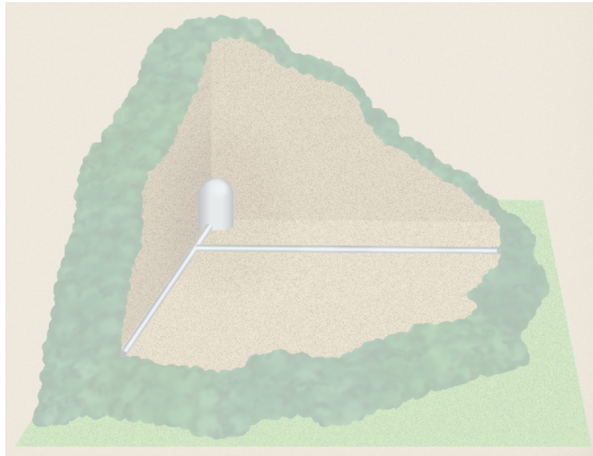
KamLAND at 1000m underground monitors one thousand tons of ultra-pure liquid scintillator with 1879 photo-sensors arrayed inside the 18m-diameter stainless steel tank.



KamLAND

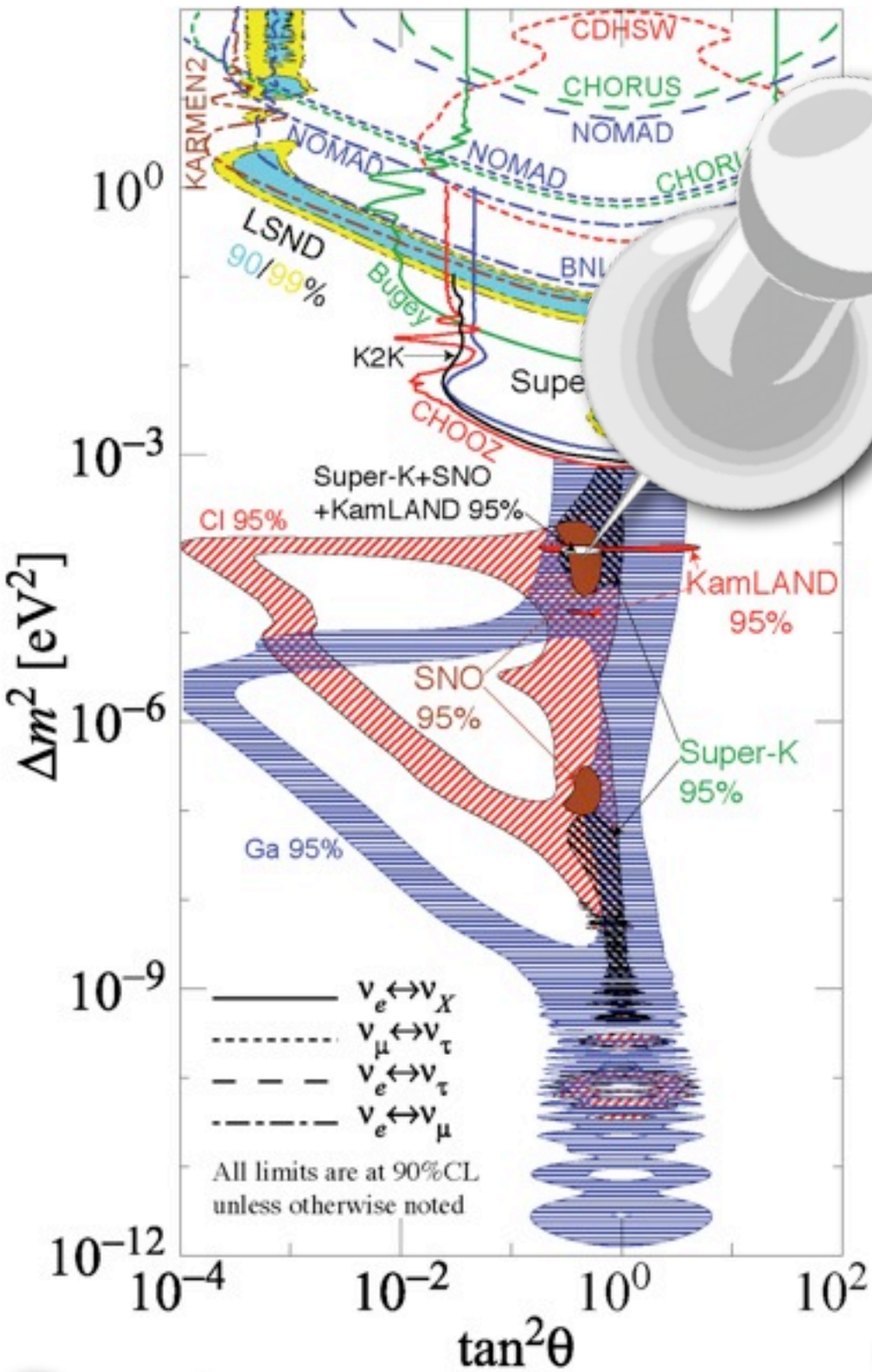
Kamioka Liquid-scintillator Anti-Neutrino Detector

Kunio Inoue

Research Center for Neutrino Science, Tohoku University

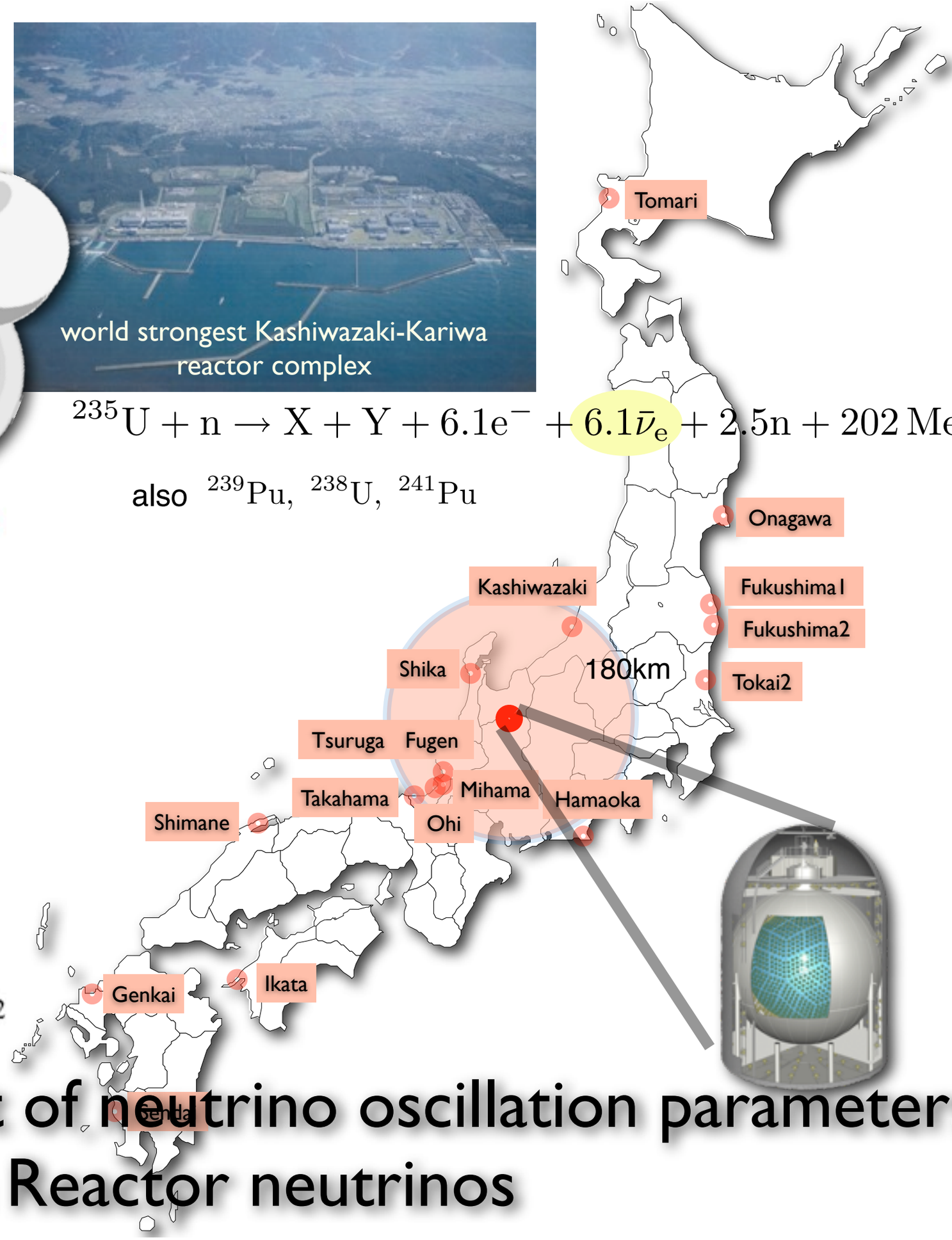
The US-Japan HEP Collaboration 30th Anniversary Symposium, 20 Oct 2010

target I



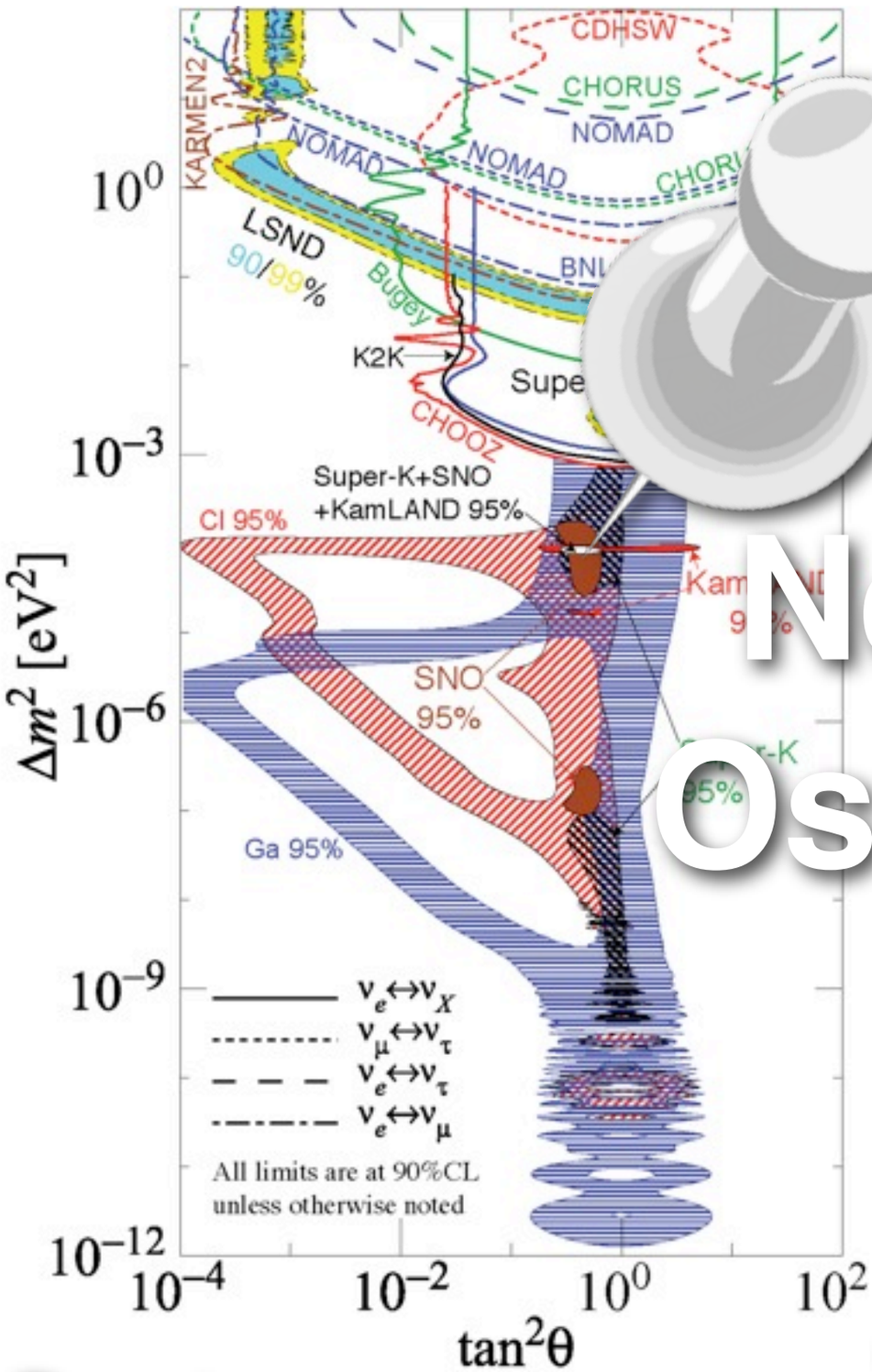
$$^{235}\mathrm{U} + \mathrm{n} \rightarrow \mathrm{X} + \mathrm{Y} + 6.1\mathrm{e}^- + 6.1\bar{\nu}_\mathrm{e} + 2.5\mathrm{n} + 202\,\mathrm{MeV}$$

