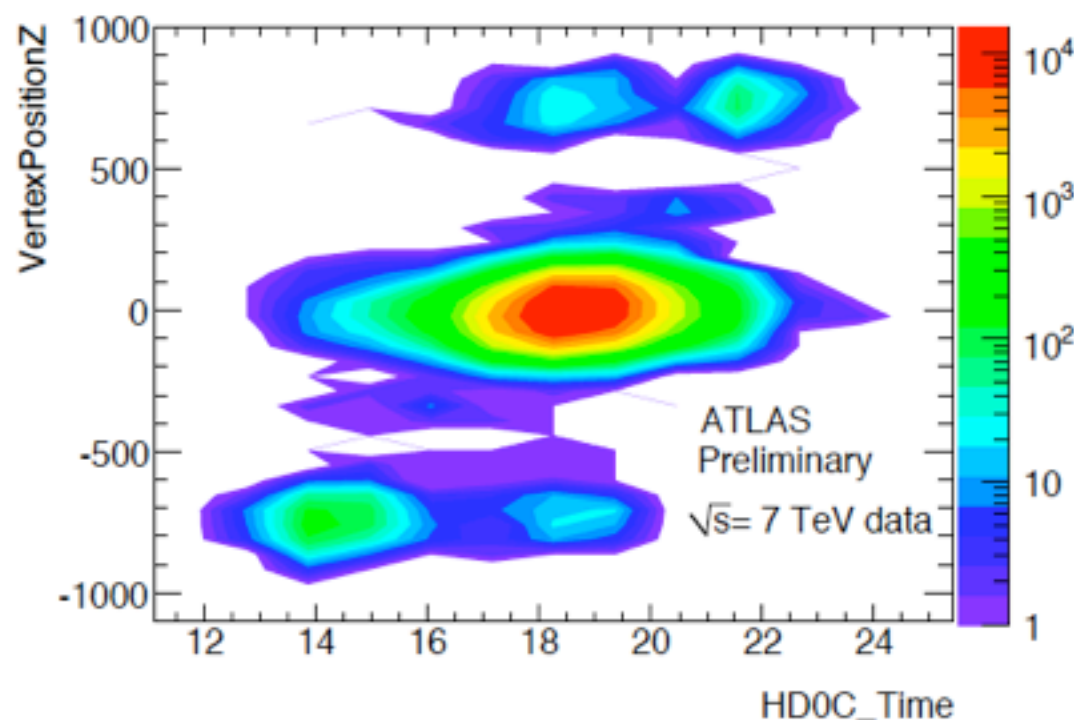# Addressing LHC pile-up using Calorimeter timing

LHC bunch length sets a natural scale. ~7.5cm bunch, 55cm betastar and 285 micro rad x-ing angle-> 170 picosec rms time spread, 4.5 cm rms vertex spread

