SNO+

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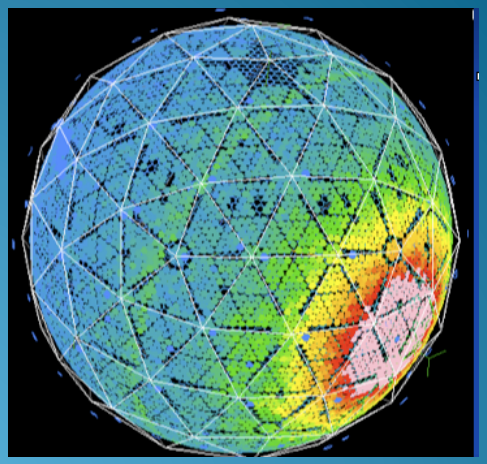
Scintillator, calibration and its rich neutrino physics program

Erice 2009



Contents

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    - pep neutrinos
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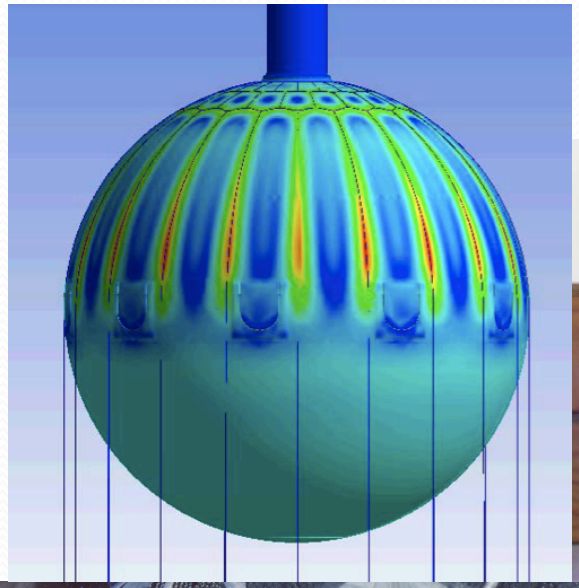
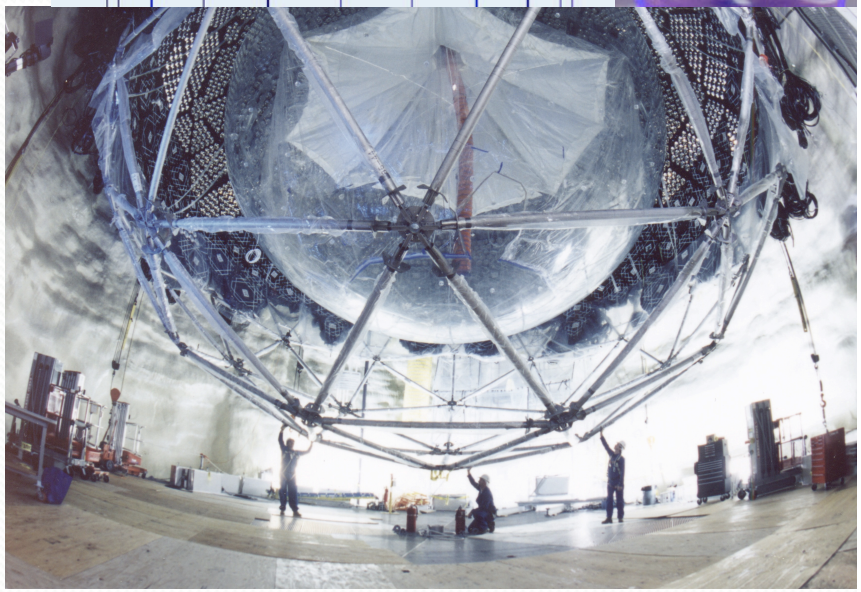
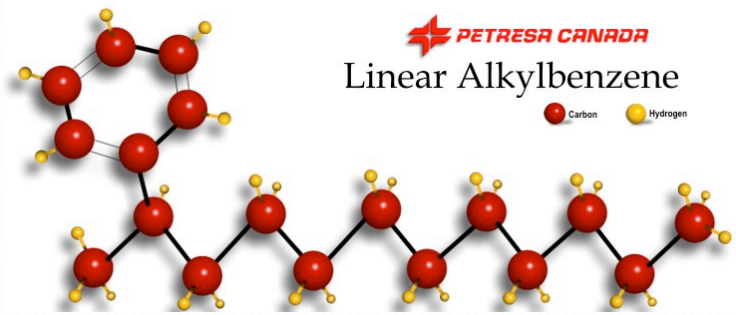
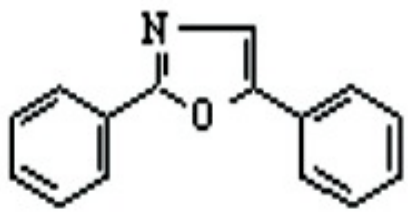
- Summary & conclusions



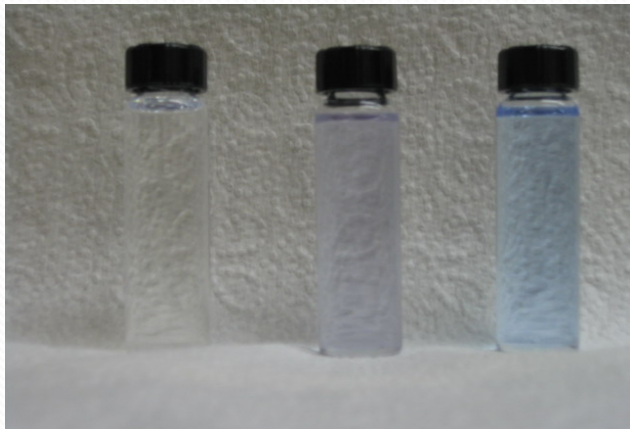


SNO+ scintillator

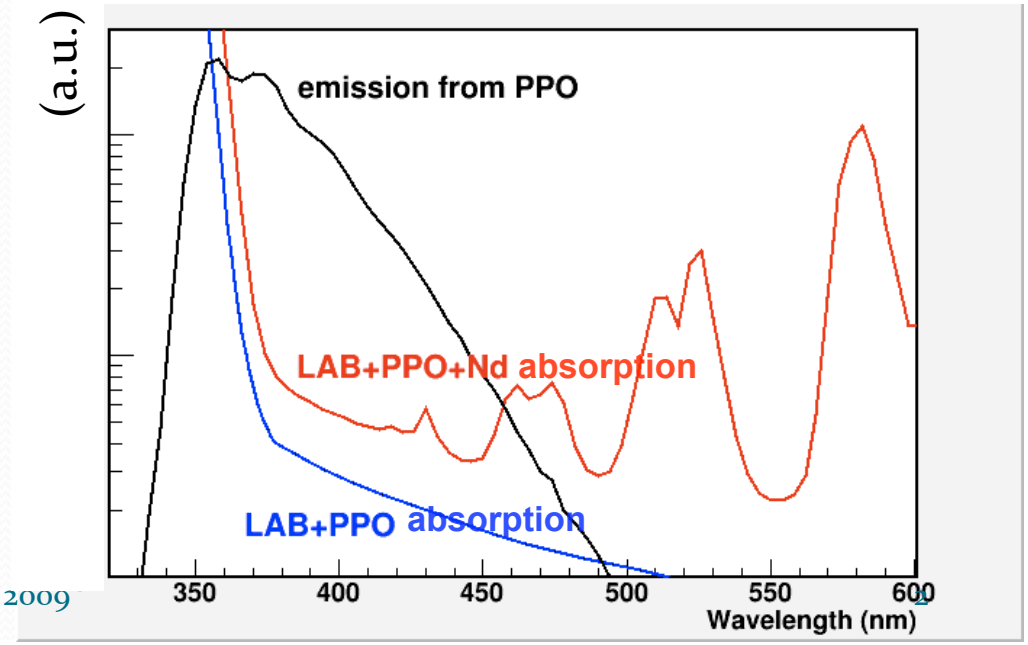




2,5-Diphenyloxazole
PPO



- Compatible with acrylic (undiluted), but not polypropylene
- Safe: high flash point, low toxicity
- High light yield, long attenuation length
- Low cost
- Density = 0.86 g/cm³ (buoyancy!)
- *Nd-carboxylate solutions have been stable at 0.1% and 1% concentrations for over 2.5 years.*