also $^{239}\mathrm{Pu}$, $^{238}\mathrm{U}$, $^{241}\mathrm{Pu}$



Precise measurement of neutrino oscillation parameters with Reactor neutrinos

target I



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Neutrino Oscillation

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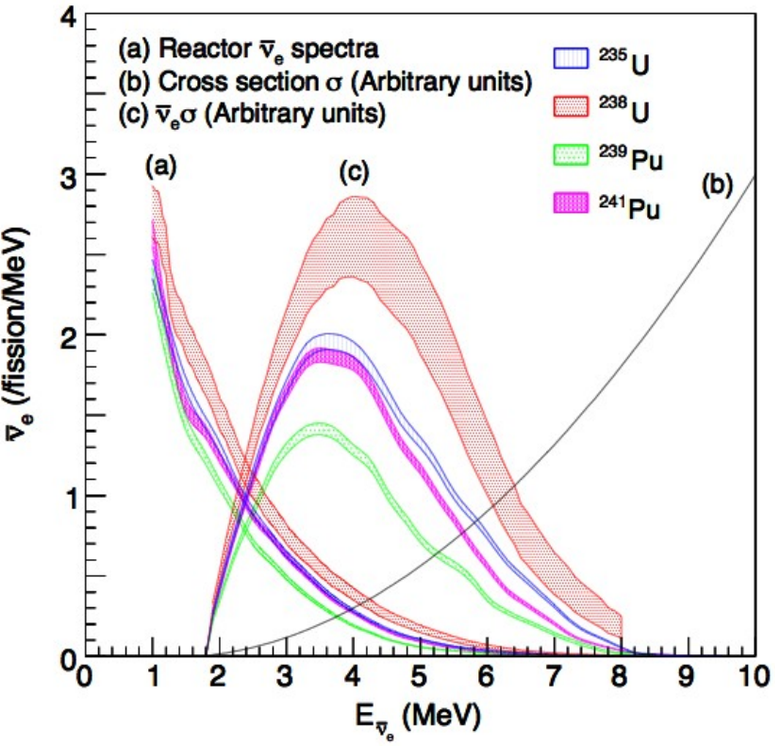
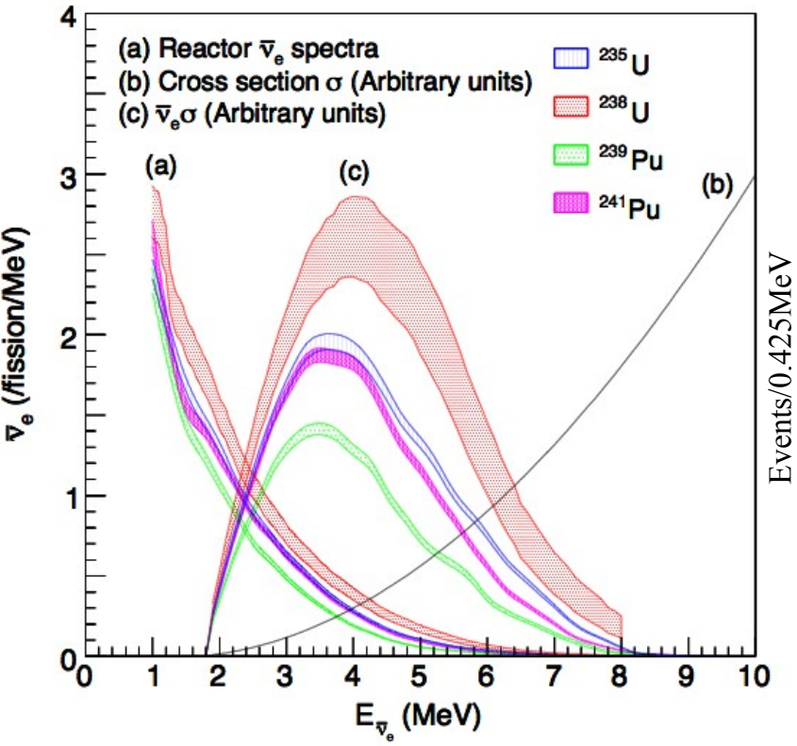
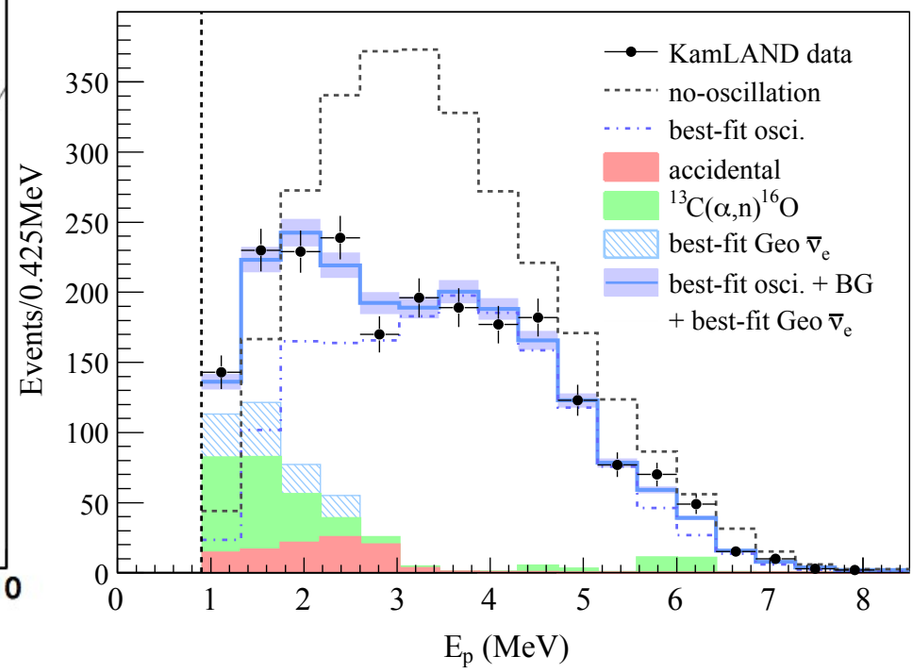


$$\bar{\nu}_e + p \rightarrow e^+ + n$$

Two-fold delayed coincidence





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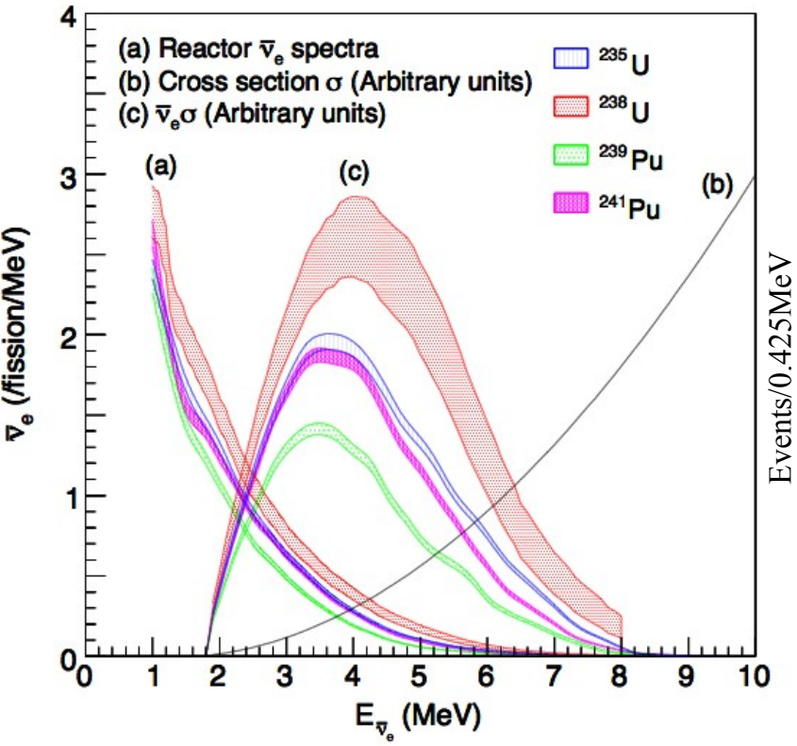

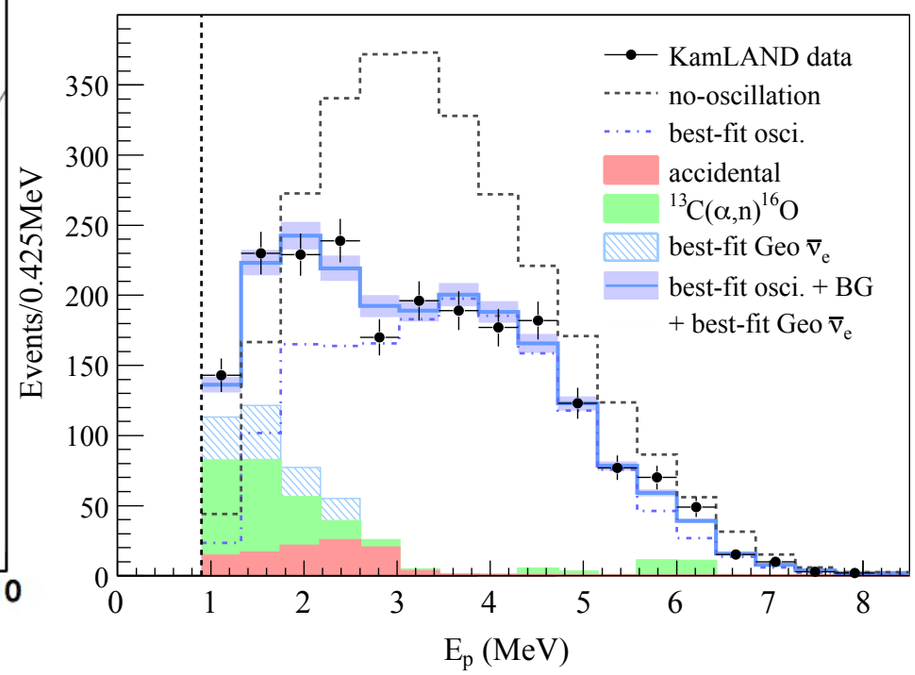

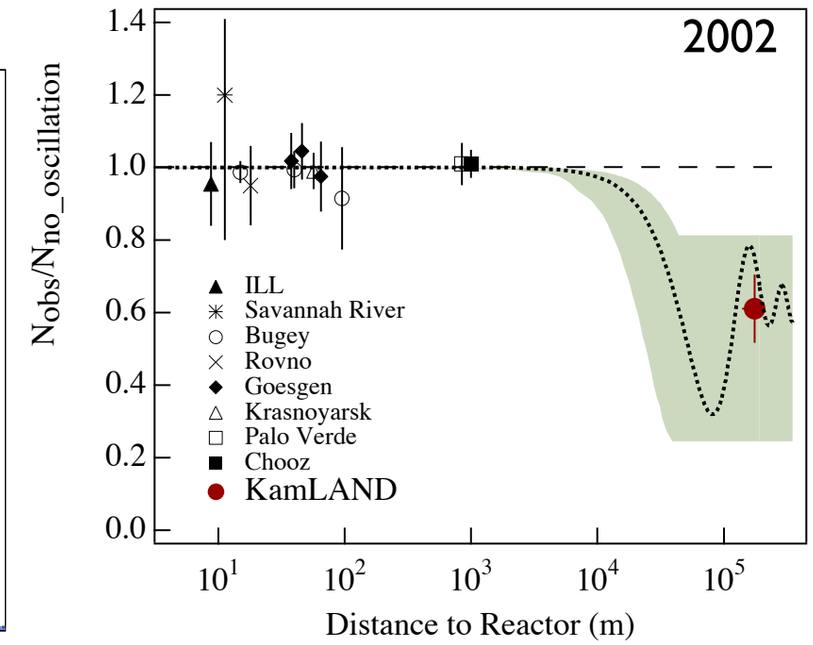

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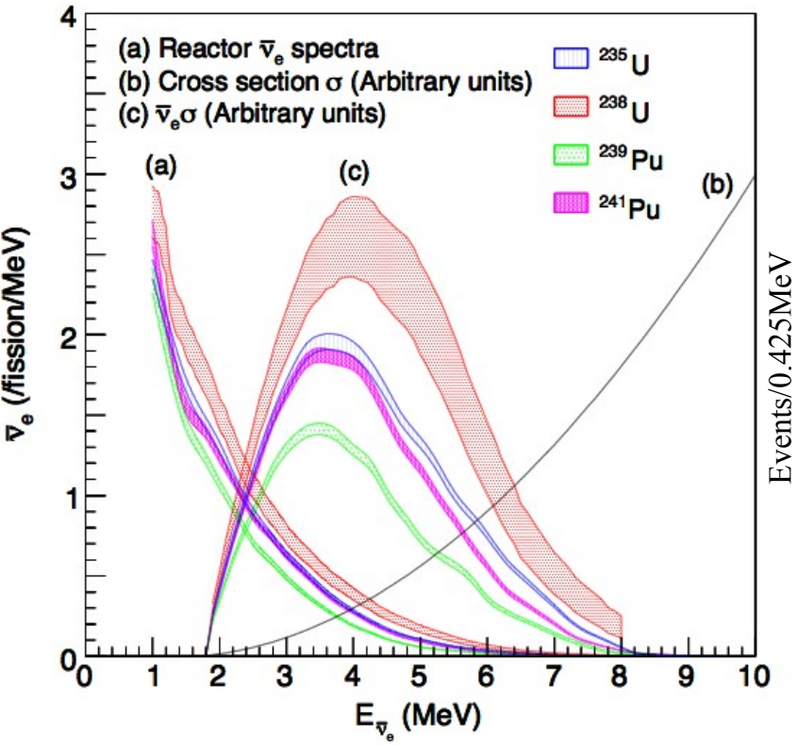
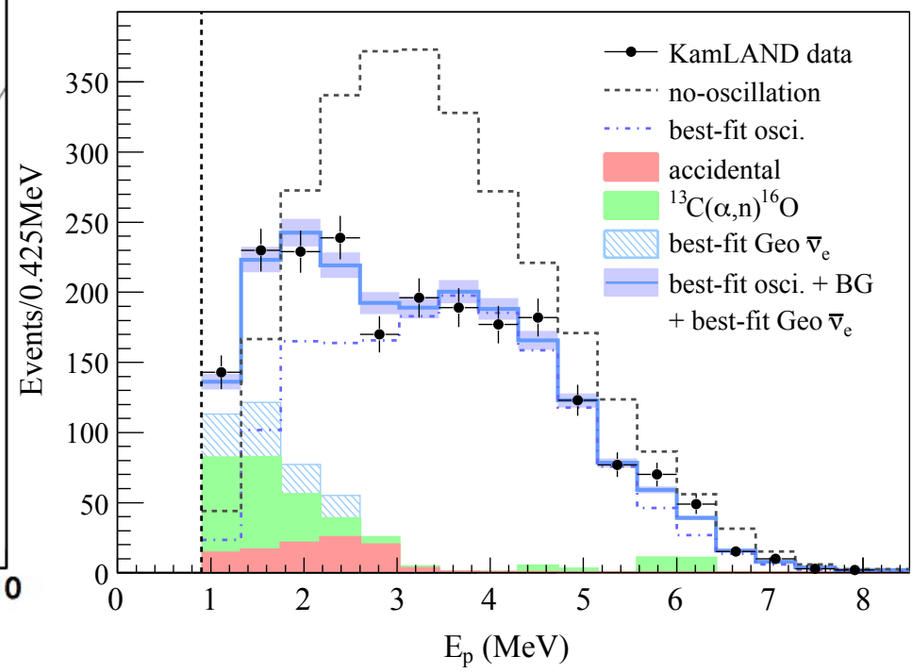
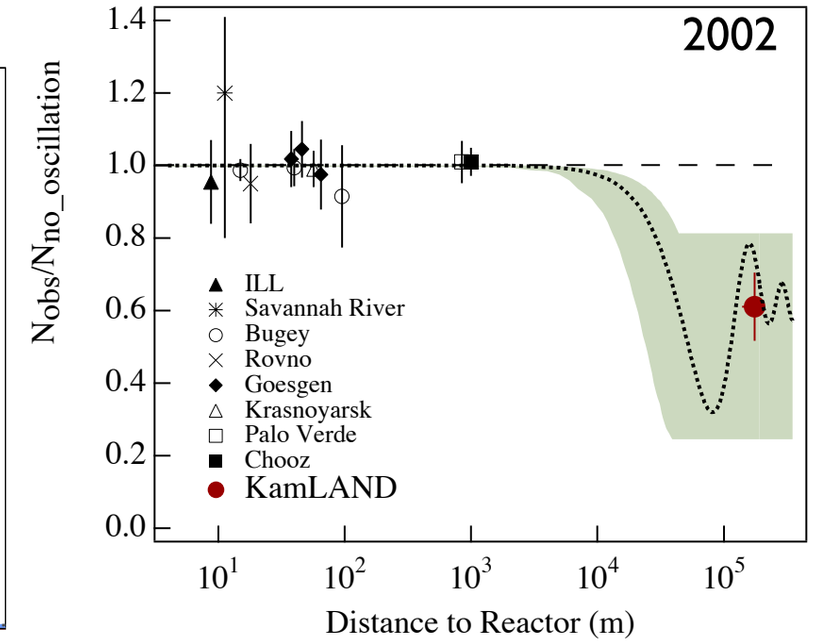
No.1 citation in physics (2003,2004)







