LiquidO SiPMs & fiber test setup @ Subatech

Mathieu BONGRAND
for the LiquidO Collaboration

July 12, 2023

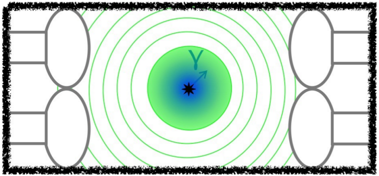
GDR Groupement de recherche
DI2I Détecteurs et Instrumentation pour les 2 Infinis

Liquid scintillators neutrino experiments

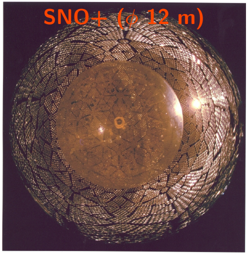
Neutrinos interactions produces scintillation light which is wavelength shifted and transported to PMTs at the edges $\rightarrow$ high transparency !

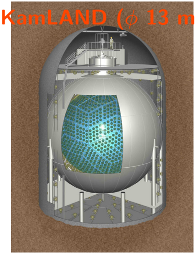
Many advantages:

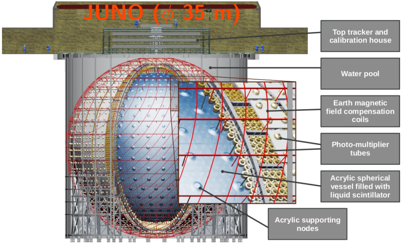
- homogeneous target
- scale and cost
- energy resolution
- radio-purity & self-shielding
- isotope loading ($<$ %)



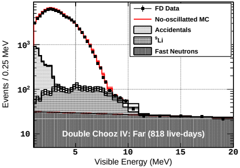
But PMT timing resolution and photo-coverage wash out the events topologies $<$ 0.5 m.







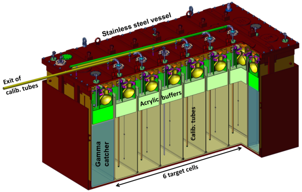
Segmented neutrino experiments



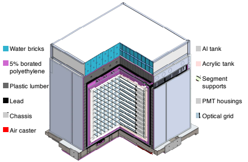
Neutrino detectors are now pushing to use segmentation

- $\bar{\nu}_e p \rightarrow e^+ n$: time and space coinc + 2 γ 511 keV
- particle tracking for high energy neutrinos

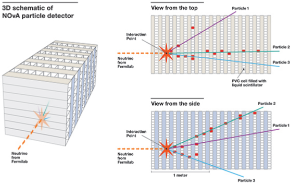
STEREO (1.6 t - 36 cm)



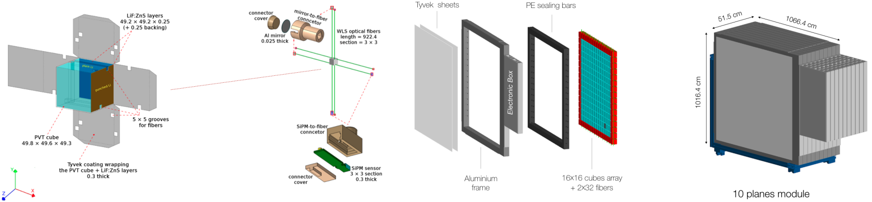
PROSPECT (3.7 t - 15 cm)



Nova (14 kt - 6×4 cm)



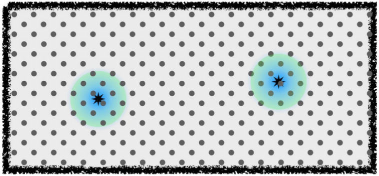
SoLid (1.6 t - 5 cm)



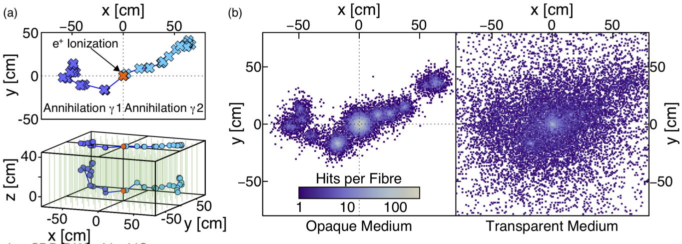
Opaque liquid scintillator

LiquidO's goal is to use an opaque liquid scintillator to preserve the local information of the particles interactions

Vertical network of optical fibers to collect the scintillation light at the interaction points, shift and transport the light to the SiPMs



