GEM High rate management

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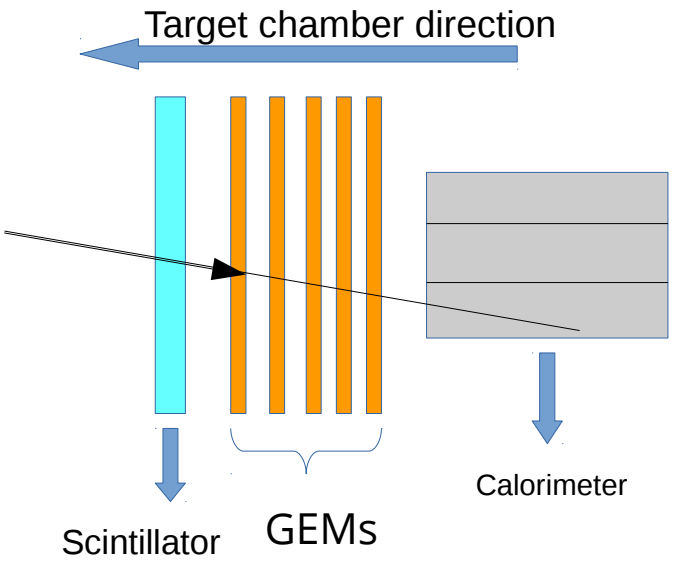
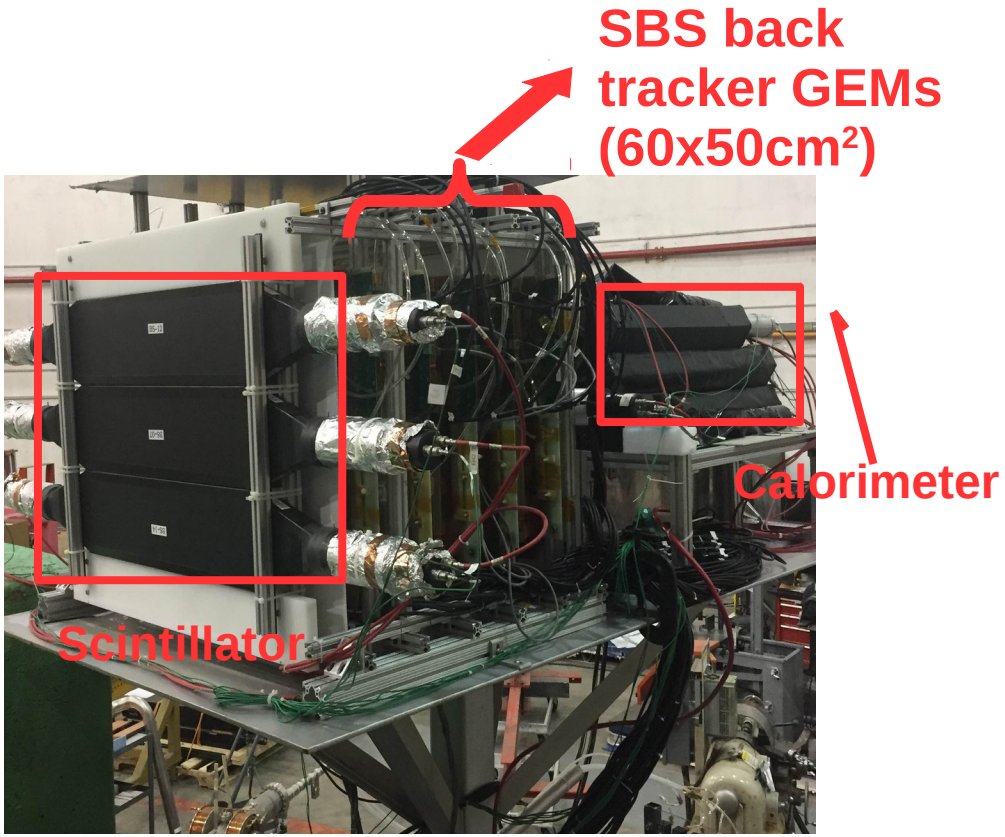
2017 SBS summer collaboration meeting

Review of GEM test in Hall A

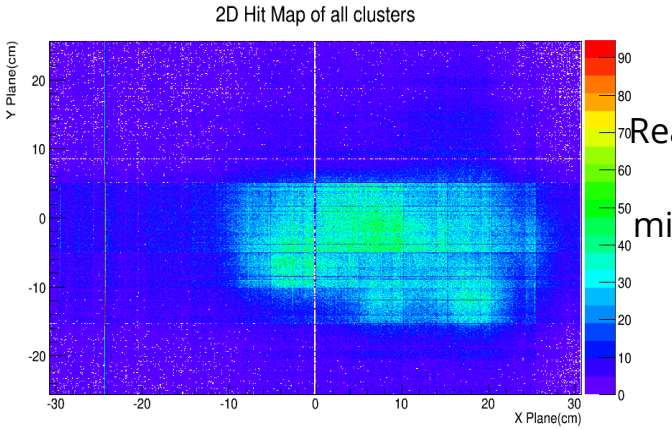




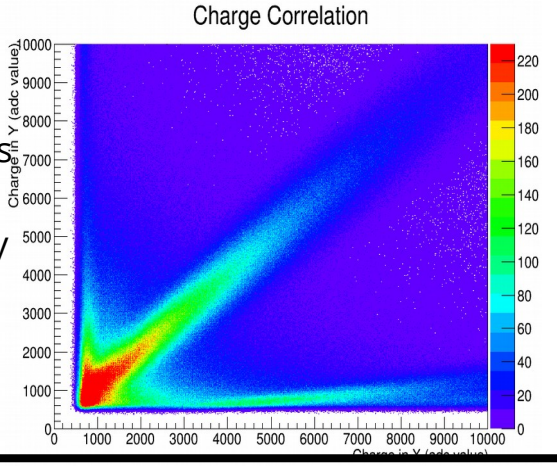
- Parastic test at 70° from beam in Hall A during DVCS/GMP experiment in Fall 2016.
- 5 60x50 cm SBS GEM modules spaced by ~13 cm.

- Gas mixture: Ar/CO^2 (75/25%) at flow rate ~5L/h
- GEM HV: ~4100V
- Triggered area: 30x30 cm^2
- The occupancy of GEMs during test was around 1.5%.

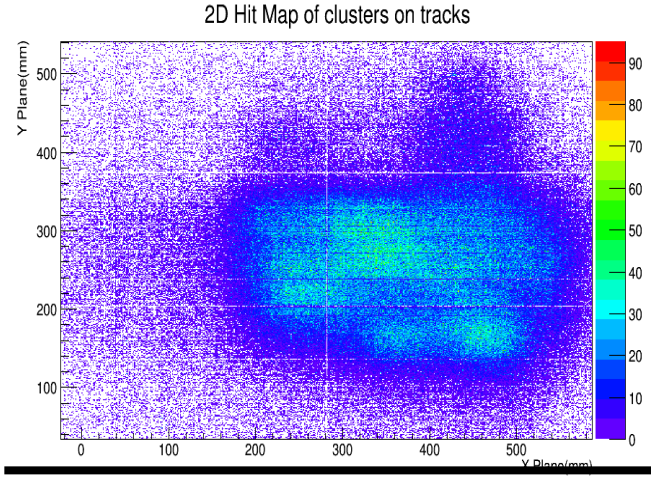
A practice run in Hall A at JLab



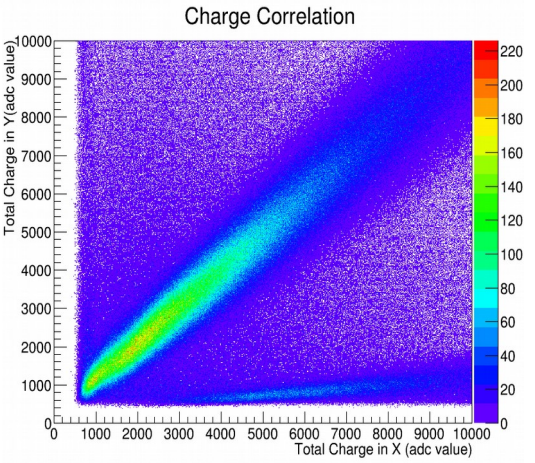
Real hits buried in accidental hits and cross-talk clusters and mismatching clusters(incorrectly paired x/y clusters)



