Large GEM trackers for high rate operation for Super Bigbite Spectrometer at Jefferson Lab

Danning Di

University of Virginia
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UNIVERSITY of VIRGINIA

2017 MPGD meeting

Jefferson Lab

Super Bigbite Spectrometer (SBS)

Polarized electron beam :
Energy: 12 GeV
Current: 85 uA
Polarization: 85%

Super Bigbite Spectrometer

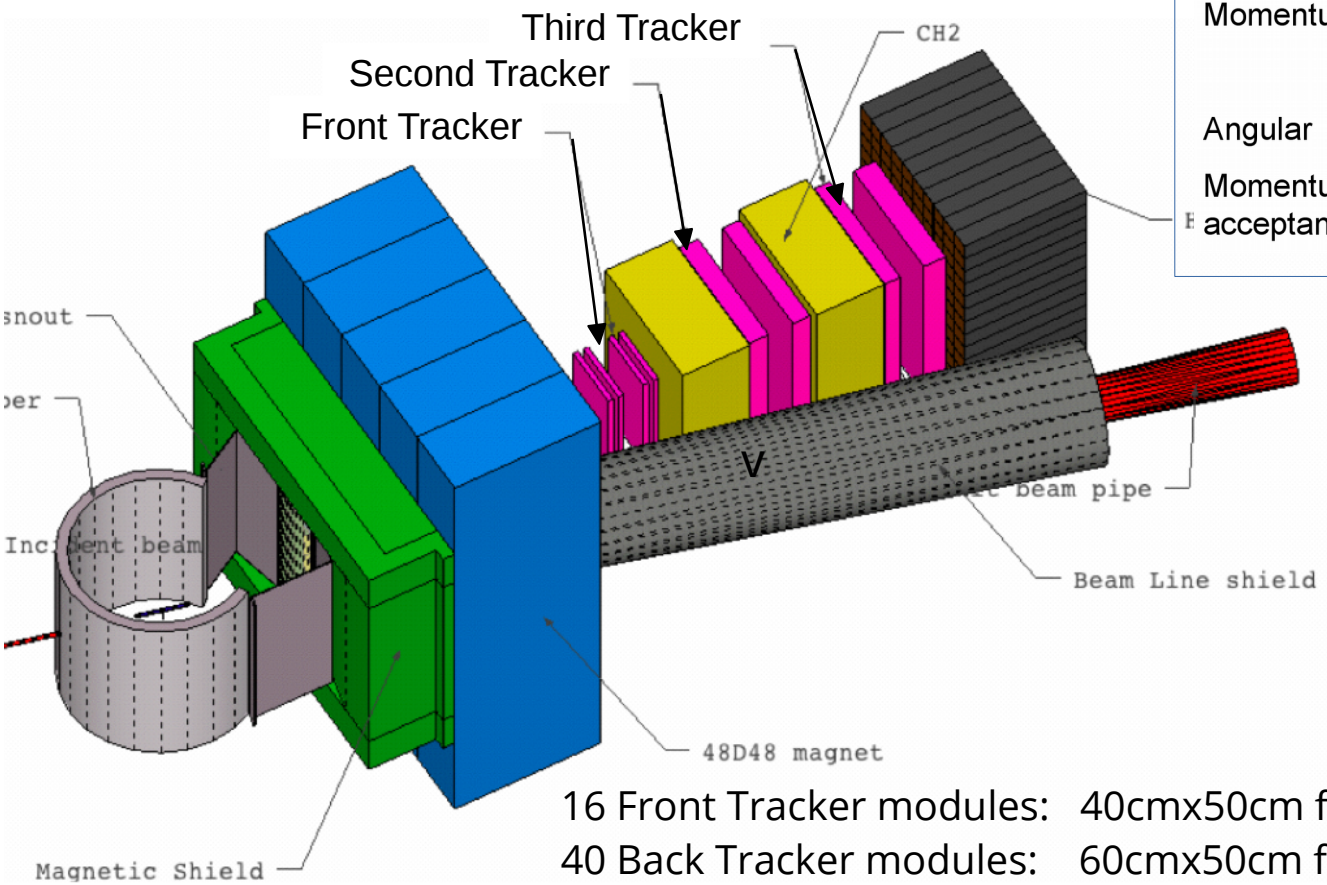
- Large acceptance
- High Luminorsity

SBS parameters:

Momentum => $\frac{\sigma_p}{P} = 0.001 \cdot P[GeV]$

Angular => $\sigma_\theta = 0.2 - 0.3$ mrad

Momentum acceptance => P range $2 - 10$ GeV/c

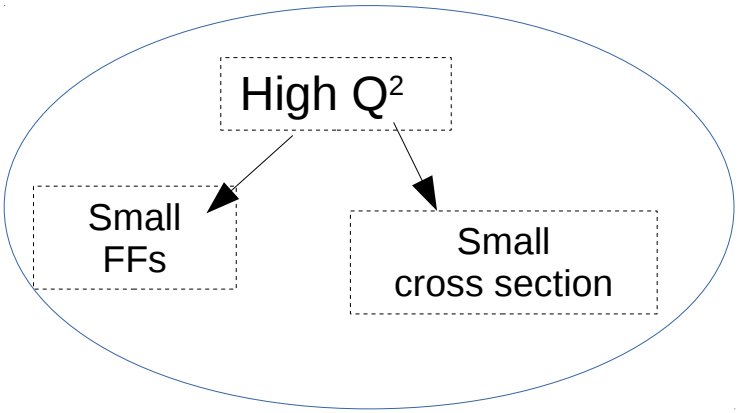


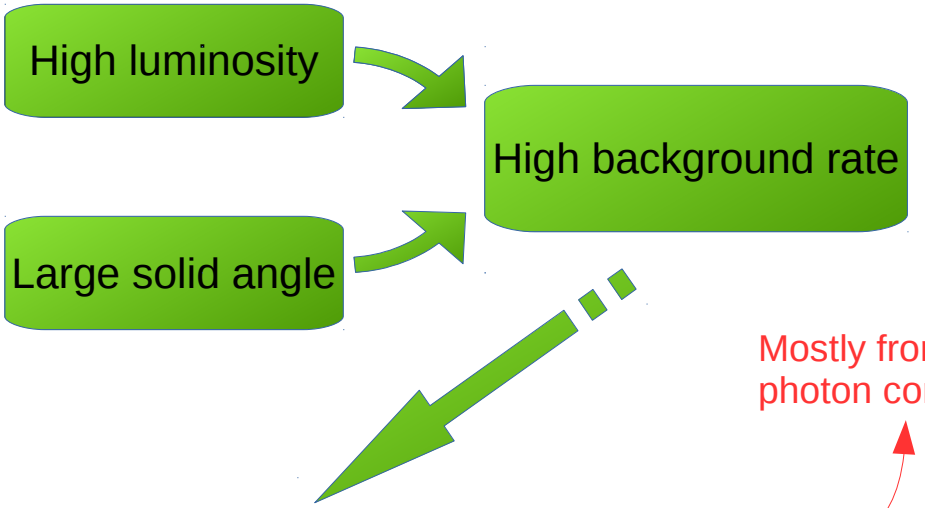
Nucleon form factors measurements at High Q2:

- GEP(5)
- GEN(2)
- GMN

16 Front Tracker modules: 40cmx50cm from INFN, 0.6 m^2 per plane
40 Back Tracker modules: 60cmx50cm from Uva, 1.2 m^2 per plane

