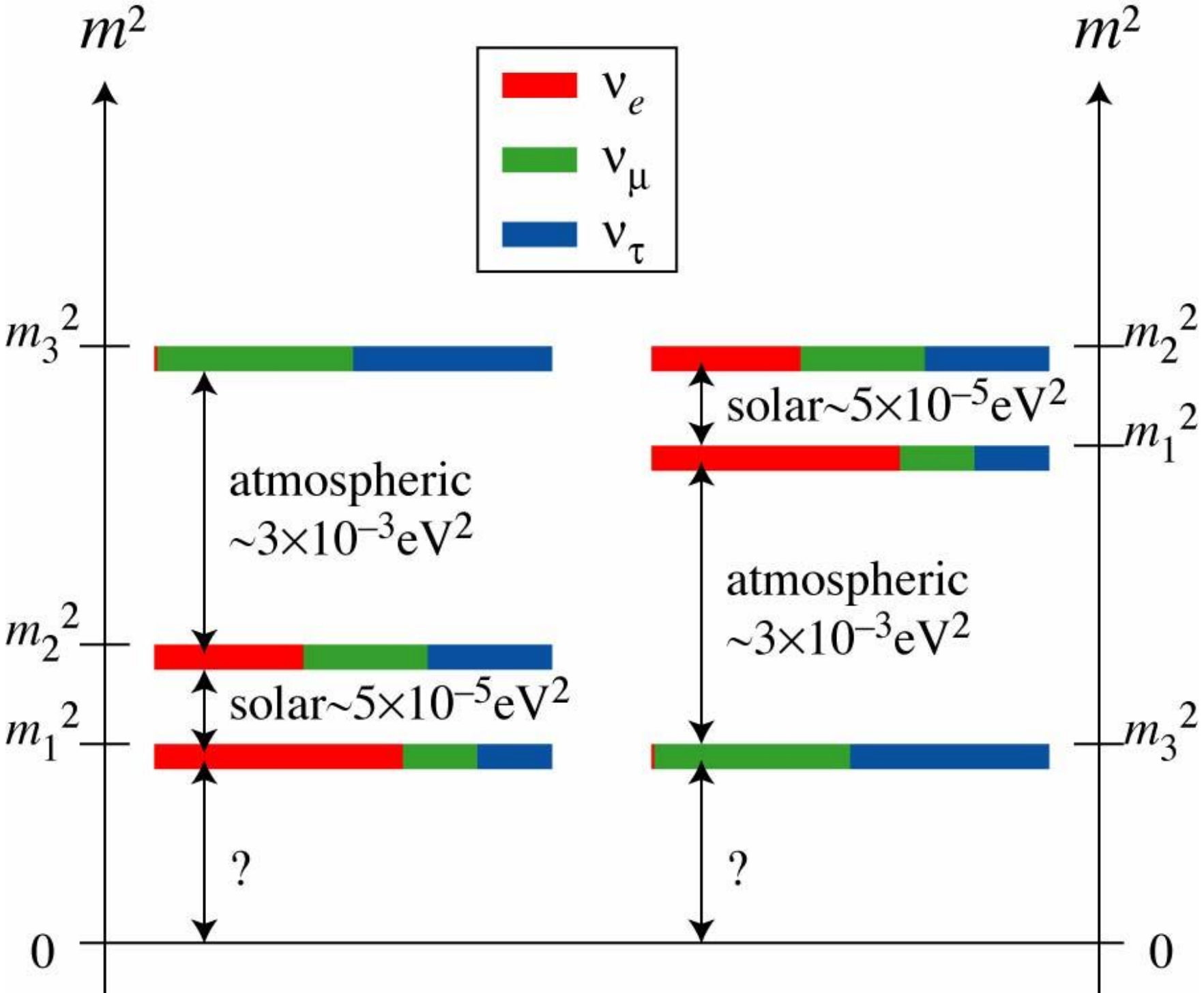
Is the Neutrino a Majorana Particle? What is its Mass?

Mike Heffner

Lawrence Livermore National Laboratory

5th Oct 2015

CPAD Instrumentation Frontier Meeting at UTA


m^2
m^2
ν_e
ν_μ
ν_τ
m_3^2
m_2^2
m_1^2
atmospheric
$\sim 3\times10^{-3}\text{eV}^2$
solar$\sim 5\times10^{-5}\text{eV}^2$
?
0
m_2^2
m_1^2
solar$\sim 5\times10^{-5}\text{eV}^2$
atmospheric
$\sim 3\times10^{-3}\text{eV}^2$
m_3^2
?
0

Are Neutrinos...

