ϕ^* in the context of H$\rightarrow \tau\tau$ decays in ATLAS

Théo MEGY
Albert-Ludwigs-Universität Freiburg
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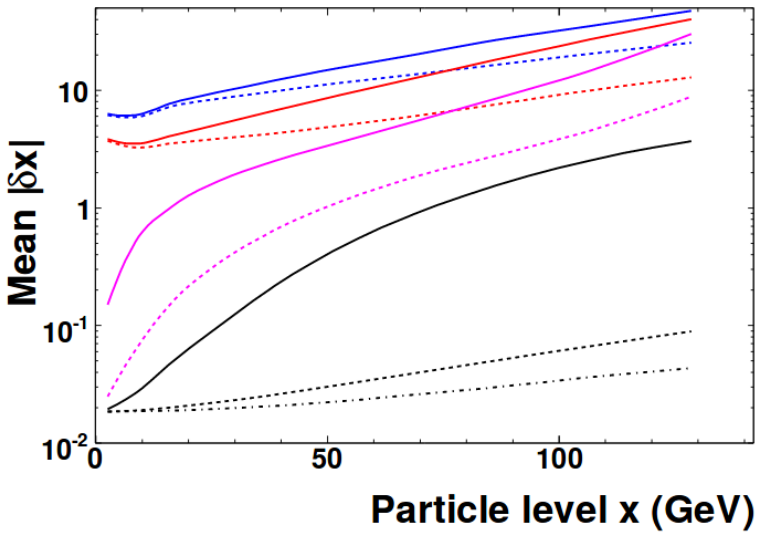
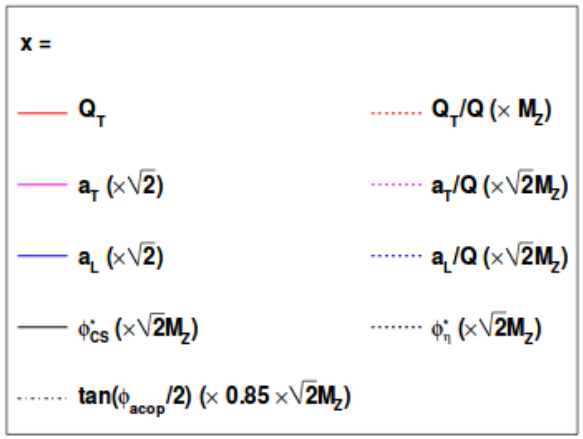
Introduction

- ϕ^* initially introduced to test QCD prediction
  - For measurements limited by experimental resolution, not statistics
  - $Z/\gamma^* \rightarrow \mu\mu$ and $Z/\gamma^* \rightarrow$ee
  - Better resolution than $p_T^{\ell\ell}$





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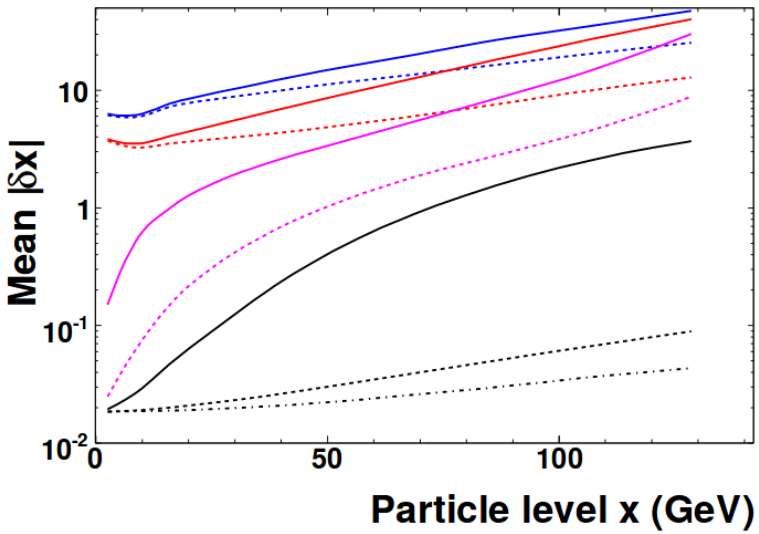
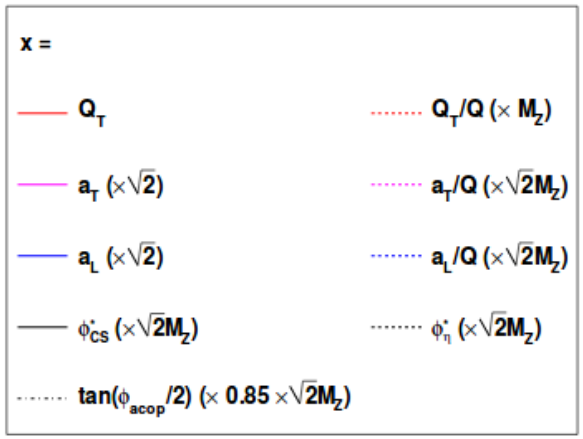




