Double Beta Decay in SNO+

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Collaboration

Outline

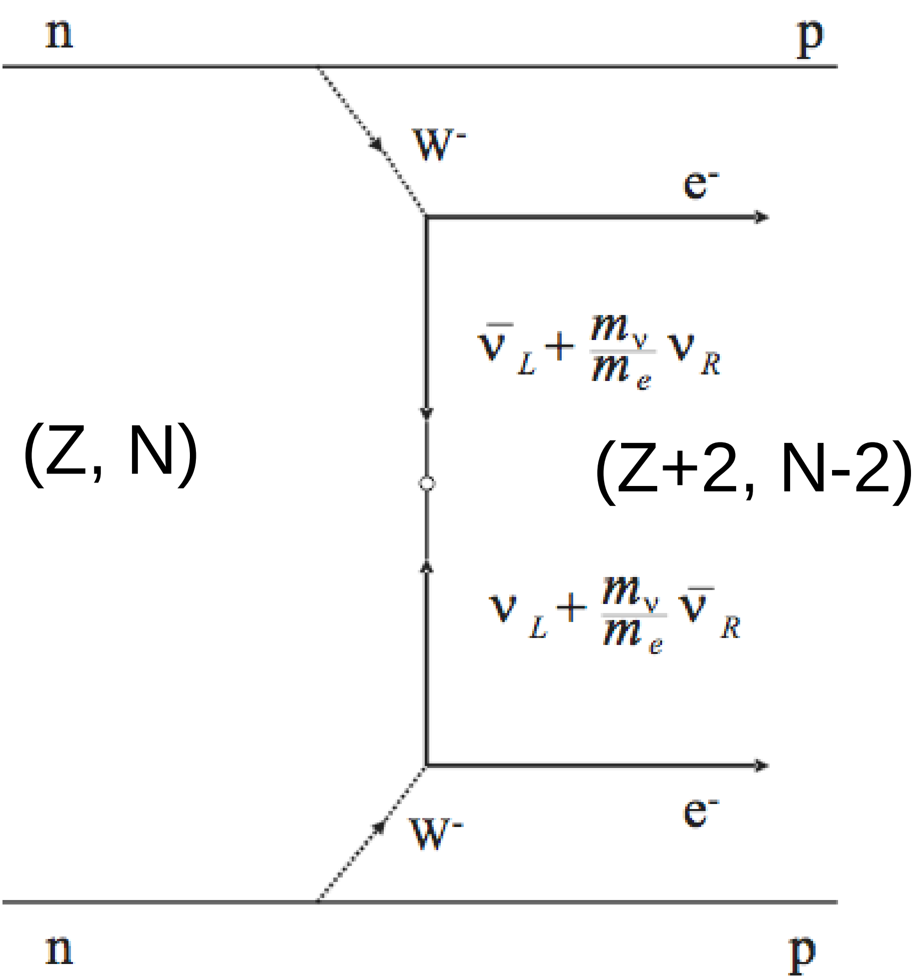
- ^{150}Nd double beta decay
- The SNO+ detector
- ^{150}Nd loaded scintillator in SNO+ detector
- The sensitivity of SNO+ to m_ν
- Comparison with other experiments
- Conclusions

Double Beta Decay

$$\beta\,\text{decay} \;:\; (Z,N) \rightarrow (Z+1,N-1)+e+\overline{\nu}_e$$

$$\beta\beta\,\text{decay} \;:\; (Z,N) \rightarrow (Z+2,N-2)+2e+2\overline{\nu}_e$$

$$0\nu\beta\beta\,\text{decay} \;:\; (Z,N) \rightarrow (Z+2,N-2)+2e$$



1. Neutrinos are Majorana particles

$$(T_{1/2})^{-1} = G^{0\nu}(Q,Z)\left|M^{0\nu}\right|^2 \left|m_{\beta\beta}\right|^2$$

$$\left|m_{\beta\beta}\right| = \left|\left|U_{e1}\right|^2 m_1 + \left|U_{e2}\right|^2 m_2 e^{i\alpha_{12}} + \left|U_{e3}\right|^2 m_3 e^{i\alpha_{13}}\right|$$

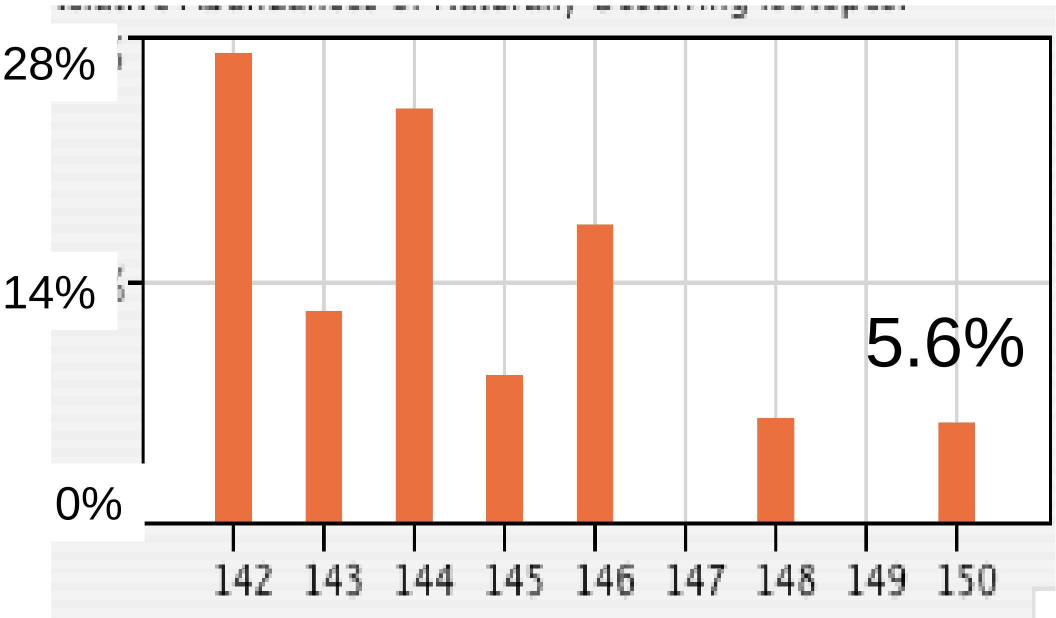
2. Neutrinos have masses

Candidates:

