Feasibility study for development of a PET device based on Multigap Resistive Plate Chambers

M.Nizam [1,2] B. Satyanarayana [1] R.R. Shinde [1] G. Majumder [1]

[1] Tata Institute of Fundamental Research, Mumbai

[2] Homi Bhabha National Institute, Mumbai

mohammad.nizam@tifr.res.in

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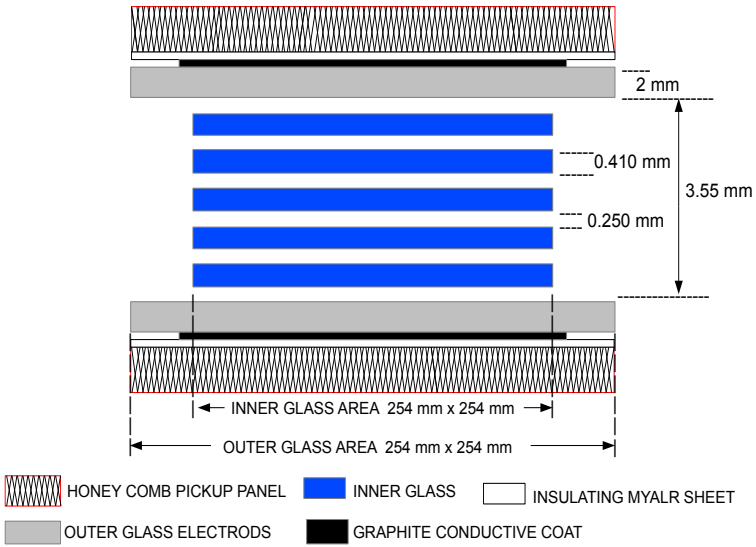
Outline

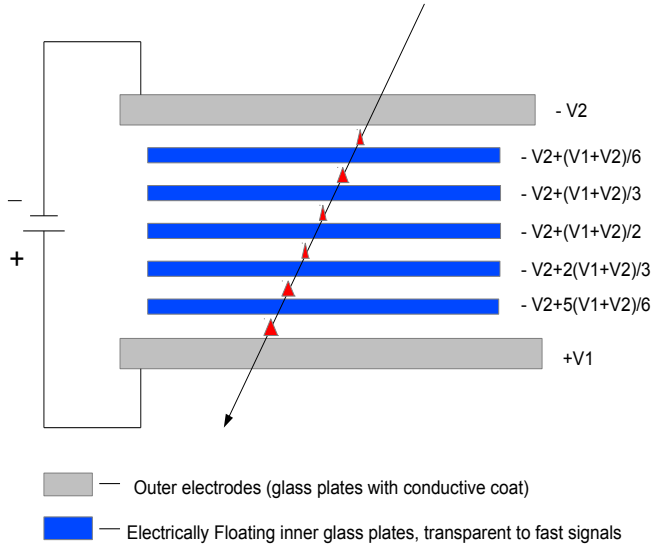
- Introduction
- Fabrication and Characterization
- MRPC PET
- Timing data
- Efficiency
- Summary and Future Plan

Introduction

- The Multigap RPCs (MRPCs) are gas ionization detectors with multiple sub gaps, made of highly resistive electrodes.



Schematic of the six-gap MRPC



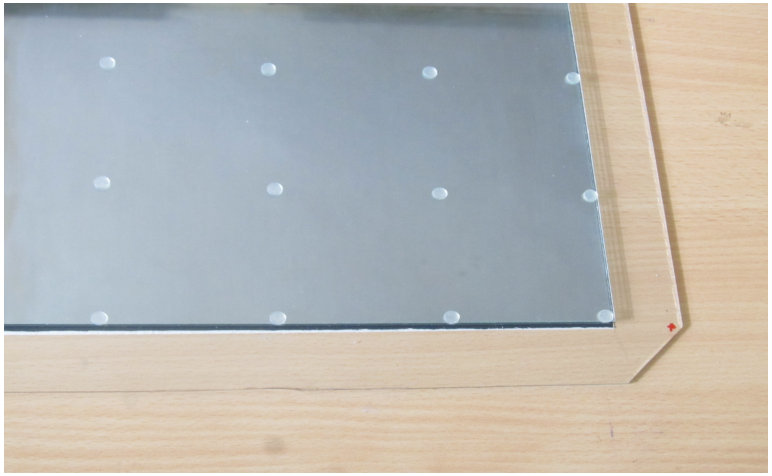
Potentials across the sub gaps of an ideal MRPC detector

- The high voltage (HV) is applied to the outermost resistive plates only, while the interior plates are electrically floating.
- Higher voltage applied mainly due to larger overall gap

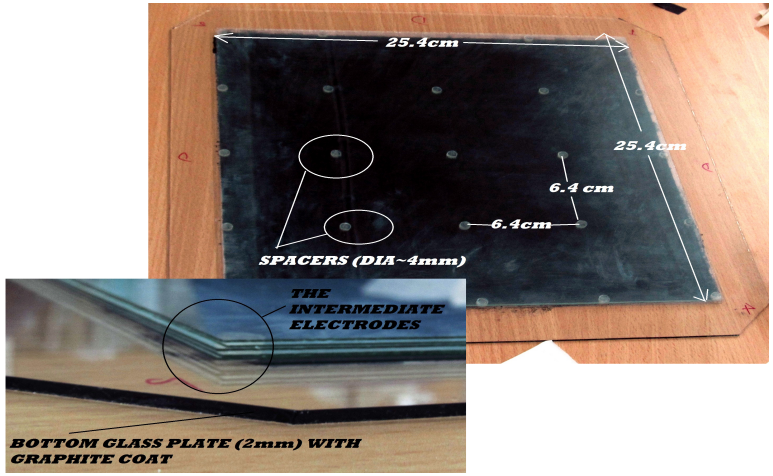
Introduction..

- A charged particle passing through the gas gaps creates simultaneous avalanches in each of the individual gas gaps.
- The fast signals in case of MRPC are produced by the flow of electrons towards the anode.
- Avalanche in any of the sub-gaps induce signals on these electrodes and the resultant signal is a summation from all the gas gaps.
- Copper pickup strips placed outside the cathode and anode collect the signal, with a reduced time jitter, through induction.
- We have fabricated six gap MRPCs (each sub gap being 250m) of dimension 27 cm $\times$ 27cm $\times$ 0.758 cm and tested in avalanche mode.
- the gas mixture being optimized to $R134a(91.2\%), C_4H_{10}(4.8\%)$ and $SF_6(4\%)$.
- Glasses of 2mm thickness coated with a conductive layer using NEROLAC paint are used for the outer electrodes.
- The surface resistances of the conductive coat are in the range (0.5-1)M$\Omega/\Box$.

Fabrication...

