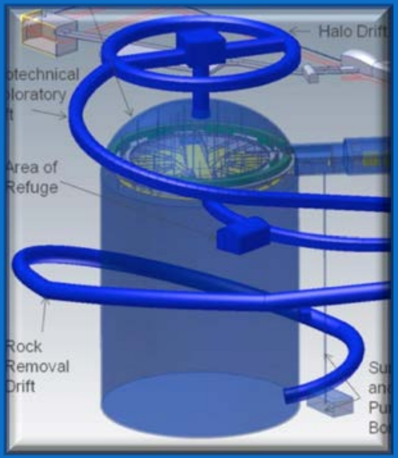
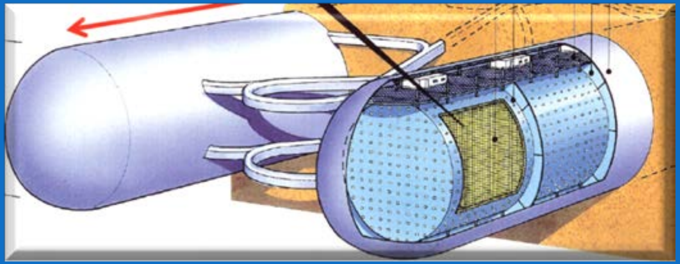
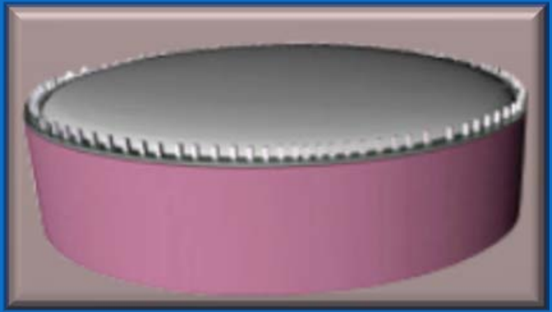
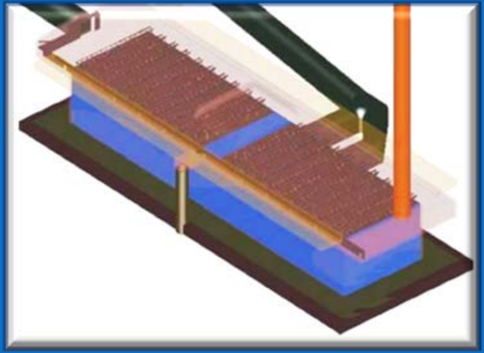
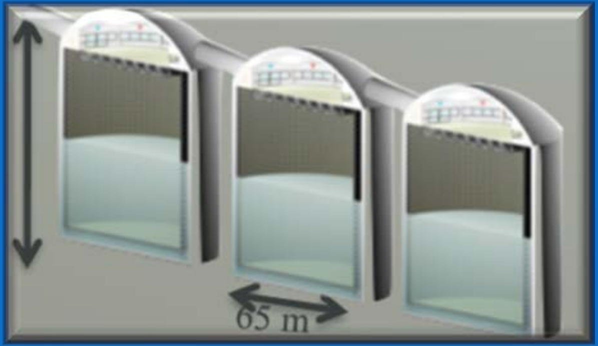
Large Detectors: Challenges