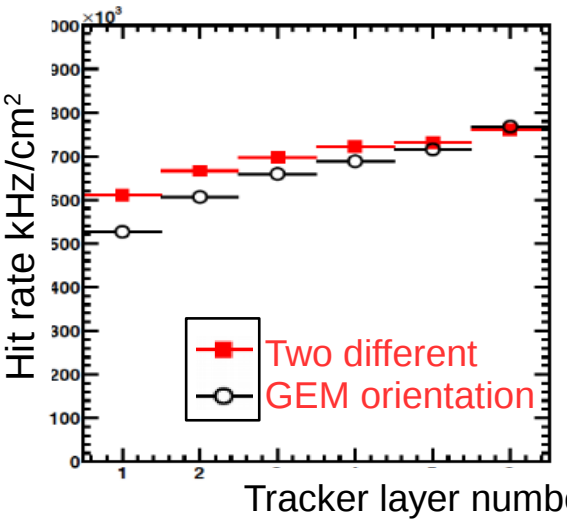
High rate



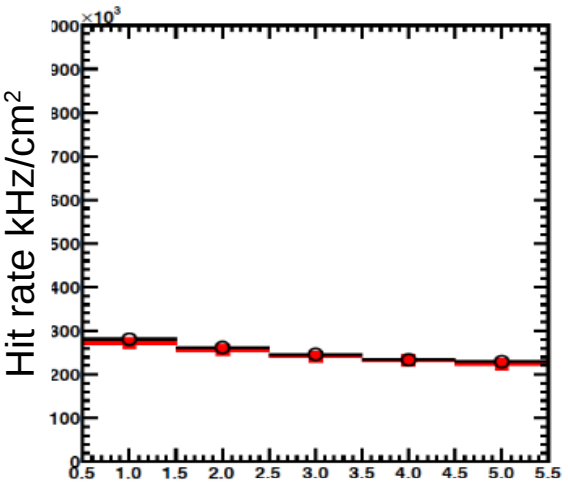


Mostly from low energy photon conversion

Front tracker hit rate

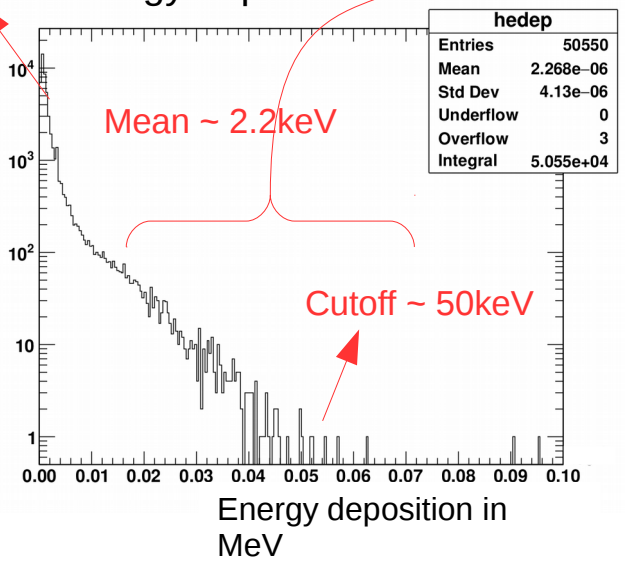


Second tracker hit rate



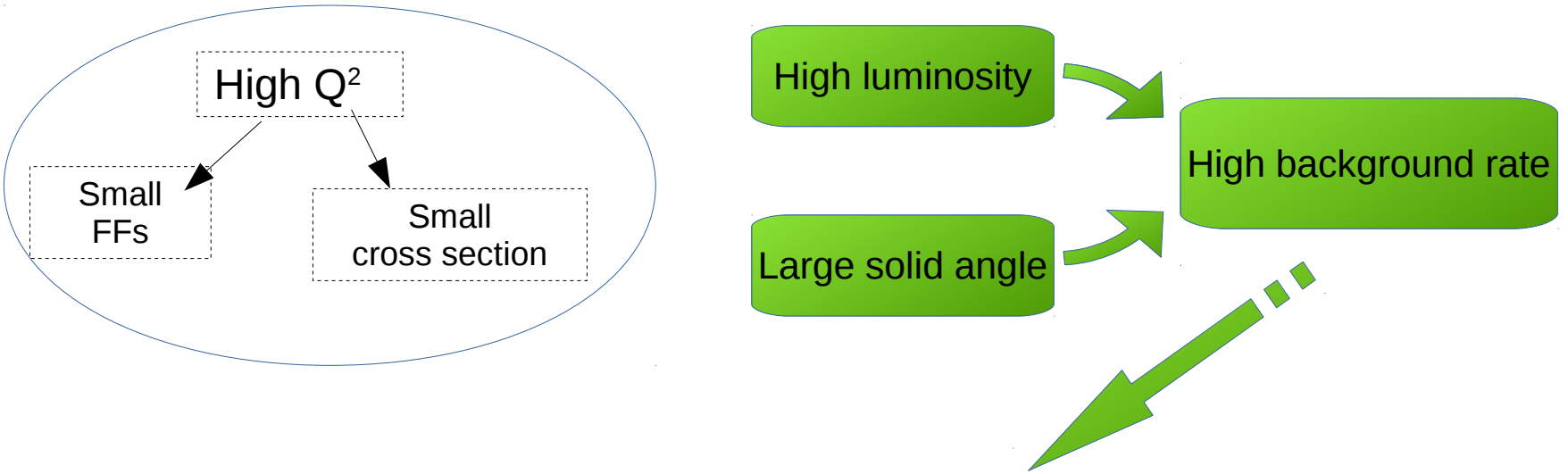
MIPs

Energy deposition distribution



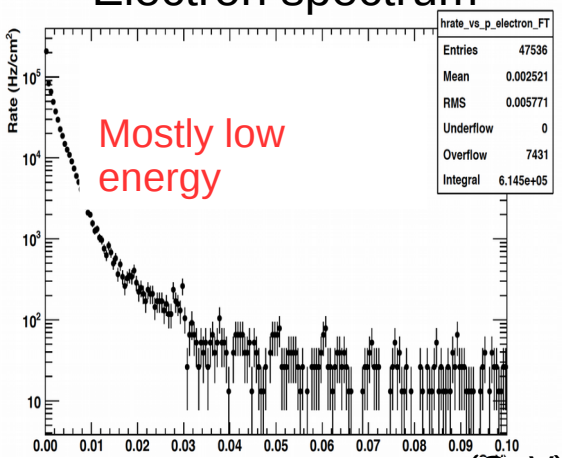
SBS simulation results of hits in GEM by **Andrew Puckett**

High rate

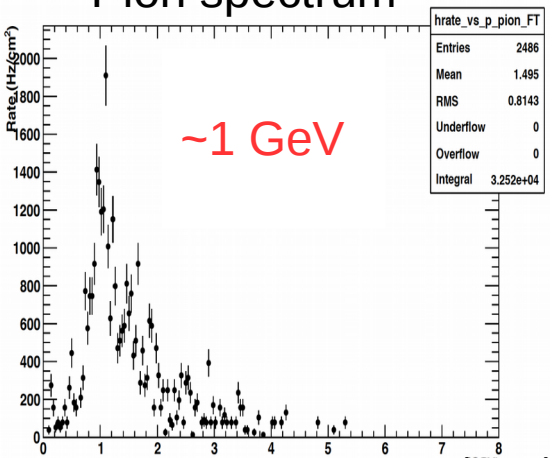


About 1/6 are pions and protons, the rest mostly low energy electrons from photon conversion

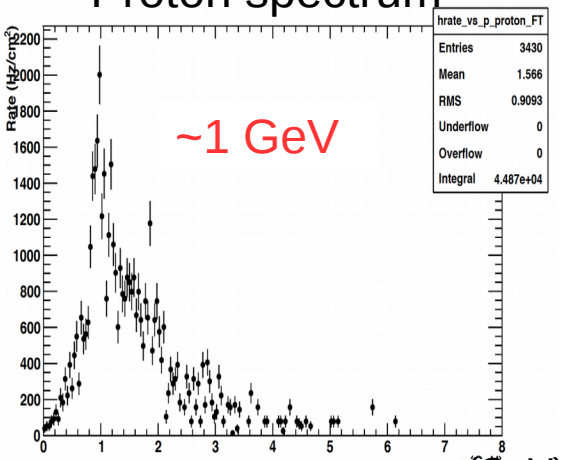
Electron spectrum



Pion spectrum



Proton spectrum

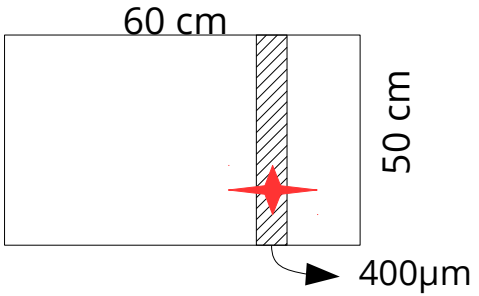


SBS simulation results of hits in GEM by **Andrew Puckett**

Challenge from high rate

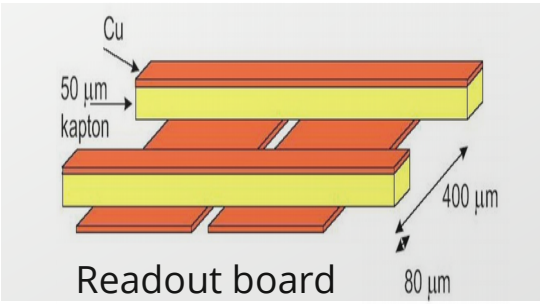
High background rate
0.15~0.8 MHz/cm2

Large area GEM

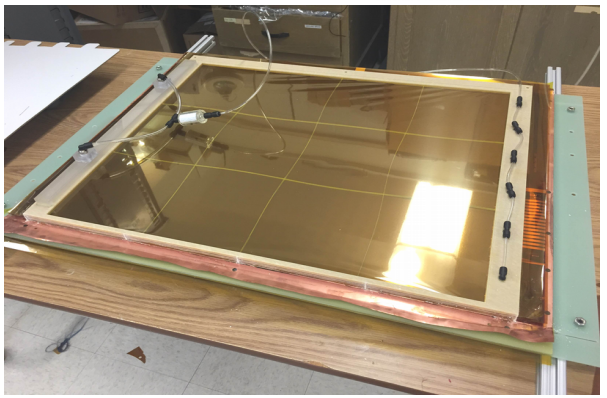


Trigger rate
~4kHz

110k channels
880 APVs



- High energy deposition
- High occupancy 35~55% (back trackers)
- Huge data volume
  Raw size, all channel 6.4GB/s

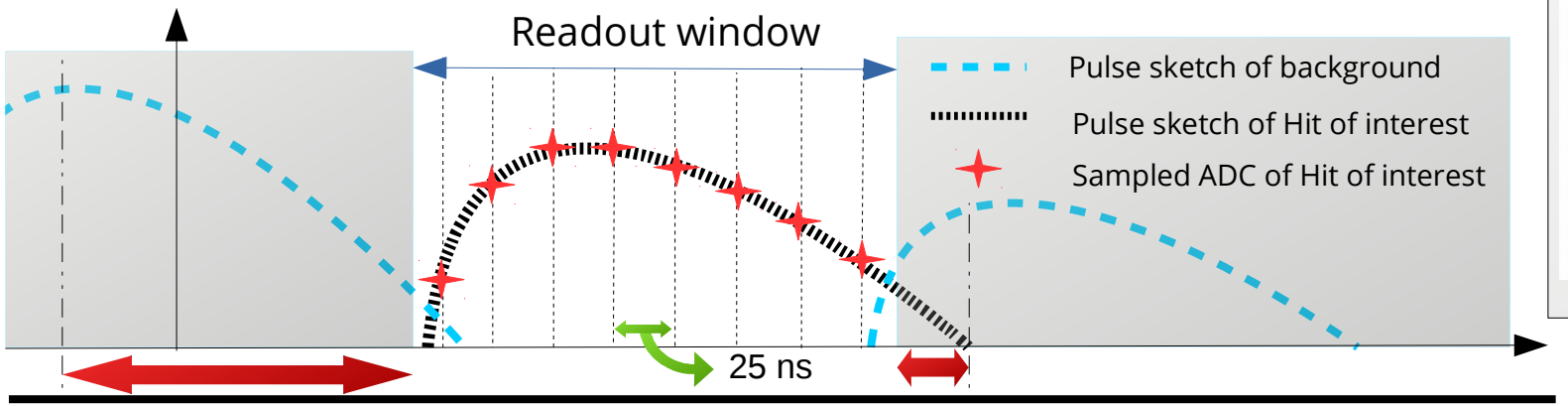


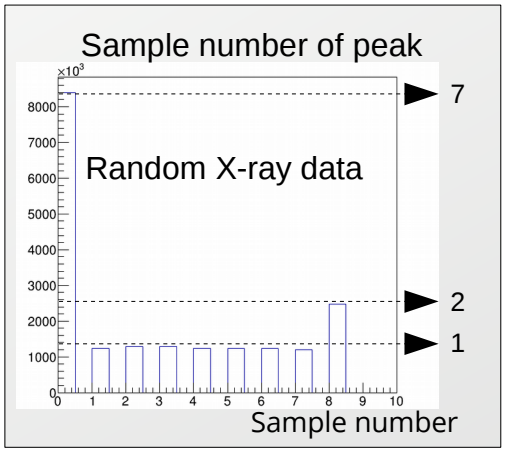
GEM module constructed at UVa

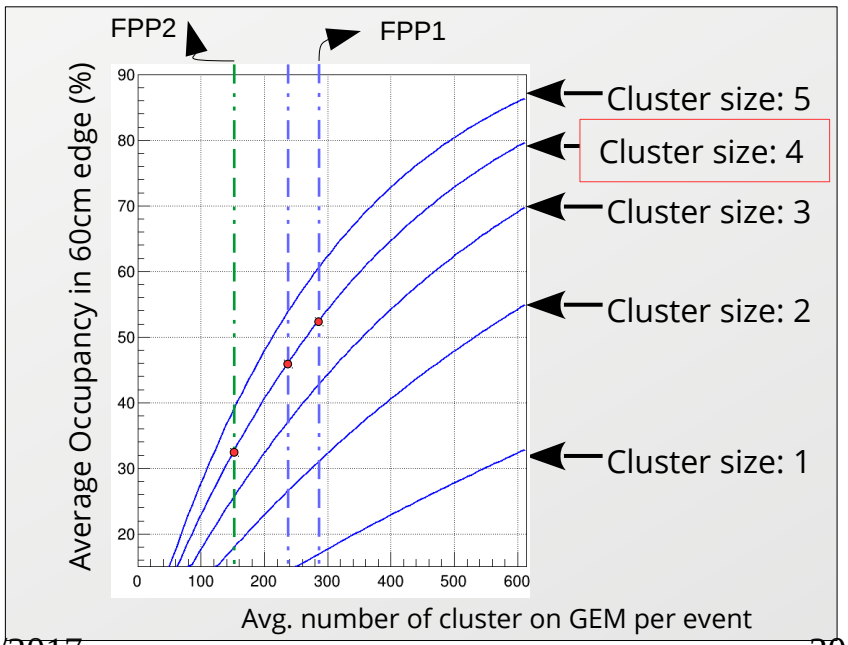
High occupancy

In case of 6 sample mode, considering 60x50cm^2 GEM:
Assuming effective time window: 150+7*25 = 325 ns
Average number of hits are:

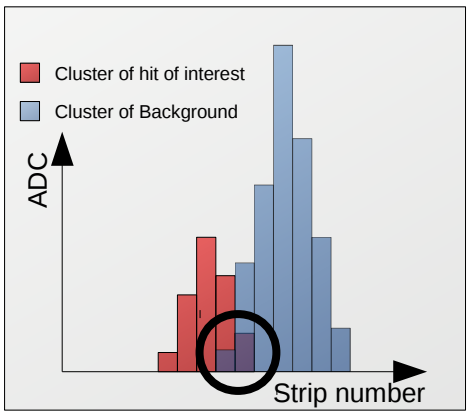
	FPP1	FPP2
Avg. hits	240-290	150



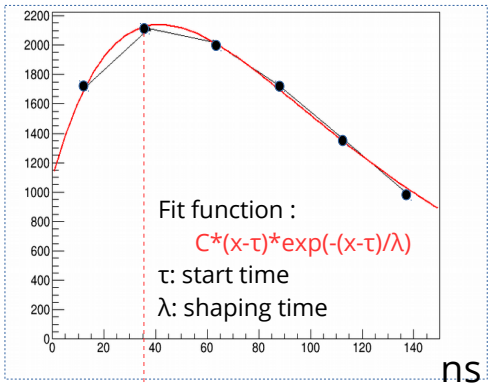




Second and third tracker strip occupancy could reach respectively 55% and 35%



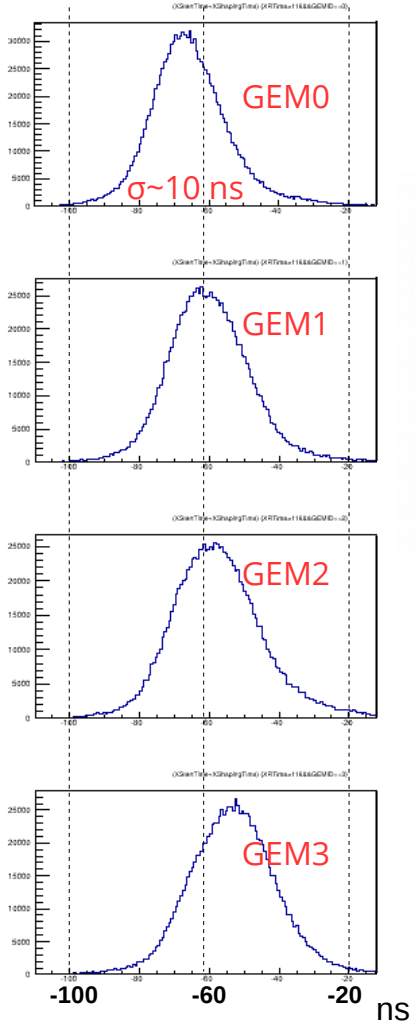
Pulse shape fit on 6 sample data



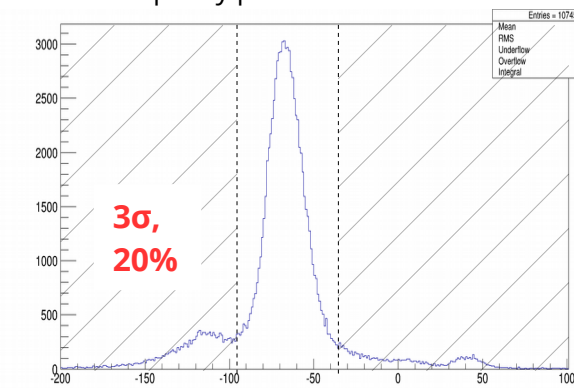
Pulse peak time

High occupancy---reject background hits and track reconstruction

Pulse peak time distribution



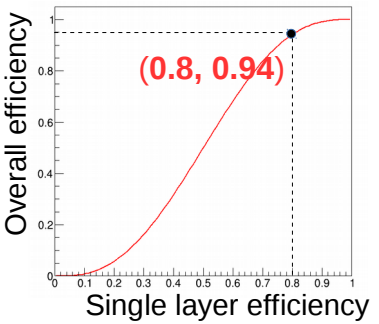
1% occupancy peak time distribution



Cost effective algorithm
(>100 hits per plane)

Track reconstruction

3 hit track efficiency



High occupancy 35~55%

Constraints from other detectors (ex. calorimeter electron arm CDET)

Reject background

1) Background tracks (mostly proton and pion)

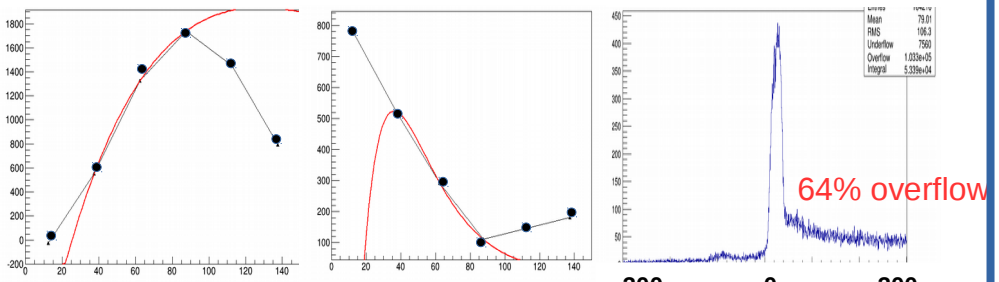
2) Accidental hit (s) (mostly photon conversion)