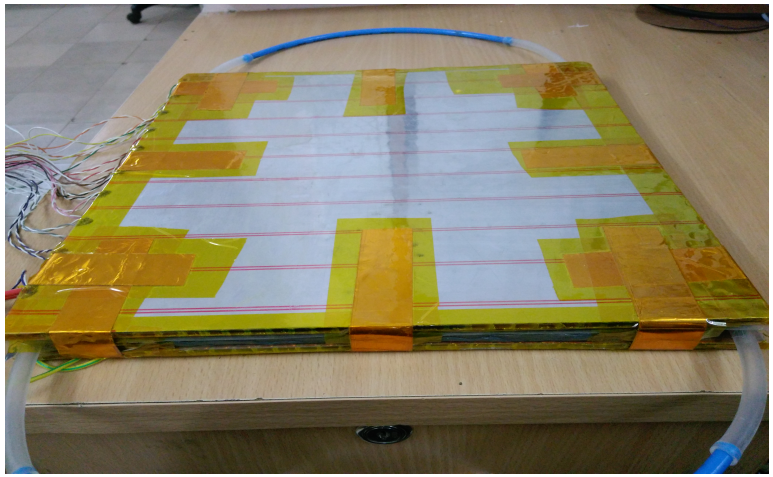


Spacers



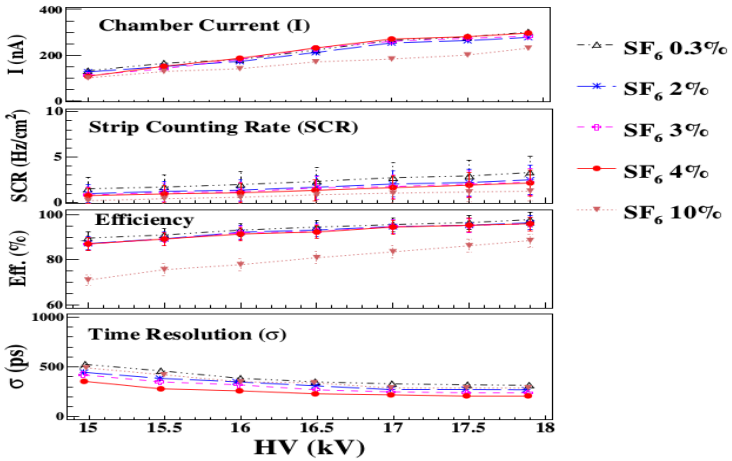
Glass dimesions

Side Spacers

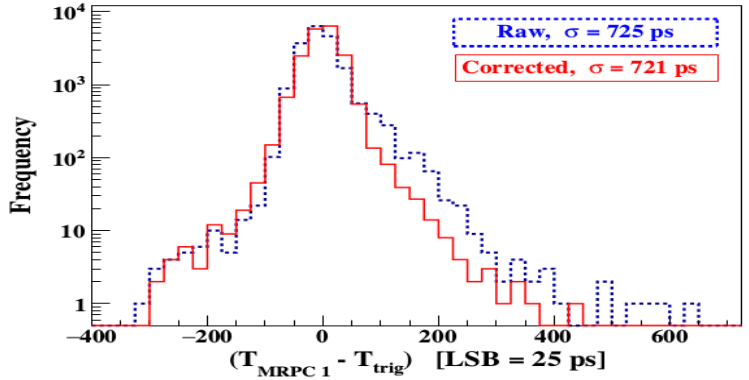


Pickup panels

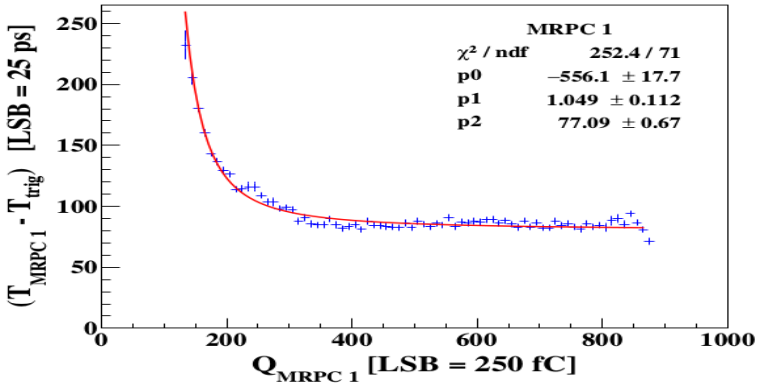
Characterization and Time Resolution



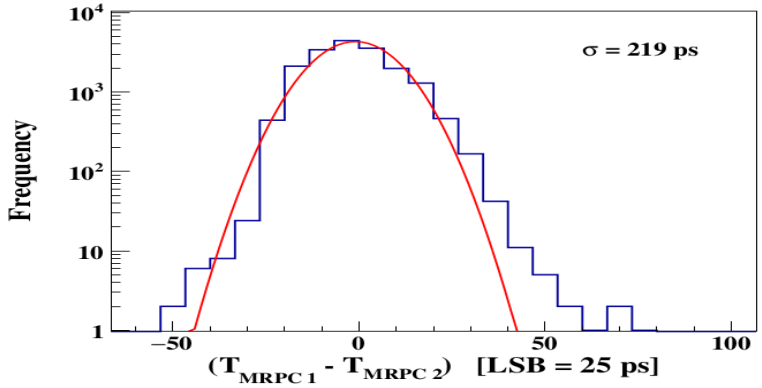
The various characteristics of an MRPC strip as a function of the high voltage



The MRPC time distribution with respect to the trigger at 17.9 kV.



The calibration graph for correcting of the MRPC time distribution for time- walk.



MRPC 1 time distribution with respect to MRPC 2 at 17.9 kV.

- Moon Moon Devi et al.(DOI:10.1140/epjc/s10052-016-4570-2)