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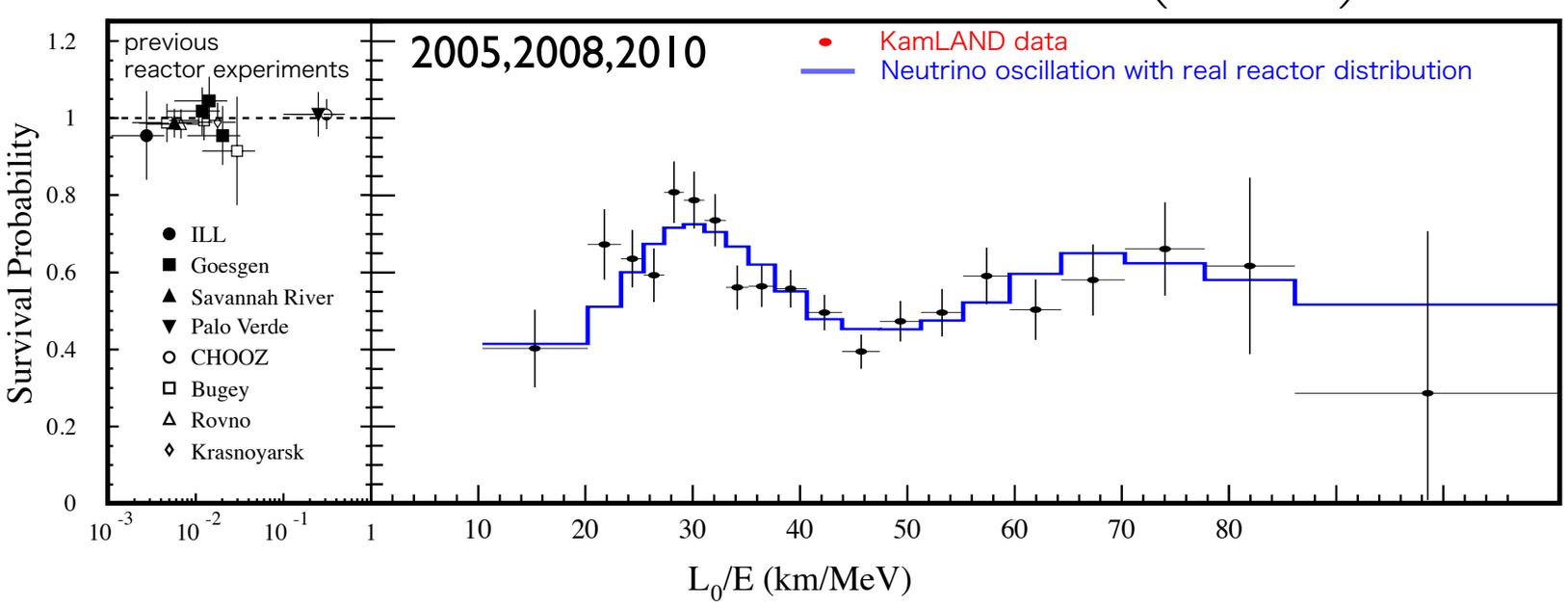
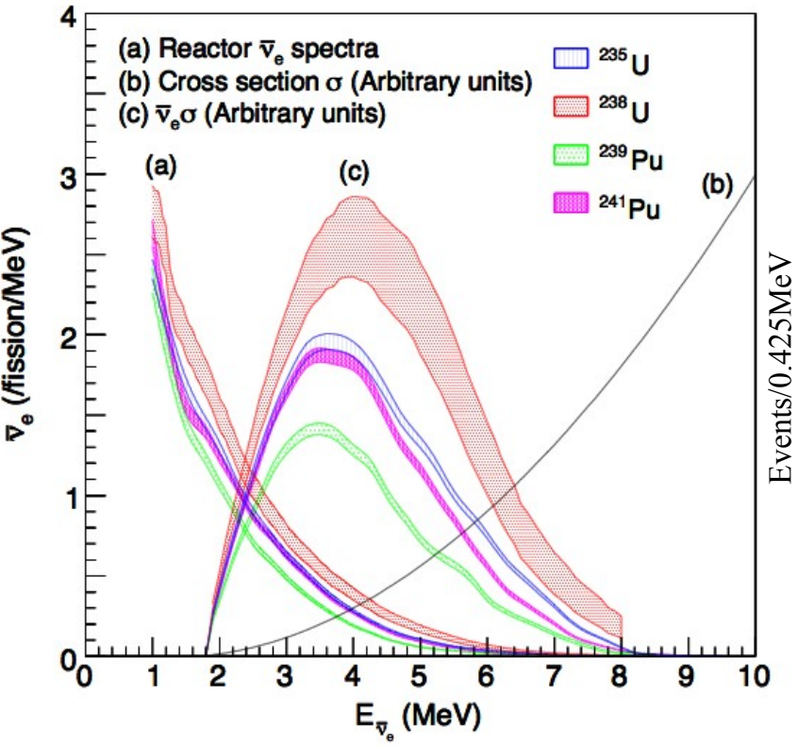
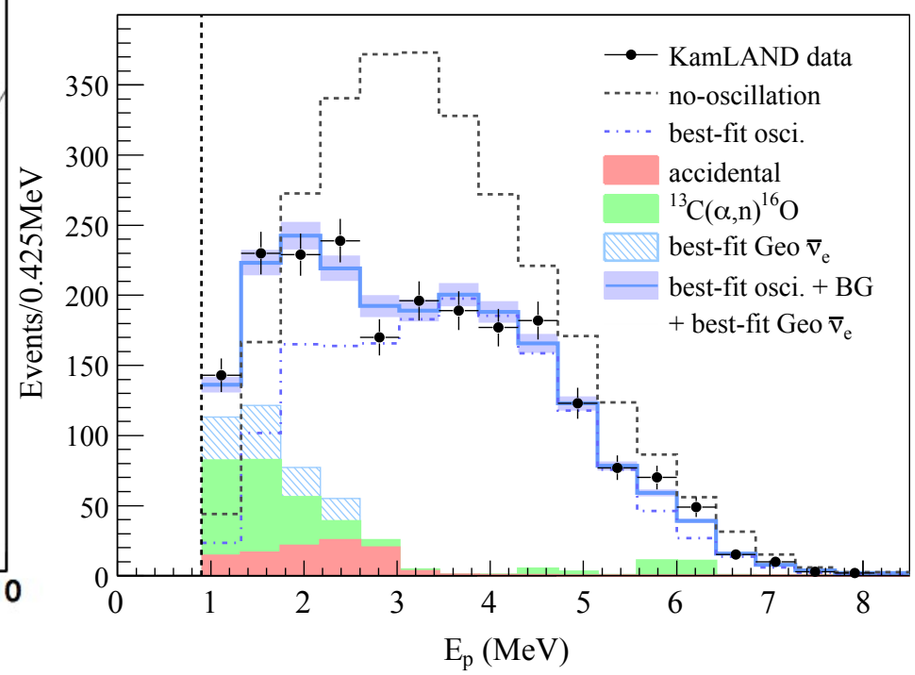
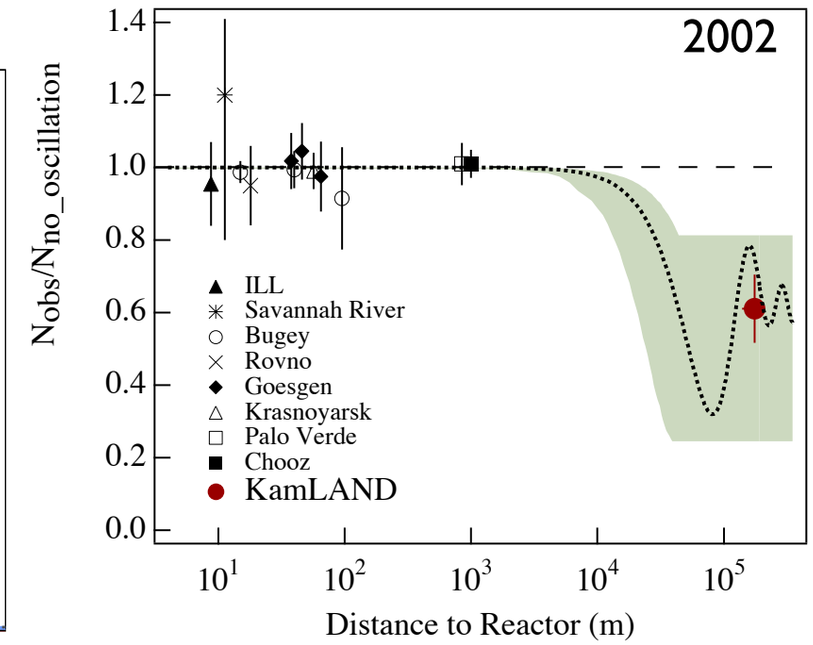


observed two cycles of oscillation

resulted in the precision measurement of Δm^2_{21}







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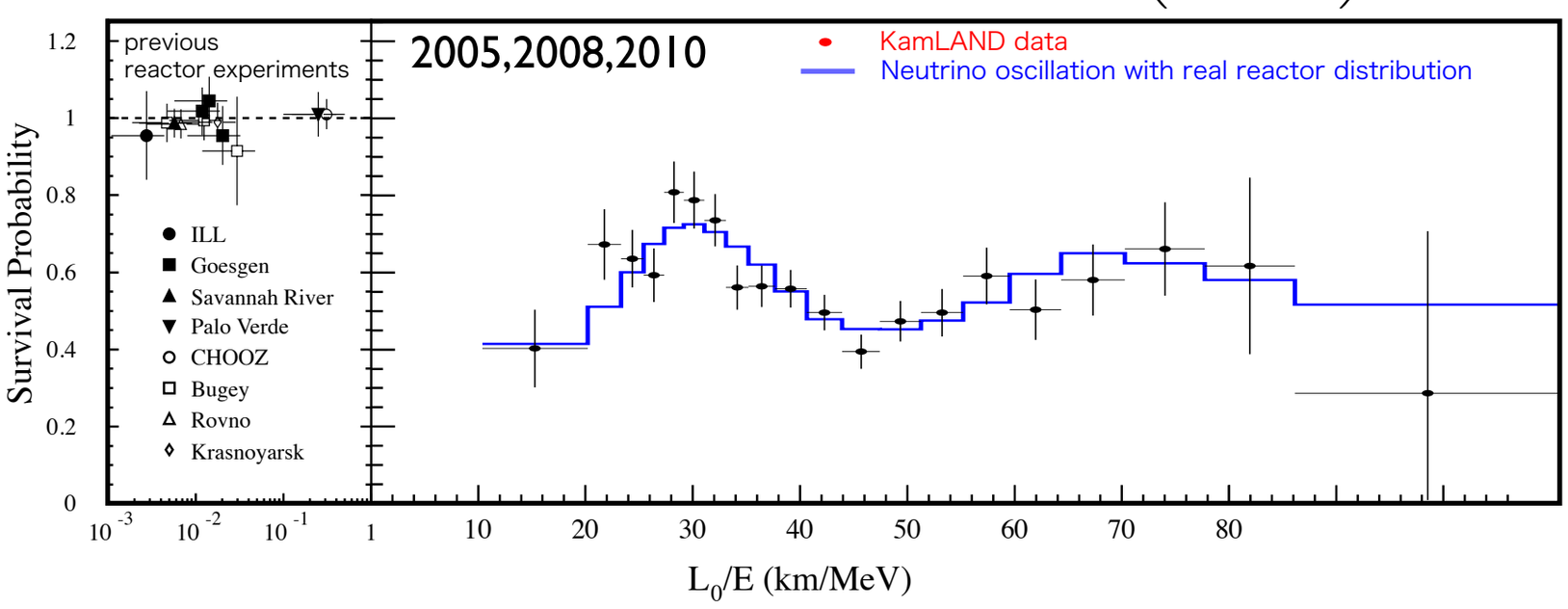

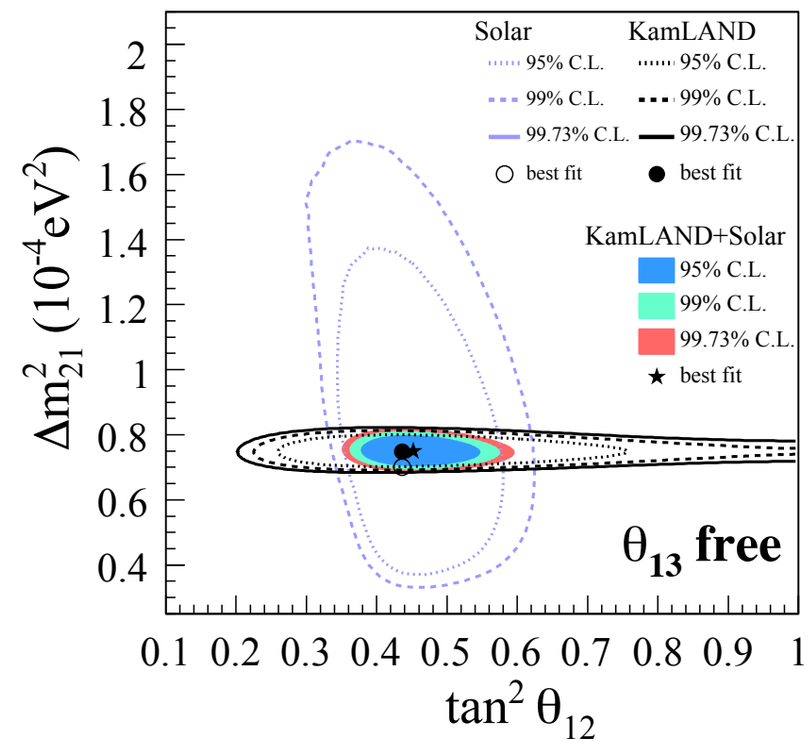

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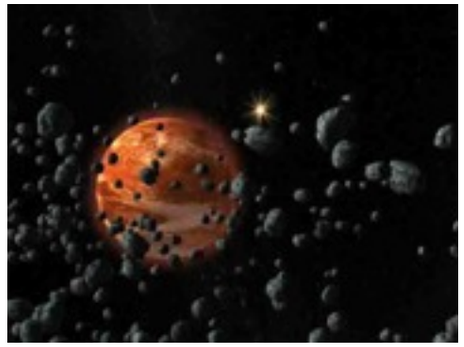
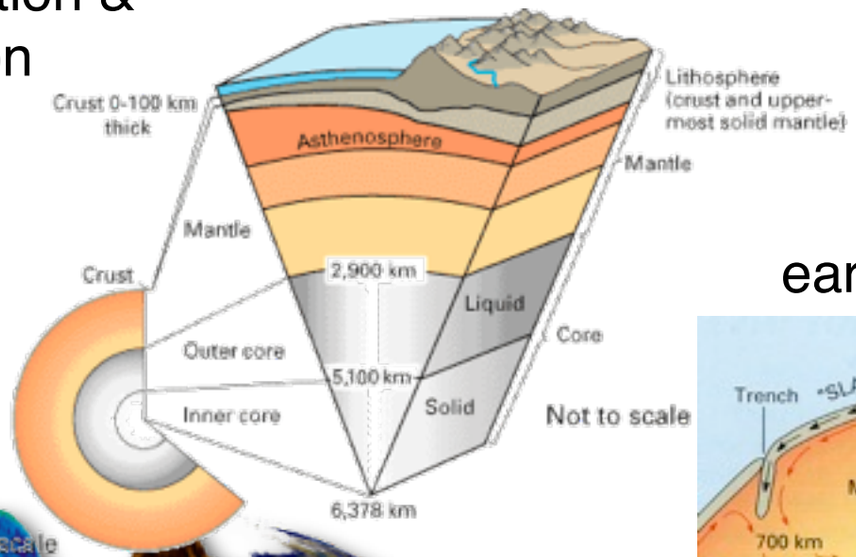
2.7% precision !

