Scintillator Purification for SNO+

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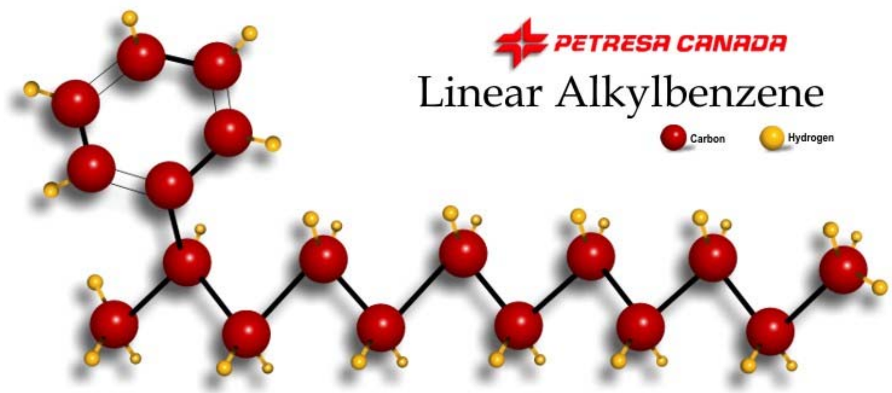
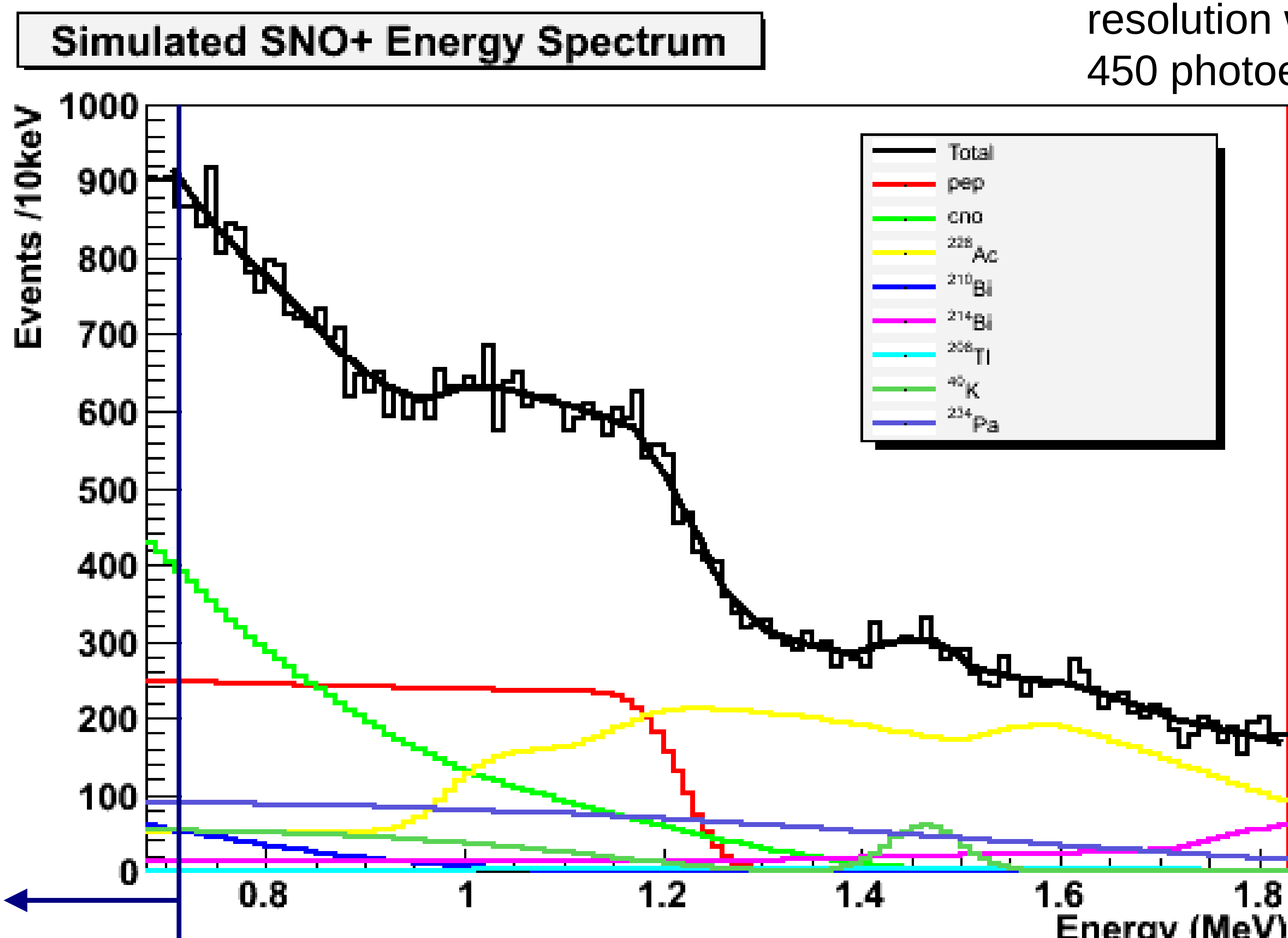
Fill SNO with Liquid Scintillator

- SNO plus liquid scintillator physics program
  - *pep* and CNO low energy solar neutrinos
    - tests the neutrino-matter interaction, sensitive to new physics
  - geo-neutrinos
  - 240 km baseline reactor oscillation confirmation
  - supernova neutrinos
  - double beta decay?!



