

# Scientific Program for Long-baseline Neutrinos

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12/1/2015

Visit of FNAL management to BNL

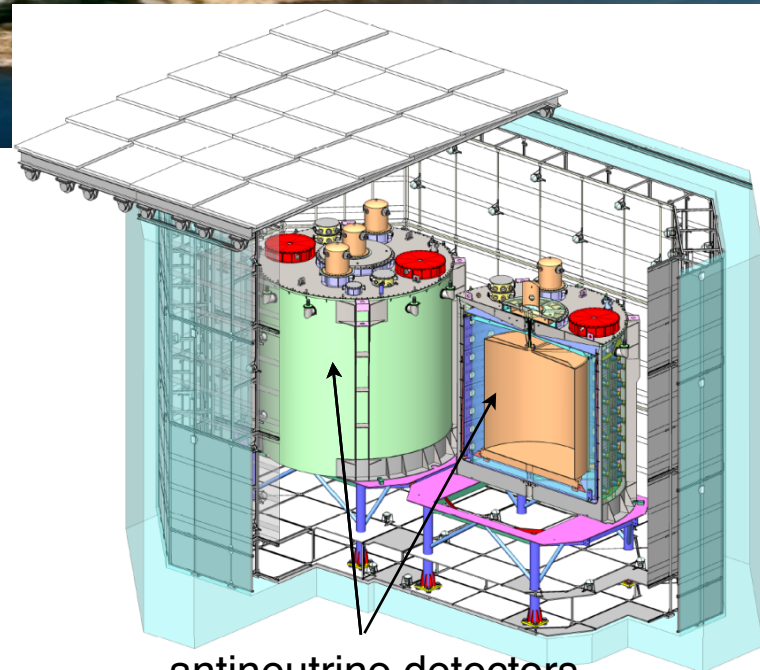
# BNL neutrino program (what we do)

- **BNL participation in accelerator neutrinos is driven by the goal of finding CP violation in neutrinos and the vision of having a capable large underground detector for proton decay and neutrino astrophysics. Our program is coherent and integrated across many experiments, and sub-projects:**
  - The Daya Bay effort has measured  $\sin^2 2\theta_{13}$ , a crucial input to the future program.
  - The MINOS effort has allowed us to precisely measure  $\Delta m^2_{32}$
  - The first MINOS  $\nu_e$  appearance result was initiated and carried out at BNL.
  - The NuMI/MINOS/MINOS+ beam effort allowed us first hand technical knowledge about the beam and an operating system for optimization of the beam spectrum for LBNF.
  - BNL expertise in LAr, electronics, and TPC design has led to leadership in MicroBoone and SBN.
  - BNL was responsible for a complete design of a water Cherenkov detector in SURF. We have detailed understanding of underground construction as well as the physics issues.
  - We have broad scientific leadership roles in LBNE and were responsible for the scientific vision set forth to P5 in the science document.
  - We have made a large investment in LBNE and would like to make LBNF successful through our participation.

# Daya Bay

The key analysis personnel from BNL: Jaffe(AC), Qian, Zhang, Ling, Whitehead, Worcester, Tang, and others...

We know this game and we have evidence of success.