ROBERT J. WILSON

COLORADO STATE UNIVERSITY

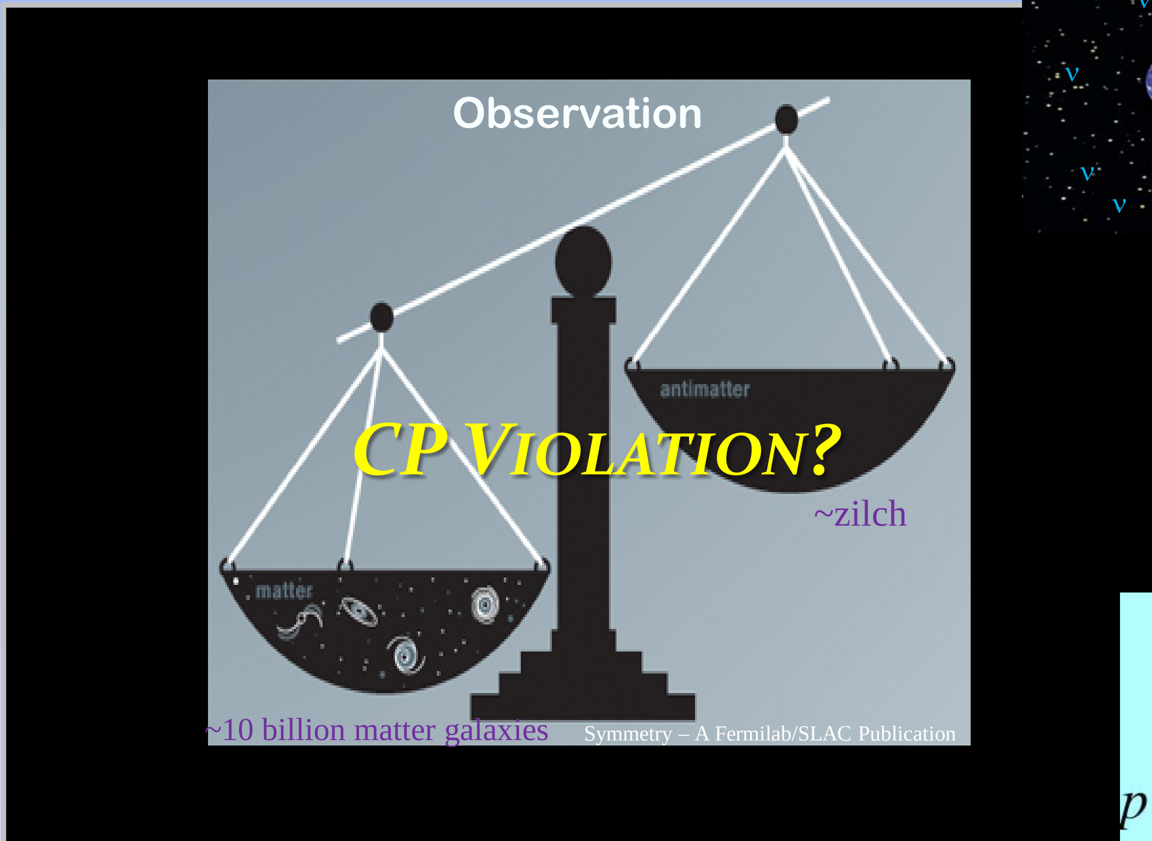
24 OCTOBER 2011, FERMILAB (VIDEO)

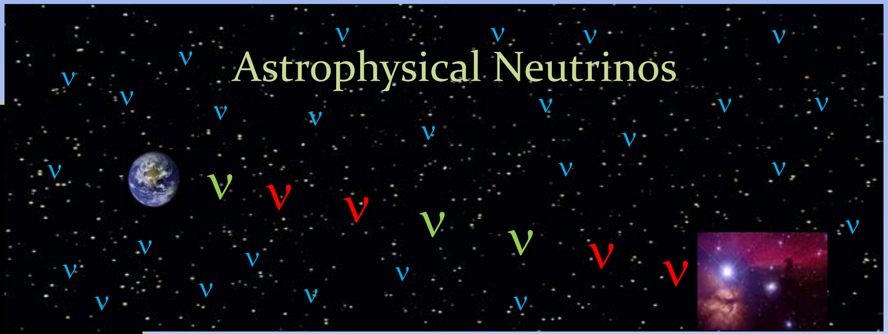
HIGH INTENSITY FRONTIER NEUTRINO WORKSHOP

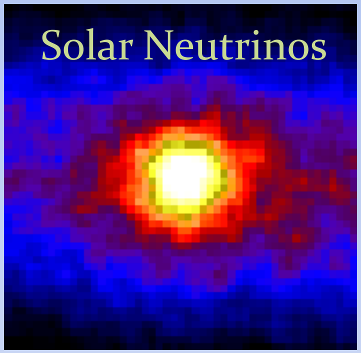
Overview

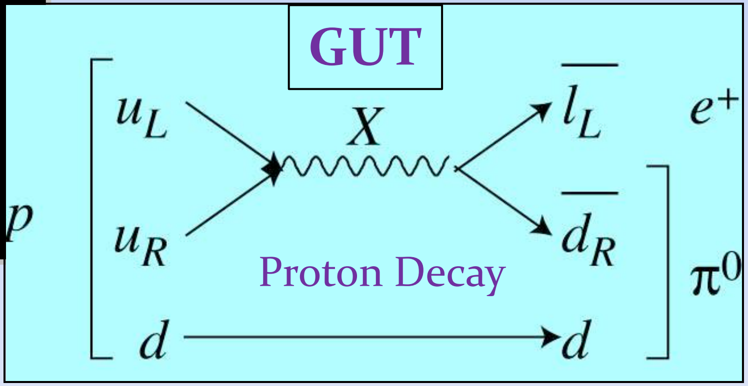
- Why Very Large Detectors
- Large Detector Technologies
- Global Status
- Summary