SNO+ Signals and Backgrounds

resolution with
450 photoelectrons/MeV



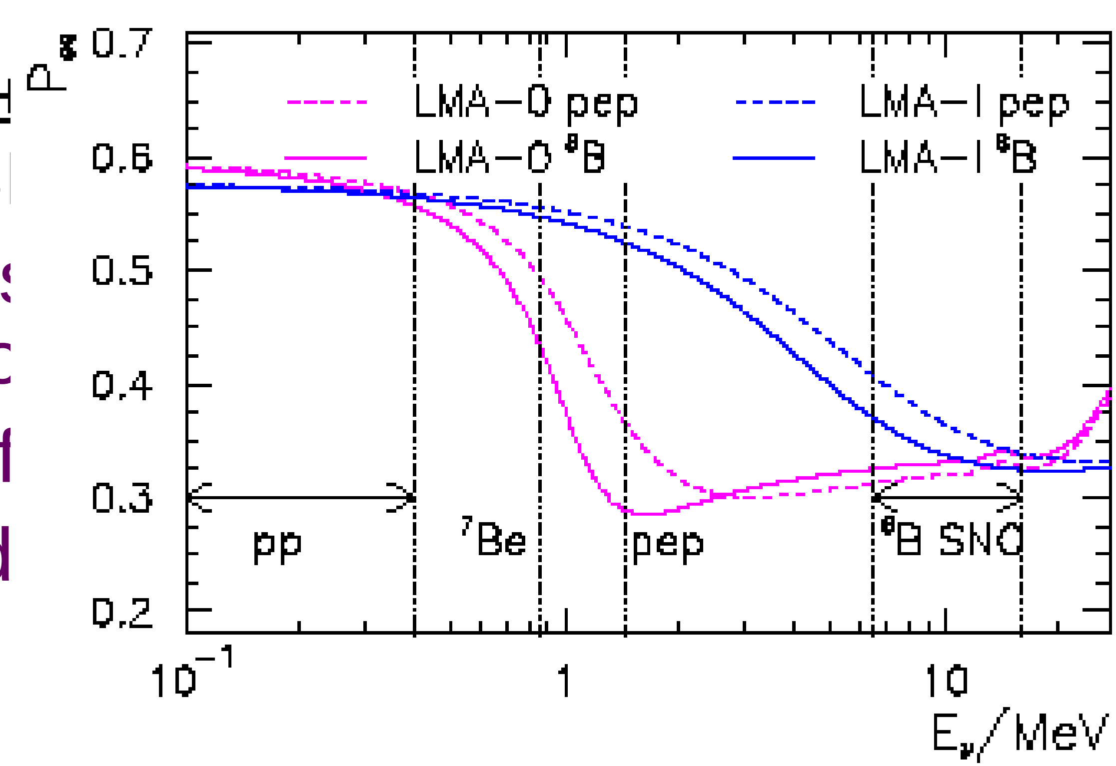
^{7}Be solar neutrinos

pep Solar ν Backgrounds

- radiopurity requirements
  - ^{40}K, ^{210}Bi (Rn daughter)
    - require KamLAND post-purification levels
  - ^{85}Kr, ^{210}Po (seen in KamLAND) not a problem since *pep* signal is at higher energy than ^{7}Be
  - U, Th not a problem at KamLAND levels of scintillator purity
  - ^{14}C not a problem since *pep* signal is at higher energy
  - ^{11}C not a problem because of depth

SNO+ Solar Neutrino Prospects

- with backgrounds at KamLAND levels
  - U, Th achieved
  - ^{210}Pb and ^{40}K post-purification KamLAND targets
- could make a ±
  (stat+syst+SS
- ...a test of the s
  MSW in the mo
- confirmation of
- CNO measured

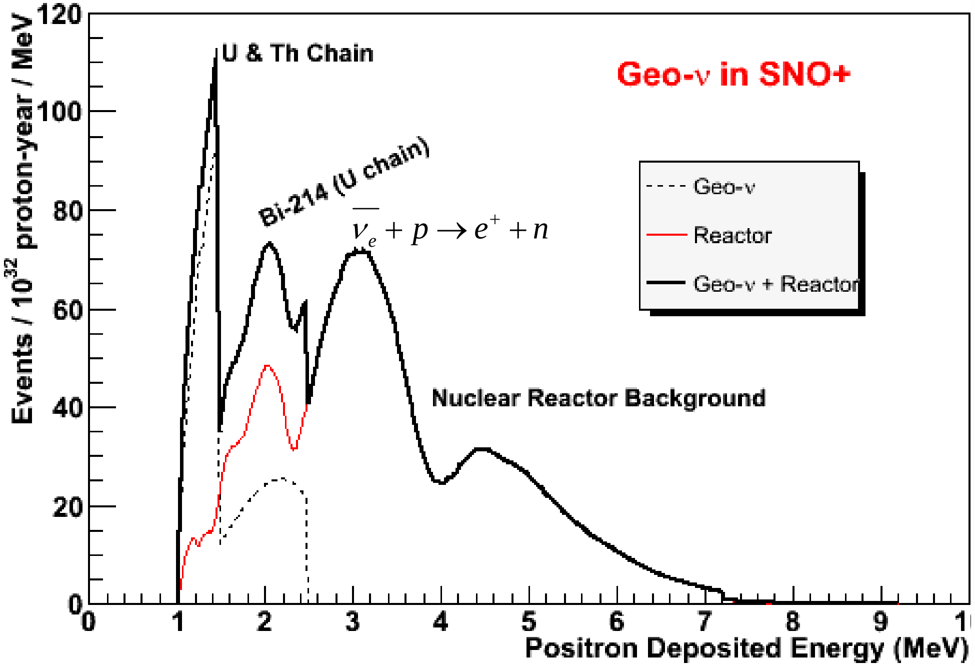


$$\overline{\nu}_e + p \rightarrow e^+ + n$$

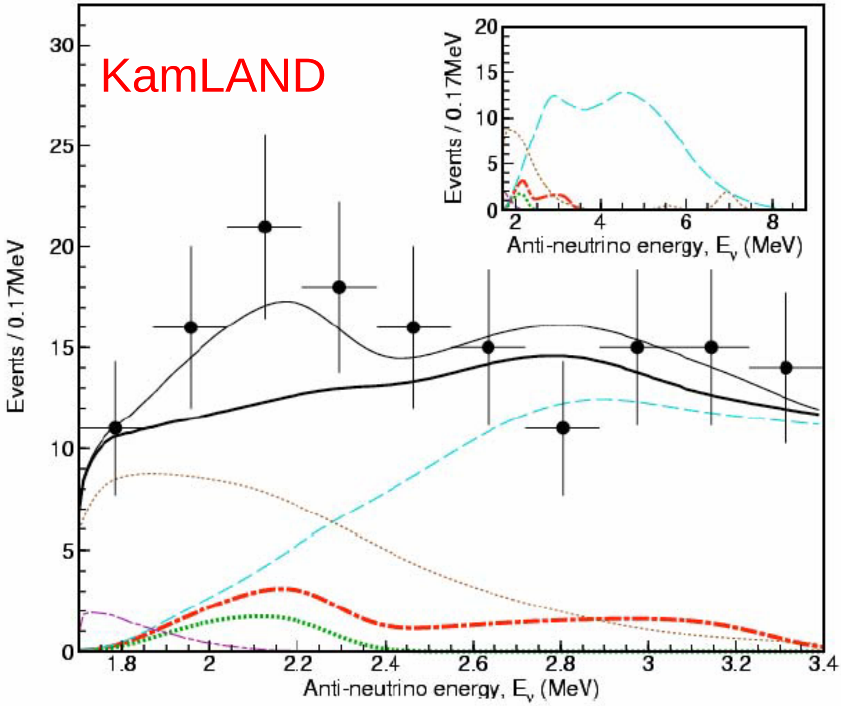
Geo-Neutrino Signal

antineutrino events：

- KamLAND: 33 events per year (1000 tons CH_2) / 142 events reactor
- SNO+: 44 events per year (1000 tons CH_2) / 38 events reactor



