CP measurement in H → τ τ

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Today's topic:

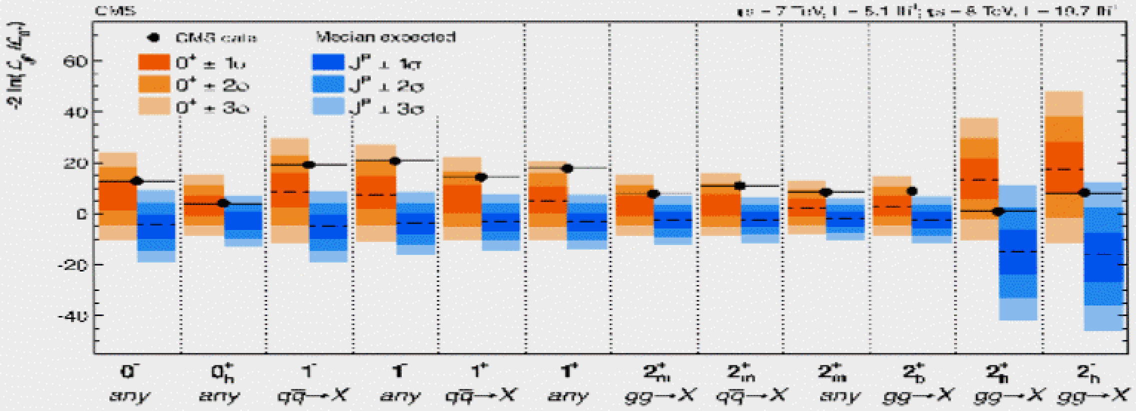
First look at CP observables
at generator level

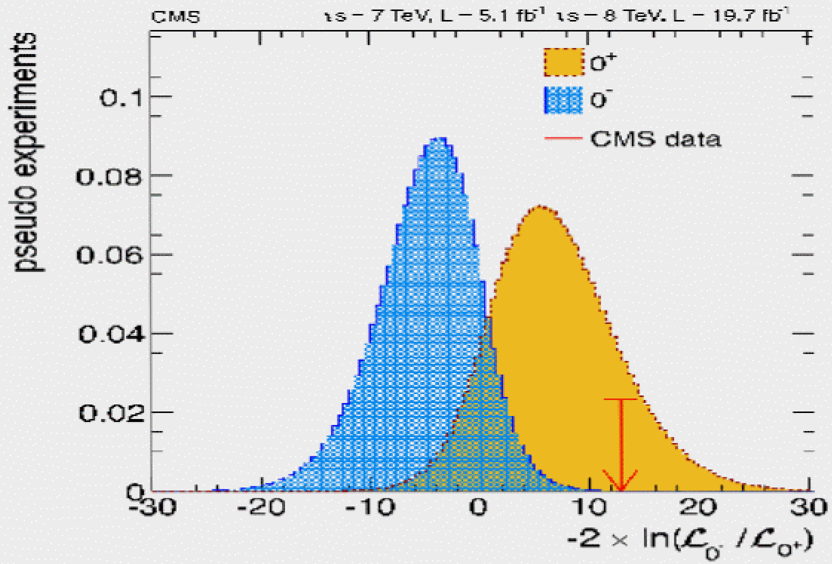
A bit of context

- SM contains only one Higgs boson → the H(125) needs to be CP-even in the model
- The H → ZZ coupling is possible at tree level only for a CP-even state
- CP measurement in the bosonic decays has ruled out the possibility of a pure CP-odd state
- However this does not exclude the possibility of CP-mixing

A bit of context

- **CP properties of H(125) have been studied in bosonic decays**





- **constraints on anomalous HVV couplings → additional information on Higgs CP**
- **although hypothesis of pure pseudoscalar state is ruled out, the H(125) state could be a mixture of CP-even and CP-odd states (with small pseudoscalar component)**

