ICARUS: a status report on the T600 detector construction and its data acquisition system

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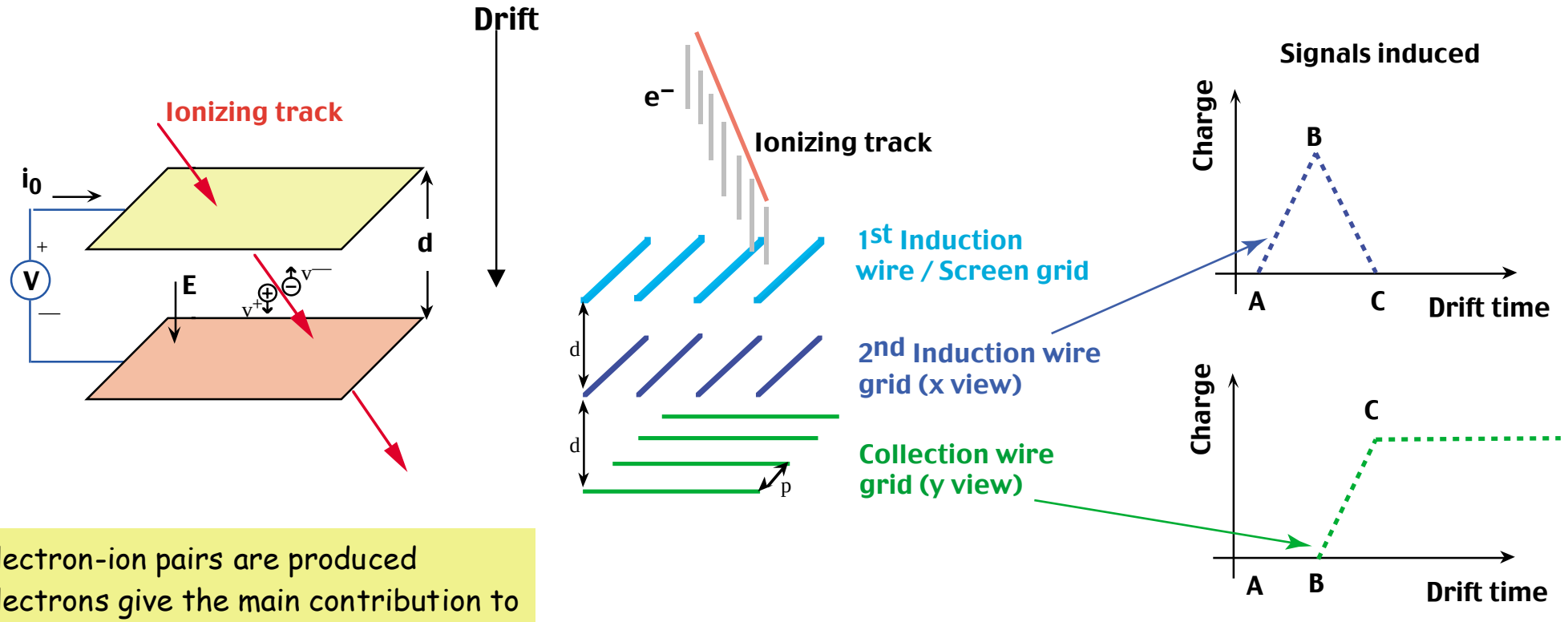
Doktorandenseminar 3-5 October 2000

Event Imaging in Liquid Argon

✶ Detect electrons produced by ionizing tracks crossing the LAr



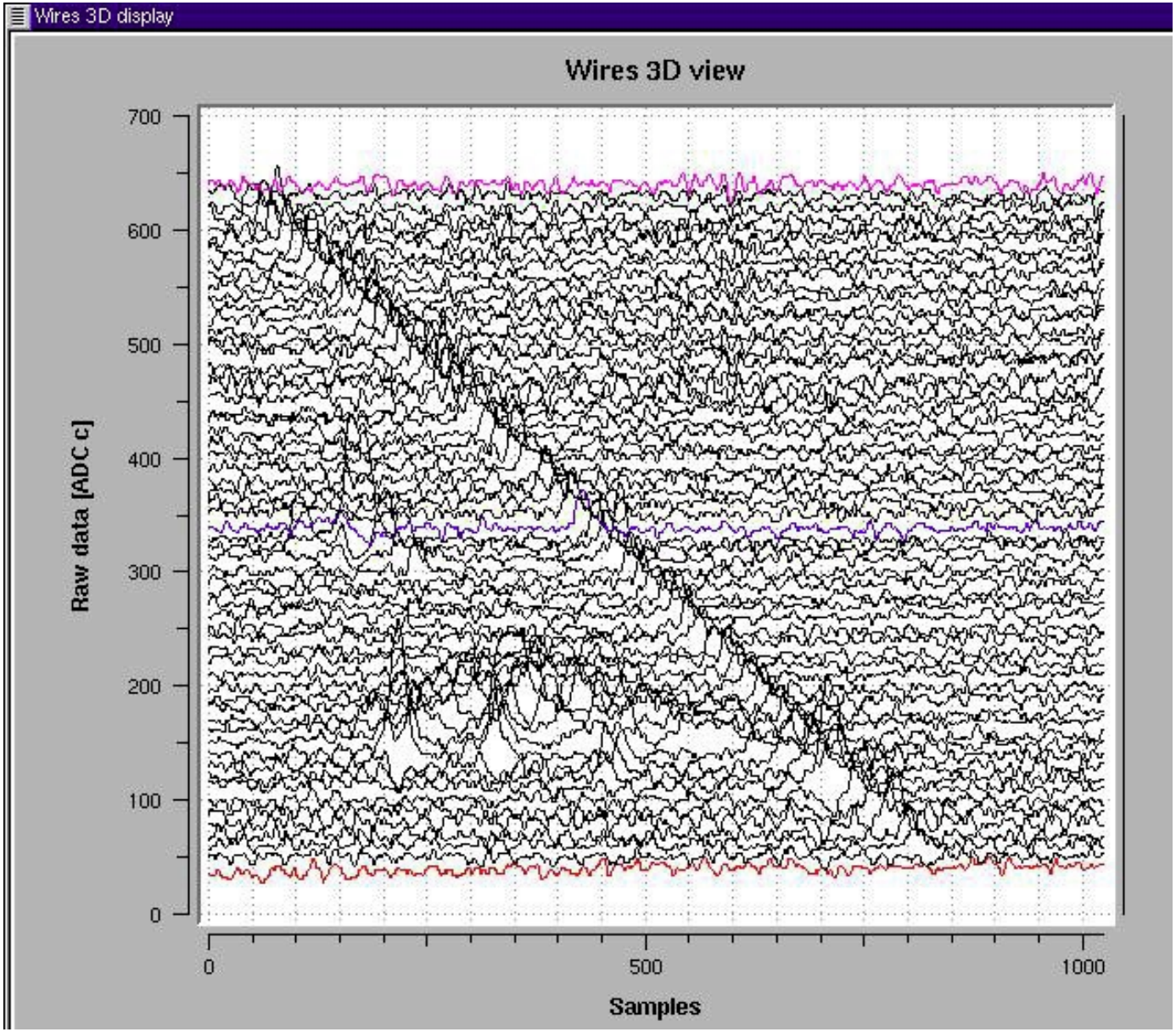
Electron-ion pairs are produced
Electrons give the main contribution to the induced current due to the much larger mobility

$$I_0 = e(v^+ + v^-)/d$$

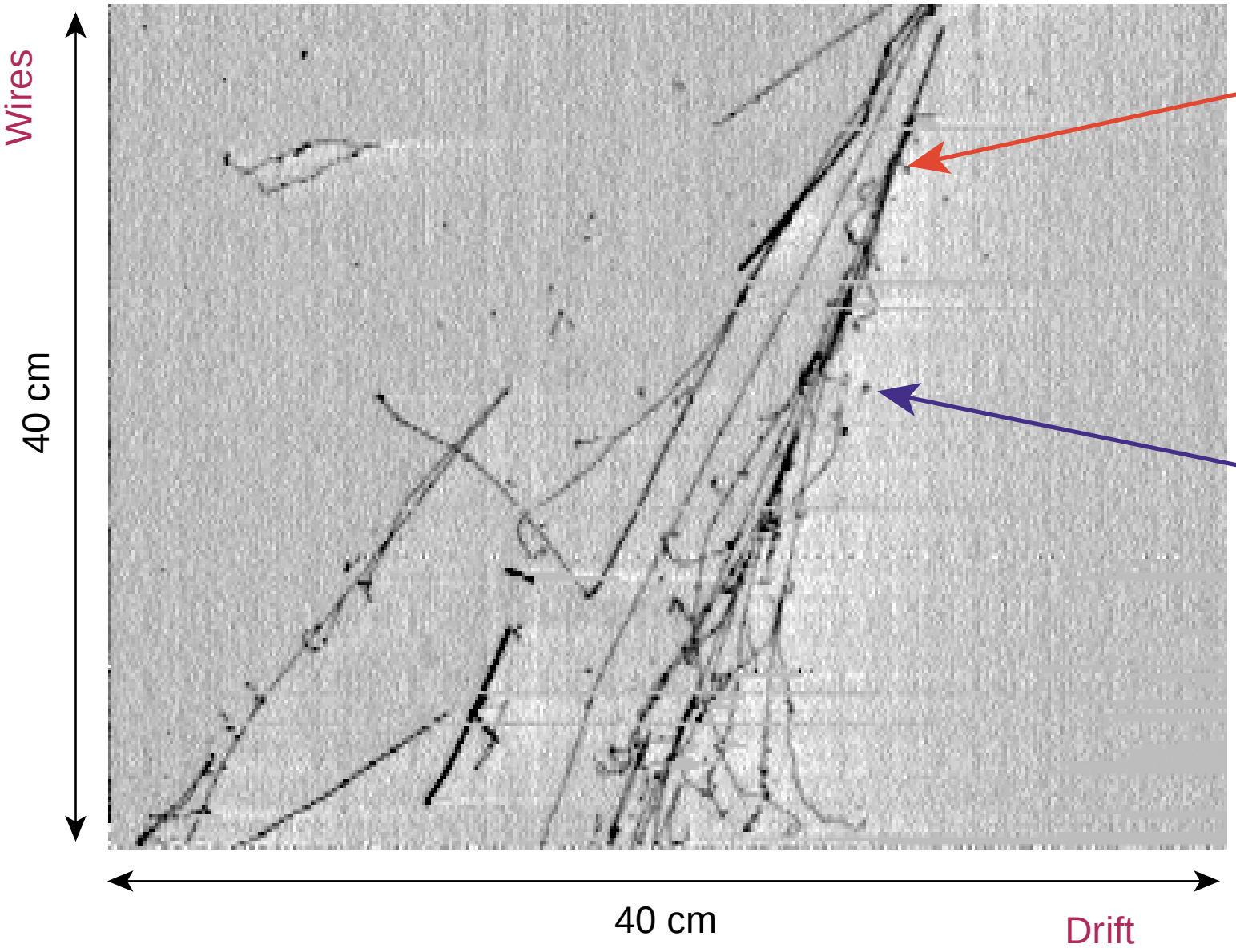
A set of wires at the end of the drift give a sampling of the track
No charge multiplication occurs near the wires ➨ electrons can be used to induce signals on subsequent wires planes with different orientations ➨ ➨ 3D imaging

ICARUS liquid argon imaging TPC (I)

Real event from 15 ton



ICARUS liquid argon imaging TPC (II)



"Bubble" size
≈ 3 x 3 x 0.2 mm^3

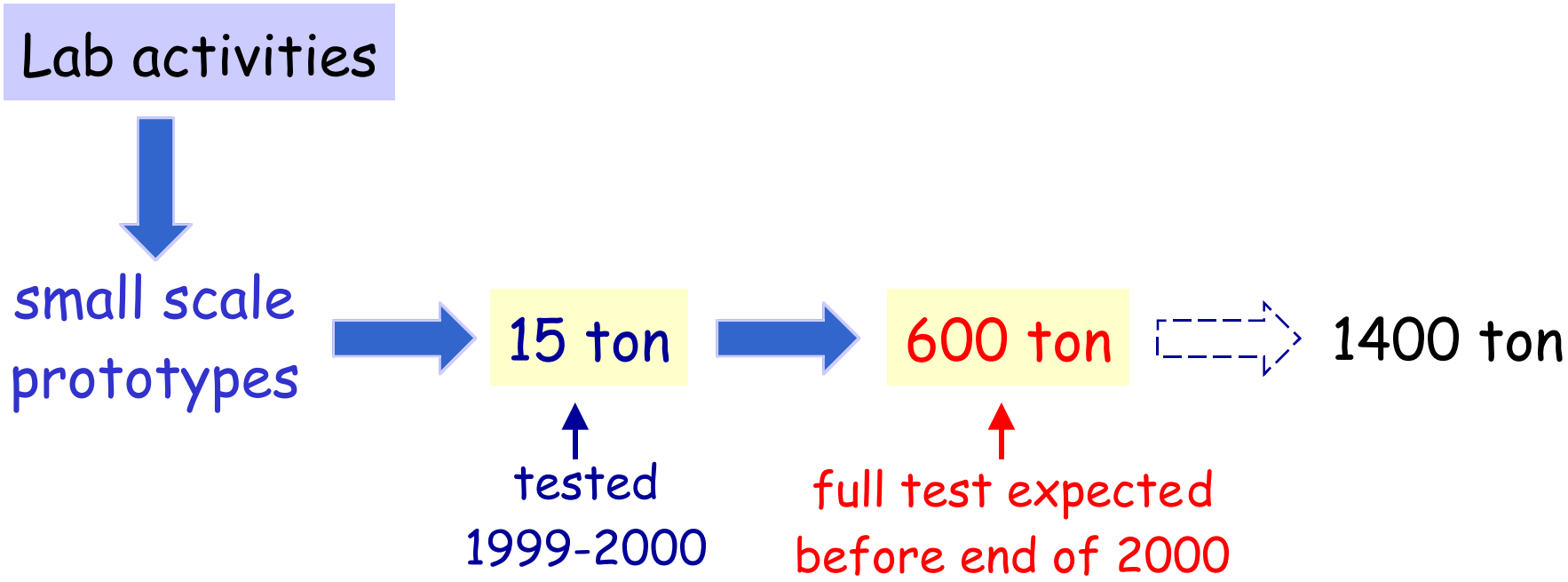
Energy deposition measured for each point

The ICARUS graded strategy

The detector is continuously sensitive, thus allowing to easily simultaneously collect atmospheric neutrinos, CNGS and other rare events like proton decay

BUT...

this physics programme requires large detector masses !



