CORTO* Platform : results and perspectives

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on behalf of the CORTO team

Mechanics
Electronics
Cabling
DAQ software
Analysis software
Calibration
Operation

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Thank you to all the contributors !!!

*** CORTO : COsmic Ray Telescope at Orsay**

Outline

1. Introduction

2. Description of the CORTO subsystems

3. Calibration

4. Conclusion

Different way to test detectors for Nuclear and Particle Physics

➞ **Radioactive sources.** The most widely and frequently used for detector testing in Nuclear and Particle Physics. There are alpha, beta, gamma and neutron sources and they cover large area of interest for particle detectors characterization with low energy ionizing particles. **(Available at LAL)**

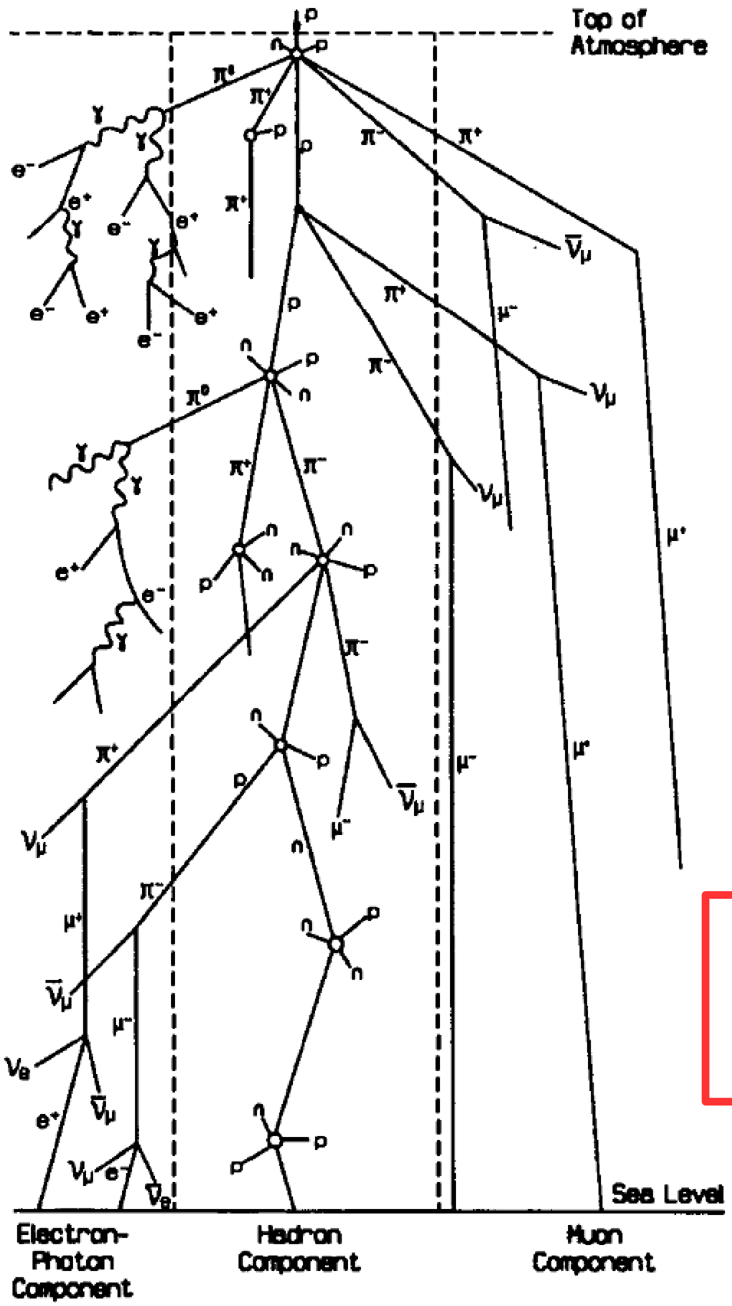
➞ **Lasers.** They are widely used in our field of activity to test different photomultipliers Si-detectors and others… With use of lasers one can measure/test timing, spacial resolution and efficiency of photo detection. They are available and relatively easy to use. **(Available at LAL)**

➞ **Particles beams.** Each detector on the final phase of developments must be tested and characterization with particle beams. There are many beams test facilities available: CERN (north area for example), BTF – Frascati in Italy, DESY and many others. Unfortunately they are VERY expensive, user time is limited and have well defined periods. **(Available at LAL – PHIL, LEETECH)**

➞ **Cosmic rays.** Usually cosmic muons are the best candidates out of cosmic rays to be used to test detectors. They have low flux* but relatively hight energy - 2 GeV in average (can be selected in a different ways). At this energy they are perfectly fit the needs of tests with MIP. **(Available at LAL – CORTO)**

*(1 / second /100 cm^2)

Cosmic rays



➡ Primary cosmic rays are protons, alphas and other heavier nuclei.

➡ They undergo the cascade hadron interaction in the atmosphere.

➡ Due to this interaction high energetic protons produce extensive air shower of the secondaries.

➡ Pions are the main component just after hadron interaction. Due to a short live time they disintegrate in flight producing muons and gammas.

➡ **Gammas** coming mostly from neutral pions - originates electro-magnetic shower component.

➡ **Muons** with hight energy mostly coming from charged pions have long enough life time to reach sea level and been detected on the earth.

[COSMIC RAY AT EARTH. Researcher's Reference Manual and Data Book. Peter K.F. Grieder.]

Objectives of CORTO

➡ For the first time project CORTO have been proposed/presented at Scientific Council by Veronique Puill in 2012.

REMINDER :
Objectives of CORTO system from the presentation in 2012 :

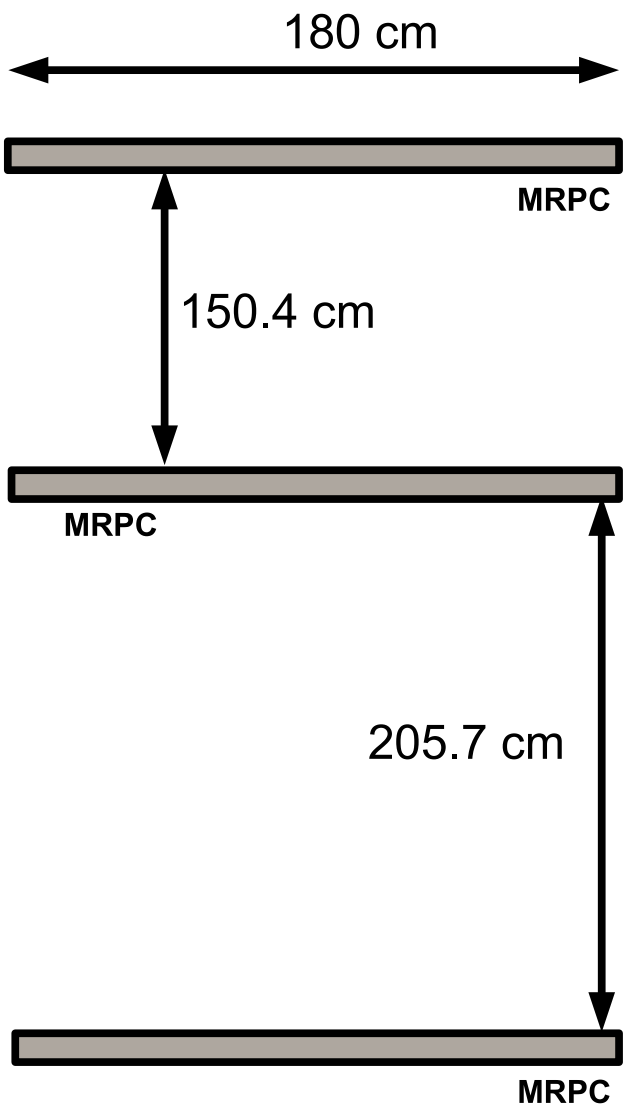
- Construct at Orsay comic muon telescope for the test of the detectors developed at LAL or by the experiments our laboratory is participating.
- It must have a reasonable price → use of detector for telescope, electronics, DAQ system already existed.
- CORTO should be easy to use → have a user friendly GUI. It should have standart connection/connectors and signals for simple integration of the tested system.
- CORTO need to have large enough dimension in order to hold inside a big sizes detectors.

We try to fulfill all the items

↓

Next slides contains the report about the progress and results

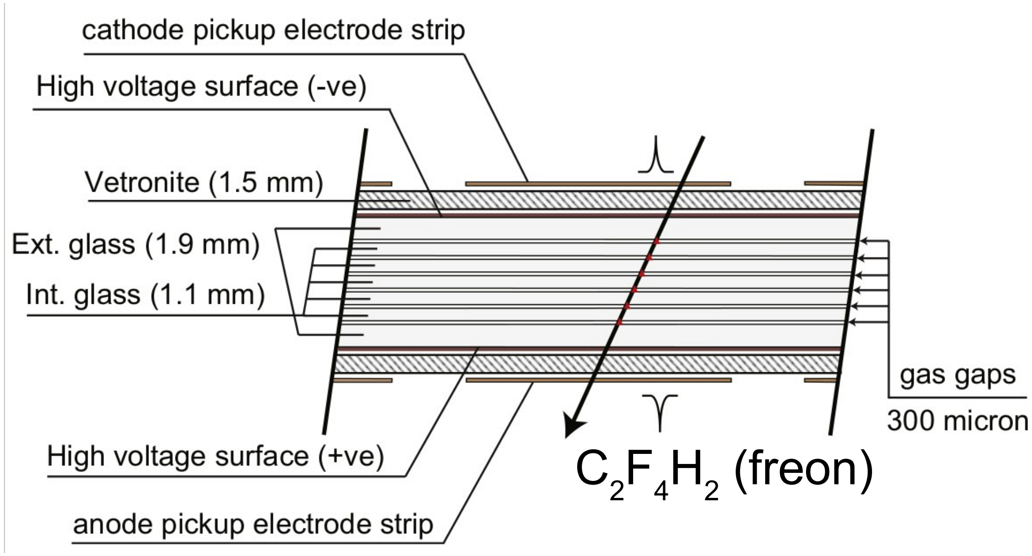
Schematic view and short component description of the CORTO

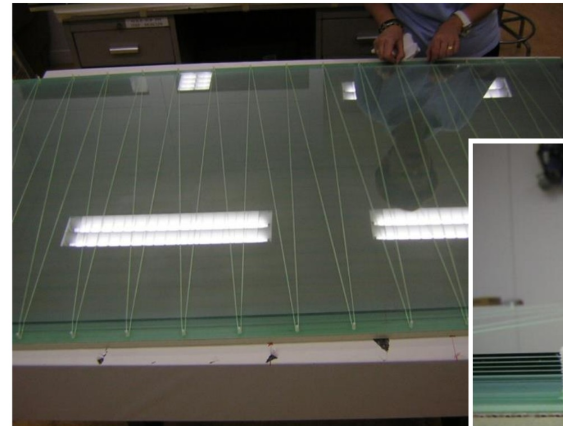


- The muon telescope composed of three MRPC*
  - Effective area : ~ 180 x 82 cm^2
  - Distances between are : 150.4 cm and 205.7 cm.
- NINO chip is front end electronics of the MRPC
  - ~ 20 ps time resolution
  - LVDS output signal
- LVDS to DC signal converter (simple R-C circuit).
- USB-WC electronics is used the readout DC signal after converter.
  - ~ 4 x 48 channels
  - 10 ps time resolution per channel
- NARVAL DAQ system used to run the CORTO
- Two DC/DC converter (positive and negative) provides H.V. to the MRPC nominal value is 18 kV.
- MRPC needs $C_2F_4H_2$ (freon) gas, with low flux : 0.5 ml/s.
- All the system located in the temperature controlled housing
- Translational stage for efficiency map measurements

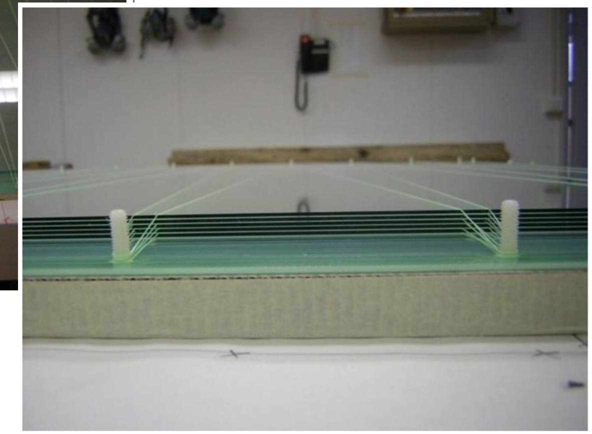
*MRPC – multigap resistive plate chamber.

MRPC – multigap resistive plate chamber





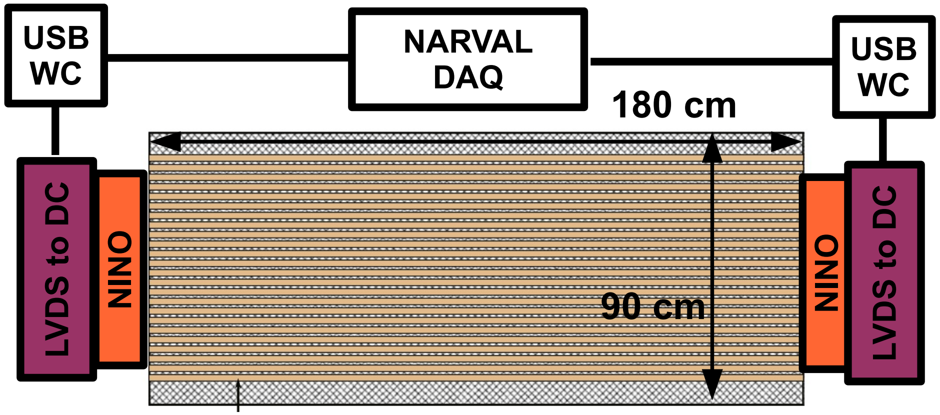
Glass fishing wire



- MRPC – Is a gas detector with 6 gaps of 300 um. The gas gaps are formed with thin glass separated by fishing wire.
- The ionizing particle (muon) creates initial charge (delta electron) inside the gas which is under 18 kV electric field accelerates and create an avalanche of secondaries.
- To stop the avalanche - dielectric glass is used. Size of the gap and H.V. choose to have gas amplification of $6*10^5 – 10^7$. 6 gaps are done to increase efficiency of the system.
- Top and bottom conducting plates (anode and cathode) detects electromagnetic interference from the avalanche which induced electrical signal on anode and cathode.
- The avalanche propagates towards anode from cathode and as a consequence induced electrical signal have of different polarity .

