Probing the Higgs CP Nature in the H→$\tau\tau$ Decay

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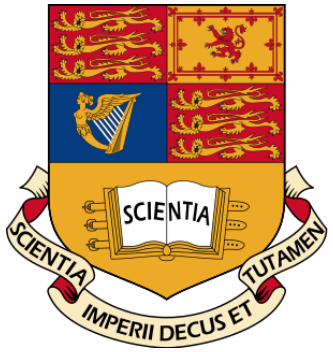
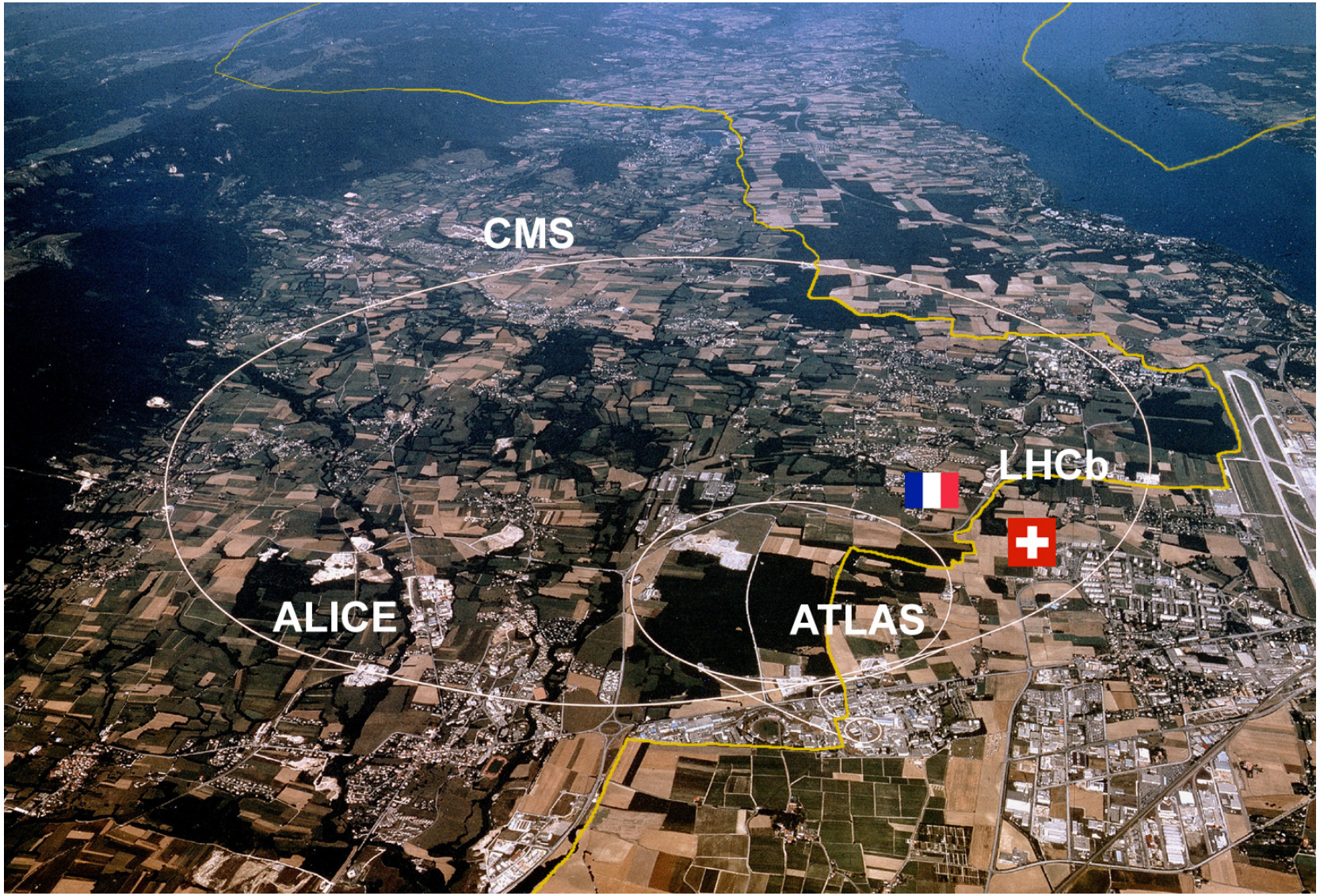
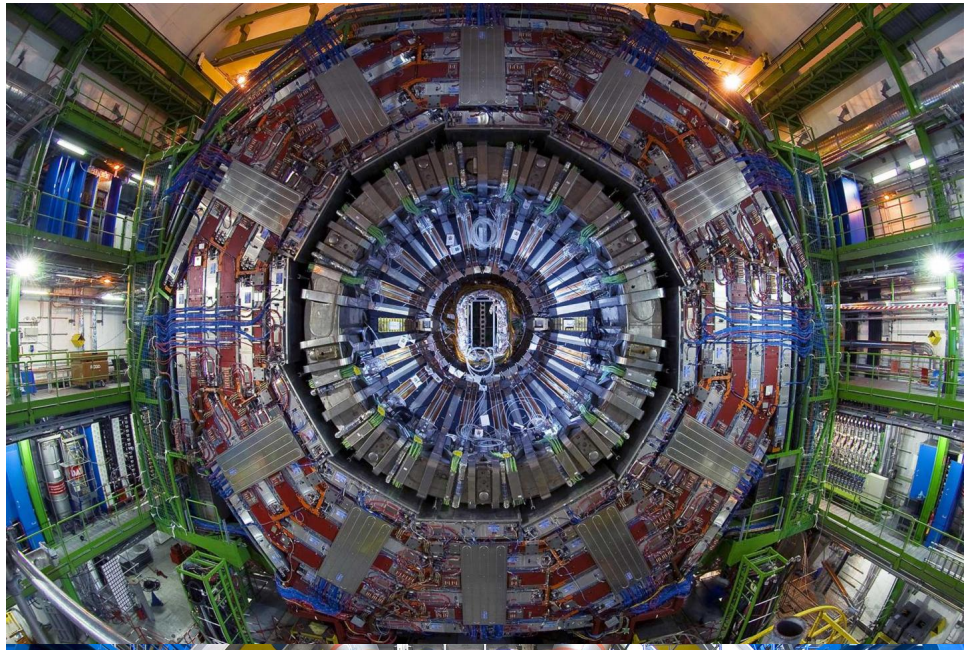
26 Feb2019



