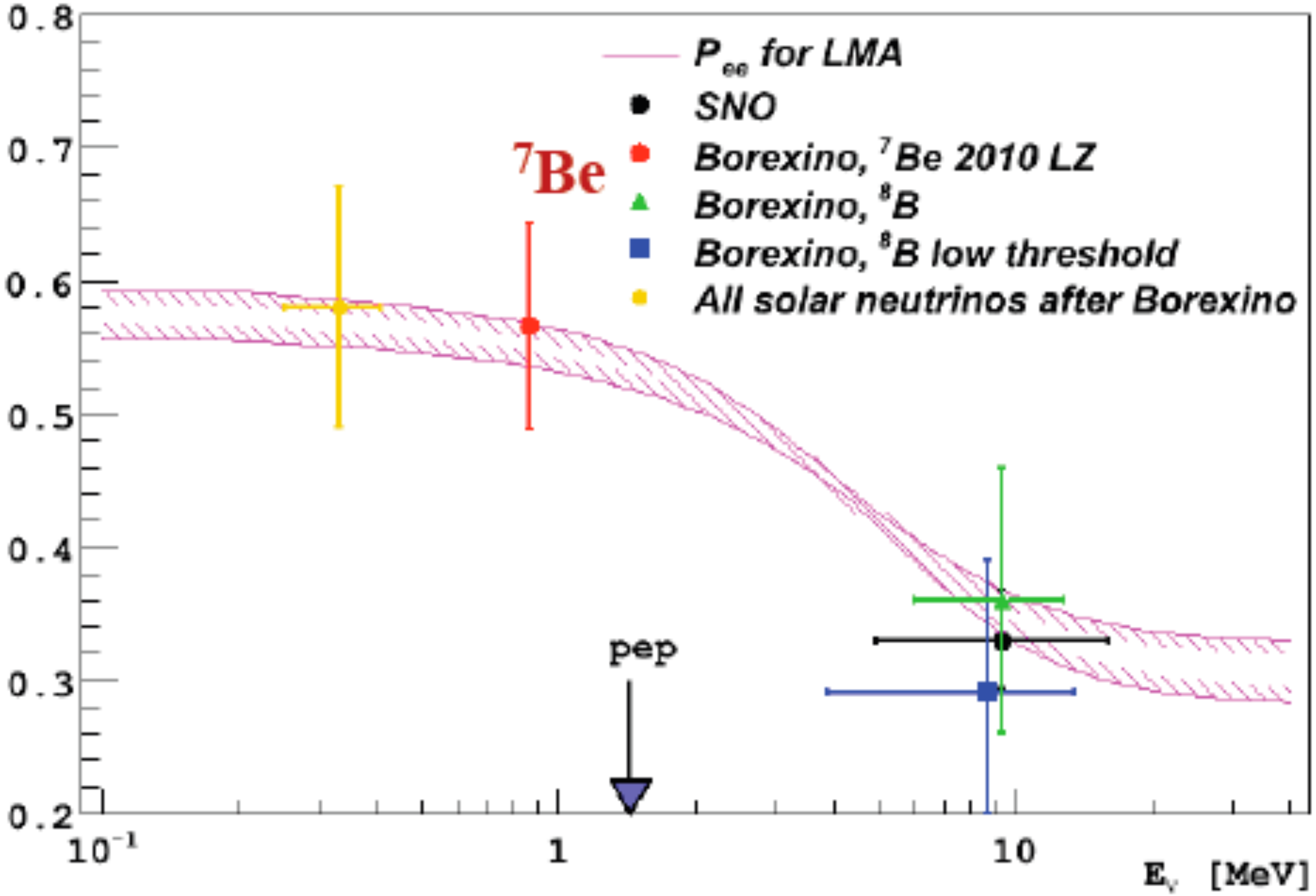
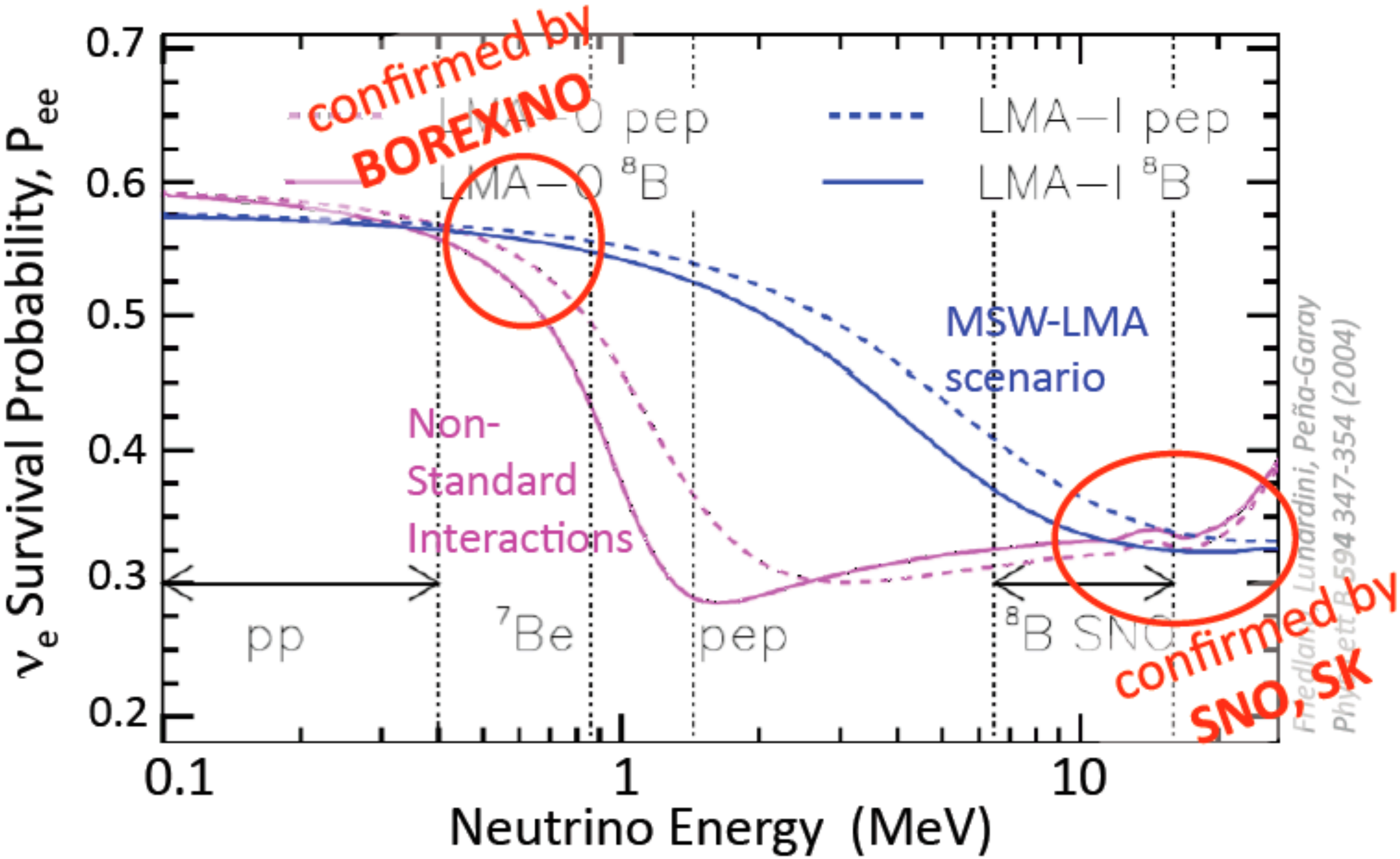
MSW-LMA oscillation model

