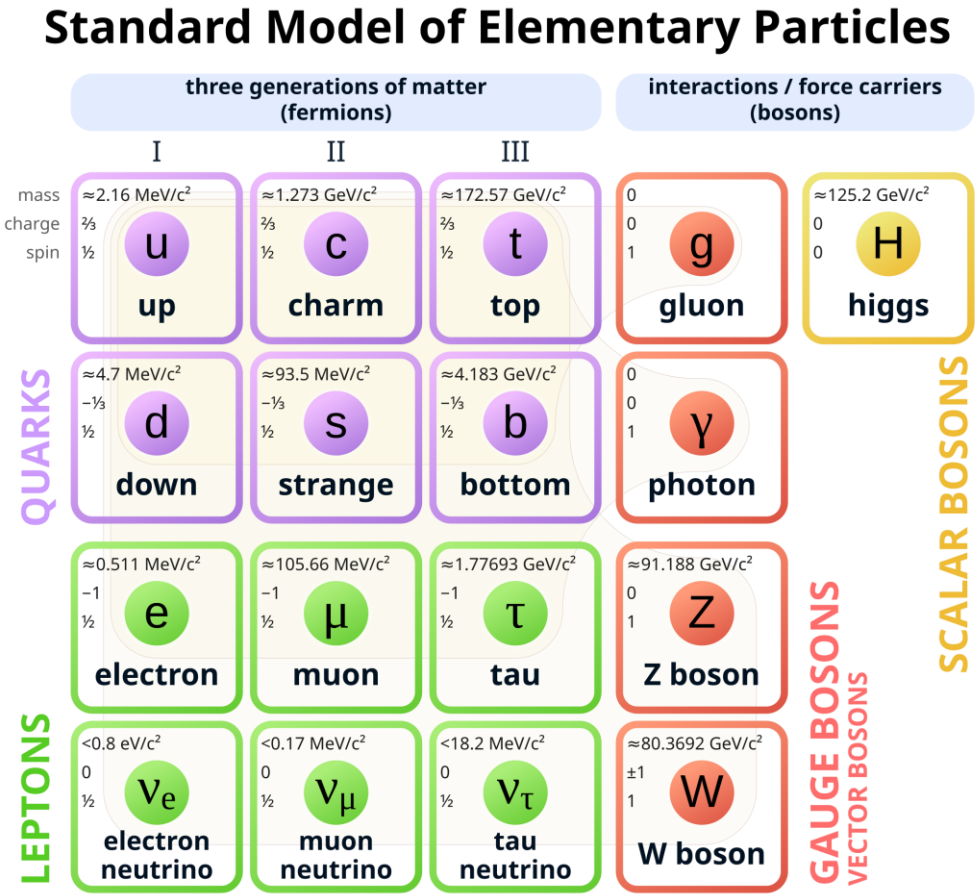
TAUS AND JETS

Introduction And Analysis

- Shweta Shankar

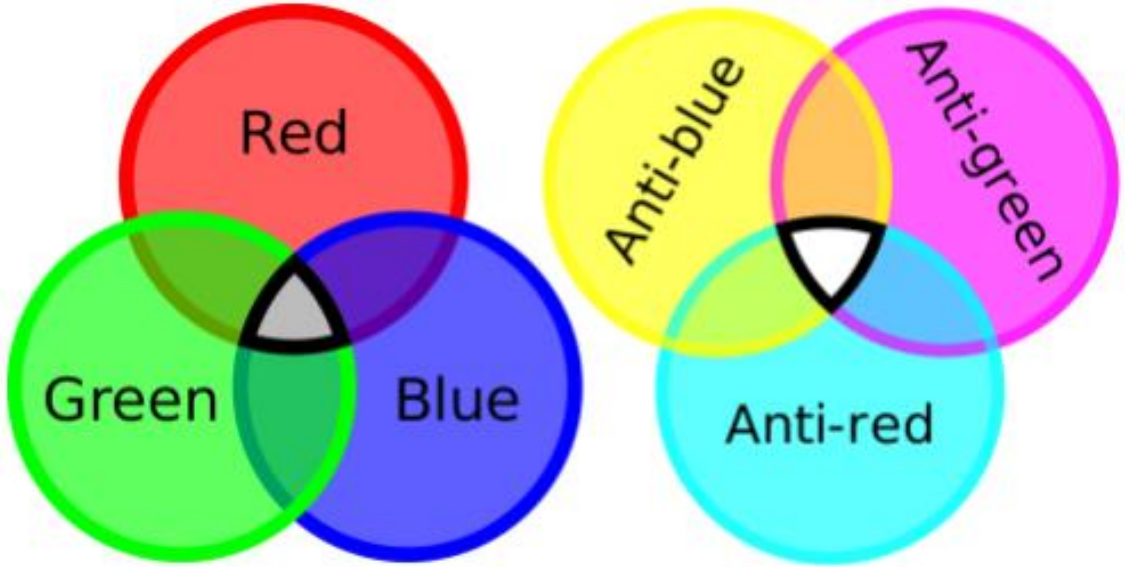
STANDARD MODEL

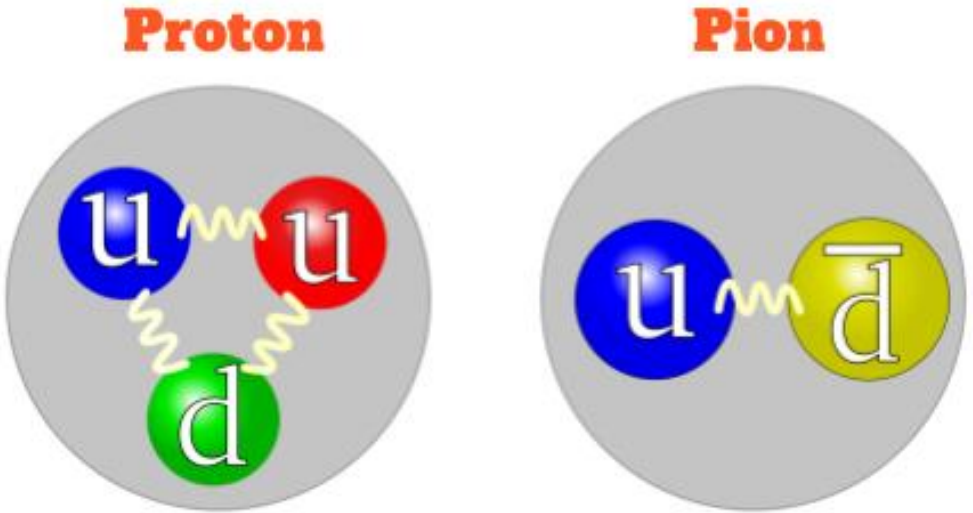
- The Standard model is a simple depiction which describes the fundamental particles in the universe.
- It depicts the following properties of each fundamental particle-symbol, charge, mass and spin.
- Quarks and gluons have another property called colour charge, which leptons and other bosons do not have.



COLOUR CHARGE

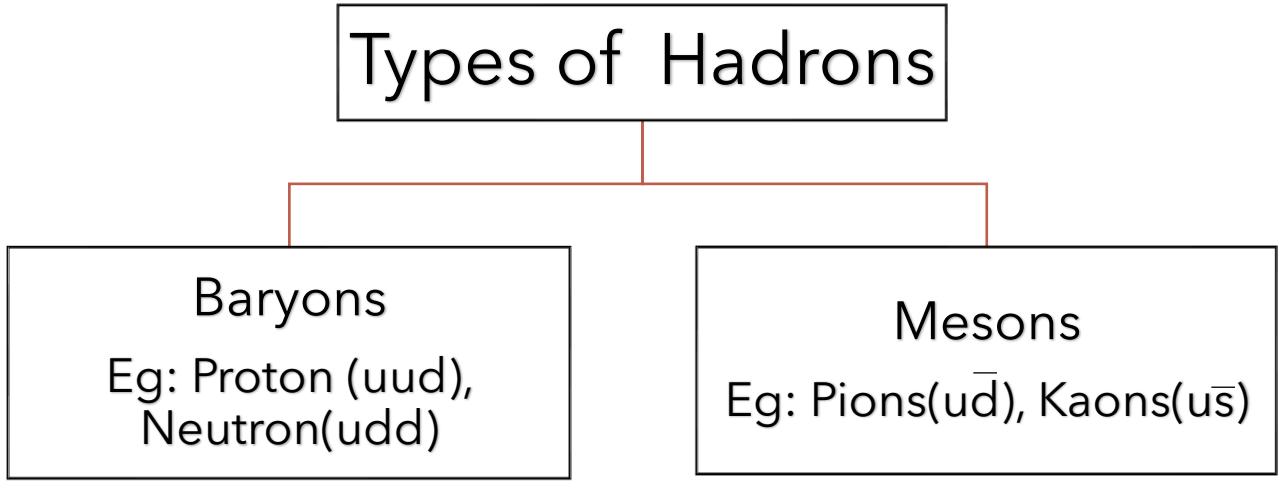
- Arose as a consequence of Pauli's Exclusion Principle.
- Quarks can be further divided into 6 types based on colour charge-
  i. 3 Colour : Red, Blue and Green.
  ii. 3 Anti-Colour : Cyan, Magenta and Yellow.
- Each gluon carries 2 colour charges. They needn't be colour neutral.
- Quarks interact among themselves through exchange of gluons, and each interaction should follow conservation of colour charge. These interactions give rise to strong force.


