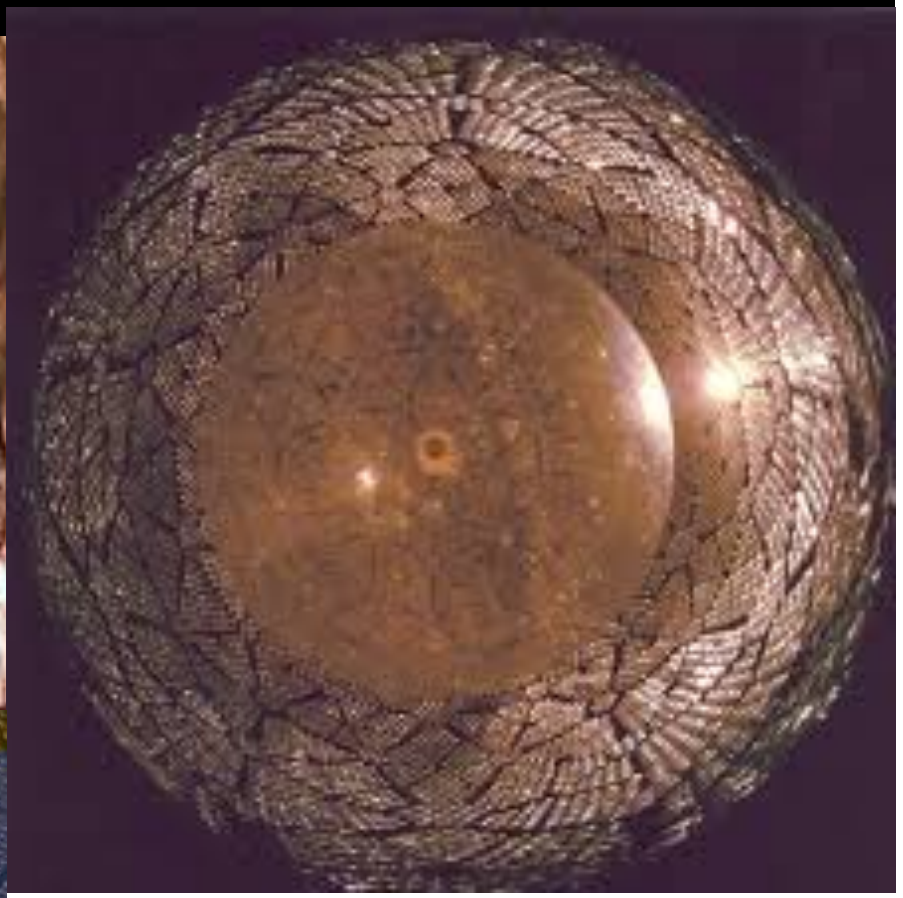
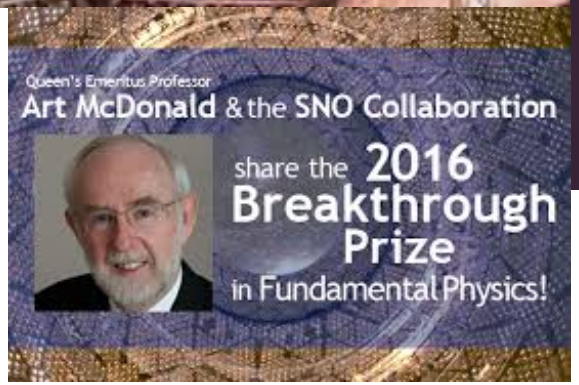
IOP HEPP Conference 2016, Sussex

Neutrinoless double beta decay at SNO+

Building on the success of SNO







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Lawrence Berkeley National Laboratory
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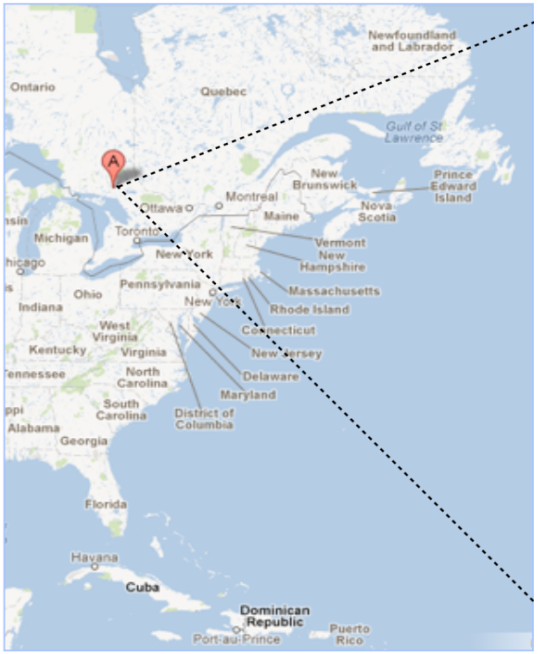
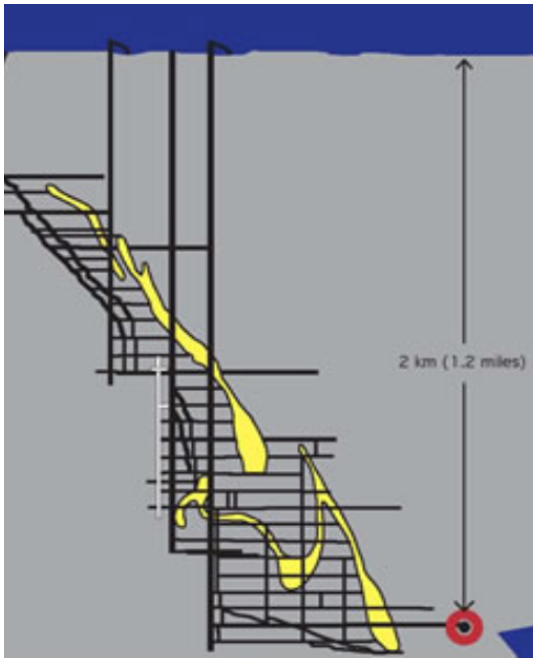
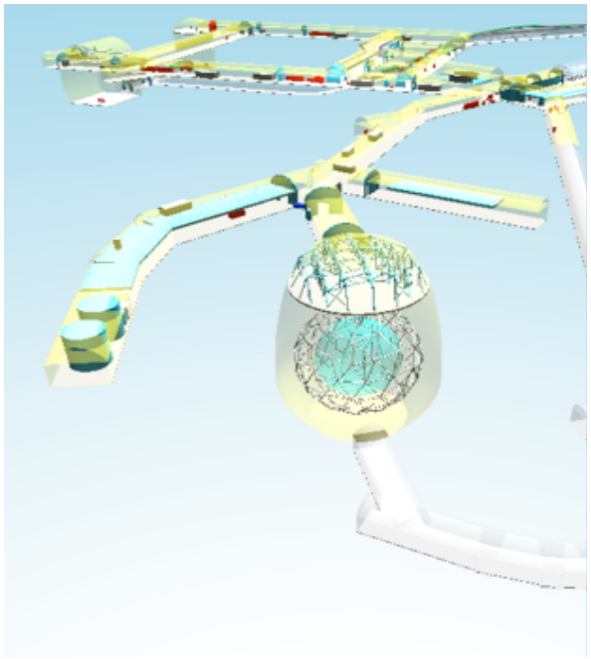
SNOLAB and SNO+







