Improved Cluster Finding in 2D GEMs

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Content

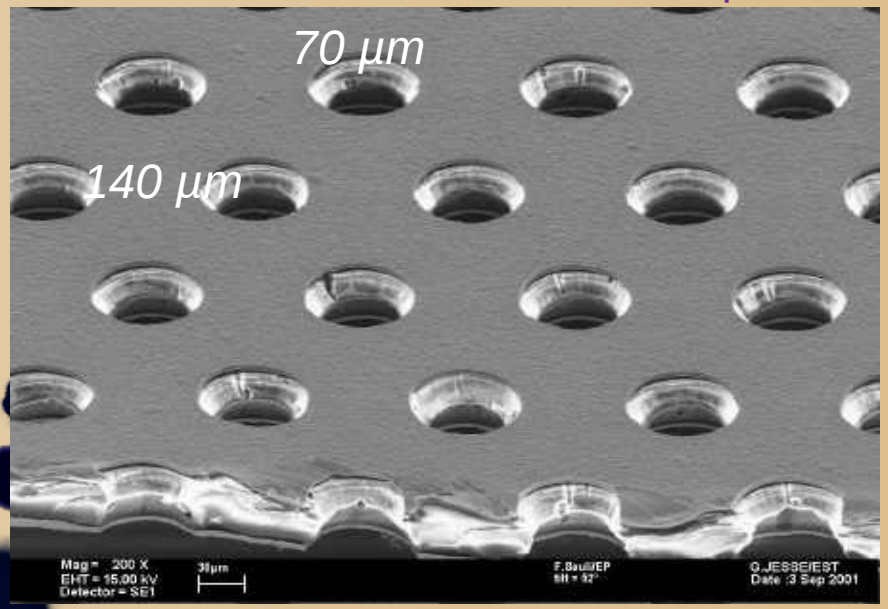
- Introduction.
- Motivation.
- Noise estimations.
- Measurement of the noise variation.
- Conclusion.

Gas Electron Multipliers (GEMs)

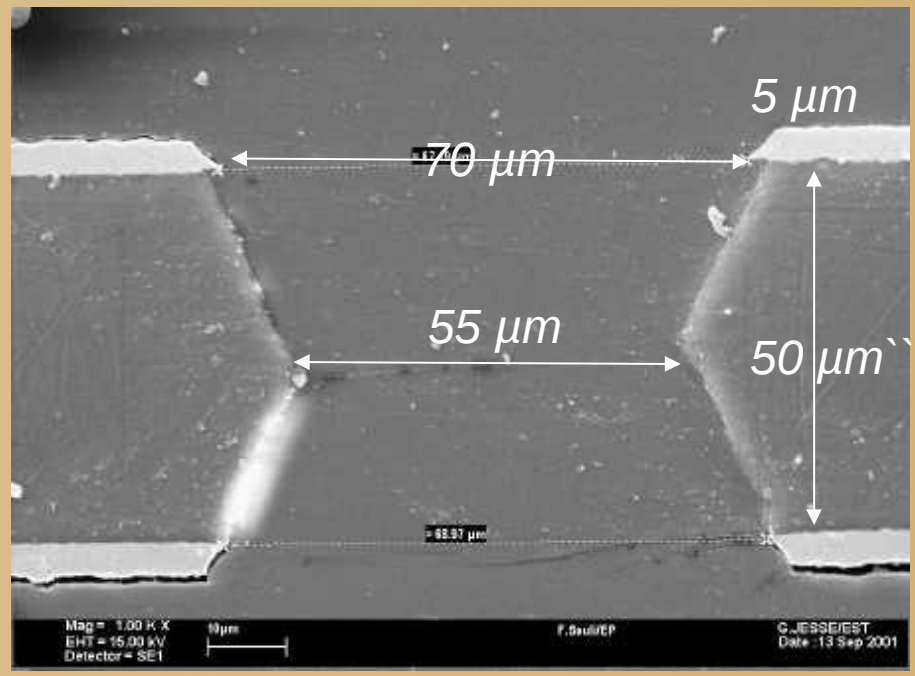
introduced b00y F. Sauli in mid 90's, F. Sauli et al., NIMA 386 (1997) 531

- GEM is a charge amplification device.
- GEM foil is a 50 μm Kapton sheet with 5 μm Cu layer on it.
- $\backsim 10^4$ holes/cm^2
- Use Ar:CO_2 (70/30) gas mixture.
- Possibility to cascade several GEM stages to reach high gains in multi-GEM detectors.

GEM foil from electron microscope



GEM hole from electron microscope



Provides,

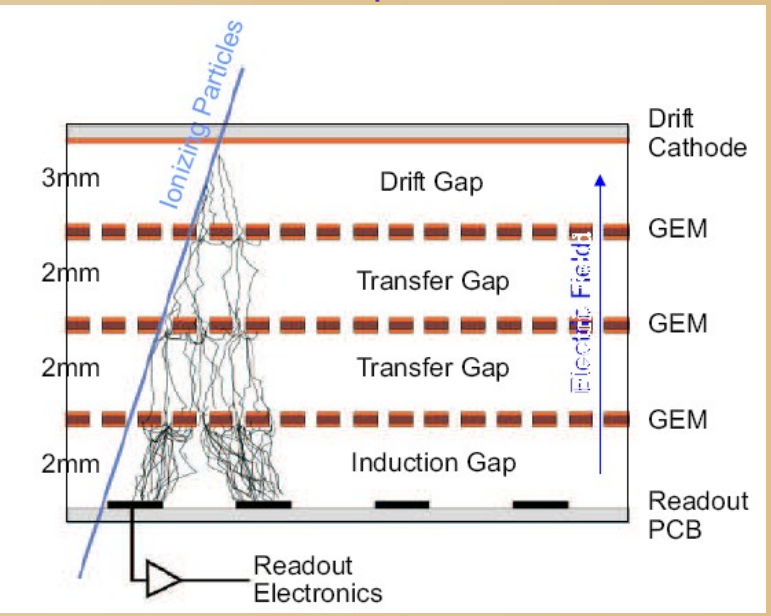
High Rate Capability.

Good spatial and angular resolution.

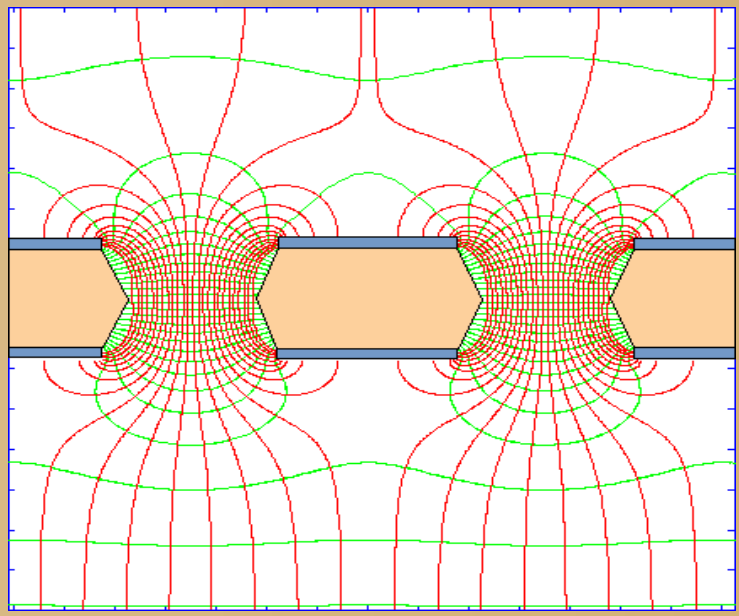
How GEM Works

- Coulomb interaction of the fast charge particles with the electrons in the atomic shells of the detector medium (Ar:CO_2 gas) creates an electron-hole pair.
- Created electrons drift towards the 1st GEM foil through the applied external electric field (Drift Field).
- Excited and ionized atoms are produced by the avalanche multiplication in the hole region due to the strong electric field.
- The created electron cloud drifts toward the 2nd GEM and repeat the multiplication process.
- The electron cloud drifts toward the readout plane (Induction gap).
- The charge is collected on a 2D readout plane, consisting of a copper strips at pitch of 400 µm and read out with electronics.

Schematics of triple-GEM detector

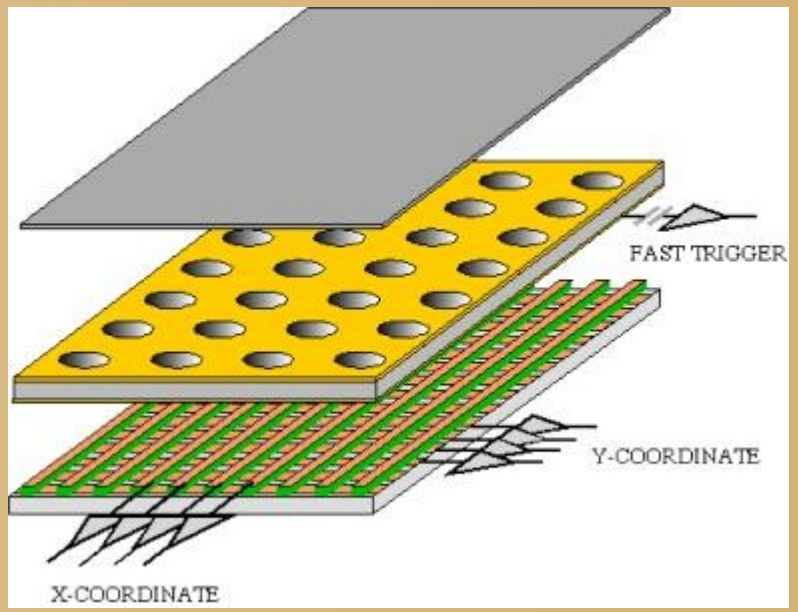


Electric field lines in a GEM hole.



What actually ADC records...?

- ADC actually records The integration of the analog pulse over time for the total charge registered by a strip and digitizes it.
- Timing (or latency) relative to the external trigger needs to be configured in order to "catch" the pulse for integration.



Motivation

- The noise present in the raw ADC affect how precise the original signal is.
- This includes random disturbances or variations which even change the original signal.
- As the signal transmitted over a long distances, these random variations become more significant.
- The raw ADC generated by the noise can be misidentified as those generated by the true cluster charges on GEMs which can produce ghost tracks.

(1) Baseline subtraction.

(2) Bin-to-bin pedestal subtraction.

The raw ADC has a pedestal and is prone to noise. The individual pedestal can be determined by averaging each channel over many events.

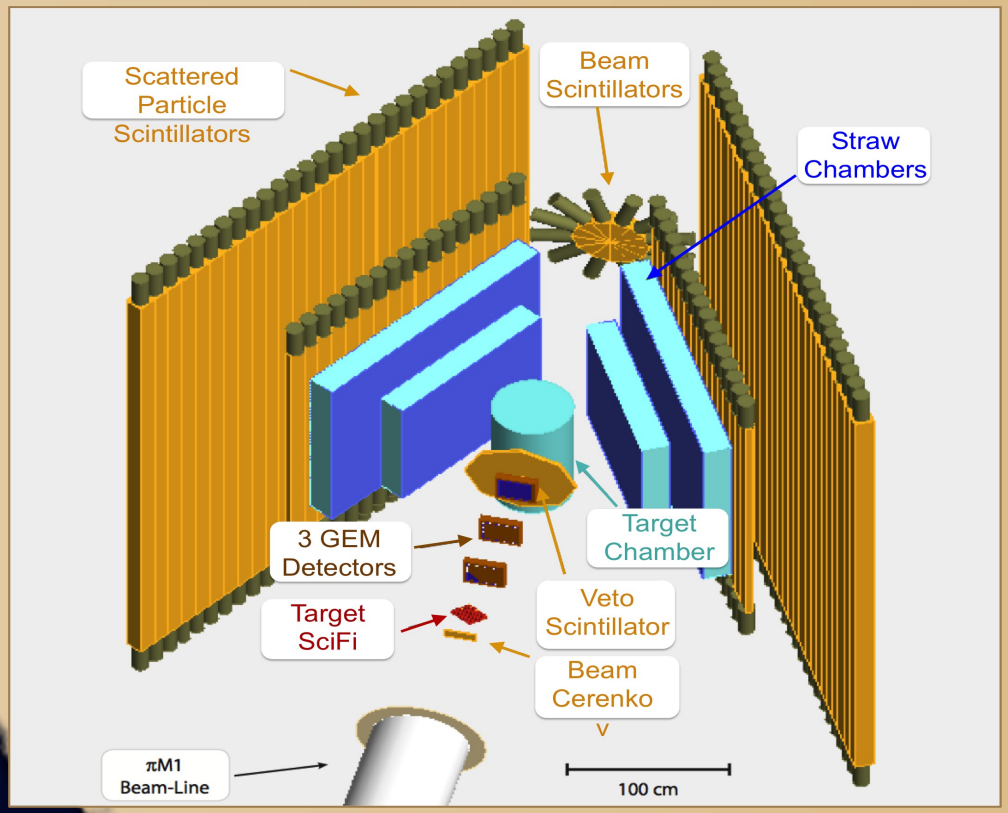
(3) Common-mode noise subtraction.