- **Goals**:
  1. Determine ϕ^* experimental resolution in the case of H$\rightarrow \tau\tau$ decays
     Compare with other dileptonic variables such as $p_T^{\ell\ell}$
  2. Determine ϕ^* potential discrimination power in the search for SM H$\rightarrow \tau\tau$

ϕ^* definition

- $\phi^* = tan(\phi_{acop}) \times sin(\theta^*)$
- $\phi_{acop} = \pi - \Delta\phi$
- Two alternative definitions of θ^*
  - In Collins Soper frame: $cos(\theta^*_{CS}) = \frac{sinh(\eta^{\ell-} - \eta^{\ell+})}{\sqrt{1+p_T^{\ell\ell}/m_{\ell\ell}}} \times \frac{2p_T^{\ell_1} p_T^{\ell_2}}{m^2_{\ell\ell}}$

    $\Rightarrow$ Depends on p_T measurement
  - $cos(\theta^*_\eta) = tanh(\frac{\eta^{l-} - \eta^{l+}}{2})$

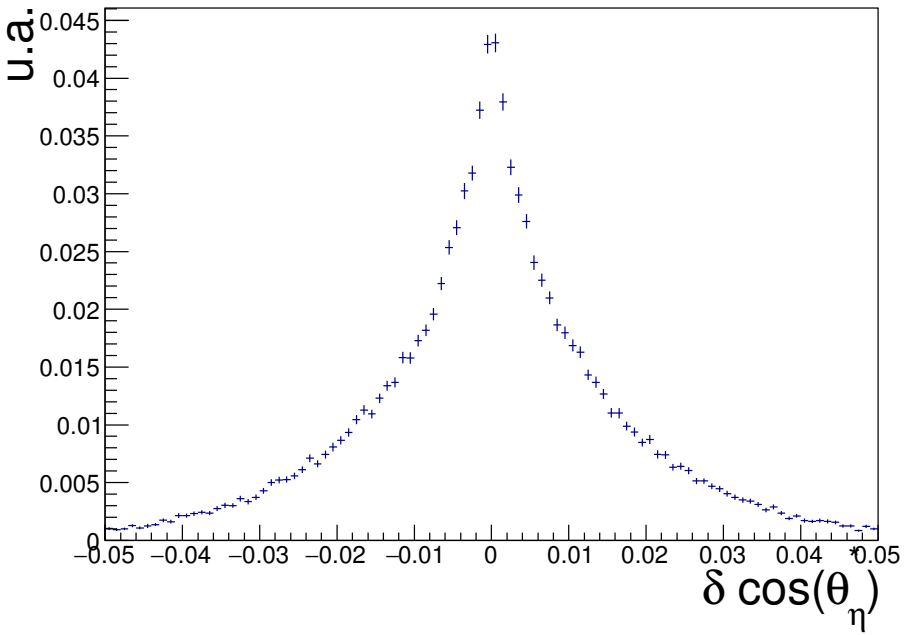
    $\Rightarrow$ Depends only on tracks directions
- Two alternative definitions of ϕ^* considered