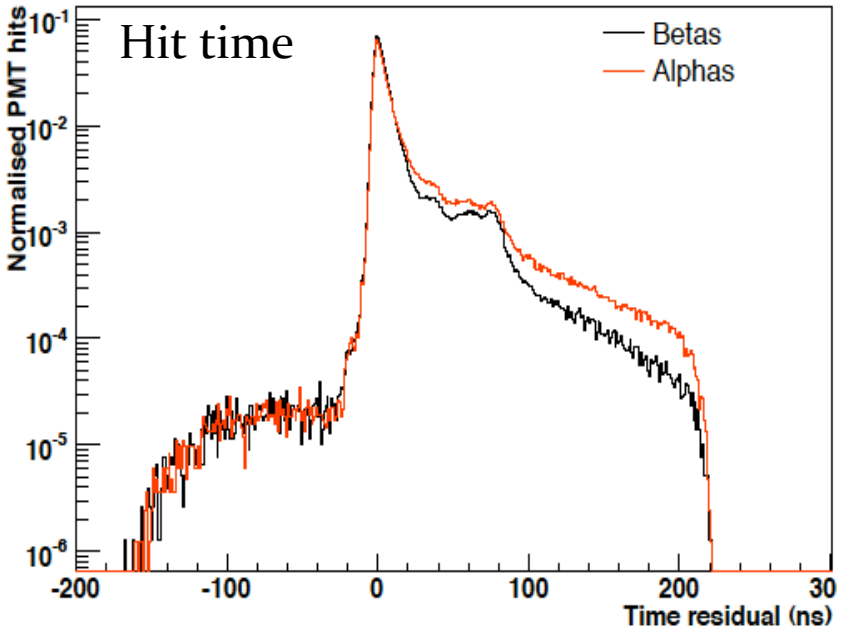


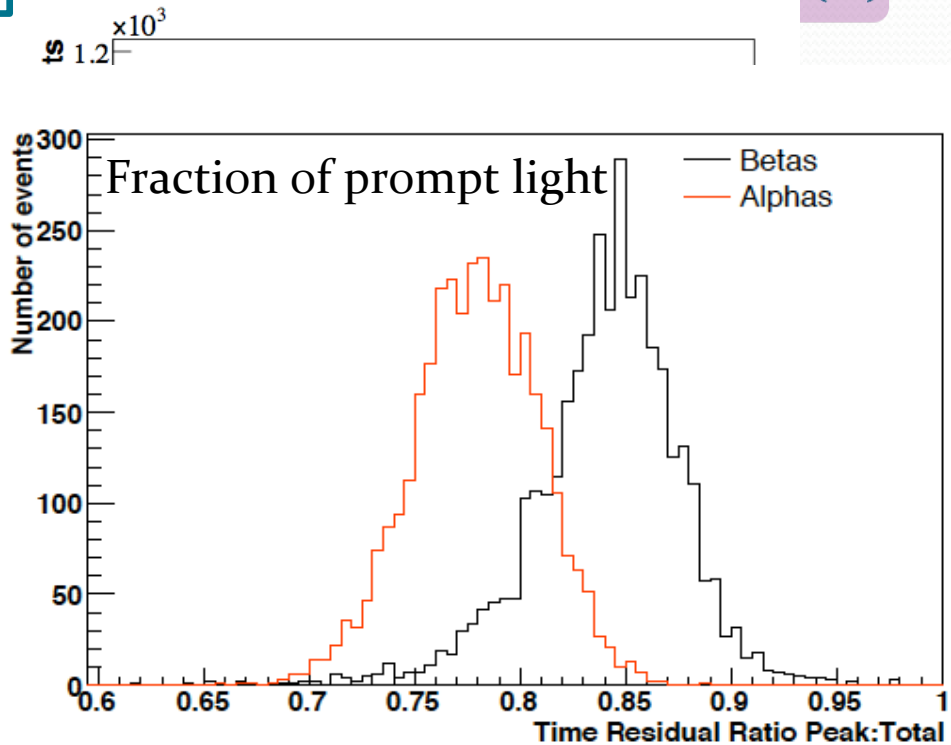
Scintillator response

- 450 observed photons per MeV
- Resolution of 5% at 1 MeV
- k_B = 71.9±3.9 μm/MeV
- We can observe the difference between αs and βs

"bucket" test in water-filled SNO+

Study response to αs (^{222}Rn) and





Fluid processing in SNO+

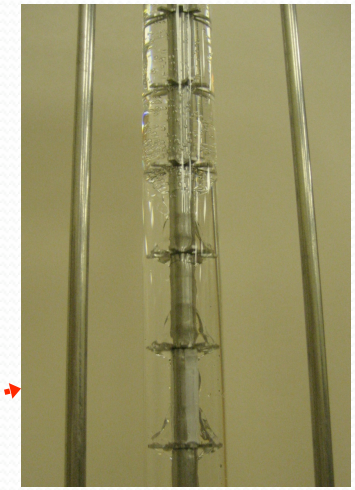
Several fluids to handle

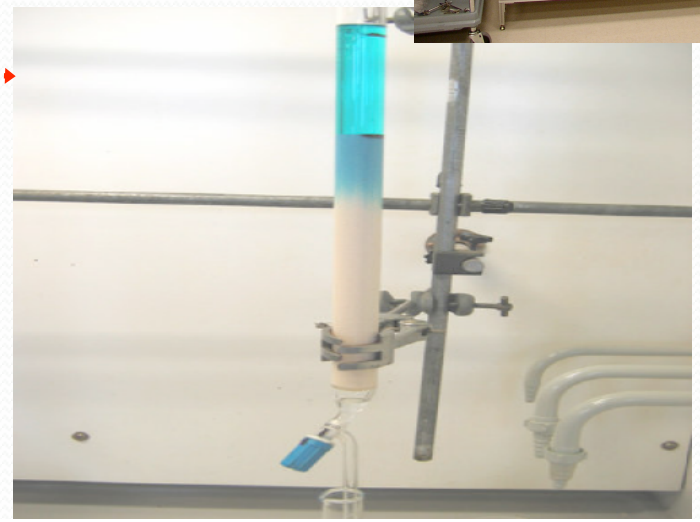
Light water, bulk scintillator, fluor (PPO) solution, neodymium-loaded compound

Scintillator purification & processing

- Purification methods:
  - water & gas stripping
  - distillation
  - metal scavenger
- Designed by KMPS (Borexino)
- Purification system pit excavation underway

