Measuring the neutrino mass

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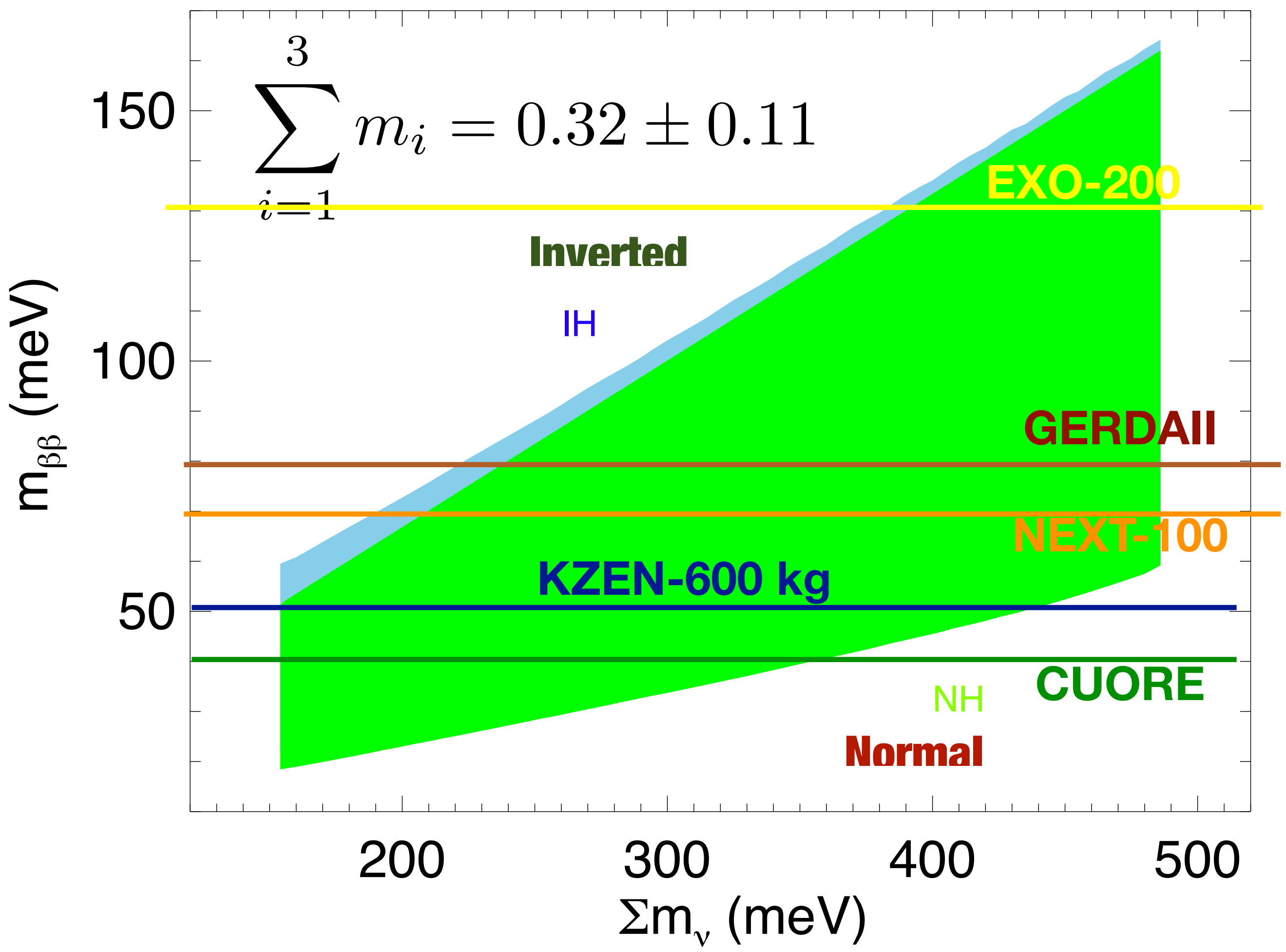
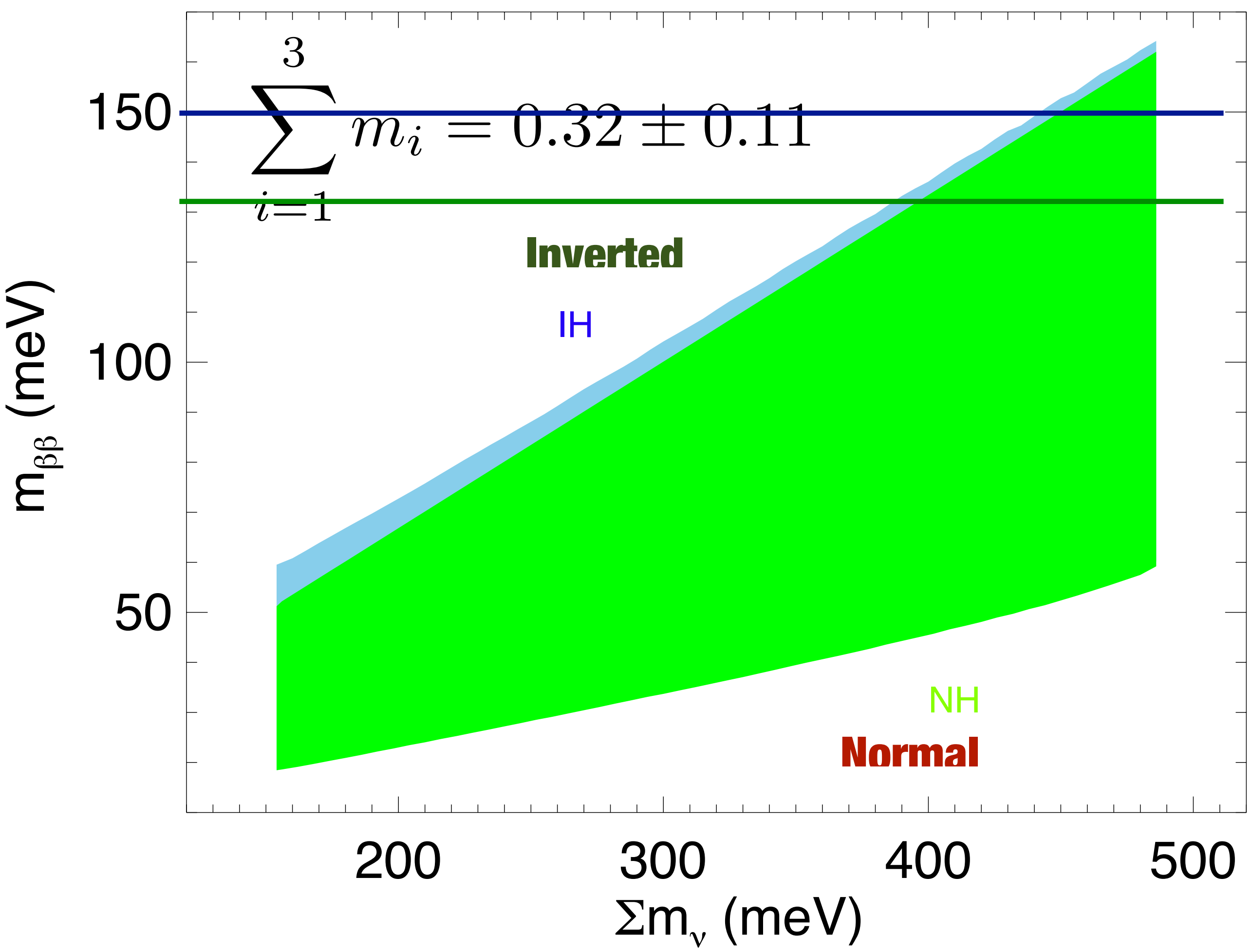
IFIC (CSIC & UV)

