Imperial College London

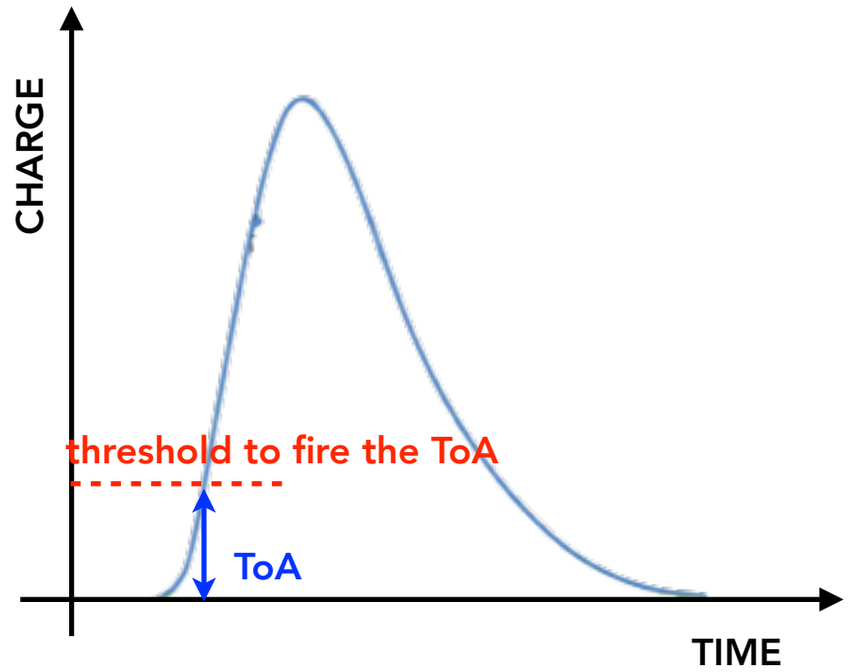
ToA in HGCAL

- bug fix and validation -

thanks Abhishek Das for spotting the bug

Time of Arrival in the HGCROC

- **The HGCROC provides a time of arrival (ToA) for signals above a given threshold**
  - a dedicated ToA TDC circuit fires the ToA, when the integrated charge is > 12fC

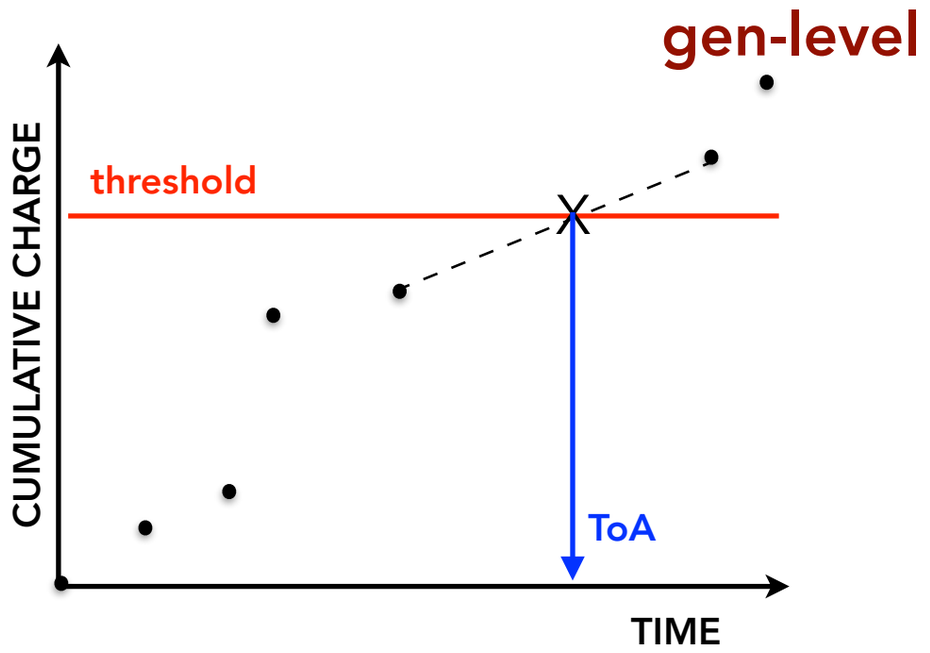


- In the CMSSW simulation, the signal formation in every cell (detID) is obtained integrating all the energy deposits, from G4+propagation, that fall in the given cell in the considered time interval (BX usually)
  - G4 energy deposits are sim-hits: each with a detID, position, energy, time
  - i.e. total charge = accumulation of sim-hits from signal and PU, in a given detID in the proper BX

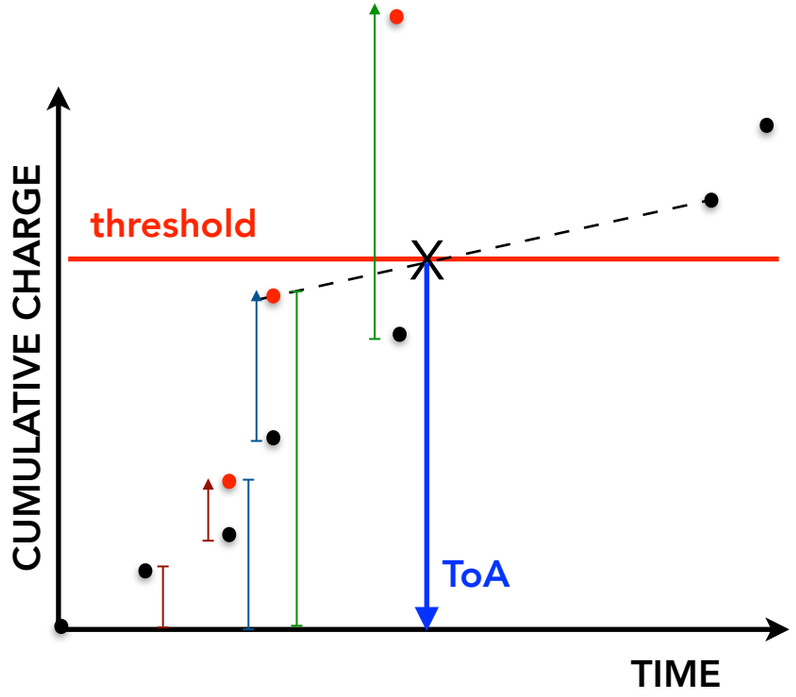
- HGCAL (electronics simulation) digitization has not a full description of the signal shaping
  - **deal with time-sorted sim-hits in each cell to get a gen-level information**
  - **inject needed realism (jitter effects, noise...) afterwords**