Red
Green
Blue
Anti-blue
Anti-green
Anti-red

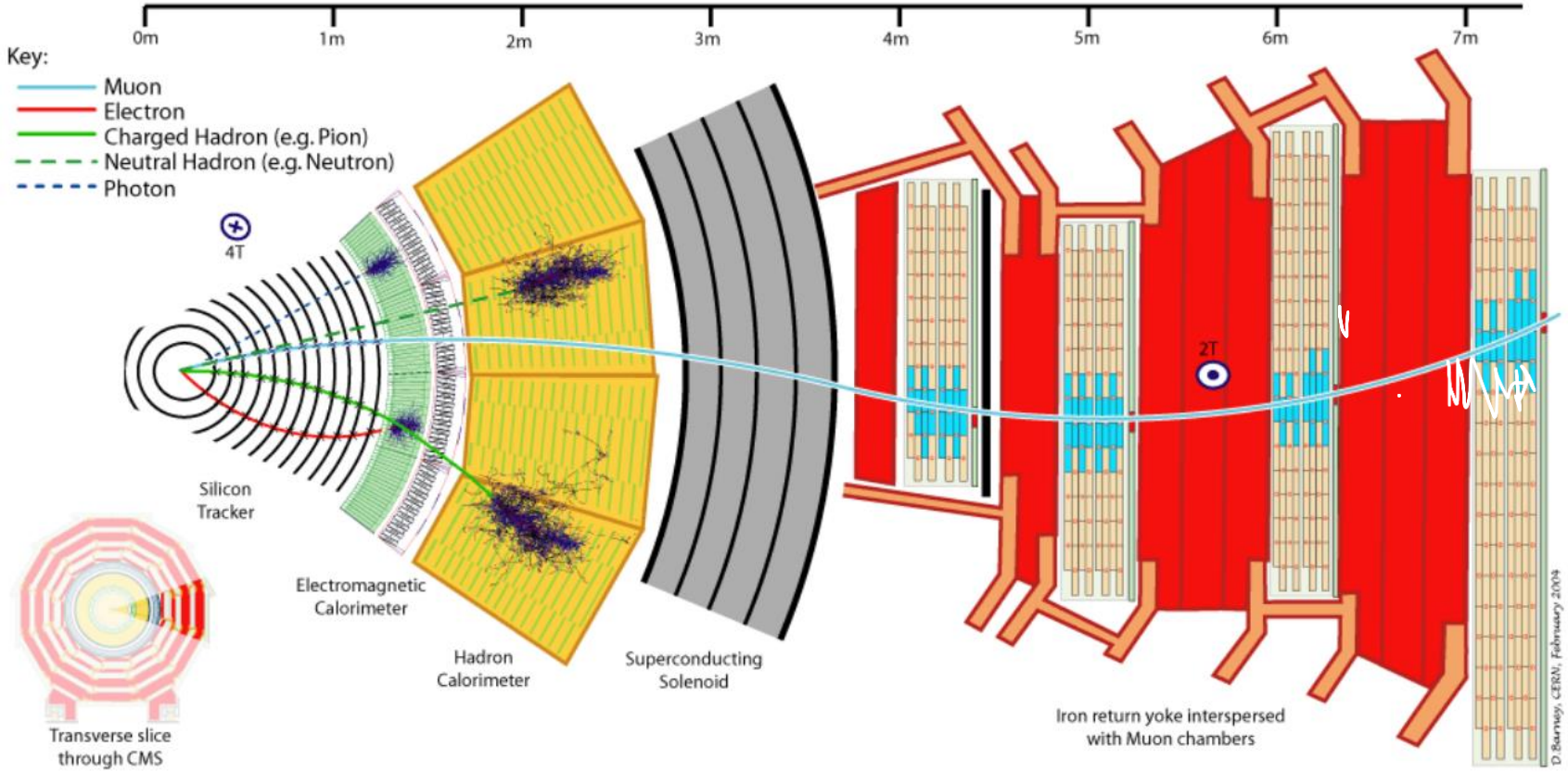

Proton
u
u
d
Pion
u
d̄

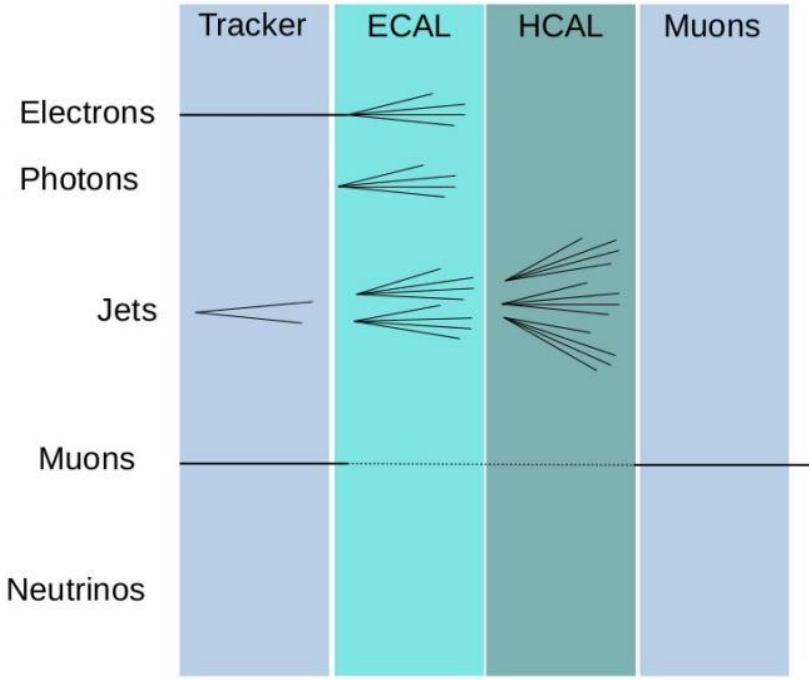
HADRONS

- Quarks cannot exist individually as they have Fractional charge and Colour charge.
- Groups of quarks come together and form colour neutral hadrons.
- Manifested hadrons are what are detected, not individual quarks!



