The **L**ong-**B**aseline **N**eutrino **E**xperiment Project

# LBNE Reconfiguration Engineering/Cost Working Group Report

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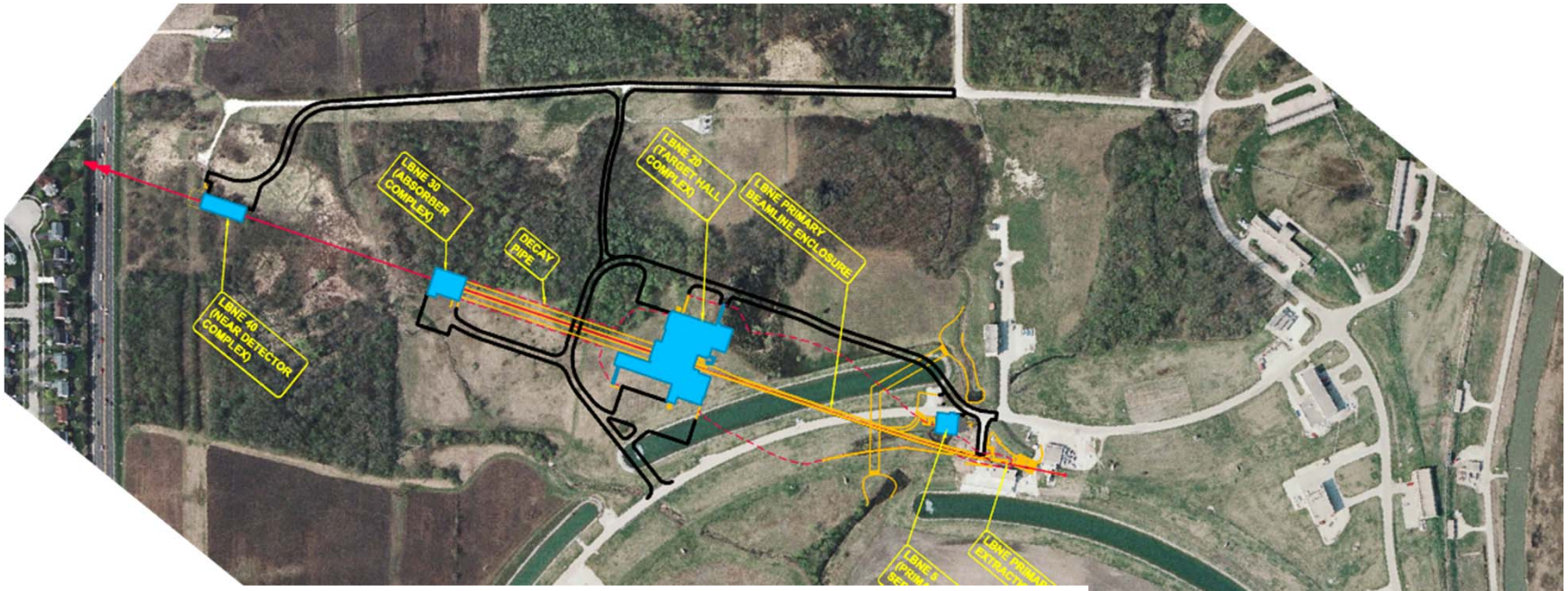
Deputy Chair, Cost and Engineering Working Group

