# The ASDC: ***A***dvanced ***S***cintillation ***D***etector ***C***oncept

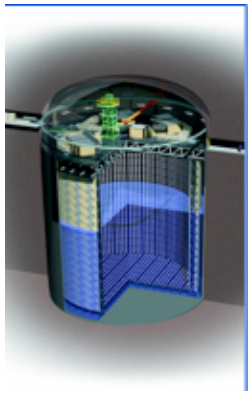
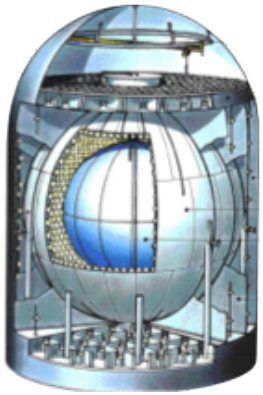
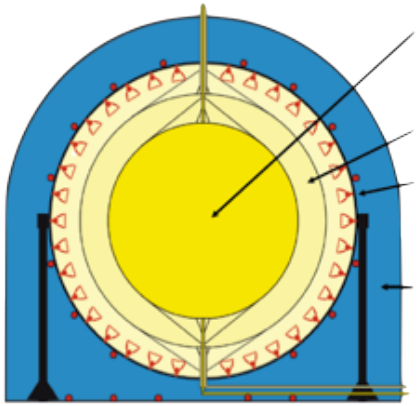
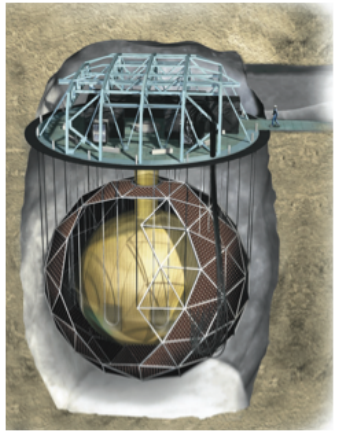
Josh R. Klein
for the ASDC Interest Group

Fundamental Symmetries Town Hall
Chicago, 2014

Detector image product of RAT-PAC

# What is the ASDC?

- **New technology with proven methodology**

1. Water-based liquid scintillator target
2. Doping with metallic ions (broad physics applications!)
3. High-efficiency, high-precision timing photo detectors
4. Deep underground location (e.g. LBNF far site)

➡ **Broad physics program!**

# Physics Program

## Broad range makes this more like a "user facility"

- Neutrinoless double beta decay
- Solar neutrinos (CNO, vacuum-matter transition)
  - see G. D. Orebi Gann FSNu town hall talk, sunday
- Nucleon decay
- Diffuse SN neutrinos, SN burst neutrinos
- Geo-neutrinos
- Long-baseline physics (mass hierarchy, CP violation)
- Source-based sterile searches (IsoDAR, Dae$\delta$alus)

(Remarkably, the same detector could in principle show that the neutrinos and antineutrinos are the same *and* that "neutrinos" and "antineutrinos" oscillate differently).

# Beyond the Physics

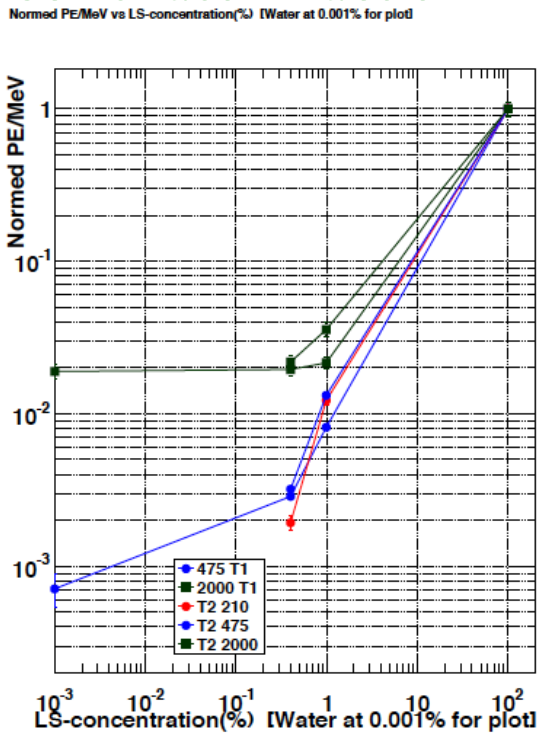
- Builds on existing investment by NSF, Sanford Lab, DOE/OHEP, DOE/NP
- Builds on existing community: Long history of WCD and LS experiments
- Builds on homegrown technology:
  - WbLS
  - Gd-loading
  - Other isotopic loading
  - LAPPDs from Chicago
  - Or PMTs from ETL
- Low technical risk=low contingency=low cost
- Broad program justifies cost: Not a "one-number" experiment

