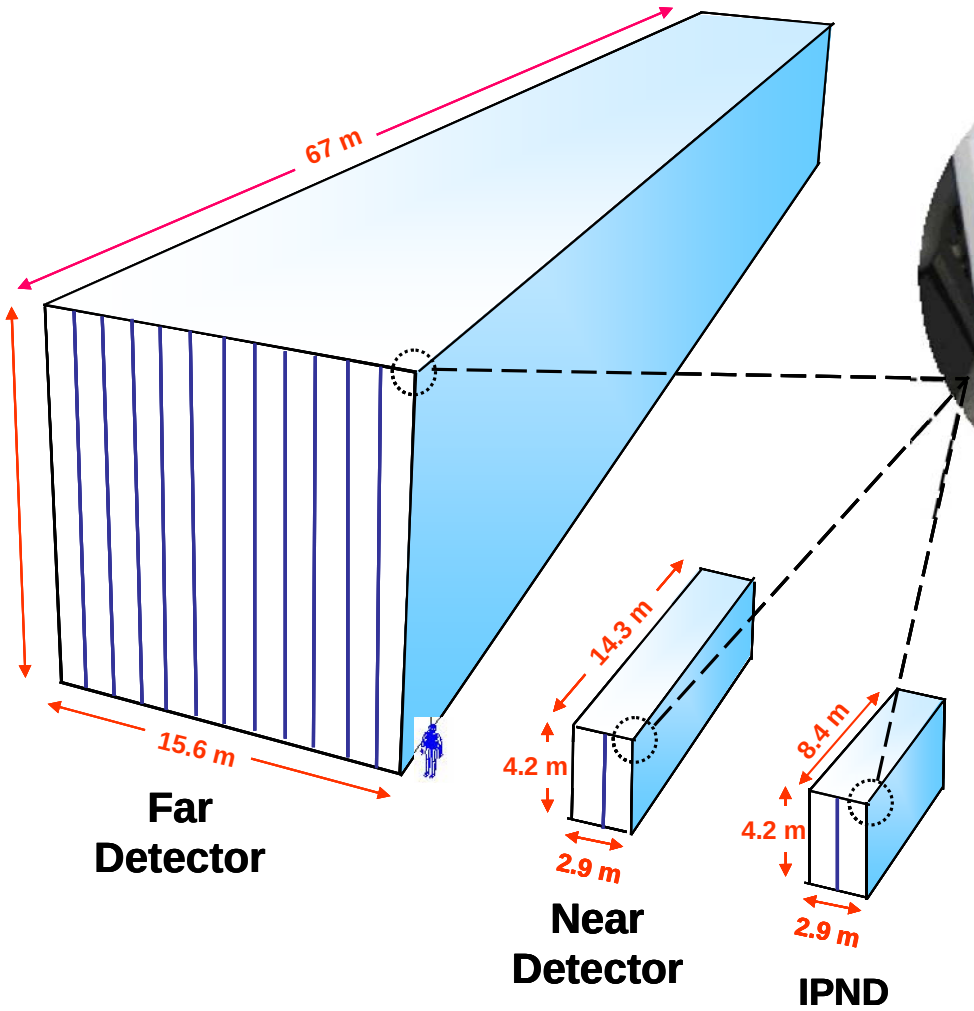


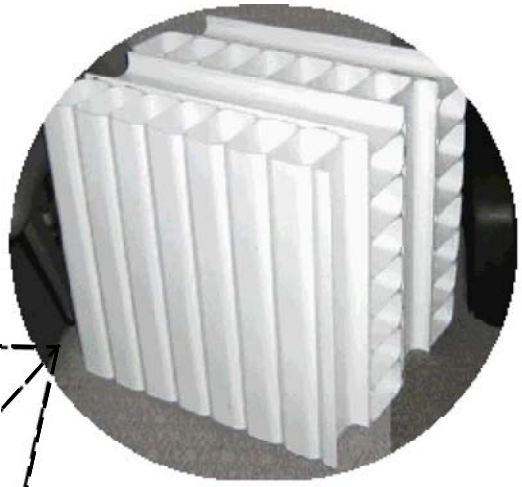
Environmental Assessment Status

- The DOE NEPA Compliance Officer agreed to a final "pre-approval draft" EA on March 26, 2008
- DOE - FSO sent the draft out for public comment on March 27 with comments due by April 30.
  - Three simple comments easily handled.
    - Illinois EPA, "no objections", reminds us of required stormwater permit
    - US Army Corps of Engineers, 3 comments on wetlands area calculations
    - Keweenaw Bay Indian Community (Michigan), "no interests regarding religious or cultural sites documented at this time in the proposed project areas", but wants to be notified if we find any.
- **The FONSI was signed on June 11, 2008**
- We need a USACE Wetlands Permit before any construction.
  - Expect permit within days.

NOvA assembles 3 Detectors

(**Collaboration** among 26 Universities & 2 Laboratories, 180 people)

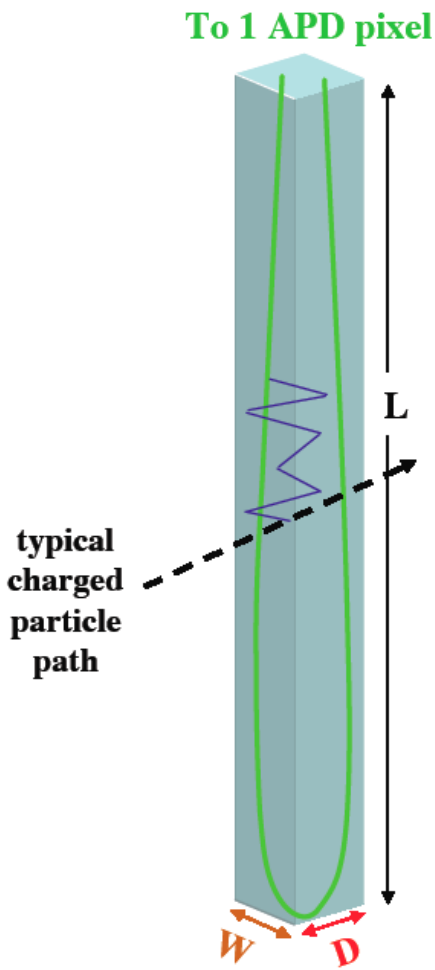




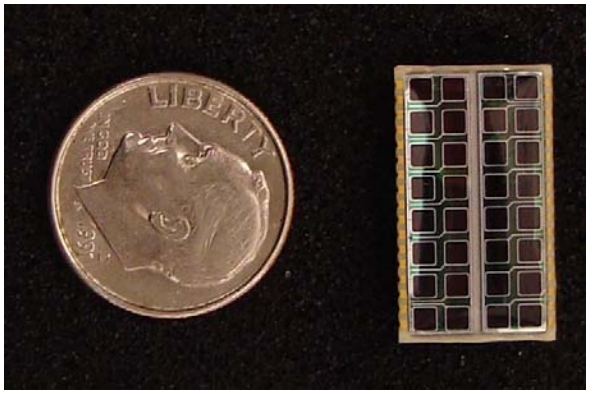
All have successive layers of vertical and horizontal cells bonded together with adhesive