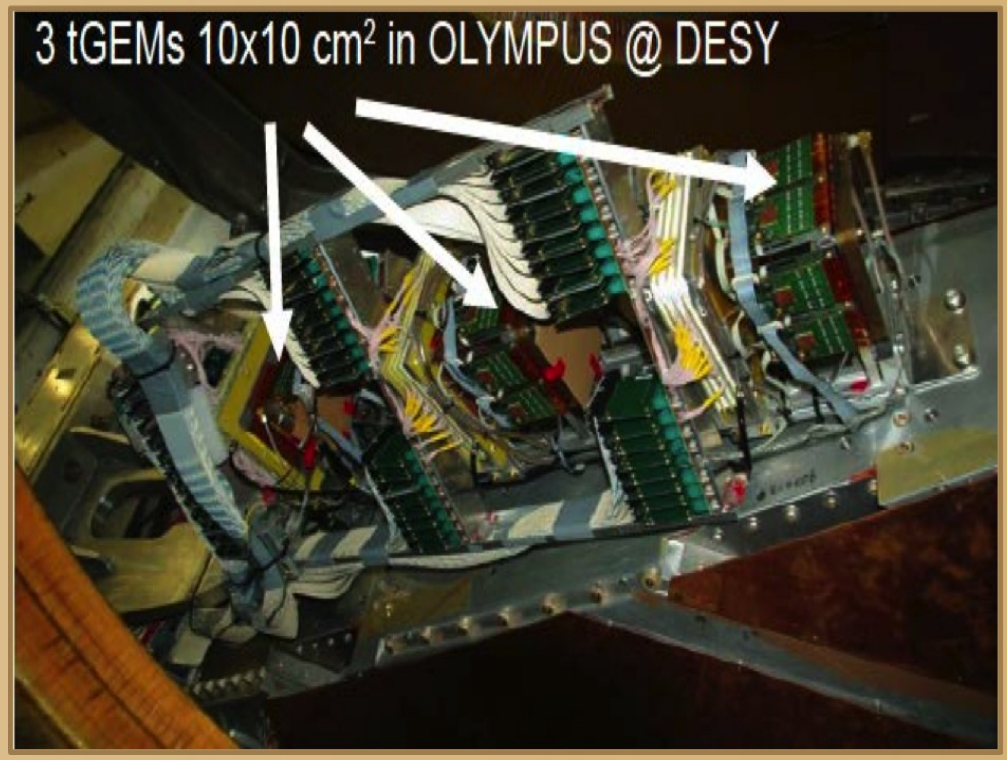
The various noise types, the so-called common-mode noise can be determined per event, a correlated up and down per event for all channels together.

(4) Measurement of the noise variation.

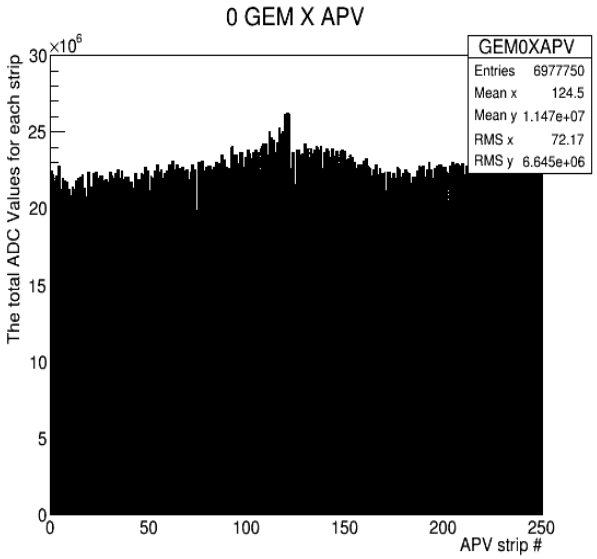
GEMs at PSI

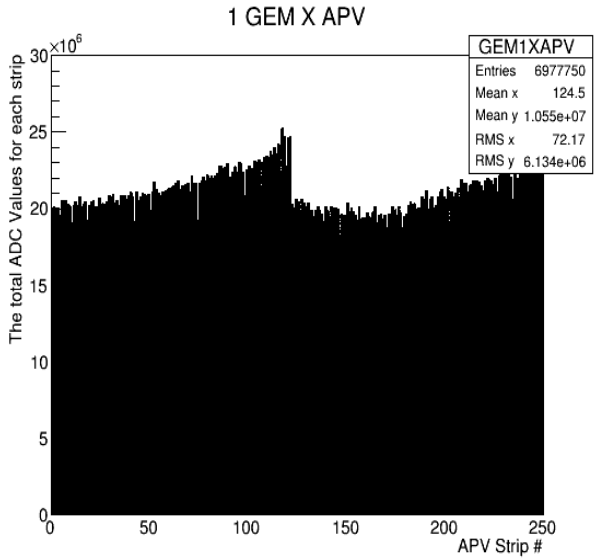
- PSI πM1 beam line provides a beam with ~2 cm radius at the scattering target.
- Use GEM detectors to determine the precise particle scattering angles.
- 3 GEMs (10 x 10 cm^2 each) along the beam line.
- Use SiPM (73 V ± 10 mV) for trigger.
- Use GEM high voltage 3800 V.

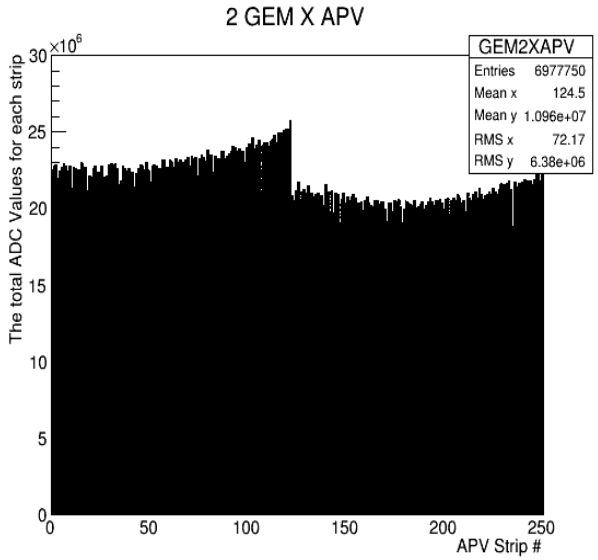


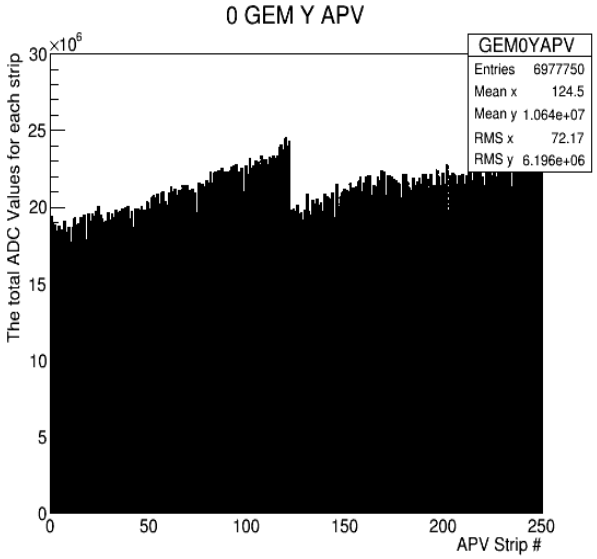


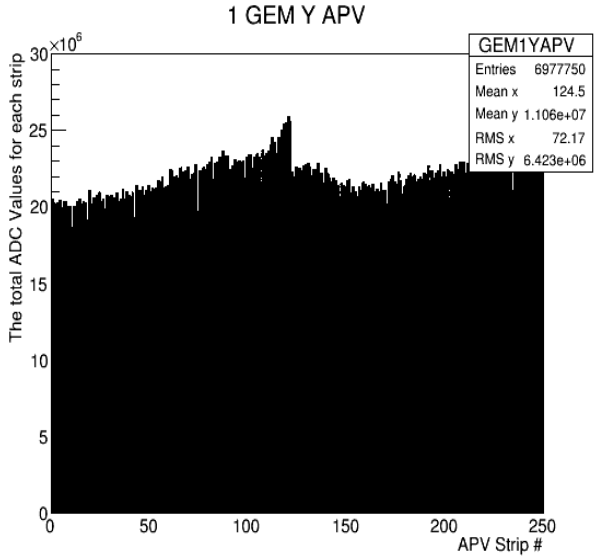
The total raw ADC vs the strip

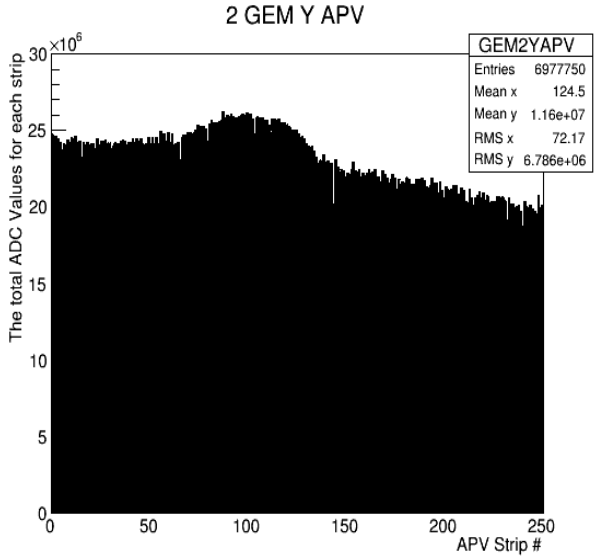








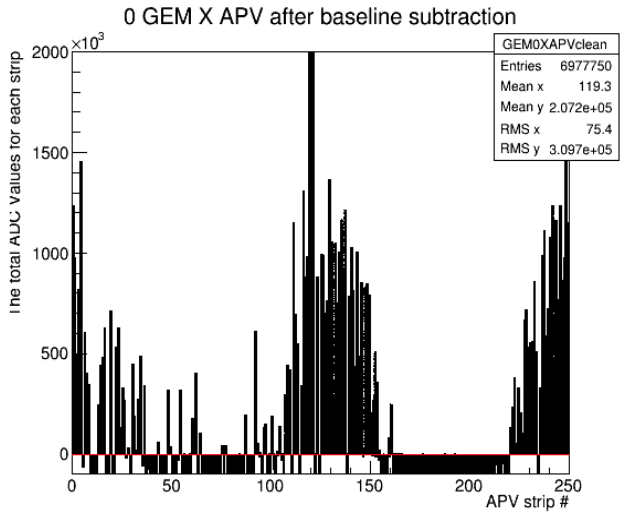


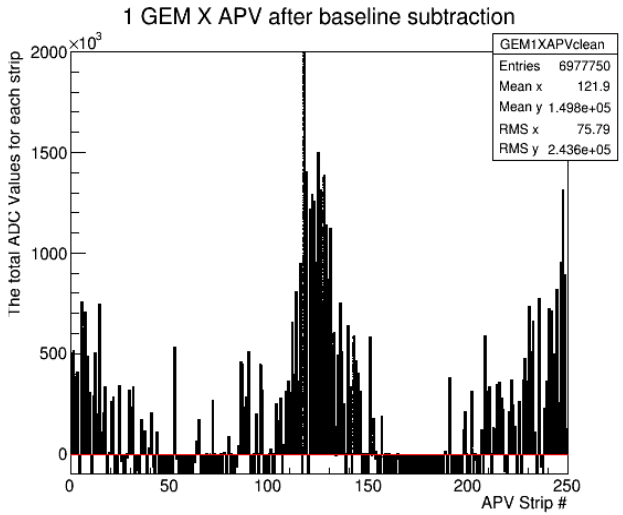


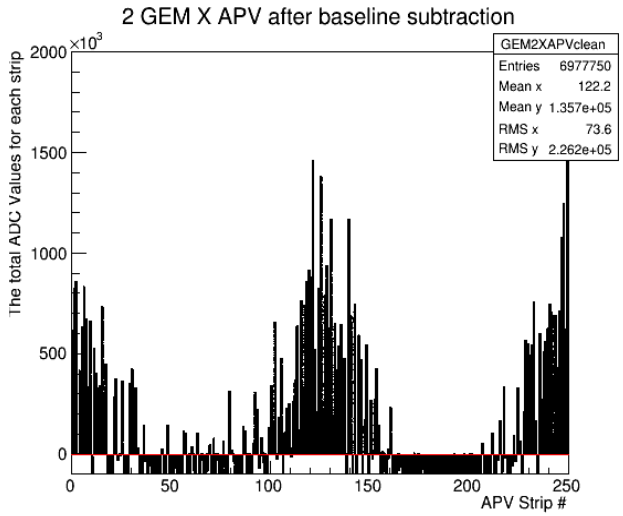
(1) Baseline subtraction (Older Method)

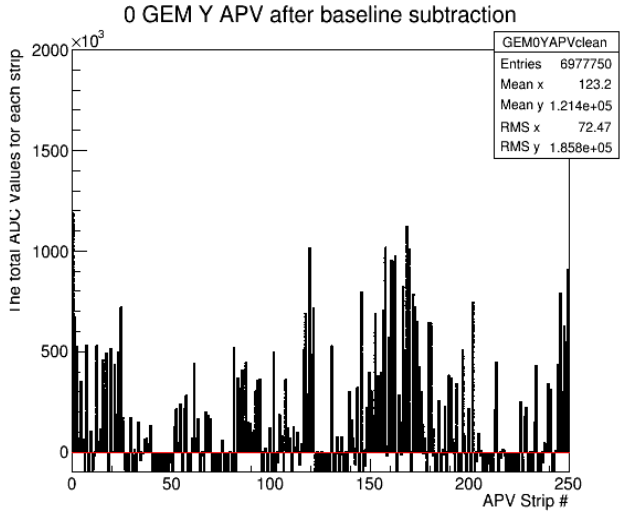
- Fit the ADC values vs strip # using the 1st order polynomial.
- Subtract the baseline determined from the fit function on each strip.
- Process in event by event.