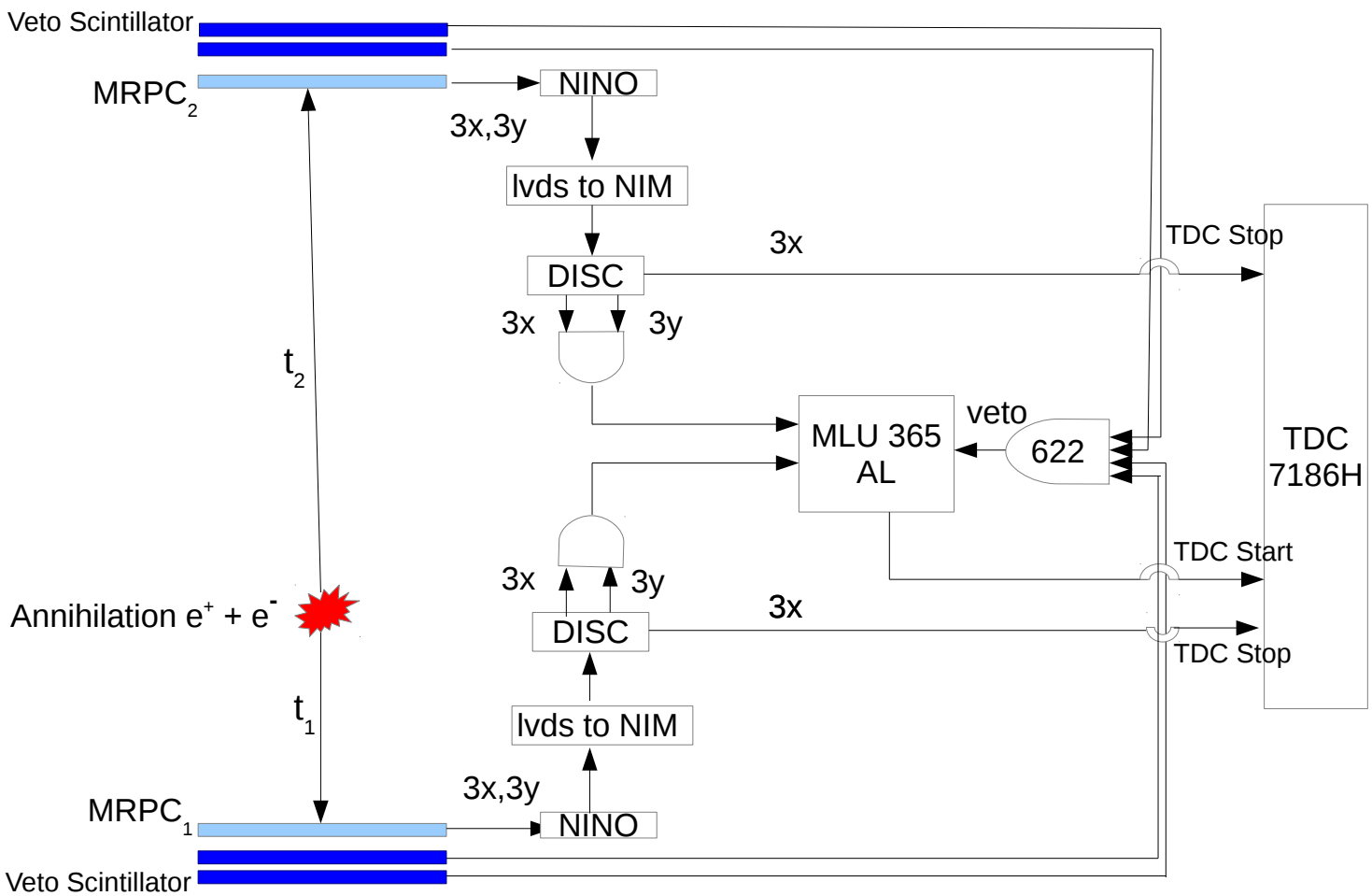
MRPC PET

- We want to use Multigap Resistive Plate Chambers (MRPCs) for their possible application in madical imaging.
- MRPCs offer better time resolution. $\sigma_t \approx 219ps$ (achieved for cosmic muons).
- A ^{22}Na source is used to get back to back 511 KeV photons.
- Two detectors are placed on both sides of the source at unequal distances.
- the signal is picked up by X-strips and Y-strips on orthogonal planes on two sides of each detector.
- the X and Y coordinates of a hit are recorded along with the time of arrival of the photon at the detector.

MRPC PET

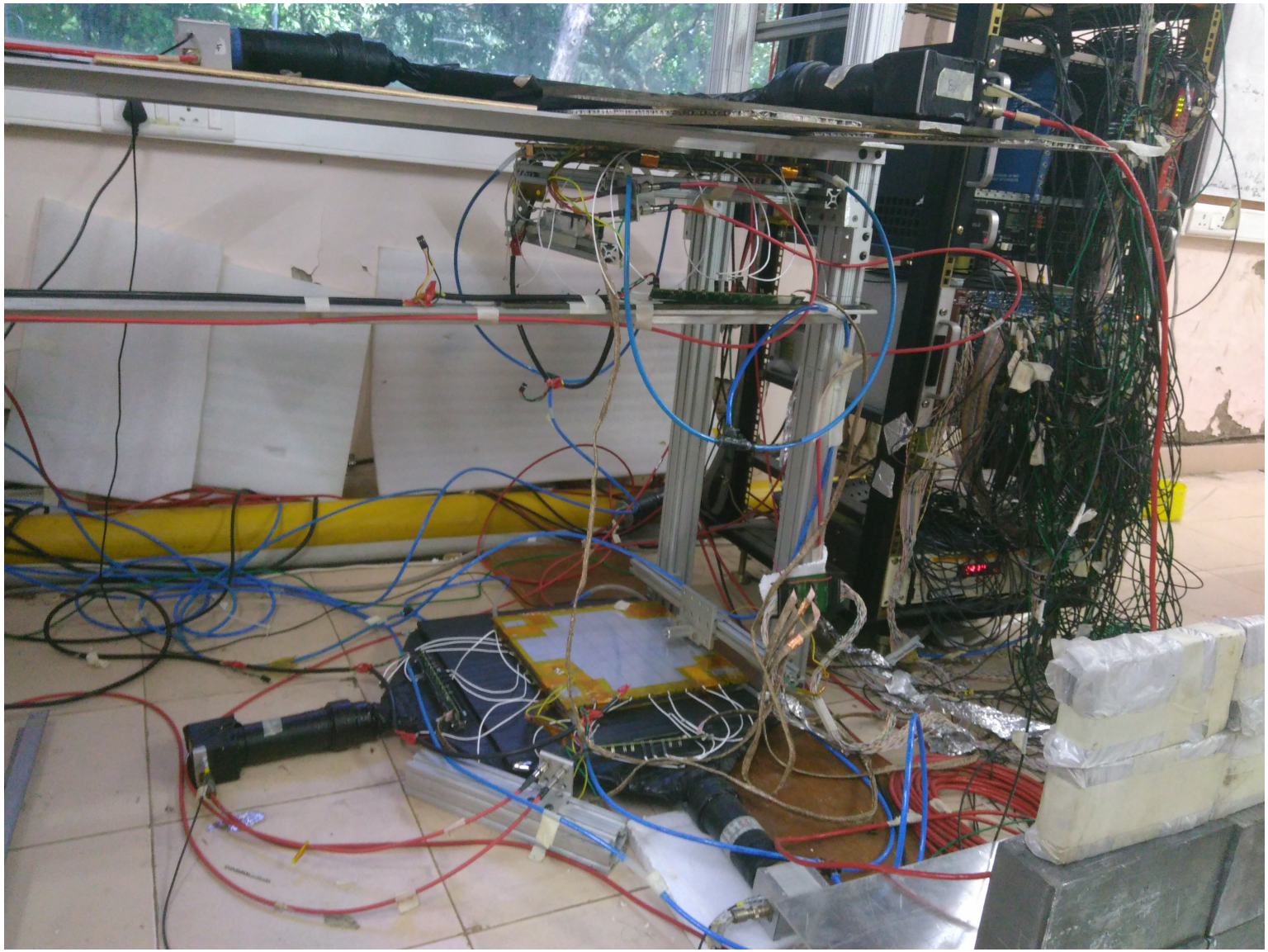
- The trigger is prodeuced by both X and Y strips. Three X and three Y strips of each detector are ORed separately and then X and Y signals are ANDed. The two AND signals from each detector are finally ANDed to form the trigger.
- Four scintillator detectors (44 cm X 44 cm) are used to veto cosmic muons. Two scintillators are placed above the top MRPC and two are placed below the bottom MRPC.
- We are reading only the X side timing information.
- We get lines of response by joining the X hits of MRPC1 and MRPC2.
- The timing Information tells us the exact position of the source on the line of response.

Detector setup (CAMAC DAQ)