The ICARUS technique - challenges

- Liquid Argon environment in big volumes:
  - Cool and maintain the temperature of the detector at T=90K with T uniformity of ±1K (uniform drift velocity)
  - Temperature gradient during cooling implies mechanical stress ➔ e.g. chamber wires contraction

- Long drift path ➔ drift electron lifetime > 1ms:
  - Clean elements (chamber structure, cryogenic instrumentation, limited degassing cables, ..)
  - Reach a purity of LAr at the level of < 0.1 ppm O_2 equivalent

These goals have been reached in laboratory environment and now they have also been reached at the industrial scale for the T600 detector thanks to the cooperation with specialized industries:

⇨ Air Liquide for Cryostat and Argon purification
⇨ BREME Tecnica for internal detector mechanics
⇨ CAEN for readout electronics

ICARUS 15 ton ($10m^3$) prototype (1999-2000)

- A recent major step of the R&D program has been the construction and operation of a **$10m^3$ prototype**

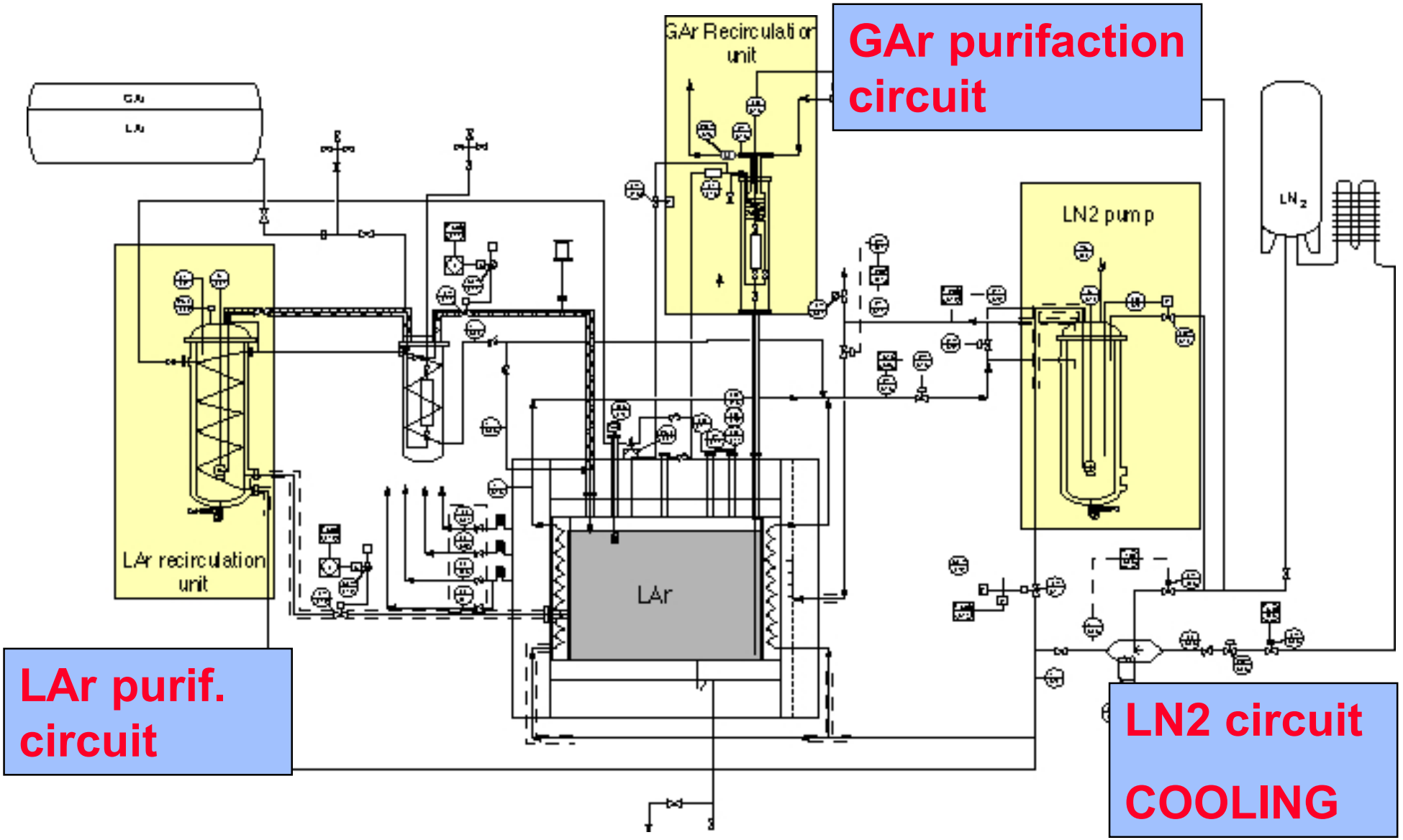
① **Test of the cryostat technology**

② **Test of the "variable-geometry" wire chamber**

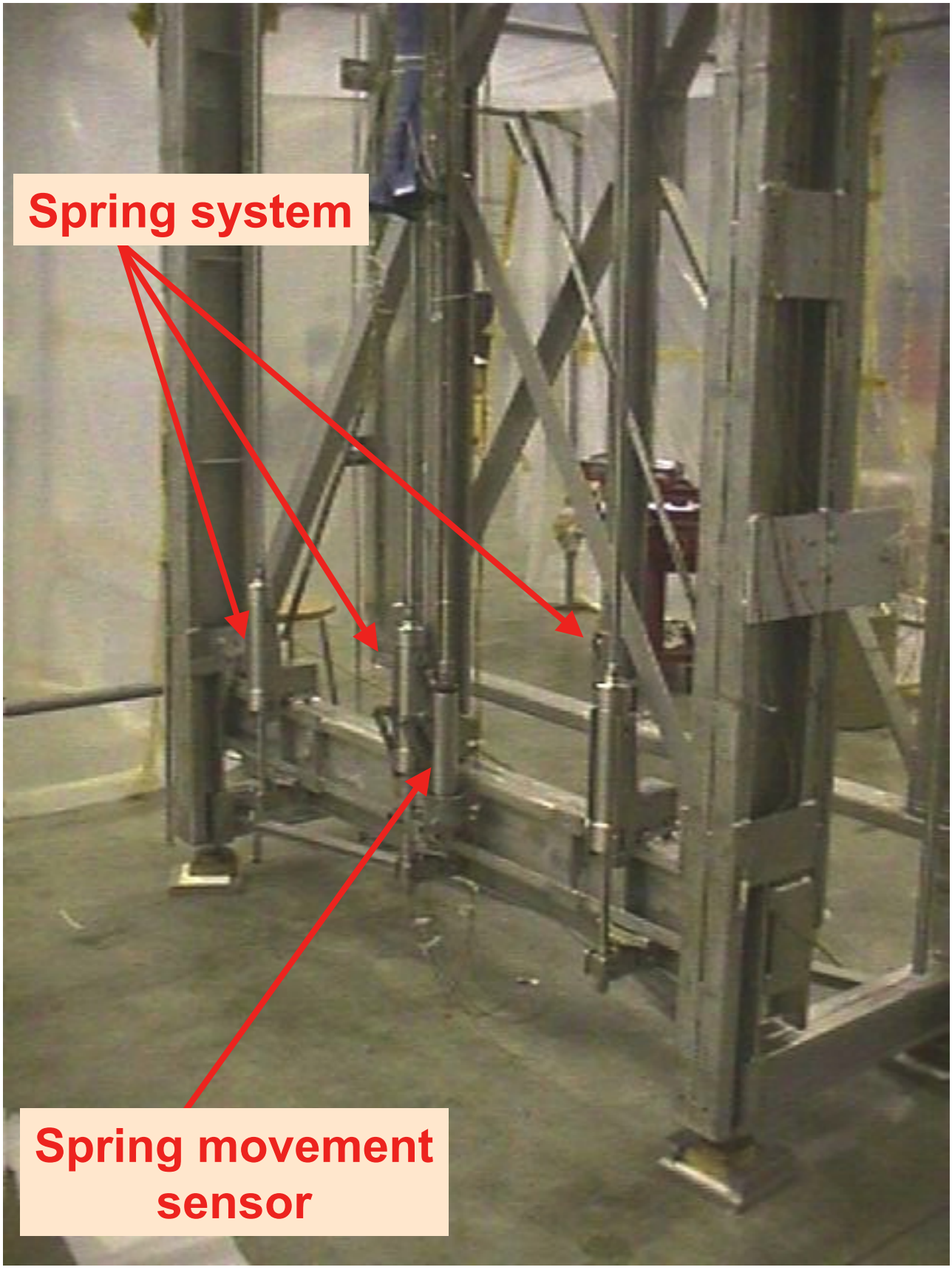
③ **Test of the liquid phase purification system; purity level exceeded 2ms electron lifetime**

T15 installation @ Pavia

Cryogenic circuit

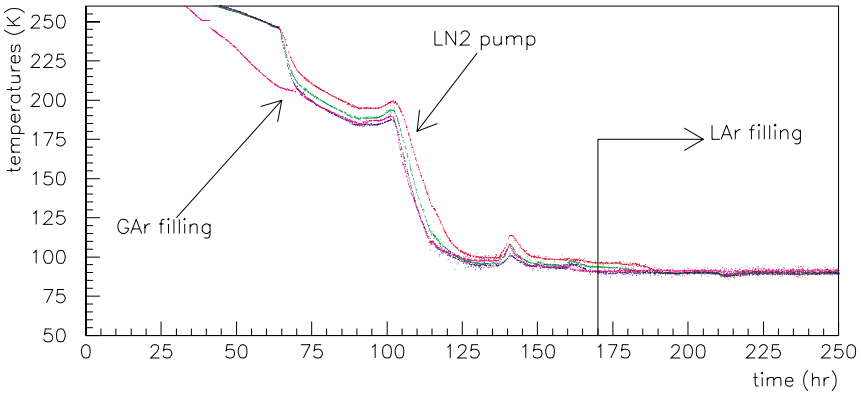


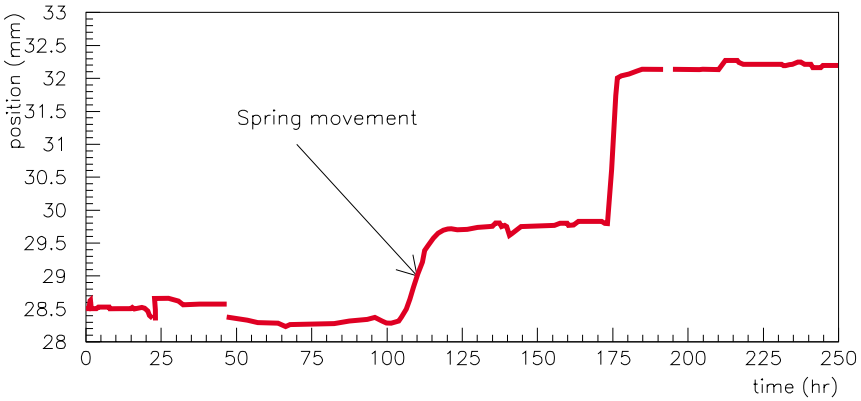
View of the ICARUS T15 internal detector



Cooling 15 ton prototype March '99

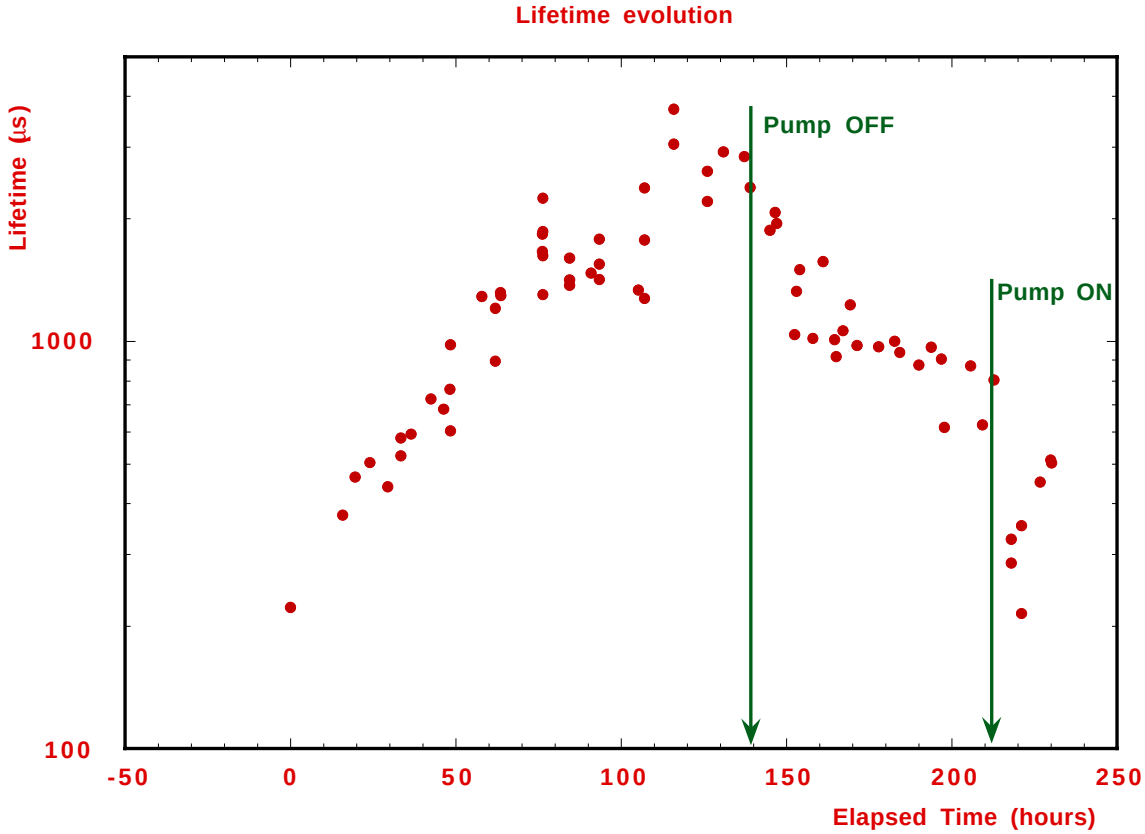
Temperature / Spring movement





✖ Confirmation of the functionality of the *variable geometry* mechanics

LAr purity



✖ **The electrons lifetime (defined as the mean time spent by a free electron in the LAr before being captured by an electronegative impurity), after about 4 days of recirculation, was between 2 ms to 3 ms.**

