From test bench to new small wheel – small strip thin gap chamber

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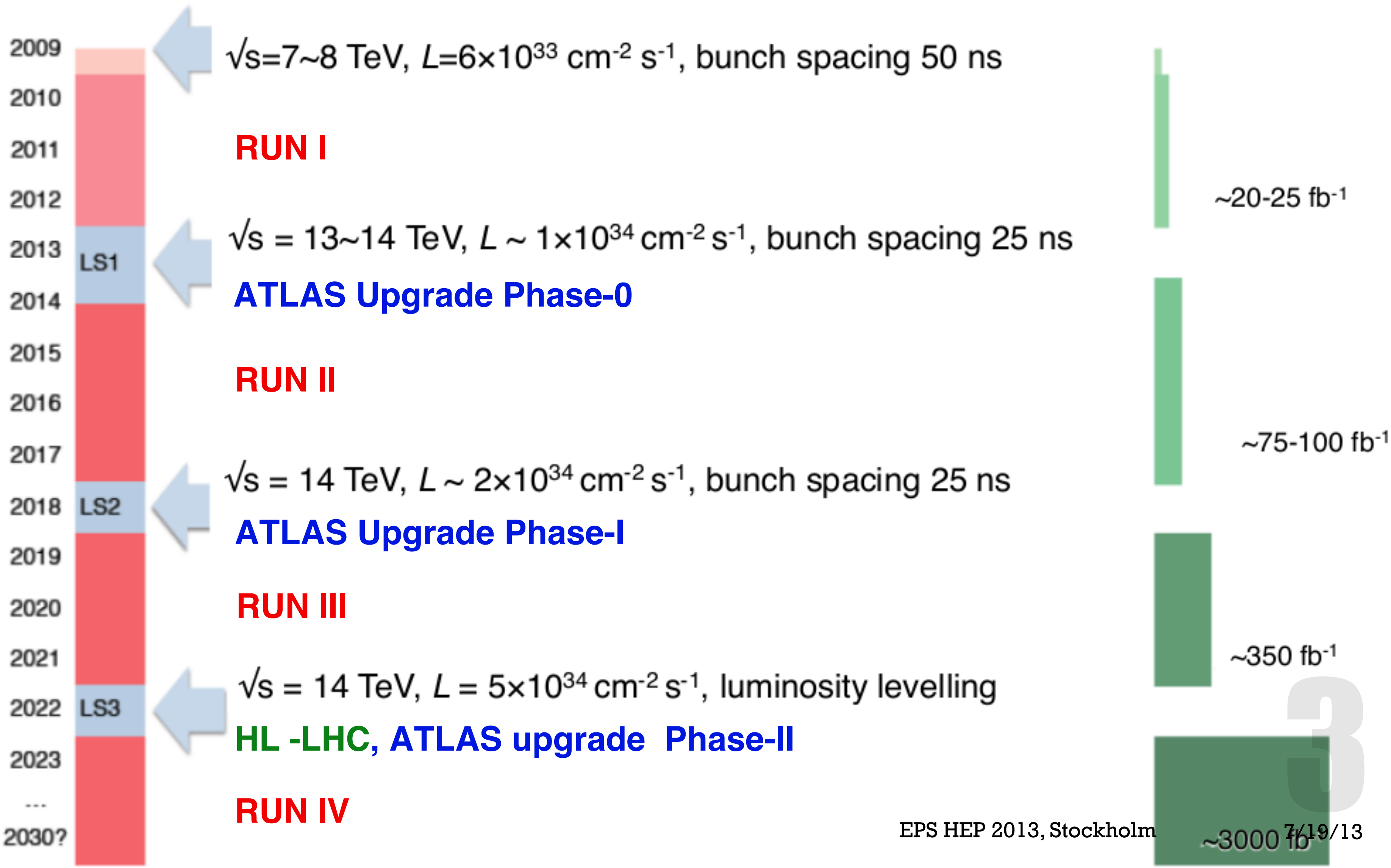
EPS HEP 2013, Stockholm

outline

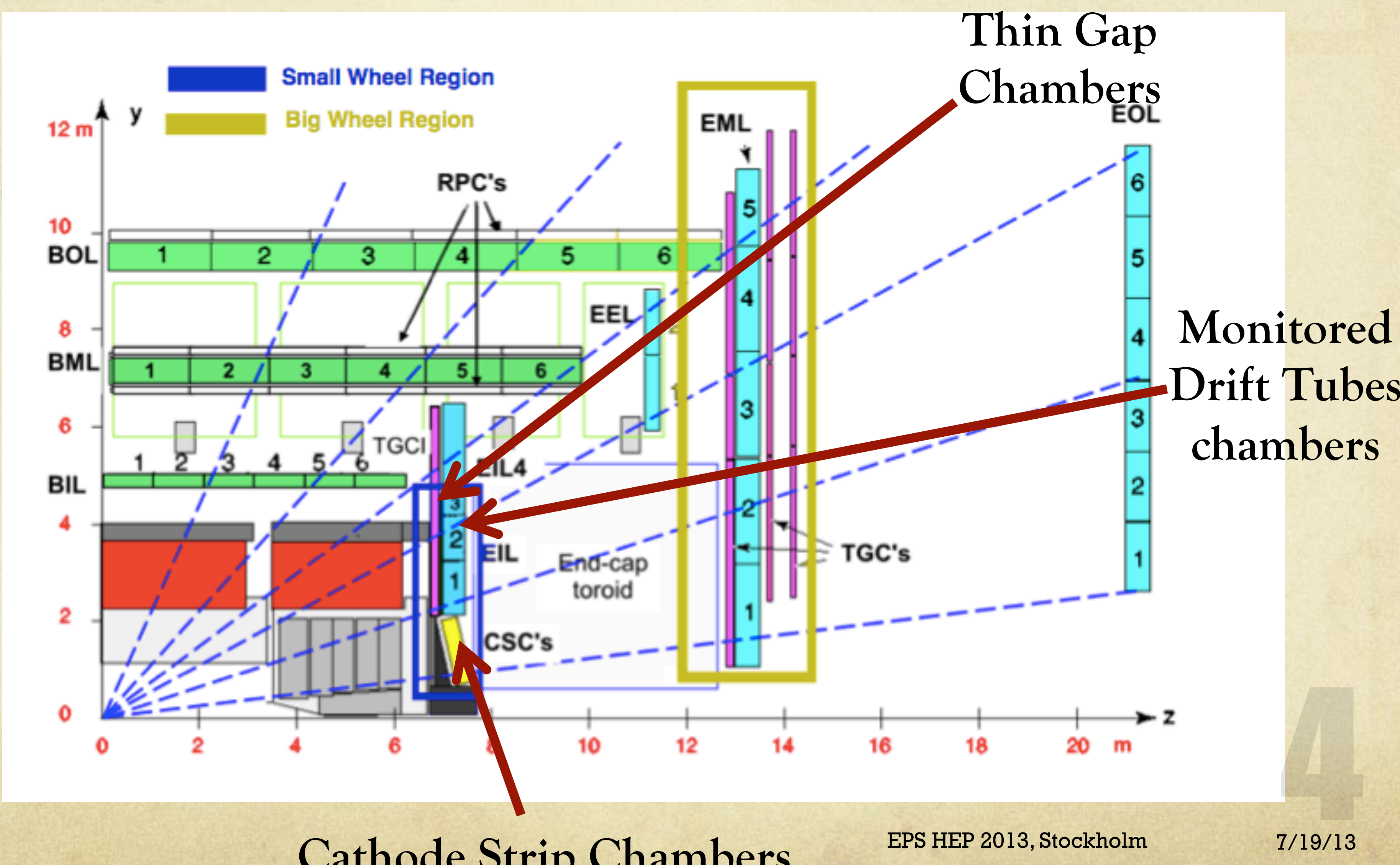
- LHC plans
- The actual small wheel
- Why a new small wheel ?
- Small Thin Gap Chambers
- Test beam and irradiation tests
- The New Small Wheel
- New front end
- Conclusion