Time of Arrival in the digitiser

- **For each Silicon cell in the HGCAL**
  - **consider all the time-ordered sim-hits that contribute to the total charge cumulated in the triggering BX (signal + PU)**
  - **fired ToA = the interpolation at threshold** between the two consecutive sim-hits, or the time of the sim-hit itself if its charge is already above threshold



- **Bug found from Abhishek Das in the interpolation step** (while studying the code to implement the premixing version)
  - **charge was re-cumulated**
  - **time sample earlier in time is identified as the one just-before-threshold**
  - **earlier time and higher charge are used as the start-point of the interpolation**
  - **end point of the interpolation is not recomputed, so remains unaffected by the bug**
  - **number of cells above threshold unaffected: flagged before the interpolation (=> no impact on efficiency)**

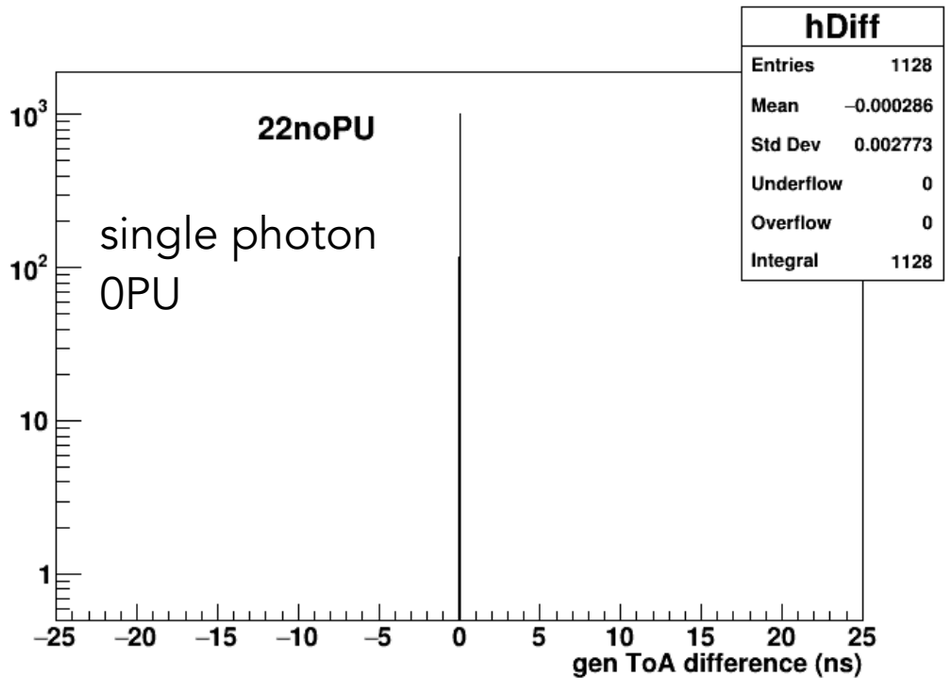


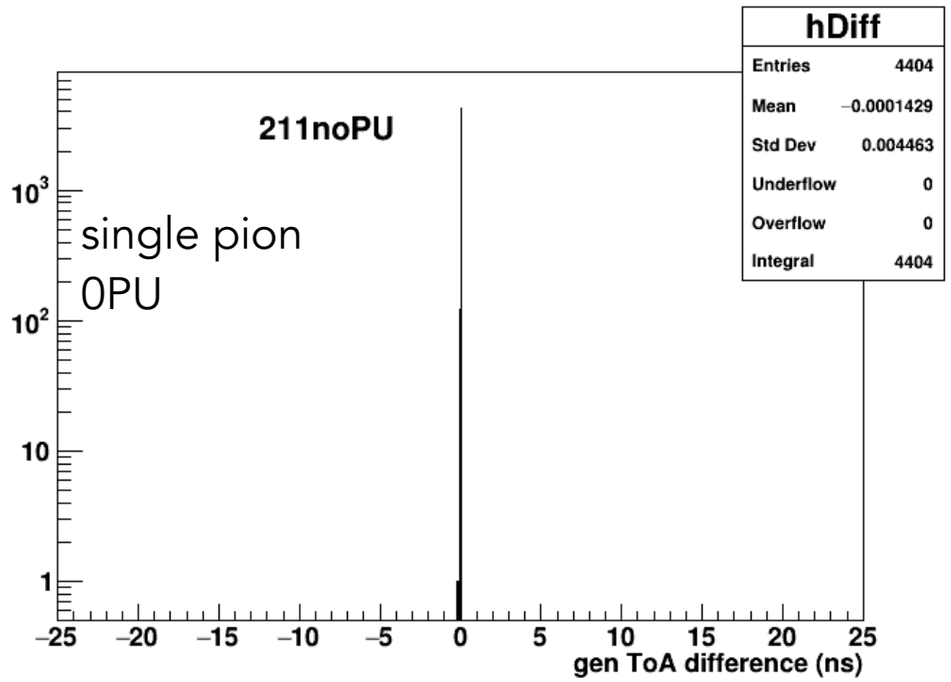
- Expect major impact with non-linear cumulation of charge (high PU)