"Majorana" Particles

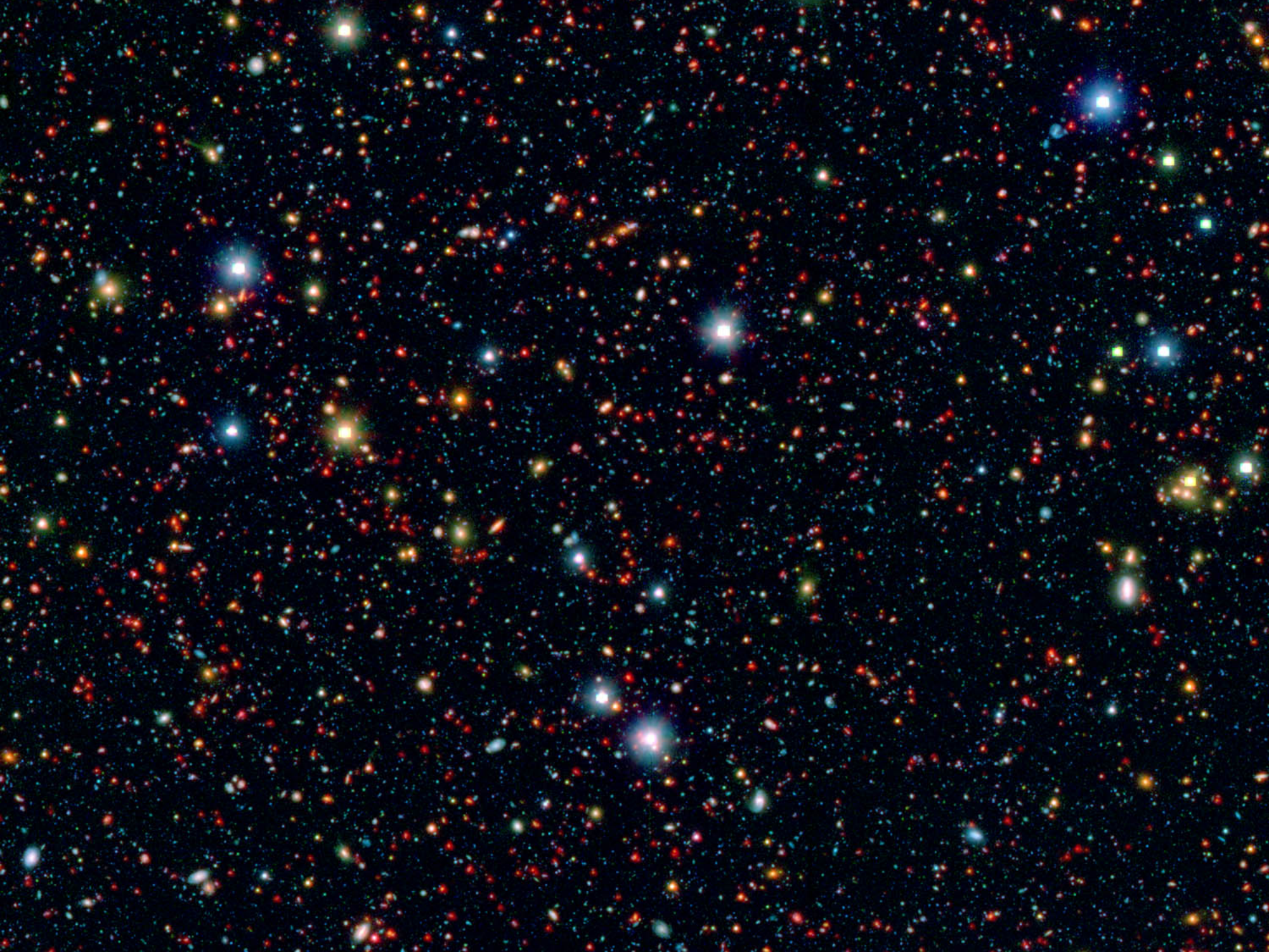
$\nu = \bar{\nu}$

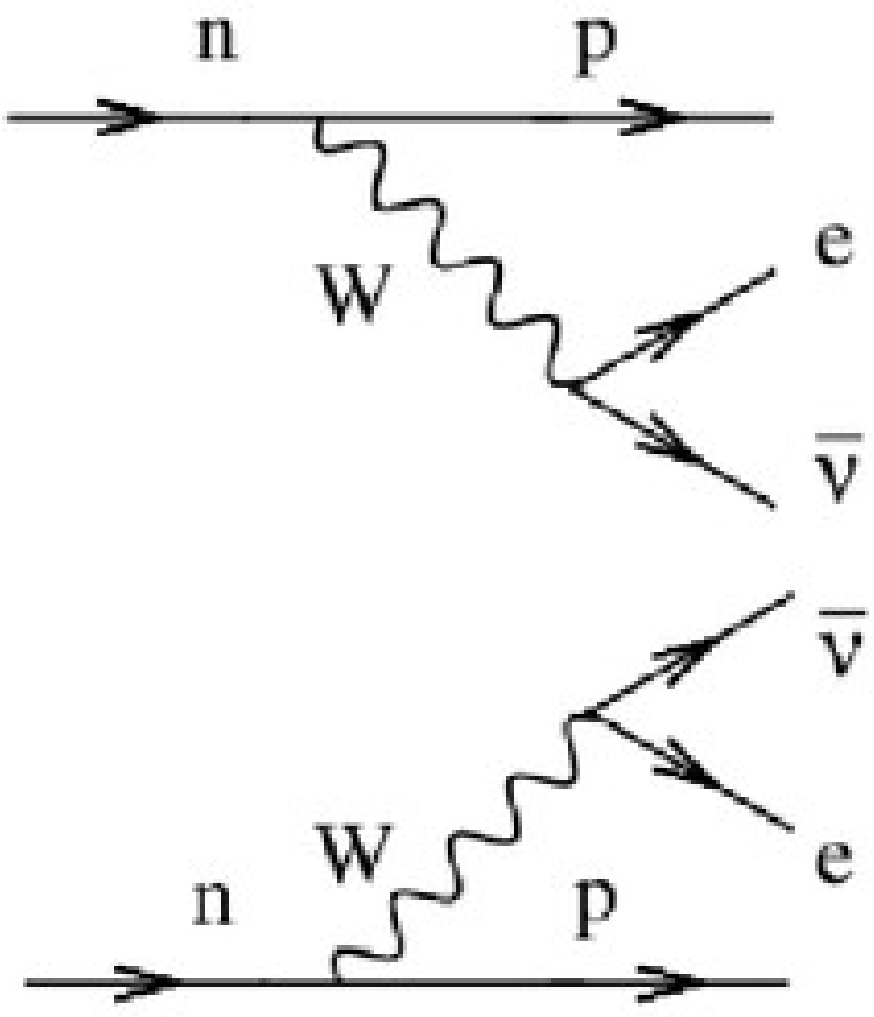
Lepton Number not Conserved.

