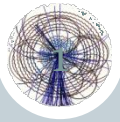
Particle Flow Event Reconstruction



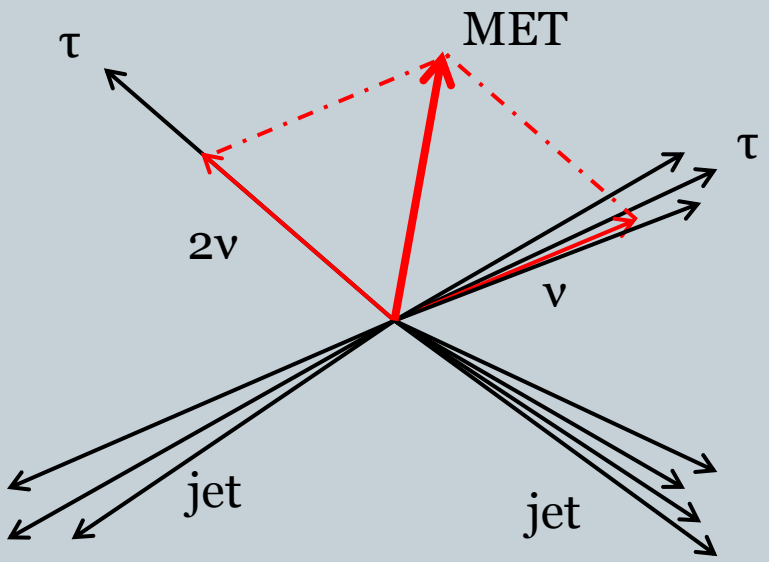
MARTYN JARVIS

Introduction

- Example Higgs analyses
- What is particle flow?
- How does it work?
- Example reconstruction of an event
- Performance
- Commissioning of the algorithm

Motivation

- Example Analysis:
- H→ττ
- For a good analysis we need:
  - Missing transverse energy measurement
  - Jet reconstruction
  - Tau reconstruction



Motivation

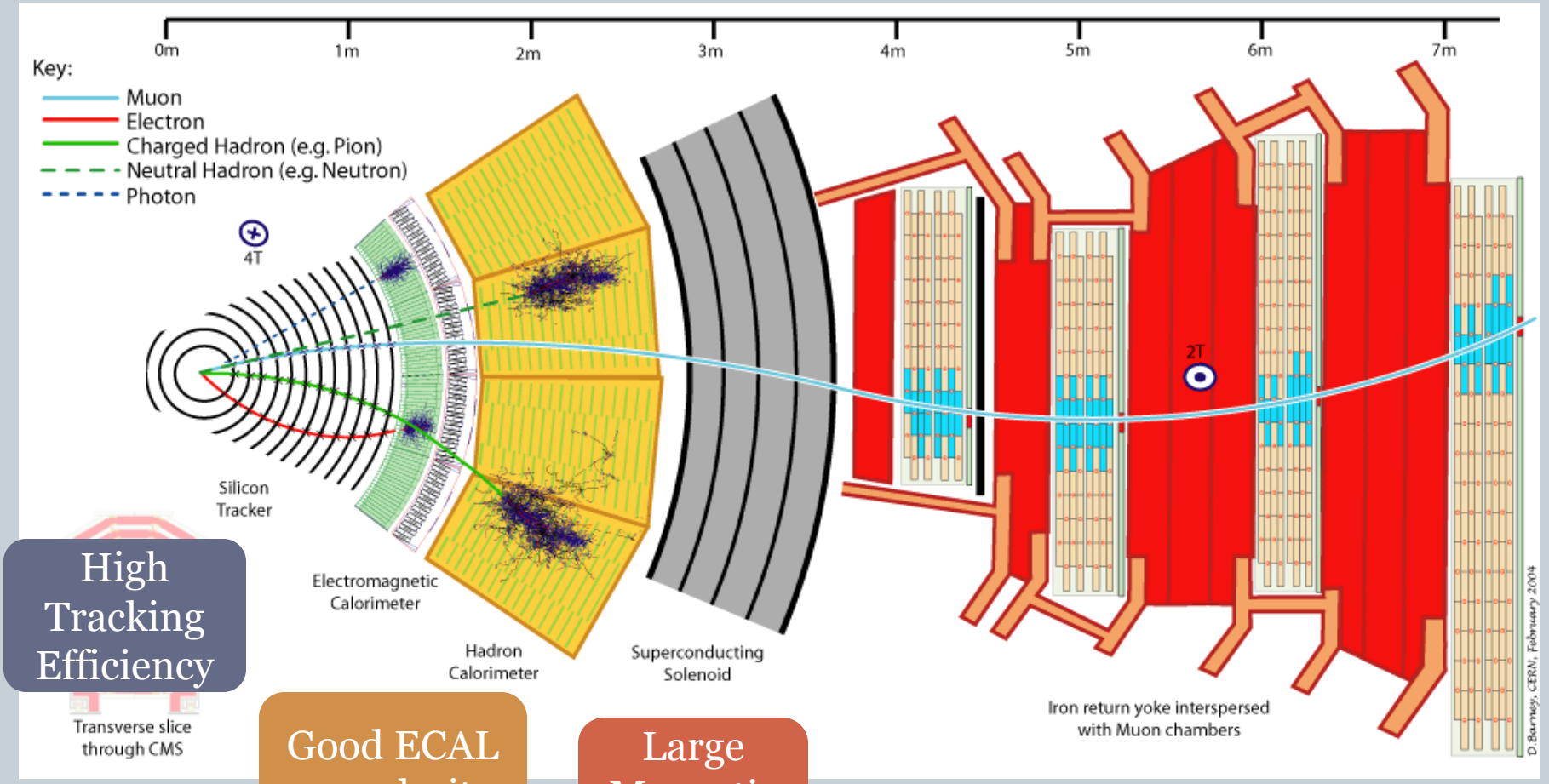
- In general, signatures of New Physics appear in final states containing:
  - Charged leptons including hadronic taus
  - High P_T jets
  - b-quarks
  - Missing transverse energy due to weakly interacting neutral particles.

- To study these signatures need a method to reconstruct and identify all particles in events as accurately as possible.
- Particle Flow techniques…

What is Particle Flow?

- Attempt to reconstruct all stable particles in an event.
  - Photons, charged and neutral hadrons, electrons, muons.
- Information from sub-detectors is combined in best possible way.
- List of particles is returned, as if it came from a MC generator.
- Higher level physics objects can be built from list of particles.
  - hadronic taus
  - jets
  - b-tagged jets
  - Missing transverse energy

CMS detector

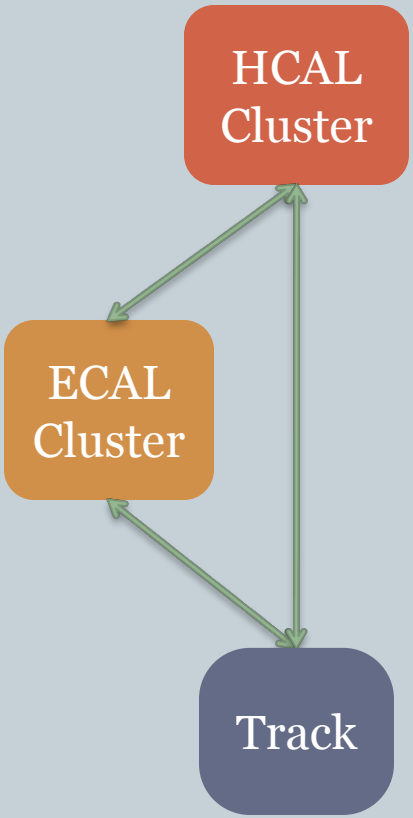


High Tracking Efficiency

Good ECAL granularity

Large Magnetic Field

Overview of Particle Flow

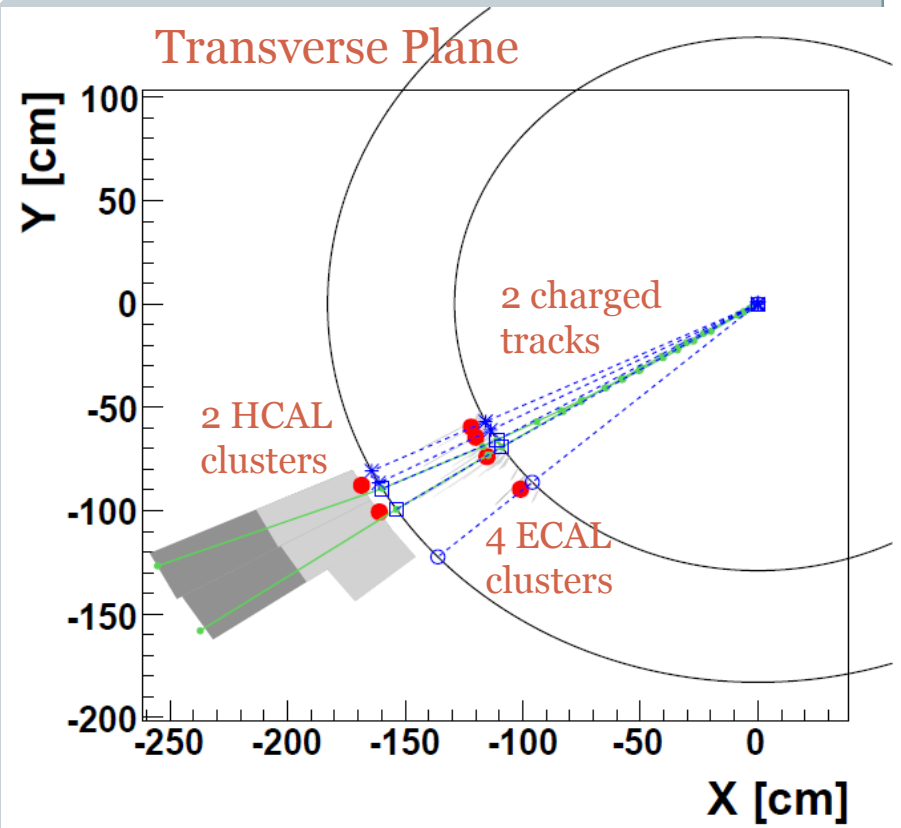


Charged hadron block

- Reconstruct elements.
  - Charged tracks, energy deposits in calo, muon tracks
- Link elements to blocks.
- Blocks interpreted as particles.
  - Example: charged hadron

