NOvA Project

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U.S. DEPARTMENT OF ENERGY

Fermilab

NOvA CD-4 Deliverables

- Upgrade the Fermilab accelerator complex proton source from pre-NOvA 320 kW to a source capable of 700 kW
  - Paul Derwent is covering this in the parallel breakout
- Build a new Far Detector Hall
  - At Ash River, Minnesota near the US-Canada border
  - The building is sized to hold an 18 kiloton detector
- Build a 14 kiloton Far Detector at Ash River
  - 15 kt could be authorized later in the project
- Build a 222 ton Near Detector
  - Which will be underground at Fermilab in the MINOS tunnel
- R&D goal: Integration Prototype Near Detector
  - With data taking on the surface near the MINOS Service building starting this fall
  - Integration Prototype = Near Detector if we are successful

Progress on the Ash River building

- An empty field last June
- This June: Service Building plus excavation with some concrete walls in place.
  - > 100 kt of rock removed, 50 kt put on access road, rest will be a berm around the building

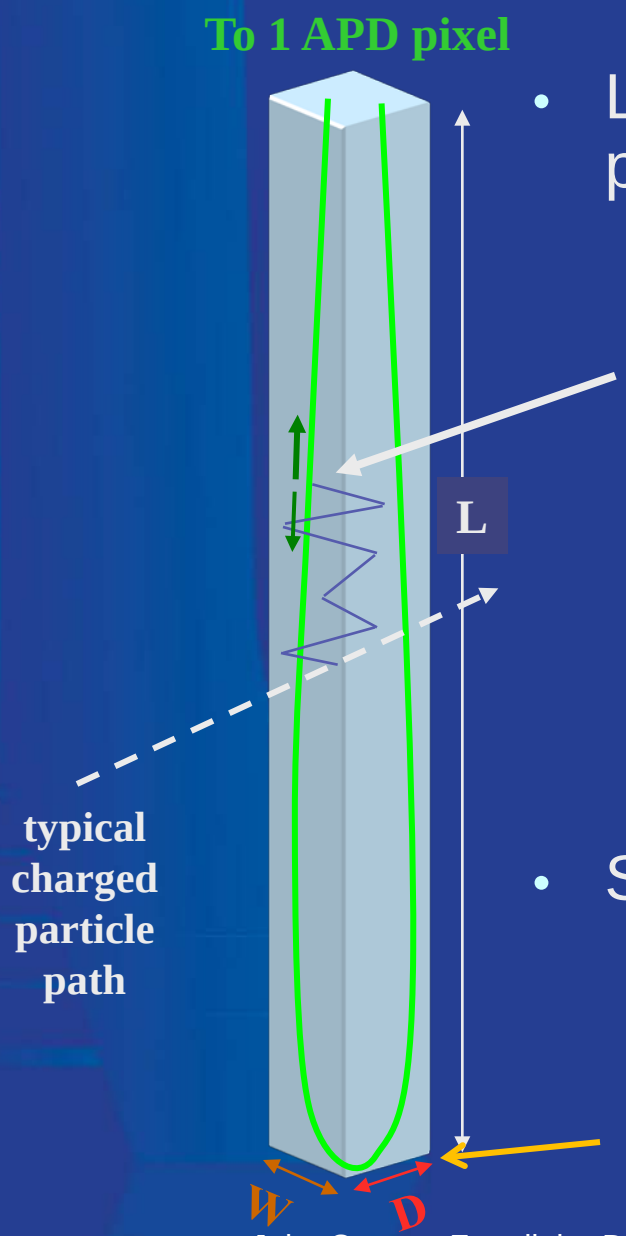
More Progress on Ash River Building

- View from the bottom
  - Some problems with over-excavation near rim
  - Solved with ~ 350 tensioned rock-bolts and concrete
  - Contractor claim pending

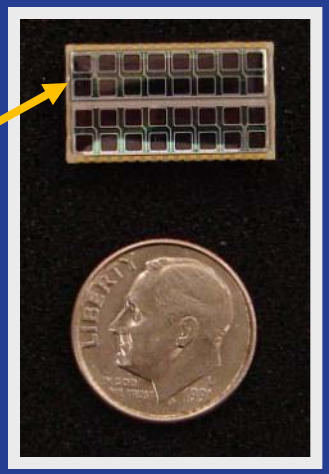
Building Cost & Contractor Claim

- Estimate at CD-2 was 47 M$ (+10 M$ contingency)
  - Costs to date are 16.0 M$
  - Costs to go are 16.5 M$
  - Cost of claim ~ 5 M$
  - So total cost will still be well below CD-2 estimate
- Excavation is complete
- Concrete is about 25% complete
  - 4,602 cubic yards of 16,081 cubic yards in place
- Current estimate for enclosed building is ~ October 1
  - We expect to get into the building to start on detector infrastructure in December

Reminder: NOvA Basic Detector Element



- Liquid scintillator in a highly reflective PVC plastic cell
  - Passage of charged particles through scintillator create light
  - Light bounces off reflective PVC walls until captured in a thin wavelength-shifting fiber
    - Typically light hits fiber within
      ~ 50 cm of particle path,
      ~ 8 reflections
  - The fiber is U-shaped and both ends terminate in one pixel of a 32-pixel avalanche photodiode (APD)



- Simple construction, just repeat 357,120 times !
  - Cells are 15 m long (so they just fit in a 53 ft semi-trailer truck)
  - For vertical cells, pressure from liquid scintillator is 19 psi at bottom

Detector progress: Commodities

- PVC Extrusions (22,000 required, 11 million pounds)
  - Recovery Act funding, ~ 22 M$
  - PVC resin from PolyOne in Pasadena, Texas
  - Extruding from Extrutech in Manitowoc, Wisconsin
  - Have final dies, tuning wall thickness, start production in August
- Wavelength Shifting Fiber (~12,000 kilometers)
  - Fiber from Kuraray in Japan
  - 1,510 kilometers already delivered
- Scintillator (~ 3 million gallons)
  - Mineral Oil contract with Renkert Oil (**fixed price**), 95% of mixture
  - Pseudocumene, 155,000 gallons, 5% of mixture
    have a good bid, should place P.O. soon
  - Wave-shifting chemicals in hand (Curtiss Laboratories, Bensalem, PA, Recovery Act)
  - Toll blending of components:
    30,000 gallons blended as test (will use in Near Detector)
- Commodity contracts in place: Reduced risk & contingency