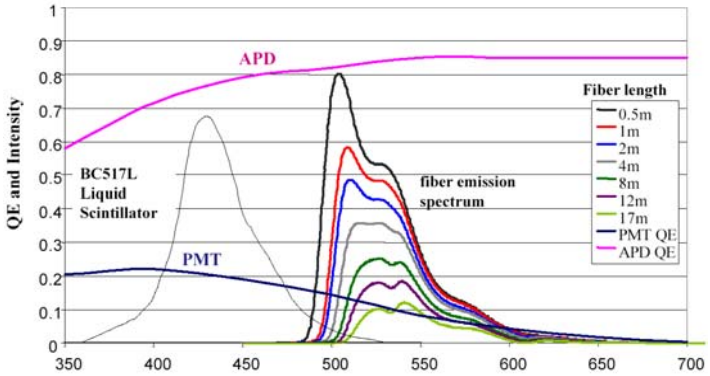
- 14,000 ton Far Detector
  - 12 by 12 extrusion modules
  - 970 layers
- 222 ton Near Detector
  - 2 by 3 extrusion modules
  - 199 layers
- 90 ton Integration Prototype Near Detector (IPND), R&D goal in 2009-10
  - 2 by 3 extrusion modules
  - 124 layers, reuse all in Near Detector

NOνA Basic Detector Element



- Liquid scintillator in a 4 cm wide, 6 cm deep, **15.7 m long**, highly reflective PVC cell.
  - Indiana + Fermilab – scintillator
  - ANL+ Fermilab - PVC
- Light is collected in a U-shaped 0.7 mm dia. wavelength-shifting fiber, both ends of which terminate in one pixel of a 32-pixel avalanche photodiode (APD).
  - Michigan State U – fiber
  - Caltech + Minnesota – APD
- The APD has peak quantum efficiency of 85% @ 525 nm
  - Gain of 100, cooled (-15°C TEC), very low noise amplifier (Fermilab).



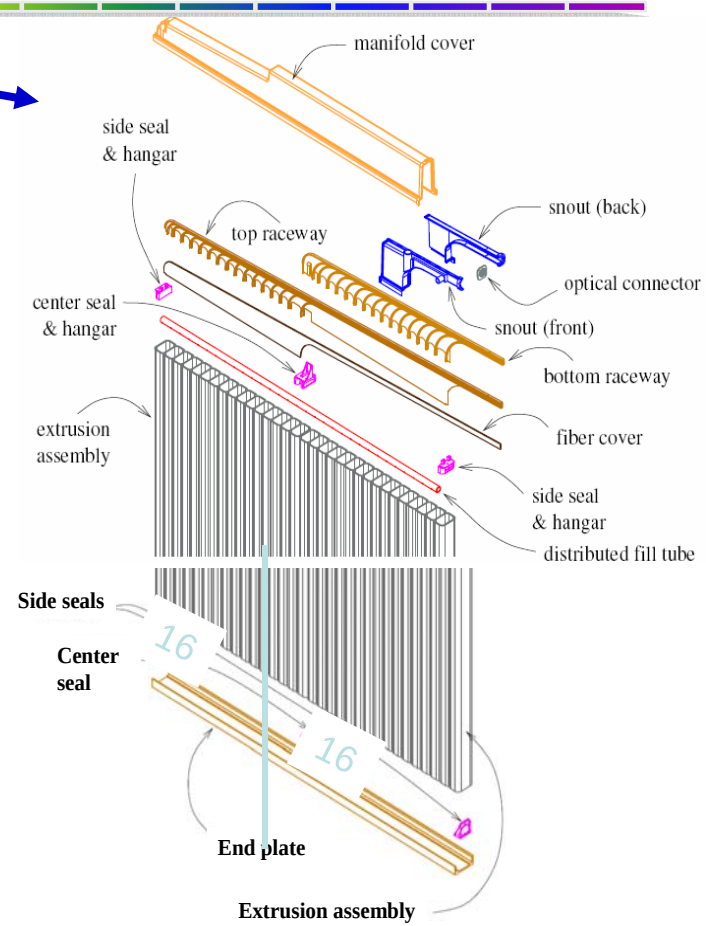


PVC Extrusions (ANL leads)

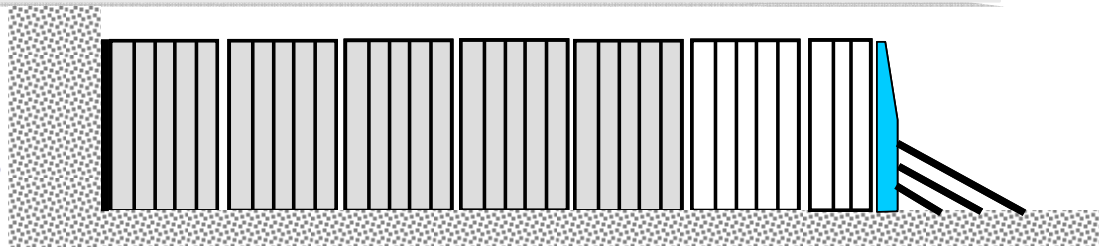
- Custom 16 cell PVC die built
- Custom PVC resin is extruded into 15 m long units.
  - 23 metric tons extruded so far
  - 4.3 kilotons in final detector
  - Different resins, N-27 now final
  - QA/ QC in development on flatness, cell wall thickness, reflectivity
- Not easy to handle and manipulate 15 m long objects!

