# The new ICARUS read-out system

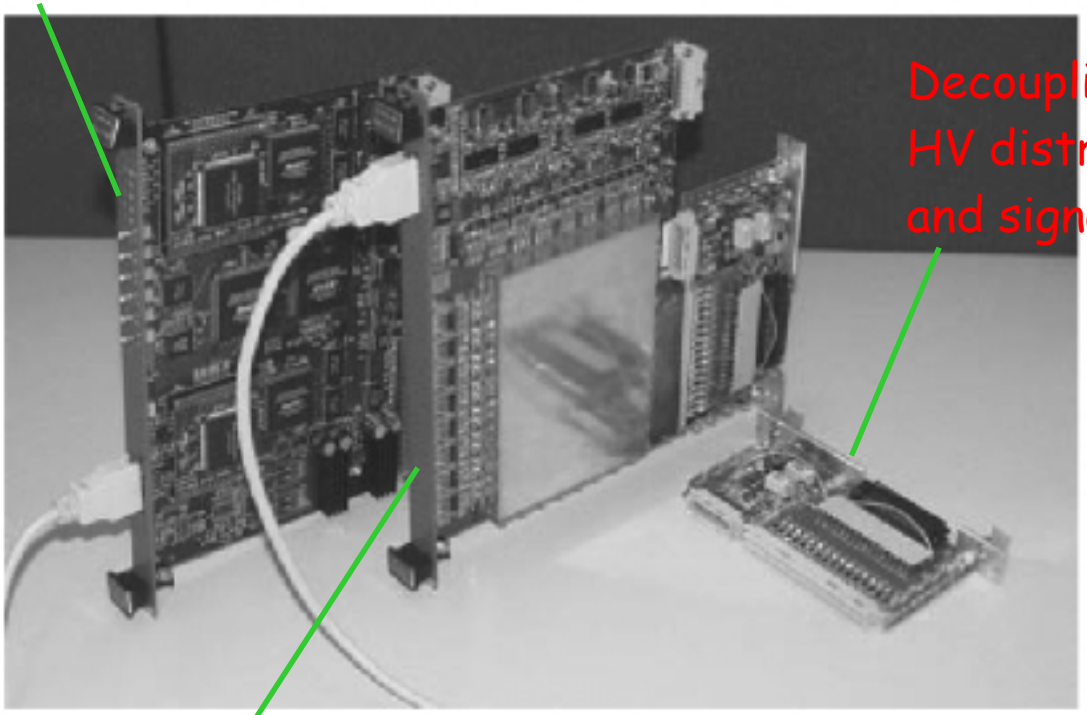
## Test results with the 50 l LAr-TPC

- ✓ Optimization on real data of S/N and shapes for the three different wire signals.
- ✓ Comparison of "all-out" with "preamp-in" front-end configurations.
- ✓ T=0 signal from scintillation as trigger enabler.
- ✓ Study of self triggering and zero-suppression with Daedalus.
- ✓ Tuning of DAQ software, on-line display and monitoring.

# The ICARUS T-600 read-out chain

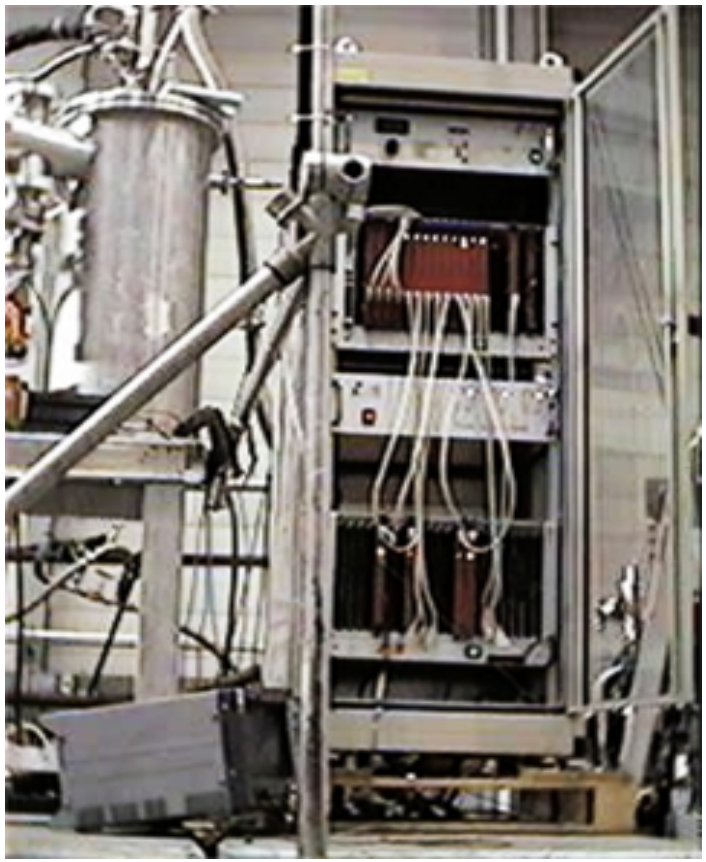
One rack fully tested and optimized with real on-line data from the 50 liter Lar TPC

CAEN-V789 board: 2 Daedalus VLSI * 16 input channels (local self-trigger & zero suppression) + memory buffers + data out on VME bus



Decoupling board: HV distribution and signal input

CAEN-V791 board: 32 pre-amplifiers + 4 multiplexers (8:1) + 4 FADC's (10 bits - 20 MHz)

