Studies of the Higgs CP properties in the τ decay channel with the CMS experiment

Claudia Pistone
III. Physikalisches Institut B

HA tautau Workshop
17.11.2015

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
DFG Deutsche Forschungsgemeinschaft

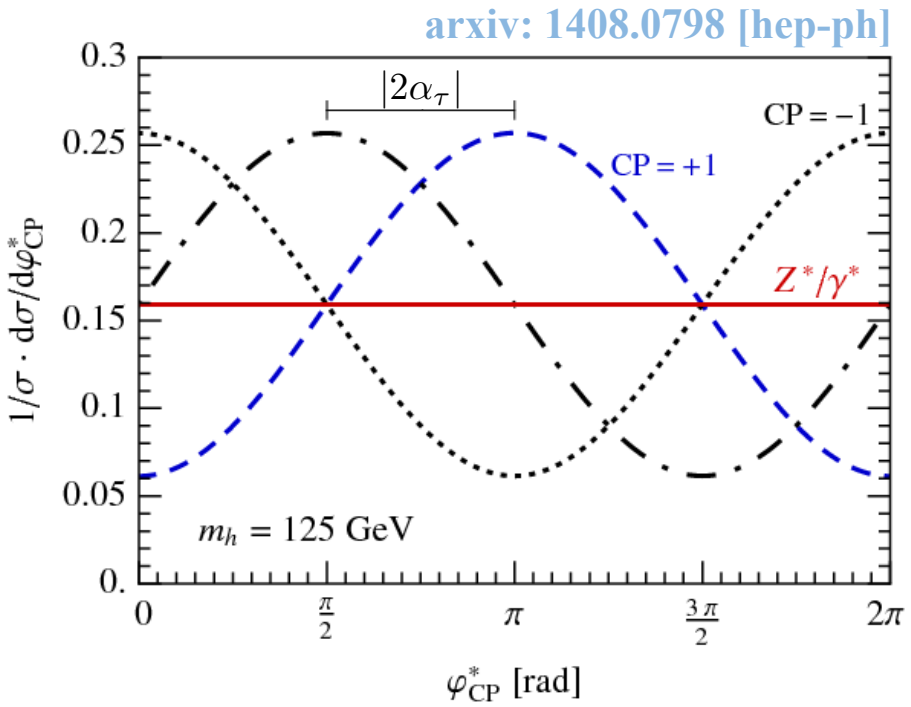
Outline

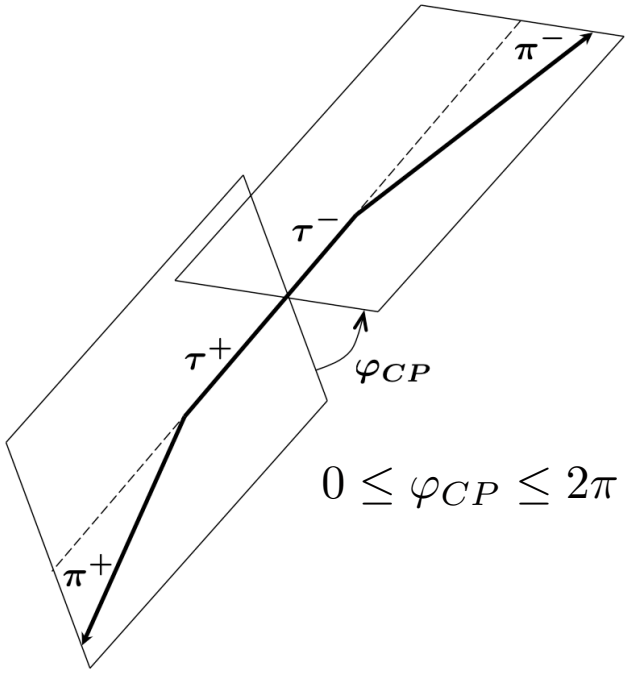
- Introduction
- Studies @ generator level
  - Transverse spin correlations → CP properties
  - Longitudinal spin correlations → spin
- Conclusions

Introduction

Angle between the decay planes of the τ's: φ_{CP}

$$\frac{1}{\Gamma}\frac{d\Gamma\left(h \to \pi^+\pi^- + 2\nu\right)}{d\varphi^*_{CP}} = \frac{1}{2\pi}\left[1 - \frac{\pi^2}{16}\cos\left(\varphi^*_{CP} - 2\alpha_\tau\right)\right]$$



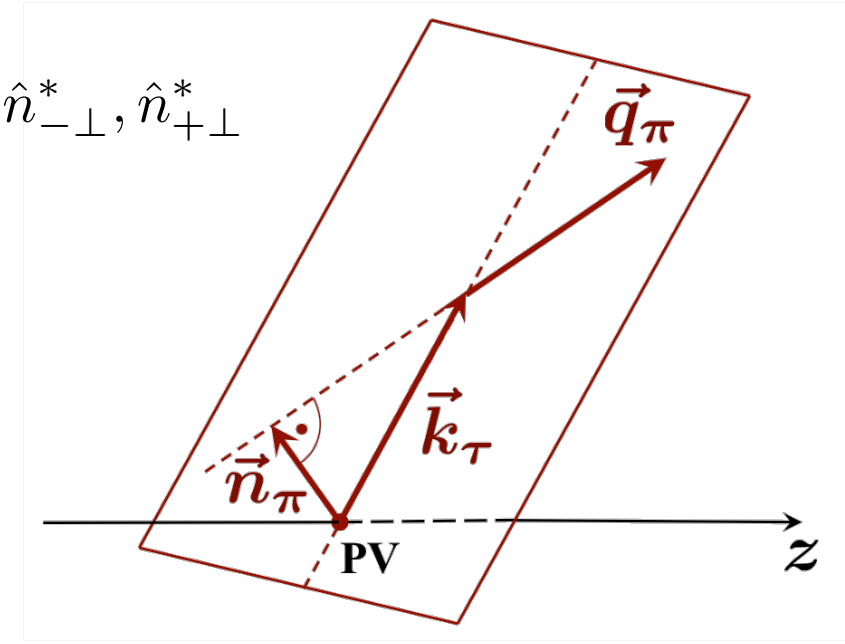


$0 \leq \varphi_{CP} \leq 2\pi$

φ^*_{CP} defined in the ZMF of the charged daughters

Method

- Impact parameter vectors in the lab frame: $\hat{n}_-, \hat{n}_+$
  - $\varphi = \angle(\hat{n}_-, \hat{n}_+)$
- Boost $\hat{n}_-, \hat{n}_+$ into ZMF of charged daughters: $\hat{n}^*_-, \hat{n}^*_+$
- Transverse components wrt $\vec{q}^*_-$ and $\vec{q}^*_+$: $\hat{n}^*_{-\perp}, \hat{n}^*_{+\perp}$
  - $\varphi^* = \angle(\hat{n}^*_{-\perp}, \hat{n}^*_{+\perp})$
- $$\varphi^*_{CP} = \begin{cases} \varphi^* & \text{if } \mathcal{O}^*_{CP} \geq 0 \\ 2\pi - \varphi^* & \text{if } \mathcal{O}^*_{CP} < 0 \end{cases}$$
  - where $\mathcal{O}^*_{CP} = \hat{q}^*_- \cdot (\hat{n}^*_{+\perp} \times \hat{n}^*_{-\perp})$