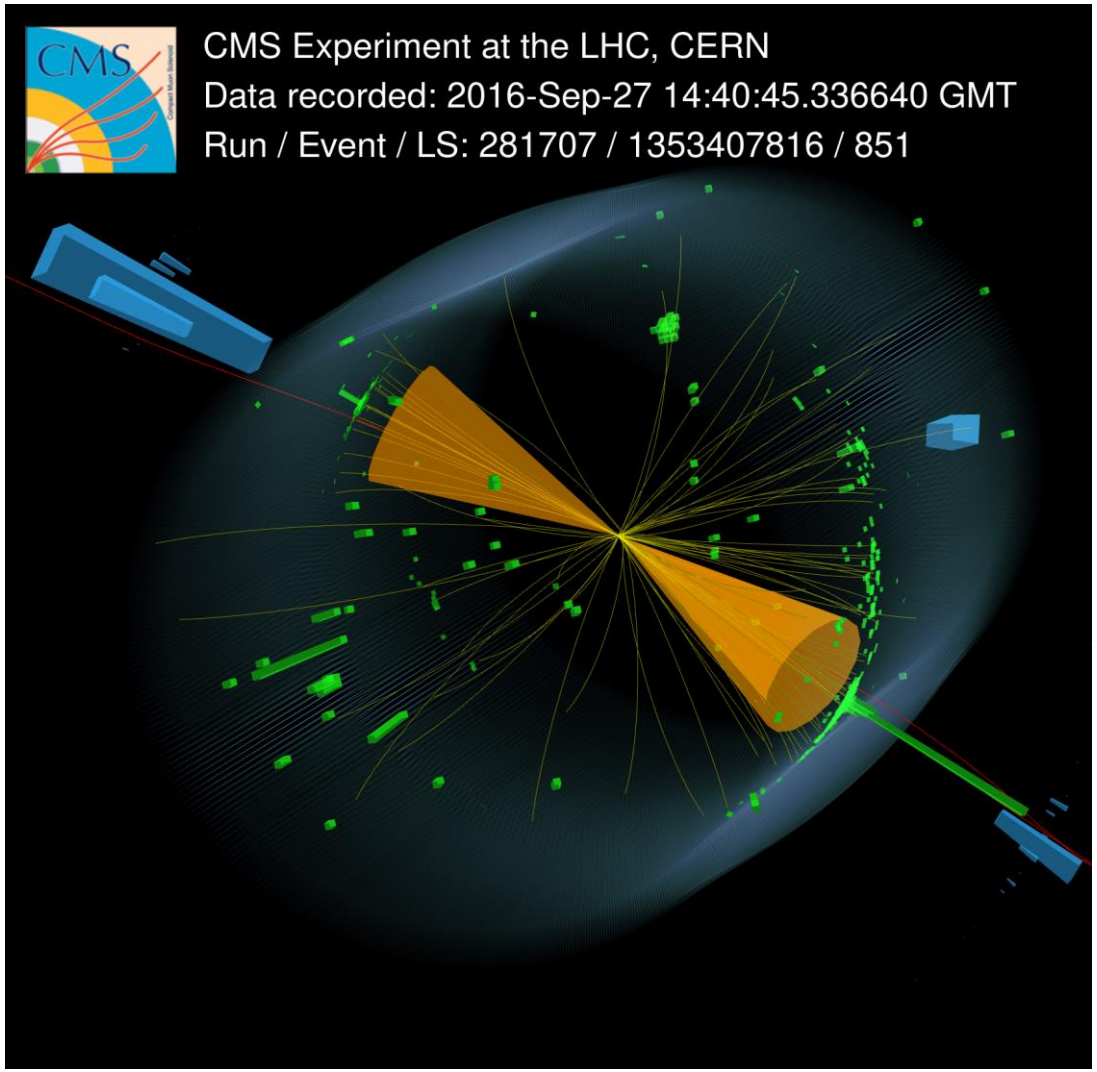
CMS PARTICLE DETECTOR

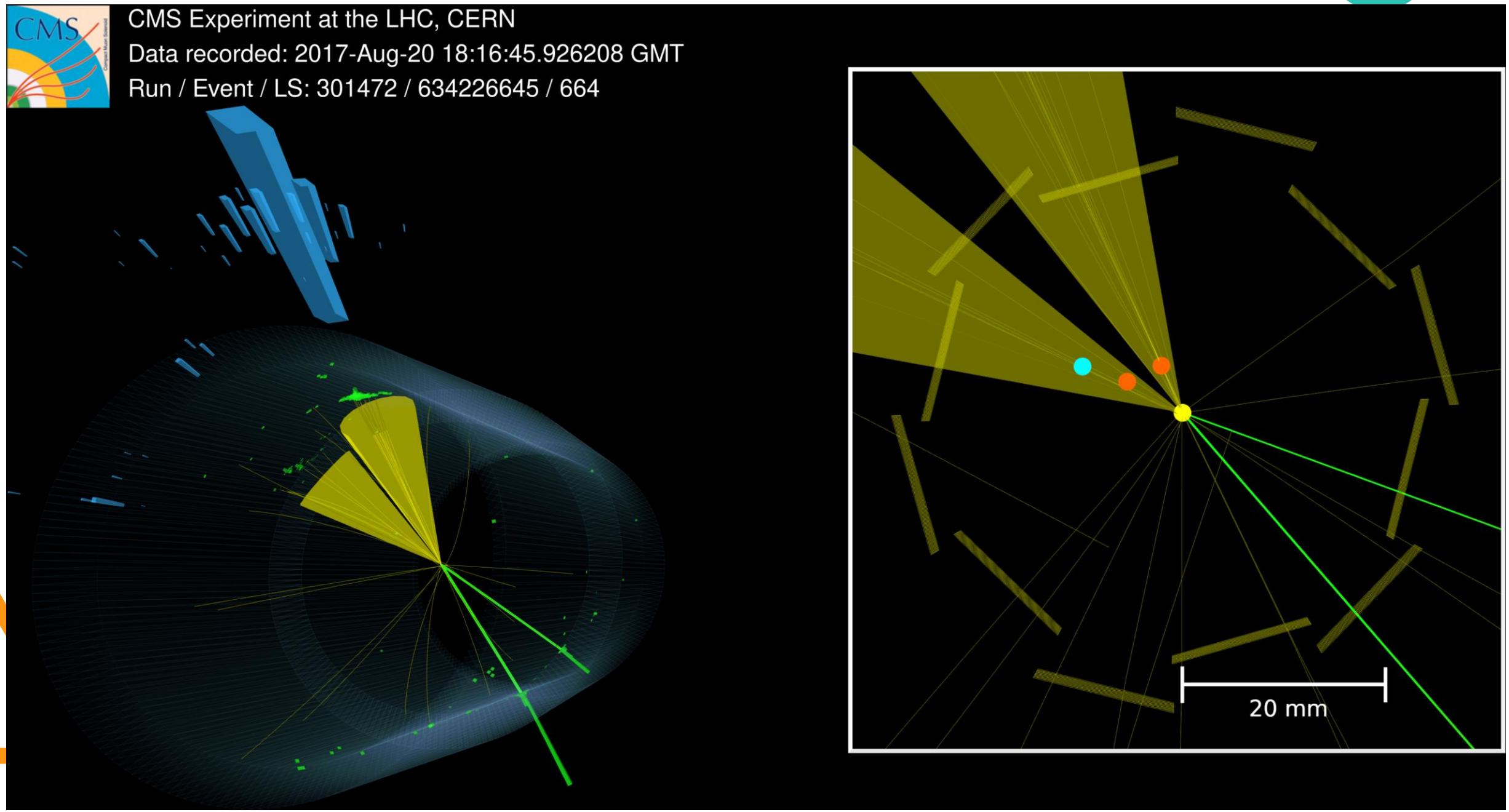




WHAT IS A JET?

- A collection of **Hadrons** which are relatively close to each other than some others, as if they are produced by the same particle, form a Jet.
- Jets are found using clustering algorithms.
- The jet properties (4-vector) must correlate well with the properties of initial particle giving rise to it.



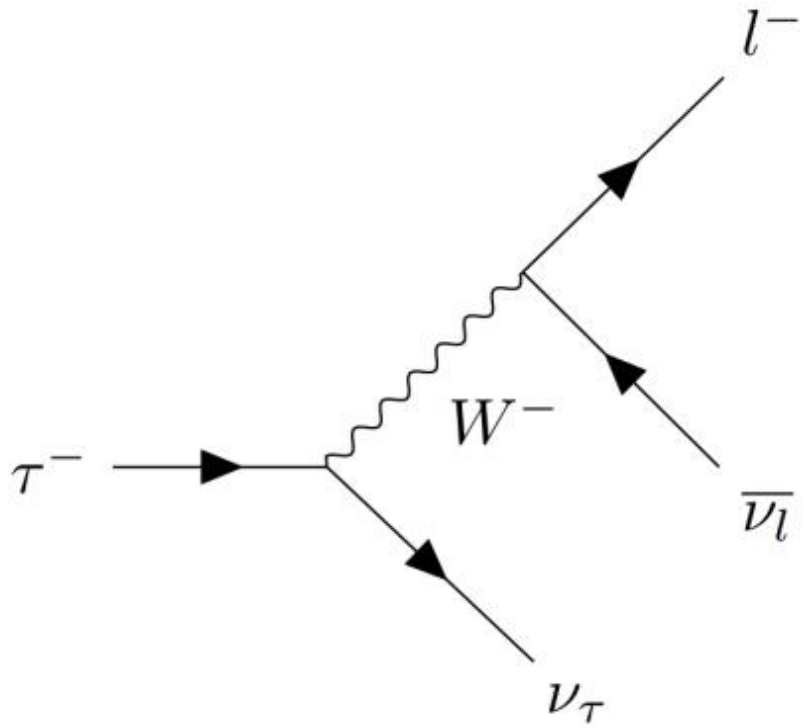

CMS Experiment at the LHC, CERN
Data recorded: 2017-Aug-20 18:16:45.926208 GMT
Run / Event / LS: 301472 / 634226645 / 664
20 mm

WHAT IS TAU?

- It is a Lepton!
- Is heavy. It's mass= 1.78 GeV.
- Has -1 charge.
- Life time= 2.8 x 10^{-13} seconds.
- Approx. Travel distance = 50 μm
- So it decays into other fundamental particles well before it can be detected.
- It can decay into a bunch of leptons or a bunch of hadrons.

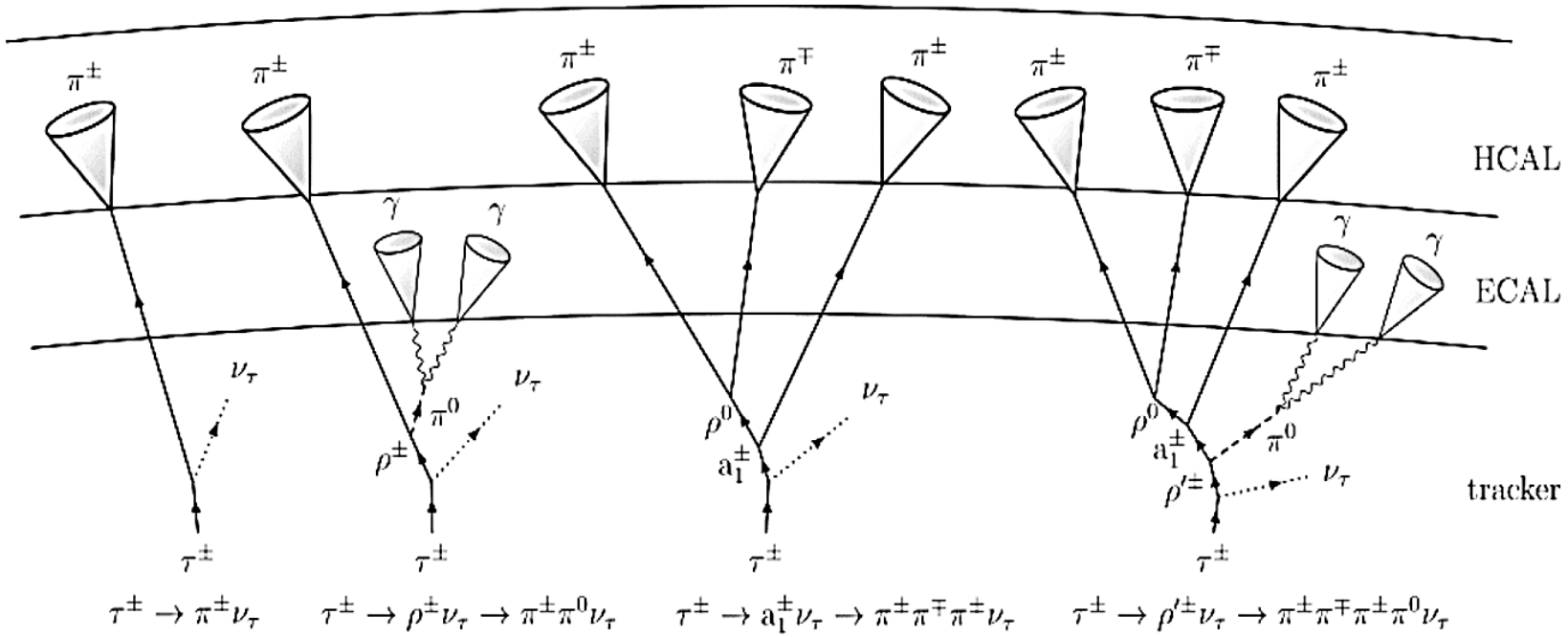
LEPTONIC DECAY OF TAUS

- A tau lepton can decay into other leptons such as electrons, muons and neutrinos.
- This is usually easy to detect as electrons and muons get detected easily.
- Presence of neutrinos found through momentum balancing.



