Performance of the ATLAS Resistive Plate Chambers

X Workshop on Resistive Plate Chambers and related detectors

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Overview

- ♦ Introduction
 - ♦ The ATLAS experiment
 - ♦ The ATLAS Muon Spectrometer
 - ♦ Resistive Plate Chambers (RPCs) of the ATLAS experiment
- ♦ RPCs performance with 2009 cosmics data
 - ♦ Cluster size
 - ♦ Spatial resolution
 - ♦ Efficiency

A Toroidal LHC ApparatuS (ATLAS)

Inner Detector: 6m long 1.1m radius inside 2T Solenoid

- Pixels
- SCT Silicon Strips
- TRT Transition Radiation Tracker e/π separation

Calorimetry $|\eta| < 4.9$

- EMBC, EMEC accordion LAr + Pb $|\eta| < 3.2$
- Tile Hadronic Fe + scintillator $|\eta| < 1.7$
- HEC Hadr end cap Cu+Lar $1.5 < |\eta| < 3.2$
- FCAL Forward calo Cu+W+Lar $3.1 < |\eta| < 4.9$

EM energy resolution

- $\sigma(E)/E = 10\%/\sqrt{E} \oplus 0.7\%$

Hadronic energy resolution (jets)

- $\sigma(E)/E = 50\%/\sqrt{E} \oplus 3\% \quad (|\eta| < 3.2)$
- $\sigma(E)/E = 100\%/\sqrt{E} \oplus 10\% \quad (|\eta| > 3.2)$

Diameter	25 m	
Barrel region lenght	26 m	
Distance between Big-Wheels	46 m	
Mass	7000 t	The same as Eiffel Tower

Muon Spectrometer: geometry in the barrel region

MDTs: precision chambers for tracking in η view – $35 \mu\text{m}$ ($|\eta| < 2.7$)

RPCs: *trigger* LVL1 + second coordinate measurement ($|\eta| < 1.05$)

In the forward region TGC chambers are used to trigger ($|\eta| < 2.4$) and measure the second coordinate ($1.05 < |\eta| < 2.7$)

Resistive Plate Chambers (RPCs) of the ATLAS experiment

- Spatial and time resolution: $\sim 10 \text{ mm} \times 1 \text{ ns}$
- High rate capability up to $\sim 1 \text{ kHz/cm}^2$
- Tested for aging up to 100 Hz/cm^2 per 10 ATLAS equivalent years with a safety factor of 5
- Used as trigger chambers of the ATLAS LVL1 trigger system
- HV $\sim 9.6 \text{ kV}$ (@ 22°C and $p = 970 \text{ mbar}$)
- Electrode plate resistivity $\sim 10^{10} \Omega \text{cm}$
- Gap width = 2 mm
- Gap internal surfaces treated with linseed oil
- Copper read-out strips for orthogonal coordinates measurement applied on both sides of the gap. Typical strip pitch $\sim 30 \text{ mm}$
- A group of strips measuring the same coordinate is defined as a read-out panel.
- Gas mixture: $\text{C}_2\text{H}_2\text{F}_4$ 94.7% - C_4H_{10} 5% - SF_6 0.3%

- **RPCs measure the coordinate orthogonal to the bending direction and therefore can reconstruct a track in 3-dimensions**

RPC calibration /1

- ◆ The ATLAS detector is fully installed in the cavern and an intense work to test the apparatus and to study in situ the detector performance is ongoing.
- ◆ RPC performance is evaluated using **tracks of cosmic muons** reconstructed by the precision tracking chambers in the barrel region (Monitored Drift Tube - MDT)
- ◆ This studies are important to verify that performances are as expected by design and to check integration of the chambers in the full apparatus.
- ◆ Results shown in the following slides are from data recorded over the **full Muon Spectrometer** (~8000 read-out panels)

RPC calibration /2

- ♦ The RPC calibration goal is to optimize working parameters of the detector
 - ♦ using dedicated high statistics data set (calibration stream) or
 - ♦ normal physics data set (full stream) as a back-up solution or for specific studies
- ♦ Results stored in the official ATLAS conditions database (COOL)
 - ♦ data available to reconstruction algorithms
- ♦ Use distributed computing resources
- ♦ The results of this talk have been obtained using the full stream

