Trigger-Hodoscope for Studies of Drift Tubes at High γ-Background

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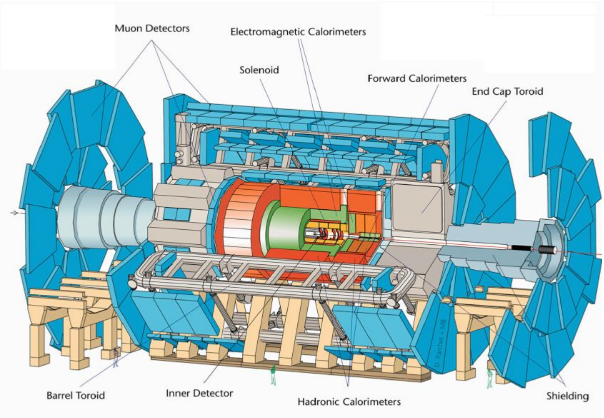
29th July, 2010

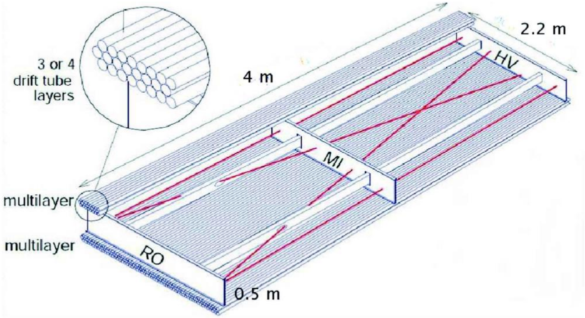
Outline

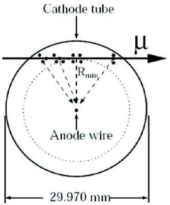
The ATLAS Detector



- Inner Detector: momentum of charged particles
- Electromagnetic Calorimeter: energy of electrons and photons
- Hadronic Calorimeter: energy of hadrons
- Muon Detector: precision chambers (MDTs, CSCs) + trigger chambers (RPCs, TGCs): position and momentum measurement of muons
- Magnet System

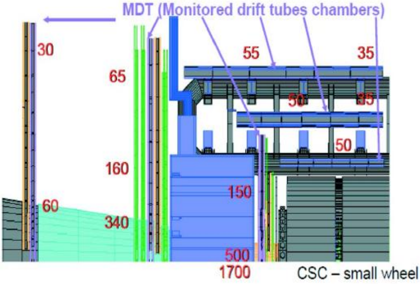
Monitored Drift Tube Chambers





- 2 multilayers consisting of 3 or 4 layers of drift tubes each
- optical systems for monitoring of deformations + temperature sensors
- spacer frame

Expected Background Rates for MDT Chambers @ ATLAS



- neutrons and γs ($\approx$ 1MeV) dominate background in ATLAS muon spectrometer
- 100 $\frac{Hz}{cm^2}$ maximum background rate for MDT-chambers @ design luminosity of $10^{34}\text{cm}^{-2}\text{s}^{-1}$ (see Baranov et al. ATL-GEN-2005-001)
- safety factor of 5 $\rightarrow$ 500 $\frac{Hz}{cm^2}$
- result: 300 kHz per tube (2 m length and 3 cm in diameter)

Upgrade to SLHC

luminosity rises by a factor of 10 $\rightarrow$ maximum background rate per tube: 3000 kHz

MDT Upgrade for SLHC Background Conditions

Alternative Drift Gas

Ar:CO_2 97:3 $\rightarrow$ Ar:CO_2:N_2, 96:3:1

Alternative Tube Geometry

reduce tube diameter: 30mm $\rightarrow$ 15mm
(reduced background rate per tube)

Performance Studies of Drift Tubes @ SLHC Background Conditions

need...

