Beam Test Simulation and GEM Analysis

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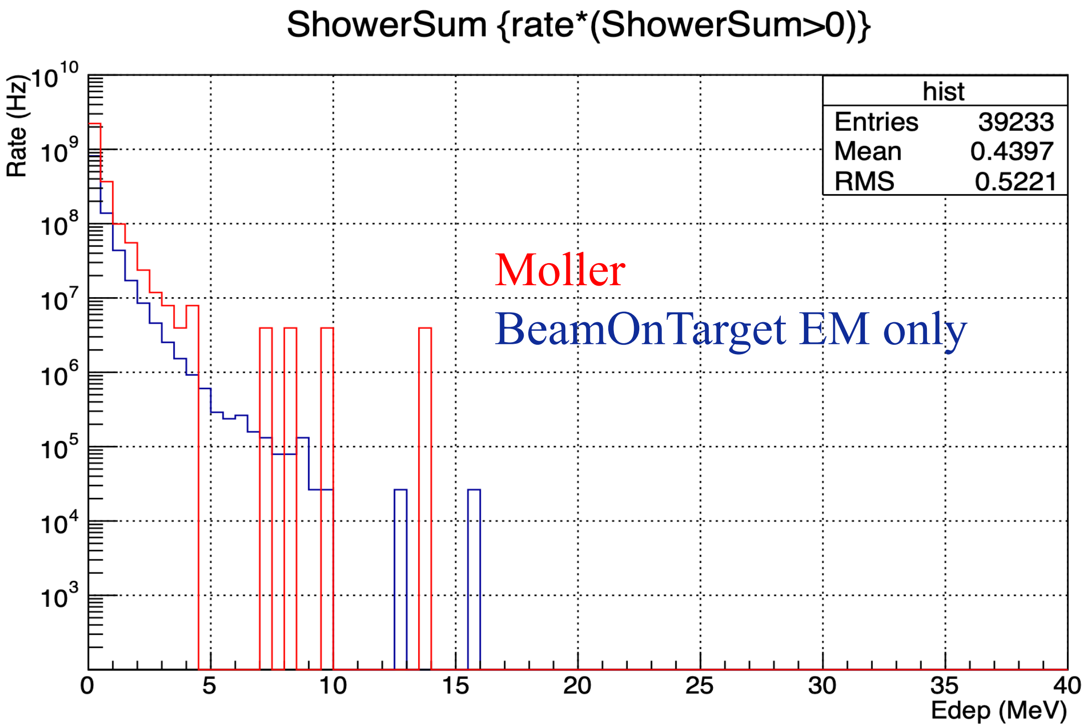
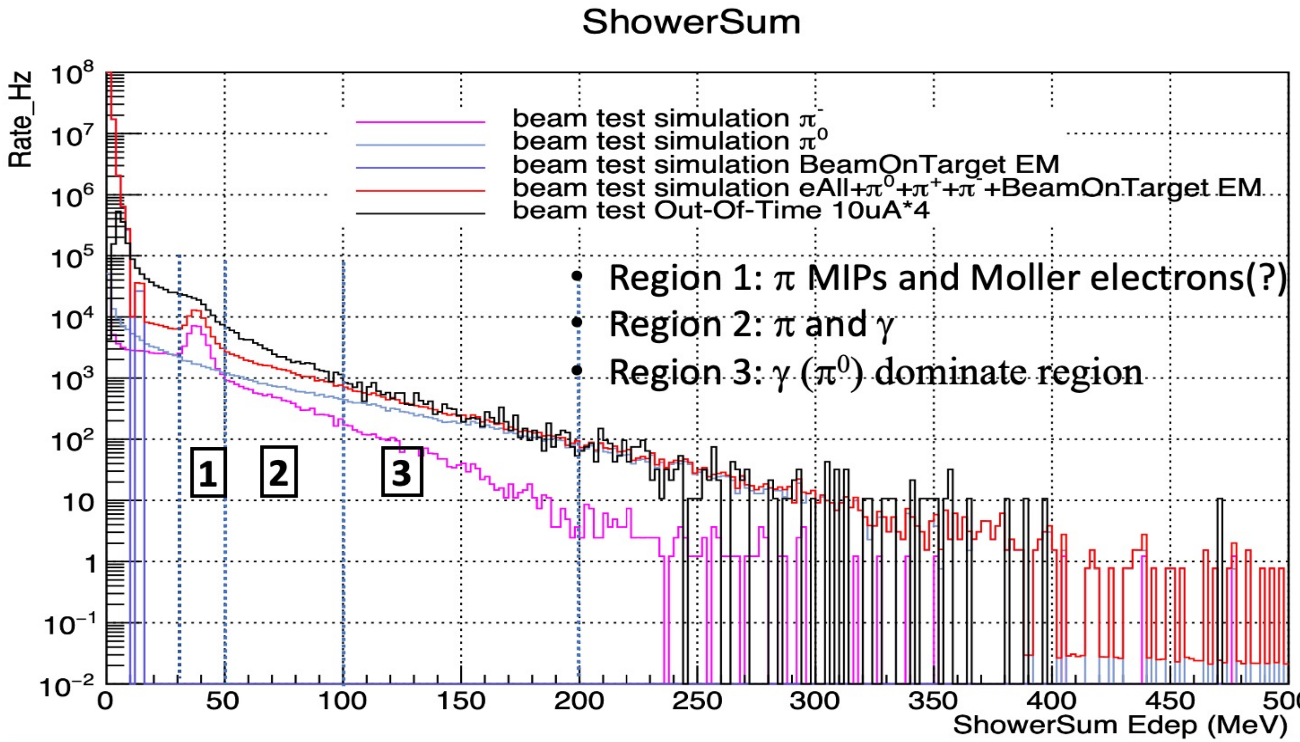
For ECal Beam Test Group

- Scintillators
- Showers
- PreShowers
- Radiation dose
- Summary and Beam Test Outcomes

To-do-list from the Last Collaboration Meeting Talk

- Study coincidence rates from timing plots and MC to find dominant contributions.
- Investigating other triggers (random/Out-of-Time) to clean up MIP spectra and help particle ID.
- Run MC for Moller? and high energy γ (π^0) to get better agreement between simulation and data.
  --- Test it with the Moller event generator from PRad:**PRadSim**/evgen/**norc**
- Rate comparison at high rates.

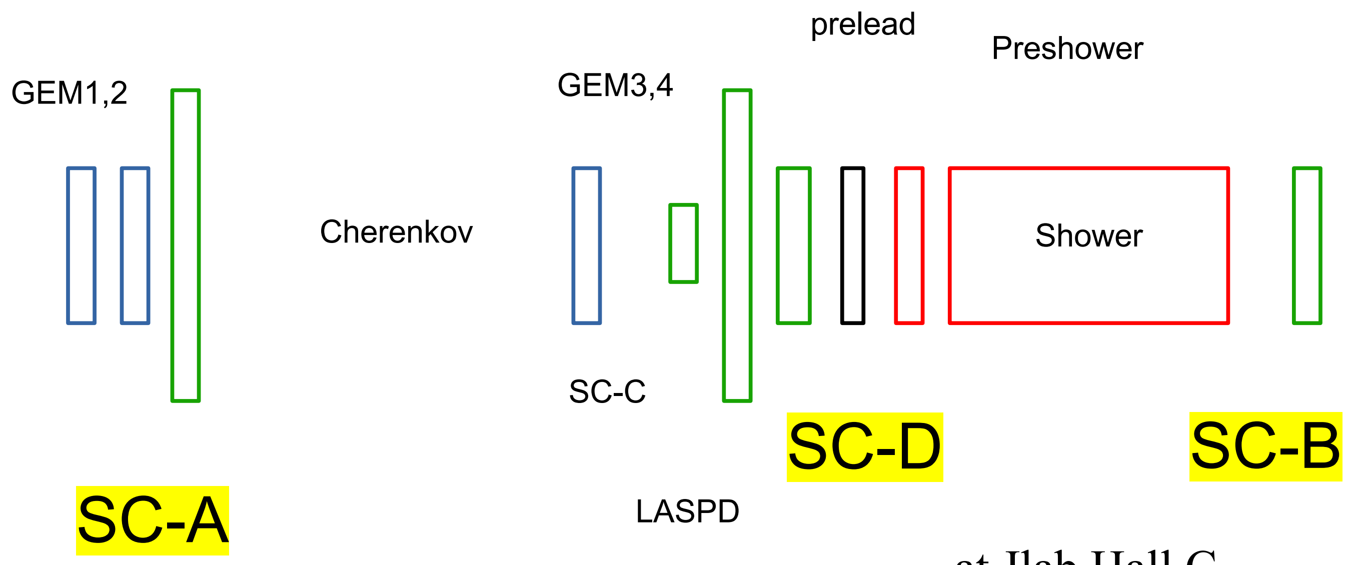




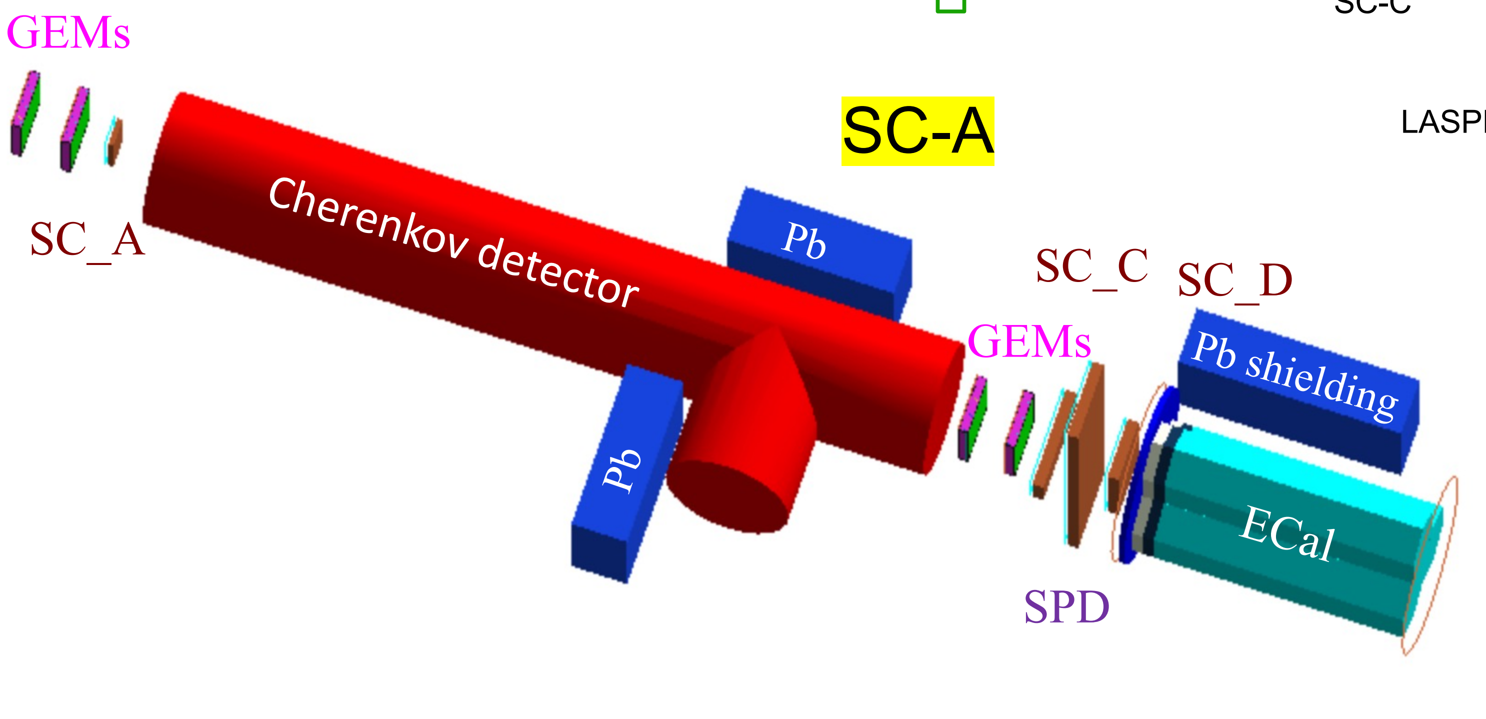
- Moller background: Generate: 2.5e8 event, only 713 of them deposited energy at Shower

Latest pre-R&D – Detector Beam Test

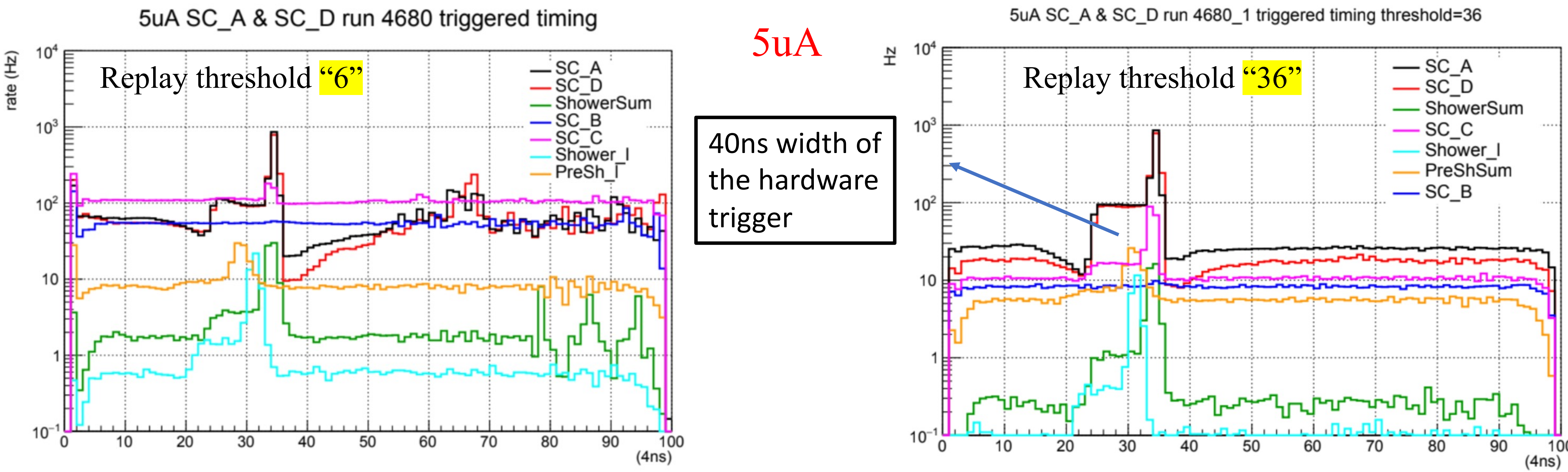
~22m away from target



at Jlab Hall C

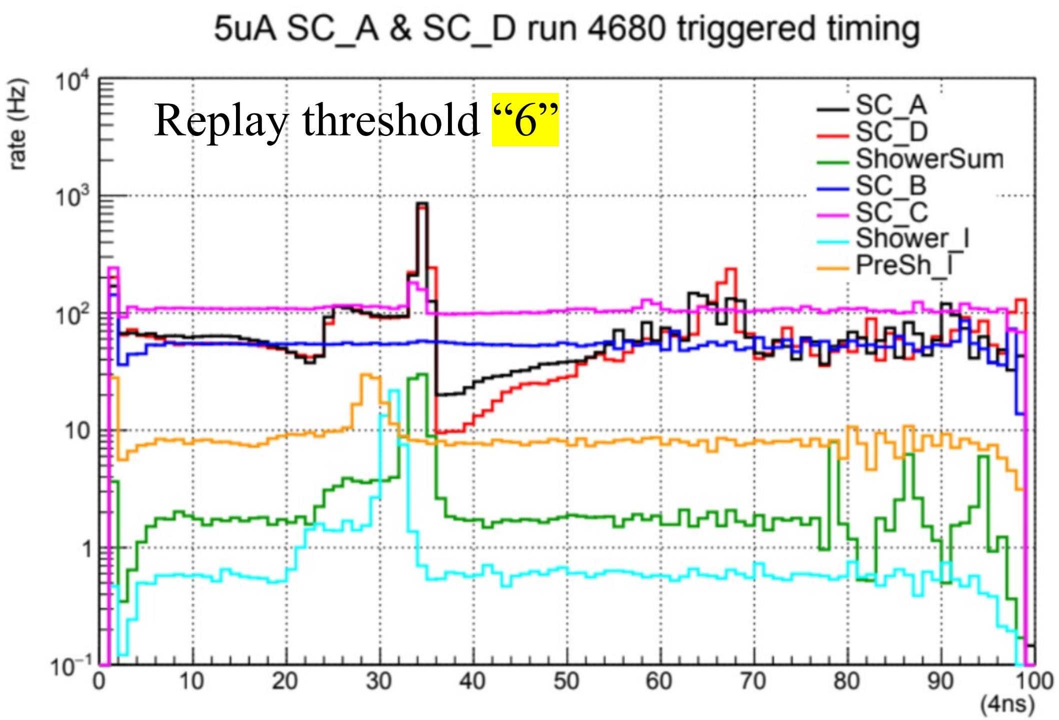


Scintillators with Coincidence Trigger

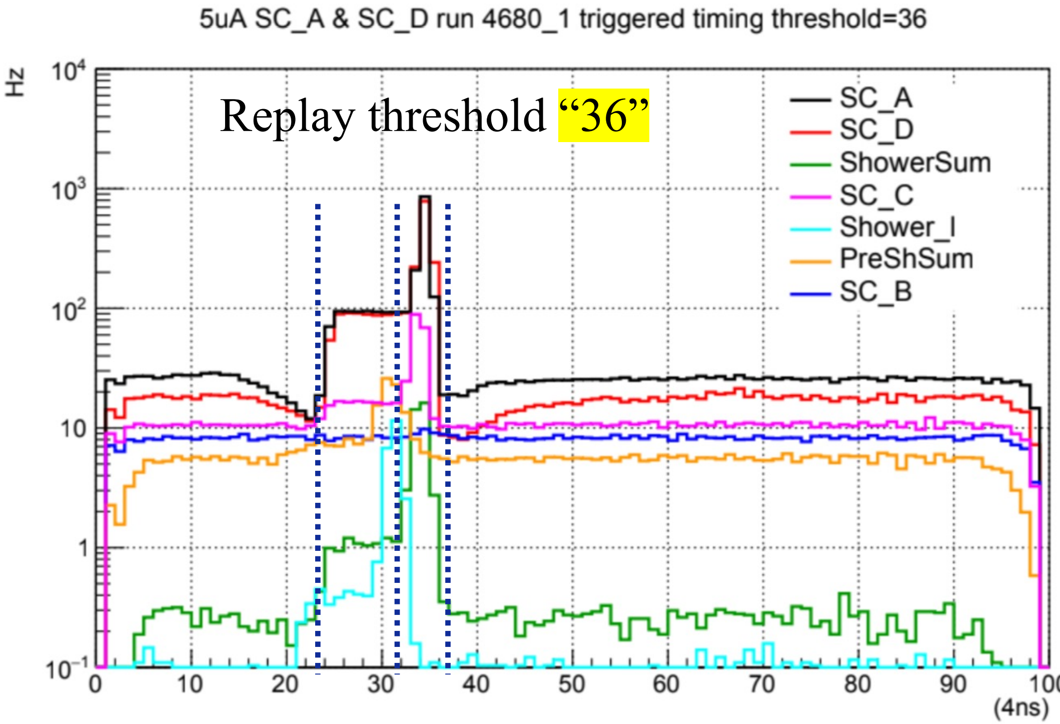


- The ShowerSum spectrum changes when the decoder threshold is raised from 6 to 36.
- The threshold=36 plot shows mostly MIP's, whereas the threshold=6 plot is dominated by the small pulses well below the MIP level.

