Reactor antineutrinos: update

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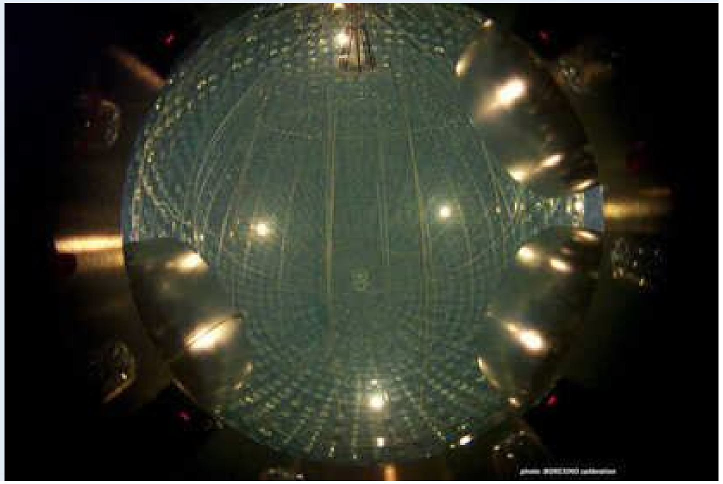
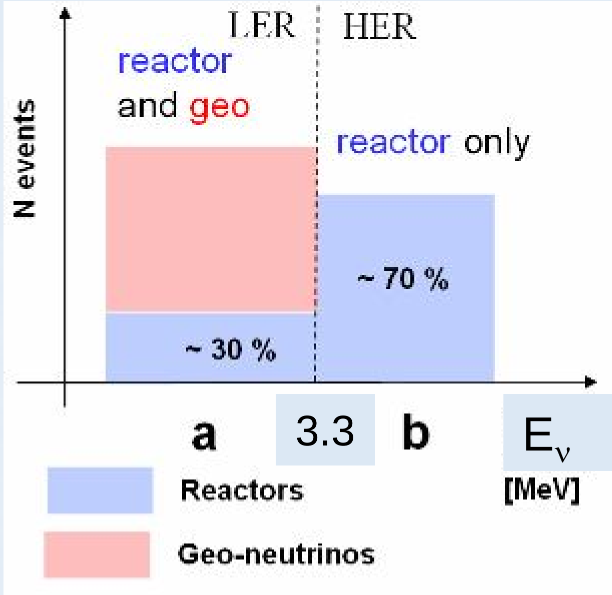
Outline

- why reactor anti-neutrinos ?
- reactors in the world
- signal calculation
- updates
- conclusion