Physics Motivation

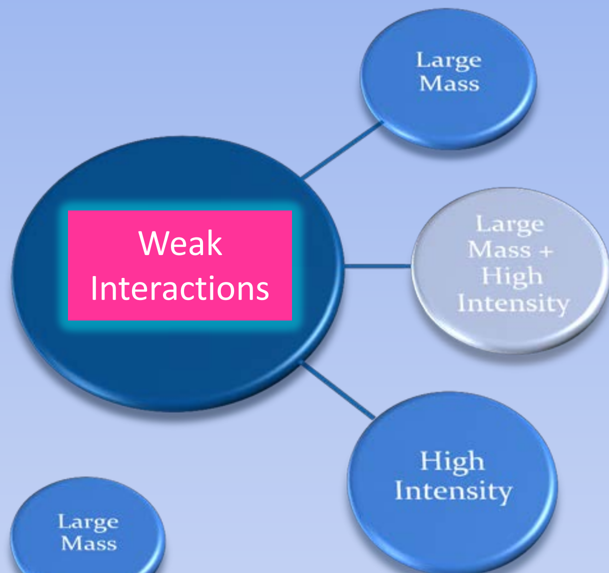


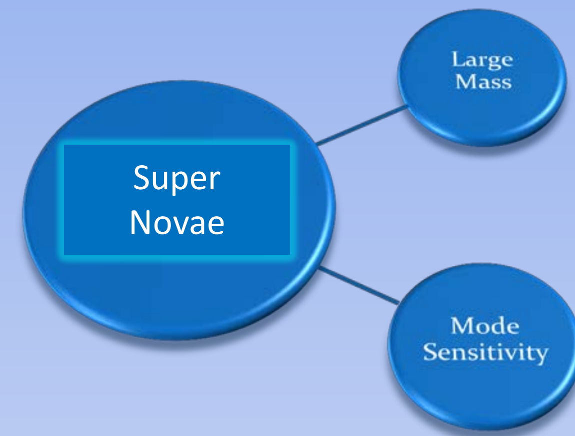


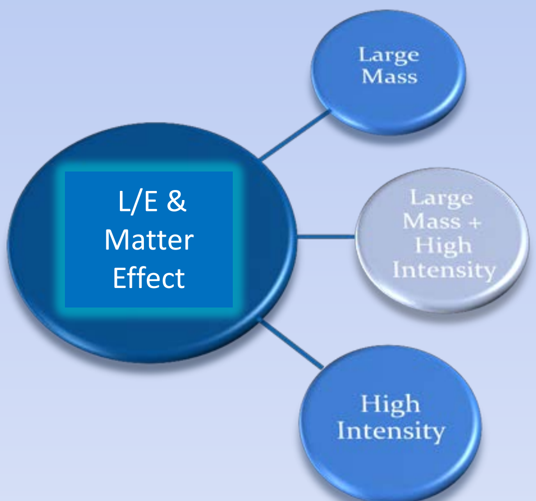


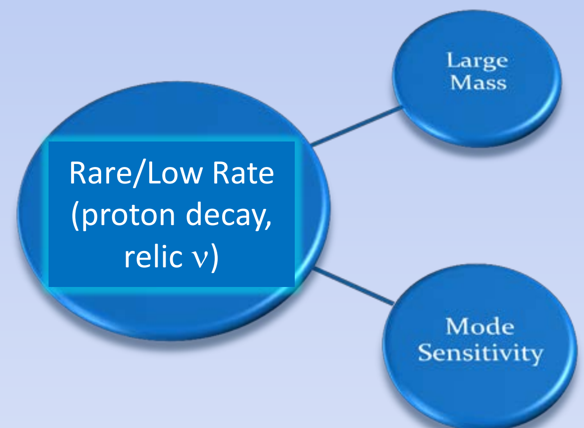


Why Large Detectors?





