Supernova Neutrinos in THEIA

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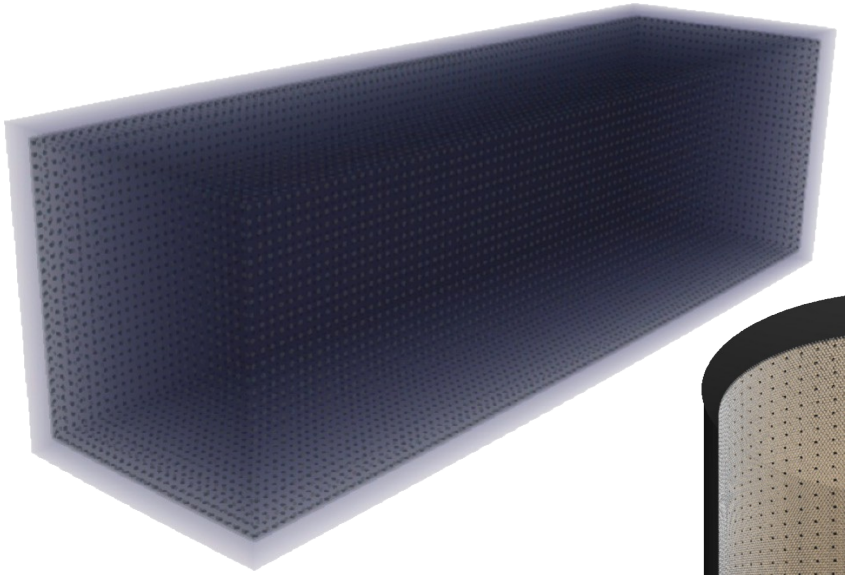
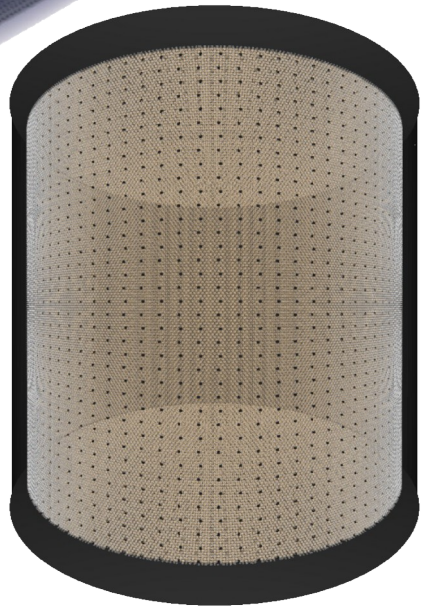
THEIA Detector

- THEIA25:
  20m × 18m × 70m ≙ 25kt
- Photosensors:
  22500 × 10″ PMTs (25% cov.)
  700 × 8″ LAPPDs (3% cov.)
- Location:
  SURF (4300 m.w.e.)
- Radiopurity:
  10^{-15}g/g ^{238}U, ^{232}Th, ^{40}K