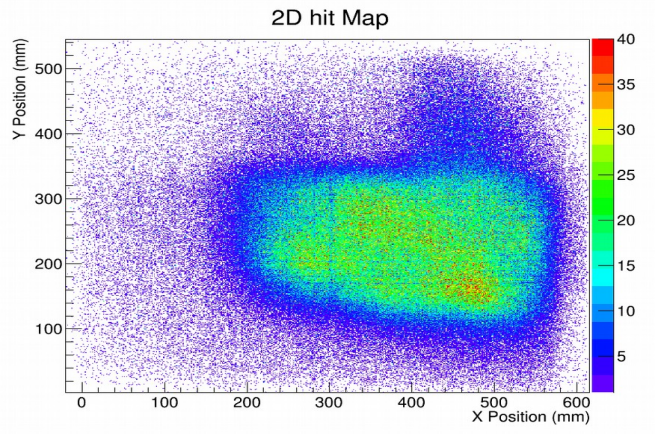
Do timing cut and tracking in x/y plane

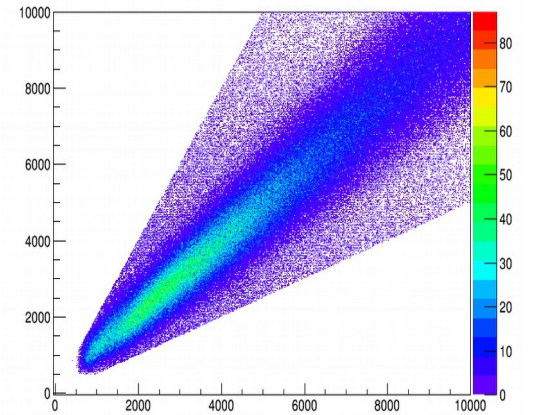


Real hits,
small part of accidental hits,
cross-talk clusters and
part of mismatching clusters



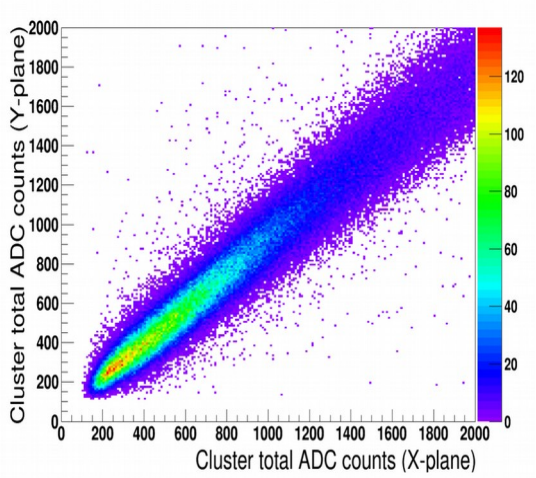
Apply cut in charge correlation and timing correlation



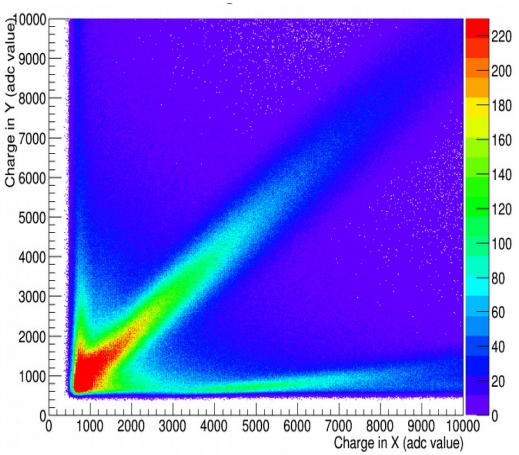


A practice run in Hall A at JLab

^{90}Sr data

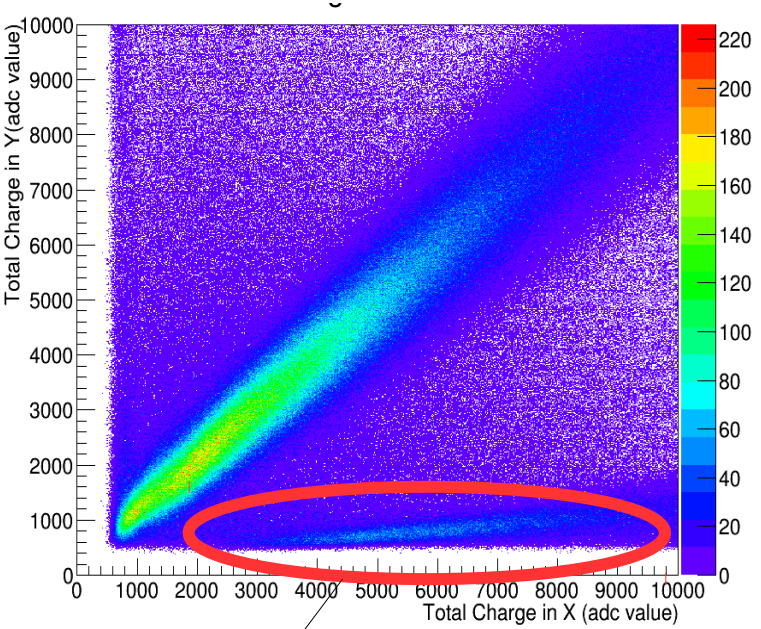


Hall A test data



Due to Mismatched clusters and cross talk

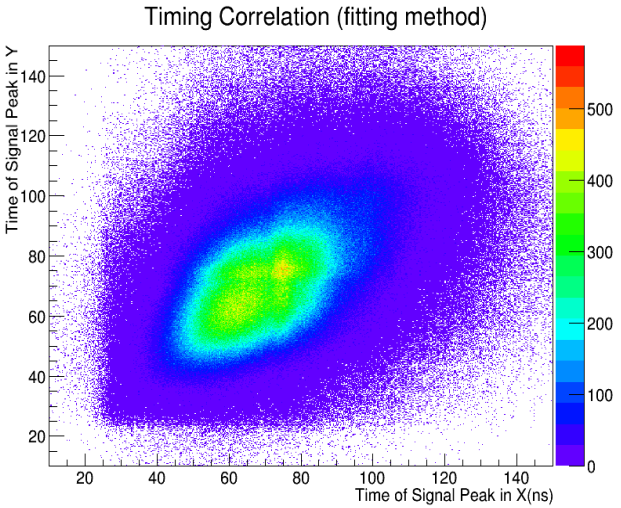
Hall A test data after tracking rejection