Calorimeter(or track) time is a tool for resolving events in the 2-d space of event time and vertex pos'n.
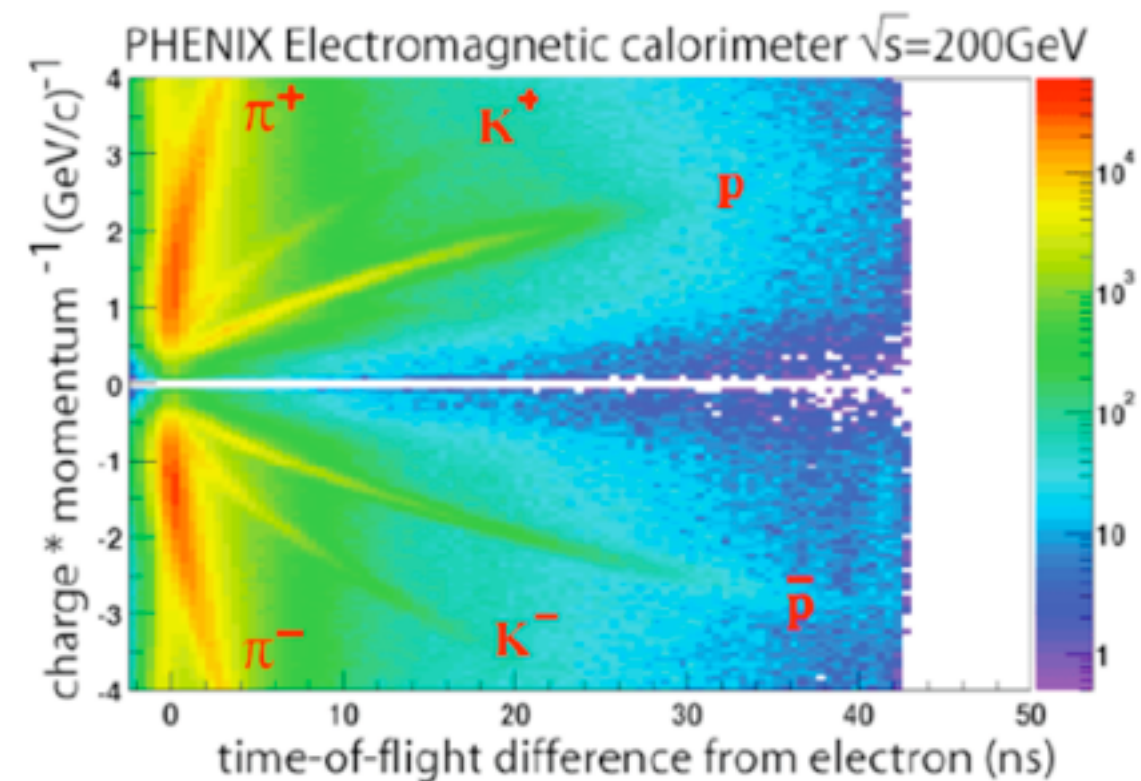
Existence proofs of calorimeters with <100 psec resol'n

BNL-Yale built ATLAS ZDC timing(Quartz-Tungsten Shashlik) resolves 400 MHz (SPS) micro-bunch structure in LHC (only LHC detector to achieve this?)
despite reduced bandwidth from low quality cable runs & 40 MSa/s sampling

15,552 tower PHENIX shashlik also used for hadron id via TOF
despite low energy deposit of ~0.5 GeV hadrons and TTS in un(longitudinally)-segmented calorimeter


The Z vertex distribution from inner tracker vs. the time of arrival of showers in ZDC-C relative to the ATLAS clock calculated from waveform reconstruction using Shannon interpolation of 40 MegaSample/sec ATLAS data (readout via the ATLAS L1calo Pre-processor modules). Typical time resolution is ~200 psec per photomultiplier (see ATL-COM-LUM-2010-022). The two areas outside the main high intensity area are due to satellite bunches. Note that this plot also provides a more precise calibration of the ZDC timing (here shown using the ZDC timing algorithm not corrected for the digitizer non-linearity discussed in ATL-COM-LUM-2010-027). With the non-linearity correction the upper and lower satellite separations are equalized.

Opportunity to employ new technologies capable of 10 times improvement in time resolution- in context of DOE ADR&D funded project (K.McDonald, S.White, co-PIs):

1)new Hybrid Avalanche Photo Detector yielding 11 picosec single photon rms response and 2 order of magnitude improvement over MCP-PMT lifetime

