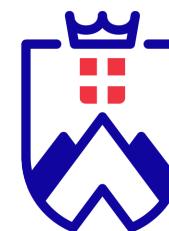
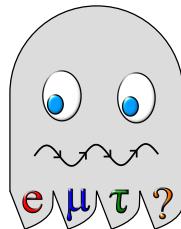


# STEREO: search for a sterile neutrino at the ILL reactor

Pablo del Amo Sánchez

(LAPP – U. Savoie Mont Blanc / IN2P3 / CNRS)



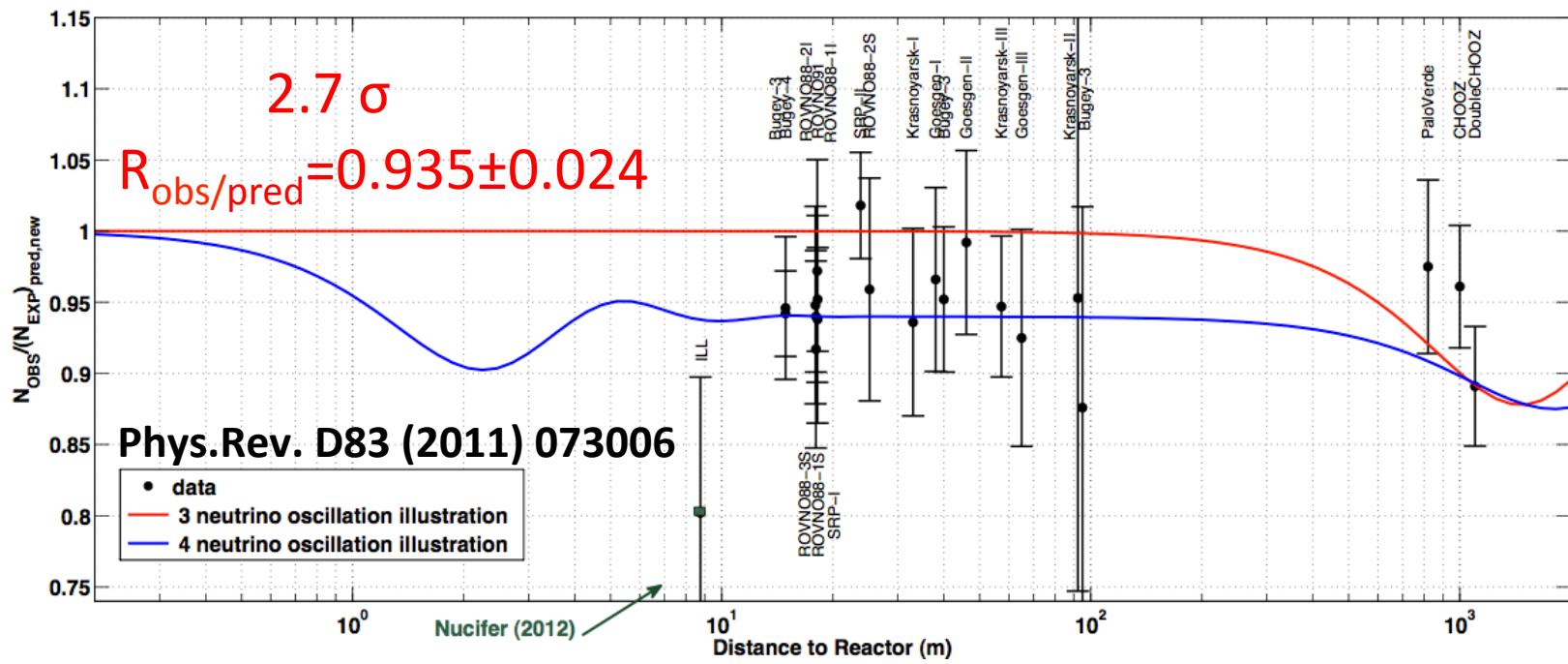
UNIVERSITÉ  
SAVOIE  
MONT BLANC

on behalf of the STEREO collaboration

# Reactor antineutrino anomaly

Re-evaluation of reactor antineutrino fluxes → 6.5 % deficit in obs. fluxes ( $2.7\sigma$ )

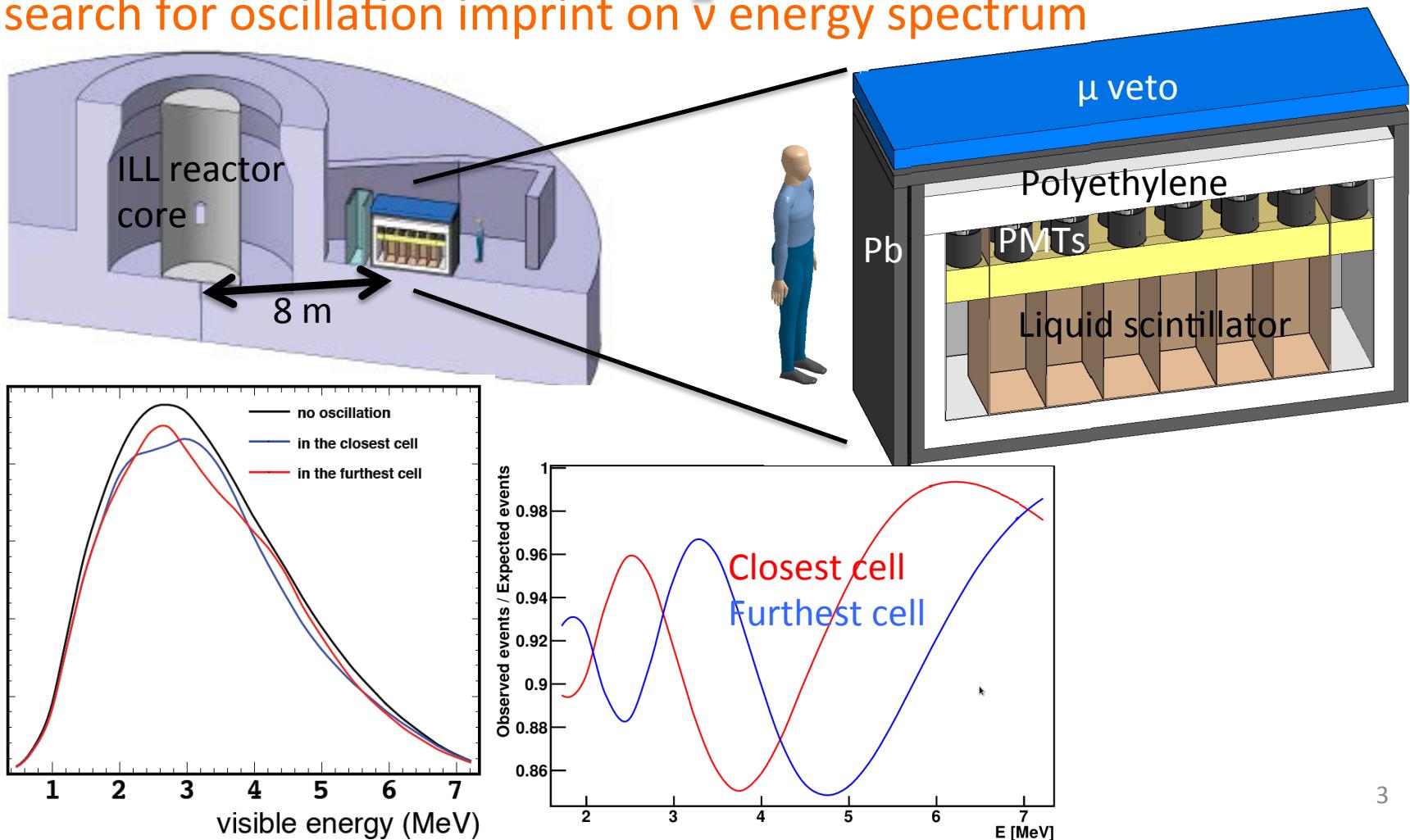
Similar ( $2.7\sigma$ ) Gallium anomaly (deficit observed in calibration runs of Ga exps)