- Depth = 2070 m (6000 m w.e.)
- ~70 muons / day in SNO+
- 10,000 sq ft Class-2000 clean room

Located a SNOLAB inside the Creighton mine near Sudbury, Canada, SNO+ is the successor to Sudbury Neutrino Observatory (SNO)

From SNO to SNO+

SNO

- Investigate the solar neutrino problem.
- Why do we observe ~1/3 less ν_e than predicted?

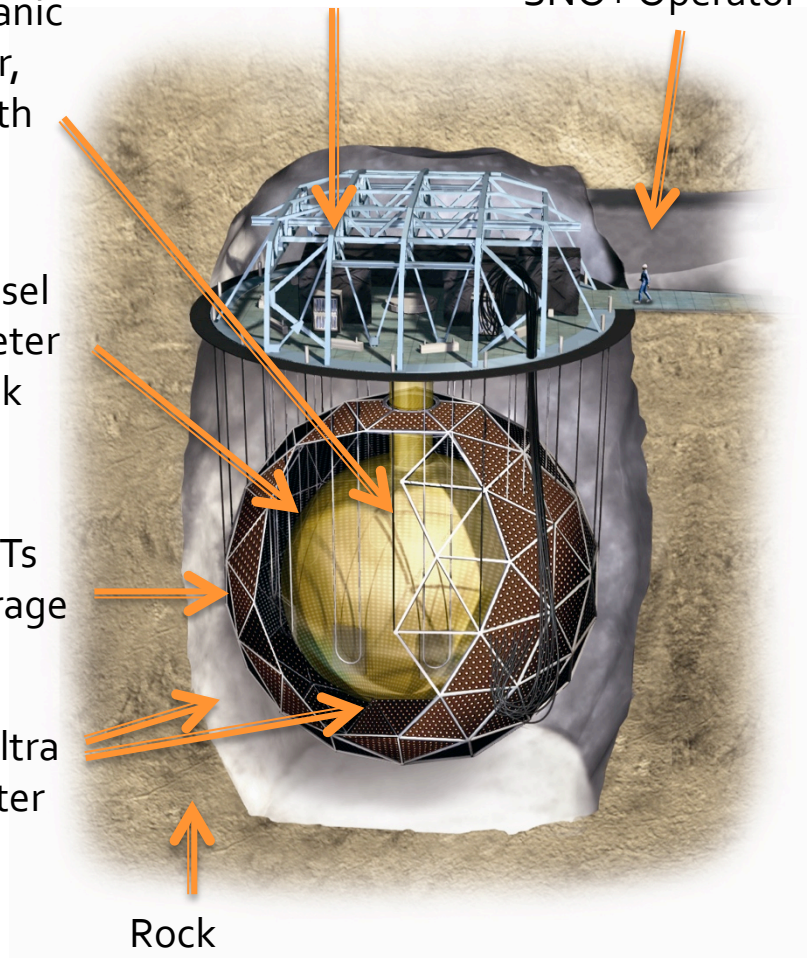
Answer:

- Neutrinos change flavour!
  (DOI: 10.1103/PhysRevC.88.025501)
- They must have mass….

SNO(+)

- Neutrinoless double beta decay.
  Is the neutrino a Majorana particle?
  (i.e. Are neutrinos and anti-neutrinos the same particle?)
- Further neutrino physics:
  - Solar (pep & CNO)
  - Geo
  - Reactor
  - Supernova
- Other physics
  - Nucleon decay
  - ALP search

SNO+ Detector

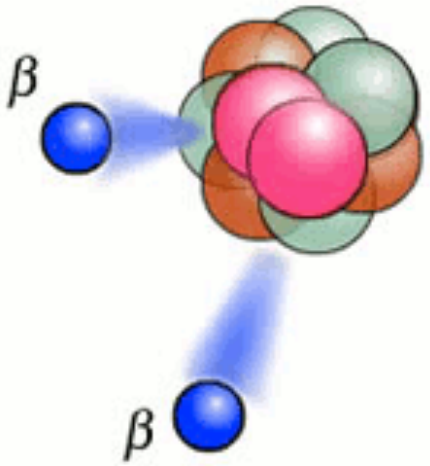


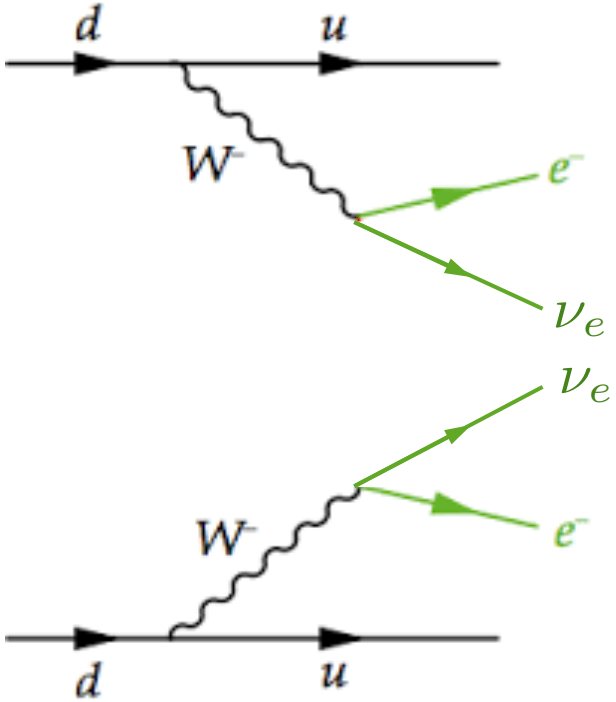
SNO+ upgrades the existing SNO detector to make a multi-purpose scintillator experiment.

