

Thu 15/10

09:00

General: Poster Session



Helmholtz Institute Mainz (HIM)

09:00 - 10:00

10:00

Introduction

Josh Klein

Helmholtz Institute Mainz (HIM)

10:00 - 10:10

Working exercise

Helmholtz Institute Mainz (HIM)

10:10 - 10:45

Coffee Break

11:00

Helmholtz Institute Mainz (HIM)

10:45 - 11:15

Working exercise

Helmholtz Institute Mainz (HIM)

11:15 - 11:50

Detector Design Options

Cadillac option



Chevy option



Yugo option



Detector Design Requirements

Table Adapted from A. Mastbaum

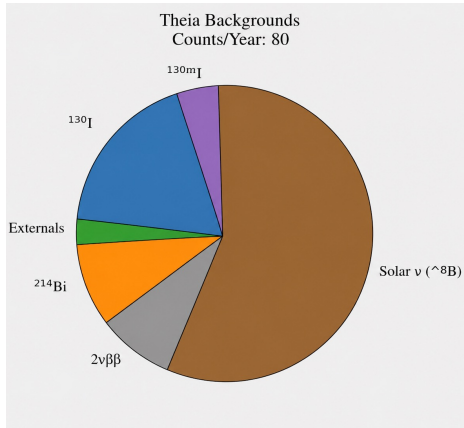
Table adapted from G. Orebi Gann

		Priorities		
Physics	Size	Ring Imaging	Light Yield	Cleanliness
NLDBD	~ few kt	Medium	Very high	Very high
Low-E solar ν (<1 MeV)	~ 10 kt	High	Very high	Very high
High-E solar ν (>1 MeV)	> 50 kt	High	Low	High
Geo/reactor $\bar{\nu}$	~ 10 kt	Low	High	Medium
DSNB	> 50 kt	Low	High	Medium
Long-baseline ν	> 50 kt	Very high	Low	Low
Nucleon decay	> 100 kt	High	High	Low

Detector Design Requirements

“Baseline” (T. Kaptanolgu, Irvine 6/26)

Theia $0\nu\beta\beta$ 10-year sensitivity with optimized ROI
50% 8B rejection, 90% signal
Common color scale up to $9.5\times$