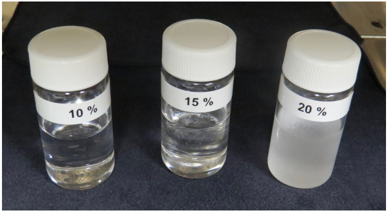
Preserves the spatial precision ($<$1 cm) and fast readout ($\sim$0.1 ns)

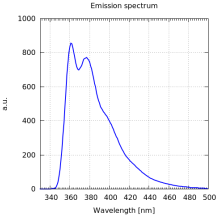


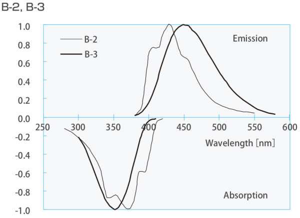
LiquidO light collection

NoWash scintillator (arXiv:1908.03334) - Kuraray B3 fibers

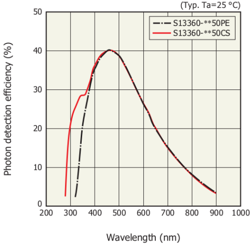
(80% LAB + 20% wax + 0.3% PPO)

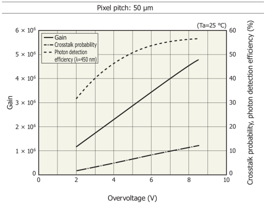


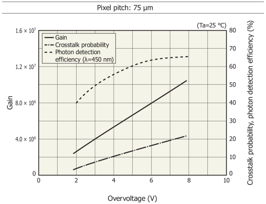




Hamamatsu MPPCs S13360-1350 / 75

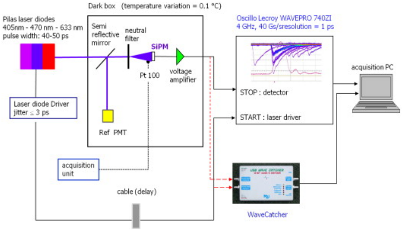


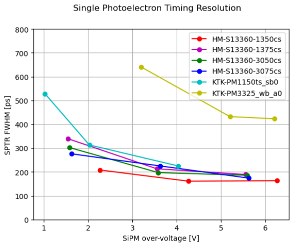




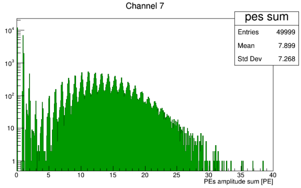
SiPMs selection & tests

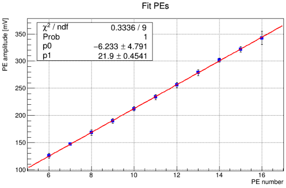
SiPMs from Hamamatsu selected for the best timing at single photon (SPTR) [V. Puill et al. NIM A 695 (2012) 354-358]

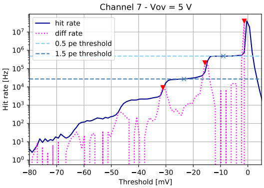




Characterization of the SiPMs e.g. @ Subatech



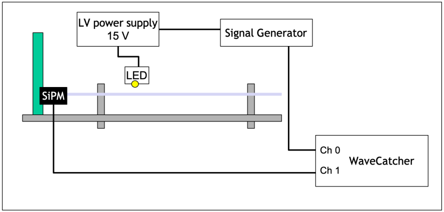


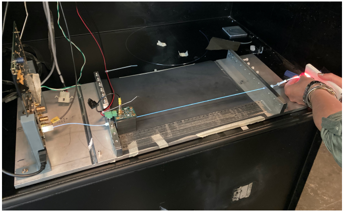
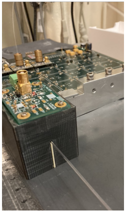
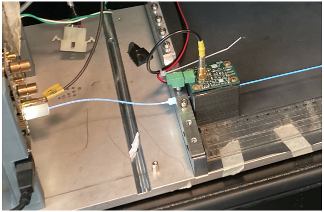
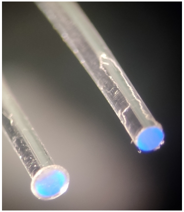
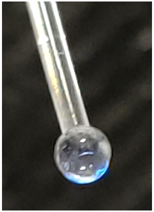


Optimization of LiquidO-type detectors

ProtO setup developed @ IJCLab for the optimization of several aspects of LiquidO-type detectors:

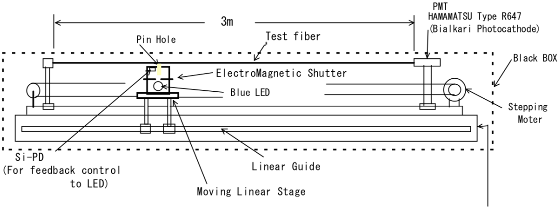
- fiber / SiPM optical coupling
- fiber support, tension & glues
- fiber polishing
- reflection at the end of the fibre

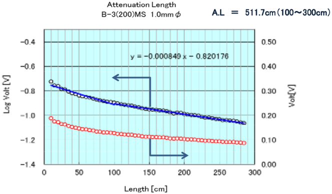


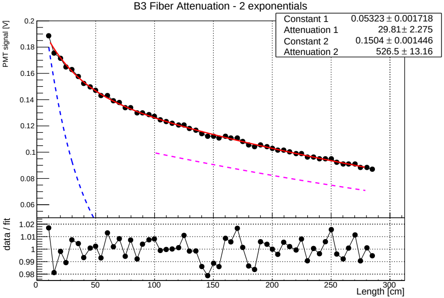






Test of fibers @ Kuraray

The goal is to reproduce the measurements of Kuraray



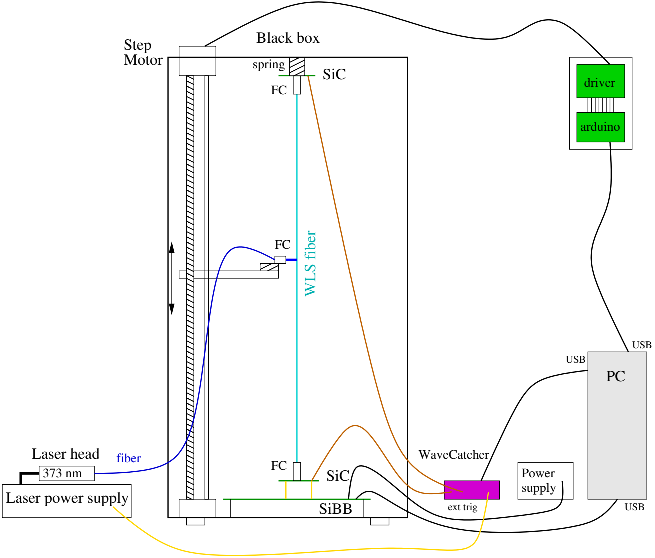




Point to point fluctuations seems to be ± 2 %

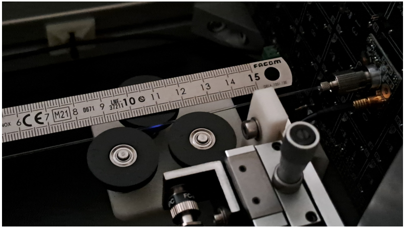
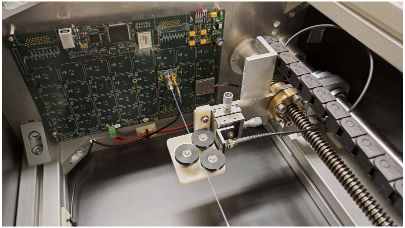
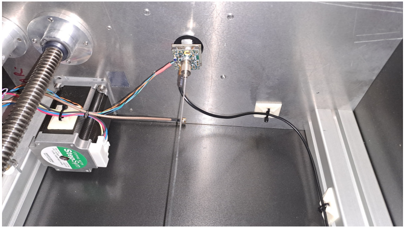
Fiber test setup principle @ Subatech

Scanning a 1 m long WLS fiber form 9.5 cm to 94.5 cm



Fiber test setup @ Subatech

The setup was first horizontal to facilitate optical adjustments

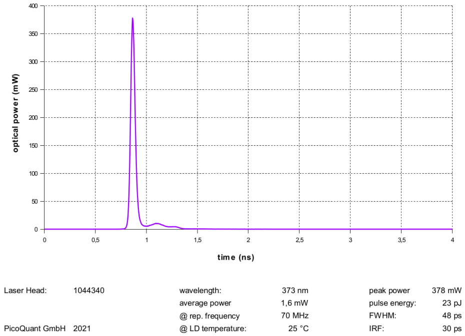





Hervé Carduner, Yann Roy, Yann Bortoli, Louis-Marie Rigalleau and Stéphane Martinez @ Subatech
& Dominique Breton and Jihane Maalmi @IJCLab