ICARUS T15 @ LNGS

- The second test phase of the T15 prototype has in addition provided:
  - ① **Long-term test of the cryostat technology**
  - ② **Test of trigger via scintillation light**
  - ③ **Large scale test of final readout electronics**

➜ *First operation of a 15 ton LAr mass as an actual "detector"*

T15 installation @ LNGS (Hall di Montaggio)

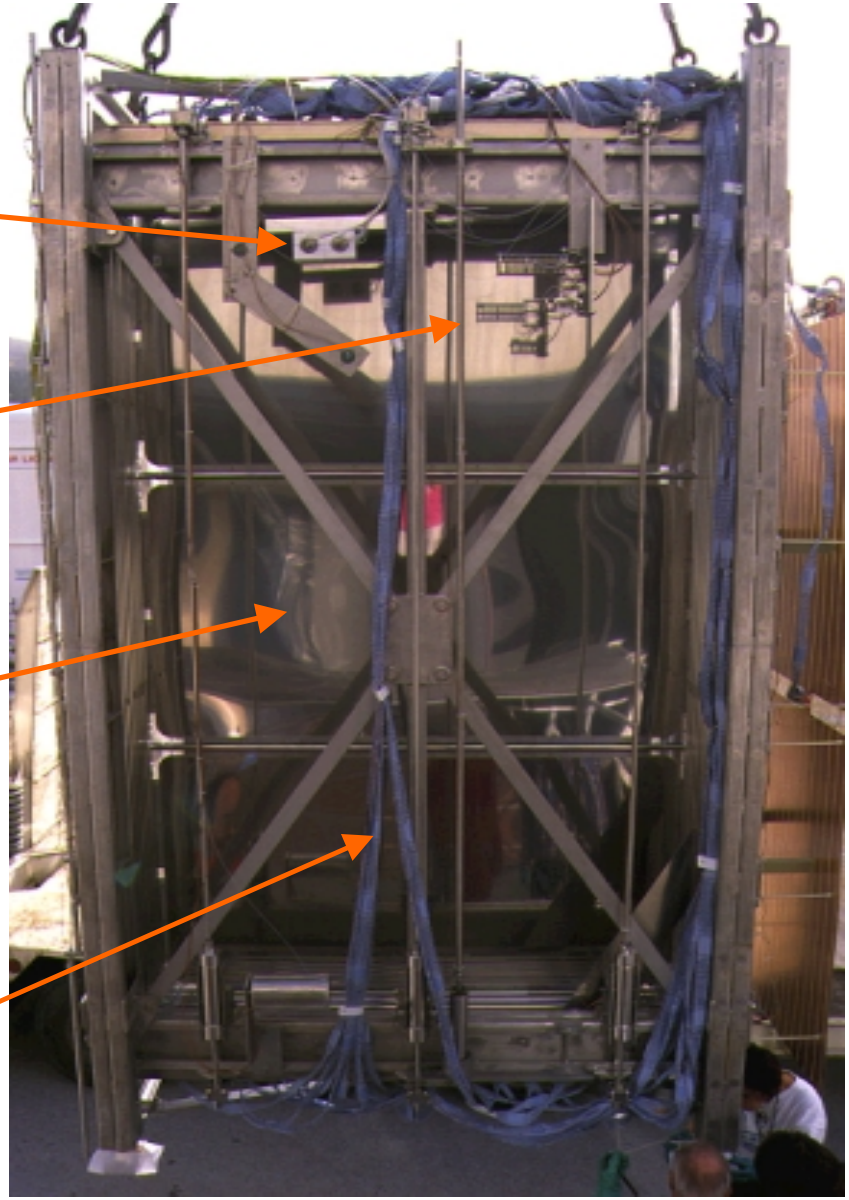
ICARUS 15 ton prototype - internal detector

Photomultipliers

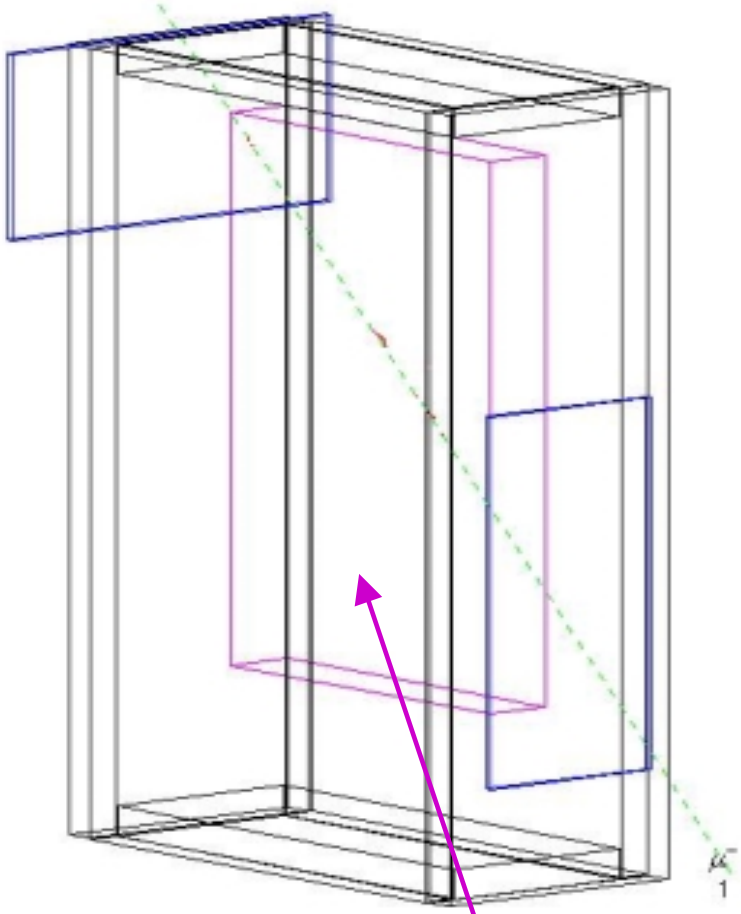
Purity Monitors

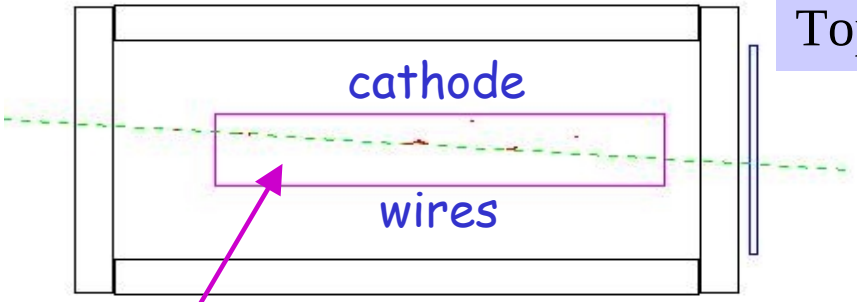
Cathode

Two wire planes (induction + collection)
928 wires/plane, all connected for readout



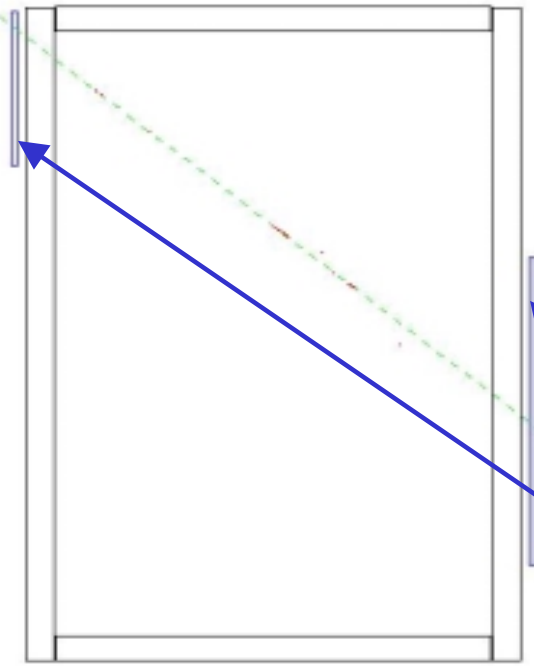
Internal volumes layout





Top View

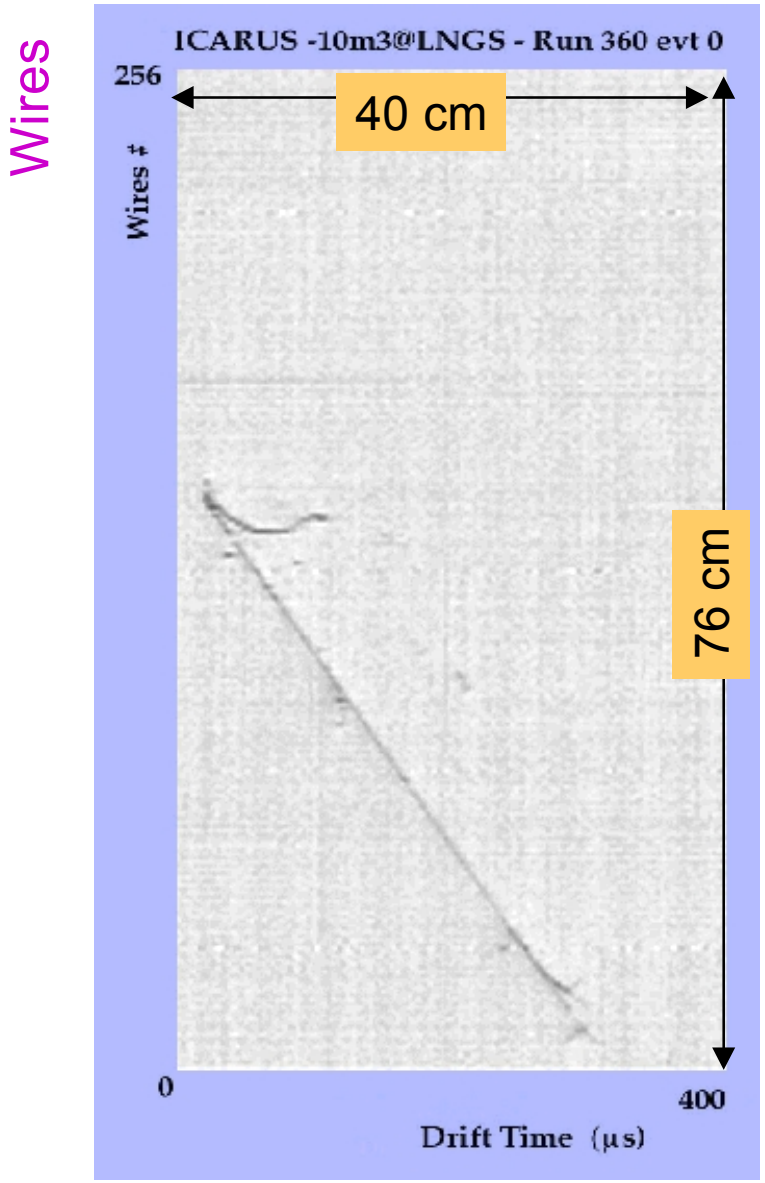
Lateral View

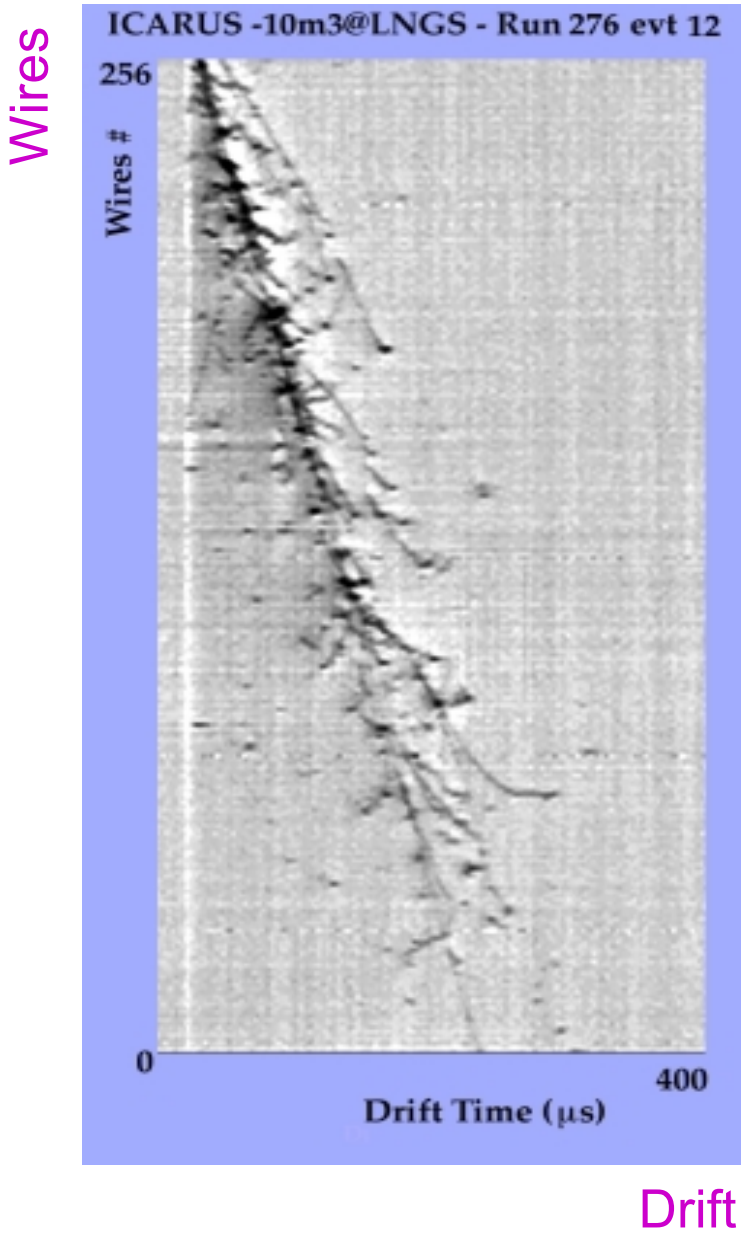


Imaging region (35 cm drift)

