Lepton Isolation: Part II

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Outline

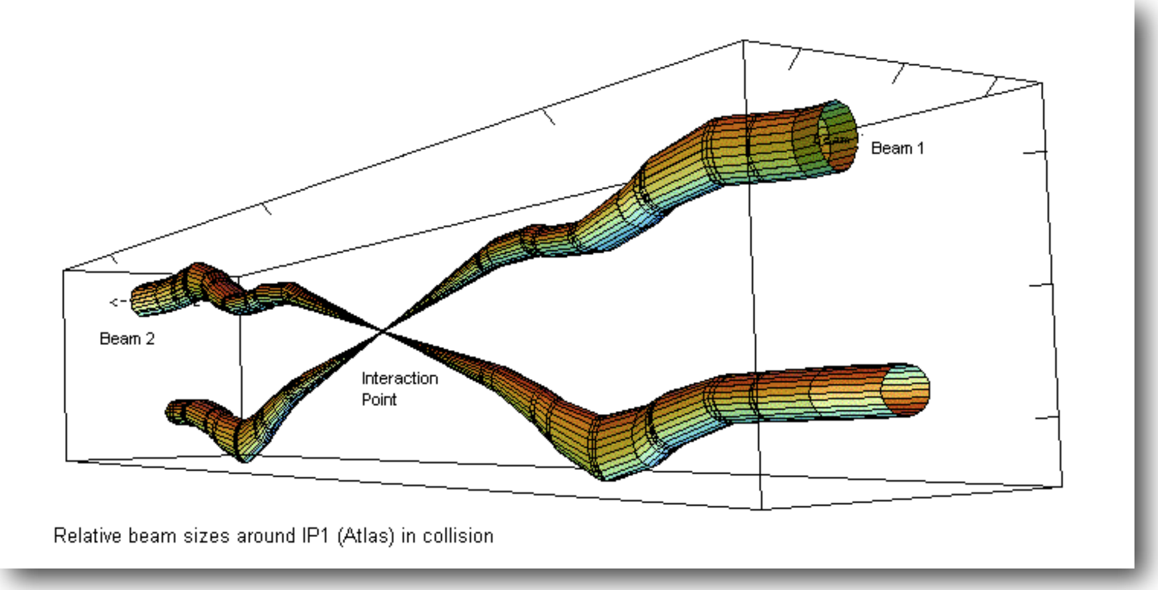
I) Event Pileup

II) Particle Flow Algorithm

III) Pileup Subtraction for Lepton Isolation

Pileup Description

- **Pileup**
  - Pileup is the average number of *pp* collisions occurring within a single beam crossing



- **Physics Motivation**
  - High luminosity is essential for searches of new rare physics processes at high energy scales, however, increasing the luminosity and reducing the bunch spacing results in pileups
  - The LHC will collide protons with an instantaneous luminosity of up to 10^{34} $cm^{-2}s^{-1}$ and a bunch spacing of 25ns

