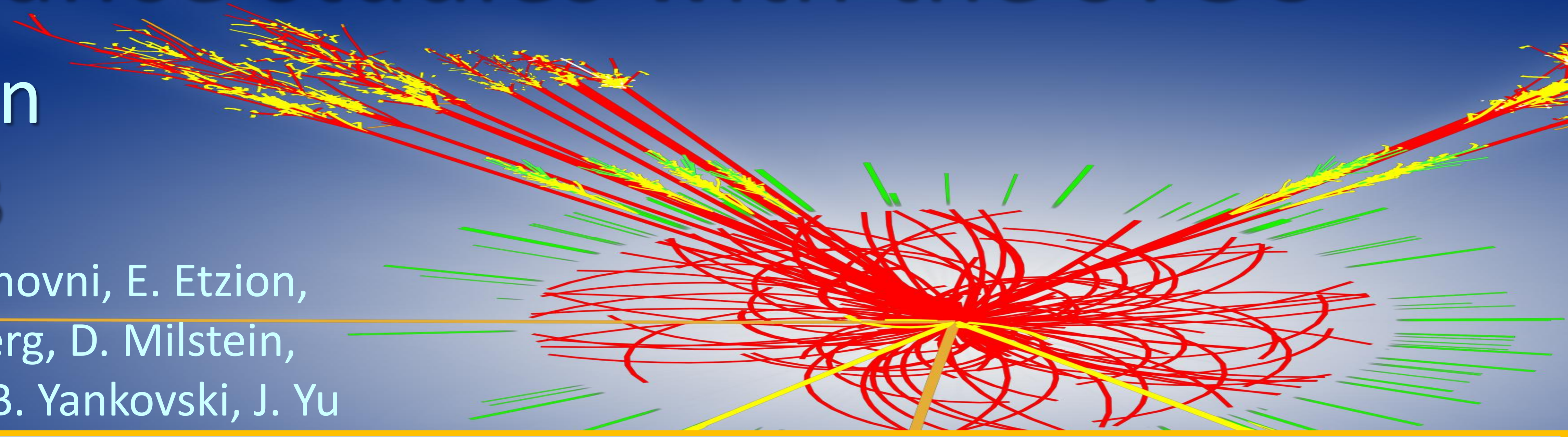
# Test beam performance studies with the sTGC

## 13TH Vienna conference on instrumentation, Feb 2013



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## Introduction

The forthcoming luminosity upgrade of LHC to super-LHC (sLHC) will increase the expected background rate in the forward region of the ATLAS Muon Spectrometer (MS) by approximately a factor of five. Some of the present Muon Spectrometer components will fail to cope with these high rates and will have to be replaced. The results of a test of a device consisting of 8 layers of Thin Gap Chambers (TGC) using the 180 GeV/c muons at the SPS-H8 muon beam at CERN are presented. The goal of the test was to study the newly developed TGC tracking and triggering performance in the LHC post-upgrade high-luminosity environment.

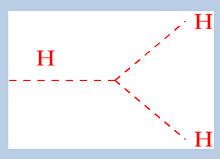
## LHC upgrade plan

Phase I: luminosity will ramp up to 2-3x$10^{34}$cm$^{-2}$s$^{-1}$, will collect integrated luminosity of ~300fb$^{-1}$ within a few years.
Phase II: luminosity will reach 5x$10^{34}$cm$^{-2}$s$^{-1}$ and aim to collect 3000fb$^{-1}$ in ~10 years.
The main requirement for the Phase I upgrade of the MUON system is to trigger on low momentum leptons under background condition much harder than the present LHC machine.

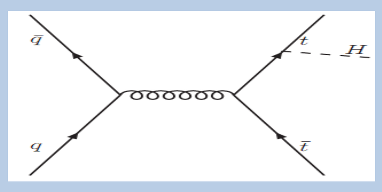
## Physics motivation

Following the discovery of the Higgs like particle, the high-Energy and High Luminosity will allow to measure the Higgs couplings, independent of QCD assumptions by measuring different final states in W+H, triggering on boosted W and looking at H->bb,ττ,μμ,WW,γγ
=>we will need single lepton trigger with moderate threshold at LV1.

