A real time algorithm for track finding in ICARUS experiment

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Authors

B. Baibussinov[a], S. Centro[a], K. Cieslik[a,b], D. Dequal[a],

C. Farnese[a], A. Fava[a], D. Gibin[a], A. Guglielmi[a],

G. Meng[a], F. Pietropaolo[a], C. Rubbia[c,d],

E. Scantamburlo[a], F. Varanini[a], S. Ventura[a]

Presented by D.Dequal

a Istituto Nazionale di Fisica Nucleare and Dept. of Physics "G. Galilei", Padova, Italy
b On leave form Institut Fizyki Jadrowej PAN, Krakov, Poland
c Laboratori Nazionali del Gran Sasso dell'INFN, Assergi (AQ), Italy
d CERN, European Laboratory for Particle Physics, Geneve, Switzerland

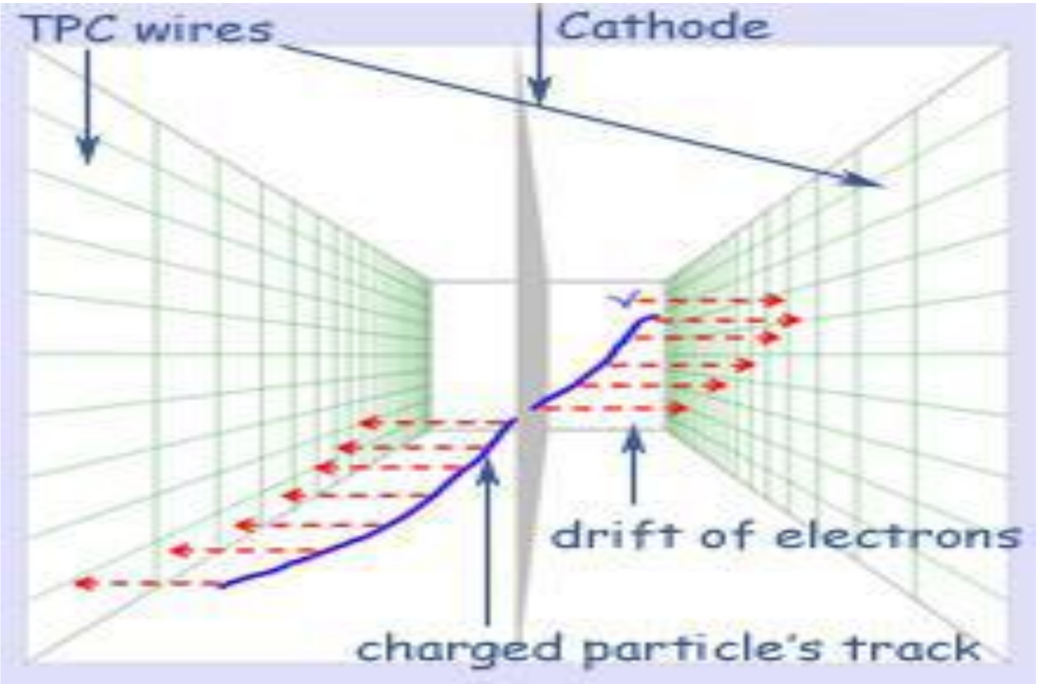
Outline

- Description of the apparatus
- ICARUS physical goals
- The trigger System
- Hit finding algorithm and R.o.I. detection
- Test on Icarino facility

LAr-TPC in a nutshell

Icarus T-600is the largest LAr TPC operating underground.

It provides calorimetric measurements as well as 3D tracks imaging



LAr acts both as target for neutrinos and as detector itself:

M.i.p. energy loss= 2,2 MeV/cm

electron/ion pairs production
≈ 5000 electrons/mm

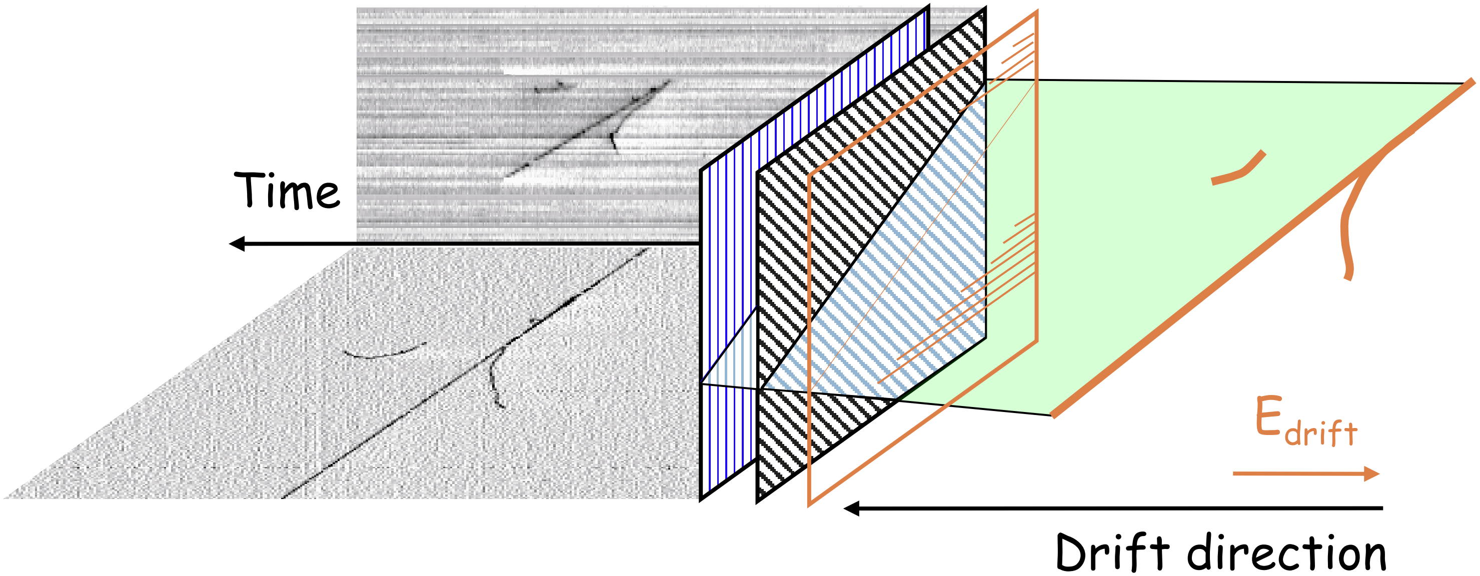
scintillation light
≈ 20000 photons/mm

(@500 V/cm external drift electric field)

3D imaging

The electric signal is collected by 3 planes of wires (54000 wires, 3 mm pitch).
2D reconstruction for 20m x 1,5 m

Scintillation light is collected by 74 PMTs placed inside the detector.
Reconstruction of the 3rd dimension 1,5 m



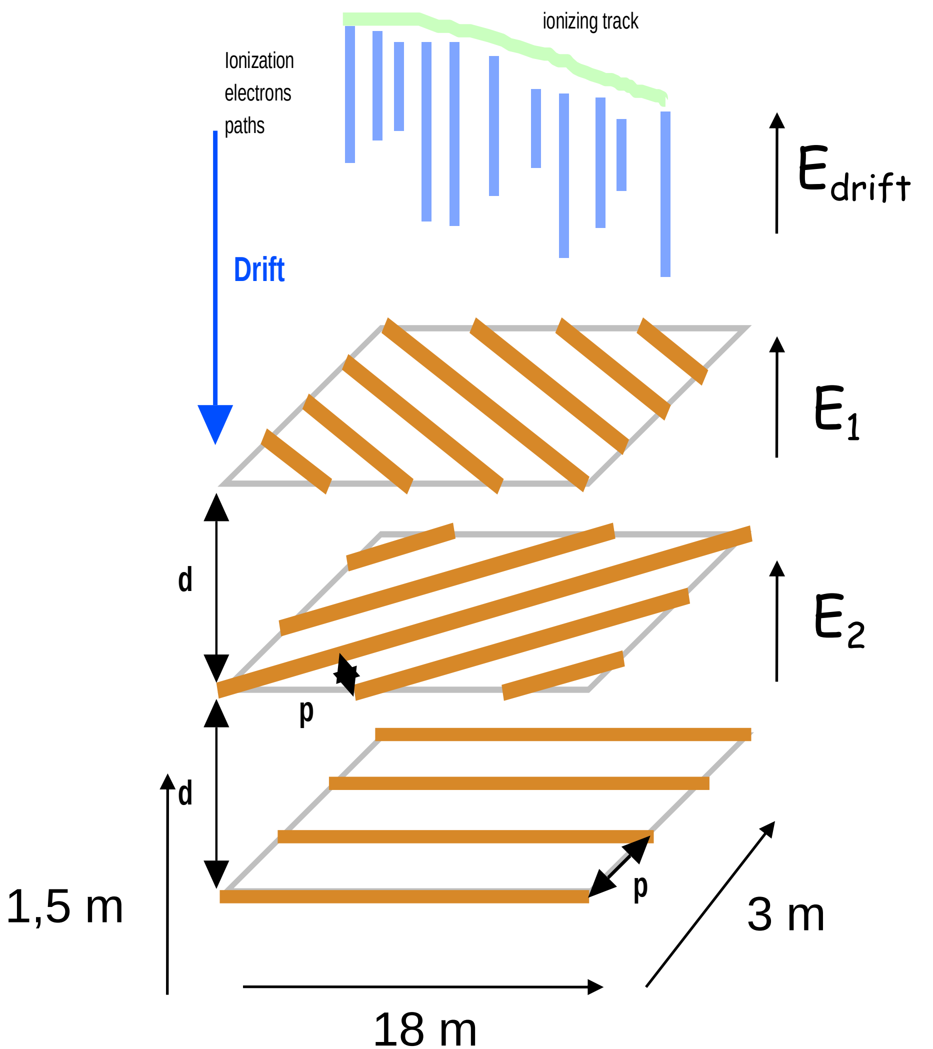
Electrons drift velocity = 1,5 mm/μs (@500V/cm).