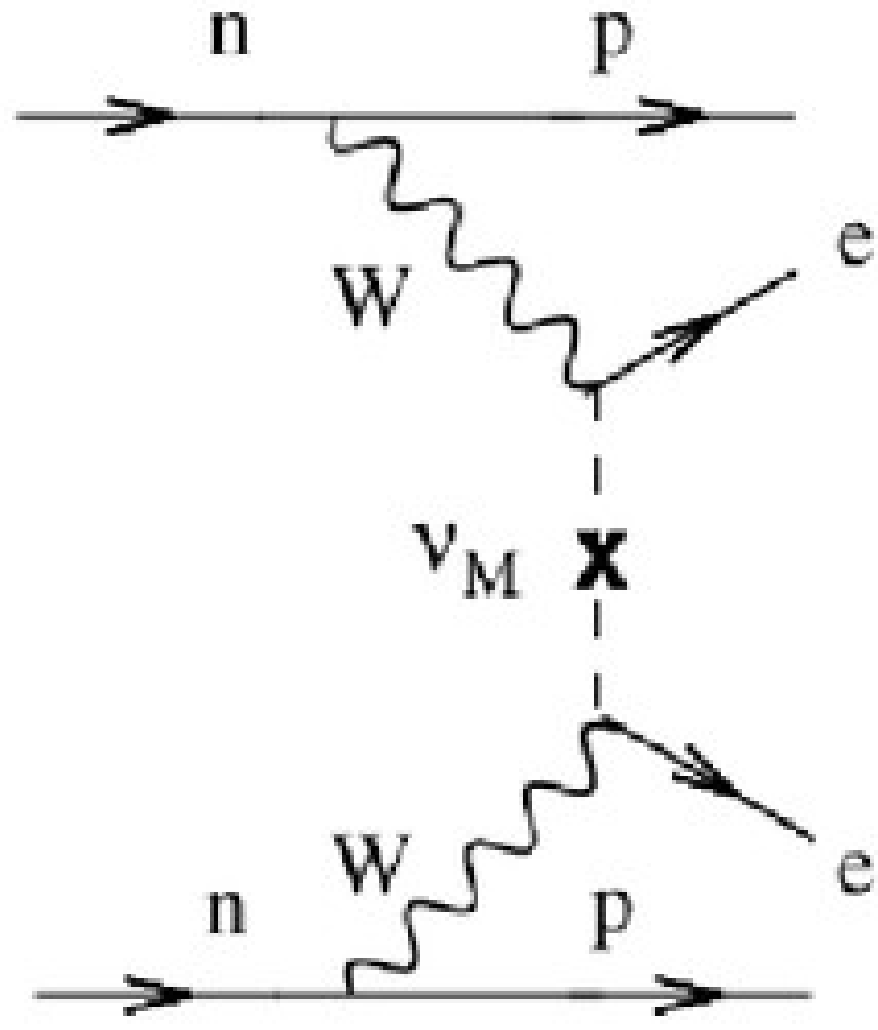
"Dirac" Particles

$\nu \neq \bar{\nu}$

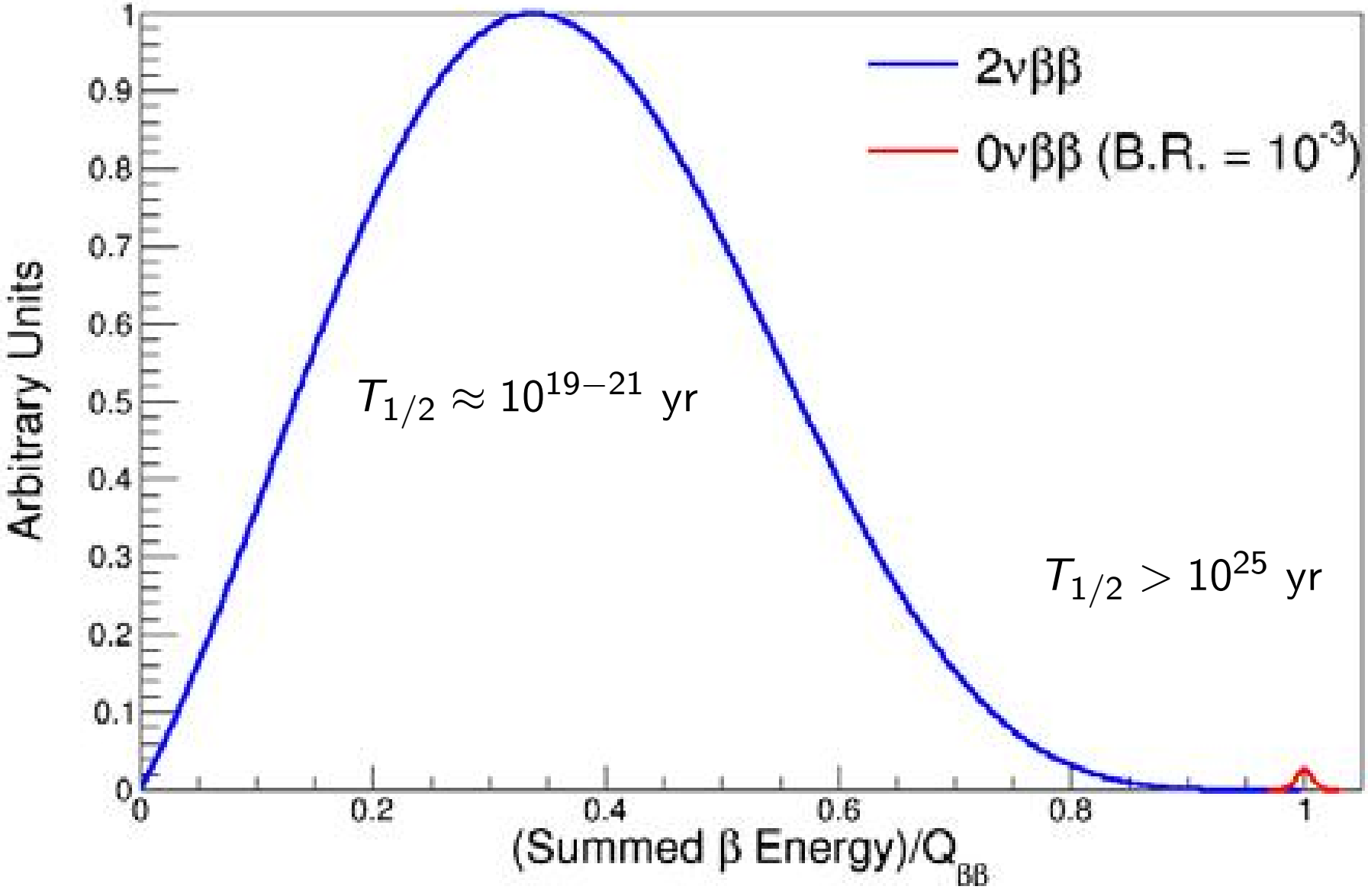