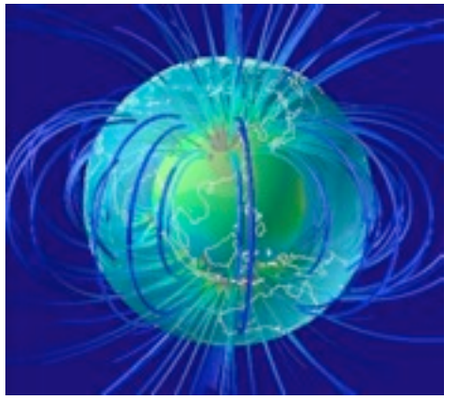
target 2

earth formation & evolution

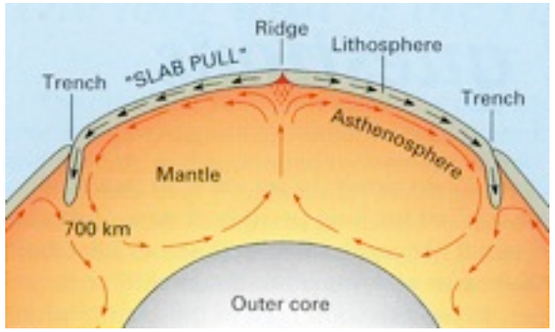


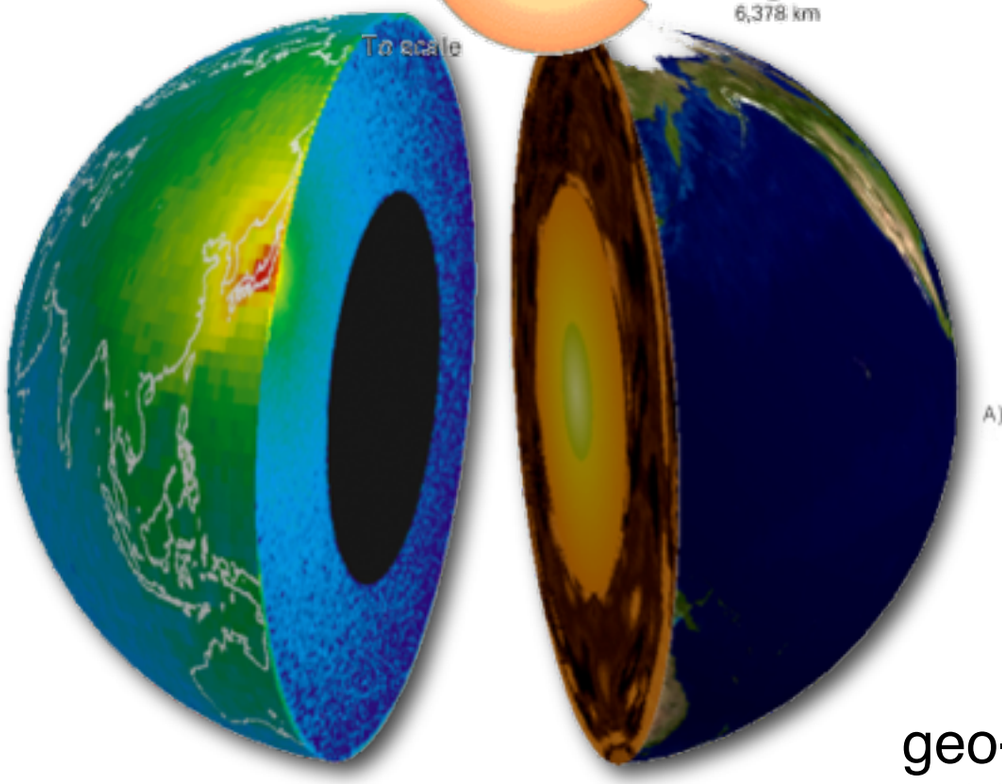


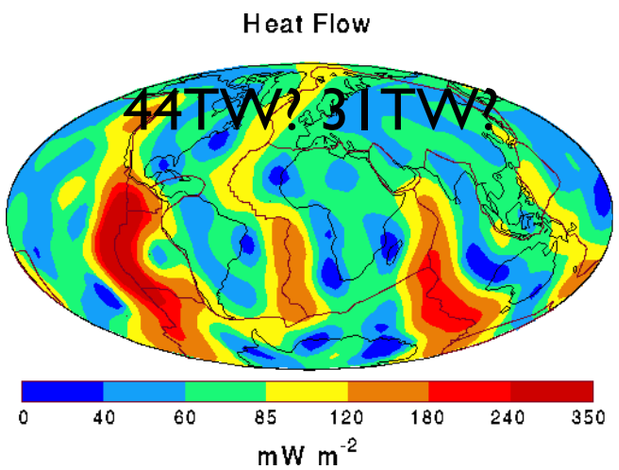
mechanism of terrestrial magnetism



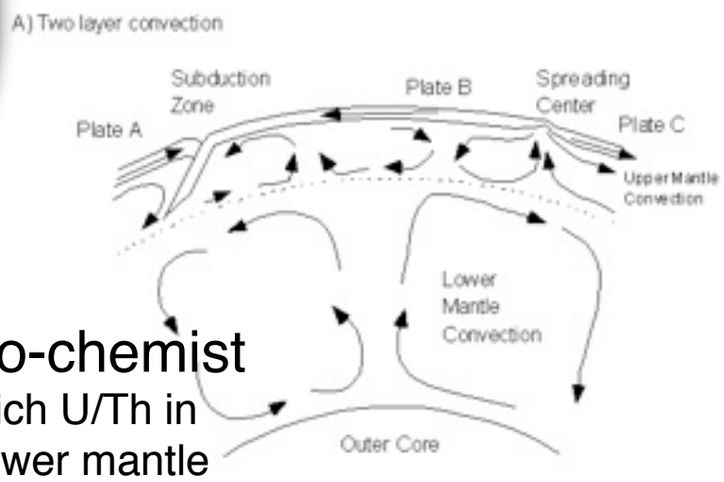
earth dynamics





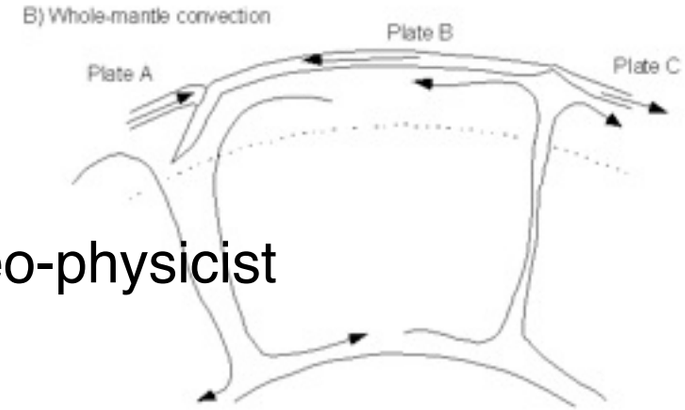


toward long-standing argument



geo-chemist

rich U/Th in lower mantle



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$$^{238}\mathrm{U} \rightarrow ^{206}\mathrm{Pb} + 8\,^{4}\mathrm{He} + 6\mathrm{e}^{-} + 6\bar{\nu}_{\mathrm{e}} + 51.7\,\mathrm{MeV}$$

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total 19TW?

Geo-neutrino brings information on heat generation and chemical composition from the interior of the earth.

target 2

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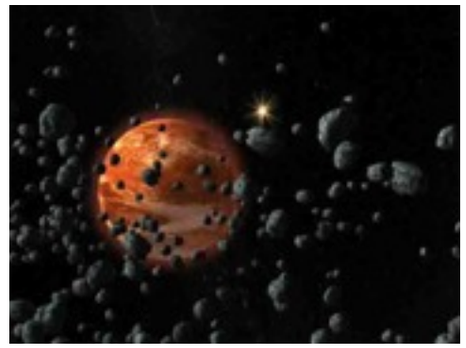

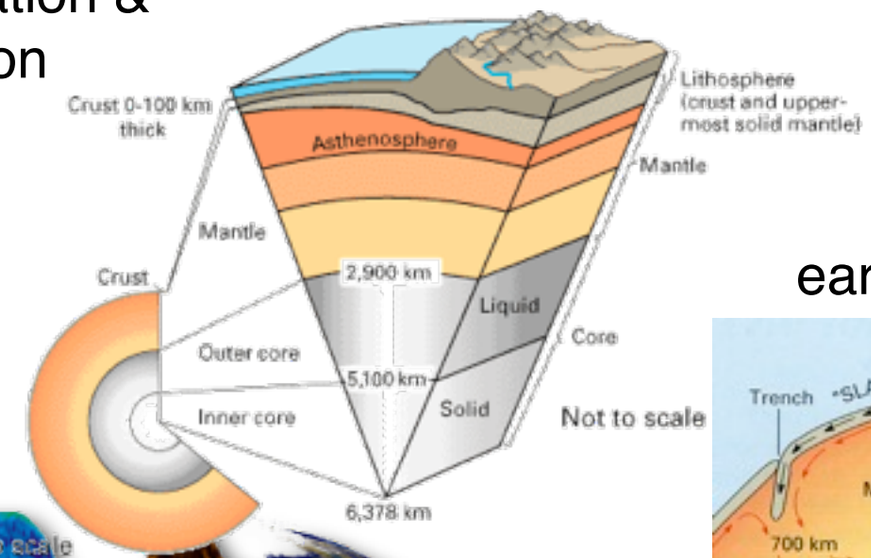

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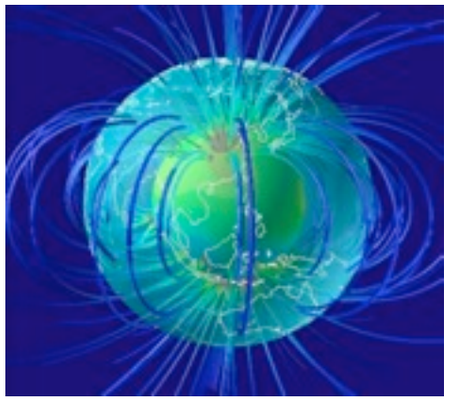

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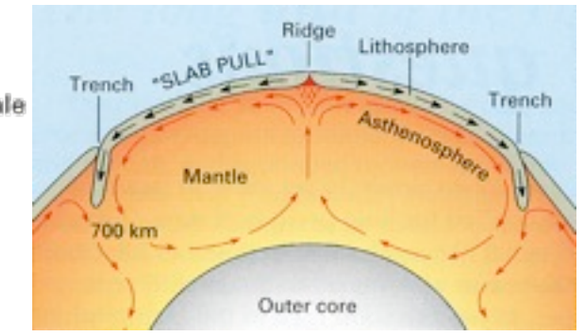
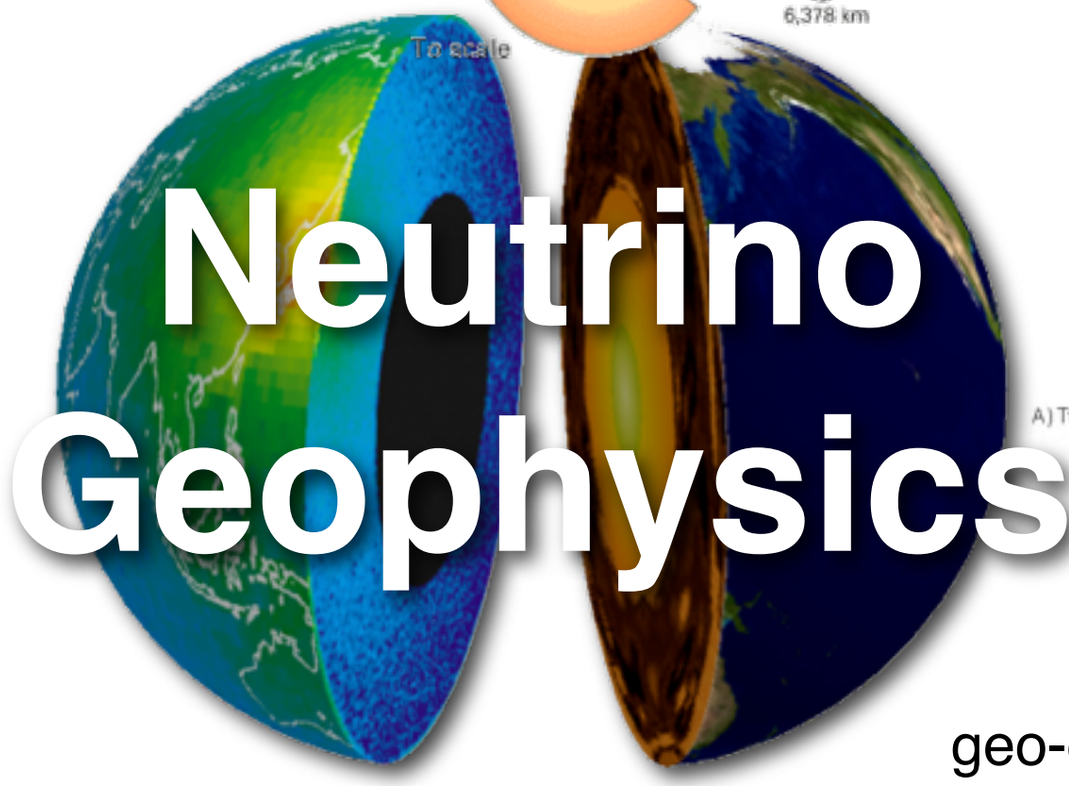
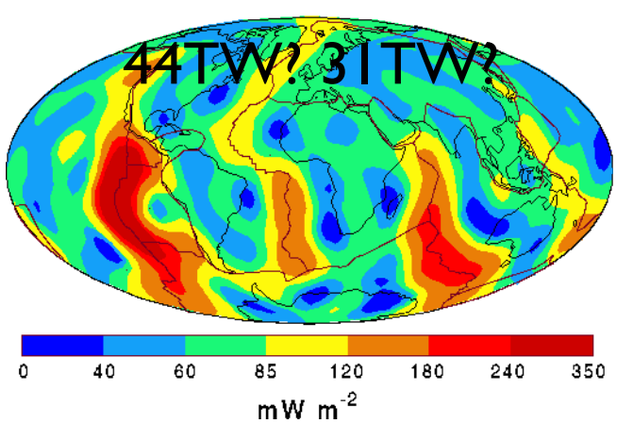




Neutrino Geophysics

Heat Flow



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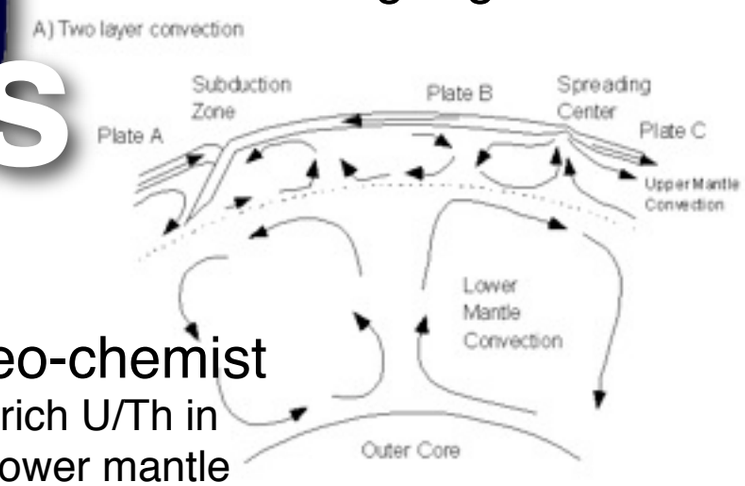