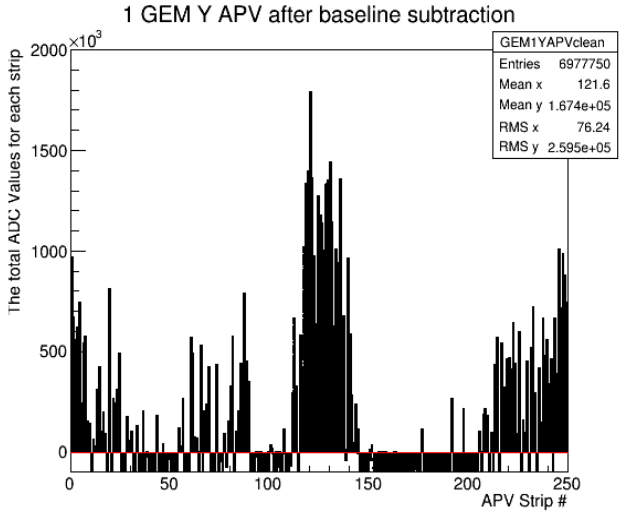
AThe total ADC on each strip after subtracting the baseline

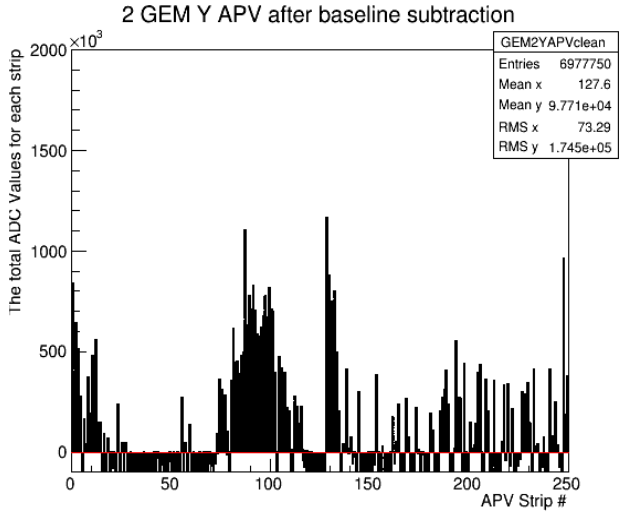








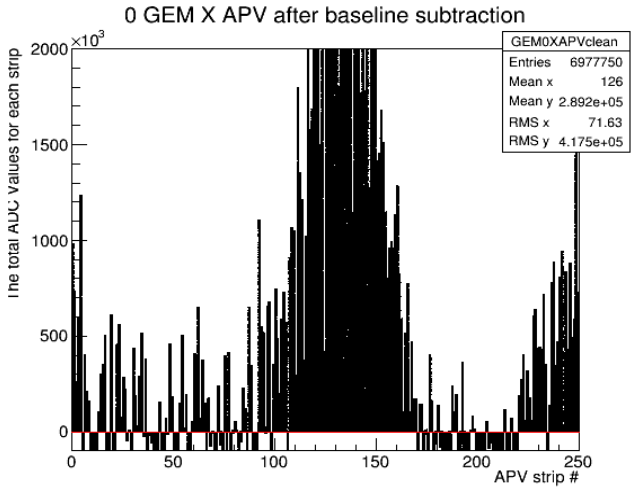


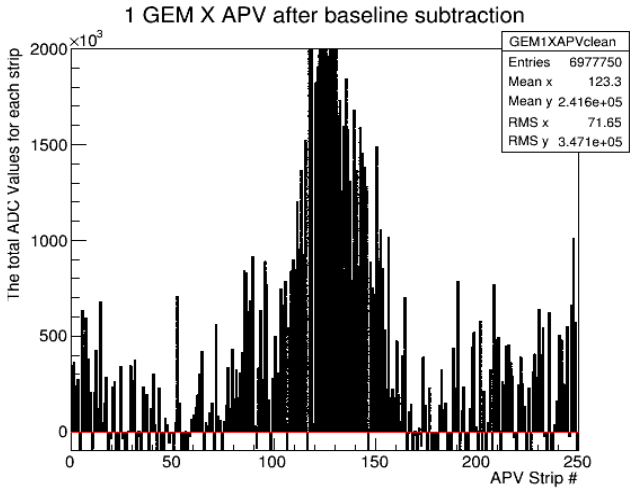


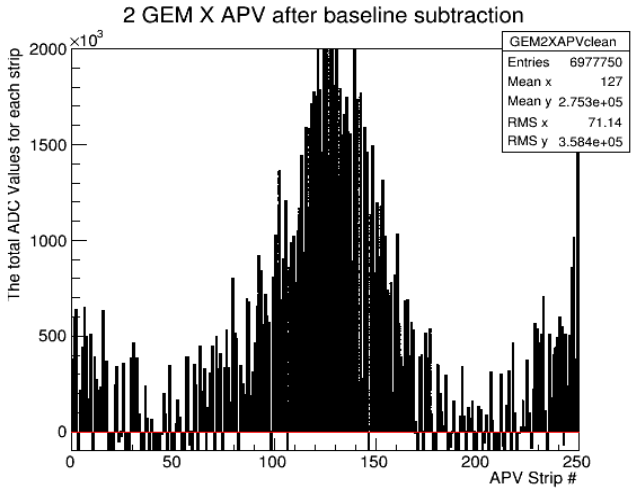
(1) Baseline subtraction (New Method)

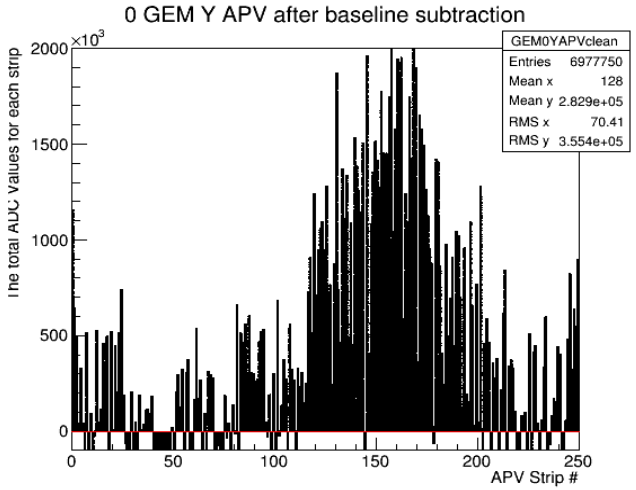
- Determined the strip,*Smax* which has the maximum ADC value.
- Fit the ADC values vs strip # “excluding the strips = *Smax* ±2” using the 1st order polynomial.
- Subtract the baseline determined from the fit function on each strip.
- Process in event by event.

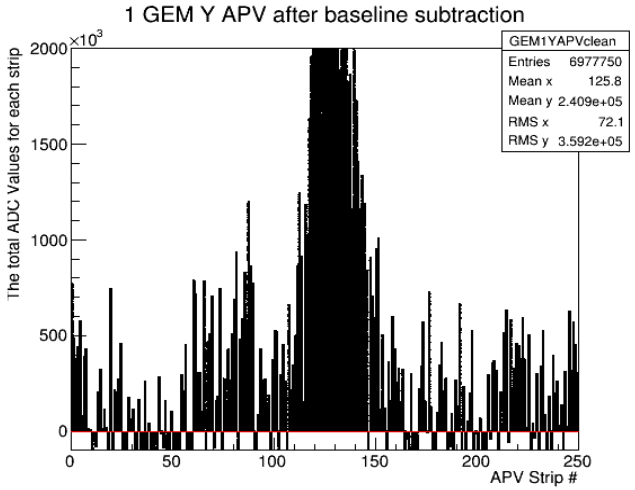
The total ADC on each strip after subtracting the new baseline

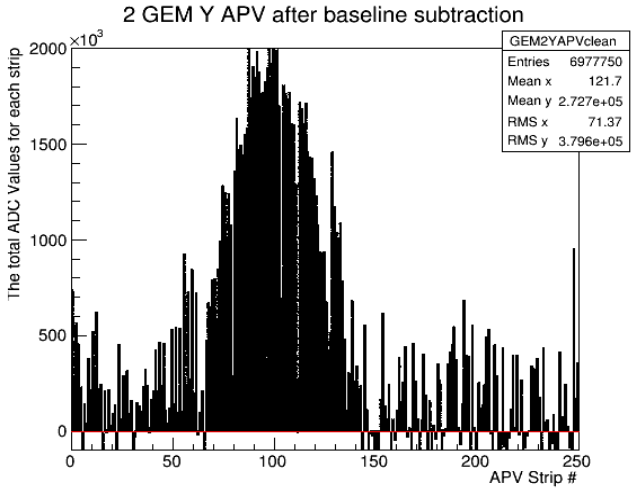






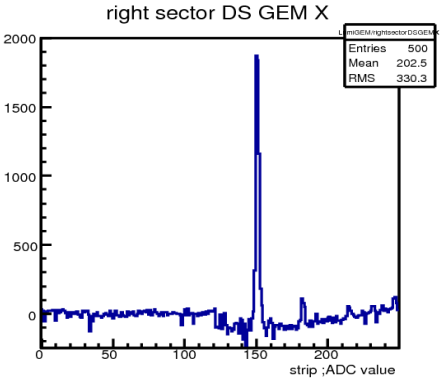


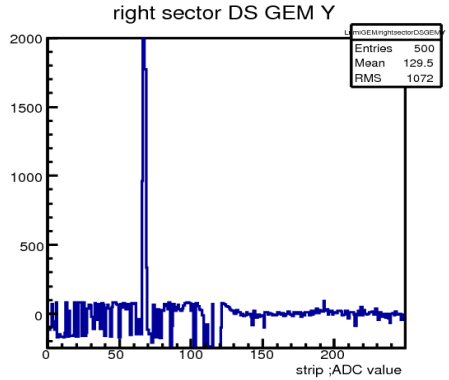


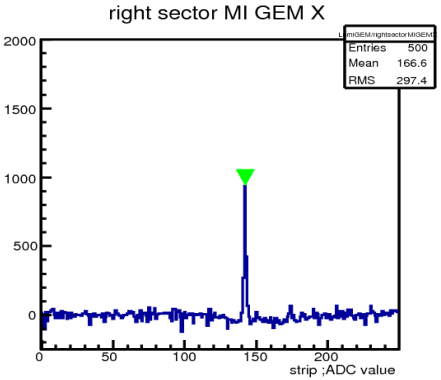


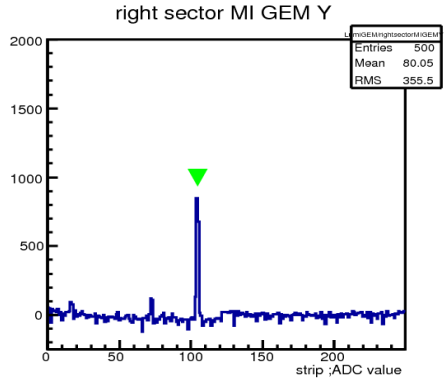
The comparison on the event display between the older method and the new method.