Test set-ups



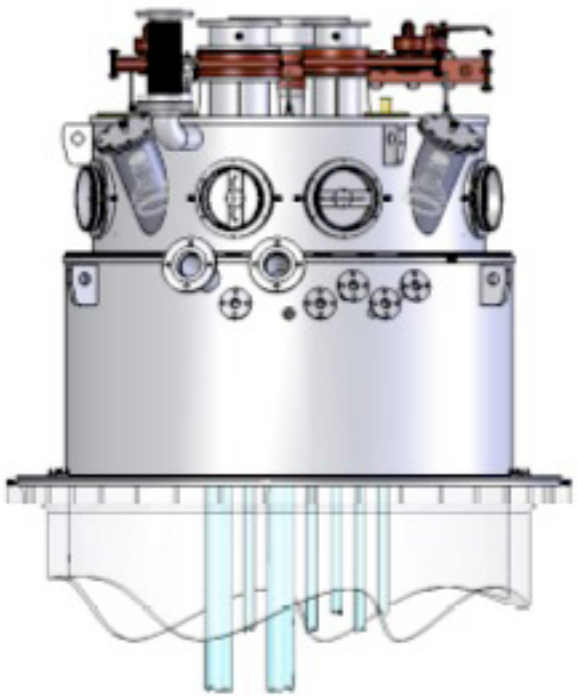


Calibration

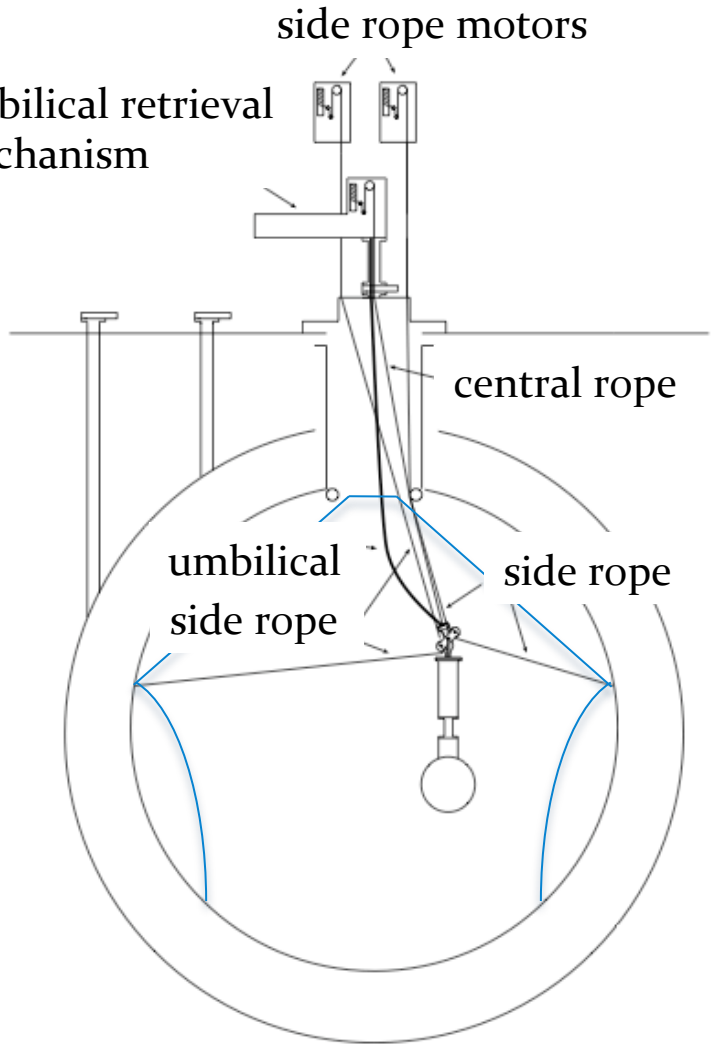
New calibration program is being developed. Following the lessons of SNO, it is focused around redundancy and continuous monitoring.

Much of the related hardware is also being adapted.

New 'glovebox'



