Calibration and quality assurance of the SoLid detector

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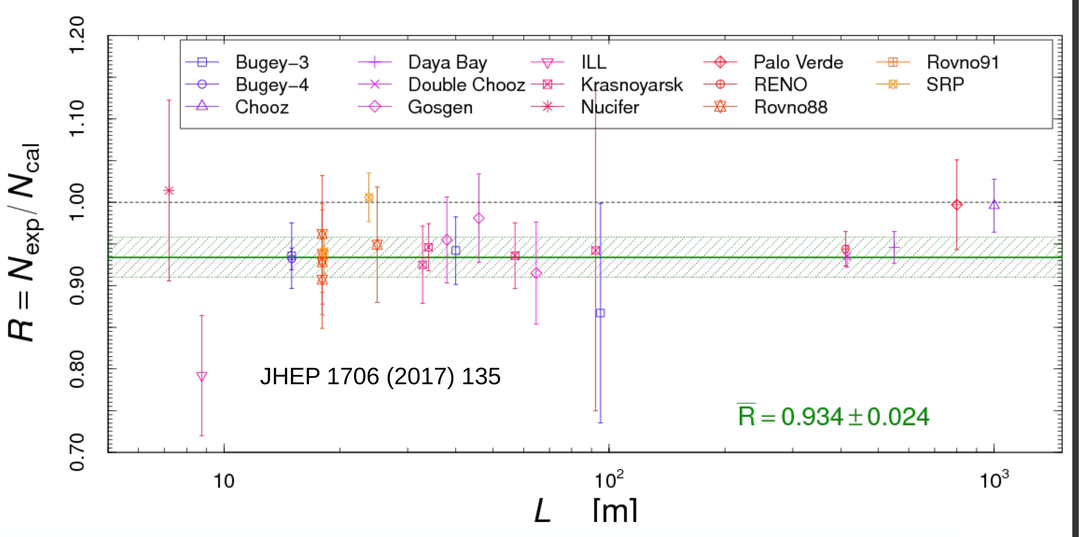
Physics motivation

- Several anomalies in previous short baseline neutrino experiments
  - Deficit of about 10% in solar radiochemical experiments → the "Gallium anomaly"
  - 6% **deficit** (~3σ) in reactor neutrino experiments when **comparing** flux measured in experiments **with (new) prediction** → **the Reactor Antineutrino Anomaly**
  - Oscillations into a **light sterile ν state** (Δm^2~1 eV^2) could account for such deficits
- **Distortion** observed around **5 MeV** ("bump") in the reactor **antineutrino** energy **spectrum**
  → **Need new short baseline experiments!**

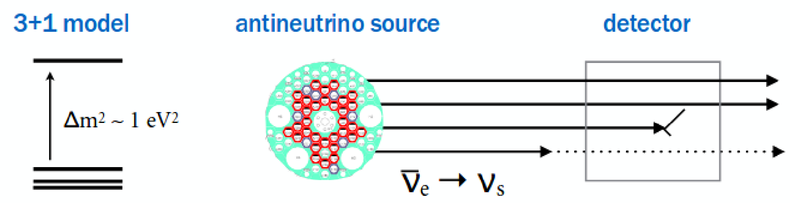


SoLid goals

- Using a **different detection technology:**
  - RAA: Search for an **energy and space oscillation** pattern at short baselines
  - 5 MeV "bump": Provide a **new** measurement of ^{235}U fuel **antineutrino spectrum**

Experimental challenges

- Very short baselines → reactor induce backgrounds
- Operation at surface → muon induce backgrounds
- **Homogeneity and calibration** of 12800 cubes
- Need to determine the **energy scale at the 2% level** and **neutron capture efficiency at the 3% level** in all the cubes

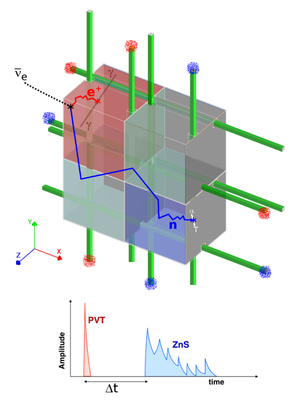


The SoLid detector

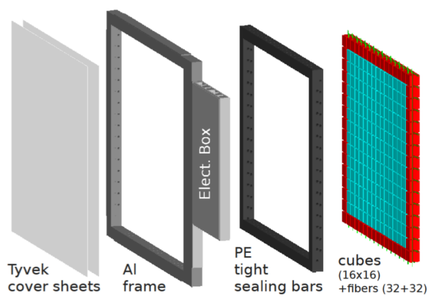
Based on inverse beta decay detection: $\overline{\nu}_e + p \rightarrow e^+ + n$