St. Andrews, INSS, 2014
Lecture 5

Majorana landscape circa 2020



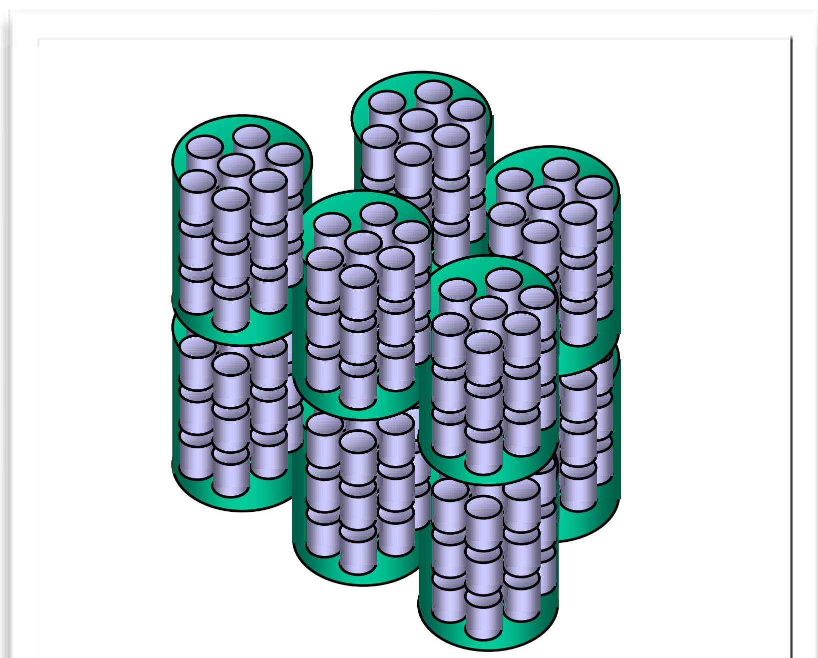


- **Larger NME**
- **Smaller NME**

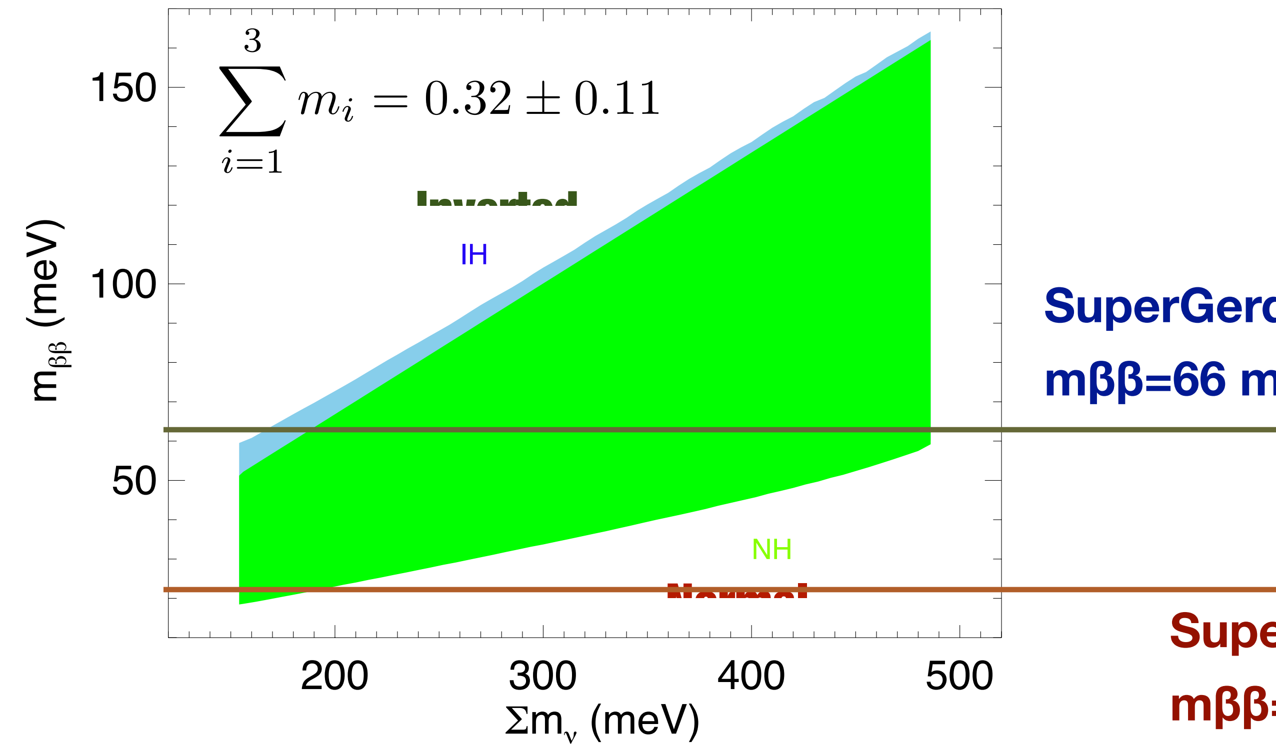
- **How do we cover the cosmo-region even for small NME?**

SuperGerda

- **Mass ~500 kg = 10 x GERDA II**
- **Total running time = 15 years (!!)**
- **Effective exposure = 5 ton year**