Scintillators with Coincidence Trigger



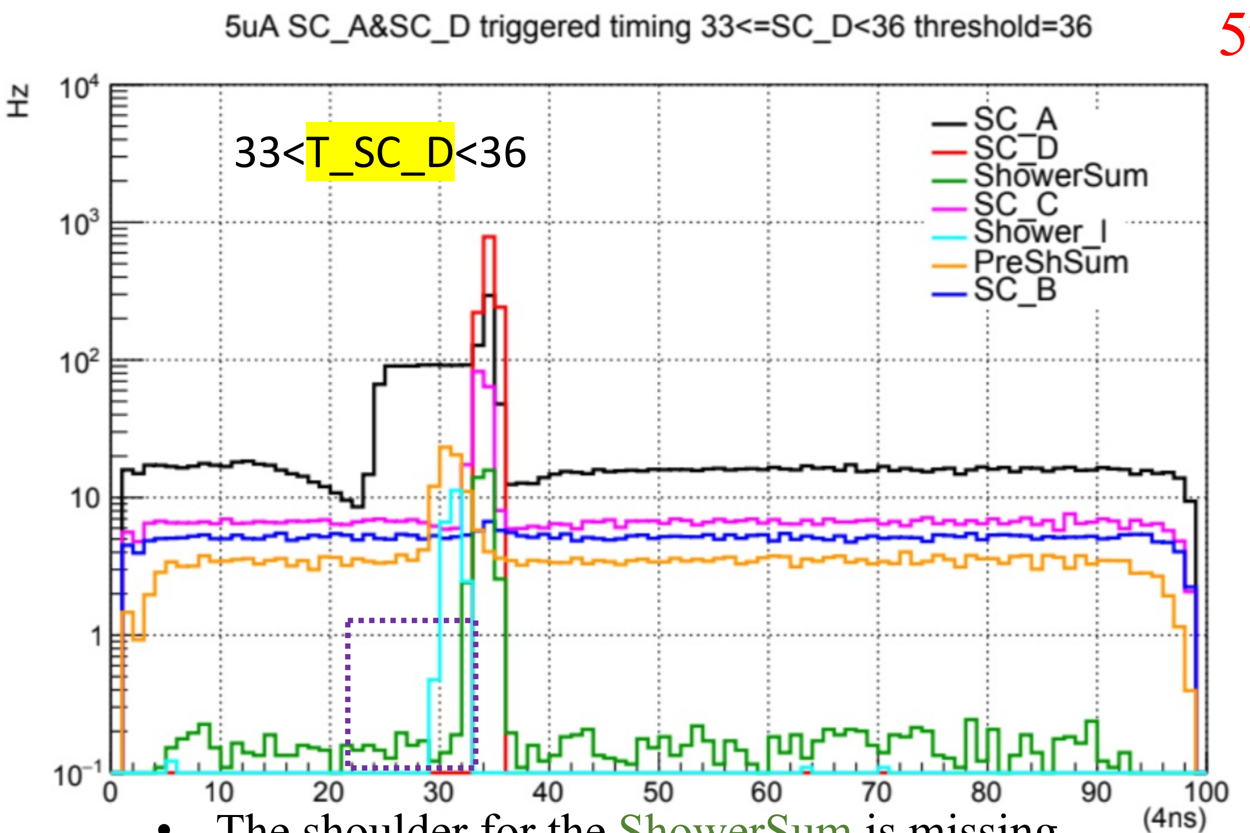
5uA



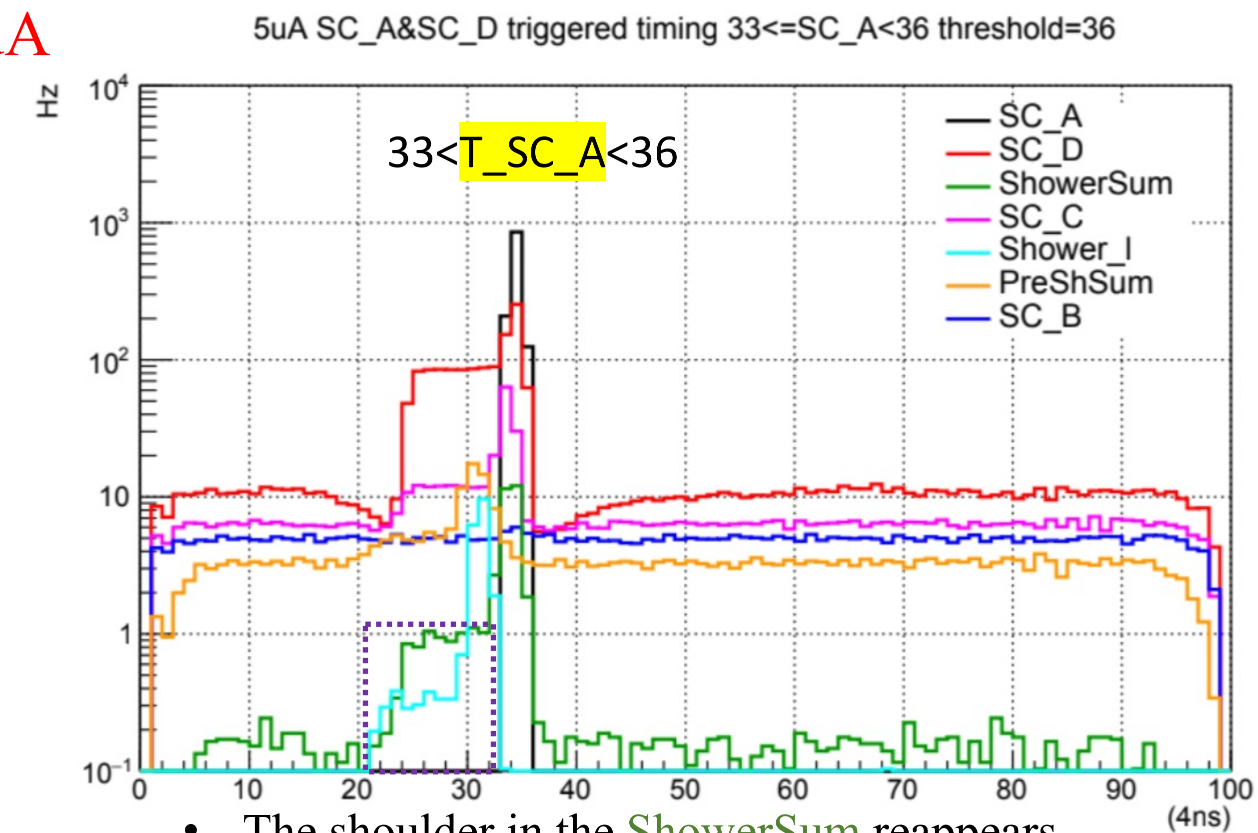
- The ShowerSum spectrum changes when the decoder threshold is raised form 6 to 36.
- The threshold=36 plot shows mostly MIP's, whereas the threshold=6 plot is dominated by the small pulses well below the MIP level.
- The different time regions have different pulse height spectra. The randoms are dominated by the smallest ShowerSum pulses and the peak is dominated by MIP's.

Scintillators with Coincidence Trigger

5uA



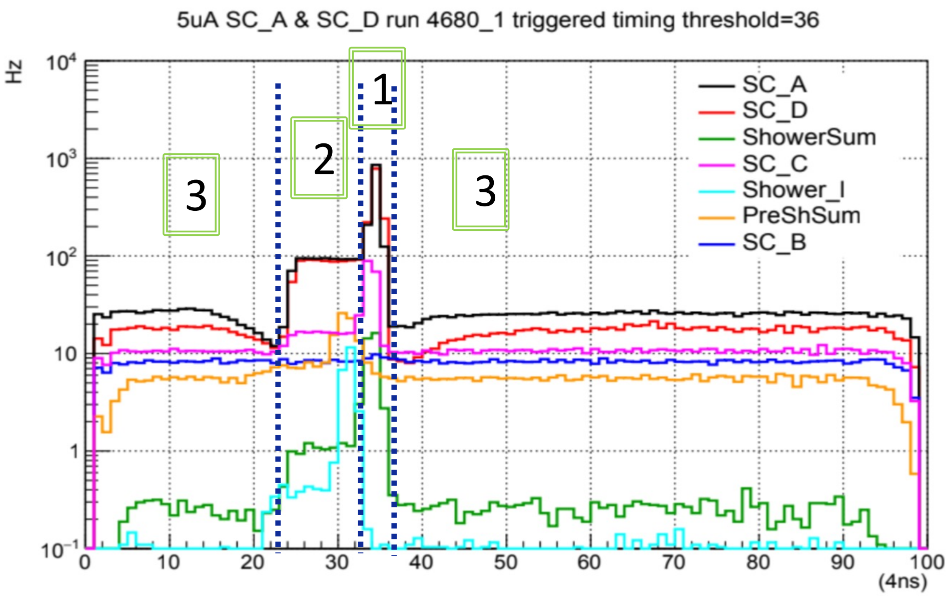
- The shoulder for the ShowerSum is missing



- The shoulder in the ShowerSum reappears.

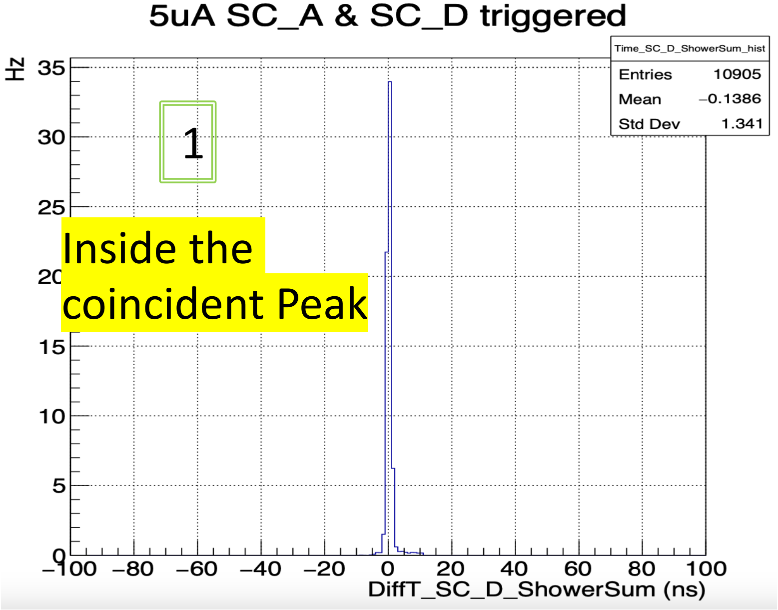
- The reason is that since most pions are relatively parallel to the beam line, if there is no SCD in coincidence, the SCA signal is not from a pion.
- This means the the MIP peak should be cleanest for a tight 4-12 ns triple coincidence, less clean for coincidences with SCD, and weakest for random triggers.

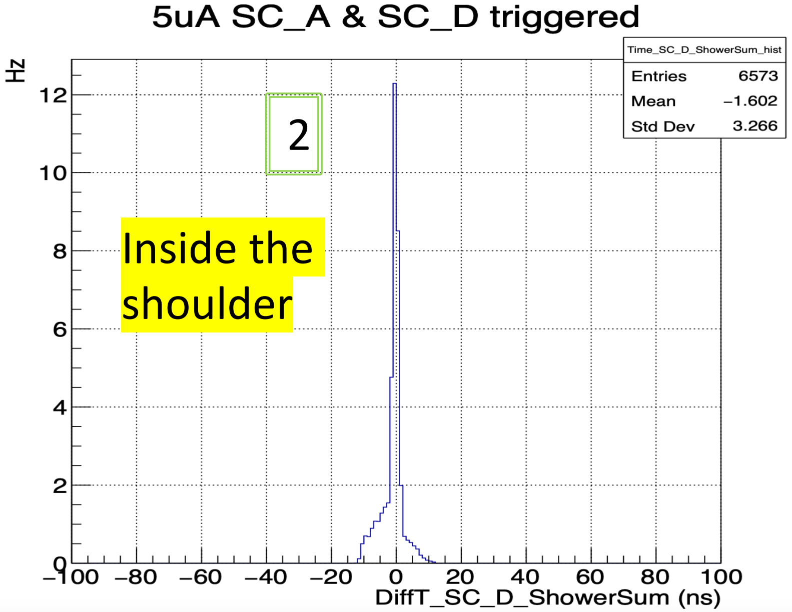
The Time Difference Between the Closet SC_D Pulse and ShowerSum

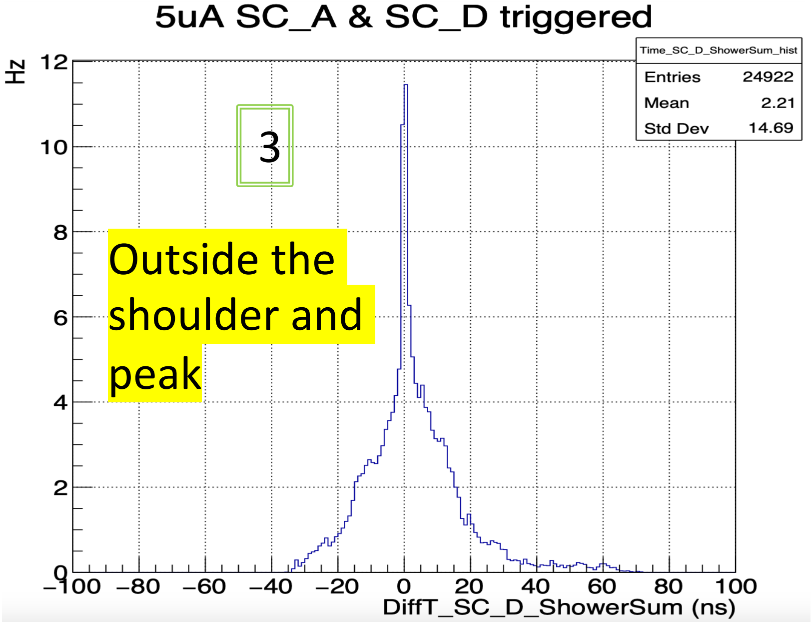


- 5uA SC_A & SC_D triggered with threshold=36
- Events with ShowerSum pulse in range 1, 2, and 3

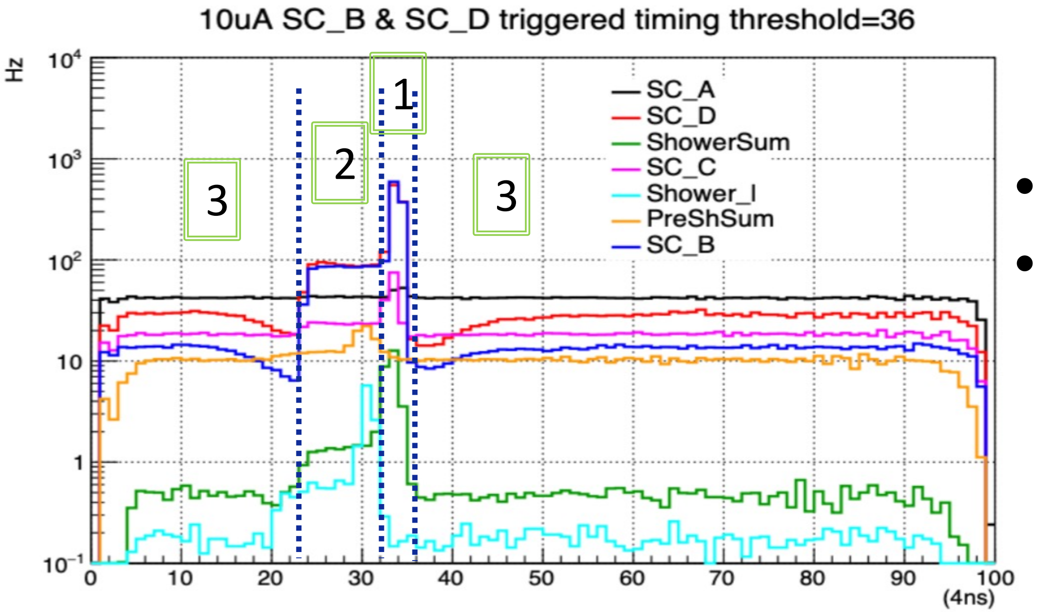
ΔT(SC_D-ShowerSum)





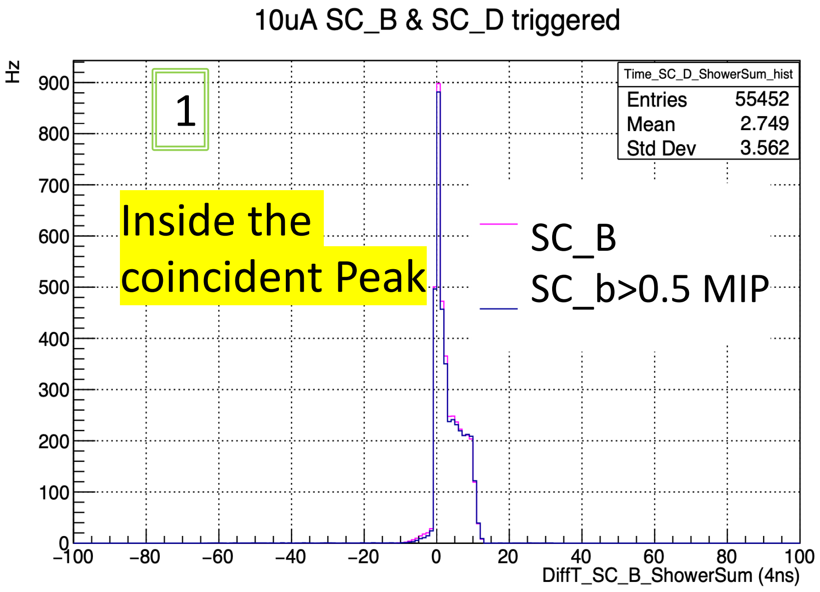


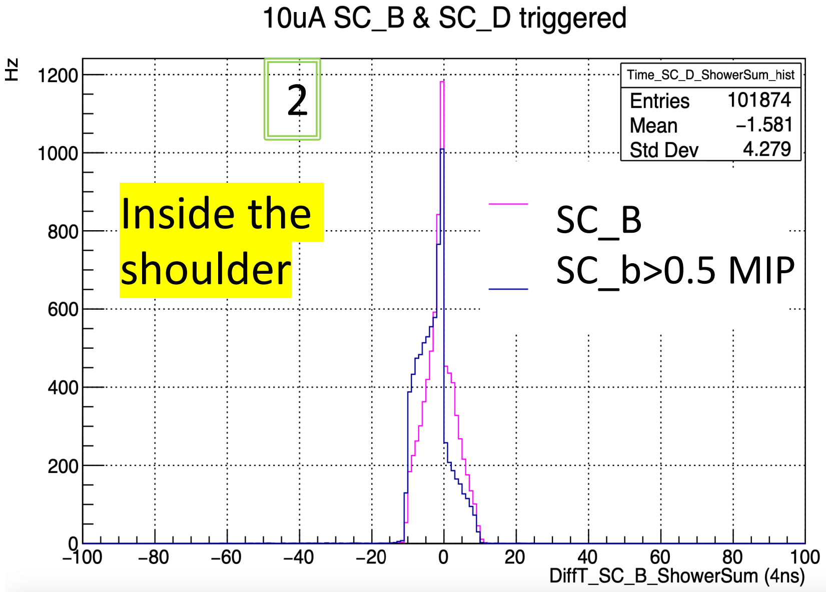
The Time Difference Between the Closet SC_B Pulse and ShowerSum

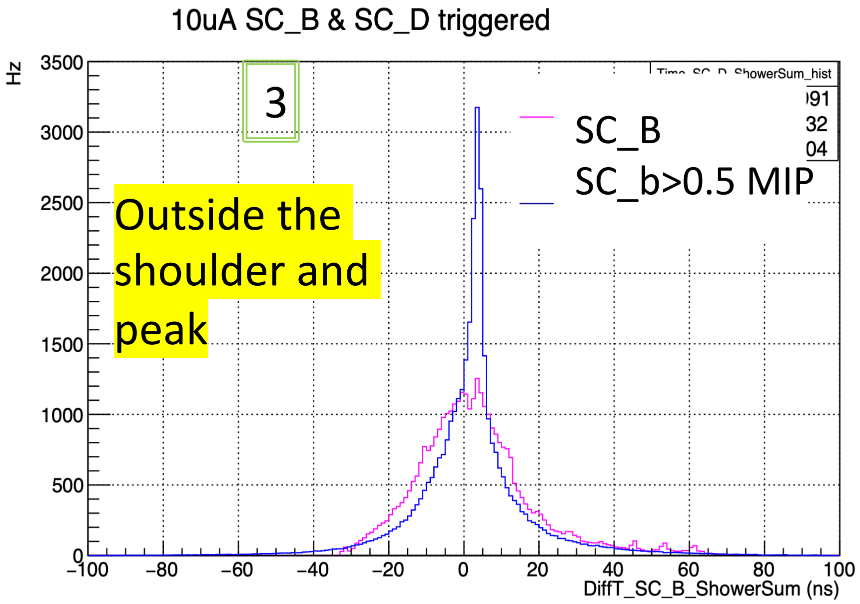


- 10uA SC_B & SC_D triggered with threshold=36
- Events with ShowerSum pulse in range 1, 2, and 3