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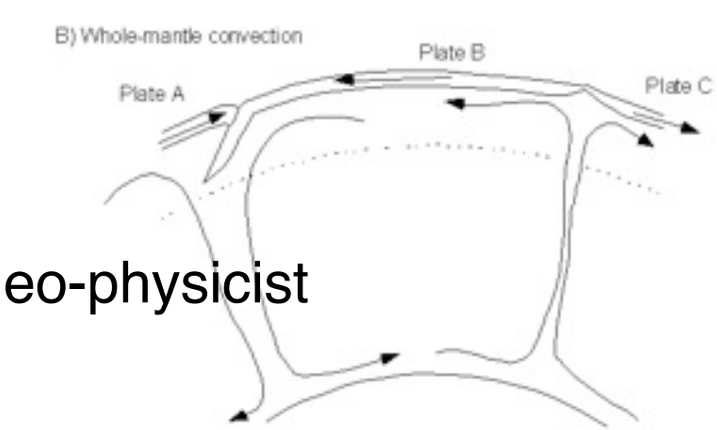

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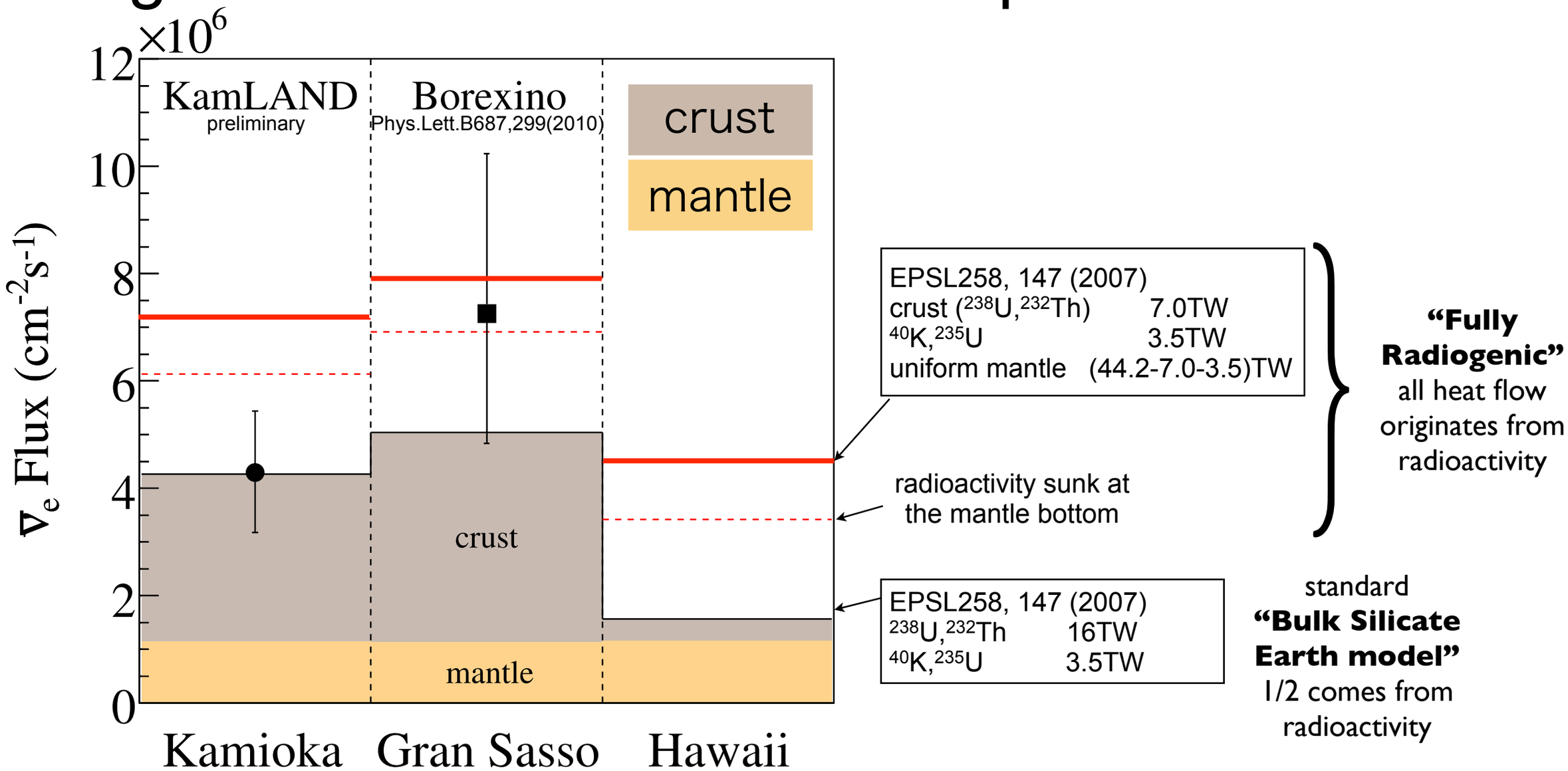
Testing models of the Earth's composition

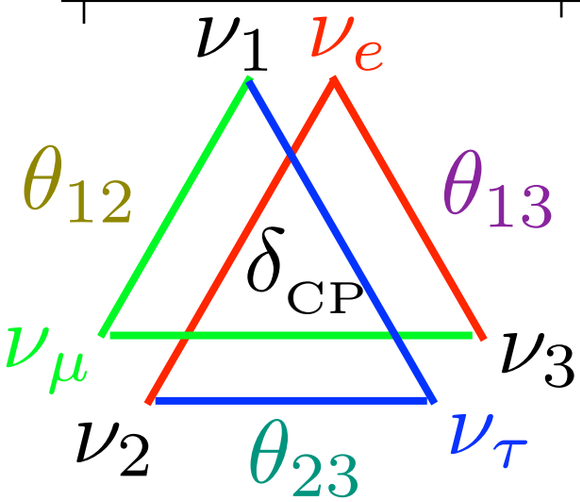


KamLAND pioneered "Neutrino Geophysics" and testing models of the Earth's composition has become possible. For the first time, fully radiogenic model (uniform mantle) was excluded at 2.4σ level. The KamLAND result agrees well with the standard BSE model.

From a geophysical point of view, extracting the mantle contribution is very important.
In the future, the combination of data from multiple sites and possible data from an oceanic experiment (where the crust is much thinner and so its contribution much smaller) will provide stronger constraints.

new target

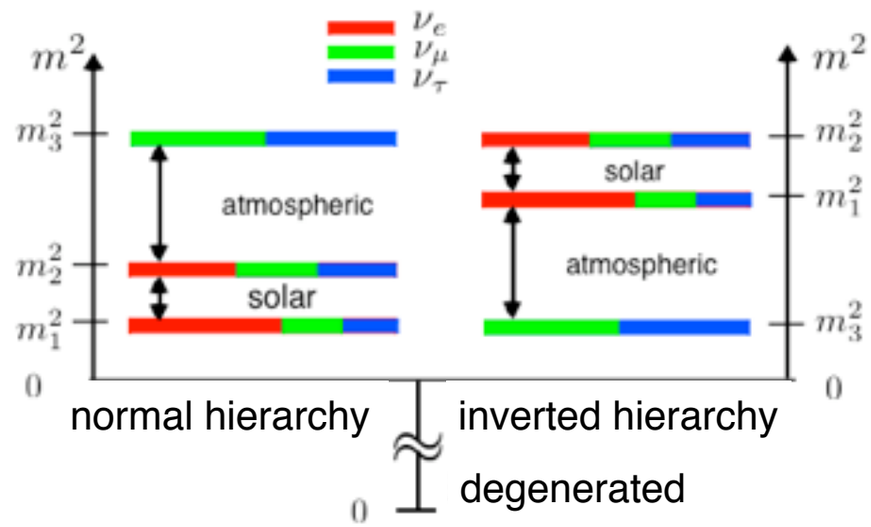
mixing angle



neutrino oscillation

great contribution of KamLAND

mass



squared-mass difference

absolute mass

beta decay

current sensitivity 2eV

planned sensitivity 0.2eV

less sensitive

cosmology

current 0.2~0.7eV

planned 0.05eV

indirect measurement

Majorana nature

$$\nu \stackrel{?}{=} \bar{\nu}$$

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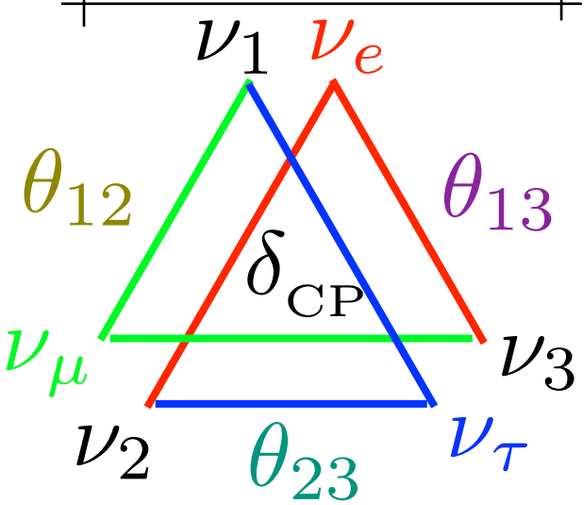

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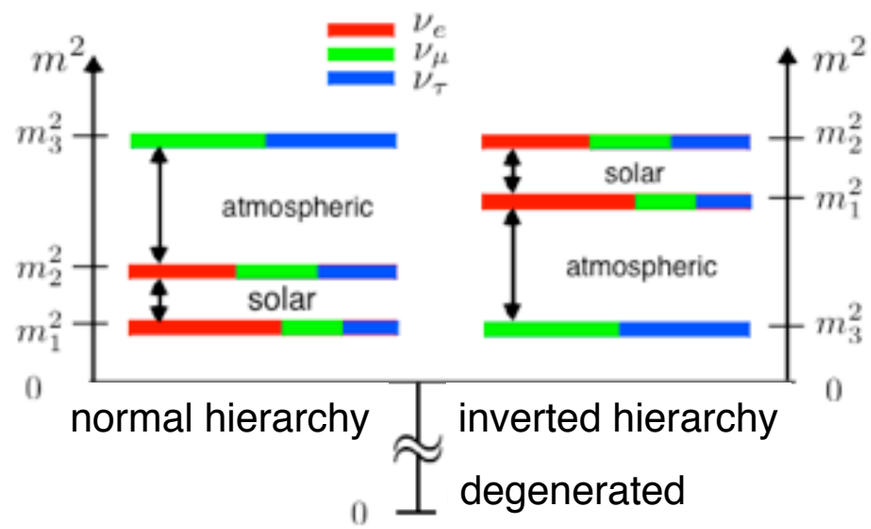

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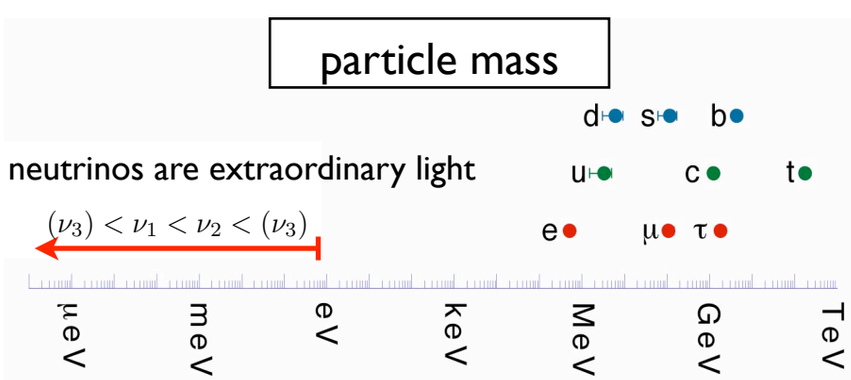
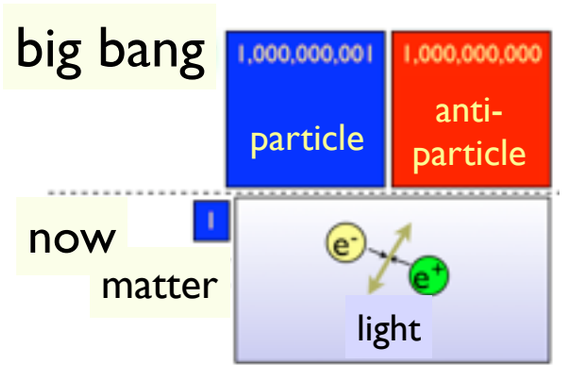


Why light?
(seesaw mechanism)

GUT?

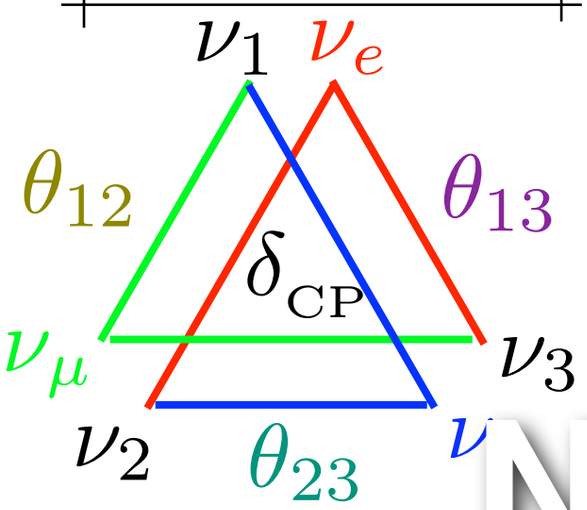
big bang



Why matter dominates?
(Leptogenesis theory)

new target

mixing angle



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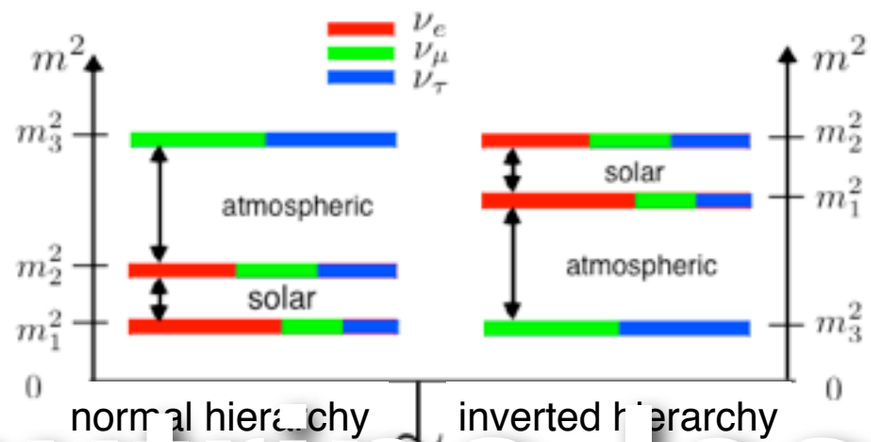