Timing cut

Compare of fit over 3 sample and 6 sample

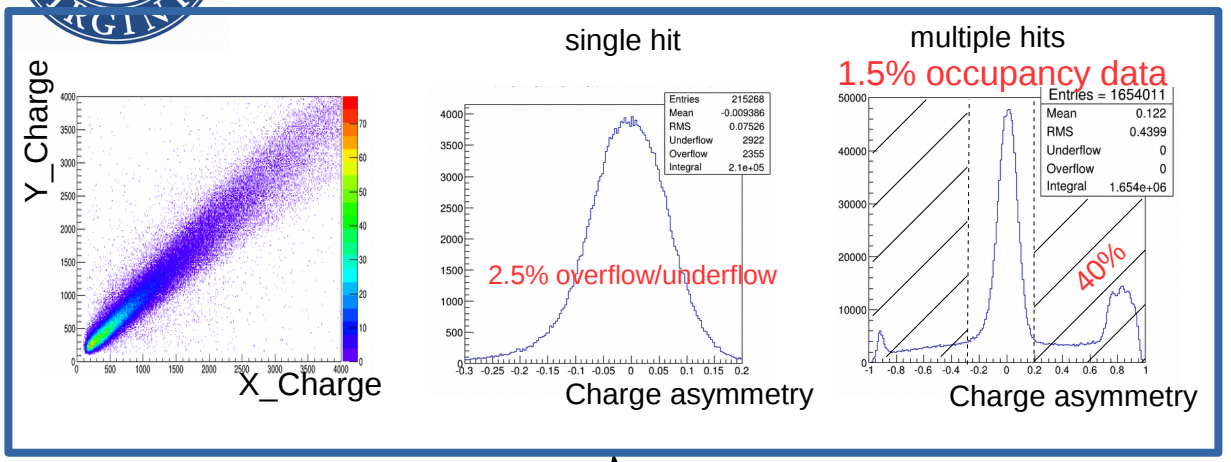
Pulse shape fit of 3 sample Data

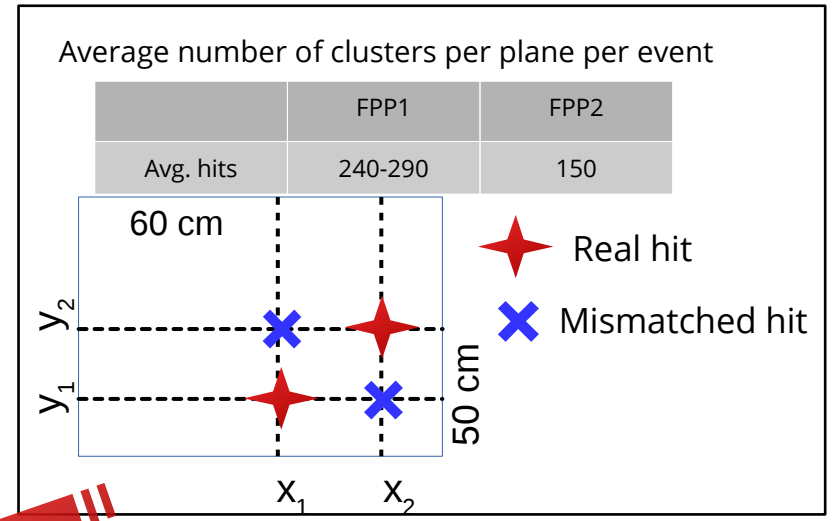
Difference



Often fit results

High occupancy---mismatching clusters



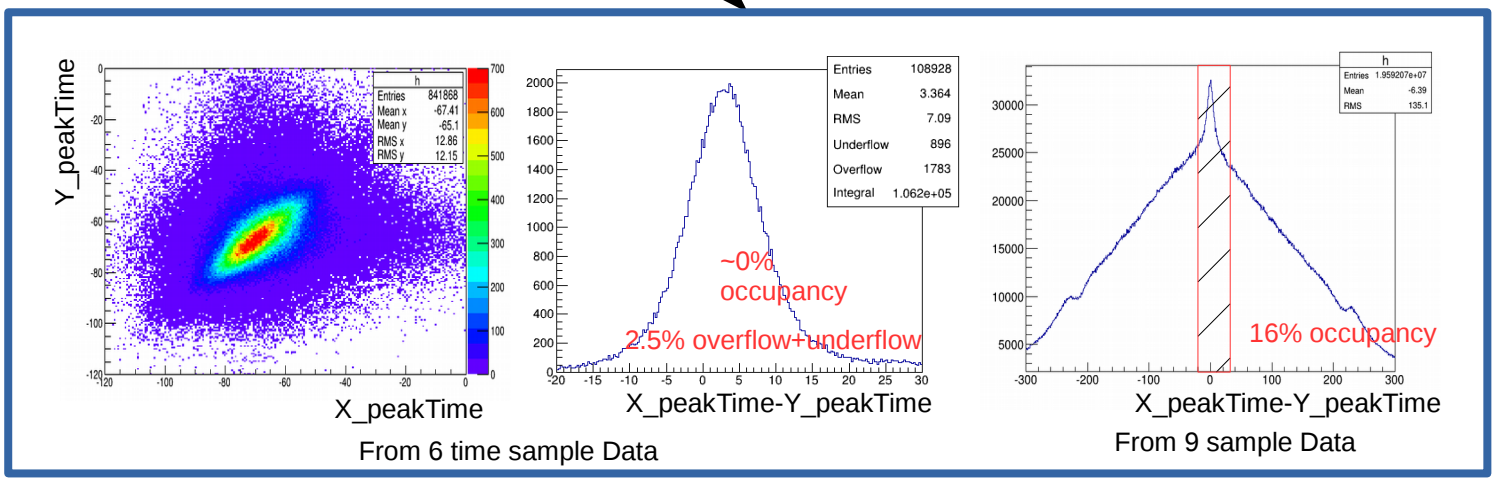


Charge correlation

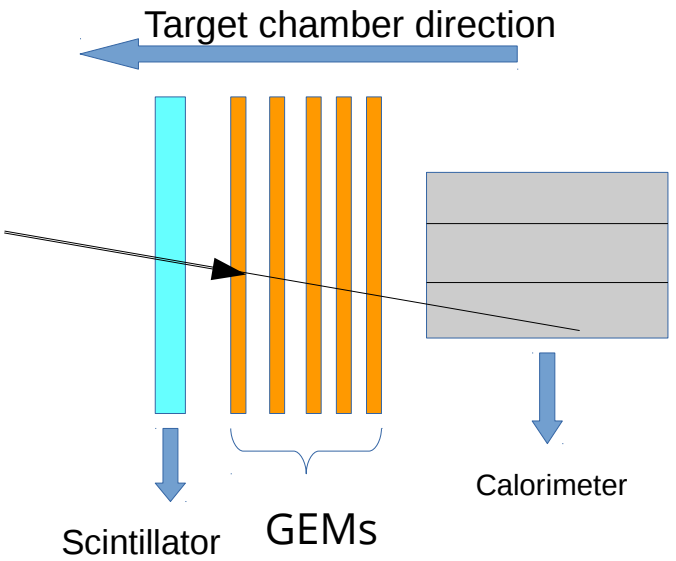
Reject mismatching cluster

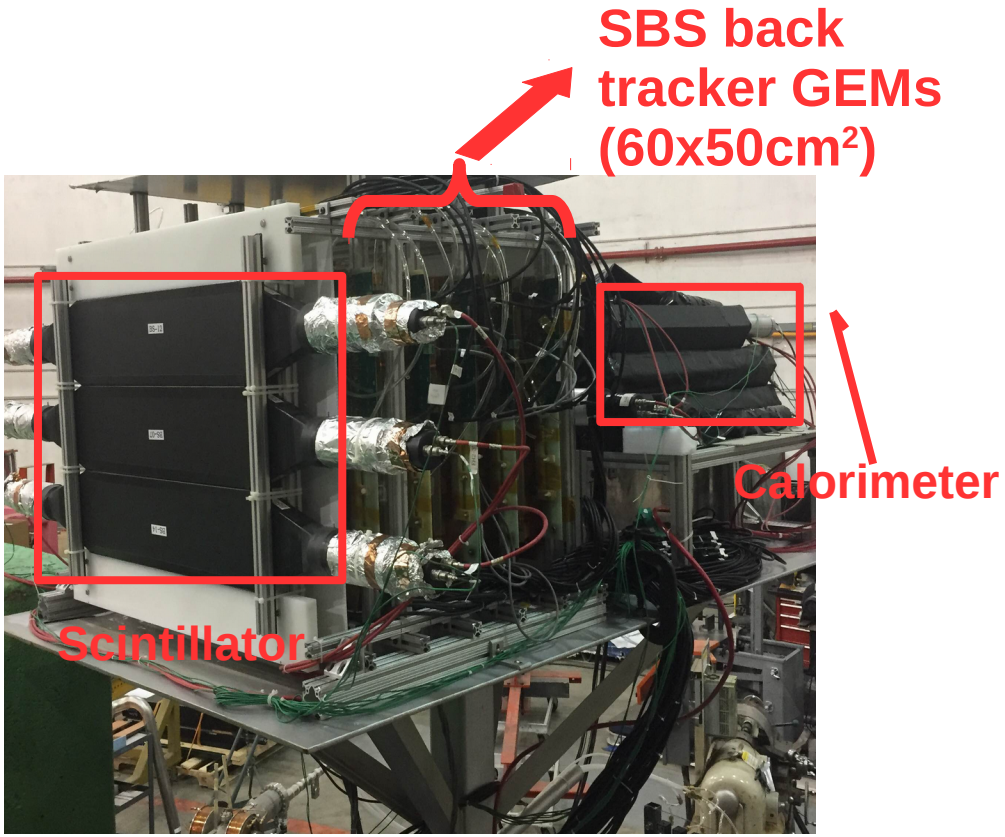
High occupancy 35~55%

Timing correlation



A practice run in Hall A at JLab

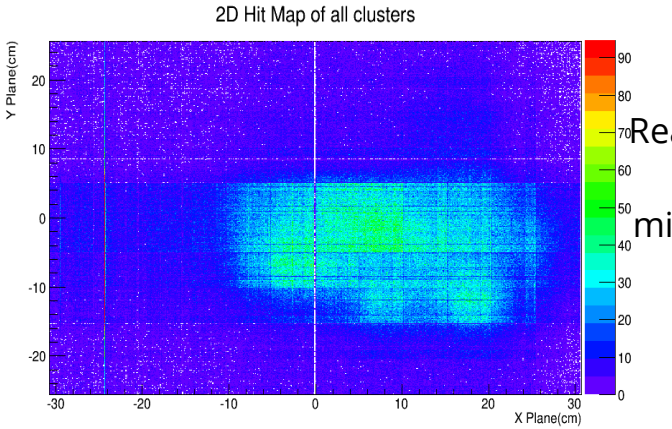




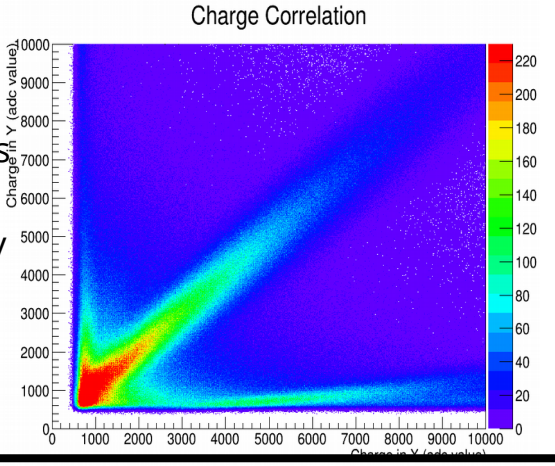
- Parastic test at 70° from beam in Hall A during DVCS/GMP experiment in Fall 2016.
- 5 60x50 cm SBS GEM modules spaced by ~13 cm.

- 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%.

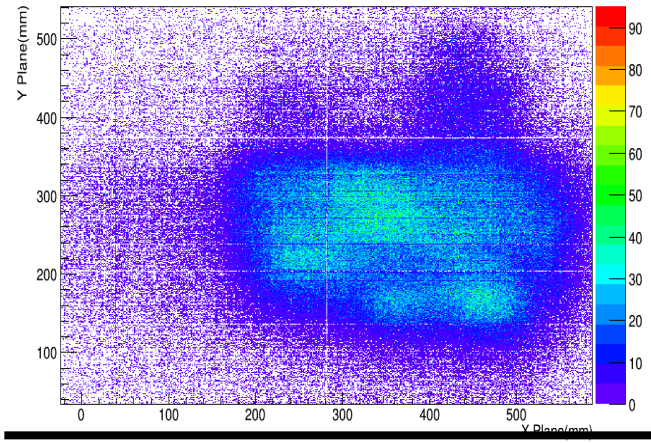
A practice run in Hall A at JLab



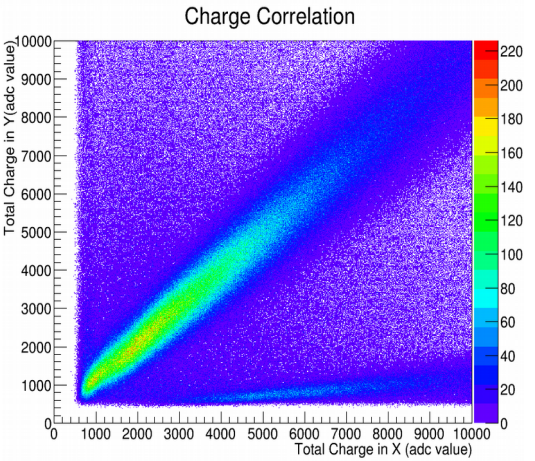
Real hits buried in accidental hits and cross-talk clusters and mismatching clusters(incorrectly paired x/y clusters)