SNO+ geo-neutrinos and reactor background



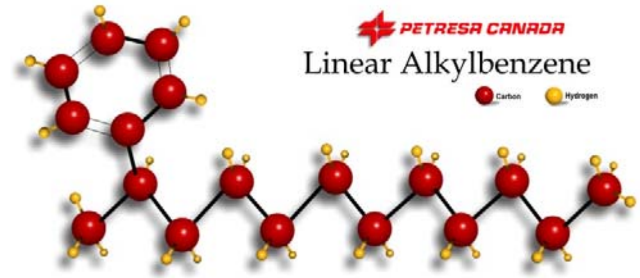
KamLAND geo-neutrino detection…July 28, 2005 in Nature

Geo-ν Backgrounds

- $^{13}C(\alpha,n)$: plan to control this background by controlling Rn exposure in the scintillator
  - KamLAND has ^{210}Pb contamination due to radon exposure during scintillator handling
  - purification to remove ^{210}Pb will help KamLAND and SNO+
- accidental backgrounds: should be small
  - like in KamLAND
- cosmogenic isotope production (e.g. ^{9}Li)
  - tiny background in KamLAND
  - even lower in SNO+

SNO+ Liquid Scintillator

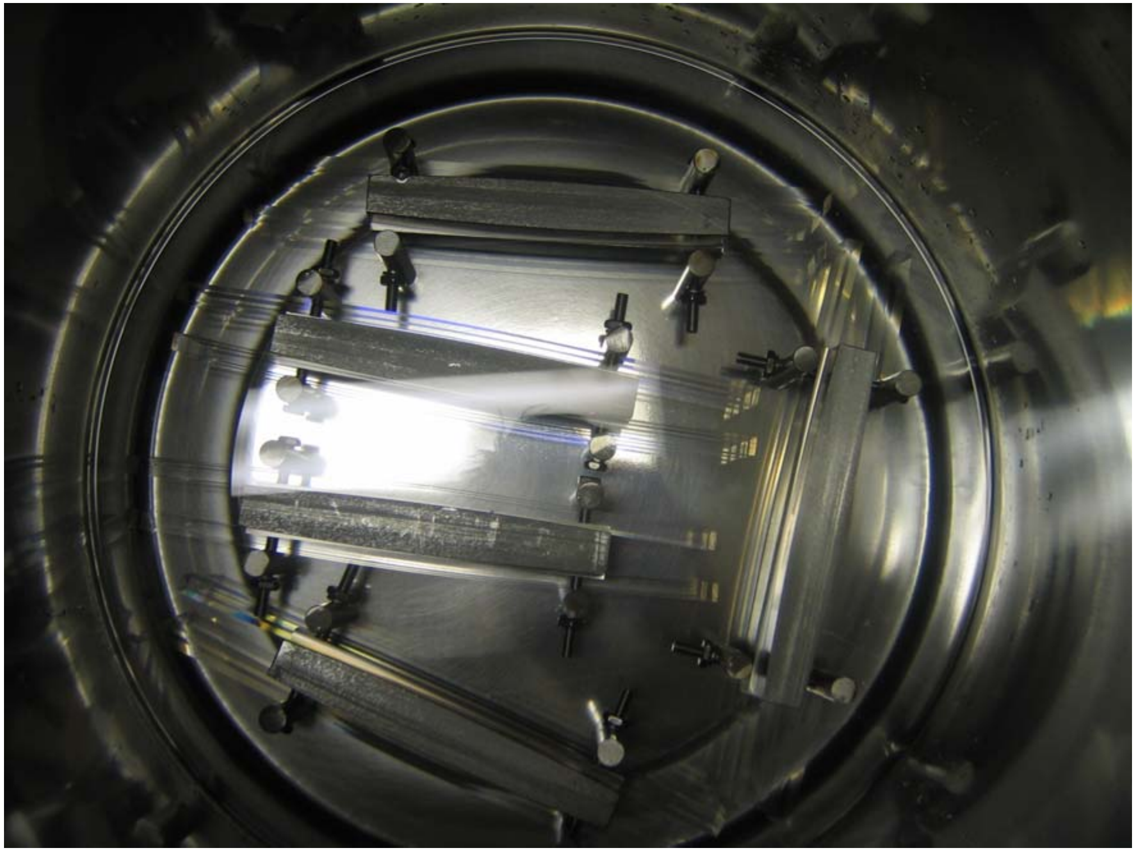
- “new” liquid scintillator
  - linear alkylbenzene
    - compatible with acrylic, undiluted
    - high light yield
    - pure (light attenuation length in excess of 20 m at 420 nm)
    - low cost
    - high flash point (130°C) safe
    - low toxicity safe
    - smallest scattering of all scintillating solvents investigated
    - density ρ = 0.86 g/cm^3
  - SNO+ light output (photoelectrons/MeV) will be approximately 3× that of KamLAND



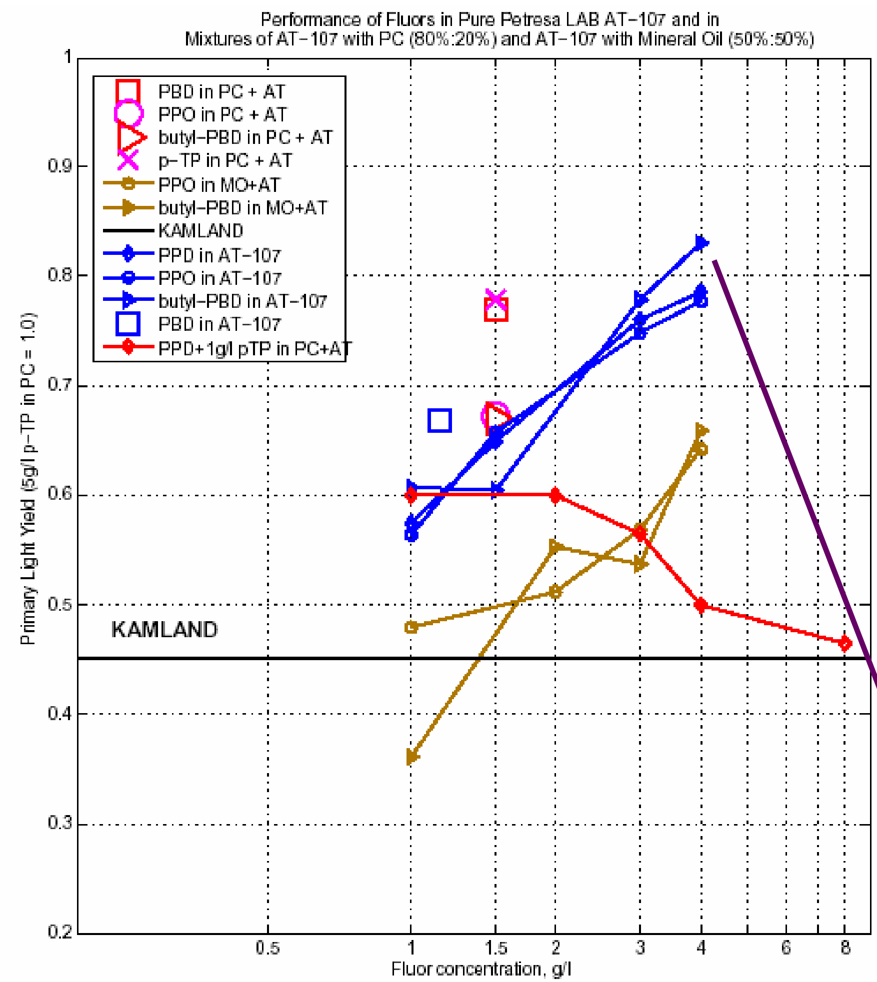
- Double CHOOZ, Daya Bay, Hano Hano, LENA, NOνA now also looking at LAB

