The ICARUS T600 LAr TPC

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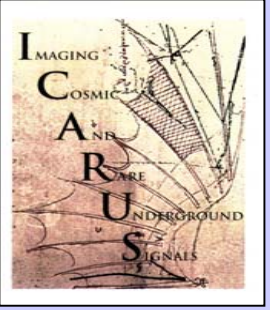
ETH Zurich

ICARUS collaboration



The ICARUS Collaboration

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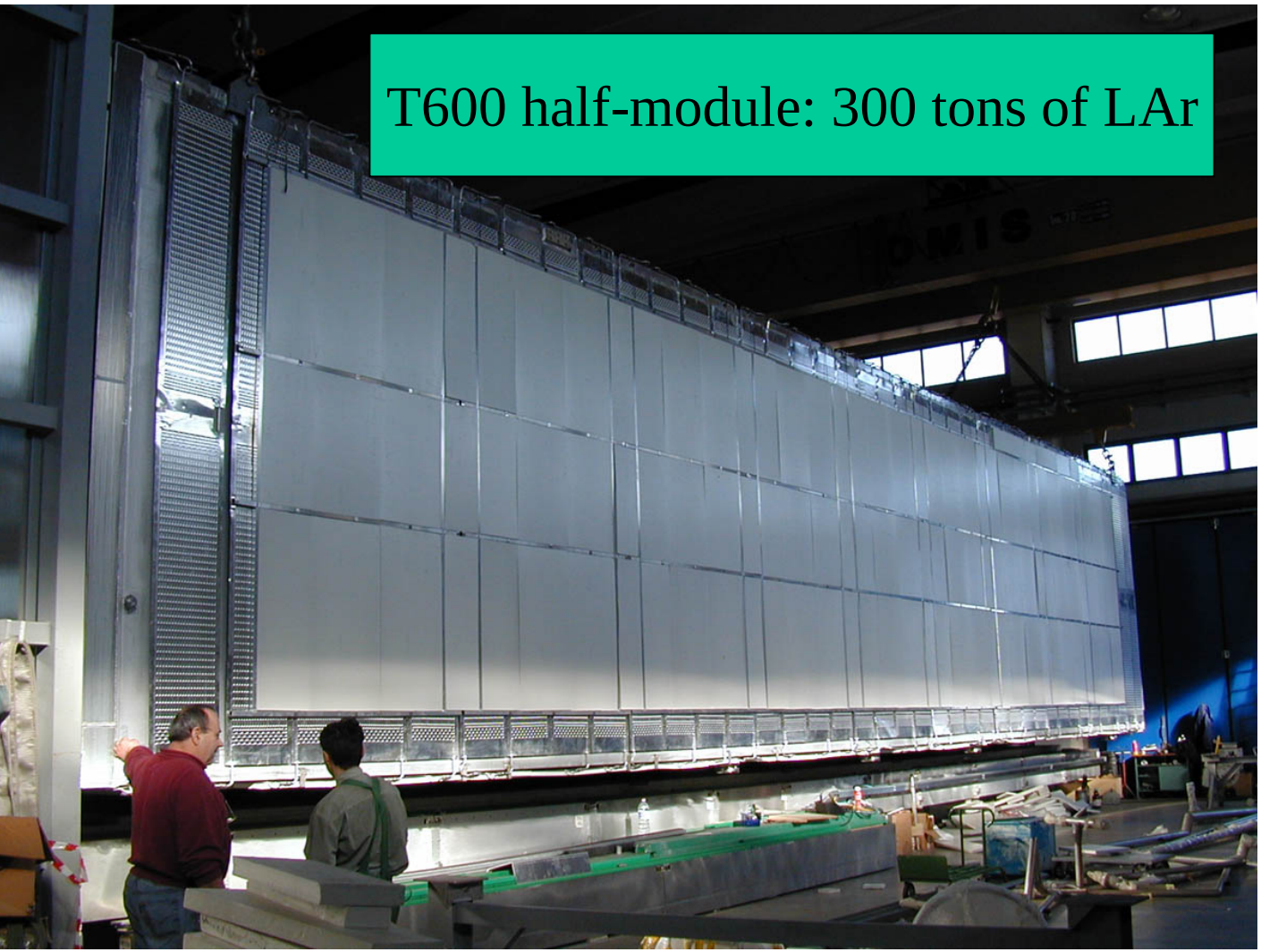
ITALY: L'Aquila, LNF, LNGS, Milano, Napoli, Padova, Pavia, Pisa, CNR Torino, Politec. Milano.
SWITZERLAND: ETHZ Zürich.
CHINA: Academia Sinica Beijing.
POLAND: Univ. of Silesia Katowice, Univ. of Mining and Metallurgy Krakow, Inst. of Nucl. Phys. Krakow, Jagellonian Univ. Krakow, Univ. of Technology Krakow, A.Soltan Inst. for Nucl. Studies Warszawa, Warsaw Univ., Wroclaw Univ.
USA: UCLA Los Angeles.
SPAIN: Univ. of Granada.

Modular design detector



The T600 module contains 2 T300 half-modules with a common thermal insulation.

The LAr drift chamber (T600 half-module)