^{48}Ca, ^{76}Ge, ^{82}Se, ^{100}Mo, ^{130}Te

^{136}Xe, ^{150}Nd …

Neodymium - ^{150}Nd



$^{150}Nd \Rightarrow {}^{150}Sm + 2e + 2\nu$

$\tau = 2.9\text{x}10^{19}$ year

$^{150}Nd \Rightarrow {}^{150}Sm + 2e$

Q = 3.37 MeV

τ = ? year

F. Avignone, Nucl. Phys. B (proc. Suppl) 143 (2005) $m_{\beta\beta}$=40 meV

Isotope	^{48}Ca	^{76}Ge	^{82}Se	^{100}Mo	^{116}Cd	^{130}Te	^{136}Xe	^{150}Nd
$T_{1/2}$ (x 10^{26} y)	30	23	9.4	3.3	13	3.9	58	0.29

V.A. Rodin et al., Nucl. Phys. A 766, 107 (2006) $m_{\beta\beta}$=50 meV

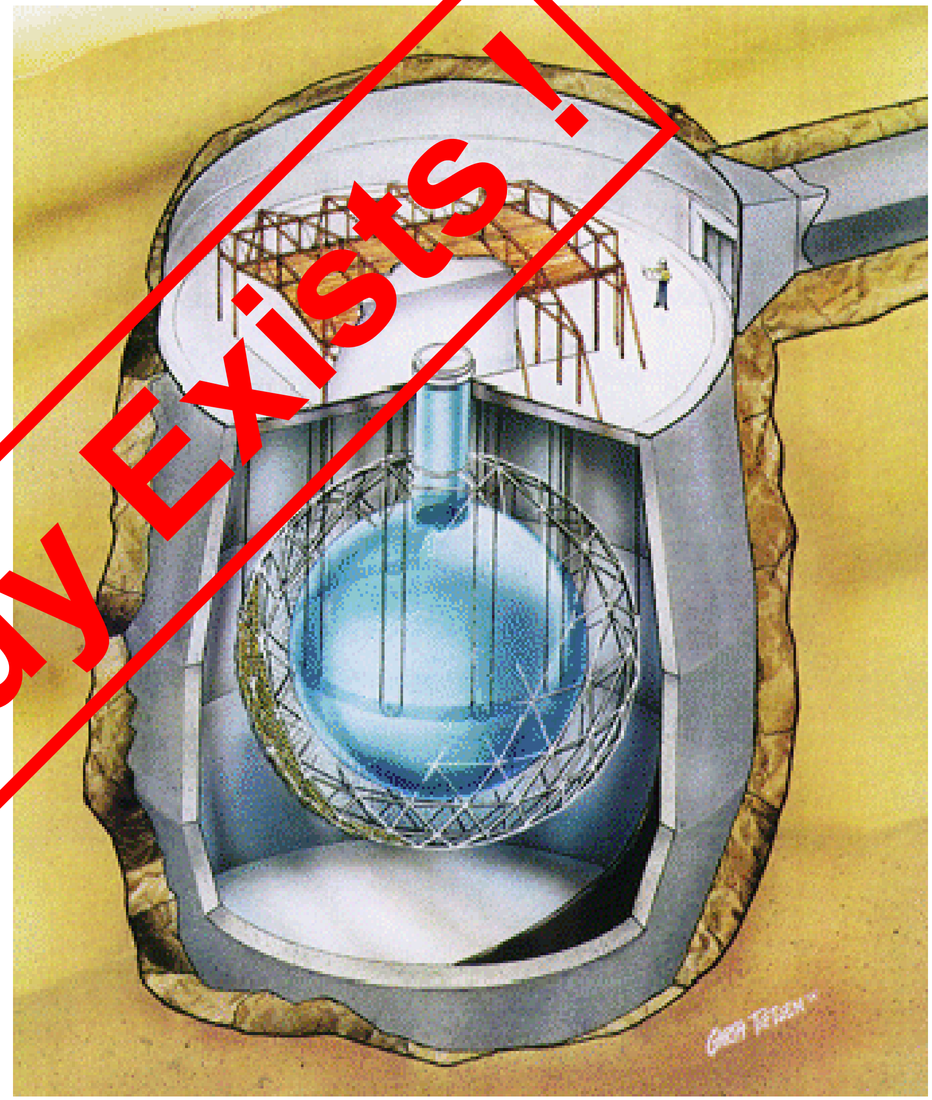
0.23

0.36

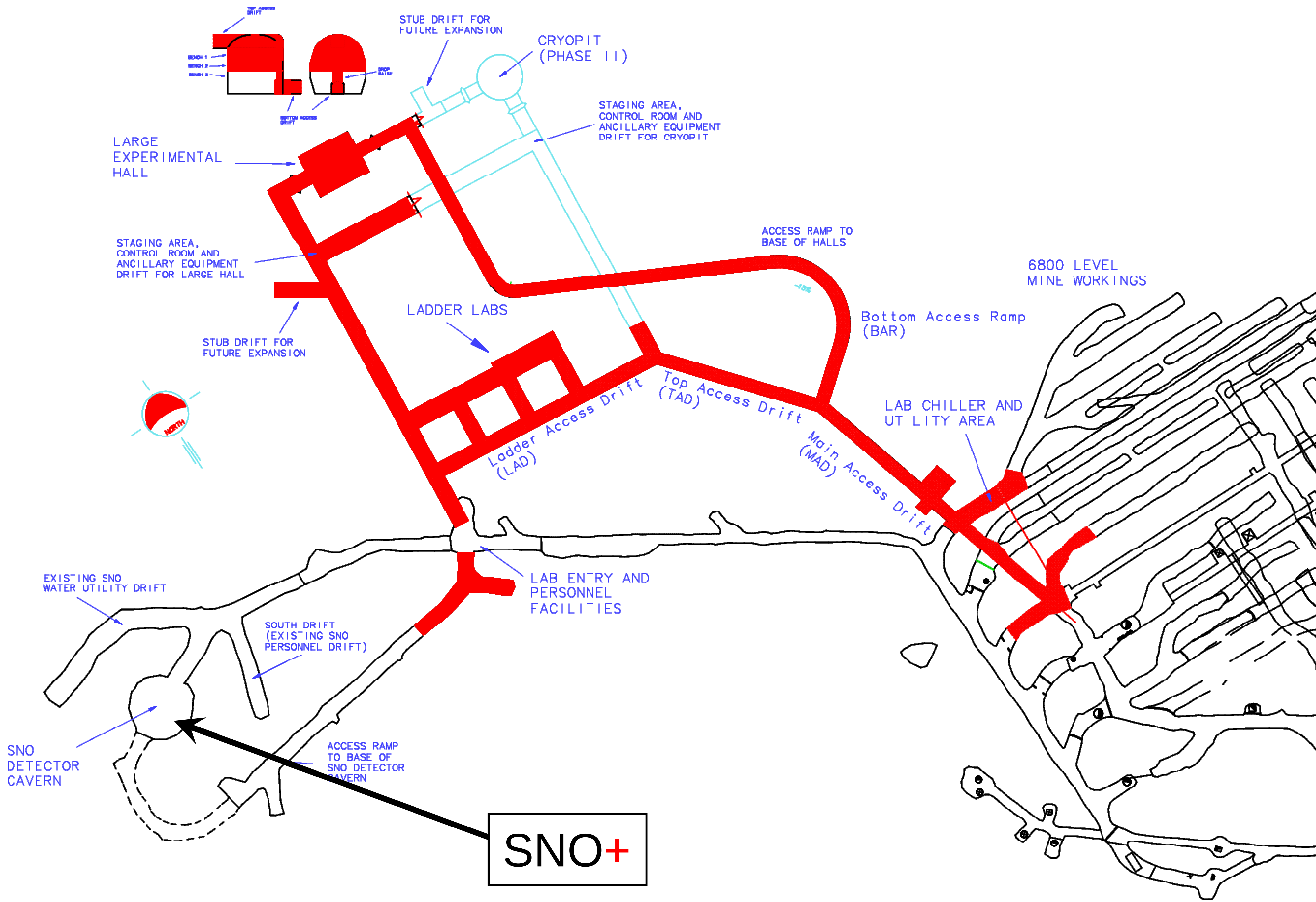
Sudbury Neutrino Observatory (SNO)

- 2092 meters deep underground
- 1000 tons of ultrapure liquid scintillator in a 12 meter diameter acrylic vessel
- 1000 tons of ultrapure D_2O in a 12 meter diameter acrylic vessel
- 7000 tons of ultrapure H_2O as shield
- 9500 PMTs mounted on a 18 meter diameter frame
- electronics, DAQ, understanding of our detector

Already Exists !

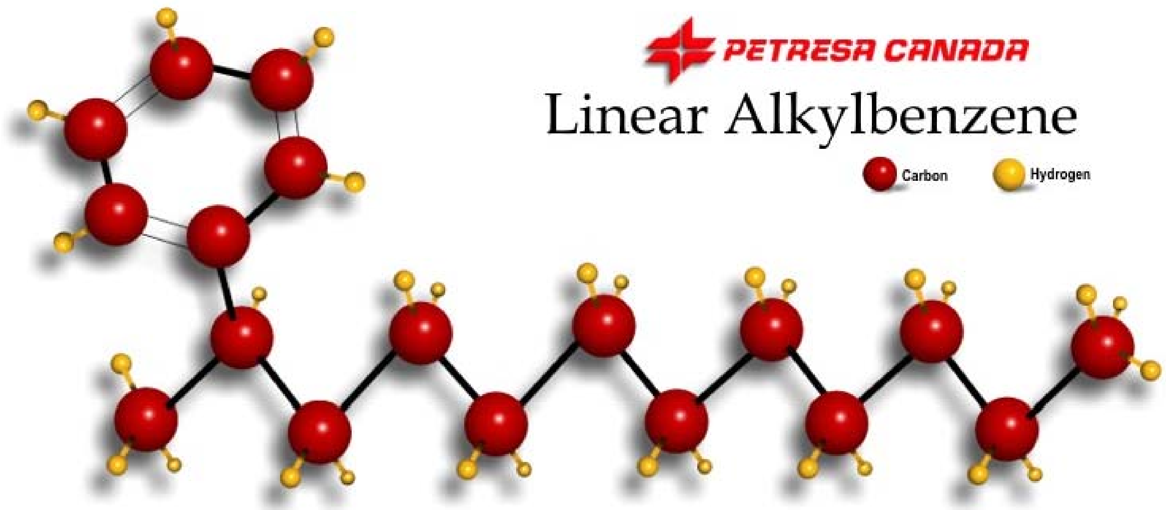


SNOLab



STUB DRIFT FOR FUTURE EXPANSION
