SoLid

Light yield and energy resolution studies

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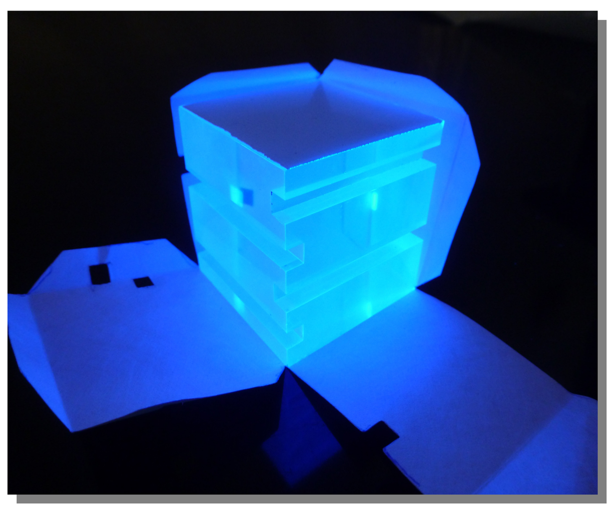
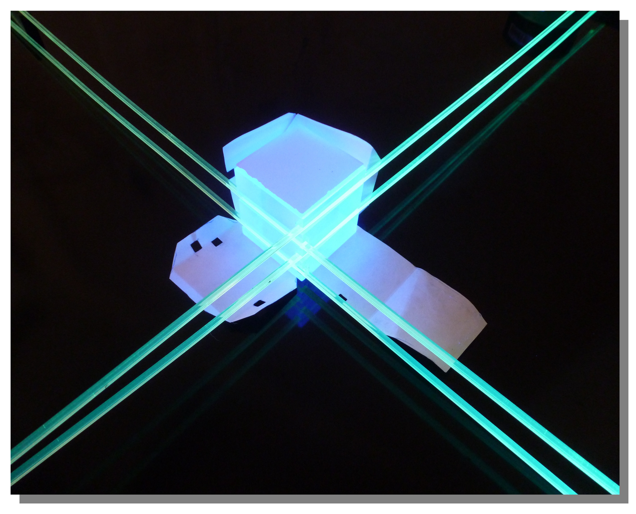
NEUTRINO2016 SOUTH KENSINGTON, LONDON

Introduction



- Anomalies in the neutrino flux from different experiments could be explained by the oscillation toward a **new sterile neutrino**.
- SoLid is a **reactor neutrino experiment** at BR2 (Mol, Belgium) which will look for neutrino oscillation at very short baseline to search for sterile neutrinos, measure precisely the ^{235}U flux and demonstrate the ability of a neutrino detector to monitor reactors.
- For SoLid phase I, we want to optimize the light yield to:
  - → improve the energy resolution
  - → get a better uniformity of the detector
  - → lower the detection threshold to increase the neutron trigger efficiency and improve the background rejection