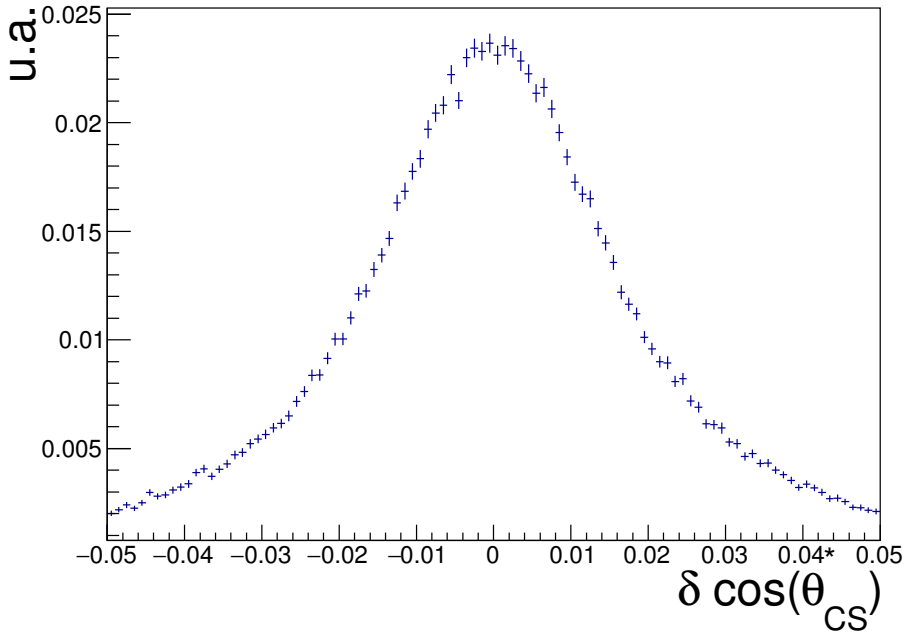
Experimental resolution - Introduction

- Definition of the **experimental resolution**: reconstructed - truth
- In the following study H$\rightarrow \tau_{lep}\tau_{lep}$
- We considered:
  - At reconstructed level: leptons from tau decay
    $\Rightarrow$ Neutrinos are missing !
  - At truth level: taus themselves
- Boosted taus $\Rightarrow$ neutrinos and lepton from decay collimated
  - Absence of neutrinos has small impact on tracks direction resolution
  - But potentially big on momenta

Experimental resolution - $\cos(\theta^*)$

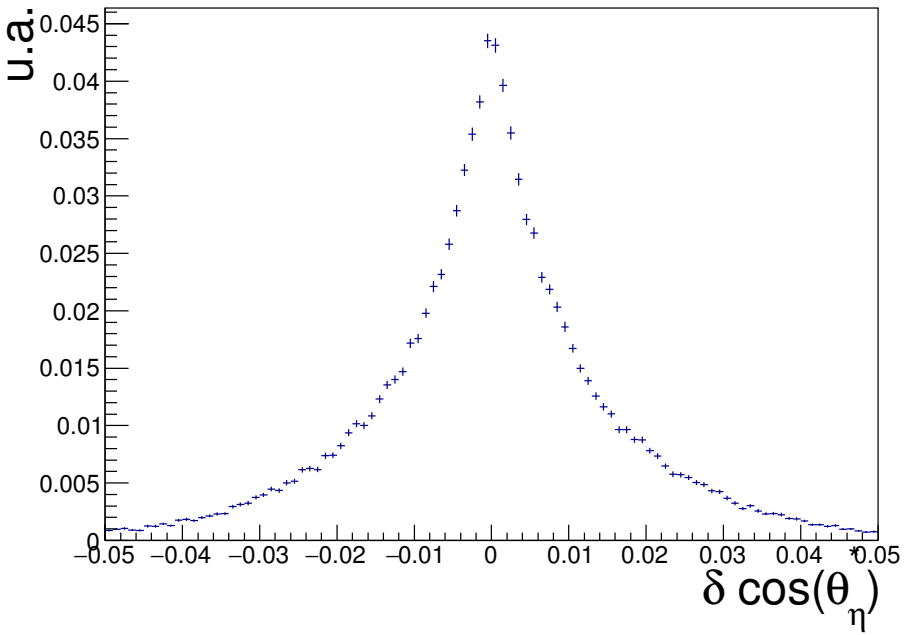
- $\cos(\theta^*_\eta)$ vs $\cos(\theta^*_{CS})$ - ggF Higgs production