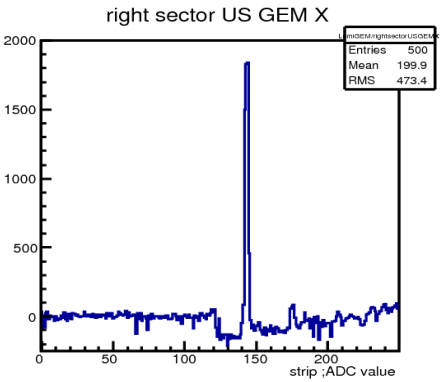
(Older Method)

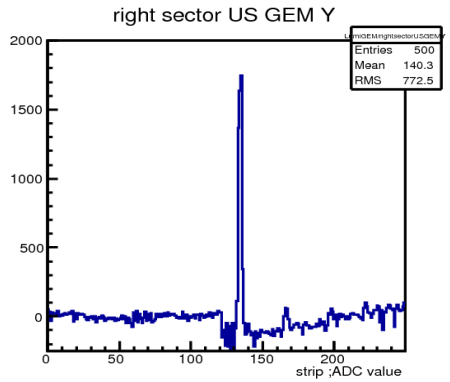




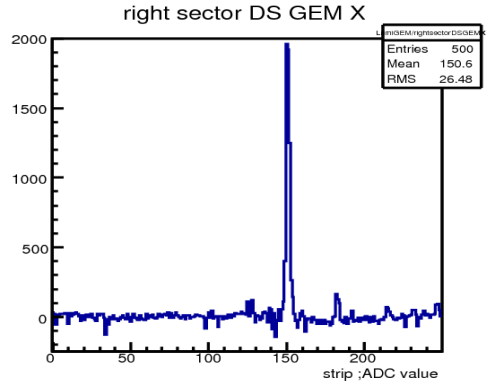


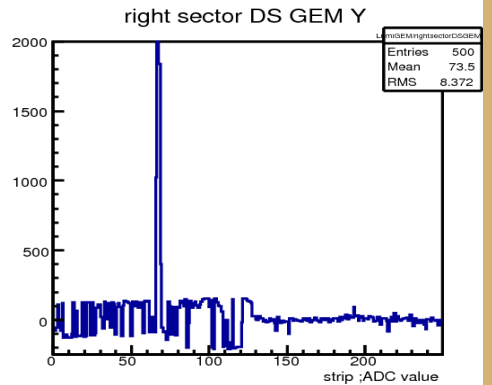


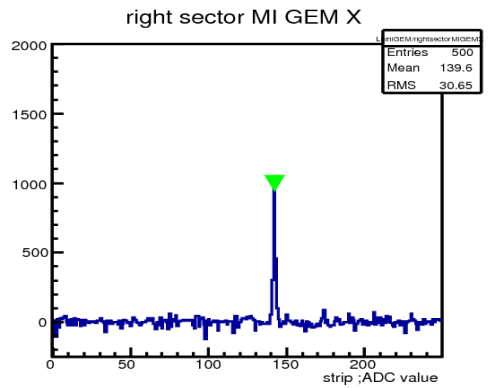


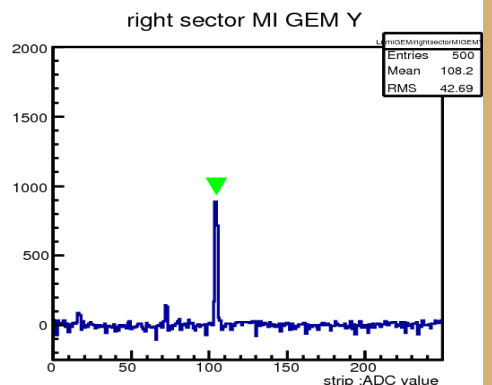


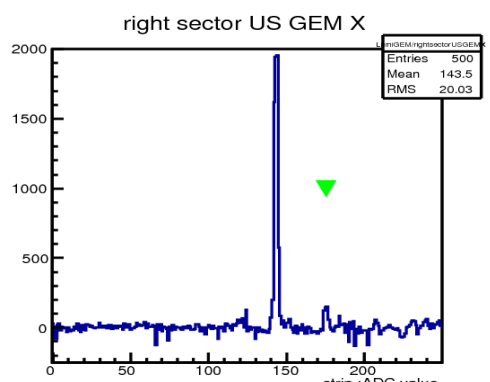
(New Method)

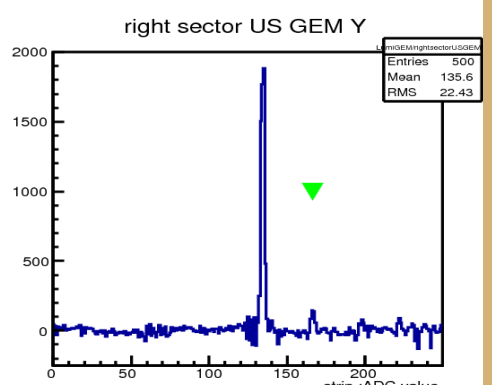






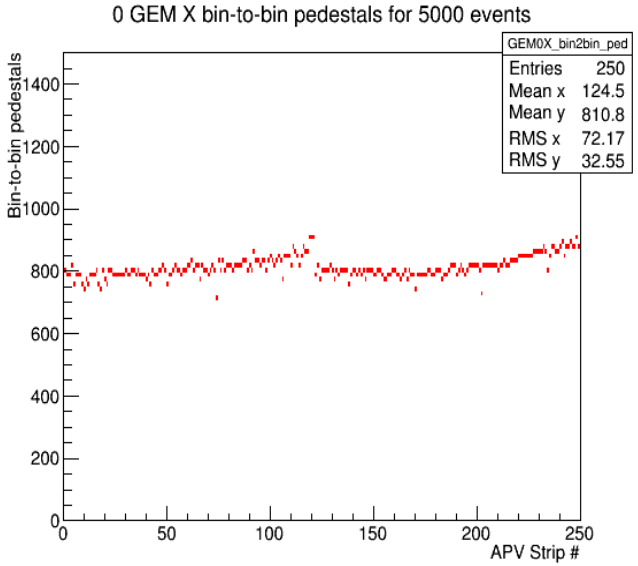


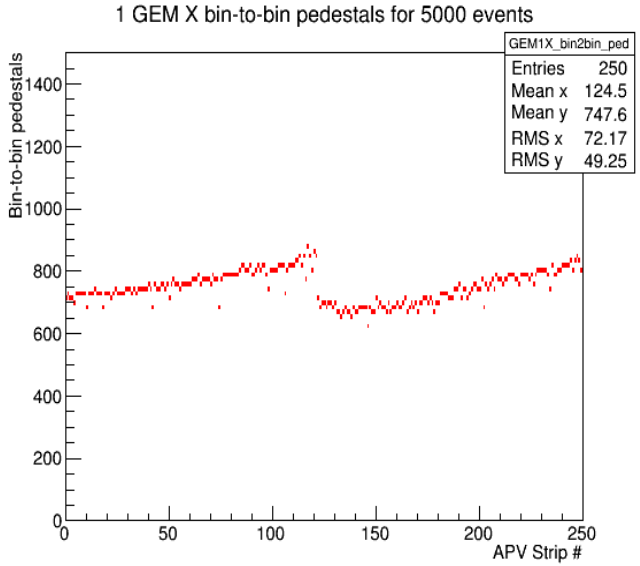


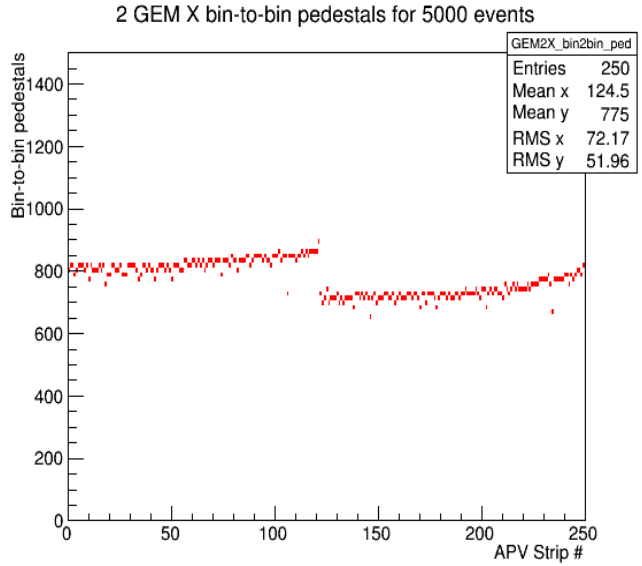


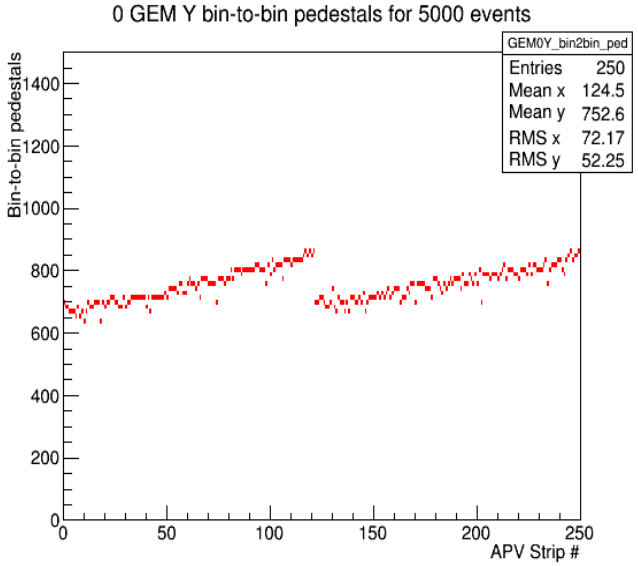
(2) Bin-to-bin pedestal subtraction.

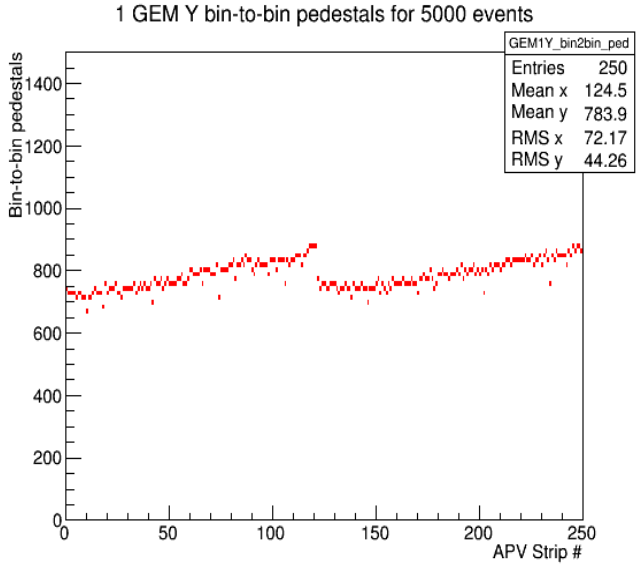
- The average ADC of 5000 events histogrammed for all channels.

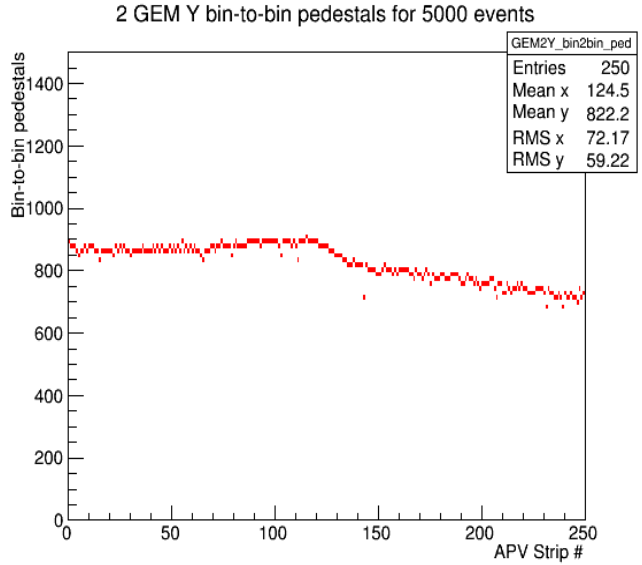






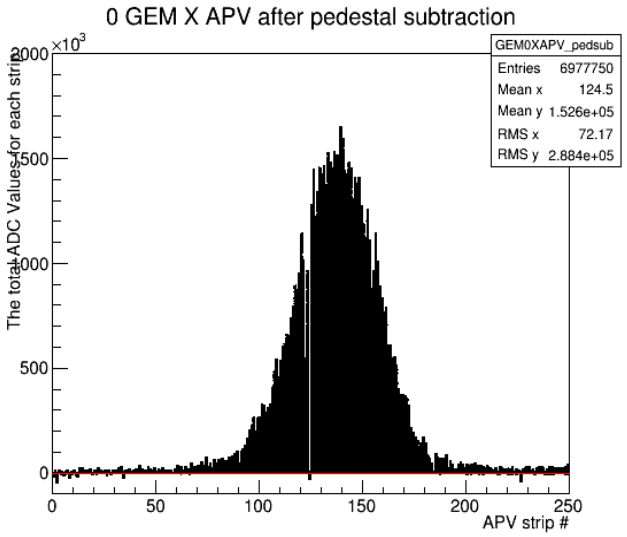


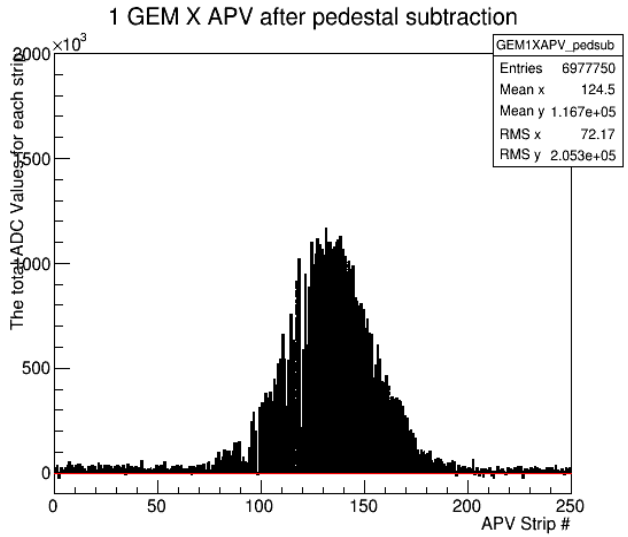


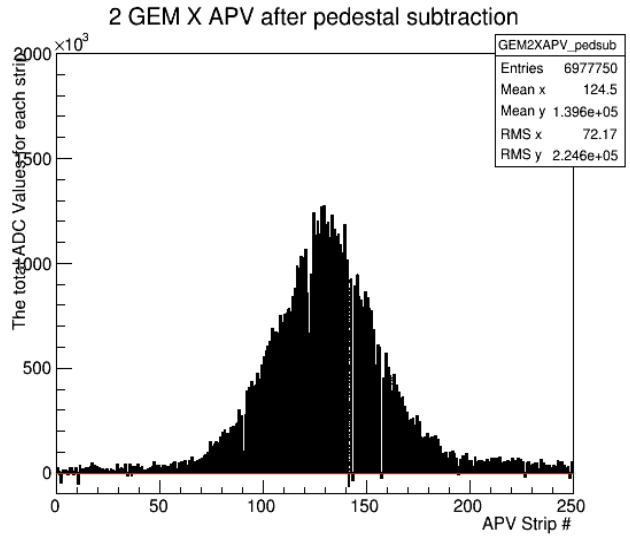


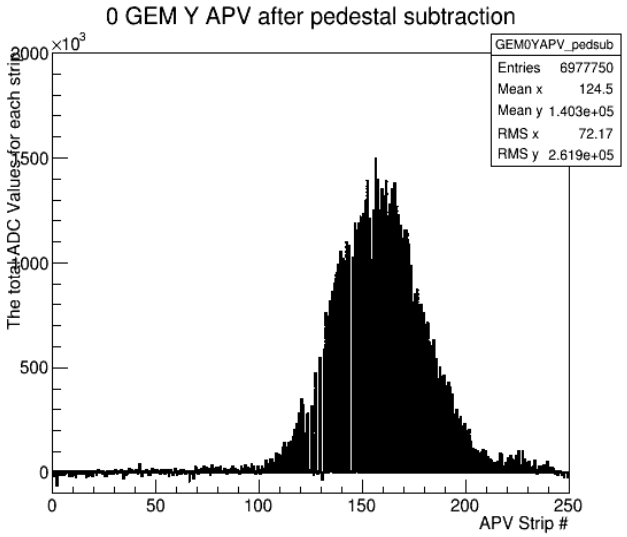
- The average ADC of 5000 events obtained for all channels. ->bin-2-bin pedestals.
- Subtract these pedestals from ADCs on each strip.
- Process in event by event.

