A brief introduction about taus

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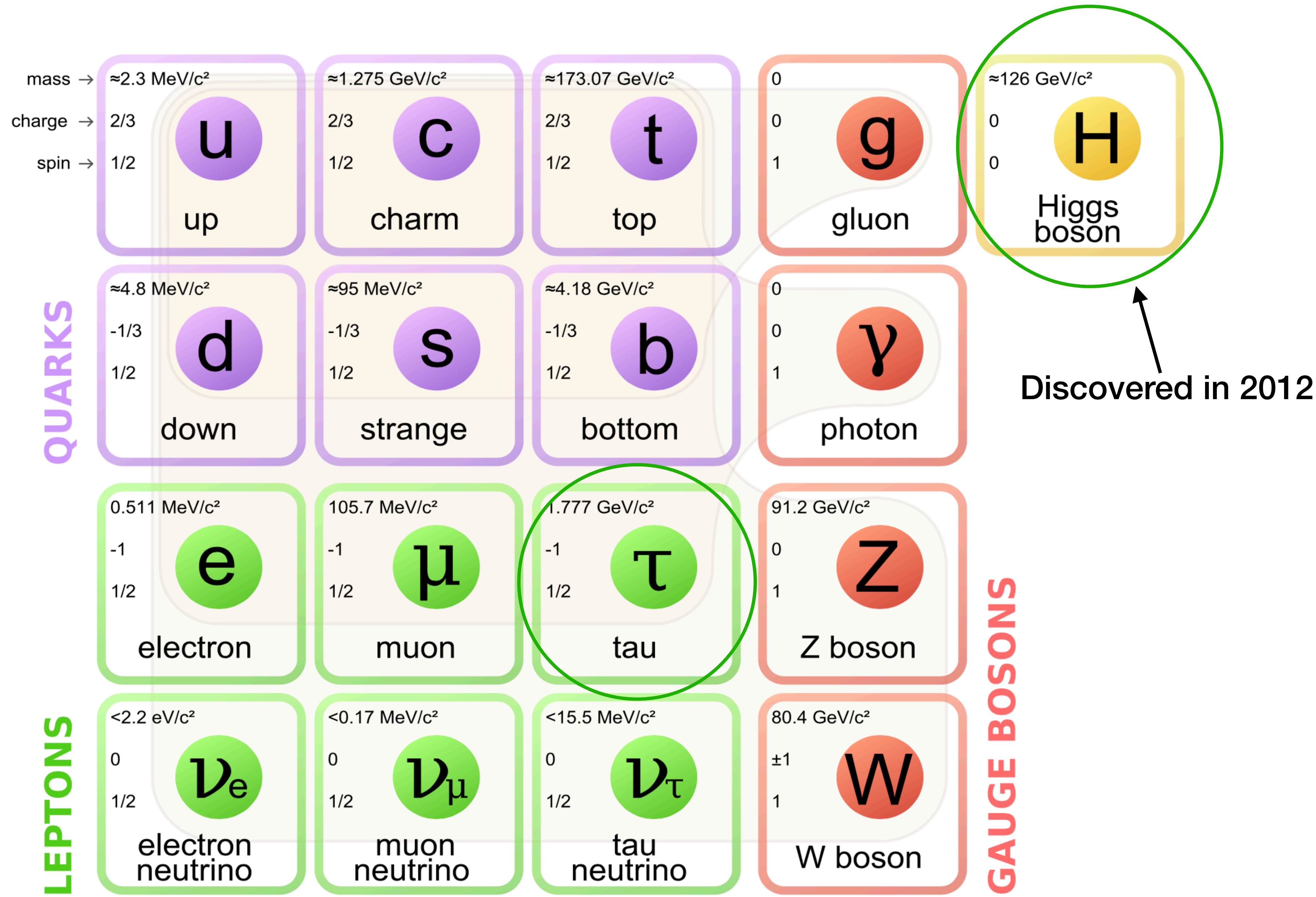
