

SiPM Pulse Study 3

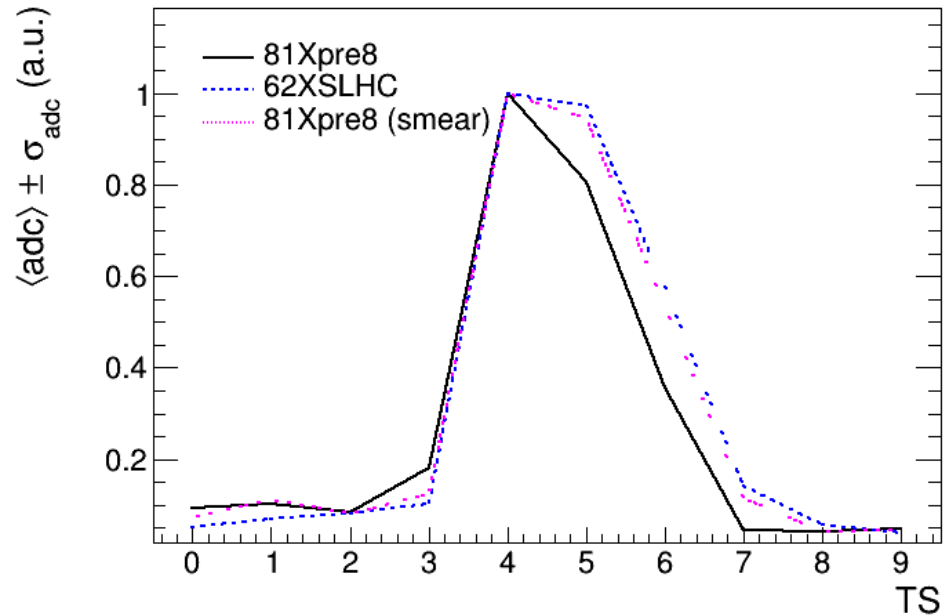
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(FNAL)