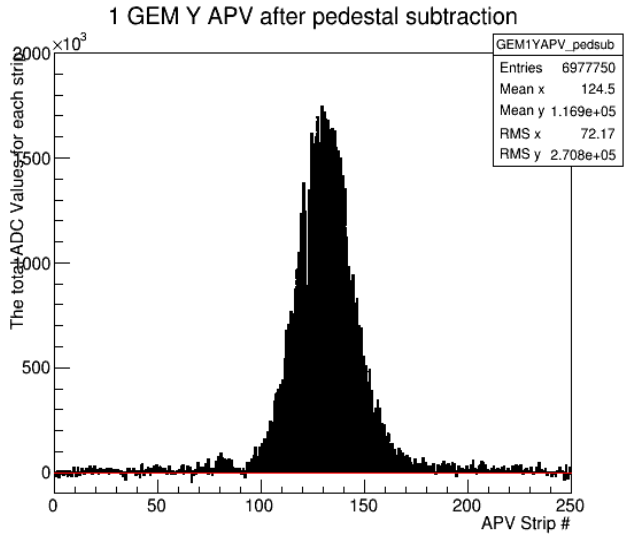
The total ADC on each strip after subtracting the bin-2-bin pedestals.

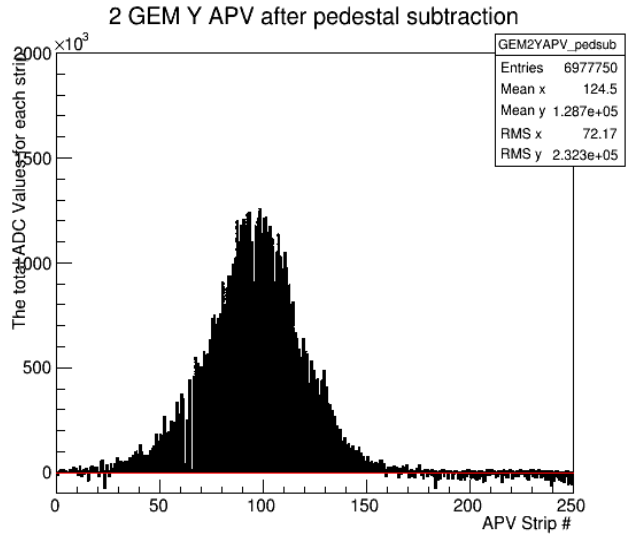








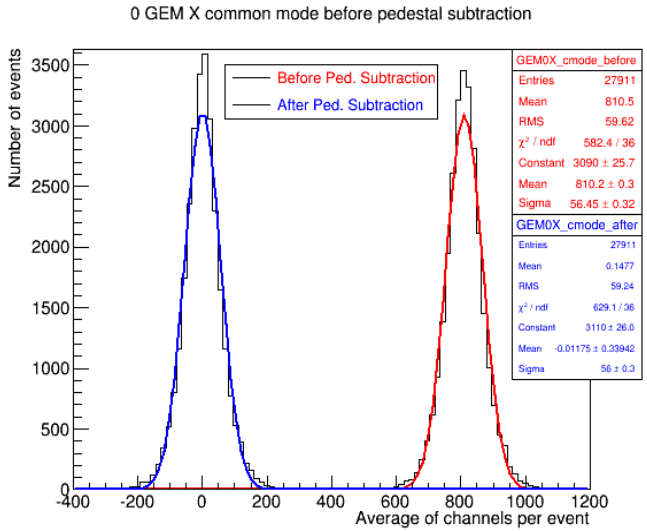


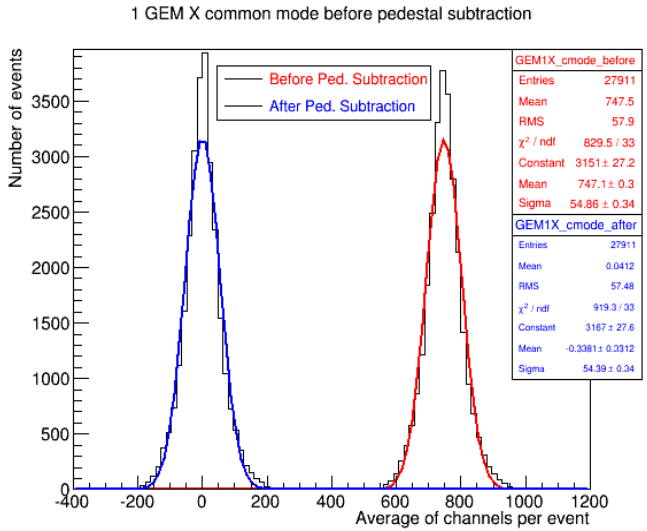


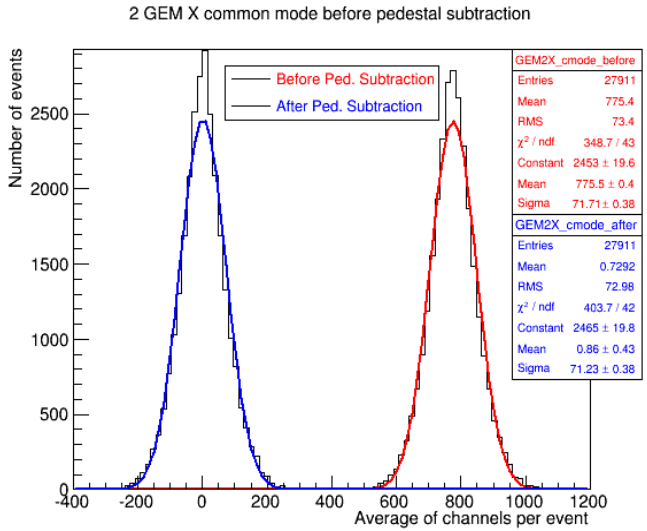
(3) Common-mode noise subtraction.

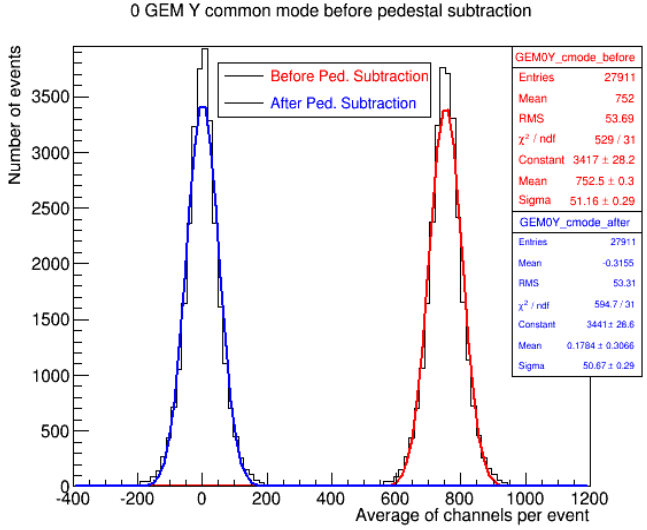
- Determined the strip, *Smax* which has the maximum ADC value.
- The average ADC of all the strips “excluding the strips = *Smax* ±2” histogrammed for
- many events.

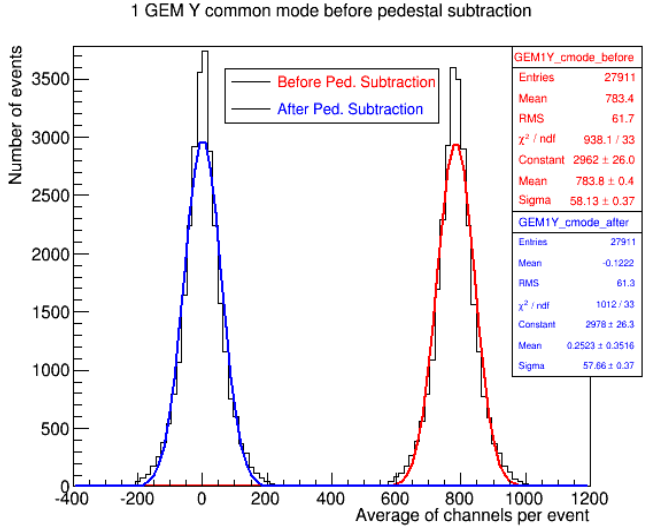
The common-mode noise before/after subtracting the bin-2-bin pedestals