The existence of a deep laboratory, a beam, and the convergence of technical developments of WbLS, fast-timing, and isotopic loading make this a unique and exciting opportunity.

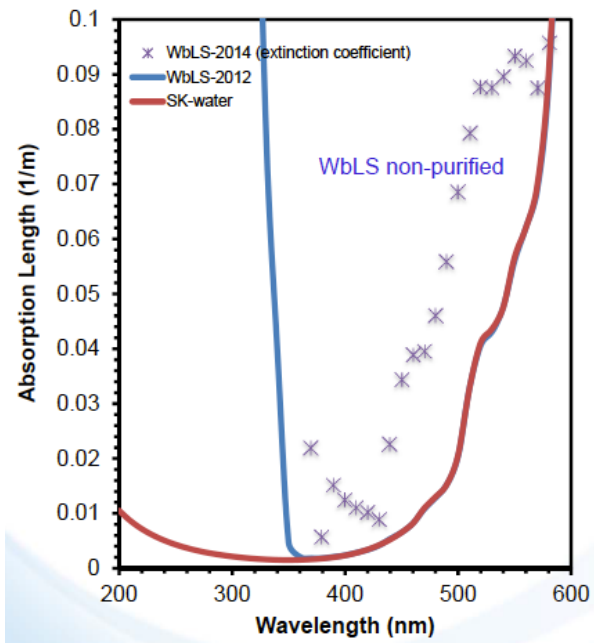
# Water-based LS

- Simple mixture of oil and water (!)
  - Minfang Yeh, BNL

Light yield scales with scintillator fraction




Attenuation more like water than scintillator

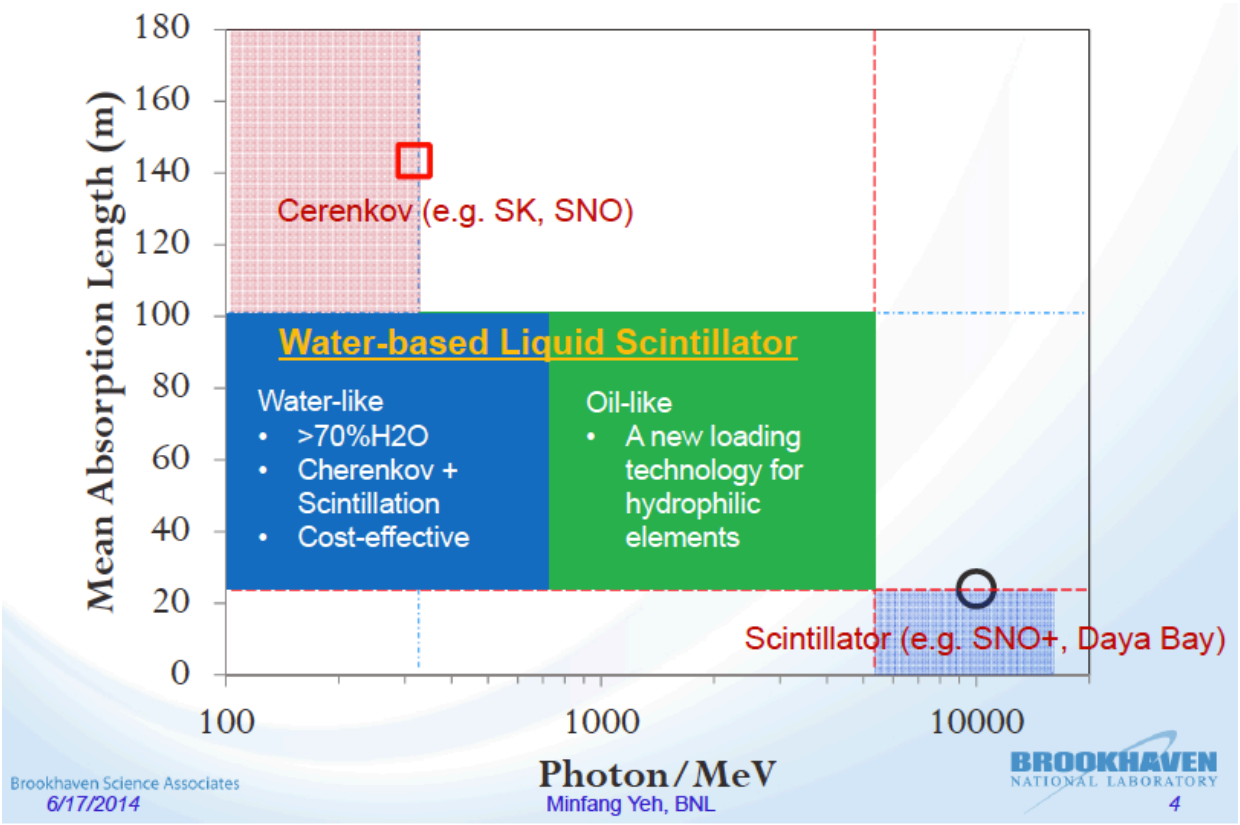



A very big detector is possible