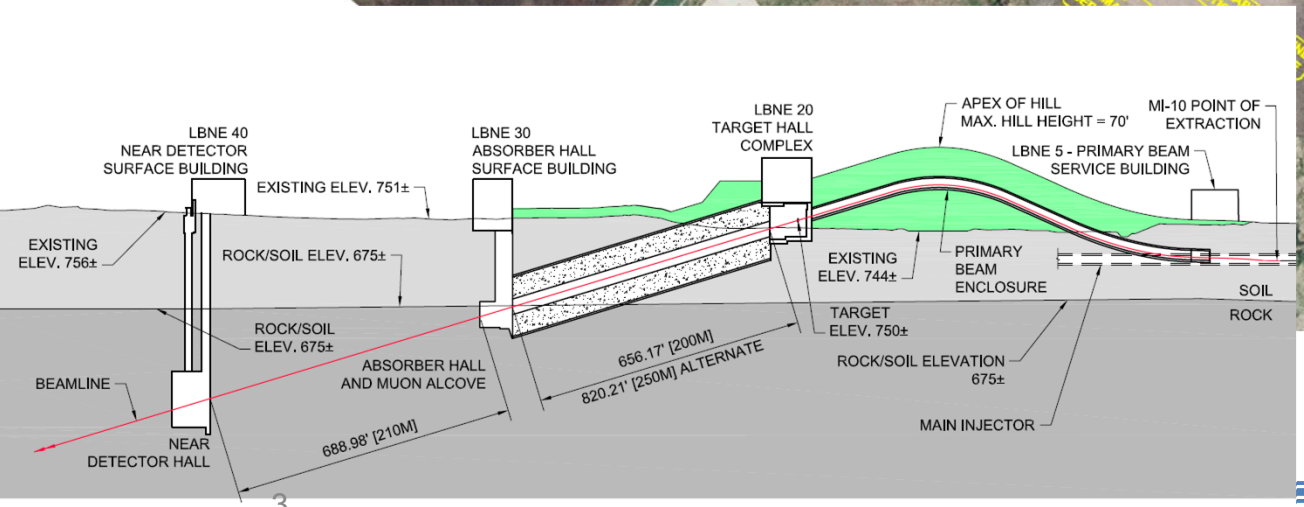
Fermilab PAC
20 June 2012

# Cost and Engineering Working Group

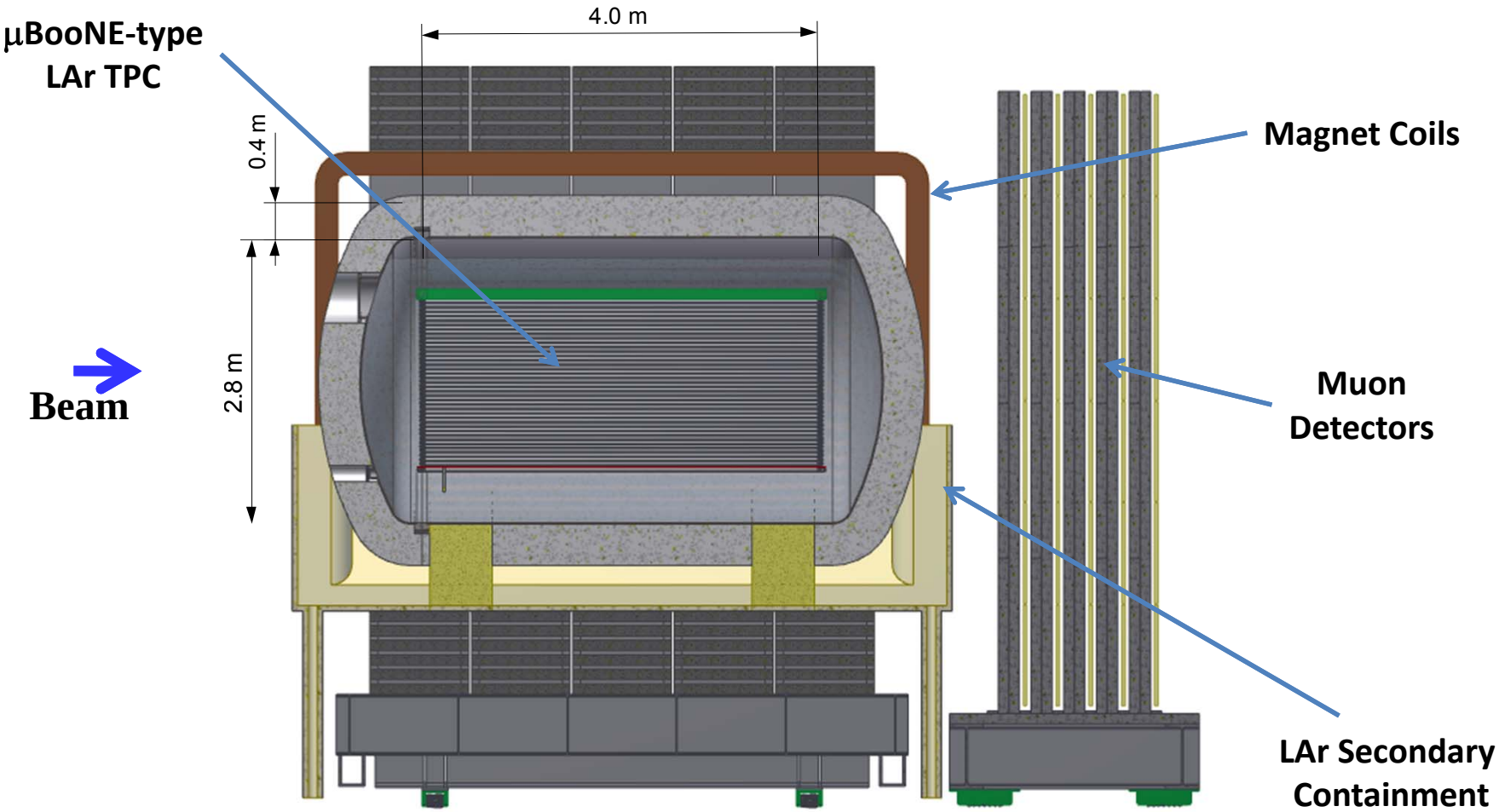
- Cost and Steering Working Group members
  - Mark Reichanadter (SLAC COO), Chair
  - Jim Strait (FNAL, LBNE Project Manager), Deputy Chair
  - Bruce Baller (FNAL, LAr Far Detector Project Manager)
  - Mike Headley (SURF Director)
  - Marvin Marshak (U of MN, Director of Soudan and Ash River Labs)
  - Christopher Mauger (LANL, LBNE Near Detector Project Manager)
  - Elaine McCluskey (FNAL, LBNE Project Engineer)
  - Bob O'Sullivan (FNAL, LBNE Project Controls Lead)
  - Vaia Papadimitriou (FNAL, LBNE Beamline Project Manager)
  - Jeff Sims (ANL, APS Upgrade Project Managment)
  - Jeffrey Appel (FNAL Directorate), Scientific Secretary
- Invited to work with the Working Group
  - Tracy Lundin (FNAL, LBNE Conventional Facilities Project Manager)
  - Jeff Dolph (BNL, LBNE Project Systems Engineer)
  - Jim Stewart (BNL, LBNE Water Detector Project Manager)
  - Joel Sefcovic (FNAL, LBNE Project Controls for Conventional Facilities)
- Plus the support of the full LBNE Team

# Neutrino Beam Design:
# MI-10 Extraction, Shallow Beam



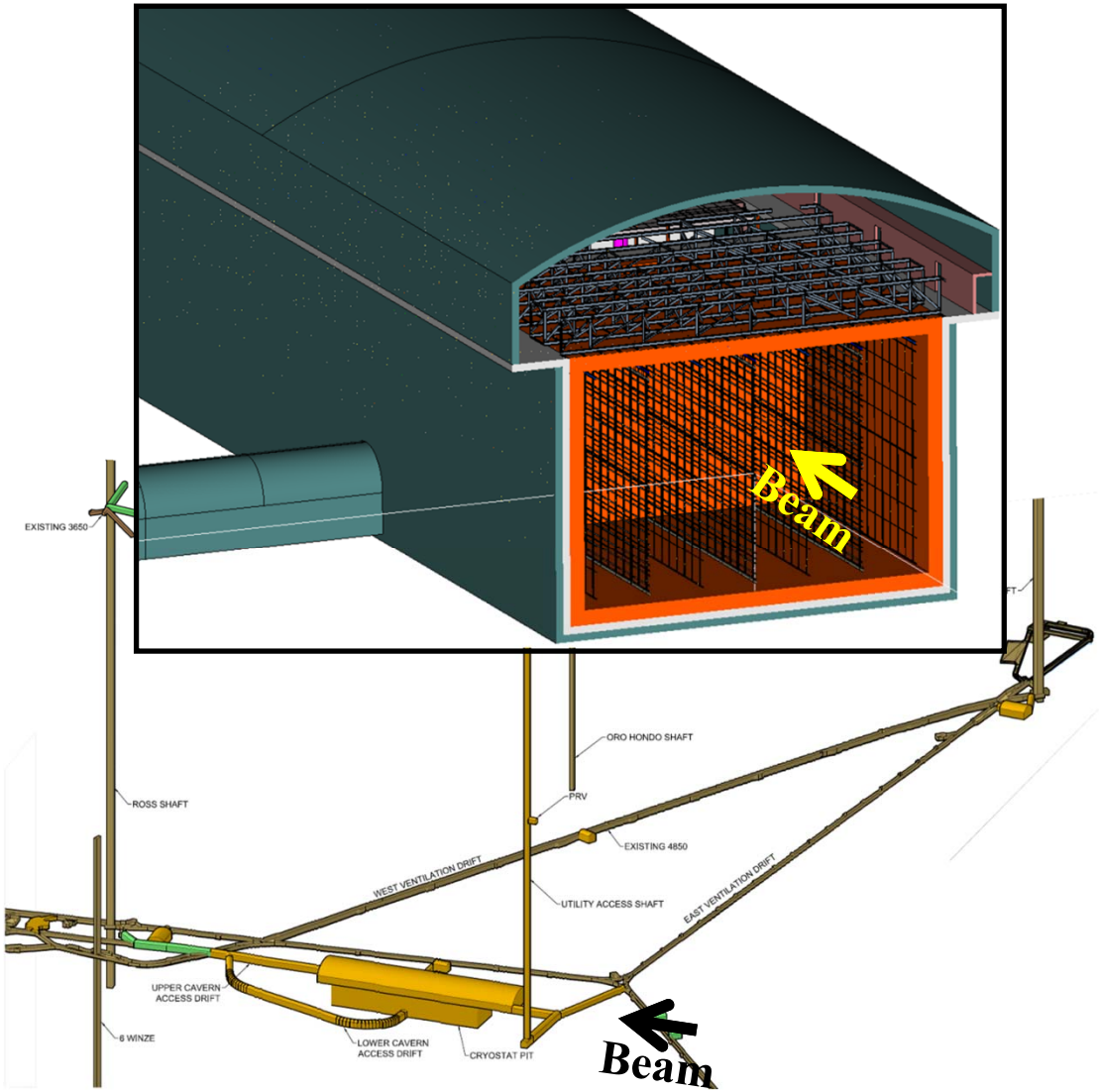



# Near Detector Design: Liquid Argon TPC




Plus an Alternate Design: Straw-Tube Tracker with embedded argon targets

# Far Detector Design: LAr TPC Detector




- Two detectors in a common cavern at 4850 ft. depth
- Active volume of each detector: 22.4 x 14 x 45.6 $m^3$
- 33 kt fiducial mass
- TPC design:
  - o 3.7 m drift length
  - o 5 mm wire spacing
  - o three stereo views

# LBNE Project Cost Estimates

- LBNE has developed a complete Conceptual Design and cost estimate, which has been reviewed many times and found to be sound. Recent Director's Review stated:

The committee finds that the Conceptual Design for the LBNE project is sound, and should achieve the Project's scientific goals. Our determination is that the level of technical detail across the entire breadth of the LBNE project is sufficient to address the question of overall capability to achieve the scientific goals, as appropriate for this stage of the project. There are a number of components of the project that have advanced well beyond the conceptual stage.

The committee is confident that the LBNE project can be ready for a CD-1 review on the time scale given to the committee, the summer of 2012, if issues related to the funding profile and the resulting schedule are resolved. The management systems and documentation for the project are appropriate for a CD-1 review.

