The LBNE Water Cherenkov Detector

Jim Stewart BNL

Advances in Neutrino Technology

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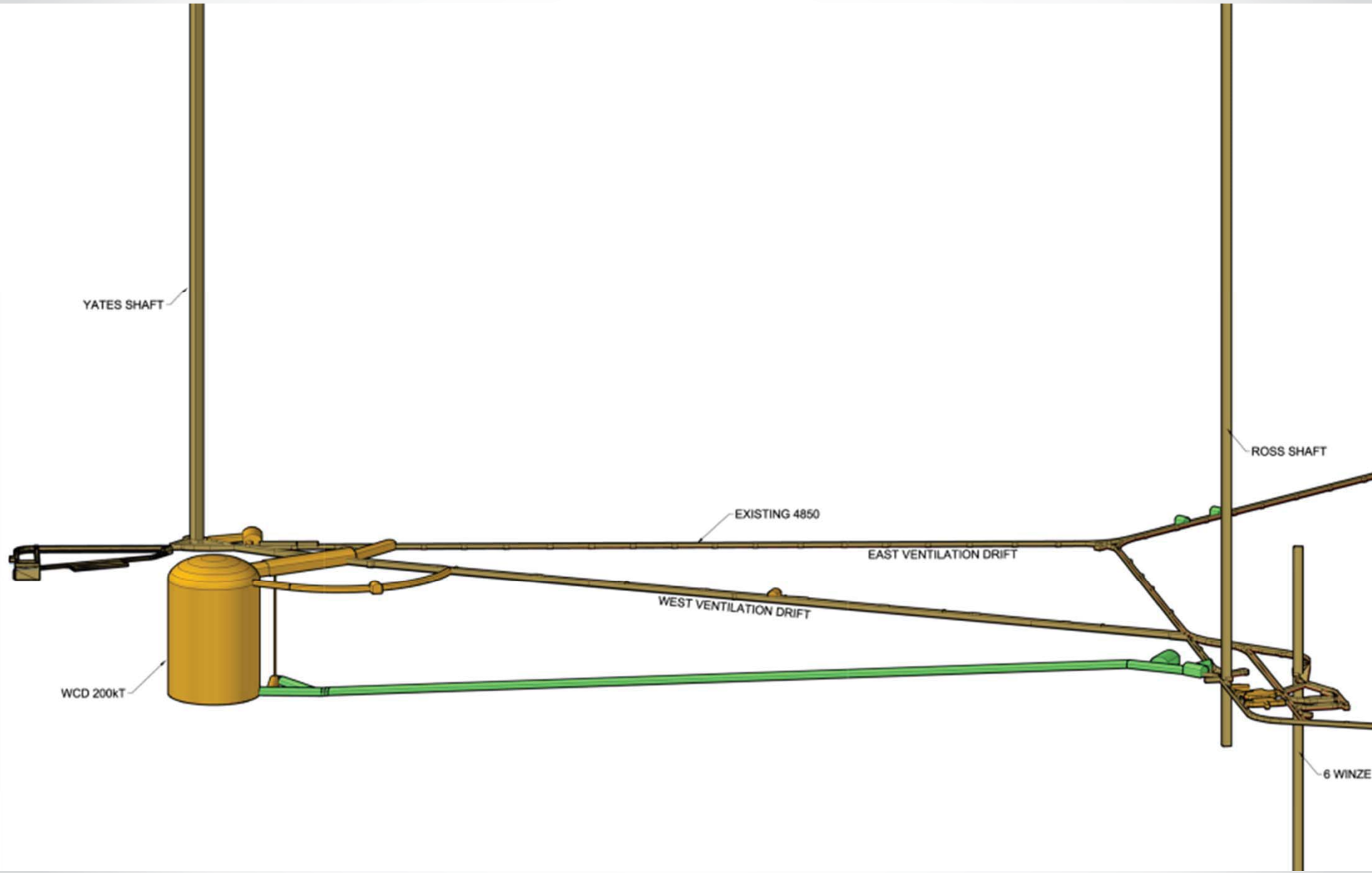
http://www.physics.drexel.edu/~neutrinoweb/ANT11/

Outline

- ~~LBNE Overview~~
- Geotechnical optimization
  - Summary of Baseline configuration
- Detector overview
  - Water Containment
  - PMT System
  - Water Purification System
- ~~Timelines and Cost~~
- Conclusions

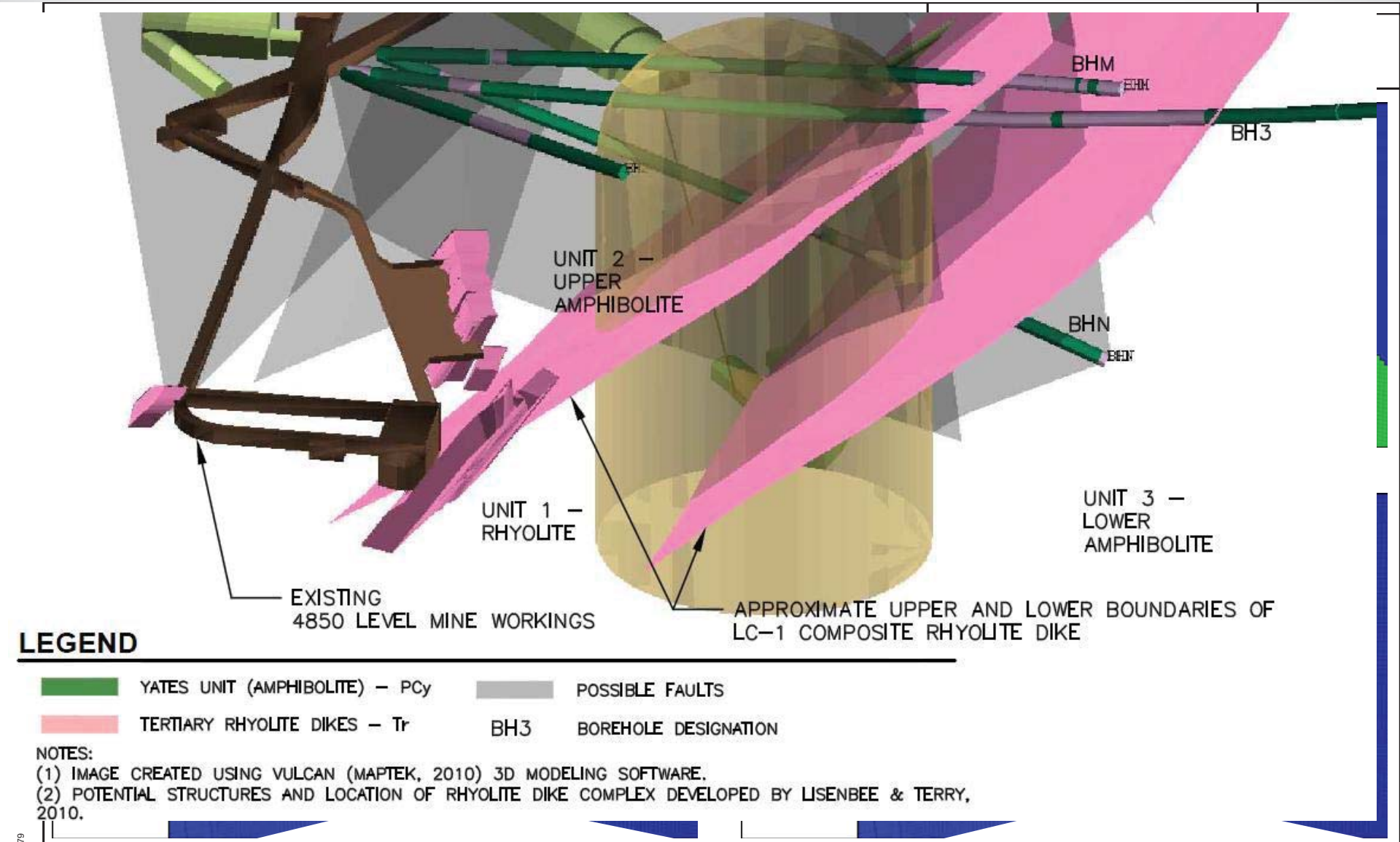
Conventional Facilities Overview – 4850ft level



Cavern Shape Alternates

Description	Dia or Width	Wall Height	Length	Conclusion
100kt cylindrical	55m	64m	-	Economical Excavation
150kt cylindrical	66m	64m	-	Economical Excavation
200kt cylindrical	66m	81m	-	Economical Excavation
300kt cylindrical deep	66m	119m	-	Disfavored due to high stress in walls
300kt cylindrical broad	87m	69m	-	Disfavored due to high stress in dome
150kt Mailbox	32m	64m	115m	Disfavored due to high stress in walls
300kt Mailbox	41m	64m	167m	Disfavored due to high stress in walls

Cavern Shape Alternates



c) Displacements – N-S section – looking NE *looking SW*

d) Displacements – E-W section – looking SW *looking NE*

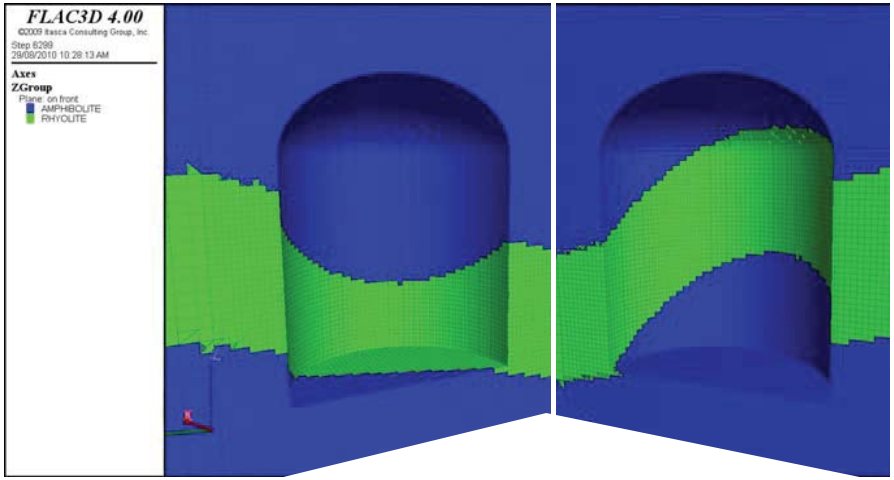
DATE: August-2010
PROJECT: 093-81779
DOC: G.G.
CHK: J.L.C. APD: R.P.
Project 093-81779

Cavern Shape Alternates

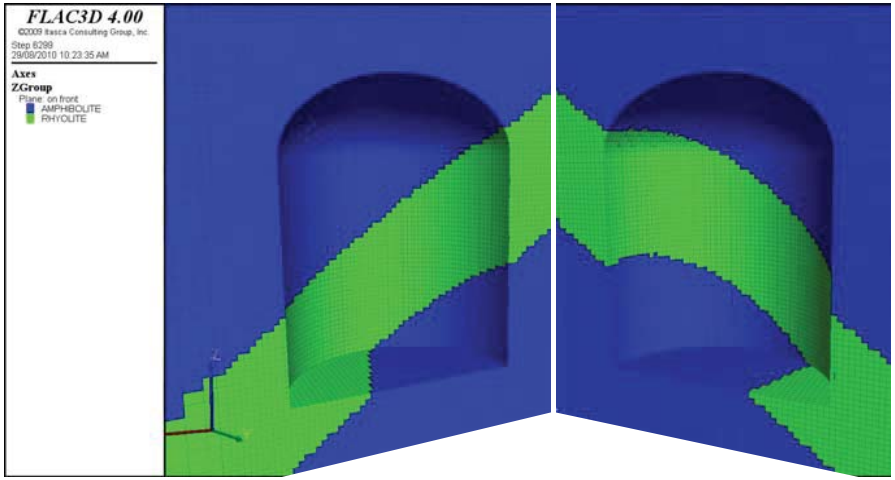
Mesh:
Near-field element size = 1.5 m
Near-field zone = 15 m

