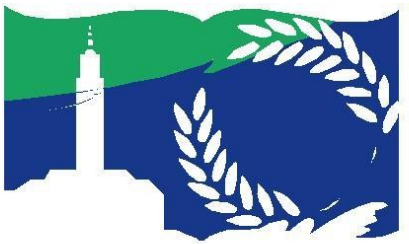
The STEREO experiment: Status report

Luis Manzanillas / LAPP

On behalf of the STEREO collaboration

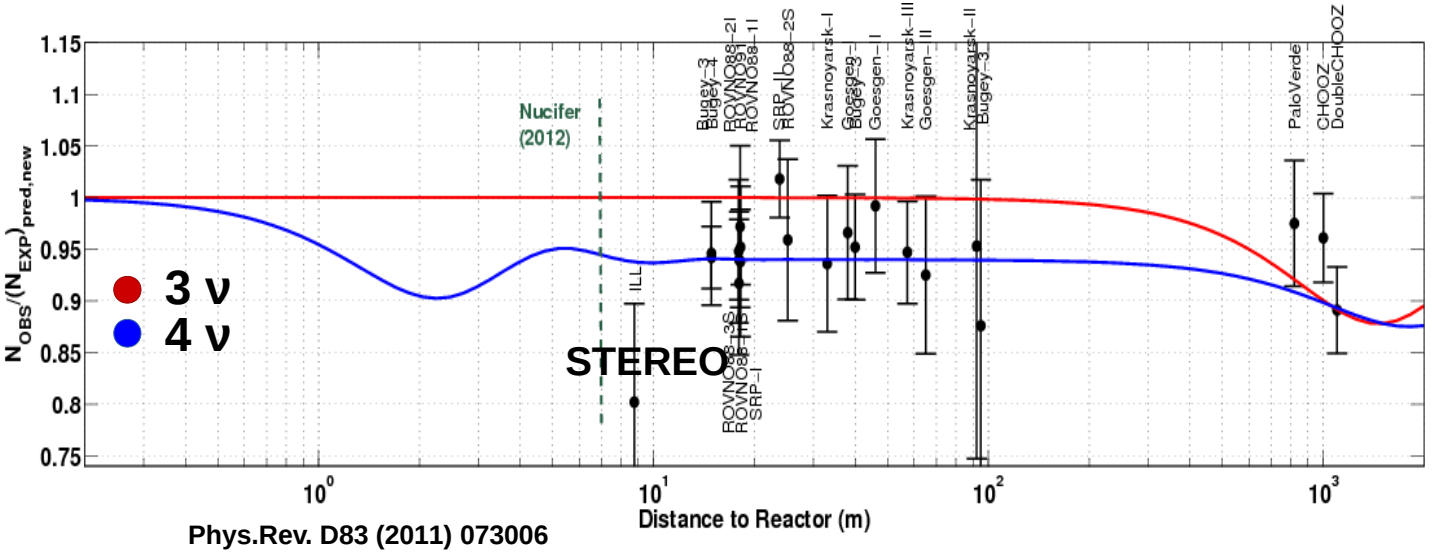
GDR neutrino
Grenoble, June 2016



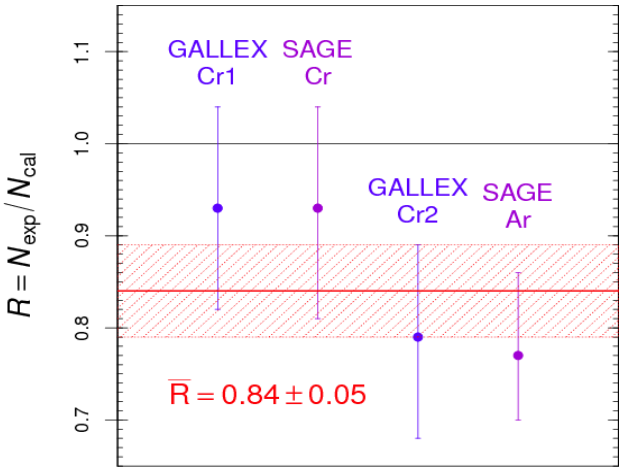
جامعة الحسن الثاني - الدار البيضاء
UNIVERSITE HASSAN II - CASABLANCA

Short baselines anomalies

- The reactor antineutrino anomaly (RAA) and gallium anomaly (GA) both show discrepancies with respect to the expectations at ~3σ level
- Oscillations into a light sterile neutrino state (Δm^2 ~1 eV) could account for such deficits