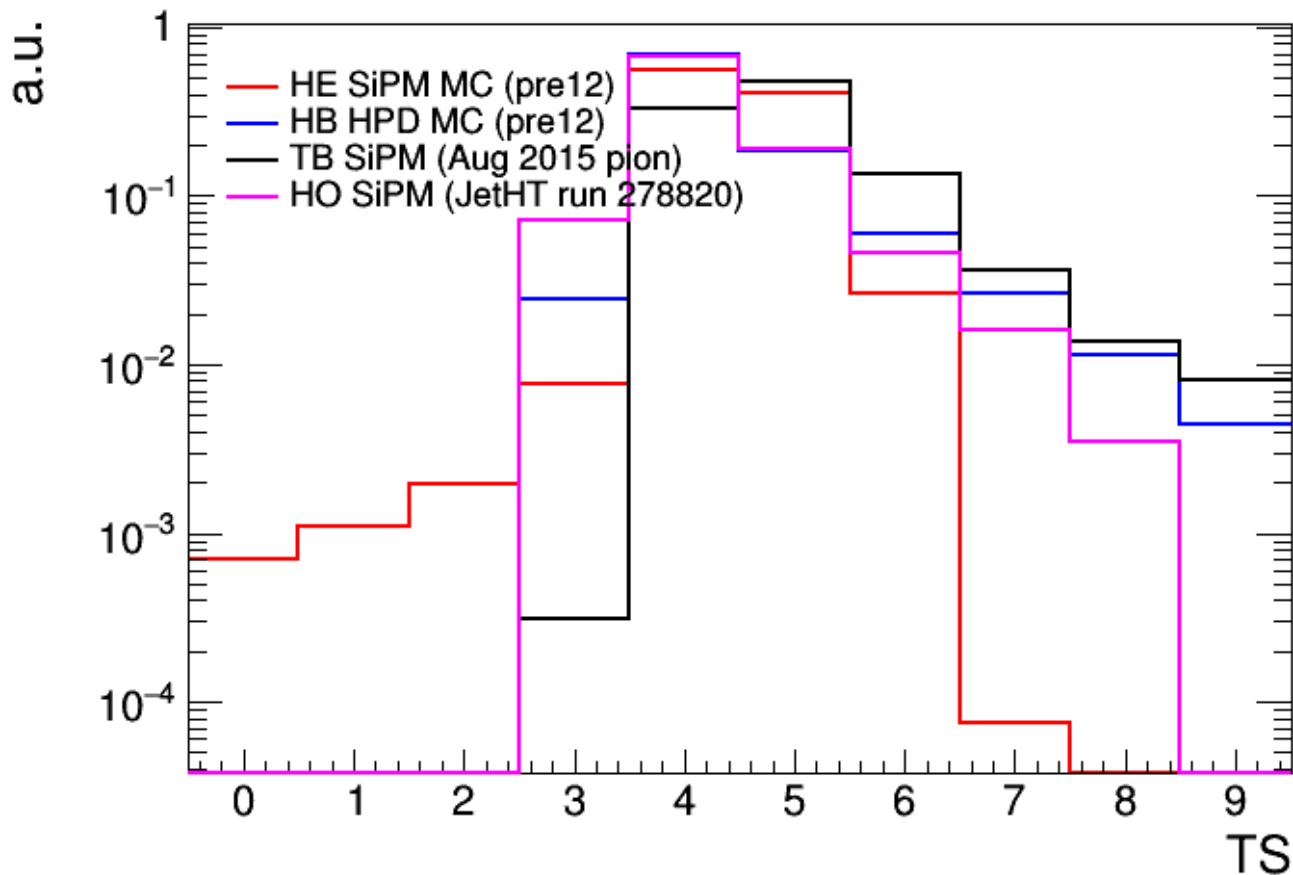
October 11, 2016

Previously...

- [sipm_pulse_shape_reco_MC.pdf](#)
- [sipm_pulse_study.pdf](#)
- [sipm_pulse_study_2.pdf](#)
- [#15834](#): restore doSiPMSmearing parameter
- Slight improvement of output pulses from DIGI simulation
- However, notable discrepancies remain in both noPU and PU samples



Output Pulse Comparison



- Average pulses in fC (normalized to unit area, data is pedestal-subtracted)
- Moderate variations between HPD MC, SiPM testbeam, and SiPMs in HO
- However, SiPM MC is markedly different from all of them

