Performance Study of HL-LHC ATLAS RPC Prototype

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In the future, the instantaneous luminosity of LHC will reach a very high level. RPC in current ATLAS cannot afford so high current.

New type of RPC with 1 mm gas gap, 1.2 mm electrodes and new high sensitivity front end electronics, has been designed for the HL-LHC ATLAS upgrade program.

- Lower current in gas gap
- Higher time and spatial resolution
- Less dead time and smaller dead region
- Suitable for the narrow space

A chamber consisting of a triplet of 50x100 cm$^2$ RPC was performed a beam test in Gif++

A full analysis has been done to study the performance
Beam Test in Gif++

- **Beam&Source**
  - Data taken with muon beam and gamma intensity up to 20 kHz per cm² estimated counting rate
  - Beam: Circle with diameter ~10cm
  - Beam rate: ~10k/spill (1 spill is about 3s)
  - Chamber distance 4.72m
  - Source full intensity: 13.9 TBq $^{137}\text{Cs}$
  - Absorption factor: $X=3.3, 10, 22, 46, 100$ (intensity attenuated by $1/X$)
  - Extend doublet test to triplet test

- **Electronic system**
  - Readout strips, amplifier inside the chamber box
  - Chamber A, B and C
  - 8 most-central readout channels along both X and Y
  - Waveform is 1024 points and 0.4ns resolution
Waveform of a random trigger

- **Photon signal:**
  - Random time in waveform
  - Small amplitude
  - Hit in single chamber

- **Muon signal:**
  - 200ns before coincidence trigger
  - Large amplitude
  - Hit in double chamber
  - Rate: ~40Hz/cm² (Only 1 signal in 400ns time window)
Effective HV is the voltage applied to gas.

EffectiveHV = AppliedHV – Current * ResistanceOfBakelite

Charge per event are larger than expected while the photon rate is lower. Correlated with threshold, gas gap and electronic system.
• Working Region in HV>5400
• High efficiency in plateau region: ~98%
  *ABS factor 22 (the green line) is similar with the real situation of LHC(600 Hz/cm² in BI region)
Time Resolution

Time difference between signals in 2 chambers. (time pass threshold)

- Electrons drift speed has a large fluctuation  
- Region in HV>5400V : RPC has a good working condition
- Time resolution around 400ps
Hit position

Amplitude vs Strip

Position distribution by fit

- Hit position is got by fitting amplitude vs strip \( f(x) = a(|x| - b)^c + d \)
- The distribution is similar to be an uniform distribution
Spatial Resolution

Position difference between signals in 2 chambers.

- Spatial resolution by fit: 0.1 cm
Cluster size modification

- Observed in doublet chambers, cluster size is very large
- Modification to chambers:
  - Surface resistivity of graphite layer: 120kOhm/square to 620kOhm/square
  - Optimize the terminal resistance
  - Isolate the strips by metal wire
- Cluster size improved
- Preliminary result
Cross-talk study

- **RPC chamber structure**
  - 3 Singlet to 1 triplet

- **Advantages:**
  - Save space
  - Coincidence trigger by itself
  - Combined measurement

- **Method:**
  - Keep 1 chamber on, 1 chamber off. Calculate the efficiency of the off chamber.

- **Result:**
  - For muon:
    - Only 1 random coincidence in 10k signals
  - For gamma:
    - Only 1 random coincidence in 20k signals
Summary

- RPC Prototypes for HL-LHC work in a good condition
  - Efficiency in plateau region: ~98%
  - Time resolution: 400ps
  - Spatial resolution: 0.1cm
  - Cluster size has been improved to a much better result
- Study of cross talk in triplet chambers
- Study the work condition of triplet chamber as a trigger model
Backup
Charge distribution for muons in different HV

Amplitude is proportional to the charge.

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Charge distribution

Entries: 806
Mean: 46.01
Std Dev: 41.92

Charge distribution for different voltages:
- charge_4600V
  - Entries: 806
  - Mean: 46.01
  - Std Dev: 41.92
- charge_4800V
  - Entries: 2637
  - Mean: 86.72
  - Std Dev: 98.24
- charge_5000V
  - Entries: 6689
  - Mean: 180.9
  - Std Dev: 175.8
- charge_5200V
  - Entries: 7027
  - Mean: 377.6
  - Std Dev: 273.6
- charge_5400V
  - Entries: 8126
  - Mean: 678.7
  - Std Dev: 358.1
- charge_5600V
  - Entries: 8201
  - Mean: 958.5
  - Std Dev: 379
- charge_5800V
  - Entries: 7500
  - Mean: 1203
  - Std Dev: 364.7
- charge_6000V
  - Entries: 9166
  - Mean: 1377
  - Std Dev: 345

Amplitude (counts) vs. Entries for different voltages.

4600V
4800V
5000V
5200V
5400V
5600V
5800V
6000V

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Efficiency vs threshold

Graph

Efficiency

HV[V]

0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

thd 4*sigma
thd 5*sigma
thd 8*sigma
thd 11*sigma
thd 14*sigma
thd 17*sigma
thd 20*sigma
thd 25*sigma
thd 30*sigma
thd 40*sigma
thd 55*sigma
thd 75*sigma
thd 100*sigma

4600 4800 5000 5200 5400 5600 5800 6000
Fit by time pass threshold

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