LHC plans

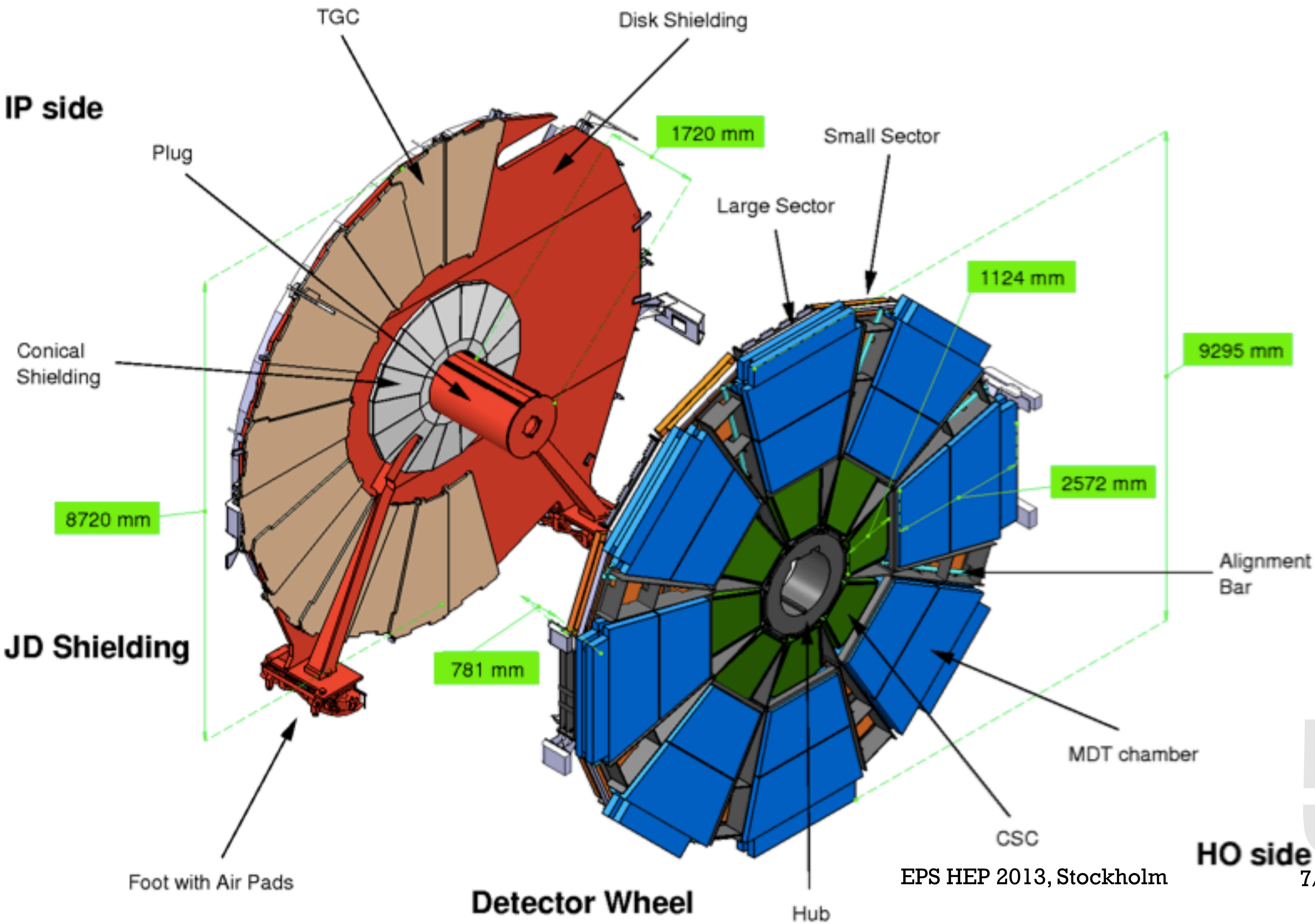


2009
2010
2011
2012
2013
LS1
2014
2015
2016
2017
2018
LS2
2019
2020
2021
2022
LS3
2023
...
2030?
√s=7~8 TeV, L=6×10^33 cm^-2 s^-1, bunch spacing 50 ns
RUN I
√s = 13~14 TeV, L ~ 1×10^34 cm^-2 s^-1, bunch spacing 25 ns
ATLAS Upgrade Phase-0
RUN II
√s = 14 TeV, L ~ 2×10^34 cm^-2 s^-1, bunch spacing 25 ns
ATLAS Upgrade Phase-I
RUN III
√s = 14 TeV, L = 5×10^34 cm^-2 s^-1, luminosity levelling
HL -LHC, ATLAS upgrade Phase-II
RUN IV
~20-25 fb^-1
~75-100 fb^-1
~350 fb^-1
~3000 fb^-1

Actual Small wheel



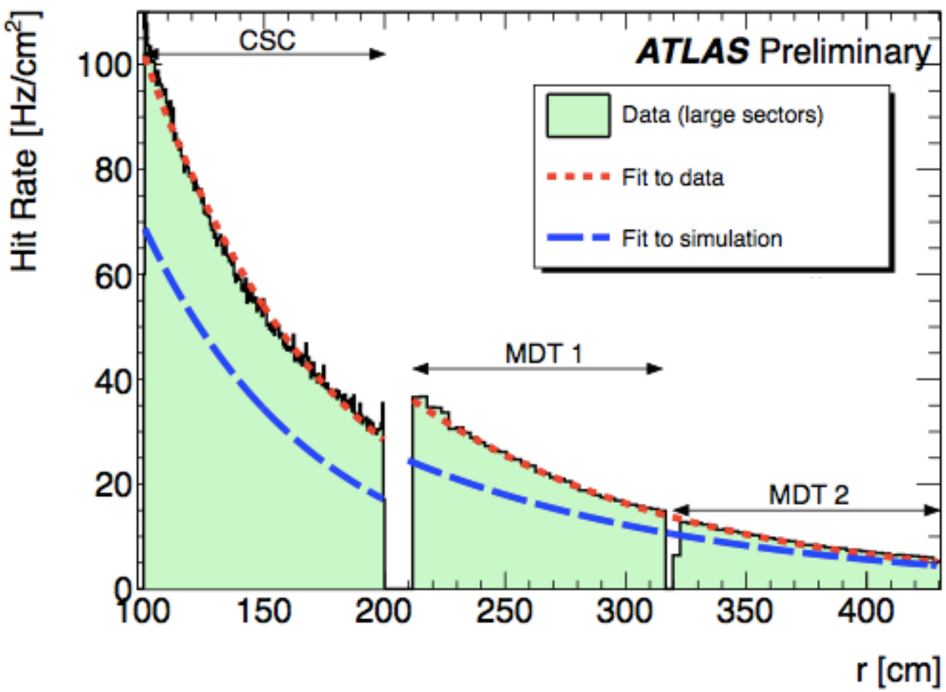
Actual Small wheel

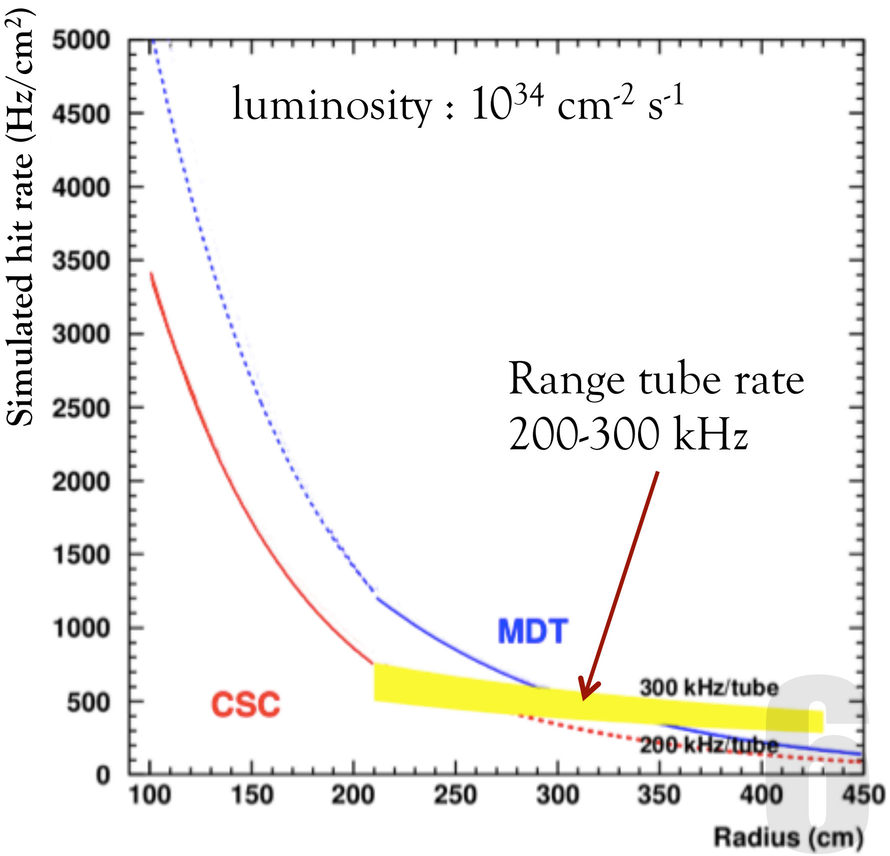


Why upgrade ?

- Performance of the muon tracking chambers will be degraded with the luminosity increase
- Muon end caps trigger will have too high fake rate

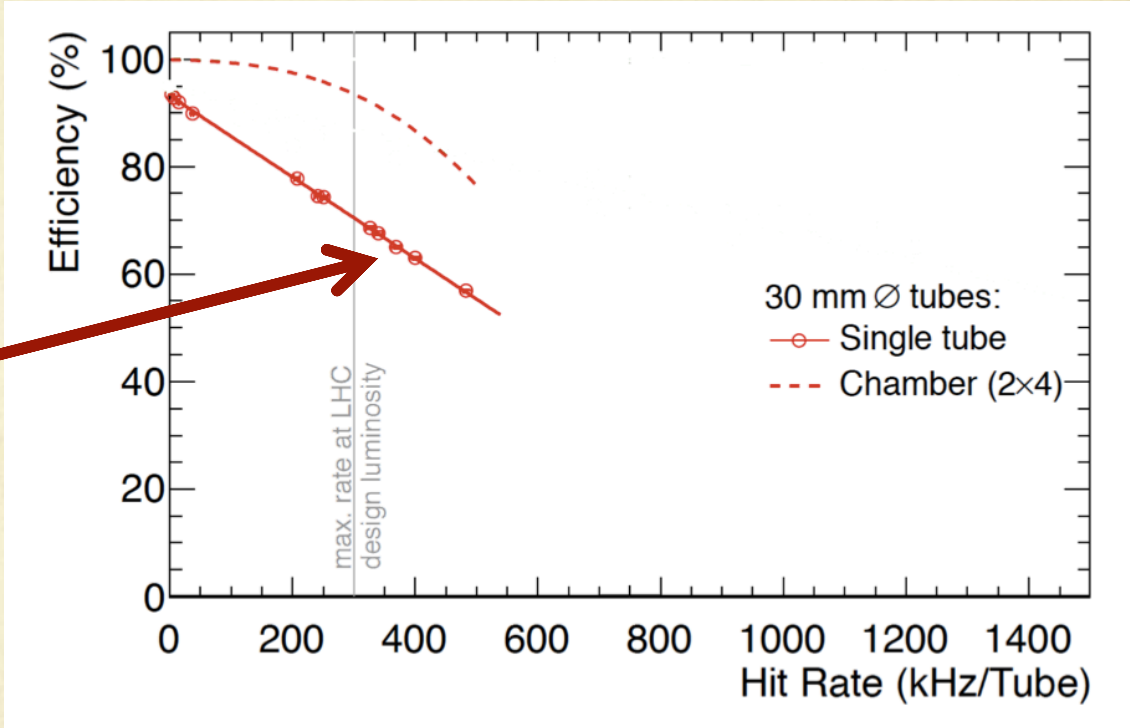
Average luminosity : 9.6 10^{32} cm^{-2} s^{-1}





MDT efficiency

H. Kroha and al, Construction and Test of a Full Prototype Drift-Tube Chamber for the Upgrade of the ATLAS Muon Spectrometer at High LHC Luminosities, Nucl.Instrum.Meth. (2012).

