Calorimeter reconstruction

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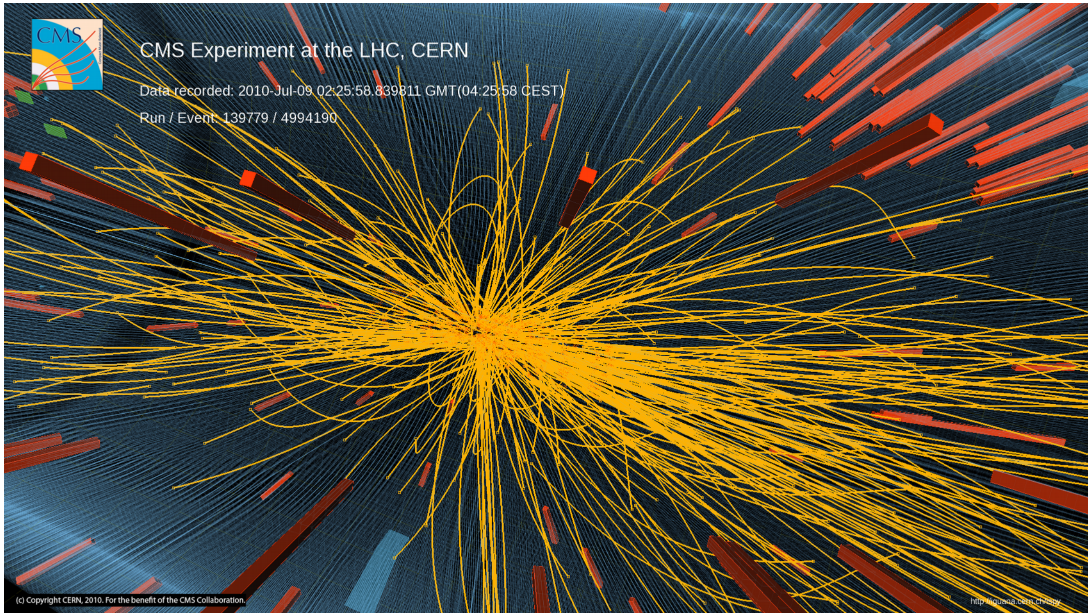
Outline

- Collisions at LHC
- Detectors and particle propagation
- Calorimeters
- Electromagnetic showers
- Jets
- Jet clustering algorithms

A collision at LHC

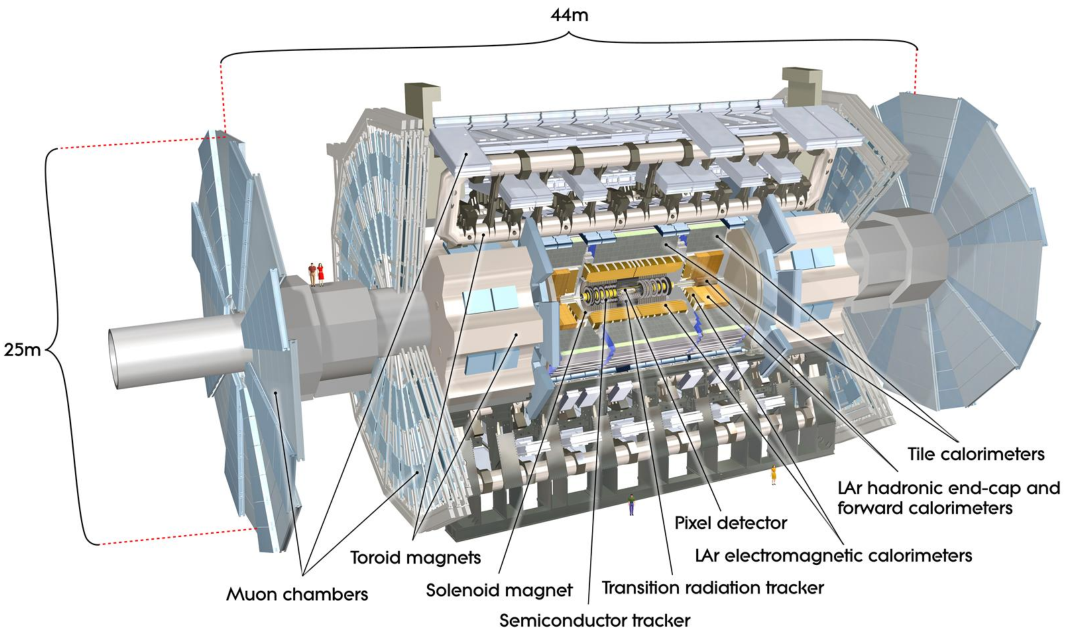
- A collision at the LHC is messy with a lot of particles shooting out
- We are interested in studying these particles and understanding the underlying physics
- In order to do this, we surround the interaction point with a detector that is capable of measuring and differentiating between different particles as best as we can