External trigger

Tracks in 15 ton prototype



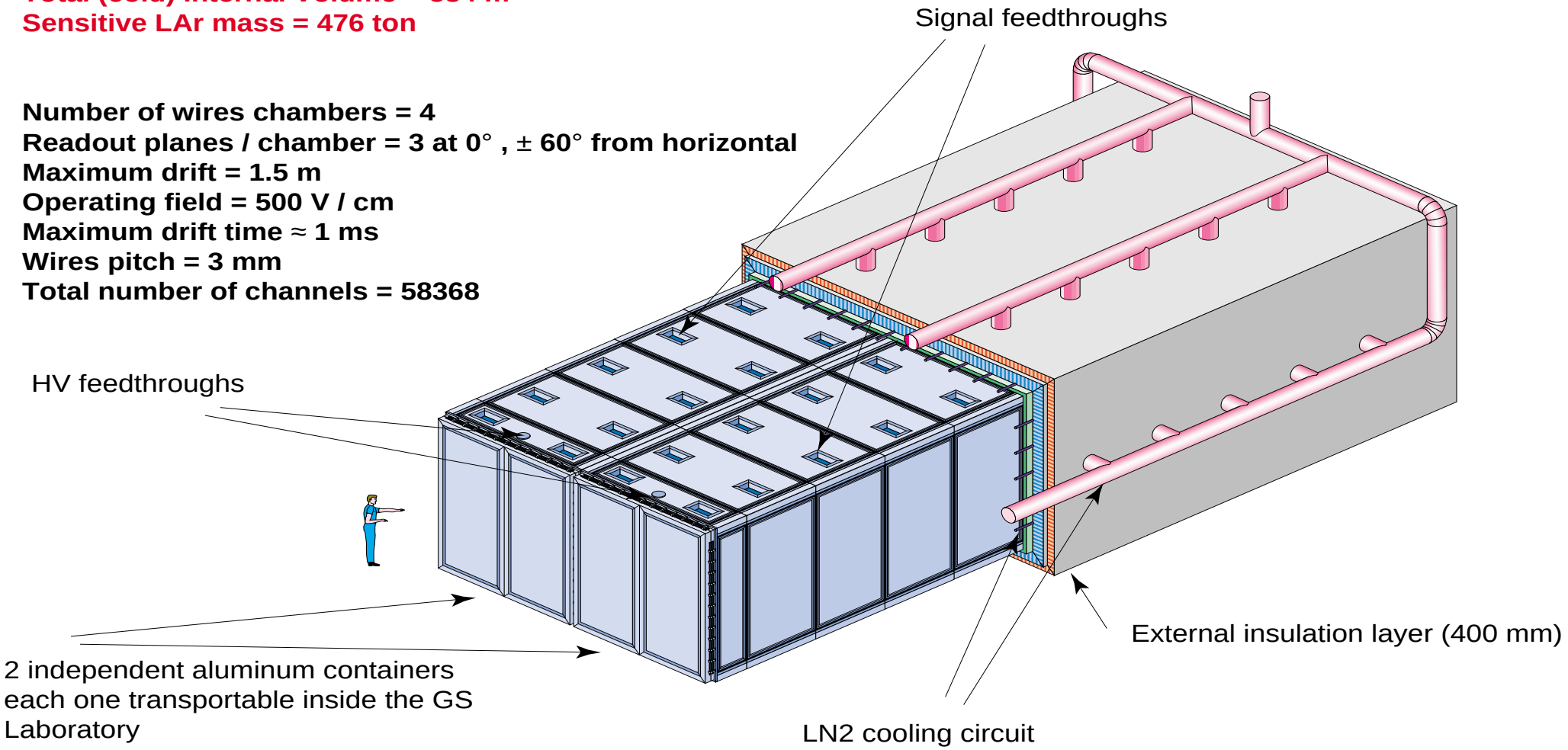


The ICARUS T600 module

Under construction

Number of independent containers = 2
Single container Internal Dimensions: Length = 19.6 m , Width = 3.9 m , Height = 4.2 m
Total (cold) Internal Volume = 534 m
Sensitive LAr mass = 476 ton

Number of wires chambers = 4
Readout planes / chamber = 3 at 0° , ± 60° from horizontal
Maximum drift = 1.5 m
Operating field = 500 V / cm
Maximum drift time ≈ 1 ms
Wires pitch = 3 mm
Total number of channels = 58368



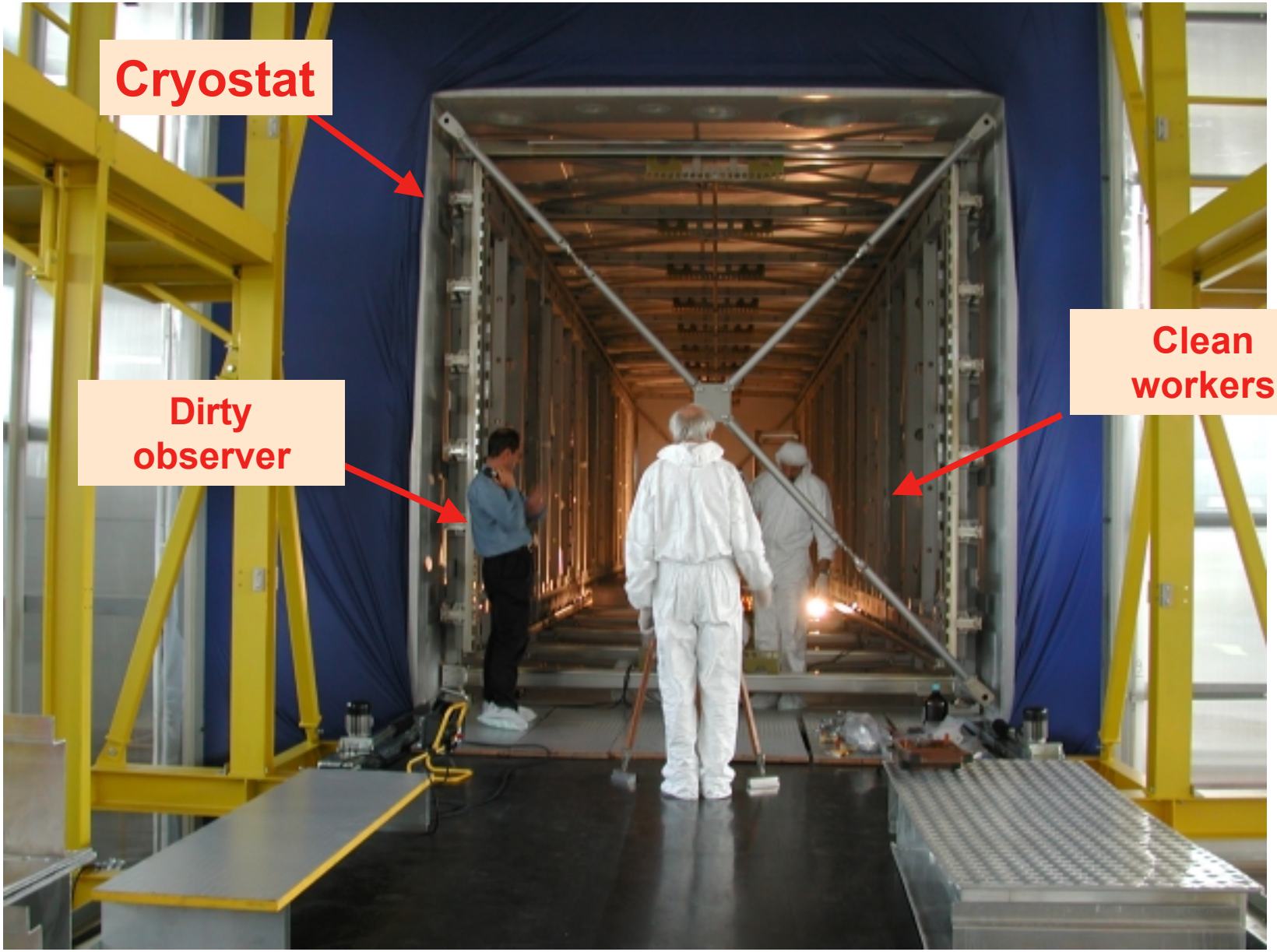
Status of the T600 assembly

- After the delivery of the first half-module, at the end of February 2000, we started the assembly of the internal detector mechanics. The mechanical frame, holding the wires and all the other detector components, has been positioned and aligned to within 0.2 mm over the full detector length (19 m).
- Wires positioning in the first half-module started in the second half of August and is now going on very quickly (about 500 wires/hour).
- The central cathode, all the auxiliary instrumentation that goes behind the chambers and part of the cables (for electronics and wires test) were installed before.
- Signal cabling will follow as soon as wires will be tensioned. Installation of race-tracks and HV divider chain will complete the assembly of the internal detector.
- Installation of thermal insulation and cryogenic system is proceeding in parallel with the internal detector assembly.

First half-module delivery in Pavia

Second half-module positioned on the insulation in Pavia

Assembly of the T600 internal detector (clean room)



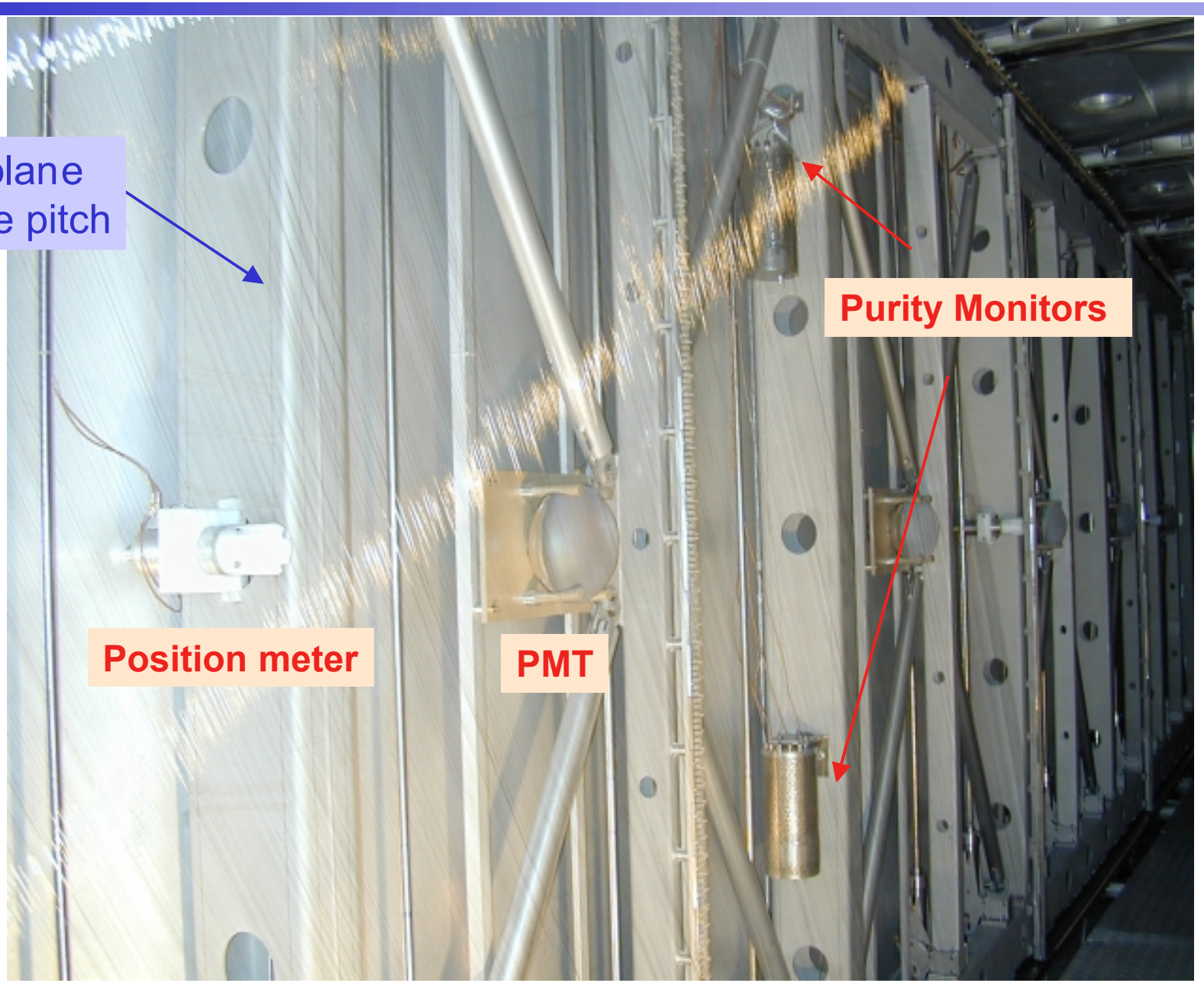
T600 internal detector: mechanical frame