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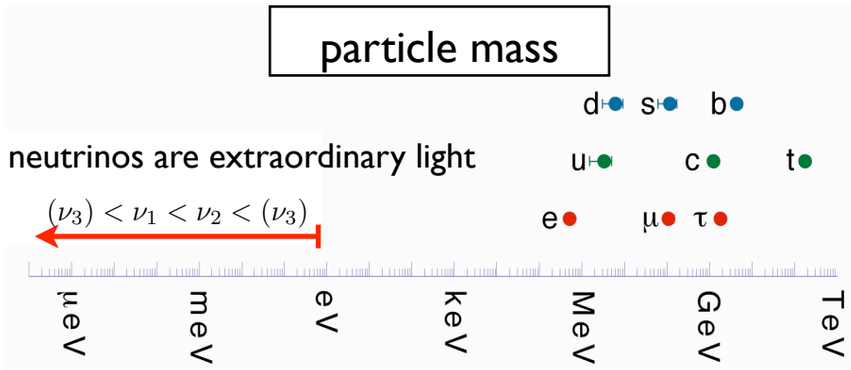

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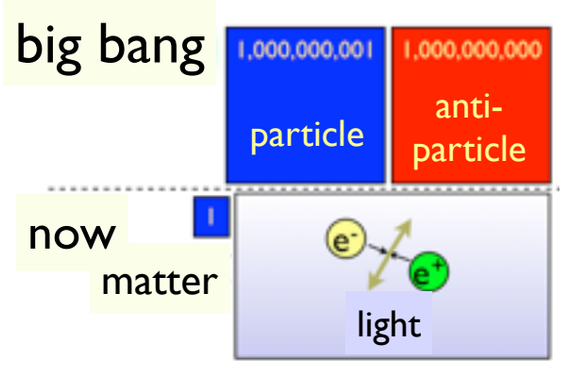

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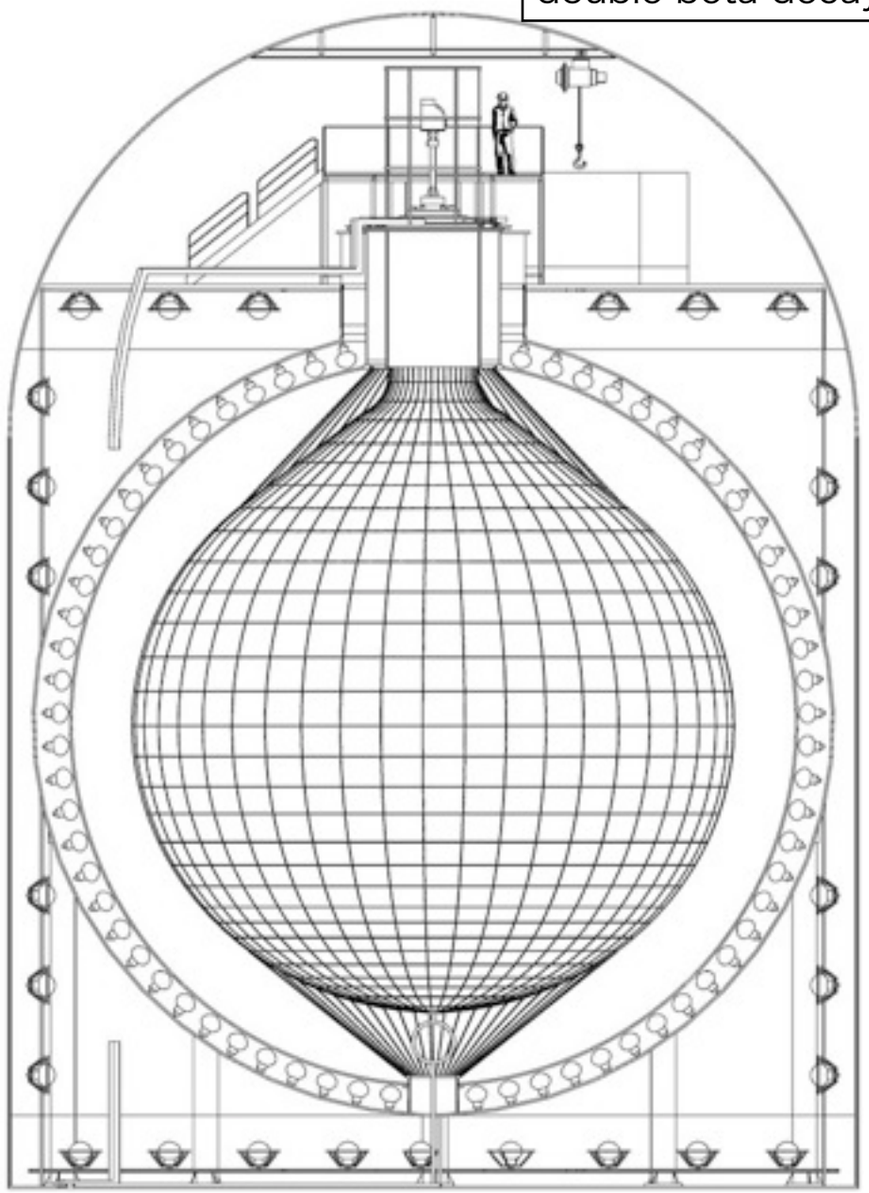
KamLAND-Zen

Zero Neutrino
double beta decay search



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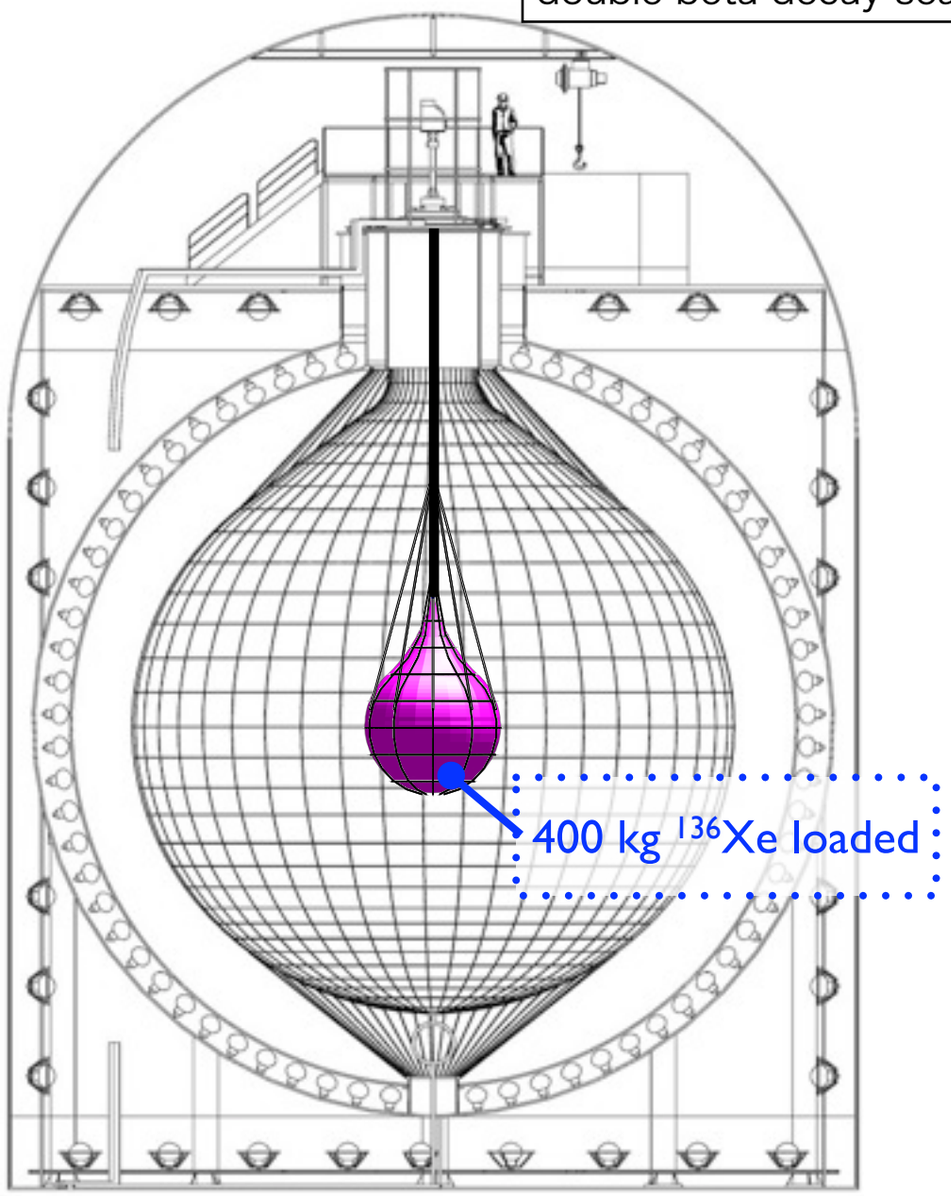

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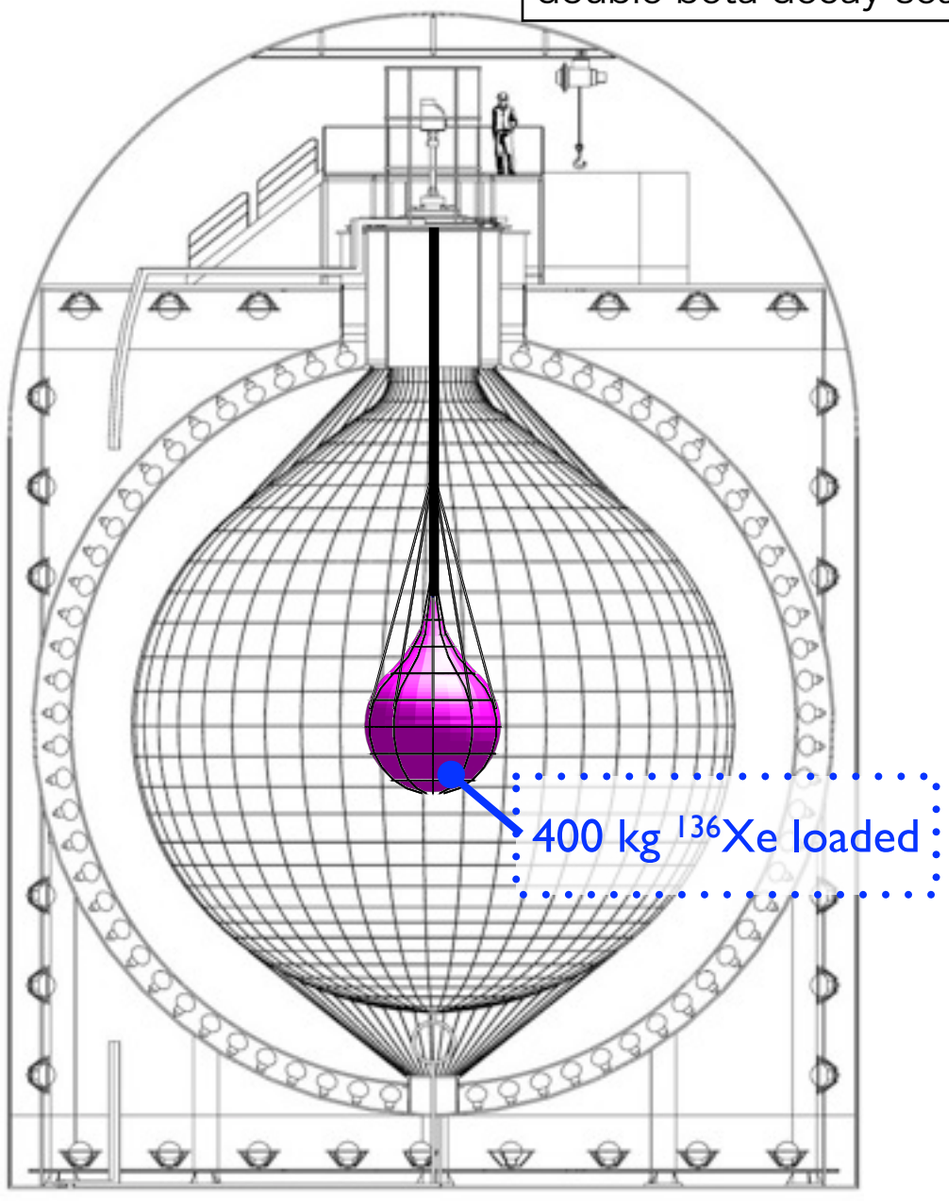
Zero Neutrino
double beta decay search

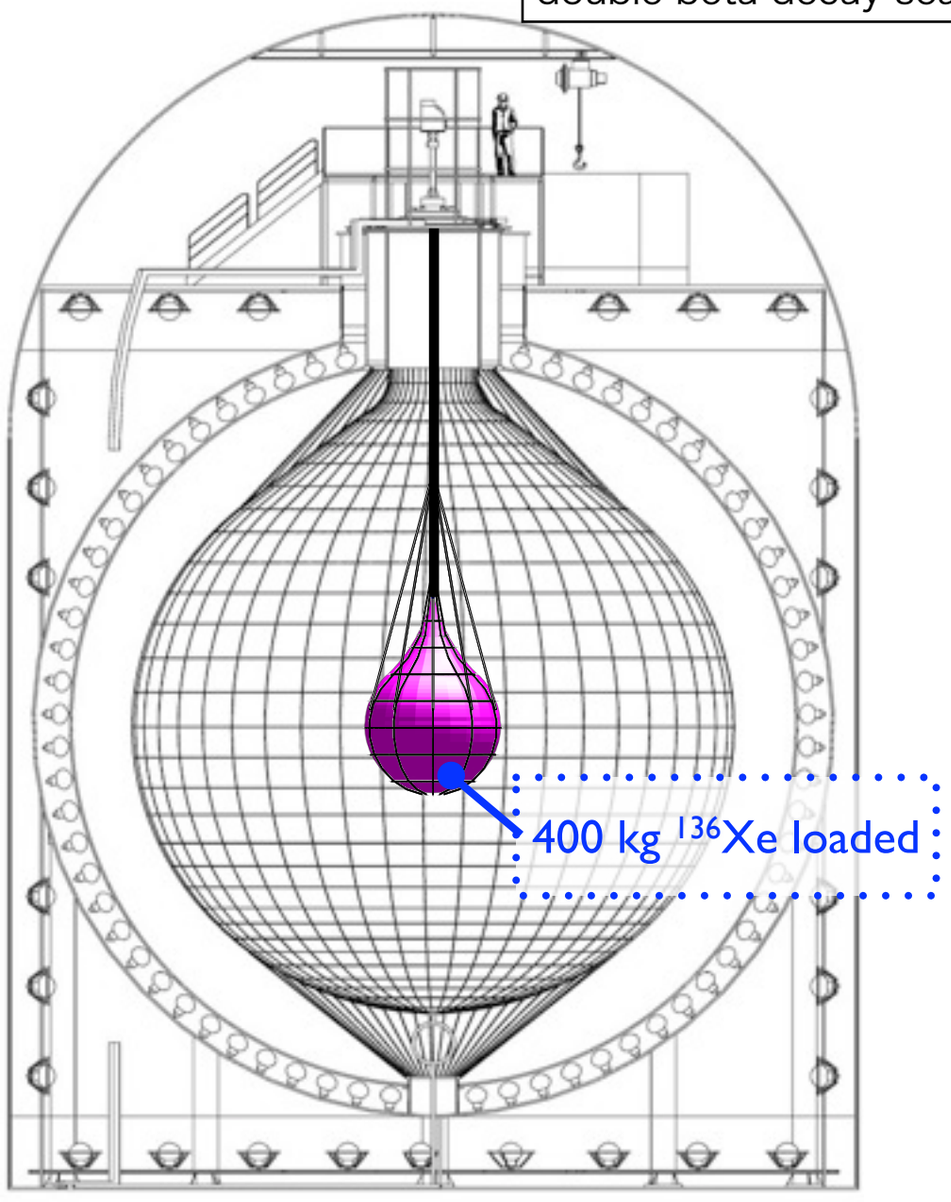


Merit of using Xe

- isotopic enrichment, purification established
- soluble to LS more than 3 wt%, easily extracted
- slow 2ν2β ($T_{1/2}$>10^{22} years) requires modest energy resolution

