Beam Test and Comparison With Simulation

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For ECal Beam Test Group

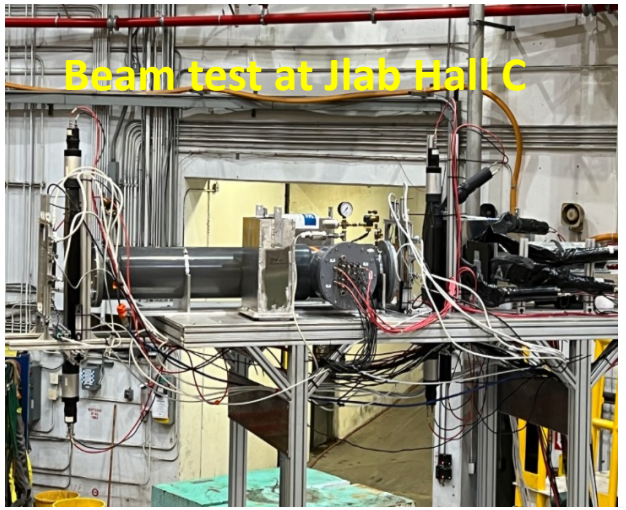
- Scintillators
- Showers
- PreShowers
- Radiation dose
- Summary and To-do-list

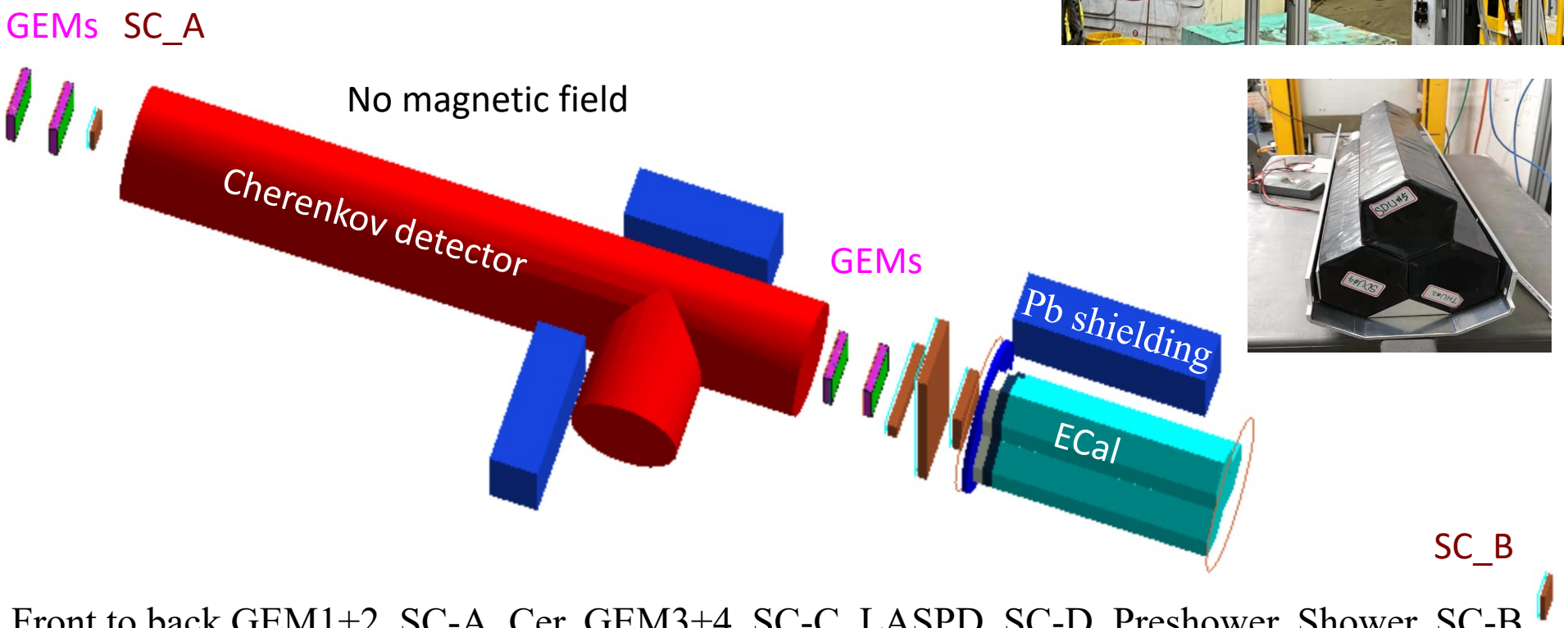
Summary of the Last Collaboration Meeting Talk

- Comparing both low and high-rate test data with simulation, the rate estimations from SoLID bggen and eAll event generators are consistent with those from the 7 deg data within 10%.
- ECal prehower and shower work very well under the actual high rate, high radiation, high background SoLID running condition, and the preshower works very well on identifying e^- at high energy region (above pion Cherenkov radiation threshold >4GeV).
- The preliminary beam test result shows that the photon rejection factor is around 7:1 based on 5uA beam test data.
- **Comparison between simulation and data** and LASPD analysis are ongoing.

Simulation for Beam Test at Jlab

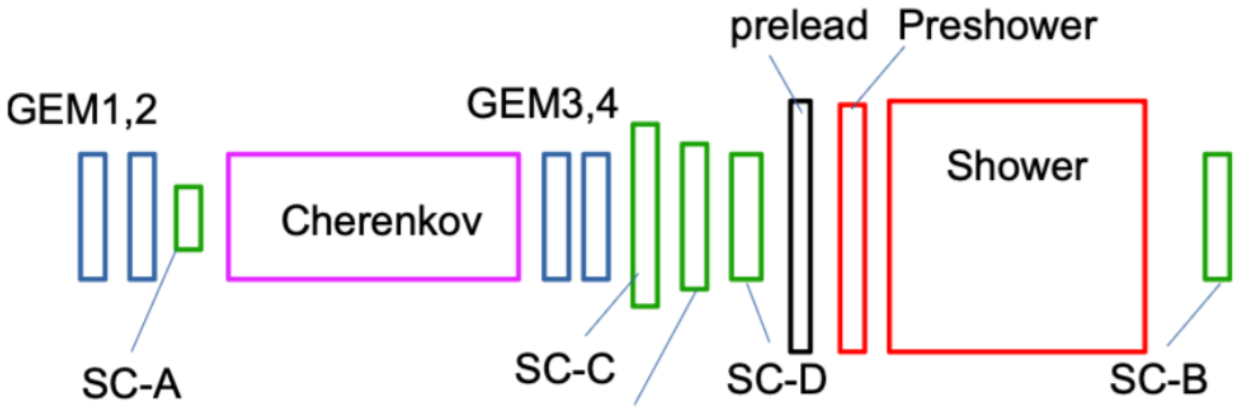
- Benchmarking simulation of rate and background
- Study ECal and LASPD performance under high rate, high radiation, high background condition
- Study ECal and LASPD PID

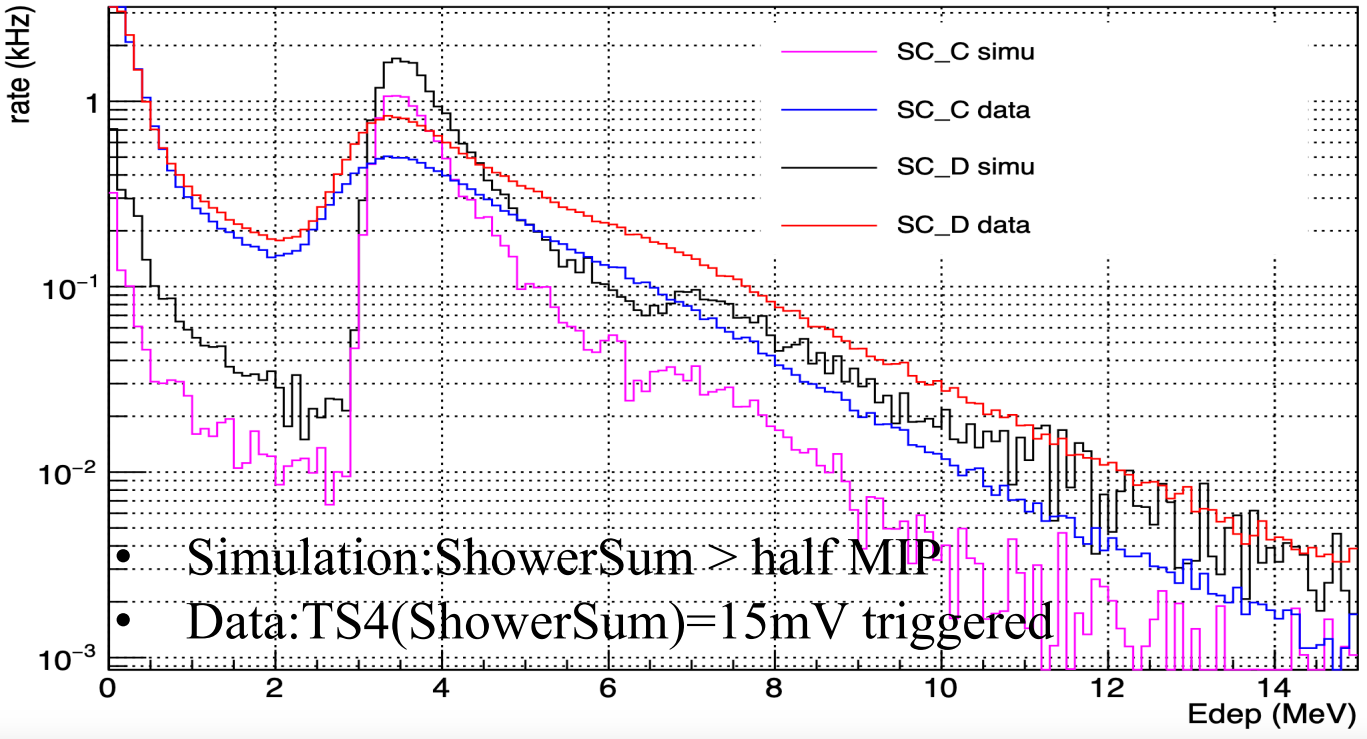




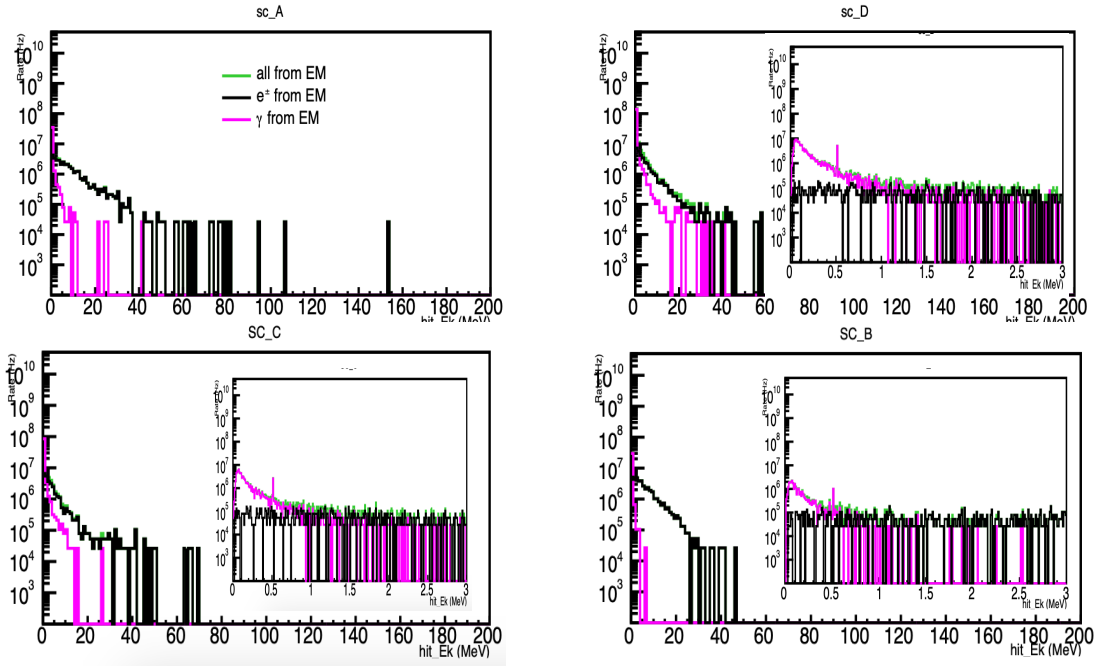
Front to back GEM1+2, SC-A, Cer, GEM3+4, SC-C, LASPD, SC-D, Preshower, Shower, SC-B

Scintillators





- Simulation:ShowerSum > half MIP
- Data:TS4(ShowerSum)=15mV triggered



Singles

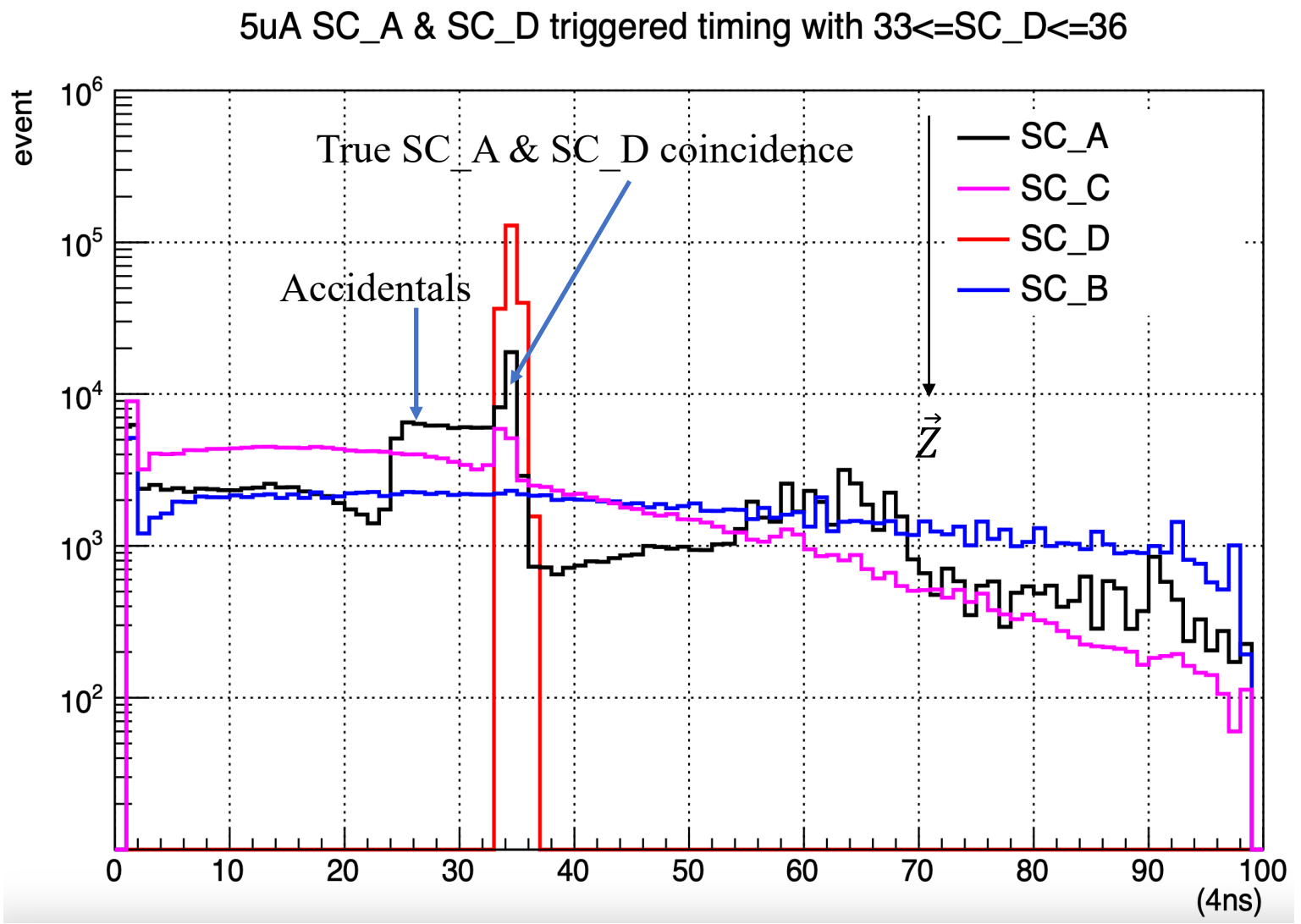
- Small pulses: photons
- MIP and above: electrons
- Source: beam pipe, some in air
- Consistent with MC
- The data is more spread out compared with MC

Scintillators with Coincidence Trigger

True coincidences (rare):

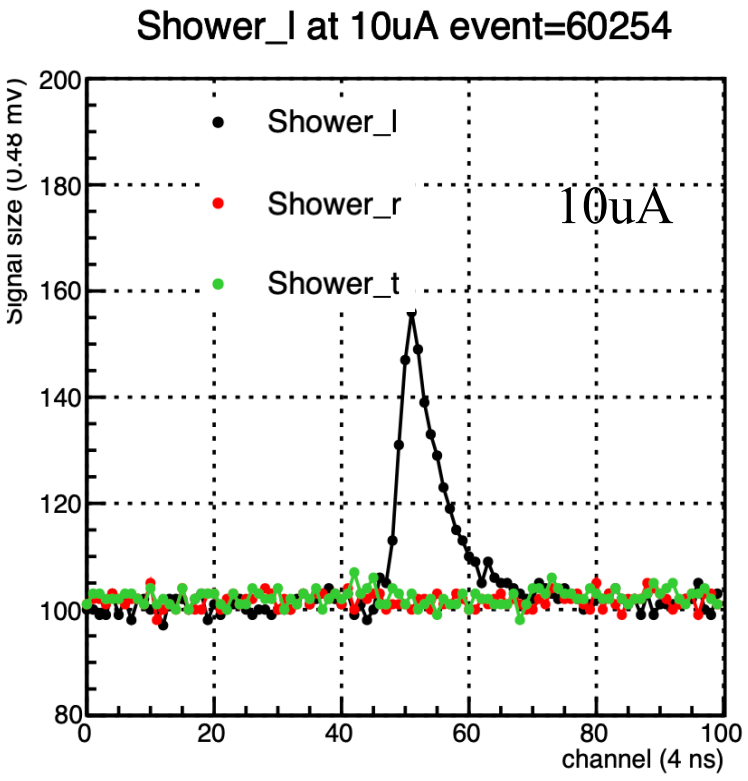
- Data shows that SC_A & SC_D trigger is mostly accidentals even at 5uA.
- Check Monte Carlo simulation agreement (ongoing, and the data is hard to interpret or simulate accurately.)

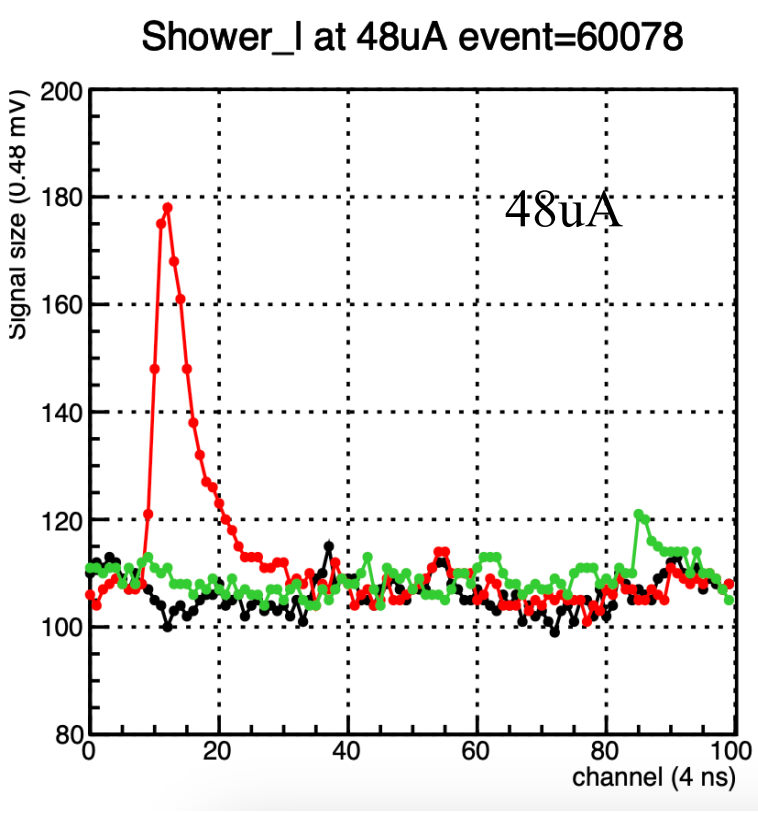
Simulation coincident pion rate: 2.1kHz

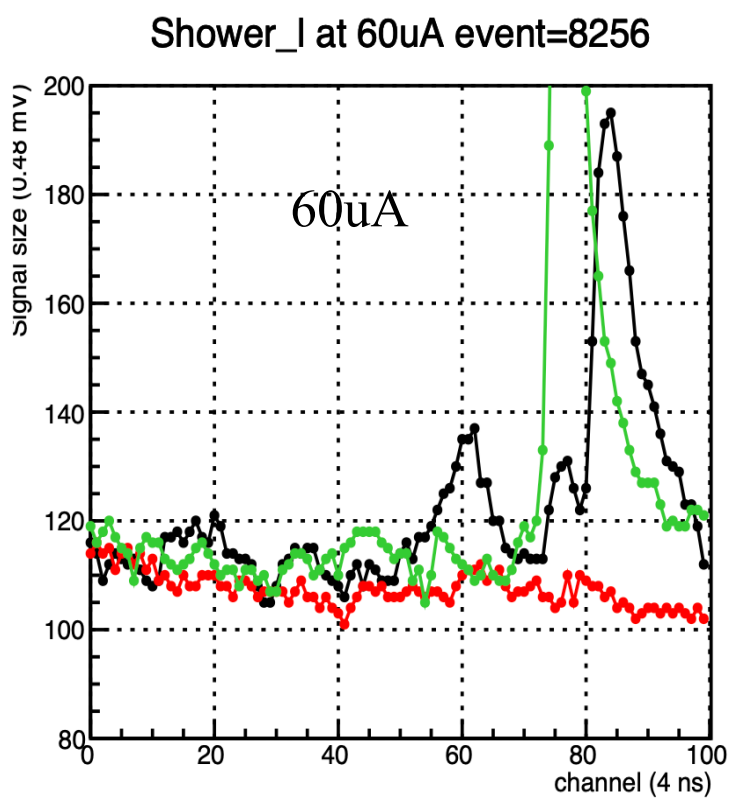


Showers with Random Trigger

- The shower baseline shift is due to tinny pulses from the multi-scattering photons by the high energy Moller electrons.

