Short Exercise on Taus

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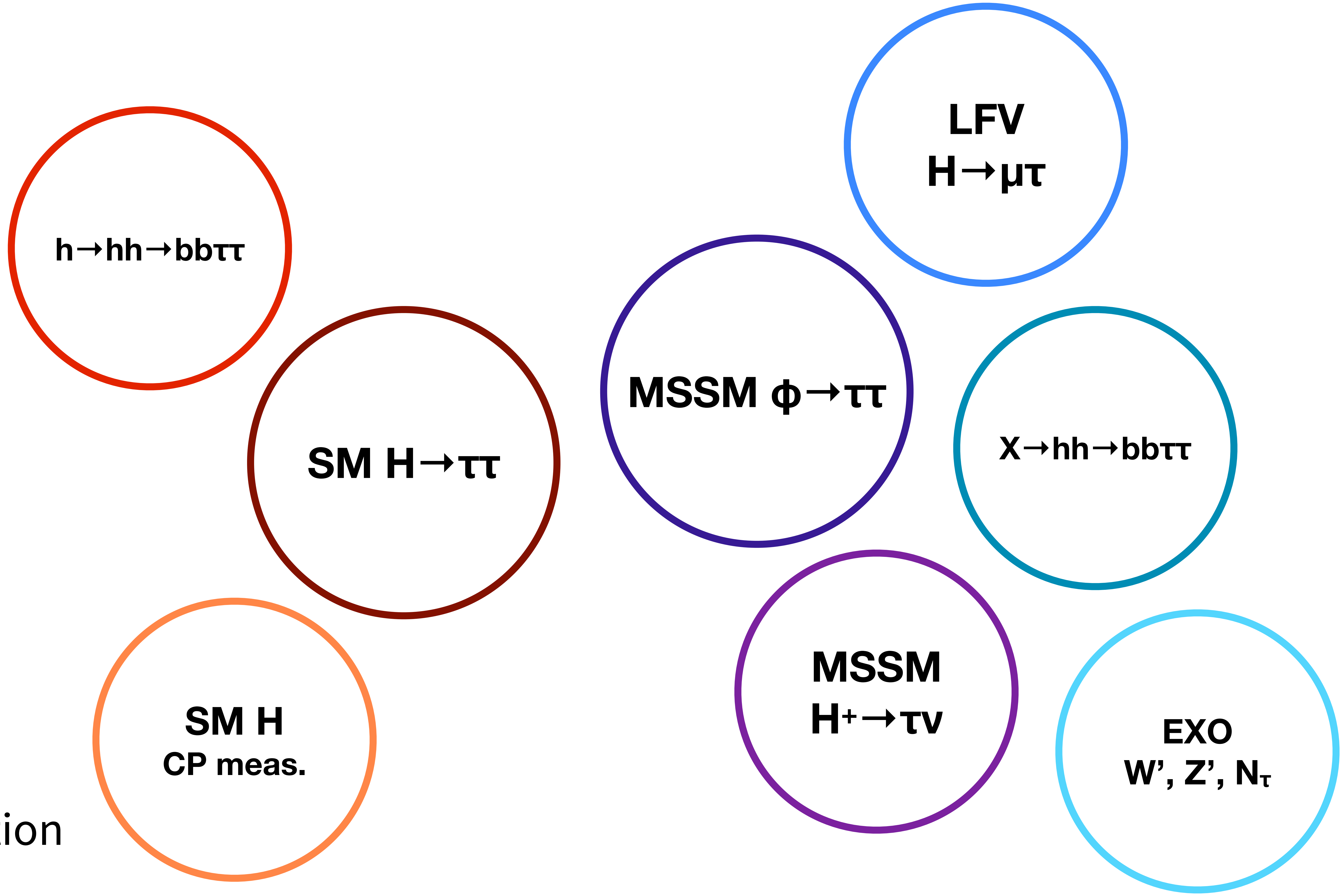
Taus play a key role in the CMS physics programme, in particular in the Higgs sector

Heaviest lepton with 1.777 GeV

- Understanding the nature of the Higgs boson
- Searching for possible additional Higgs bosons
- Other searches where Higgs-like couplings play a role

Flavour puzzles

- Lepton universality
- Lepton flavour violation
- Other searches where 3rd generation plays a special role



Profile of the tau lepton

- m_τ = 1.777 GeV:
  τ is the only lepton heavy enough to decay into hadrons
- Finite lifetime 2.91E-13 s, cτ = 90 µm → travels O(mm) at few tens GeV boost
- Around 35% of tau decays to lighter leptons and neutrinos
- **65% decays to hadrons** + neutrino
  - need to reconstruct different decay modes

Decay mode	Meson resonance	$\mathcal{B}$ [%]
$\tau^- \to e^- \overline{\nu}_e \nu_\tau$		17.8
$\tau^- \to \mu^- \overline{\nu}_\mu \nu_\tau$		17.4
$\tau^- \to h^- \nu_\tau$		11.5
$\tau^- \to h^- \pi^0 \nu_\tau$	$\rho(770)$	26.0
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	$a_1(1260)$	10.8
$\tau^- \to h^- h^+ h^- \nu_\tau$	$a_1(1260)$	9.8
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$		4.8
Other modes with hadrons		1.8
All modes containing hadrons		64.8

- We often say “tau” when we mean “hadronic tau decay”
- Tau reconstruction in CMS and the Tau POG are about **tau decays to hadrons**!