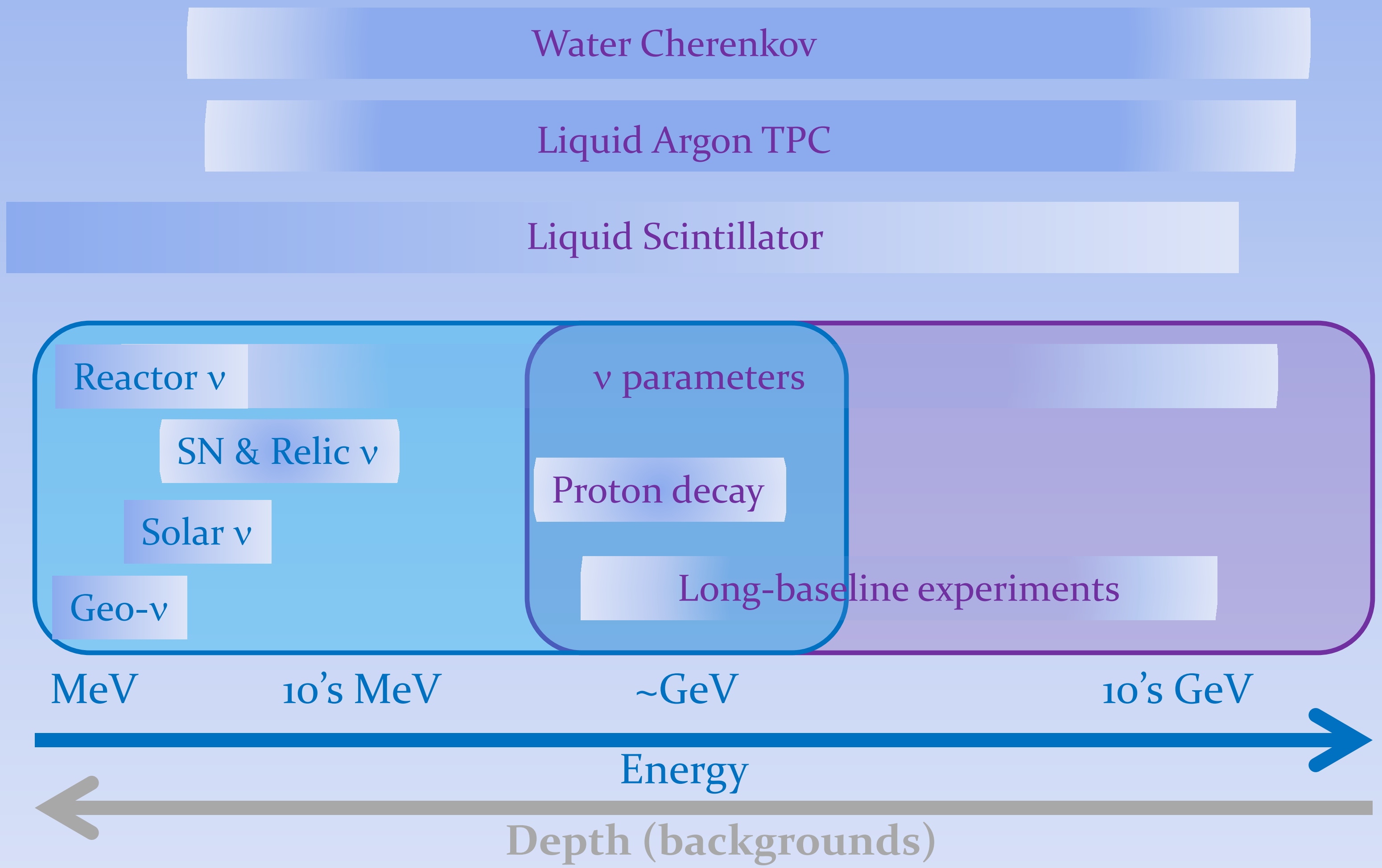




Need the largest *feasible detectors**

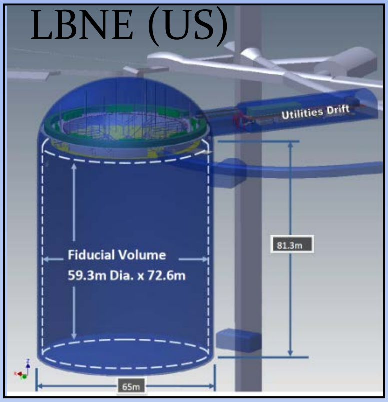
* technically, fiscally, politically, …

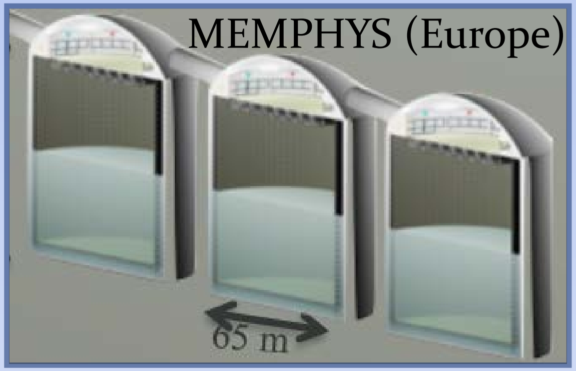
Large Detector Technology

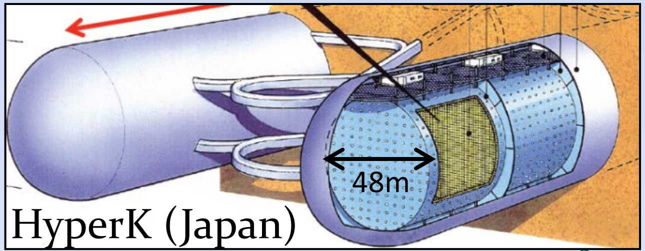


Water Cherenkov Detectors

- Mature technology
  - ~30 years experience
  - IMB, Kamioka, Super-K
- Modest extrapolation from current experiments
  - No critical path R&D for essential components
- Challenges
  - Very large mass
  - Cavity excavation
  - Tank/liner construction
  - Photosensor implosion
  - "Old technology"
- Need depth, fine granularity, Gd doping for lower energy physics
  - In tension with larger mass for fixed budget