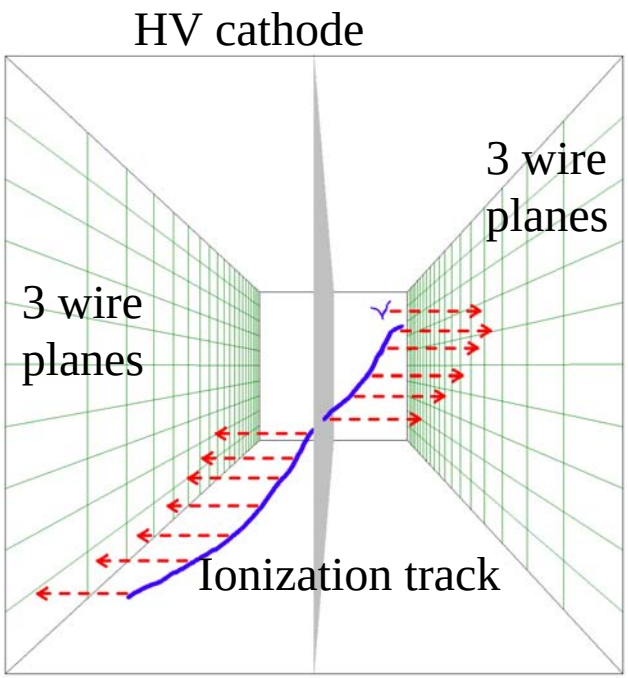
Drift field: 500 V/cm

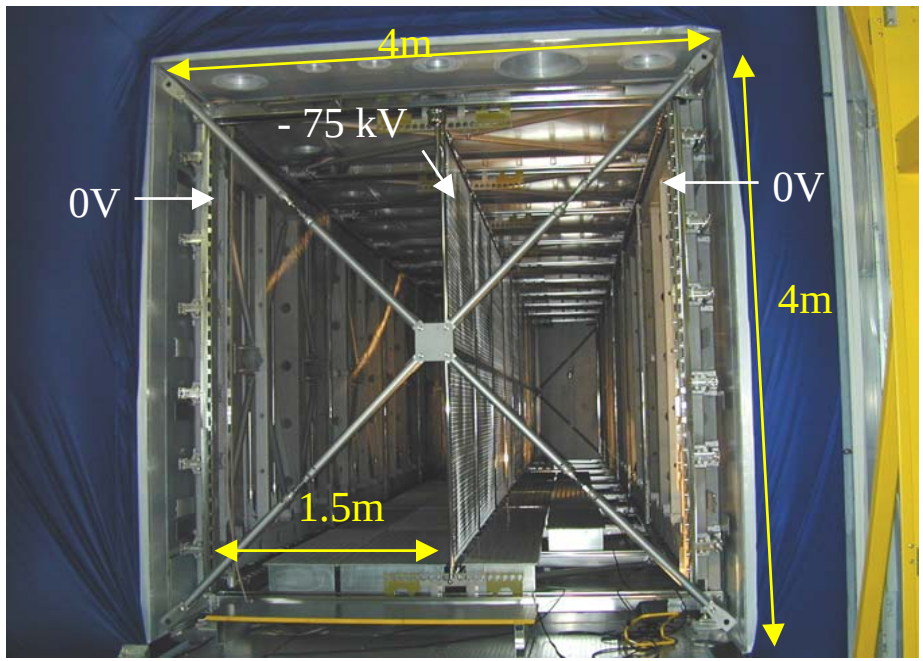
Drift velocity: 1.5 mm/μs

Maximal drift time: 1 ms

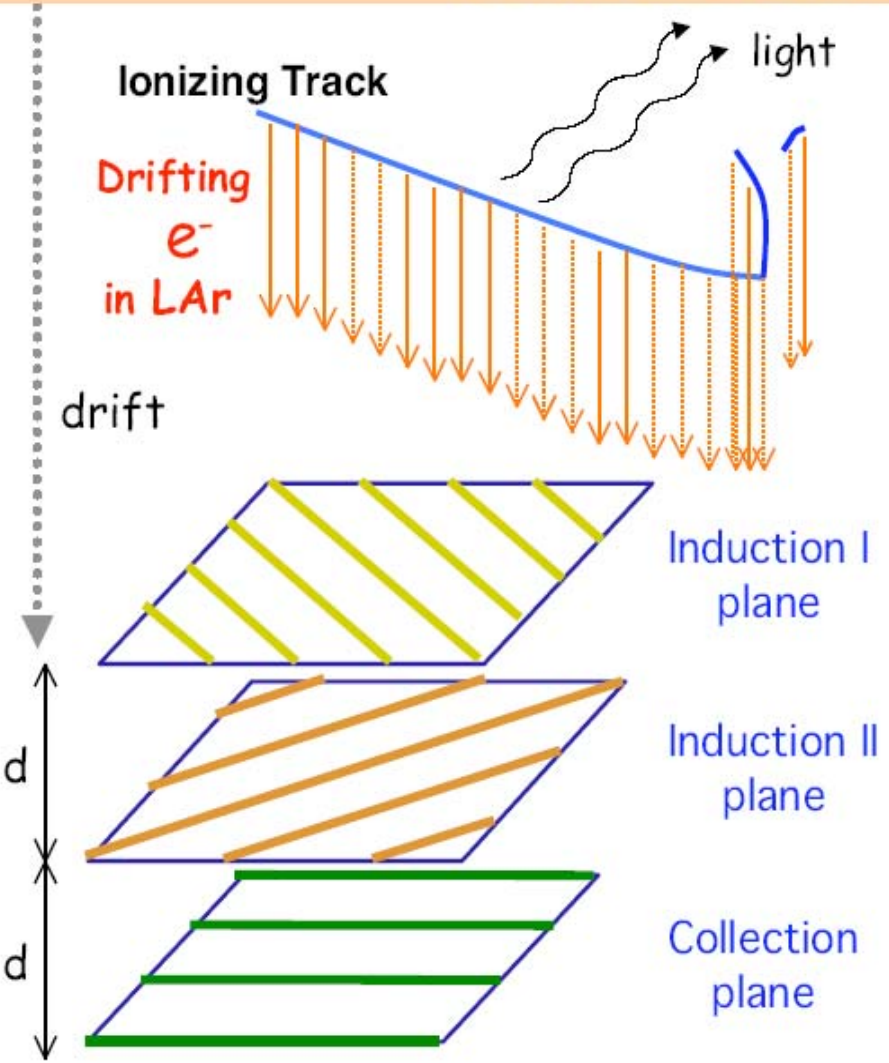
Electron lifetime: > 1 ms

LAr purity: < 0.1 ppb (O_2 eqiv.)





Detection Principle



Density 1.4 g/cm^3
Radiation length 14 cm
Interaction length 80 cm
dE/dx(mip) = 2.1 MeV/cm
T=88K @ 1 bar

✓ About 12000 electron-ion pairs per mm of mip track are produced. About 40% recombine in our nominal drift field. When the left-over charges drift, they induce a signal on the wires.

✓ Since the mobility of electrons is much higher than that of ions, only electrons contribute to the observed signal.

✓ Electrons can drift over macroscopic distances if argon very pure (e.g. ≈ meter drift requires purity of <1 in 10^{10} atoms)

✓ Multiple non-destructing readout wire plans can be assembled for multi-views.

The LAr drift chamber

3 wire planes (no charge amplification):

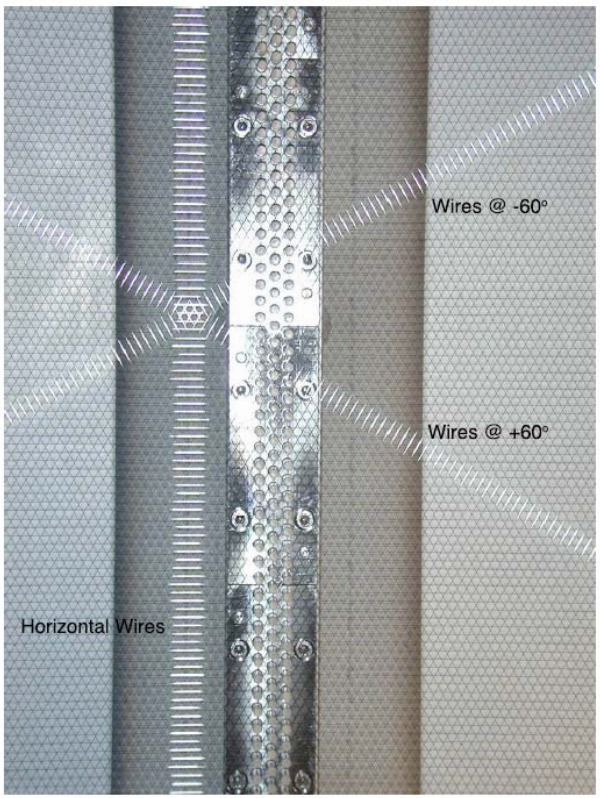
1.Plane: Induction 1, horizontal wires (9m)

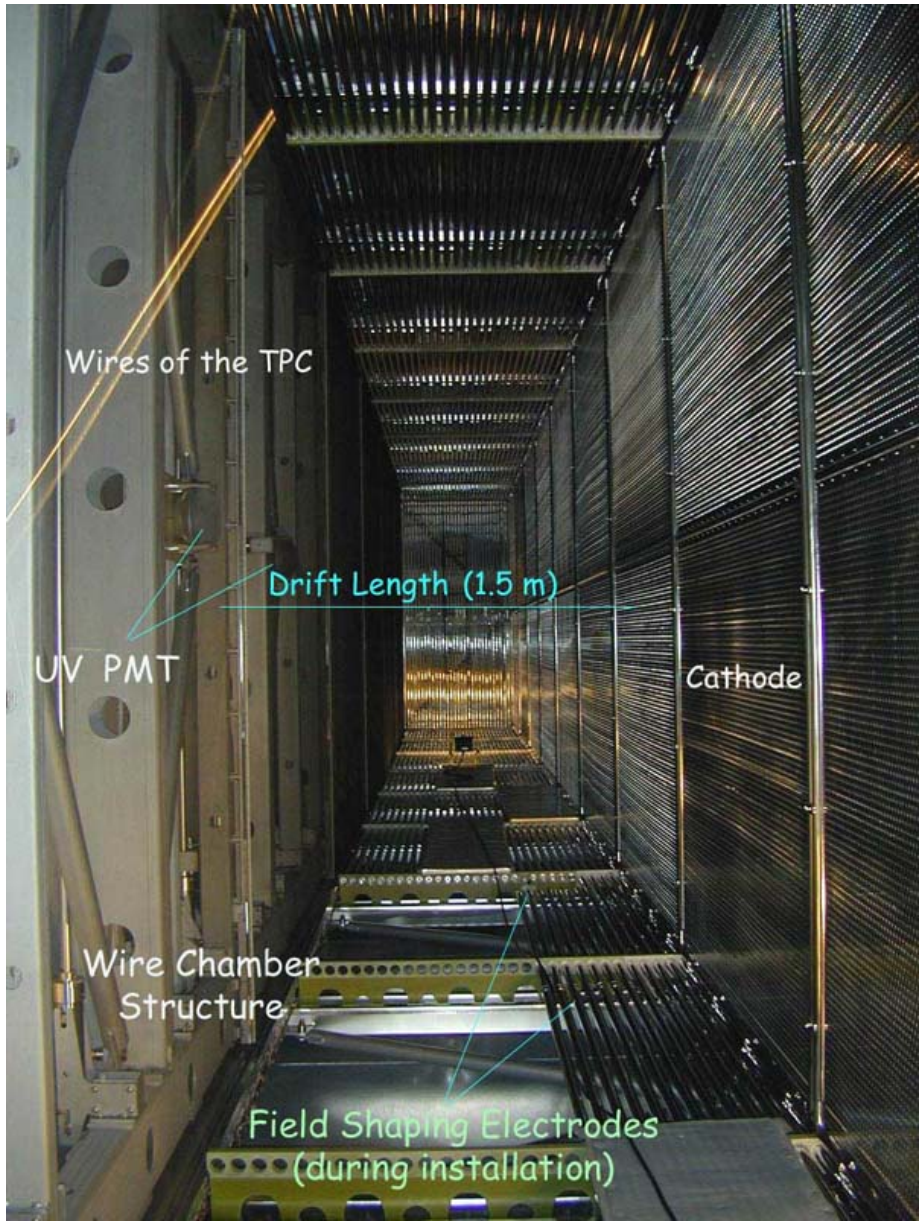
2.Plane: Induction 2, $+60^0$

3.Plane: Collection, -60^0

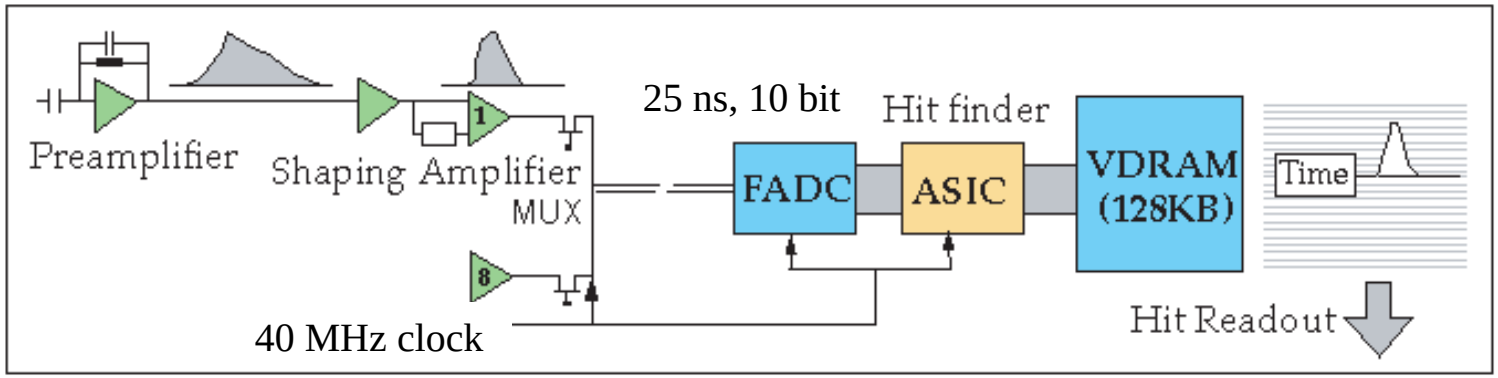
Distance between planes: 3 mm.