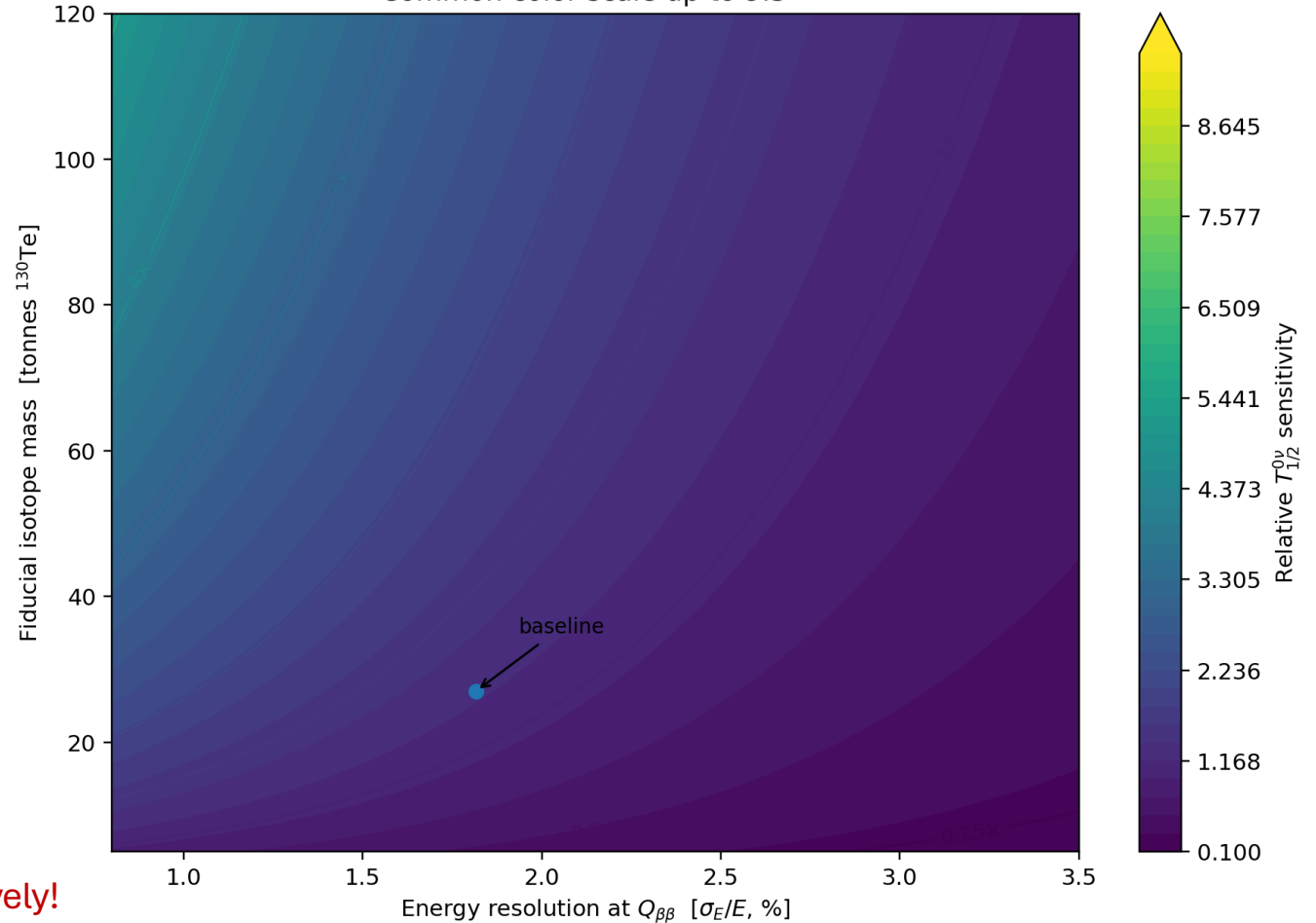


For fiducial Te mass of 27 tons
(440 tons natural Te)

$$T_{1/2} > \sim 5 \times 10^{27} \text{ y}$$

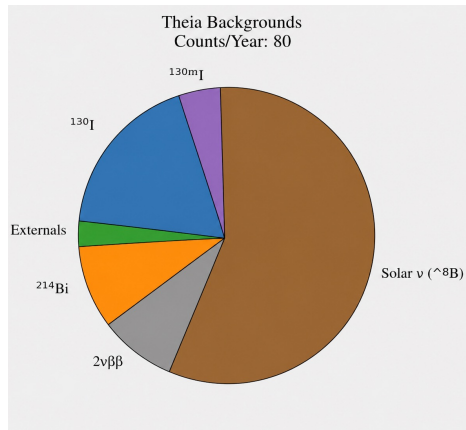
(=1 on color scale)

Do not take this plot too quantitatively!



Detector Design Requirements

“Baseline” (T. Kaptanolgu, Irvine 6/26)