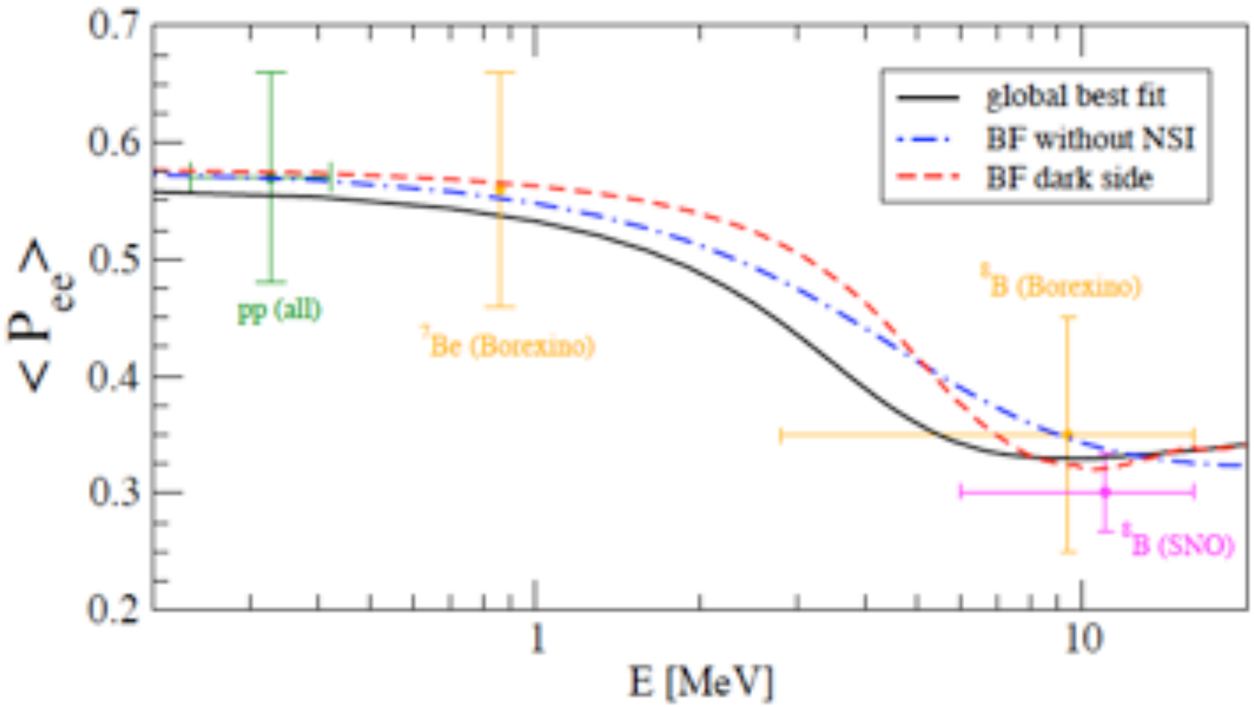


$P_{ee}(\text{Vac}) - P_{ee}(\text{matter}) = 0.27\ (1.9\sigma)$



confirmed by
BOREXINO
LMA−0 pep
LMA−0 ⁸B
LMA−I pep
LMA−I ⁸B
MSW-LMA
scenario
Non-
Standard
Interactions
pp
⁷Be
pep
⁸B SNO
confirmed by
SNO, SK
νe Survival Probability, Pee
Neutrino Energy (MeV)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
10
Friedland, Lunardini, Peña-Garay
Phys. Lett. B 594 347-354 (2004)

A.Bolanos,……J.Valle; Phys. Review, D79 (2009)
F.Escribuela,….J.Valle;arXiv:0907.2630v3 -11 dec 2009



Borexino search for day/night effect

- passage through Earth matter might influence ν_e survival probability, predicted for LOW scenario
- similar effect predicted for mass varying neutrinos

P.C. de Holanda, JCAP07 (2009) 024

Model	P_{ee}	A_{DN}
LMA	0.64±0.07	≈0
LOW	0.58±0.05	0.23±0.11
MaVaN		-0.23

Be7 Day spectrum fit 387.46 days
Be7 Night spectrum 401.57

$$ADN = \frac{N-D}{(N+D)/2} = 0.007 + -0.073$$

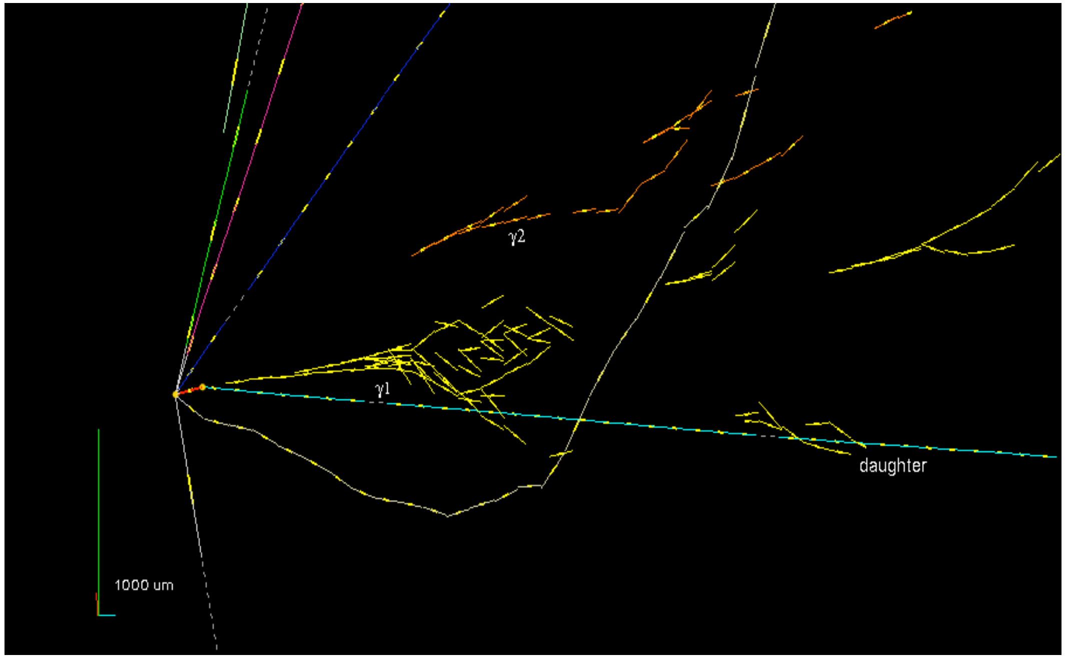
$$\sigma_{ADN} \approx \sqrt{2}\,\frac{\sigma_{Be7}^{Night}}{Be7^{Night}} \approx \sqrt{2}\,\frac{\sigma_{Be7}^{Day}}{Be7^{Day}}$$