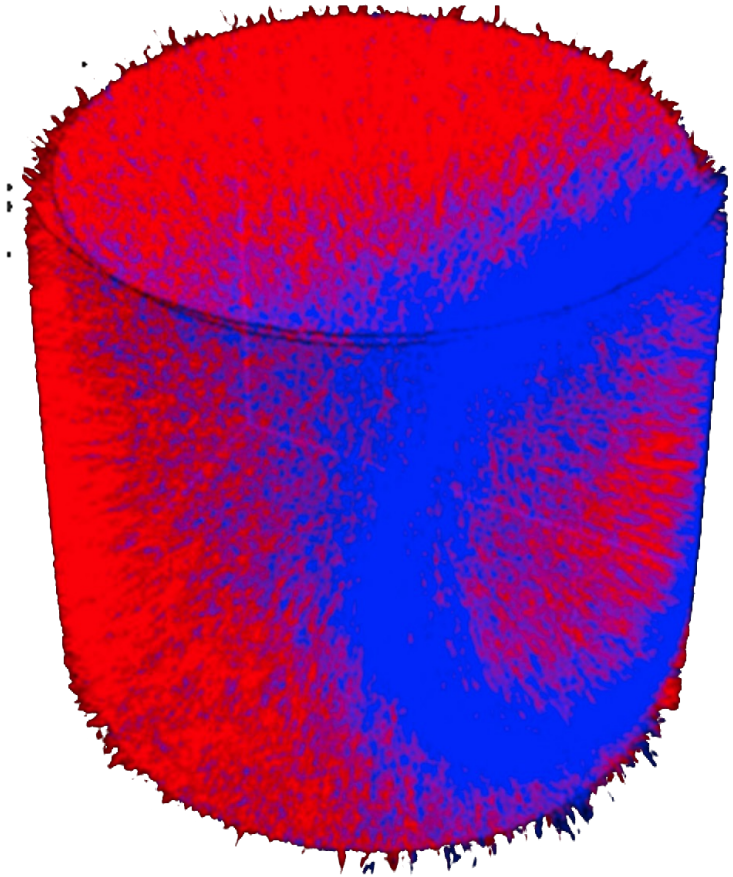




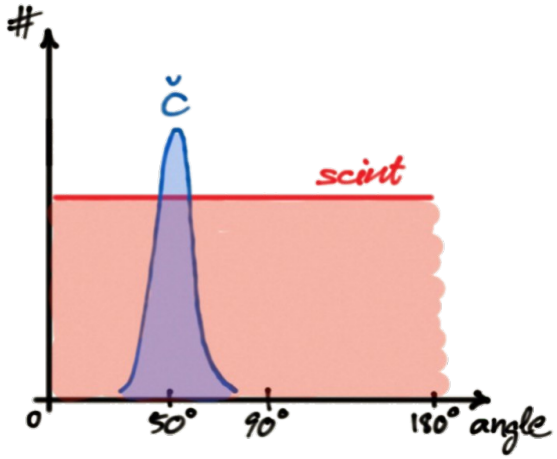
- THEIA100:
  50m × 50m ≙ 100kt

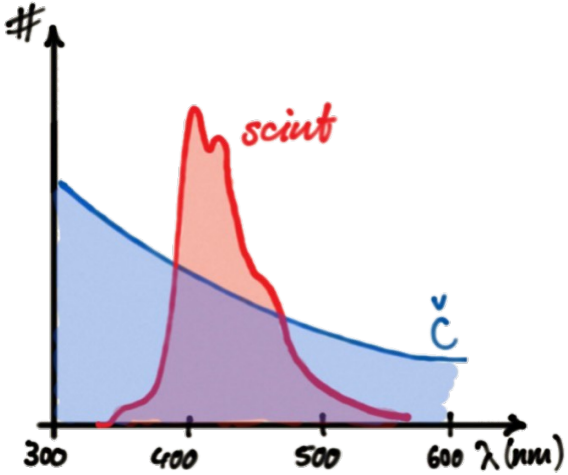
Water-based Liquid Scintillators

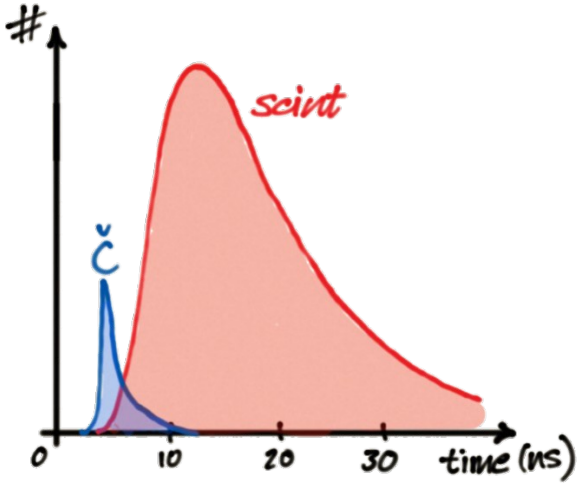
- Cherenkov:
  - Directional Information
  - Particle Identification
- Scintillation:
  - Energy Resolution
  - Low Threshold
- C/S-ratio:
  - Background Rejection



