Results of beam tests 2011

CMS GEM Upgrade Workshop III
18-20 April 2012

Stefano Colafranceschi

Test beam motivations

- Evaluate performance of small and full-scale GEM based prototypes in muon and pion beams.
  - Comparison between single mask and standard double mask foils
  - Performance in intense magnetic field (3T)
  - Gas Studies (time and space resolution..)
  - Noise studies
  - New readout system (RD51 SRS)

Testing prototypes…

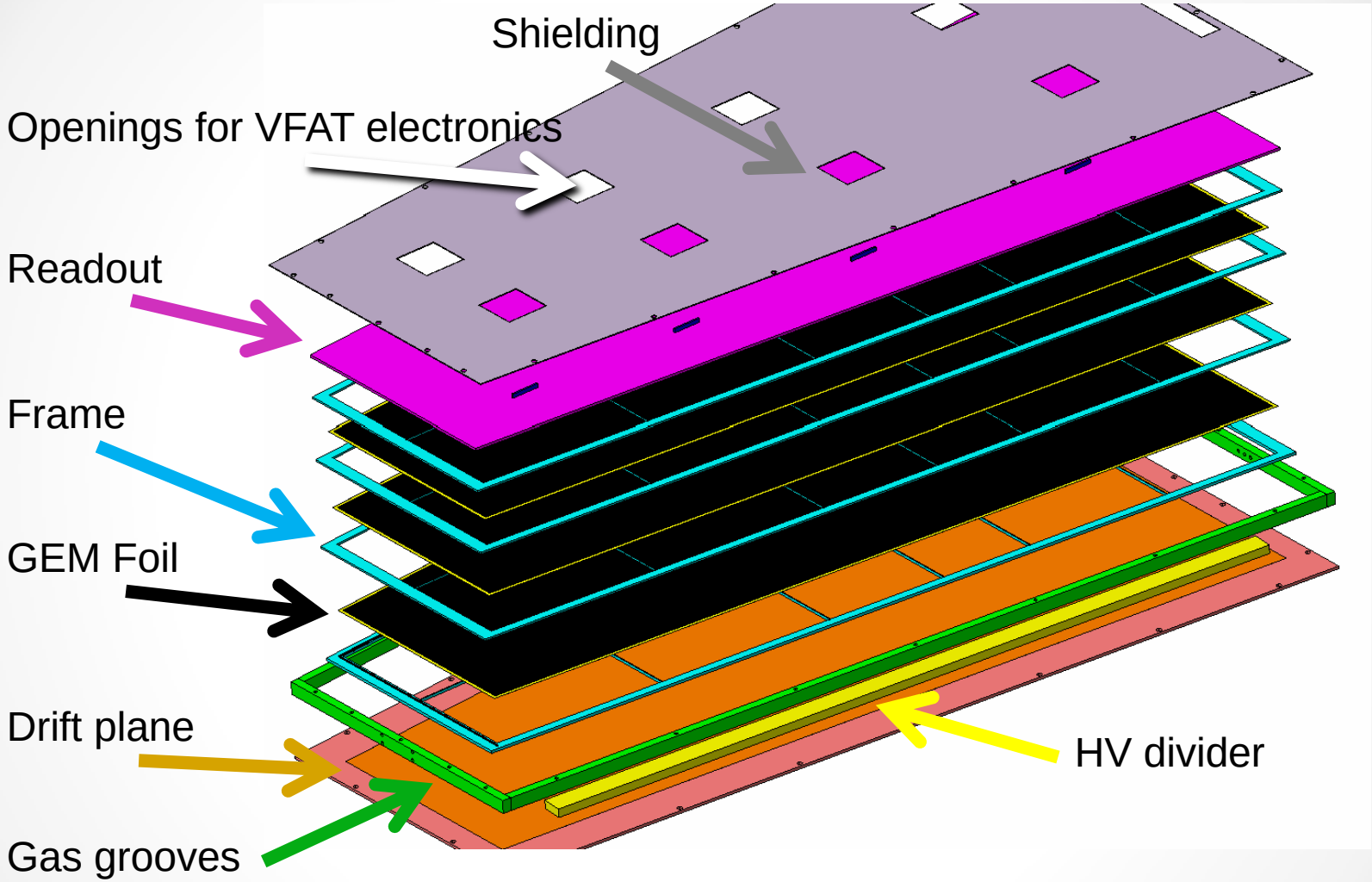
Small-prototypes

- CMS_timing_GEM: Standard double mask 10x10cm^2 1D readout (3/1-2/2/1-2); 256 channels 2010
  - SingleMaskGEM: **Single Mask** 10x10cm^2 2D readout (3/2/2/2) 512 channels 2010
    - CMS_Proto_III **Single Mask** 10x10cm^2 [N2] (3/1/2/1); 256 channels 2011
    - Korean_I Double Mask 7x7cm^2 (3/2/2/2); 256 channels 2011
    - CMS_Proto_IV **Single Mask** 30x30cm^2 [N2] (3/1/2/1); 256 channels 2011

Full-scale prototypes

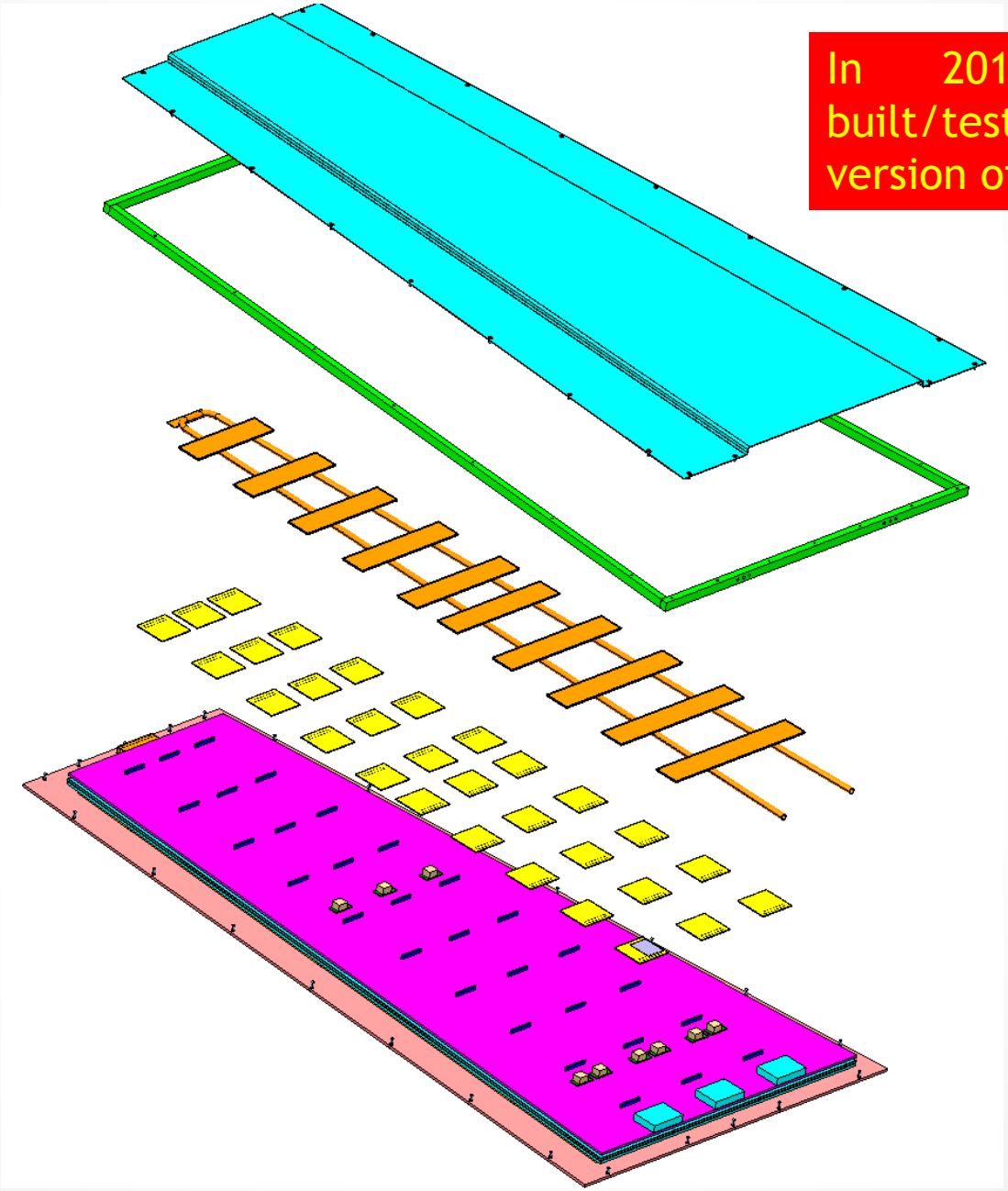
- GE1/1_I: **Single Mask** 990 x (440-220)cm^2 1D readout (3/2/2/2); 1024 channels 2010
- GE1/1_II: **Single Mask** 990 x (440-220)cm^2 1D readout (3/1/2/1); 3072 channels 2011
- GE1/1_III: **Single Mask** 990 x (440-220)cm^2 1D readout (3/1/2/1); 3184 channels 2012
- GE1/1_IV: **Single Mask** 990 x (440-220)cm^2 1D readout (3/1/2/1); 3184 channels 2012

Full scale prototype GE1/1_I



The first full-scale prototype was build/tested in 2010

Full scale prototype GE1/1_II

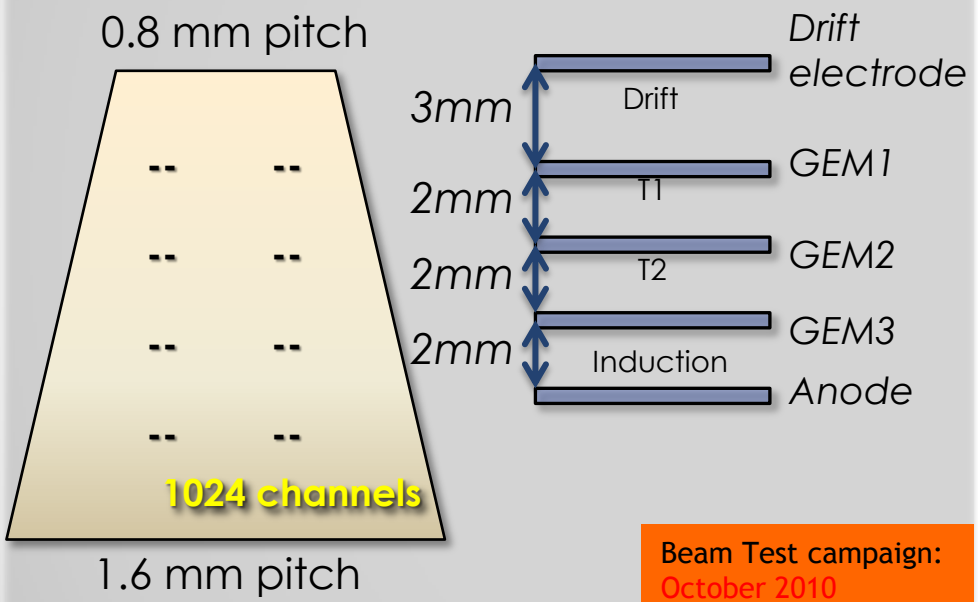


In 2011 we have built/tested the second version of the prototype

Full scale prototypes

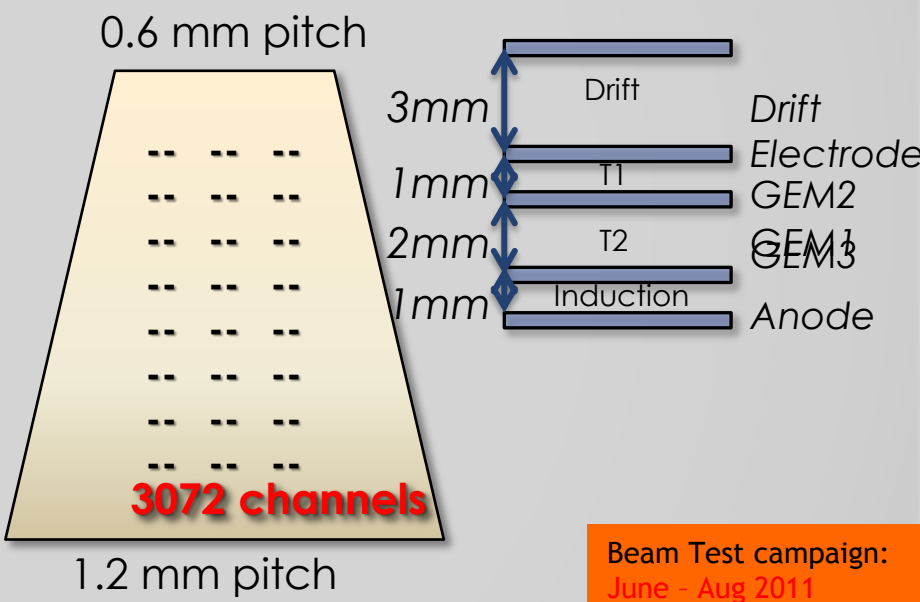
Single mask technique
1D read-out
GEMs active areas: 990 mm x (220-445) mm
Gas mixtures: Ar/CO_2 (70:30, 90:10) or $Ar/CO_2/CF_4$ (45:15:40, 60:20:20)
Gas flow: 5 l/h