Glossary

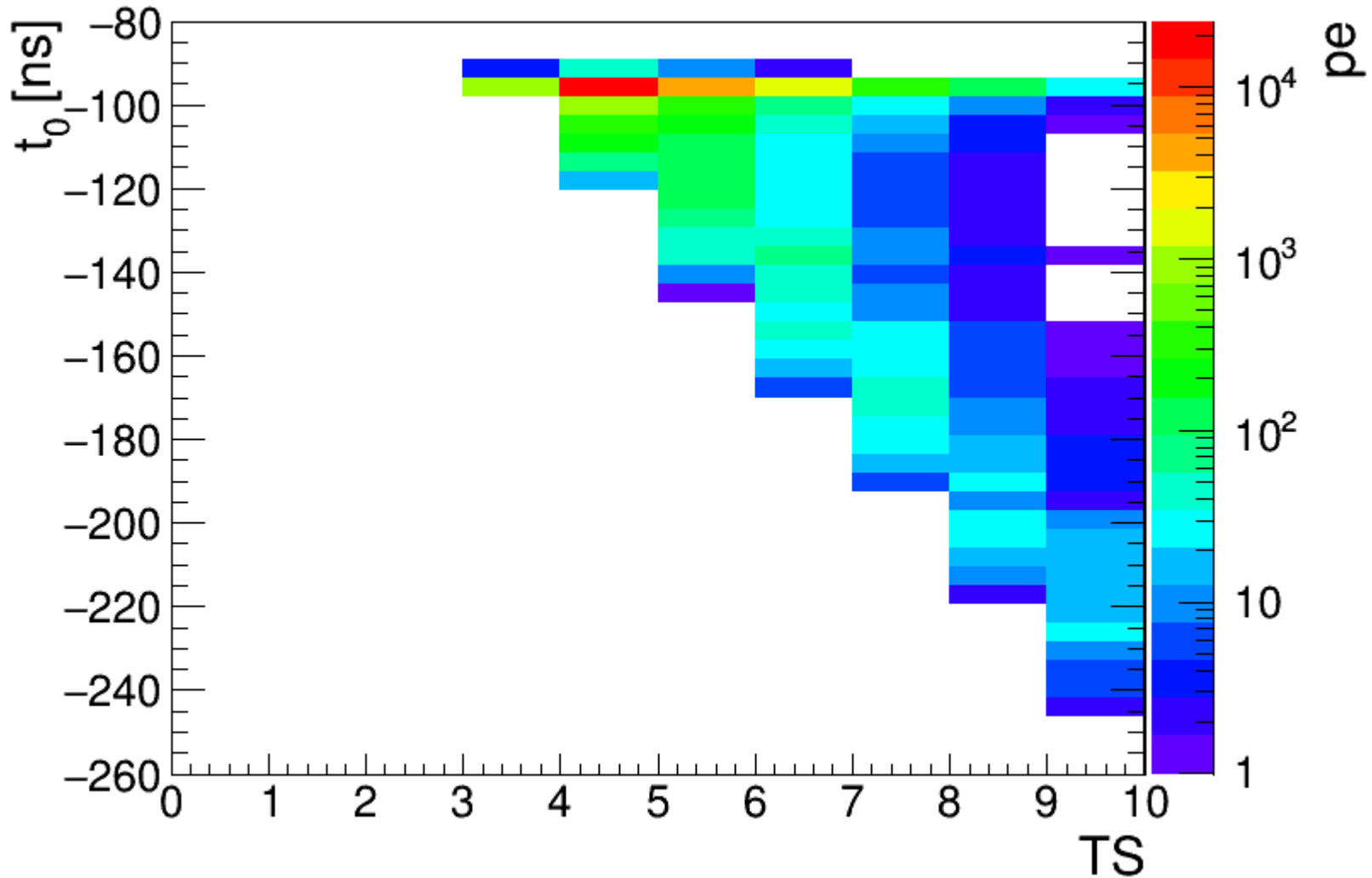
- n_{pe} = number of photoelectrons
- $\text{Pois}(x)$ = throw Poisson random number with mean x
- E_{sim} = SimHit energy
- f_{sam} = sampling factor
- $g_{GeV/fC}$ = gain [GeV/fC]
- $g_{fC/pe}$ = photoelectronsToAnalog [fC/pe]
- t_{rise} = rise time of pulse shape [ns]
- t_{phase} = pars.timePhase [ns]
- t_{sim} = SimHit time [ns]
- t_{flight} = time of flight for cell [ns]
- t_{bunch} = bunch spacing [ns]
- b_{max} = pars.binOfMaximum
- b_{shift} = CaloHitResponse::thePhaseShift_
- $pulse[]$ = CaloSample array of pe vs. TS
- $\text{Shape}(t)$ = evaluate pulse shape function for time t [ns]
- $Y11()$ = throw random number according to Y11 pulse distribution [ns]
- $photons[]$ = array of pe vs. precise time bin (used internally for SiPM sim)

HPD Output Pulse MC

- Input: SimHits, HPD pulse shape (convolution of HPD, Y11)
 - $n_{pe} = \text{Pois}(E_{sim} \cdot f_{sam} / g_{GeV/fC} / g_{fC/pe})$
 - $t_0 = t_{rise} + t_{phase} - (t_{sim} - t_{flight}) - t_{bunch} \cdot (b_{max} - b_{shift})$
 $= 0 + 6 - ([6:500] - [6:20]) - 25 \cdot (5 - 1)$
 - $t_{bin} = t_0$
for bin in 0..10:
if $t_{bin} \geq 0$: pulse[bin] = Shape(t_{bin}) · n_{pe}
 $t_{bin} += t_{bunch}$
- $t_0 + b_1 \cdot t_{bunch} \geq 0, b_1 \in \mathbb{Z}$
- $b_1 = \text{ceil}[-t_0/t_{bunch}] = \text{ceil}[(t_{sim} - t_{flight} - t_{rise} - t_{phase})/t_{bunch} + (b_{max} - b_{shift})]$
 $b_1 \sim t_{sim}$