- Higher level physics objects are built from particles
- Physics analyses…

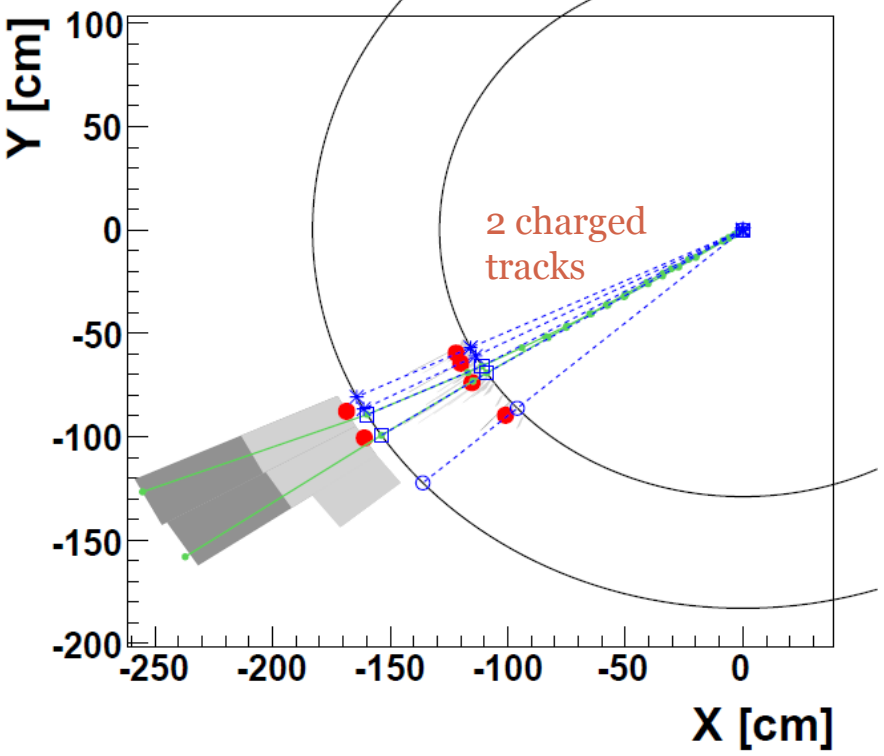
Particle Flow Elements



$$(\pi^+, \pi^-, \pi^0, \mathrm{K}^0_\mathrm{L})$$

Particle Flow Elements

Transverse Plane



Track

Track

$$(\pi^+, \pi^-, \pi^0, \mathrm{K}^0_\mathrm{L})$$

Particle Flow Elements

ECAL Cluster

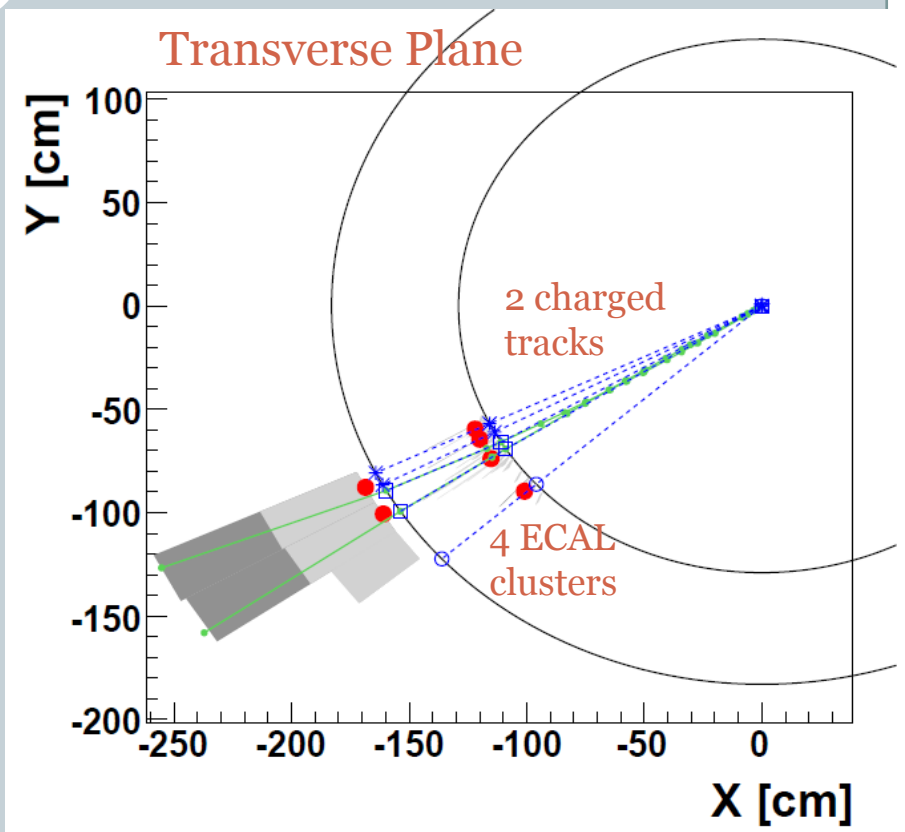
ECAL Cluster

ECAL Cluster

ECAL Cluster

Track

Track



$$(\pi^+, \pi^-, \pi^0, K_L^0)$$

Particle Flow Elements

HCAL Cluster

HCAL Cluster

ECAL Cluster

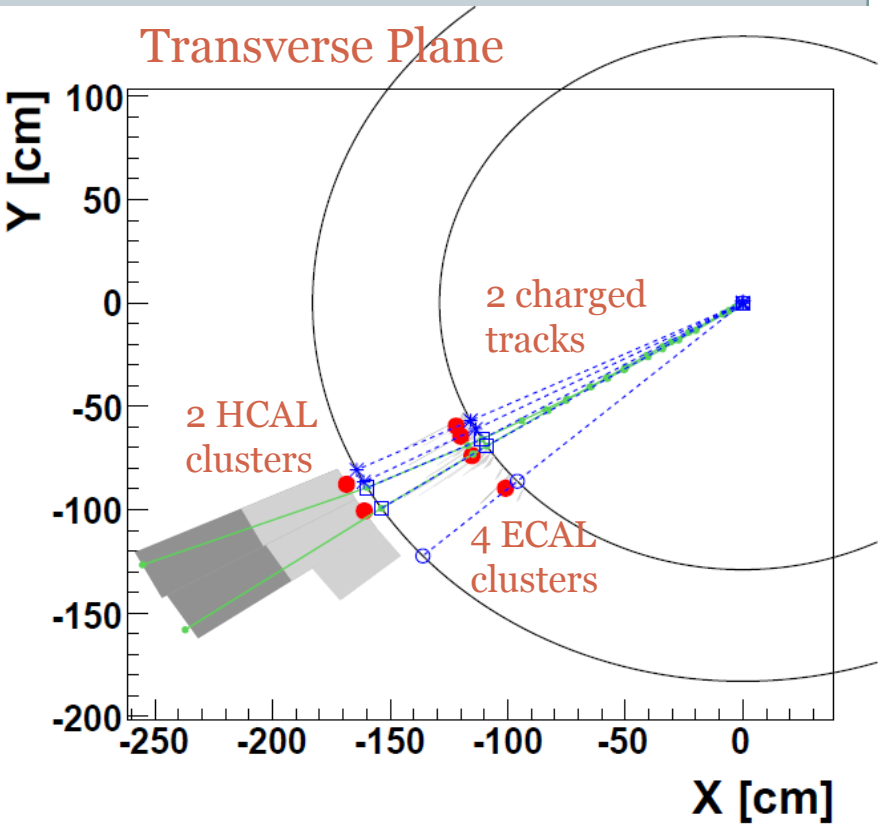
ECAL Cluster

ECAL Cluster

ECAL Cluster

Track

Track



$$(\pi^+, \pi^-, \pi^0, K_L^0)$$

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Linking Algorithm: Track-ECAL clusters