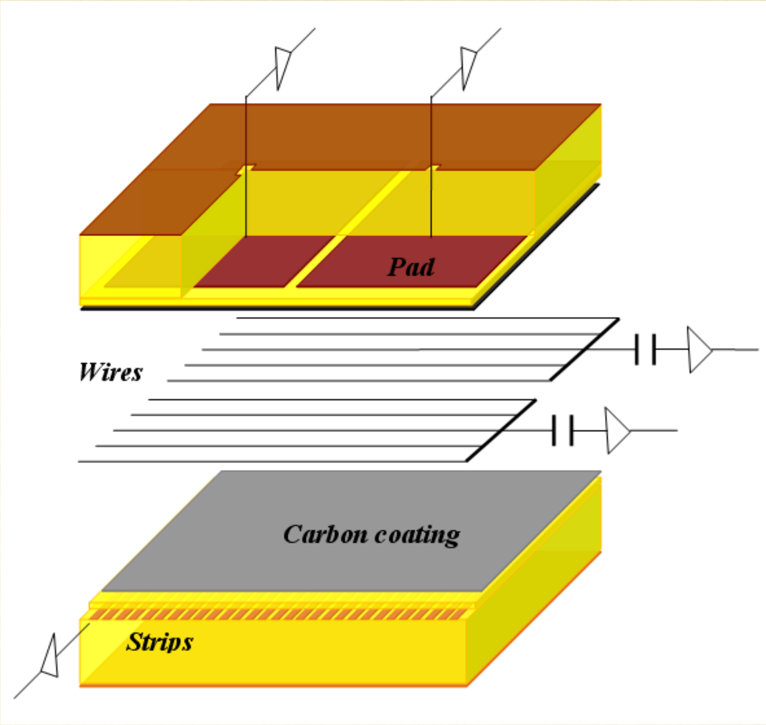


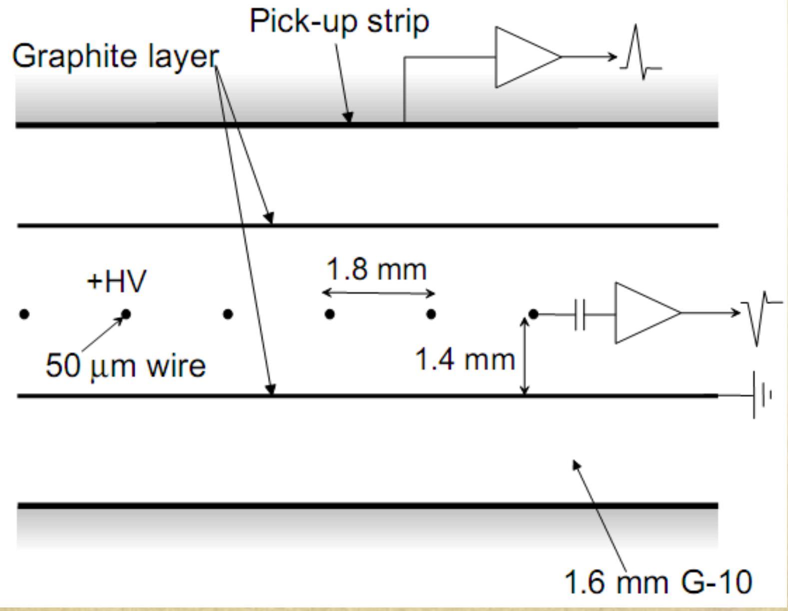
Loss at least 35% at high luminosity

New Small wheel is needed with :
100 μm resolution
Online muon track reconstruction with 1 mrad precision

Small Thin Gap Chamber

sTGC geometry	
Wire-carbon gap	1.4 mm
Wire-wire space	1.8 mm
Strip pitch	3.2 mm
Inter strip gap	0.5 mm
Gas mixure	CO_2:n-pentane (55:45)
Wire potential	2.9 kV





Quadruplet = 4 sTGCs :

4 wires planes

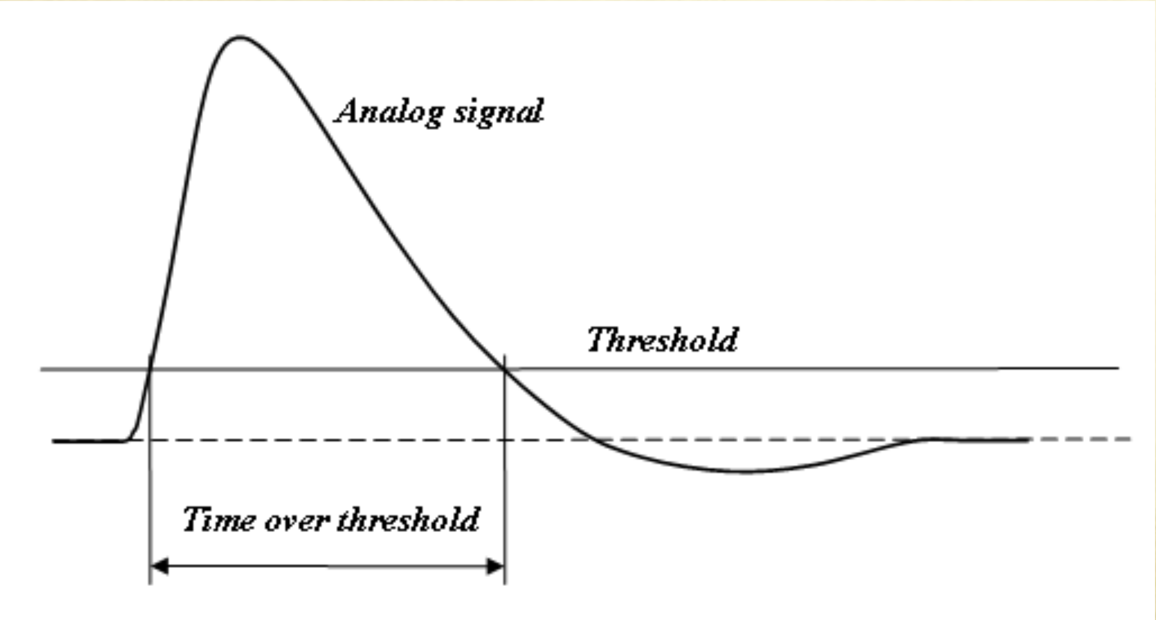
4 strips planes

4 pads planes

sTGC Front End for the test benches

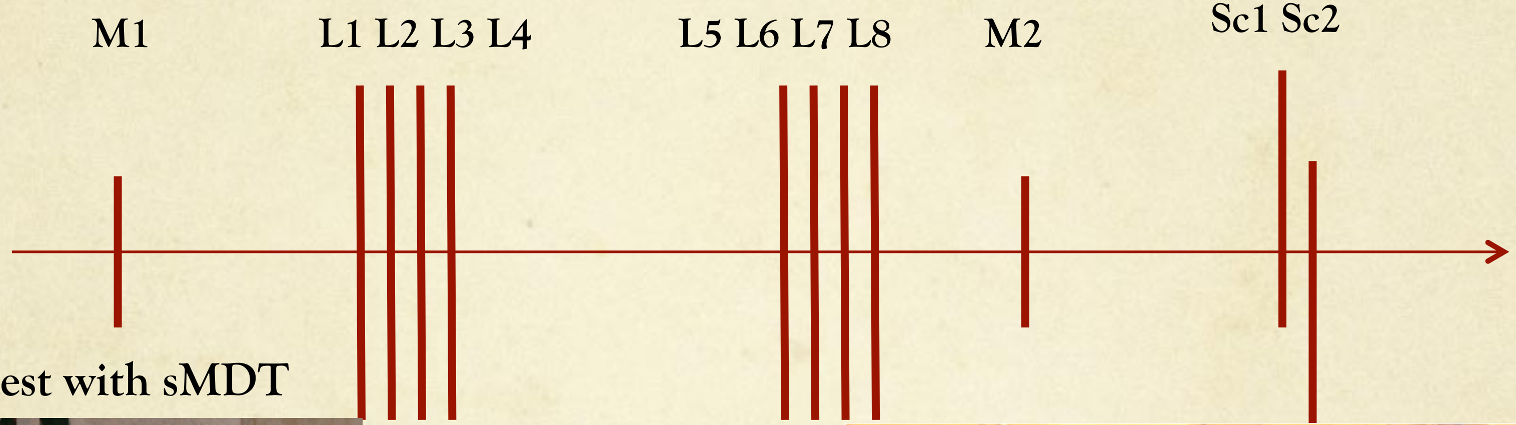
- From 2008 to mid 2012, the Amplifier Shaper Discriminator (ASD) developed by KEK was used
- Peaking time : 17 ns ; Gain 0.8 V/pC
- Provides an analog and digital signal

ASD IC for the thin gap chambers in the LHC ATLAS experiment, Sasaki, O., Nuclear Science Symposium, 1998. Conference Record. 1998 IEEE

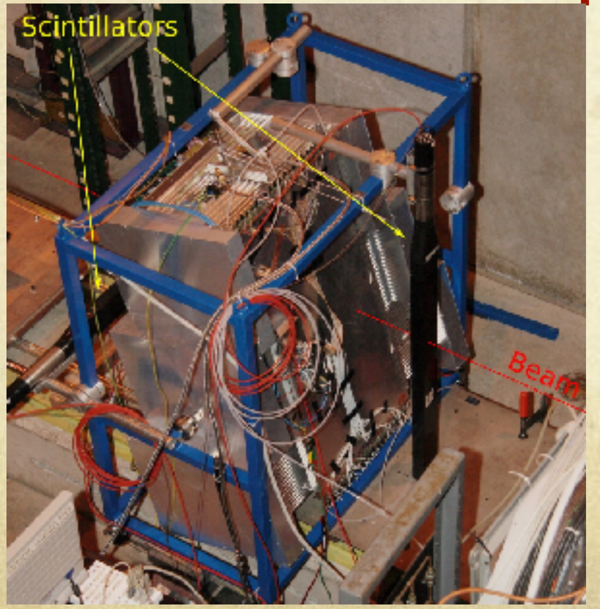


Muon test beam set up

- Muon test beams at CERN (180 Gev)
- two quadruplets equipped with ASD, two monitor chambers (small TGC chambers M1 and M2) and two scintillators