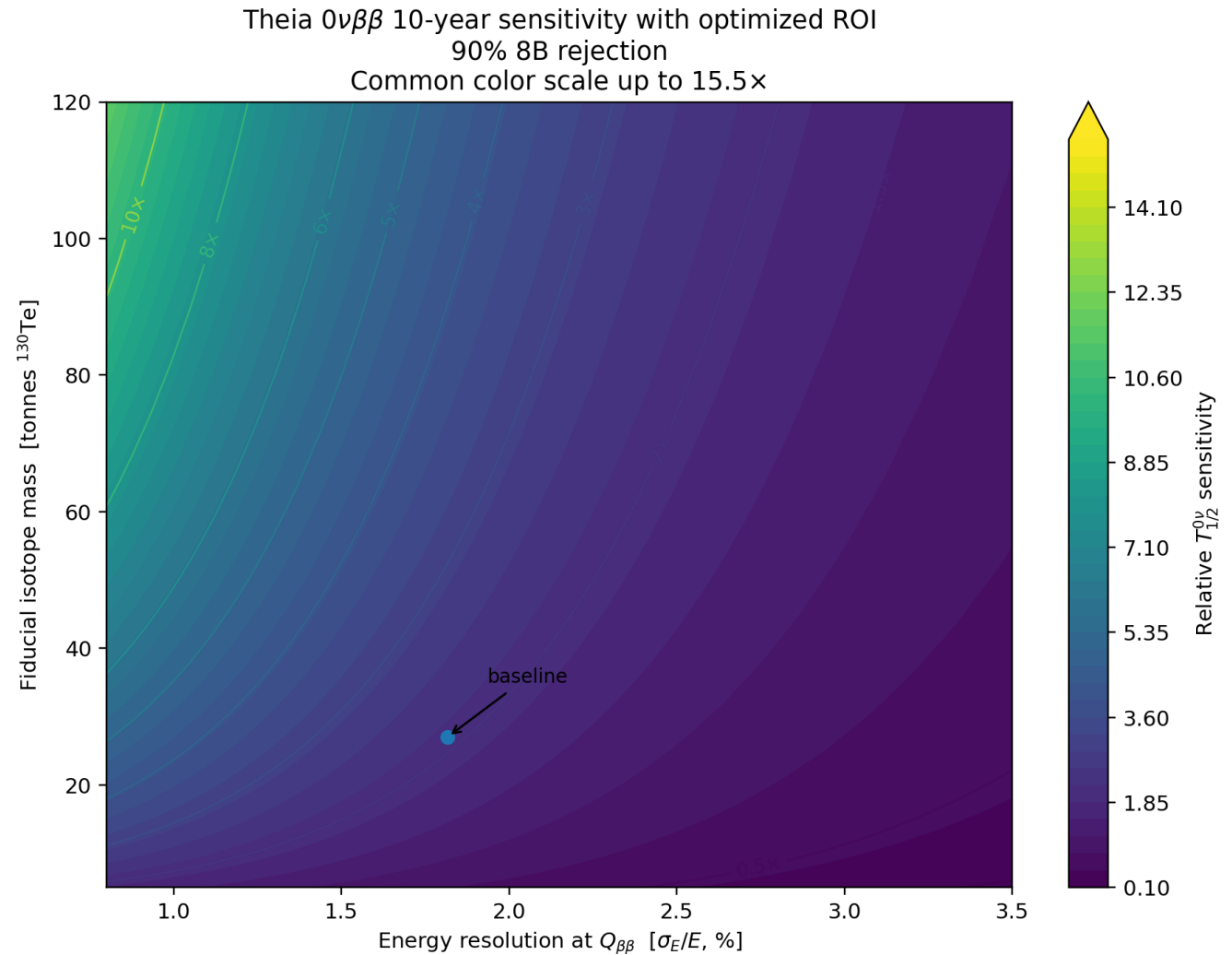


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Detector Design Requirements

So...if we wanted to do 10x better on $0\nu\beta\beta$:

- Need resolution $\sim 1\%$
- ^8B rejection of $\sim 90\%$
- Fiducial isotopic mass of > 100 tons ^{130}Te

Or we would need to break the generic scaling relation vs. energy resolution (e.g., with some kind of PID or fitting approach or AI/ML which can do ANYTHING)

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Not unexpectedly, the broader program, except maybe LBL physics, is enhanced by all of these things---no tension with, say, ^8B MSW transition (unless you want.e.g., ^7Li in simultaneously)

Detector Design Requirements

So...if we wanted to do 10x better on $0\nu\beta\beta$ half-life:

- Need resolution $\sim 1\%$
- ^8B rejection of $\sim 90\%$
- Fiducial isotopic mass of > 100 tons ^{130}Te
 - Resolution means light yield ($1\% = 10,000$ photons = 4000 photons/MeV at 2.5 MeV)
(Or does it? Could we use, say, multiple scattering via Cherenkov to help? Etc.)
 - ^8B rejection means some kind of Cherenkov measurement
 - Fiducial mass means larger fiducial volume (and more isotope)

Detector Design Requirements

Also: can improve by 4x with

- Need resolution $\sim 1.5\%$ (~ 1800 pe/MeV)
- ^8B rejection of $\sim 90\%$
- Fiducial isotopic mass of > 45 tons ^{130}Te

Even this requires significant improvement over JUNO

And before we even talk about cosmogenics and BiPos and iodine and externals...