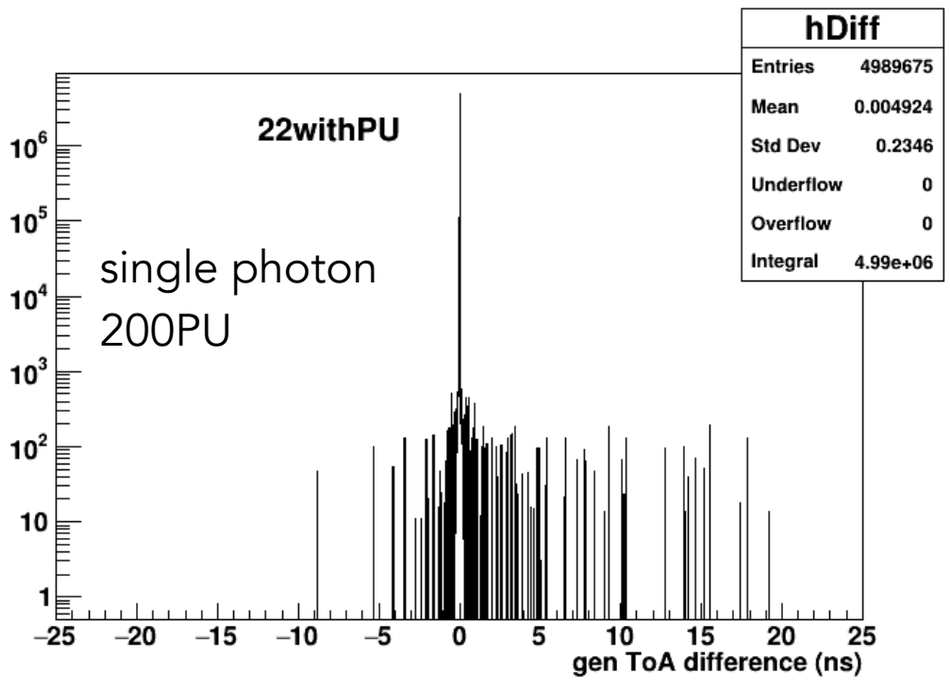
recHit by recHit comparison

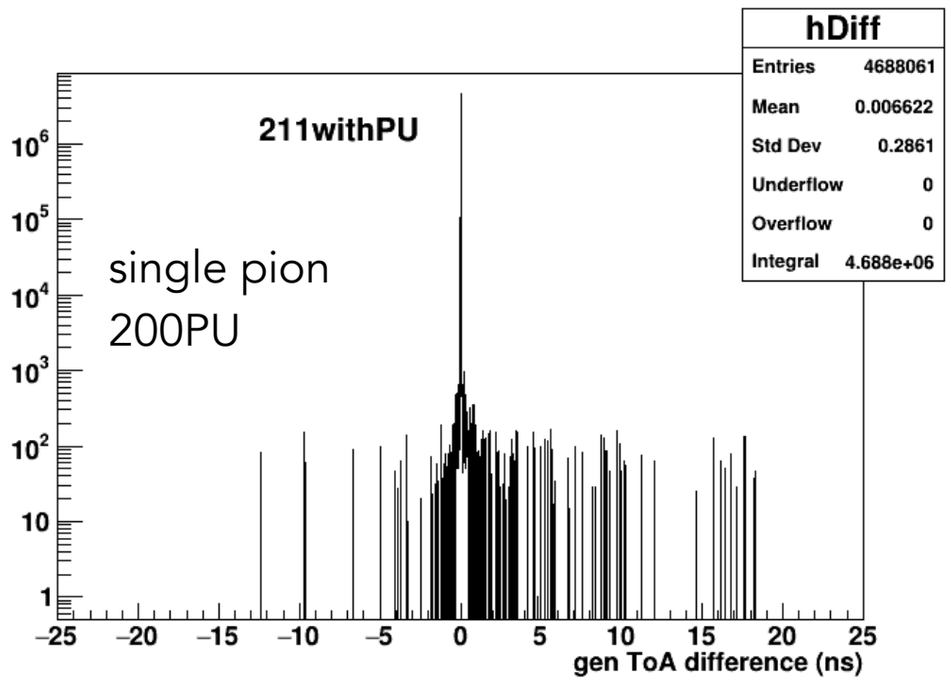
- genToA difference (bug - fix)
  - main effect at high PU as expected

CMSSW_11_1_X (v10)