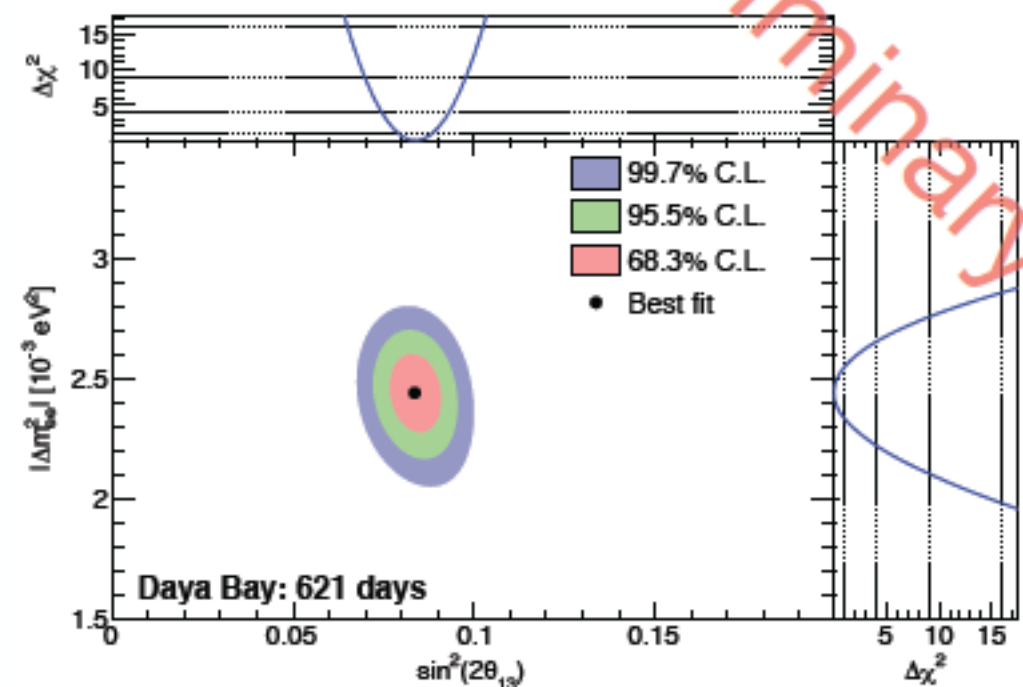
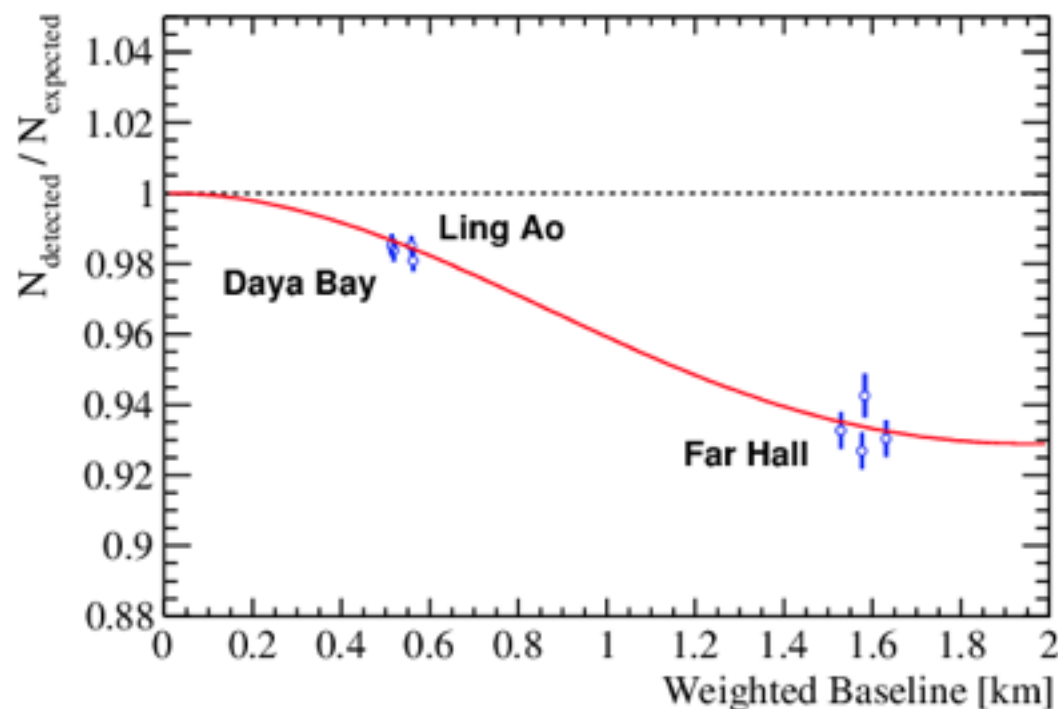


antineutrino detectors

Observe electron-antineutrino disappearance  
six 2.9 GWth reactors  
eight 20-ton detectors: 4 near (~500m), 4 far (~1650m)  
190 days of running

$$\sin^2 2\theta_{13} = 0.084 \pm 0.005 \text{ (stat+sys)}$$

Preliminary from Neutrino 2014. Publication is in progress.  
Future projected error is 0.003.