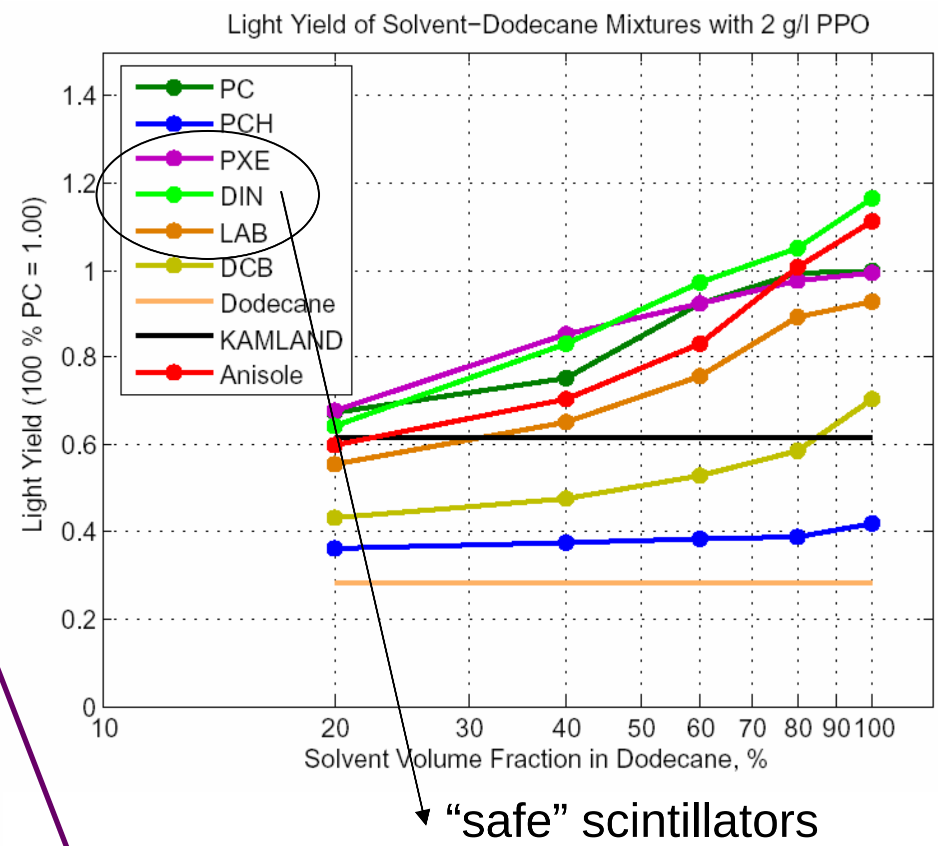
Scintillator-Acrylic Compatibility

- ASTM D543 “Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents”