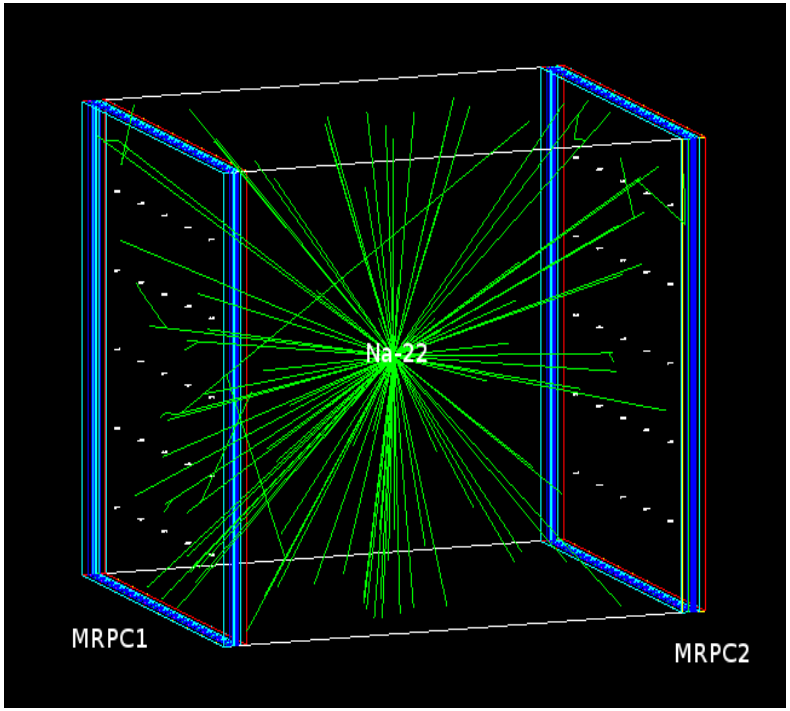


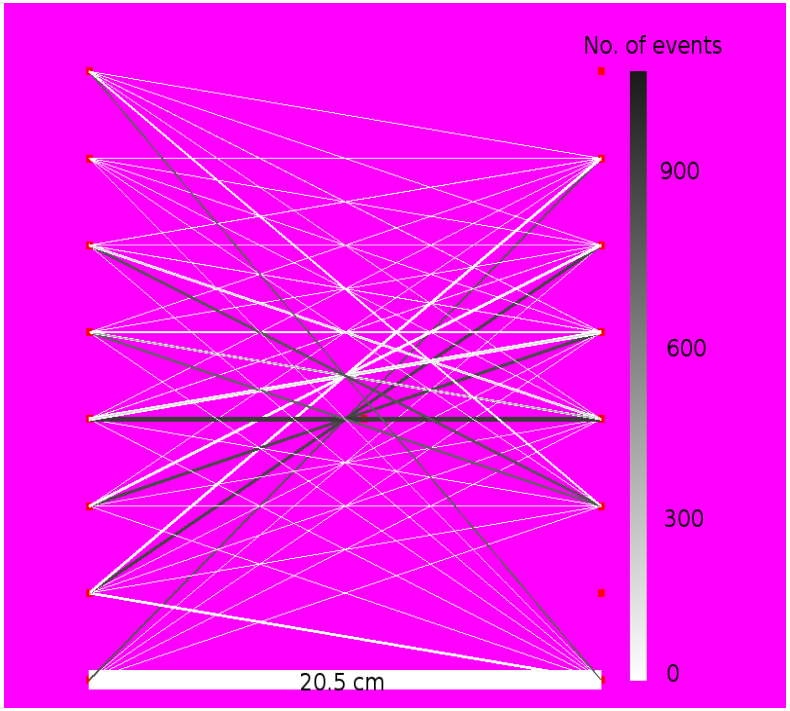
Block Diagram of the Setup

Detector setup



Lines of response





Lines of response

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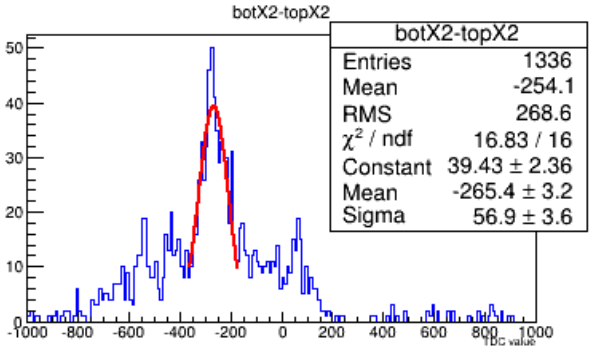
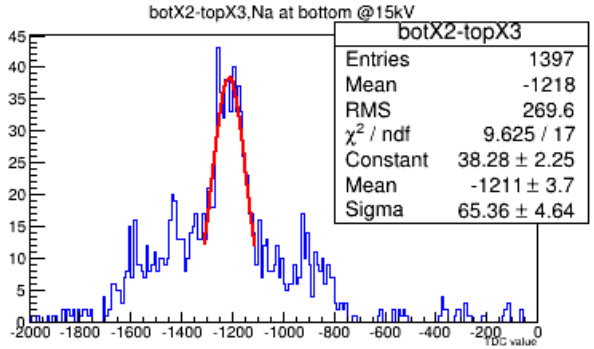
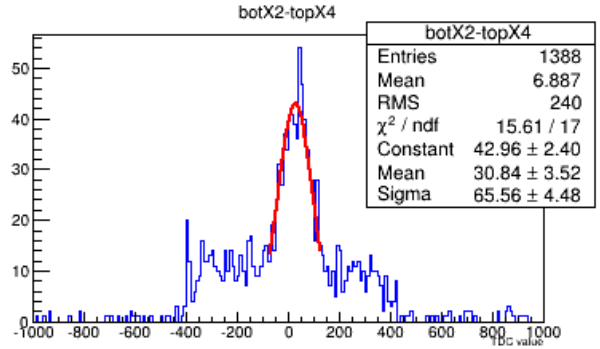
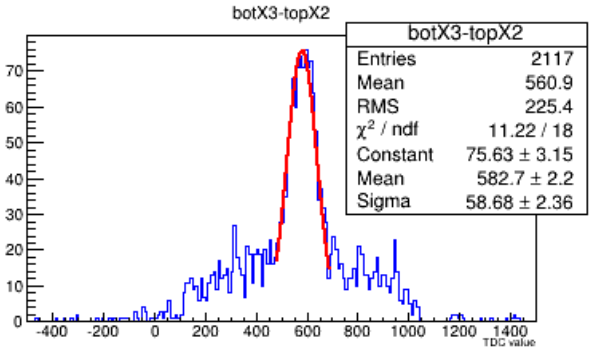
- The source is placed assymitrically with respect to the two MRPCs.
- Z coordinates is given by the time of arrival on the detectors.
  $\triangle t = t_{MRPC1} - t_{MRPC2}$
- The position accuracy is given by $\triangle L = c \times \sigma_t/2$
  $\triangle L$ = FWHM in the position accuracy, σ_t=rms time accuracy per photon.

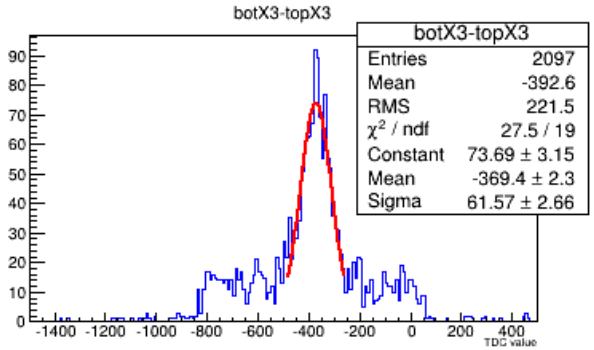
$\triangle t$ of three central strips, L = 45 cm @15.0 kV, source at bottom