CP measurement in $H \to \tau\tau$

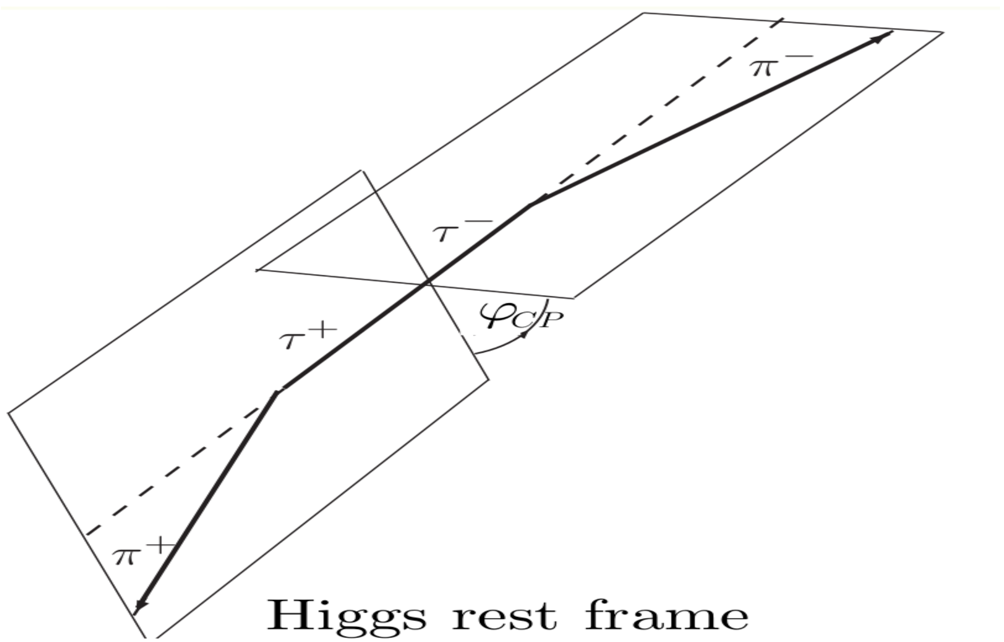
- CP-mixing could show up in the $H \to \tau\tau$ coupling at the leading order:
  - $L = -\frac{m_\tau}{v} k_\tau (\cos\phi_\tau \bar{\tau}\tau + \sin\phi_\tau \bar{\tau} i \gamma_5 \tau) h$
  - The SM prediction corresponds to taking $\phi_\tau = 0$
- To measure ϕ_τ we need to look at the spin correlation:

π^- and π^+ are preferably antiparallel

π^- and π^+ are preferably parallel

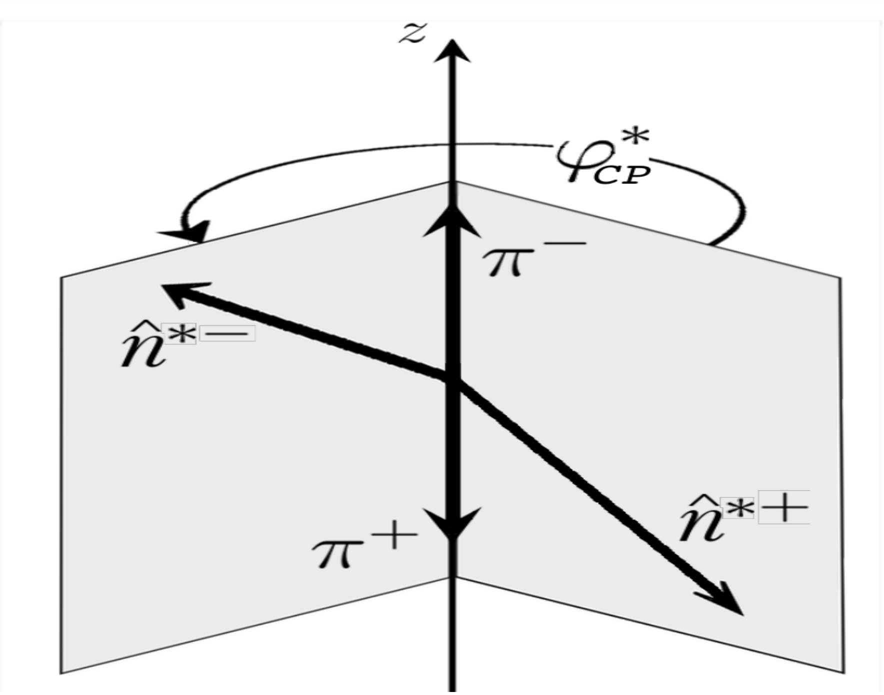
CP measurement in H→τ τ

- To access the spin correlation we need to measure the angle between the τ decay planes
- Measurement in the Higgs rest frame is not feasible since we don't measure neutrinos



