Pile-up Noise Measurements in Tile Calorimeter of the ATLAS detector

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January 18, 2017
Pile-up is multiple p-p interactions at the same bunch crossing. They affect the measurement of jet kinematics.

Outlook

\[ \langle \mu \rangle = \frac{\sigma_{\text{inel}} \mathcal{L}}{f_{\text{LHC}} n_{\text{bunch}}} \]

\[ \mathcal{L} = 10^{34} \text{cm}^{-2}s^{-1} \quad \sigma_{\text{inel}} = 80 \text{mb} \]

\[ f_{\text{LHC}} = 11245 \text{Hz} \quad n_{\text{bunch}} = 2496 \]

**Importance:**
- Jets reconstruction algorithm uses topological clusters as input
- Topological cluster is made of energetically significant cells

**Purpose:**
- Measurement of pile-up noise constants in the Tile calorimeter cells
ATLAS Experiment

Goals:
- more precise measurements of Standard Model parameters
- search for new physics phenomena

Detectors:
- inner tracking detector
- electromagnetic and hadron calorimeters: LAr, Tile
- muon spectrometer

The ATLAS detector composition.
Tile Calorimeter

- a central **hadronic** calorimeter
- **sampling detector**: scintillating plastic "tiles" + layers of steel absorber
- **high-granularity** detector: 5182 cells, including special cells; 3 radial layers; 64 azimuthal modules; $|\eta| < 1.7$ coverage
- measures hadrons, jets kinematics, taus, missing $E_T$
**p-p Collisions and Pile-up Noise**

**p-p interactions:**
- **hard**: deep inelastic high-\(p_t\) parton-parton scattering
- **soft**: inelastic parton-parton interaction at low-\(p_t\) range

**pile-up affects measurements**

**In-time pile-up:**
- simultaneous \(p-p\) collisions

**Out-of-time pile-up:**
- impact of the past/future collisions on the signal shape in the current bunch-crossing
The Total Noise Measurement

- data 2016
- MC 2016

**Measurement:**
- The total noise $\sigma_{tot}$ is the width of the cell energy distribution
- $\sigma_{tot}$ has two components: electronics noise and pile-up noise
- $\sigma_{elec}$ is measured with pedestal runs

The energy distributions in A14 Tile Calorimeter cell in data ○ and MC ■ at $\mu = 18$ and $\mu = 32$. 
Total noise in a cell is a function of the average number of interactions $<\mu>$.

$$\sigma_{tot} = \sqrt{\sigma_{el}^2 + \sigma_{pile-up}^2 \frac{<\mu>}{k_L}}$$

- applying fit to the "the total noise $-<\mu>$" with function, where $k_L$ is a scaling factor
- extracting $\sigma_{pile-up}$

Pile-up dependence of the total noise in data ◯ and MC ■.
Pile-up noise activity in the Tile calorimeter cells. The reference cell is the \textbf{BC4}.

The highest pile-up is for \textit{A} – cells, the lowest one is for \textit{D} – cells.
The total noise in the Tile calorimeter cells is measured in $p$-$p$ collision data at 13 TeV centre-of-mass energy collected in 2016, as well as in Monte Carlo.

The pile-up noise depends on the cell position: the cells with highest pile-up level are in the $A$–layer and scintillator cells, the ones with low pile-up activity are in the $D$–layer.

MC (Pythia 8) tuned to RUN-I well describes the soft component of the hard $p$-$p$ collisions.

The pile-up noise constants were calculated for all the Tile calorimeter cells and implemented into condition data base; they are used for by the collaboration throughout jet reconstruction in RUN-II.