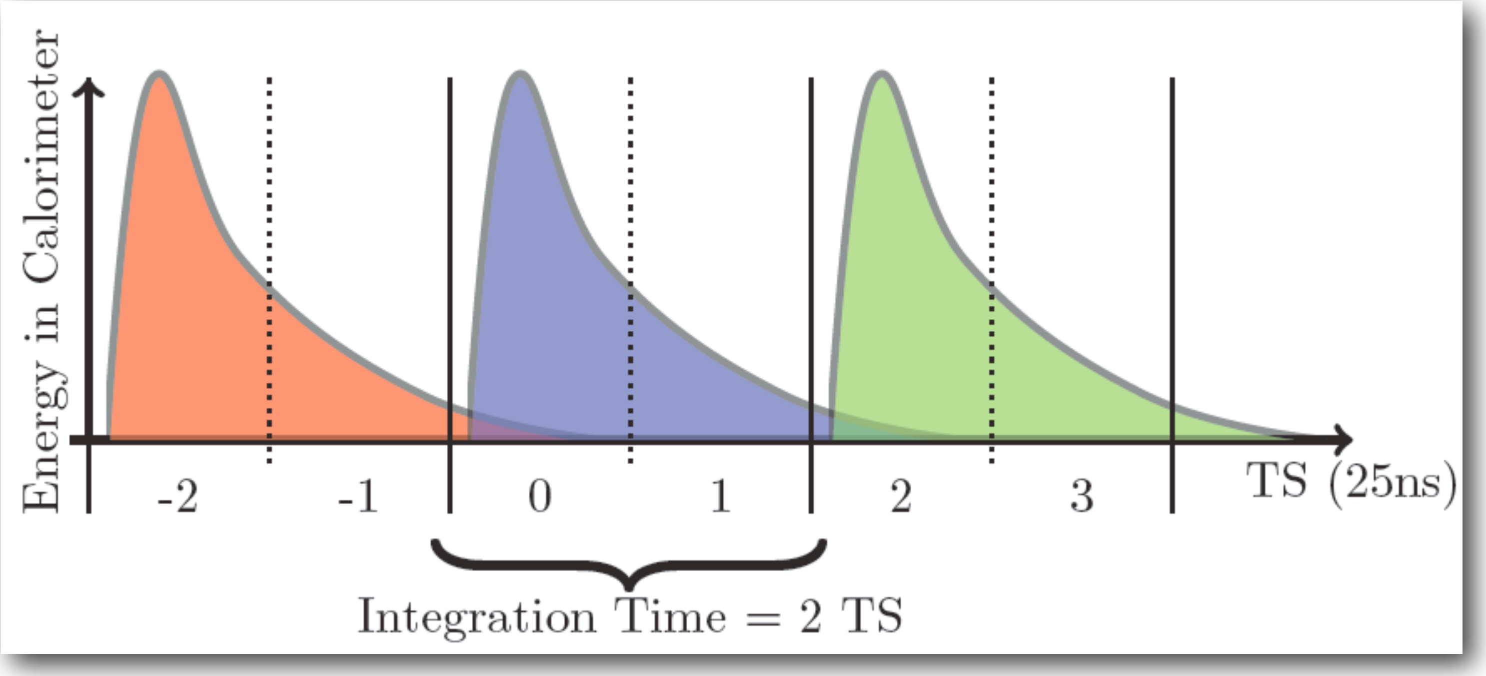
Types of Pileup

- **Three Major Types of Pileup:** Classify pileup based upon the time at which the additional energy enters the calorimeter system

    I) **In-time (IT) pileup:** Energy from *pp* collisions in the **current** bunch-crossing other than that at the hard scatter primary vertex. This is the largest source of pileup energy

    II) **Early Out-Of-Time (EOOT) pileup:** Refers to energy left in the calorimeters from **previous** bunch crossings

    III) **Late Out-Of-Time (LOOT) pileup:** Refers to energy from **later** bunch crossings



Calculating Pileup

- We may very simply calculate the pileup with the following formula

$$< N_p >= \sigma_{\text{inel}} L \tau_b$$

where N_p is the bunch size, σ_{inel} is the total inelastic cross section, L is the luminosity of the beam and τ_b is the bunch spacing