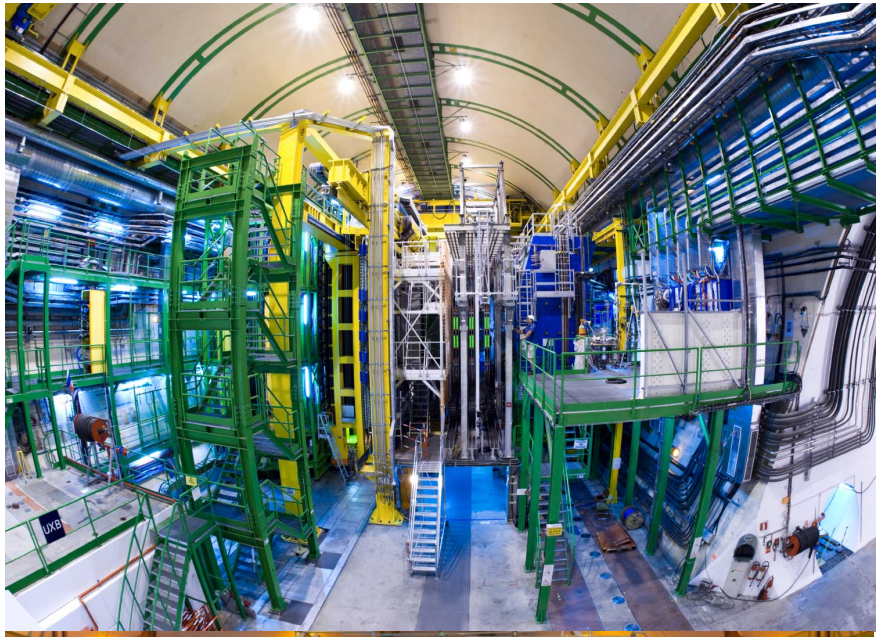
The Large Hadron Collider (LHC)



