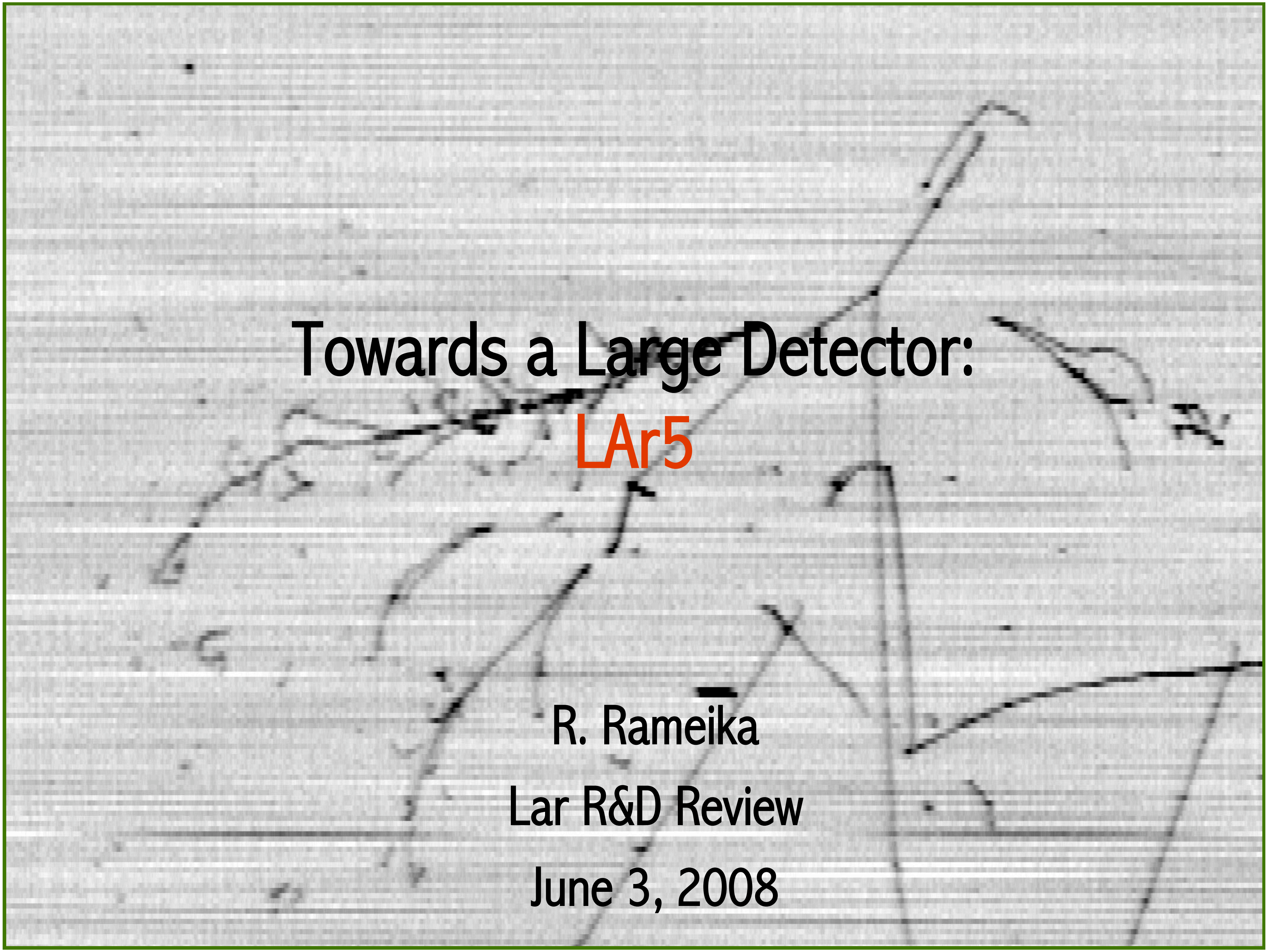


Towards a Large Detector:

LAr5

R. Rameika

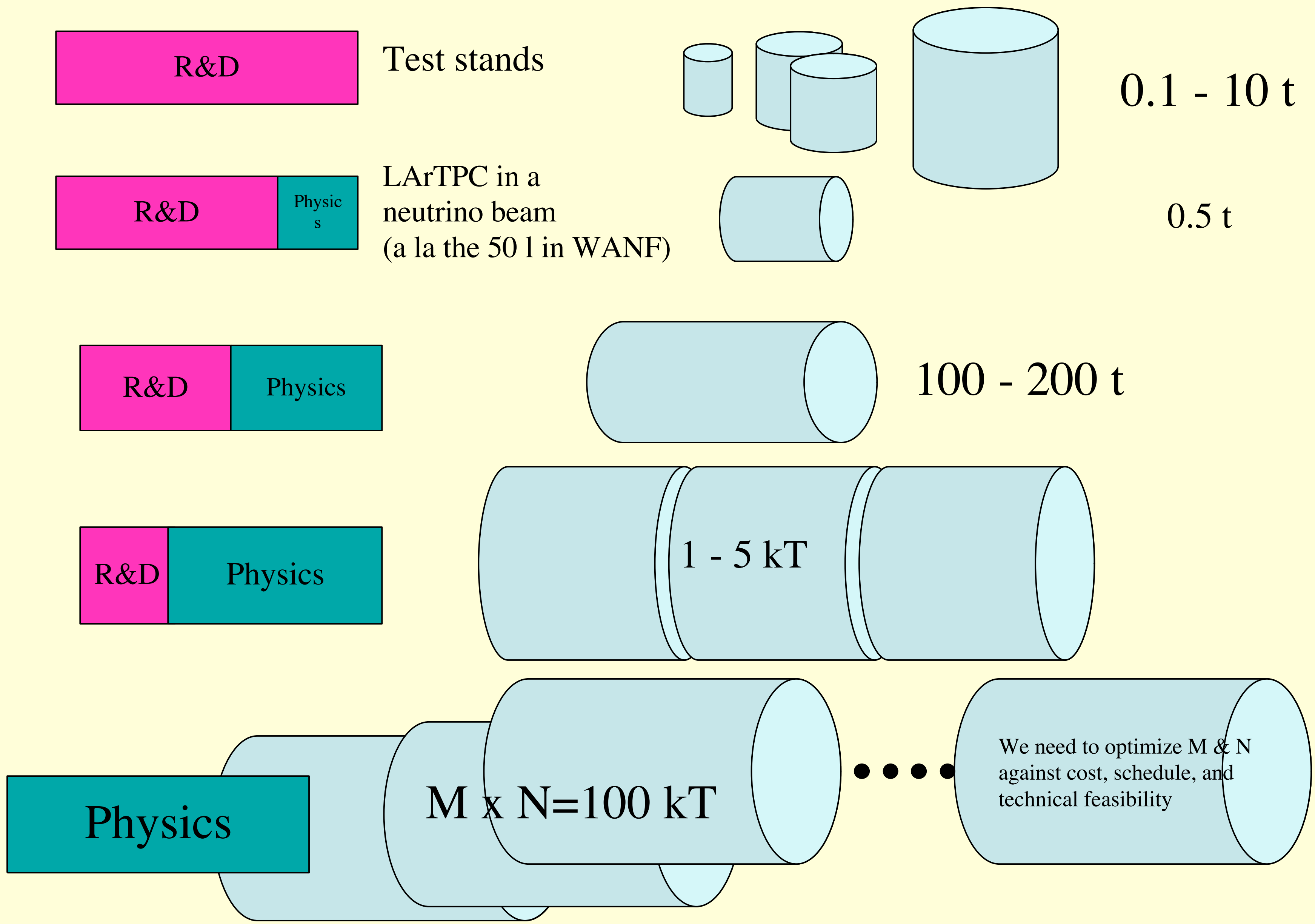
Lar R&D Review

June 3, 2008

Outline

- Why a 5 kiloton step?
- Siting Options
- Technical Issues
  - Evolution from MicroBooNE
  - Unique to larger detectors
- Schedule Considerations
- Conclusion