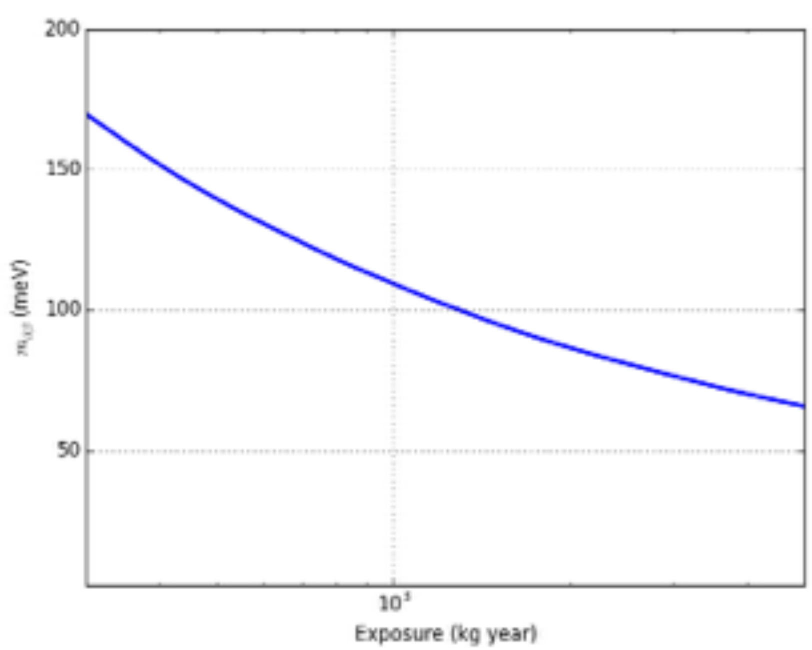


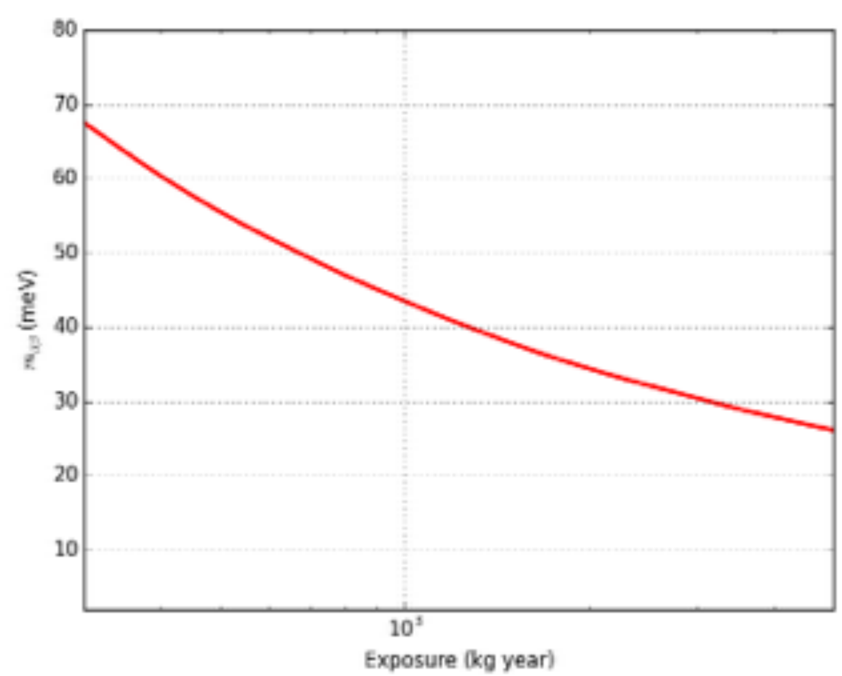
210 2.35 kg crystals



SuperGerda ISM
mββ=66 meV

SuperGerda IBM2
mββ=26 meV





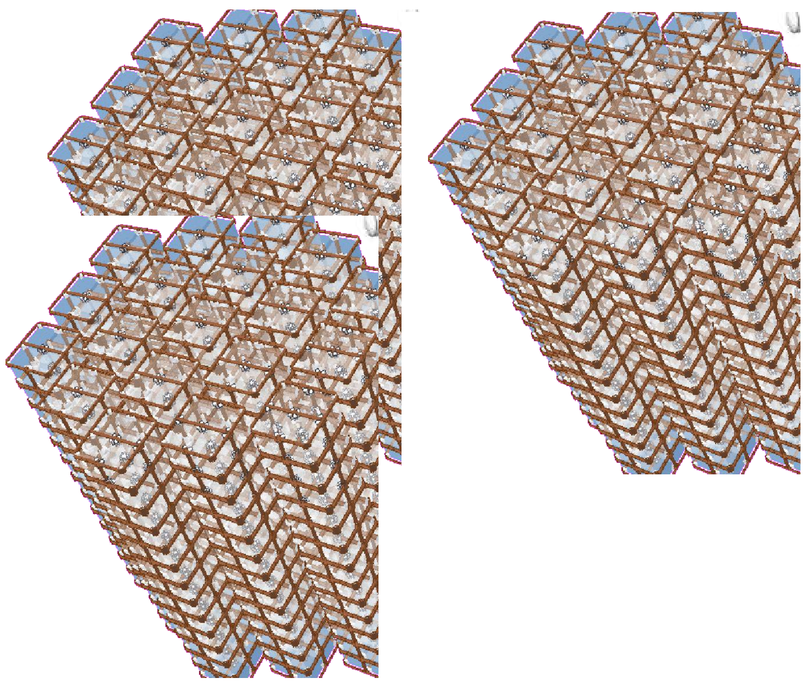
efficiency = 0.62

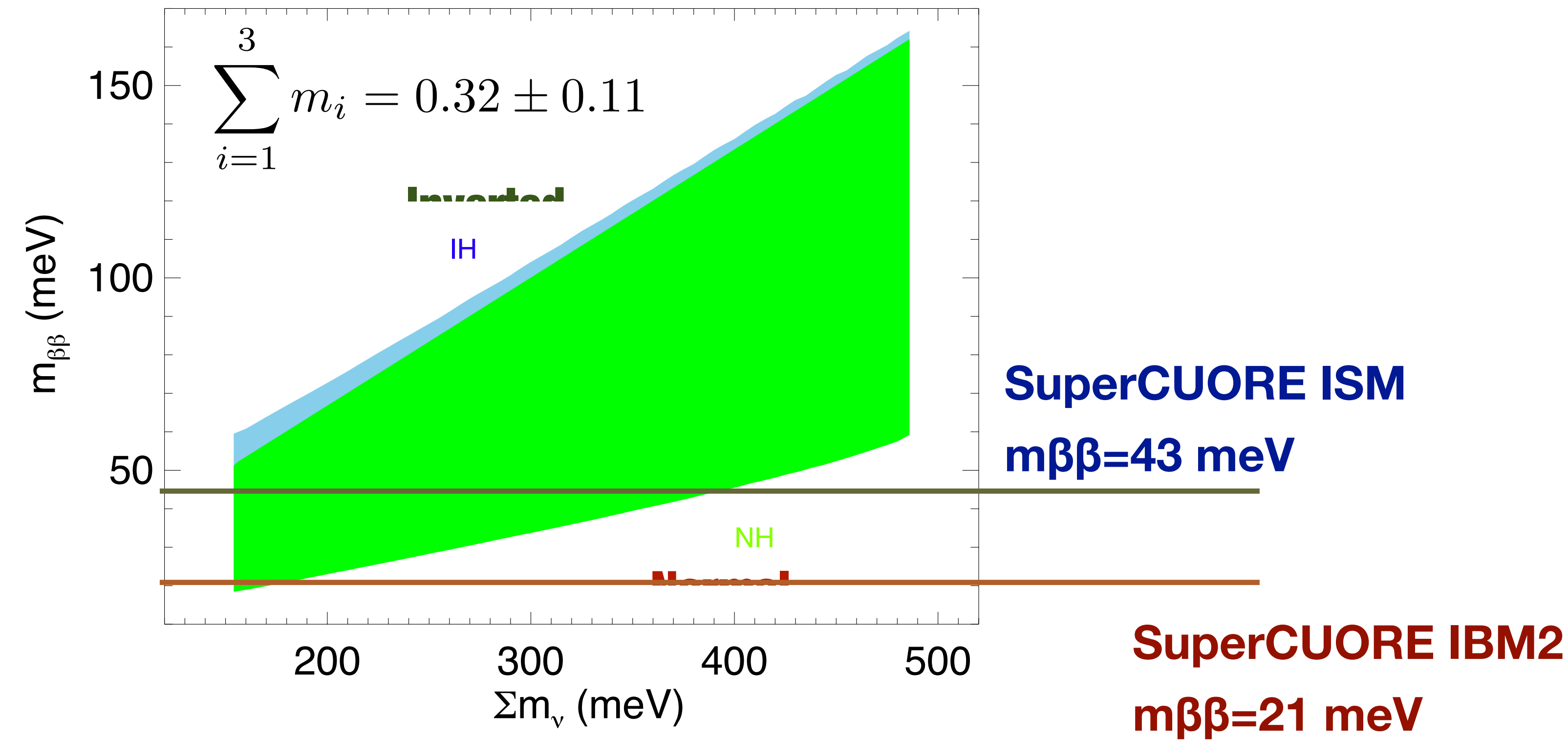
ΔE = 0.1 % at 2.6 MeV

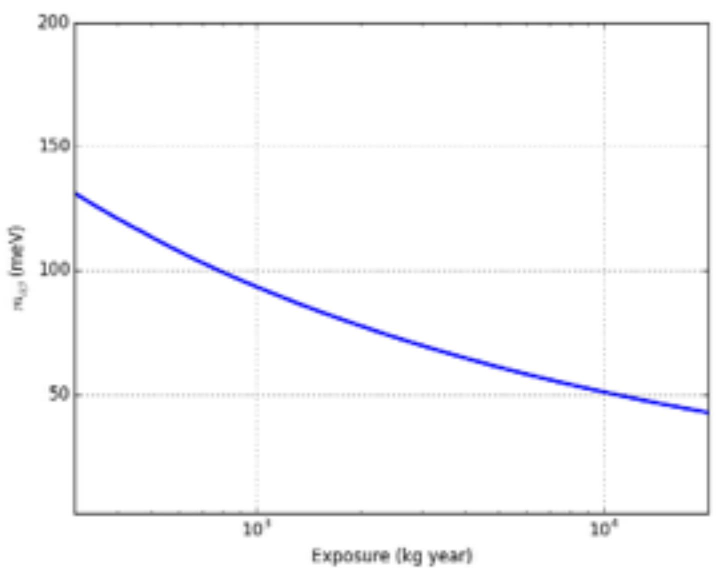
B = 1. x 10^{-3} ckky

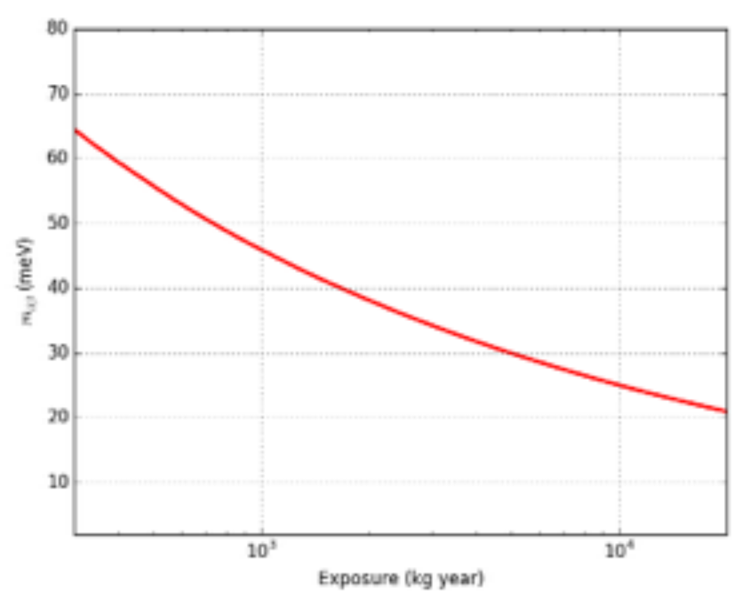
SuperCuore

- **Mass (isotope) ~2 ton = 10 x CUORE**
- **3 super-towers + enriched Tl**
- **Effective exposure = 20 ton year**





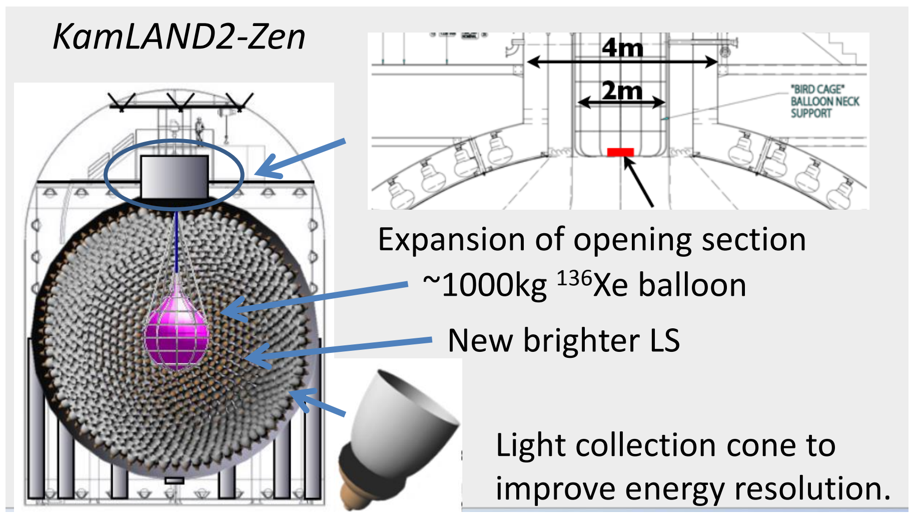


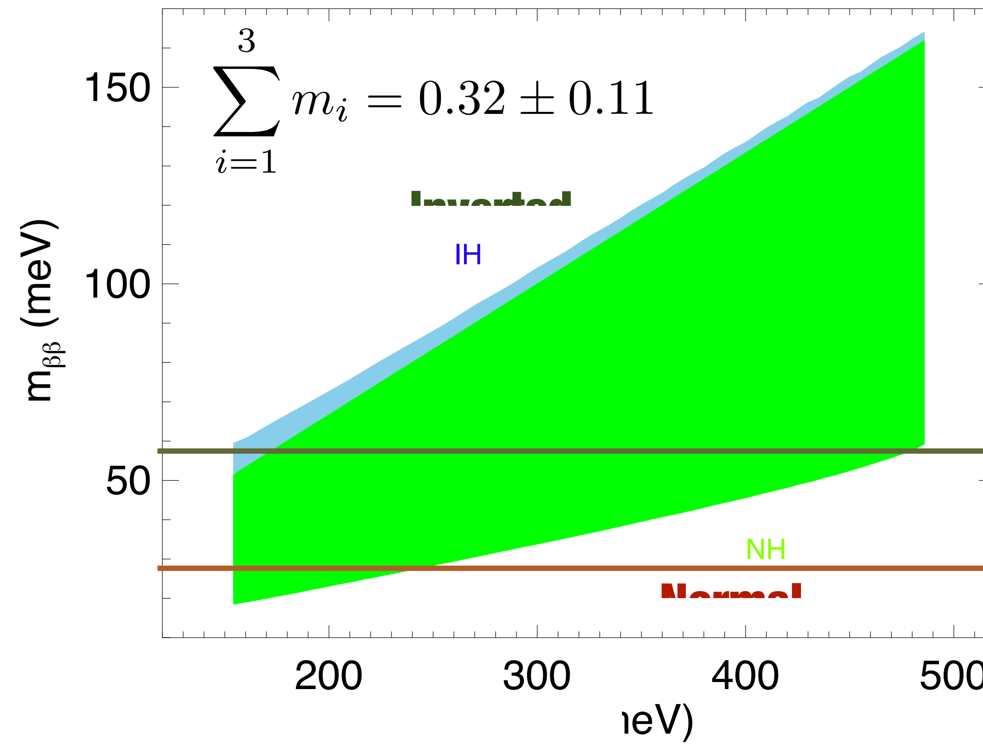


- efficiency = 0.87
- ΔE = 0.2 % at 2.6 MeV
- B = 1. x 10^{-2} ckky

KZen-II

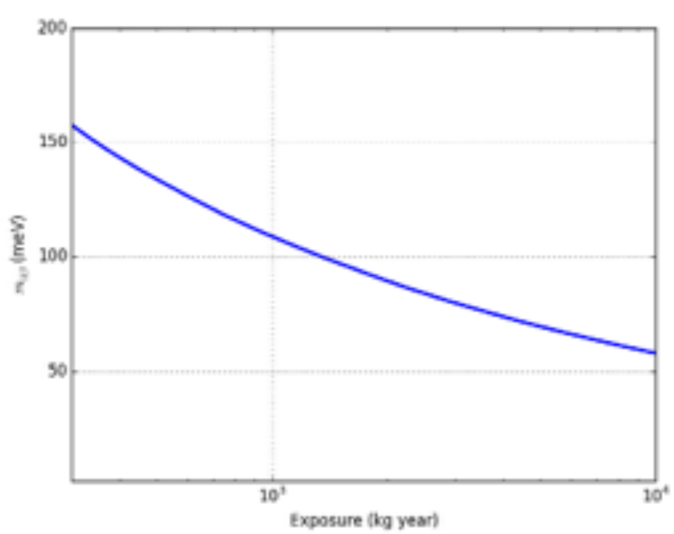
- **Mass (isotope) ~1 ton = 10 x KZENI**
- **Improve resolution to 6% FWHM**
- **Effective exposure = 10 ton year**