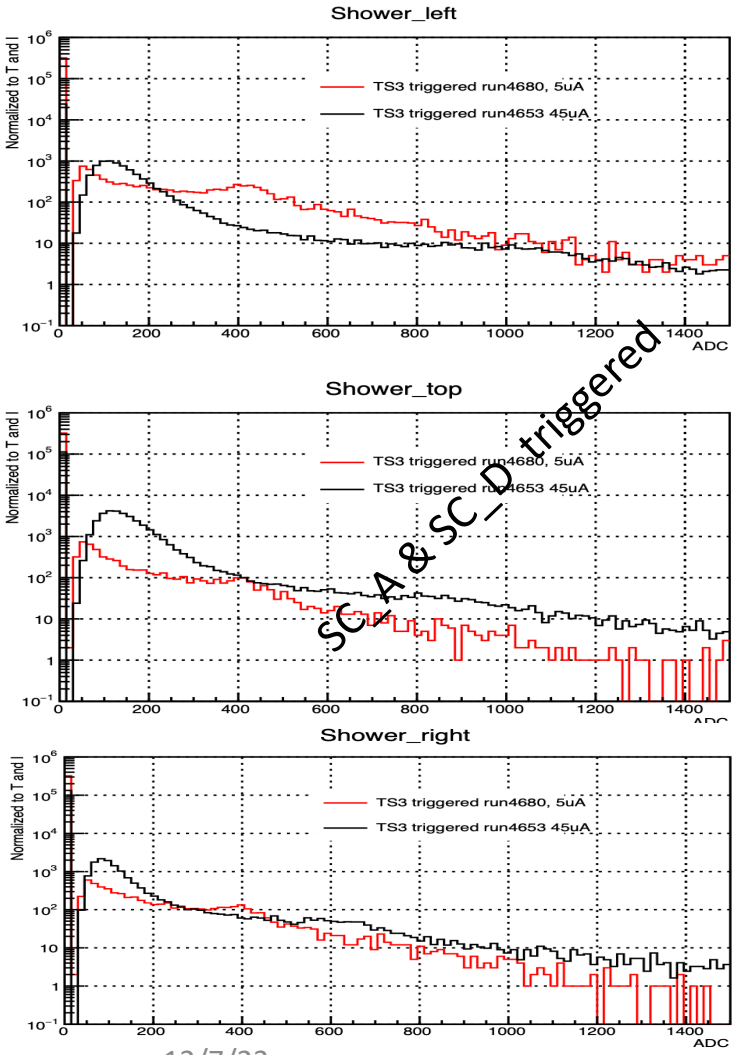




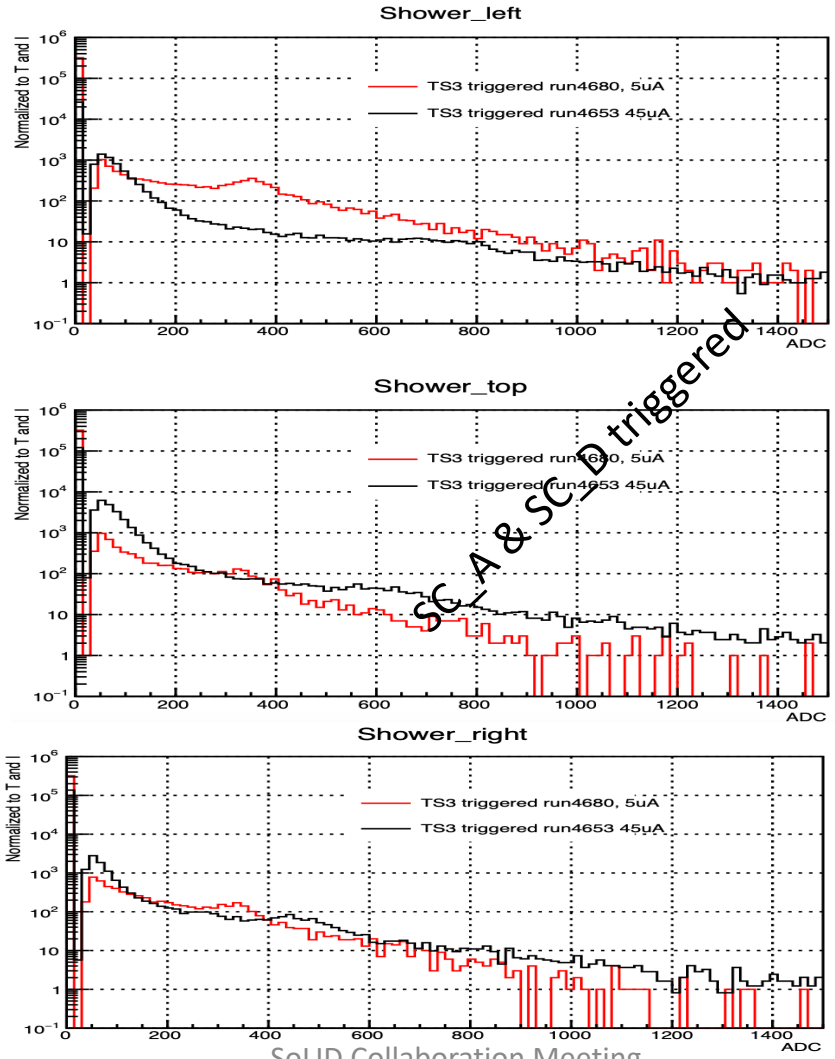


Shower Gain-Shift Correction

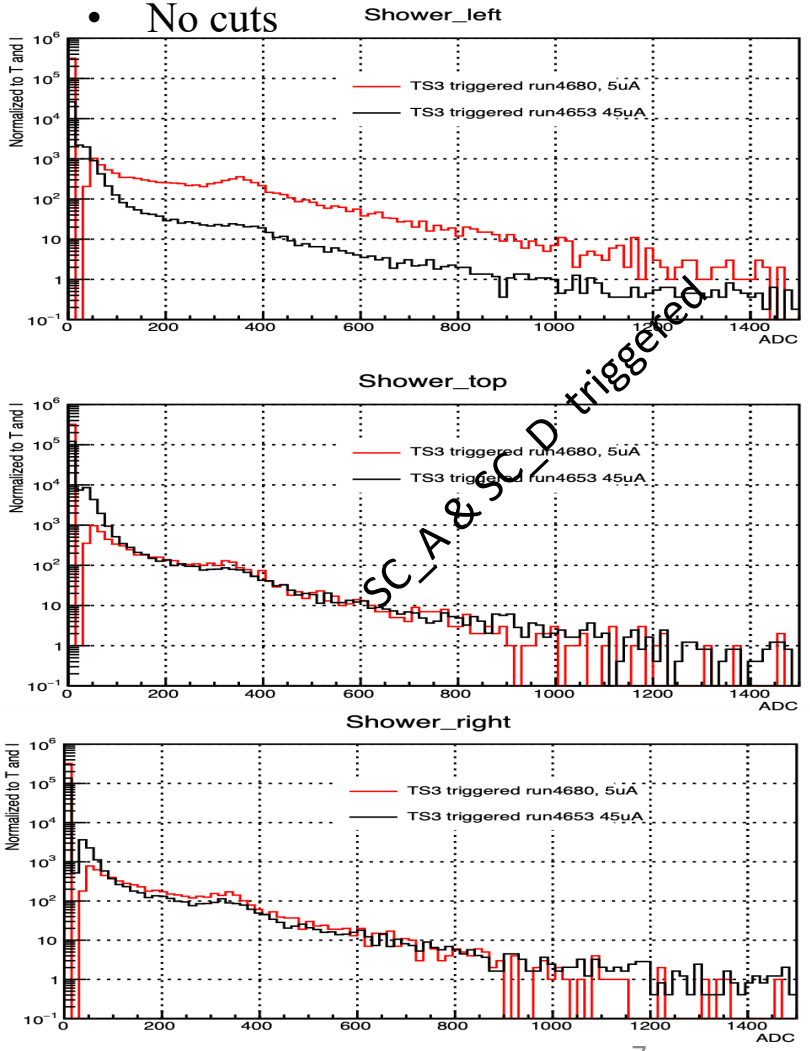
- No correction no cut



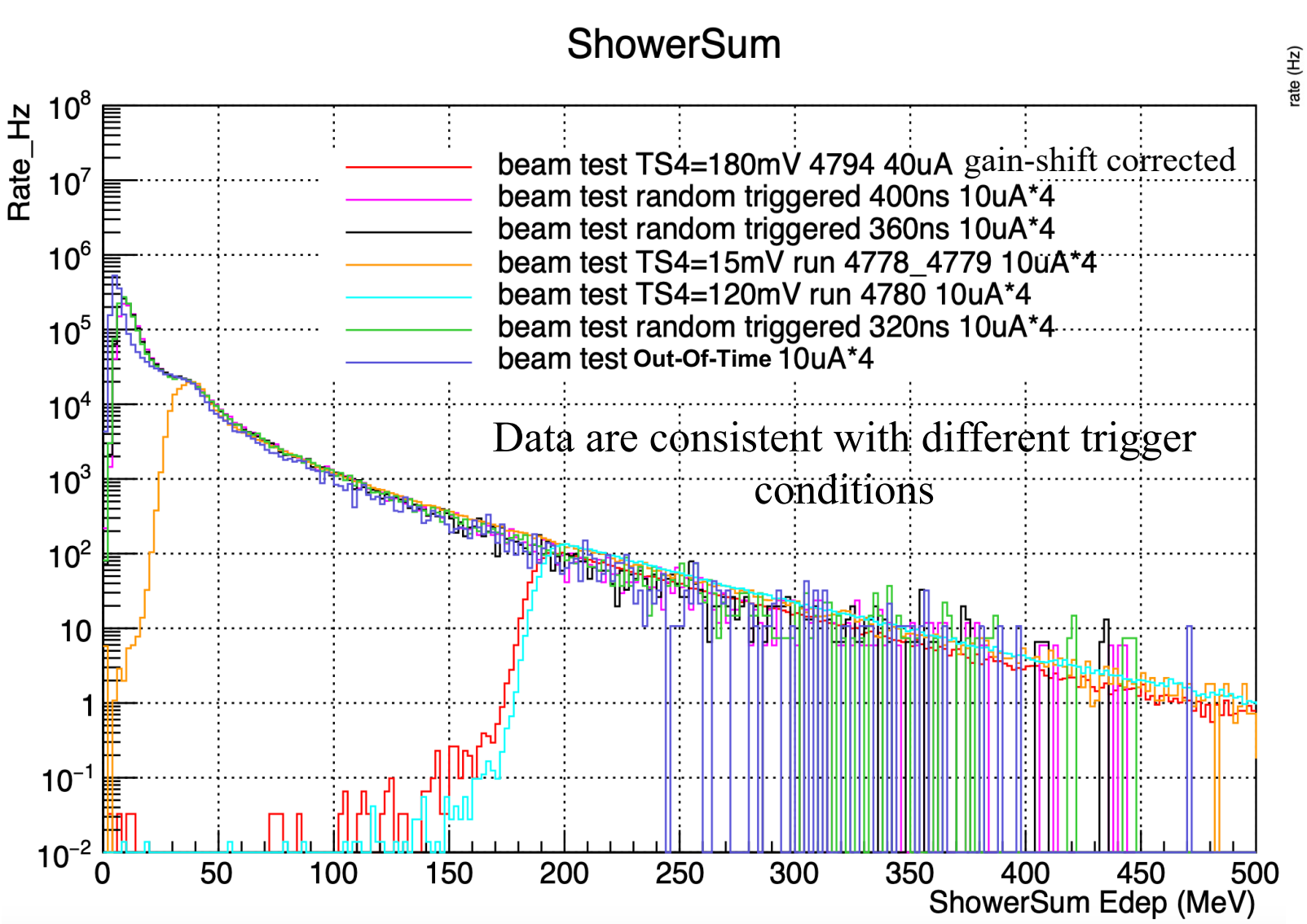
- Fix 40ns TW
- Baseline shift correction
- No cuts

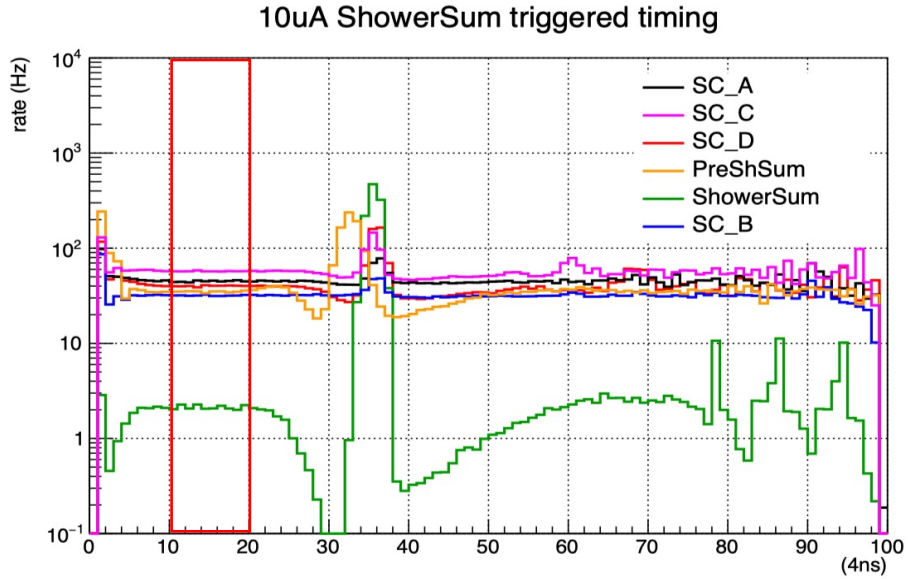


- Fix 40ns TW
- Baseline shift correction
- Gain shift correction
- No cuts



Showers Data Comparison with the ShowerSum Trigger



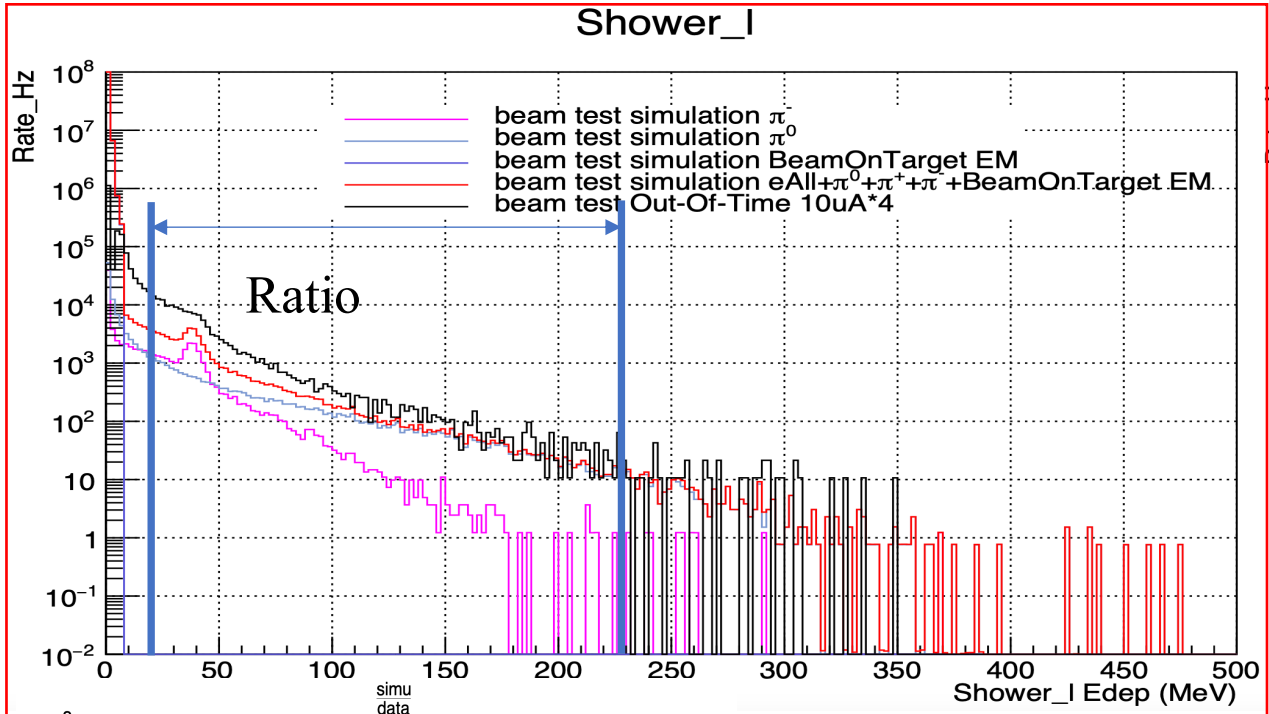


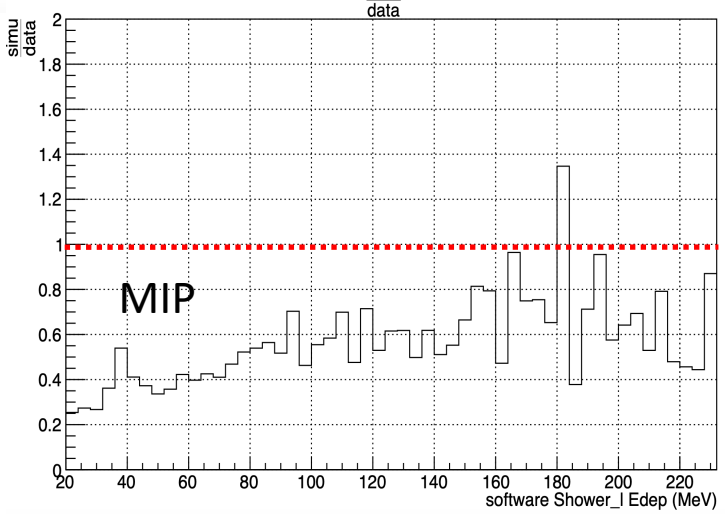
- Data: ShowerSum=Shower_l+Shower_r+Shower_t

✓ Data self consistency: Good!

- **Random trigger event** rates 1/(N_total*400ns) = 0.677s
- **10uA TS4 triggered events**: pre-scale factor PS4=7: pow(2,6)+1=65
- **10uA TS4 trigger only** with PS4=0
- **40uA TS4 triggered events** including gain-shift correction
- **Out-Of-Time events**: 40ns