Could be explained by sterile  $\nu$ ,  $\Delta m^2 \sim 2 \text{ eV}^2$ ,  $\sin^2(2\theta_{ee}) \sim 0.1$ ,  $L_{\text{osc}} \approx 4 \text{ m}$

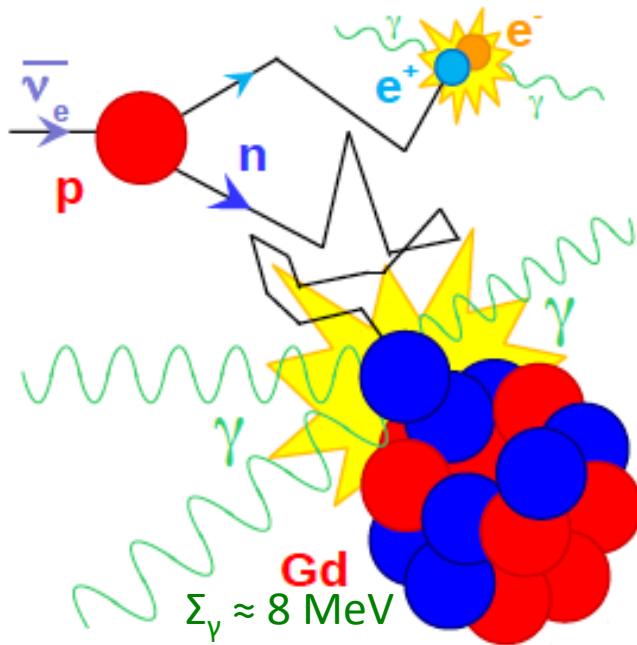
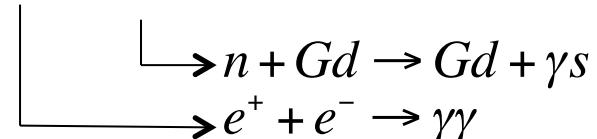
# The STEREO experiment

- Not just another flux measurement: in very short baselines, search for oscillation imprint on  $\bar{\nu}$  energy spectrum

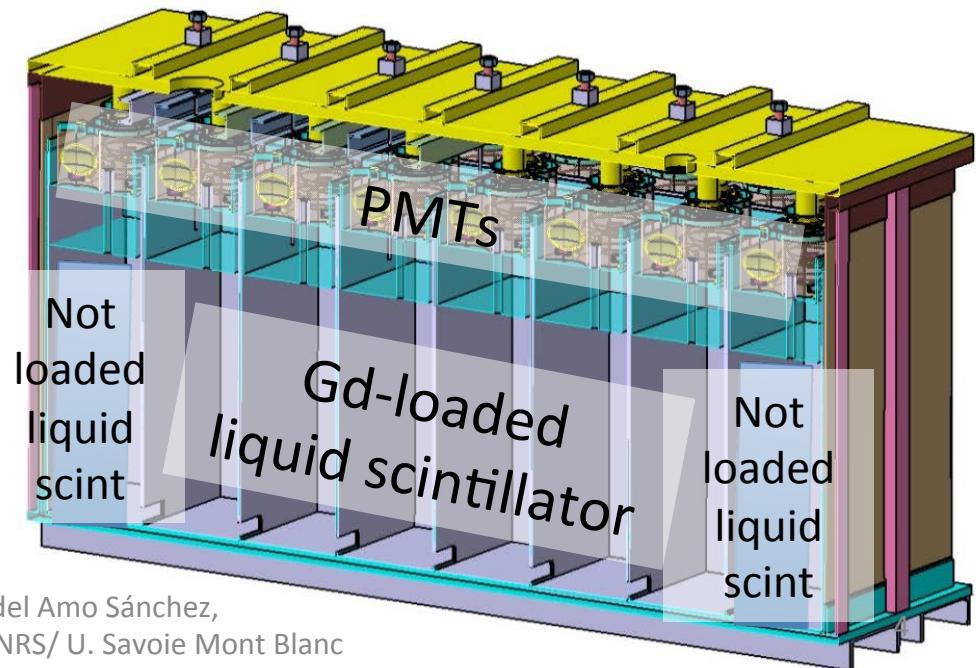


# The STEREO detector

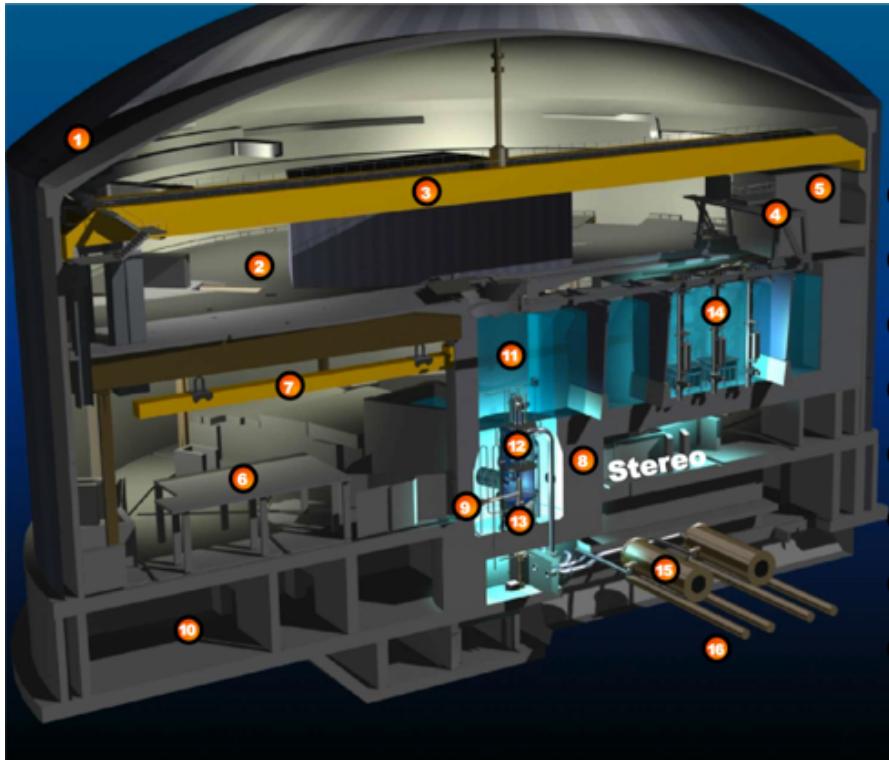
- $\bar{\nu}$  detection via inverse beta decay:  $\bar{\nu}_e + p \rightarrow e^+ + n$
- Signature: prompt ( $e^+$  annihilation)  
AND delayed ( $n$  capture on Gd)  $\sim 15 \mu\text{s}$  later



