



Measurement of the Charge Induced on the Readout Strips of a GE1/1 Detector Prototype for the CMS Muon Endcap GEM Upgrade

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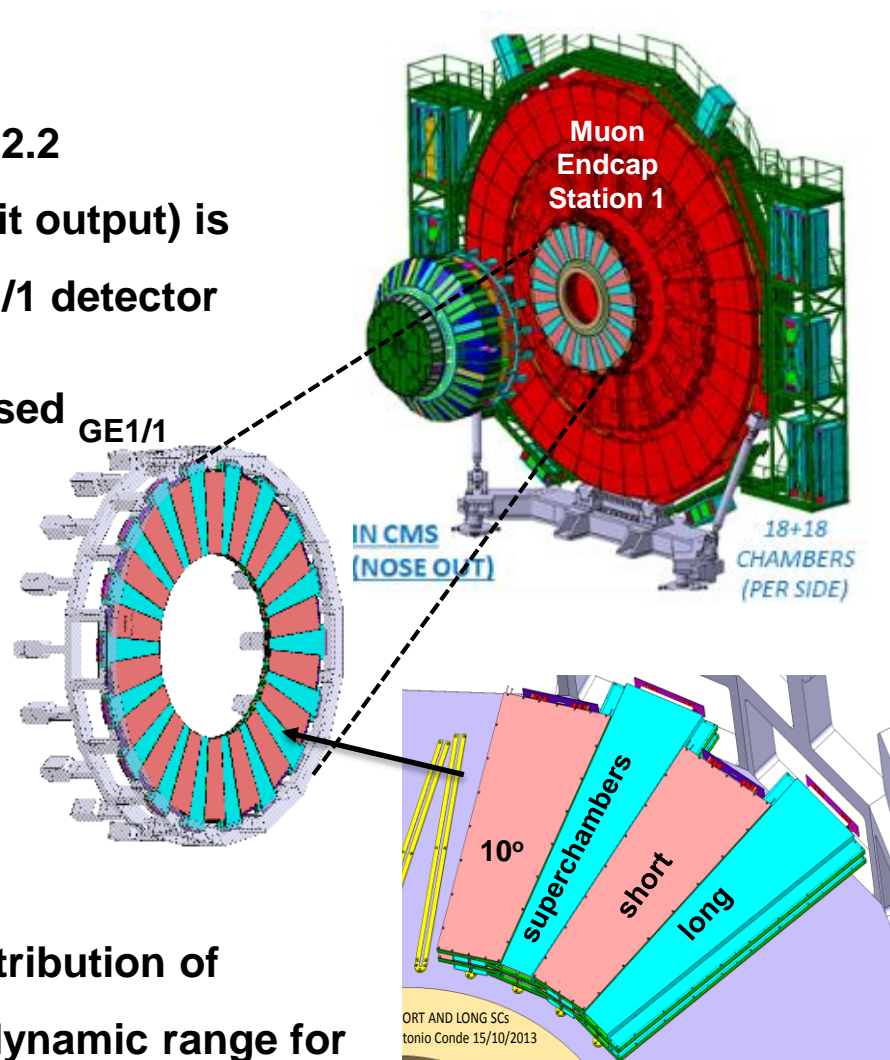
M. Hohlmann, A. Zhang

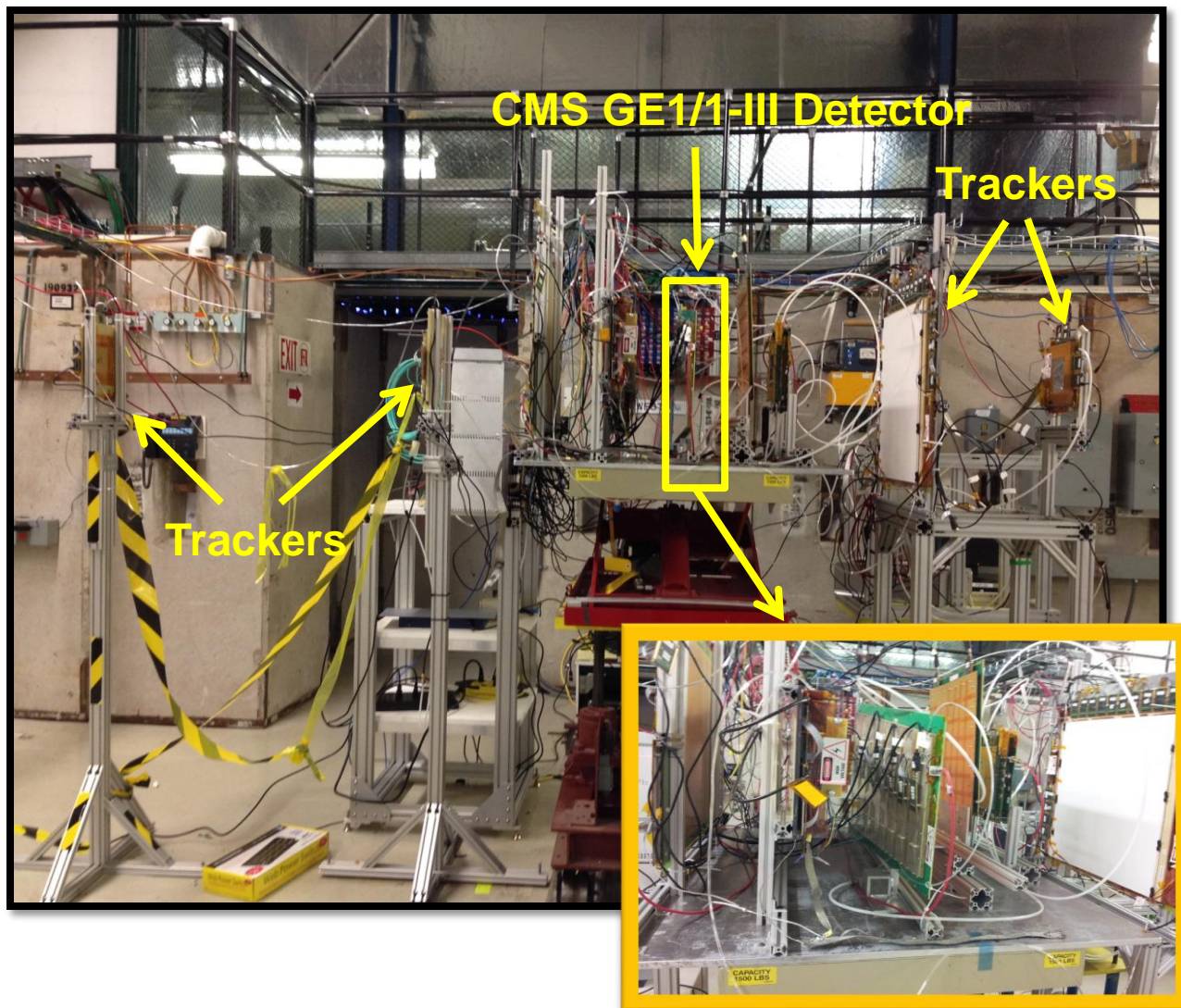
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CMS GEM Workshop XII