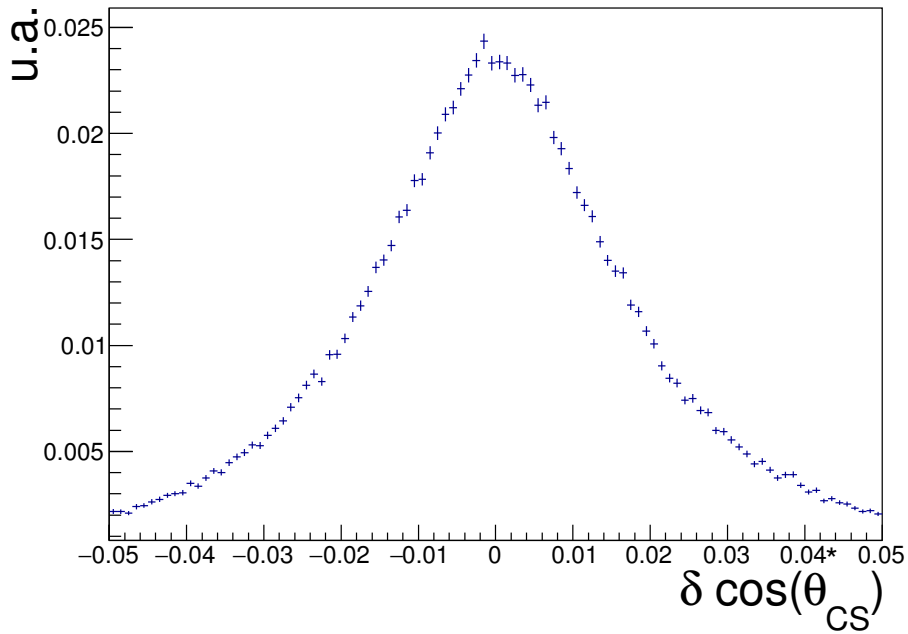




Experimental resolution - $\cos(\theta^*)$

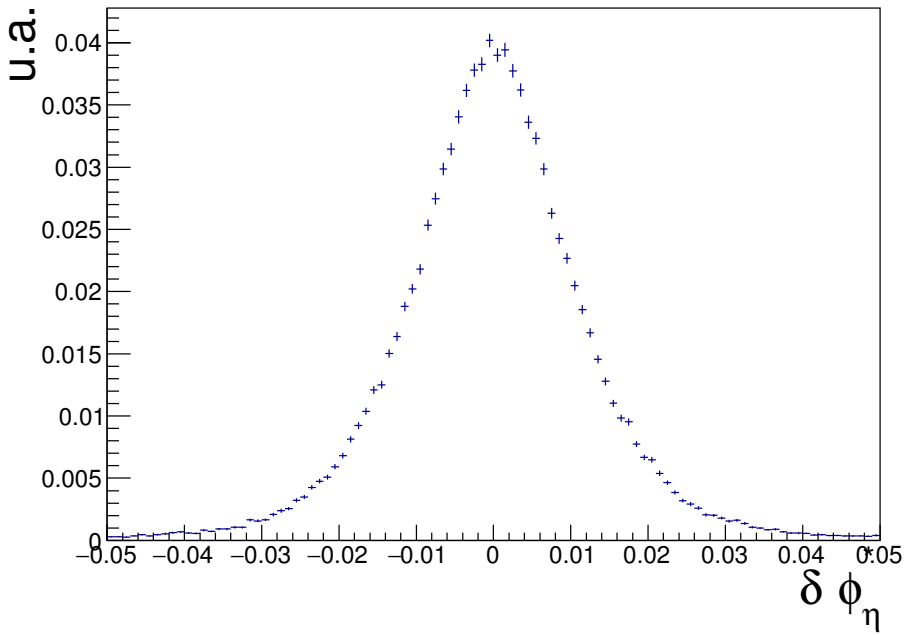
- $\cos(\theta^*_\eta)$ vs $\cos(\theta^*_{CS})$ - VBF Higgs production