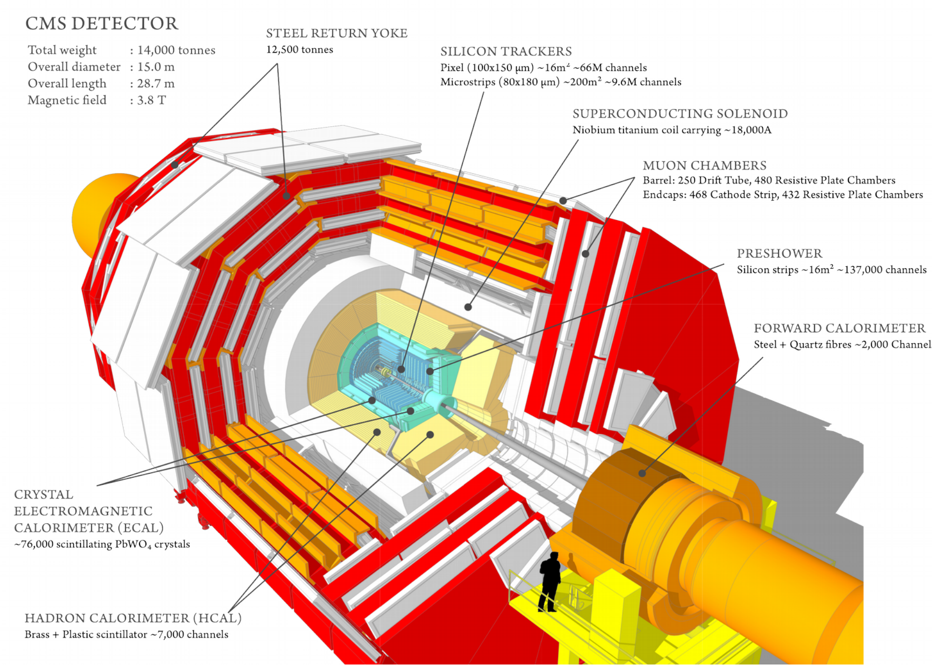
Detectors

- We will focus on ATLAS and CMS, which are the two multi-purpose detectors at LHC.