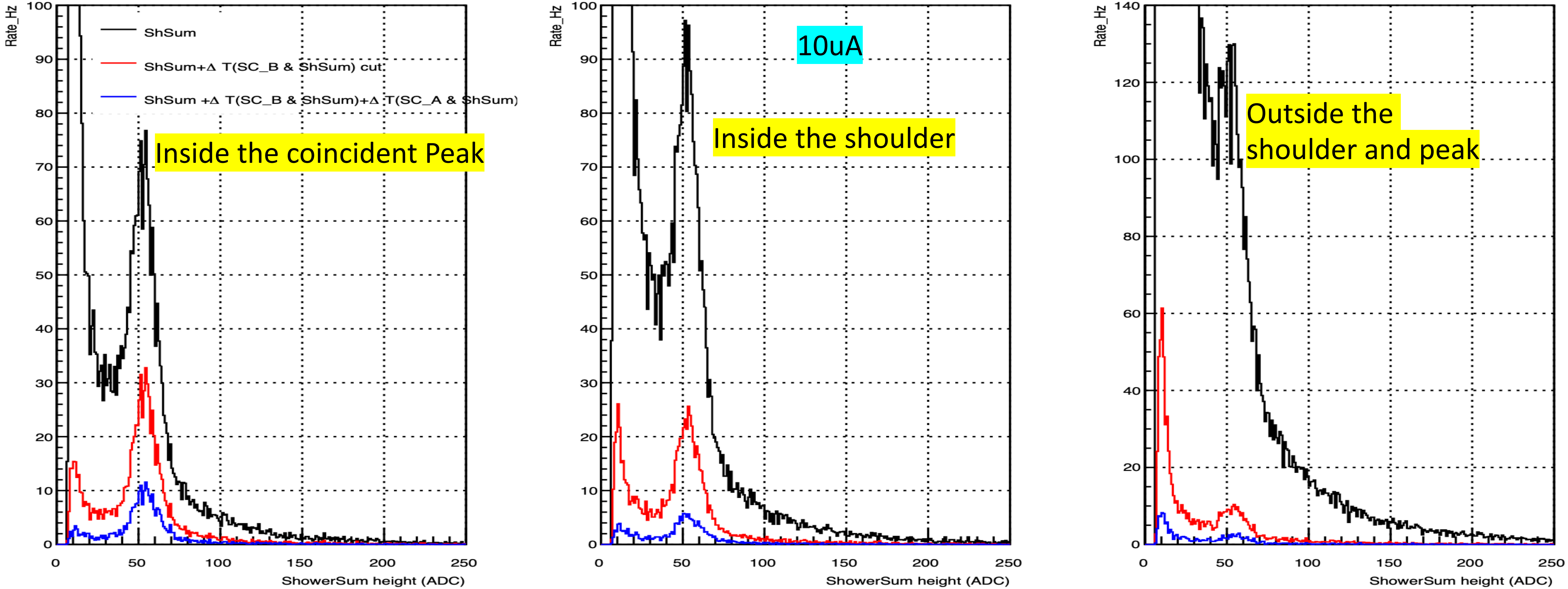
ΔT(SC_B-ShowerSum)





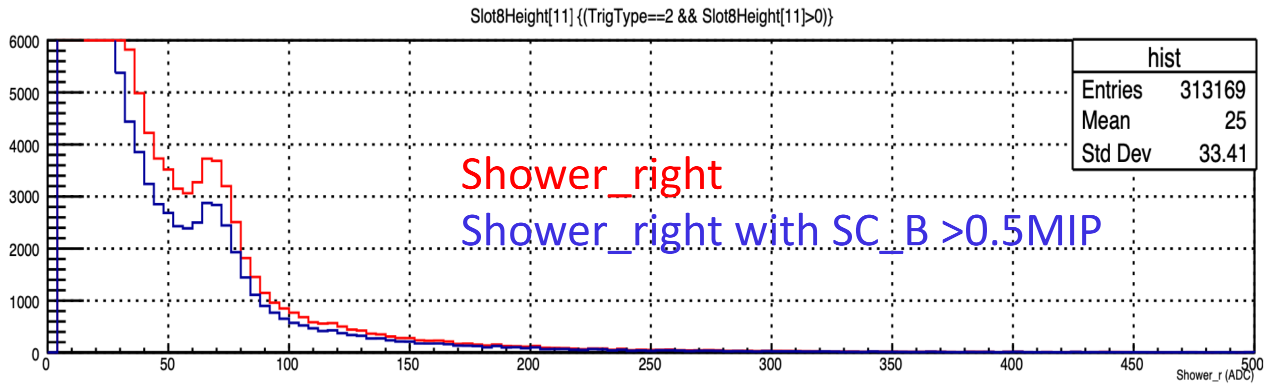


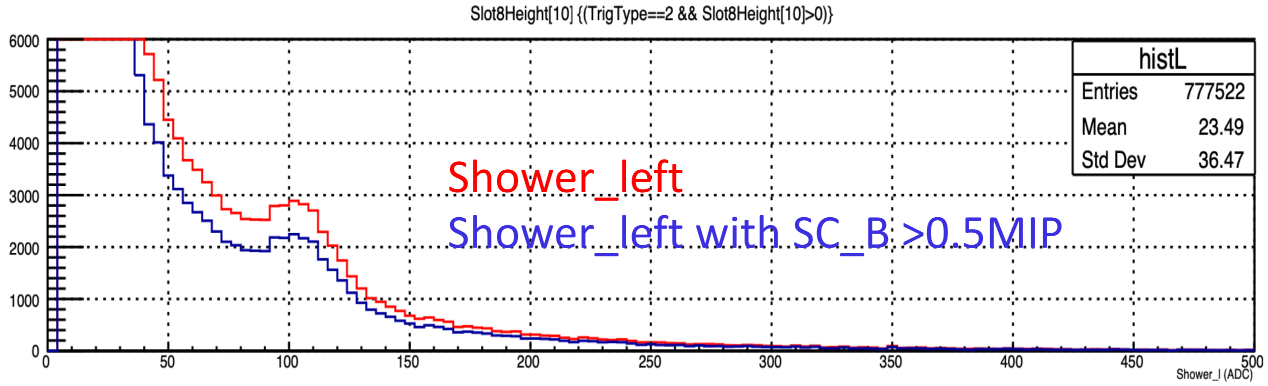
10uA ShowerSum MIP Comparison with the SC_B & SC_D triggered

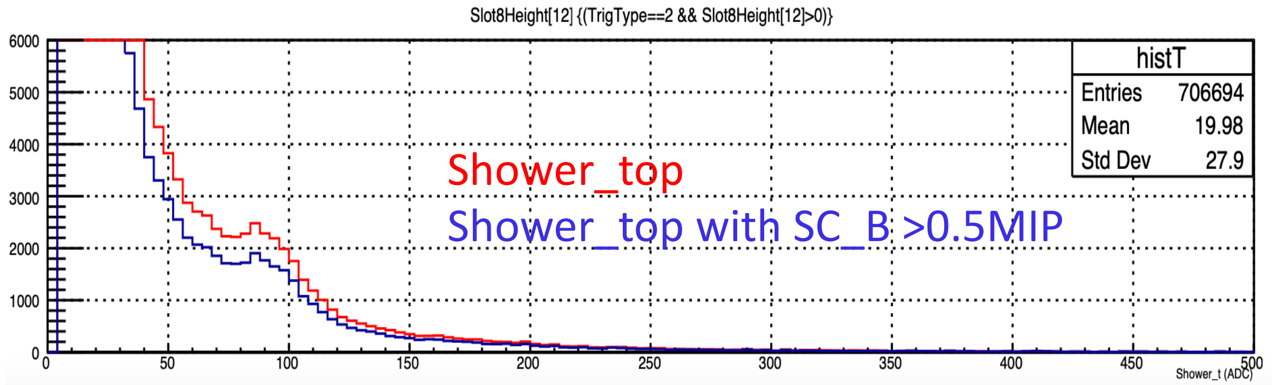


- Cuts: Trigger+ShowerSum signal+ΔT(SC_B-ShowerSum)+ΔT(SC_A-ShowerSum)
- ΔT(ShowerSum-SC_B) coincidence cut + ΔT(ShowerSum-PreSh) coincidence cuts work the best to clean up the MIPs.

45uA ShowerSum MIP Comparison







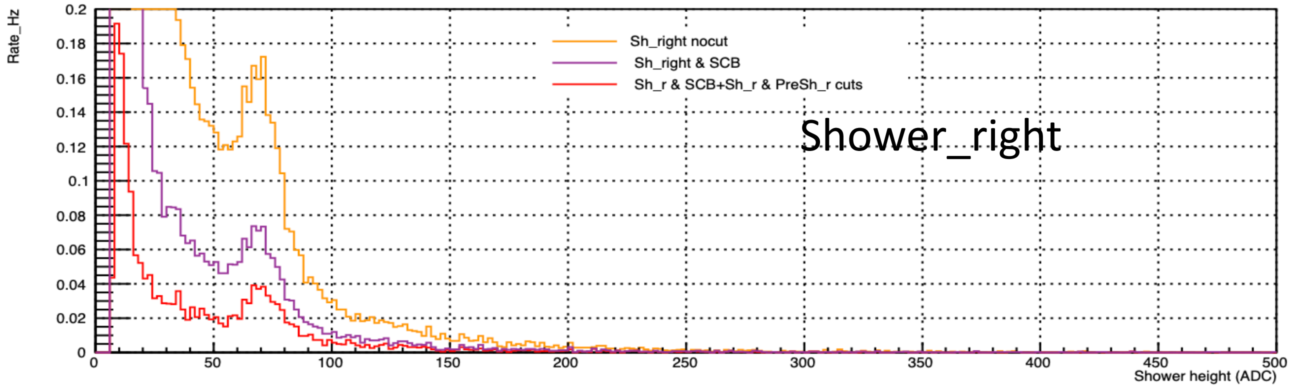
45uA run4653:

- Trigger: SC_B & SC_D
- SC_B height>0.5 MIP (500 ADC)

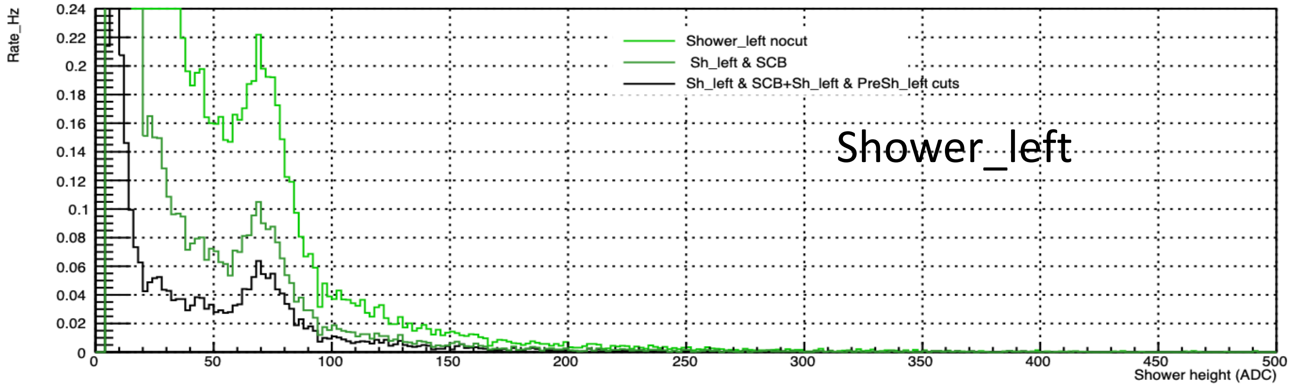
Observations:

- Gain shifts
- SC_B height >0.5 MIP cut doesn’t clean up MIP peaks

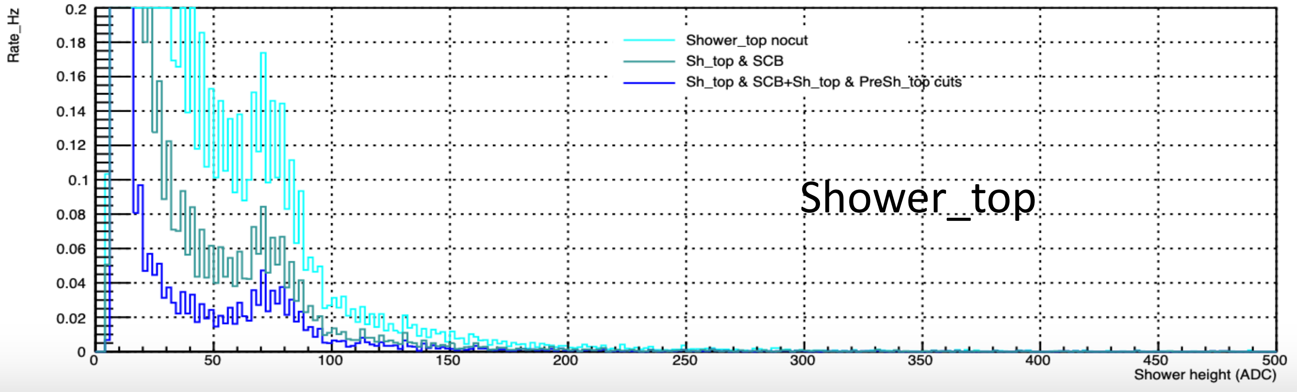
45uA ShowerSum MIP Comparison with Gain Correction



45 uA Shower_left inside peak



45 uA Shower_top inside peak



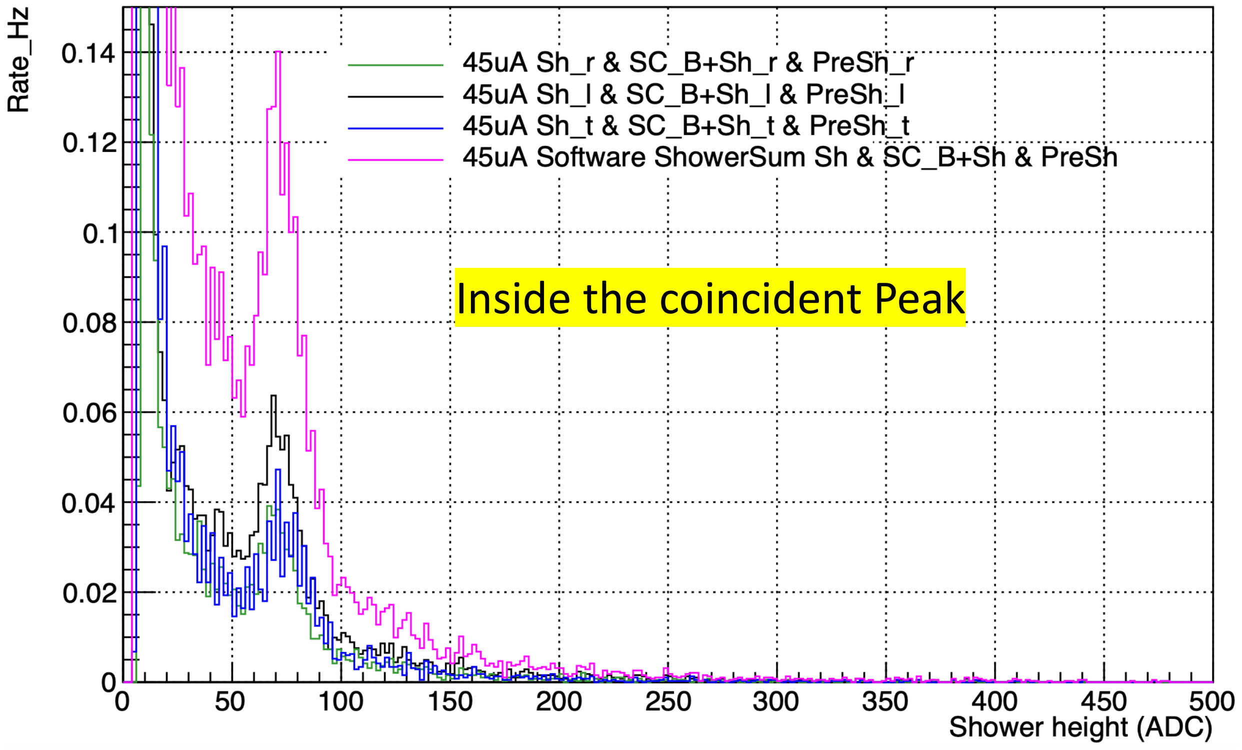
Events with shower signal inside the SC_B & SC_D coincident Peak

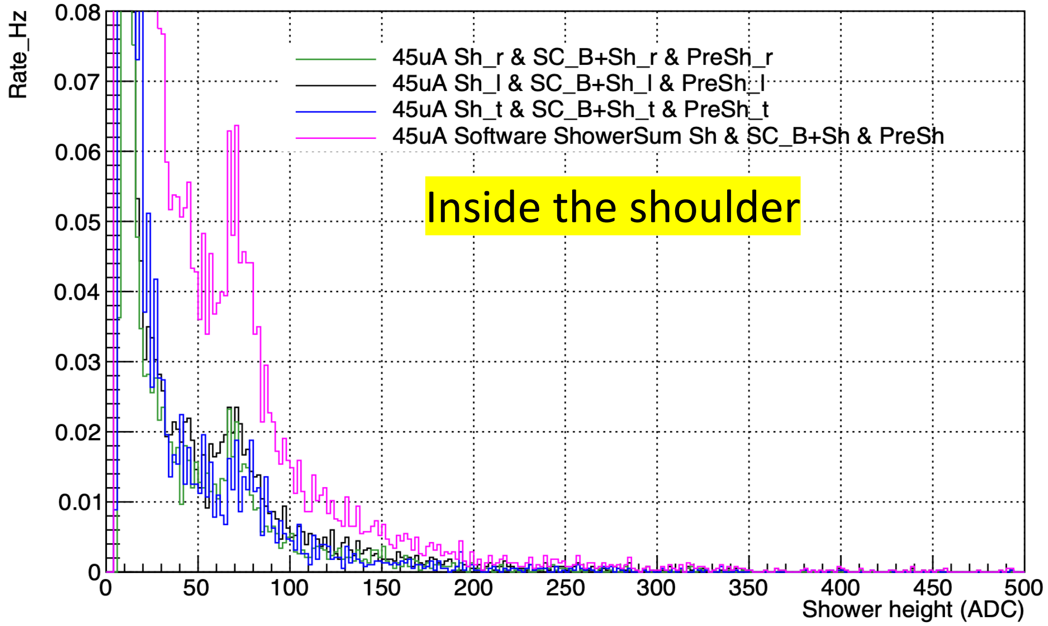
Trigger only
Trigger+ ΔT (Sh_right & SC_B) cut
Trigger+ ΔT (Sh_right & SC_B)+ ΔT (Sh_right & PreSh_right)+ cut

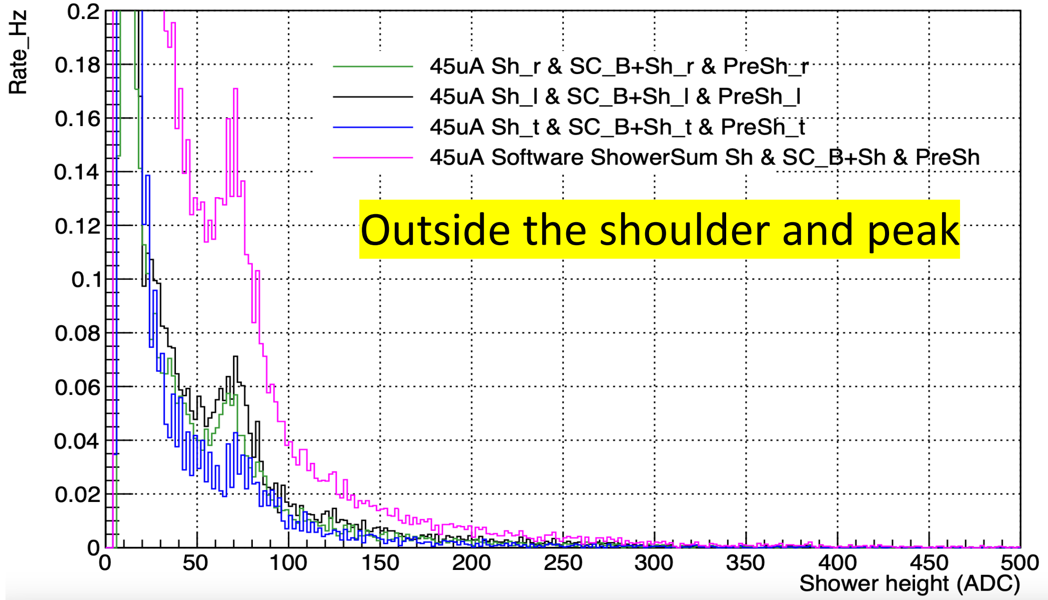
Trigger only
Trigger+ ΔT (Sh_left & SC_B) cut
Trigger+ ΔT (Sh_left & SC_B)+ ΔT (Sh_left & PreSh_left)+ cut

Trigger only
Trigger+ ΔT (Sh_top & SC_B) cut
Trigger+ ΔT (Sh_top & SC_B)+ ΔT (Sh_top & PreSh_top)+ cut

