

Measurement of τ -spin correlations in $Z/\gamma^* \rightarrow \tau\tau$ decays

DPG Frühjahrstagung 2016 Hamburg

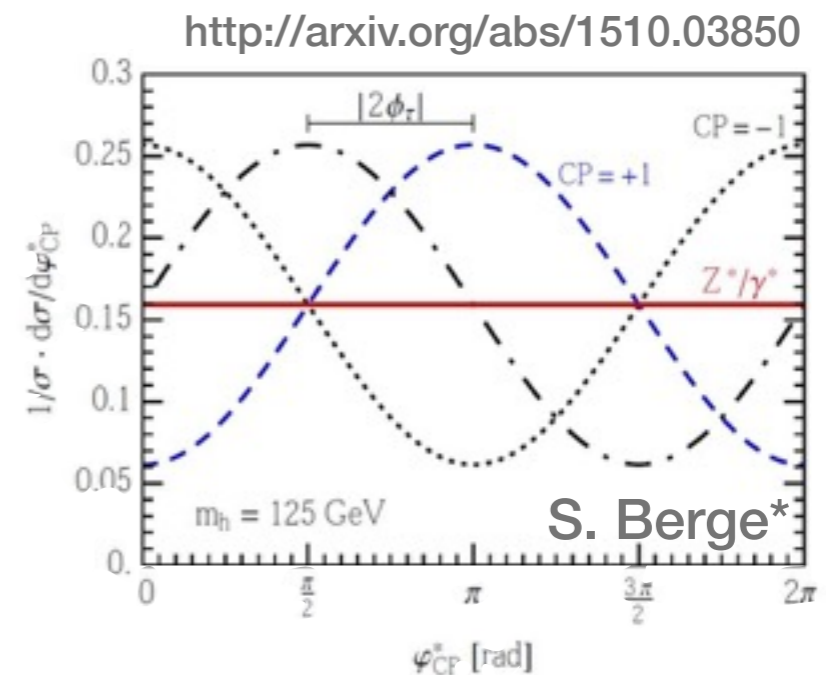
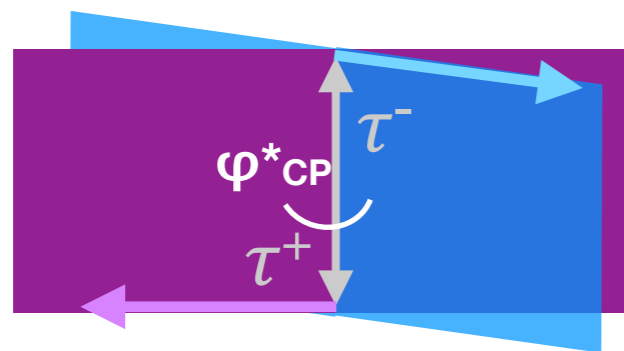
01/03/2015

Maike Hansen



Motivation

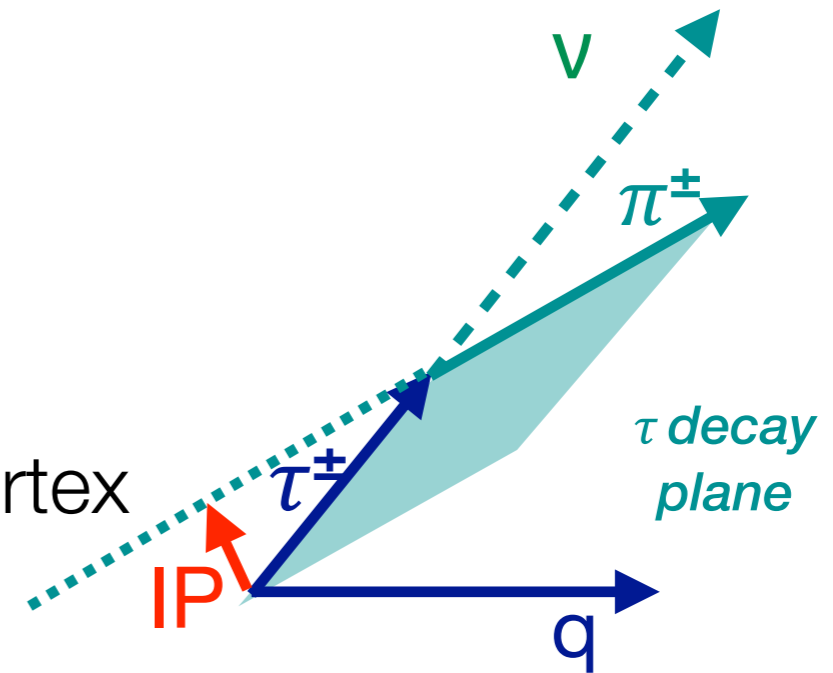
- BSM models predict **CP even & odd H** with **mixing** angle ϕ_τ
- Extract mixing angle from transverse τ spin correlations in $H \rightarrow \tau_{\text{had}} \tau_{\text{had}}$



- Reconstruct τ decay planes & measure angle φ_{CP}^* between them
- Plot differential x-section as a function of φ_{CP}^*
- Mixing angle from phase shift with respect to CP-even prediction
- Need Run-2 Tau Reconstruction (T87.1 - P. Wagner - Thursday 13.45)

Reconstruction of the τ decay planes

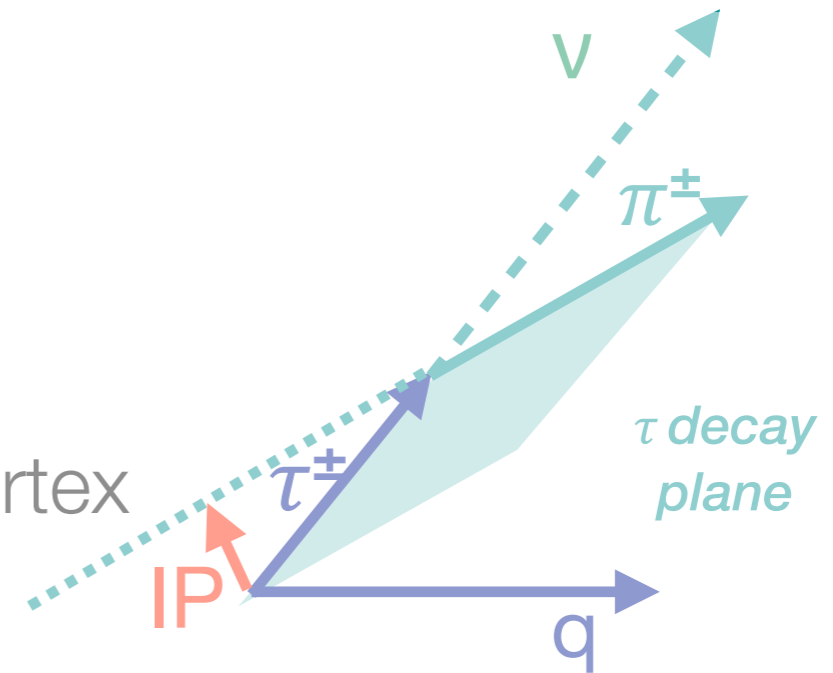
$\tau^\pm \rightarrow \pi^\pm \nu$ (1p0n) BR $\sim 10\%$
Reconstruct τ^\pm decay planes from 3D
track impact parameter and primary vertex



Reconstruction of the τ decay planes

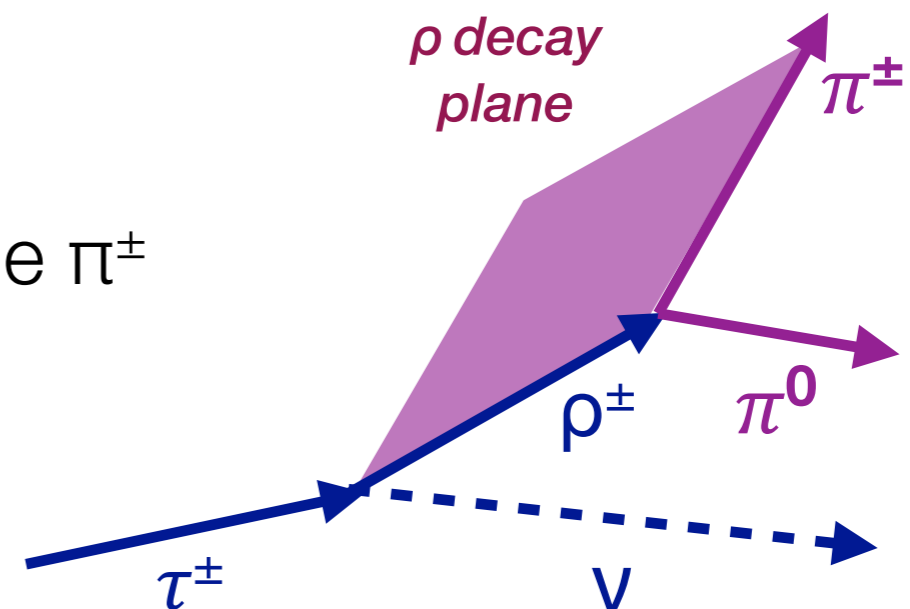
$\tau^\pm \rightarrow \pi^\pm \nu$ (1p0n) BR $\sim 10\%$