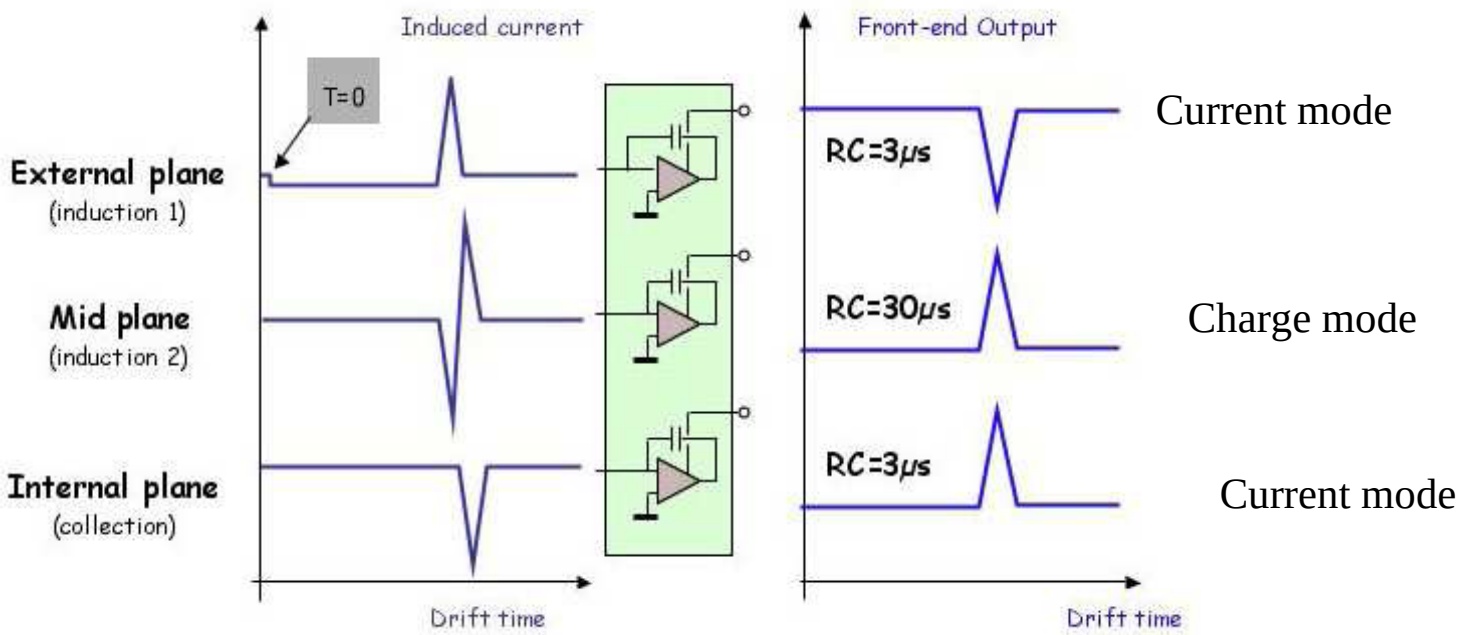
Wire pitch: 3 mm.





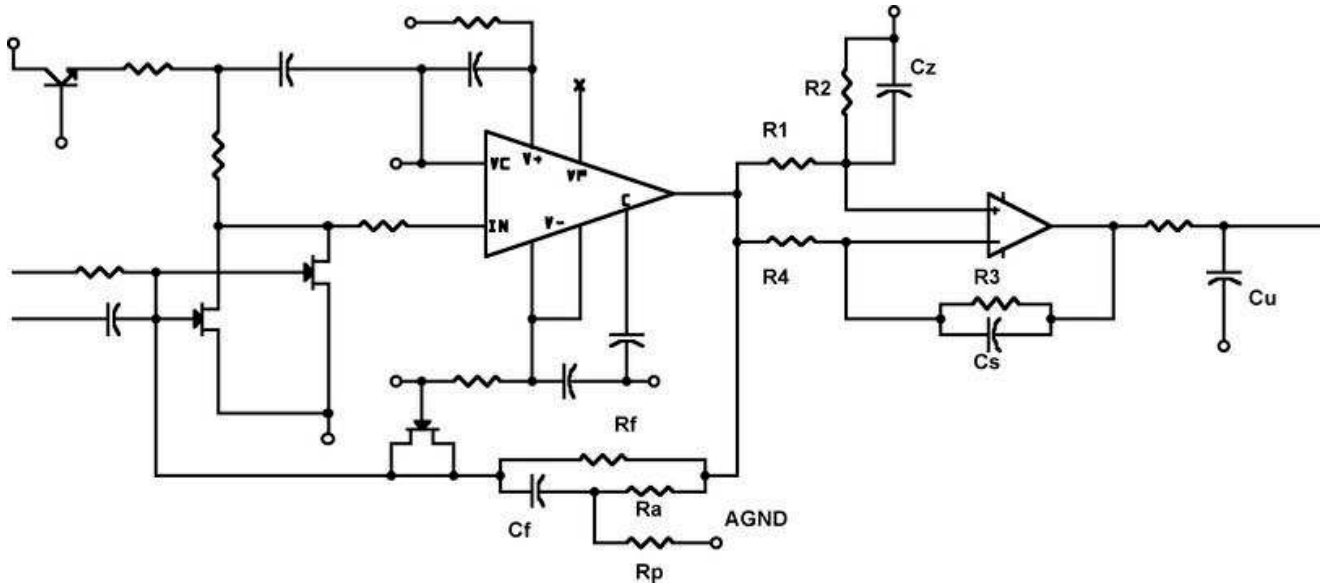
Readout electronics





A wire signal is sampled every 400 ns (about 0.5 mm drift)

Preamp



Signal of a minimum ionizing particle: 2 fC/wire (10-12 ADC counts).

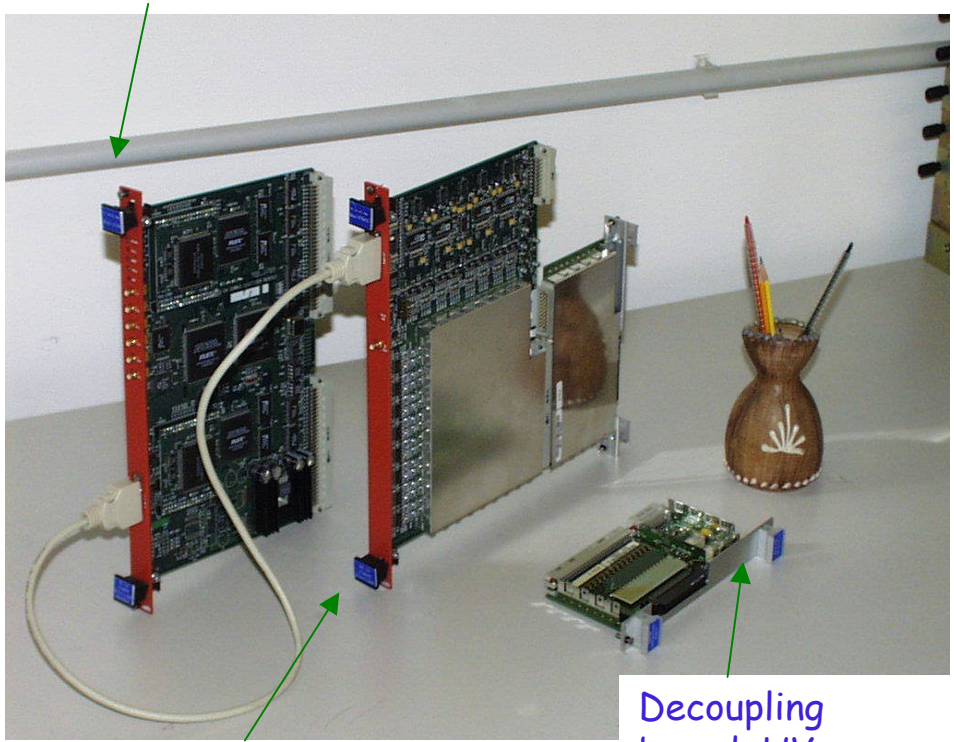
Electronic Noise: 1.2 ADC counts

No amplification at the wires!

