Test of spatial resolution and trigger efficiency of a combined Thin Gap and Fast Drift Tube Chambers for high-luminosity LHC upgrades

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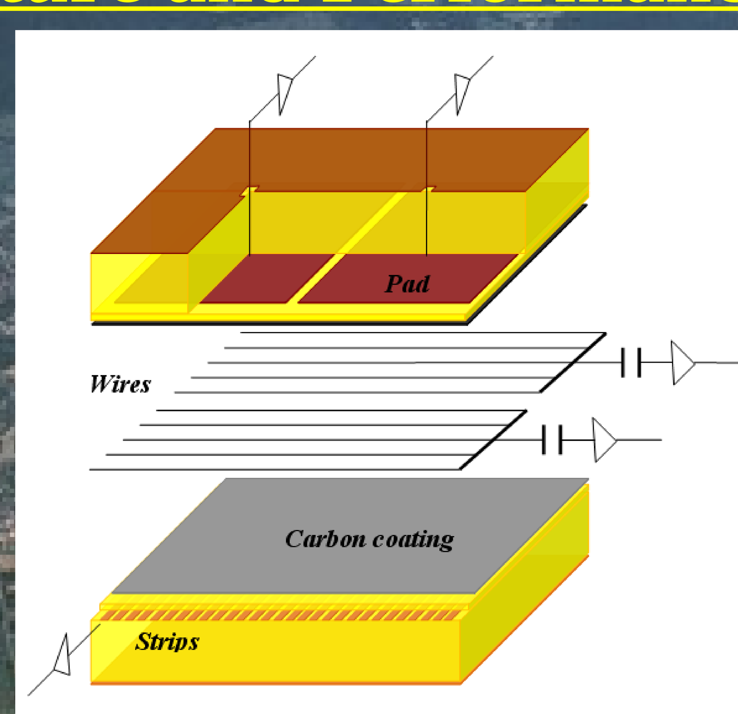
The forthcoming upgrade of LHC to super-LHC will increase the expected background rate in the forward region of the ATLAS Muon Spectrometer by approximately the factor of five. Some of the present Muon Spectrometer components will fail to cope with these high rates and will have to be replaced. The higher rate of photons and minimum ionizing particles should be matched by a comparable increase in the rate capability of the various detector components. The results of a test of a device consisting of Thin Gap Chambers (TGC) and a fast drift tube chamber (DT) using the 180 GeV/c muons at the SPS-H8 muon beam at CERN are presented. The aim of the test was to study the combined TGC-DT system as tracking and triggering device in the ATLAS muon spectrometer after high-luminosity upgrades of the LHC.

Thin Gap Chamber Structure and Performance

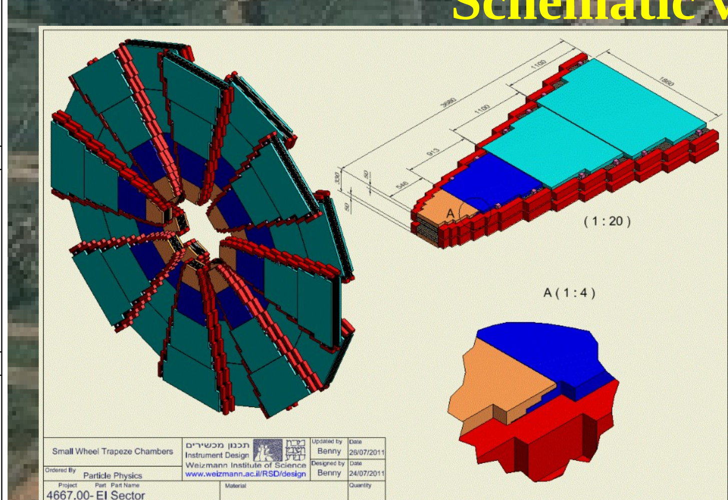
TGC is a a multiwire chamber with operational gas a mixture of 55% CO_2 and 45% n-pentane. Each gas gap contains: a series of pad readouts for trigger signal, strip readout for high position accuracy and a perpendicular wire readout for a second coordinate measurement. Two TGC quadruplets of 1.2 × 0.5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