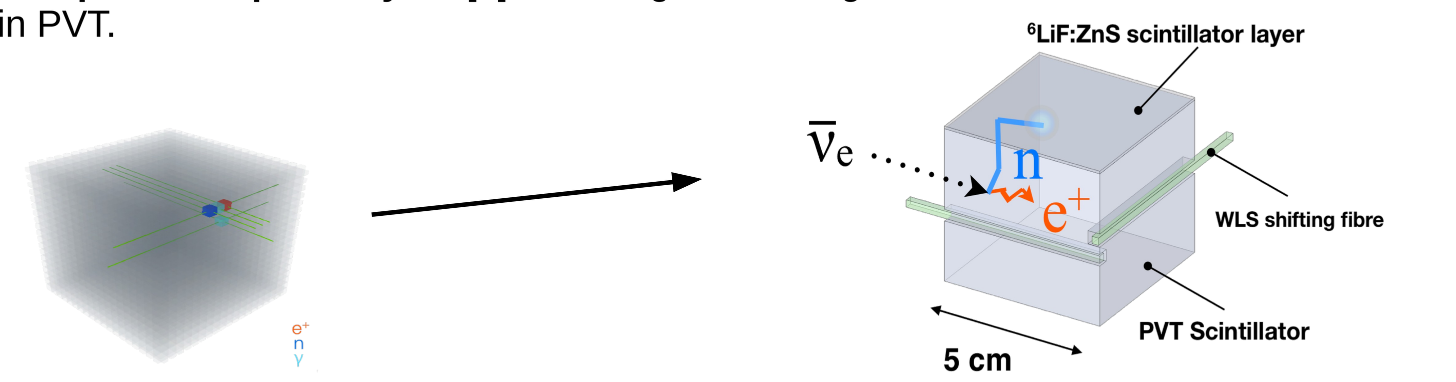


SoLid detector

The SoLid detector detects neutrinos through inverse beta decays :

$\bar{\nu}_e$ **+ p → e$^+$ + n.**

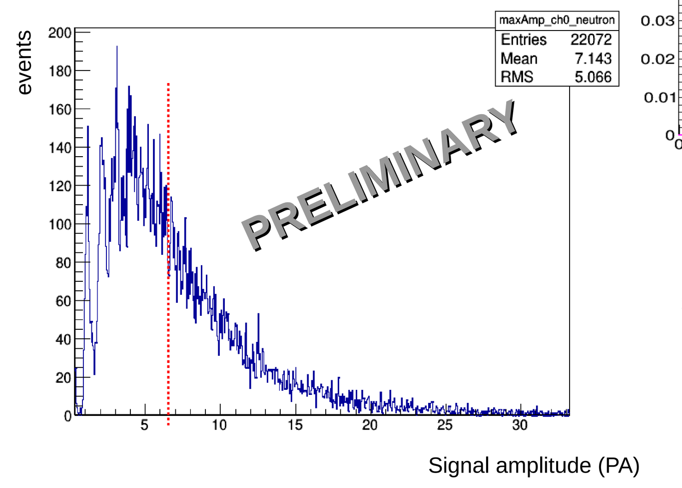
- highly segmented: 5x5x5 cm^3 voxels
- innovative **hybrid technology: 2 different scintillators** with different time response [2] wrapped in Tyvek:
  - e$^+$ detected in cubes made of Polyvinyl-Toluene (PVT)
  - neutrons detected in ^{6}LiF:ZnS sheets put on each PVT cube (n + ^{6}Li → ^{3}H + α)
- Wavelength shifting fibers bring the scintillating light to SiPM
- Digitisation of the SiPM pulses (65 MS/s)
- Efficient **pulse shape analysis** [3] to distinguish the signals from neutrons in ^{6}LiF:ZnS and e+ in PVT.



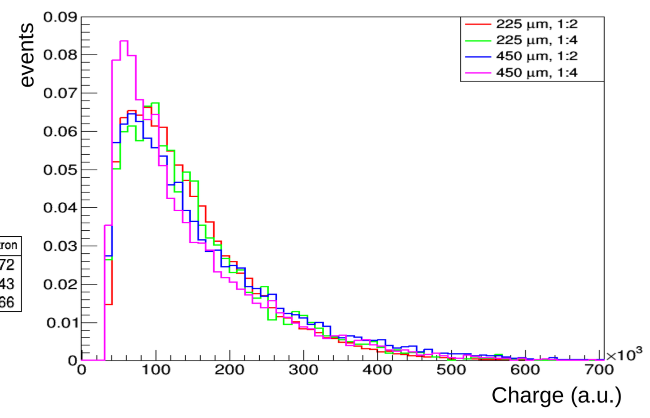
^{6}LiF-ZnS(Ag) neutron screen

Good light yield is essential for achieving high neutron detection efficiency. The amount of light detected from neutron absorptions in ^{6}LiF-ZnS screens depend on:

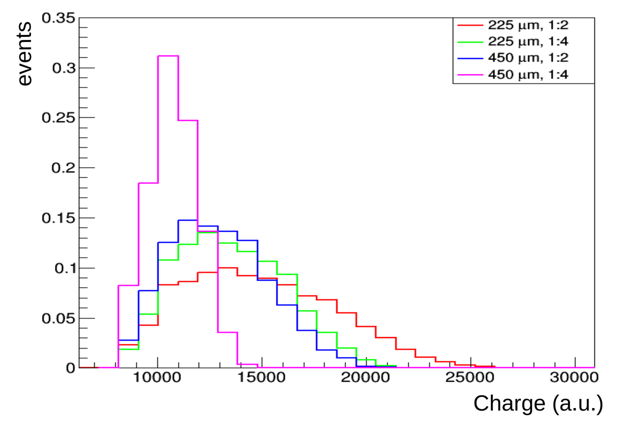
- Thickness of the screen
- Ratio of the ^{6}LiF to ZnS
- Light collection efficiency



SiPM amplitude distribution for all events and for events that pass SM1-like trigger conditions (48 ns coincidence window, 6.5 PA threshold)



Distribution of PMT signals from thermal neutrons absorbed in different ^{6}LiF-ZnS screens.

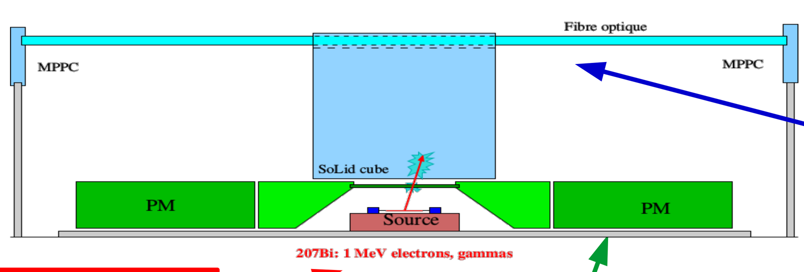


Distribution of PMT signals from 5 MeV alphas absorbed on the opposite side of different ^{6}LiF-ZnS screens.

→ To achieve the best efficiency, 225 µm thick screens with ^{6}LiF:ZnS mass ratio of 1:2 are used in SoLid.
→ In SM1, the neutron efficiency was low due to a high trigger threshold. In Phase I, this issue is solved by identifying the neutrons on FPGA.

PVT test bench

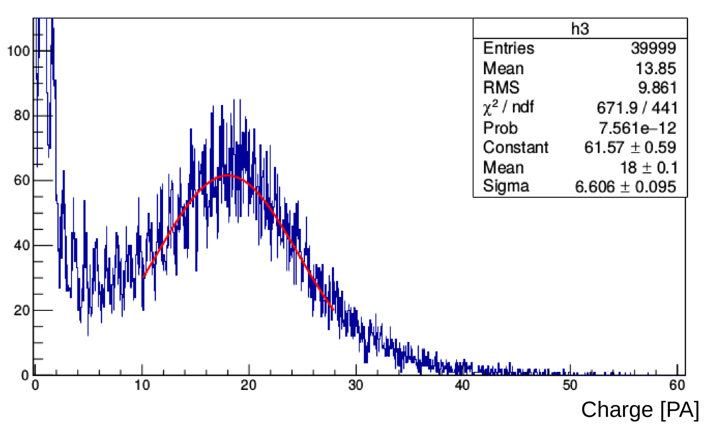
Test bench at LAL Orsay, France, to study the positron light yield in the PVT:



The **SoLid type detector** is composed of one or several cubes with optical fibers and MPPCs.
We can change:
- the wrapping of the cube
- the number of ZnS sheets
- the number and type of fibers and their mirrors
- the cube position along the fiber
- …

a ^{207}**Bi source** produces conversion electrons with a peak energy of 1 MeV by decays through electron capture to excited states of ^{207}Pb.