Like the other fermions




n
p
W
e
$\bar{\nu}$
$\bar{\nu}$
W
n
p
e


n
p
W
e
ν_M
X
W
n
p
e

$$\frac{1}{T_{1/2}} = < m_\nu >^2 G|M|^2$$



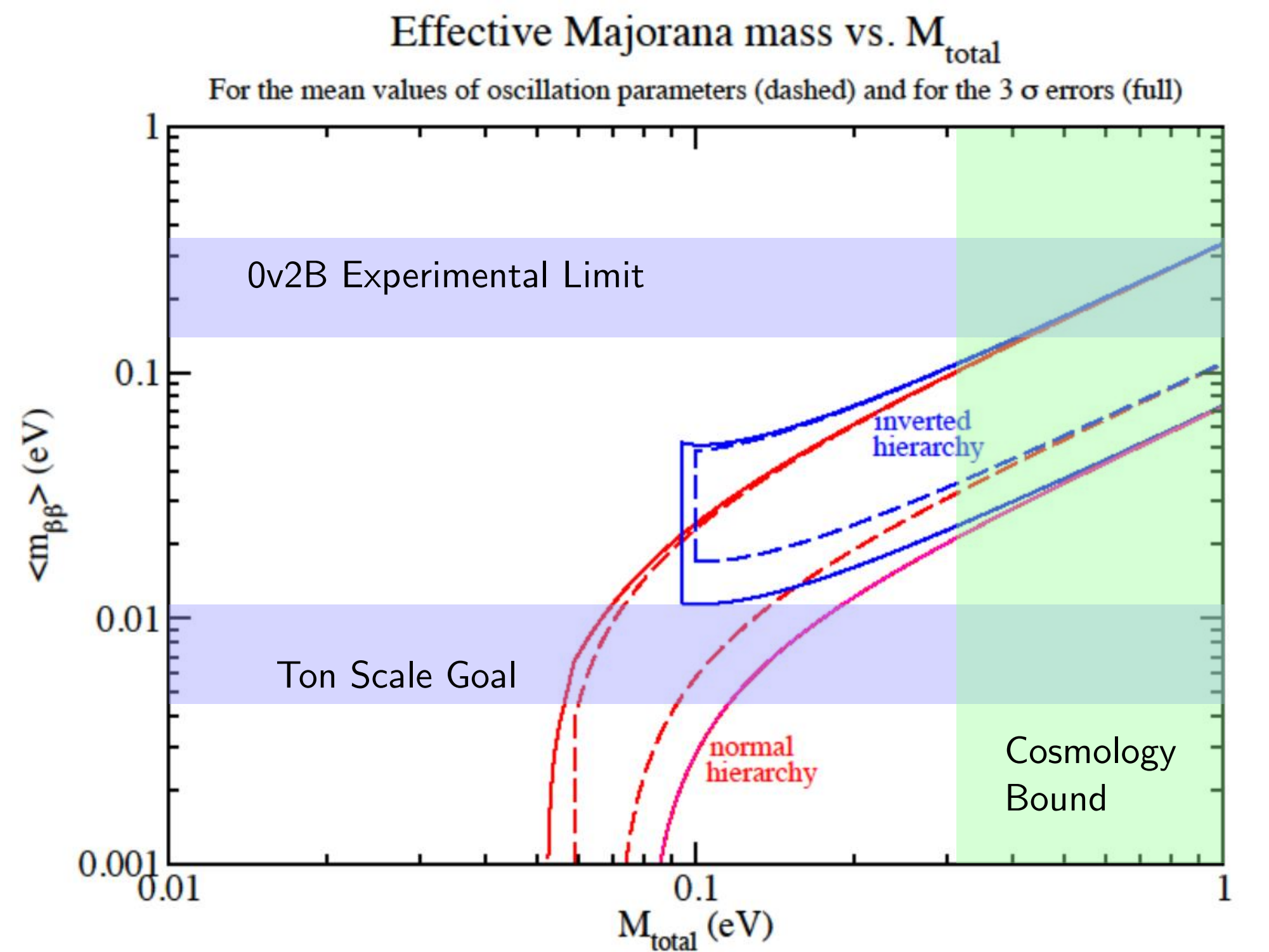
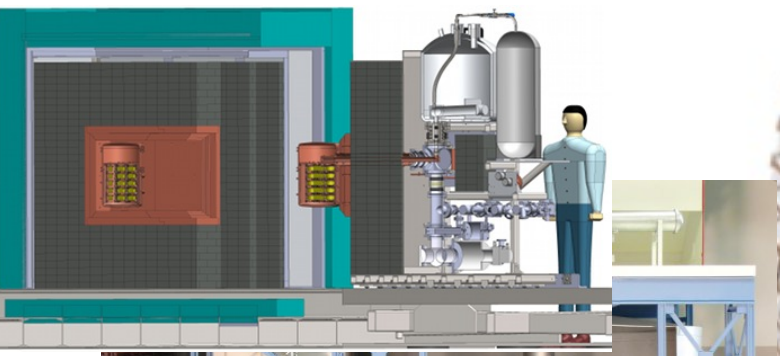
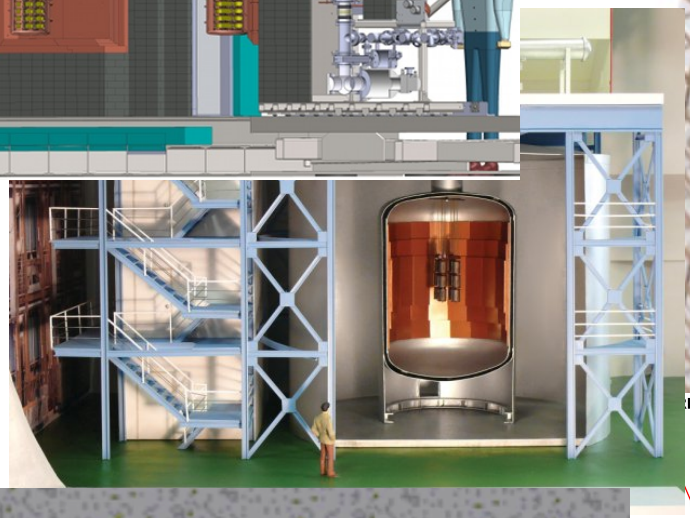