HCAL Cluster

HCAL Cluster

ECAL Cluster

ECAL Cluster

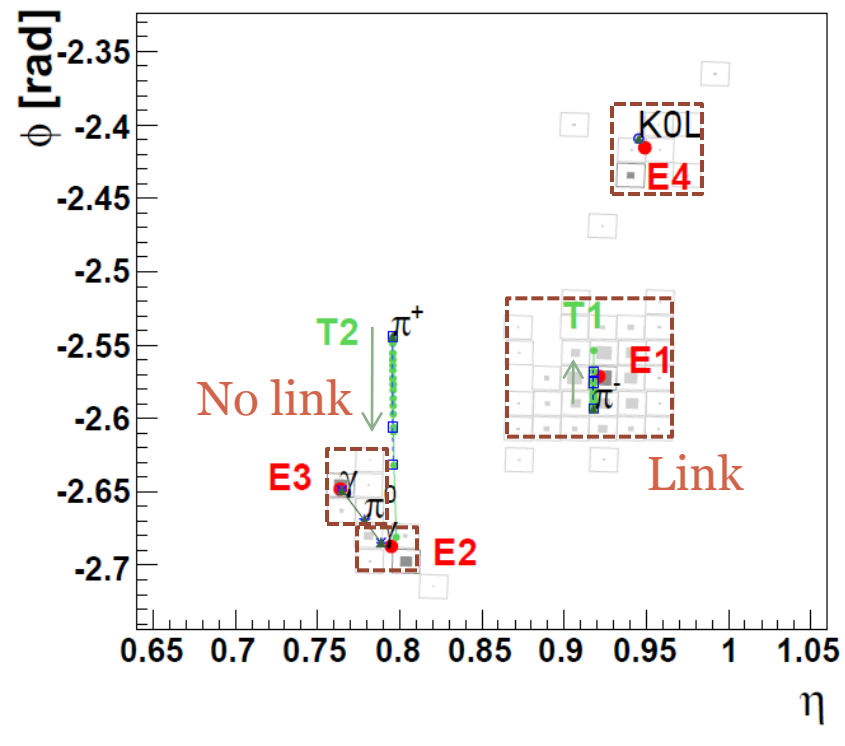
ECAL Cluster

ECAL Cluster

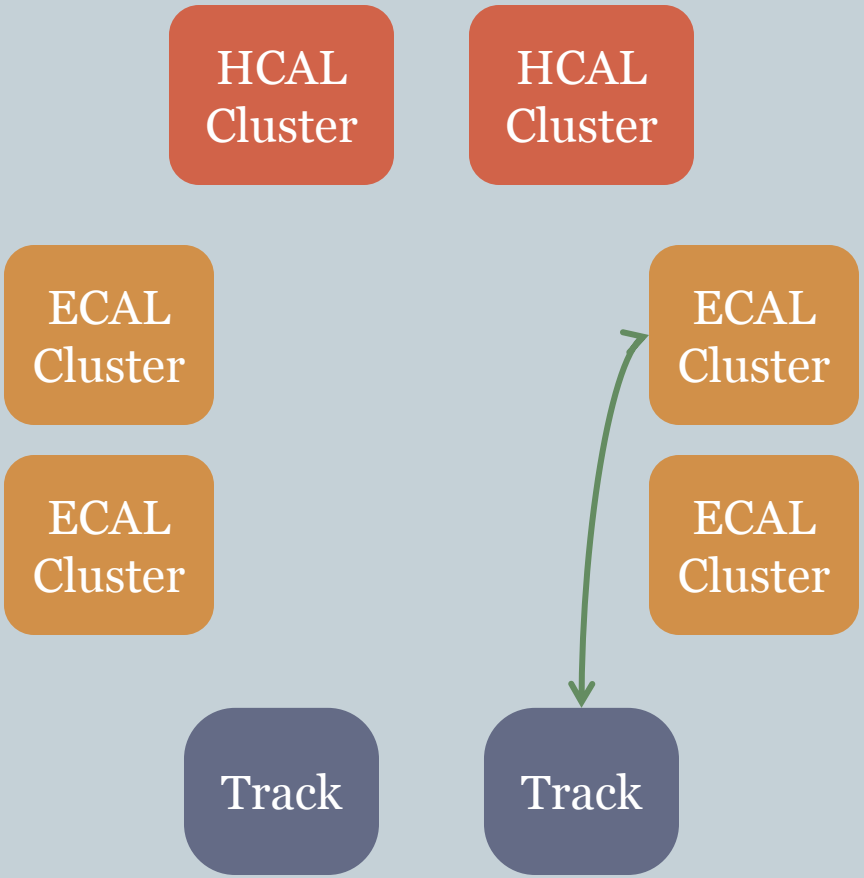
Track

Track

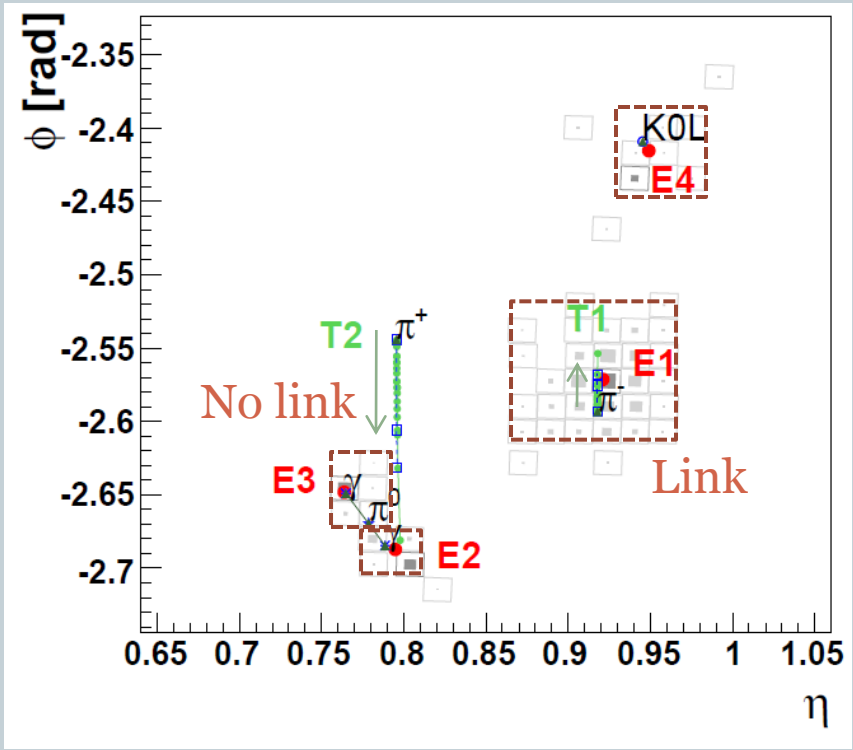
ECAL, (η,φ) plane



Linking Algorithm: Track-ECAL clusters



ECAL, (η,φ) plane



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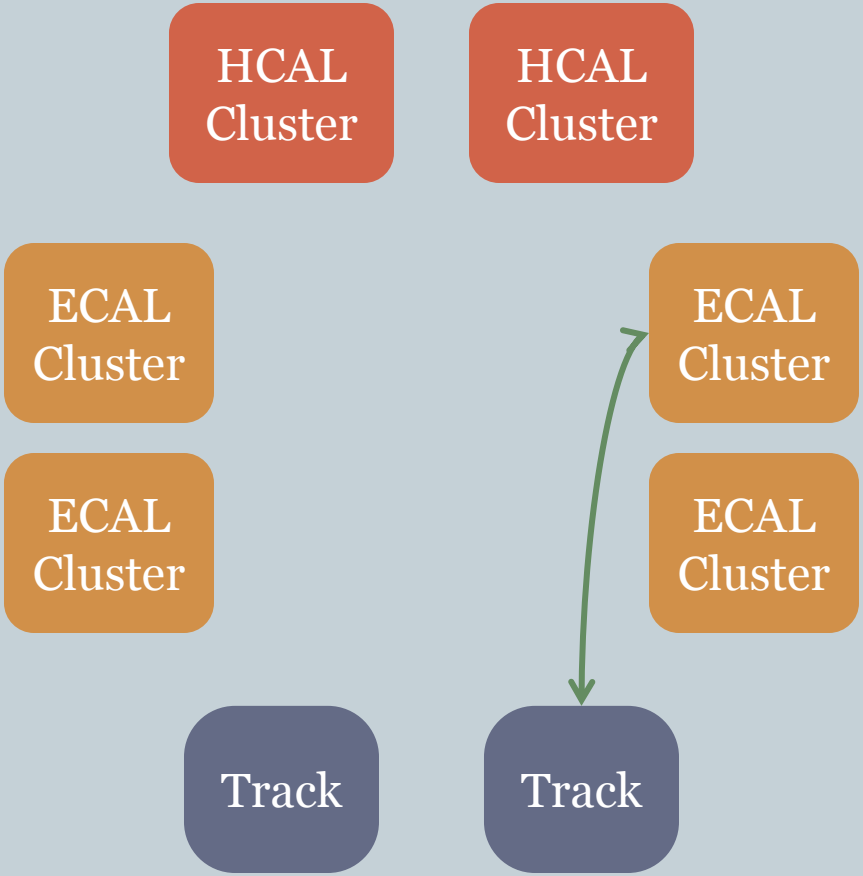
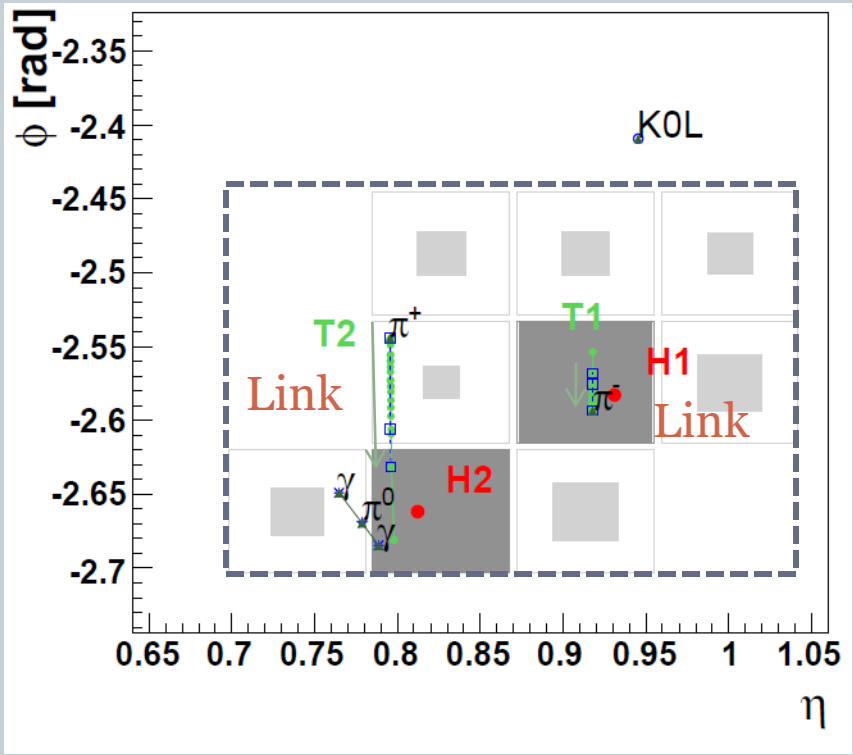
Linking Algorithm: Track-HCAL clusters