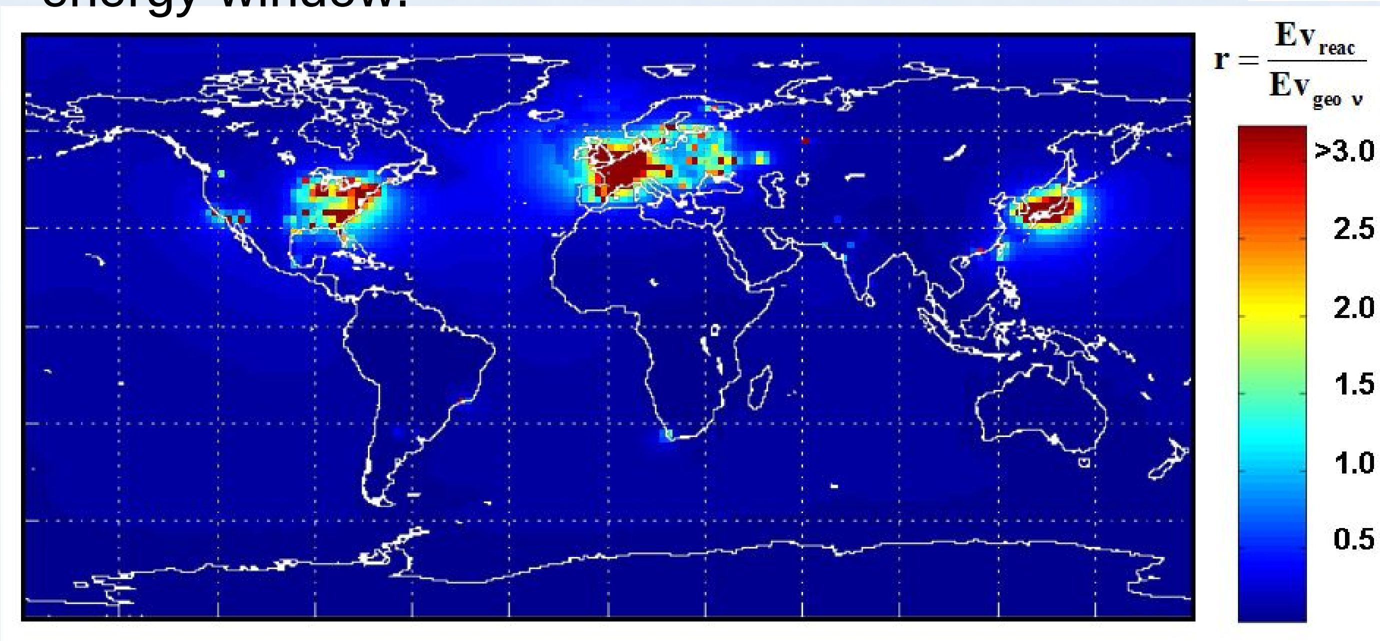


Why reactor antineutrinos?

- Reactor antineutrinos are the main source of background in geo neutrinos detection