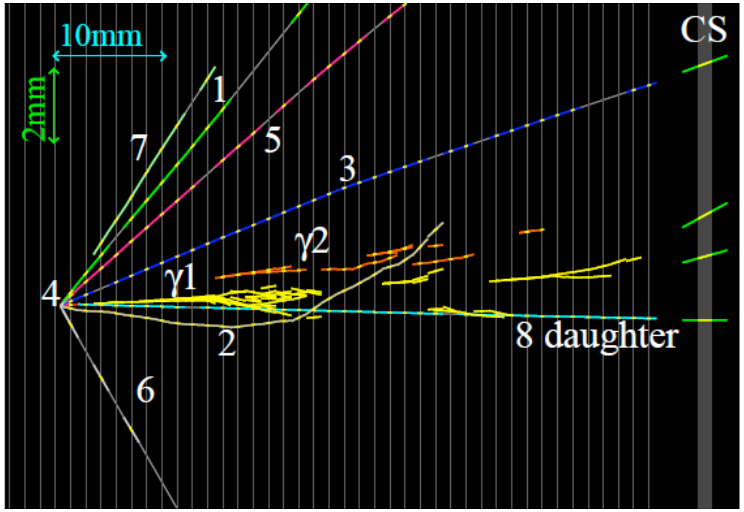
Conclusions

- Models leading "naturally" to NSI imply:
  - $O(10^{-3})$ bounds on the NSI
  - Relations between matter and production/detection NSI
- Probing $O(10^{-3})$ NSI at future facilities very challenging but not impossible, near detectors excellent probes
- Saturating the mild model-independent bounds on matter NSI and decoupling them from production/detection requires strong fine tuning

OPERA: the first ν_τ candidate event

Physics Letters B 691 (2010) 138-145
http://arxiv.org/abs/1006.1623



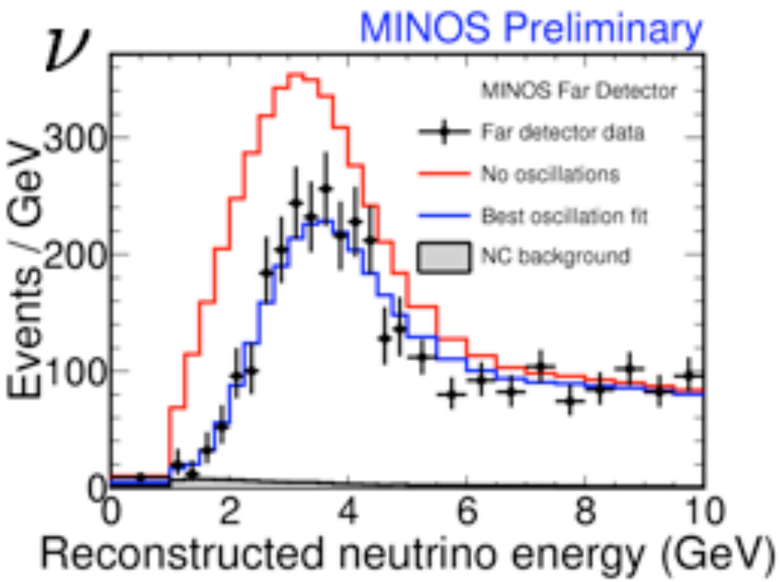


- The primary neutrino interaction consists of 7 tracks of which one exhibits a visible kink
- Two electromagnetic showers caused by γ-rays, associated with the event, have been located (total radiation length downstream the vertices: 6.5 X_0)

2ry vtx compatible with: $\tau \rightarrow h\ (n\pi^0)\ \nu_\tau$

Background fluctuation probabilities to 1 event:

1-prong hadron channel only: P=1.8% → 2.36 σ significance
All tau decay modes included in search: P=4.5% → 2.01 σ significance



MINOS Results

$\nu_\mu \longrightarrow \nu_\mu \qquad \bar{\nu}_\mu \longrightarrow \bar{\nu}_\mu$

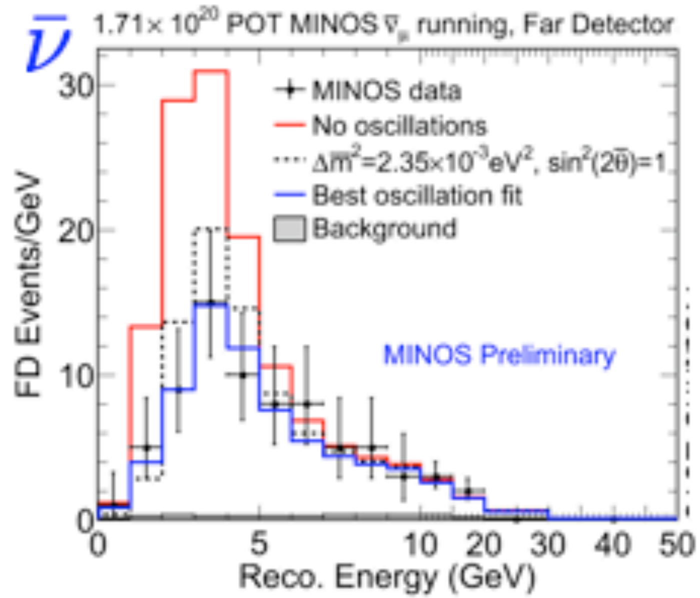
$$|\Delta m^2| = 2.35^{+0.11}_{-0.08} \times 10^{-3}\mathrm{eV}^2$$

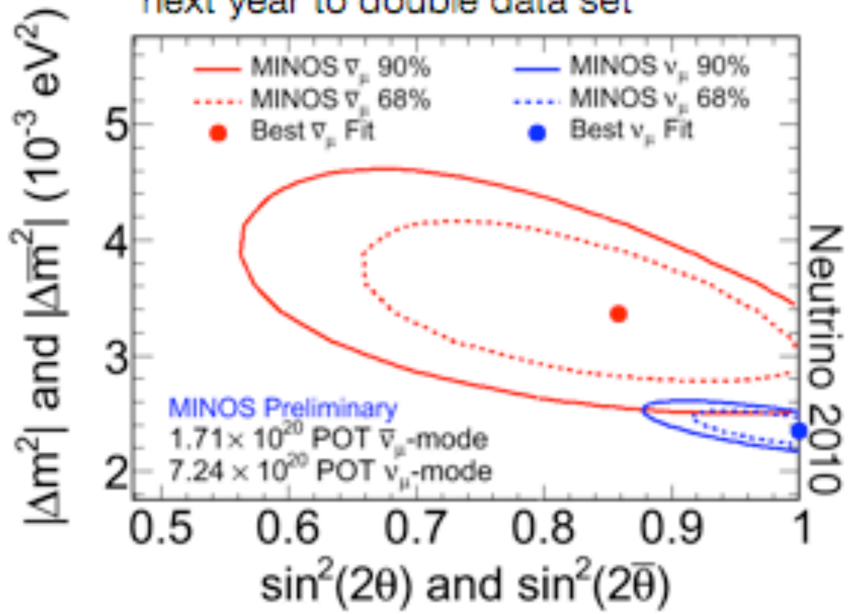
$$\sin^2(2\theta) > 0.91\ (90\%\mathrm{C.L.})$$