Electronics cross talk to remove

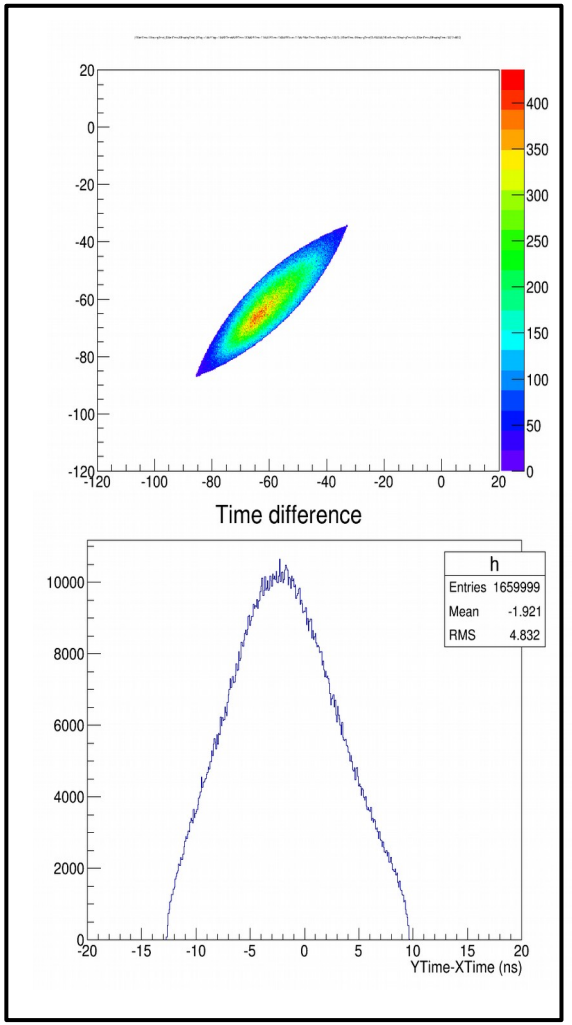
A practice run in Hall A at JLab

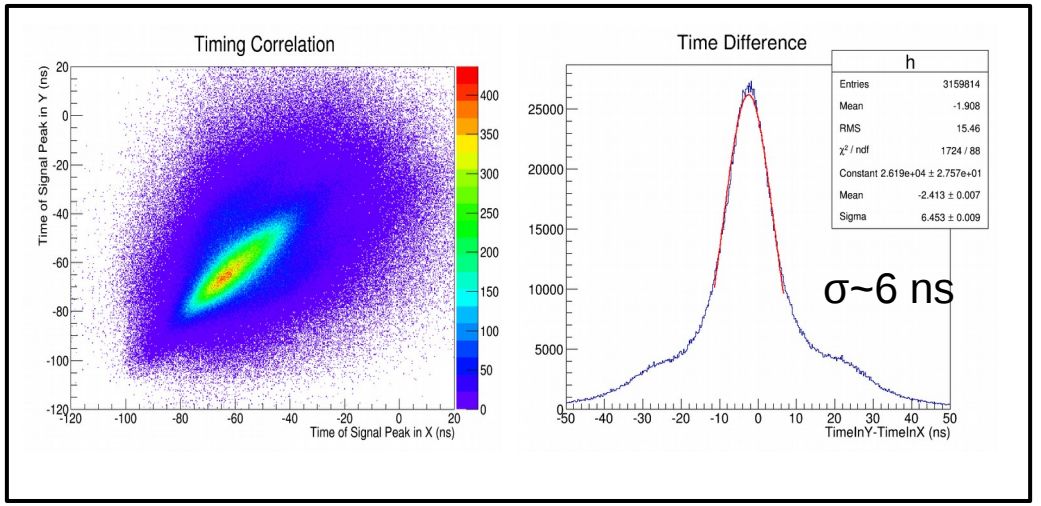
From fit of 6 time sample



Correcting the phase of trigger in APV clock

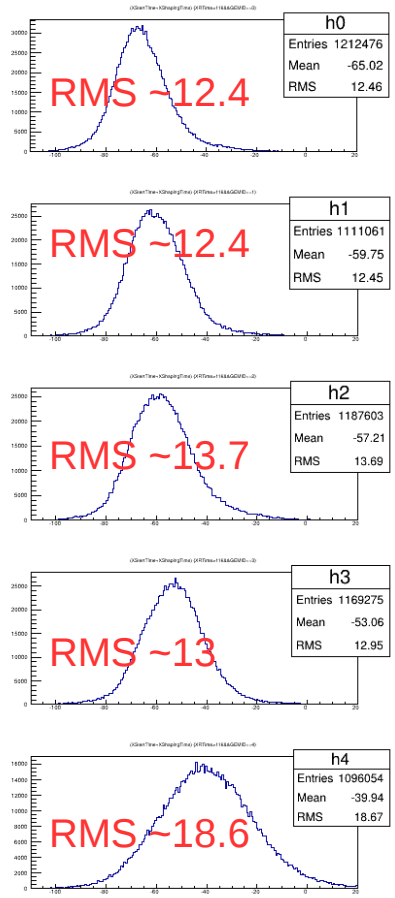
Cut off weakly timing correlated clusters





