Performance of a Large-Area Triple-GEM Detector in a Particle Beam

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on behalf of the GEM Collaboration (GEMs for CMS)

gas electron multiplier (GEM) micro-pattern gas detector (MPGD)

GEM Collaboration (GEMs for CMS)

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Motivation for GEM detectors in CMS

existing CMS forward muon systems:

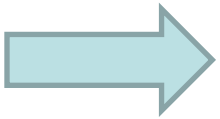
cathode strip chambers, $0.8 < |\eta| < 2.4$

resistive plate chambers, $|\eta| < 1.6$

dual detection systems for high trigger and reconstruction efficiency

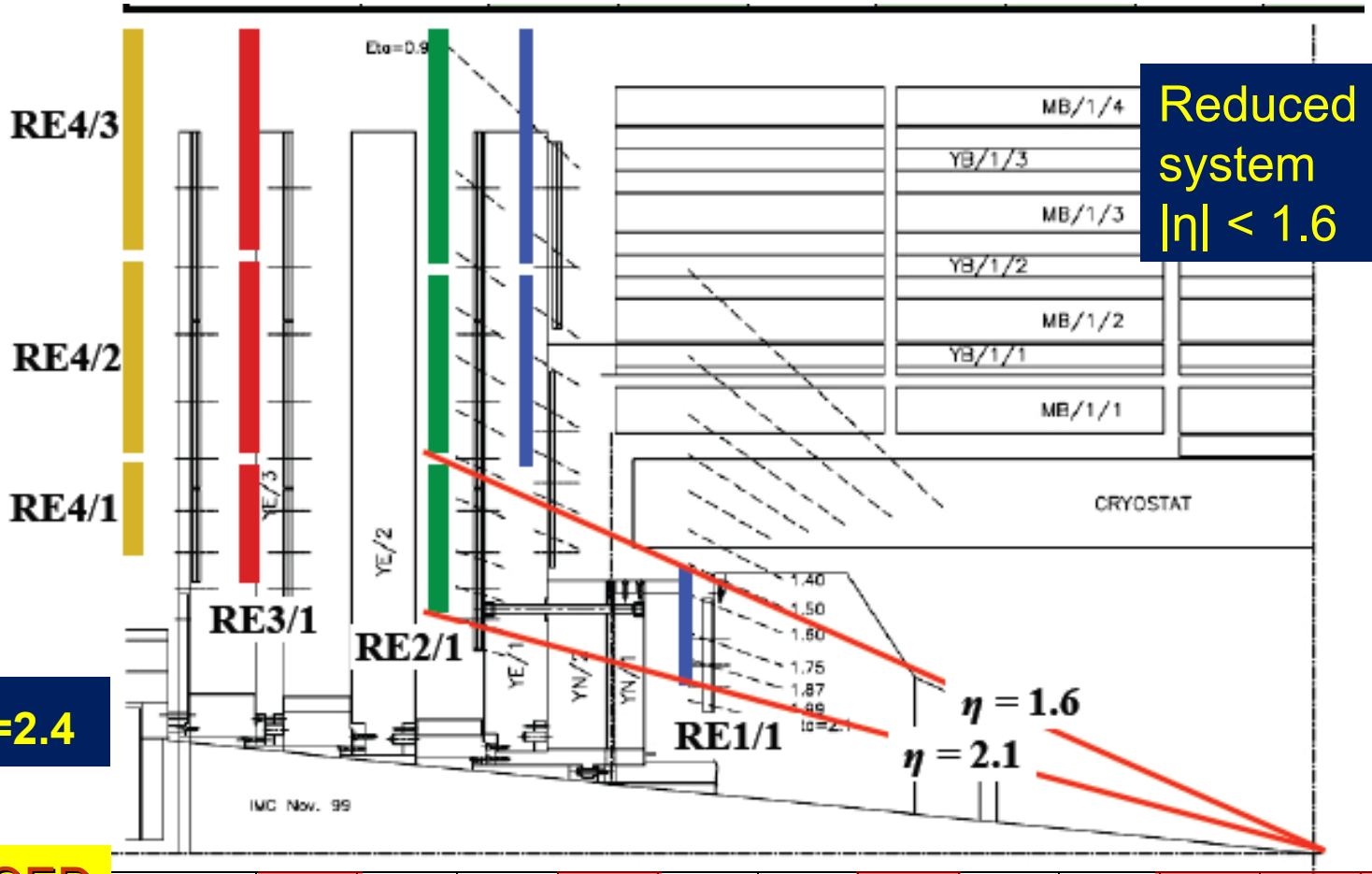
after LHC upgrade (>2016), luminosity ~ 10^{34} cm^{-2} sec^{-1}