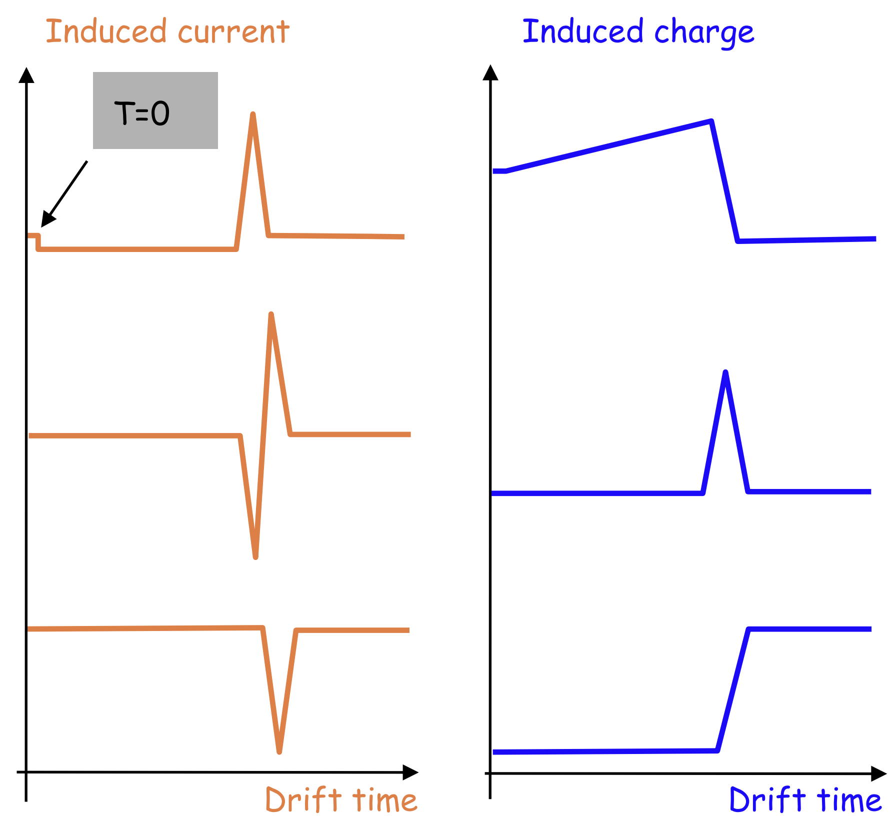
Wires read-out

Non-destructive read-out is guaranteed by grid transparency condition:

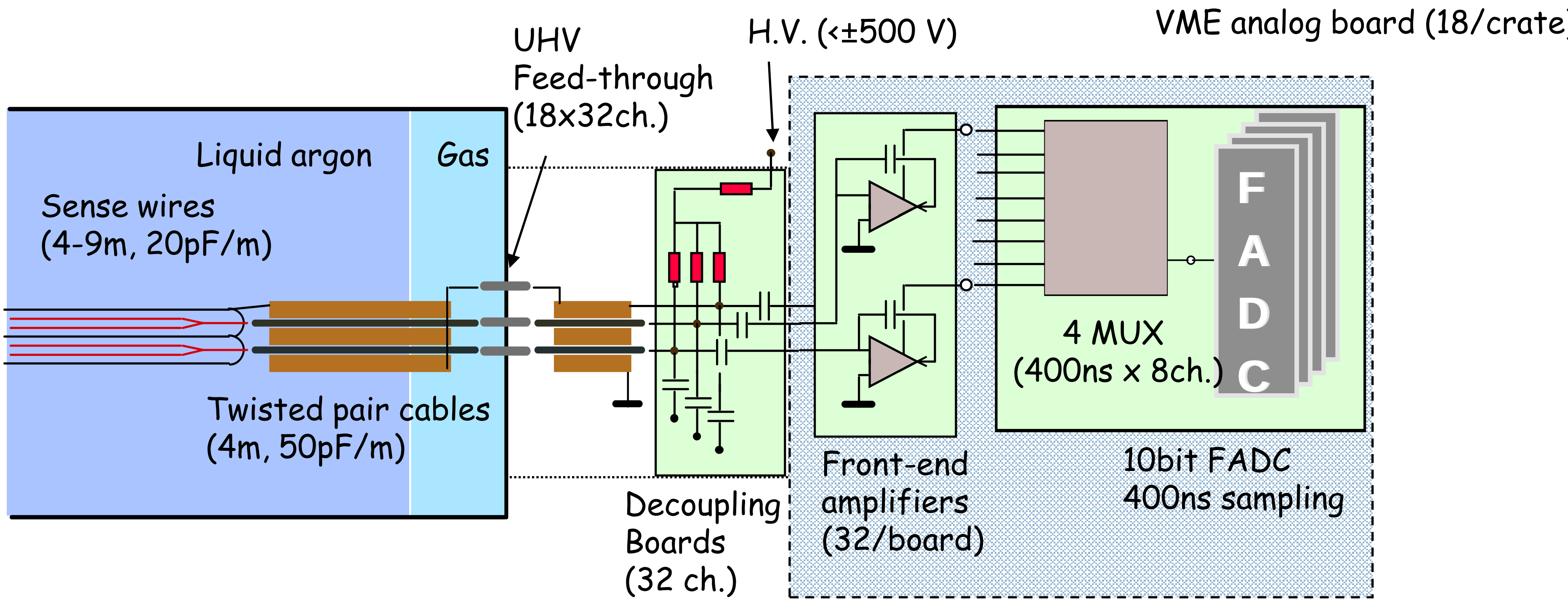
$E_1/E_{drift} = E_2/E_1 > (1+\rho)/(1-\rho)$

$\rho = 2\pi r/p$ (r=wire radius)





Front-end electronics



- ≈ 54000 channels
- 1664boards
- 96 crates

High gain, 15 ADC for 3 mm m.i.p. (15000 electrons)

Low noise, r.m.s. = 1ADC (1000 electrons equivalent)

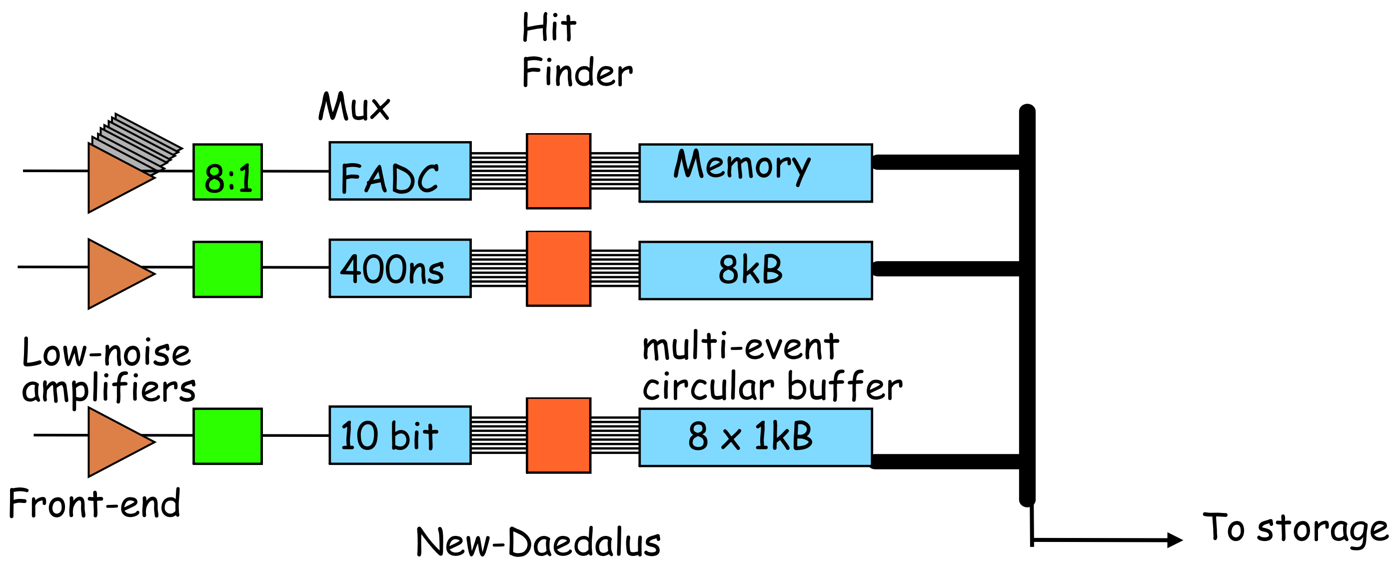
Read-out principle

Requirements:

- Continuously sensitive
- Self-triggering

Solution:

- Multi buffering
- Hit finding
- Boards independency



A trigger for physics

ICARUS physical goals:

- $\nu\mu \rightarrow \nu\tau$ oscillation on CerN to Gran Sasso neutrinos beam
- Proton decay
- Atmospheric and solar neutrinos
- Super Nova explosion

Event type	Events/year	Energy	# wires	# samples
Vμ CNGS	1200	17 GeV	25000	2500
Ve CNGS	10	17 GeV	25000	2500
V atm	25/50	10 MeV-100GeV	25000	2500
V sol	300	10 MeV	2000	2500
V SN	10/100	10 MeV	2000	2500
Proton decay	?	800 MeV	2000	2500

Triggering resources

- PMTs
  - Pros: t_0
  - Cons: not localized, inefficient for small charge deposition

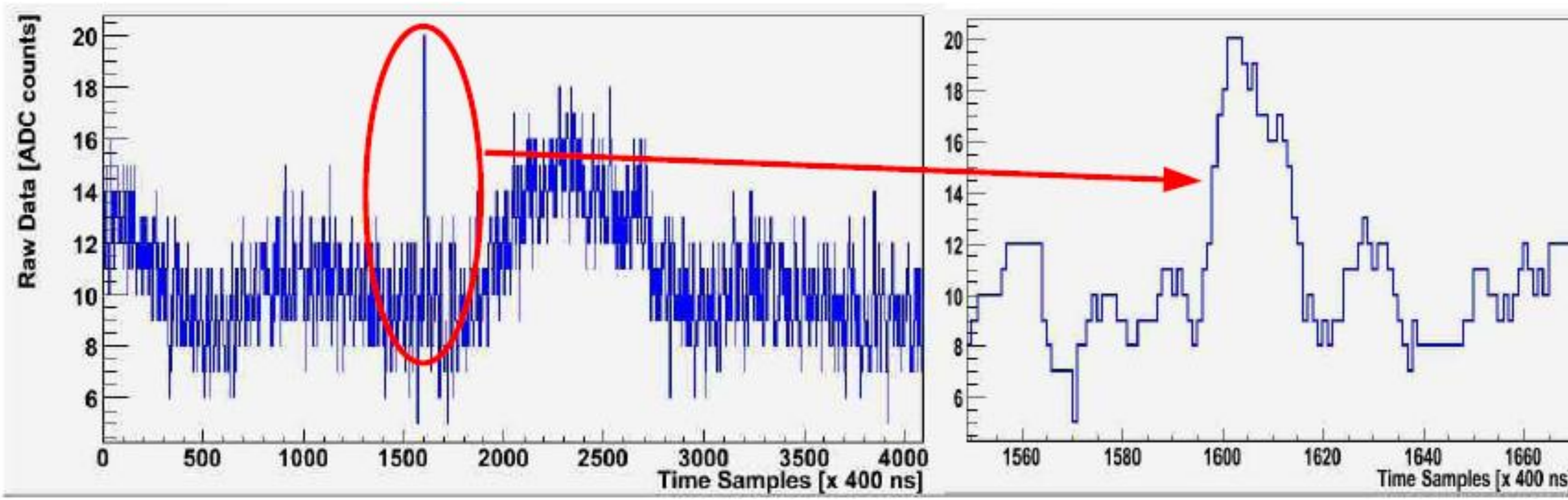
- Wires (see below)
  - Pros: localized, sensitive to small charge deposition
  - Cons: sensitive to neutron capture background

- CNGS
  - Pros: 100% efficiency on CNGS events
  - Cons: not localized, high rate of empty events

Triggering modes

- External trigger:
  - Limited in bandwidth (≈1 Hz max rate for 1.5 ms drift). Maximum of eight events pile-up before deadtime.
- External Enable:
  - Bandwidth allows up to 1k event "tiles" (25 μs • 16 wires) per second per readout crate. NewDaedalus thresholds can be more tolerant without over-flooding readout.
  - Internal FIFO's can accept up to 128 fragments.
- Open Shutter:
  - 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.