CRYOPIT (PHASE II)
STAGING AREA, CONTROL ROOM AND ANCILLARY EQUIPMENT DRIFT FOR CRYOPIT
LARGE EXPERIMENTAL HALL
STAGING AREA, CONTROL ROOM AND ANCILLARY EQUIPMENT DRIFT FOR LARGE HALL
ACCESS RAMP TO BASE OF HALLS
6800 LEVEL MINE WORKINGS
LADDER LABS
Bottom Access Ramp (BAR)
STUB DRIFT FOR FUTURE EXPANSION
Top Access Drift (TAD)
Ladder Access Drift (LAD)
LAB CHILLER AND UTILITY AREA
Main Access Drift (MAD)
NORTH
EXISTING SNO WATER UTILITY DRIFT
LAB ENTRY AND PERSONNEL FACILITIES
SOUTH DRIFT (EXISTING SNO PERSONNEL DRIFT)
SNO DETECTOR CAVERN
ACCESS RAMP TO BASE OF SNO DETECTOR CAVERN
SNO+

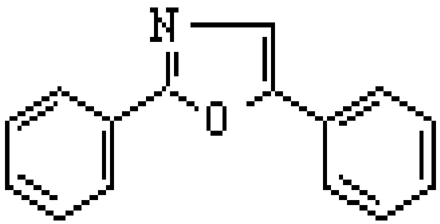
Scintillator in SNO+



- compatible with acrylic, undiluted
- high light yield (because it's undiluted)
- Pure, light attenuation length in excess of 20 m at 420 nm
- high flash point (130°C) safe
- low toxicity safe
- low cost (relative to other organic solvents)
- smallest scattering of all scintillating solvents investigated
- Petresa Canada plant in Quebec makes 120 kton/year, $1600 per ton delivered.