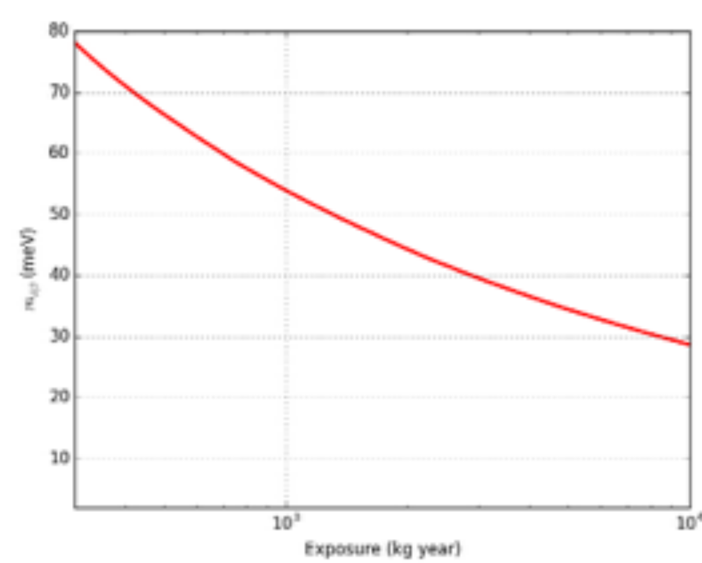




SuperKZEN ISM
mββ=58 meV

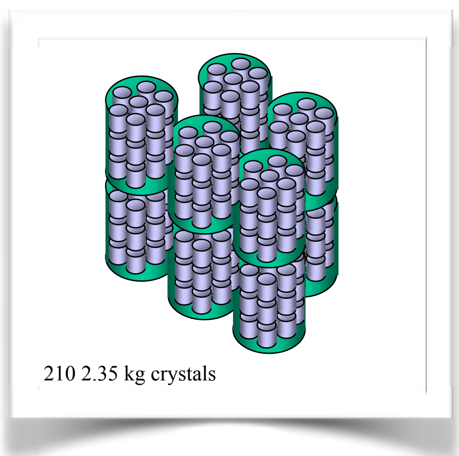
SuperKZEN IBM2
mββ=29 meV

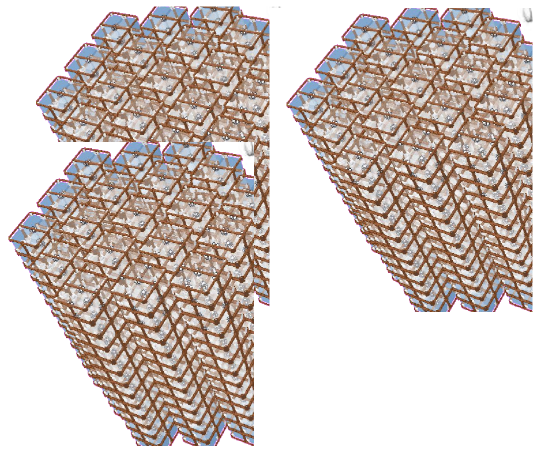


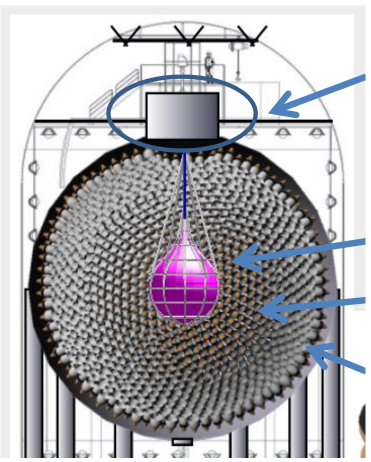


- efficiency = 0.55
- ΔE = 6 % at 2.5 MeV
- B = 1. x 10^{-4} ckky

Assessment: Calorimeters





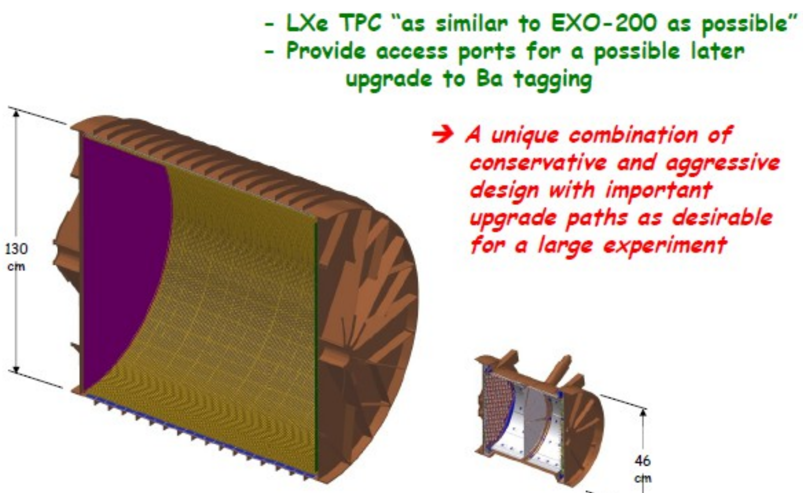


- GERDA & CUORE: increase the mass by a factor ~10
  - Maintain or moderately improve the best expected performance (resolution and B index) of GERDA II and CUORE.
  - Challenge: effort & cost to scale up detectors to very large masses.
  - Advantage: clear signature if signal is observed
- KamLAND-Zen
  - Increase the mass up to allowed load in LS (~1 ton)
  - Improve BI by a factor 6-7 wrt KamLAND-ZEN I and improve resolution by a factor ~2
  - Advantage: Moderate cost (xenon already in hand), feasibility
  - Challenge: Counting experiment, no clear signature, normalisation

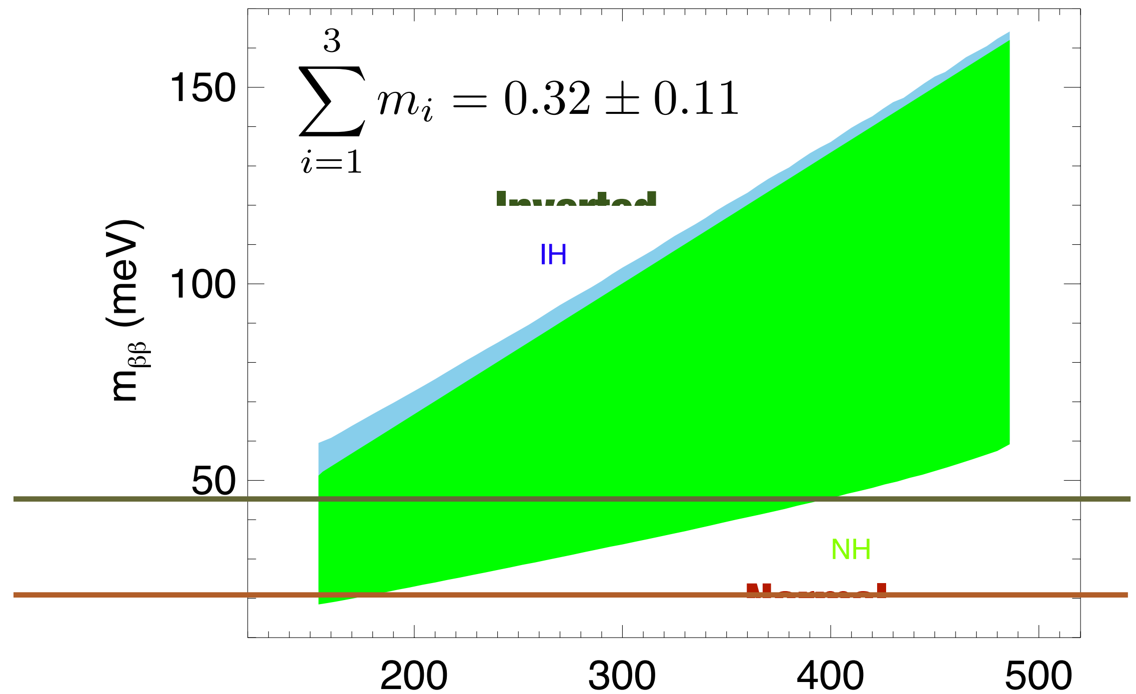
NEXO

- **Mass ~5 ton = 20 x EXO-200**
- **Effective mass: ~3 ton Effective exposure = 30 ton year**