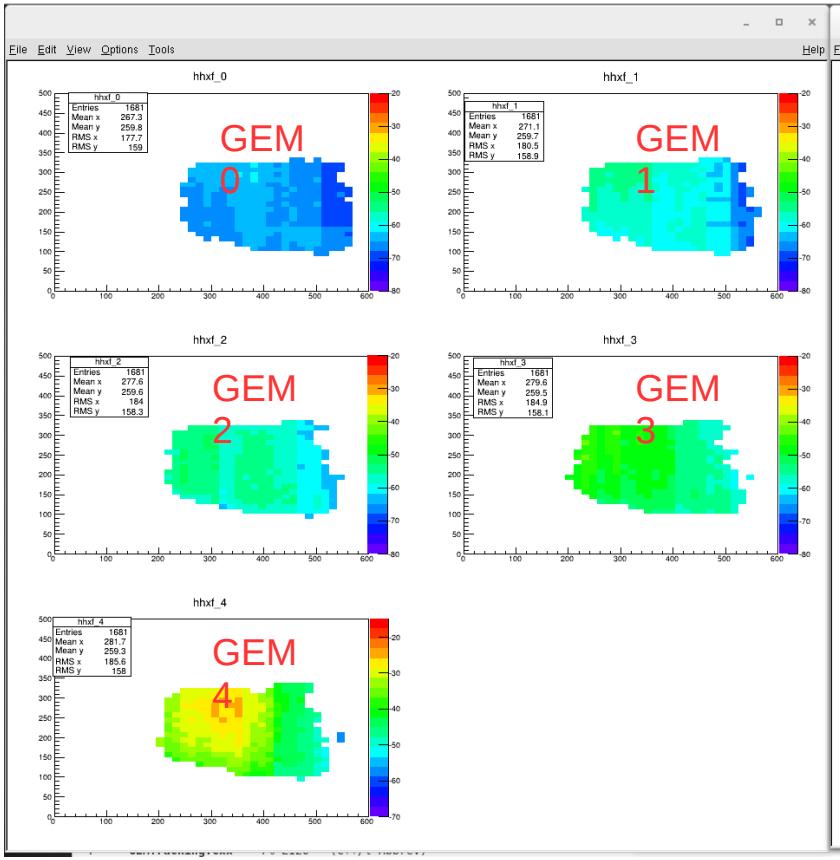
Before correcting localized offset

Overall Time distribution

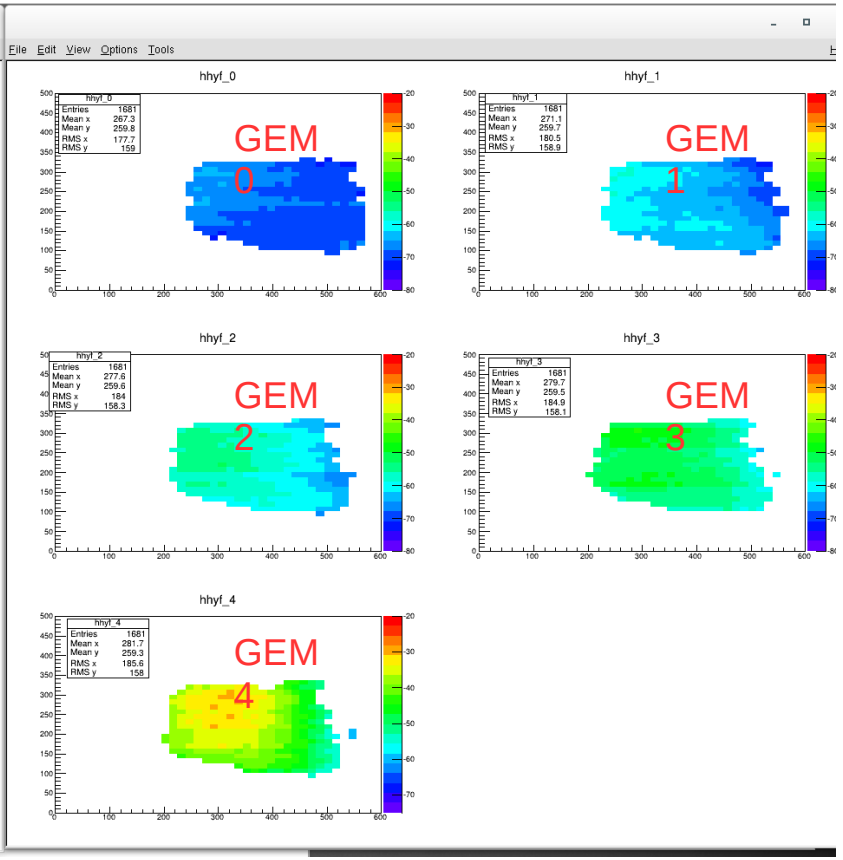


Localized Time distribution

Peak time in X

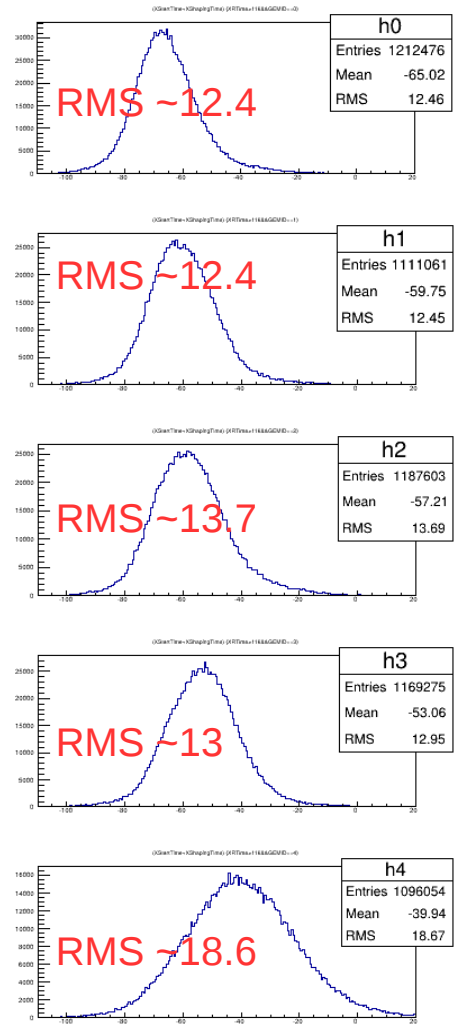


Peak time in Y

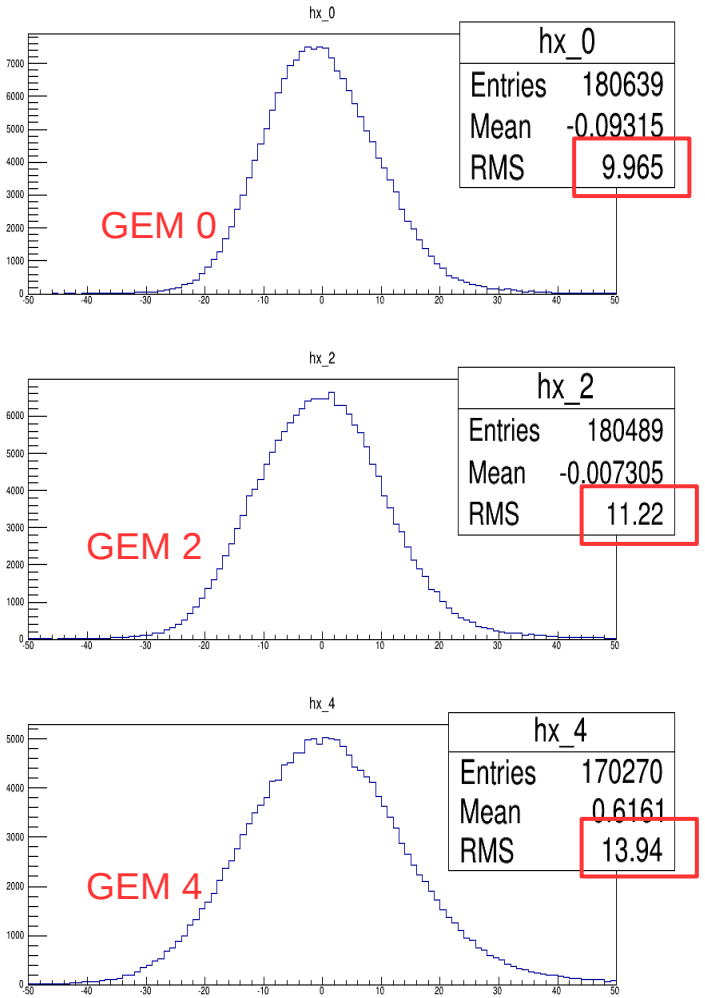


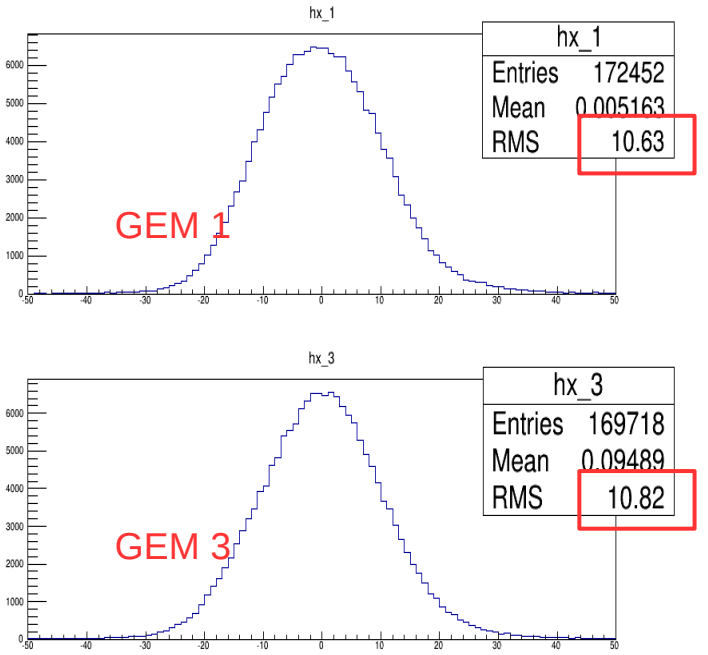
After correcting localized offset

Overall Time distribution(before)

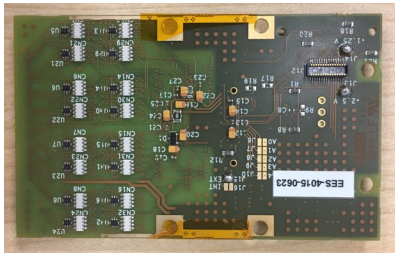


Overall Time distribution(After)