Given the breadth of the LBNE project, and the wealth of documentation associated with the project, the committee examined selective portions of the documents to evaluate the quality of the information. Our finding is that the technical information, costing information, task level duration estimates, Value Engineering information, etc. is of high quality.

# Reconfiguration Process: Constraints and Assumptions

- Designs and cost estimates based as much as possible on the reviewed Reference Design.
- Cost of each phase should be no more than $700-800M.
- Cost range (CD-1 level) for first phase should be consistent with CD-0 range of $660-940M.
- Annual expenditures should not exceed ~$120M
- Sanford Lab (SURF), Soudan Lab and Ash River sites all will be operated independently of LBNE.
  => Operating costs are not the responsibility of the LBNE Project during its construction.

# System Options Considered

- LAr Far Detectors of 5, 17 and 34 kt fiducial mass.
  - Simplified cryo system for underground installations
    => Drives significant cost reduction in CF as well.

- Conventional Facilities (CF) to support the 3 detector sizes at
  - Homestake underground (4850L ≈ 4300 mwe)
  - Soudan underground (27$^{th}$ level ≈ 2100 mwe)
  - On surface at Homestake, Soudan, Ash River

- LBNE beamline to Homestake
  - Simplifications to lower cost without loss of functionality
  - Staging of some aspects for initial 700 kW operation

- NuMI beamline
  - Upgraded for 700 kW operation in low energy configuration
  - Upgraded for operation well beyond design lifetime

# System Options Considered

- Near Detector – Homestake options
  - Full LBNE Near Detector
  - Phase 1 mini Near Detector in 6.7 m diameter “man hole”
  - Tertiary muon monitors only in phase 1

- Near Detector – NuMI options
  - LBNE-type Near Detector modified to fit in MINOS cavern
  - Use existing detectors (MINOS, MINERvA, NOvA) in phase 1

# LAr Cryogenic System Simplification

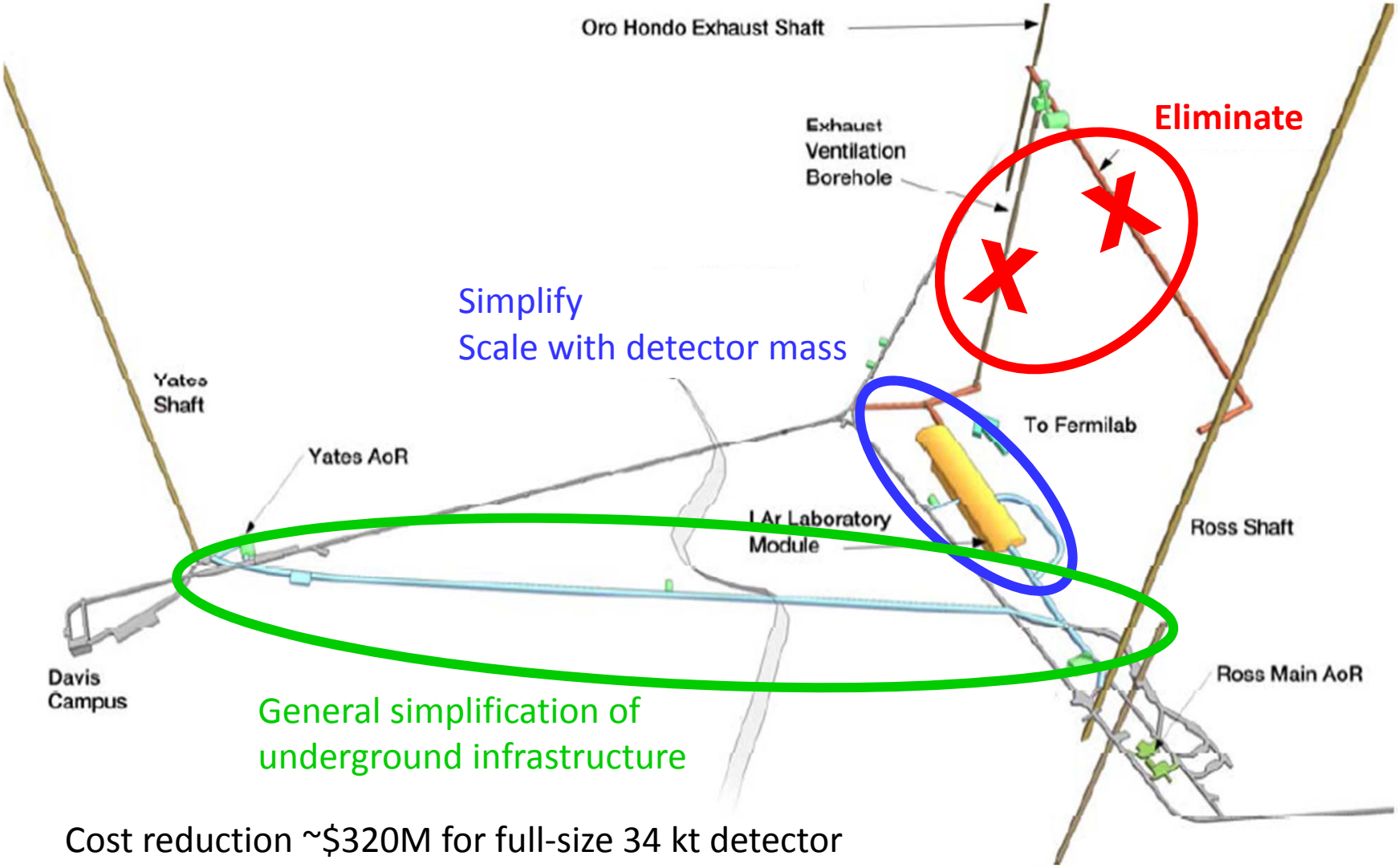
Simplifications in the underground design

- Move refrigerator compressors to the surface.
- Argon delivery underground as cold gas rather than liquid => significantly simplified plumbing down the shaft.
- Cryo pipes down the Ross Shaft rather than Oro Hondo Shaft => shorter piping runs.

Net reduction in estimated cost of technical systems ~$40M.

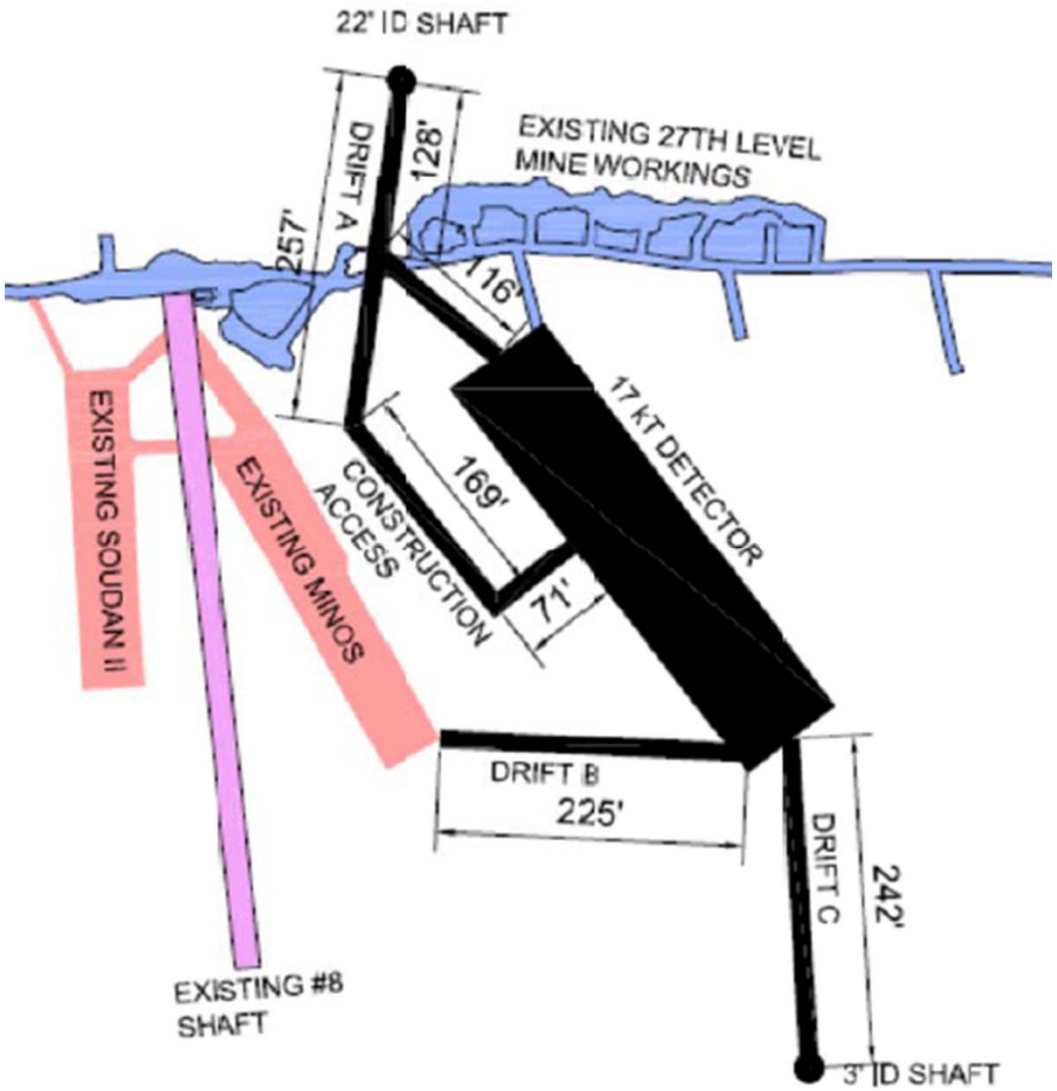
Larger reduction in conventional facilities (see next slide)