Picosecond UV Laser source

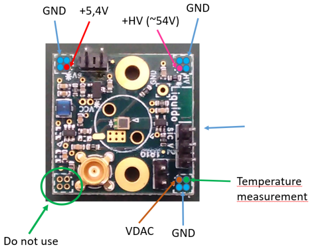
PicoQuant pulsed laser diode

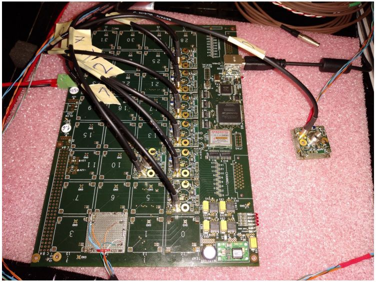
- Picosecond pulsed drivers: Taïko PDL M1 - 1 diode
- Diode: 375 nm / 48 ps FWHM - 0.2-2 mW (5e7 γ)
- Fiber coupling: beam shape gaussian + guillotine + filter space



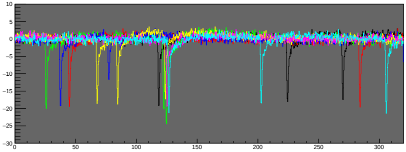
Dedicated electronics from IJCLab

- SiCs boards: SiPM - 20-dB RF amplifier - T°C probe
- SiBB: 32 ch - LV & HV - DACs and T°C HV loop - interfaces





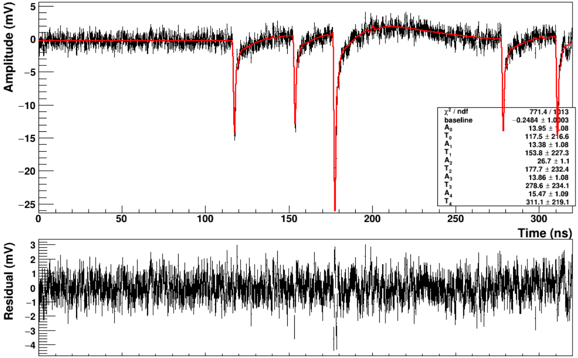
Digitization with WaveCatcher [D. Breton et al. NIM A 629 (2011) 123-132]



SiPMs pulses reconstruction

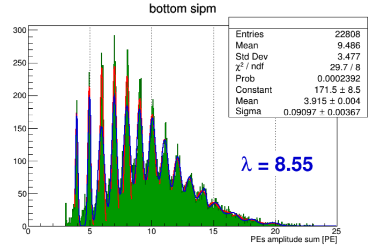
Recozor algorithm developped for Double Chooz adapted for SiPM pulses

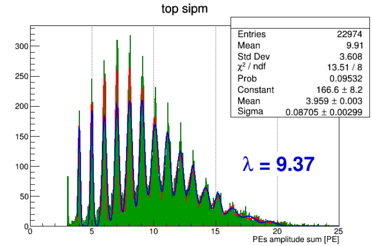
Each PE time and amplitude is reconstructed in the sampling window (1024 samples - 3.2 GS/s)

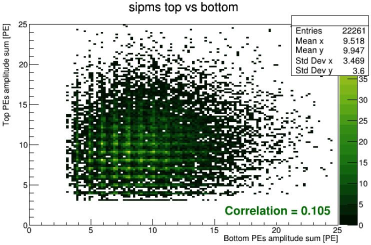


Fiber scan with low light level

Laser beam at initial position (0) of the WLS fiber (9.5 cm from bottom)





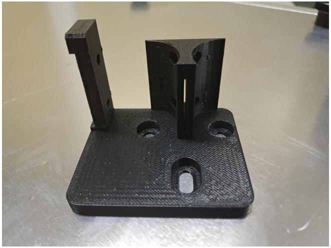


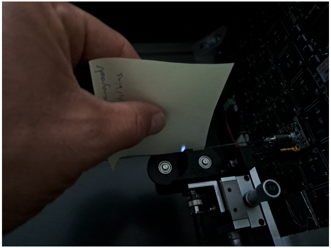
Fits are rather instable
Correlation between channels is low

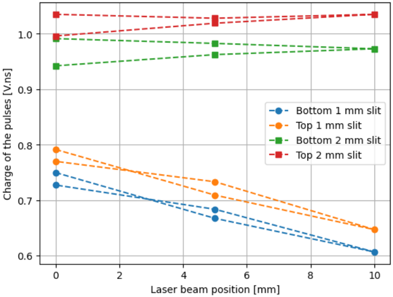
Coincidence trigger on sipms - laser rate @ 500 kHz - using recozor

