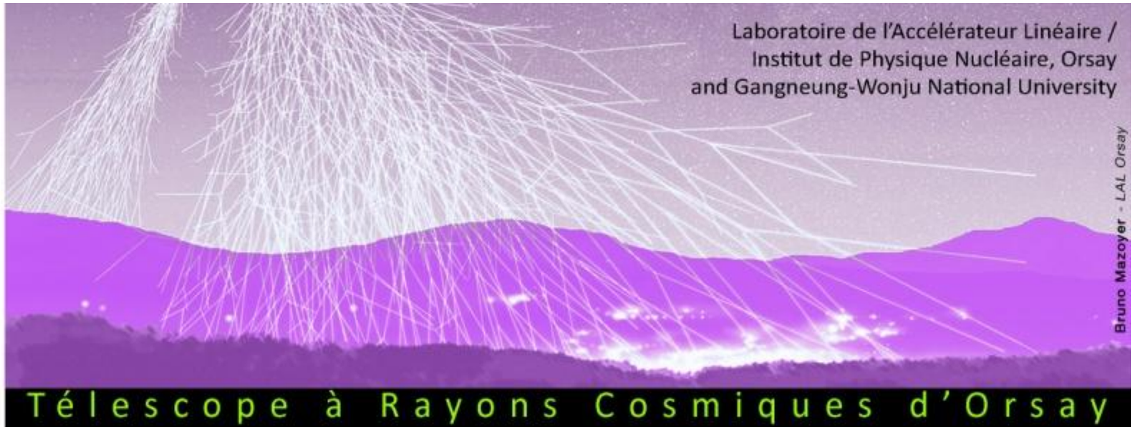


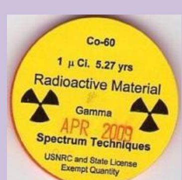
COsmic Ray Telescope @ Orsay

Véronique Puill

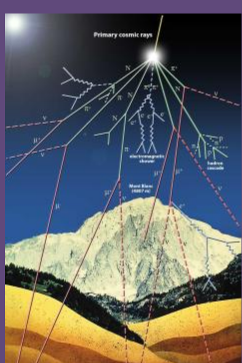
on behalf of the CORTO team

E. Bals, D. Breton, L. Burmistrov, F. Campos, V. Chaumat, C. Cheikali, B. Genolini,
X. Grave, Mimae Kim, D.W. Kim, J. Maalmi, J. Peyre, A. Stocchi, C. Sylvia, J.F Vagnucci

How can we test particles detectors ?

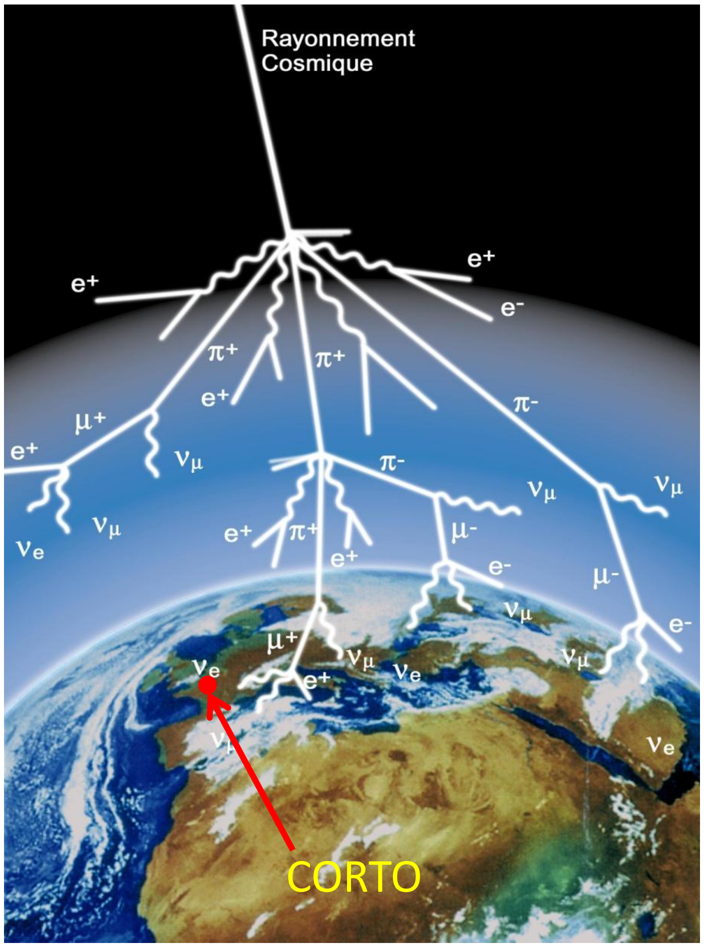
	Advantages	**Drawbacks**
Luminous sources 	• triggered system • easy to use	* difficult to find a light source that correctly simulates a particle behavior inside the interaction medium (amount of photons, spreading of the shower, …) * safety procedures to follow * need to build a system to move the laser source above the detector to be tested
Radioactive sources 	the energy deposition is a good approximation of the reality	* difficulty to perform a good collimation in order to obtain a point like source * no trigger * need to build a system to move the source above the detector to test * need to wait for a long time to obtain an authorization from authorities to use a radioactive source (6 months …) * heavy safety obligations …

How can we test particles detectors ?

	Avdantages	Drawbacks
Beam test 	Real conditions of use of the detector (choice of the particle, of its energy)	*need to plan the access to the infrastructures (CERN, DESY, …) * heavy preparation of the tests procedure * expenses for the travels and staying abroad
Cosmic Ray telescope 	* Cosmic rays are free… * tests of detectors with real charged particles * all the surface of the detector is touched --> no need of manipulation of a source * facility easy to access and to use	* Low event rate :~1 $\mu/cm^2/mn$ * only Muons

COsmic Ray Telescope at Orsay

This project aims at developing a detector testing platform using cosmic rays, named CORTO, with the following specifications:



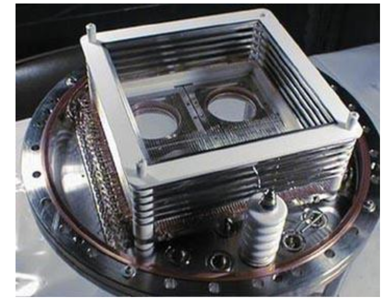
- ◆ low cost facility→ use of detectors for the hodoscope, electronics and data acquisition system developed in the framework of other experiments
- ◆ user-friendly acquisition system →"plug-and-play" facility
- ◆ large enough to perform test of detectors of various geometries and sizes

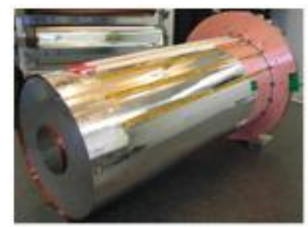
COsmic Ray Telescope at Orsay

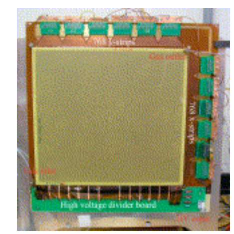
CORTO for Hight Energy Physics

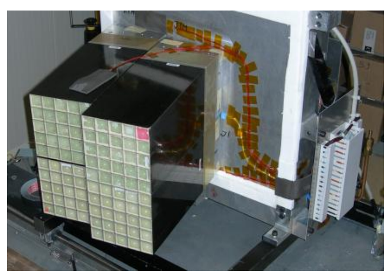
Study of:

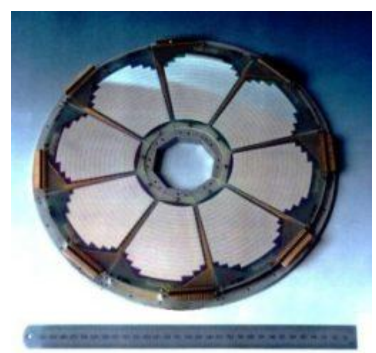
- Cherenkov detectors for PID
- scintillators
- large gaseous detectors
- prototypes of TPC
- semi-conductor detector for tracking
- calorimeter proto
- …

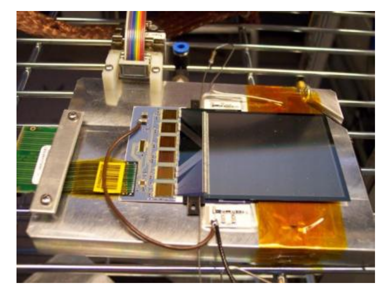




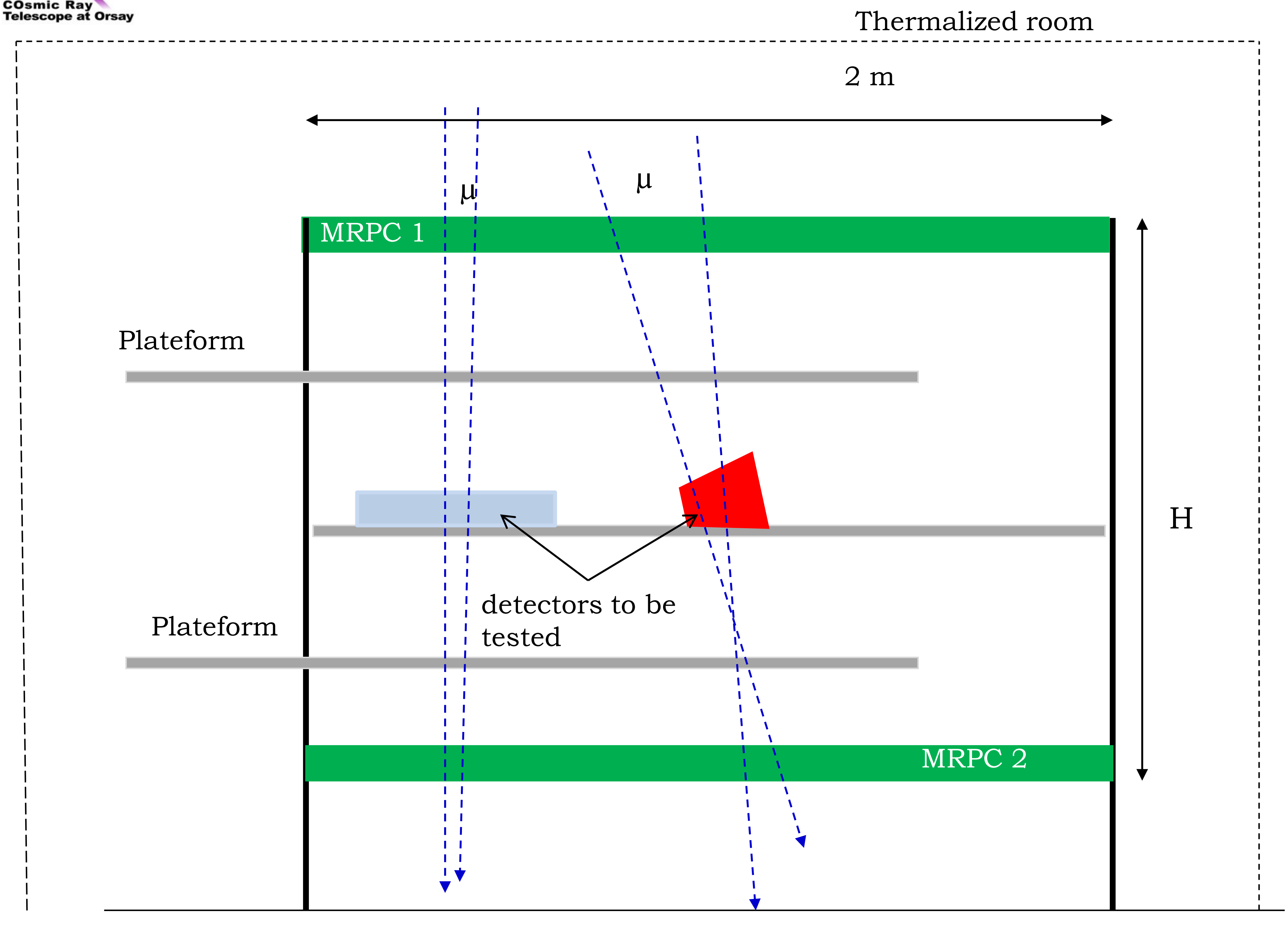








Principle of CORTO

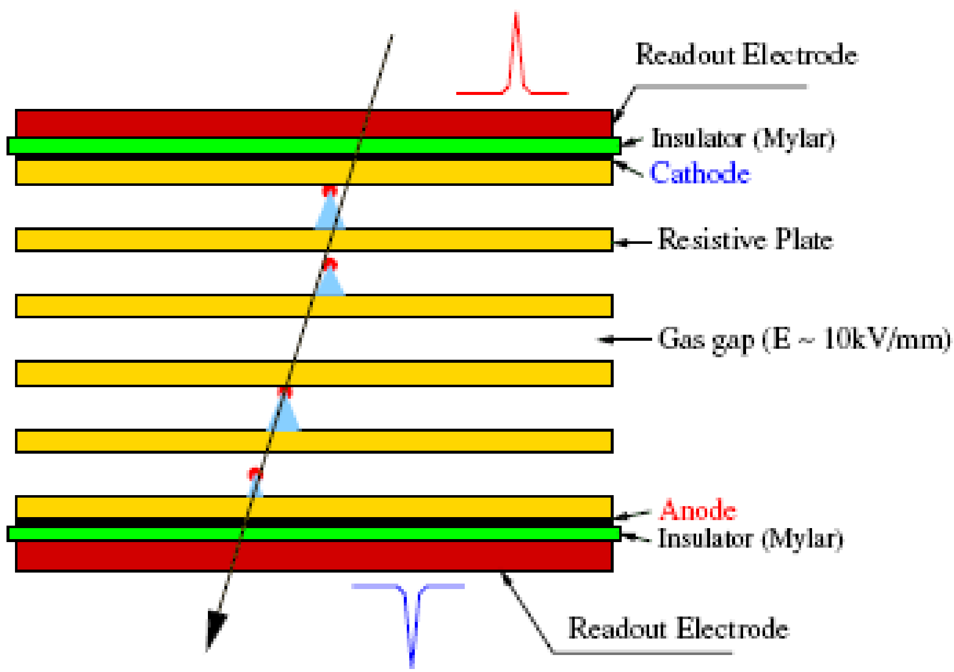


Hodoscope : use of the MRPC

Multi-gap Resistive Plate Chambers

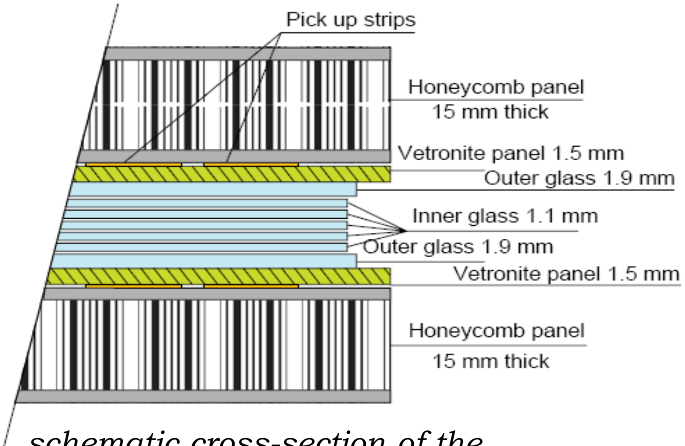
the gas volume in is divided into several gaps

the internal electrodes become transparent to the avalanches in each gap and the cumulative effect of all these avalanches is induced on the external electrodes



Hodoscope : use of the MRPCs developed and built at CERN

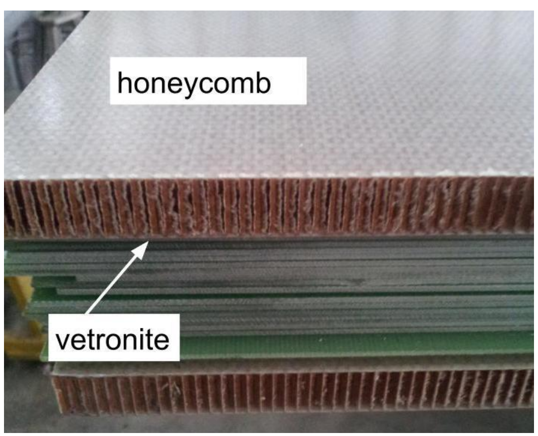
COsmic Ray Telescope at Orsay

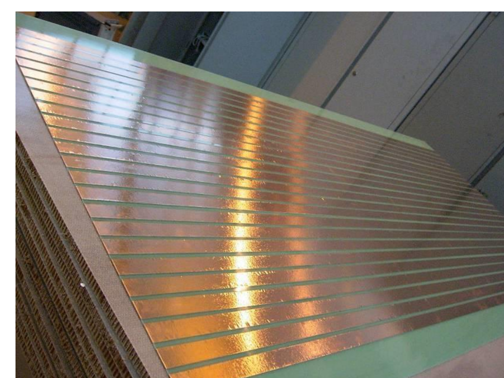


schematic cross-section of the MRPC. Each MRPC consists of six gas gaps (300 µm thick) obtained interleaving two glasses with five floating glasses.