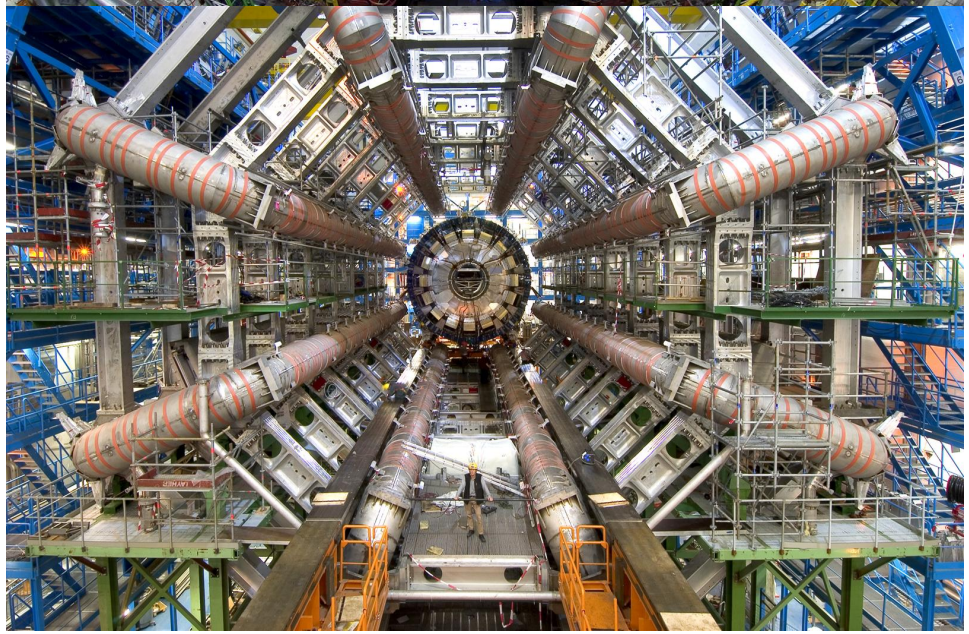
LHC Detectors



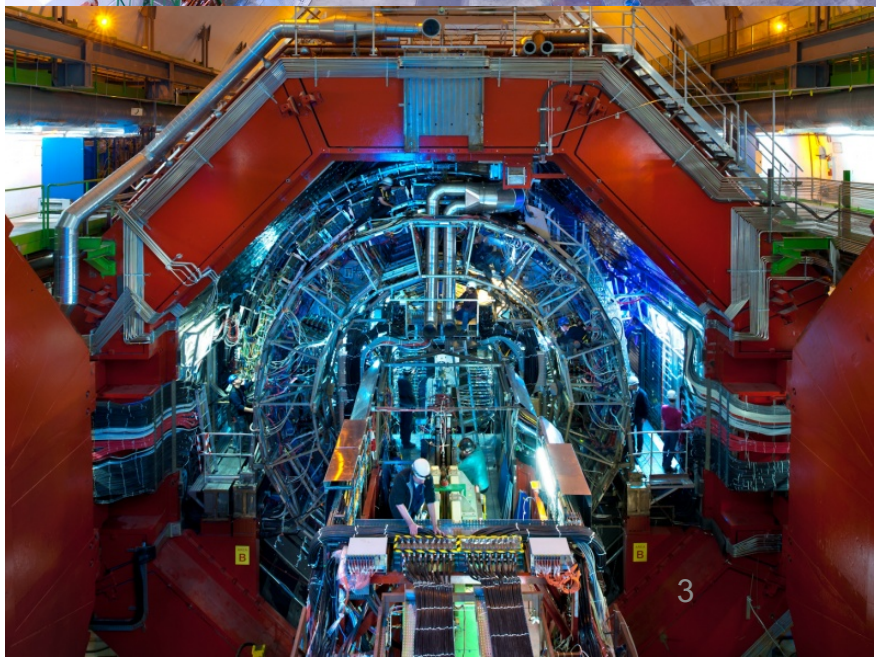
CMS



LHCb

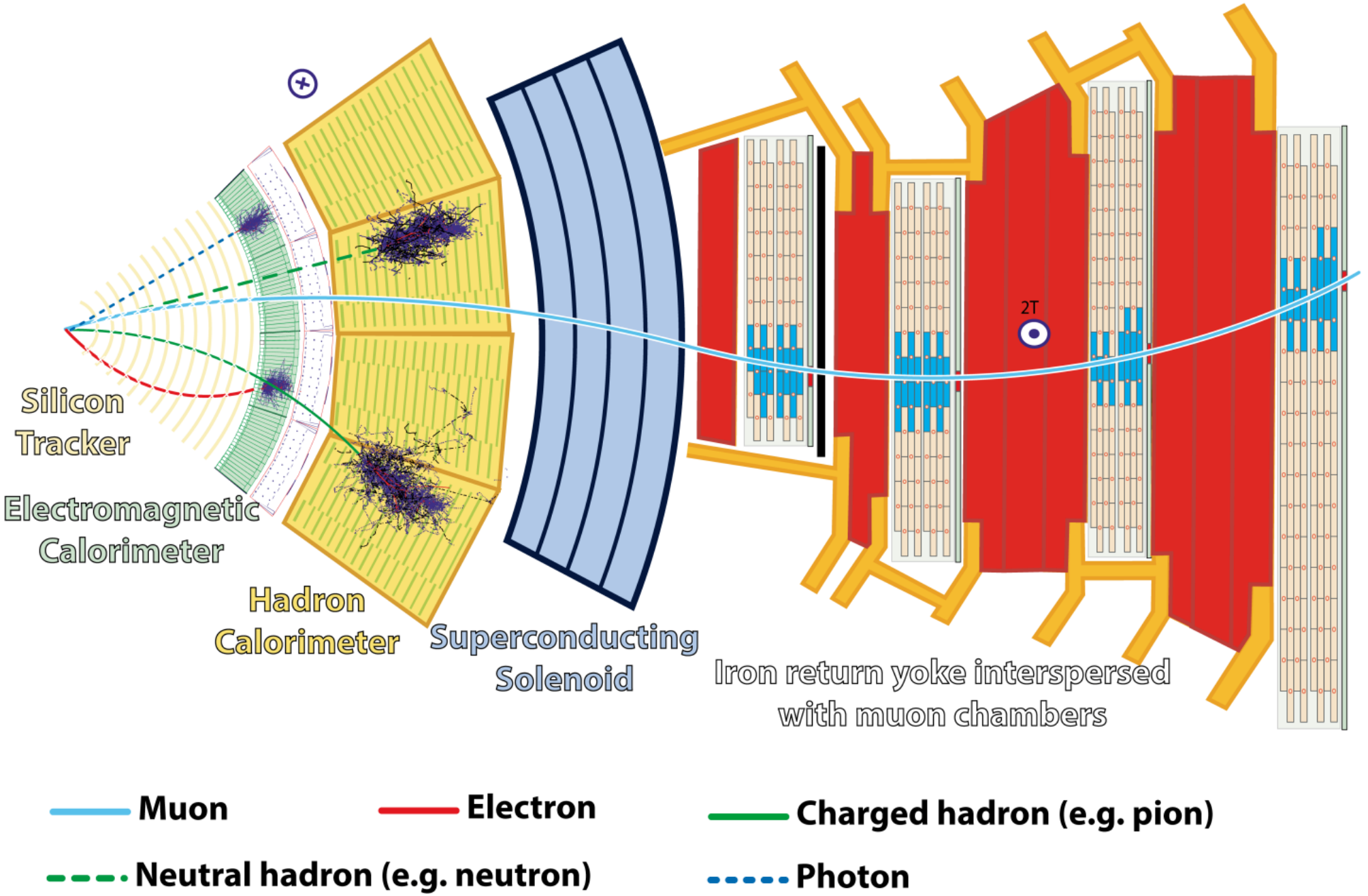


ATLAS



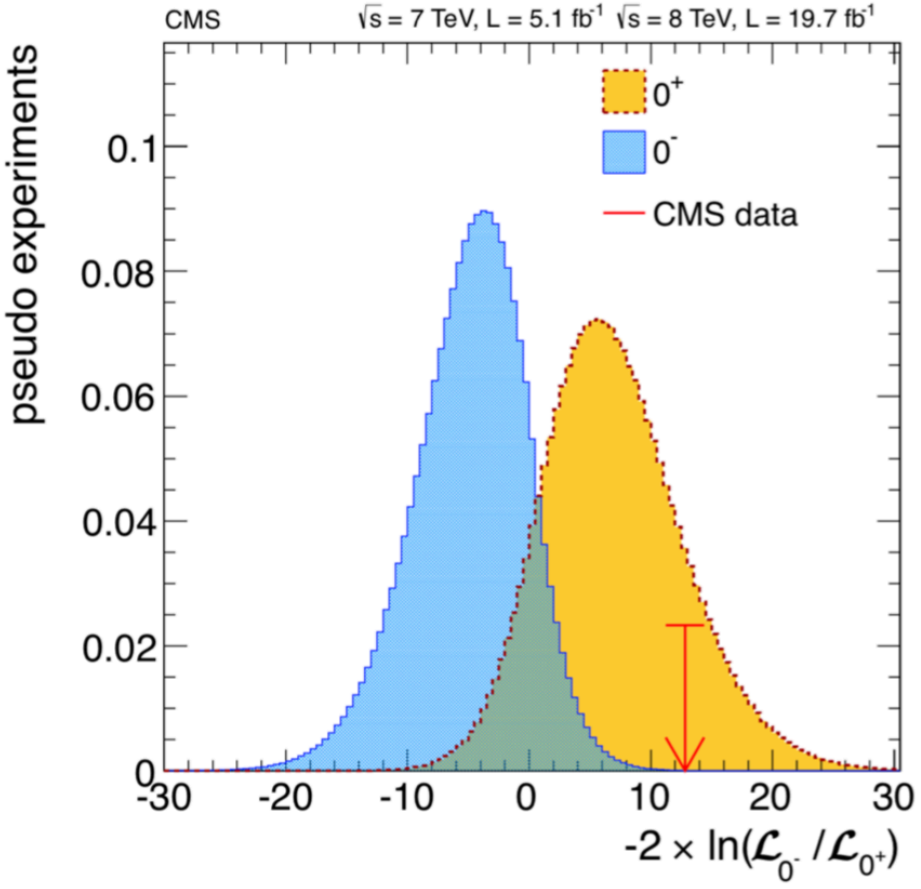
ALICE

The Compact Muon Solenoid (CMS) cross sectional view



Motivation

- Measuring properties of the Higgs: CP nature
- Already measured in $H \rightarrow ZZ^* \rightarrow 4l$
- CMS & ATLAS data disfavored pseudoscalar component of the Higgs
- No surprise! If pseudoscalar component exists, subdominant in $H \rightarrow ZZ^*$



Motivation

- But comparable level contribution in $H \to f\bar{f}$
- Yukawa Lagrangian for τ and Higgs interaction:

$$L_Y = -g_\tau(\cos\phi_\tau \bar{\tau}\tau + \sin\phi_\tau \bar{\tau} i\gamma_5 \tau)h$$

- $\phi_\tau = 0$ => pure scalar
- $\phi_\tau = \pi/2$ => pure pseudoscalar
- $0 < \phi_\tau < \pi/2$ => mixing state

- Final goal: measuring ϕ_τ

Measurement method

Higgs: J=0

So for $|\tau^+\tau^-\rangle$:

if $S = 1 \quad \Rightarrow \quad L = 1$

if $S = 0 \quad \Rightarrow \quad L = 0$

$$CP\,|\tau^+\tau^-\rangle = (-1)^{L+S} \cdot (-1)^{L+1}\,|\tau^+\tau^-\rangle = (-1)^{2L+S+1}\,|\tau^+\tau^-\rangle = (-1)^{S+1}\,|\tau^+\tau^-\rangle$$