LAB Light Yield



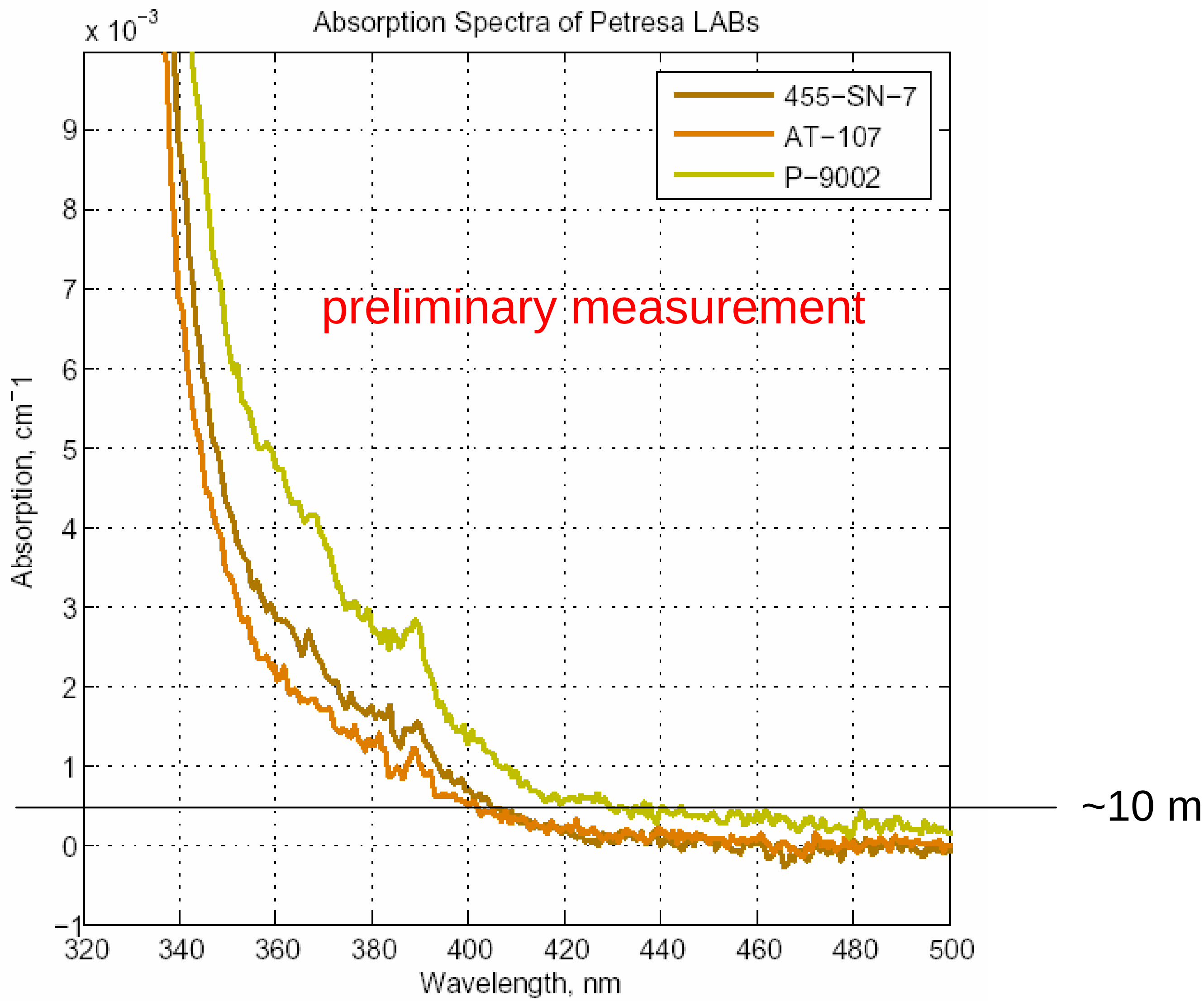


LAB has 50-75% greater light yield than KamLAND scintillator

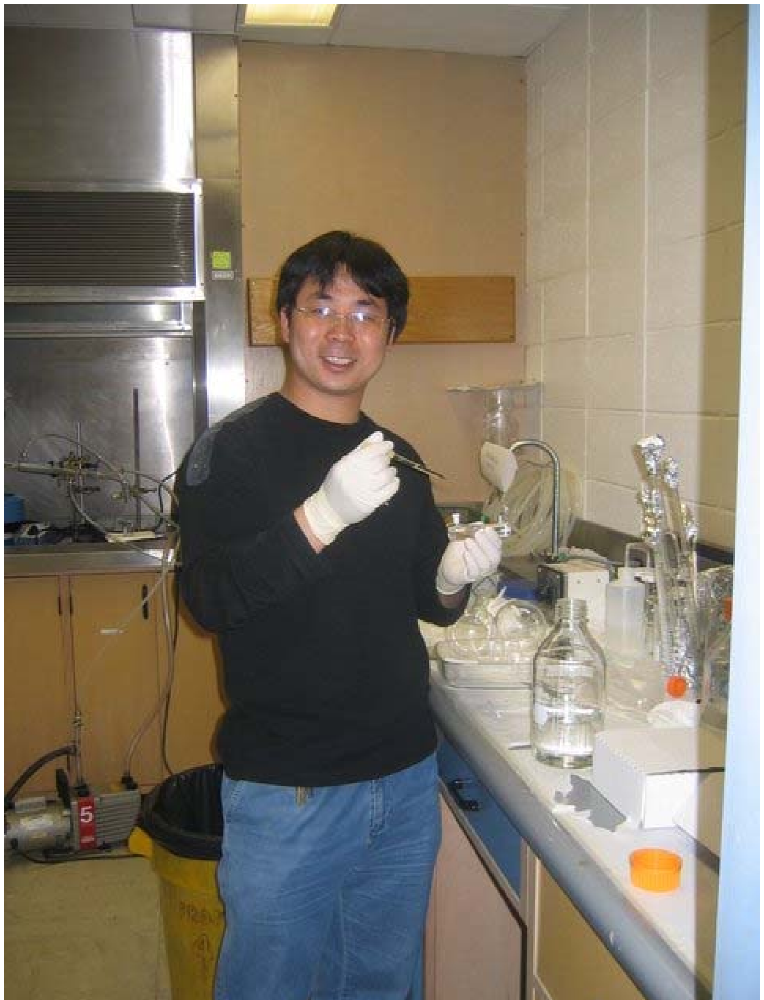
LAB Light Attenuation Length

Petresa LAB as received

attenuation length exceeds 20 m at 420 nm

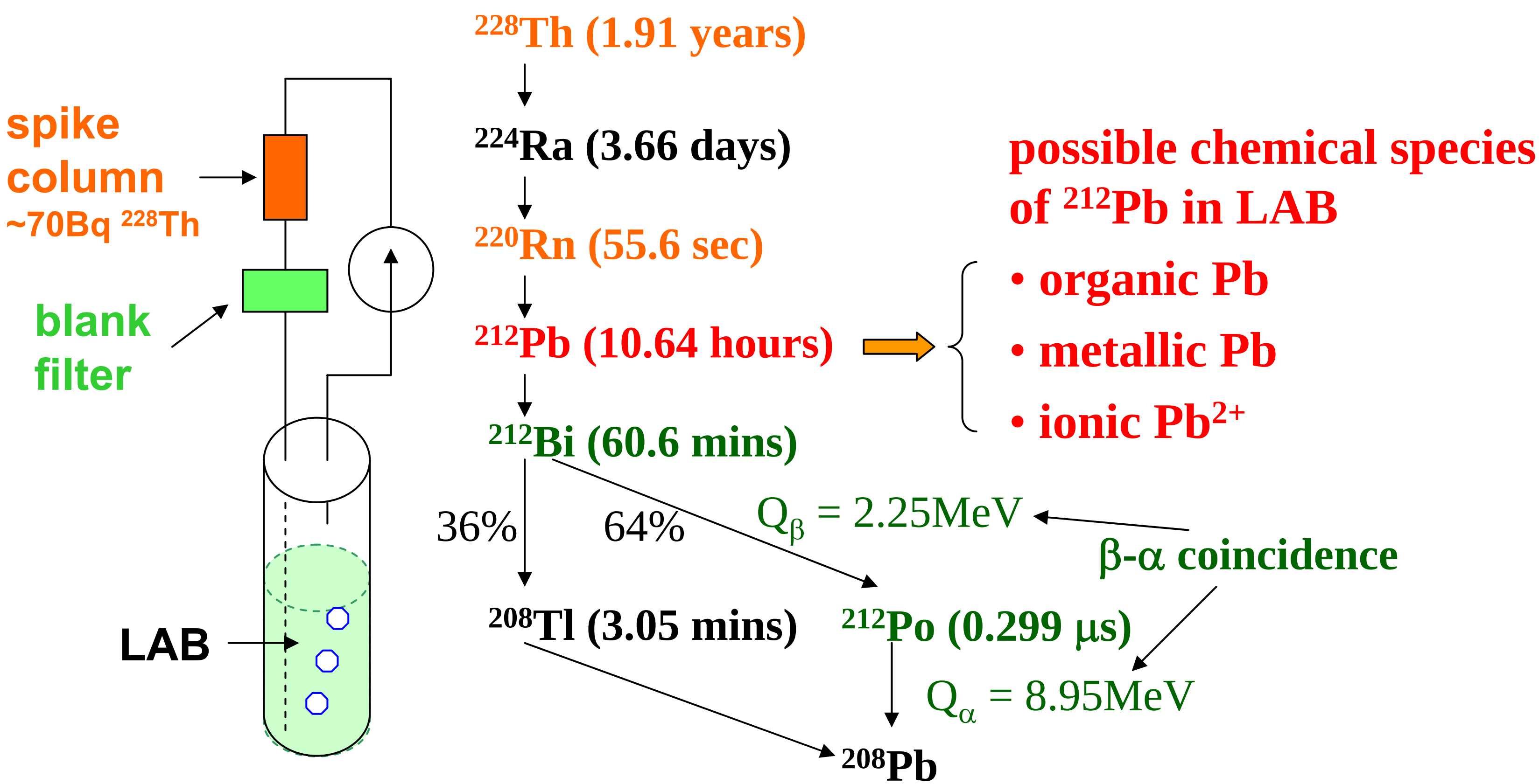


Scintillator Purification Tests



Purification Spike Tests

^{220}Rn from the ^{228}Th spiked HZrO-silica gel column is bubbled into LAB, which decays to ^{212}Pb and counted by β-α coincidence liquid scintillation counting