Evolution of a Liquid Argon Physics Program

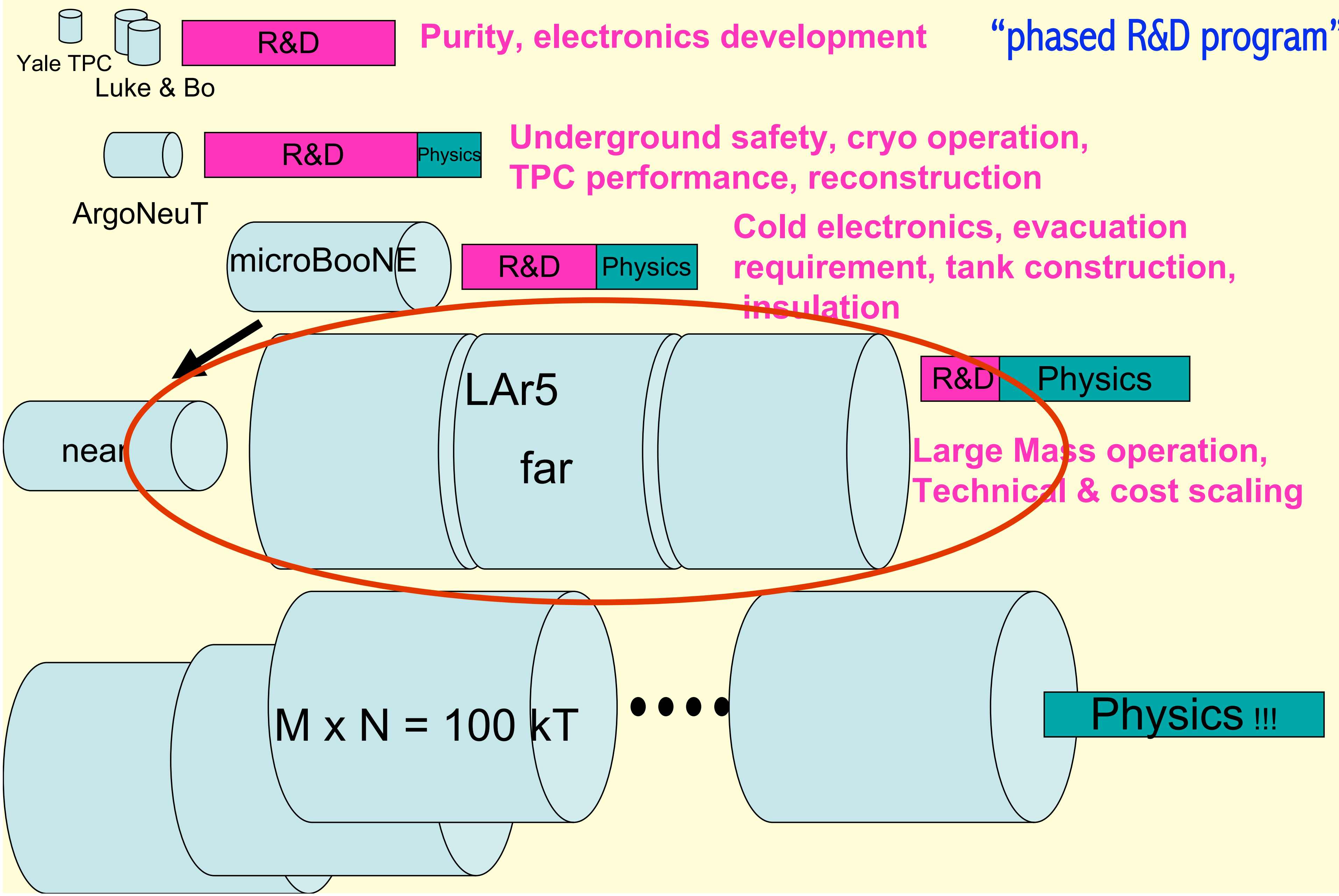


Why a 5 kiloton step?

- From a purely technical point of view, the step after the 100 - 200 t detector, could be 1 to 5 kilotons
  - The main technical purpose of this step is to determine construction techniques and the scaling laws, especially in regards to cost
- Location of 1 - 5 kilotons
  - 1 kT in a near location gets lots of events; does near detector physics - no oscillation physics
  - 5 kT in a far location is about the smallest one can build and have decent sensitivity to physics measurements

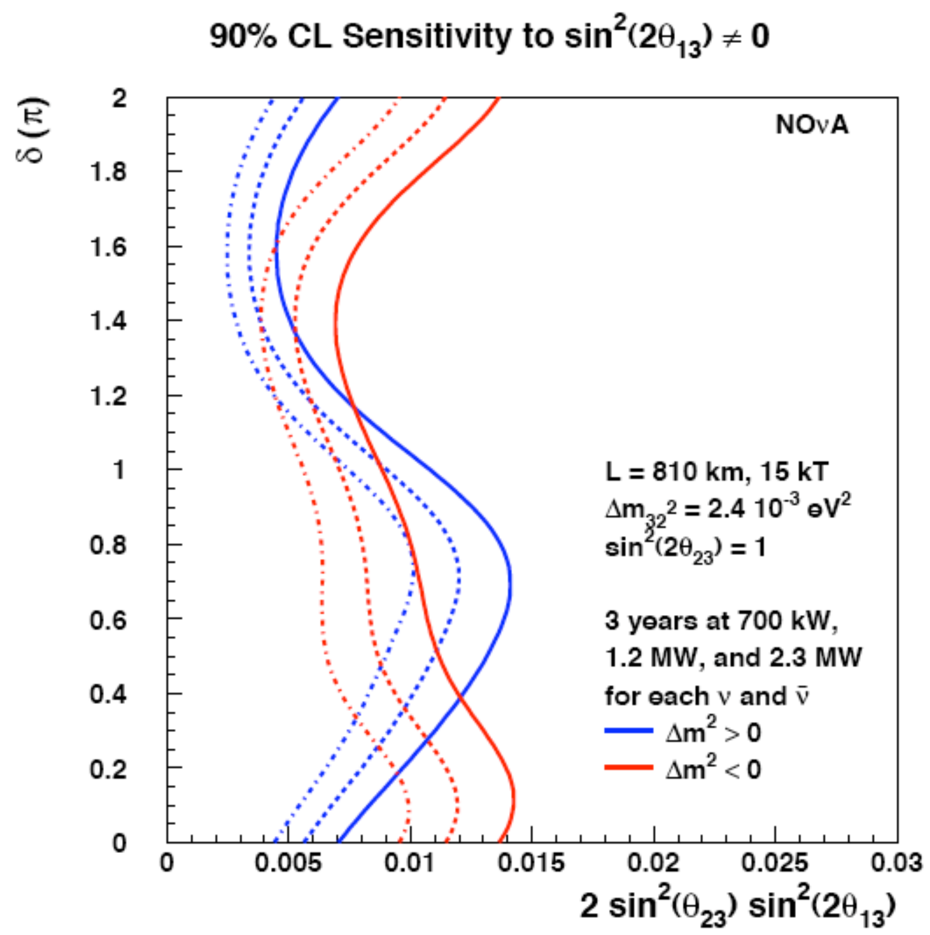
5kT is an appropriate step in mass and has compelling physics potential

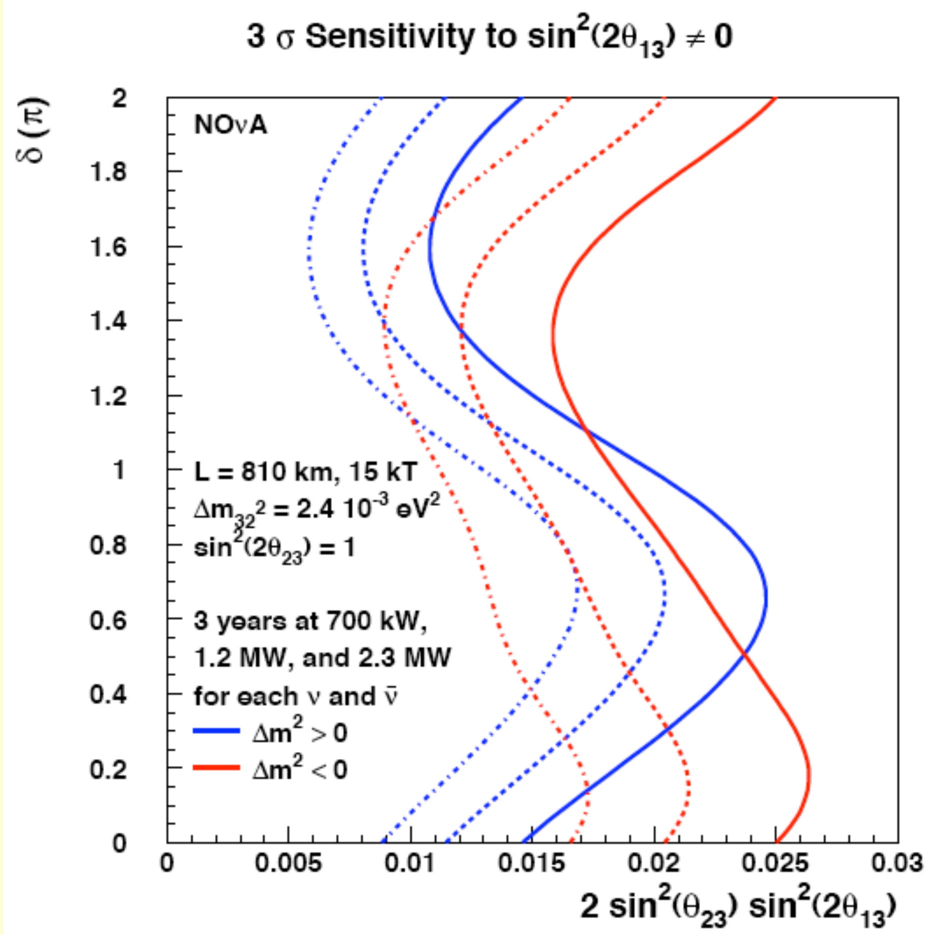
Evolution of the Liquid Argon Physics Program



NOvA sensitivity to $\sin^2(2\theta_{13}) \neq 0$

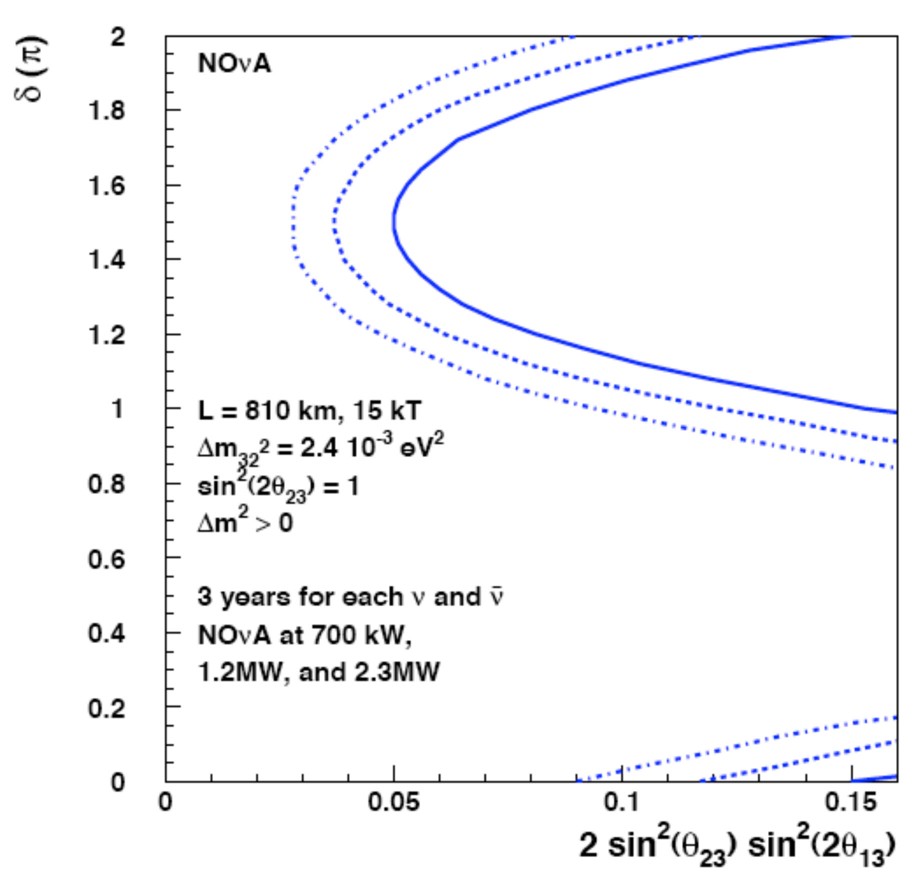
(P5)