increased track density due to large # of interactions per bunch crossing



complete and preserve dual system concept

RPC Endcap Muon System



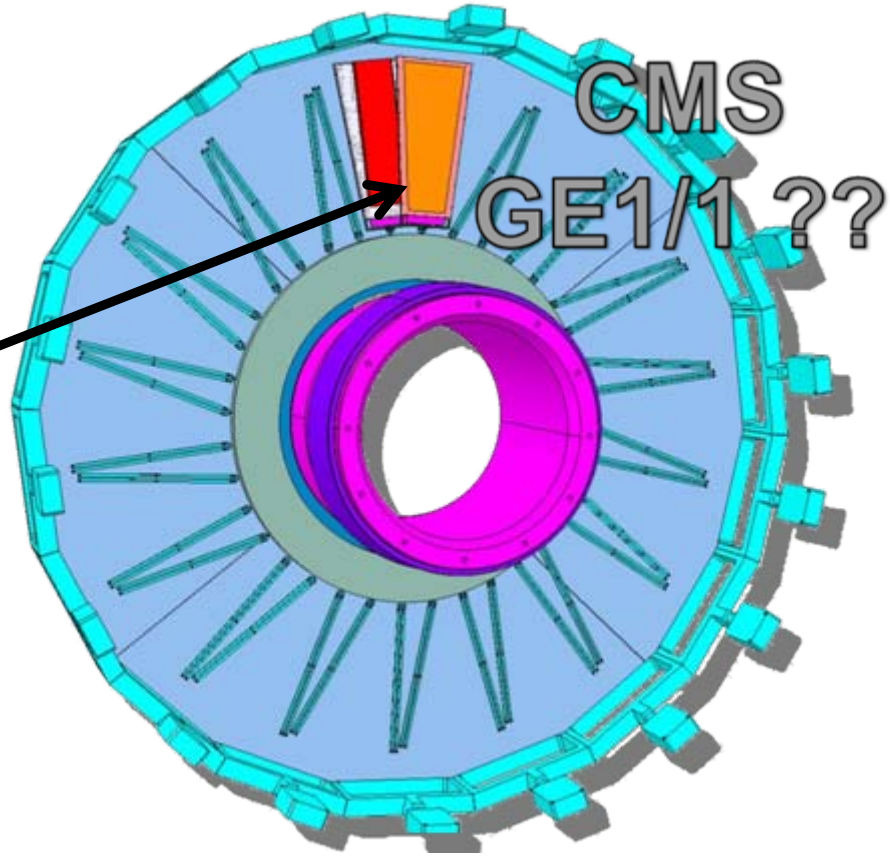
Reduced RE system
|η| < 1.6

η =2.4

STAGED

	RE 1/1	RE 1/2	RE 1/3	RE 2/1	RE 2/2	RE 2/3	RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2	RE 4/3
No. of chambers	36*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*

View of First Endcap Station



GEM properties and requirements in CMS

time resolution ~4 ns adequate for 25 ns interval between bunch crossings

$\mathscr{L}$ in range 10^{34} - 10^{35} $cm^{-2}s^{-1}$ gives high-η charged particle flux 0.5k to 30k $cm^{-2}s^{-1}$

operation with non-flammable Ar/CO_2 gas mixture is highly desirable in the limited-access environment