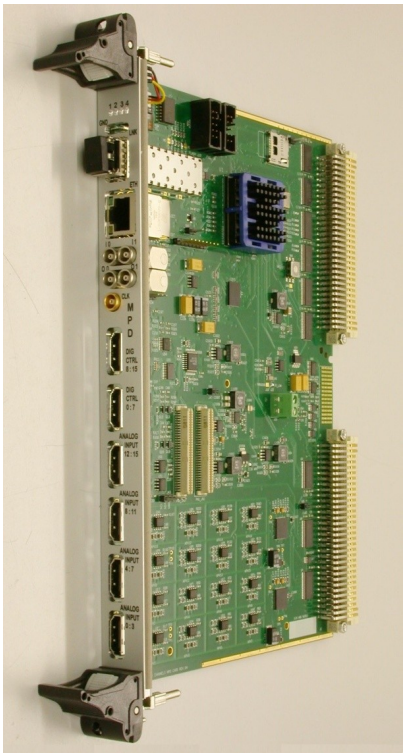


Data acquisition

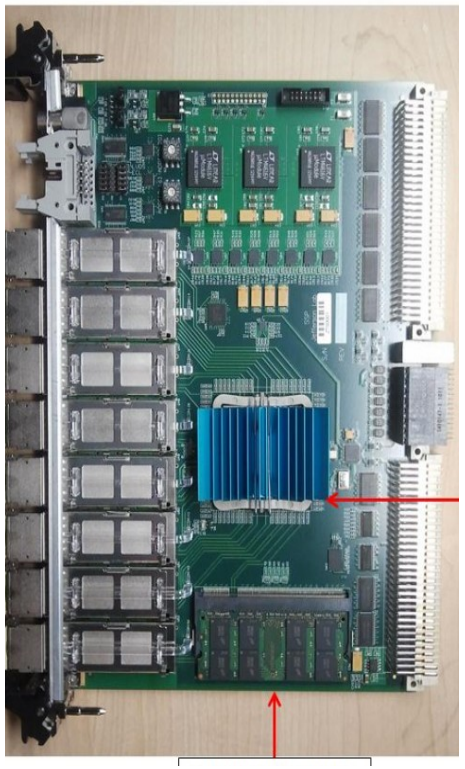


APV-25 FEC

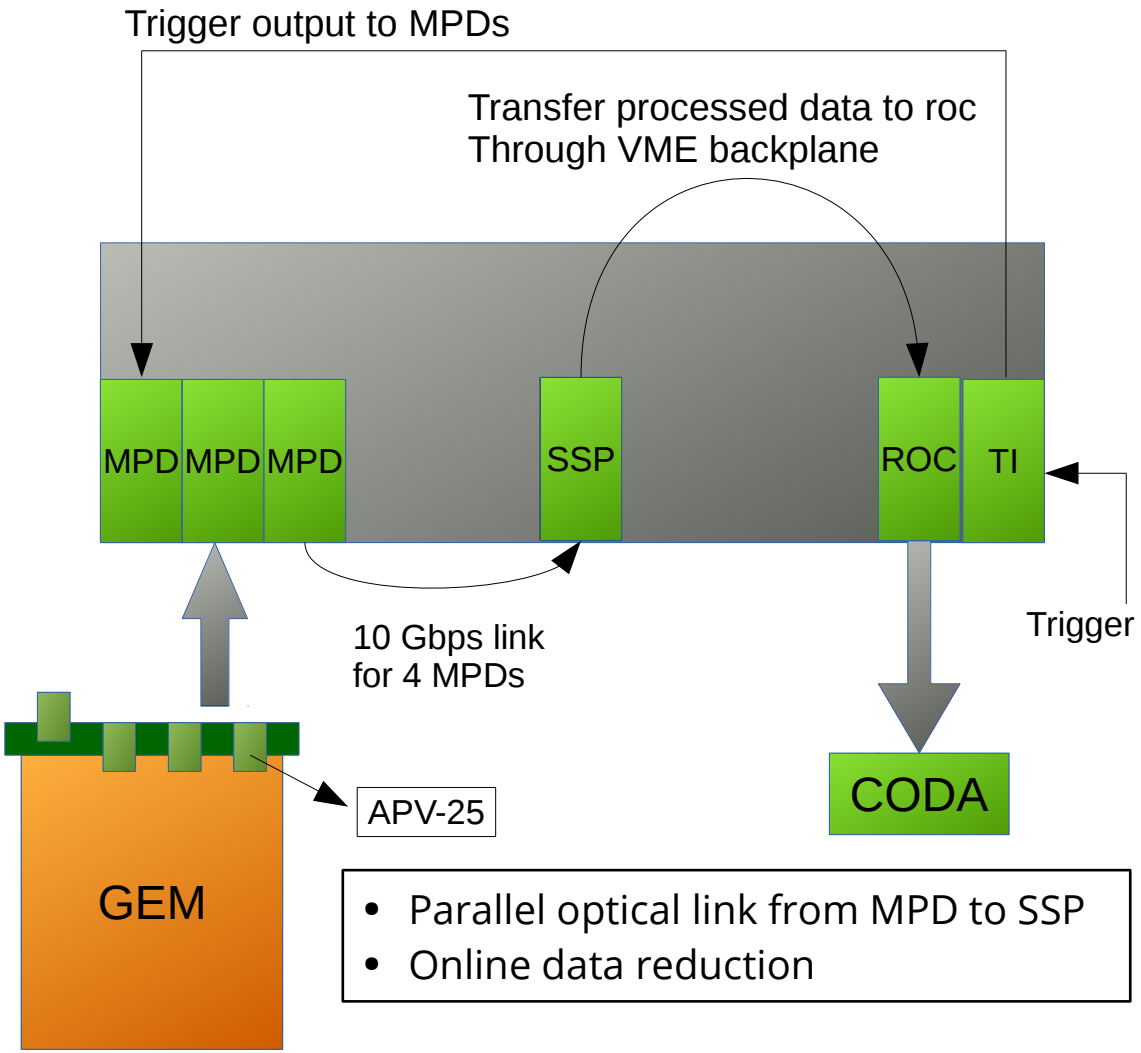
GMN(GEN): 304 APVs and 23 MPDs
GEP: 1204 APVs and 94 MPDs
Rates to achieve: 5 kHz



FPGA based digitizer
MPD(INFN, Paolo)



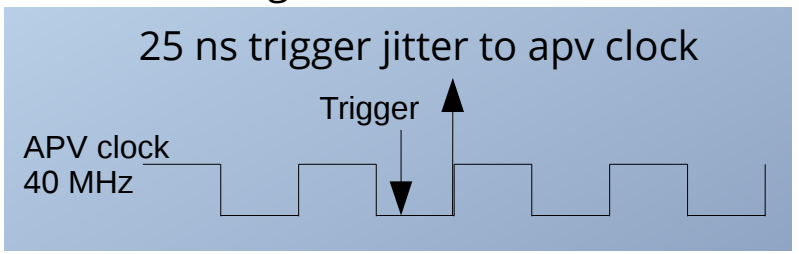
Subsystem processor
(SSP)

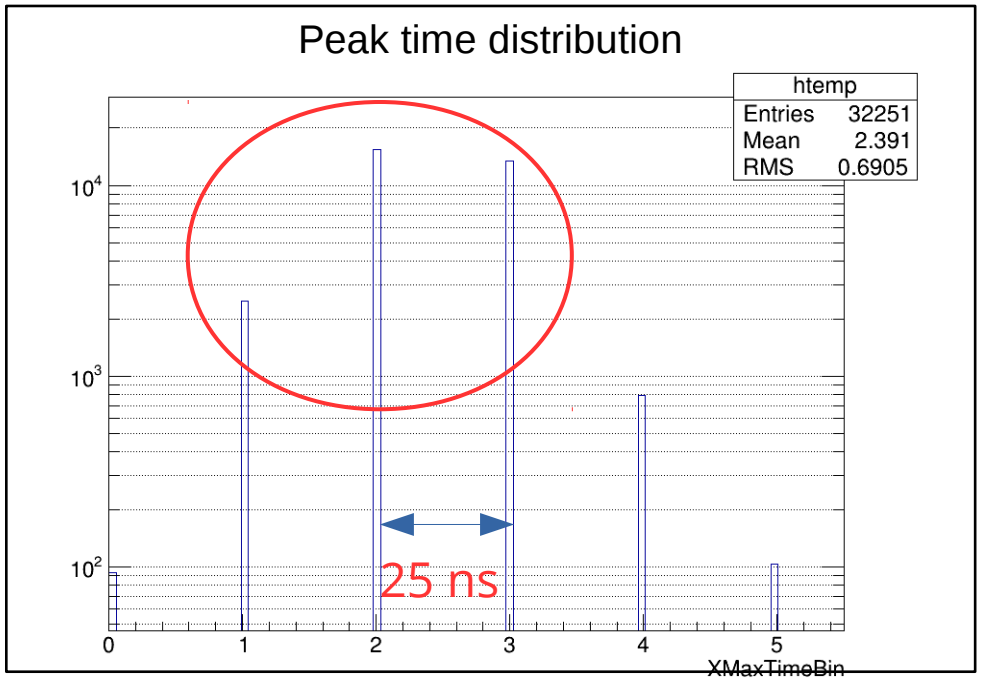


- Parallel optical link from MPD to SSP
- Online data reduction

3 sample OR 6 sample

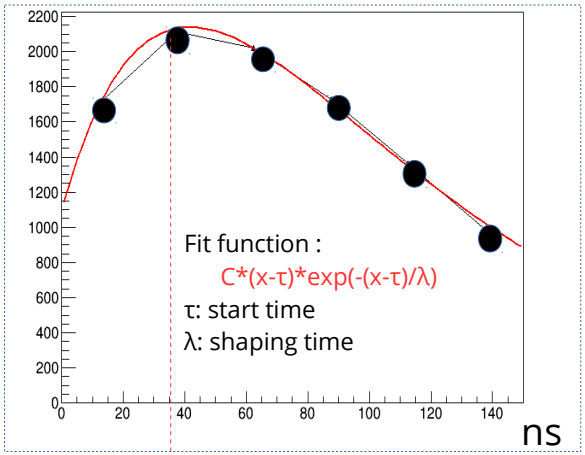
- APV-25 can be run at 1,3 or 6 sample mode. Each sample's length is 25 ns.
- Peak time spreads over 3 sample
  - Intrinsic GEM timing resolution
  - 25 ns trigger jitter relative to the APV-25 clock
  - localized timing offset



