A two level trigger system for the ICARUS LAr-TPC

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on behalf of the ICARUS collaboration

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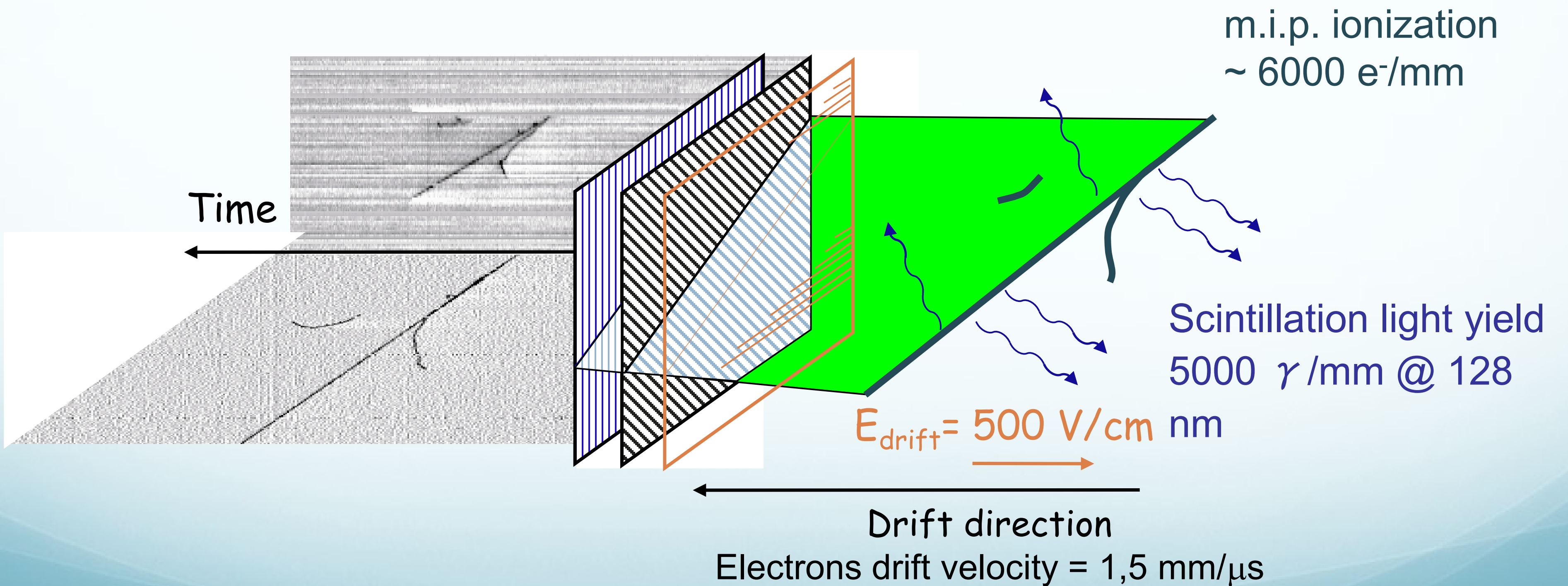
Layout

- Detector concept
- Electronics and Data Acquisition
- Triggering resources and solutions
- Current status and performances
- Conclusions

LAr TPC principle

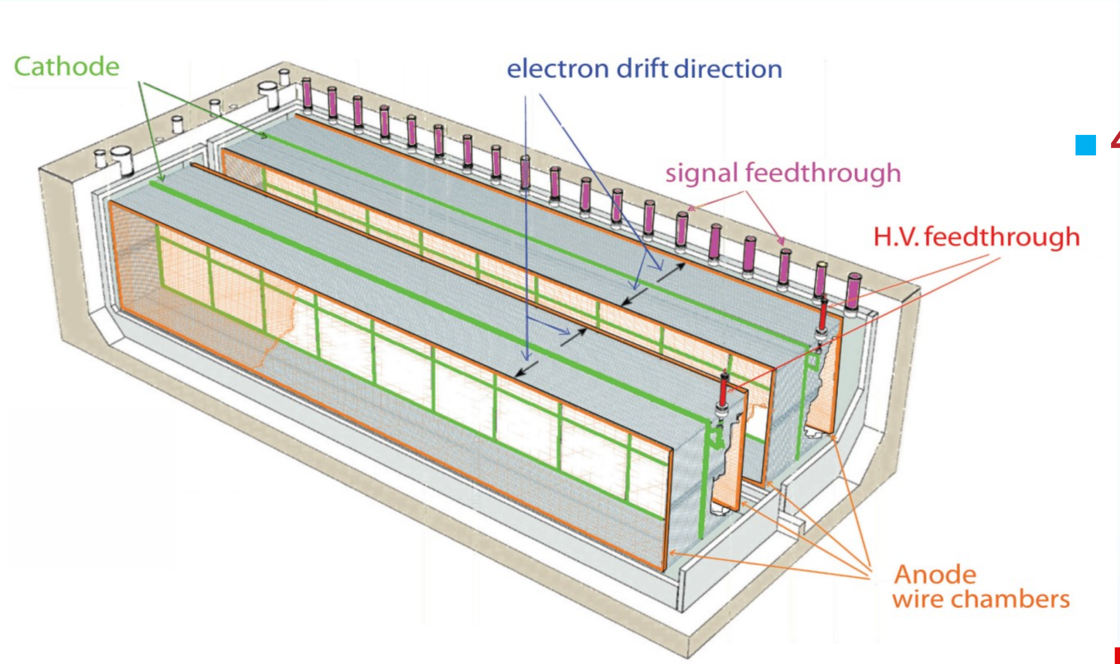
LAr TPC proposed as an "electronic bubble chamber" [C.Rubbia: CERN-EP/7708 (1977)]. High granularity (~ 1 mm^3),excellent calorimetric properties, particle identification (through dE/dx over range) plus:

- Continuously sensitive
- Self triggering
- Very large masses



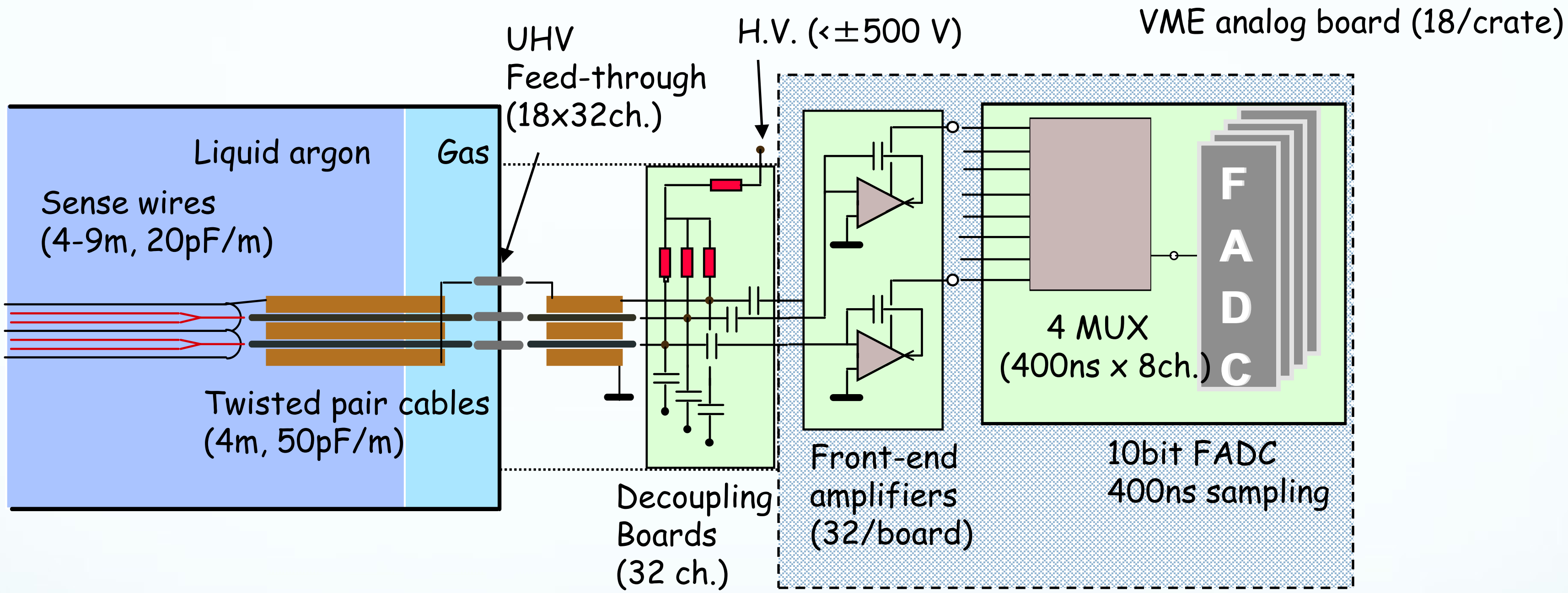
Key issue: Reduce the electro-negative molecules (0_2, H_2O, CO_2) below 0,1 ppb leads to 3ms of electron lifetime, max. sign. attenuation = 30%

The ICARUS detector



- 4 wire chambers:
  - 2 chambers per module
  - 3 readout wire planes per chamber, wires at 0, ±60°
  - ≈ 54000 wires, 3 mm pitch, 3 mm plane spacing
- PMT for scintillation light:
  - (20+54) PMTs, 8” Ø
  - VUV sensitive (128nm) with wave shifter (TPB)
- Two identical modules
  - 3.6 x 3.9 x 19.6 ≈ 275 m^3 each
  - Liquid Ar active mass: ≈ 476 t
  - Drift length = 1.5 m