Separating Scintillation And Cherenkov



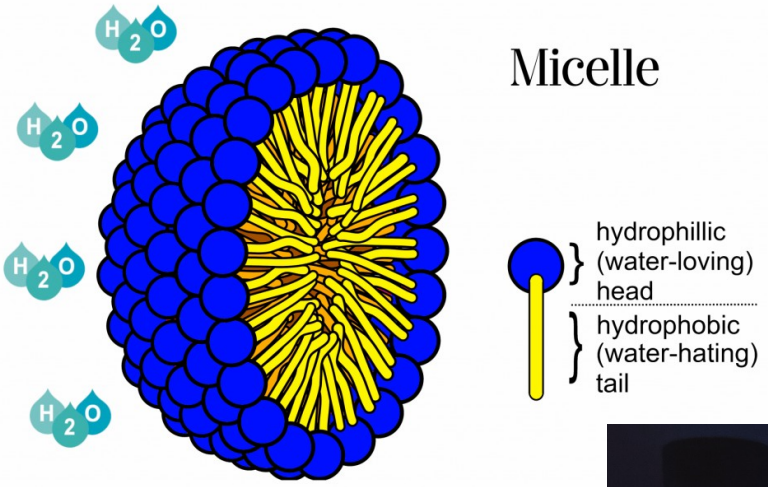


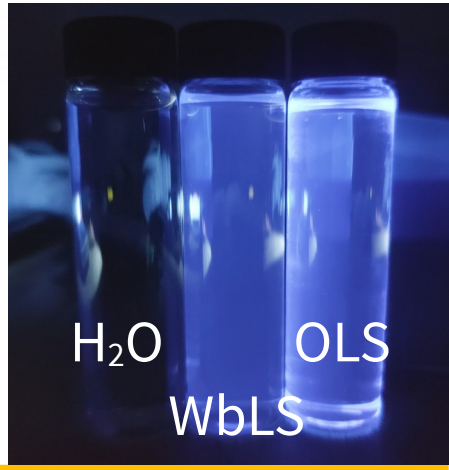


- Angular Emission
- Wavelength
- Timing Profile

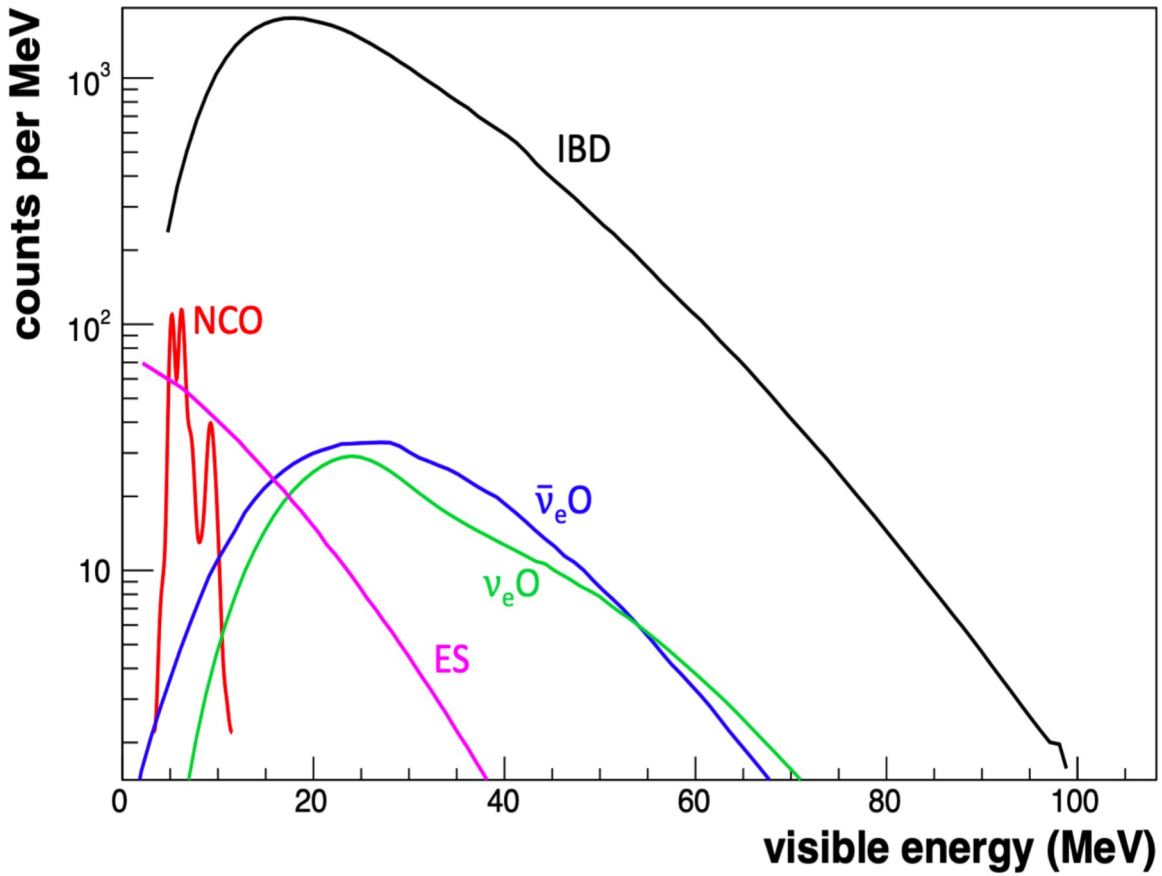
WbLS Recipe

- ~ 10% LS inside Surfactant Micelle Dissolved in Water
- Water-based Slow Scintillator to Delay LS Emission Further Away From Cherenkov Light
- Possibility of Metal Loading (e.g. Gadolinium for n Capture)