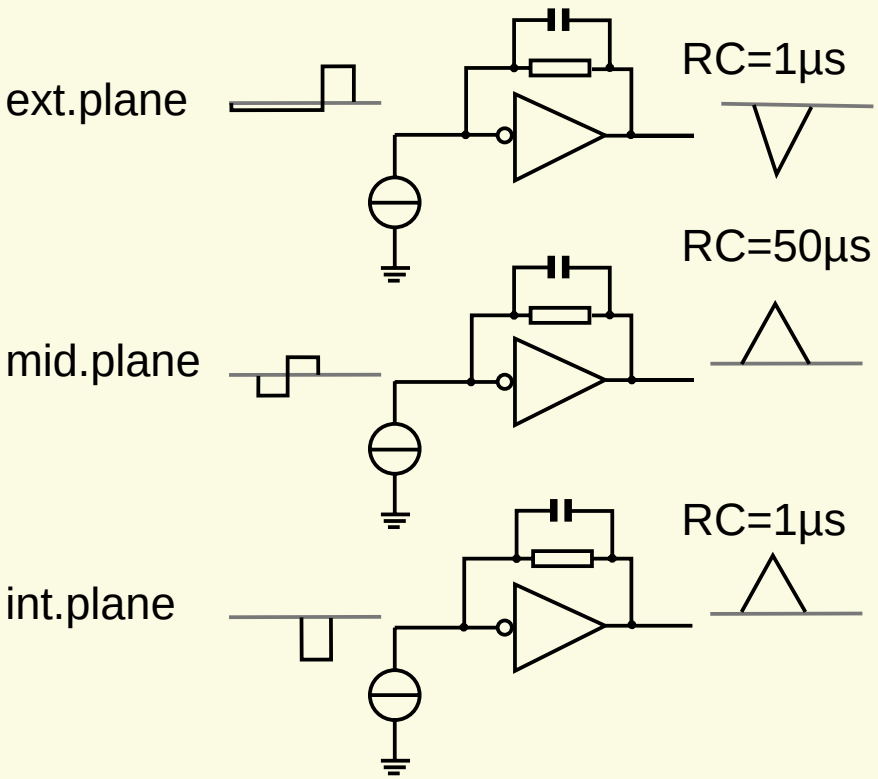


# Test set-up with the 50 l LAr-TPC

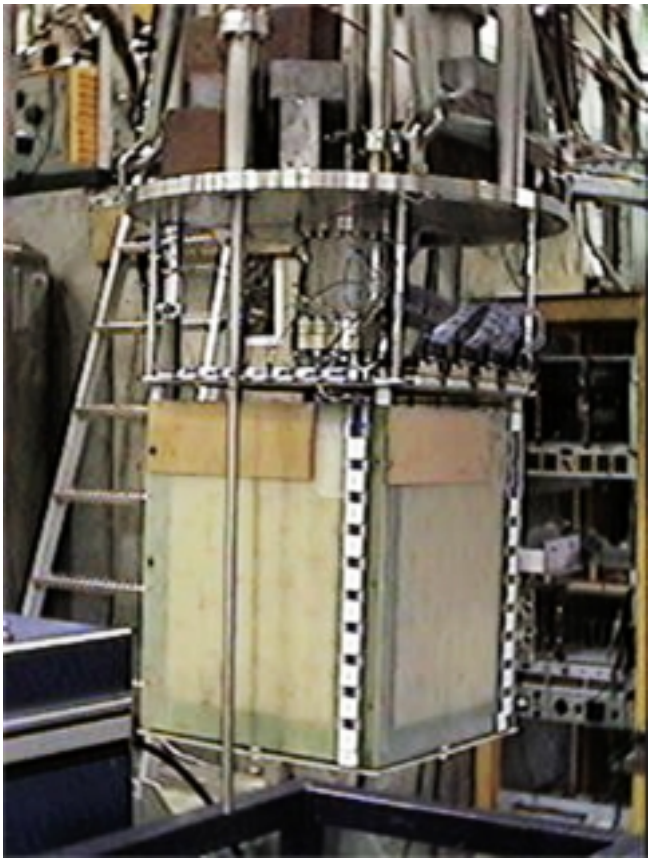
- ✓ One complete rack shipped to CERN.
  - Housing the Analogue boards (V791C, V791Q), the Digital boards (V789 and V816), the Decoupling boards (DB), Power supplies and Control units.
  - Fully tested and validated in Padova. Serving 576 channels (18 boards • 32 channels per board).
- ✓ Conditions as close as possible to final layout of T-600.
  - Three-wire-plane configuration (total read-out channel = 256).
  - Electric field in drift volume: 500 V/cm.
  - T600 feed-through.
  - ≈180 pF input capacit. (2 m of T600 cables + connectors + wires in LAr).
  - HV distributed on wires from decoupling boards through cables.
  - One PMT (EMI 9426) for Ar scintillation placed in gas phase for T=0.

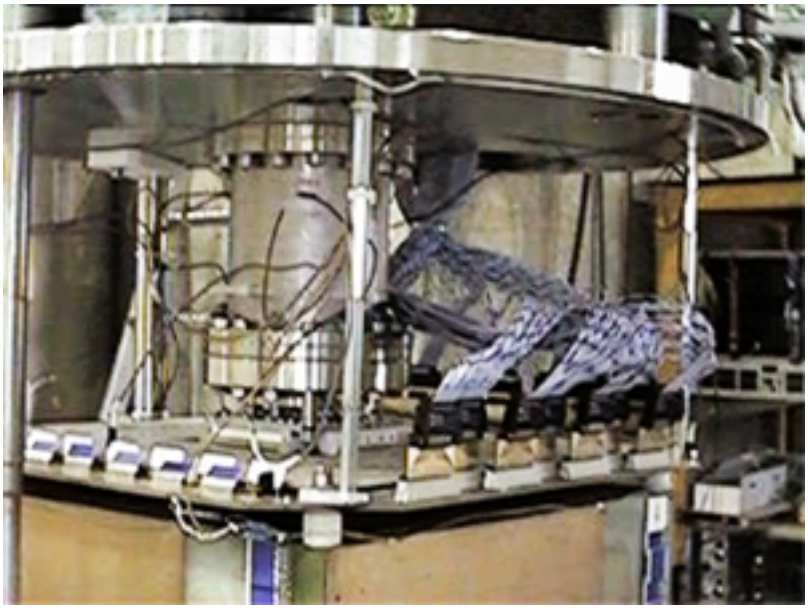
# Input signals & pre-amp feedback RC

- ✓ Ext. & Int. planes:
  - Approx. unipolar input signal
  - Width ≥ 3 μs
  - Short RC ("quasi-current" mode) to minimized pile-up
- ✓ Mid. Plane:
  - Bipolar signal
  - Long RC ("quasi-charge" mode) to get triangular signals