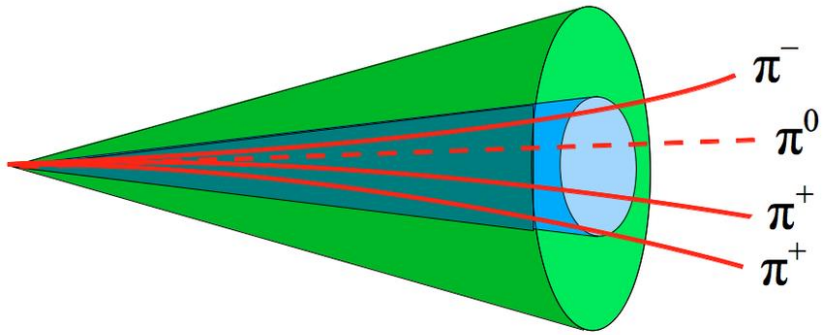
HADRONIC DECAY OF TAUS

- A tau lepton can also decay into a bunch of hadrons, usually into pions, through modes, 1-prong or 3 prong.

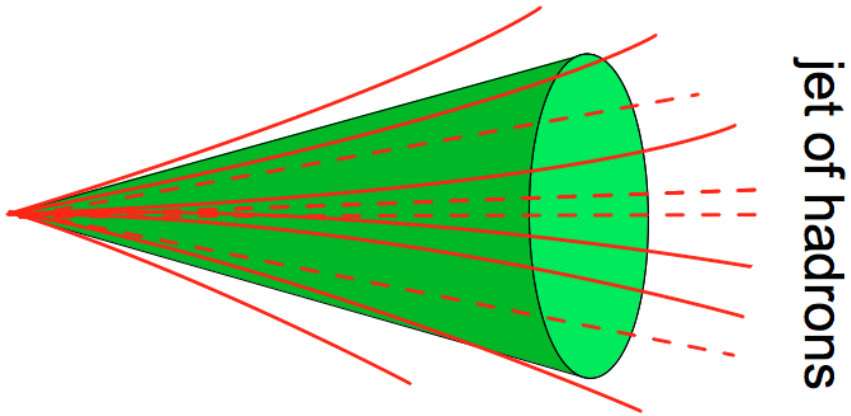


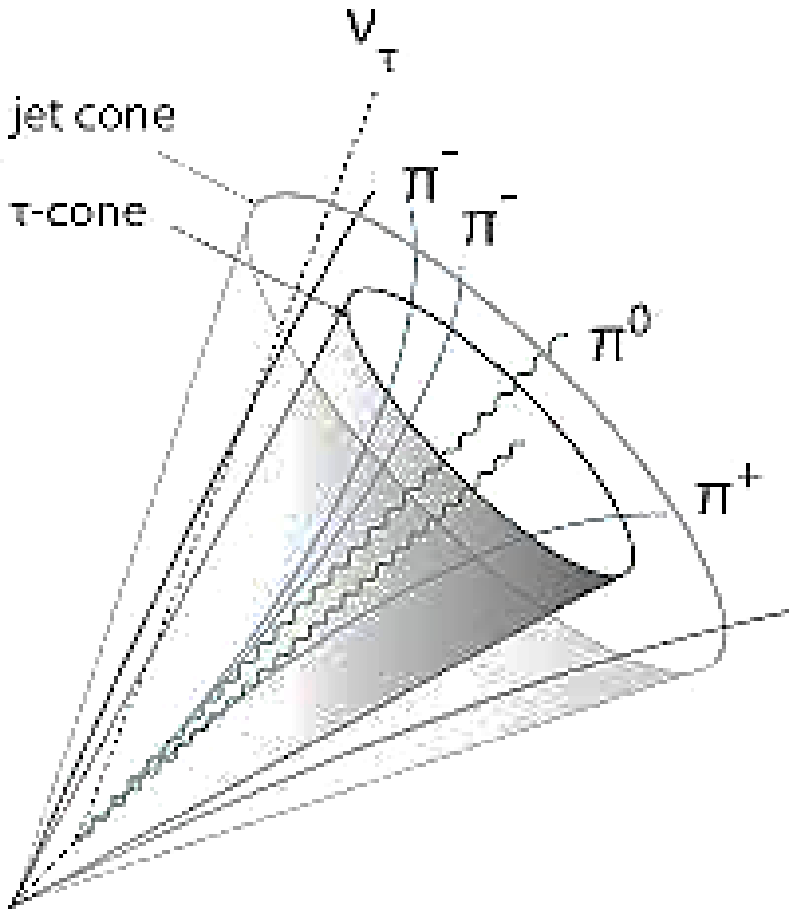
HADRONICALLY DECAYING TAU AND JET SIMILARITY

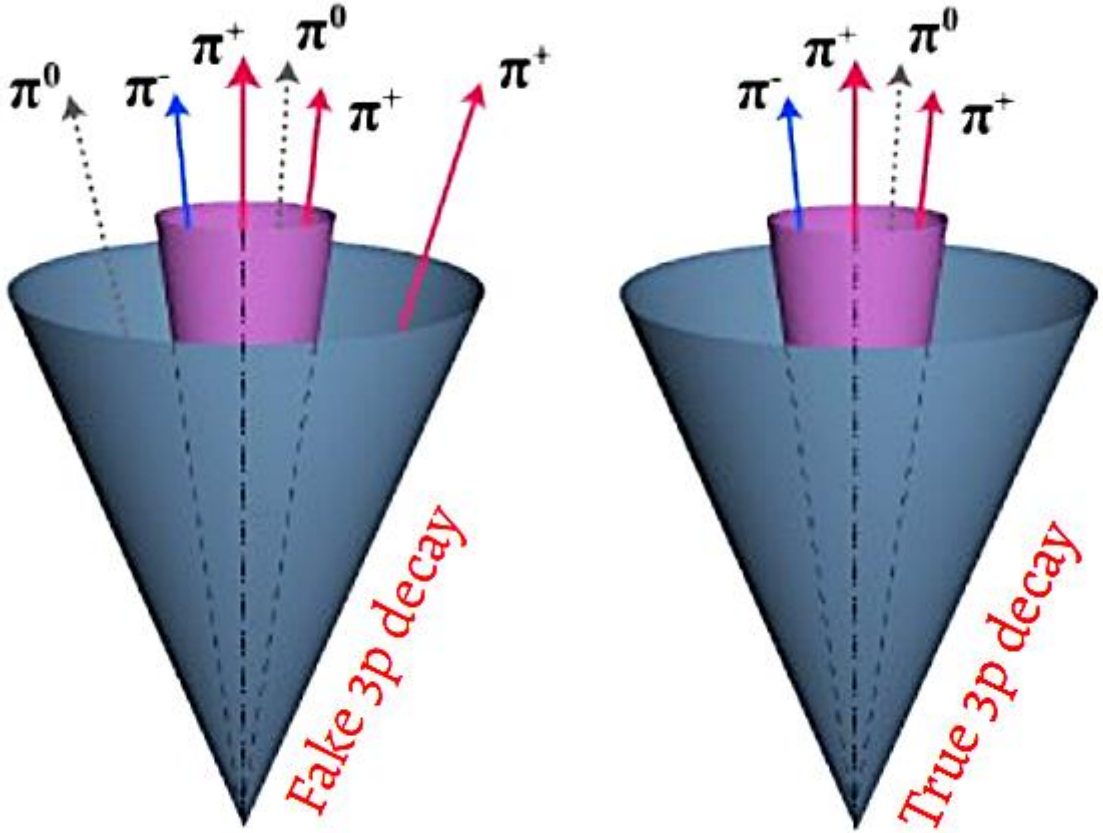
- Signal Signature of Tau.



- Signal Signature of Jet.




ν τ
jet cone
τ-cone
π⁻
π⁻
π⁰
π⁺


π⁰
π⁻
π⁺
π⁰
π⁺
π⁺
Fake 3p decay
π⁻
π⁺
π⁰
π⁺
True 3p decay

FAKE RATE ANALYSIS

- Tau signals and jet signals clearly look very similar, hence each can fake to be the other!
- What is the rate at which a Jet fakes a Tau? NOT DEFINITE!
- Fake Rate was calculated with the following :-

$$\text{Fake Rate} = \frac{\text{Number of Jets matching Taus}}{\text{Total number of Jets}}$$

- This rate changes with application of a certain condition on selection criteria of Jets.