45uA ShowerSum MIP Comparison

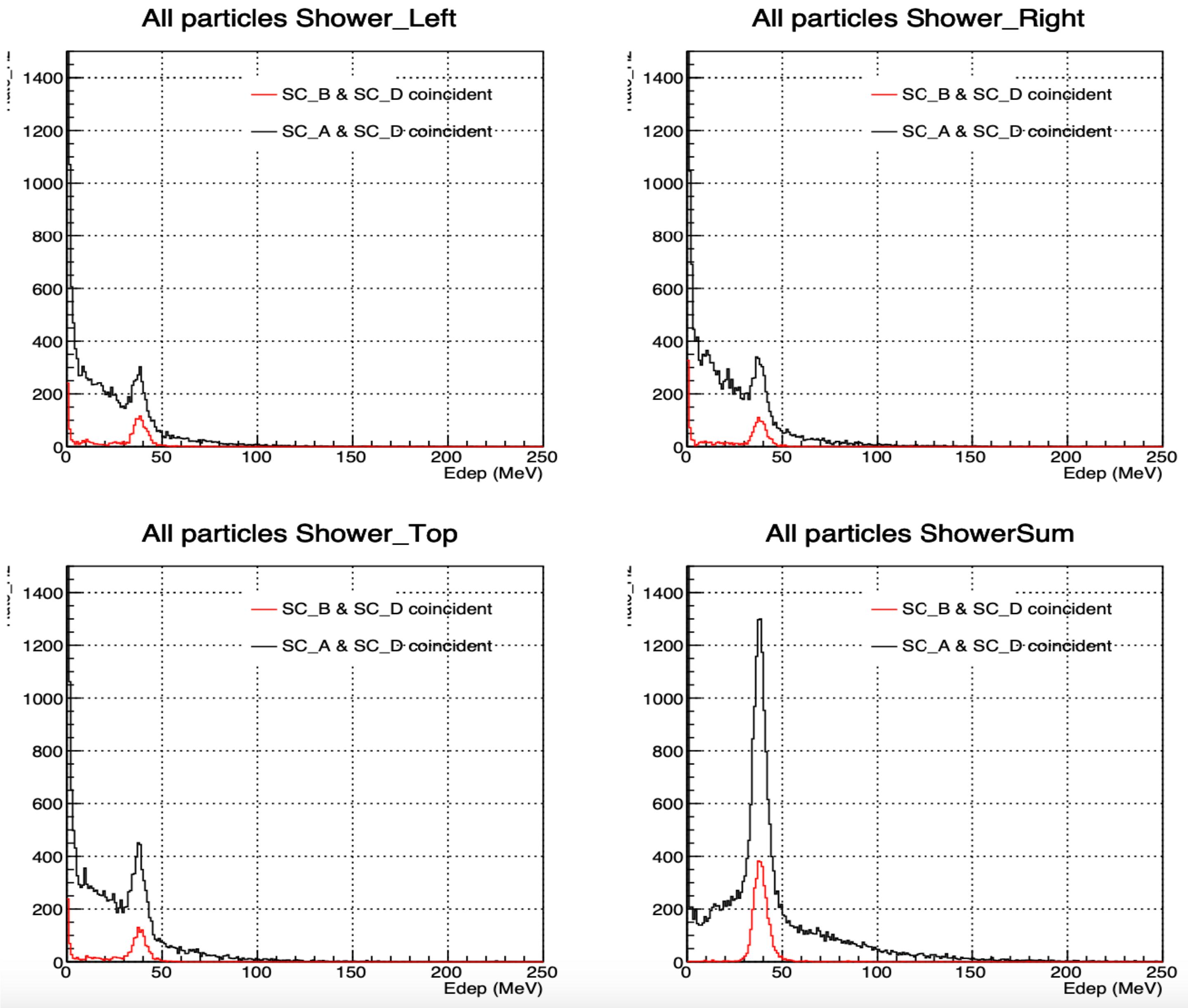






- For high-rate data, MIP peaks can be cleaned up by applying the coincident timing cut ΔT(ShSum-SC_B), SC_B and PreShSum.

Simulation MIP Comparison



- The simulation plots show that the SC_B & SC_D coincidence cut works better on isolating shower MIP peaks.

Single Detector Rate Comparison between Simulation and Scaled Data

- Using timing plots to get data rate

Detector	e^- kHz/cm^2	π^- kHz/cm^2	π^+ kHz/cm^2	π^0 kHz/cm^2	EM kHz/cm^2	total kHz/cm^2	Scaled 5uA data kHz/cm^2
SC_A (0.87MIP)	8.66e-5	0.35	0.22	0.068	869.01	869.6	720.0
SC_D (0.78MIP)	1.35e-4	0.41	0.26	0.16	257.9	258.7	197.4
PreShSum 0.5 MIP	8.2e-5	0.26	0.16	0.23	20.3	21.0	17.9
ShowerSum 0.5 MIP	7.1e-5	0.21	0.13	0.2	0	0.54	0.45
SC_B (0.8 MIP)	1.11e-5	0.079	0.038	0.029	701.85	702.0	600.0

Scintillator Coincidence Rates Comparison between Simulation and Scaled Data

- Using timing plots SC_A & SC_D to get data rate

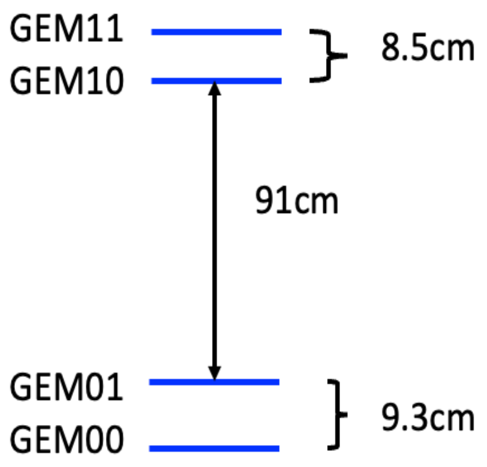
Detector	e^- kHz/cm^2	π^- kHz/cm^2	π^+ kHz/cm^2	π^0 kHz/cm^2	EM kHz/cm^2	total kHz/cm^2	Scaled 5uA data kHz/cm^2
SC_A	7.3e-5	0.27	0.16	0.034	4.9	5.36	4.85
SC_D	2.7e-5	0.098	0.058	0.013	1.8	1.97	1.80
PreShSum	9.0e-6	0.033	0.019	0.0046	0.61	0.67	0.60
ShowerSum	9.0e-6	0.033	0.019	0.0046	0.61	0.67	0.60
SC_B	5.5e-5	0.2	0.11	0.028	3.7	4.07	3.64

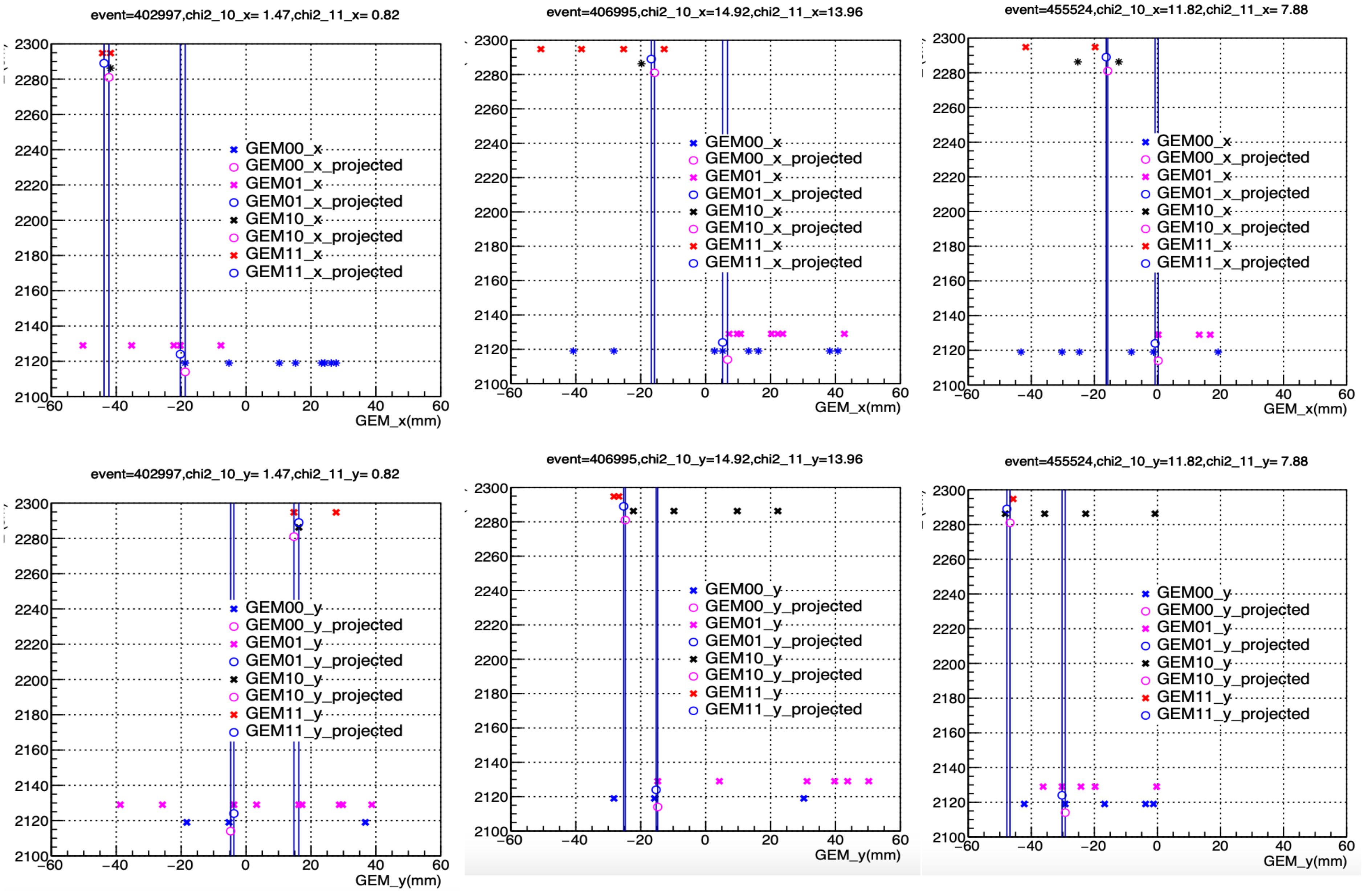
- Using timing plots SC_B & SC_D to get data rate

Detector	e^- kHz/cm^2	π^- kHz/cm^2	π^+ kHz/cm^2	π^0 kHz/cm^2	EM kHz/cm^2	total kHz/cm^2	Scaled 10uA data kHz/cm^2
SC_A	1.76e-6	0.043	0.018	7.9e-4	0	0.062	0.076
SC_D	6.5e-7	0.016	0.0067	2.9e-4	0	0.023	0.028
PreShSum	2.2e-7	0.0053	0.0024	9.8e-5	0	0.0078	0.009
ShowerSum	2.2e-7	0.0053	0.0024	9.8e-5	0	0.0078	0.009
SC_B	1.3e-6	0.032	0.015	6.0e-4	0	0.047	0.055

GEM Analysis

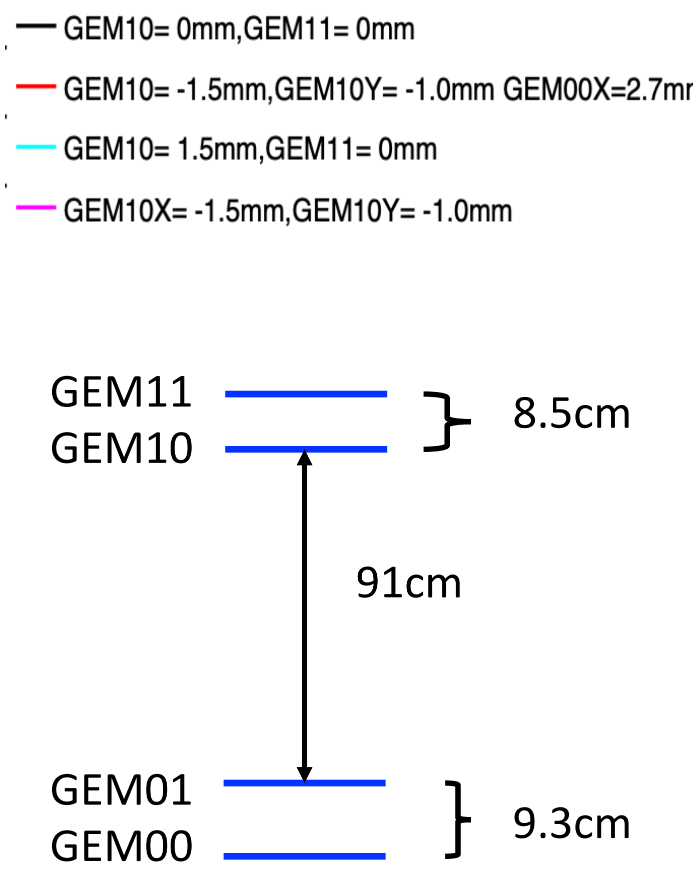
- 10uA run 4779
- Charge pion candidates
- Chambers are still misaligned?

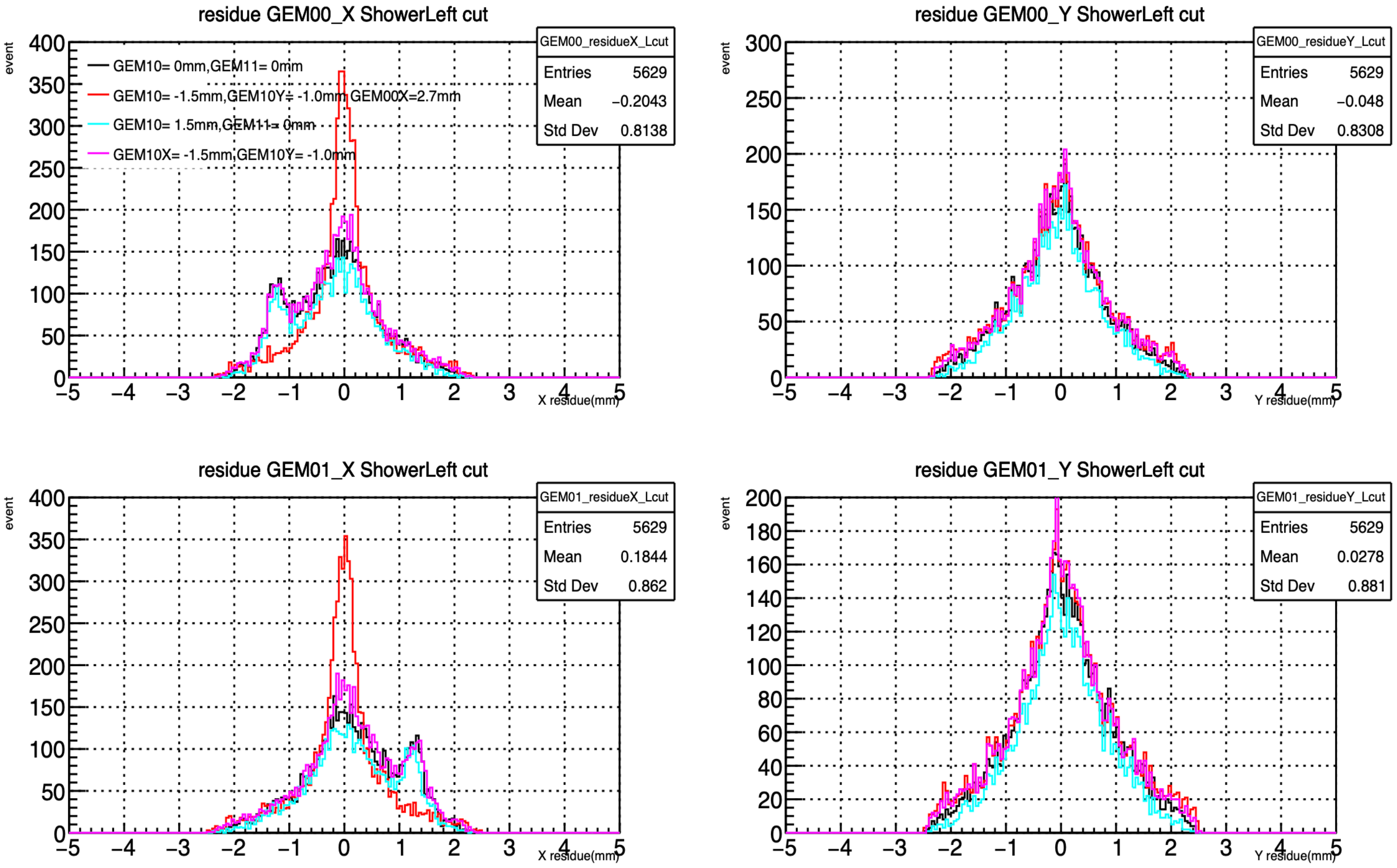




Residue Plots of the Upstream GEMs---Checking Alignment

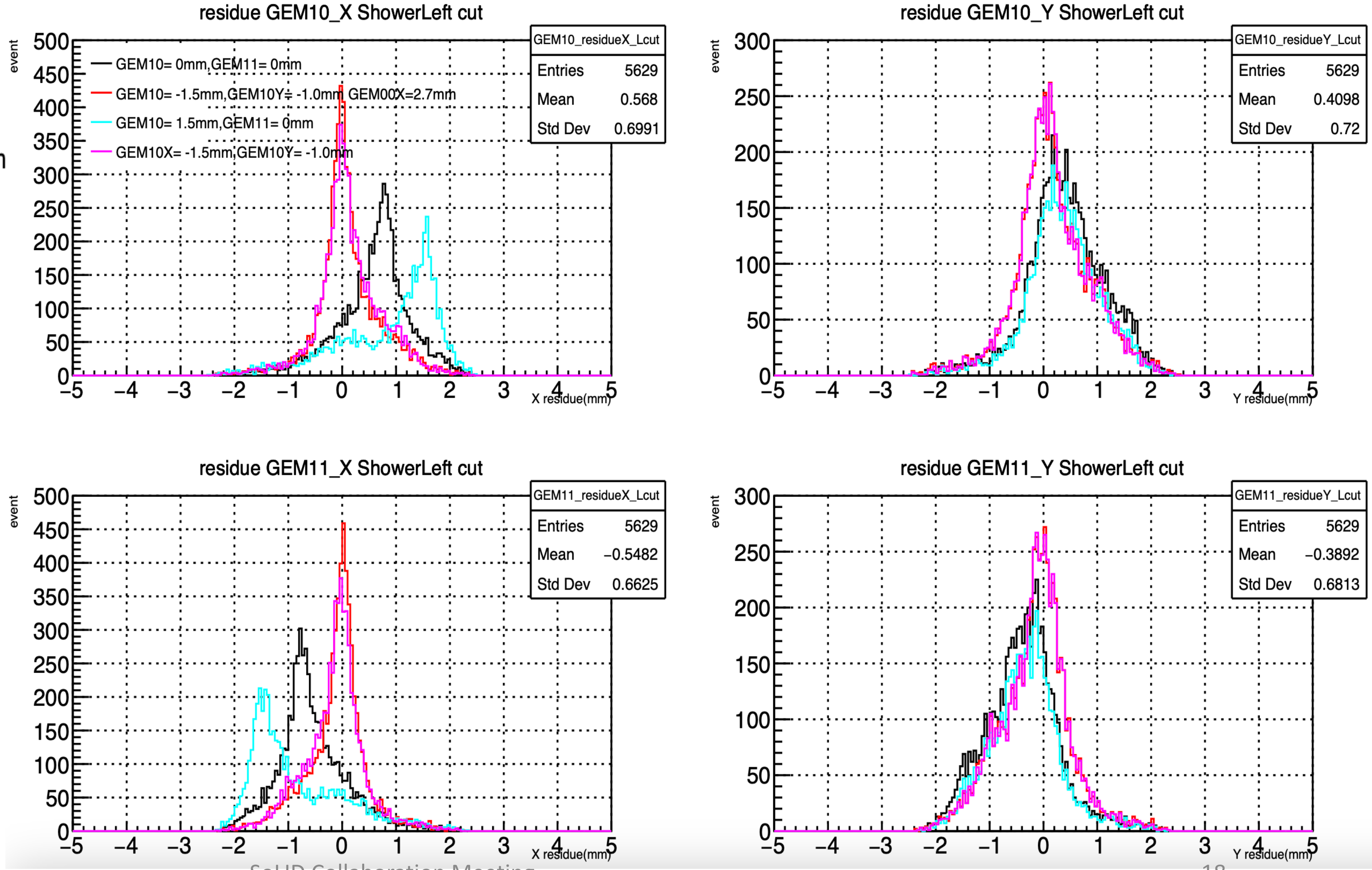
- 10uA 18deg data with 4 hits on the track, TS4=15mV trigger and Chi2<3 cuts





Residue Plots of the Downstream GEMs---Checking Alignment

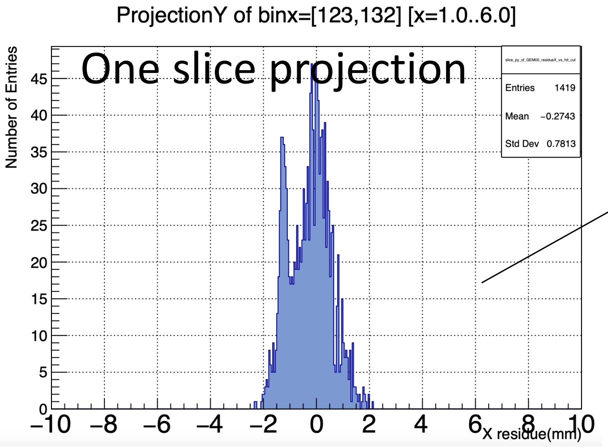
- 10uA 18deg data with 4 hits on the track, TS4=15mV trigger and Chi2<3 cuts



- Set the offset to GEM10 or GEM11 move both downstream GEMs simultaneously on Y and X.