Extrusion Module details

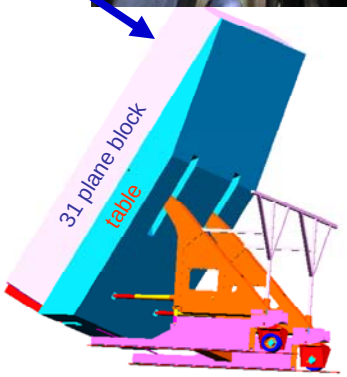
- **Extrusions assembled in to modules with complicated ends – module is primary containment vessel**
  - U of Minnesota, Twin Cities
  - Automation required to assemble 11,160 modules
- **Modules ultimately filled with 4 million gallons of scintillator**
  - Mineral Oil, Pseudocumene, waveshifting powders
  - Indiana University
  - Early R&D blended 5 gallon samples, have now blended 4,500 gallon, intend to use a Toll Blender to blend about 4 million gallons
- **Electronics**
  - Front End Boards (FEB, ~12,000 required, Harvard)
  - Data Control Modules (~ 200 required, Fermilab)
    - Each collect serial data from 64 FEBs
  - Timing / Command (~10 required, Fermilab)



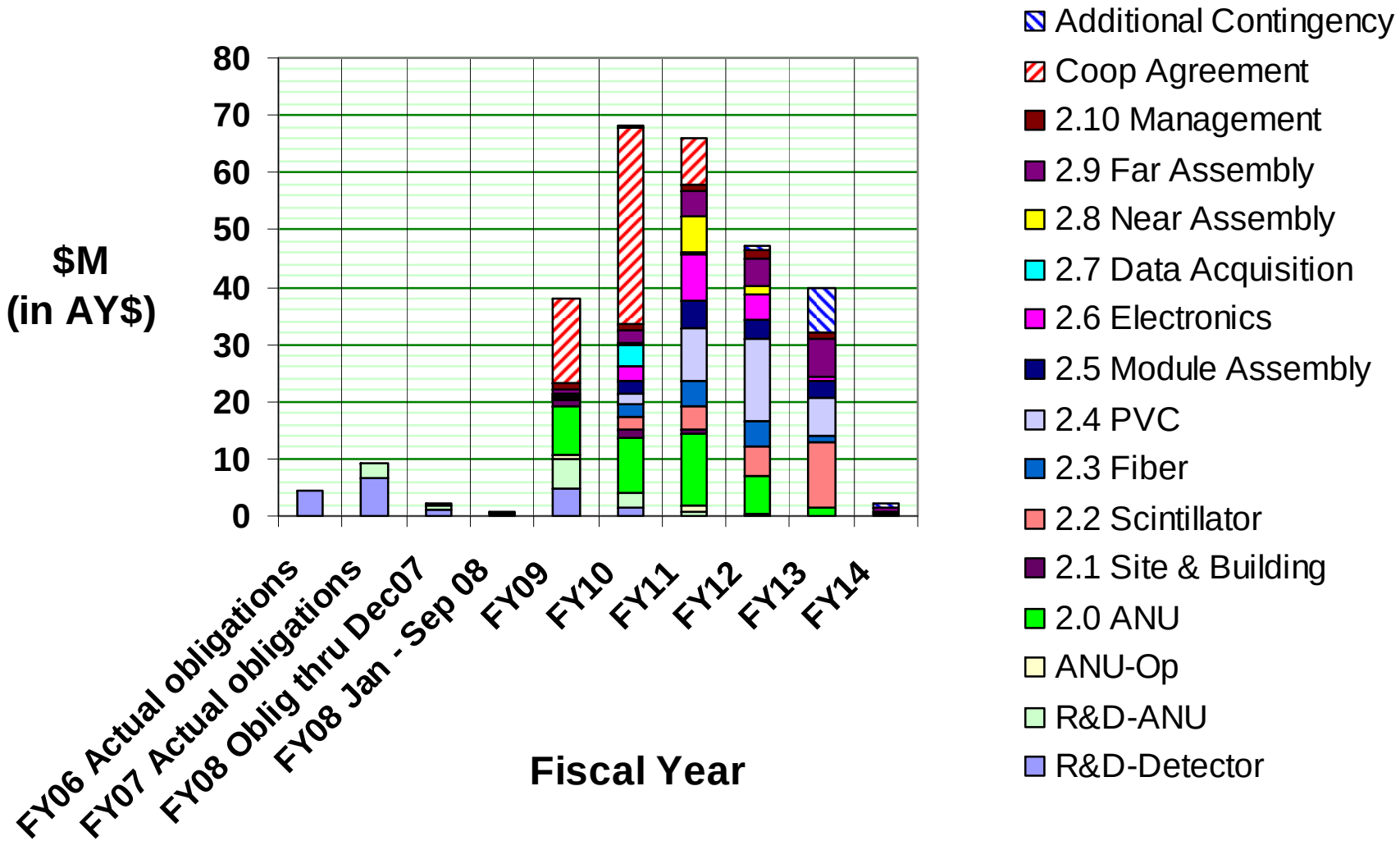
Detector Assembly



- Thirty blocks, each 31 planes
  - each plane with 12 extrusion modules
- Vacuum Lifter
  - Being assembled at ANL
- Adhesive Machine
  - Being assembled at ANL
- Pivoter (Fermilab design)
  - External review complete
- Several structure tests
  - Near Detector Prototype completed
    - Early extrusions, built at ANL, tested with overpressure, compare FEA
  - Full Height Pressure Test w scintillator
    - 1 module at Fermilab, started
  - Full Size Assembly Prototype on floor
    - 8 layers, starting at ANL in January
  - Full Height Assembly Prototype (future)
    - Minnesota modules, glue 1/12th of a 31 plane block at ANL, protoype pivoter at Fermilab in CDF Building



NOvA Baseline Funding Profile



Summary

- **NOvA has a CD-2 baseline with a TPC of $ 278 M**
  - And has CD-3a for a limited $ 19 M set of critical path / long leadtime items
  - Expect a CD-3b Review spring / summer 2009,
    "when final design is complete"
  - Trying to match CD-3b to FRA EVMS Certification by Oct 1, 2009
    - This date is assumed in our baseline schedule, risks are documented

- **NOvA has spent ~ $ 16.8 M through FY08**
- **NOvA has ~ $ 19.4 M of funding authority during the FY09 Continuing Resolution**
- **NOvA is exercising EVMS now**
  - Some parts have been in place since CD-1 (May 07)
  - Some parts are being tweaked now to match the new Fermilab FRA Policy and Procedures.
  - SEE NEXT segment of discussion

BACKUP SLIDES

WBS/OBS

(Work Breakdown Structure / Organizational Breakdown Structure)