DUSEL – Homestake Mine
FLAC3D Modelling
150 kt Circular Cavern Geometry

FIGURE 26



a) FLAC3D mesh – N-S section – looking NE *looking SW*



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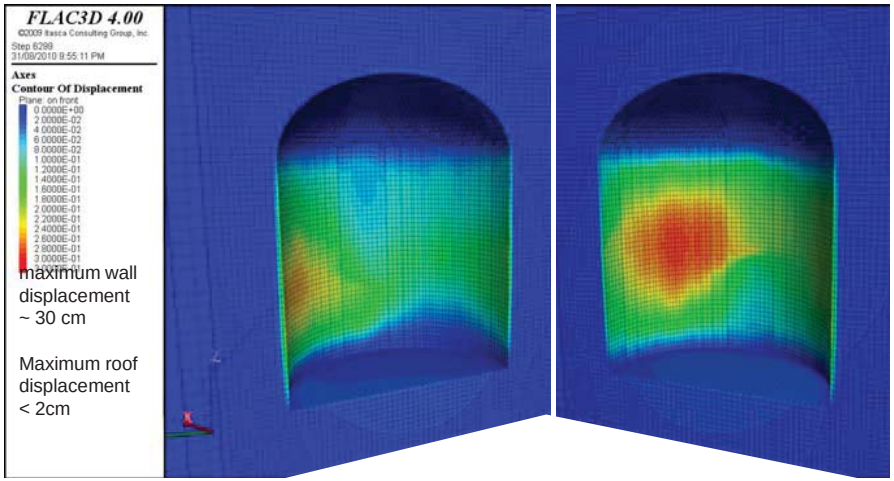
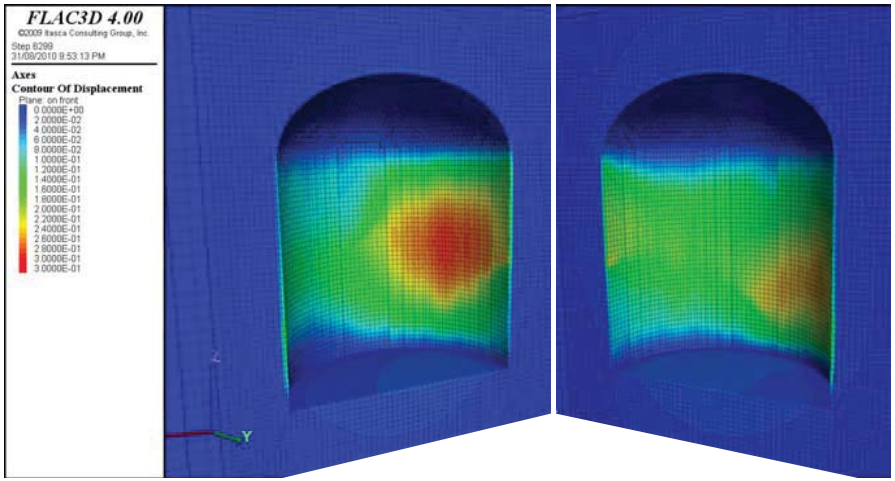


maximum wall displacement ~ 30 cm

Maximum roof displacement < 2cm

c) Displacements – N-S section – looking NE *looking SW*



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Golder Associates

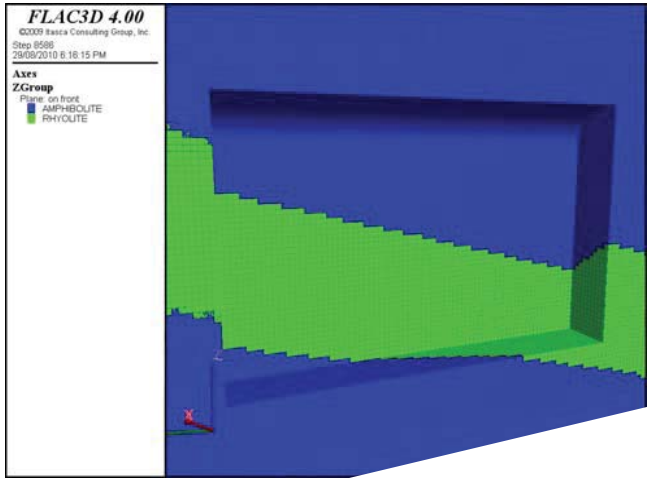
Project: 093-81779 Drawn: JLC Reviewed: JLC Rev.: 12-Jun-2010 N:\Active\2010\2009\Other offices\093-81779 DUSEL

Cavern Shape Alternates

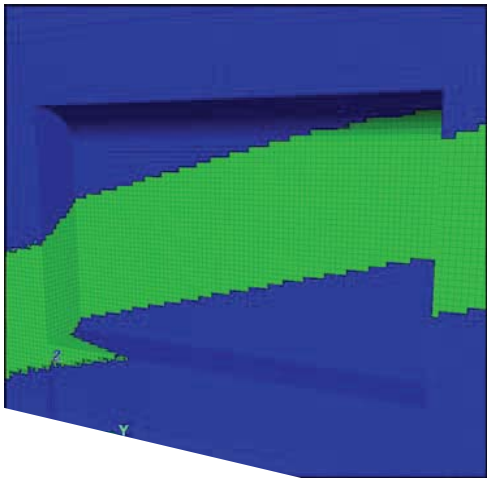
Mesh:
Near-field element size = 1.5 m
Near-field zone = 15 m

DUSEL – Homestake Mine
FLAC3D Modelling
150 kt Mailbox Cavern Geometry

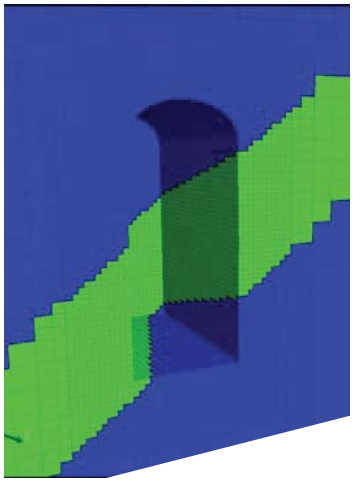
FIGURE 32



a) FLAC3D mesh – N-S section – looking NE



looking SW



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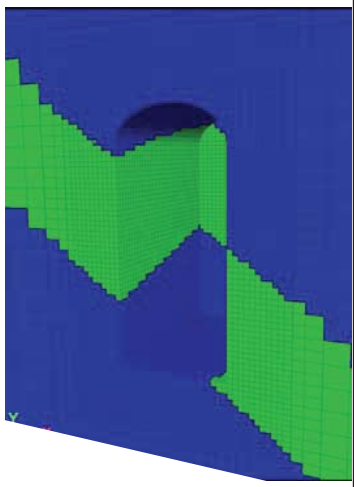
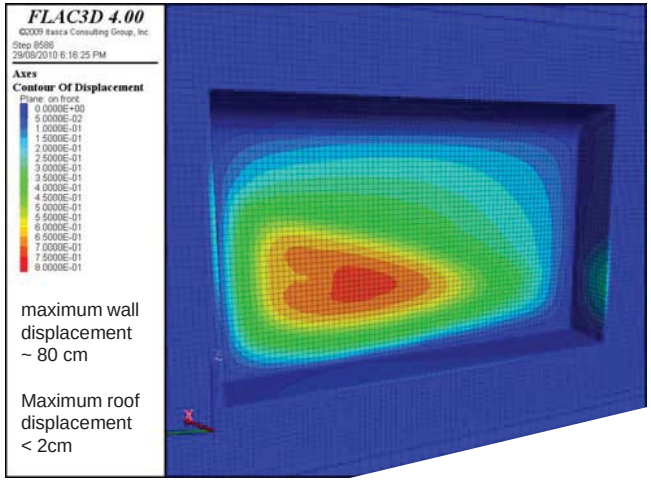


looking NE



maximum wall displacement ~ 80 cm

Maximum roof displacement < 2cm

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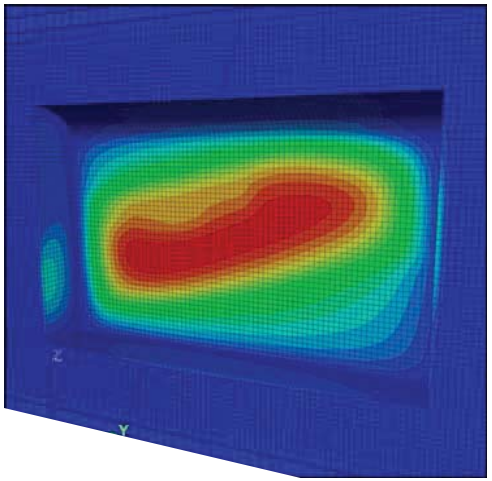

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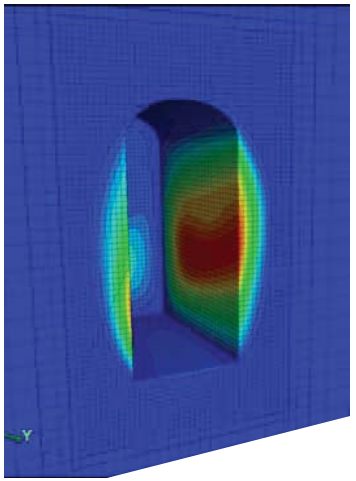

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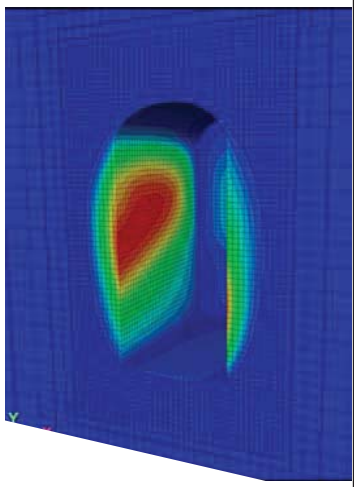