T600 internal detector: view of the cathode

Wire installation in T600 first half-module

C.Carpanese, ETH Zürich, 3/10/2000

T600 internal detector: sensors

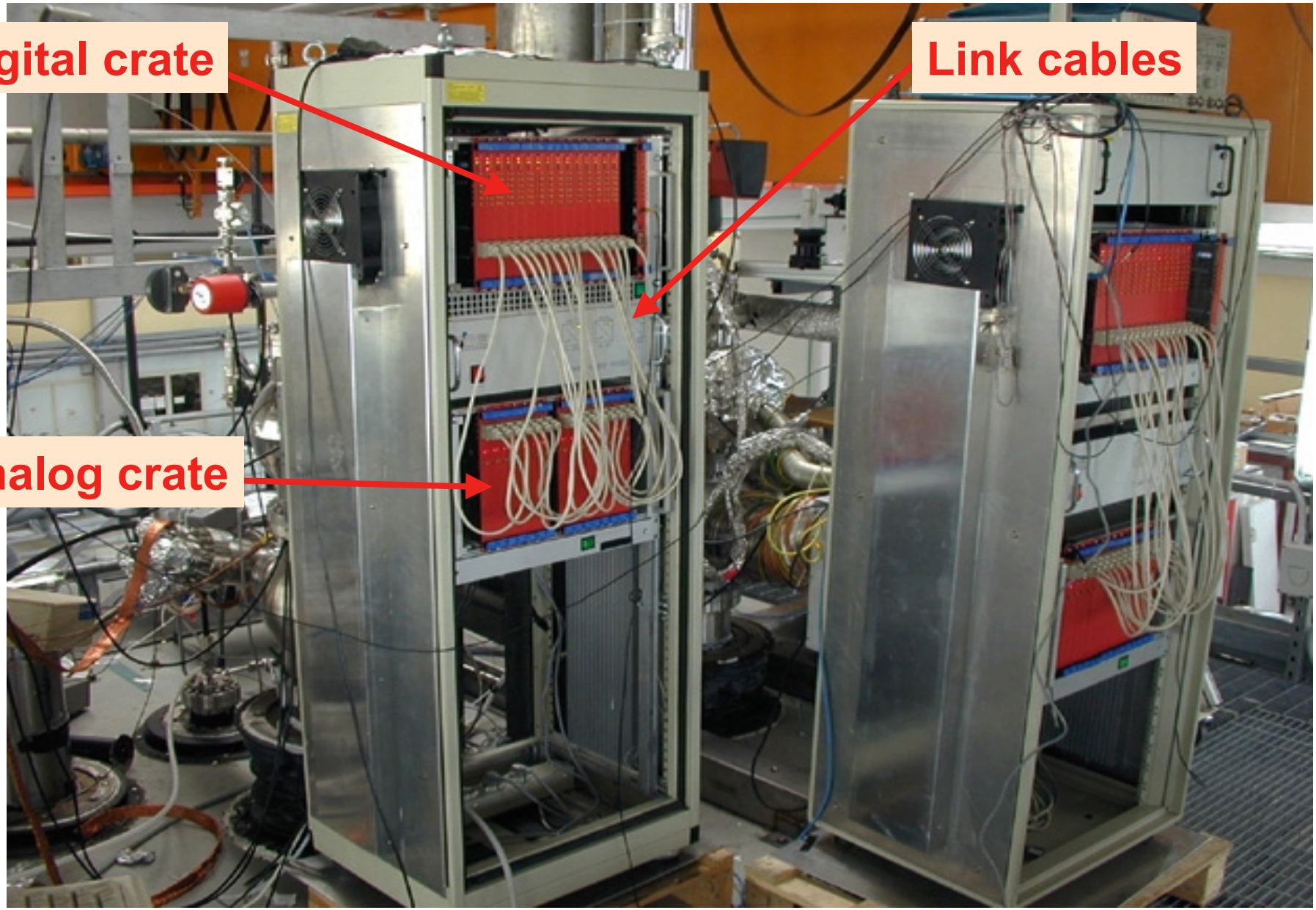


Wires separators

T600 detector: view of the roof during the insulation assembly

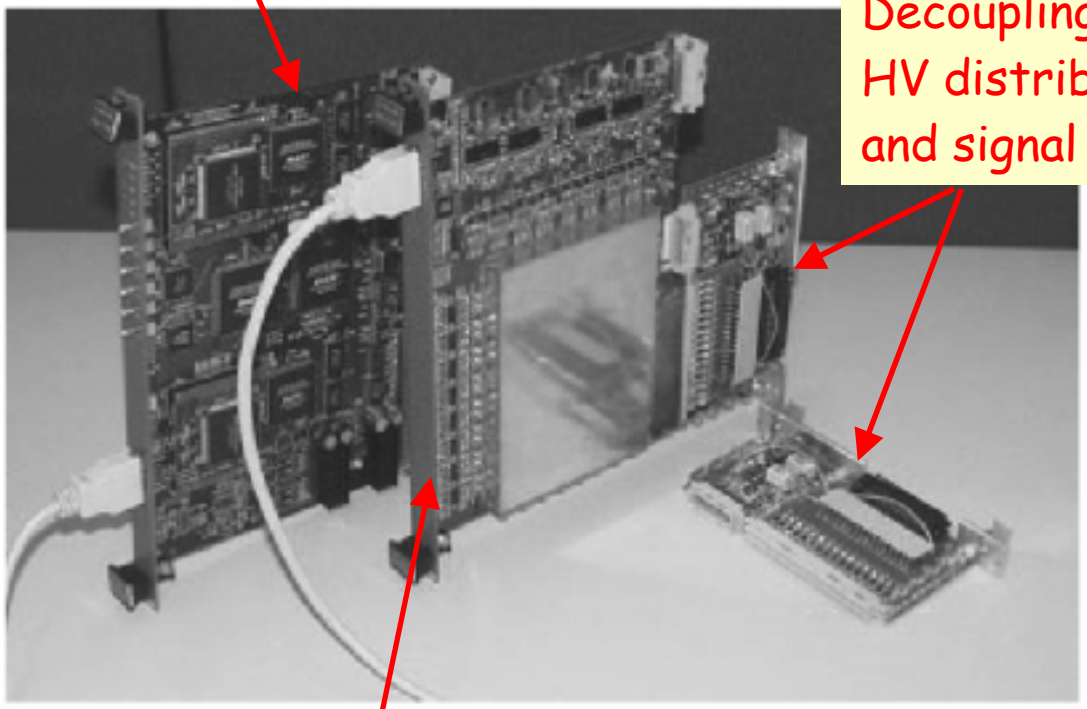
Signal feedthroughs flange

Electronics racks



The T600 readout chain

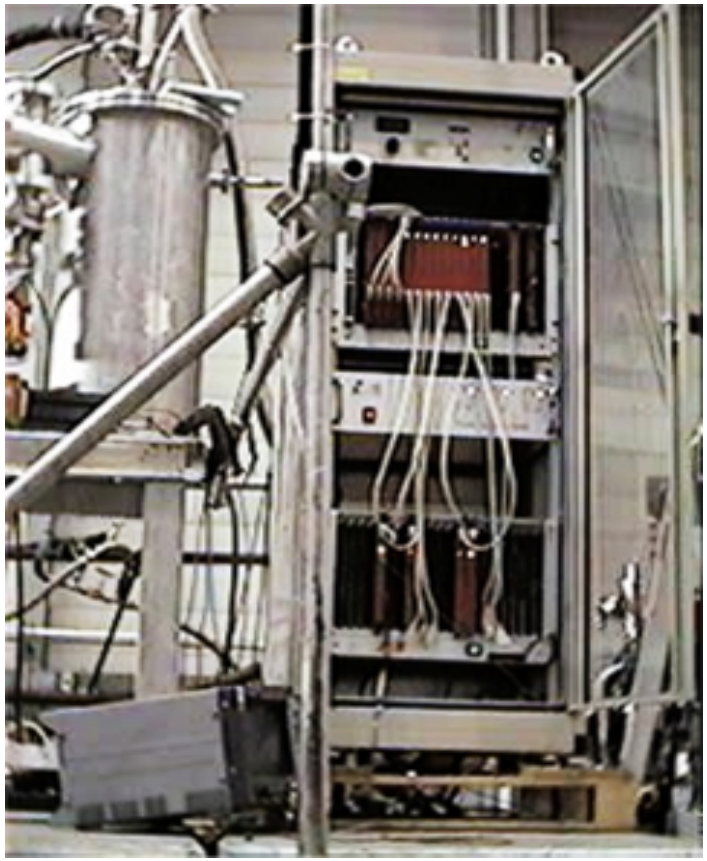
CAEN-V789 board: 2 Daedalus VLSI * 16 input channels (local self-trigger & zero suppression) + memory buffers + data out on VME bus



Decoupling board: HV distribution and signal input

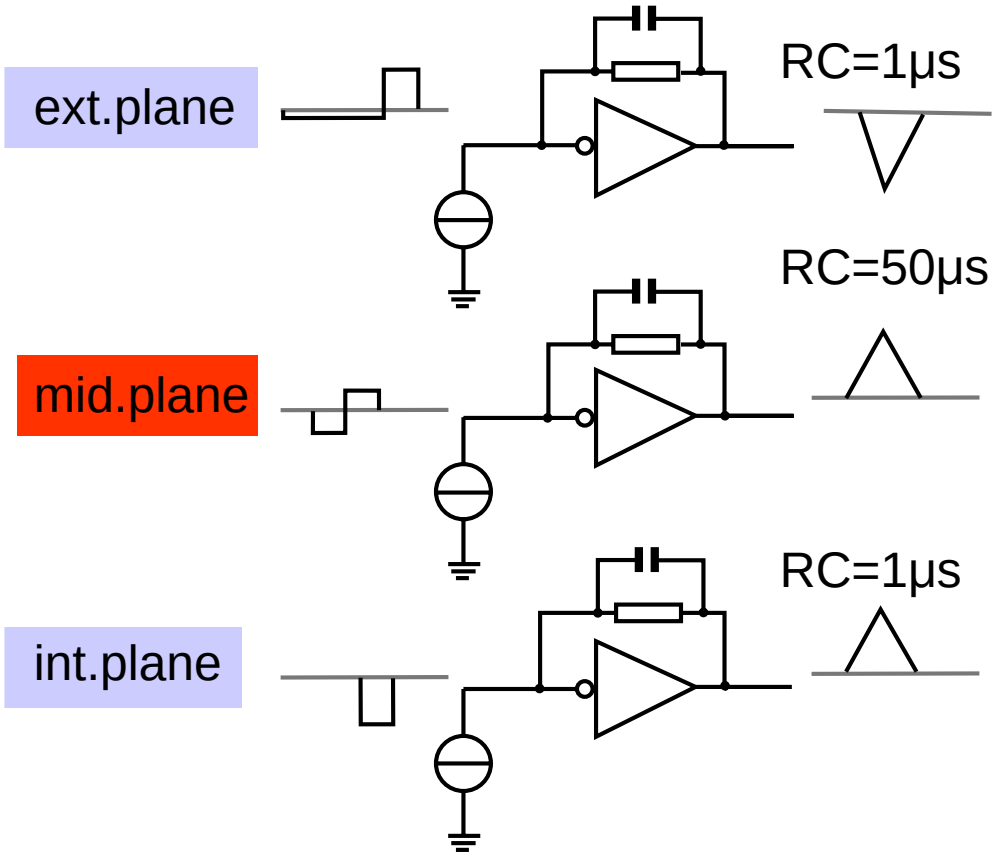
CAEN-V791 board: 32 pre-amplifiers + 4 multiplexers (8:1) + 4 FADC's (10 bits - 20 MHz)