Read-out scheme

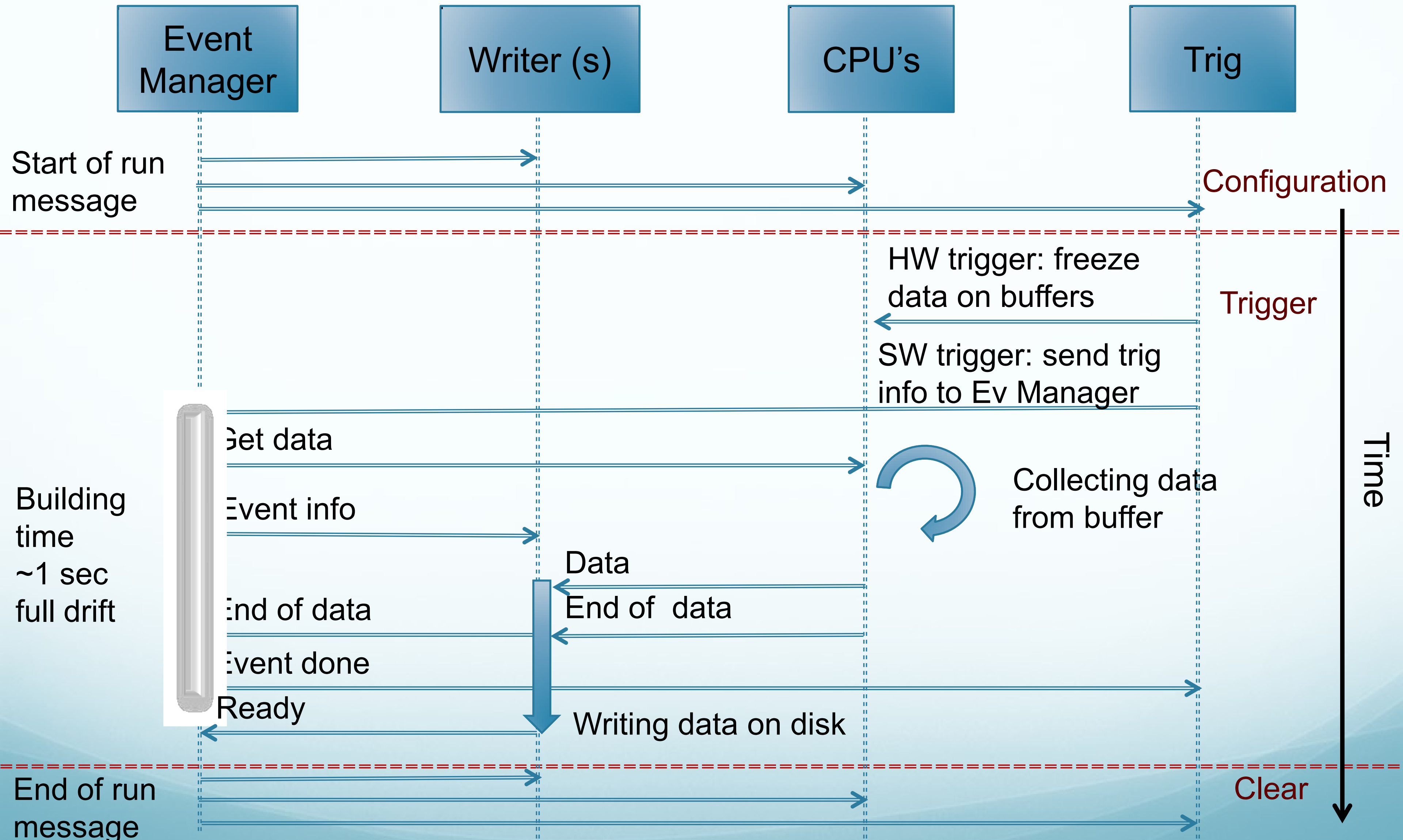


- ≈ 54000 channels
- 1664boards (32 channels per board)
- 96 crates (18 boards per crate)
- 1 CPU per crate

- 12000 e⁻ m.i.p. signal
- 1000 e⁻ E.N.C.
- 10 bit sampling @2,5 MHz

- Multi buffering (up to 8 full drift)
- Hit finding
- Boards independency

TDAQ process



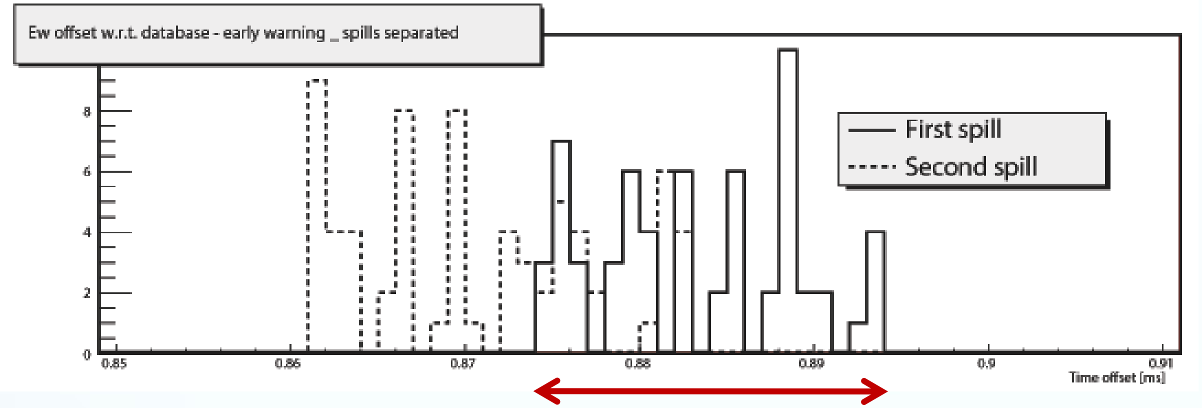
Triggering resources

- Timing information: “Early warning” message sent from CERN at each SPS proton extraction
  - Full trigger efficiency on CNGS events
  - 28800 trigger per day, only 30 events expected (ν interaction in ICARUS and surrounding rock). S/bkg ~ 1/1000
  - 2nd level trigger needed (implemented in 2011)

- Light signal collected by 74 PMTs
  - CNGS + atmospheric neutrinos + cosmic rays
  - Gives the time of interaction (T_0), necessary for complete 3D reconstruction

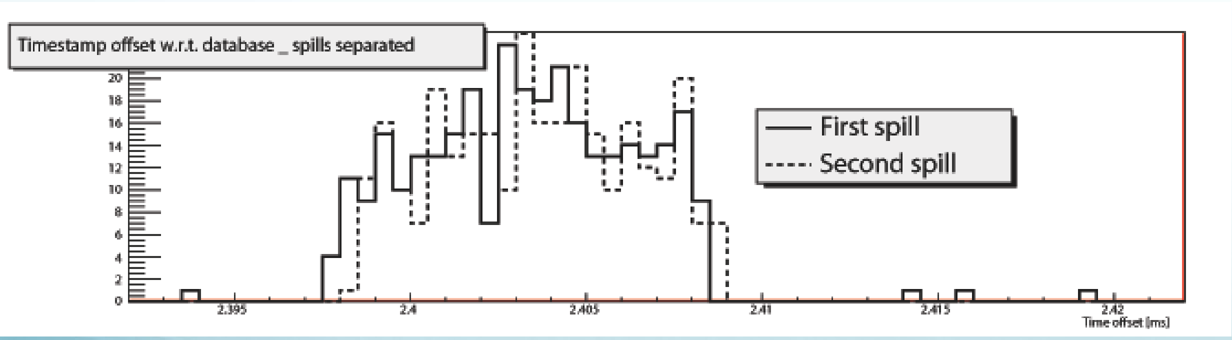
- Charge signal on TPC wire planes
  - CNGS + atmospheric neutrinos + c-rays + solar neutrinos (down several MeV)
  - High efficiency shown by Icarino test facility [*B Baibussinov et al 2010 JINST* ***5*** *P12006*]
  - Need hardware upgrade for atmospheric and solar (in commissioning)

Timing information from CERN



~20 μs = Ew accourancy

An “early warning” (Ew) message is sent from CERN to LNGS 150 ms before each extraction. This message contains the predicted extraction time.