Method at the generator level

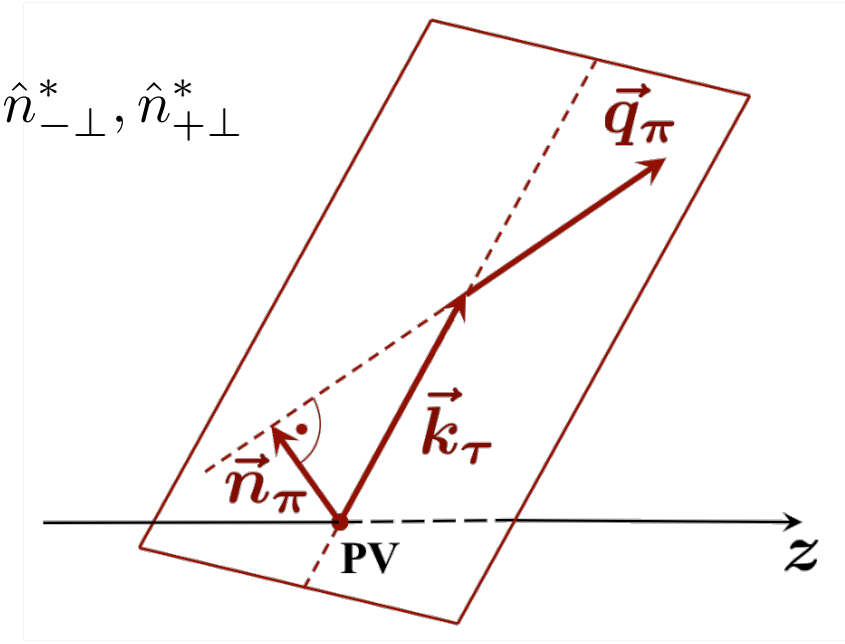
- Impact parameter vectors in the lab frame: $\hat{n}_-, \hat{n}_+$
  - $\varphi = \angle(\hat{n}_-, \hat{n}_+)$

into di-tau RF

- Boost $\hat{n}_-, \hat{n}_+$ into ZMF of ~~charged~~ daughters: $\hat{n}^*_-, \hat{n}^*_+$

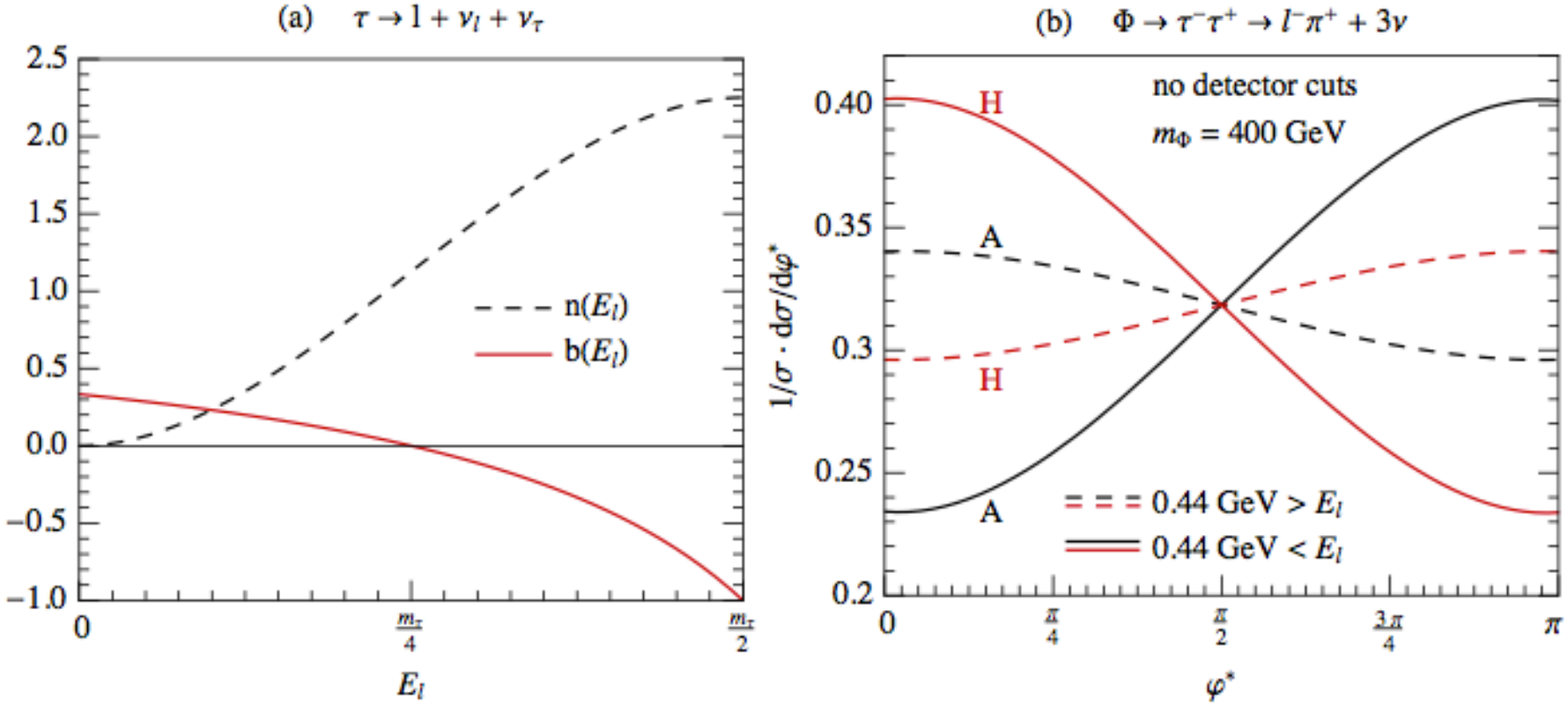
- Transverse components wrt $\vec{q}^*_-$ and $\vec{q}^*_+$: $\hat{n}^*_{-\perp}, \hat{n}^*_{+\perp}$
  - $\varphi^* = \angle(\hat{n}^*_{-\perp}, \hat{n}^*_{+\perp})$