Fast timing distinguishes Cherlight from Scintlight

New particle ID techniques possible

# Flexible Target Medium



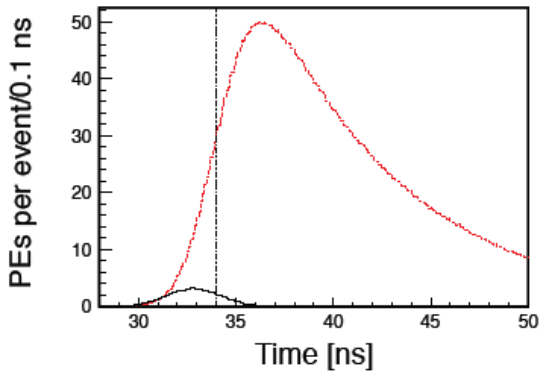

Can increase scintillator fraction for more light yield

Or timing fro better Cher/scint separation

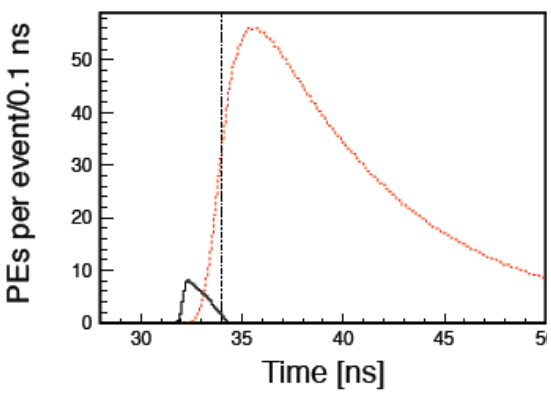
And load a large variety of metals: Te, Gd, Li….

# Photon detection

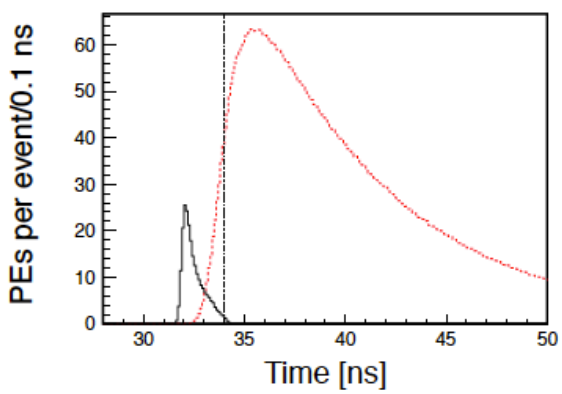
Cherenkov (prompt, scarce)
Scintillation (delayed, abundant, tunable)