Use of MRPC developed for another experiment (designed for the ALICE-TOF @ CERN) that fulfill our requirements.

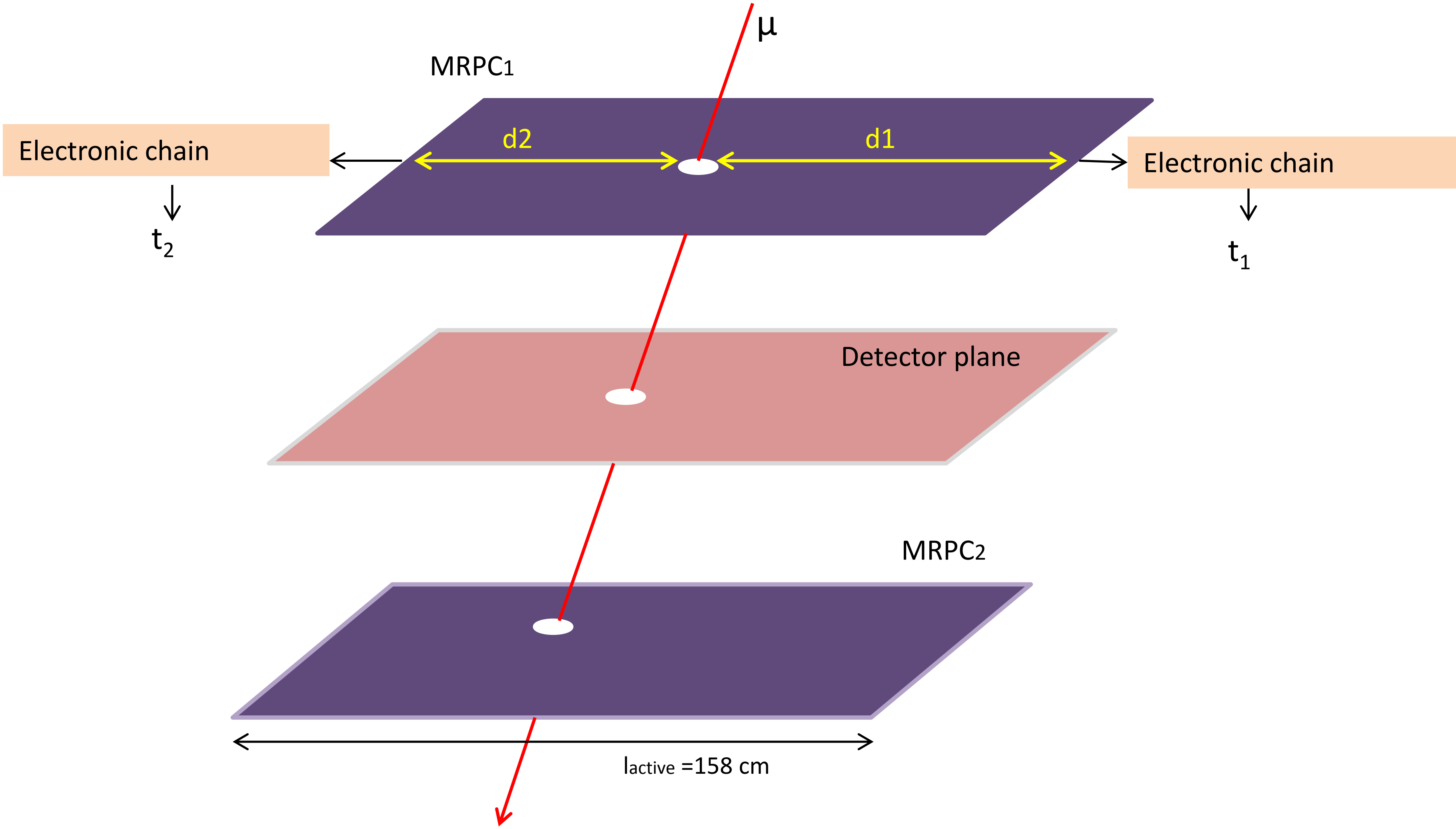
- Dimensions (L x l x e) = 200 x 100 x 6 cm^3
- active area : 180 x 80 cm^2
- gas: Freon $C_2H_2F_4$
- max HV : 20 kV





C. Williams, CERN   *D.W Kim, M. Kim, Univ Seoul*

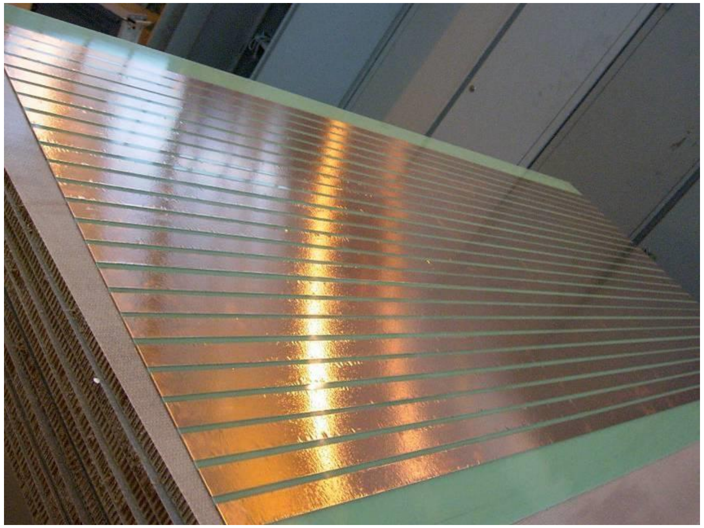
Principle of the μ track measurement



v : propagation speed of the signal in the strip

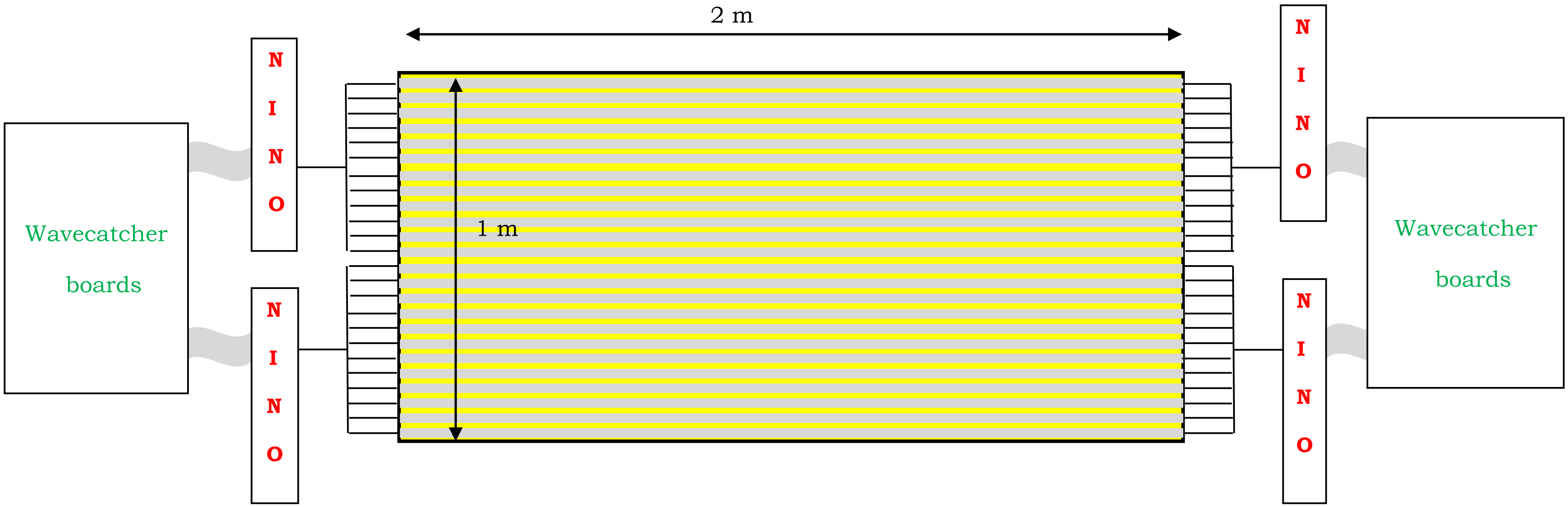
$$d_1 = v \times t_1$$
$$d_2 = v \times t_2$$

MRPC electrode and readout chain



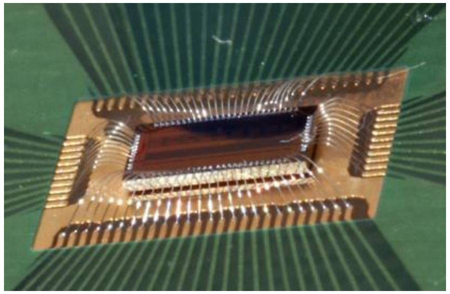
Segmented electrodes: 24 strips

Each strip: 2 m long, 25 mm wide



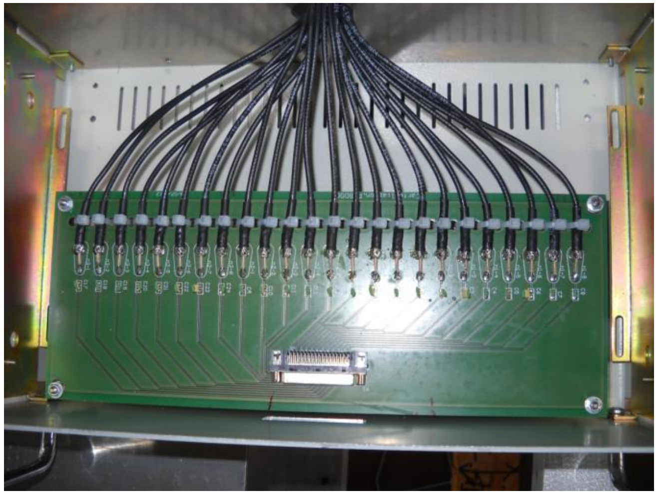
MRPC signal treatment

The signal collected on the strips is sent to front-end electronics based on ultra-fast camplifier/ discriminator cards based on NINO-ASIC chips developed at CERN (F. Anghinolfi).



- 8 channels → 6 NINO cards/ MRPC
- Timing resolution: jitter < 10 ps RMS

→ it is the coincidence of the NINO signals that gives the trigger



V. Chaumat, F. Campos

NINO output = LVDS signal
Wavecatcher input = unipolar signal

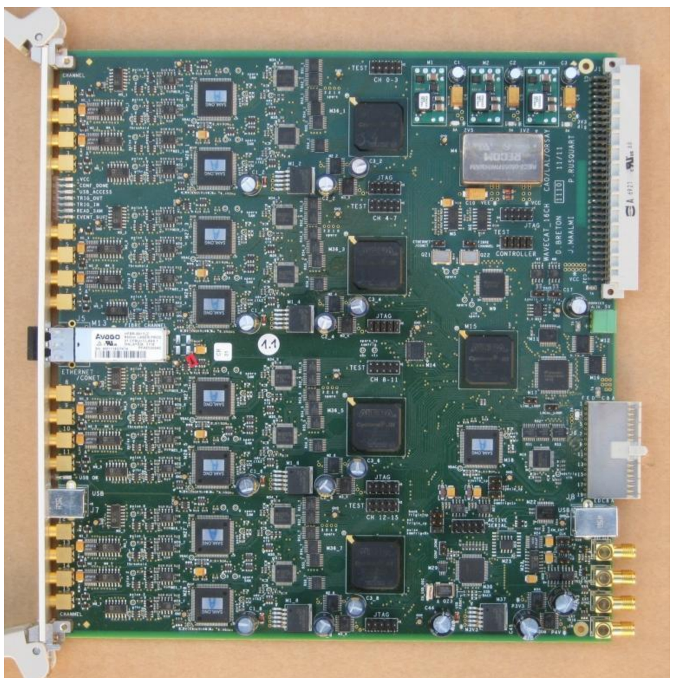
⇓

build of an interface card to connect the 2 systems

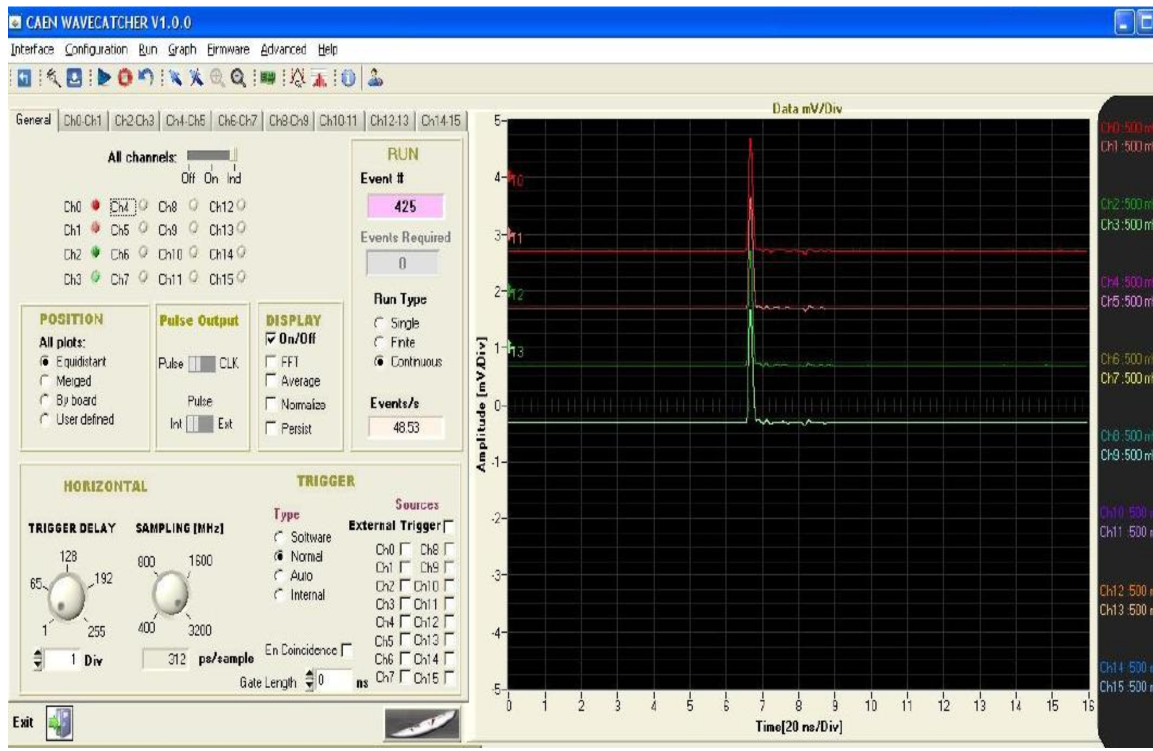
Readout of the NINO signals

All the electronics signals produced by the hodoscope will be read out by the WaveCatcher, a board (D. Breton, LAL – E. Delagnes, CEA) based on a new generation of ultra fast analog memories. The 16-channel WaveCatcher board provide high performances:

- 12-bit 500-MHz-bandwidth digitizers
- sampling between 400 MS/s and 3.2 GS/s
- time precision of 10 ps

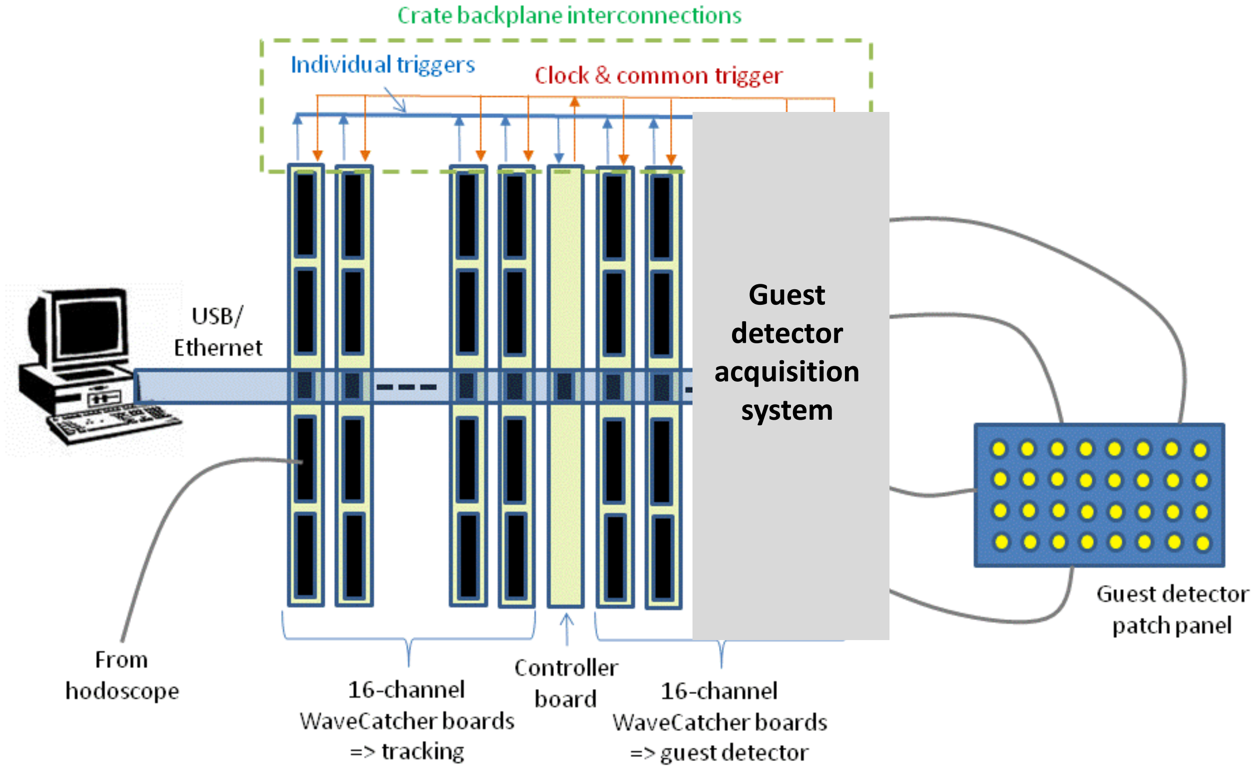


D. Breton, PhotoDet 2012



Analysis & interface software (J. Maalmi)

Acquisition system



The tracking system (hodoscope) requires <u>6 WaveCatcher boards</u>.

The readout of the detector under study in the telescope will be made either by WaveCatcher boards (4 boards, 64 channels), or by the user. For the first solution, a patch panel will be made available next to the telescope center to offer an easy interface for the user to connect his own signals from the guest detector under test. In the case of an acquisition performed by the user himself, the trigger of the telescope will be made available to synchronize the signals of the detectors with the telescope ones.

NARVAL

Nouvelle Acquisition temps Réel Version 1.14 Avec Linux

The data acquisition environment will be based on NARVAL (X. Grave, IPN) : an ADA framework for Distributed Acquisition Systems developed by IPN Orsay. NARVAL is a framework that eases setting up of experimental data acquisition. It is written in ADA (using object oriented programming), and supports user plugins written in C or C++.

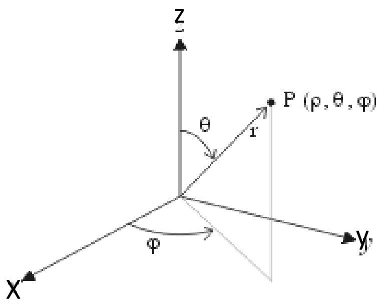
NARVAL users:

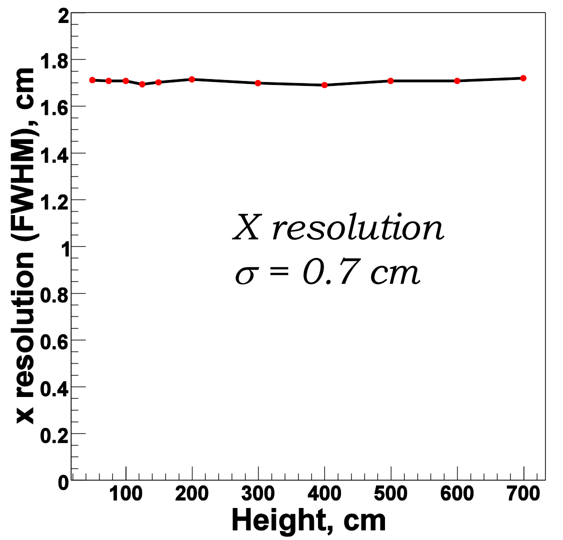
- l'IPN : ALTO, ANDROMEDE, DataFlow d'AGATA
- le CSNSM : scanning table of AGATA
- le GANIL : official DAQ
- le LPC Caen : Faster

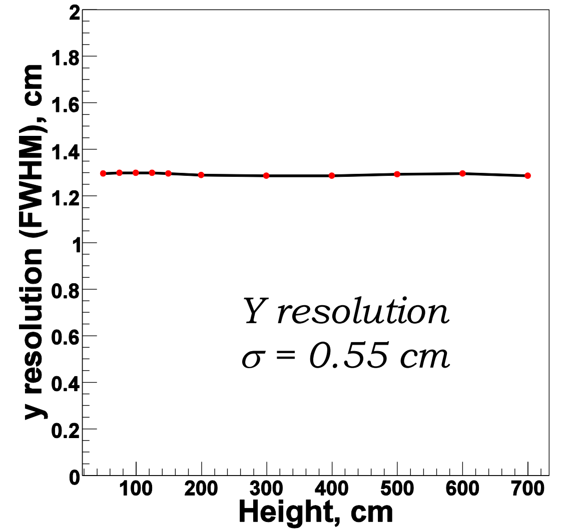
NARVAL for CORTO :

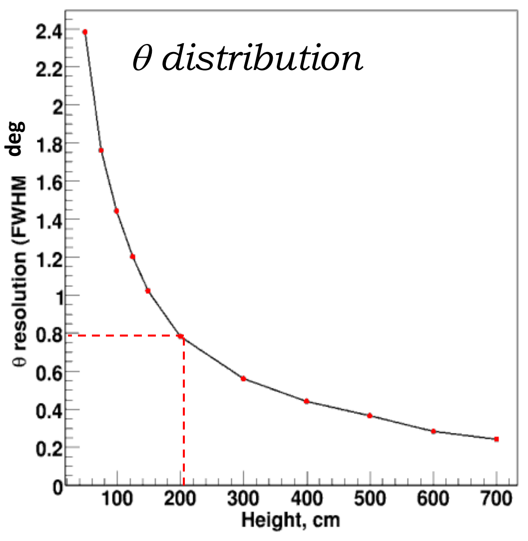
- ➢ Readout of the WaveCatcher signals
- ➢ Filter generation (selection of tracks)
- ➢ Event builder
- ➢ Histogramming
- ➢ Store data online

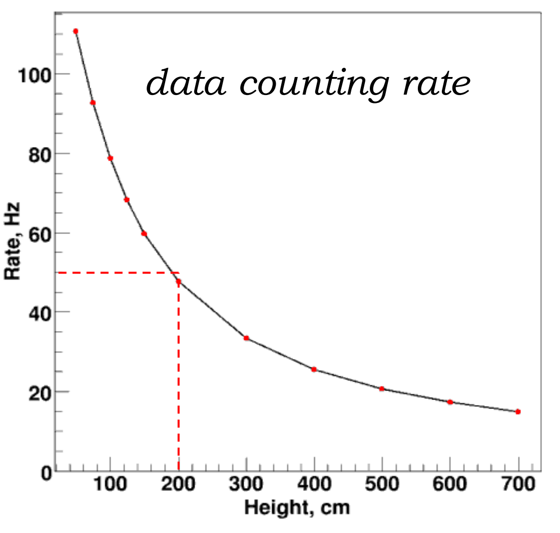
Simulation of CORTO





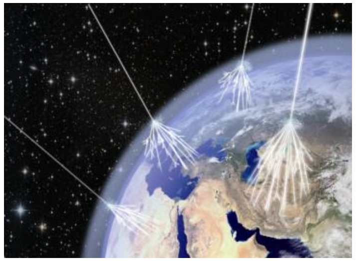






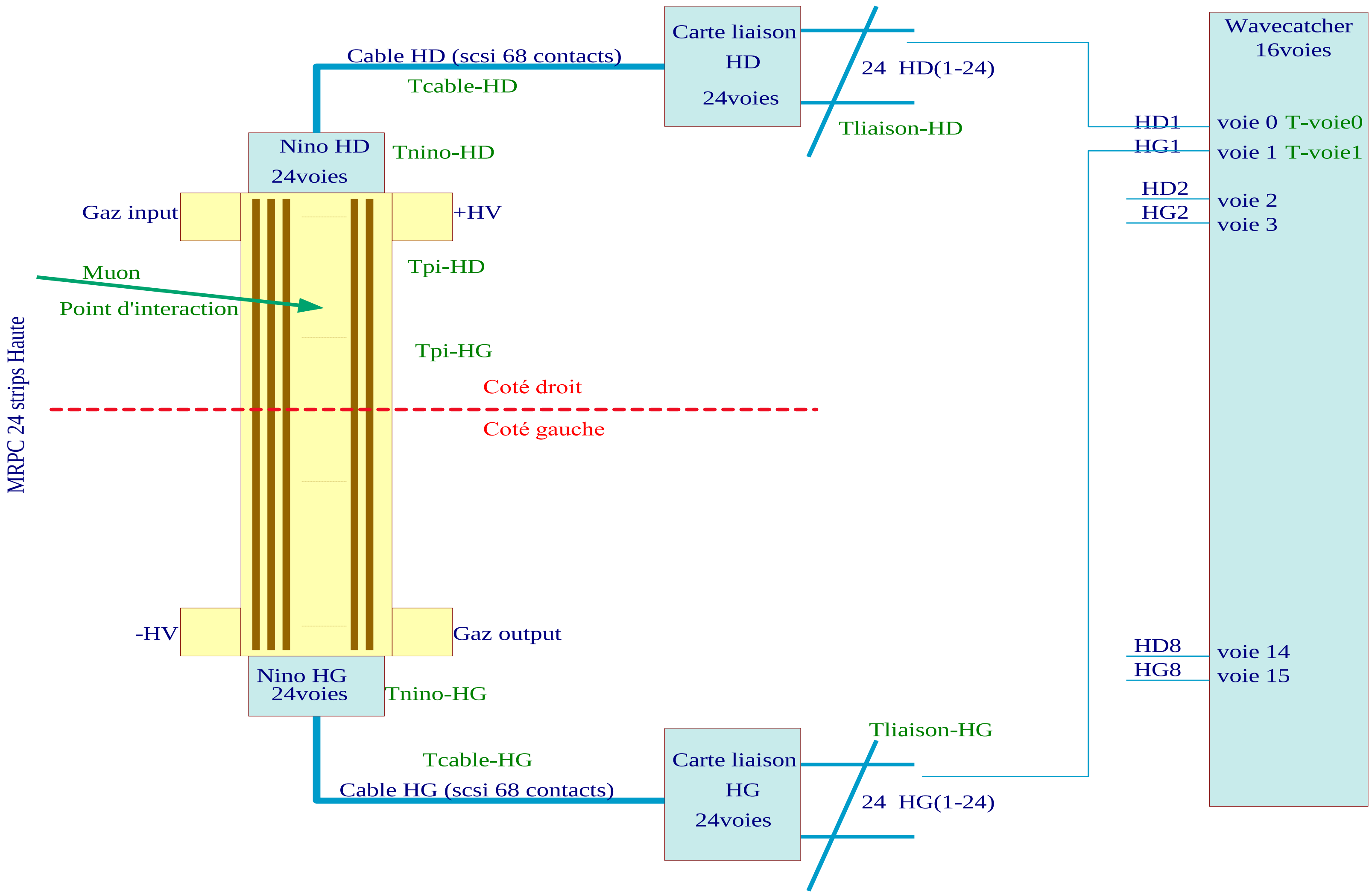
L. Burmistrov

CORTO specifications



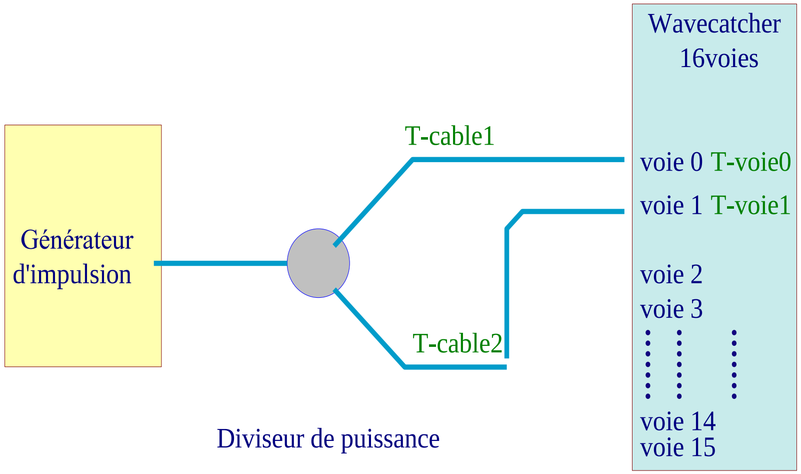
- Effective area = 1,28 m^2
- Angular resolution < 1° in θ and 3° in φ
- Position resolution ~ 1 cm^2
- Counting rate ~40 events s^{-1}
- Time resolution ~ 70 ps
- Registration efficiency > 95 %
- User-friendly acquisition interface