# The current BNL team on LBNF. ~38

<p>Kettell, Steve, H. Jaffe, David E. , Lanni, Francesco, Littenberg, Laurence, Marciano, William, Parsa, Zohreh, Samios, Nicholas, <b>Bishai, Mary</b>, Diwan, Milind, Qian, Xin, Worcester, Elizabeth</p>	<p>Physics, simulations, collaboration management, ~4-5 FTE</p>
<p>Radeka, Veljko, Rescia, Sergio , Chen, Hucheng, Yeh, Minfang, Thorn, Craig, <b>Stewart, James</b>, Morse, William, Yu, Bo, <b>Hackenberg, Robert</b>, de Geronimo, Gianluigi Gill, Ronald, Worcester, Matt, <b>Penka Novakova</b></p>	<p>Liquid argon technology, project management, ~4 FTE (includes effort on local R&amp;D, and 35 ton, but not microboone)</p>
<p>Adams, David Viren, Brett Potekhin, Maxim</p>	<p>Software development and management, ~2.5 FTE</p>
<p>Brown, Ralph, <b>Dolph, Jeffrey</b>, Mahler, George, Sharma, Rahul, Simos, Nikolaos,</p>	<p>Engineering, ~2.5 FTE</p>
<p>Hans, Sunej, Joshi, Jyoti Kirby, Brian, Li, Shaorui Li, Yichen, Mooney, Michael Zhang, Chao</p>	<p>Postdoc, ~2.5 FTE Time shared with other experiments. (Daya Bay, Microboone, etc.)</p>

**This effort is across many departments and disciplines. It has grown steadily in concert with other efforts and has the flexibility to be increased significantly whenever needed.**

Key project people in RED

# Identification of the scientific opportunity.

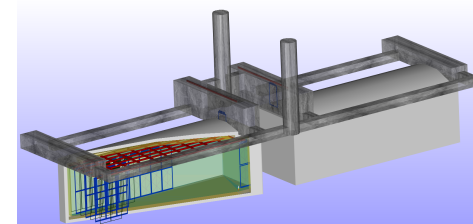
- The design for a US based CP violation program with a conventional beam started at BNL ten years ago before we knew the solar LMA solution and  $\theta_{13}$  (See BNL-69395 (2002)).
- A Joint BNL-FNAL study was launched in 2006, and the results were reviewed by an international NUSAG panel in 2007, and later by P5 (2008).
- BNL physicists pointed out that the scale of the program needed is only weakly dependent on  $\theta_{13}$  because the CP asymmetry is smaller for larger  $\theta_{13}$
- The scientific choices have been heavily influenced by BNL, and the current design will continue to be improved.
- The investment into this program requested by P5 in 2008 and carried out by the DOE/NSF was timely and has paid off. We now know
  - The scientific capability of the enterprise.
  - Have a science and engineering team that is very strong.
  - Have conceptual designs for beam, both water and LAR technologies.



# BNL played an active role in LBNE collaboration Organization.

- Oct. 2008 UDIG workshop at BNL and first collaboration meeting.
- Oct. 2008 Institutional board formed and Interim Executive Board meetings
- Nov. 2008 Collaboration mission statement.
- Dec. 2008 Collaboration Depth justification document completed. BNL-81896-IR, Fermilab-TM-2424-E, LBNL-1348E
- Jan. 2009 Collaboration proposal to NSF (S4 solicitation) for design work.
- Meetings: Feb. 2009-Davis, July 2009-FNAL, Oct. 2009-Deadwood, Jan-2010-FNAL, May 25-28-2010 Deadwood, Sep. 12-2010-FNAL, Jan-2011-UCLA, July13-15-FNAL.
- by 2009 the collaboration was sufficiently organized with governance rules in time for CD0. Project got organized later.
- First phase of work on the CDR finished 2010 and there were internal mini-reviews (Sep. 2010 thru Nov. 2010) ([http://lbne.fnal.gov/reviews/reviews\\_index.html](http://lbne.fnal.gov/reviews/reviews_index.html))
- NRC committee review (Dec2010-March2011).
- Marx committee (review at SLAC April 14-15 2011)
- A complete record of collaboration organization and minutes is in DOCDB.