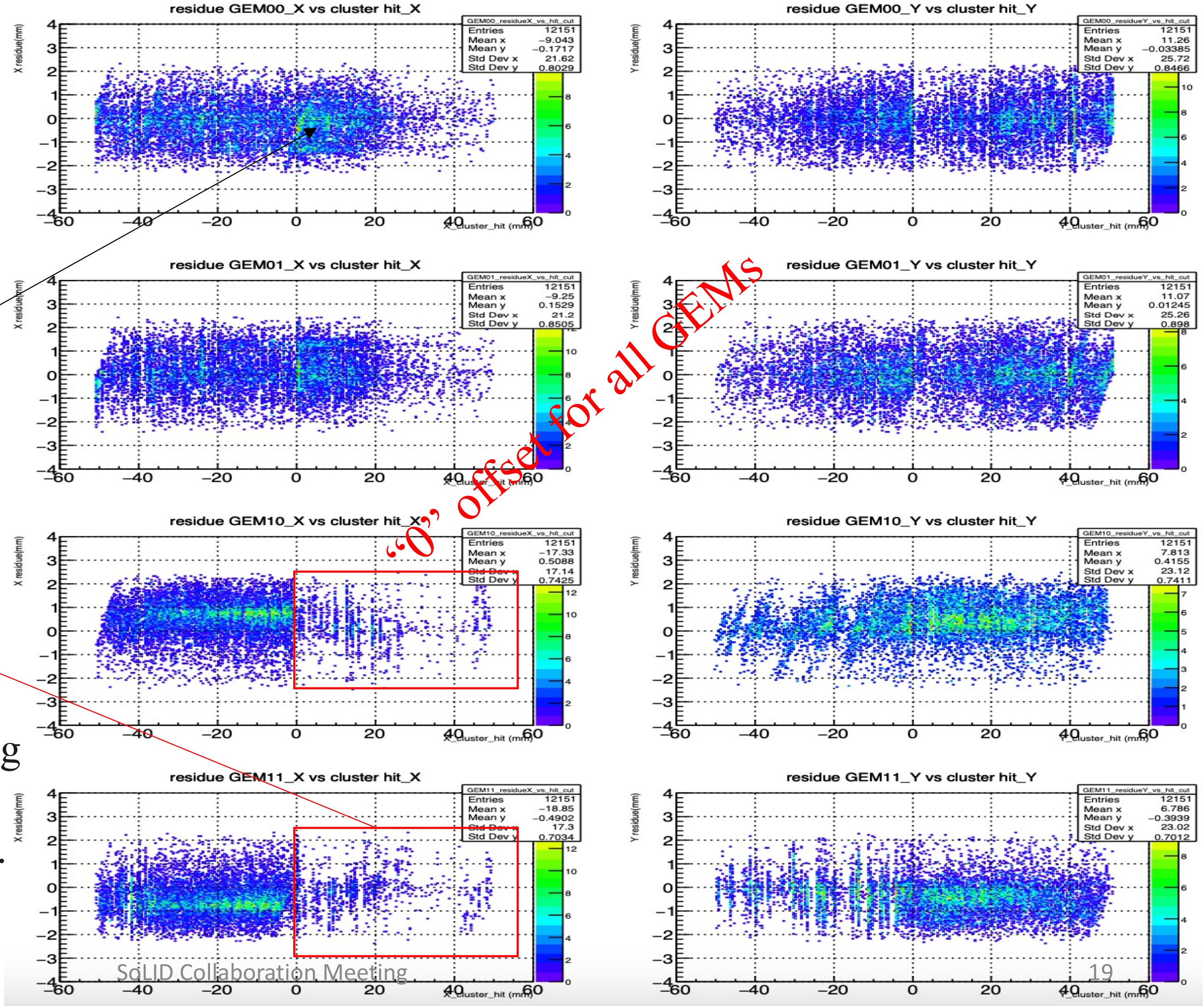
2D-Residue vs Cluster Hits on the Tracks Plots

- 10uA 18deg data with 4 hits on the track, TS4=15mV trigger and Chi2<3 cuts



- APV fine-tune parameters have been removed to reduce backgrounds, which can cause the inefficiency on the right side of GEMs
- The 2mm is the grid size for the tracking algorithm.
- The hard cuts from matching algorithm.

There's no angle misalignment



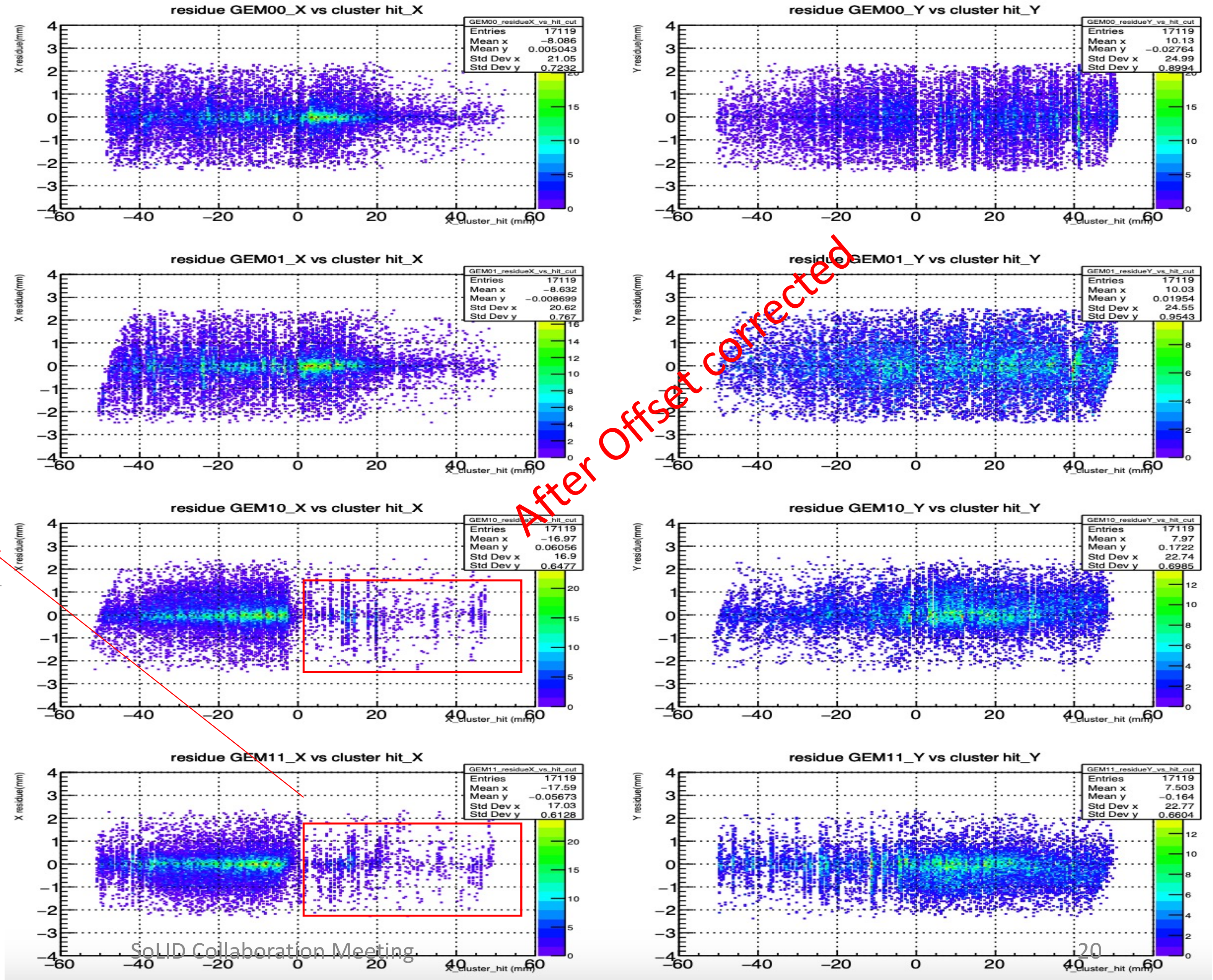
2D-Residue vs Cluster Hits on the Tracks Plots

- 10uA 18deg data with 4 hits on the track, TS4=15mV trigger and Chi2<3 cuts

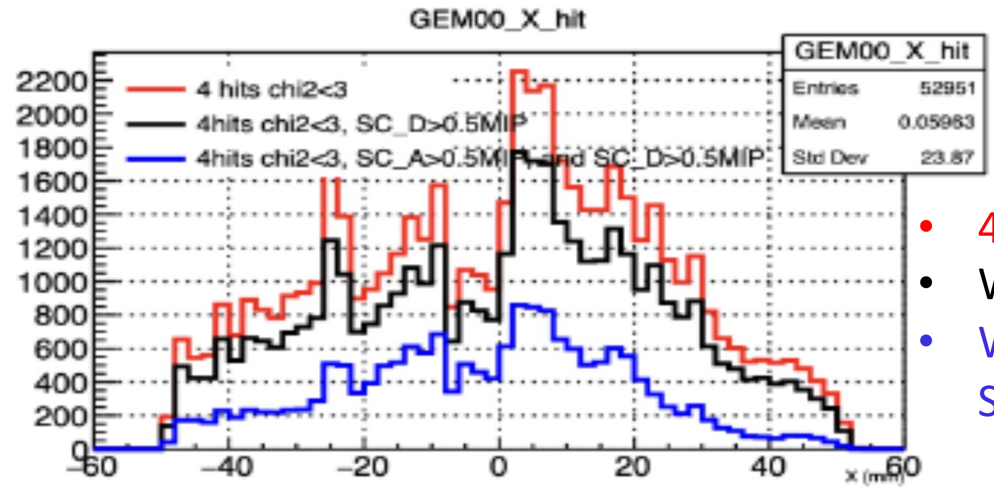
Add offsets to GEM10 and GEM00
GEM00_X_offset= 2.7mm
GEM10_X_offset= -1.5mm
GEM10_Y_offset= -1.0mm

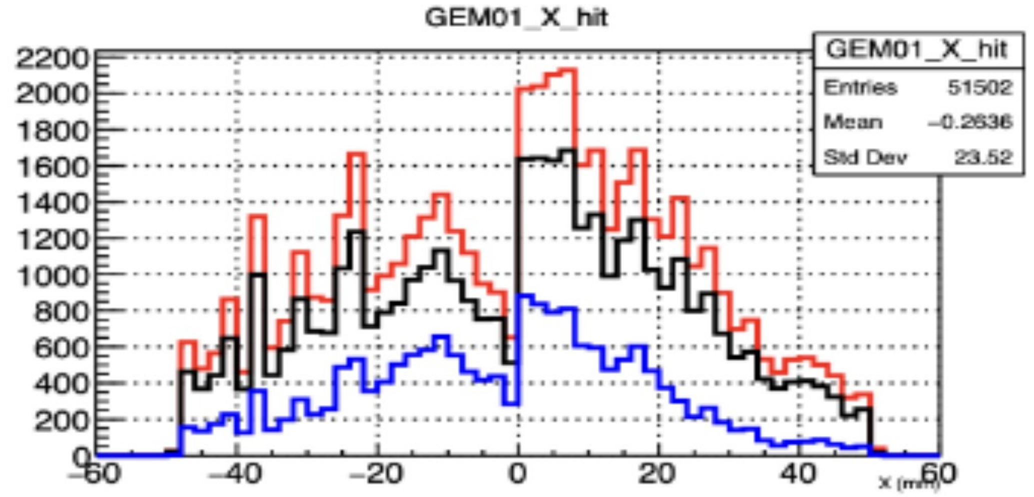
- APV fine-tune parameters have been removed to reduce backgrounds, which can cause the inefficiency on the right side of GEMs

There's no angle misalignment

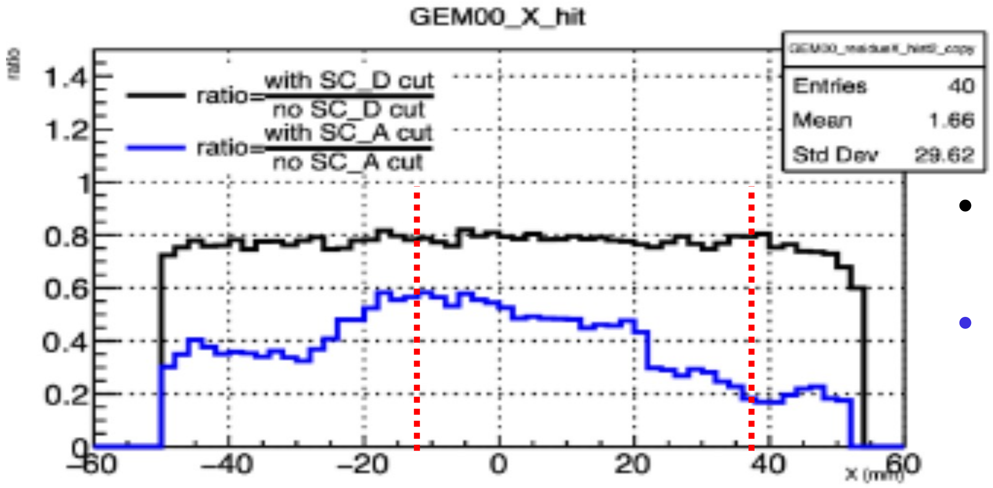


GEM Cluster Hits on the Tracks **w/wo** SCs Cuts

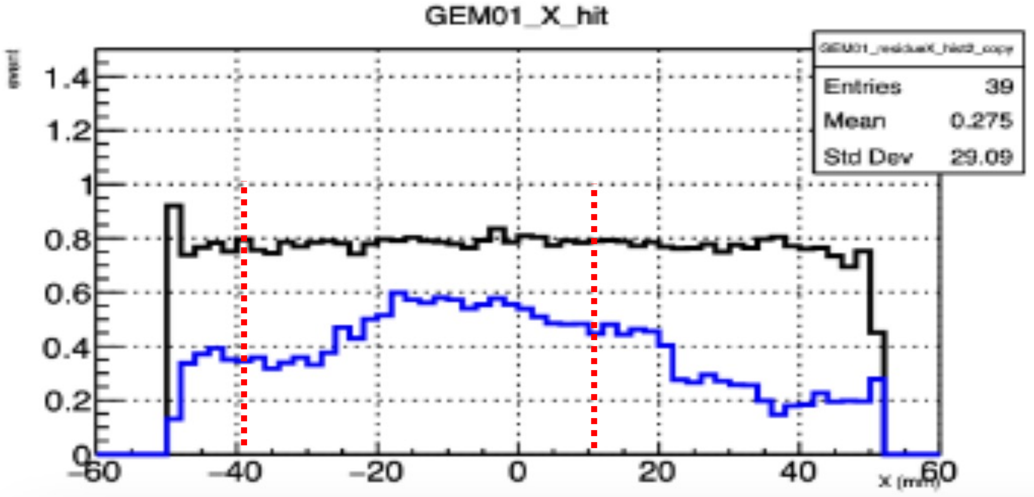




- 4 hits on the tracks
- With SC_D >0.5 MIP
- With SC_A>0.5 MIP+ SC_D>0.5 cuts



- Ratio with/witout SC_D cut
- Ratio with/without SC_A cut



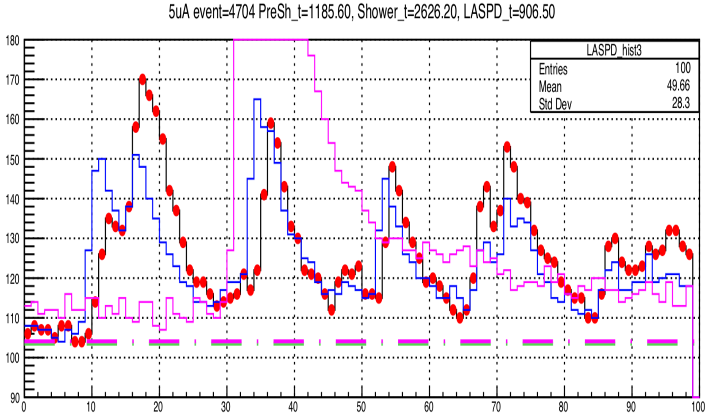
- The cut on SC_A should eliminate good tracks for x>25 mm or x<-25 mm.
- There is little evidence that the SC_A cut reduces events for x<-25 mm.
- The SC_A cut does reduce events for x>0.25 cm

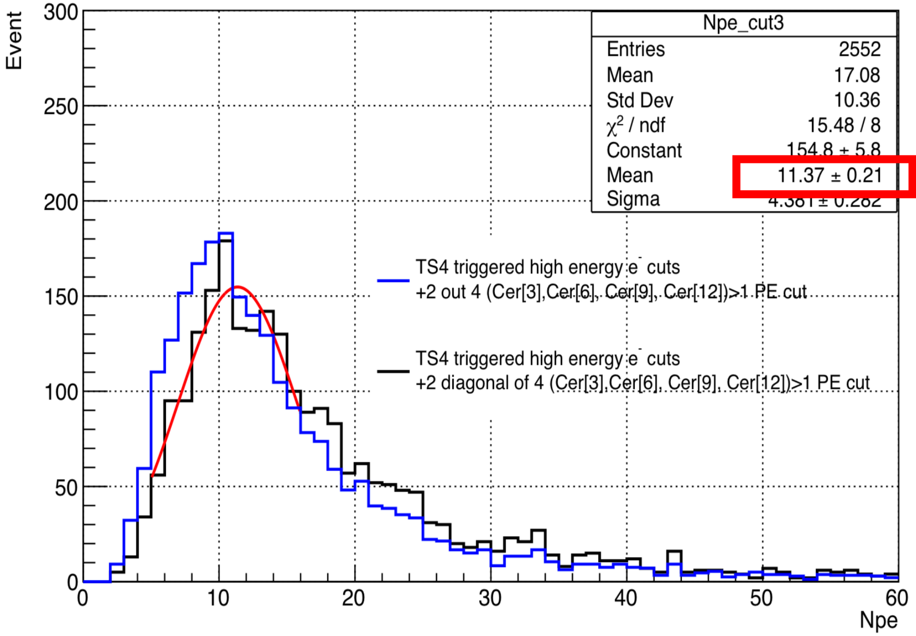
Summary and Outlook

- ❑ Timing plots are useful for understanding singles rates and coincidence rates.
- ❑ The cuts on DT of SC_B and Shower and DT of Shower and Preshower can clean up MIPs for 45uA data.
- ❑ The comparison of rates from timing plots and the Monte Carlo indicate that single detector simulation rates are <25 % higher than that of the beam test data, while for the simulated scintillator SC_A and SC_D coincidence rates are <15% higher and the simulated SC_B and SC_D coincidence rates are <20% lower that that of the beam test data.
- ❑ The best GEM quadrants works reasonable with the tracks based on the detection efficiency < 50%, and the other quadrants are much worse. Due to the reason of not setting GEMs properly, it is not worth to do further analysis at this point.
- ❑ For setting GEM detectors properly, it requires low-rate condition to do the alignment and the APV gain checking.
- ❖ Apply the same method to the 65uA data (run 4685 and 4686) with SC_B & SC_D trigger.

