THEIA: An Advanced Optical Detector Concept

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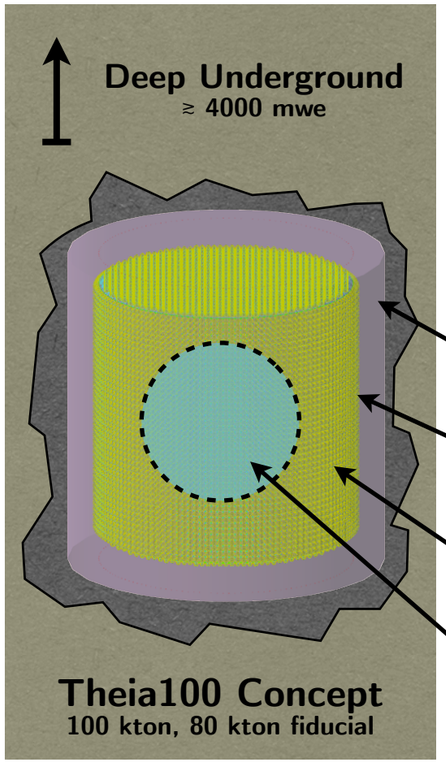


A detector combining **large mass**, an **underground location**, **novel target**, and **fast photon detectors**

Outer H_2O Shielding
Active veto system

Photodetector Array
20-90% active coverage (phased)

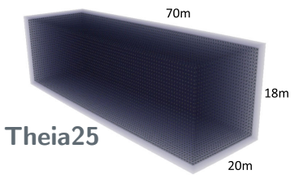
Target Volume
Novel LS such as WbLS, isotope loading

Inner Balloon
Deployable inner volume

Example Configurations

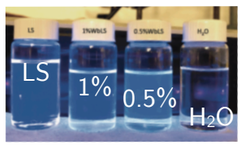
Theia25 — 25 kton, DUNE module-like

Theia100 — 100 kton, new SURF cavern



Pursuing a suite of **enabling technologies**:

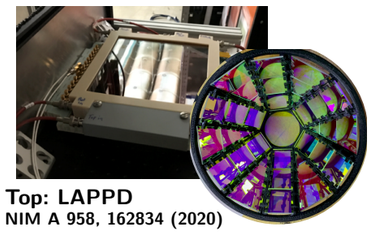
WbLS: Water-Based Liquid Scintillators



See NIM A 660, 51 (2011)

Water with a small admixture of liquid scintillator (LS) enables combined **Cherenkov + Scintillation** measurements

Next-Generation Photon Detectors

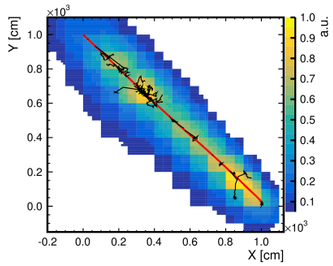


Top: LAPPD
NIM A 958, 162834 (2020)

Right: Dichroicon
PRD 101, 072002 (2020)

Exploring novel photon detectors with **fast timing** and **spectral sorting**

Advanced Vertex Reconstruction



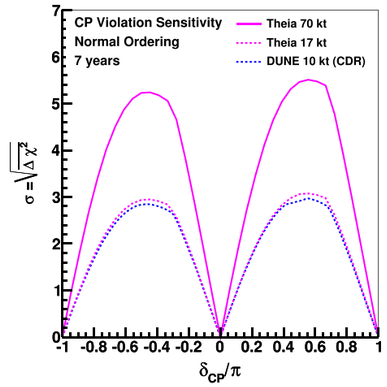
JINST 13, P07005 (2018)

Fully leveraging photon information to enable **tracking** and **particle ID**

A **broad program** of MeV-scale to GeV-scale physics: EPJC **80**:416 (2020)