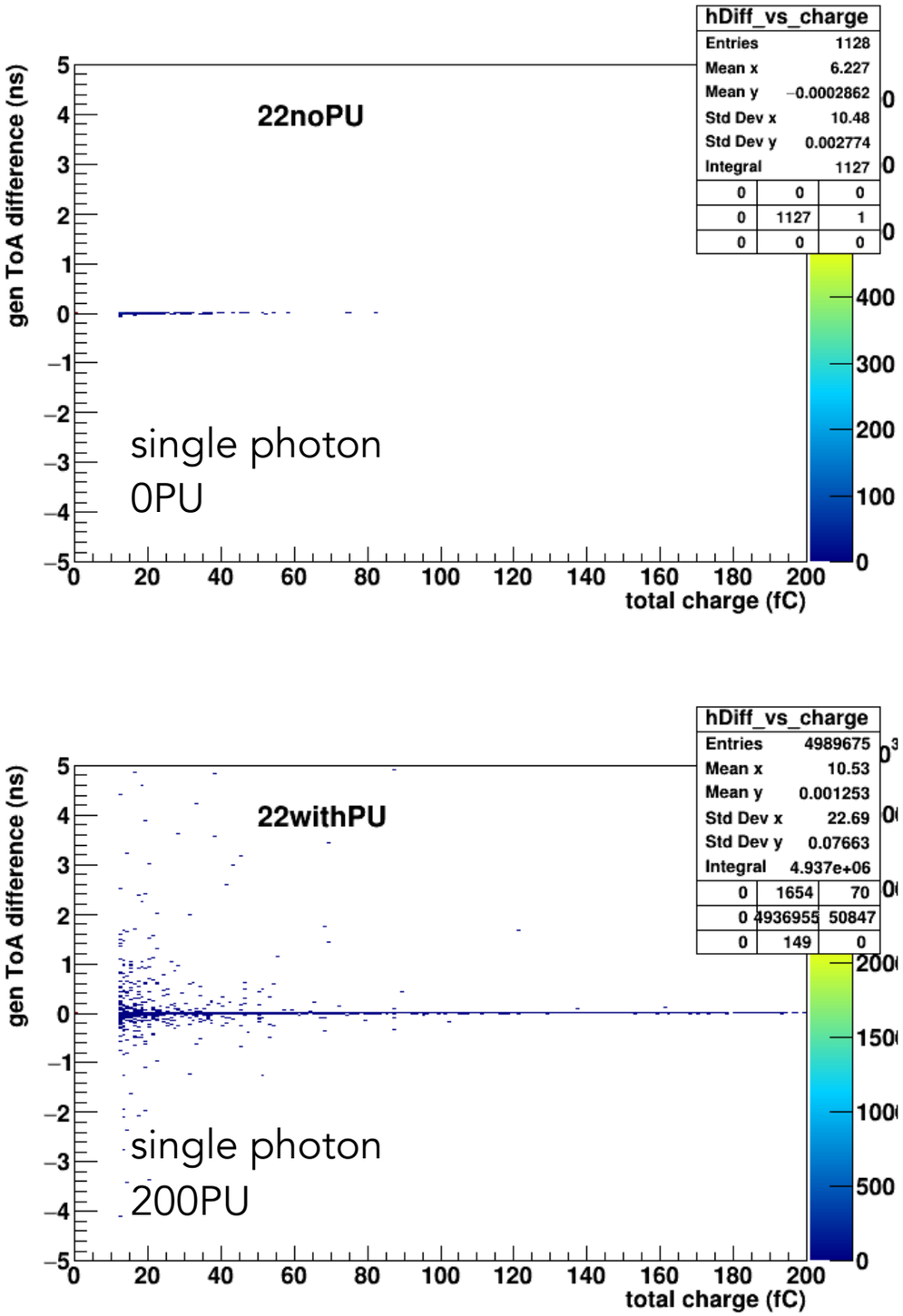


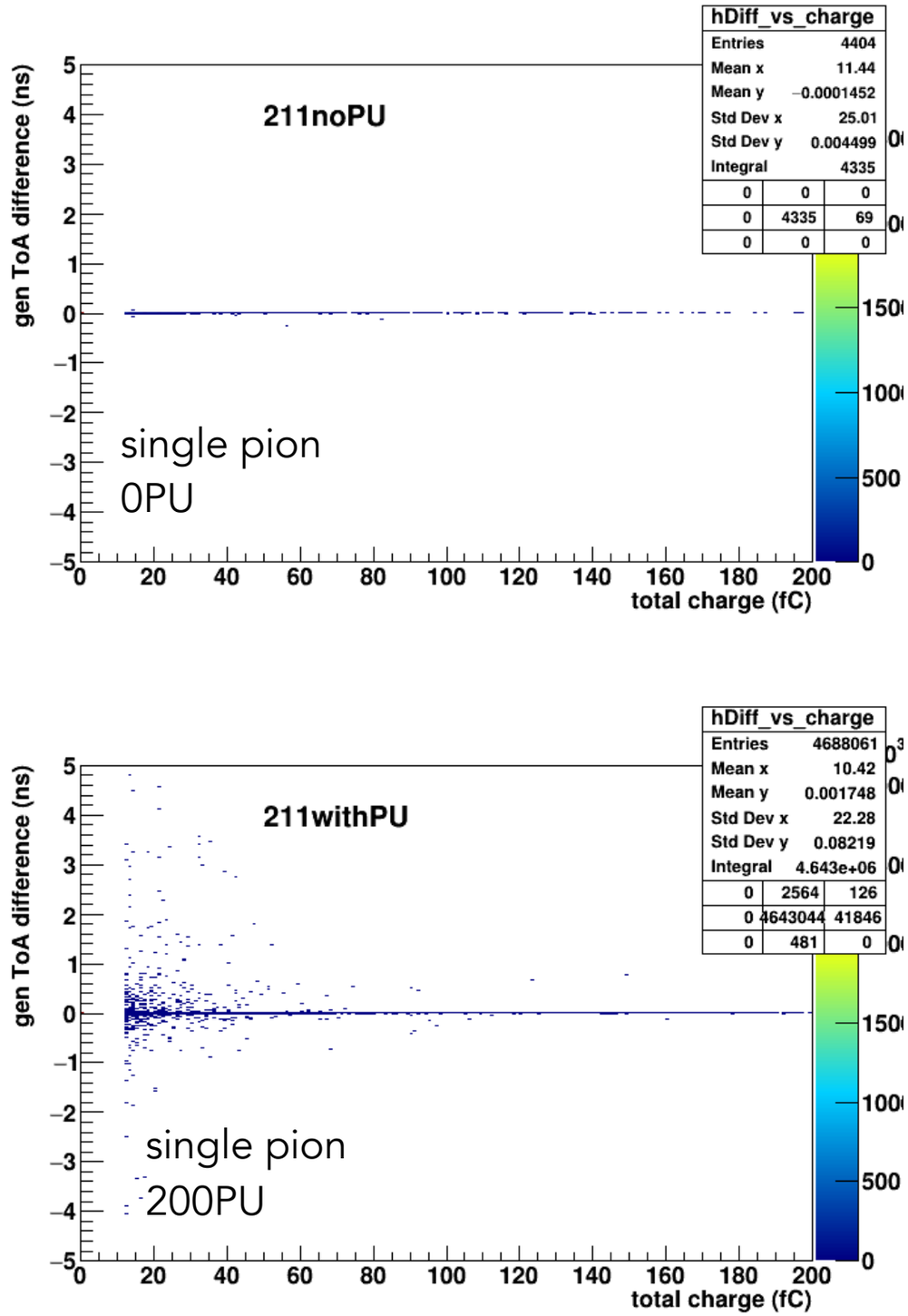




recHit by recHit comparison

- genToA difference vs recHit charge
  - effect mainly at low charge.
  - Reminder: the genToA is then smeared according to the expected resolution