# Far Detector Underground at Homestake




Cost reduction ~$320M for full-size 34 kt detector

# Far Detector Underground at Soudan




- Design and cost estimates developed by contractors to U of MN.
- Two new shafts for safe access and control of ventilation.
- Requires development of surface facilities at each of the two new shafts.

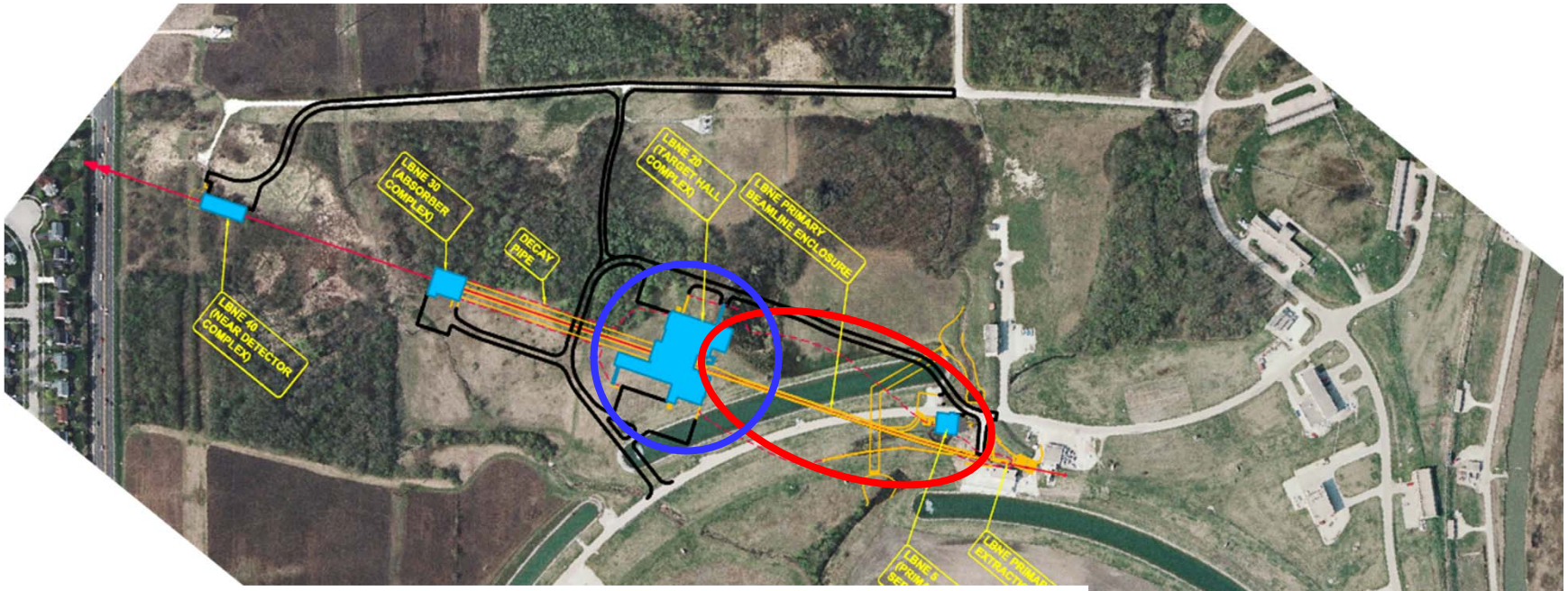
# Potential locations of new shafts

# Potential Surface Detector Locations at Soudan

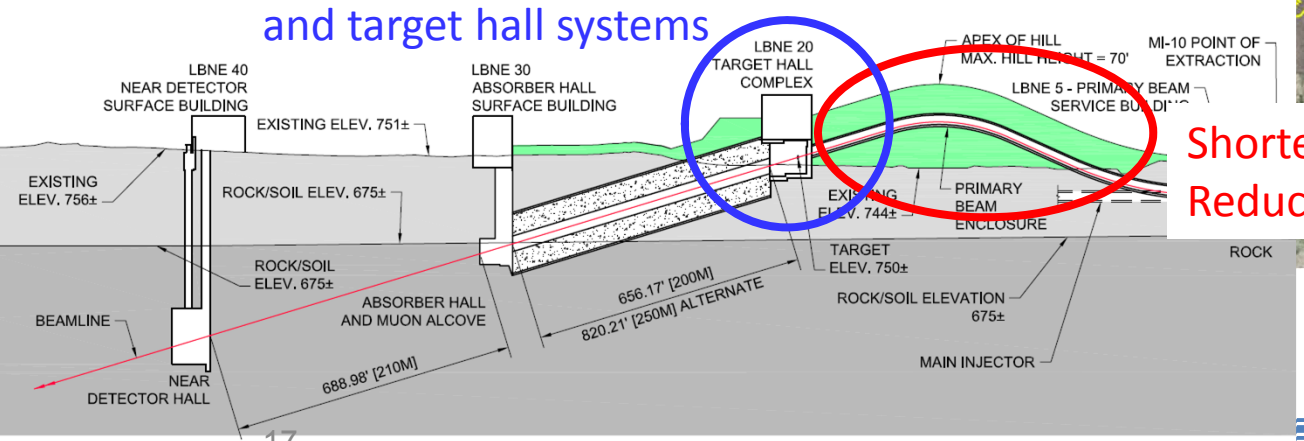
# Candidate Surface Detector Site at Ash River

# Candidate Surface Detector Site at Homestake

# LBNE Neutrino Beam




Simplified target hall
and target hall systems




Shorten primary beamline,
Reduce hill height

# LBNE Beam Cost Reductions
# (FY2010 $M, estimate uncertainty contingency)

| Simplify Technical Systems Design | Cost Savings |
|---|---|
| Shorten primary beam 148' | 0.8 |
| Eliminate OTR profile monitor | 0.2 |
| Re-optimize beam loss calculation labor | 0.5 |
| Reduced target shield pile | 4.4 |
| Recycle old shielding steel | 1.3 |
| No target chase water-cooling panels in phase 1 | 3.7 |
| NuMI design target and horns (200 kA) | 13.0 |
| Reduced target R&D in phase 1 | 3.0 |
| NuMI design target hall instrumentation | 2.3 |
| Combined target-baffle module | 0.7 |
| No in-chase target handler | 7.7 |
| Reduce and combine vision systems | 0.7 |
| **Total - technical systems** | **38.2** |

| Re-use NuMI beamline components | Cost Savings |
|---|---|
| NuMI horn PS + stripline | 3.6 |
| Beamline Magnets | 1.3 |
| Magnet power supplies | 0.5 |
| Primary beam instrumentation | 1.0 |
| Target | 0.8 |
| Target hall instrumentation | 1.9 |
| **Total - reusing NuMI components** | **9.5** |

| Simplify Conventional Facilities Design | Cost Savings |
|---|---|
| Target Hall Complex Reconfiguration | 30.2 |
| Shorten primary beam 148' | 6.6 |
| Reduced tritium interceptor | 1.4 |
| **Total - Conventional Facilities** | **38.2** |

| | |
|---|---|
| **Grand Total** | **85.9** |

*Including <u>all</u> contingency and escalation* *$110M*

# NuMI Beamline

- Need a redesign of target-horn system to operate at 700 kW in low-energy configuration.
  This and other system modifications ≈ $13M.