HCAL, (η,φ) plane



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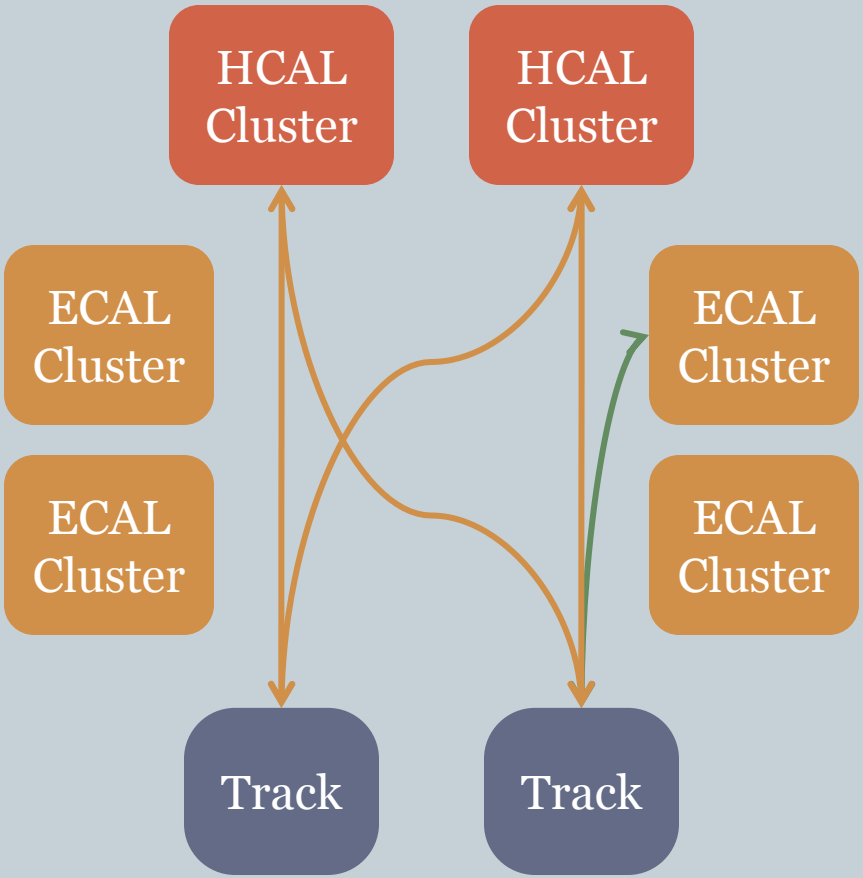
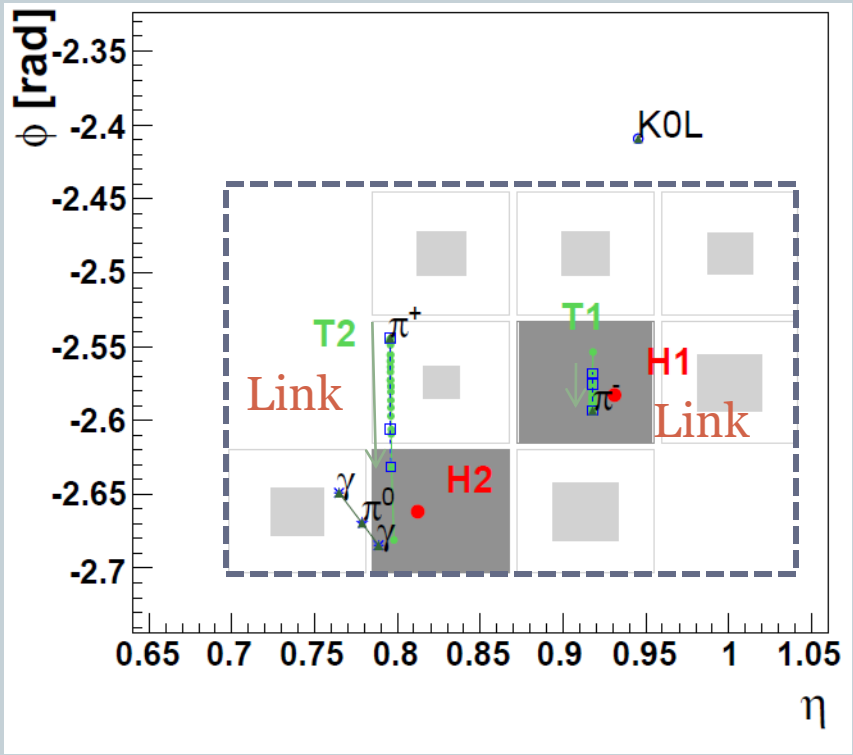
Linking Algorithm: Track-HCAL clusters