J. Cooper, Project Manager
R. Ray, Deputy Project Manager
N. Grossman, Associate Project Manager

- 2.0 **Accelerator & NuMI Upgrades (ANU)** — N Grossman, E. McCluskey, de
- 2.1 **Far Site & Building** — S. Dixon
- 2.2 **Scintillator** — S. Mufson
- 2.3 **Fiber** — C. Bromberg
- 2.4 **PVC Extrusions** — R. Talaga
- 2.5 **PVC Modules** — K. Heller
- 2.6 **Electronics** & 2.7 **Data Acquisition** — L. Mualem
- 2.8 **Near Detector** & 2.9 **Far Detector Assembly** — P. Lukens
- 2.10 **Project Management**

WBS 2.x for the construction project, similar WBS 1.x for R&D/Ops

Project Office Staff:

Dave Pushka, Mechanical Project Engineer
John Oliver, Electronics Project Engineer
Anna Pla-Dalmau, Project Chemist
Suzanne Pasek, Project Financial Officer
Bill Freeman, Project Scheduler
Ken Doman, ANU scheduler
Harry Ferguson, Assistant Project Scheduler

Keith Schuh, ES&H Detector, EA, pSAD
Mike Andrews, ES&H for Accelerator side
Alan Wehmann, websites / document databases
Nancy Grossman, QA oversight
Elaine McCluskey, Configuration Control
Bob Bernstein, Expediter & Document Coord.
Jon Paley, databases

Project Documentation for CD process

NOvA Documents
- Document Database
- CDR
- Proposal

Reference
- P5 report
- NuSAG report
- CD0
- CD1

Director's Mini-Review of the NOvA Project, April 17, 2008

Link to the Directorate Web page for this review

Review Overview Information

- Technical Design Report (TDR)
- Project Parameter Sheets

Other Review Documents

- Key Assumptions [NEW]
- Project Execution Plan (PEP) [still updating]
- Acquisition Strategy
- Project Management Plan (PMP) [still updating]
- Acquisition Plan
- Quality Management Plan (QA)
- Risk Management Plan
  - Risk Summaries (includes high, medium & low) [NEW Management Risks]
- Integrated Safety Managment Program (ISM)
- Security Vulnerability Assessment
- Contingency Analysis Rules
- Configuration Management Plan
  - List of Managed Documents
  - Change Request List [NEW]
  - Change Request Report by Approval Status [NEW]
- Requirements Documents
- Monthly Reports [NEW months added with EVMS reports]
- Fermilab Guidance on Sustainable Buildings
  - NOvA Sustainble Building LEED checklist
  - Correspondence with Univ. of Minnesota on LEED [NEW]
- Design Reviews
  - Consolidated List of Comments with updated status [NEW]
- Value Management/Engineering documents

Other Review Documents (con't)

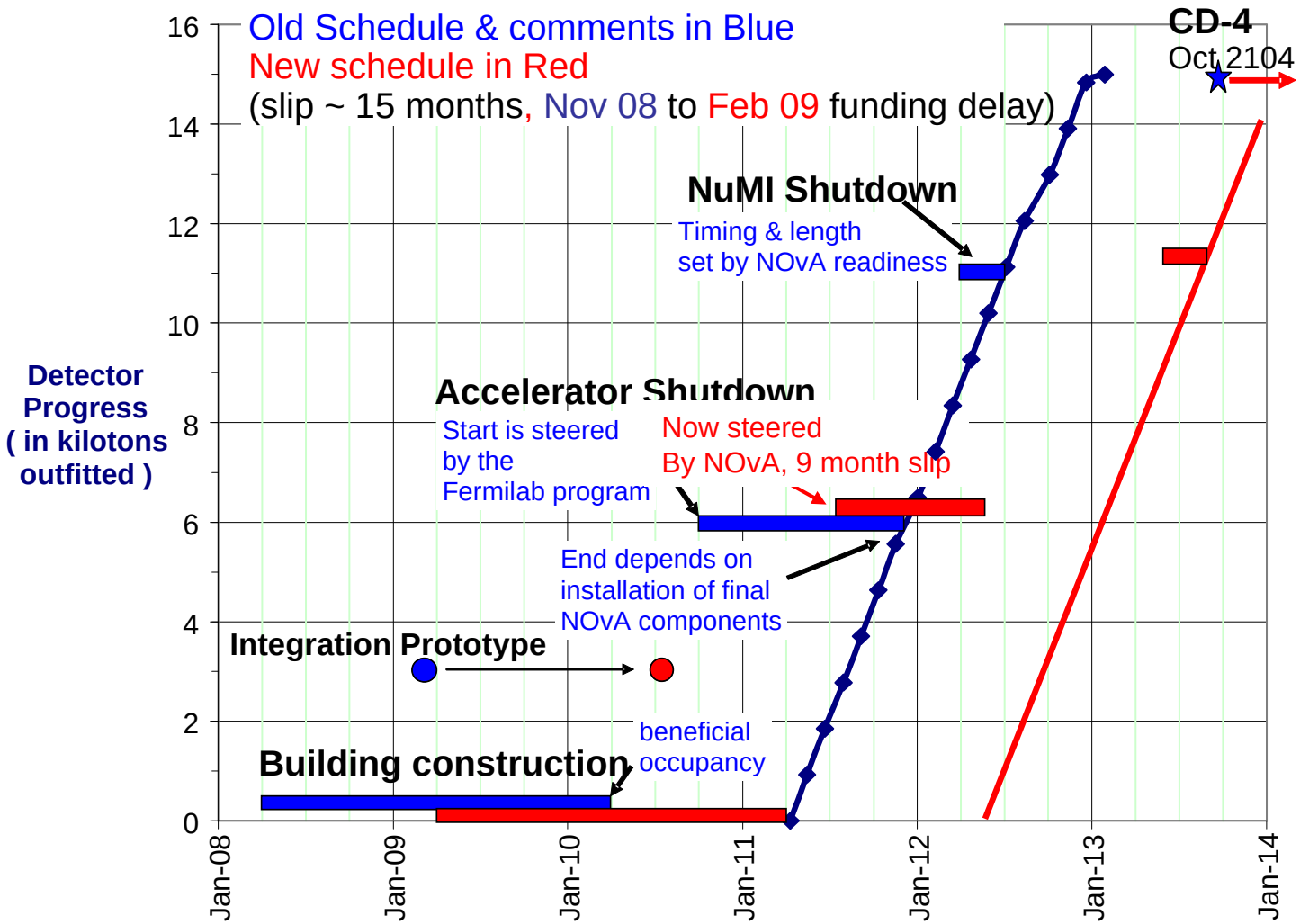
- MOUs [NEW Fermilab Directorate MOU], SOWs and Work Authorizations
- Environmental Assessment (EA) [NEW version submitted for 30 day public comment]
  - Tritium Reference Document
  - Accident Reference Document
- Minnesota EA Worksheet
- Updated Hazard Analysis - Detector [NEW]
- Updated Hazard Analysis - Accelerator
- draft PSAD
- Start-up Test Plan
- Earned Value Management System (EVMS)
  - NOvA specific EVMS
- Project Organization Chart
  - Responsibility Assignment Matrix [NEW]

