

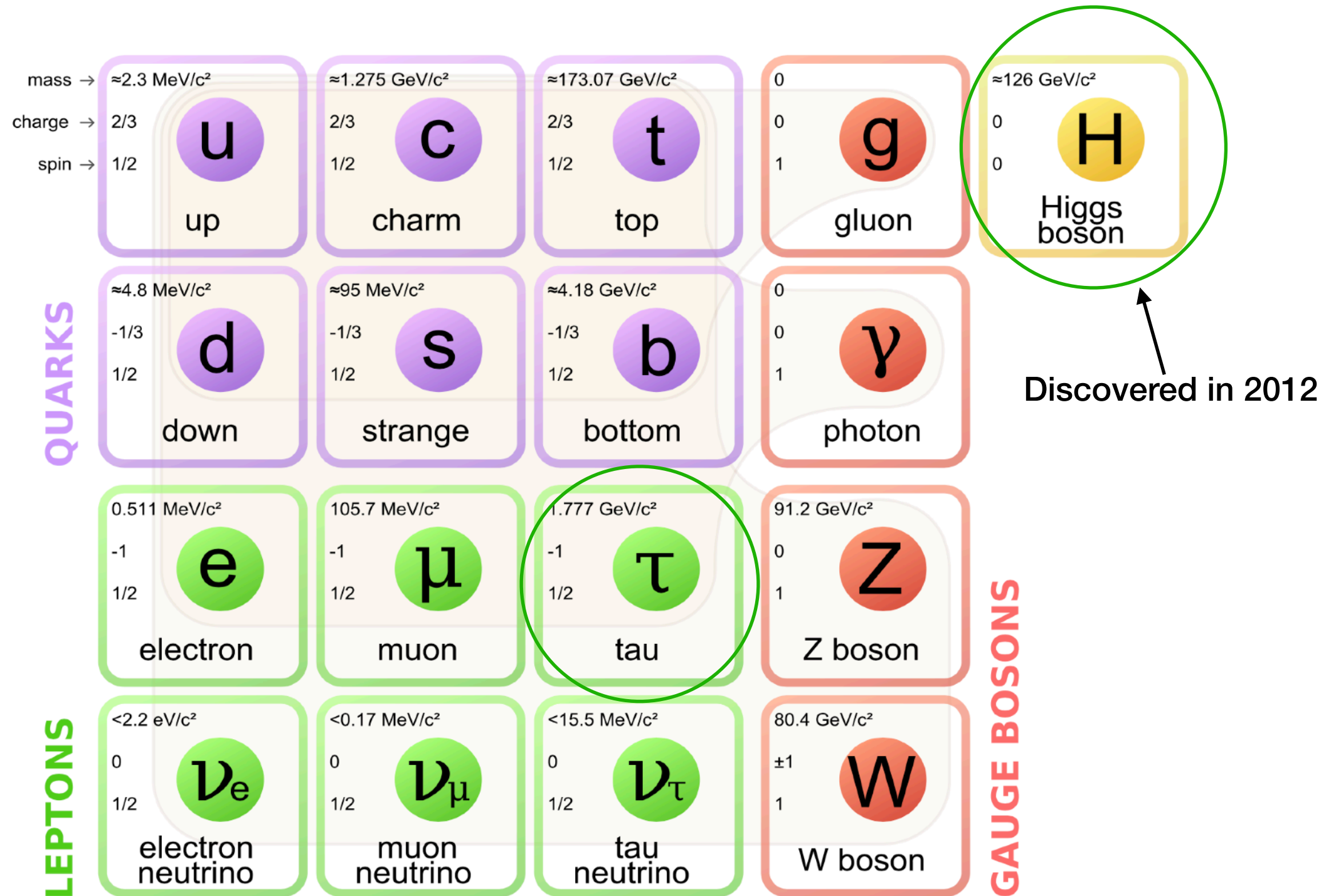
A brief introduction about taus

Feng Zhang on behalf of Tau team