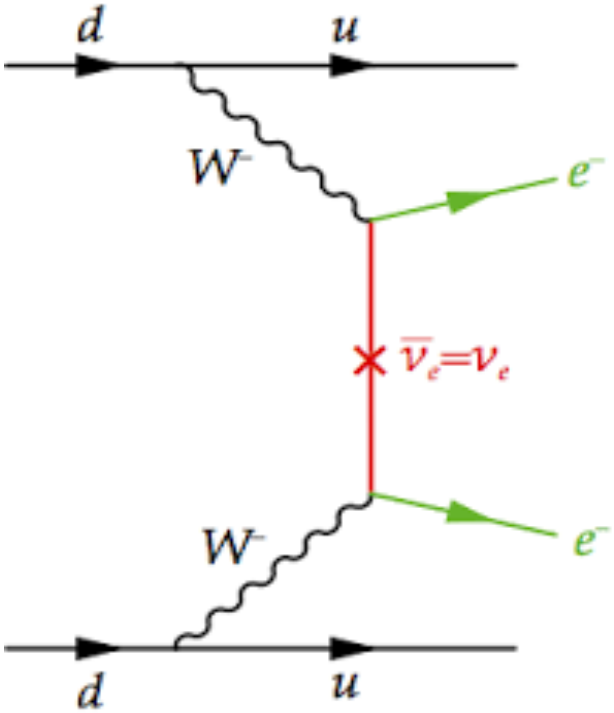
- Replace heavy water with Liquid scintillator (LAB)
- Upgrade trigger and electronics to handle order of magnitude increase in event rate
- Load scintillator mixture with ^{nat}Te ~34% of which is ^{130}Te, a known double beta decay isotope
  - Phase 1: 0.5% ^{nat}Te Loading
  - Phase 2: 3-5% ^{nat}Te loading (planned)

Neutrinoless double beta decay ($0\nu\beta\beta$)

Neutrinoless double beta decay (ovββ)



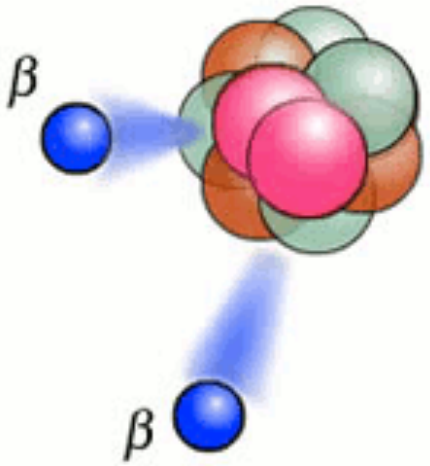


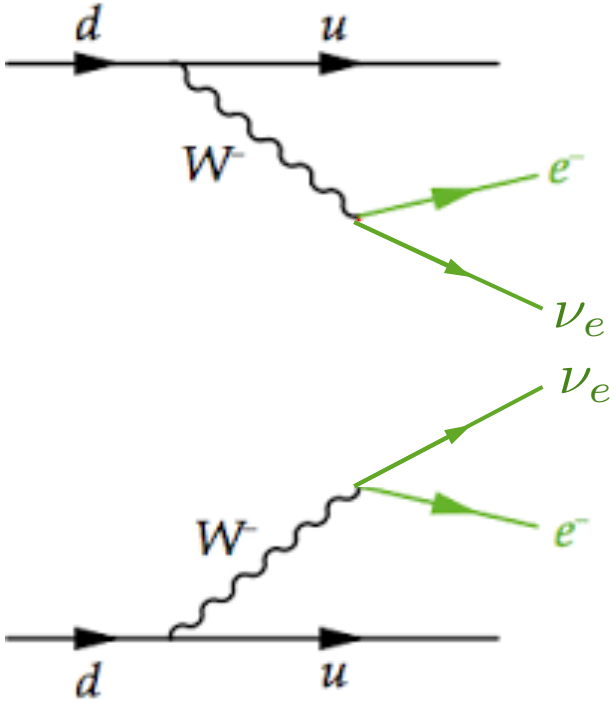


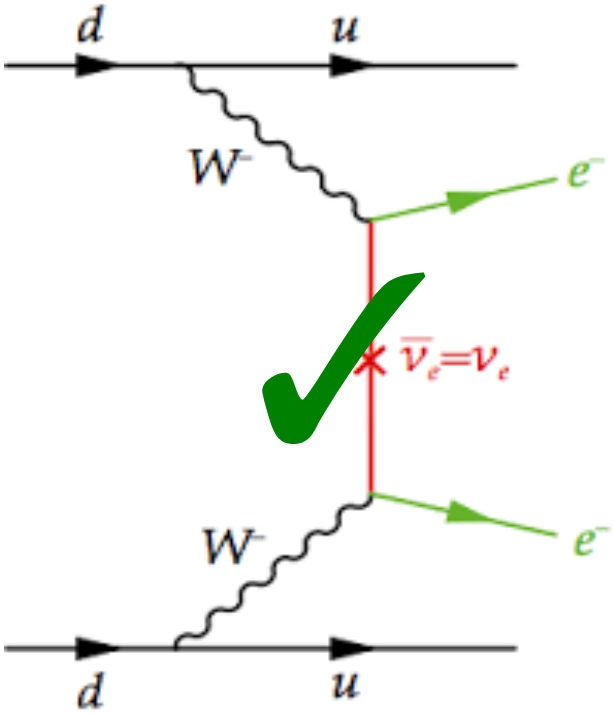
Answers to the questions:

- Lepton number violation?
- Dirac or Majorana ?
- Normal or inverted hierarchy?