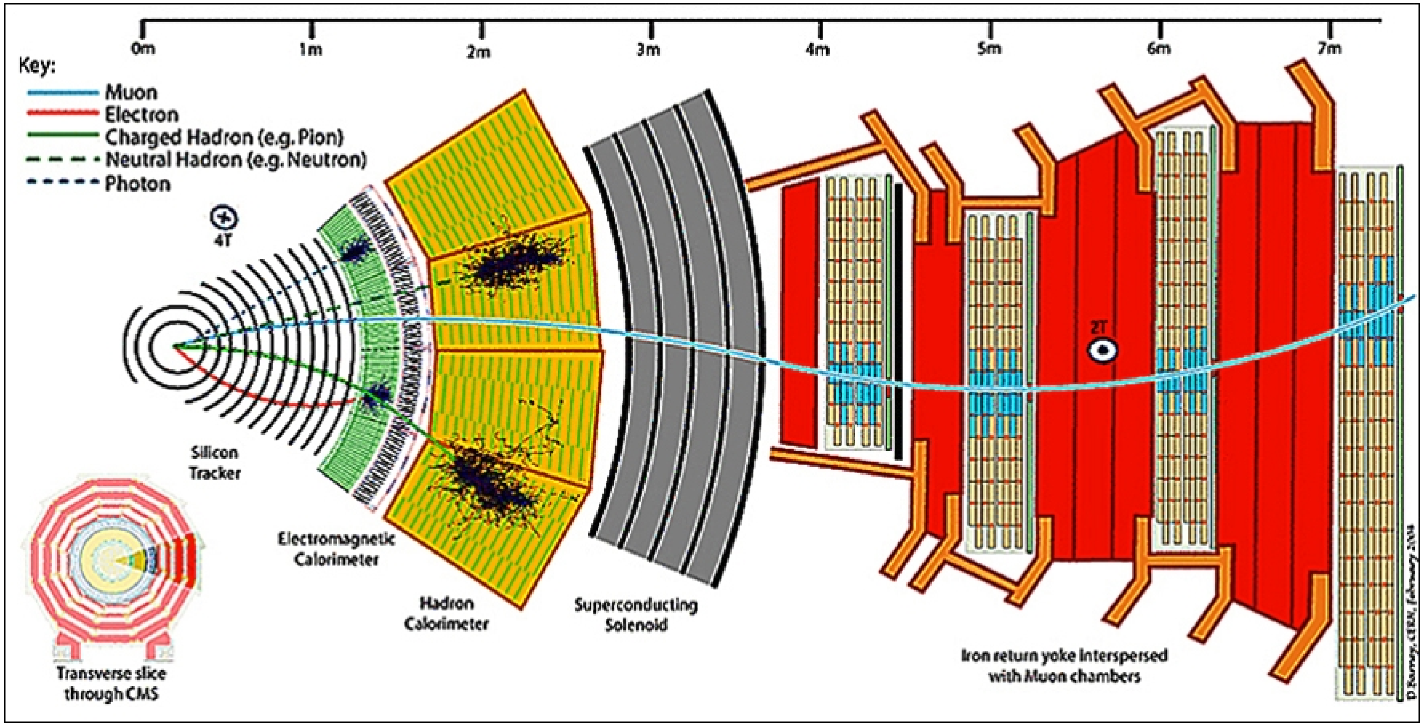
ATLAS



CMS



Particle propagation



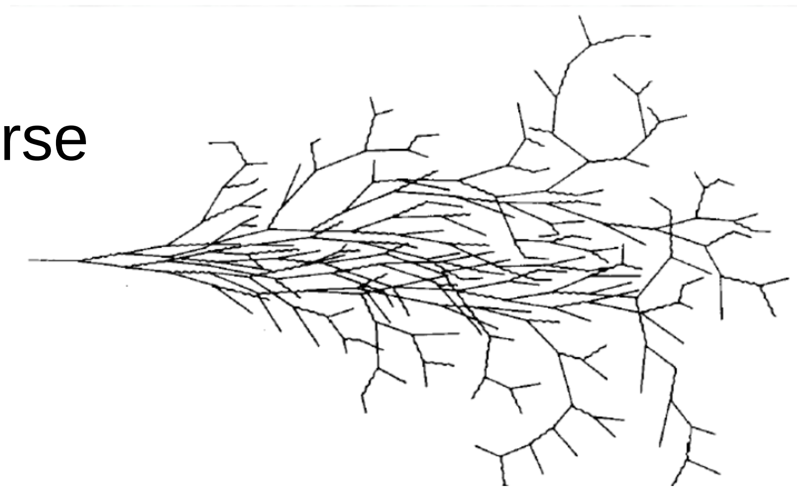
- Tracker measures the momentum of the charged particles (more on them in Patrick's presentation)
- Calorimeters measure the energy deposits
- These detectors act complimentary to each other

Calorimeters

- Energy is measured by total absorption and usually combined with spatial information (reconstruction)
- When a particle (jet) propagates through a material, it looses energy via bremsstrahlung, photon pair production, ionization, etc.
- We are interested in particles like electrons, photons and also hadrons like pions, kaons and also jets (a group of hadrons).

Electromagnetic calorimeter

- Electrons and photons loose energy by the creation of electromagnetic showers (bremsstrahlung and photon pair production)
- The characteristic interaction distance for an EM interaction depends is the radiation length X_0 and is dependent on the material
- At high energies, bremsstrahlung and photon pair production dominate and as energy falls below a critical energy, ionization dominates and eventually leads to the particle being stopped in the detector
- This results in longitudinal an transverse showers in the electromagnetic calorimeter



Calorimeter types

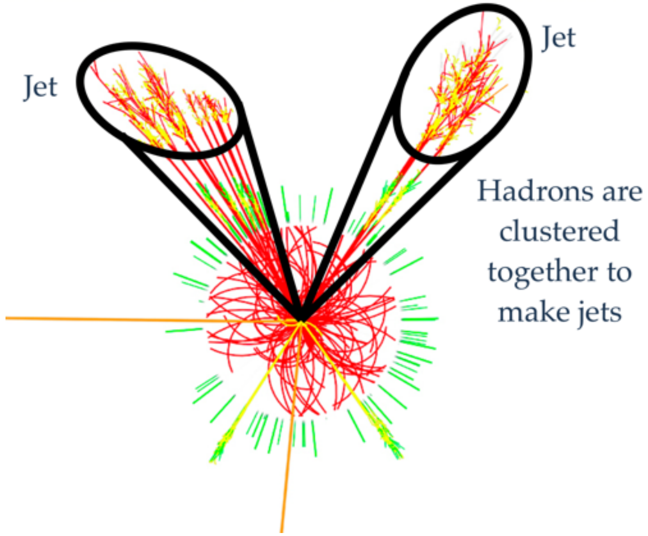
- Two types of calorimeters:
  - *Homogeneous calorimeter*
    - Entire volume is sensitive.
    - May be built with heavy scintillating crystals or non-scintillating Cherenkov radiators.