ICARUS read-out chain (INFN Padova)

Signal UHV feed-through:
576 channels (18 connectors x 32)
+ HV wire biasing

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



CAEN-V791 board: 32 pre-amplifiers + 4 multiplexers (8:1) + 4 FADC's (10 bits - 40 MHz: 2.5 M samples/s/wire)

Decoupling board: HV distribution and signal input

commercially available

Scintillation light readout (INFN Pavia): t_0 of drift time

- Commercial PMT with large area
  - ↙Glass-window
- Scintillation VUV λ = 128 nm
  - ↙Wavelength-shifter (TPB)
- Immersed T(LAr) = 87 K

PMT's mounted behind wire planes

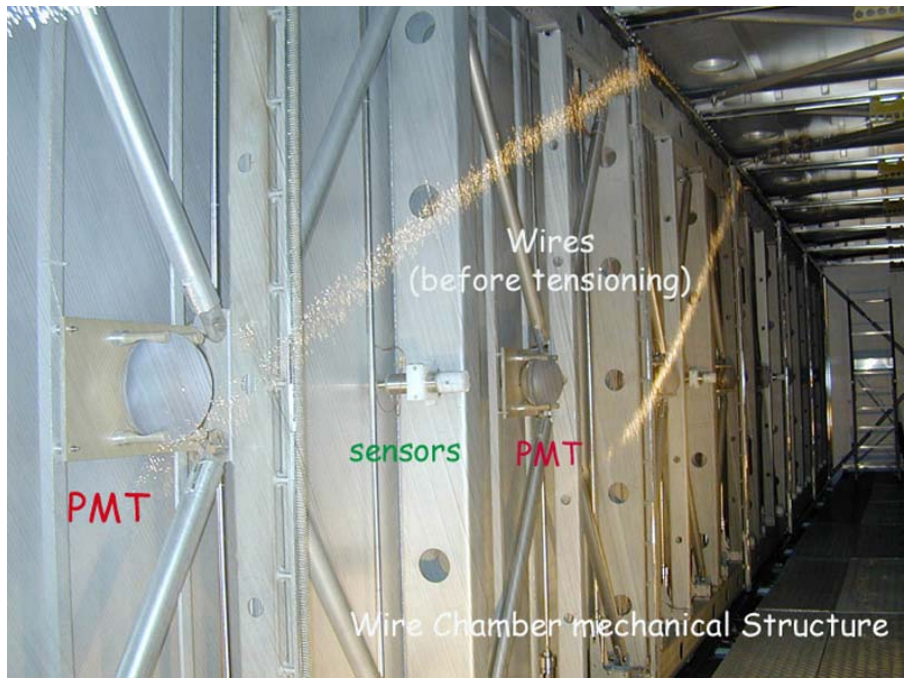
Electron Tubes 9357FLA

8" PMT (bialkali with Pt deposit)

G = 1 x 10^7 @ ~1400 V

peak Q.E. (400-420 nm) ~ 18 % (≈10% cold)

T_{rise} ~ 5 ns, FWHM ~ 8 ns



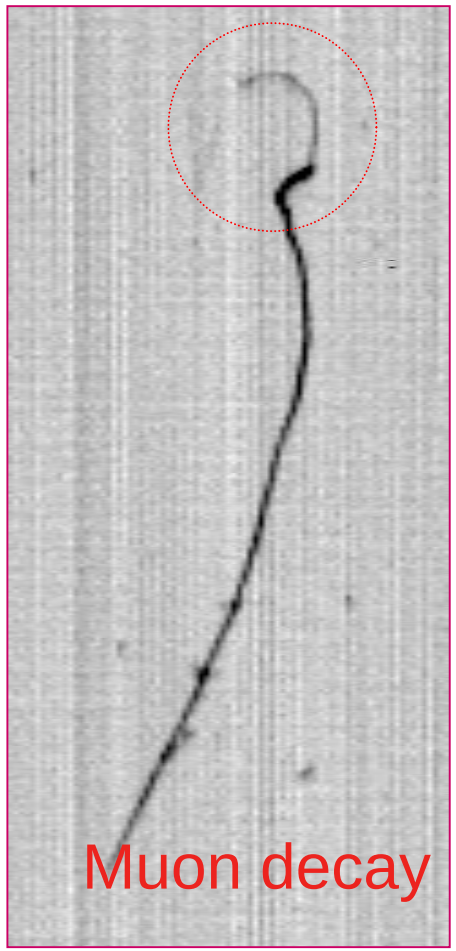
Test run in Pavia summer 2001

100 days of data taking

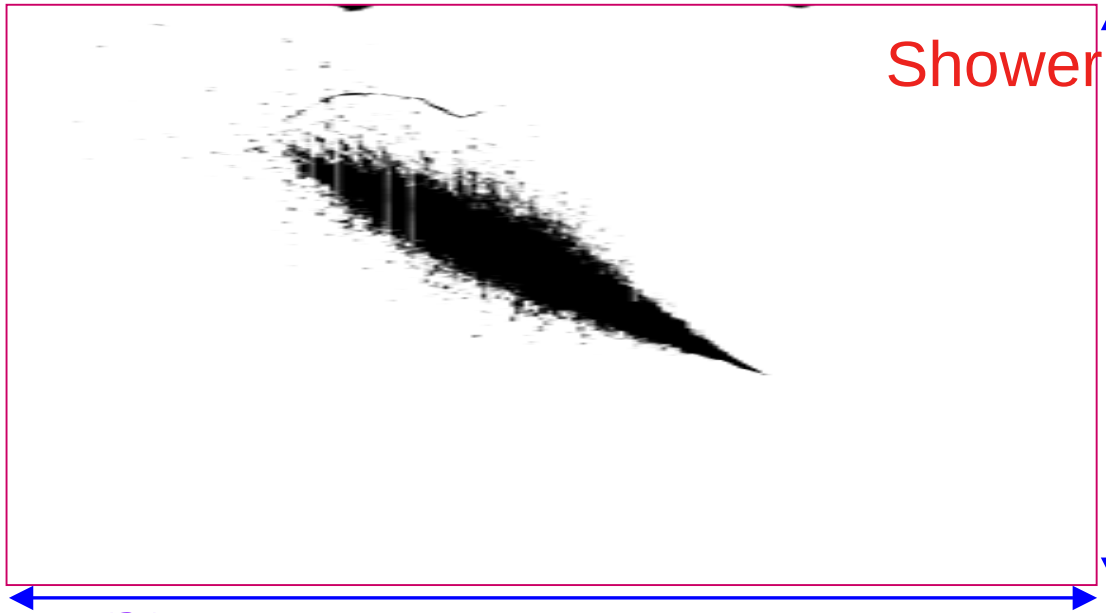
28’000 cosmic ray triggers

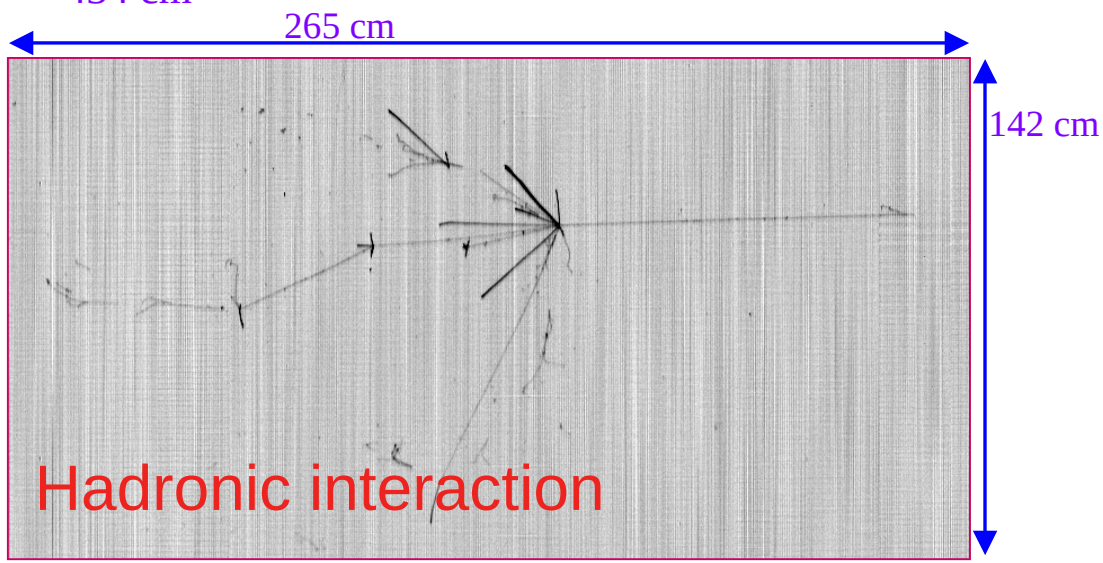
Visual scanning results (May 03)	
Shower	1000
Muon decay/stopping	3516
Hadron interaction	1183
V_0	65
Long track	972
Muon bremstrahlung	2179
Multiple showers	1155
Multiple muons	304