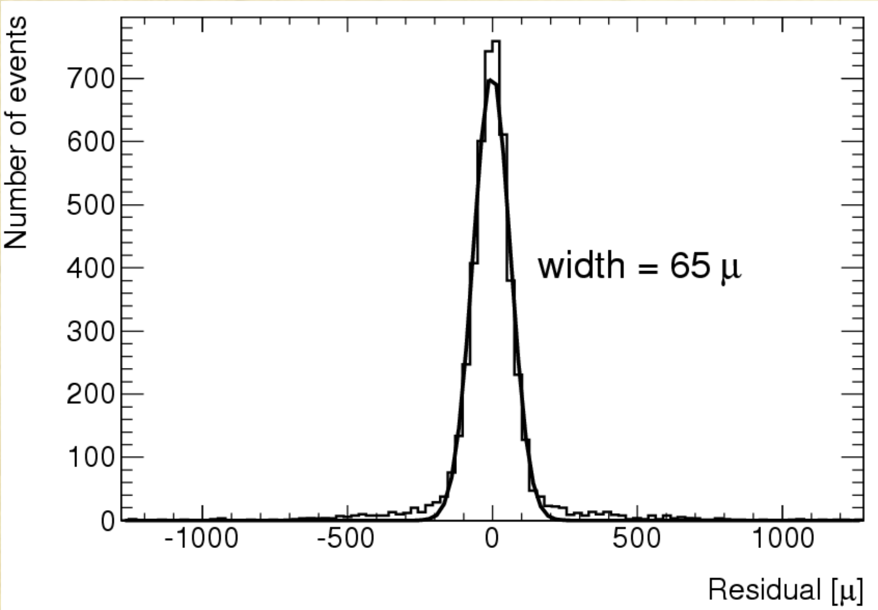
Combined test with sMDT



Mechanical system that allows to rotate the TGC with high accuracy

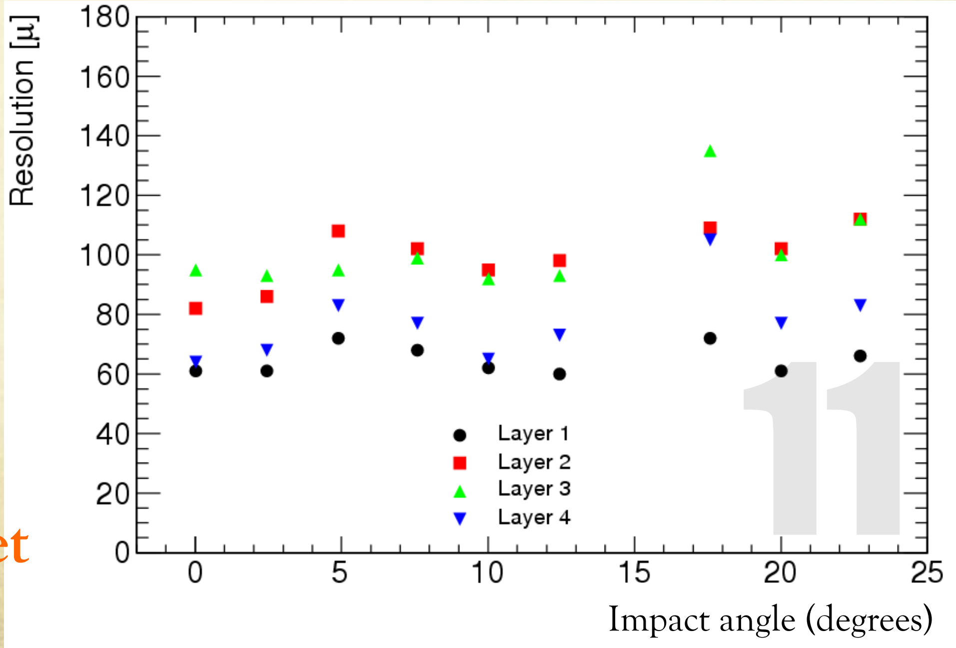
Test of spatial resolution and trigger efficiency of a combined Thin Gap and Fast Drift Tube Chambers for high-luminosity LHC upgrades Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2011 IEEE

Position resolution



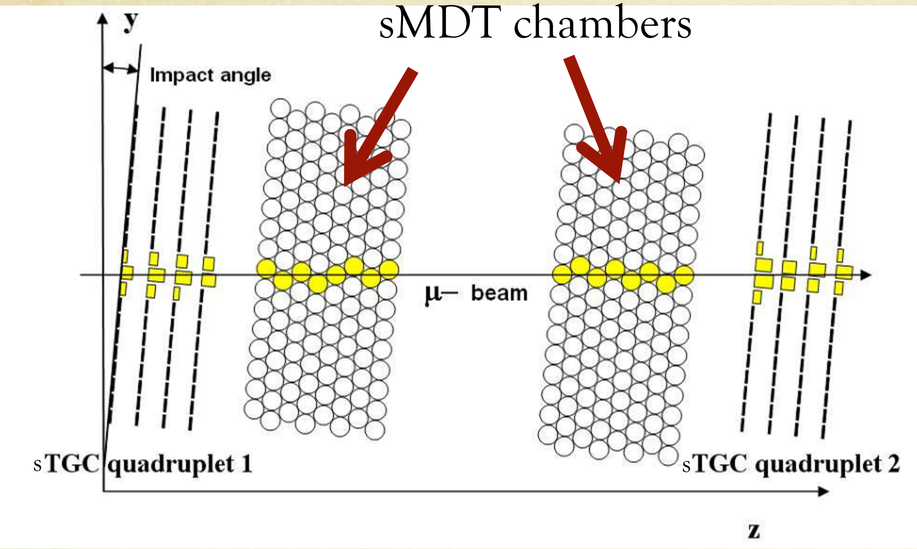
Resolution : difference between expected position from track fit (3 planes) and measured position (4th plane)

Position resolution as a function of the incidence angle for the different layers of a sTGC

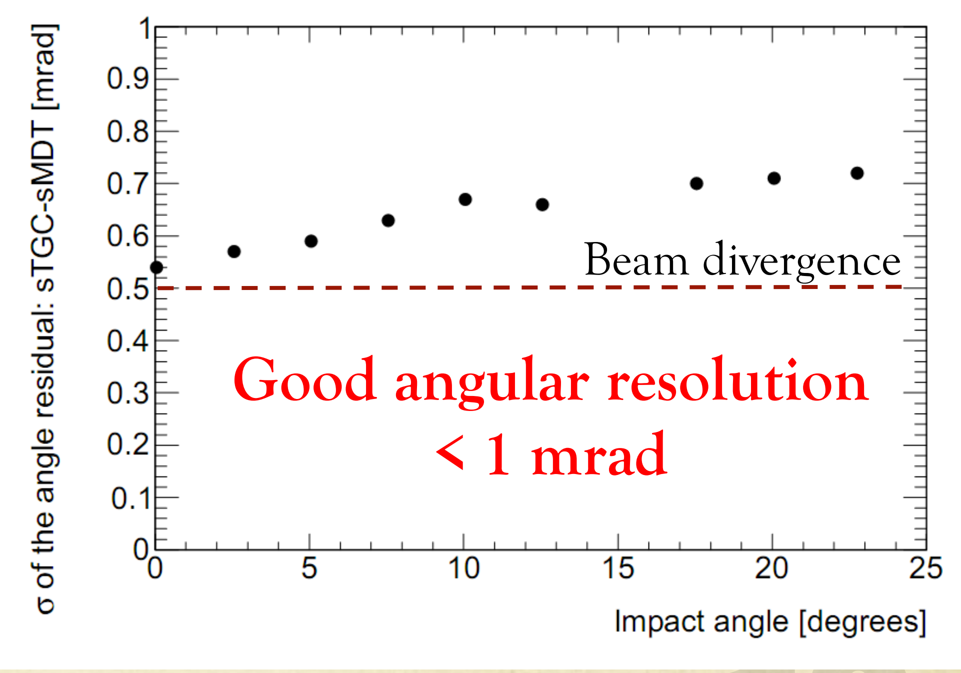


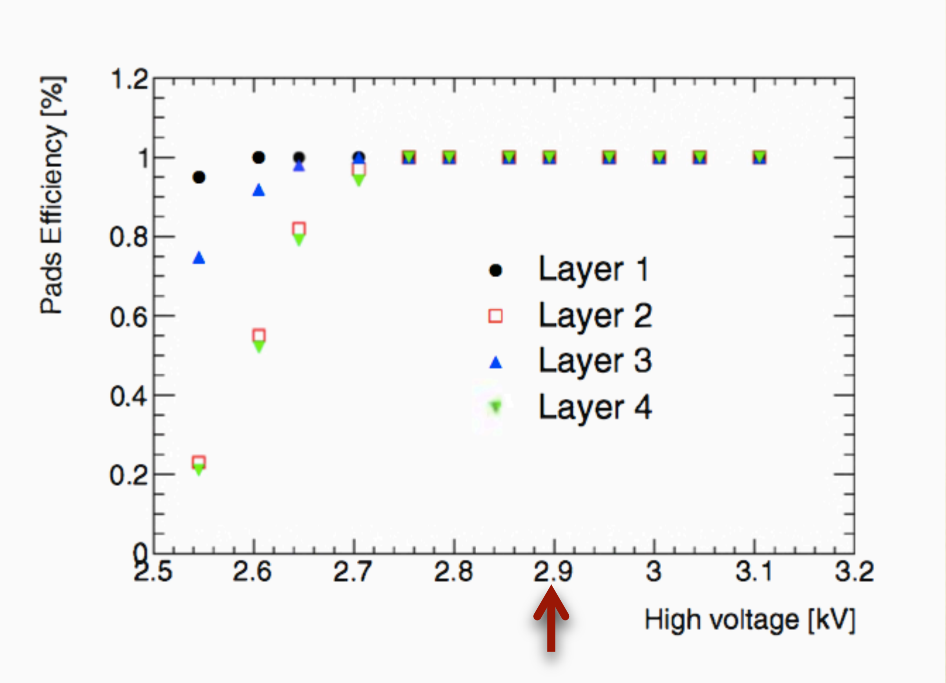
Good homogeneity of the quadruplet
Resolution < 100 μm