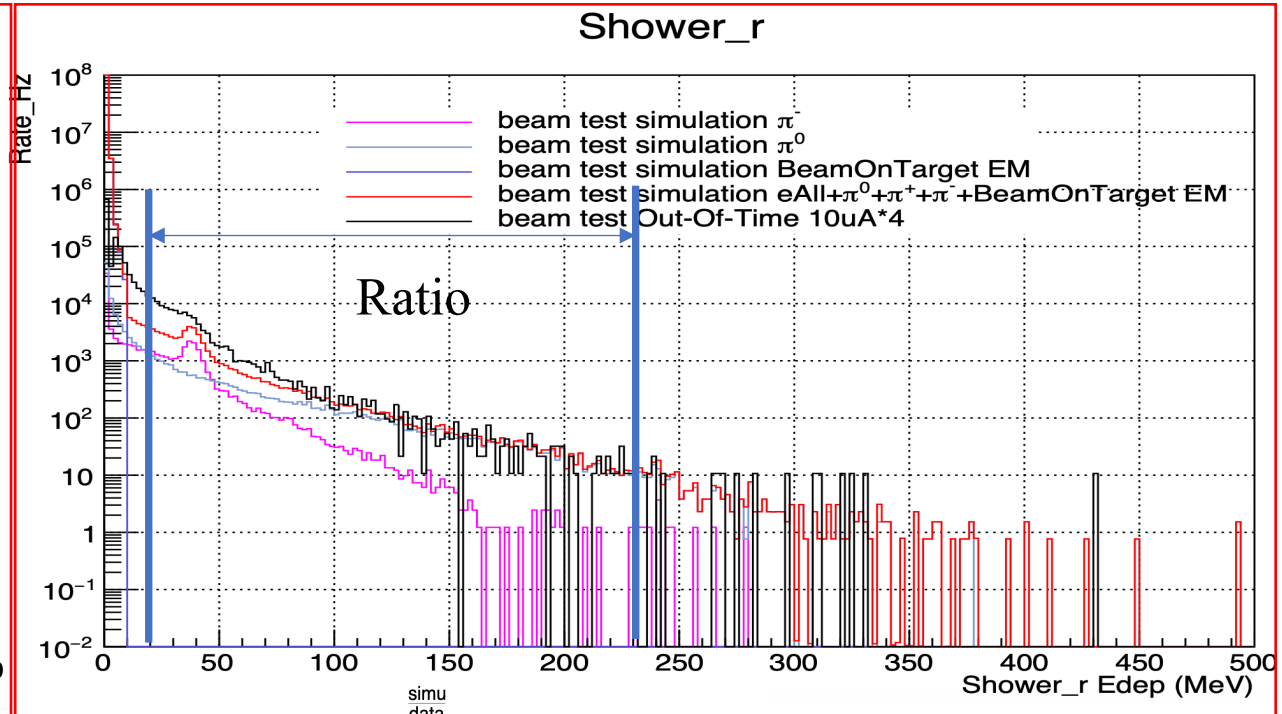
Showers Data and Simulation Comparison

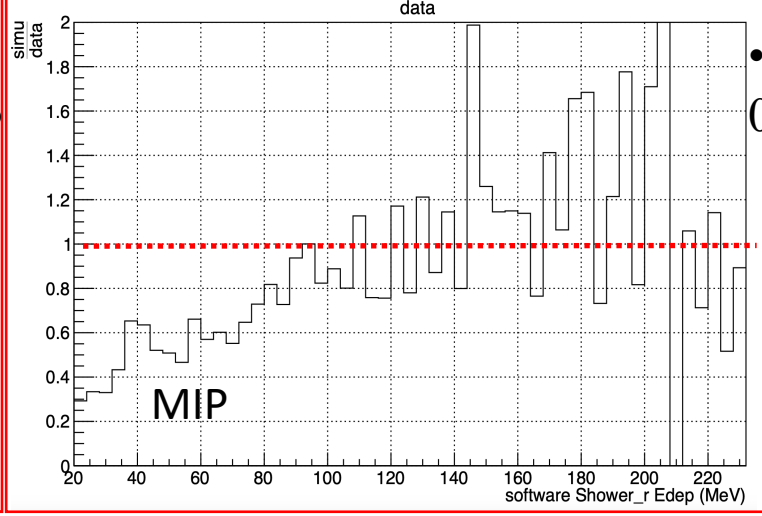




- Ratio = Sim/data

0.5 MIP<Shower_l<6 MIP

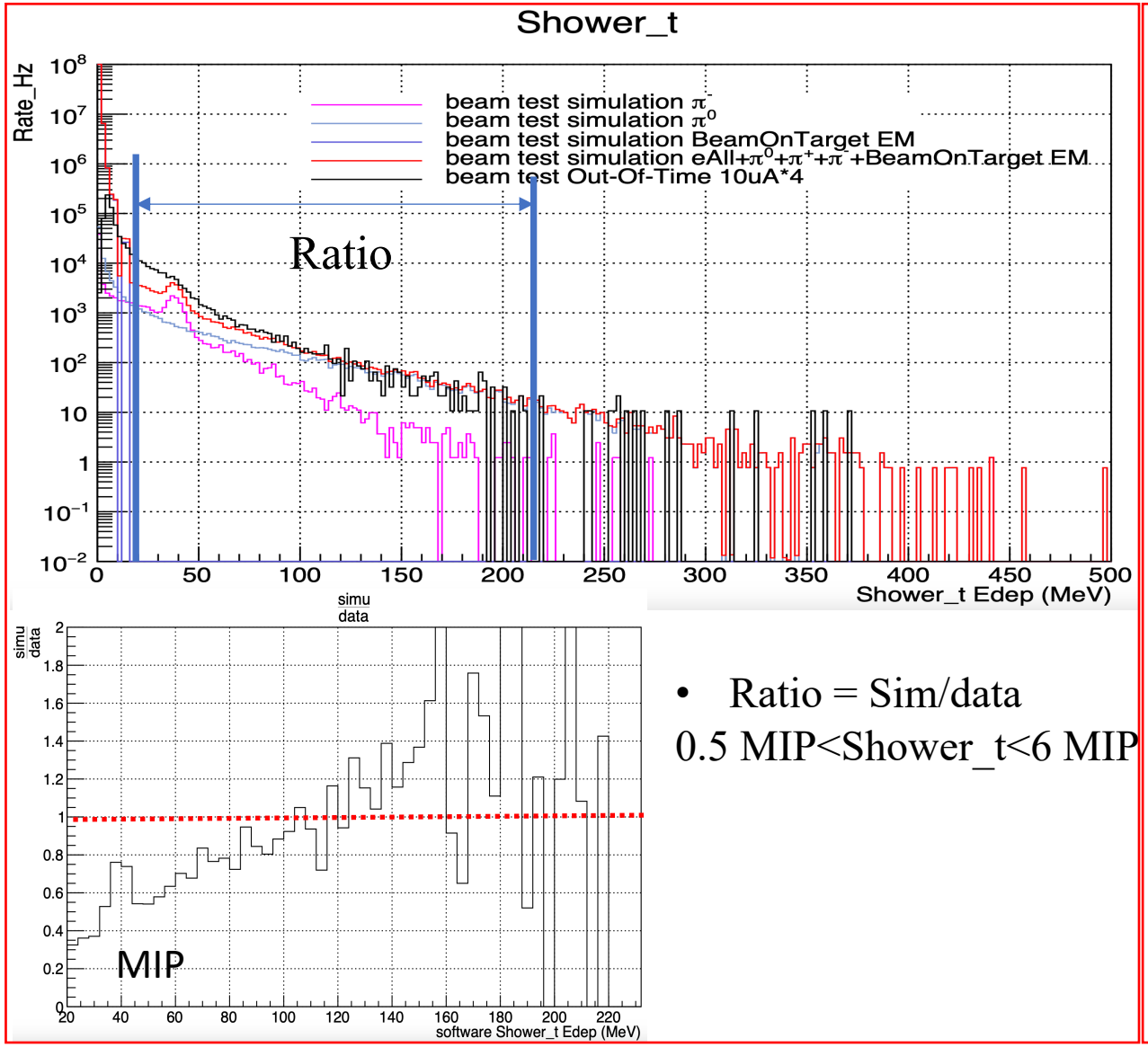




- Ratio = Sim/data

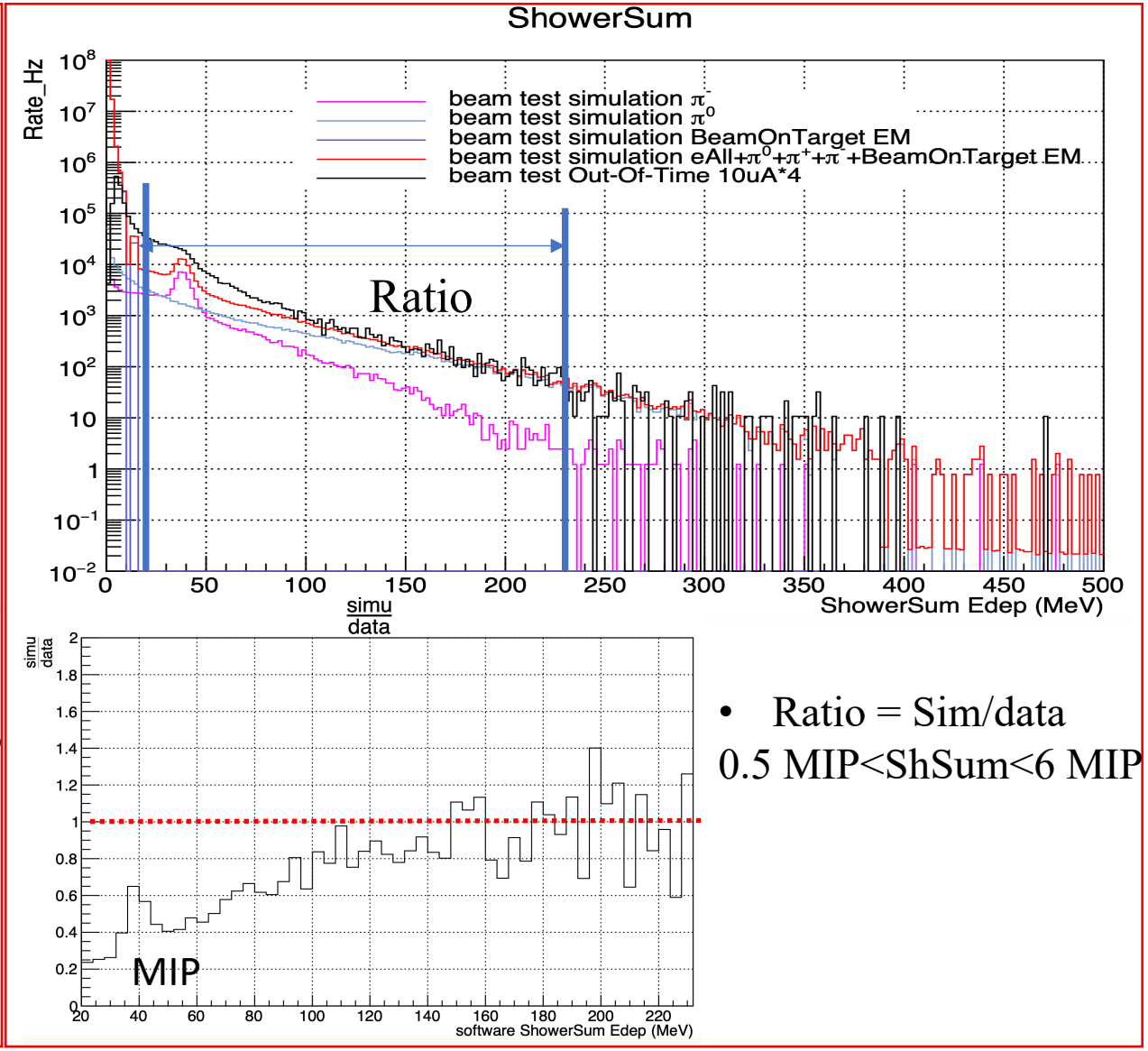
0.5 MIP<Shower_r<6 MIP

Showers Data and Simulation Comparison



- Ratio = Sim/data

0.5 MIP<Shower_t<6 MIP

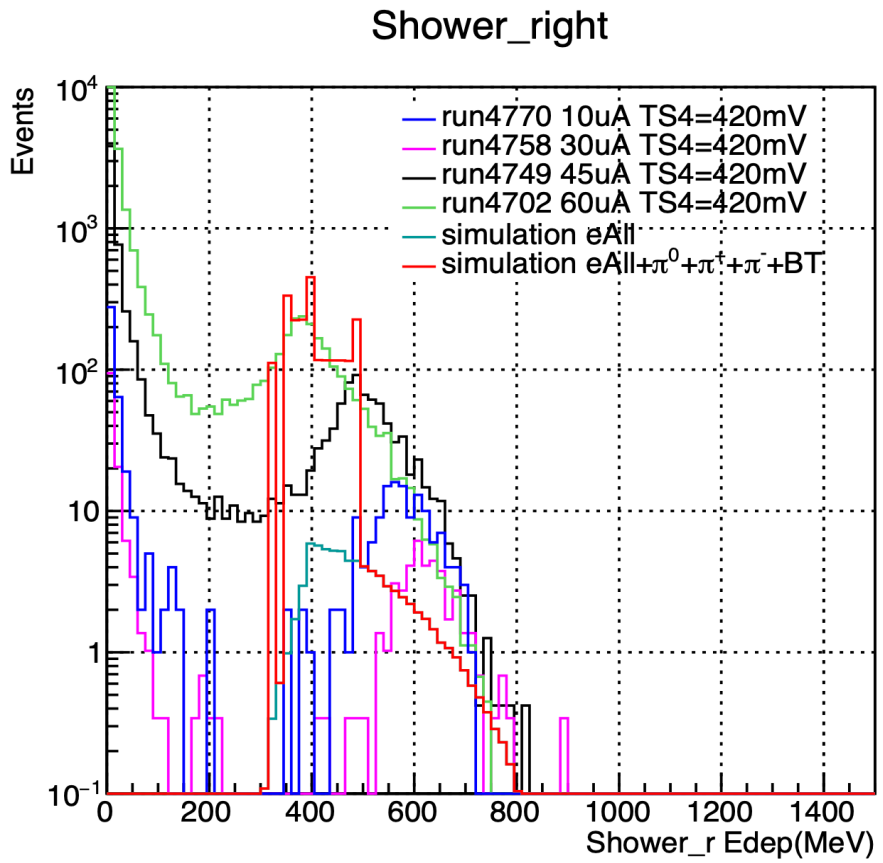


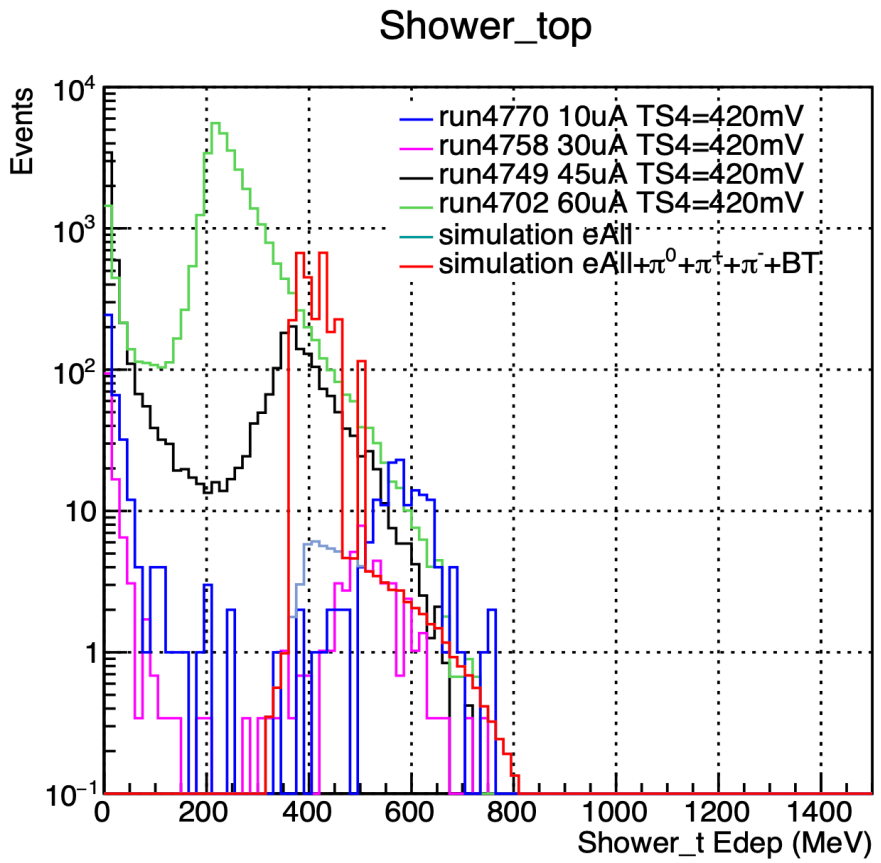
- Ratio = Sim/data

0.5 MIP<ShSum<6 MIP

General agreement, but background near MIP peak not understood.

Showers Comparison for End Points



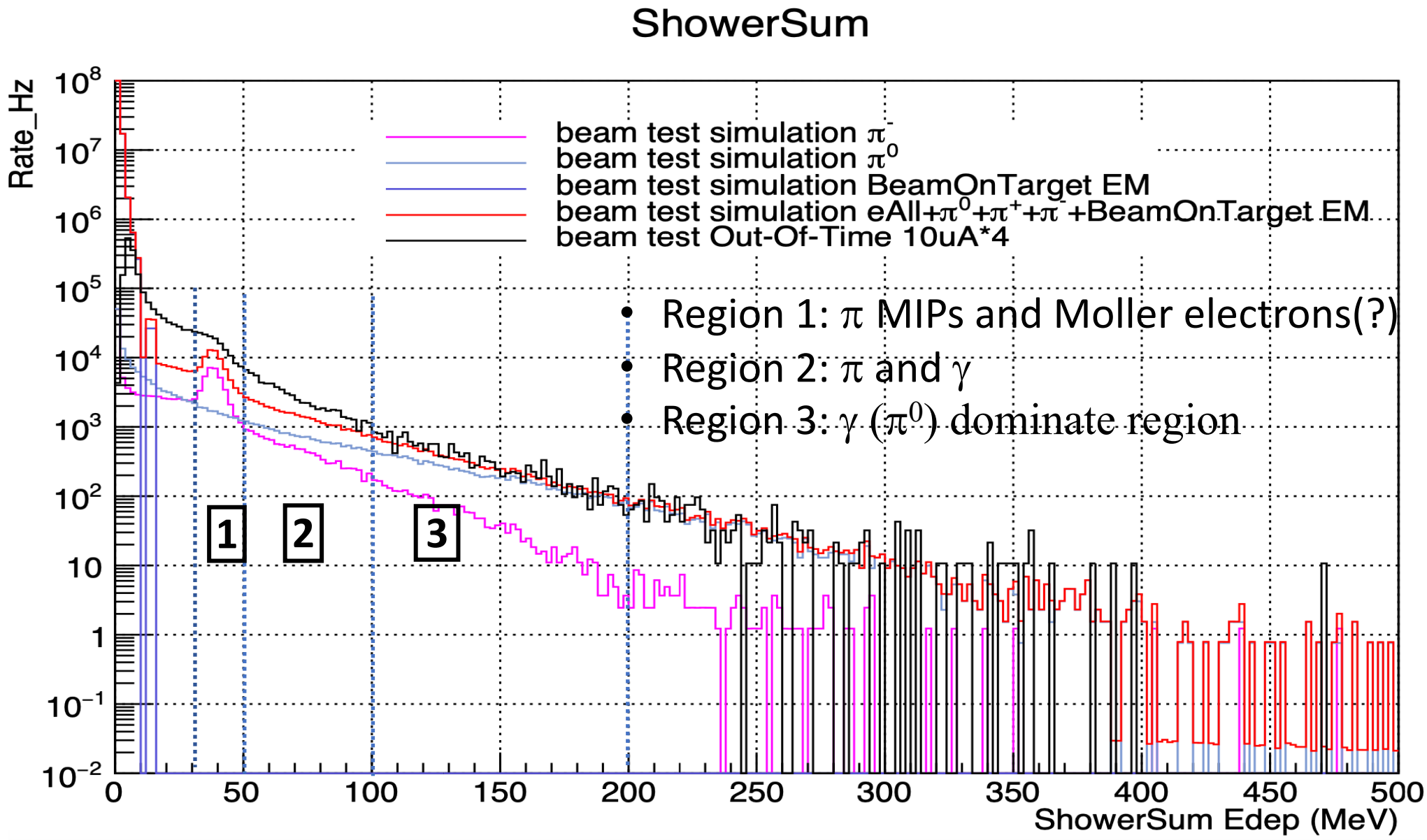


Highest E region:

- The gain-shift correction
- Need more π^0 MC
- Efficient way to gain statistics quickly

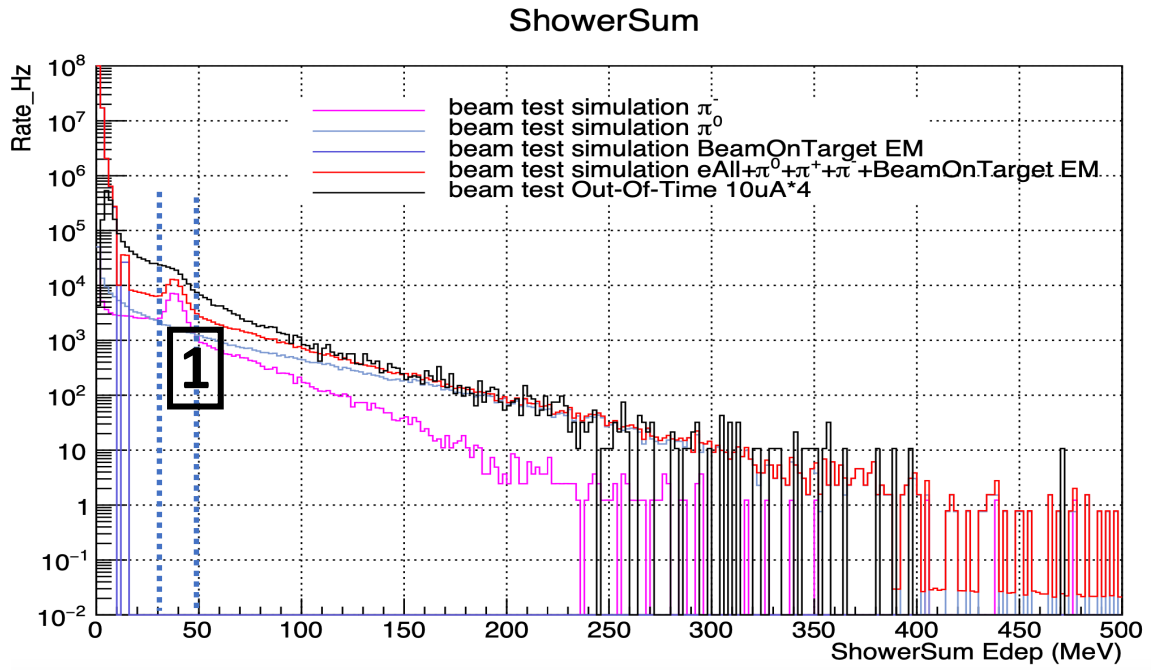
It is ongoing.

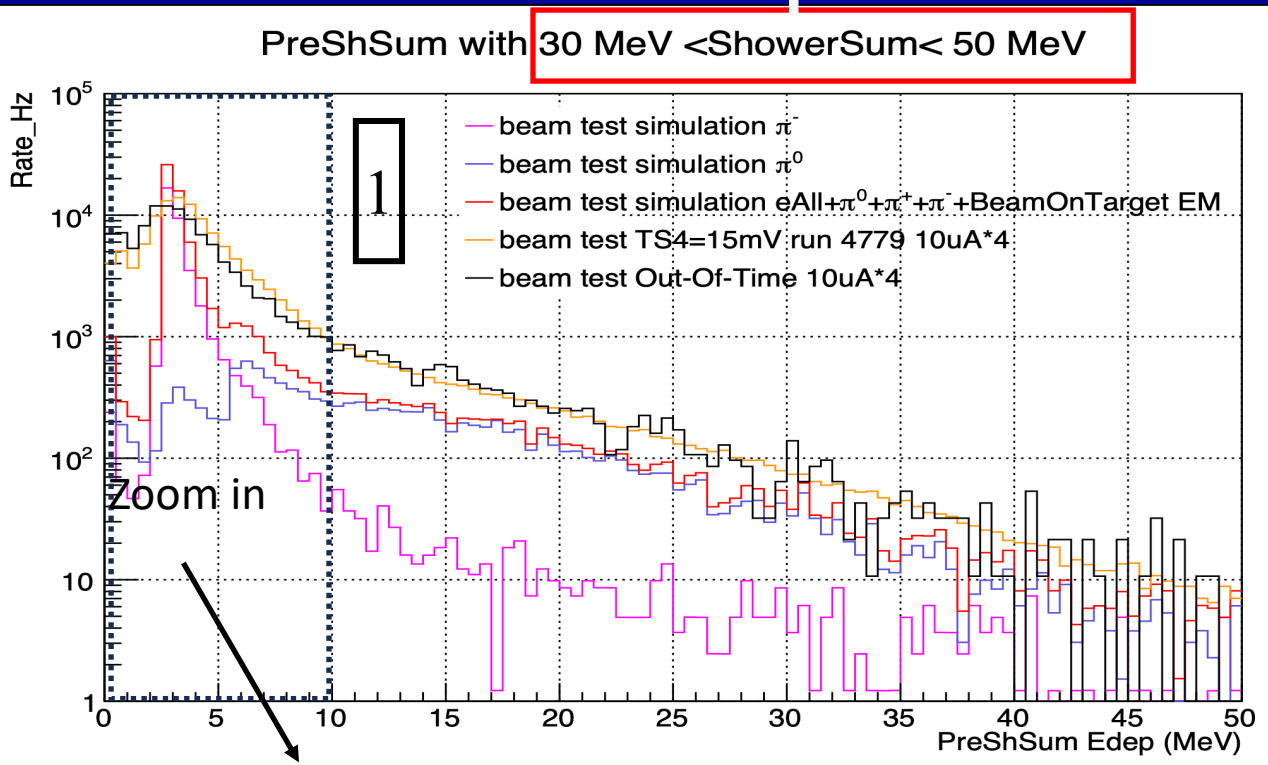
ShowerSum Simulation



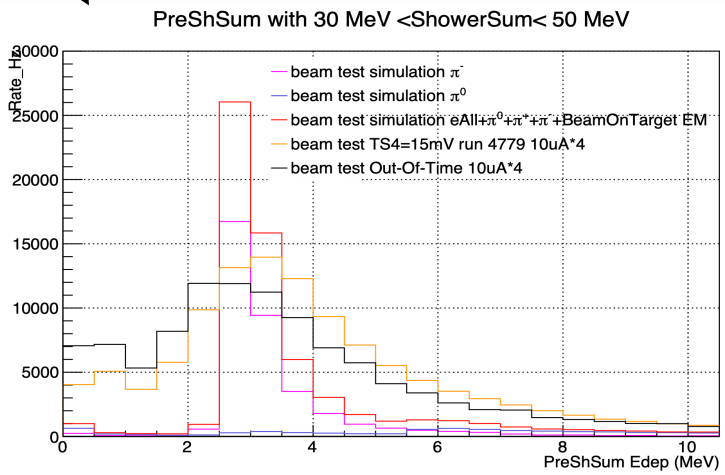
- Region 1: π MIPs and Moller electrons(?)
- Region 2: π and γ
- Region 3: γ (π^0) dominate region

PreShowers Data and Simulation Comparison



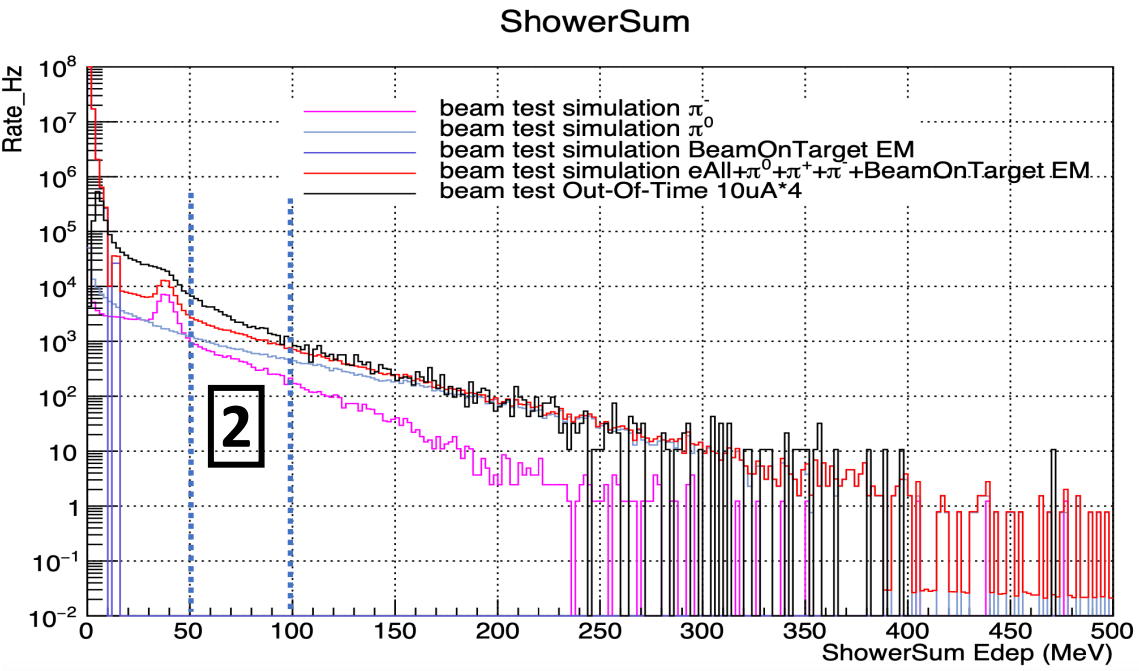


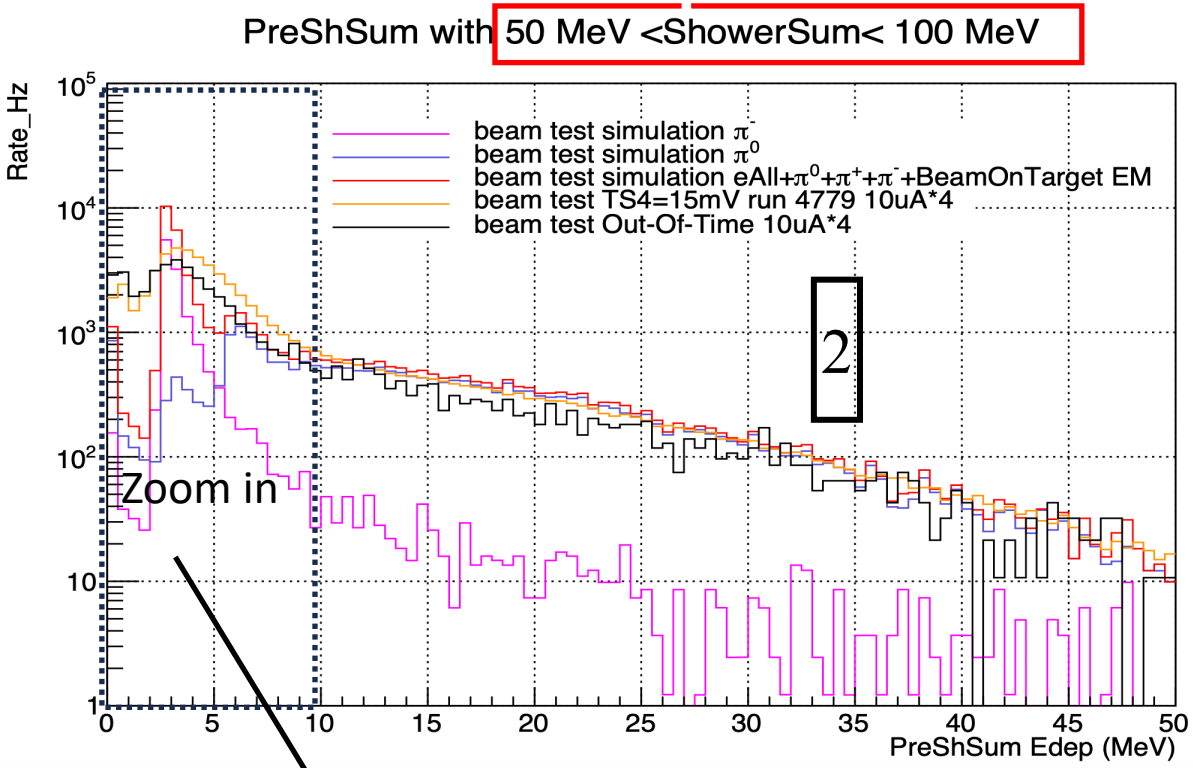
- **Region 1: π MIPs and Moller electrons (?)**
- Region 2: π and γ
- Region 3: γ (π^0) dominate region

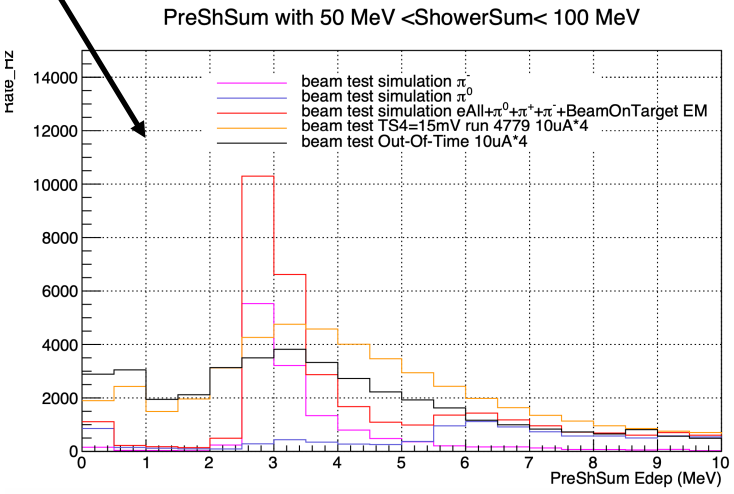


- Region 1: summary
  - ➢ The simulation is higher than the charge pion data,
  - ➢ The simulation needs more smearing.