- $E(\bar{\nu}) \approx E(\text{prompt}) + 0.78 \text{ MeV}$
- Good energy resolution!

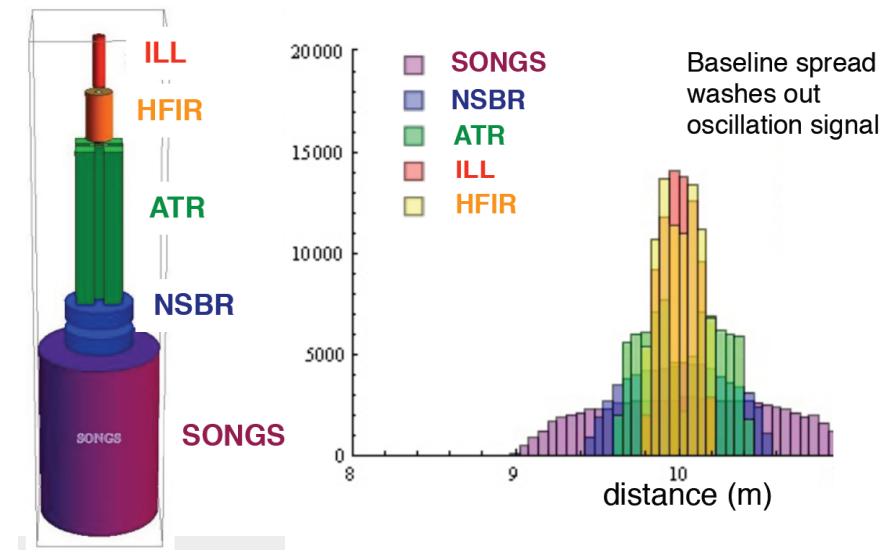


# ILL reactor

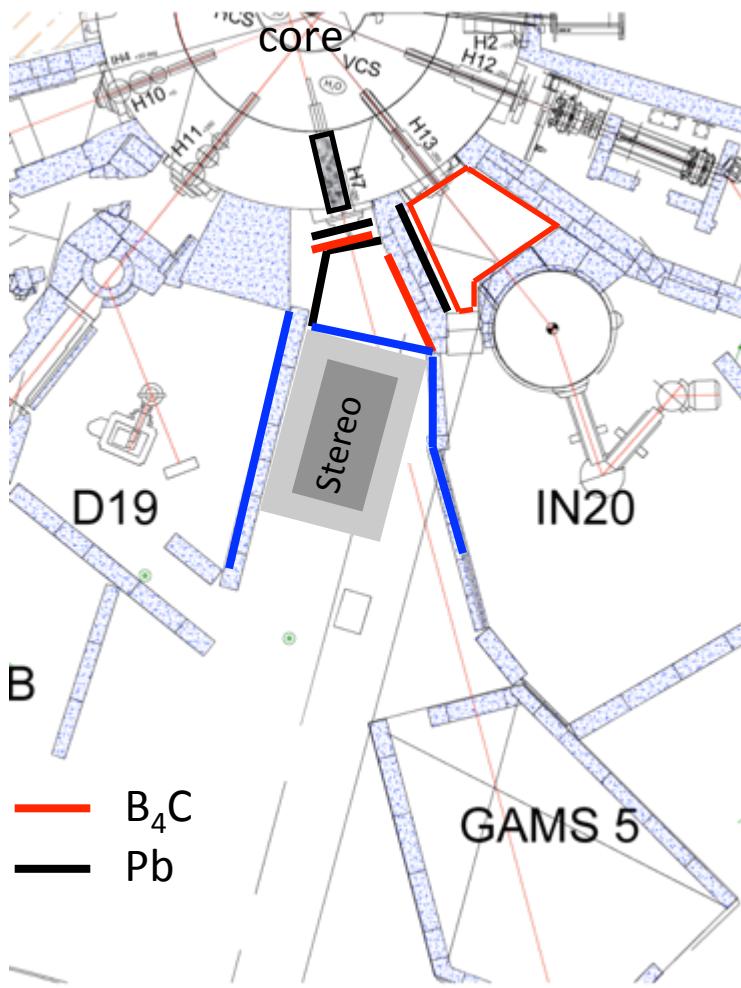


- 58 MW, high  $^{235}\text{U}$  enrichment
- 3 to 4 cycles/year, 50 days/cycle
- Water channel overburden, 15 m.w.e.
- STEREO baseline  $\langle L \rangle = 10$  m
- High  $\gamma$  and n flux

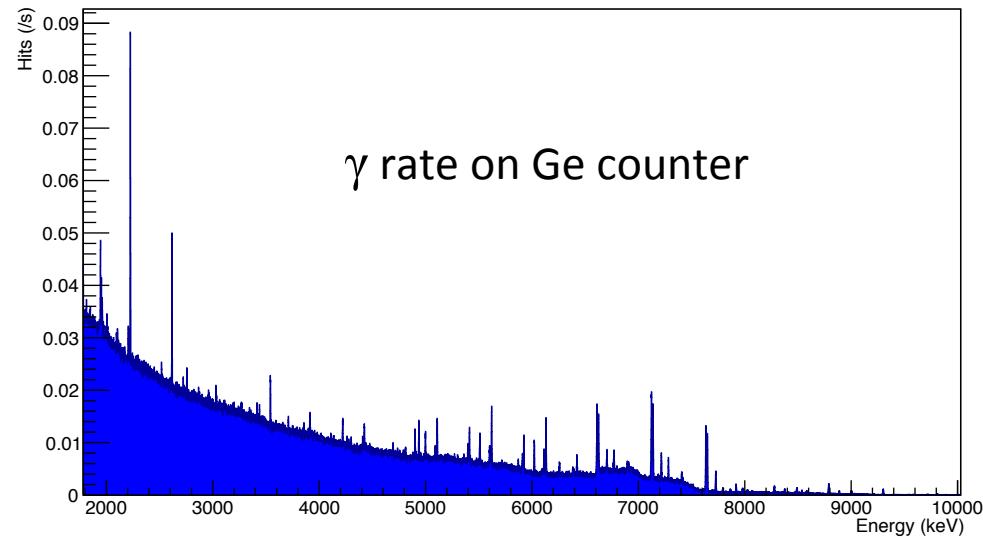
- Since  $\langle L_{\text{osc}} \rangle \approx 4$  m, need **VERY COMPACT** nuclear reactor core
- Institute Laue-Langevin (Grenoble, France), diameter = 39 cm



