MRPC-based Muon Telescope Detector(MTD) in STAR@RHIC

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Outline:

Introduction
Design Concept
Final Design
Performance
Installation in STAR
Summary

Physics at RHIC

- A hot, dense medium with partonic degrees of freedom created at RHIC:
  ---Jet quenching
  ---Baryon enhancement,
  ---Number of constituent quark scaling in elliptic flow
  ---…..

- Next:
- Is the system thermalized and how does the system thermalize?
- What are the properties of the system?
- What is the phase structure of QCD matter?
- What exotic particles are produced at RHIC?
- What is the mechanism for partonic energy loss?
- What is the nature of the initial state in nuclear collisions
- …

Muons: Penetrating Probes

The initial temperature of QGP; the mass origin of hadrons; color screening features of heavy quarkonia

Measurements	Physics
low mass di-muons	**thermal radiation of QGP;** **in-medium modifications of vector meson (ρ ω ϕ) (chiral symmetry restoration)**
intermediate mass di-muons	**thermal radiation of QGP;**
large mass: heavy quarkonia	**T of QGP, color screening, quarkonium production mechanism.**

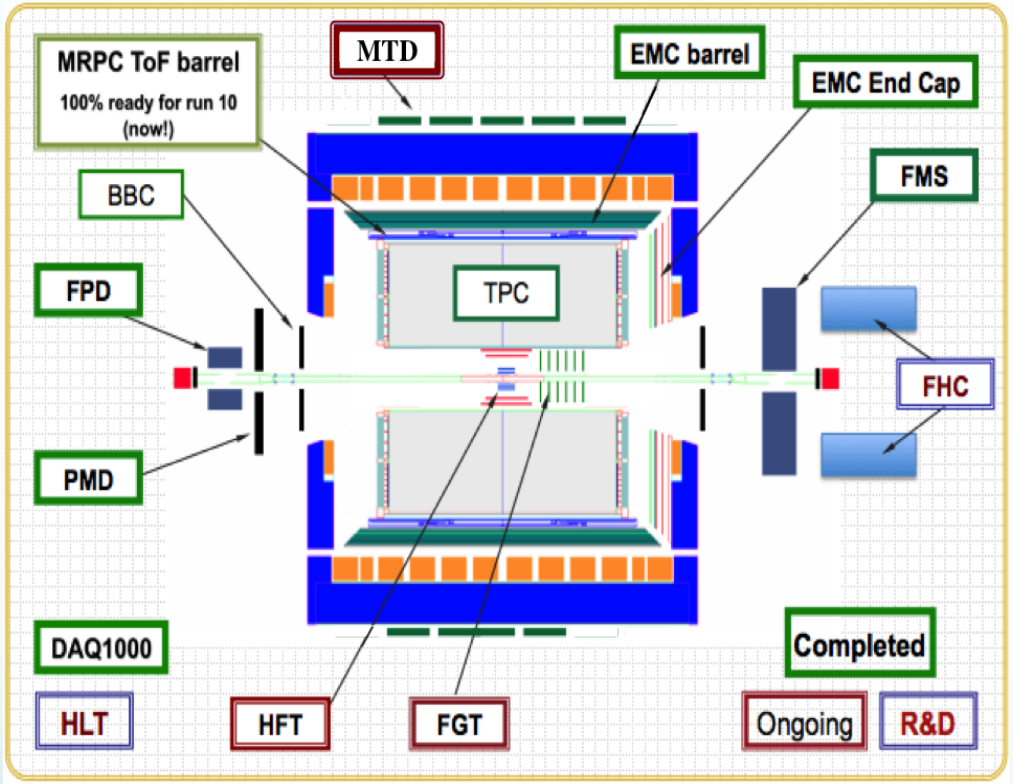
Physics motivation of MTD

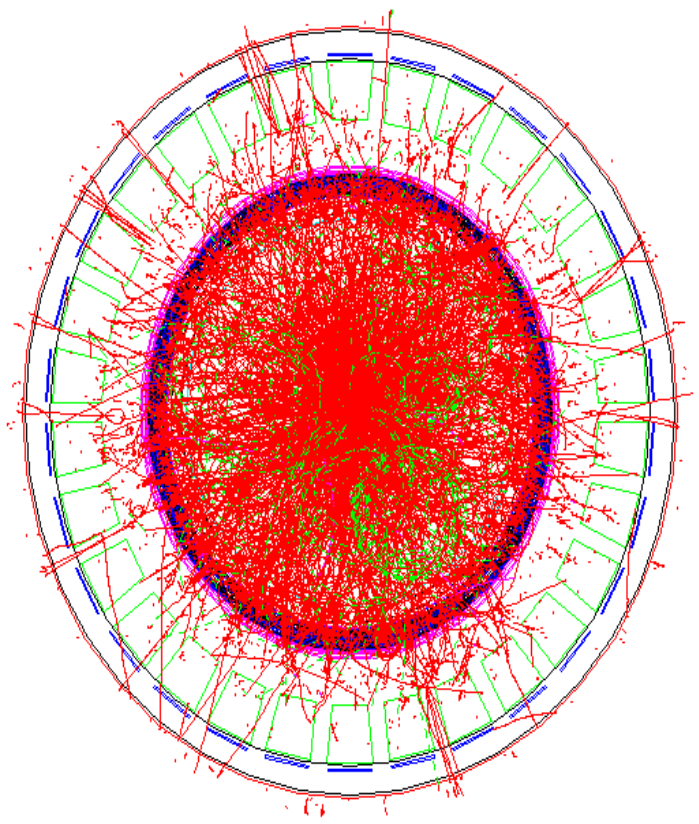
A large area of muon telescope detector (MTD) at mid-rapidity, allows for the detection of

- di-muon pairs from QGP thermal radiation, quarkonia, light vector mesons, possible correlations of quarks and gluons as resonances in QGP, and Drell-Yan production
- single muons from the semi- leptonic decays of heavy flavor hadrons
- advantages over electrons: no γ conversion, much less Dalitz decay contribution, less affected by radiative losses in the detector materials, trigger capability in Au+Au
- trigger capability for low to high pT J/ψ in central Au+Au collsions
  excellent mass resolution, separate different upsilon states
  e-muon correlation to distinguish heavy flavor production from initial lepton pair production

J. Phys. G: Nucl. Part. Phys. 36(2009) 095001

Concept of Design of the STAR-MTD





J. Phys. G: Nucl. Part. Phys. 36(2009) 095001

MTD System Requirement

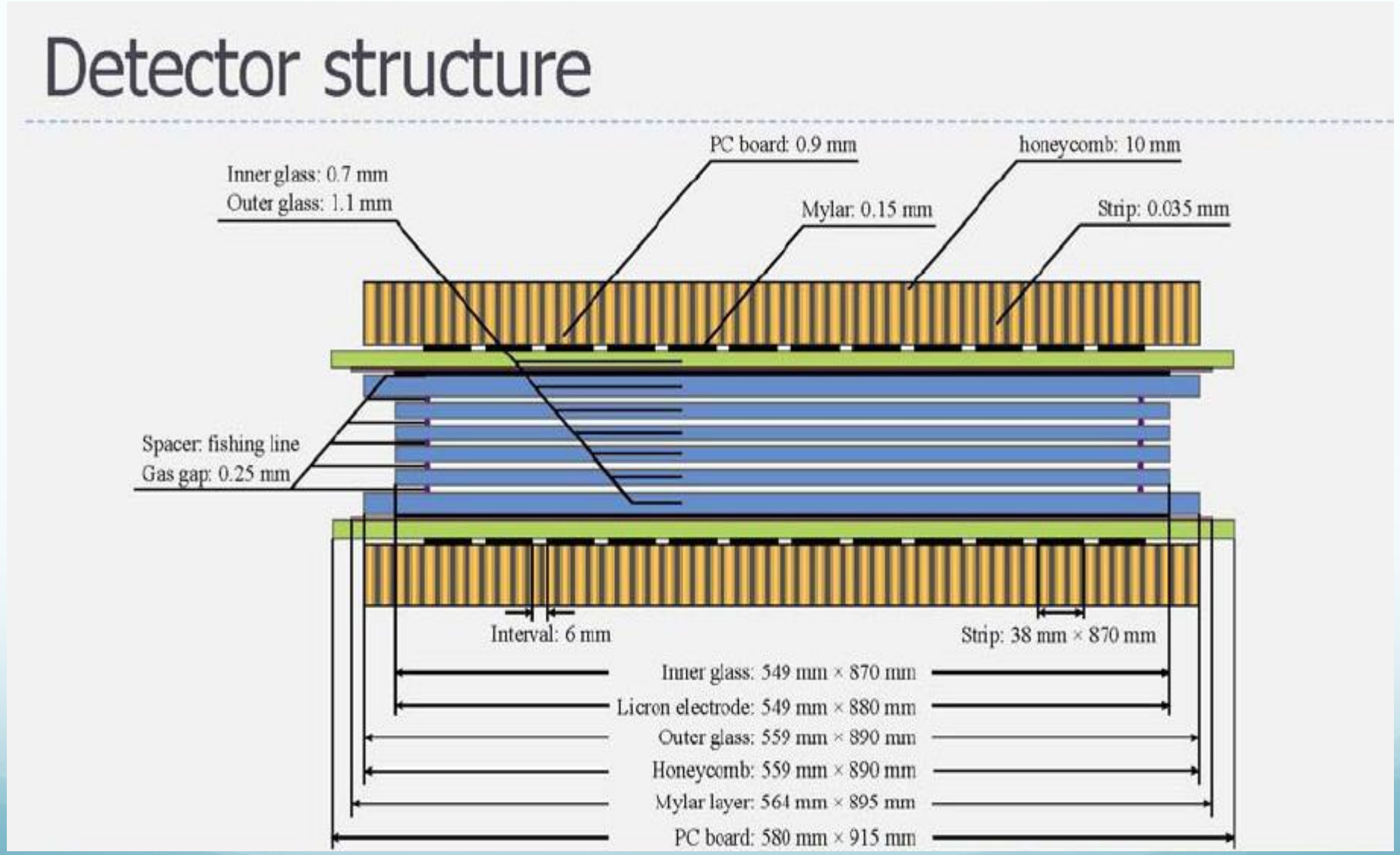
- **Time resolution less than 100 ps, spatial resolution ~ 1 cm.**
- **The mechanics design must allow a convenient replacement of individual MTD box and access to the BEMC box.**
- **The system must be able to operate in the fringe field from 0.5 Tesla STAR magnet field.**
- **The system must operate at low noise rate. The total noise rate should be less than 1 Hz/cm^2.**

MRPC is one of the best suited technology for the purpose.