PreShowers Data Simulation Comparison

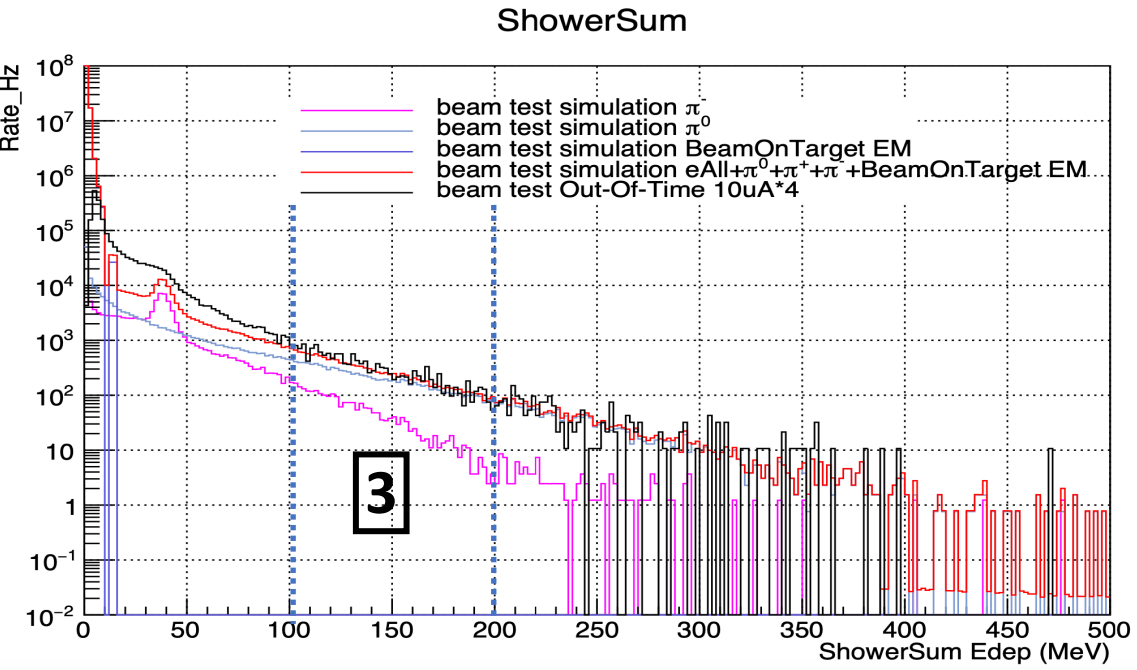


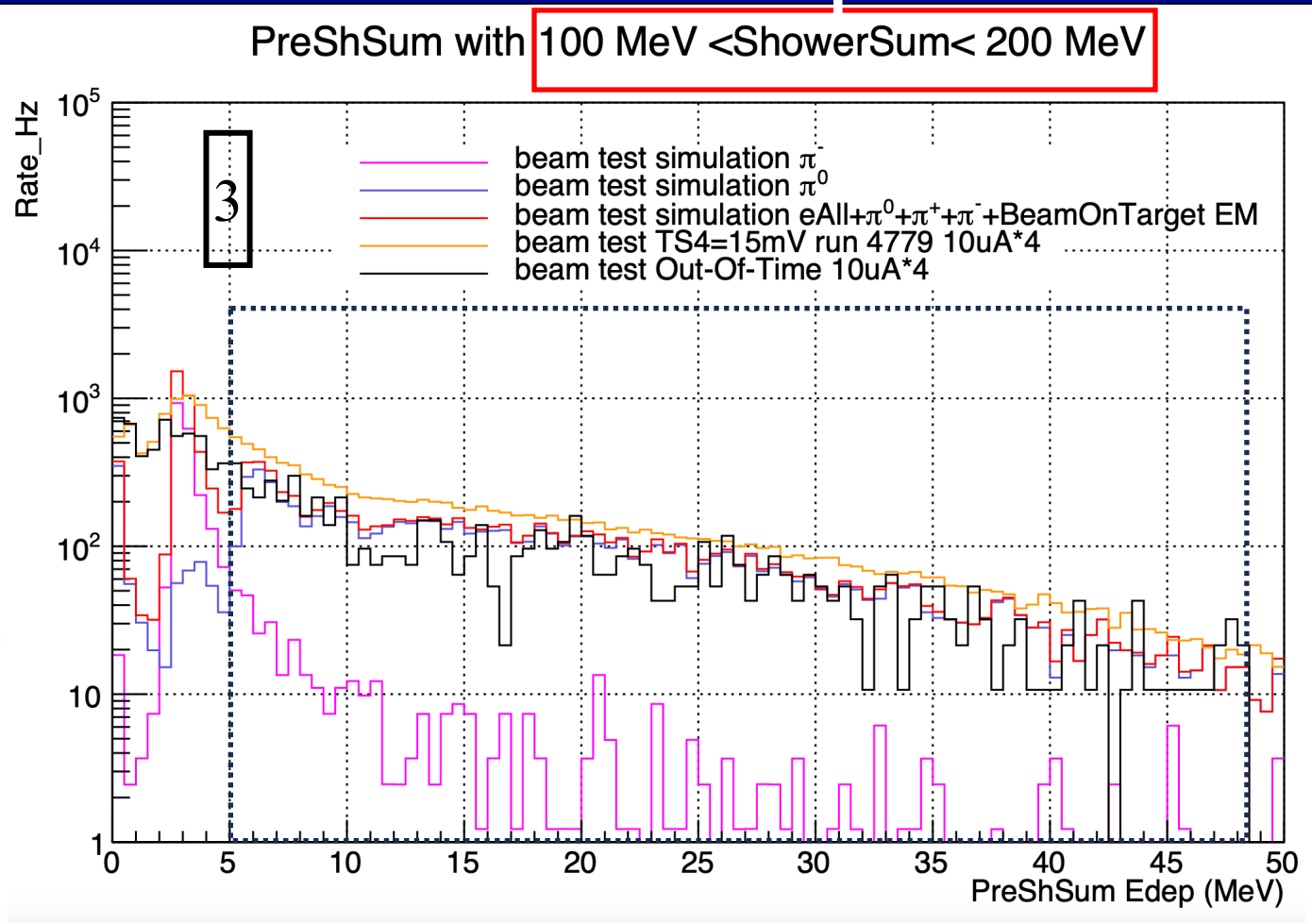




- Region 1: π MIPs and Moller electrons(?)
- **Region 2: π and γ**
- Region 3: γ (π^0) dominate region
- Region 2: summary
  - ➢ The simulation is <30 % higher than the charge pion data,
  - ➢ The simulation needs more smearing.

PreShowers Data and Simulation Comparison



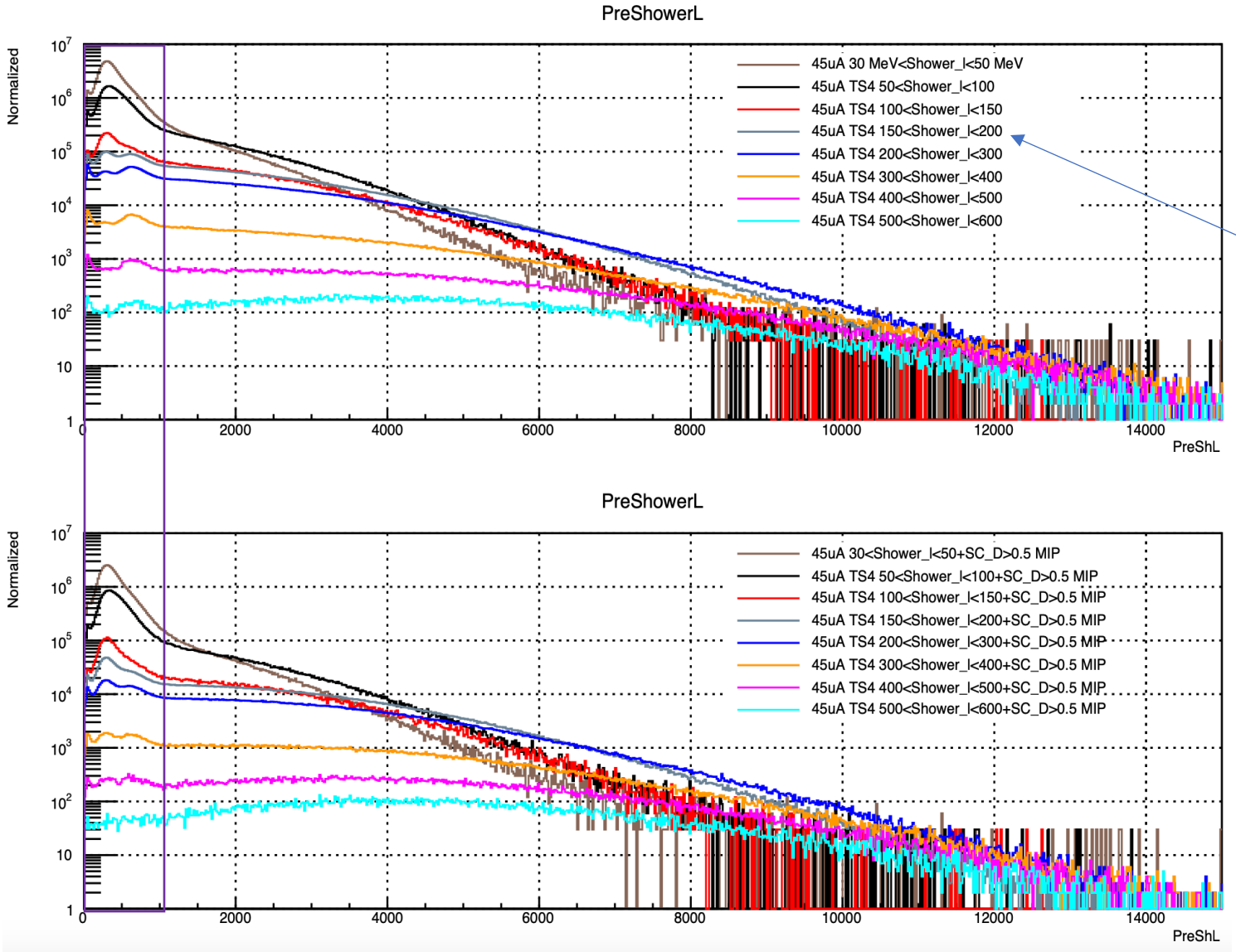


- Region 1: π MIPs and Moller(?)
- Region 2: π and γ
- **Region 3: γ (π^0) dominate region**

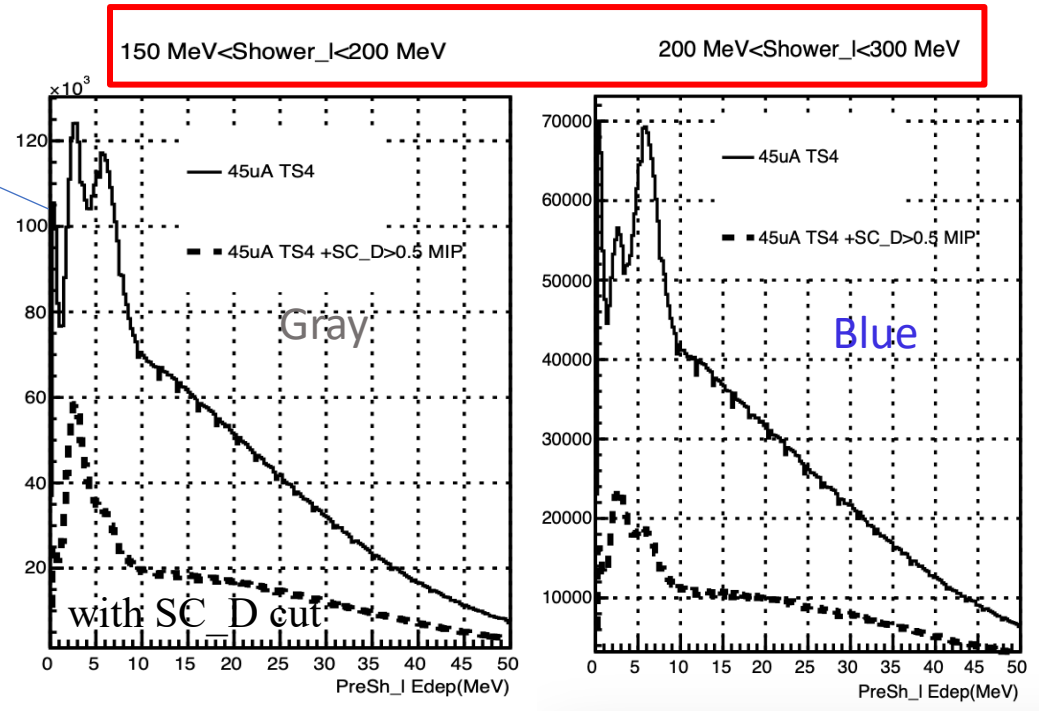
- Region 3: summary
- π^0 data agrees with the simulation

➢ The simulation needs more smearing.

PreShower Response

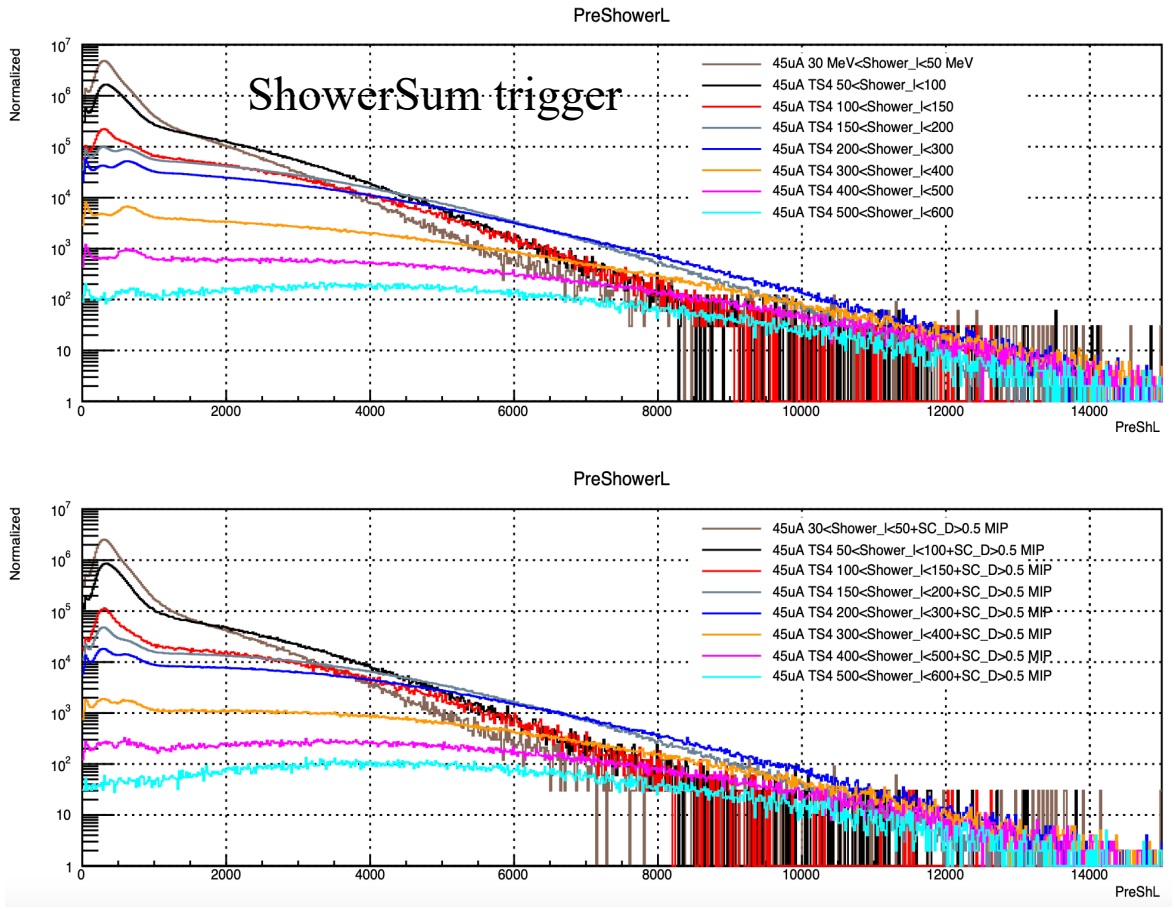


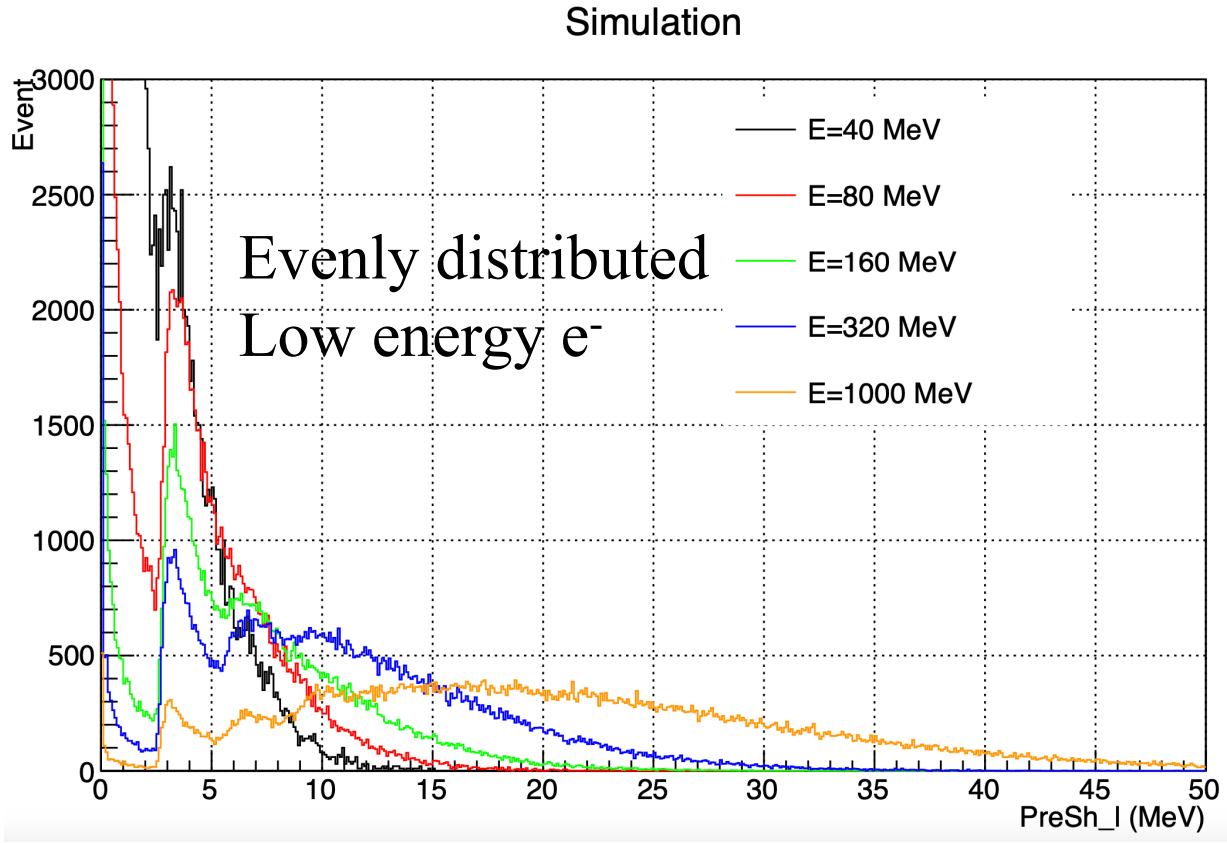
Shower energy cut to select the regions



- PreShower can provide information on γ to charged π ratio.
- PreShower features are compared to the simulation.

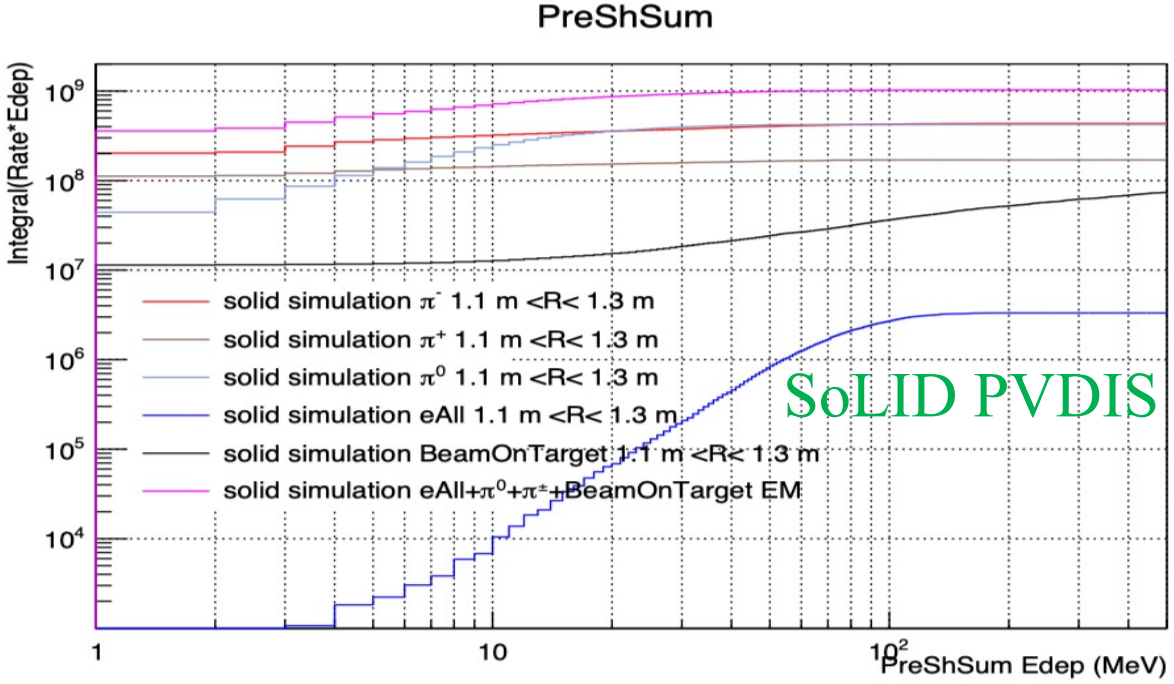
PreShower Response

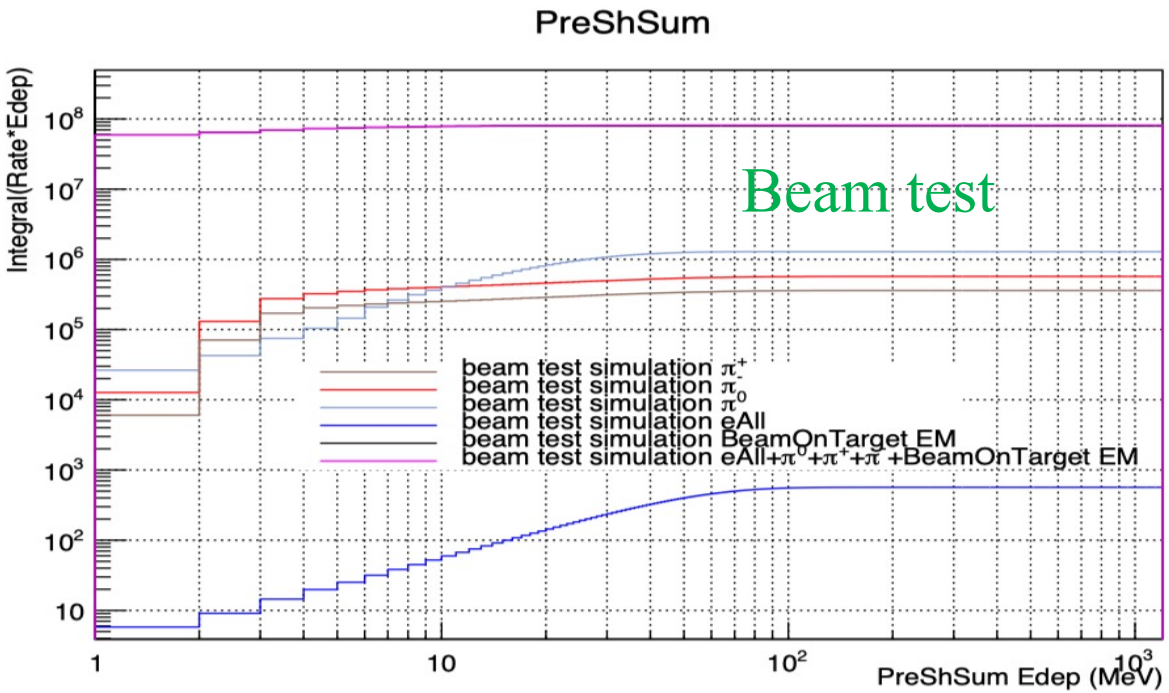




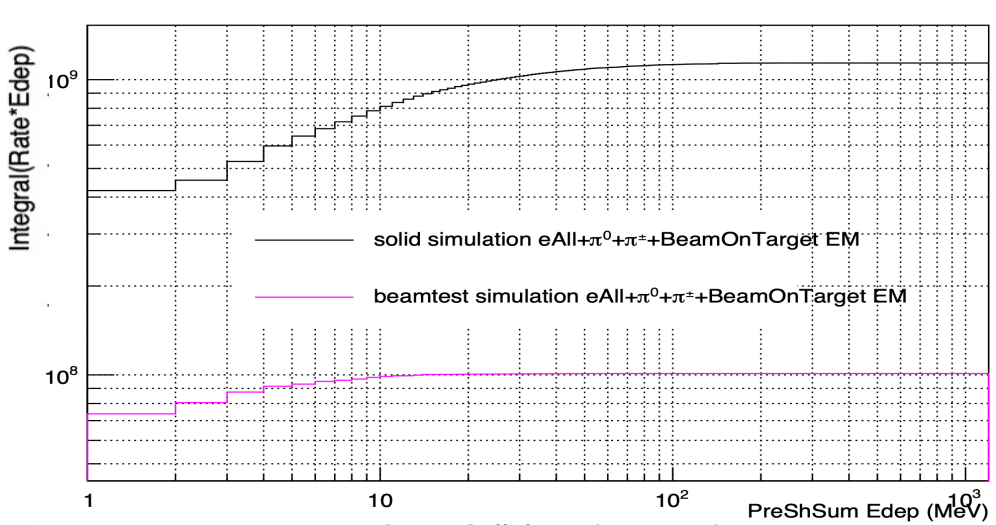
- PreShower response for the low energy electrons is very different.
- The preshower can be used to clean up the MIP at high rate.