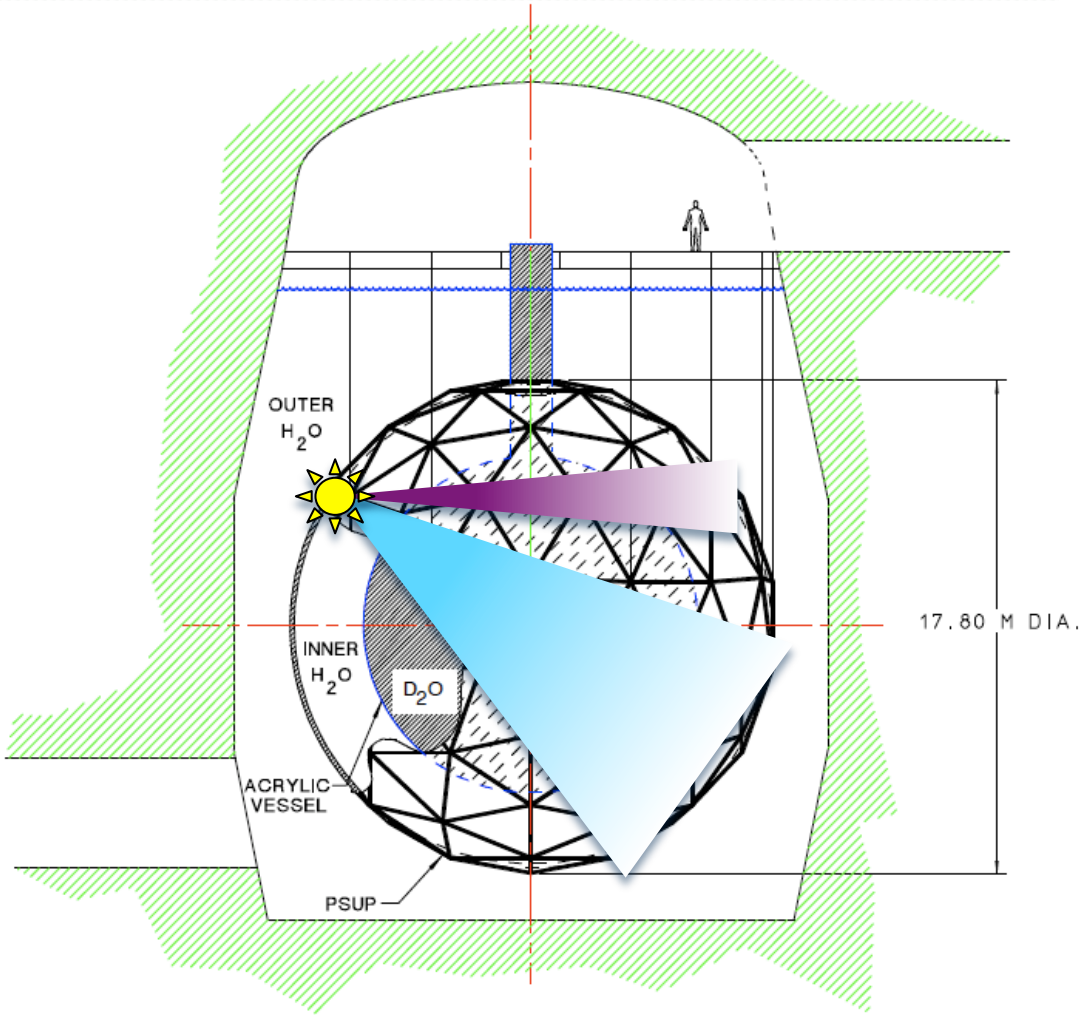
Adapted manipulator system



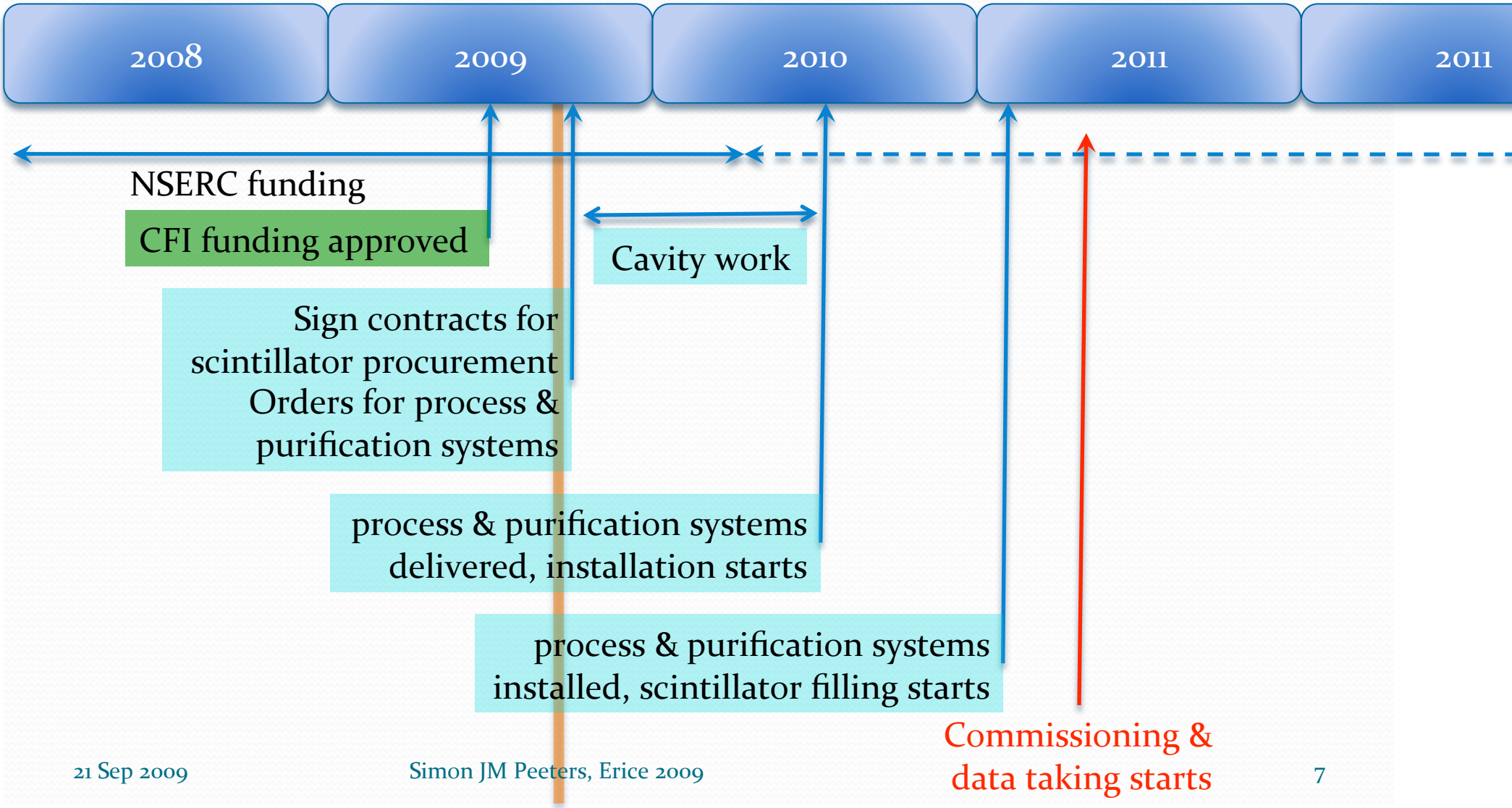
Embedded LED Light Injection Entity (ELLIE)

Collimated fibres mounted on the PMT holding structure emitting LED light for:

- Timing calibration (fast light pulses, broad bundles)
- Absorption length monitoring (different wavelengths, collimated bundles)
- Position reference for camera system (diffused, continuous light)

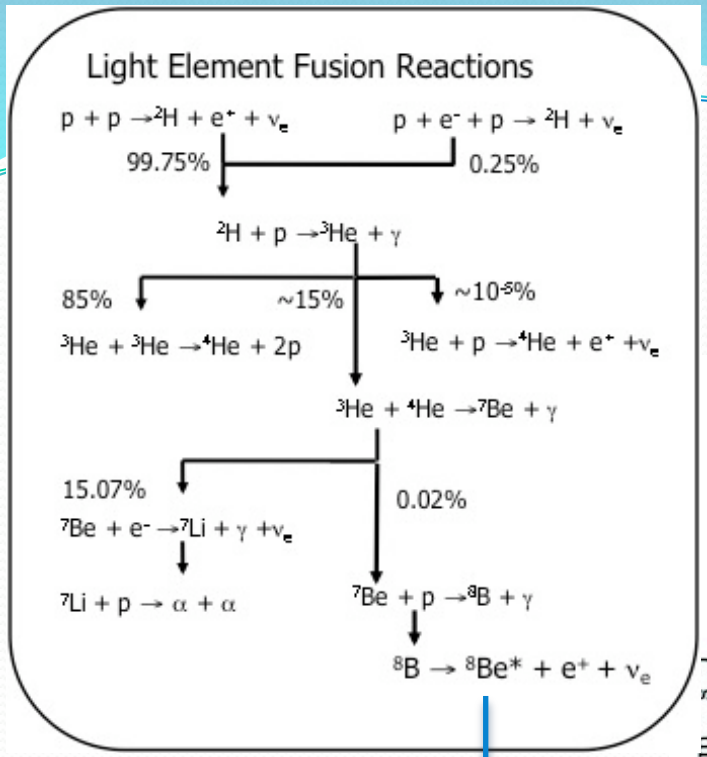


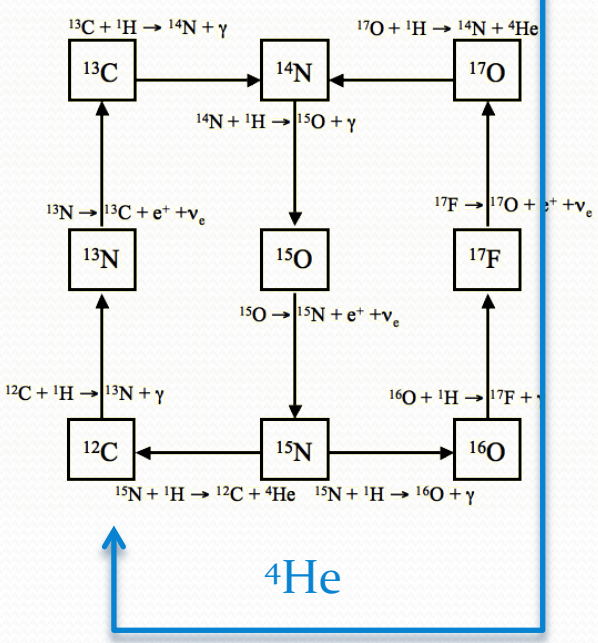
SNO+ program (selection thereof)