Reconstructing taus: The hadrons-plus-strips algorithm

- Input: **charged hadrons, electrons, and photons** reconstructed by the CMS **particle-flow** algorithm
- **Reconstructed decay modes**
  - **1-prong**, **1-prong + nπ^0**, **3-prong**, **3-prong + π^0** (new!)
    - Charged **Hadrons** *h* can be either π or *K*, but predominantly π
      ($m_{\pi^\pm}$ hypothesis assumed in reconstruction)
  - π^0 are reconstructed from *e* and γ deposits in rectangular regions in ECAL, called **strips**

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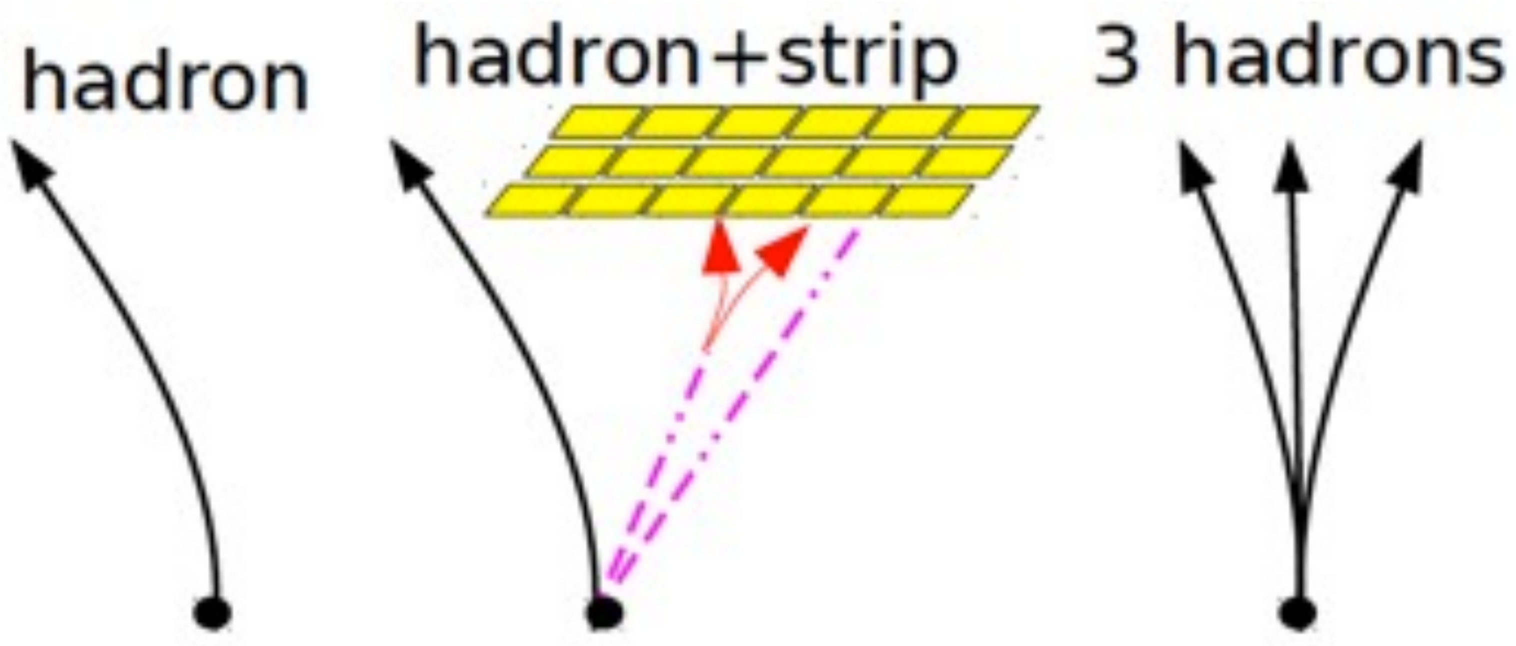