HV discharges at low rate and are non-destructive allowing long-term (10 year) stable operation

need to verify that large-area chamber will have only small gain loss after accumulated charge of 0.05 to 30 C/cm^2, expected after 10 years, depending on the integrated luminosity

Gain after irradiation of small area prototype*

detector properties:

- triple-GEM
- 10cm×10cm
- 128 strips with 0.8 mm pitch (1-d readout)
- Ar/CO_2 90:10 mixture

X-ray source with Cu target

initial gain ~2300 at 3550 V

<5% gain reduction after 20 C cm^{-2} exposure

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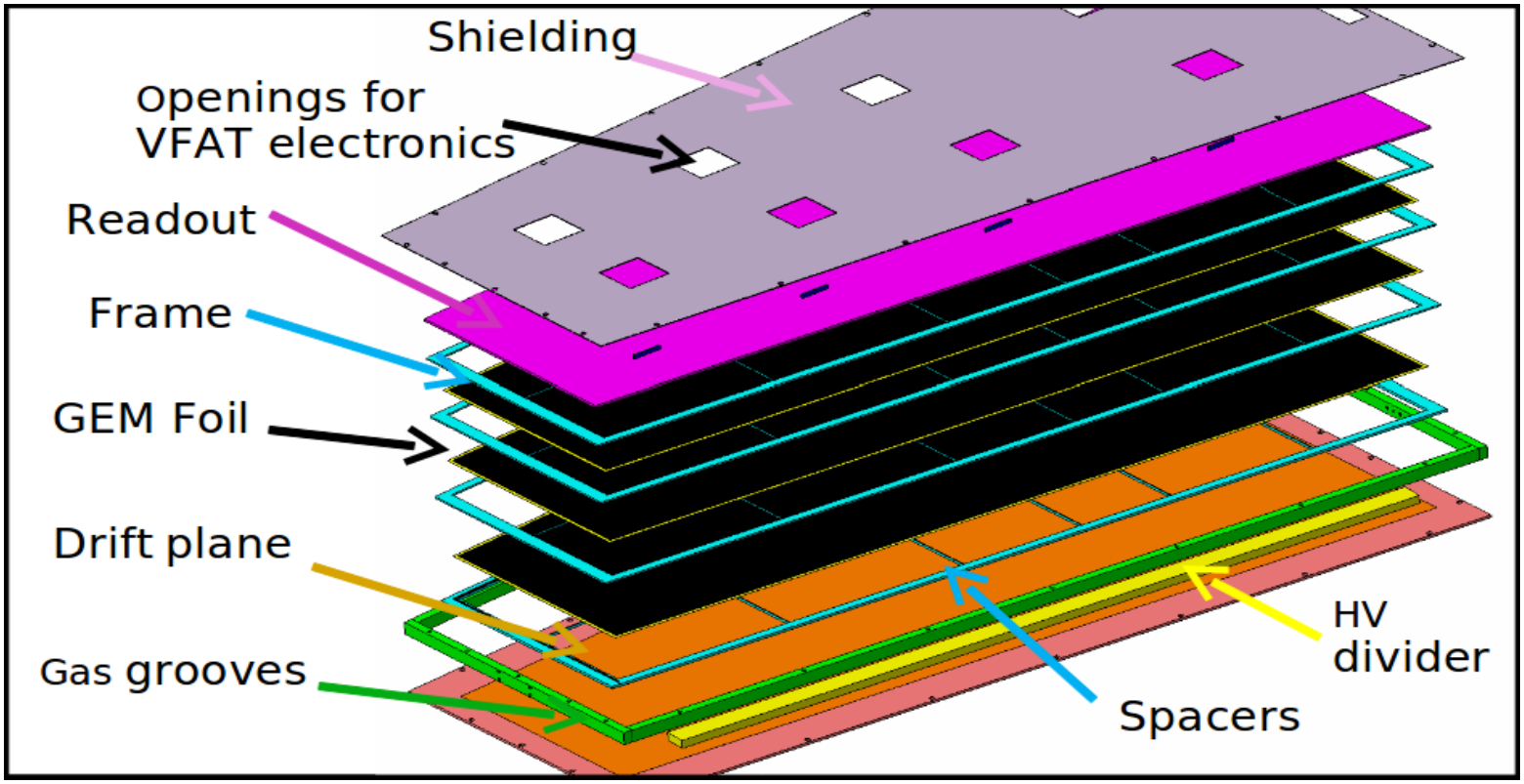
*D. Abbaneo et al., Proc. 2010 IEEE Nuc. Sci. Symp., Knoxville, TN, [arXiv:1012.3675 physics.ins-det]