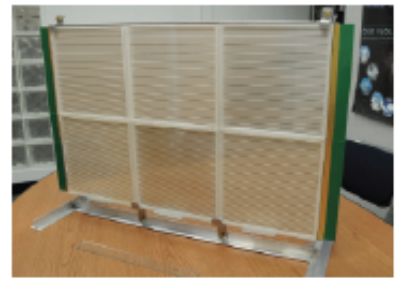

Simulation with 1.3 ns timing of standard PMT



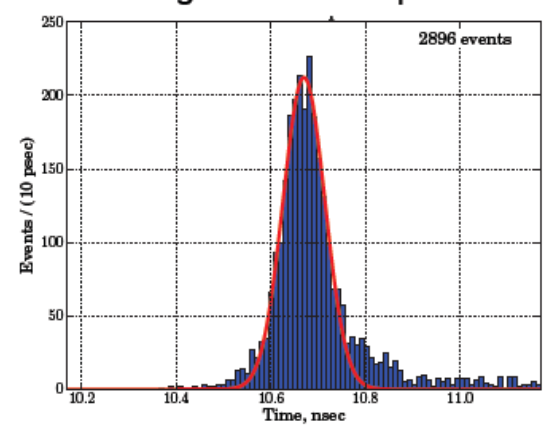

Assume 0.1 ns time resolution
e.g. LAPPDs
OR red-sensitive PMT




LAPPD Development



single PE: σ ~ 44 psec

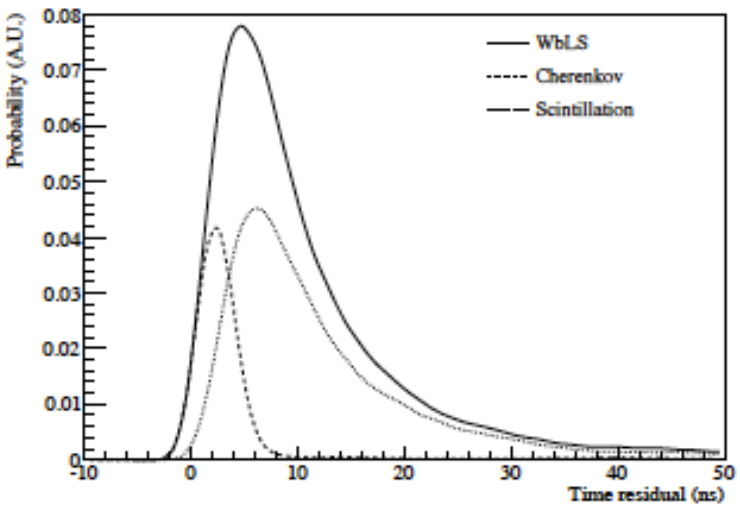


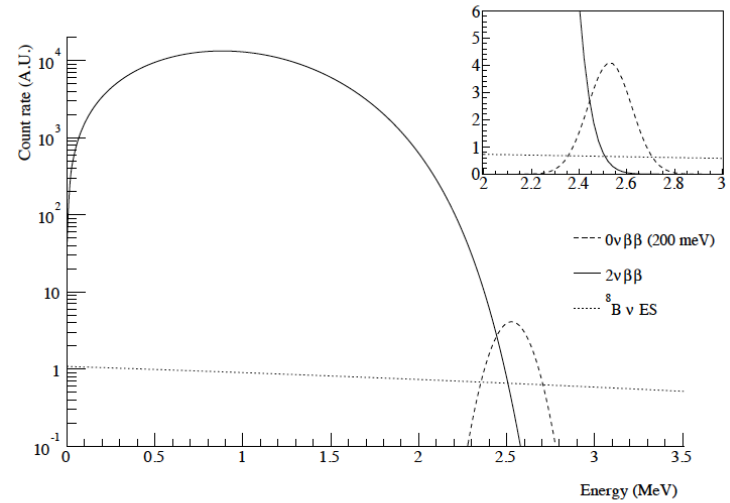

Cherenkov/scintillation separation => particle ID, background rejection

C. Aberle et al, JINST 9 P06012 (2014)

# Double Beta Decay

Use of timing to separate Cher / scint components allows directional cut to reject dominant $^{8}B$ solar $\nu$ background



