Calibration of the ICARUS cryogenic photo-detection system at FNAL

M.Bonesini[1], R. Benocci[1], R.Bertoni[1], A. Chatterjee[2], M. Diwan[3], A. Menegolli[4], G. Raselli[4], M. Rossella[4], A. Scarpelli[3], N. Suarez[2]

for the ICARUS Collaboration

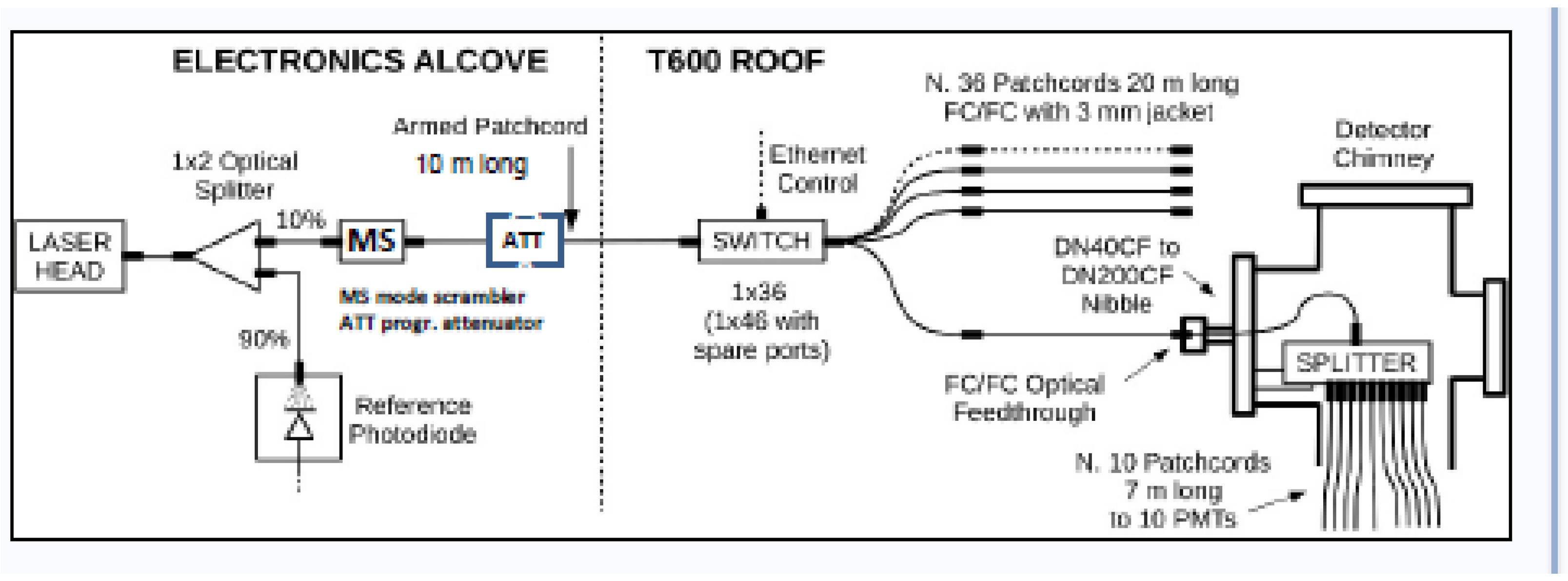
[1]University and INFN *Sezione di Milano Bicocca* (Italy) ; [2]*University of Pittsburg (USA);* [3] *BNL (USA),* [4] *University and INFN Sezione di Pavia (Italy)*

Scintillation light (at 128 nm) is detected by a system of 360 PMTs directly immersed in liquid Argon (5% coverage, 15 p.e./MeV). **The photo-detection system will allow to:**

- Identify the time of occurrence (t_0) of any ionizing event in the TPC with **O(1 ns) resolution**
- Localize events with < 50 cm spatial resolution and determine their rough topology
- **Generate a trigger signal for readout**

- The ICARUS PMTs system, together with **the CRT will allow to mitigate the large rate (~10 kHz) of cosmic ray events through the LAr TPCs, due to its location at shallow depth with a limited overburden.**

The PMTs timing/gain equalization is performed by using fast laser pulses . The laser pulse is sent to each PMT (360) via a distribution system based on a Hamamatsu PLP10 diode laser, **a** Mode Scrambler (MS), a programmable attenuator**(ATT),** a 10 m armed fiber patch cable, 20m fiber patch cords (36), VACOM UHV optical feed-throughs (36), fused fiber splitters (36) and one optical switch