Ge1/1_I (2010)



Beam Test campaign:
October 2010

Ge1/1_II (2011)



Beam Test campaign:
June - Aug 2011

GE1/1_II vs GE1/1_I

- Increased number of channels (from 1024 to 3072)
- Reduced strip pitch
- Reduced T1 and induction gap -> new HV divider!

2011 test beam campaign summary

- June – July 2011

CMS_timing_GEM, GE1/1_I, GE1/1_II

- Efficiency, time resolution and space resolution with and without magnetic field

- August 2011

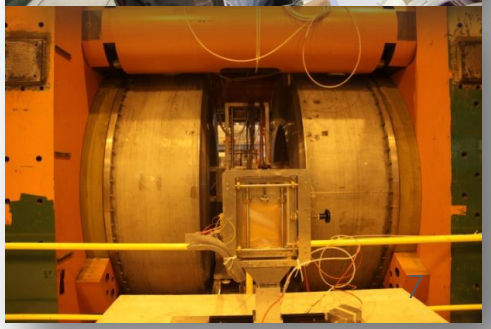
CMS_timing_GEM, GE1/1_II

- Testing new electronics (RD51 SRS, APV25)
- Electronics studies with the VFAT2

- Septemebr 2011

CMS_timing_GEM, GE1/1_II

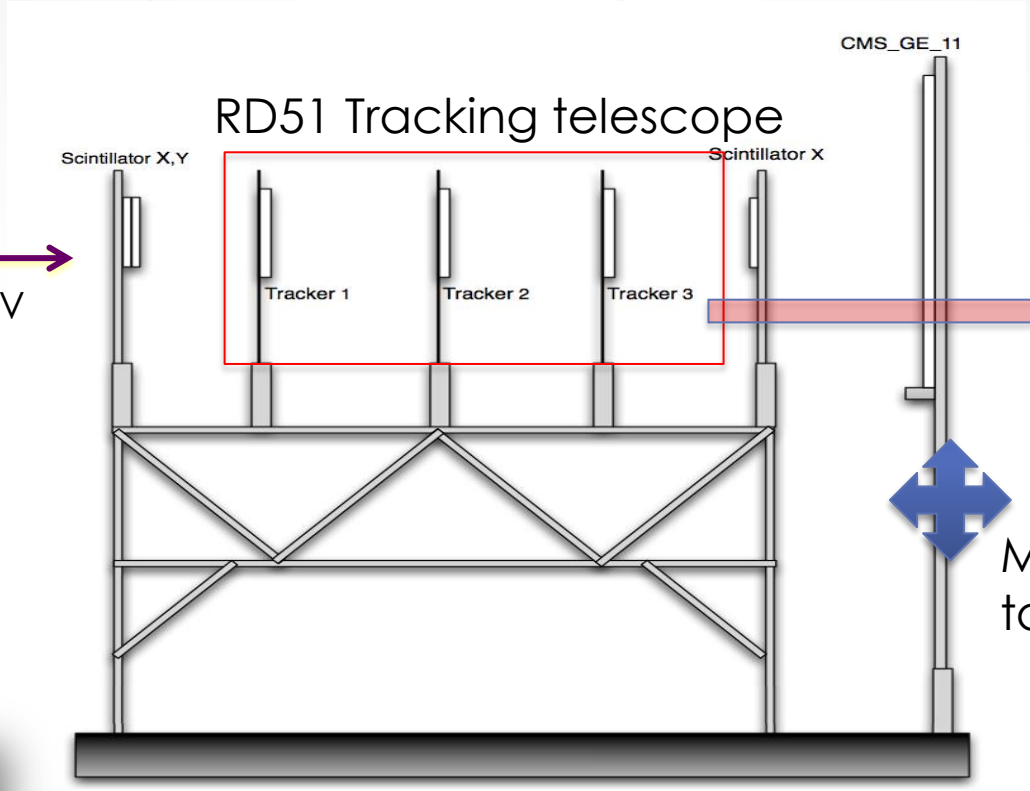
- Time resolution studies
- Gas studies
- Electronics studies with the VFAT2



The experimental setup@H4 (SPS RD51)

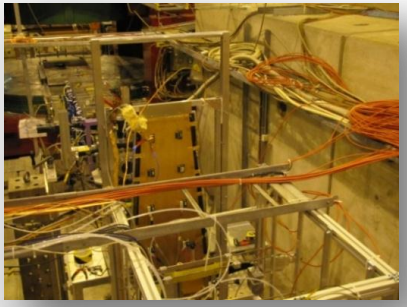
Beam line

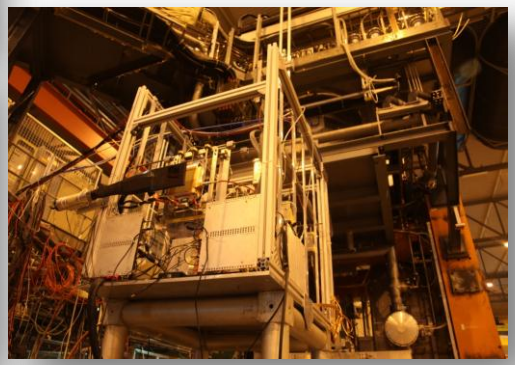
Muon/pion 150GeV

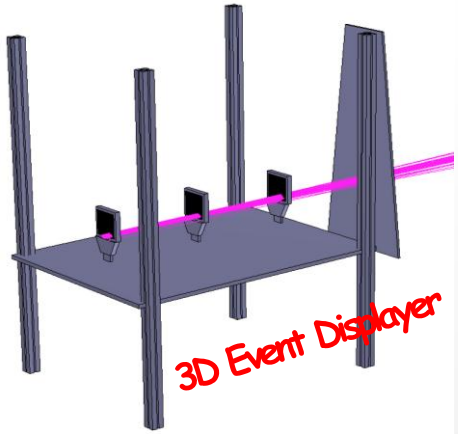


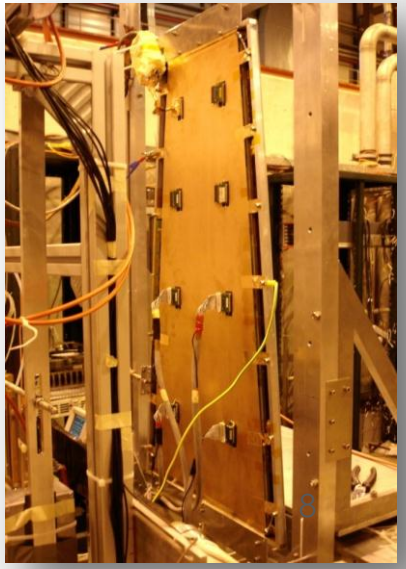
*3 * 10x10cm^2*
standard GEMs
2D readout
256 channel x,y
Strip pitch
0.4mm

Movable table

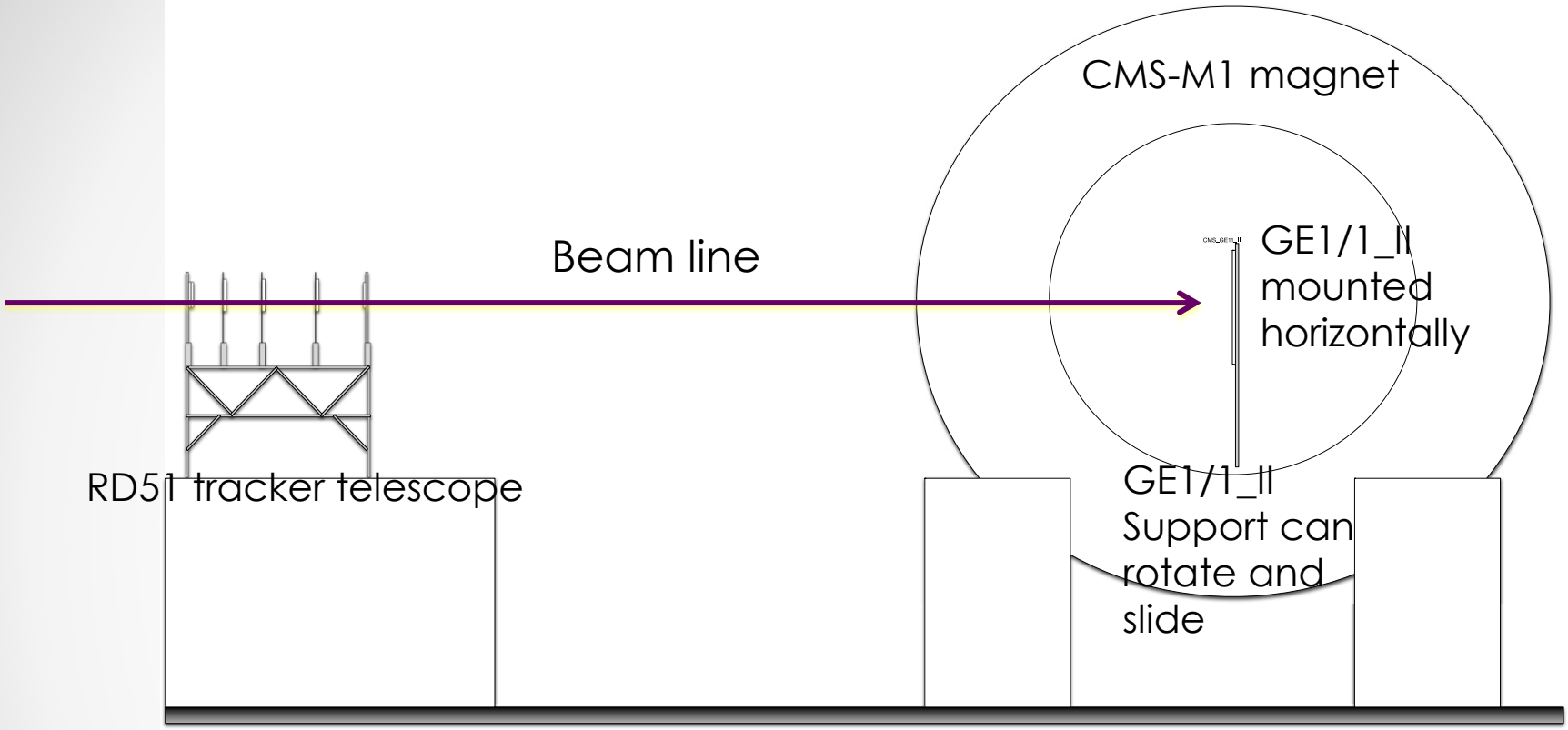








The experimental setup@H2 (CMS-M1)



Full scale prototypes and timing GEM were positioned in Y-Z plane inside the solenoid.