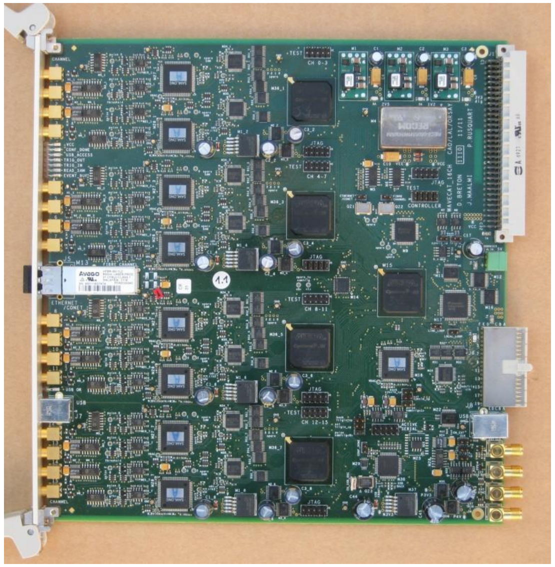
Electronics diagram of CORTO

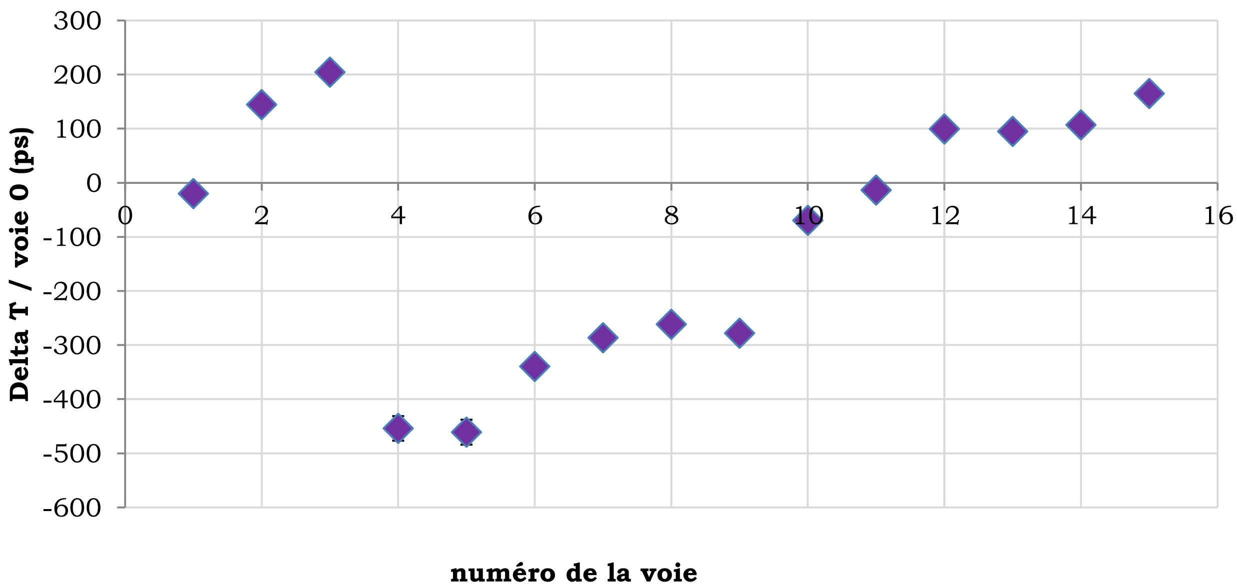


V. Chaumat

Calibration of the WaveCatcher boards





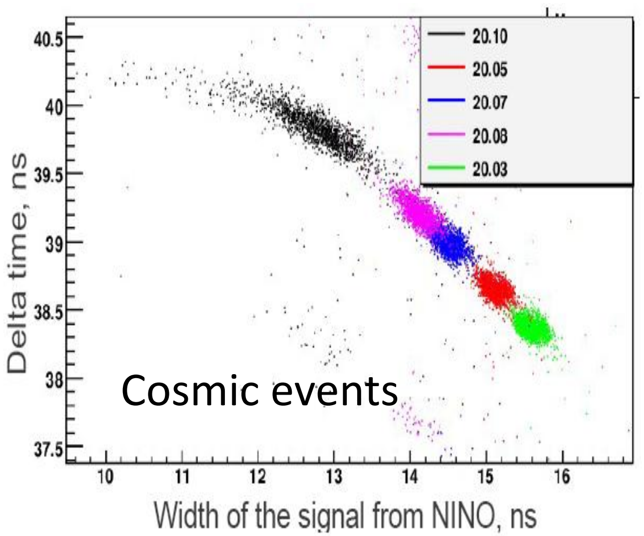


Timing difference of the channels 2 to 15 with the channel 0

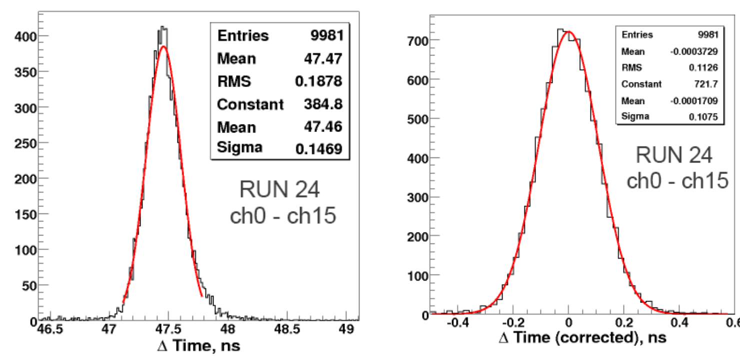
V. Chaumat, E. Bals, C. Sylvia

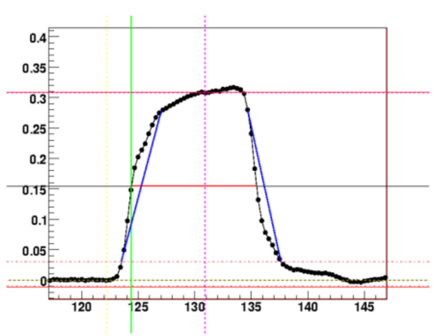
Calibration of the NINO boards

First try: we performed the NINO calibration by injecting a signal on the channels corresponding to the right and the left side of each strip and measuring the difference of time (Δt) between the 2 NINO outputs … Bad idea because Δt varies linearly as a function of the width of the signal



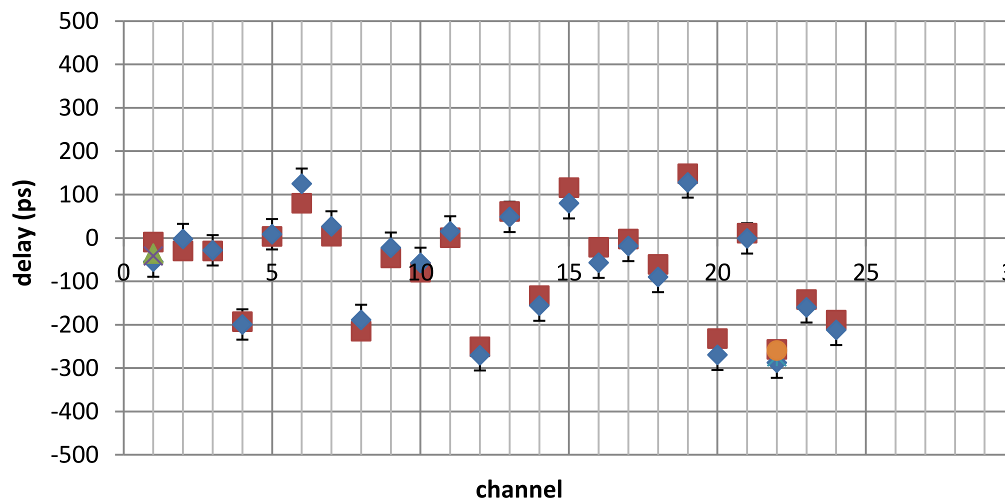
We perform again this calibration with different width of signal





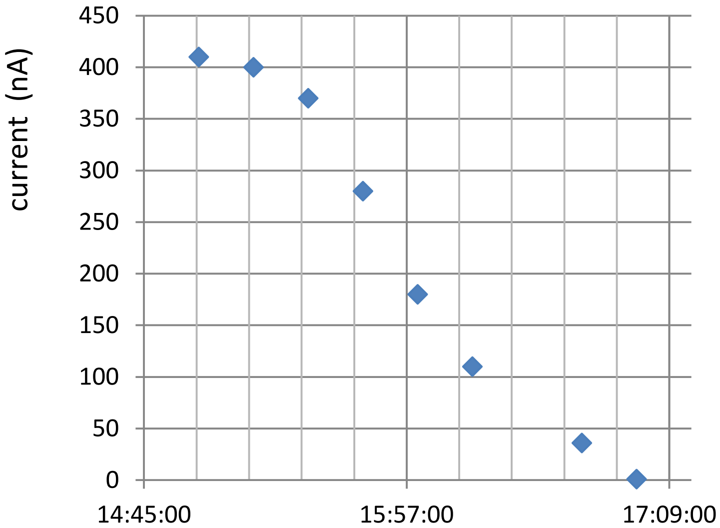
NINO signal

Δt between right and left of a strip after correction

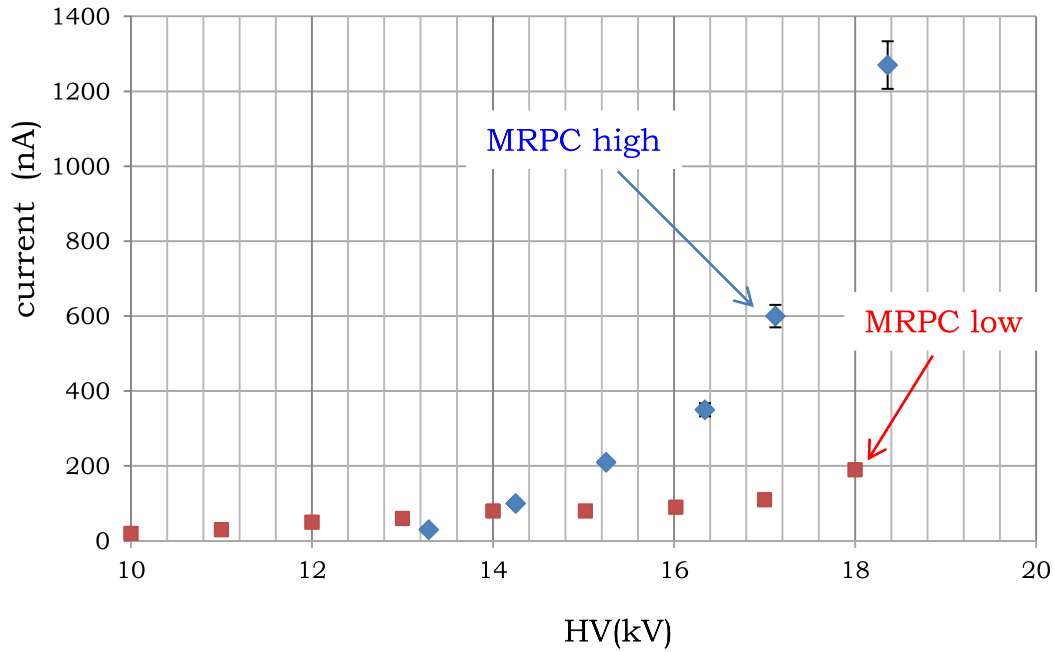


MRPCs tests

current(nA) à 15KV



Id as a function of the bias voltage



At lower voltages the primary ionization cluster formations does not lead to avalanches. As the voltage increases there is an increased gas gain and the current becomes substantial.

The current is determined mainly by the resistance of the spacers, the gas composition and the applied voltage

MRPCs tests

Other resistance tests (not planed ...)

✓ Bias a the MRPC at the maximum voltage (20 kV) in 1 s instead of 1 mn

→ OK ...

✓ Inflating due to an overpressure

→ OK ...

✓ Bias voltage >> max : 22 kV instead of 20

→ OK ...

→ MRPC : robust detector ...

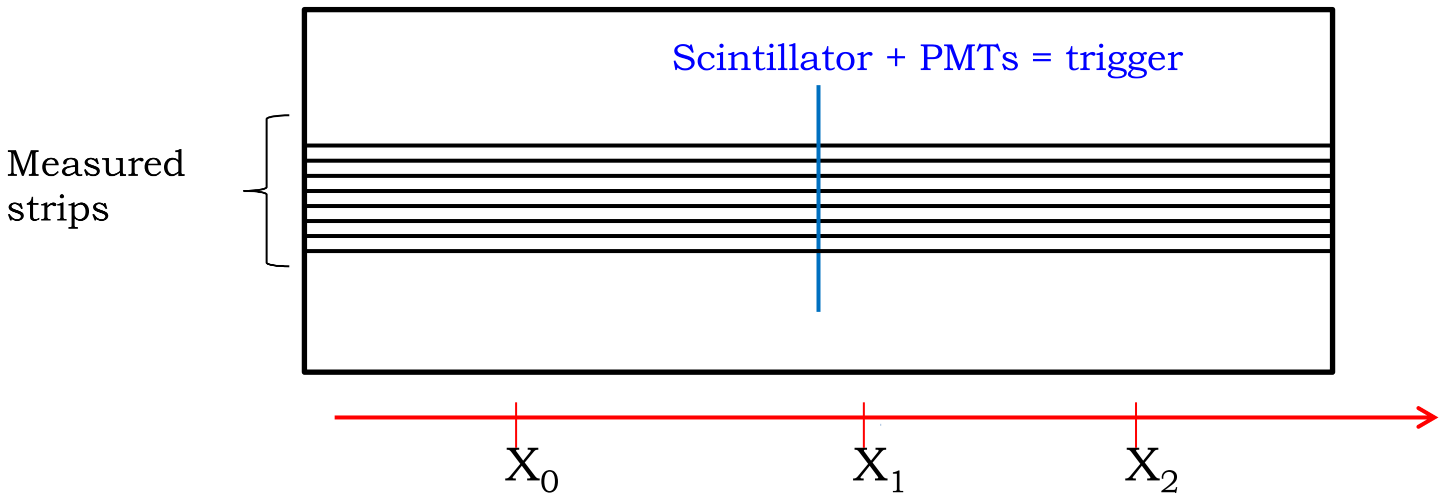
V. Chaumat, V. Puill, C. Sylvia

Study of the MRPCs: work under progress

- Location of the strips
- Efficiency measurement
- Timing resolution measurement
- Position resolution measurement