A few nice events from the test run



Run 960, Event 4 Collection Left





Run 308, Event 160 Collection Left

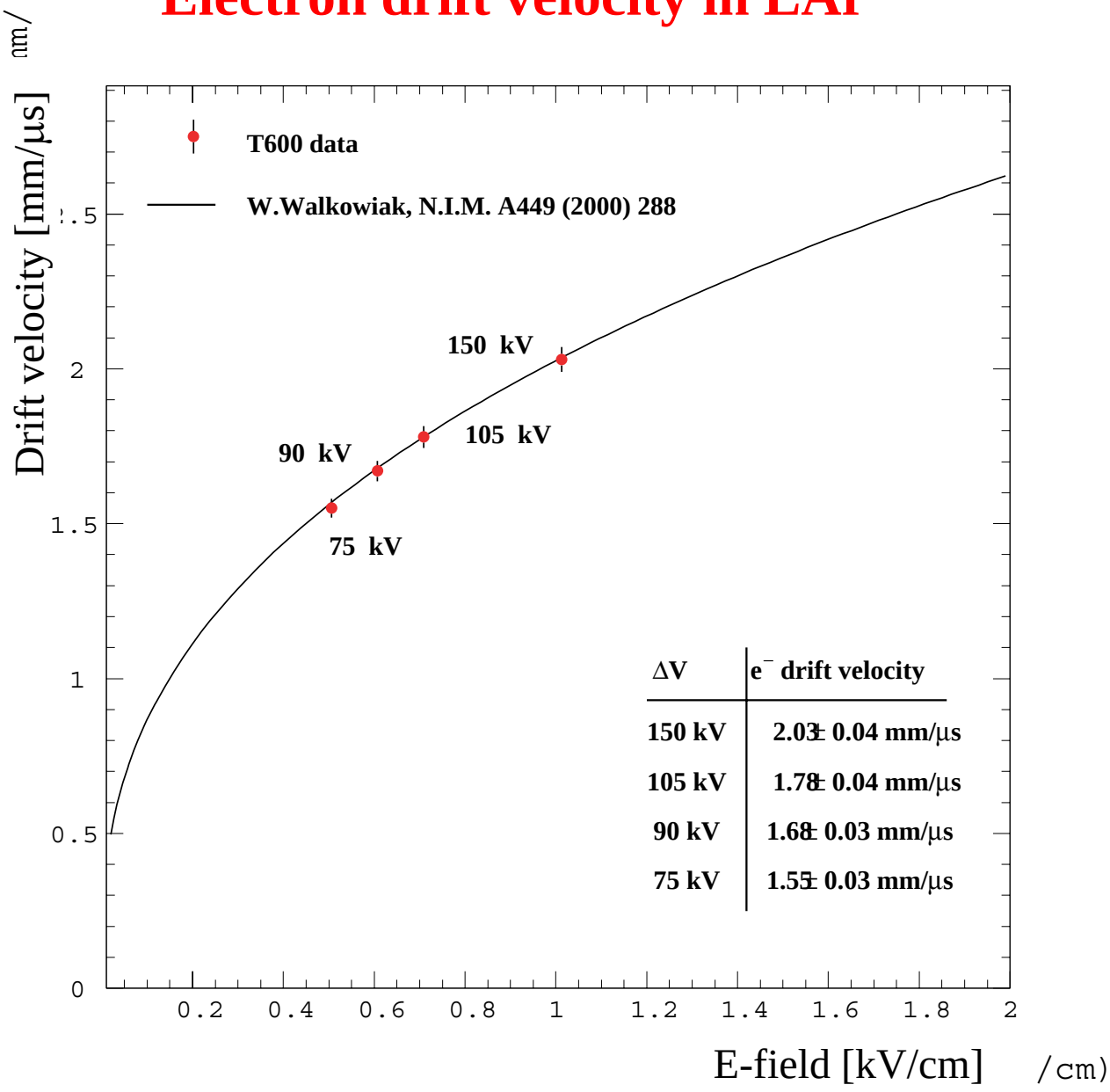
Important results from test run

- Measure drift velocity
- Measure lifetime of free electrons in LAr
- Determine recombination rate of the electrons
- Develop hit finding and 3D track reconstruction software

Full spatial and calorimetric reconstruction of events

Measure Michel spectrum from a sample of stopped muons.

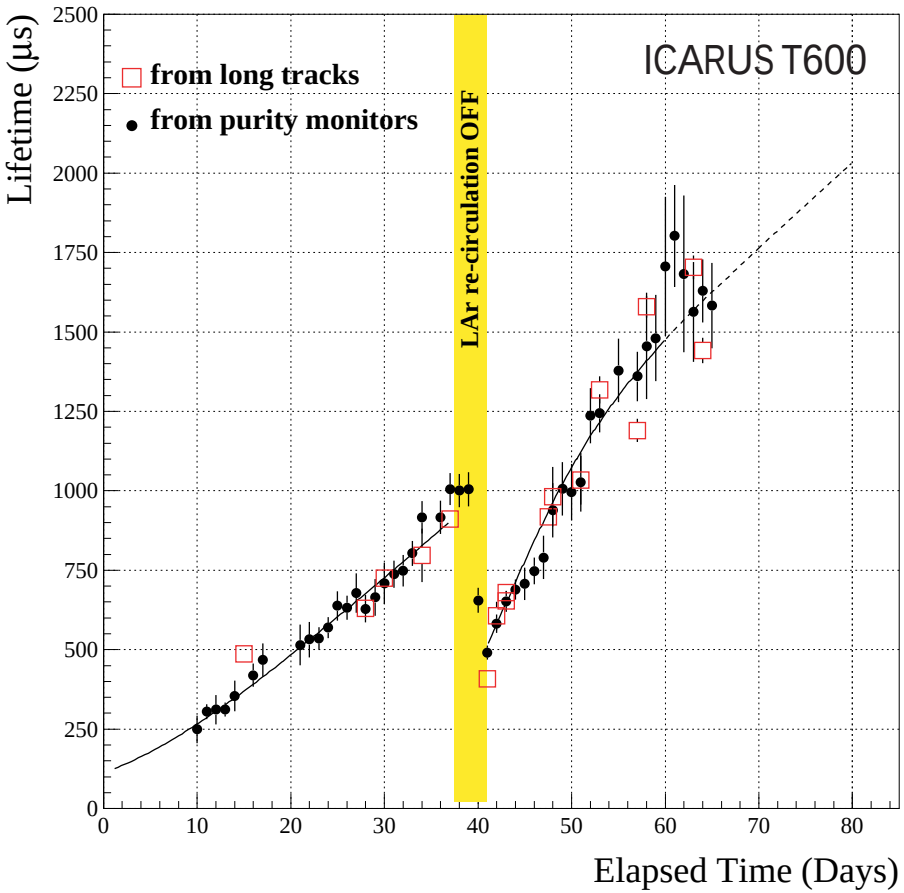
Electron drift velocity in LAr



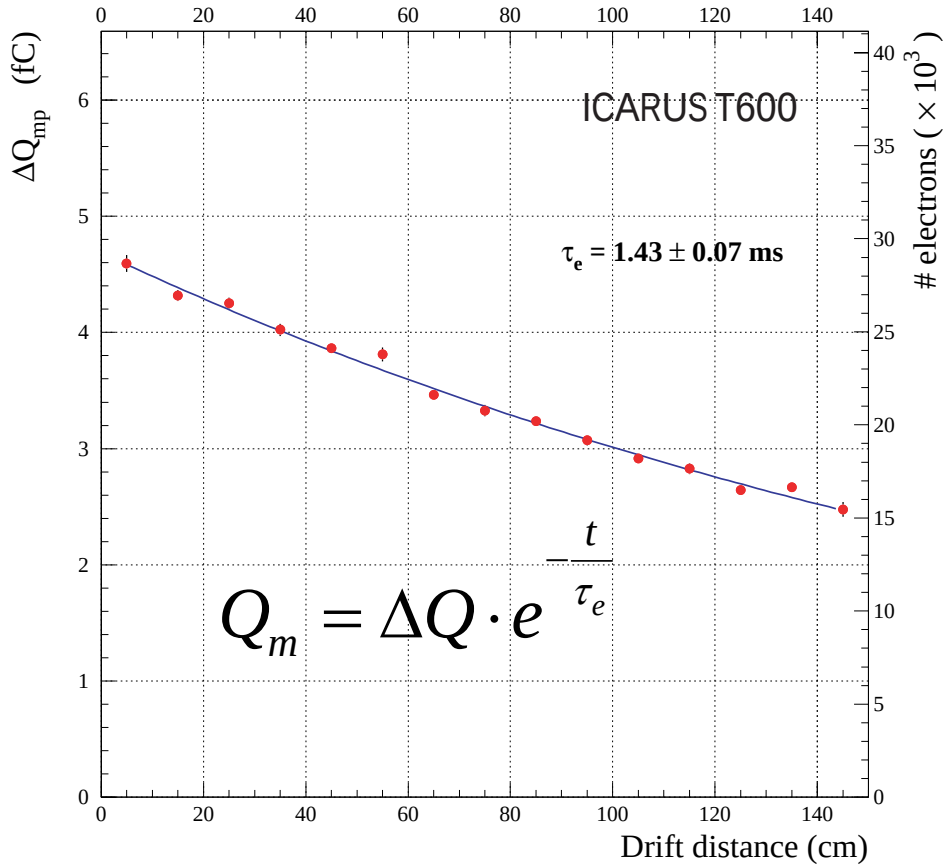
ΔV	e^- drift velocity
150 kV	2.03 ± 0.04 mm/μs
105 kV	1.78 ± 0.04 mm/μs
90 kV	1.68 ± 0.03 mm/μs
75 kV	1.55 ± 0.03 mm/μs