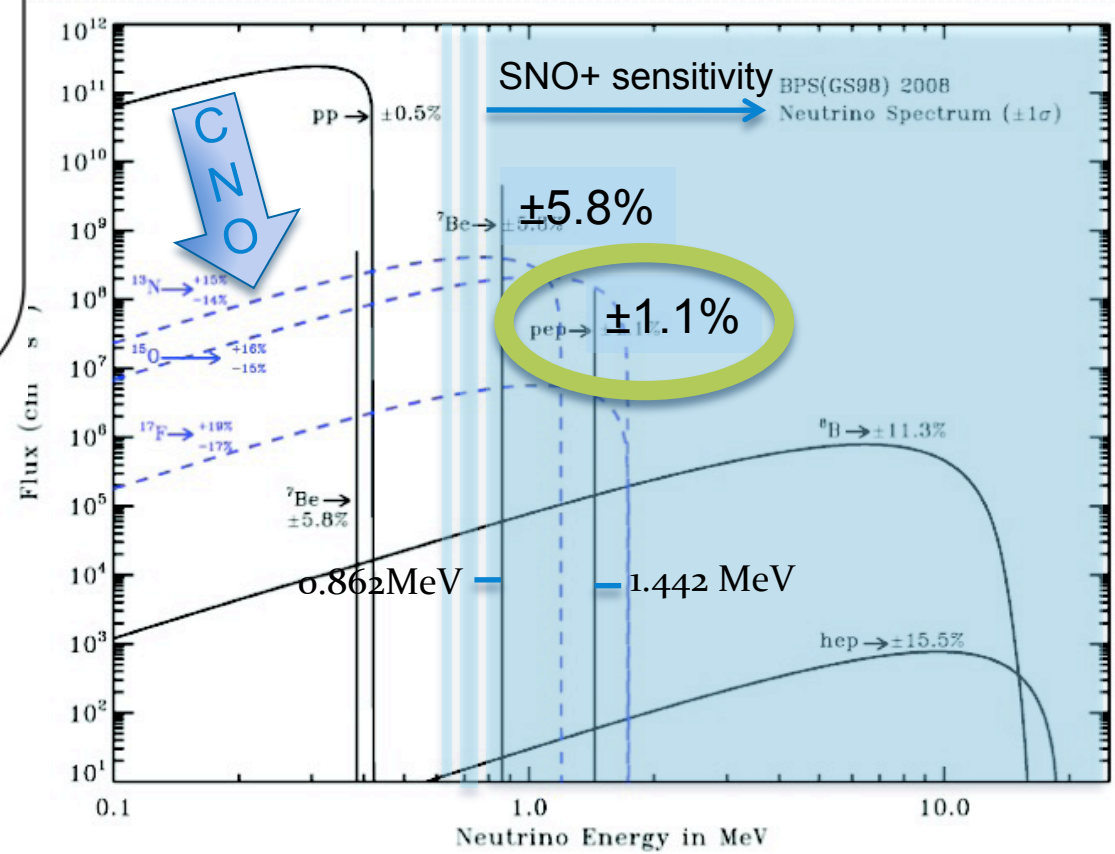


(non-DBD) Neutrino Physics

Solar neutrinos



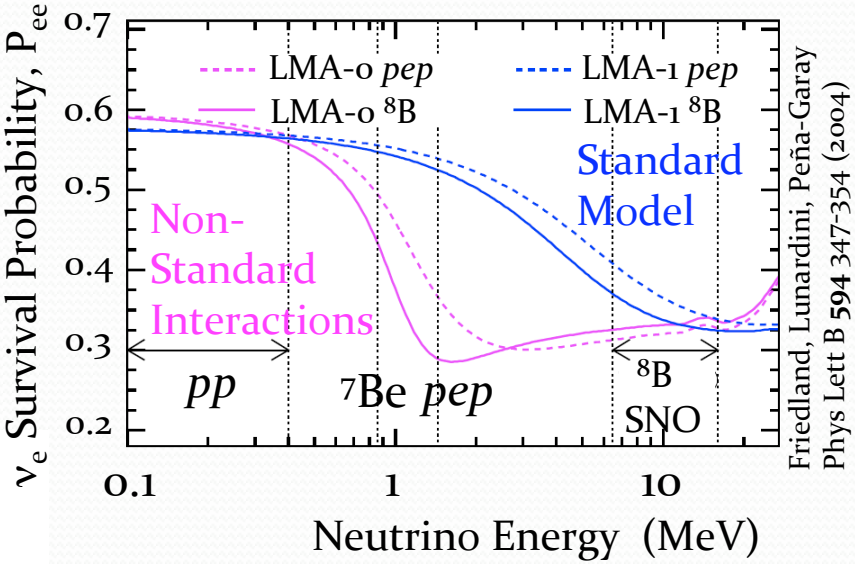




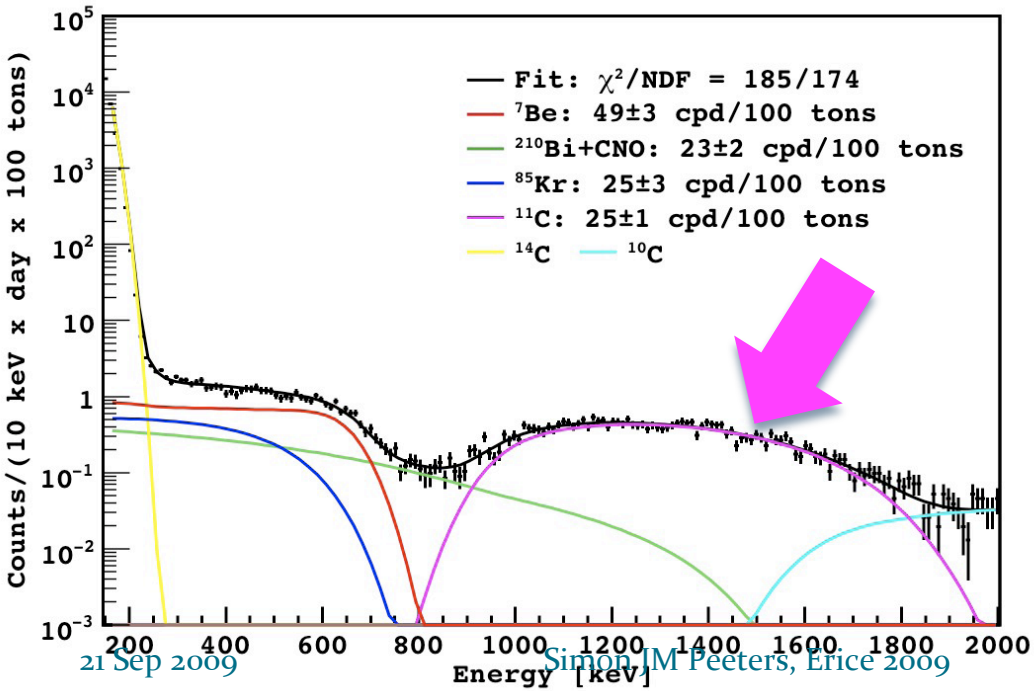
Observed in (pure) LS by elastic scattering on electrons.

pep neutrinos

P_{ee} for pep is very sensitive to NSI
(see also H. Minakata's talk)



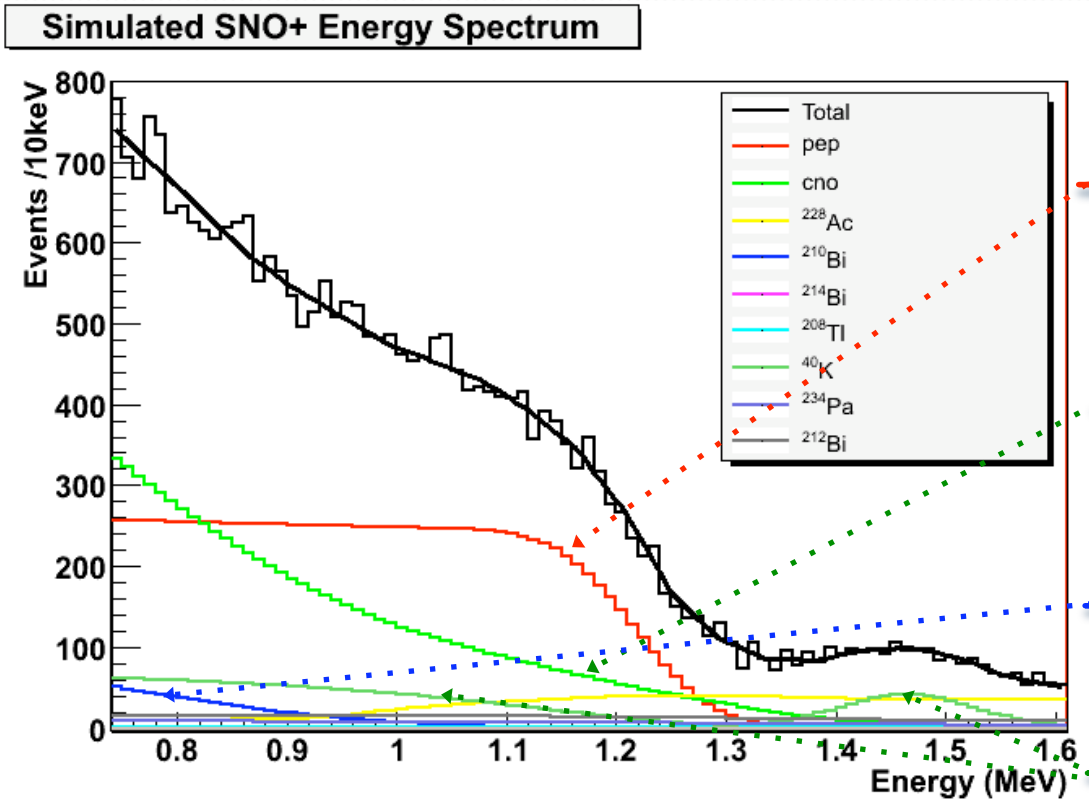
Borexino Collaboration, Phys. Rev. Lett. 101, 091302 (2008)