LAB and Fluor

- works fine with standard fluors
  - PPO, butyl-PBD, PPD
  - 2 g/L concentration works fine



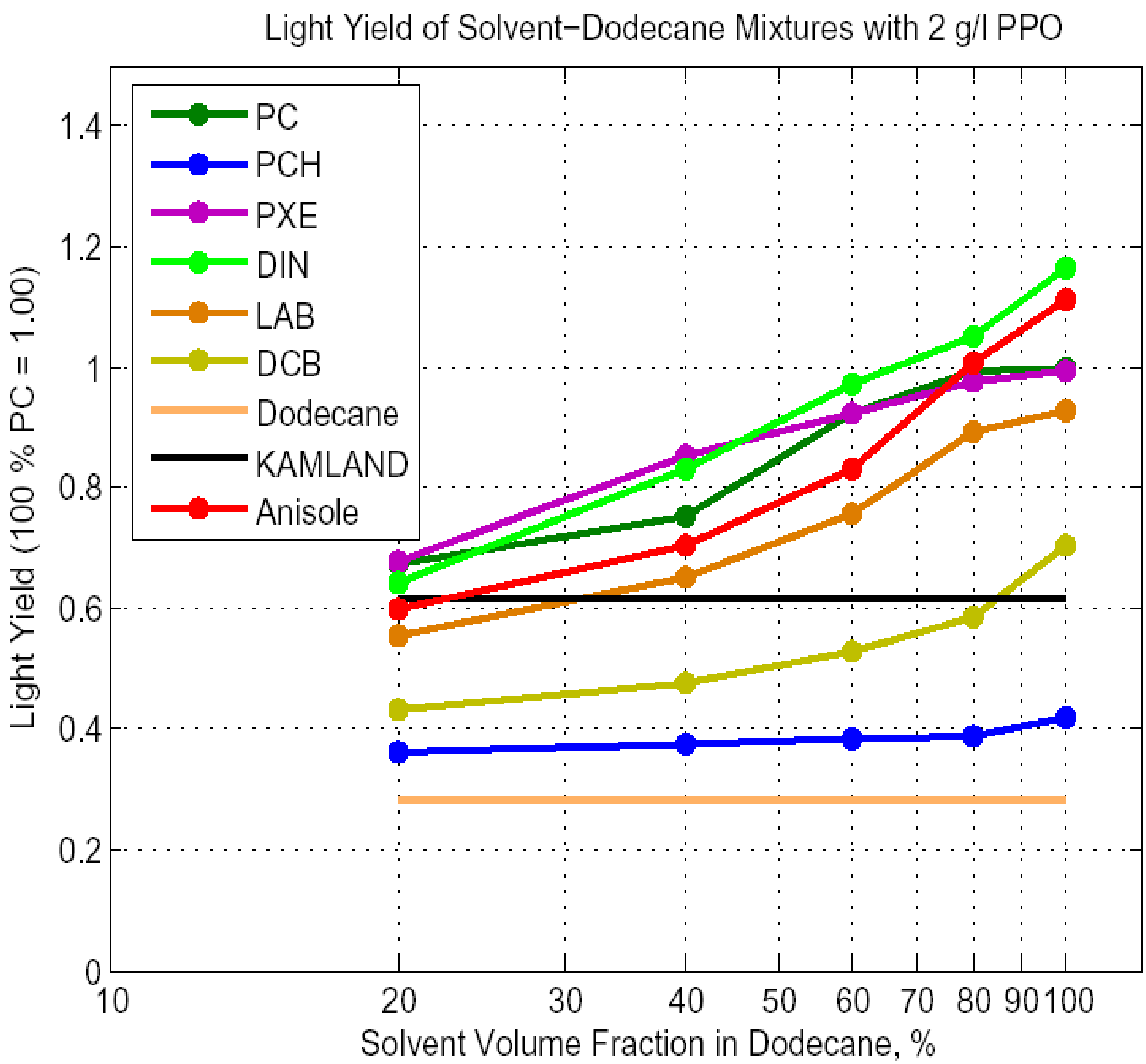
LAB-PPO energy transfer efficiency

PPO [g/L]	Method 1	Method 2
32	n/a	90.7%
4	80%	80%
2	72%	73%
1	60%	61%
0.5	46%	55%
0.25	35%	47%
0.1	23%	n/a
0.02	5.6%	n/a

Method 1 (fluorescence emission method): measure the fluorescence excitation and emission of PPO-LAB solution; excitation at 318nm (LAB excitation), integrate emission range from 320 to 550nm (PPO emission)