- φ_{CP}
  $\varphi^*_{CP} = \begin{cases} \varphi^* & \text{if } \mathcal{O}^*_{CP} \geq 0 \\ 2\pi - \varphi^* & \text{if } \mathcal{O}^*_{CP} < 0 \end{cases}$
  - where $\mathcal{O}^*_{CP} = \hat{q}^*_- \cdot (\hat{n}^*_{+\perp} \times \hat{n}^*_{-\perp})$

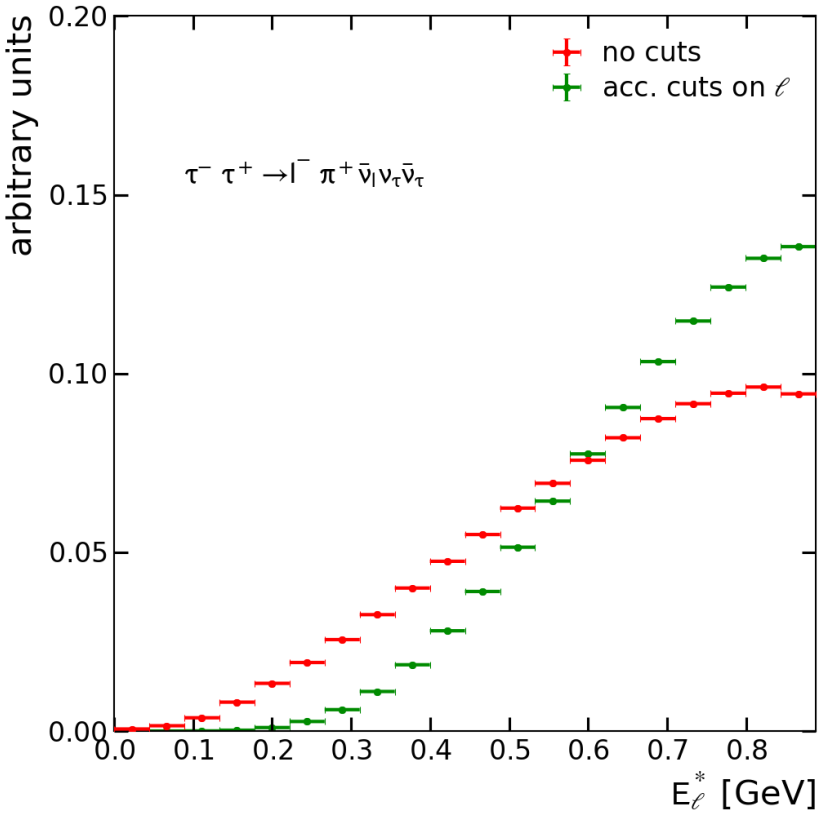


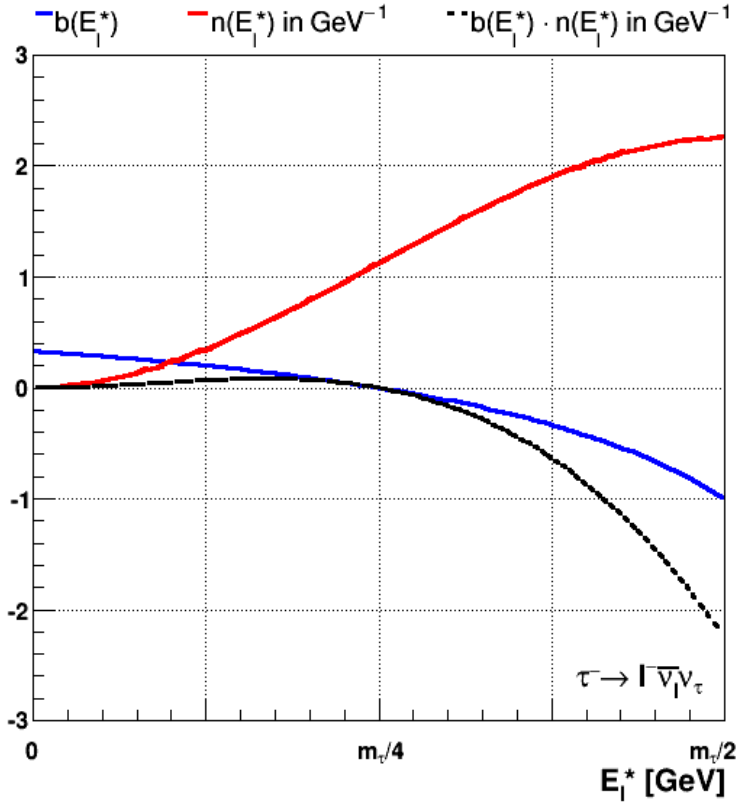
Spectral functions – lepton-pion final state

arxiv: 1108.0670 [hep-ph]