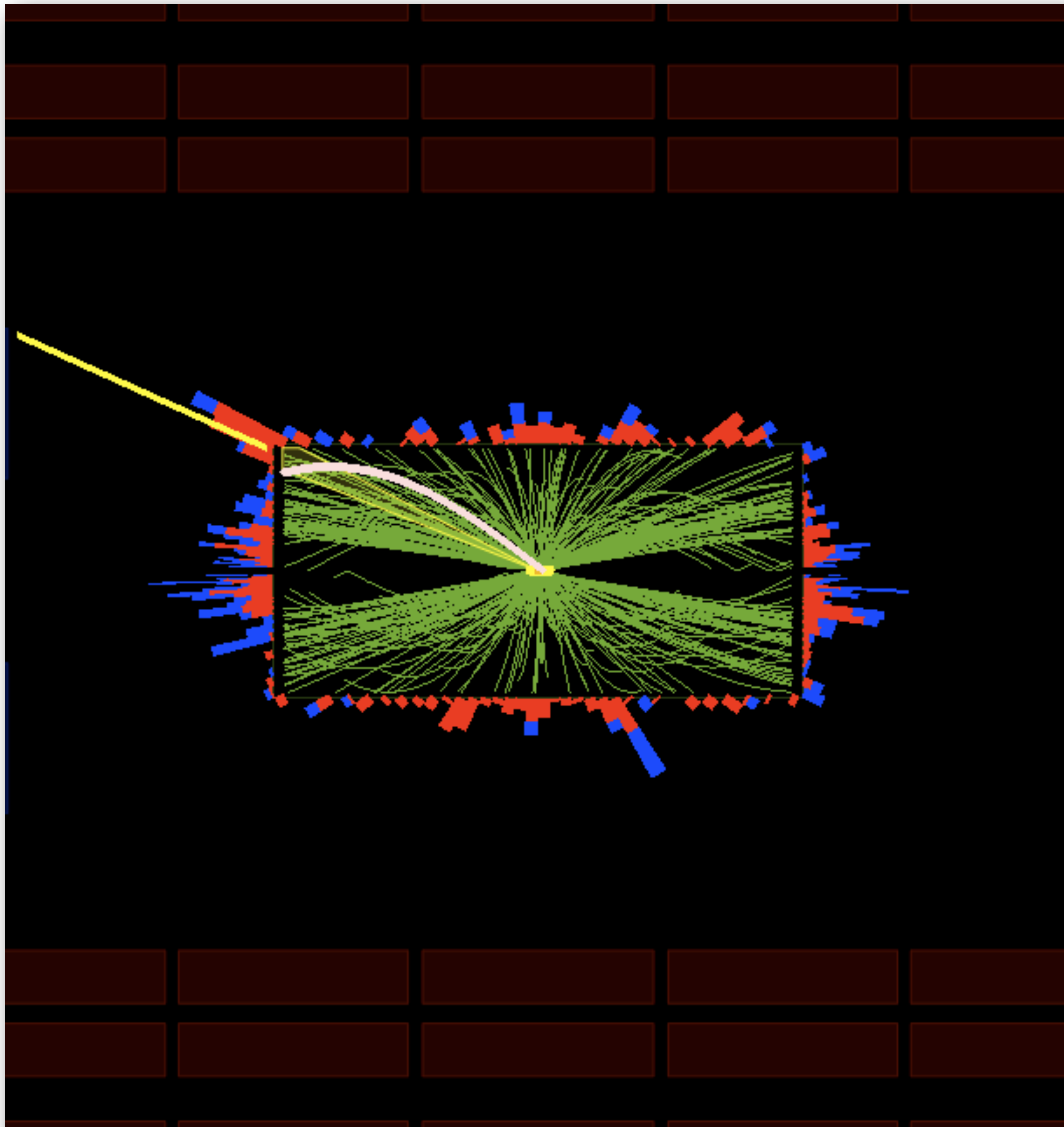
- To get a sense for what pileup we might expect under different running conditions, below is a table in convenient units. We will expect to run at 50ns bunch spacing, which translates into 1400 bunches in the collider at once, half the design limit of the machine