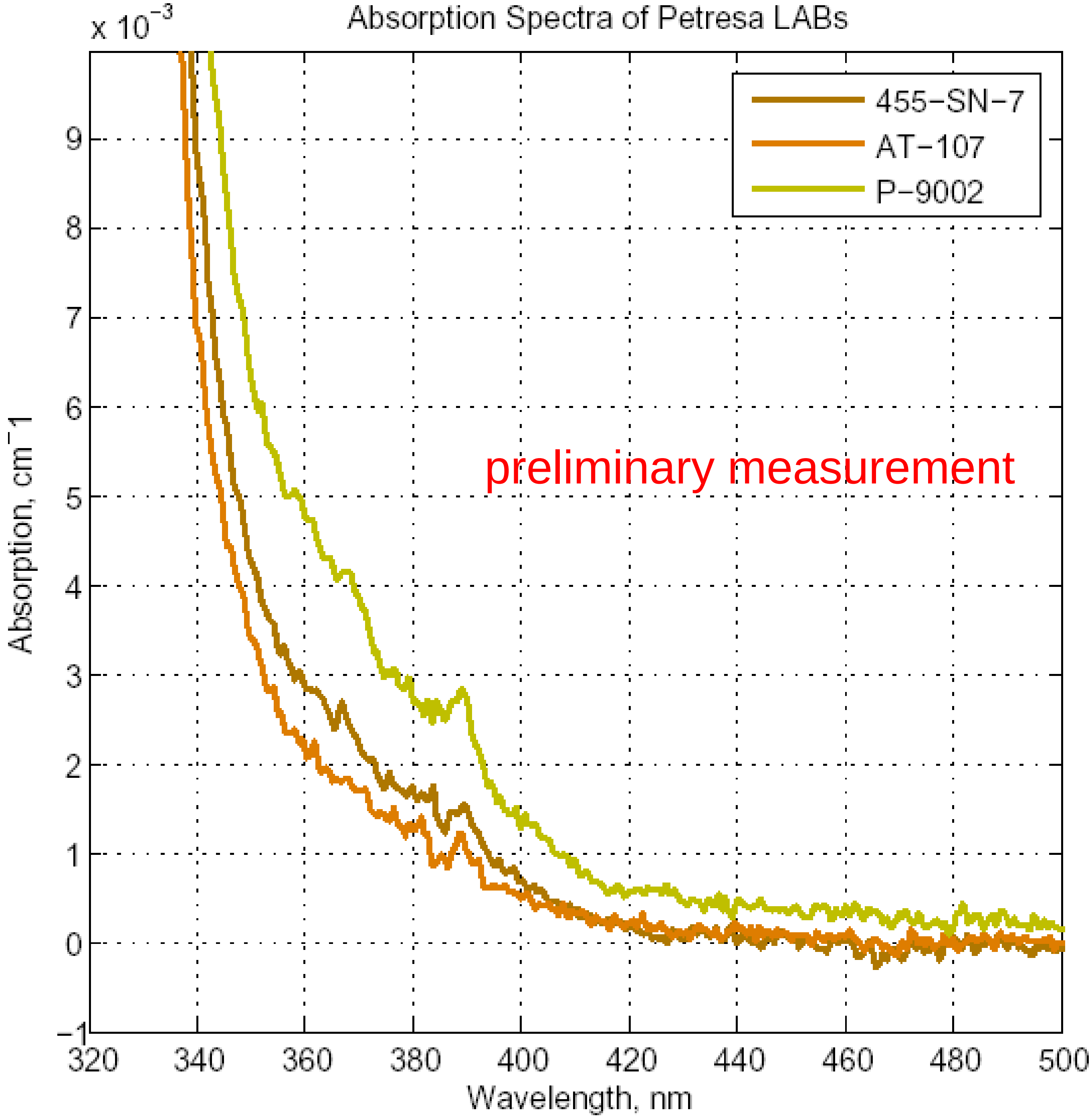
Method 2 (decay time method): excitation at 250nm, emission 360nm, measure the decay times of PPO-LAB solution, compare to the decay time of pure PPO

Light Yield

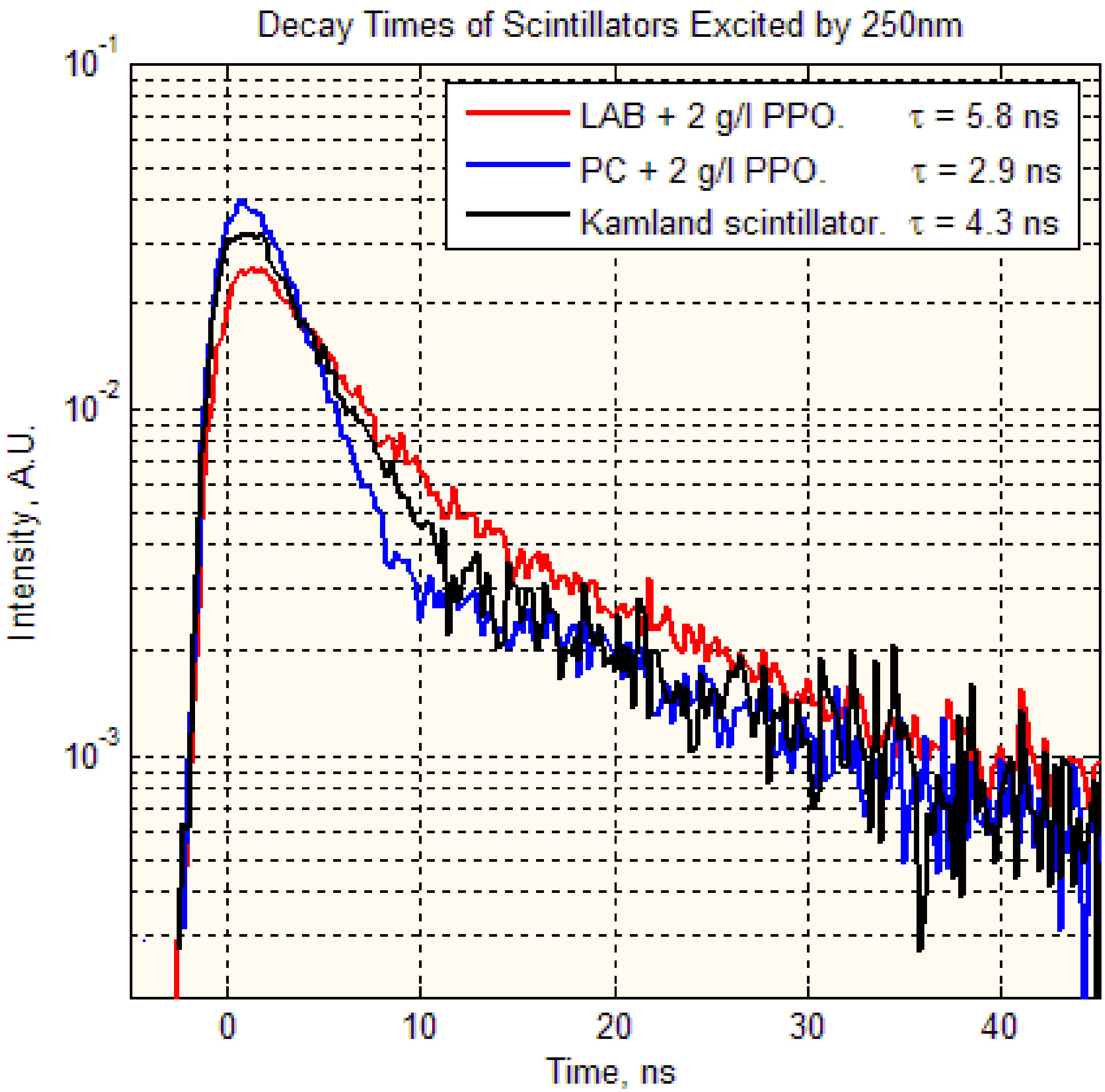


Light Yield of Solvent−Dodecane Mixtures with 2 g/l PPO
PC
PCH
PXE
DIN
LAB
DCB
Dodecane
KAMLAND
Anisole
Light Yield (100 % PC = 1.00)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
10
20
30
40
50
60
70
80
90
100
Solvent Volume Fraction in Dodecane, %