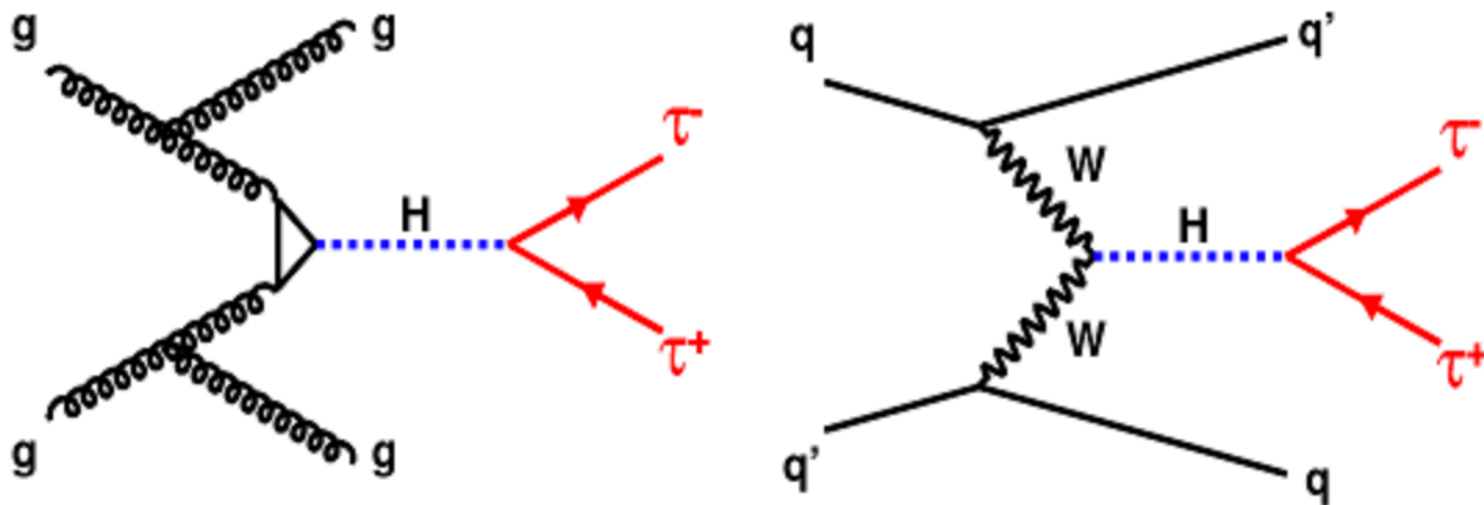
CMS DAS @LPC

08/01/2024

Elementary particle family