Neutrinoless double beta decay (ovββ)







If we see it:

- **Lepton number violation?**
- **Dirac or Majorana ?**
- **Normal or inverted hierarchy?**

Neutrinoless double beta decay (0νββ)

- Allowed if $\nu = \bar{\nu}$, $m_X > 0$ for any mass eigenstate
- Explicitly violates lepton number conservation
- Rare: $\Gamma = G|M|^2|m_{\beta\beta}|^2, t^{0\nu}_{1/2} > 10^{21} y$
- Signature is a monoenergetic peak at 2nuBB Q-value
- ^{130}Te :
  - $Q_{\beta\beta}$ = 2527.518 ± 0.013 keV

- Dirac or Majorana ?
- Lepton number violation?
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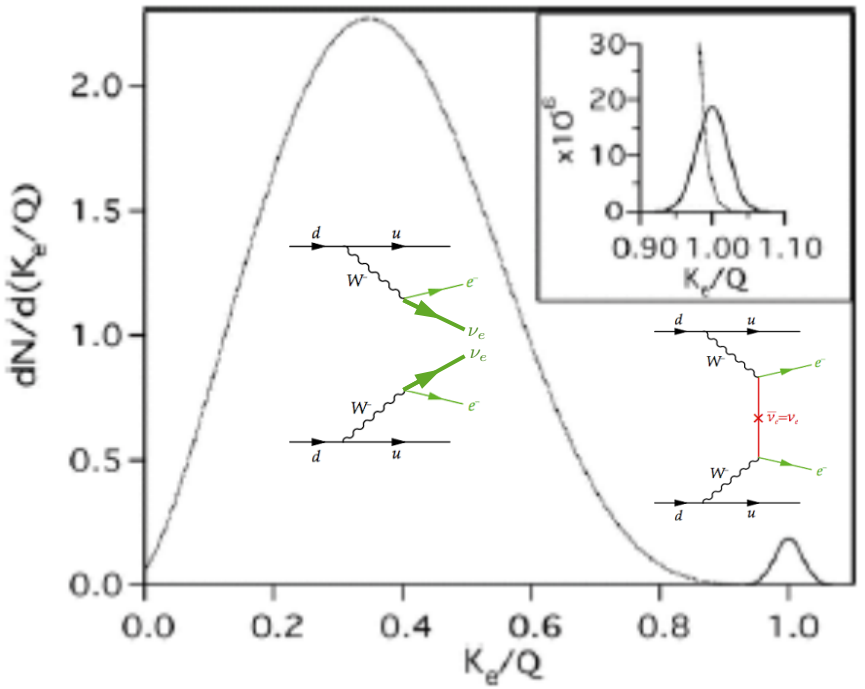

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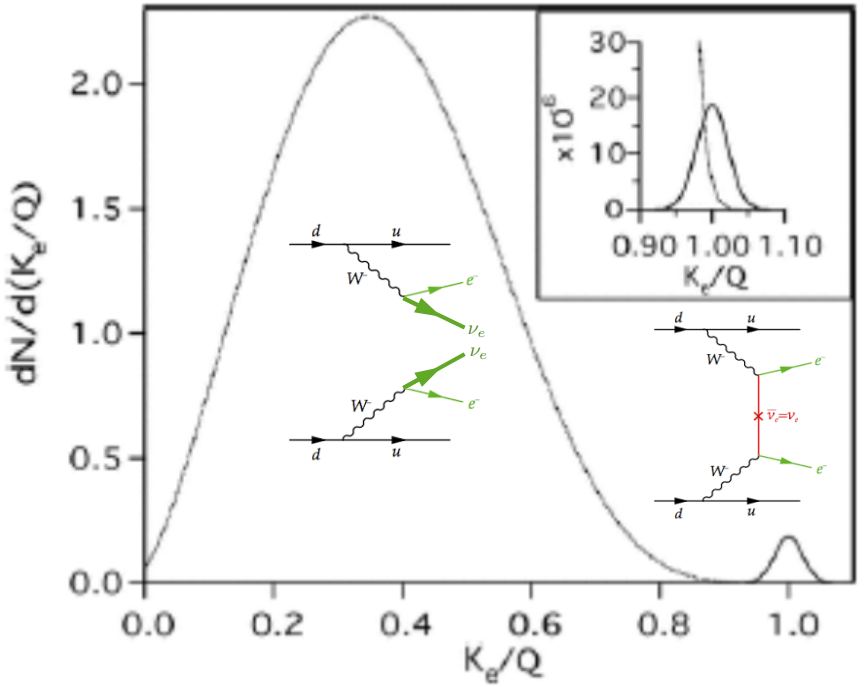

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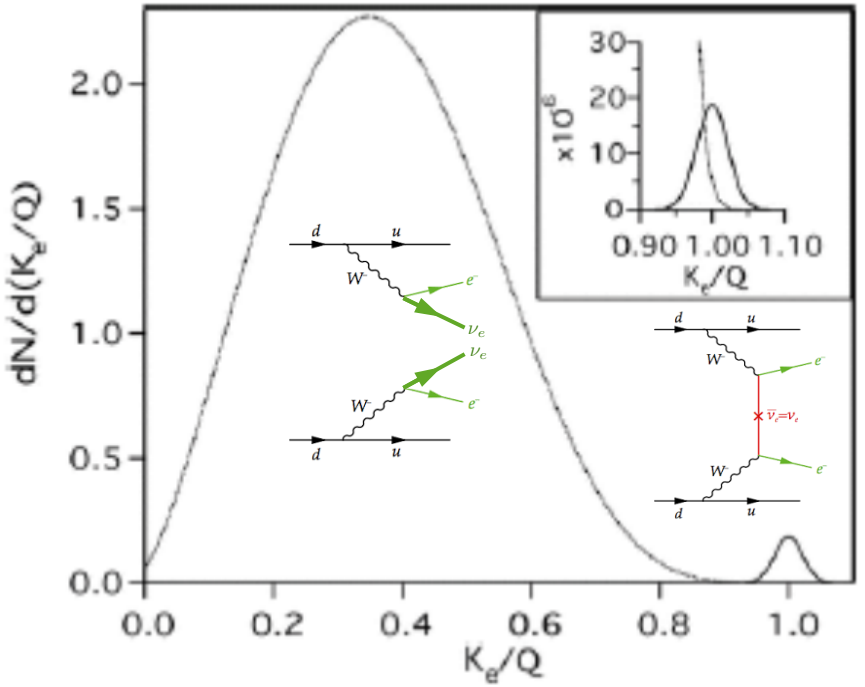