Reconstruct τ^\pm decay planes from 3D track impact parameter and primary vertex



$\tau^\pm \rightarrow \rho^\pm \nu \rightarrow \pi^\pm \pi^0 \nu$ (1p1n) BR $\sim 25\%$

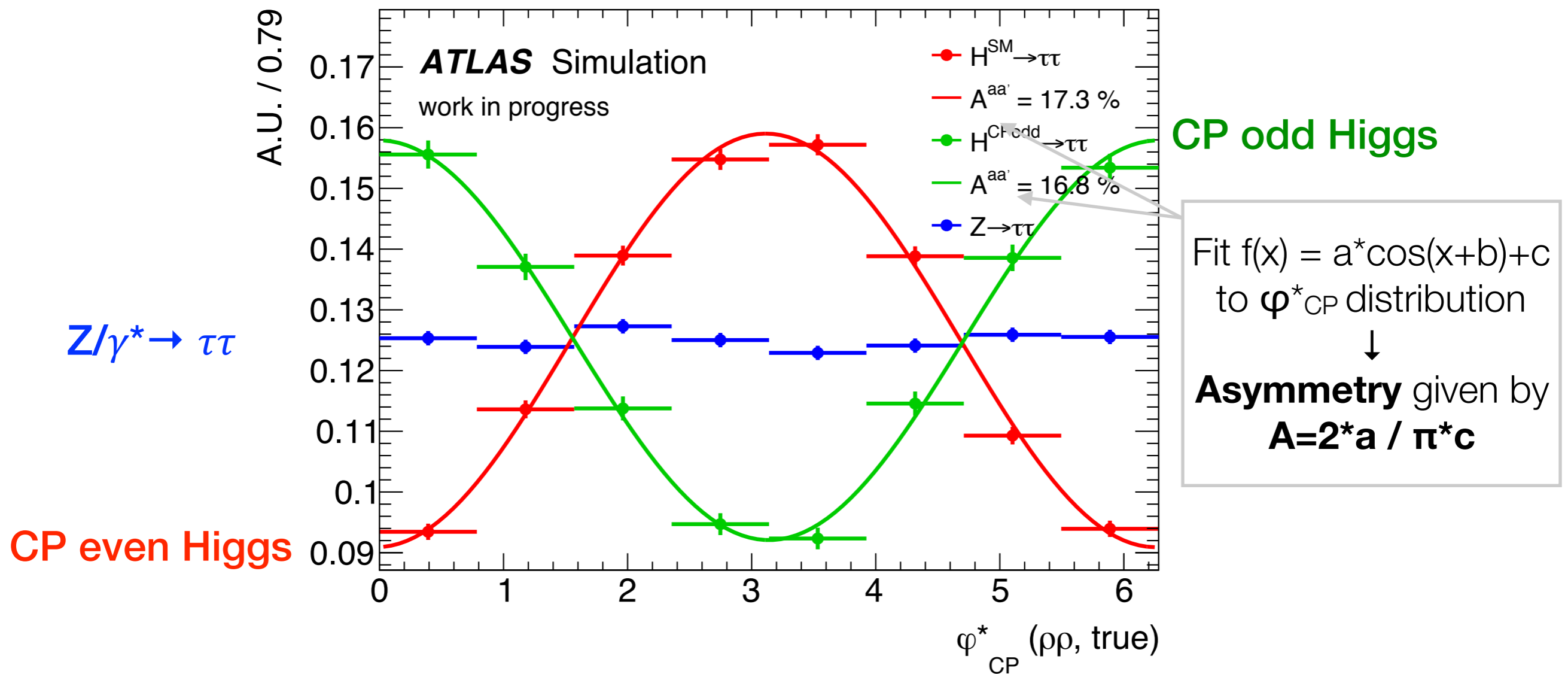
Reconstruct ρ^\pm decay planes from the π^\pm & π^0 4-vectors



*For more details: T46.4 - M. Hübner

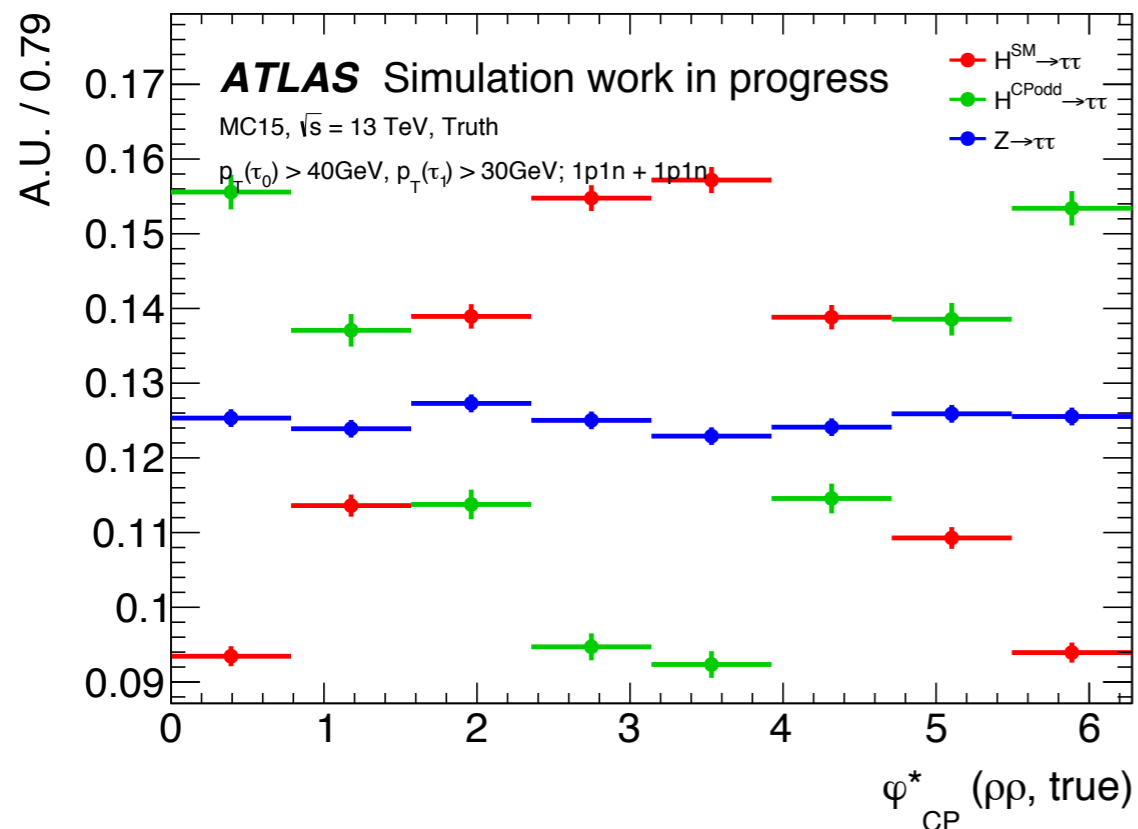
Differential cross-section as a function of φ_{CP}^*

- Apply methods to H and $Z/\gamma^* \rightarrow \tau_{had} \tau_{had}$ events (13TeV, 720 fb⁻¹)