# Backgrounds



- On site measurements ( $\gamma$ , n,  $\mu$ )



- High  $\gamma$  and n flux → accidentals, correlated background:
  - n<sub>fast</sub> → proton recoil (prompt) + n capture (delayed)
    - Concrete+Pb plug for neutron line
    - B<sub>4</sub>C and Pb on walls of nearby sources

Borated CH<sub>2</sub>

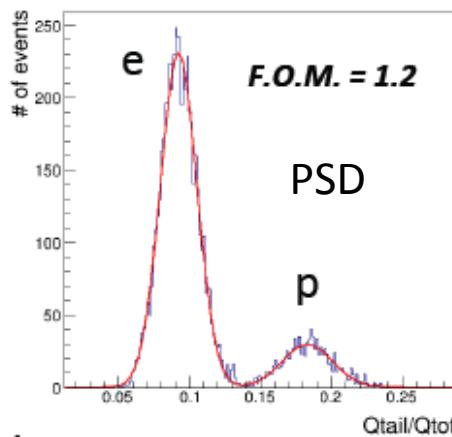
Muon detector

Borated CH<sub>2</sub>

Pb

# Backgrounds

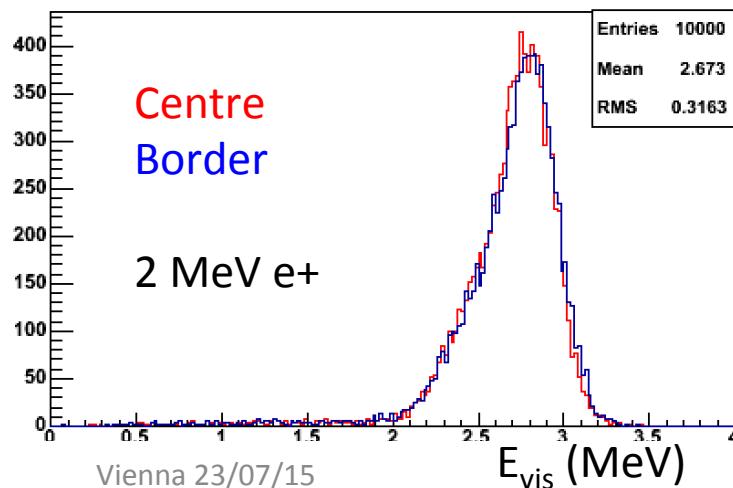
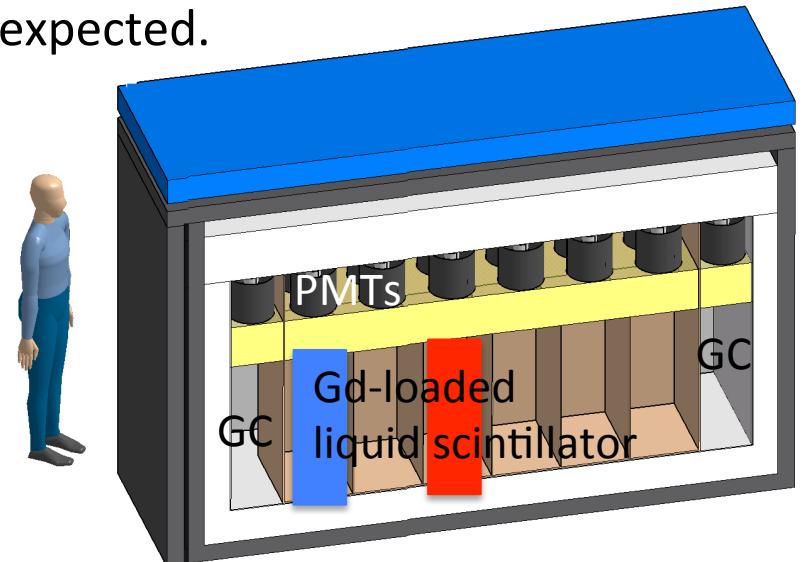
- On site measurements ( $\gamma$ , n,  $\mu$ )
- High  $\gamma$  and n flux from reactor
- $n_{\text{fast}} \rightarrow p$  recoil (prompt) + n capture (del.)
- Shield STEREO from them:
  - Concrete+Pb plug for neutron line
  - B<sub>4</sub>C and Pb on walls of nearby sources
  - CH<sub>2</sub> and Pb envelope around detector
- PSD in liquid scintillator for  $n_{\text{fast}}$
- $n_{\text{fast}}$  from cosmic rays
  - Water channel overburden (15 mwe)
  - Muon veto above detector
  - Reactor OFF measurement
- Check background models by shifting detector along axis



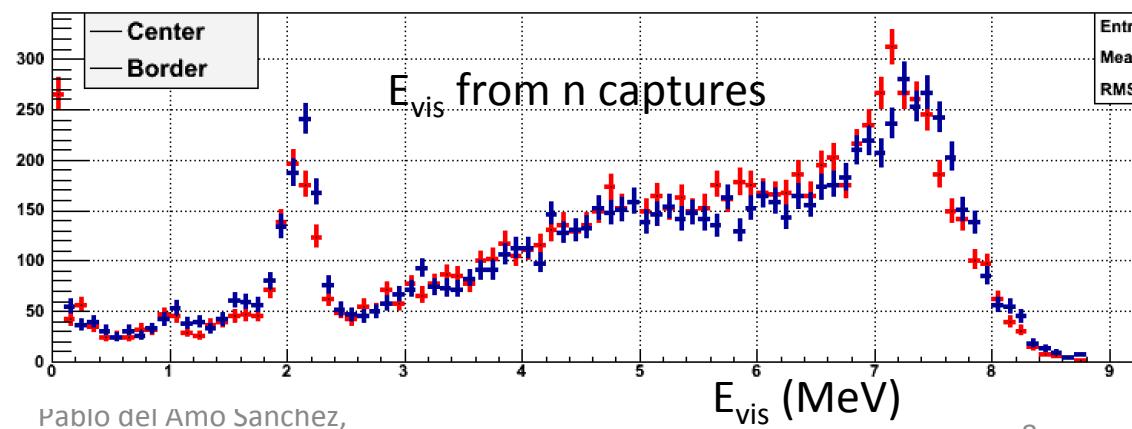
# Detector response

Minimise asymmetries among cells.