Angular resolution and pads efficiency



Combined test beam with sMDT chambers in muon beam (180 GeV) at CERN

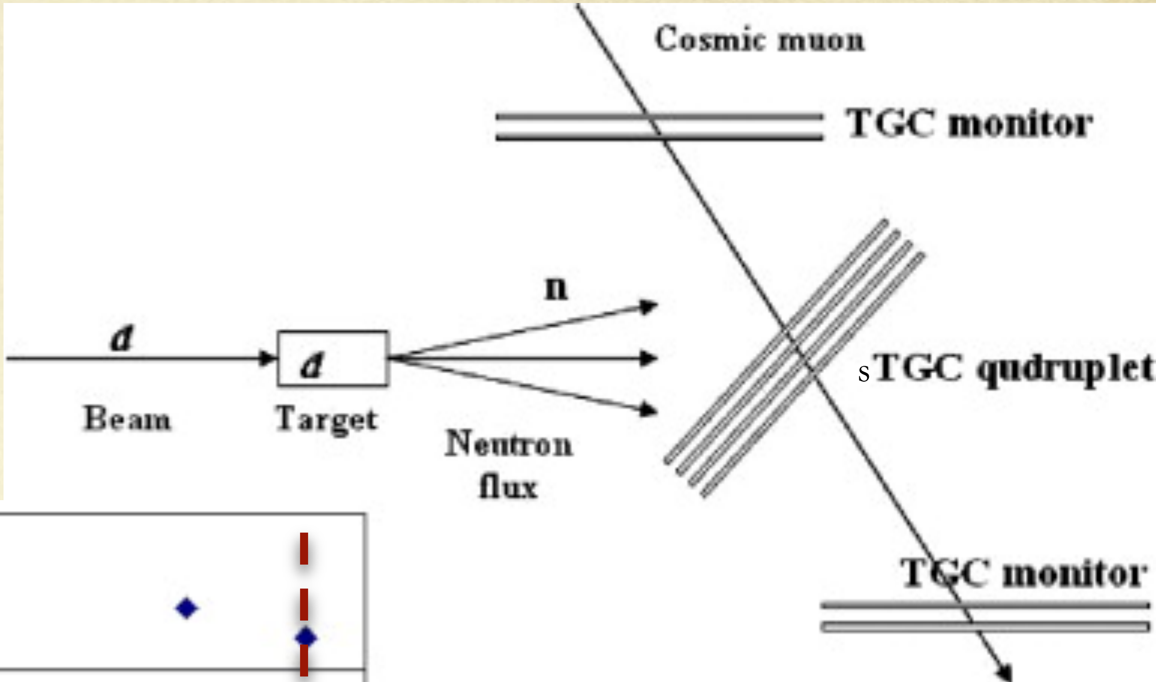


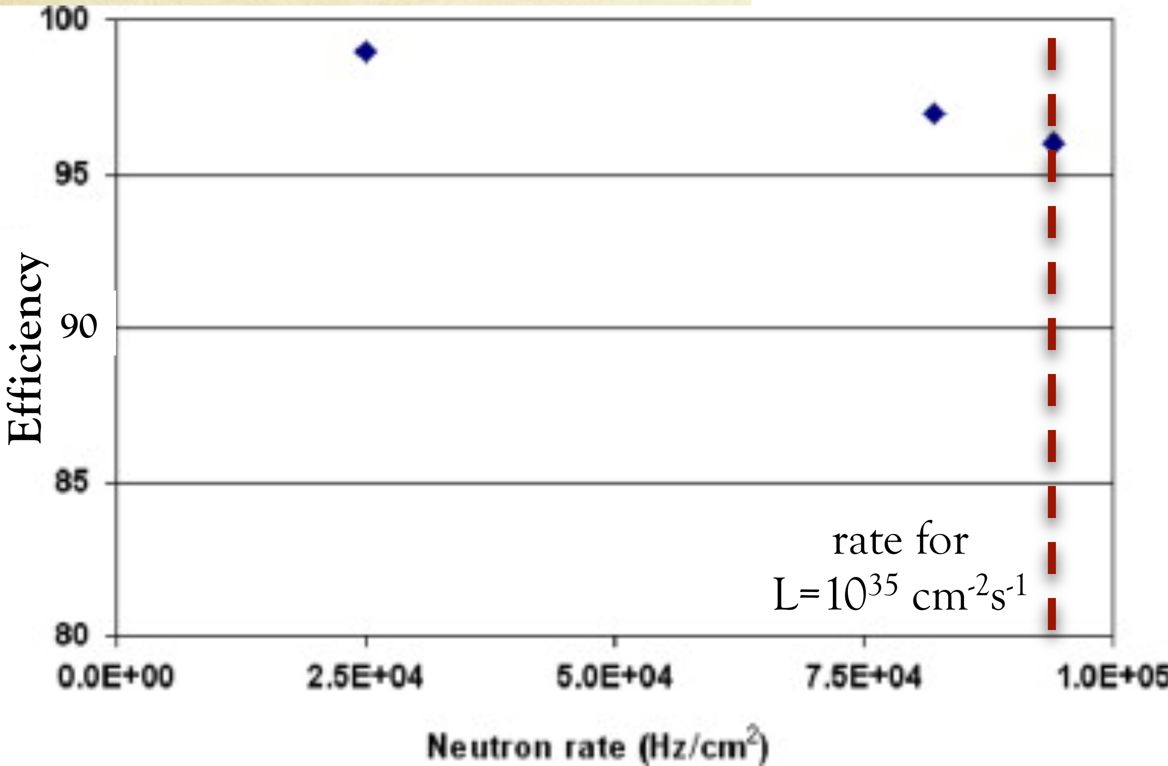


Efficiency above 99% for all layers above 2.75 kV

Irradiation with neutrons

Test in Demokritos (Greece) : Cosmic muons tracking under neutron (5.5-6.5 MeV) irradiation



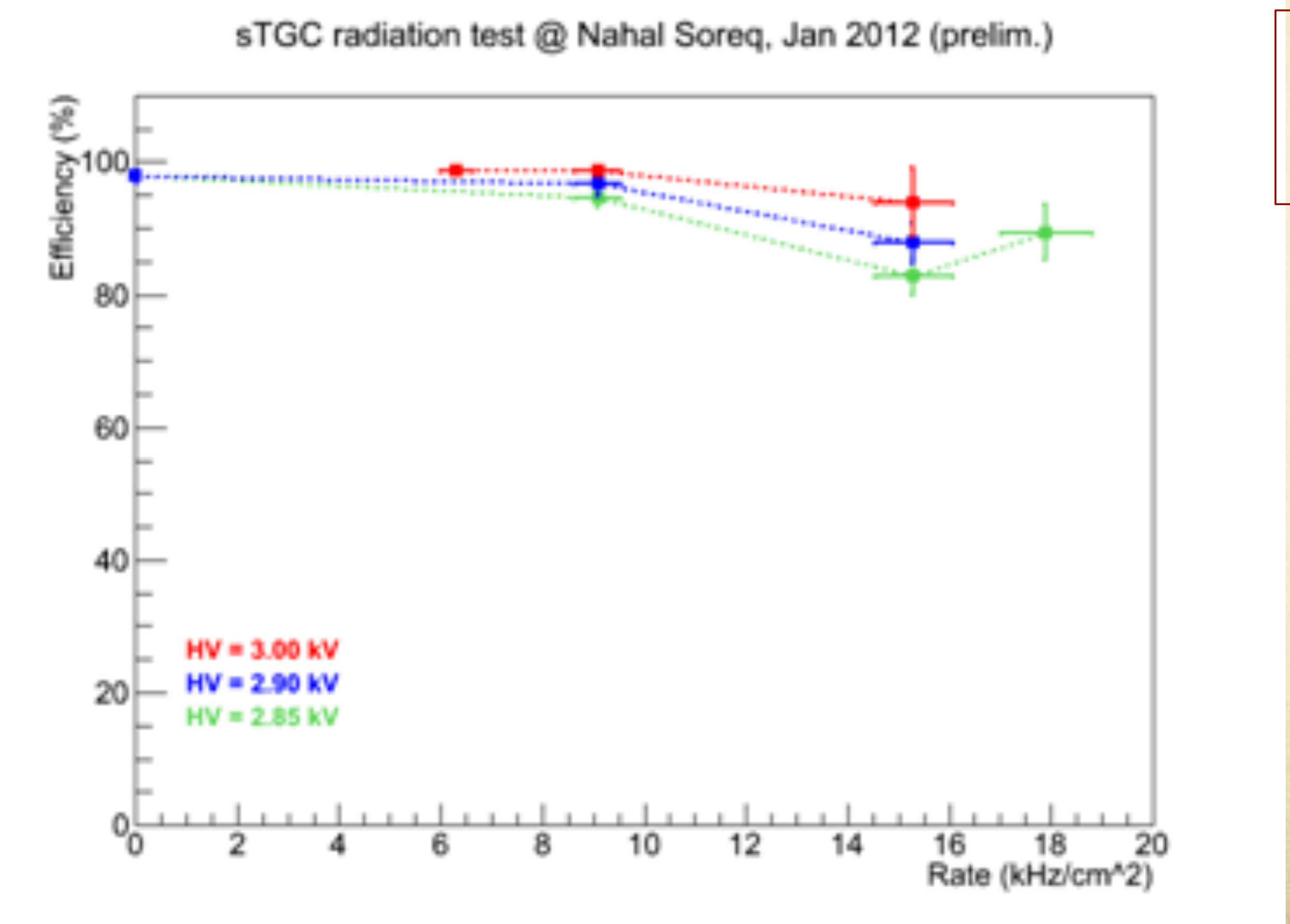


No drastic degradation of the efficiency : less than 4% at the highest dose rate

No sparks observed

Irradiation with ^{60}Co source

Tests at Nahal Soreq (IL).
Cosmic muons detection under gamma (~50 Ci ^{60}Co source) irradiation.
sTGC is 120x70cm2 was totally irradiated.