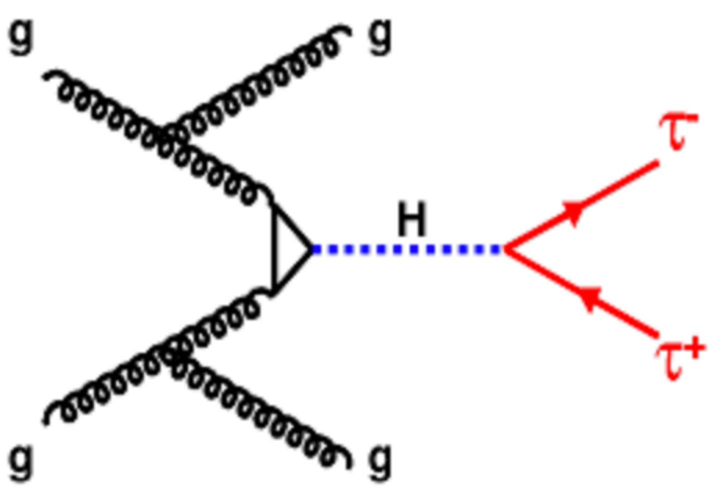
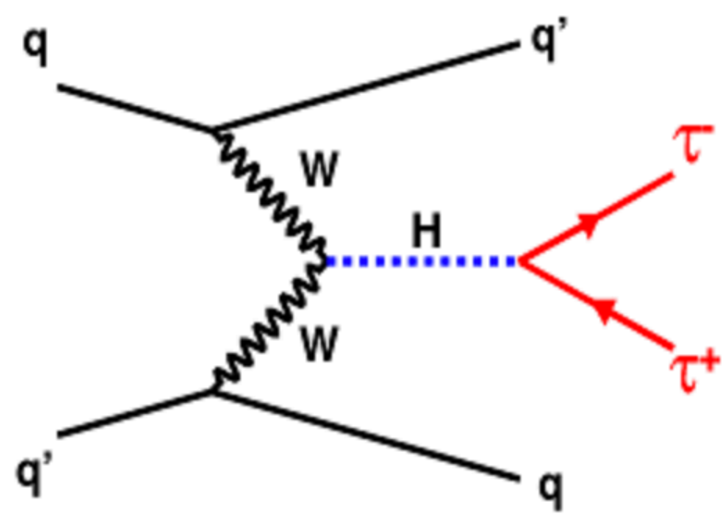
LHC Mentorship