- Radiological / lifetime issues for extended running
  - Tritium buildup in ground and surface water, either just from integrated running or from possible drainage system problems.
  - Water cooling system in decay pipe and absorber
  - Decay pipe window

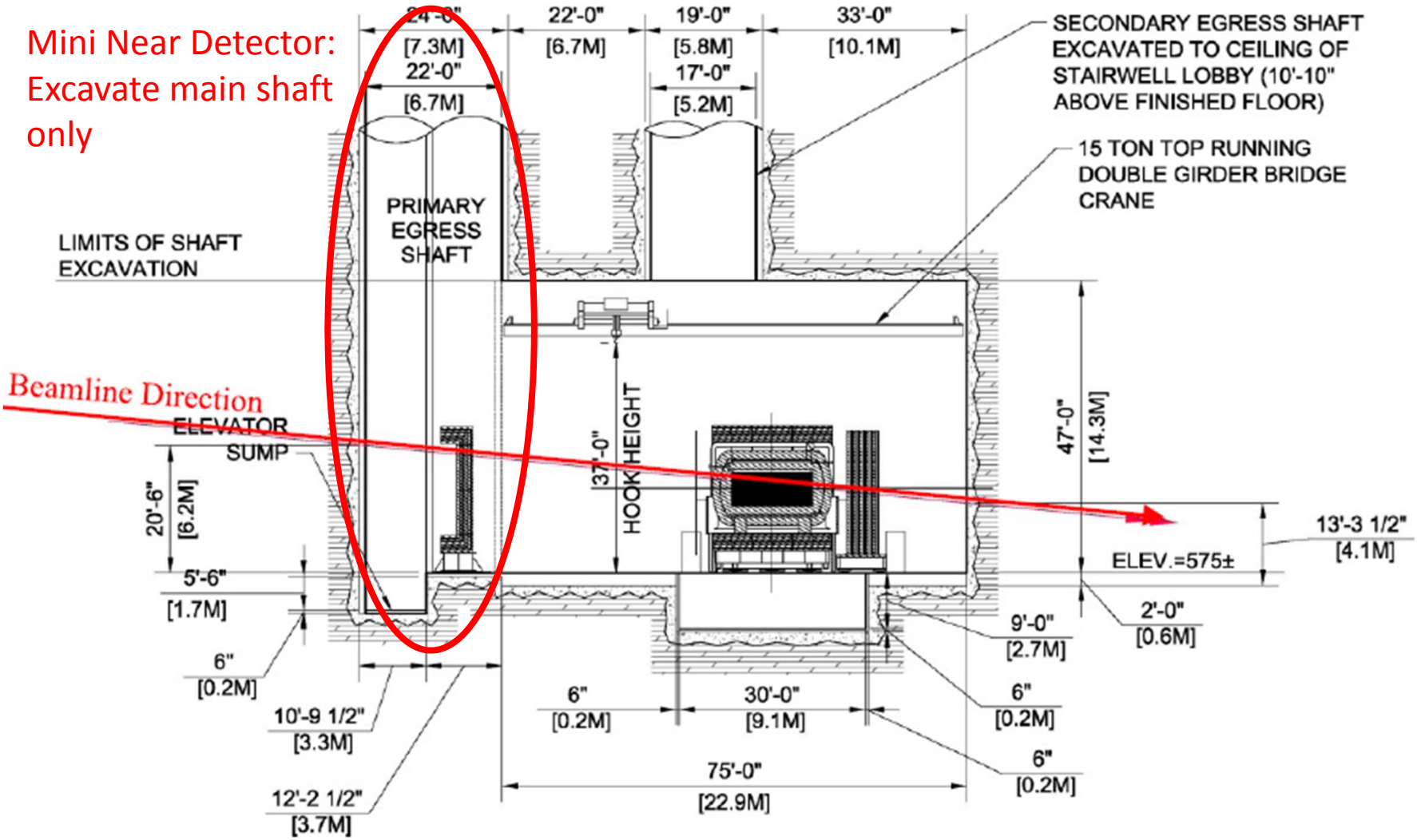
  Include allowance of ~$30M for possible preventive mitigation.

- Fundamental limitations:
  - Cannot be upgraded to beam power much above 1 MW
  - Cannot run proton beam much below 120 GeV

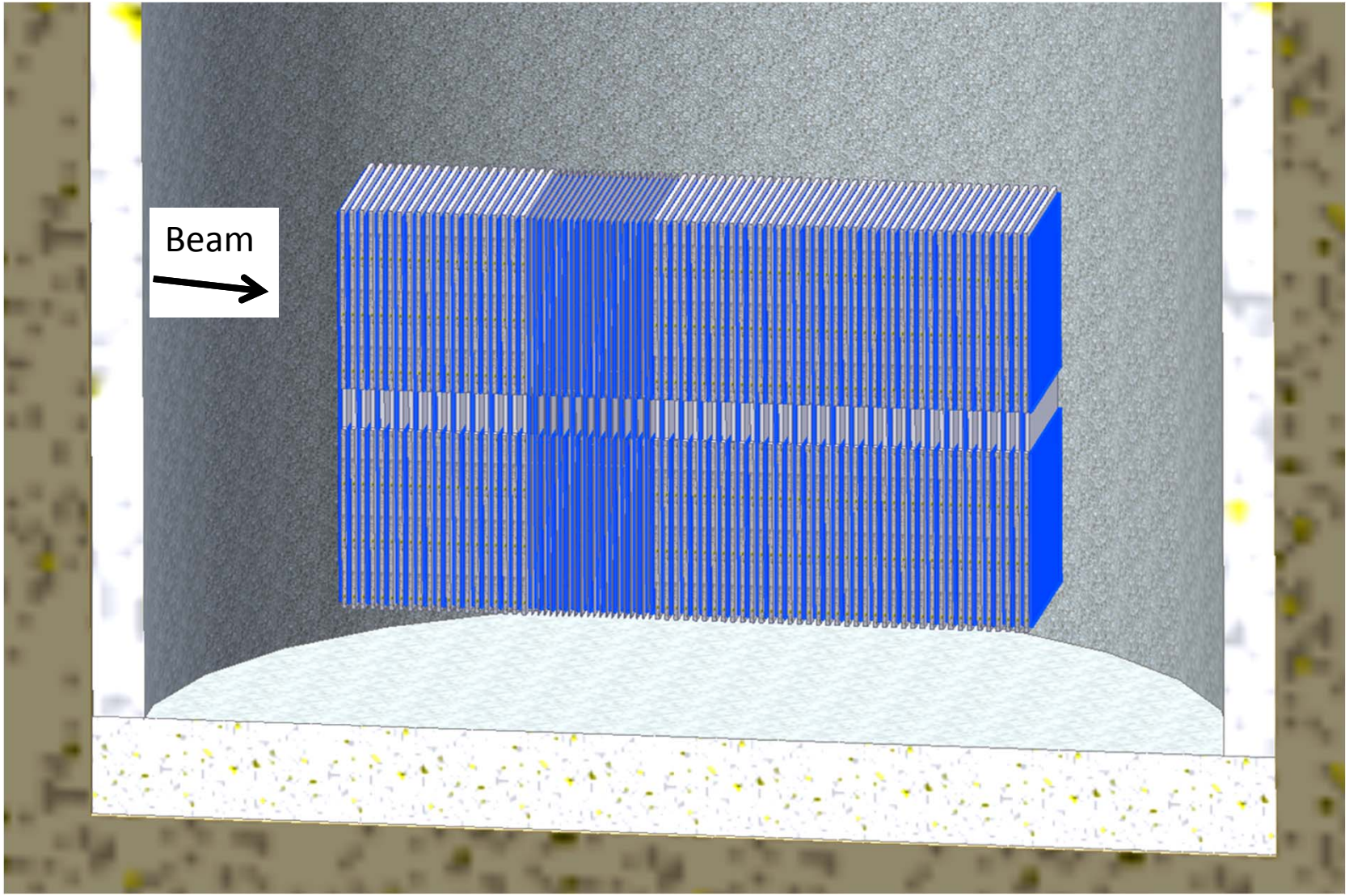
  The only mitigation would be to build a new beamline.

