

# Updates of the Readout System for Beam Background Merging

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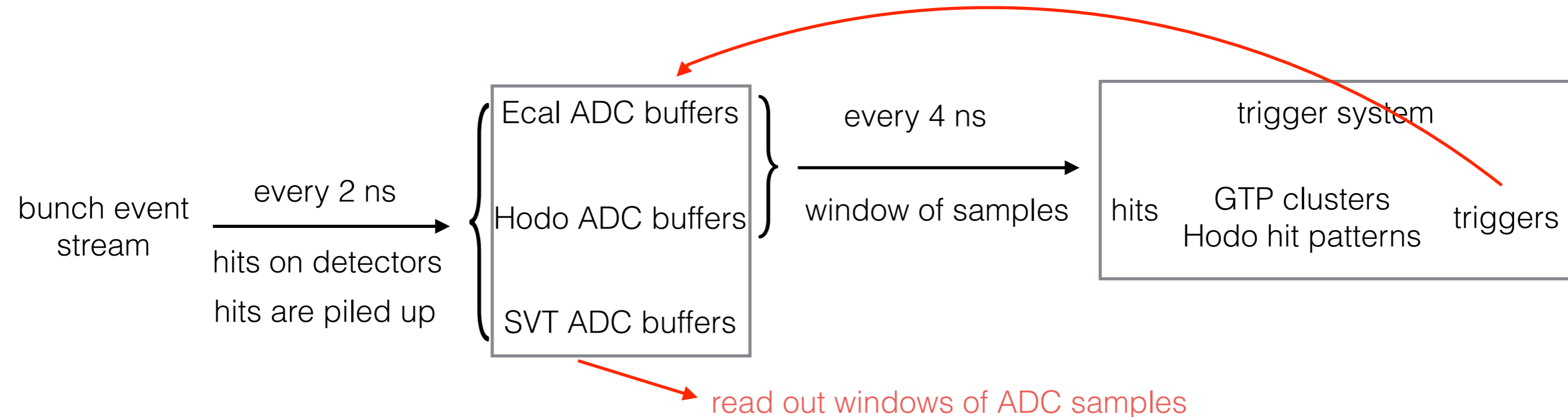
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# Overview

- To take into account of beam background effects on MC samples, signal events are required to be merged with beam background.
  - To significantly speed up MC production and improve quality of MC samples, we attempt to merge pulser data with MC signal samples.
  - After pulser data and MC data are overlaid, events include two groups of collections:
    - Pulser data: ADC samples for Ecal, hodoscope, and SVT
      - Ecal: 48 samples, 192 ns time window (4 ns clock-cycle for FADC250)
      - Hodo: 32 samples, 128 ns time window (4 ns clock-cycle for FADC250)
      - SVT: 6 samples, 144 ns time window (24 ns clock-cycle for APV25)
- Ecal:  
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
- Hodo:  
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
- SVT:  
01                    02                    03                    04                    05                    06
- MC data: MC particles, hits for Ecal, hodoscope and SVT
- To apply overlaid data, the readout system needs to be updated.

# How to Update Readout?

The readout system is emulation of the DAQ system



For an overlaid event, ADC samples from pulser data are merged with digitized MC hits. Merged samples are buffered for usage of the trigger system and readout of triggered events.

# How to Merge?

- Three different cases are handled separately:
  - If pulser data does not have a channel in MC data,
    - directly buffer samples
  - If MC data does not have a channel in pulser data,
    - add noise into MC hits
    - convert MC hits into a window of ADC samples
    - add pedestal
    - buffer samples
  - If MC data has a channel that is also in pulser data,
    - convert MC hits into a window of ADC samples
    - merge with samples of pulser data
    - buffer merged samples
- Note: if a ADC sample is (or merged with) a sample from pulser data, noise and pedestal should not be added; if a ADC sample is produced from MC data, noise and pedestal should be added

# Software updates: Input for readout with beam background merging

- Original data are MC signal events from SLIC, and experimental events from pulser data
  1. Evio to LCIO for pulser data
  2. Event overlay: Overlay MC events from SLIC and experimental events from pulser data with application of the tool DataOverlayDriver developed by Jeremy
  3. Spacing: Space overlaid events with interval of 250. Although loops of drivers are actually time basis, we use `process(EventHeader event)` for loop, which is event basis. After digitization, samples of one overlaid events will be handled in a time window and the trigger system handles ADC sample buffers clock-cycle by clock-cycle, so empty events need to inserted into neighbored overlaid events to provide enough space for the time window.
- After merging and spacing, we obtain overlaid events with collections for MC hits and ADC samples of pulser data, and there are 249 empty events between neighbored overlaid events

# Software updates: steering file for Readout

<execute>

<!-- SLiC Data Drivers -->

<driver name="EcalHitsOutputDriver"/>

<driver name="MCParticleOutputDriver"/>

<driver name="HodoscopeHitsOutputDriver"/>

<driver name="TrackerHitsSVTOutputDriver"/>

<driver name="TrackerHitsEcalOutputDriver"/>

<!-- Pulser Data Drivers -->

**<driver name="EcalPulserDataInjectDriver"/> // New driver to globally buffer Ecal ADC samples**

**<driver name="HodoPulserDataInjectDriver"/> // New driver to globally buffer hodoscope ADC samples**

<!-- SVT Readout Drivers -->

**<driver name="SVTReadoutDriver" /> // Need to be updated to handle pulser data**

<!-- Hodoscope Readout Simulation Drivers -->

<driver name="HodoscopePreprocessingDriver"/>

**<driver name="HodoscopeDigitizationDriver"/>**

<driver name="HodoscopeRawConverterDriver"/>

<driver name="HodoscopePatternDriver"/>

**Both of hodoscope and Ecal digitization drivers are based on DigitizationReadoutDriver. DigitizationReadoutDriver needs to be updated to handle pulser data**