RPC calibration /3

- ◆ Results include several detector-related quantities:
 - ◆ Efficiency
 - ◆ Cluster size (CS)
 - ◆ Space residuals
- ◆ Using precise tracking from MDT chambers
 - ◆ bias on measurements due the trigger is removed during off-line analysis
 - ◆ extrapolation to RPC layers takes into account materials and magnetic field
 - ◆ precise extrapolation allows to determine spatial resolution and to study small local effects
- ◆ Granularity up to the strip level
 - ◆ Averages per panel provided as well
 - ◆ If not otherwise specified each entry in the following histograms represents a panel

Results

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Cluster size /1

- ◆ Mean panel cluster size for different chambers type
- ◆ Calculated requiring 1 or 2 muon tracks in the event

- ◆ Cluster size BM chambers

- ◆ Cluster size for BO chambers

Cluster size /2

Cluster size for different V_{th} values

HV = 9000 V

- At 9000 V the cluster size has only a very low dependency on V_{th} , as expected
- NB: higher V_{th} values correspond to effective looser threshold

Cluster size dependence on HV

$V_{th} = 1000$ mV

- Dependence on HV at fixed V_{th} is as expected

Spatial resolution

- Considering only η view to exploit MDT tracking precision
- Gaussian fit of residual distribution
- Sigma from the fit = resolution
- Separate cluster size = 1, 2
- Residuals are normalized to strip width to ease the comparison between different chambers

$$\text{Residual} = z_{\text{RPC Cluster}} - z_{\text{MDT Track}}$$

- Spatial resolution normalized to strip pitch (~ 30 mm) for clusters of size 1(2) in blue (red)
- Better resolution for cluster size 2 as expected

Efficiency vs sector

- ◆ Efficiency determination algorithm:
 - ◆ Extrapolate each muon track, reconstructed from MDT hits, to an RPC plane
 - ◆ Check if in a region of ± 70 mm around the impact point an RPC hit is present
- ◆ Note: time acceptance window for hits is 200 ns
- ◆ The blue distribution shows panels with a panel mean hit time less than 25 ns (1 bunch crossing), i.e. close to the border of the time acceptance window
- ◆ this can cause loss of hits
- ◆ NB: readout timing is being tuned to eliminate this effect

- ◆ Efficiency vs sector
- ◆ All chambers @9600 V except for sectors 4, 5, 6 @9400 V

Efficiency vs cluster size

- ◆ Efficiency vs cluster size for BO chambers @9600 V
- ◆ Efficiency not corrected for pressure and temperature
- ◆ Efficiency vs cluster size behaves as expected

Chamber alignment

- ◆ The mean value of the residual distribution of each ETA panel is plotted for different sectors
- ◆ Displacement of RPC panels wrt MDT chambers up to fraction of millimeters is detectable thanks to the very MDT high tracking precision
- ◆ Sectors 1, 2, 8, 9, 10, 16 are missing due to low statistics (vertical sectors)

Tools

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Muon calibration stream

- ◆ A detailed and reliable measurement of the detector response, up to the level of the individual strip, needs a significant number of muon tracks to be analyzed
- ◆ A dedicated stream has been foreseen to answer to this necessities, called *muon calibration stream*.
 - ◆ It contains the output of the Level 1 muon trigger (before any Level 2 selection).
 - ◆ It comes at a much higher rate (~ 1 kHz), i.e. much higher statistics, than the events selected by the full trigger chain with a rate (~ 100 Hz)
 - ◆ Each muon calibration stream event contains *only hits from the muon spectrometer*, in a region where a muon trigger occurred
- ◆ The analysis is splitted in two separate steps
 - ◆ Creation of dedicated RPC calibration ntuples
 - ◆ Processing of the ntuples to obtain calibration results