nEXO: a 5 tonnes of enriched Xe

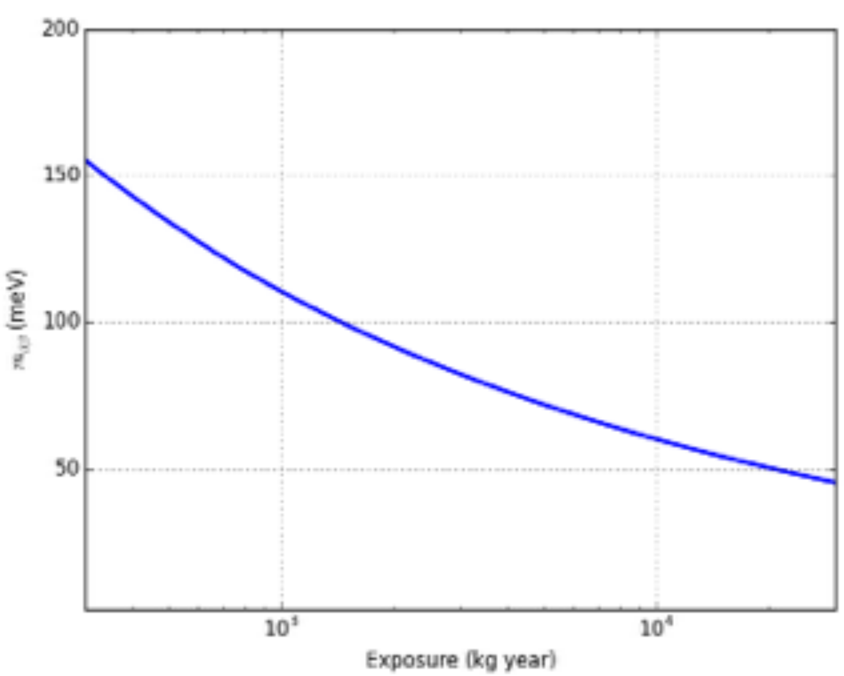


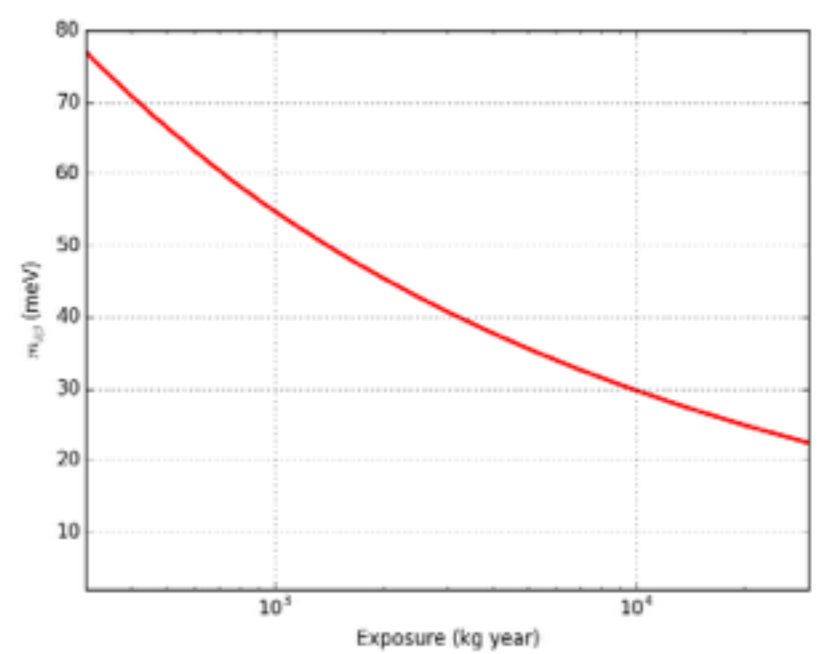
expect better self-shielding, tracking



NEXO ISM
mββ=45 meV

NEXO IBM2
mββ=23 meV

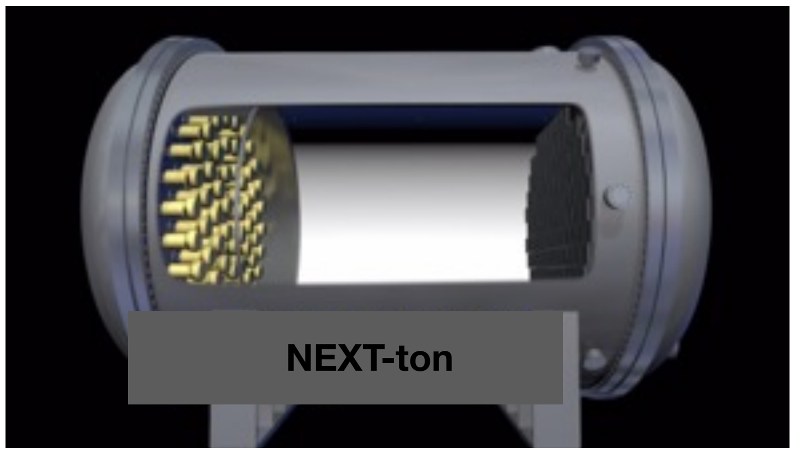


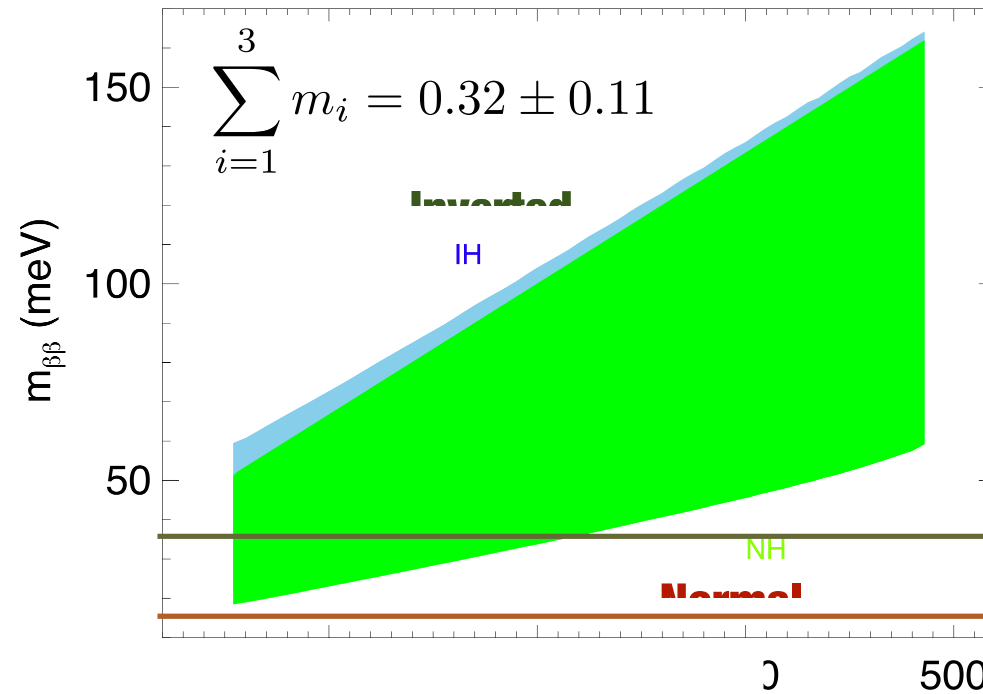


- efficiency = 0.85
- ΔE = 3.6 % at 2.5 MeV
- B = 5. x 10^{-4} ckky

NEXT-ton

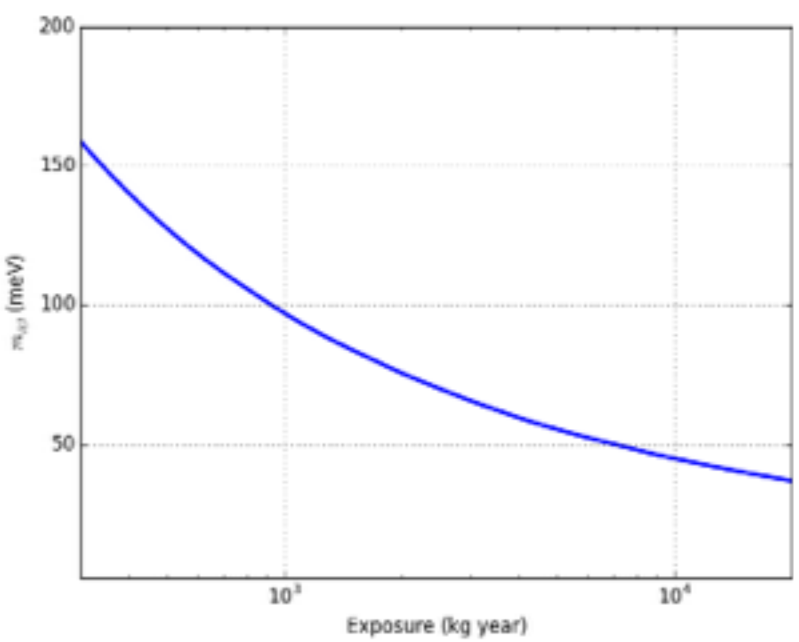
- **Mass ~2 ton = 20 x NEXT-100**
- **Increase pressure to 20 bar**
- **Effective exposure = 20 ton year**

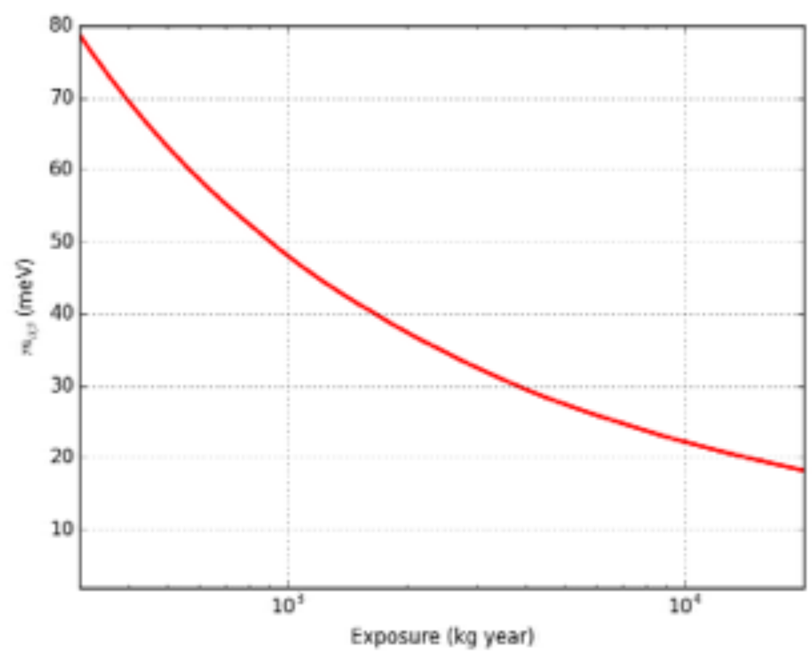




NextTon ISM
mββ=37 meV

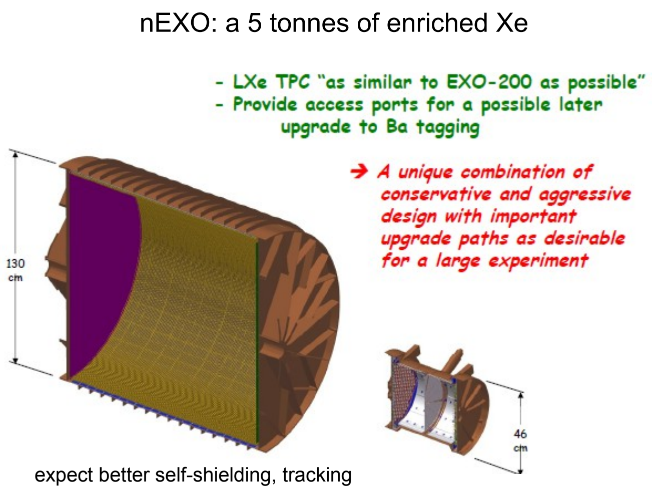
NextTom IBM2
mββ=18 meV

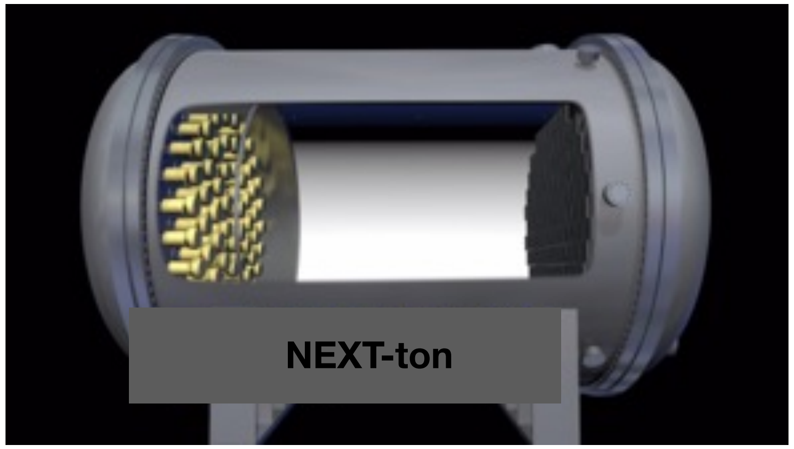




- efficiency = 0.3
- ΔE = 0.5 % at 2.5 MeV
- B = 1. x 10^{-4} ckky

Assessment: TPCs

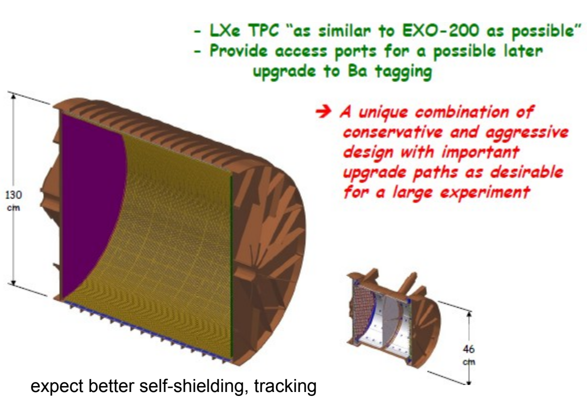




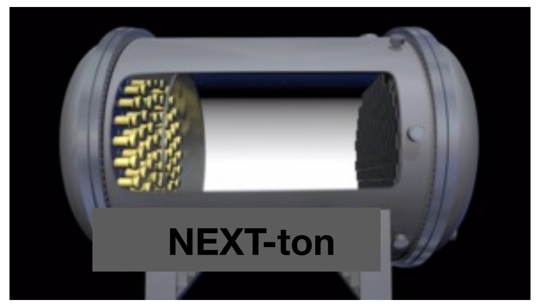
- **NEXO: increase the mass by a factor ~20 (5 ton total)**
  - **Maintain or moderately improve energy resolution**
  - **Improve BI ~10 by self-shielding (give up 2 of 5 ton)**
  - **Challenge: light absorption, normalisation. No striking signature**
  - **Advantage: excellent economy of scale**
- **NEXT-TON**
  - **Moderately improve energy resolution (wrt projected in NEXT-100)**
  - **Improve BI by (at least) a factor 5 wrt NEXT (scale, improve topology)**
  - **Advantage: clear signature, including topological signal**
  - **Challenge: large TPC.**