- 3D highly **segmented composite detector**
  - 5 cm **PVT** cubes for e^+ interaction
  - 2 layers / cube of **LiF:ZnS**(Ag) for neutron detection
  - 50 planes of 16*16 cubes
- Neutron capture on Li in ZnS layer :
  $n + {}^6Li \rightarrow {}^3H + \alpha + 4.78$ MeV
- Signals of n and e/γ very different
  - → PSD discrimination + neutron trigger
- Signals read out by 3200 wavelength shifting fibers + SiPMs

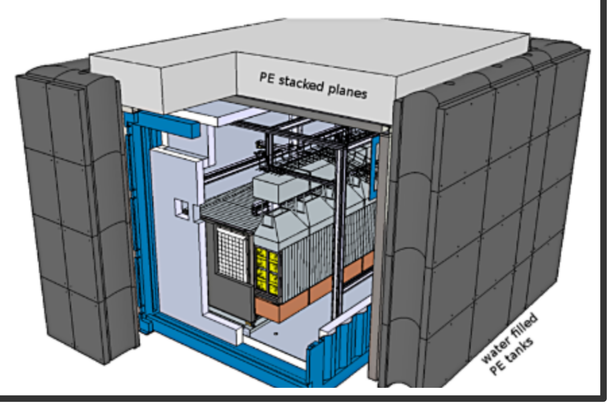
Cubes



Plane



Full detector

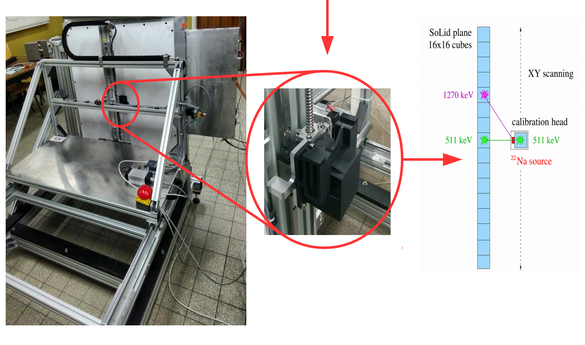


Quality assurance with CALIPSO

- Ensure correct operation and quality of all components before commissioning → guarantees homogeneous response
- **Individual plane calibration**
- Automated robot to place **radioactive sources in front of each cube**
- Calibration during detector construction
  - ^{22}Na for electronic signals (**ES)** and AmBe/^{252}Cf for nuclear signals (**NS)**
  - **AmBe/^{252}Cf** calibrated at the 1% level at NPL (UK)
- Preliminary detector performance

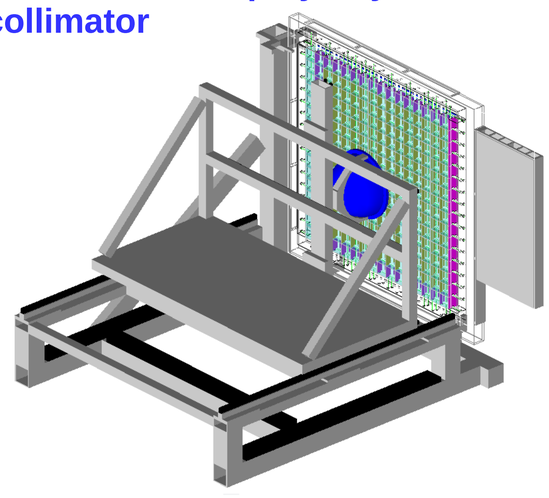
Gamma mode

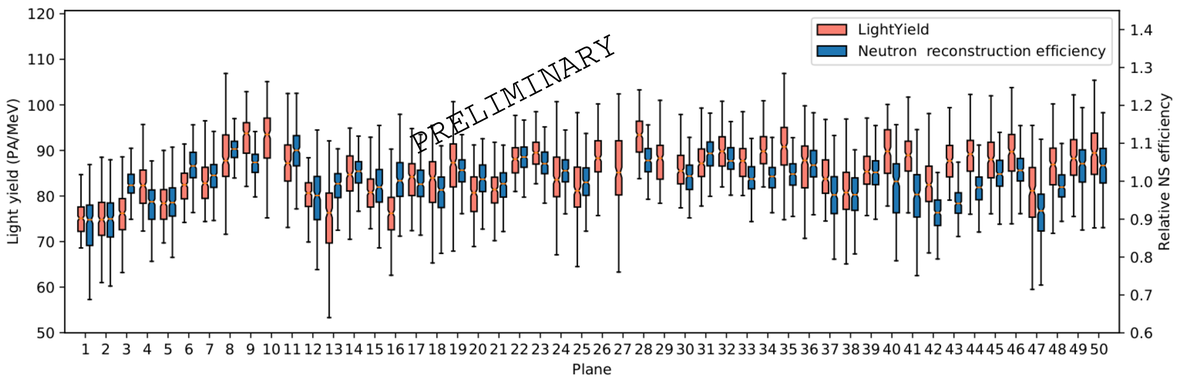
^{22}Na source with **external trigger**