KamLAND-Zen

Zero Neutrino
double beta decay search



Merit of using KamLAND

- ultra low radioactivity environment based on ultra pure LS and 9m radius active shield
  U: <3.5x10^{-18} g/g, Th: <5.2x10^{-17} g/g
- no modification to the detector is necessary
- high sensitivity with low cost (1st phase budget secured, 220 kg in hand, 200kg purchase going on)
  ~60 meV in 2 year
- reactor and geo- antineutrino observations continue
- high scalability (2nd phase)
  1000 kg ^{136}Xe, improvement of energy resolution with light concentrators and brighter LS (~30M$)
  ~20 meV in 5 years

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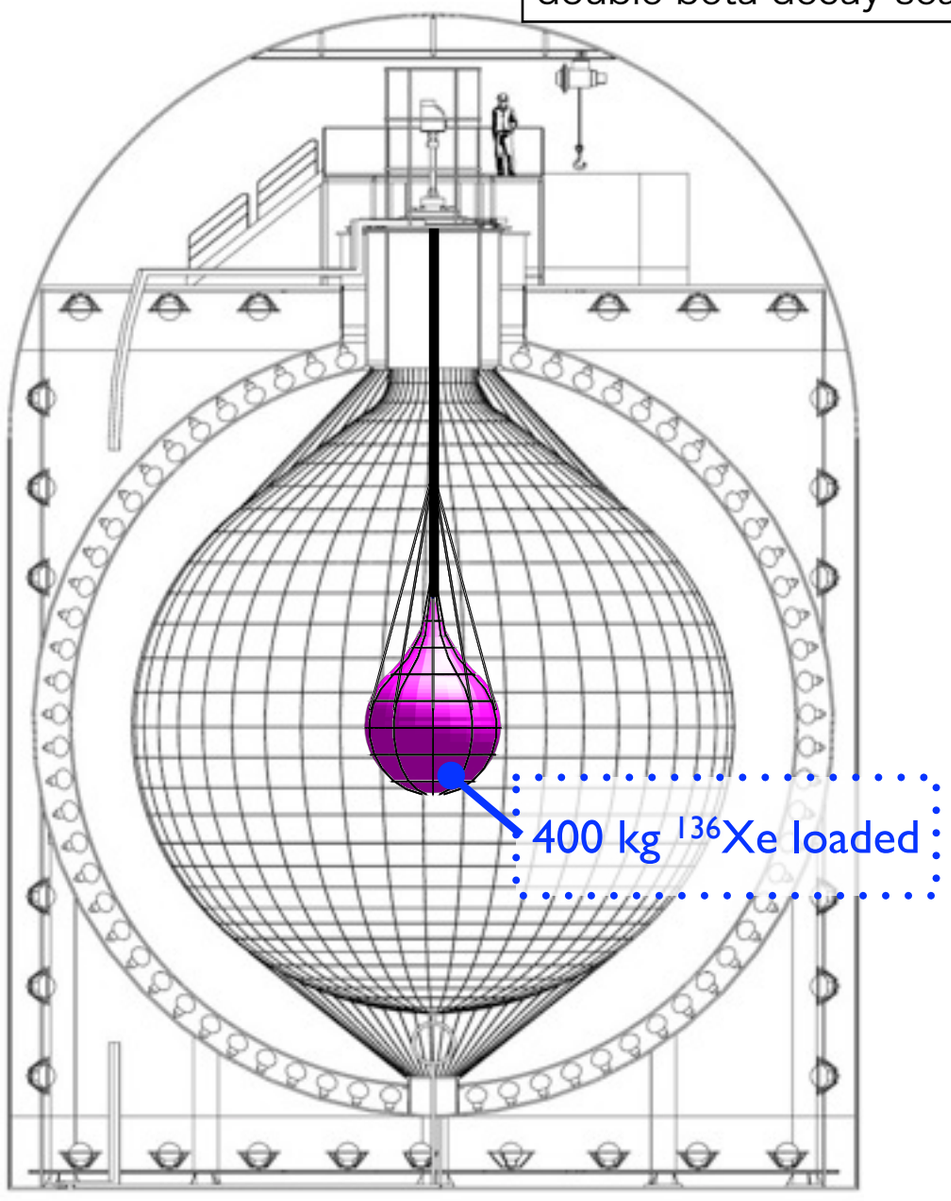
KamLAND-Zen

Zero Neutrino
double beta decay search



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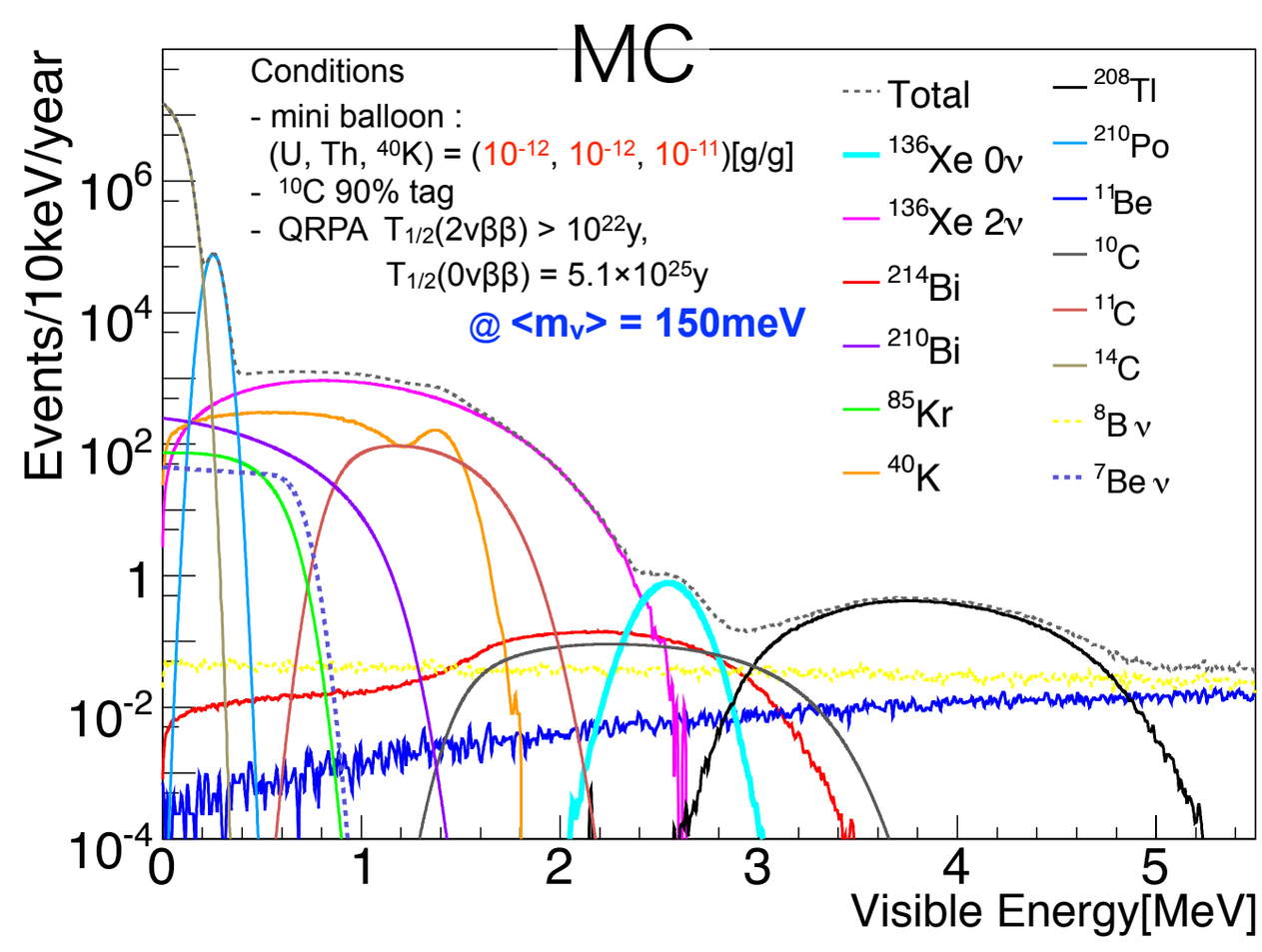
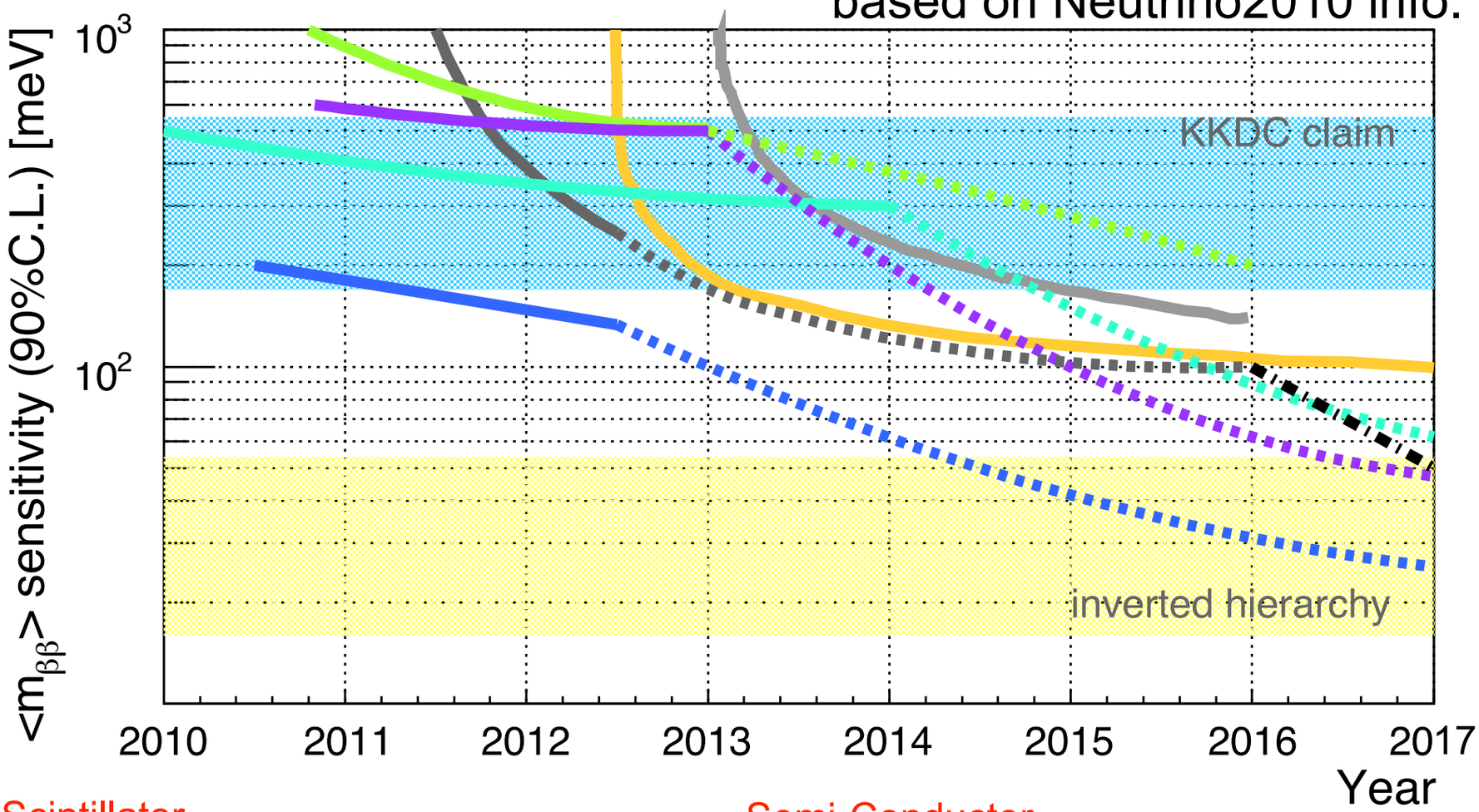
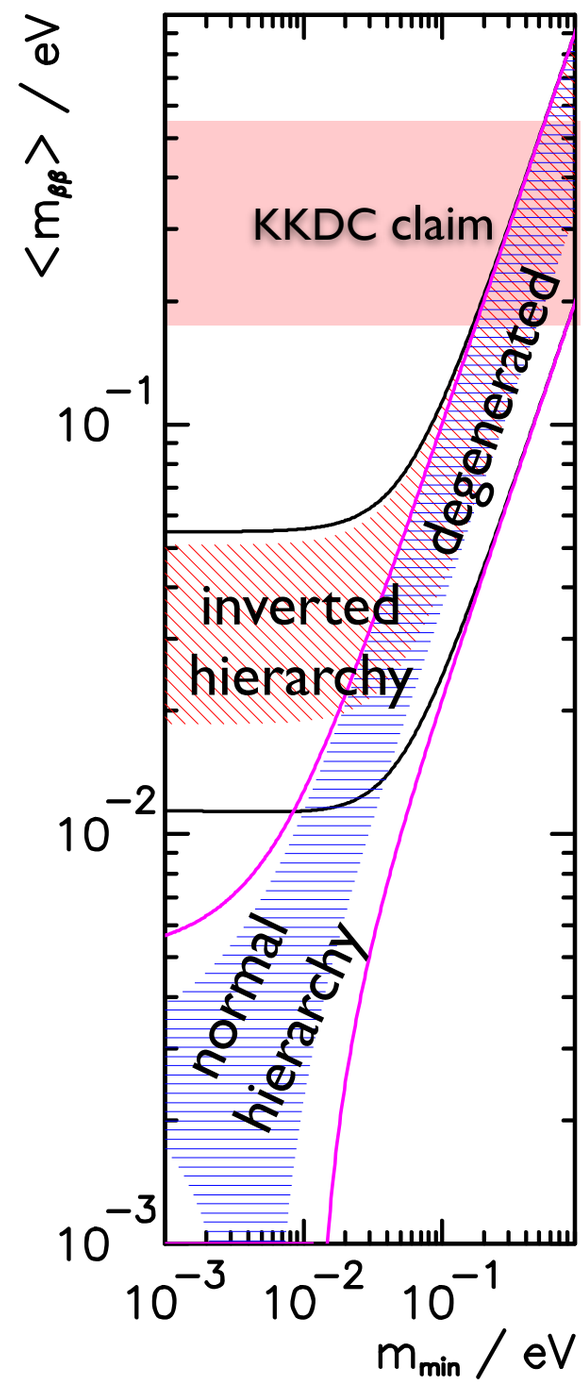


KamLAND-Zen starts in 2011

based on Neutrino2010 info.