$$|\Delta \bar{m}^2| = 3.36^{+0.45}_{-0.40} \times 10^{-3}\ \mathrm{eV}^2$$

$$\sin^2 2\bar{\theta} = 0.86 \pm 0.11$$

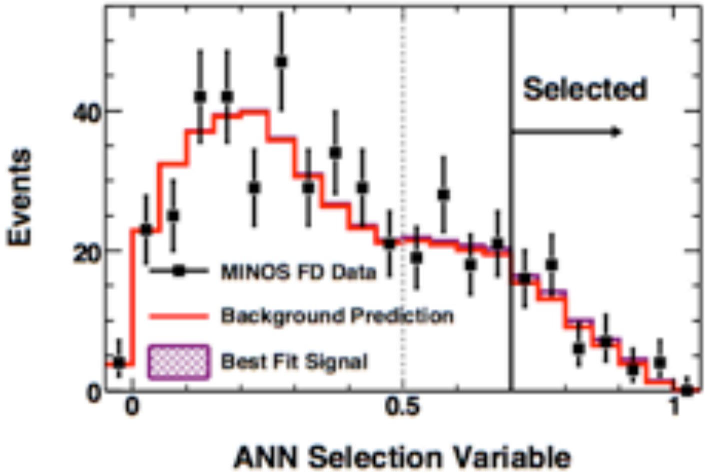
- ~2 sigma discrepancy
- Additional antineutrino running during next year to double data set