M.Abbrescia et al. Nuclear Instruments and Methods in Physics Research A 593 (2008) 263 – 268

Electronics to readout MRPC



24 readout copper strips on the vetronite.

- Anode and Cathode plates have 24 readout strips
- NINO is front-end readout electronics

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

- LVDS to DC signal converter (simple R-C circuit).
- USB-WC electronics
- NARVAL software

LVDS in

DC out

NARVAL

DAQ

M.Abbrescia *et al.* Nuclear Instruments and Methods in Physics Research A 593 (2008) 263 – 268

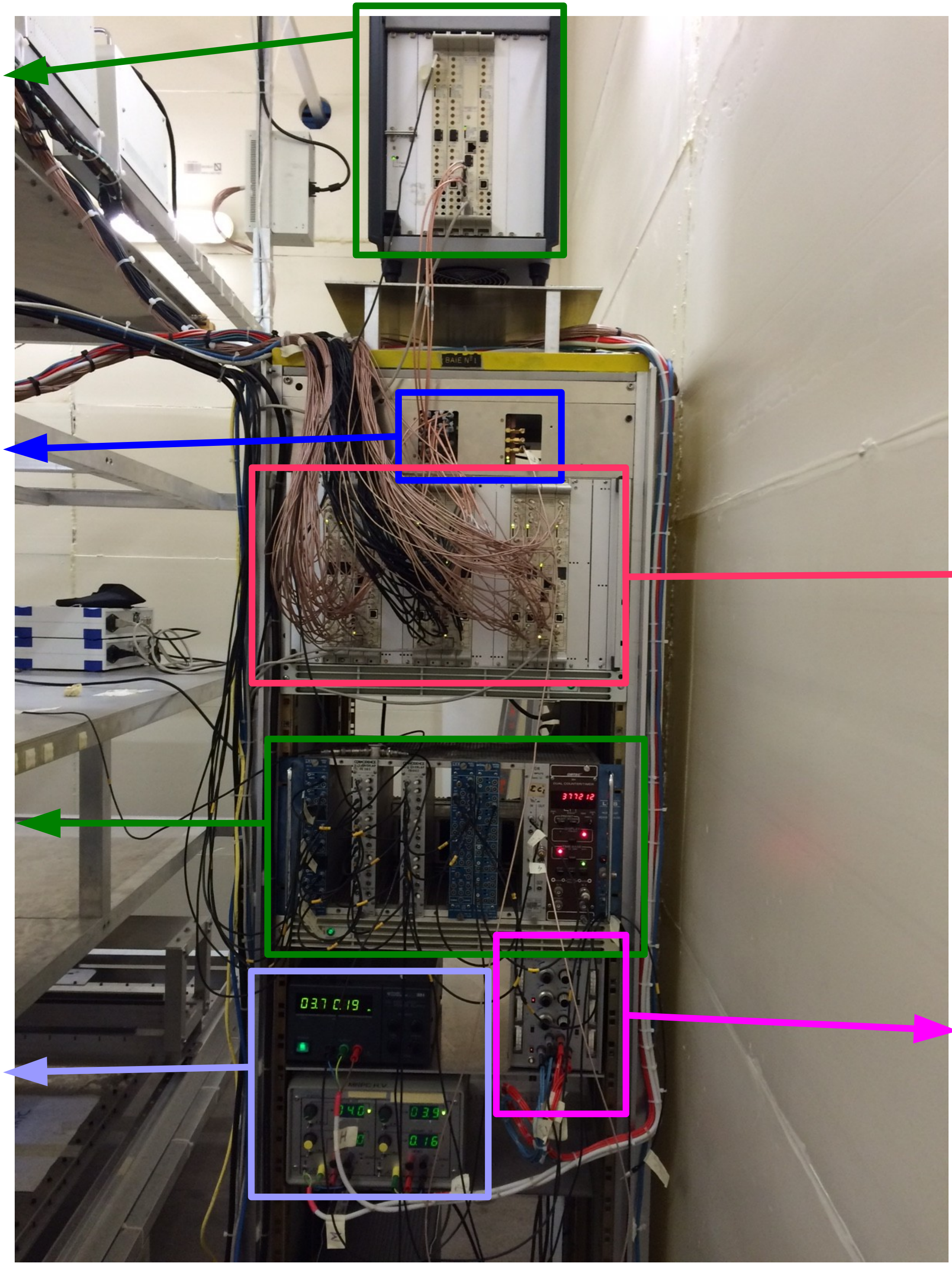
F. Anghinolfi *et al.* IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 51, NO. 5, OCTOBER 2004

D. Breton *et al.* “Picosecond time measurement using ultra fast analog memories”, (TWEPP-09), Paris-2009

CORTO electronics

48 channels USB-WC electronics for user

Main control board of USB-WC



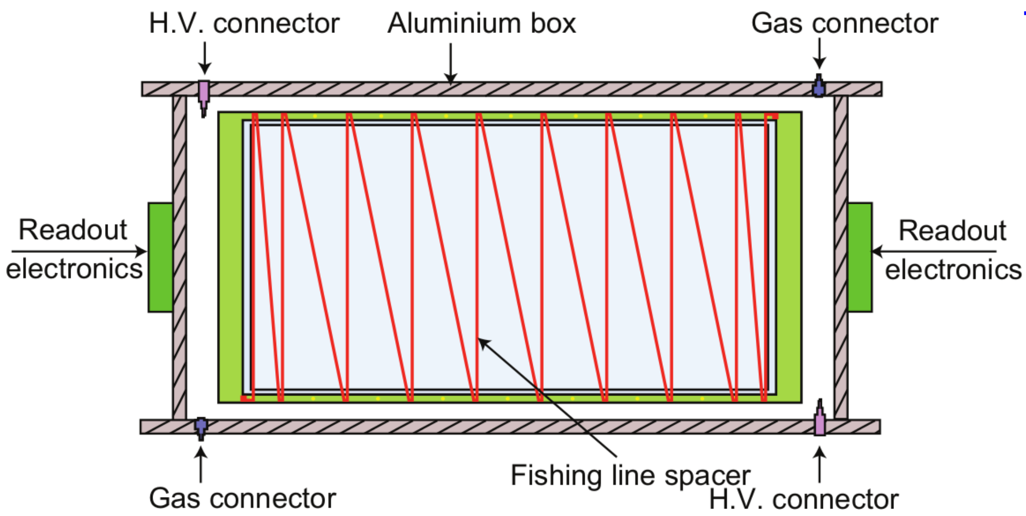
3 x 48 channels USB-WC electronics to readout MRPC

External trigger logical module

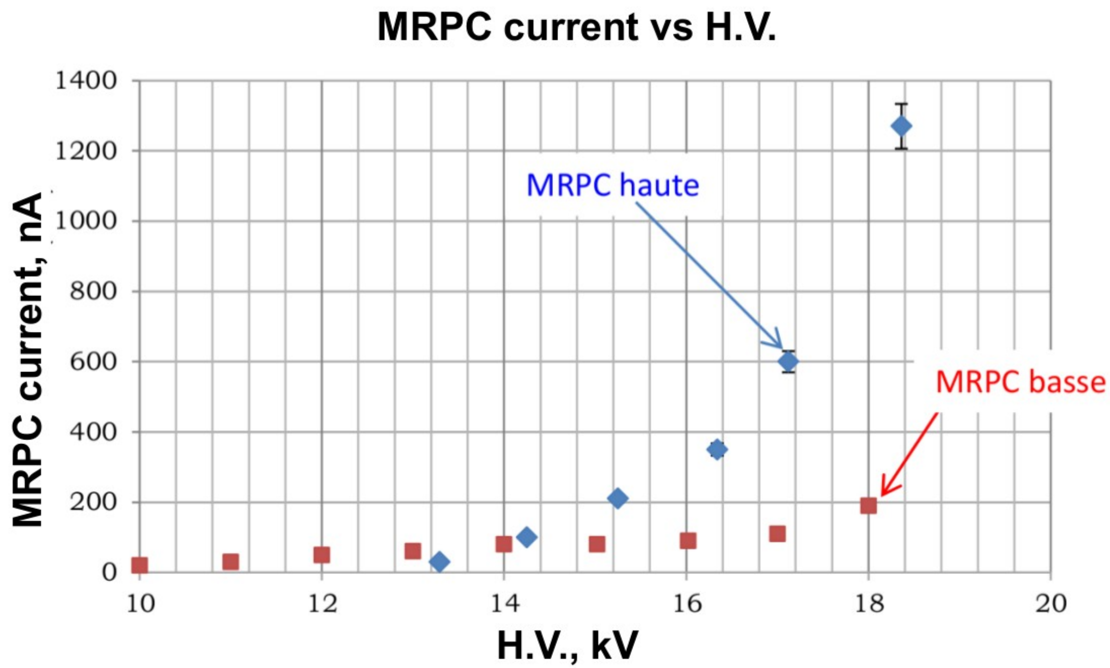
MRPC power supply

NINO power supply

H.V. and Gas system of the MRPC



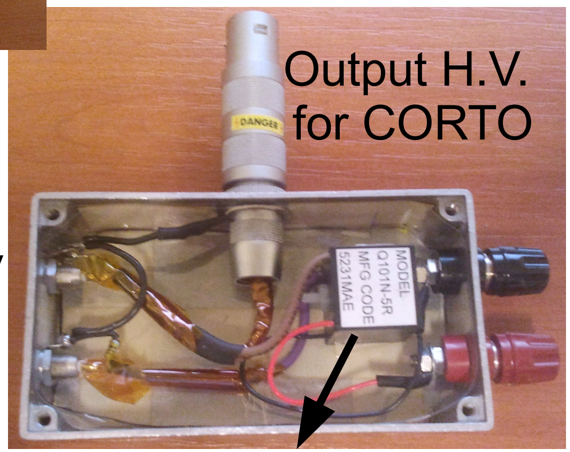
- Aluminum box contains the MRPC “active” parts.
- This housing have interfaces for :
  - Readout electronics
  - H.V. Supply and monitoring
  - Gas system
- MRPC need H.V. up to 18 kV.
- Very low consumption of current : maximum is 1500 nA



H.V. supply system of MRPC and its control.