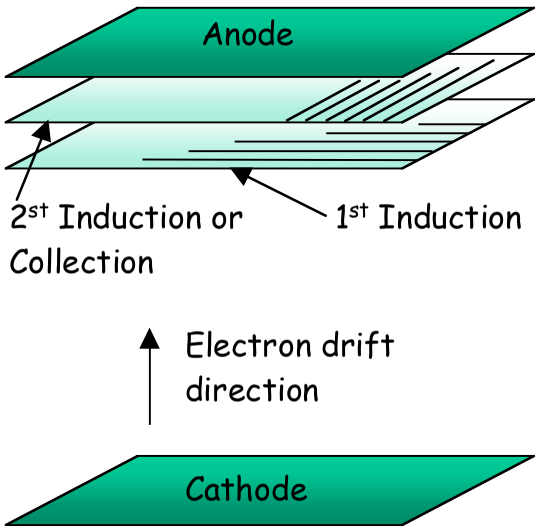


# The 50 liter LAr-TPC





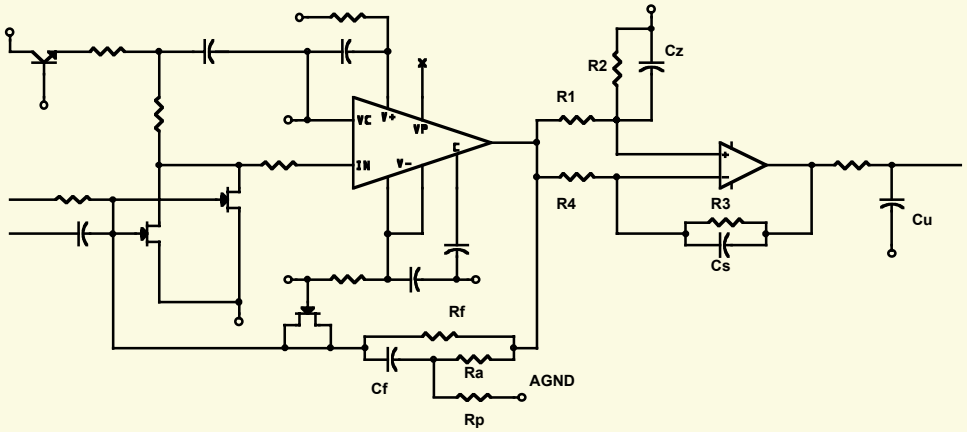
Read-out electrodes configuration



# Optimization of the Analogue boards

First versions did not meet requests!
(signals too small, too narrow)

- ✓ Goals (V791C & V791 Q):
  - Signal P.H. ≈ 12 ADC for 3 mm m.ip.
  - Noise r.m.s ≈ 1 ADC
  - FWHM ≈ 5 μs
- ✓ Action on:
  - feedback RC
  - Shaper gain and bandwidth
- ✓ Results:

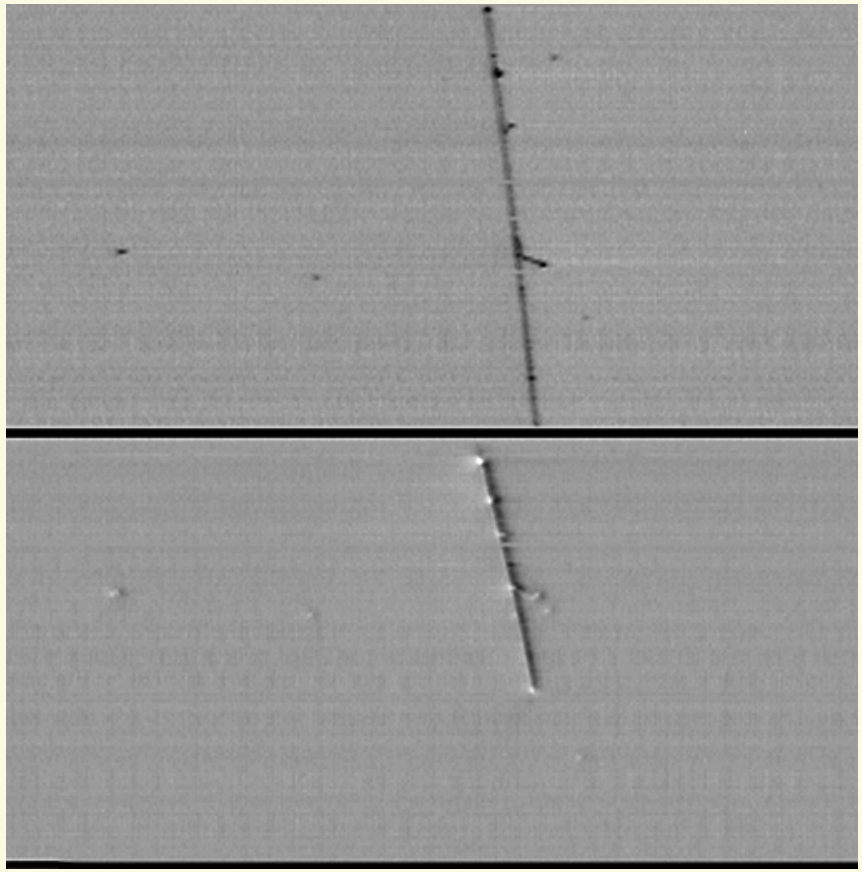



| Model | Rf | Cf | Rp | Ra | R1 | R2 | R3 | R4 | Cs | Cu | Cz |
|---|---|---|---|---|---|---|---|---|---|---|---|
| V791C | 10 MΩ | 3.3 pF ±10% | 1.2 kΩ | 22 kΩ | 100 kΩ | 270 kΩ | 27 kΩ | 10 kΩ | 39 pF | 2.2 nF | 1 μF |
| V791Q | 100 MΩ | 1 pF ±10% | ∞ Ω | 0 Ω | 33 kΩ | 270 kΩ | 270 kΩ | 33 kΩ | 3.9 pF | 2.2 nF | 1 nF |