Radiation Dose for Preshowers Based on the Simulation





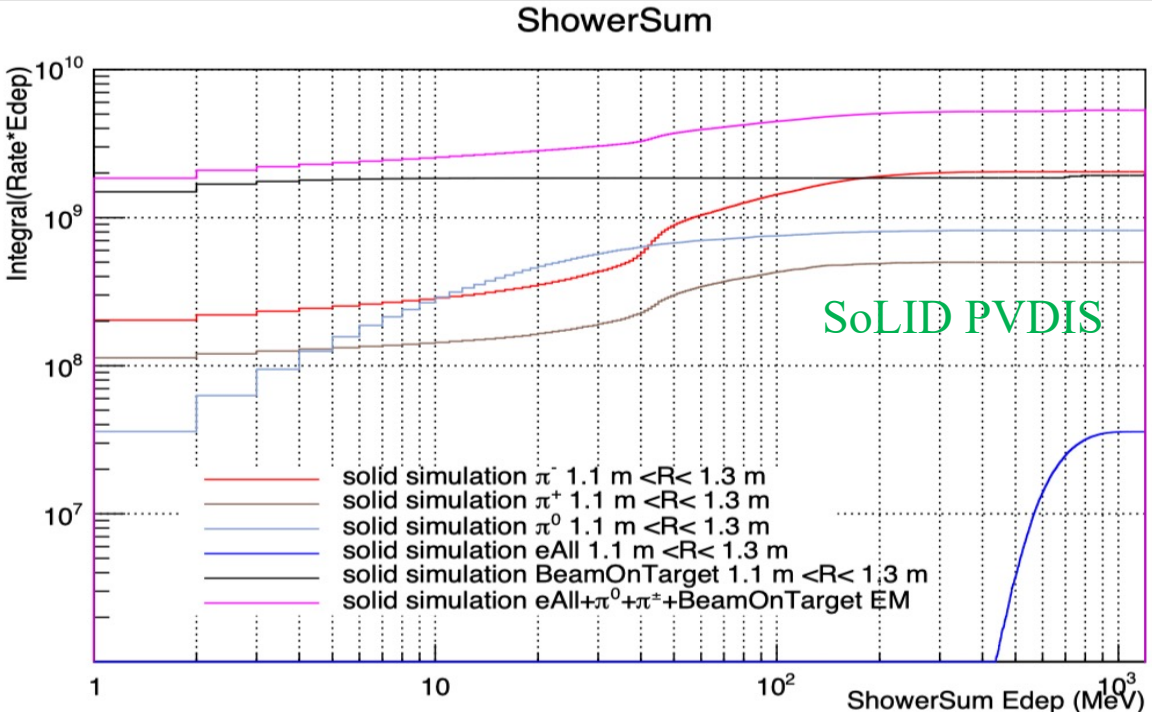
- The background is completely different between the SoLID and beamtest
- SoLID PVDIS /Beam test(50uA)
  Radiation dose ratio ~ 4

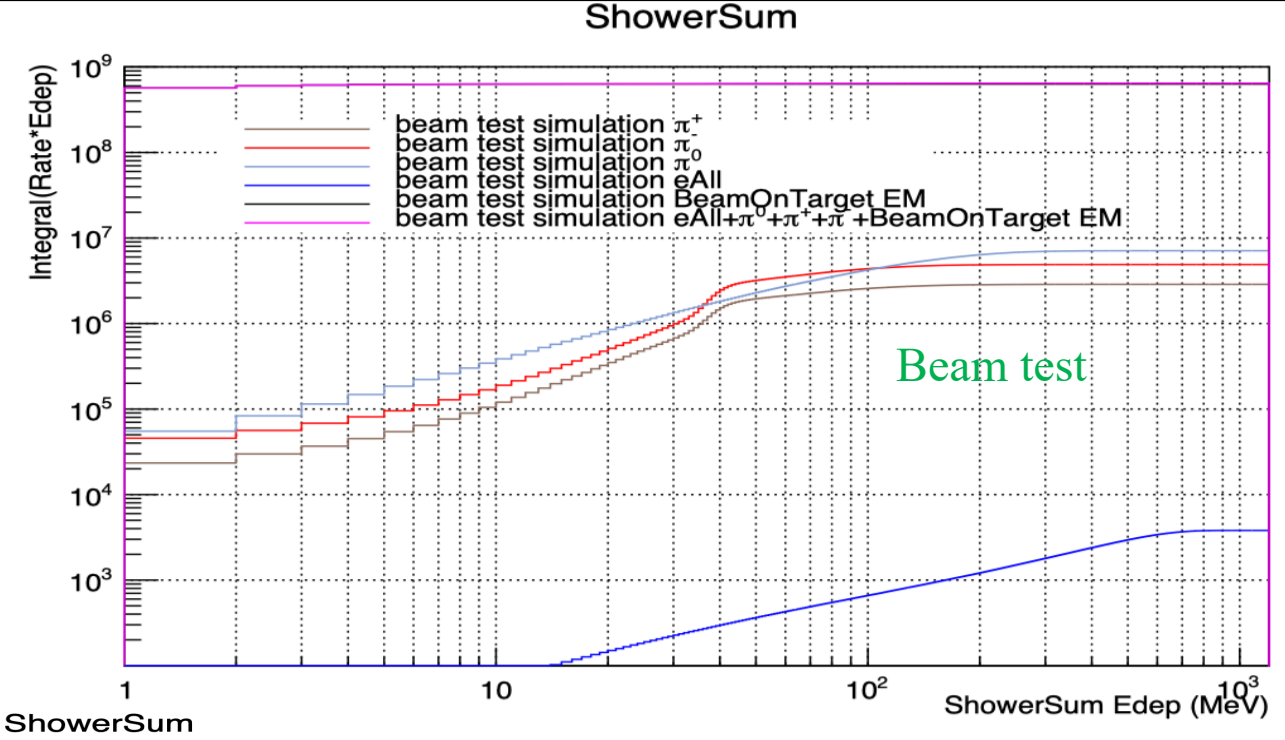


Radiation dose beam test:

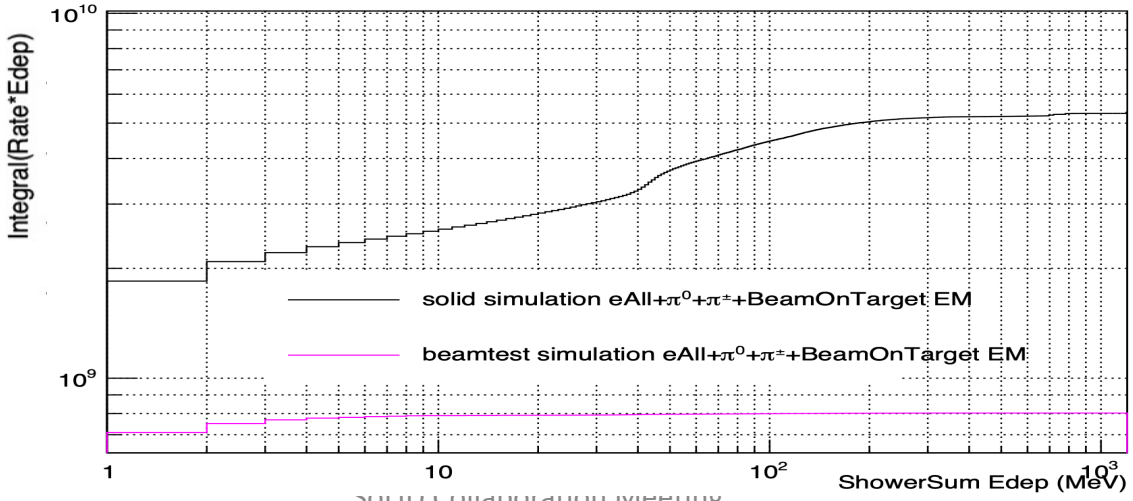
1.01e8MeV/s*(30*24*60*60)s/(3*101.3*2cm^3*1g/cm^3)=4.37e+14MeV/kg=69 J/kg =**6.9 krad** at preshower

Radiation Dose for Showers Based on the Simulation





SoLID PVDIS/Beam test (50uA)
Radiation dose ratio ~3



ECal Rate Comparison at 18 deg

- **18 deg—beam test luminosity@10uA 10cm LD2: 6.4e^{37} SoLID PVDIS 4cm LD2 @ 50uA: 1.27e^{39}**

Detector Maximum Rate (MHz)	SIDIS ^{3}He	J/ψ	PVDIS	Beam Test data	Beam Test simulation	Comment
SPD_LA	4.5	9.2		10.2 (5uA)		Cut below MIP
EC_preshower_FA	3.3	7.65	9.0	2.24/3=0.75 (10uA)	1.59/3=0.53 (10uA)	Cut below MIP
EC_shower_FA	0.92	2.344	0.9	0.1/3=0.03 (10uA)	0.042/3=0.014 (10uA)	Cut below MIP

(Table 25 from SoLID PreCDR)

- based on 5uA run 4680 wavefrom from https://userweb.jlab.org/~tianye/SoLID/ECAL_beamtest_simulation_2022/run4680_LASPD_rate_pulse.pdf
- based on 10 uA Out-Of-Time events

Summary and To-Do-List

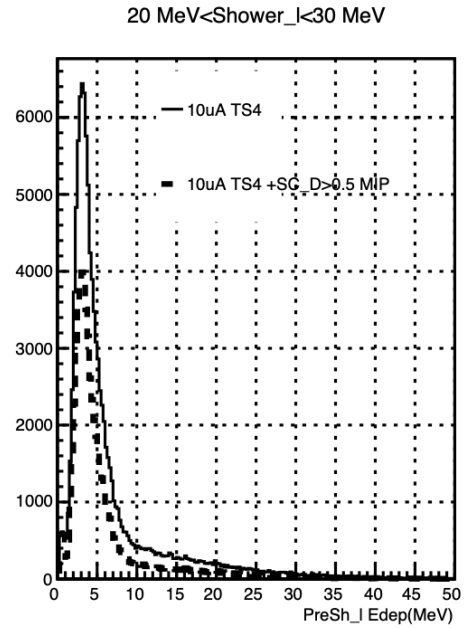
❑ Scintillator trigger coincidences dominated by accidentals, even at 5 uA. Therefore, data triggered by scintillator coincidences are hard to interpret or simulate accurately.

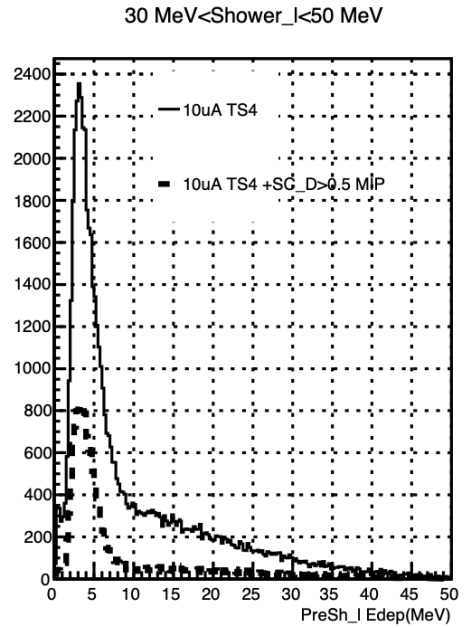
❑ Use ShowerSum only trigger, either hardware or software. General agreement, but background near MIP peak not understood.

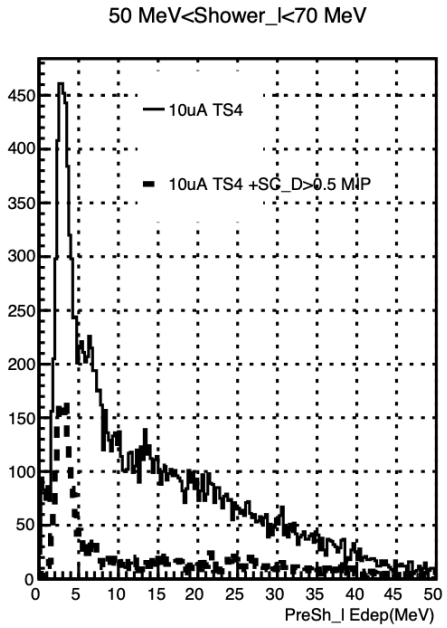
❑ PreShower's response for the low energy electrons is very different depending their energies, which can provide information on photon to charged pion ratio.

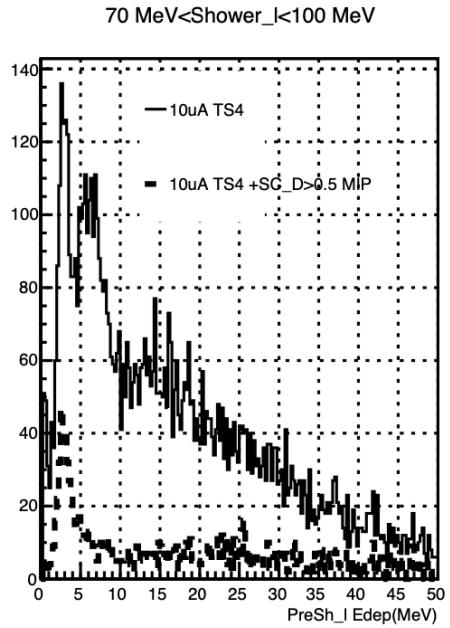
- ➢ Run MC for Moller? and high energy γ (π^0) to get better agreement between simulation and data.
- ➢ Study coincidence rates from timing plots and MC to find dominant contributions.
- ➢ Investigating other triggers (random/Out-of-Time) to clean up MIP spectra and help particle ID.
- ➢ Rate comparison at high rates.