HCAL, (η,φ) plane



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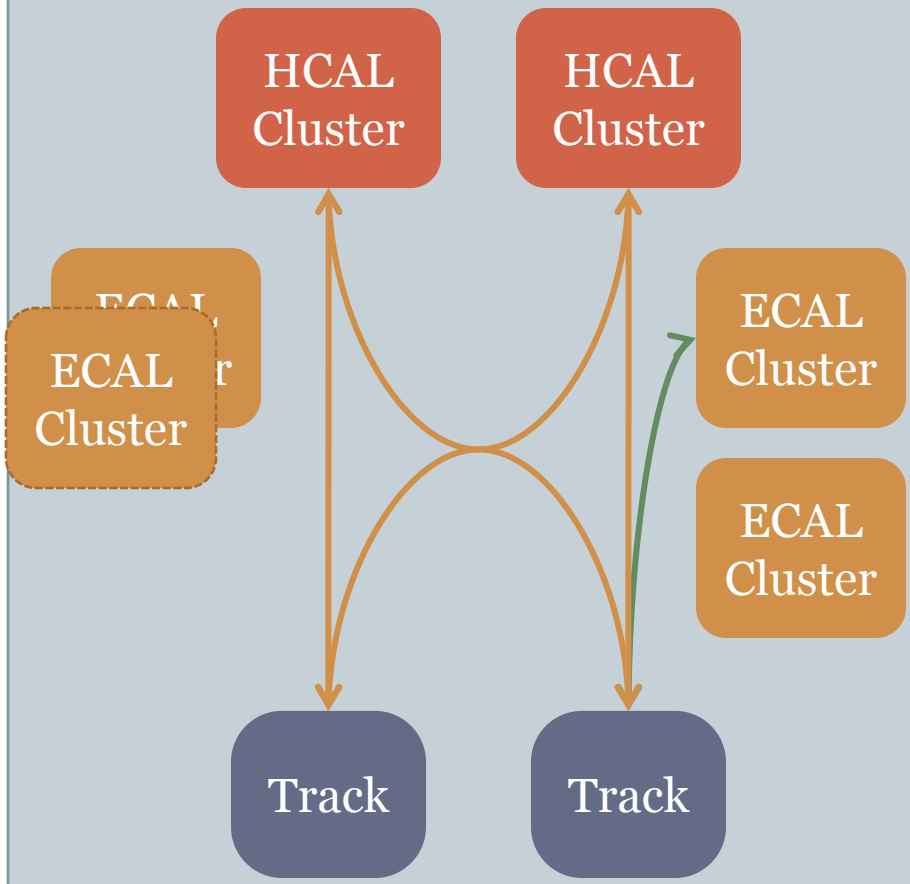
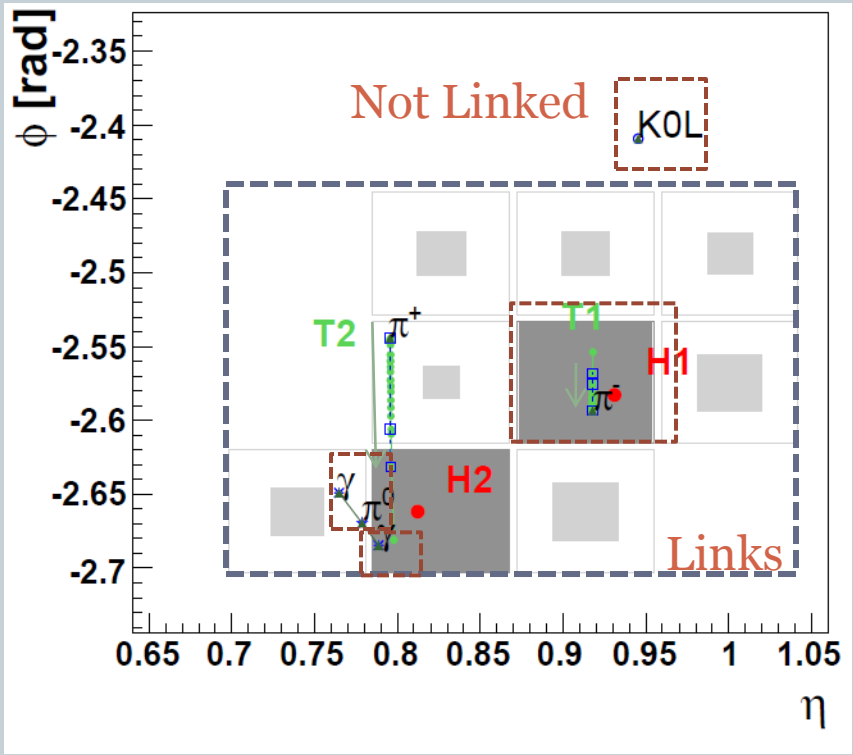
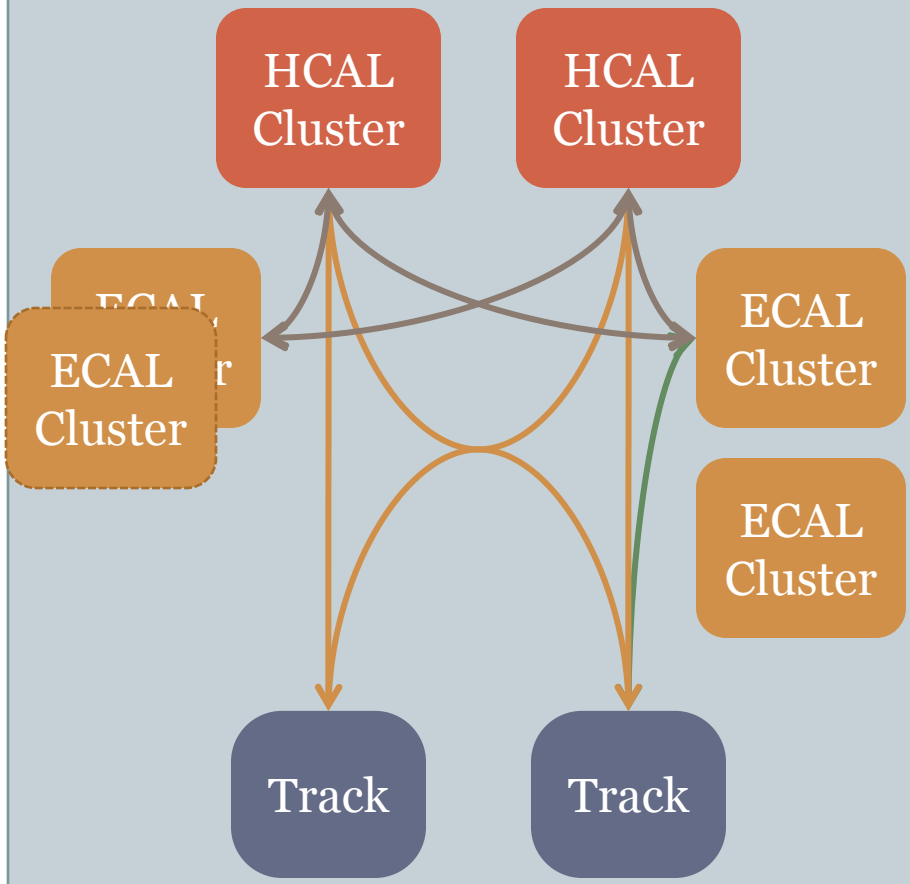
Linking Algorithm: HCAL-ECAL clusters