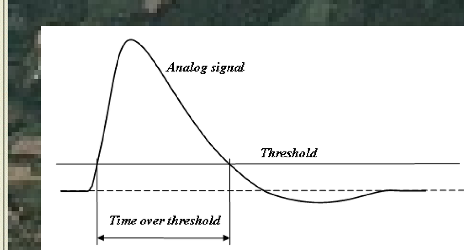
Schematic view of the TGC

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

TGC parameters

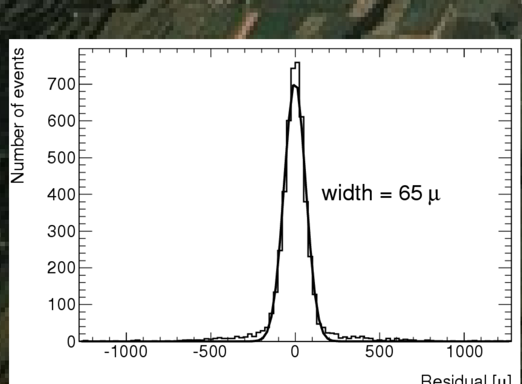


Small wheel trapeze chambers

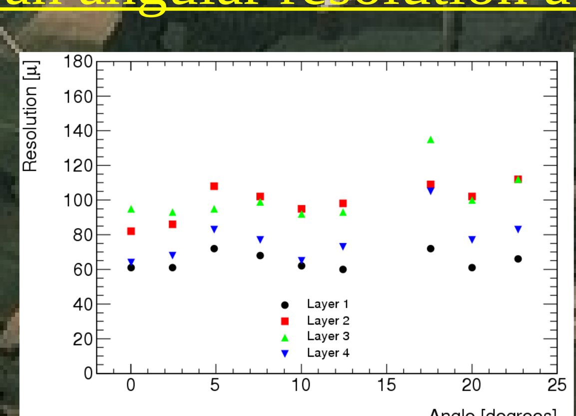


Time-over-Threshold method used for readout

Spatial an angular resolution achieved by the TGC



Spatial residual: fit predicted position minus measured one



Spatial resolution dependence on the impact angle

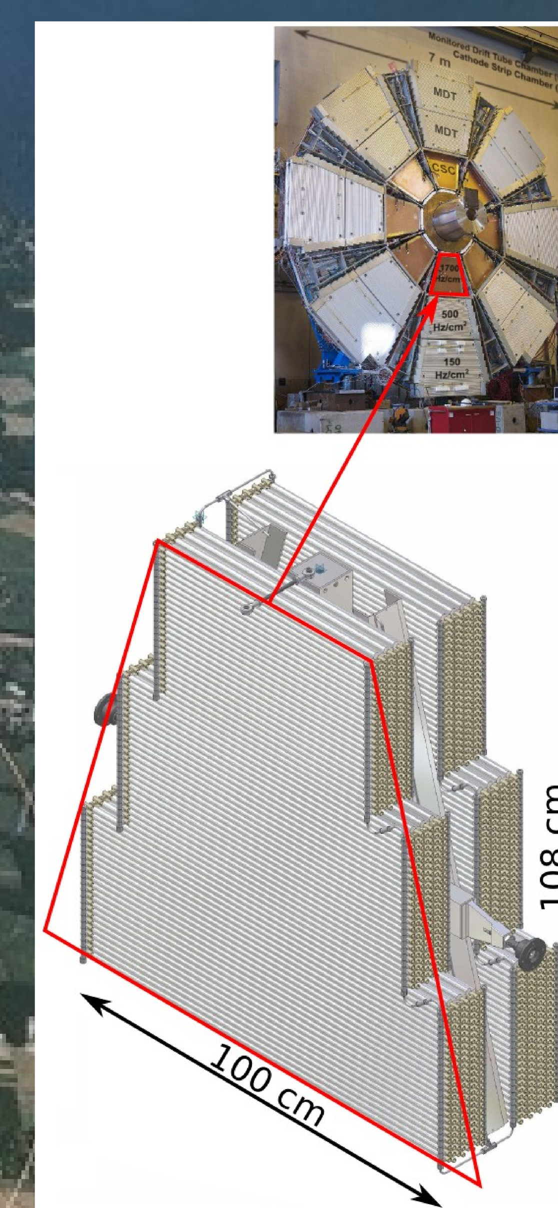
A single gap spatial resolution of 70 μ and an angular resolution of 0.4 mrad was achieved with the two TGC quadruplets for 40 cm distance between them. The details of the trajectory fit procedure can be found in:

Nucl.Instrum.Meth.A628:177-181,2011 [arXiv:1006.0135v2]

Drift Tube Chamber Design and Performance

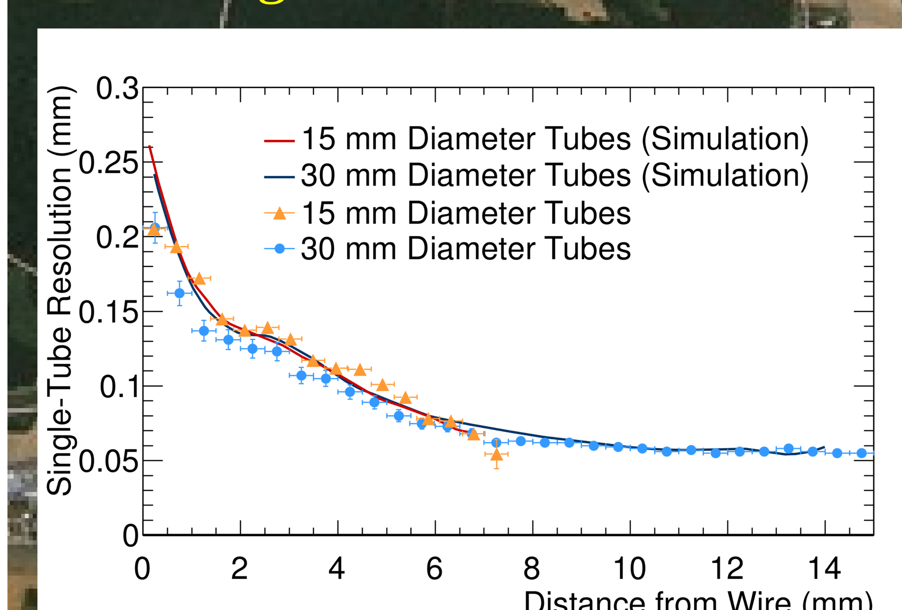
The Drift Tube Technology is already used in the muon tracking chambers in ATLAS and provides excellent performance. To increase the rate capabilities for sLHC luminosity, the diameter was reduced to 15 mm. This reduces the occupancy by a factor 7 (2 times smaller surface, 3.5 times shorter drift time). The resolution and efficiency stays at the very high level of the 30 mm drift tubes already used in ATLAS.

A first prototype chamber with 1152 tubes was build to and excessively tested in a high background environment and the CERN muon beam.

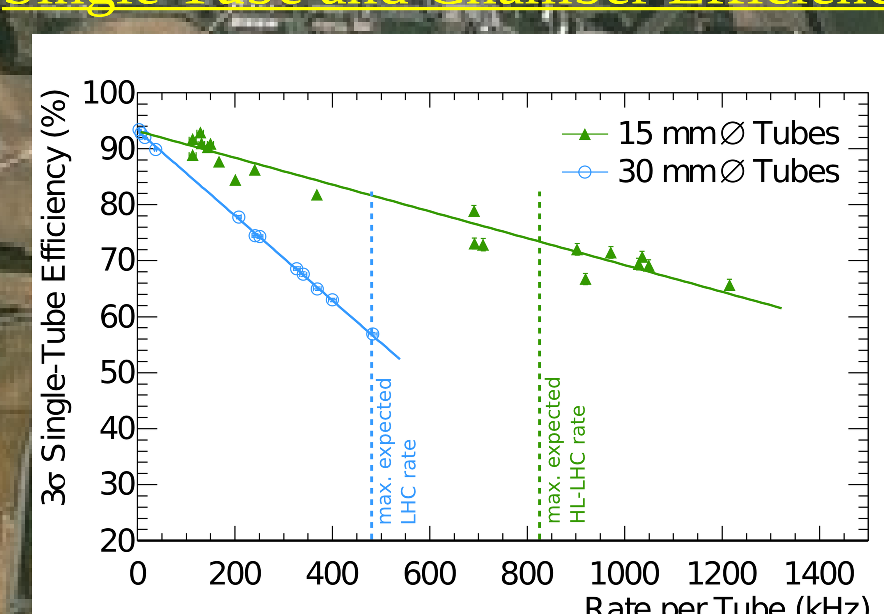


Tube Diameter	15 mm
Gas Mixture	Ar/CO2 (93:7)
Pressure	3 bar absolut
Wire	50 µm W/Re
Tube Wall	0.4 mm Al
Operating Voltage	2730 V
Maximum Drift Time	185 ns
Gas gain	20,000