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

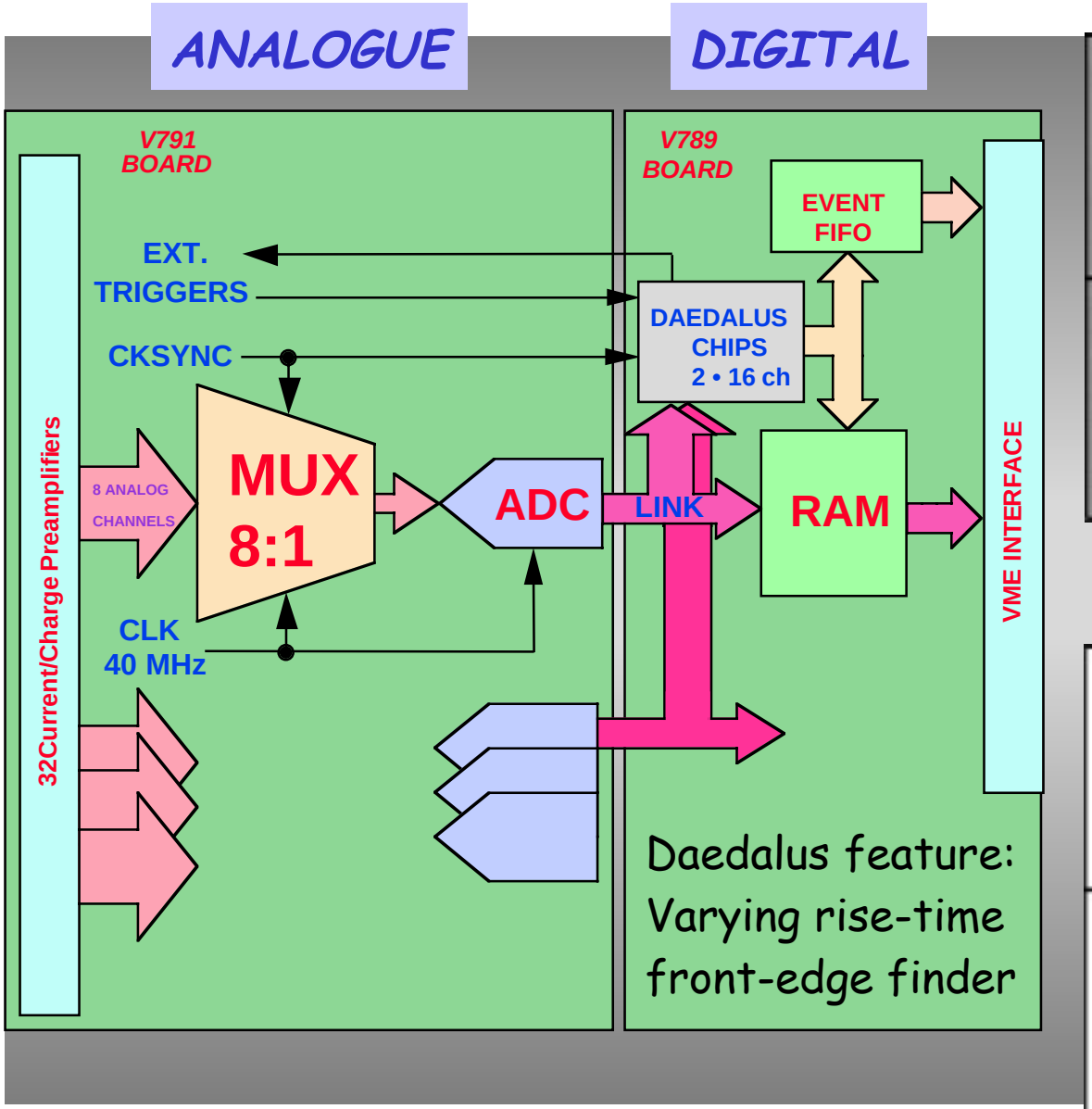


Input signals & pre-amp feedback RC

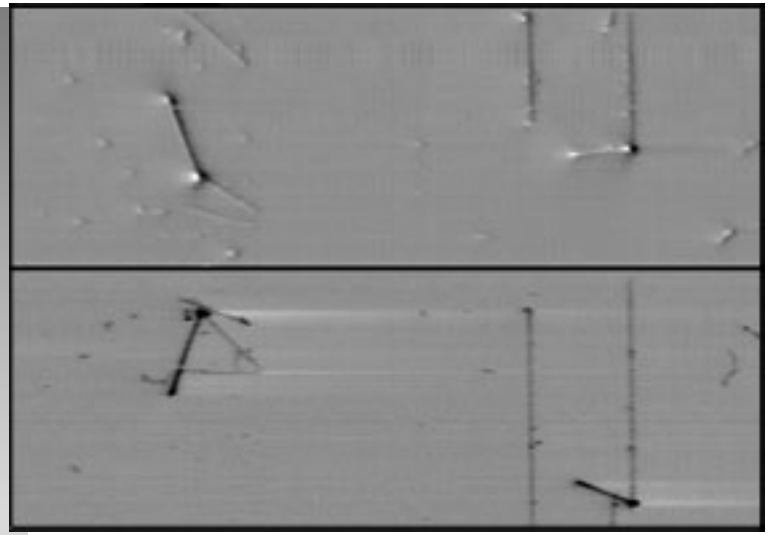
- External & Internal planes:
  - Approx. unipolar input signal
  - Width ≥ 3 μs
  - Short RC ("quasi-current" mode) to minimized pile-up
- Middle Plane:
  - Bipolar signal
  - Long RC ("quasi-charge" mode) to get triangular signals



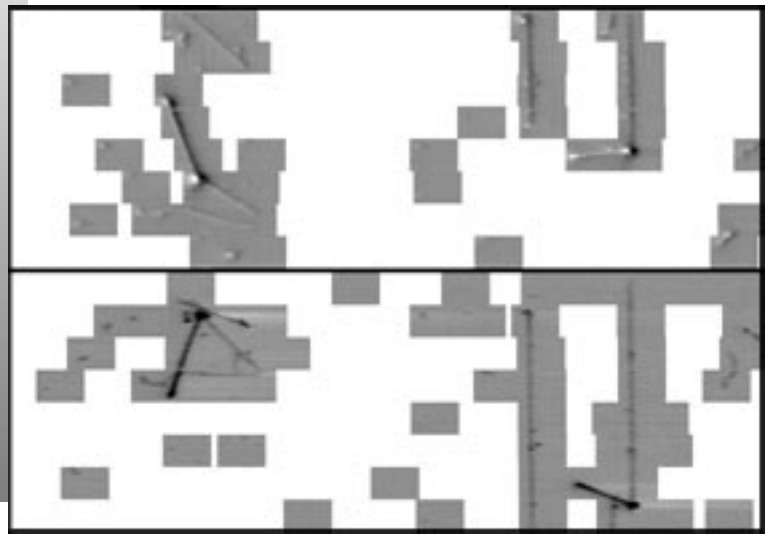
Daedalus chip as on-line zero suppressor and local trigger enabler



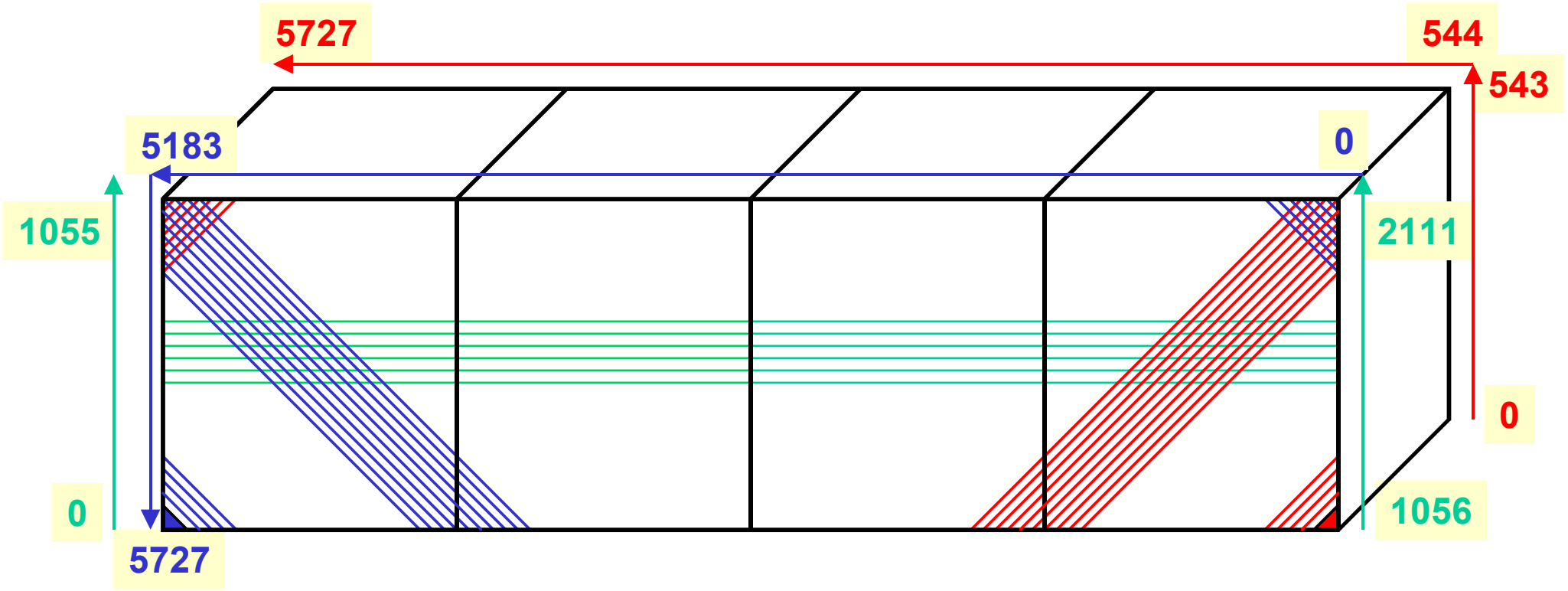
Raw data (ext. trigger)



Reduced data



T600 wire numbering and event size



Induction 1	[0 ÷ 2111]
Induction 2	[0 ÷ 5727]
Collection	[0 ÷ 5727]

Induction 1	2112 x 4096 x 2B ≈ 17 MB
Induction 2	5728 x 4096 x 2B ≈ 47 MB
Collection	5728 x 4096 x 2B ≈ 47 MB