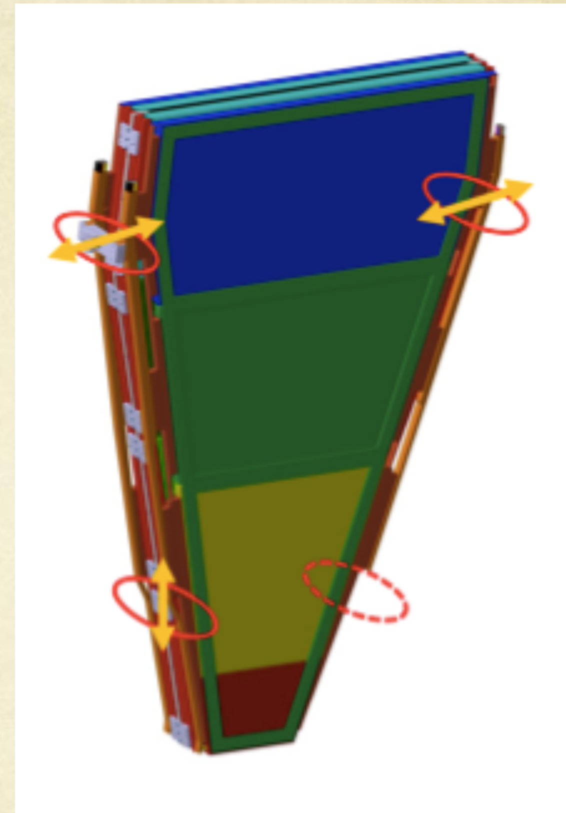


Position resolution and efficiency measurements with large scale Thin Gap Chambers for the super LHC, arXiv:1006.0135 [physics.ins-det]

No efficiency deterioration observed for a flux of 2.10^4 Hz/cm2

New Small Wheel

- Decision to build the NSW with 2 chamber technologies :
  - sTGC devoted to the level 1 trigger
  - micro mesh gaseous structure or Micromegas (MM) dedicated to precision tracking
- The sTGC-MM is a fully redundant system :
  - sTGC can measure muon track with high precision
  - MM can confirm the muon track existence



New FE ASIC for the NSW : VMM

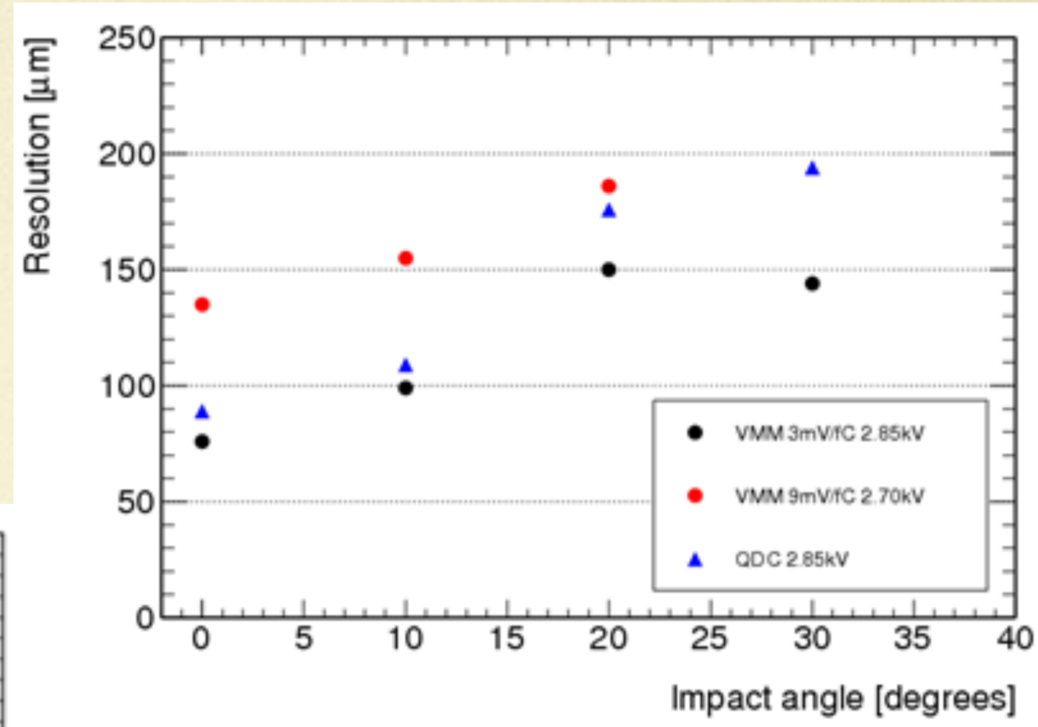
- New ASIC common for MM and sTGC designed in 2011. we received it in 2012
- Front end provides
  - 64 channels
  - Time to peak
  - Time over threshold
  - Adjustable gain : from 0.5 to 9 V/pC
  - Adjustable peaking time : from 25 to 200 ns
  - Threshold per channel

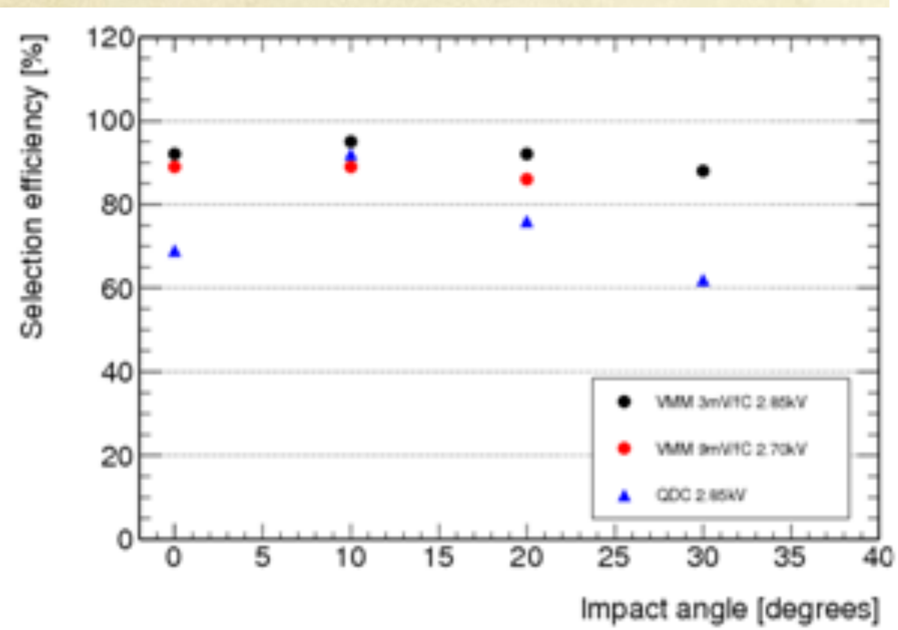
VMM1—An ASIC for Micropattern Detectors, G de Geronimo IEEE Trans.Nucl.Sci. 99 (2013) 1–8.

Result sTGC strip + VMM1

In last test beam, strip readout was realized with ASD and VMM

- ▲ ASD analog output (HV=2.85 kV)
- ● VMM 3mV/fC (HV=2.85kV)
- ● VMM 9mV/fC (HV=2.7kV)





Except for a few minor problems, all VMM features are working

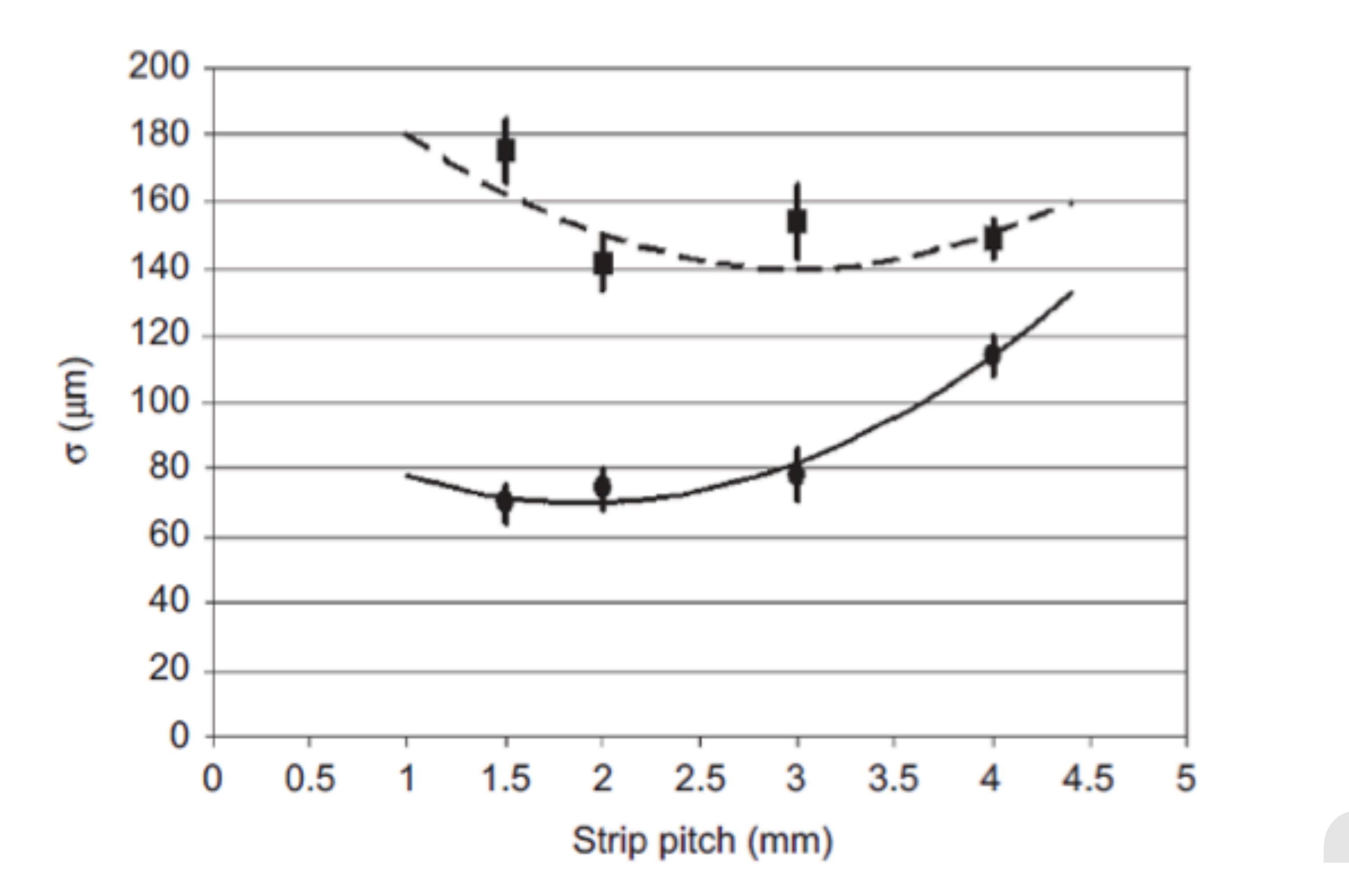
VMM2

Conclusion

- sTGC are able to support high flux radiation without loss of trigger efficiency and position resolution
- Sandwich with micromegas : MM for tracking purpose and sTGC for trigger (fully redundant)
- First prototype of a new front end designed for MM and sTGC gave good results
- NSW will be able to provide muon level 1 information and good tracking system at luminosities up to $10^{35} cm^{-2} s^{-1}$