The tracker (3 10x10cms^2 standard Triple-GEM detectors and 3 scintilators) were located on the z axis – 5 m before the magnet.

Beam direction along the (-) X axis.

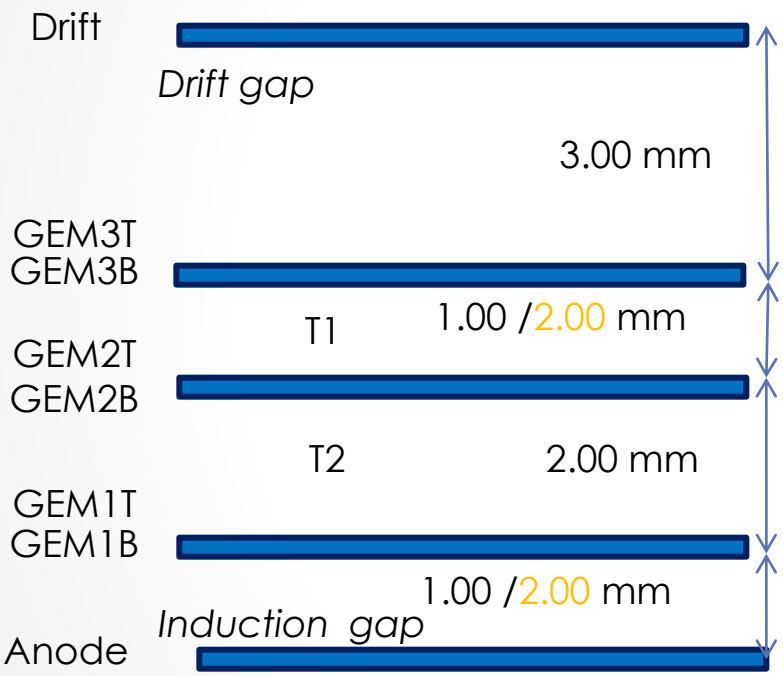
Magnetic field at 800 A = 0.68 T
Magnetic field at 1200 A = 1.0 T
Magnetic field at 2000 A = 1.68 T

Magnetic field higher than 1.68T affects PMTs.

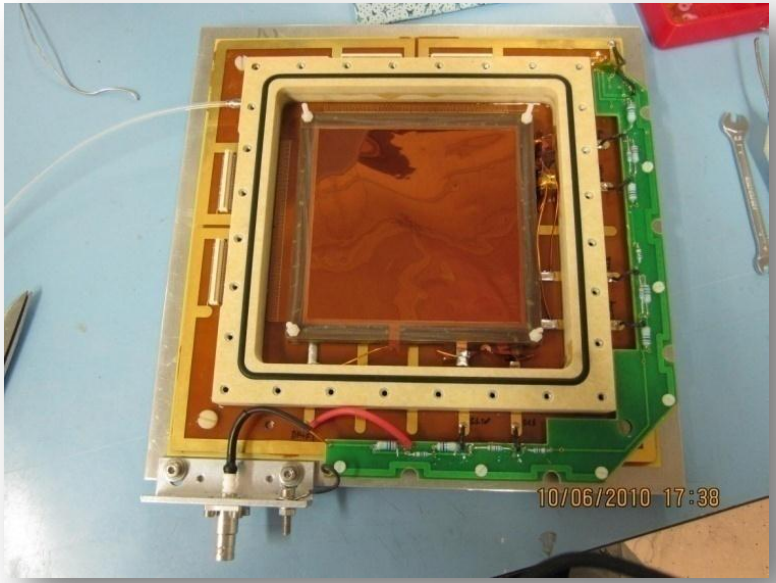
Timing studies@H4 (SPS RD51)

From 2010!

Detector Configuration

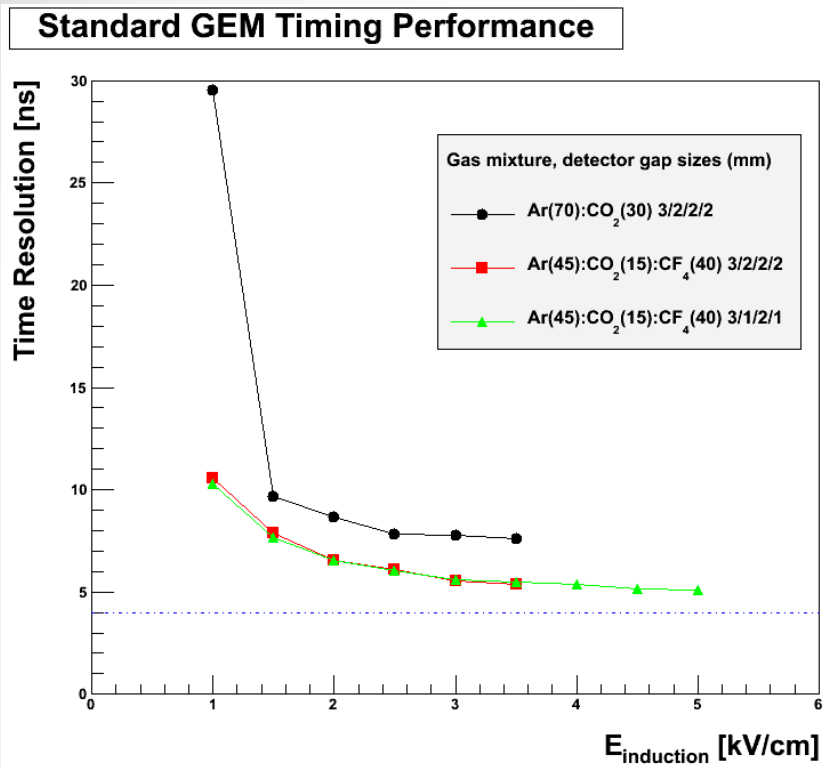


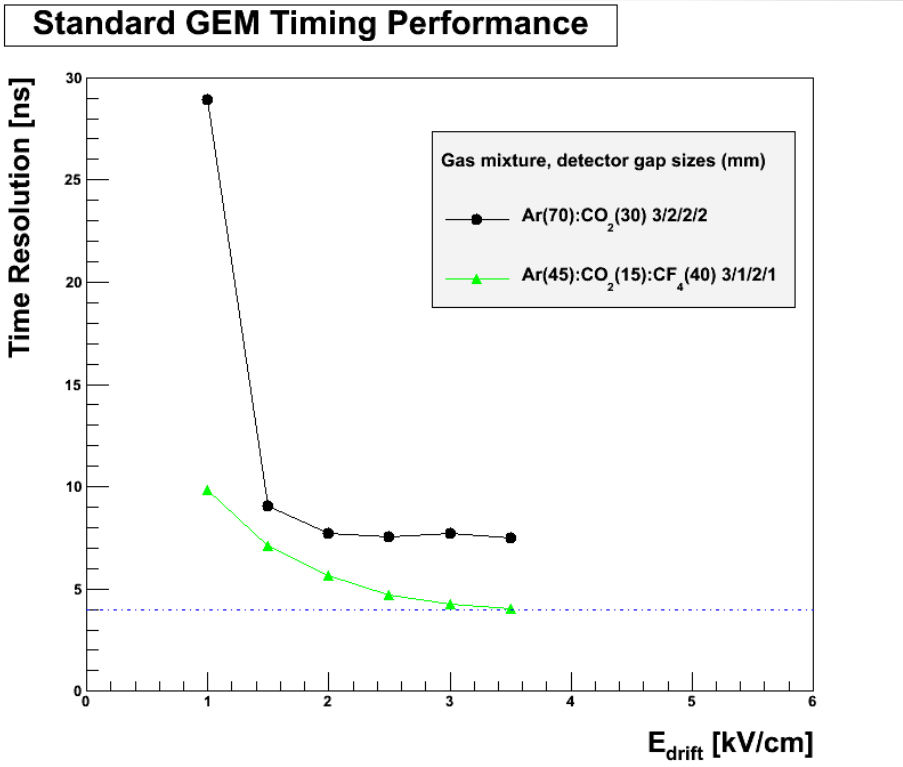
- GEMs active area: 10 x 10 cm^2
- Double mask standard triple GEM
- 1D readout (128 ch on X)
- Strip pitch =0.8mm
- Gas mixture:
- Ar/CO_2 (70/30, 90/10)
- Ar/CO2/CF4 (45/15/40, 60/20/20)
- Gas flow: ~ 5 l/h
- Beam Test (June & August 2010)



Timing studies

From 2010!





Custom made HV divider for Standard Triple-GEM

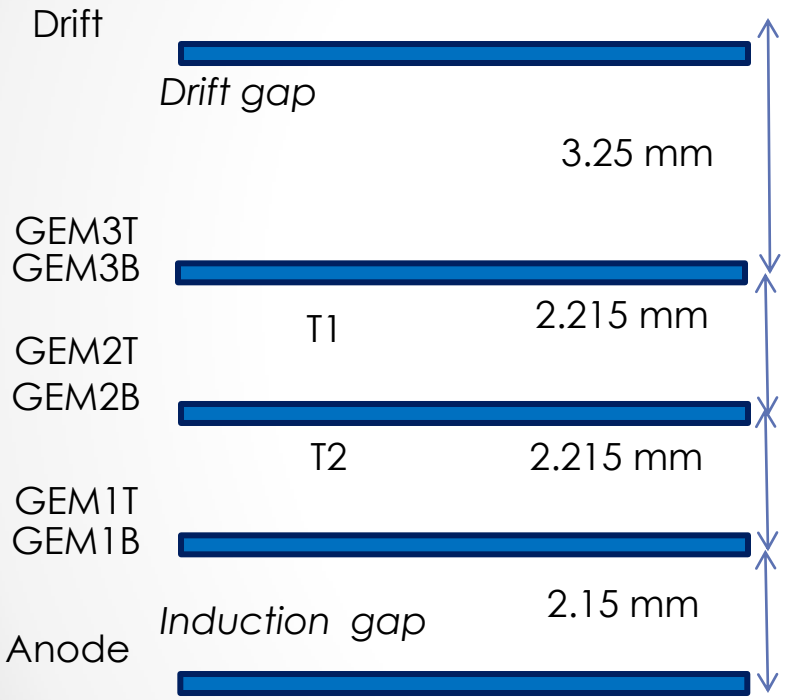
Clear effect of gas mixture, induction and drift field

Timing resolution of ~4ns achieved

Single-mask studies

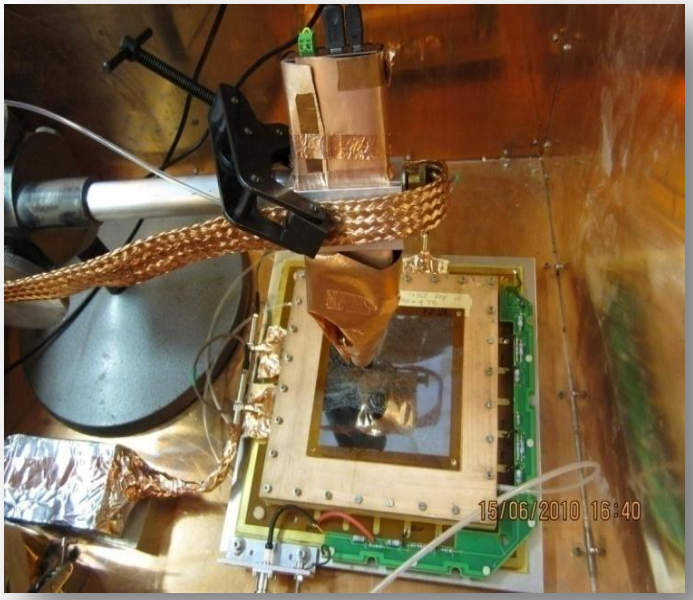
From 2010!