τ-spin analyzing power – lepton-pion final state

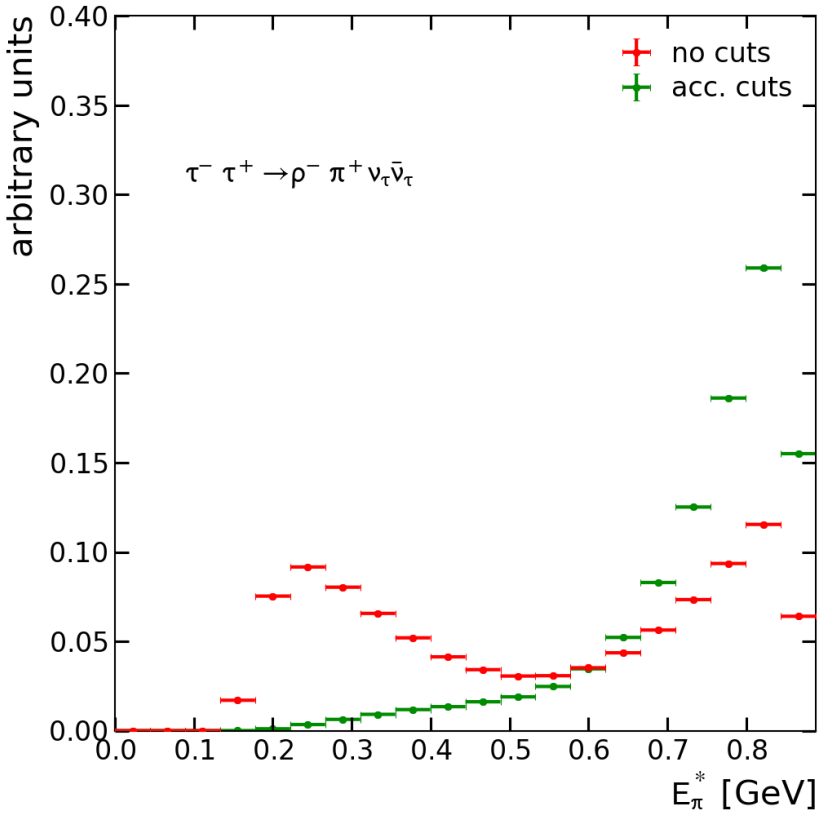


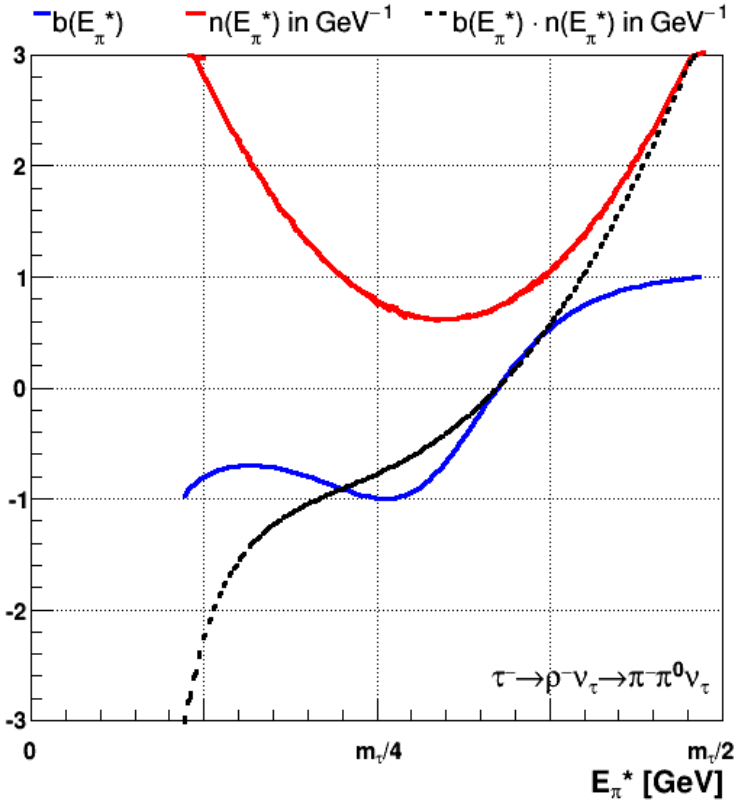


$$p_T^{\mu(e)} \geq 20(24)\ \text{GeV},\ |\eta^{\ell}| \leq 2.1$$

CMS-AN-2013-178

τ-spin analyzing power – hadronic final state (ρ)

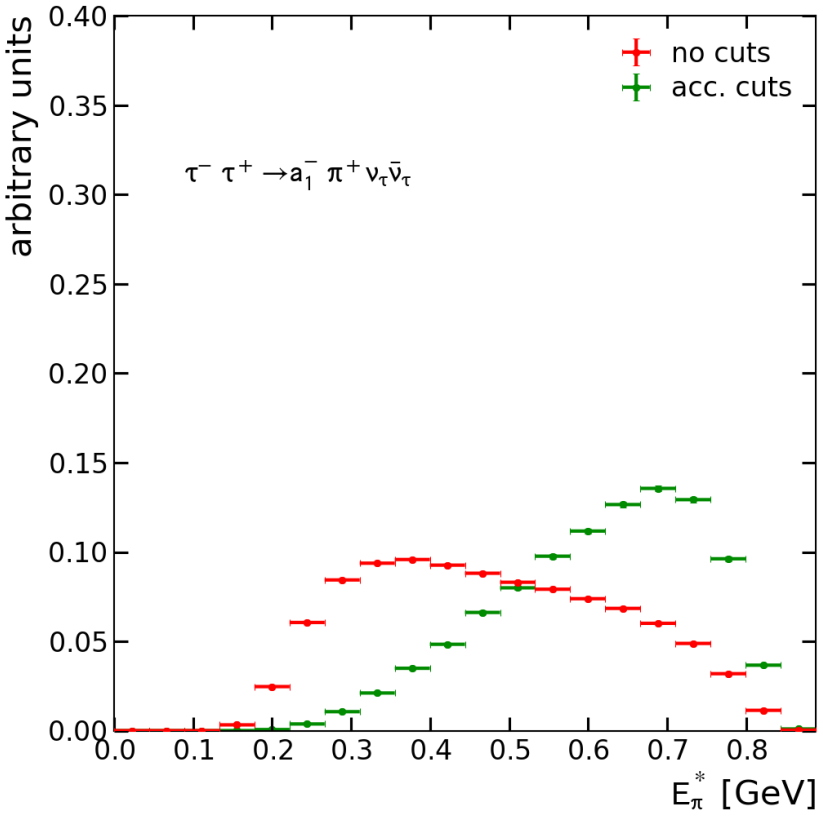


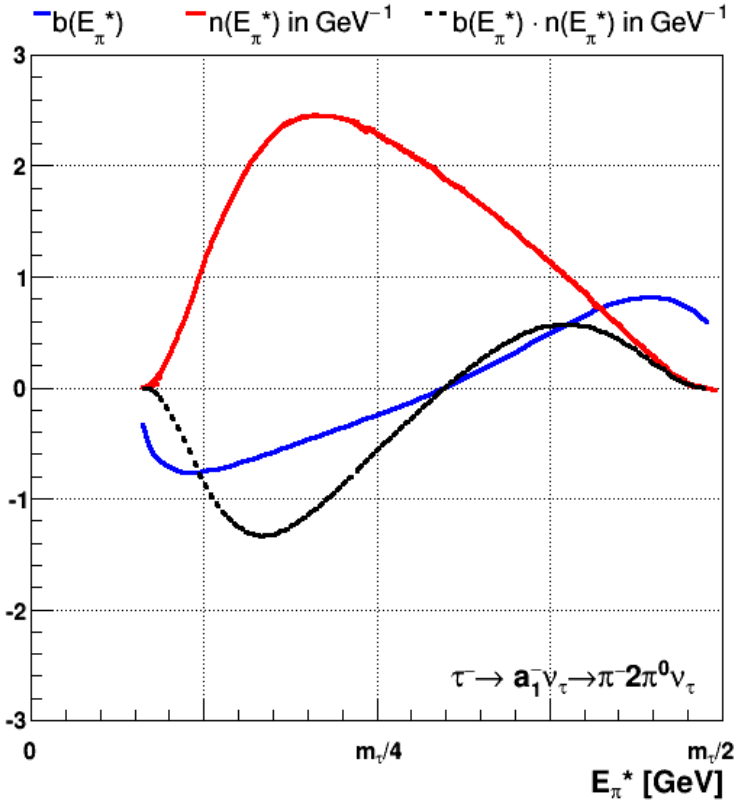


$$p_T^\pi \geq 45 \text{ GeV}, \; |\eta^\pi| \leq 2.1$$

CMS-AN-2013-189

τ-spin analyzing power – hadronic final state (a_1)