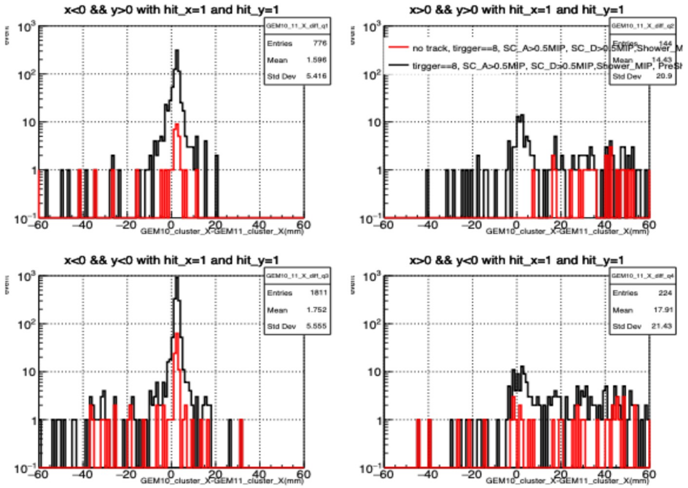
Beam Test Outcomes

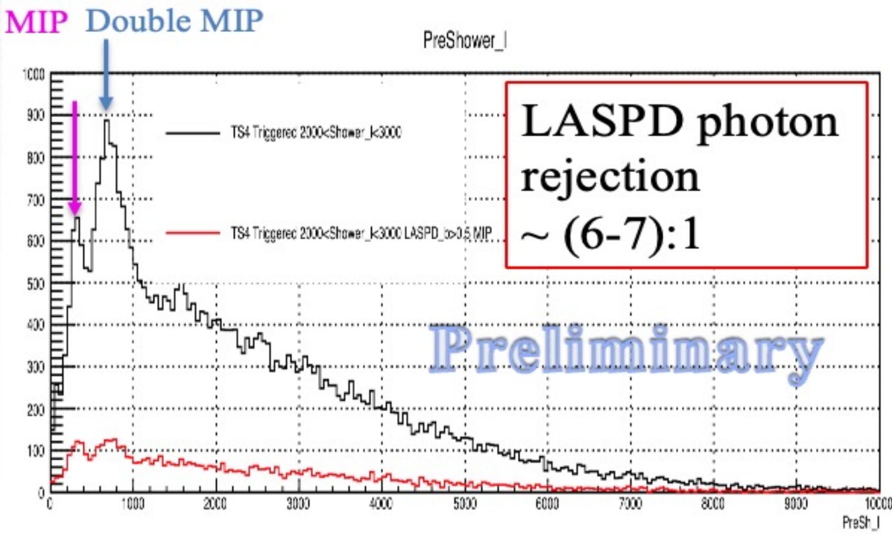
- Cherenkov Detector: 11Npe ---1/2 of the simulation, which is constant with 2020 Cherenkov beam test.
- LASPD Detector:





- GEM Detectors: Need low-rate condition to setup

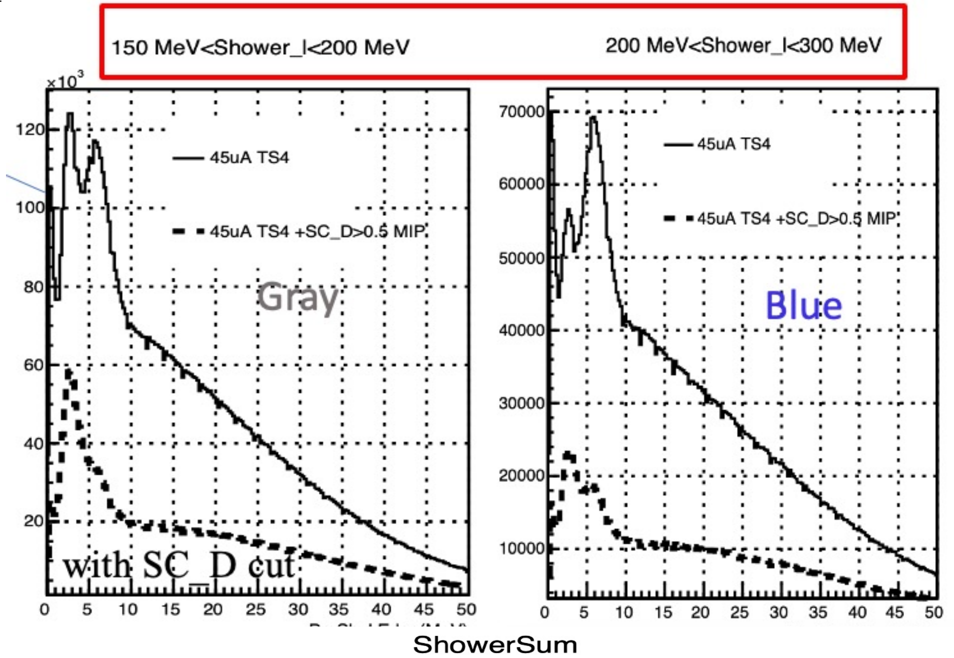


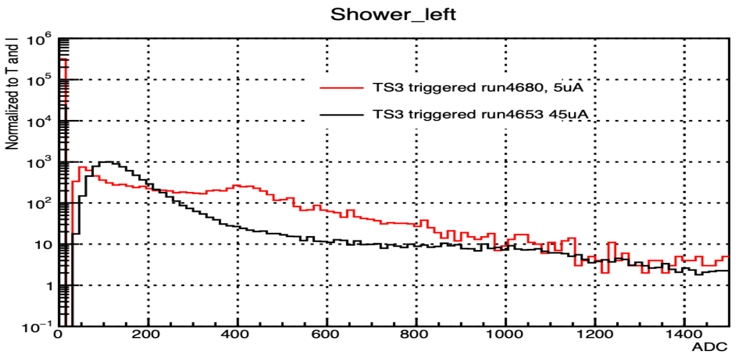


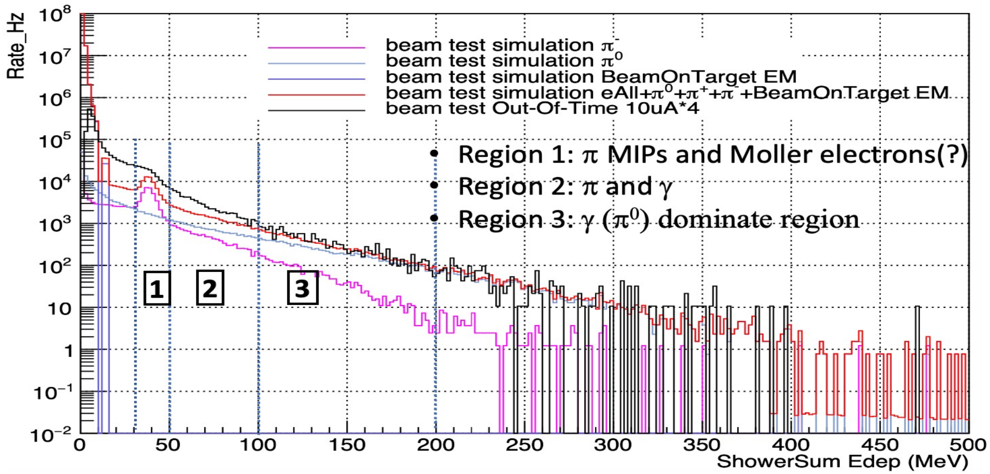
Beam Test Outcomes

- ➢ Cherenkov Detector: 11Npe ---1/2 of the simulation, which is constant with 2020 Cherenkov beam test.
- ➢ LASPD Detector:
- ➢ GEM Detectors: Need low-rate condition to setup
- ➢ PreShower: response for the low energy electrons is very different depending on their energies, which can provide information on photon to charged pion ratio.
- ➢ Shower:
  - The shower baseline shift is due to tinny pulses from the multi-scattering photons by the high energy Moller electrons.
  - Shower gain shift

Shower energy cut to select the regions





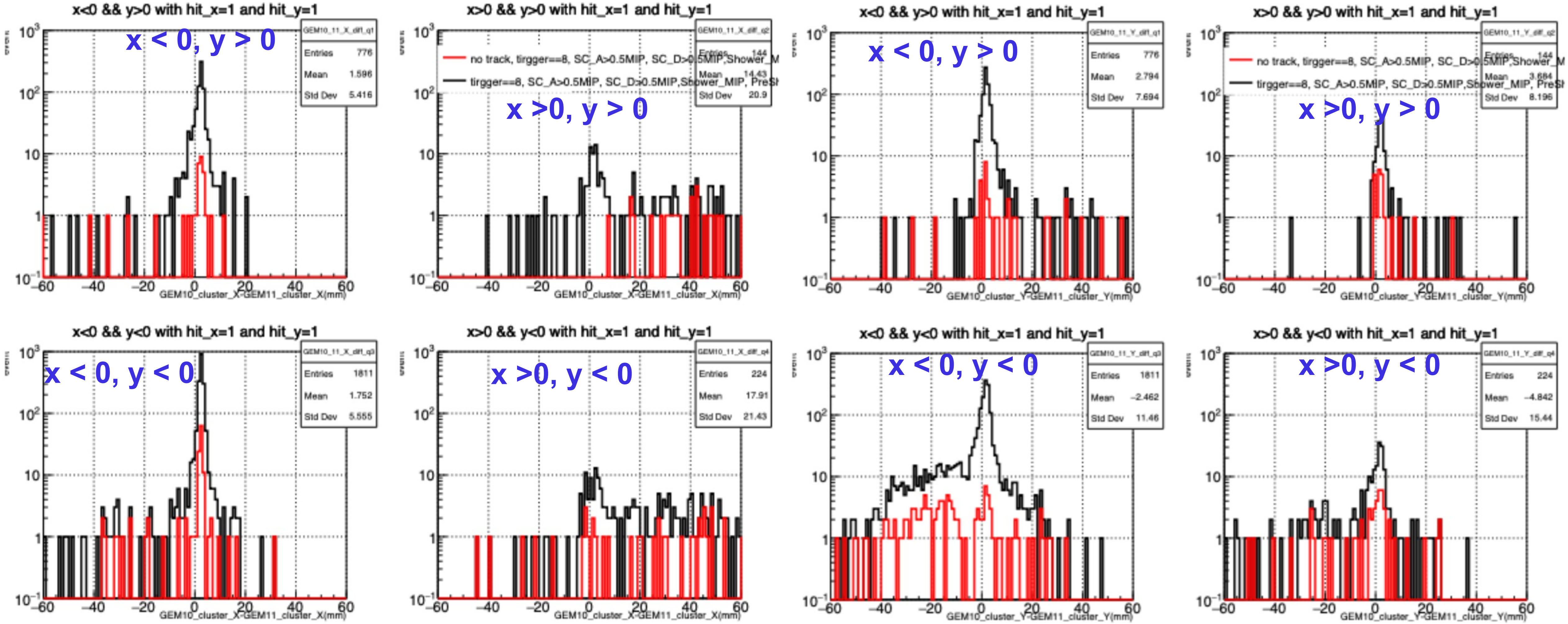


Thank you!

Backup

GEM Cluster Raw Hits Only

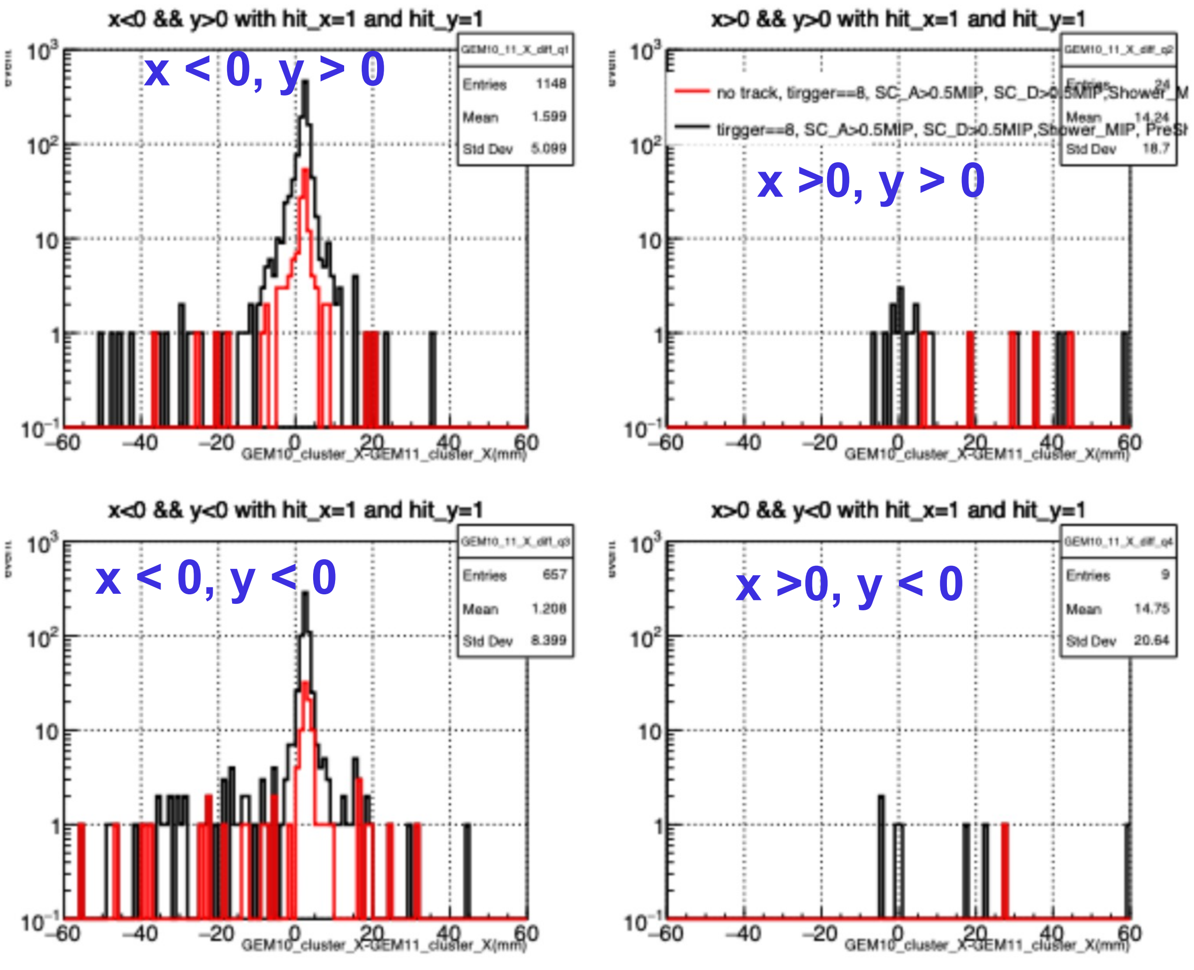
Cluster GEM10_X - GEM11_X | **Cluster GEM10_Y - GEM11_Y**



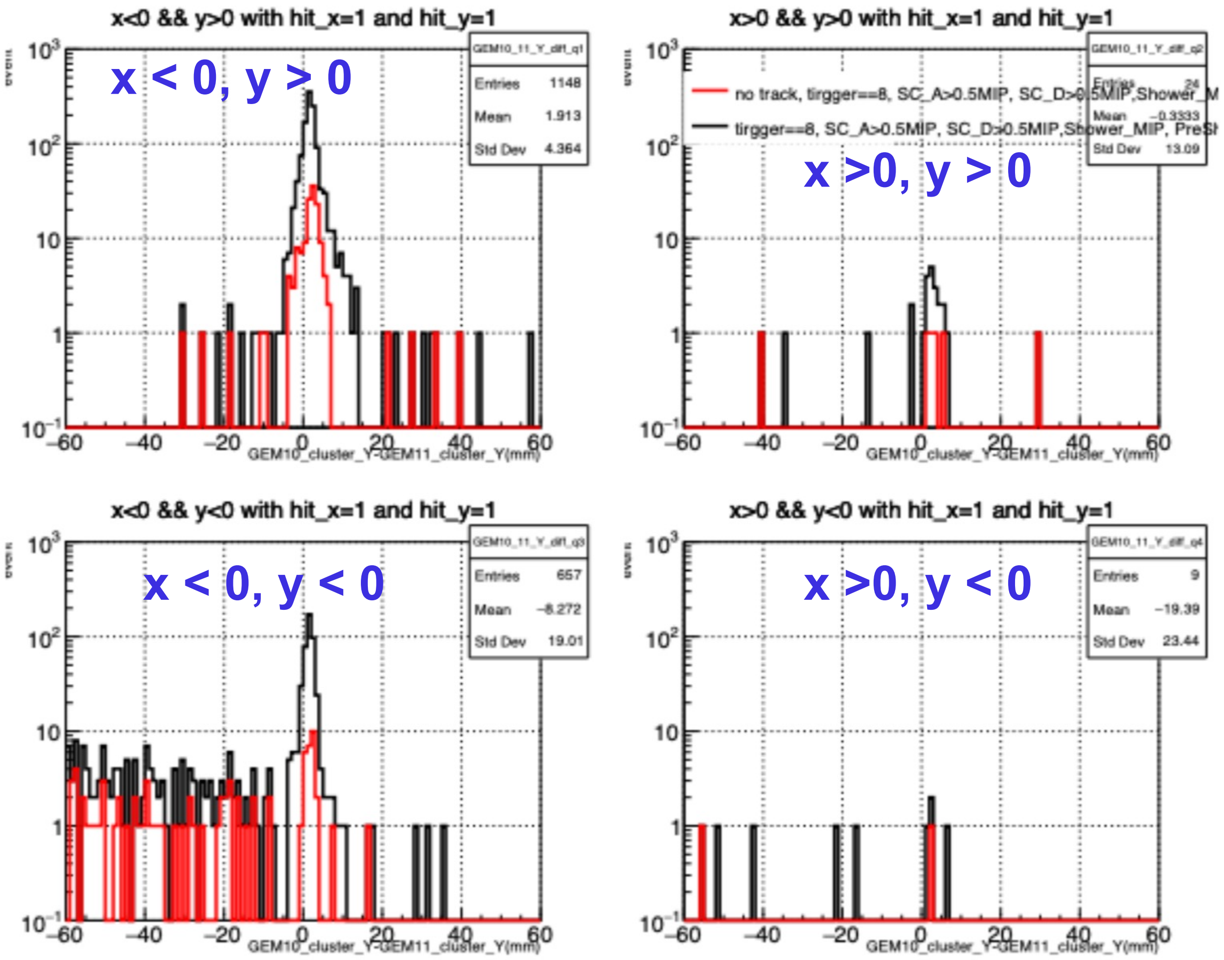
- Improvement shown with APV correction and hotspot removing, but it is not significant enough to recover the low count area at the right side of the downstream GMEs.
- It requires low-rate condition to do the alignment and the APV gain checking.