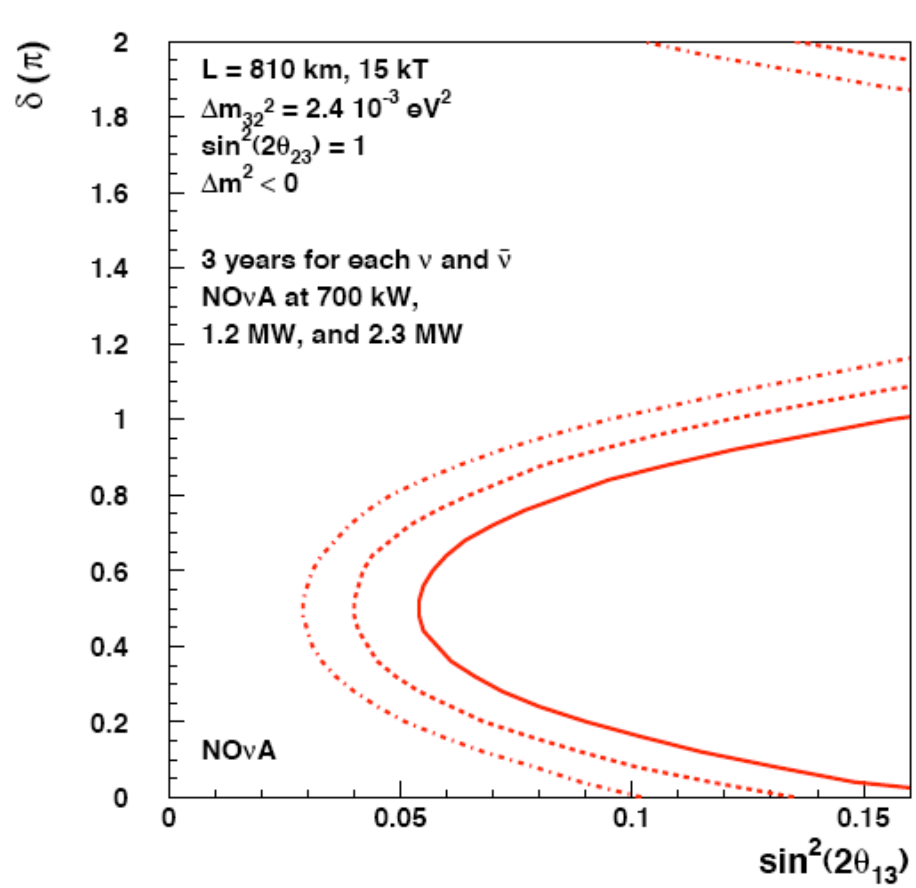


NOνA 95% CL Resolution of the Mass Ordering

(P5)

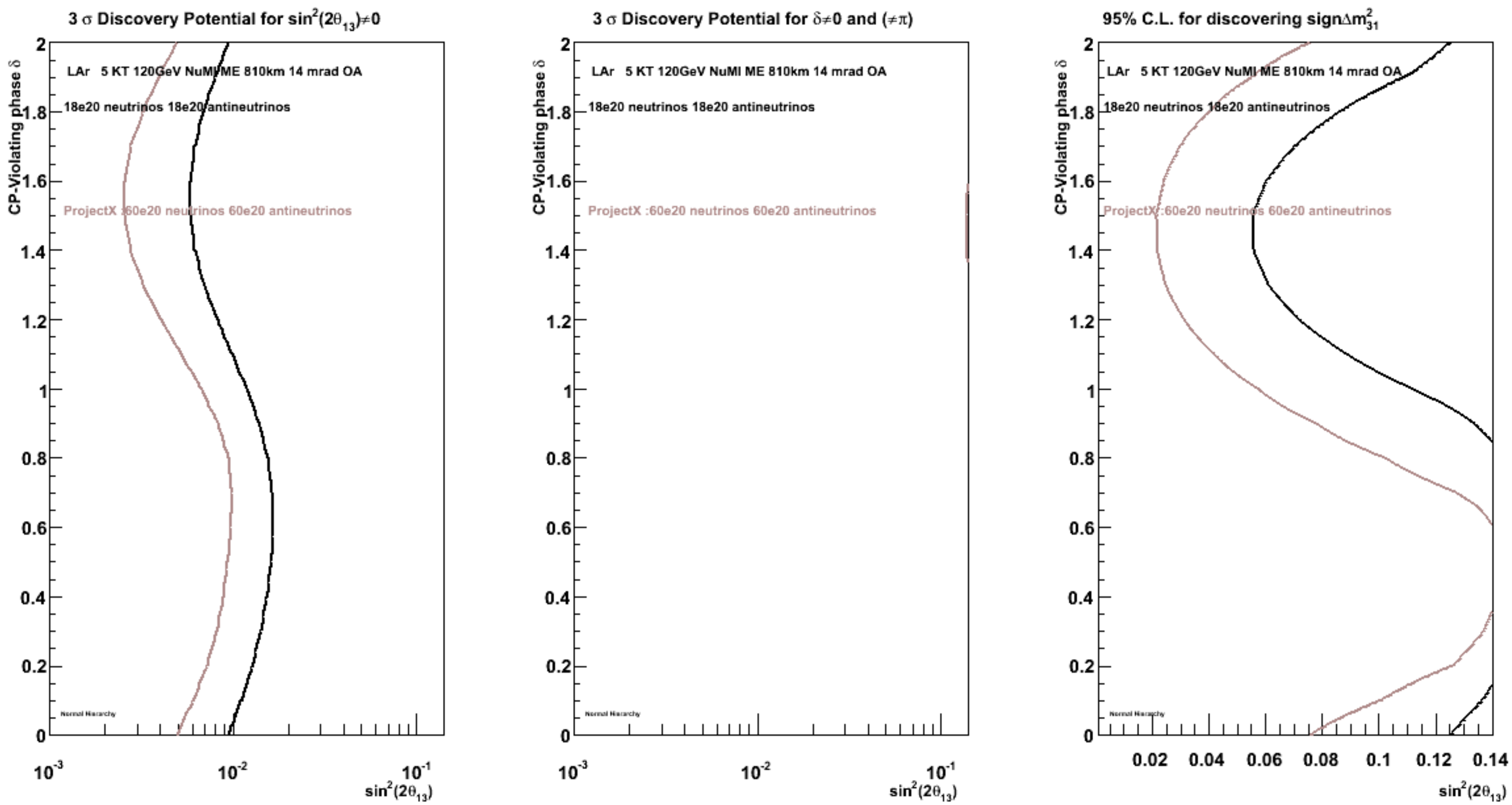


Normal Ordering

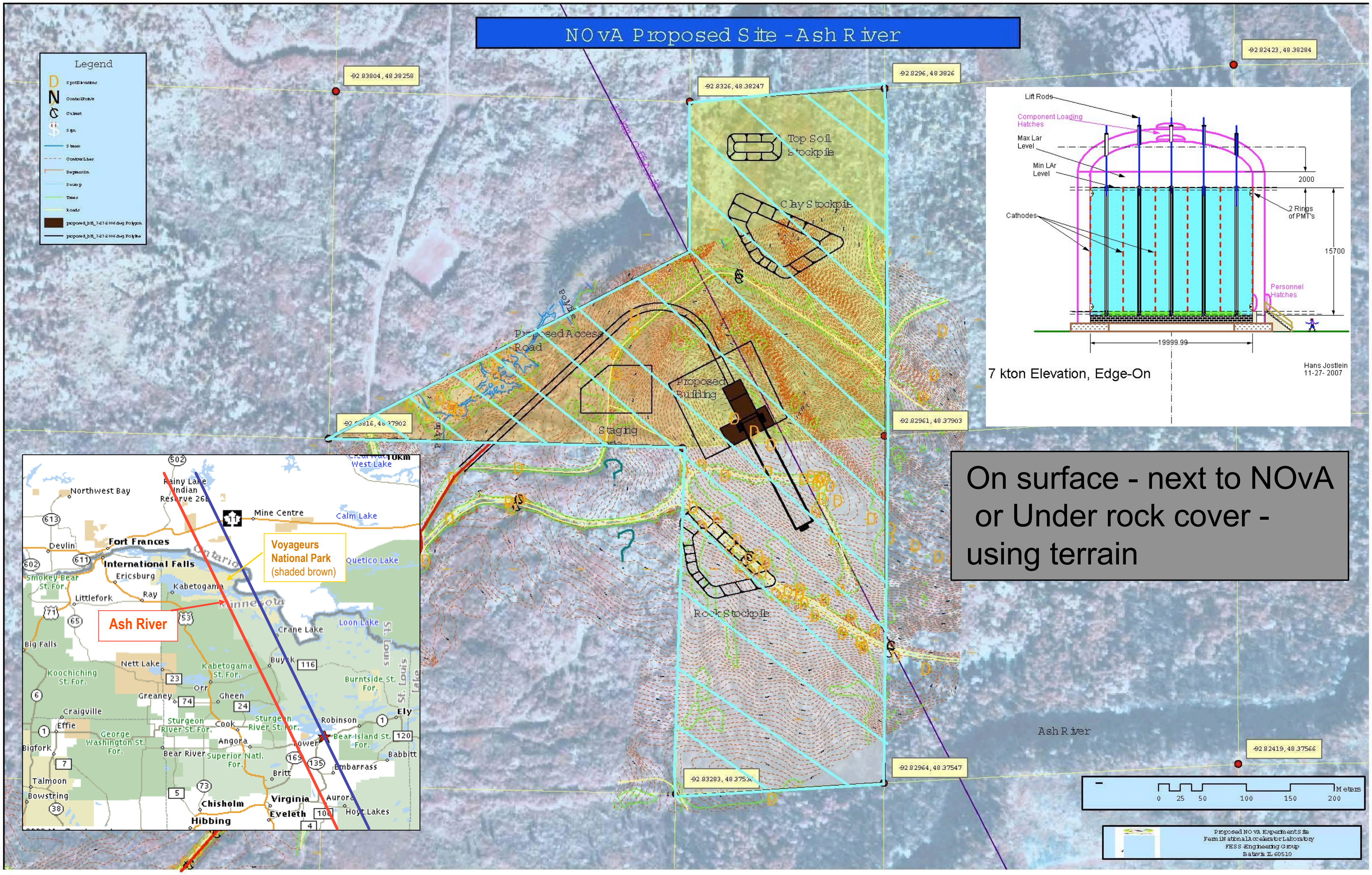


Inverted Ordering

LAr5 @ Ash River (ME)