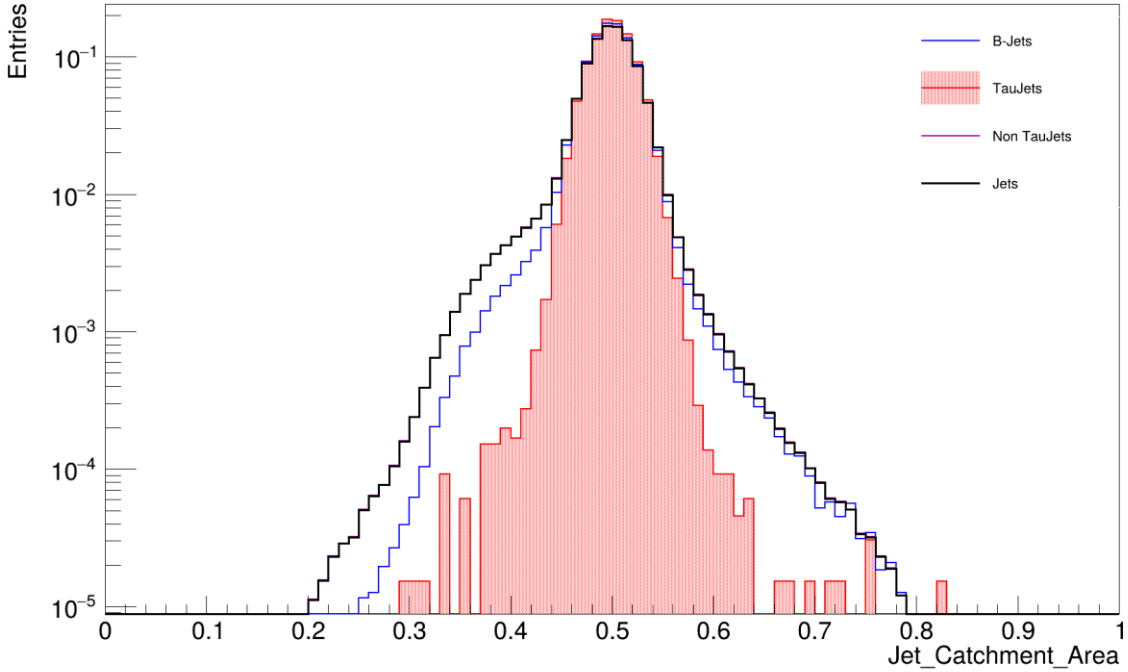
JET PROPERTIES WHICH I USED FOR SELECTION

- Jet Catchment Area
- Jet mass
- Jet_btagDeepFlavB
- Charged Electromagnetic Energy Fraction
- Charged Hadron Energy Fraction
- Number of particles in the jet
- Neutral Electromagnetic Energy Fraction
- Neutral Hadron Energy Fraction

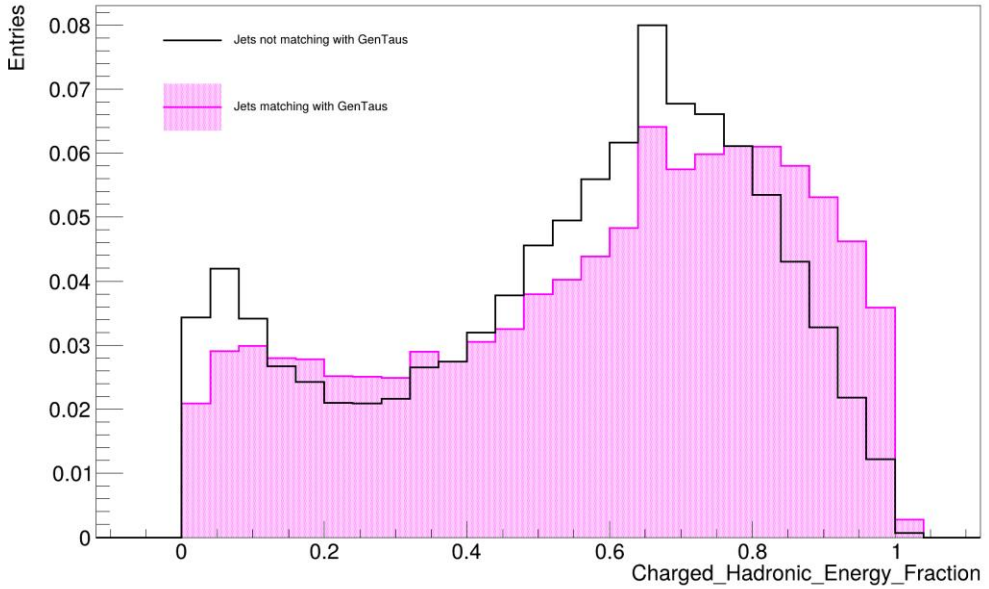
AREA RESTRICTION

Fake rate before this restriction – 0.00445 ± 0.00008

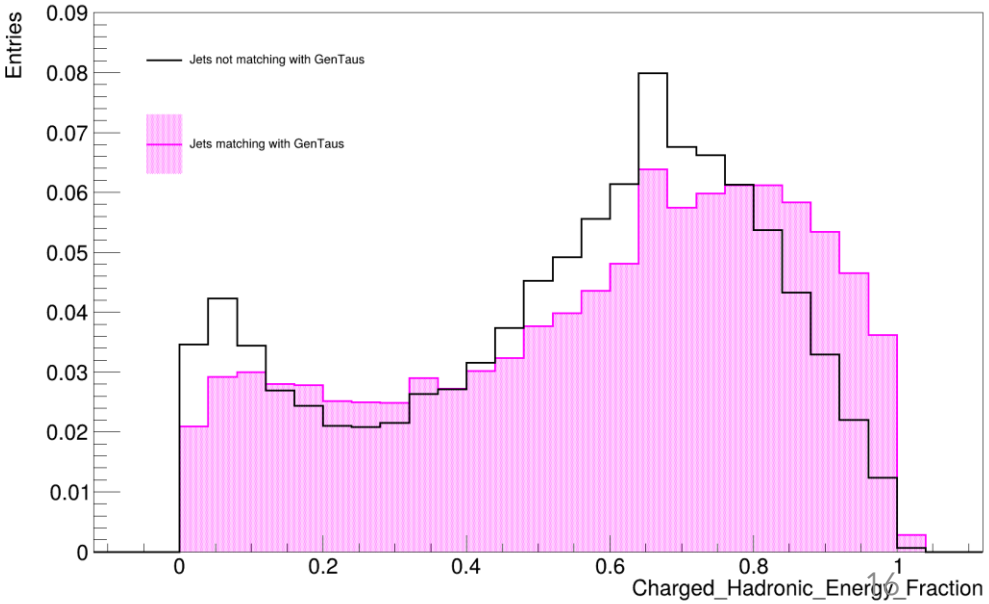
Fake rate after this restriction – 0.00451 ± 0.00008