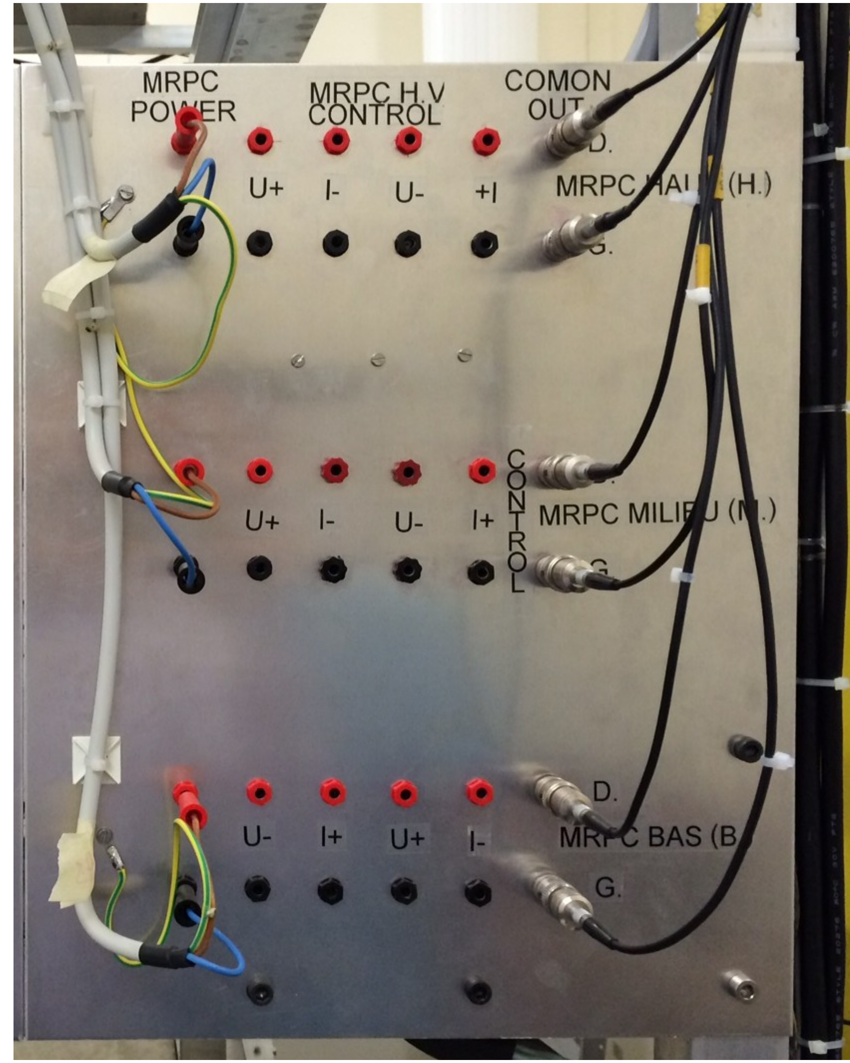
Monitor of V

Monitor of I



DC/DC converter

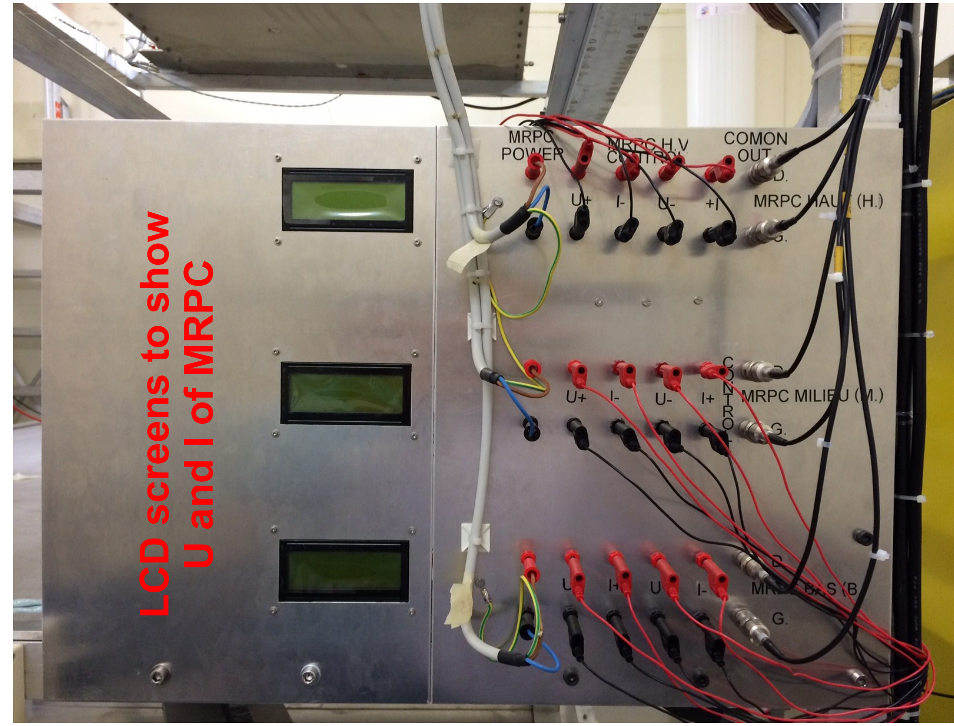
Input voltage
0 – 10 V



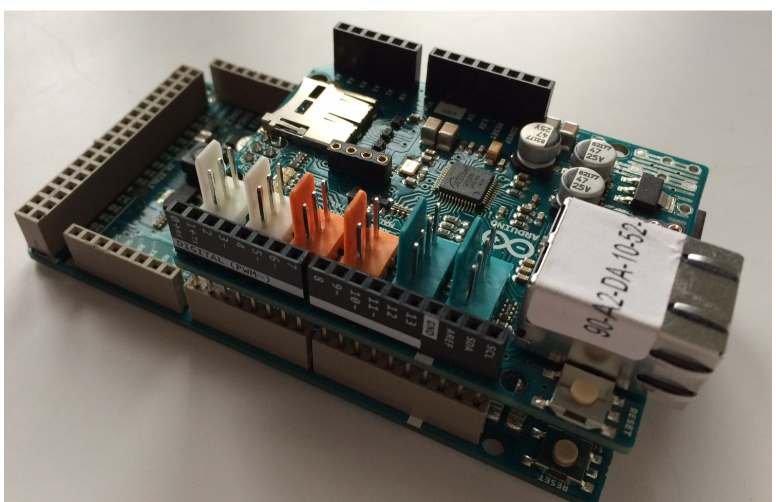
- We use DC/DC converter to supply CORTO with H.V.
- DC/DC converter “amplify” input low voltage in 1000 times.
- Simple voltage divider used to monitor the H.V.
- For one MRPC we have positive and negative H.V. module.
- For one H.V. module we have V and I control.
- For CORTO in total we have 6 H.V. module and 12 monitors of current and voltage.

Automatized control and monitoring H.V. system of MRPC

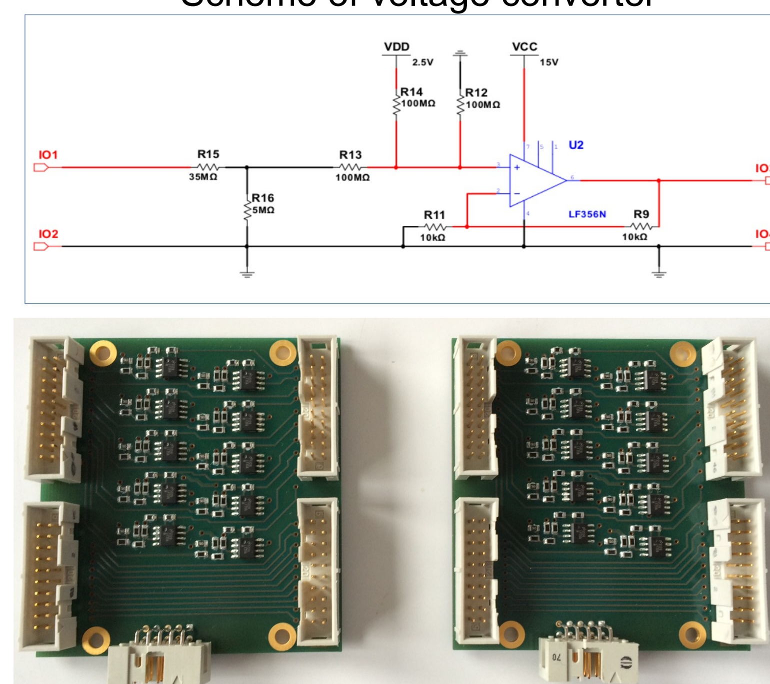
- There are 12 measurements to be monitored for CORTO H.V. system.
- Automatize of the measurements was required.
- We use Arduino DUE Micro-controller to readout the voltages from MRPC via voltage converter board.
- Arduino DUE connected to the LAL network via Ethernet shield.
- Develop voltage converter: input ± 20 V (from MRPC); output is 0 − 3.3 V.



Arduino DUE with Ethernet shield



Scheme of voltage converter



H.V. system and its control. Temperature control system.

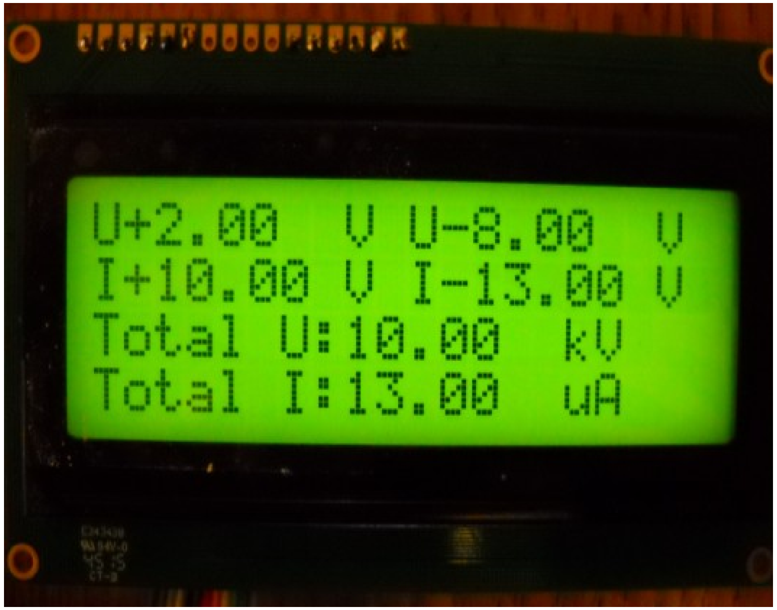
- Arduino DUE have web-server running and can be accessed from any PC connected to internal network of LAL. The measured information can be written to a PC disc.
- We use Arduino DUE to monitor temperature. There are 10 sensors foreseen to measure and log the temperature.

CORTO LAL IN2P3

Voltage measurements.

MRPC	BOTTOM	MIDDLE	TOP
U +	2.00 V	9.00 V	8.00 V
U -	7.00 V	10.00 V	10.00 V
I +	10.00 V	8.00 V	9.00 V
I -	13.00 V	9.00 V	3.00 V
Total U	9.00 kV	19.00 kV	18.00 kV
Total I	14.00 uA	-2.00 uA	-6.00 uA

Same information displayed on the LCD screen.



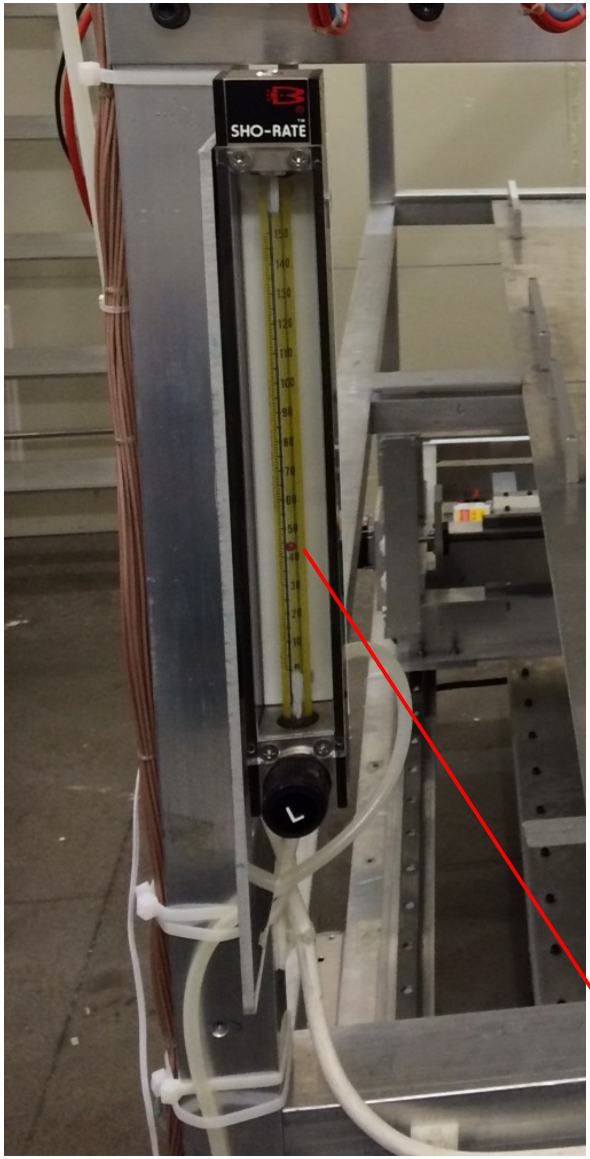
Temperature measurements.

Sensor ID	01	02	03	04	05	06	07	08	09	10
Temperaure	-127.00 °C	-127.00 °C	-127.00 °C	-127.00 °C	-127.00 °C	-127.00 °C	-127.00 °C	-127.00 °C	-127.00 °C	-127.00 °C

Session started **3 : 15 : 49 : 22** *[dd:hh:mm:ss] ago.*

Gas control system of the MRPC

➔ To run MRPC properly the $C_2F_4H_2$ (freon) gas, with low flux : 0.5 ml/s is required.



Brooks Model 1350 Sho-Rate TM low-flow gas flow meter.

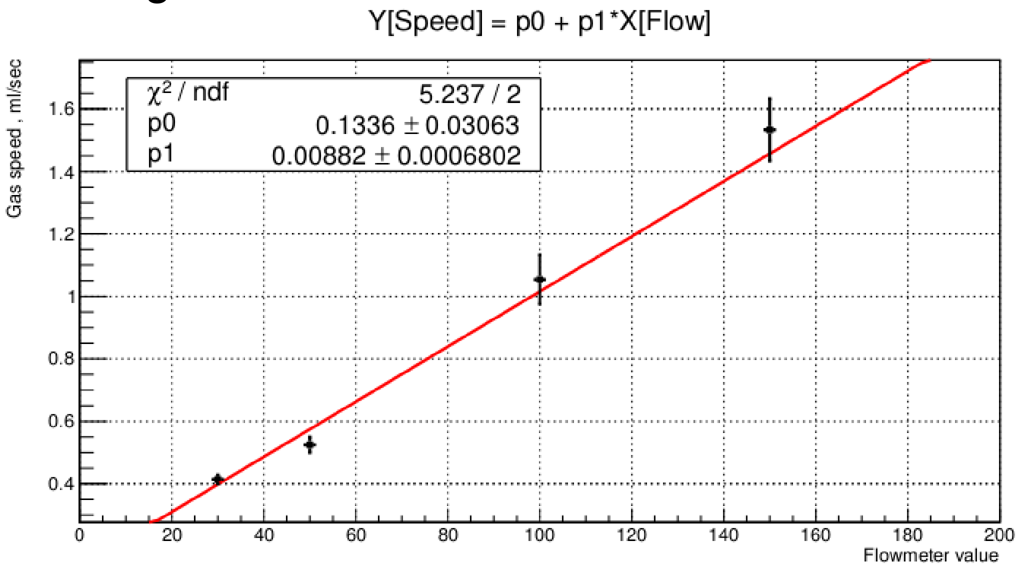
Bottle of freon gas.

➔ The bottle (20 L) of freon installed just next to the CORTO.

➔ Enough to run constantly during 4-5 Months.

➔ Flow meter used to adjust and measure gas consumption.

➔ Crosscheck calibration of the control system has been done.



Light plastic ball shows the gas consumption.