Cost and Schedule from the RLS

- Guide to the Open Plan Views of the NOvA Schedule
- "Schedule on a page" [still updating]
- Budget and Contingency (R & D) [still updating]
- Budget and Contingency (Construction) [still updating]
- Activity Notes (R & D) [still updating]
- Activity Notes (Construction) [still updating]
- Gantt Chart (R & D) [still updating]
- Gantt Chart (Construction) [still updating]
- Basis of Estimate

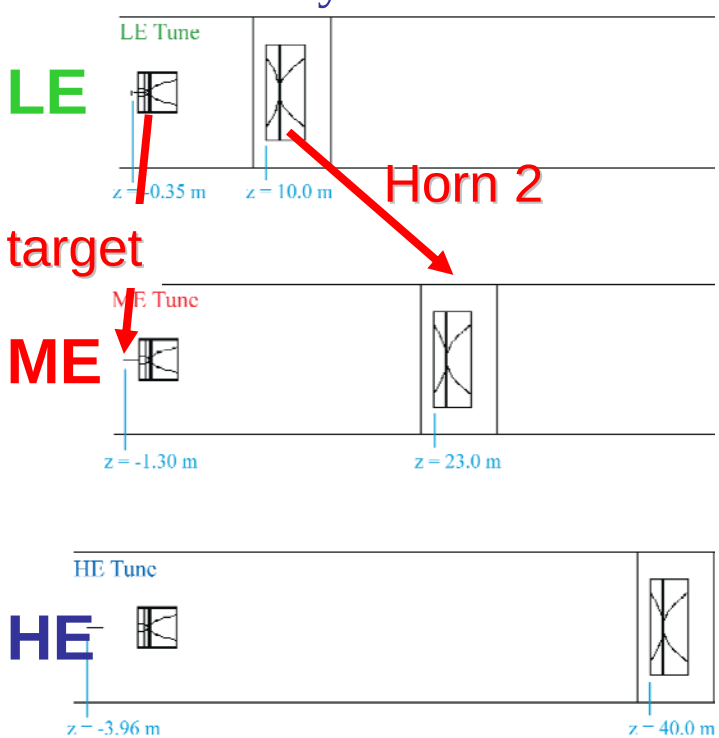
- 45 different types of NOvA documents
- 682 separate NOvA documents (443 are the Basis of Estimate record)
- **~ 7,000 pages of documentation altogether**

Graphic Schedule

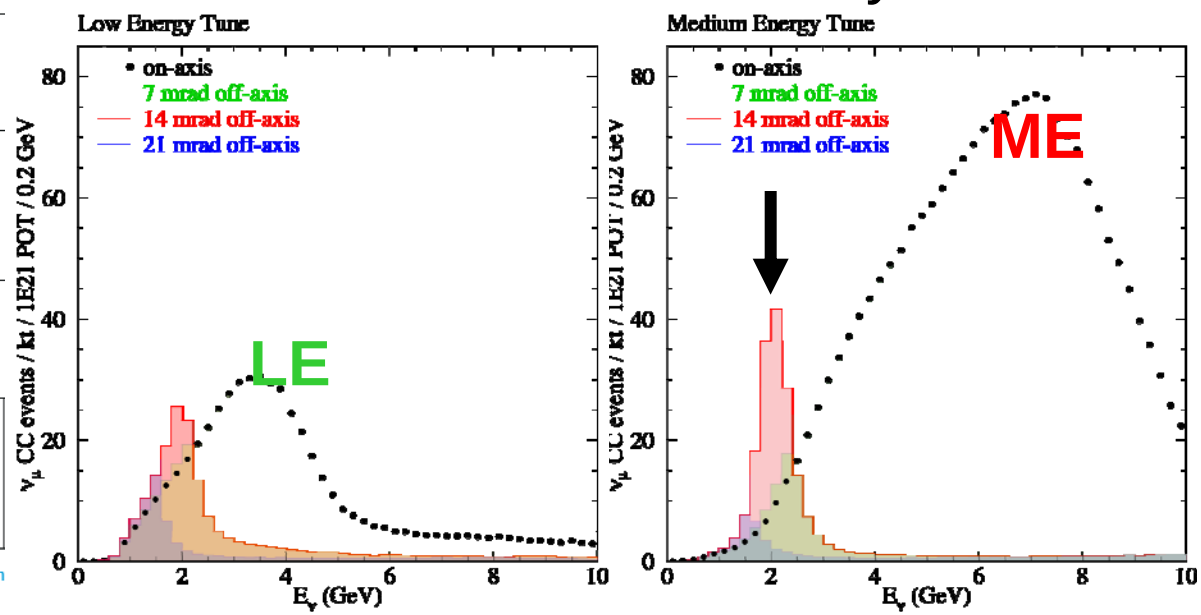


Accelerator and NuMI Upgrades

- NuMI Beamline
  - New Medium Energy (ME) target, upstream from current Low Energy (LE) target
  - Stripline extension so focusing Horn #2 can move to medium energy position
  - Cooling modifications and power supply upgrades to handle the 700 kW and faster cycle time