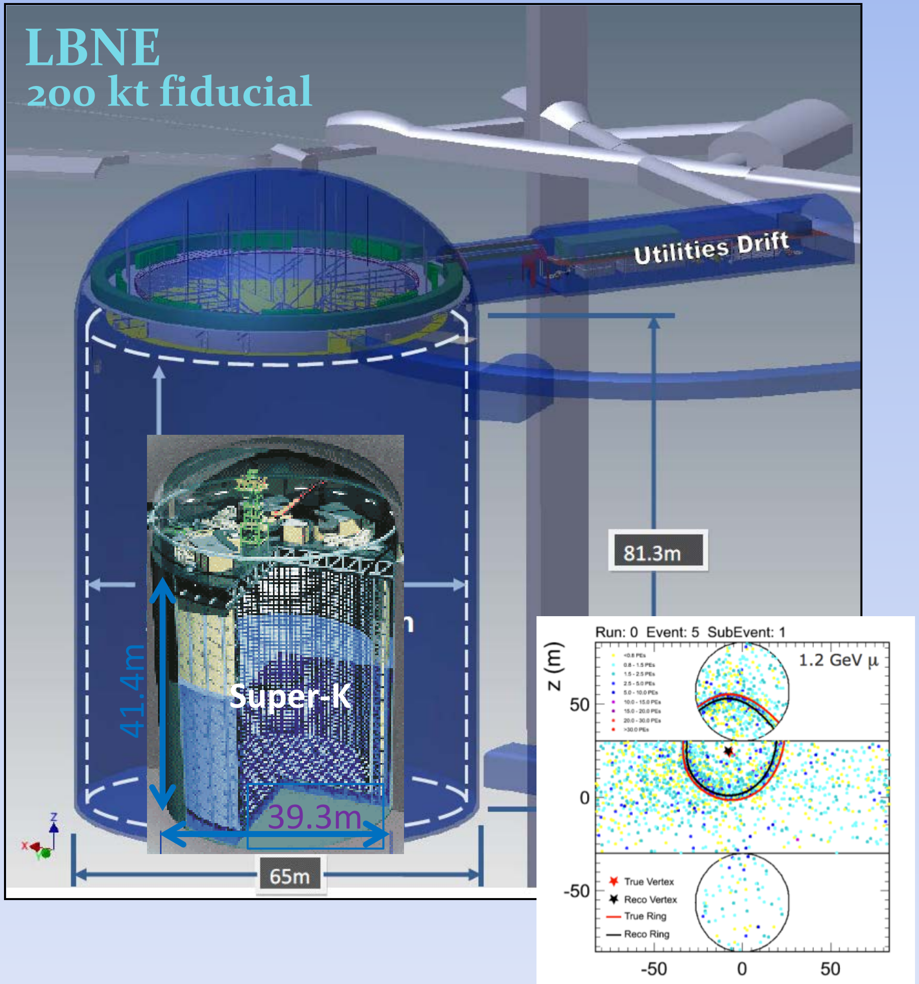






Water Cherenkov Detectors

- LBNE (US) WCD
  - 81.3 m x ϕ 65.0 m cylinder
  - Total/fiducial mass 260/200 kt
- Super-Kamiokande
  - 41.4 m x ϕ 39.3 m cylinder
  - Total/fiducial mass 50/22.5 kt
- LBNE WCD/Super-K Scale-Up
  - Linear dimensions: 2.0 x ϕ 1.65
  - Mass: 5.2/8.9
- Hyper-K (Japan)
  - Two x 250 m x ϕ ~48 m cylindrical egg
  - Total/fiducial mass: 990/560 kt
- MEMPHYS (Europe)
  - N x 65 m x ϕ 65.0 m cylinder
  - Total/fiducial mass N x ~200/147 kt