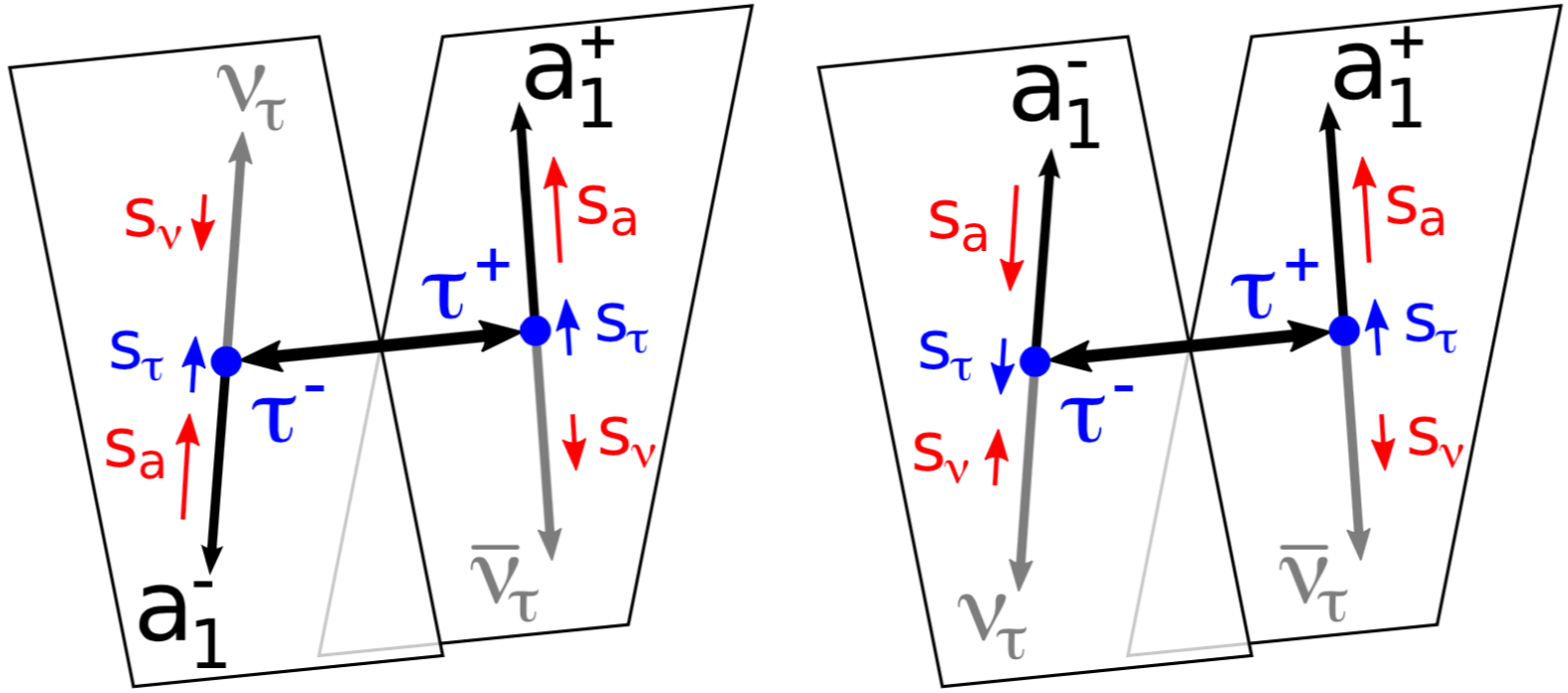
S = 0 => CP = -1 => Pseudoscalar

S = 1 => CP = 1 => Scalar

Problem reduced to: measuring the spin

Measurement method

- Measuring $|\tau^+\tau^-\rangle$ spin
- Parity violated in weak interaction (neutrino handedness pinned down)
- So the angle between decay planes is sensitive to CP