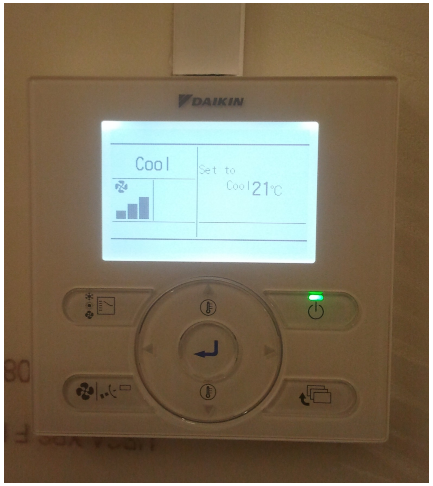
Housing of the CORTO

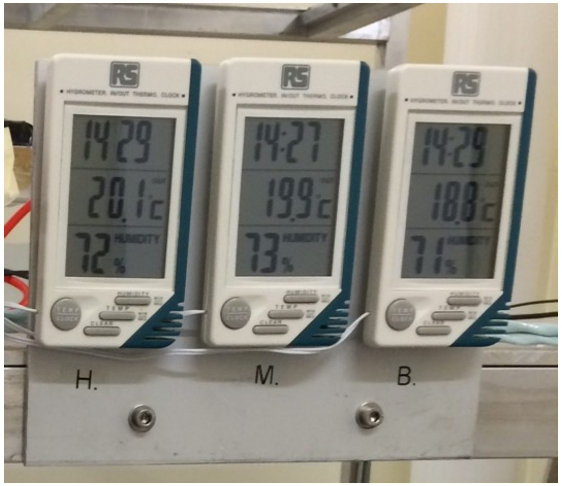
- Have dedicated space well separated from the rest of the hall.
- Define space for infrastructure.
- Temperature and humidity stabilization.

Air conditioner system of CORTO

- CORTO hall have annual and day/night temperature and humidity variation.
- For stable operation of MRPC and tested detectors air conditioner system was required.

Control panel of the air conditioner system

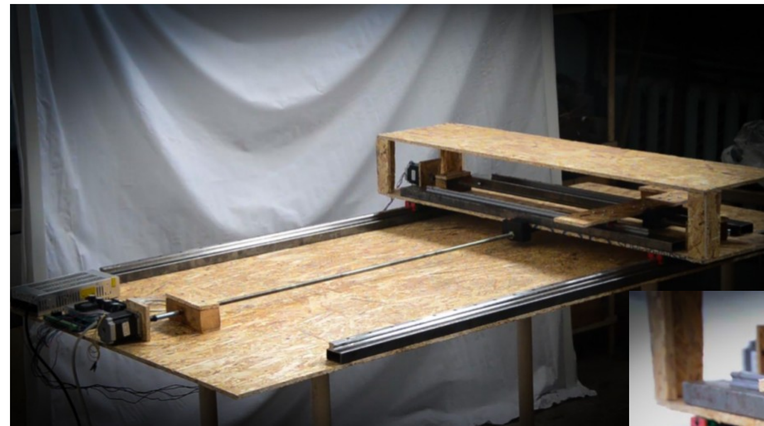




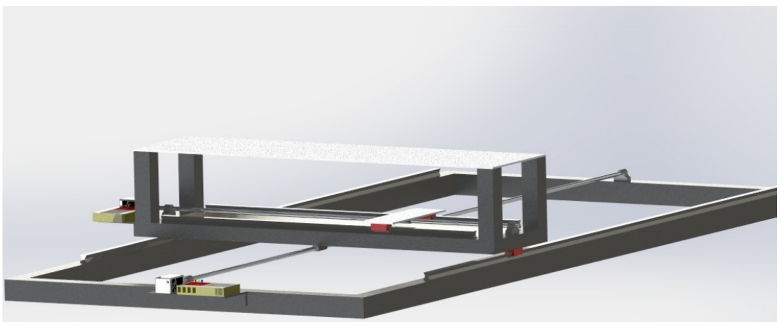
Temperature and humidity control for each MRPC

Translation stage for CORTO.

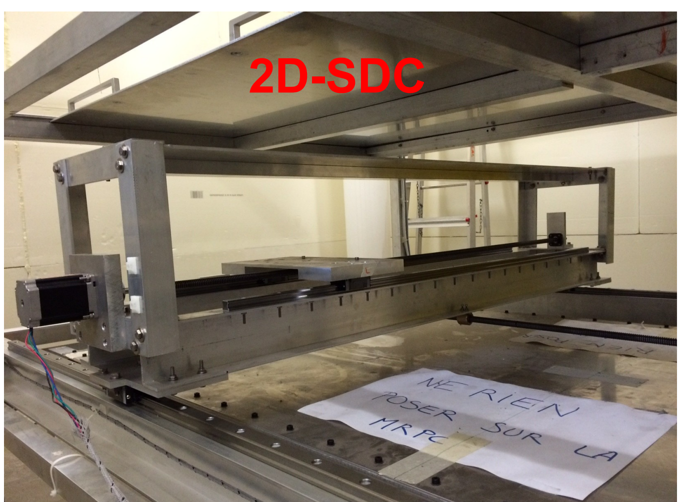
- To measure MRPC detection efficiency map - 2D scanning devise for CORTO (2D-SDC) has been constructed.
- It consist of : mechanical structure, two stepper motors with two drivers, power supplies.
- Arduino UNO with Ethernet shield is used to control the translational stage via PC.
- Maximum load : 20 kg.
- Precision : 100 um in both axis.



First prototype constructed in Kiev TS University



Virtual model of the 2D SDC



Translation stage for CORTO (GUI).

- Graphic User Interface (GUI) written using MATALB. It is Linux, Window, MacOS compatible.
- GUI allows to control the translation stage speed, acceleration, create moving trajectory and set waiting time in each point of the trajectory.
- Accessible from any PC connected to LAL internal network

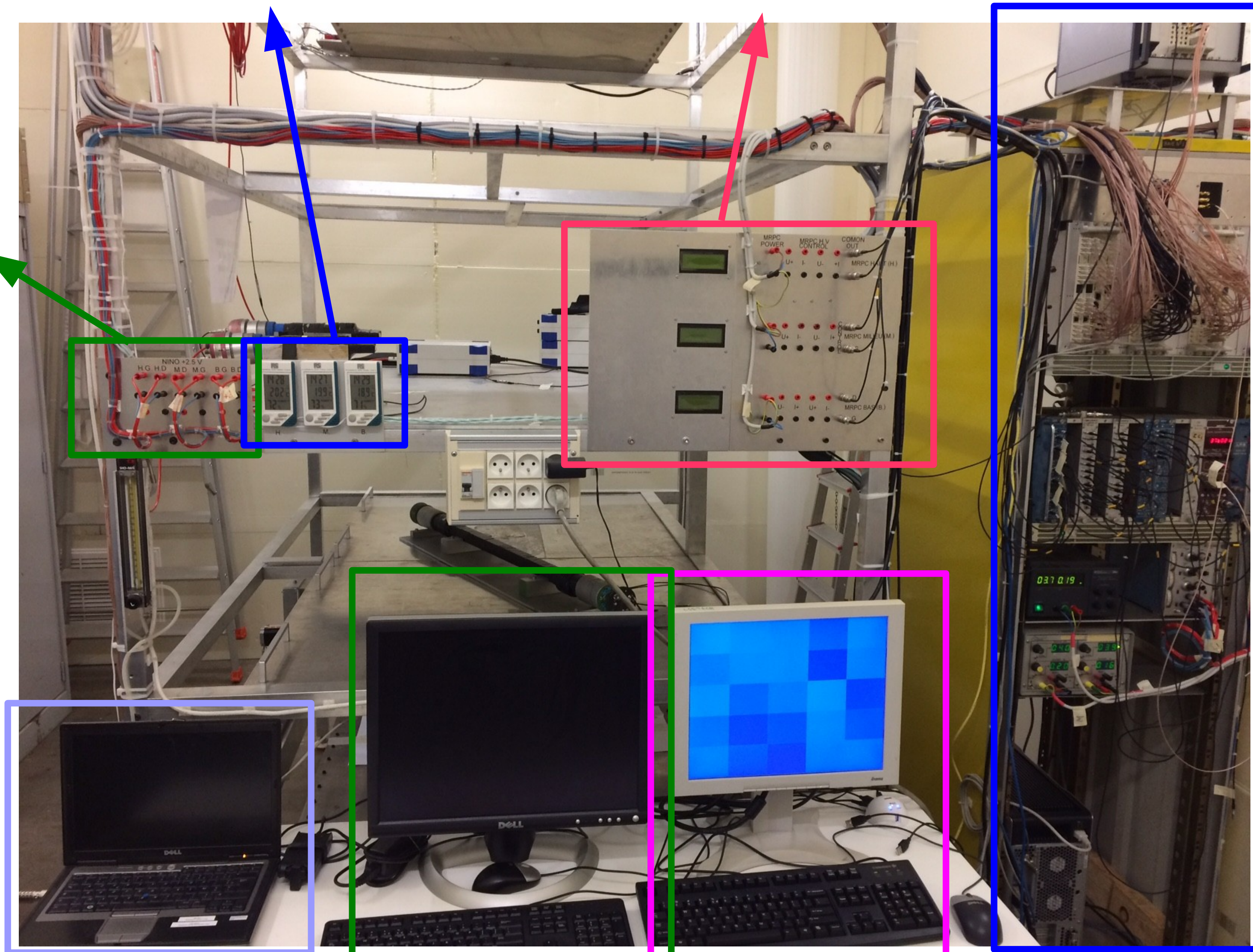
CORTO control panel

Temperature and humidity for each MRPC

U+, I+, U-, I- control for each MRPC

NINO power supply

CORTO Electronics rack



Laptop to pilot translational stage

Central data analisys PC to be installed in future

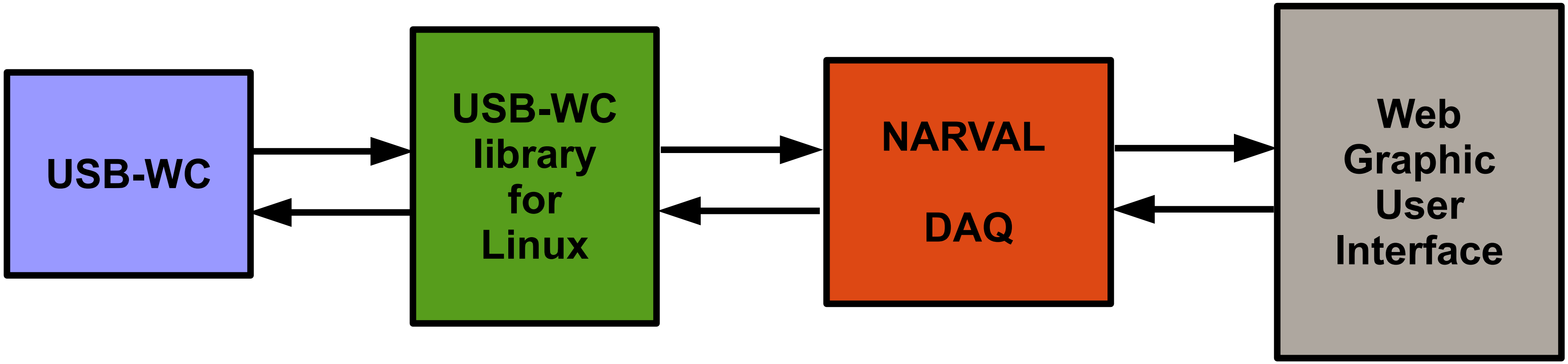
Central DAQ Lunix PC with NARVAL software

NARVAL

- **N**ouvelle **A**cquisition temps **R**éel **V**ersion 1.14 **A**vec **L**inux
- NARVAL is a Modular Distributed Data Acquisition System with Ada 95 and RTAI
- It is developed by X. Grave and supported by IPN + CSNSM + GANI
- This system is used by many different applications:

  IPN : ALTO, ANDROMEDE, DataFlow of AGATA
  CSNSM : scanning table of AGATA
  GANIL : official acquisition system
  LPC Caen : Faster

- A lot of efforts has been done by NARVAL team and USB-WC team to make CORTO DAQ run with NARVAL.