Nucl. Instr. and Meth. A, 593 (2008), p. 307

Nucl. Instr. and Meth. A, 640 (2011), p. 85

Design of MRPC

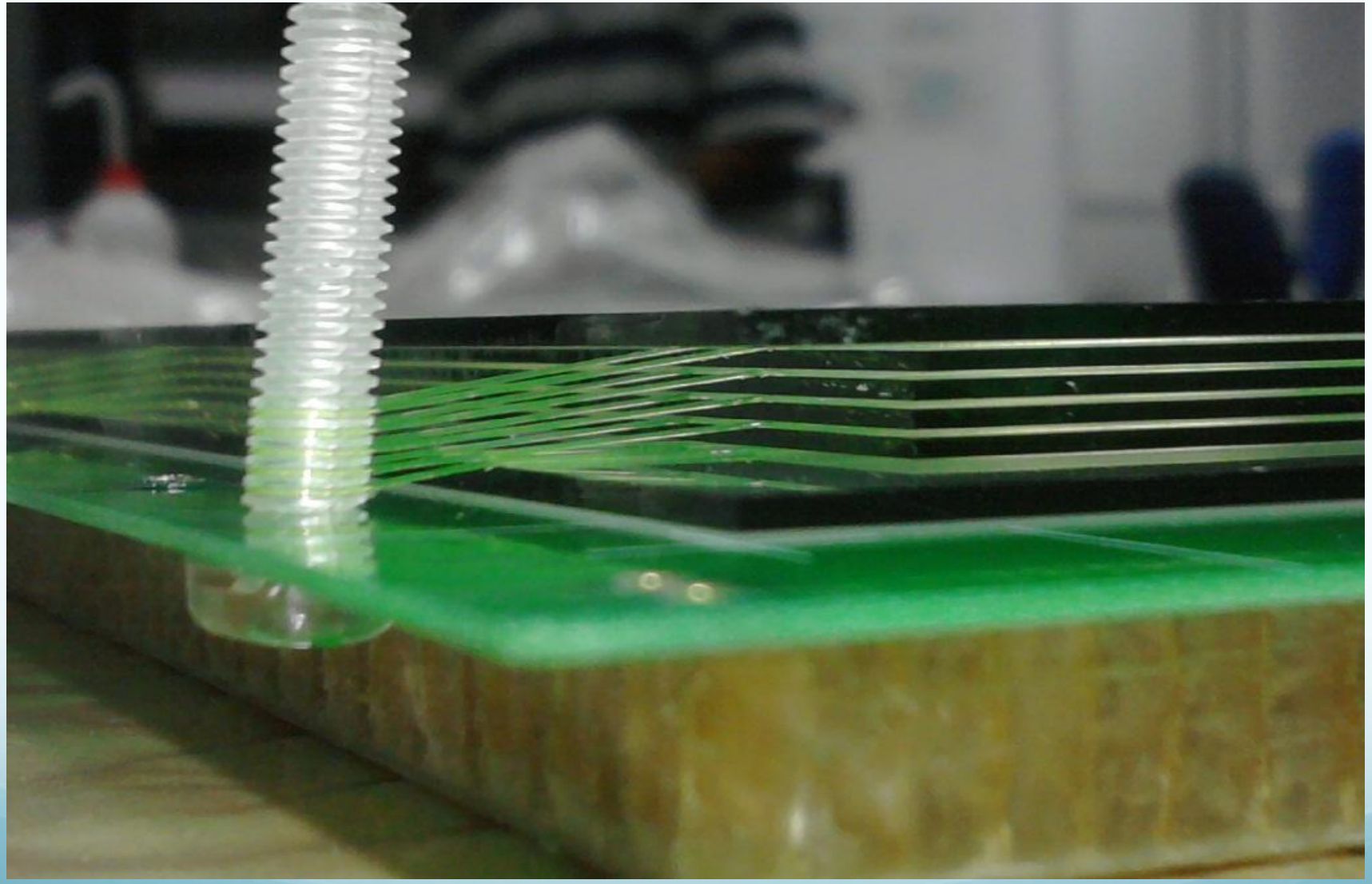


The materials for one MRPC module

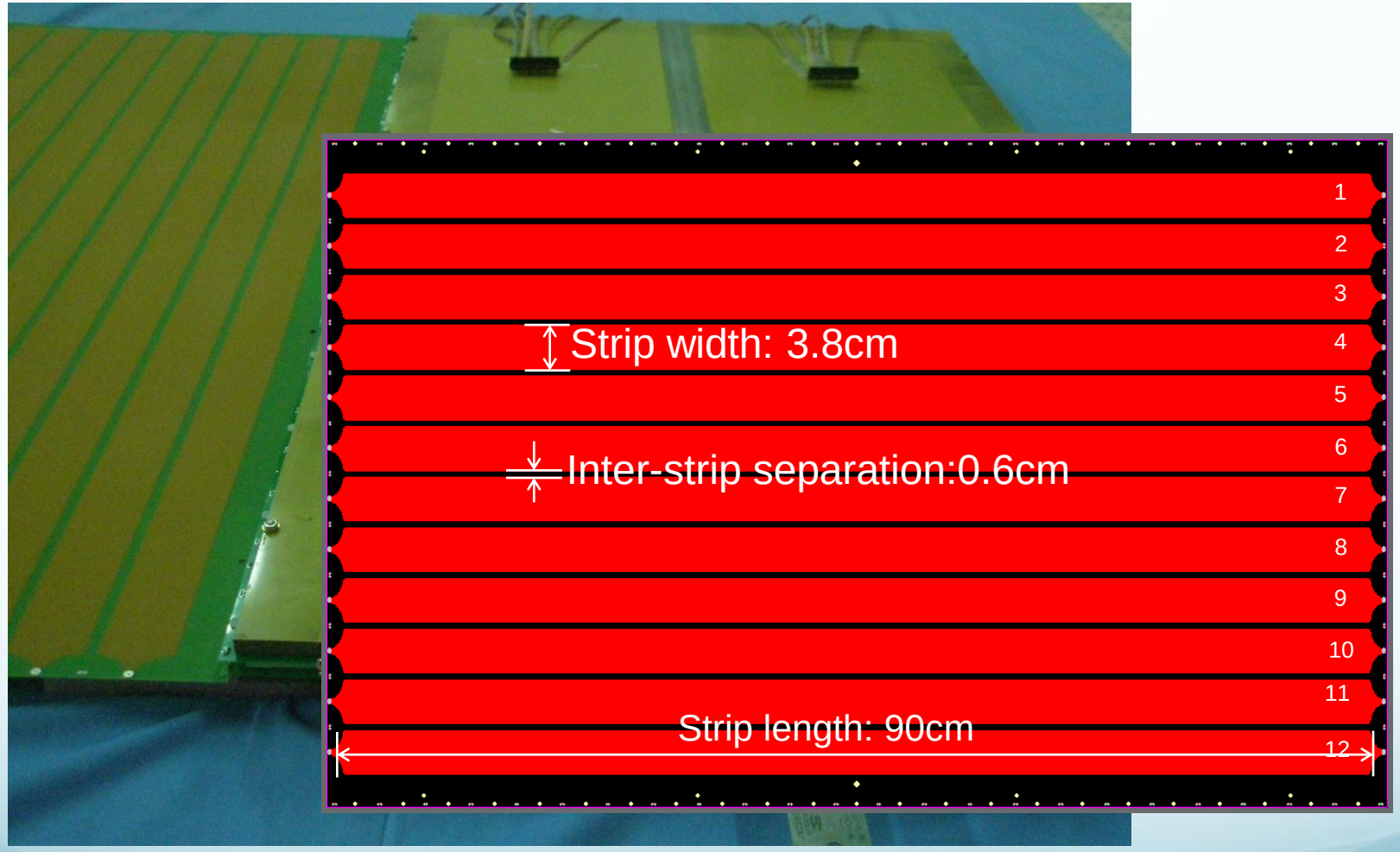
Material	Dimension (mm)	Tolerance (mm)	Quantity
Outer glass	890×559×1.1	±0.5, ±0.5 ,±0.02	2
Inner glass	870×549×0.7	±0.5, ±0.5, ±0.02	4
Graphite electrode	888×557×0.1	-0.5	2
Mylar film	895×564×0.15	±0.1	2
Honeycomb board	890×559×10	±1.0, ±1.0	2
PCB	915×580×0.9 12strips, 38×870/strip	±0.5	2
Fishing Line	Diameter 0.25	±0.005	
Nylon screw			24
Side spacer(poly carbonate)			8
HV lead	60cm	±1	2
Signal lead	60cm	±1	4