CP measurement in H→τ τ

- The measurement for the acoplanarity angle is done in the ZMF of the charged π
- For decays in one $\pi^{\pm}$ the choice is to use the IP vectors to identify the decay planes
- When π^0s are present they can be used instead of the IP



IP method and results

Boost $n^{*\pm} = (0, \hat{n}^{\pm})$ into ZMF of $\pi^{\pm}$

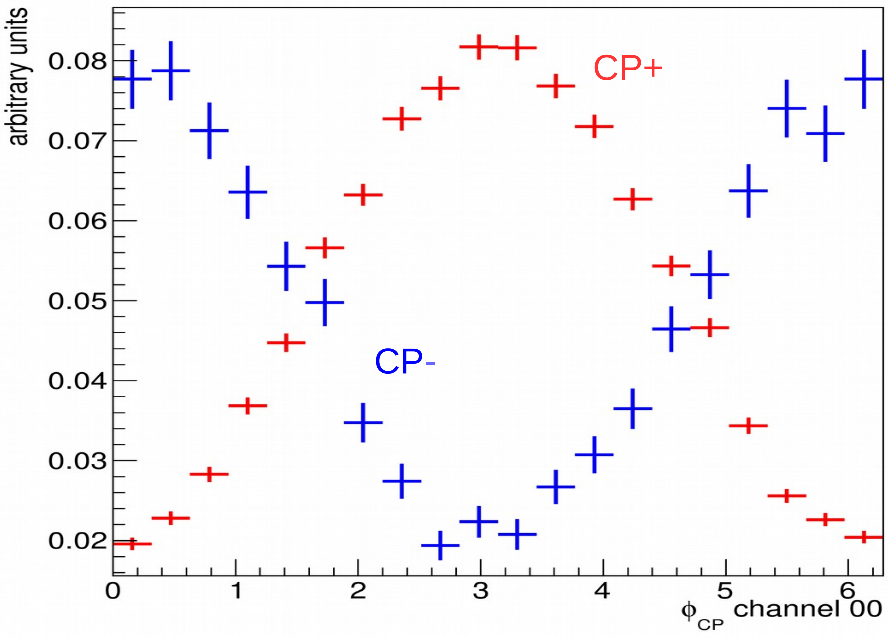
Use transverse components with respect to the pi momenta in that frame: $\hat{n}_{\perp}^{*\pm}$

$$\phi^* = \arccos(\hat{n}_{\perp}^{*+} \cdot \hat{n}_{\perp}^{*-})$$

$$O_{CP}^* = \hat{q}^{*-} \cdot (\hat{n}_{\perp}^{*+} \times \hat{n}_{\perp}^{*-})$$

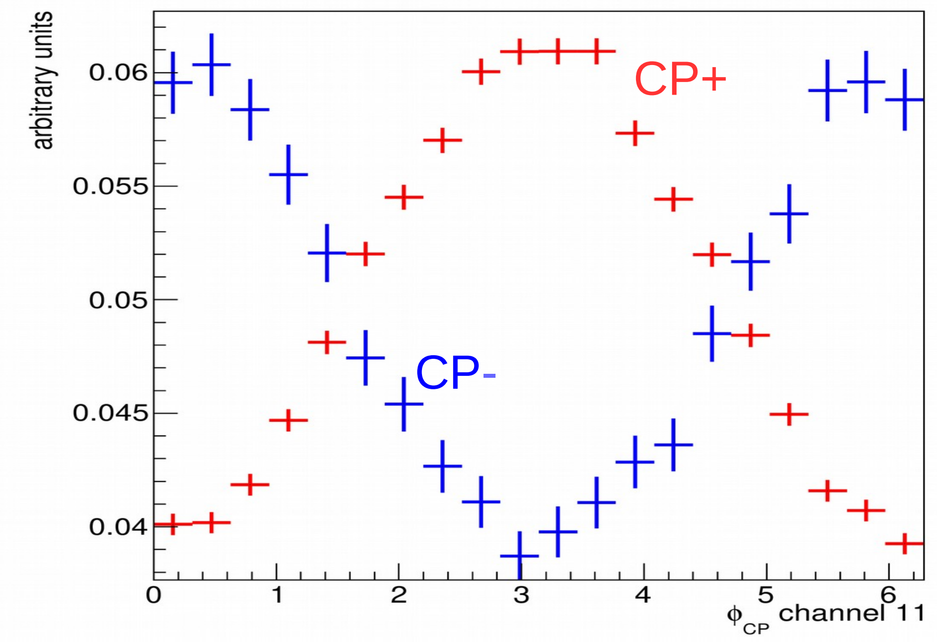
$$\phi_{CP} = \begin{cases} \phi^* & \text{if } O_{CP}^* \geqslant 0 \\ 2\pi - \phi^* & \text{if } O_{CP}^* < 0 \end{cases}$$