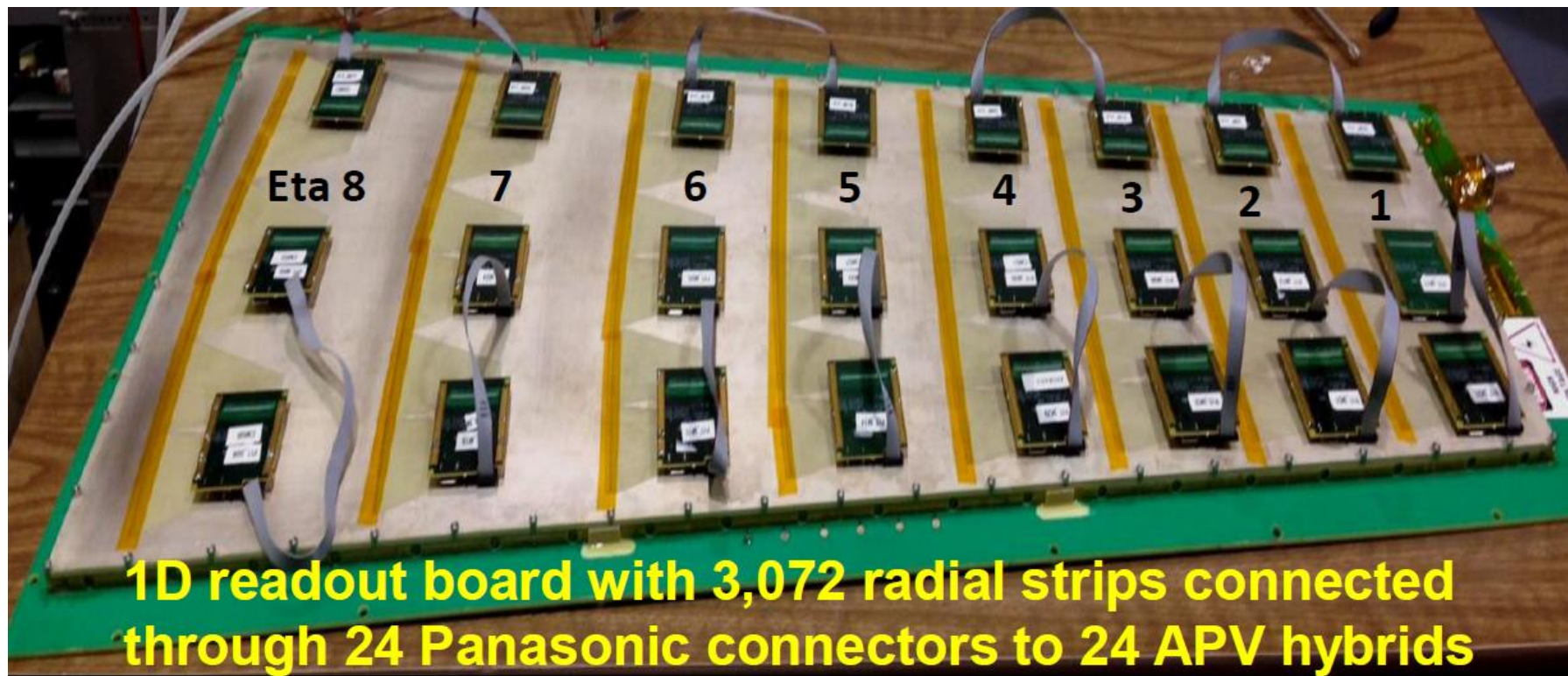
10/07/2015

- During Long shut down 2 (LS-2)
 - Installing GE1/1 in high- η region $1.6 < |\eta| < 2.2$
 - VFAT3 front-end chip (provides binary hit output) is being designed to read output from GE1/1 detector
- Charge induced on GE1/1 readout strips is used as input for the amplifier-shaper of the VFAT3 chip.
- For retaining good quality of signal, it is important to match the dynamic range of the induced charge to dynamic range of the chip input
- At Florida Tech, we measured the charge distribution of GE1/1-III prototype detector to estimate the dynamic range for the input charge using pulse height sensitive APV-25 chip





- Gas mixture used in all detectors: Ar/CO₂ 70:30
- Beam Energies:
 1. Mixed hadrons: 32 GeV
 2. Proton: 120 GeV
- Three 10 cm × 10 cm & one 50 cm × 50 cm GEM trackers with 2D readout area @ 4200V
- DAQ with RD51 SRS
- GE1/1-III detector tests:
 - High voltage scan from 2900V to 3350V
- Operating voltage: 3250V (50V above the start of efficiency plateau)



- Each η -sector has 384 radial strip and total 3072
- APV-25 chip is used to read signal from readout strips
- Strip pitch = $455\mu\text{rad}$

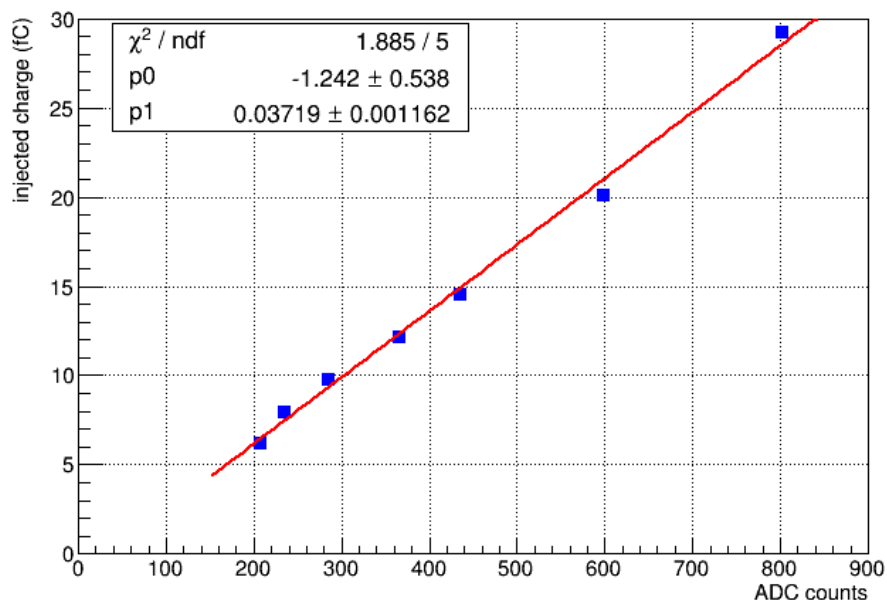
ADC to fC Conversion

- For VFAT3 the input charge given in fC units and APV-25 reads charge in ADC counts.
- Using APV calibration data (From Kondo Gnanvo, Univ. of Virginia), charge conversion formula for ADC to fC is

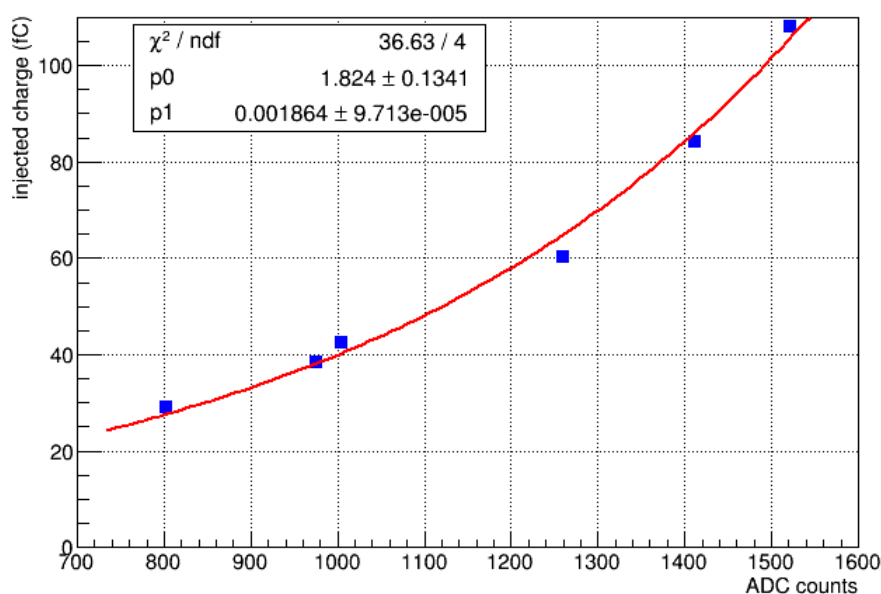
$$1\text{ADC} = 0.03719\text{fC for ADC} < 800 \text{ (Linear)}$$

$$\text{Charge (fC)} = \exp [1.8 + (0.0018 \cdot \text{ADC})] \text{ for ADC} > 800 \text{ (Non-Linear)}$$