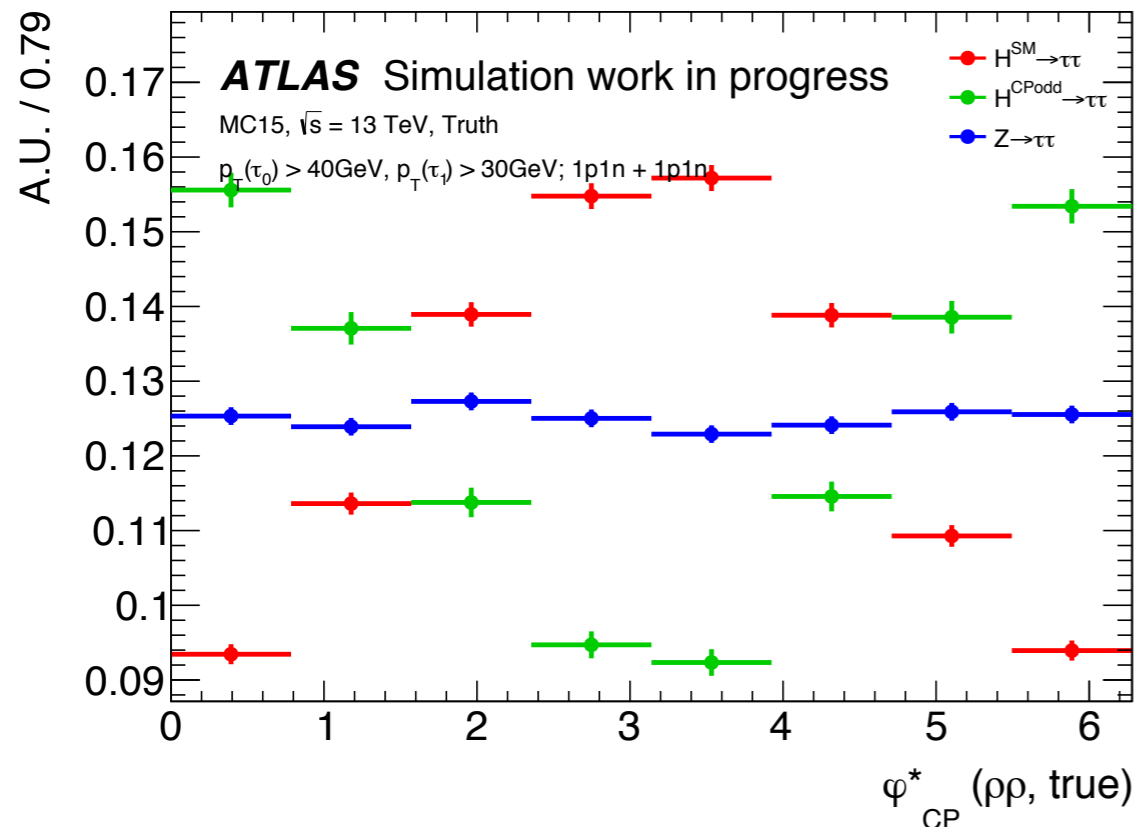
Application to $Z/\gamma^* \rightarrow \tau_{\text{had}} \tau_{\text{had}}$ decays

- Apply methods to H and $Z/\gamma^* \rightarrow \tau_{\text{had}} \tau_{\text{had}}$ events
- Use $Z/\gamma^* \rightarrow \tau_{\text{had}} \tau_{\text{had}}$ events to calibrate the methods & estimate the expected sensitivity



Application to $Z/\gamma^* \rightarrow \tau_{\text{had}} \tau_{\text{had}}$ decays

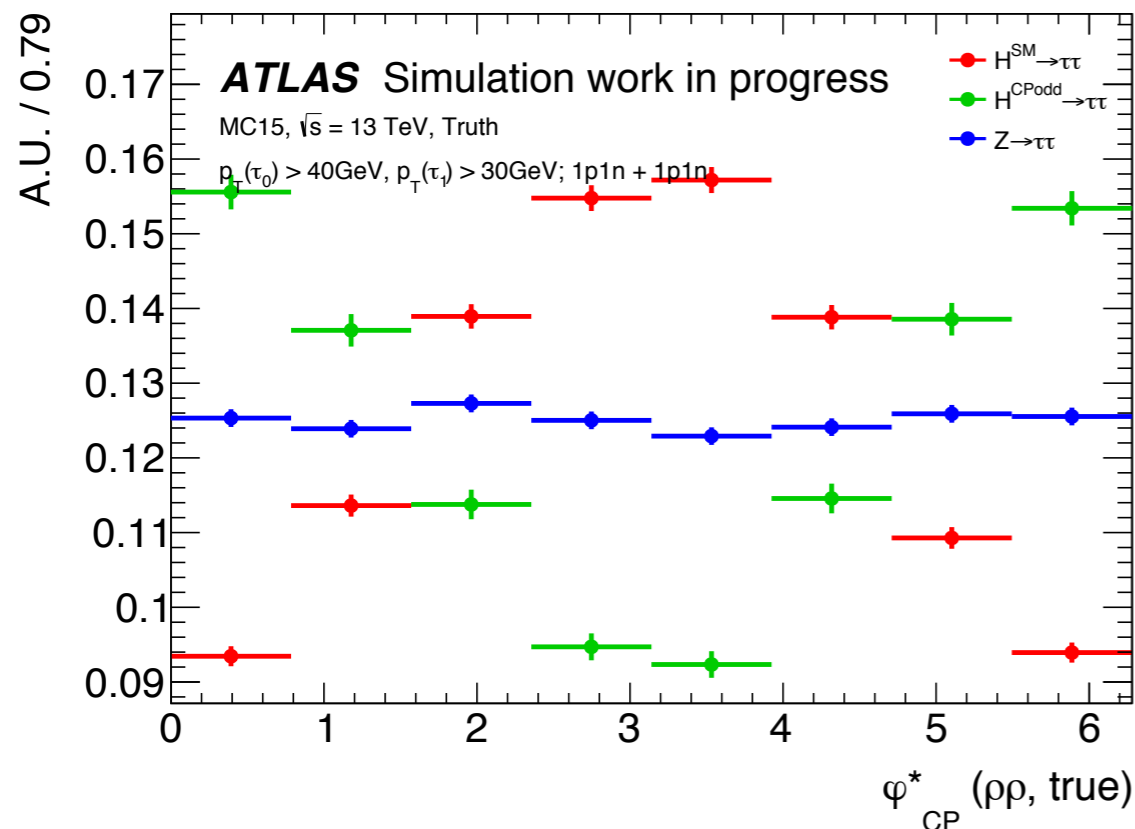
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But in $Z \rightarrow \tau\tau$ there is no φ_{CP}^* dependence of the x-section...

Application to $Z/\gamma^* \rightarrow \tau_{\text{had}} \tau_{\text{had}}$ decays

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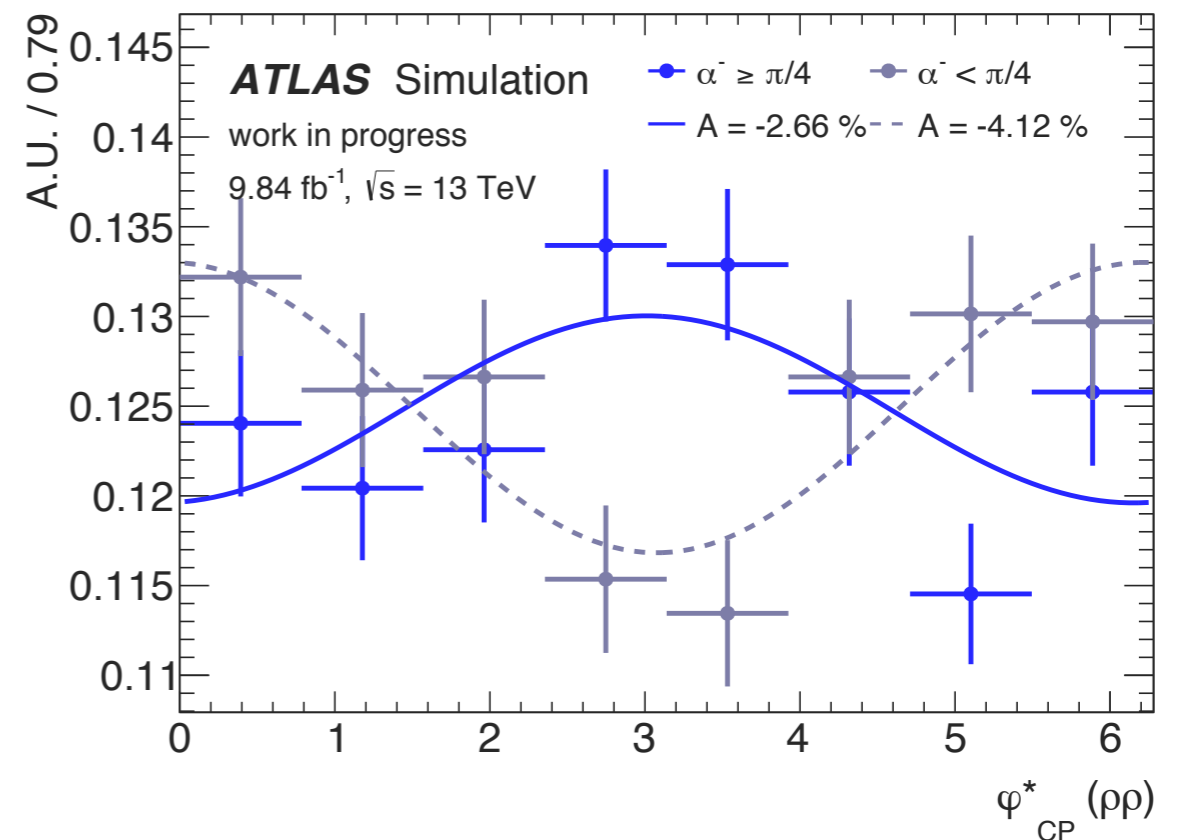
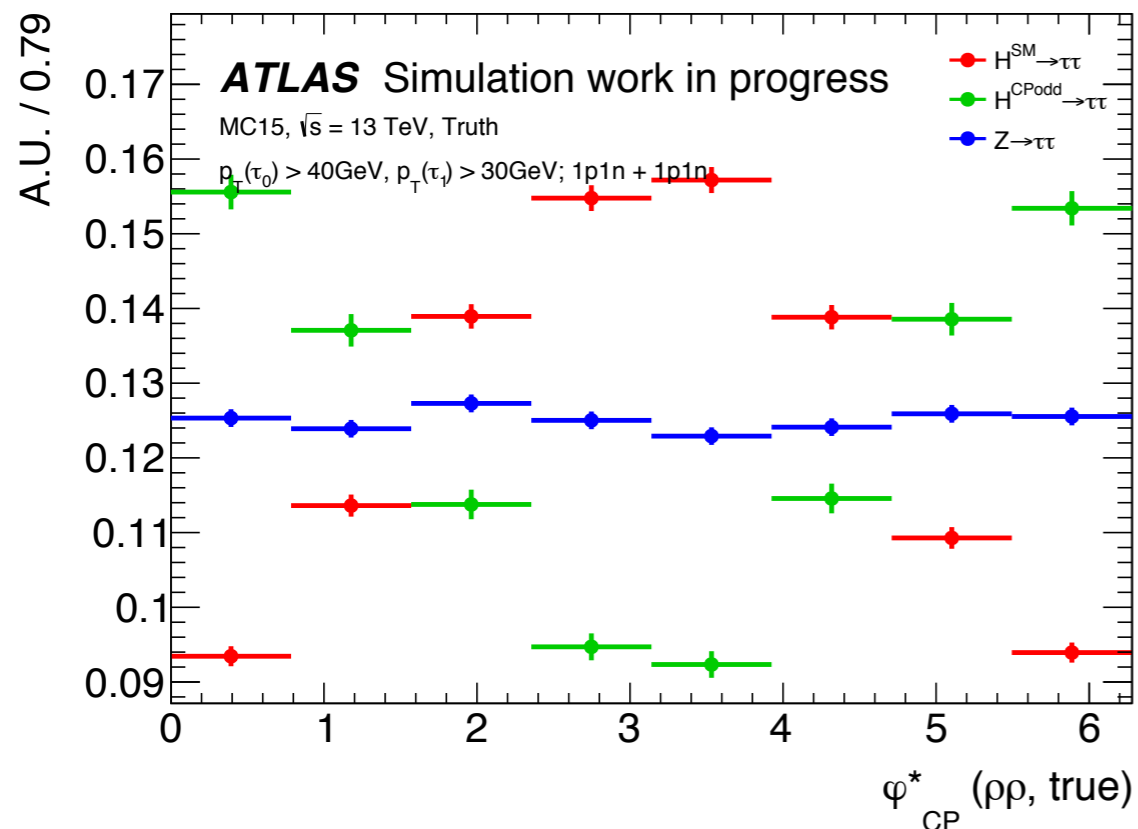