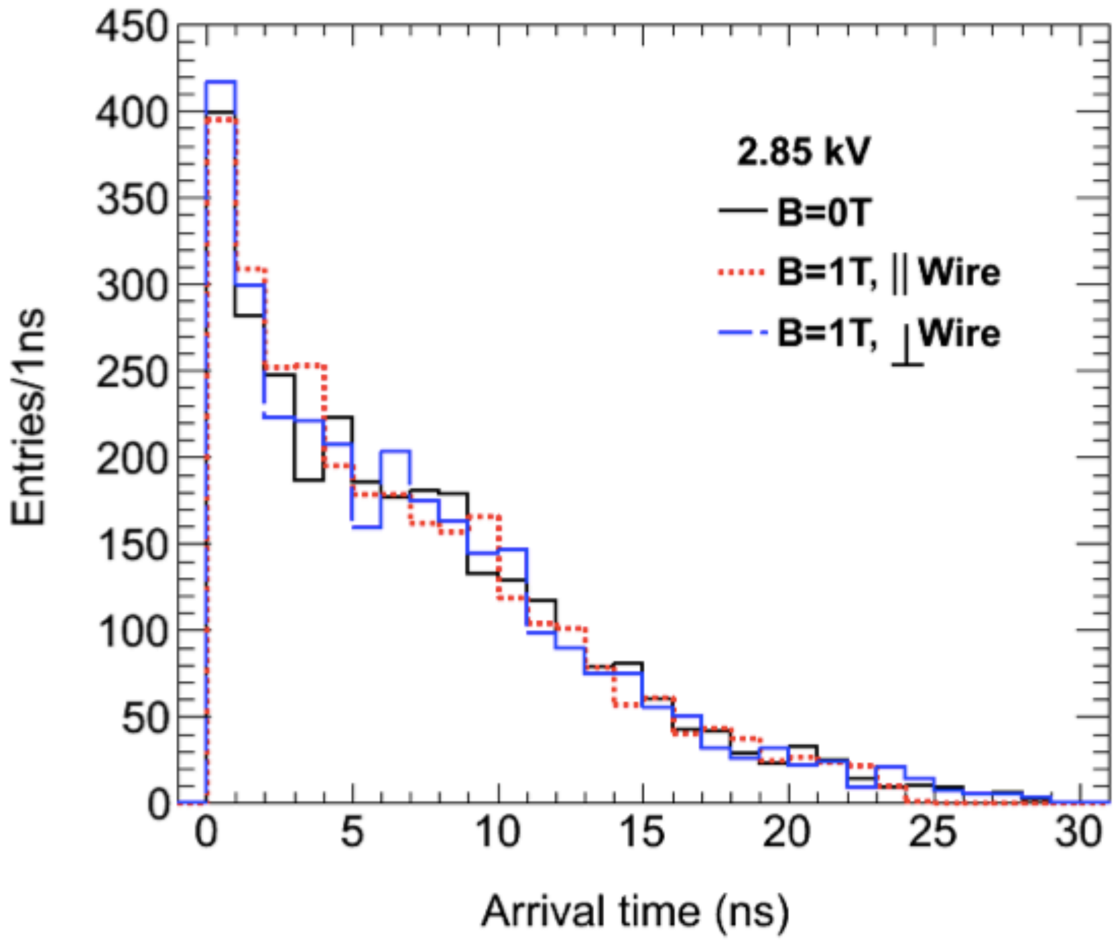
Backup slides

Strips pitch



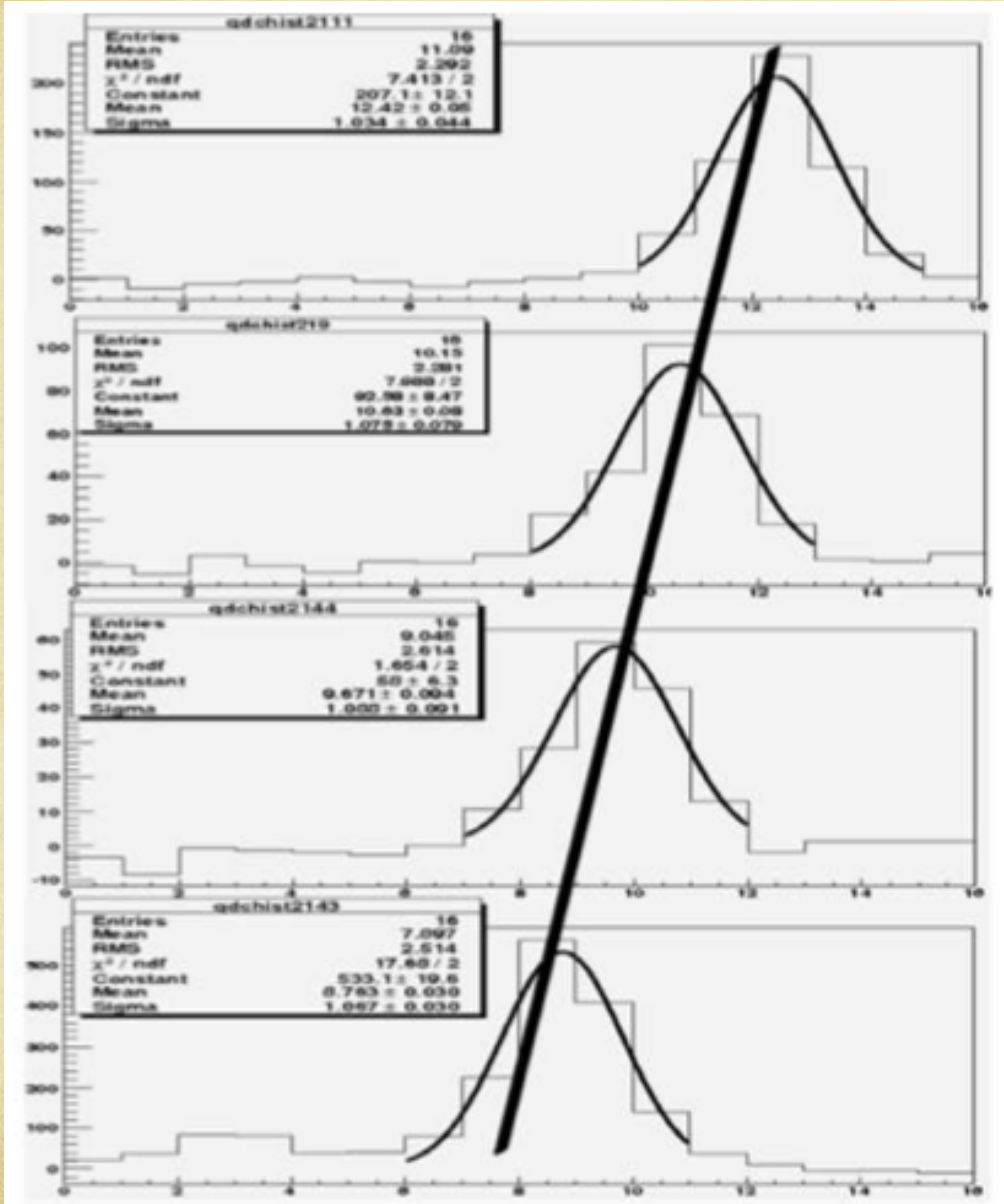
Average position resolution for two different incident angles (0-10°, circles) and (20-30°, squares) using charge division between strips. The values shown have been averaged over different HV settings.

Magnetic field



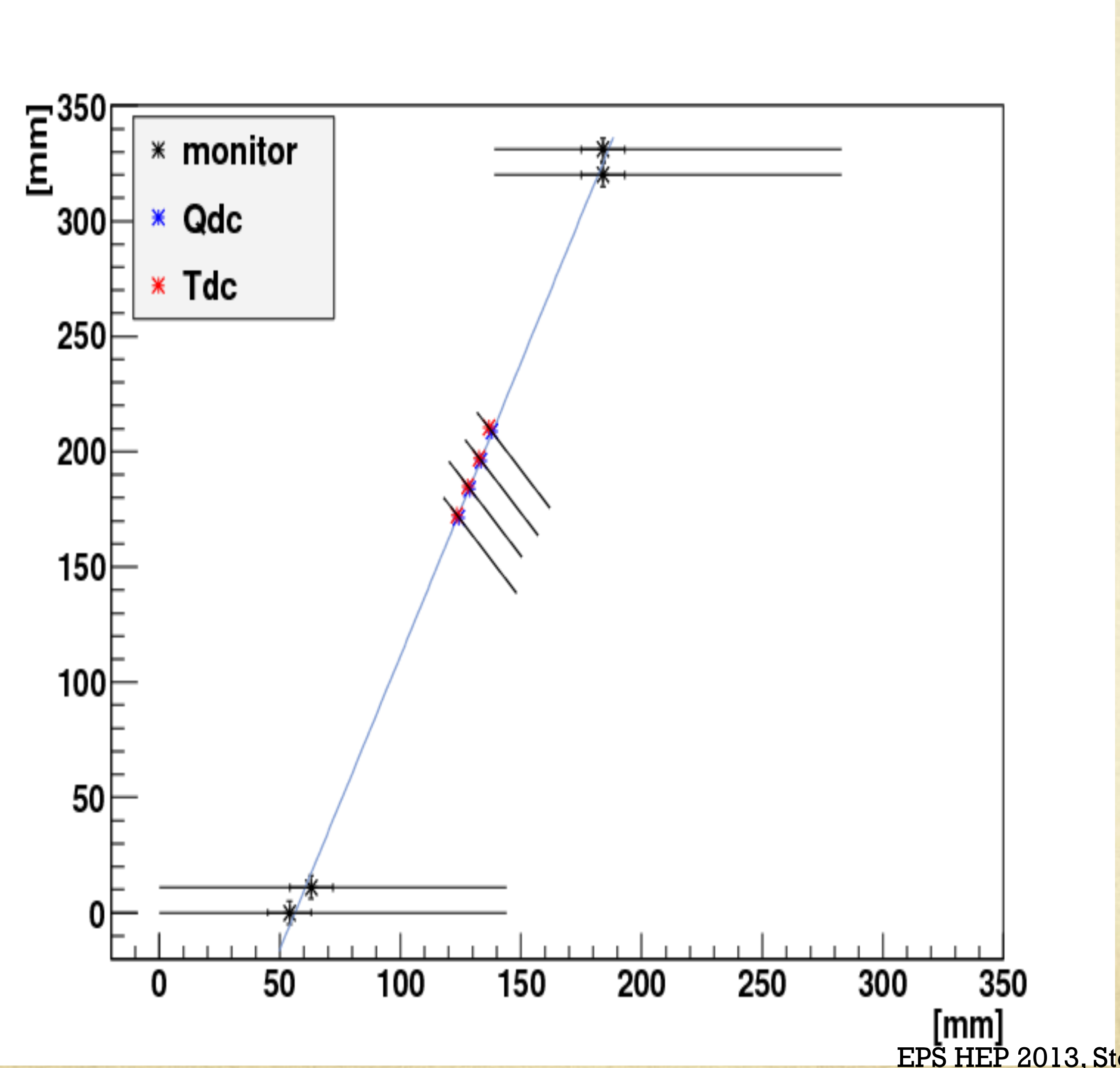
Comparison of simulated earliest cluster arrival time distributions for normal incident muon tracks with and without magnetic fields.