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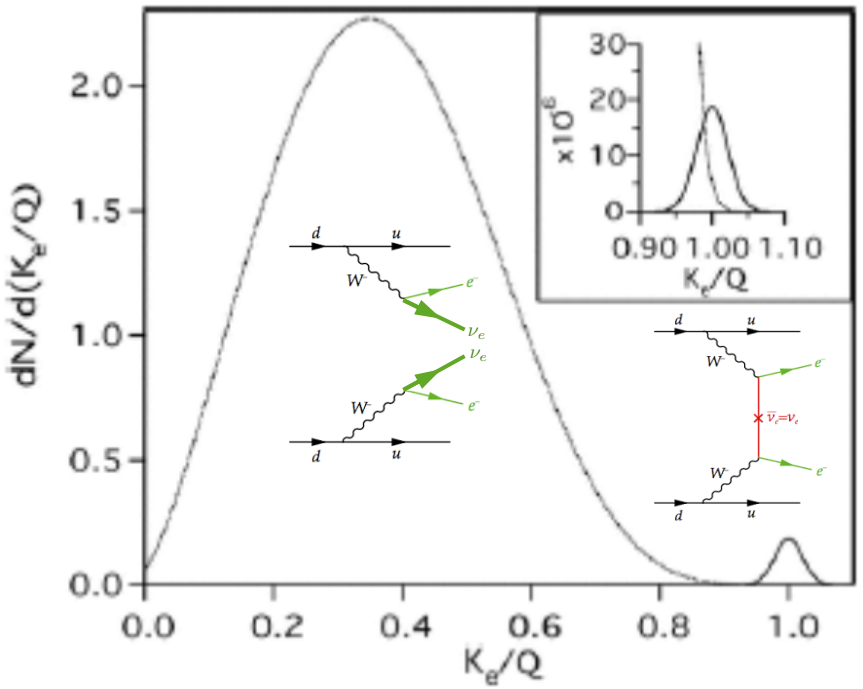
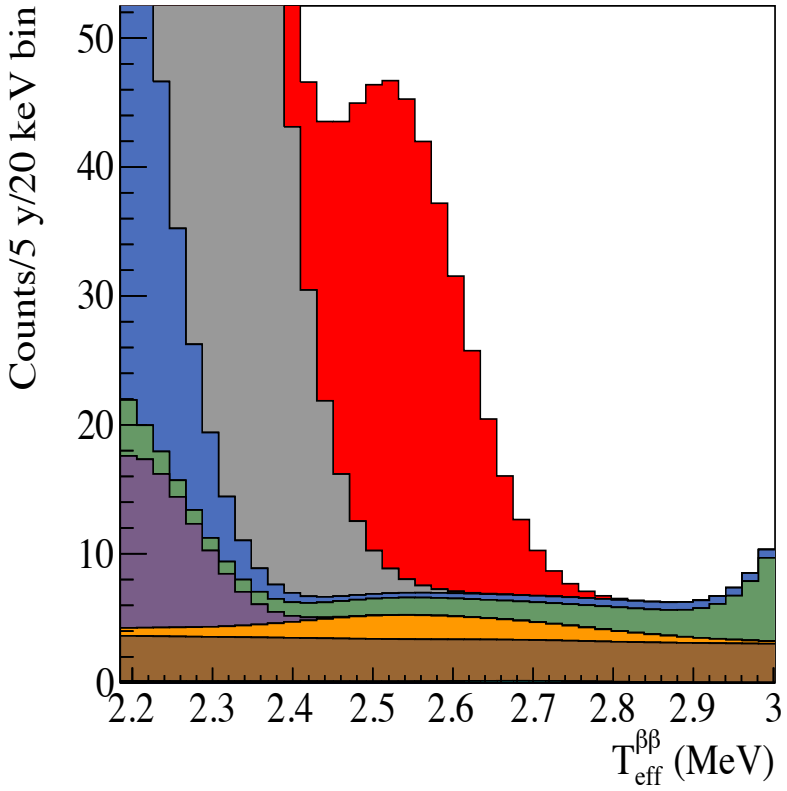


SNO+ : ^{nat}Te loading 0.5 %

5 years



- 0νββ (200 meV)
- 2νββ
- U Chain
- Th Chain
- (α, n)
- External
- ^{8}B ν ES
- Cosmogenic

Assumptions:

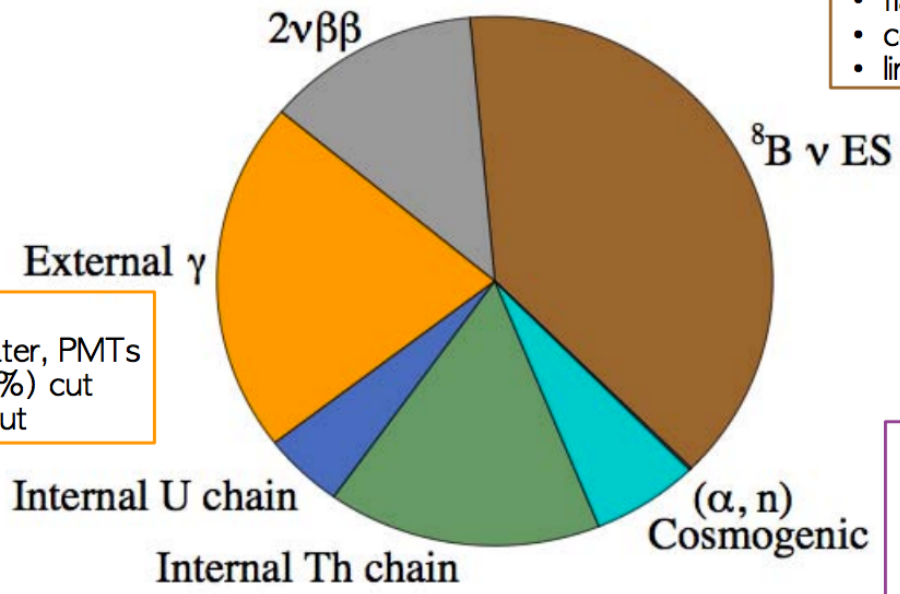
- $M^{0\nu} = 4.03$ (IBM-2)
- $G^{0\nu} = 3.69 \times 10^{-14}$ y^{-1}
- R < 3.5 m (FV = 20%)
- > 99.99% (98%) rejection of ^{214}BiPo (^{212}BiPo)
- Light yield 390 NHits/MeV