But in $Z \rightarrow \tau\tau$ there is no φ_{CP}^* dependence of the x-section...

However, we can generate an artificial cosine dependence by splitting the phase space!

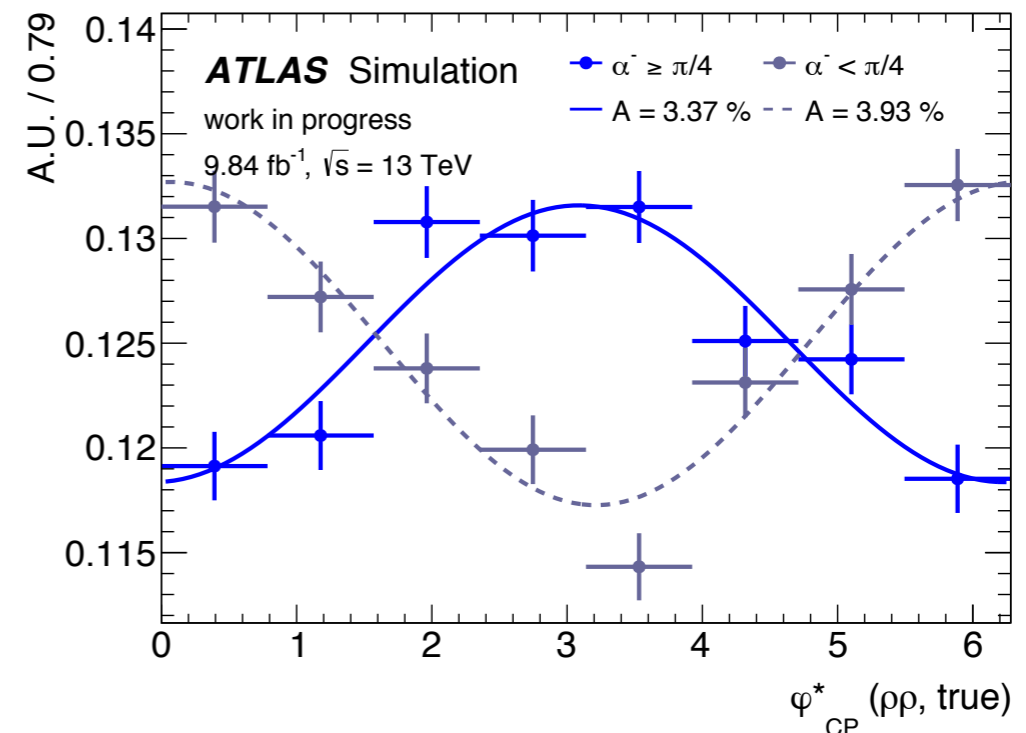
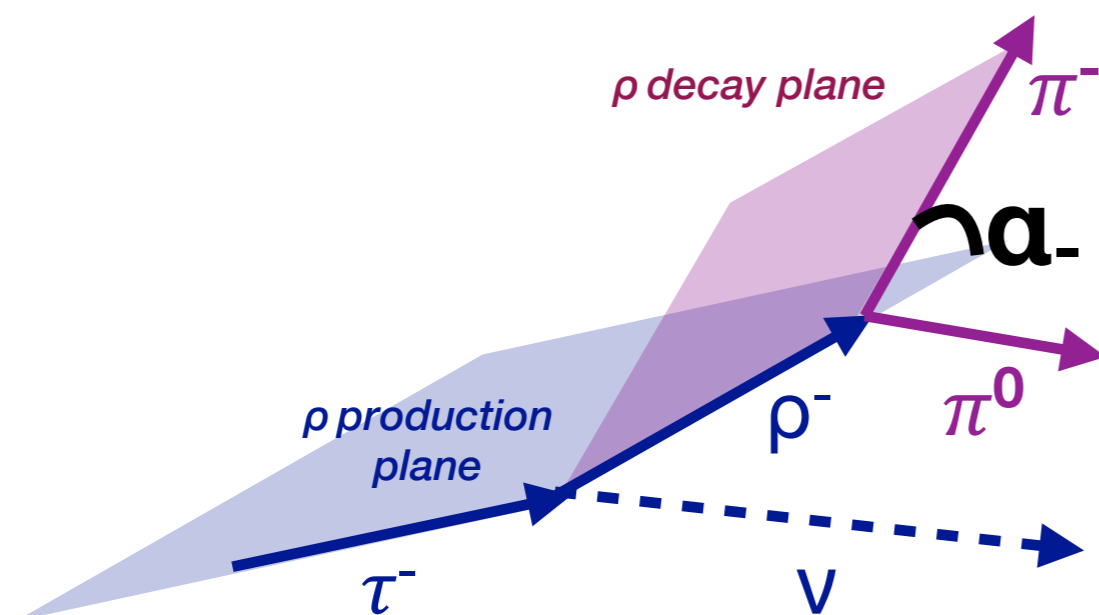
Application to $Z/\gamma^* \rightarrow \tau_{\text{had}} \tau_{\text{had}}$ decays

- Apply methods to H and $Z/\gamma^* \rightarrow \tau_{\text{had}} \tau_{\text{had}}$ events
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How to split the phase space?