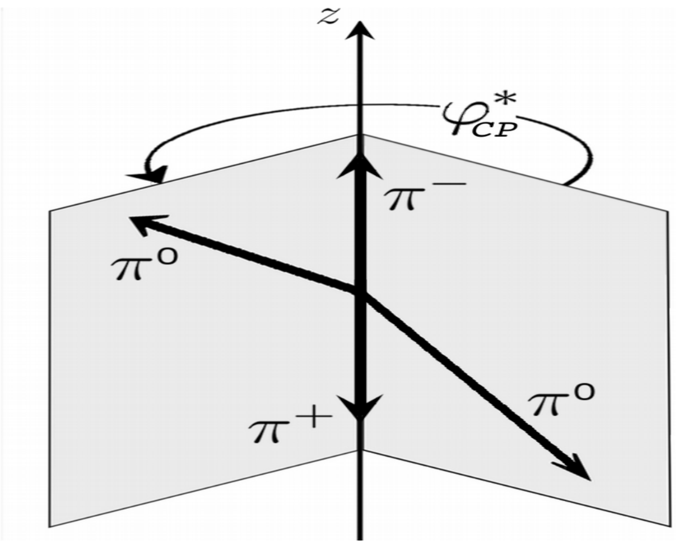
Decay mode 1: $\tau^{\pm} \rightarrow \pi^{\pm}$
Decay mode 2: $\tau^{\pm} \rightarrow \pi^{\pm}$



Results using π^0s

Decay mode 1: $\tau^{\pm} \rightarrow \pi^{\pm} + \pi^0$
Decay mode 2: $\tau^{\pm} \rightarrow \pi^{\pm} + \pi^0$



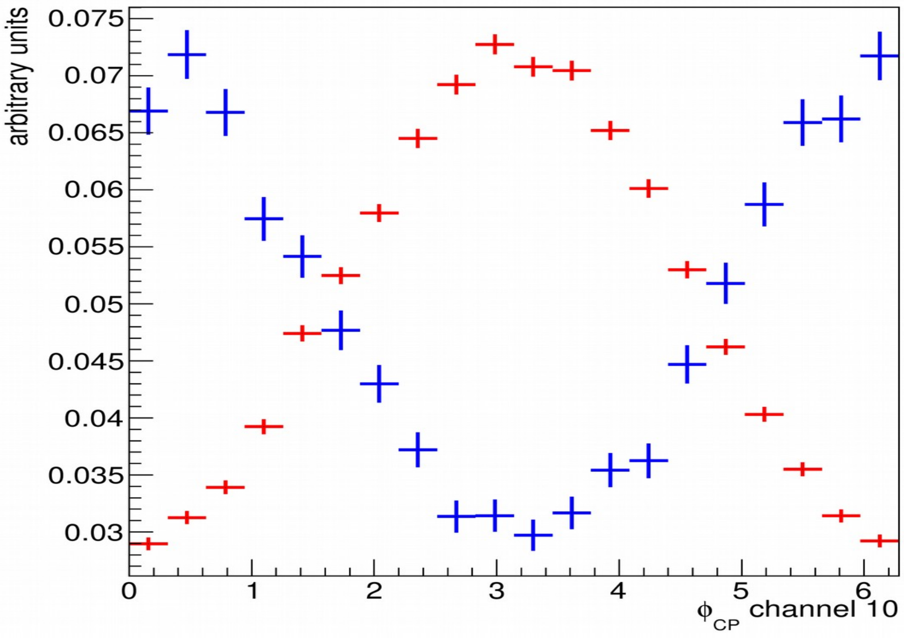


The π^0 momenta is boosted in the ZMF of the charged π.