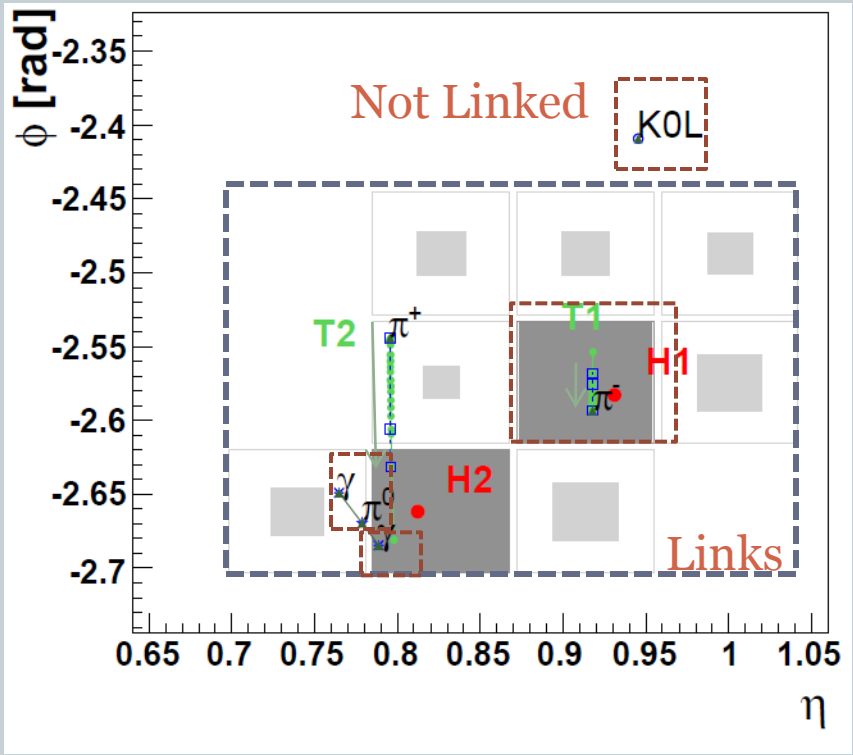
HCAL, (η,φ) plane



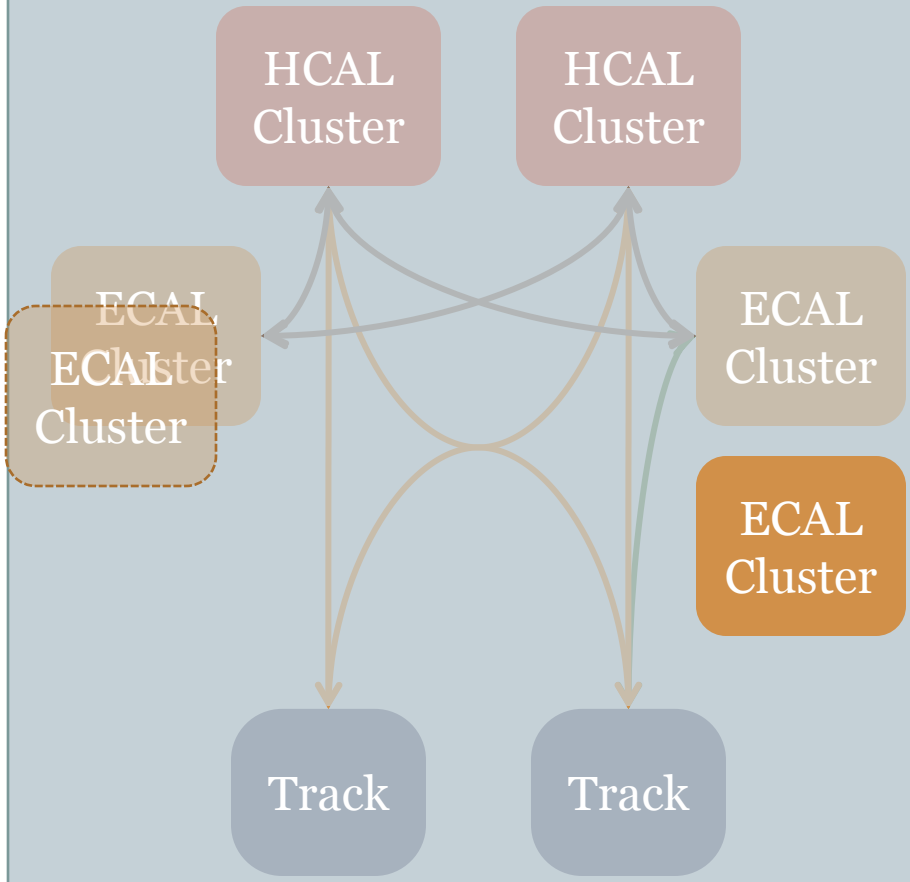
Linking Algorithm: HCAL-ECAL clusters



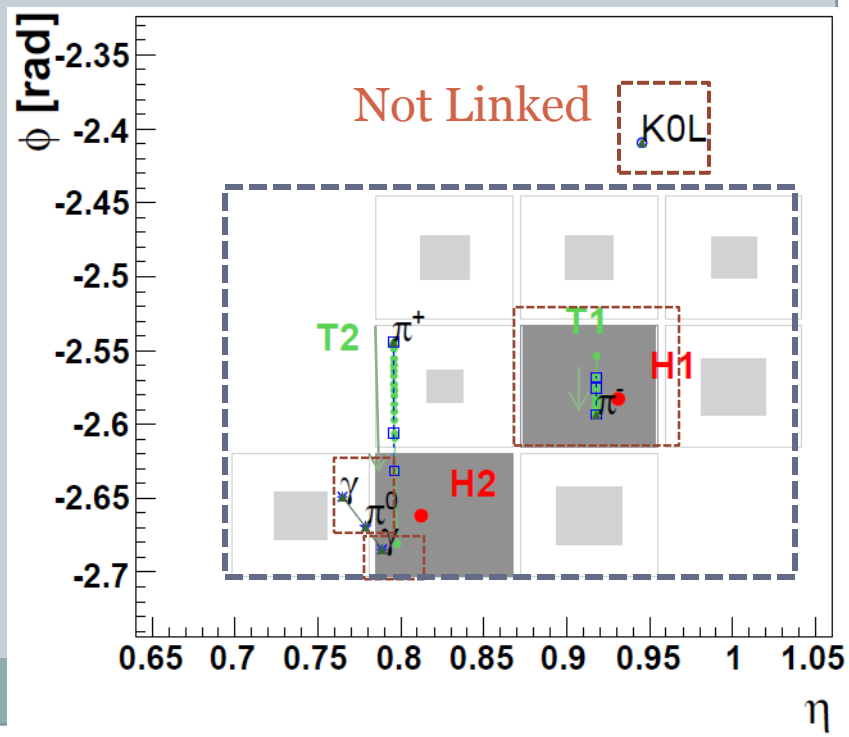
HCAL, (η,φ) plane



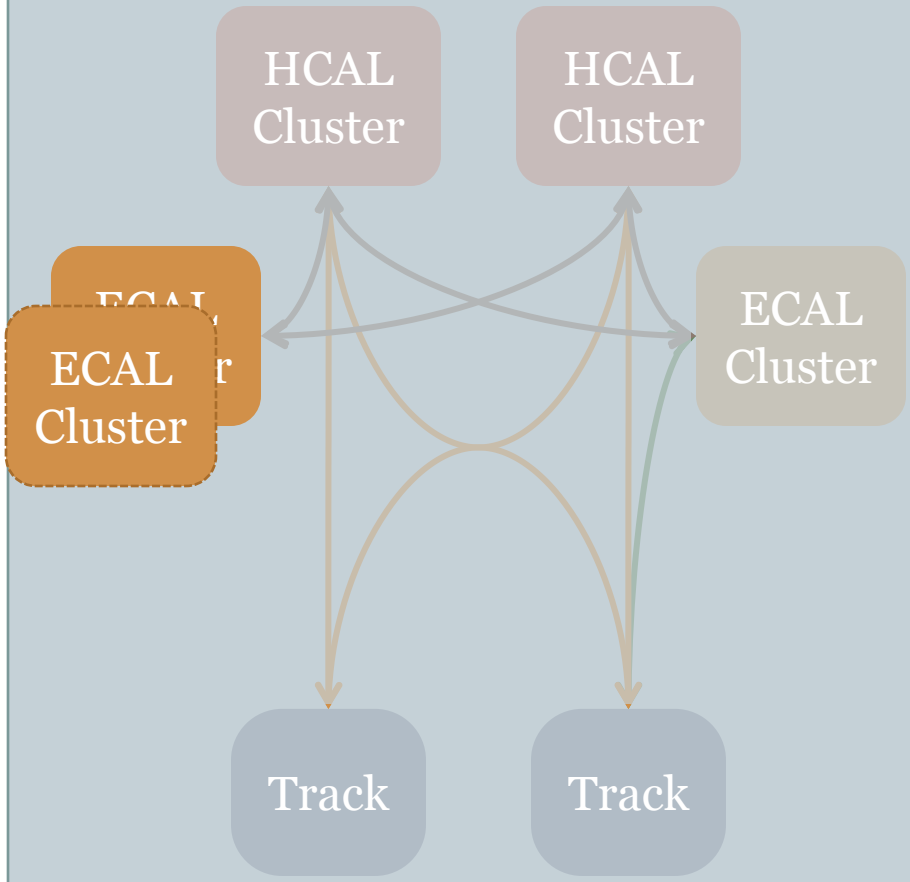
Particle Identification



- Two Blocks
- Lone deposit in ECAL interpreted as a photon.
- Block is removed.

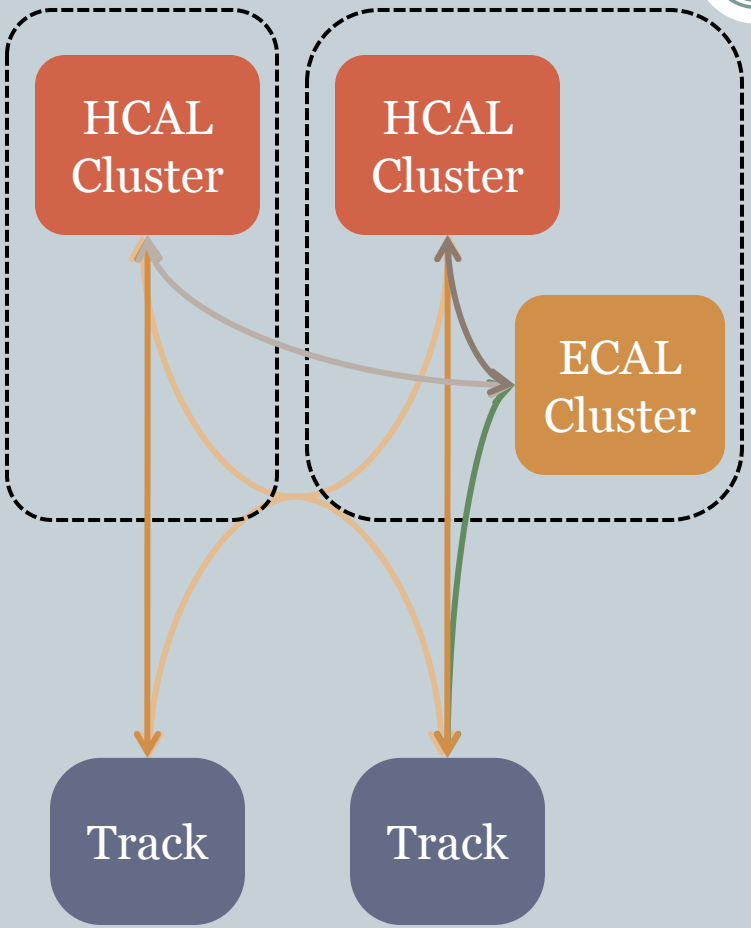


Particle Identification



- Two ECAL clusters without tracks
- Interpreted as two more photons.
- Elements are removed from the block.

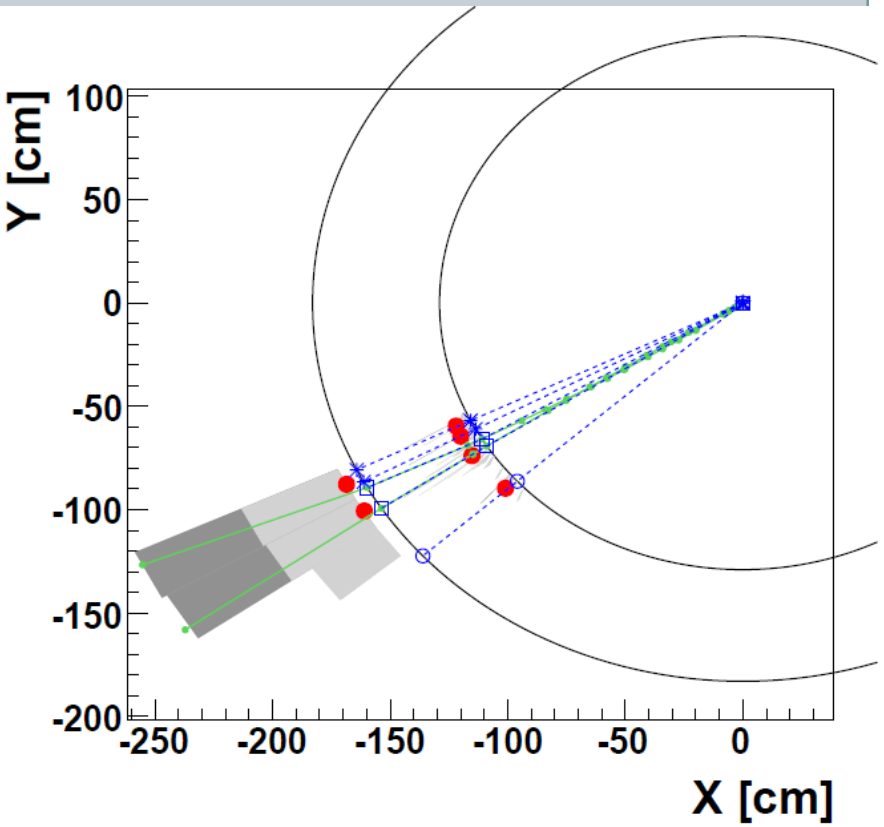
Particle Identification



- Closest links are kept.
- Energy (E) in calorimeters calculated.
  - HCAL + ECAL
- Track momentum (P) calculated
- If $E>P+\sigma_{calo}$
  - Charged Hadrons
  - Excess energy assigned to:
    - Neutral hadrons (excess HCAL)
    - Photons (ECAL)
- Else if $E<P+\sigma_{calo}$
  - Look for mis-measured tracks or more muons.