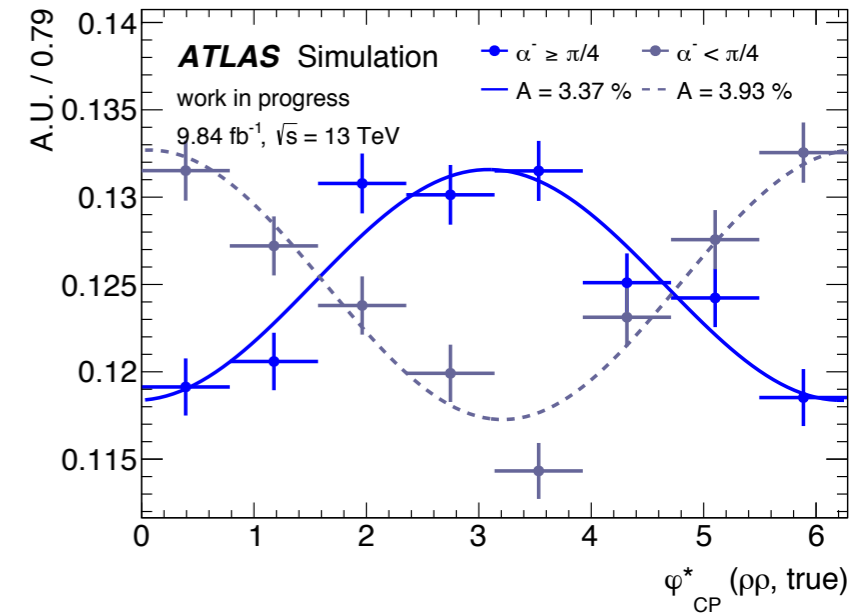
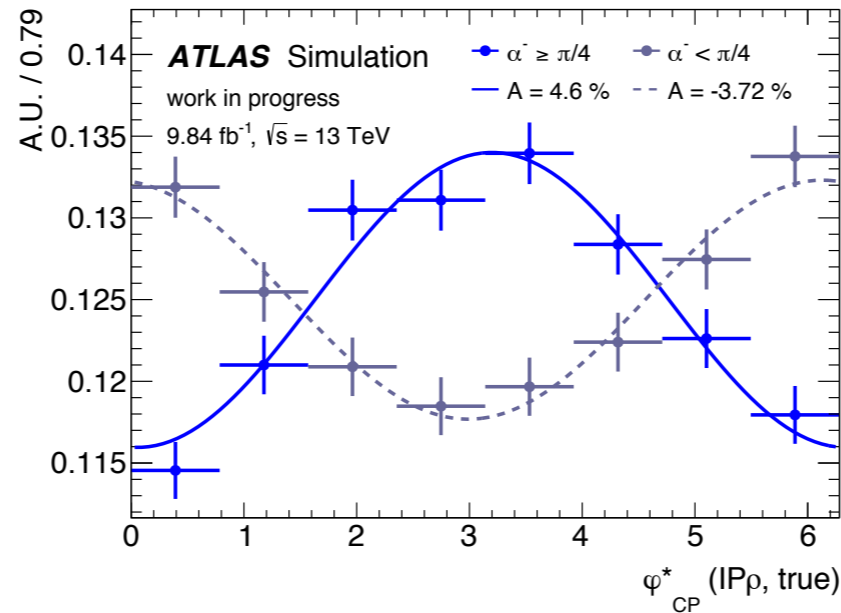
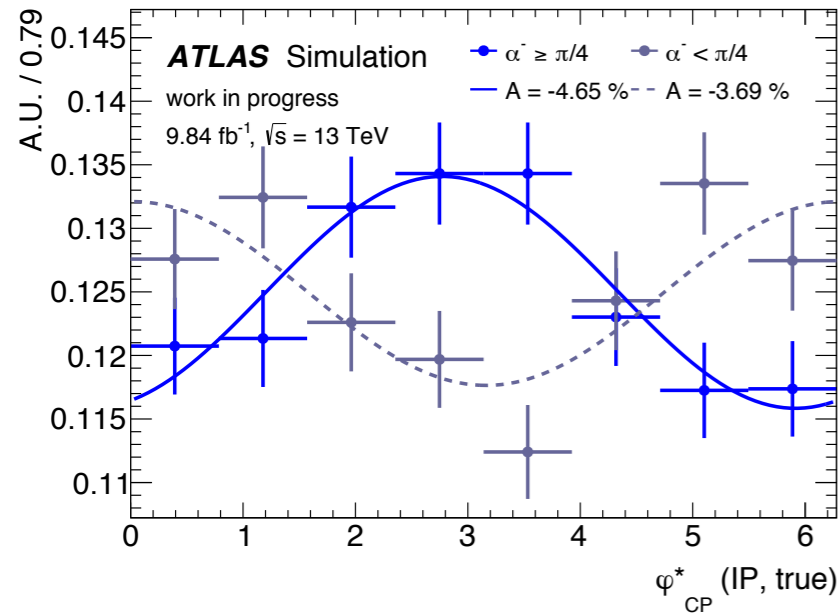
- Split phase space based on π^- being rather parallel or perpendicular to τ^-/ρ^- -production plane
- Plot diff. cross-section vs. φ_{CP}^* for each subsets



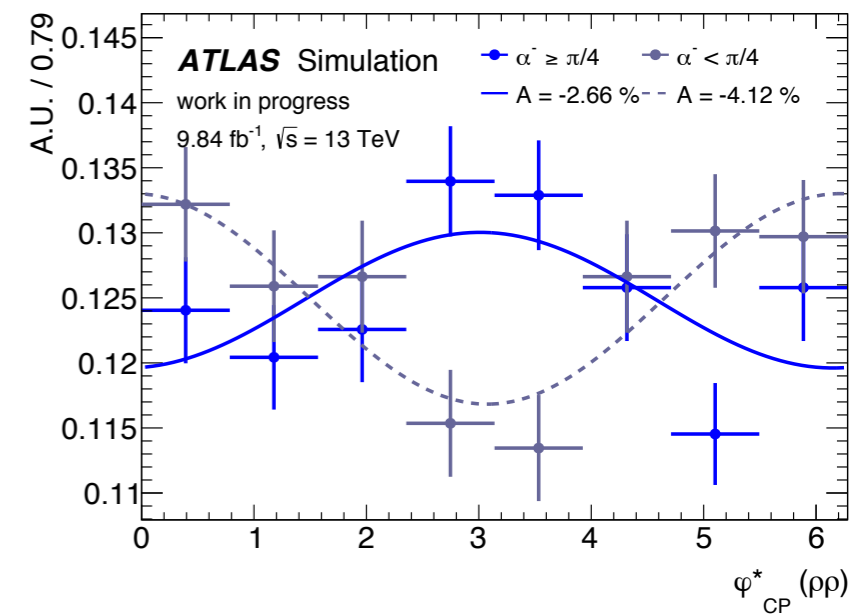
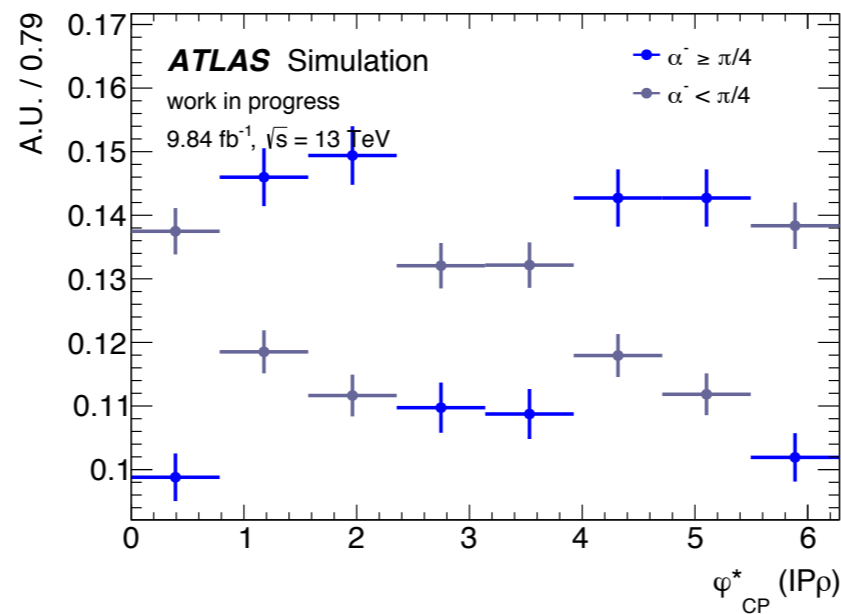
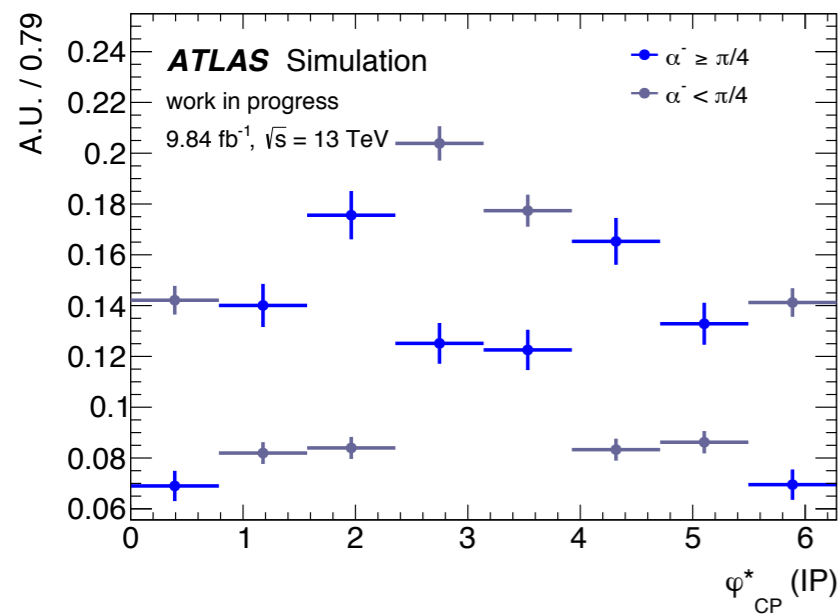
- One shows CP-even, the other CP-odd like distribution
→ Generate artificial cosine dependence in $Z/\gamma^* \rightarrow \tau\tau$