Detector Configuration



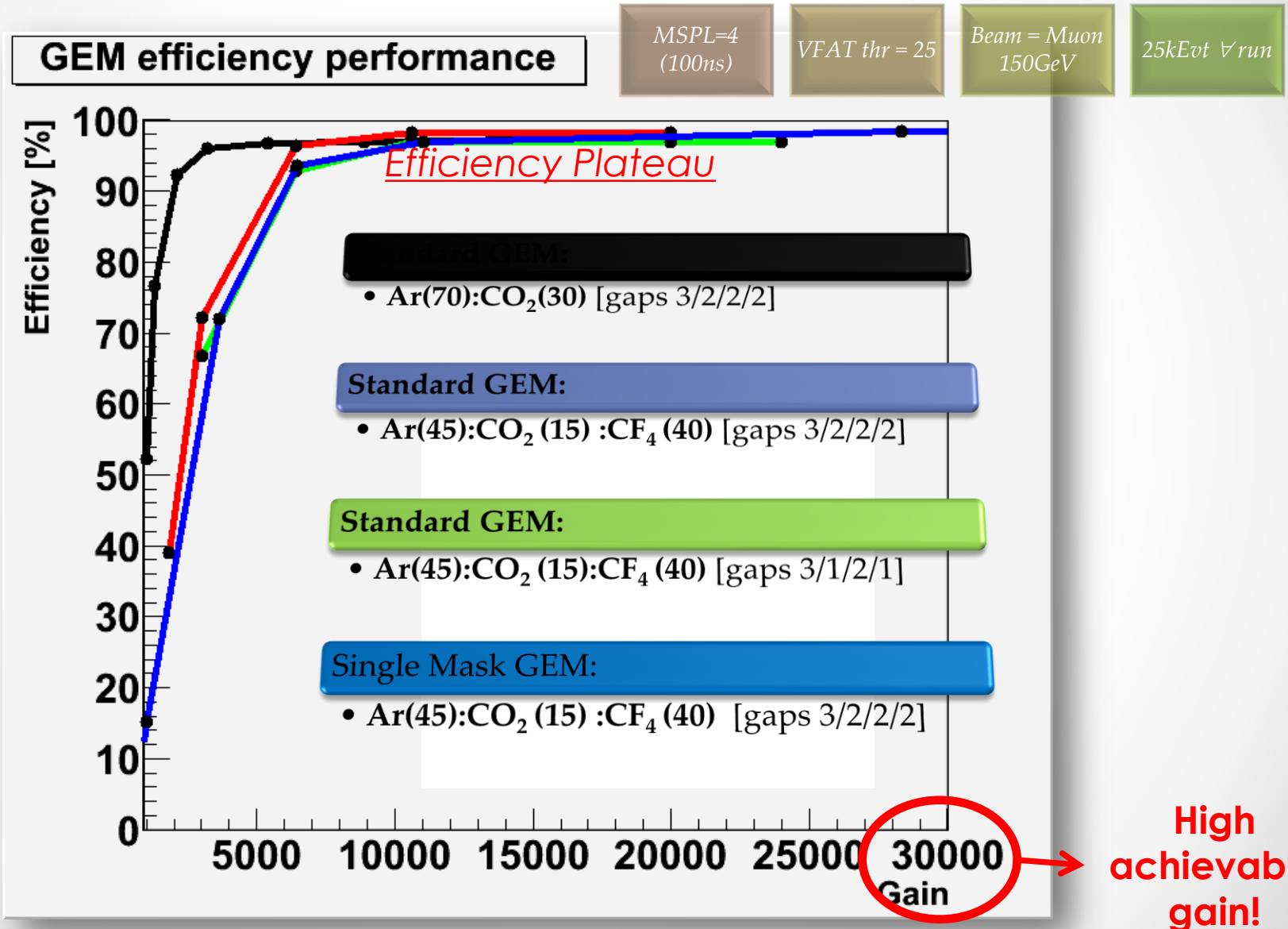
- GEMs active area: 10 x 10 cm^2
- Single mask triple GEM
- 2D readout (256 ch on X, 128 on Y)
- Strip pitch =0.4mm)
- Gas mixture:
- Ar/CO_2 (70/30, 90/10)
- Ar/CO2/CF4 (45/15/40, 60/20/20)
- Gas flow: ~ 5 l/h

Single Mask technology provides 100% alignment of the holes



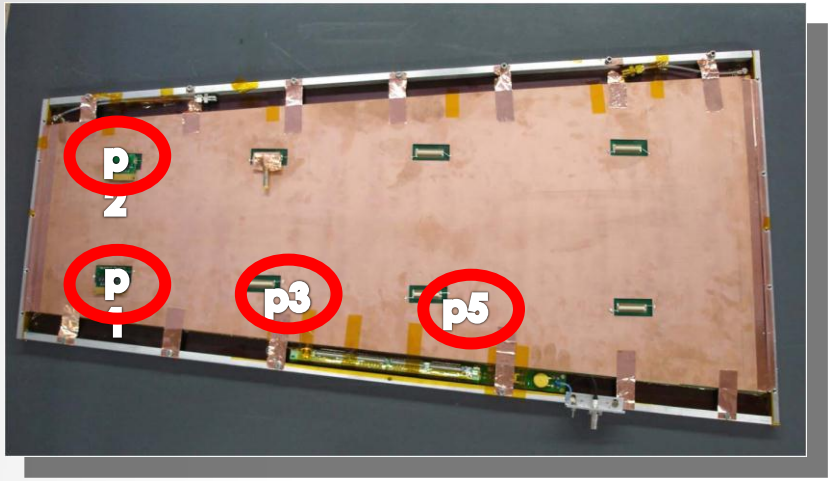
Single-mask studies

From 2010!



GE11_I from October 2010 TB

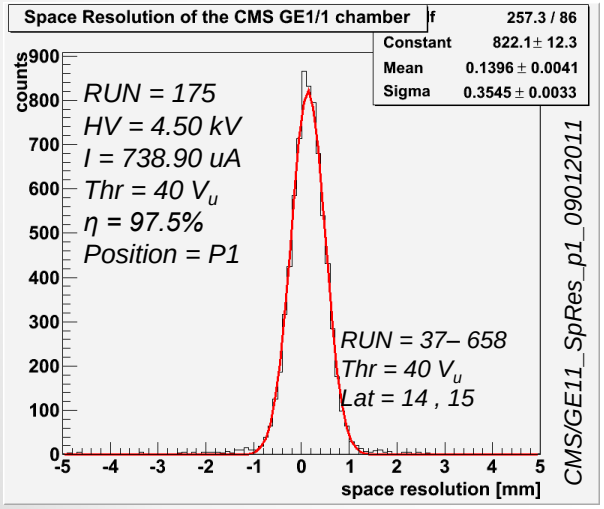
From 2010!

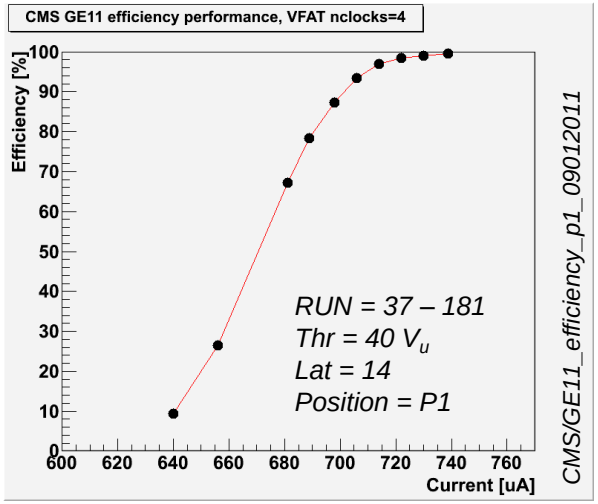


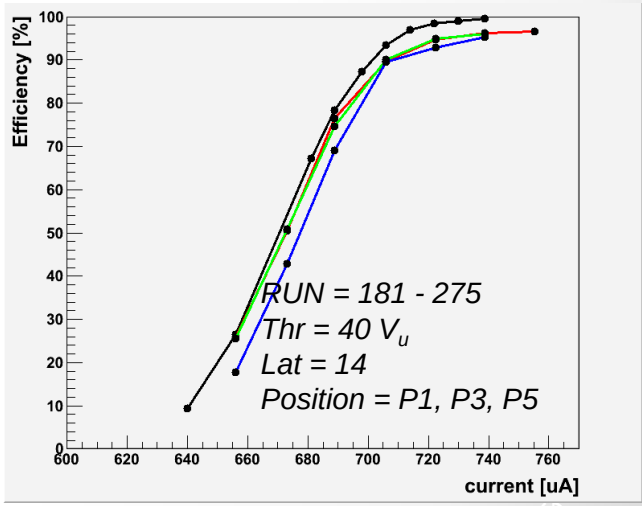
Data-taking focused on different points along the GE1/1.
Preliminary results show good performance.

•*DATA TAKING SUMMARY*

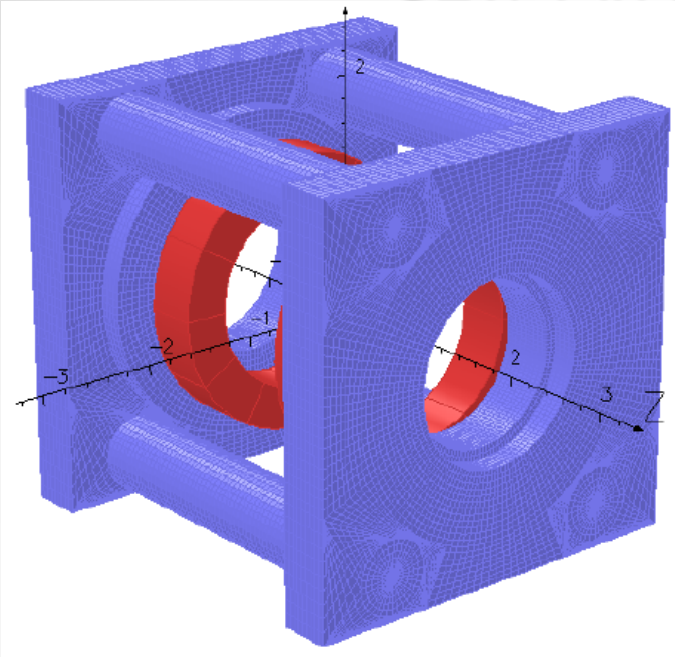
- *650 Runs all over detector surface p1, p2, p3, p5*
- *Gas used: Ar:C02 (70:30)*
- *HV SCAN with thr/latency scan (p1-5) [3.9 to 4.5 kV]*
- *Single mask small prototype HV scan (also thr./lat.)*







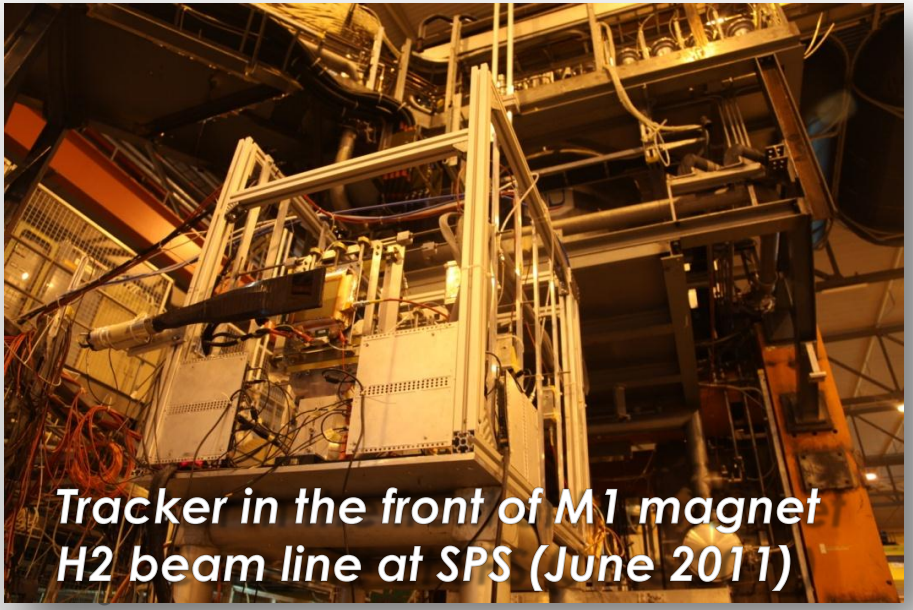
GE1/1 in a strong magnetic field



Full scale prototypes and timing GEM were positioned in Y-Z plane inside the solenoid.