2) Deep-Depleted APD for direct charged particle detection
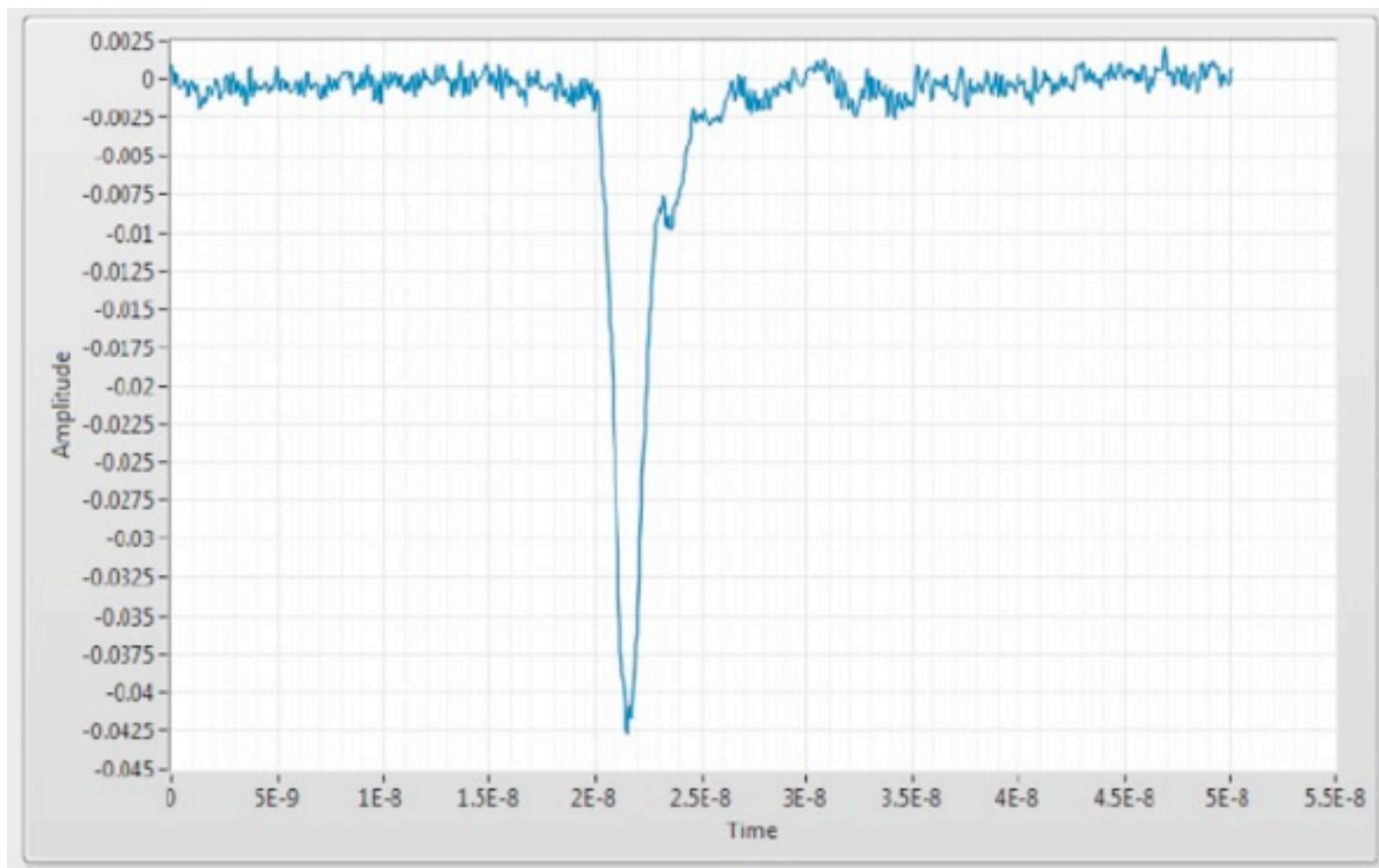
signal from 1 MIP crossing APD
0.5 nsec risetime
6000 e-h pairs
~200 APD gain
hard to do worse than 10 picosec rms TOF!!

->demonstrate rad hardness anticipated from CMS APD scaling laws

->battle test in LHC environment before LS1

->explore application in upgraded CMS calorimetry designs

*Current LHC expertise in fast timing resides in ALICE (C.Williams TOF) but limited to low rates (Glass conductivity)