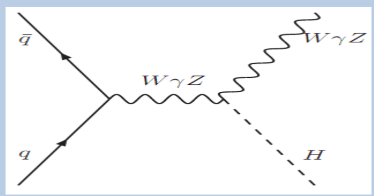
Various process requiring Lepton trigger



Higgs self coupling



coupling to UP-like quarks



Yukawa couplings to vector bosons

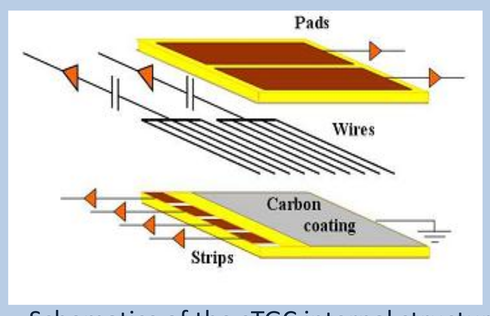
## VMM as a sTGC Front End (FE) ASIC

The VMM ASIC is designed by BNL for use as FE ASIC for sTGC and micromegas.
The VMM works in 3 modes:
**STRIPS** - To collect and measure the charge induced in strips for charge interpolation and calculation of centroid of event.
**WIRES** - Produce a logic signal.
**PADS** - Logic output signals used in building a trigger pointer to relevant strips.
In this application, the timing of the output signal edge is relevant to identify the bunch crossing of the event.

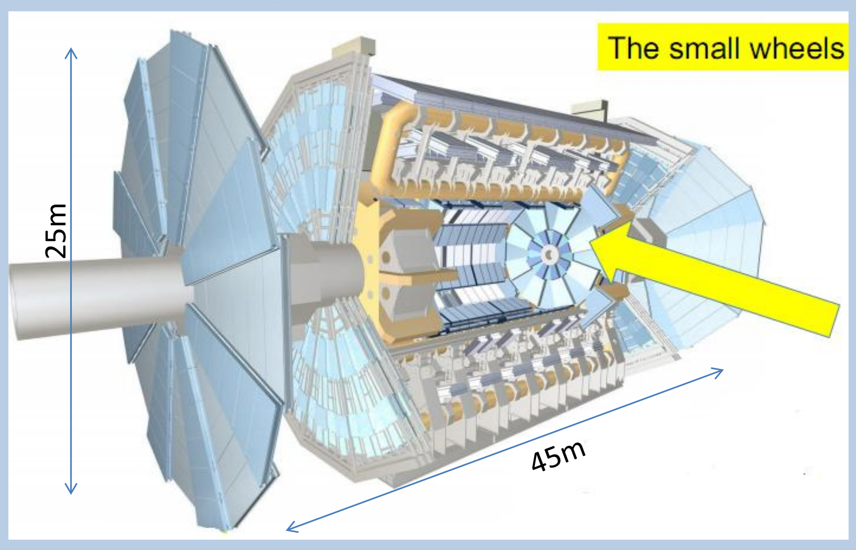
**Charge-to-Peak-Value**
The peak value is proportional to the induced charge.
Two method were tested:
1. Measuring the peak value for each strip above threshold.
2. Reading neighboring channel-The high signal, from the central strip which passes the threshold, enables the neighboring channels to be read out.
In this way there are always at least three signals for charge interpolation calculation.

## Thin Gap Chamber (TGC)

TGC is a multiwire chamber operating with a gas mixture of 55% $CO_2$ and 45% n-pentane. Each gas gap contains: a series of pad readouts for trigger signal, strip readout for high position accuracy and a perpendicular wire readout for a second coordinate measurement. Two TGC quadruplets of 1.2 × 0.5 $m^2$ size, containing four sensitive gaps were used for the test. The four gaps fit within a total thickness of 50 mm.