Both the Daya Bay and LBNE experience in collaboration building have provided us a deep understanding of how to do this internationally. In particular, there are many elementary mistakes to be avoided.



# Events versus BNL; technical work excluded

Event	BNL role
NSB turned off DUSEL	Worked with DUSEL staff on civil requirements: (Russo,Dolph,Novacova,Stewart, Diwan.) Reconsideration of the beam (Stewart)
2011 Review from the NRC/BPA committee	Scientific input for the NRC review. Case studies organized for WCD and LAR (Bishai, Diwan)
Marx/Reichanadter committee	Organized for a review of the technical and cost details of WCD. Technical review of LAR TPC and electronics. (Diwan, Bishai, Dolph, Russo,Thorn, BoYu)
Science capability and cost/schedule reviews (fall2011)	Review organization, presentations (Diwan, Bishai,Thorn) CDR preparation (Viren, Kettell, Tanaka, Ling, Stewart, Dolph, Novacova, Thorn, BoYu)
Far detector Technology Choice	Exec Board meeting organization (Diwan), DOE/FNAL documentation (Diwan). Reorganization of the effort (Kettell, Stewart, Littenberg, Dolph, Novacova, Thorn, BoYu)
Reconfiguration panel (2012)	Cost/Schedule group (Stewart, Dolph, Novakova), Physics Group (Diwan, Bishai, Worcester)
CDI director's review (2012)	Full scope CDR (the entire BNL team).WCD CDR was completed also.
CDI review (2012)	CDR (the entire team from BNL was involved at all levels, physics, engineers, costs)
Community Summer Study (2013)	Scientific Opportunities Document
Software/Computing, R&D organization and review (2014)	Large organizational task across many institutions (Viren, Potekhin, Diwan, Adams, Stewart)
P5 (2014)	LBNE Science Document (edited by a large team with leadership from BNL)

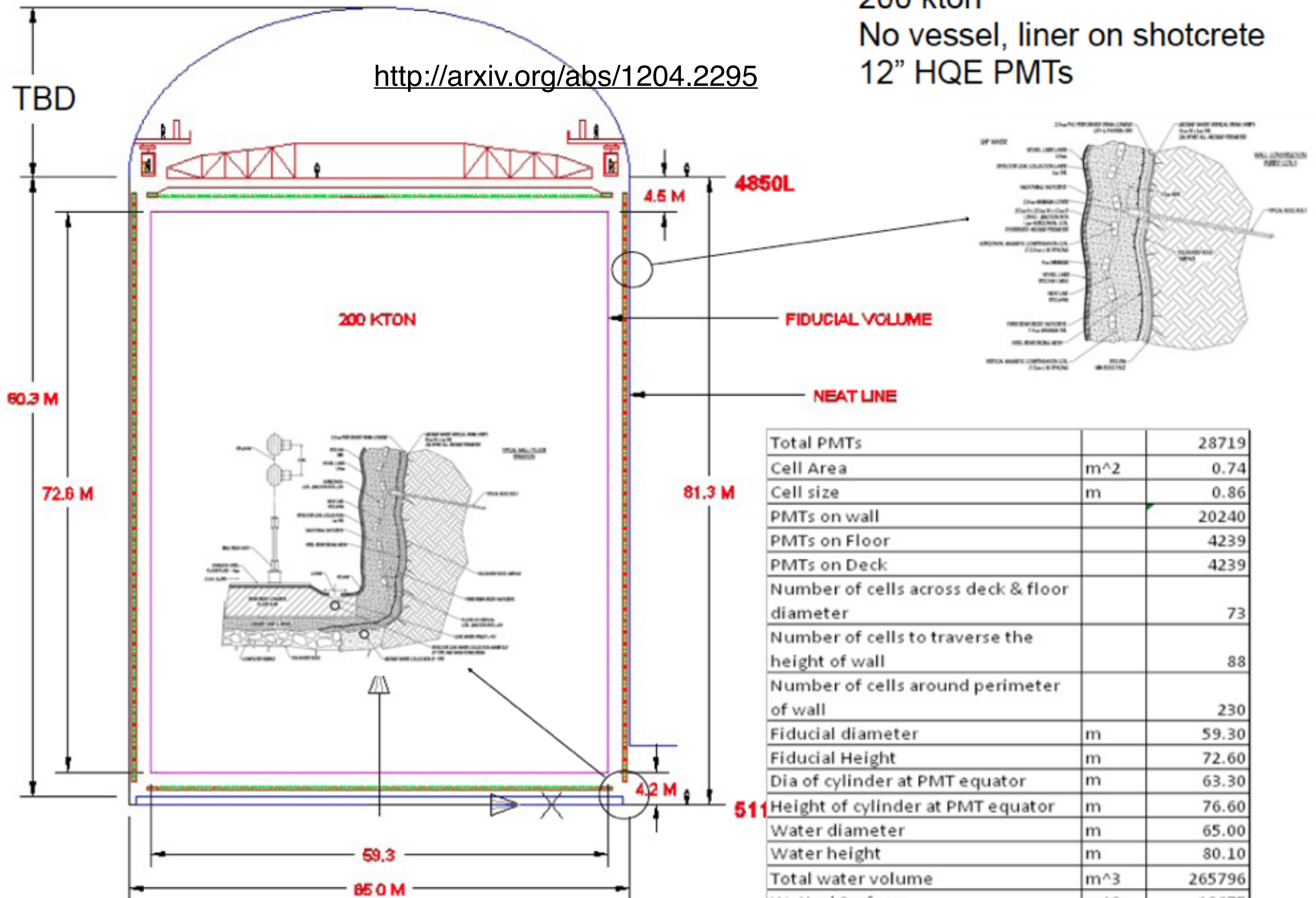
# A water Cherenkov detector ? Please talk to us first before buying one !