apv25 gain



apv25 gain

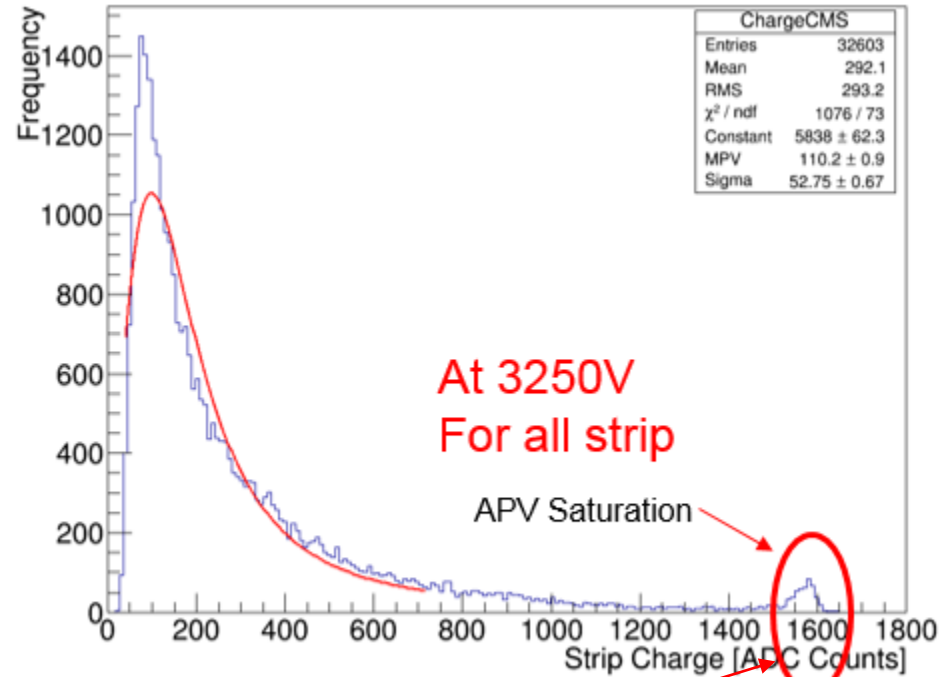




GE1/1-III: Charge Distribution



Strip charge distribution

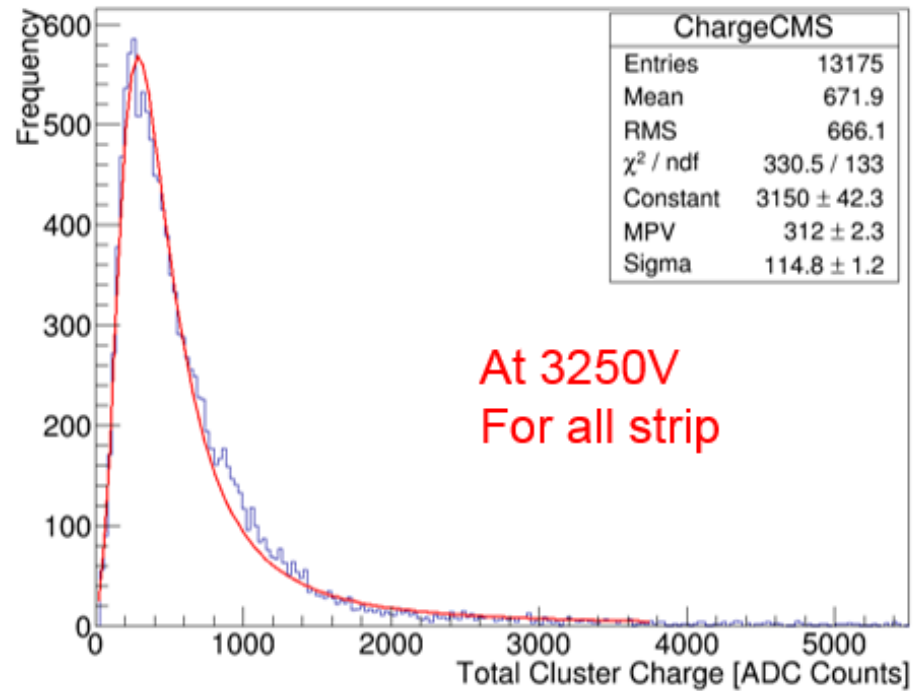


At 3250V
For all strip

APV Saturation
These events are excluded
from calculations

Mean charge (Operating Voltage) = 292ADC \approx 11fC
MPV (Operating Voltage) = 110.2ADC \approx 4fC

Total cluster charge distribution



At 3250V
For all strip

Calculation for charge

$$\begin{aligned} N_T &= 29e \text{ for } 3\text{mm} \\ N_T \times G &> 29 \times 8000 = 232ke \\ &= 37.12fC \\ &= 964ADC \end{aligned}$$

Approximate gain at 3250V

Mean, Landau MPV and RMS width in both cases were plotted using different cuts on strip cluster size i.e. for all strip clusters, 1-strip, 2-strip and 3strip cluster so on..