- No difference in  $\nu$  energy reconstruction expected.  
(RMS  $\approx 12\%$  for  $E_{\text{vis}} \approx 3 \text{ MeV}$ )
- 4% difference in neutron efficiency  
due to lack of Gd in Gamma Catcher  
**(61% centre vs 57% border)**



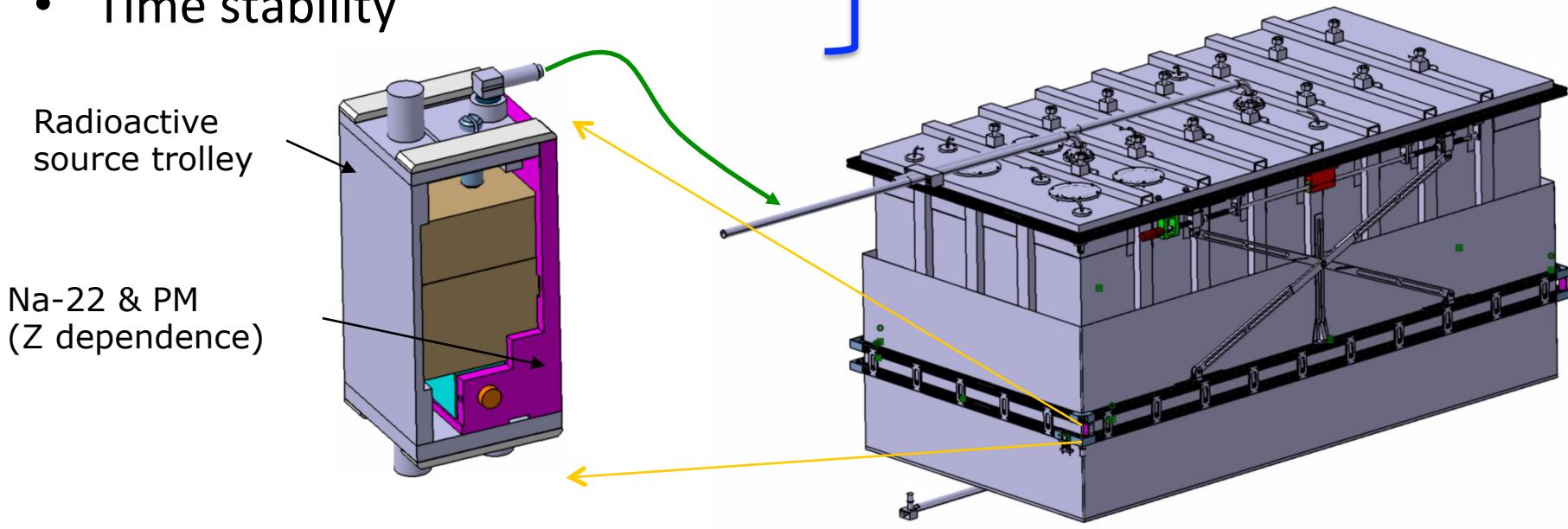
Vienna 23/07/15  
EPS HEP 2015



Pablo del Amo Sanchez,  
LAPP - IN2P3 - CNRS / U. Savoie Mont Blanc

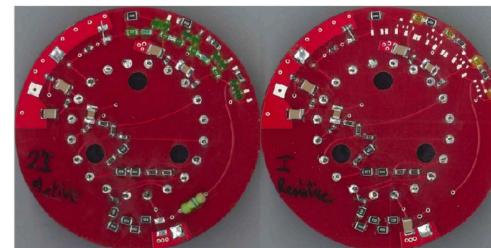
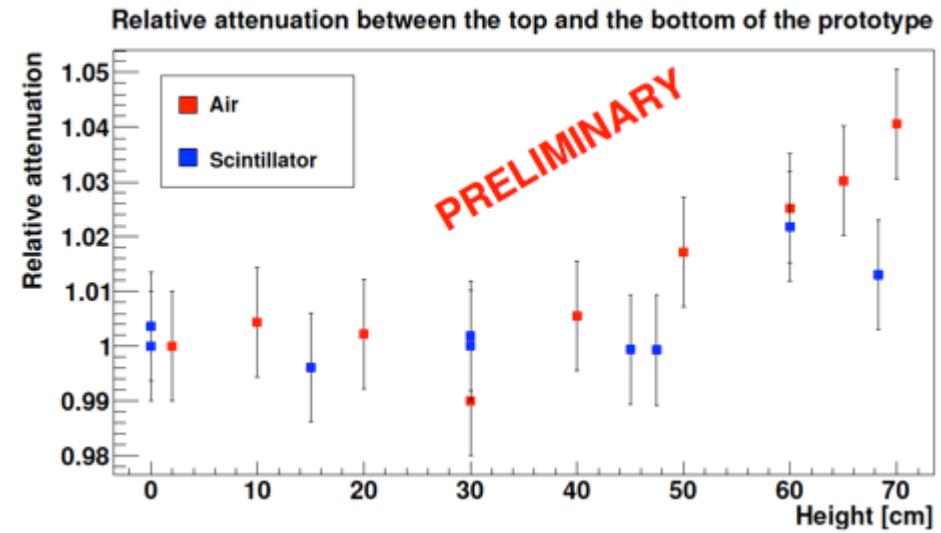
# Calibration system

- Energy scale and neutron capture efficiency
  - Detector response inhomogeneities ( $Z$  dependence, centre vs border)
  - Time stability
- Radioactive sources  
LED emitters + optic fibers