looking NE

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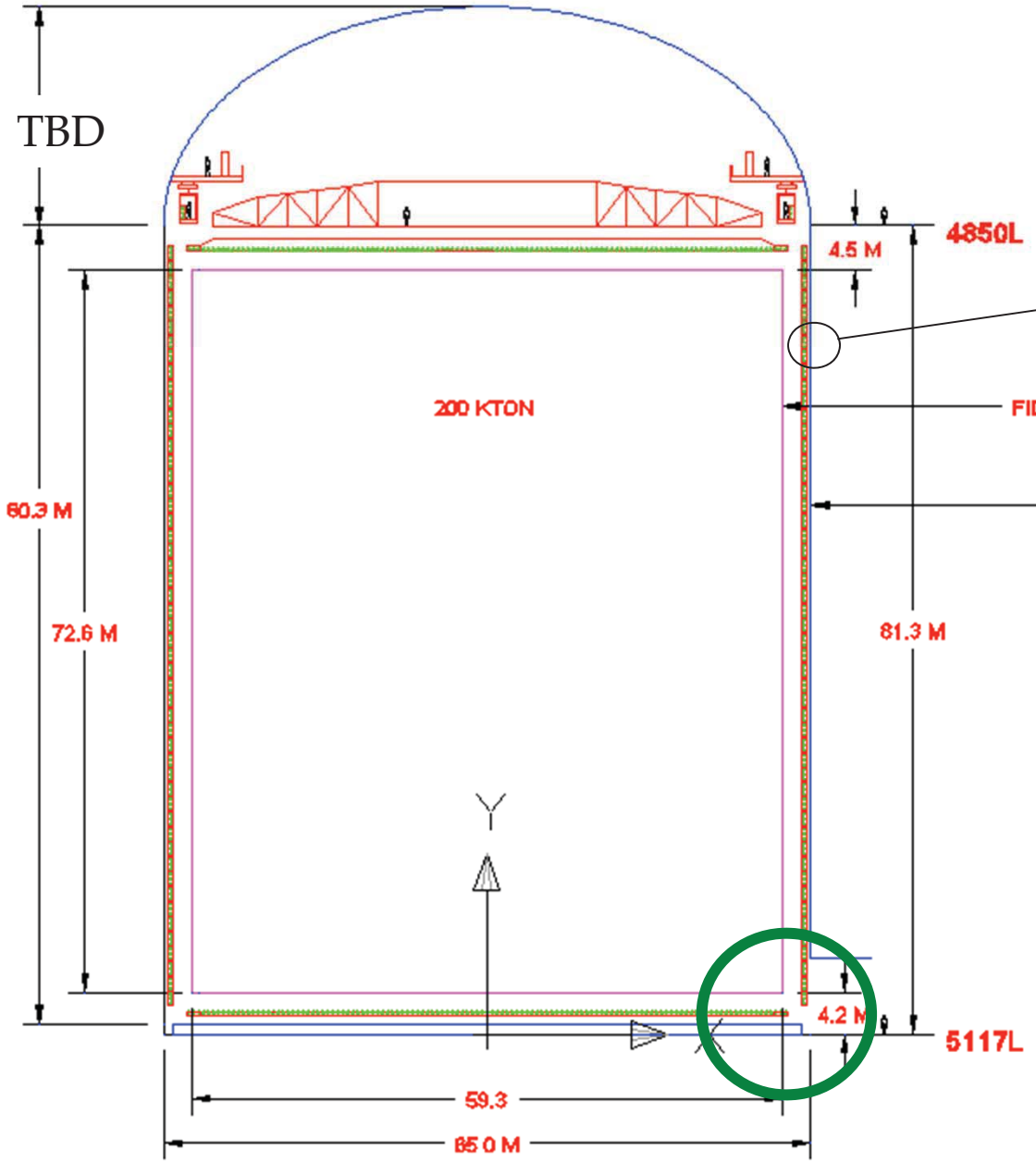
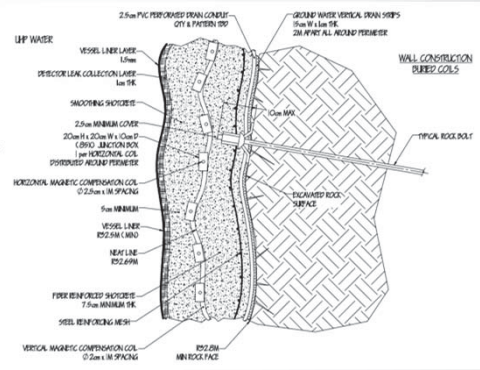
The LBNE WCD Cavern

- A 200kt detector design is selected based on an upright cylindrical excavation with dimension of 65mØ 81.3m high.
- April 2011 the Large Cavity Advisory Board reviewed prospects for a 200kt cavern.
  - "A combination of favorable rock mass strength and structural conditions and an in situ stress field that is reasonably benign means that a stable 65 m diameter 102 m high vertical cylindrical cavern can be constructed at the selected location on the 4850 level of the Homestake mine."
- Details of the excavation are in David Vardiman's talk on Wednesday morning.

200 kton
No vessel, liner on shotcrete
12” HQE PMTs

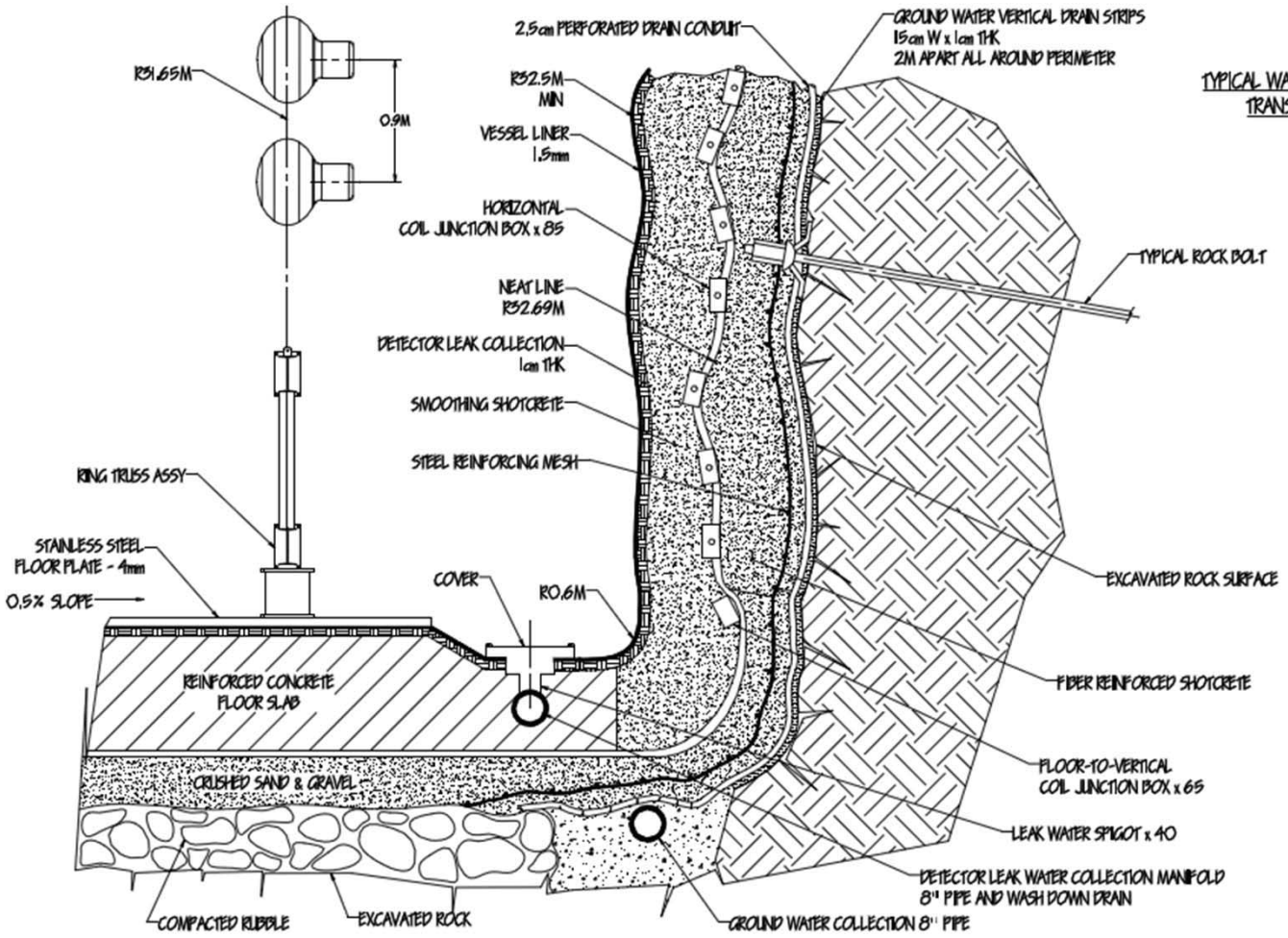




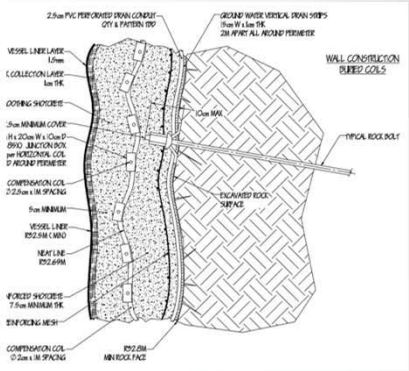
Total PMTs		28719
Cell Area	m^2	0.74
Cell size	m	0.86
PMTs on wall		20240
PMTs on Floor		4239
PMTs on Deck		4239
Number of cells across deck & floor diameter		73
Number of cells to traverse the height of wall		88
Number of cells around perimeter of wall		230
Fiducial diameter	m	59.30
Fiducial Height	m	72.60
Dia of cylinder at PMT equator	m	63.30
Height of cylinder at PMT equator	m	76.60
Water diameter	m	65.00
Water height	m	80.10
Total water volume	m^3	265796
Wetted Surface	m^2	19675
Surface to volume ratio	m^-1	0.074

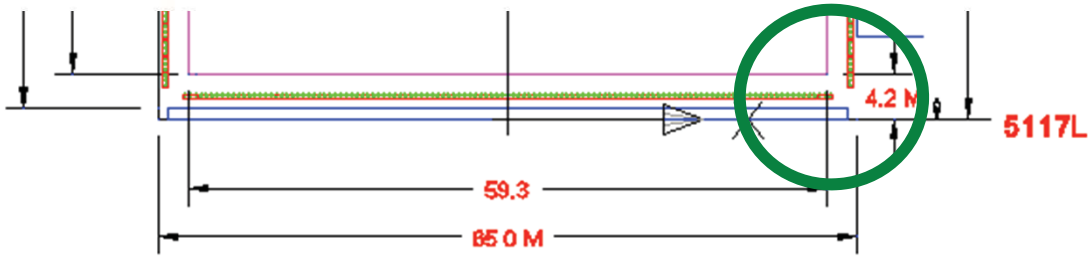
liner on shotcrete

PMTs



TYPICAL WALL / FLOOR TRANSITION





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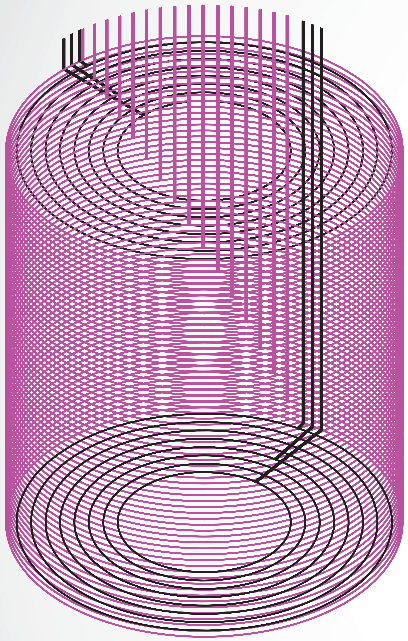
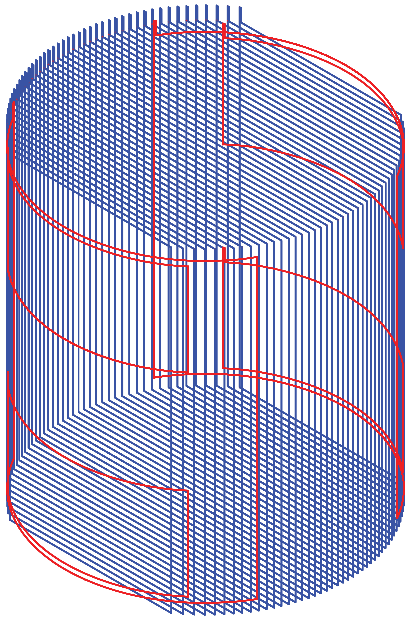
Magnetic Field Compensation - Coils





Horizontal coils

- 81 coils along wall
  - 1m spacing
- 11Circular coils top/bot

Vertical Coils

- 58 Vertical loops
  - 1m spacing

Saddle Coils

- 4 sets

Residual Field
<50mG for 75% of PMTs
<100mG for 95% of PMTs
<150mG for all PMTs

- Wall coils buried under Shotcrete
- Distance of 83cm from excavated surface to PMT equator sets coil spacing
  - Many more coils than Super-K