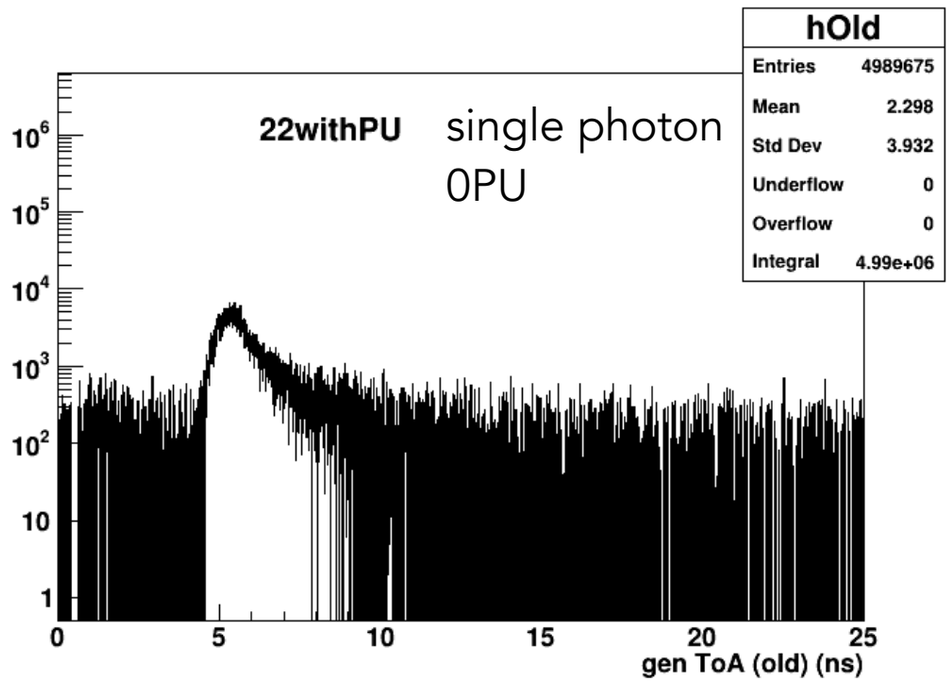


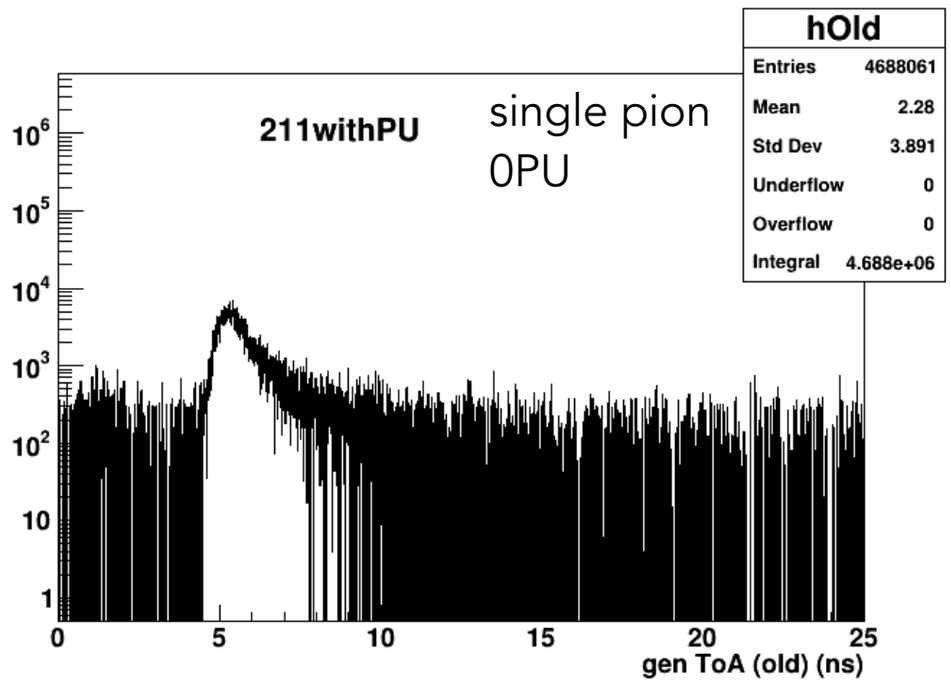


looking at recHits

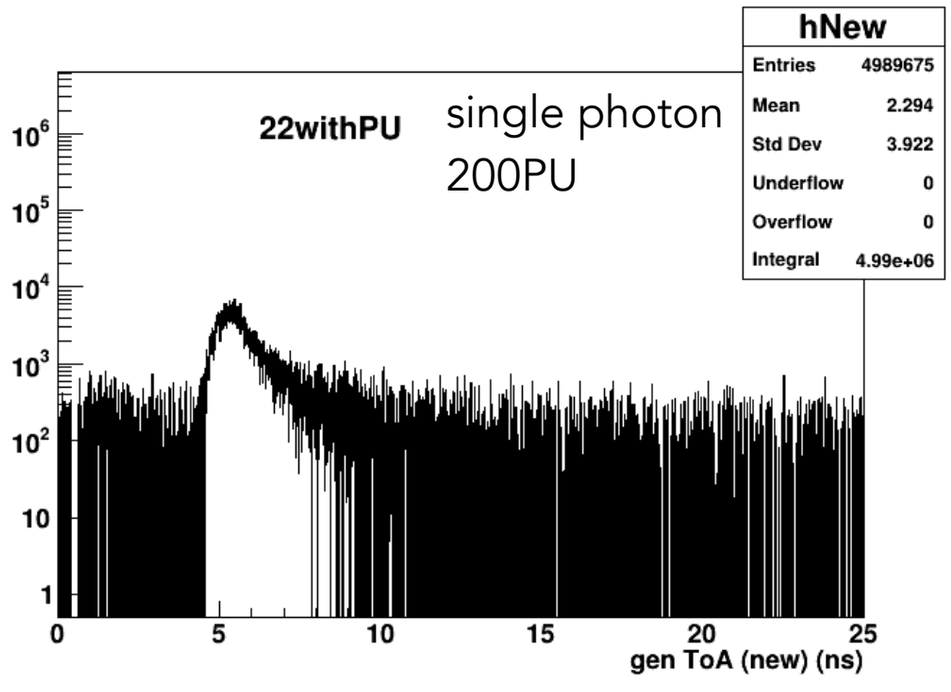
- On average same distributions

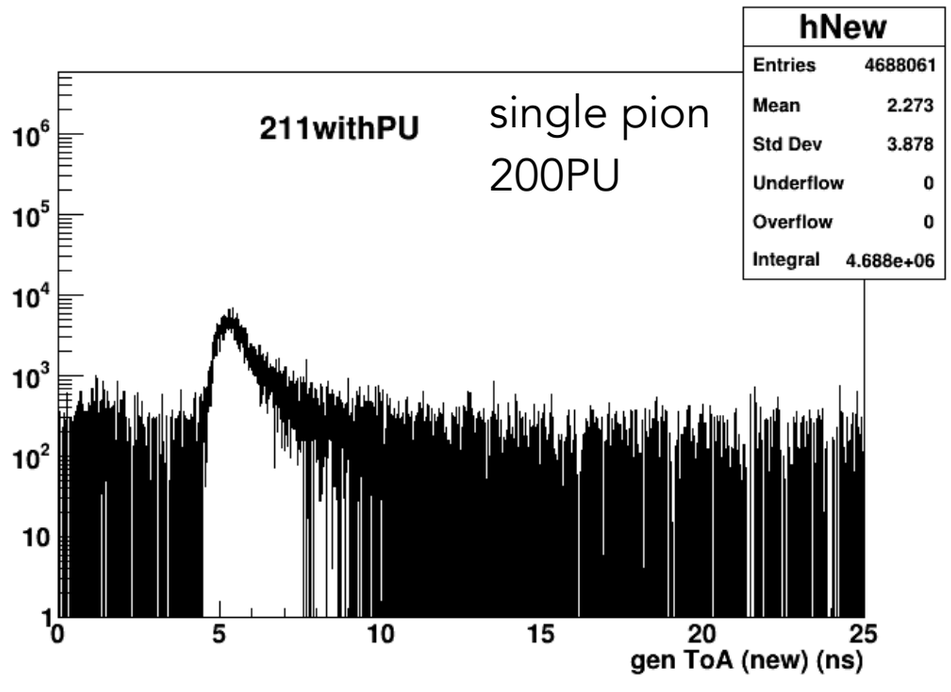
with bug





with fix





Full validation