Detector Progress: PVC Module Production

- Module factory is at the University of Minnesota
- 515 Near Detector PVC modules completed
  - Now building 40 modules per week
  - “Good” module output now at 99%
  - But 10-20% fail QA at Argonne (more detail coming)
- Factory moved to new large warehouse in April
  - 125,000 square feet, plan to build 120 modules/day for Far Detector
  - Half for factory, half for storage of extrusions / completed modules

Detector Progress: Electronics

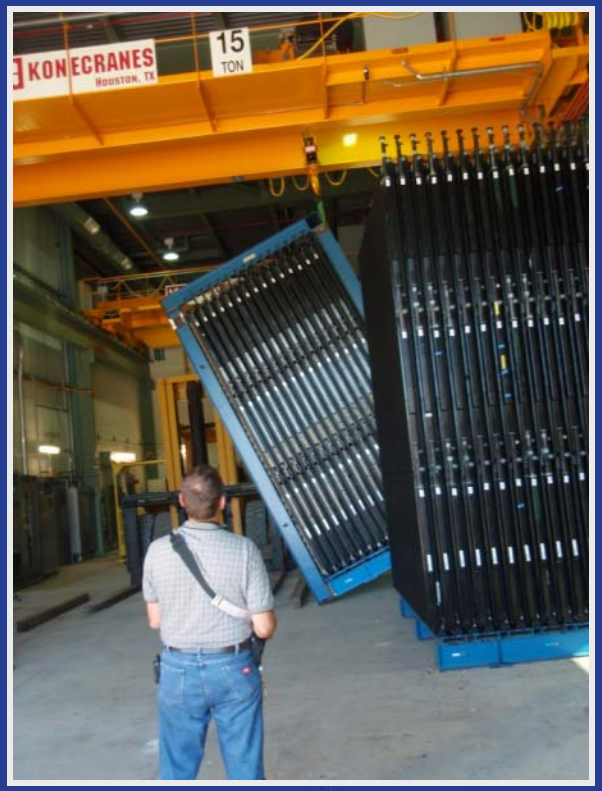
- Avalanche Photo diodes (APDs)
  - Hamamatsu production delivery for Near Detector, July 29
- Front End Board (FEB-4)
  - First 75 on their way to Fermilab from Harvard
  - 475 more are at the Assembler Vendor for the Near Detector
- Data Concentrator Modules (DCMs)
  - Each read out 64 FEBs
  - 16 in hand for Near (Fermilab)
- Time Distribution Units (TDUs)
  - 2 in hand, need 6 for Near (Fermilab)
- Data Acquisition / Networking / Computers
  - All in hand, work being done from Control Room in WH
- Power Distribution
  - Have crates and cards for Near Det., testing at Univ of Virginia

Detector Progress: Assembly

- Assembly of Near Detector Modules at Argonne
  - Blocks of 31 planes
  - 2 verticals, followed by 3 horizontals, repeat….
- 4 blocks assembled
  - 2 to go + few modules for a Muon Catcher
  - Proceeding to outfit blocks at Fermilab
  - Power supplies, electronics, cables, cooling, scintillator plumbing

ANL stacking and gluing

ANL → Fermilab



Detector Progress: Assembly

- New Near Detector Building at Fermilab
  - On surface for parasitic running starting this fall
  - Includes all features of Ash River building so we can test outfitting & filling methods and adjust if necessary
  - Last of features is a rolling access platform to reach top of detector from top catwalk (coming this week)

7/09/2010

1st two blocks (of 6) in place

7/02/10

rolling access platform at vendor

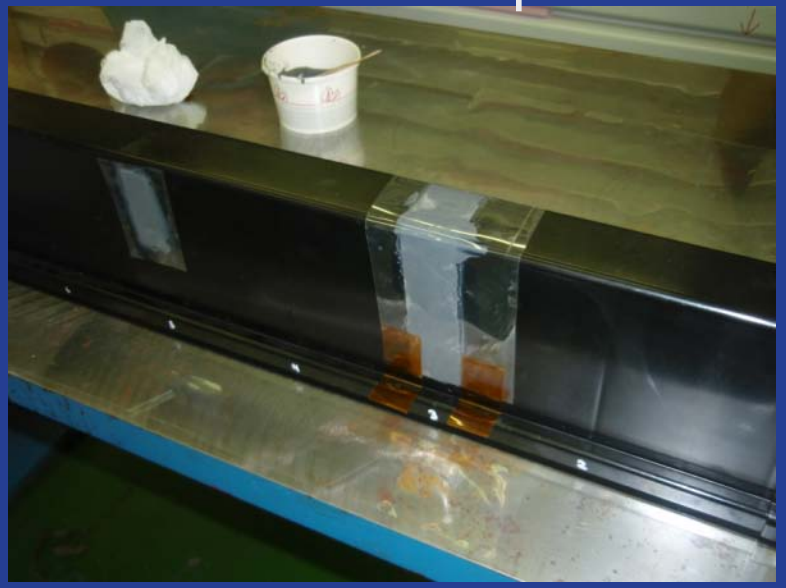
Detector Assembly: PROBLEM

- **Cracks in the fiber manifolds**
  - Develop somewhere in the construction at Minneapolis & Argonne, and/or in transportation from Minneapolis to Argonne to Fermilab
  - About 15% of the manifolds we can see have cracks
    (some spots inaccessible for the last six weeks)
  - Typically start as a ½ inch hairline, then grow

Detector Assembly: Repair Plan

5 cracks in this position

42 cracks in this position



- First, plug the observed cracks with 3M-2216
  - First trial on a saw cut shown above
  - Next try on an extra module at ANL, also saw cut, but can pressure test the result with apparatus at ANL
- Second, reinforce **ALL** the manifold covers
  - Concept in hand, no trials yet