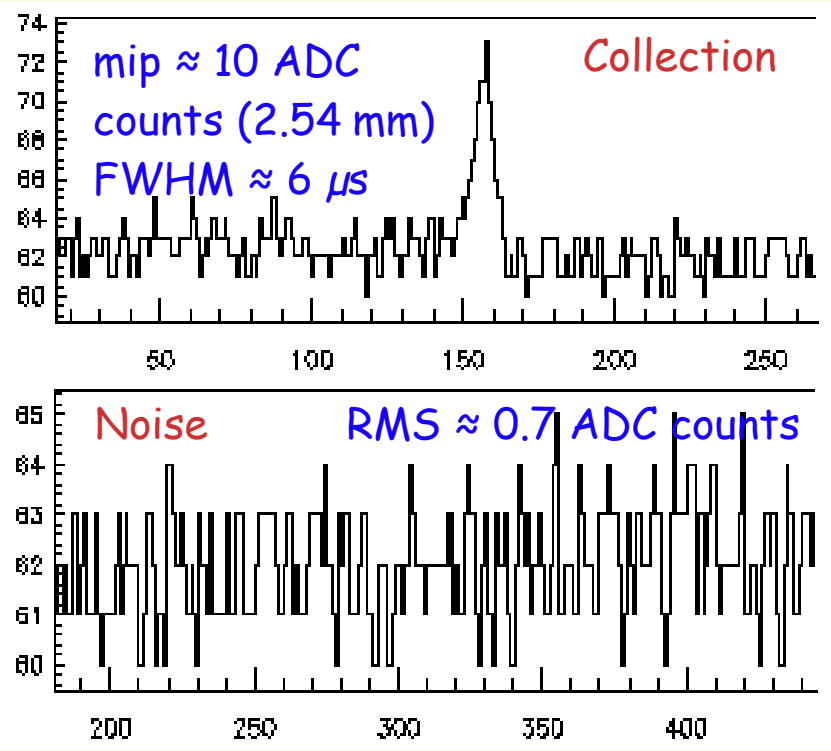
Overall decay time constants: ≈ 3 μs (V791C) , ≈ 40 μs (V791Q)

# Events with old electronics

- ✓ Preamplifiers in liquid Argon (very low input capacitance)



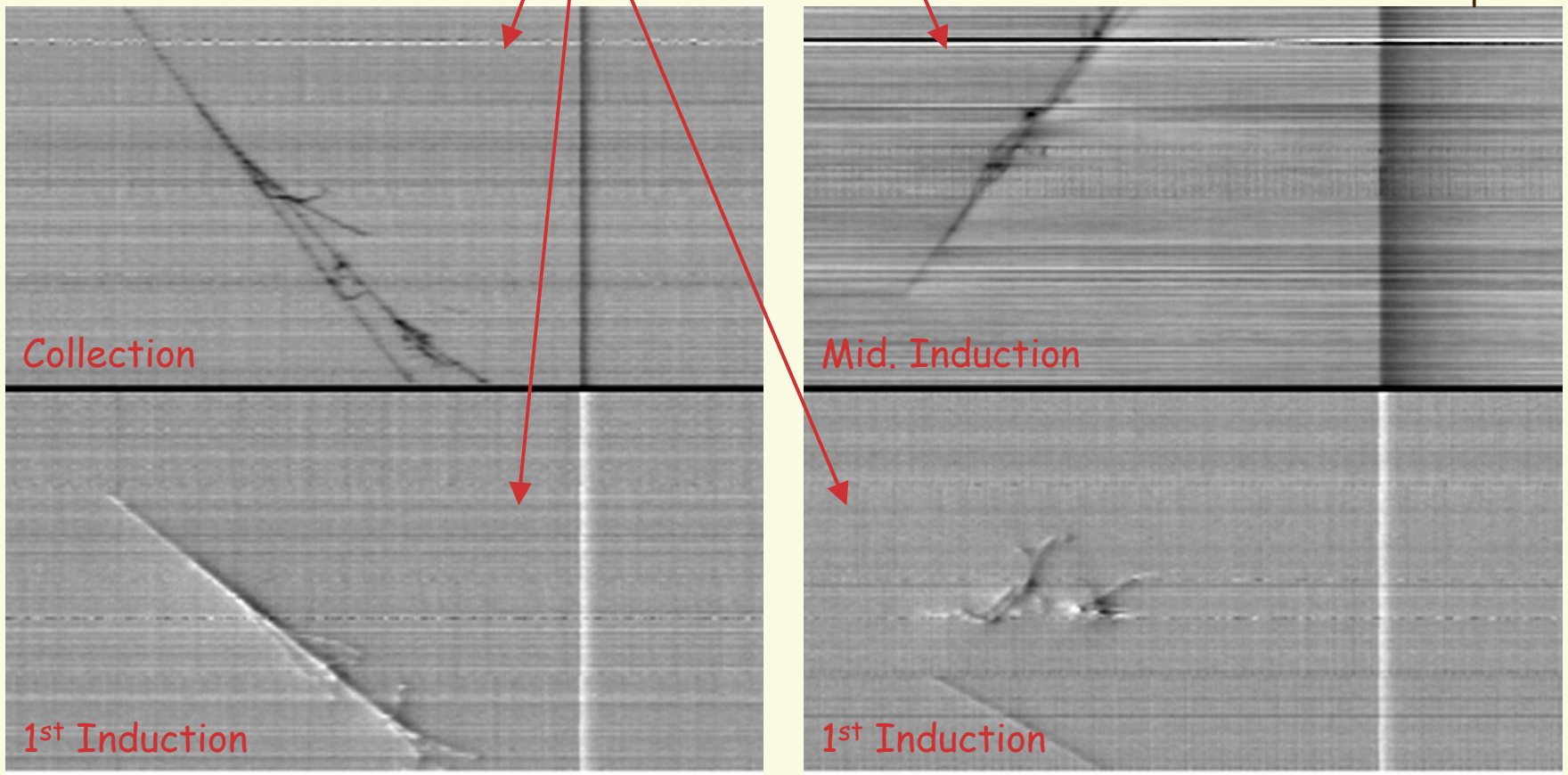
(horiz. axis unit = 800 ns)