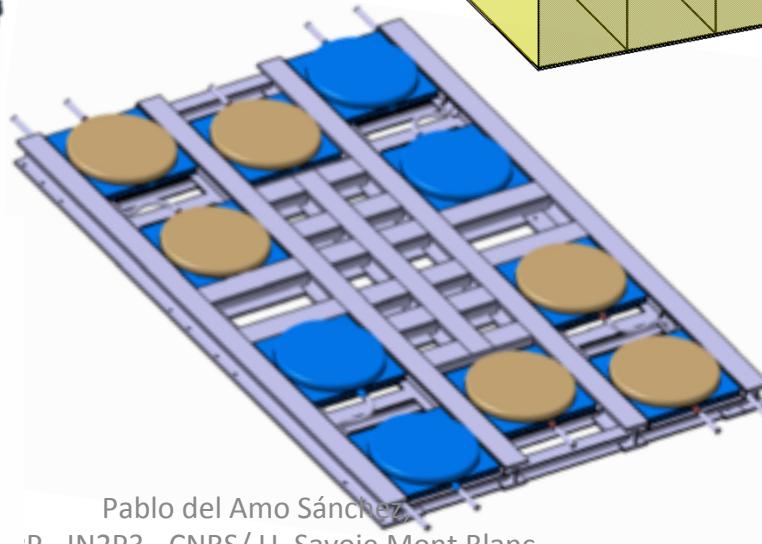
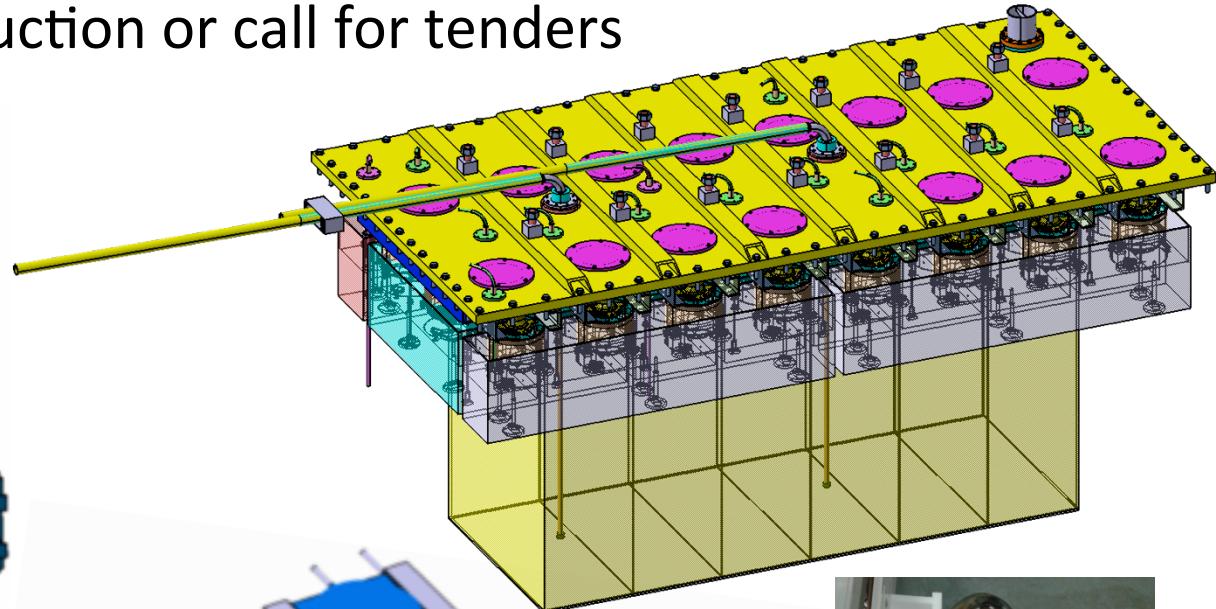
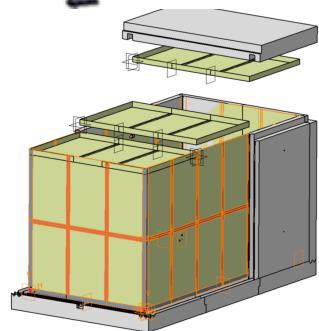
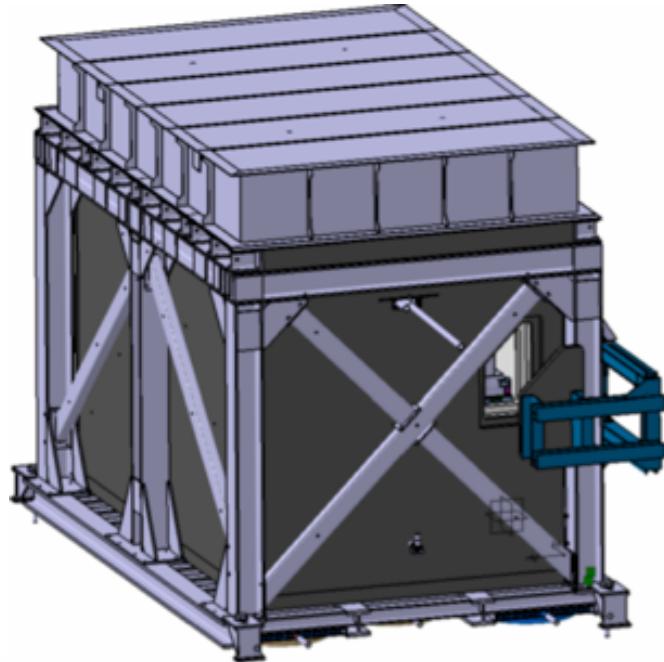
# Prototypes

- Prototypes of inner detector, muon veto, electronics, DAQ, LED monitoring, radioactive source calibration, produced and tested