Elementary particle family

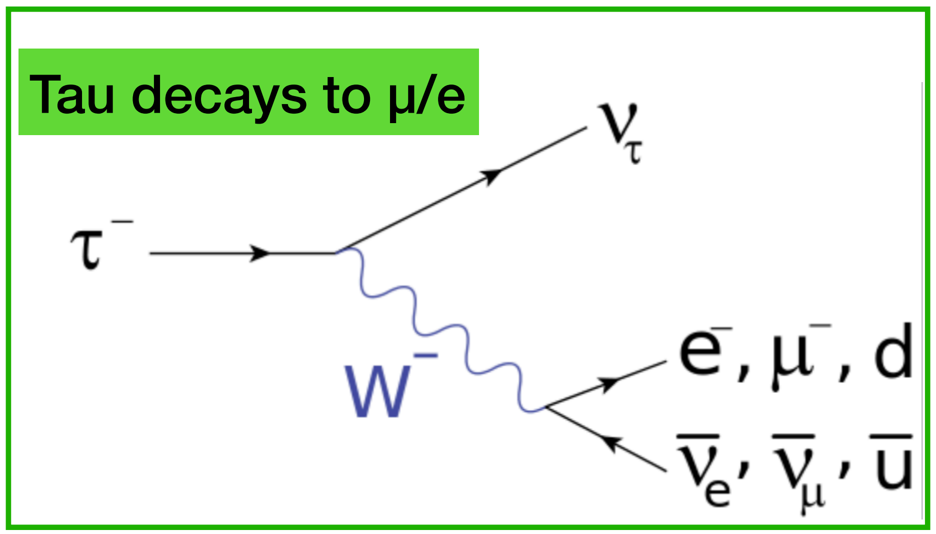


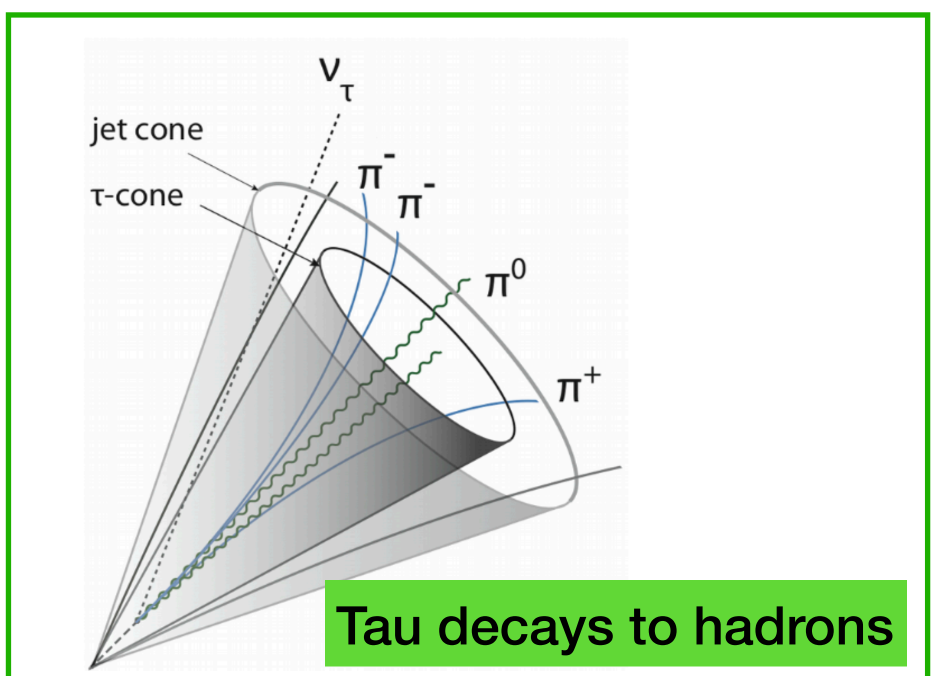
Why taus

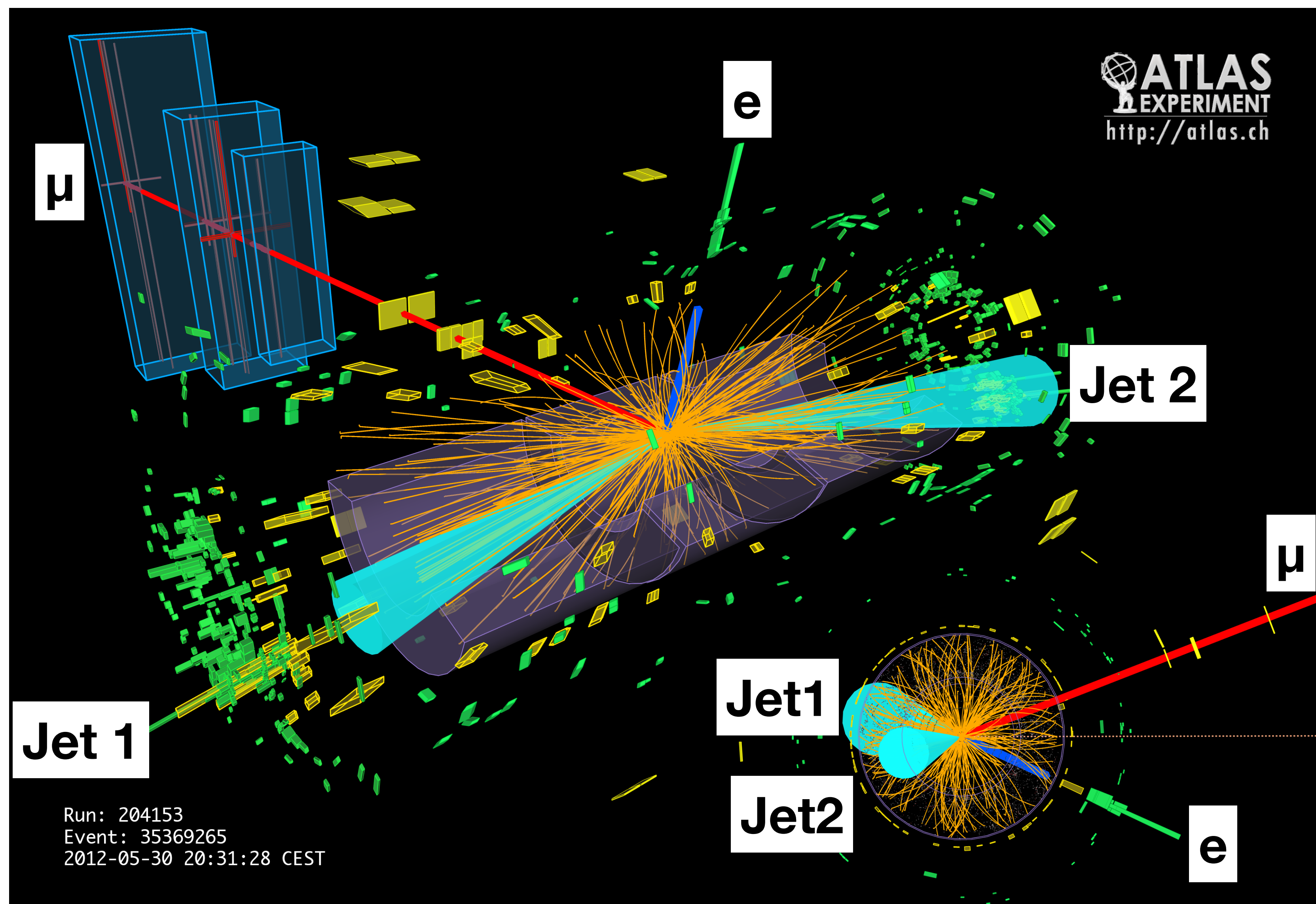




- Heaviest lepton: 1.78 GeV
- Understanding the nature of Higgs boson
- Search for Higgs-like couplings
- Puzzles about lepton universality and flavor violation