NOvA is off-axis at 14 mrad for increased 2 GeV ν yield



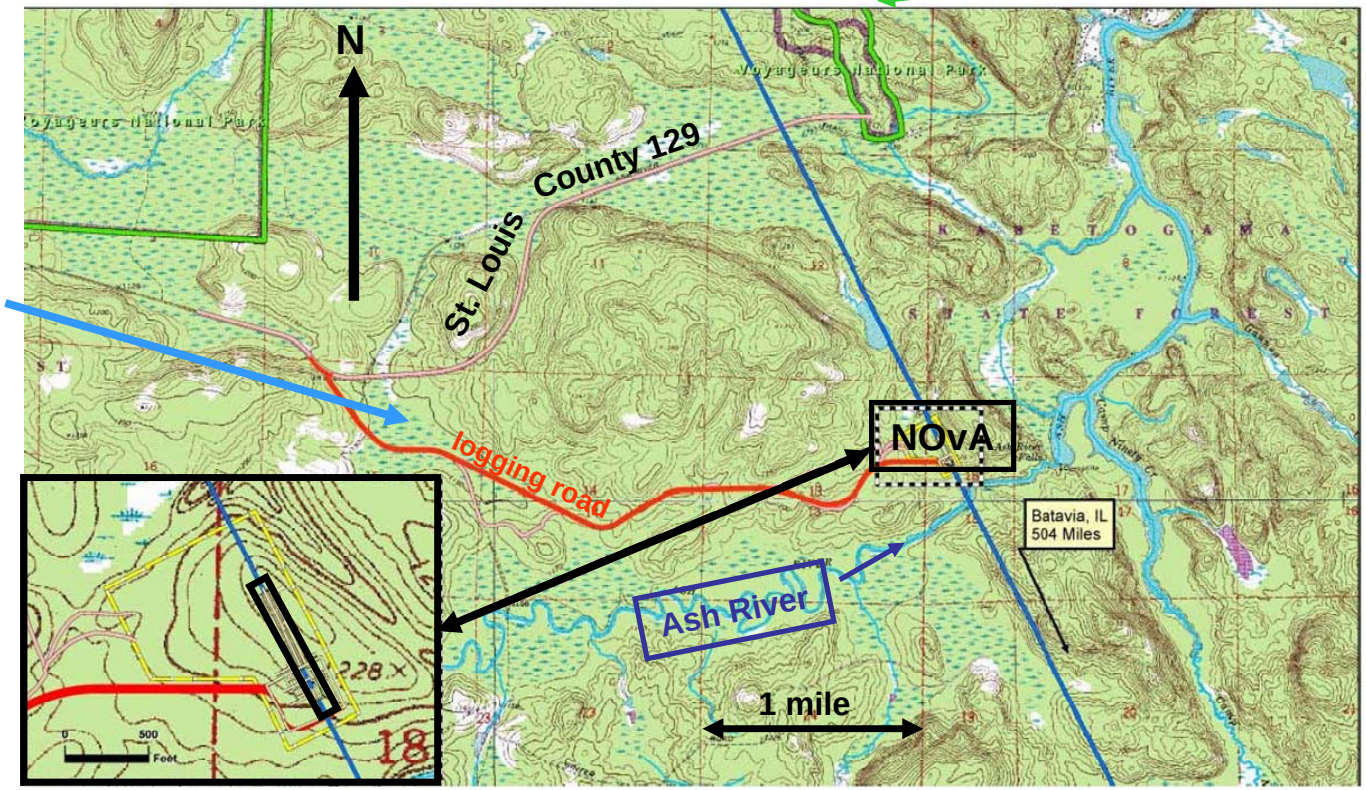
Ash River Site

- The 3.6 mile access road has a complete design and is ready for bid:
  - roadbed, utility corridor,
  - curves straightened, borings done all along the route
  - ~ 40 drawings
  - Need wetlands permit, but for an existing logging road