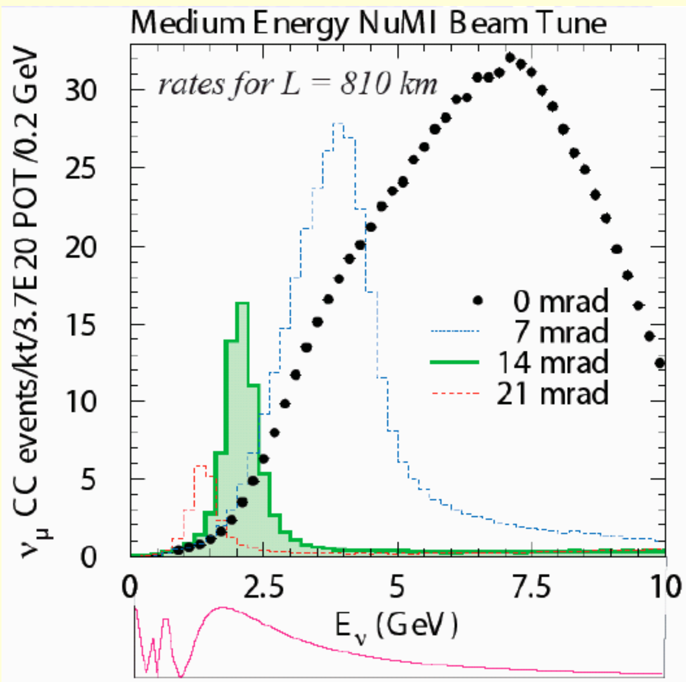


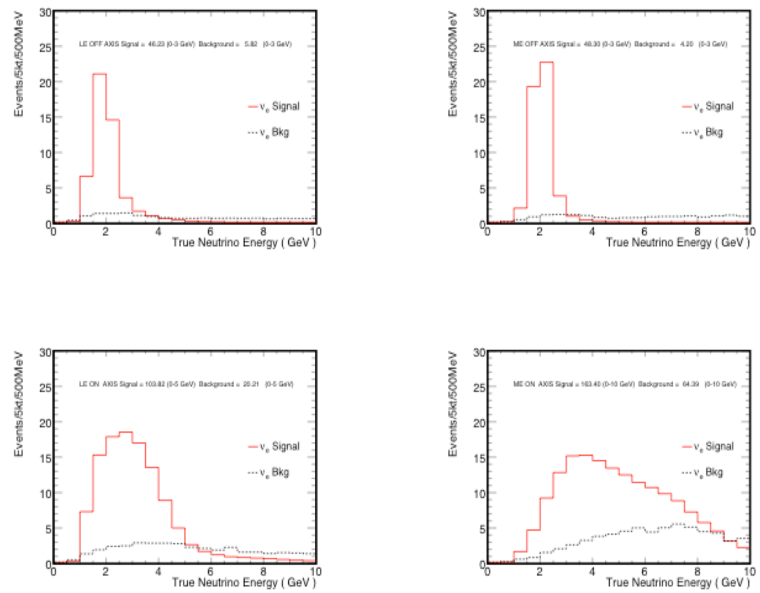
Siting options at Ash River



Detector Siting Options

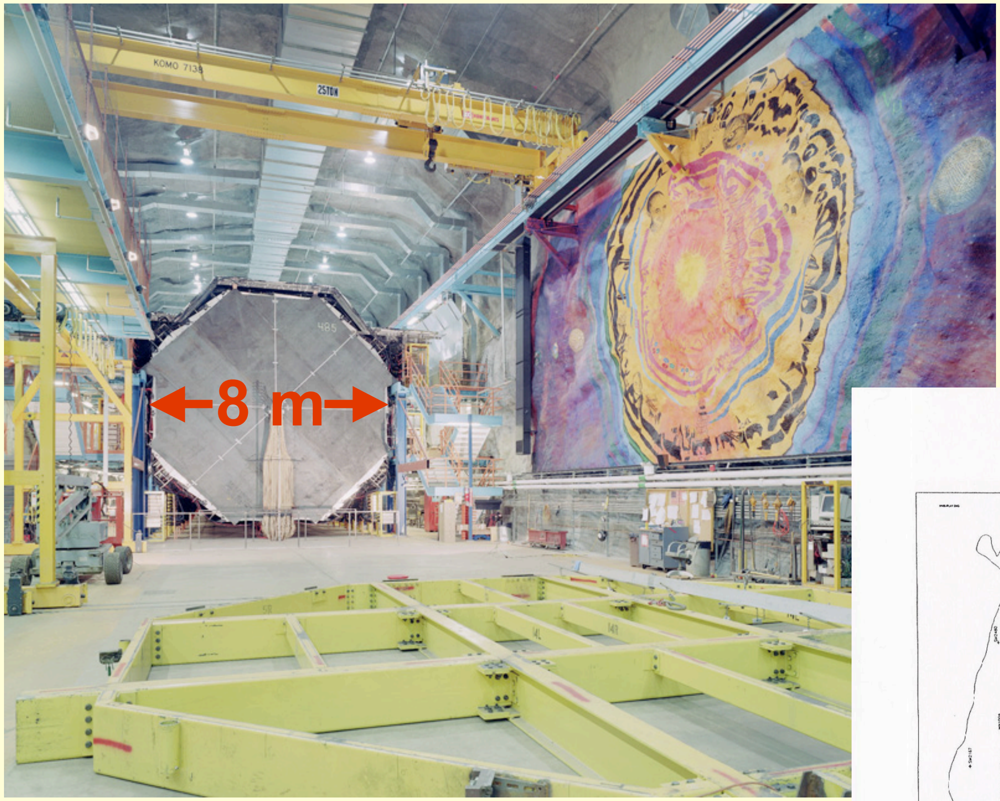
- Off-axis neutrinos
  - Reduced backgrounds from neutral current interactions
    - Reason for NOvA choice
  - Lower the energy to get closer to the oscillation maximum
    - Reason for the MODULAr choice
- On-axis neutrinos
  - Broadband beam : more events, both signal and background
  - On-axis option can be considered if the detector has excellent NC π^0/γ rejection

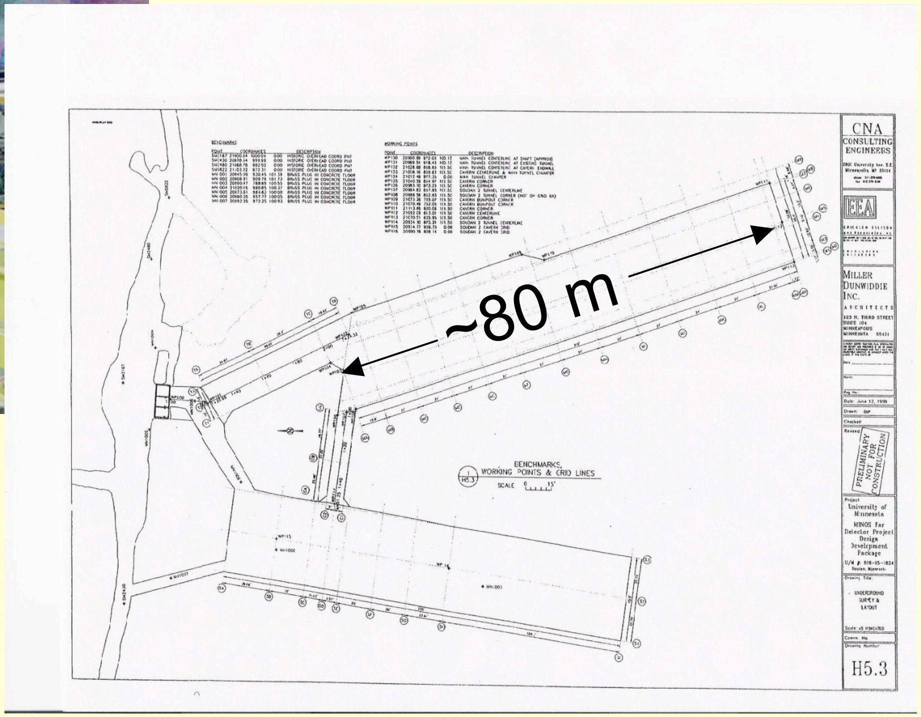




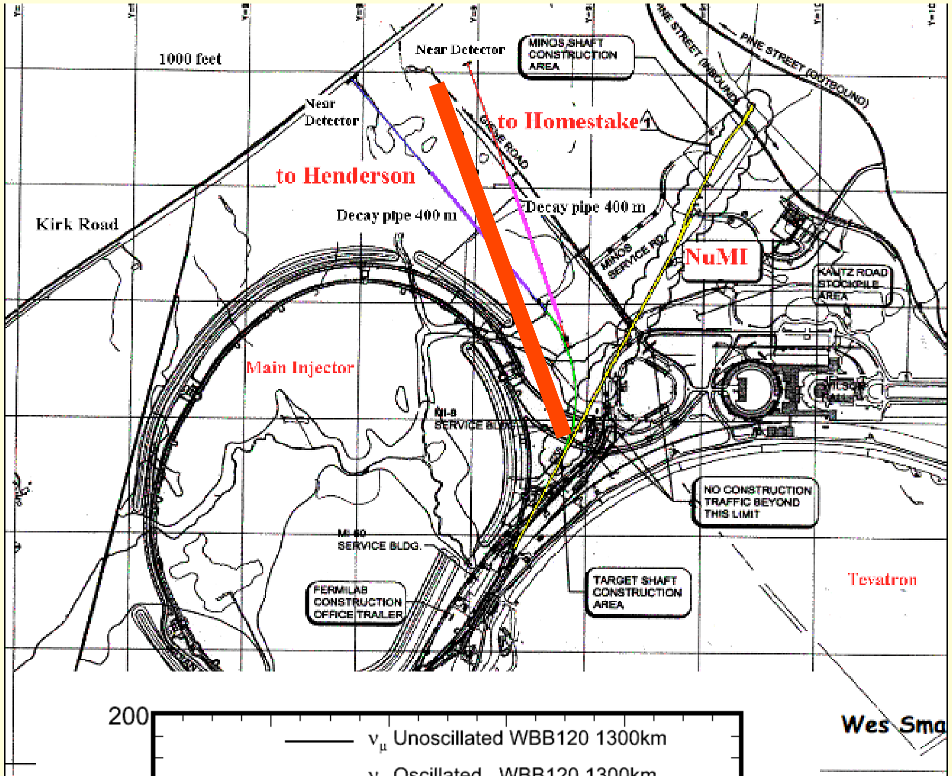
ν_e signal for $\sin^2 2\theta_{13} = 0.1$