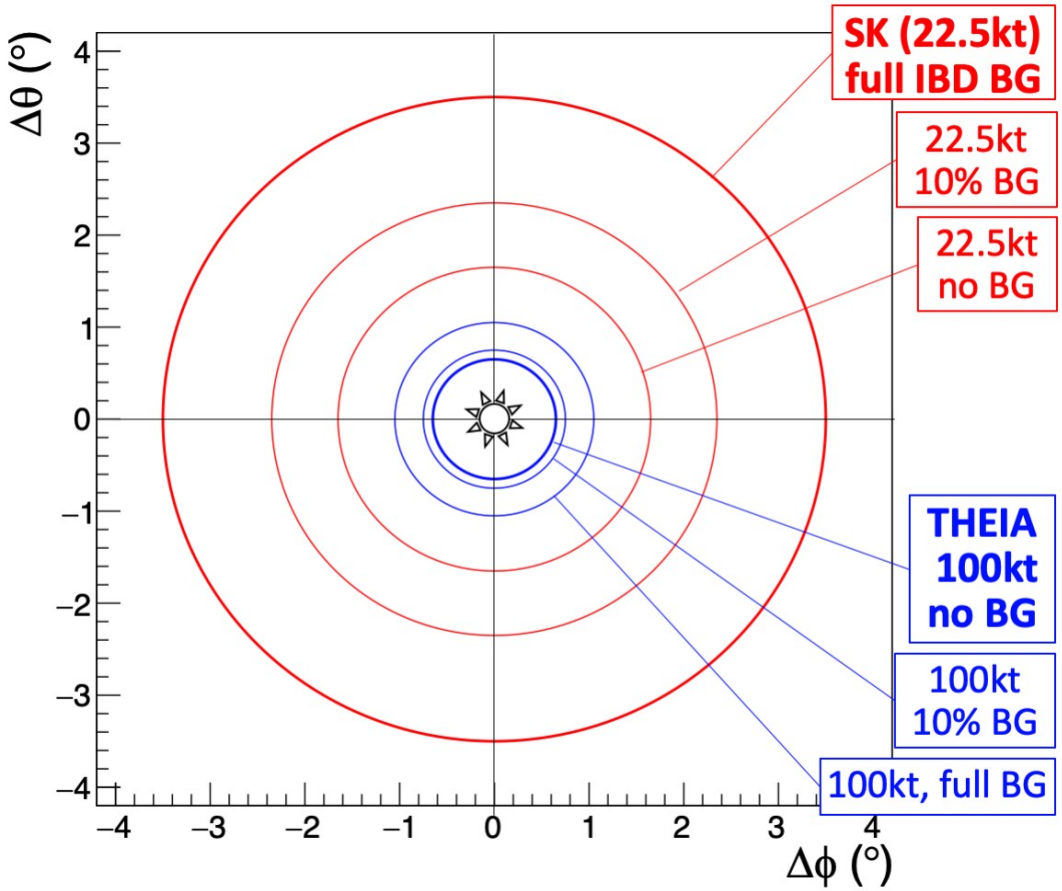
(Galactic) Supernova Neutrinos



- 100kt WbLS (10% LS)
- 10kpc Distance
- GVKM Model

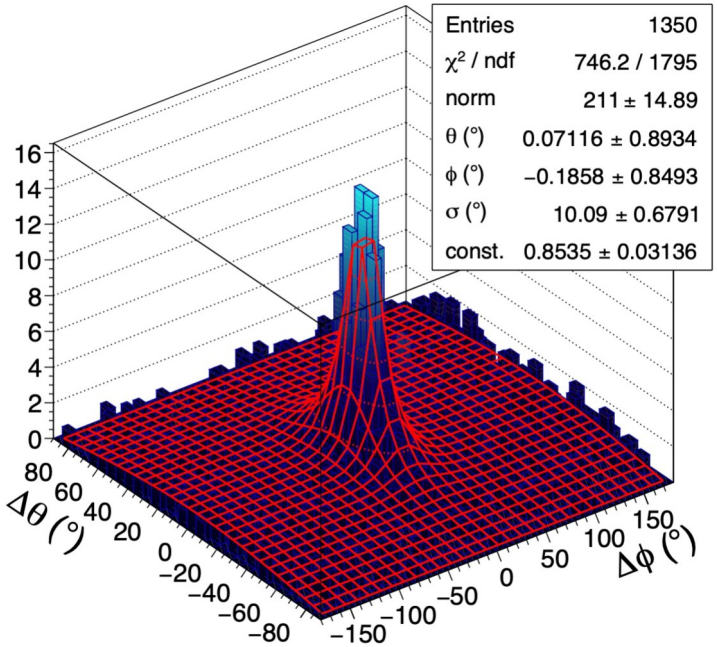
IBD	$\bar{\nu}_e + p \rightarrow n + e^+$	19,800
NCO	$^{16}\mathrm{O}(\nu,\nu)^{16}\mathrm{O}^*$	1,100
ES	$\nu_e + e \rightarrow e + \nu_e$	960
$\bar{\nu}_e$O	$^{16}\mathrm{O}(\bar{\nu}_e, e^+)^{16}\mathrm{N}$	440
ν_eO	$^{16}\mathrm{O}(\nu_e, e^-)^{16}\mathrm{F}$	340