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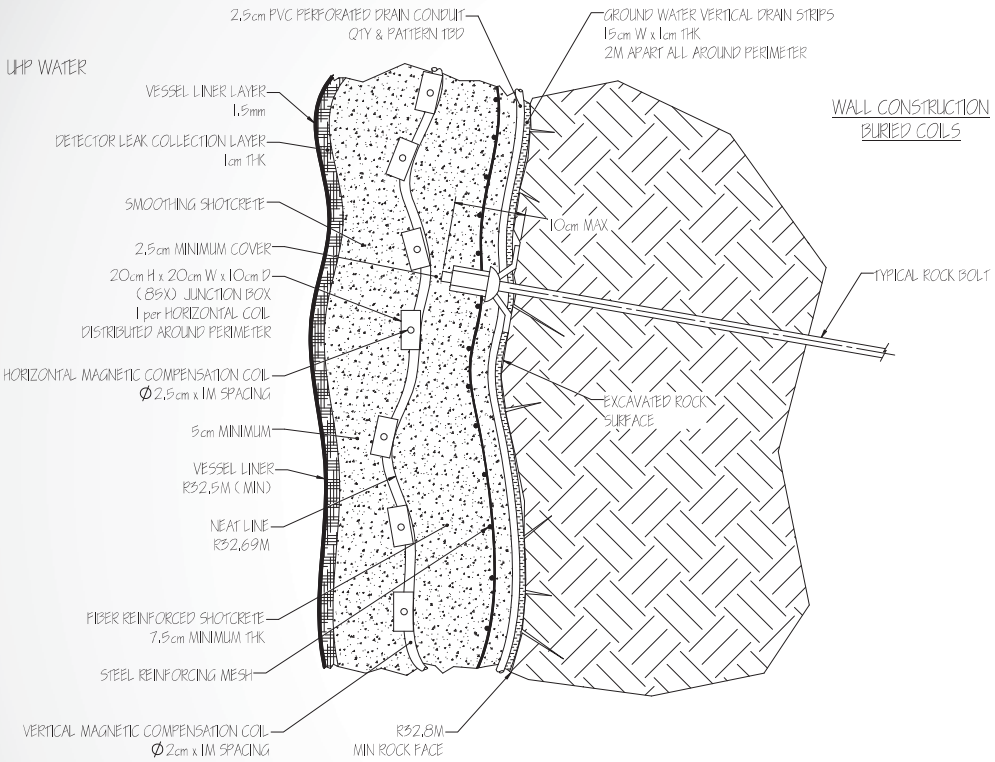

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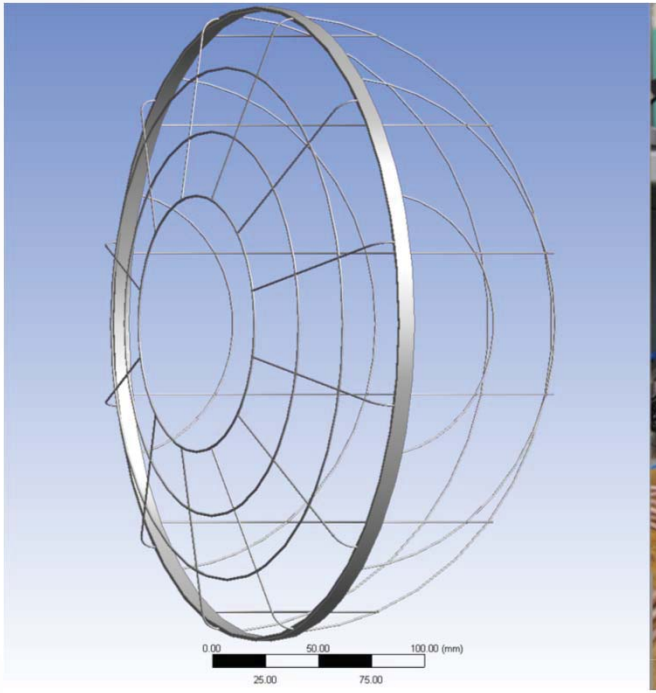
Passive Magnetic Compensation



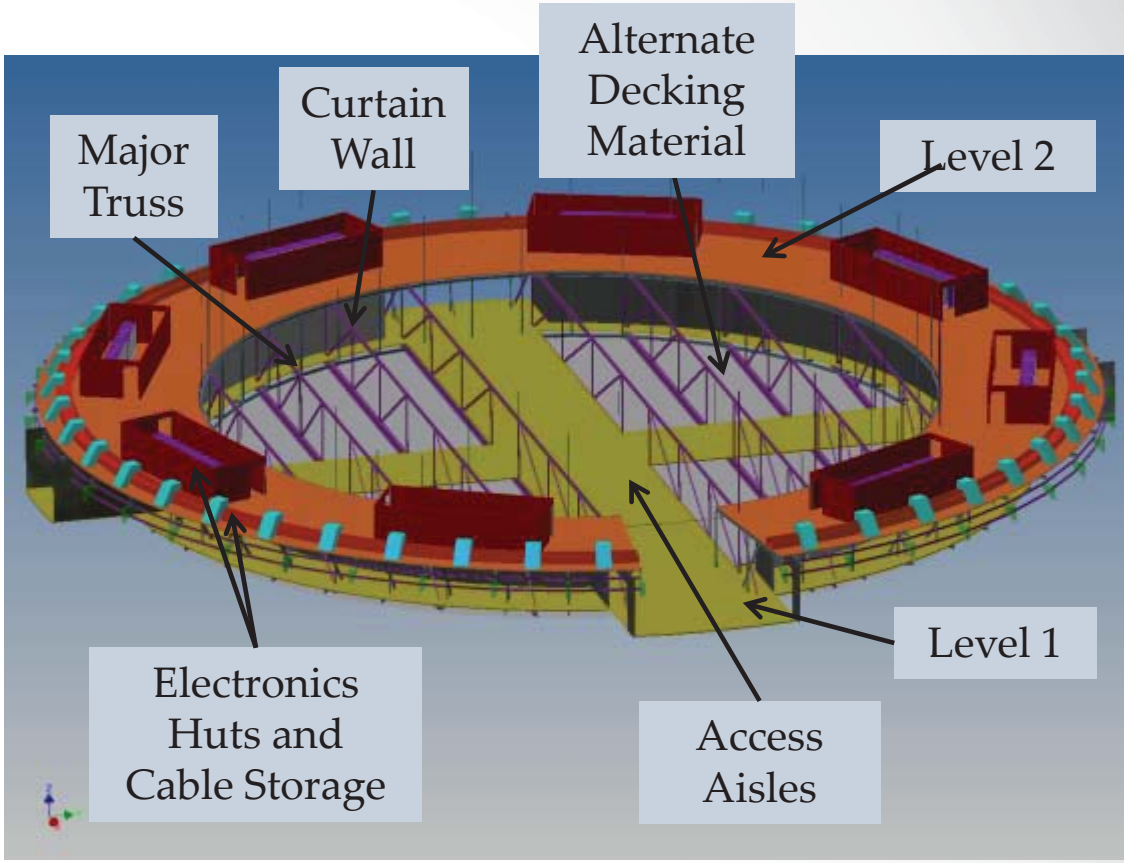
IceCube Mu-metal Cage for 10" PMT

Daya Bay Finemet Cone on 8" PMT

- Investigating passive shielding for the PMTs.
  - Mu-metal wire frame, Foil shield, or combination
- PMT QE vs Field measured for 10” PMTs
  - 12” Hamamatsu PMTs will be measured soon

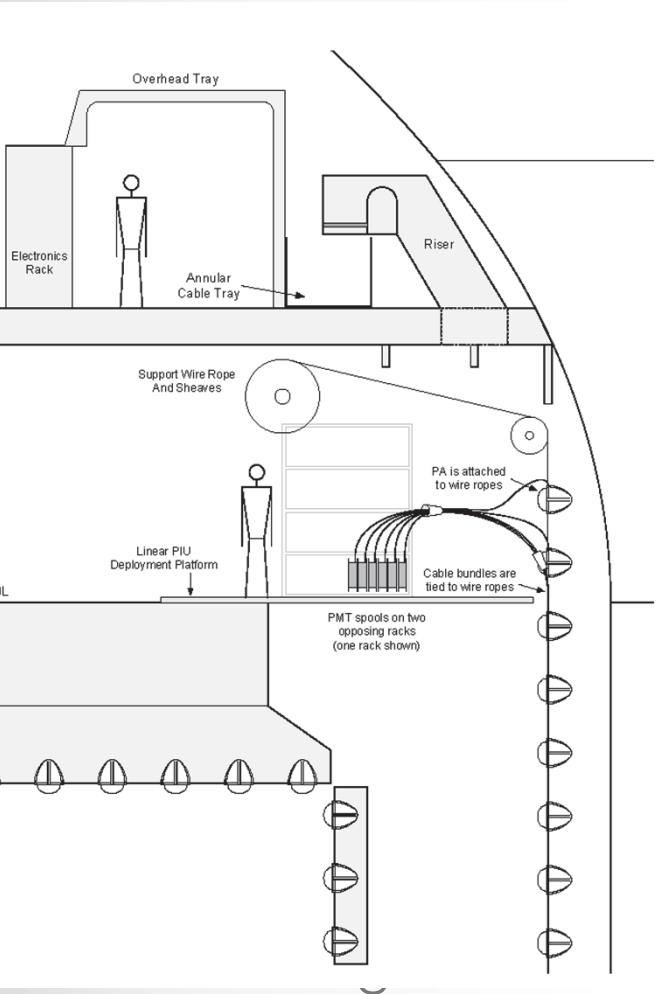
Water Cherenkov Deck

- 10 m wide balcony for electronics and cable storage.
- 46 korbels support balcony from roof
- Inner deck supported by 8-10 major trusses 4m high
- 1-1.5 run between the major trusses
- Stainless steel working surface
- Gondolas are planned along the outer perimeter for accessing the wall/PMTs

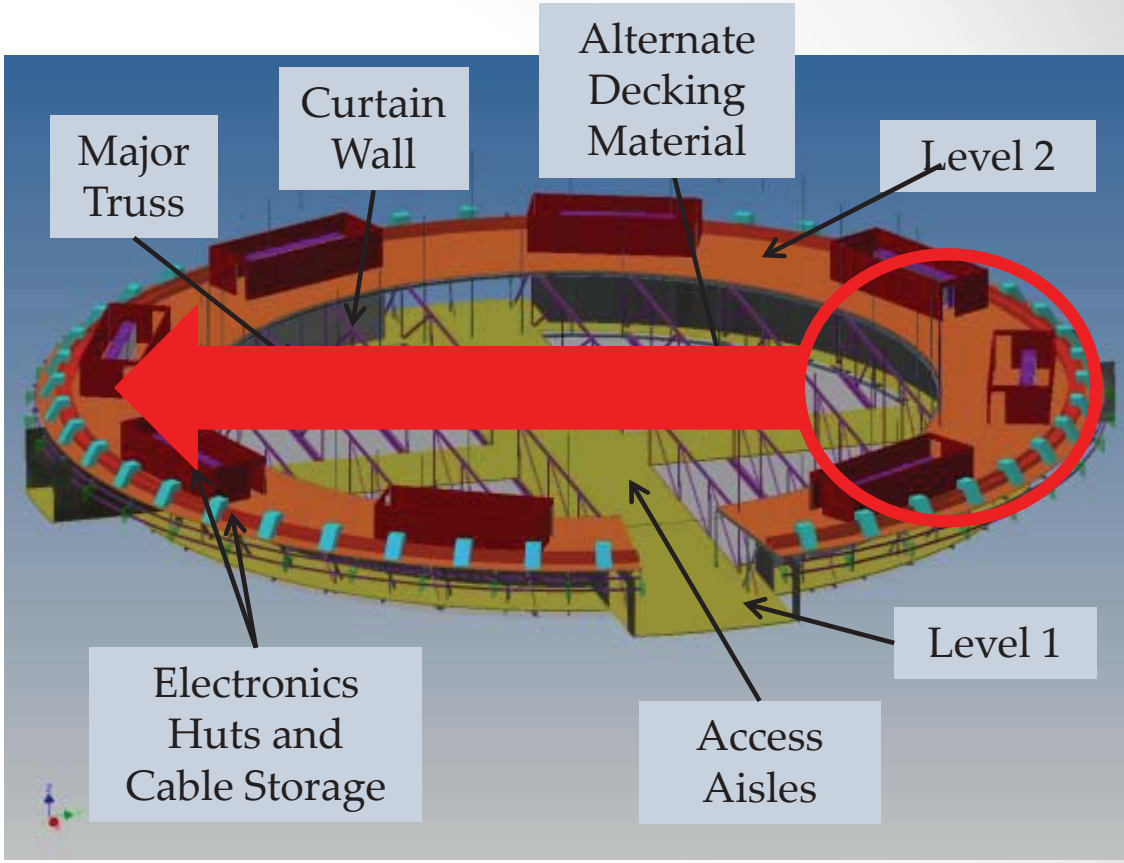


- Wall PMTs installed from a work platform under the balcony.