	$T_{1/2}$ [yr]	$m_{0\nu\beta\beta}$ [meV]
1 year	8×10^{25}	75.2
5 years	1.96×10^{26}	38 - 92

SNO+ : ^{nat}Te loading 0.5 %

Two neutrino mode 2v$\beta\beta$:
- asymmetric ROI around the 0v$\beta\beta$ signal
- limited by energy resolution

^{8}B solar neutrinos:
- flat spectrum
- constrained by SNO/SK data
- limited by resolution



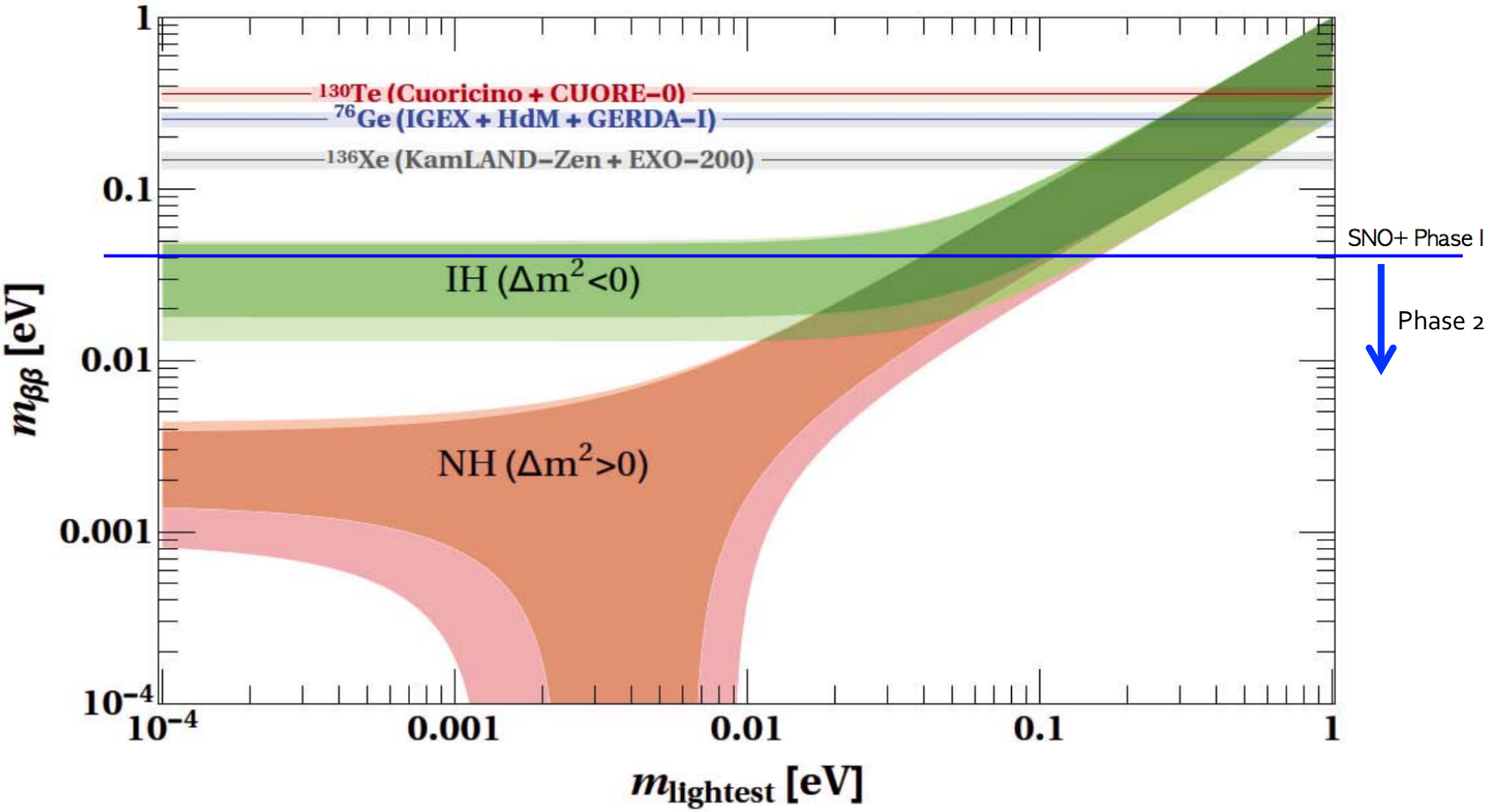
External gammas:
- from AV, ropes, water, PMTs
- fiducial volume (20%) cut
- 50% rejection LH cut

(a,n):
- alpha-capture on ^{13}C/^{18}O
- production of neutrons
- thermal neutron capture
- delayed coincidence tagging

Internal U/Th chain:
- ^{214}BiPo, ^{212}BiPo
- $\beta - \alpha$ delayed coincidence tagging 100% rejection in ROI
- In-window trigger: x50 rejection

Cosmogenic:
- ^{60}Co, ^{110m}Ag, ^{88}Y, ^{22}Na
- mitigation: purification + "cool-down" UG
- aimed: less than 1 ev/yr in ROI/FV