“Sounds hard”

Detector Design Parameters

1. (Loaded) Scintillator:

We need to break the downscaling of light yield with load

Or use xenon or another isotope with less quenching

Or increase the intrinsic light yield by a lot (beyond DIN...?)

Or invent a new way to increase *detected* light yield (exotic WLS...)

Detector Design Parameters

2. Photosensor coverage and PDE

- Coverage is physically limited to ~80% (unless hex-concentrators or dichroicons are used, maybe)
- PMT total area vs pixels
- Is there a PMT QE breakthrough pending? (> 40%??)
- Is there a PMT collection efficiency breakthrough pending (I don't think so)

Detector Design Parameters

3. Detector shape (and number...)

- Long and skinny limits fiducialization and light yield
- Also any concentrator field-of-view
- Spherical is definitely the “cadillac” option
- Should we just put more than 1 detector in these tubular cavities?

Detector Design Parameters

4. Detector depth and location

- SNOLAB (better be) deep enough
- SURF...probably
- Anywhere else? Boulby, Kamioka...?

Detector Design Parameters

5. Isotopic containment

- None? (No)
- Acrylic vessel?
- Balloon?
- Scintillating balloon?

Detector Design Parameters

6. Photon sensor timing

- Eos PMTs are excellent for 8” but faster (and smaller) PMTs exist
 - Go fully multi-PMT assemblies?
- Timing affects reconstruction, Cher/scint, multi-site --- lots of goodness
- In the scheme of things, may not be a big cost driver (compared to others)

Detector Design Parameters

7. Photon collection

- Are dichroicons necessary for ^8B rejection? Broader program?
- Can this enhance light yield by sorting to “better” sensor?
- Would allow both fast scintillator and Cher/scint separation
- Are standard or hex reflectors a win (like K2Z)?