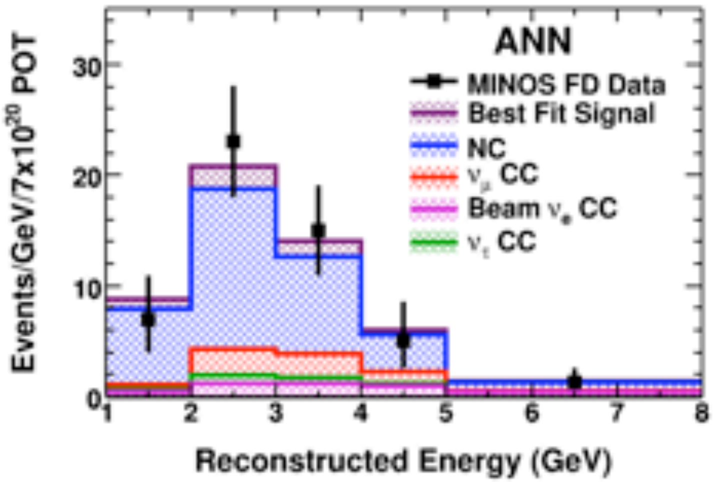


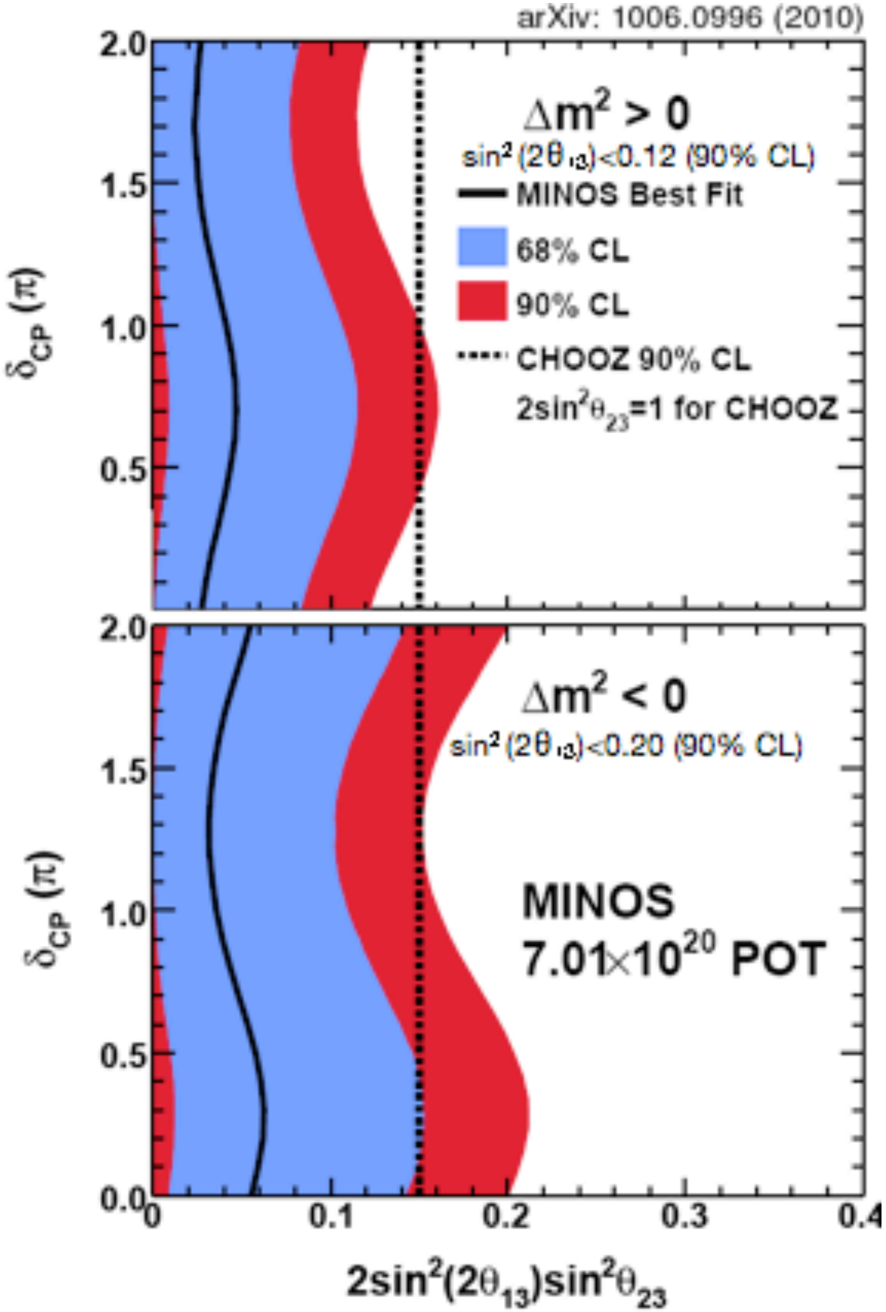


MINOS Results

$$\nu_\mu \rightarrow \nu_e$$





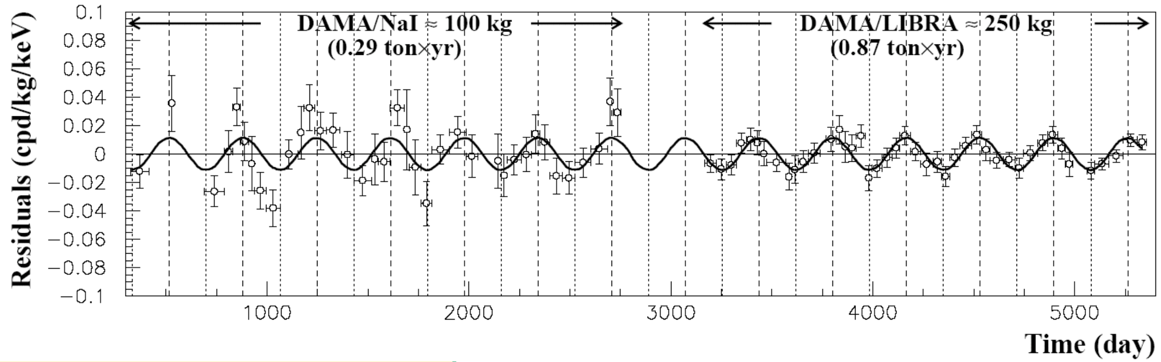


Dark Matter investigation by model-independent annual modulation signature - 1

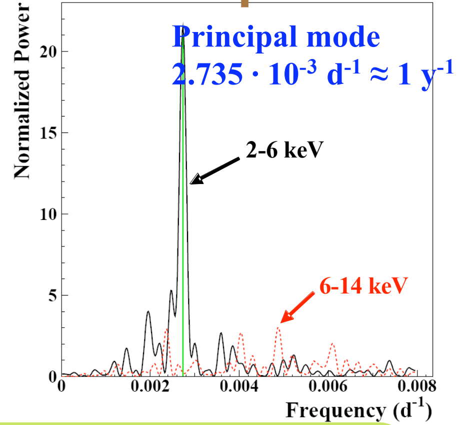
DAMA/NaI (7 years) + DAMA/LIBRA (6 years). Total exposure: **1.17 ton×yr** (the **largest** exposure ever collected in this field)

EPJC 56(2008)333, EPJC 67(2010)39

Experimental single-hit residuals rate *vs* time in 2-6 keV



Power spectrum



$A\cos[\omega(t-t_0)]$

continuous line: t_0 = 152.5 d, T = 1.00 y

A=(0.0114±0.0013) cpd/kg/keV

χ^2/dof = 64.7/79 8.8 σ C.L.

Absence of modulation? No

χ^2/dof=140/80 P(A=0) = 4.3×10^{-5}

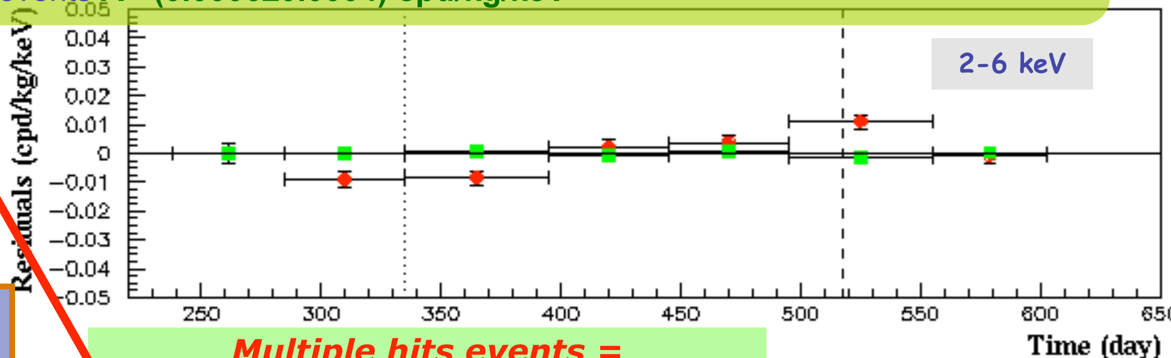
fit with all the parameters free:

A = (0.0116 ± 0.0013) cpd/kg/keV

t_0 = (146±7) d

T = (0.999±0.002) y

Comparison between **single hit residual rate (red points)** and **multiple hit residual rate (green points)** for (DAMA/LIBRA 1-6); Clear modulation in the single hit events; No modulation in the residual rate of the multiple hit events **A=-(0.0006±0.0004) cpd/kg/keV**



Multiple hits events = Dark Matter particle "switched off"

No systematics or side reaction able to account for the measured modulation amplitude and to satisfy all the peculiarities of the signature

This result offers an additional strong support for the presence of DM particles in the galactic halo further excluding any side effect either from hardware or from software procedures or from background

The data favor the presence of a modulated behaviour with all the proper features for DM particles in the galactic halo at about 9σ C.L.

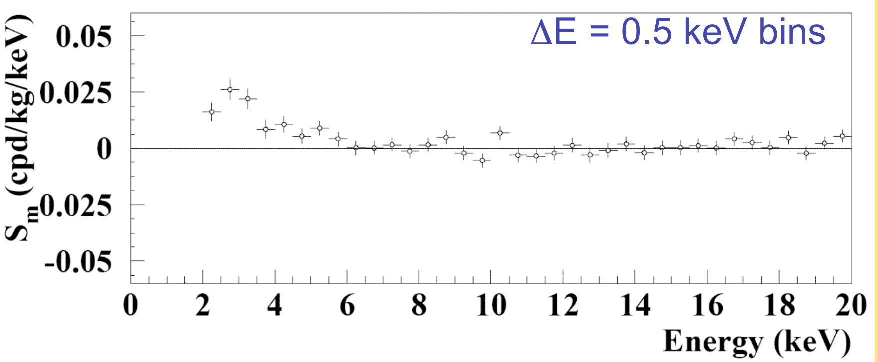
Dark Matter investigation by model-independent annual modulation signaure - 2

DAMA/NaI (7 years) + DAMA/LIBRA (6 years). Total exposure: **1.17 ton×yr**
(the **largest** exposure ever collected in this field)

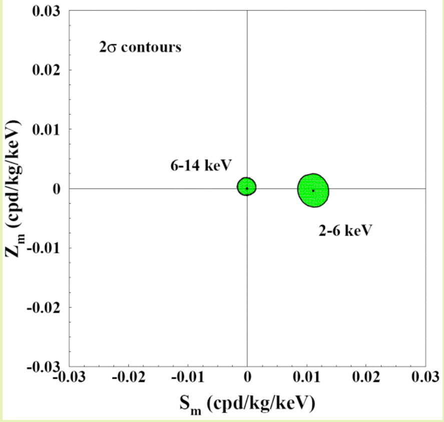
EPJC 56(2008)333
EPJC 67(2010)39

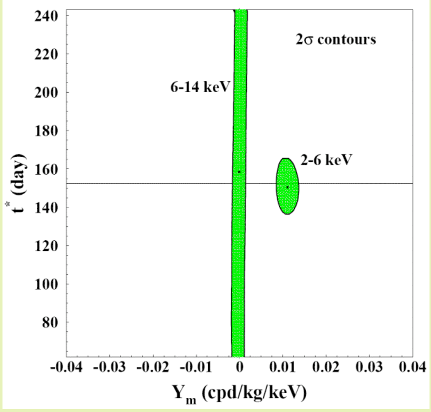
$$R(t) = S_0 + S_m \cos[\omega(t - t_0)]$$

here $T=2\pi/\omega=1$ yr and $t_0= 152.5$ day



$$R(t) = S_0 + S_m \cos[\omega(t - t_0)] + Z_m \sin[\omega(t - t_0)] = S_0 + Y_m \cos[\omega(t - t^*)]$$