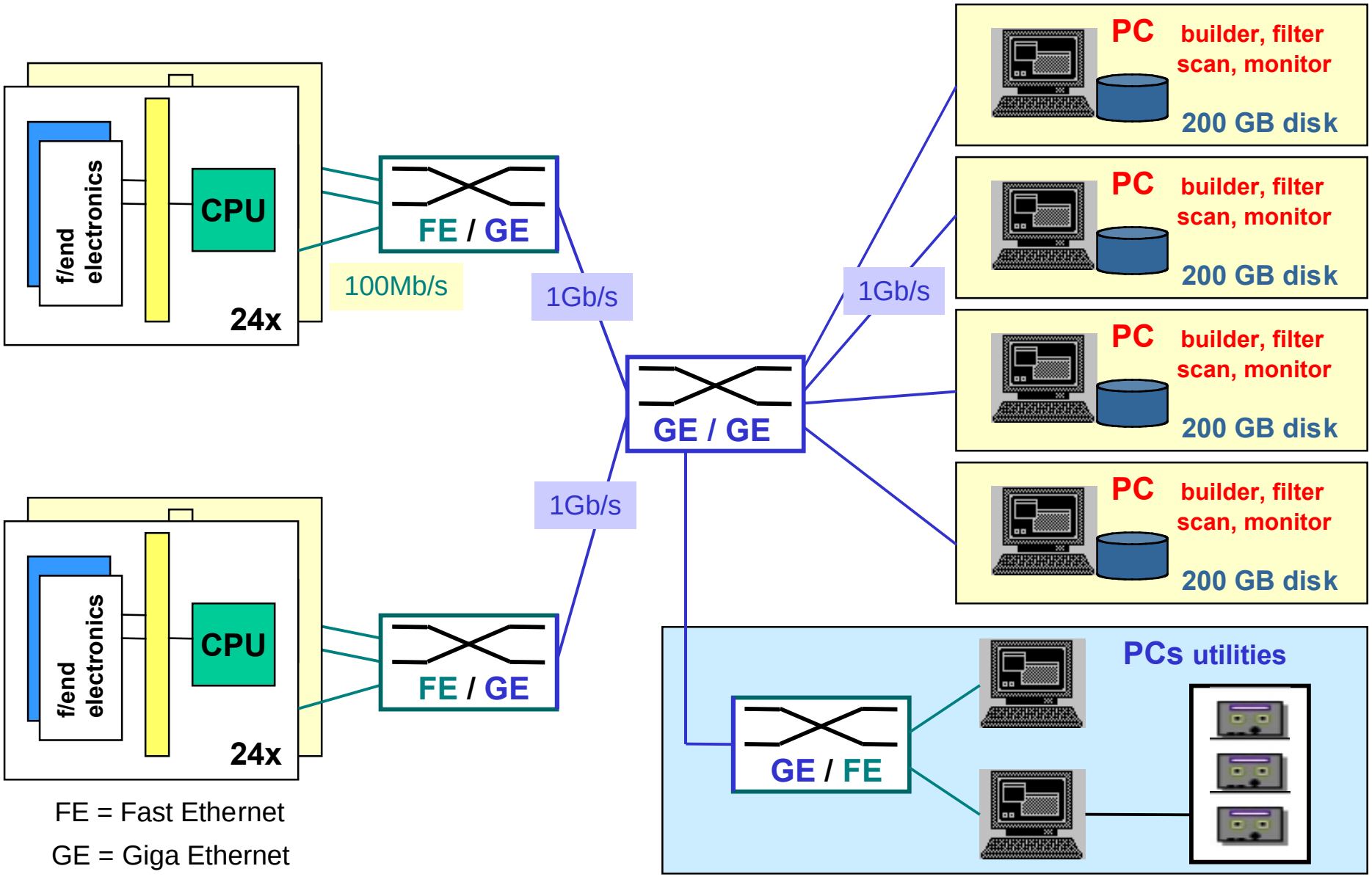
Total event size 111 MB/chamber

Trigger system

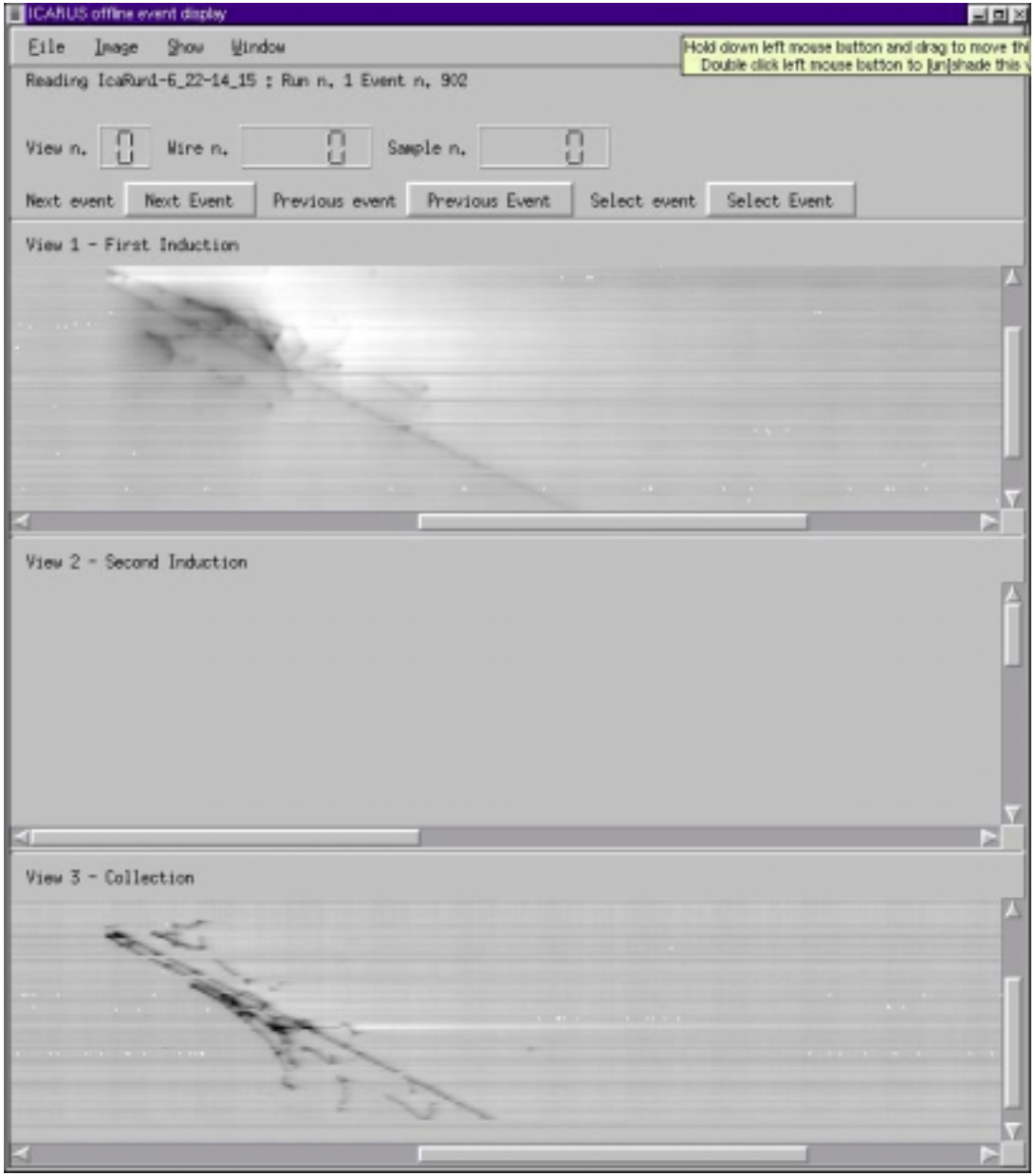
- Despite the detector is self-triggerable, for the first run of T600 in Pavia we have foreseen a DAQ system able to acquire full drift events and to apply some preliminary filtering on the data

- The trigger will be a combination of signals coming from:
  - **Scintillators**, located outside the detector, for long tracks and localized muons detection
  - **PMTs**, located inside the detector, useful to test scintillation light trigger efficiency. The chosen PMTs (8" EMI, with special treated bialkali photocathode to work at cryogenic temperature) have a wavelength shifter (TPG = TetraPhenylButadiene) deposited on the glass window in order to shift the VUV wavelength of LAr (λ=128 nm) to visible light
  - **Daedalus** chips, to test and tune the standalone triggering procedures

DAQ system layout (T600 semi-module readout)

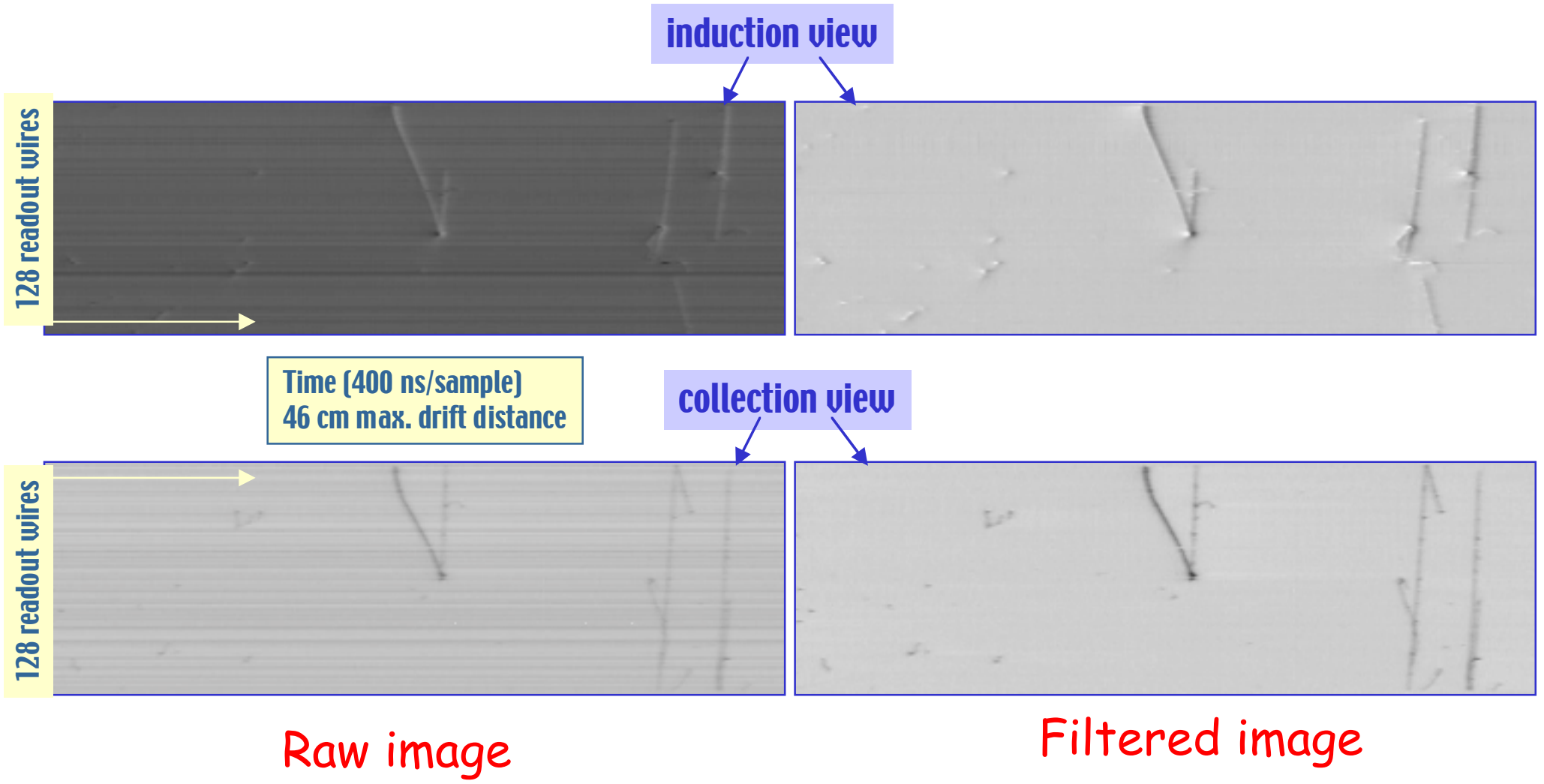


Scanning offline display "*Qscan*"

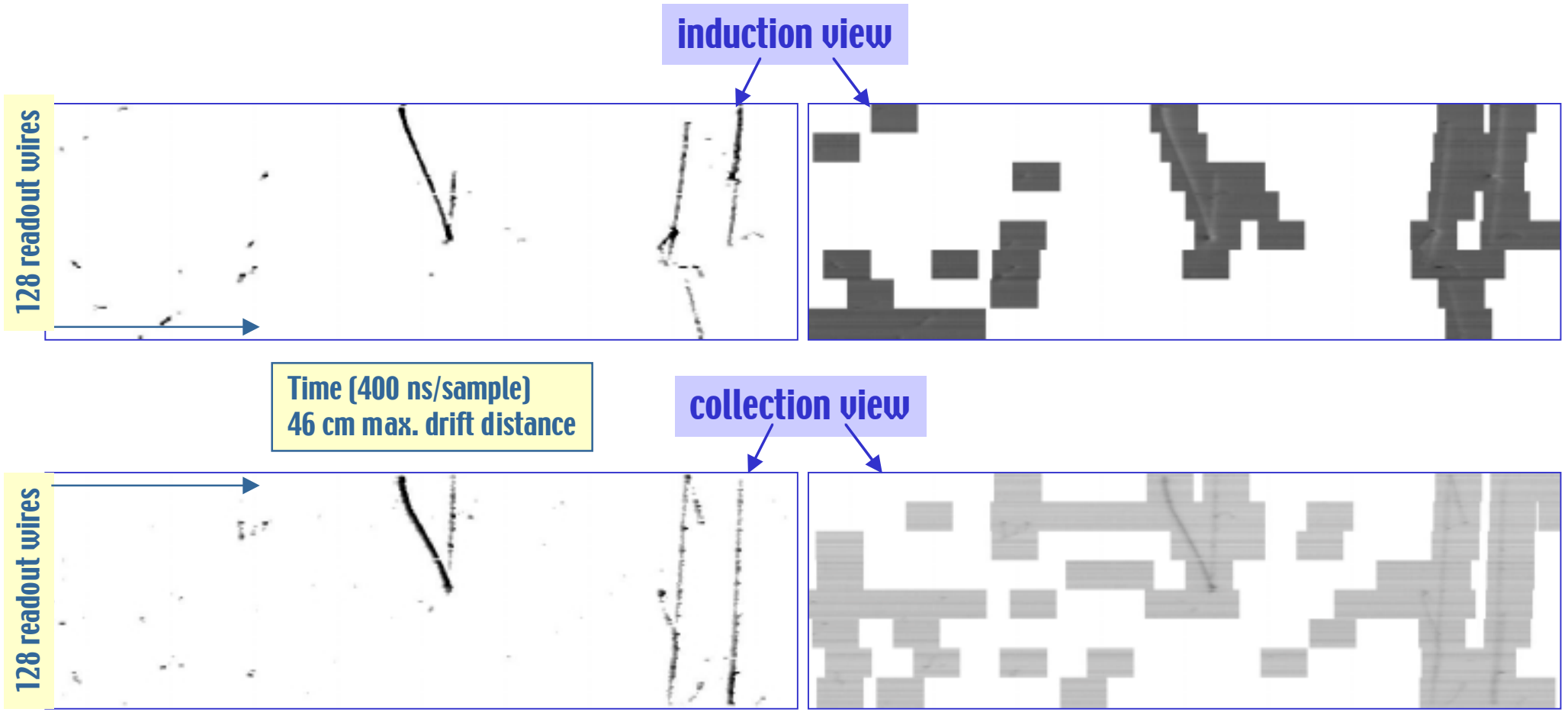


- Runs under Linux, uses Qt C++ libraries
- Display **all ICARUS prototypes** events
- Show **different images** of the same event (raw data, filtered view, simulation of new readout electronics on full drift events)
- Several **tools** (zoom, single wire signal, wires 3D view, test of Daedalus efficiency, saving of images in many graphic formats, event selection, RMS and FFT calculation on wires)

Example: 50L event (I)



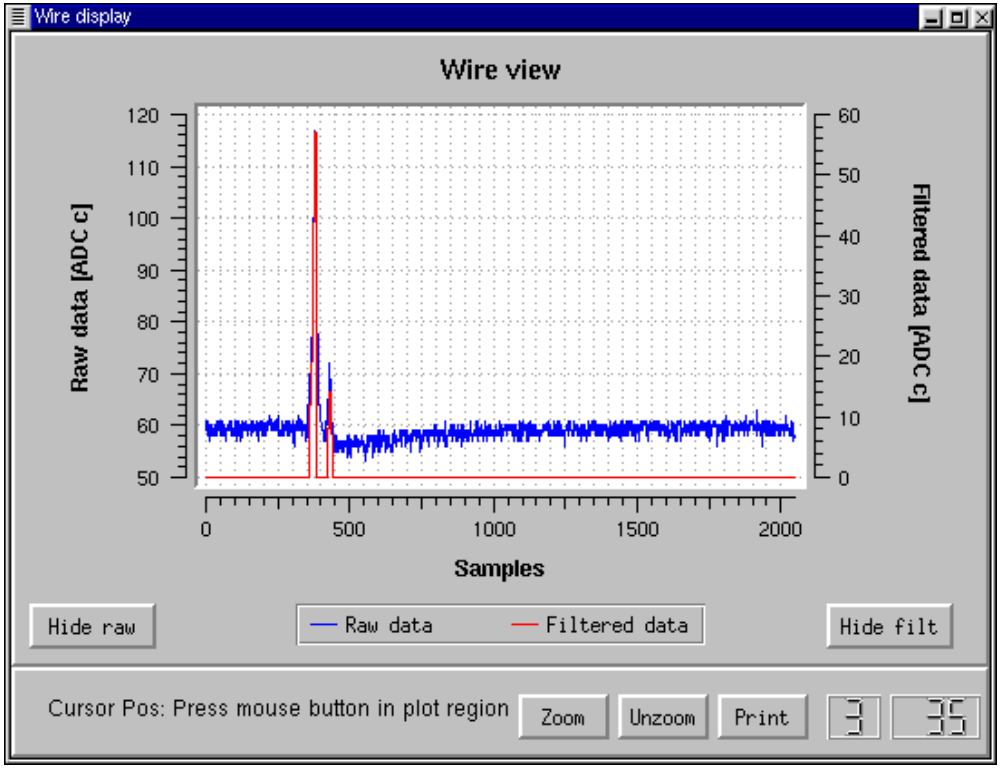
Example: 50L event (II)