Pointing Accuracy



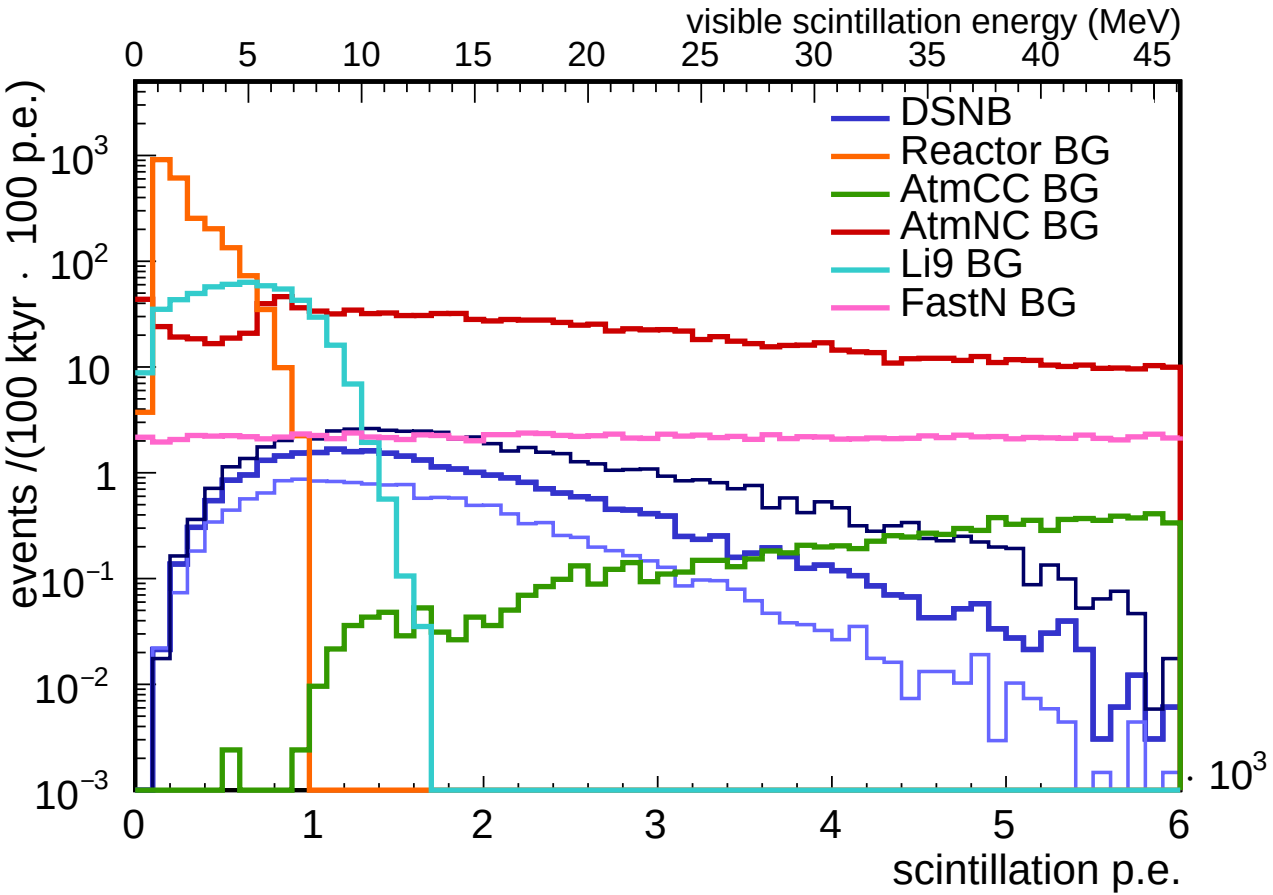
From Cherenkov Direction:

<1° (THEIA100) 2° (THEIA25)