200 kton

No vessel, liner on shotcrete

12" HQE PMTs

<http://arxiv.org/abs/1204.2295>



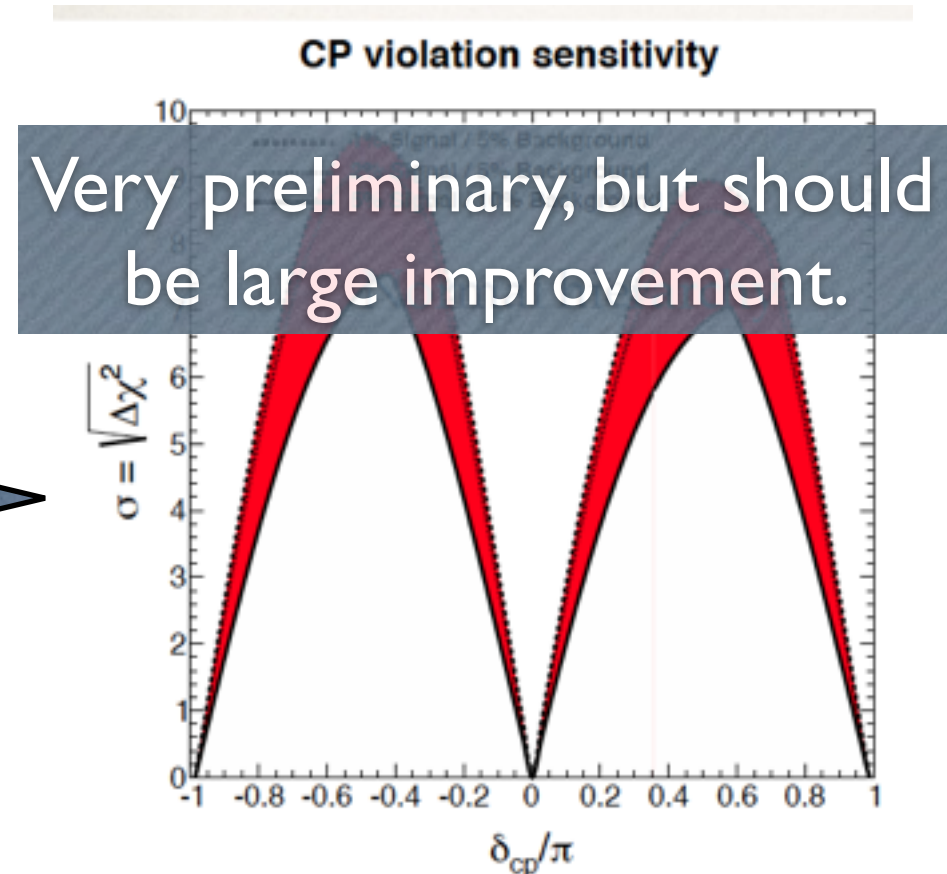
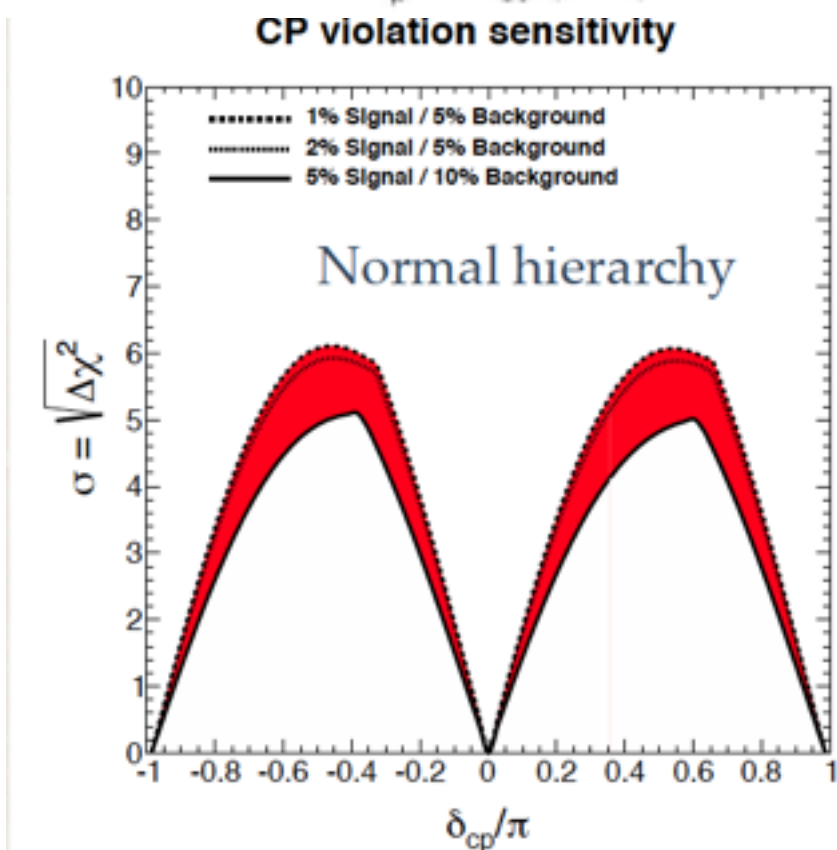
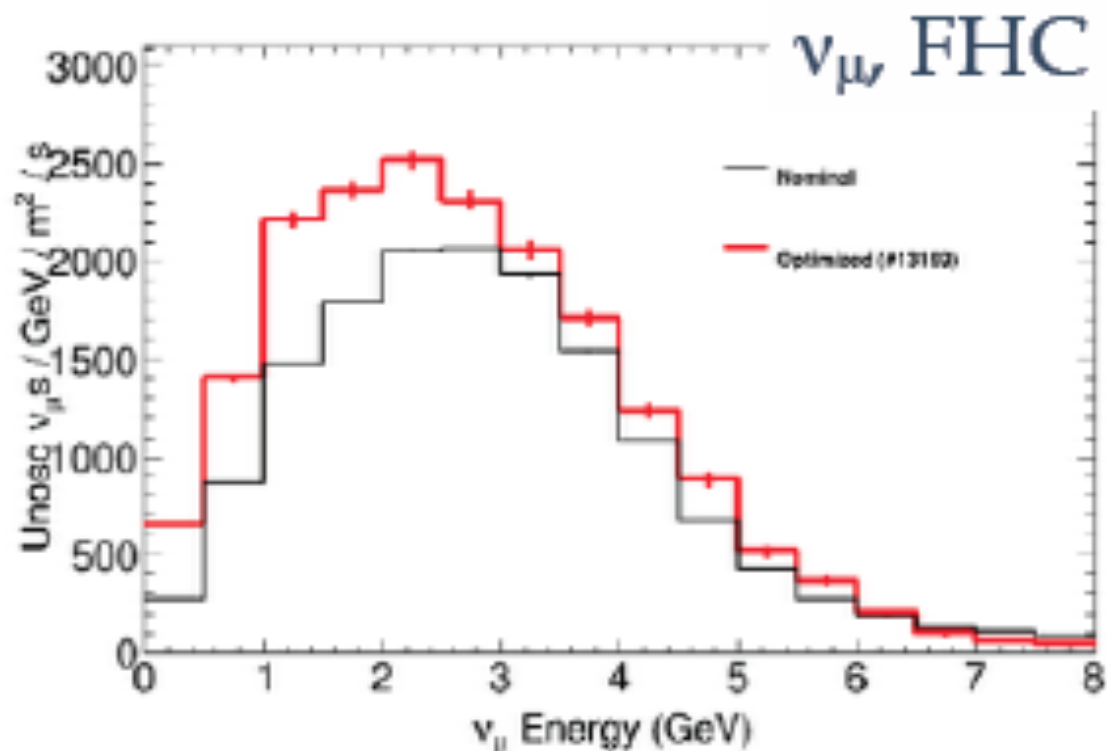
Total PMTs		28719
Cell Area	m <sup>2</sup>	0.74
Cell size	m	0.86
PMTs on wall		20240
PMTs on Floor		4239
PMTs on Deck		4239
Number of cells across deck & floor diameter		73
Number of cells to traverse the height of wall		88
Number of cells around perimeter of wall		230
Fiducial diameter	m	59.30
Fiducial 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 <sup>3</sup>	265796
Wetted Surface	m <sup>2</sup>	19675
Surface to volume ratio	m <sup>-1</sup>	0.074