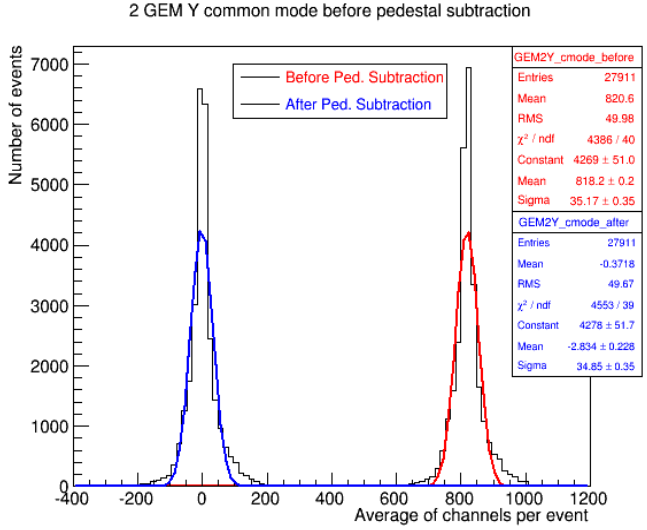




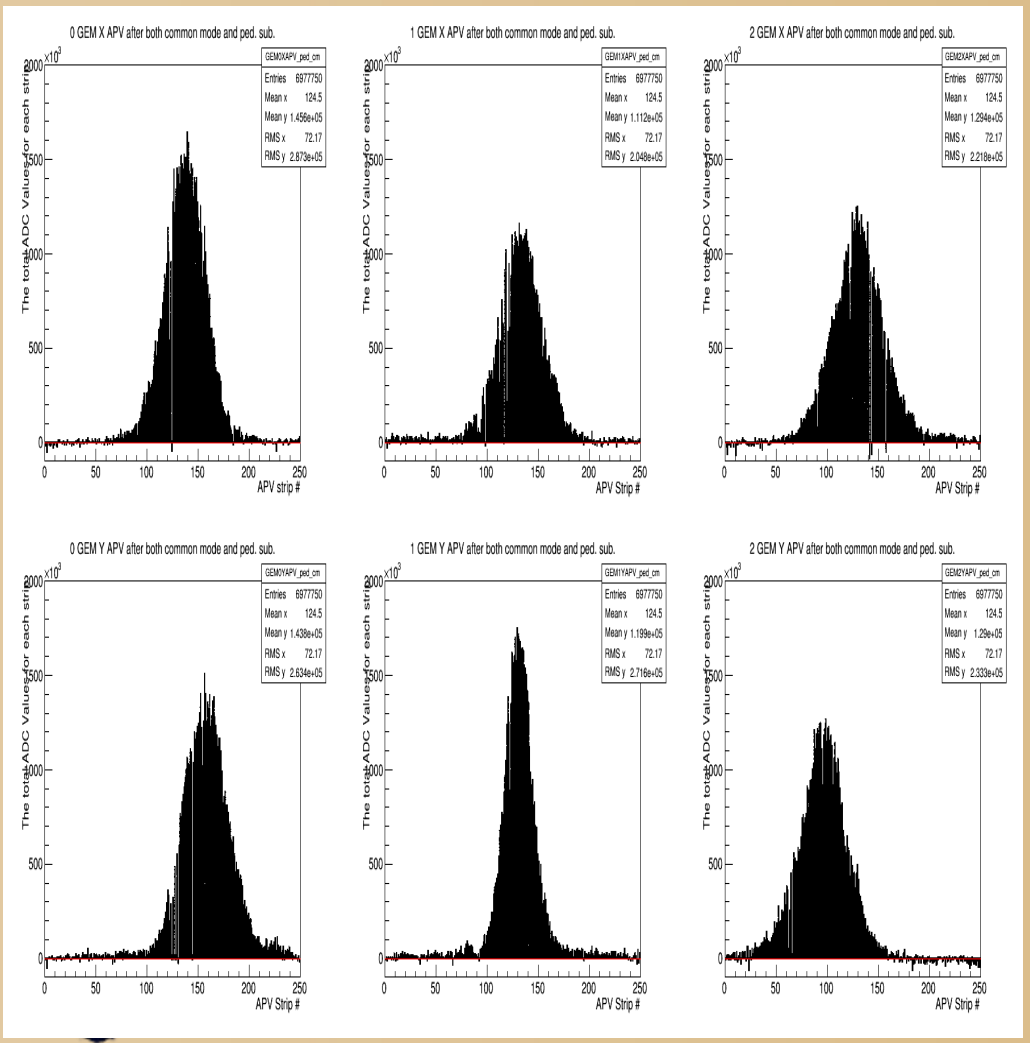


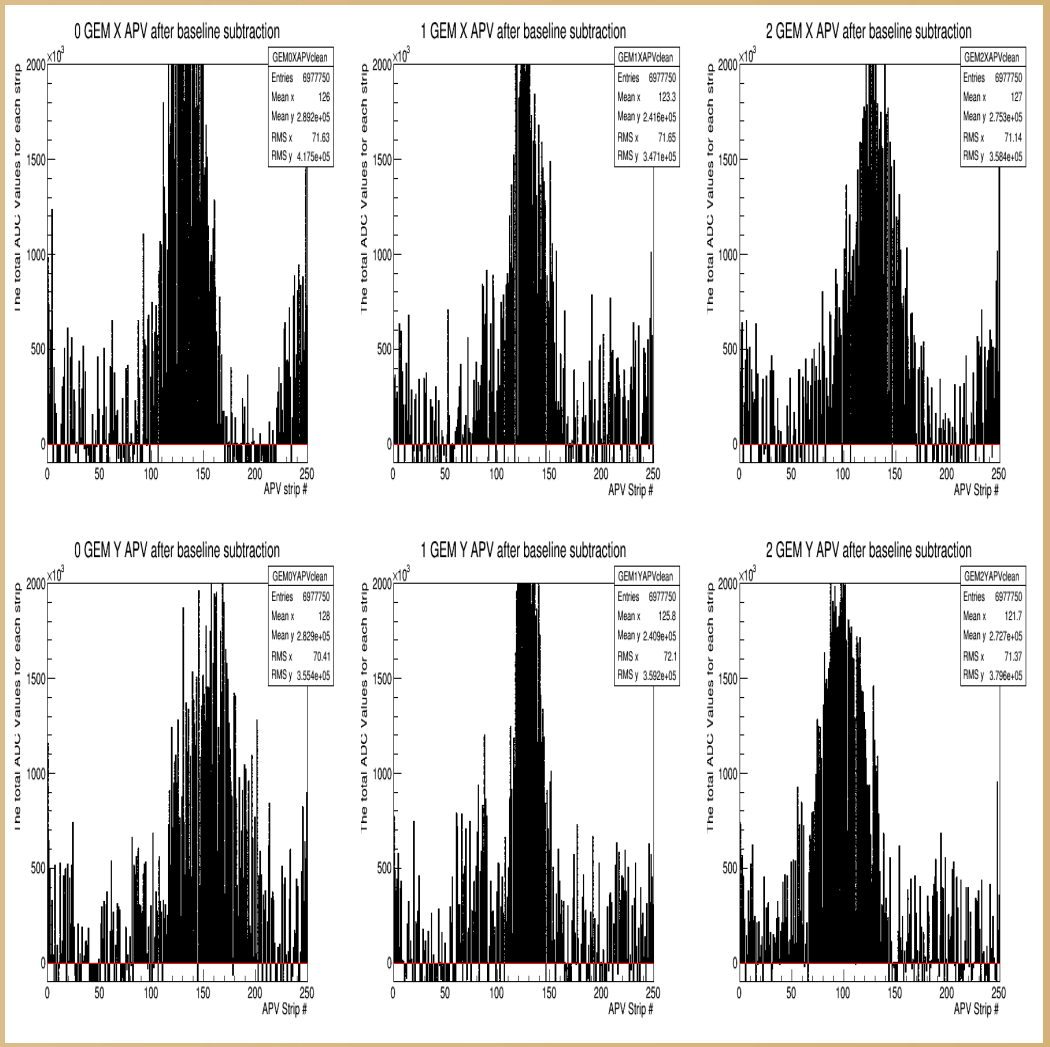






The total ADC on each strip after subtracting both the bin-2-bin pedestals and the common-mode noise (left) and after subtracting the baseline (right)



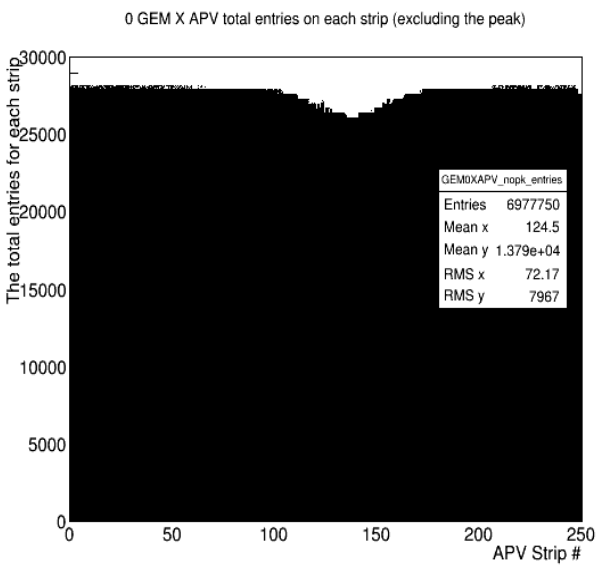


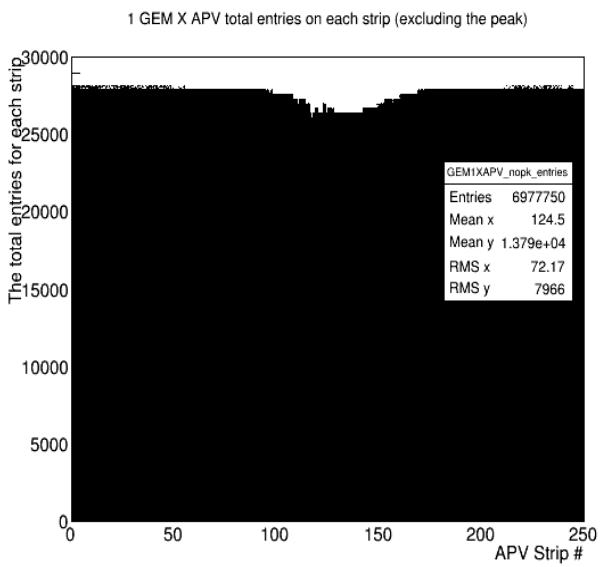
The bin-2-bin pedestal and common-mode subtraction works better than the baseline subtraction !

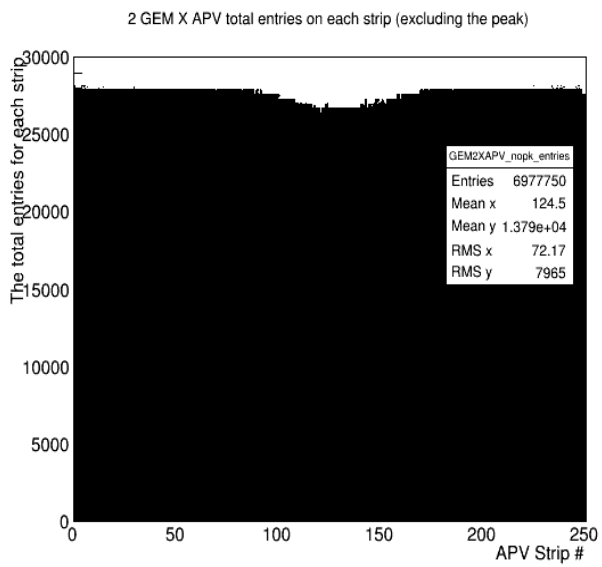
(4) Measurement of the noise.

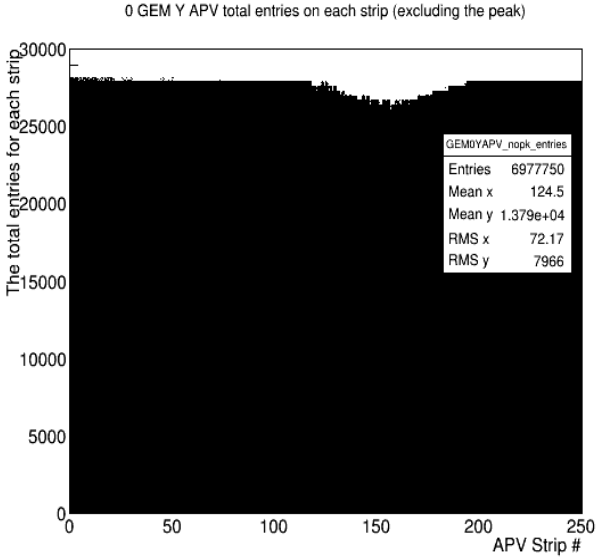
- Determined the strip, *Smax* which has the maximum ADC value.
- The average ADC for all the strips “excluding the strips = *Smax* ±2” histogrammed for many events.
- The Y projection (= the projection of the “grass” left and right of the peak) is obtained for,
  - No background subtraction.
  - Only baseline subtraction.
  - Only common-mode subtraction.
  - Only bin-2-bin pedestal subtraction.
  - Both bin-2-bin pedestal and common-mode subtraction.

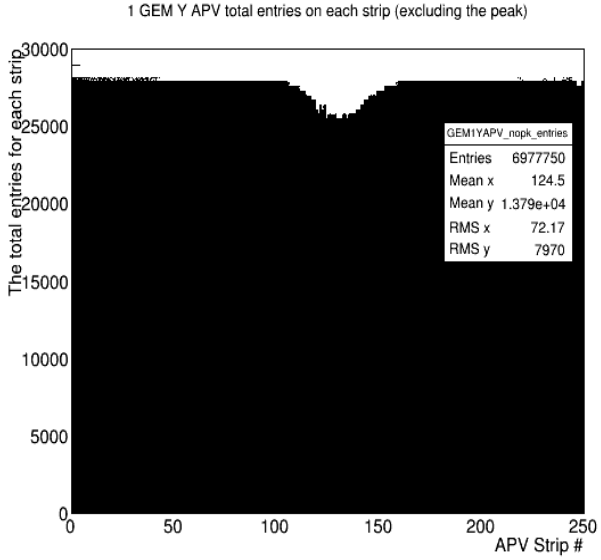
The number of total entries on each bin (excluded the cluster strips)