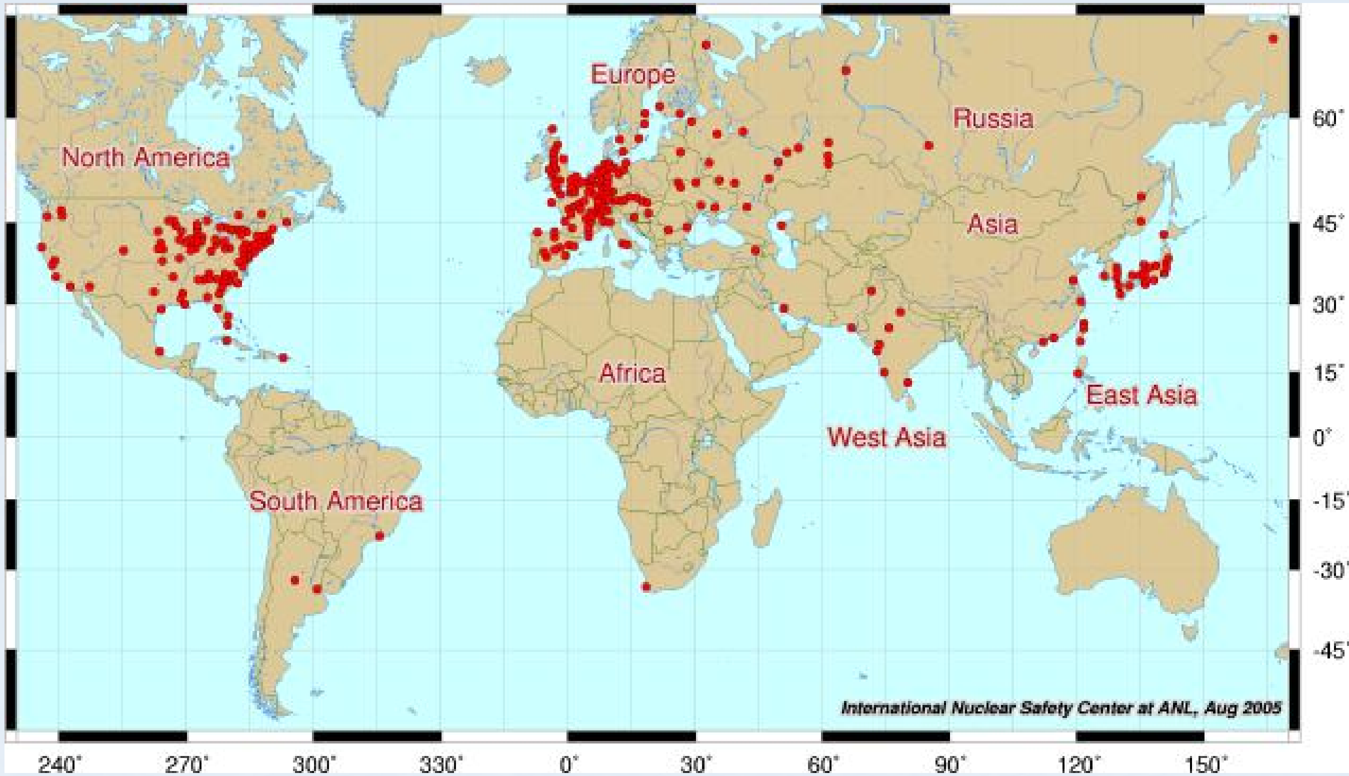
The map below* is based on 2000 IAEA database and considering all reactors at full power. The ratio r is referred to the geo-neutrino energy window.