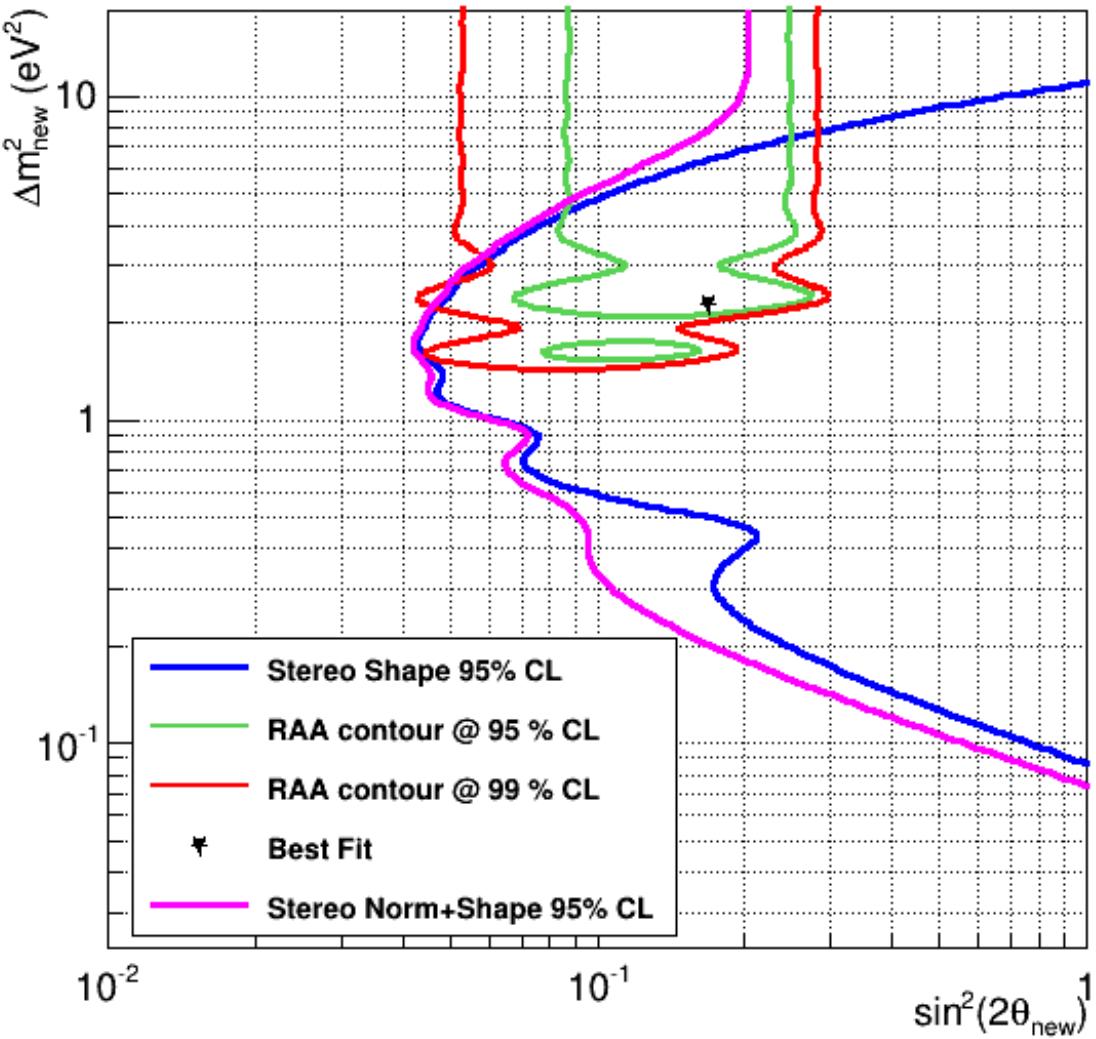
# Production

- Most items in production or call for tenders



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# Expected sensitivity



- 300 days,  $\sim 480 \nu_e/\text{day}$
- $L_0 = 10.0 \text{ m}$
- $E_{\text{prompt}} > 2 \text{ MeV}$   
 $E_{\text{delayed}} > 5 \text{ MeV}$
- $\delta E_{\text{scale}} = 2\%$
- All syst. of predicted spectra
- S/B = 1.5, 1/E + flat
- Norm:
  - 3.7% absolute norm.
  - 1.7% relative norm. between cells

# Timeline

- Oct 2013 – France's ANR funding
- 2013-2015 – design and production; background studies at ILL and additional shielding
- First half of 2016 – installation, mounting, commissionning
- June 2016 – Filling of detector with liquid scintillator
- Summer 2016 – start of data taking
- Late 2016/early 2017 – first physics results

# Conclusions

- STEREO will test the Reactor Antineutrino Anomaly and has the sensitivity to exclude or confirm the sterile  $\nu$  hypothesis
- Data taking to start in Summer 2016



Laboratoire d'Annecy-le-Vieux  
de Physique des Particules



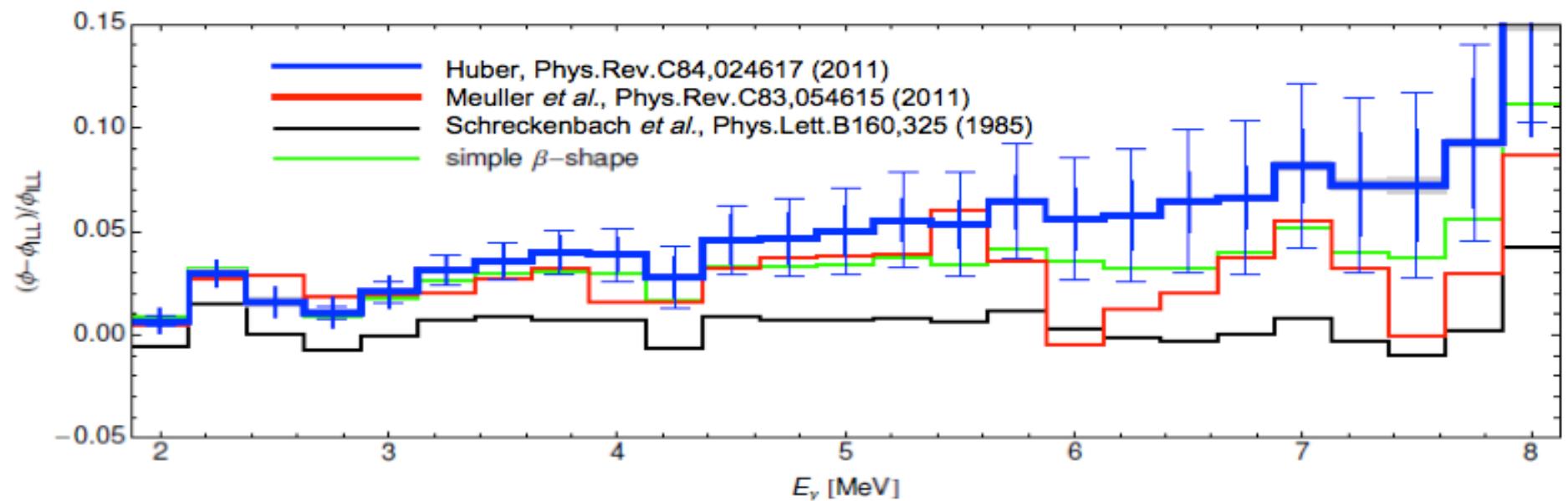
- Stay tuned!