Effective Majorana mass vs. M_{total}
For the mean values of oscillation parameters (dashed) and for the 3 σ errors (full)
0v2B Experimental Limit
Ton Scale Goal
Cosmology Bound
inverted hierarchy
normal hierarchy
$<m_{\beta\beta}>$ (eV)
M_{total} (eV)
1
0.1
0.01
0.001
0.01
0.1
1

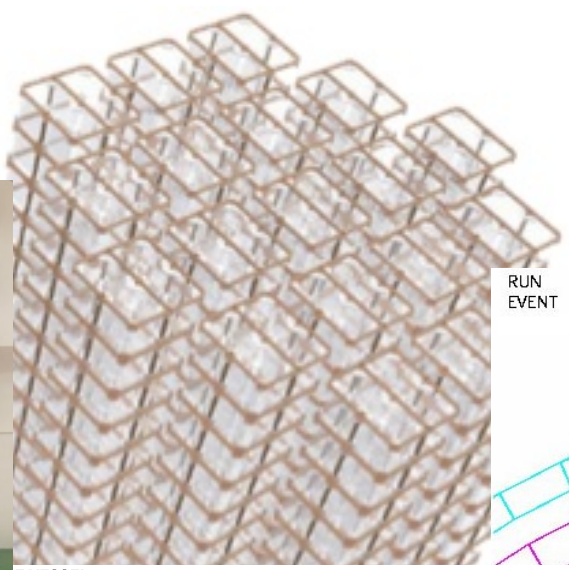
Table 1: Main characteristics of isotopes suitable for $0\nu\beta\beta$ decay search. The $Q_{\beta\beta}$ values and isotopic abundances are from [10] except for $Q_{\beta\beta}$ of ^{136}Xe taken from [11]. $G^{0\nu}$ factors are from [12]. The 2013 world production rates refer to elements with natural isotopic composition; the Xe value is taken from [13], all others from [14]. The related experiments are divided in: operational (o), in preparation (p) and R&D test projects (t). Experiments denoted with ($*$) plan to include more than one $\beta\beta$ isotope or consider still several isotopic options. The energy resolutions (in terms of FWHM/E) as well as the approximative fiducial $\beta\beta$ masses were deduced from [8]-[15].