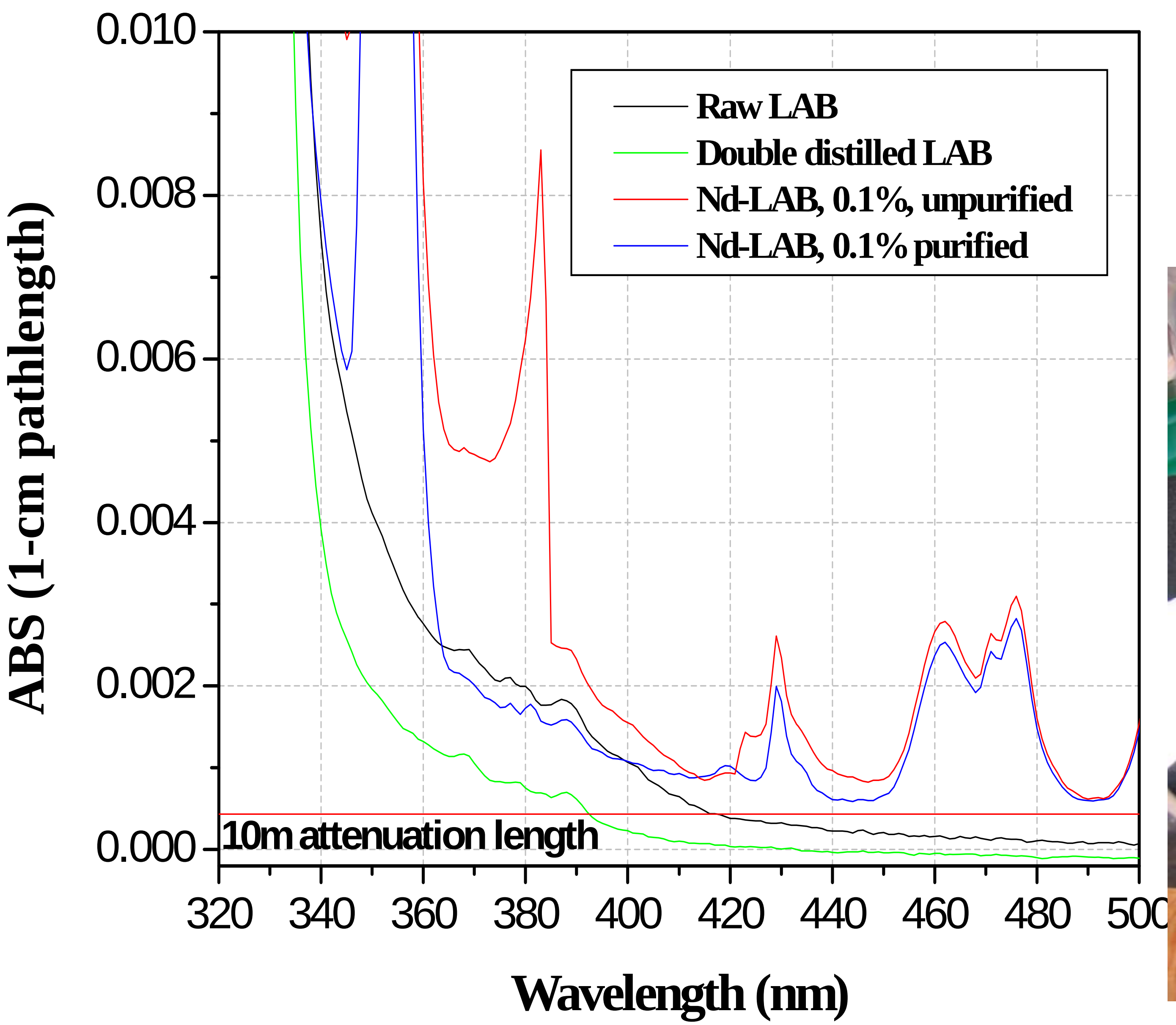
Attenuation

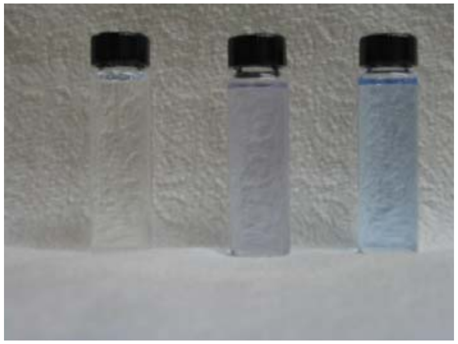


Decay Times of Scintillations



Nd Loaded LAB

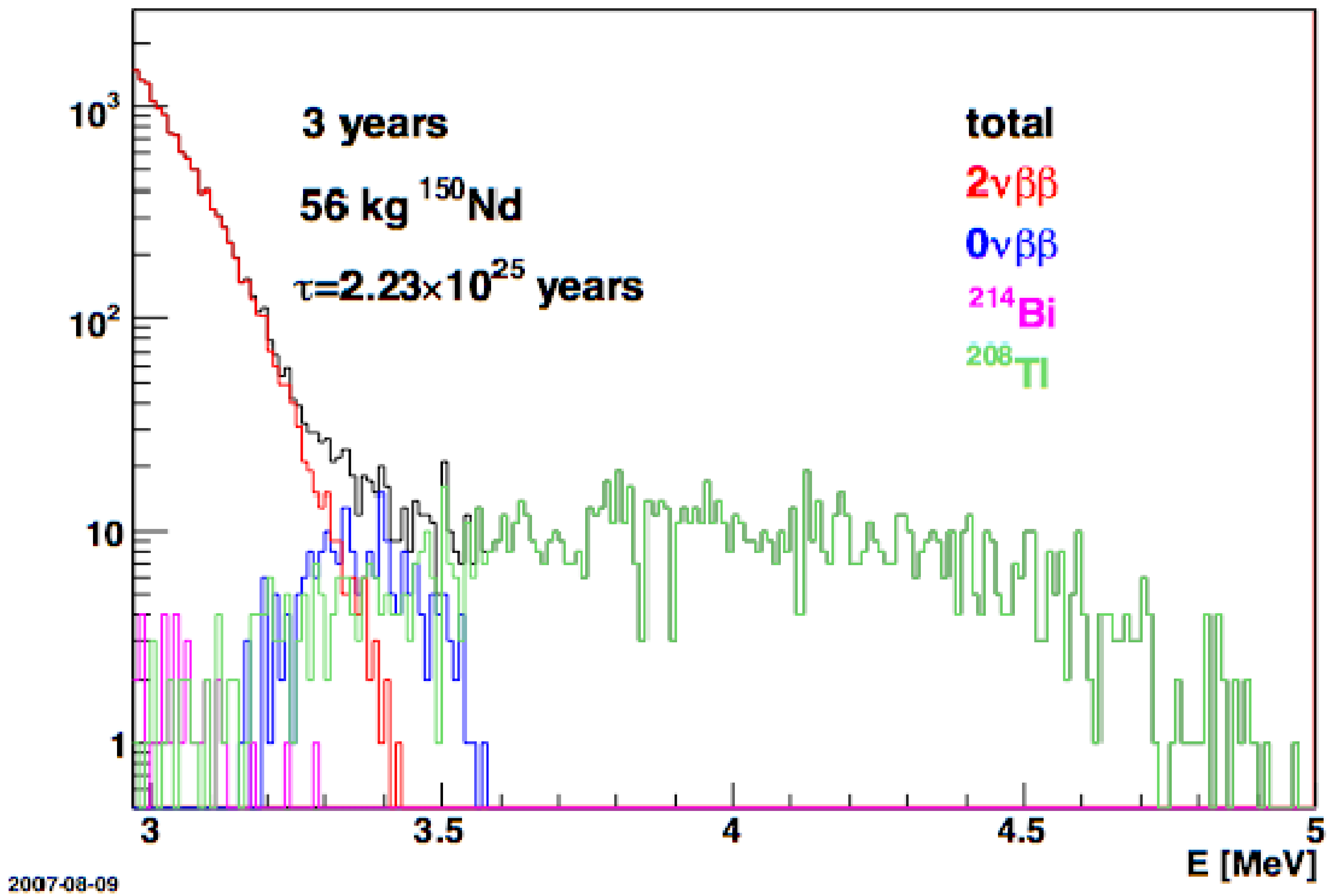




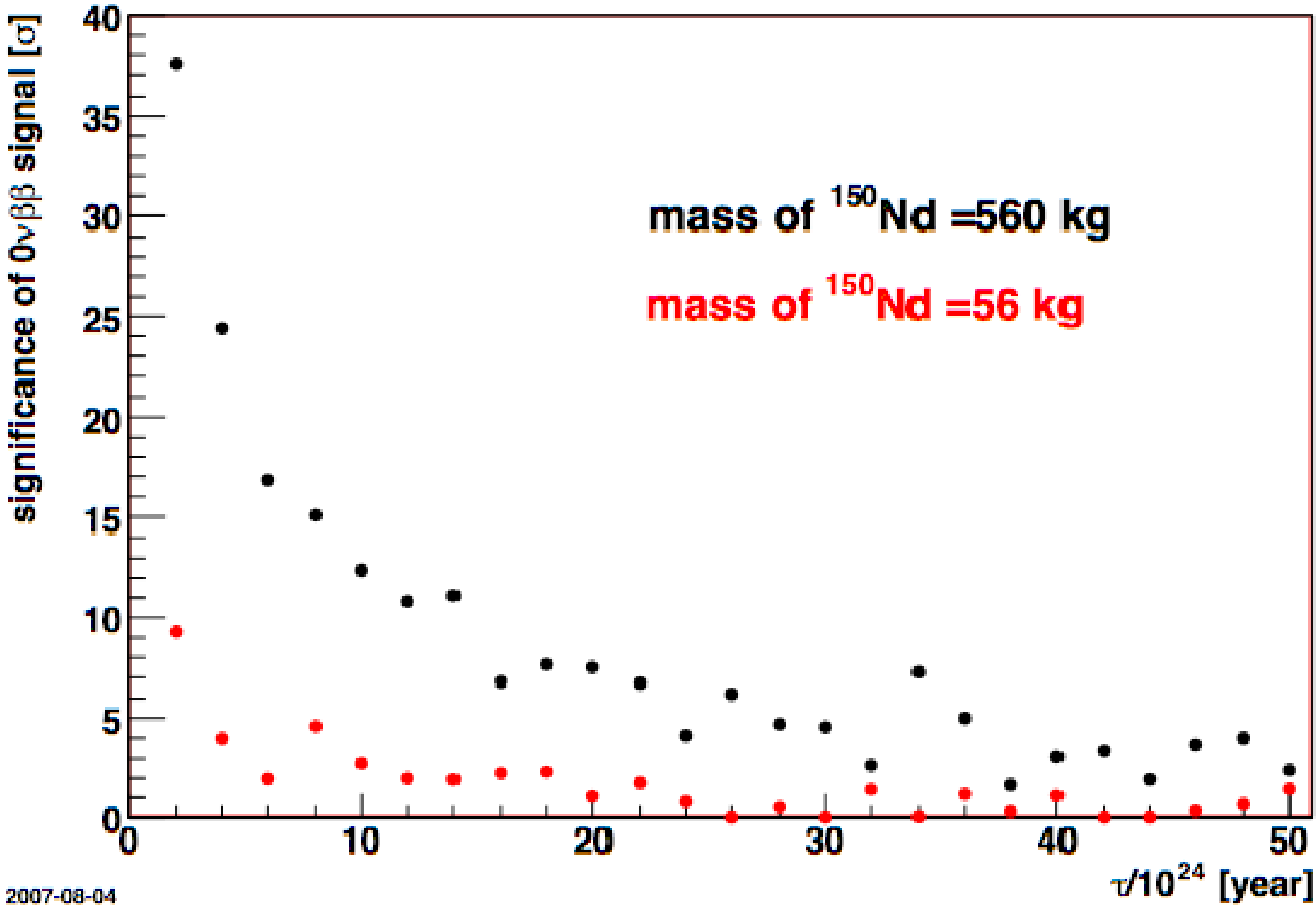
Other Studies

- Acrylic vessel holding structure
- Long time stability of Nd loaded LAB with acrylic
- Optics of Nd loaded LAB
- Upgrade of electronic system
- Modification of software packages, Monte Carlo