Phys.Rev. D83 (2011) 073006

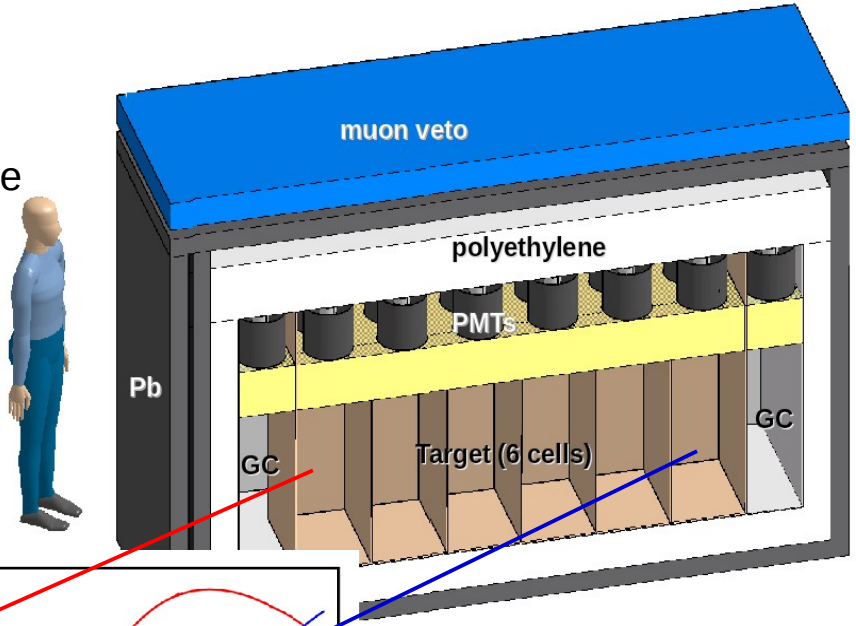


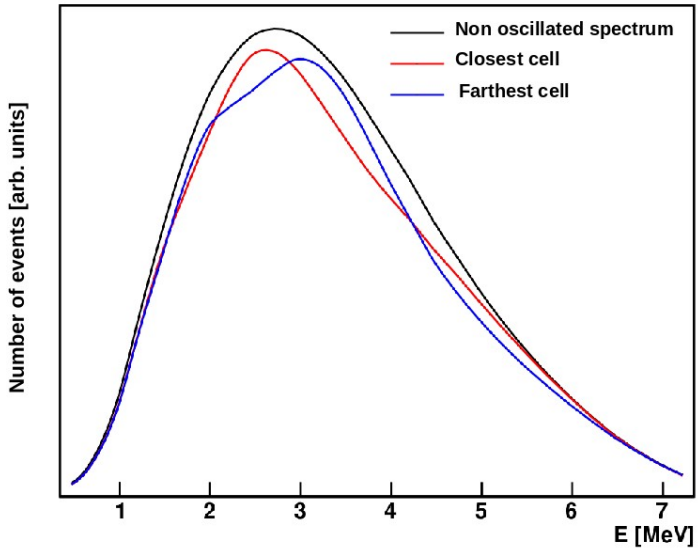
J.Phys. G43 (2016) 033001

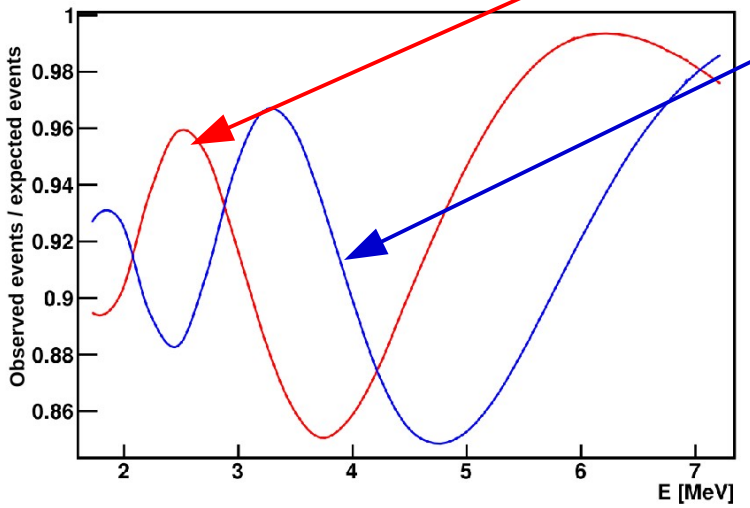
The STEREO experiment

Goal: Search for an **oscillation** by looking for a **distortion** of the reactor $\bar{\nu}_e$ energy spectrum at different baselines

$$P^{3+1}_{\bar{\nu}_e \to \bar{\nu}_e} = 1 - \sin^2(2\theta_{14}) \sin(1.27 \Delta m^2_{41} L/E)$$

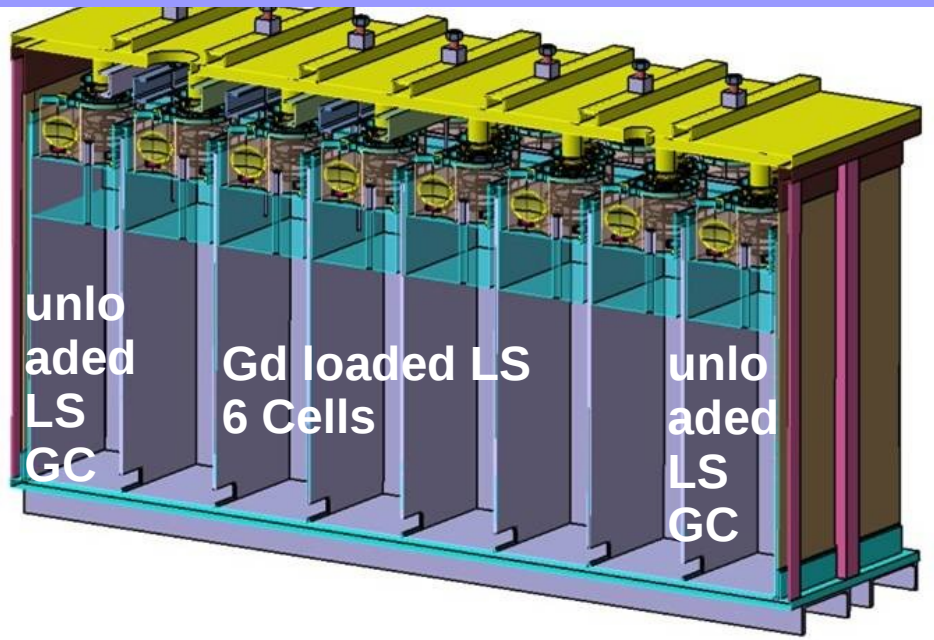






$\Delta m^2 = 2.3\ eV^2$
$Sin^2(2\theta) = 0.17$

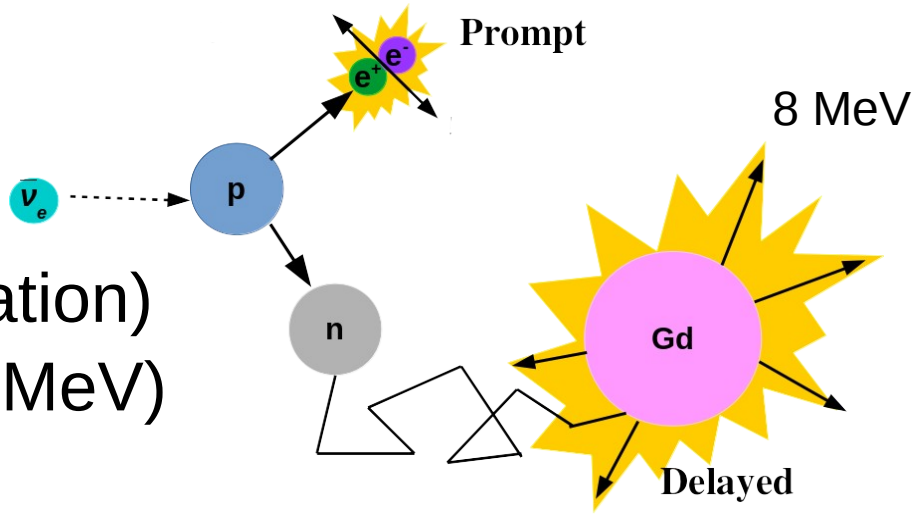
The STEREO detector



2 m^3 of Gd loaded liquid scintillator (LS) **segmented** in 6 cells surrounded by unloaded LS (gamma catcher, GC)

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

Coincidence of Prompt (e^+ + annihilation) and Delayed (n-Gd ≈ γ cascade of 8MeV) signals in a time window of 50 μs