Single Tube resolution



Single Tube and Chamber Efficiency

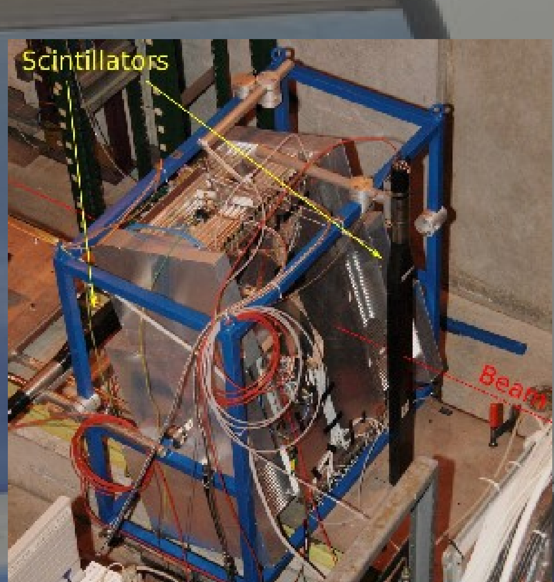


For more details please see Talk N5.5

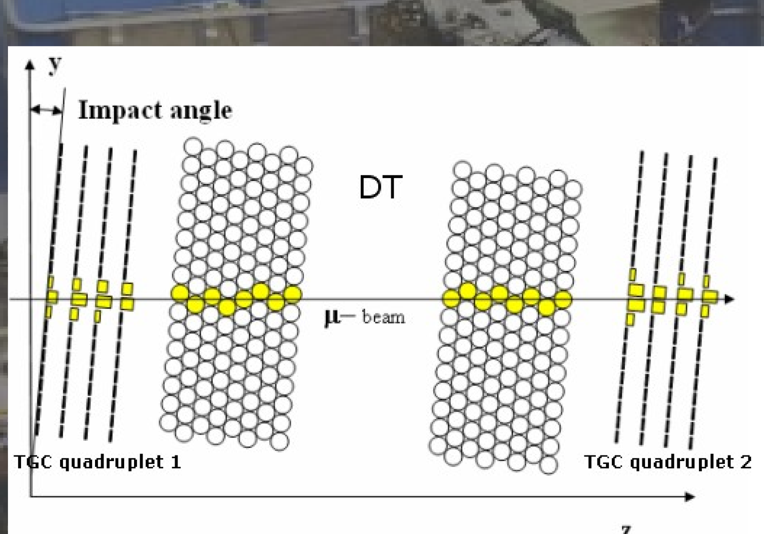
Combined TGC-DT test

Test scheme

The 180 GeV/c muons at the SPS-H8 muon beam at CERN were used. The TGC quadruplets were put on both sides of the DT.