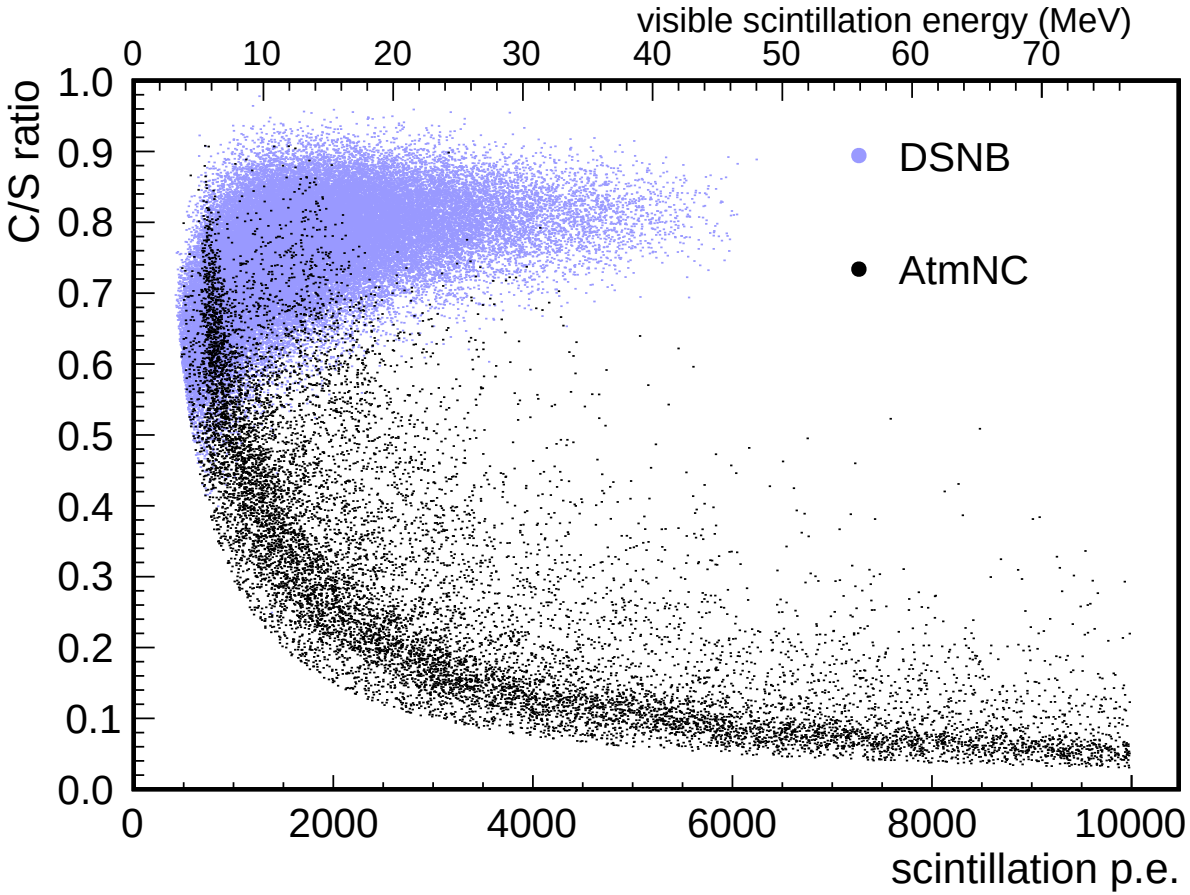
Diffuse Supernova Neutrino Background

- $\overline{\nu}_e$ Flux: $\mathcal{O}(100\ \mathrm{cm}^{-2}\mathrm{s}^{-1})$
  $\hat{=}\ \sim 17^{+34}_{-8}$ evts/(100 kt yr)
- Backgrounds:
  - ^{9}Li (μ-induced)
    530±106/(100 kt yr)
  - Fast n (μ-induced)
    113.2/(100 kt yr)
  - Atm ν ($\pi \longrightarrow \mu + \nu_\mu$)
    48±17/(100 kt yr)



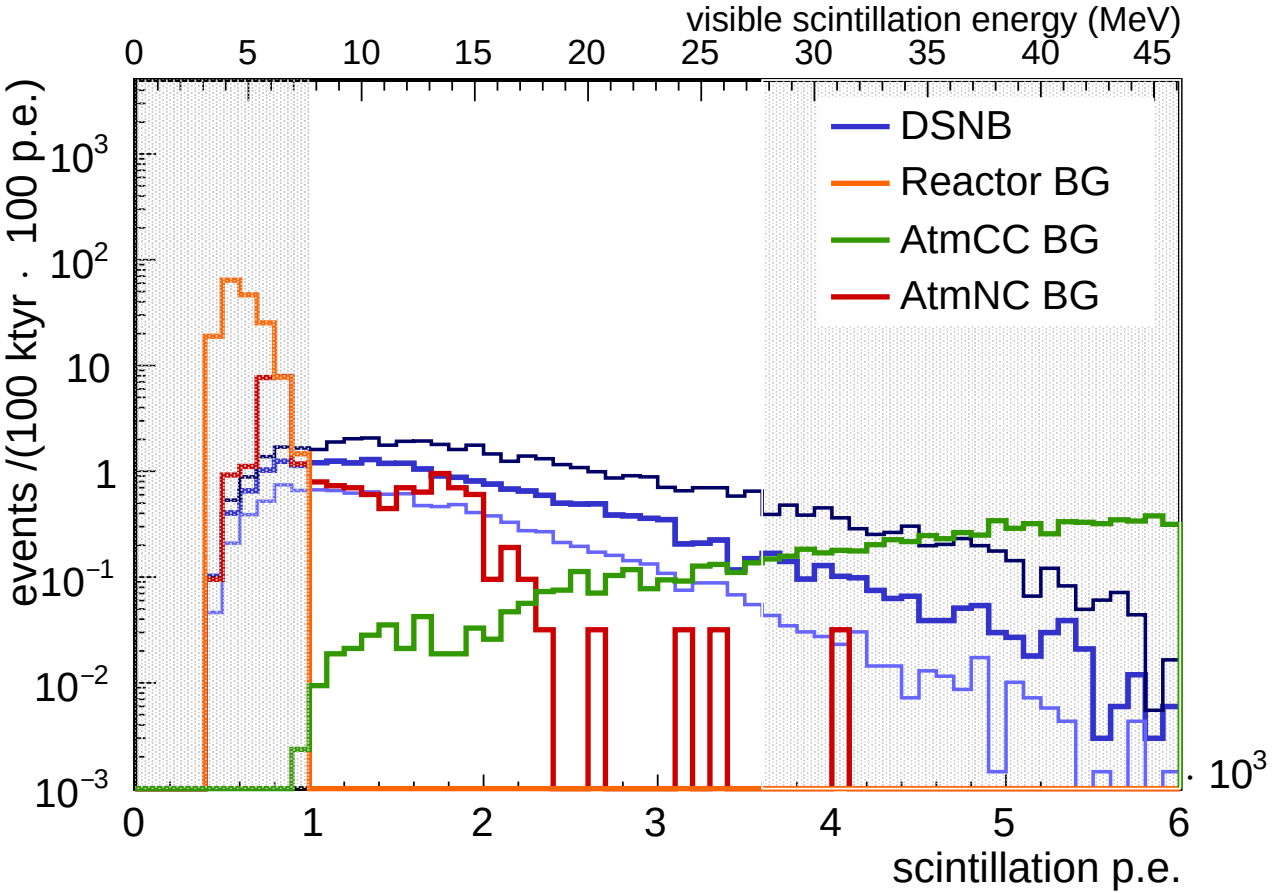
Background Rejection

- Quality Cuts:
  - ^{9}Li, τ=257ms:
    2s time cut, 5m radius cut around μ track
  - Fast n:
    1.5m FVC (THEIA25)
    2.5m FVC (THEIA100)
  - Atm. NC:
    Energy-dep. C/S cut