Scintillator

- KamLAND (^{136}Xe, 400kg)
- KamLAND (^{136}Xe, 1000kg)
- SNO+ (^{150}Nd), 56kg
- CANDLES III (^{48}Ca 300g)
- CANDLES IV (^{48}Ca 3kg)

Tracking

- NEMO-3 (^{100}Mo 7kg)
- SuperNEMO (^{150}Nd or ^{82}Se 100-200)

Semi-Conductor

- MAJORANA (^{76}Ge), 30-60kg
- GERDA phaseI(^{76}Ge:17.66kg)
- GERDA phaseII(^{76}Ge:37.5kg)
- GERDA phaseIII + MAJORANA(^{76}Ge:~80kg)

Bolometer

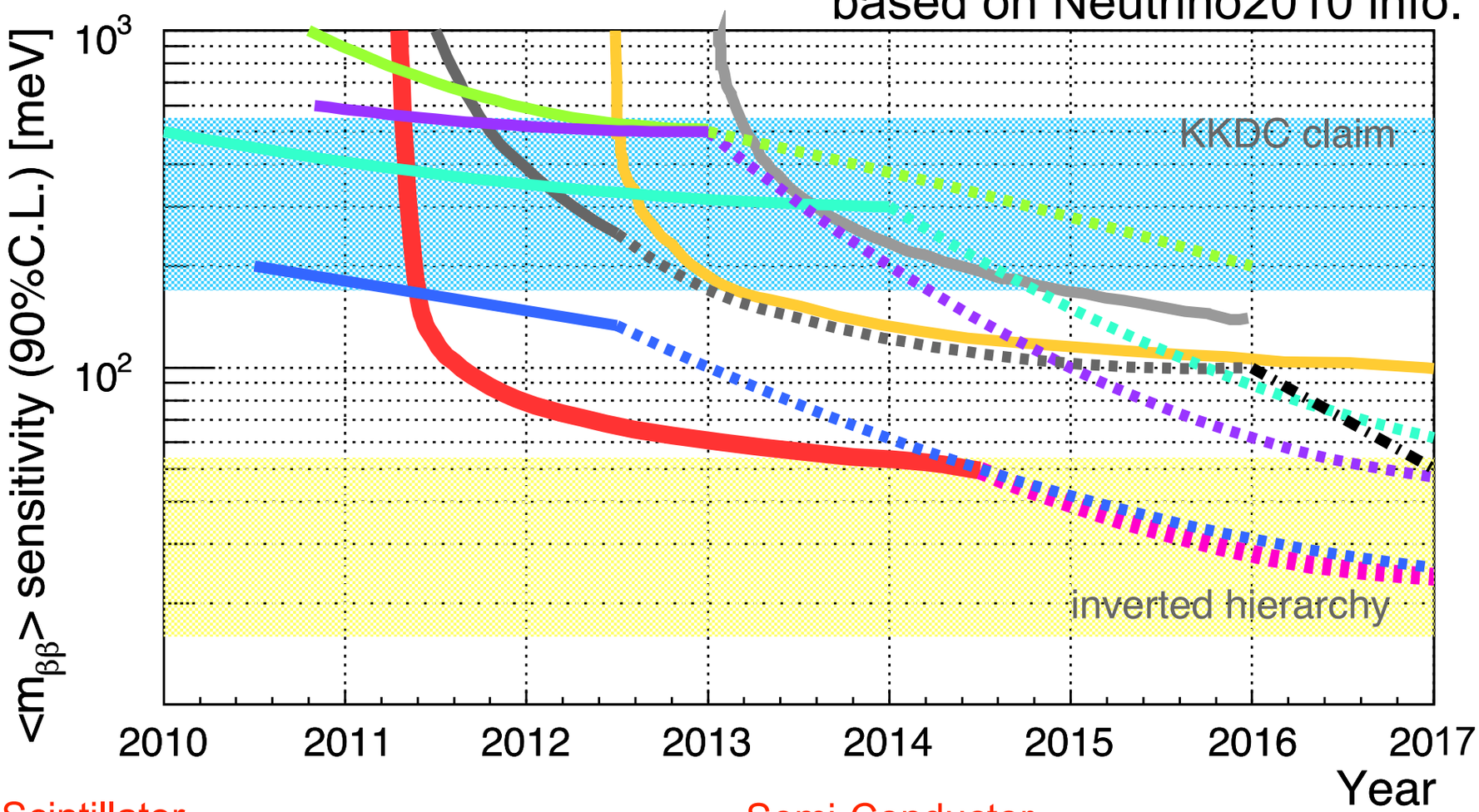
- CUORE-0 (^{130}Te ~10kg)
- CUORE (^{130}Te 204kg)

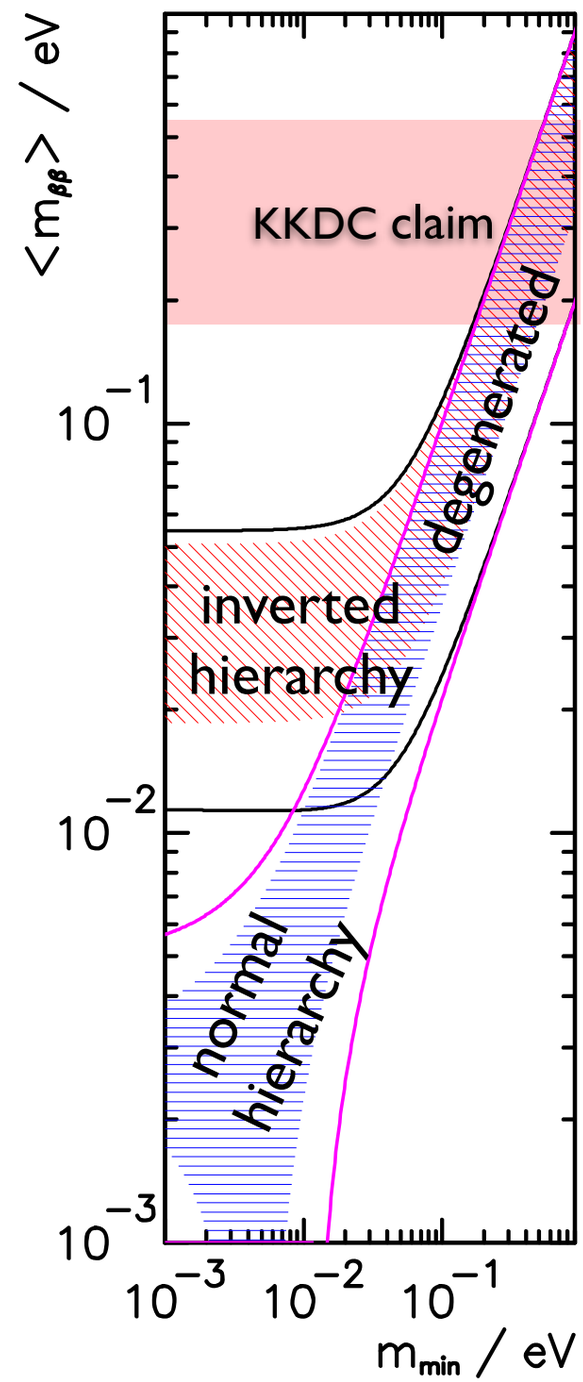
Liquid TPC

- EXO-200 (^{136}Xe 200kg)
- EXO (^{136}Xe 1t)

KamLAND-Zen starts in 2011

based on Neutrino2010 info.





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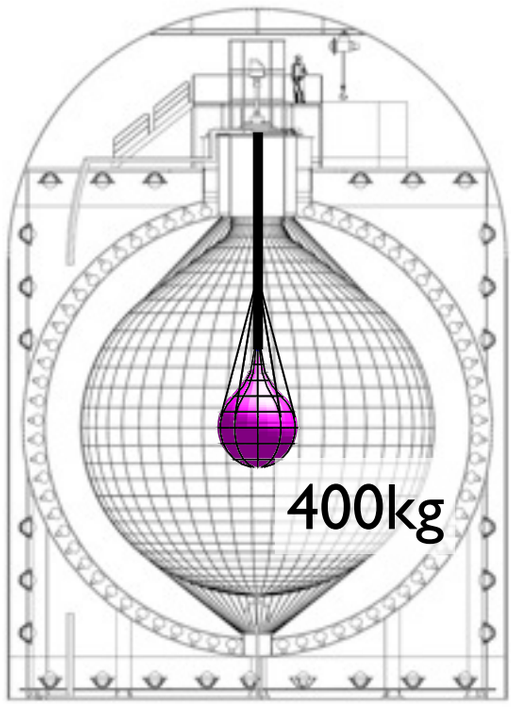
KamLAND-Zen future prospects

KamLAND-Zen



2011~

covers degenerated ~60meV

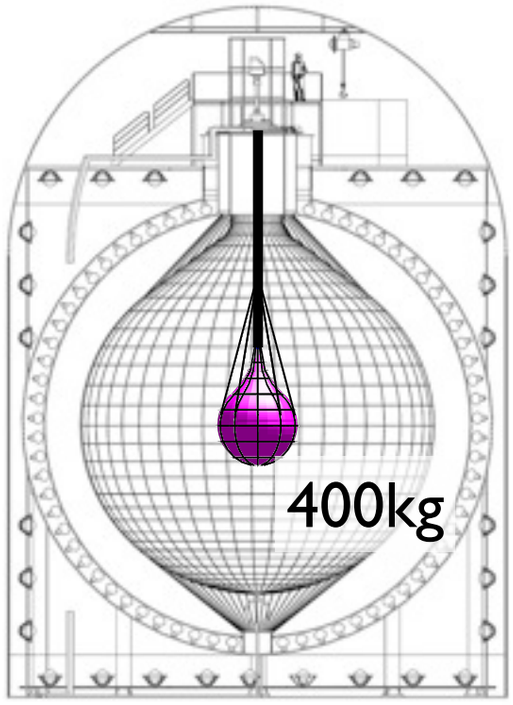
forthcoming

partially funded

dream

KamLAND-Zen future prospects

KamLAND-Zen



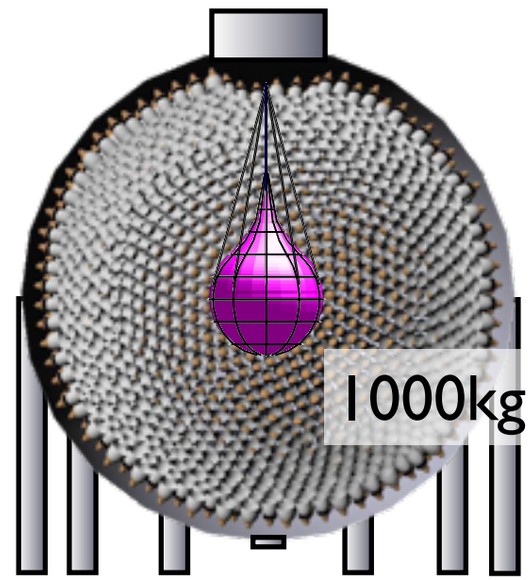
2011~

covers degenerated

~60meV

forthcoming

KamLAND2-Zen



2014~?

covers inverted hierarchy

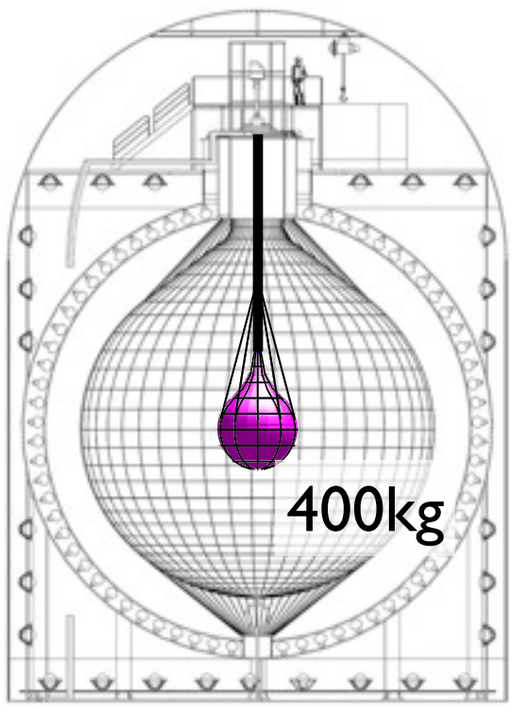
~20meV

light-concentrator
& brighter LS

dream

KamLAND-Zen future prospects

KamLAND-Zen



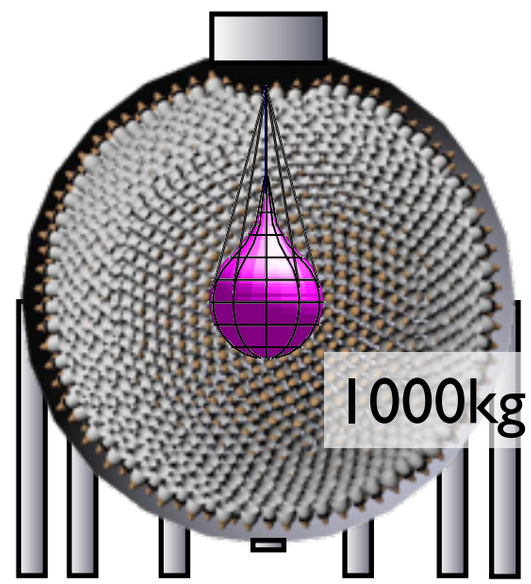
2011~

covers degenerated

~60meV

forthcoming

KamLAND2-Zen



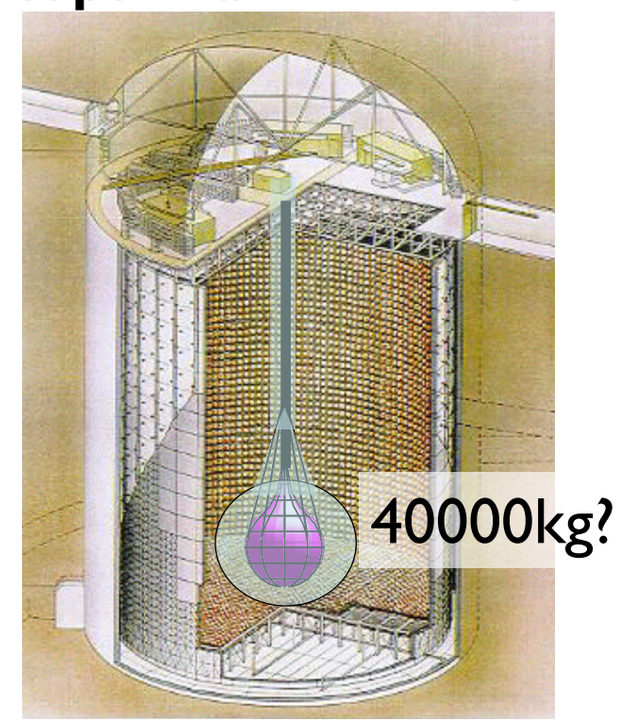
2014~?

covers inverted hierarchy

~20meV

light-concentrator
& brighter LS

Super-KamLAND-Zen



2020~??

reaches normal hierarchy

~8meV

high pressure Xe
imaging device w/ ~1% coverage

KamLAND US-Japan collaboration

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(Dated: September 27, 2010)

65 members in 2010

KamLAND-Zen US-Japan collaboration

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35 members for the moment