The tracker (3 10x10 single mask triple GEM detectors and 3 scintilators) were located among the X axis – 5 m before the magnet.

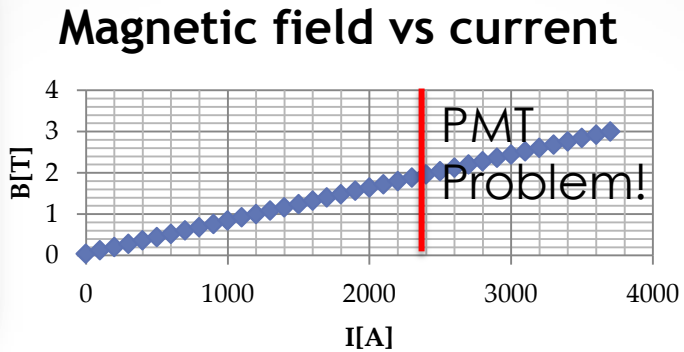
Beam direction along the (-) X axis.

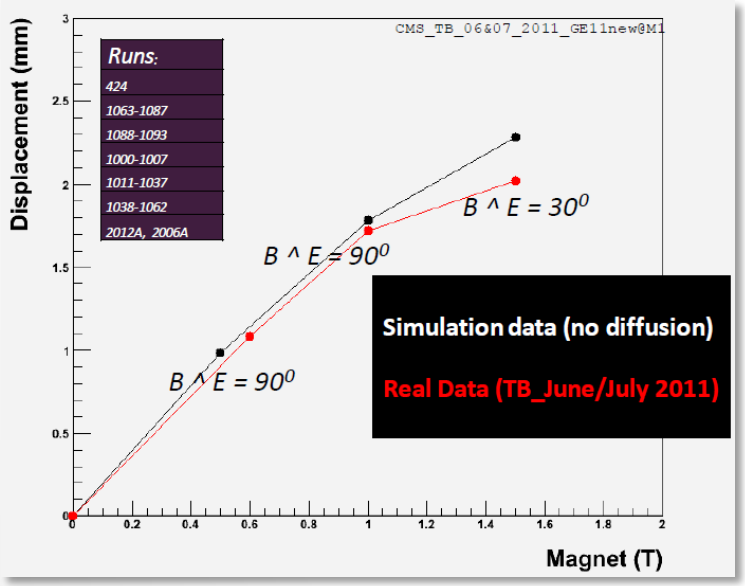


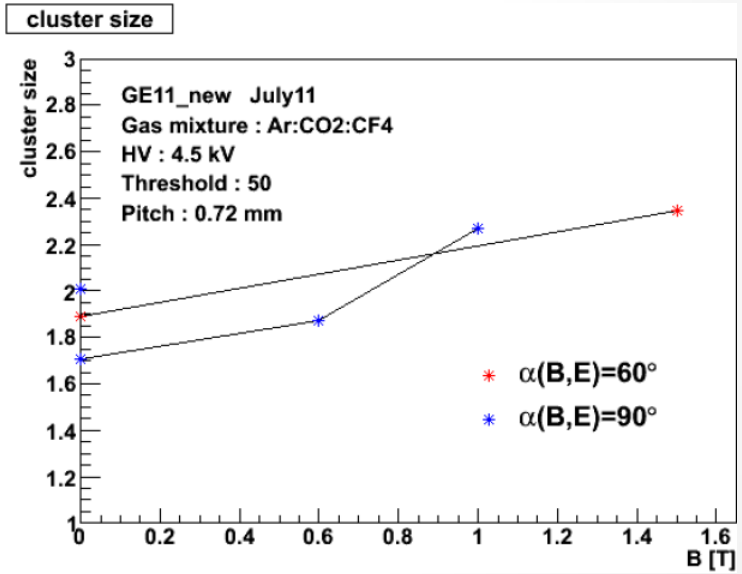
Tracker in the front of M1 magnet H2 beam line at SPS (June 2011)

Prototypes inside the M1 magnet – view from the side H2 beam line at SPS (June 2011)

GE1/1 in a strong magnetic field





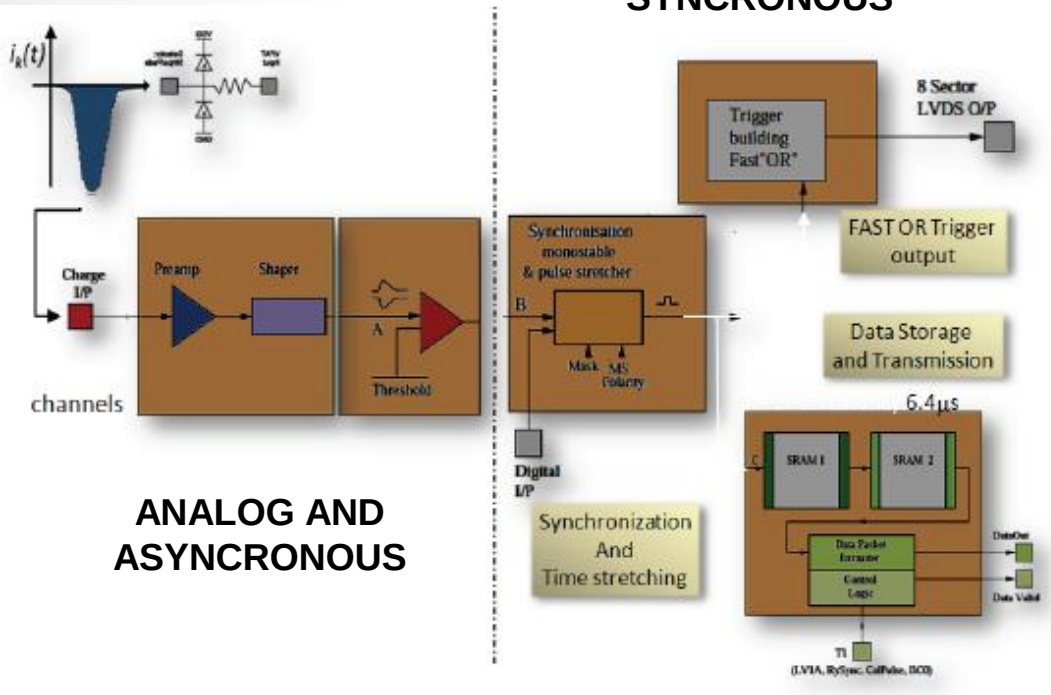


- Displacement due to magnetic field measured at the beam matches with GARFIELD simulations.
- Increasing the magnetic field no clear effect is visible in the cluster size.

TURBO and VFAT2

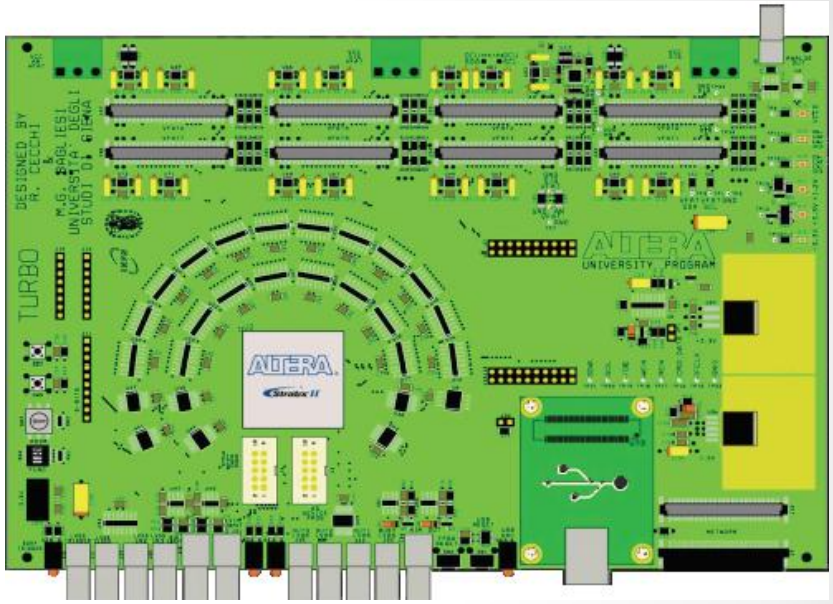
The VFAT(TOTEM) is a digital on/off chip for tracking and triggering with an adjustable threshold for each of the 128 channels; it uses 0.25μm CMOS technology and its trigger function provides programmable "fast OR" information based on the region of the sensor hit.

DIGITAL AND SYNCRONOUS



ANALOG AND ASYNCRONOUS

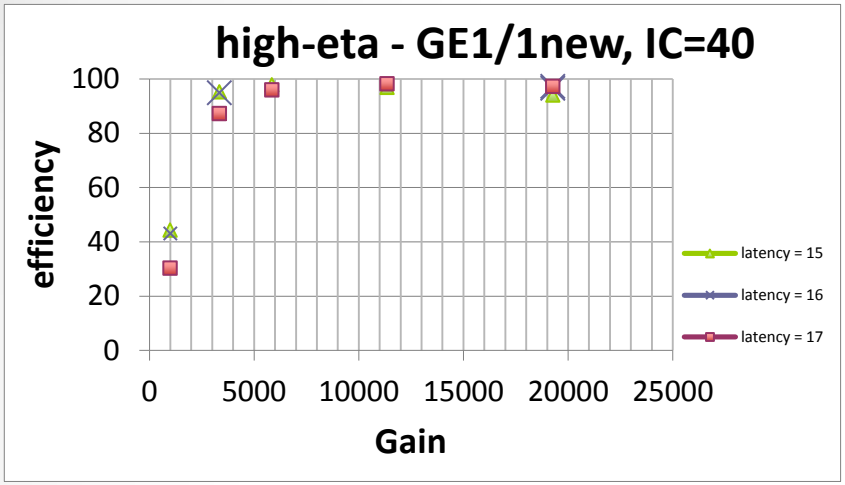
Turbo board layout

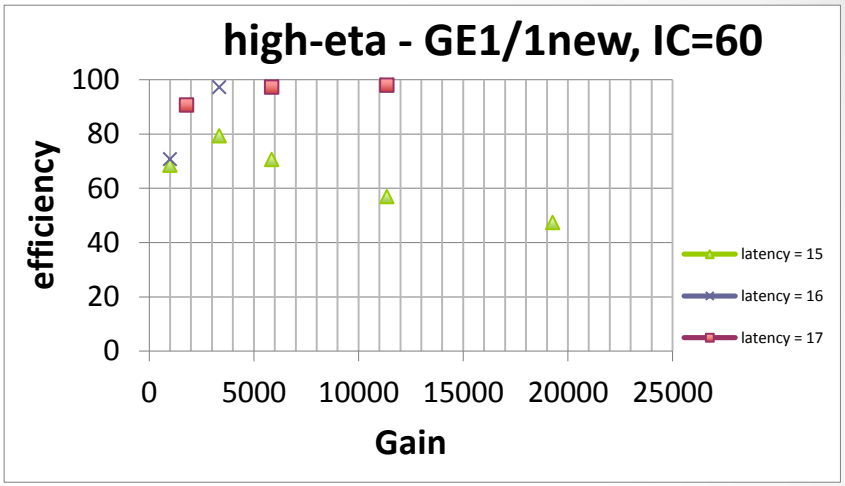


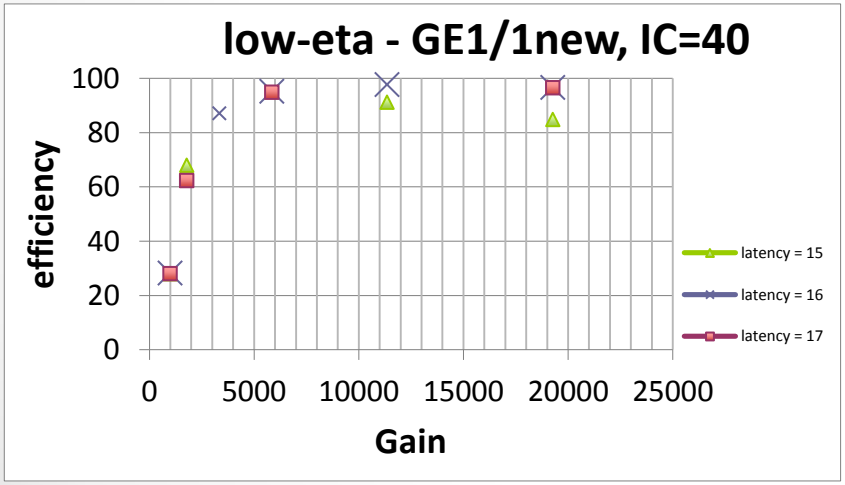
For prototype testing we used electronics developed by INFN (Siena and Pisa), based on the TOTEM VFAT chip.