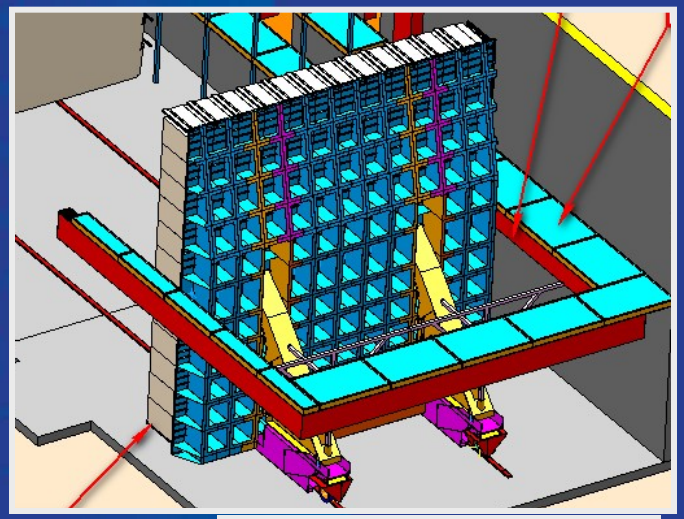
Detector Assembly: Crack **Prevention**

- Still need to pin down the cause(s)
  - All manifolds are thinner (~0.100” vs 0.140”) on the crack side
  - Finite Element Analysis indicates a high stress point where the majority of cracks appear

    High Stress due to 20 psi overpressure test of assembled modules at Minnesota to check for leaks, now changing to 10 & 5 psi as a test
  - Cracks appear on horizontal and vertical modules
  - Cracks appear no matter where they were in a stack as shipped from Minnesota
  - Cracks on first 3 blocks were noticed only when they got to Fermilab – so transportation is suspect as a cause
  - BUT on July 6, hairline cracks in Block #4 observed at Argonne before shipping
  - July 7: Solar heating of modules (not in blocks) at ANL induced cracks
  - Flow analysis back from consultant, several suggestions: interior support ribs too large, mold temp too hot, mold pressure released too early so mold core is likely shifting, processing window for this part is narrow, other fill methods would likely give better results
- Time was built into our baseline schedule for final design of the manifolds to match the final extrusions
  - Need to resolve this problem by ~ Oct-Nov to stay on schedule

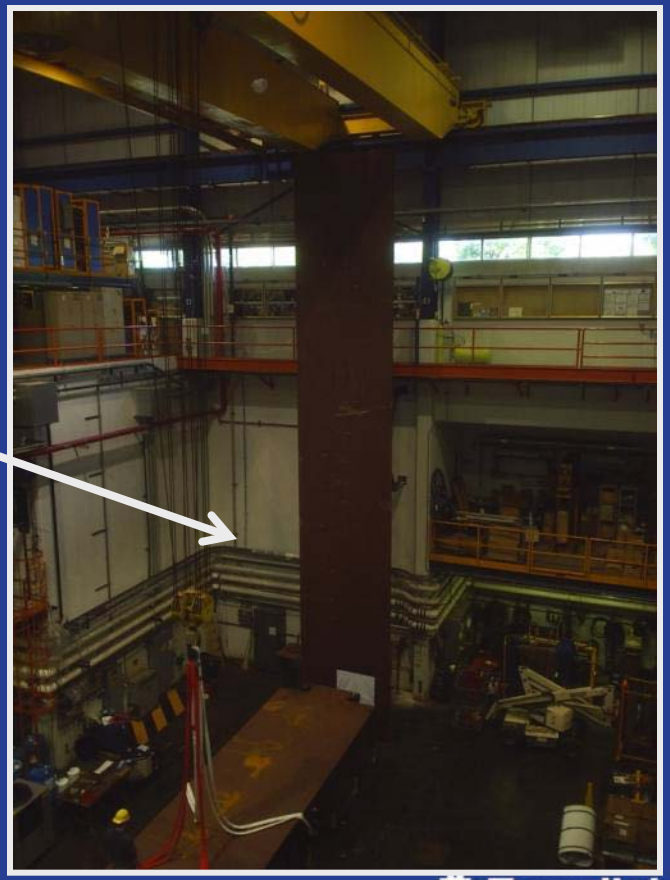
Detector Progress: Assembly

- Another prototype still remains, the Full Height Engineering Prototype (FHEP) at Fermilab, CDF deep pit
  - Tests the Pivoter machine to be used at Ash River
  - Tests full height modules in a block at full pressure (water)
  - Parts in hand, starting assembly