Building MRPC Module

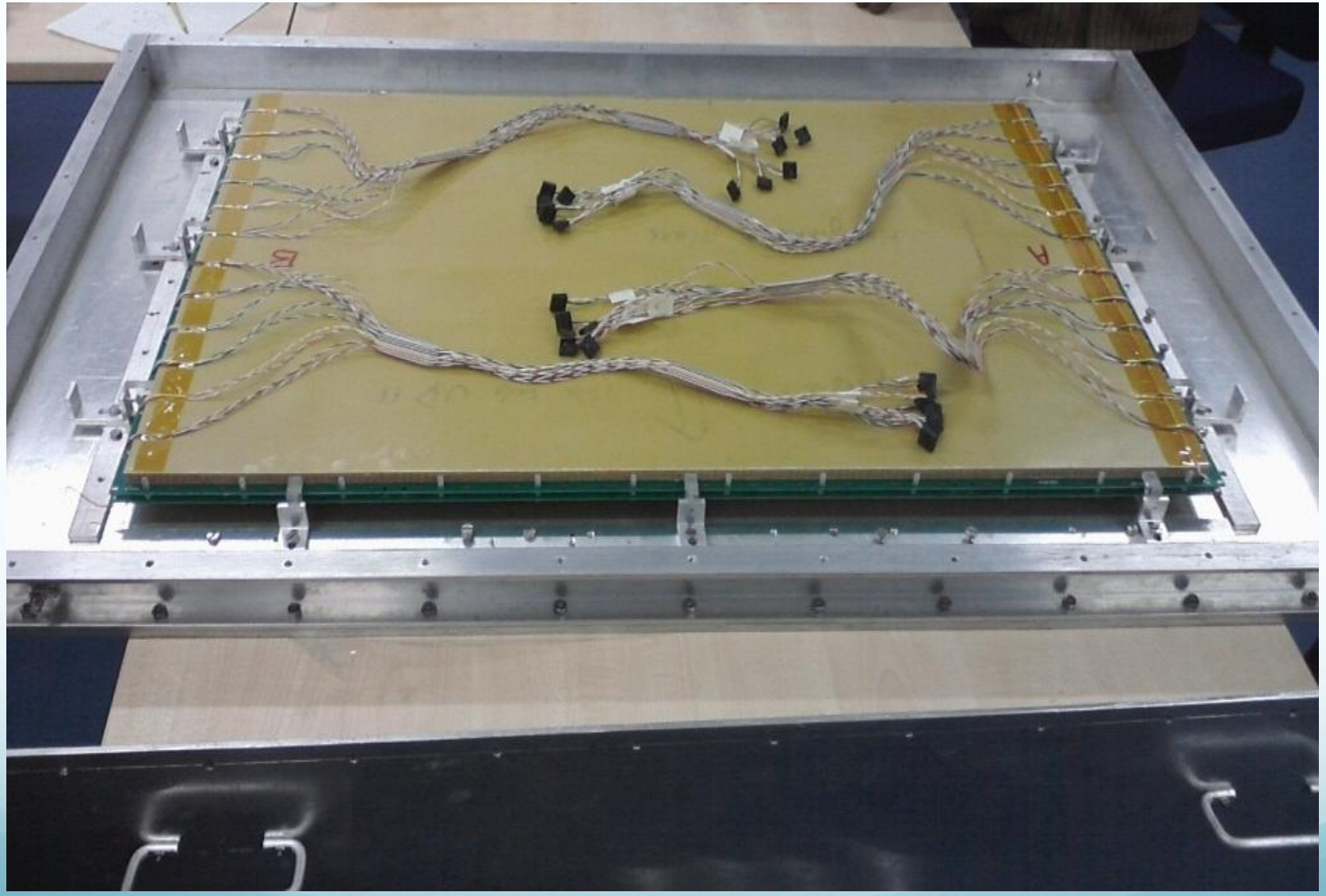
Building MRPC Module



Readout Strip

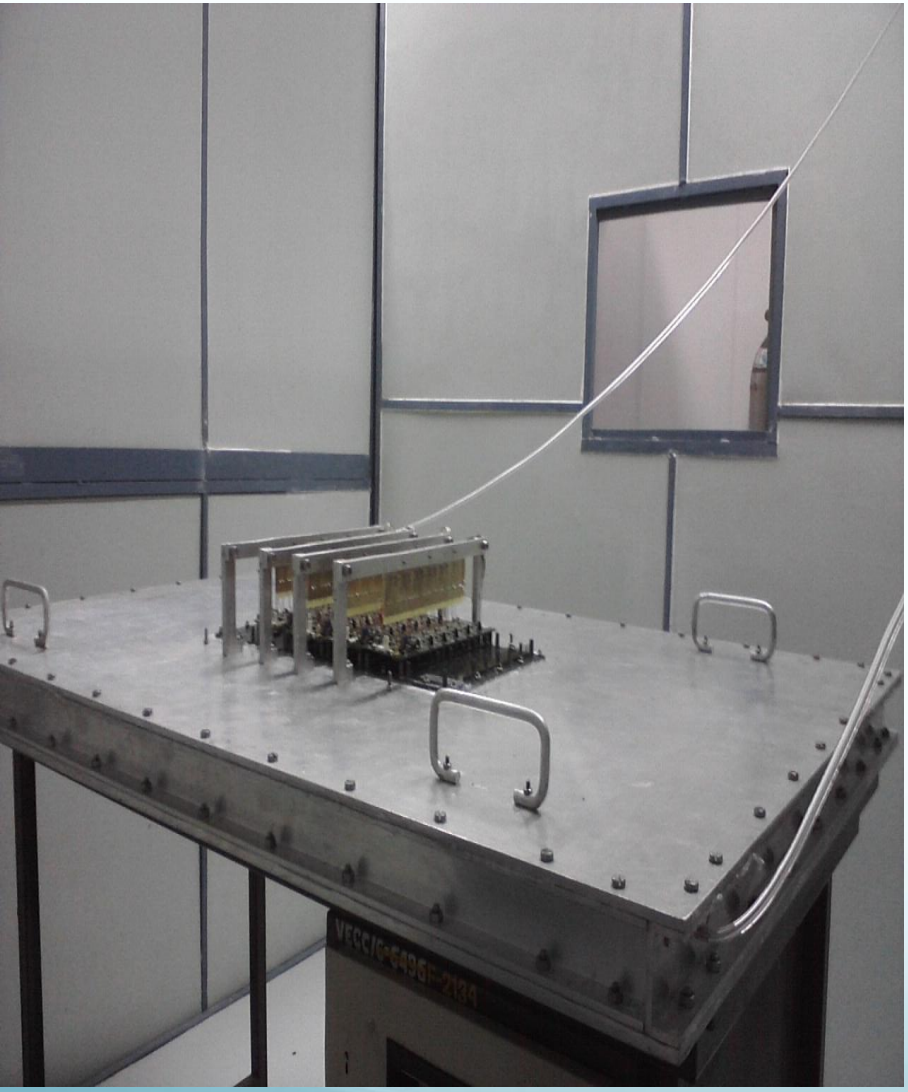


Building MRPC Module

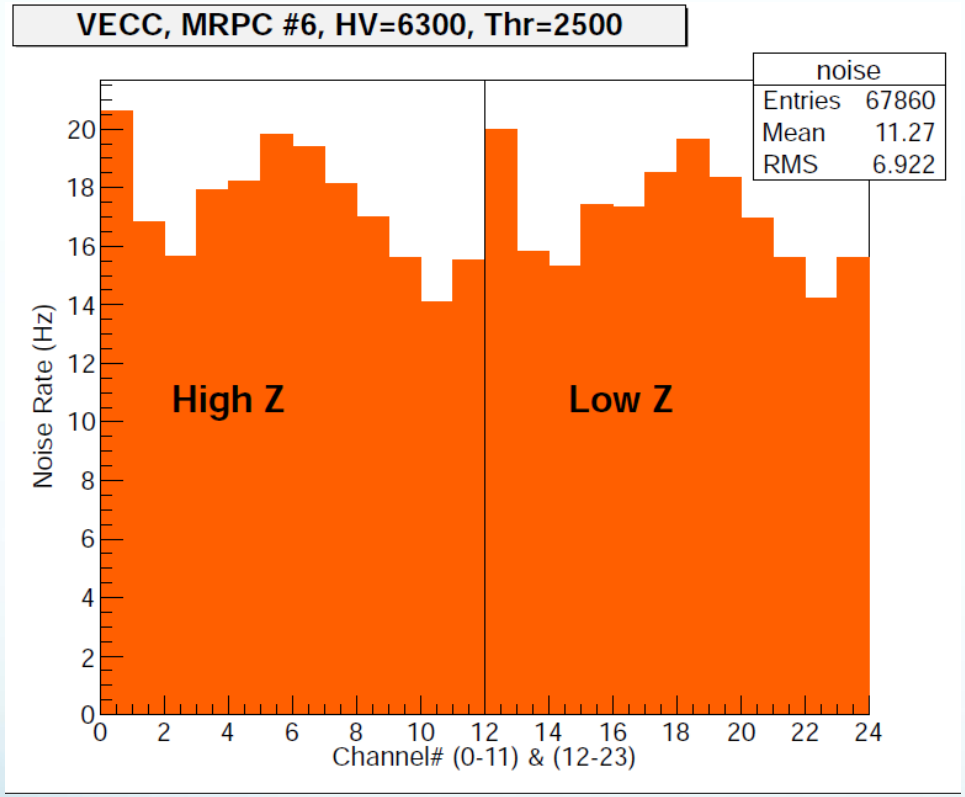


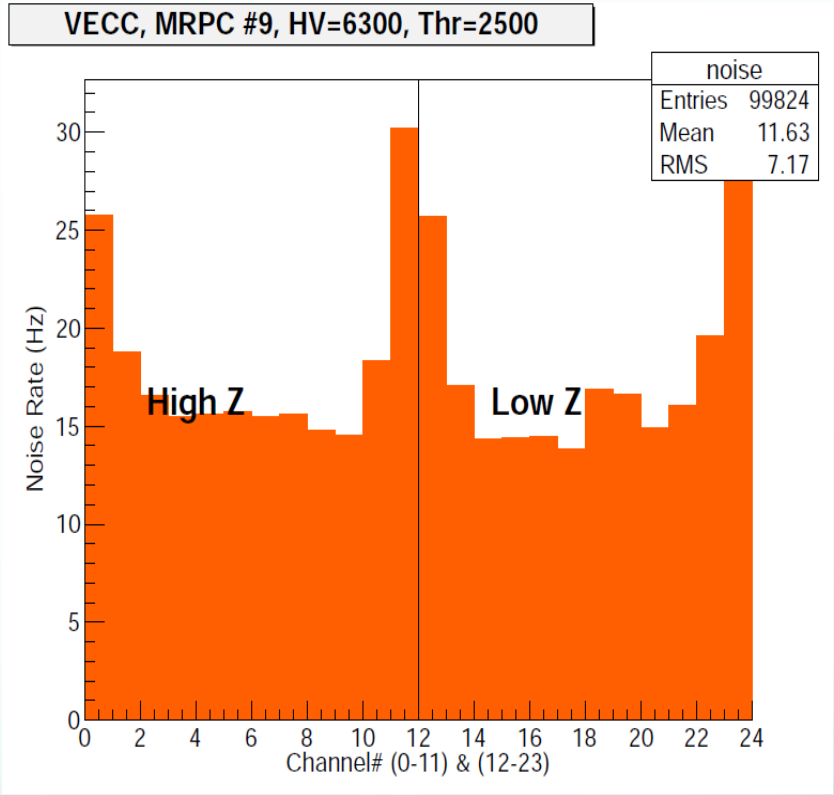
Gas Connection and Gas distribution at VECC

Freon(R134a):Isobutane(95:5)