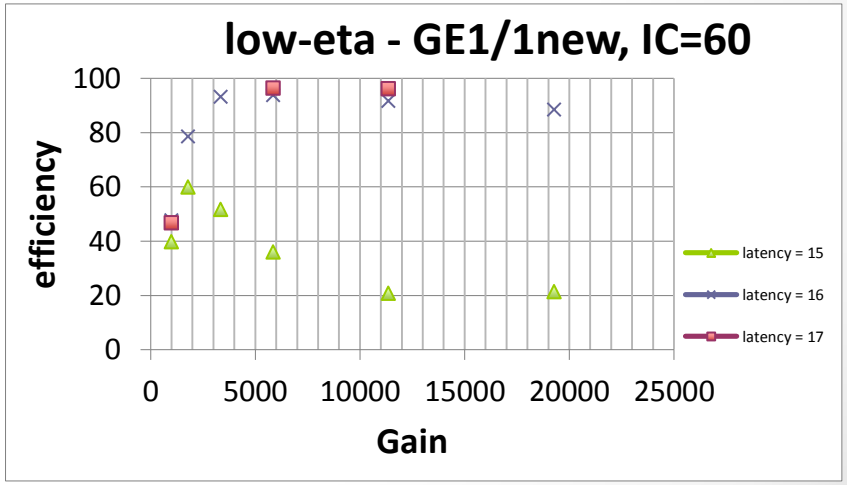
Efficiency studies along with VFAT2 comparator current (IC)

Fully efficiency is reached at gain ~7000 and VFAT2 threshold=12 for $Ar/CO_2/CF_4$ 45/15/40.

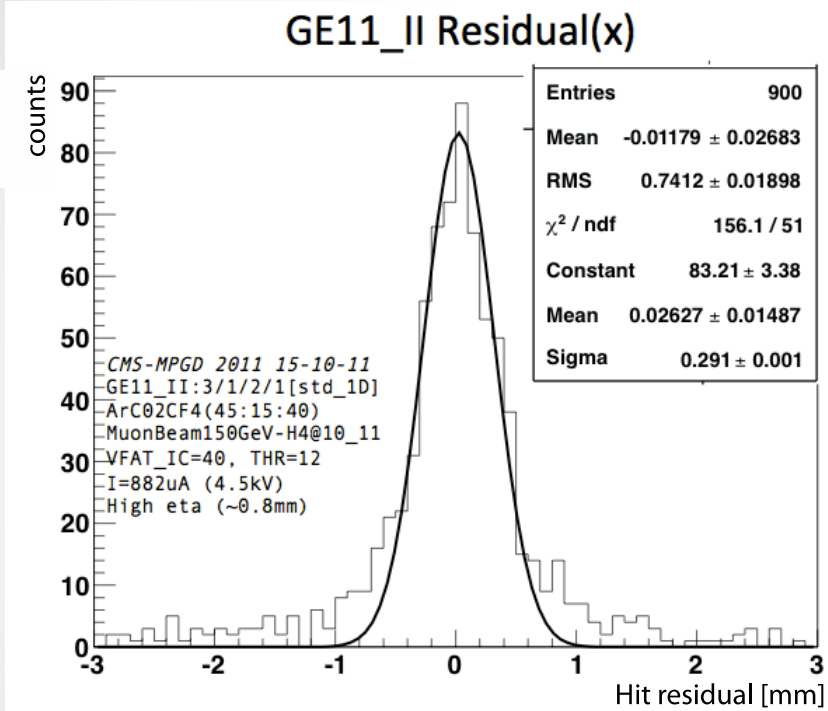


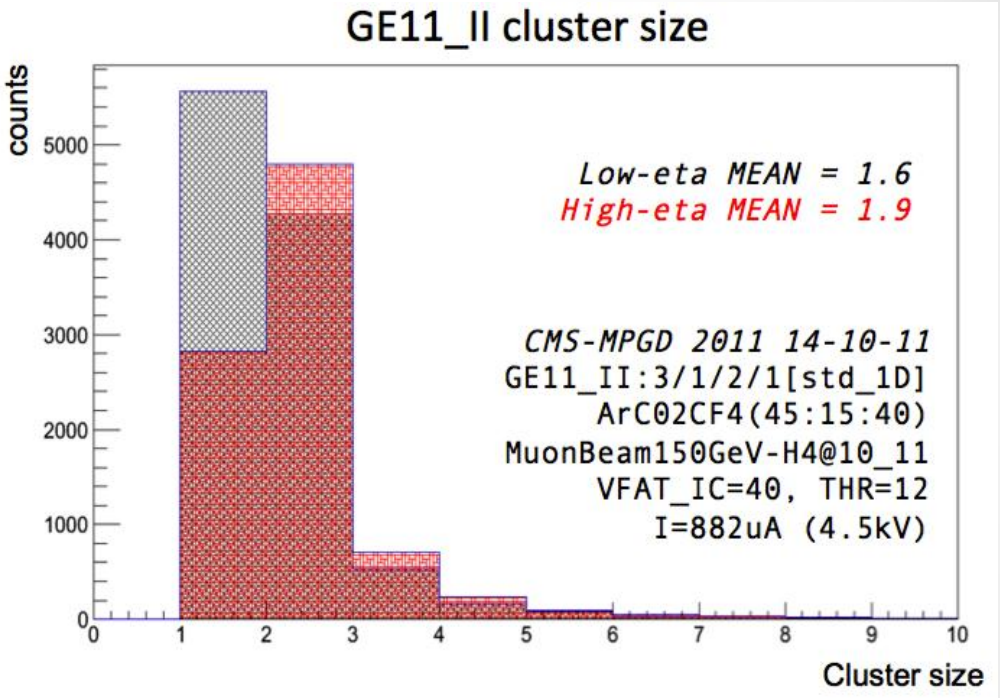






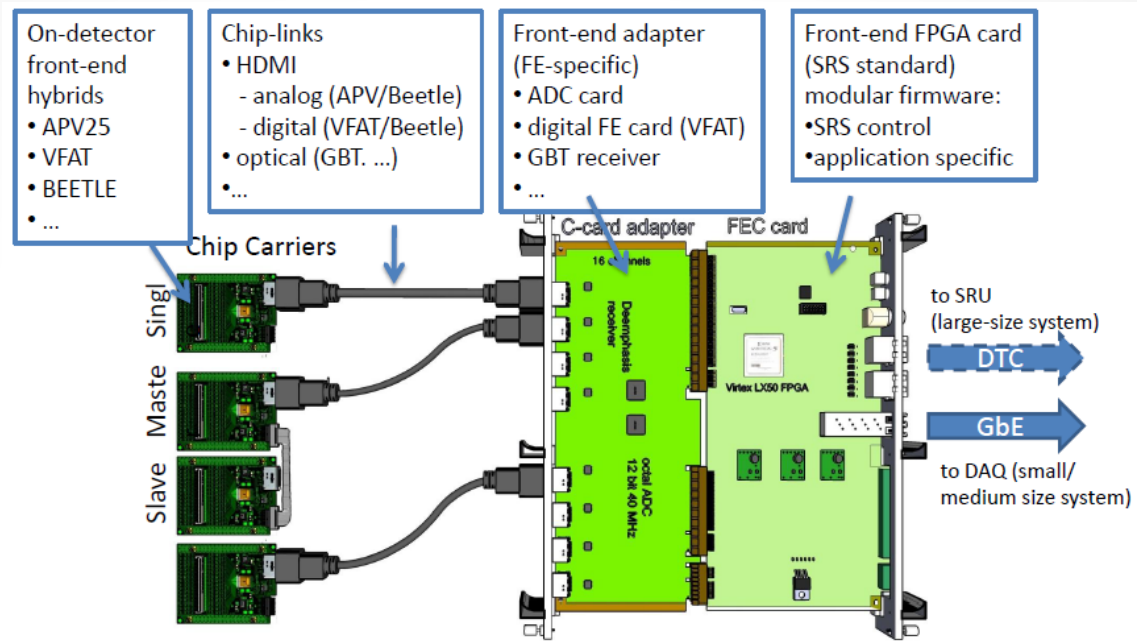
GE1/1 performance

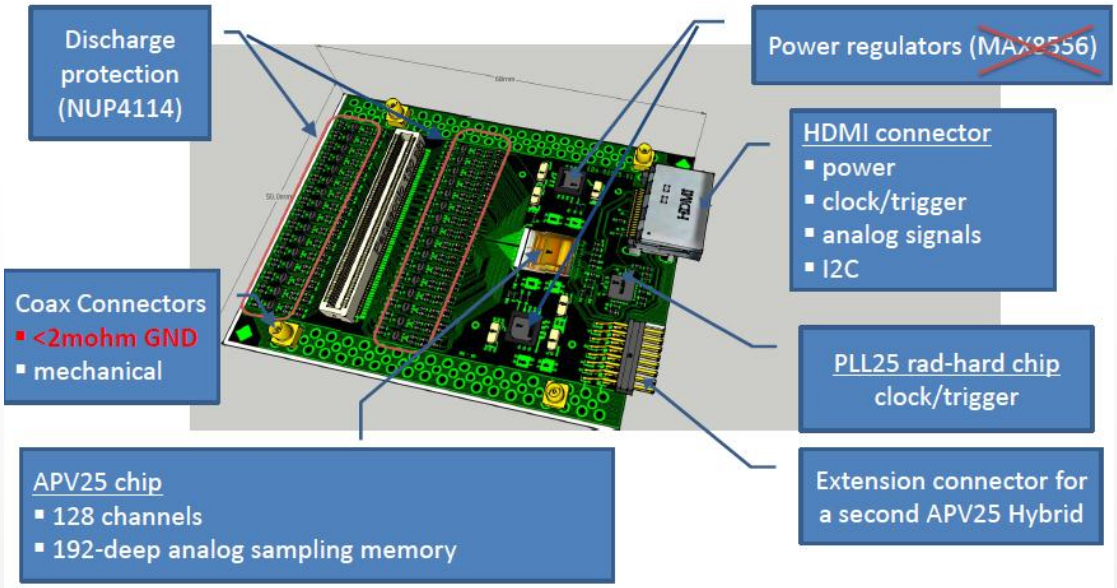




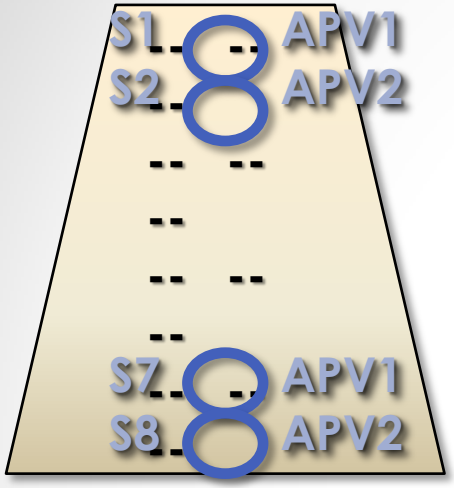
Ge1/1_II behaved excellently with stable, safe and reliable operation!