M.i.p. signal

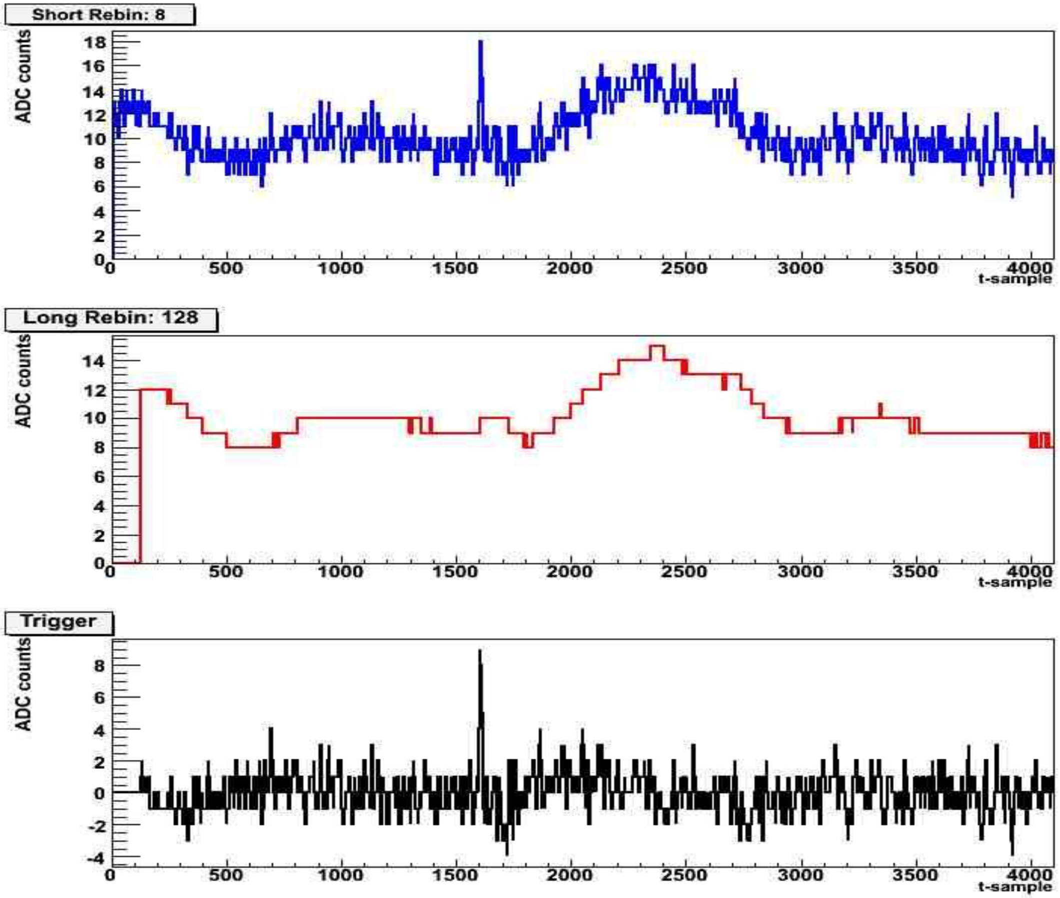


M.i.p. signal: 15 ADC counts, 30/40 t-samples

Low frequency noise: ≈ 10 ADC counts, ≈ 2000 t-samples

High frequency noise: ≈ ±2 ADC counts, ≈ 5 t-samples

New hit finding algorithm



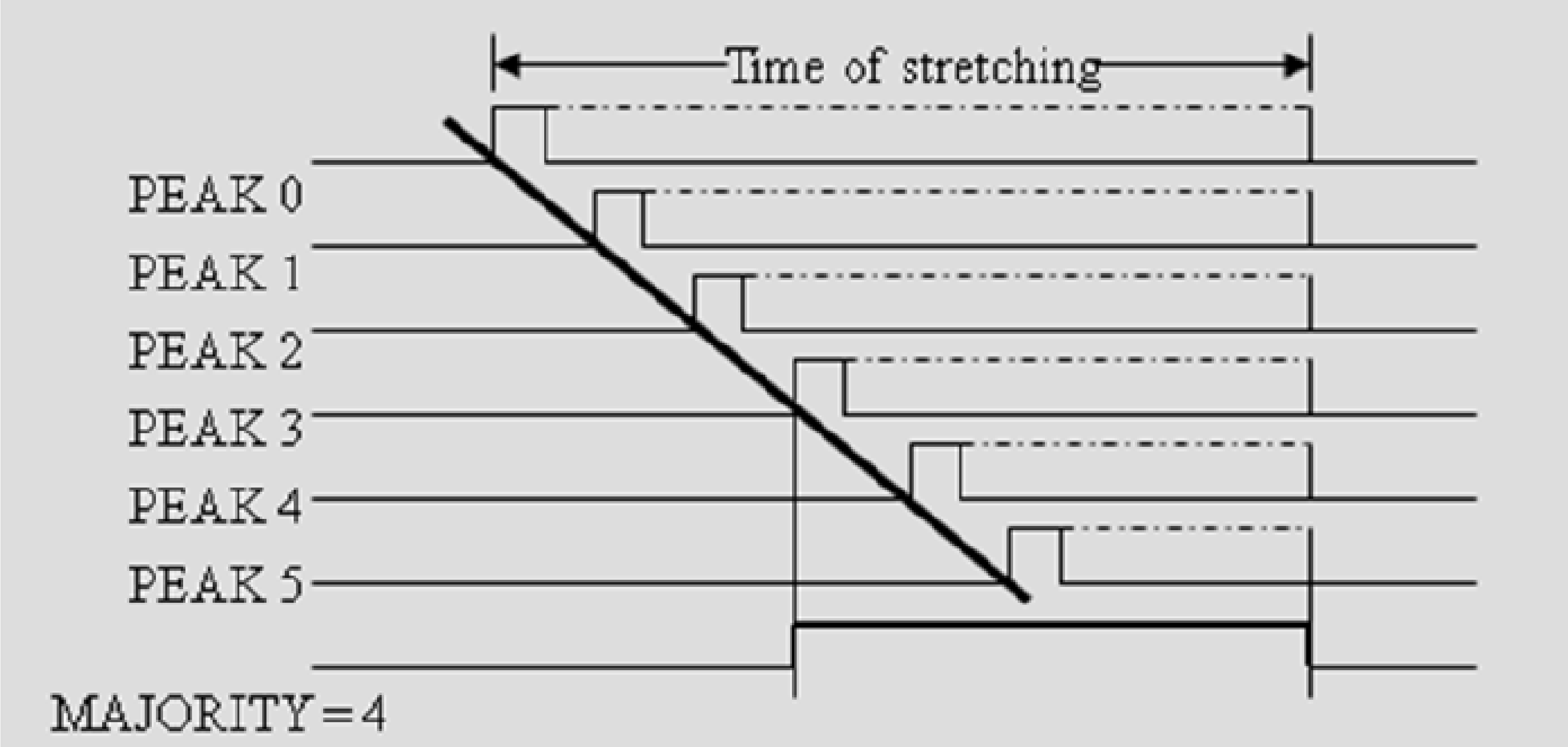
$$Q_8(t) = \frac{1}{8}\sum_{i=0}^{8} Q(t-i)$$

$$Q_{128}(t) = \frac{1}{128}\sum_{i=0}^{128} Q(t-i)$$

$$S(t) = Q_8(t) - Q_{128}(t)$$

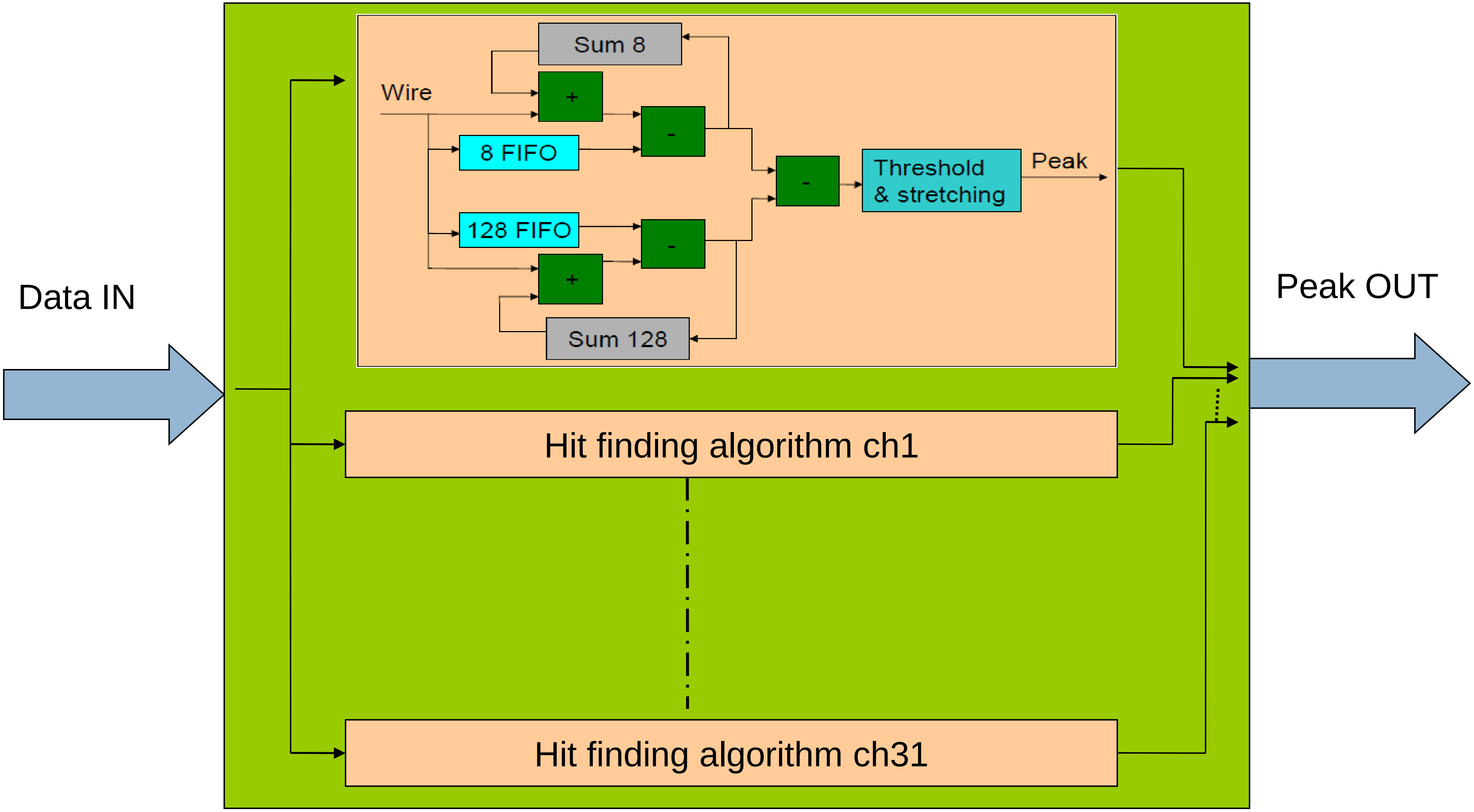
8 samples average to reduce high frequency oscillation
128 samples average to follow baseline modulation
A peak signal is generated when S(t) goes over threshold