Depth is important:
SNO+ (6000 mwe),
compared to:

- Borexino (3500 mwe),
- KamLAND (2700 mwe)

Solar signal & backgrounds



***pep* signal**
(4000 events/yr)
After 3 years: ~5% uncertainty

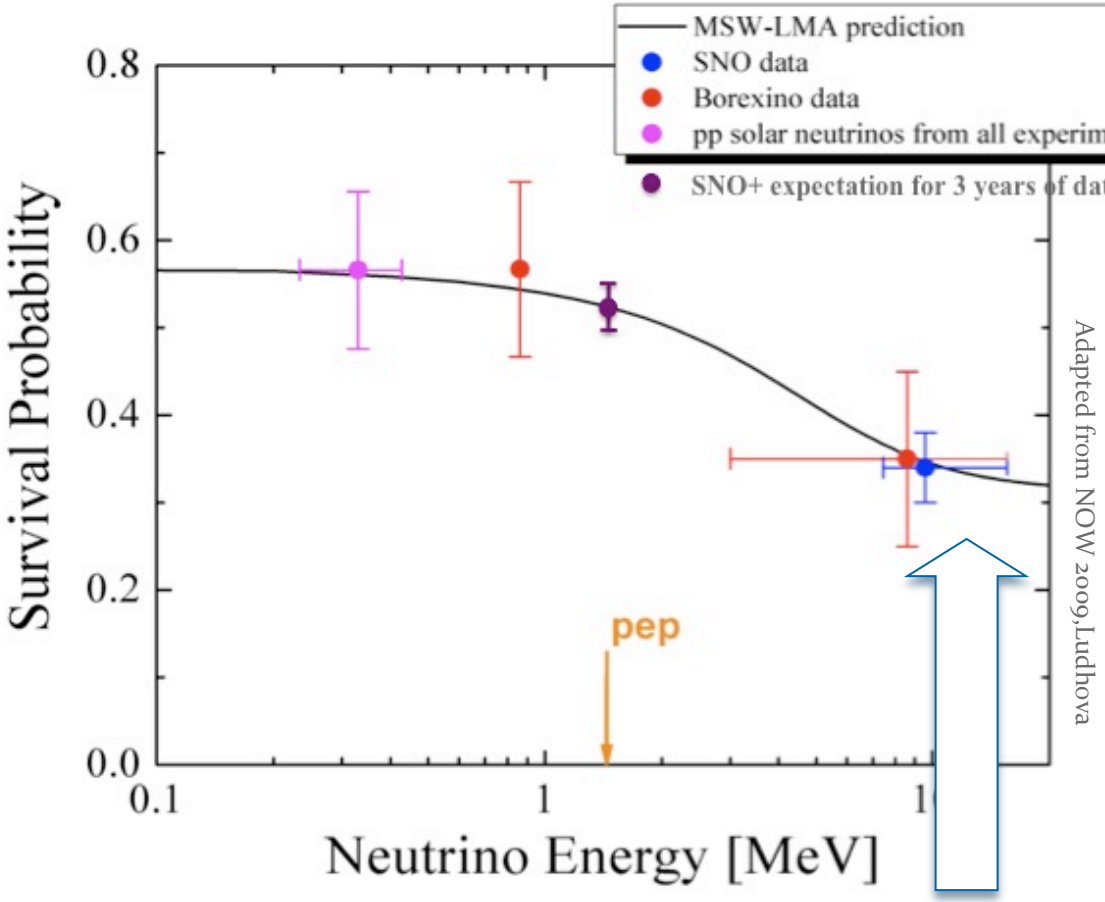
CNO Signal
After 3 years: ~8% uncertainty

^{210}Bi background
Can be inferred from ^{210}Po peak

^{40}K background
Can be constrained by peak

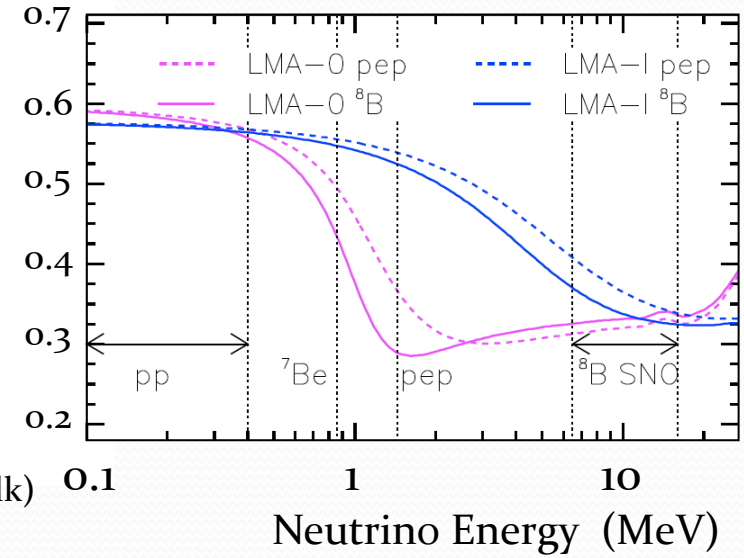
^{210}Bi (U), ^{40}K are most important for solar studies.
Borexino has demonstrated similar levels of backgrounds.

pep expectation



Compare with (previously shown) NSI expectations:

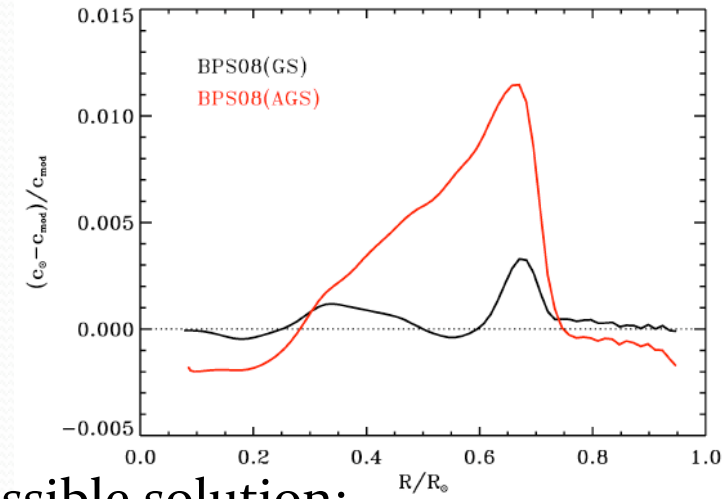
Friedland, Lunardini, Peña-Garay
Phys Lett B **594** 347-354 (2004)



Additional constraints from SK (see M Shiozawa's talk)

CNO & the solar opacity problem

Incompatible with helioseismology measurements:



Possible solution:

(see Haxton and Serenelli, Ap. J. 687, 678 (2008))

core is different than the convective zone (opacity).

(See also A. Kopylov's talk)

Improved 3D hydrodynamic modeling (Asplund, Grevesse and Sauval, 2005) of result in lower Z by a factor of almost 2!