      Example: CMS electromagnetic calorimeter ($PbWO_4$)
  - *Sampling calorimeter*
    - Metallic absorber sandwiched with an active medium.
    - The active medium may be a scintillator, ionizing noble liquid, gas chamber, semiconductor or a Cherenkov radiator

      Example: ATLAS electromagnetic calorimeter (LAr with lead absorbers)

Jets

- Quarks can radiate gluons and gluons can generate quark-anti quark pairs in addition to radiating more gluons
- Due to color confinement, these should combine to form colorless hadrons
- Gluon radiation is dominant in the direction of initial parton
- This results in a bunch of hadrons traveling in roughly same direction
- As these hadrons are heavier, they reach the hadronic calorimeter
- You will end up getting a bunch of energy deposits nearby in the calorimeter that you can combine to form jets

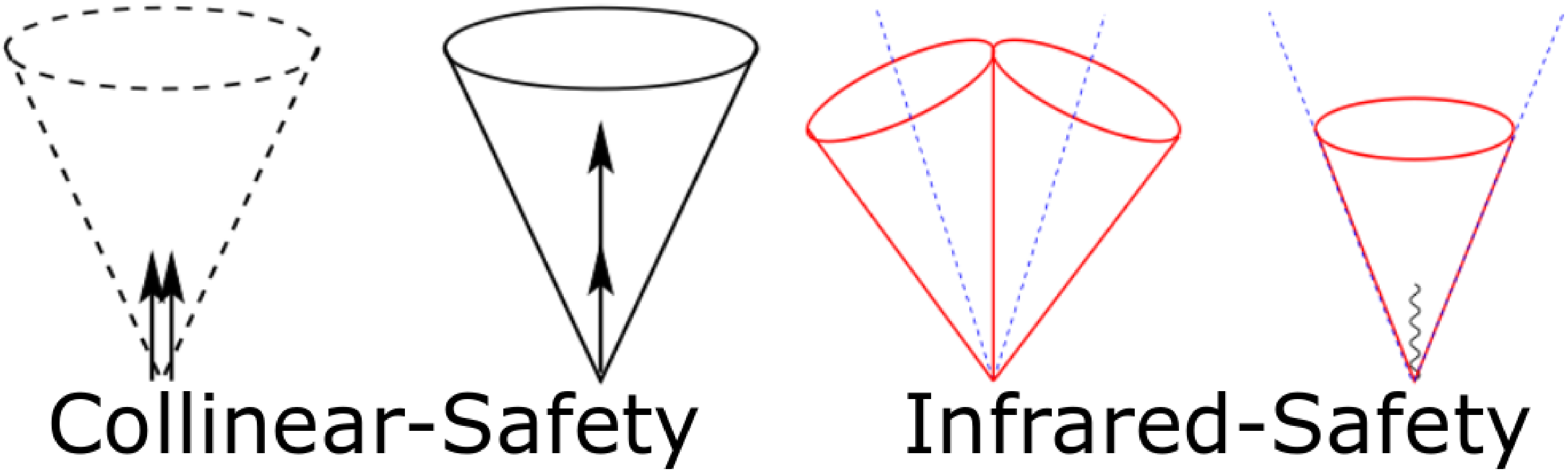


Hits → Jets

- After a collision, you get a bunch of hits in the calorimeter that you need to combine to form jets
- At low energy experiments, it was easier to group the hits by eye balling
- However, at hadron colliders, we need sophisticated algorithms to cluster a bunch of hits together
- You can cluster hits based on the geometry ie. the angular separation or their energy deposits
- Lets look at a few jet clustering algorithms