# BACK UP

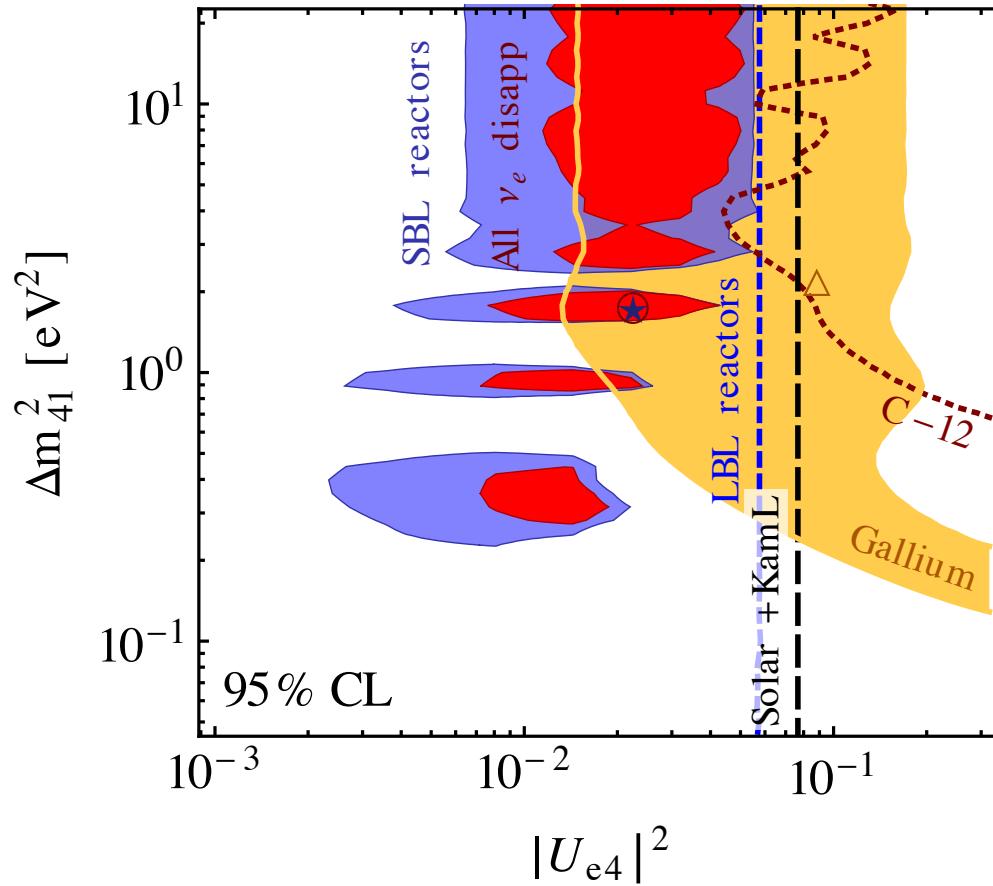
# Reactor $\bar{\nu}$ flux

PRC83, 054615 (2011)

PRC84, 024617 (2011)



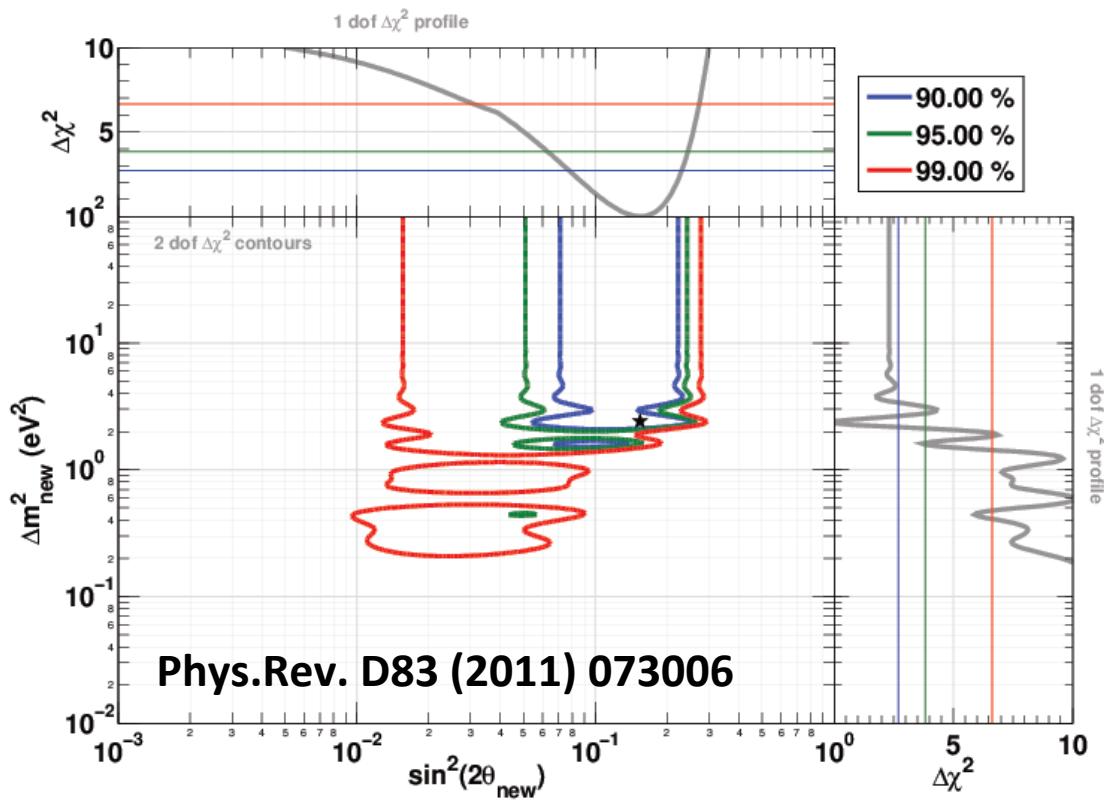
# Reactor antineutrino anomaly



Kopp et al, JHEP 1305:050, 2013

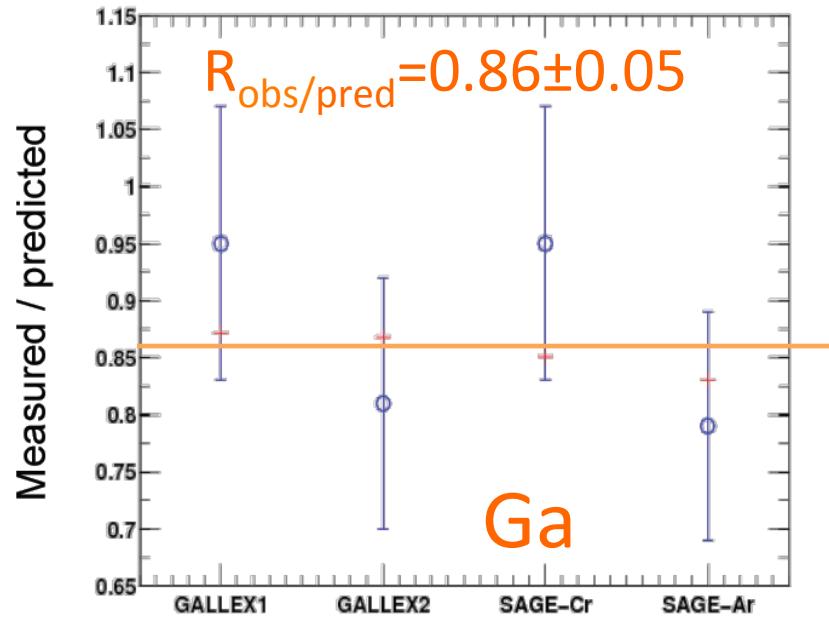
# Reactor+Ga anomalies fit

- Both reactor and Ga anomalies can be explained by 1 sterile  $\nu$



$$\begin{aligned}\Delta m^2 &\sim 2 \text{ eV}^2 \\ \sin^2(2\theta_{ee}) &\sim 0.2 \\ L_{\text{osc}} &\sim 2 \text{ m}\end{aligned}$$

# Gallium anomaly



# Shielding