Need of a trigger system:

scintillator + PMT

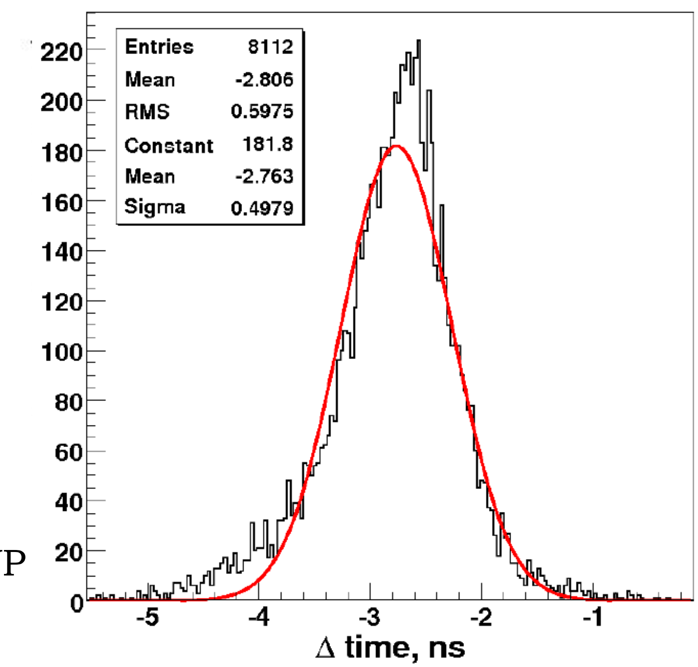


Trigger system: configuration 1

5 x 5 cm^2 trigger counters

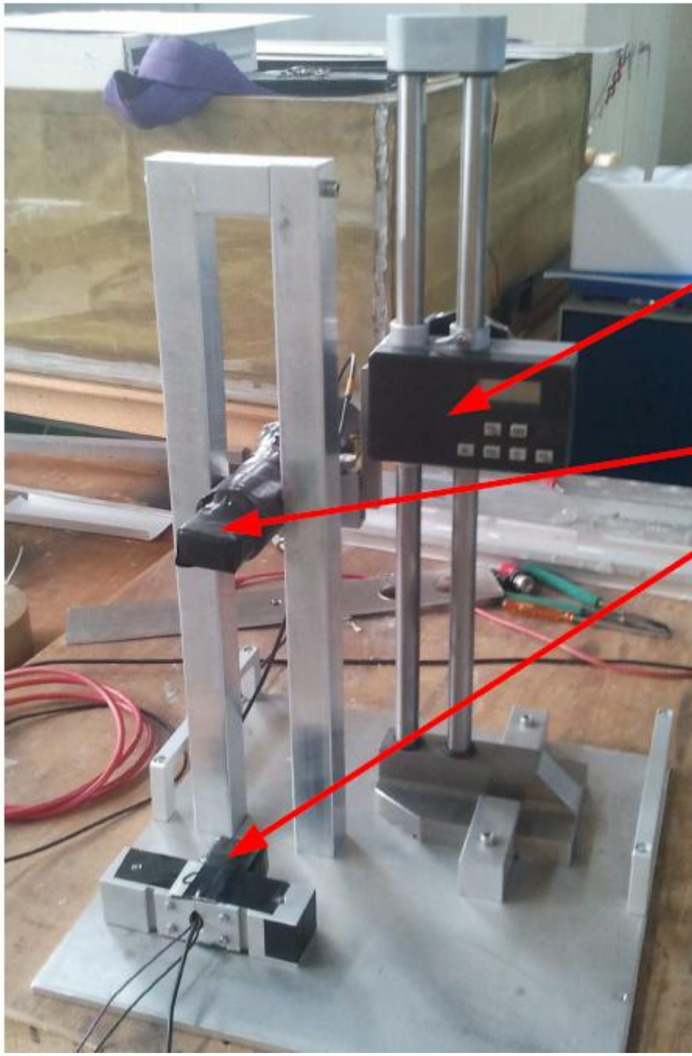
Two 50 x 50 x 15 mm^3 plastic scintillators + 56 AVP 03 A PMT

L. Burmistrov



Time resolution per channel = 498 ps /Sqrt (2) = **352 ps**

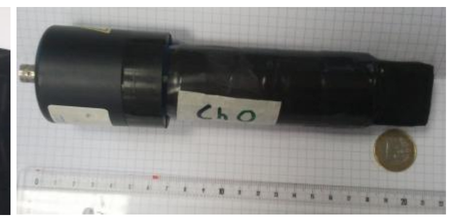
Trigger system: configuration 2

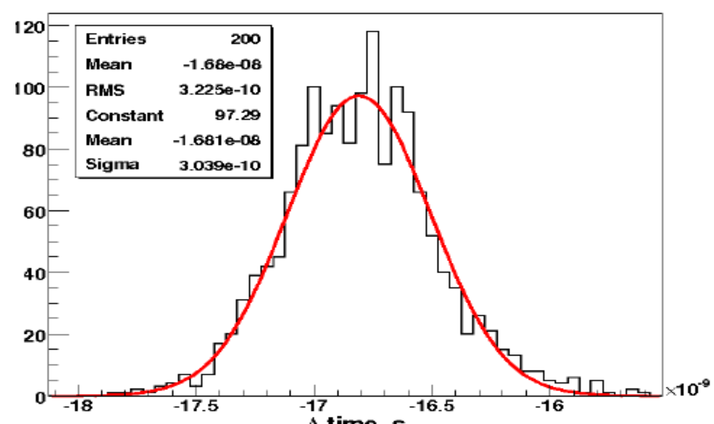


J.F Vagnucci

Measurements of the distance between detectors.

3 x 3 cm^2 triggers counters

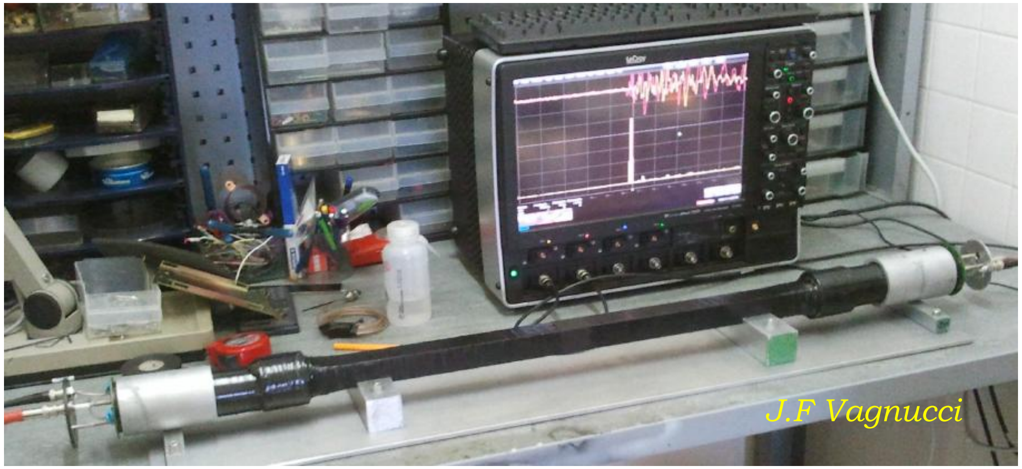




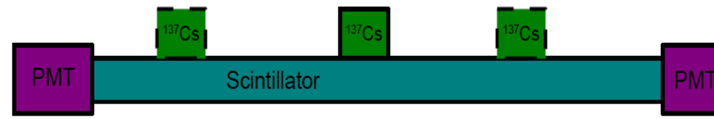
Time resolution per channel
= 304 ps /Sqrt (2) = **215 ps**

L. Burmistrov

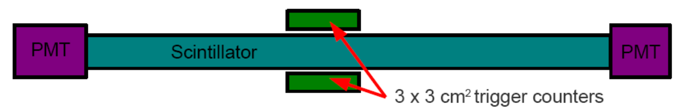
Trigger system: configuration 3



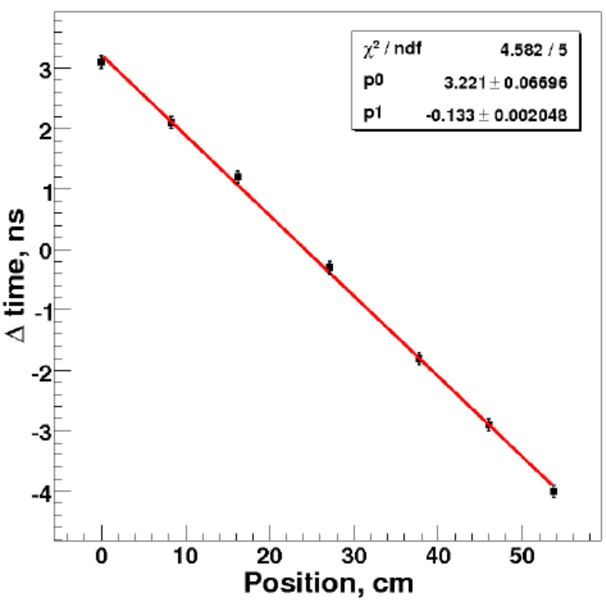
Calibration with a Cs137 source

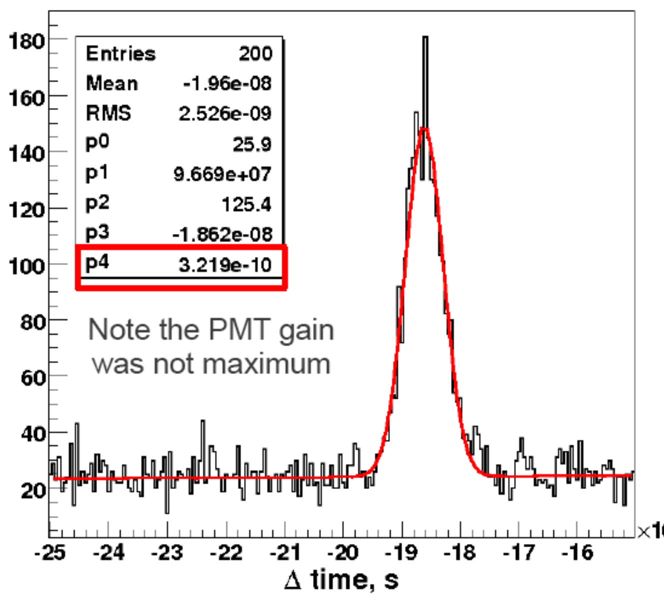


Calibration with Muons



Triggered by the TOP counter.



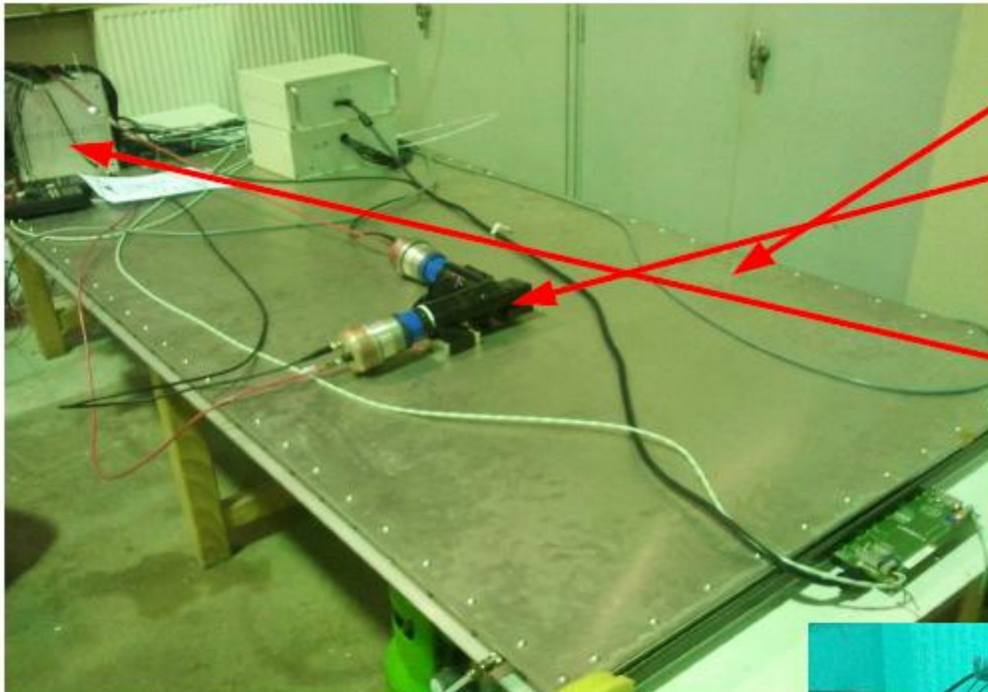


L. Burmistrov

Position resolution
= 322 [ps] /133[ps/cm] = **2.4 cm**

Should be 100 ps according to IPN → to be investigated

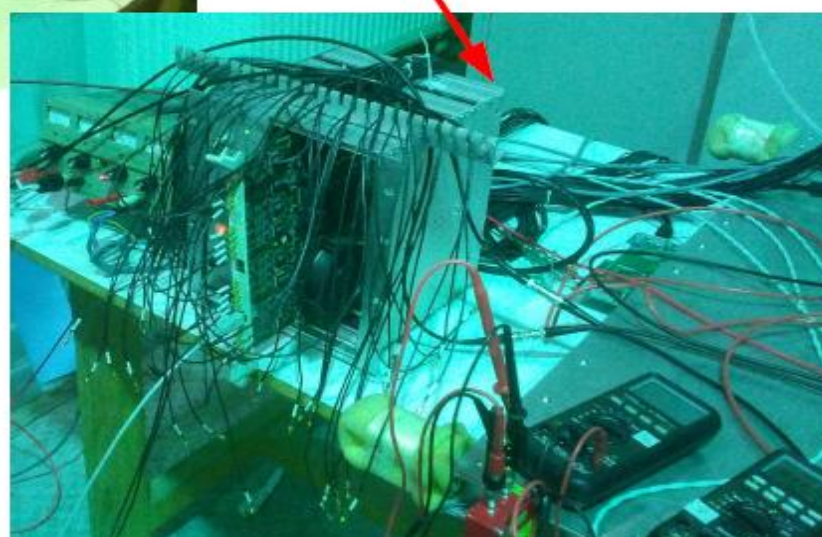
1ers tests of MRPCs with Muons



MRPC 2 x 1 m^2

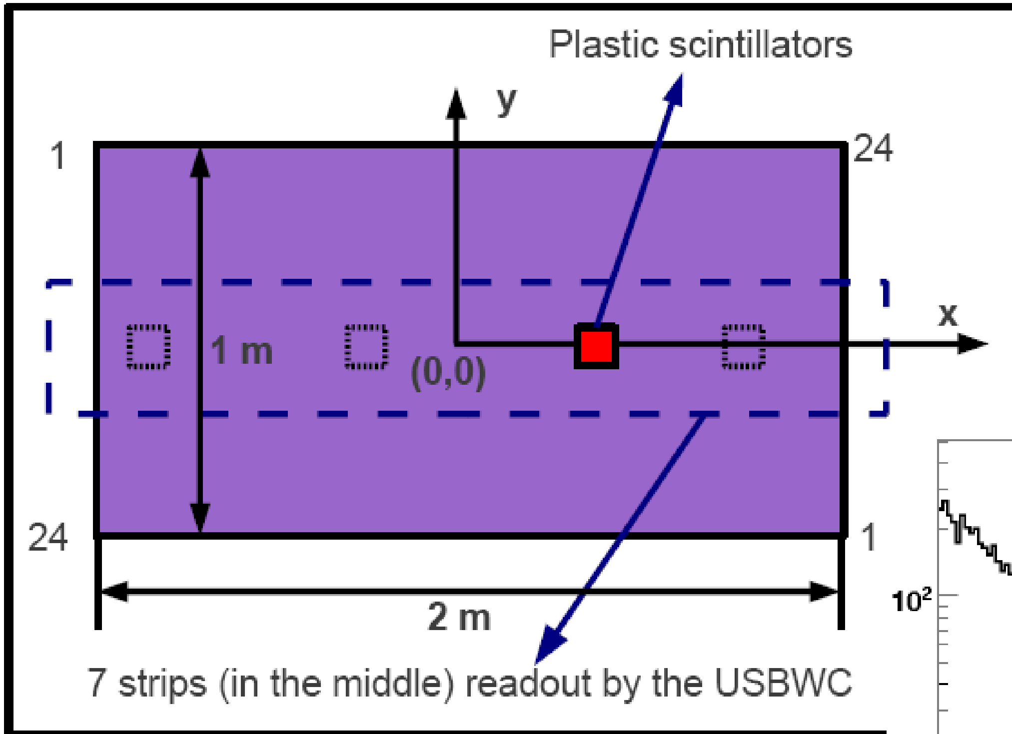
Two plastic scintillators attached to the PMT's 5 x 5 cm^2

7 strips (in the middle) readout by the USBWC



E. Bals, L. Burmistroc, V. Chaumat, V. Puill, C. Sylvia

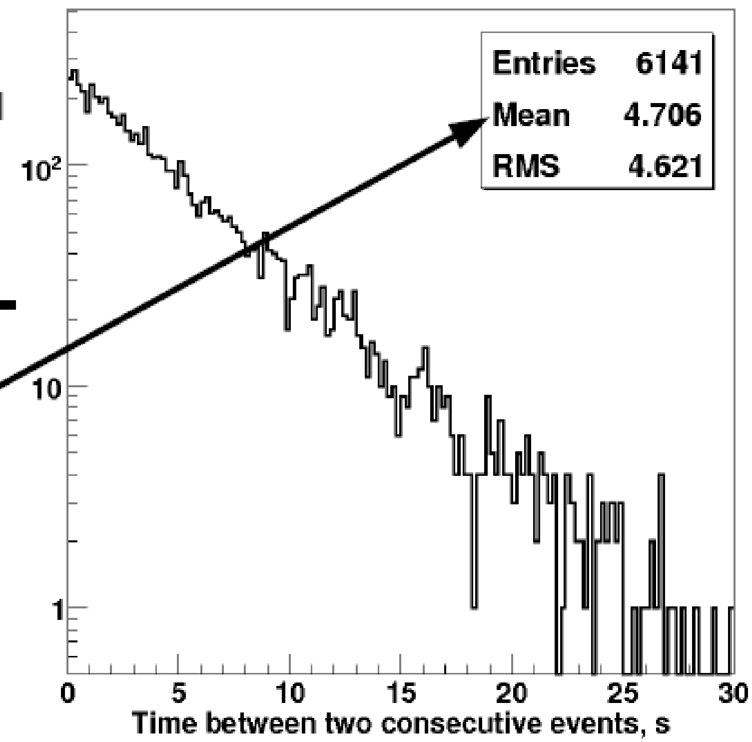
1ers tests of MRPCs with Muons



HV (MRPC) +/- 7 kV
Makes in total 14 kV.