SNO+: ^{nat}Te loading 0.5 %



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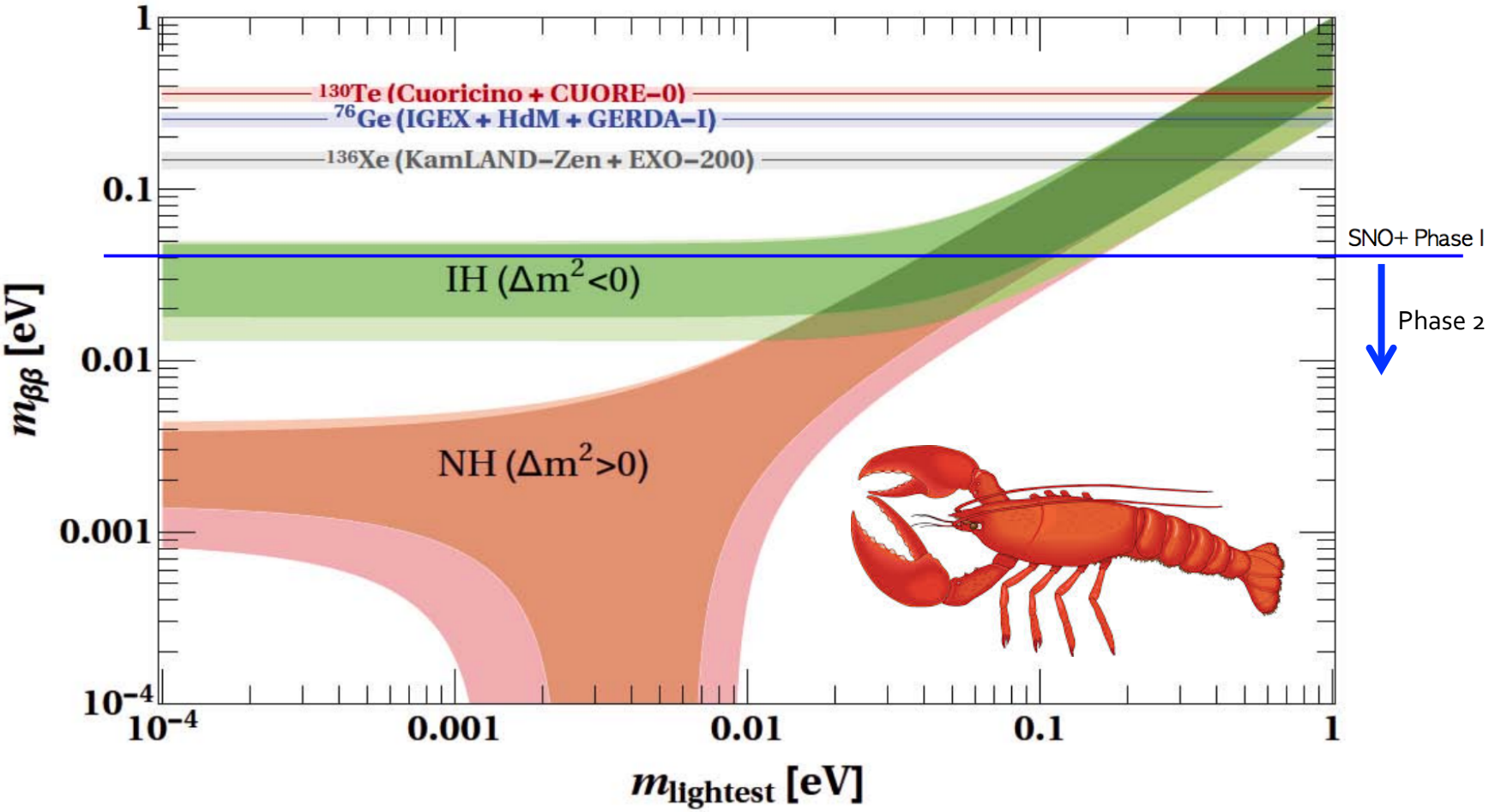
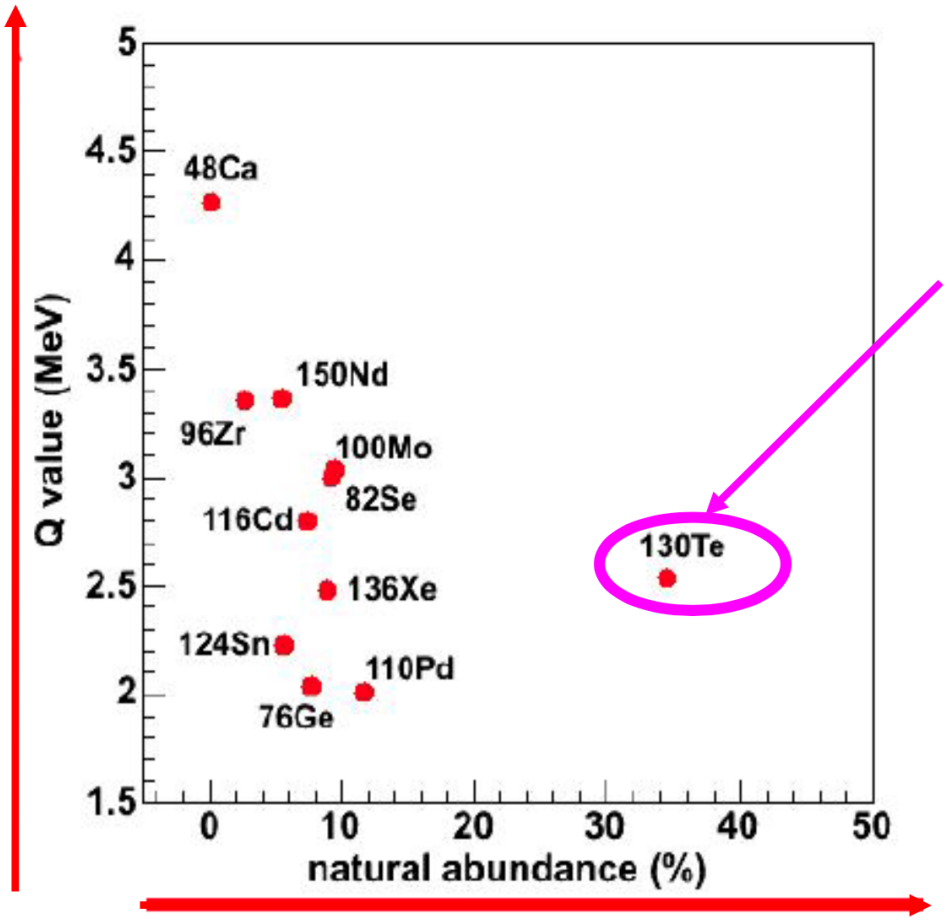