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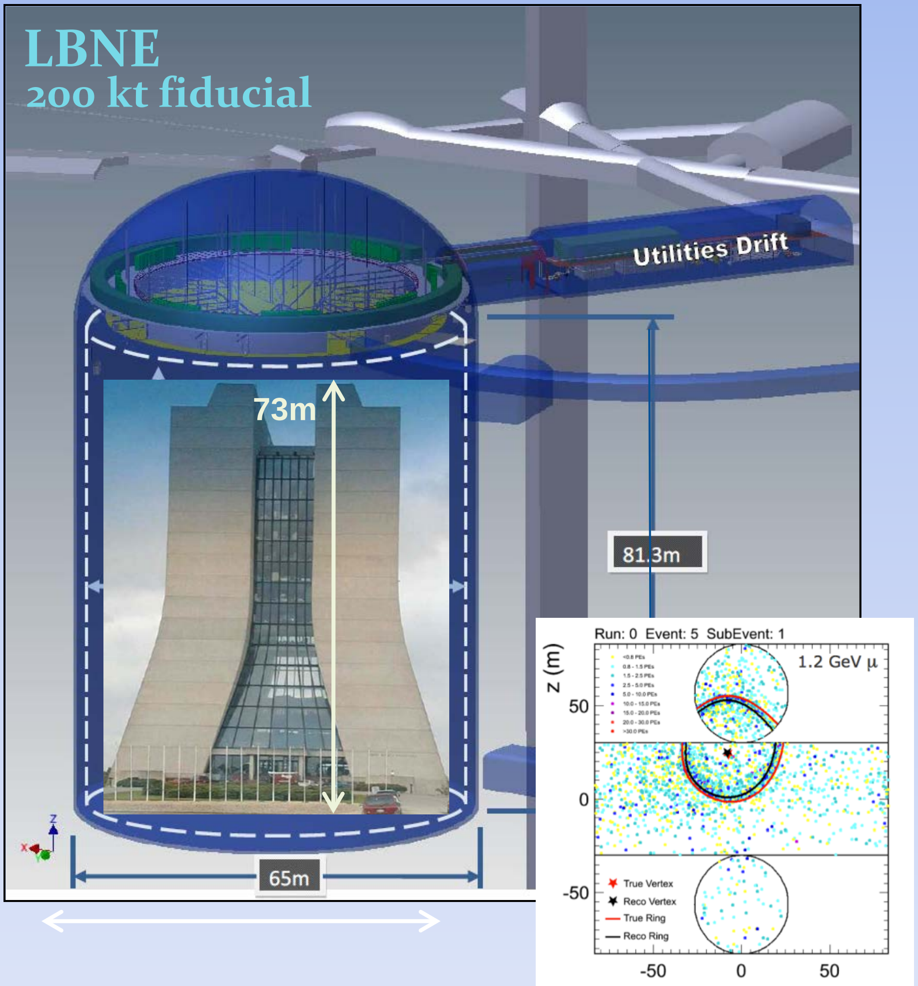
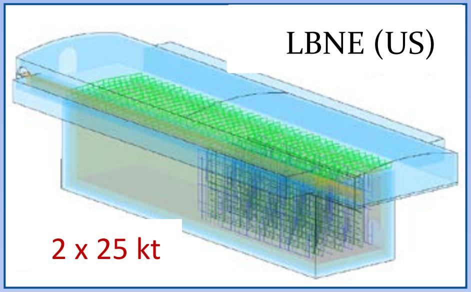
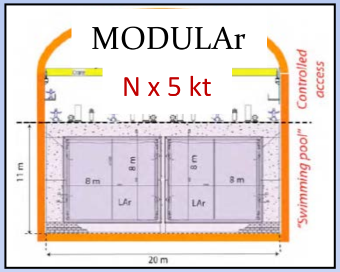
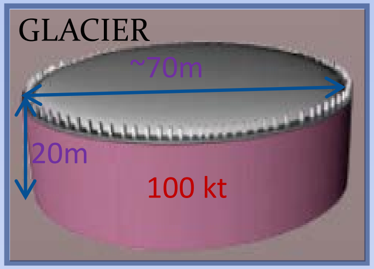


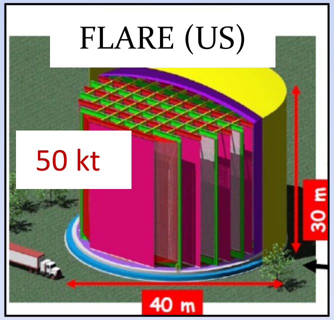
Liquid Argon TPCs

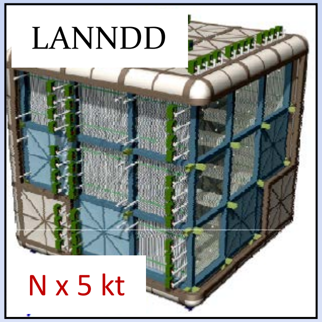
- "Electronic Bubble Chamber"
  - Millimeter resolution over very large volume
  - ~x6 signal efficiency for ν_e appearance compared to water
- Modest operating experience
  - ~25 years R&D and prototypes
  - ICARUS - T600 beam 2010
  - LAr calorimeters mature technology
- Challenges
  - Large size extrapolation from current experiments
  - Large intermediate-scale (1 kt) prototype
  - Target (LAr) cost
  - Purity, underground cryogenics
  - Backgrounds for low energy physics