GEM Cluster Raw Hits Only

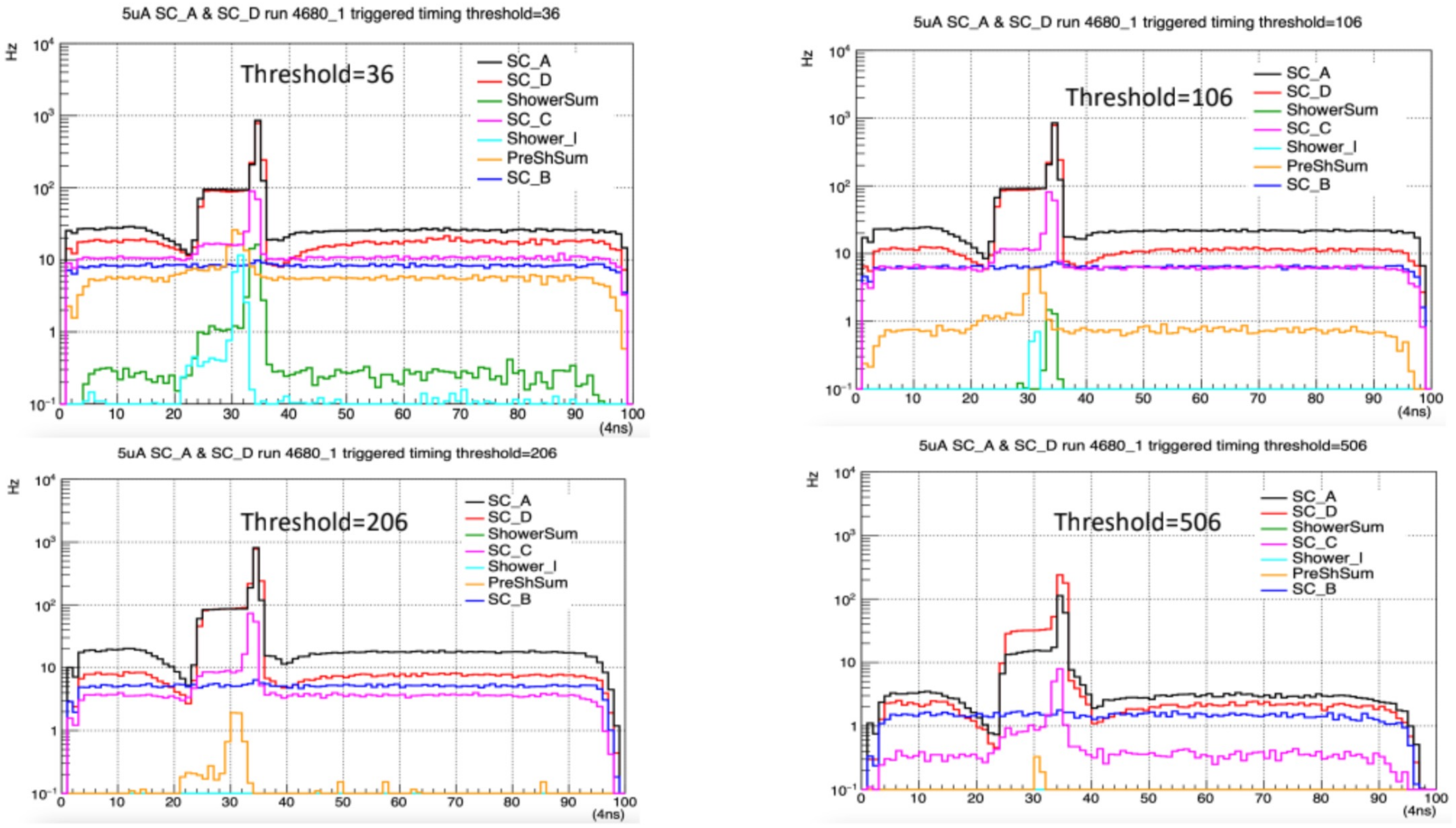
Cluster GEM10_X - GEM11_X



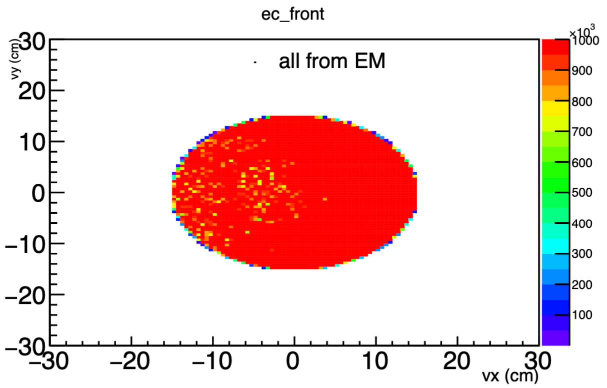
Cluster GEM10_Y - GEM11_Y

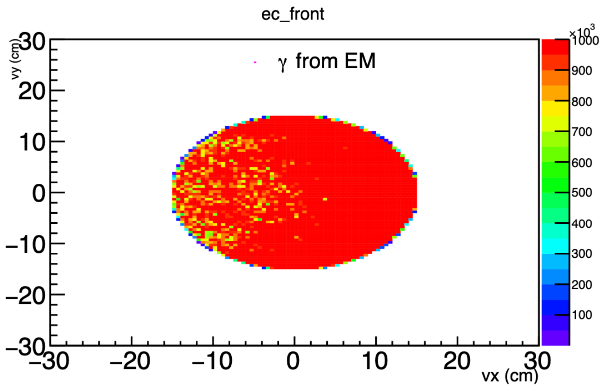


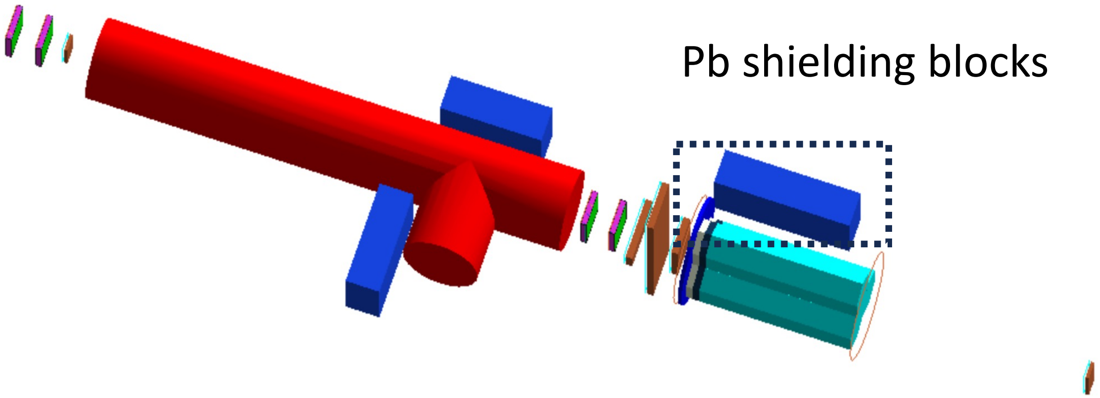
- **Only one hit on each downstream GEM detectors**
- The ”left” quadrants are more efficient than the right quadrants, and the top left quadrant is the most efficient part of the downstream GEMs.


5uA SC_A & SC_D run 4680_1 triggered timing threshold=36
Threshold=36
SC_A
SC_D
ShowerSum
SC_C
Shower_I
PreShSum
SC_B
Hz
(4ns)
5uA SC_A & SC_D run 4680_1 triggered timing threshold=106
Threshold=106
5uA SC_A & SC_D run 4680_1 triggered timing threshold=206
Threshold=206
5uA SC_A & SC_D run 4680_1 triggered timing threshold=506
Threshold=506

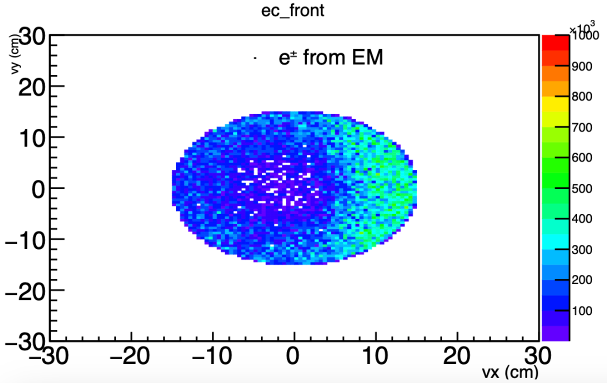
Low energy backgrounds shielded by Pb blocks



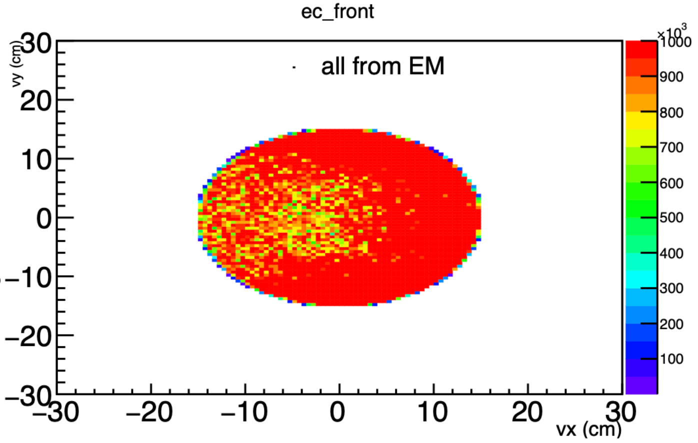


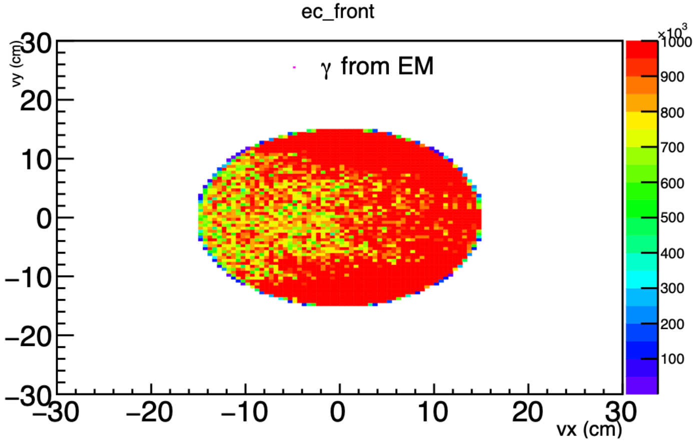


Pb shielding blocks

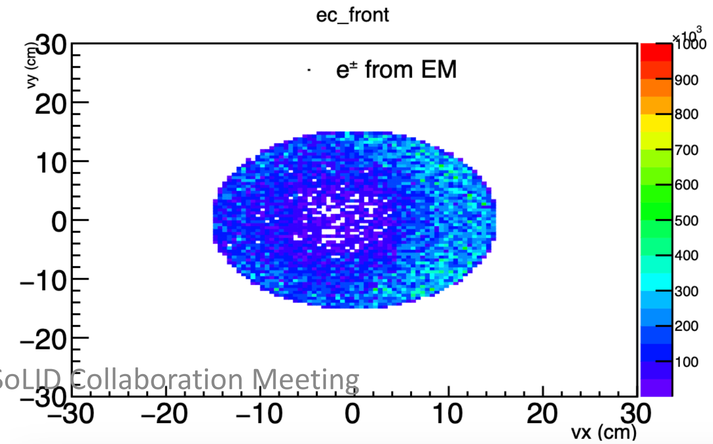


- EM background without pb shielding blocks



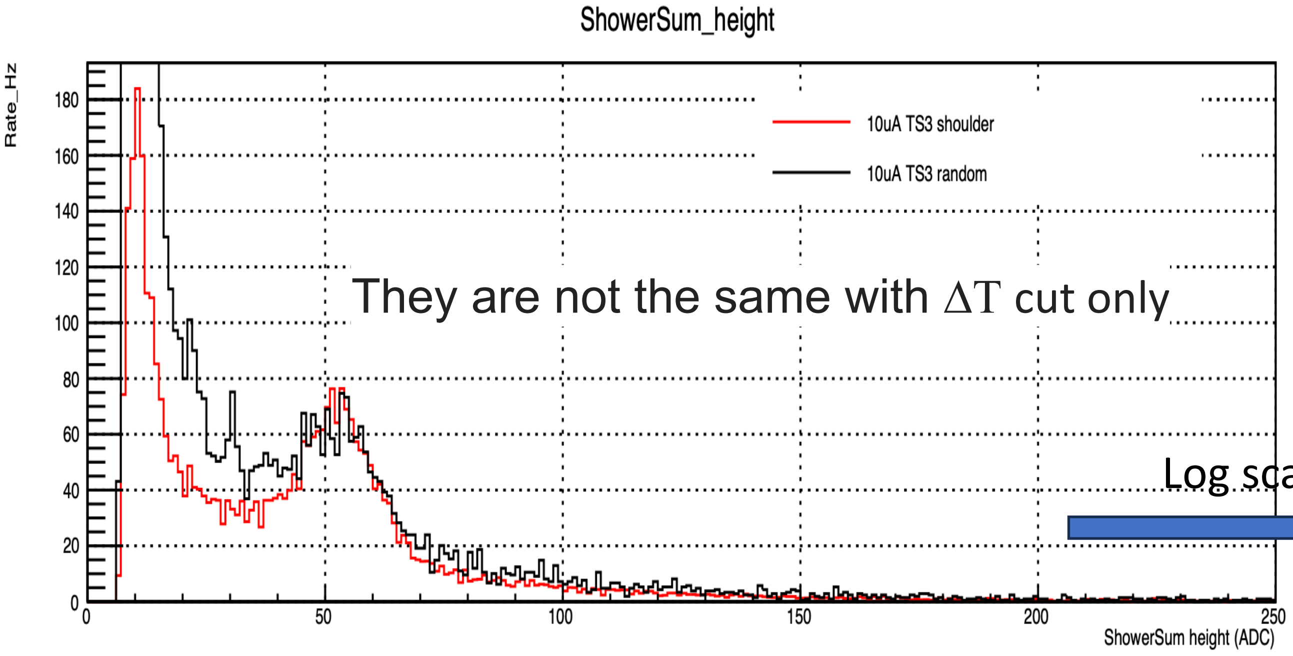


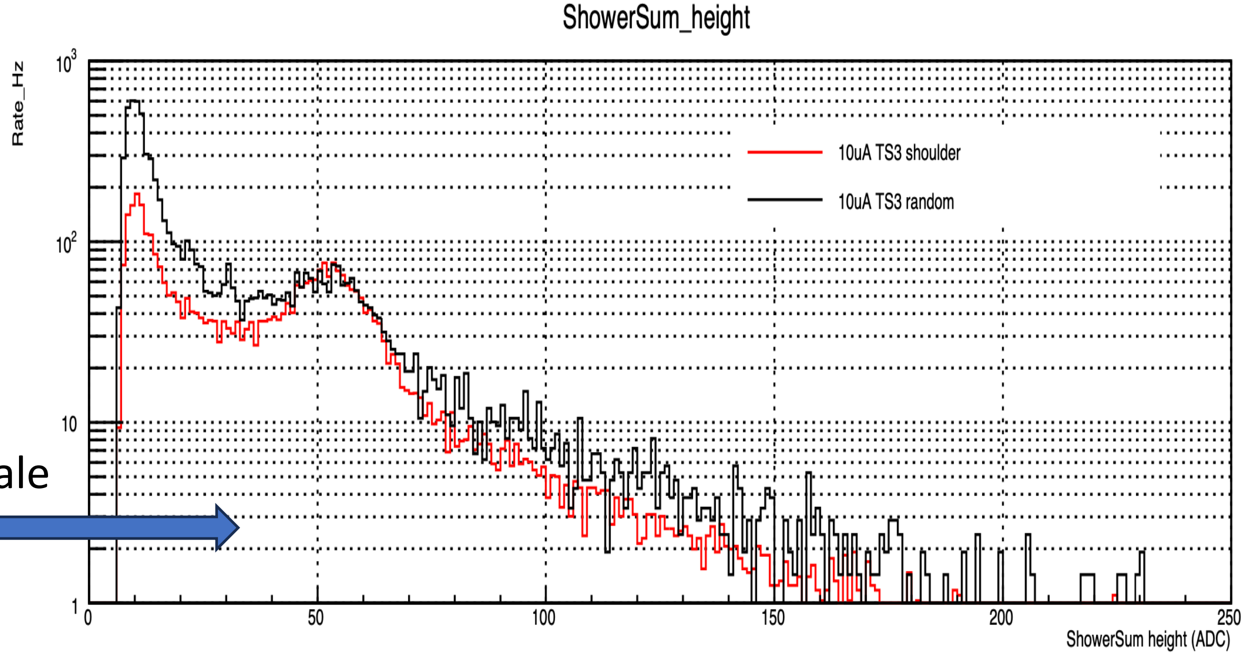
- The Pb shielding block beside Ecal reduces the gamma background in the center region of ECal
- Requiring the coincidence with SC_D should clean up the MIP region in the data.

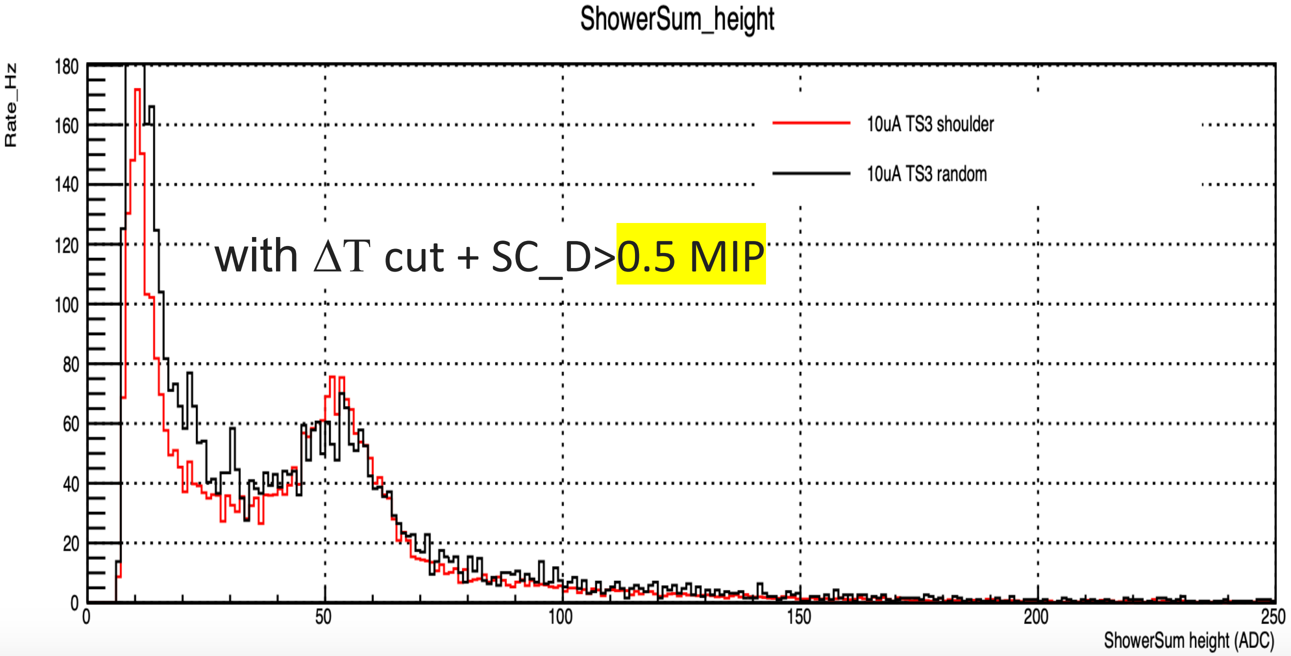


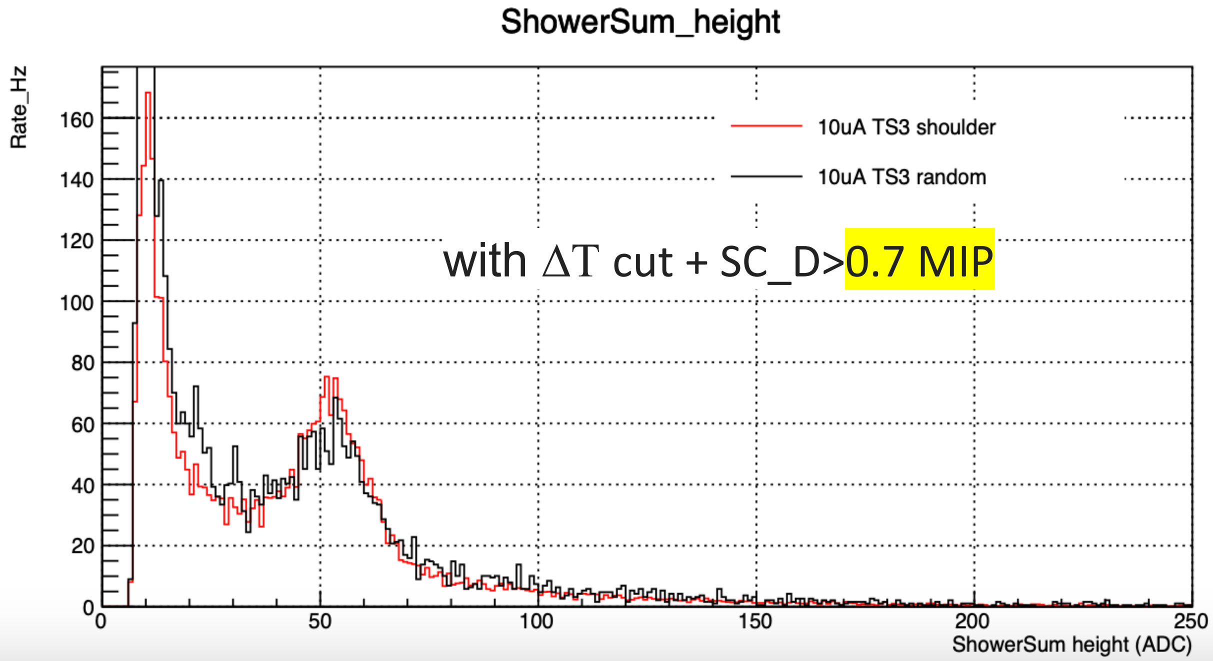
- EM background with pb shielding blocks