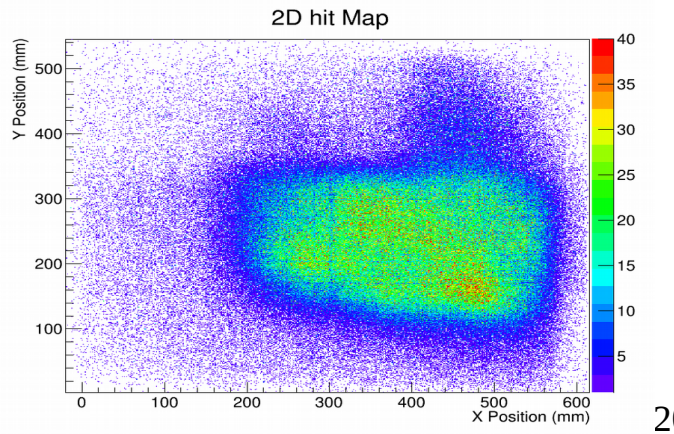
Do timing cut and tracking in x/y plane

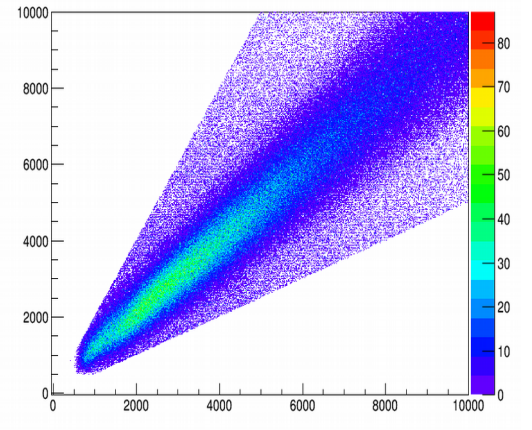


Real hits,
small part of accidental hits,
cross-talk clusters and
part of mismatching clusters



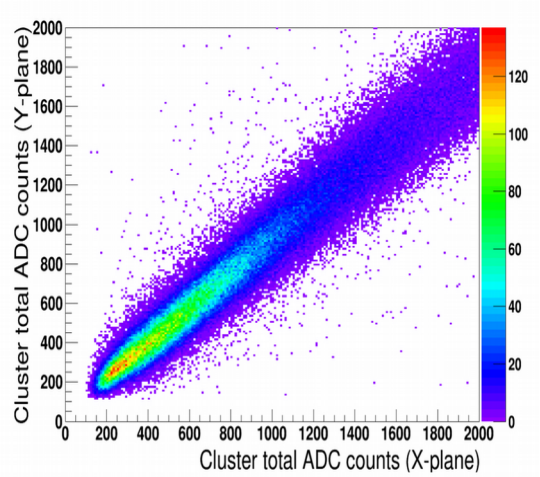
Apply cut in charge correlation and timing correlation



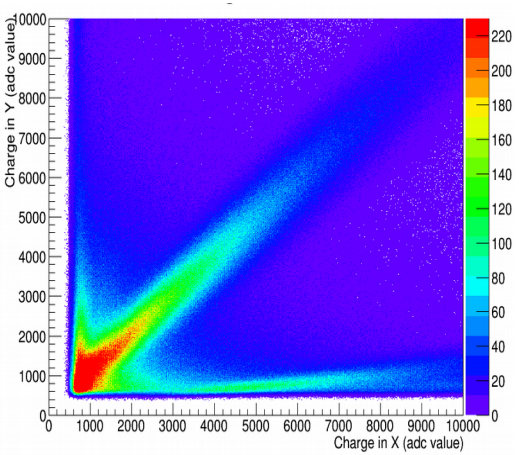


A practice run in Hall A at JLab

^{90}Sr data

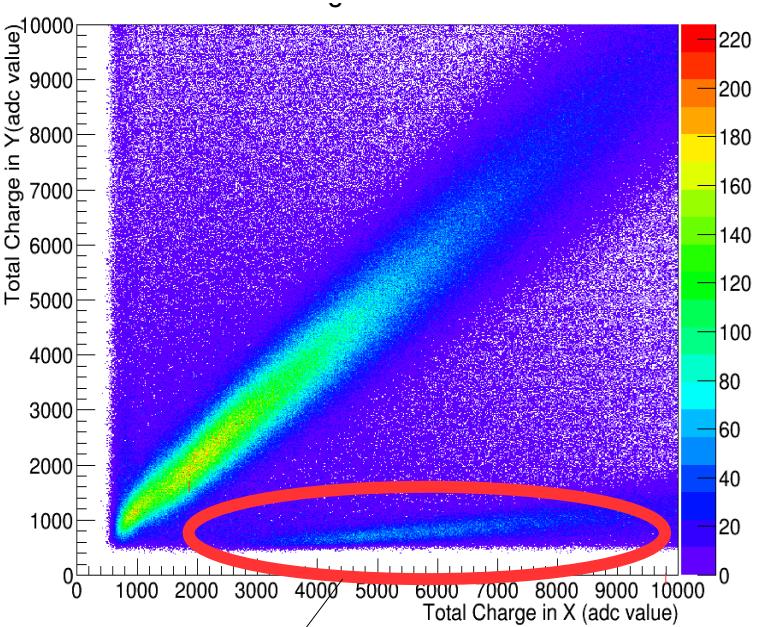


Hall A test data



Due to Mismatched clusters and cross talk

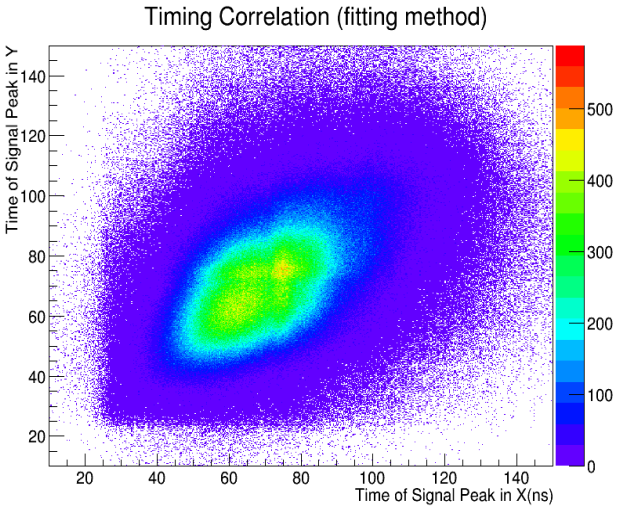
Hall A test data after tracking rejection



Electronics cross talk to remove

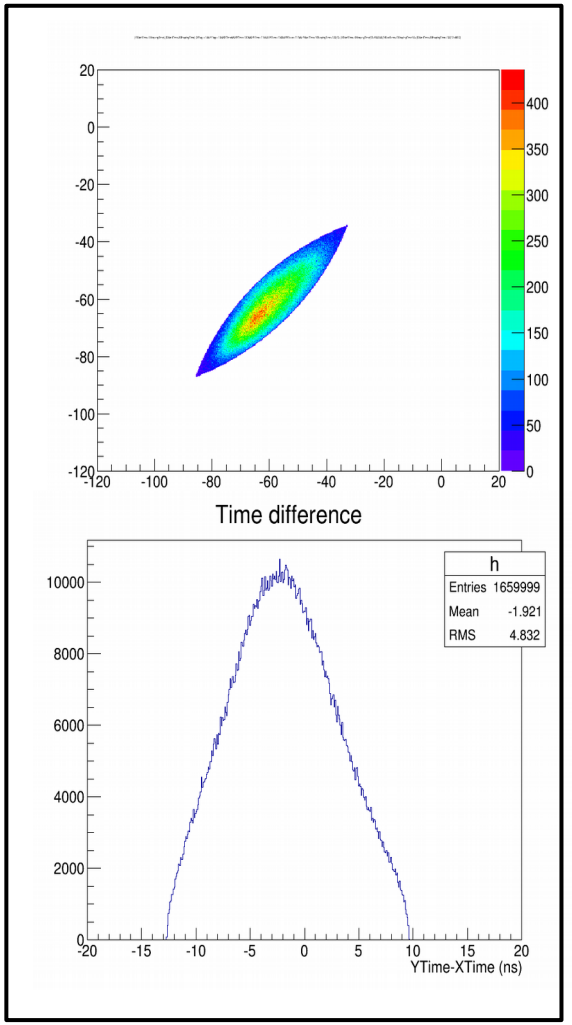
A practice run in Hall A at JLab

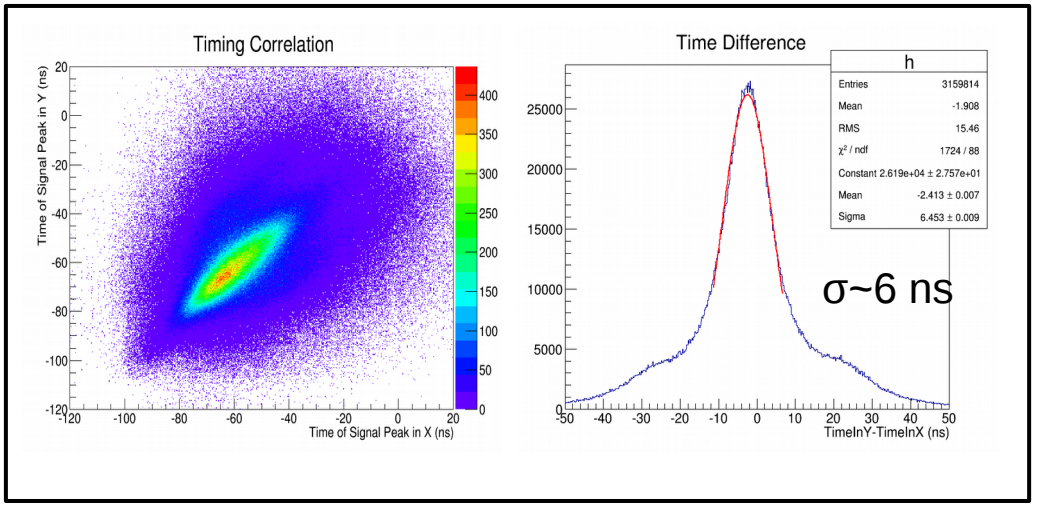
From fit of 6 time sample



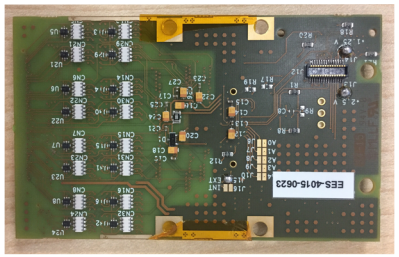
Correcting the phase of trigger in APV clock