Before restriction



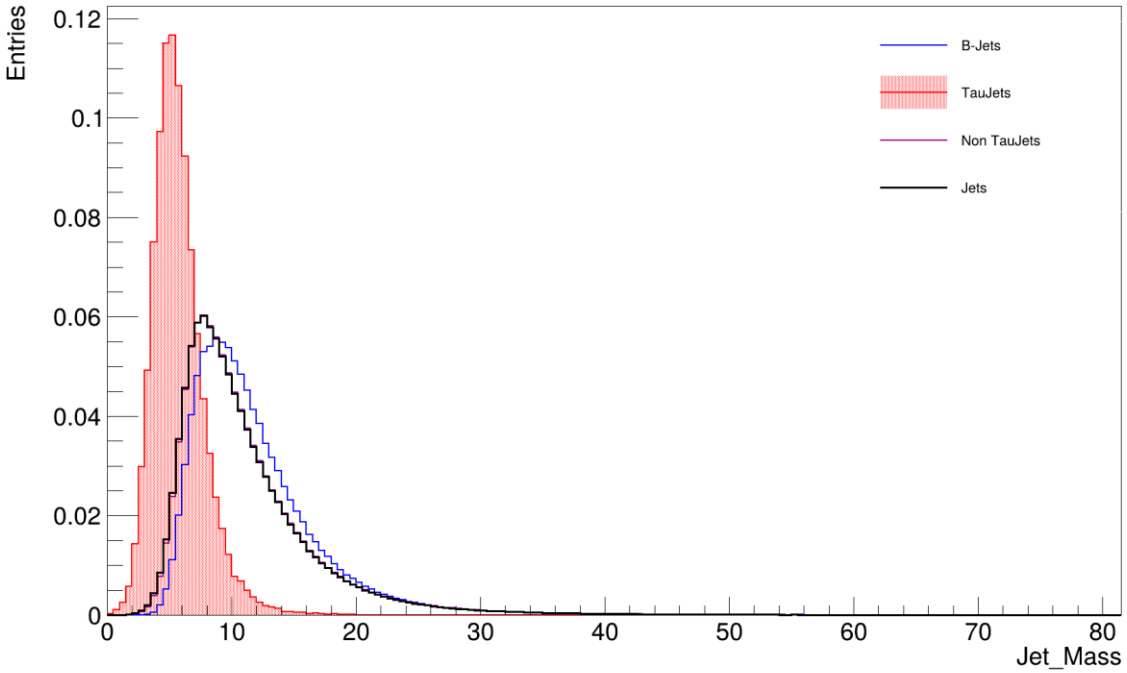
After restriction



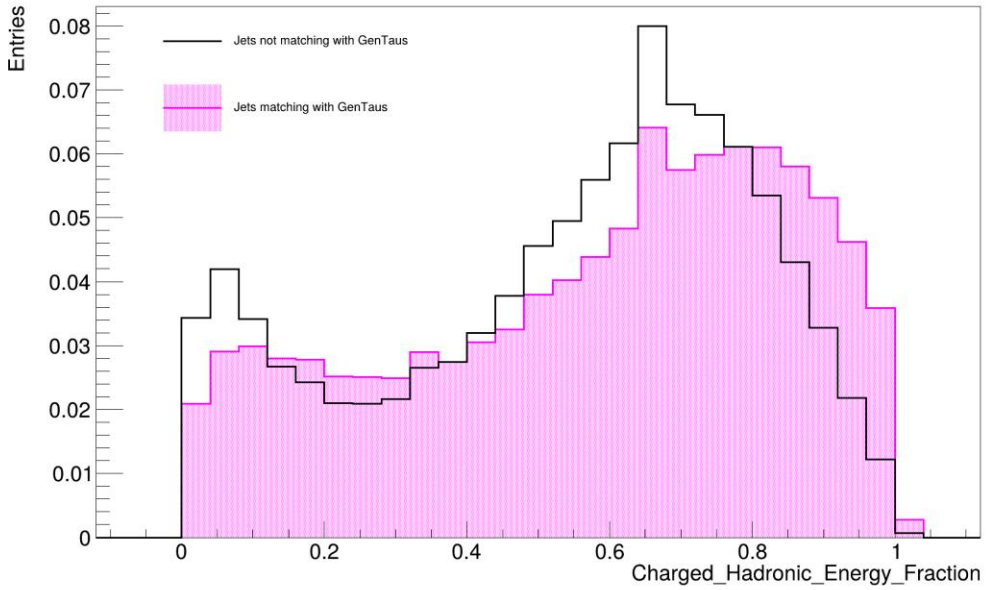
AREA+MASS RESTRICTION

Fake rate before this restriction – 0.00451 ± 0.00008

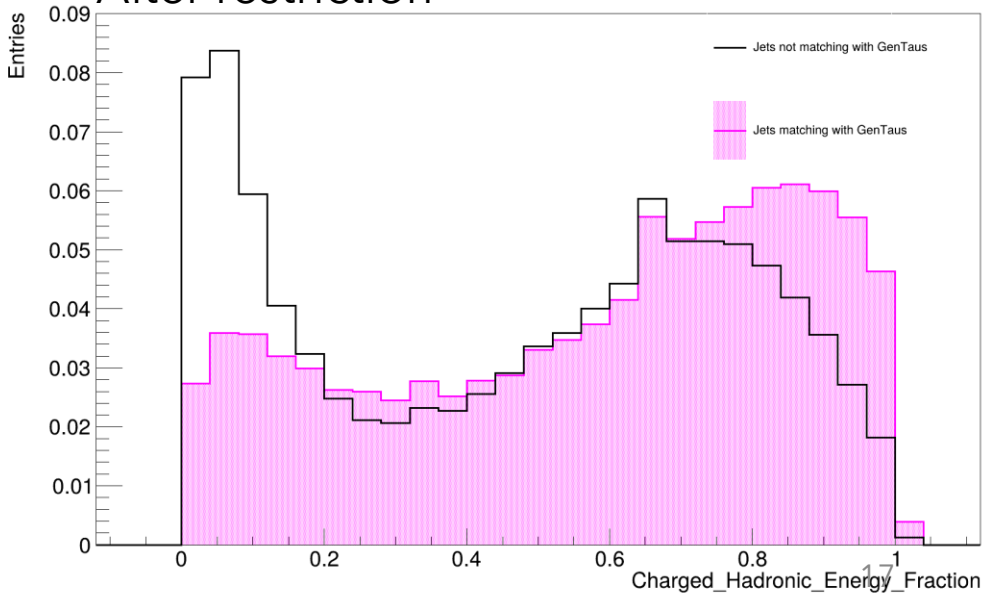
Fake rate after this restriction – 0.0089 ± 0.0002



Before restriction



After restriction



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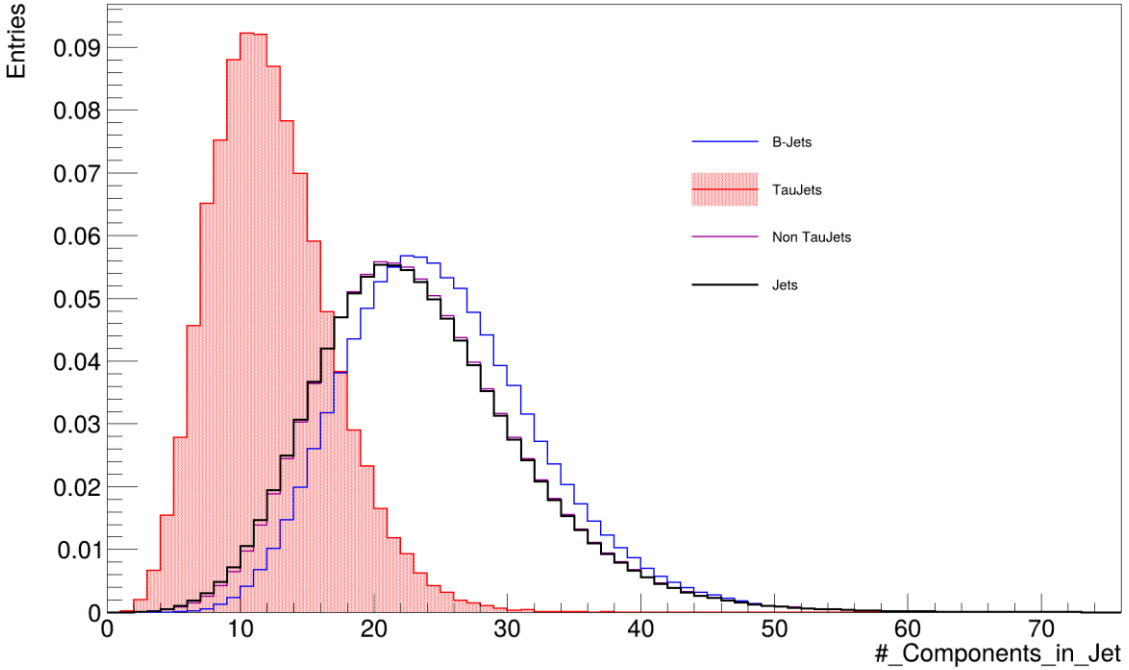
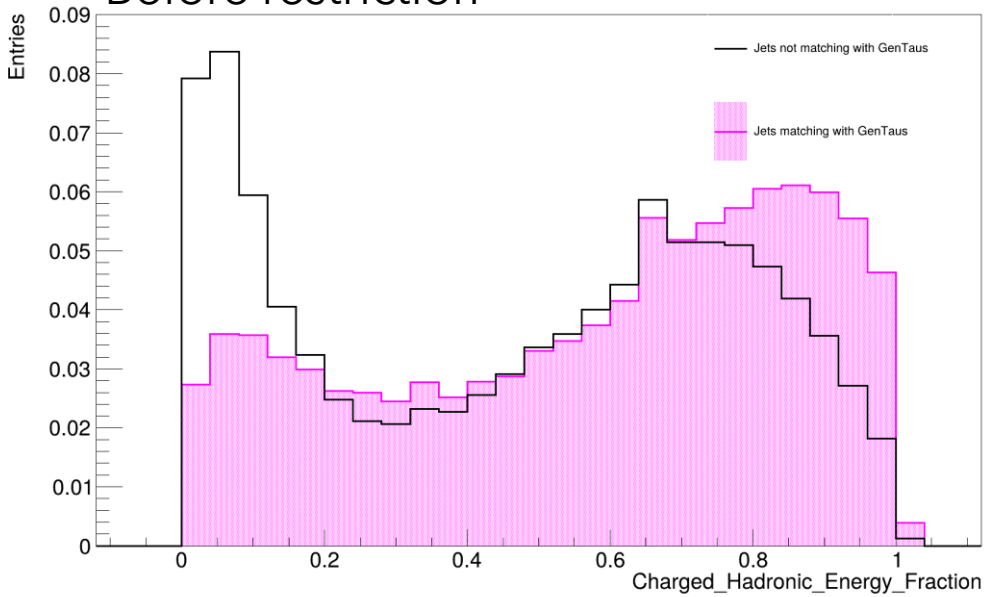
AREA+MASS +NC RESTRICTION

Fake rate before this restriction – 0.0089 ± 0.0002

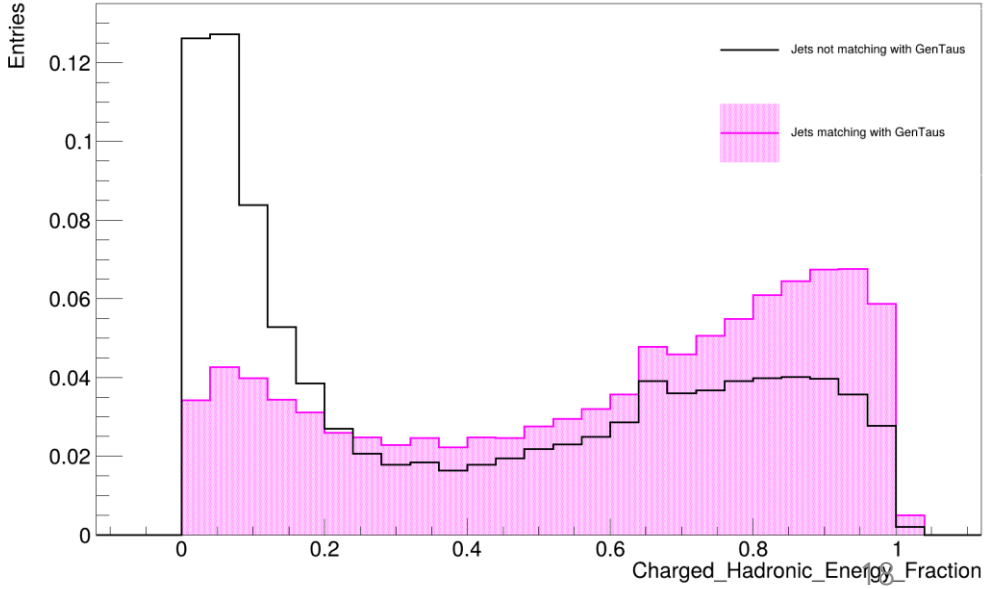
Fake rate after this restriction – 0.0122 ± 0.0003