Water Extraction

- spike LAB or water with ^{212}Pb
- mix them together, then let gravity separate the two phases
- ionic Pb should partition to the water phase
- sample LAB, count ^{212}Pb $\beta-\alpha$
- tried also with 0.1 M nitric acid

Water Extraction Efficiency

exp-ID	spiked in	extracted by	extraction efficiency
water extraction from spiked LAB			
PbSp2	24.6g LAB	19.6g UPW	<19.6%
LAB extraction from spiked UPW			
PbSp4	20.5g UPW	8.1g LAB	<0.5%
acid extraction from spiked LAB			
PbSp6-3	15.1g LAB	10g 0.1M HNO3	<15.5%

conclusions:

1) Pb in the scintillator is probably not just ionic
2) ionic Pb doesn’t go into scintillator
3) water or acid extraction is not so effective

Adsorption Column

- silica gel or alumina
- spike LAB, mix with above (or flow through column)
- Pb gets adsorbed by silica gel or alumina
- count ^{212}Pb $\beta-\alpha$

Adsorption Purification Efficiency

exp-ID	spiked in	extracted by	extraction efficiency	K_d
ThRaSp6-1hr	12.1g LAB	0.1g Al2O3	97.4±0.2%	4536±507
ThRaSp6-2hr	11.8g LAB	0.12g Al2O3	97.8±0.2%	4411±429
ThRaSp7-1hr	11.9g LAB	0.1g silica gel	98.0±0.1%	5674±634
ThRaSp7-2hr	11.5g LAB	0.1g silica gel	95.1±0.3%	2211±247

conclusions:

1) adsorption works
2) around 98% efficiency (far from optimized)
3) need to examine column regeneration (future work)

Vacuum Distillation

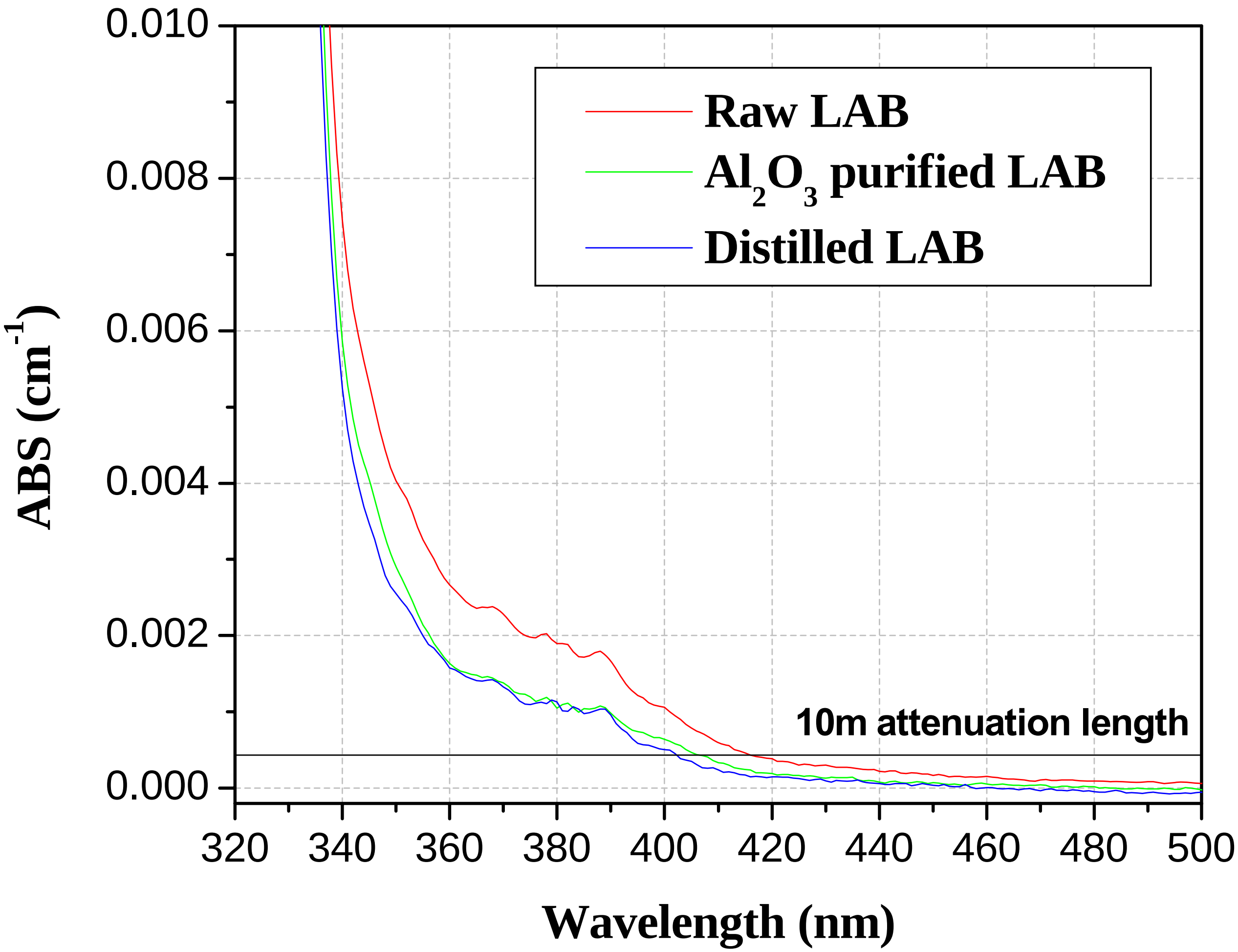
- 50 mL spiked LAB was distilled
  - 70-90°C and 50 microns vacuum
  - note: boiling point at 1 atm is ~300°C