Examples of tau involved analyses

SM $H \to \tau\tau$

LFV $H \to \mu\tau$

$X \to HH \to bb\tau\tau$

SM H CP measurements

MSSM $\Phi \to \tau\tau$

EXO $W'/Z' \to \tau\nu/\tau\tau$

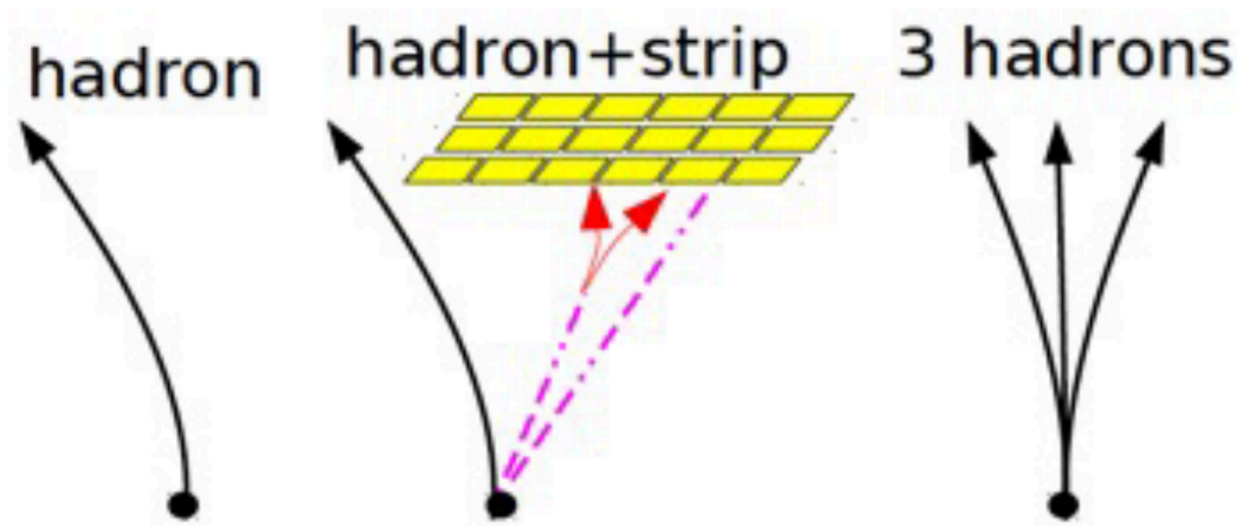
MSSM $H^{+} \to \tau\nu$

Profile of the tau lepton

Decay mode	Meson resonance	$\mathcal{B}$ [%]
$\tau^- \to e^- \bar{\nu}_e \nu_\tau$		17.8
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$		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

- Tau is the only lepton heavy enough to decay into hadrons
- Finite lifetime 0.29 picosecond, nearly light speed (c ≈ 300K km/s), totally flight distance ≈ 90μm
- Around 35% of tau decays into light leptons and neutrinos
- 65% decays into hadrons + neutrinos
    - Reconstruct different decay modes to identify taus
    - We often say “taus” meaning “hadronic decay taus”

Tau reconstruction: hadrons-plus-strips algorithm



- π^0 are reconstructed from e and γ deposits in rectangular regions in ECAL, called **strips**

- **Input: charged hadrons, electrons, and photons reconstructed by the CMS particle-flow algorithm from a jet cone**
- **Reconstructed decay modes of taus:**
  - 1-prong
  - 1-prong + π^0
  - 3-prongs (+ π^0 s)
- Charged hadrons (h) can be pions (predominately), Kaons