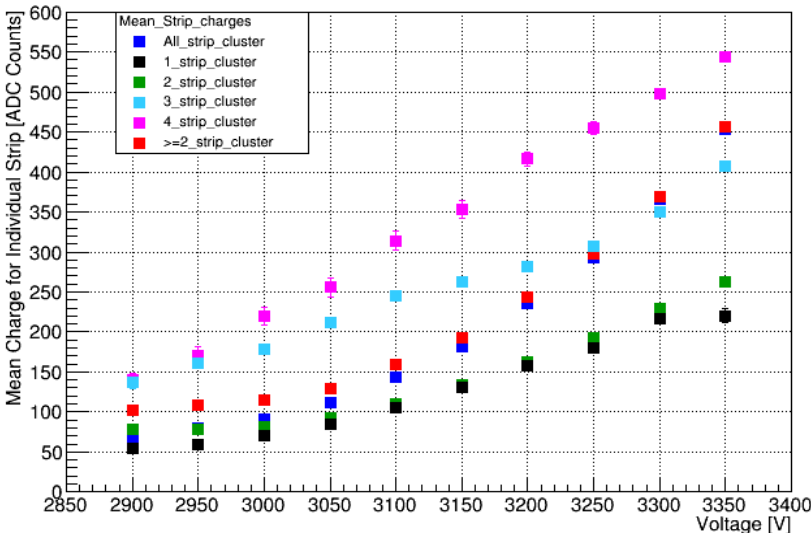


Mean Charge



Strip charge

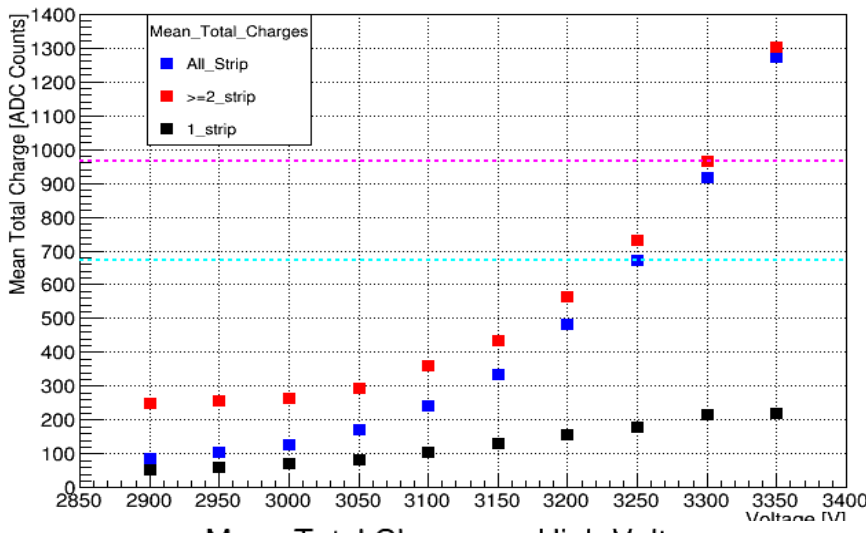
Mean Strip Charge vs. High Voltage



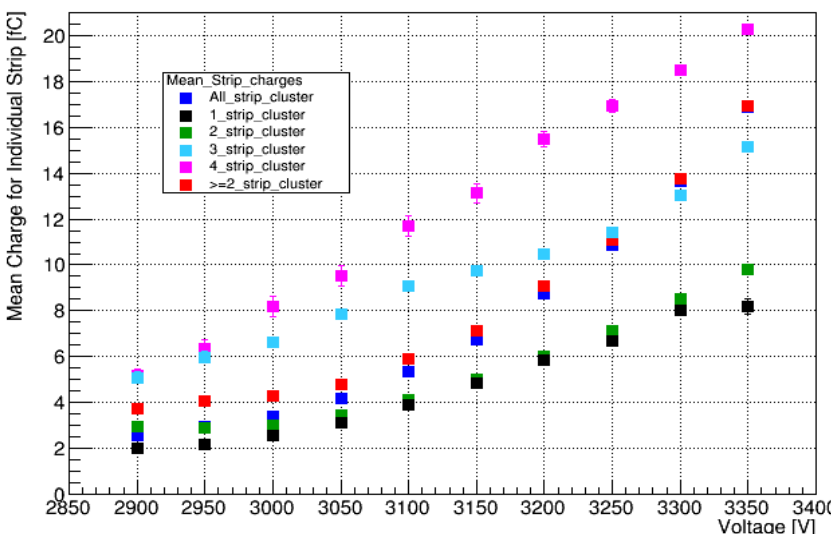
ADC

Total cluster charge

Mean Total Charge vs. High Voltage

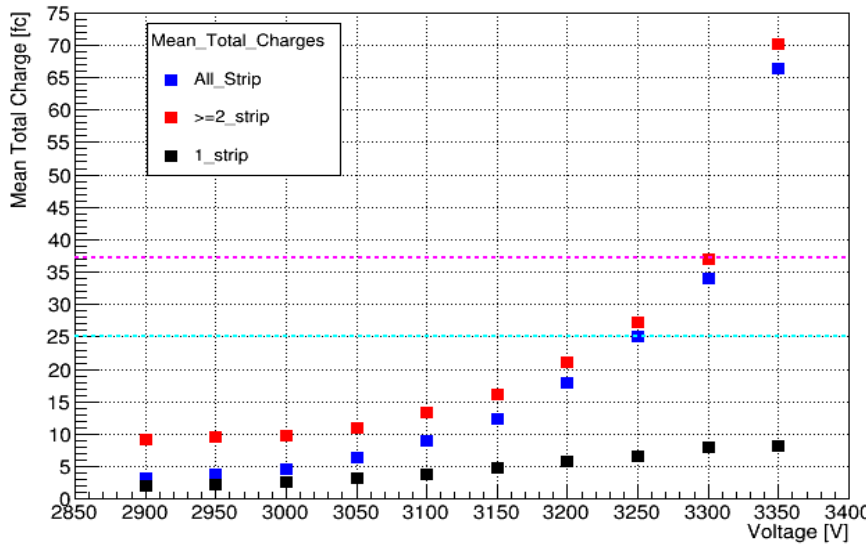


Mean Strip Charge vs. High Voltage



fC

Mean Total Charge vs. High Voltage



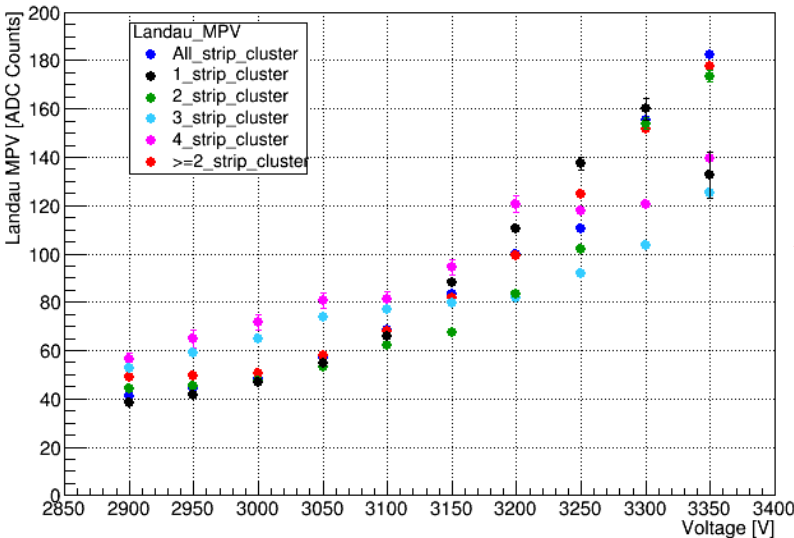


Landau MPV



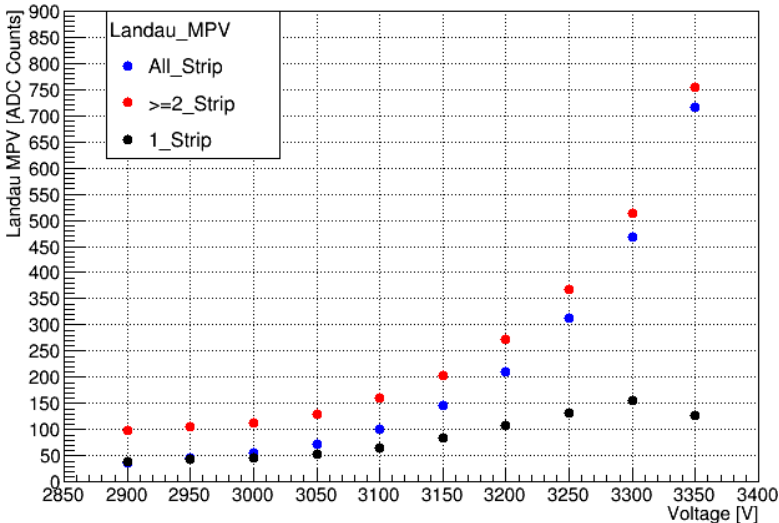
Strip charge

Landau MPV vs. High Voltage



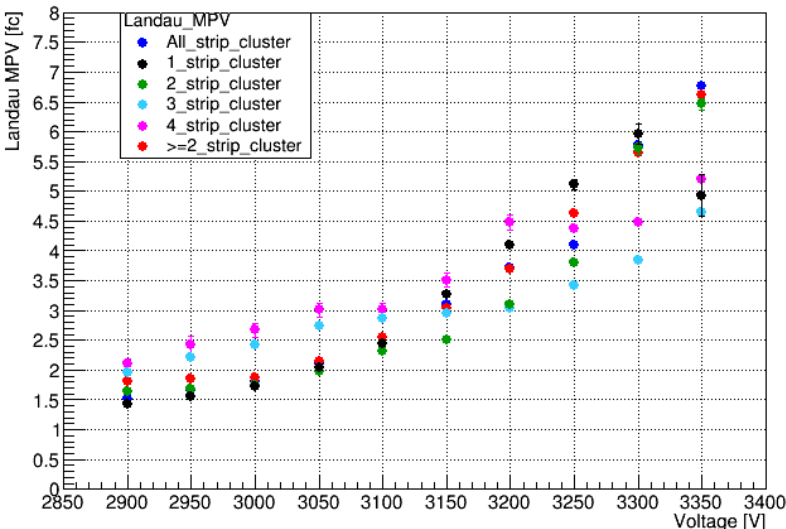
Total cluster charge

Landau MPV vs. High Voltage

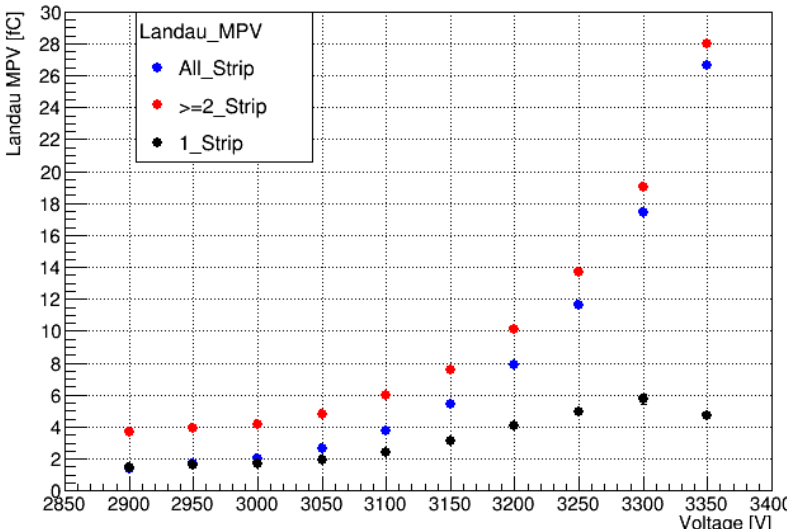


ADC