Long-Baseline Neutrino Oscillations

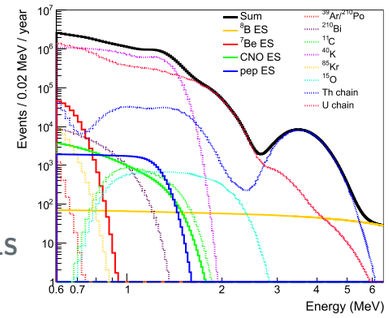
- With location at SURF and a water-based target, complementary to DUNE
- Nine-sample likelihood fit with systematics at DUNE CDR levels
- Further gains possible with fast timing and WbLS-based PID



Solar Neutrinos

- Probe CNO neutrinos and the MSW transition
- 5–10% measurement of CNO achievable with a low-energy ES channel
- Potential high-precision CC using ^{7}Li loading and deexcitation ɣ tag

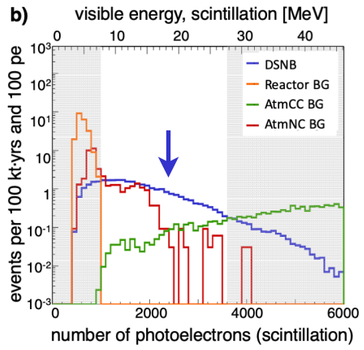
25 kton, 5% WbLS



Supernova & DSNB Neutrinos

- Large-stats $\overline{\nu}_e$ IBD complementary to DUNE
- Scintillation enhances n tag for low-background ES
- Pointing <1° achievable
- Excellent DSNB potential: O(100) events in Theia100 → 5σ discovery in 1 year

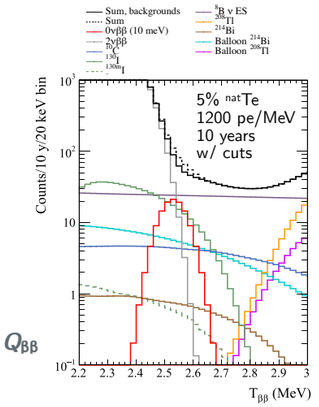
DSNB signal after cuts



Neutrinoless Double-Beta Decay

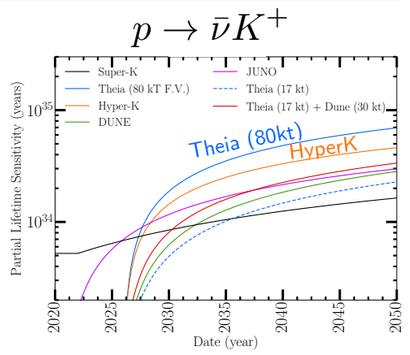
- Large mass of Te or Xe loaded in an inner LS balloon
- Liquid Scintillator scalability, additional Cherenkov solar neutrino rejection and PID
- One-bin counting analysis:
  - 5% ^{nat}Te: $T_{1/2} > 1.1\times10^{28}$ y
  - 3% ^{enr}Xe: $T_{1/2} > 2.0\times10^{28}$ y

Signal and backgrounds near $Q_{\beta\beta}$



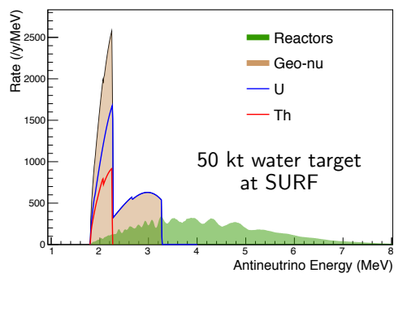
Nucleon Decay

- Very low backgrounds and low thresholds
- Tagging of sub-Cherenkov mesons (K^+) with WbLS
- Complementary to DUNE, HK searches, leading in invisible nucleon decays



Geoneutrinos & Reactor Antineutrinos

- High-stats geoneutrinos complementary to KamLAND, Borexino
- ^{1}H capture tagging
- Low NC rates relative to LS detectors
- Directionality potential



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