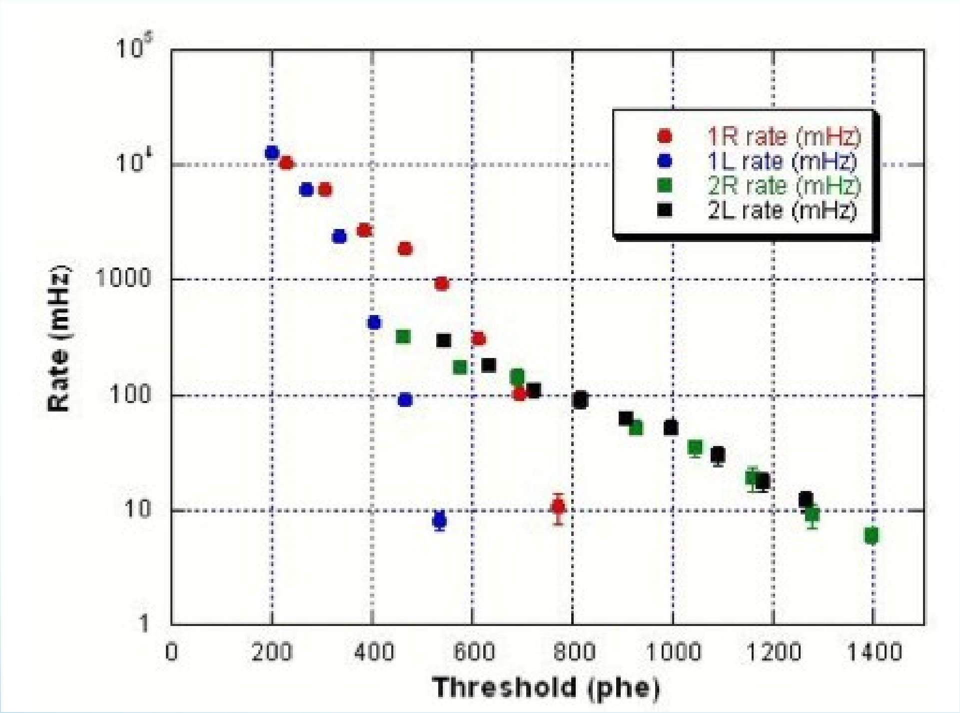


10.5 μs = Spill width

The precision of this prediction is ~20 μs >> jitter of local clock (GPS based). Still enough for triggering purpose.

Combining timing and PMT

The sum of the analogue signals from all the PMTs of each chamber is discriminated with a dual threshold.



2010 trigger setup

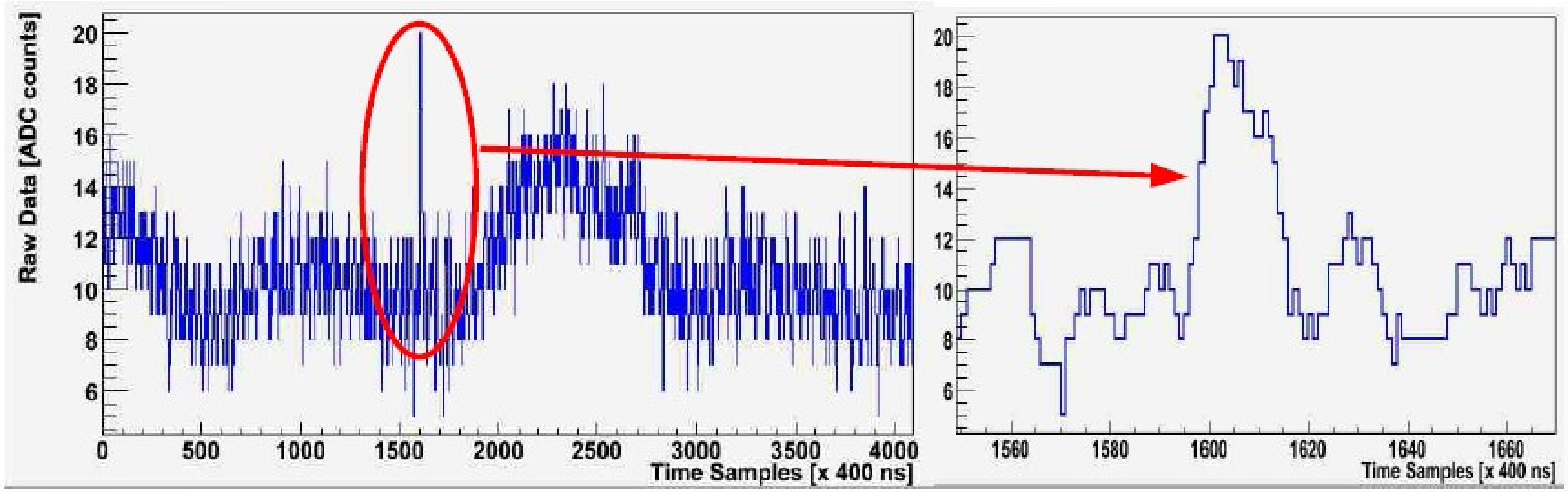
- C-rays trigger: HT + coincidence LT
- CNGS trigger: single LT

Dark count rates allow a minimum threshold of ~1000 phe$^-$ (HT) for the sum signal of each chamber.