Landau MPV vs. High Voltage



Landau MPV [fc] vs. High Voltage



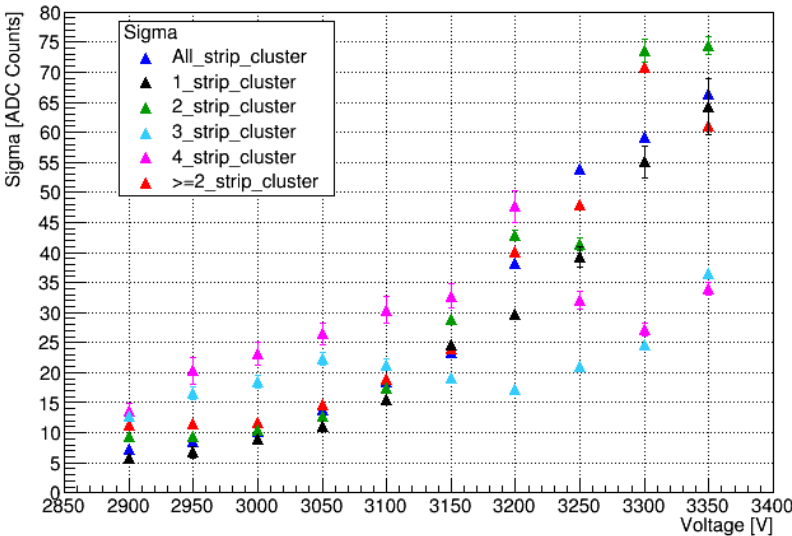
fC



RMS Width

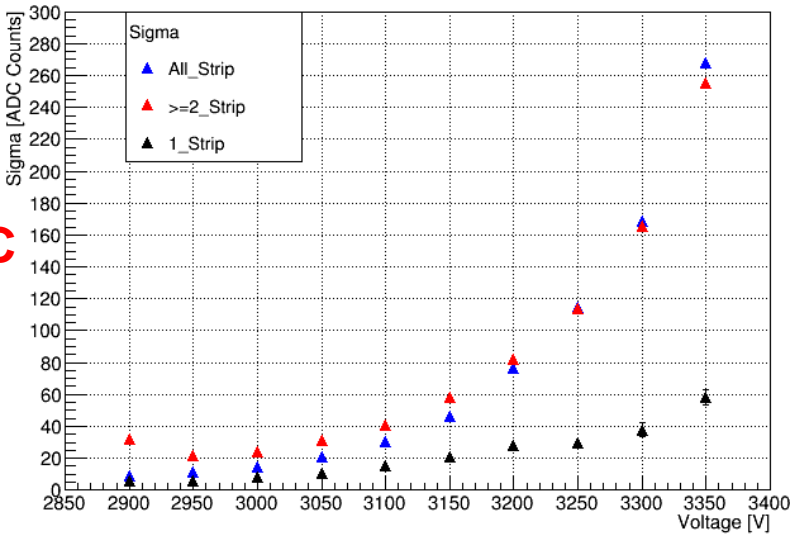


Strip charge
Sigma vs. High Voltage

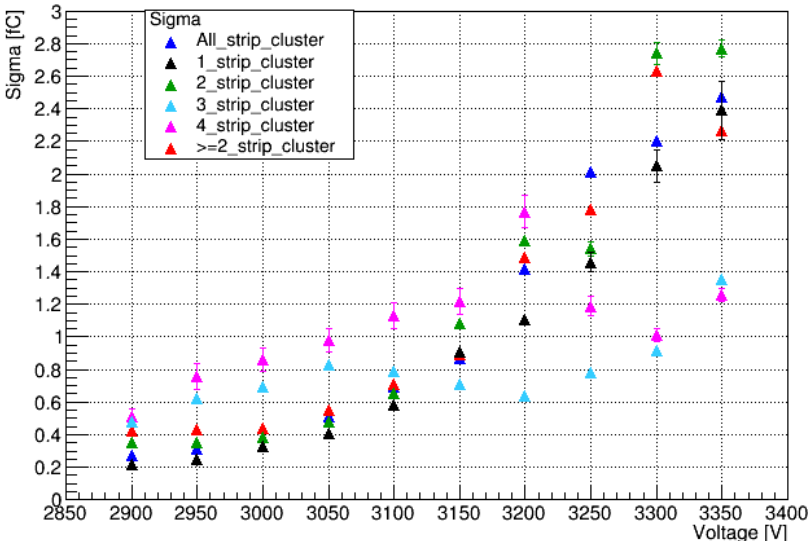


Total cluster charge
Sigma vs. High Voltage

ADC

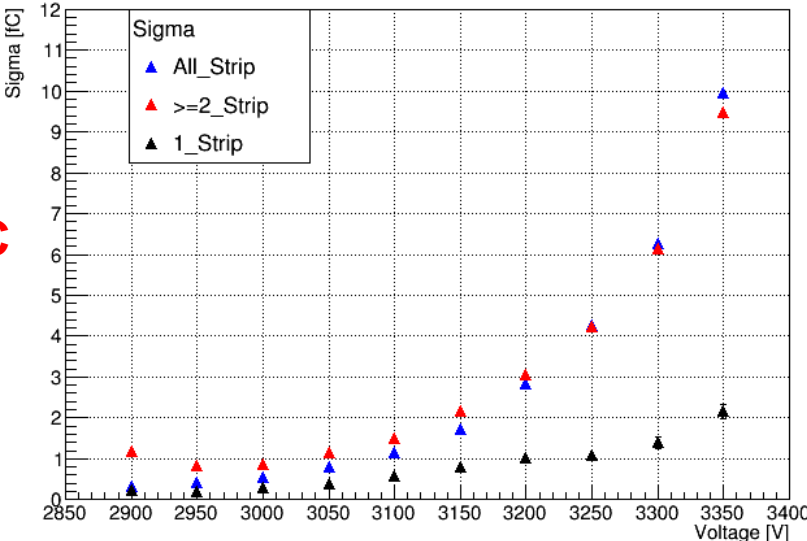


Sigma vs. High Voltage



Sigma vs. High Voltage

fC



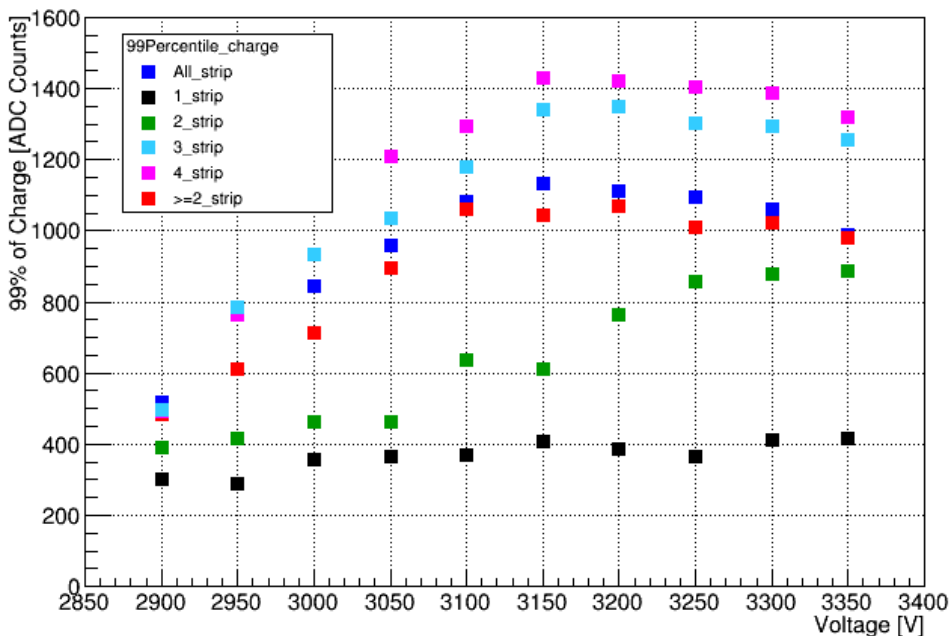


99 Percentile of charge



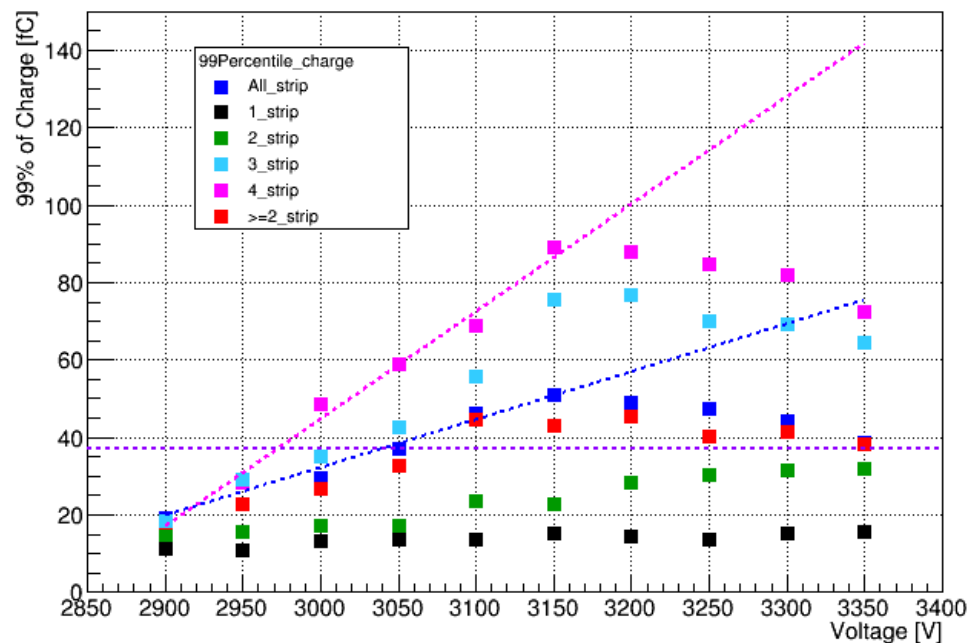
ADC

99% of Charge vs. High Voltage



fC

99% of Charge vs. High Voltage



99% (operating voltage) = ~115fC
99% (Max HV) = ~140fC

A Large-area GEM detector with ZZ r/o