Large area prototype "GE1/1" construction*

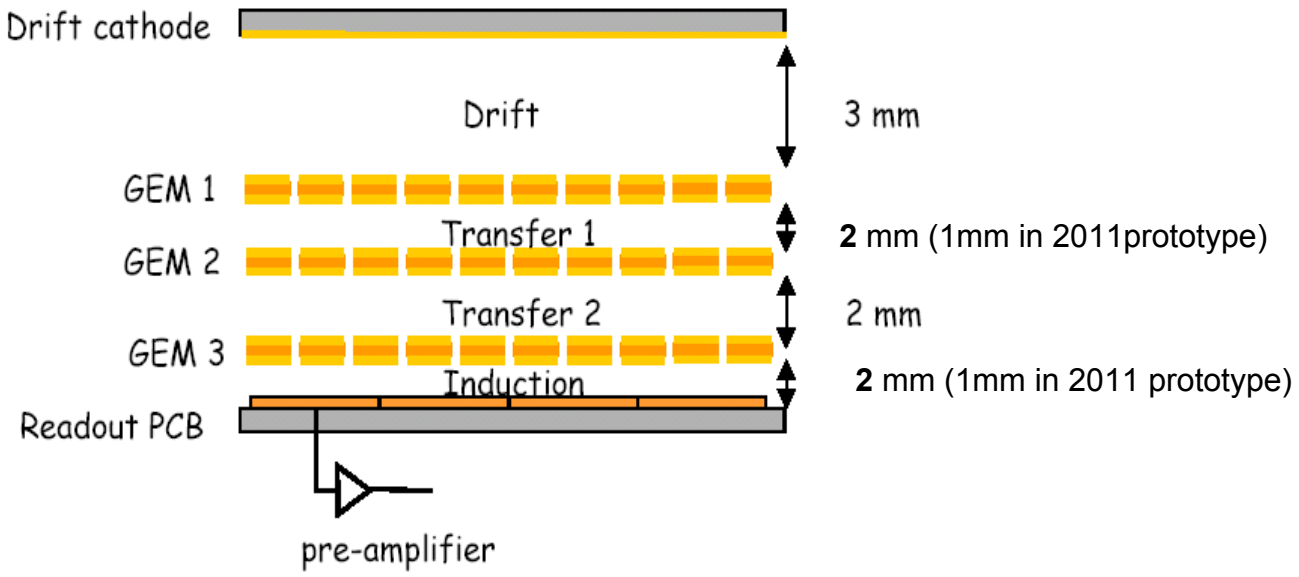


trapezoidal geometry, 990mm × (220 – 455) mm

single mask GEM foils, readout 0.8 – 1.6 mm strip pitch

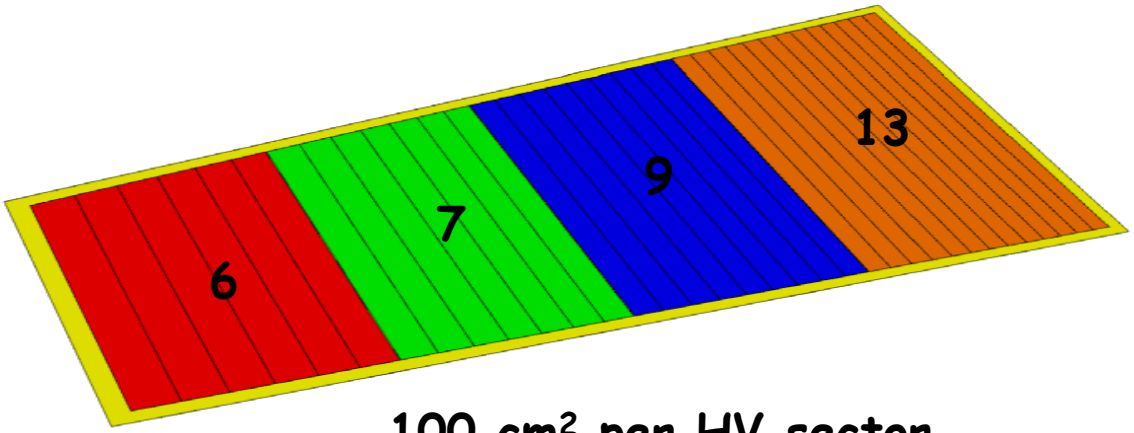
* D. Abbaneo et al., 2010 IEEE Nucl. Sci. Symp. Conf. Rec. 