<!-- Calorimeter Readout Simulation Drivers -->

**<driver name="EcalDigitizationDriver"/>**

<driver name="EcalRawConverterDriver"/>

<driver name="GTPReadoutDriver"/>

<!-- Trigger Simulation -->

<driver name="SinglesTrigger"/>

<!-- LCIO Output and Data Management Driver -->

<driver name="ReadoutManagerDriver"/>

<driver name="CleanupDriver" />

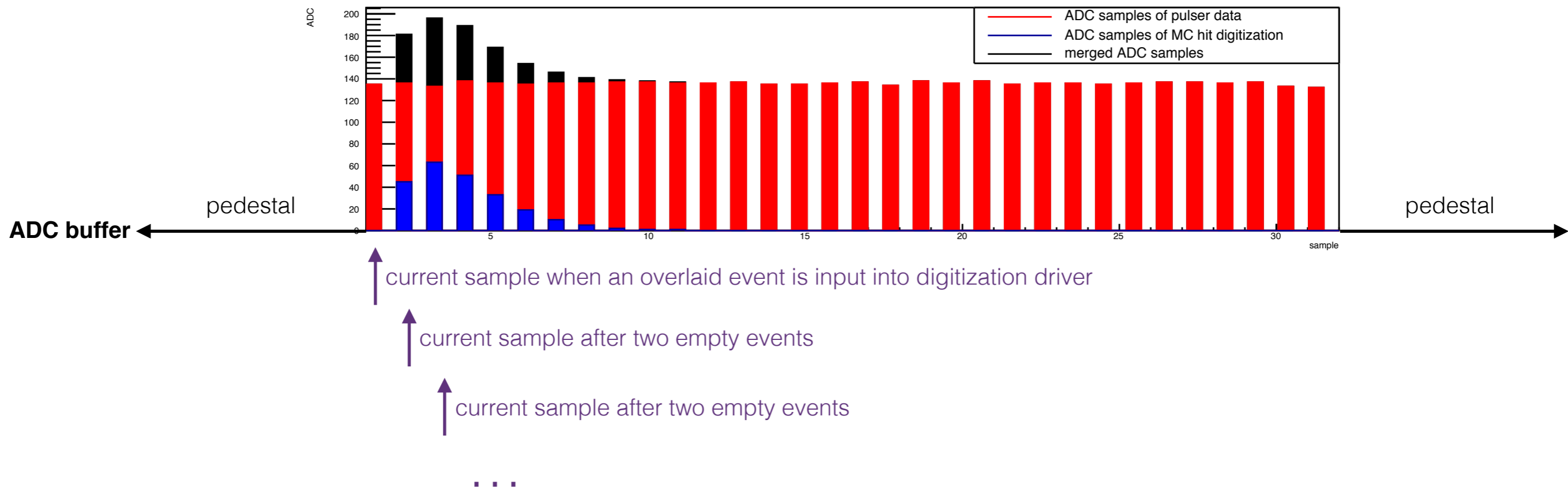
</execute>

# Software updates: new drivers in the readout system

- `PulserDataReadoutDriver`: a base driver to take in collections of pulser data
- `RawTrackerHitReadoutDriver`: a driver to take in collections of pulser data with type of `RawTrackerHit` (ADC sample collections for Ecal, hodo and SVT)
- `DigitizationWithPulserDataMergingReadoutDriver`: developed based on `DigitizationReadoutDriver`; a base class to obtain MC hits and pulser samples, digitize MC hits and merge with pulser samples, apply pulse integration algorithm to construct raw hits for usage of the trigger system
- `EcalDigitizationWithPulserDataMergingReadoutDriver`: a digitization driver for Ecal
- `HodoscopeDigitizationWithPulserDataMergingReadoutDriver`: a digitization driver for hodoscope

# Software updates: Demonstration for Merging

ADC samples for a hodoscope channel



After MC data is merged with pulser data, ADC samples are buffered. Then, ADC buffers are used for the pulse integration algorithm, while the current sample in each ADC buffer moves one step every two empty events (i.e. one clock-cycle).



# Effects of Merging on Trigger

- 1000 tritrig events of 2019 MC are used for tests:
  - With beam background merging (run with new system): 105 triggered events
  - Without beam background merging (run with old system): 103 triggered events
- Comparing event numbers between two files from output of the readout systems, where event number in files is identical to event number in SLIC file.
  - Event numbers of 101 triggered events are the same. Note: readout output could be different between events with the same event number. For events with merging, ADC samples could be changed due to merging, or extra channels from pulser data are read out
  - 4 triggered events exist in the file with merging, but do not in the file without merging
    - 3 events have no hodoscope hits in MC data
    - 1 event has a hodoscope hit in MC data, but energy deposit is too small
    - After merging, hits from pulser data are added into the trigger system, and triggers are produced for such events
  - 2 triggered events exist in the file without merging, but do not in the file with merging: due to pulser data merging, distributions of ADC samples in buffers changes comparing to without merging. Further, hit distributions of Ecal and hodoscope after pulse integration could change at some clock-cycles. For these two events, geometry matching fails after pulser data merging.

# Summary

- The readout system is updated for beam background merging.
  - Updates for Ecal and hodoscope have been done.
  - Merged ADC samples for the new system can be applied like digitized ADC samples in the old system so that the trigger system does not need to be changed.
  - Updates for SVT need to be supported by SVT experts.
- All new drivers are developed in a new package `org.hps.digi` so that the old readout system keeps available.
- `hps-java` branch: `iss225`
- Preliminary tests show that the new readout system works well.