2nd step of the algorithm

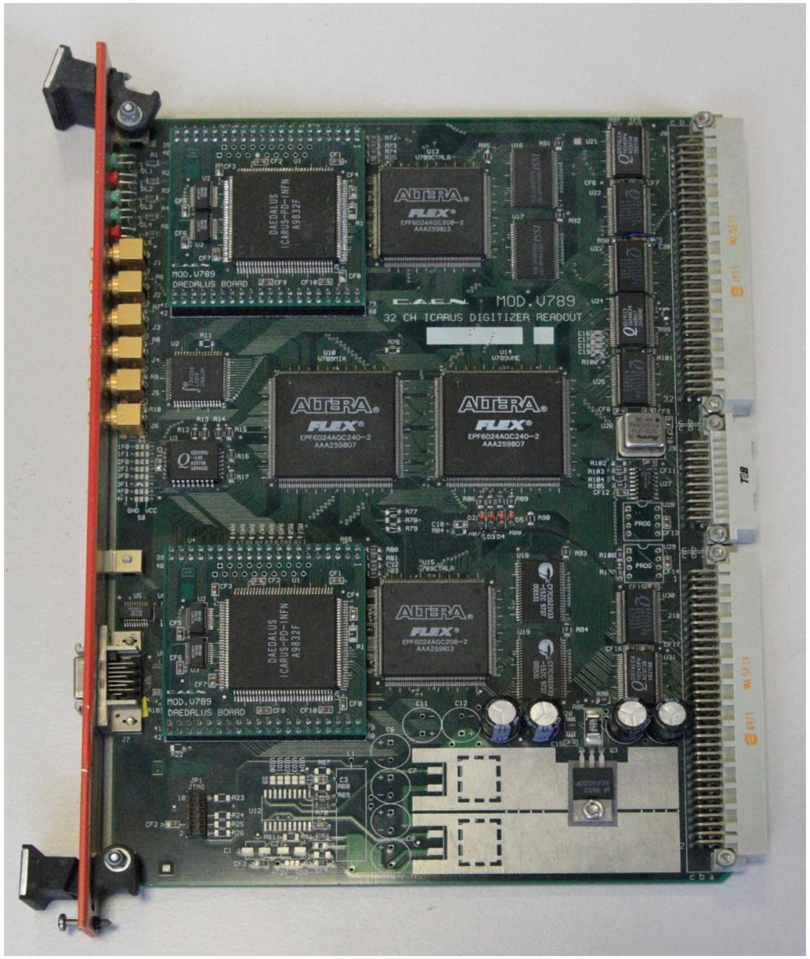


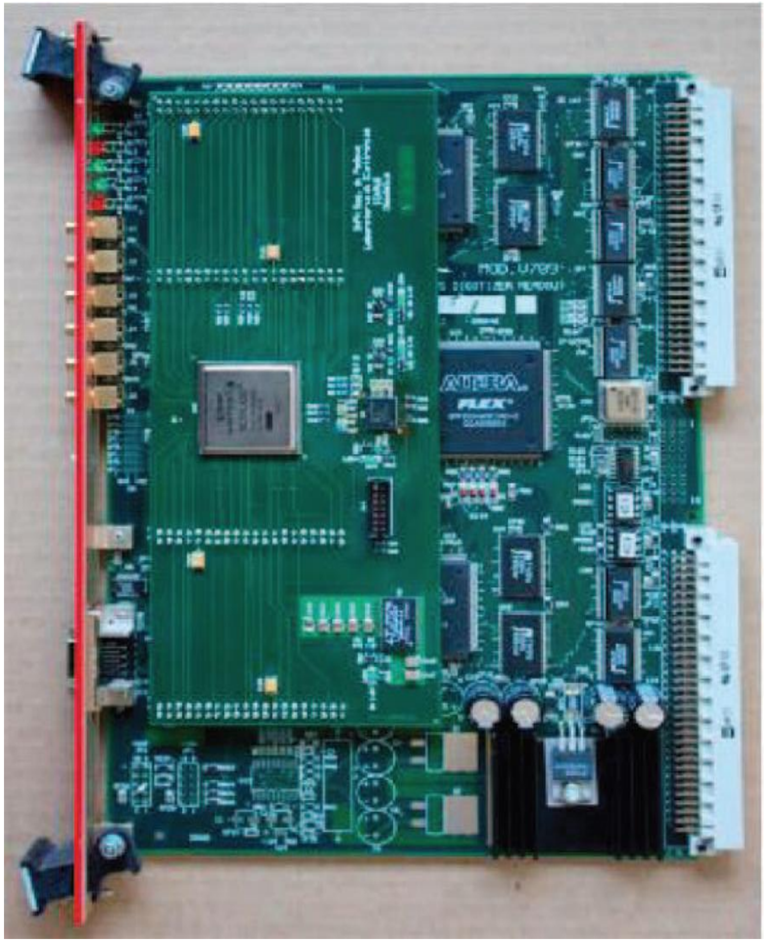
Peak stretching ranging from 25 μs to 125 μs to guarantee high efficiency for inclined tracks

Block diagram



From Daedalus to NewDaedalus

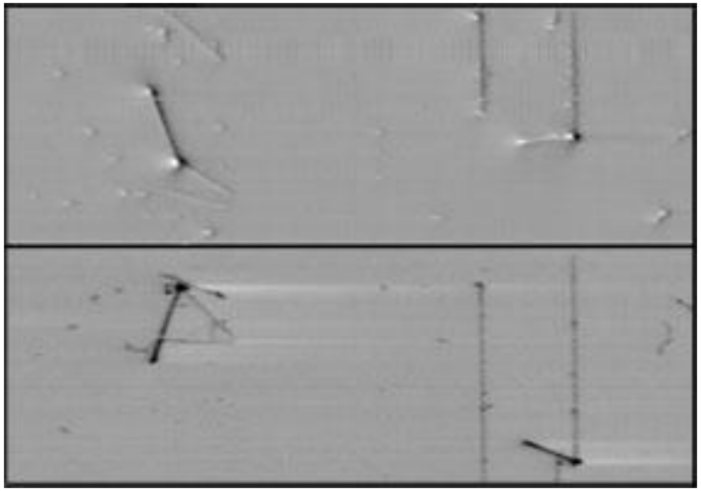




Daedalus:
VLSI 0,5 μm
CMOS gate array

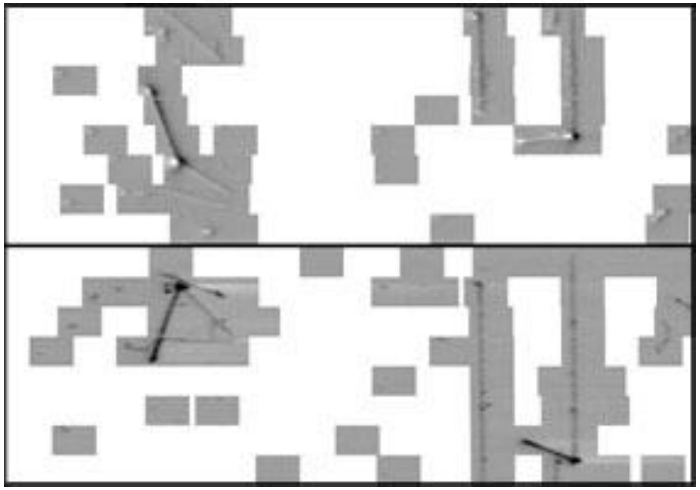
NewDaedalus:
Xilinx Virtex 5 FPGA (prototype)
Xilinx Spartan 6 FPGA (production)

NewDaedalus as R.o.I. selector



Full drift image

Triggered on PMTs



Reduced drift image

Triggered on PMTs

Reduced with NewDaedalus R.o.I. selection

Icarino test facility

Same electronic chain used for the ICARUS detector

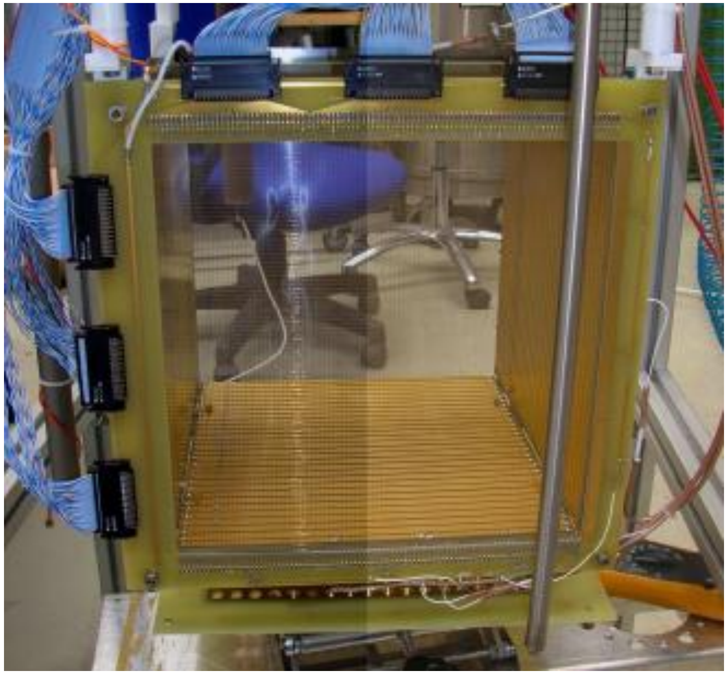
Icarino has been running in 2009 for testing on-line lossless data compression and trigger capabilities of NewDaedalus chip

The Icarino chamber

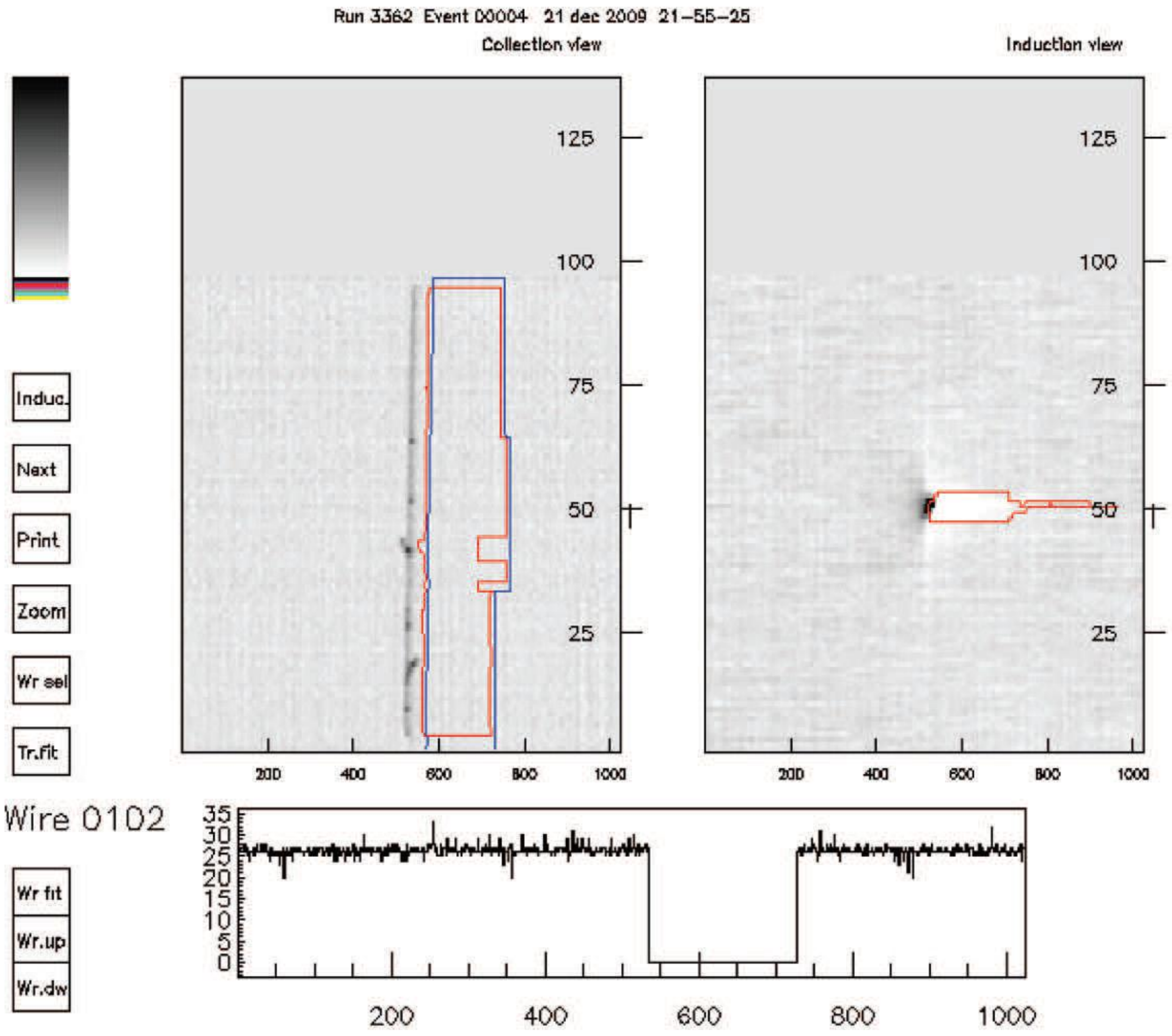
Active mass: 38 Kg
Active volume :32 ,6 x 32,6 x 29,4 cm^3