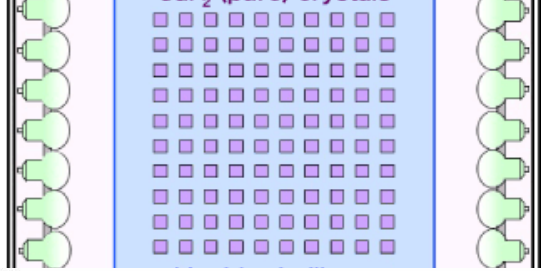
isotope	$Q_{\beta\beta}$ (keV)	$G^{0\nu}$ (10^{-15}yr^{-1})	nat. abundance (%)	prod. 2013 (tons)	experiment / R&D	FWHM/E at $Q_{\beta\beta}$ (%)	fiducial $\beta\beta$ mass (kg)
^{48}Ca	4273.7	24.81	0.187	–	CANDLES^{t}	–	6→>40
^{76}Ge	2039.1	2.36	7.8	155	GERDA^{o}	0.1-0.3	15→30
					Majorana Dem.^{p}	0.1	25
^{82}Se	2995.5	10.16	9.2	>2.3×10^{3}	SuperNEMO ^{p*}	4	7→100
					LUCIFER ^{t}	0.3	–
^{100}Mo	3035.0	15.92	9.6	2.7×10^{5}	MOON^{t*}	–	–
					AMoRE^{t}	–	100
^{116}Cd	2809.1	16.70	7.6	2.2×10^{4}	COBRA^{t*}	–	–
^{130}Te	2530.3	14.22	34.5	>95	CUORE $^{o/p}$	0.2	10→200
					SNO+ ^{p}	~10	160-270
^{136}Xe	2457.8	14.58	8.9	3-4	EXO^{o}	4	80
					KamLAND-Zen^{o}	10	150→260-340
					NEXT^{p}	0.6	9→90
^{150}Nd	3367.3	63.03	5.6	~1.7×10^{4}	DCBA^{t*}	–	–