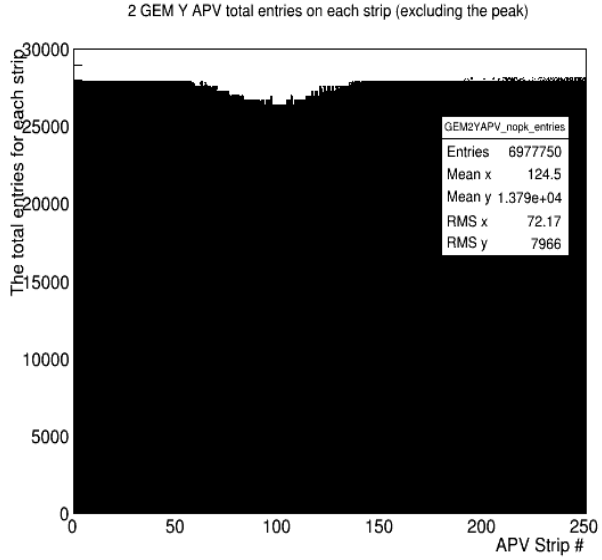






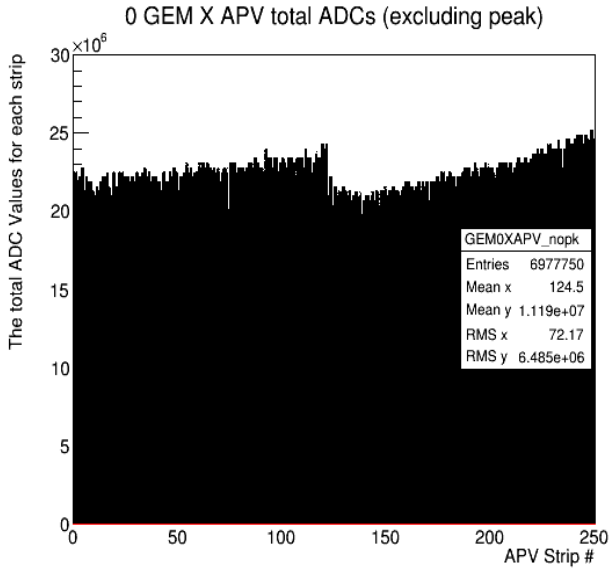


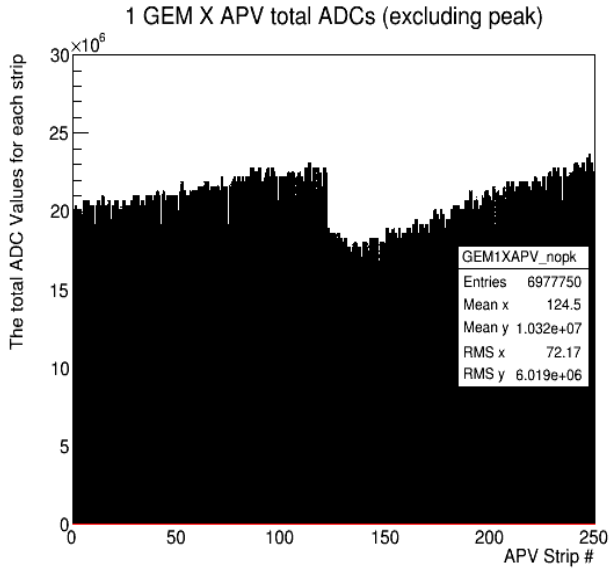


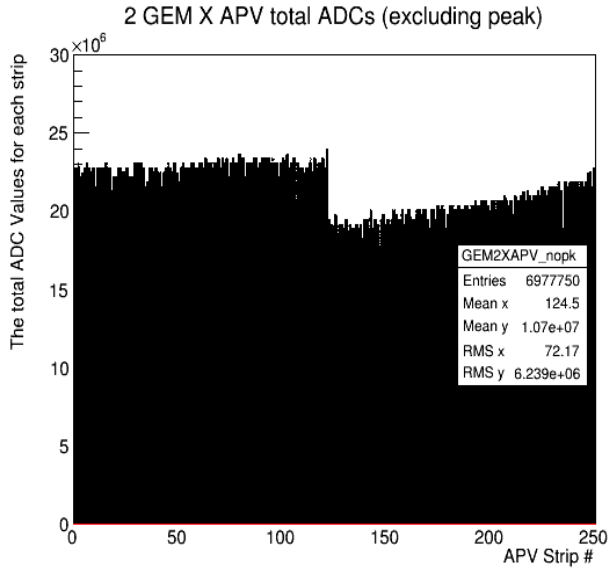


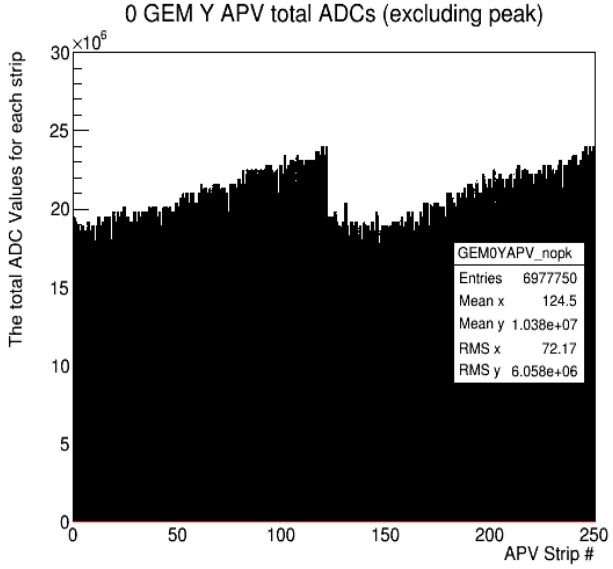
The sum of all ADCs on each bin (excluded the cluster strips)

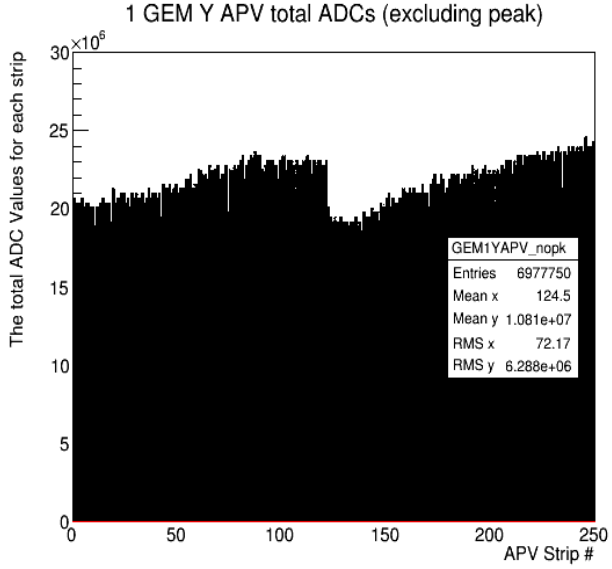
- No background subtraction.

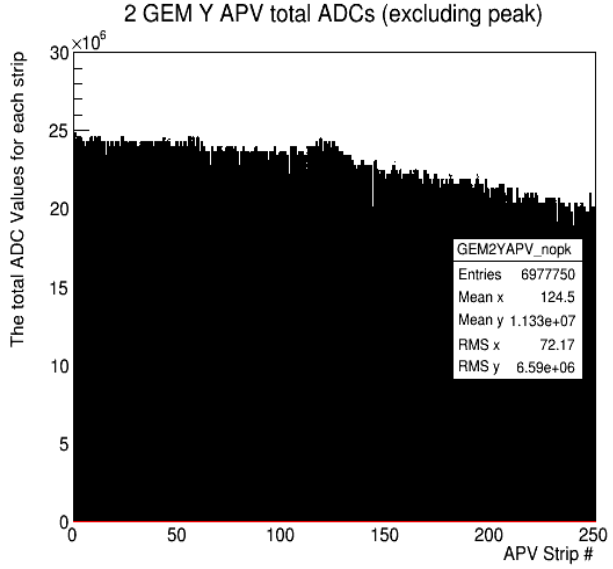




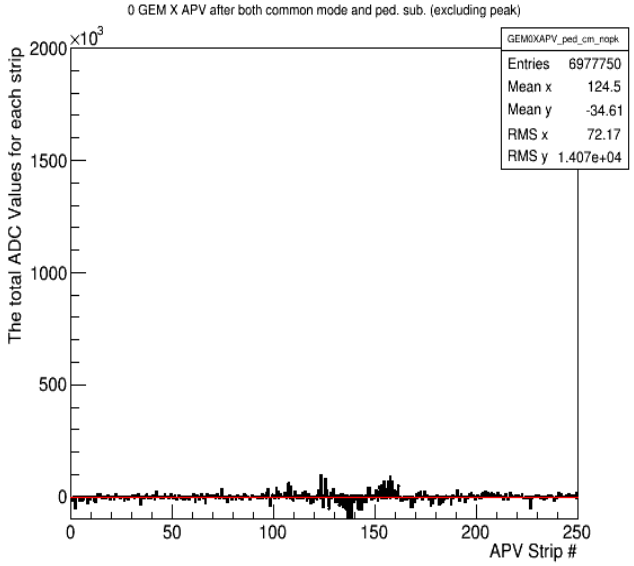


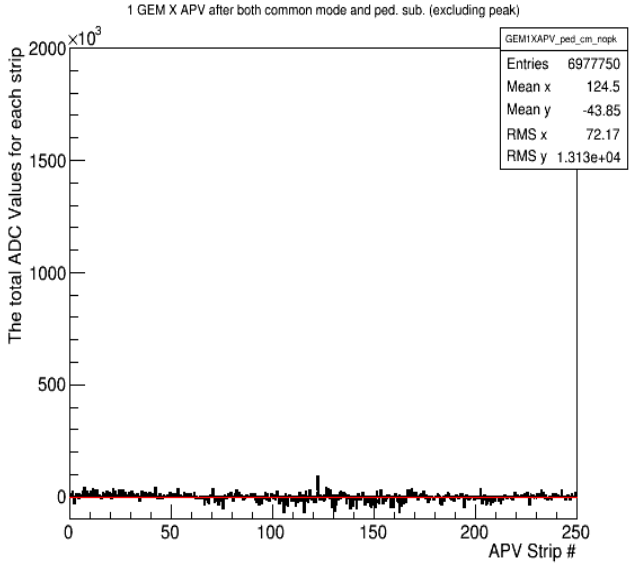


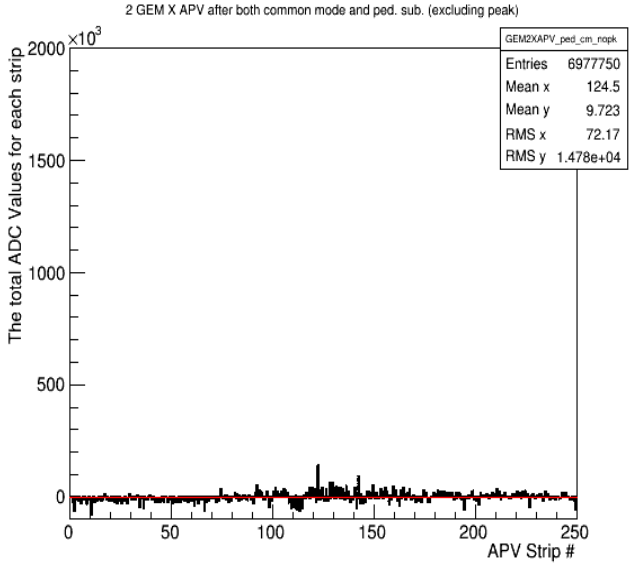


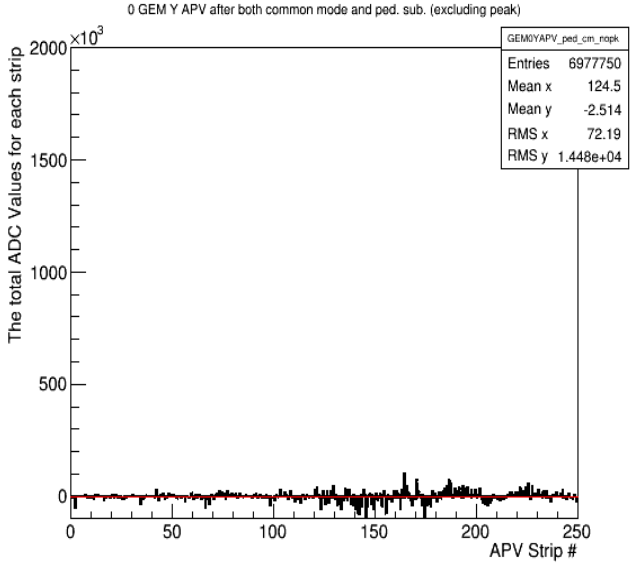


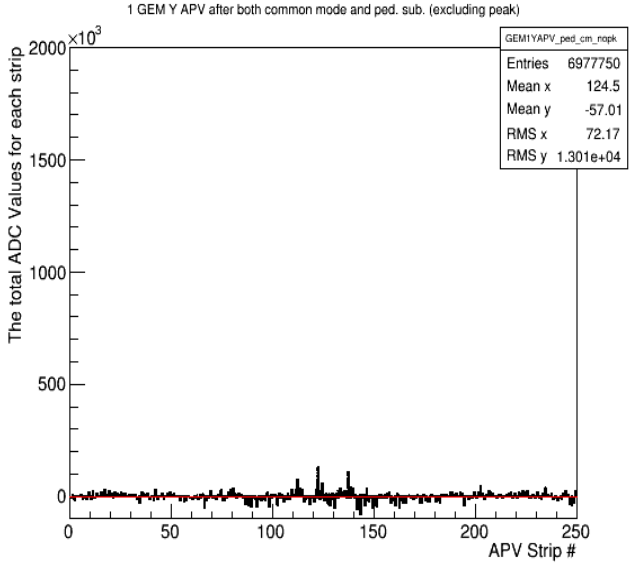
➔ Both bin-2-bin pedestal and common-mode subtraction.