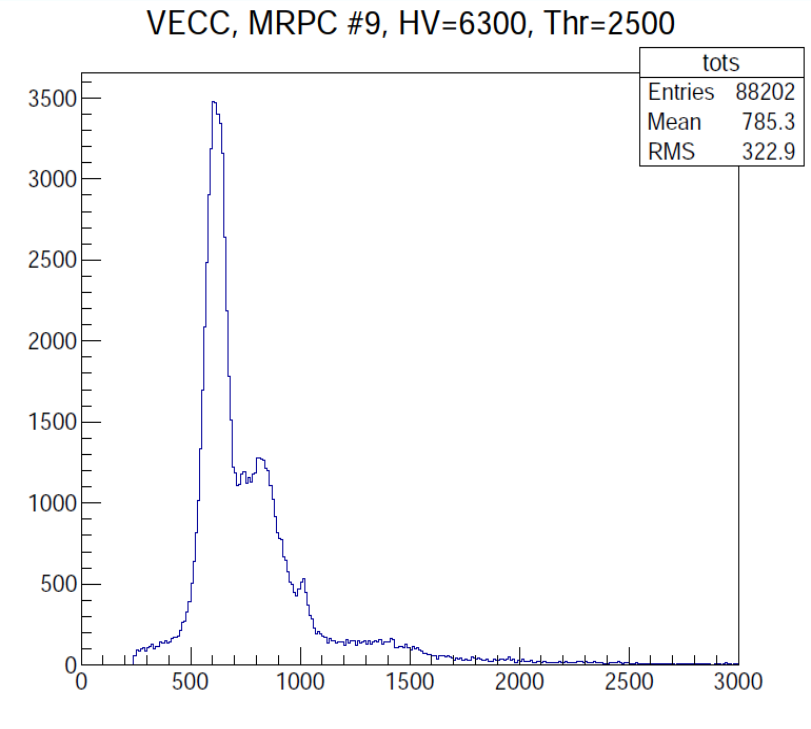
Noise Study


VECC, MRPC #6, HV=6300, Thr=2500
noise
Entries 67860
Mean 11.27
RMS 6.922
High Z
Low Z
Noise Rate (Hz)
Channel# (0-11) & (12-23)

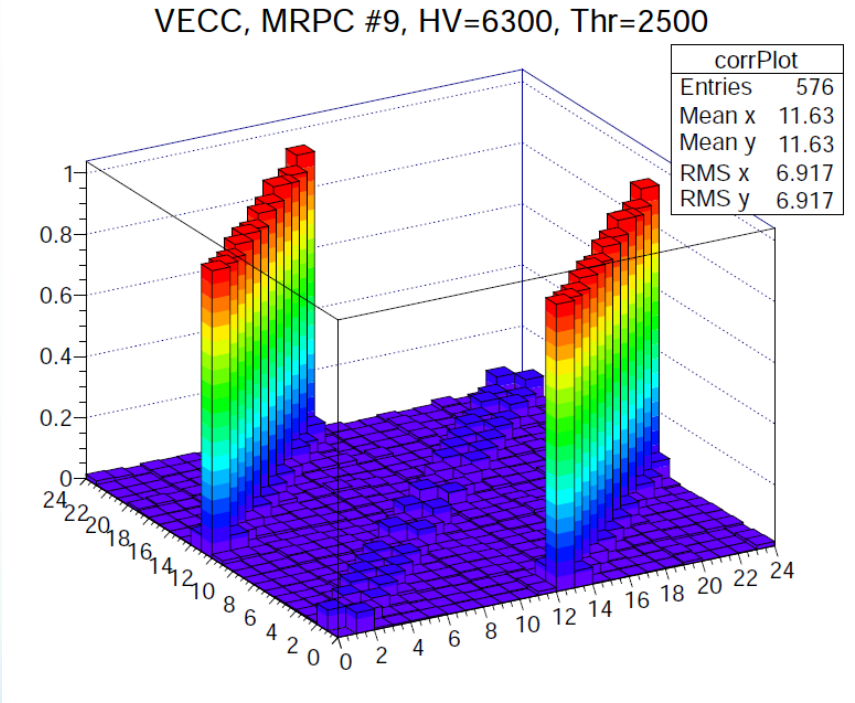

VECC, MRPC #9, HV=6300, Thr=2500
noise
Entries 99824
Mean 11.63
RMS 7.17
High Z
Low Z
Noise Rate (Hz)
Channel# (0-11) & (12-23)

Noise Study

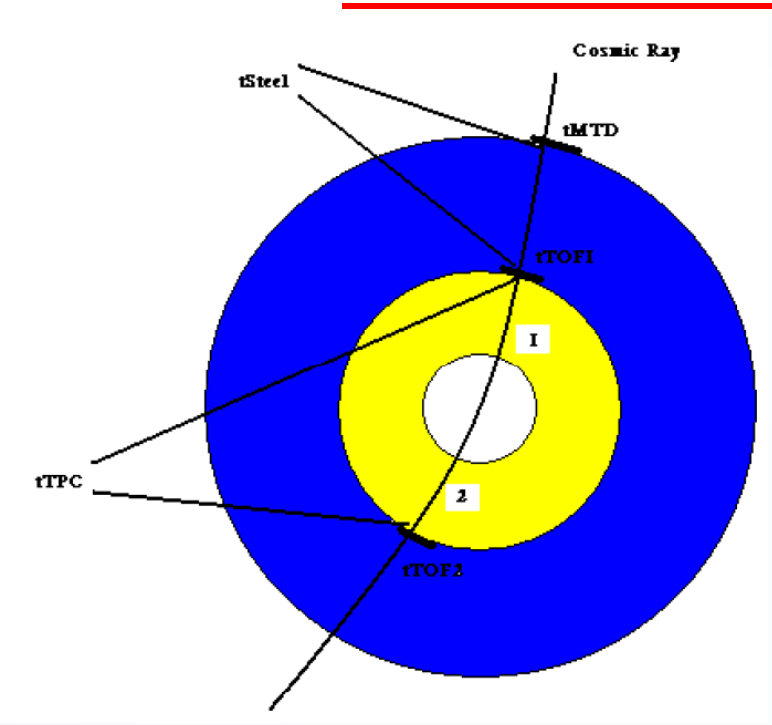
Time over threshold Spectra



Correlation between Pick up strips



Performance: Cosmic Ray tests in STAR



Schematic view of cosmic Ray events in STAR.

tMTD is calculated by averaging the times from two ends of an MTD strip so that it does not depend on the hit position on the strip.

tTOF1 and tTOF2 are calibrated times associated with TOF hits due to the cosmic ray muons.

tTPC is the calculated time of flight between two TOF trays 1 and 2 with the pathlength and momentum information from TPC.

tSteel is the time of flight from MTD to TOF.

Time diff. between TOF and TPC measured:

$$\Delta t_0 = (tTOF2 - tTOF1 - tTPC)$$

$$\sigma\Delta t_0 = \sqrt{2}\sigma TOF$$

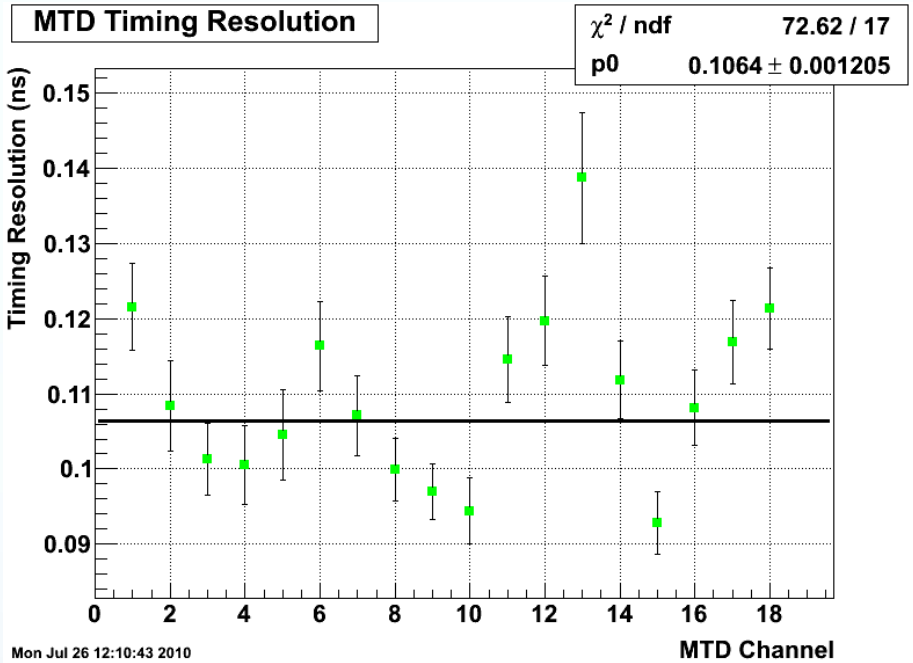
The time difference between TOF+MTD and TPC measured time is

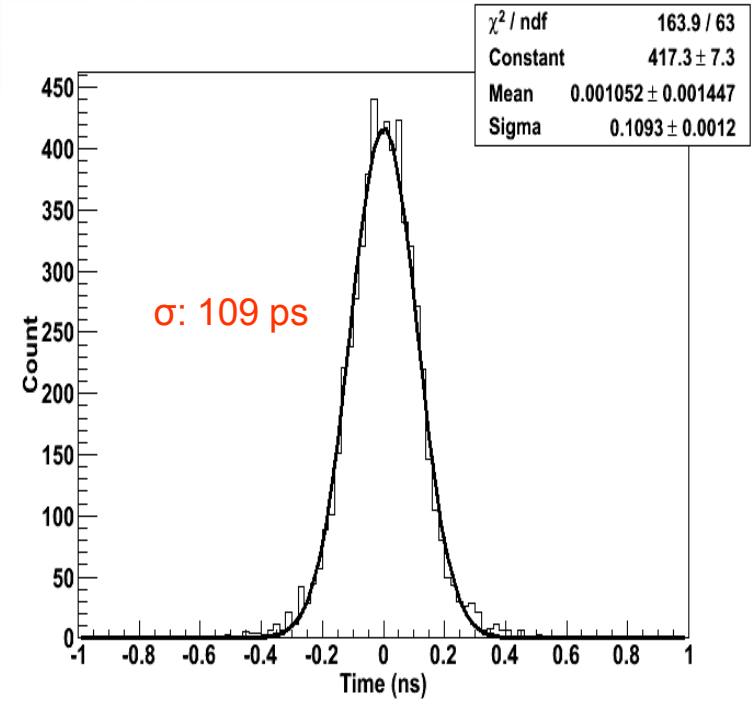
Δt = (tTOF2 – tTPC + tTOF1)/2 – tMTD - tSteel