Cut off weakly timing correlated clusters



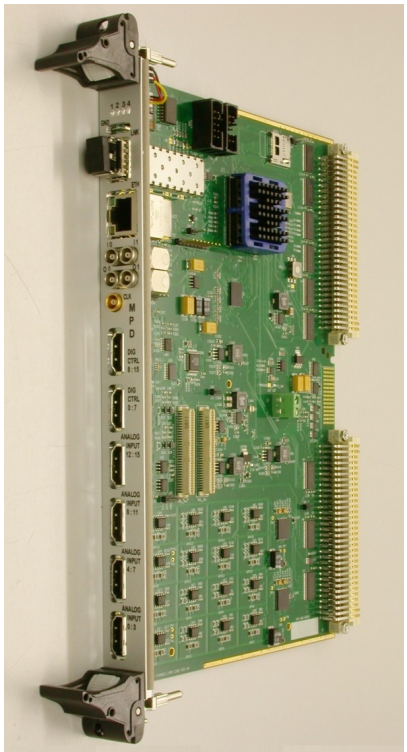


Data acquisition

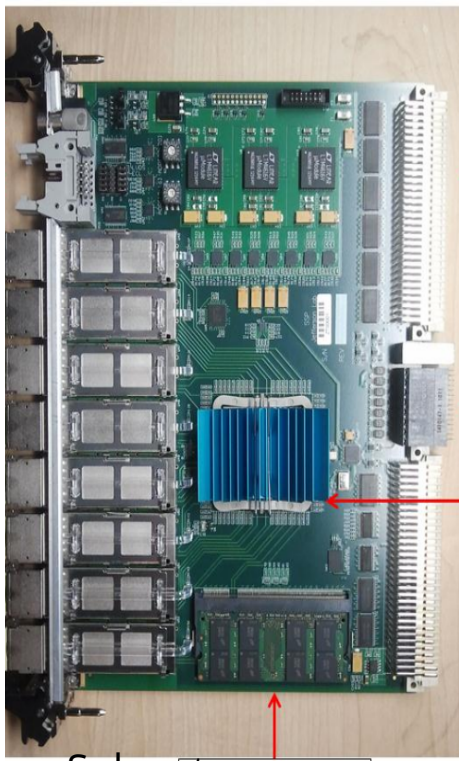


APV-25 FEC

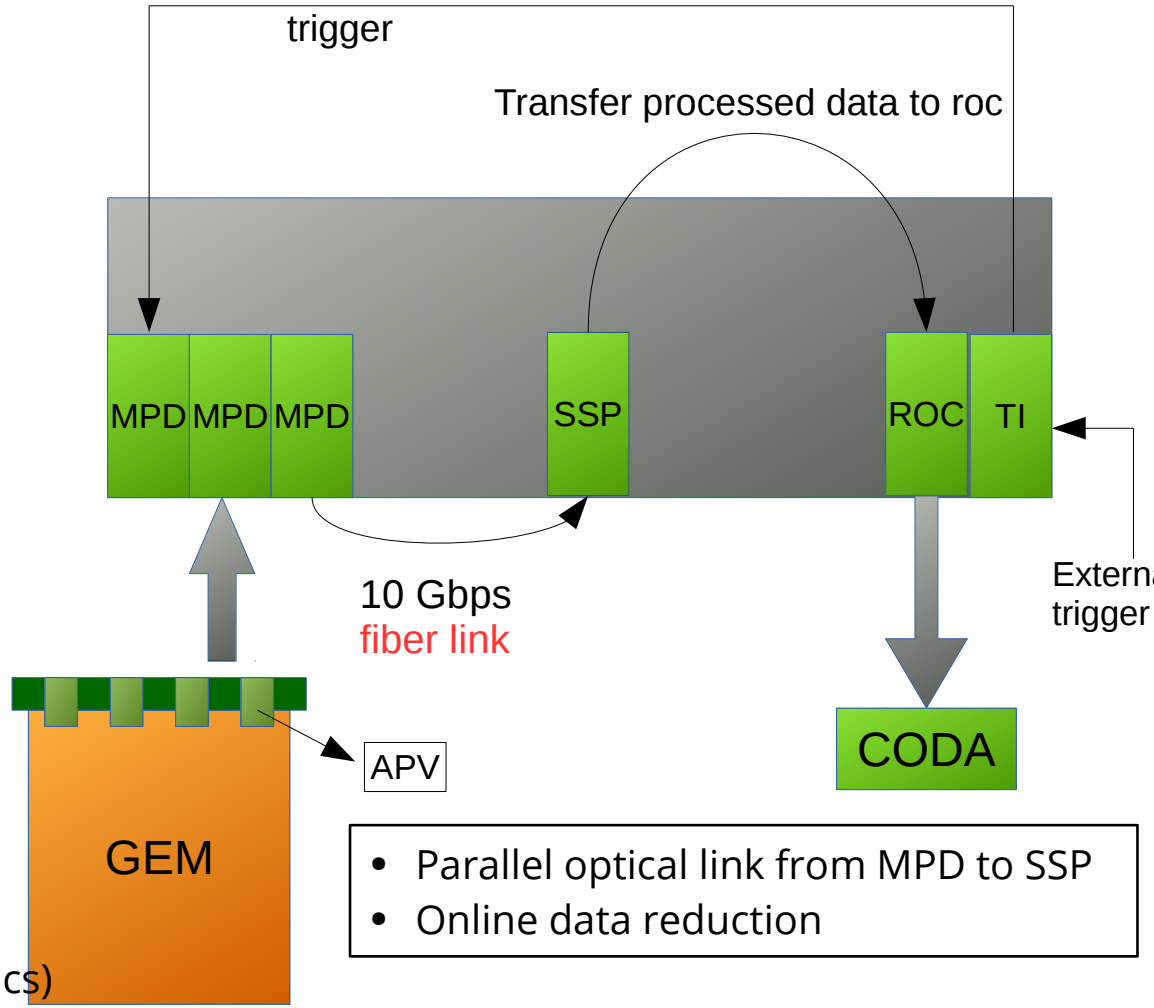
SBS requirements: 2-4kHz
Data injecting rate on each SSP at 2 kHz: 1000 MB/s



FPGA based digitizer
MPD(INFN, Paolo)

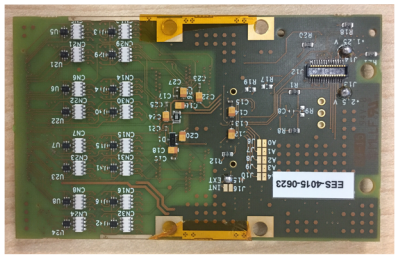


Subsystem processor
(JLab customized electronics)



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

Data acquisition



APV-25 FEC

Case of 16bit word each channel reading 6 sample:

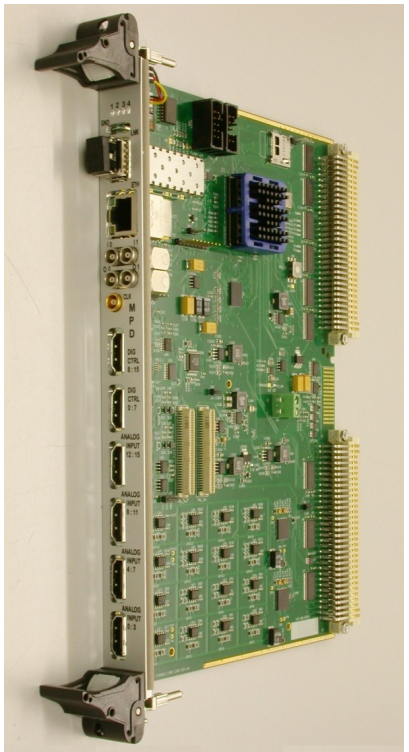
2Byte*128(channels)*6(time sample)=1536 Bytes/APV-25

in case of 4kHz trigger rate:

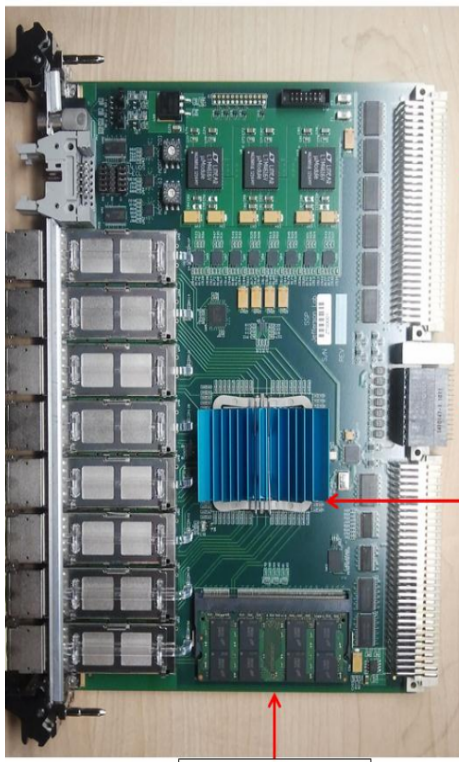
Volume going out from MPD to SSP: 92 MBytes/s

Volume injected into SSP: 24 MPD each ssp:

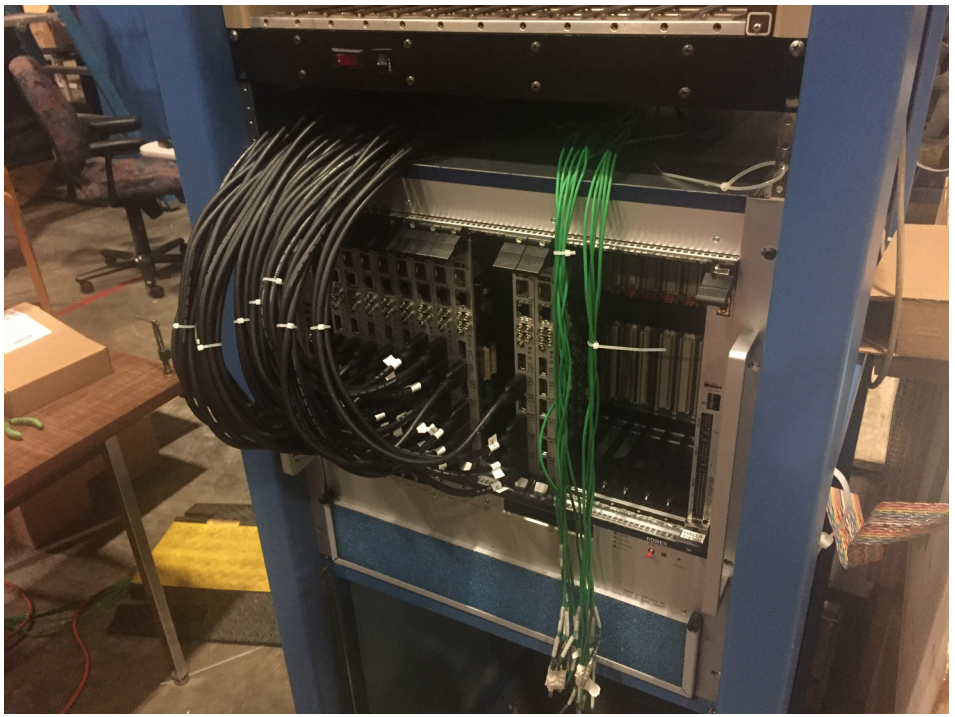
92MB*10+74MB*14=2GB/s (where bottle neck sits right now)



FPGA based digitizer
MPD(INFN, Paolo)