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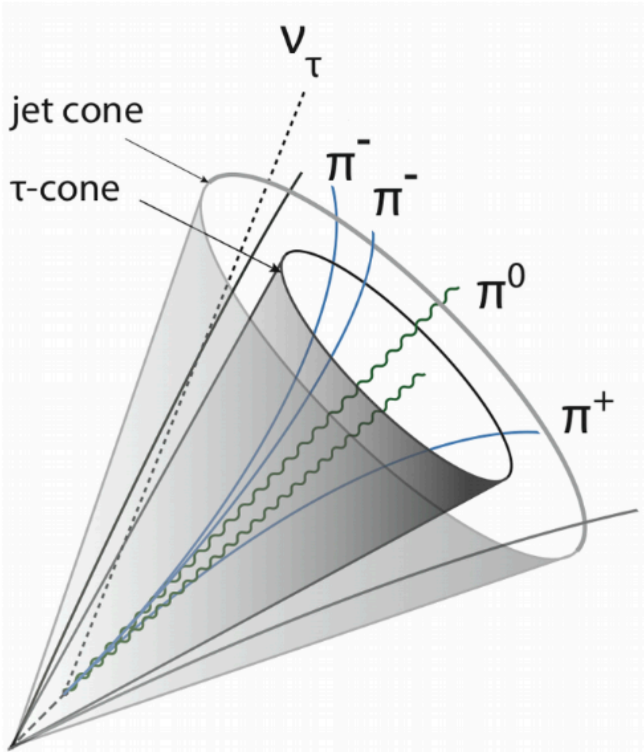
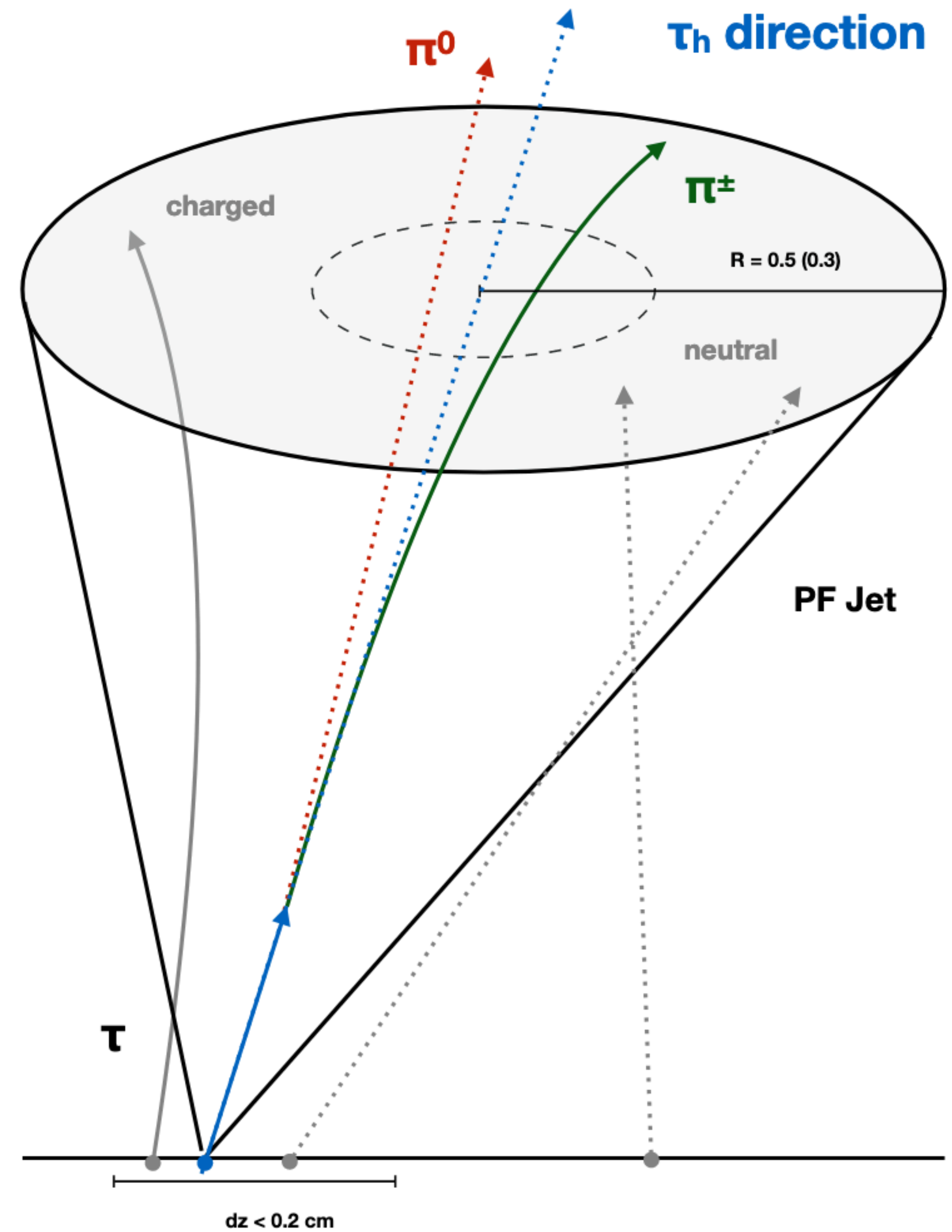
- You will learn more about it in the first exercise

Find taus amongst jets, electrons, muons



- Quark and gluon formed jets are abundant at the LHC
- They usually contain charged hadrons and π0 s and lead to reconstructed tau candidates



- Distinguishing taus from them are essential:
  - Multiplicity, isolation (transverse momentum sum of particles other than the tau decay products)
  - No intermediate resonances with defined mass
  - Tau lifetime

- Multiplevariable (MVA) classifier:
  - Combine different piece of information above
  - Distinguish taus from jets, electrons, muons
- Deep neural network (DeepTau) classifier:
  - Advanced machine learning technique

- You will 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 many other new physics searches

- Significant algorithmic advances are still possible as recently demonstrated by new Deep neural network classifiers

- You will learn:
  - How taus are reconstructed and how efficient the tau reconstruction algorithm is
  - How well we can currently distinguish taus from jets (possibly electrons and muons)

- The goal is to:
  - Equip you with basic understanding of tau reconstruction and identification in CMS
  - Give you ideas how you can help improve taus!