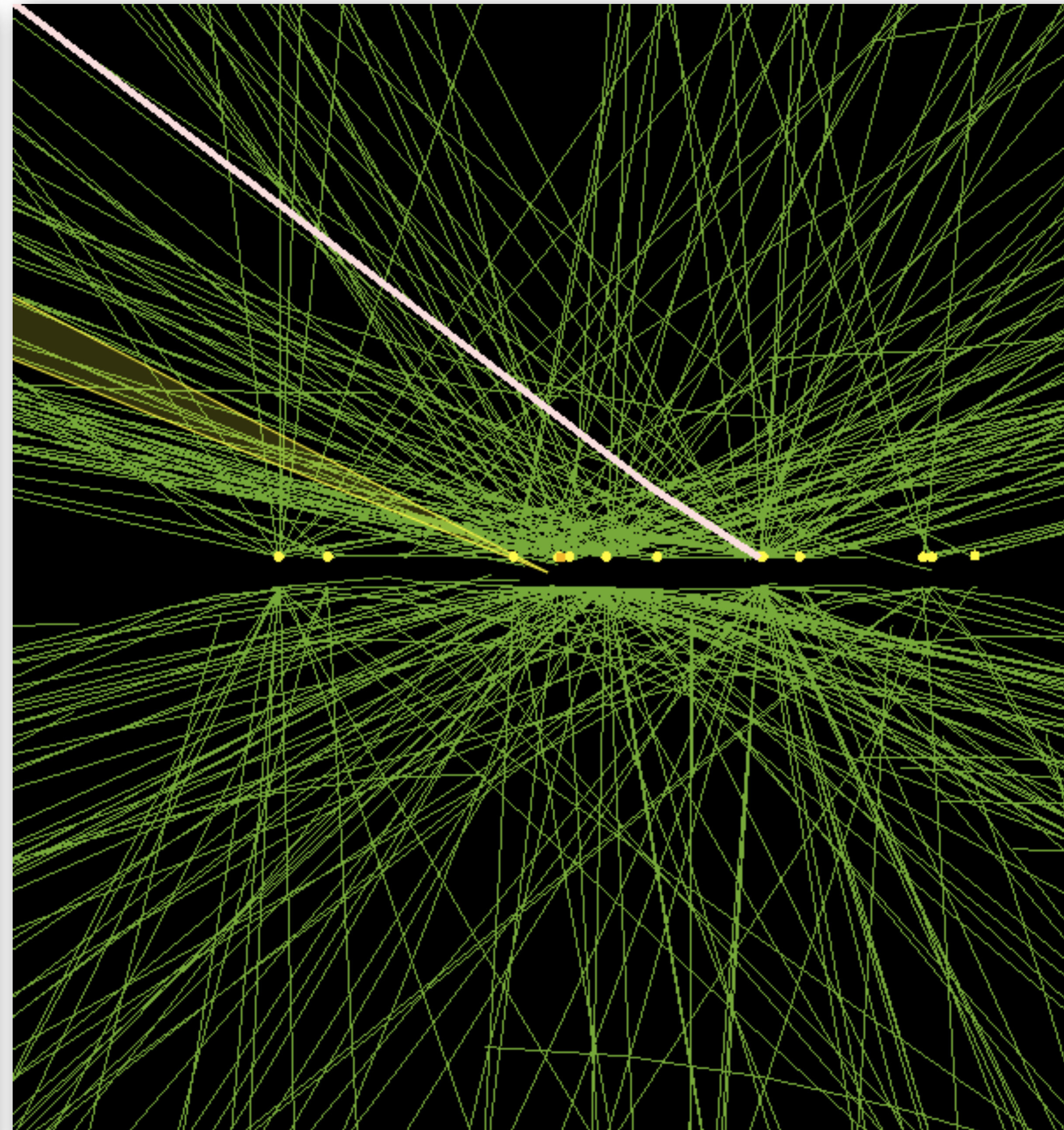
$$< N_{\text{pileup}} >= \frac{\sigma_{\text{inel}}}{(1 \text{ b})} \times \frac{L}{(10^{33} \text{ cm}^{-2}\text{s}^{-1})} \times \frac{\tau_b}{(1 \text{ ns})}$$

Facility	$\sqrt{s}$ [TeV]	σ_{inel} [mb]	L [10^{34} cm^{-2}s^{-1}]	τ_b [ns]	$< N_p >$	$< N_p > +2\sigma$
LHC (2012)	8	71.5	.75	50	27	38
LHC (nominal)	14	76	1	25	19	28
LHC (50 ns)	14	76	1	50	38	50

Analysis: From this equation, we see that $<N_{pileup}>$ is the directly proportional to the Luminosity and the bunch spacing

Visualizing Pileup in the Event Display





Particle Flow Description

- **Description:** The Particle Flow (PF) algorithm aims at reconstructing and identifying all stable particles in the event: electrons, muons, charged and neutral hadrons, photons via a **combination of all CMS sub-detectors.**
  - Previous generations of analysis relied on the creation of physics objects via specific sub-detectors, PF uses a physically motivated approach to bring together information from all sub-detectors
- **Super Basic Algorithm:**
  - Tracks are extrapolated through the calorimeter, if they fall within the boundary of one or more clusters, the clusters are associated with the track. Find and identify particles in the following order:

    I) Muons

    II) Electrons

    III) Converted photons

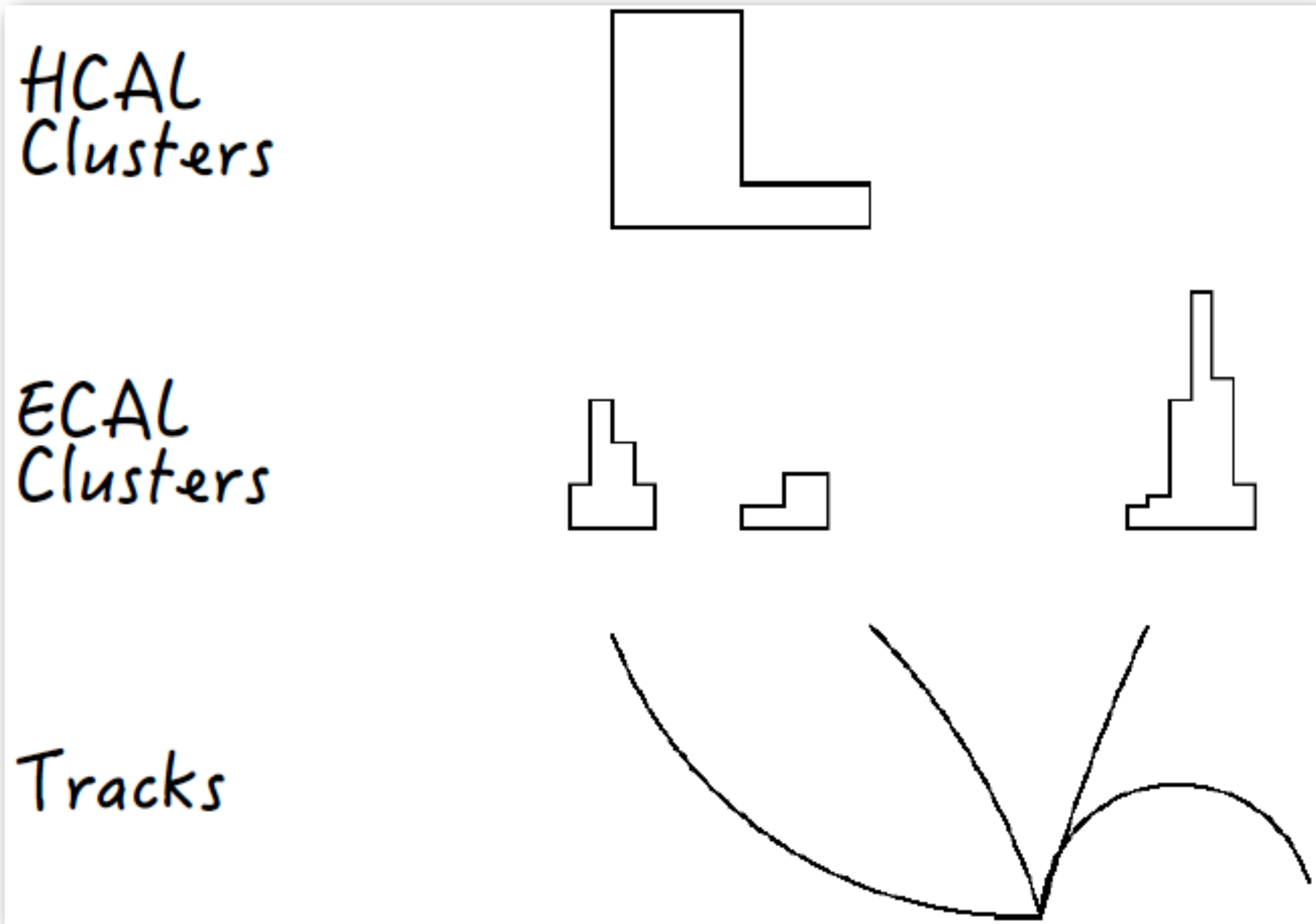
    IV) Charged hadrons

    V) Short-lived hadrons (VO's)