1909-1913; arXiv:1012.1524v2 [physics.ins-det]

Large area prototype "GE1/1" construction*



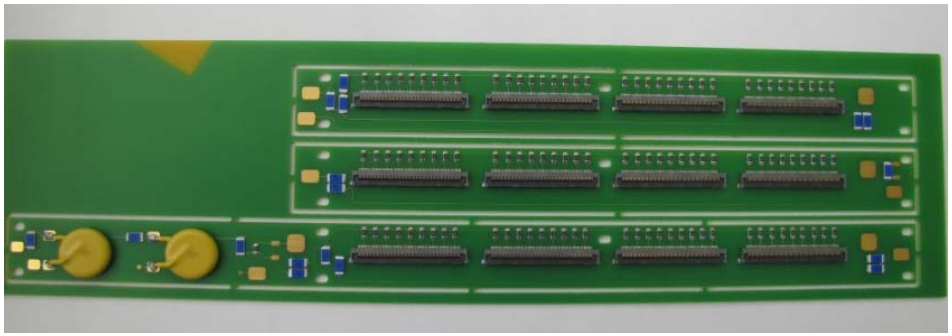
Gas mixture: Ar/CO2 (70/30)
Gas flow: ~ 5 l/h

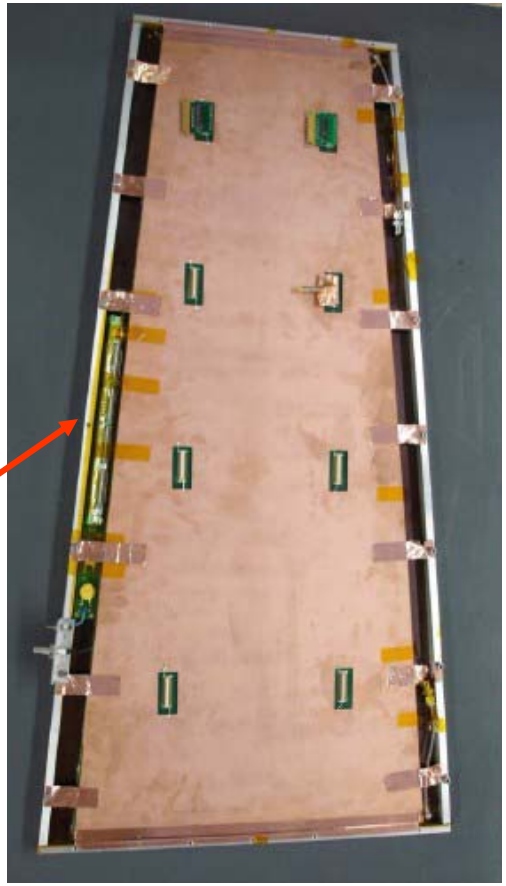
Large area prototype "GE1/1" construction*