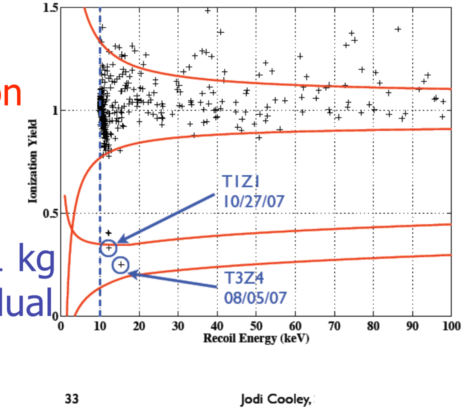
- **No modulation above 6 keV**
- **No modulation in the whole energy spectrum**
- **No modulation in the 2-6 keV multiple-hit events**

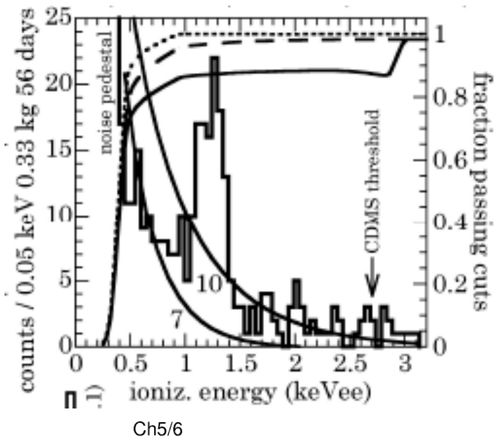
No systematics or side processes able to quantitatively account for the measured modulation amplitude and to simultaneously satisfy the many peculiarities of the signature are available.

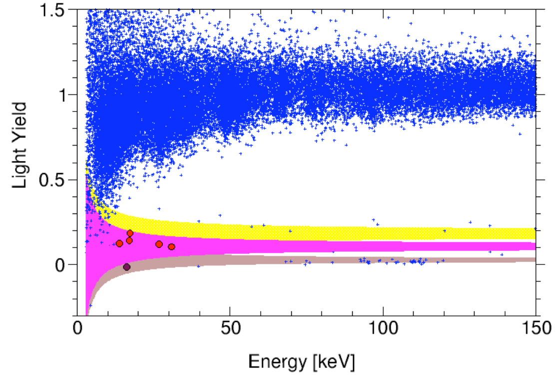
- **Compatibility with many low and high mass DM candidates, interaction types and astrophysical scenarios, and in particular with recent positive model dependent hints from direct or indirect searches**
- **No other experiment exists whose result can be – at least in principle – directly compared in a model-independent way with those by DAMA/NaI & DAMA/LIBRA**

Example 2010 – Positive recoil-like excesses in different kinds of direct searches

- **CoGeNT**: low-energy rise in the spectrum (irriducible by the applied background reduction procedures)
- **CDMS**: after data selection and cuts, 2 Ge candidate recoils survive in an exposure of 194.1 kg x day (0.8 estimated as expected from residual background)
- **CRESST**: after data selection and cuts, 32 O candidate recoils survive in an exposure of ≈ 400 kg x day (8.7±1.2 estimated as expected from residual background)







All these recoil-like excesses, if interpreted in WIMP scenarios, are also compatible with the DAMA annual modulation result

Some recent literature discussing compatibility in various frameworks e.g.:

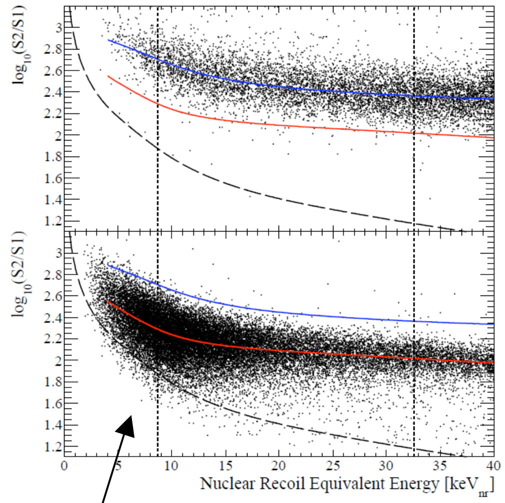
- Light WIMP DM (arXiv:1003.0014,arXiv:1007.1005v2)
- Low mass neutralino in effMSSM (PRD81(2010)107302,arXiv:0912.4025)
- Inelastic DM (PRD79(2009)043513, arXiv:1007.2688)
- Mirror DM (arXiv:10010096)
- Resonant DM (arXiv:0909.2900)
- DM from exotic 4th generation quarks (arXiv:1002.3366)
- Light Neutralino DM (arXiv:1009.0549)
- Composite DM (arXiv:1003.1144)
- Light scalar WIMP through Higgs portal (arXiv:1003.2595)
- SD Inelastic DM (arXiv:0912.4264)
- Complex Scalar Dark Matter (arXiv:1005.3328)
- Light Neutralinos (arXiv:1003.0682)
- ... and more considering the uncertainties

Recent results of a liquid noble gas experiment: XENON100

(arXiv:1005.0380)

Experimental site: Gran Sasso (1400 m depth)
Target material: ^{nat}Xe
Target mass: ≈161 kg (fiducial: 40 kg)
Used exposure: 11.7 day

Many cuts are applied, each of them can introduce systematics. The systematics can be variable along the data taking period; can they and the related efficiencies be suitably evaluated in short period calibration ?



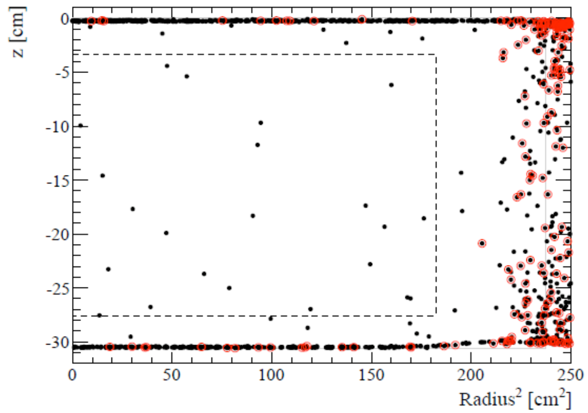
Cuts Explanation (see Xenon-10)

QC0: Basic quality cuts	QC1: Fiducial volume cuts	QC2: High level cuts
Designed to remove noisy events, events with unphysical parameters or events which are not interesting for a WIMP search	Because of the high stopping power of LXe, fiducialization is a very effective way of reducing background.	Cuts based on the distribution of the S1 signal on the top and bottom PMTs. They are designed to remove events with anomalous or unusual S1 patterns
■ S1 coincidence cut ■ S1 single peak cut ■ S2 saturation cut ■ S2 single peak cut ■ S2 width cut ■ S2 χ^2 cut	■ $r < 80$ mm ■ $15\,\mu s < dt < 65\,\mu s$	■ S1 top-bottom asymetry cut ■ S1 top RMS cut ■ S1 bottom RMS cut

see Guillaume Plante, Columbia, APS Talk

Noble Liquids / Dark Matter — Rick Gaitskell, Brown University, DOE

- Statistical discrimination between electrons (e^-/γ, top) and nuclear recoils (bottom). The two populations are quite overlapped.