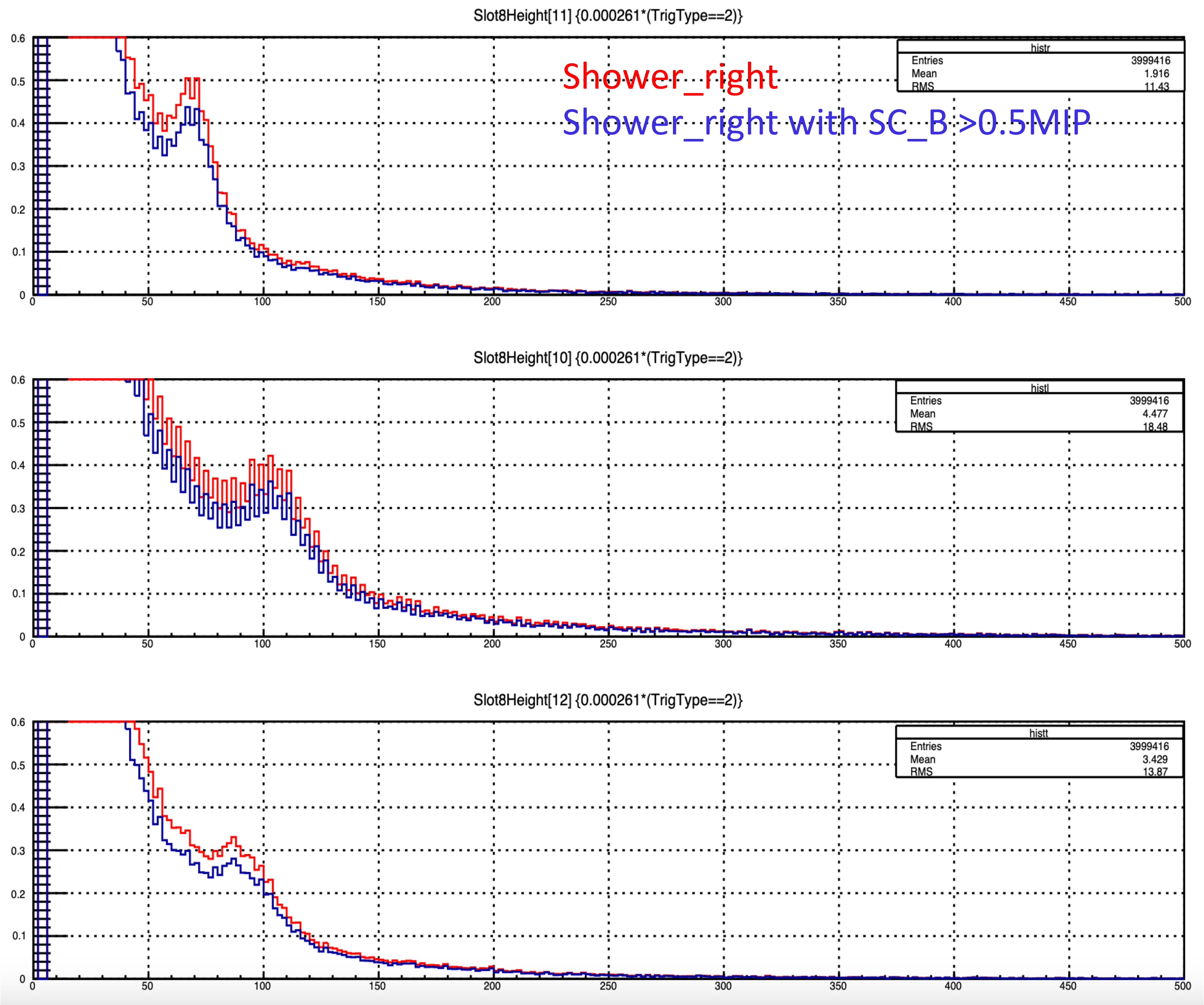
Compare Shoulder and randoms for 10 MuA data with high statistics

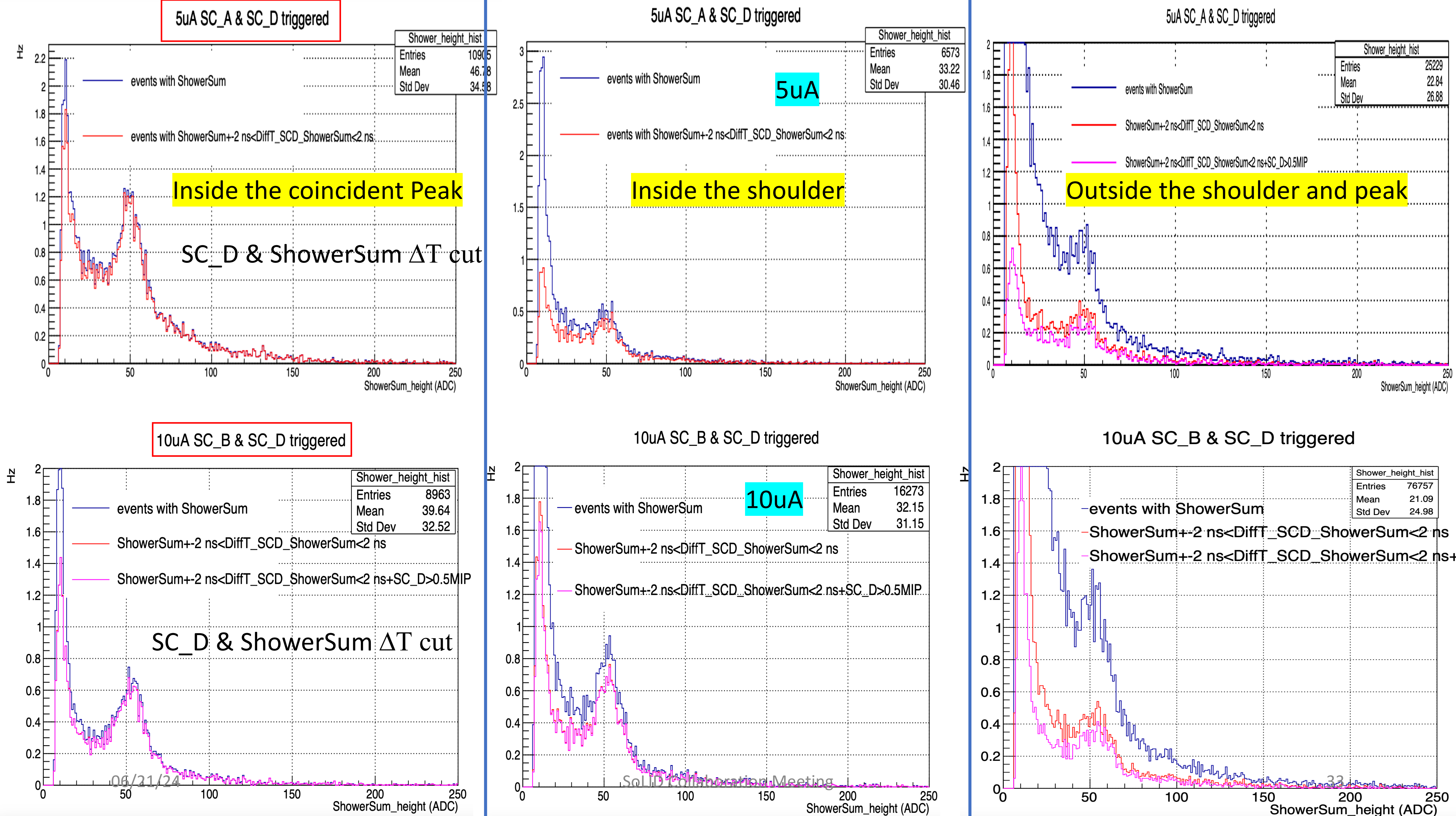






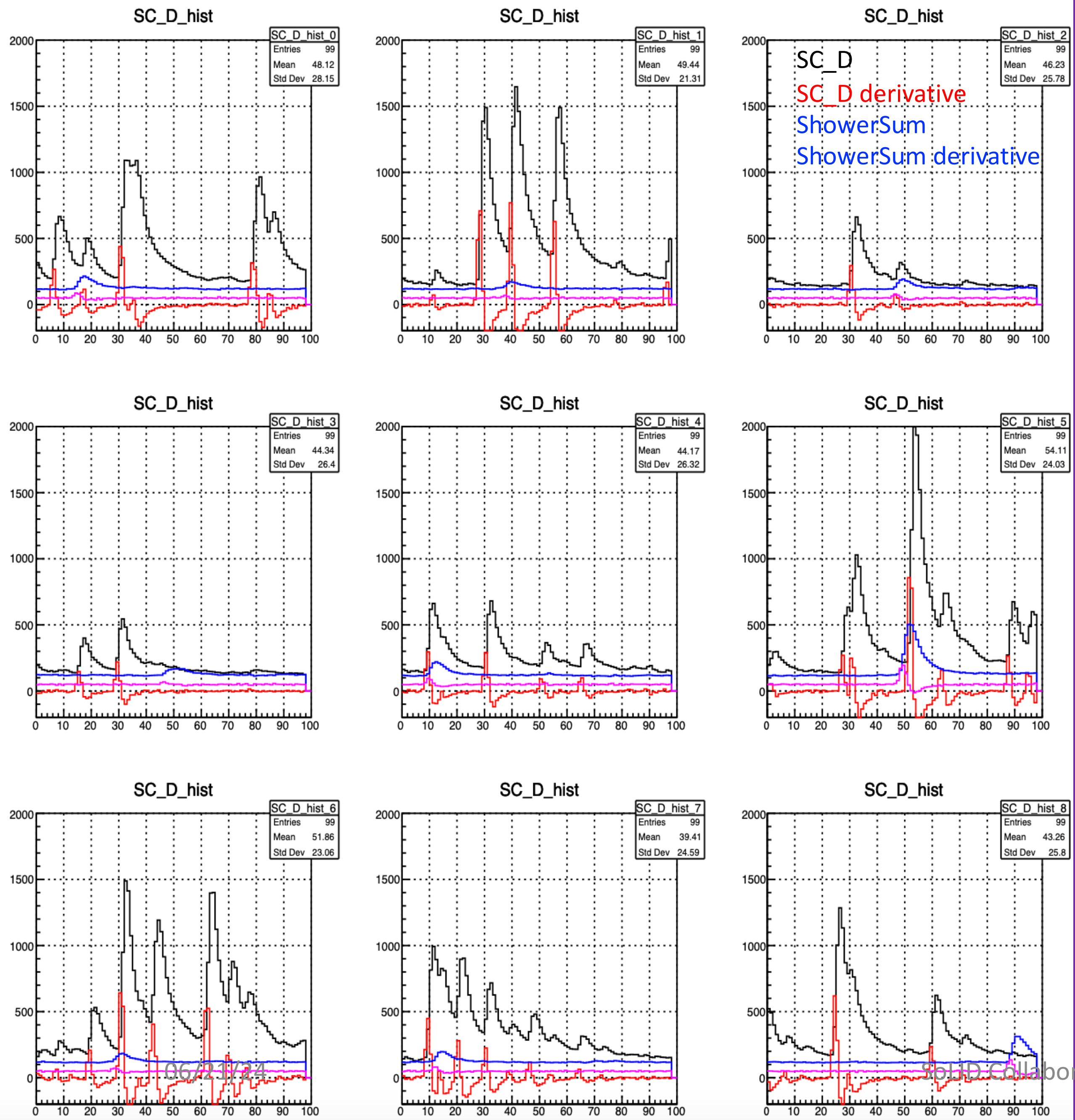



Slot8Height[11] {0.000261*(TrigType==2)}
histr
Entries 3999416
Mean 1.916
RMS 11.43
Shower_right
Shower_right with SC_B >0.5MIP
Slot8Height[10] {0.000261*(TrigType==2)}
histl
Entries 3999416
Mean 4.477
RMS 18.48
Slot8Height[12] {0.000261*(TrigType==2)}
histt
Entries 3999416
Mean 3.429
RMS 13.87

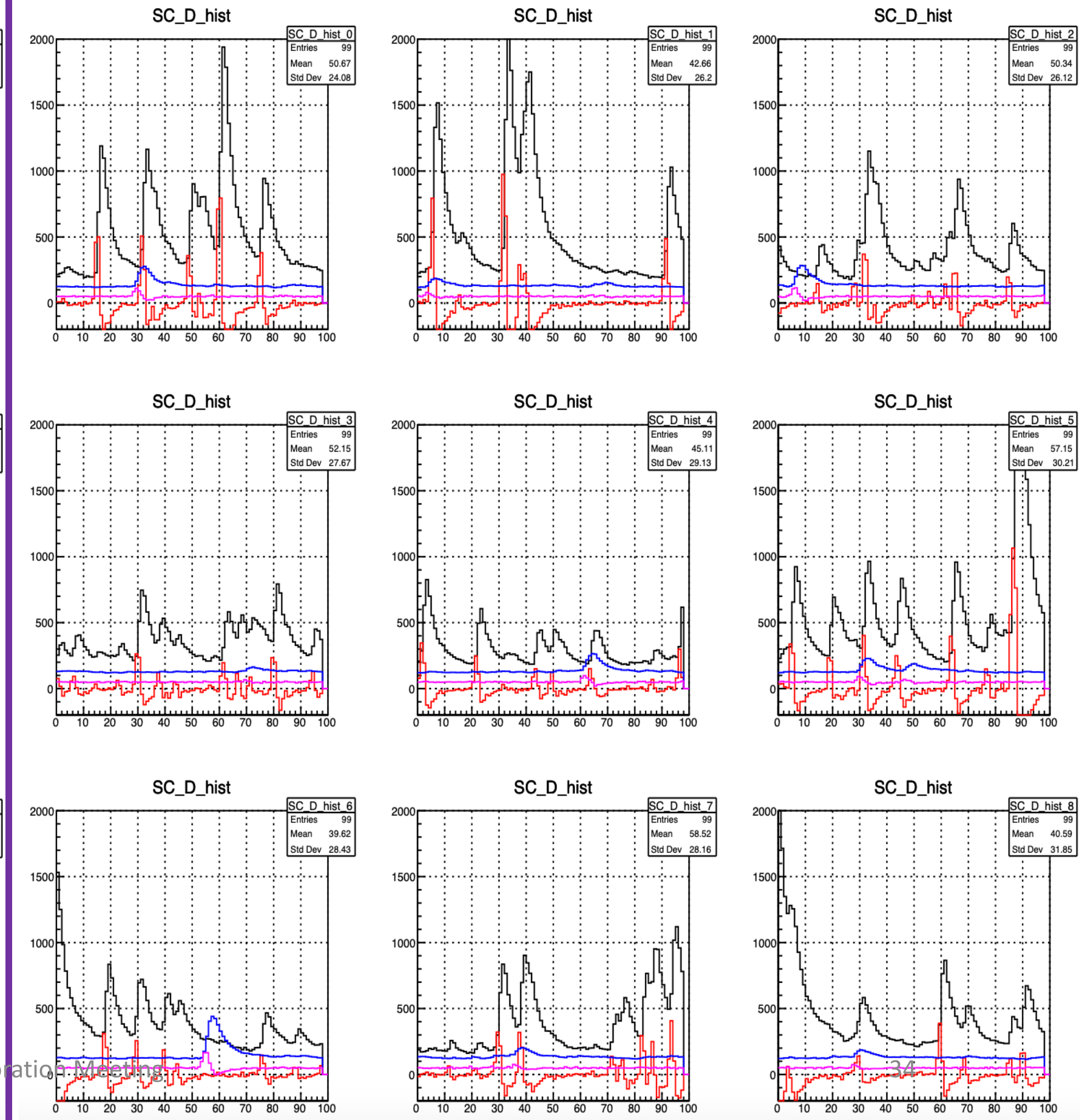


5uA SC_A & SC_D triggered
Shower_height_hist
Entries 10905
Mean 46.78
Std Dev 34.58
events with ShowerSum
events with ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns
Inside the coincident Peak
SC_D & ShowerSum ΔT cut
ShowerSum_height (ADC)
Hz
5uA SC_A & SC_D triggered
Shower_height_hist
Entries 6573
Mean 33.22
Std Dev 30.46
events with ShowerSum
events with ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns
5uA
Inside the shoulder
ShowerSum_height (ADC)
5uA SC_A & SC_D triggered
Shower_height_hist
Entries 25229
Mean 22.84
Std Dev 26.88
events with ShowerSum
ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns
ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns+SC_D>0.5MIP
Outside the shoulder and peak
ShowerSum_height (ADC)
10uA SC_B & SC_D triggered
Shower_height_hist
Entries 8963
Mean 39.64
Std Dev 32.52
events with ShowerSum
ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns
ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns+SC_D>0.5MIP
SC_D & ShowerSum ΔT cut
ShowerSum_height (ADC)
Hz
10uA SC_B & SC_D triggered
Shower_height_hist
Entries 16273
Mean 32.15
Std Dev 31.15
events with ShowerSum
ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns
ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns+SC_D>0.5MIP
10uA
ShowerSum_height (ADC)
Hz
10uA SC_B & SC_D triggered
Shower_height_hist
Entries 76757
Mean 21.09
Std Dev 24.98
events with ShowerSum
ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns
ShowerSum+-2 ns<DiffT_SCD_ShowerSum<2 ns+
ShowerSum_height (ADC)
Hz

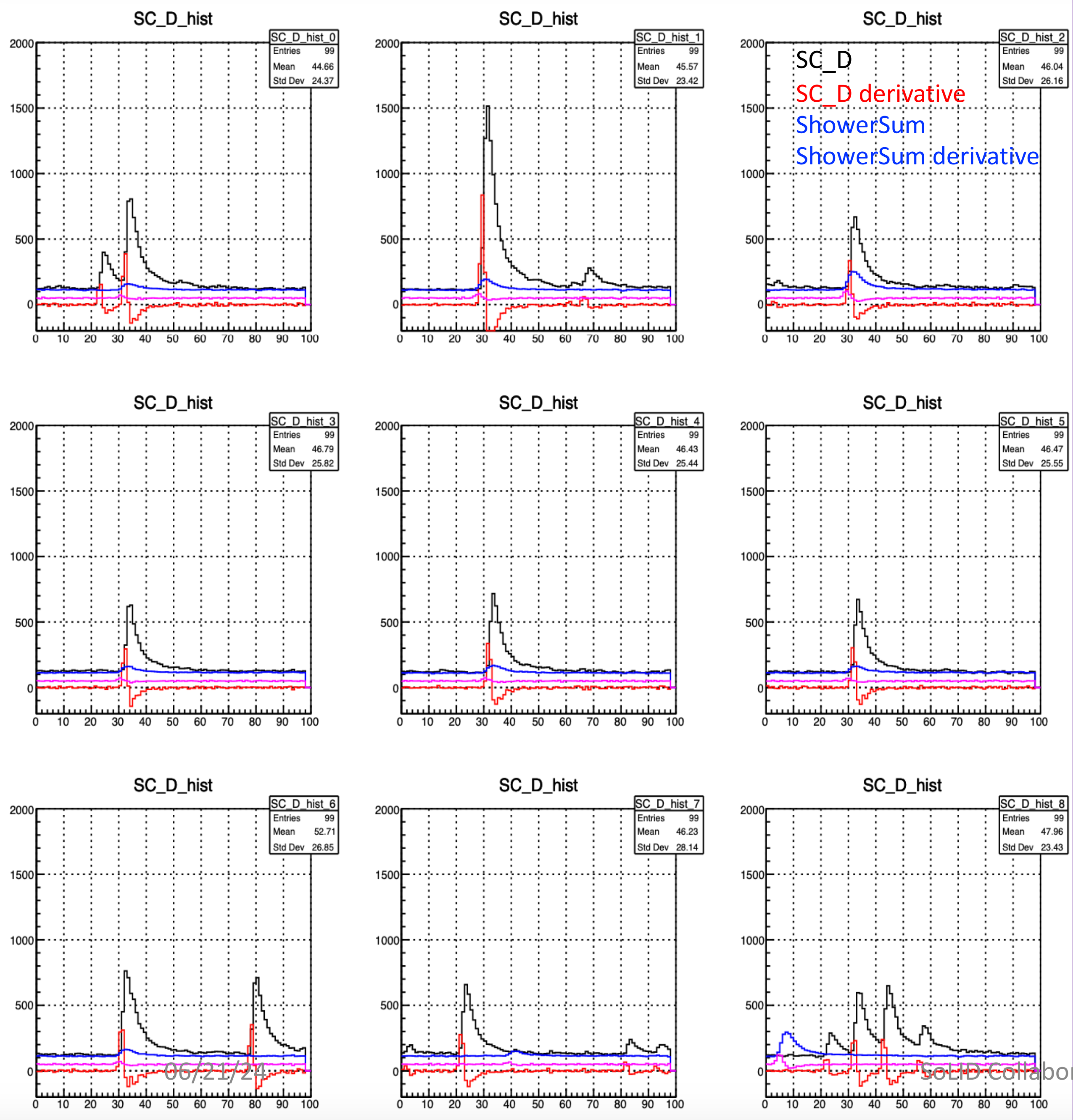
30uA SC_D & SC_B triggered



45uA SC_D & SC_A triggered



5uA SC_D & SC_A triggered



10uA SC_D & SC_B triggered