Negligible coherent noise !

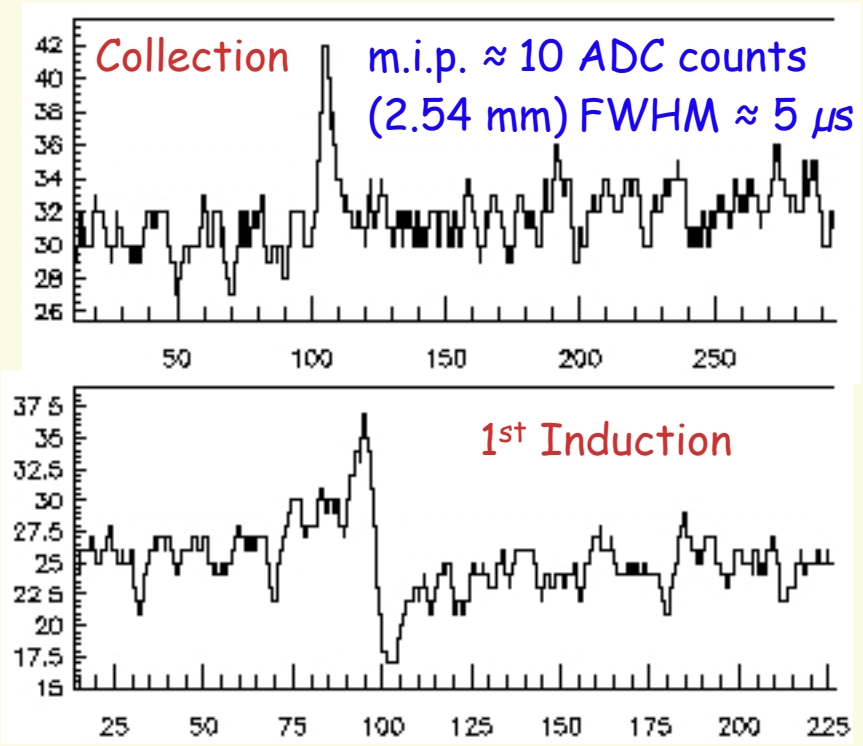
# Performance of the V791 boards

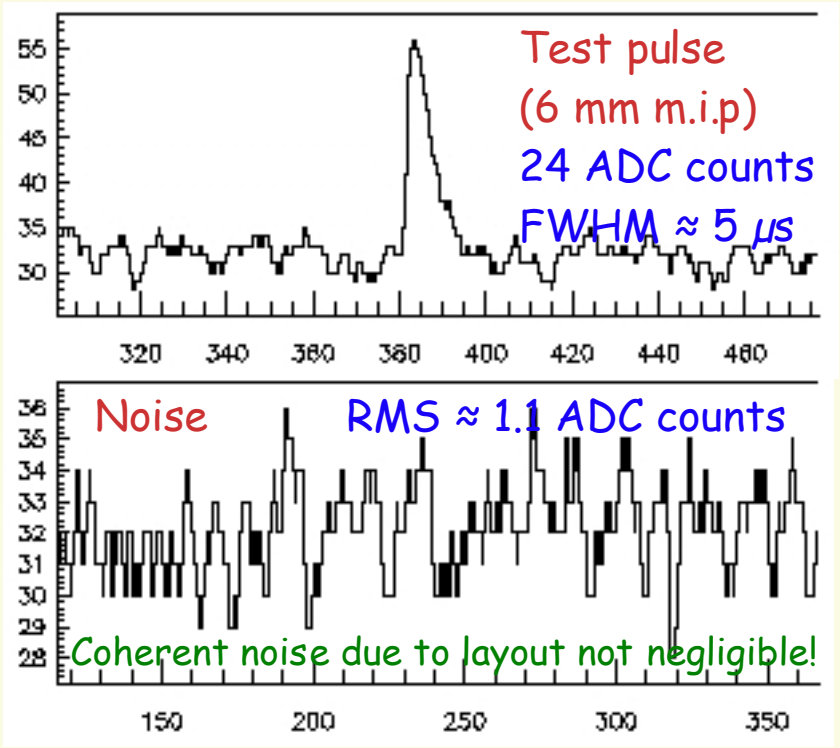
- ✓ Events (with PMT global trigger)



# Performance of the V791C boards

- ✓ Single wire waveforms (horiz. axis unit = 800 ns)