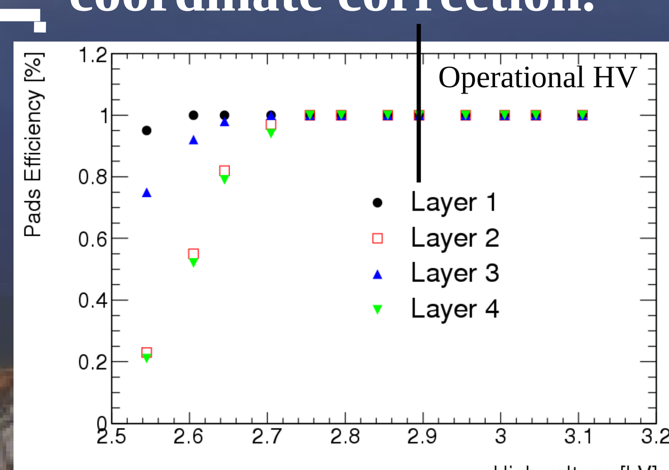
DT with 2 TGC quadruplets



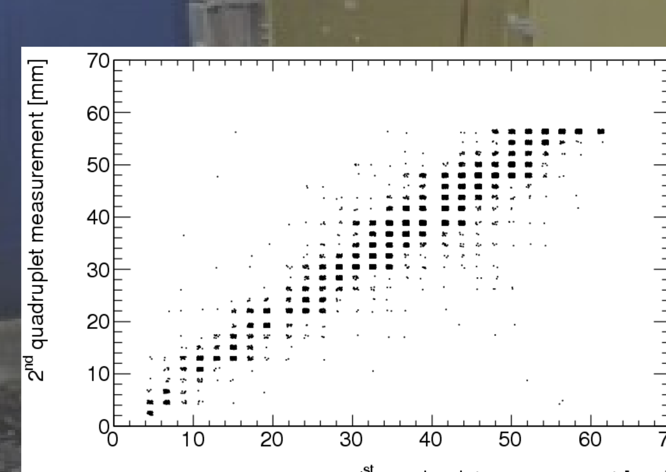
Principal scheme of the test

TGC pads: trigger and 2nd coordinate correction

Signal coincidences from the TGC pads were used to provide the trigger for the combined TGC-DT device. Also, pads are very nicely correlated as a position measurement device and are used for the DT second coordinate correction.

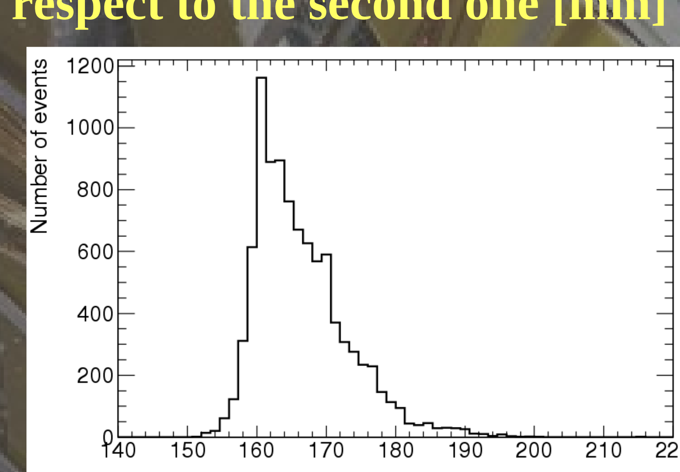


Pads efficiency vs. the high voltage

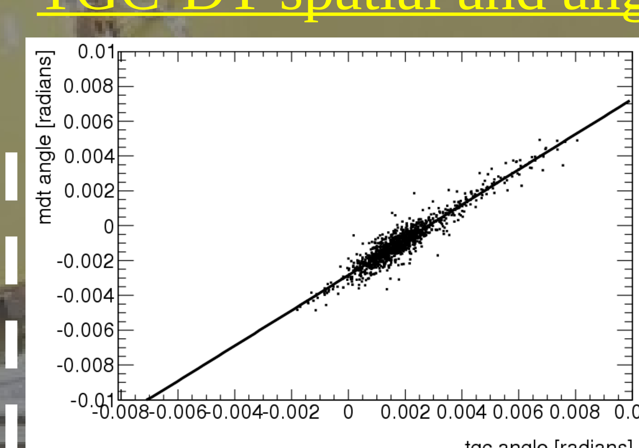


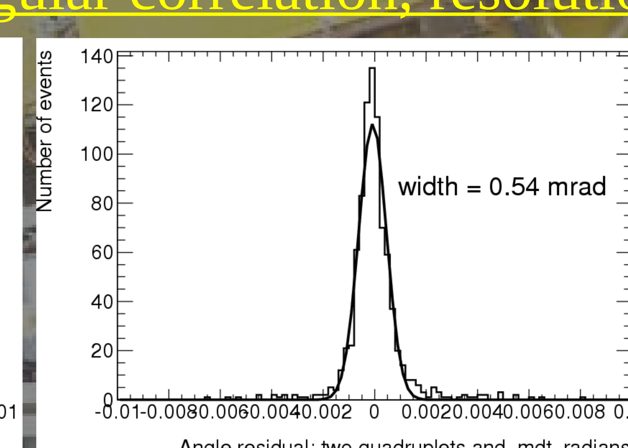
Second coordinate position measurement: 1st quadruplet with respect to the second one [mm]

Time difference between 3-out-of-4 pad trigger with respect to the beam scintillator in units of 0.8 ns. 99% of the distribution is within 25 ns.