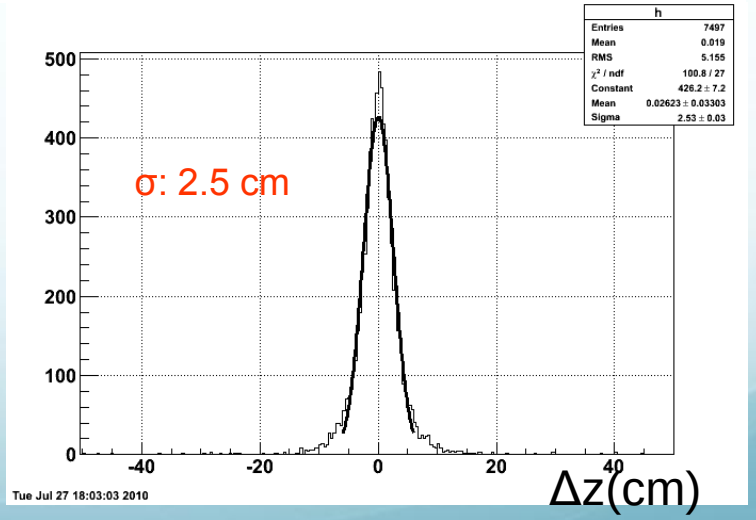
$$\sigma\Delta t = \sqrt{\sigma MTD^2 + (\sigma TOF^2)/2}$$

Nucl. Instr. and Meth. A, 762 (2014), p. 1

Performance: Cosmic Ray tests in STAR





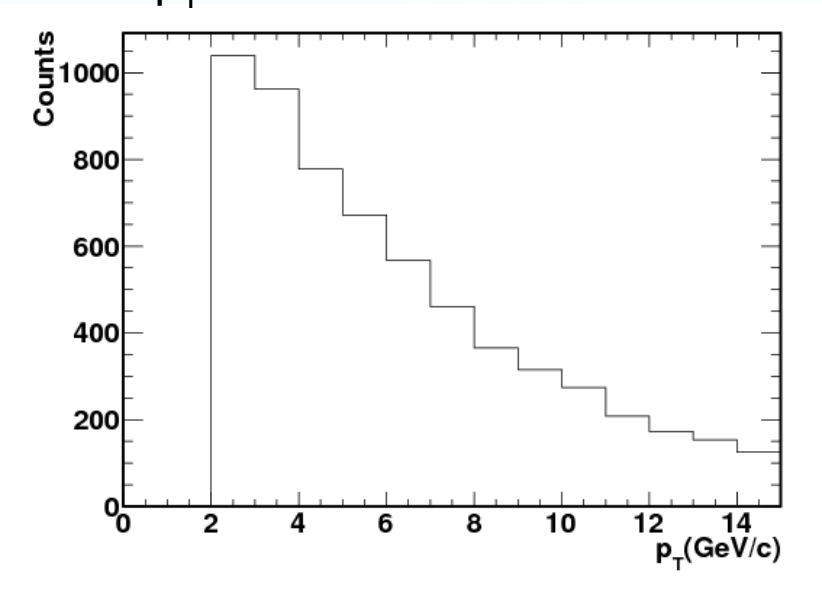


MTD+TOF timing resolution: ~109ps
Timing resolution from TOF: ~46ps
MTD timing resolution: ~99ps
Position Resolution: ~1 cm.

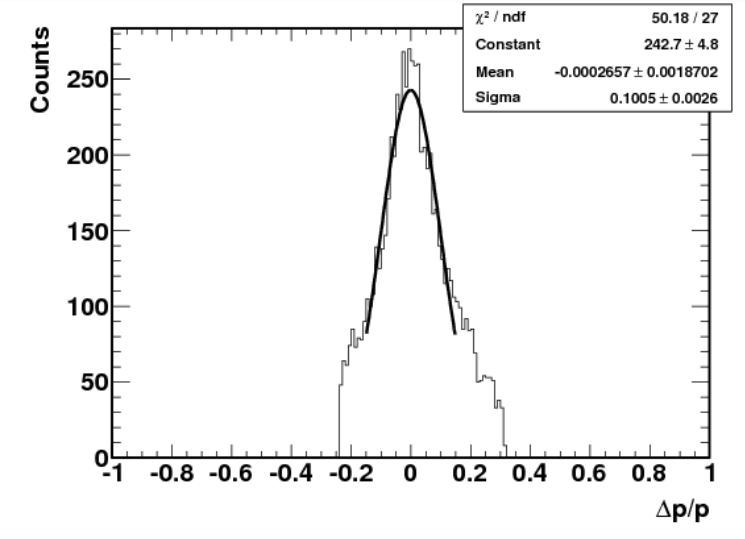
Nucl. Instr. and Meth. A, 762 (2014)1

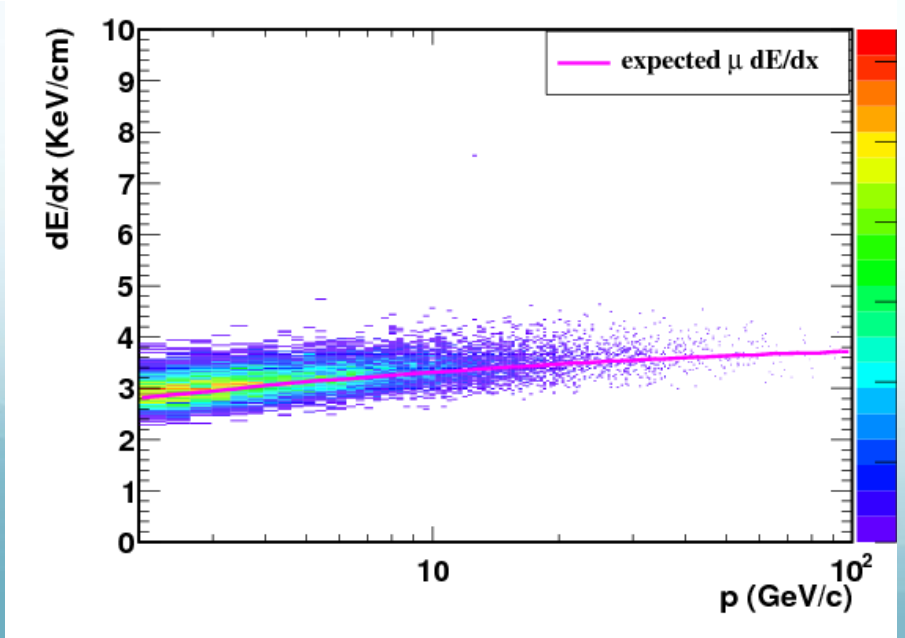
Performance: Muon Identification

p_T dist. of cosmic muons



Relative p_T diff. of the two tracks



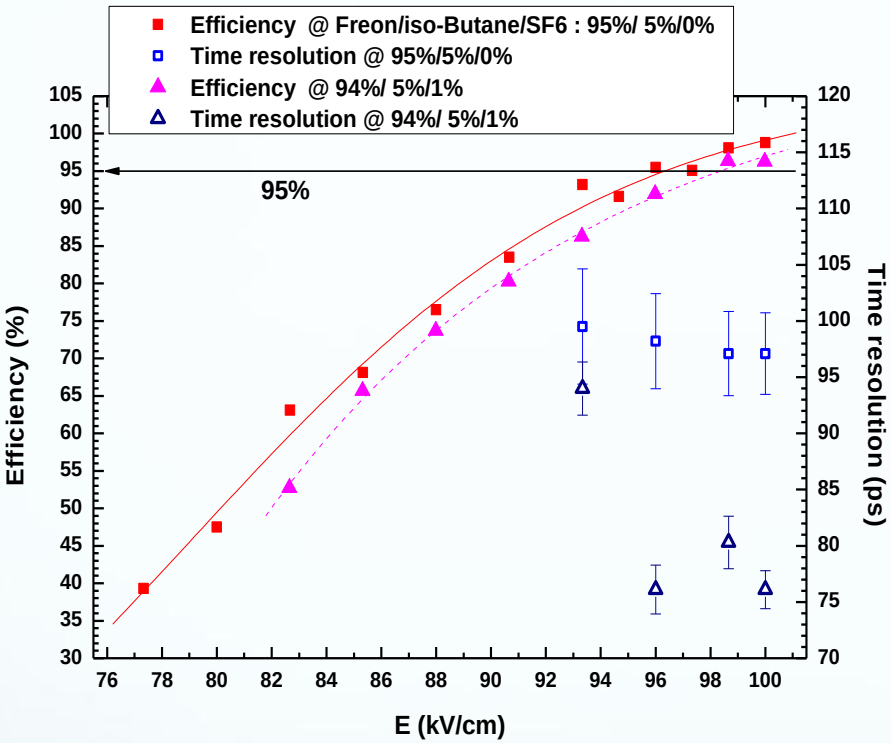


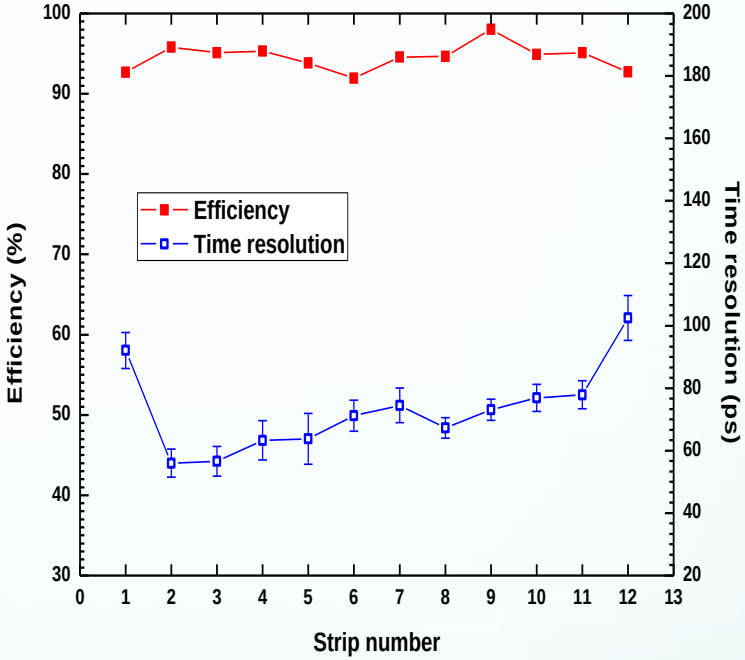
Average p_T ~ 6 GeV/C
$\Delta p/p$ ~ 10%
dE/dx as expected from Bichsel function.