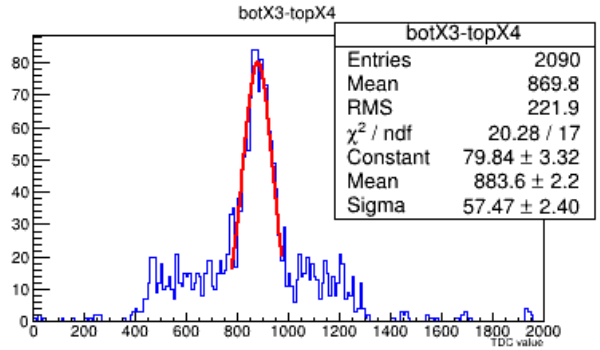


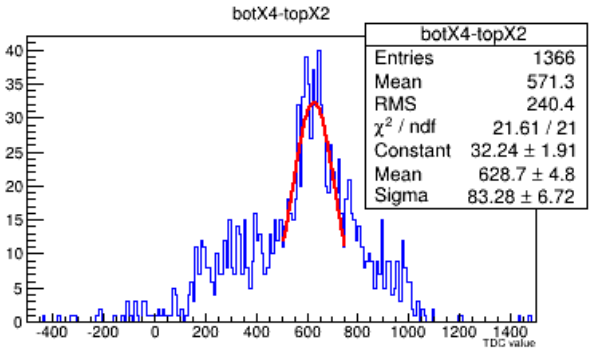


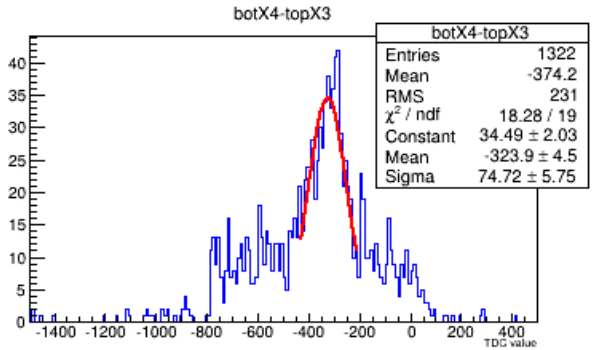


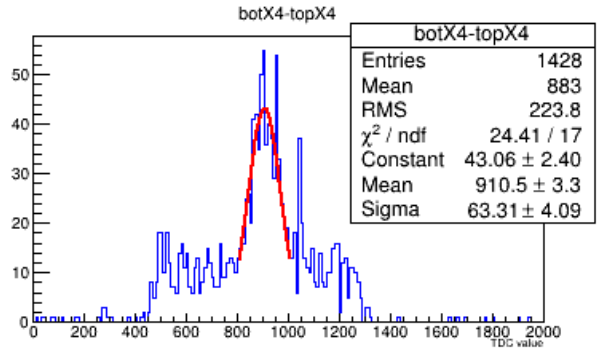






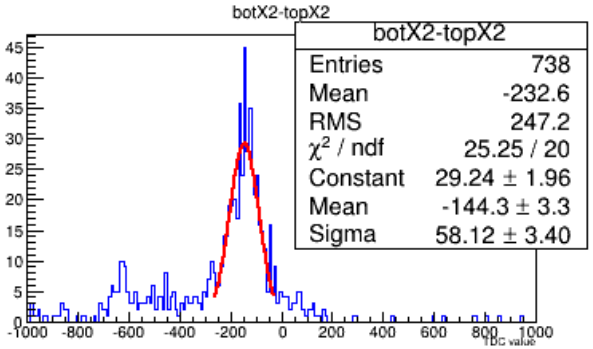


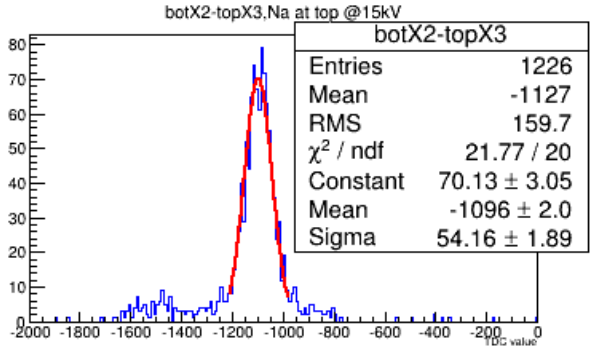


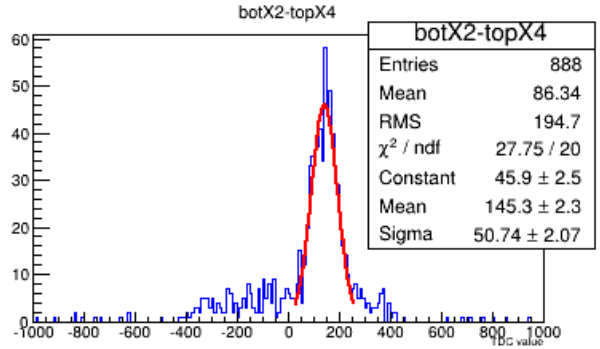


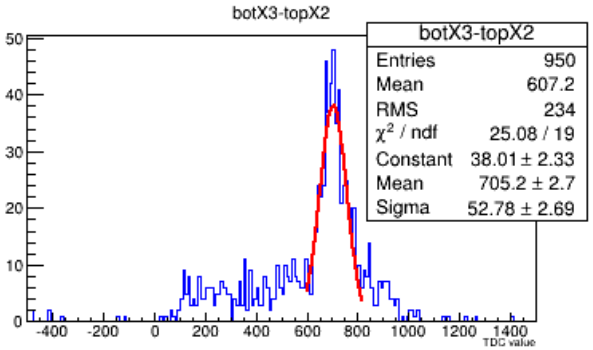
$\triangle t$ of 2nd,3rd and 4th strips, Source at 3rd strip of bottom MRPC

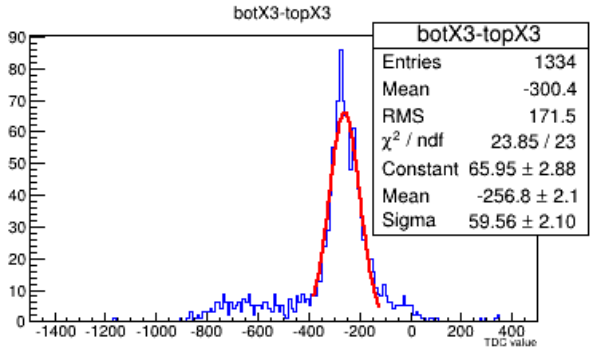
$\triangle t$ of three central strips, L = 45 cm @15.0 kV, source at Top