2 planes of wires:

96 horizontal wires (collection)
96 vertical wires (induction)



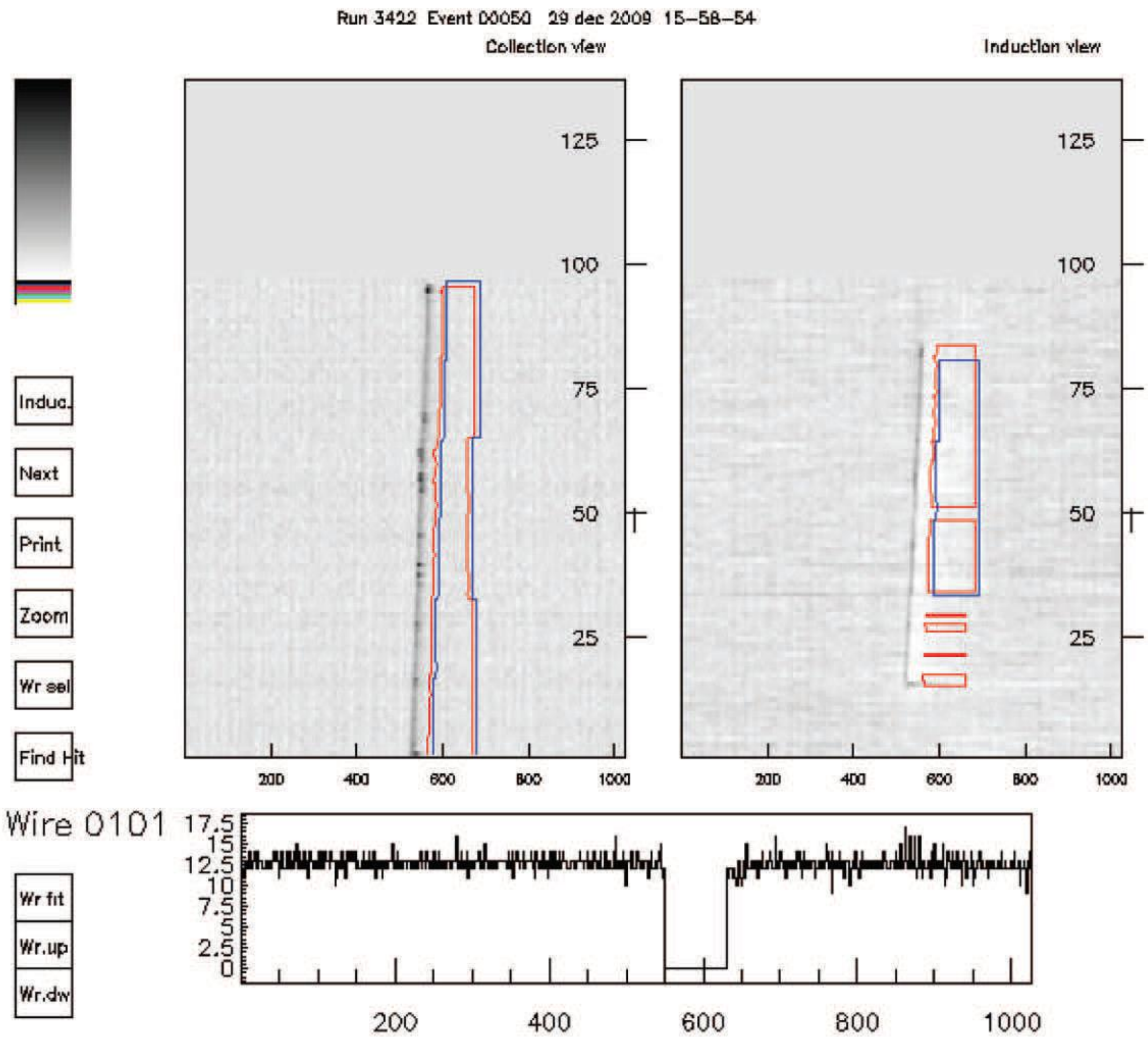
Vertical through-going muon



Red line: Peak signal (thre. = 6)

Blue line: Majority signal (maj. = 8)

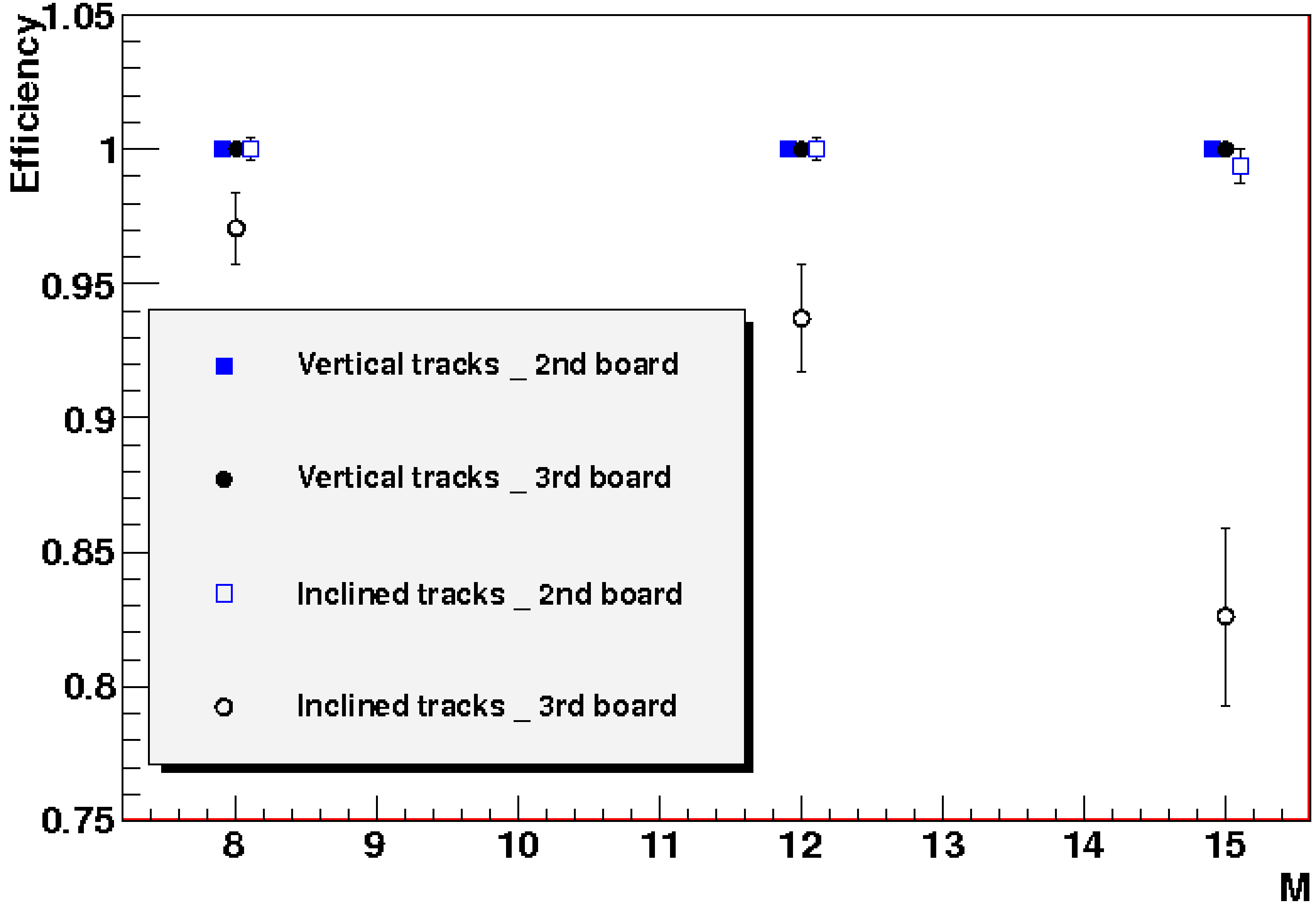
Inclined through-going muon



Red line: Peak signal (thre. = 6)