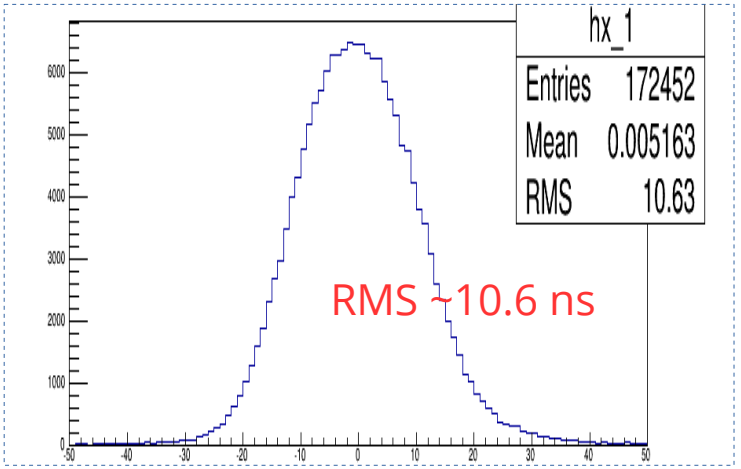


Raw data from APV

6 sample raw data and fit



Pulse peak time

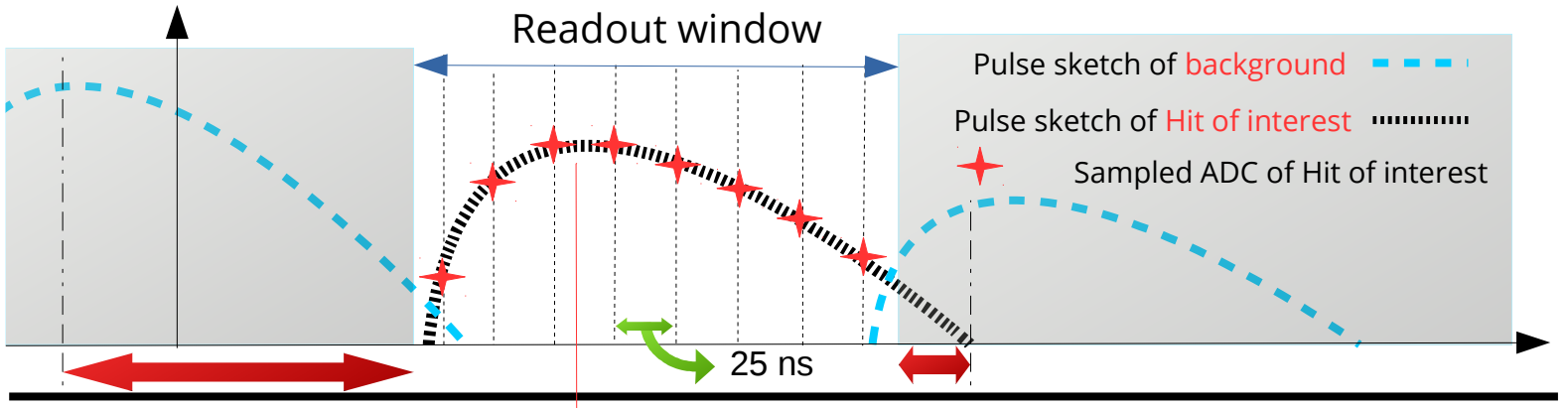


GEM timing resolution from fitting over 6 sample data

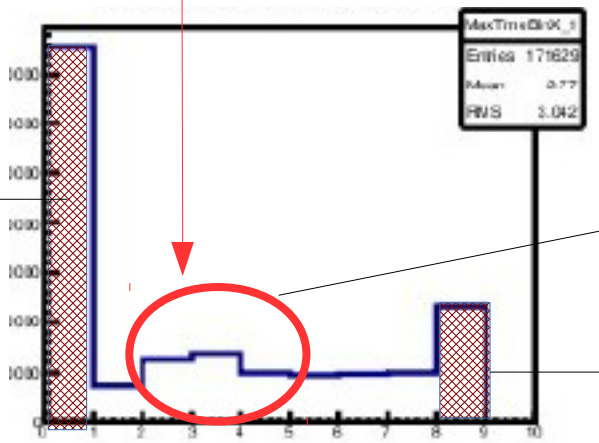
After offline trigger correction and local timing correction

3 sample OR 6 sample

Triggered hits and background hits



Sample number of peak



Background has peak before 1st sample

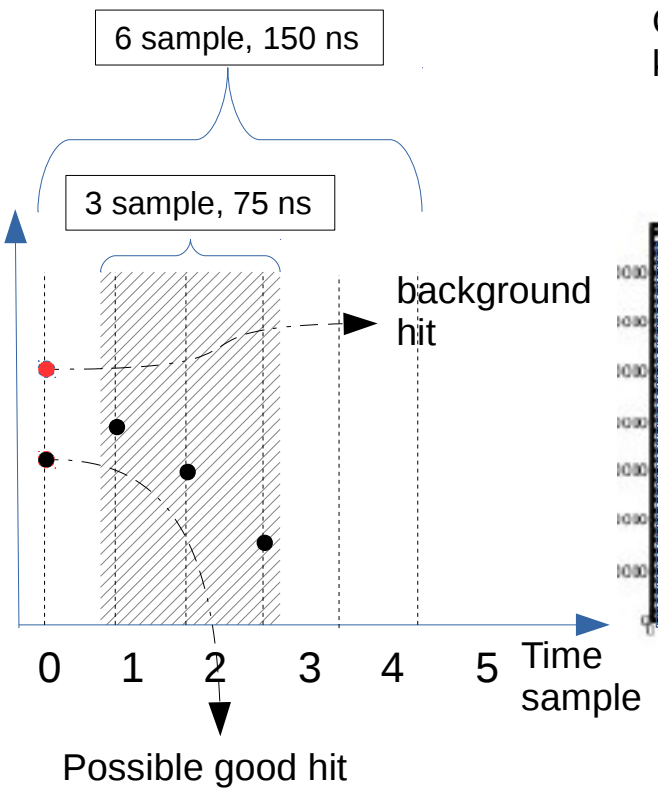
Good hits has peak in these time sample

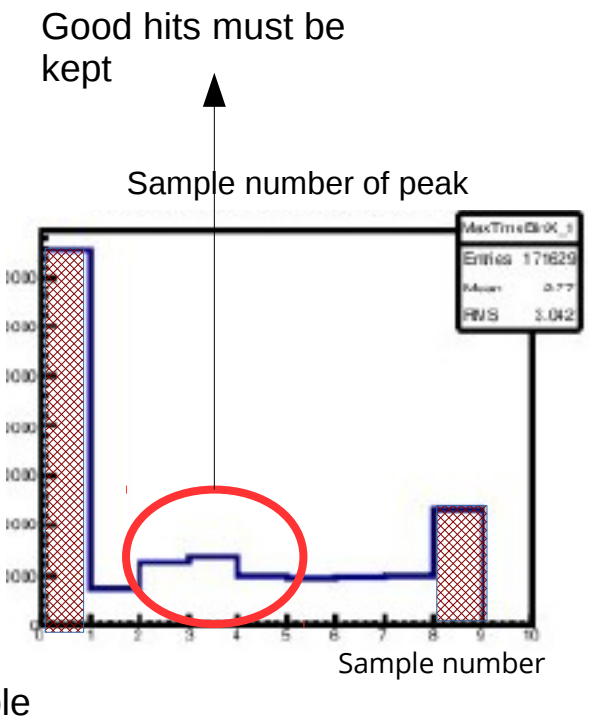
Background hits has peak after last sample

3 sample OR 6 sample

3 sample mode:
- Pros: less raw data volume
- Cons :
  - less information for offline analysis
  - Unable to remove background hits
  - More data volume with available online cuts