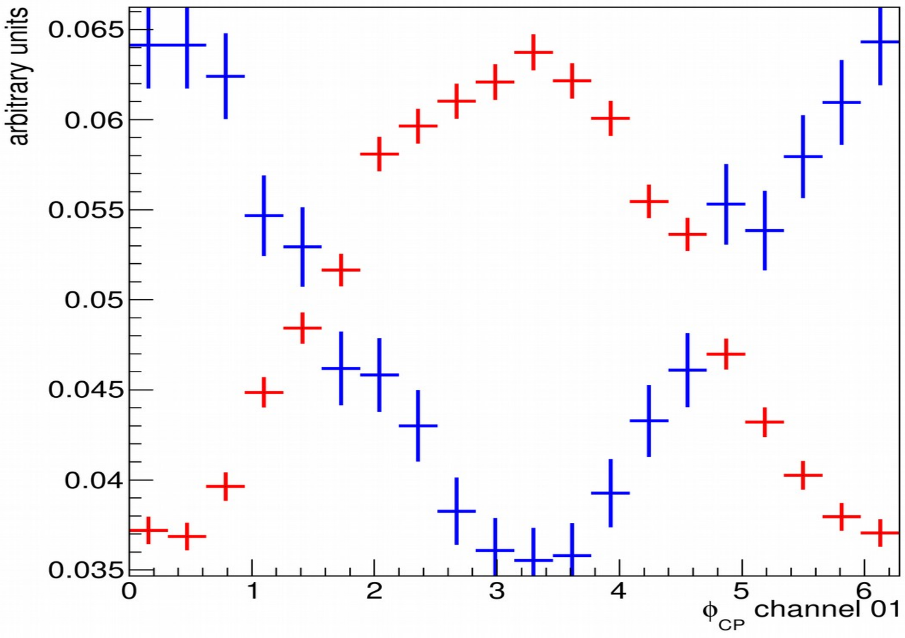
The acoplanarity angle is calculated in a similar way.

Mixed cases

Decay mode 1: $\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{0}$
Decay mode 2: $\tau^{\pm} \rightarrow \pi^{\pm}$

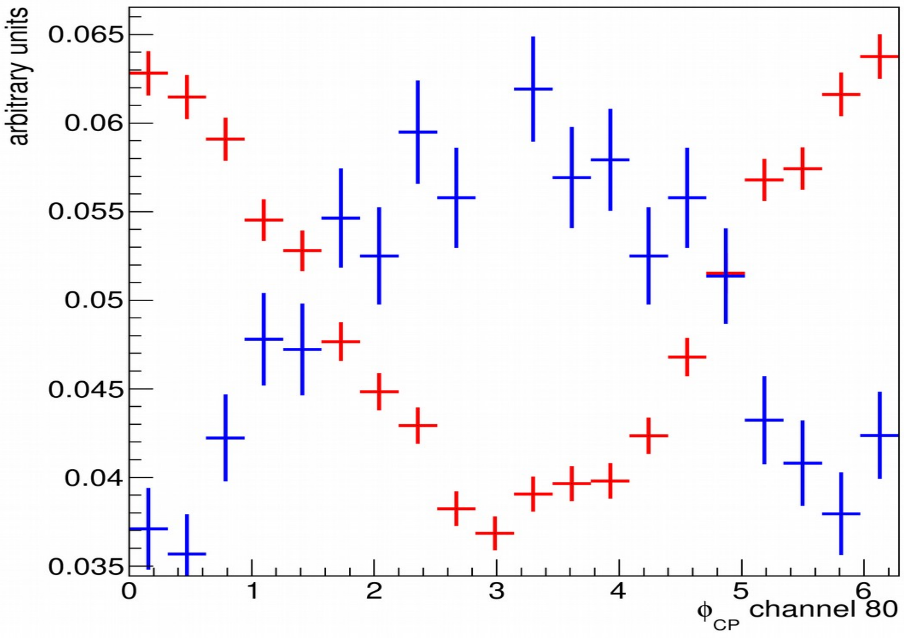


Decay mode 1: $\tau^{\pm} \rightarrow \pi^{\pm}$
Decay mode 2: $\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{0}$