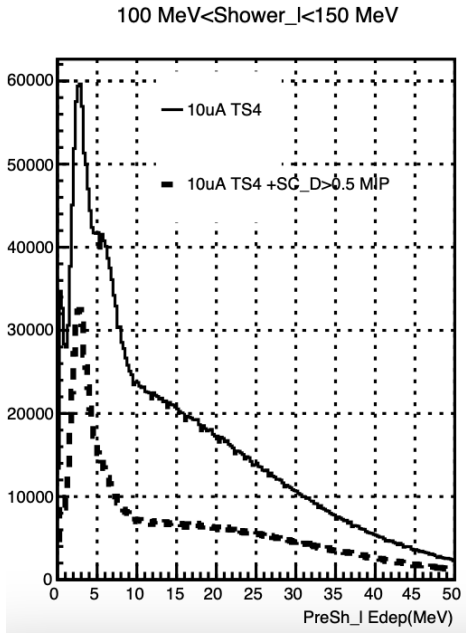
Backup

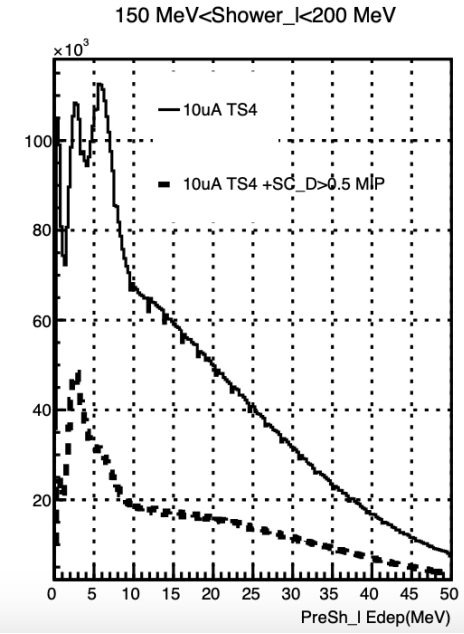

20 MeV<Shower_I<30 MeV
10uA TS4
10uA TS4 +SC_D>0.5 MIP
PreSh_I Edep(MeV)

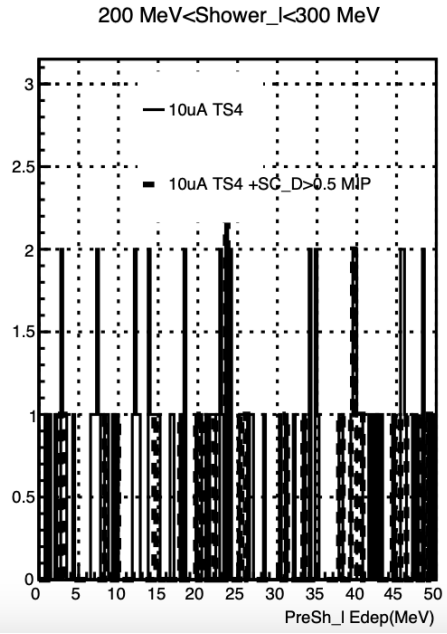

30 MeV<Shower_I<50 MeV
10uA TS4
10uA TS4 +SC_D>0.5 MIP
PreSh_I Edep(MeV)

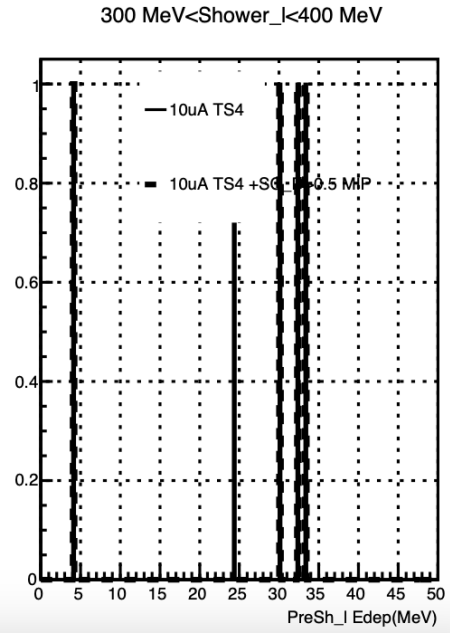

50 MeV<Shower_I<70 MeV
10uA TS4
10uA TS4 +SC_D>0.5 MIP
PreSh_I Edep(MeV)


70 MeV<Shower_I<100 MeV
10uA TS4
10uA TS4 +SC_D>0.5 MIP
PreSh_I Edep(MeV)

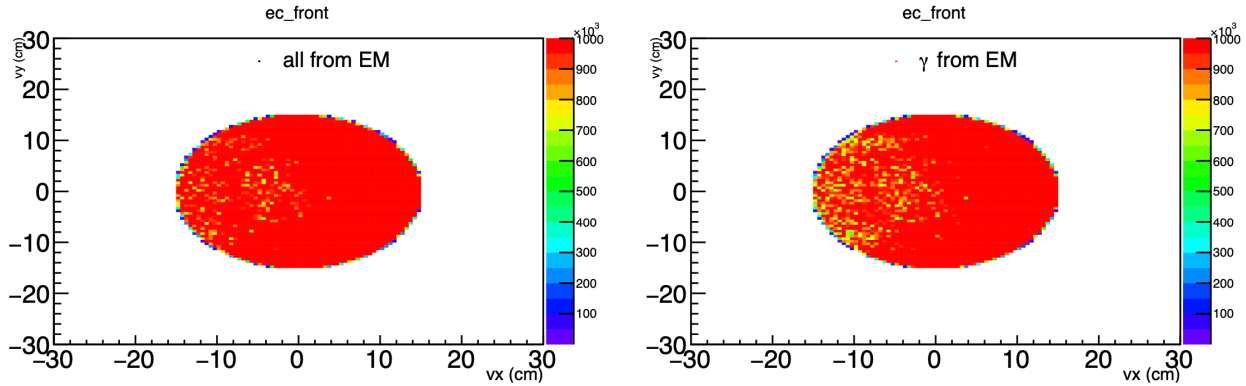

100 MeV<Shower_I<150 MeV
10uA TS4
10uA TS4 +SC_D>0.5 MIP
PreSh_I Edep(MeV)

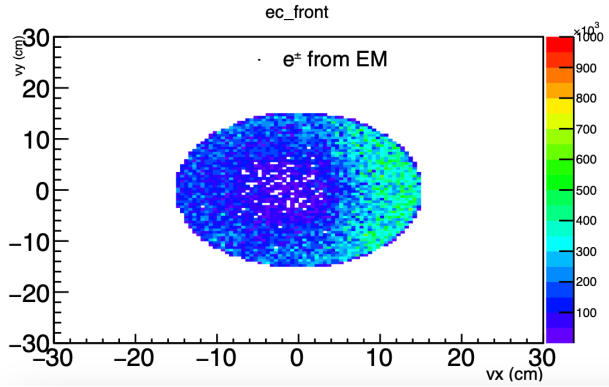

150 MeV<Shower_I<200 MeV
×10^3
10uA TS4
10uA TS4 +SC_D>0.5 MIP
PreSh_I Edep(MeV)

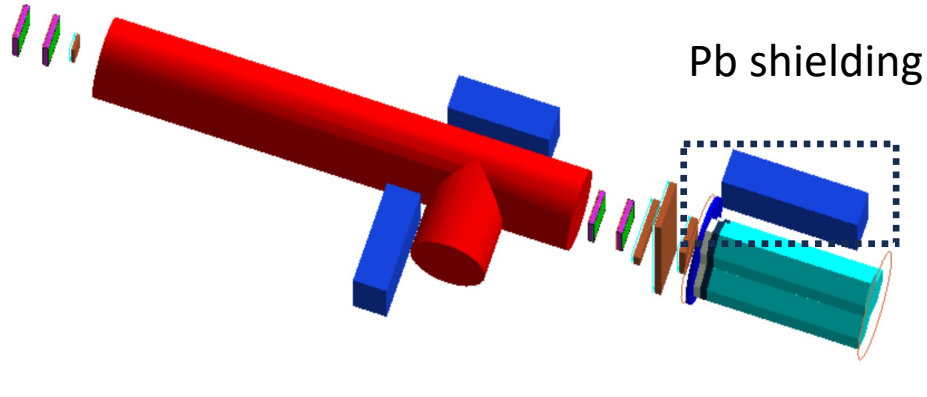

200 MeV<Shower_I<300 MeV
10uA TS4
10uA TS4 +SC_D>0.5 MIP
PreSh_I Edep(MeV)


300 MeV<Shower_I<400 MeV
10uA TS4
10uA TS4 +SC_D>0.5 MIP
PreSh_I Edep(MeV)

Low energy backgrounds shielded by Pb blocks

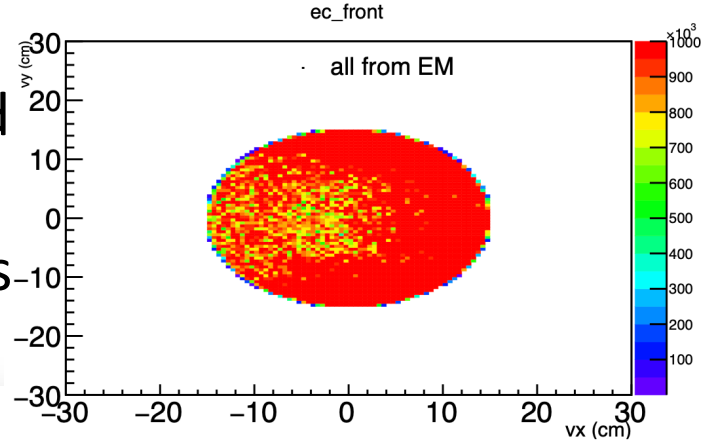


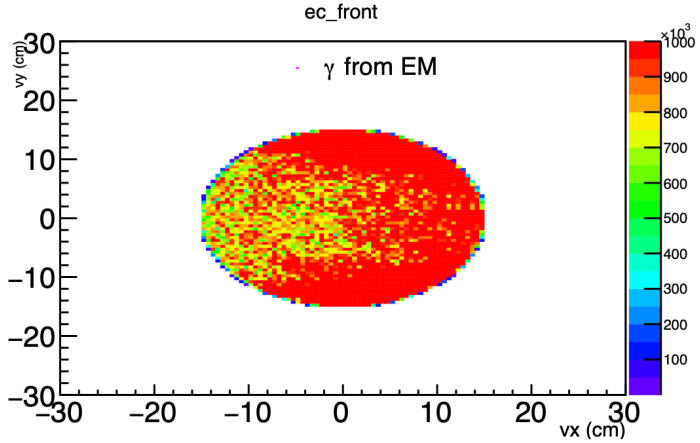


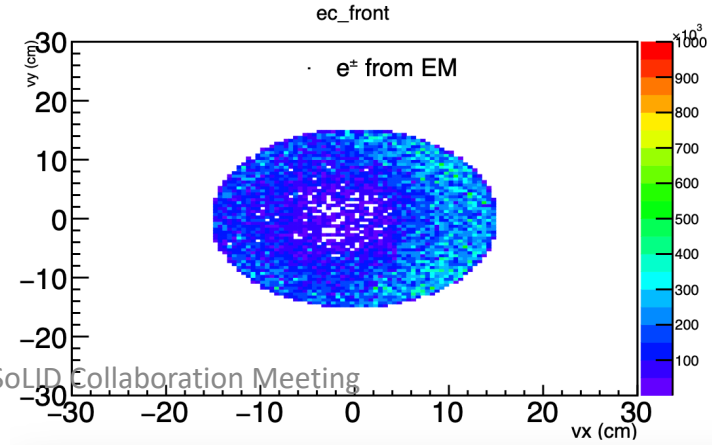


Pb shielding blocks

- EM background without pb shielding blocks



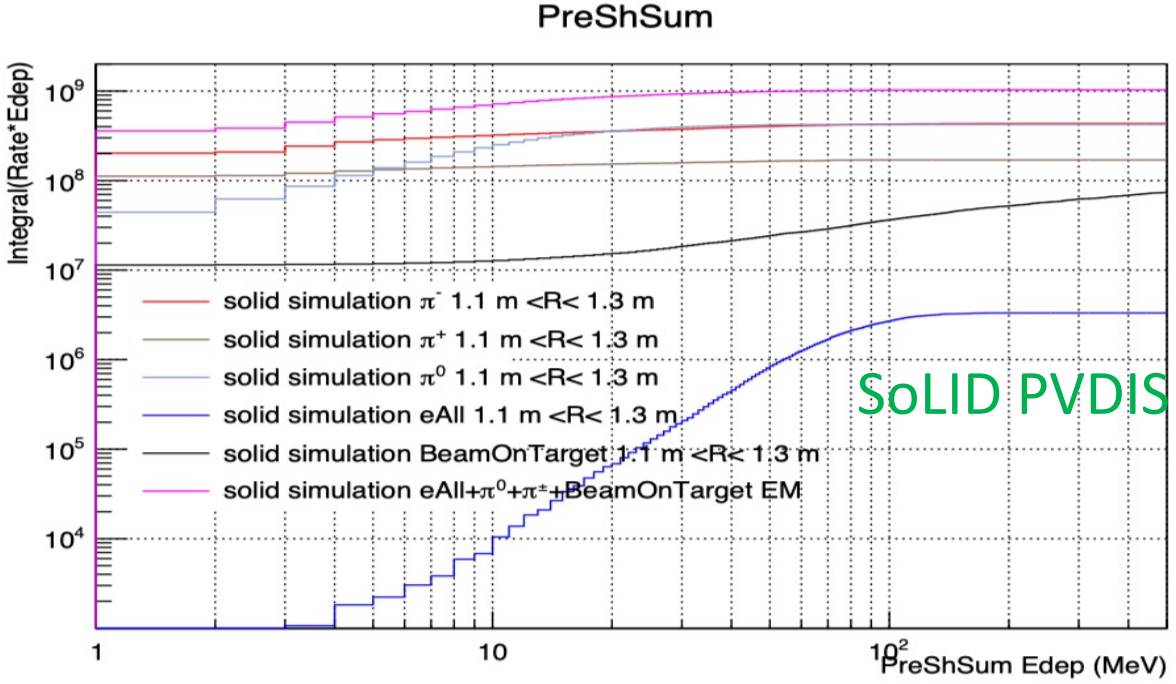


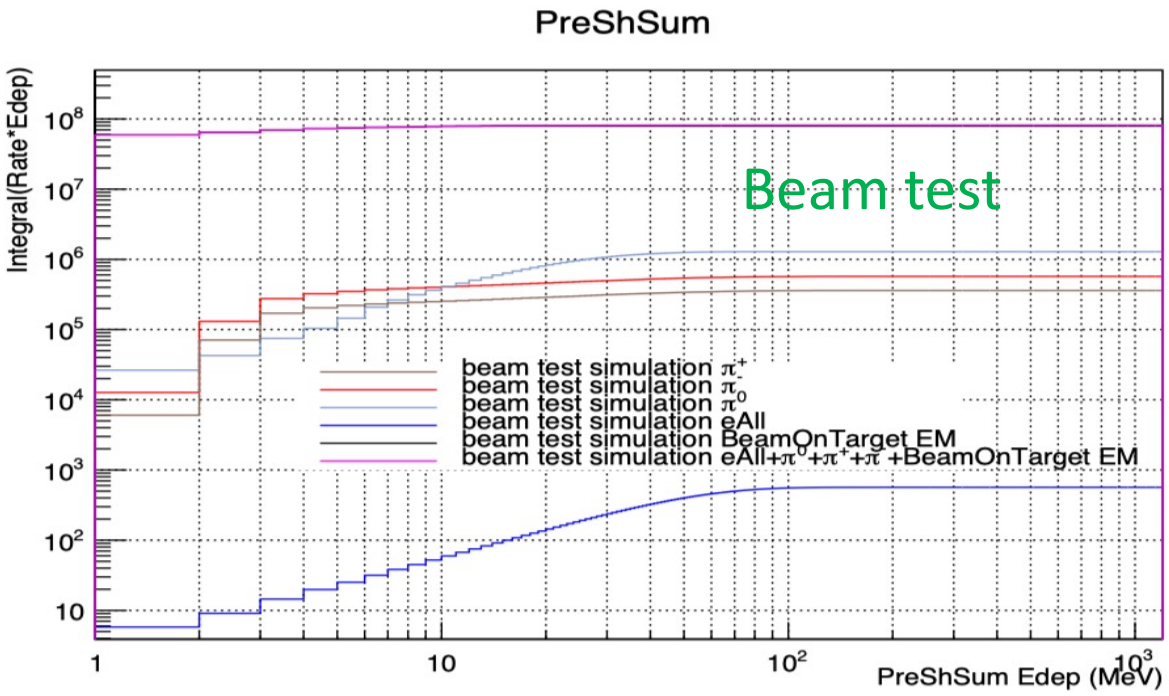


- The Pb shielding block beside Ecal reduces the gamma background in the center region of ECal
- Requiring the coincidence with SC_D should clean up the MIP region in the data.

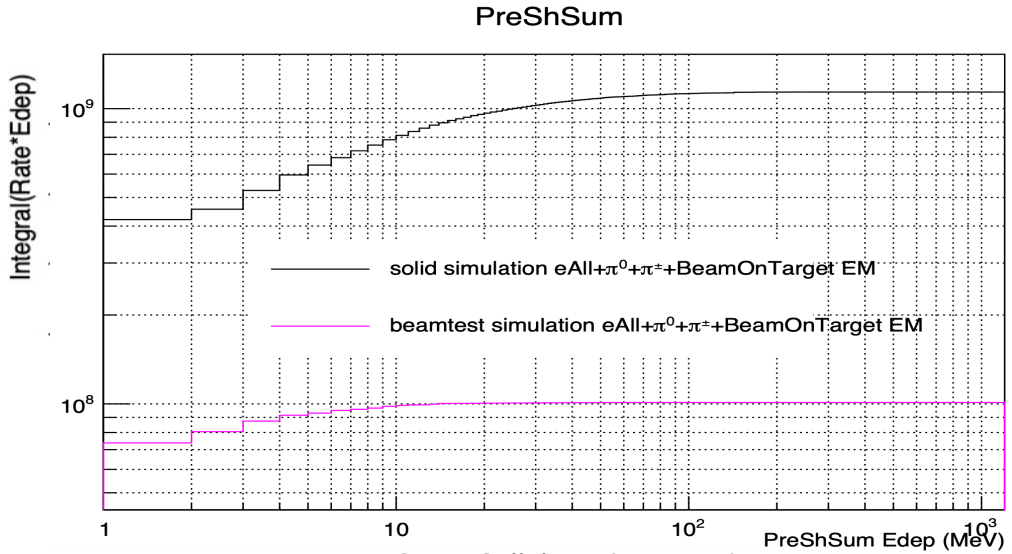
- EM background with pb shielding blocks

Radiation Dose for Preshowers Based on the Simulation





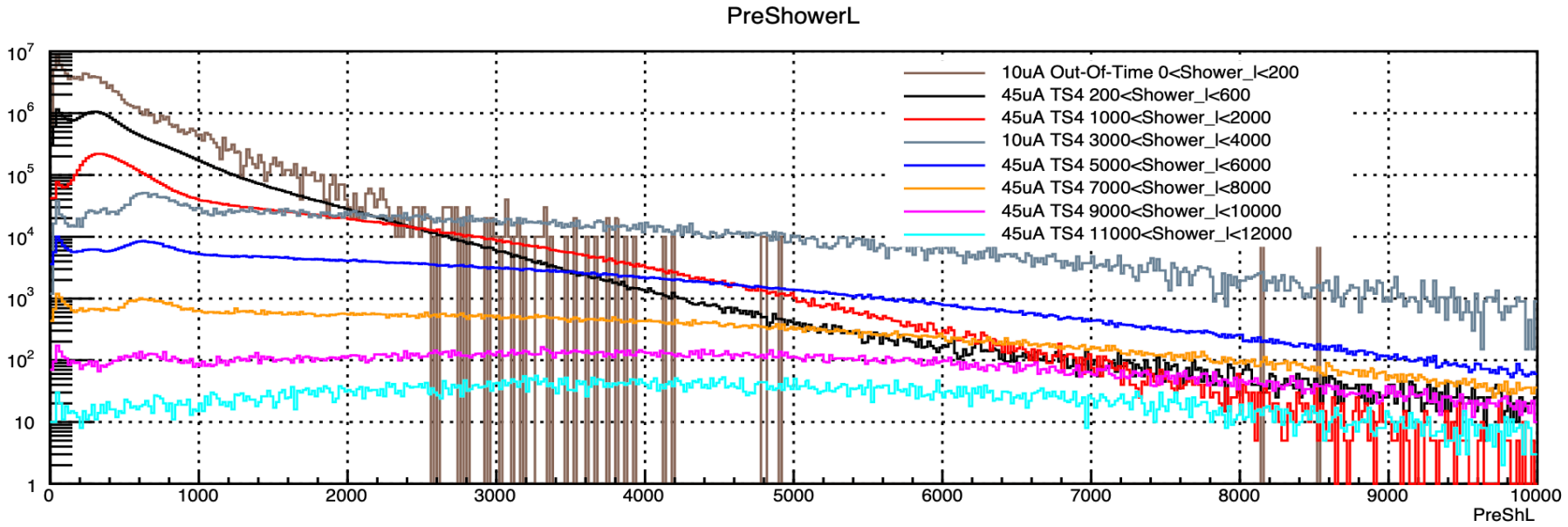
SoLID PVDIS/Beam test
Radiation dose ratio ~ 4

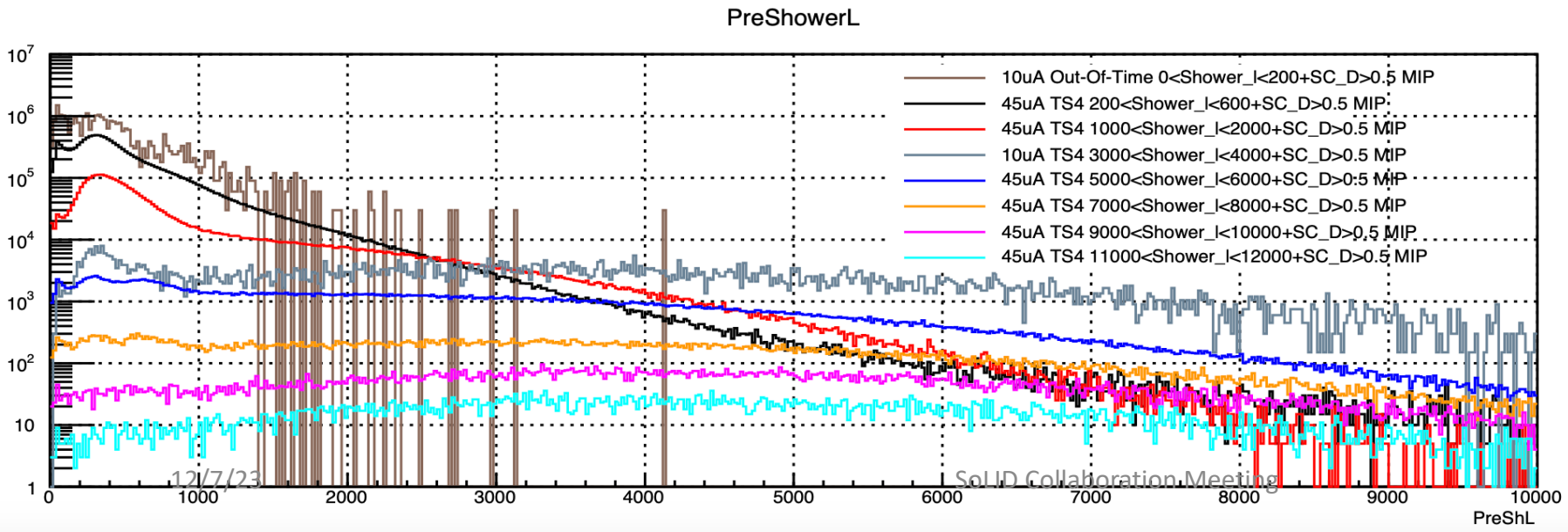


Radiation dose beam test:
1.01e8MeV/s*(30*24*60*60)s/(3*101.3*2cm^3*1g/cm^3)=4.37e+14MeV/kg=69 J/kg
=6.9 krad at preshower

24.6 krad at SC_A.

PreShower Data





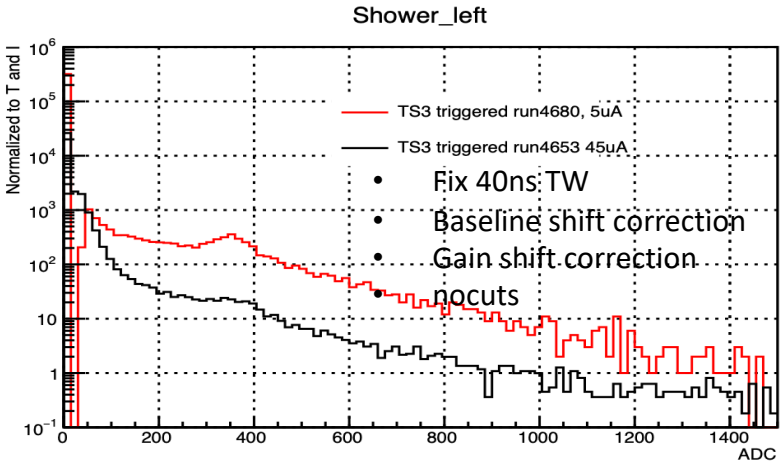
Preshower: See distinct regions:

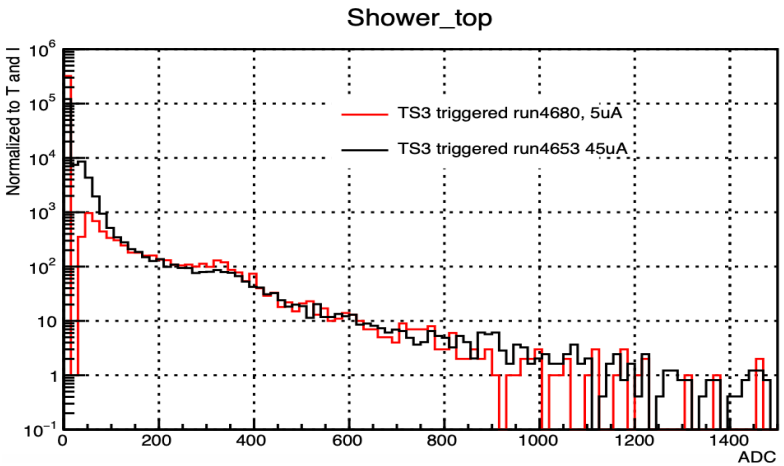
a. Lowest: fat distribution from Mollers?

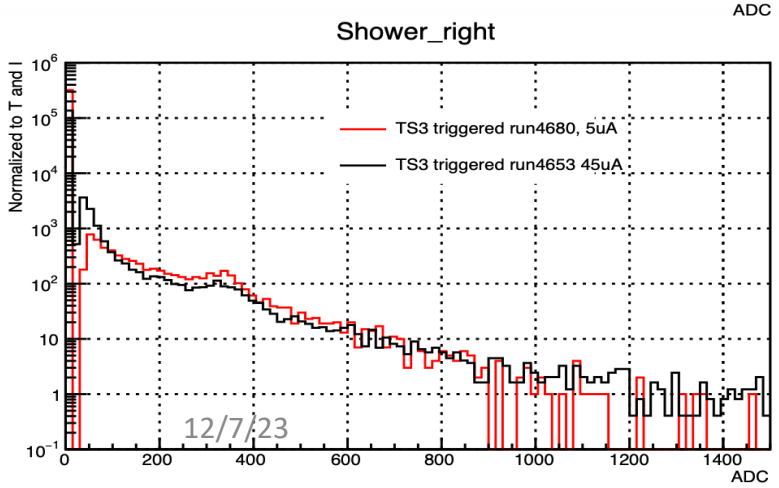
b. Next: See MIP's from pions and double MIP's from photons: SC_D rejectd double MIP's

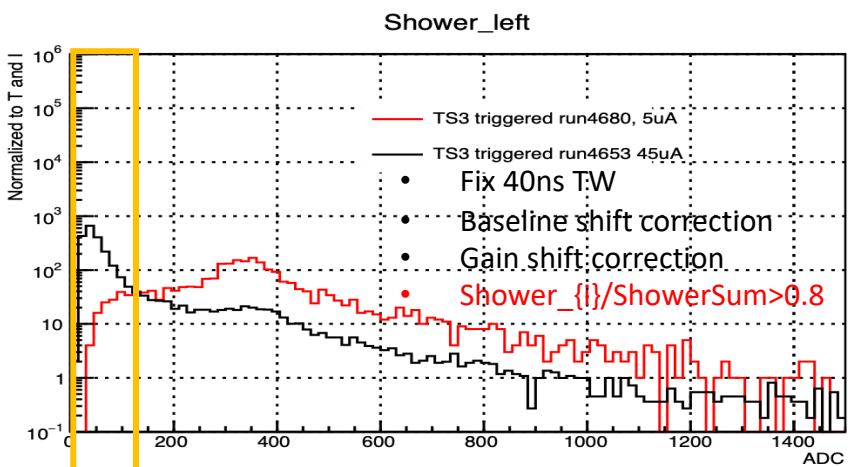
c. Next: Negligible pion MIP's

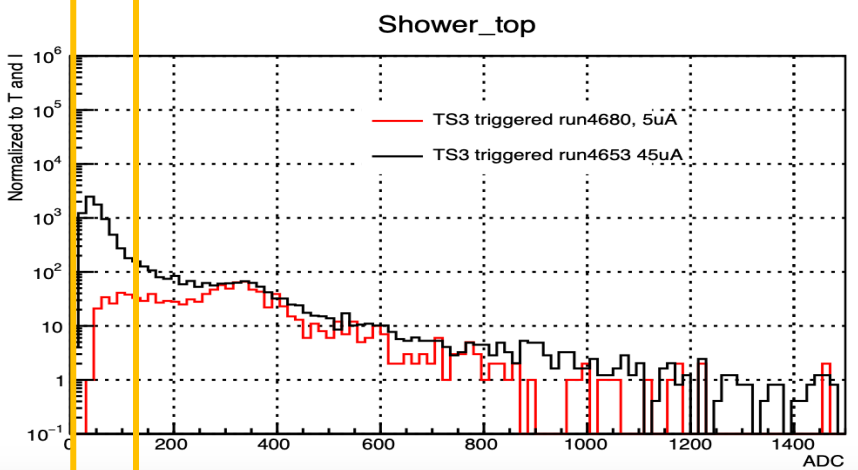
d. Highest energies: Most pulses >>MIP's

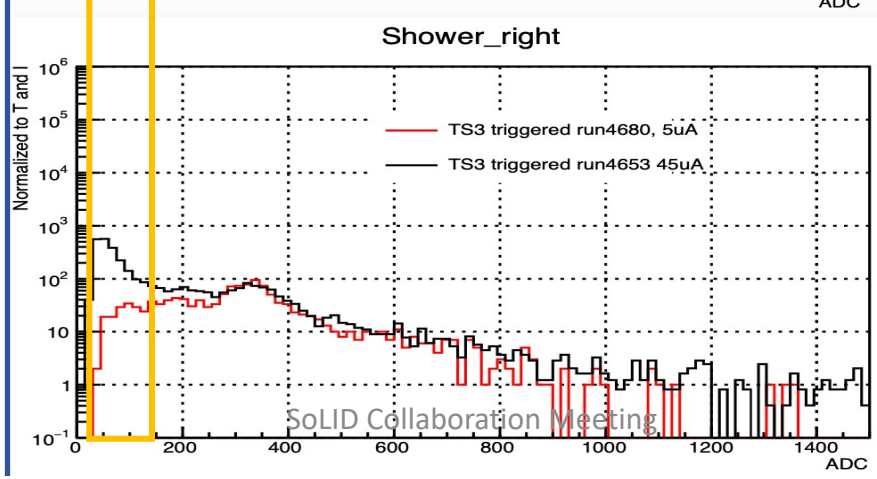

Shower_left
Normalized to T and I
TS3 triggered run4680, 5uA
TS3 triggered run4653 45uA
• Fix 40ns TW
• Baseline shift correction
• Gain shift correction
• nocuts
ADC

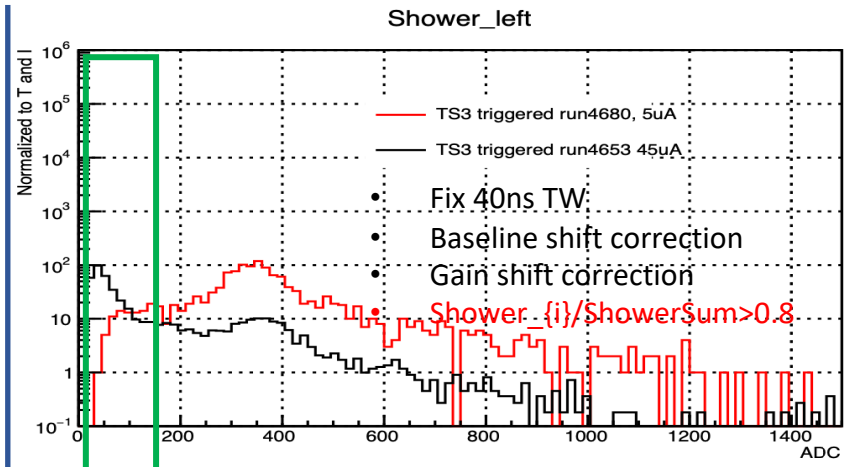

Shower_top
Normalized to T and I
TS3 triggered run4680, 5uA
TS3 triggered run4653 45uA
ADC

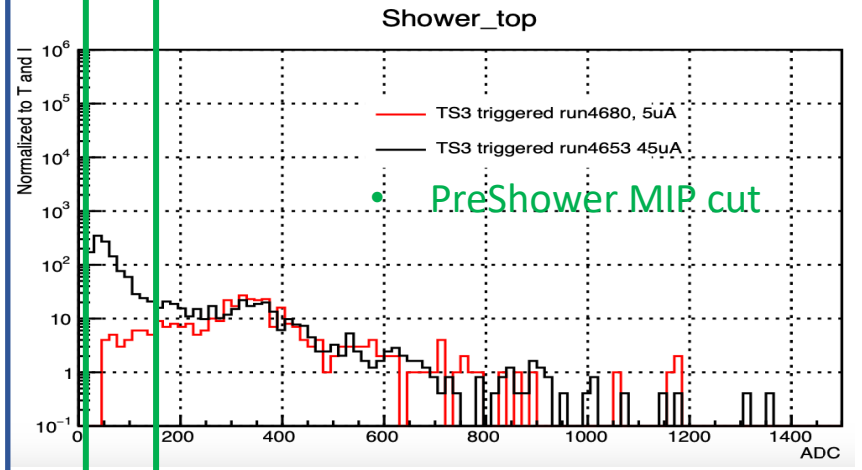

Shower_right
Normalized to T and I
TS3 triggered run4680, 5uA
TS3 triggered run4653 45uA
ADC

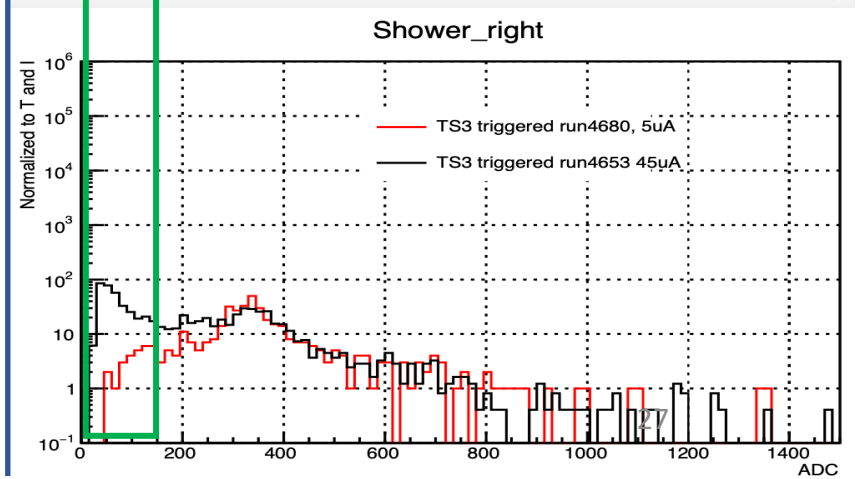

Shower_left
Normalized to T and I
TS3 triggered run4680, 5uA
TS3 triggered run4653 45uA
• Fix 40ns TW
• Baseline shift correction
• Gain shift correction
• Shower_{i}/ShowerSum>0.8
ADC