6 sample mode:
- Pros:
  - more information for offline study
  - Able to remove 70% data with simple online cut based on timing
  - Less data volume with available online cuts compared to 3 sample mode
- Cons:
  - More raw data volume, but not a bottle neck





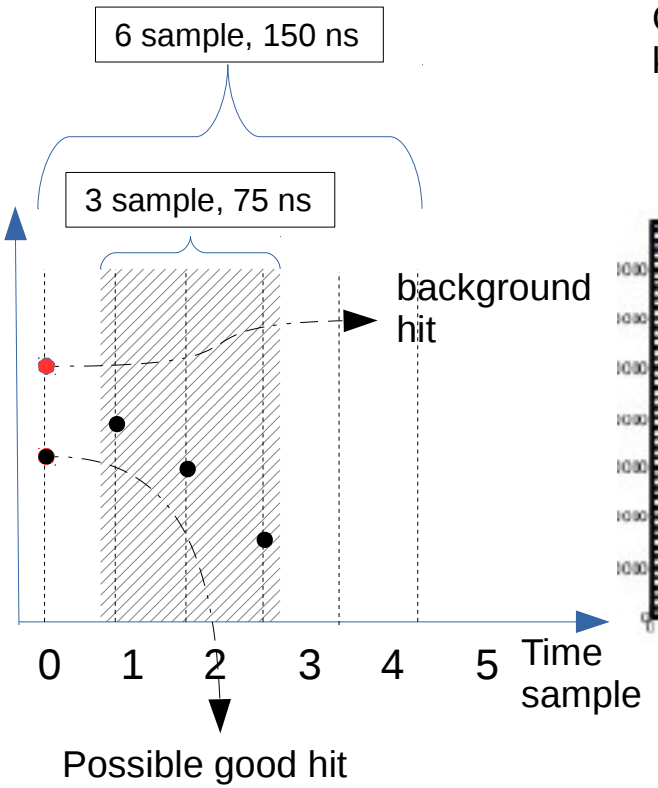
GMN	Window for background	Background remaining after simple online timing cut	Number of 32-bit word per channel	Rates at 5kHz after zero suppression and simple timing cut per APV(total 310)
3 TS	250 ns	250 ns	2	1 (310) Mbytes/s
6 TS	325 ns	100 ns	3	0.6 (190) Mbytes/s

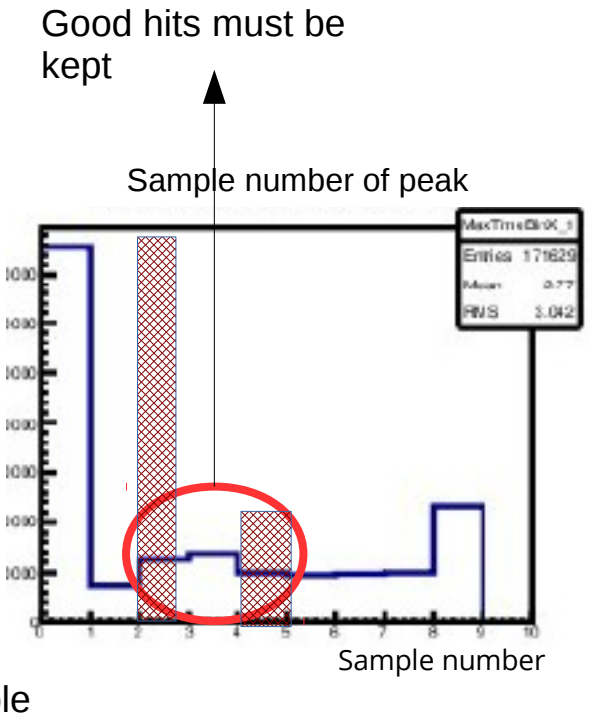
3 sample OR 6 sample

3 sample mode:
- Pros: less raw data volume
- Cons :
  - less information for offline analysis
  - Unable to remove background hits
  - More data volume with available online cuts

6 sample mode:
- Pros:
  - more information for offline study
  - Able to remove 70% data with simple online cut based on timing
  - Less data volume with available online cuts compared to 3 sample mode
- Cons:
  - More raw data volume, but not a bottle neck

6 sample mode is overall better than 3 sample mode





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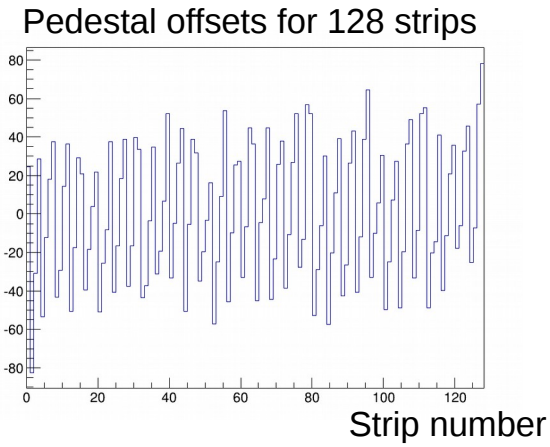
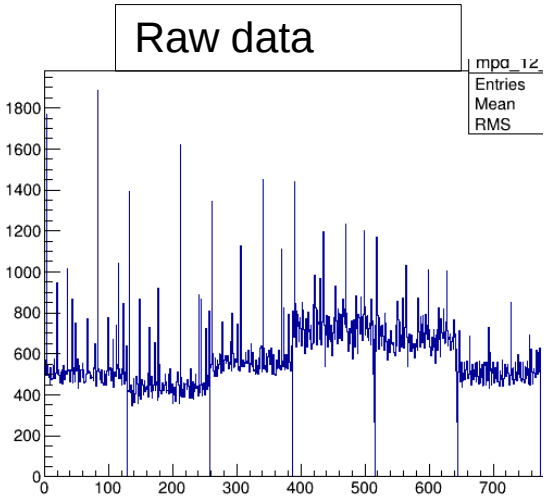
Online data processing on SSP

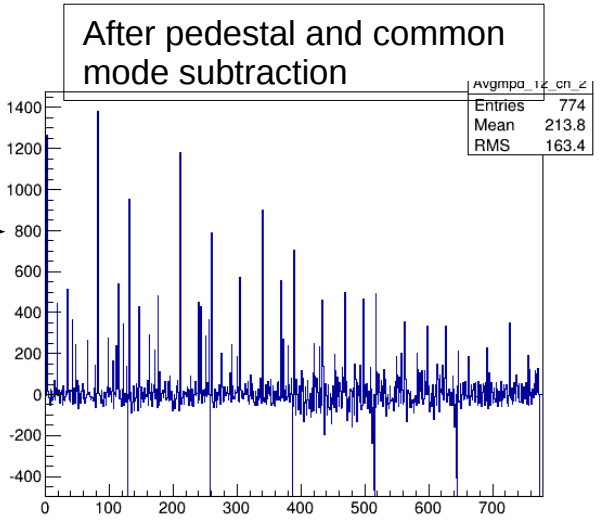
Online data processing is essential to achieve high rates.

- **Zero suppression**
  - **Offset correction** of each channel. Channels has offset relative to each other.
  - **Common mode subtraction**. The group of 128 channels jumps randomly from event to event and sample to sample.
  - After these the ADCs of each strip/sample become meaningful and can be zero suppressed.
- **Timing cut**
  - Cut signals has its peak in either first time sample or last time sample





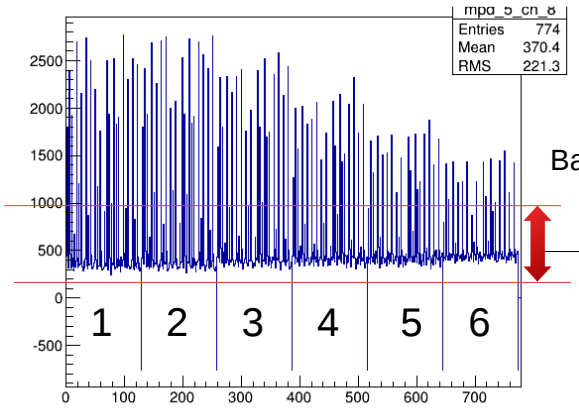
- **Offset correction to each strips** offsets calculated from pedestal runs, fixed value
- **Common mode subtraction** common mode needs to be calculated in real time for each apv, each time sample. Challenge for online processing