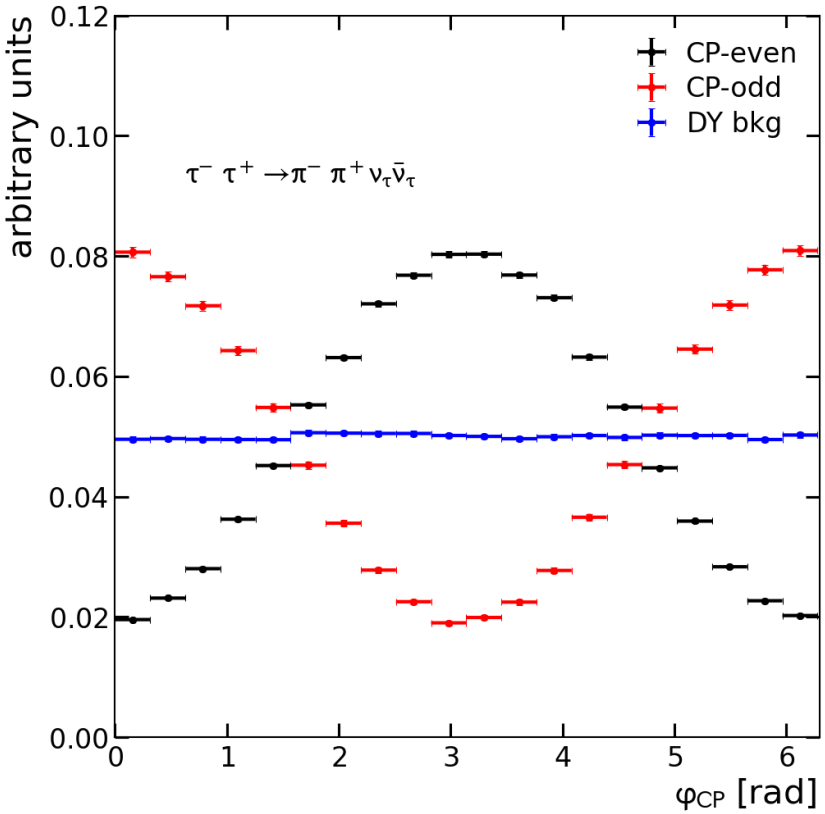


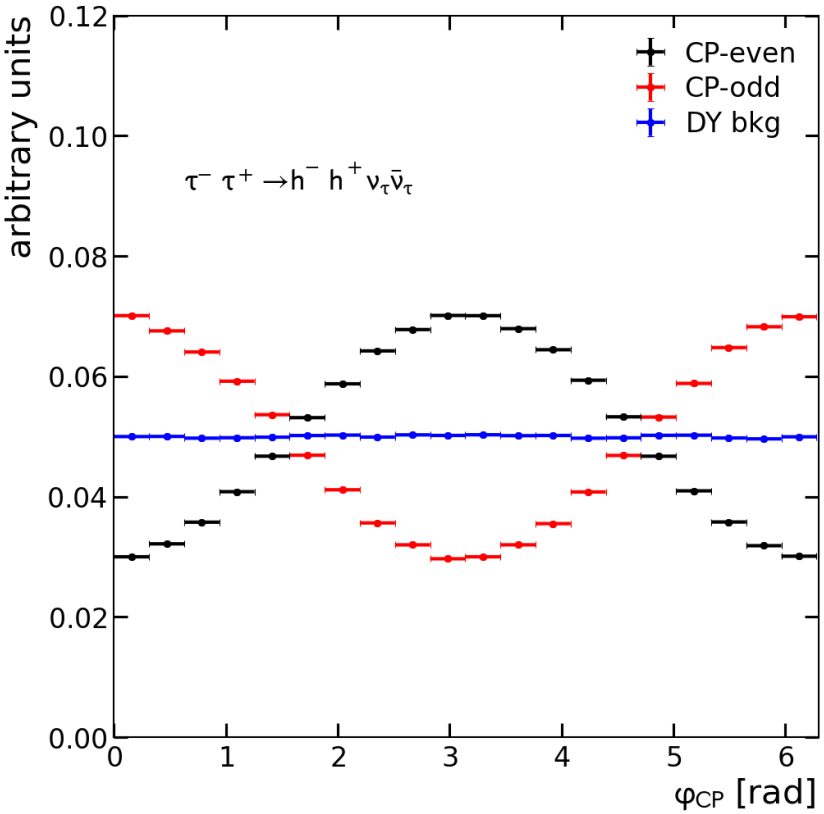


$$p_T^\pi \geq 45 \text{ GeV}, \; |\eta^\pi| \leq 2.1$$

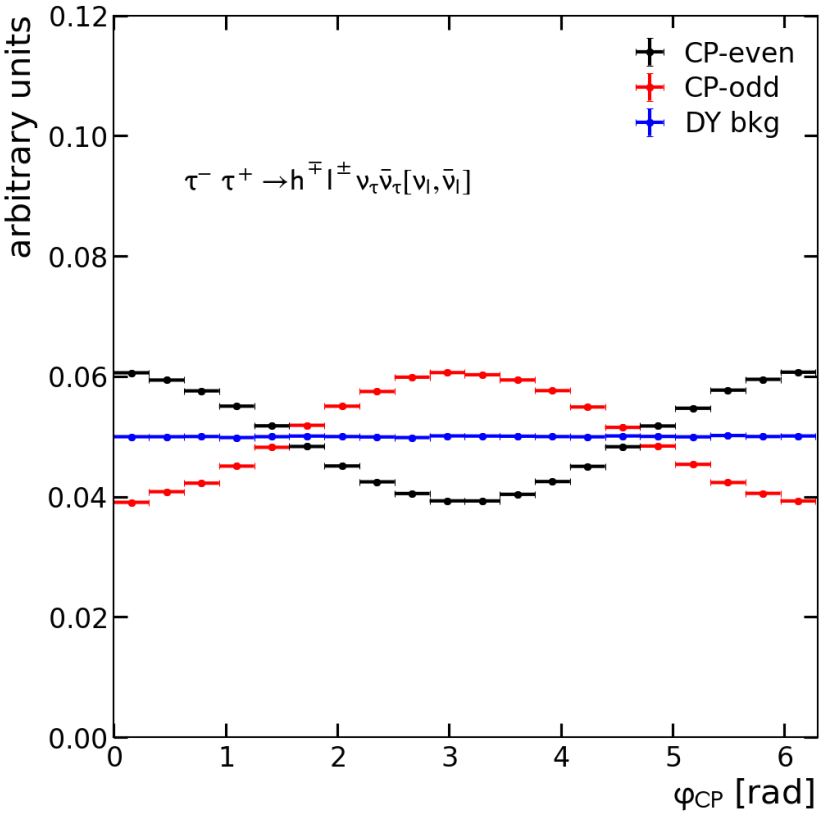
CMS-AN-2013-189

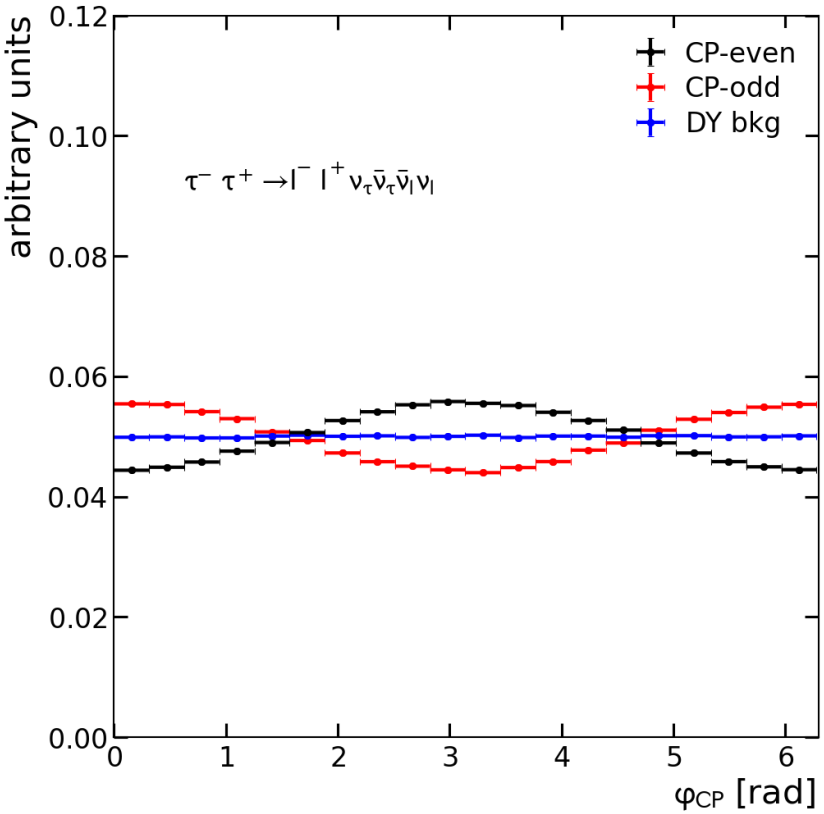
φ_{CP} distribution



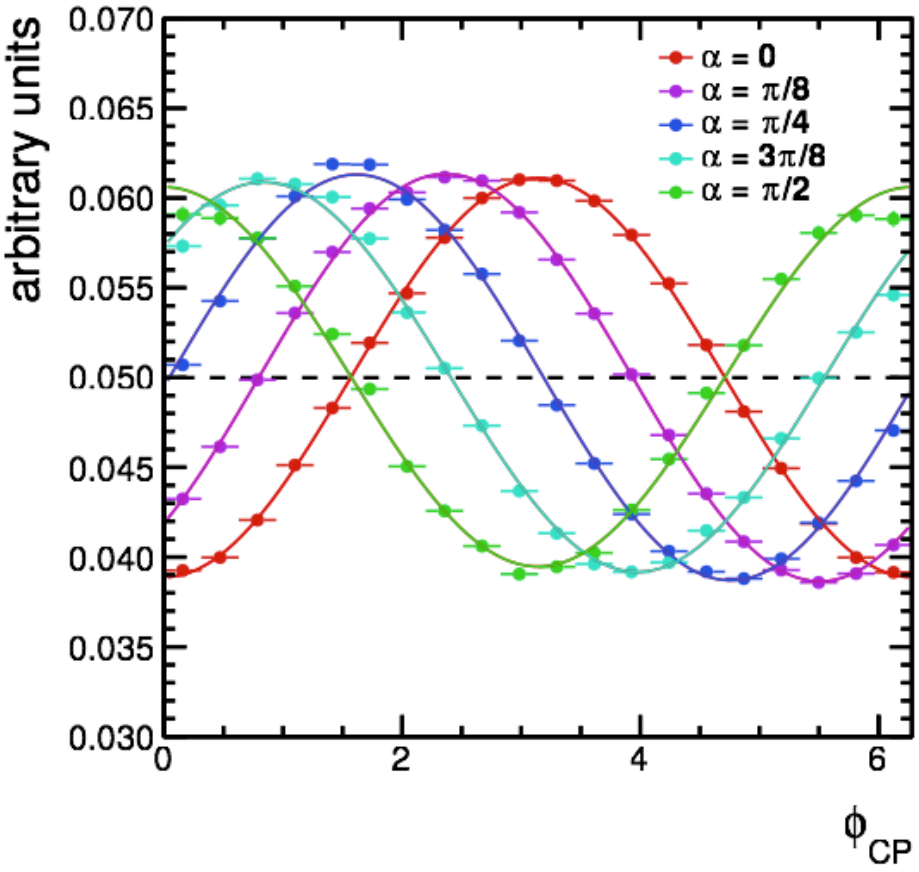