Shower_top
Normalized to T and I
TS3 triggered run4680, 5uA
TS3 triggered run4653 45uA
ADC

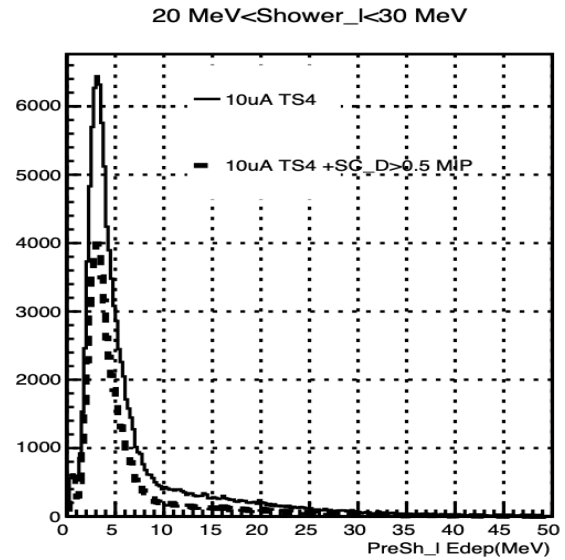

Shower_right
Normalized to T and I
TS3 triggered run4680, 5uA
TS3 triggered run4653 45uA
ADC

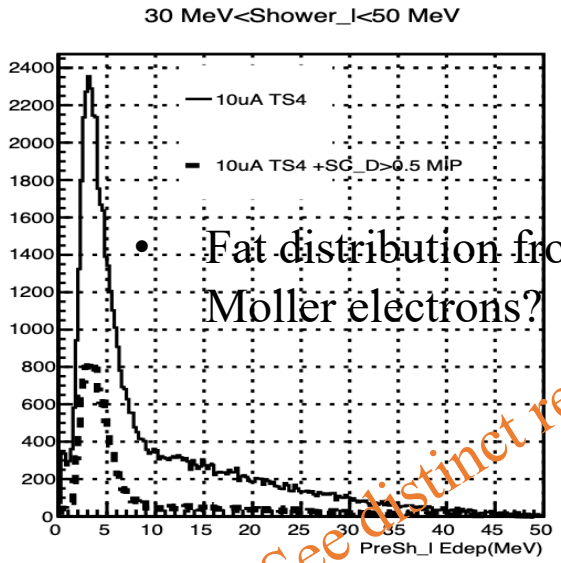

Shower_left
Normalized to T and I
TS3 triggered run4680, 5uA
TS3 triggered run4653 45uA
• Fix 40ns TW
• Baseline shift correction
• Gain shift correction
• Shower_{i}/ShowerSum>0.8
ADC

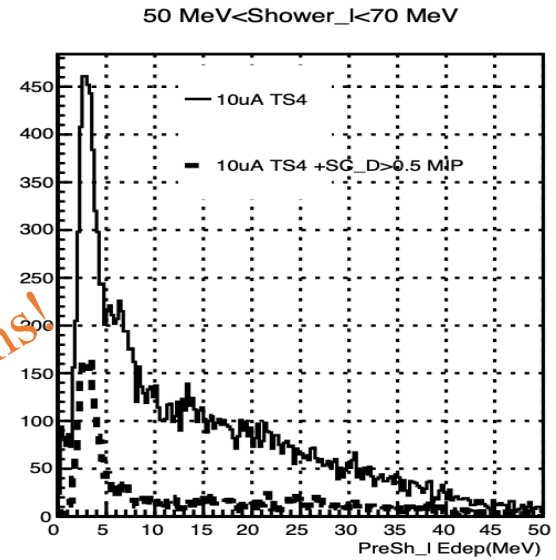

Shower_top
Normalized to T and I
TS3 triggered run4680, 5uA
TS3 triggered run4653 45uA
• PreShower MIP cut
ADC

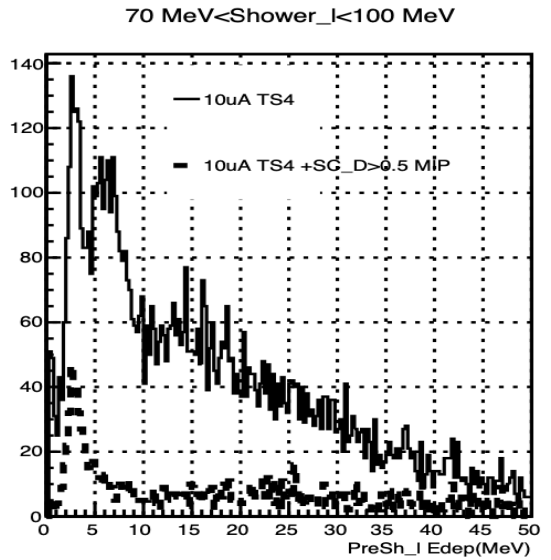

Shower_right
Normalized to T and I
TS3 triggered run4680, 5uA
TS3 triggered run4653 45uA
ADC

PreShower Response





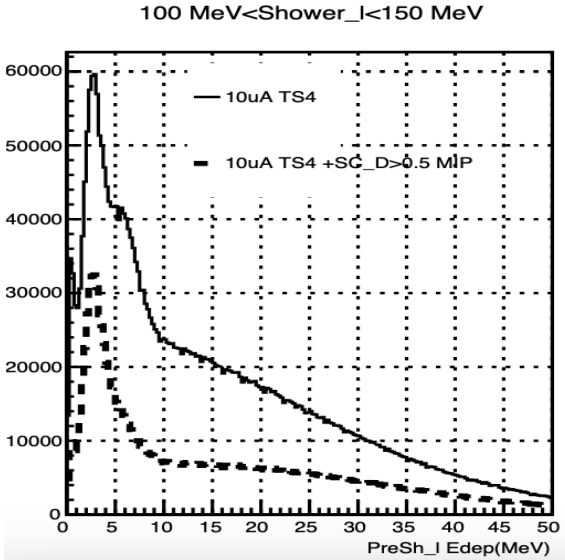




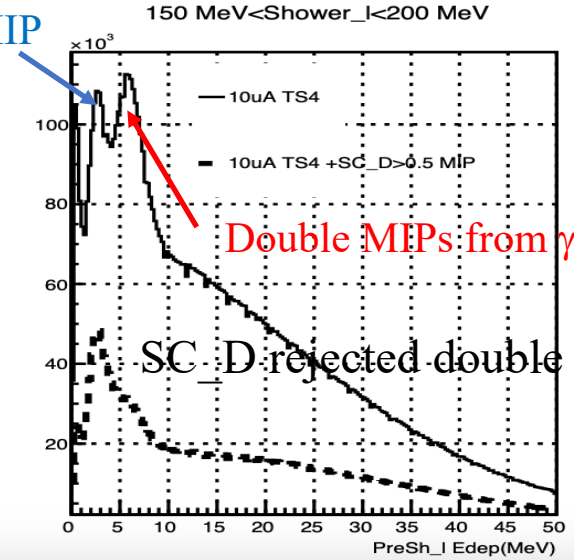
- Fat distribution from Moller electrons?

See distinct regions!

Acceptance ratio: SC_D/Shower_Sum=1/3

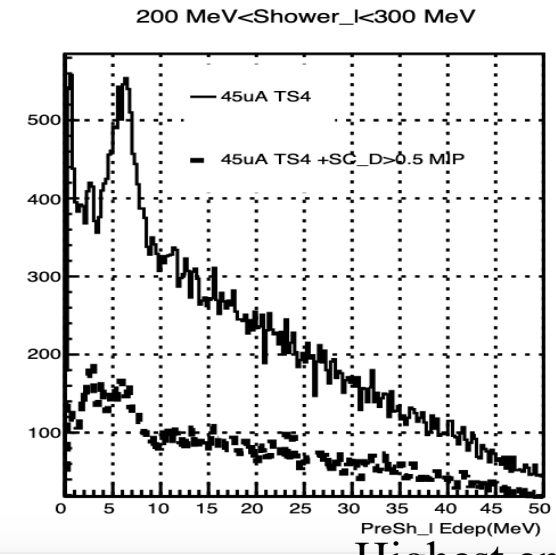


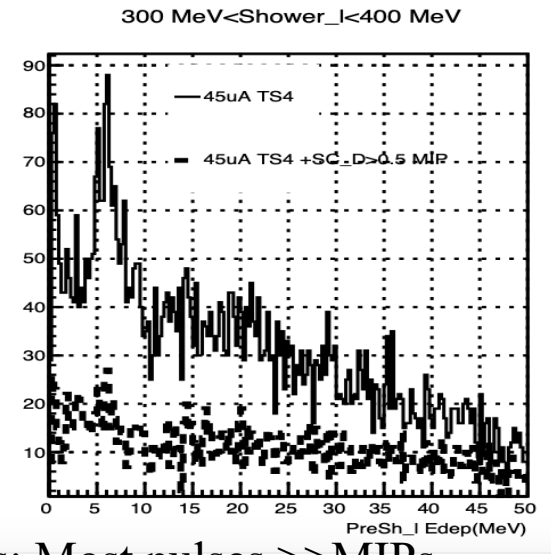
π MIP



Double MIPs from γ

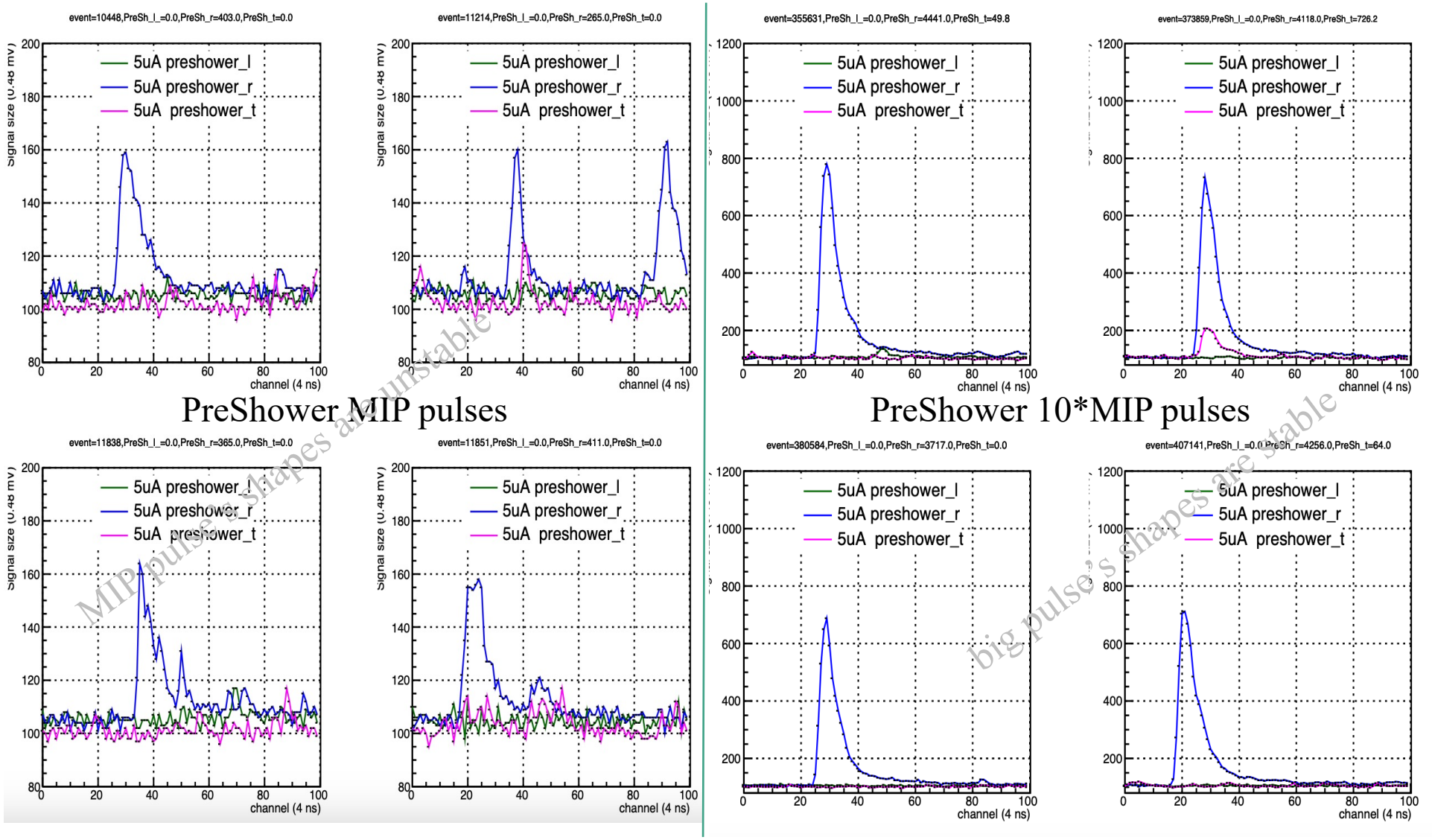
SC_D rejected double MIP





Highest energies: Most pulses >>MIPs

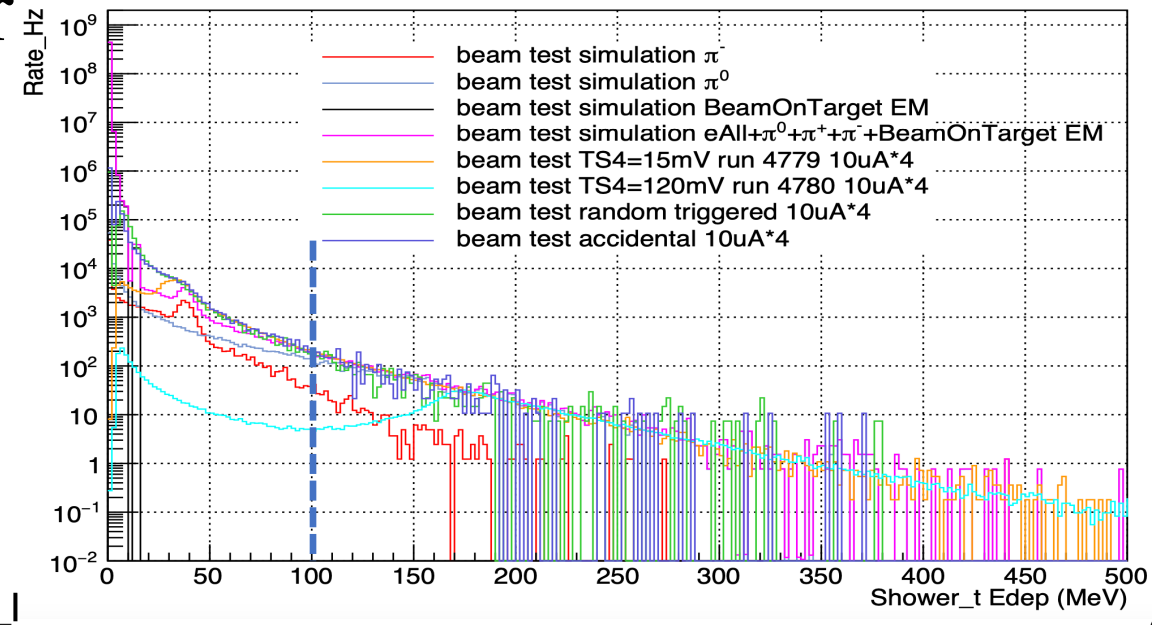
18 Deg Data Analysis is Ongoing



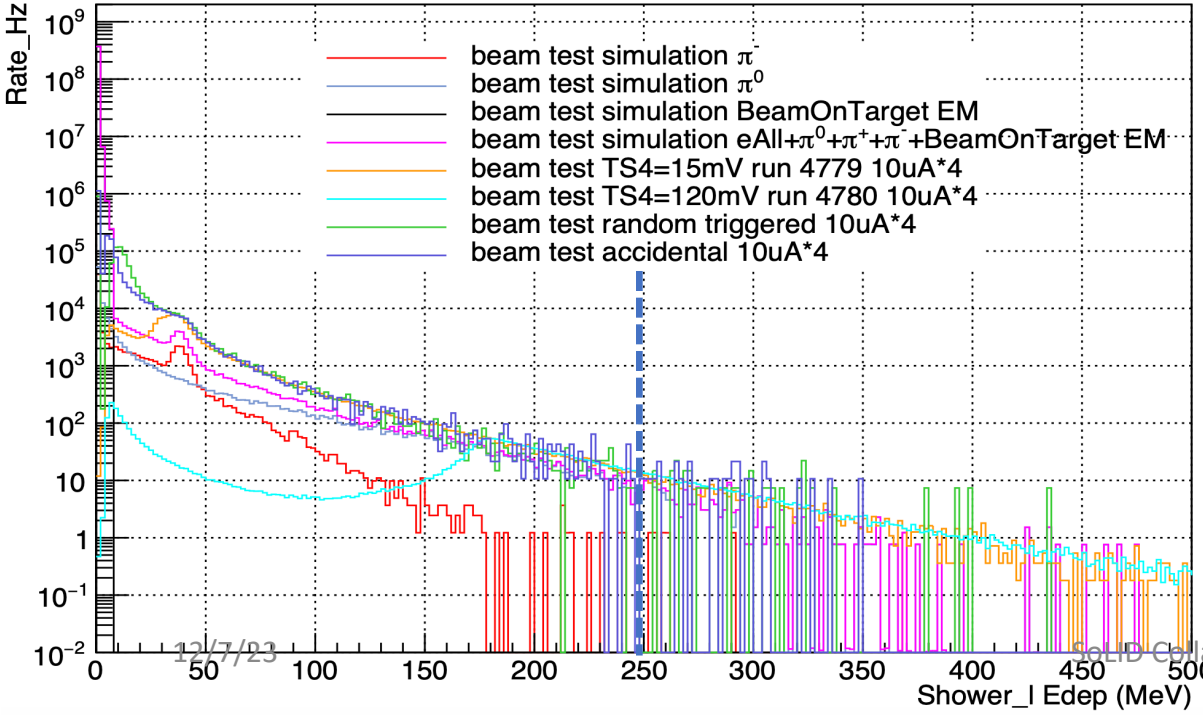
- Analog signals are digitized by the JLab FADC250, a 16-channel 12-bit FADC sampling at 250 MHz.
- We plan to record the entire waveform for PVDIS (pile up is going to be significant)
- 40ns integral window