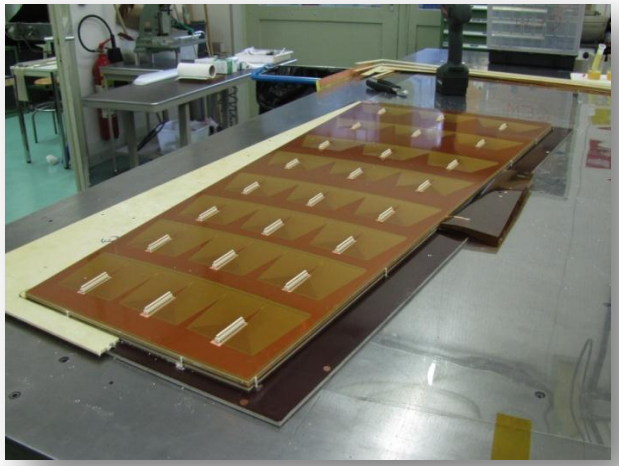
Scalable Readout System (SRS) and APV25 chip





Data-taking with APV25





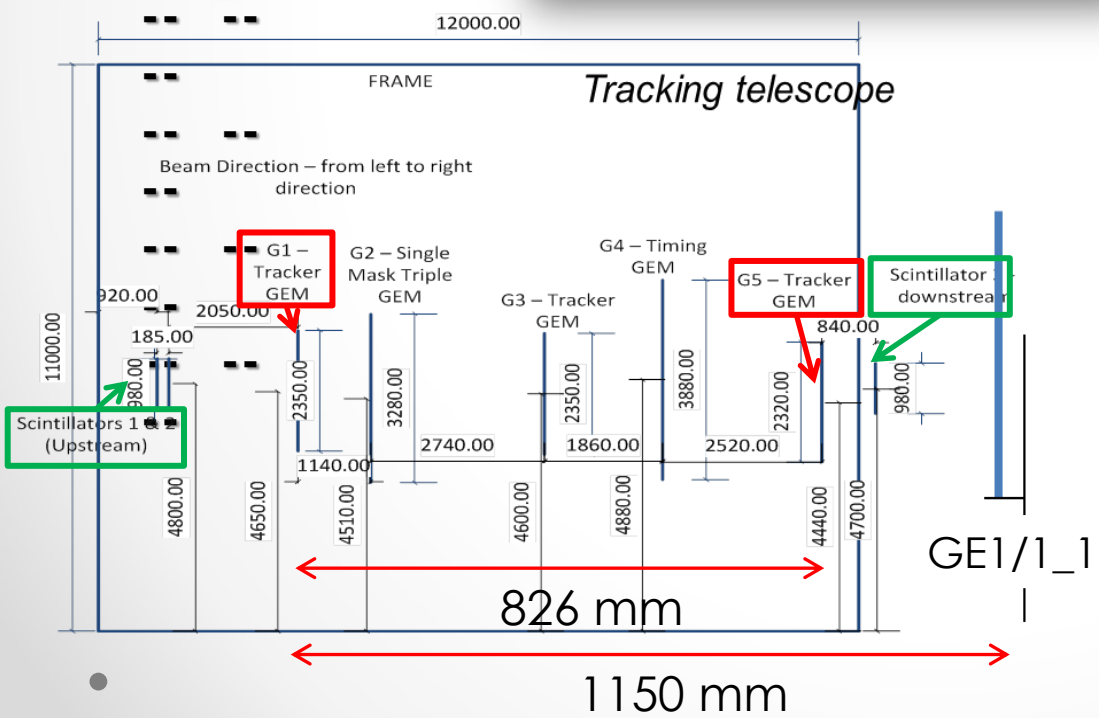
GEM active area: 990 x (220-445) mm

Single mask triple GEM

Gas mixture: $Ar/CO_2/CF4$ (45:15:40)