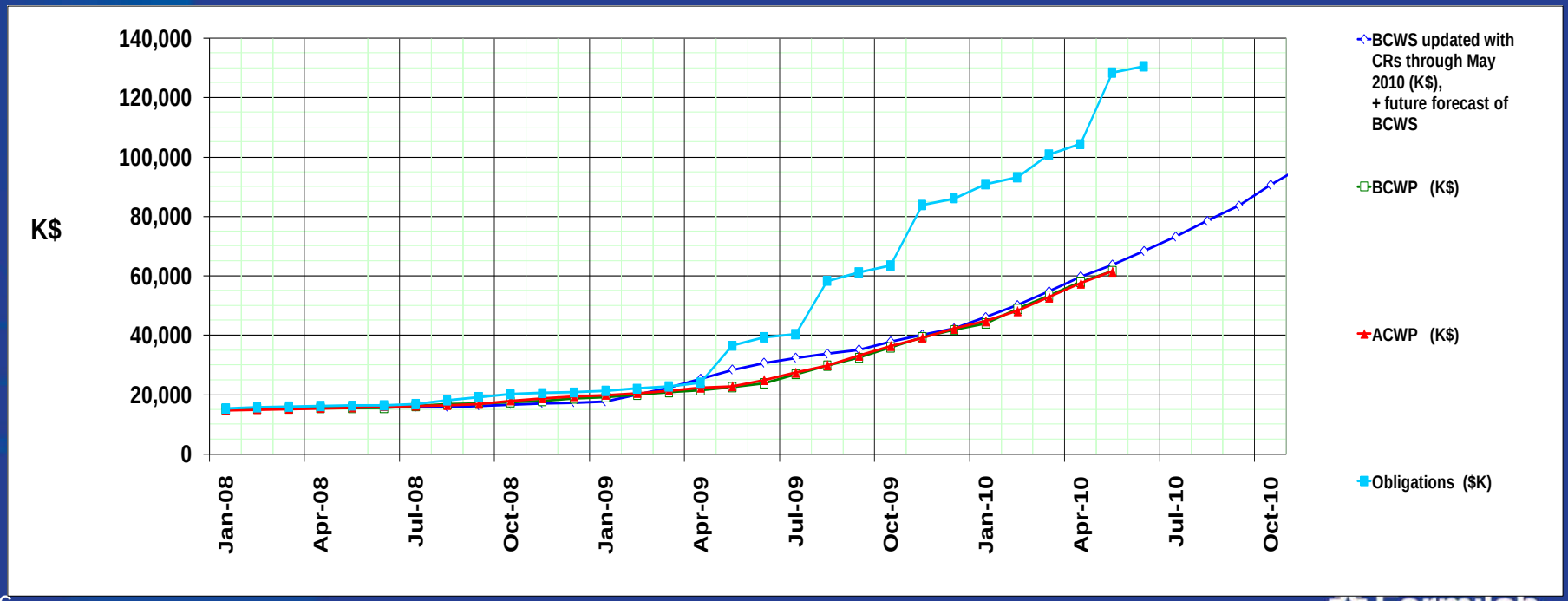
Pivoter at Ash River

FHEP at CDF



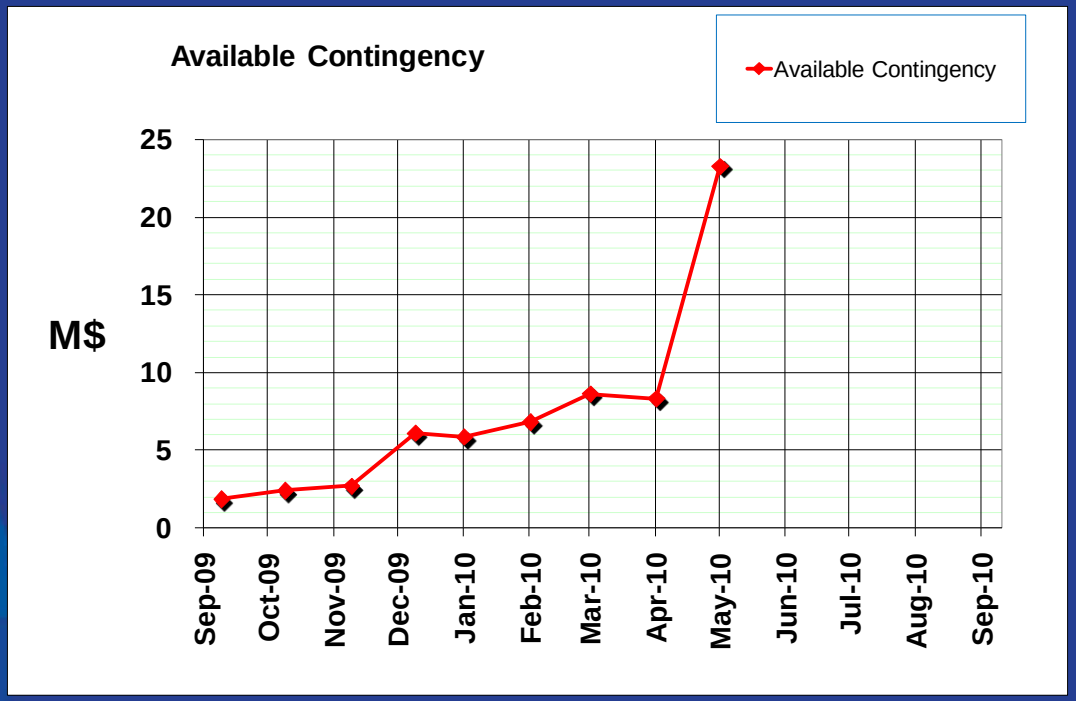
Project Progress: Spending Status

- Last July we had obligated 40 M$, costed 27 M$
  - The project was 20% obligated and 12% complete
- As of June 2010 have obligated 130 M$, costed 62 M$
  - The project is 60% obligated and 29% complete
  - The Estimate at Completion has gone from 202 M$ to 213 M$
- The 55 M$ of Recovery Act funds are 96% obligated and about 35% costed



Project Progress: Contingency Status

- Placing contracts for the building and for all the Detector commodities has generated substantial AVAILABLE CONTINGENCY
  - Assigned contingency is assigned task by task according to risk
  - Remaining contingency is "Available"
- Next DOE Independent Project Review (Lehman) must address a plan for this contingency



Project Progress: contingency thoughts

- **First** we use Available contingency to
  - **Reduce project risk, Hold the project schedule, Advance the project schedule**
- Examples are typically in the 50 – 250 K$ class
  - Full mock up of Near Detector in Near Detector Surface building at Fermilab, including catwalks & rolling access platform like that planned for Ash River
  - Commercial powered access platforms around pivoter at Ash River
  - Pay to store mixed scintillator, buffer at Toll Blender or elsewhere
  - Based on early IPND/Near experience think about other ways to shorten the Ash River assembly time;
    Re-examine number of people in crew, number of shifts, number of days worked per week…..
  - Build more Recycler Quads in advance of shutdown to shorten 2012 shutdown
  - Buy larger water chiller for NuMI to get extra cooling margin, 350 ton vs. current plan of 300 ton
  - Recommission Fermilab long beam tube oven to avoid risk that industry can only do short tubes which implies more kicker magnets needed for NOvA

Project Progress: contingency thoughts

- Second, we think about larger changes within our scope
- **Bottom line is (Detector Mass)*(Beam / unit time)*(time)**
- Mass:
  - Build up to 4 kt more, current estimate is ~9.5 M$/kt incl. a 30% contingency
  - Build a larger Near Detector cavern, helps to understand the LSND / MiniBooNE anti-neutrino effect by changing E at a fixed L. ~ 1M$
  - Add additional Barite shielding over detector? Double thick for ~ 0.6 M$
- Beam/unit time (NOvA needs 9 Hz Booster, now at ~ 6 Hz due to losses)
  - If lower losses in Booster, then can run more Booster cycles for NOvA
  - Administrative loss limit is for personnel who have to repair the old tube-based RF stations in the tunnel. A Solid State Upgrade to RF is already engineered, 2 of 19 stations installed, current estimate is ~ 6 M$ to finish.
  - RFQ as start of Linac, current estimate is ~0.7 M$. Also may decrease Booster losses. Needs quantitative analysis of "also may". (BNL experience)
- Time - This is mostly about accelerator reliability
  - Increase Main Injector Cooling Ponds, ~ 8 M$ (less if tap MR ponds?)
  - 20th Booster RF cavity (need 18 operational, only have 19 now) $?