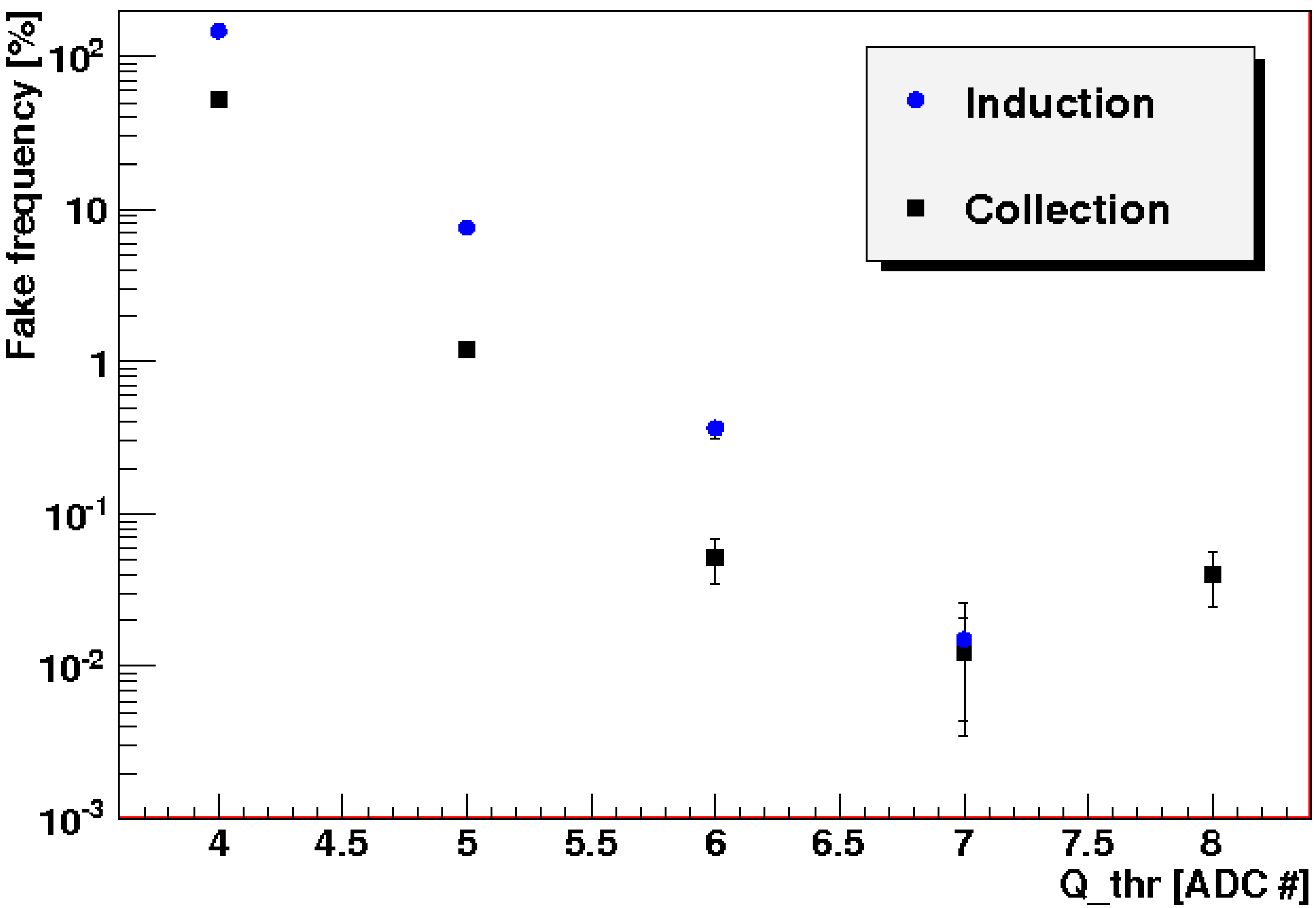
Blue line: Majority signal (maj .= 8)