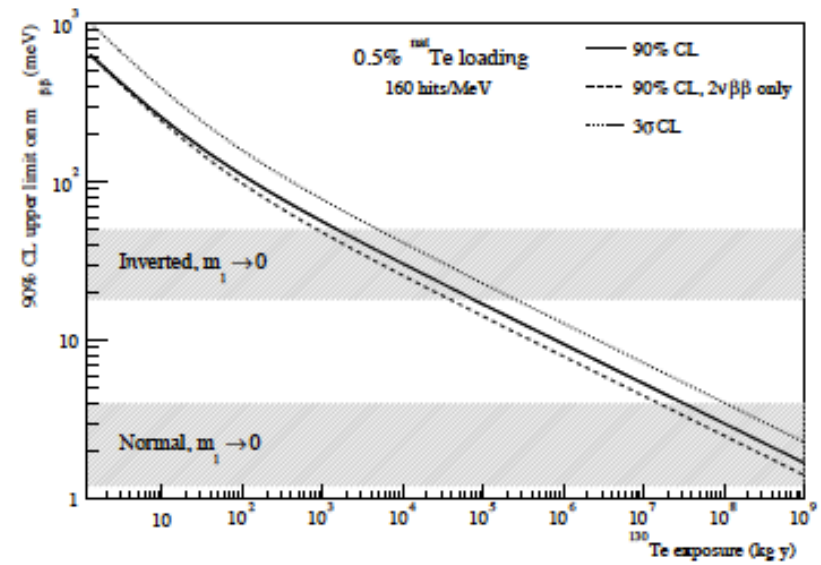

*Example spectrum with 300 pe/MeV ($\sigma_E = 3.6\%$)*

Particle ID & coincidence tags for int bkg

Large monolithic design: fiducialization renders external bkg negligible

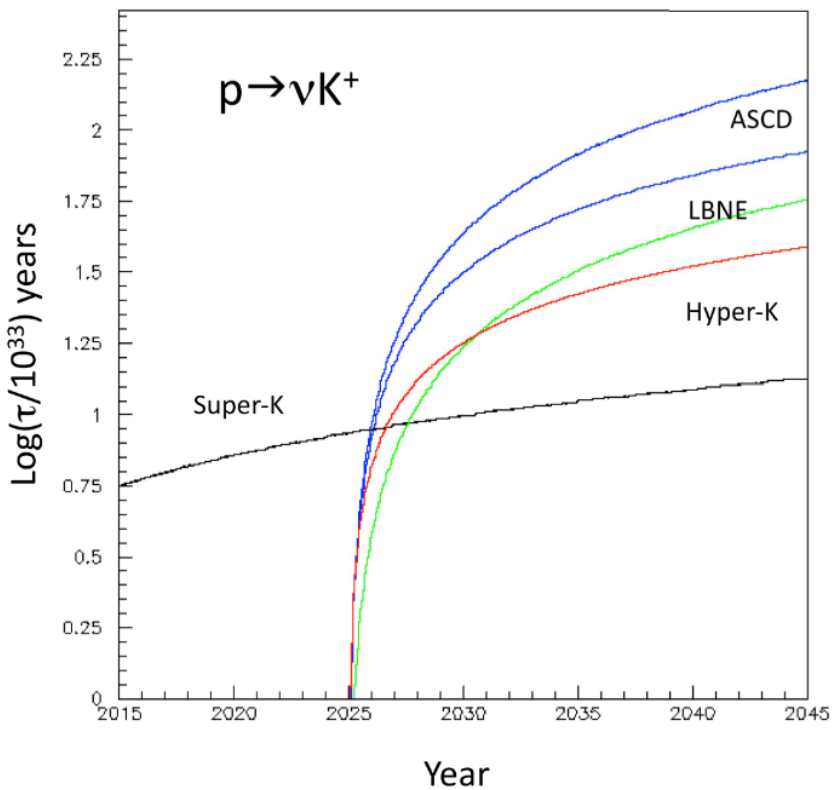
0.5% loading ($^{nat}Te$) in 50kT (30kT fid)
⇛ 50T $^{130}Te$