- How to run CORTO DAQ is described on wiki page:

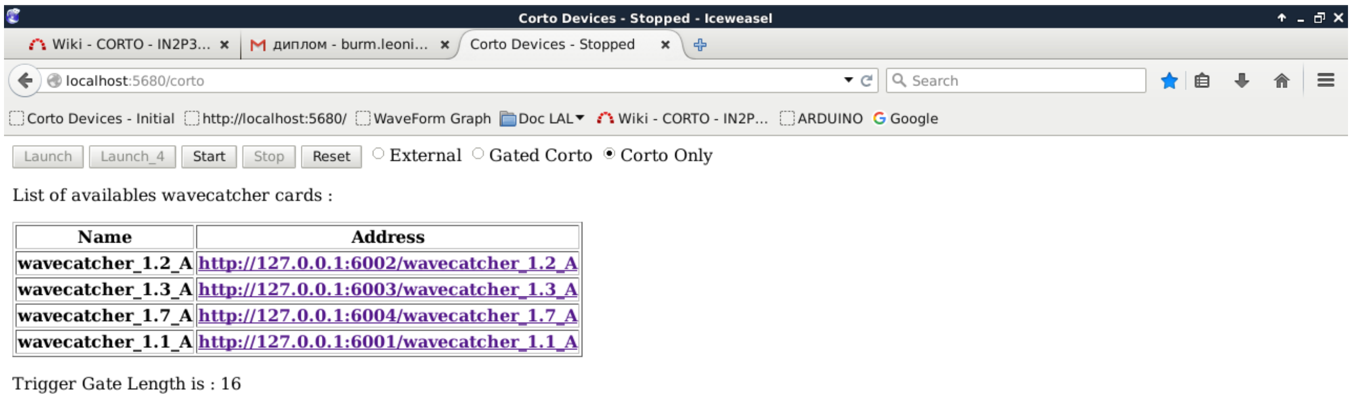
  https://forge.in2p3.fr/projects/corto/wiki

CORTO Web Graphic User Interface

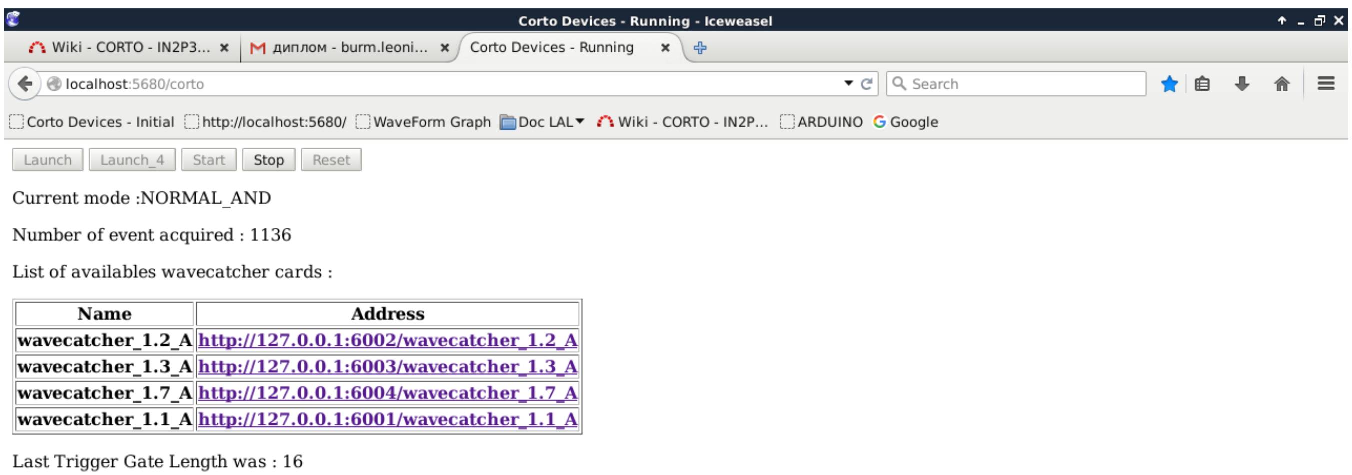
- For usual run of CORTO three simple steps need to be done

Start NARVAL and choose mode of running

Choose trigger mode



Start acquisition



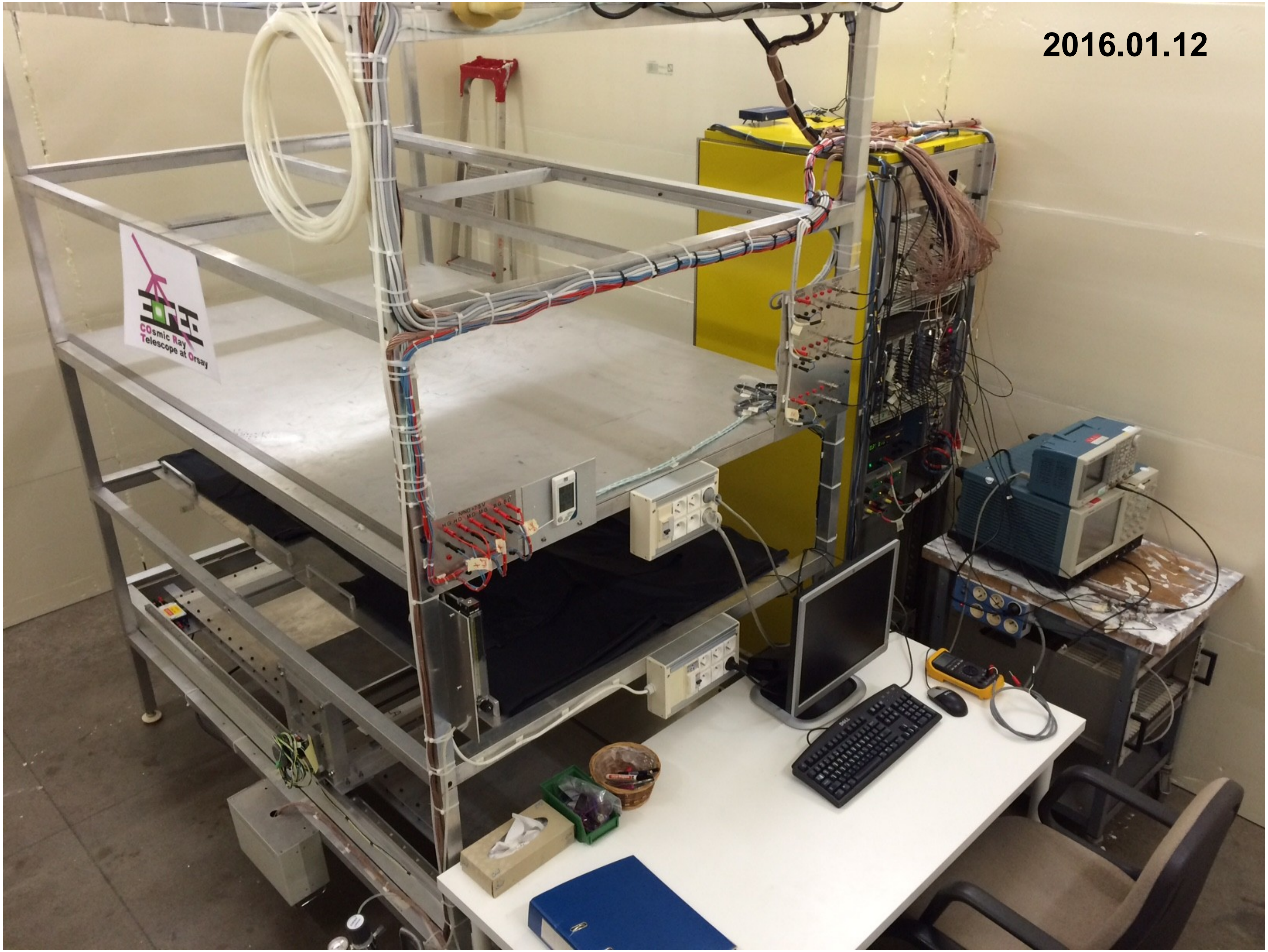
- Setups of USB-WC parameters can be changed via xml file

Old versions of CORTO

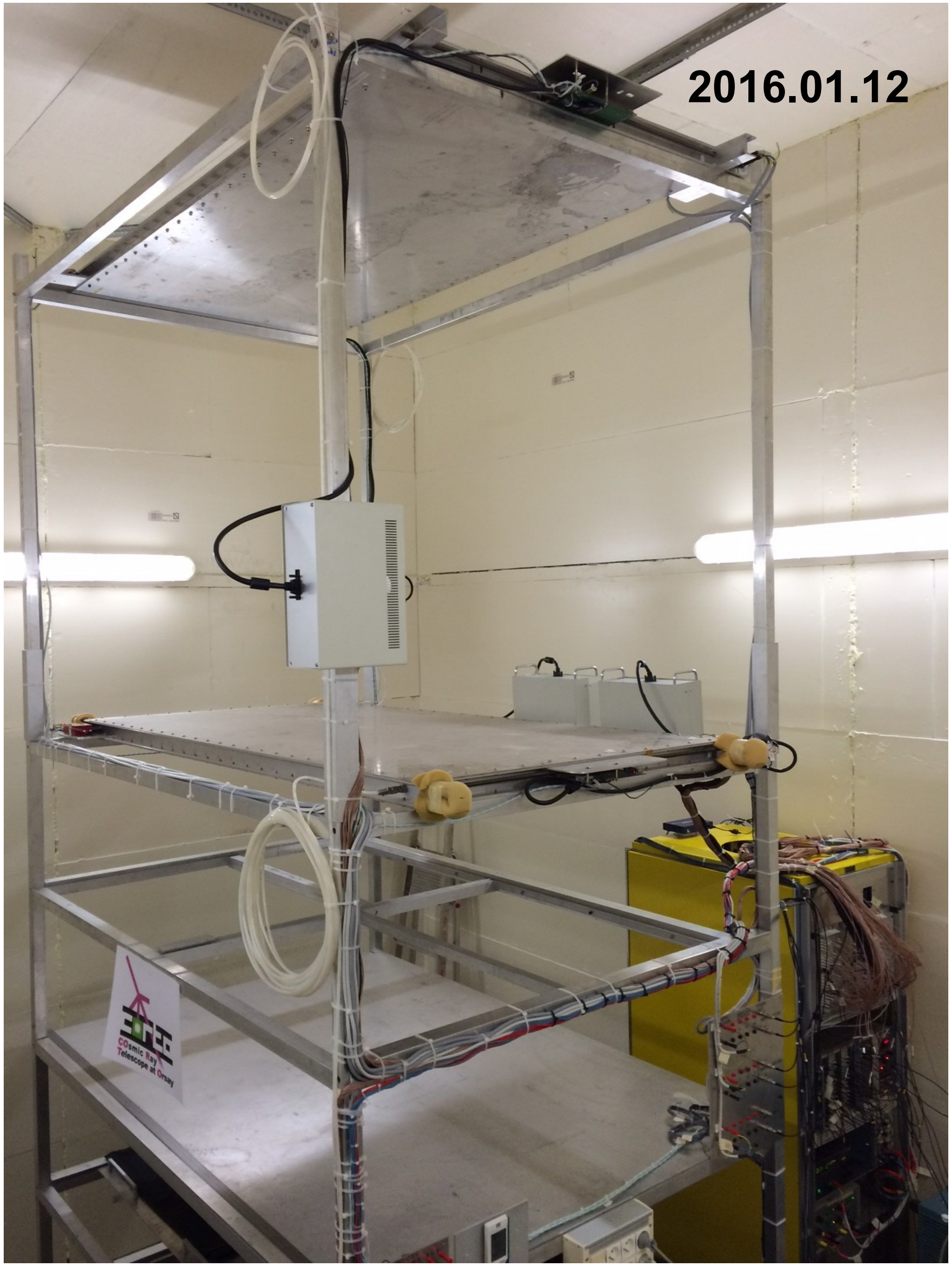
Old versions of CORTO

Old versions of CORTO

Present versions of CORTO

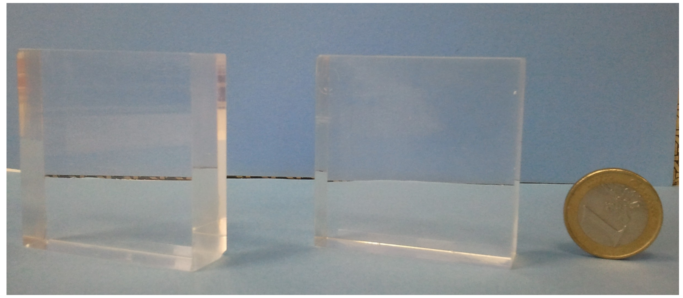


Present versions of CORTO

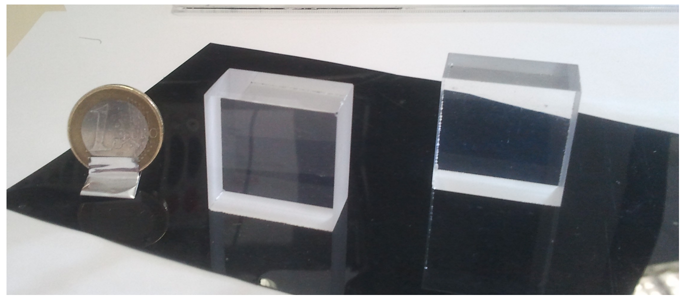


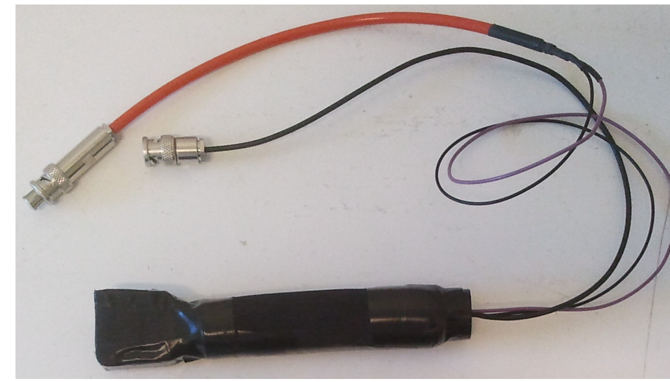
Devices for CORTO calibration

- $5 \times 5 \times 1.5$ cm^3 plastic scintillator + PMT

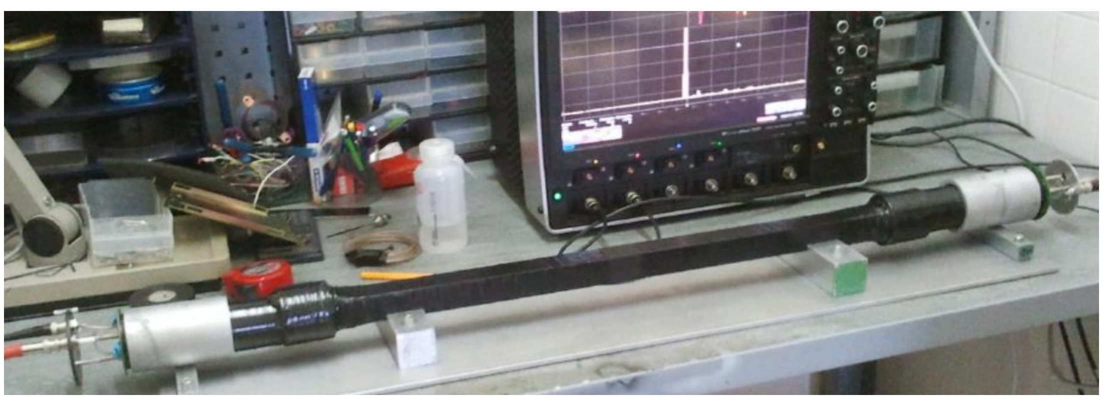


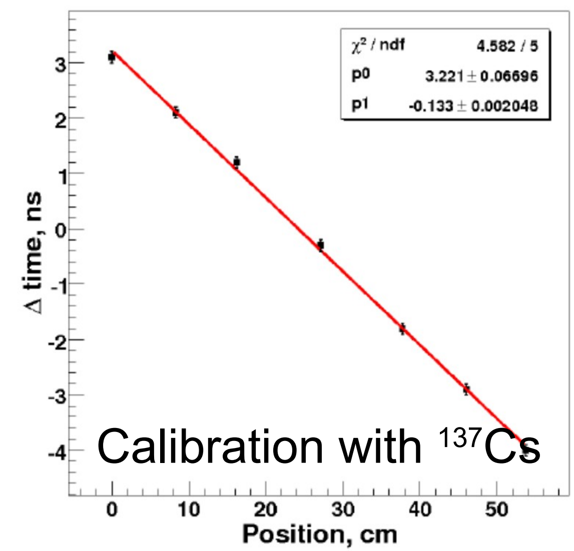
- $3 \times 3 \times 1.5$ cm^3 plastic scintillator + PMT