# LBNE Near Detector

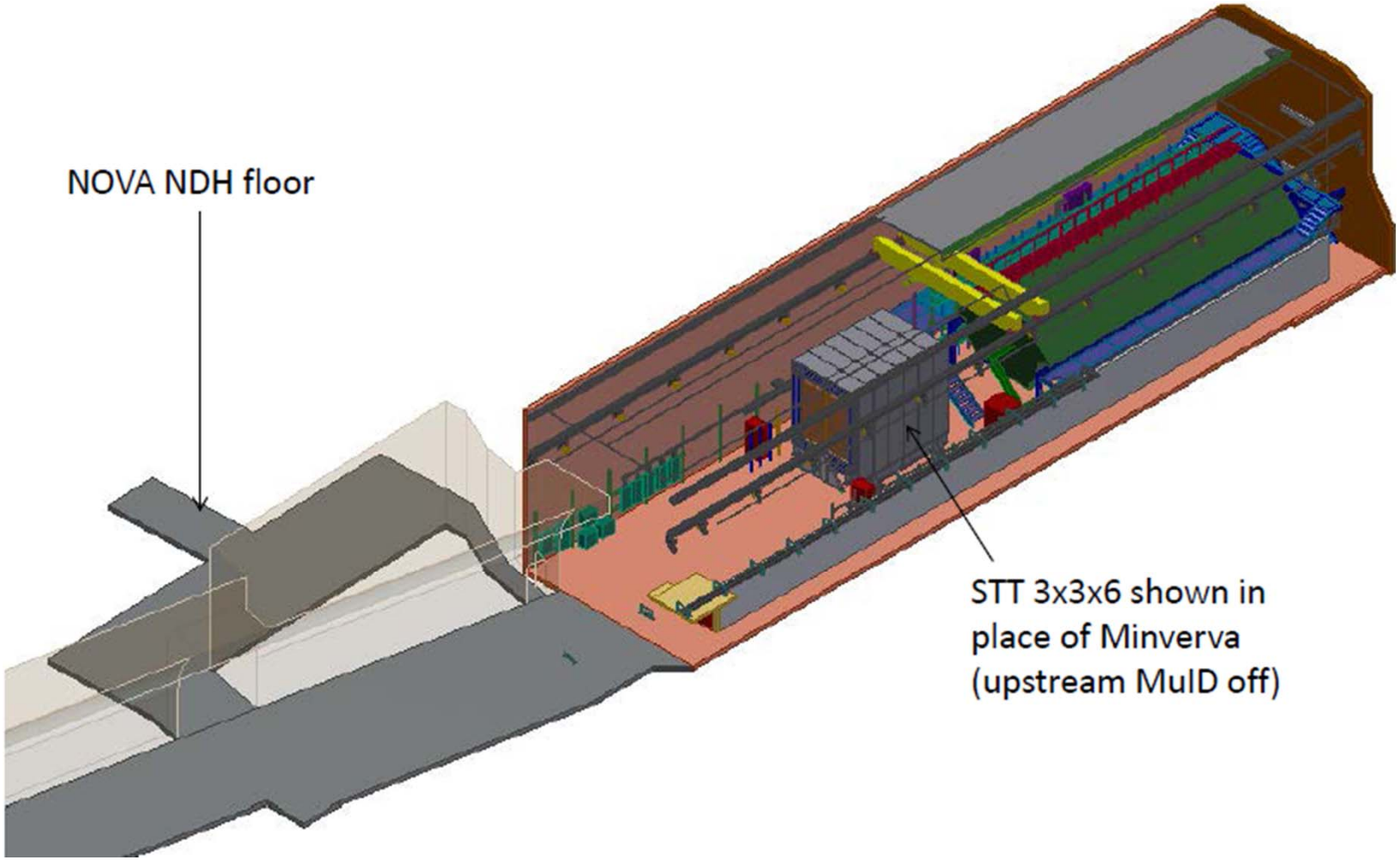
Mini Near Detector: Excavate main shaft only



# Mini Near Detector in Shaft



# Modified LBNE Near Detector in NuMI Near Hall



# Cost Estimate Methodology

- To the greatest extent possible, base estimates on well-reviewed LBNE cost estimates.
- New cost estimates developed for Soudan underground construction using U of MN A/E consultants.
- CF for surface construction based on actual NOvA costs.
- Value Engineering applied by reducing scope – simplifying or eliminating items not absolutely necessary – but utilizing the same fixed and unit costs developed for the reference design.
- Contingency applied at the same rates as in the reference design.
- Escalation estimated from the escalation tables used for the reference design and an assumed completion in FY2022.
- CD-1-type cost range estimated as same percentage range as for reference design.

# Summary Cost Estimate Tables - Homestake

| | FY2010 M$ | | | | AY M$ | AY M$ | | Top |
|---|---|---|---|---|---|---|---|---|
| | Base | | | | Esc. | Range | | End |
| | Budget | Total | Cont. | TPC3 | @ 1.25 | 0.75 | 1.13 | Cont. |
| 34 kt detector at Hometake (surface) + LBNE beam (phase 1) + no ND | | | | | | | | |
| Total | 644 | 247 | 38% | 892 | **1,115** | 830 | 1270 | 58% |
| Project Office | 42 | 15 | 36% | 57 | 71 | | | |
| Near Site Cost | 247 | 89 | 36% | 335 | 419 | | | |
| Far Site Cost | 356 | 144 | 40% | 499 | 624 | | | |
| 17 kt detector at Hometake (surface) + LBNE beam (phase 1) + no ND | | | | | | | | |
| Total | 528 | 203 | 38% | 730 | **913** | 680 | 1040 | 58% |
| Project Office | 38 | 13 | 36% | 51 | 64 | | | |
| Near Site Cost | 247 | 89 | 36% | 335 | 419 | | | |
| Far Site Cost | 243 | 100 | 41% | 343 | 429 | | | |
| *10 kt detector at Hometake (surface) + LBNE beam (phase 1) + no ND* | | | | | | | | |
| *Total* | *457* | *174* | *38%* | *631* | ***789*** | *590* | *900* | *58%* |
| *Project Office* | *35* | *13* | *36%* | *48* | *60* | | | |
| *Near Site Cost* | *247* | *89* | *36%* | *335* | *419* | | | |
| *Far Site Cost* | *175* | *73* | *42%* | *248* | *310* | | | |
| 5 kt detector at Hometake (surface) + LBNE beam (phase 1) + no ND | | | | | | | | |
| Total | 406 | 154 | 38% | 560 | **700** | 520 | 790 | 55% |
| Project Office | 33 | 12 | 36% | 45 | 56 | | | |
| Near Site Cost | 247 | 89 | 36% | 335 | 419 | | | |
| Far Site Cost | 127 | 53 | 42% | 180 | 225 | | | |