It is also possible to enable the coincidence of two lower threshold (~100 phe$^-$, LT) of the single module keeping dark counts low.

The single low threshold can be enabled in coincidence with the 60μs gate of proton extraction from SPS

M.i.p. charge signal on wire chamber

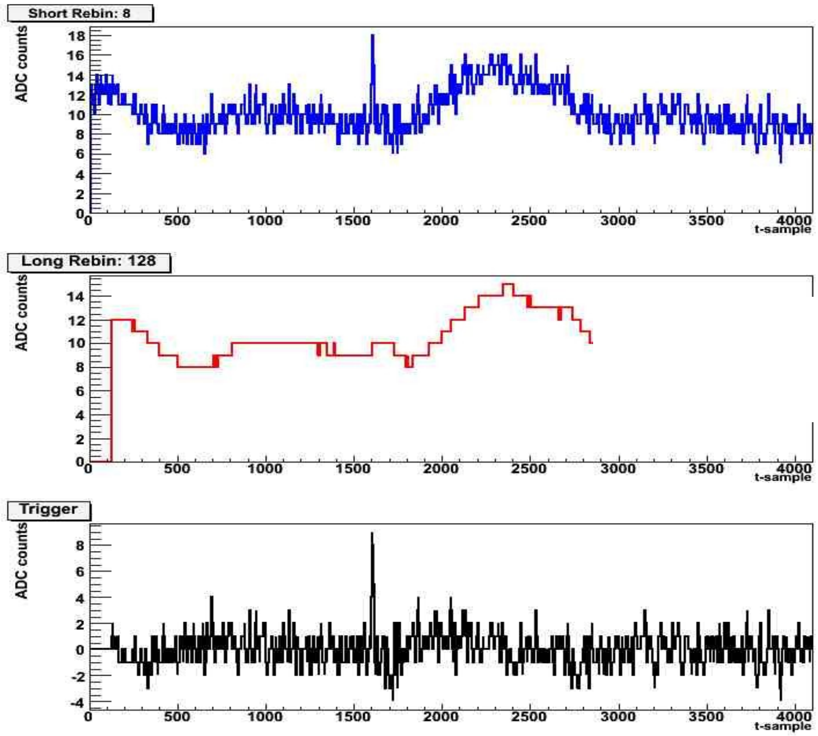


M.i.p. signal: 15 ADC counts, 30/40 t-samples

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

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

Hit finding algorithm



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

8 samples average to reduce high frequency oscillation

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

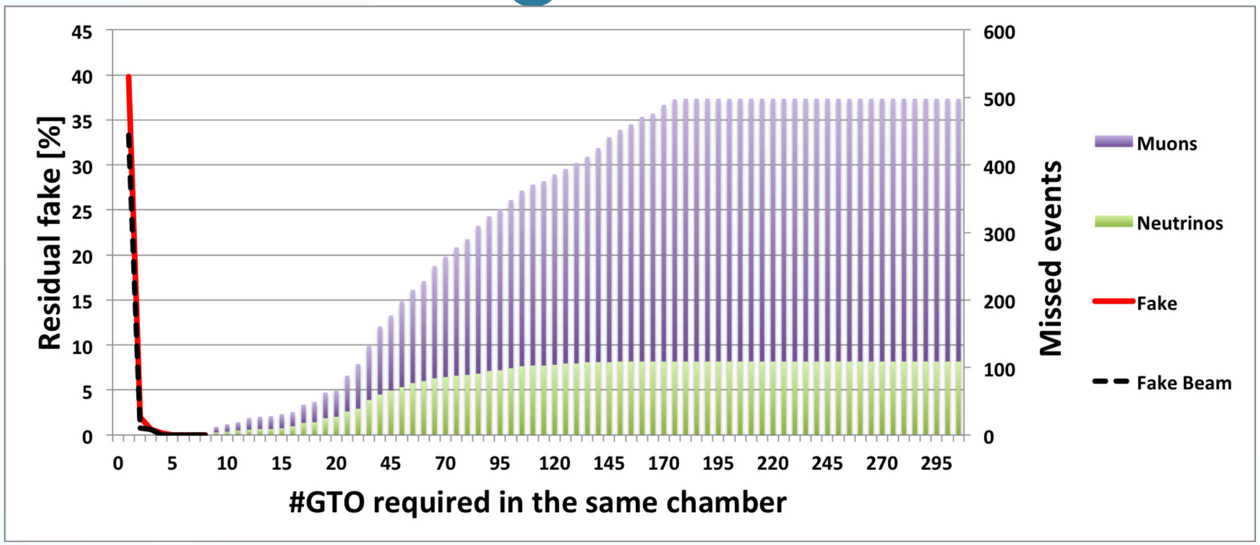
128 samples average to follow baseline modulation