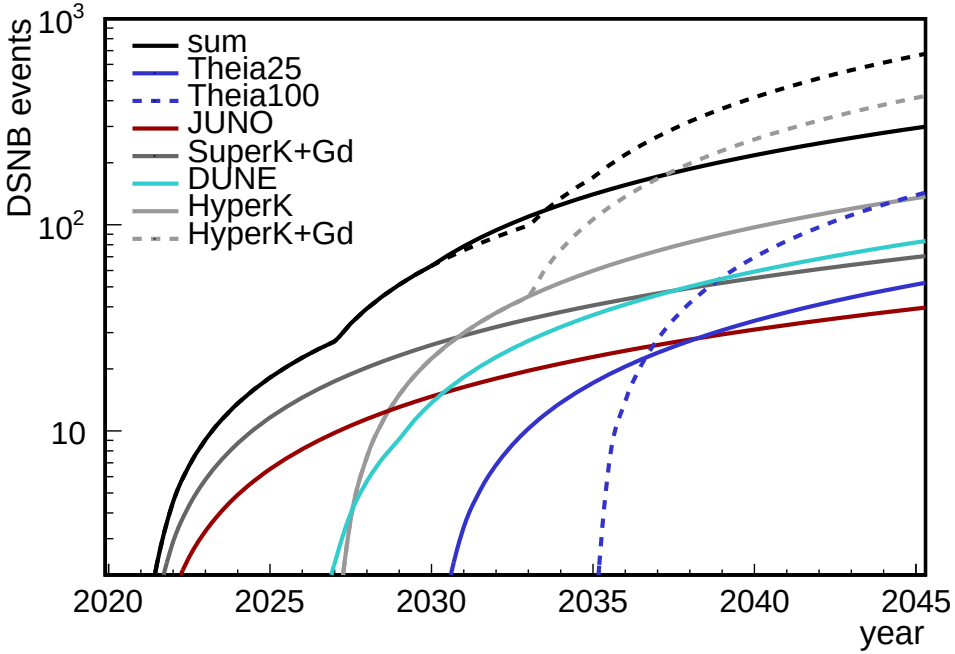
Expected DSNB Results

- $\bar{\nu}_e$ Flux:
  $\mathcal{O}(100\ \mathrm{cm}^{-2}\mathrm{s}^{-1}) \triangleq$
  $\sim 17^{+34}_{-8}$ evts /(100 kt yr)
- Backgrounds:
  9±2 evts /(100 kt yr)
- Discovery:
  5σ after 190 kt yr
  ≙ 2.4yr (THEIA100)
  ≙ 9.5yr (THEIA25)