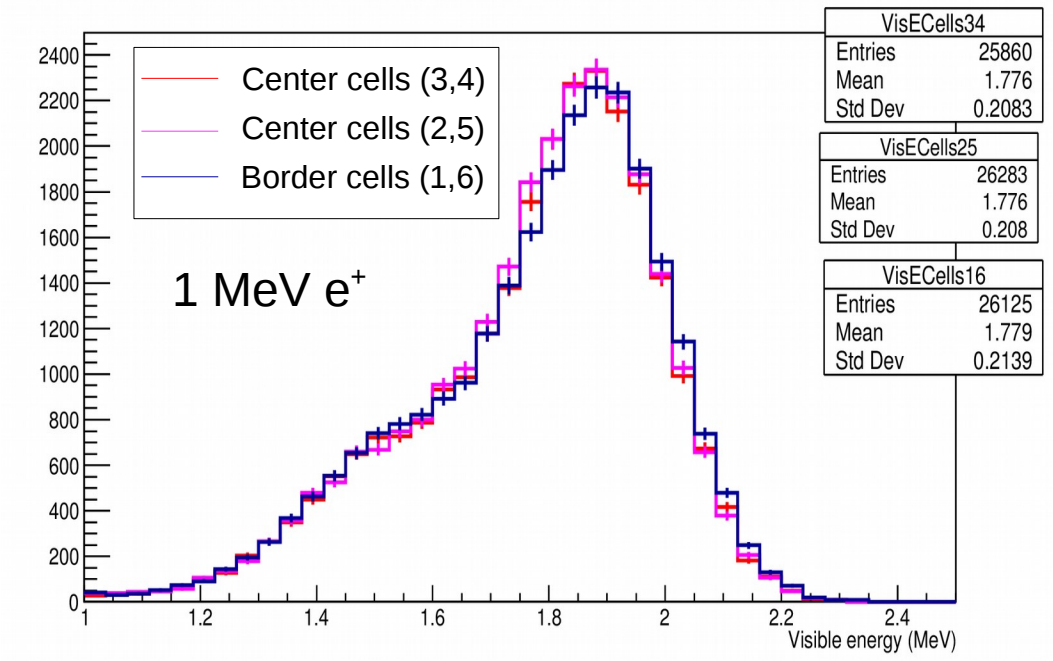


Detector response

- **Maximize uniformity between cells**
- Expected resolution of 12% at 2 MeV

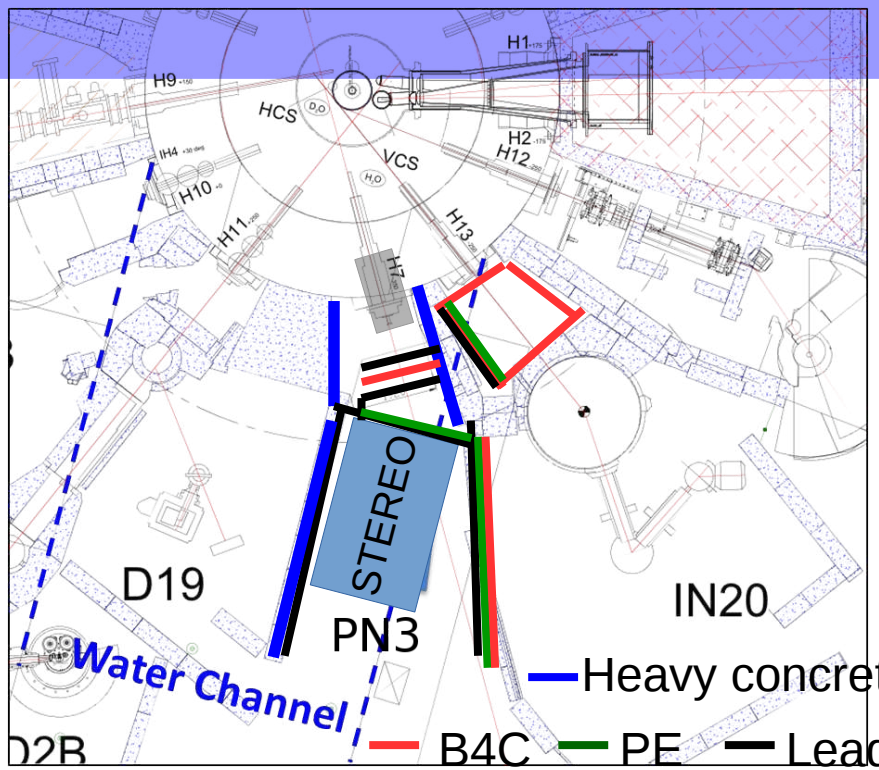
  → Tiny difference between a central and a border cell!
- n capture efficiency: only 4% of difference between a central vs a border cell

Detailed Geant4 simulation of the detector response



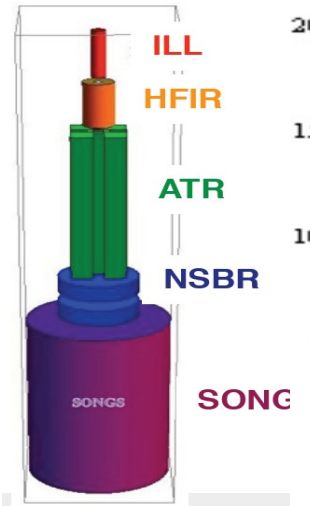
The STEREO site and ILL reactor

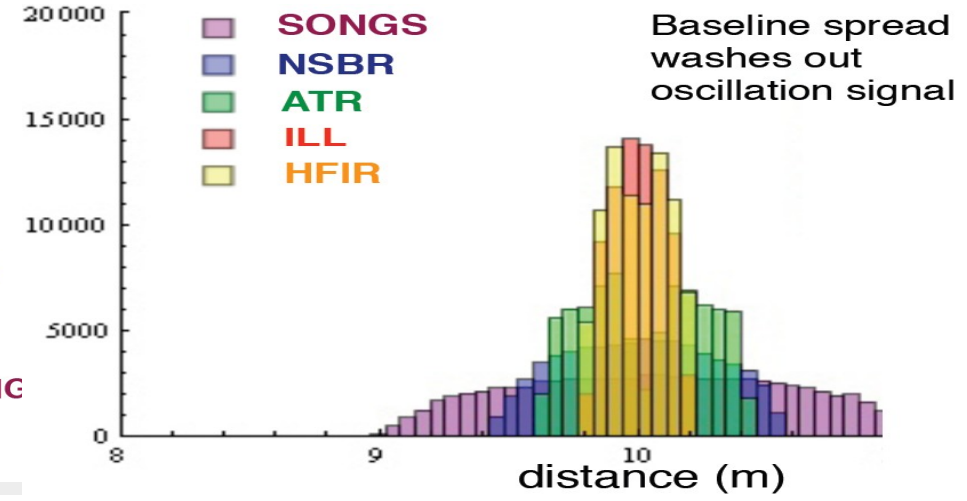
- Very compact reactor core (diameter = 37 cm)
- 58 MW, highly ^{235}U enriched
- Water channel overburden, 15 m.w.e
- 10.2 m from reactor core to center of STEREO



- High n and gamma flux
- Magnetic field from IN20
- → Need heavy shielding

  (Lead + B4C + Polyethylene +soft iron, μ-metal)



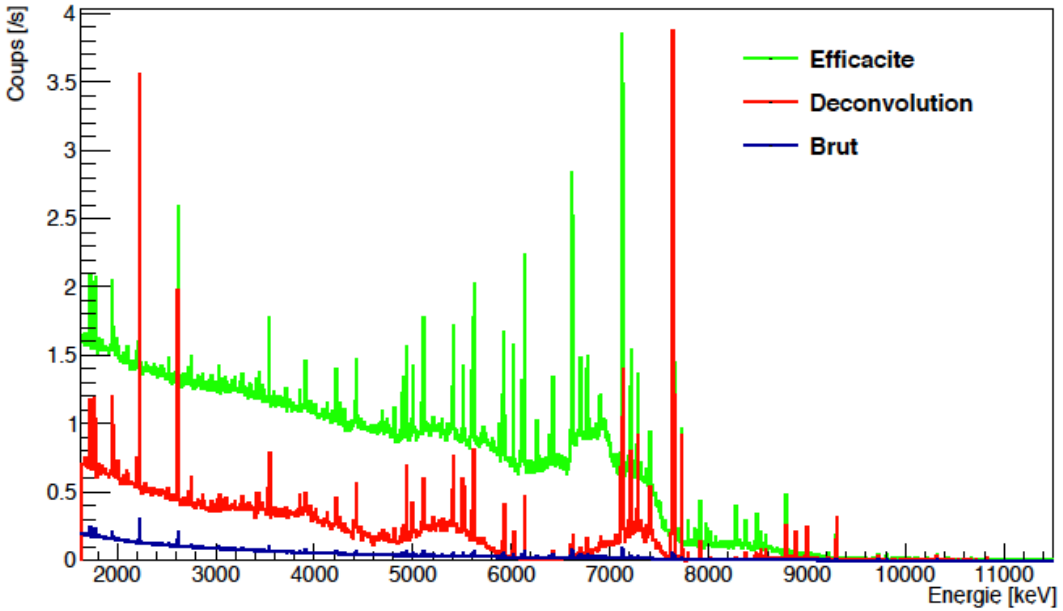


Background

- Mapping of the STEREO casemate using Ge, NaI, He3 and Ne213 detectors
- Measurements of muon rates
- Mapping of magnetic field