Source	BPS08(GS)	BPS08(AGS)	Difference
pp	$5.97(1 \pm 0.006)$	$6.04(1 \pm 0.005)$	1.2%
pep	$1.41(1 \pm 0.011)$	$1.45(1 \pm 0.010)$	2.8%
hep	$7.90(1 \pm 0.15)$	$8.22(1 \pm 0.15)$	4.1%
^{7}Be	$5.07(1 \pm 0.06)$	$4.55(1 \pm 0.06)$	10%
^{8}B	$5.94((1 \pm 0.11)$	$4.72(1 \pm 0.11)$	21%
^{13}N	$2.88(1 \pm 0.15)$	$1.89(^{+0.14}_{-0.13})$	34%
^{15}O	$2.15(^{+0.17}_{-0.16})$	$1.34(^{+0.16}_{-0.15})$	31%
^{17}F	$5.82(^{+0.19}_{-0.17})$	$3.25(^{+0.16}_{-0.15})$	44%
Cl	$8.46^{+0.87}_{-0.88}$	$6.86^{+0.[illegible]}_{-0.7[illegible]}$	
Ga	$127.9^{+8.1}_{-8.2}$	$120.5^{+6.9}_{-7.1}$	
	High Z	Low Z	

arXiv:0811.2424

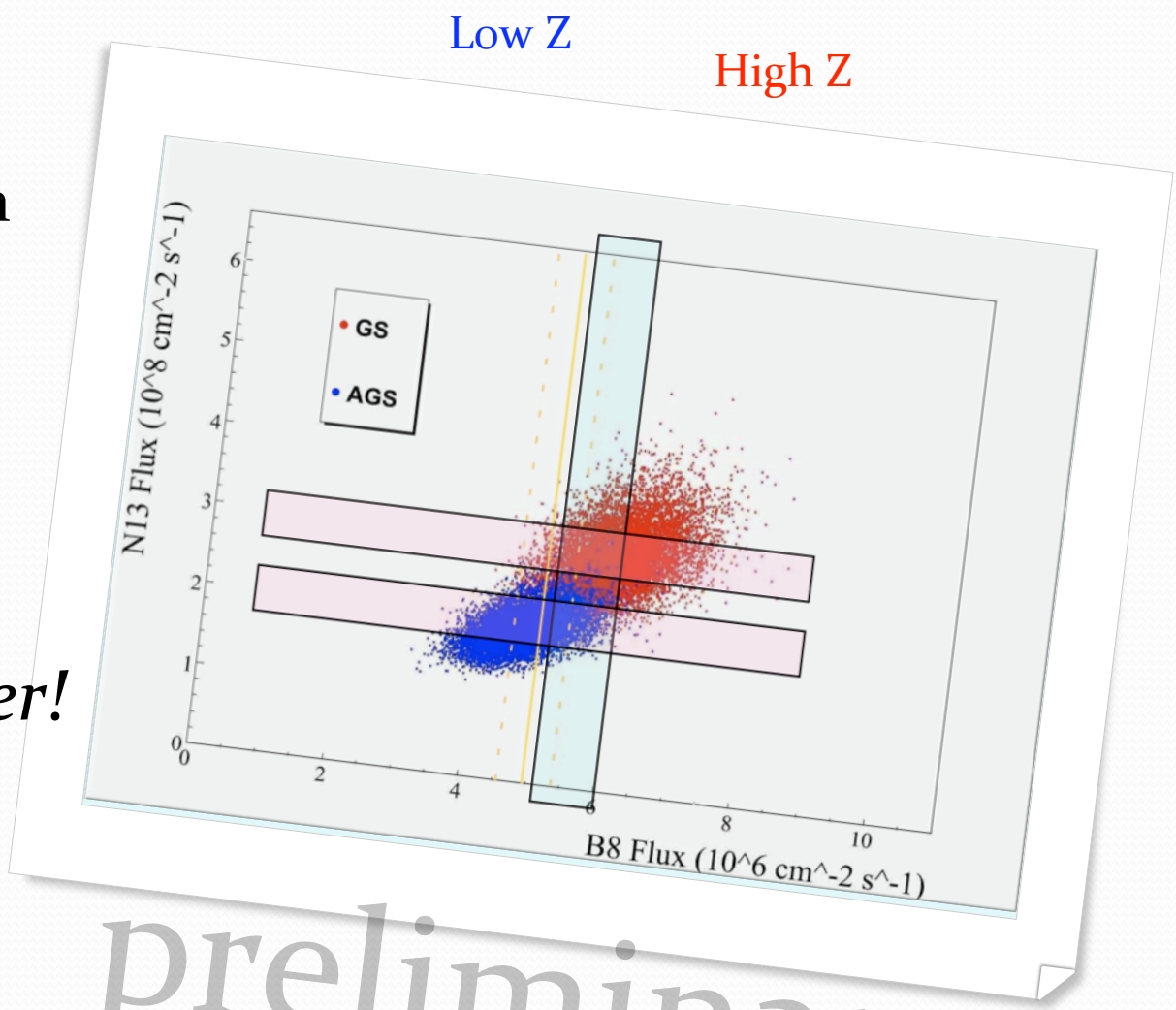
probe solar core with neutrinos

CNO

Use ^{8}B to constrain the environmental variations relevant for CNO

SNO & SNO+ working together!

(Assuming measurement of CNO to ~10%)