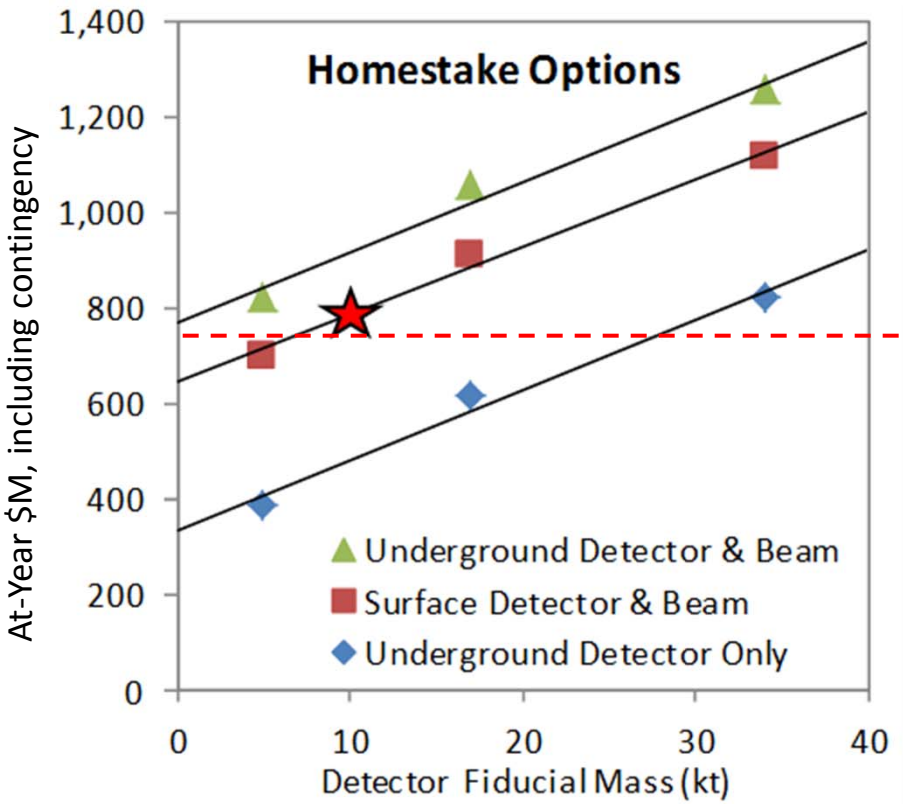
# Summary Cost Estimate Tables - Soudan

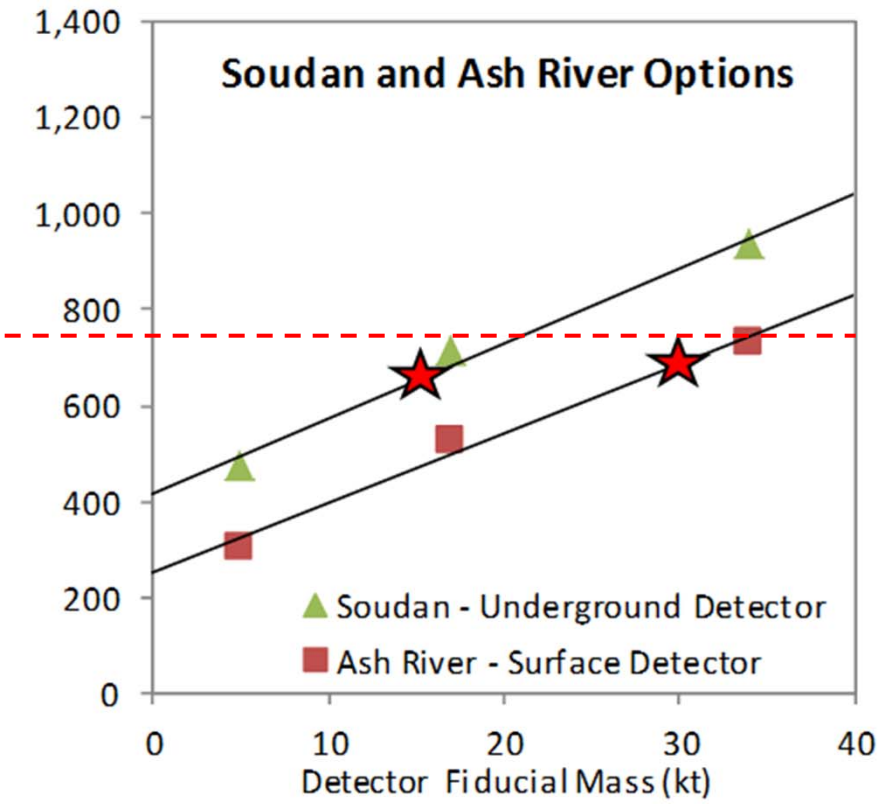
| | FY2010 M$ | | | | AY M$ | AY M$ Range | | Top |
|---|---|---|---|---|---|---|---|---|
| | Base Budget | Total | Cont. | TPC3 | Esc. @ 1.25 | 0.75 | 1.13 | End Cont. |
| 34 kt detector at Soudan (2340) + NuMI LE Beam (700 kW) + no ND | | | | | | | | |
| Total | 529 | 220 | 0.42 | 749 | **936** | 700 | 1060 | 60% |
| Project Office | 38 | 14 | 36% | 52 | 65 | | | |
| Near Detector | | | - | | | | | |
| NuMI upgrades/maintenance | 25 | 10 | 40% | 35 | 44 | | | |
| Far Site Cost | 465 | 196 | 42% | 662 | 827 | | | |
| 17 kt detector at Soudan (2340) + NuMI LE Beam (700 kW) + no ND | | | | | | | | |
| Total | 403 | 169 | 0.42 | 572 | **715** | 530 | 810 | 61% |
| Project Office | 33 | 12 | 36% | 45 | 57 | | | |
| Near Detector | | | - | | | | | |
| NuMI upgrades/maintenance | 25 | 10 | 40% | 35 | 44 | | | |
| Far Site Cost | 345 | 147 | 43% | 492 | 615 | | | |
| *15 kt detector at Soudan (2340) + NuMI LE Beam (700 kW) + no ND* | | | | | | | | |
| *Total* | *385* | *162* | *42%* | *540* | ***675*** | *500* | *770* | *60%* |
| *Project Office* | *32* | *12* | *36%* | *44* | *55* | | | |
| *Near Detector* | | | - | | | | | |
| *NuMI upgrades/maintenance* | *25* | *10* | *40%* | *35* | *44* | | | |
| *Far Site Cost* | *328* | *141* | *43%* | *461* | *577* | | | |
| 5 kt detector at Soudan (2340) + NuMI LE Beam (700 kW) + no ND | | | | | | | | |
| Total | 269 | 113 | 0.42 | 382 | **477** | 360 | 540 | 61% |

# Summary Cost Estimate Tables – Ash River

| | FY2010 M$ | | | | AY M$ | AY M$ | | Top |
|---|---|---|---|---|---|---|---|---|
| | Base | | | | Esc. | Range | | End |
| | Budget | Total | Cont. | TPC3 | @ 1.25 | 0.75 | 1.13 | Cont. |
| 34 kt detector at Ash River (surface) + NuMI LE beam (700 kW) + no ND | | | | | | | | |
| Total | 419 | 167 | 40% | 586 | **732** | 550 | 830 | 59% |
| Project Office | 34 | 12 | 36% | 46 | 57 | | | |
| Near Detector | | | - | | | | | |
| NuMI upgrades/maintenance | 25 | 10 | 40% | 35 | 44 | | | |
| Far Site Cost | 360 | 145 | 40% | 505 | 631 | | | |
| *30 kt detector at Ash River (surface) + NuMI LE Beam (700 kW) + no ND* | | | | | | | | |
| *Total* | *391* | *156* | *40%* | *547* | ***684*** | *510* | *780* | *60%* |
| *Project Office* | *33* | *12* | *36%* | *44* | *55* | | | |
| *Near Detector* | | | - | | | | | |
| *NuMI upgrades/maintenance* | *25* | *10* | *40%* | *35* | *44* | | | |
| *Far Site Cost* | *333* | *135* | *40%* | *468* | *585* | | | |
| 17 kt detector at Ash River (surface) + NuMI LE beam (700 kW) + no ND | | | | | | | | |
| Total | 300 | 121 | 41% | 421 | **527** | 390 | 600 | 60% |
| Project Office | 29 | 10 | 36% | 39 | 48 | | | |
| Near Detector | | | - | | | | | |
| NuMI upgrades/maintenance | 25 | 10 | 40% | 35 | 44 | | | |
| Far Site Cost | 246 | 101 | 41% | 348 | 435 | | | |
| 5 kt detector at Ash River (surface) + NuMI LE beam (700 kW) + no ND | | | | | | | | |
| Total | 174 | 71 | 41% | 245 | **306** | 230 | 350 | 61% |