Distillation Efficiency

- >99.85% efficiency

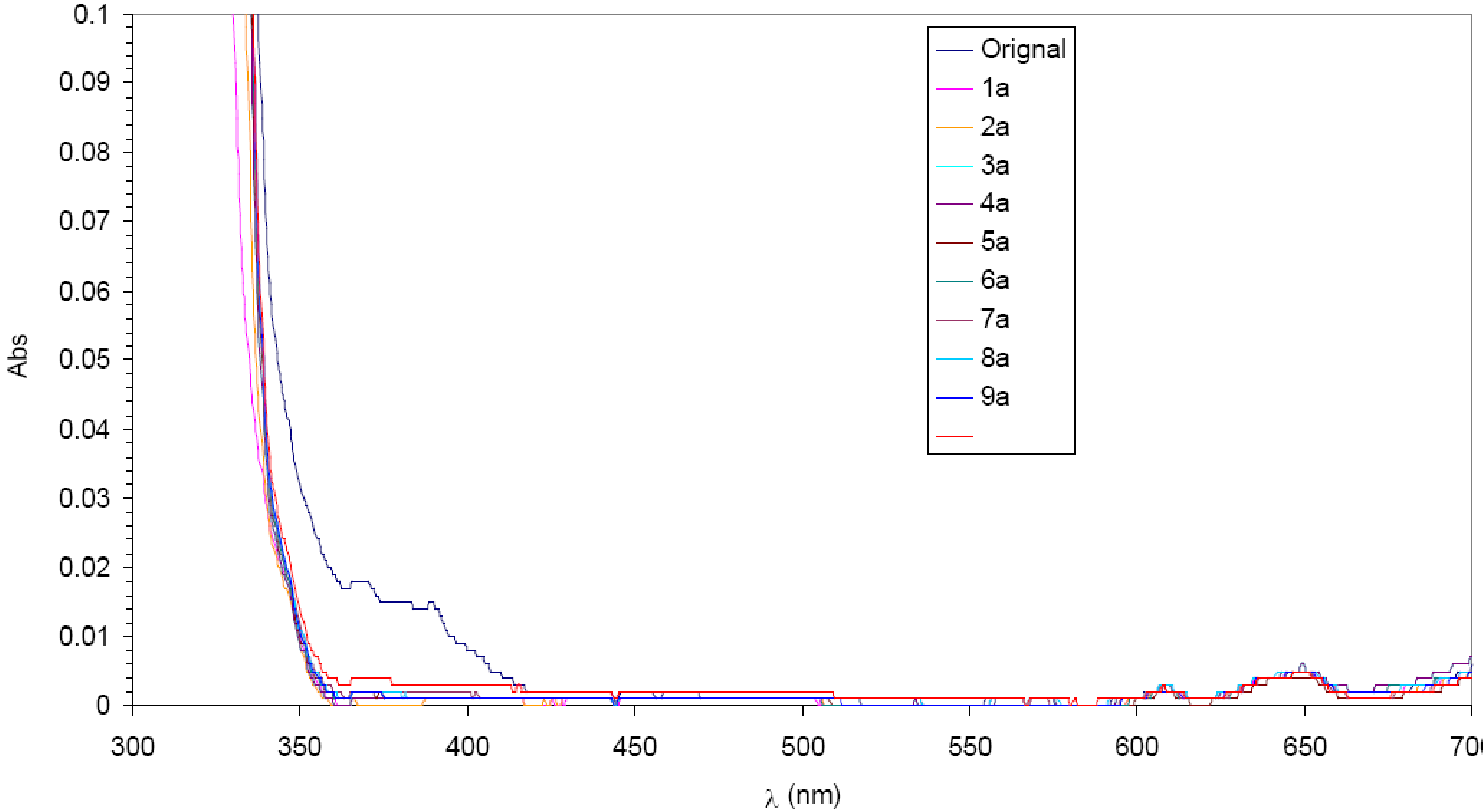
- all ^{212}Pb removed, counted at blank levels
- stronger spike needed to measure the reduction factor
- single pass is surely better than 10^3
- consistent with KamLAND observation of effectiveness of distillation at 10^4 to 10^5 level

Scintillator Optical Purification



More Optical Purification

- dry column purification at BNL



Conclusions and Future Work

- vacuum distillation to be built for SNO+ scintillator purification
- initial tests were successful in distilling LAB and PPO together (due to similar boiling points)
- larger spike tests are planned
- will continue to look at column purification and other techniques such as OSN (organic solvent nanofiltration)

SNO+ Collaboration

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students and research associate working on scintillator purification

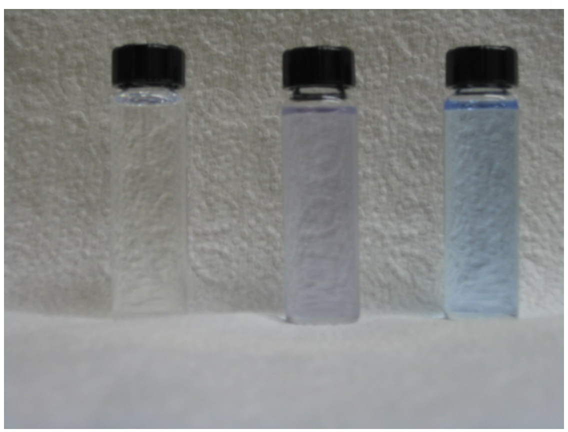
Double Beta Decay: SNO++

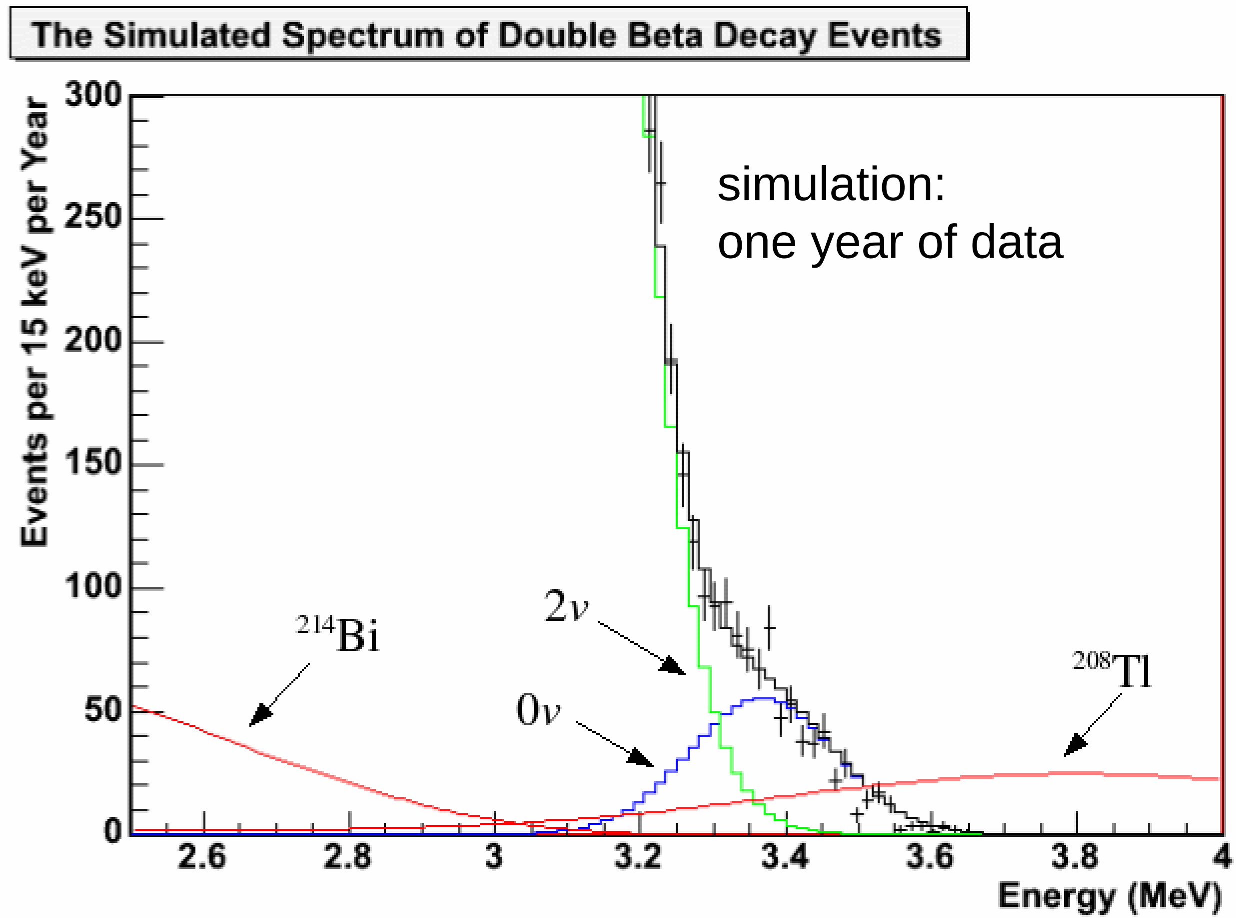
- SNO plus liquid scintillator plus double beta decay isotopes
- we are interested in ^{150}Nd
- enormous quantities and fast rate give high statistics and helps to compensate for poor energy resolution
- 1% natural Nd (or 0.1% loading of 56% enriched ^{150}Nd) is 560 kg of isotope
- Nd-carboxylate dissolved in scintillator