Asymmetry in simulated $Z/\gamma^* \rightarrow \tau\tau$ (13TeV, 10 fb⁻¹)

Generator-Level



After Reconstruction



Event selection

same as Run I $H \rightarrow \tau\tau$ Selection

Preselection

- 1 medium, 1 tight (isolated, opposite sign)
- $p_T(\tau_1) > 40 \text{ GeV}$, $p_T(\tau_2) > 30 \text{ GeV}$
- τ s have 1 or 3 tracks
- Lepton Veto
- $\Delta\eta < 1.5$
- $\text{MET} > 20 \text{ GeV}$
- $0.8 < \Delta R < 2.4$

Z 0-jet Region

Preselection

- + 2 **tight** τ s (suppress QCD)
- + **$70 < M_{\text{mmc}} < 115 \text{ GeV}$** (Z-peak)
- + # Jets = 0 (Modelling of transverse spin correlations well understood here, working on validation of Z+jets together with Stefan Berge)
- Region to select mostly Z's but **not optimised for $Z \rightarrow \tau_{\text{had}}\tau_{\text{had}}$ yet!**

Higgs Signal Region

Preselection

- + **$M_{\text{mmc}} > 115 \text{ GeV}$**

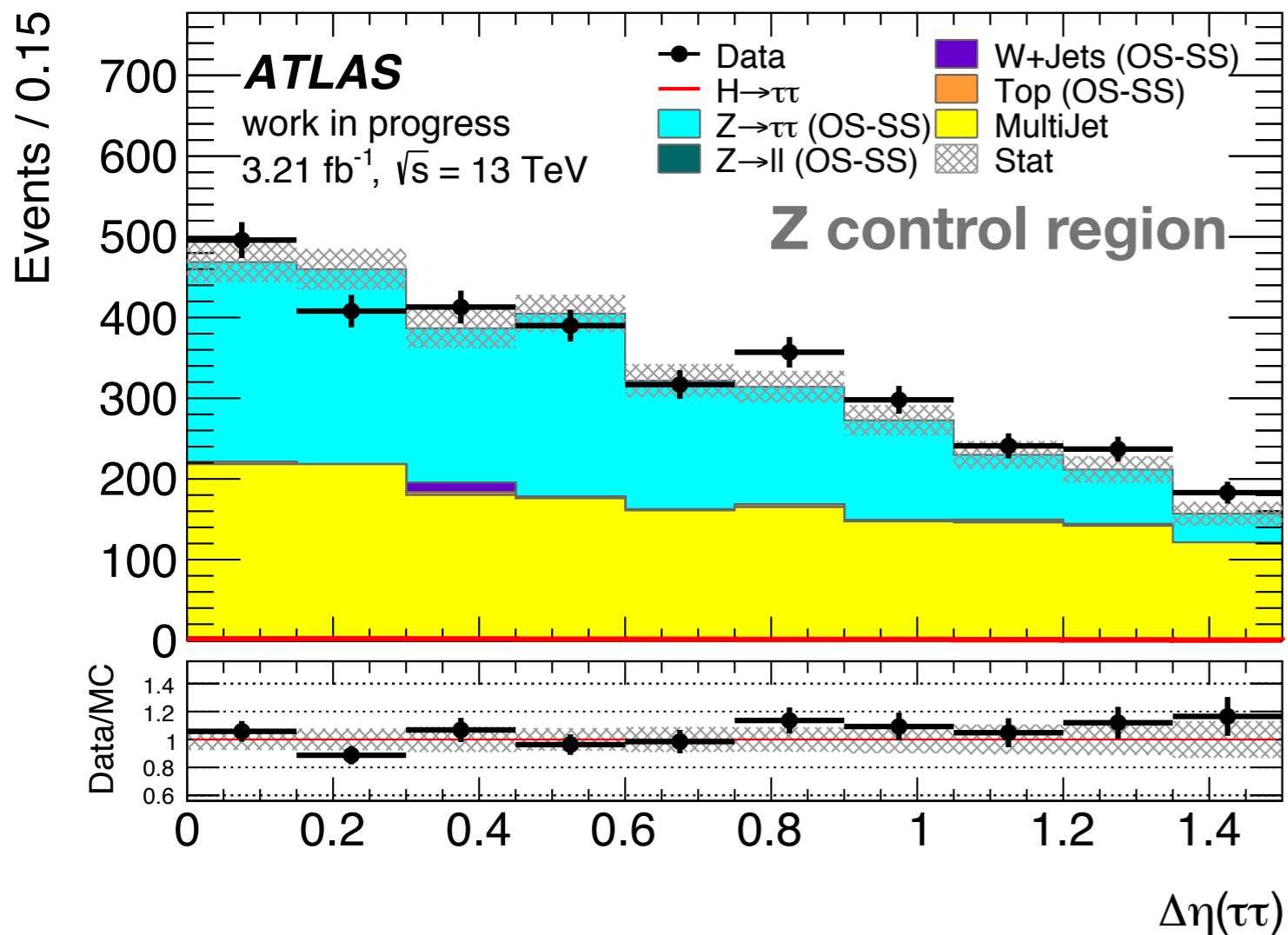
Boosted
VBF

Z Control Region

Preselection

- + **$70 < M_{\text{mmc}} < 115 \text{ GeV}$** (Z-peak)
- Close to Higgs signal region

Data Monte-Carlo comparison



Z/γ* → ττ

- Powheg-Pythia Monte Carlo
- Sherpa 2.2 MC will be available soon
- Validation of the modelling of transverse spin correlations in Z+jets events together with Stefan Berge is ongoing

Multijet

- Estimated from Data using OS-SS Method

Everything else

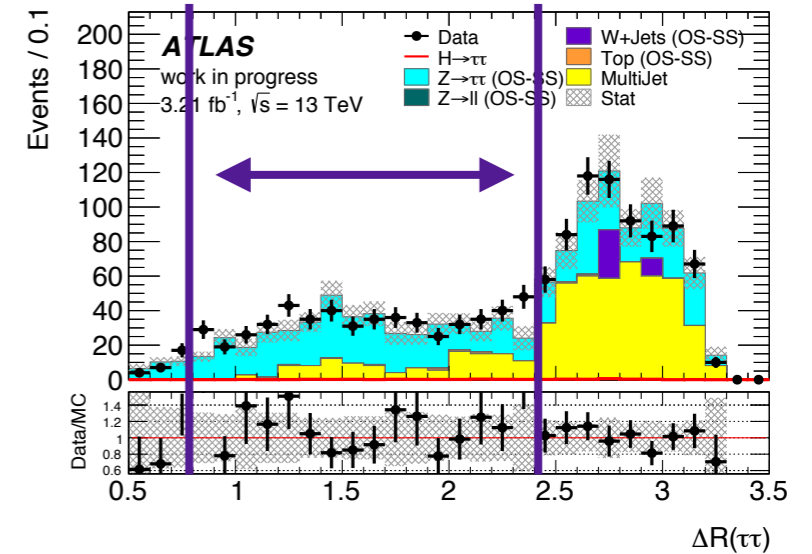
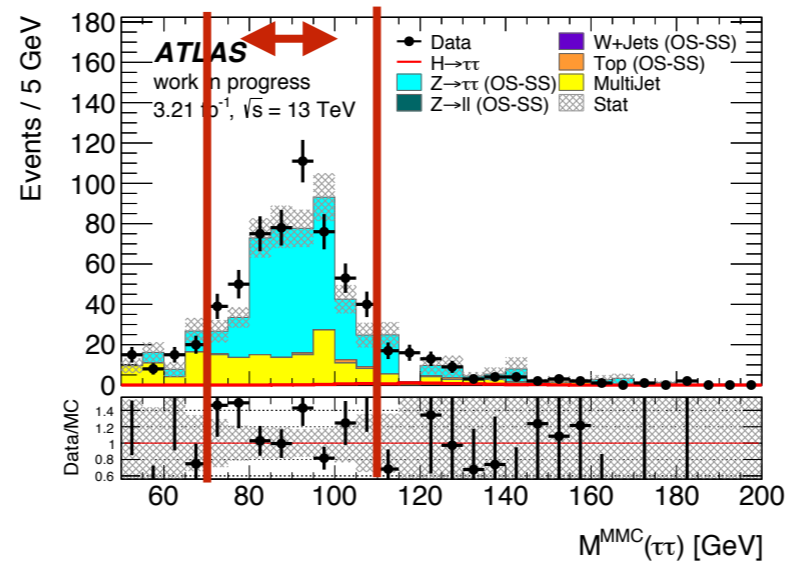
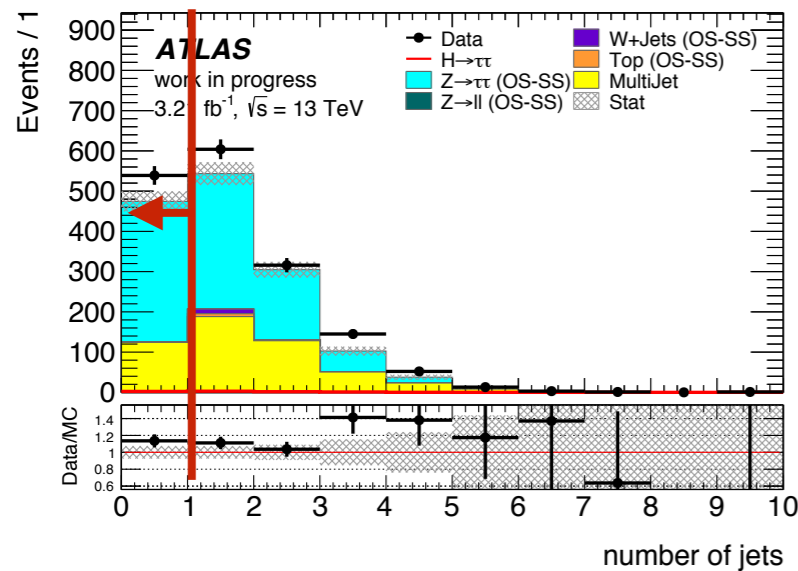
- From Monte Carlo