φ_{CP} distribution



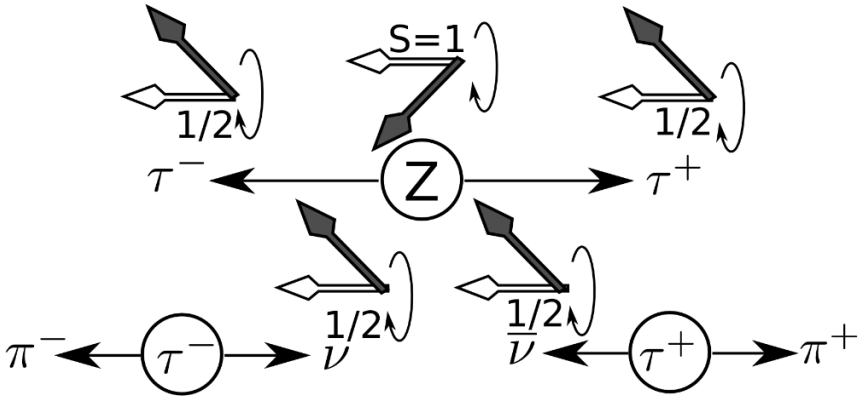


φ_{CP} distribution for different α_τ

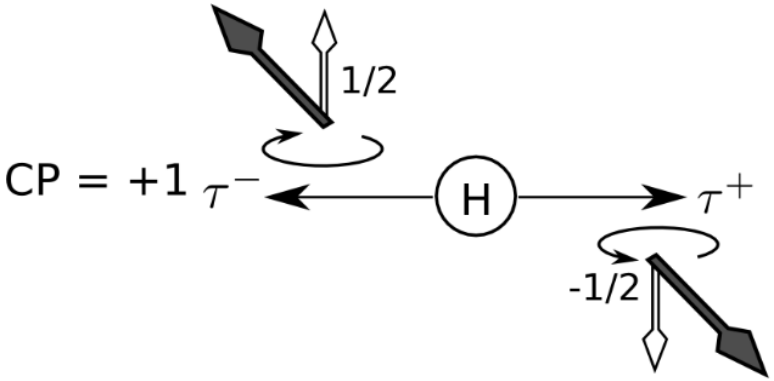


Longitudinal spin correlations

Longitudinal polarization in di-τ RF



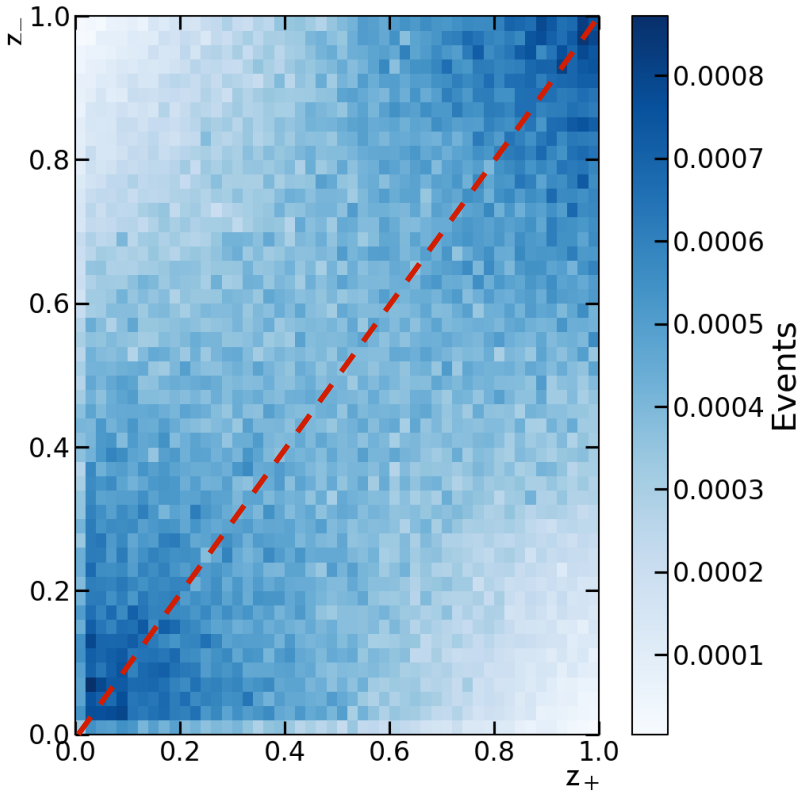