	r
Kamioka	6.7
Sudbury	1.1
Gran Sasso	0.9
Pyhäsalmi	0.5
Baksan	0.2
Homestake	0.2
Hawaii	0.1
Curacao	0.1

*Fiorentini et al - Earth Moon Planets - 2006

Nuclear power plants in the world

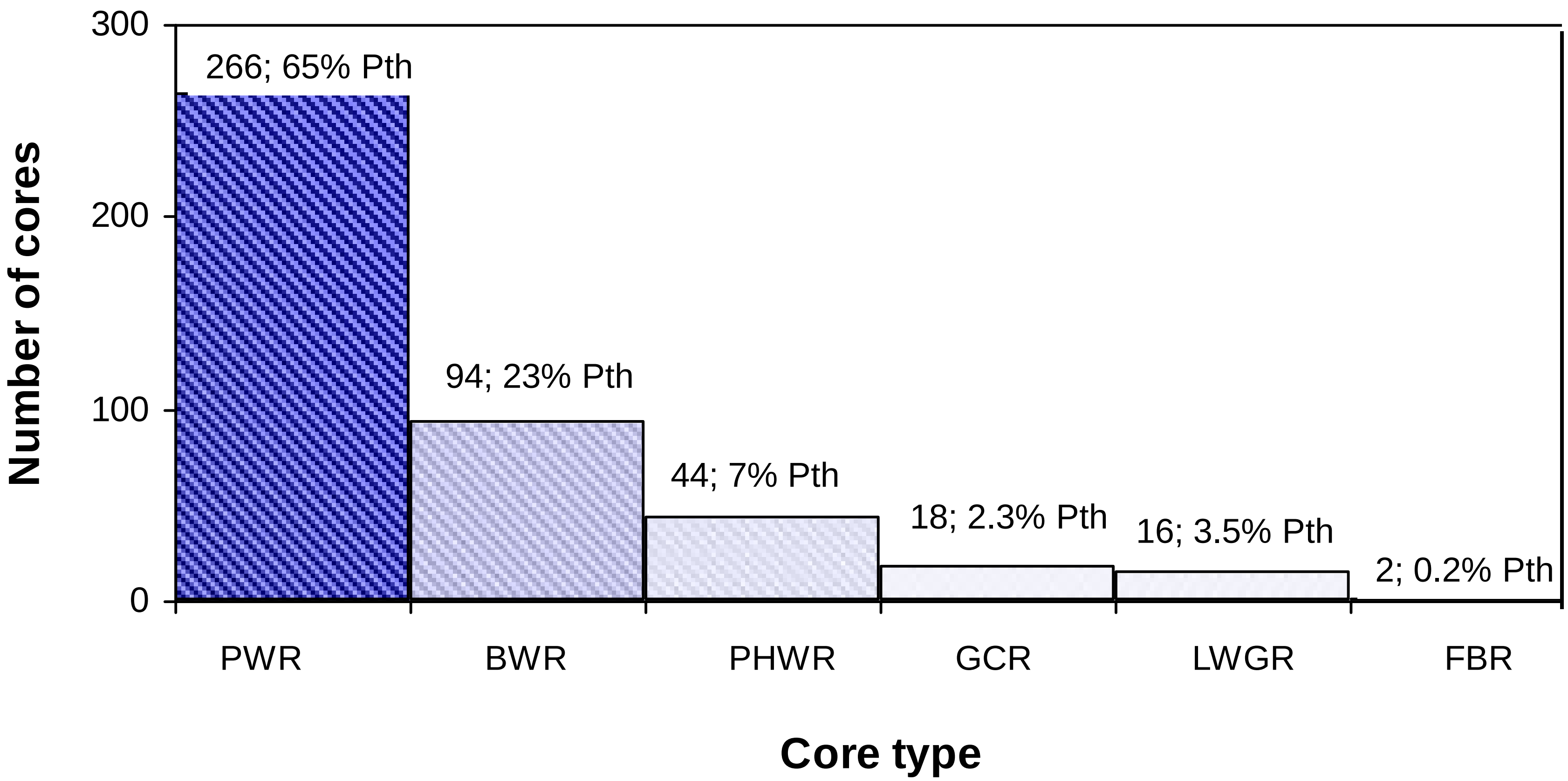


	#cores	Pth [GW]
Europe + Russia	197	519
North America	122	353
Japan+ Korea	76	201
Others	45	75
Total:	440	1148

- Mean thermal power for core: 2.6 GWth

at 31 Dec. 2009

Reactors by type



PWR	Pressurized (light) Water Reactor
BWR	Boiling Water Reactor
PHWR	Pressurized Heavy Water Reactor

GCR	Gas Cooled Reactor
LWGR	Light Water Graphite mod.
FBR	Fast Breeder Reactor

Signal calculation

DETECTOR
- ε=100% detection efficiency
- τ =1 year
- N_p=10^32

ν PHYSICS
- P_{ee}= survival probability
- $\sigma(E)$= cross section

anti-ν_e +p -> e^+ +n

E_{th}=1.806 MeV

(calculation from Vissani and Strumia 2003)

$$N_{TOT} = \varepsilon \ N_p \ \tau \sum_{i=1}^{N_{reactor}} \frac{P_i}{4\pi d_i^2} < LF_i > \int dE_\nu \sum_{k=1}^{Nfuel} \frac{p_k}{Q_k} \ \lambda_k(E_\nu) P_{ee}(E_\nu, d_i) \ \sigma(E_\nu)$$

REACTOR
- d_i =reactor distance
- P_i=reference thermal power
- LF= Load Factor
- p_k= power fraction

NUC. PHYS.
- Q_k =energy released for fission
- λ_k =reactor anti-neutrino spectrum