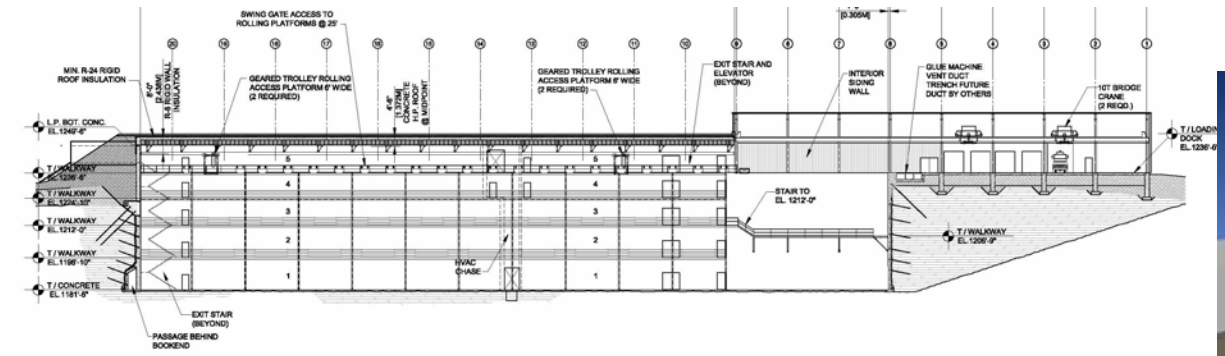
National Park boundaries

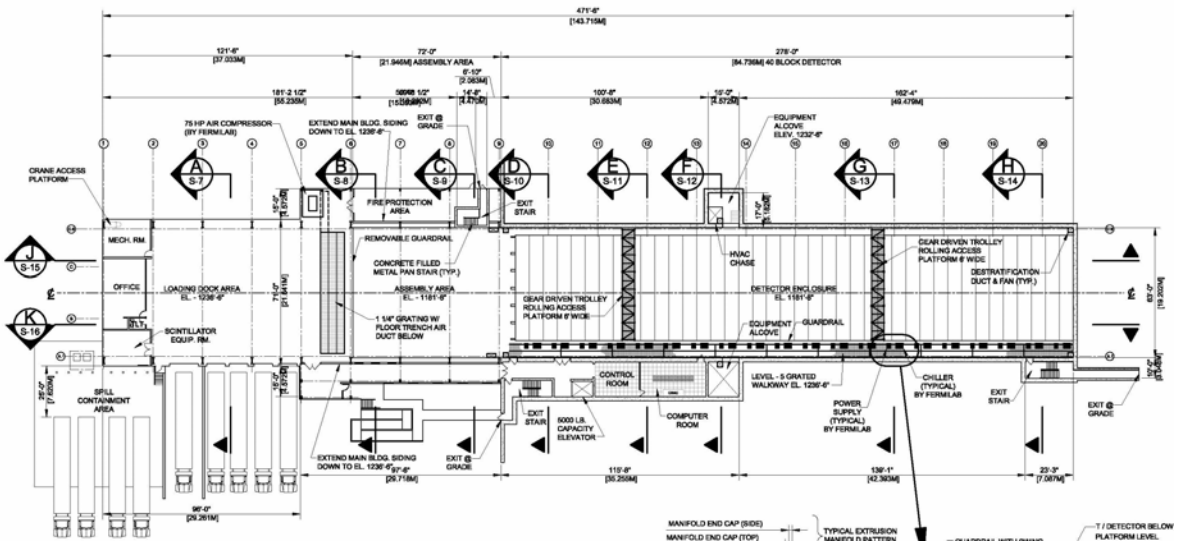
wetlands

NOvA site is on a hill

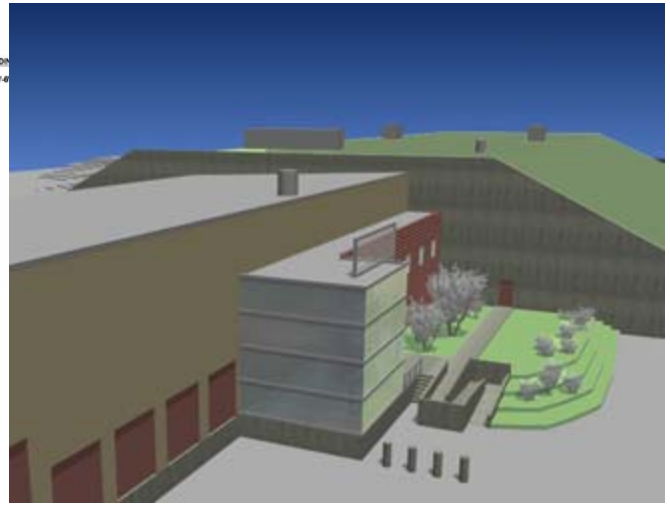


Far Detector Hall





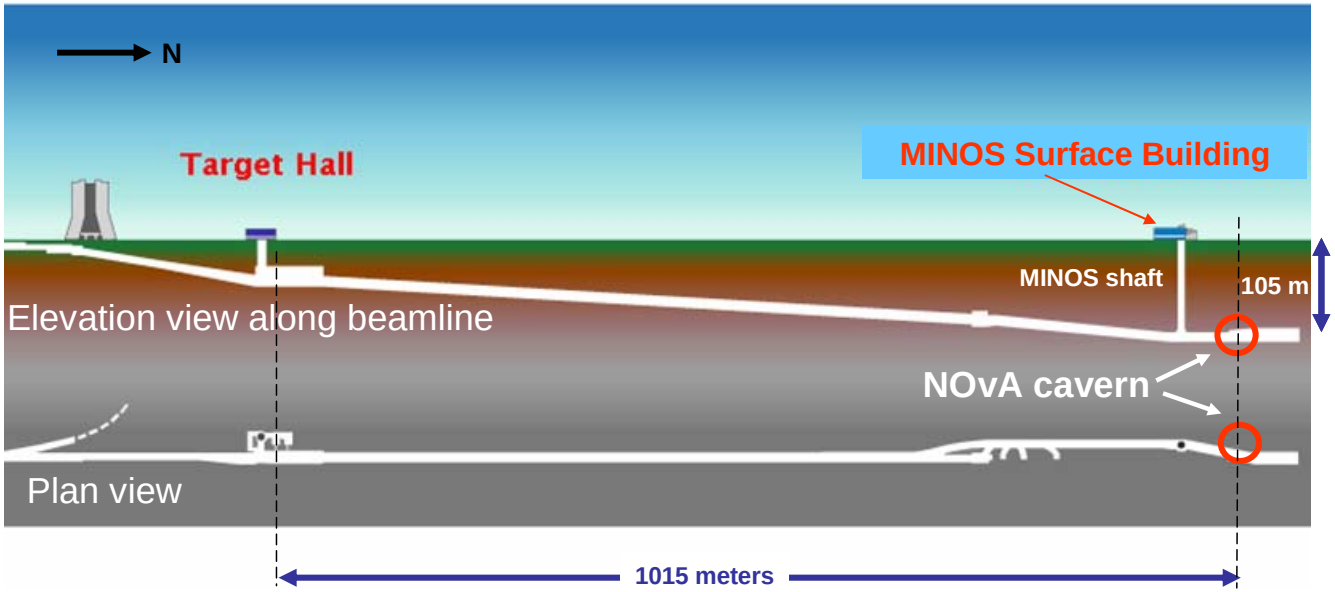
Surface View looking South

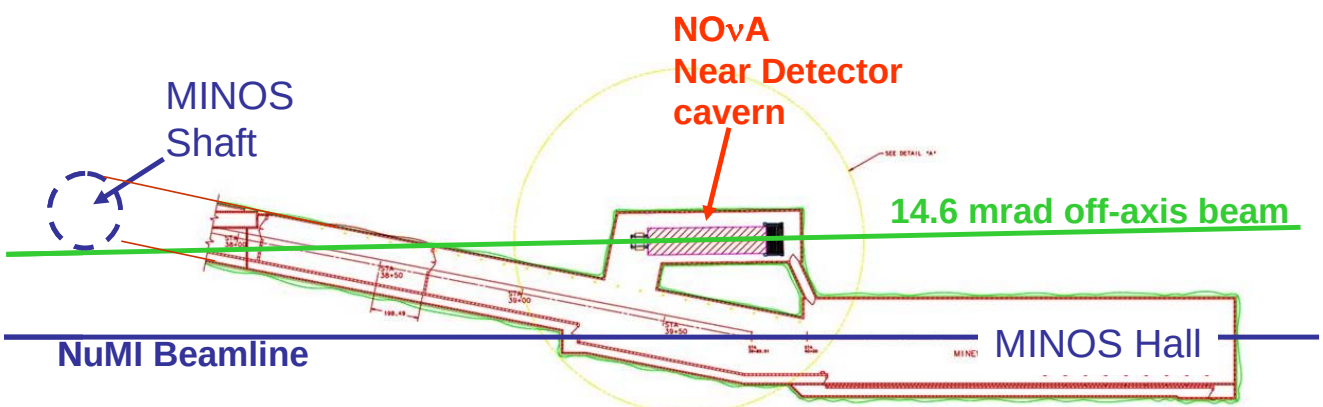


- There is enough room in the building for 18 kt, which can be built if we can preserve half of our contingency.