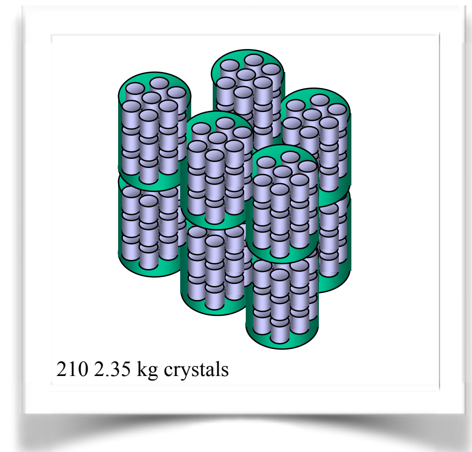
Assessment: The next generation

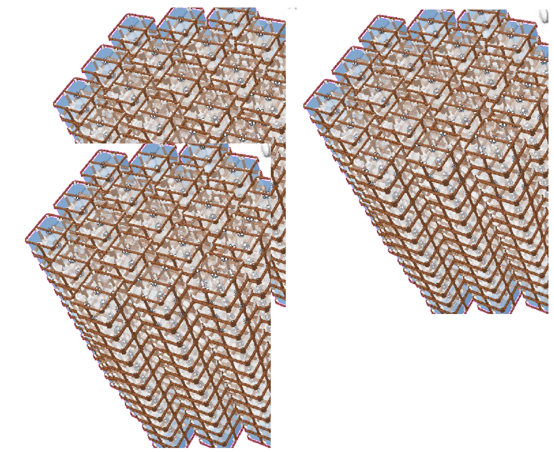
nEXO: a 5 tonnes of enriched Xe

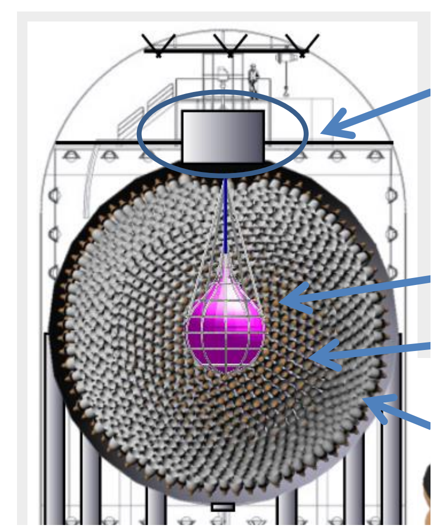


expect better self-shielding, tracking

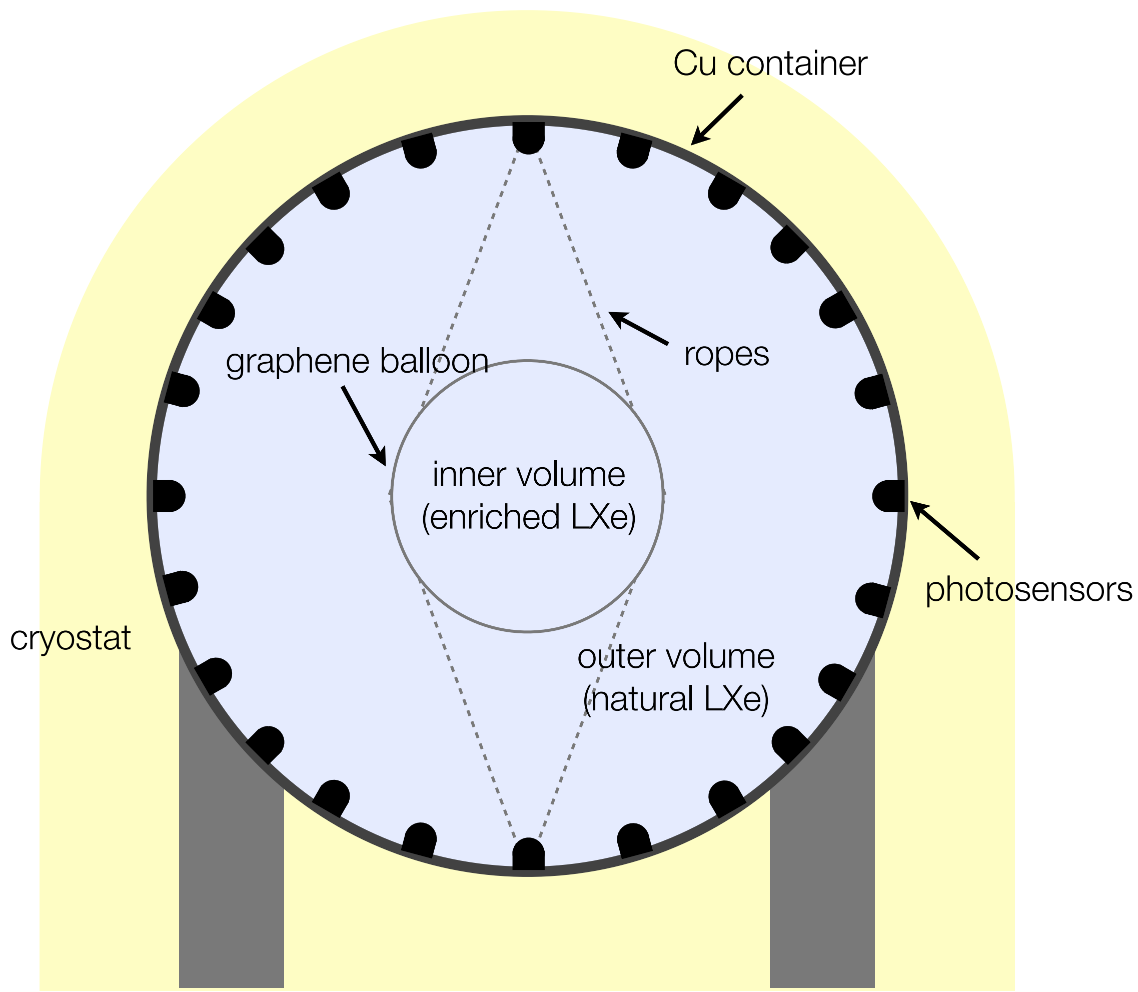








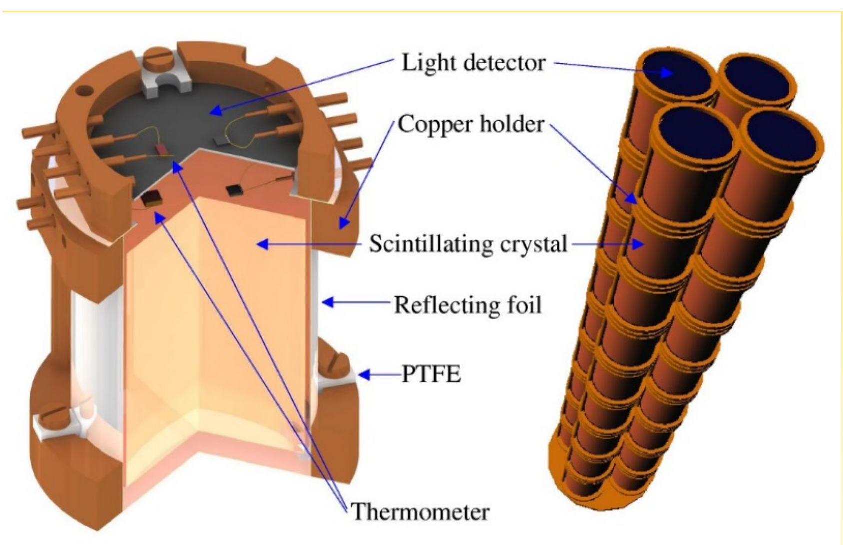
- **Super-Gerda: 26-66 meV**
- **Super-Cuore: 21-43 meV**
- **KamLAND-Zen-II: 29-48 meV**
- **NEXO: 23-45 meV**
- **NEXT-TON: 18-37 meV**
- **Cover the cosmological relevant region (inverse hierarchy) only if NME is high**

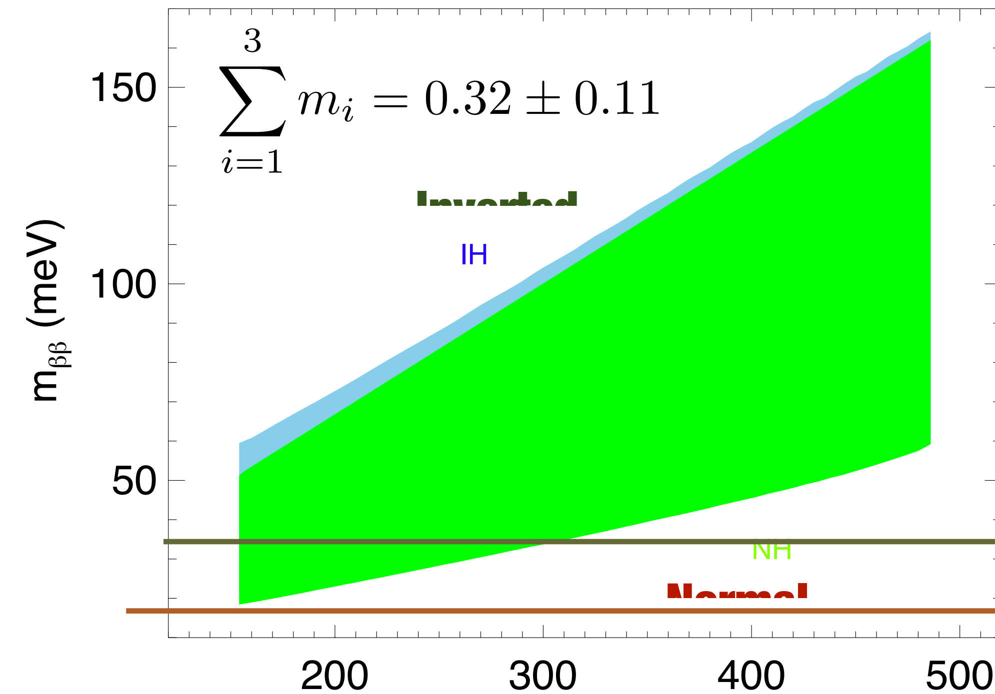


Exploring new ideas

GrandLucifer

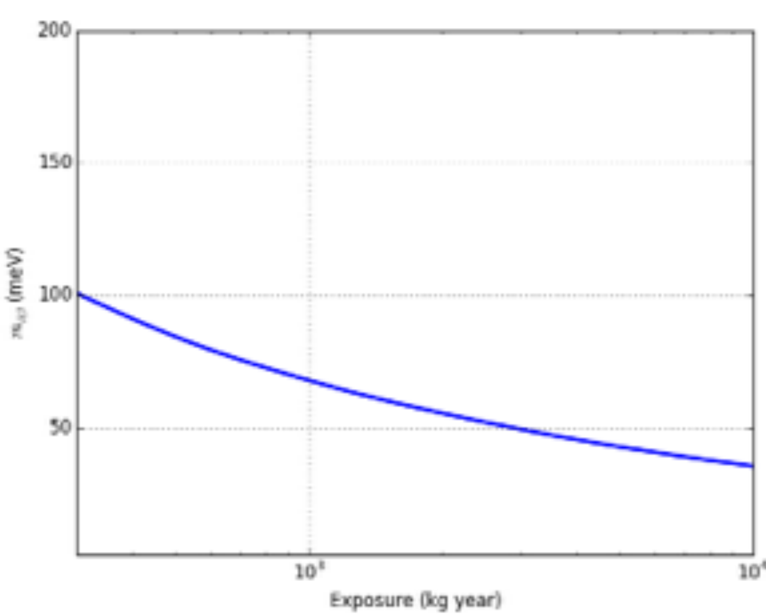
- **Mass ~1ton = 50 x Lucifer**
- **Effective exposure = 10 ton year**