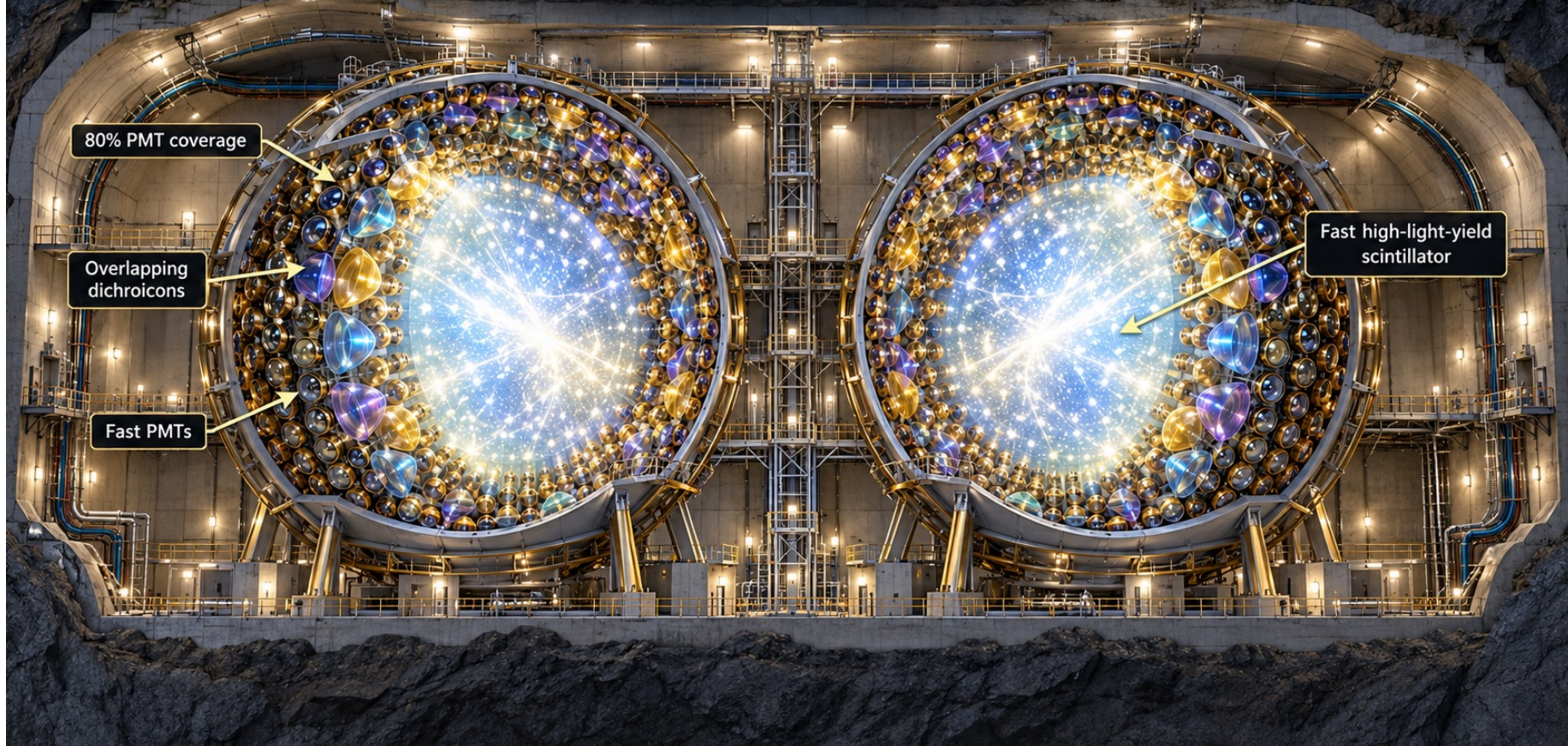
Detector Design Parameters

8. DAQ

- Multi-pe sensitivity is critical for resolution, maybe PID and recon
- Whether WFD or analog processing or something else mostly drives cost, not (probably?) performance