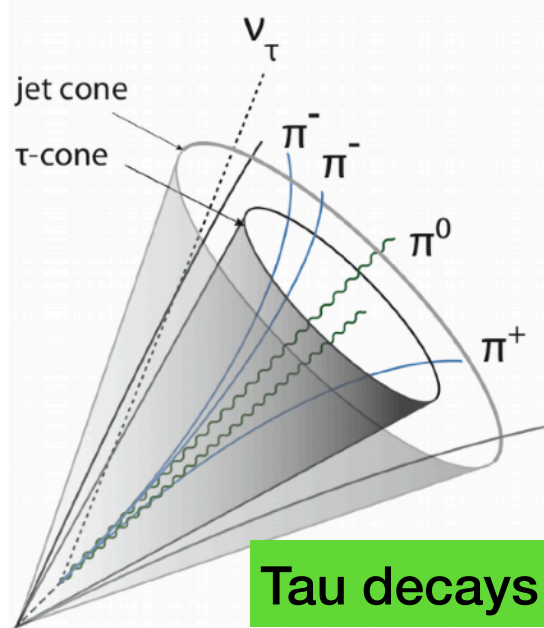
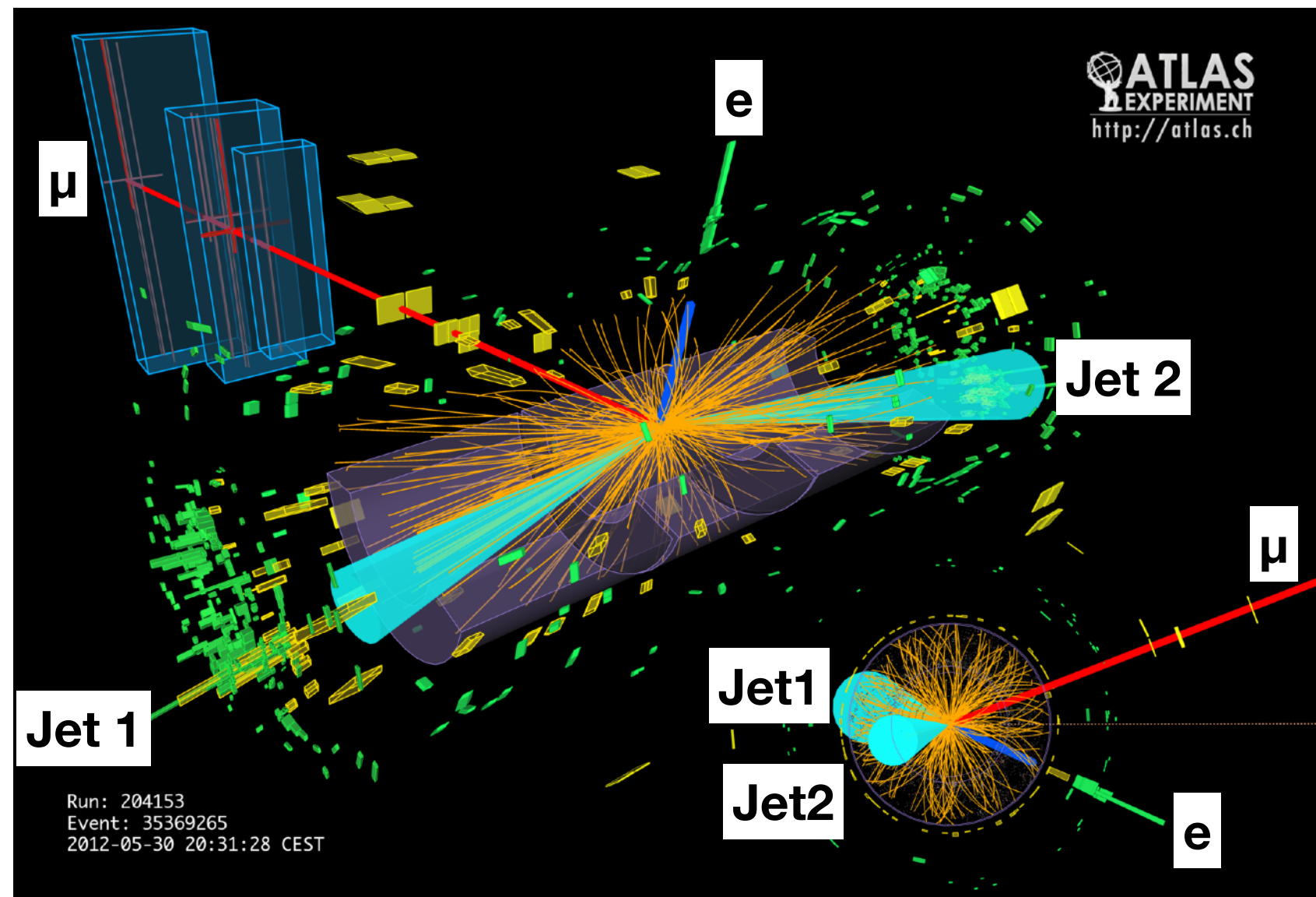
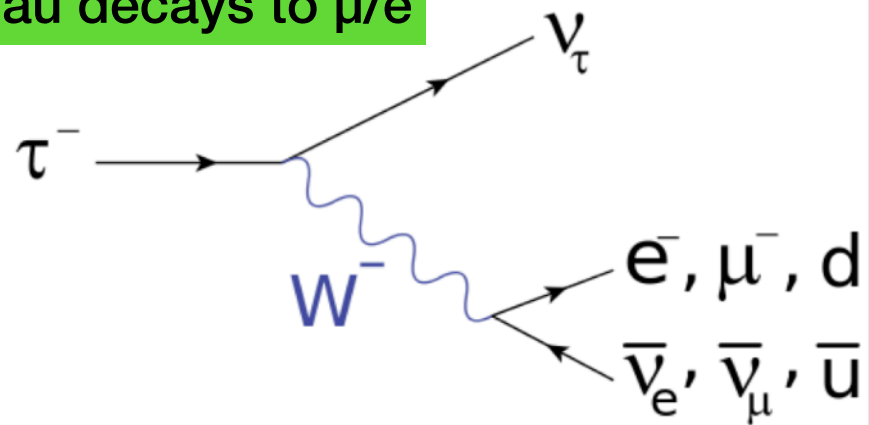