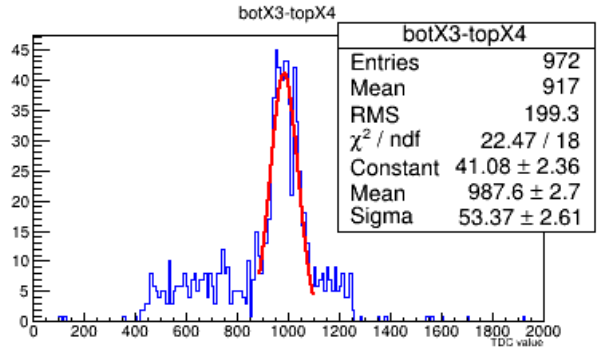


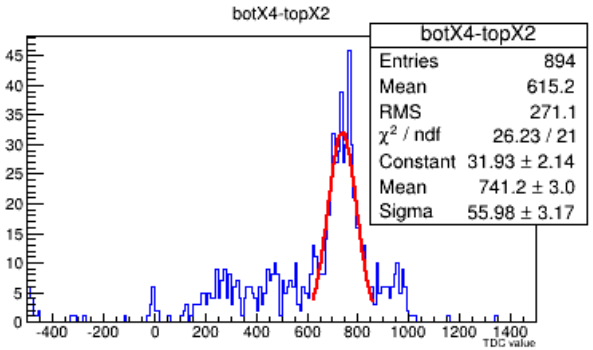


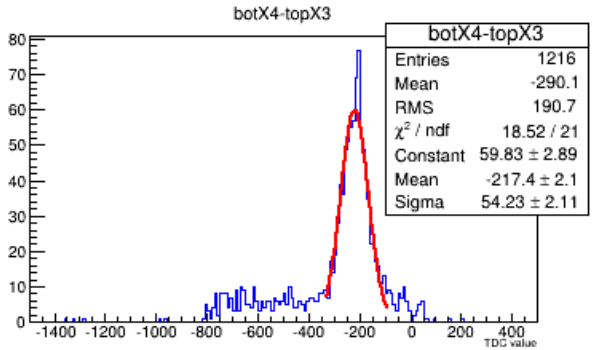


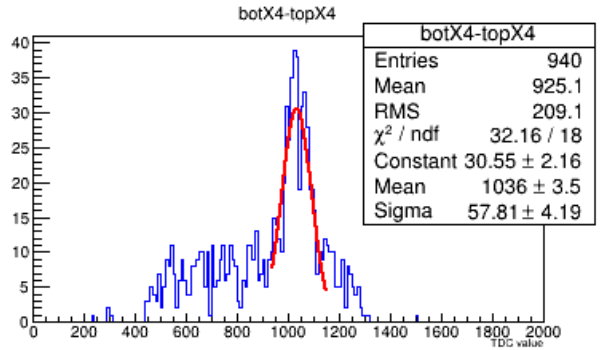






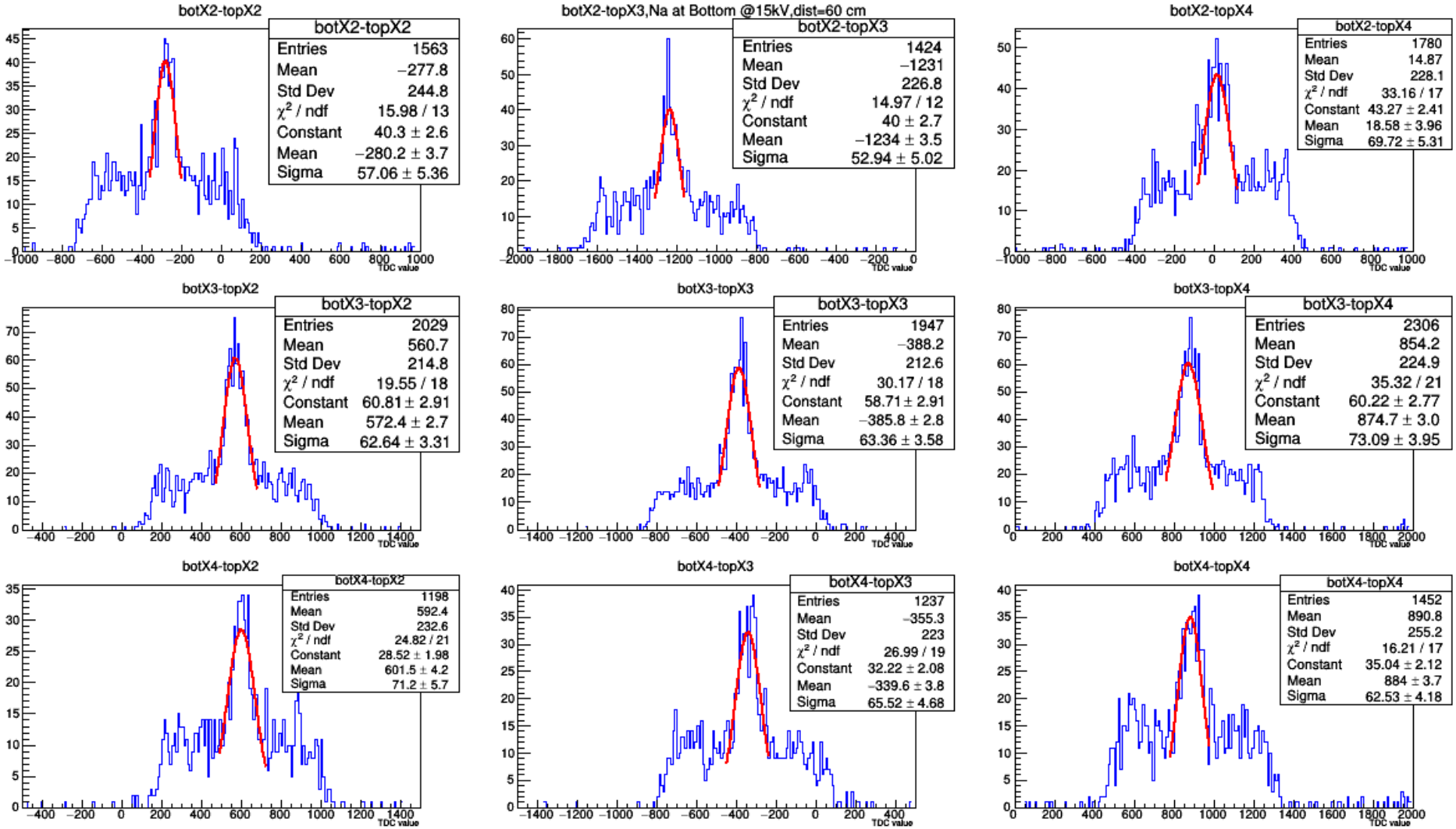






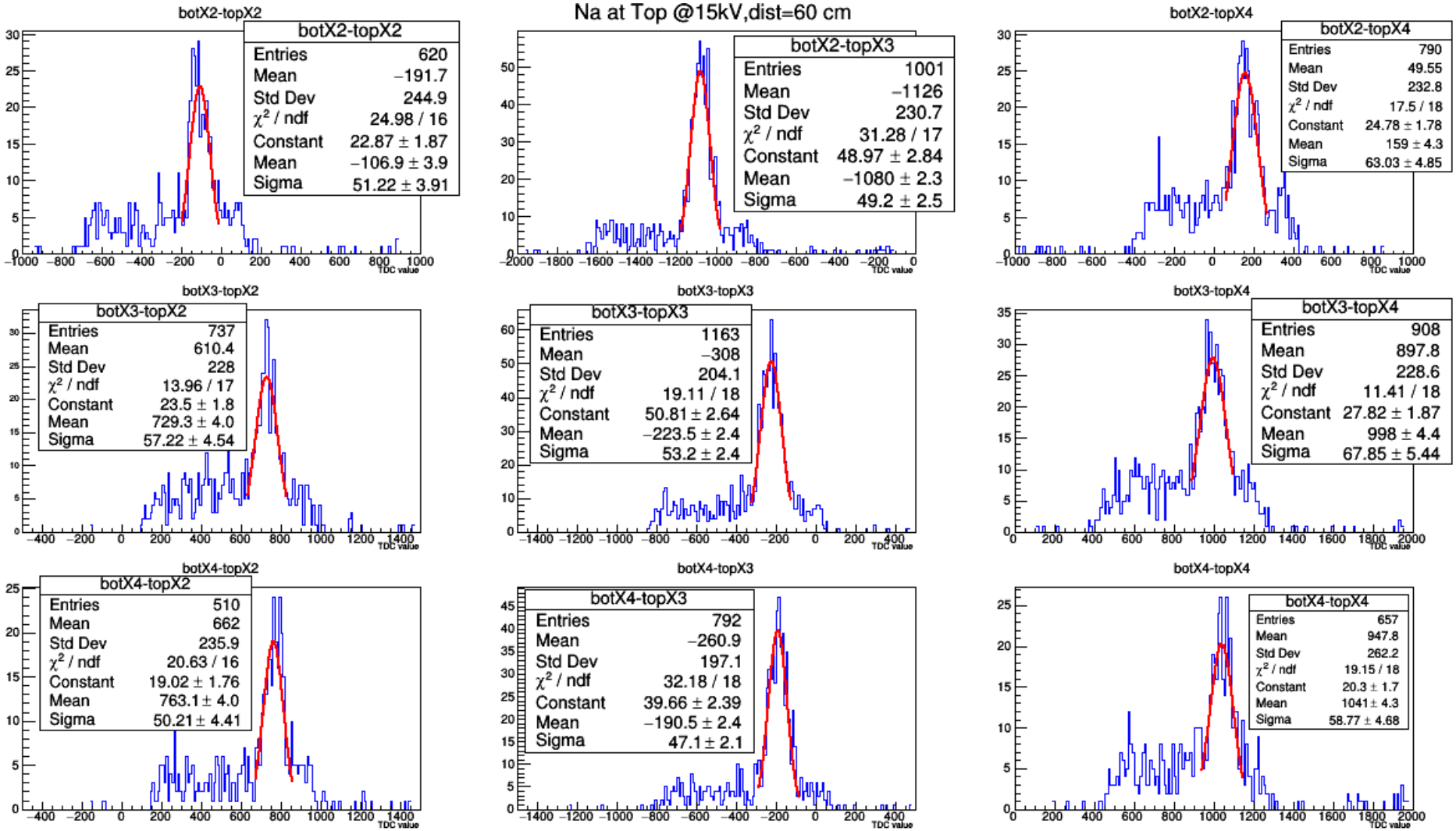
$\triangle t$ of 2nd,3rd and 4th strips, Source at 3rd strip of top MRPC