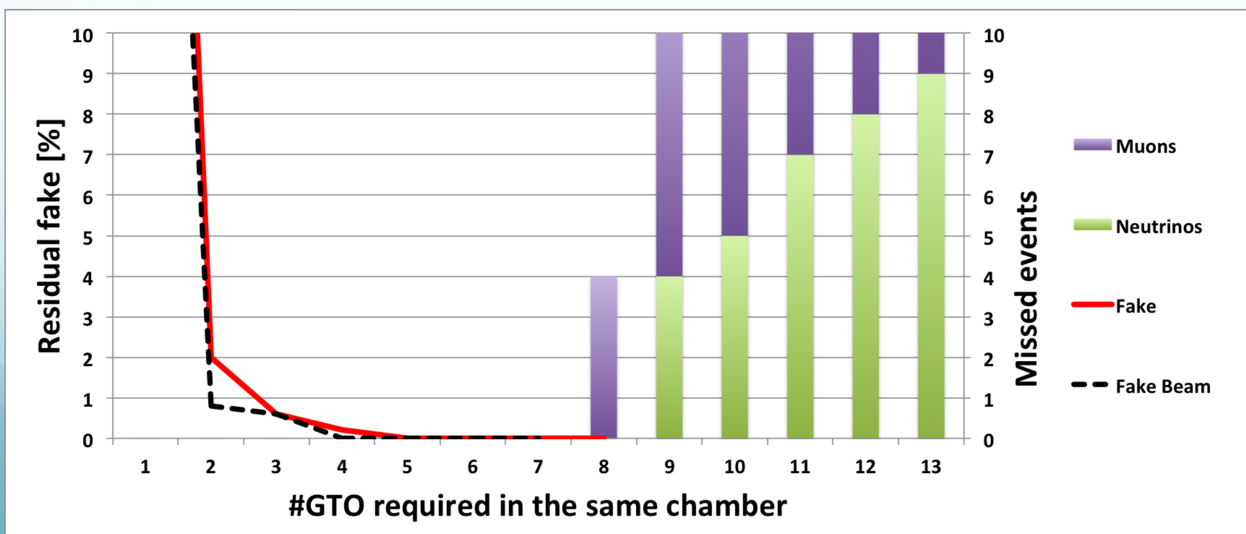
$$S(t) = Q_8(t) - Q_{128}(t)$$

A peak signal is generated when S(t) goes over threshold

A majority stage over 16 consecutive wires (corresponding to ~5cm) has been included to reduce fake trigger, while keeping an high efficiency for small events. Taking the logical OR of the two majority coming from the same board, a local trigger signal can be generated (GTO: global trigger out)

Combining timing and charge signal on wire camber





A first trigger is given at every extraction (every 3 sec).

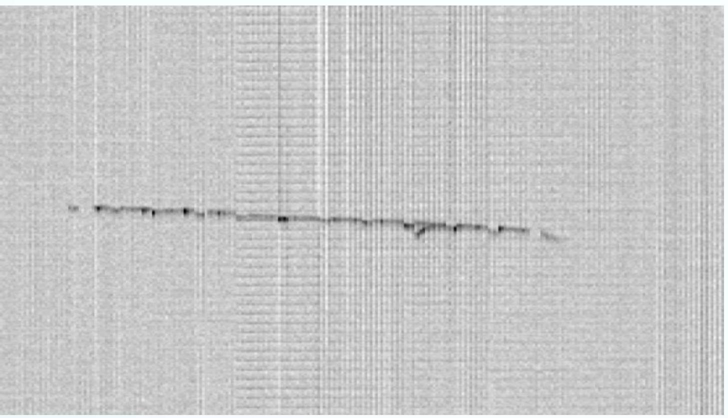
The event is then scanned with the hit finding algorithm

Only if the charge deposition is above a certain threshold the event is kept

Full efficiency on 2010 data triggered by PMT. The rejection factor exceeds 1000 requiring 7 ADC count for the single hit and a majority of 12 over 16

2 level trigger events

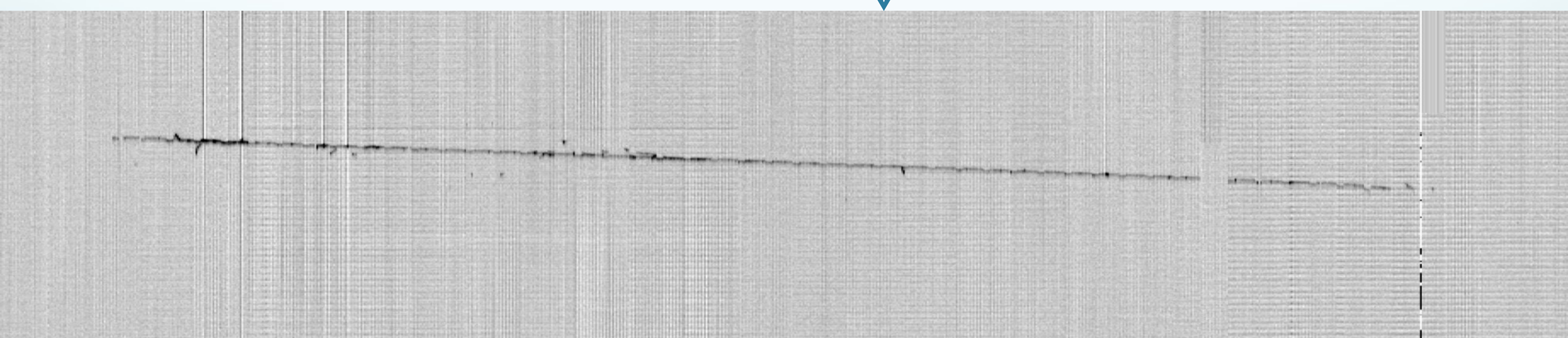
In 2011 the 2 level trigger system, based on the combination of timing + charge, has been implemented. In the first months of data collection 3 events where triggered only by this setup, requiring the presence of 6 GTO in the same chamber. All of them where muons from ν interaction with surrounding rock