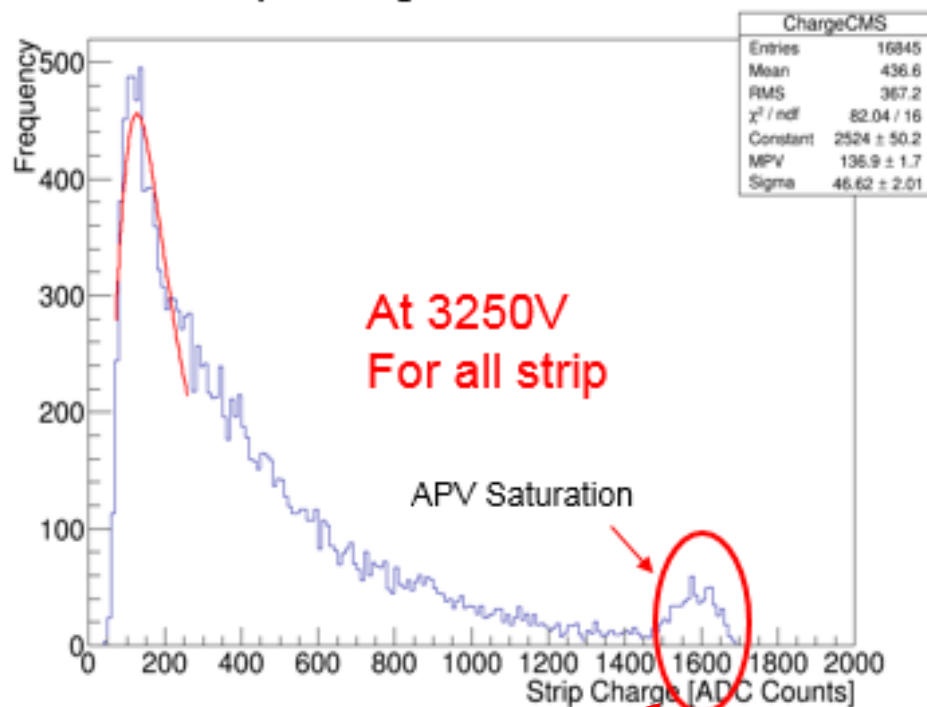
- Each eta sector has 128 radial zigzag strips, hence total 1024 strips
- Strip pitch = $1.37\text{mrad} = 1370\mu\text{rad}$
- Readout channels reduced by factor of 3
- More economical readout structure and hence proposes for GE2/1



Zigzag r/o: Charge Distribution

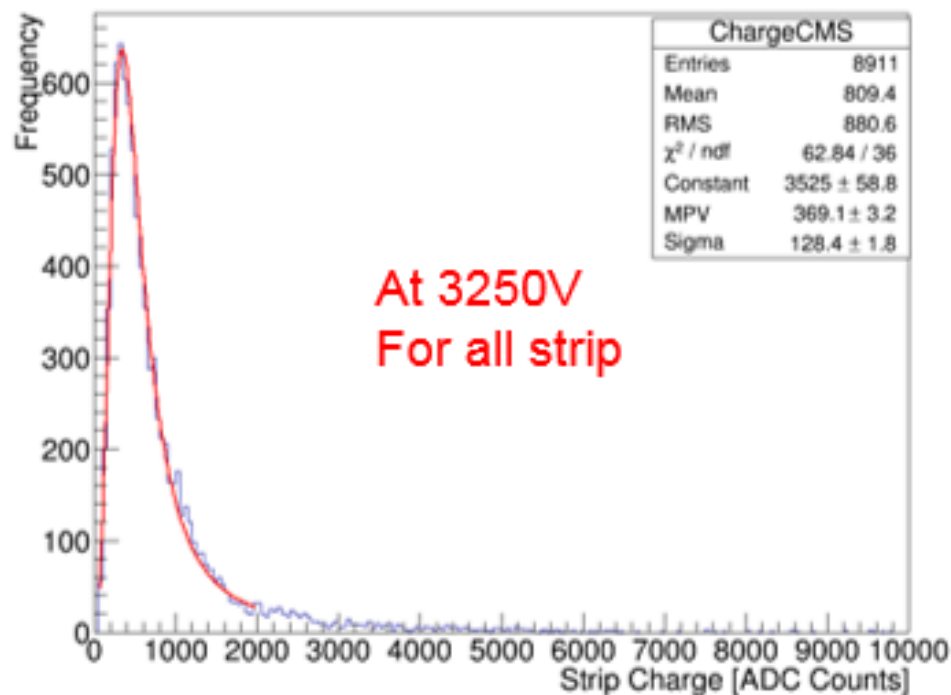


Strip charge distribution



APV Saturation
These events are excluded
from calculations

Total cluster charge distribution



Calculated charge is same as GE1/1
i.e. 37.12fC or 964ADC
(Drift gap is same i.e. 3mm)

Mean charge (Operating Voltage) = 436.6ADC = \sim 16fC
MPV (Operating Voltage) = 136.9ADC = \sim 6fC