HPD: t_0 vs Output Pulse

- Correct proportionality is observed

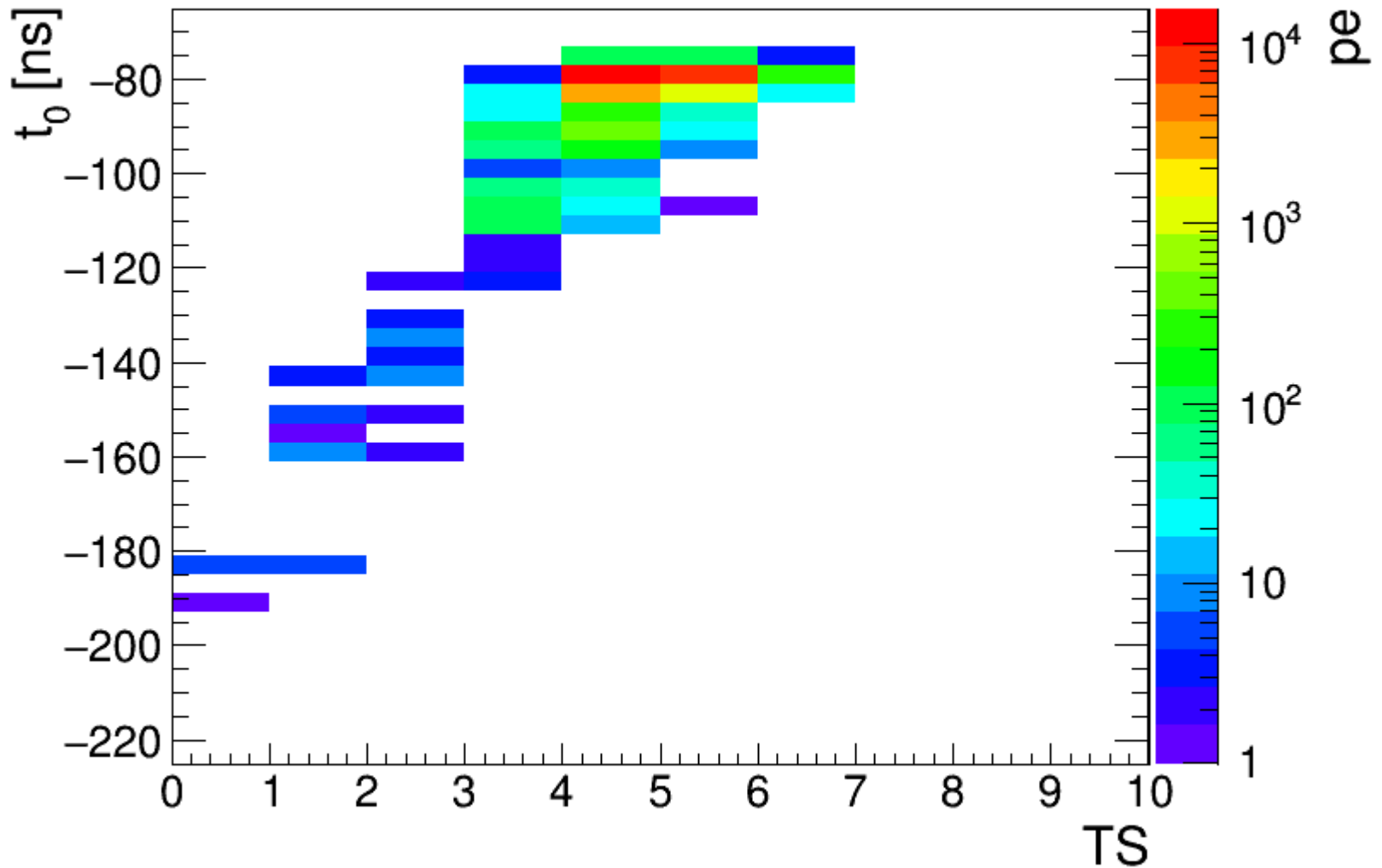


SiPM Output Pulse MC

- Input: SimHits, SiPM pulse shape, Y11 pulse shape (separate)
 - $n_{pe} = \text{round}[\text{Pois}(E_{sim} \cdot f_{sam} / g_{GeV/fC} / g_{fC/pe})]$
 - $t_0 = t_{rise} + t_{phase} - (t_{sim} - t_{flight}) - t_{bunch} \cdot (b_{max} - b_{shift}) + t_{bunch} \cdot b_{max} + 50$
 $= t_{rise} + t_{phase} - (t_{sim} - t_{flight}) + t_{bunch} \cdot b_{shift} + 50$
 $= 16.65 + 6 - ([6:500] - [6:20]) + 25 + 50$
 - for p in 0..n_{pe}:
 $t_{bin} = \text{round}[(Y11() + t_0) / 0.5]$
 if $t_{bin} \geq 0$: photons[t_{bin}] += 1
 - for b in photons:
 evaluate SiPM pulse starting in precise bin b with magnitude photons[b]
- $t_{bin} \sim -t_{sim} !!!$