Subsystem
processor

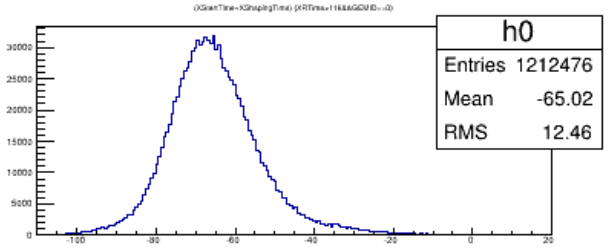


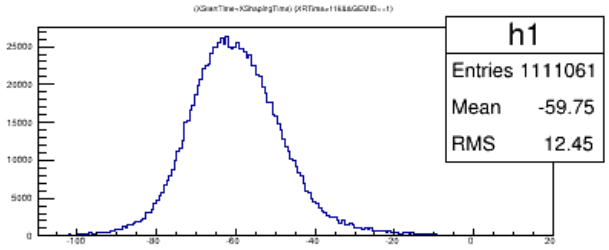
- Parallel optical link from MPD to SSP
- Online data reduction

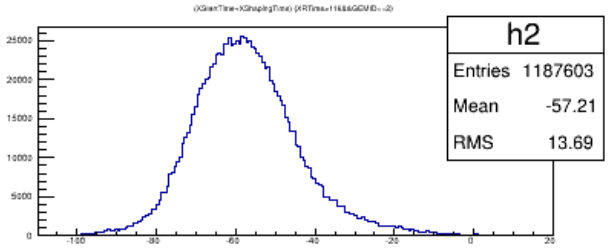
Conclusion and outlook

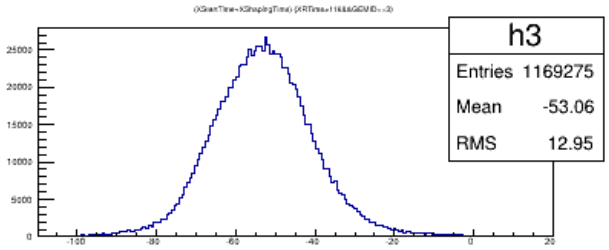
- 40 SBS back tracker GEM modules has been built and tested at University of Virginia.
- SBS has trigger requirement of ~4kHz. Back tracker GEMs has about 30~50% occupancy and will experience huge charge deposition.
  - **High data volume:** 4 kHz trigger rate combined with 110,000 channels to read makes the data volume extremely large. The current scheme is to do parallel reading from MPD to SSP and then do data reduction on SSP.
  - **High occupancy:** A series of hit selection method is introduced. The method has been tested with 1.5% occupancy and works and needs to be tested with higher occupancy comparable with 30~50%.
  - High charge deposition: A X-Ray test box was built at UVa to test GEMs under similar charge deposition(up to 4 mC/cm^2/Day, after amplification) two years ago and a few issues was discovered and solved.
- Another test at JLab in 2017 Fall is being planned to test with higher occupancy.

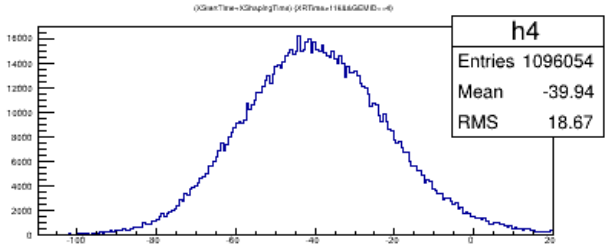
Backup slides











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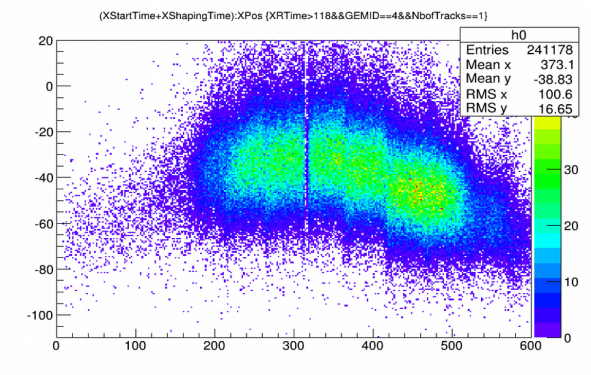

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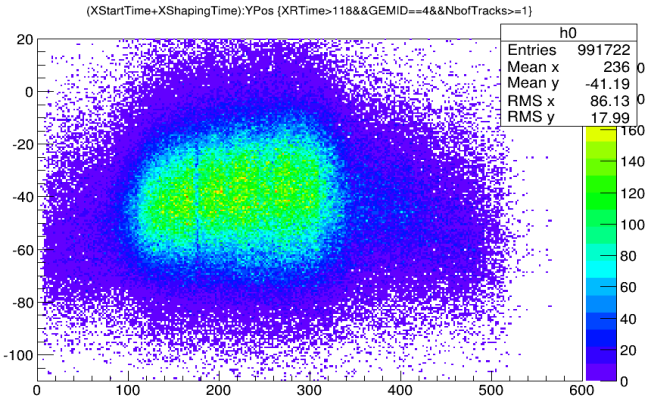
XT



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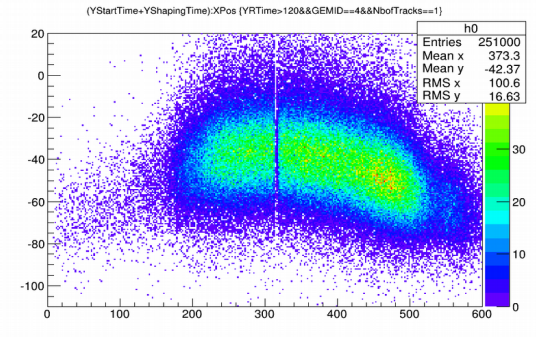
YT



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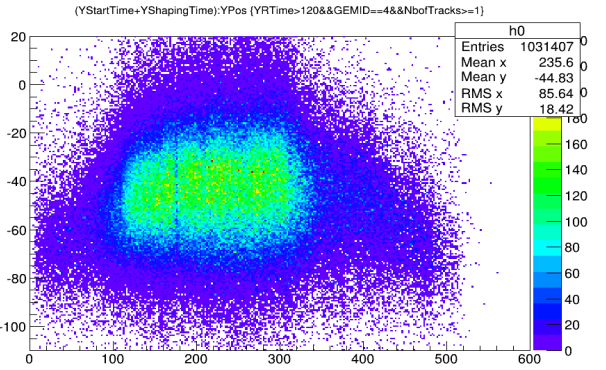
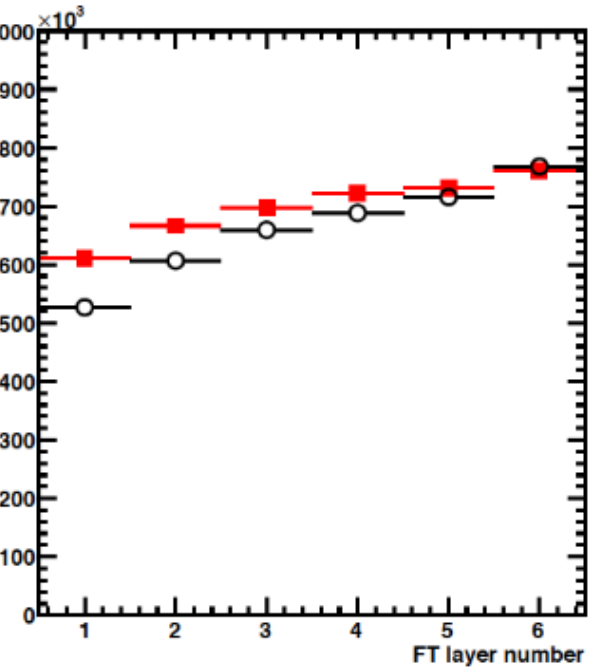
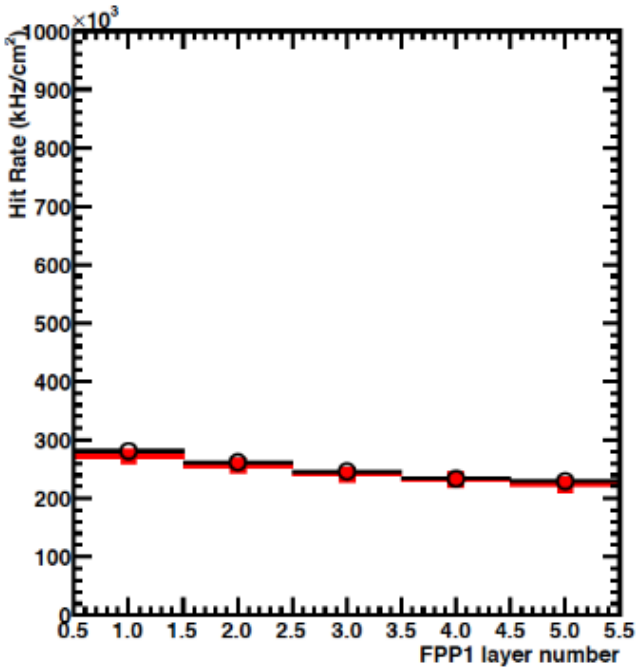