Schematics of the sTGC internal structure



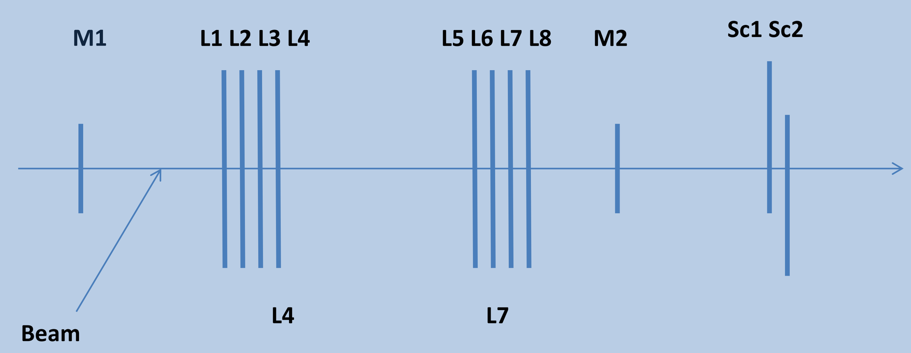

The ATLAS detector

| TGC geometry | |
|---|---|
| Wire-carbon gap | 1.4 mm |
| Wire-wire space | 1.8 mm |
| Strip-carbon gap | 0.1 mm |
| Strip pitch | 3.2 mm |
| Inter-strip gap | 0.5 mm |
| **Prototype** | |
| Wire length in layers | 0.4 m |
| Number of wires ganged together | 5 |
| Strip length | 0.6 m |
| Pad size | 8.7x8.7 $cm^2$ |
| Carbon plan resistance | 70KΩ/square |
| HV blocking capacitance | 470 pF |
| **Readout** | |
| Preamplifier gain | 0.8V/pC |
| Integration time | 16 ns |
| Main amplifier gain | 7 |
| Equivalent noise charge | 7500 electrons at $C_D$=150 pF |

TGC parameters

## Experimental setup

**Muon test beam setup**
using two quadruplets containing 8 layers of TGC, two scintillators and two monitors for trigger tests.




The aim of the test was to check the position resolution using the new VMM FE readout.
For cross-check the QDC readout was connected to two layers.

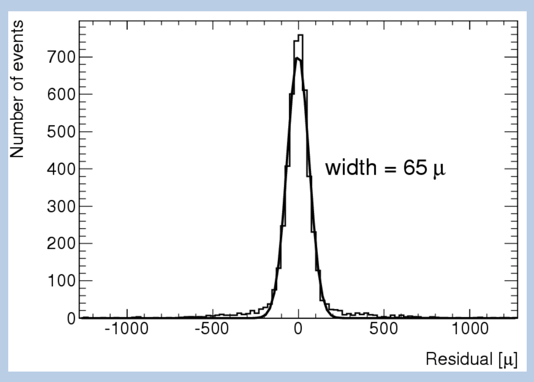
**Results**
Comparison between VMM to QDC shows a very good agreement.

| Impact angle[deg] | QDC resolution[μm] | VMM resolution[μm] |
|---|---|---|
| 0 | 83 | 77 |
| 10 | 96 | 126 |
| 20 | 167 | 166 |

## Earlier tracking studies

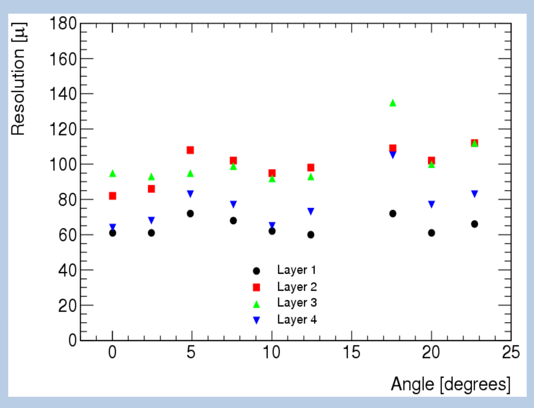
**QDC (Charge to Digital Conversion) readout**
Analog readout for measuring the induced charge on the strips.
A single gap spatial resolution of 70 μ and an angular resolution of 0.4 mrad was achieved with the two TGC quadruplets for 40 cm distance between them. The details of the trajectory fit procedure can be found in: Nucl.Instrum.Meth.A628:177-181,2011 [arXiv:1006.0135v2]

Very good spatial resolution but the analog readout setup require long cables that delay the signal and make it impossible for trigger use.



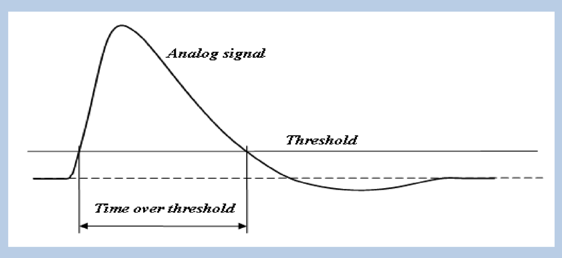

Spatial residual: fit predicted position minus measured one

**TMC (Time to Digital Conversion) readout**
Fast Digital readout to measure Time Over Threshold.
The resolution as a function of different impact angle are very good.