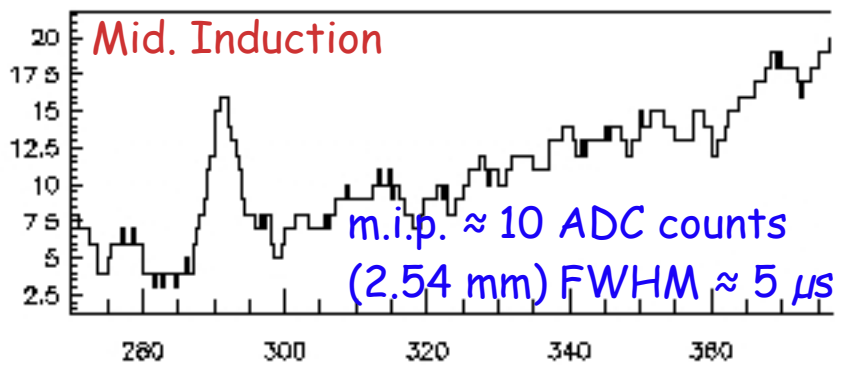


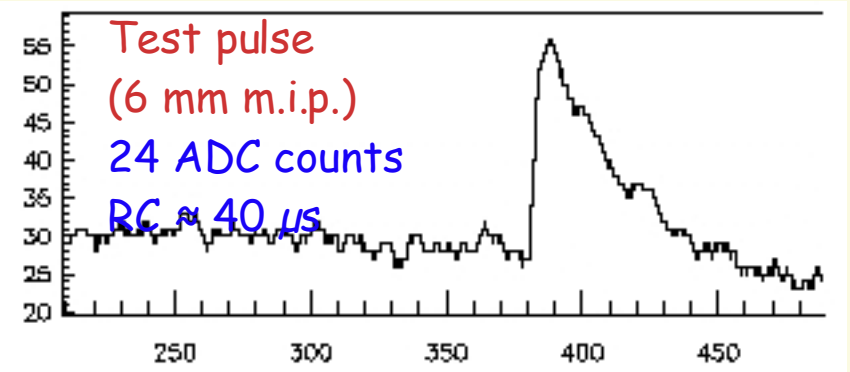



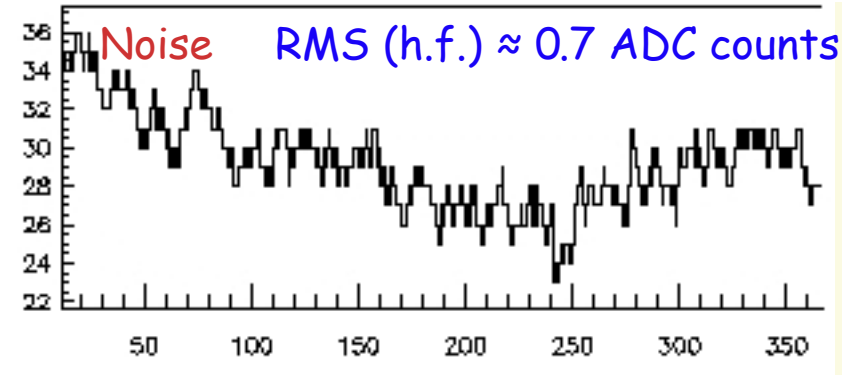

- ✓ Very similar to old electronics except for residual coherent noise !

# Performance of the V791Q boards

- ✓ Single wire waveforms (horiz. axis unit = 800 ns)




- ✓ Pulse height & shape from mid. plane wires very similar to those from collection plane wires.
- ✓ High frecuency S/N also comparable.
- ✓ Low frequency minimised by shaper.

Low frequency noise visible but not dangerous!

# Recording the PMT prompt signal

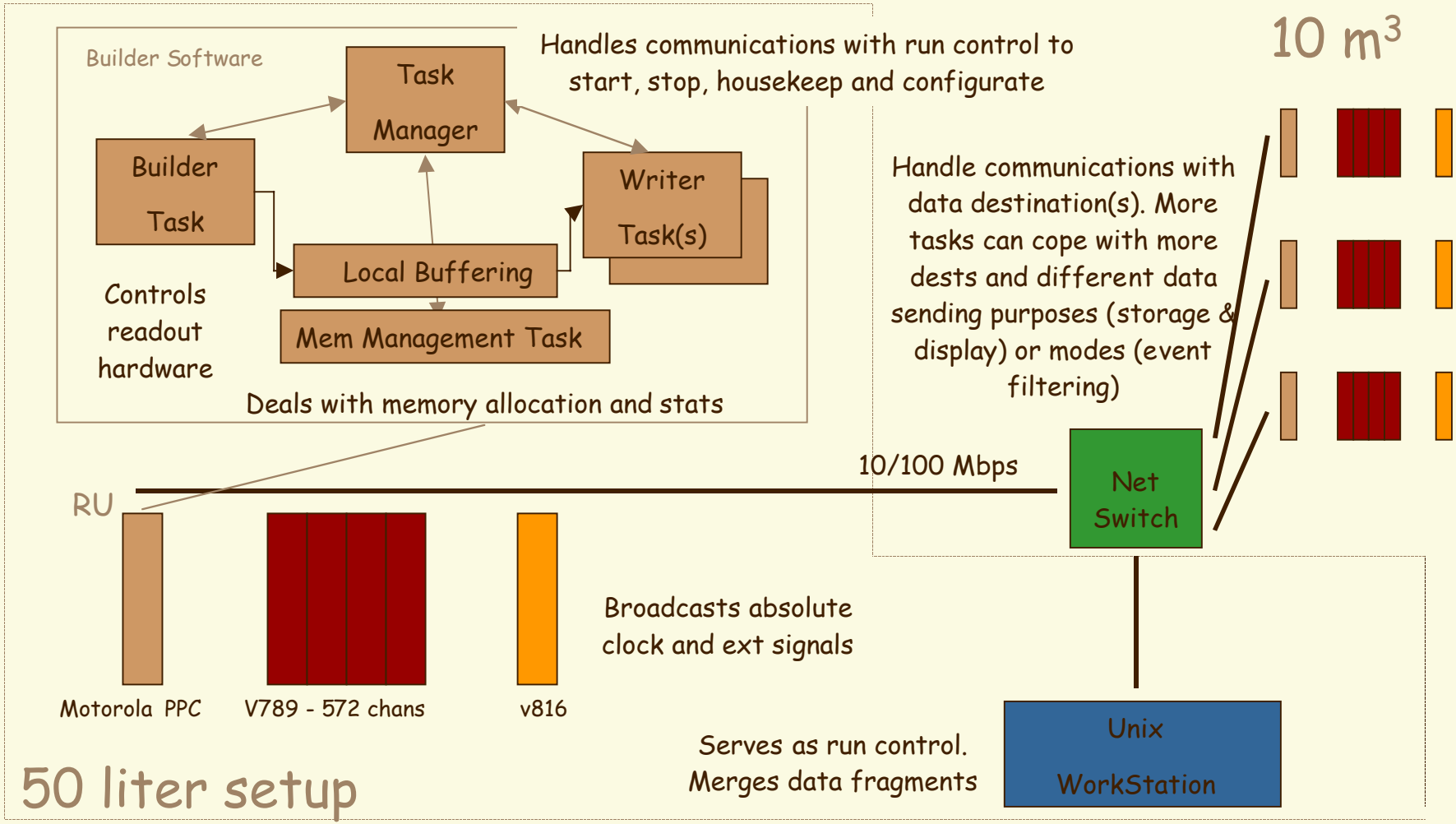
## ✓ PMT Characteristics:

- EMI 9426 with $MgF_2$ window ($\phi$ =2 inches)
- Q.E. (@ 128 nm) ≈ 20-25 %
- Gain (@ 1380 V) ≈ $10^6$
- Tipical m.i.p. signal:
  tens of photoelectrons
- Signal width ≈ 30 ns (base)
- Housed in evacuated case with $MgF_2$ window (located in Ar gas phase)

## ✓ Use:

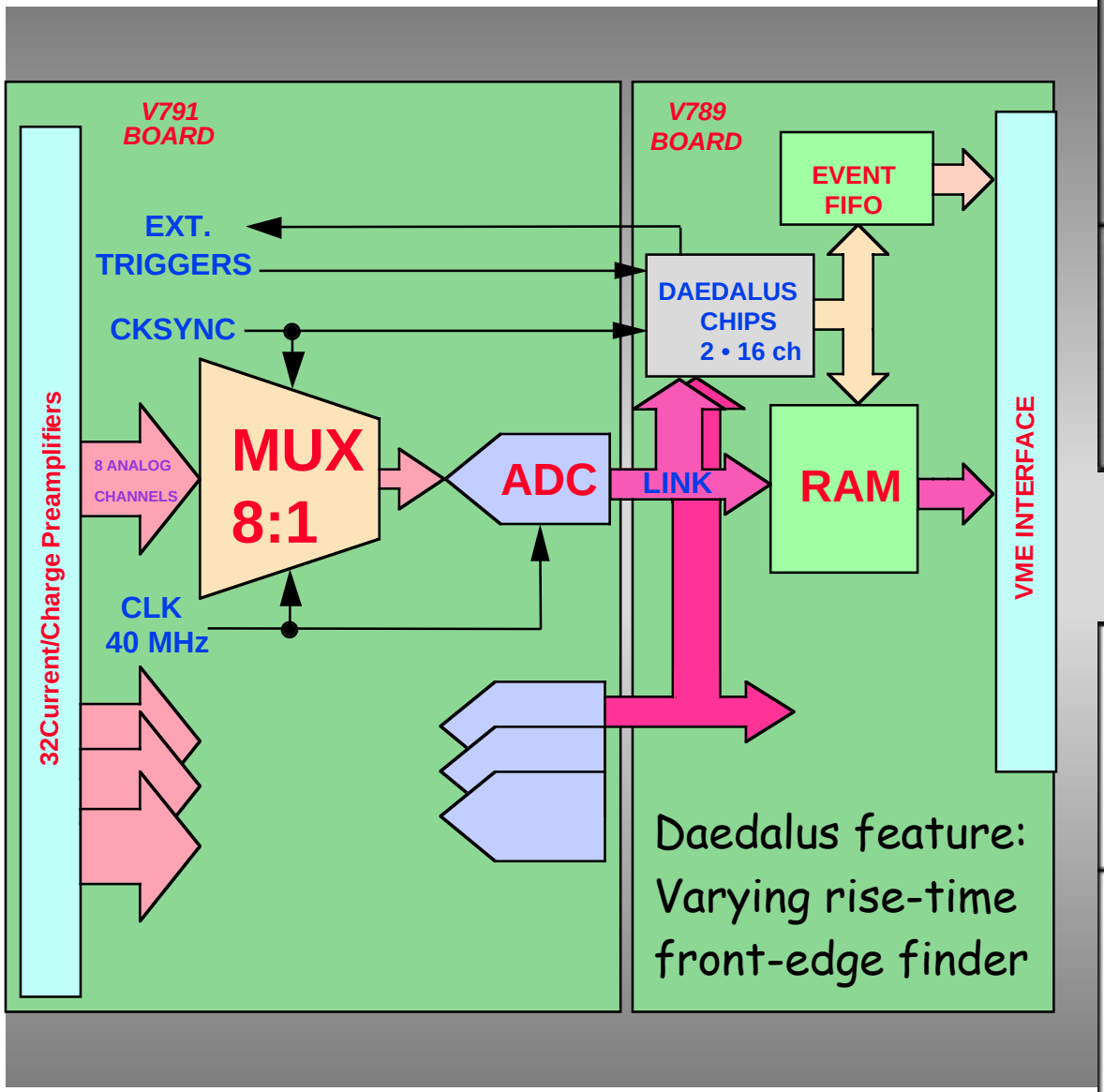
- Global external trigger
- Internal trigger enabler
- Recorded with a modified version of the V791Q board:
  - Pre-amp sensitivity:
    1 pC = 25 mV
    Decay time ≈ 400 $\mu$s
  - No multiplexer :
    50 ns sampling time
  - 4 channels per board
  - Muon signal in the 50 l LAr-TPC
    ≥ 50 mV