The use of the GRID

- ♦ In order to gain time, both steps need to be parallelized
 - ♦ Ntuple production via the GRID
 - ♦ Automatic splitting: for example, one job per input file
 - ♦ Ntuples registered on the GRID (in a dataset) for later access
 - ♦ Calibration results obtained through ROOT macro
 - ♦ Input is one or more file from datasets obtained in previous steps
 - ♦ Output is text file in a custom format with a summary of all relevant information
 - ♦ Written to a dataset as well, and output from several jobs can be easily merged
 - ♦ The merging step is where one can choose how many runs to group together

Conclusions

- ♦ The ATLAS RPC system is a very complex setup, which will allow to perform large scale studies of the detector performance with unprecedented sensitivity
- ♦ An extensive set of measurements has been already done using cosmic rays
- ♦ Preliminary results shown here are in agreement with expectations from early data/operation
- ♦ Analysis tools are ready to take advantage of muons from collisions, when enough statistics is collected

A muon collision candidate

Backup slides

Muon Spectrometer: layout

Monitored drift tubes - Coverage - Number of chambers - Number of channels - Function	MDT $ \eta < 2.7$ (innermost layer: $ \eta < 2.0$) 1088 339 000 Precision tracking
Cathode strip chambers - Coverage - Number of chambers - Number of channels - Function	CSC $2.0 < \eta < 2.7$ 32 31 000 Precision tracking
Resistive plate chambers - Coverage - Number of chambers - Number of channels - Function	RPC $ \eta < 1.05$ 544 359 000 Triggering, second coordinate
Thin gap chambers - Coverage - Number of chambers - Number of channels - Function	TGC $1.05 < \eta < 2.7$ (2.4 for triggering) 3588 318 000 Triggering, second coordinate

- ◆ The Muon Spectrometer of the ATLAS experiment is a very complex system:
- ◆ chambers of four different technologies are present (RPC, MDT, CSC, TGC)
- ◆ covers a very large area (10.000 m²)
- ◆ ~ 10⁶ read-out channels

Muon Spectrometer: momentum measurement

- ◆ Built to provide an excellent muon trigger and Bunch Crossing (BC) identification
- ◆ Achieve high precision momentum measurement

Type	Function	Chamber resolution (RMS) in			Measurements/track		Number of	
		z/R	ϕ	time	barrel	end-cap	chambers	channels
MDT	tracking	35 μm (z)	—	—	20	20	1088 (1150)	339k (354k)
CSC	tracking	40 μm (R)	5 mm	7 ns	—	4	32	30.7k
RPC	trigger	10 mm (z)	10 mm	1.5 ns	6	—	544 (606)	359k (373k)
TGC	trigger	2–6 mm (R)	3–7 mm	4 ns	—	9	3588	318k

Analysis strategy

- ◆ In order to ensure redundancy/robustness, a twofold strategy is used for RPC detector studies
 - ◆ Exploiting the precise tracking from the MDTs:
 - ◆ bias on measurements due the trigger conditions is removed during off-line analysis
 - ◆ extrapolation to RPC layers takes into account materials and magnetic field
 - ◆ precise extrapolation allows to determine spatial resolution and to study small local effects
 - ◆ applicable only to runs with MDTs on
 - ◆ Using standalone tracking (see Angelo Guida's talk at this conference/session)
 - ◆ does not depend on MDTs
 - ◆ dedicated tracking algo avoids reconstruction bias on efficiency (by not using hits of a given layer)
 - ◆ magnetic field/material effects not implemented yet
 - ◆ extrapolation precision limited by RPC granularity

Hits & clusters

Hits

- ◆ The signal induced on a strip and read out by the front-end electronics is defined as a hit

Clusters

A cluster is a group of hits from contiguous strips fulfilling the following rules:

- ◆ time difference between hits is < 15 ns
- ◆ time associated to a cluster is chosen as the minimum time of the hits in the cluster
- ◆ at each cluster is associated a “size” that is the number of hits in the cluster
- ◆ the position of the cluster is the centre of mass of the hits

Extrapolation of RPC triggered tracks to surface