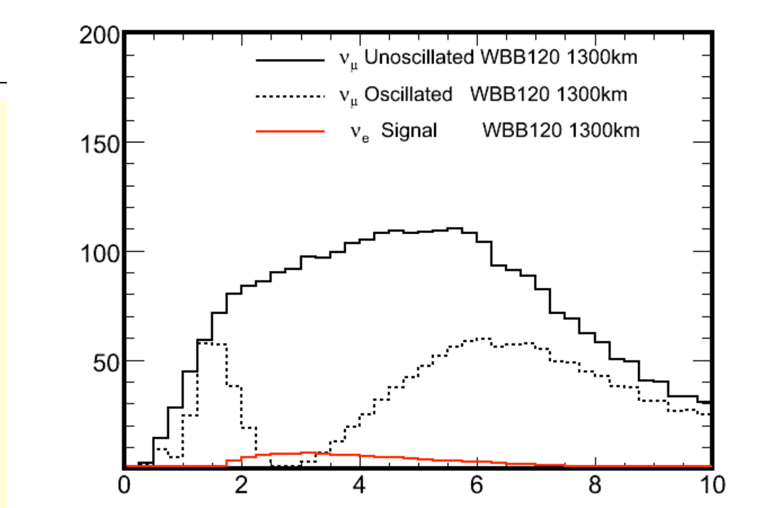
The MINOS Cavern at the Soudan Underground Laboratory

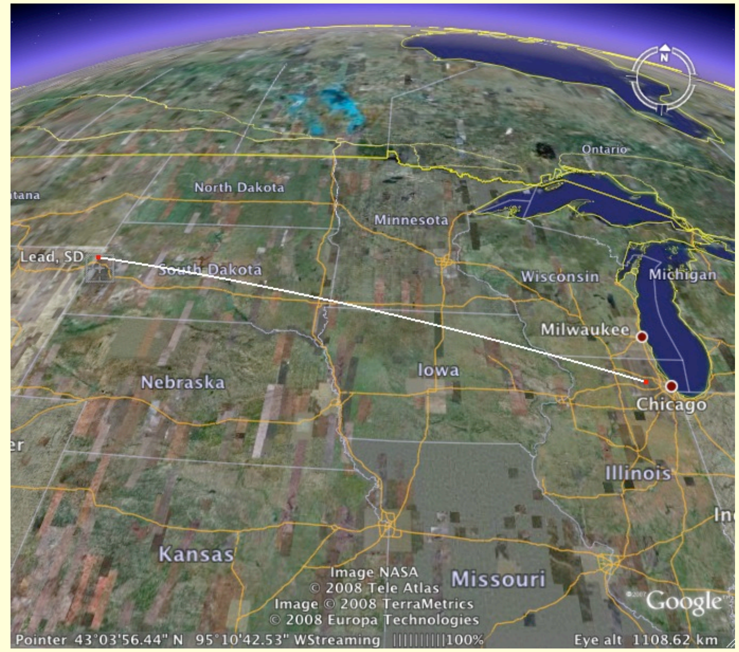




The DUSEL Option





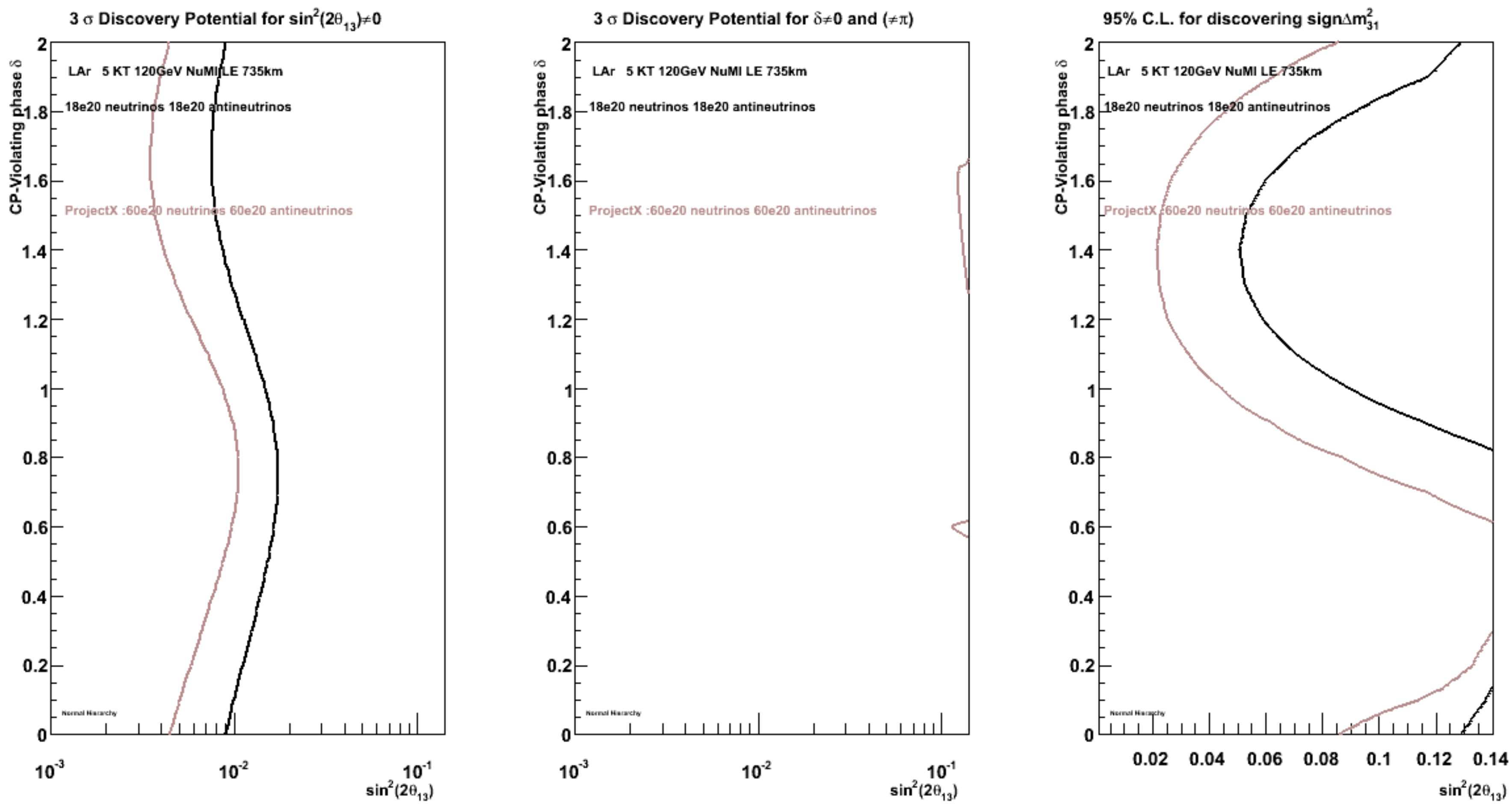


L = 1300 km (more matter effect in the oscillations

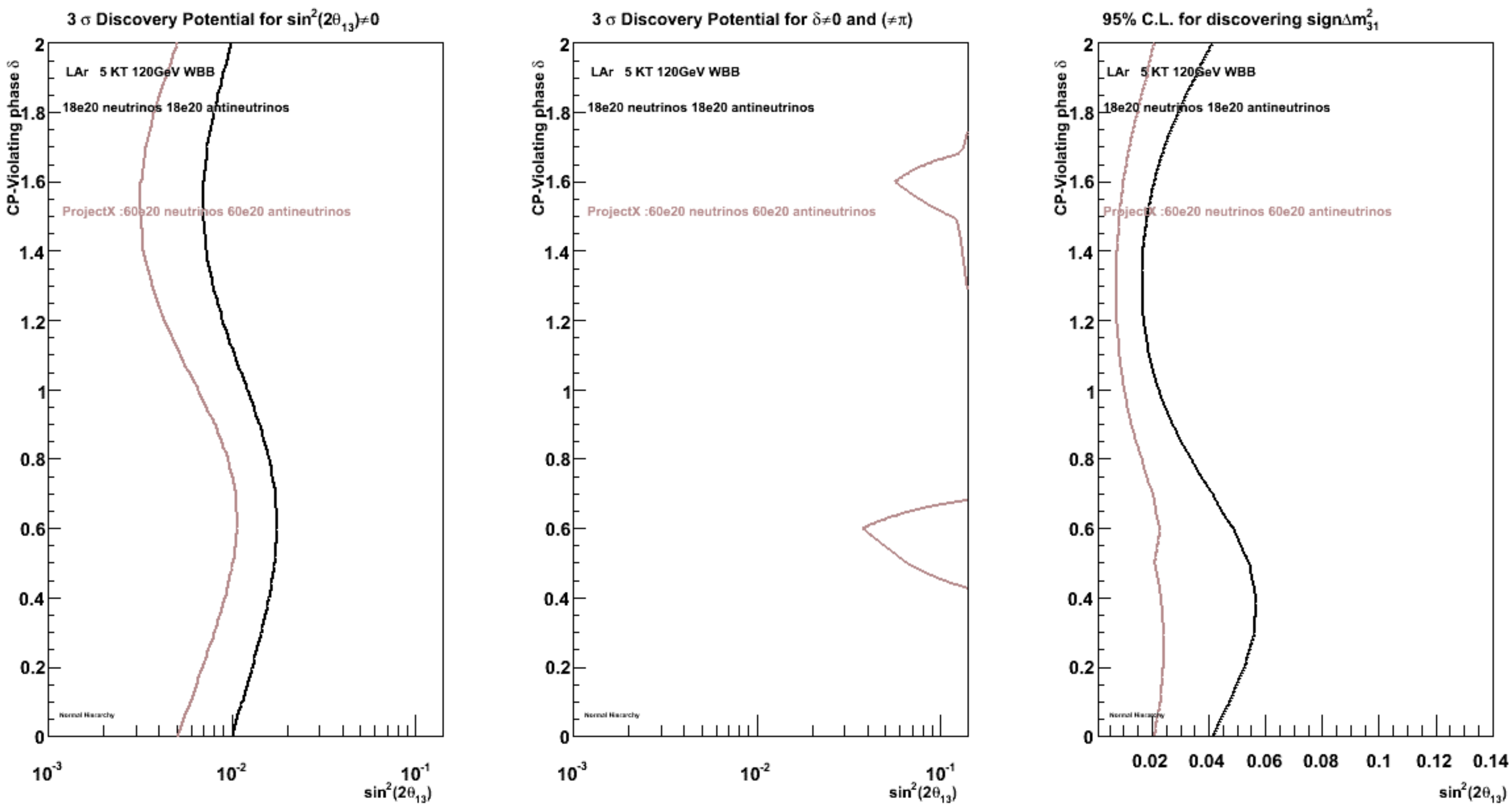
Oscillation maximum at higher energies

Broad band beam can cover 1st and 2nd maximum

LAr5 @ SOUDAN (LE)