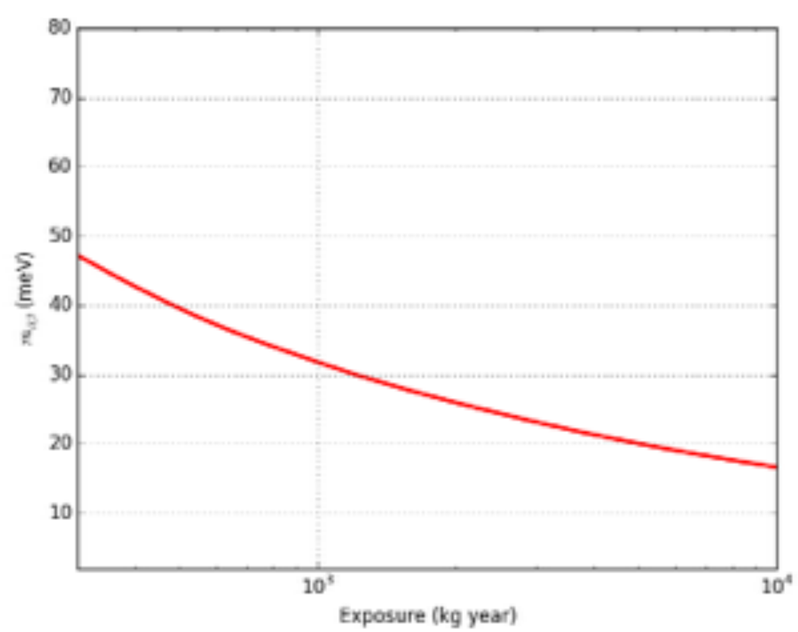




GrandLucifer ISM
mββ=35 meV

GrandLucifer IBM2
mββ=17 meV

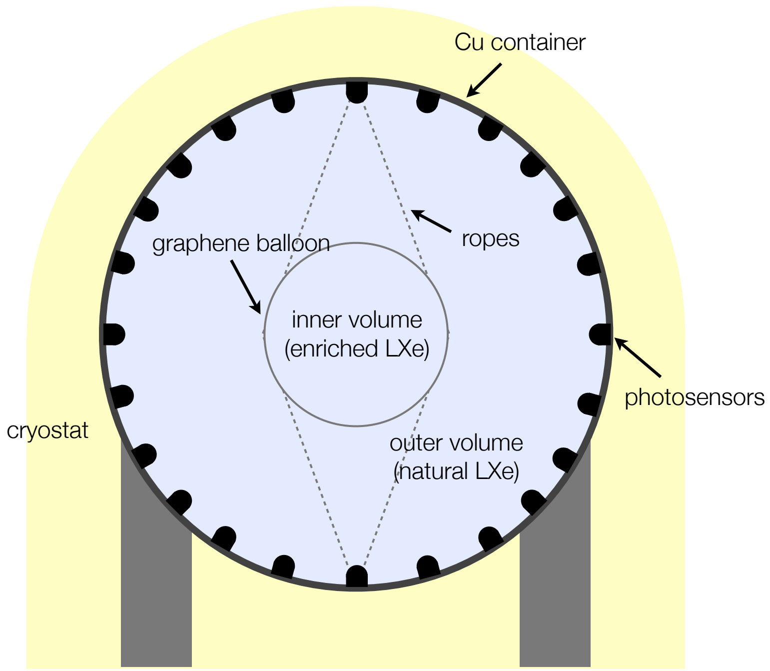


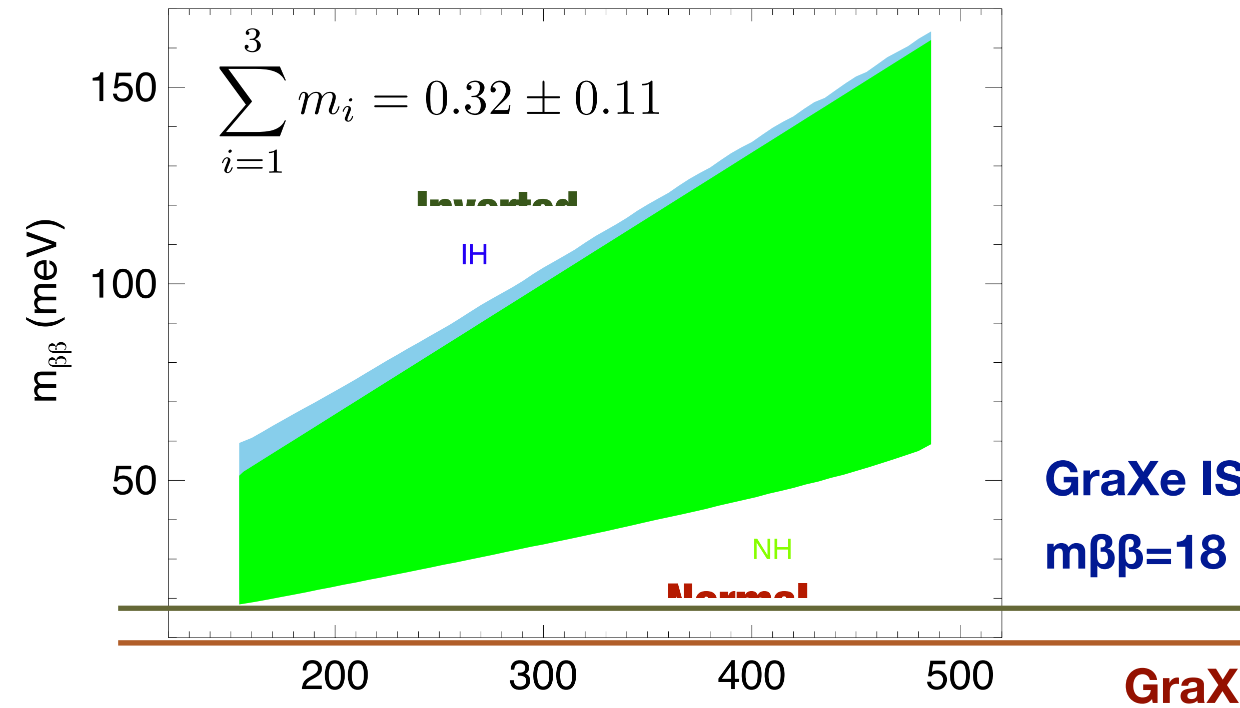


- efficiency = 0.65
- ΔE = 0.03 % at 2.9 MeV
- B = 1. x 10^{-3} ckky

GraXe

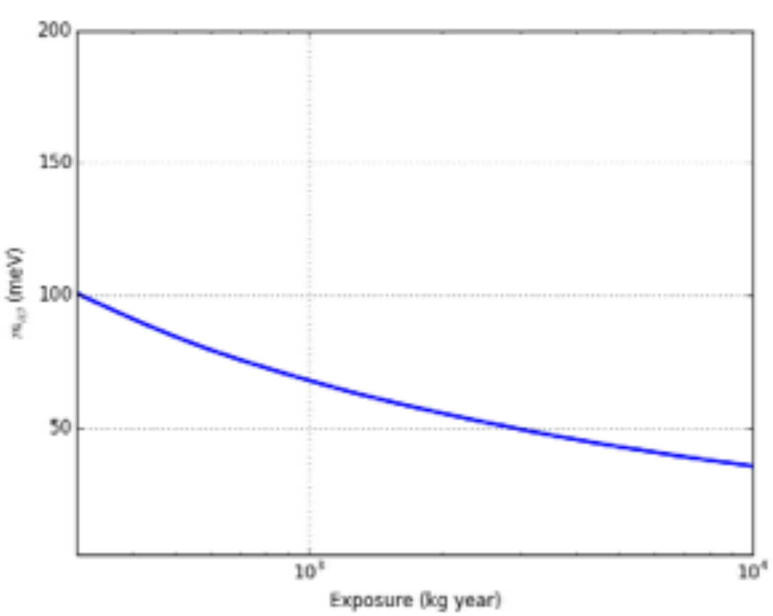
- **Mass ~3ton enriched in balloon, 20 ton LXe shield**
- **Effective exposure = 30 ton year**