Data

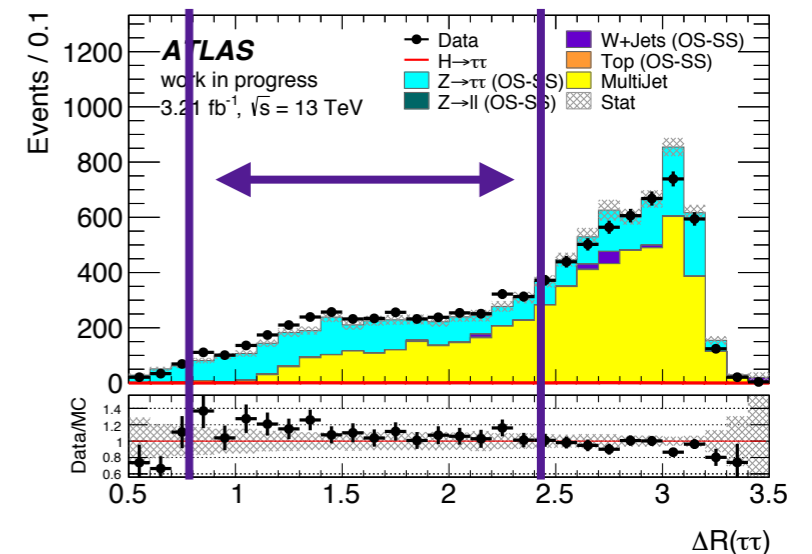
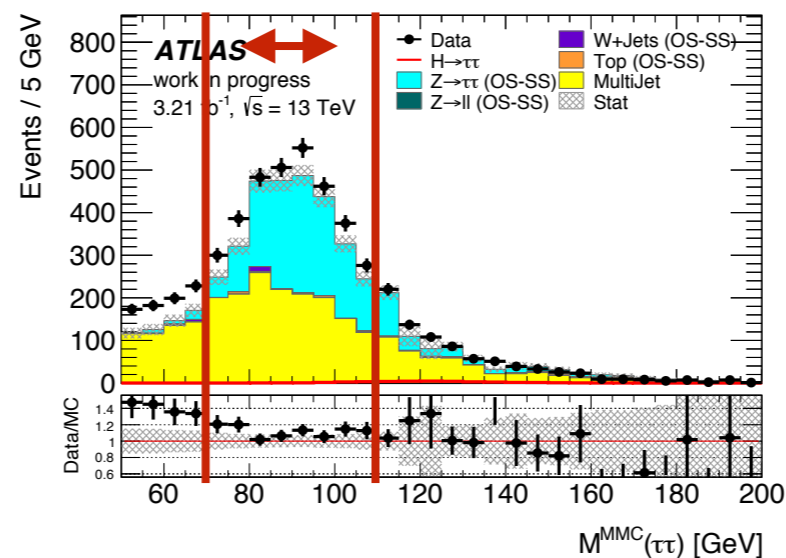
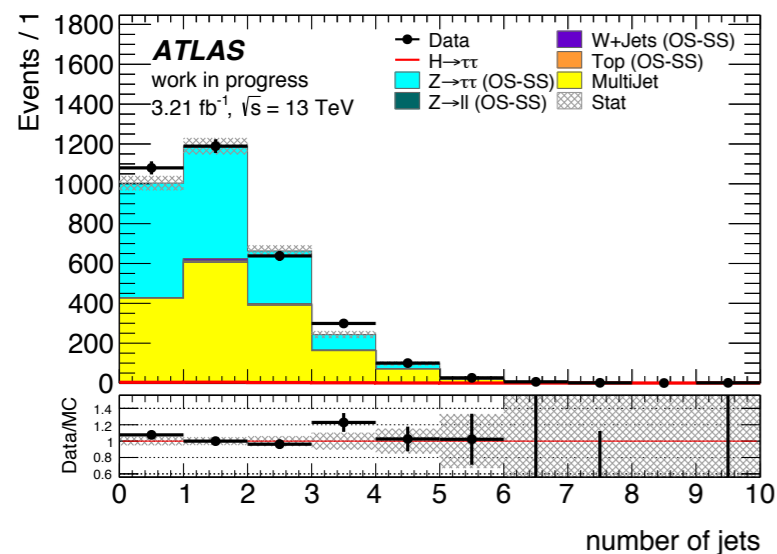
- LHC Run-2, 2015 dataset, 3.21 fb⁻¹ at 13 TeV

Control distributions in Z regions (13 TeV, 3.21 fb⁻¹)

Z 0-jet Region

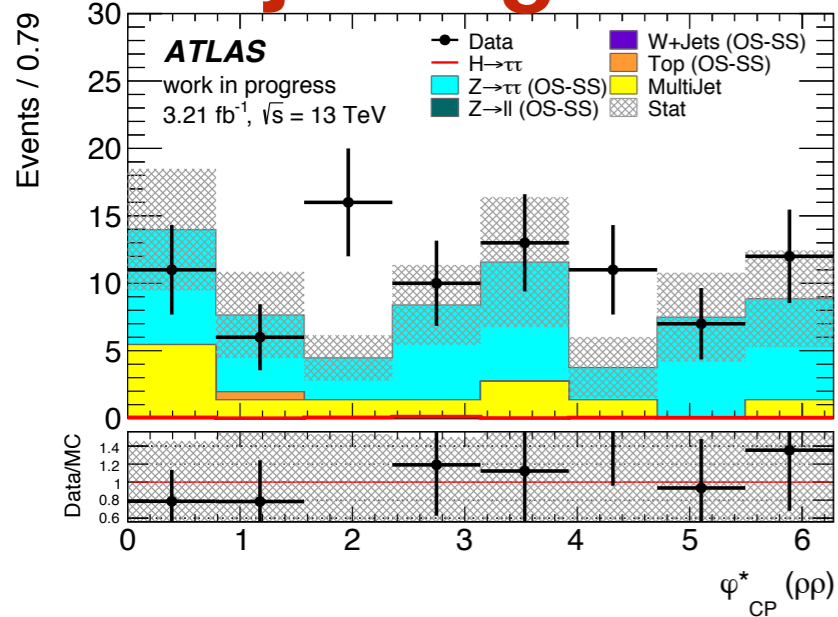


Z control region

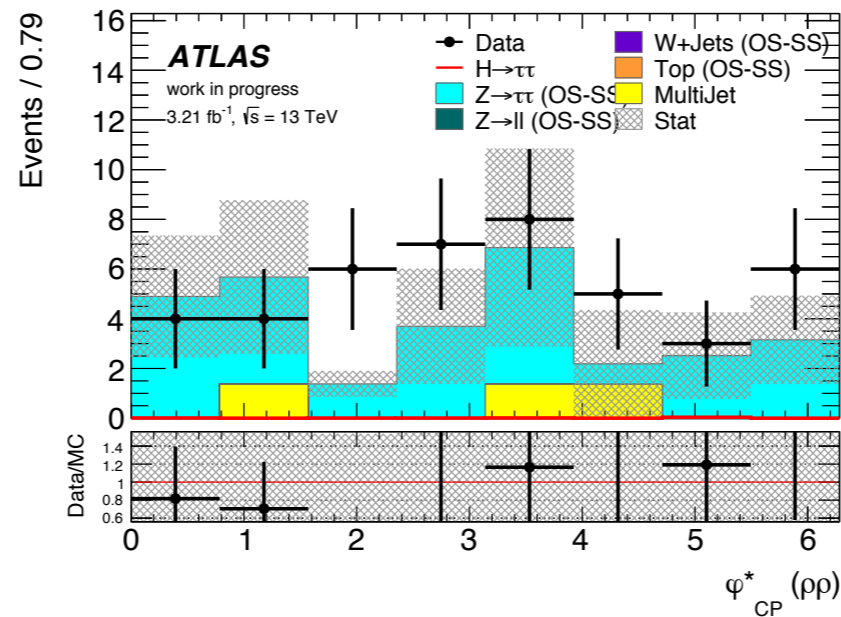


First Look at φ^*_{CP} modulation in the $1p1n-1p1n$ $\tau\text{-}\tau$ decay channel (13 TeV, 3.21 fb^{-1})