Before restriction

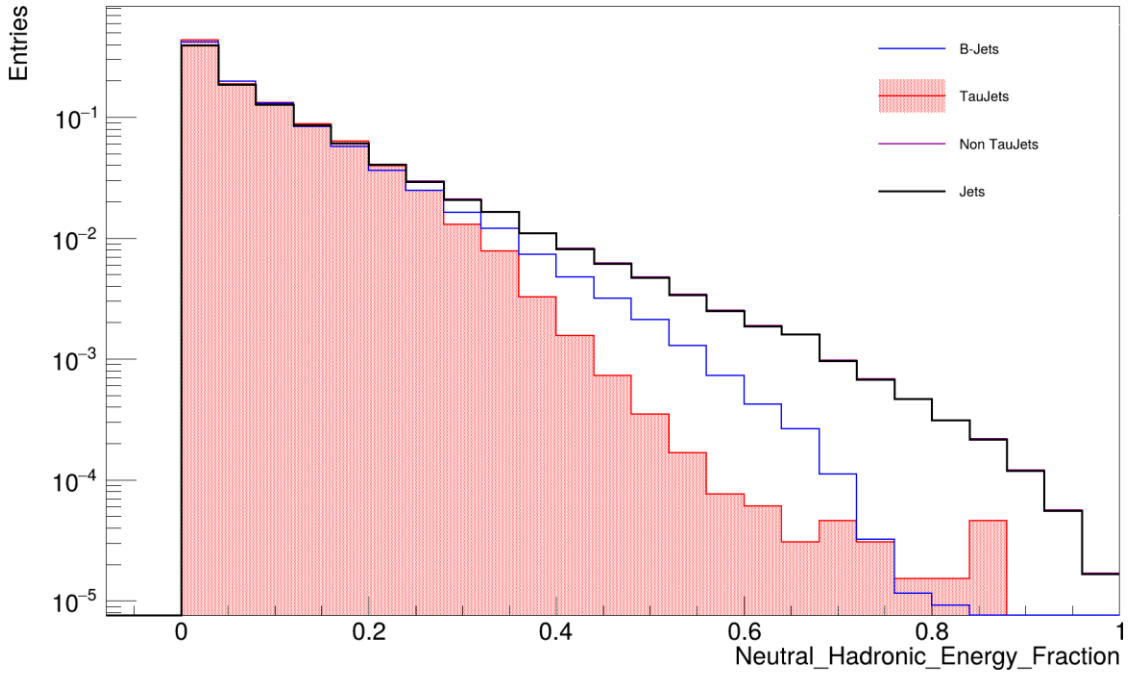


After restriction

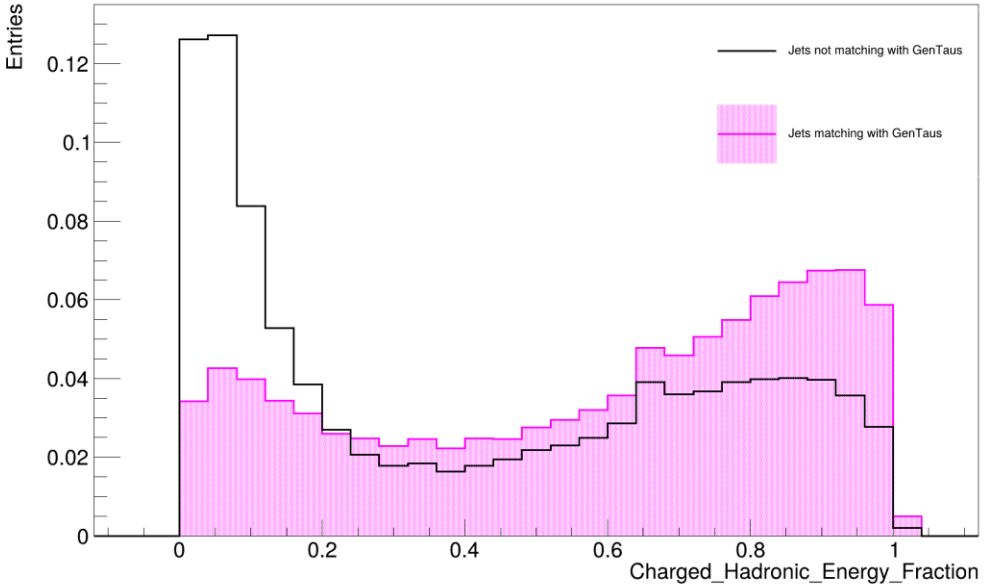


AREA +MASS +NC+ NEHEF RESTRICTION

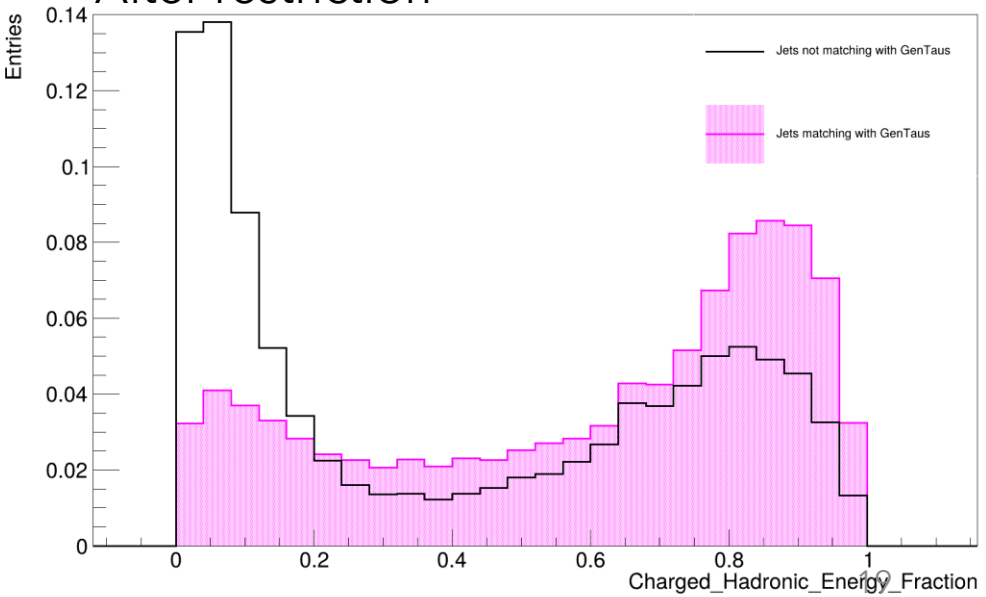
Fake rate before restriction –
0.0122 ± 0.0003
Fake rate after area restriction –
0.0135 ± 0.0004