Conclusions & outlook

- SNO+ is a large liquid scintillator experiment, re-using the SNO detector.
- Physics priority: $0\nu\beta\beta$ search with ^{130}Te
- A 'Phase 1' loading of 0.5 % ^{nat}Te will begin to probe into the inverted hierarchy, competitive with CUORE and KamLAND-Zen
- Inverted hierarchy largely explored in the planned phase 2
- Water fill data to start June 2016
- Te-loaded phase to start in 2017

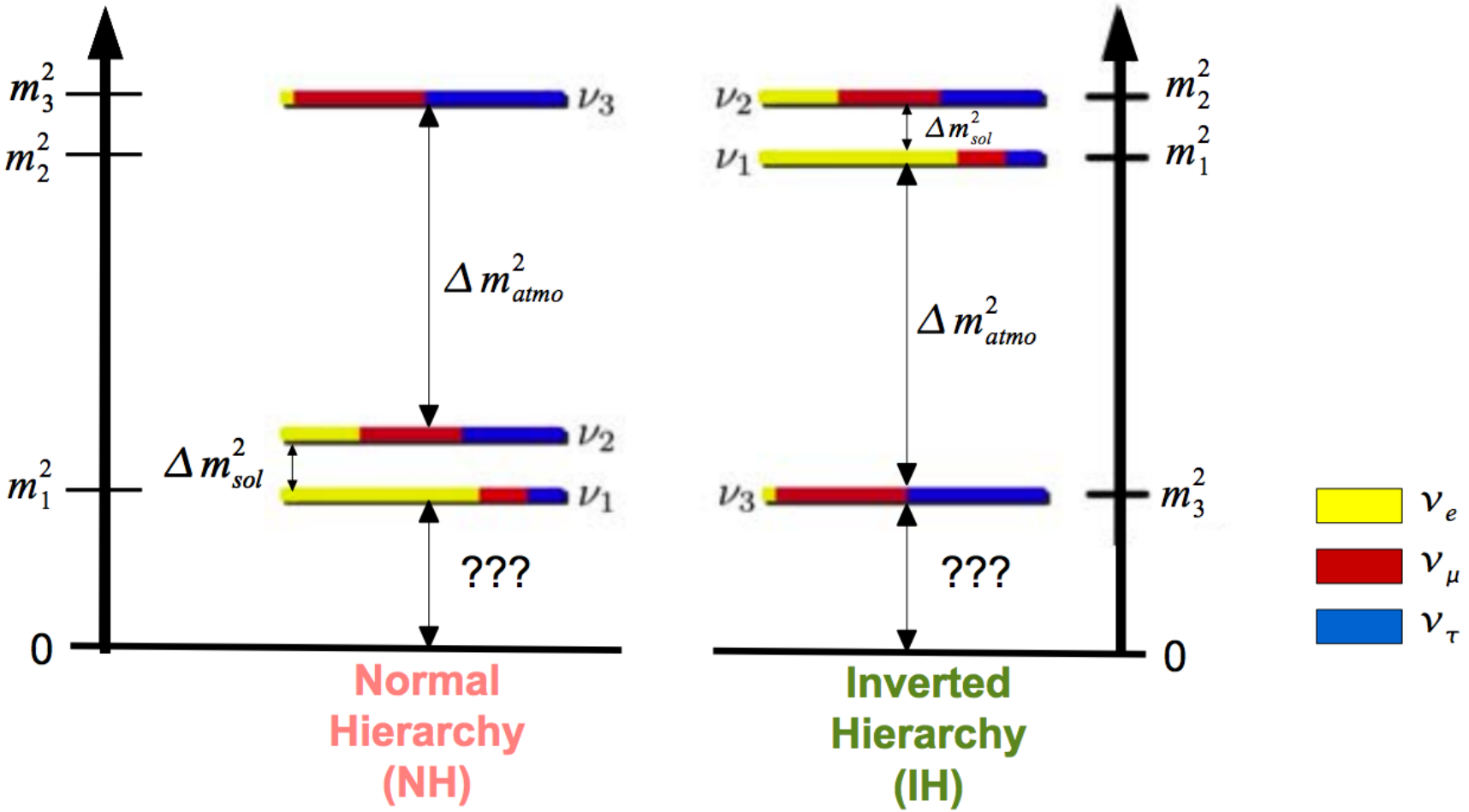
Backup slides…

ovββ isotopes



Decay candidate	Q value (MeV)	natural abundance (%)
$^{48}Ca \rightarrow ^{48}Ti$	4.271	0.187
$^{76}Ge \rightarrow ^{76}Se$	2.040	7.8
$^{82}Se \rightarrow ^{82}Kr$	2.995	9.2
$^{96}Zr \rightarrow ^{96}Mo$	3.350	2.8
$^{100}Mo \rightarrow ^{100}Ru$	3.034	9.6
$^{110}Pd \rightarrow ^{110}Cd$	2.013	11.8
$^{116}Cd \rightarrow ^{116}Sn$	2.802	7.5
$^{124}Sn \rightarrow ^{124}Te$	2.228	5.64
$^{130}Te \rightarrow ^{130}Xe$	2.533	34.1
$^{136}Xe \rightarrow ^{136}Ba$	2.479	8.9
$^{150}Nd \rightarrow ^{150}Sm$	3.367	5.6

Heirarchy


m_3^2
m_2^2
m_1^2
0
ν_3
ν_2
ν_1
Δm^2_{atmo}
Δm^2_{sol}
???
Normal Hierarchy (NH)
ν_2
ν_1
ν_3
Δm^2_{sol}
Δm^2_{atmo}
???
m_2^2
m_1^2
m_3^2
0
Inverted Hierarchy (IH)
ν_e
ν_μ
ν_τ