- Tiny exposure
- Disuniformity of the detector: intrinsic limit?
- Correction procedures applied: which systematics?
- Small light responses (2.2 ph.e./keVee) ⇒ energy threshold at few keV unsafe
- Questionable light responses for electrons and recoils at low energy
- Physical energy threshold unproved by source calibrations
- Poor energy resolution; resolution at threshold unknown

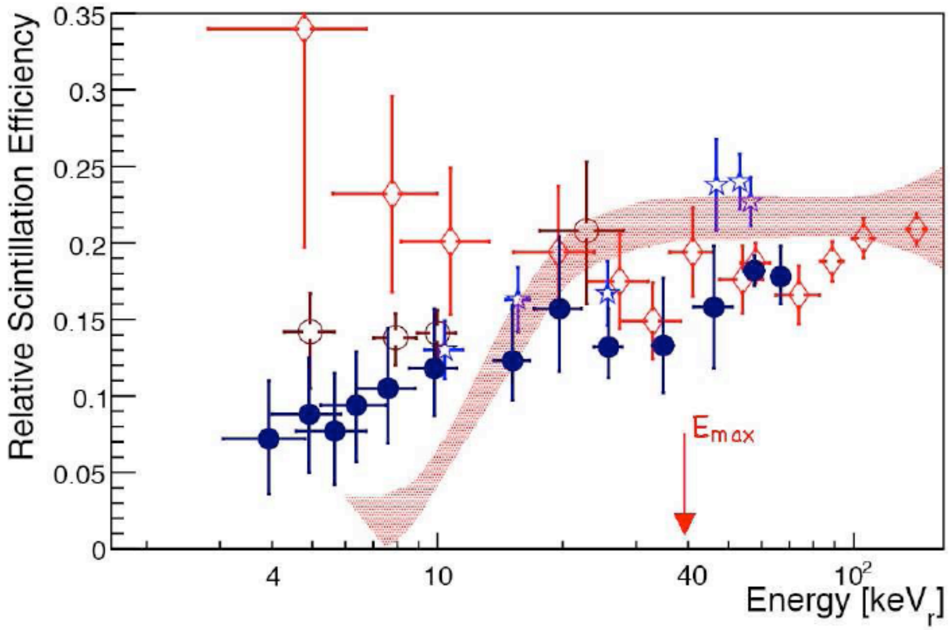
- no event in the 50% efficiency window in the discrimination plot surviving the many applied cuts
- sospicious residual background rate

What about the low-mass WIMP sensitivity claimed by XENON-100?

see also: arXiv:1005.08380
arXiv:1006.2031
arXiv:1005.3723

- A low mass WIMP (7 GeV) can induce a maximum recoil energy of 4 keVr to a Xe nucleus: 90% of the events are below 1.5 keVr.
- Tail distribution is more sensitive to the experimental (small number of ph.el./keV, small energy resolution, stability of the energy scale, stability of all the selection windows, ...) and theoretical (models, parameters, such as escape velocity, form factors, ...) uncertainties
- L_{eff} is assumed by XENON-100 either constant at 0.12 below 10 keVr or extrapolated. But this is not the case.

- ***L_{eff} drastically drops at lower energy?***
- ***Kinematic cutoff?***
- ***More precise measurements and/or more reliable theoretical evaluations required.***



However, in the doubt the most cautious approach is needed

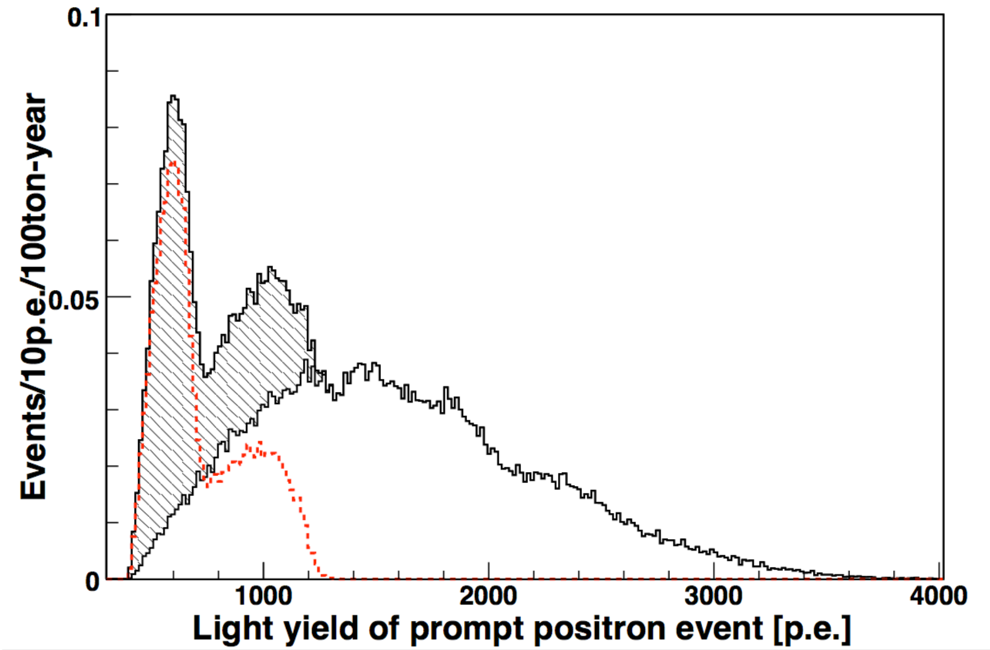
•**BOREXINO** Data set: from Dec 2007 to Dec 2009