Particle Identification

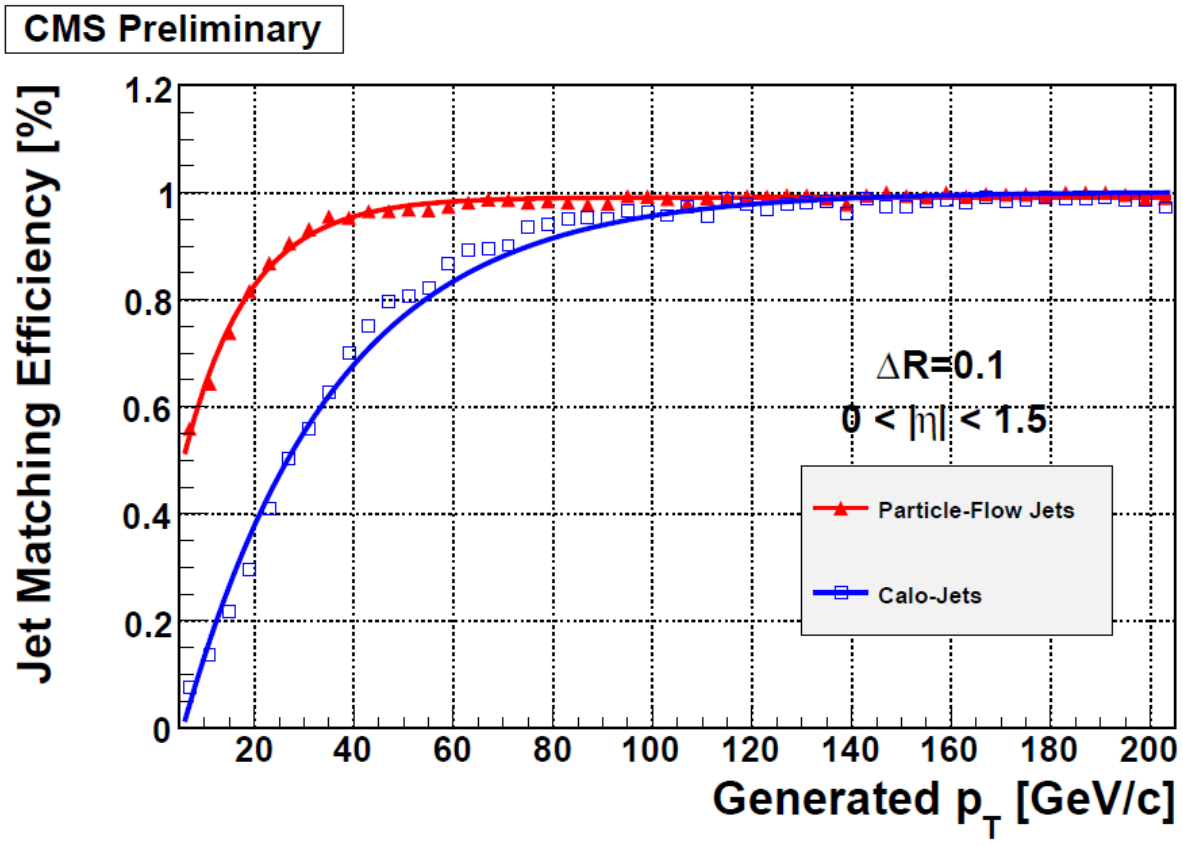
- List of particles is returned from the PFA.
  - Two oppositely charged hadrons ($\pi^-\pi^+$)
  - Two photons (π^0)
  - Additional photon (K_L^0)
- This list of particles can be passed to a jet clustering algorithm
- Energy of charged particles is measured more accurately.
  - Measurement of the jet energy will therefore be more accurate



$$(\pi^+, \pi^-, \pi^0, K_L^0)$$

Performance with Jets

- MC full sim
- Iterative cone algorithm
- Barrel Region
- Matching distance of 0.1



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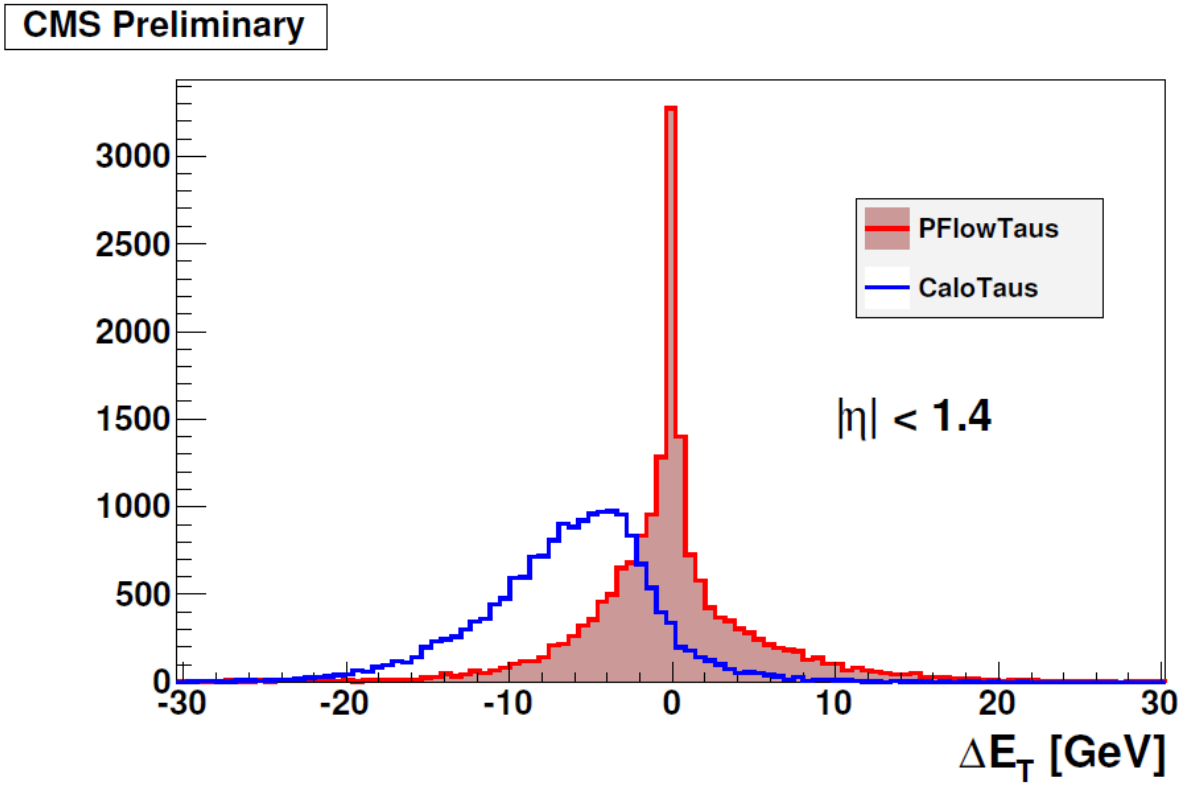
Performance with Taus

- MC full sim Ztautau
- Barrel region
- Accurate measurement of energy and good resolution
- End caps not so good...
- Tau direction measurement also benefits from PF