K=235U, 238U, 239Pu , 241Pu

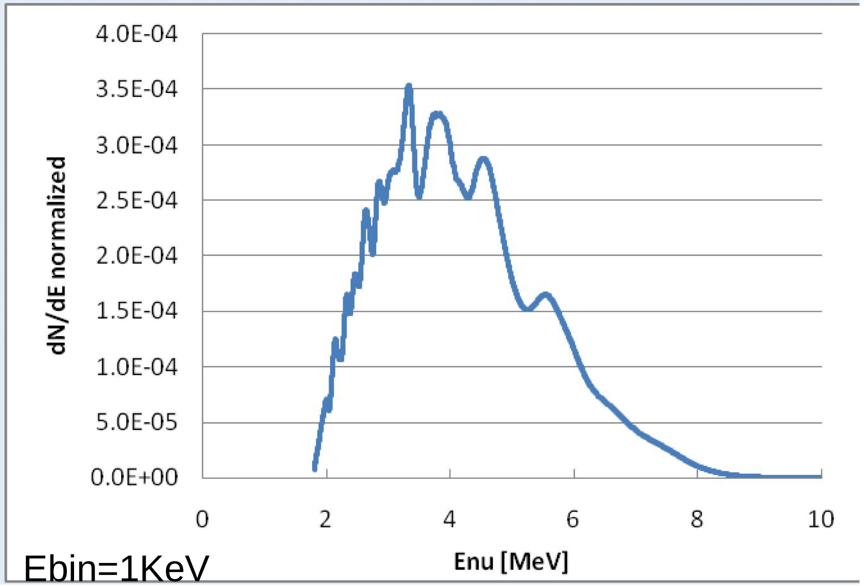
Starting point: March 2010

Δm^2=7.65E-5 eV2
θ12=33.46°

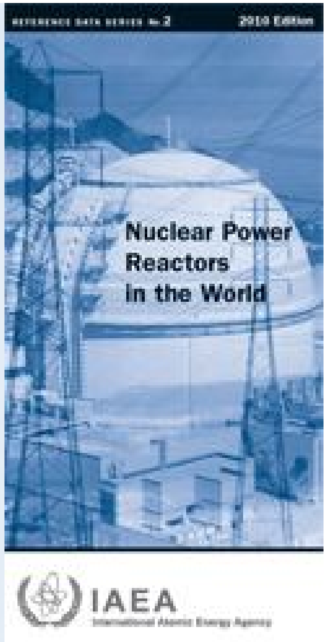
- vacuum oscill, 2 neutrinos
- "standard" PWR fuel +35 mox
- LF : 1 Jan 2008 - 31 Dec 2008
- spectrum:Huber &Schwetz 2004
- 100% detection efficiency
- Enu= 1.8-10 MeV

Power Fraction				
	235U	238U	239Pu	241Pu
PWR	0.56	0.08	0.3	0,06
MOX	0	0.08	0.708	0.212

S=93.3 (1 ± 5.4%) TNU



Update 1: LF for 2009-2010



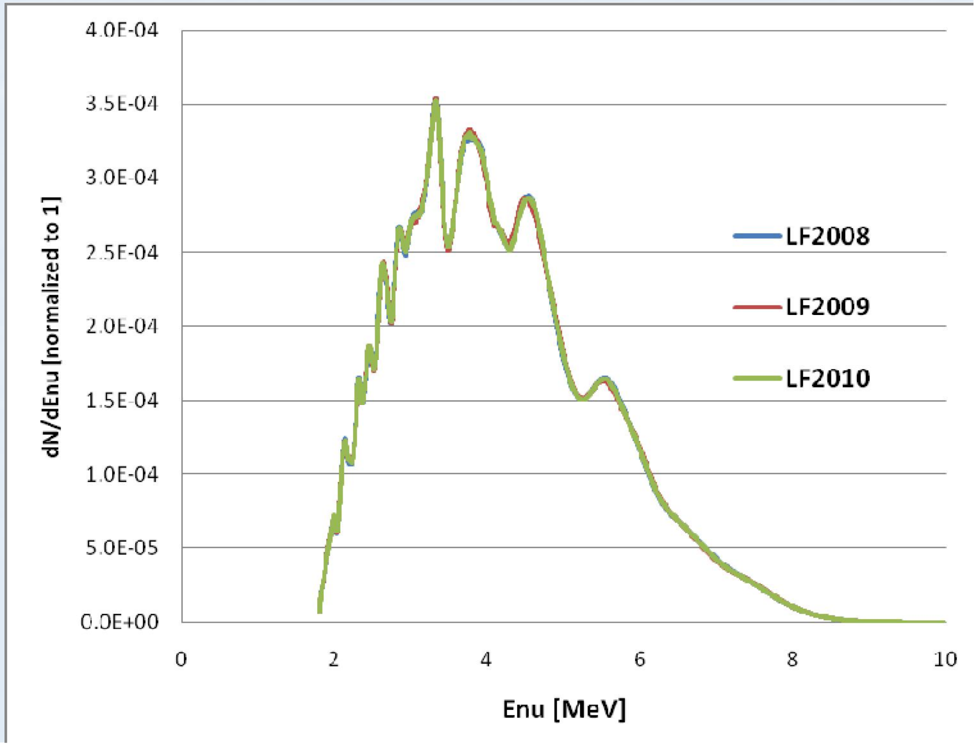
- Expected Signal at LNGS (100% effic.) by using LF of different years (weighted average with days in each monthes):