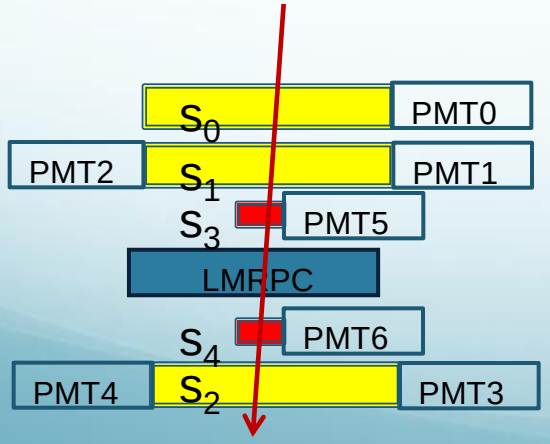
→ Clean Muon Signal

Nucl. Instr. and Meth. A, 762 (2014)1 .

Performance : Cosmic Tests



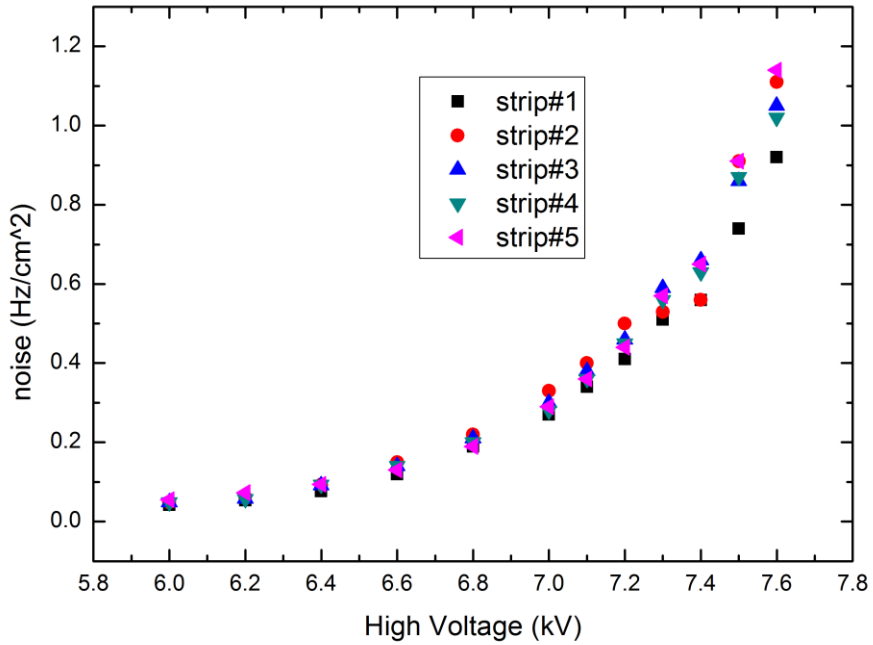




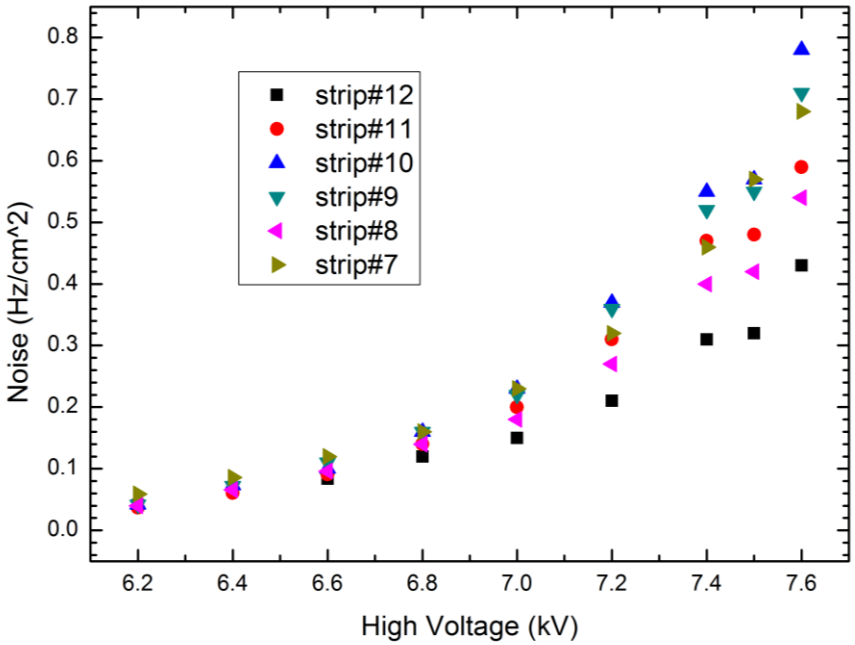
Yi Wang, et al. Nuclear Inst. and Methods in Physics Research A.
DOI information: 10.1016/j.nima.2011.03.012