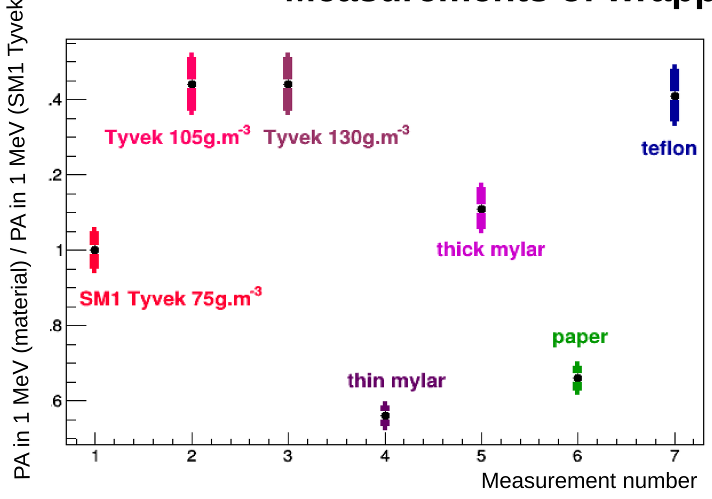
an **external trigger** with 2 PMTs and a 110 µm scintillator triggers in coincidence on the 1 MeV conversion electrons only (not gammas).



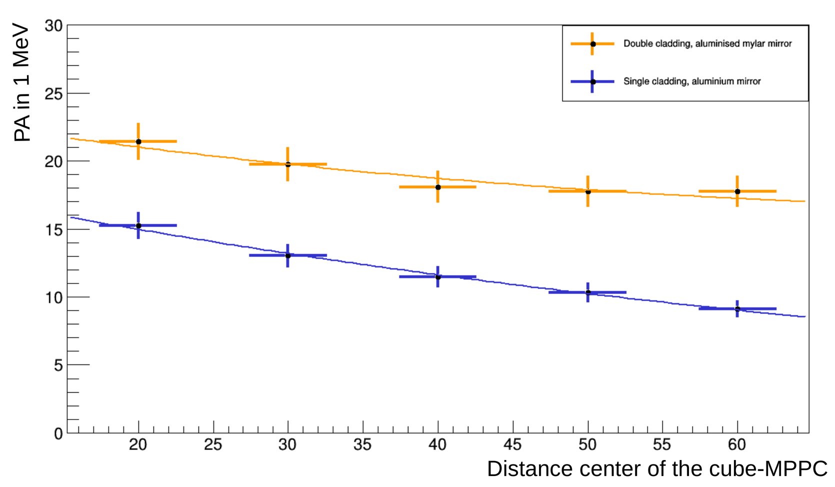
The number of PA at 1 MeV is obtained after :
- converting each MPPC pulse charge in photo-avalanches (PA) by fitting each PA peak.
- summing the charge of both SiPM for every event.
- fitting the spectrum with a gaussian.

Uncertainties :
- systematic error : 5 %
- statistical error : 0.2 %

Measurements of wrapping and attenuation:

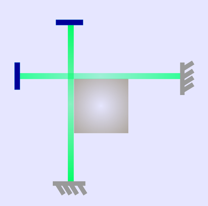
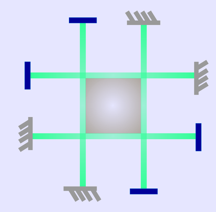


Test of different wrapping materials. Results are shown relatively to the Tyvek used in SM1

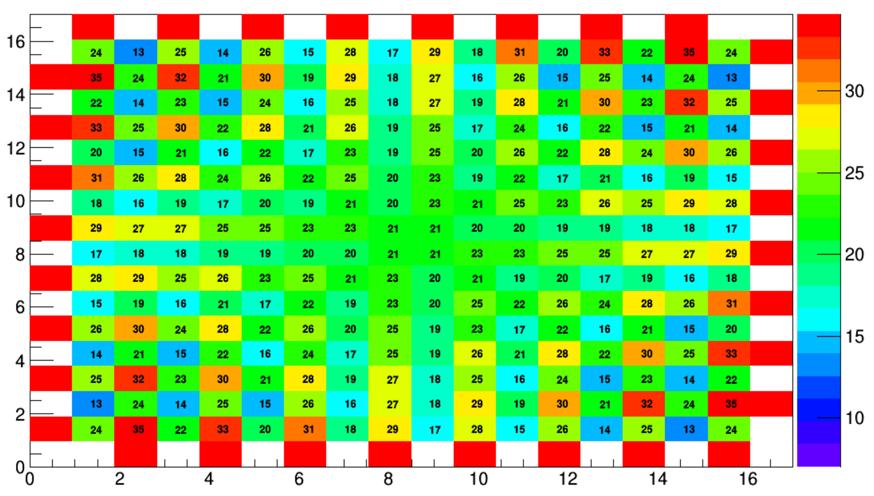


Test of attenuation in a single-clad fiber with aluminium mirror (like SM1) and in a double-clad fiber with aluminised mylar mirror (like SoLid phase I)