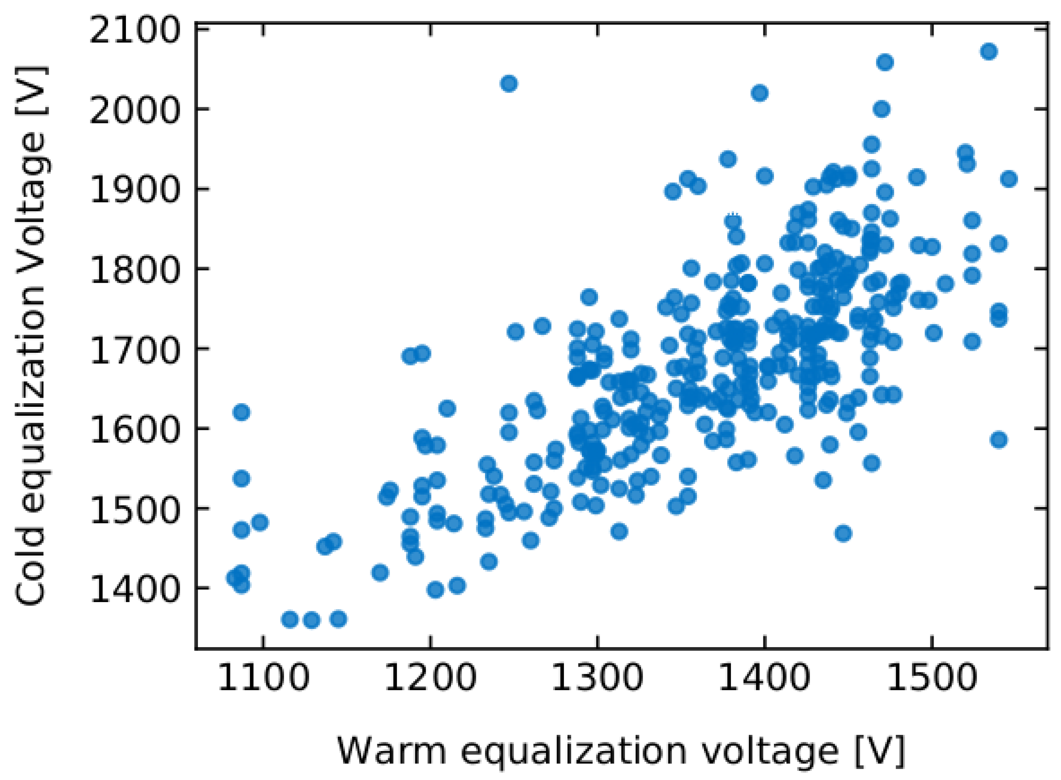
Problem: light pulses must have minimal time dispersion and signal attenuation at delivery point in front of the PMTs. In addition must have a minimal spread **in channel to channel** total delay (DT) and **delivered power** of the signal in front of the PMTs.

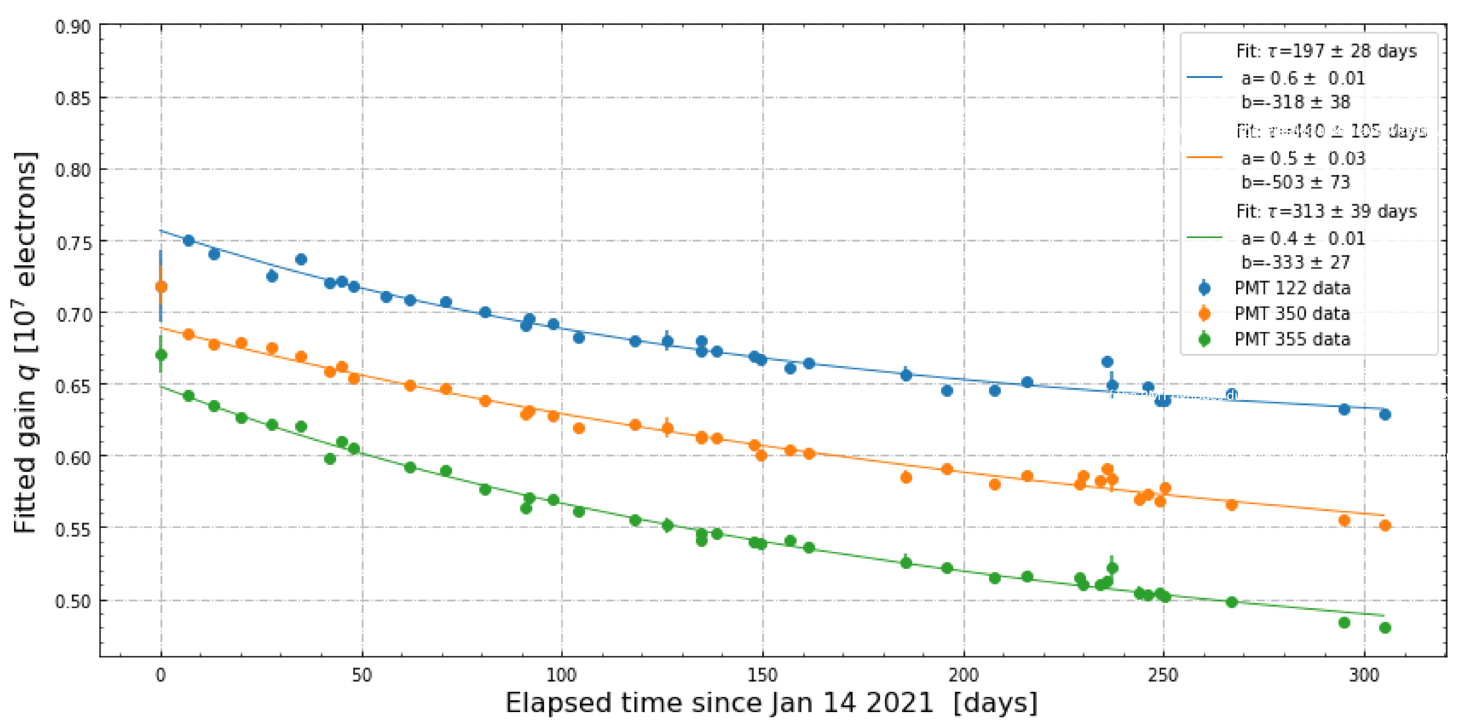
Strategy:

- ***characterize*** *components for use at 400 nm, taking into account timin properties /attenuation*
- *use low cost components, e.g. laser diodes ($) instead of Q-switched lasers ($$) and Telecom ready components*

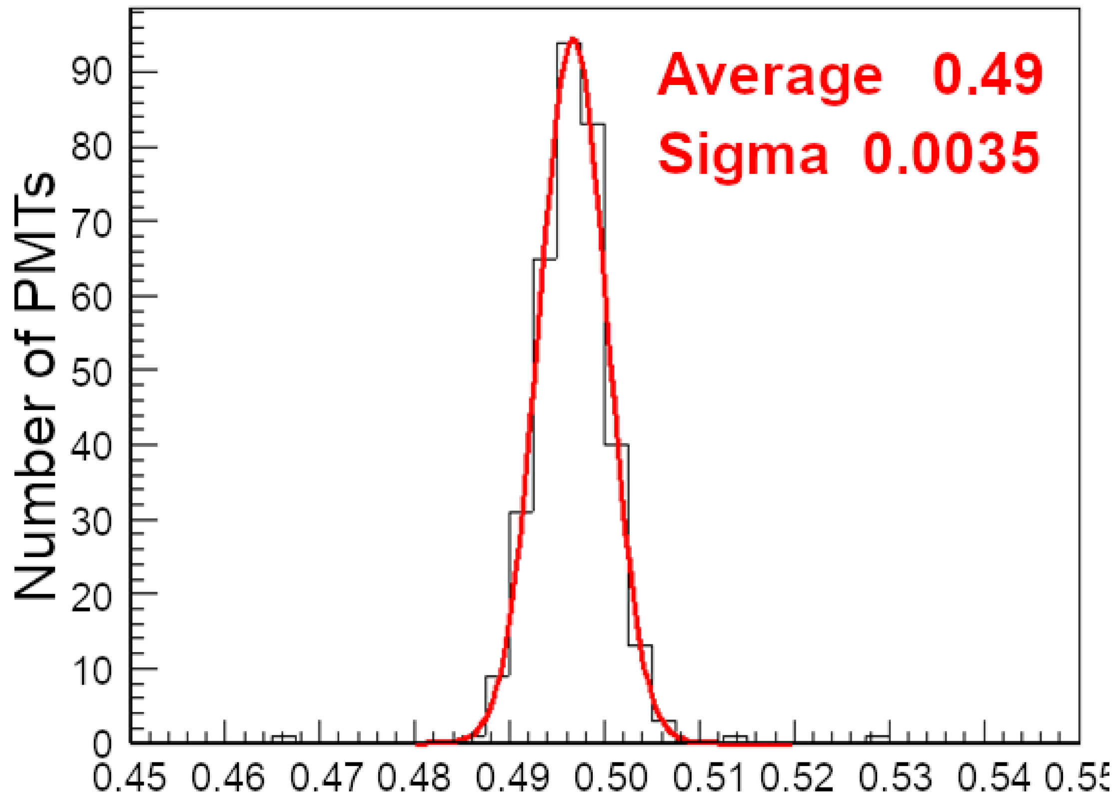
Cons: low peak power (< 1 W) **power budget** in the calibration system is a ***must*** (use multimode (MM) fibers instead of single mode(SM) fibers to reduce injection problems, losses …)

- ***Total delays (ΔT):*** **~250 ns with a spread over 360 channels < 200 ps, measured both in situ and in lab**
- ***Attenuation (up to UHV flanges): 4.59 ±0.16 dB over 36 flanges***
- ***Attenuation of 7m injection patches: 0.61±0.06 dB*** **(over the full 410 sample, the best 360 were used).**
- **The system was designed with a spread < 5% for the light output of the 360 calibration channels [worse in situ due to mechanics alignment problem of the injection fiber holder vs PMTs' surface] and a spread in total delays < 0.1% .**





Ttracking of PMT response with time



Equalization at 1% level using SER (final tuning with background γ's)