Gas flow: ~ 5 l/h

Ar/CO_2 (70:30) for the trackers 1 & 2



APV1 – APV2 to S1 & S2

Muons, 150 GeV, 100K events

Pions, 150 GeV, 250K events

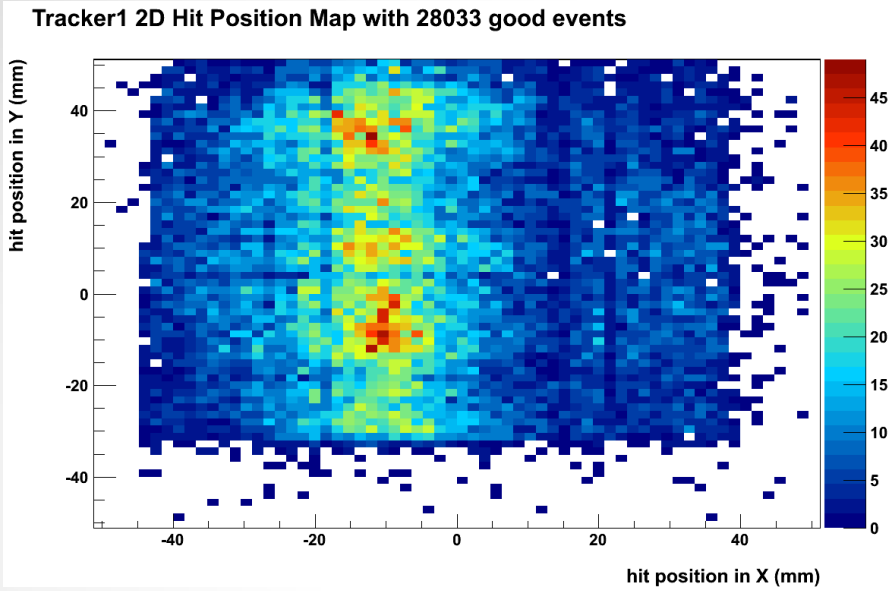
Pedestal run, 10K events

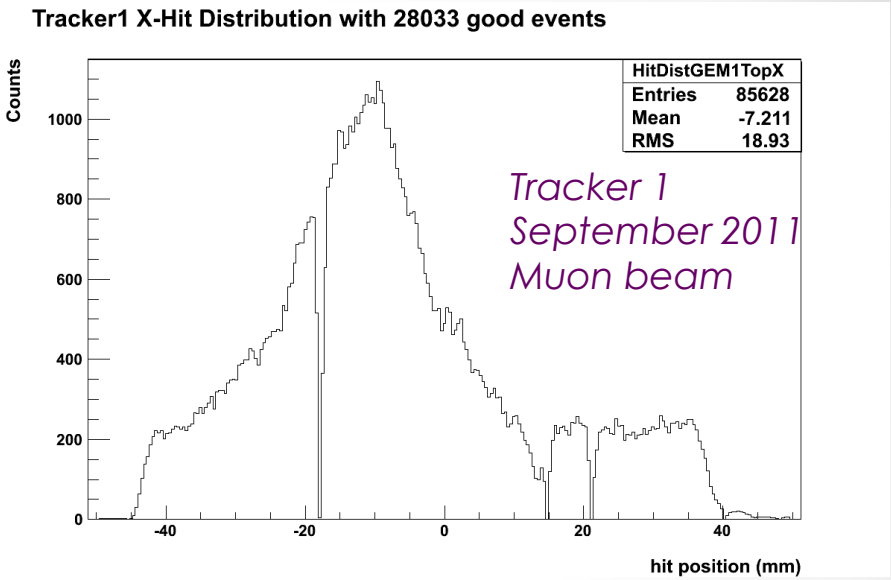
APV1 – APV2 to S7 & S8

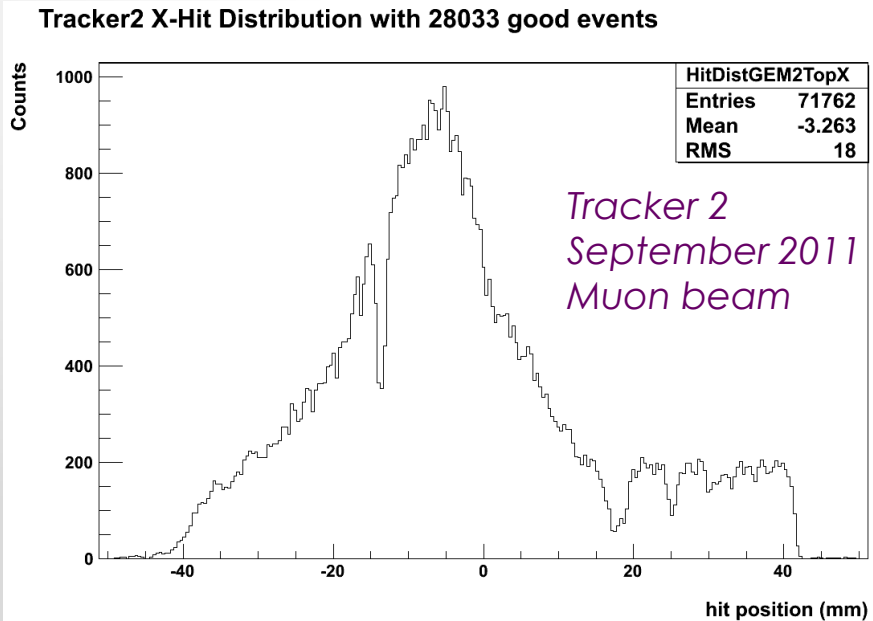
Muons, 150 GeV, 250K events

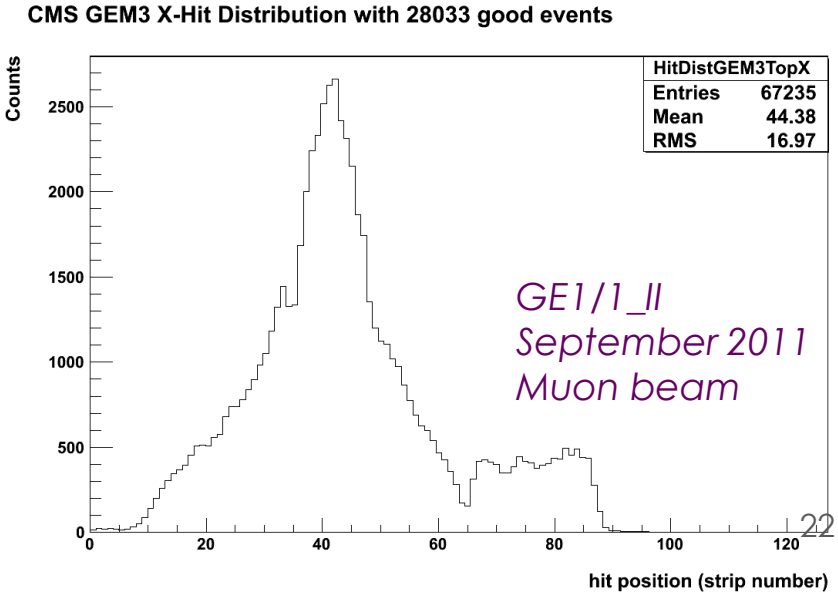
pedestal run, 10K events

Data-taking with APV25

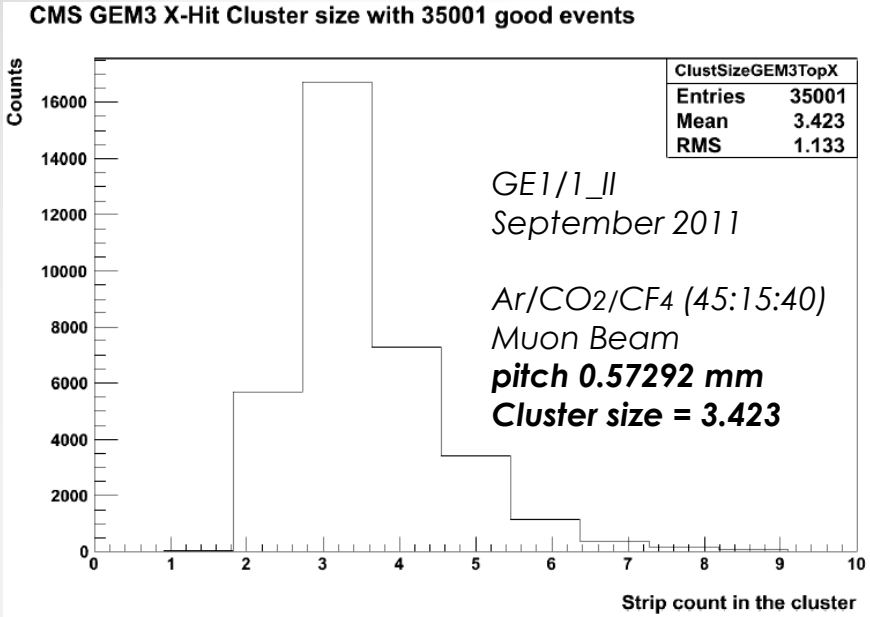


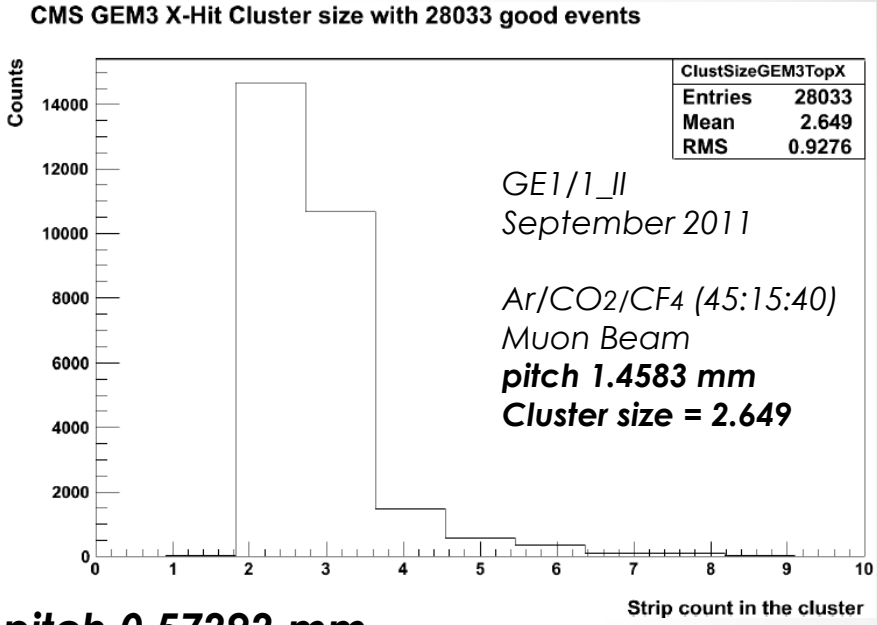


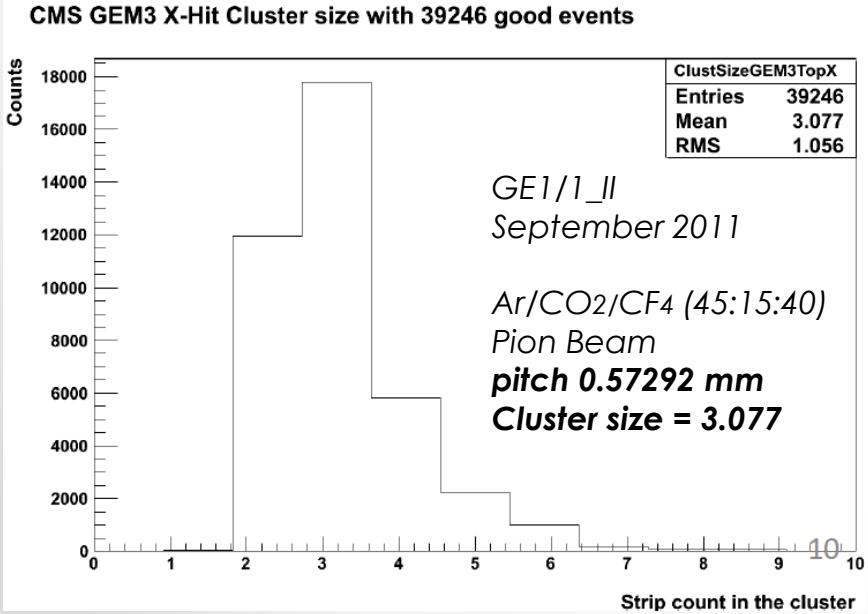




Data-taking with APV25

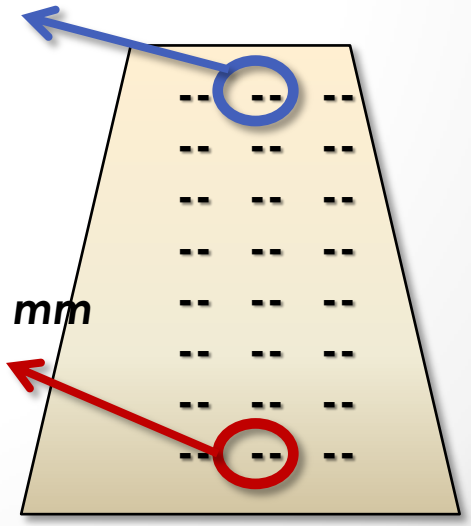




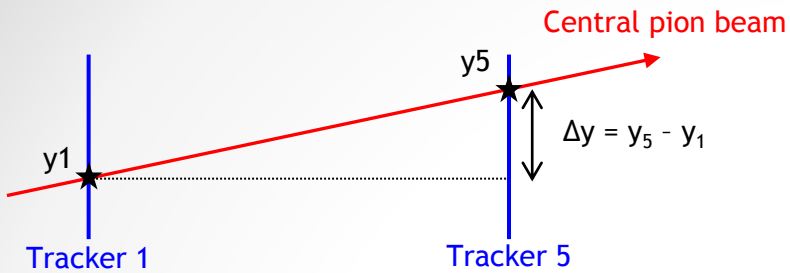


pitch 0.57292 mm

pitch 1.4583 mm



Spatial resolution measurement using pulse height information



Assuming that Tracker 1 and Tracker 5, which share the same construction, have the same spatial resolutions ($\sigma_{y5} = \sigma_{y1}$) and that the beam divergence in y is negligible in the center, we have for the width of the Δy distribution $\sigma^2_{\Delta y} = \sigma^2_{y5} + \sigma^2_{y1} = 2\sigma^2_y$, or

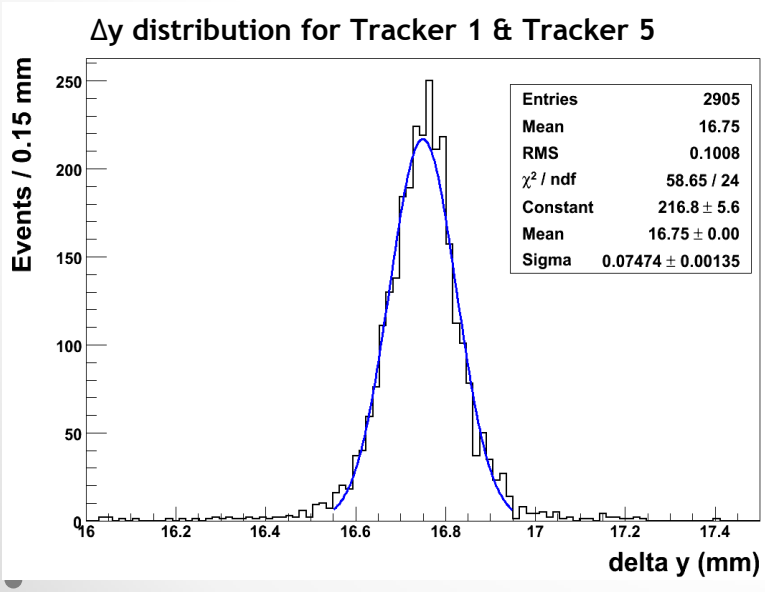
$$\sigma_y = \sigma_{\Delta y} / \sqrt{2} = 53 \text{ um}$$

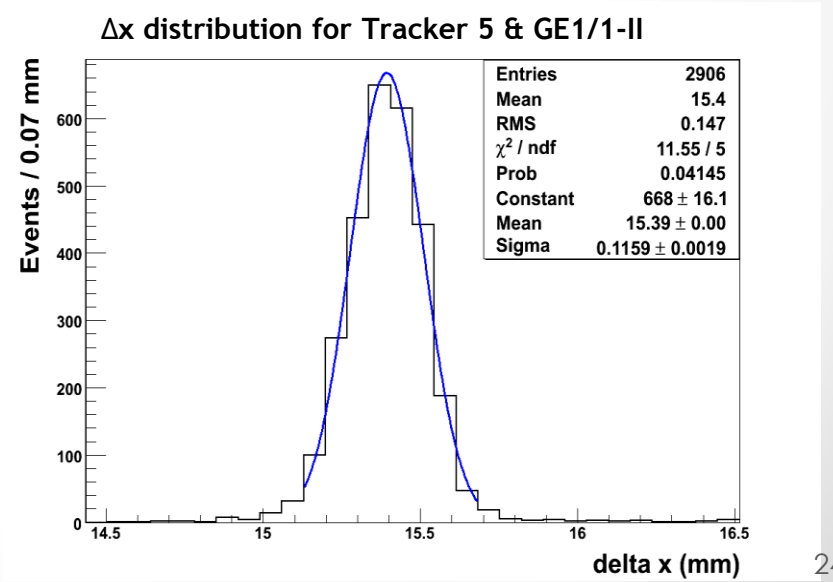
Hit positions in x and y are computed from the mean (or "center-of-gravity") of the corresponding strip cluster using analog pulse height information for each strip.

It is a reasonable assumption that $\sigma_{x5} \approx 53$ mm if $\sigma_{y5} = 53$ um because the x and y strips in Tracker 5 have the same pitch, and an upper bound on the spatial resolution of the GE1/1-II prototype achievable with analog pulse height information can be established as $\sigma_{x\,GE1/1} \leq \sqrt{(\sigma^2_{\Delta x} - \sigma^2_{x5})}$, i.e.

$\sigma_{x\,GE1/1} \leq$ **103 um** (in section with smallest strip pitch).

It is an upper bound as any remaining beam divergences in x will still contribute to the width of the Δx distribution below.





Conclusions and Plans for 2012

During 2011 we have consolidated our understanding of the performance of large area GEM detectors, we are going to start another challenging year with 4 test beam periods to test new prototypes with enhanced performance.

1) Commissioning of GE1/1_III&IV (NS2 technique)
2) GE1/1_III&IV validation of new ceramic HV divider (final layout)
3) Measurement of timing properties (with/without magnet)
4) Measurement of efficiency (with/without magnet)
5) Measurement of cluster size/occupancy (with/without magnet)
6) Measurement of space resolution function of strip pitch (with/without magnet)
7) Chamber testing along with VFAT/APV chips and TURBO/SRS electronics
8) Noise studies with new readout, new hybrids, new ground configuration
9) Commissioning of new VFAT hybrid (for the SRS)
10) Gas studies
11) Detector 2D imaging/uniformity studies