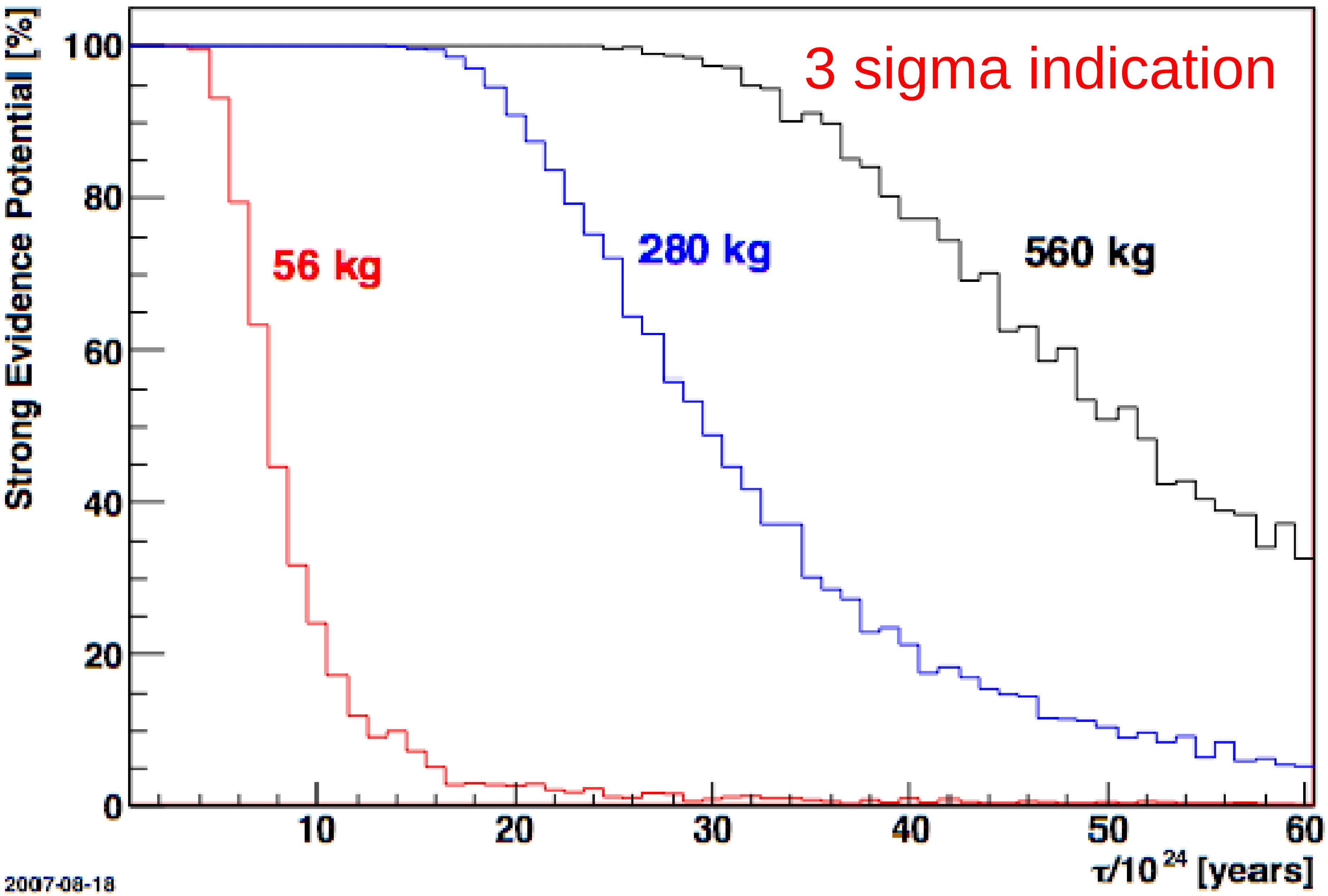
Energy Spectrum in SNO+



Extract Number of 0νββ Events



Discovery Potential



Comparison

Experiment	Isotope	Enriched isotope mass (kg)	$T_{1/2}$ (yr)	$<m_\nu>$ (eV)	Start	Status
CUORE	^{130}Te	203	$2.1\ 10^{26}$	0.03 - 0.07*	2011	Funded
GERDA phase I phase II	^{76}Ge	17.9 40	$3.\ 10^{25}$ $2.\ 10^{26}$	0.2 – 0.5* 0.07 – 0.2*	2009 2011	Funded Funded
Majorana	^{76}Ge	30 - 60	1.10^{26}	0.1 – 0.3*	2011	Funded
EXO-200	^{136}Xe	200	$6.4\ 10^{25}$	0.2 - 0.7*	2008	Funded
SuperNEMO	^{82}Se ^{150}Nd	100 100	$2.\ 10^{26}$ 10^{26}	0.05- 0.09* 0.07	2011	R&D
CANDLES	^{48}Ca	0.5		~0.5	2008	Funded
MOON II	^{100}Mo	120		0.09 – 0.13	?	R&D
DCBA	^{150}Nd	20			?	R&D
SNO+	^{150}Nd	150 - 500	$1\ 10^{25}$	~0.08	2009-10	R&D
COBRA	116Cd, ^{130}Te	420				R&D

Fabrice Piquemal, Lepton Photon 2007

Calculation with NME from Rodin et al., Suhonen et al., Caurier et al. PMN07

Conclusions

- The ^{150}Nd is a good candidate for $0\nu\beta\beta$ decay due to large Q and favorable nuclear matrix element
- The Nd can be dissolved into SNO+ liquid scintillator with long term stability and good optics.
- The large statistics compensate the relatively poor energy resolution in SNO+. The sensitivity to neutrino mass is comparable with other experiments
- The SNO detector has been built. We could start SNO+ soon.