100 cm² per HV sector

compact HV divider boards with surface mount components





GE1/1 tested in 150 GeV extracted beam

setup in RD51 area of H4 SPS
150 GeV μ/π test beam, Oct. 2010

4 η sectors with 2 ϕ sections

8 front-end readout boards with 128 channel VFAT chip

multi-conductor cables to common DAQ board

VFAT* front-end electronics

GE1/1 read out by single VFAT chip

VFAT properties:

- CERN-designed ASIC
- front-end readout of silicon and gas detectors
- 128 channels; each channel:
  - two-stage preamplifier
  - comparator with adjustable threshold
  - binary output
- fabrication process: 0.25 micron line-width CMOS
- chip size 9.4 × 7.6 mm^2
- programmable "OR" function over region of inputs for trigger current use with GEM and CSC detectors in TOTEM experiment

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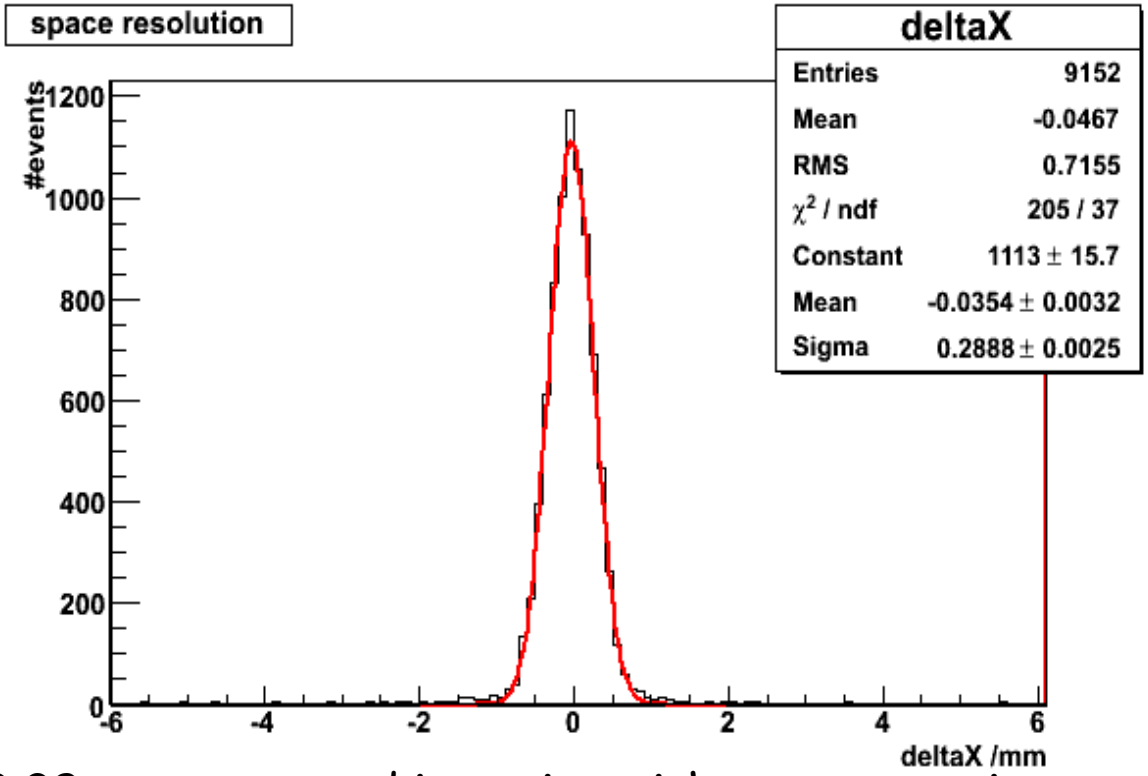
* P. Aspell et al., Proc. "Electronics for particle physics", Naxos 544-548 (2008)