•Total live time: **537.2 live days**

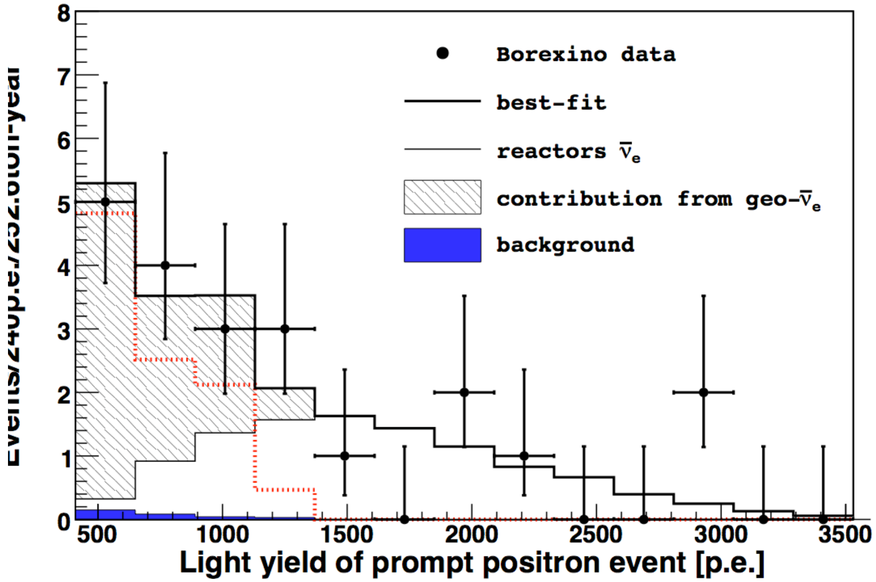
•Fiducial exposure after muon cuts and including detection efficiency: **252.6 ton-year**

•**21 anti-ν candidates selected**

MC spectra for likelihood function

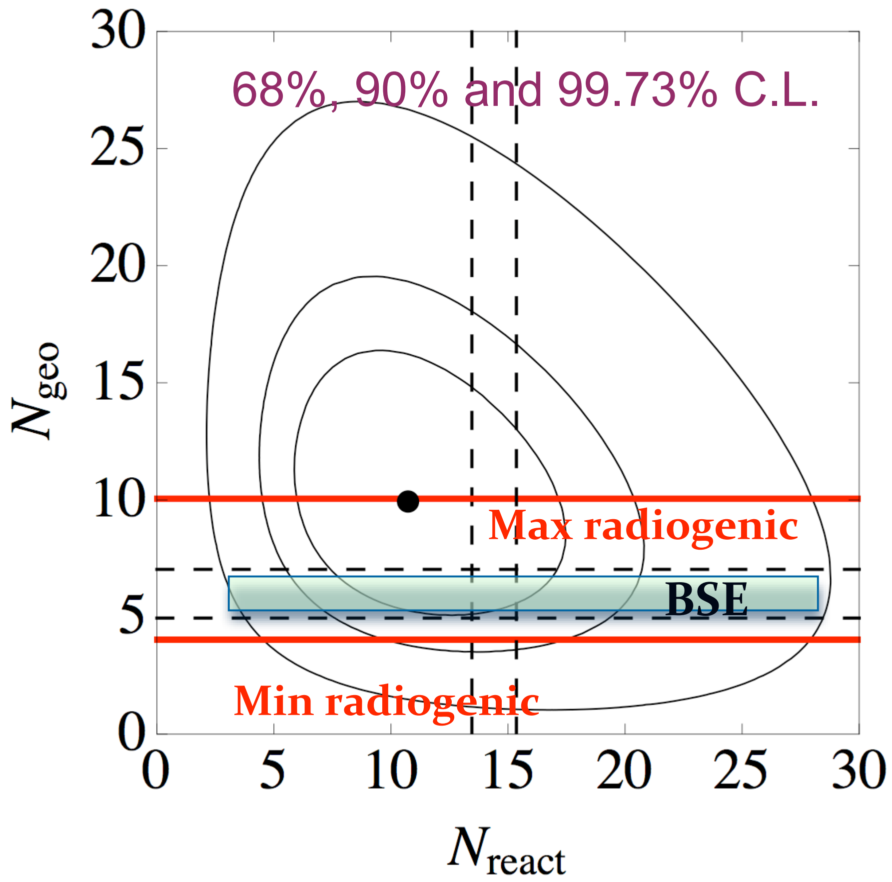


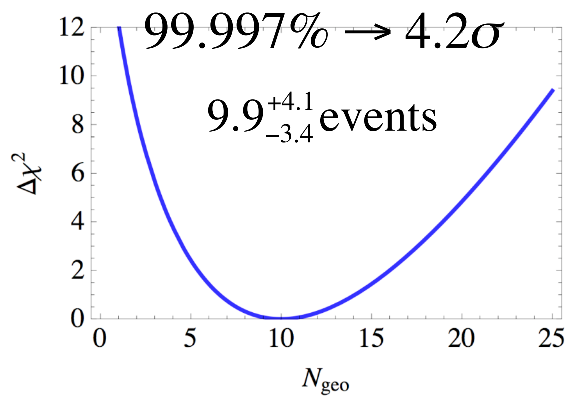
Unbinned ML best fit



Best-fit parameters from the likelihood analysis

Total heat flow :
31±1 TW or **44±1 TW**

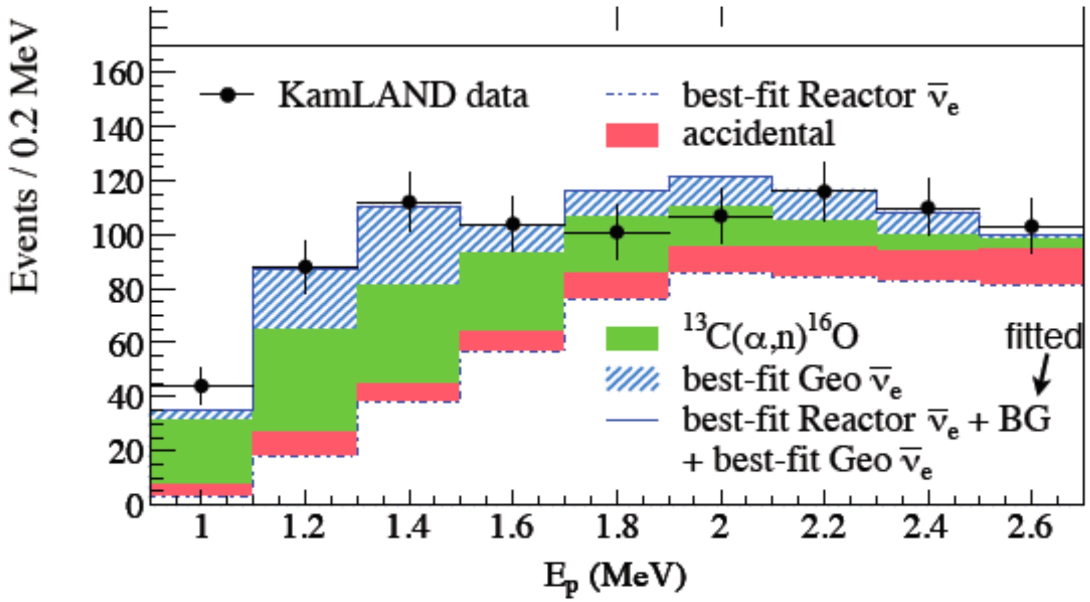




$N_{react} = 10.7^{+4.3}_{-3.4}$

base line of 1000km
No oscillation rejected at 2.9σ

Phys. Letters B 687(2010)299



S/B ≈ 5:1 in BX

S/B ≈1:7 in Kamland

New release from
Kamland (June 2010)
7 years of data taking