Why taus



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

Tau decays to μ/e



Tau decays to hadrons

Examples of tau involved analyses

SM $H \rightarrow \tau\tau$

LFV $H \rightarrow \mu\tau$

$X \rightarrow HH \rightarrow bb\tau\tau$

SM H CP
measurements

MSSM $\Phi \rightarrow \tau\tau$

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

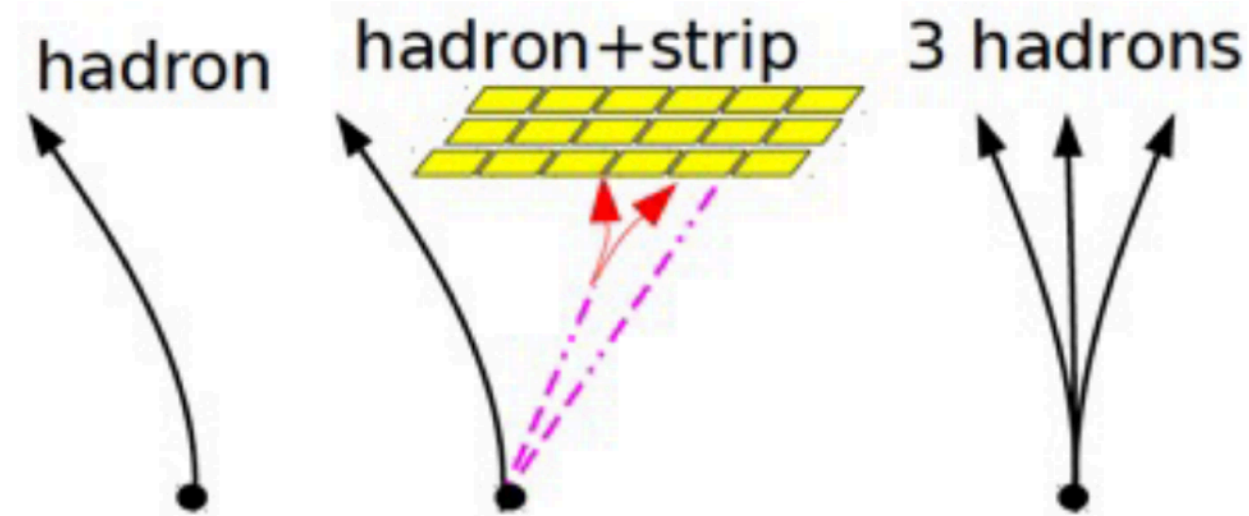
MSSM $H^+ \rightarrow \tau\nu$

Profile of the tau lepton

Decay mode	Meson resonance	\mathcal{B} [%]
$\tau^- \rightarrow e^- \bar{\nu}_e \nu_\tau$		17.8
$\tau^- \rightarrow \mu^- \bar{\nu}_\mu \nu_\tau$		17.4
$\tau^- \rightarrow h^- \nu_\tau$		11.5
$\tau^- \rightarrow h^- \pi^0 \nu_\tau$	$\rho(770)$	26.0
$\tau^- \rightarrow h^- \pi^0 \pi^0 \nu_\tau$	$a_1(1260)$	10.8
$\tau^- \rightarrow h^- h^+ h^- \nu_\tau$	$a_1(1260)$	9.8
$\tau^- \rightarrow h^- h^+ h^- \pi^0 \nu_\tau$		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 ($c \approx 300K$ km/s), totally flight distance $\approx 90\mu\text{m}$
- 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



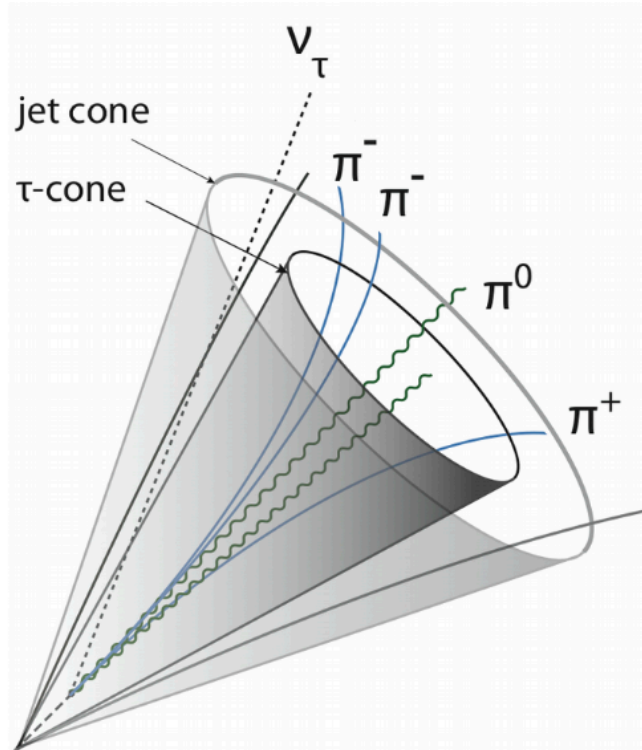
- π^0 are reconstructed from e and γ deposits in rectangular regions in ECAL, called **strips**