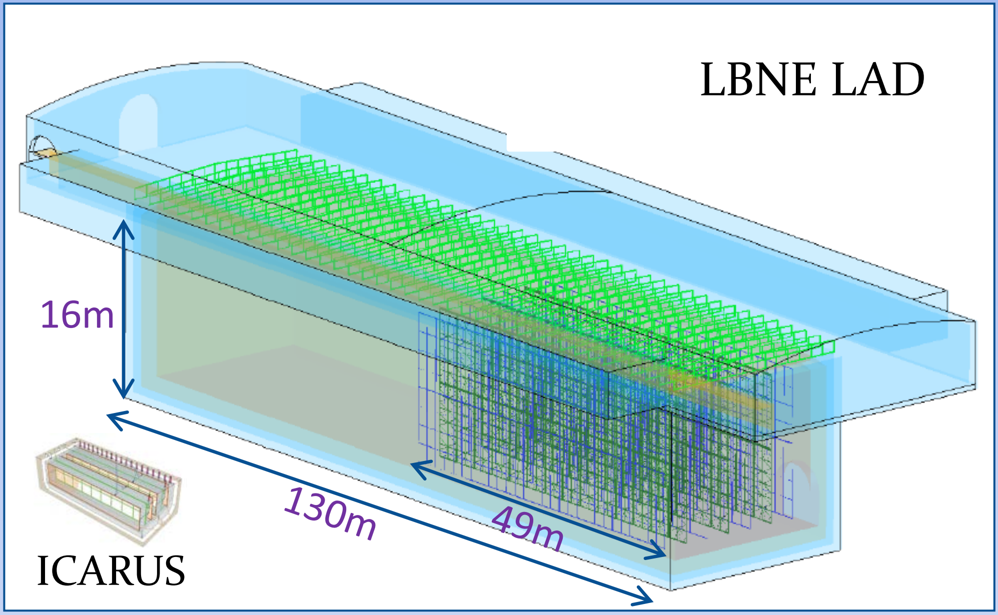




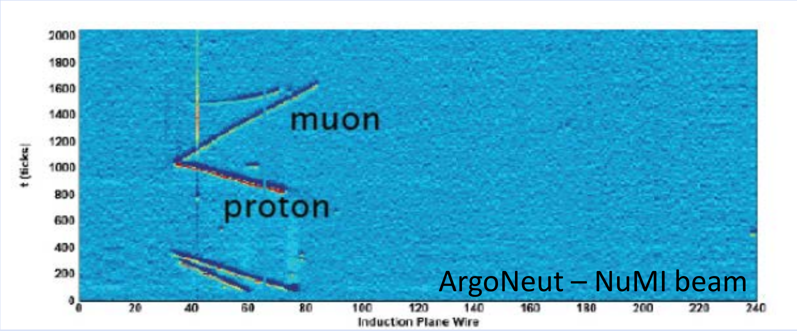


Liquid Argon TPCs

- **LBNE (US) LAD**
  - **Two x 24m x 16m x 49m cryostats**
  - **Total/fiducial mass: 50/32.6 kt**
- **ICARUS**
  - **Two x 3.6m x 3.9m x 19.6m cryostats**
  - **Total/fiducial mass: 0.6/0.48 kt**
- **LBNE LAD/ICARUS Scale-Up**
  - **Linear dimensions: 6.7 x 4.1 x 2.5**
  - **Mass: 42/34**

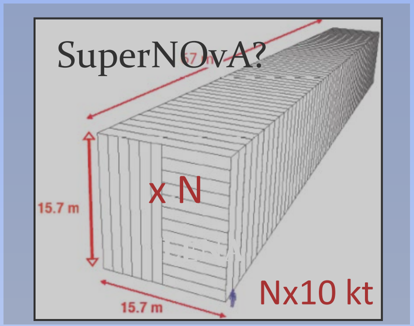


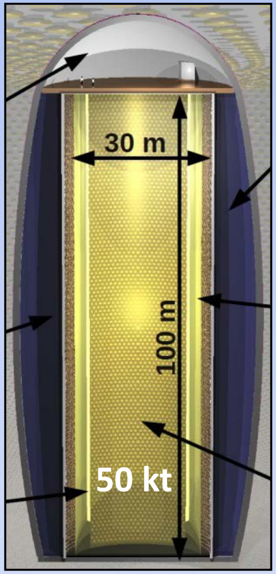
- GLACIER (Europe)
  - 20 m x ϕ 70 m cylinder
  - Total mass: 100 kt
- LANNDD (US/Italy)
  - N x 5 m x 5 m x 5m
  - Maximum total active mass 122 kt

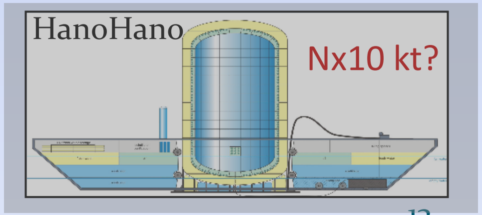


Liquid Scintillator Detectors

- Mature technology
  - KamLAND, BOREXINO
  - No critical path R&D for essential components
- Monolithic detectors optimized for low energy physics
  - Very good energy resolution and v. low threshold
  - Need depth, high granularity of photosensors
- Large size extrapolation from current experiments
- Challenges
  - Cavity excavation
  - Tank construction
  - Photosensor cost
  - Photosensor implosion
  - Performance for long-baseline neutrinos