LF2008 93.3 TNU

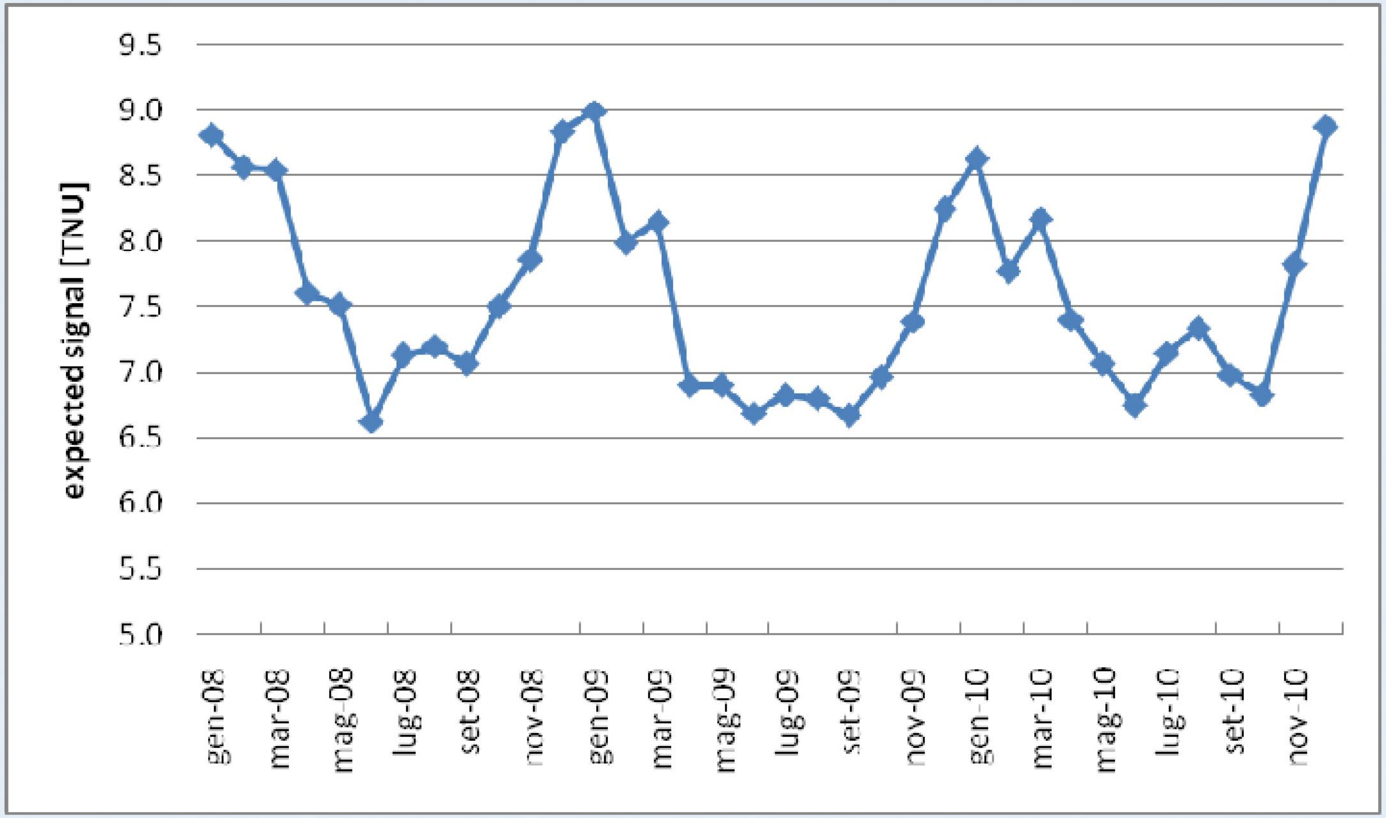
LF2009 88.6 TNU

LF2010 90.8 TNU

av. value: 90.9 TNU



LF and time variation



- about 30% variation (max-min)
- few events for month

-100% efficiency

- Np=10^{32} protons