Track fit



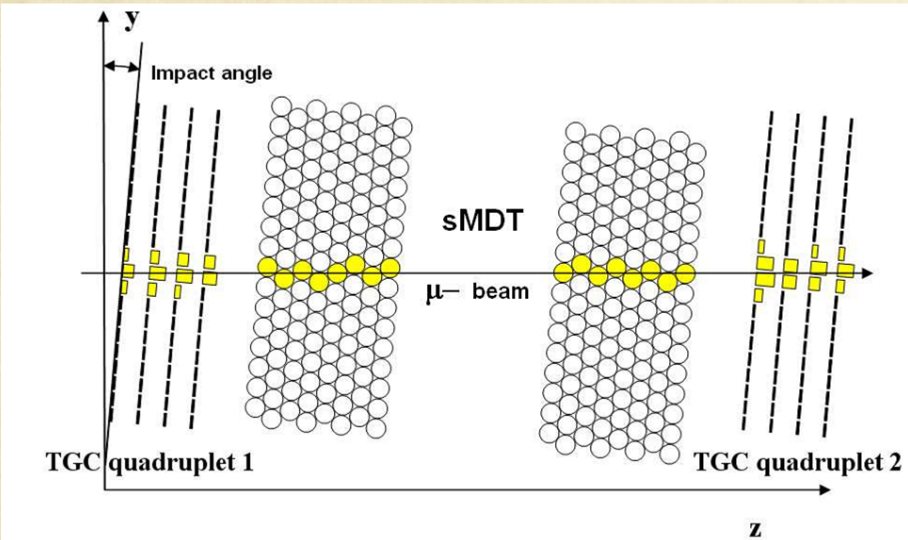
qdchist2111
Entries 16
Mean 11.09
RMS 2.292
χ² / ndf 7.413 / 2
Constant 207.1 ± 12.1
Mean 12.42 ± 0.05
Sigma 1.034 ± 0.044
qdchist219
qdchist2144
qdchist2143

Cosmic muon under irradiation

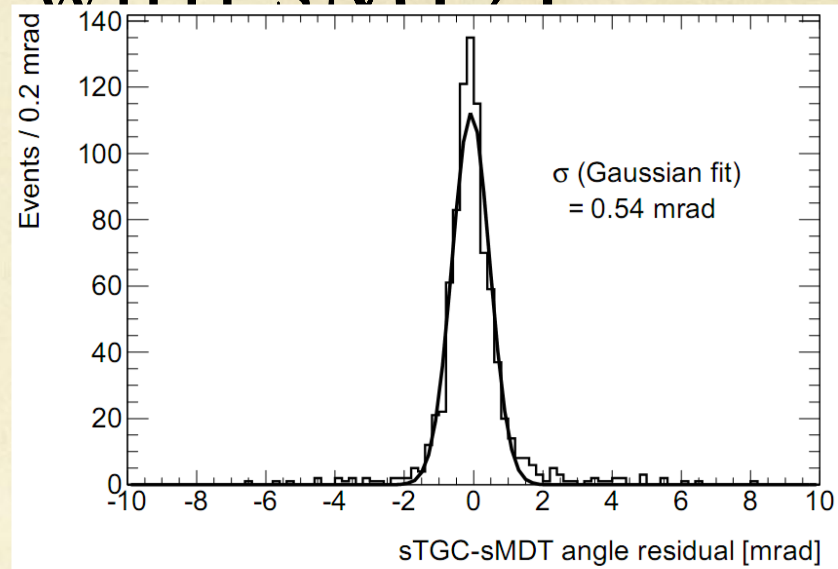


Muons test beam at CERN-combined test with sMDT

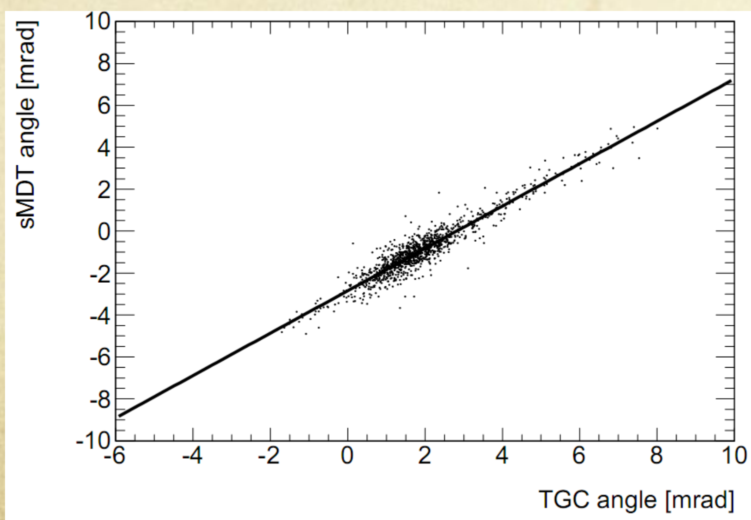
Test setup, typical event



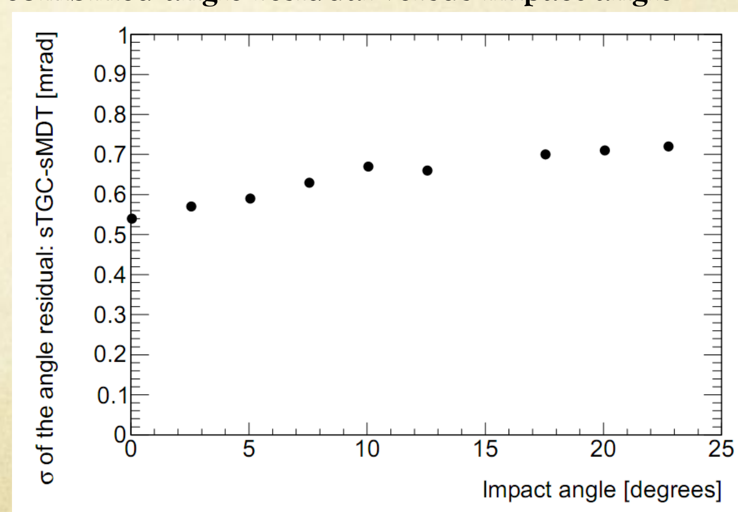
The combined angle residual distribution



The combined angular correlation



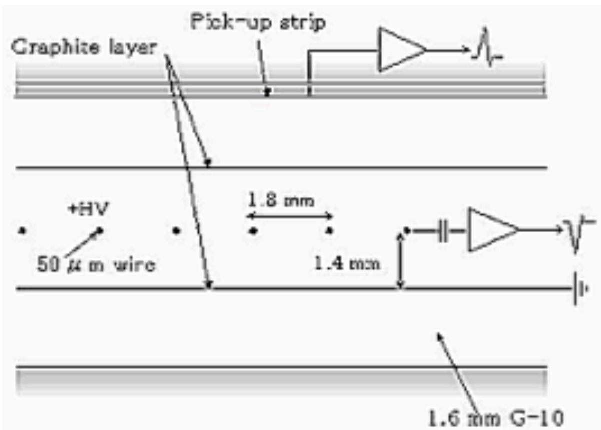
σ of the combined angle residual versus impact angle



University of Roma
"Tor Vergata"

ATLAS

TGC detector



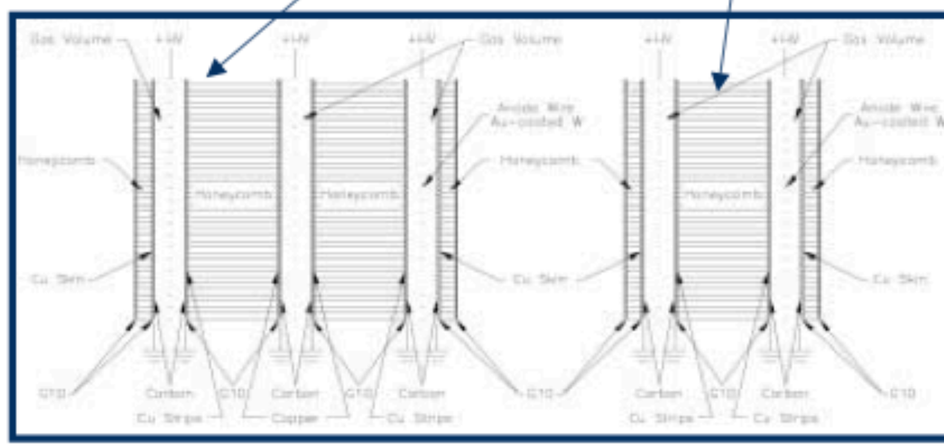
Gas gap : 2.8 mm
Anode wire pitch : 1.8 mm
HV: 3.0 KV
Gas gain: 10^6
Gas mixture : CO_2 / n-C_5H_{12} (55%/45%)

Read-out :

- **wires**
  (read out in group of 4 - 20)
- **strips**
  (pitch : 15mm- 49mm)

Triplet

Doublet



Efficiency : > 99 % for 25 ns gate