Implementing and testing online data processing(reduction) is a key recommendation from GMN experiment readiness review committee

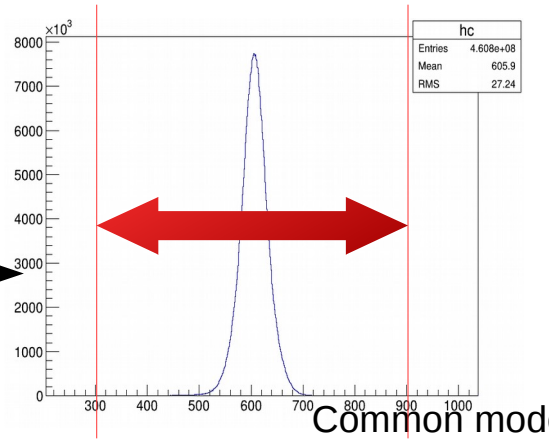
Zero suppression on SSP—new common mode algorithm

Raw data of APV in 6 sample mode
34 strips fired



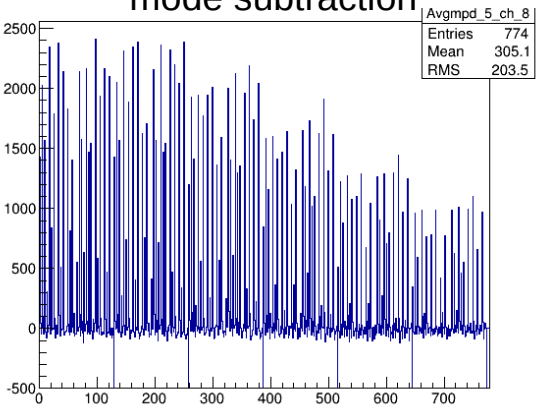
Baseline constantly moving from event to event

Common mode over 600k events



Common mode

After pedestal and common mode subtraction



Deduct common mode and pedestal

Previous method to calculate common mode

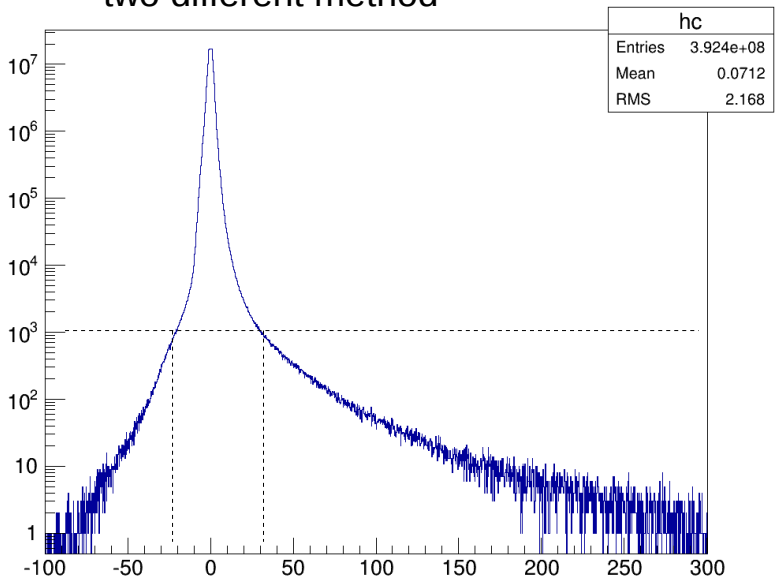
- Base on channel order after sorting:
  - Sort 128 channels
  - Take Average of the middle 50 strips
- Too expensive doing sorting constantly for every APV, every time sample in real time

New method to calculate common mode

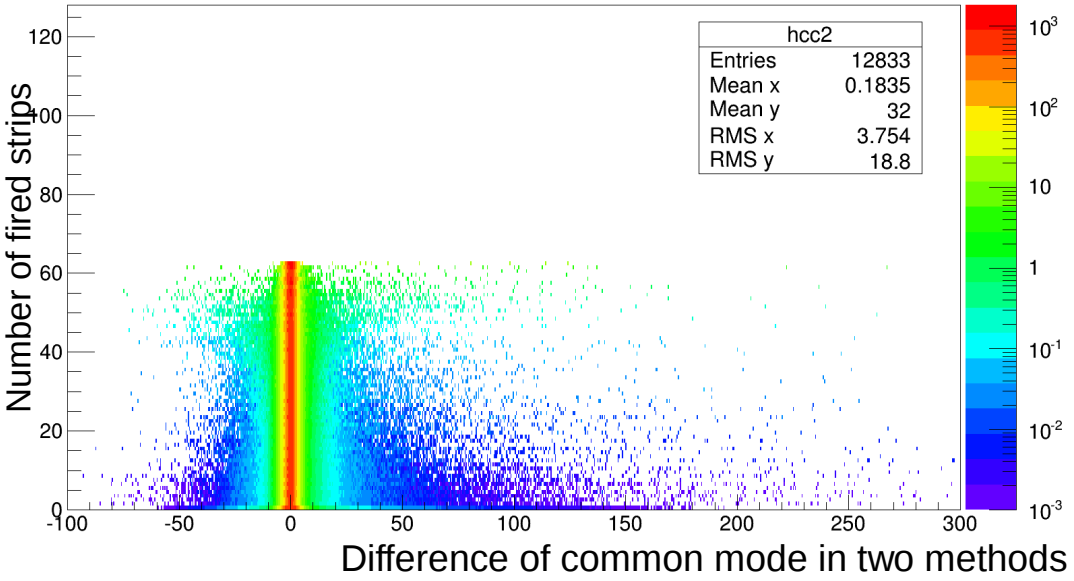
- Base on channel ADC:
  - Select rough range of common mode according to “Sorting” method.
  - Remove channels having adc outside the range in step 1 and get average(A) using remaining channels
  - Remove channels that is outside the average(A) plus/minus 100 adc(about 5 times of pedestal rms) and get average as common mode
- Time needed 25% compared to sorting
- Tested offline with Hall A data, local occupancy 50% situation, similar results compared to sorting method(next slide)

Zero suppression on SSP—new common mode algorithm

Difference of common mode from two different method



2D map of number of fired strips and difference of common mode from two different method



- Online data processing algorithm is ready to be implemented into SSP and ready to be tested as soon as current MPD-SSP data transfer issue solved.
- Plan to test the whole online data processing with X-ray data at UVa or possible beam time this Fall in Hall C

GMN

Some facts/numbers on GEM readout in GMN

- 304 APVs, about 40k channels, 23 MPDs
- 6 time sample
- Trigger rate: 5 kHz
- Background rate: 100kHz/cm^2
- Average cluster size: 4

From MPD to SSP(able to reach 5 kHz):

- At most 15 APVs per MPD, 4 Bytes per channel per sample,
  15*4*128*6 = 230 MB/s
- Link limit: 10Gbps/4(4 MPDs use 1 link)~ ***250MB/s (can easily bump up to 300MB/s)***

From SSP to roc(able to reach 5 kHz):

- Total 4.7 GB/s going into SSP 4.7 GB/s
- After zero suppression, fraction left: 25% ----1.175GB/s
- Timing cut removing signal has peak in first or last sample: 31% ----370MB/s
- Packing 6 sample into 3 4Bytes word: 50% ----190MB/s
- Spreading data to 2 or 3 VME crate?
- VME backplane limit: ***110MB/s***

This assumed background distributes randomly and evenly

Data packing

8 bits	12 bits	12 bits
ch_No.	sample_1	sample_2
ch_No.	sample_3	sample_4
ch_No.	sample_5	sample_6

GEP has 1.2k(4 times) APVs and double(or triple) size occupancy.
The current procedure for GMN will be far from enough to reach 5 kHz.
Additional method must be planned

GEP occupancy estimation

6 sample mode:

Effective time window: ~325 ns

Average number of hits over whole active area are: 325ns*Area*Rate

	FPP1	FPP2	Front Tracker
Avg. hits	240-290	150	330-520
occupancy	45%-55%	35%	60%-75%

$$strip\,occupancy = 1 - \left(1 - \frac{clusterSize}{totalStrips}\right)^{Avghits}$$