Noise level @different gas mixture

95%Freon/5%iso-butane



94%Freon/5%iso-butane/1% SF6

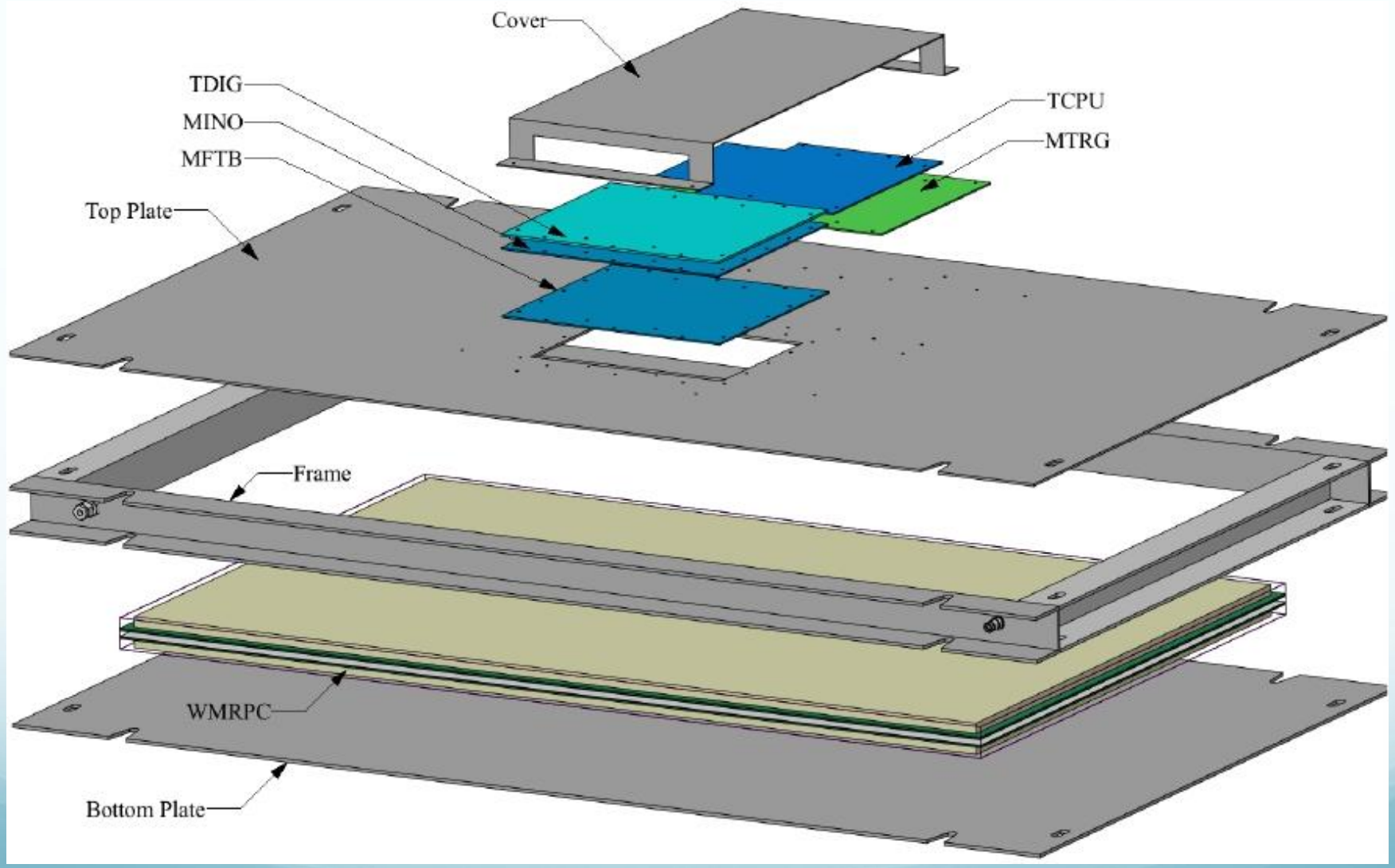


Noise < 0.6 Hz/cm^2 @ 7200V

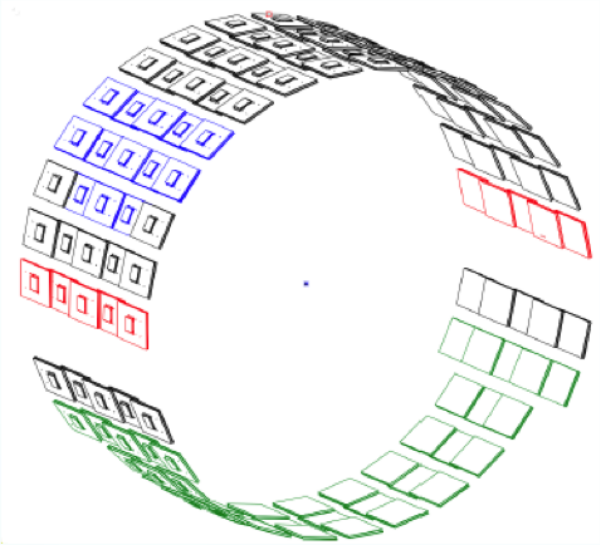
Noise < 0.4 Hz/cm^2 @ 7200V

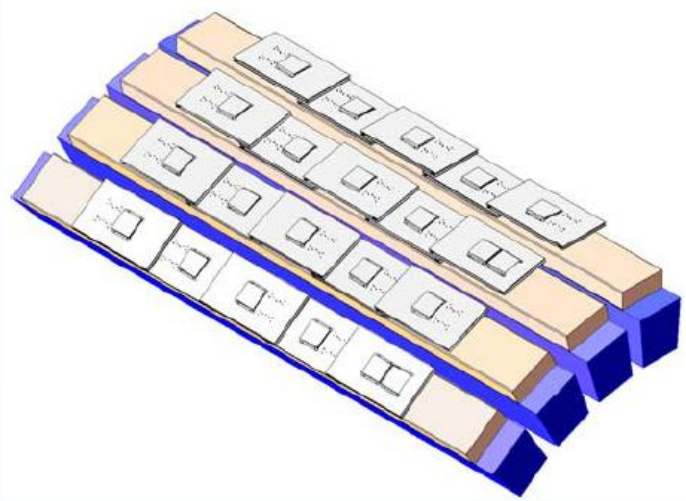
Installation in STAR

MTD TRAY

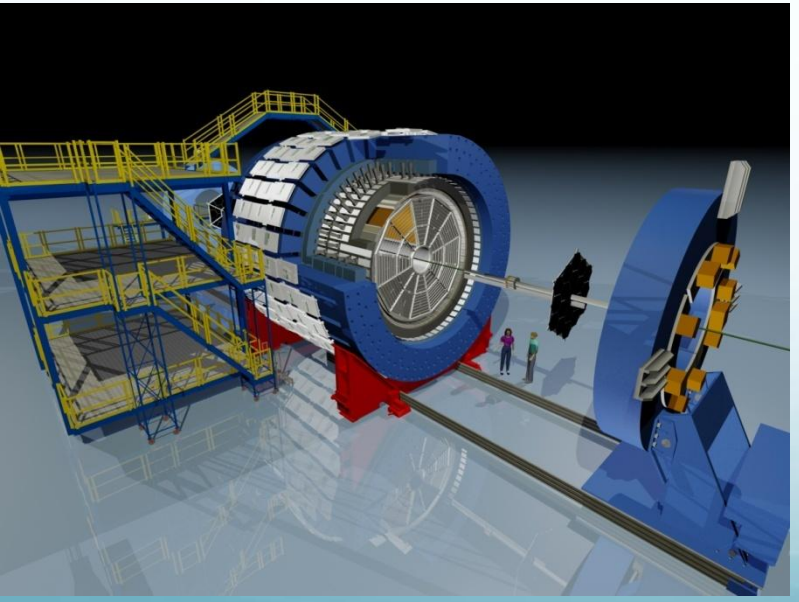


Installation in STAR





Multi-gap Resistive Plate Chamber (MRPC): gas detector, avalanche mode

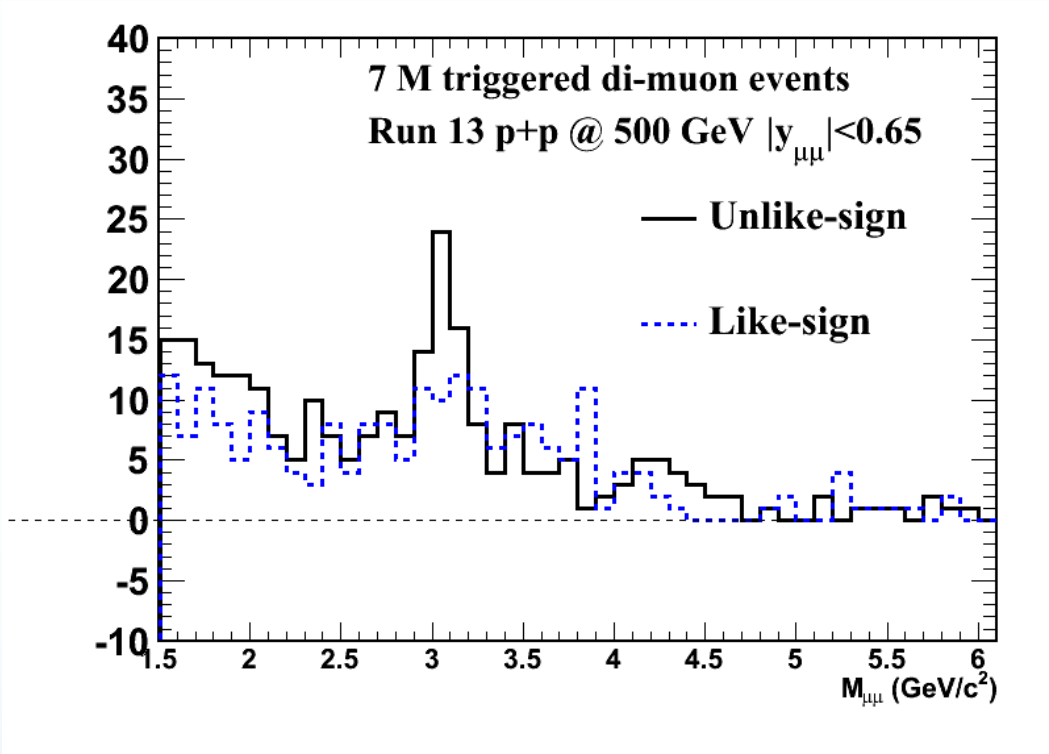


A detector with long-MRPCs covers the whole iron bars and leave the gaps in-between uncovered. Acceptance: 45% at $|\eta|<0.5$

122 modules, 1464 readout strips, 2928 readout Channels (All are installed now in 2014)

Performance in Run13

Run 13: J/ψ signals observed in p+p 510 GeV collisions



Run 14:
Sampled 11 nb^{-1} 200 GeV Au+Au collisions for quarkonium physics.

Summary

MTD will help to understand the QGP physics better at RHIC.

About 100 ps timing resolution and 1-2 cm position resolution.

Noise rate bellow 1.0 Hz/cm^2.

All modules have been fabricated and installed in STAR experiment.

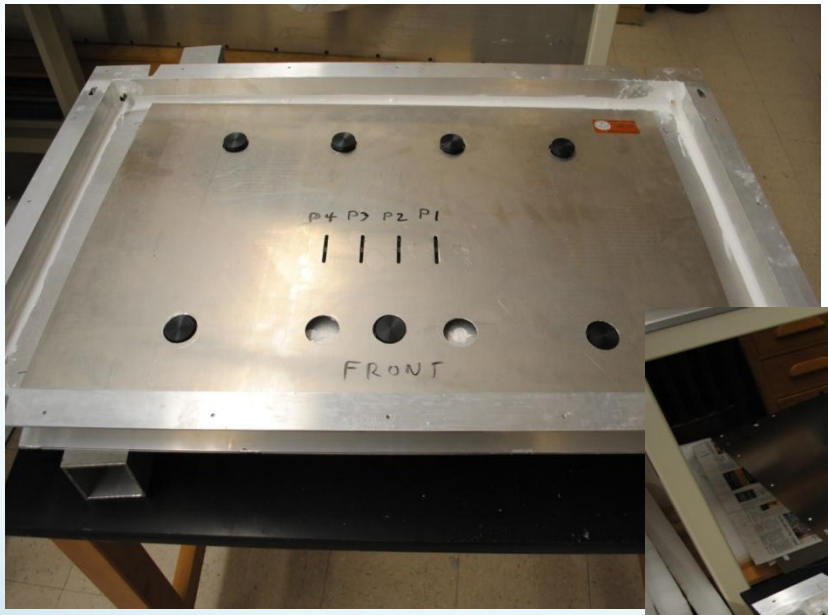
Excellent data collection in Run14.

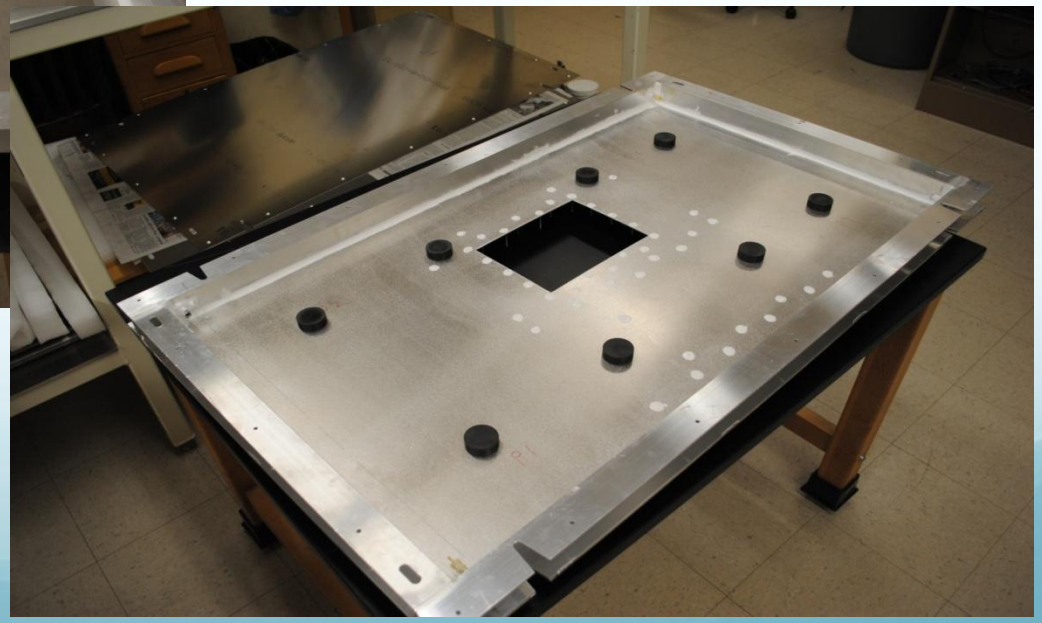
Physics Results to come soon !