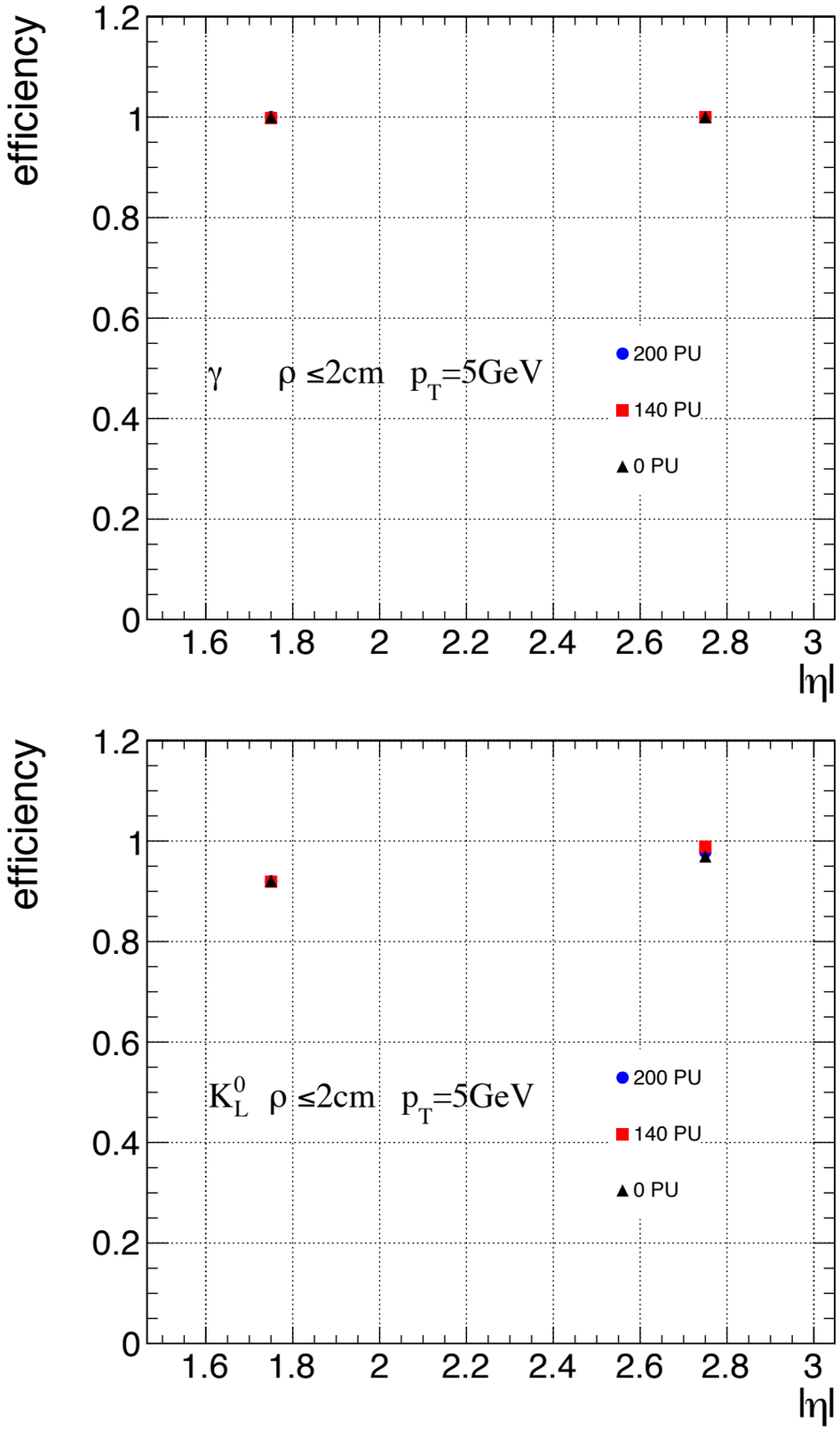
- Repeat analysis done for the TDR: performance of full shower looking at recHits in a cylinder around the shower axis
  - shower axis from gen direction
  - 2cm radius
  - ≥ 3 hits requirement, truncation + average time on the surviving hits