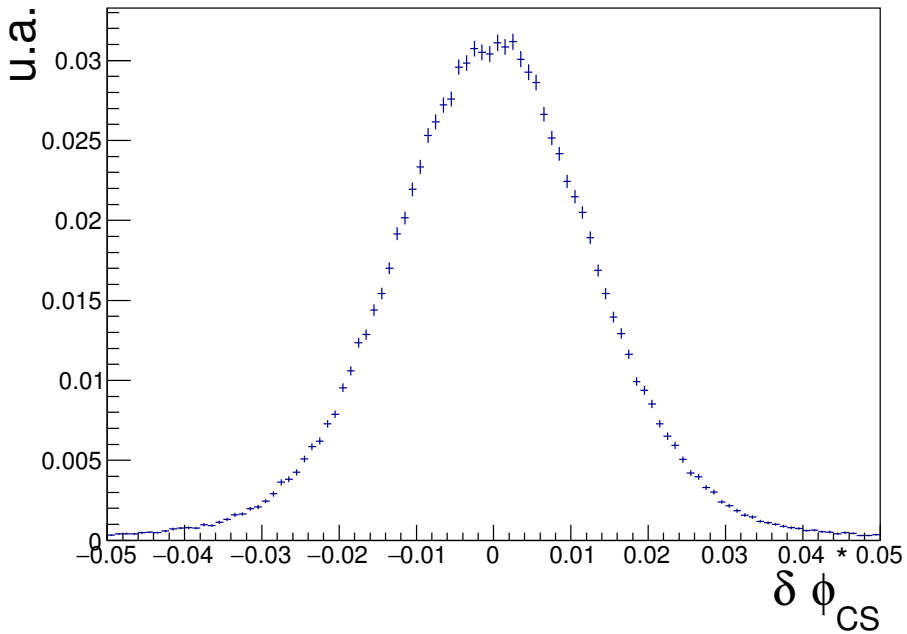




Experimental resolution - ϕ^*

- ϕ^*_η vs ϕ^*_{CS} - ggF Higgs production





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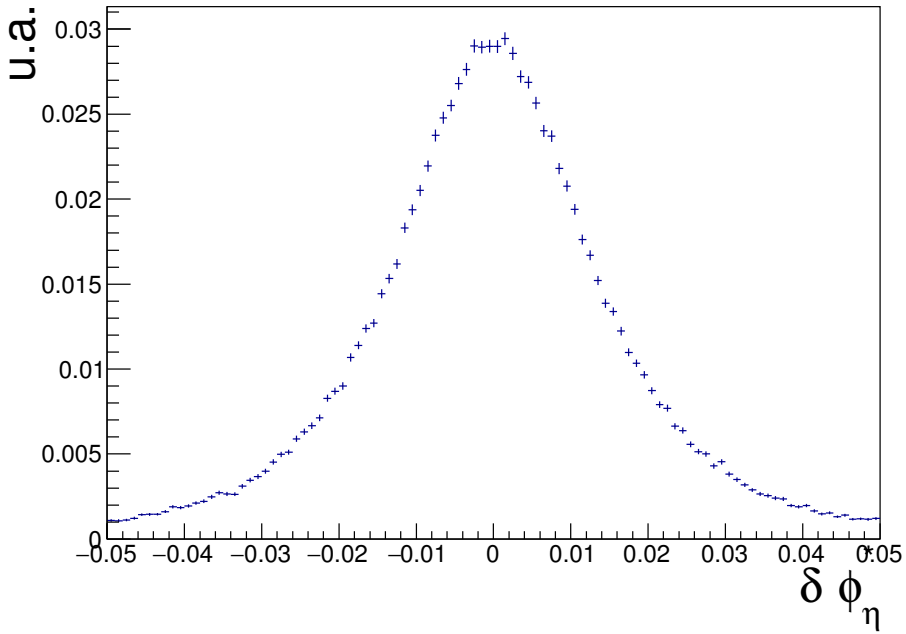
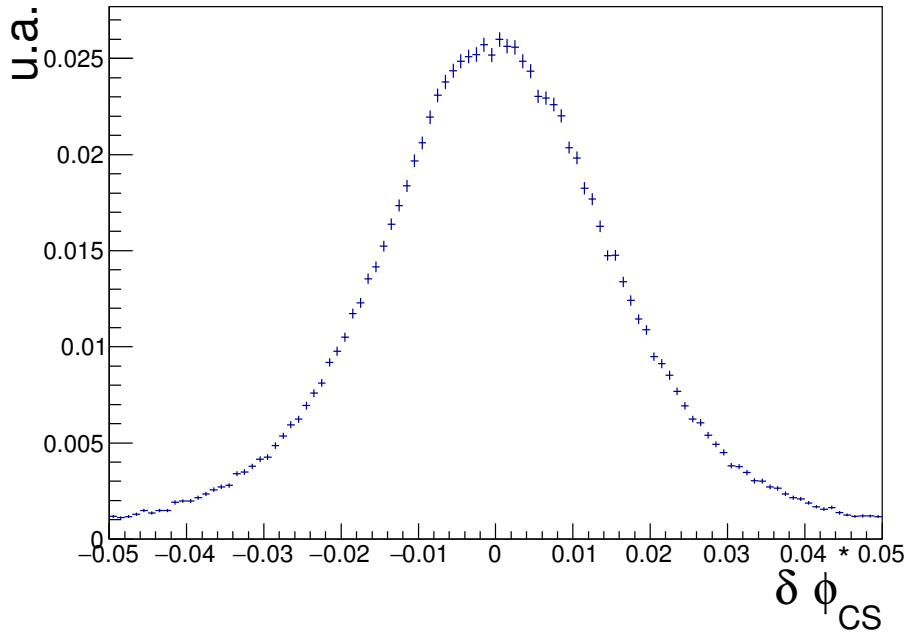