Cadillac Theia option

Two spherical detectors in mailbox cavity



Chevy Theia option

Long cylindrical detector in mailbox cavity



50% PMT coverage

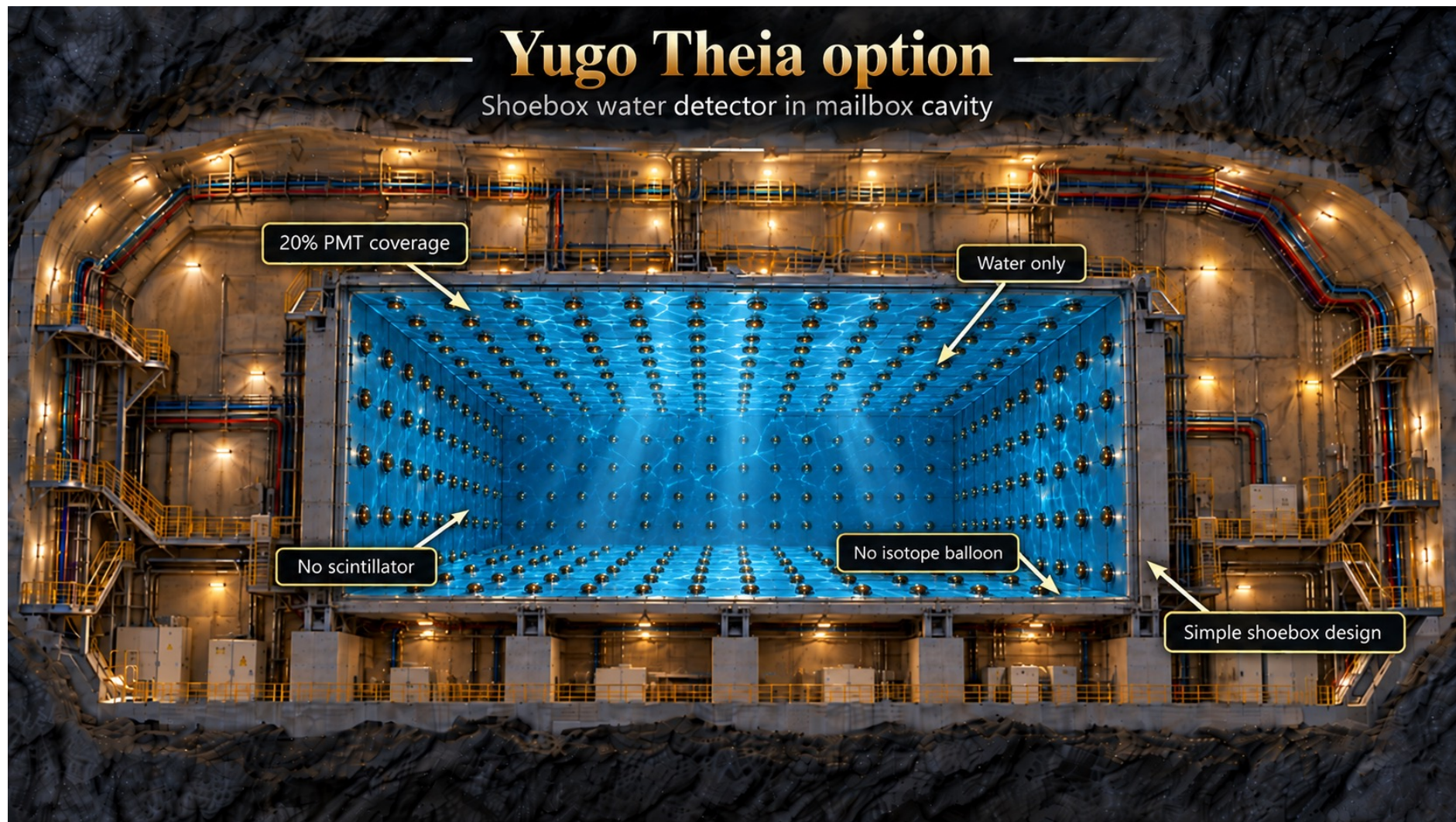
Nylon sausage balloon
for isotope

No dichroicons

Practical cylindrical design

Yugo Theia option

Shoobox water detector in mailbox cavity



Target Material	WbLS • Good Cher/scint ratio • Good optics (maybe?) • Low(ish) Cost • Tunable light yield • neutrino NC reaction on O • Easy to load isotopes • Low scint yield • High density • Low index of refraction • High(ish) Z • Hard (er) to clean	Liquid Scintillator • Good scint light yield • High index (good Chertons) • Easy to clean • Poor(er) optics • High cost • Poor Cher/scint ratio	Fast Liquid Scintillator • Good recon • Good multi-site • Easy to clean • Poor(er) optics • High cost • Poor Cherenkov ID	Slow Liquid Scintillator • Great Cher/scint separation • Easy to clean • Poor(er) optics • High cost • Poor multi-site/recon	LAr • "Perfect" Cher/scint separation • Easy to clean from heavy contaminants (U, Th) • Great optics • Super scint light yield • Great PSD (a/b) • Intrinsic bkds: 39Ar, 42Ar/42K, 38Cl • High multiple scattering • Requires WLS • cryostat reduces fid. Vol
Photon Sensors/collectors	LAPPDs • Excellent timing • High pixelization • Dichroicons with planar sensors? • Low(er) QE than HQE PMTs • High cost	R14688s (Eos) • Very good timing • Very good QE • Not cheap/m²	10-20" PMTs (7081, H-K, etc.) • Cheap(er) per m² • Very good QE • Poor(er) timing • May need pressure test or encapsulation	SiPMs • Excellent QE • Excellent timing • Problematic dark rate • Very expensive/m²	Dichroicons • Excellent Cher/scint sep even in fast, high ly scintillator • Cost ~ sensor cost • Response is complex • Cher yield is low
Location	SURF FD4 • Exists! • Beam physics • Good depth • But DUNE • Shape not optimal	SURF Other • Better shape? • No DUNE • Excellent depth • Beam physics • Does not exist	SNOLAB • Better shape? • No DUNE • Excellent depth • Does not exist • No beam	Boulby • Better shape • No DUNE • Does not exist • No beam • Depth is an issue	Kamioka/S-K • Better shape • No DUNE • Beam • Exists! • Depth is maybe an issue