- Long trigger counter
  $60 \times 3 \times 3$ cm^3 plastic scintillator + PMT





- Long thin trigger counter : $80 \times 1 \times 1$ cm^3 plastic scintillator + PMT

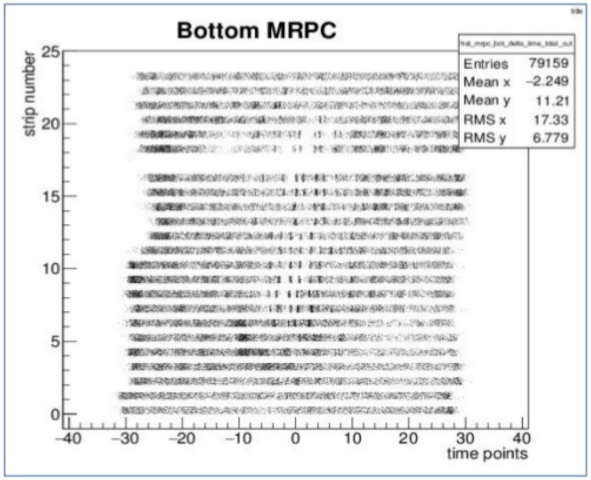
Analysis software

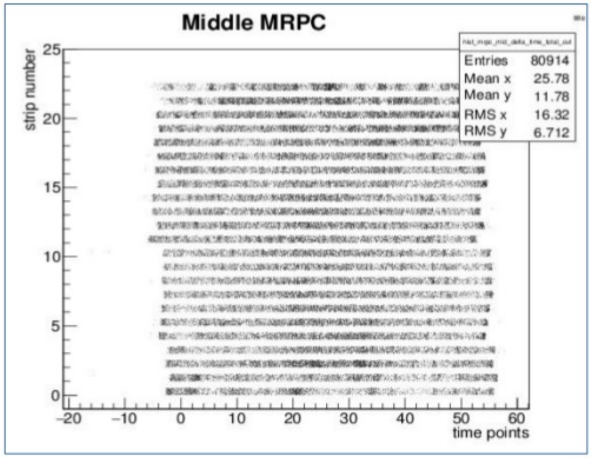
- NARVAL provides raw data files in binary format which contain waveform and measurements for each channel.
- We develop software for analysis based on C++ and ROOT.
- Interface between user and analysis software done via ASCII format .dat files.
- Data analysis done in three steps :
  - Conversion of raw data files into root format.
  - Analysis of the waveforms → retracting of the parameters
    - Time, charge, amplitude, width ...
  - Track reconstruction and production of the output root file with information about the track and measurements from the USER USB-WC electronics.
- Analysis done automatically by simply running runAll.bash bash script from the terminal.
- Analysis can be done in parallel to the data taking.

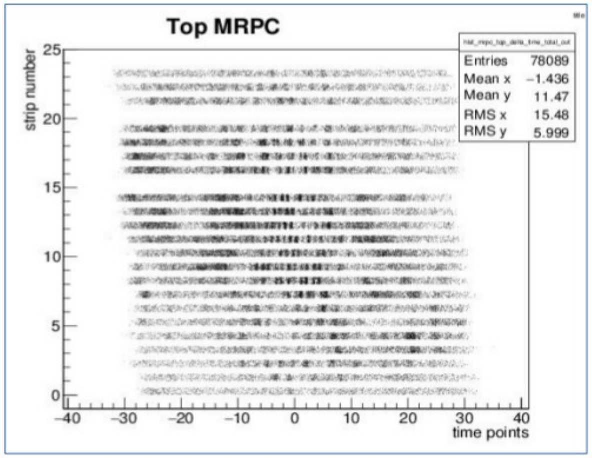
Electronic chain delay calibration

- Due to different signal cable tract delays calibration need to be done.
- For this we use long thin 80 x 1 x 1 cm^3 plastic scintillator + PMT.

Before





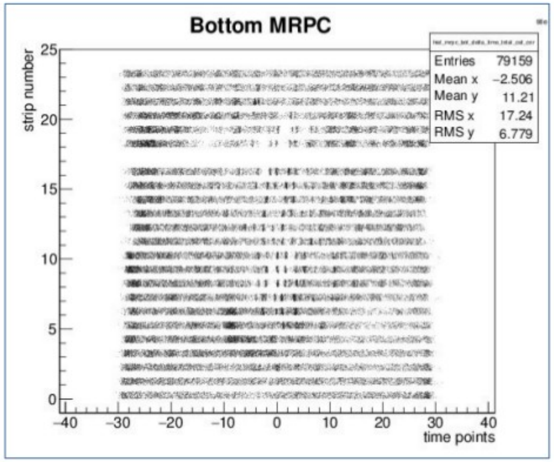


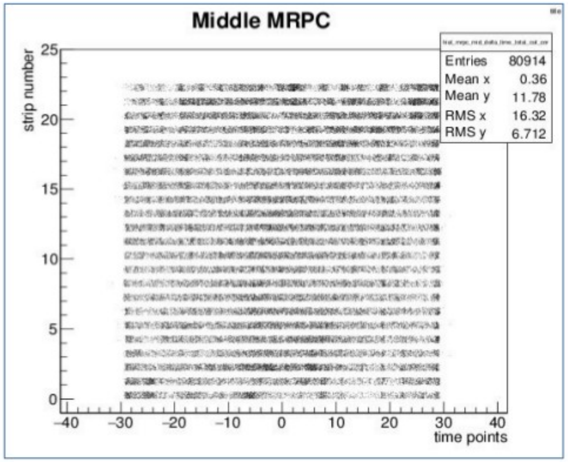
Bottom MRPC.

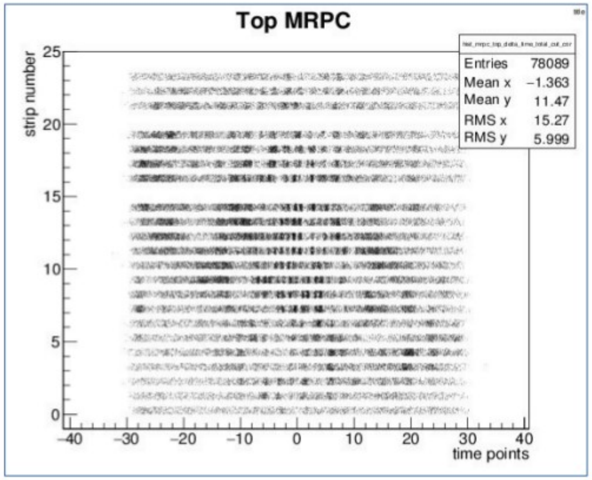
Middle MRPC.

Top MRPC.

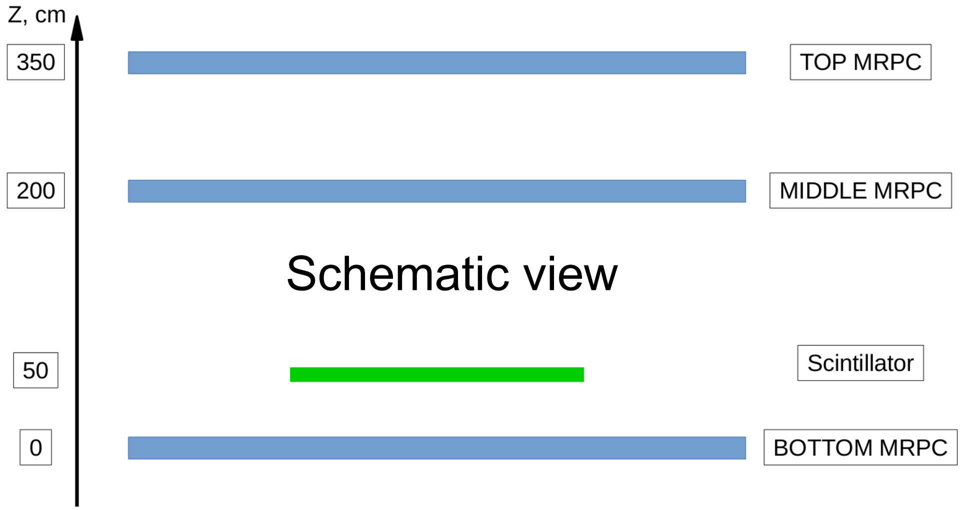
After



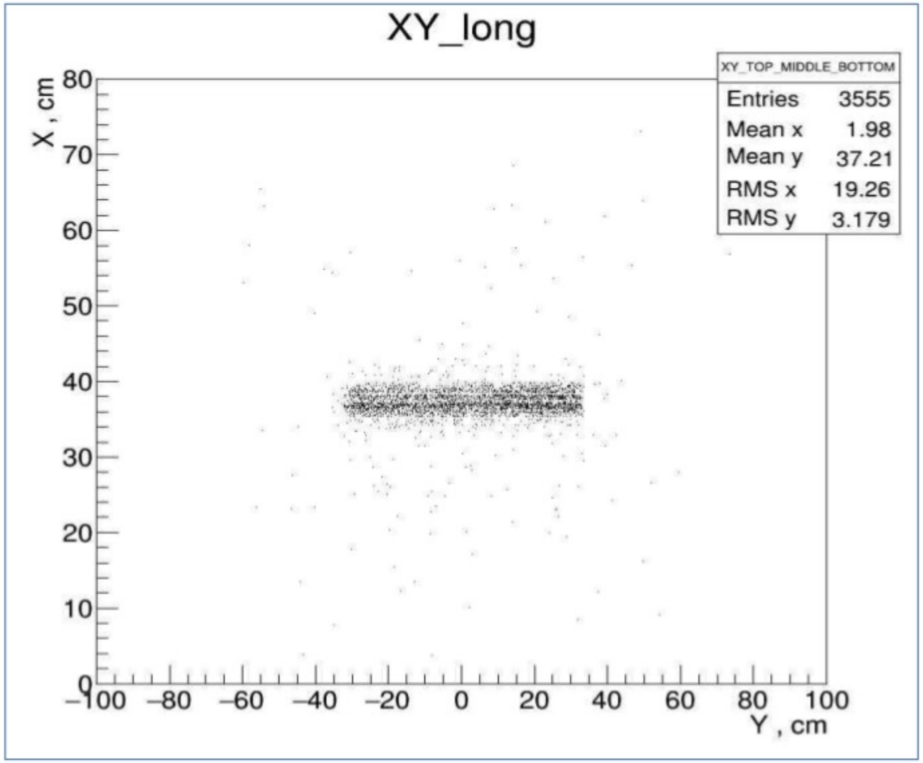




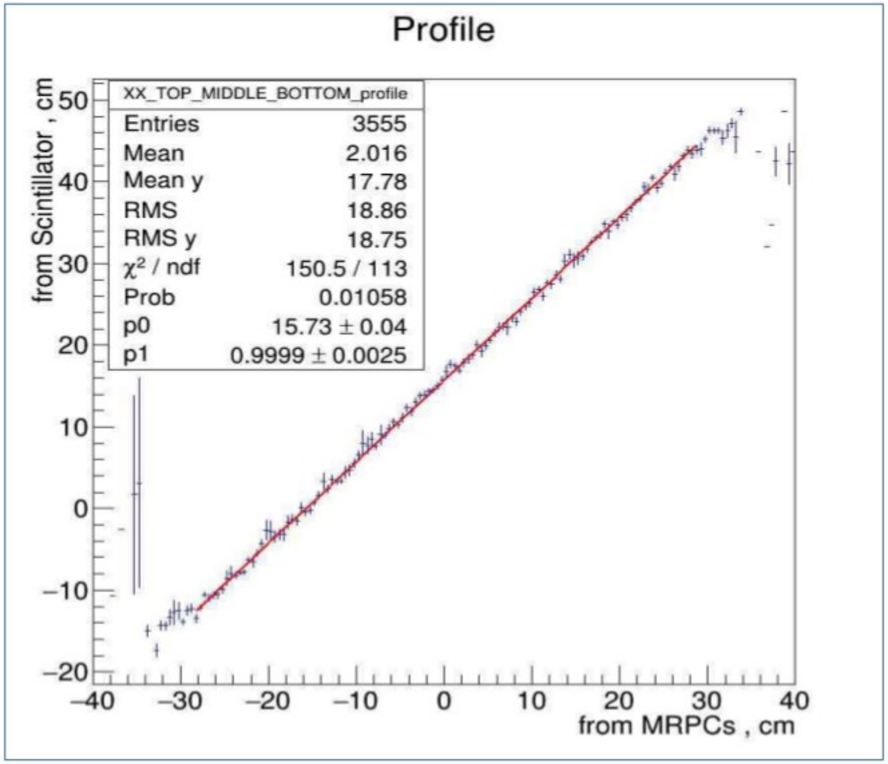
Validation of the track reconstruction algorithm