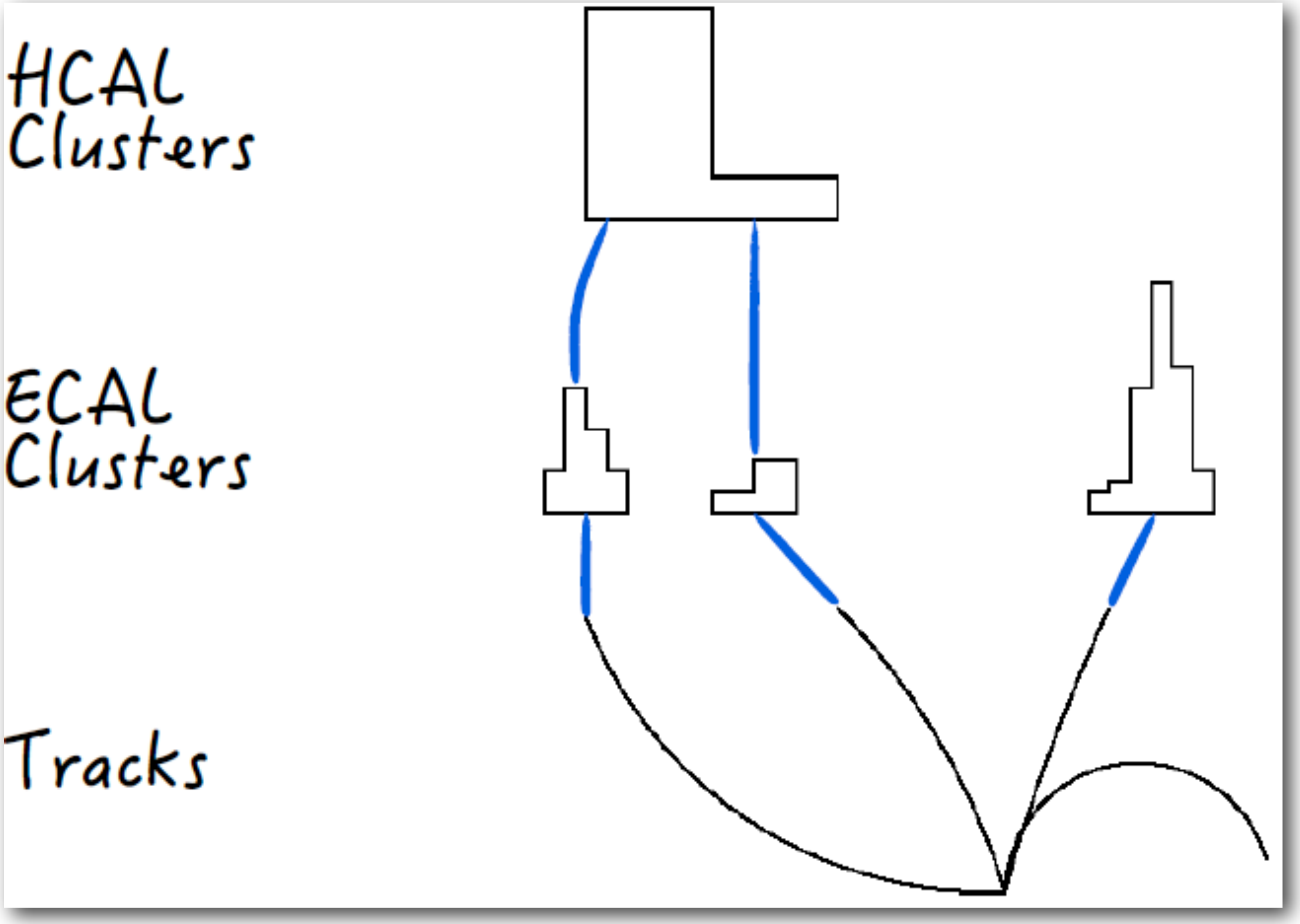
    VI) Photons

    VII) The remainder is neutral hadrons
  - Resulting list of particles is used to reconstruct jets, MET, reconstruct and identify taus from decay products and to measure the isolation of particles