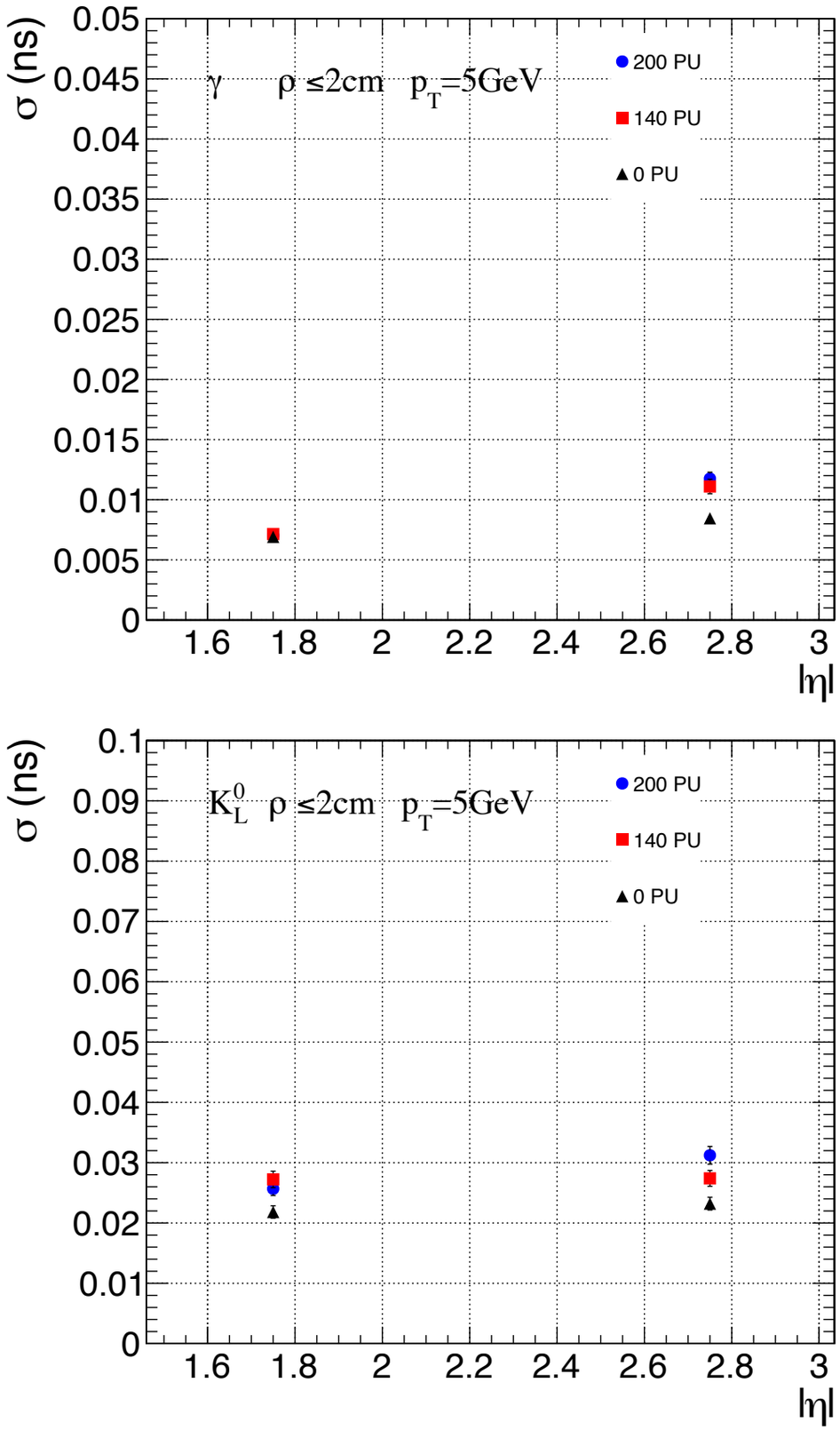
- Just focus on 200PU: single photon and single K0L at pt = 5GeV
  - neutral particles to exploit directly the direction from the gen-particle

- In the following:
  - efficiency = fraction of events with ≥ 3 hits with time
    => fraction of showers for which a timing information can be computed
  - resolution = sigma of the gaussian fit to the distribution of the times of the showers over all the events (time-of-flight corrected)

Plots from TDR

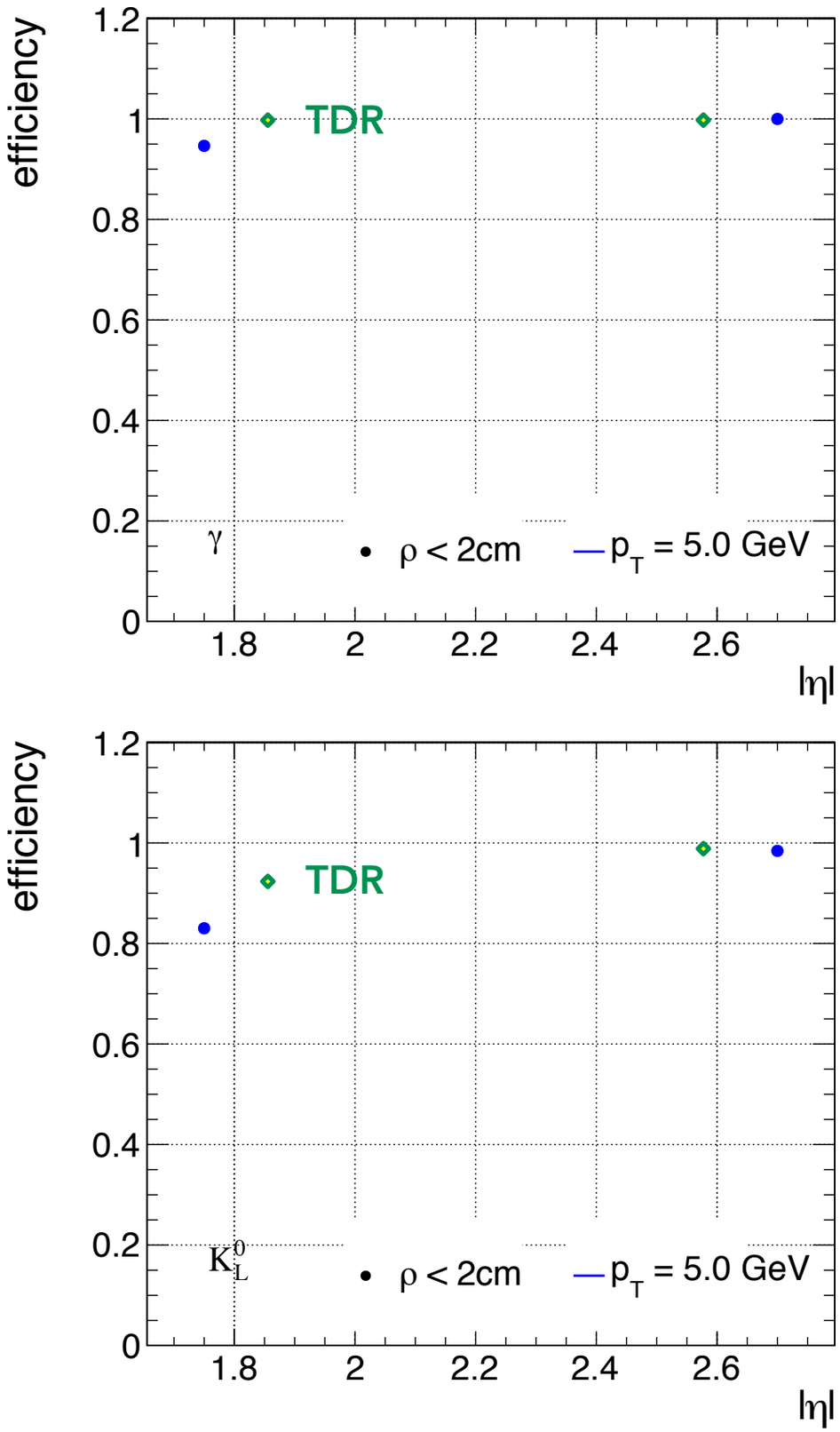
- In CMSSW_9_4_0, just focus on blue dots (at 200PU)