Directionality studies

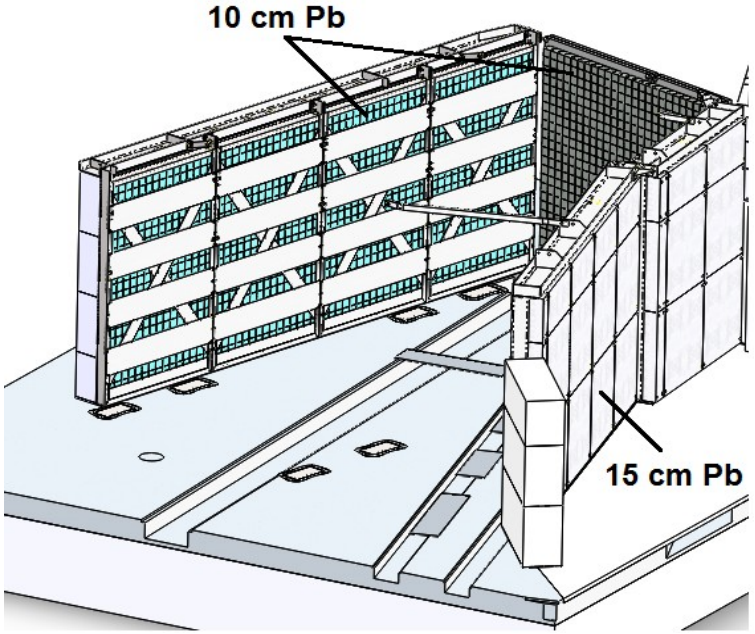
Deconvoluted γ-spectrum



- Main sources identified, extra protection added
- New campaign of measurements ongoing to validate shielding

External shielding

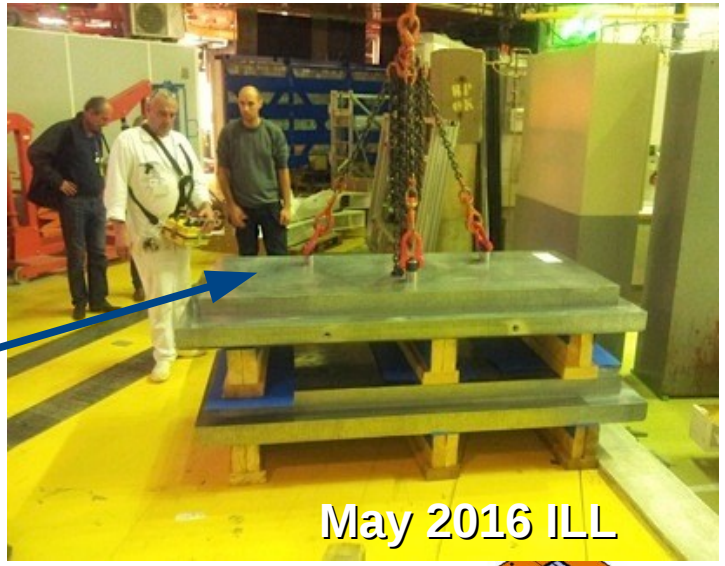
- D19: 10 cm of lead + B4C
- Front Wall: Plug in H7 tube + 10 cm of polyethylene + 10 cm of Lead
- IN20: 10 cm of borated polyethylene + 15 cm of Lead + B4C
- **Installation completed!**



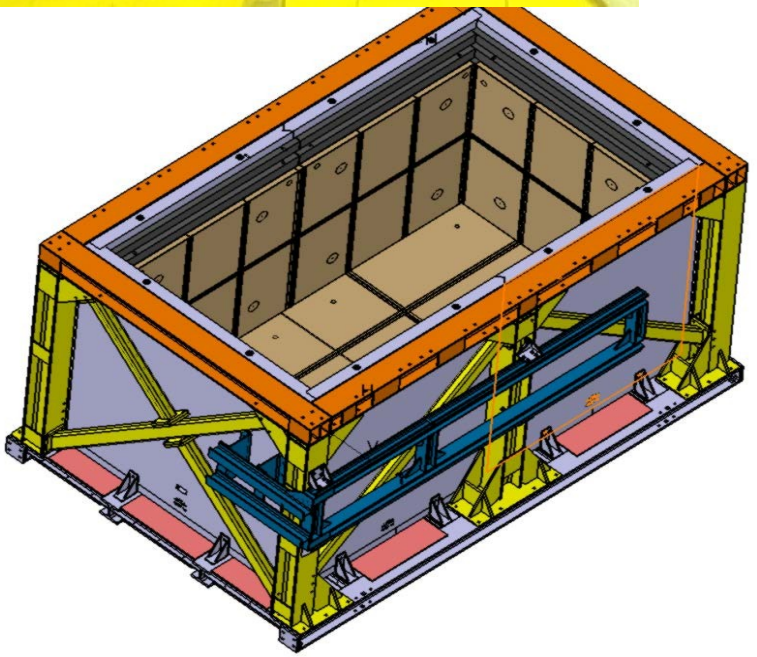
New record of speed lead wall mounting!

Internal shielding

- Magnetic shielding (soft iron + μ-metal delivery in June)
- 6 tons of polyethylene (delivery in July)
- 65 tons of lead (delivered and ready for mounting)



Mounting ongoing



Muon veto

- 396x240x26 cm^3 of pure water with 4MU at 6 ppm
- 20 PMTs with 2 layers of μ-metal

- Efficiency > 99%
- Stable through time
- μ-veto ready to be moved to ILL (end July)!

Inner detector

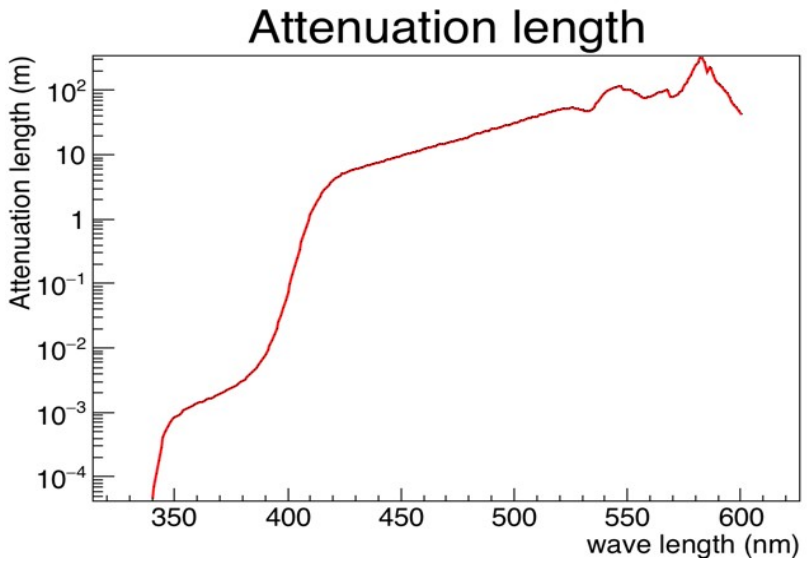
- Double stainless steel vessel
- Acrylic buffer between PMTs and LS
- VM2000 in the cell walls