...γ-background

$\Rightarrow$ **Gamma Irradiation Facility** (= test area for particle detectors at CERN)

- γ-source (^{137}Cs with E_γ=662keV, 560GBq) to simulate SLHC background conditions
- maximum γ-flux: $10^6 cm^{-2}s^{-1}$; system of lead filters in front of source allows to adjust photon rate (e.g. $\frac{1}{5}$, $\frac{1}{2}$ $\times$ maximum flux)

...Muons

cosmic muons

Performance Studies of Drift Tubes @ SLHC Background Conditions

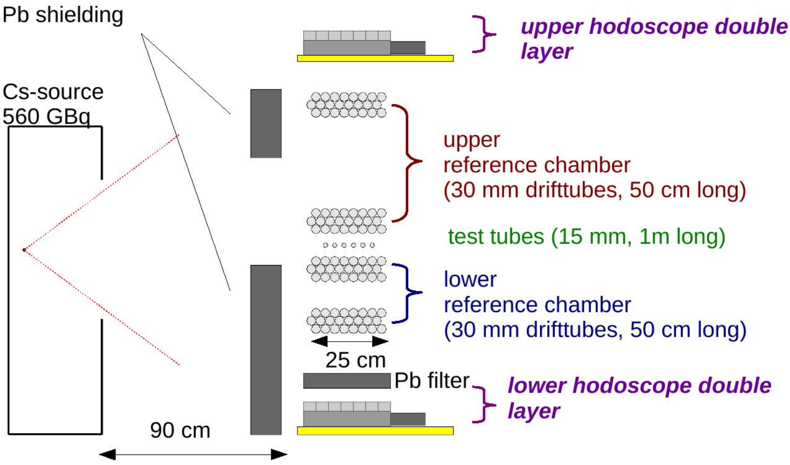
need also...

..Trigger Unit

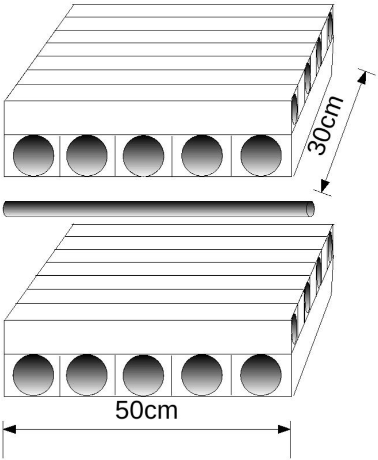
- distinguish between signal (cosmic muons) and background (γ) hits
- provide information about time of muon transition
- definition of muon track $\rightarrow$ pre-selection of drift tubes hit by muons

$\Rightarrow$ segmented 4-layer scintillator-trigger-hodoscope

Setup for Drift Tube Studies



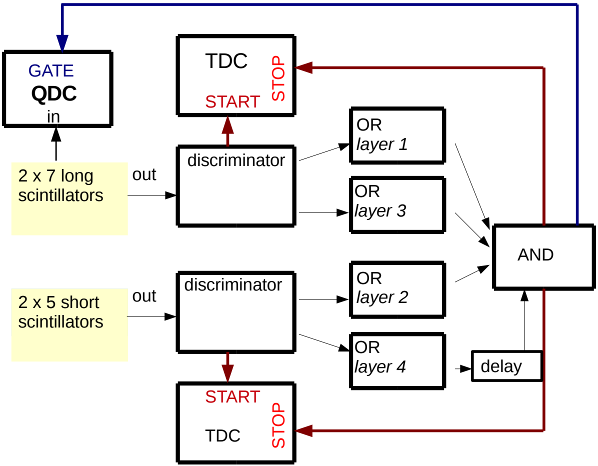
Hodoscope Setup



- 24 scintillators arranged in 4 layers
- 2 double layers with drift detectors in between
- 2 layers with 5 short scintillators (30 cm x 4.5 cm x 9 cm, TDC spectra)
- 2 layers with 7 long scintillators (50 cm x 4 cm 3cm, adapted to drift tube geometry)
- crossed scintillator geometry