Project Progress: contingency thoughts

- These larger (multi-M$) uses of Available Contingency will require agreement with the Laboratory and OHEP.
- My current philosophy is conservative:
  - We do not yet have a building at Ash River but do have a 5 M$ contractor claim
  - We don't have a final price from Hamamatsu on APDs.
    For the Near Detector we pay $1250 each. For the Far Detector they "guestimate" $450 each and we need 11,000 of them = 5 M$. (or 14 M$)
    Hamamatsu won't give us a firmer price until they see the yield in our 550 part order during August.
  - The Near Detector crack problem is a worry. We may need to build a complete 2nd Near Detector to replace this Integration Prototype. ~ 5 M$.
  - Our Integration Prototype experience suggests we might need more prototyping, e.g. a 2nd Full Height Engineering Prototype with final extrusions and final manifolds. We don't want any surprises at Ash River.
  - **We should understand the above before spending available contingency.**
  - Should have resolution in 6-9 months, similar scale for Accel Div taskforce
- We need to understand just WHEN each of the possible contingency uses needs to occur to stay well within CD-4. [List + $ + dates] constitutes a "contingency spend plan".

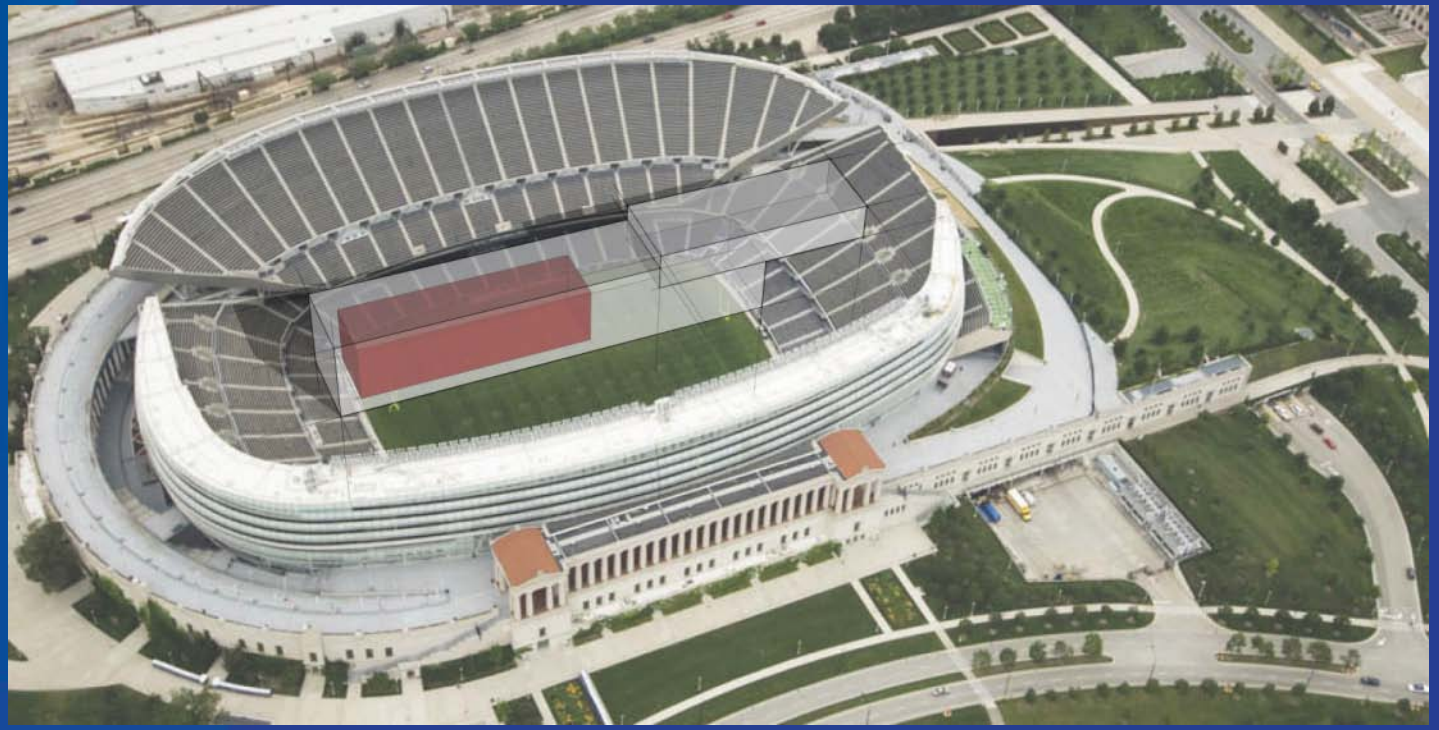
Project Schedule

- We have 303 days of float between the last deliverable milestone of “Neutrino events seen in last superblock at Ash River” and CD-4.
  - No slip in schedule since January 2008
- Expect:
  - Operation of Near Detector on the surface this Fall
  - Building occupancy for Pivoter in December 2010
  - Start detector construction at Ash River in July 2011
  - Accelerator shutdown for NOvA, March 2012 – Feb 2013

    Should have a few blocks (1-2 kt) of the Far Detector operating just before the 2012 shutdown begins
  - At end of Accelerator shutdown, NOvA is operating about 2/3 of the Far Detector and the Accelerator is commissioning 700 kW beam.
  - CD-4 is November 2014

SUMMARY

- The project has taken great strides during the last year.
- The project is in a great position with available contingency
- The project is on schedule.