Adding an optical slit

We have produced two optical slits (1 or 2 mm wide) with 3D printer



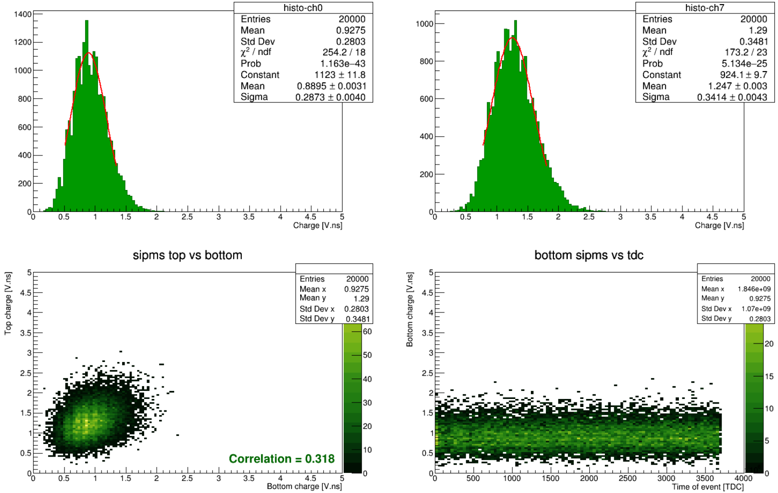




The 2 mm wide optical slit gives better stability

Fiber scanning with 2 mm optical slit

Laser beam at central position (400 $\leftrightarrow$ 49.5 cm from bottom)
About 30% light reduction with the optical slit



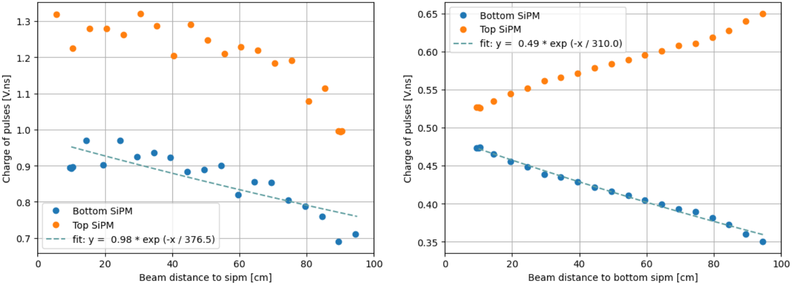
External trigger - laser rate @ 100 kHz - compute negative area of the pulses

Preliminary attenuation measurement

First test with an old fiber having surface defects and not correct gluing or optical coupling to SiPMs

Some point to point variations observed to be ∼5% for now

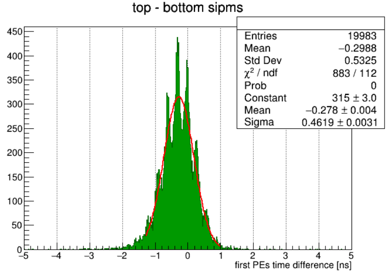
But good correlation in both channels when plotting the ratios (right)
$\langle q_i(x) \rangle = q_i(x) \ / \ (q_i(x) + q_j(x))$ → better formula

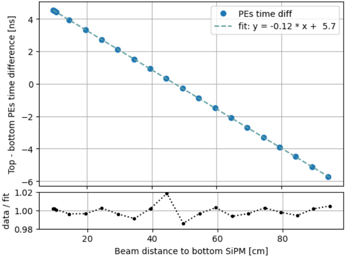


Seems to point to surface defects → better fiber under preparation

Preliminary position from time difference

Using recozor and look at the time difference between the first top and bottom PEs (spikes due to the sampling frequency and PE time determination from recozor)

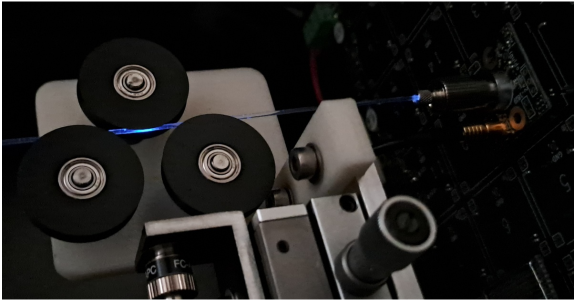




First simple Gaussian fit of the time difference as a function of the laser beam position provides a precision of 0.6% RMS

Summary

- A ProtO setup @ IJCLab allowed to tune the fiber support, the coupling to SiPM, the fiber polishing and to test glues
- A fiber setup @ Subatech started to measure attenuation and timing performances
- Next step is to prepare a new fiber with correct glue and optical coupling



- Design and build a >4 m long setup in liquid scintillator @ Subatech

Thank you for your attention