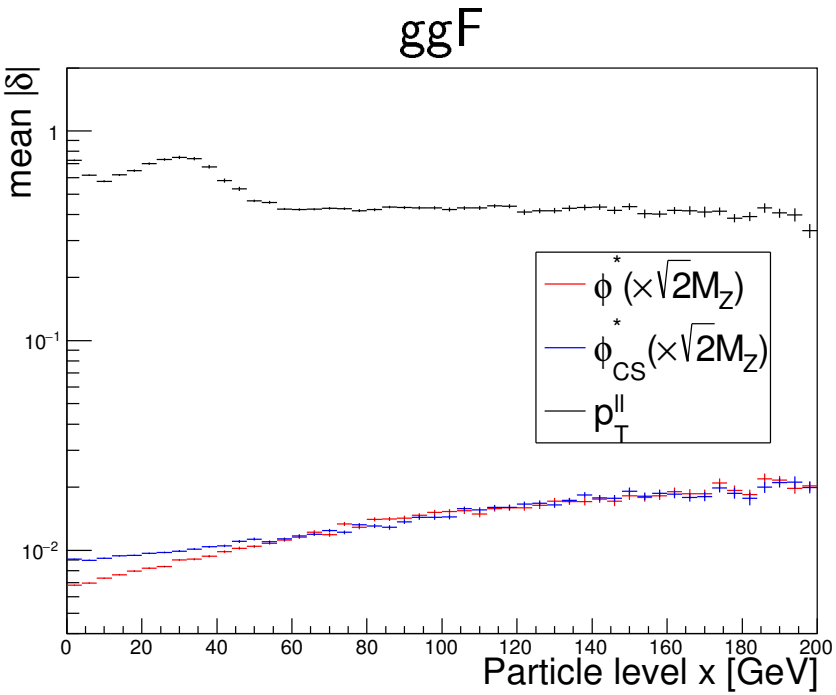


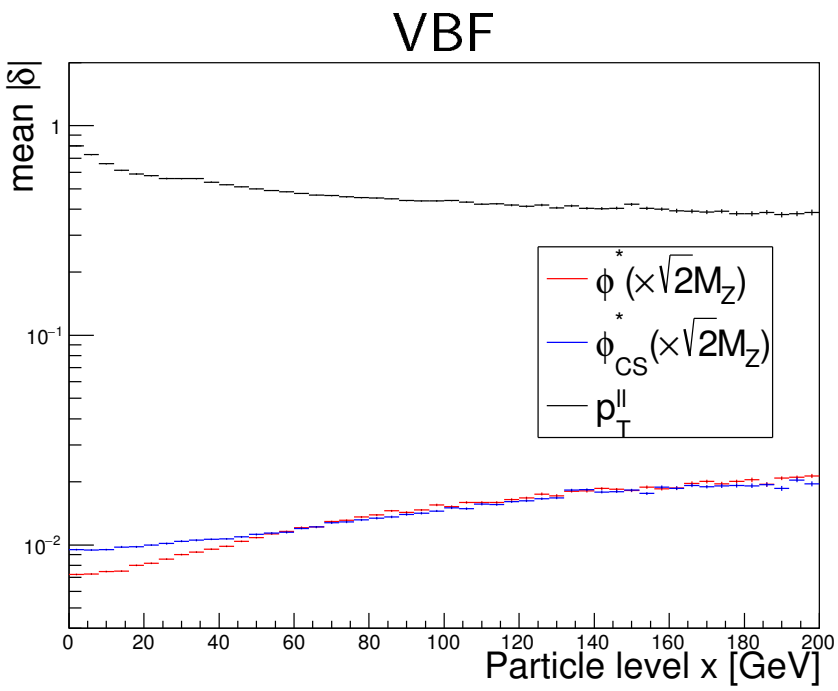
- Difference less clear than for $\cos(\theta^*)$
- Total resolution dominated by $\Delta\phi$?

  $\Rightarrow$ Need to check $\Delta\phi$ resolution to conclude

Experimental resolution - ϕ^* vs $p_T^{\ell\ell}$

- Compare ϕ^*_η and ϕ^*_{CS} with $p_T^{\ell\ell}$
- Mean resolution vs considered variable





ϕ^* in the search for H$\rightarrow \tau\tau$

- Can ϕ^* help separating signal from backgrounds ?
- **Signal**: ggF and VBF production modes
- **Backgrounds considered**:
  - Z+jets: Z$\rightarrow \ell\ell$ and Z$\rightarrow \tau\tau$
  - $t\bar{t}$ and single top

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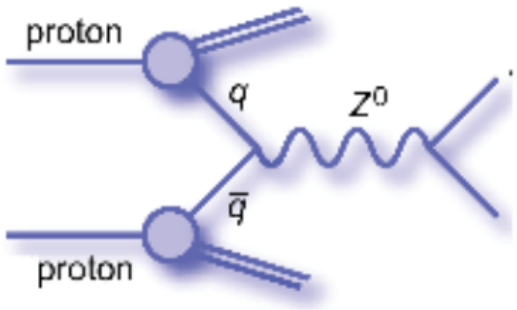

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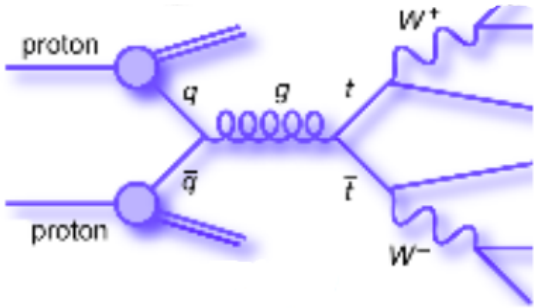