- 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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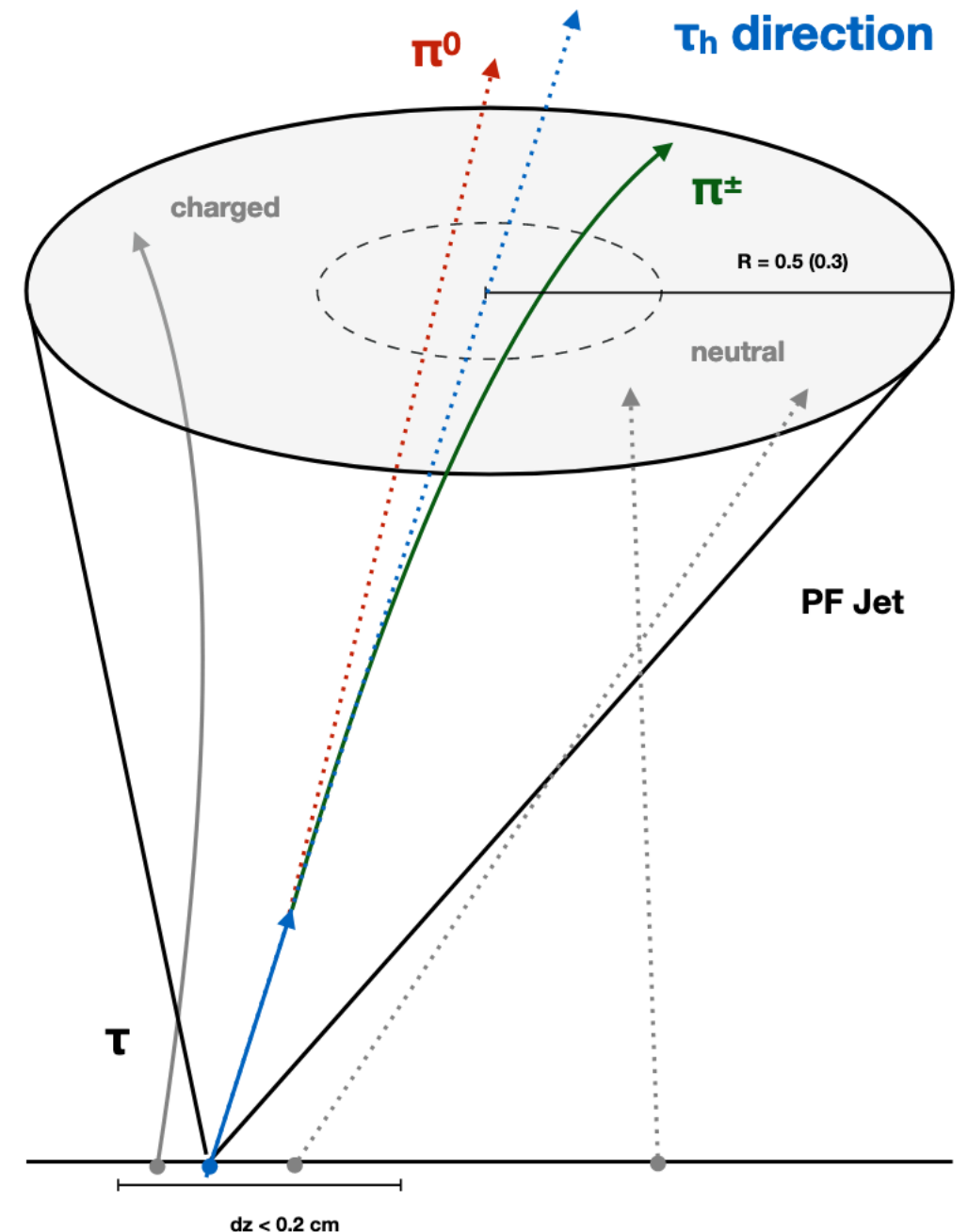
- You will learn more about it in the first exercise

Find taus amongst jets, electrons, muons



- Quark and gluon formed jets are abundant at the LHC
- They usually contain charged hadrons and π^0 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
- Multivariable (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!