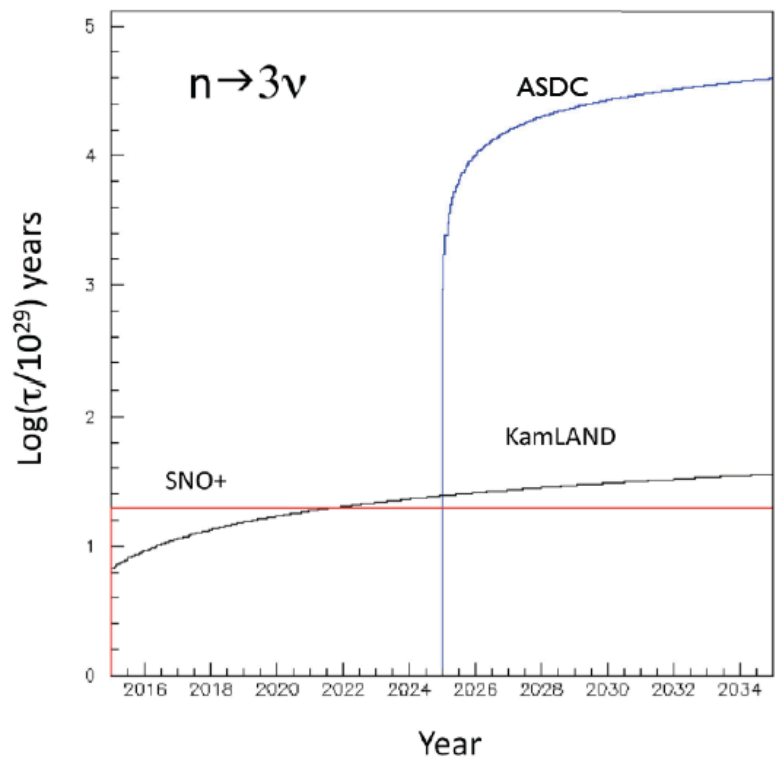
**⇛ 3 $\sigma$ discovery for $m_{\beta\beta}$=15meV in 10 yrs**



# Nucleon Decay

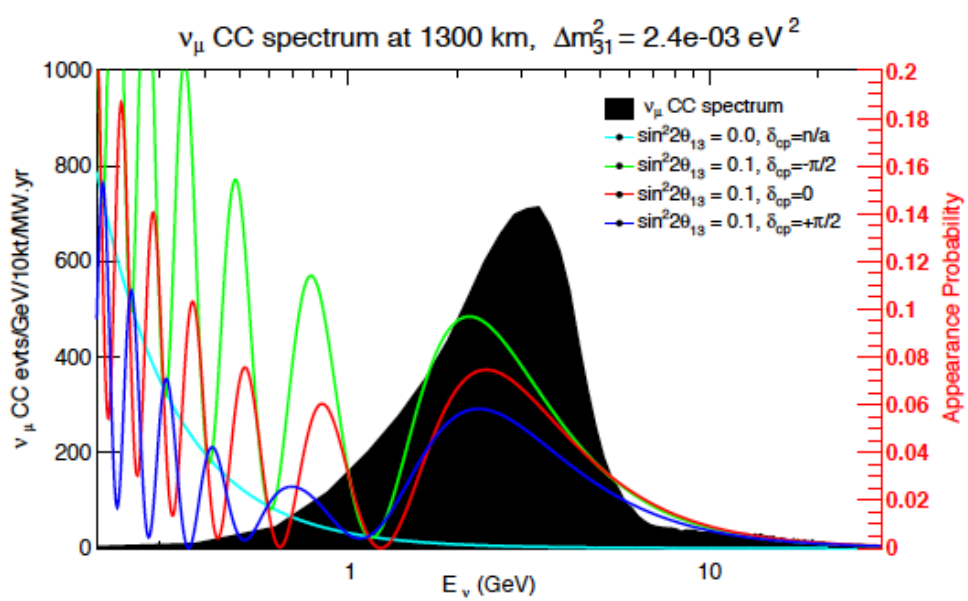
- Visible $K^+$ in "heavy q"-dominated $p \rightarrow \nu K^+$
- Deep, low threshold, + n tagging give unprecedented $n \rightarrow 3\nu$ sensitivity