Backup slides

Institutional contributions by WBS Level 2

- Accelerator and NuMI Upgrades
  - **Fermilab,** U Texas Austin
- Site and Building
  - **Fermilab, U of Minnesota**
- Scintillator
  - **Indiana U**, Fermilab, Southern Methodist U
- Fiber
  - **Michigan State U**, U Texas Dallas, UCLA
- PVC Extrusions
  - **ANL**, Fermilab, U of Minnesota
- Extrusion Modules
  - **U of Minnesota**
- Electronics
  - **Caltech, Harvard, U of Virginia**, Indiana, Tufts U, Fermilab, Minnesota
- Data Acquisition
  - **Fermilab**, Minnesota, Indiana, U of South Carolina, U of Minnesota Duluth
- Detector Assembly
  - **ANL, Fermilab,** Minnesota

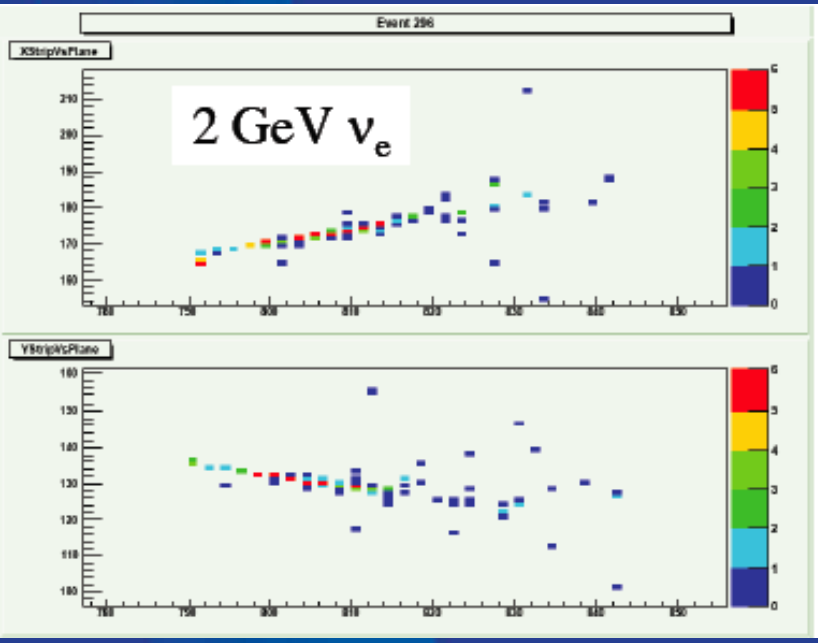
What NOvA can do in various θ_{13} scenarios

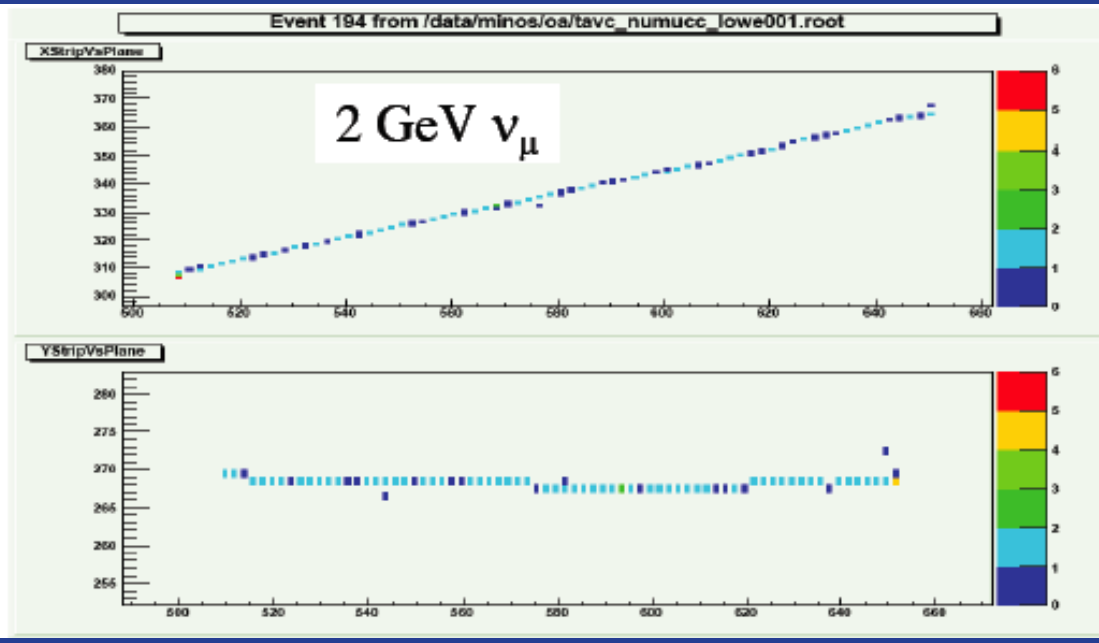
- **$\sin^2(2\theta_{13}) \approx 0.1$**
  - Determine the mass ordering for half of the δ space at the 1-3 σ level; combining with T2K, determine the mass ordering for the other half of the δ range at 1-2 σ level.
  - Exclude about half of the δ space at the 1-2 σ level.
  - Combining with Daya Bay, determine whether ν_3 couples more strongly to ν_μ or ν_τ at the 2 σ level if $\sin^2(2\theta_{23}) < 0.97$. (See G. Feldman talk at P5, Feb 2008)
- **$\sin^2(2\theta_{13}) \approx 0.06$**
  - Determine the mass ordering for half of the δ space at the 1-2 σ level; combining with T2K, determine the mass ordering for the other half of the δ range at 1-2 σ level.
  - Exclude about half of the δ space at the 1-2 σ level.
  - Combining with Daya Bay, determine whether ν_3 couples more strongly to ν_μ or ν_τ at the 2 σ level if $\sin^2(2\theta_{23}) < 0.94$. (See G. Feldman talk at P5, Feb 2008)
- **$\sin^2(2\theta_{13}) \approx 0.03$**
  - Determine the mass ordering for a quarter of the δ space at the 1 σ level.
  - Exclude about half of the δ space at the 1-2 σ level.
- **$\sin^2(2\theta_{13}) \approx 0.01$**
  - See a signal at the 1-3 σ level, confirming weak signals seen in other experiments. **(Or, we might be another voice to sort out conflicting results from Double CHOOZ, Daya Bay, RENO, T2K)**

NOvA Event Quality

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

A 2-GeV muon is 60 planes long.