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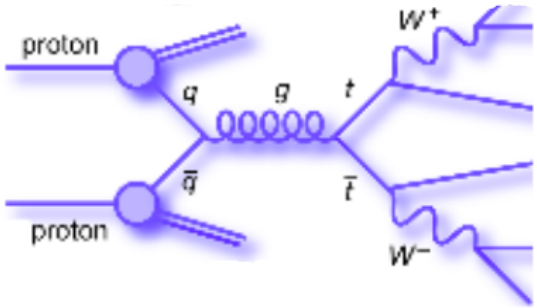
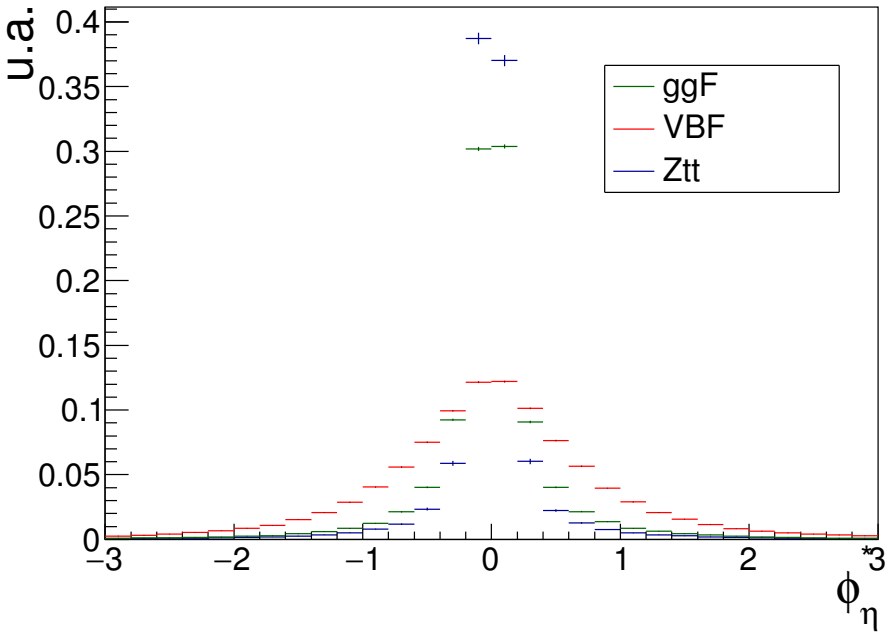
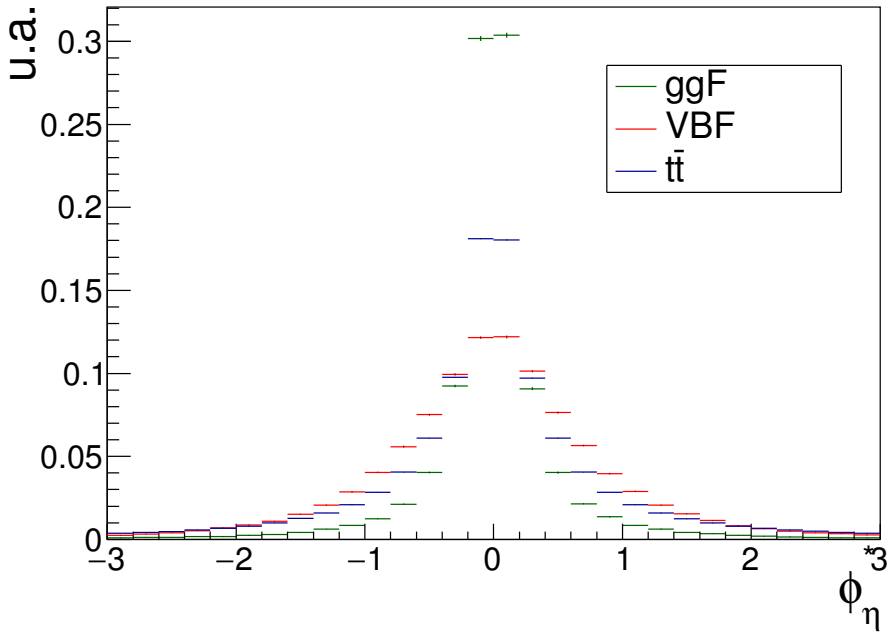


- Compare MC shape for signals and backgrounds
  - With a loose selection
  - In the actual signal regions of the analysis

ϕ^* in the search for H$\rightarrow \tau\tau$

- Shape comparison with a loose selection
  - Lepton triggers
    with corresponding momentum cuts (typically 20 GeV)





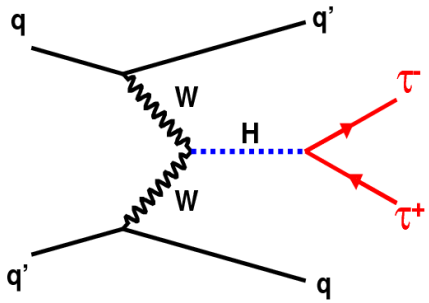
ϕ^* in the search for H$\rightarrow \tau\tau$

- Definition of 2 categories to select events from both production mode:

- **VBF category**

  $\Rightarrow$ Particular topology: 2 forward high p_T jets

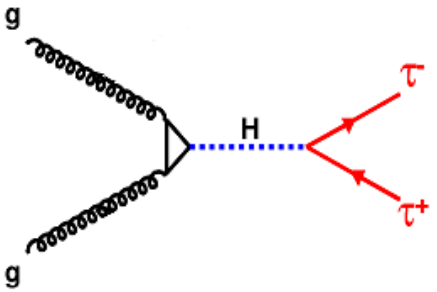
  - $N_{jets} \geq 2$, $p_T^{j1} > 50$ GeV and $p_T^{j2} > 30$ GeV
  - $\Delta\eta(j1, j2) > 3.0$
  - $m_{\tau\tau}^{vis} > 40$ GeV