Free electron lifetime in LAr

Measured lifetime



Collected charge

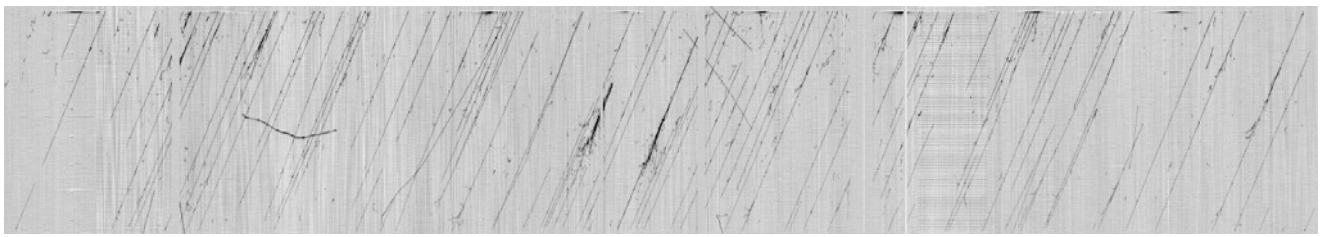


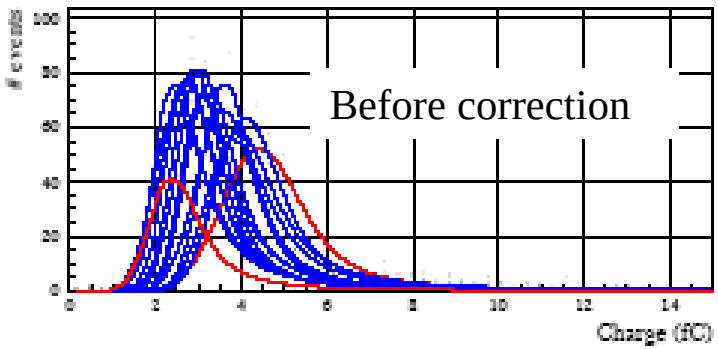
Calorimetry: dE/dx lifetime correction

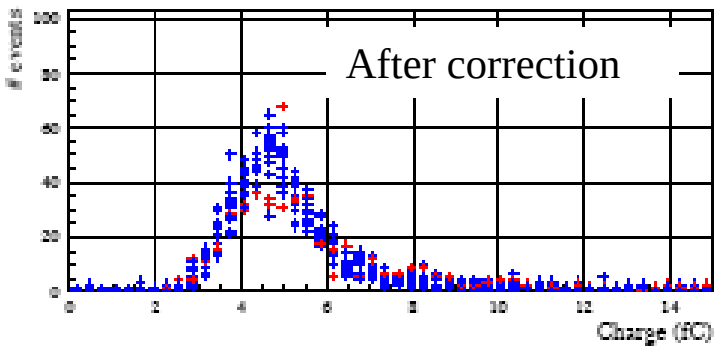
Multimuon event (collection view) : split parallel muon tracks crossing the chamber from the cathode to the wire planes into 15 bins in t_{drift}.

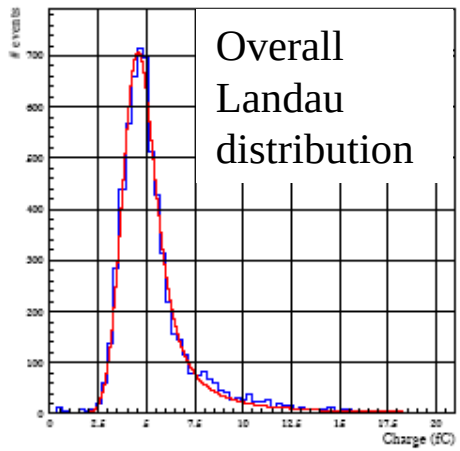
Wire no.

t_{drift}









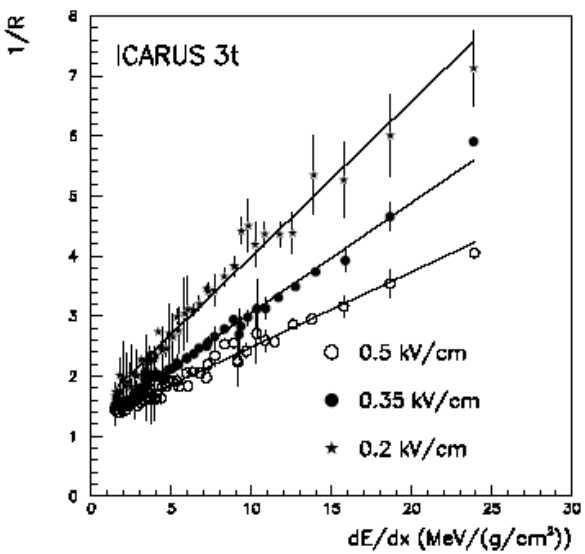
$$Q_m = Q_0 \cdot e^{-\frac{t}{\tau_e}}$$

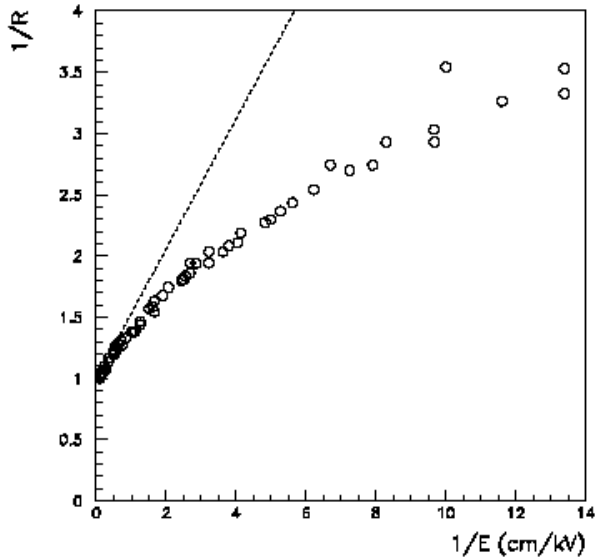
Calorimetry: Correction for electron-ion recombination in LAr

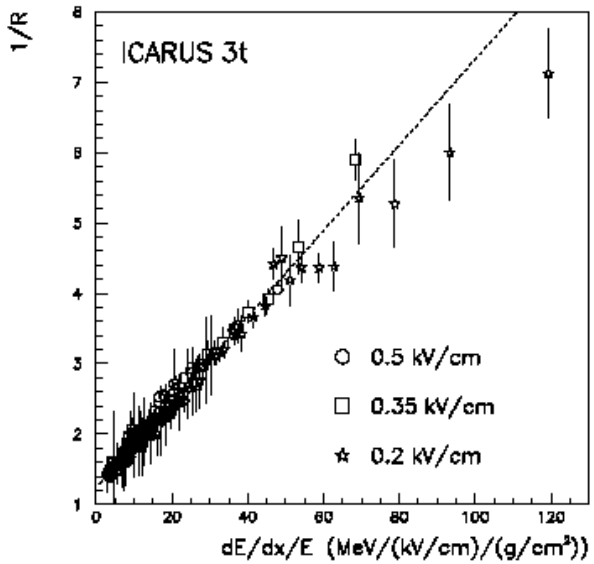
The recombination depends on the ionization density and the electric field.

Use a phenomenological Birks model:

$$Q = A\frac{Q_0}{1 + k\dfrac{dE/dx}{|\vec{E}|}} = R \cdot Q_0 \qquad \frac{1}{R} \propto \frac{dE/dx}{|\vec{E}|}$$