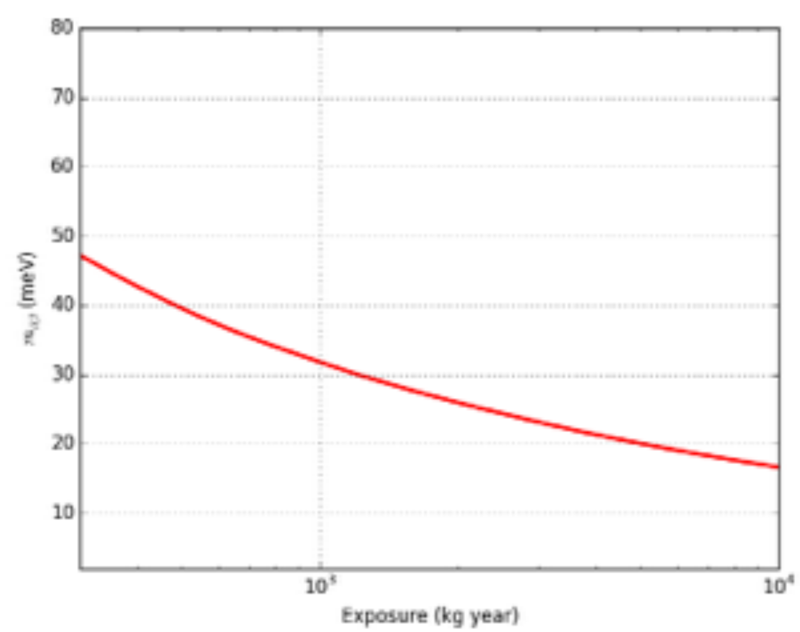




GraXe ISM
mββ=18 meV

GraXe IBM2
mββ=9 meV

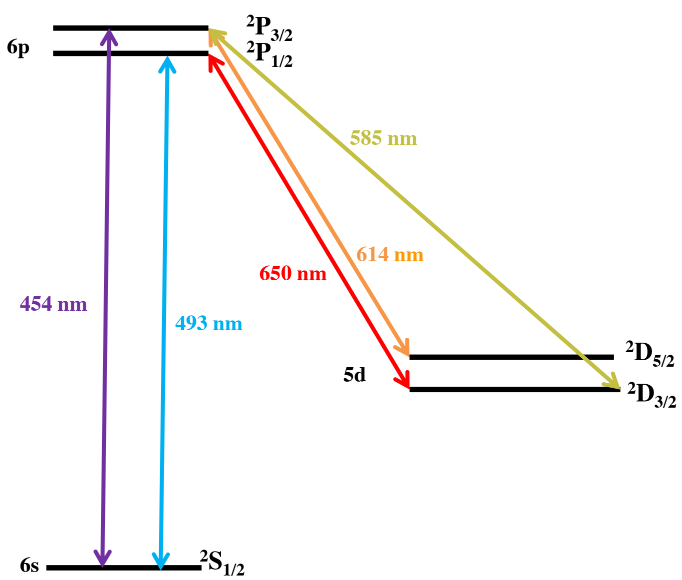


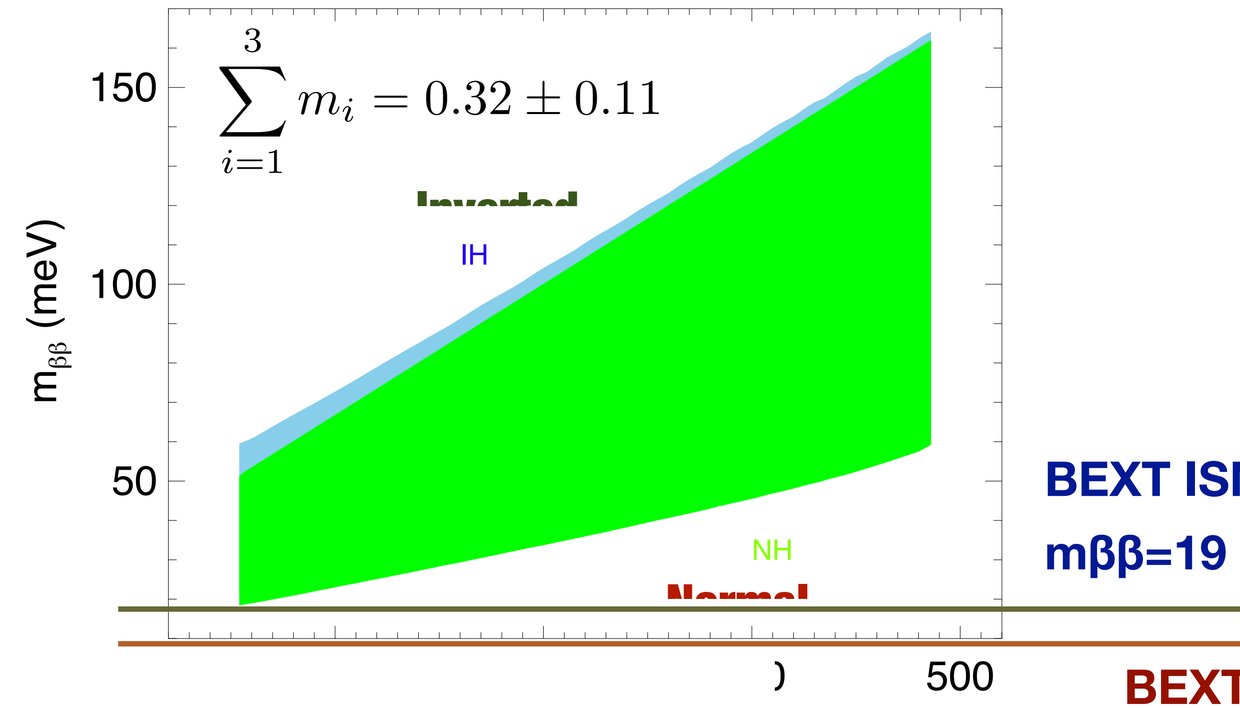


- efficiency = 0.85
- ΔE = 3.6 % at 2.5 MeV
- B = 1. x 10^{-5} ckky

BEXT

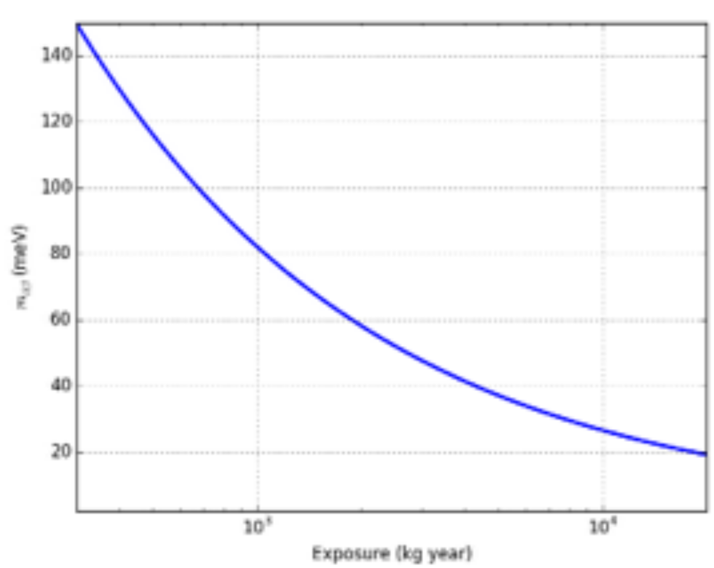
- **Mass ~2 ton Effective exposure = 20 ton year**

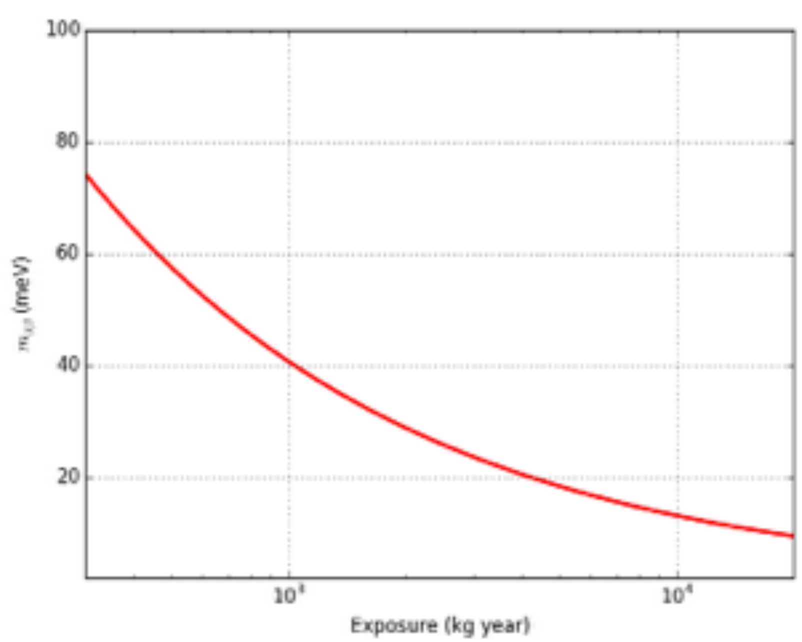




BEXT ISM
mββ=19 meV

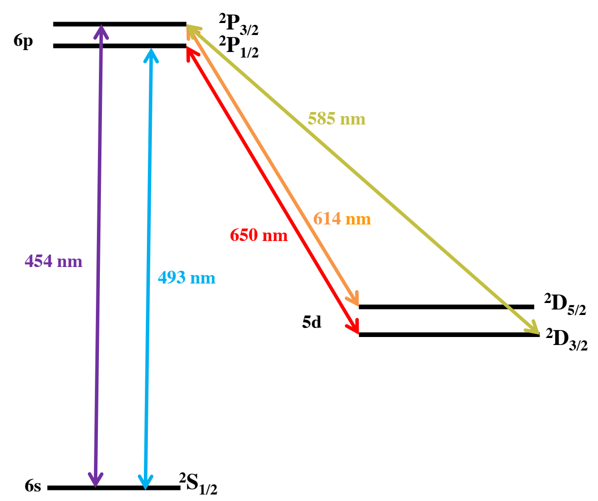
BEXT IBM2
mββ=9 meV

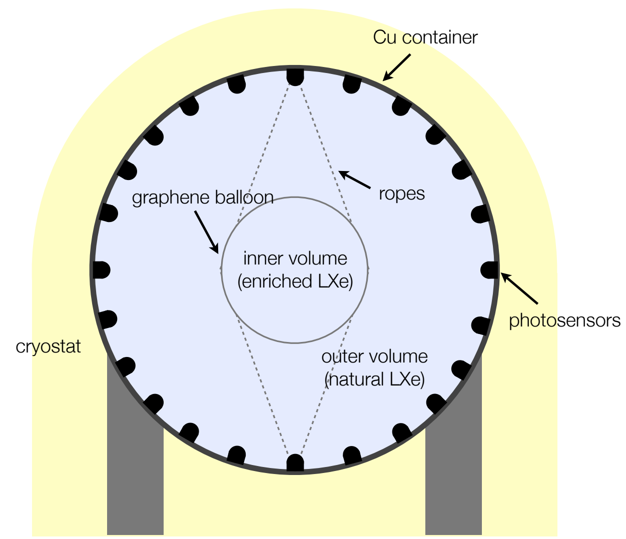


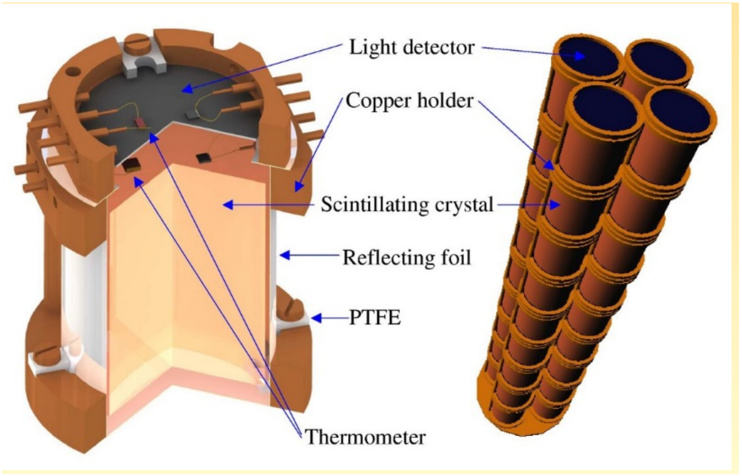


- efficiency = 0.3
- ΔE = 0.5 % at 2.5 MeV
- B = 1. x 10^{-6} ckky

Assessment: NEW ideas







- **The three experiments discussed essentially cover the inverse hierarchy even for pessimistic case of NME.**
- **They are examples of ideas that require technological break-throughs (large graphene balloon, barium tagging, large-scale scintillation bolometers) *and* large target masses.**
- **Discovering that the neutrino is a Majorana particle is possible, but requires a brave heart.**