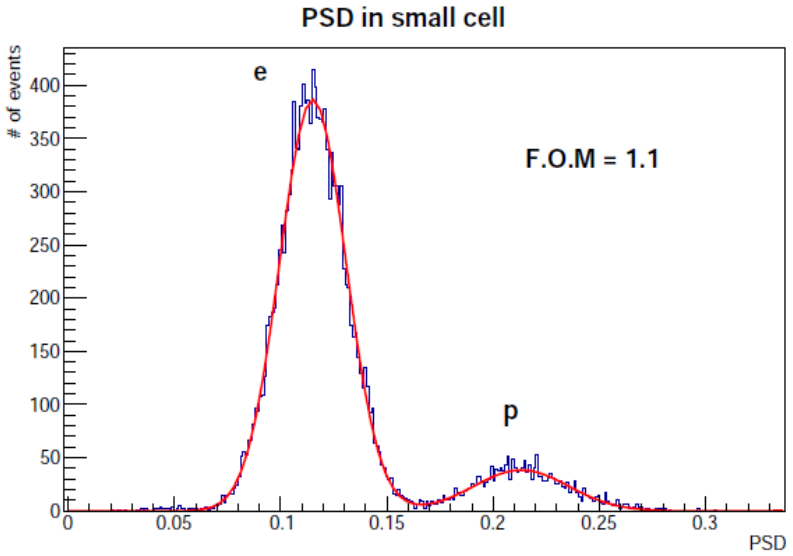
Detector moved to ILL and ready for installation !!!

The STEREO liquid

- **Composition**:
  - 75% LAB → delivered
  - 20% PXE → column purified
  - 5% DIN → column purified
  - PPO + bis-MSB →ready
  - Gd complex (0.2% Gd) + 1% THF →ready

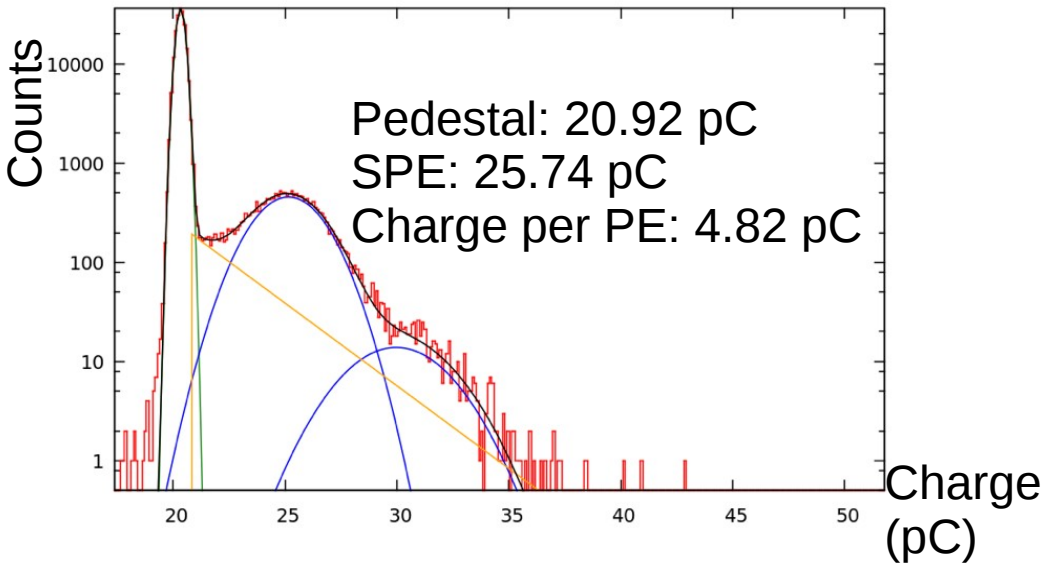
- Light yield ≈ 6000 photons / MeV
- Attenuation length > 5m in final mixture !





PMTs

- HAMAMATSU R5912-100
  - Quantum efficiency ≈ 30%
  - Dark rate: 3000 Hz
  - Peak / valley ratio: 2.7
  - Transit time spread: 3.5 ns

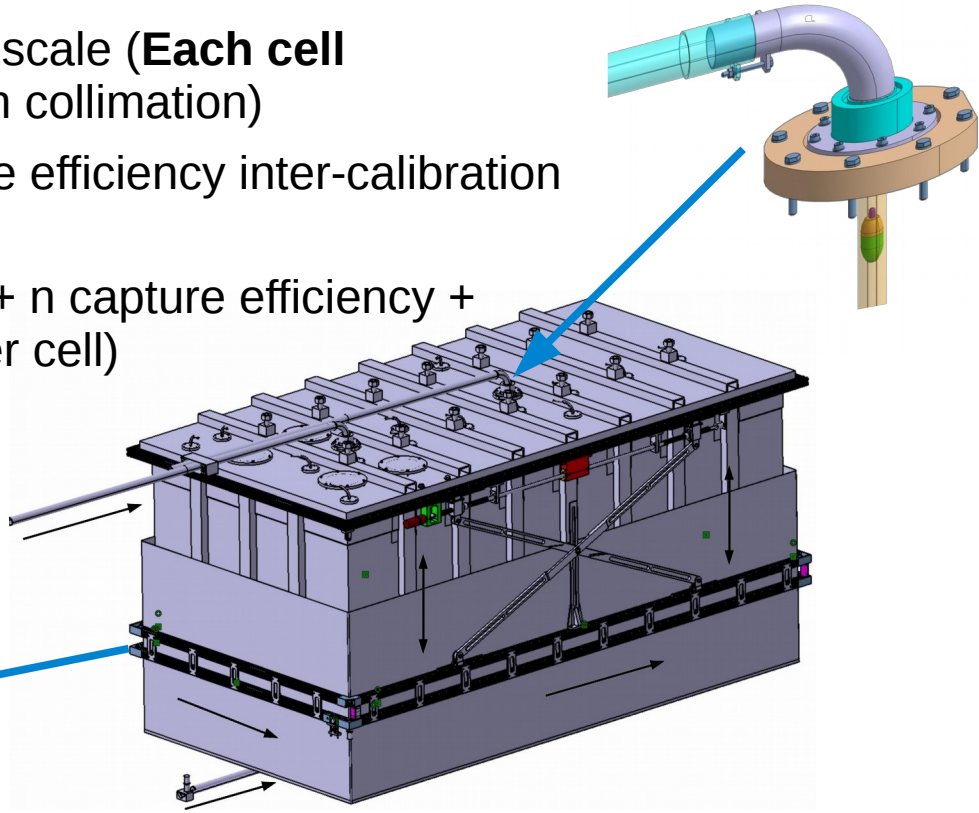


PMT setup at MPIK Heidelberg

All PMTs tested and installed in the inner detector!