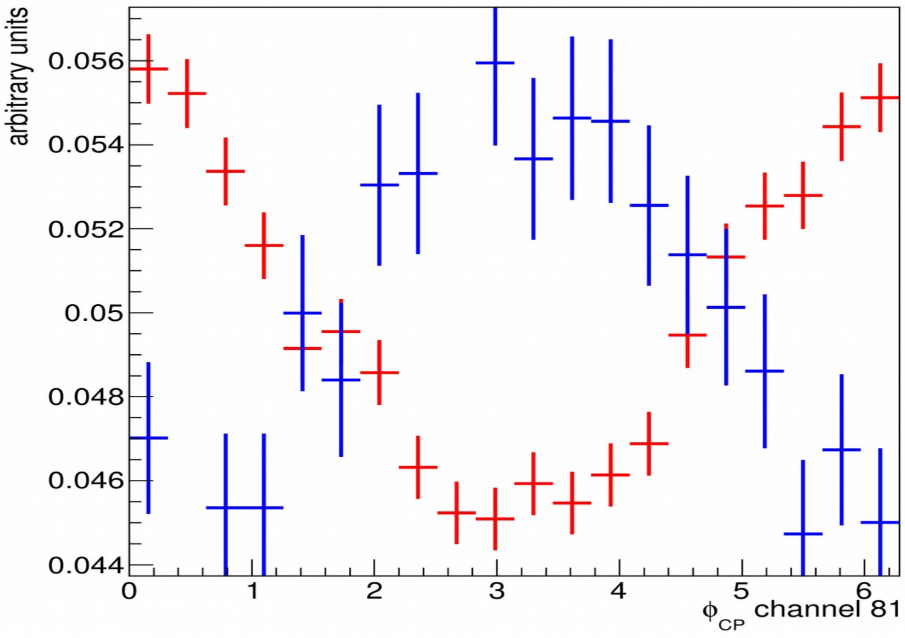


Using a muon as prong

Decay mode 1: $\tau^{\pm} \rightarrow \mu^{\pm}$
Decay mode 2: $\tau^{\pm} \rightarrow \pi^{\pm}$

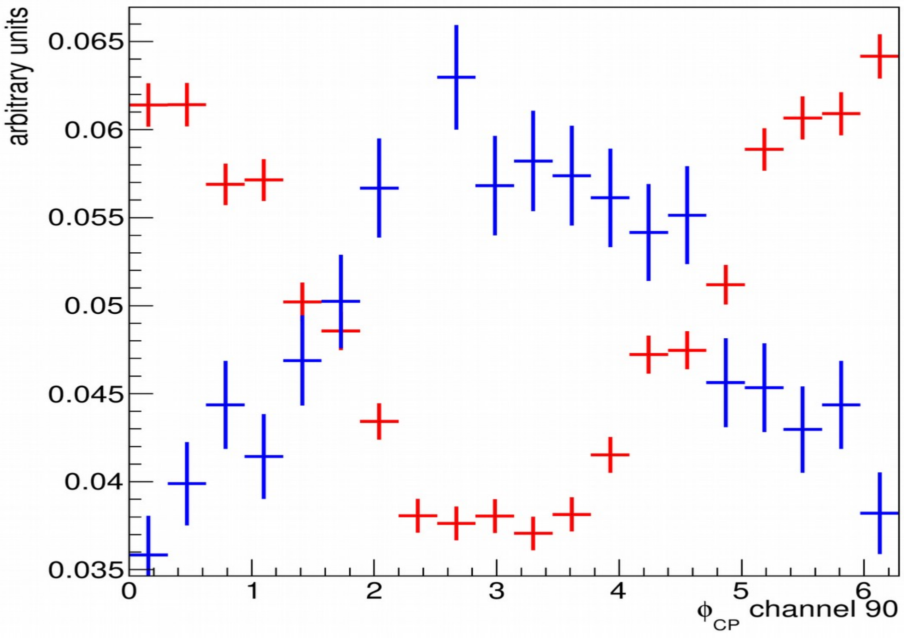


Decay mode 1: $\tau^{\pm} \rightarrow \mu^{\pm}$
Decay mode 2: $\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{0}$