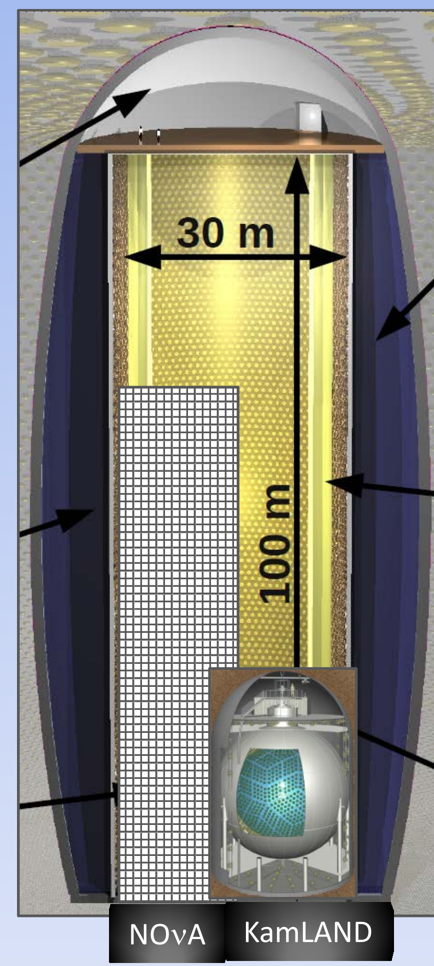


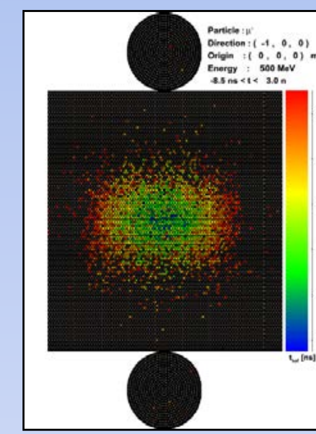




Liquid Scintillator Detectors

- **LENA**
  - **100 m x ϕ 30 m cylinder**
  - **Total/fiducial mass 50/?? kt**
- **KamLAND**
  - **ϕ 13 m sphere LS**
  - **Total/fiducial mass 1.0/0.5 kt**
- **LENA/KamLAND Scale-Up**
  - **Height/width: 7.7 x 2.3**
  - **Mass: 50/?100**
- NoVA
  - 15.6 m x 15.6 m x 67 m
  - Total/fiducial mass: 15/9.8 kt




TOF-corrected 1st hit

Global Status

US

- Long-Baseline Neutrino Experiment (LBNE) Science Collaboration
  - 320 collaborators, 60 institutions, 5 countries
- Site selected : Homestake, SD (1300 km from Fermilab)
  - Cost-effectiveness of Homestake for LBNE and other underground projects (Dark Matter, $0\nu\beta\beta$) under review by DOE
- Two far detector technologies: WCD + LAr TPC $\rightarrow$ selection by end of this year
- LBNE Project approval status: CD-0 “Project Definition” $\rightarrow$ CD-1 spring 2012

Europe

- EU-funded LAGUNA* evolved to LAGUNA-LBNO: 13 countries – 2011-14
- Far detector technologies: MEMPHYS 500-kt WC, GLACIER 100-kt LAr TPC, LENA 50-kt liquid scintillator
- LAGUNA seven sites $\rightarrow$ focus on two sites (130 km and 2300 km from CERN)
  - Frejus, France : 500-kt WCD
  - Pyhasalmi, Finland : 100-kt LAr TPC + (?)magnetized muon ranger; 50-kt LS
- Critical decision : 2014?

*Large Apparatus for Grand Unification and Neutrino Astrophysics

Global Status

Asia

- Three sites (295 km, 295+1050km, 658 km from JPARC)
  - Hyper-Kamiokande – 2 x 500-kt WCD
  - Kamioka and Korea – 2 x 500-kt WCD (not clear if this option still being pursued)
  - JPARC-to-Okinoshima (Japanese island) – 100-kt LAr (GLACIER)
- Site studies – primarily for Hyper-K
- Status : Hyper-K Letter of Intent September 2011
- LAr R&D

- International Workshop on Next generation Nucleon decay and Neutrino detectors : NNNxx series
  - First in 1999 at Stony Brook University
  - Rotates US-Europe-Japan
  - 12^{th} workshop : NNN11 next month in Zurich

Conclusion

- 10 years of studies and reviews conclude that a very large detector and very long baseline are needed to answer fundamental questions
- Higher power neutrino beams will significantly accelerate the rate of discovery and the total science output
- Understanding supernovae is central to our understanding of many aspects of the universe
- Proton decay and other new physics can only be probed with very large detectors
- Complementary detector technologies would optimize the global science program