Individual Shower Comparison

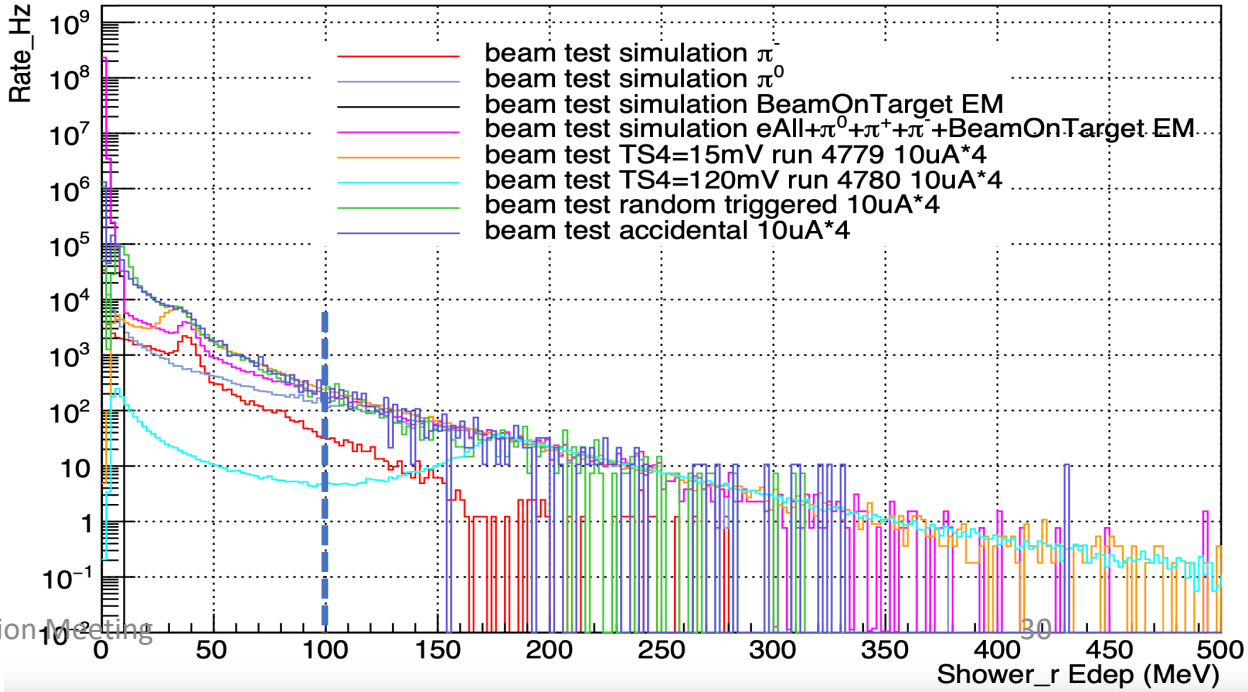
Shower_t



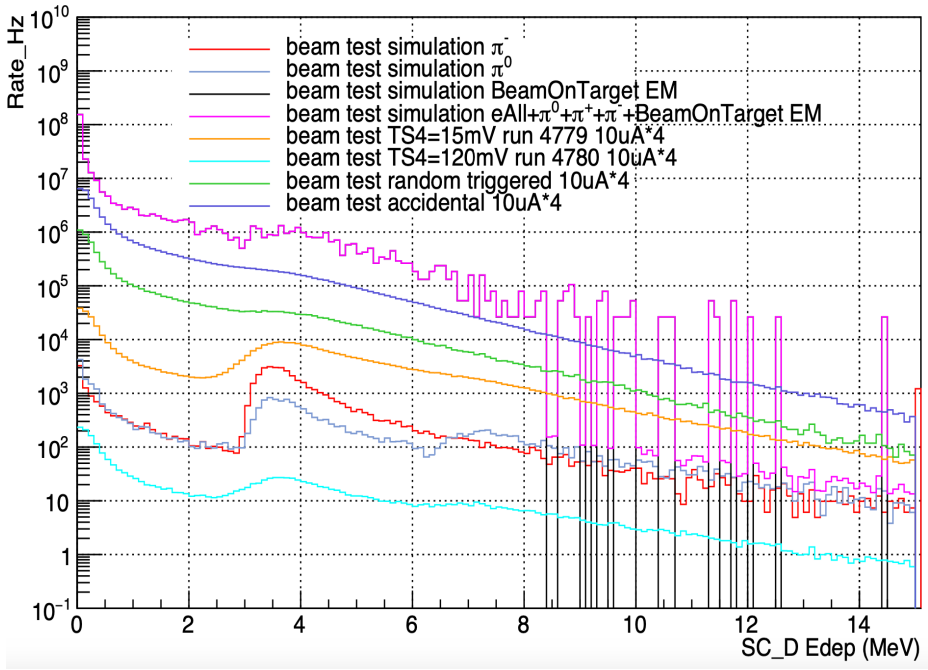
Shower_l



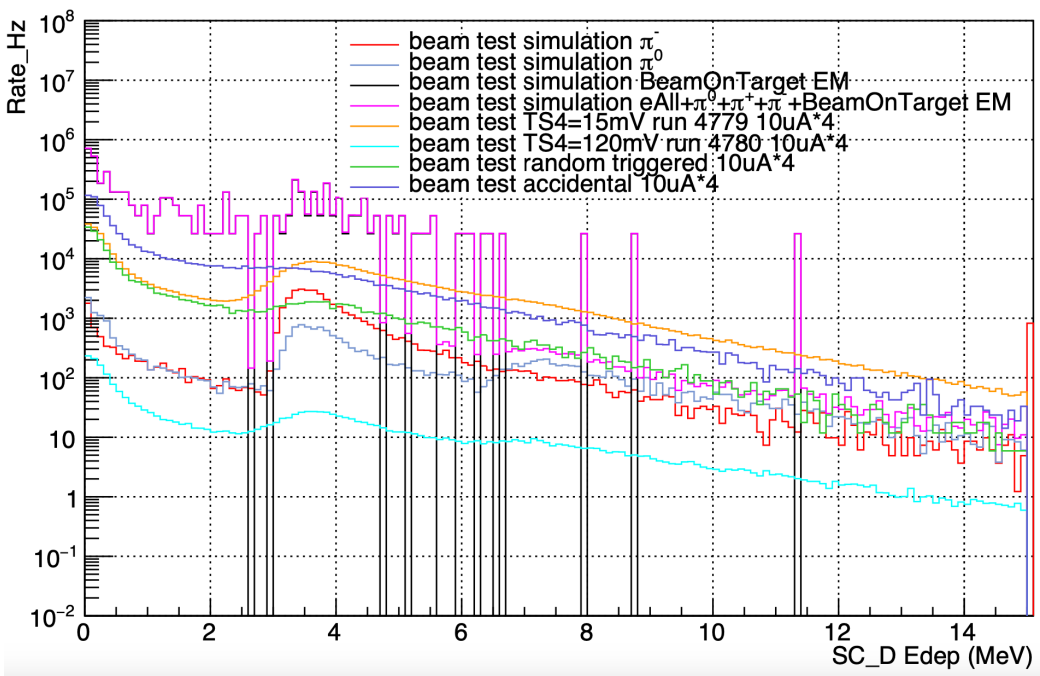
Shower_r



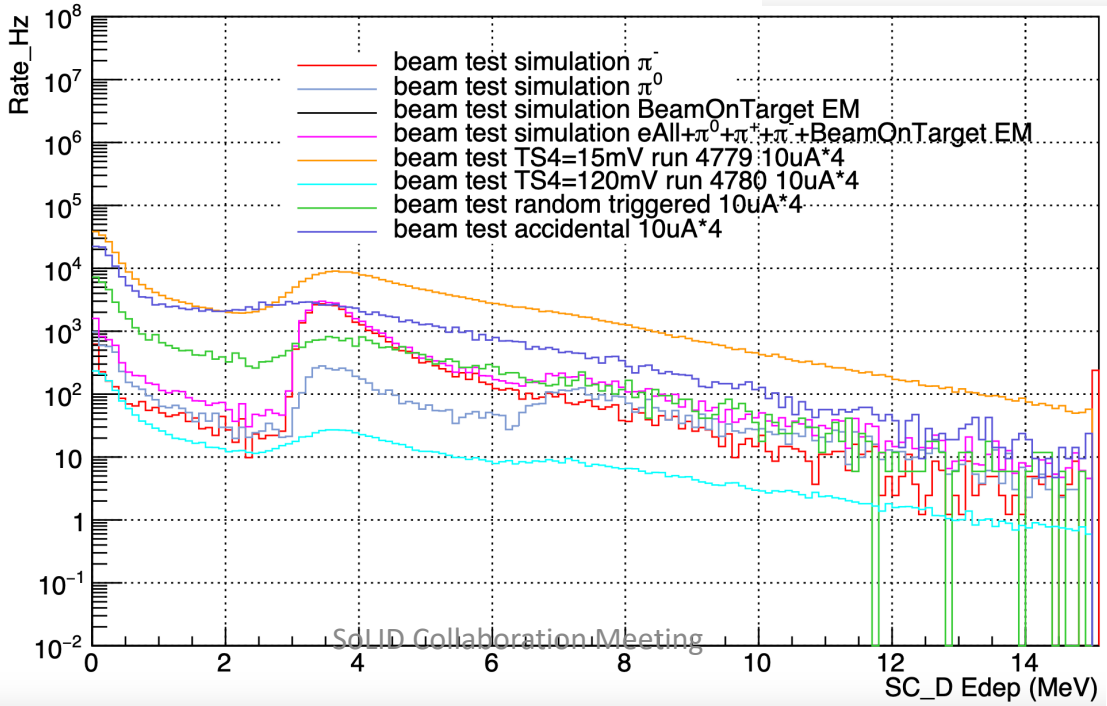
SC_D



SC_D>0 && ShowerSum_software>0



SC_D>0 && ShowerSum_software>0.5MIP



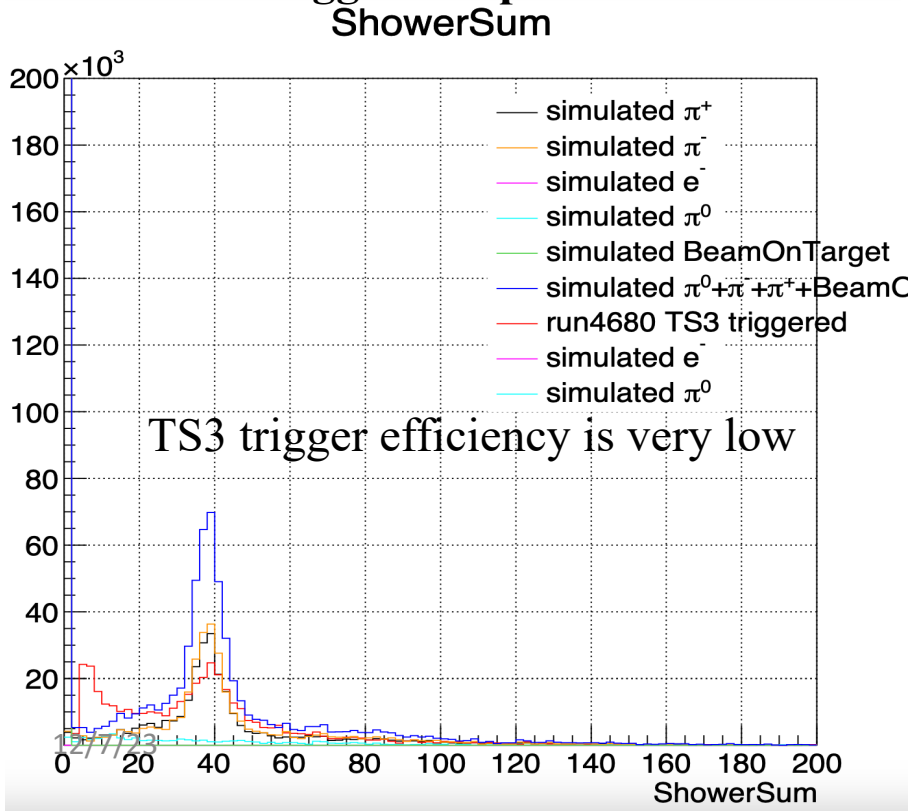
Need to check the waveforms

Simulation and Data comparison

- MIP comparison
- Coincident trigger: 5uA TS3 trigger (SC_A>0.5MIP & SC_D>0.5MIP)
- Single trigger: 10uA TS4= 15mV trigger (ShowrSum>0.5MIP)
- Random trigger: 10uA TS=253, run 4779_0, and 40uA TS=253, run 4794_0

  A table to summarize the rate of individual detector with threshold> 0.5 MIP

Coincident trigger comparison



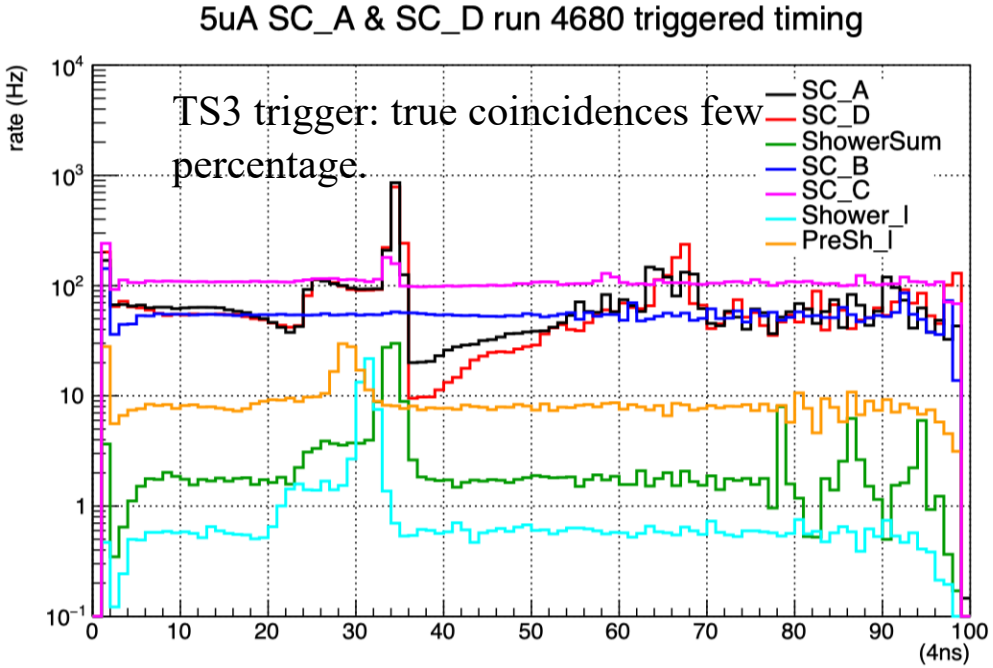
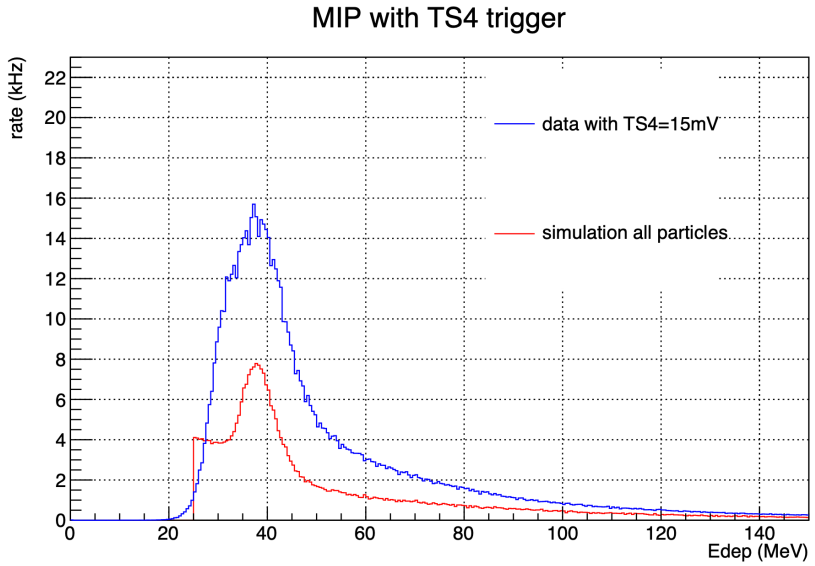


Figure 10: Timing information of run 4680 with the SC_A & SC_D trigger at 5μA. Here Y axis is normalized to $\frac{event}{\Delta T}$ (rate)

Single trigger: ShowerSum> 0.5 MIP



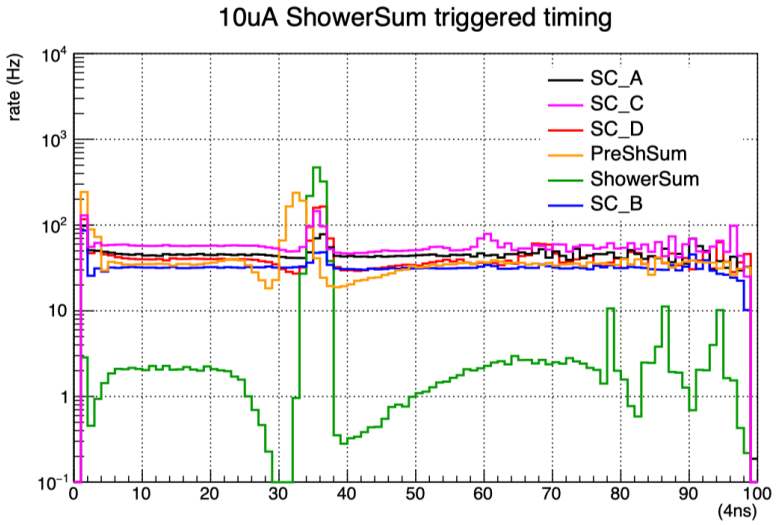
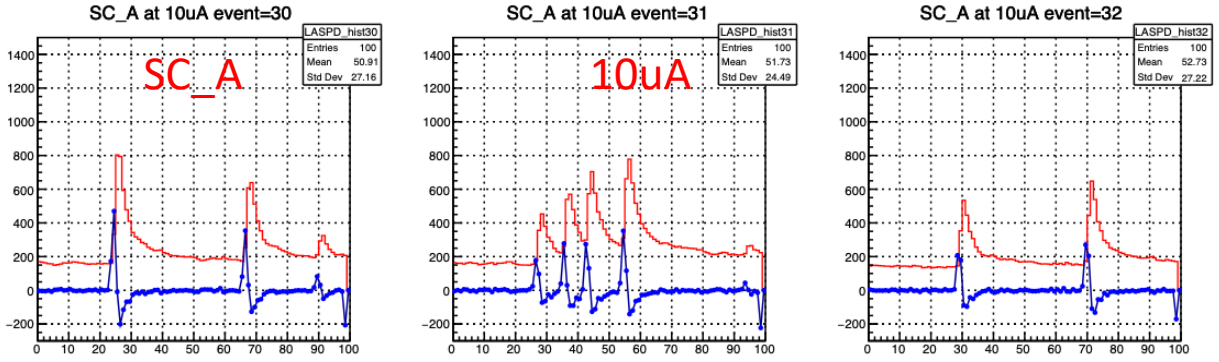
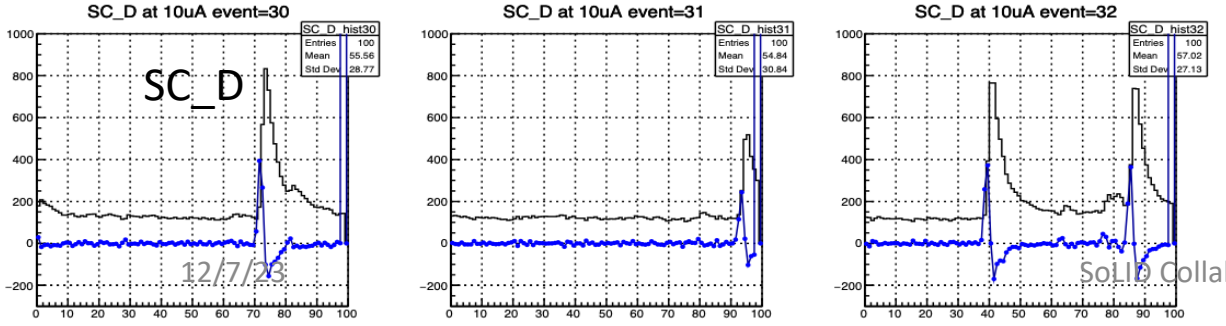
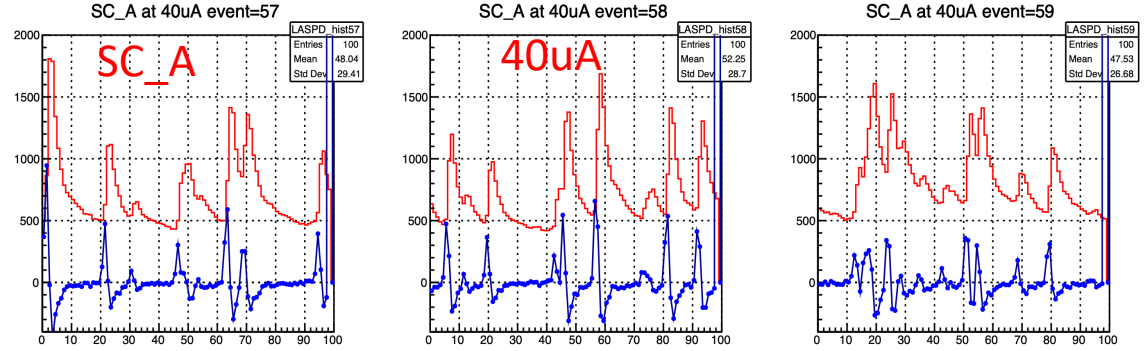


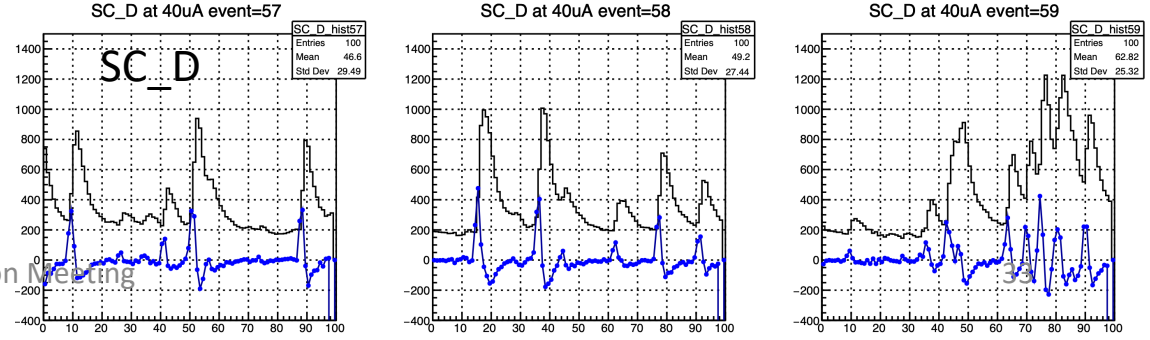
Figure 15: Timing information of run 4779 with the ShowerSum= 15 mV trigger at 10μA. Here Y axis is normalized to $\frac{event}{\Delta T}$ (rate)

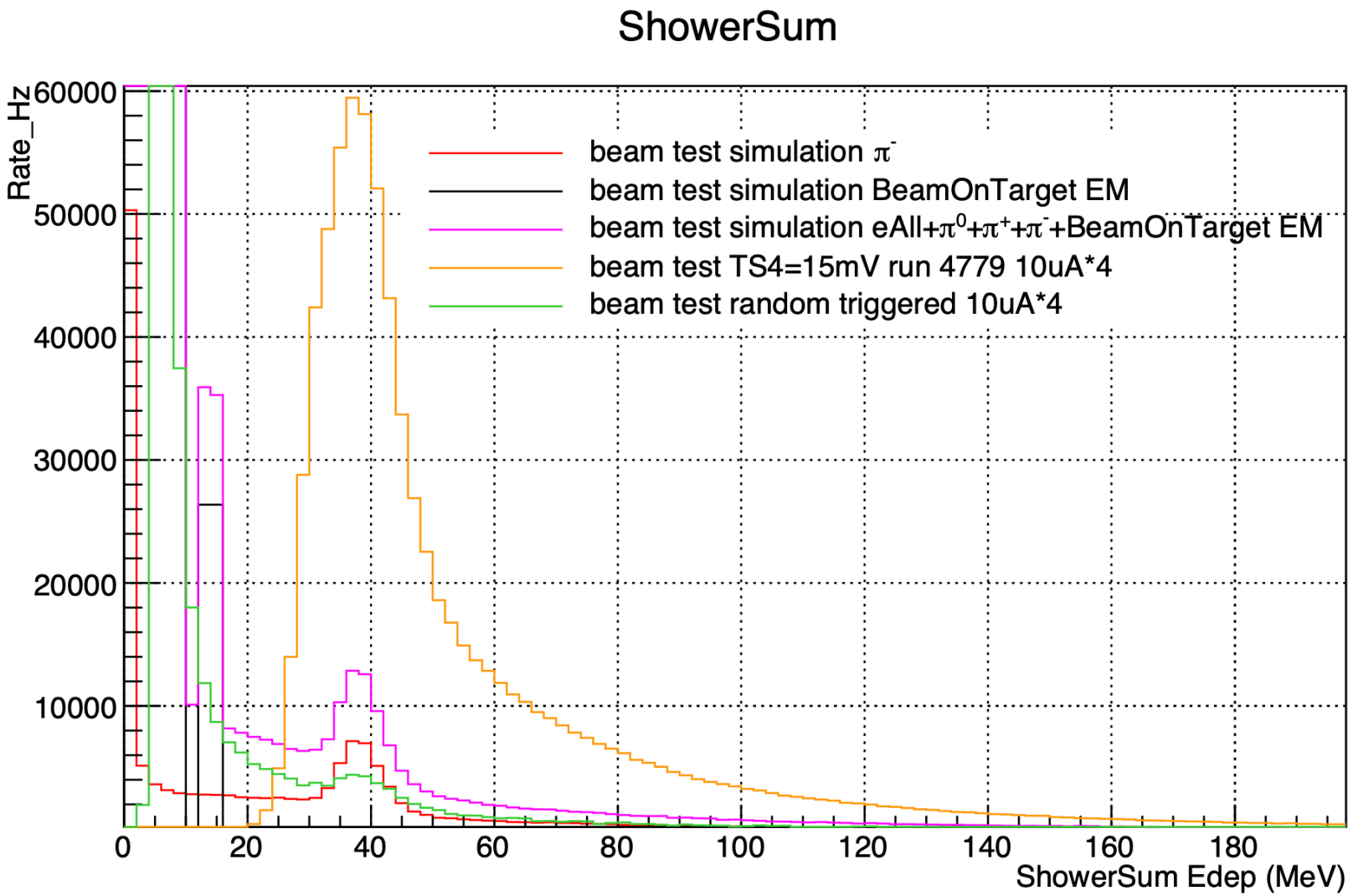
Random trigger: single rate and coincidence rate











A table for individual detector rate with 0.5 MIP threshold

Detector	10μA 0.5MIP cut MHz	40μA 0.5MIP cut MHz
SC_A	4.91	15.9
SC_D	1.87	7.52

Detector	e^- kHz/cm2	π^- kHz/cm2	π^+ kHz/cm2	π^0 kHz/cm2	EM kHz/cm2	total MHz/cm2	scale data MHz/cm2
SC_A	1.9e-4	0.69	0.67	0.19	985.0	0.99	0.52
Cherenkov (Npe>0)	1.3e-4	5.3e-3	4.2e-3	0.12	16.4	0.0165	
SC_D	3.2e-4	0.77	0.77	0.45	377.4	0.38	0.074

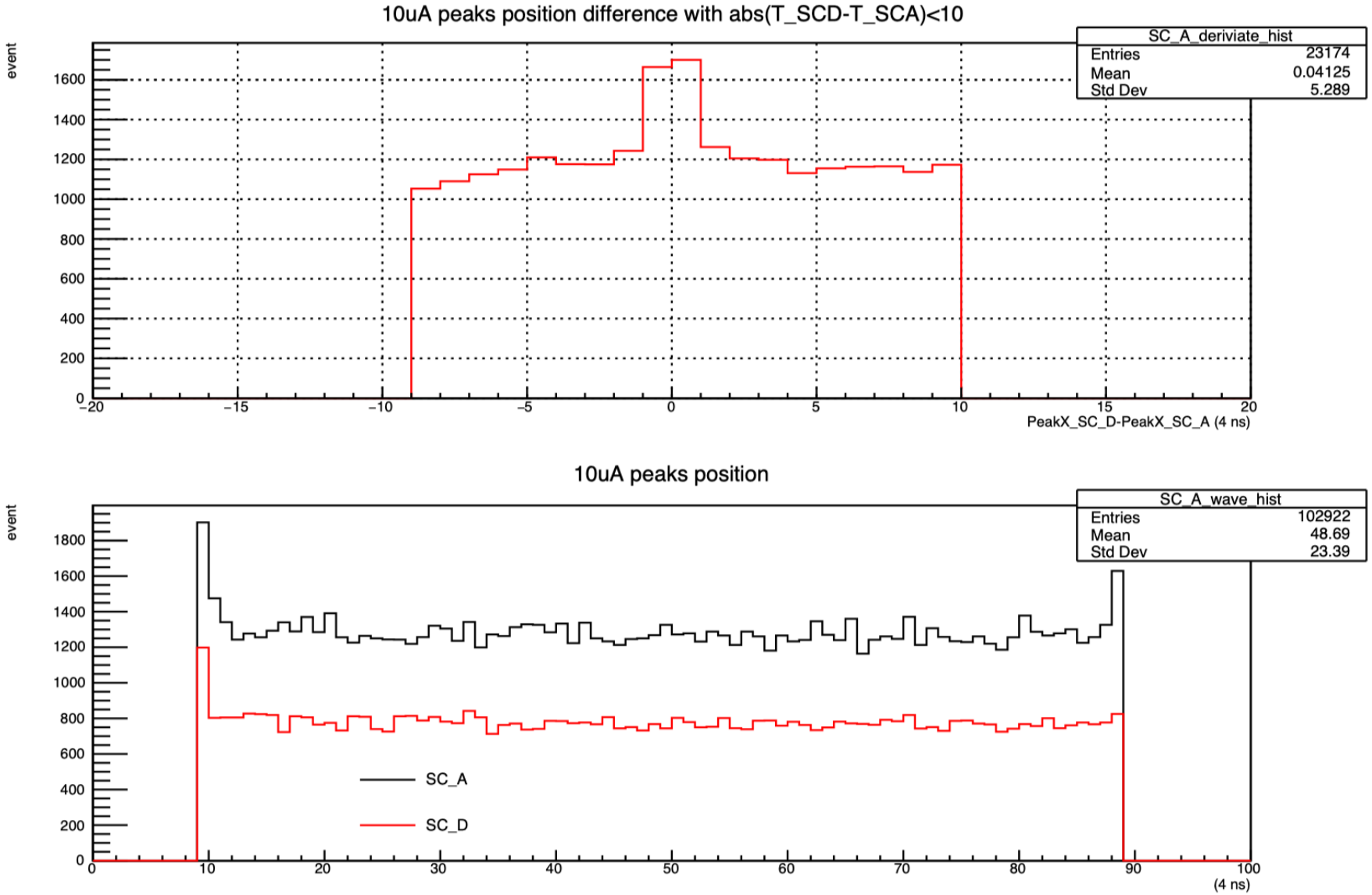


Figure 23: Timing information of run 4779 with the random trigger at 10μA. The total number of the random trigger event is 100k