$\triangle t$ of three central strips, L = 60 cm @15.0 kV, source at bottom



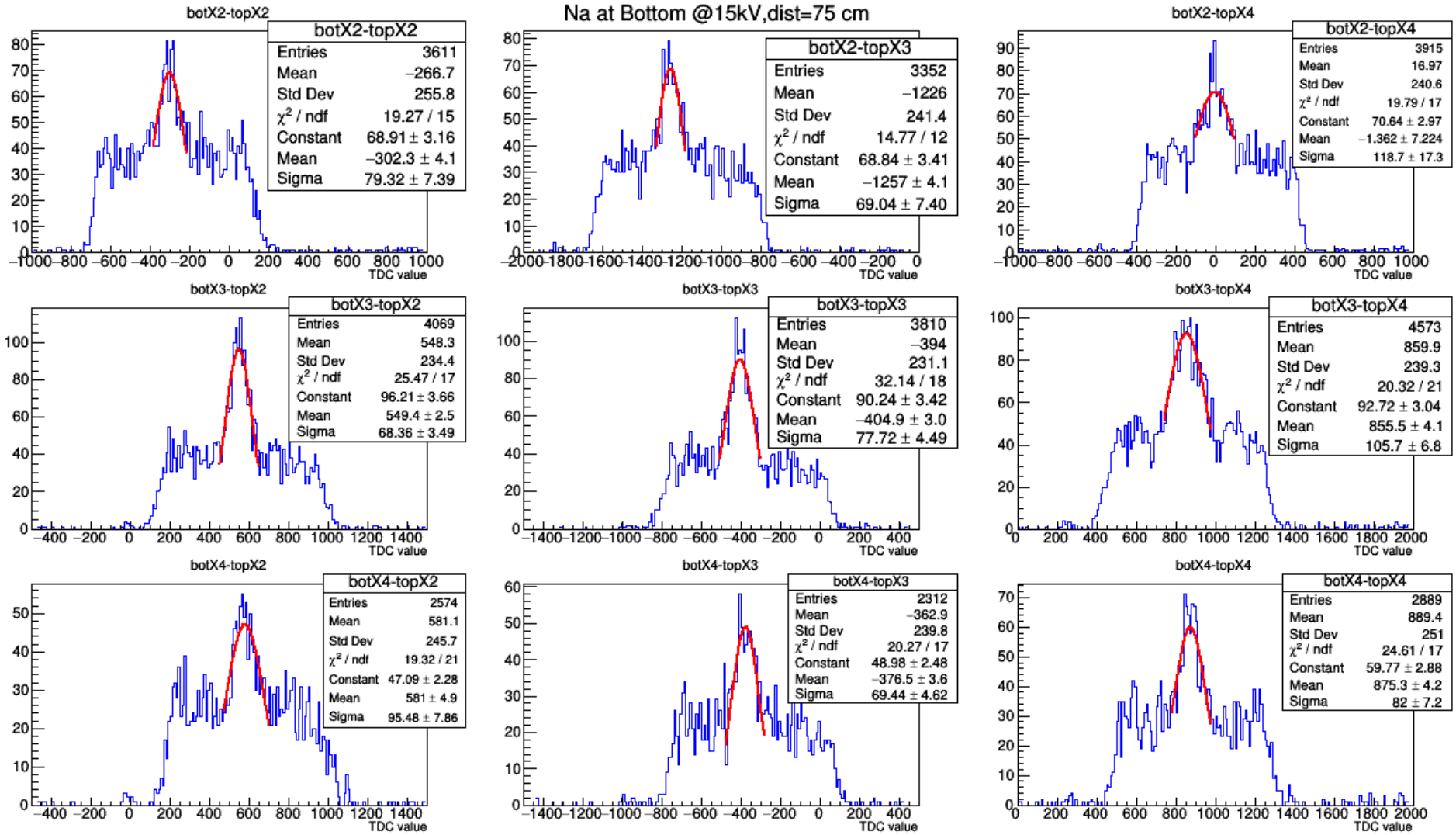
$\triangle t$ of 2nd,3rd and 4th strips, source at 3rd strip of bottom MRPC

$\triangle t$ of three central strips, L = 60 cm @15.0 kV, source at top



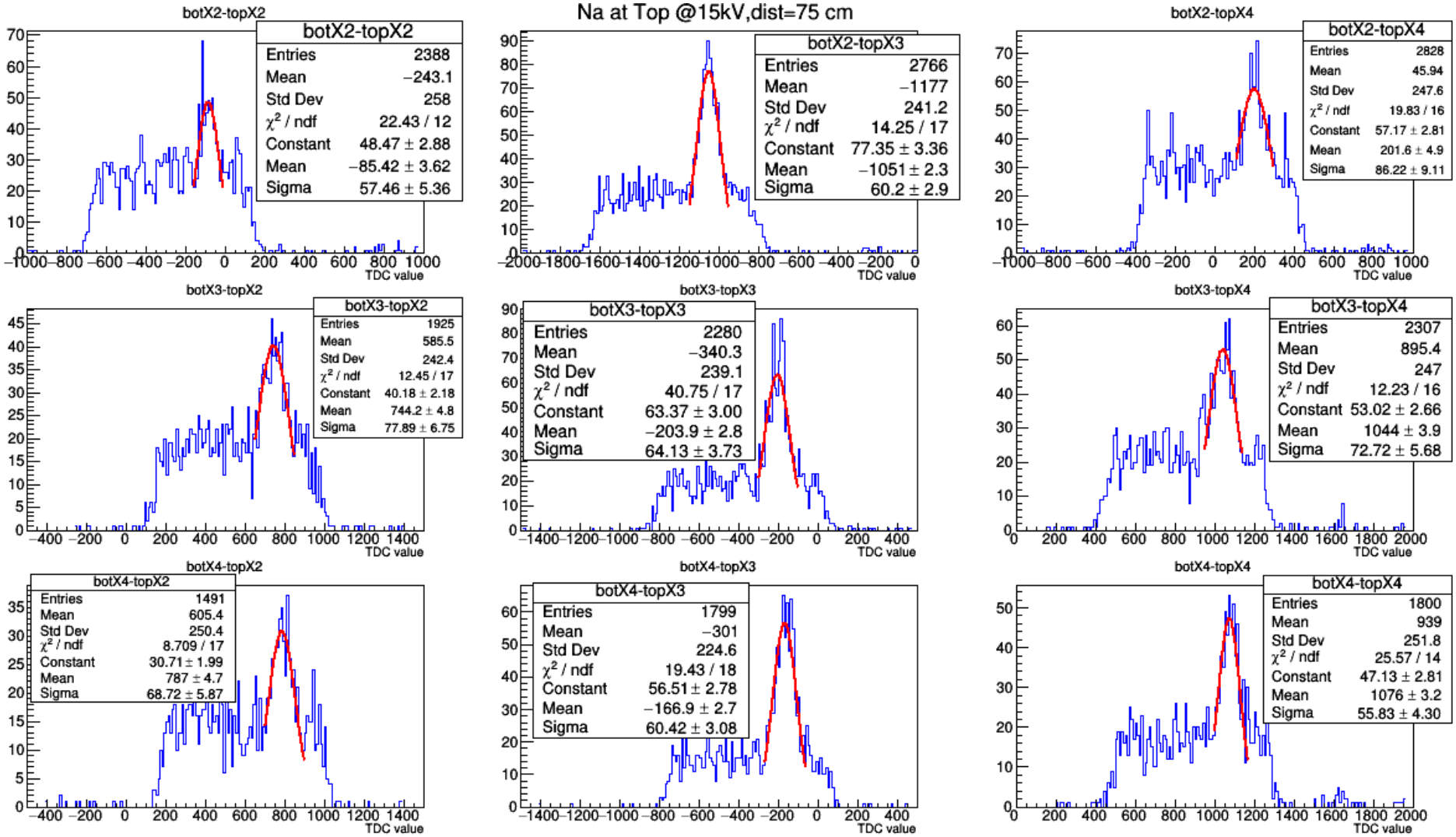
$\triangle t$ of 2nd,3rd and 4th strips, source at 3rd strip of top MRPC