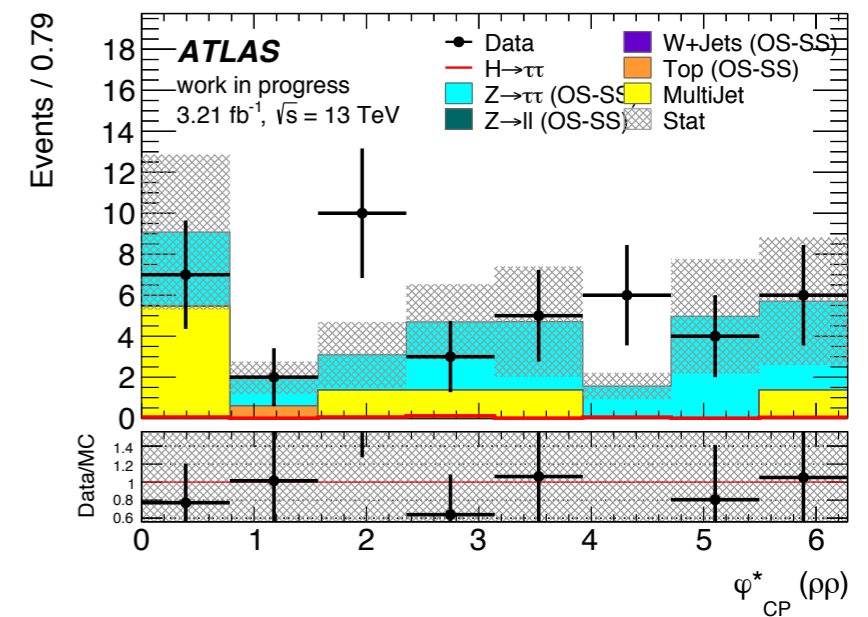
Z 0-jet region



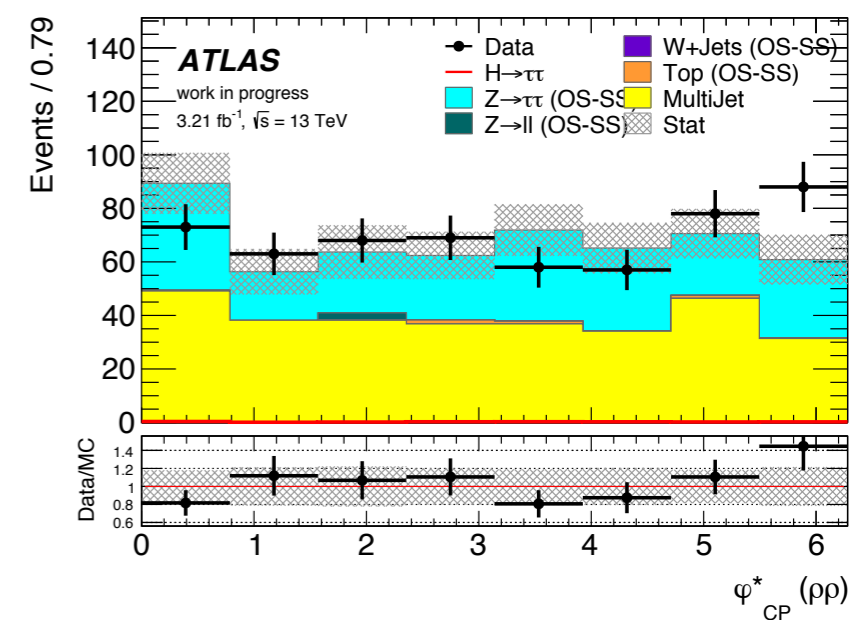
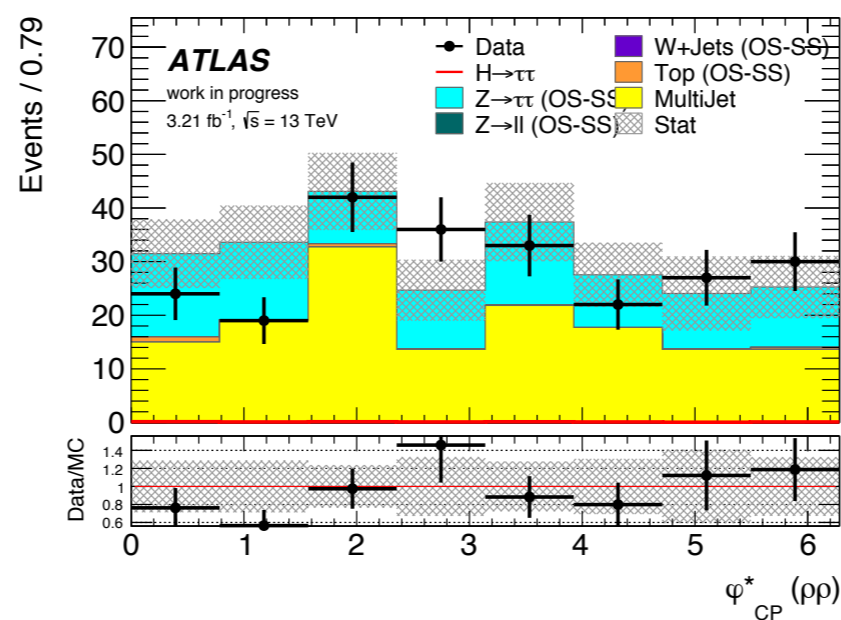
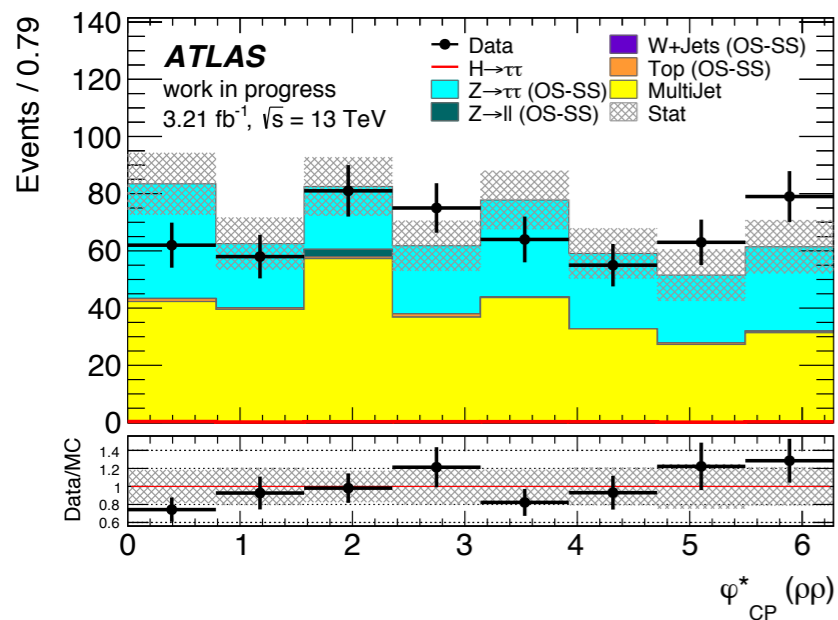
$\alpha < \pi/4$



$\alpha > \pi/4$



Z control region



Summary & Outlook

- CP admixture in $H \rightarrow \tau_{\text{had}} \tau_{\text{had}}$ can be extracted from distribution of the angle between the τ -decay planes φ_{CP}^*
 - Decay plane reconstruction depends on τ -decay mode \Rightarrow Need Run-2 τ -reco
 - Introduce artificial φ_{CP}^* modulation in $Z/\gamma^* \rightarrow \tau\tau$ events by splitting the decay phase space \Rightarrow Study systematics & calibrate all reconstruction methods
- \rightarrow Fit φ_{CP}^* modulation in the Z-Regions for all τ -decay mode combinations
- Basic event selection identical to Run-1 $H \rightarrow \tau\tau$ preselection
 - Challenging to get pure Z-sample in fully hadronic mode \rightarrow optimise event selection in Z-regions for $Z \rightarrow \tau_{\text{had}} \tau_{\text{had}}$
- \rightarrow Looks already promising given that we expect much more data for 2016

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Thank you for your attention!