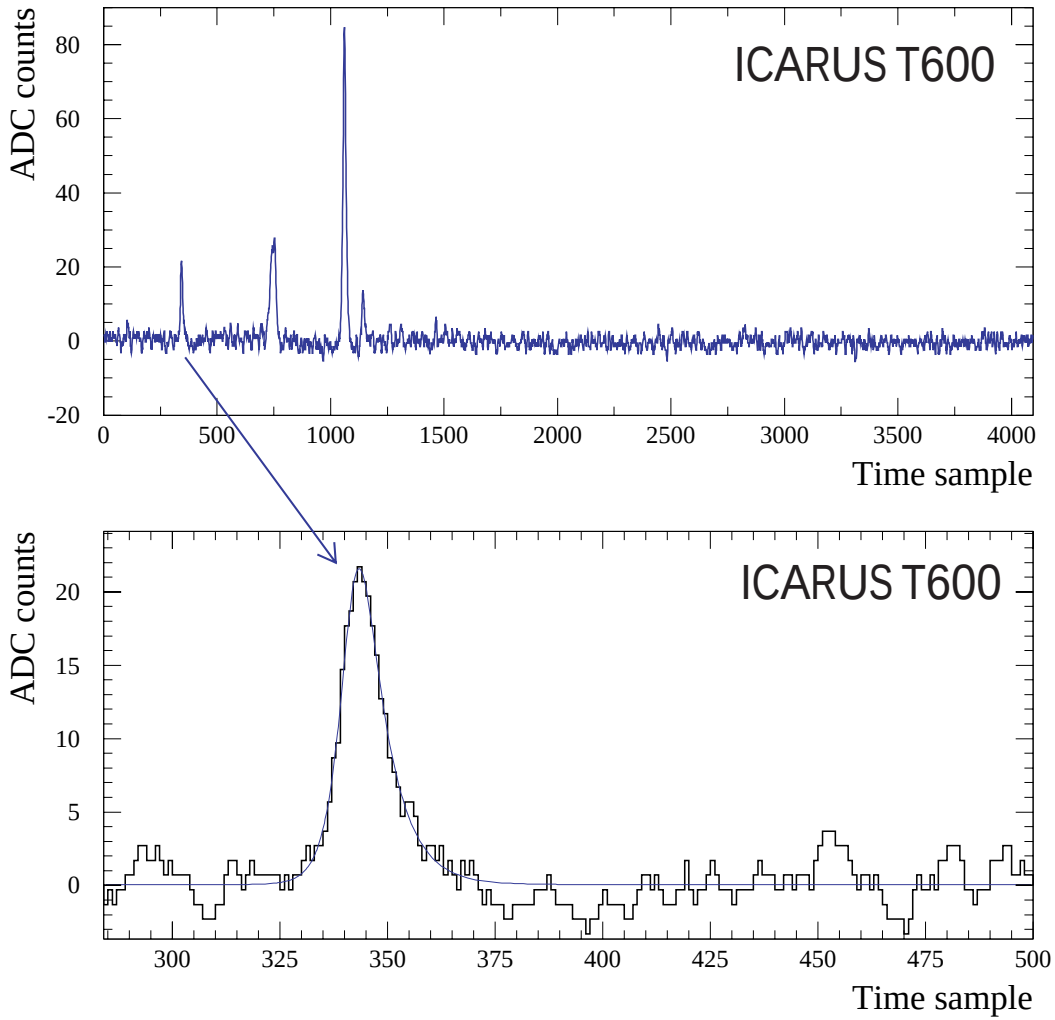






Track reconstruction: Fitting hits

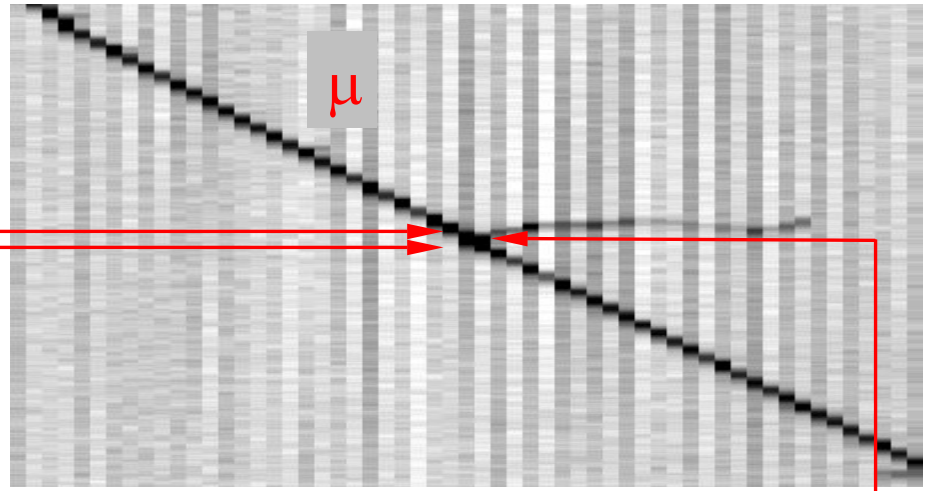
1. Fitting hits (collection plane)



Fit function:

$$f(t) = B + A\frac{e^{-\frac{t-t_0}{\tau_1}}}{1+e^{-\frac{t-t_0}{\tau_2}}}$$

δ-rays

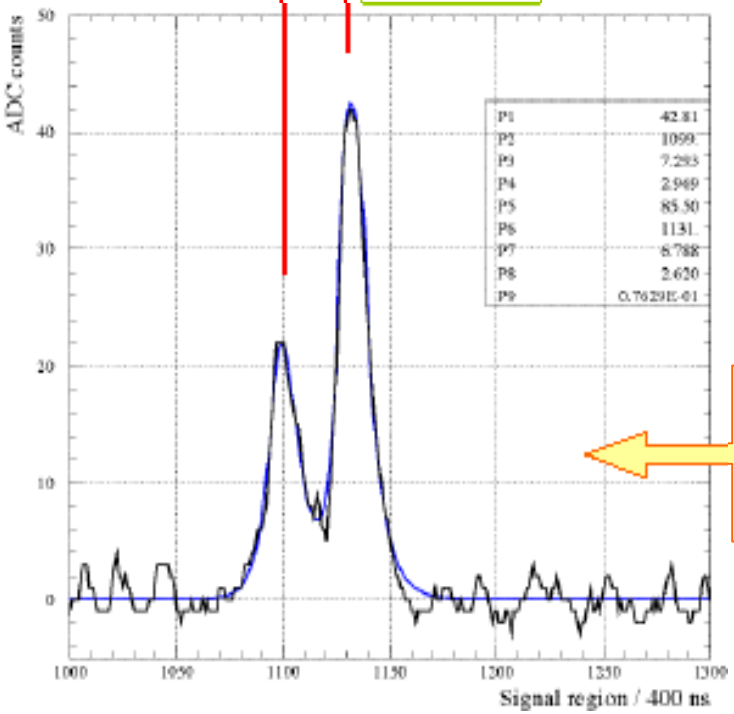


T600 Data

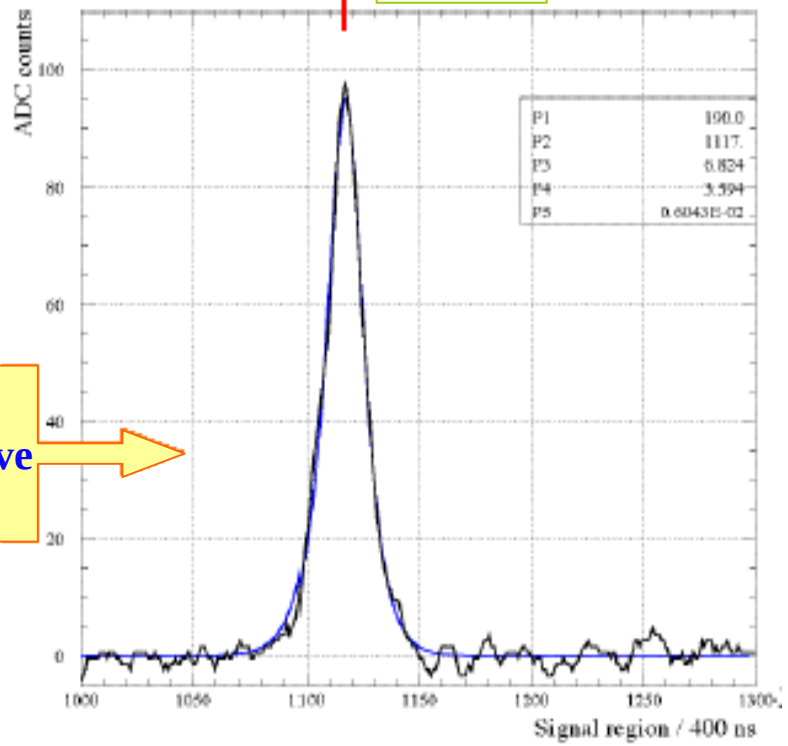
1.8 MeV

3.2 MeV

10 MeV

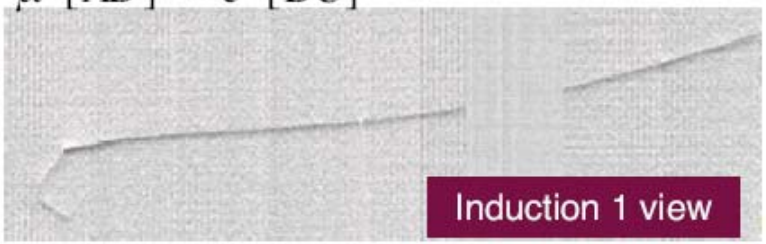


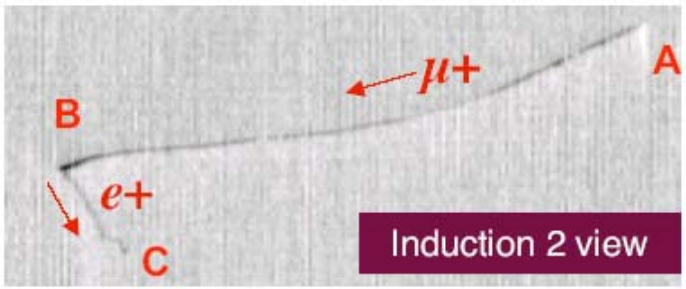
Two consecutive wires

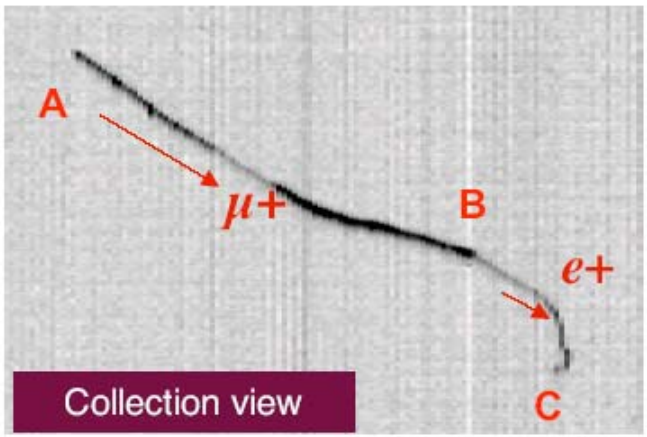


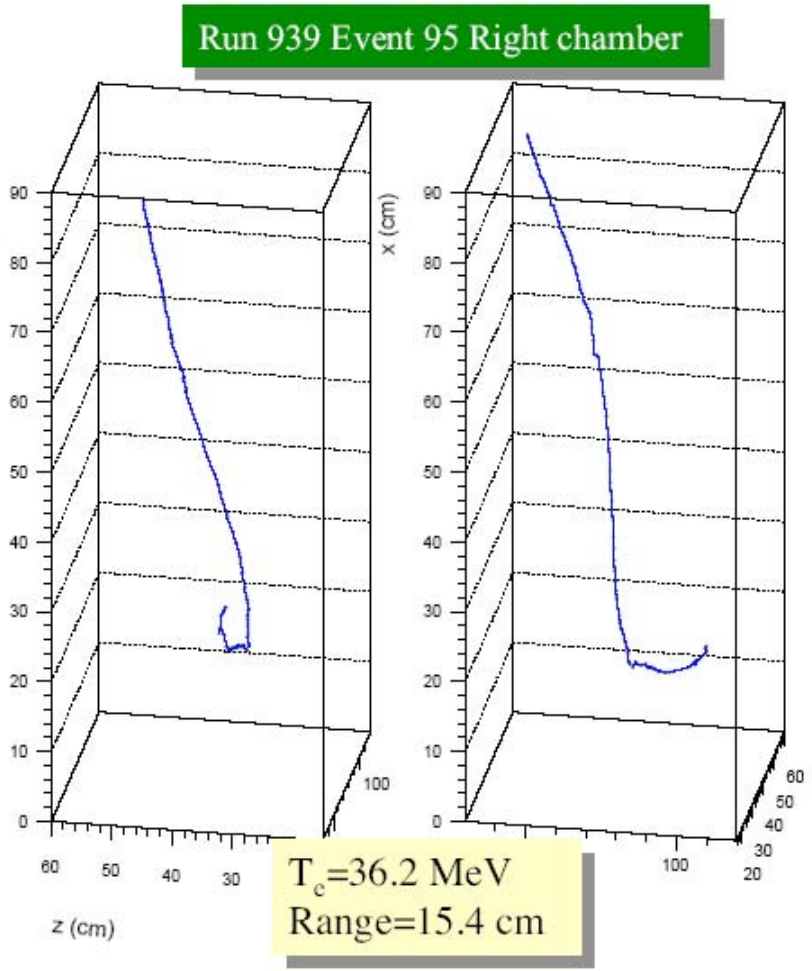
3D event reconstruction: Stopping muon

$\mu^+[AB] \rightarrow e^+[BC]$



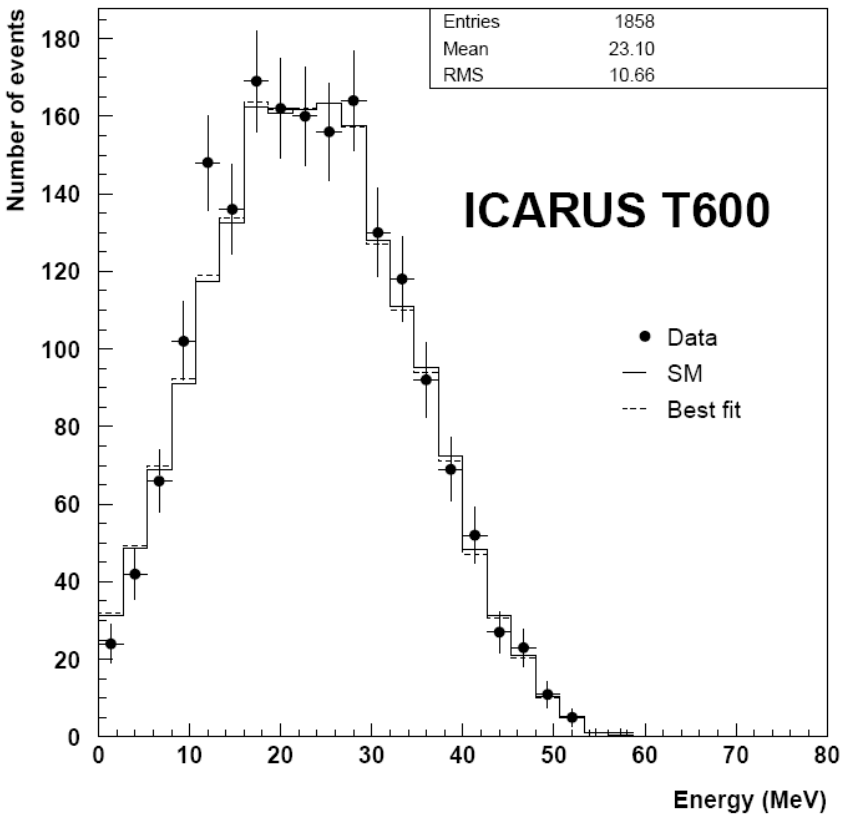






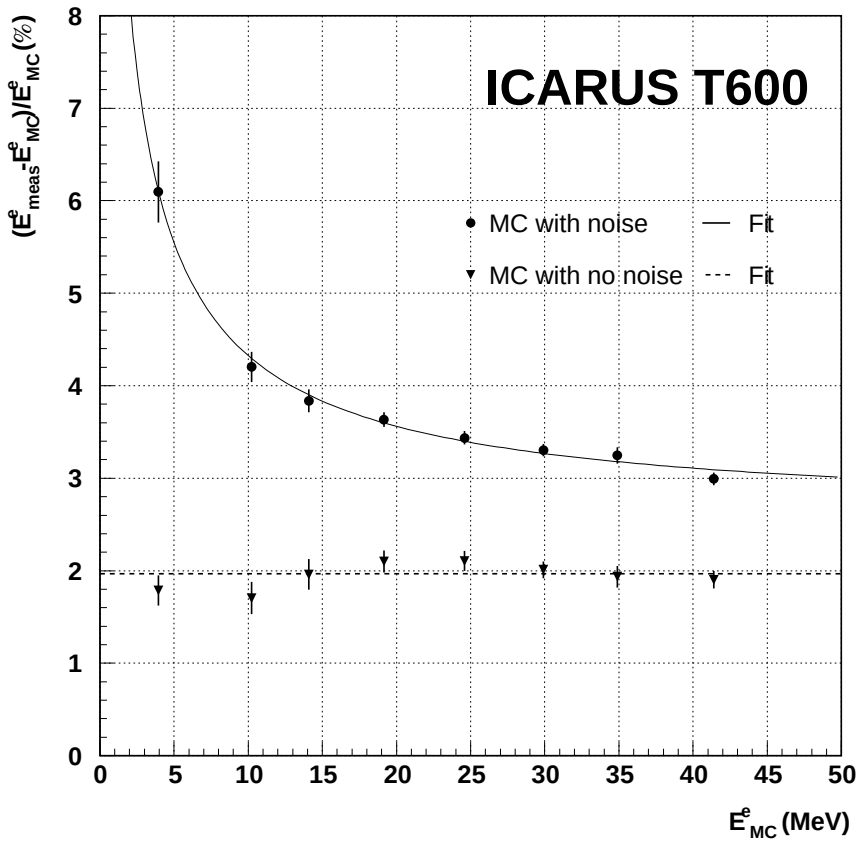
Detector performance: Measured Michel spectrum from the sample of stopped muons

Measured Michel spectrum



Energy resolution:

$$\frac{E_{meas} - E_{MC}}{E_{MC}} = \frac{(11 \pm 1)\%}{\sqrt{E[MeV]}} \oplus (2.5 \pm 0.3)\%$$



Present status

T600 to be moved from Pavia to LNGS end of this month, installation approved

Safety studies going on at LNGS (e.g. ventilation system)

Ready for data taking with T600 (hopefully) by end of 2005

Conclusions

- The ICARUS LAr TPC is a mature and powerful technology.
- The detector offers high resolution 3D track reconstruction and excellent fine grain calorimetric properties.
- Hit finding and 3D track reconstruction algorithms were developed and tested.
- Calorimetric event reconstruction, taking into account the electron lifetime and the electron ion recombination, was achieved.
- The Michel ρ parameter was determined from the decay spectrum of stopped muons, demonstrating the ability of the detector in a physics analysis.

According to our experience, the drift length can be extended. See talk on future plans by A. Rubbia.