- For this we use long trigger counter 60 x 3 x 3 cm^3 plastic scintillator + PMT
- We reconstruct detector geometrical sizes (X vs Y histogram)
- We reconstruct track position with CORTO and long trigger counter (profile)



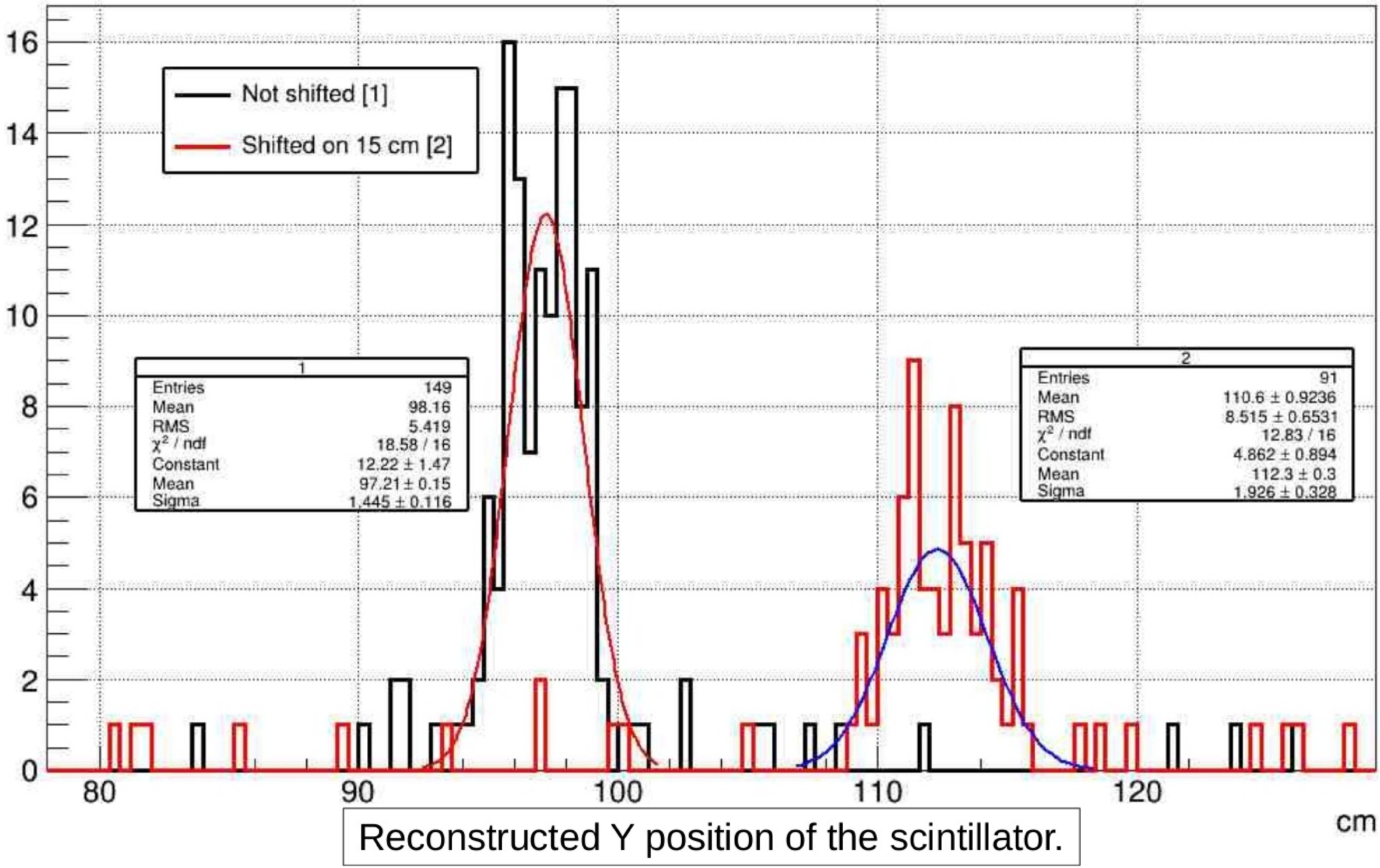
XY position of the Long scintillator.



Profile.

CORTO position and time resolution

- For this we use 3 x 3 x 1.5 cm^3 plastic scintillator + PMT.
- We measure 1.44 cm position resolution which corresponds to 90 ps time resolution.

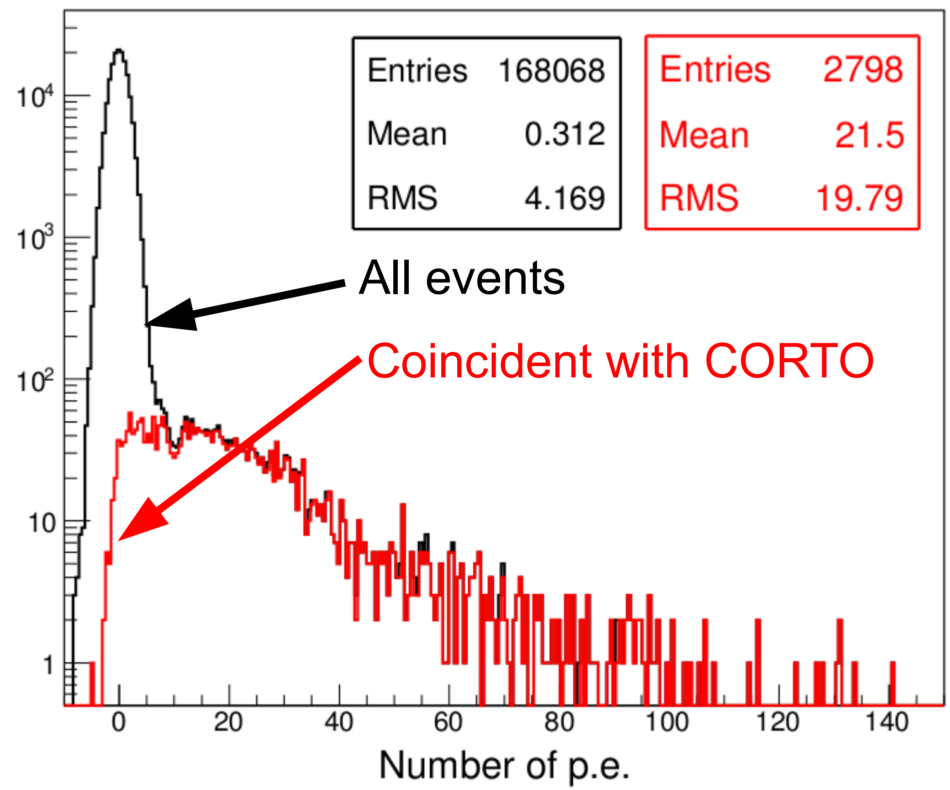


Tested detectors : CpFM

Test with cosmics (IEEE-2013, Seoul)

- Before beam tests of the prototype we performed measurements with cosmic muons reconstructed with CORTO (Cosmic Ray Telescope at Orsay)

Results



- In average for all incoming muons we detected 21 p.e.

Tested detectors : Diamond detector

LAL internship report of Illia Khvastunov,
September-November, 2013
March-April, 2014

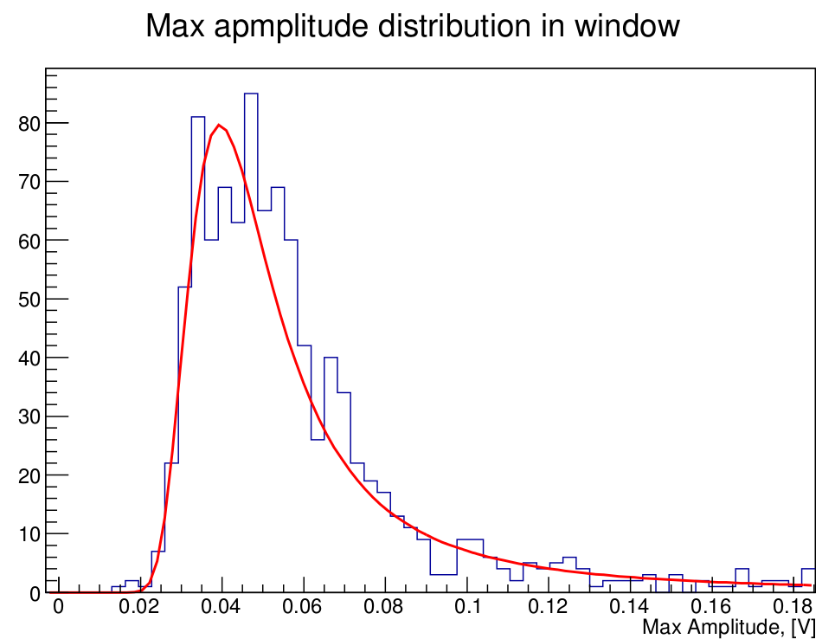
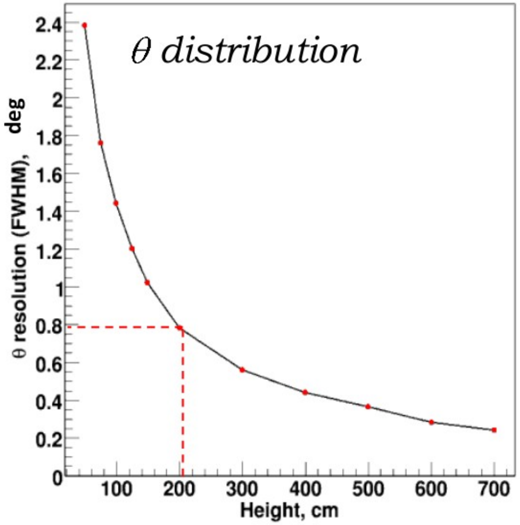


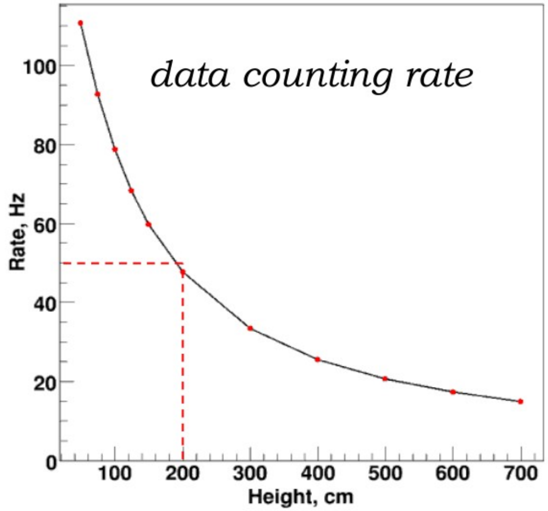
Figure 12: Maximum Amplitude distribution in window

Totally it was obtained 32225 events during 10 days of experiment, that corresponds to 2.267 events per minute. Expected muon events was app. 1000. ROOT TSpectrum class was implemented for peaks finding in waveform. It was found 975 peaks in the arbitrary time window(between 102.5 ns and 125 ns). Outside arbitrary window there aren't true events, so from data analysis bins from outside arbitrary window noise RMS can be found. It's yielded 12.8 mV. In Fig.12 is shown the maximum amplitude distribution in arbitrary window for that events, where peak finder found a peak. This distribution can be also describe using Landau distribution.

Simulation of the CORTO

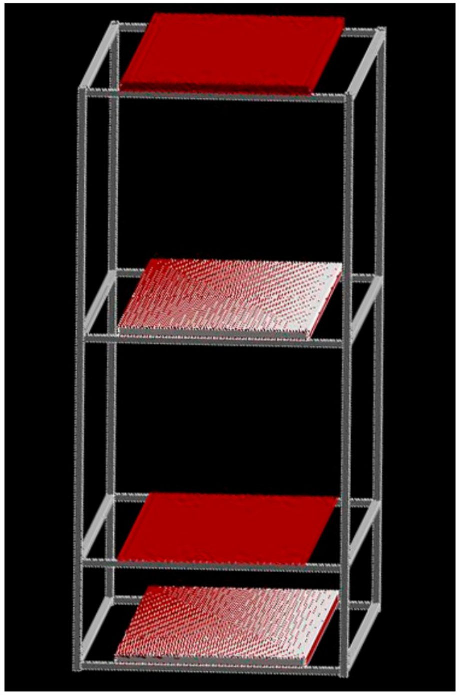
- Fast parametric simulation based on C++ and root

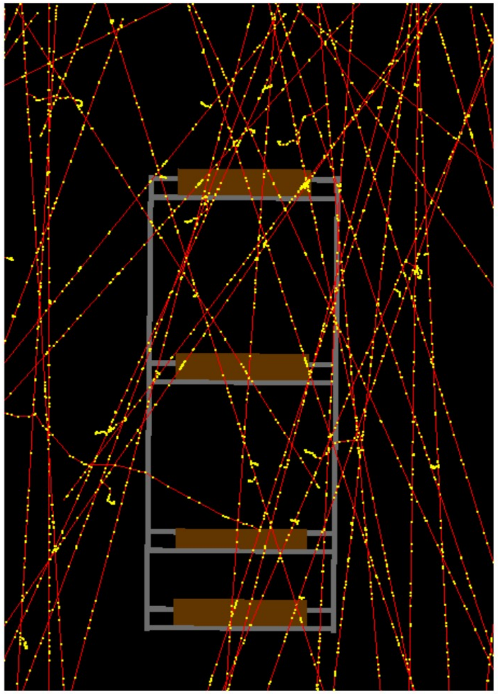




- Include approximate geometry of MRPC without internal structure.
- No mechanical structure
- No interaction of the muon with material only provides intersection points
- Take into account only angular distribution of cosmic muon

- Geant4 simulation





- Include precise geometry of the MRPC.
- Mechanical structure
- Interaction of the muon with material and decay.
- Take into account angular, momentum distribution of cosmic muon and correlation between them.