A good jet algorithm

- Insensitive to pile up and underlying events
- Collinear and infrared safe
- Fast



k_T algorithm

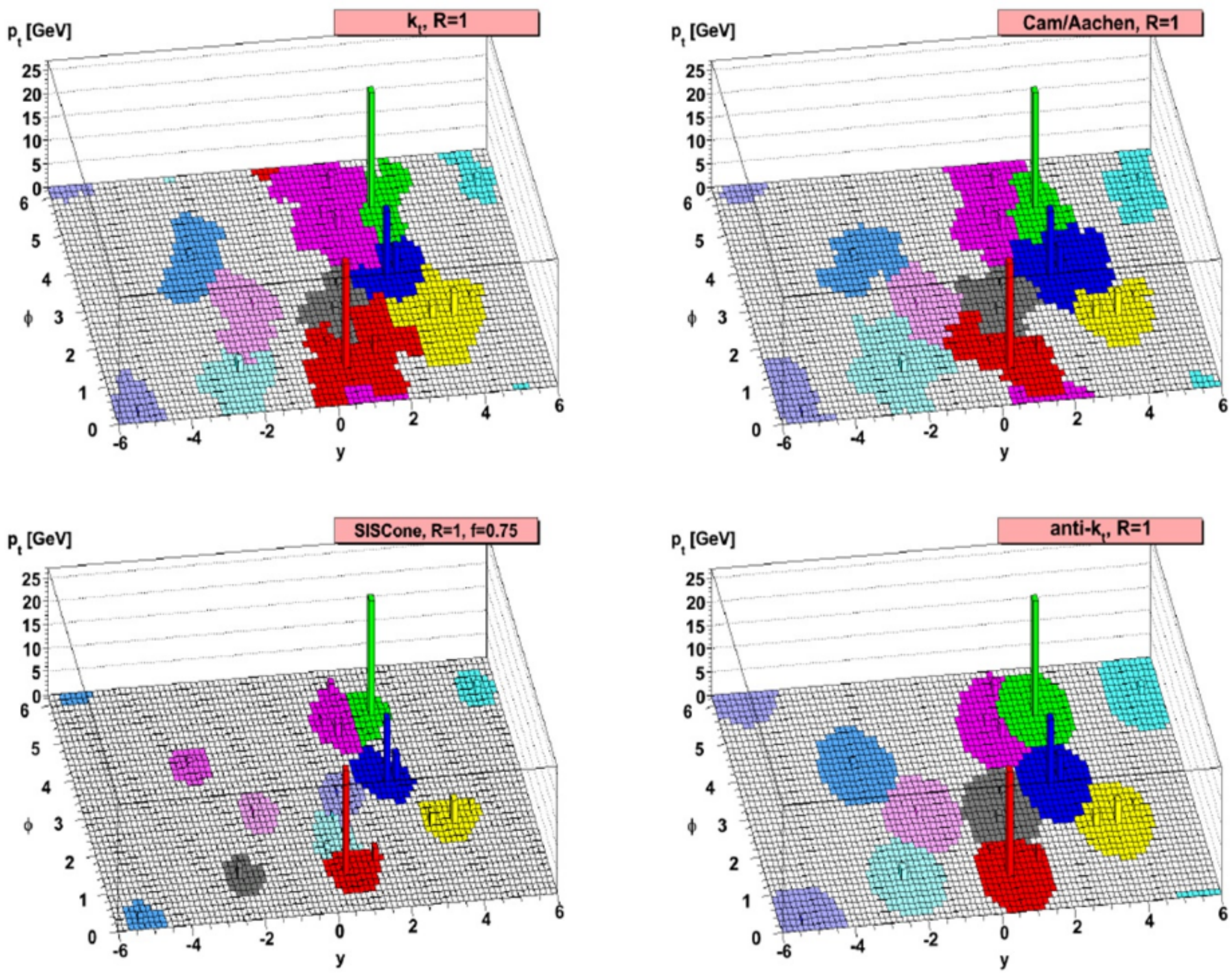
- Metric used for combination: $M_{ij}^2 = 2 \min(E_i^2, E_j^2)(1-\cos\theta_{ij})$
- It is a sequential recombination algorithm: Combine particles starting from closest ones and iterate the combination until no particles are left
- Use the above metric to calculate distance between different hits and combine the two with the least distance (if its below a fixed cut) and continue to do this until all hits are exhausted.
- Here, we start by combining the hits with lowest energy deposits
- As a result, the algorithm is susceptible to underlying event and pile up

Anti-k_T algorithm

- Metric: $D_{ij} = \min\left(E_i^{-2}, E_j^{-2}\right) \frac{R_{ij}}{D}$
- This is also a sequential clustering algorithm
- Here, we start by combining hits with the highest energy deposits rather than softest as was done in k_T algorithm
- This algorithm is hence not sensitive to underlying events and pile up

Other algorithms

- SIS-cone (purely cone based algorithm)
- Cambridge/Aachen (purely spatial but very good to study jet substructure)
- Comparison:



Summary

- Energy measurement is very important to study s the physics in a collision event.
- Clustering of energy deposits to obtain jets and particles is non trivial and a complicated procedure
- There are many details to jet clustering not discussed here
- These days we have tools to study the jet substructure in detail

References

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