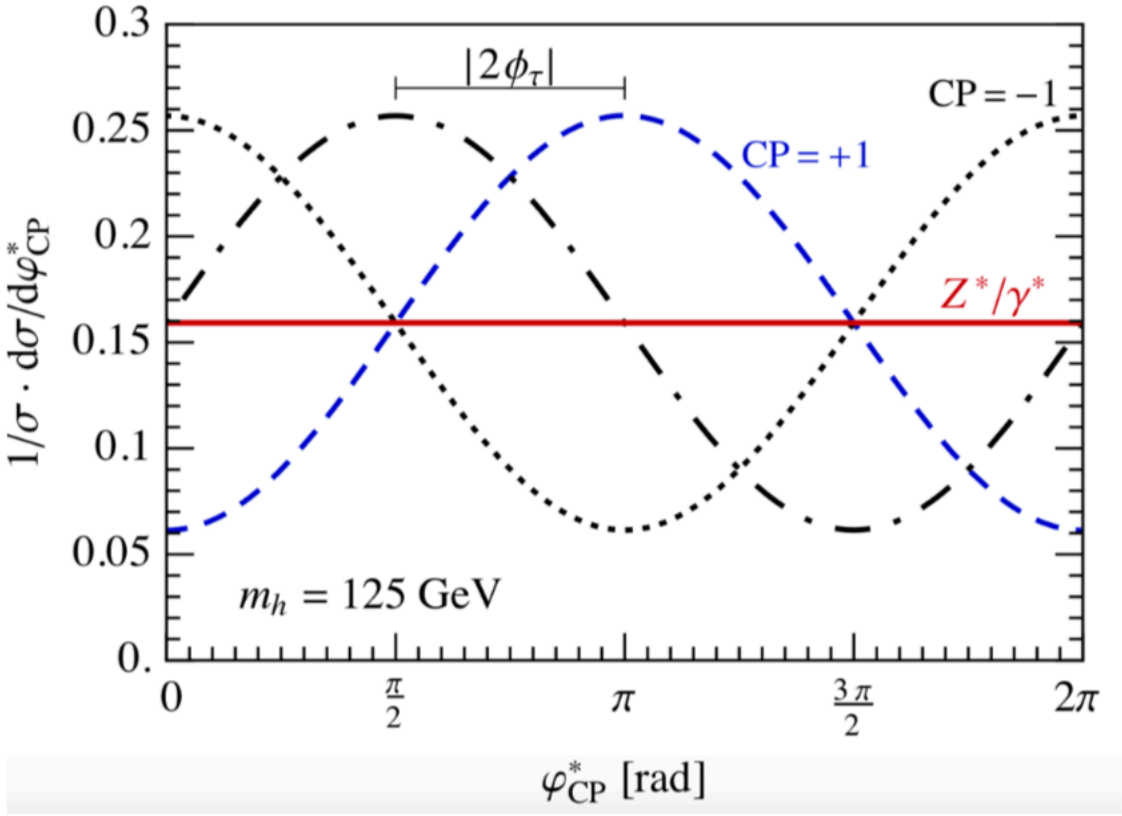


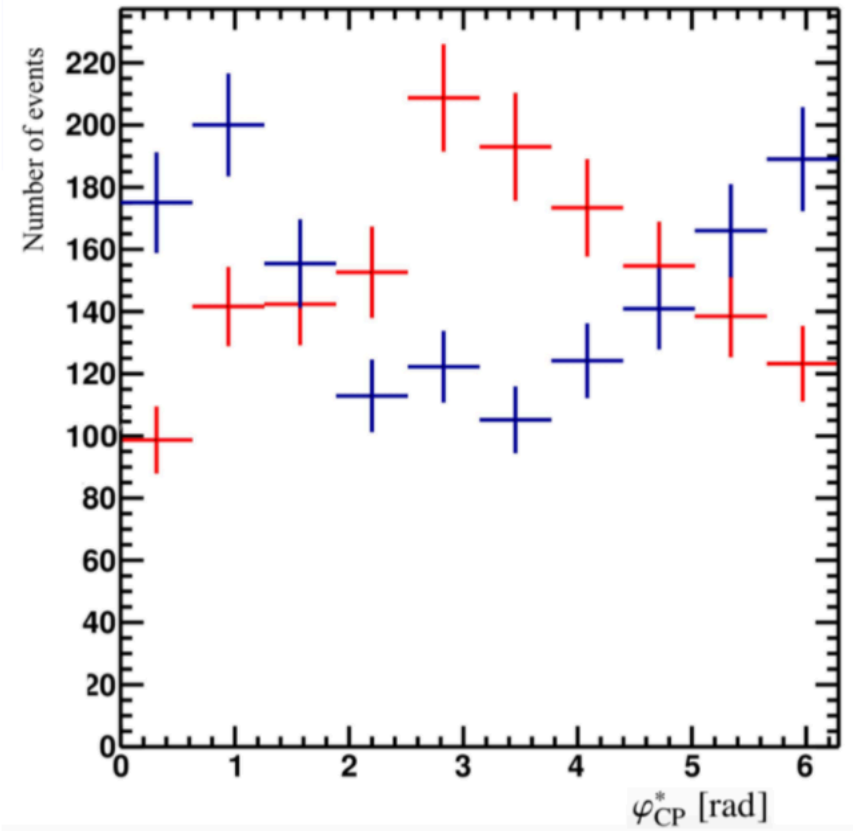
(a) Decay planes for $S = 1$ (scalar). (b) Decay planes for $S = 0$ (pseudoscalar).

Problem reduced to: measuring the angle

Results and Future work

- The angle between the planes discriminates different CP states
- Monte Carlo on the recent CMS data shows the discrimination power
- Further improvement on sensitivity needed to decrease statistics error





Conclusion

- $H \rightarrow \tau^+\tau^-$ decay can unravel the CP nature of the Higgs
- The angle between the decay planes of the taus is sensitive to the Higgs CP
- We will soon analyze the recent CMS data to measure the CP of the Higgs in $H \rightarrow \tau^+\tau^-$ for the first time!

Thank you!

Backup

Tau decay modes

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
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	$a_1(1260)$	9.5
$\tau^- \to h^- h^+ h^- \nu_\tau$	$a_1(1260)$	9.8
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$		4.8
Other modes with hadrons		3.2
All modes containing hadrons		64.8

1 prong ~47%

3 prongs ~15%