Neutron mode

^{252}Cf source with **polyethylene collimator**



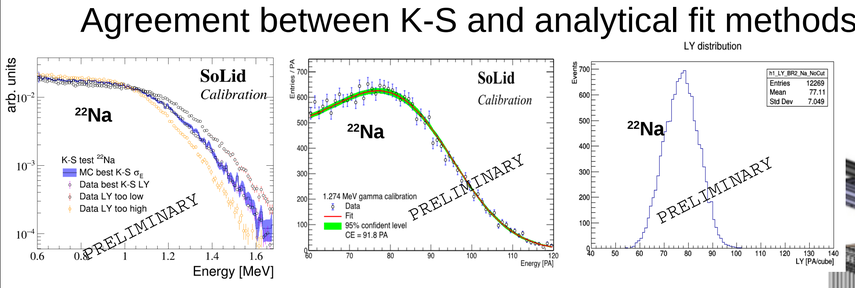


LY larger than 60 PA/MeV and n efficiency larger than 60 %

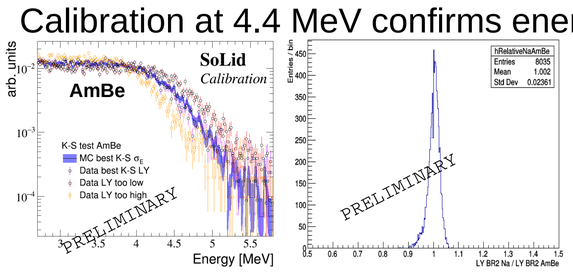
Calibration with CROSS and muons

- **Global detector calibration**
- Automated robot to place **radioactive source between modules** (10 planes)
- Calibration during reactor OFF periods
  - ^{22}Na, ^{137}Cs, ^{60}Co, ^{207}Bi, AmBe, ^{252}Cf
  - No photopeak in PVT cubes → use Compton edge to determine light yield
    - Kolmogorov test (K-S) and analytical fit methods employed → good control of systematics
- **Energy scale + n capture** efficiency measured with the first calibration campaign **in 12800 cubes**

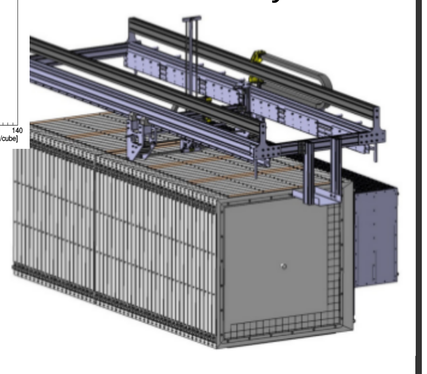
Agreement between K-S and analytical fit methods



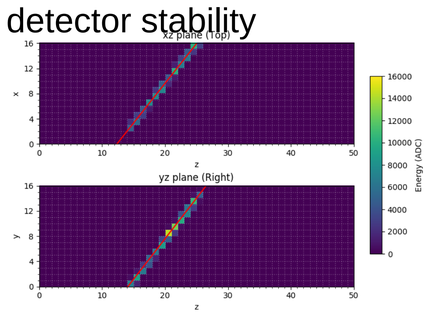
Calibration at 4.4 MeV confirms energy linearity



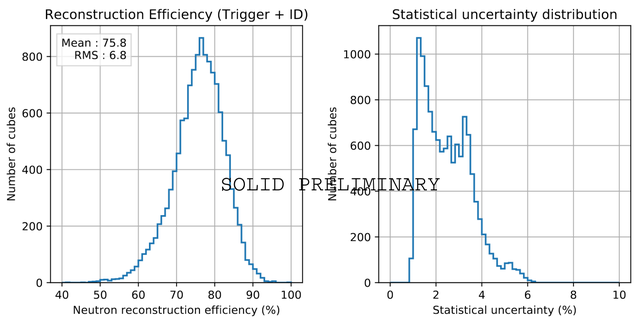
CROSS system



Muons are used to monitor detector stability



Neutron detection efficiency determined in all 12800 cubes



Conclusions:

- Quality assurance process completed successfully → good detector homogeneity
- Minor problems identified and fixed
- First calibration campaign completed → preliminary results of energy scale and neutron capture efficiency in all 12800 cubes
- More calibration data with different sources expected in the next reactor OFF periods