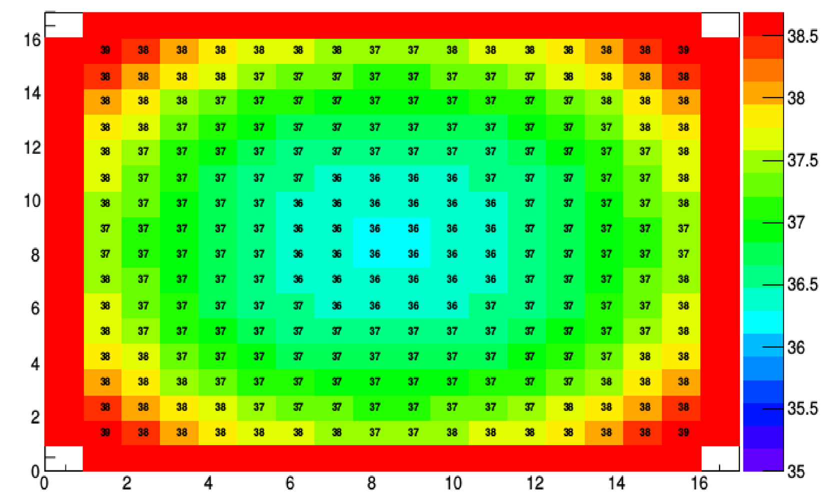
Results of PVT light yield studies

Detector component	Results
Wrapping of the cubes *SM1 : Tyvek of 75g.m^{-3}*	**+30% for thicker Tyvek** *SoLid phase I : Tyvek of 105g.m^{-3}*
Number of ZnS layers *SM1 : 1 ZnS Sheet*	**-10 % per ZnS sheet added** *SoLid phase I : 2 ZnS sheets to increase the neutron detection efficiency and reduce capture time*
Optical fibers *SM1 : single-clad fibers*	**Single → Double cladding fiber :+38 %** *SoLid phase I : double-clad fibers*
Mirrors *SM1 : aluminium mirrors*	**Aluminium mirror → aluminised mylar mirror :+20 %** *SoLid phase I : aluminised mylar mirrors*
Configuration *SM1 : 2 fibers, 1 SiPM per fiber*	 SM1 : 2 Fibers →  SoLid phase I : 4 Fibers PA per fiber: **-29%** PA per cube: **+43%** *SoLid phase I: 4 fibers to increase the light yield per cube*

From test bench measurements: number of PA/cube for 1 MeV deposited in a plan of SM1 (left) and in a plan of SoLid phase I (right). Red boxes indicate SiPM positions.



Average PA/cube = 22.4



Average PA/cube = 37.2

Conclusion

- We have **increased the light yield by 66 %** on the test-bench (from 22.4 for SM1 configuration to 37.2 PA/cube/MeV for SoLid phase I configuration)
- This **improves the energy resolution on the test bench from 21 % to 16 % at 1 MeV** and the **largest relative variation of the detector from 98 % to 8 %.**
- We will also improve the amount of light detected by increasing the SiPM overvoltage and reducing temperature to get a **14% energy resolution for SoLid phase I**
  (from 1.5 V to 2.5 V overvoltage we increase the detection efficiency from 23% to 31%).
  → This is very promising for SoLid phase 1 sensitivity to the reactor anomalies Δm^2.

Other SoLid posters at Neutrino2016:
[1] *The SoLid experiment.* L. N. Kalousis
[2] *SoLid detector technology.* M. Labare
[3] *Inverse Beta Decay signatures at SoLid.* D. Saunders