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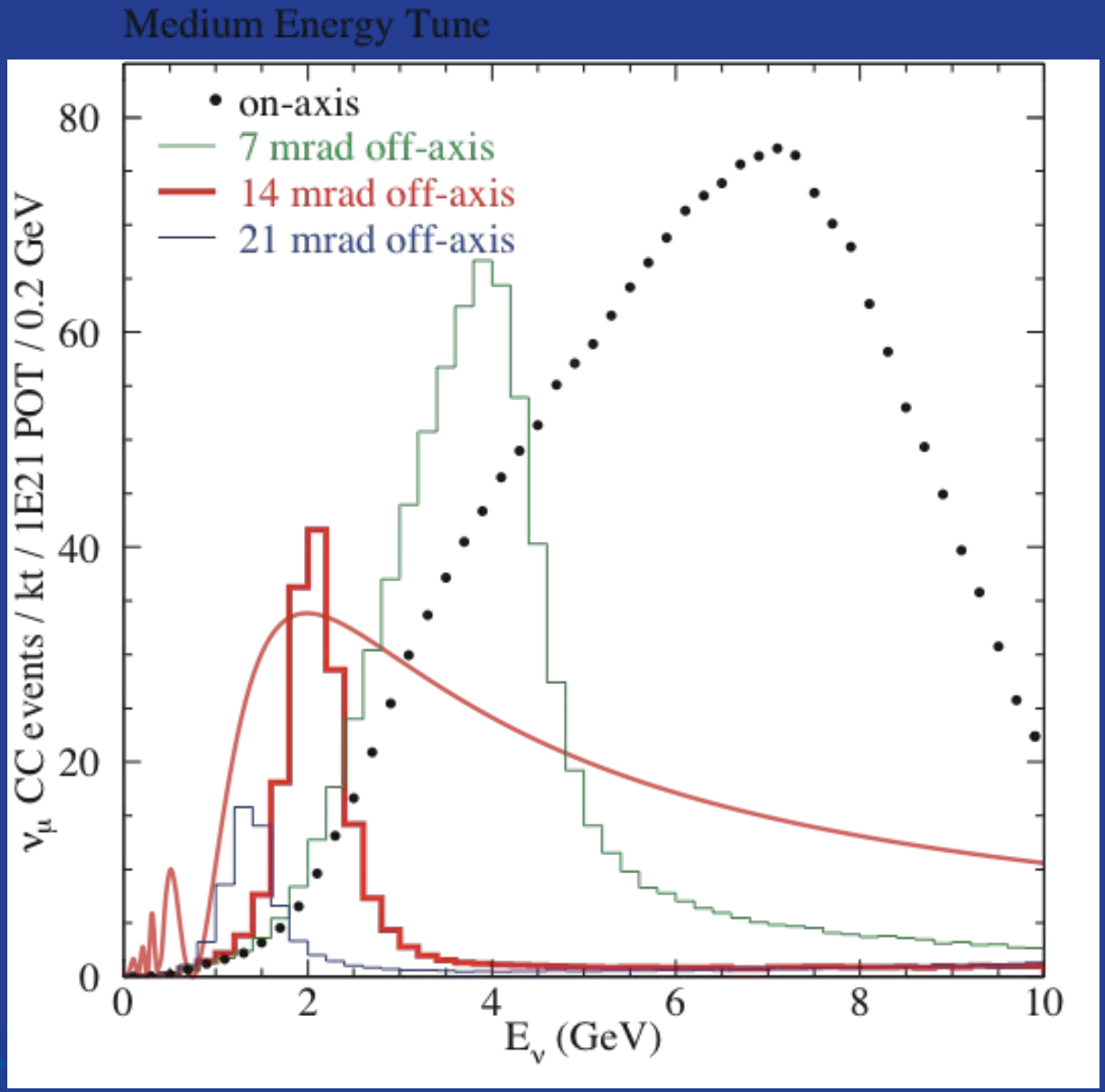
Off-Axis Beam