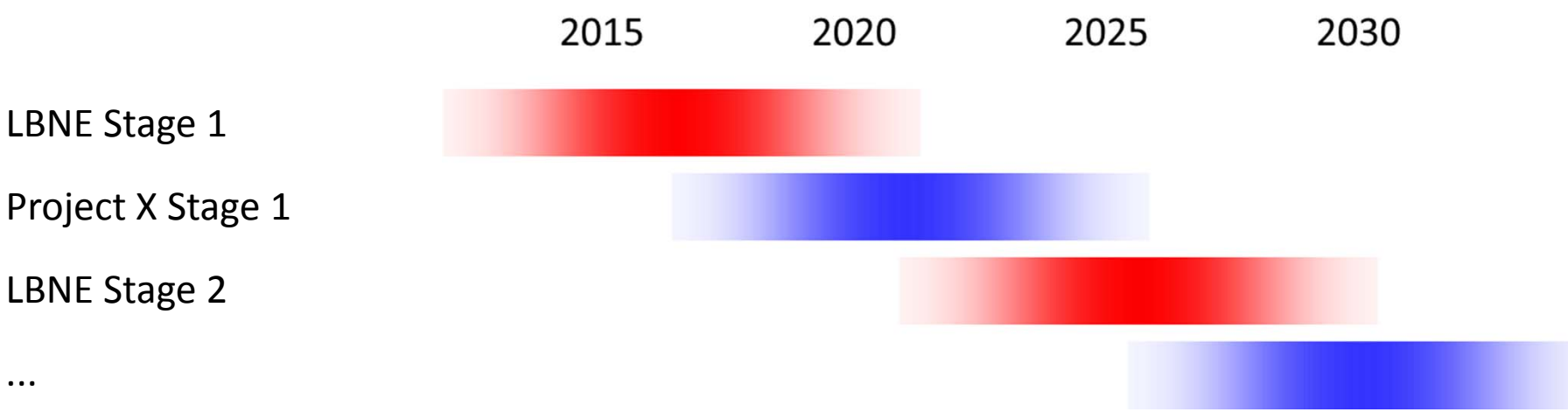
# Cost vs. Detector Mass



# Phasing Possibilities: An Example*

1) LBNE Phase 1: 10 kt LAr detector on surface at Homestake + LBNE beamline (700 kW)
2) Project X Phase 1 → 1.2 MW LBNE beam
3) LBNE Phase 2: a) Near Detector,
   b) ~20 kt underground far detector

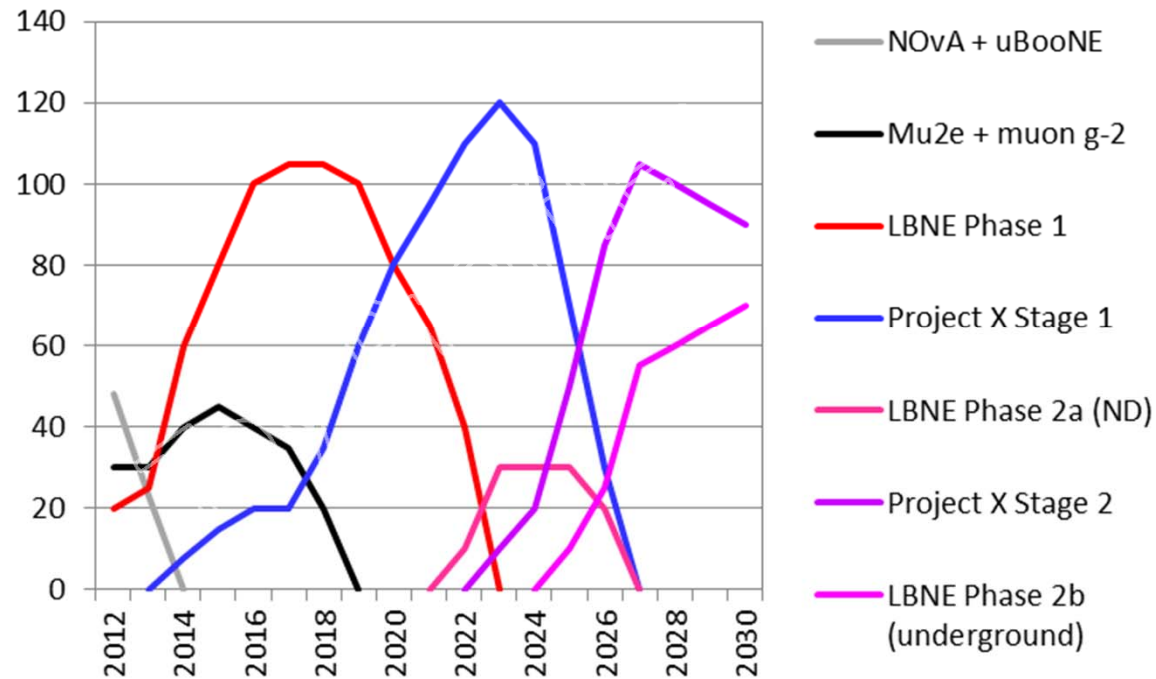



*A little beyond what is in the Eng/Cost WG report

# Phasing Possibilities: Another Example*

1) LBNE Phase 1: 10 kt LAr detector on surface at Homestake + LBNE beamline (700 kW)
2) Project X Phase 1 → 1.2 MW LBNE beam
3) LBNE Phase 2a: Near Detector
4) Project X Phase 2
5) LBNE Phase 2b: ~25 kt underground far detector

*Expanded collaboration could allow part or all of Phase 2a or 2b into Phase 1.*




*A little beyond what is in the Eng/Cost WG report

# Work in Progress

For the final Steering Committee report:

- Add discussion on the relative risks of each of the scenarios..
- Add a chapter comparing the scope and cost estimates presented here with those of the LBNE reference design.

For the final Steering Committee report and beyond:

- Study physics reach without near neutrino detector – at what exposure must we have a near detector to limit systematic errors and is this consistent with phase 2a?
- Develop mitigation of cosmic ray background in surface detector and update designs as new understanding develops.

# Plan Towards CD-1

| | |
|---|---|
| Complete Final Report of the Steering Committee | Jun 2012 |
| Update conceptual designs and sub-project cost and schedule estimates | Jun-Sep 2012 |
| Update integrated resource loaded schedule and complete other project documents | Oct-Nov 2012 |
| Director's pre-CD-1 Review | Dec 2012 |
| DOE (Lehman) CD-1 Review | Feb 2013 |
| CD-1 Approval | Apr 2013 |

# Summary

- The Engineering/Cost Working Group has developed designs and cost estimates for many options for far detectors, near detectors and neutrino beamlines.
- From these, three viable options for Phase 1 of a reconfigured LBNE have been identified by the Steering Committee.
- LBNE is adapting its design and project plan based on the preferred Phase 1 option of a 10 kt detector at Homestake with a new neutrino beam.
- The LBNE Project is working towards a CD-1 decision in spring 2013.
- We are exploring how to expand the LBNE collaboration to allow us to come closer to the original LBNE plan in Phase 1.