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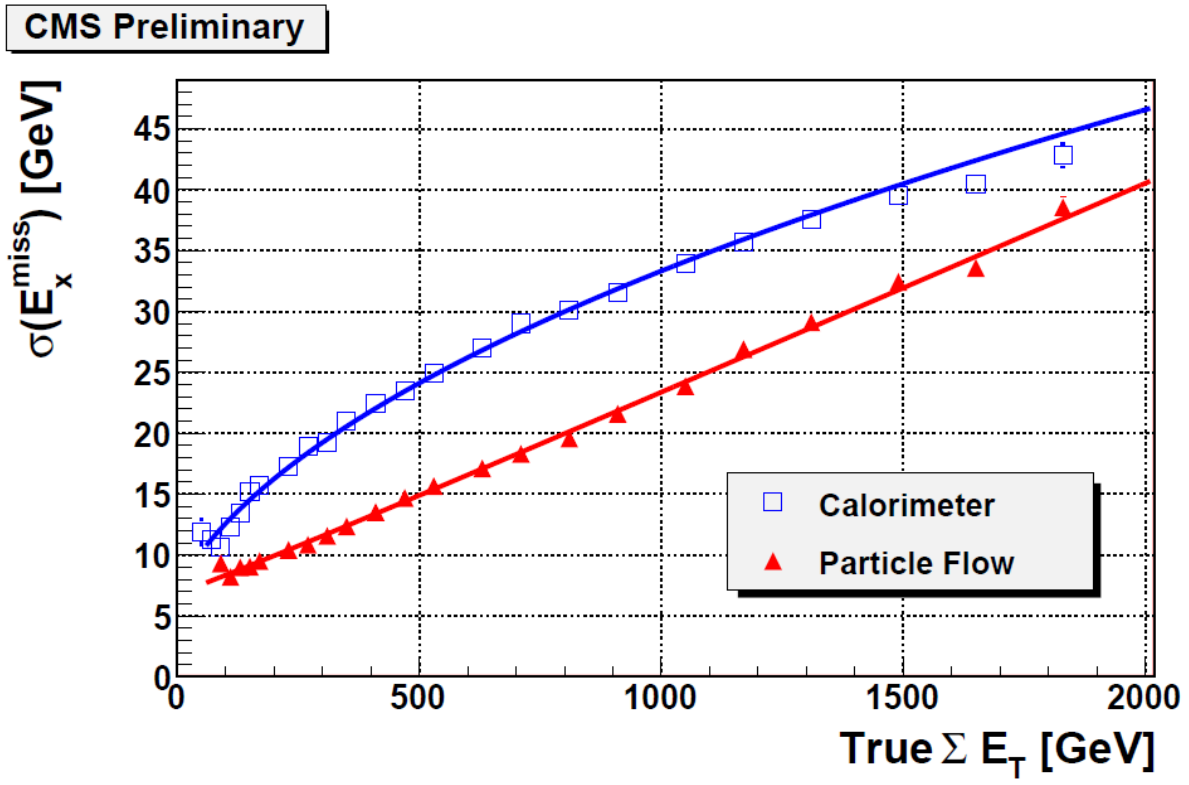
Performance with Missing Energy

- Data sample used should have zero missing energy.
- PF provides a better resolution of MET



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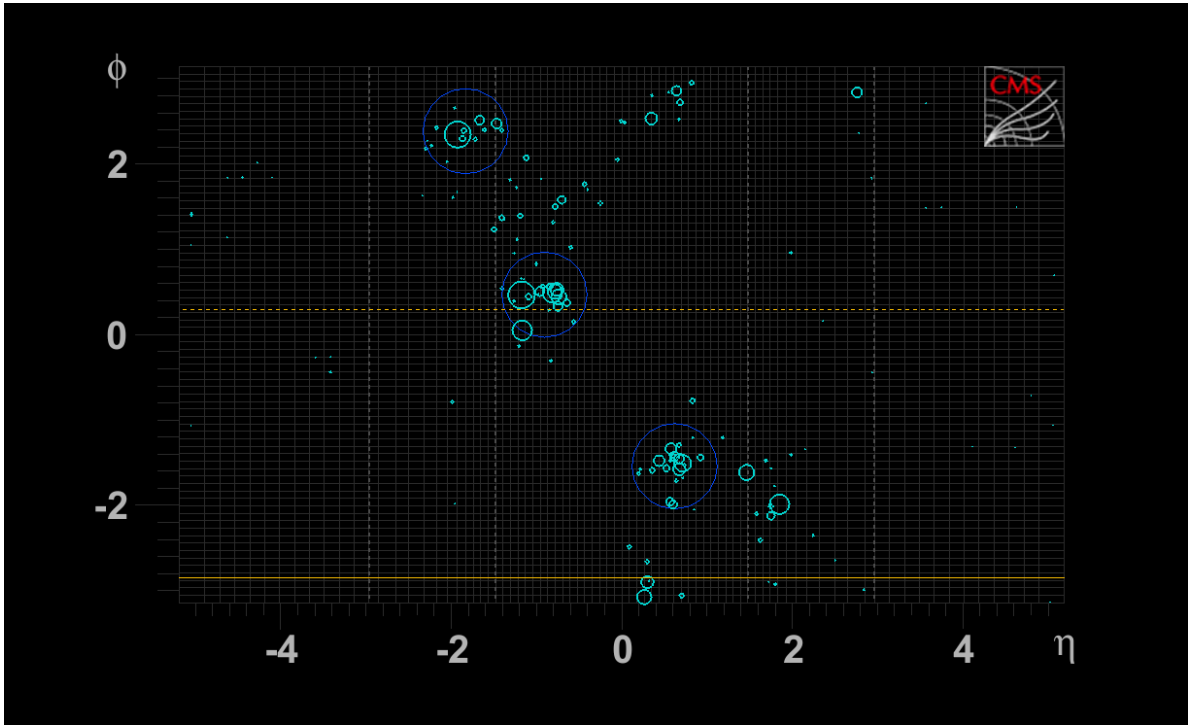
Commissioning

In December 2009 CMS recorded 215 771 events at a centre-of-mass energy of 0.9 TeV. A few thousand events at 2.36 TeV were also recorded.

Reconstructed particles are indicated by small circles with radius proportional to P_T .

3 high PT jets larger, thinner circles.

The missing transverse energy is estimated to be 1.9 GeV



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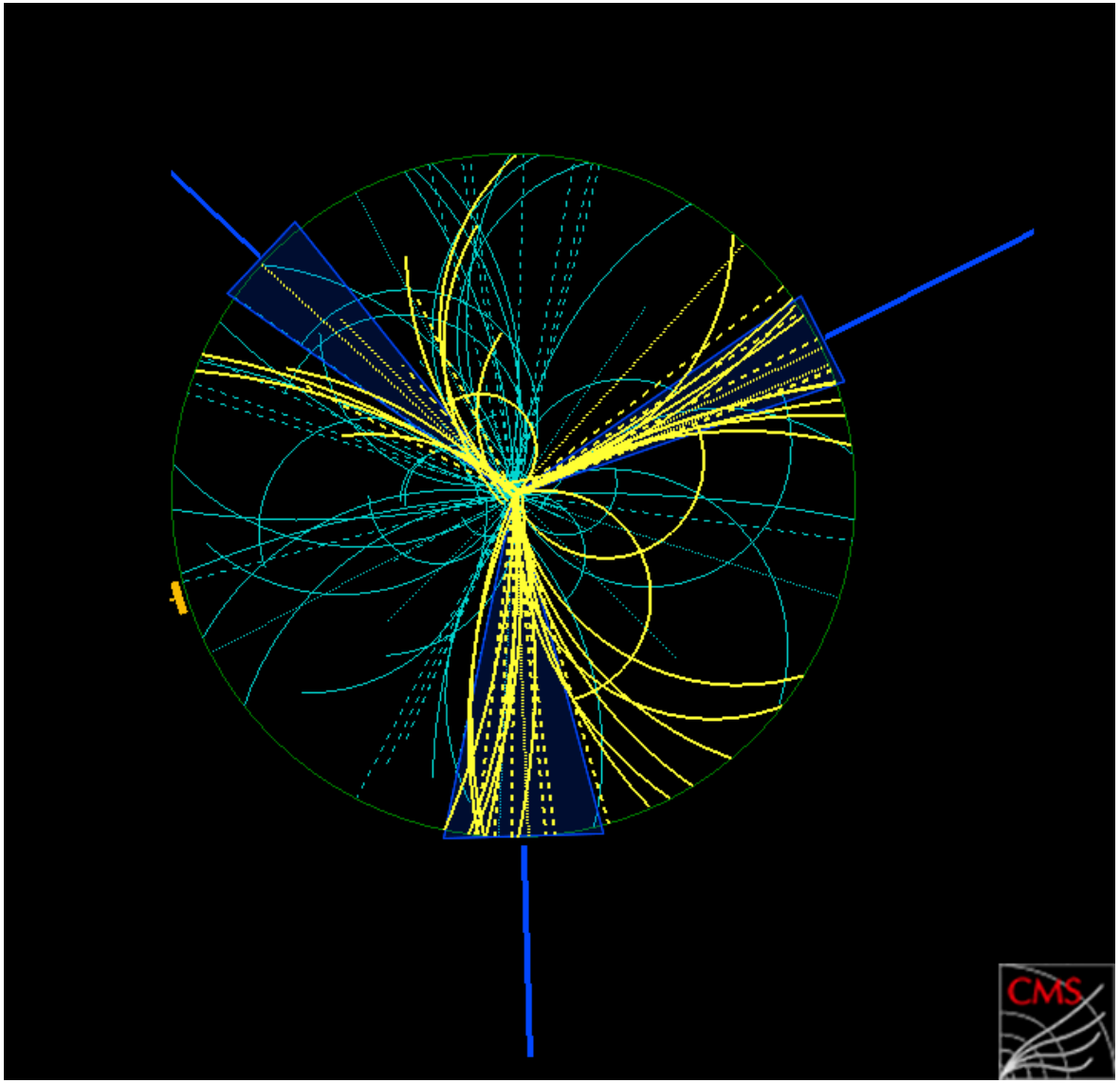

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Conclusion

- By combining the information from the various CMS sub-detectors the reconstruction of objects such as taus, jets and missing energy can be greatly improved.
- The energy and the direction measurements are improved by using more accurate information such as the tracker.
- This will benefit most CMS analyses.

Motivation

- Example:
- ttH, H→bb
- For a good analysis we need:
  - Missing transverse energy measurement
  - Jet reconstruction
  - b-tagging