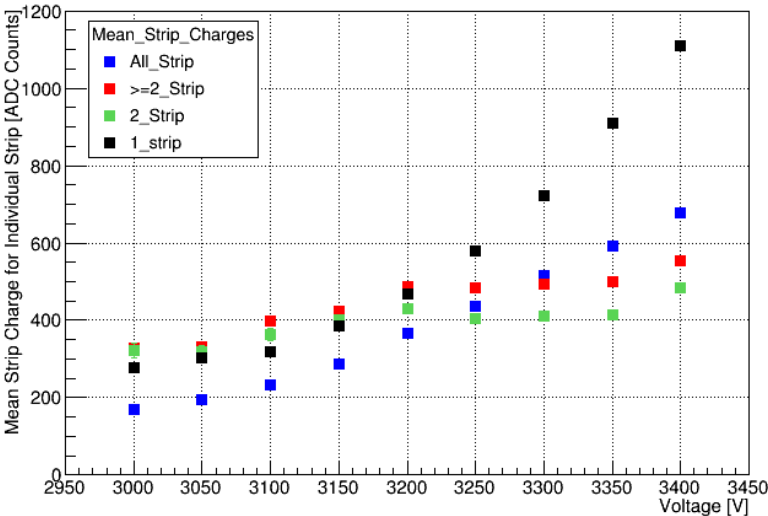


Mean Charge



Strip charge

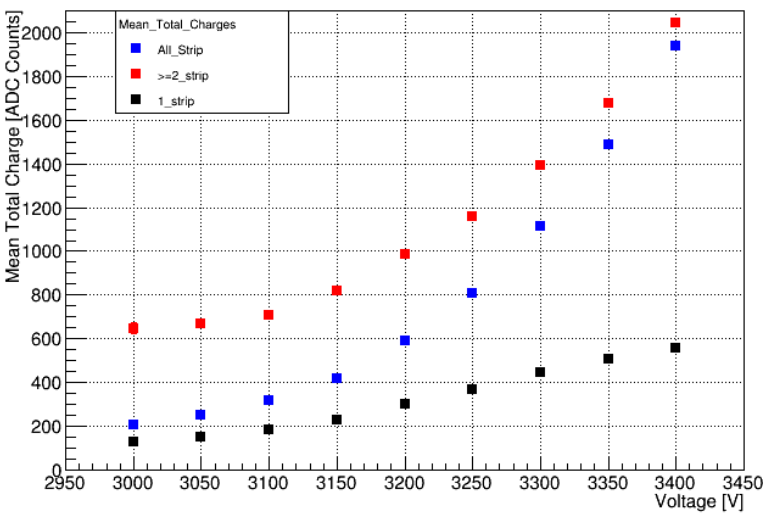
Mean Strip Charge vs. High Voltage



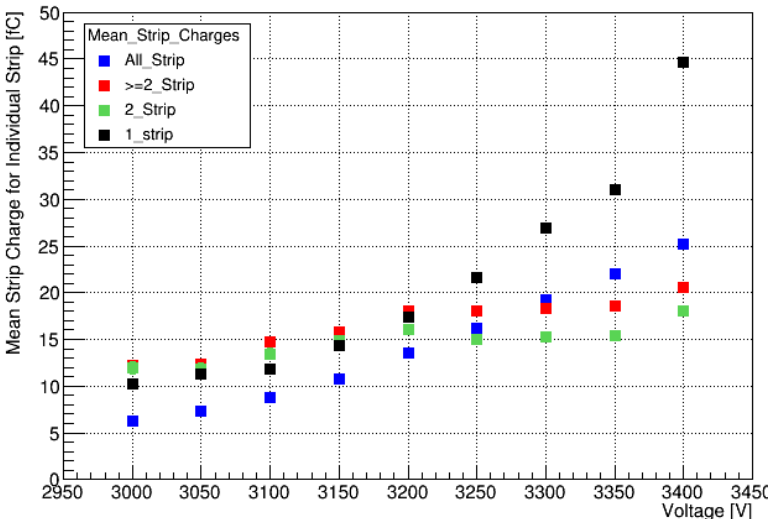
ADC

Total cluster charge

Mean Total Charge vs. High Voltage

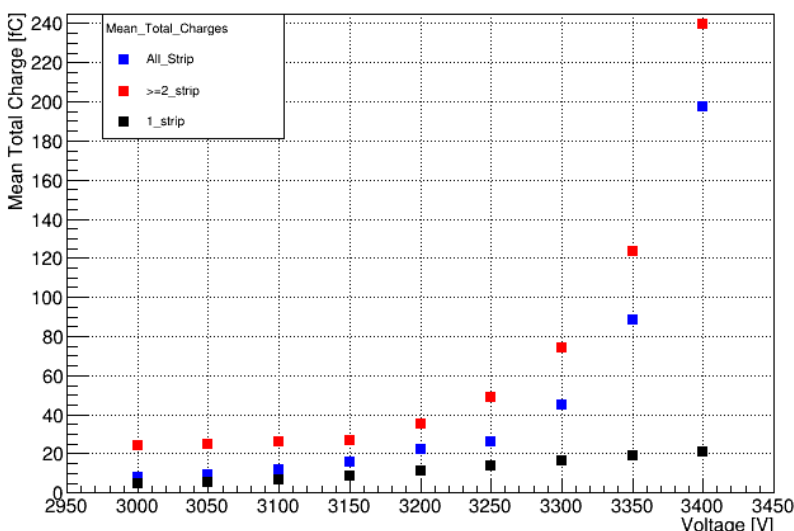


Mean Strip Charge vs. High Voltage



fC

Mean Total Charge vs. High Voltage



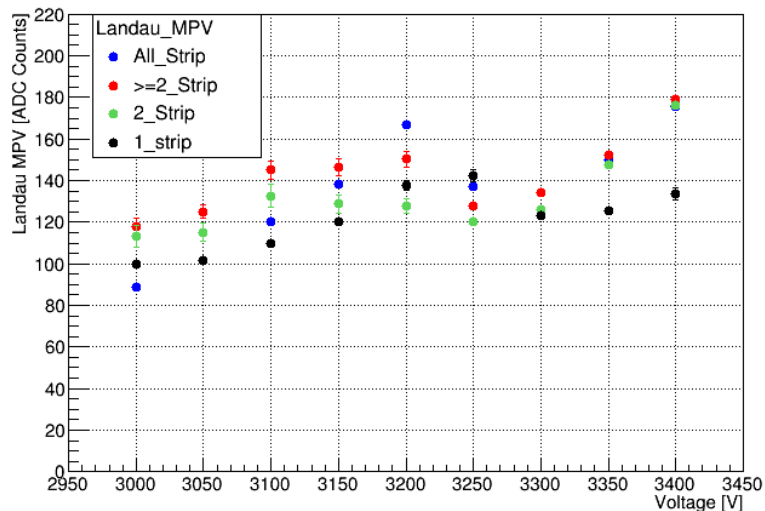


Landau MPV



Strip charge

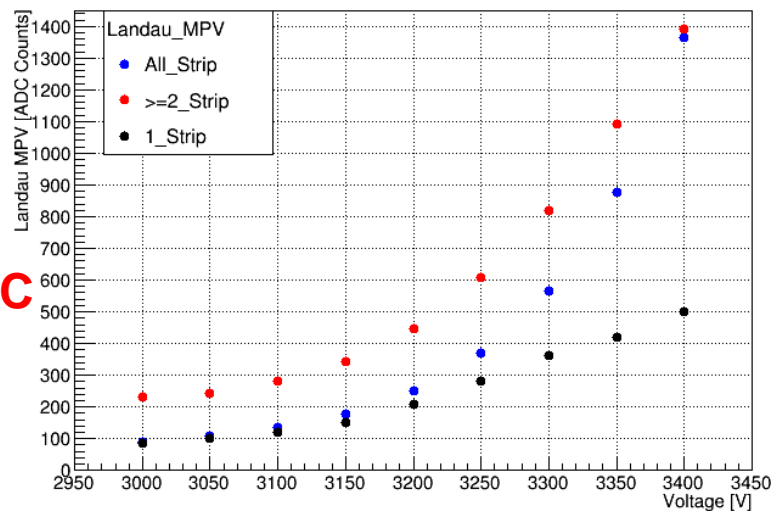
Landau MPV vs. High Voltage



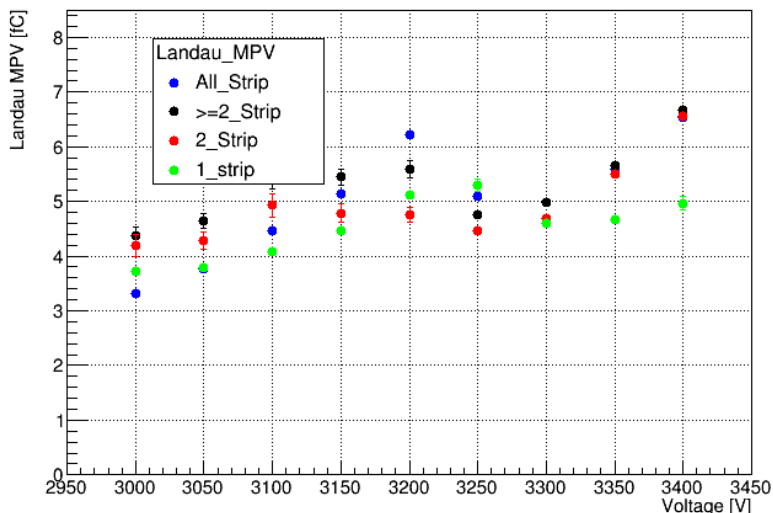
Total cluster charge

Landau MPV vs. High Voltage

ADC

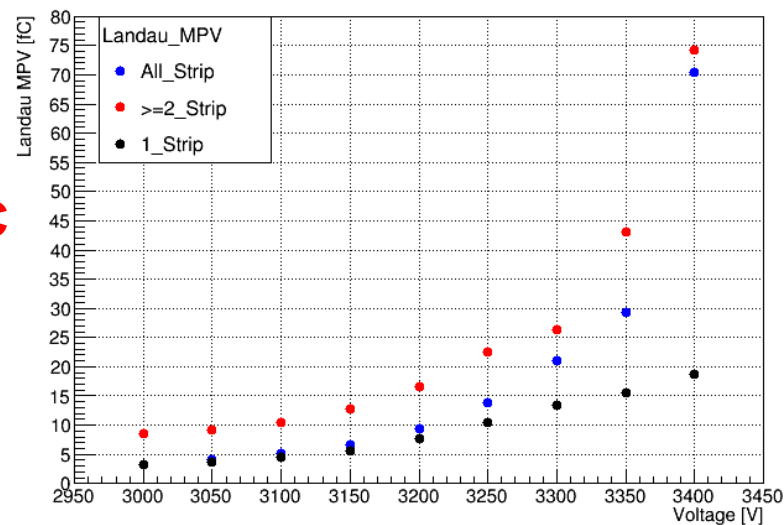


Landau MPV vs. High Voltage



Landau MPV vs. High Voltage

fC

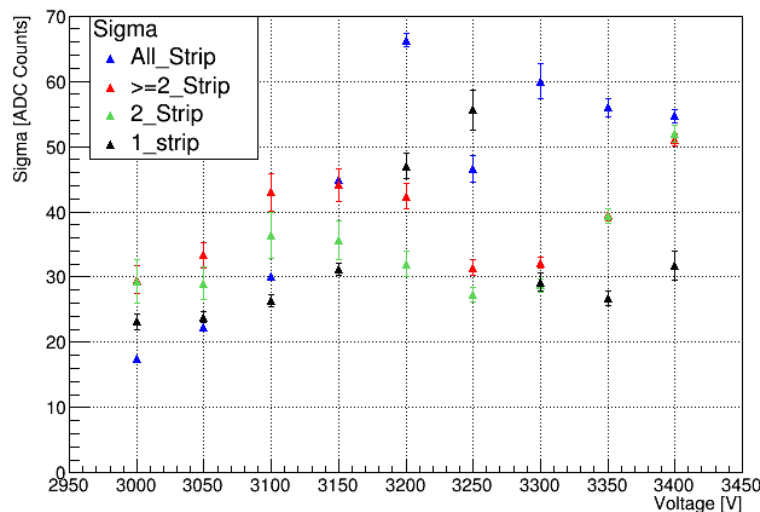




RMS Width

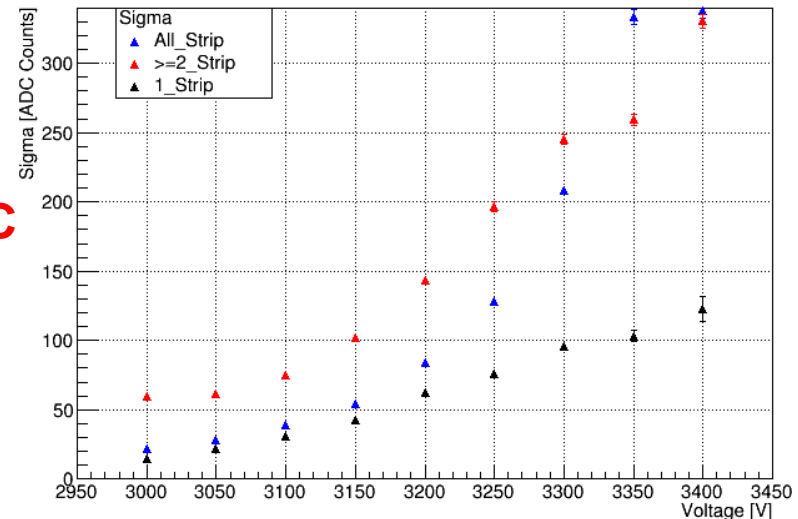


Strip charge
Sigma vs. High Voltage

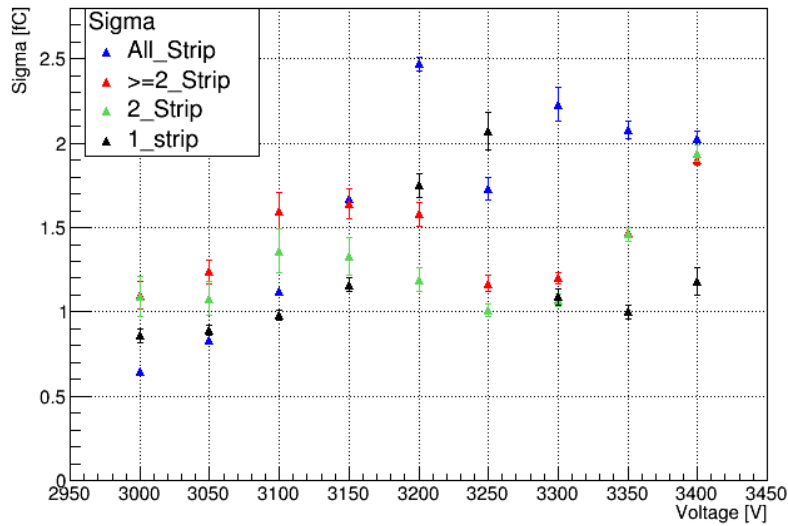


Total cluster charge
Sigma vs. High Voltage

ADC

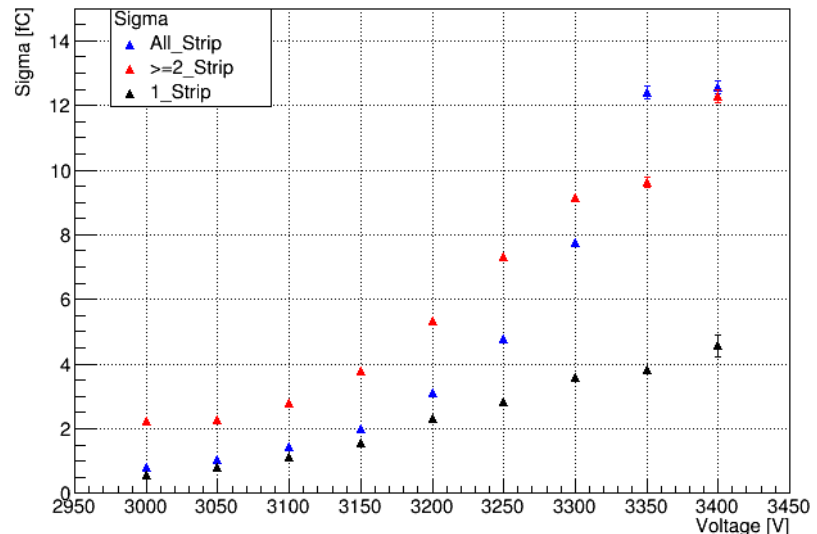


Sigma vs. High Voltage



Sigma vs. High Voltage

fC



- Measured induced charge with GE1/1-III detector using analog APV-25 hybrid chip.

For GE1/1 Detector:

- Mean charge (operating voltage)= $\sim 11\text{fC}$ and Mean charge (max voltage)= $\sim 17\text{fC}$
 - MPV (operating voltage)= 4fC and MPV (max voltage)= $\sim 6.5\text{fC}$
 - 99% (operating voltage) = $115\text{fC}_{(\text{expected})}$ and $85_{(\text{measured})}$
 - 99% (max voltage) = $140\text{fC}_{(\text{expected})}$ and $\sim 70_{(\text{measured})}$
- For detector with ZZ r/o:
 - Mean charge (operating voltage)= $\sim 16\text{fC}$ and Mean charge (max voltage)= $\sim 20\text{fC}$
 - MPV (operating voltage)= 6fC and MPV (max voltage)= $\sim 6.5\text{fC}$
 - Dynamic charge range for ZZ r/o detector is higher than the GE1/1 detector as expected, because pitch of ZZ r/o strips is larger than the GE1/1 r/o strip.
 - These measurements can be used to optimize the dynamic range of the input circuitry in the VFAT3 design.
 - CMS Technical Note on Strip Charge Measurement is in preparation

Thank You!!!