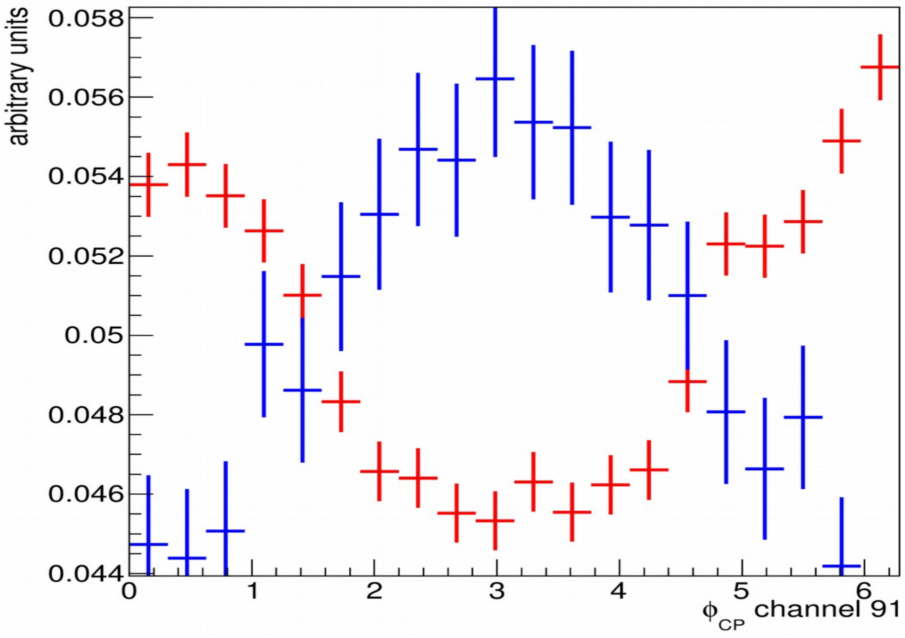


Using an electron as prong

Decay mode 1: $\tau^{\pm} \rightarrow e^{\pm}$
Decay mode 2: $\tau^{\pm} \rightarrow \pi^{\pm}$

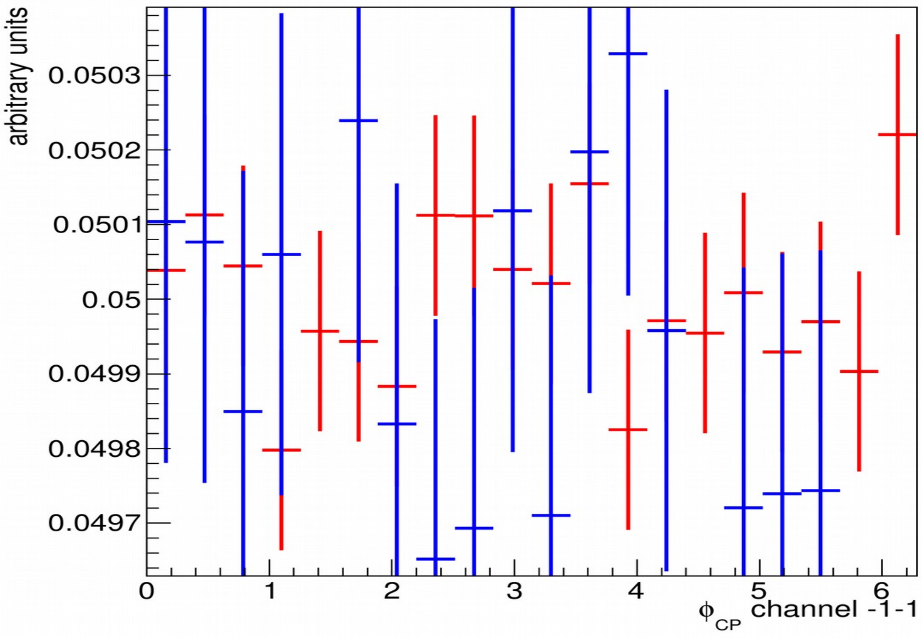


Decay mode 1: $\tau^{\pm} \rightarrow e^{\pm}$
Decay mode 2: $\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{0}$



Using 1 generic charged prong

Decay mode 1: $\tau^{\pm} \rightarrow$ charged prong
Decay mode 2: $\tau^{\pm} \rightarrow$ charged prong



Decay mode 1: $\tau^{\pm} \rightarrow \pi^{\pm}$
Decay mode 2: $\tau^{\pm} \rightarrow$ charged prong