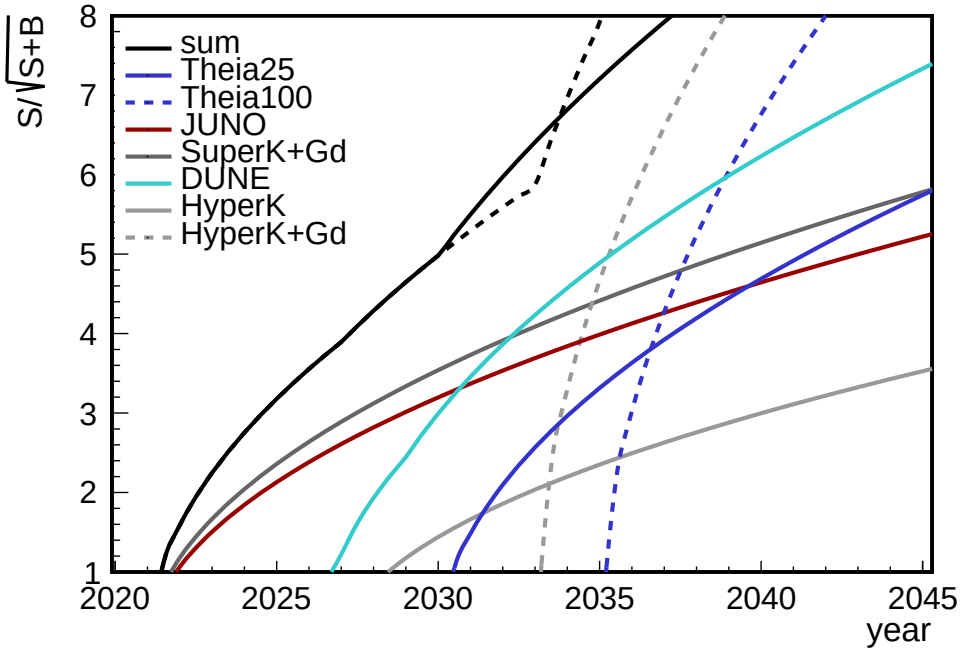


Detector Comparison

Signal Rate

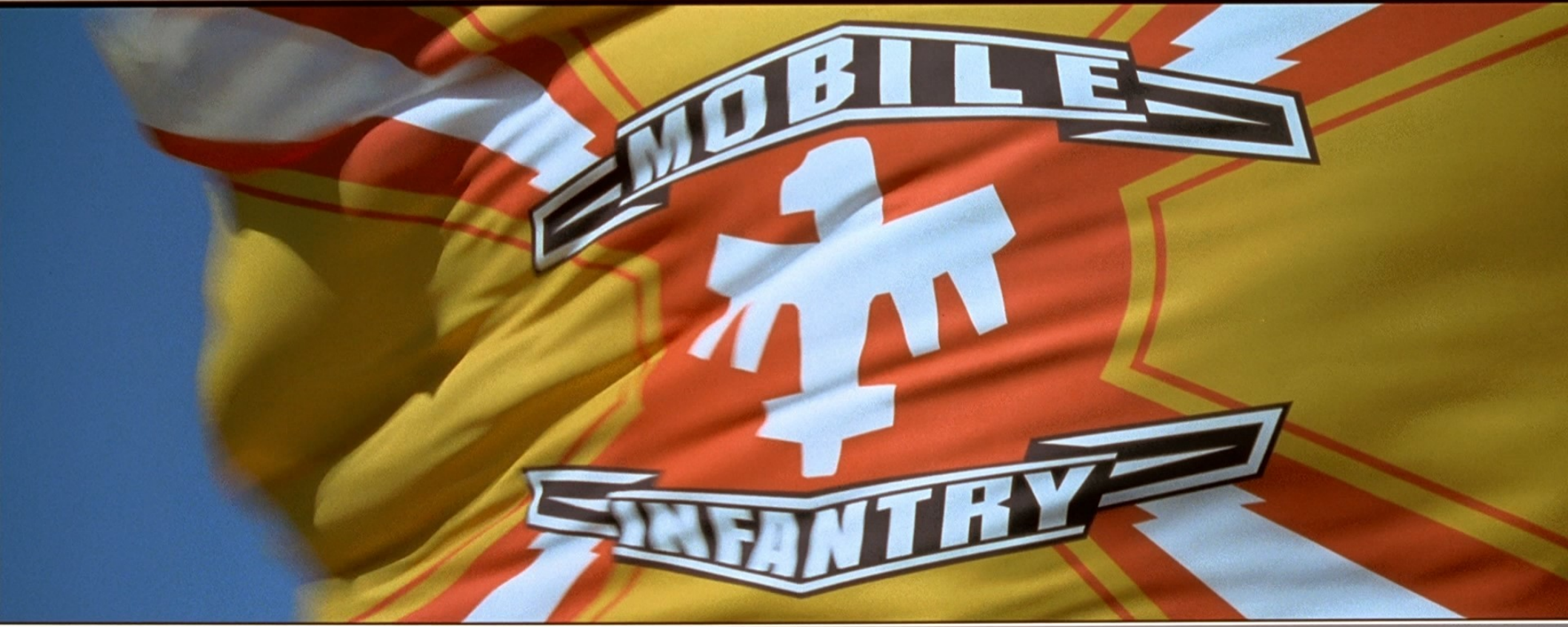


Signal Significance



Thank You For Your Attention!

FEDERAL GALAXY TOP NEWS ENLIST EXIT



WOULD YOU LIKE TO KNOW MORE?

GVKM Model

- ArXiv:0902.0317
- Core-Collapse Supernova
- 3-Flavor Framework
- ν-Matter- & ν-ν-Coupling
- Adiabatic Density Profile
- Multiple Resonances

- $\Delta m_{12}^2 = 8 \times 10^{-5} eV^2$
- $\sin^2 2\theta_{12} = 0.83$
- $|\Delta m_{23}^2| = 3 \times 10^{-3} eV^2$
- $\sin^2 2\theta_{23} = 1$
- $\delta_{CP}=0$
- Depends on MO and θ_{13}

^{9}Li-Background

- Created by Cosmic μ
- Spallation on ^{16}O/^{12}C
- Only ^{9}Li with Sufficient Energy to Mimick ν-Signal
- $$^{9}\mathrm{Li} \xrightarrow[50\,\%]{} {}^{9}\mathrm{Be} + \beta^{-}$$
  $$^{9}\mathrm{Li} \xrightarrow[50\,\%]{} {}^{9}\mathrm{Be}^{*} + \beta^{-}$$
  $$\rightarrow {}^{9}\mathrm{Be}^{*} \longrightarrow {}^{8}\mathrm{Be} + n$$

- Solution:
  - Place Detector Underground (Reduce μ Rate)
  - Veto Around μ-Tracks (In THEIA: 5m, 2s)

Fast-n-Background

- Created by Cosmic μ
- μ Produce n by Reaction with Surrounding Material (Rock)
- Elastic Scattering of n Mimicks β Signal
- Thermalization+Capture of n as Delayed Coincidence

- Solution:
  - Place Detector Underground (Reduce μ Rate)
  - Veto Around μ-Tracks (In THEIA: 5m, 2s)
  - Fiducial Volume Cut to Remove n from Surrounding Rock (In THEIA: 1.5m/2.5m)

Atmospheric-ν-Background

- From Decay of π, Created in Atmosphere by Cosmic Rays
- $\pi \longrightarrow \mu + \nu_\mu$

  $\mu \longrightarrow e + \nu_e + \nu_\mu$
- Possible NC or CC Interaction
- Solution:
  - If NC: Cut on C/S Ratio (Recoil Not Large Enough for Much Cherenkov Light)
  - If CC: Expected Background Rate Below DSNB Signal