Daedalus filtered image

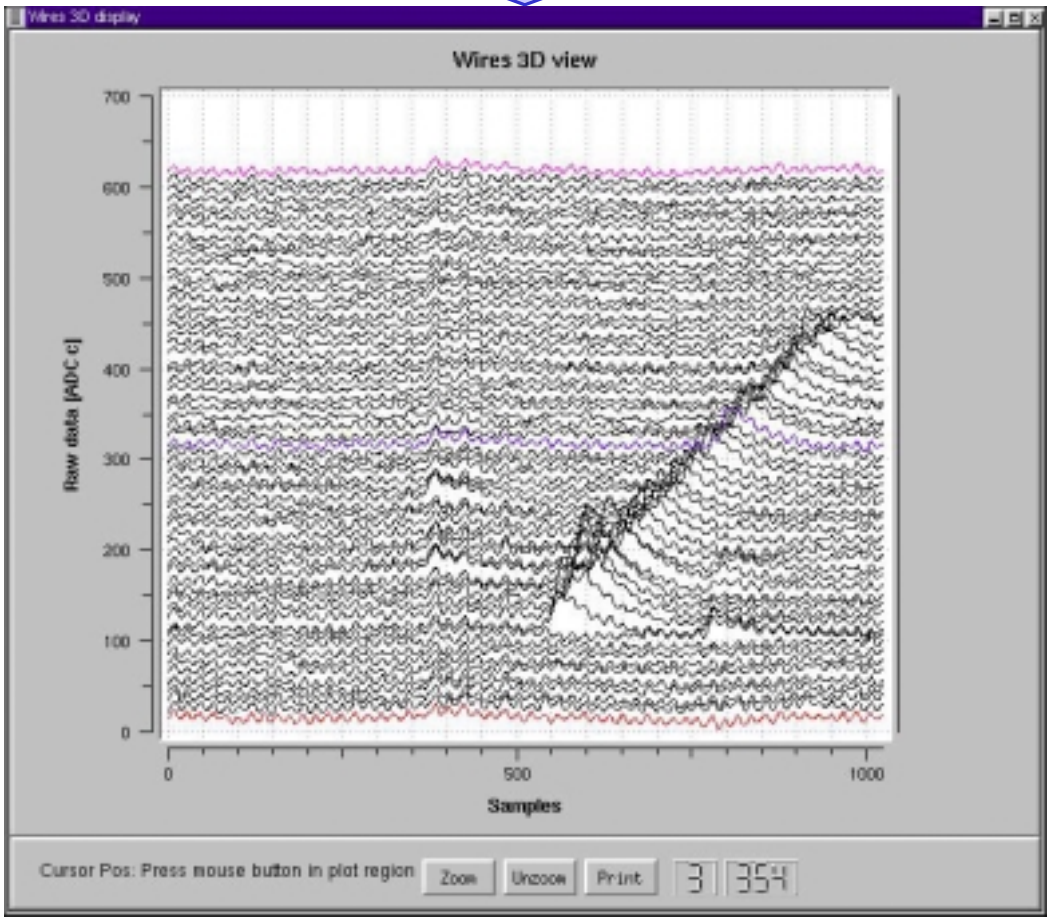
Zero skipping simulation image

Wires displays

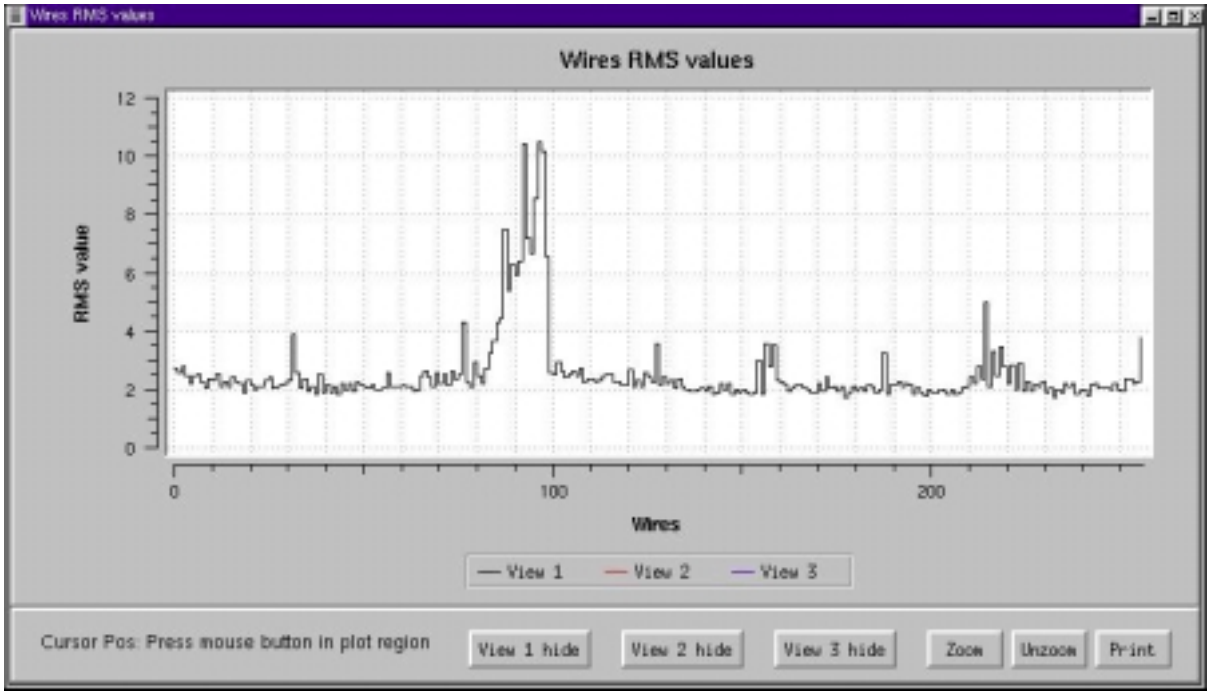


- Single wire display
- Zoom/unzoom on wire
- Display view and wire coordinates

- 3D wires display
- Highlights tracks
- Easy to see correlated noise (e.g. HV ripple)



Wires RMS and FFT displays

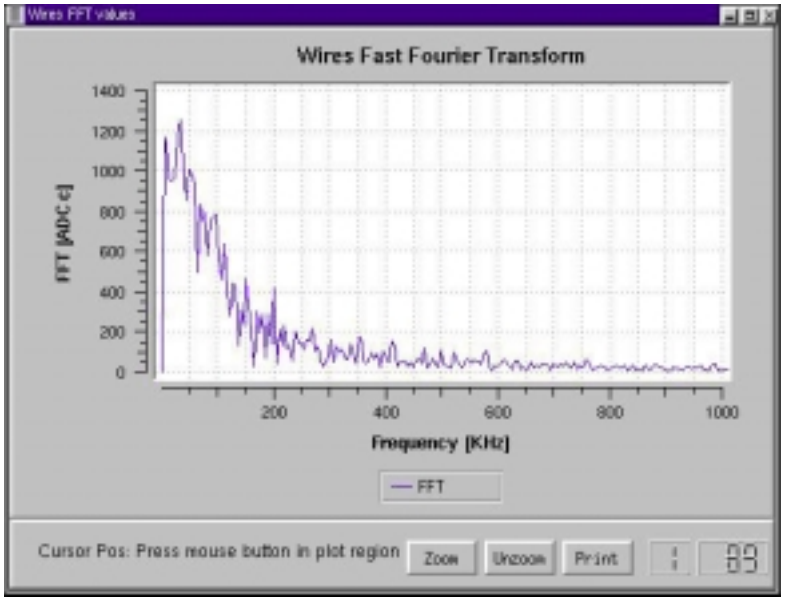


FFT display:

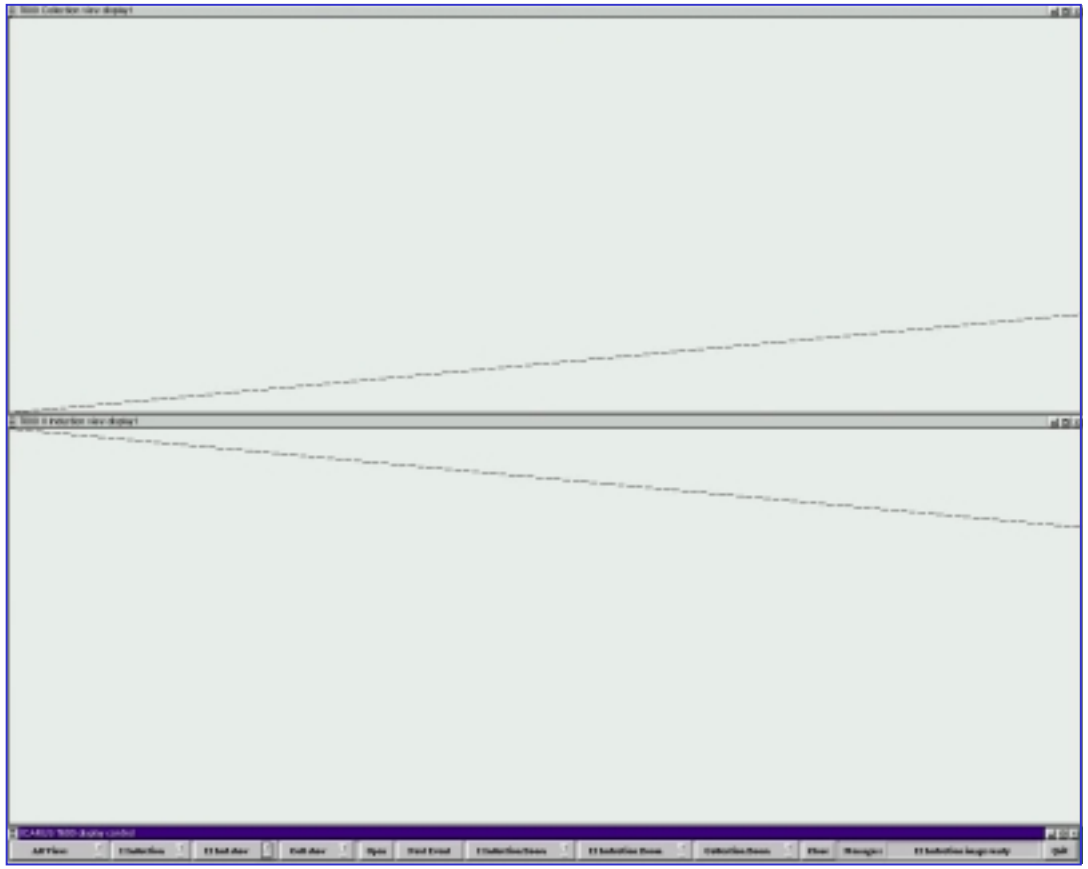
- Information on noise components

RMS display:

- Useful for wires test and noise measurements
- Easy to localize signal



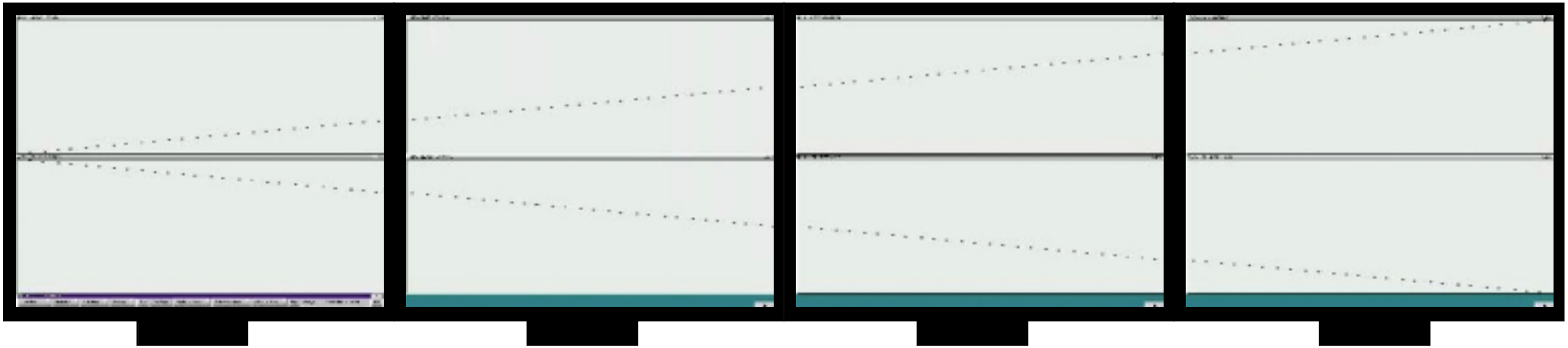
T600 online display "Qdisp"



- Runs under Linux, uses Qt C++ libraries
- Common routines with Qscan
- 4 screens to display two main views (± 60° wires), only one control bar
- Testing MultiHead solutions: Matrox G400 graphic card (Dual Head display support), XFree86 4.0.1 (Xinerama configuration), max. resolution per screen 1280x1024 ⇒ total resolution

5120 x 1024

Online display example



- 4 screens full image (5727 wires x 4096 samples ⇒ 18 m x 1.5 m)
- Images are view from top of the T600 detector
- Possibility to use new high resolution 42" Plasma Displays for better performances
- Possibility to zoom image until detector resolution

Conclusions

- T600 construction is advanced:
  - Two wires planes already positioned on the two chambers
  - Installation of electronics racks will start in a few days
  - Online and offline DAQ programs (event filtering algorithms, event display programs, slow control system, etc..) are being extensively tested on simulated data and on data coming from the 10 m^3 prototype. The control room, that contains only PCs, communications and storage units, is going to be setup starting from next week
- Startup procedures for the operation of the T600 (vacuum pumping) are expected to start at the beginning of November

Will the 18 m long track be our Christmas gift?