$\Rightarrow$ unambiguous muon trigger via 4 layer coincidence (20ns overlap time)

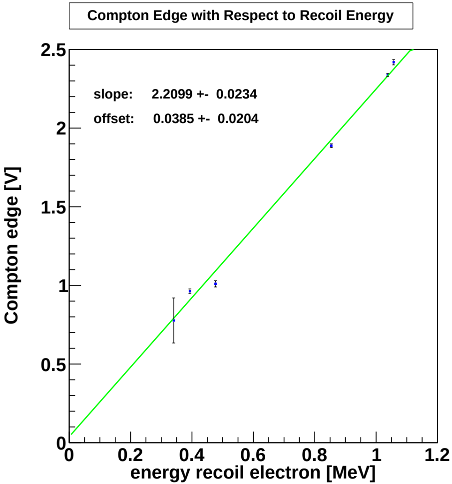
Hodoscope: Electronic Setup



Scintillator - Photomultiplier Units

- organic BC-400 plastic scintillators, 30 years old + newly machined
- scintillators wrapped into Al-foil and light-tight tape
- plexiglas block on one end (light guide to PM)
- silicon grease between plexiglas and phototube (light coupling)

Scintillator-PM Units - Energy Response

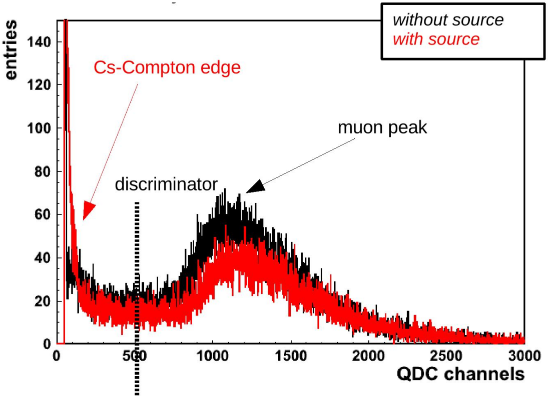


- γ-spectra of ^{22}Na, ^{60}Co, ^{137}Cs, ^{207}Bi (ADC readout)
- energy transfer via Compton scattering
- continuous distribution, maximum energy transfer @ Compton edge:

$$E_{Compton} = E_{\gamma} \frac{2E_{\gamma}/m_e c^2}{1+2E_{\gamma}/m_e c^2}$$

$\Rightarrow$ measured pulse height vs. $E_{Compton}$: linear relation

Pulse Height: Muon vs. Background (γ) Hits



- ^{137}Cs Compton edge: 0.48MeV vs muon: 6.4MeV (MIP with $\frac{dE}{dx}$=2.13 MeV/cm)
- good separation between background and muon hits
- muon peaks matched via photomultiplier HV

$\Rightarrow$ set global discriminator threshold to suppress background hits

Muon Trigger

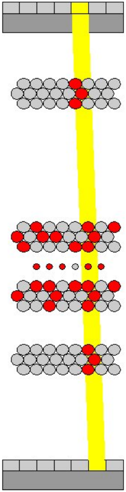
- four layer coincidence
- optimized discriminator thresholds

$\Rightarrow$ trigger rate: **1 Hz**
without source and @ maximum background flux ($10^6 cm^{-2} s^{-1}$)

$\Rightarrow$ constant trigger rate **indicates reliable muon trigger**,
(+ offline check due to pulse height (QDC) spectra)

Preselection of Drift Tubes Hit by Muons

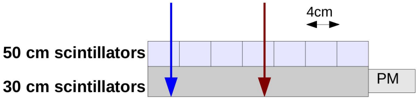
- well defined muon road due to data from 50cm scintillators (in agreement with data from reference chambers)
- allow only tubes within muon road (yellow area) for analysis of drift time data to reduce background