The calibration system

- Three subsystems:
  - Automated circulation around detector → Energy scale (**Each cell independently** + GC + vertical dependence with collimation)
  - Automated movement under detector → n capture efficiency inter-calibration (**1 reference point in each cell**)
  - Three manual calibration tubes → Energy scale + n capture efficiency + vertical dependence (Two central and one border cell)

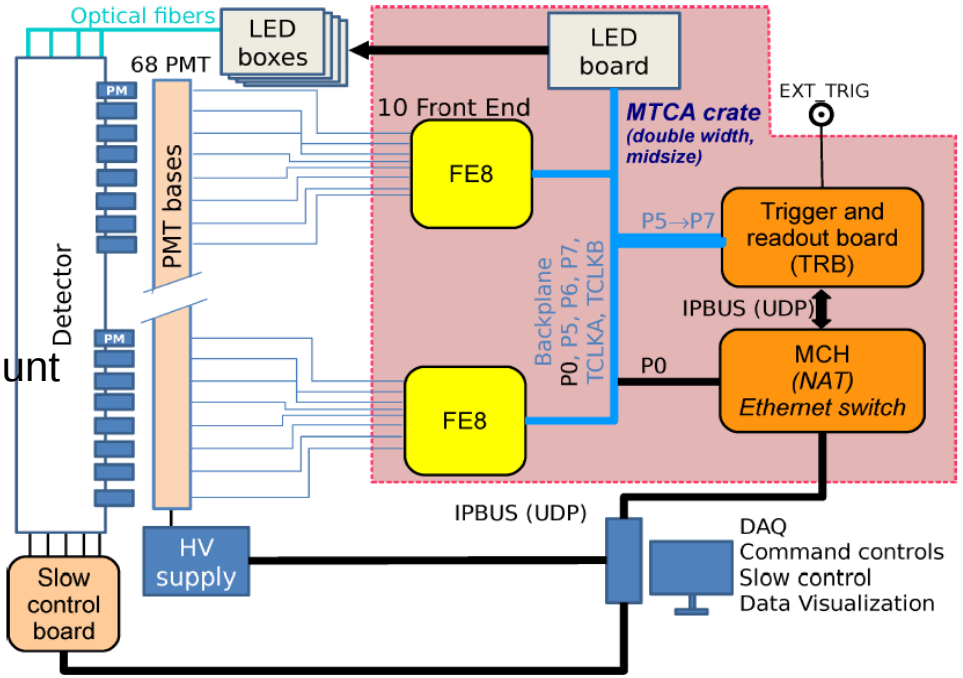


Sources: ^{22}Na, AmBe, ^{252}Cf, n-H, n-Fe

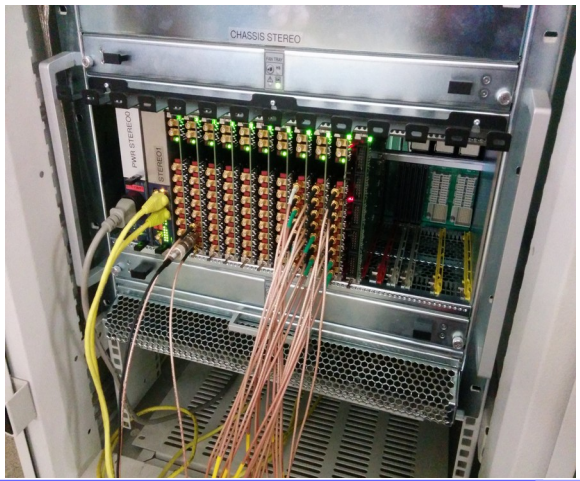
Testing system → installation in summer 2016

Electronics

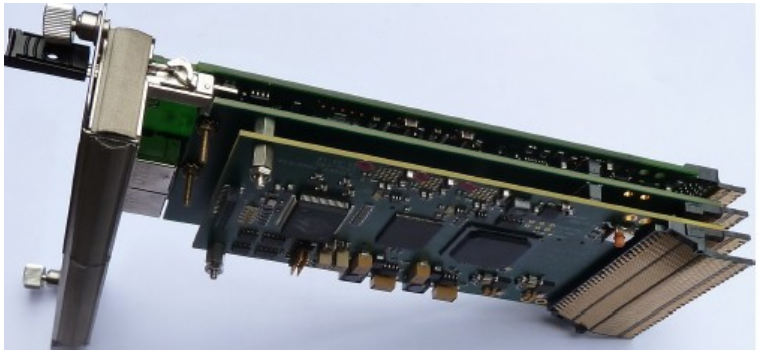
- Electronics hosted in a µTCA crate
- Front-end boards tested and validated
  - Qtot, Qtail, tCFD and pulse
  - 8-channel FADC 14 bits 250 MHz sampling
  - Gain x1 and x20 for SPE
  - First level trigger programmable
- Trigger board: second level programmable taking into account Target, Gamma Catcher and µ-veto
- LED board for light calibration (light injection at 3 vertical positions in each cell)
- Extensively tested using µ-veto