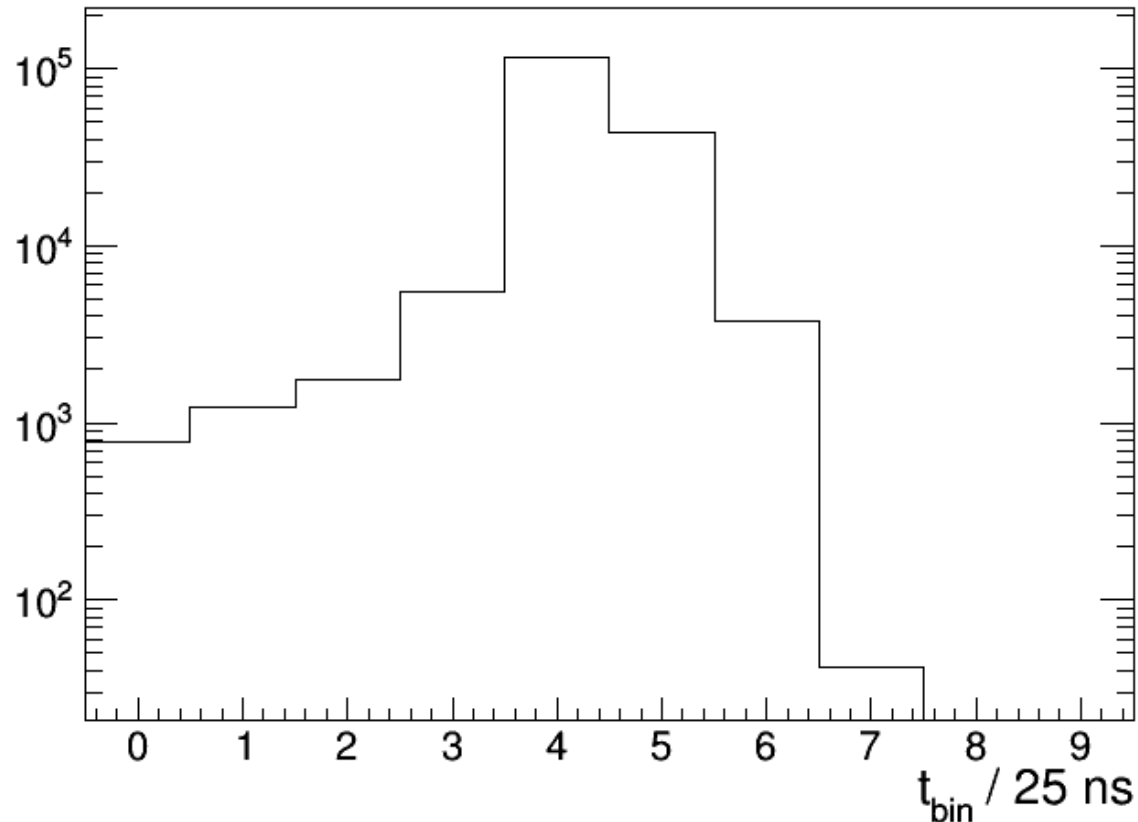
SiPM: t_0 vs Output Pulse

- Wrong proportionality is observed



SiPM: Another Suggestive Plot

- Just plot $t_{\text{bin}} \cdot 0.5/25$, recalling $t_{\text{bin}} = \text{round}[(Y11() + t_0)/0.5]$
- Compare to slide 3:
already a similar shape, without even evaluating SiPM pulse