Spatial resolution dependence on the impact angle

The big Problem with this method is the low reconstruction efficiency due to the use of threshold that lower the multiplicity (not possible to measure neighbors channels below threshold)

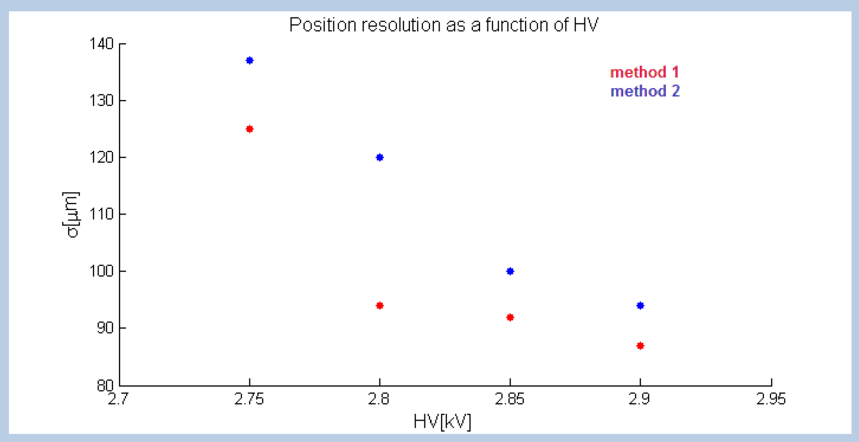



Time-over-Threshold method

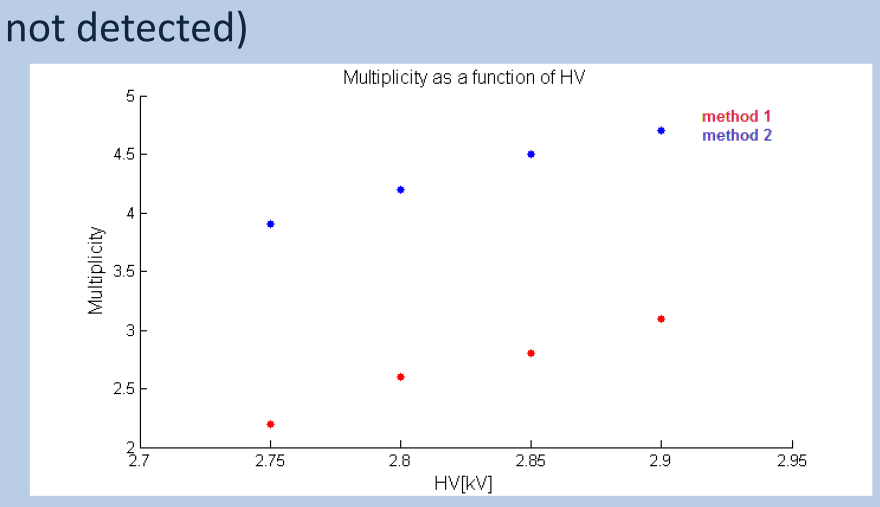
## VMM test result

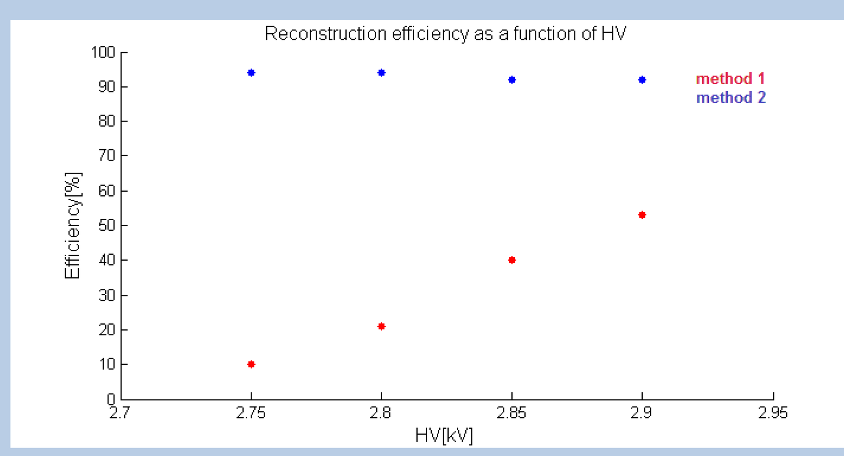
Test the two VMM methods using charge to peak value.

**Position resolution**:
Both methods agree and meet the requirements




**Reconstruction Efficiency:**
Method 2 efficiency is higher than 92% in all HV range.
Method 1 has less efficiency due to lower multiplicity (neighboring channels below threshold not detected)




## Conclusions

The VMM FE electronic showed a very good spatial and angular resolution, comparable with previous results using QDC and TMC electronics.
VMM neighboring channels read out below the threshold provide high multiplicity which results in efficiency above 92%.