µTCA crate



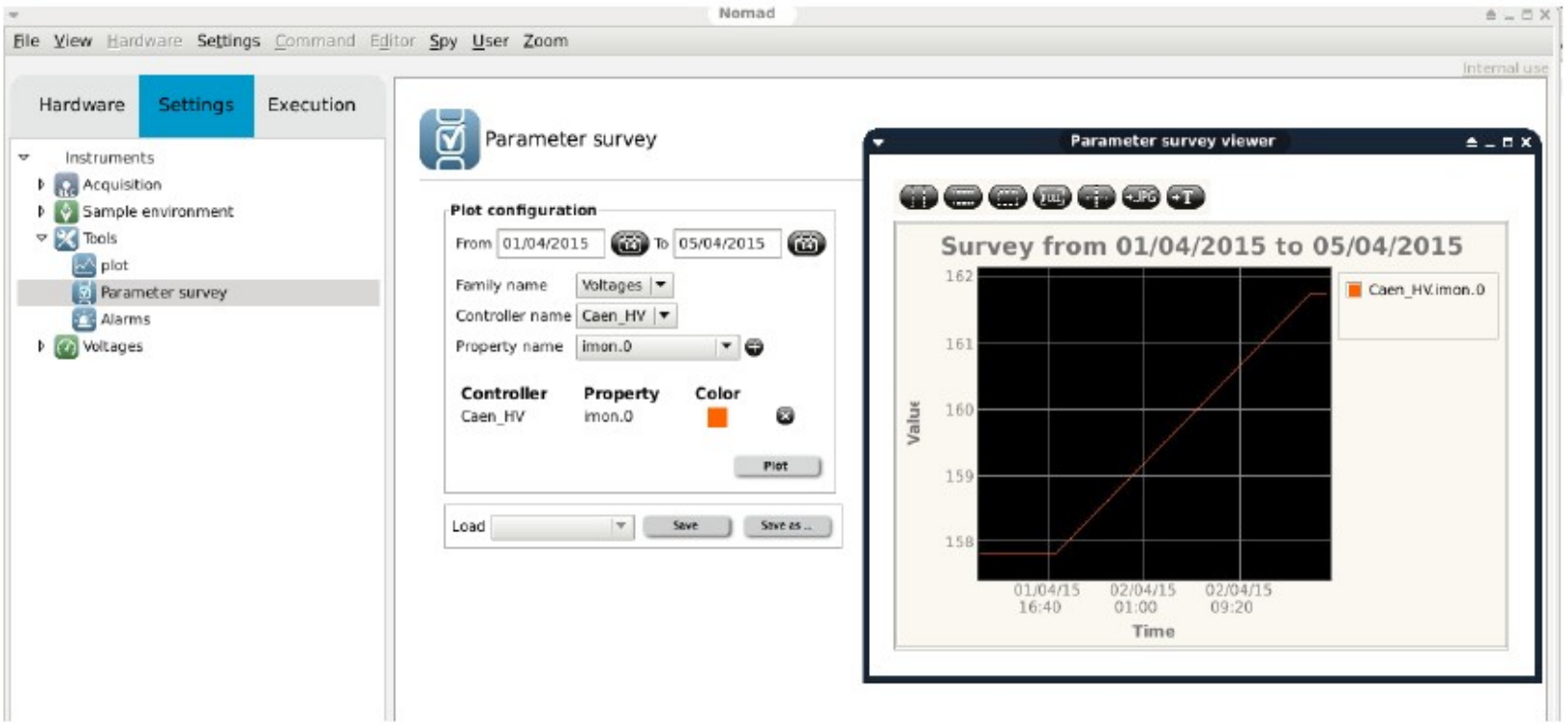
Trigger board



PMT basis

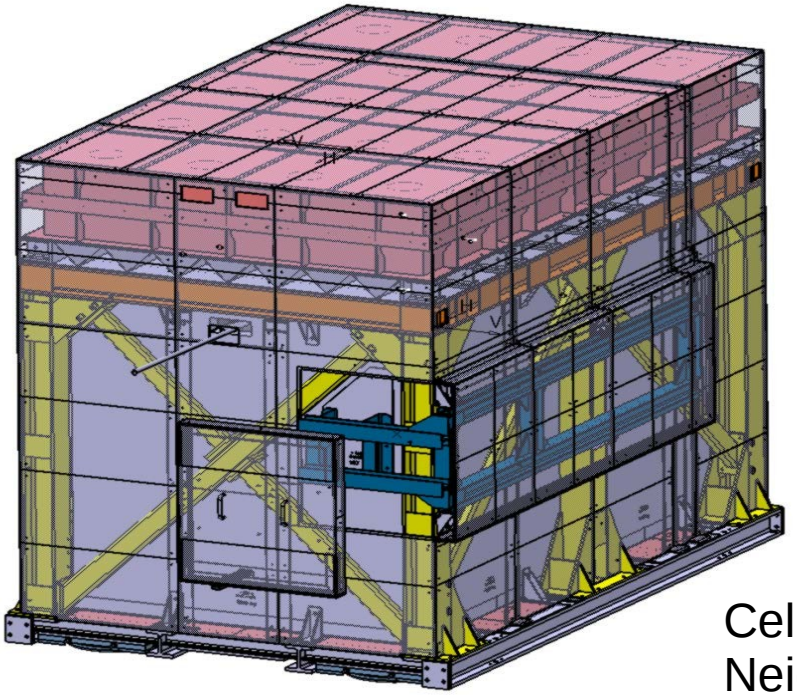
Data acquisition

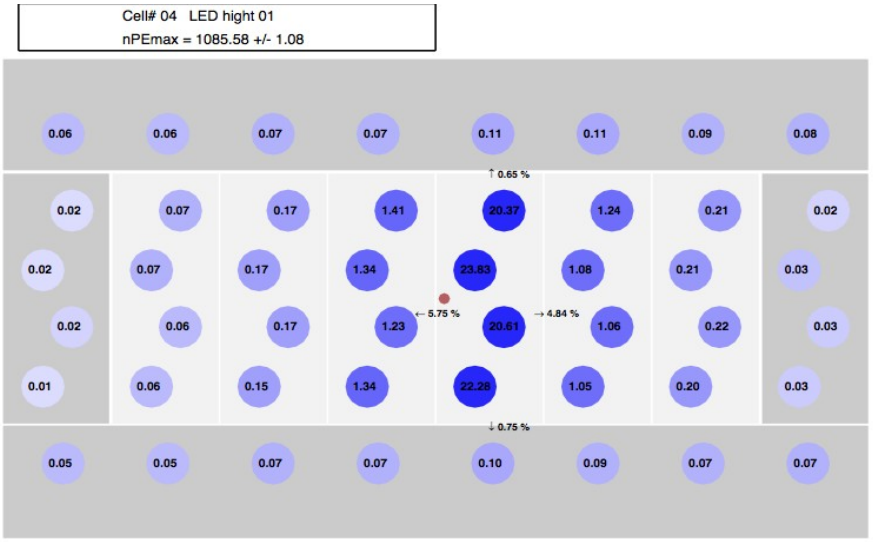
- Data acquisition using NOMAD (standard ILL software)
- Slow control and monitoring ready
- All the chain successfully tested using LEDs



Installation status

- Tested detector and acquisition with LEDs in air
  → Fine tuning of simulation started
- Mounting of support structure ongoing
- Filling STEREO with LS in September

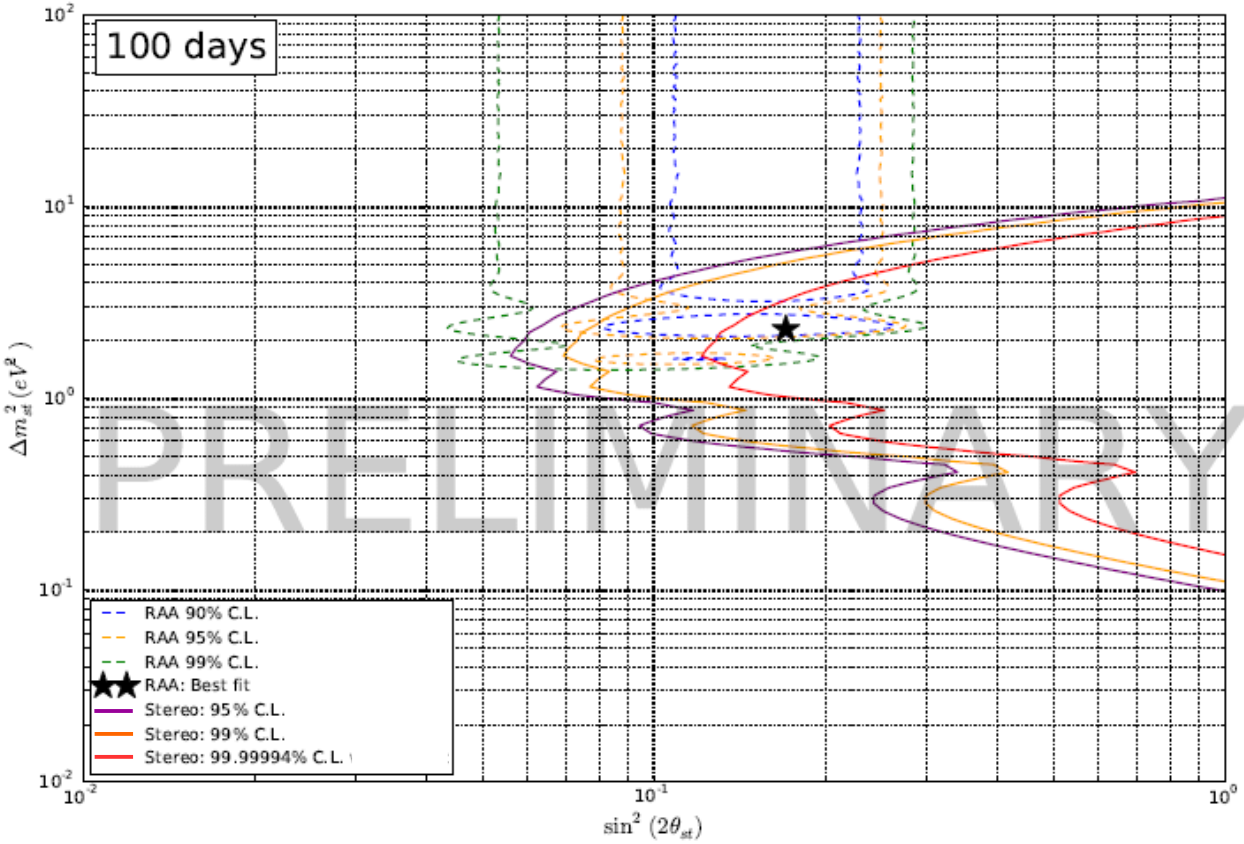




Cell of LED: 87%
Neighboring: ~11%
GC: ~1%
Other Cells: ~1%

Expected sensitivity and first physics results

Possible to exclude at 5σ the best fit parameters region with only 100 days of data! (expected 1st half 2017)