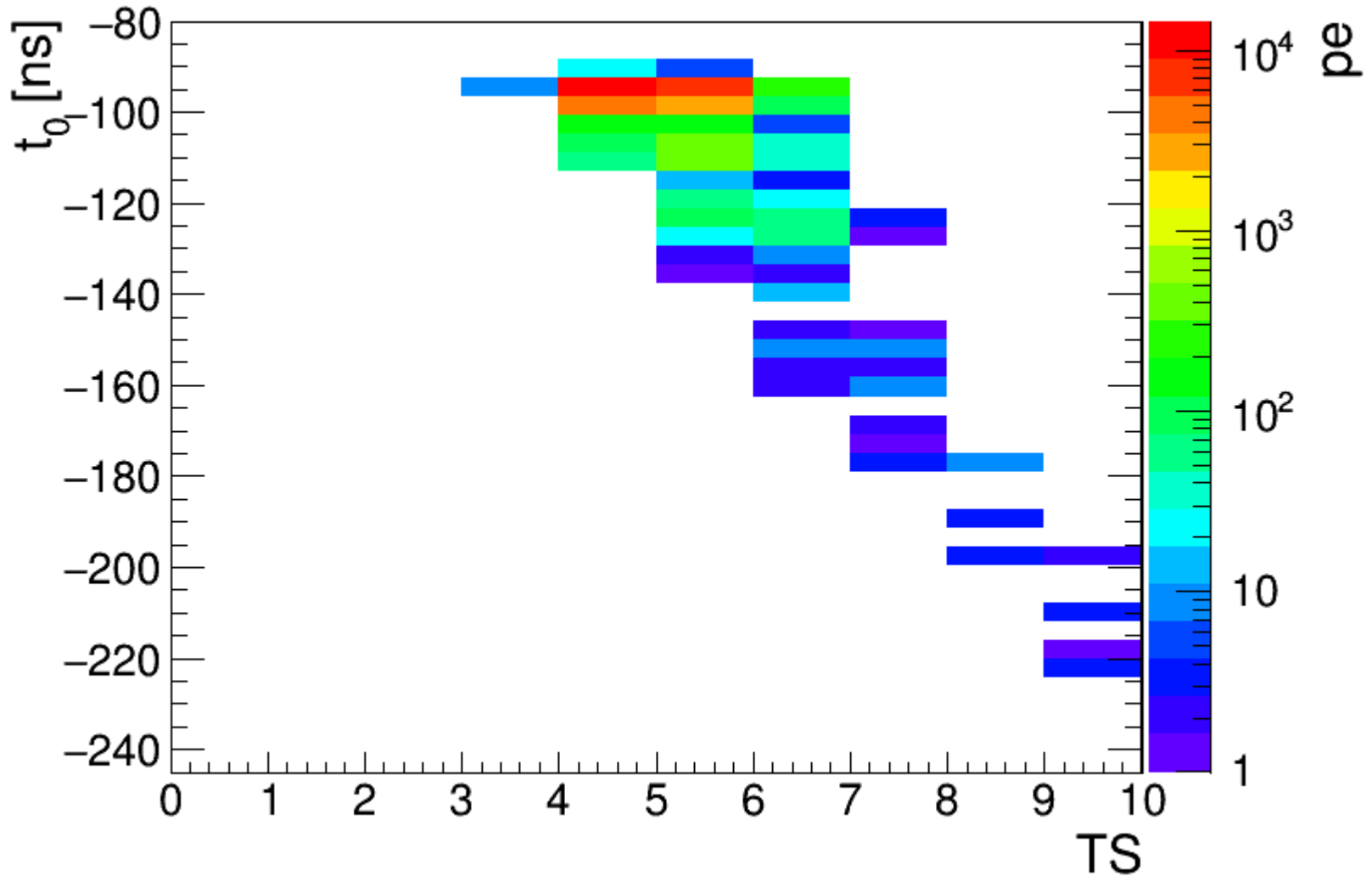


SiPM Output Pulse MC: Revision

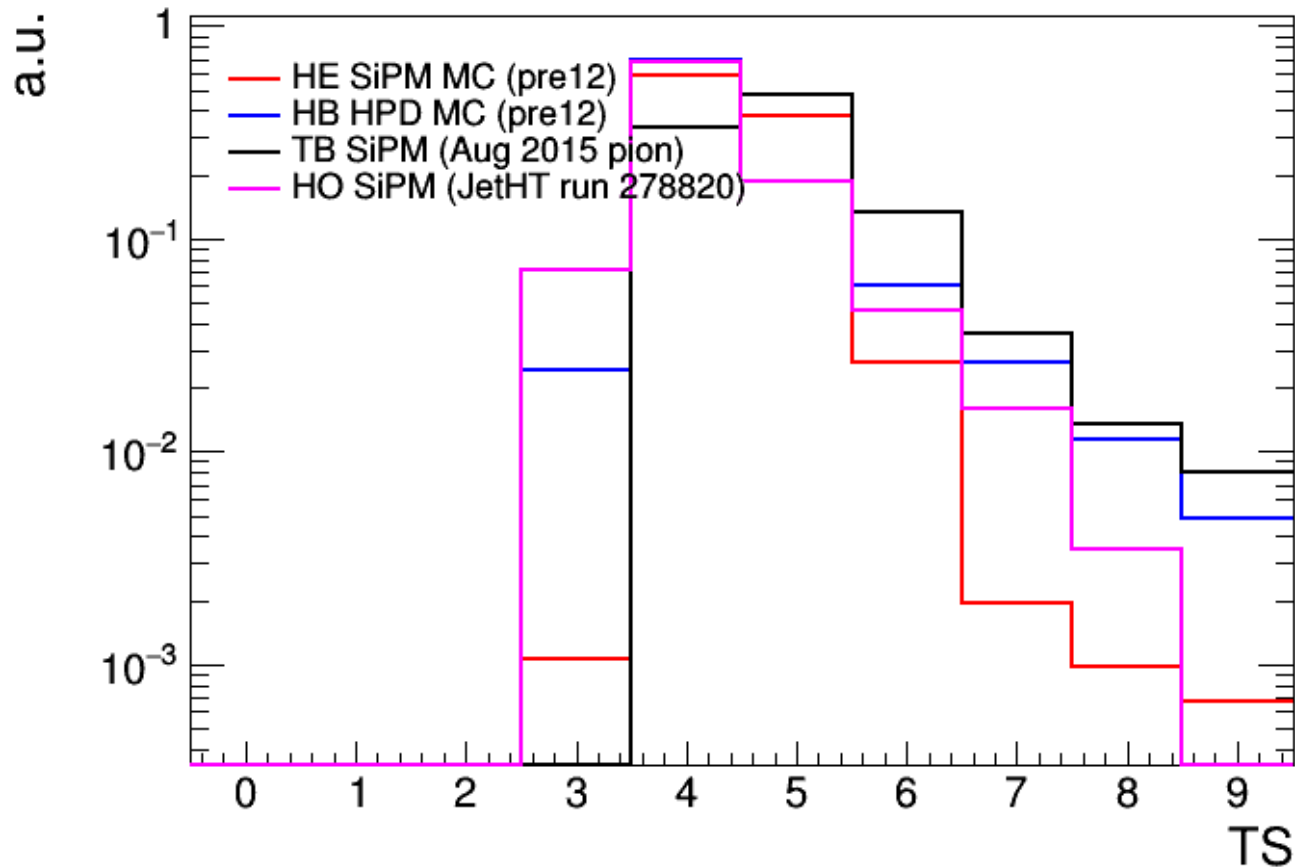
- Input: SimHits, SiPM pulse shape, Y11 pulse shape (separate)
- $n_{pe} = \text{round}[\text{Pois}(E_{sim} \cdot f_{sam} / g_{GeV/fC} / g_{fC/pe})]$
- $t_0 = t_{rise} + t_{phase} - (t_{sim} - t_{flight}) - t_{bunch} \cdot (b_{max} - b_{shift})$
 $= 0 + 6 - ([6:500] - [6:20]) - 25 \cdot (5 - 1)$
- $t_{bin} = -t_0 / 0.5$
for p in 0.. n_{pe} :
 $t'_{bin} = \text{round}[Y11() / 0.5 + t_{bin}]$
 if $t'_{bin} \geq 0$: photons[t'_{bin}] += 1
- for b in photons:
 evaluate SiPM pulse starting in precise bin b with magnitude photons[b]

SiPM: t_0 vs Output Pulse Revised

- Correct proportionality!



Output Pulse Comparison Revised



- SiPM MC shape much more similar to others after revision
- Still some difference in the high tail

Conclusion

- After intensive study, problem with SiPM output pulses has been determined
- A fix is proposed and being tested
- Branch with various debugging printouts and macros used in this study:
https://github.com/kpedro88/cmssw/tree/DebugPulses_810pre12
- Branch with fix only:
<https://github.com/kpedro88/cmssw/tree/Phase1-HE8>

Backup