We measure detector response on muons in different places.

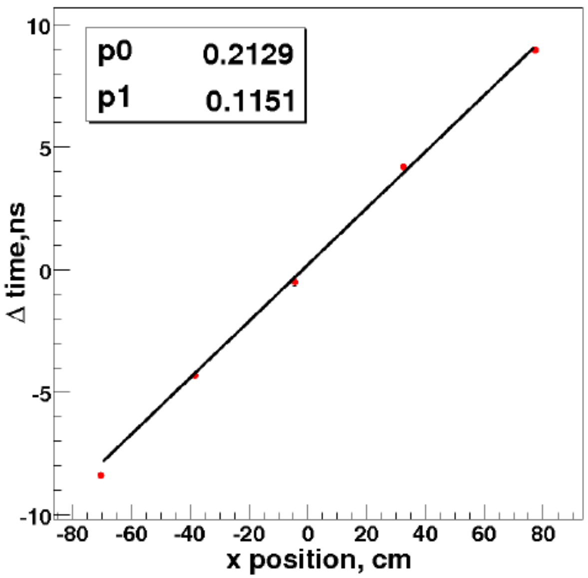
Muons detected by the triggers (plastic scintillators).

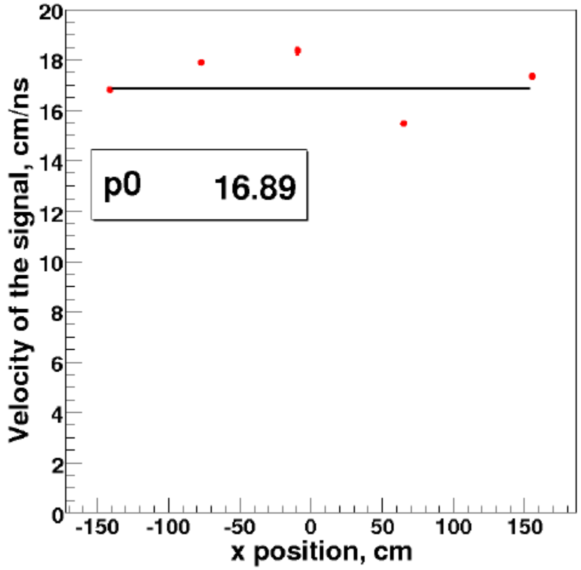


We detect muon every ~ 4.7 s

1ers tests of MRPCs with Muons

1st results

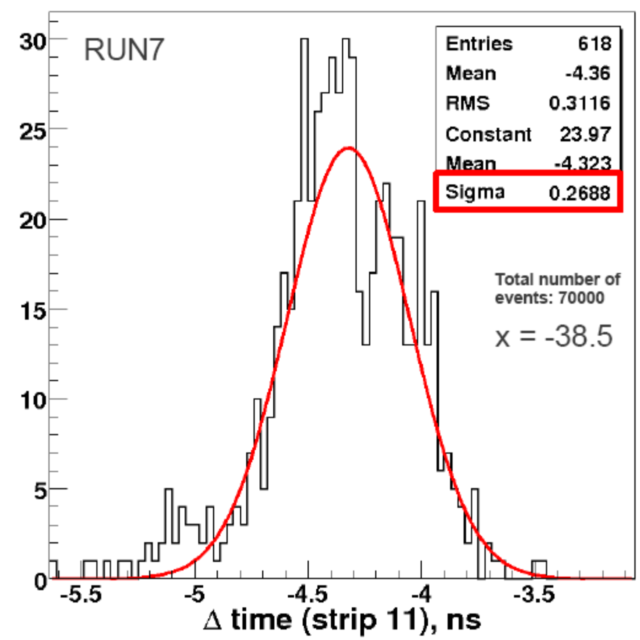




Speed of the signal inside the strip ≈ 16.8 cm/ns

Best timing resolution ~150 – 200 ps

But results with 400 ps … → more systematics studies needed



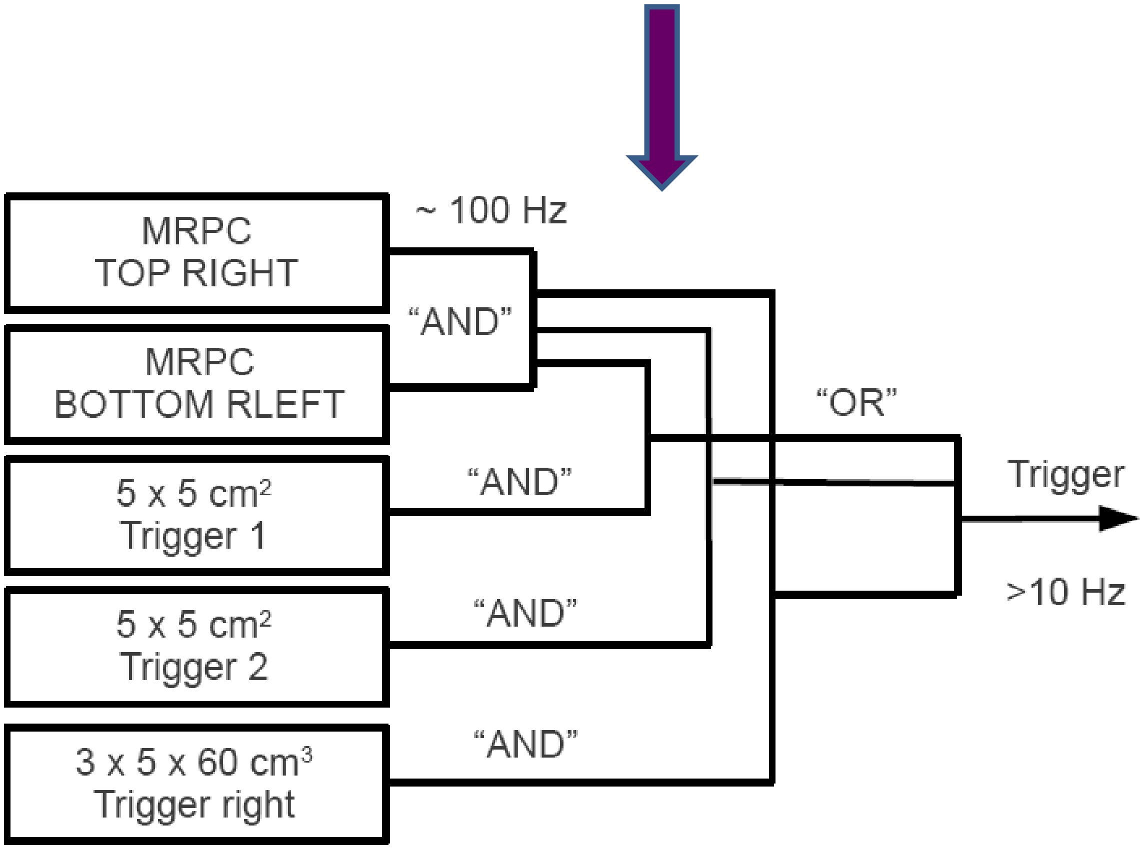
L. Burmistrov

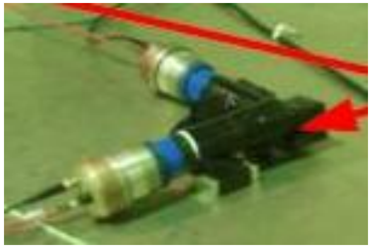
Temporary readout chain

64ch Wavecatcher crate not yet available → build of a temporary chain with 32 channels

Each NINO card has a common « OR » output signal

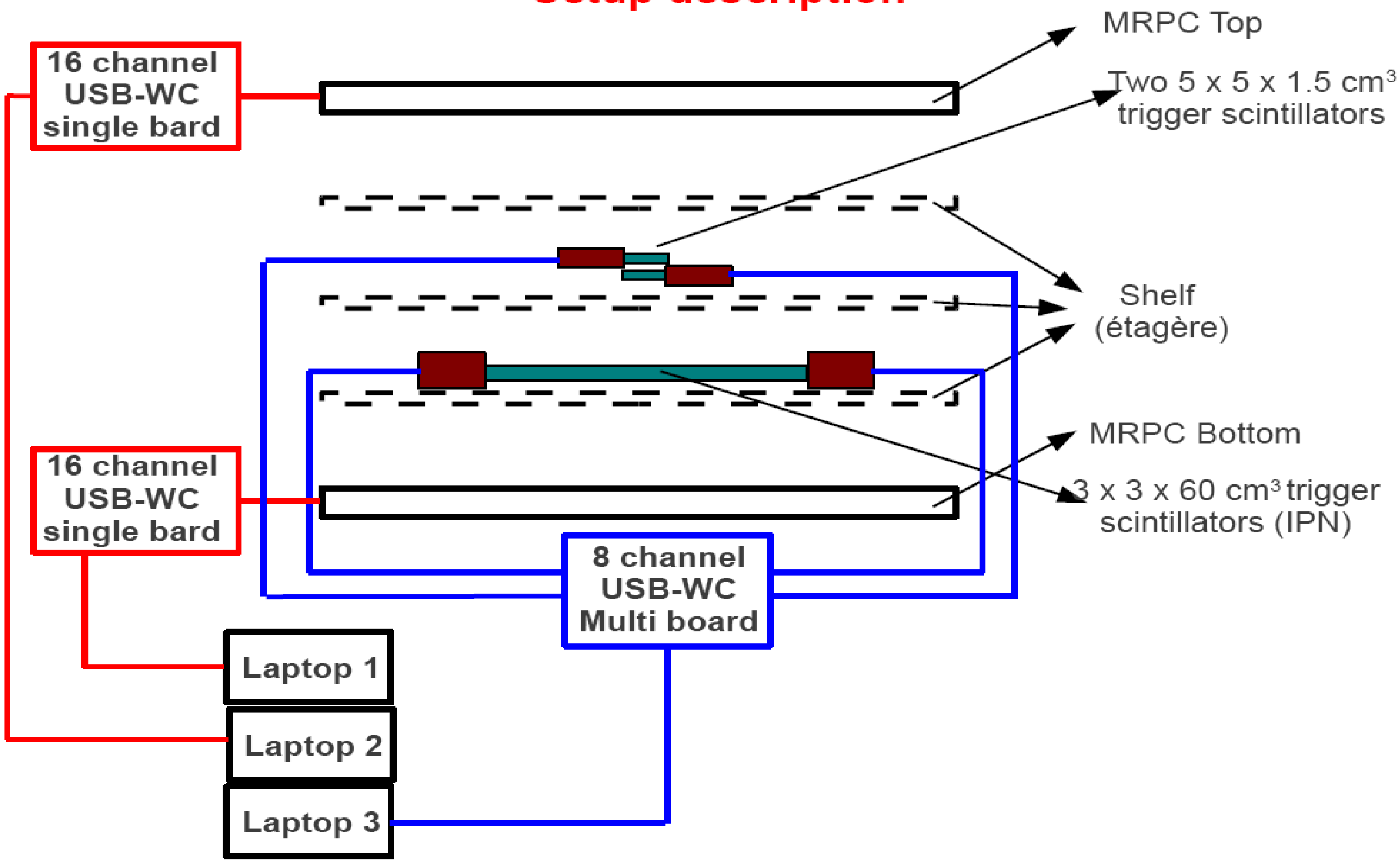
We use the scintillator configurations 1 + 3 and use them in coincidence with the « OR » of the MRPC to trigger for the WaveCatcher boards





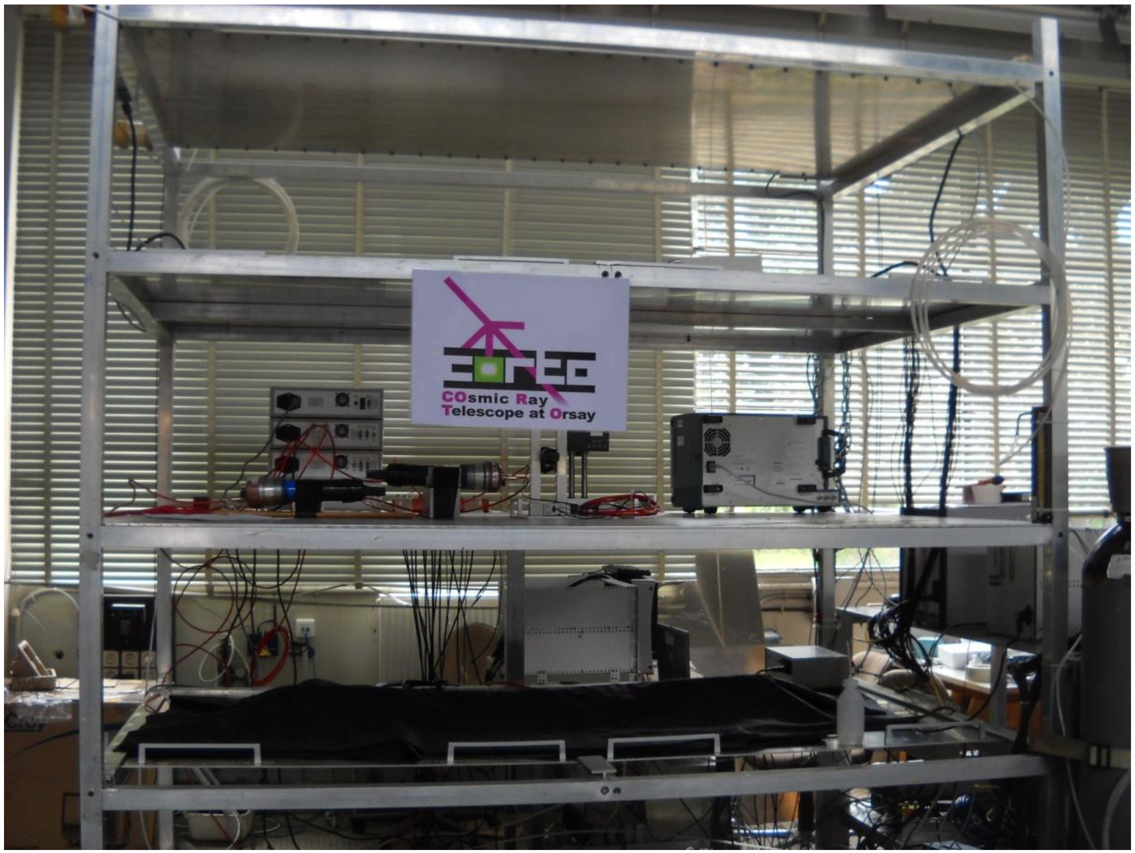
Temporary readout chain

Setup description



The 3 DAQ laptops are running independently → need to be synchronized in time in order to merge the date between them.