E_{dep}= 93 MeV

E_{dep}= 570 MeV

0,44 m

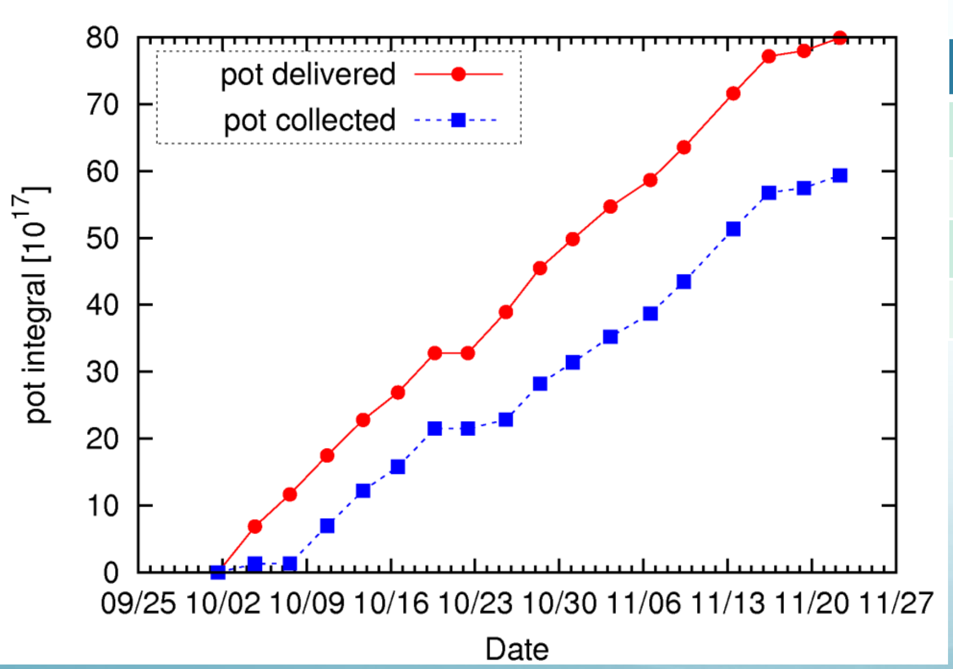


2,83m

CNGS run statistics

Up to now 90% of 2010 run has been scanned (corresponding to 5,2 10^{18} over 5,8 10^{18} p.o.t). Detector livetime up to 90% since Nov 1st

Scanning of 2011 run has just started. Il will permit a cross check of the efficiency of the two independent source.

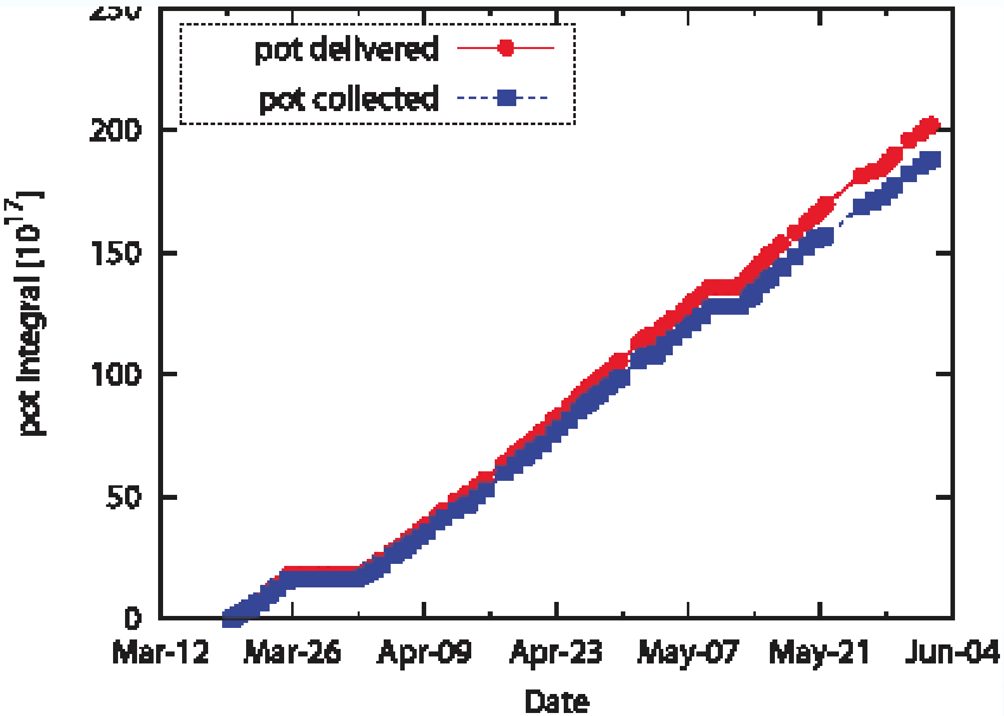


Event type	Collected	Expected**
ν_μ CC	108	115
ν NC	36	37
ν XC *	6	-
Total	150	152

*Events at edges, with μ track too short to be visually recognized: further analysis needed.

** Active mass = 434 ton (taking into account missing electronics and edges)

2011 CNGS run



3 level veto to assign different priority to different trigger sources:

- 5 buffers: all trigger enable (cosmic + CNGS)
- 2 buffers: reserved for CNGS events (timing + charge or timing + light)
- Last buffer: reserved for CNGS events with light detection

Detector livetime = 93% during 2011 CNGS run. Dead time for different veto level is:

- Cosmic: 8,5%
- Timing + charge: 1,7%
- Timing + light: no dead time in 3 months

Conclusions

- Detector uptime > 90% since Nov 2010, dead-time for CNGS event greatly reduced in 2011 run
- Trigger setup of 2010 has been studied and qualified
- An hit finding algorithm has been qualified over the CNGS event of 2010 run
- A two level trigger has been implemented, tested, and gave the first results
- A complete check of the two trigger sources will be done with the 2011 data

Thank you!