Nuclear and Particle Physics Proceedings 260 (2015) 188–193

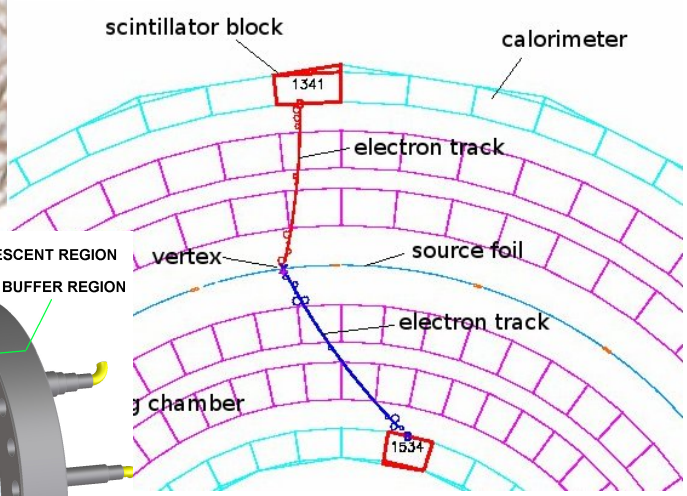


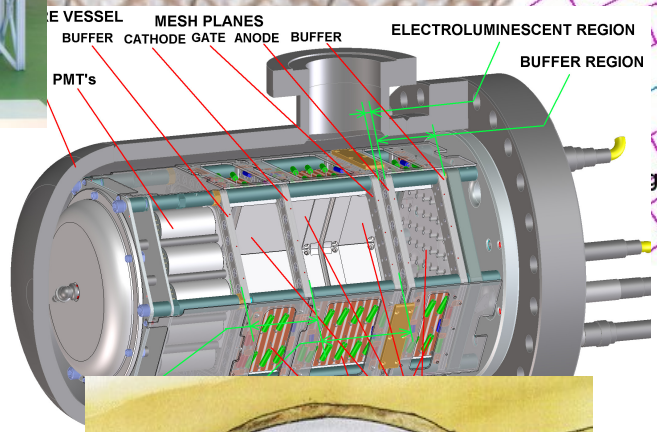


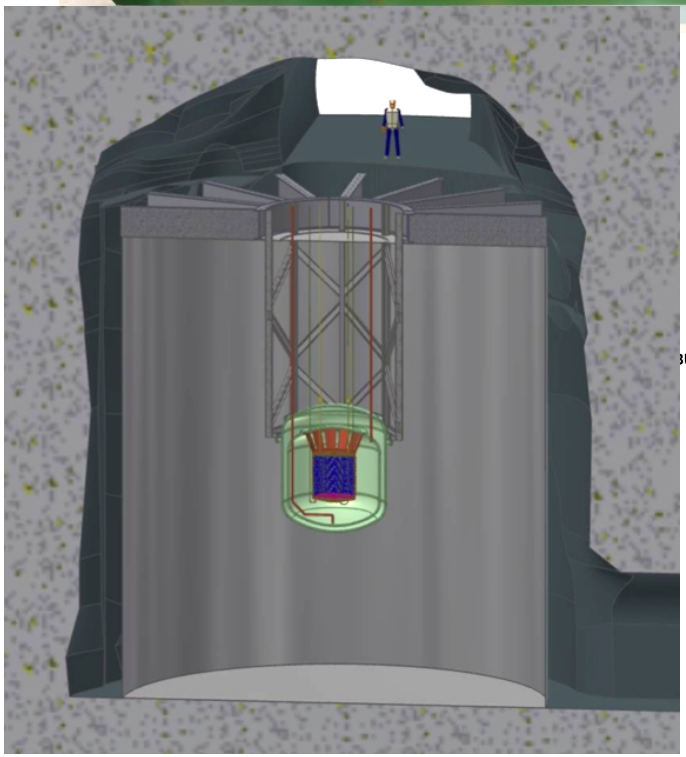


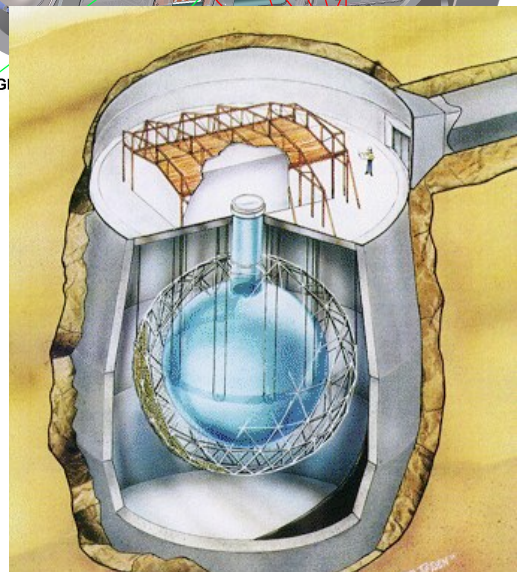


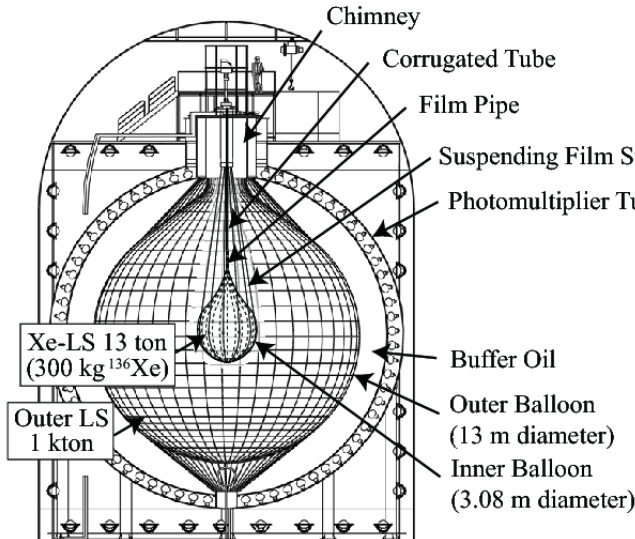
RUN 3930
EVENT 42373
E SUM 2.875 MeV











Final Thoughts

- We know quite a bit about the neutrino, but...
- We don't know the mass scale and if it is Majorana.
- $0\nu2\beta$ experiments that span the inverted mass hierarchy are likely to generate a important result for particle physics.
  - 0v2B observation $\rightarrow$ Majorana
  - 0v2B limit + constraint of mass or hierarchy $\rightarrow$ Dirac
- Instrumentation R&D for this topic has common elements with other particle physics priorities.
- The next big experiment will be run by NP, but the result is central to the interests of the HEP community.