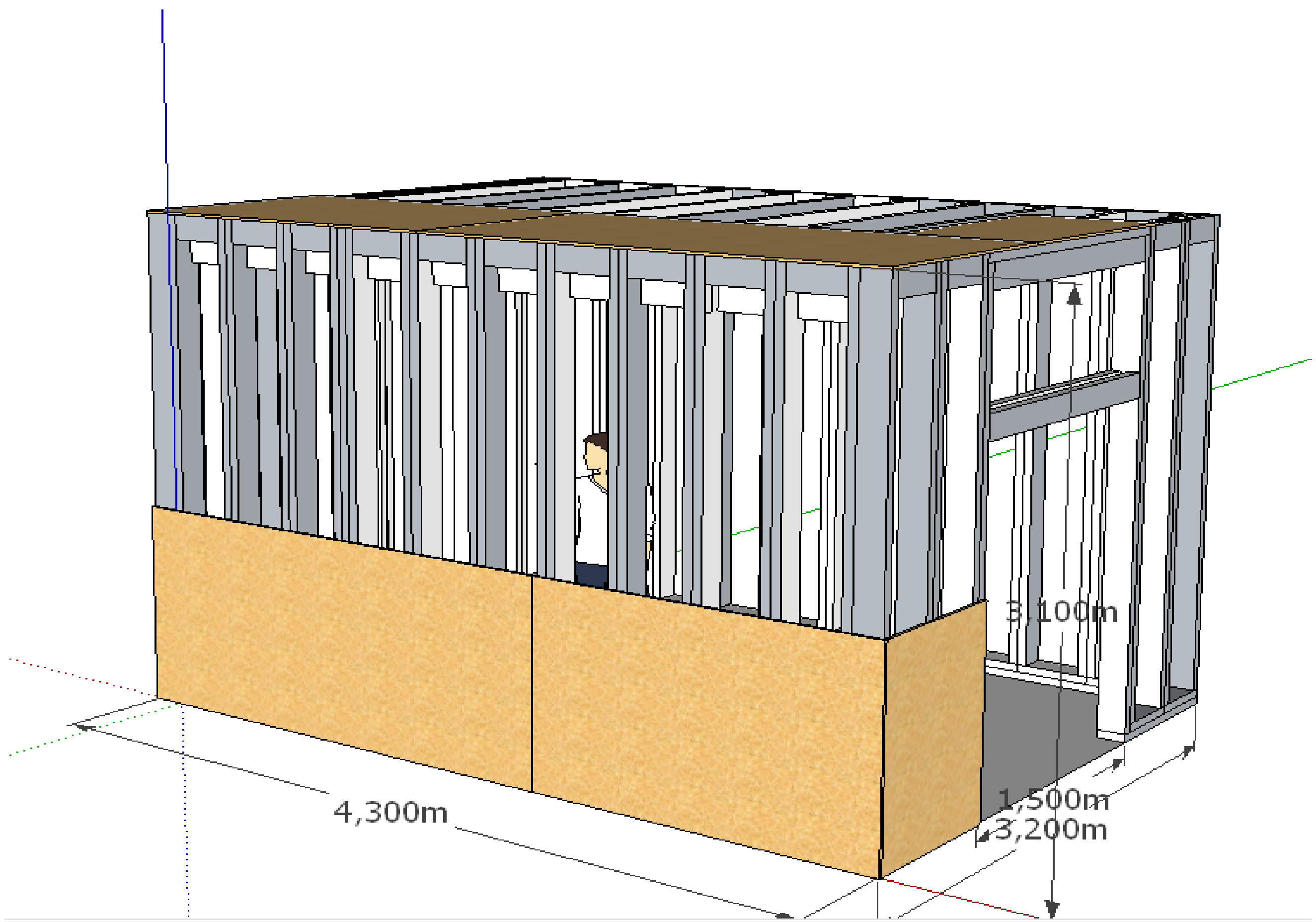
CORTO today



Metalic structure built by J.F Vagnucci

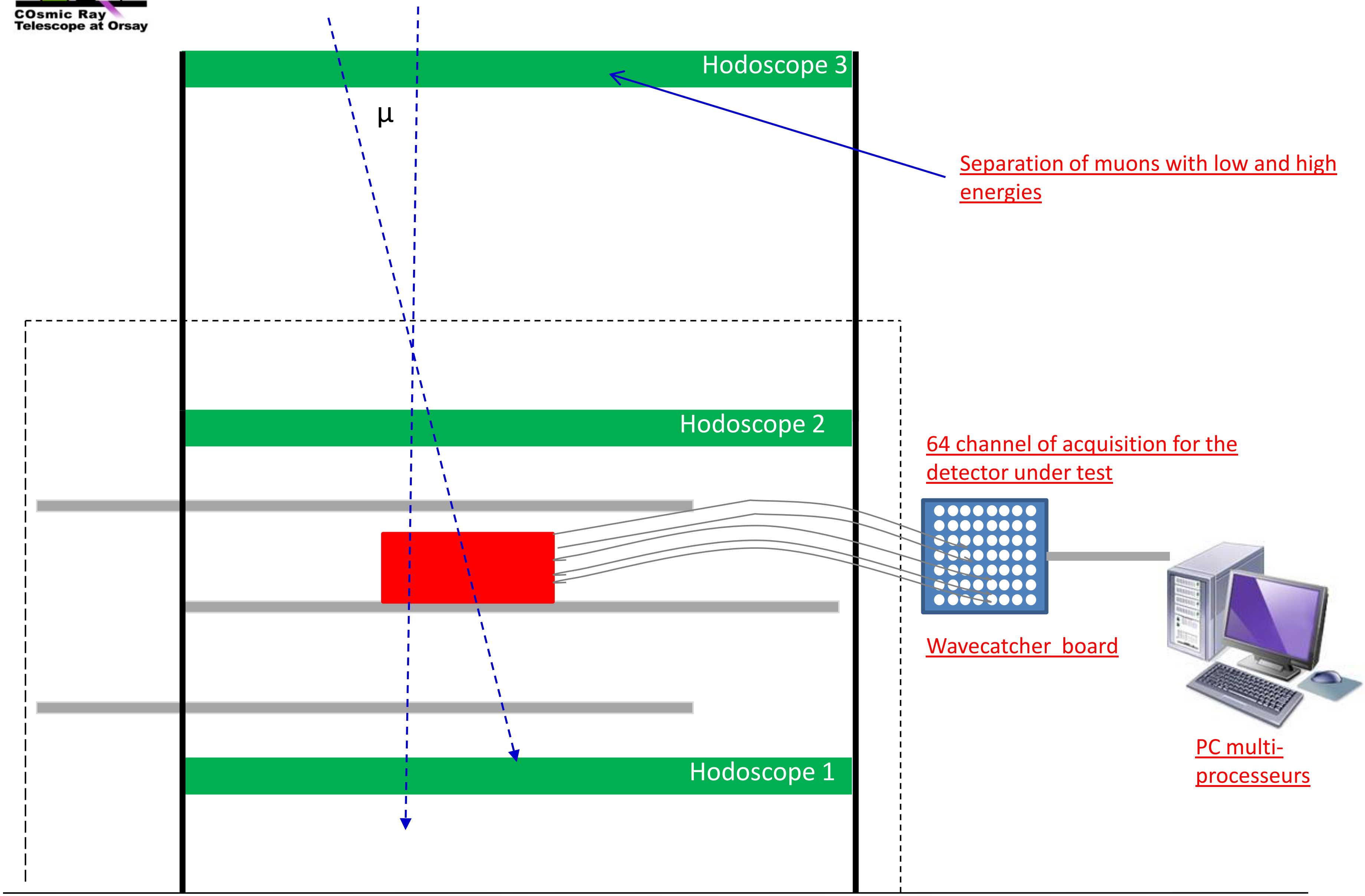
Next step 1: the CORTO casemate

Will be built this Autumn (with wood) with air conditioning (+/- 2 °C of variation) and gas leakage detection.

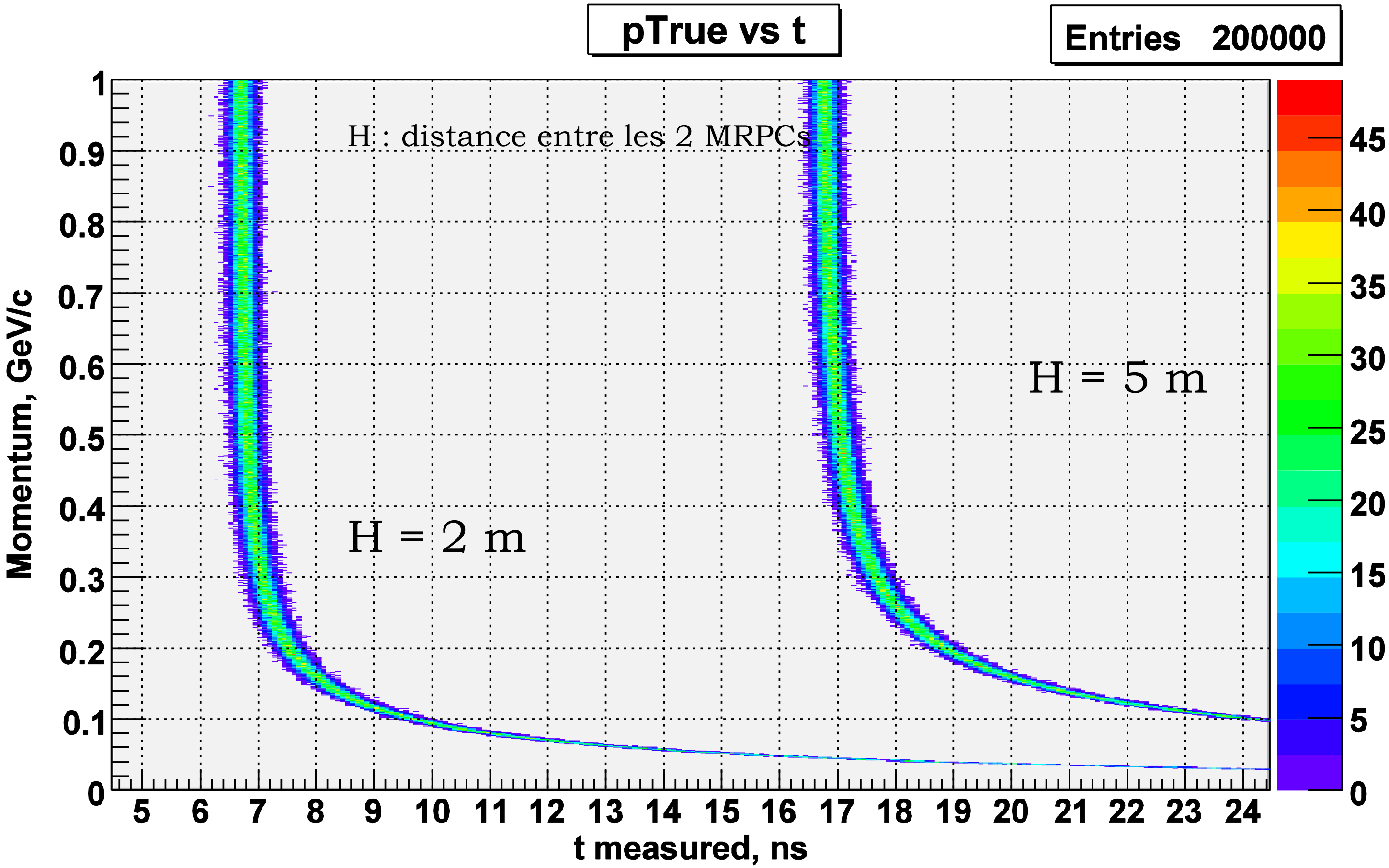


F. Campos

Next step 2: Upgrade of CORTO



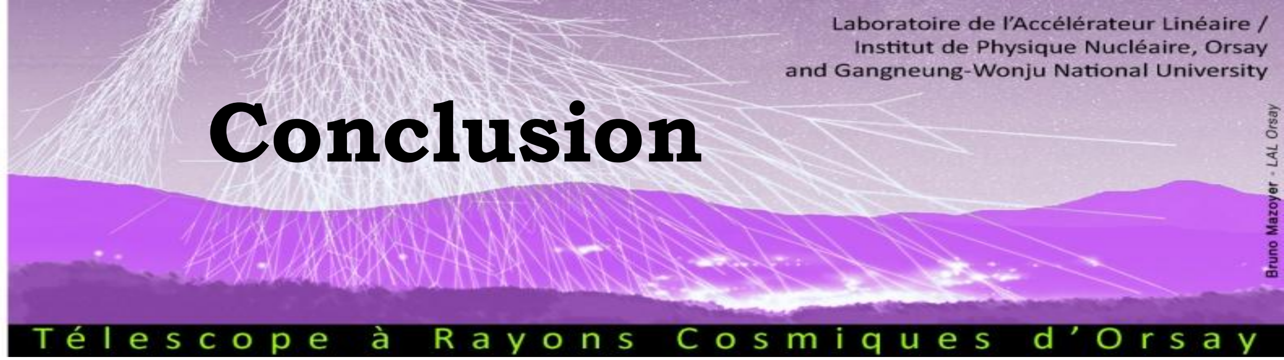
Muon separation power



muon separation power between 0.4 GeV/c and 2 GeV/c momentum as a function of L

Conclusion

COsmic Ray Telescope at Orsay



CORTO is a local project with 2 aims:

- build a cosmic rays platform for the study of Particles detectors for High Energy Physics, Nuclear Physics, …
- participate to the laboratory work of the Master classes of Orsay

✓ the calibration of the electronic chain is made
✓ the calibration of the MRPC is ongoing
✓ the mounting of the acquisition chain is just finished → first tracks soon

Planned upgrade before the end of the year: third detection plane

Upgrade not financed: build of a calorimeter for the determination of the Muon range of energy.

NINO

An ultra fast front-end preamplifier-discriminator chip NINO has been developed for use in the ALICE Time-Of-Flight detector. The chip has 8 channels. Each channel is designed with an amplifier with less than 1 ns peaking time, a discriminator with a minimum detection threshold of 10fC and an output stage.

The output pulse has minimum time jitter (less than 25ps) on the front edge, and the pulse width is dependent of the input signal charge. Each channel consumes 27mW, and the 8 channels fit in a 2x4mm^2 ASIC processed in IBM 0.25µm CMOS technology.

TABLE I
NINO CHIP SPECIFICATIONS

Parameter	Value
Peaking time	1ns
Signal range	100fC-2pC
Noise (with detector)	< 5000 e- rms
Front edge time jitter	< 25ps rms
Power consumption	30 mW/ch
Discriminator threshold	10fC to 100fC
Differential Input impedance	40Ω< Zin < 75Ω
Output interface	LVDS

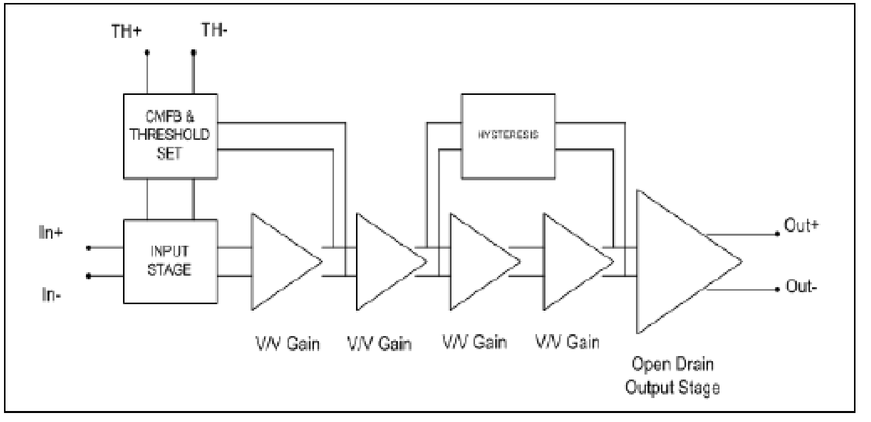


Fig. 1. Functional block diagram for one channel of the NINO chip.