$\triangle t$ of three central strips, L = 75 cm @15.0 kV, source at bottom



$\triangle t$ of 2nd,3rd and 4th strips, source at 3rd strip of bottom MRPC

$\triangle t$ of three central strips, L = 75 cm @15.0 kV, source at top



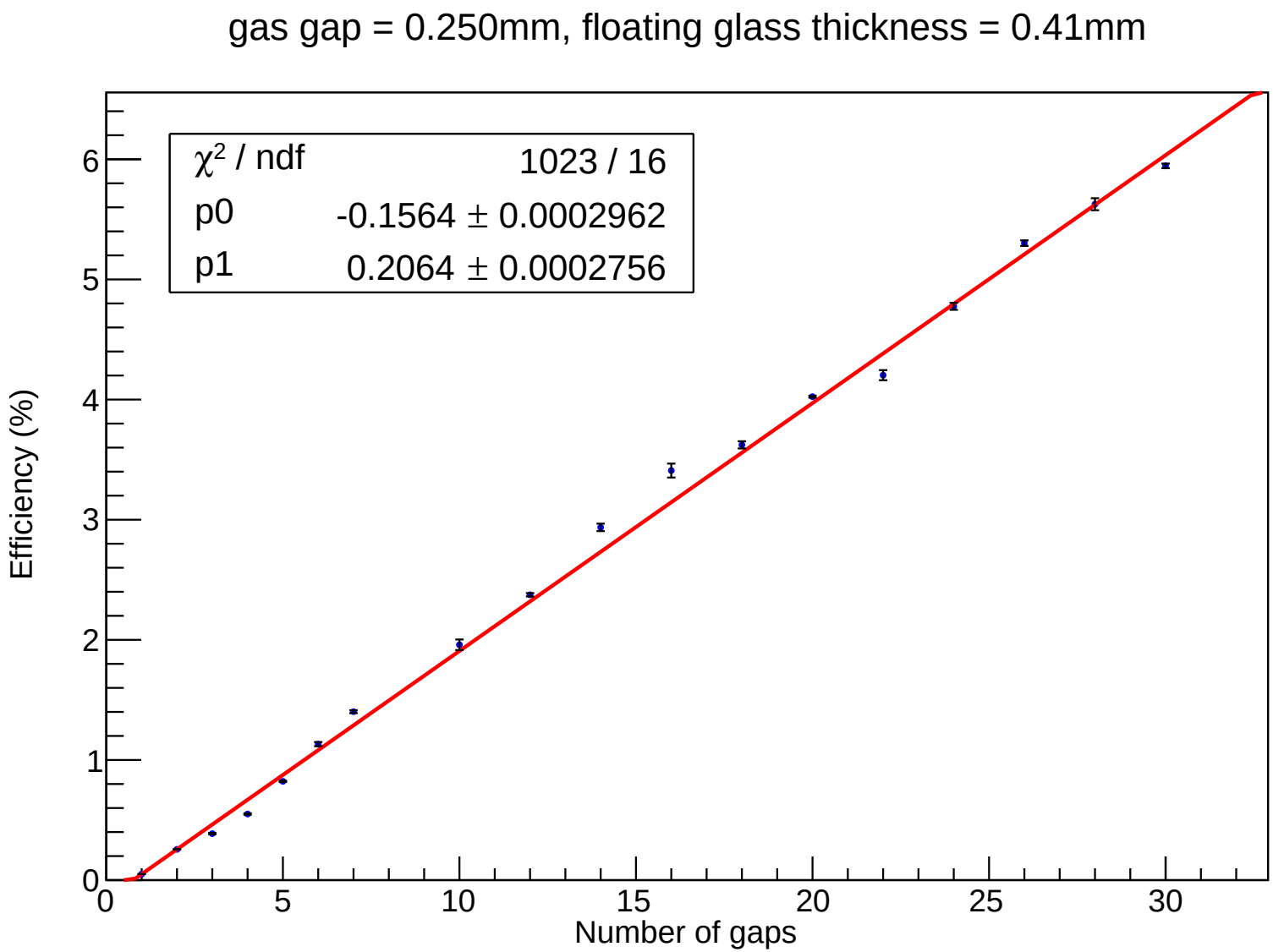
$\triangle t$ of 2nd,3rd and 4th strips, source at 3rd strip of top MRPC

TOF calculation

Distance b/w MRPCs	Source at bottom MRPC Δt_1	Source at top MRPC Δt_2	diff=$\lvert\Delta t_1 - \Delta t_2\rvert/2$	Time of flight(TOF) = diff x 25 ps	Actual TOF
45 cm	Mean= -369.4 ± 2.3 Sigma= 61.57 ± 2.7	Mean=-256.8 ± 2.1 Sigma=59.56 ± 2.1	56.3 ± 2.2	1.41 ± 0.05 ns	1.5 ns
60 cm	Mean=-385.8 ± 2.8 Sigma=63.36 ± 3.6	Mean=-223.5 ± 2.4 Sigma= -53.2 ± 2.4	81.2 ± 2.6	2.03 ± 0.07 ns	2.0 ns
75 cm	Mean=-404.9 ± 3.0 Sigma=77.72 ± 4.5	Mean=-204.0 ± 2.7 Sigma=63.85 ± 3.6	100.5 ± 2.8	2.51 ± 0.07 ns	2.5 ns

TOF for different separation between MRPCs, source is at the centre of the 3rd strip for all cases.

Efficiency v/s Number of gaps (GEANT4)



Efficiency v/s number of gaps

Summary and Future Plan

- We need to understand systematics and apply corrections to achieve better time resolution.
- Efficiency is very low, increasing the number of gaps and using converter material will increase the efficiency.
- Both X and Y timings to precisely locate the source position.
- Fabricating MRPCs with lead coating on the inner wall of the outer electrode.
- Narrow pickup strips for better position resolution.
- FPGA based DAQ system.
- Charge information along with the digital signal using Anusparsh to correct for the time walk.


Thank you!