LAr5 @ L = 1300 km



Pros and Cons of the NuMI Options

- Cons :
  - The NuMI beam exists; the baseline is limited to 735km on axis and 810 km off-axis; the decay pipe geometry is optimized for high energy
  - The Ash River site is being developed for NOvA; additional site development might not be practical on a fast time scale
  - The Soudan cavern holds a maximum of ~5kT : no upgrade path
  - Physics reach is comparable to NOvA : good for θ_{13}, limited for mass hierarchy

Pros and Cons of the NuMI Options

- Pros :
  - The NuMI beam exists; it will be upgraded to 700kW for NOvA
  - Ash River
    - The Ash River site will be developed for NOvA; LAr5 could benefit from the infrastructure
  - Soudan
    - The SOUDAN cavern + laboratory infrastructure exists; MINOS will complete its running ~2011; disassembly and removal of MINOS was built into the planning
    - The cavern holds a maximum of ~5kT : no scope creep!
    - Requires us to address underground construction & operation
    - The underground location eliminates the concern about surface operation (which in principle is possible, but likely to lead to additional challenges)
      - Any detector constructed for proton decay will need to be at depth
      - This 5kT may be able to make a contribution to the $p \rightarrow K\nu$ search
  - Physics reach is comparable to NOvA → ~doubling the mass

Pros and Cons of the DUSEL Option

- Cons :
  - The DUSEL beam doesn't exist; minimum 5 year, >$200M construction project
  - DUSEL caverns do not exist, even for 5 kT; preliminary estimate at 300' level ~$25M
- Pros :
  - The DUSEL beam doesn't exit : we can design an optimized beam
  - The cavern doesn't exist ; can be planned for future expansion
  - Two options for depth : 300' drive-in, 4850' to be developed
  - The underground location eliminates the concern about surface operation (which in principle is possible, but likely to lead to additional challenges)
    - Any detector constructed for proton decay will need to be at depth
    - This 5kT may be able to make a contribution to the $p \rightarrow K\nu$ search
  - Plans for an early implementation in progress (SUSEL) [April Workshop]
  - Physics reach for θ_{13} is comparable to NOvA; better for mass hierarchy
  - Eventually sensitivity to CP Violation

Technical Issues

Many technical issues will be addressed directly in the design, construction, and operation of the MicroBooNE detector, however for the larger scale there are many more unique issues

- Design Considerations
  - Liquid Argon purity → maximum drift → channel count
  - Thermal insulation → Operation cost
  - Location : surface/underground
    - Cryostat design
    - Cryogenic Safety
    - Cosmic ray backgrounds
    - Cavern/enclosure design
- Scaling considerations
  - Modularity
  - Shape
  - Total-Fiducial-Active volume ratio
  - Number of electronic channels
  - Surface-to-volume ratio (heat input and wall outgassing)
  - Cryostat thermal insulation techniques
  - Materials and construction techniques

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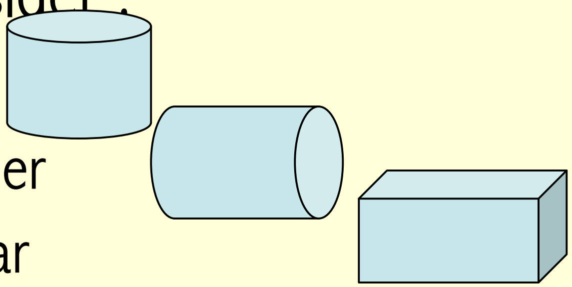
  - Cryostat thermal insulation techniques
  - Materials and construction techniques

Cavern/enclosure design

Content from Chris L. presentations……

Cryostat Shape

- Three options to consider :
  - 1) Upright cylinder
  - 2) Longitudinal cylinder
  - 3) Square/Rectangular



- Mechanical Engineering input :
  - Option 1 is the most straight forward, economical device
- Cavern engineering input :
  - Options 2 and 3 are more favorable

- Study in progress to evaluate the cost and technical tradeoffs

ICARUS concept evolution : Project MODULAr

arXiv:0704.1422v1 [hep-ph] 11 Apr 2007

A new, very massive modular Liquid Argon Imaging Chamber to detect low energy off-axis neutrinos from the CNGS beam.

(Project MODULAr)

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Abstract.

The paper is considering an opportunity for the CERN/GranSasso (CNGS) neutrino complex, concurrent time-wise with T2K and NOvA. It is a preliminary description of a ≈ 20 kt fiducial volume LAr-TPC following very closely the technology developed for the ICARUS-T600, which will be operational as CNGS2 early in 2008.

The present preliminary proposal, called MODULAr, is focused on the following three main activities, for which we seek an extended international collaboration:

(1) *the neutrino beam* from the CERN 400 GeV proton beam and an optimised horn focussing, eventually with an increased intensity in the framework of the LHC accelerator improvement programme.

(2) A *new experimental area* LNGS-B, of at least 50'000 m^3 at 10 km off-axis from the main Laboratory, eventually upgradable to larger sizes. As a comparison, the present LNGS laboratory has three halls for a total of 180'000 m^3. A location is under consideration at about 1.2 km equivalent water depth. The bubble chamber like imaging and the very fine calorimetry of the LAr-TPC detector will ensure the best background recognition not only from the off-axis neutrinos from the CNGS but also for proton decay and cosmic neutrinos.

(3) *A new LAr Imaging* detector, at least initially with about 20 kt fiducial mass. Such an increase in the volume over the current ICARUS T600 needs to be carefully considered. It is concluded that a single, huge volume of such a magnitude is uneconomical and inoperable for many reasons. A very large mass is best realised with a modular set of many identical, but independent units, each of about 5 kt, "cloning" the basic technology of the T600. Several of such modular units will be such as to reach at least 20 kt as initial sensitive volume. Further phases may foresee extensions of MODULAr to a mass required by the future physics goals.

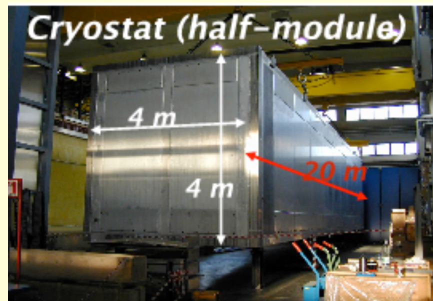
Compared with large water Cherenkov (T2K) and fine grained scintillators (NOvA), the LAr-TPC offers a higher detection efficiency for a given mass and lower backgrounds, since virtually all channels may be unambiguously recognized. In addition to the search for θ_{13} oscillations and CP violation, it would be possible to collect a large number of accurately identified cosmic ray neutrino events and perform search for proton decay in the exotic channels.

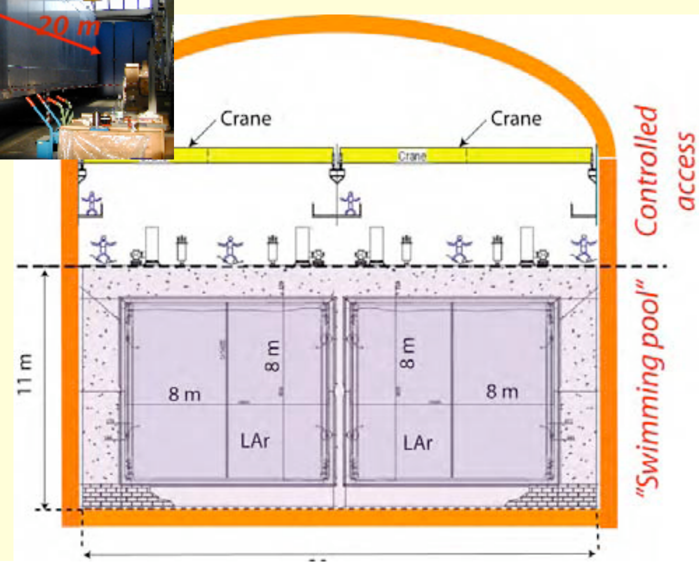
The experiment might reasonably be operational in about 4/5 years, provided a new hall is excavated in the vicinity of the Gran Sasso Laboratory and adequate funding and participation are made available.