Water Cherenkov Deck



wall/PMTs



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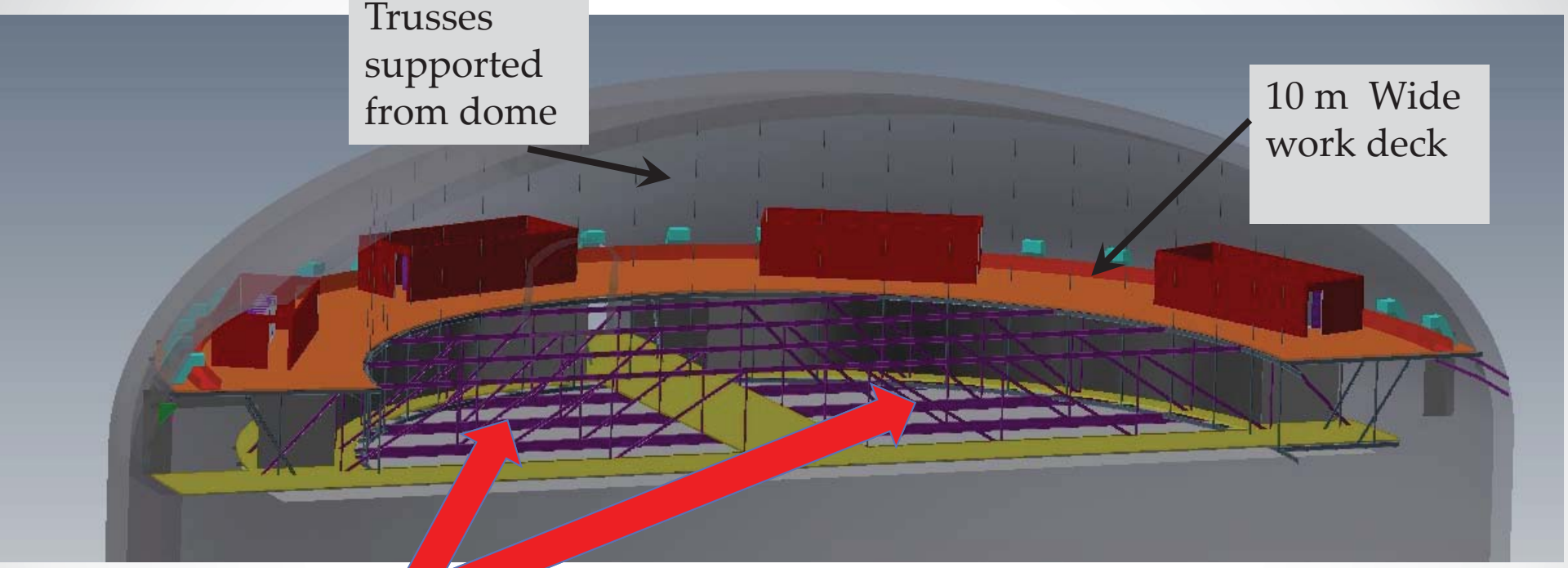
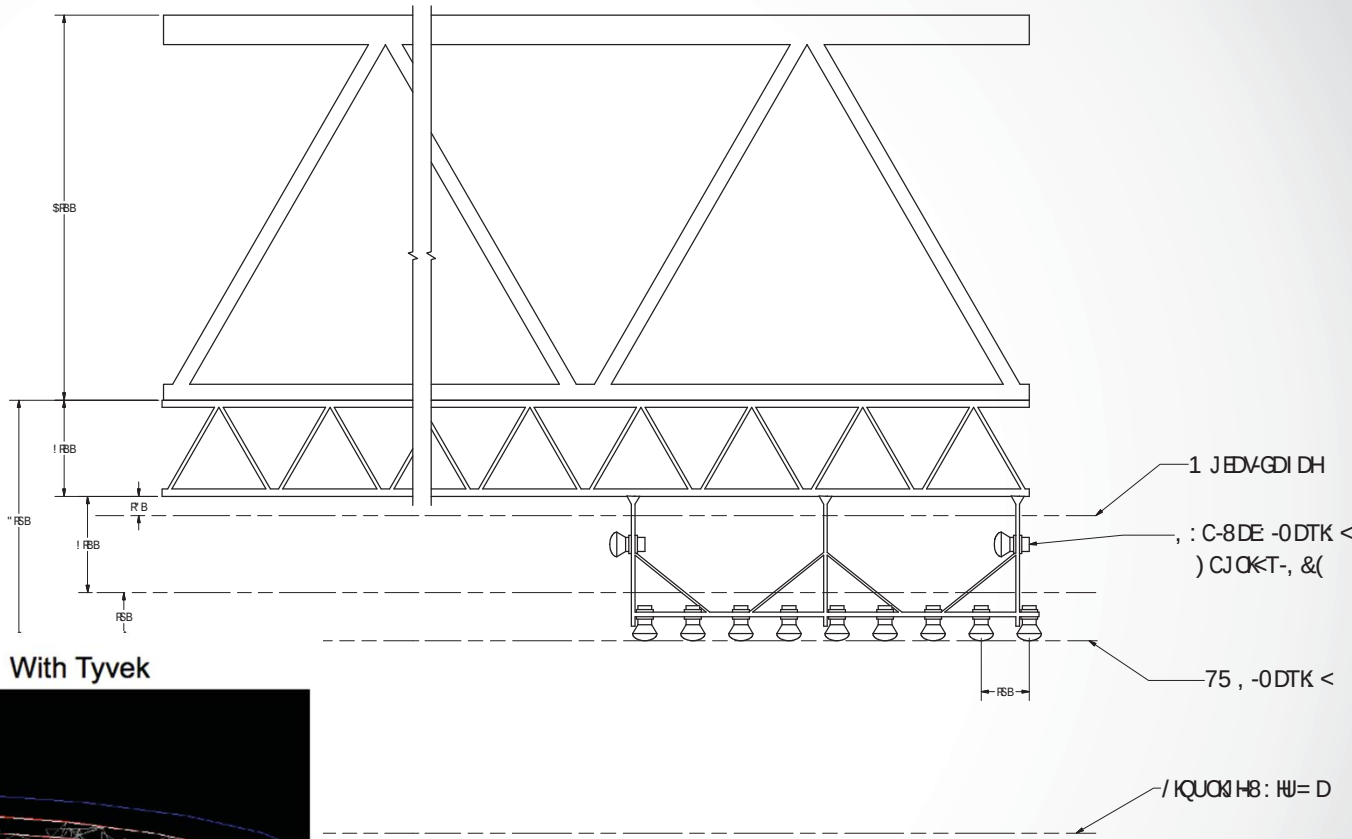
Light Weight Deck Design

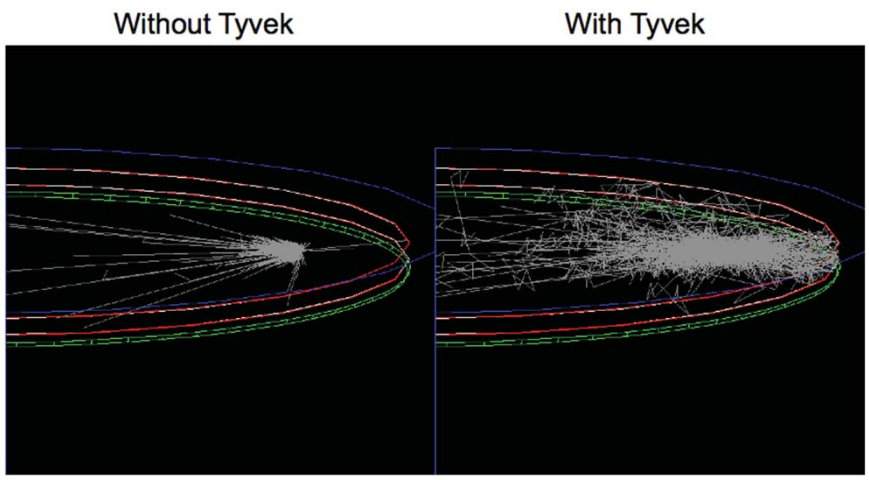


Investigating low mass tensile architecture design

Top Veto Included in Reference Design

- Used scaled Super-K data without outer detector cut to determine background in LBNE

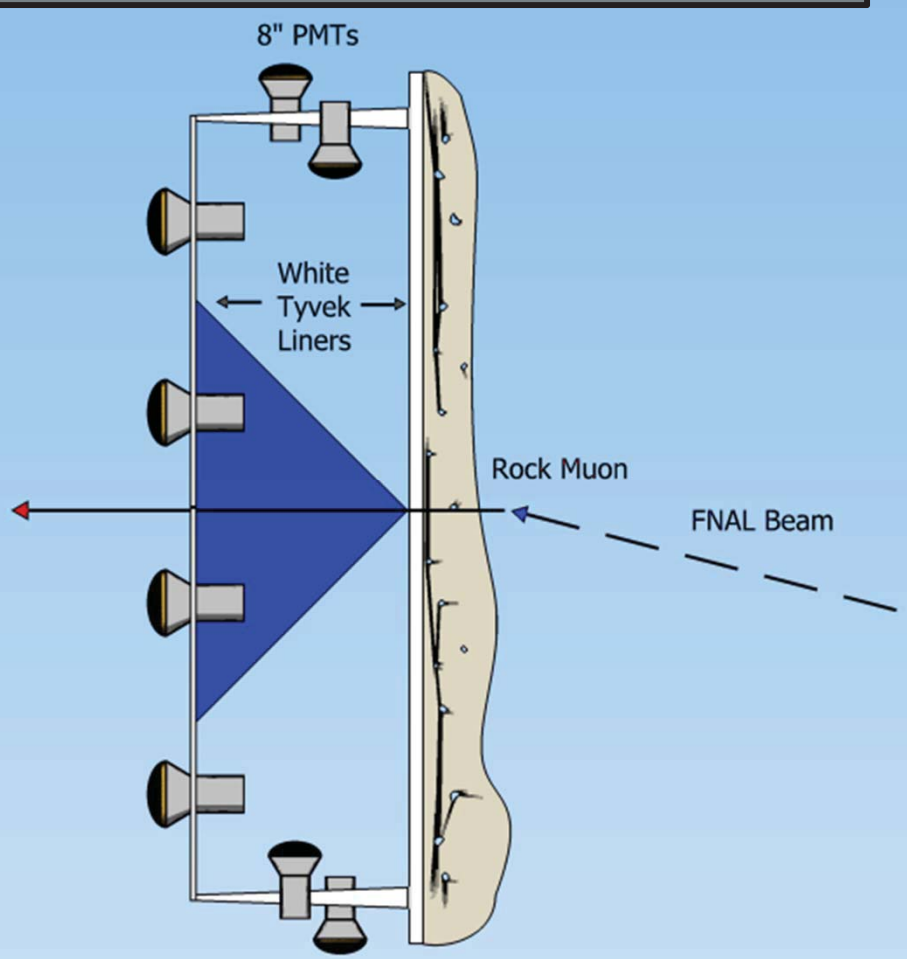




- With only Top Veto achieved <1% BG in fully contained atmospheric neutrino events.
  - Required a 100 MeV energy threshold

"Side veto" Concept Being Developed

- 85cm space is planned between the PMT equator and the wall.
- Simple prototype measurements indicate that a veto with efficiency >90% can be installed in this volume.
- More detailed measurements are planned.
- Simulations will be performed to determine the impact on physics.