Beam test spatial resolution results

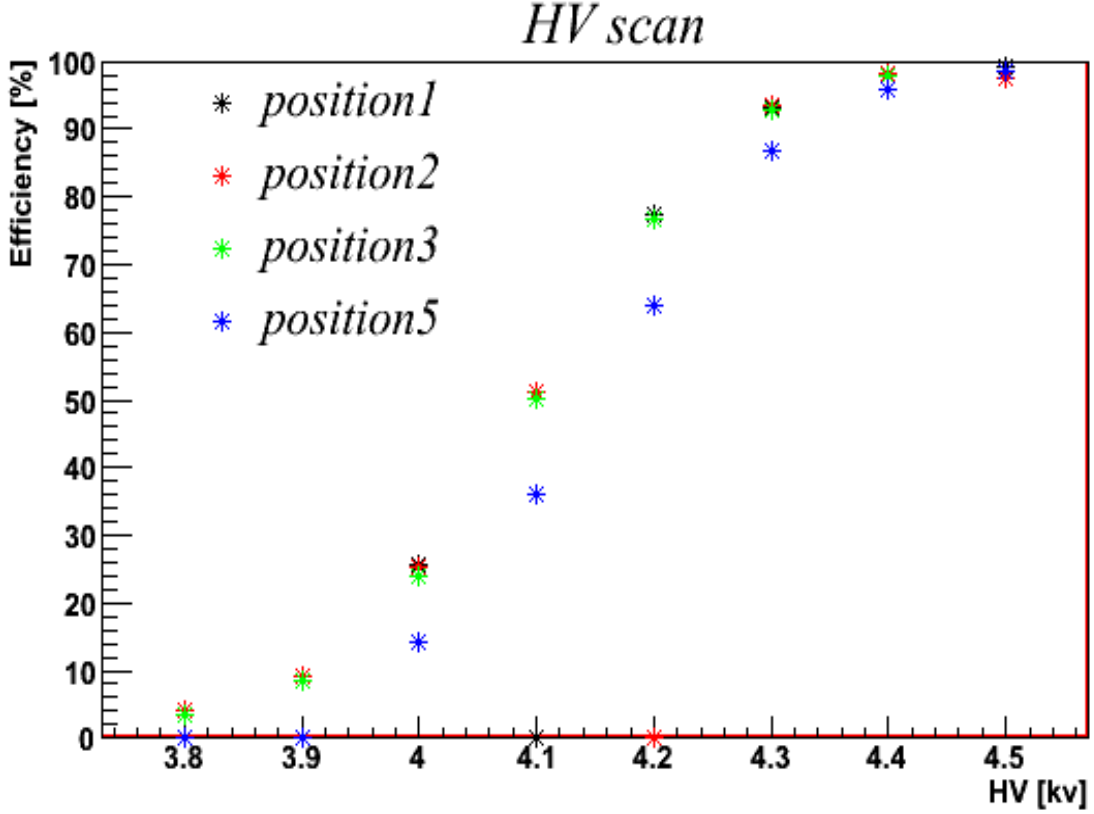
small-area GEMs measure hit position in large-area GEM



spatial resolution of 0.29 mm measured in region with average strip pitch of 1.1 mm

expected resolution of 0.31 mm for single-strip clusters using $1/\sqrt{12}$ of average strip pitch

Beam test efficiency results



efficiency ~98% at full operating voltage

Current activity

new prototype chamber with 3/1/2/1 mm gaps

old and new prototypes set up in H4 beam with 3 T magnetic field

operation in progress

Summary

Triple-GEM detectors are an excellent candidate for a new small-angle ($|\eta| > 1.6$) muon system in an upgraded CMS.

A large area (1m×0.5m) prototype was operated in a secondary test beam at CERN in Oct. 2010.

Spatial resolution of ~300 microns is demonstrated with efficiency ~98%.

Two large area chambers are currently installed in the test beam inside a 3T magnetic field.