- **Boosted category**

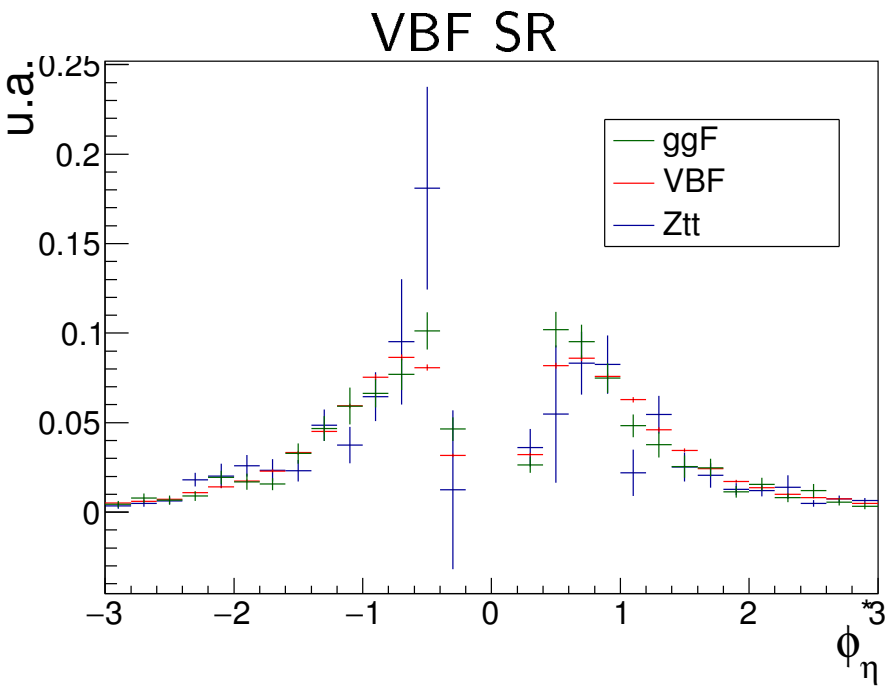
  $\Rightarrow$ Enriched in ggF

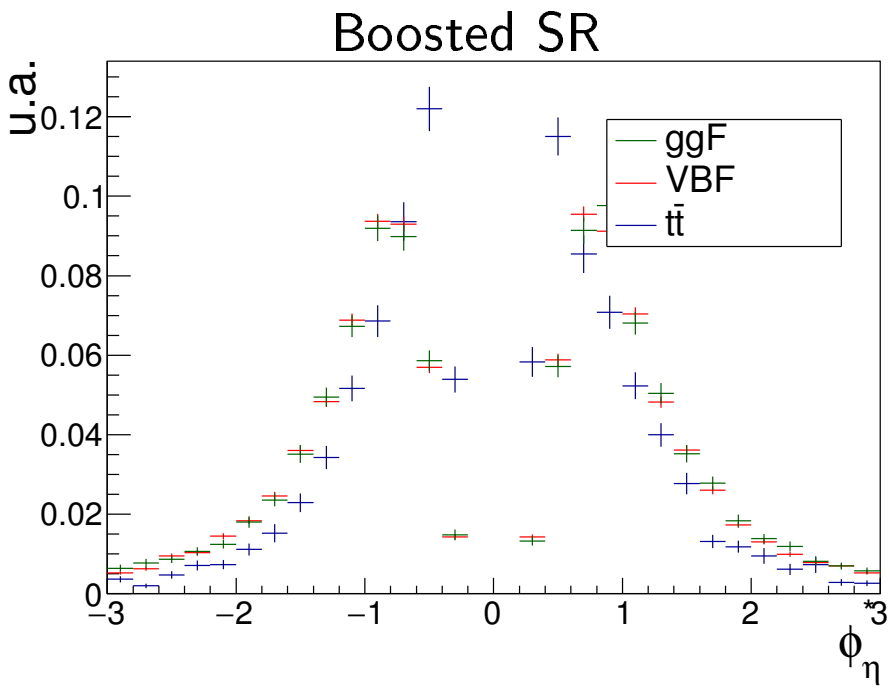
  - Failing VBF selection
  - $p_T^H > 100$ GeV



ϕ^* in the search for H$\rightarrow \tau\tau$

- Shape comparison in Boosted and VBF signal regions





Summary

- Variable introduced to test QCD prediction with better resolution
  - Based on $Z/\gamma^* \rightarrow \mu\mu$ and $Z/\gamma^* \rightarrow ee$
- Reproduce resolution studies for $H \rightarrow \tau\tau$
  - Definition of ϕ^* ?
  - Resolution: ϕ^* vs $p_T^{\ell\ell}$
- Separation power in SM $H \rightarrow \tau\tau$ search
  - Potential improvement for loose selection
  - Not really promising in actual signal region