1. Overview and Perspective
This work investigates improvements to the HCAL signal amplitude reconstruction done online for mitigating the effects of pileup that degrade the performance of the Level-1 (L1) Trigger system. The energy scale and resolution of L1 trigger energies can be biased by the presence of pileup interactions, leading to increased trigger rates. A pulse-shape-filtering scheme is developed with a weight that is optimized to minimize the effects of out-of-time pileup.

2. Extracting Filter Weights
Simulated signal pulses are compared with and without pileup present in order to quantify how much fractional overlap there is from pileup. The filter weight is quantified as the fraction, individually for each tower $|\eta|$, of the barrel and endcap regions of HCAL.

3. Improved Online Energy Reconstruction

**Low Energy Regime:**
- The pileup dominant energy regime; best demonstrating pileup’s effect on final signal reconstruction.
- **Proposed scheme** prevents bias in energy scale w.r.t. offline.

**High Energy Regime:**
- Not a pileup dominant regime; validates pileup subtraction behavior, which should have little impact here.
- Both the proposed and current scheme perform similarly in this regime.

4. Robustness Against Pileup
The current and proposed schemes are used for signal amplitude reconstruction in four different pileup scenarios with underlying $t\bar{t}$ events.

**Energy Scale w.r.t. Offline:**
- The current scheme yields an energy scale that is sensitive to the level of and biased by pileup.
- The proposed scheme maintains a much more uniform energy scale across HCAL, regardless of pileup.

**Energy Resolution w.r.t. Offline:**
- Energy resolution obtained from current scheme is degraded by pileup.
- In any pileup environment, proposed scheme allows for better, uniform energy resolution.

5. Impact on the Level-1 Trigger
The resultant L1 rates for different multiplicity jet triggers (above left), MET triggers (bottom left); and the efficiency of a single jet > 60 GeV trigger (above right), MET > 100 GeV trigger (bottom right) when using the current and proposed schemes. Rates are measured using a simulated zero bias sample while the trigger efficiency is measured in a simulated $t\bar{t}$ sample. For both L1 objects, the proposed scheme reduces rates without reducing efficiency.

6. Summary
The proposed scheme shows promising results for mitigating pileup with a beneficial impact at L1. We anticipate implementing the scheme in HCAL DAQ hardware for use during the next CMS data taking period.