Back Up Slides

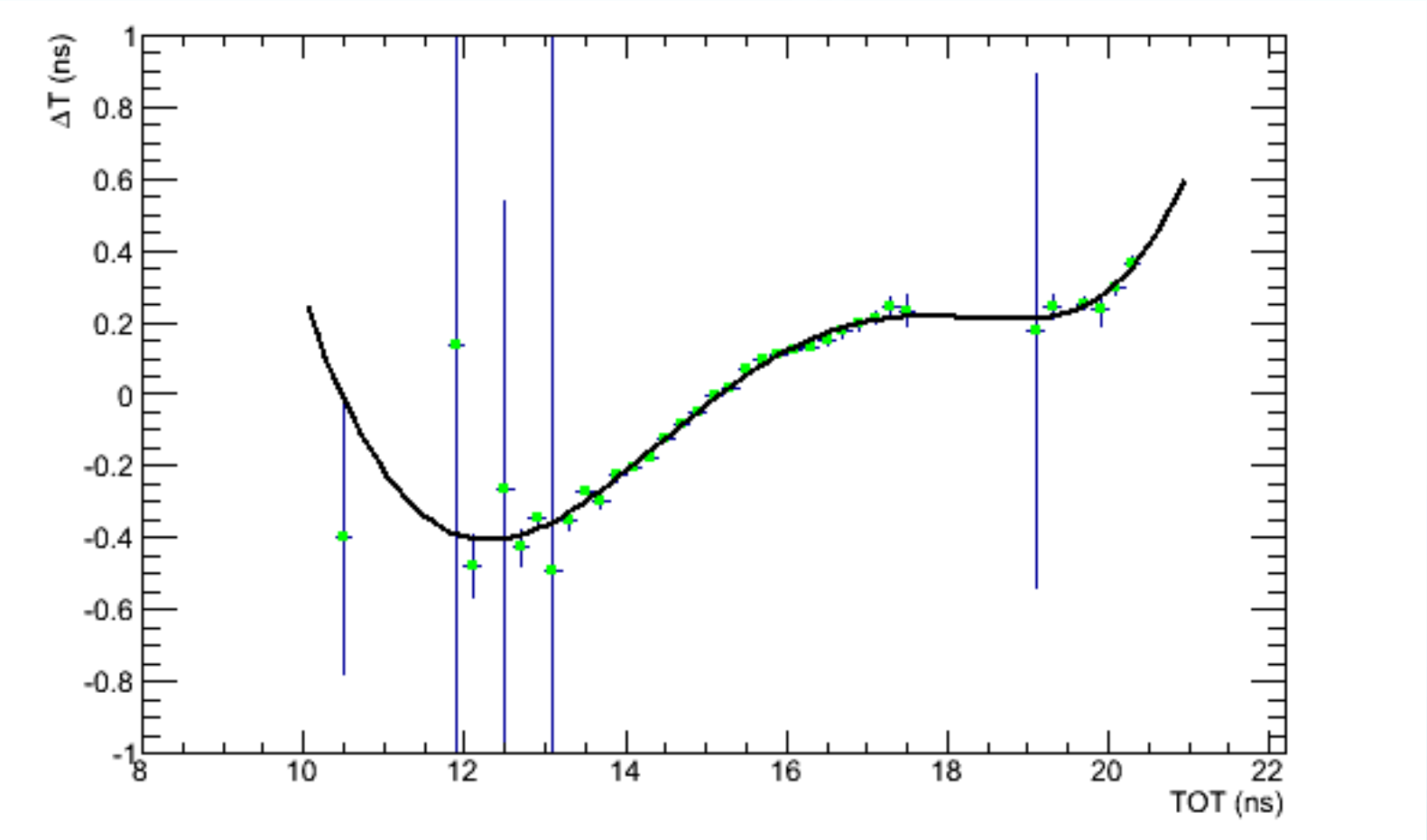
Tray assembly

- Measure MRPC thickness & fabricate delrin spacers
- Install spacers



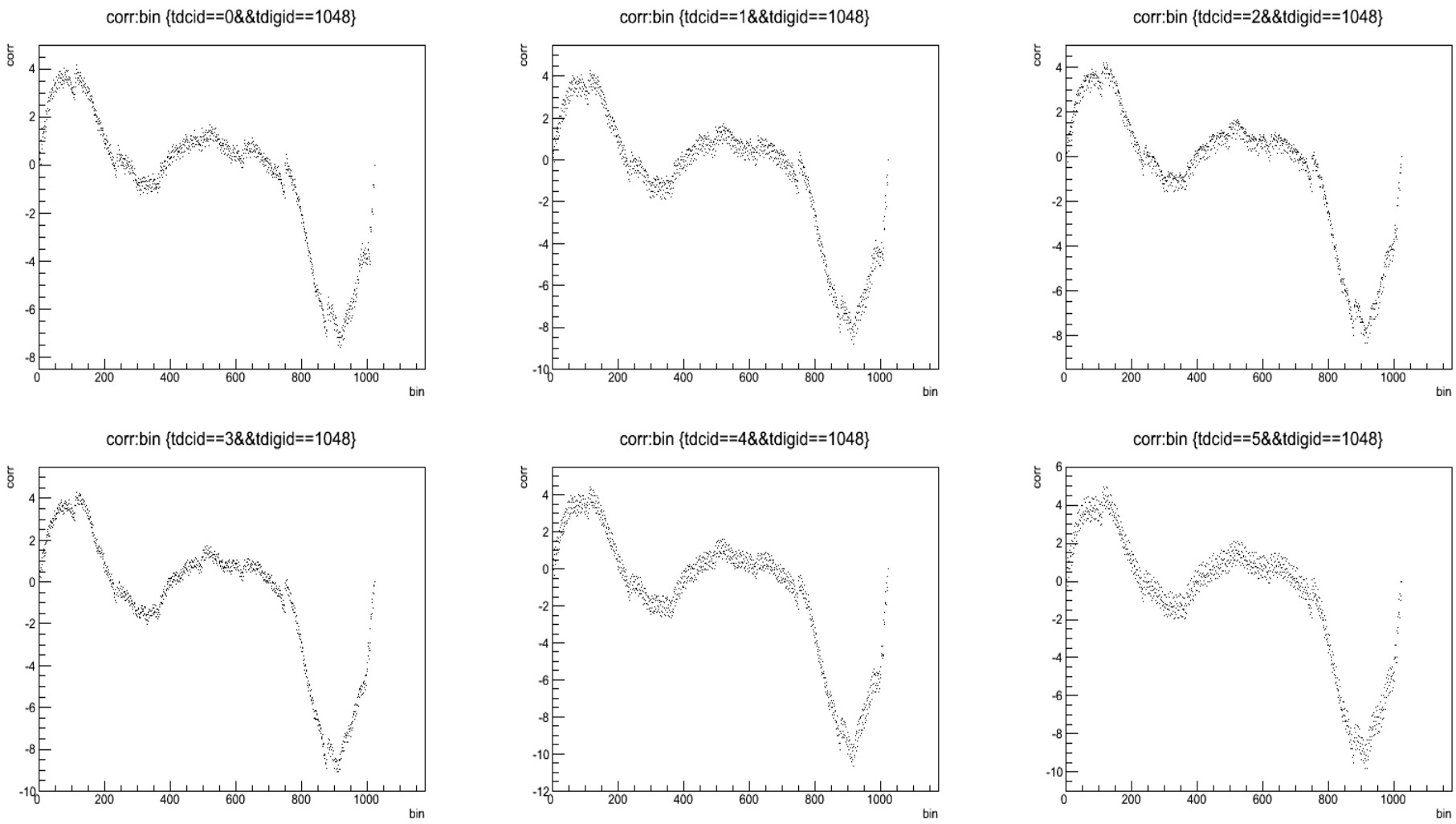


Slewing Correction

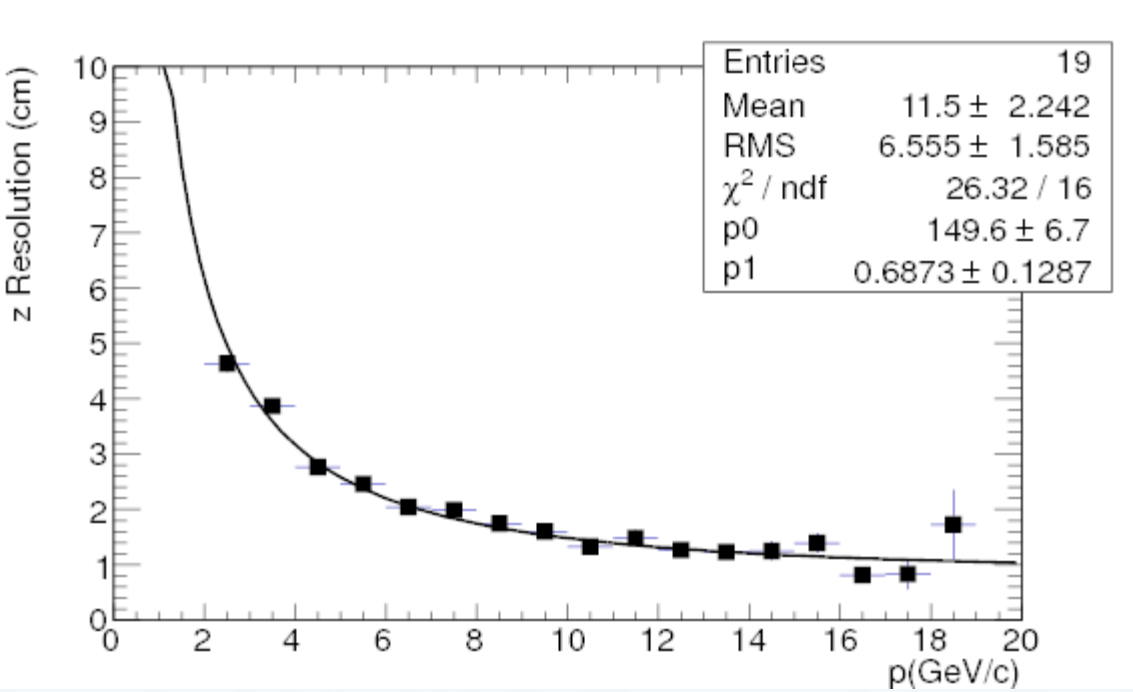


Fit gaus means with a 5th order polynomial function. Slewing correction is done by subracting the function value from Δt according to its ToT value. Slewing correction only done in the ToT range where polynomial fit is good.

INL Correction



When we get a MTD hit time form a tdc, we apply INL (integral nonlinearity) correction to it.


Entries 19
Mean 11.5 ± 2.242
RMS 6.555 ± 1.585
χ² / ndf 26.32 / 16
p0 149.6 ± 6.7
p1 0.6873 ± 0.1287
z Resolution (cm)
p(GeV/c)
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
18
20