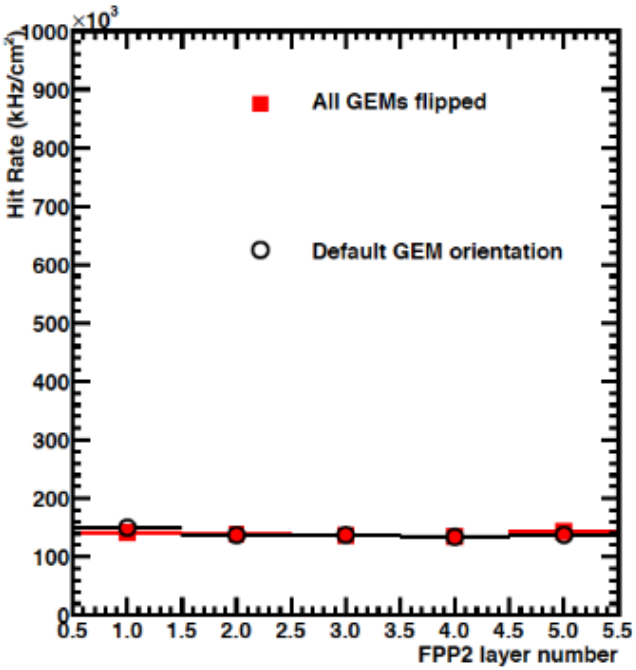
Y

Backup slides

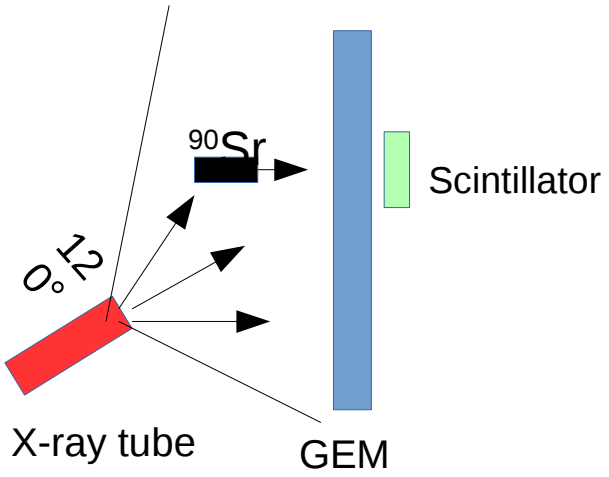
GEM Rate Update







Xray Test Setup



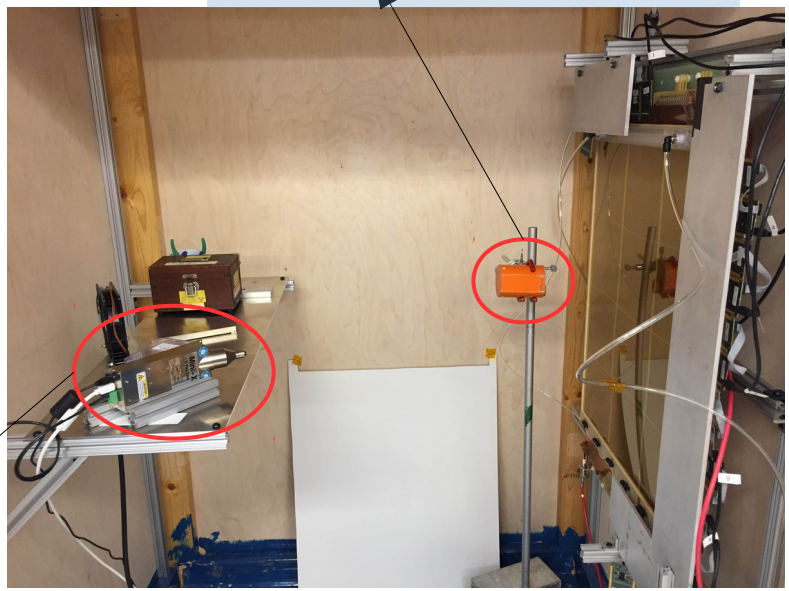
X-ray generator specification:

- Photon energy range: up to 50 keV
- Output flux: 24 MHz/cm^2 on the surface of GEM (20 keV/5 μA)
- Angular distribution: uniform within 60°

This setup provides:

- Charge deposition in GEM: up to 3.4*10^{11} electrons/cm^2/s , which is equivalent to about 7MHz/cm^2 MIP.
- Photon rate at gem surface: up to 100MHz/cm^2 of photons.(conversion rate about 0.5% to electrons for ionization to happen)

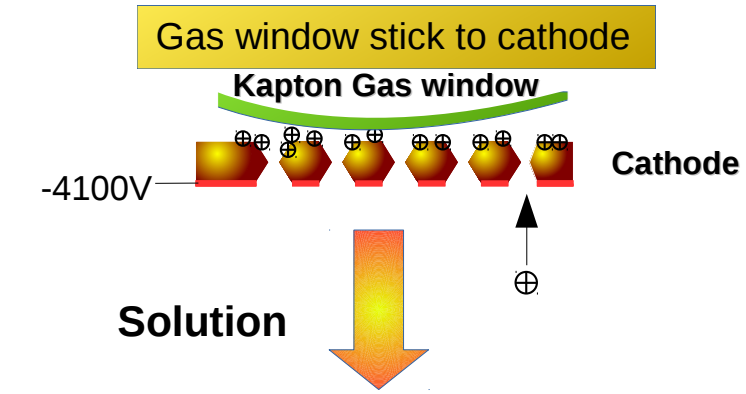
^{90}Sr source(simulating real hit)



X-ray generator as background

R&D on SBS GEM at UVa

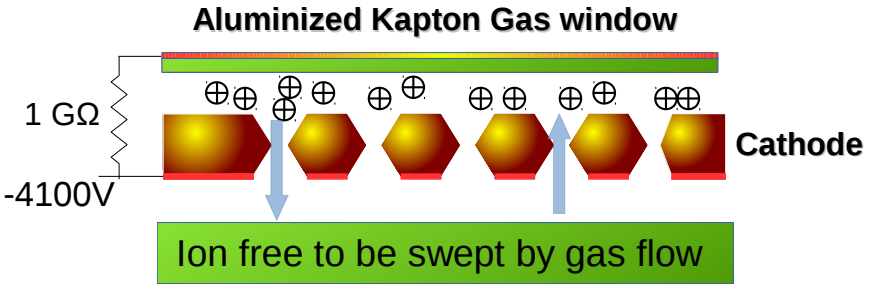
Gas window and cathode

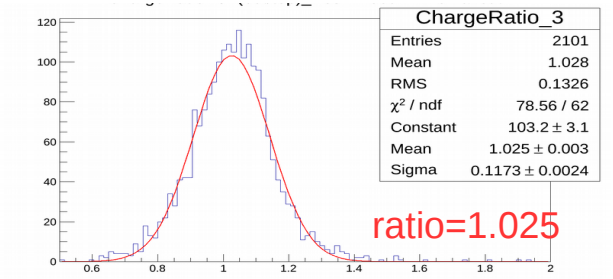


Problem: Charge ratio between top strip and bottom strip can increases from 1.3(low rate cosmic) to 2.2(High rate proton)

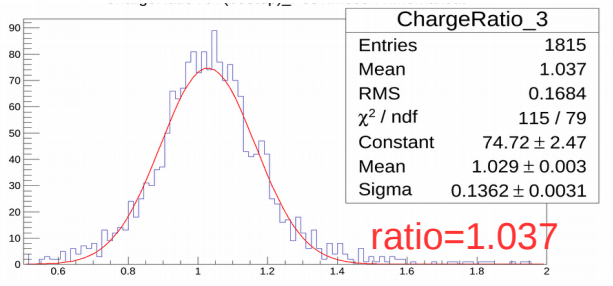
Due to: There are extra kapton between top and bottom strips

Solution: Optical inspection on readout plane before construct each GEM chamber, The charge sharing is not dependent on rate anymore





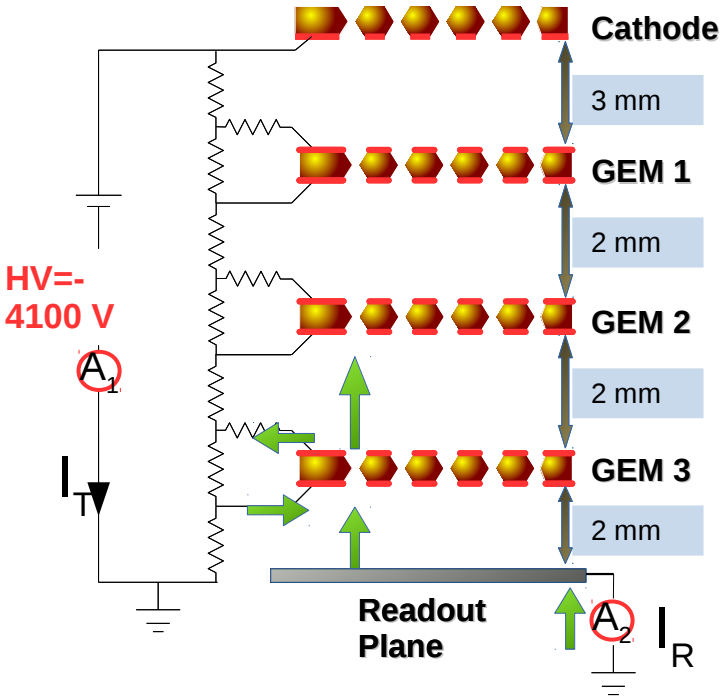
Only ^{90}Sr: Very low back ground

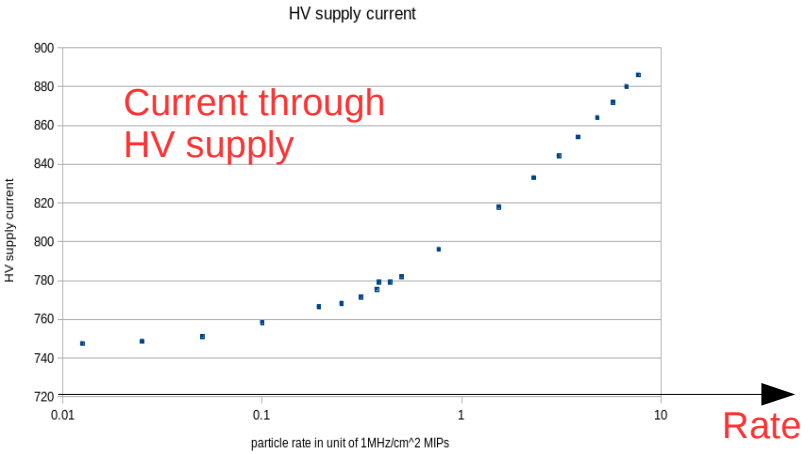


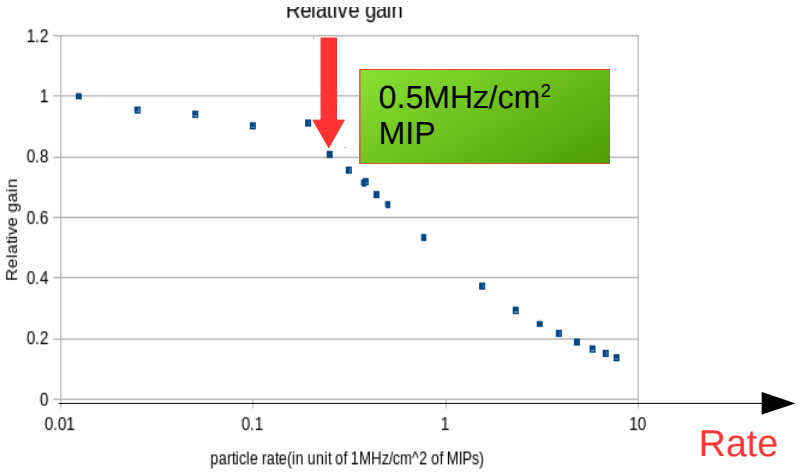
^{90}Sr + X-ray:
Charge equivalent to 0.5 MHz/cm^2 MIP

R&D on SBS GEM at UVa

Effective gain







At -4100V, the nominal current through divider is 746.8 μA, with X-ray irradiating the whole gem, the current can increase 30% due to GEM foil currents, this greatly modified the voltage distribution amoung resisters on HV divider, leading to a drop on gain drop.