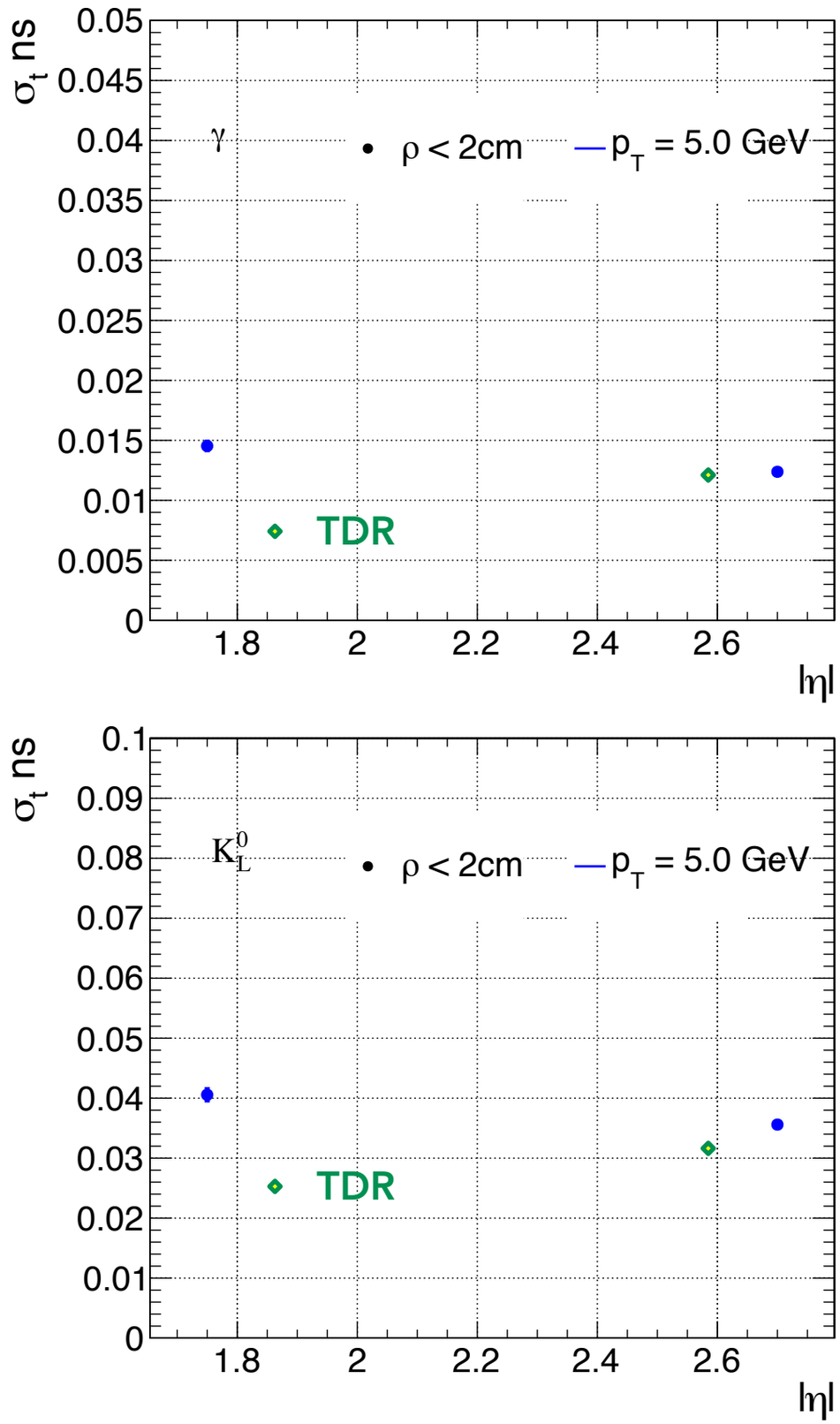




New performance

- comparison with points from previous slide (TDR) at 200PU ◆ (shift in eta for readability)





Summary

- Observed worst performance at low eta (Si 300um mainly)
- Change observed also on the efficiency: this is not related to the bug!
- Could be related to the change in the noise and the geometry configuration...
  - from https://github.com/cms-sw/cmssw/blob/master/SimCalorimetry/HGCalSimProducers/python/hgcalDigitizer_cfi.py#L9-L10

```
9   nonAgedNoises  = [2100.0,2100.0,1600.0] #100,200,300 um (in electrons)
10  nonAgedNoises_v9 = [2000.0,2400.0,2000.0] # 120,200,300 um (in electrons)
```

2100, 2100, 1600 => TDR version
2000, 2400, 200 => same as v10, corresponding to noise [0.32041, 0.384492, 0.32041] fC

- Impact of the bug under control, and on the whole negligible

BACKUP