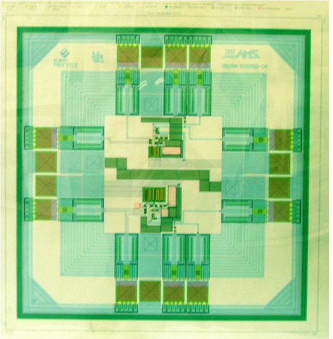
Backup slides

Low Noise Preamplifier

Mip signal ~ 12000 e^- (inc. recombinantion)

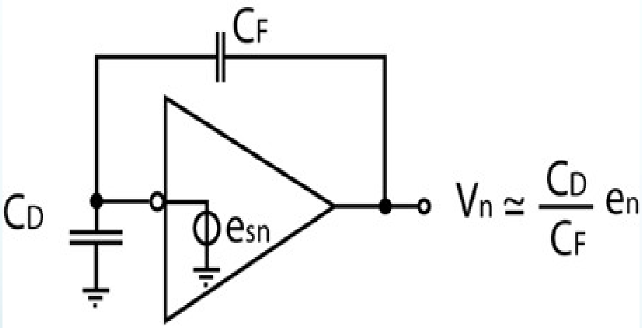
Detector capacitance C_D~ 400 pF

The need of high g_m and low parallel noise leads to a jFET input stage



Custom IC in BiCMOS technology

- Classical **unfolded** cascode integrator
- External input stage jFET's
  - Two IF4500 (Interfet) or BF861/2/3 (Philips) in parallel to increase g_m (50-60 mS)
- External feedback network
  - Allow sensitivity and decay time optimization
  - High value f.b. resistor (100MΩ) reduce parallel noise

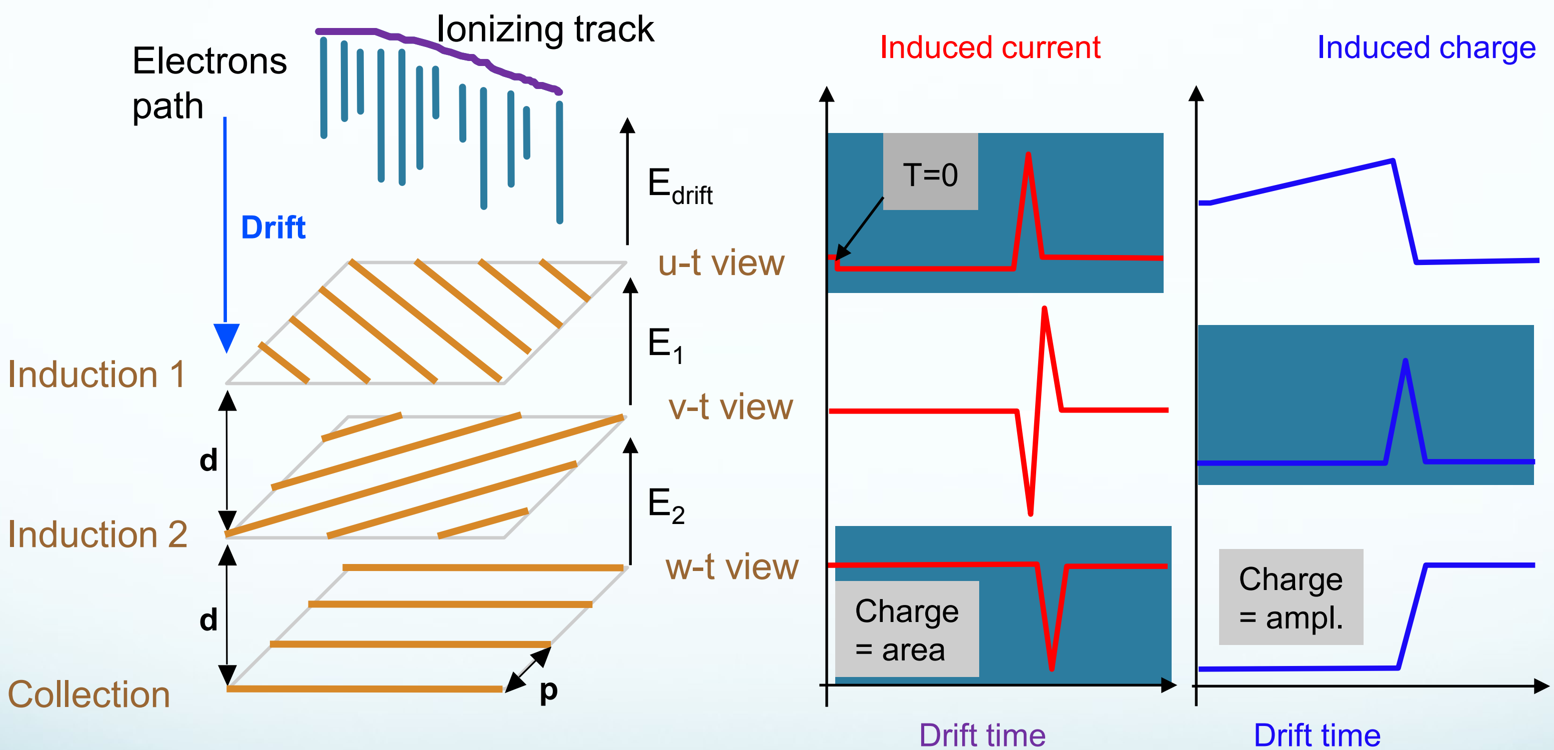


$$e_{sn}^2 \propto \frac{1}{g_m}$$

Sensitivity ≈ 6 mV/fC
Dynamic range > 200 fC
Linearity < 0.5% @ full scale
Gain 6.5±.5 mV/fC,

Gain uniformity < 3%
E.N.C. ≈ (350 + 2.5 x C_D) el ≈ 1200 el.
Power consumption ≈ 40 mW/channel
1LSB = 1 mV

3D reconstruction



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

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

$$\rho = 2\pi r/p \qquad \text{(r=wire radius)}$$

PMT

Length and diameter	293 mm; 203 mm
Windows	sand-blasted glass
Cathode size	190 mm
Cathode type	K_2CsSb on Pt layer
Spectral response	300-500 nm
Dynodes	12LF CsSb
SER peak-to-valley	2.3
Rise time ; FWHM	5 ns; 8 ns
Max gain	5×10^7
Quantum eff. (blue)	20%
HV for 10^7 gain	1500 V

74 PMTs in the detector:

- 20 in Module I
- 54 in Module II

The sum of the analogue signals from all the PMTs of each chamber is discriminated with a dual threshold.