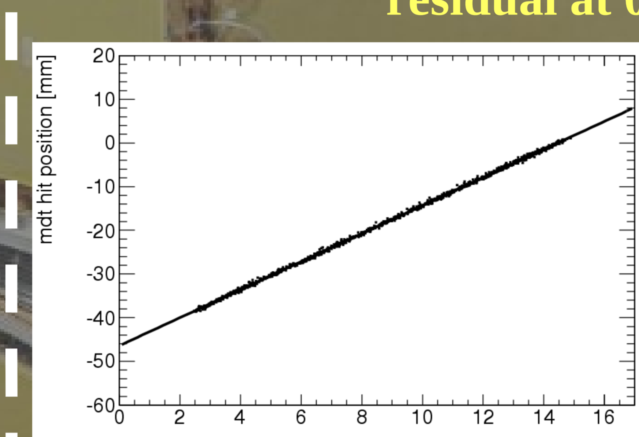


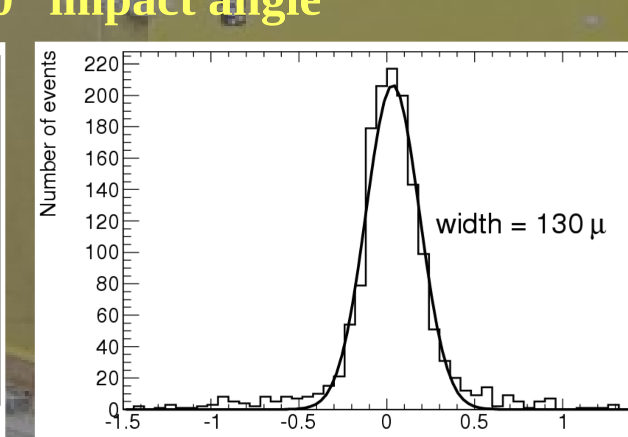
TGC-DT spatial and angular correlation, resolution



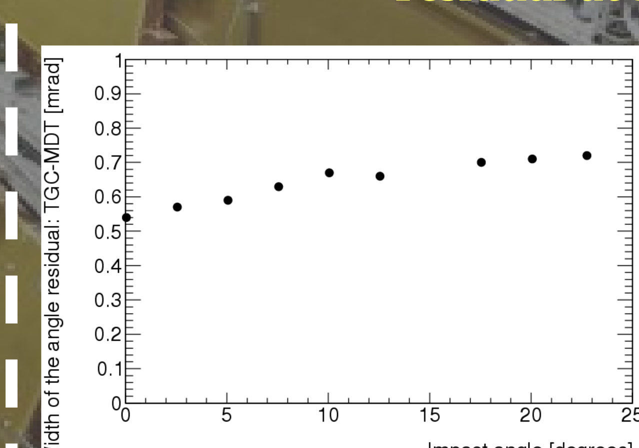


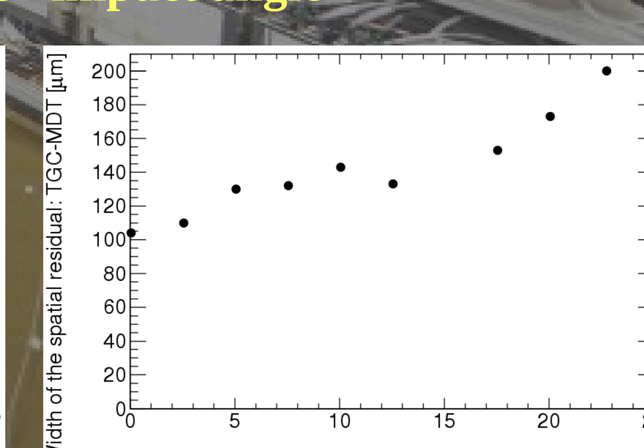
TGC-DT angular correlation and residual at 0° impact angle





TGC-DT spatial correlation and residual at 5° impact angle





Angular and spatial residual vs. impact angle

Conclusions:

The combination of TGC and DT offers an attractive solution for triggering and measuring muons at the sLHC . The analysis of the recorded data shows a very good correlation between the TGC and DT track position and inclination. This technology has high rate capabilities over large areas, good spatial and angular resolutions: better than 0.4 mrad and 100μ, fast response, and the option to combine trigger and tracking, all within a reasonable cost.