Near Detector Cavern

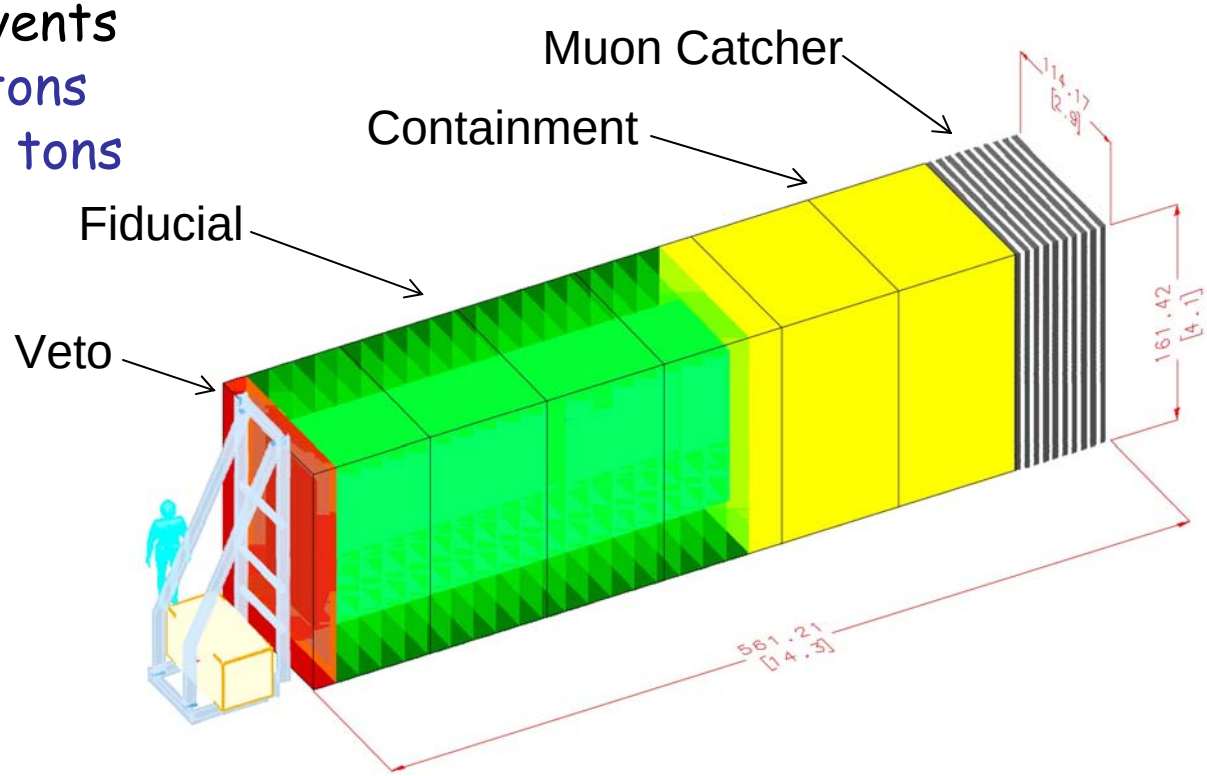
The Near detector requires excavation of a small new cavern underground
~ 1000 cubic yards



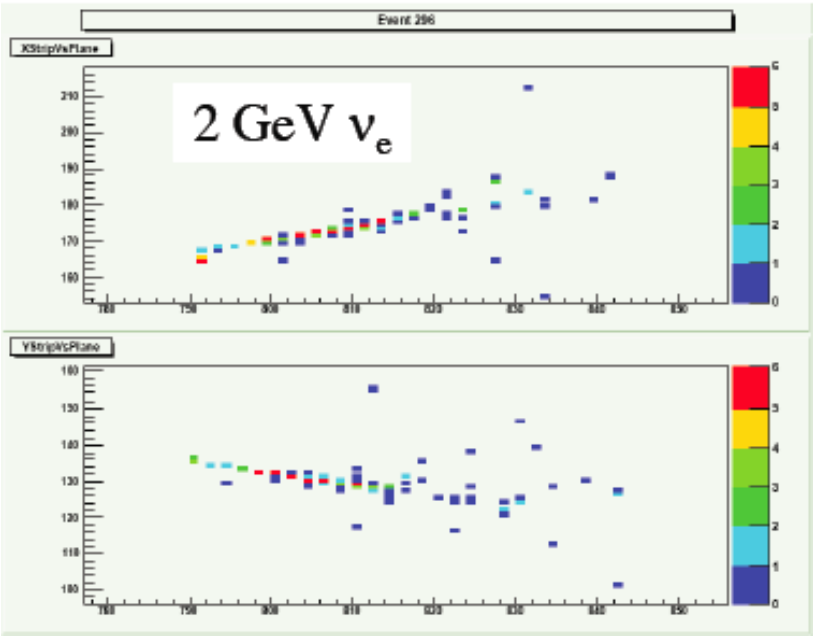
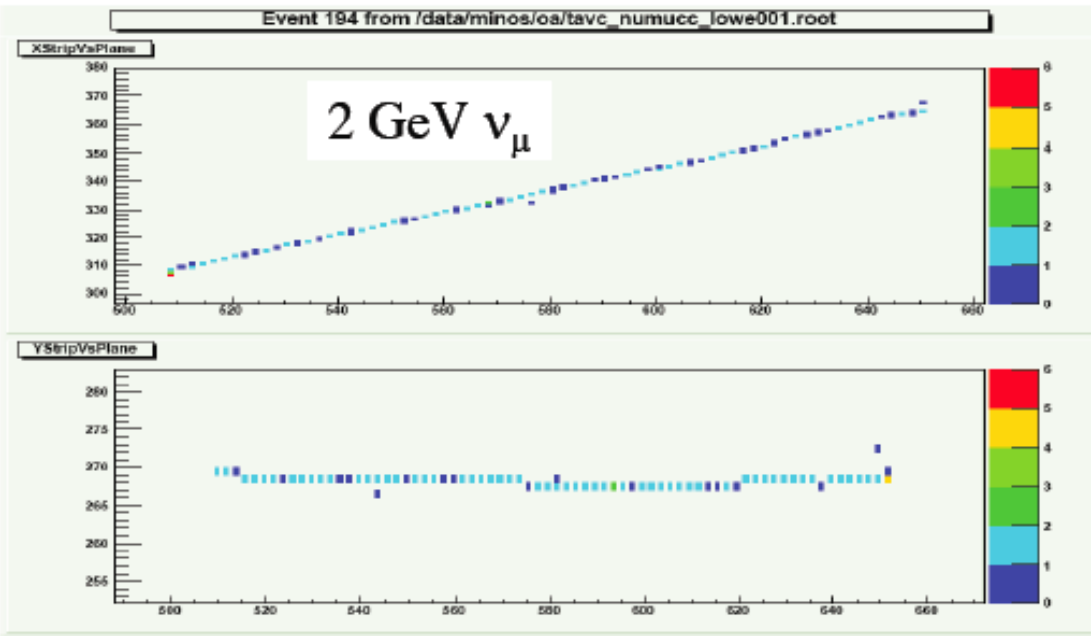


Near Detector

- Identical to Far Detector, just smaller.
- Oriented at the same off-axis angle as the Far Detector
- Contains 2 GeV ν events
- Total mass of 215 tons
- Fiducial mass of 20 tons



NOvA Event Quality

Longitudinal sampling is 0.15 X0, which gives excellent μ-*e* separation.

A 2-GeV muon is 60 planes long.