- 400 ν events / day
- Signal / Bkg ≈ 1.5
- L0 = 10 m
- E_{prompt} > 2MeV

  $E_{delayed}$ > 5MeV
- All systematics of predicted spectra
- δE_{scale} < 2%

Conclusions

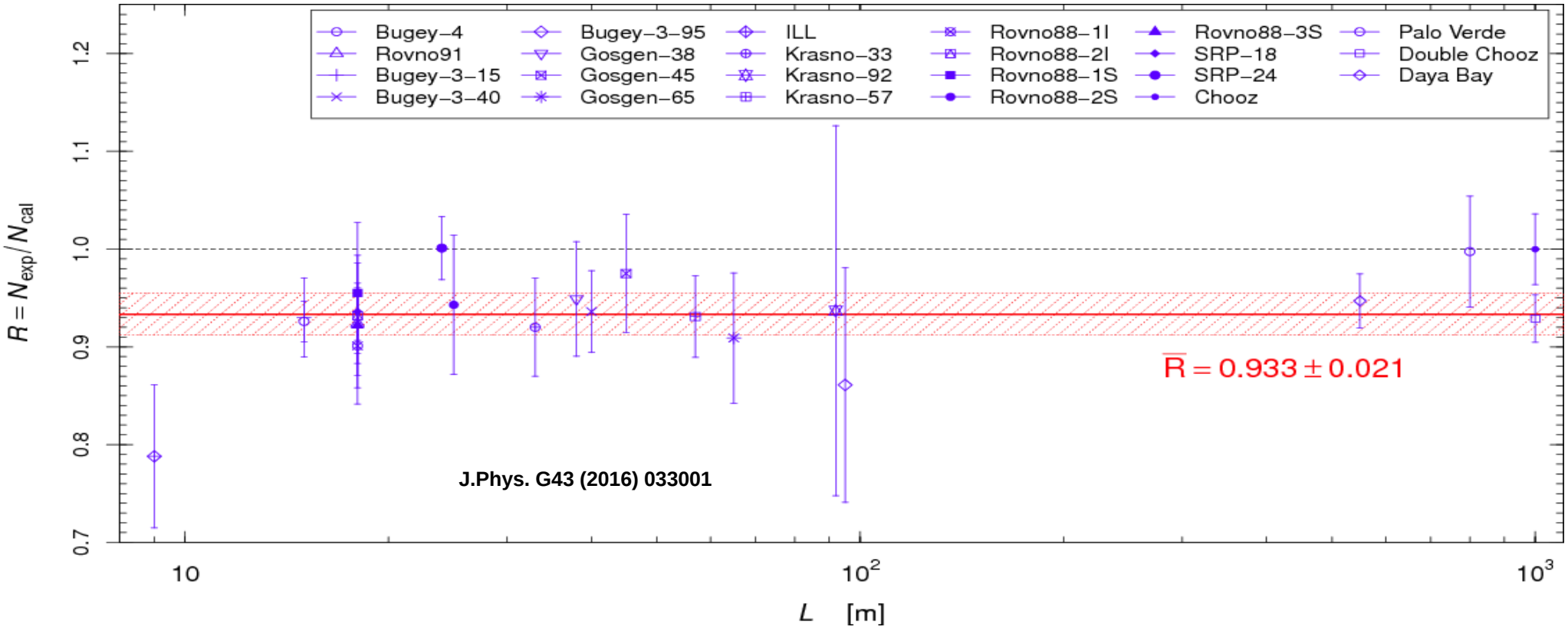
- All large items delivered at ILL
- Reinforcement of casemate shielding completed
- Installation started → mounting support structure
- Detector ready for filling → September 2016
- Objective: commissioning in autumn 2016
  - → 100 days of data taking before winter break
  - → First physics results, first half of 2017

DATA IS COMING!!!

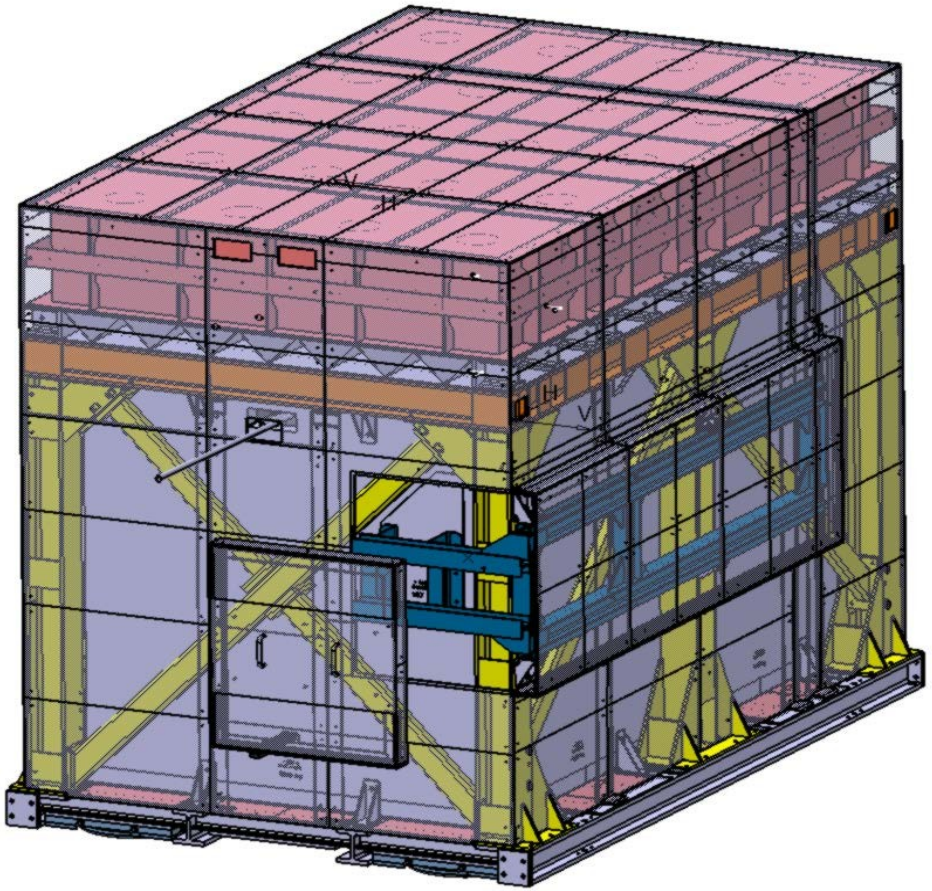
Thanks for your attention!

Backup

RAA after Double-Chooz and Daya-Bay



Mounting procedure



Support structure → Lead → Polyethylene → B shielding + Inner Detector → Calibration system → Cabling, tests → Muon veto → STEREO in casemate → Filling with LS