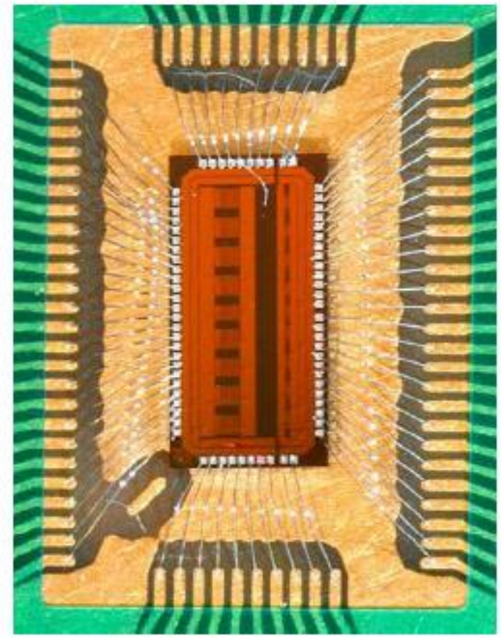
NINO Integrated Circuit

- **Implemented in a 0.25 µm CMOS technology**
- **Integrated Circuit is 2 × 4 mm^2**
- **8 channels**

  - Differential Inputs (can be operated in single-ended mode)
  - Differential design throughout the channel: differential outputs

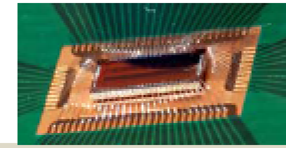
- **Fast low-power amplifier-discriminator**

  - Optimized to minimize jitter (1 ns peaking time)
  - Power consumption < 40 mW/channel
  - Time over Threshold measurement of input charge
  - developed for detectors with up to 10 pF capacitance

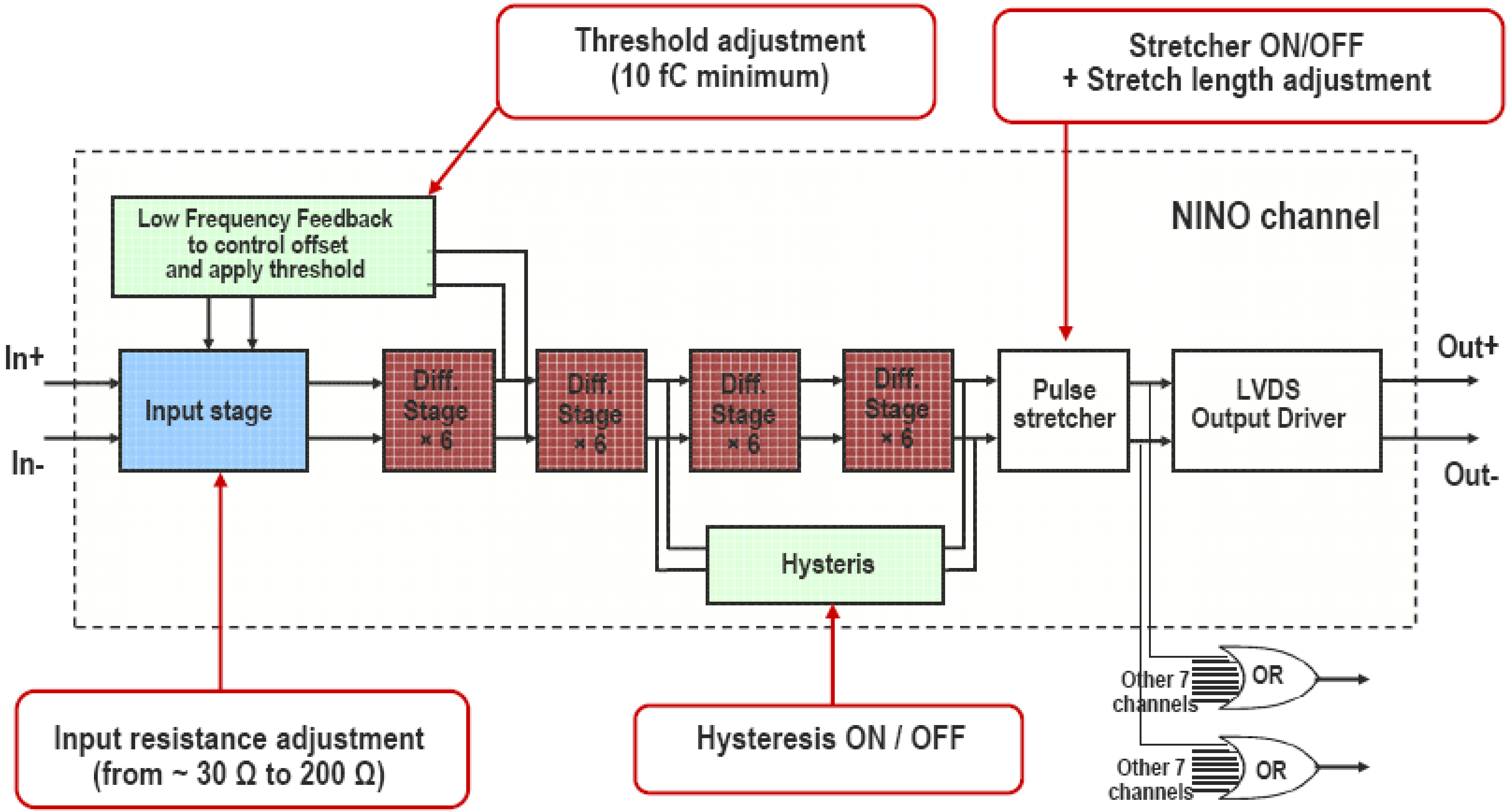


Picture of a NINO IC mounted on a PCB

NINO Integrated Circuit

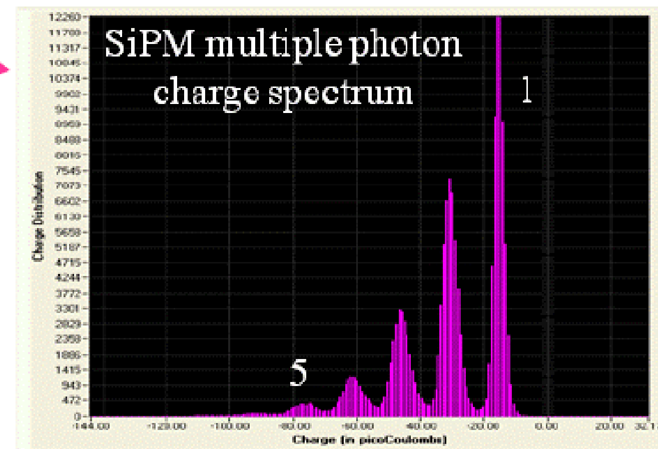


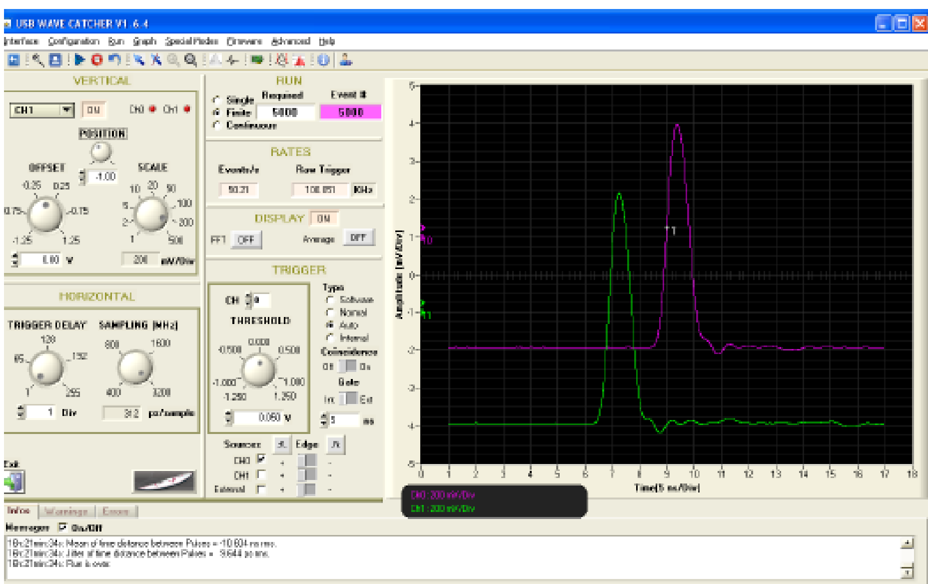
- Channel architecture



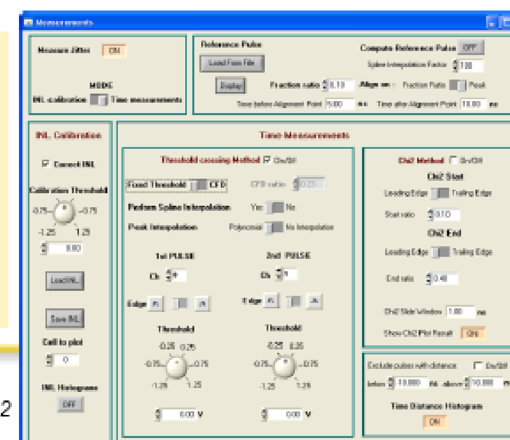
Board Specific Features

- Possibility to add **an individual DC offset** on each signal
- Individual **trigger discriminator** on each channel
- External and internal trigger + numerous modes of **triggering on coïncidence** (11 possibilities including two pulses on the same channel) => useful for afterpulse studies
- **Real time trigger counting** independent of acquisition rate
- **Embedded charge mode** (integration starts on threshold or at a fixed location) => high rates (~ 7 kEvents/s)
- **Embedded pulse generators** for reflectometry applications





This oscilloscope-like software was developed by the team.

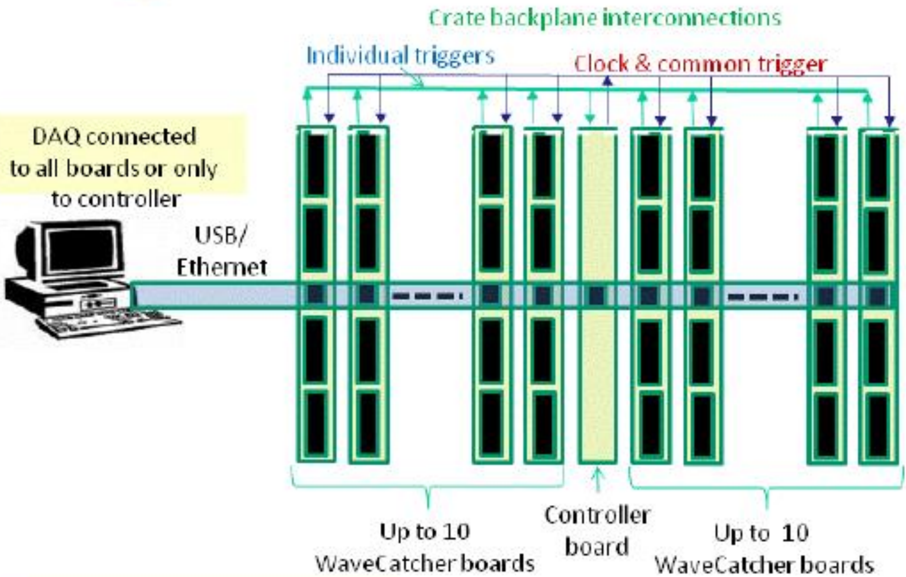


Summary of the WaveCatcher performances.

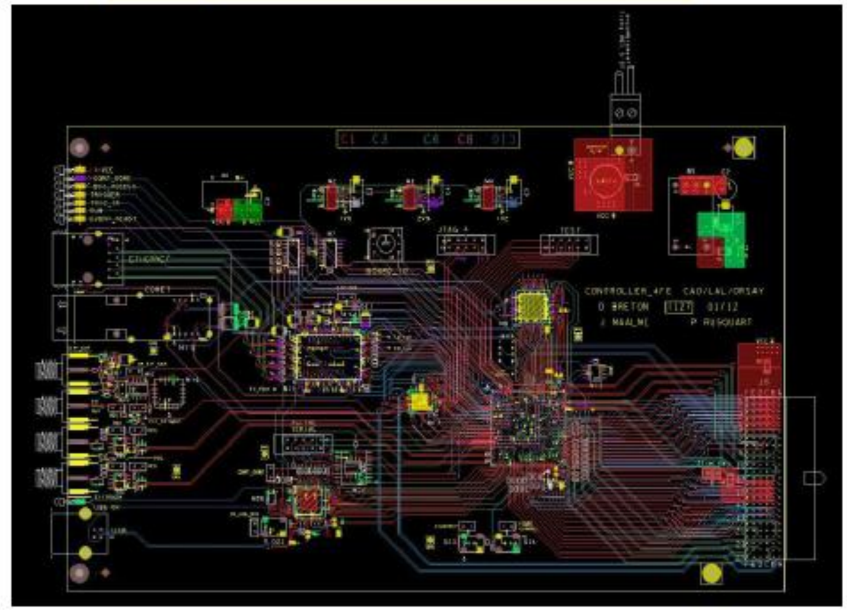
- **2** DC-coupled **1024-deep channels** with 50-Ohm active input impedance
- **±1.25V** dynamic Range, with full range 16-bit individual tunable offsets
- 2 individual **pulse generators** for test and reflectometry applications.
- On-board **charge integration** calculation.
- Integrated **raw trigger rate** counters
- **Bandwidth ~ 500MHz**
- **Signal/noise ratio**: **11.8 bits rms**
  (noise = **650 µV RMS**)
- **Sampling Frequency**: **400MS/s to 3.2GS/s**
- Max consumption on +5V: **0.5A**

- **Absolute time precision** in a channel (typical):
  - without time calibration: ~20ps rms (3.2GS/s)
  - **after time calibration** **~10ps rms** (3.2GS/s)
- **Relative time precision** between channels: **<5ps rms**.
- **Trigger sources**: software, external, internal, threshold on signals,
- **11 modes of trigger** coincidence
- Acquisition rate (**full events**) Up to **~1 kHz** over 2 full channels
- Acquisition rate (**charge mode**) Up to **~7 kHz** over 2 channels

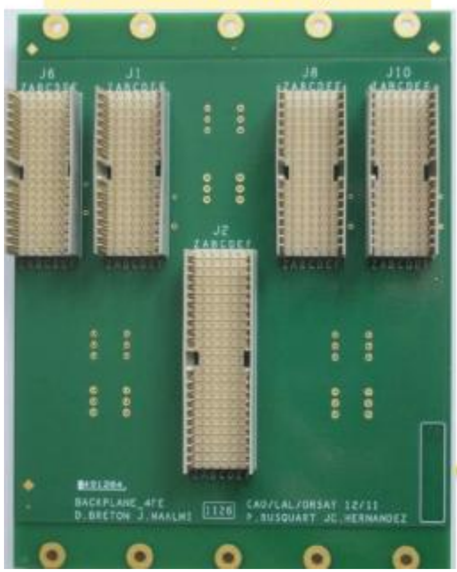
Building large scale systems



Layout of the controller board



64-channel backplane



- To synchronise N boards a controller board is needed + backplane for the interconnections
- we are building a very compact 64-channel system:
  → will soon be used for the CORTO Cosmic Ray Telescope at Orsay
- we are also building a 320-channel system in 6U-crate (SuperNemo experiment)