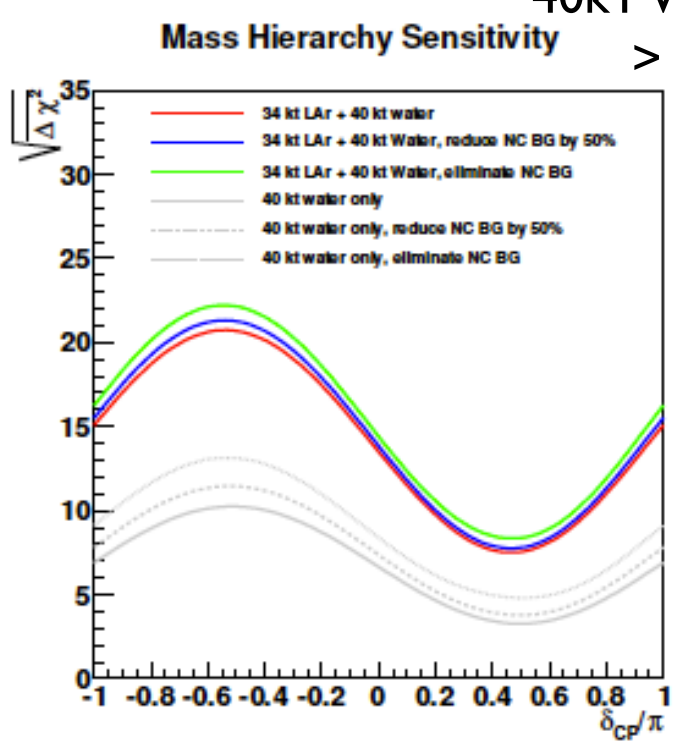



# Long-baseline

- Cherenkov ring+timing+scintlight for reconstruction and particle ID
- Would operate alongside LBNF LAr-TPC
- Adding mass in a systematically different way
- Big mass means sensitivity to second oscillation maximum




MH sensitivity for 40kT WbLS alone > 4.8 $\sigma$




P5 recommended large WCD in "unrestricted" scenario

# ASDC "Interest Group"

- Workshop held May 17/18 (LBNL): 27 participants, 17 talks
- Concept paper available arXiv:1409.5864
- 49 authors (potential PIs), 22 institutions (US and Germany)

BOREXINO, LBNE, KamLAND, SNO, Double CHOOZ, SNO+, Daya Bay, LENA, KamLAND-Zen, MiniBooNE, Super-Kamiokande, WATCHMAN, ANNIE, T2K…

- Large international community with interest and experience
- Dedicated session @ NNN 2014 (International workshop on Next-Generation Nucleon Decay and Neutrino Detectors, Paris)
- New involvement welcome! (Contact G. D. Orebi Gann, B. Svoboda, E. Blucher, J. R. Klein, M. Yeh)

**Advanced Scintillator Detector Concept (ASDC):**

**A Concept Paper on the Physics Potential of Water-Based Liquid Scintillator**

J. R. Alonso,[1] N. Barros,[2] M. Bergevin,[3] A. Bernstein,[4] L. Bignell,[5] E. Blucher,[6] F. Calaprice,[7] J. M. Conrad,[1] F. B. Descamps,[8] M. V. Diwan,[5] D. A. Dwyer,[8] S. T. Dye,[9] A. Elagin,[6] P. Feng,[10] C. Grant,[3] S. Grullon,[2] S. Hans,[5] D. E. Jaffe,[5] S. H. Kettell,[5] J. R. Klein,[2] K. Lande,[2] J. G. Learned,[11] K. B. Luk,[8,12] J. Maricic,[11] P. Marleau,[10] A. Mastbaum,[2] W. F. McDonough,[13] L. Oberauer,[14] G. D. Orebi Gann*,[8,12,†] R. Rosero,[5] S. D. Rountree,[15] M. C. Sanchez,[16] M. H. Shaevitz,[17] T. M. Shokair,[18] M. B. Smy,[19] M. Strait,[6] R. Svoboda,[3] N. Tolich,[20] M. R. Vagins,[19] K. A. van Bibber,[18] B. Viren,[5] R. B. Vogelaar,[15] M. J. Wetstein,[6] L. Winslow,[1] B. Wonsak,[21] E. T. Worcester,[5] M. Wurm,[22] M. Yeh,[5] and C. Zhang[5]

# Back up

# Prospects

| EXPERIMENT | WbLS | Doping | Other |
|---|---|---|---|
| SNO+ | 90% + | 0.3-3% $^{130}$Te | |
| Prospect | 70% + | 0.1% Gd or $^{6}$Li | |
| WATCHMAN | 1% | 0.1% Gd | LAPPDs |
| T2K | 10% | -- | |
| ANNIE | 1% | 0.1% Gd | LAPPDs |
| Medical apps | 1-5% | high Z for TOF-PET | |

Oil-like

Water-like