PMT Selection

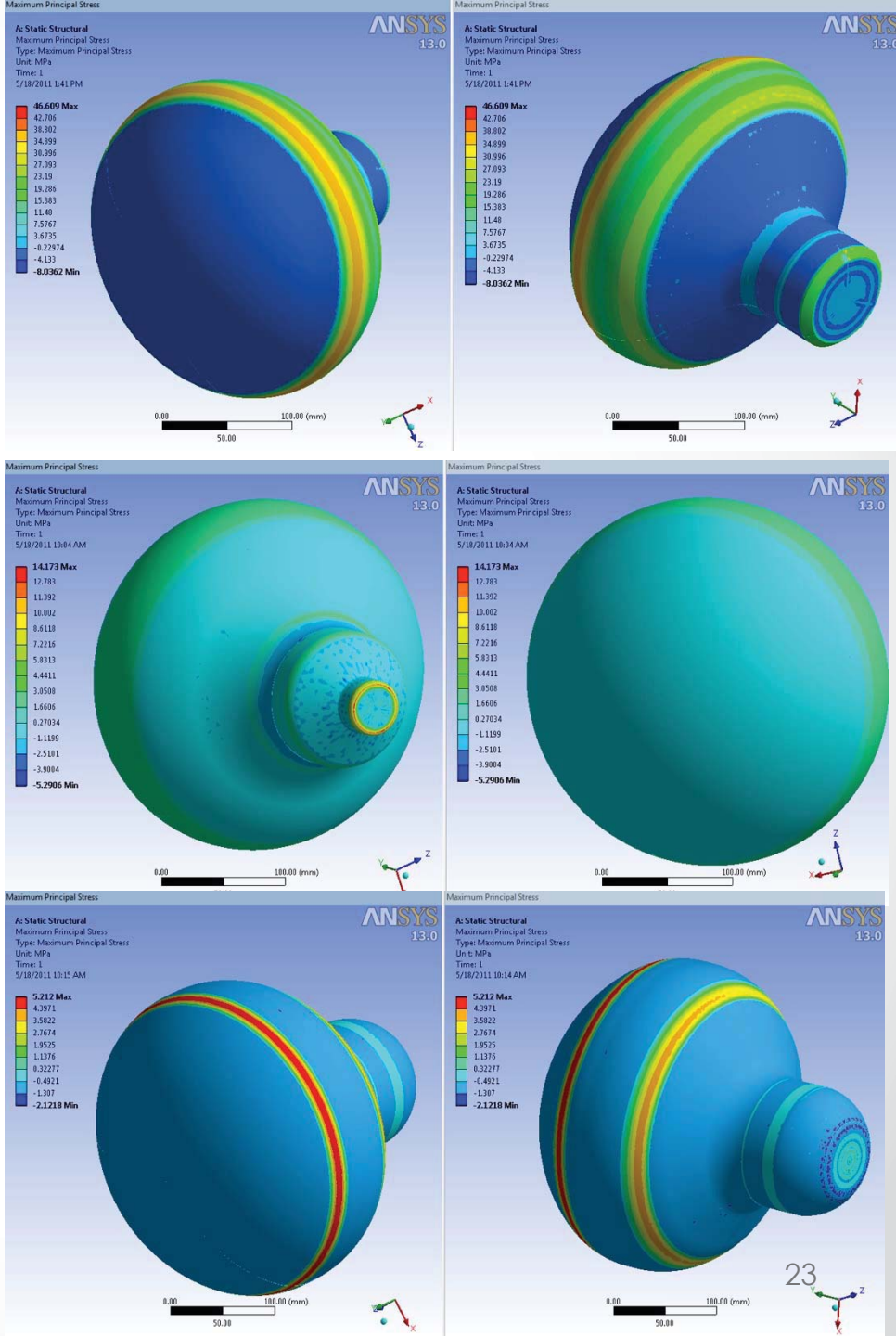
- A request for information was sent to PMT vendors with the LBNE specifications.
  - Hamamatsu and ADIT/ETL expressed interest and are developing PMTs
- Candidate PMTs are:
  - 10" Hamamatsu HQE
  - 12" Hamamatsu HQE PMT (Under development)
  - 11" ADIT/ETL PMT (Under Development)
- First 12" Hamamatsu High QE PMTs under test
- First 11" ADIT/ETL mechanical samples available
  - Prototype working ADIT/ETL 11" PMTs also on order, scheduled to arrive ~Nov.2011.

Process of working with vendors toward the final selection is underway

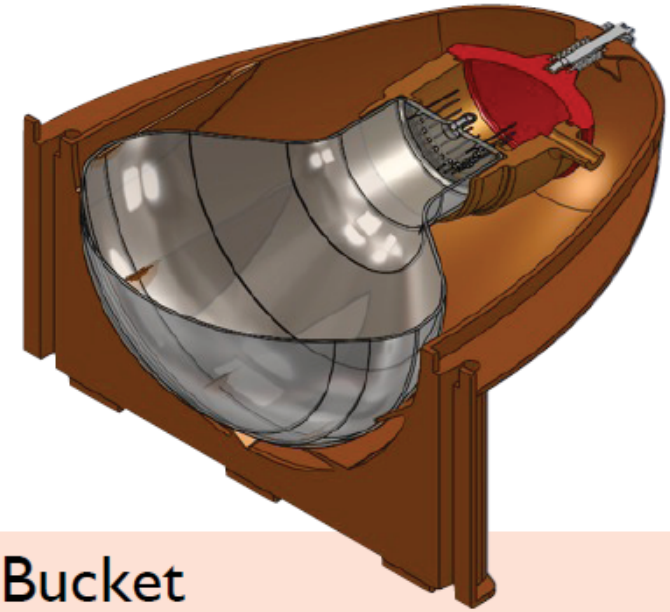
PMT Stress Analysis

- Stress analysis, glass thickness, profile measurements have been done on 10", 12" Hamamatsu PMTs and 11" ETL PMTs.
- 10 and 12" PMTs have been pressure tested under rapid pressure rise conditions.
- Slow pressure rise test setup is being prepared to study aging effect of glass on mechanical strength.
- So far mechanical strength of 10" PMT is found to be far below the 11" and 12" tubes for rapid pressure rise conditions.

Expect newer tubes will have sufficient pressure rating

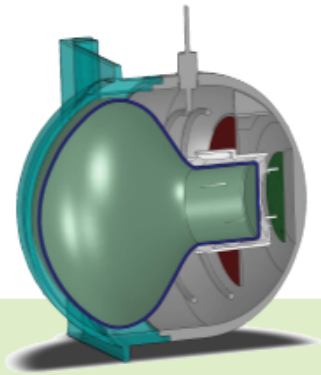


PA Housing Options Under Development



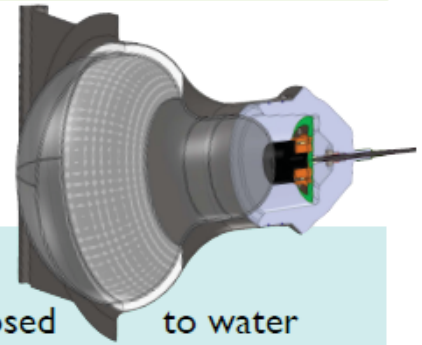
Bucket

- Shell around back side may reduce impact of PMT implosion
  - ➡ *Implosion dynamics under study by simulation and planned tests*
- Base cup protects pins area from hydrostatic pressure
- Bulb is fully exposed to hydrostatic pressure



Pressure Hull

- Acrylic dome and back-shell protects entire PMT from hydrostatic pressure
  - ➡ *Backup design (risks of implosion in other housing designs still being assessed)*
- Light loss in 1cm acrylic, 6mm gel is 5-7%
  - ➡ *Need more PMTs, also other extra costs*



Form-Fit

- Front of bulb exposed to water
- Back-shell sealed to PMT near equator
- Back of bulb and base at 1 bar air pressure
  - ➡ *Addresses known concentration of stress in these parts of the PMT glass (12")*

Images from D. Wahl@PSL, T. Benson@UWI

PMT Coverage (How Many?)

- Used the R11781 12" Hamamatsu PMT for present design
  - Final PMT decision will be result of a detailed procurement process.
- If selected the HQE version would be used.
- Peak QE for 10" tubes is 35% higher then NQE tubes.
- Assumed a 30% increase in peak QE for the 12" to be conservative.
- HQE tubes are blue enhanced so this corresponds to about a 60% increase in light yield in air.

- The 200kt detector was modeled in MC
  - The PMT and water characteristics included
  - Model was verified with cross check to Super-K
- 38k tubes had equal light yield to Super-K II
- Assume a 40% increase in light yield is possible with use of Winston cones or scintillator plates.
- Present design is based on 29,000 12" PMTs with light collectors.

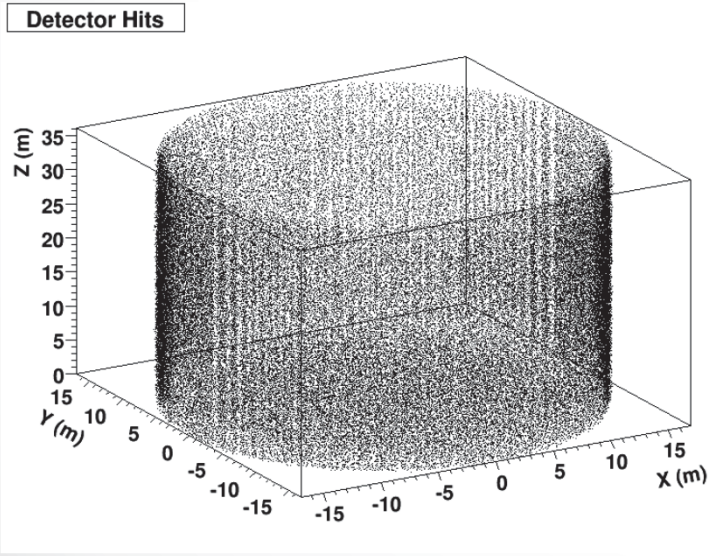
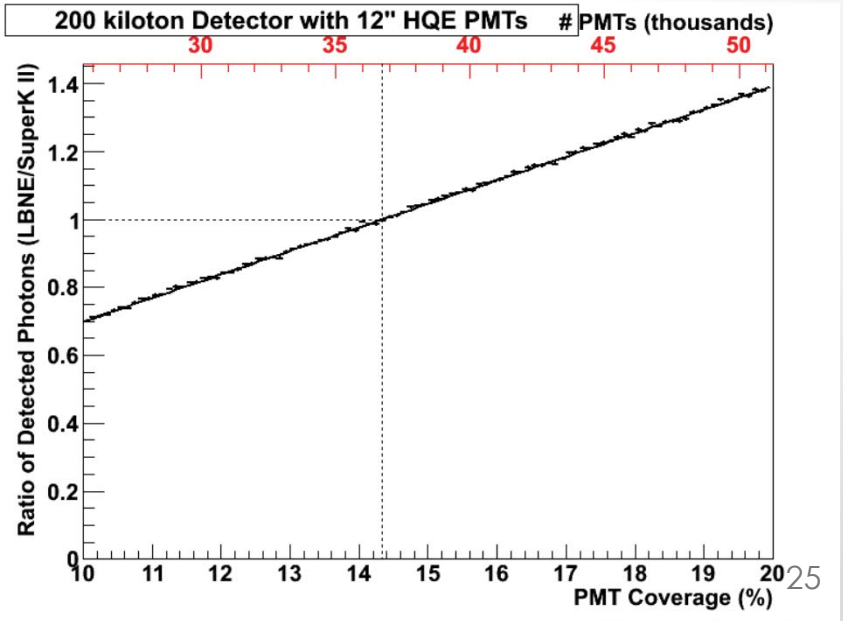
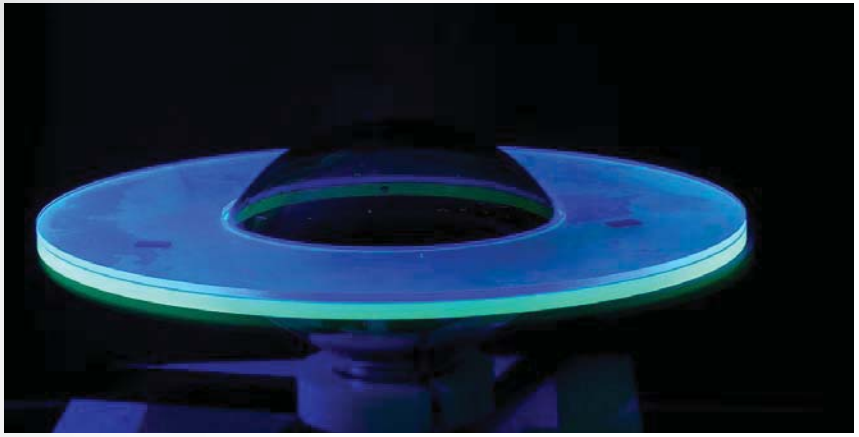


Figure 5: Target Hits for the Simulated SuperK II Detector



WLS Plates

IMB used WLS plates: 1.5 factor increase in light collection



Prototype 1 (BC-499-76)

UV → blue

ID: 10", OD 20", 5 mm thick

Polyvinyl toluene (PVT) base

Fluor: POPOP + ??