Update 2: PHWR fuel

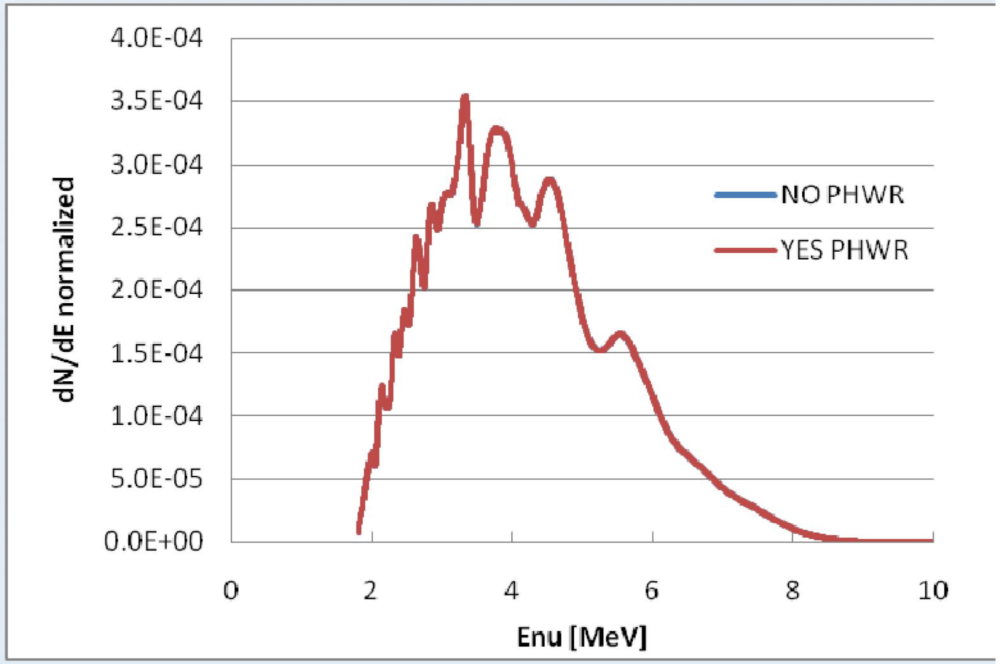
	235U	238U	239Pu	241Pu
PWR	0.56	0.08	0.3	0.06
PHWR	0.54	0.41	0.02	0.024

- In 2010, 46 PHWR cores in the world (2 cores in Romania)

- No effect on signal:

NO PHWR 90.9 TNU

YES PHWR 90.9 TNU

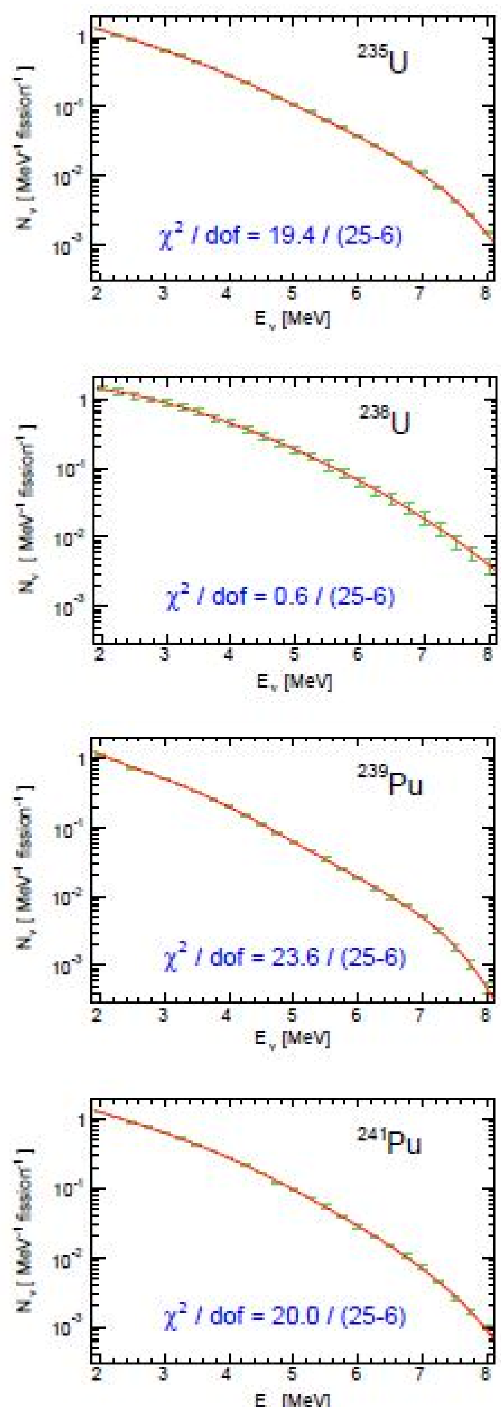


Update 3: reactor antinu spectrum

1)Huber and Schwetz 2004
(used in geo nu –paper)

2) Mueller et al. 2011

“...While the shapes of the spectra and their uncertainties are comparable to that of the previous analysis ..., the normalization is shifted by about +3% on average...”

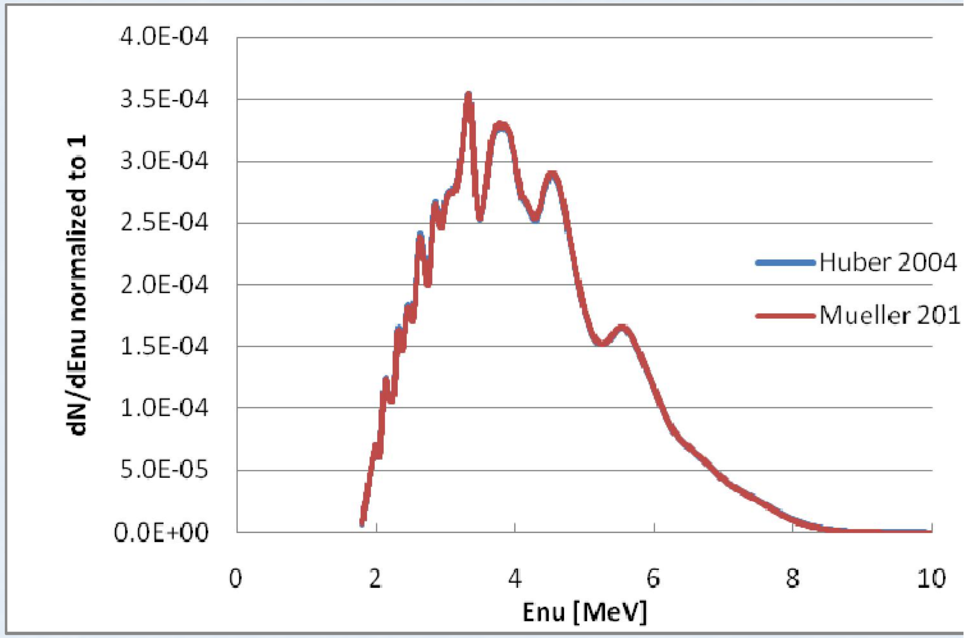


Antinu spectrum and signal

- The predicted signal at LNGS, 100% efficiency, averaged on 3 years is:

Huber 2004: 90.9 TNU

Mueller2011: 94.1 TNU



- By using Mueller 2011 the signal increases (+ 3.5%)

Conclusion

- By using:
  - <LF> in 3 years (2008-2009-2010)
  - PHWR fuel
  - reactor antinu spectra from Mueller et al 2011
  - 100% detection efficiency
  - Enu = [1.8 -10 MeV]
  - Oscillation in matter : +0.6%
  - Spent fuel: + 1%

One has: S=95.6 (1 ± 5.4%) TNU

i.e.:

$N_{reactor}$=17.2 (1 ± 5.4%) events/300ton/yr

Nprotons=6.02 E+28 /ton
yr=365 d