(April 9,2007)

[A] Corresponding author: Carlo.Rubbia@cern.ch

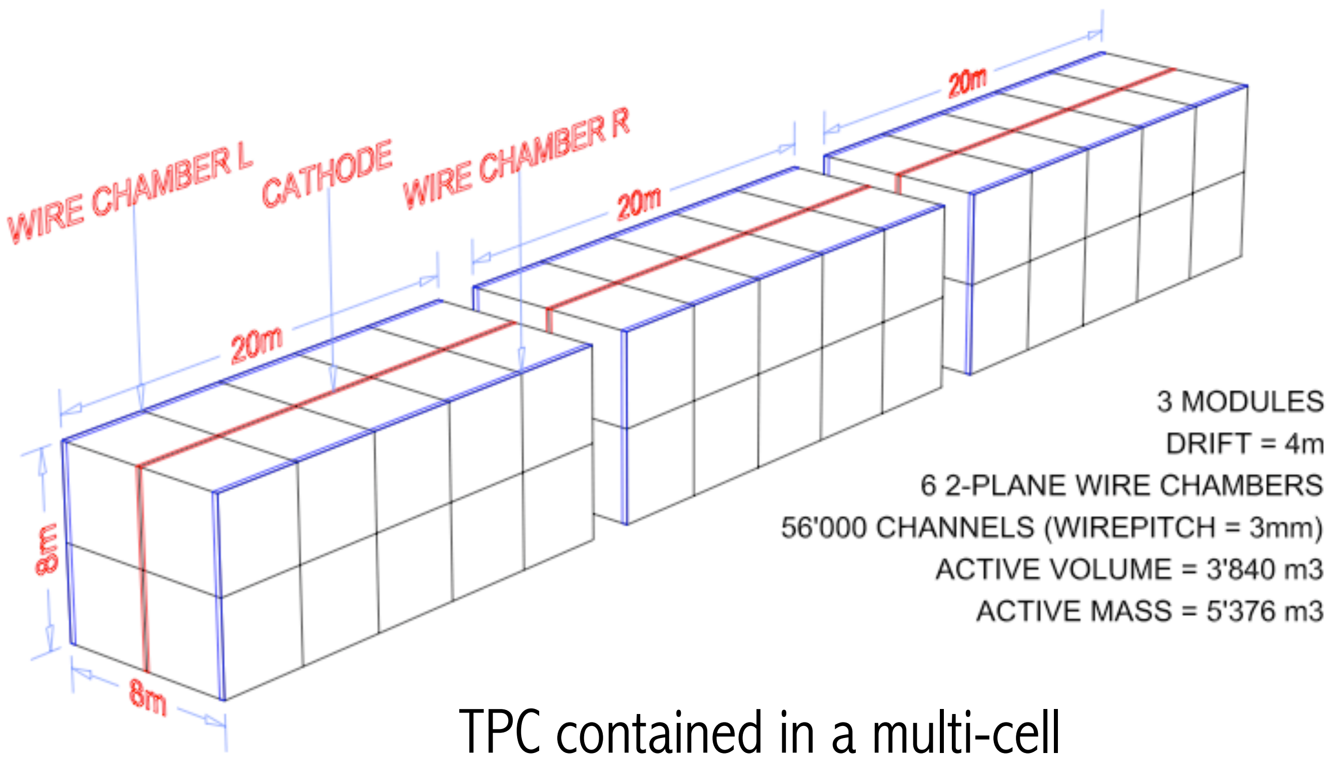
- ~20kT fiducial volume, modeled after ICARUS T-600
  - Upgraded neutrino beam from the 400 GeV CERN SPS
  - New experimental area 10 km off-axis of CNGS neutrino beam
  - Multiple 5kT LArTPCs
    - ($8x8x60 m^3$ per 5kT unit)





LANNDD Modular Concept

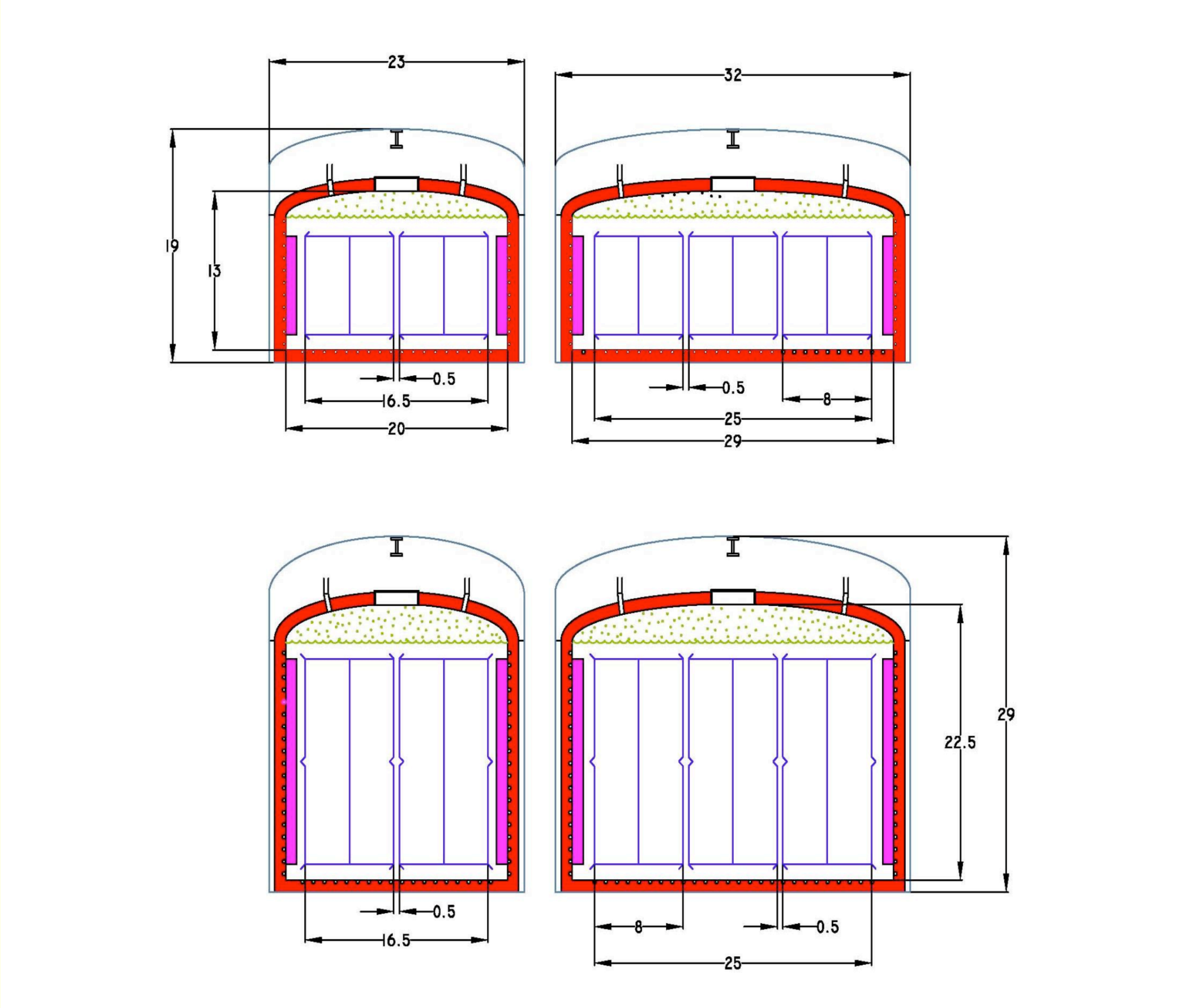
5 kT is 8 x8 x 60 m^3



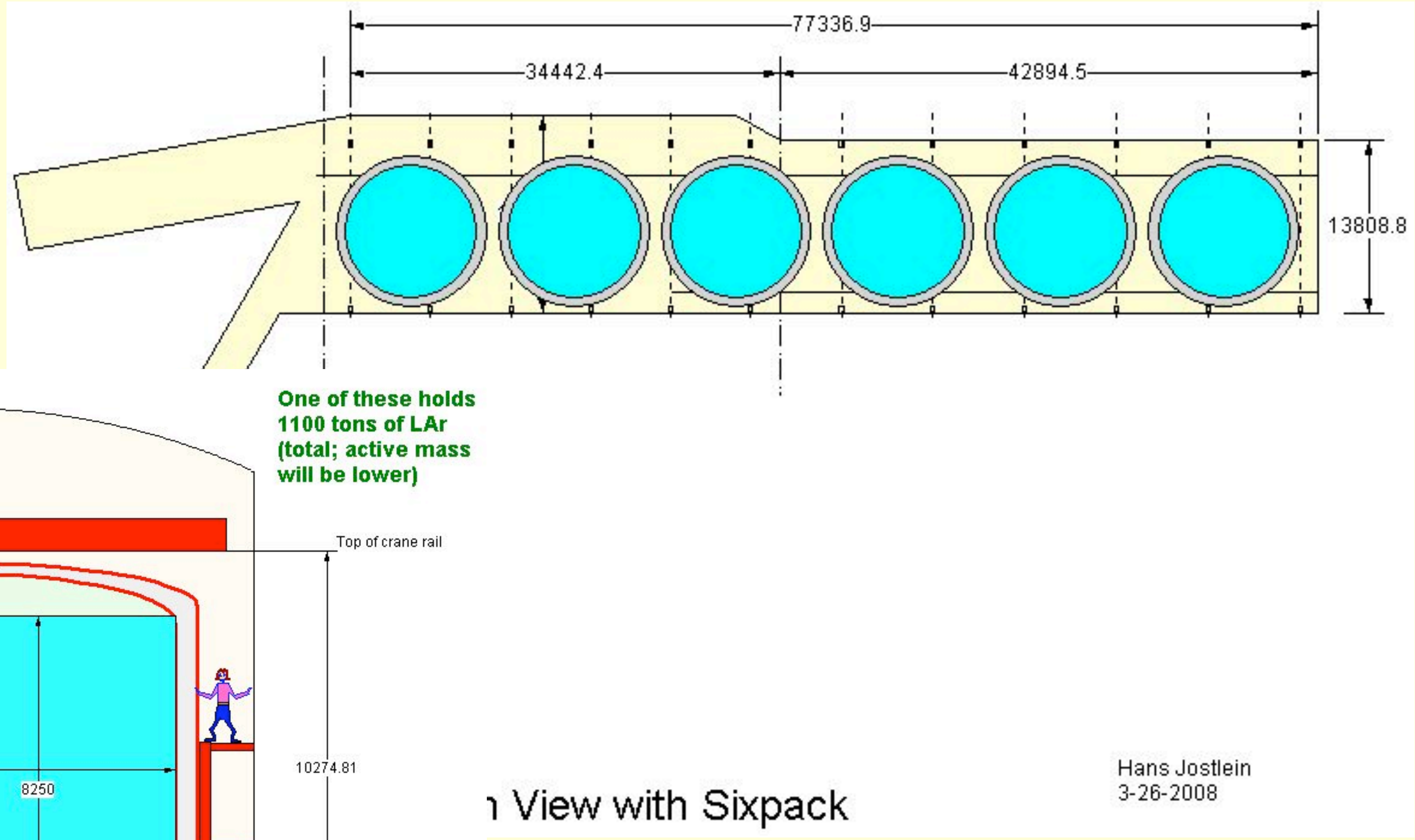
TPC contained in a multi-cell mechanical structure