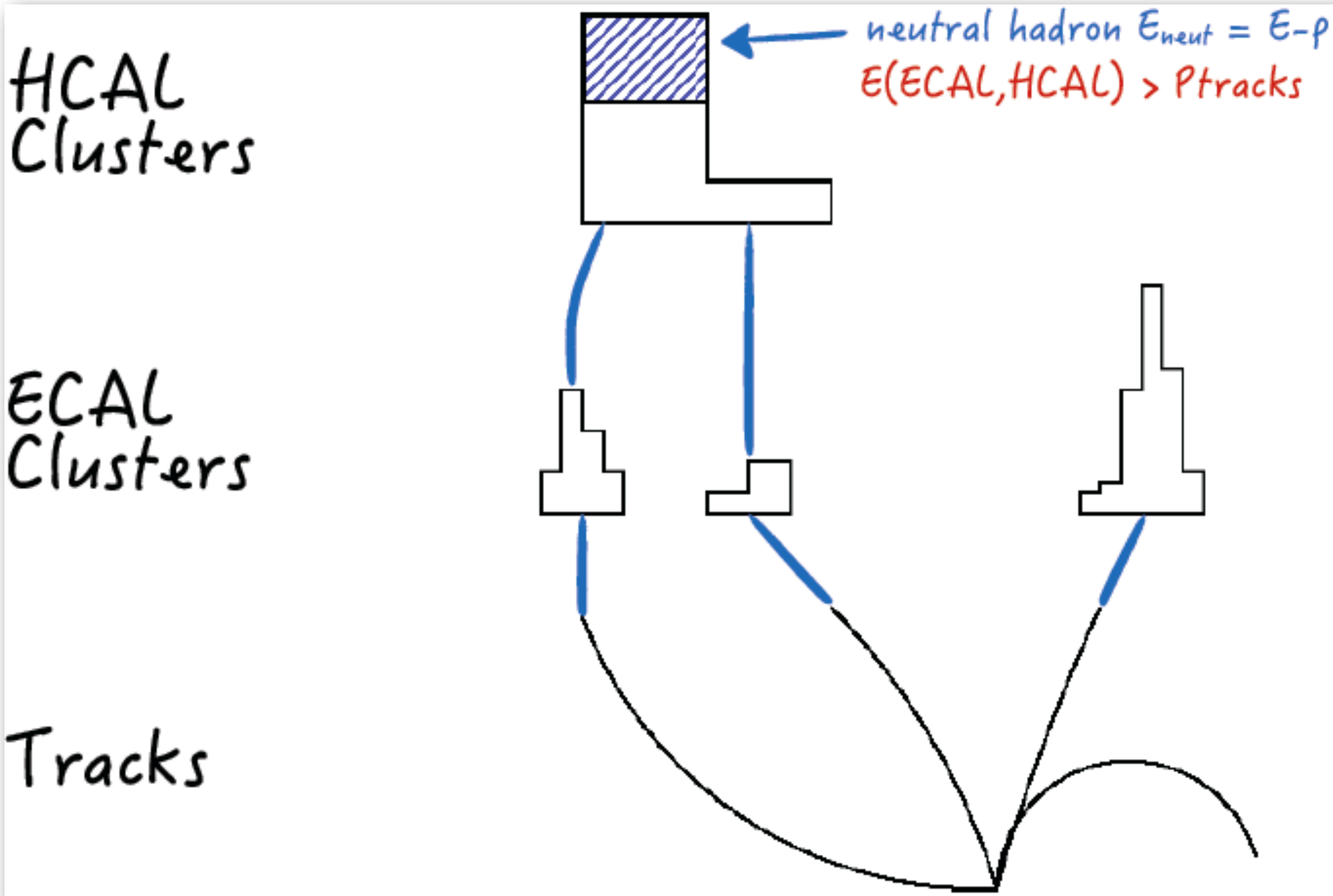
Particle Flow Algorithm



Particle Flow Algorithm



Particle Flow Algorithm



Pileup Subtraction Motivation

- **Motivation:**
  - Extracting the precise information from the final states in the presence of pileup is difficult and confounded by ambient energy resulting from other collisions that were not detected within the tracker.
  - This extra energy must be accounted for when attempting lepton isolation
- **Difficulty:**
  - With O(20) pp interactions per event, we can distinguish charged particles to separate vertices, however, neutral particles may not be constructed this way since calorimeters do not have the angular resolution to reconstruct the original vertex of interaction
  - Kinematic measurements for the leptons are affected by the pileup and resolution is reduced

Pileup Subtraction Algorithm

- **Basic algorithm for each Event:**

  I) Subtract the tracks not associated with the Primary Vertex. The beams at the LHC have a longitudinal spread, so we may associate each charged particle with a distinct primary vertex that corresponds to a single *pp* interaction.

  II) Subtract the calorimeter deposits in the ECAL and HCAL, associated with the tracks.

  III) The remaining calorimeter energy is then estimated per unit area and calculated via the following formula

$$\rho = \text{median}\left[\left\{\frac{p_{tj}}{A_j}\right\}\right]$$

  where ρ is the level of diffuse noise, the amount of transverse momentum added to the event per unit area, p_{tj} is the measured momenta of the j^{th} lepton and A_j is the area of the cone size for lepton j

  With this, we may deduct $A_j\rho$ to arrive at a modified transverse momentum

$$p_{tj}^{(\text{sub})} = p_{tj} - A_j\rho$$

Sources

- http://www.t2.ucsd.edu/twiki2/pub/UCSDTier2/AnalysisTutorial/AN2012_067_v6.pdf
- http://cds.cern.ch/record/922757/files/lhcc-2006-001.pdf
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