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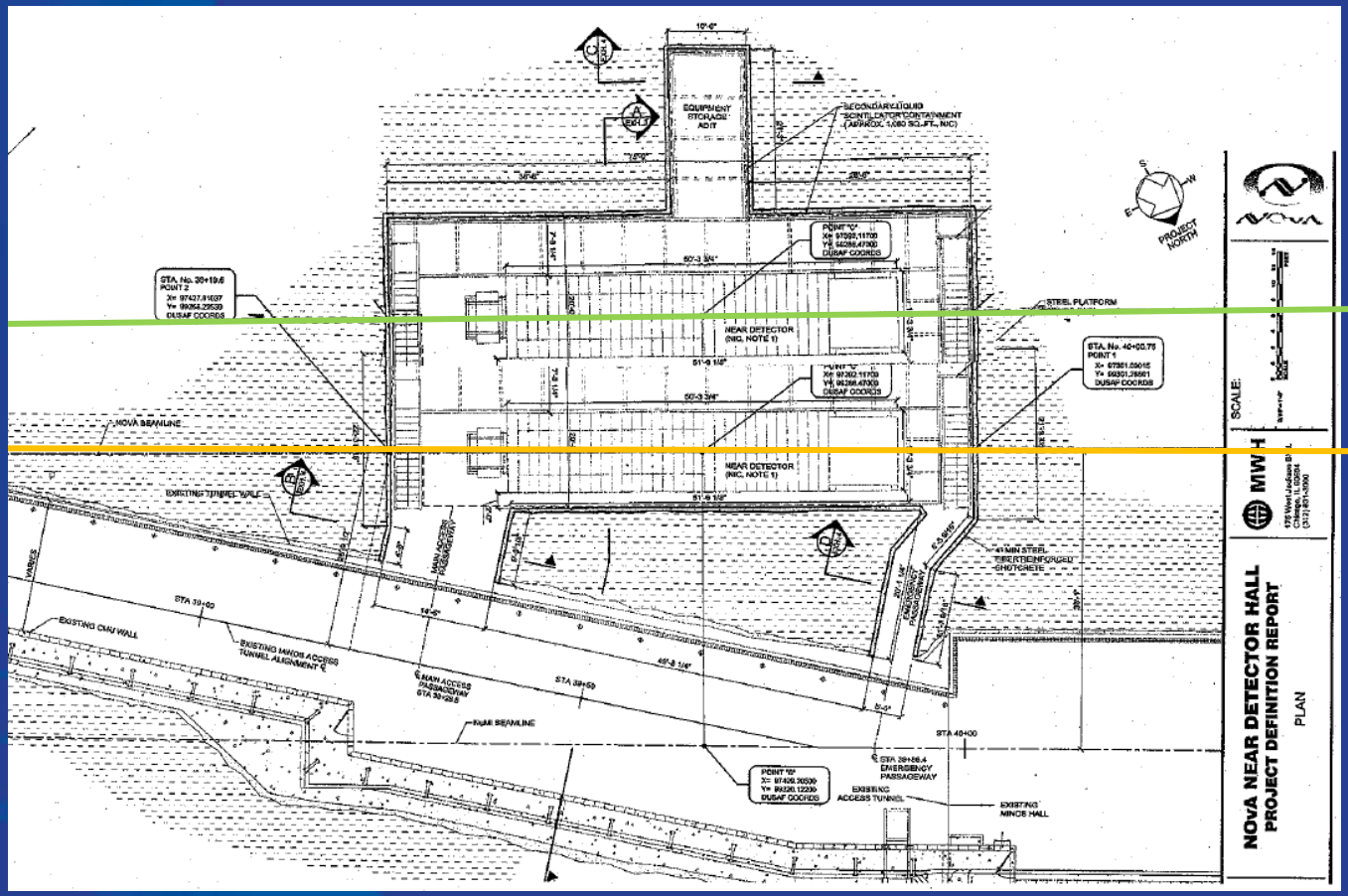
LSND/ MiniBooNE effect: Larger Near Cavern ?

- Checking cost with A/E firm.
- Expect small increment (~1M$) since cost is dominated by mobilization and prep to move all MINOS hall power across tunnel

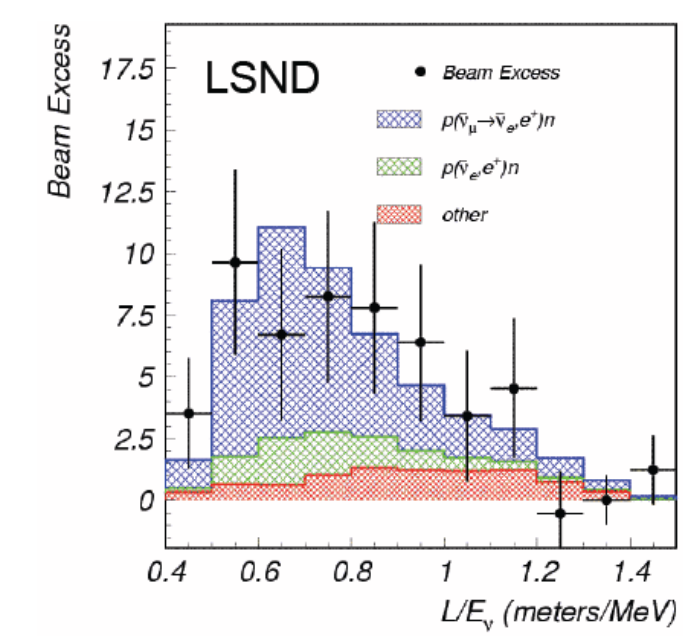


21 mrad, E=1 GeV, L/E~1

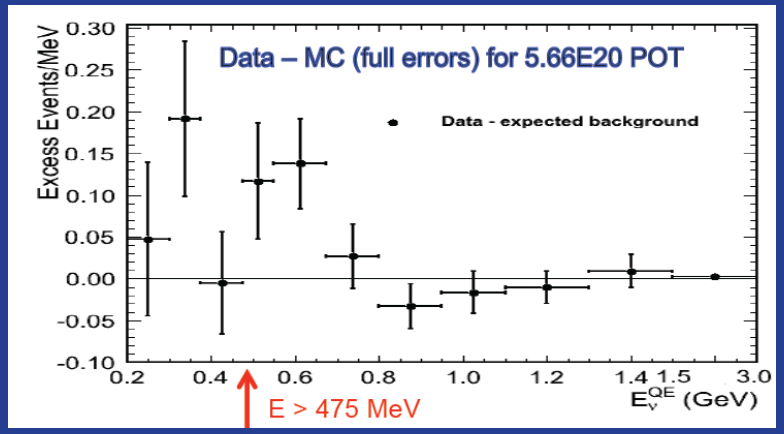
14 mrad, E=2 GeV, L/E~0.5

This is the angle to Ash River

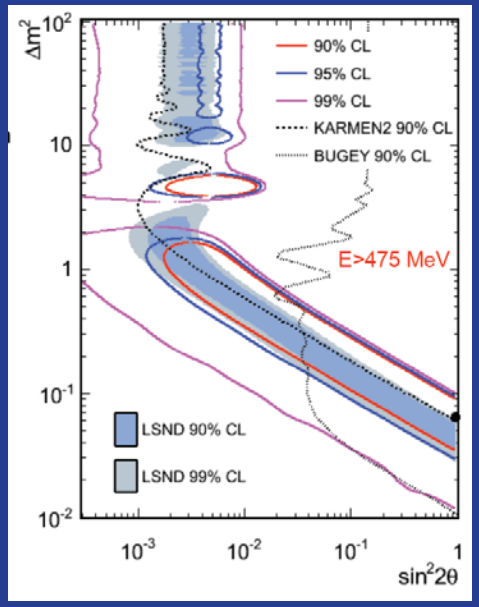
LSND/ MiniBooNE effect:



MiniBooNE anti-neutrino



L/E (km/GeV) ~1 ~0.5



MINOS anti-neutrino effect?

- Rough scaling of NOvA capability from TDR, more detailed work is in progress