Also new: **2-prong (+ π^0)**

- Recovery decay modes for 3-prong tau decays where one *h* is not reconstructed

You'll learn more about it in the first exercise

Finding taus amongst jets, electrons, and muons

Quark or gluon jets are **abundant** at the LHC

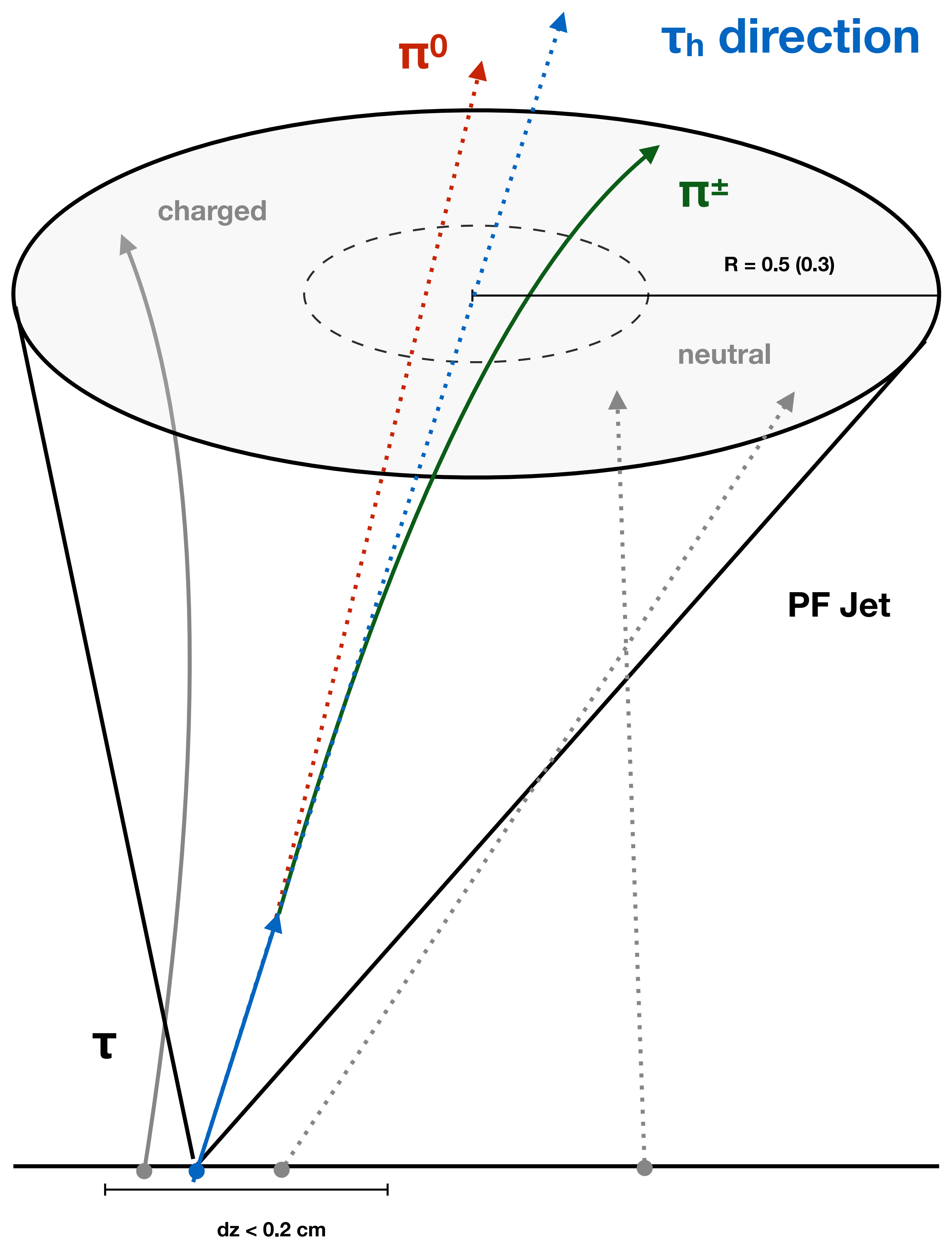
They usually contain charged hadrons and π^0s and lead to reconstructed tau candidates

Distinguishing taus from them is essential:

- Multiplicity, isolation (e.g. pT sum of particles other than the tau decay products)
- No intermediate resonances with defined mass
- Tau lifetime

We combine different pieces of information in multivariate classifiers to distinguish taus from jets (and also electrons and muons), nowadays using a classifier using a deep neural network called **DeepTau**

*Electrons can also look **very** similar to 1-prong taus, and it's also important to distinguish 1-prong taus from muons*



You'll learn more about it in the second exercise

Conclusion

Tau reconstruction is **complex and challenging** but well worth the effort given its **importance in Higgs physics, lepton universality, and various other searches**

Significant algorithmic advances are still possible as recently demonstrated by new decay modes and the new DeepTau classifiers

You will learn, with the help of two Jupyter notebooks:

1. How taus are reconstructed and how efficient the tau reconstruction algorithm is

2. How well we can currently distinguish taus from jets (and possibly electrons and muons)

The goal is to

- **equip you with a basic understanding of tau reconstruction and identification in CMS**

- **give you ideas how you can help improve taus**