Both pions in the same direction or in the opposite direction wrt to the τ direction of flight



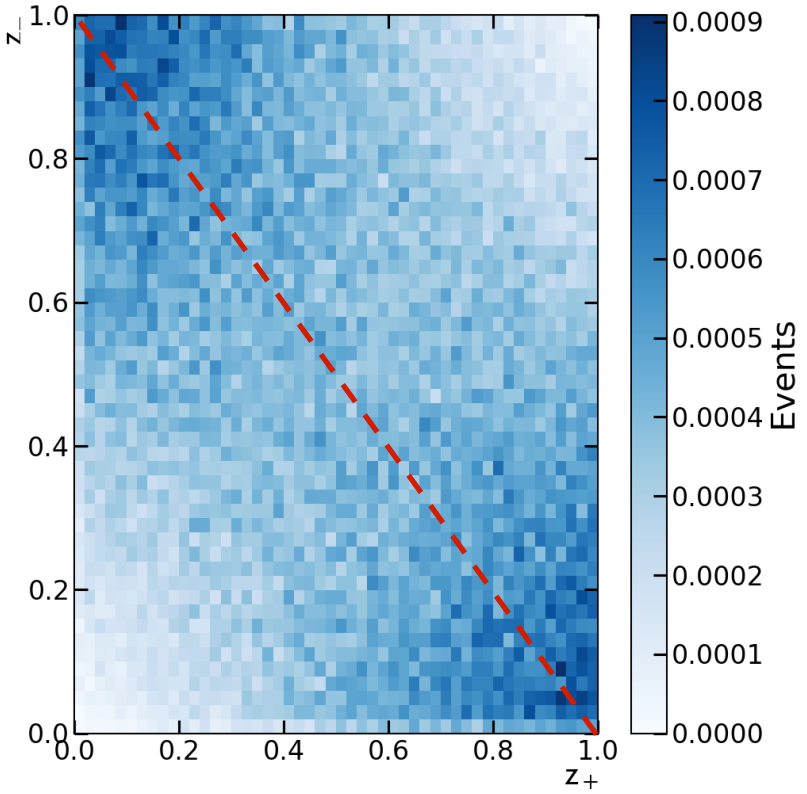
One pion in the same direction and one pion in the opposite direction wrt to the τ direction of flight if longitudinal component of the τ spin are correlated

Correlation of z_- vs z_+

DY (spin-1 decays)