Index of refraction = 1.58

Density = 1.04 g/cm^3

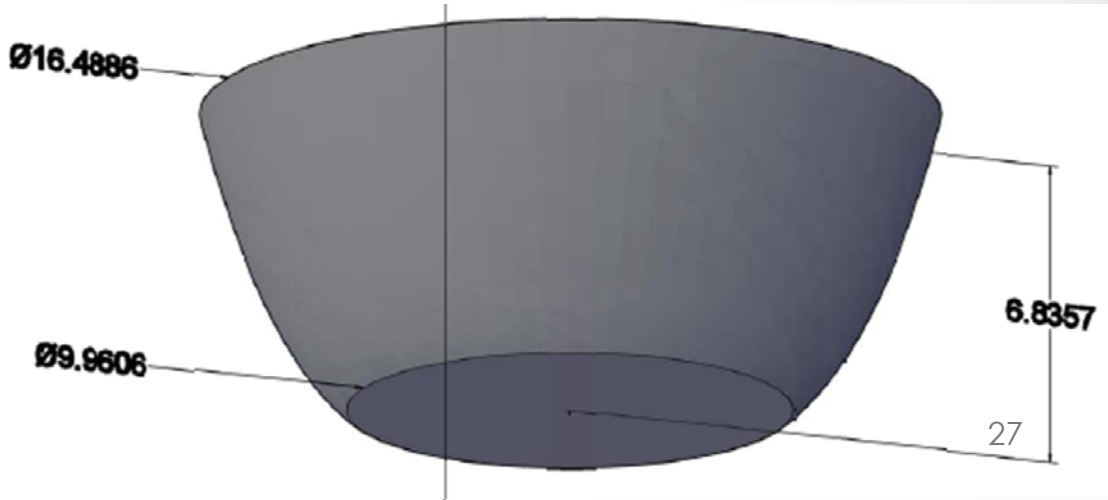
Decay time = 2.1 ns

Vendor: Saint-Gobain

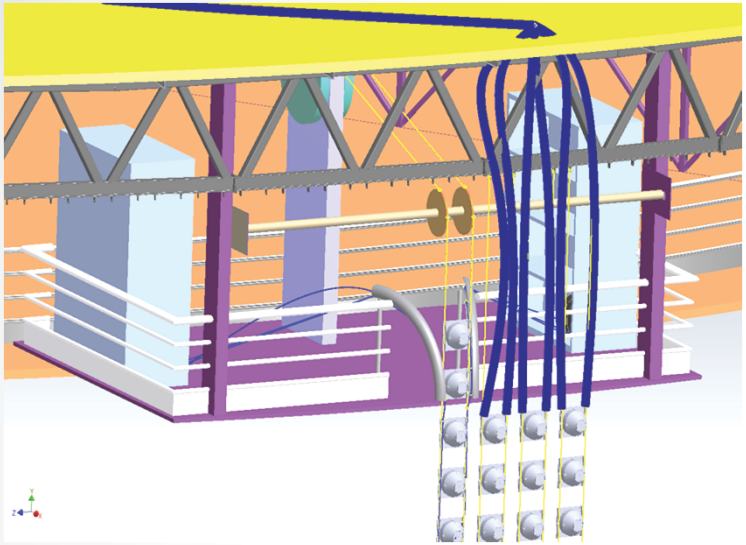
- Stand alone simulation showed light collection increase of 50% or more depending on the size of the plate, fluor, decay time.
  - 40% was assumed in PMT number evaluation.
- The effect of timing degradation on vertex resolution is under study in WCSim.
  - 2.1ns decay is less than the corresponding vertex resolution.
- Re-transmitted light should be modeled.
- Additional prototype studied are needed
  - Optimize doping, coupling
- A full reconstruction study with the scintillators included is necessary.

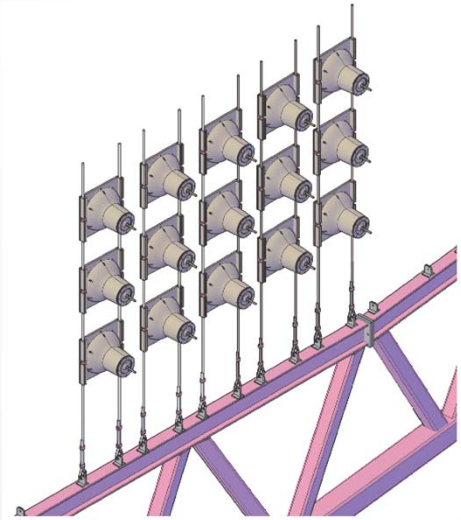
Winston Cone Design

- ~60° opening angle, same height above PMT face
- 10" diameter at base increasing 16.5"
- Al coating with additional protective (under investigation)
- Increases light acceptance by 60%
  - SNO and Borexino designs increased acceptance by 1.75 and 2.5 factor
- Need to understand impact of shadowing on fiducial volume and ring reconstruction.
  - Need detailed reconstruction code for LBNE

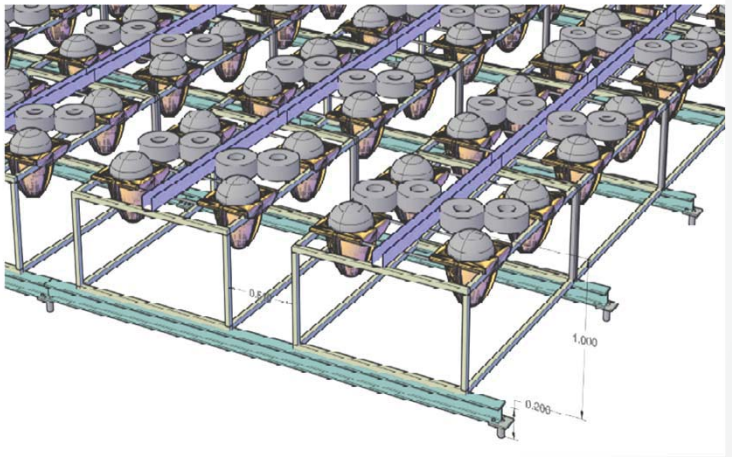


PMT Deployment



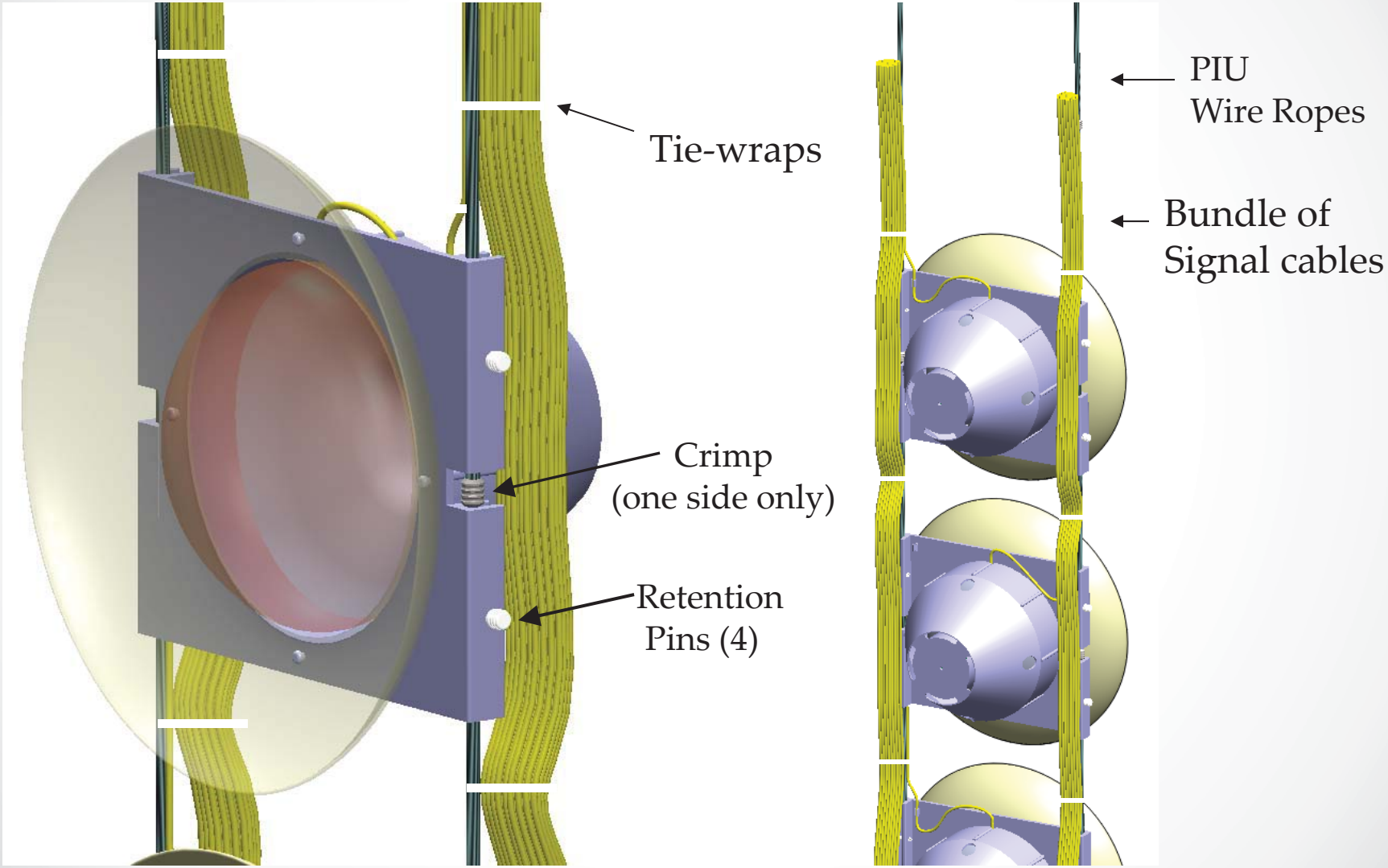


- Wall PMTs deployed from deck and supported on steel cables
- No attachment to wall
- Buoyant force resisted by ring truss on floor
- Signal cables supported by steel cables and routed to balcony