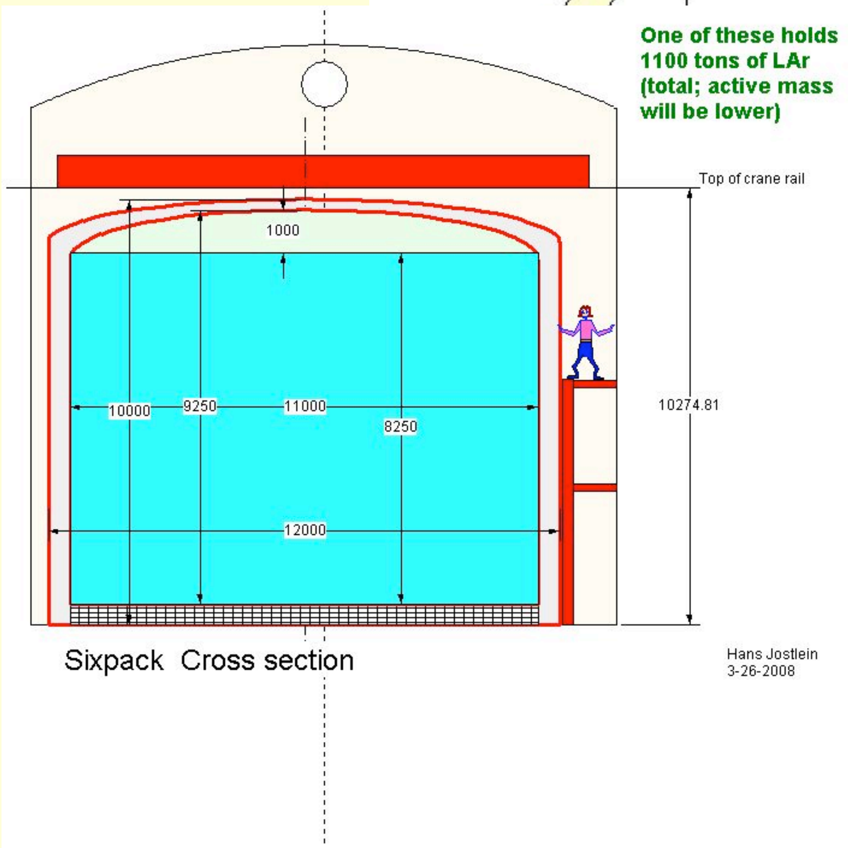
Drawing courtesy of D. Cline and F. Sergiampietri

Strawmans for multiple modules at DUSEL



Upright cylinder concept : fit into MINOS Soudan Cavern





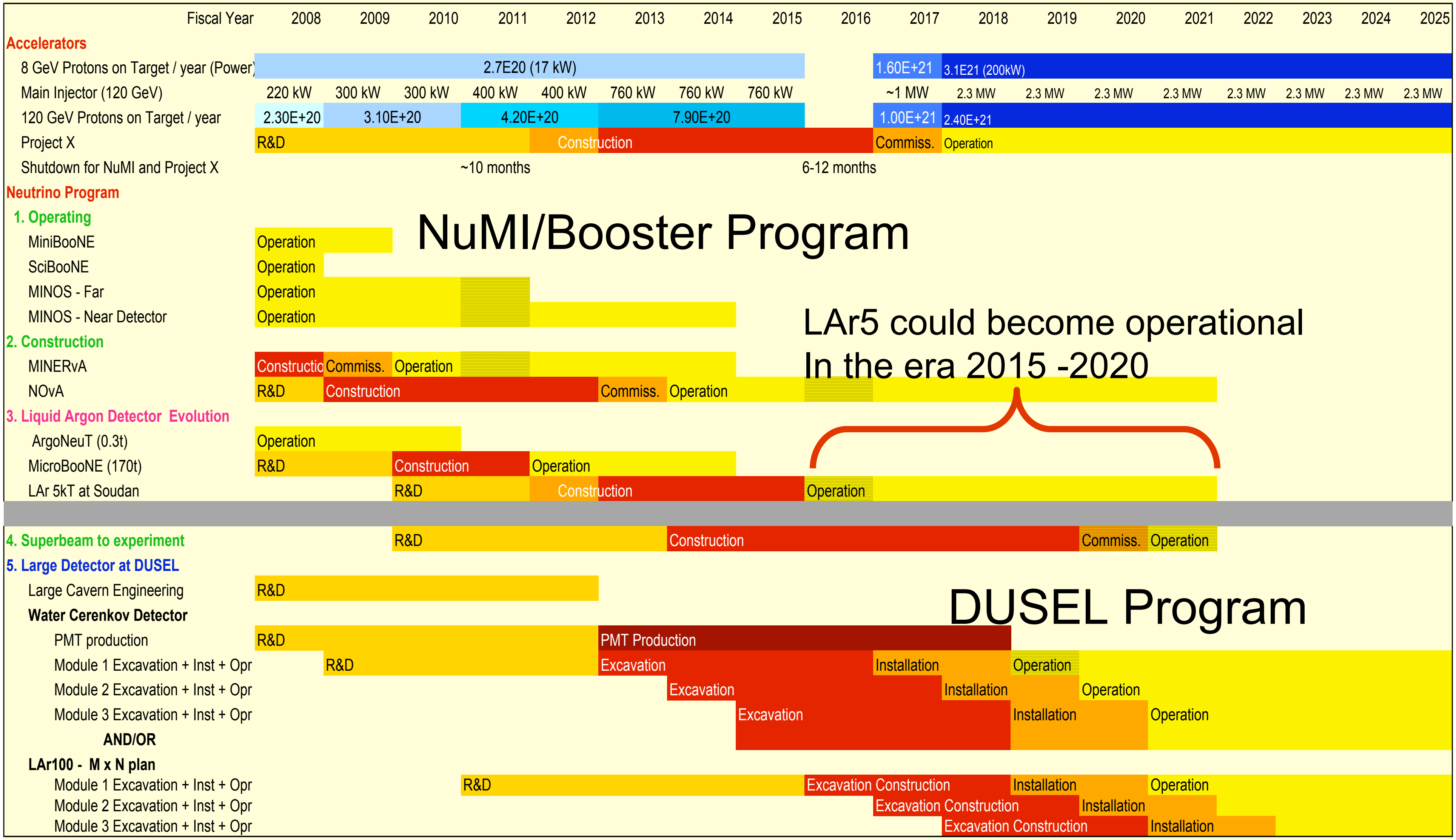
Cryogenic Safety

Working on this slide from calculations and Mitigations deveolped by Rich Schmidt…

Electronics Channels

- Summary of a PRELIMINARY study from Bruce looking at efficiency as a function of wire spacing.

Schedule considerations



Conclusions

- We believe that a 5 kiloton liquid argon neutrino detector is the appropriate size to plan for the next step (after MicroBooNE) in developing this detector technology
- A 5kT detector has powerful physics potential, in either the NuMI or DUSEL locations
- The major technological design issues that will be addressed in the R&D program are :
  - Cryostat/TPC configuration
  - Installation/construction techniques
  - Mitigation of safety issues (containment, egress)
  - Per channel cost of electronics
  - Total Project Cost estimate
- The PAC has encouraged the laboratory to provide **engineering and design support** to work on the technical issues
- We believe we can address most of the issues over the next two years

P-982 LOI

Contributors and Potential Collaborators

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Backup Slides

Large LAr Detector - on surface

From

DRAFT

LOI for

LAr5 @

Ash River

Task	per unit estimate
Liquid Argon procurement & delivery	\$1 Million per kiloton
Cryogenic Tank fabrication	\$3.75 M + 0.4M/kiloton
Cryogenic Tank Roof customizing	\$4500/m^2
Purification and Cryo System fabrication	\$4M
TPC and Cathode System	\$50K/panel
Electronics, Data Acquisition and Slow Control	\$200K + \$50/channel
Cables in and out of cryostat	\$50/channel
Photmultiplier Tubes and Readout	\$7.5K/pmt
Detector Installation and Integration	\$200K/month
Engineering and Engineering Support	\$150K per person-year

Table 1: *Preliminary* estimates of per unit cost drivers.

Parameter	5 kT	7 kT	10 kT
Cryogenic Tank diameter(m)	15	19	24
Cryogenic Tank height (m)	14	15	16 m
Cryogenic Tank volume (m^3)	2500	4250	7235
Tank roof area (m^2)	177	283	452
TPC sense panels (#)	20	29	44
Sense wires per panel (30^0) (#)	2700	2700	2700
TPC interleaved cathode panels (#)	18	28	40
TPC circumferential gradient panels (#)	20	24	36
Electronics channels (#)	54,000	78,300	118,800
Photomultiplier tubes (#)	48	60	72

Table 2: Detector parameters used for estimating the cost range of a Liquid Argon detector in the 5-10 kiloton mass range.

WORK IN PROGRESS

Preliminary

	5 kton	7 kton	10 kton
Site Preparation and Infrastructure	[illegible]0		
Liquid Argon Procurement and Delivery	$5[illegible]0,[illegible]	$7,000,000	$10,000,000
Tank	$[illegible]7[illegible],000	$6,550,000	$7,750,000
Tank Customizing	[illegible]96,[illegible]00	[illegible]1,273,500	$2,034,000
Argon Purification and and Cryo Systems	$4[illegible],000	$4,000,000	$4,000,000
TPC Panels	$2,900,000	$4,050,000	$6,000,000
Electronics & Readout	$5,600,000	$8,030,000	$12,080,000
Photomultiplier Tubes	$360,000	$450,000	$540,000
Installation and Integration	$2,400,000	$2,800,000	$3,200,000
Engineering	$7,500,000	$7,500,000	$7,500,000
Base Cost	**$34,306,500**	**$41,653,500**	**$53,104,000**
Cost per kiloton	$6,861,300	$5,950,500	$5,310,400
Contingency (50%)	$17,153,250	$20,826,750	$26,552,000
Total	$51,459,750	$62,480,250	$79,656,000

What we know about cost scaling