Time Resolution of TDC Spectra

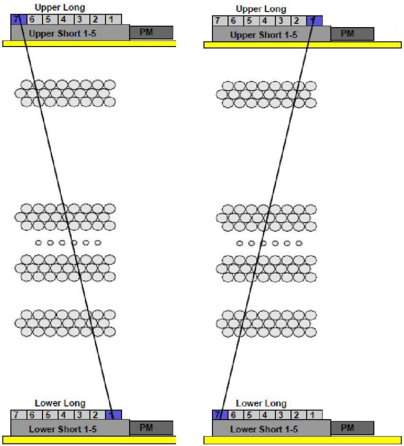
- time correction: transit time of scintillation light within scintillator has to be taken into consideration
- 50cm scintillators give information where short scintillators were hit by muon

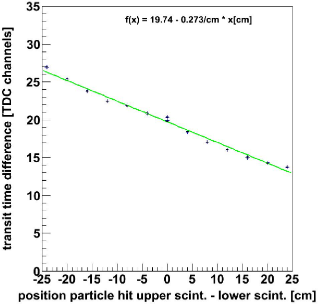
⇒ **time resolution is limited by transit time of scintillation light for a distance of 4cm**



Transit Time of Scintillation Light

TDC(upper scint.) - TDC(lower scint.) = transit time difference of scintillation light in scintillators + time of flight of muon





$\rightarrow$ speed of light in scintillator:

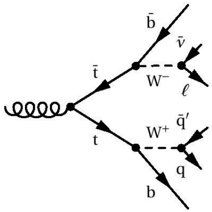
$\frac{1}{0.27} \frac{cm}{TDC \ \ channel}$ (1 TDC channel = 0.3 ns)

$\rightarrow$ time resolution: 0.5 ns

Muons in $t\bar{t}$-Decays

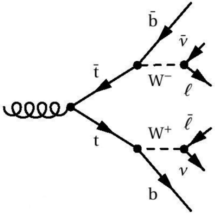
Standard Modell: $\mathrm{t} \longrightarrow \mathrm{b} + \mathrm{W}$
further W-decay: leptonic (lepton + neutrino), hadronic (2 jets)

Semileptonic $t\bar{t}$-Decay:



- 4 jets (2 b-jets)
- 1 lepton (e, μ, τs excluded)
- missing E_T (1 neutrino)

Dileptonic $t\bar{t}$-Decay:



- 2 b-jets
- 2 leptons (e, μ, τs excluded)
- missing E_T (2 neutrinos)

Branching Ratio of Semileptonic and Dileptonic $t\bar{t}$ Decays

Standard Model prediction

$$R_{dileptonic/semileptonic} = \frac{\left(\frac{1}{9} \times \frac{1}{9}\right)_{ee} + \left(\frac{1}{9} \times \frac{1}{9}\right)_{\mu\mu} + \left(2 \times \frac{1}{9} \times \frac{1}{9}\right)_{\mu e}}{\left(2 \times \frac{1}{9} \times \frac{2}{3}\right)_{e+jets} + \left(2 \times \frac{1}{9} \times \frac{2}{3}\right)_{\mu+jets}} = \frac{1}{6}$$

physics beyond the Standard Model...

... would give rise to new top decay channels

- t $\rightarrow H^{\pm} + b$
- ...

$\Rightarrow$ modification of branching ratio $R_{dileptonic/semileptonic}$

cut-based analysis: good measurement of p_{μ} $\rightarrow$ higher precision for selection efficiency (cut on muon p_T) and thus for $R_{dileptonic/semileptonic}$:)

Summary

- performance studies for drift tube upgrade @ SLHC background conditions require trigger unit
- constructed segmented, 4-layer scintillator hodoscope
- good separation between background and muon hits due to
  - 4-layer coincidence
  - optimized threshold values for discriminators
- definition of muon road possible
- TDC-spectra: time resolution of 0.5ns (limited due to finite transit time of scintillation light)