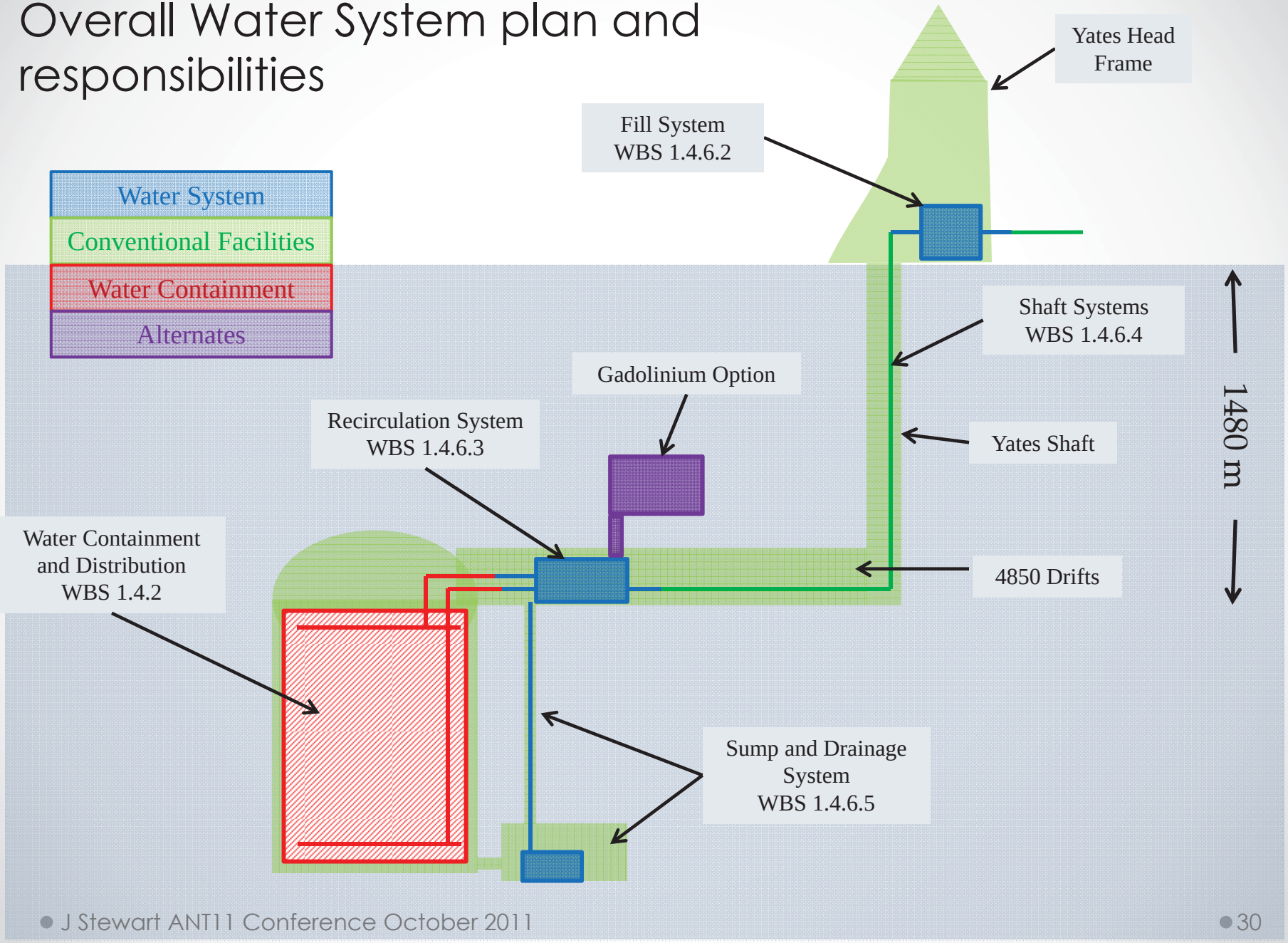


- Floor PMTs supported on frames on floor
- Access isles between tight but possible
- Cables routed to perimeter and up to balcony
- Deck PMTs supported similarly but inverted

Linear PIU with signal cables

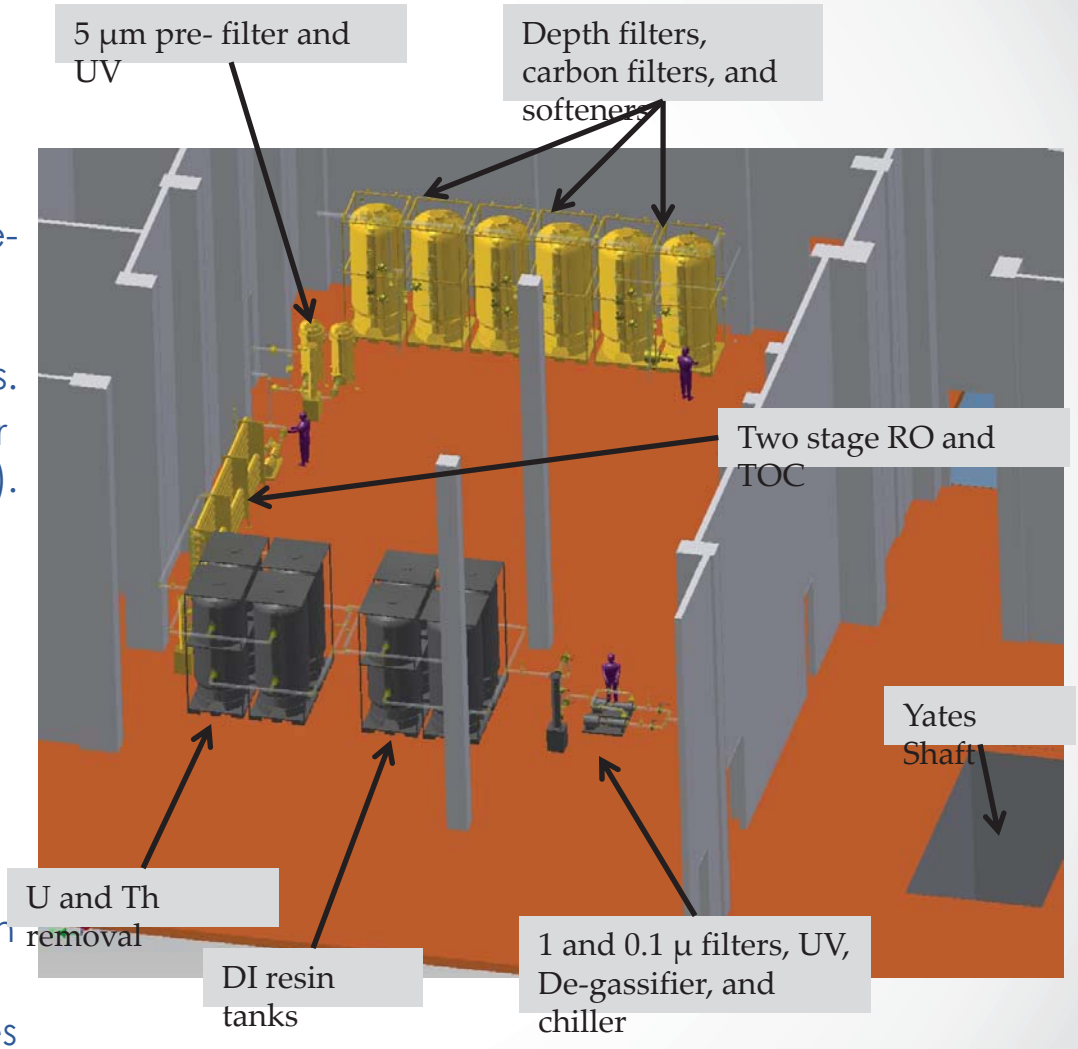


Overall Water System plan and responsibilities

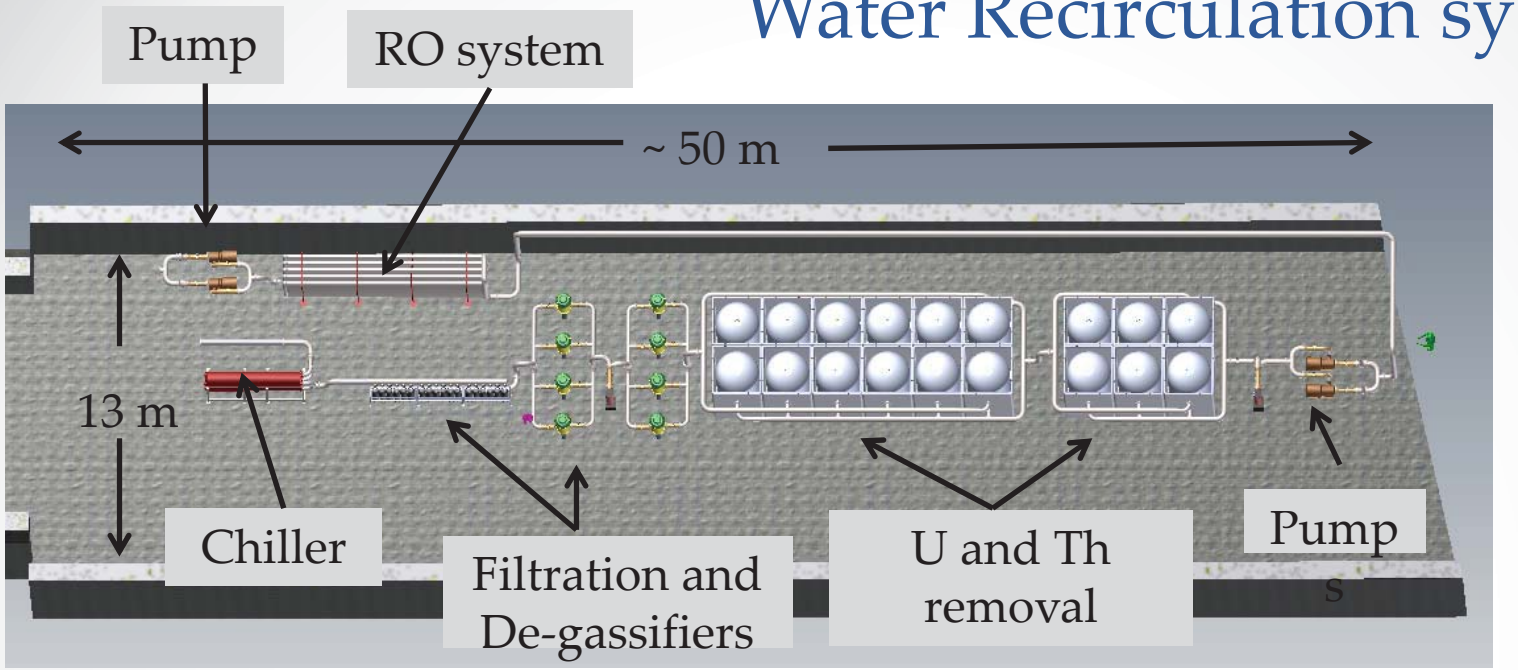


Surface Fill System

- 250 gpm filling capacity.
  - 6 month fill time
  - Limited by the supply of municipal water.
- Depth and carbon filters, softeners, pre-filters, and UV will remove silt, micro-organisims, and particulates to the 5 µm to prepare for the R.O. membranes.
- The R.O. output will go to a UV-oxidizer unit called TOC (total organic carbon).
- The water will then go to a sodium exchange anion resin to remove uranium and thorium. This will be followed by a mixed bed deionizer.
- More filtration down to 0.1 µm, UV sterilization, and a de-gassifier to remove oxygen, CO_2, and radon.
- Then to a chiller to adjust the temperature before being piped down to the detector level of the mine.
- Layout available in existing room (Yates Crusher Room).



Water Recirculation system



- The underground system consists of multiple pumps, R.O., U/Th removal, de-ionizers, multiple filtration stages, de-gassifiers, UV sterilization, TOC, and a chiller system.
- 1200 gpm recirculation rate .
  - Scaling Super-K flow by volume/surface area gives ~1320/~760 gpm
- Temperature maintained at <13°C
- The system design is very flexible and does not preclude the addition of gadolinium to the detector.
- A 3D conceptual layout is available.

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Conclusions

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- The Collaboration will select the detector technology for LBNE this year.
- The DOE will have decided the program for underground science in America with a year from now.
- The design for a 200(250) kt fiducial volume (total volume) detector is at or beyond the conceptual level.
- Rapid progress is possible if funding is available.

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