NewDaedalus efficiency

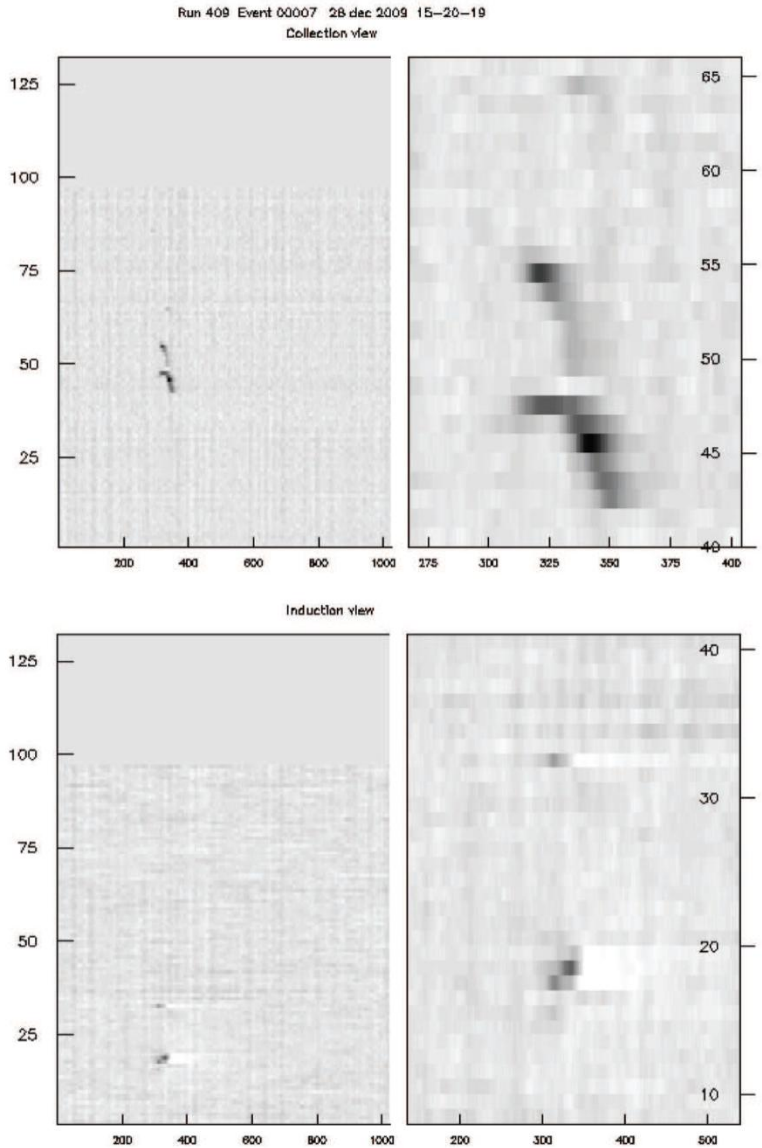


Threshold = 6 ADC

NewDaedalus rate of fake



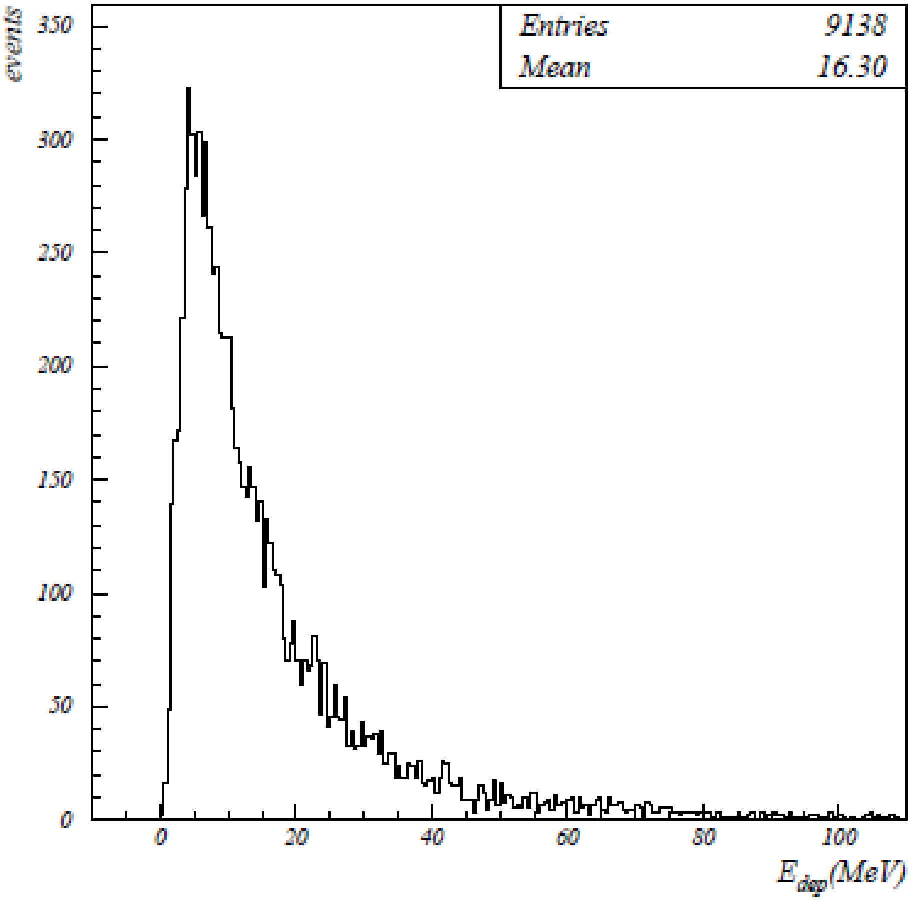
Small charge deposition setup

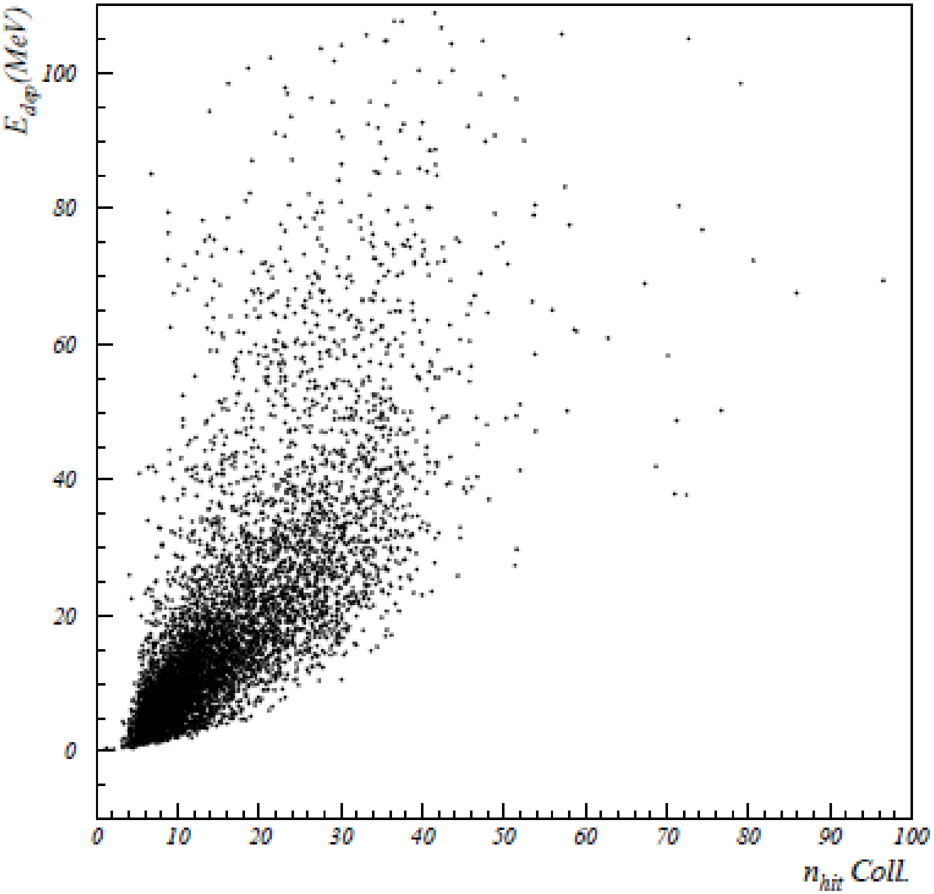


Central collection board NewDaedalus signal used as trigger

Lateral collection boards NewDaedalus signals used as veto

Small charge deposition spectrum

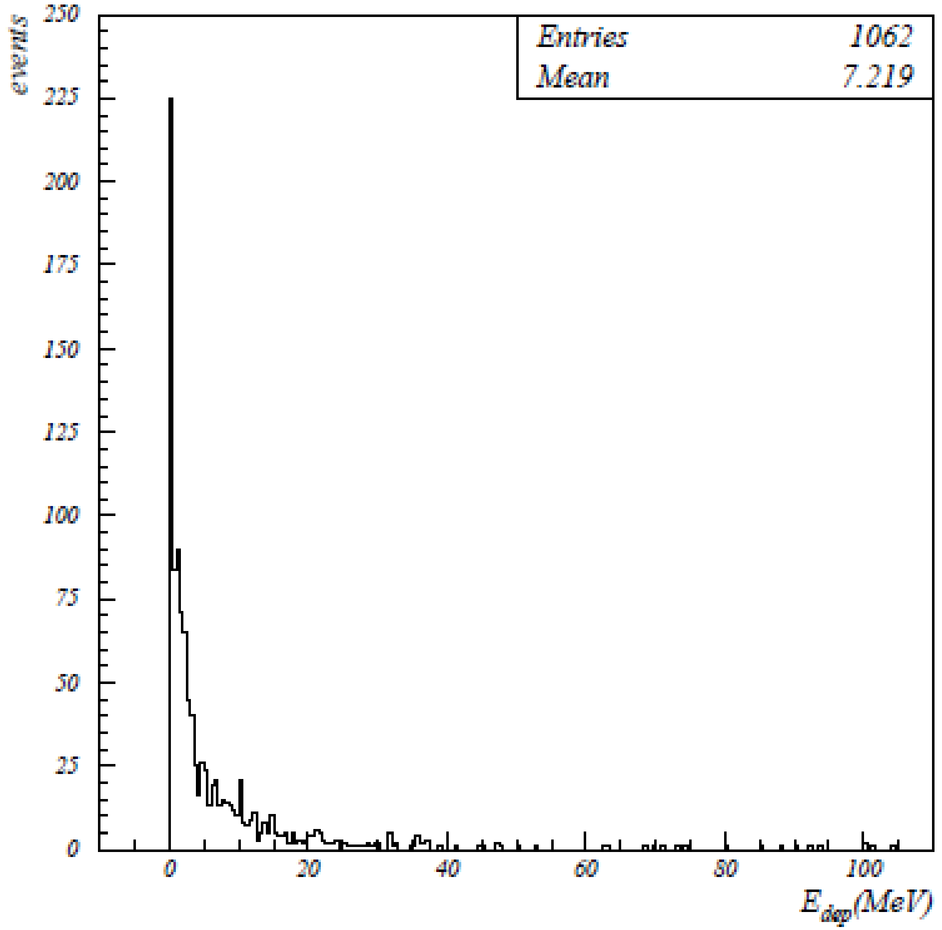


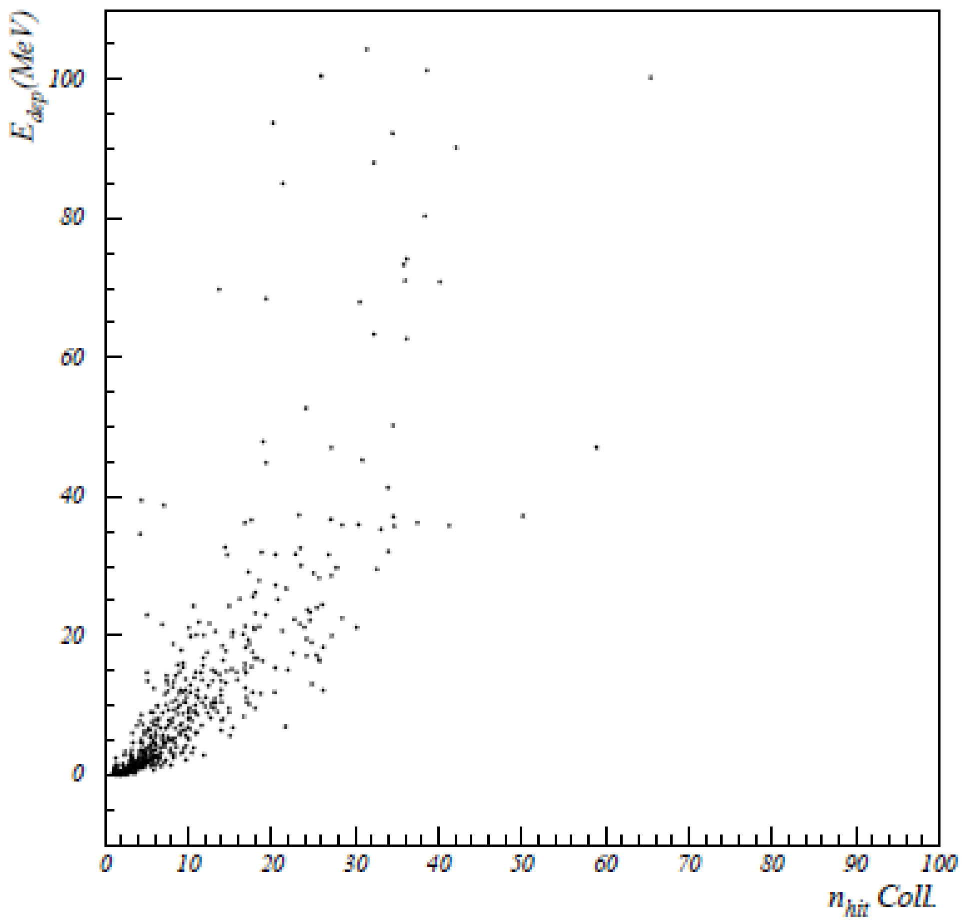


Histogram of the energy deposition of the events taken with the small charge deposition setup

Threshold = 6 ADC   Majority = 4

Small charge deposition spectrum





Histogram of the energy deposition of the events taken with the small charge deposition setup

Threshold = 5 ADC   Majority = 3

Conclusions

- R.o.I. algorithm has been implemented and successfully tested
- Sensitivity of the detector can be pushed to few MeV
- First prototype will be implemented in ICARUS after the commissioning phase
- Application to install NewDaedalus chip on the whole detector before March 2011, before CNGS beam start