# Present DAQ structure

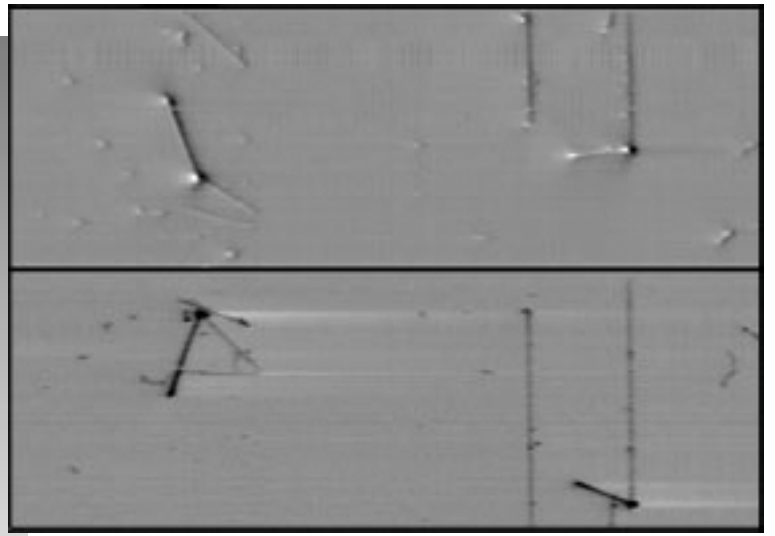



50 liter setup

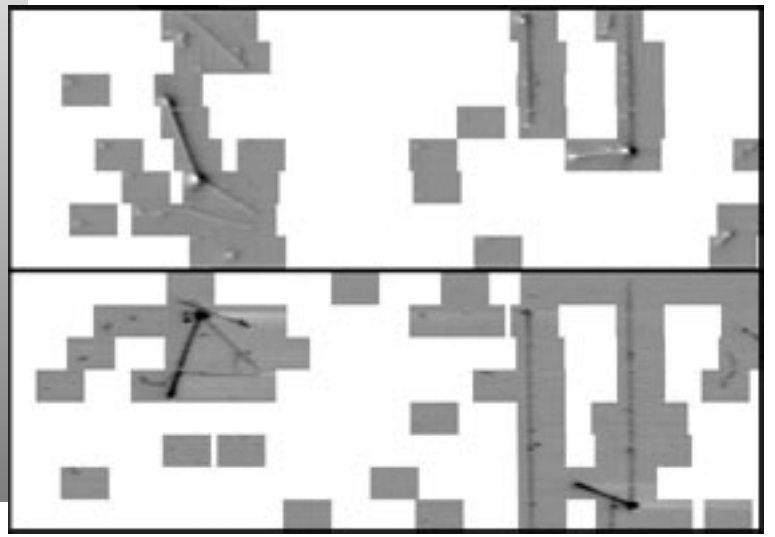
# Daedalus chip as on-line zero suppressor and local trigger enabler




Raw data (ext. trigger)



Reduced data



# Event builder operating modes

- ✓ **External trigger:** PMT Analog OR + Full Drift Imaging
  - Like the old Icarus readout. Limited in bandwidth (≈1 Hz max rate for 1.5 ms drift). Maximum of two events pile-up before deadtime.
- ✓ **External Enable:** PMT Analog OR + Daedalus hit finding
  - Bandwidth allows up to 1k event "tiles" (25 $\mu$s • 16 wires) per second per readout crate. Daedalus thresholds can be more tolerant without overflooding readout.
  - Internal FIFO's can accept up to 128 fragments.
- ✓ **Open Shutter:** Daedalus hit finding
  - Same bandwidth as above. Useful to collect low energy events.
  - Drawback is that correlated noise bursts even at low repetition rate (few per second) would easily saturate the DAQ channel.

# DAQ status

- Ongoing tests:
  - Prototype event builder tested on the 50 liter LAr-TPC. Event fragments forwarded via tcp/ip socket, also used for run control. Data streamed by pushing (no event requests) with the tcp/ip intrinsic flow control. Merging done at reception.
  - Found serious problem with the absolute clock tagging, resulted inconsistent from board to board. Presently under investigation by Caen. Also affected Daedalus efficiency evaluation, since internal triggers cannot be correlated.
  - Particular effort and time put in finding the correct layout for grounding (which results very detector and environment dependent), to minimize coherent noise level and reduce bursty pick-ups which would very quickly saturate internal triggering.
  - On-line event display still under construction. A preliminary library handles the event reconstruction (temporary storage of fragments, handling of housekeeping tags which signals that all data for a given time window have been collected) and interfaces to off-line event display. Present data format to be integrated with further info for the off-line (run configuration, detector configuration, etc.).

# DAQ status

## ✓ Readout hardware:

- Two racks already operational. Two more ready to be assembled.
- Under production:
  - Decoupling Board (postponed due to crosstalk problem - now solved);
  - Modified versions of the V791 (C&Q) by CAEN, according to the new shaping configuration;
  - Slow Control Boards.
- Four CPU's and one 12 port 100 Mbps switch ready to be installed.

## ✓ Works in progress:

- One rack already installed and working on the 10 $m^3$ at LNGS.
- DAQ campaign successfully started also on the 10 $m^3$ .
- Next racks will follow upon receiving of DB's and V791's (≈ 2 months).
- Integration of several racks will put under spot the scalability issues of the system.
- The DAQ chain handles up to few Mbytes per second per crate (≈ 500 Daedalus "tiles" per second): a plan on how to organize the handling of the collected data is under study.