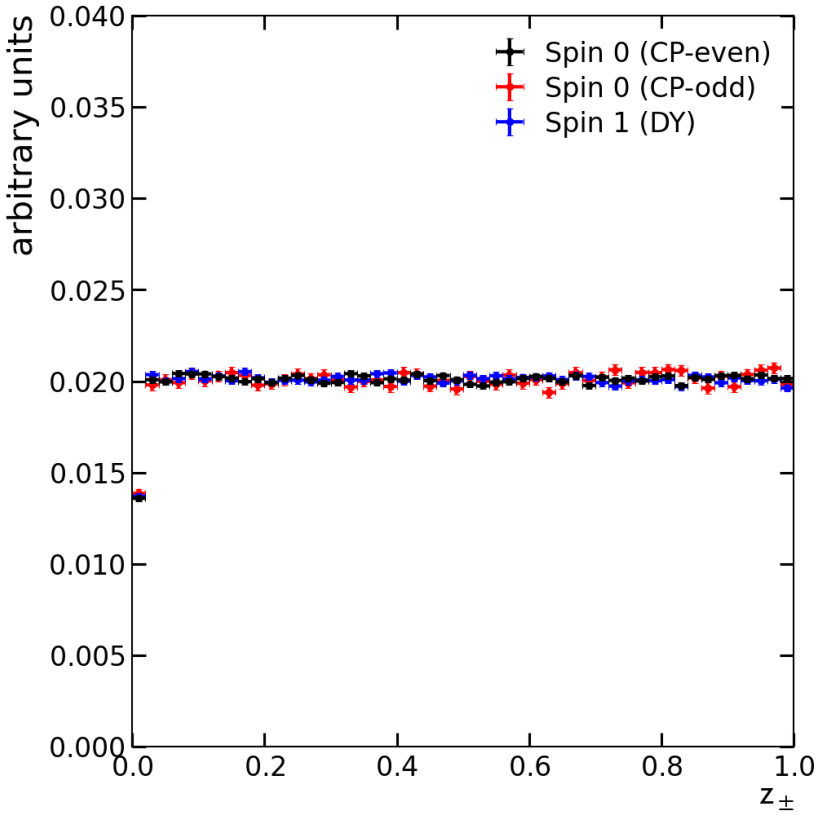
CP-odd (spin-0 particle)



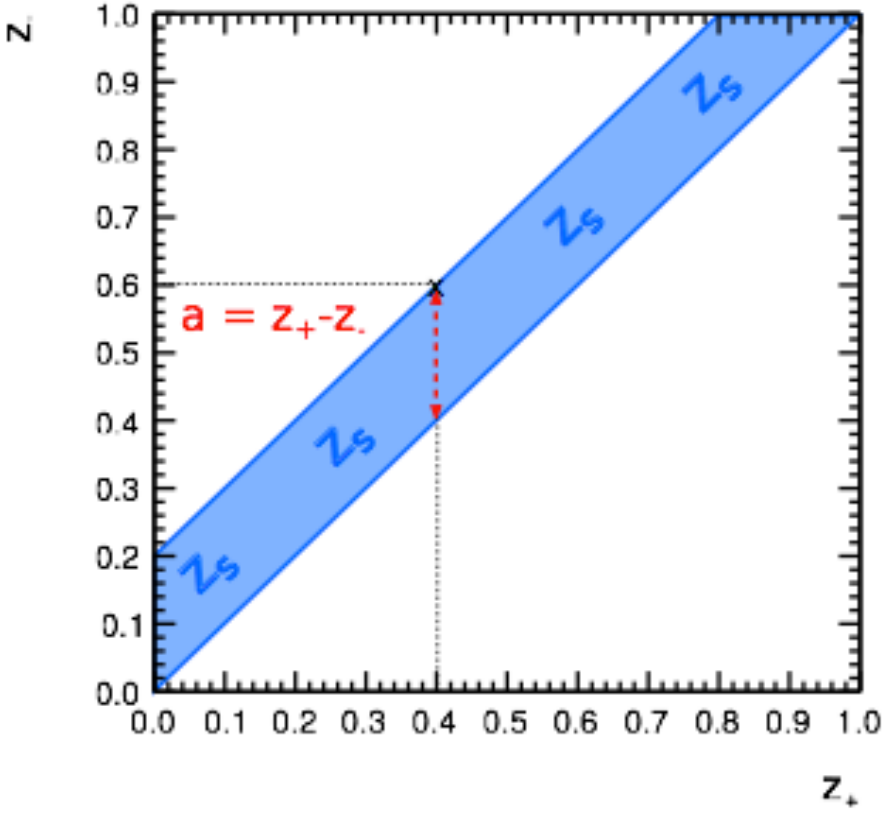
$$z_\pm = \frac{2E^*_{\pi^\pm}}{\sqrt{s}} = \frac{2E^*_{\pi^\pm}}{M}$$

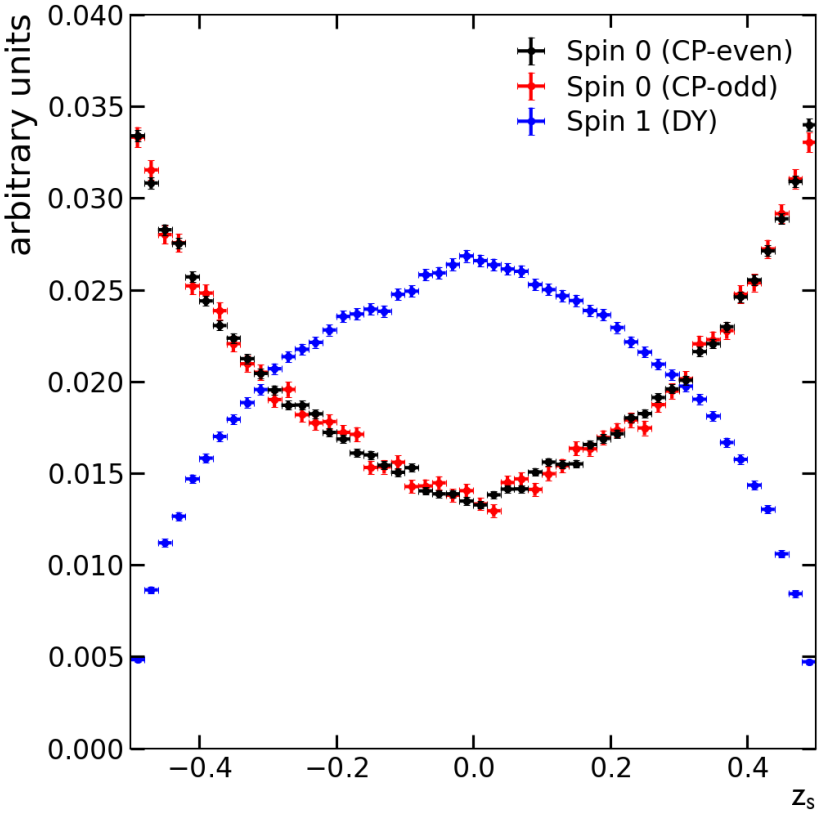
arxiv: 0101311 [hep-ph]

$z_{\pm}$ distributions



z_s distributions





Conclusions

Conclusions

- Studies at generator level
  - The method for CP studies works
  - Validation of the code
- Needed some “tuning” at reconstruction level

Backup

Why is DY flat?