Budget

Mini CS LAL : 33000 € du LAL + 10000 € de l'IPN

financement de la version V1 de CORTO

ERM Université Paris Sud : 25700 €

financement de la version V2 de CORTO (une 3ième MRPC + climatisation)

P2IO Jouvence de plateforme : 6000 €

financement d'un système d'acquisition pour les utilisateurs

P2IO financement de TP : 6000 €

Total (hors TP) : 74700 €

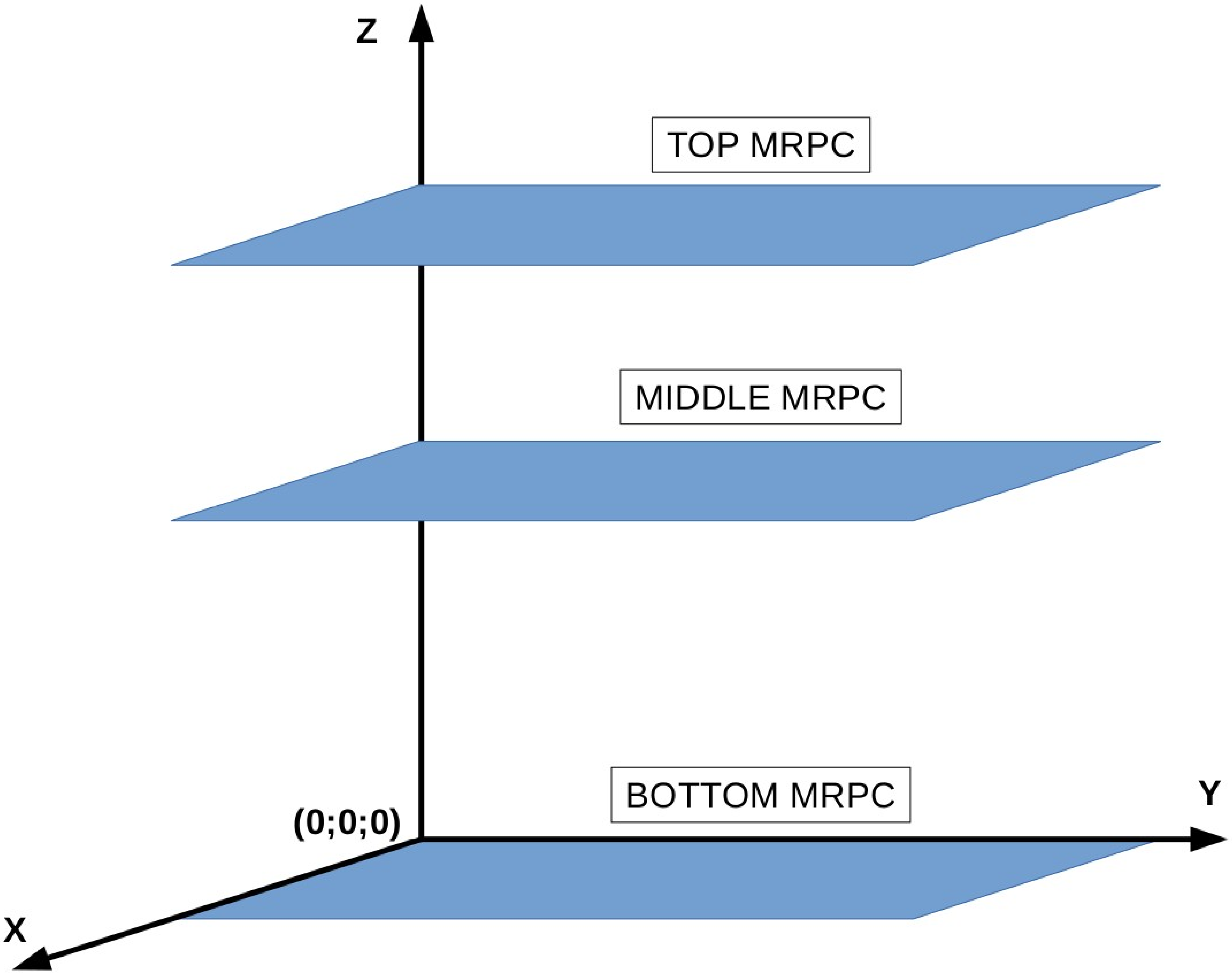
Conclusions

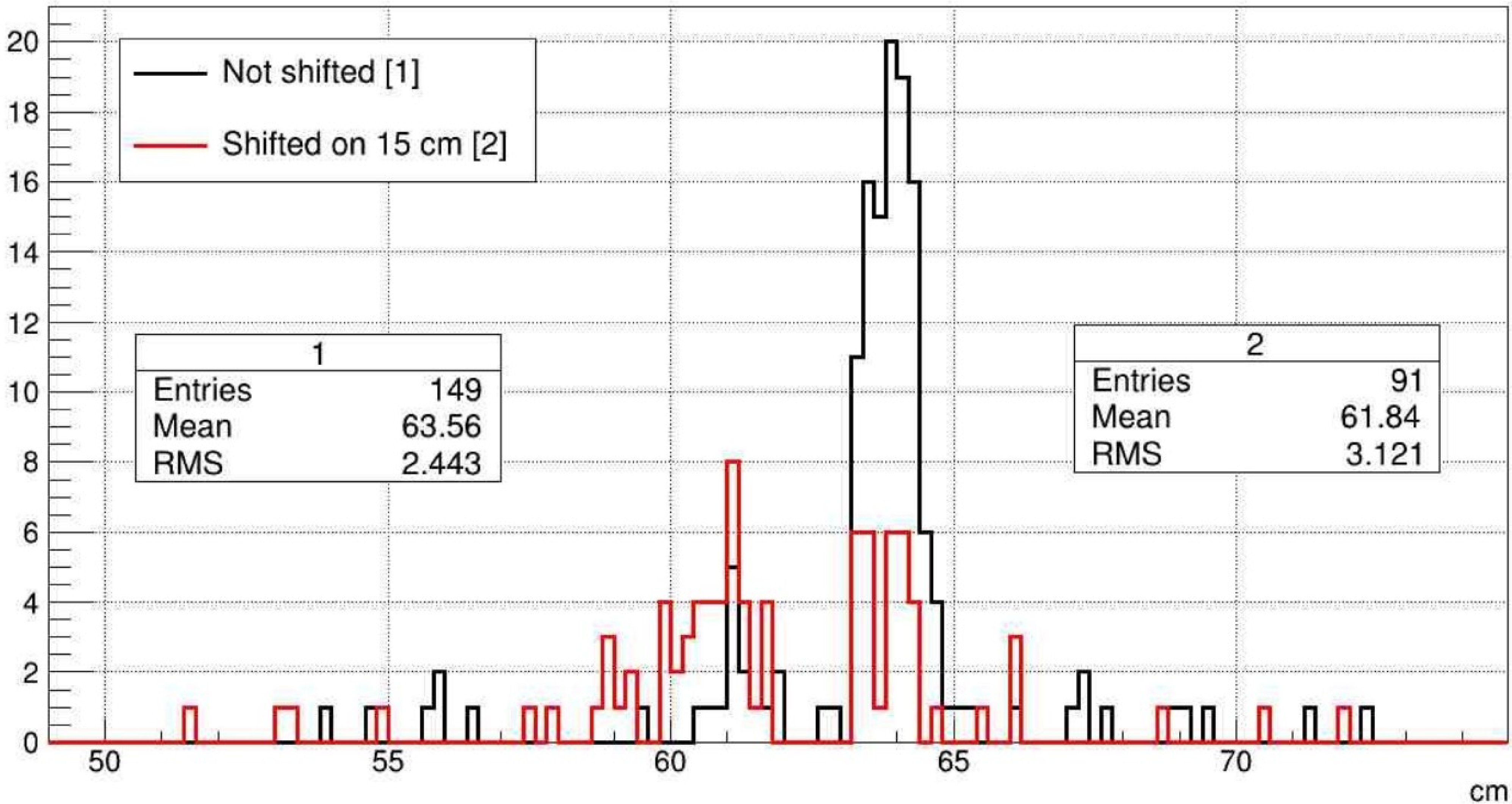
- CORTO system has been developed, constructed and calibrated at LAL.
- Position resolution measured to be 1.5 cm along MRPC strip and 0.7 cm in perpendicular direction.
- Time resolution 90 ps.
- In near future we will test:
  - CpFM upgrade
  - FTOF
  - Start quartz counter for beam test of HGDT detector
- During construction/calibration period we had 3 students working on CORTO.
- 3 Master 1 thesis are written about CORTO
- CORTO platform planed to be used for student practical work
  - For physics students : muon lifetime, efficiency calibration, muon tomography ?
  - For engineer students : translational stage calibration, programing of Arduino micro controller.
- Impatiently waiting for users internal/external users.

Thank you very much for your attention

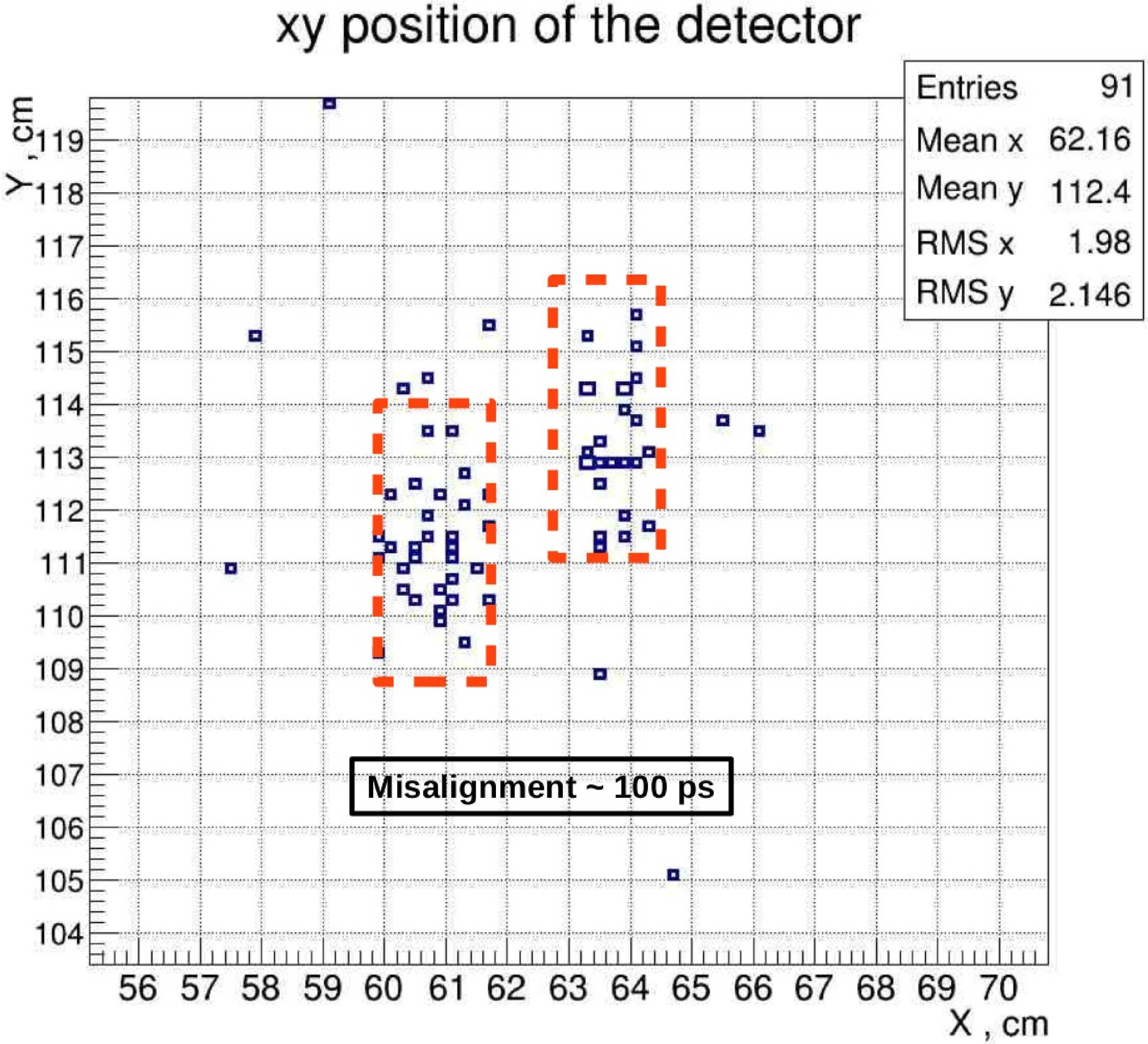
Backup slide

CORTO coordinate system.





Reconstructed X position of the scintillator.


xy position of the detector
Entries 91
Mean x 62.16
Mean y 112.4
RMS x 1.98
RMS y 2.146
Y , cm
X , cm
119
118
117
116
115
114
113
112
111
110
109
108
107
106
105
104
56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
Misalignment ~ 100 ps