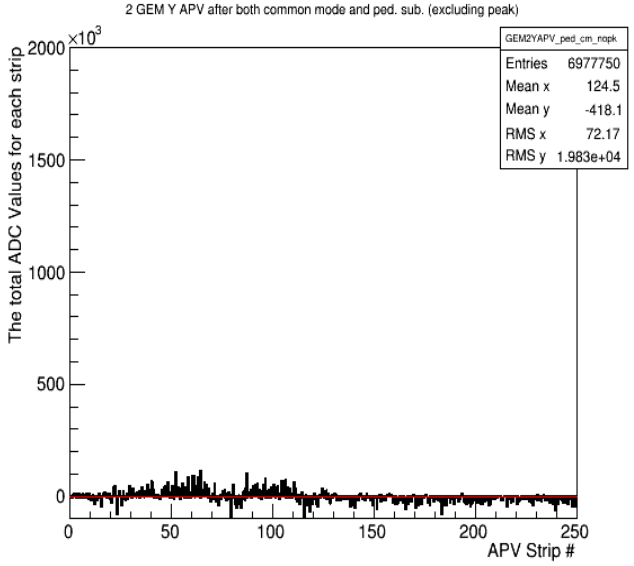






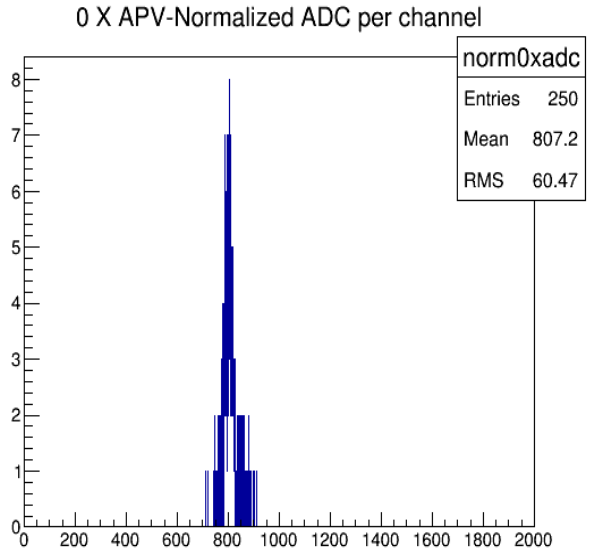


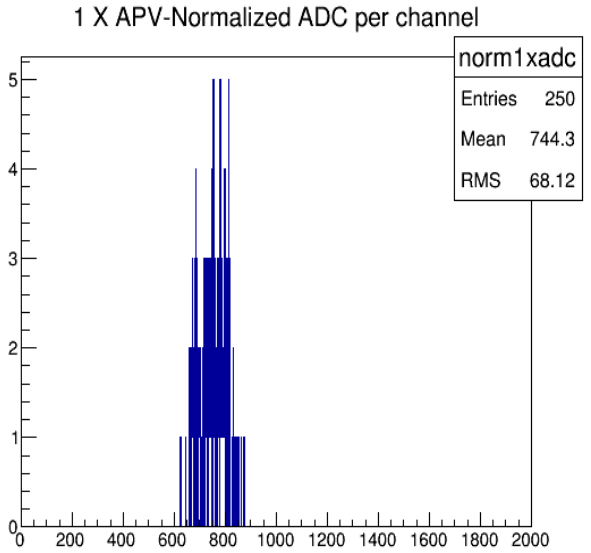


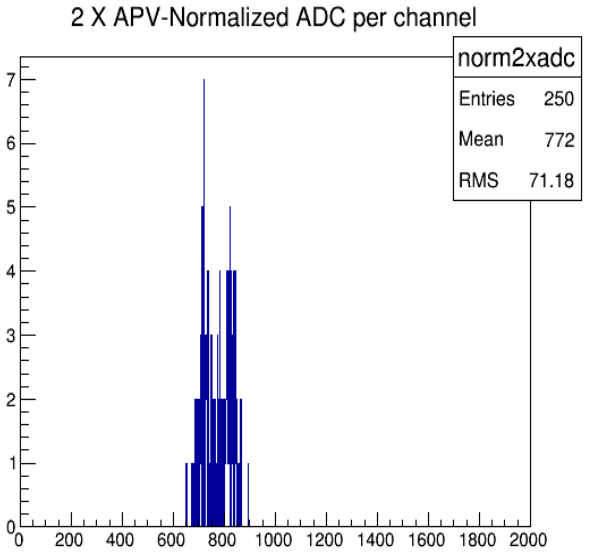


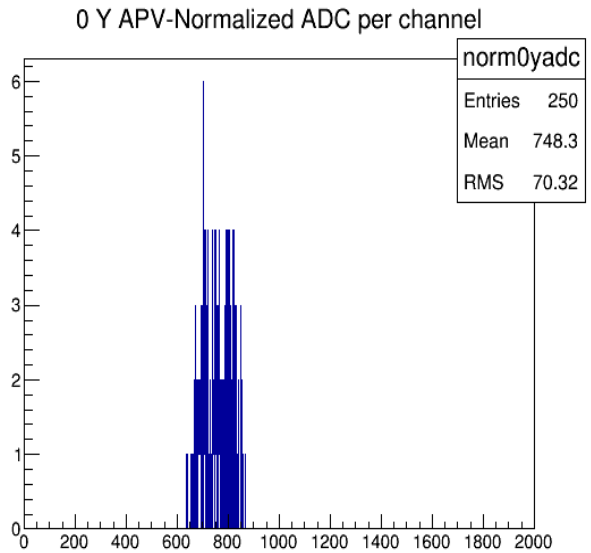
The variance of noise for raw ADCs (No background subtraction)

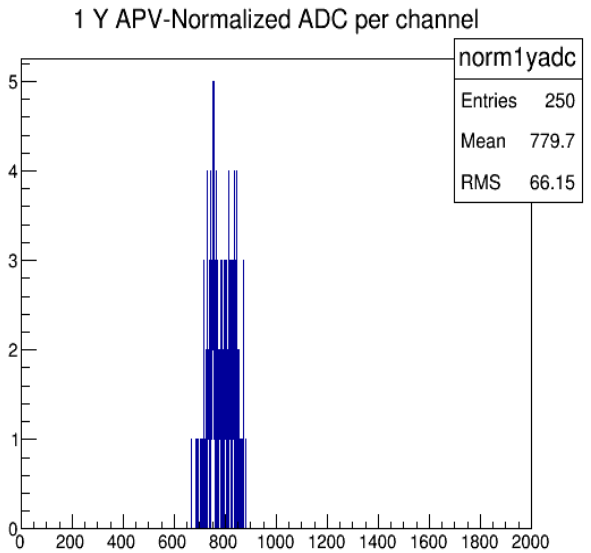
(in units of ADC channels)

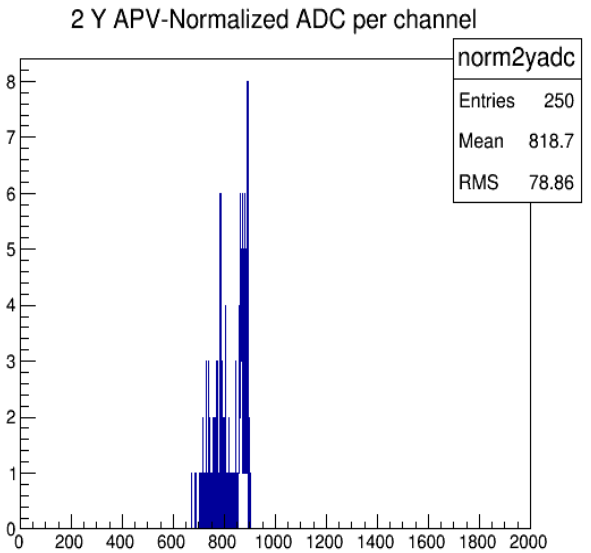








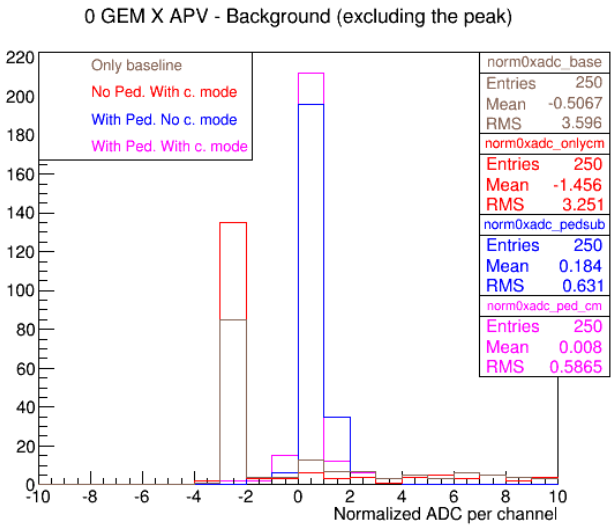


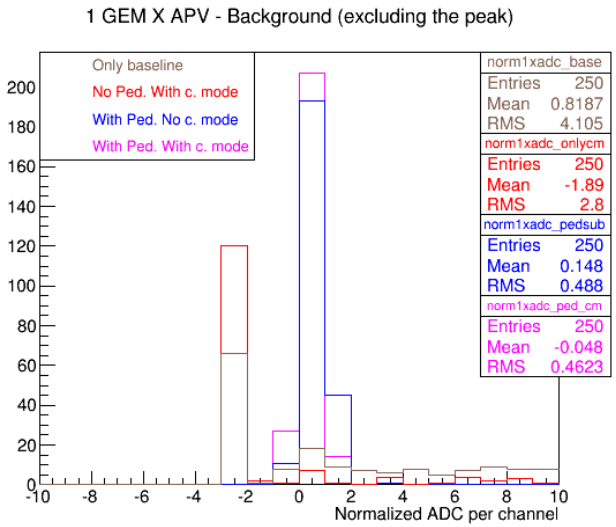


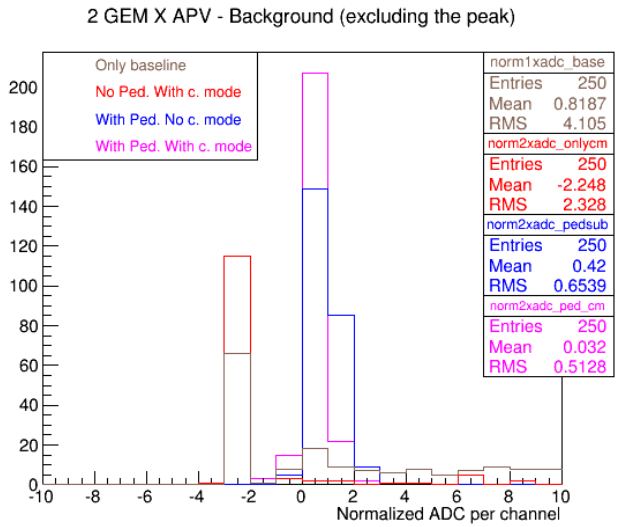
AThe variance of noise for

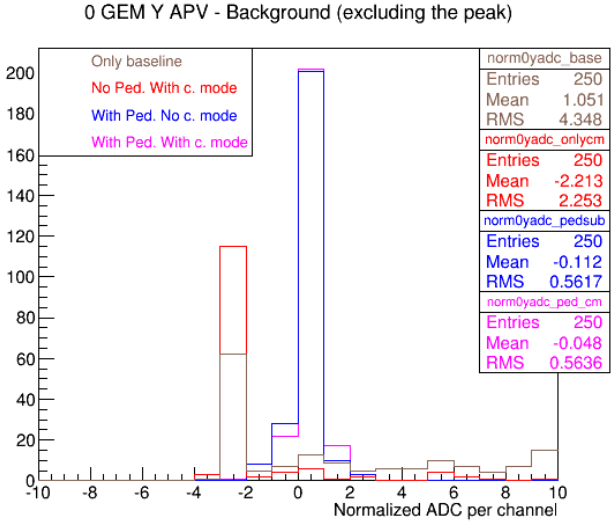
B
- Only baseline subtraction.
- Only common-mode subtraction.
- Only bin-2-bin pedestal subtraction.
- Both bin-2-bin pedestal and common-mode subtraction

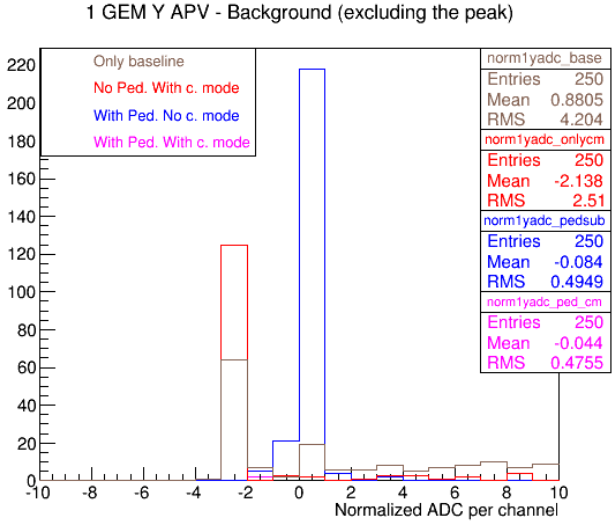
A(in units of ADC channels)

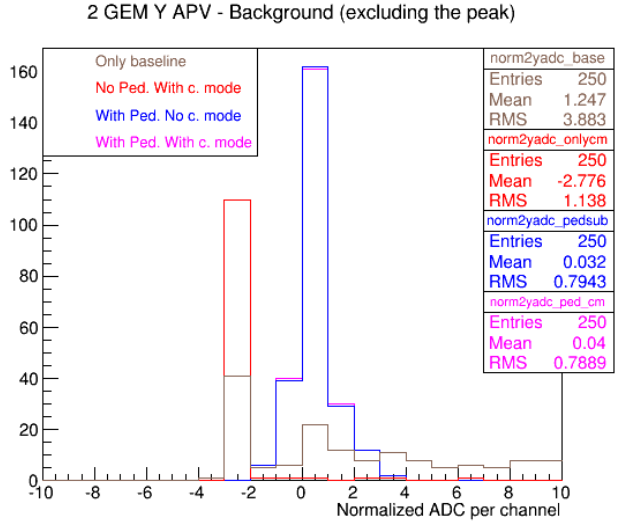












Conclusion

- Both common-mode and bin-2-bin pedestals subtracted, the 'grass' shows the smallest noise fluctuations.
- The bin-2-bin pedestal and common-mode subtraction work effectively than the baseline subtraction.

Will focus on ..

- Gain matching: After background subtraction, the distribution of average maximum bin values, fitted ampitudes, average subtracted ADC in every bin (normalized to entries) etc....