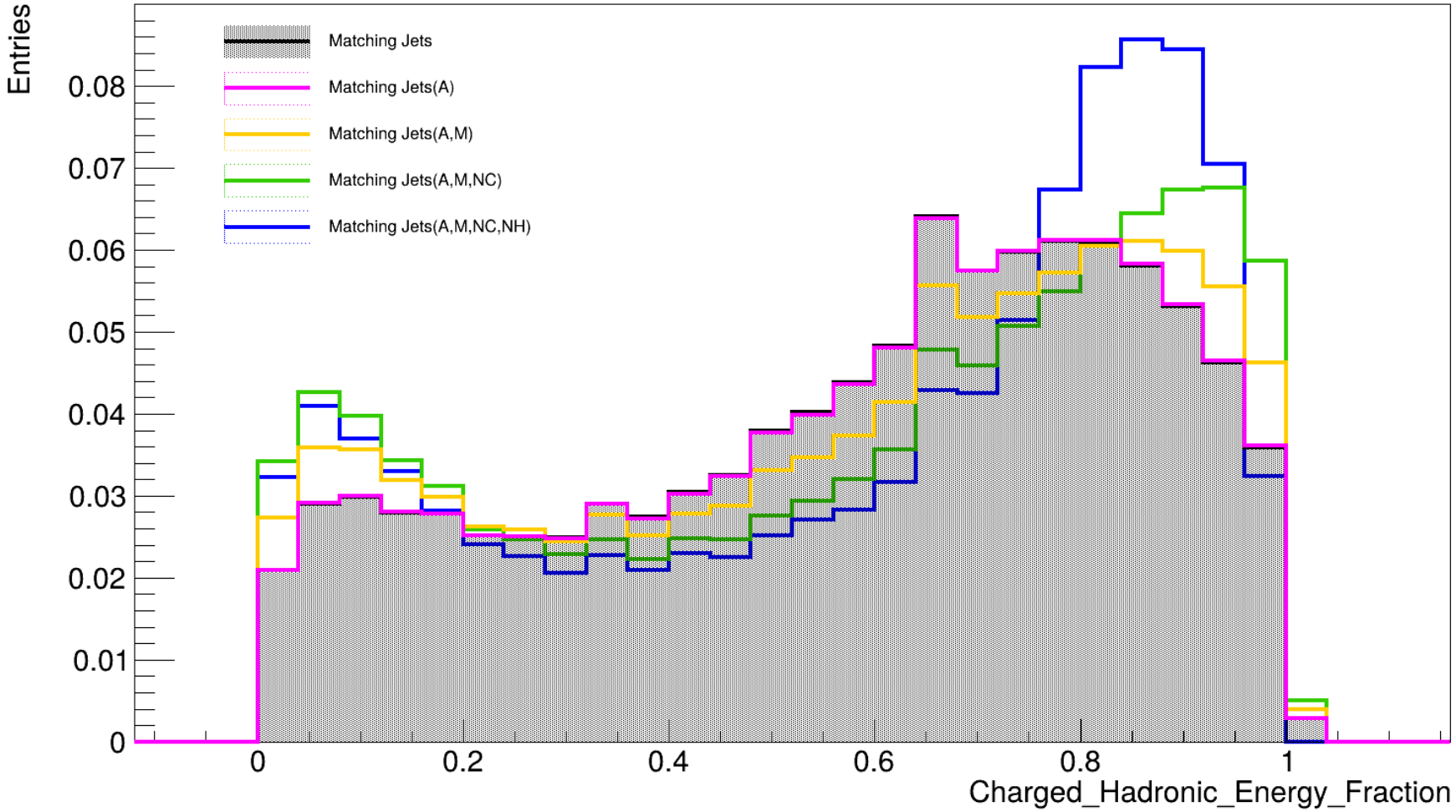
Before restriction

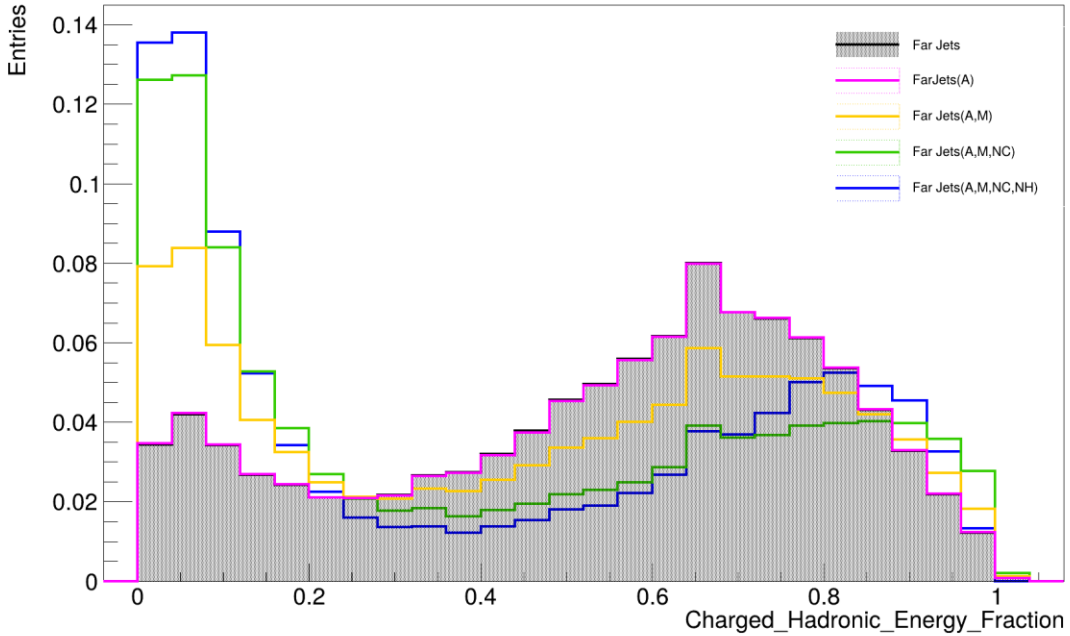


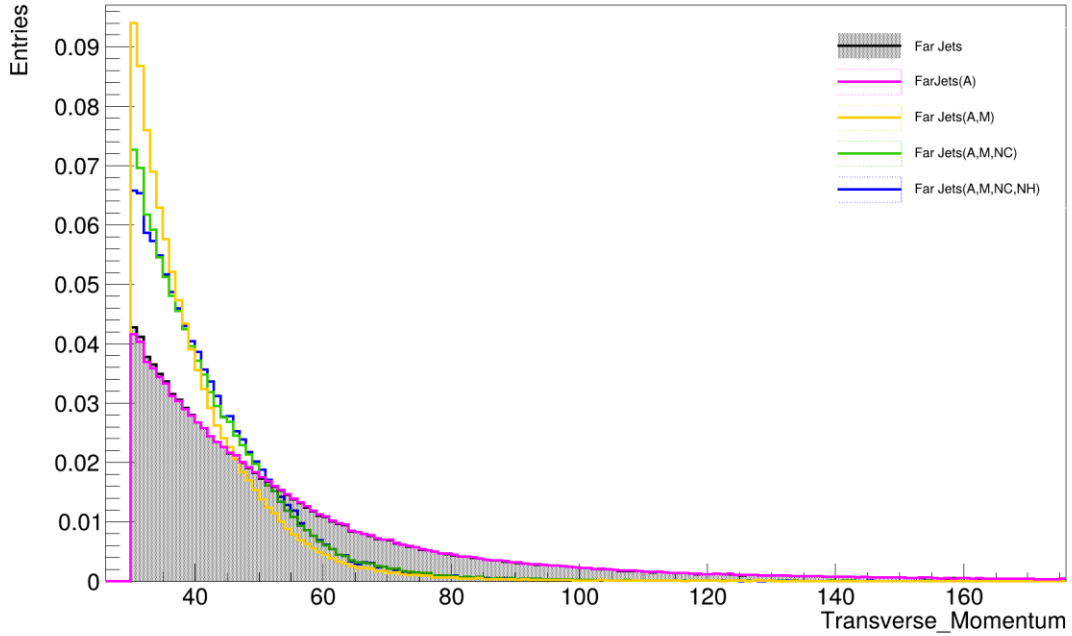
After restriction

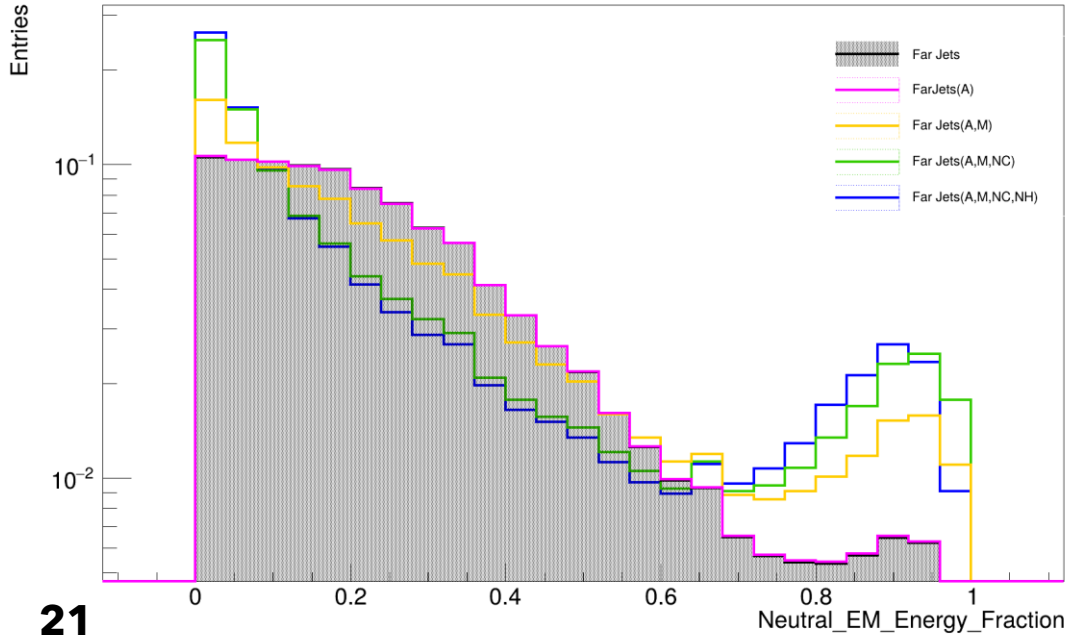


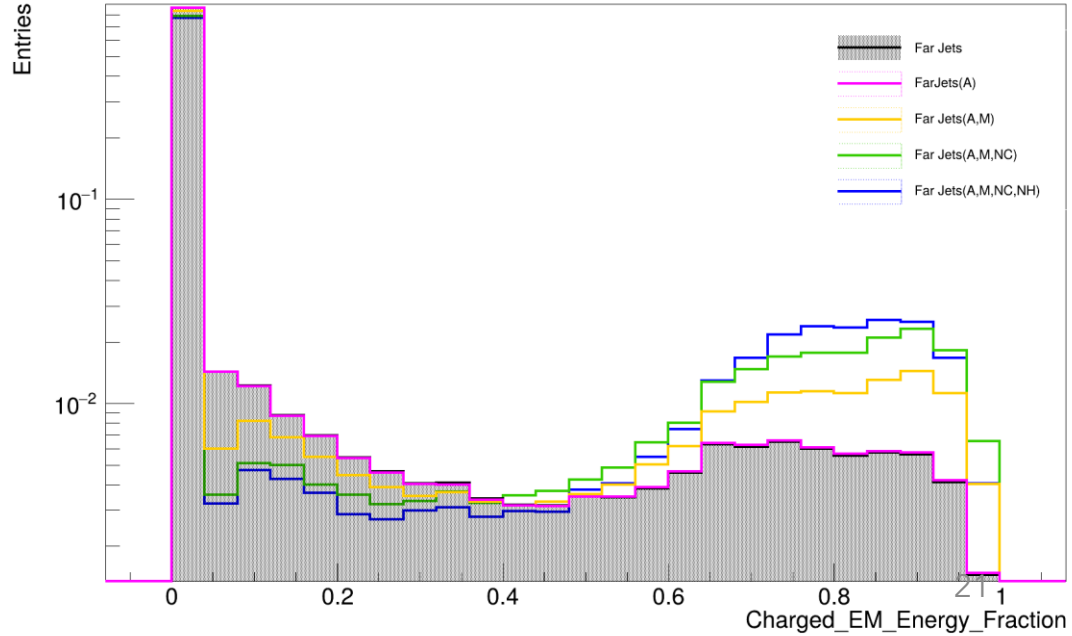
OVERLAID PLOT OF MATCHING JET




Entries
Far Jets
FarJets(A)
Far Jets(A,M)
Far Jets(A,M,NC)
Far Jets(A,M,NC,NH)
Charged_Hadronic_Energy_Fraction


Entries
Far Jets
FarJets(A)
Far Jets(A,M)
Far Jets(A,M,NC)
Far Jets(A,M,NC,NH)
Transverse_Momentum


Entries
Far Jets
FarJets(A)
Far Jets(A,M)
Far Jets(A,M,NC)
Far Jets(A,M,NC,NH)
Neutral_EM_Energy_Fraction


Entries
Far Jets
FarJets(A)
Far Jets(A,M)
Far Jets(A,M,NC)
Far Jets(A,M,NC,NH)
Charged_EM_Energy_Fraction

THANK YOU!