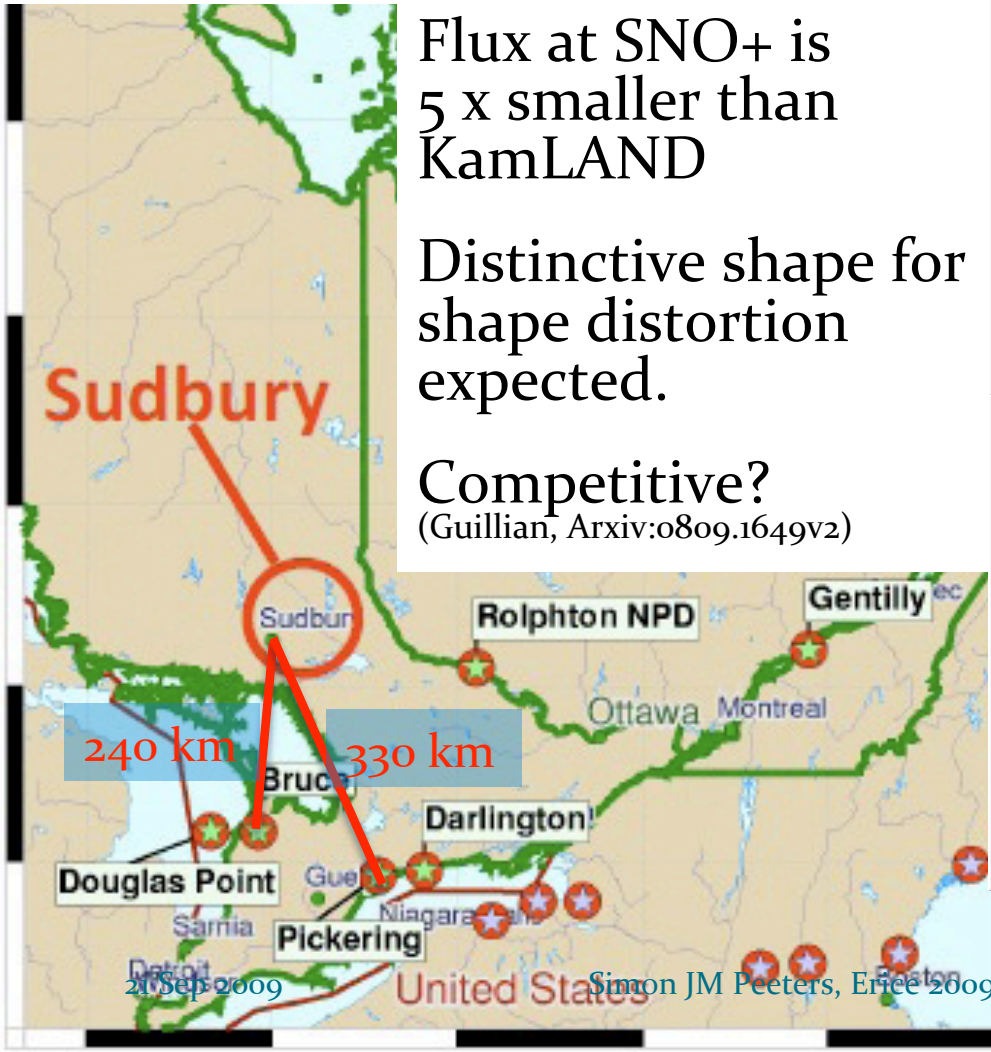
Reactor anti-neutrinos

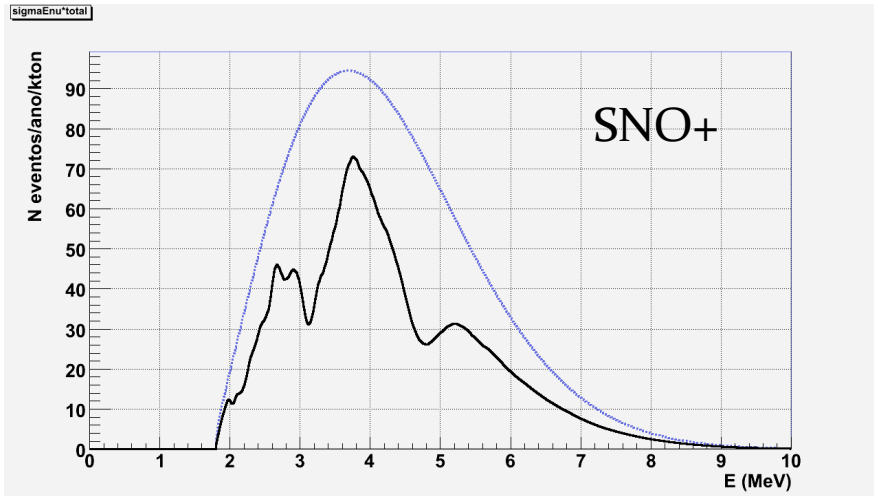
Observe via IBD: $\bar{\nu}_e + p \rightarrow n + e^+$

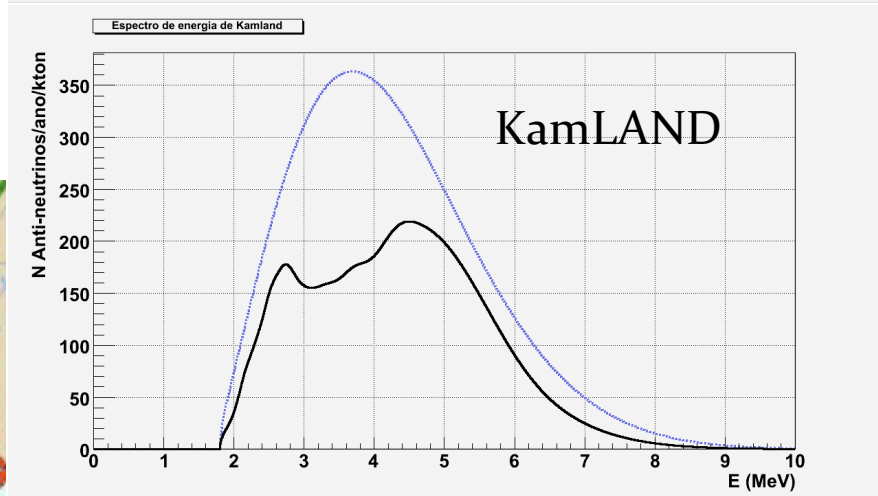
Flux at SNO+ is 5 x smaller than KamLAND

Distinctive shape for shape distortion expected.

Competitive?
(Guillian, Arxiv:0809.1649v2)



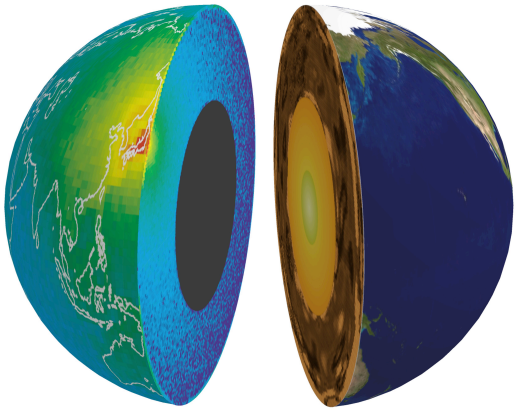




Geo anti-neutrinos

(see also S.Smith's talk)

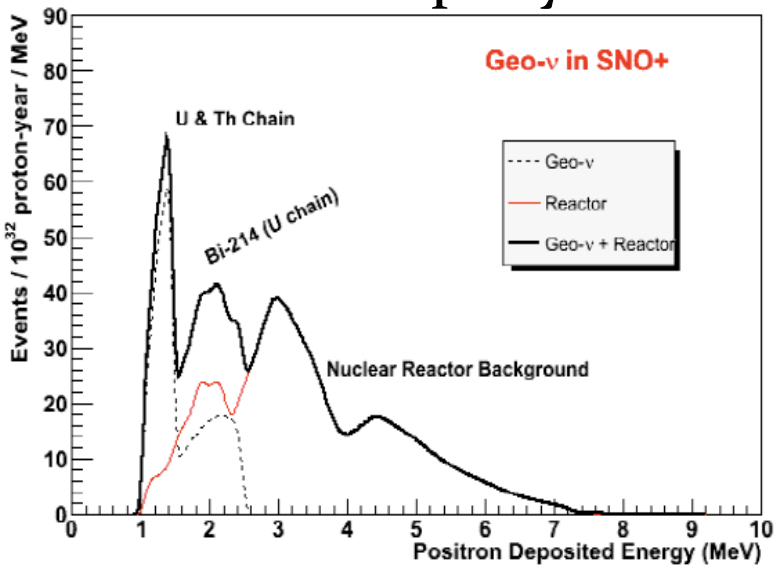
Check models of radiogenic heat production inside the earth



1000 tons CH2:

- KamLAND: 33 geoneutrino and 142 reactor events per year
- SNO+: 44 geoneutrino and 38 reactor events per year

- SNOLAB has simple well-understood geology: significant continental crust plus mantle (20% from mantle)



Supernova neutrinos

(see also G.Raffelt's talk)

SNO+ is planning to (re)join SNEWS

	Neutrino Reaction	Expected Counts
Charged Current	$\nu_e + p \rightarrow n + e^+$	260
CC = 47%	$\nu_e + {}^{12}C \rightarrow {}^{12}N + e^-$	30
	$\nu_e + {}^{12}C \rightarrow {}^{12}B + e^+$	10
Neutral Current	$\nu_x + {}^{12}C \rightarrow {}^{12}C^* + \nu_x$	60
NC = 51%	$\nu_x + p \rightarrow \nu_x + p$	270
Elastic Scattering	$\nu_x + e \rightarrow \nu_x + e^-$	12
ES = 2%	**TOTAL**	**642**

Nominal Signal for 10 kpc

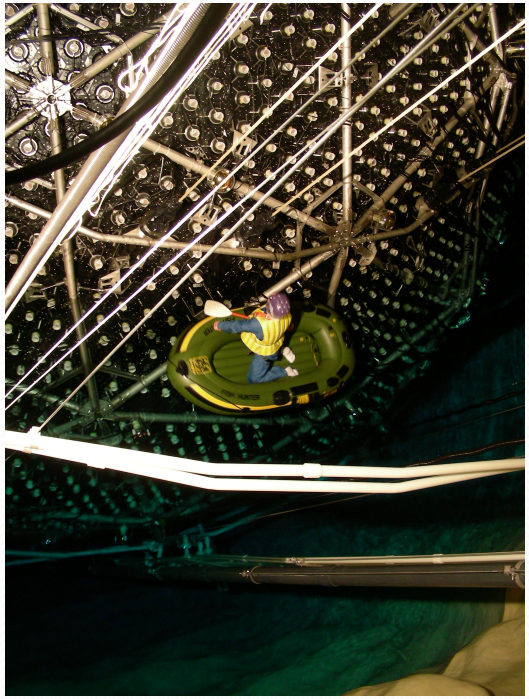
SNO+ electronics will be upgraded (see C. Kraus' talk) and therefore able to handle very high data rates.
(Special SN calibration source is being developed to test the DAQ)

Summary

- SNO+ to start data taking in 2011.
- Main focus $0\nu\beta\beta$

  (as discussed by C. Kraus)

  However, SNO+ can do more: *a multitude of exciting neutrino measurements will be made as well!*
- Funding is complete.
- Activities to prepare for construction in the cavity and on the fluid processing.



SNO+ has seen its first (fluffy) neutrinos (www.particlezoo.net)

Thank you for your attention