# Recent Important Work

This remarkable effort has highlighted

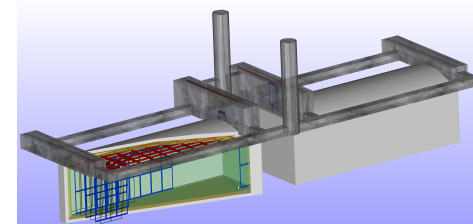
- 1) Leadership from young individuals (Laura Fields and collaborators.)
- 2) A diverse team with expertise: on the scientific side (as demonstrated in the baseline optimization paper), beam technology, beam Geant simulation, Fast Monte Carlo, accurate and accepted calculation of the sensitivity and its correlations.



From Laura Fields (Northwestern)

# Conclusion

- BNL has important assets on LBNF
  - Large scientific and technical effort
  - Base of knowledge on scientific arguments.
  - A large experience base on detector technologies for water Cherenkov, Liquid Argon as well as liquid scintillator technologies.
  - Personnel with detailed and active knowledge of science and engineering requirements for the entire project including underground construction.
  - Well-developed (well documented) partnerships with FNAL and other labs and universities.
- We want to make LBNF successful.



# Project Office - Systems Engineering

## Project Systems Engineer – Jeff Dolph

- Responsible for implementation and management of the Project:
  - And Subprojects' Requirements for science (w/Milind, Vaia, Christopher and Jim) and engineering (all tech systems and w/NS & FS CF) including FNAL transition from DOORS to TeamCenter requirements database
  - Configuration Management and Change Control
  - Interface Control including communications between CF & A/E
  - Risk Management
  - Quality Assurance
  - Value Engineering
- Engineering Integration through implementation of FNAL TeamCenter and other institutions' interface with TeamCenter (coordinating with PIP-II for consistency of processes)
- Engineering to Science interface by direct communication with Spokespersons (example: collaboration assessment of FS CF)
- Chair of weekly Project Management meeting which includes spokespersons
- Involved Project meetings with LBNO
- Frequent time at FNAL