Klapdor-Kleingrothaus et al.,
Phys. Lett. B **586,** 198, (2004)

Test $<m_\nu> = 150$ meV

0ν: 1000 events per year with 1% natural Nd-loaded liquid scintillator in SNO++





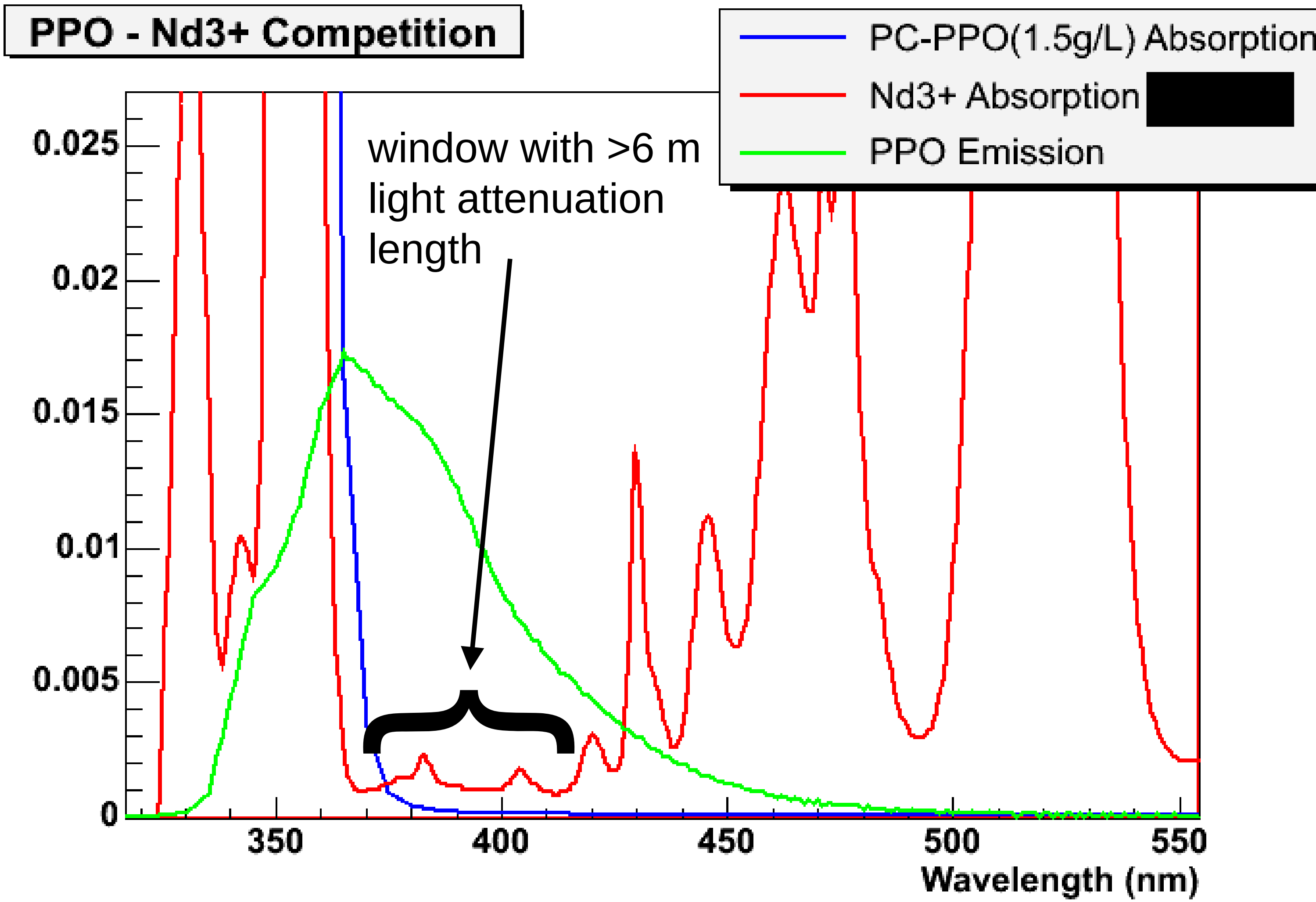
maximum likelihood statistical test of the shape to determine 0ν and 2ν components…~240 units of $\Delta\chi^2$ significance after only 1 year!

SNO++ Double Beta Sensitivity

- insensitive to internal radon backgrounds
- insensitive to external backgrounds (2.6 MeV γ)
- internal Th is the main concern
  - and 2ν background, of course

- for m_ν = 50 meV, $0\nu\beta\beta$ signal is ~50 events/yr in the upper-half of the peak, with S:B about 1:1
  - based upon KamLAND Th levels in scintillator and known 2ν double beta decay backgrounds
- understanding energy response is critical
- ...potential is there for a double beta decay experiment

Nd-carboxylate in Pseudocumene



Nd Double Beta Decay Experiment

- we can make Nd-loaded LAB scintillator
- French AVLIS facility could enrich 100's of kg of ^{150}Nd
- Monte Carlo shows 0.1% Nd-loaded LAB scintillator has 400 photoelectrons/MeV light output (which is enough)

- ...can we purify Nd-loaded scintillator?